

RESEARCH AND INNOVATION (R&I) ECOSYSTEM

From deep understanding to implementation of practical,
sustainable solutions

ACCC research and innovation approach represents a broad range of science-based approaches, methodologies, best practises and new knowledge, as well as pilots applicable to plans and decisions towards carbon and climate neutrality, regulation, new businesses and innovations, improved general knowledge and awareness

This document is a living document (established 15th June 2023, 2nd version October 2025) of the “ACCC R&I ENVIRONMENT & ROADMAP”. The document has been written by the ACCC research and impact teams of the Institute for Atmospheric and Earth System Research (INAR) at the University of Helsinki⁽¹⁾, Finnish Meteorological Institute⁽²⁾, Faculty of Engineering and Natural Sciences | Physics | Aerosol Physics at the Tampere University⁽³⁾ and University of Eastern Finland⁽⁴⁾. This document is the first version of a living document / interactive document, which will be expanded in a cumulatively manner by the ACCC teams. (Version 21112025)



Chapters: Motivation by Kulmala, M. Lohila, A-I., Partanen, I. **Part 1:** based on the ACCC Academy of Finland proposal (2021-2024) modified by Lappalainen, H.K., Pauli, A., Keronen. J., Paatero, S., Lintunen, A., Kulmala, M., **Part II:** chapter contributors in alphabetical order: Asmi, E. ⁽²⁾ (2.6.9), Berninger F. (chapter 2.5.3), Dal Maso M. ⁽³⁾ (2.2.3), Ehn, M. ⁽¹⁾ (2.3.2), Ezhova, E. ⁽¹⁾ (2.3.1), Gregow H. ⁽²⁾ (2.2.4), Höckerstedt L. ⁽²⁾ (2.5.3), Hyvärinen A. ⁽²⁾ (2.5.9), Häme S. ⁽¹⁾ (2.3.1, 2.3.3), Jokinen H. ⁽¹⁾ (2.4.2), Järvi L. (2.3.2), Kangasniemi O. ⁽³⁾ (2.4.2), Kühn T. ⁽²⁾ (2.2.4), Kokkonen T. ⁽¹⁾ (2.4.2), Kujansuu J. ⁽¹⁾ (2.5.6, 2.5.8), Kulmala M. ⁽¹⁾, Lappalainen H.K. ⁽¹⁾ (2.5.9, 2.6.1-2.6.3), Lauri K. (2.4.2), Lehtipalo K. ⁽¹⁾ (2.2.4), Lintunen A. ⁽¹⁾ (2.2.2), Mahura A. ⁽¹⁾ (2.3.5), Makkonen R. ⁽²⁾ (2.3.5), Martikainen S. (2.4.2), Matkala L. (2.3.3), Mazon S. ⁽¹⁾ (2.5.7), Nieminen T. ⁽¹⁾ (2.4.2), Paasonen P. ⁽¹⁾ (2.2.3), Paatero S. ⁽¹⁾ (2.5.2), Rantanen R. ⁽¹⁾ (2.6.4), Rasilo T. ⁽¹⁾ (2.3.3), Riuttanen L. ⁽¹⁾ (2.4.2), Ruuskanen T. ⁽¹⁾ (2.4.3), Rönkkö T. ⁽³⁾ (2.5.3), Shahzad G. ⁽¹⁾ (2.5.8), Siili T. ⁽²⁾ (2.5.3), Sofiev M. ⁽²⁾ (2.3.1; 2.6.10), Taipale U. ⁽¹⁾ (2.4.3), Vainio M (2.4.2), Vakkari V. (2.5.9), Virkki S. (2.3.3)

Appendix Project portfolio: Häme, S., Lintunen, A., Lappalainen H.K (INAR), Siili T., Kühn T. (FMI), Kangasniemi O. (TAU), Martikainen S., Honkonen T. (UEF), Yumineva Y. (UEF)

References Alla Borisova (UH)

Managing Editor Hanna K.Lappalainen (INAR), Silja Häme (INAR), Anna Lintunen (INAR)

Editor(s) Silja Häme (INAR), Anneli Pauli (INAR 1st version), Tero Siili (FMI 1st version), Tii Suokivi (INAR)

Infographs Mikko Kulmala (UH)

Photos: Juho Aalto, Pia Anttila, Lee Mauldin, Agnes Meyer-Brandis

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ON ACCC RESEARCH AND INNOVATION (R&I) ECOSYSTEM AND ROADMAP

The Atmosphere and Climate Competence Center (ACCC) is a Finnish flagship funded by the Research Council of Finland, currently for years 2020-2028. ACCC is based on a partnership of Institute of Atmospheric and Earth System Research INAR at the University of Helsinki, Finnish Meteorological Institute, Tampere University and University of Eastern Finland. Our vision is “towards safe climate and clean air”. ACCC partners bridge research on atmospheric chemistry and physics, climate, ecology, soil science, social science, economics and law with high societal impact on climate and air quality related policies, services, innovations, new businesses and wide-ranging capacity building on climate competences. Our approach is based on deep scientific understanding of the land-atmosphere interactions and feedbacks, and provides practical solutions on climate neutrality and beyond. Our aim is to lead global inter-disciplinary climate and atmospheric sciences, continuously developing our research infrastructures in Finland, as part of European and global scientific networks including building new capabilities on comprehensive data gathering with open data policy. We cover basic science, applications and innovations. We welcome contributions from all stakeholders and collaborators. The foreseen outcomes are disseminated on national, EU and international scales.

In this document we present our multiscale research and innovation ecosystem. Based on this we will develop and present our own ACCC roadmap because:

- An integrated, holistic and realistic science-based roadmap is missing, due to the lack of interdisciplinary approach
- There is a clear need for more research and innovation to become globally carbon neutral and furthermore climate neutral and beyond
- There is a need for a bottom-up approach to integrate our research and impact activities to a concise living document
- By meeting the ACCC aims and forming a strong research and innovation ecosystem we can have realistic views and offer realistic and reliable solutions to be globally carbon and climate neutral and beyond



Academician of Science, Markku Kulmala
ACCC Director

**) “The Intergovernmental Panel on Climate Change (IPCC) (2018) defined climate neutrality as the “concept of a state in which human activities result in no net effect on the climate system”, in other words: anthropogenic emissions of GHGs are balanced by anthropogenic removals over a certain period.”*

FOREWORD

The Atmosphere and Climate Competence Center (ACCC) is a project funded by the Research Council of Finland for years 2020-2028. It is based on 18 years as a Finnish Center of Excellence in atmospheric sciences. The partners of ACCC are the Institute for Atmospheric and Earth System Research INAR at the University of Helsinki (UH), Finnish Meteorological Institute (FMI), University of Tampere (TAU) and University of Eastern Finland (UEF). The ACCC carries out an intensive research, innovation and impact agenda in collaboration with organizations of public and private sectors. We aim at novel research and innovation ecosystem for atmospheric and environmental sciences by transforming excellent science into viable solutions.

The aim of this document is to introduce the ACCC Research and Innovation (R&I) Ecosystem. Here we describe the cooperation within the four organisations forming the ACCC itself, as well as our wide national and international collaborations. We call all this as the ACCC “ecosystem” i.e. research and innovation environment. The document will be utilized and updated along the way based on the contributions and input from our stakeholders and collaborators. This is a living document utilising joint visions, knowledge, and efforts to establish a document on an interactive e-platform. This platform can include roadmaps from our collaborators, too.



MOTIVATION

Climate change and poor air quality create severe problems in all sectors of the society. They must be simultaneously mitigated in the coming years. Sustainable methods and means for adaptation are also a must. There is a need to improve climate projections and to develop terrestrial carbon sequestration options by taking into account interlinked climate forcers like aerosol and trace gases. By incorporating a relevant research and innovation ecosystem we can have realistic approaches to meet the target of a carbon- and climate-neutral (and beyond) society in Finland and apply the solutions to European and global level. With deep emission reductions and scaling up Carbon Dioxide Removal to about 20 Gt CO₂ yr⁻¹ on 2050s even returning to an atmospheric CO₂ concentration of 350 ppm within this century could be possible (Figure 1).

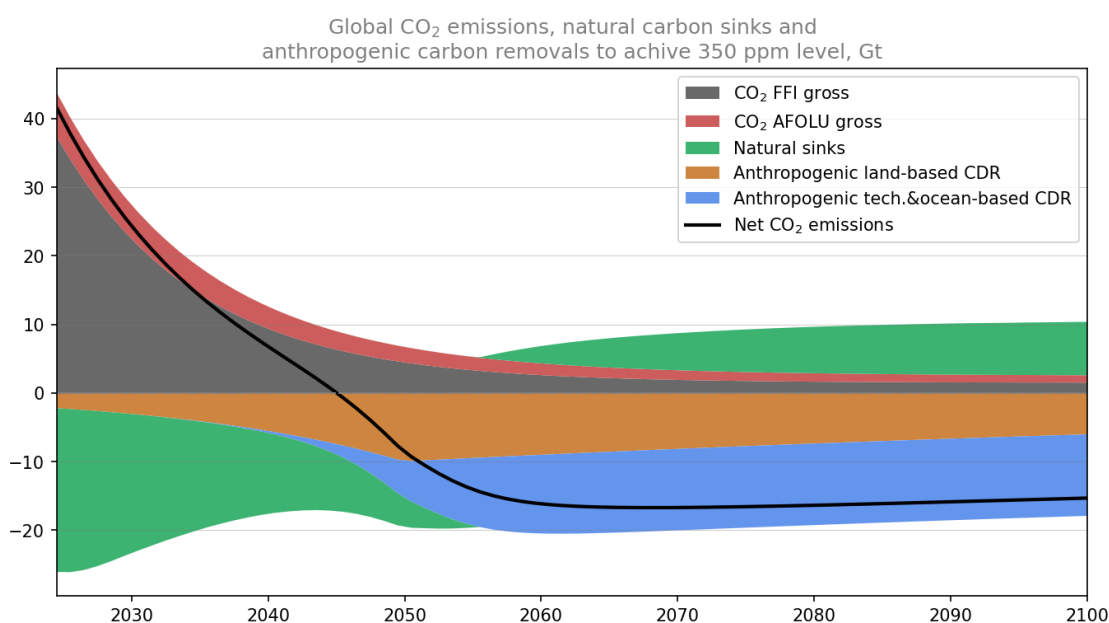


Figure 1: CO₂ emissions and sinks in an idealized scenario of how CO₂ concentration of 350 ppm could be achieved during this century. In this scenario, the residual CO₂ emissions from fossil fuels and industry (FFI) decrease towards 1.5 Gt CO₂ yr⁻¹. Gross CO₂ emissions from Agriculture, Forestry and Other Land uses (AFOLU) are assumed to decline similarly towards 1 Gt CO₂ yr⁻¹. Simultaneously, both land-based and novel Carbon Dioxide Removal (CDR) are assumed to grow fast from their current volumes. Land-based CDR is assumed to grow exponentially from 2 Gt CO₂ yr⁻¹ to 10 Gt CO₂ yr⁻¹ by 2050 and decline slowly with saturating sinks to 6 Gt CO₂ yr⁻¹ by 2100 (cumulatively 530 Gt CO₂ between 2024 and 2100). Novel CDR is assumed to have a logistic (S-shaped) growth from 1.35 Mt CO₂ yr⁻¹ to a level of around 12 Gt CO₂ yr⁻¹ by 2060s 2100 (cumulatively 600 Gt CO₂). With these anthropogenic emissions, natural carbon sinks declined steadily and turned into sources in mid 2050s based on simulations with a simple climate model FaiR (Leach et al., 2021; Smith et al., 2024).

We need to upgrade the existing monitoring and forecasting systems of the terrestrial carbon cycle to an entirely new level in order to better understand both natural and anthropogenic carbon sources and sinks. To achieve this, we have to carry out more and better measurements spanning from laboratory/test bed/pilot levels all the way to a global scale

Furthermore, understanding atmospheric processes affecting air quality and health need to be enhanced. The global annual cost of climate change health impacts is estimated to reach hundreds of billions of euros by 2030 (UNEP 2016) and increase sharply with the current level of global warming.

To develop sustainable solutions to all burning grand challenges while providing emerging business opportunities for various industries. European Green Deal Investment will mobilize at least 1 trillion euros of sustainable investments over the next decade (COM 2020). There is an urgent need for new verification systems to inform the design of economically and socially optimal sustainability strategies and climate-neutrality pathways to meet the Paris Agreement climate targets (Kriegler et al. 2018).

1. PART I ACCC FLAGSHIP FRAMEWORK

Vision

Safe climate and clean air

Destination by 2028

The ACCC is a world-leading atmosphere and climate competence center of interdisciplinary research and innovation. We have an efficient research and innovation ecosystem that is in active interaction with the climate and air quality policy and decision makers, private sector and civil society. We provide science-based knowledge and methods, for instance regarding efficient ways to sequester CO₂ from the atmosphere and reliably verify it, towards a climate neutral and beyond in Finland, in the EU, and globally. Via our knowledge production we contribute to effective climate policies, means to increase biological carbon sinks and storages as well as to mitigation and adaptation plans nationally and internationally.

Central idea from the perspectives of research and impact

Our co-operation with companies aims at boosting new practical solutions for instance in the development of new atmospheric measurement instruments, improved climate – air quality analysis and verification services, which can be utilized for example by global auditing sector (compensation schemes, EU's planned Carbon Boarder Adjustment Mechanism). ACCC significantly contributes to the integrated global climate observation system by leading or being a significant partner in European Research infrastructures in the environmental domain, providing novel education and distributing new knowledge on climate change to public. During the second four-year period, ACCC together with its collaborators and stakeholders is carrying out a research and impact agenda consolidating an efficient national and international business ecosystem for atmospheric and environmental sciences by transforming excellent science into solutions.

**” Safe climate
and clean air ”**

Aims

The ACCC aims for the flagship terms 2020-2024 /2025-2028 are to provide beyond state-of-the-art scientific knowledge on two of the most urgent global Grand Challenges, climate change and deteriorating air quality, by quantifying forests, agriculture, peatland and oceans as carbon and GHG sources, sinks and storages/reservoirs and by understanding role of atmospheric aerosols in this context.

- model the behavior of GHG sinks and storages in the warming world and identify means to increase biological GHG sinks and storages
- reveal new knowledge on Earth surface-atmosphere interactions and identify means to simultaneously mitigate climate change, enhance adaptation and improve air quality
- co-create science-based solutions towards global climate neutrality and beyond, including also research on climate law and other relevant legislative issues
- establish an international and interactive atmospheric and environmental research – business innovation environment in Finland.
- to establish an ACCC Service Portal to collect big data from comprehensive observations and multiscale models to be based on open access according to the FAIR principles (Findable, Accessible, Interoperable and Reusable)

Competences

ACCC is a community with around 800 researchers, coordinators and technical experts working on atmospheric research and innovation paying special attention to impact. ACCC competences are based on several disciplines: physics, chemistry, meteorology, forest sciences, biology, microbiology, ecology, geography, computing sciences, economics, statistics, engineering, law and political sciences. ACCC provides also education programs in these fields, carries out a visiting professor program, hires Professors of Practice and develops ACCC Innovation Forum as a tool to enhance multistakeholder cooperation in various practical ways.

Pitch

- To achieve safe climate, we must reduce greenhouse gas emissions and increase carbon sinks and storages significantly. Biological carbon sinks - forests, agriculture, peatland, oceans – play a major role in this.
- Simultaneously, we need to be aware of the comprehensive climate impacts of different ecosystems beyond GHG, such as their role in forming atmospheric aerosol particles and clouds
- To achieve clean air, we must reduce pollutant emissions and understand the air quality pollution cocktail.
- The Atmosphere and Climate Competence Center (ACCC) Flagship studies climate change and deteriorating air quality by quantifying carbon sinks and storages as well as anthropogenic and natural greenhouse gas emissions
- Our vision is safe climate and clean air.
- The ACCC is a partnership of the Institute for Atmospheric and Earth System Research INAR at the University of Helsinki, Finnish Meteorological Institute, University of Eastern Finland and Tampere University, with connections to over 500 research institutes globally and to about 100 companies
- We perform interdisciplinary research from molecular to global scale and focus on climate change, air quality, biogeochemical cycles and ecosystem processes.
- We are in active interaction with policy makers, private sector and civil society, and collaborate with an increasing number of stakeholders in and outside of Finland.
- We take actions to ensure that our research can lead to new innovations and have an impact on climate policies and contribute to new businesses.

2. PART II ACCC RESEARCH & INNOVATION ECOSYSTEM

2.1 ACCC R&I ECOSYSTEM IN A NUTSHELL

In PART II, we introduce the ACCC competences on research, research infrastructures, knowledge exchange and interaction, business & innovation and science-for-society dialogue (Figure 2). This includes a cumulative picture of the Academy of Finland and EU funded of the ACCC projects starting from in 2021.

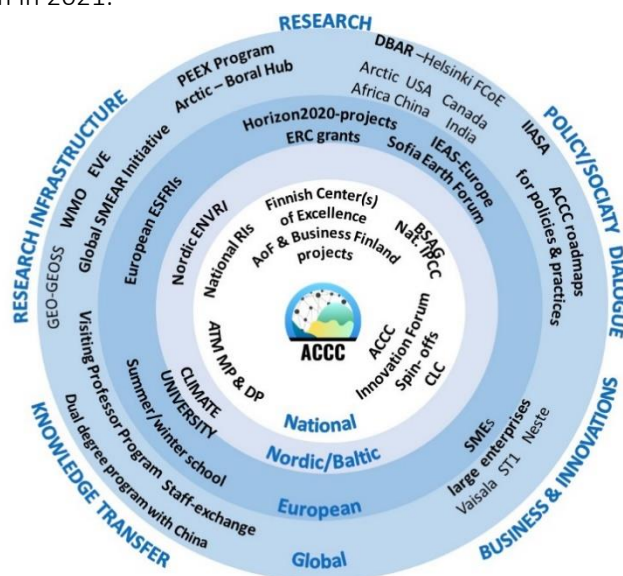


Figure 2. The main assets and collaborator frameworks of the ACCC R&I ecosystem scheme. Abbreviations in alphabetical order: **ATM MP & DP** = Master and Doctoral Programs in Atmospheric Sciences, **Arctic-Boreal Hub** = U-Arctic Thematic network, **BSAG** = Baltic Sea Action Group, **CLC** = Climate Leadership Coalition, **DBAR** = Digital Belt and Road Program, **ERC-grants** = European Research Council grants, **ESFRI** = the European Strategy Forum on Research Infrastructures,

EVE = Earth Virtualization Engines, **GlobalSMEAR** = Global Observatory on Stations Measuring Atmosphere-Earth Surface Relations, **IEAS-Europe** = International Eurasian Academy of Sciences, **IIASA** = International Institute for Applied Systems Analysis, **Nat. IPCC** = National IPCC working group, **Nordic Univ. Hub** = Nordic University Hub in Atmospheric and Earth System Sciences, **PEEX** = Pan-Eurasian Experiment Program, **WMO** = World Meteorological Organization.

The components to meet global grand challenges, including climate neutrality and beyond are:

- excellent science – quality, critical mass and interdisciplinary research (chapter 2.2)
- world-class Research Infrastructures (RIs) – an integrated EU- and global network of RIs (chapter 2.3)
- capacity building, education and training (chapter 2.4)
- business & innovation (chapter 2.5)
- international partnerships (chapter 2.6)
- society dialog (chapter 2.7)

The ACCC research and innovation ecosystem builds on these components. In order to boost the R&I ecosystem and research impact ACCC has organized three Research Programs (RPs) and an Impact

Program (IP) with 16 IP tasks (Figure 3). The ACCC research programs are aimed at quantifying the potential of the land-based climate change mitigation (RP1), understanding the climate – air quality interactions (RP2) and understanding how the climate change affects societies and how societies can adapt to climate change (RP3). The three RPs also have interlinkages. The Impact Program and its impact tasks stem from the research programs, but the impact tasks focus on co-creation and collaboration with the stakeholders, i.e. focus on the use of the gained research data and knowledge. The Impact Program tasks cover topics on carbon sinks of the agricultural and forested lands (IP1, IP2), climate neutrality of the companies (IP3), climate neutral cities & health (IP4), novel carbon and atmospheric observation techniques (IP5, IP6), air pollution cocktail in megacities (IP7), climate analytic solutions (IP8), new collaboration via the “CC - AQ forum” re-named as “Supporting policies and practices” (IP9), Pan-Eurasian Experiment (PEEX) Program (IP10), Global SMEAR for the Earth Observatory (IP11), science diplomacy (IP12) and Climate University with massive on-line education (IP13). The new IP tasks for 2025-2028 are the “Safer Climate Initiative” (IP14), “Global South” (IP15) and the “ACCC Roadmap” (IP16).

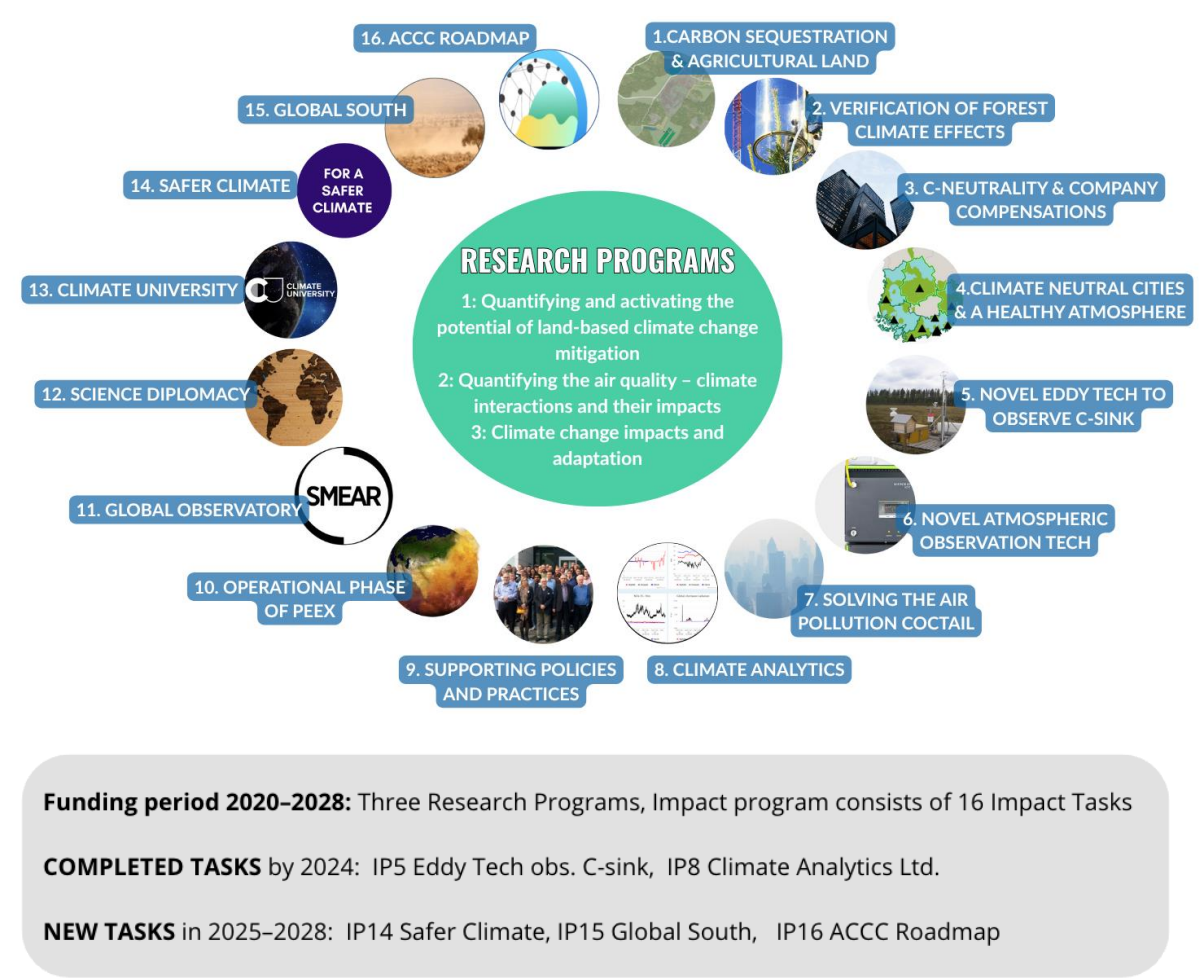


Figure 3. The ACCC Flagship approach with 3 research programs and impact program of 13 impact tasks in 2020-2024. IP5 “Novel Eddy Tech. to observe carbon sink” and IP8 “Climate Analytics Finland

The eight-year period in the Research Council of Finland Flagship program enables the consolidation and strengthening of our research and innovation ecosystem to become internationally recognized.

Ltd.” have been concluded in 2023. For the period 2025-2028 three new IP tasks have been added “Safer Climate Initiative”, “Global South” and “ACCC Roadmap”.

Externally funded projects are the core of the ACCC Research and Impact Programmes. The ACCC carries out annually over 200 projects with a large number of partners and stakeholders. In the APPENDIX “Project Portfolio” the ensemble of ongoing projects (funded by the Research Council of Finland, Business Finland, European Union Horizon 2020 and Horizon Europe, European Space Agency, private foundations) are introduced in different ACCC sectors e.g. research, research infrastructure and education. The ACCC R&I ecosystem includes other externally funded activities, like projects funded by several foundations and ministries like Ministry of Education and Culture, Finland.



(Chapter 2.5), boosts the use of research findings in an innovation ecosystem and enhances birth of new practical solutions and internal innovation screening (internal Slush event) will be carried out in 2025-2028. Such solutions can be for example new atmospheric instruments, climate/air quality analysis services or improved verification services for global auditing sector. In addition, ACCC has signed Letters of Commitment(s) (LoCs) with 52 organizations (status in October 2025; see APPENDIX III LIST OF ACCC COLLABORATORS (LoC)).

The ACCC research and innovation ecosystem includes over 600 stakeholders representing partners from different public and private sectors of the society (e.g. academic, government, ministries, church, NGOs, cities, municipalities and different types of networks or coalitions, including extensive EU research infrastructures (Figure 4.). The ACCC collaboration and interaction with stakeholders facilitates climate policies and optimized mitigation and adaptation plans from national to international scales. The company collaboration, like the ACCC Innovation Forum



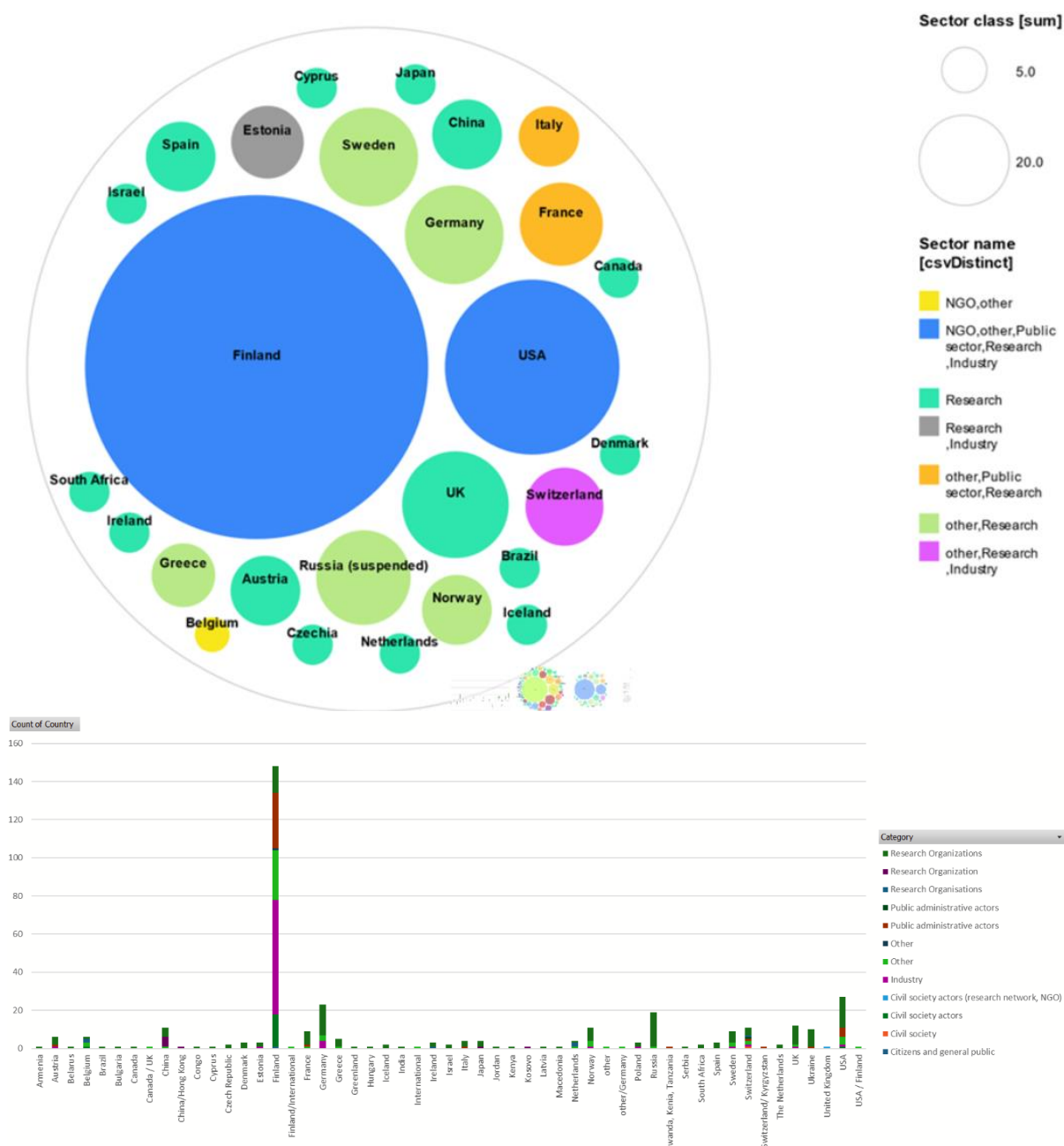
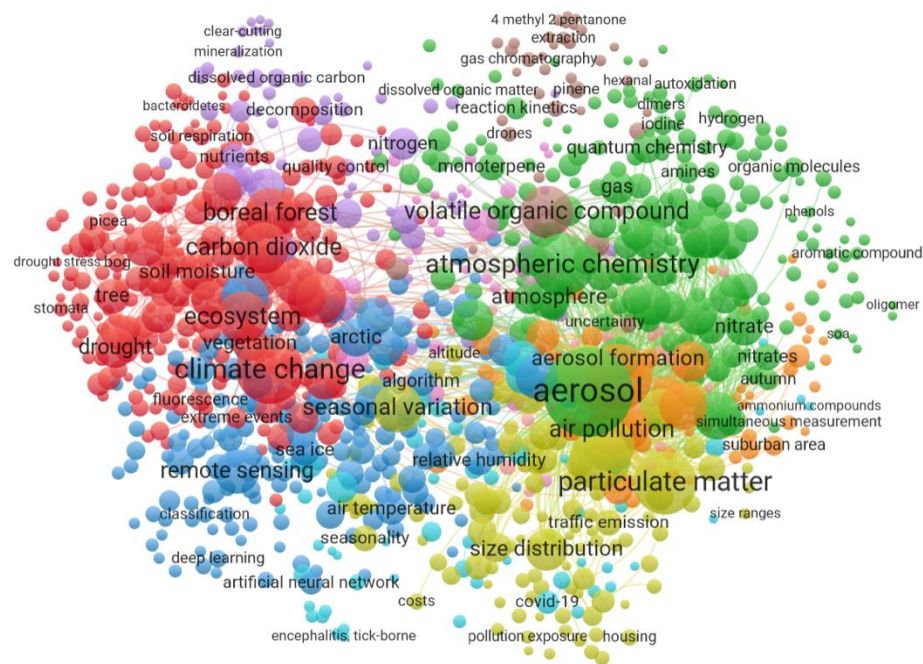


Figure 4. The ACCC stakeholders by country (a) and by country and sector (b). ACCC stakeholders by country and sectors. Circles = each circle represents a country, and the size of the circle is proportional to the number of stakeholders from that country. Color = indicates which combination of sectors are present in that in circle (country). Sectors include NGOs (9), Public sector (87), Industry (160), Research (312), and other (55). Finland and USA include stakeholders from all five sectors. Data used is the list of ACCC stakeholders by sector and country, visualized using RawGraphs (Infograph, Mikko Kulmala). Stacked bar chart illustrates the distribution and count of various organizational categories (like Industry, Research, and Public Actors) across different countries and regional groupings. Visualized using Excel (Mikko Kulmala).

2.2 RESEARCH

2.2.1 Research overview



ACCC research programs produce knowledge and develop methods on atmosphere-ecosystem interactions, which can for instance be used to verify greenhouse gas emissions and sinks, identify key drivers and processes behind pollution episodes, and identify feedback processes between ecosystems, climate and air quality. ACCC research produces strong science-based knowledge and know-how useful to policies in forestry, agriculture and other land use, food production, air quality and health.

In Finland, the carbon neutrality goal highlights the importance of the Land Use, Land-Use Change and Forestry (LULUCF) sector. Optimization of land-use between forestry, forest conservation and agriculture will lead to well targeted regional and global integration of forest and climate policies. The profound process understanding of GHG fluxes and other climate forcers when combined with ecosystem processes understanding paves the way for extending the efficient land use sector mitigation activities outside the Arctic-Boreal ecosystems.

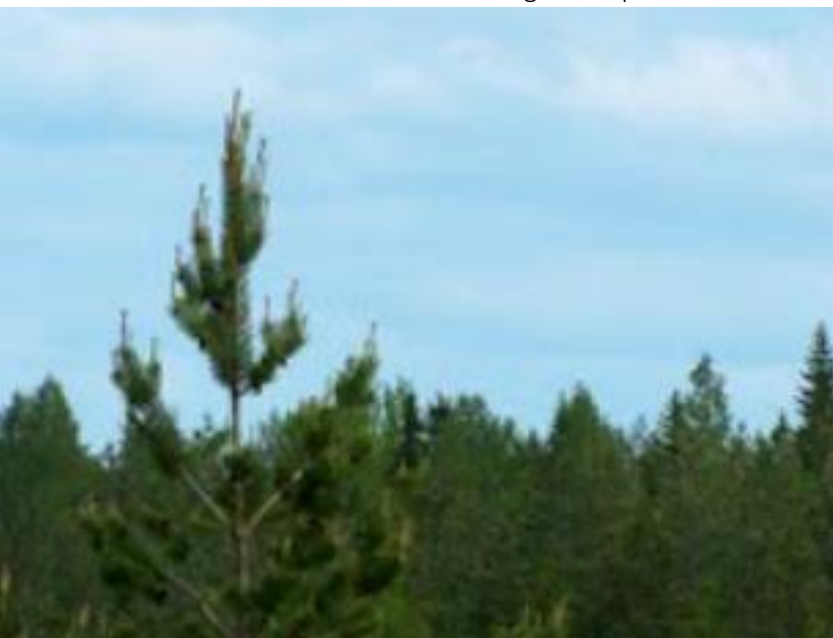
In addition, ACCC improves the tools currently applied for the Finnish and European air quality legislation in terms of their applicability to quantify both climate and health impacts of technological solutions and systemic changes towards non-fossil society.

One key target is to improve air quality and climate impact analysis on the use of renewable fuels and/or electricity instead of fossil fuels in traffic. Our advancements in verifying natural carbon sinks and quantifying climate impacts of combustion emissions allow development of effective and verifiable options for emission compensation.

The ACCC research programs (RPs 1,2,3) collaborate within the research environment by organising opportunities for interaction in terms of workshops and symposia, writing joint publications and journal special issues, providing input for national and EU regulation proposals, and actively developing further research activities e.g. via joint proposals. As a whole the ACCC research outcomes, quantified assessments are disseminated to policy making and co-design processes at large scales (see PART 3 Roadmap by 2028). This activity connects the ACCC work to international bodies and invites them to co-design the main deliverables enabling large-scale influence on policy making at regional and global scales.

2.2.2 Quantifying and activating the potential of land-based climate change mitigation (Research program 1)

Terrestrial ecosystems take up one third of the carbon dioxide emitted annually by human activity (Friedlingstein et al., 2022) and are thus crucial for regional and global climate neutrality targets. Despite the importance of terrestrial carbon sinks on climate, we still lack understanding of how different land use and management practices affect local carbon sinks and sources. In addition to



carbon sinks (Aslan et al. 2024; De Quesada et al. 2025), terrestrial ecosystems have other climate effects, such as albedo, aerosol-cloud-climate (Ke et al. 2025; Kulmala et al. 2024; Peräkylä et al. 2025; Virtanen et al. 2025; Kulmala et al., 2020) and water cycle effects, that feed back to ecosystem functioning and plant growth (Bilchner et al., 2024; Ezhova et al., 2025). These climate impacts are less studied. In practice, photosynthesis is always accompanied with emissions of volatile organic compounds to the atmosphere as a side product, and therefore carbon sinks are connected to aerosol production and furthermore to aerosol-cloud-climate interactions (Petäjä et al., 2022; Yli-Juuti et al., 2021).

Despite of increasing understanding of the various interactions and feedbacks that exist between the different Earth components, i.e. the biosphere, atmosphere, hydrosphere and geosphere, and the source of uncertainty these feedbacks bring to climate estimates, the different Earth components are typically studied separately. Such an approach does not allow for study of the interfaces between the Earth components (such as between the biosphere and the atmosphere), where the interactions and feedbacks take place. The mitigation pathways like restoration of peatlands, afforestation of agricultural fields, managing forests and agricultural lands for increased carbon stocks are recognized to include large uncertainties (Harper et al., 2018; Kalliokoski et al.; 2018, Demenois et al., 2020) whose unraveling calls for a transdisciplinary research. Furthermore, as cities globally are increasingly interested on reaching carbon neutrality or even negativity, climate mitigation potential is gaining more and more attention. ACCC will provide the needed information to support their planning and decision making towards carbon neutral future.

Our aim is to quantify and activate the potential of land-based climate change mitigation, by 1) improving estimates and verification of GHG sources and sinks in terrestrial ecosystems (including inland waters), 2) producing reliable predictions and verification of terrestrial feedbacks to radiative forcing, 3) quantifying the full climate impacts of land use, land use changes and forestry,

accounting for GHG balances, albedo effects, aerosol-cloud-climate and water cycle effects, and feedbacks to ecosystems, and 4) identifying and developing agricultural practices optimizing soil carbon sequestration, as well as stand-level forest management practices that simultaneously optimize the value of carbon storage (including long-lived wood products), biodiversity, and the economic value of forest production. We use our comprehensive, integrated long-term field measurements from SMEAR stations (Kulmala 2018; 2021) that allow studying the interactions and feedbacks between the different Earth components. The field measurements are combined with carefully designed manipulative field and laboratory experiments, satellite observations and multiscale modelling.



To quantify different climate impacts of terrestrial ecosystems and their interactions and feedbacks as well as to gain knowledge that helps solving interlinked environmental grand challenges a holistic approach is needed. This calls for integrated measurements, but also for transdisciplinary collaboration and active interaction with different stakeholders. To get from deep understanding to reliable verification and practical solutions the ACCC RP1 ecosystem consists of ACCC research organizations, science collaborations (e.g. Luke, SYKE), education collaborations (all Finnish universities through Climate University), research infrastructure collaborations (e.g. INAR RI, ICOS, ACTRIS, eLTER, AnaEE), collaboration with enterprises (food, forest and technology companies), cities (e.g. Turku, Espoo, Helsinki, Lahti, Joensuu) and associations (e.g. Tapio, MTK, Metsäteollisuus ry.) and interaction with policy makers. New scientific knowledge can be applied via various routes into mitigation actions, but it always involves farmers or forest owners. In between, there are various simultaneous pathways through open online education, associations and other organizations involved in knowledge transfer, policy making and legislation, general knowledge and consumer behavior, open data solutions to support practical decision making and other verification activities.

For the project details see APPENDIX “Project Portfolio”

Projects on carbon balance and sequestration in agriculture lands

- *Integrated Research Infrastructure Services for Climate Change Risks ([IRISCC](#))*
- *Multi-benefit solutions to climate-smart agriculture ([MULTA](#))*
- *From Footprints to Digital Handprints - Carbon and greenhouse gas budget of agriculture ([FF2DH](#))*

Projects on carbon balance and climate mitigation in forests, peatlands and lakes

- *Holistic infrastructure for knowledge on land-use sector carbon sinks and emissions tracking ([HIKET](#))*
- *Quantifying the potential of boreal peatland rewetting for climate change mitigation ([SA-RESPIT](#))*

- *Peatland restoration for greenhouse gas emission reduction and carbon sequestration in the Baltic Sea region ([EU-LIFE Peat Carbon](#))*
- *The role of snowpack and soil freezing in controlling winter season wetland methane emissions ([SA-WINMET](#))*
- *Using remote sensing observations together with a novel terrestrial biosphere model to understand global carbon and nitrogen cycles ([RESEMON](#))*
- *Fiducial Reference Measurements for Greenhouse Gases ([FRM4GHG](#))*
- *Upgrading knowledge and solutions to fast-track wetland restoration across Europe ([EU-WETHORIZONS](#))*
- *Verifying Emissions of Climate Forcers ([EU-EYE-CLIMA](#))*
- *Mechanistic remote sensing of forest climate impacts ([MONOCLE](#))*

Mitigation

- *Quantifying the potential of boreal peatland rewetting for climate change mitigation ([RESPEAT](#))*
- *Impact of Nanoplastics Pollution on aquatic and atmospheric Environments ([NaPue](#))*
- *Wetland restoration for the future ([ALFAWETLANDS](#))*

Forests, tree ecophysiology projects

- *Resolved optical ecophysiology: leaf level ([REDEYE](#))*
- *The Hidden Role of Gases in Trees ([HidRoGaT](#))*
- *The role of bark in tree survival under drought stress ([ROBAST](#))*



2.2.3 Air quality– climate interactions (Research program 2)



The composition of the Earth’s atmosphere is a crucial factor that influences the human population and the whole ecosystem. Human activities cause significant change to this composition, which leads to a number of negative effects. The most crucial are the ongoing warming of the climate and unhealthy air quality. These developments threaten to move humanity and the whole ecosystem out of the safe operating space of planetary boundaries (Rockström et al., 2009). Furthermore, due to the ongoing green transition with decreasing carbon emissions and enhanced emission technologies we are expecting large changes in the atmospheric composition particularly in urban areas where population is most exposed to pollutants. It is commonly accepted that urgent action to avoid further deterioration of the atmosphere is required. However, actions to address climate change and air pollution are undertaken separately.

This separation is artificial, unnecessary, inefficient, and even dangerous: climate change and air pollution share many of the same root causes, and their causal chains from the initial human action to observable effect include the same compounds as well as physical and chemical processes (Fiore et al., 2012; Samset, 2018). Despite this, communities involved in climate research often operate separately from researchers working in the air quality field, and climate targets of human activities are considered separately from air quality objectives. Thus, activities and emissions are evaluated either based on their impact on climate, or the potential harm they may cause to the health of organisms, but not both simultaneously. This may lead to situations where regulation in one area leads to either joint positives (e.g., black carbon) or opposite effects (sulphur emission regulation), possibly leading even to wrong conclusions of the impacts and the best mitigation measures.

In research program 2, we study the atmospheric processes where this dual impact has been identified, with the aim of providing research results on both the climatic and human health aspects of air pollutants. The emphasis in our studies is on aerosol formation and emissions, since aerosol particles are the main concern in air quality deterioration and the largest source of uncertainties in the predictions of the future state of the climate due to their interactions with clouds and radiation. To improve understanding of health and climate effects of aerosols, we conduct research to quantify how primary aerosol (i.e., particles emitted to atmosphere already as particles) and secondary aerosol formation (i.e., formation of particulate matter from gas phase molecules in the atmosphere) from anthropogenic and biogenic sources shape the atmospheric particle concentrations and size distributions in different environments and under different meteorological conditions from anthropogenic aerosols in the lower troposphere to fire smoke in free troposphere and airplane trails in UTLS. We investigate the influence of primary and secondary aerosols on climate by improving the description of airborne formation, anthropogenic and natural emissions and atmospheric processes of

aerosols in different scale models under scenarios considering atmospheric feedbacks, environmental changes, technological advancements and systemic level changes. We also synthesize the in-situ and remote-sensing observations and model simulations to evaluate the models and to determine the processes that are not well presented in them. Finally, we study the legal frameworks related to climate and air quality policies and disseminate the conceptual and quantitative understanding arising from our research towards the decision makers and general public.

We have identified a number of target areas which are under active study and which we develop to understand: i) atmospheric inorganic and organic chemistry leading to secondary aerosol formation in high and low pollution environments, ii) number and size distribution of aerosol particles emitted from different anthropogenic activities, including the particulate matter forming immediately after the emissions to atmosphere from combustion sources, iii) co-emissions of primary particles and secondary aerosol precursors with the emphasis on traffic sources, iv) influence of local and regional meteorological conditions on aerosol formation and the interactions between air pollution and meteorology. These research areas are closely linked with changes in the technological matrix resulting from both climate- and air quality –based regulatory actions, and the aim of the research program is to accelerate the path of the new scientific knowledge to relevant stakeholders in the field.

The relevant research environments in our field comprises of companies, research institutes, research organisations and governing bodies. ACCC RP2 has created links with a number of them:

- Research institutes involved in impact assessments: International Institute for Applied System Analysis (IIASA), Finnish Environmental Institute (SYKE), Netherlands Organisation for Applied Scientific Research (TNO), Swedish Environmental Research Institute (IVL), Onera
- Cities and regional-level actors: Helsinki Region Environmental Services (HSY), Cities of Helsinki and Tampere (FI)
- Ministries, such as the Ministry of the Environment
- Universities within and outside Europe: Nanjing University, Beijing University of Chemical Technology (BUCT), Indian Institute of Technology (IIT) Delhi, Tsinghua University, LAT
- International projects multiple partners and their own stakeholder networks such as
 - DownToTen (<http://www.downtoten.com/>)
 - SCIPPER (<https://www.scipper-project.eu/>)
 - Tube (<https://www.cam.ac.uk/stories/london-underground-pollution>)
- Direct collaboration with companies working on measurement and instrumentation in the climate, emissions, and air quality space: Airmodus, Pegasor, Dekati, Vaisala, UseLess
- International-level communities for that collect together researchers and other actors in specific topics, such as the Copernicus Atmosphere Monitoring Service CAMS, European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) and the atmospheric modelling community

For the project details see APPENDIX “Project Portfolio”

Climate modelling projects

- *Constrained aerosol forcing for improved climate projections (FORCeS)*
- *Climate relevant interactions and feedbacks: the key role of sea ice and snow in the polar and global climate system (CRices)*
- *GreenFeedBack*
- *Non-CO2 forcers and their climate, weather, air quality and health impacts (FOCI)*
- *Digital Twin of Earth system for Cryosphere, Land surface and related interactions (TerraDT)*

Weather modelling projects

- *Unifying Numerical Weather Prediction and Precise Orbit Determination of Global Navigation Satellite Systems*

- Quantifying controls on the intensity, variability and impacts of extreme European STORMS

Atmospheric chemistry, BVOCs and aerosols projects

- Satellites supporting air quality monitoring in Finland, projects 1 and 2
- Processes in organic aerosol particles in the boreal environment (PROBE)
- Chasing pre-industrial aerosols, ERC project (CHAPAs)
- Deep into abyss: resolving the charger ions
- Molecular understanding on the aerosol formation in the high Arctic
- Antarctic Climate Forcing Aerosol (ACFA)
- Importance of aqueous phase processing of organic aerosols in Boreal areas (AquBor)
- Rate estimation and uncertainty quantification of aerosol microphysical processes
- Grow or die: new particle growth in the polluted environments
- Soil reactive emissions from boreal forests: impact of soil properties and effects on atmospheric chemistry (SOREMI)
- Vegetation Fires and Smoke Pollution Warning and Advisory System for Europe (VFSP-WASE)

Biogenic Volatile Organic Compounds (BVOCs), bioaerosols, and peatland projects

- Quantifying missing pieces of the boreal BVOC budget: exchange of BVOCs in boreal peatlands and implications for the formation of secondary organic aerosols
- Sesquiterpene emissions and their impact on atmospheric chemistry (SEIAC)
- A SYstem for reaL-time obserVation of Aeroallergens (SYLVA)
- Towards an overarching understanding of fungal spore dispersion across scales: combining eDNA and flow cytometry with integrated atmopsheric modelling for applications in bioaerosol and biodiversity monitoring (SPORELIFE)

Air Quality, health, and traffic projects

- Autoxidation of Anthropogenic Volatile Organic Compounds (AVOC) as a Source of Urban Air Pollution (ADAPT)
- Transport derived ultrafines and the brain effects (TUBE)
- Shipping Contributions to Inland Pollution Push for the Enforcement of Regulations (SCIPPER)
- Emission Factors of Primary Particles, Secondary Particulate Matter and NO_x for the Passenger Car Fleet in Finland (EFFi)

CouSCOUS - Sustainable urban development emerging from the merger of cutting-edge Climate, Social and Computer Sciences

Ocean studies

- Polar Regions in the Earth System (PolarRES)
- The impact of Antarctic Ice Sheet - Southern Ocean interactions on marine ice sheet stability and ocean circulation (COLD)
- Impact of Nanoplastics Pollution on aquatic and atmospheric Environments (NaPuE)

Nitrogen studies

- A combined experiment and modelling approach to quantify the nitrous oxide budget of permafrost regions (N-PERM)
- Microbial mechanisms regulating N₂O metabolism in above-ground vegetation - significant northern N₂O sink?
- Emissions of reactive nitrogen gases (HONO and NO) from northern peatlands - Unraveling the nitrogen cycle in northern soils under changing climate (ERNO)
- Fate of nitrogen released from thawing permafrost: from microbial transformations to gaseous losses (Thaw-N)

Greenhouse gases and improving the satellite retrievals projects

- Methane in the Arctic in support of Arctic Methane and Permafrost Challenge (AMPAC) (MethaneCAMP)
- Study on Improved Glint Retrieval for CO₂M (SNOWITE)
- Urban challenge of CO₂ observing satellites: From aerosol scattering towards verifying CO₂ emission reductions from space (CitySpot)

2.2.4 Climate change impacts and adaptation (Research program 3)



The impacts of climate change are manifold and include many risks, even existential. While it is paramount to continue efforts to mitigate climate change as much as possible, it is also important to brace for the changes that can no longer be avoided. Many extreme weather events (e.g., droughts, heavy rain, flooding, windstorms) are projected to both intensify and occur more frequently in the future, and climate zones are projected to shift. This may have effects on, e.g., security, human health, economy, and biodiversity and the whole ecosystem. In order for society to adapt to climate change, we need to understand and quantify the risks involved. Further research is needed to find solutions to climate change

adaptation and how to effectively implement them. At the same time, it is important to consider climate change adaptation and mitigation simultaneously to maximise synergies and minimize conflicts. We also need to understand how to prioritise different solutions, which may be different for different locations. For instance, in city planning, measures to adapt to the impacts of heat waves may stand in contradiction to climate change mitigation aims.

In addition, research is needed on how to legally enact and support climate change adaptation and mitigation at all levels of legislation. It is important that climate legislation is transparent and just for everybody. Furthermore, climate change mitigation in the required time frame is not achievable through legislation alone but also requires a shift in human attitude and behaviour. Therefore, continued effort is needed to increase the dialogue between the science community, education providers, stakeholders, and the public. It is important to understand how to present research results to different audiences in order to best serve the needed societal transition.

Our aim is to quantify the extent of different climate change impacts, particularly in the Nordic countries, and to study options to prepare society for these impacts by 1) monitoring weather variables that contribute to climate change impacts, 2) quantifying climate risks, which is a combination of climate hazard, exposure, and vulnerability, 3) identify different physical, legal, and societal options to climate change adaptation and mitigation, and 4) study how climate change impacts, mitigation, and adaptation affect society, infrastructure, and economy.



We use existing climate model data combined with data from a constantly increasing number of weather observations, socio-economic and demographic data and scenarios, as well as the latest

knowledge on climate vulnerability. We also develop new methods to model the impacts of climate change by combining modelling tools from different fields of science.

We constantly work on improving climate science communication through many different channels, including for this purpose designed websites ilmastokatsaus.fi and ilmasto-opas.fi, and developing new climate services.

To quantify the different physical and societal impacts of climate change requires a multi-disciplinary collaboration of researchers from different fields, including climate, social, economic, legal sciences. It also requires active interaction with different stakeholders and the broader public. The ACCC RP3 ecosystem consists of the ACCC research organizations and other research collaborators like the Finnish Environmental Institute (SYKE).

For the project details see APPENDIX “Project Portfolio”

CC impacts and adaptation projects

- *Artificial Intelligence for Urban Low-Emission Autonomous Traffic ([AlforLessAuto](#))*
- *Individuals, communities, and municipalities mitigating climate change by carbon smart green space ([CO-CARBON](#))*
- *Urban green space solutions in carbon neutral cities ([CarboCity](#))*
- *Water-based solutions for carbon storage, people and wilderness ([WaterLANDS](#))*
- *Locally tailored climate service for Finland ([TAPSI](#))*
- *Carbon NEutral MUunicipalities and REgions ([CANEMURE](#))*
- *CLIMAtE risk and vulnerability Assessment framework and toolboX ([CLIMAAX](#))*
- *Piloting Innovative Insurance for Adaptation ([PIISA](#))*
- *Validated Local Risk Actionable Data for Adaptation ([VALORADA](#))*
- *CRITICAL action planning over EXtreme-Scale DATA ([CREXDATA](#))*
- *Smart Land Use Policy for Sustainable Urbanization ([SmartLand](#))*
- *Heat and Health in the Changing Climate ([HEATCLIM](#))*
- *Securing Nordic linear infrastructure networks against climate induced natural hazards (Nordforsk NordicLink)*
- *[DestinE Climate Digital Twin](#)*
- *Adaptation Means of Reindeer Husbandry ([CLIMINI](#))*
- *Exposure to heat and air pollution in EUrope – cardiopulmonary impacts and benefits of mitigation and adaptation ([EXHAUSTION](#))*
- *MARine and WEather events in the changing CLimate as potential external hazards to nuclear safety ([MAWECLI](#))*
- *Vector-borne diseases and climate change in finland: mapping, modelling, mitigation ([VECLIMIT](#))*
- *Climate change and Health: Adapting to Mental, Physical and Societal challenges ([CHAMPS](#))*
- *CRYOsphere Science Concluding in new Observations and Productive Exploitation ([CryoSCOPE](#))*
- *[DestinE Climate Digital Twin stage 2](#)*
- *[ILMOS Uusimaa](#)*

Green transition projects

- *Pilot Application in Urban Landscapes - Towards integrated city observatories for greenhouse gases ([PAUL](#))*
- *Assessing Sectoral Perspectives on Climate Transitions to support the Global Stocktake and subsequent NDCs ([NDC Aspects](#))*
- *The European Green Deal: Governing the EU's Transition towards Climate Neutrality and Sustainability, EU – Jean Monnet Network project ([GreenDeal-NET](#))*
- *Leaving No One Lost in Transition: Citizens and the Legitimacy of Finland's Transition to a Carbon Neutral Welfare State ([2035legitimacy.fi](#))*

- Facing system change together: Citizen deliberation in informed and just climate transitions (FACTOR)
- Strengthening democratic governance for climate transitions (RETOOL)

Climate law projects

- Investment, Infrastructure, Innovation and sector Integration: TRAnsformative policies for a ClimaTe-neutral European UnION (www.4i-traction.eu) (4I-TRACTION)
- Transformative Transparency? Assessing the Effects of Reporting and Review in the International Climate Change Regime (TRANSCLIM)
- Resilient forest value chains – enhancing resilience through natural and socio-economic responses (RESONATE)
- Finnish Scenarios for Climate Change Research Addressing Policies, Regions, and Integrated Systems (FINSCAPES)
- Achieving High-Integrity Voluntary Climate Action (ACHIEVE)
- Voluntary carbon offsetting in (climate) action: Perception coalitions, representations, and regulation (OFFCORR)
- Science-based legal pathways to reduce black carbon emissions in the EU and China. Towards integrated climate – air quality approaches (ClimAirPathways)
- Regulatory Cooperation on Carbon Standards (RECOSTA)

Education projects

- Learning of the competencies of effective climate change mitigation and adaptation in the education system (ClimComp)

2.2.5 Finnish Center(s) of Excellence (FCoEs)

In the ACCC R&I ecosystem we have three Centres of Excellence funded by the Academy of Finland. “Centre of Excellence in Tree Biology” (INAR, <https://www.helsinki.fi/en/researchgroups/centre-of-excellence-in-tree-biology>) in 2022-2029, studies the carbon sequestration in trees. The potential improvement of sequestration to mitigate climate change requires knowledge from and interaction between many scientific disciplines and sectors of society. Understanding of the carbon sink effect in trees at a molecular level is still relatively superficial compared to many other aspects of this complex problem.

The Centre of Excellence Virtual laboratory for molecular level atmospheric transformations” (VILMA, <https://wiki.helsinki.fi/display/VILMA/>) (INAR, TUNI), in 2022-2029, aims to generate a virtual laboratory composed of multitude of digital twins of real-life instruments commonly used to study the state of the atmospheric environment. This virtual laboratory approach tackles the huge combinatorial problem related to atmospheric particulate matter formation and evolution to resolve the processes controlling ambient new particle formation and growth under various experimental conditions relevant to Earth's atmosphere. The CoE VILMA combines atmospheric and computer science to construct a virtual laboratory for atmospheric aerosol formation, interactively integrating experimental and theoretical state-of-the art methods from the fields of chemistry, physics and artificial intelligence.

The “Centre of Excellence of Inverse Modelling and Imaging” (INVERSE FINLAND, <https://www.helsinki.fi/en/researchgroups/centre-of-excellence-of-inverse-modelling-and-imaging>) (UH, FMI, TUNI), 2018-2025, is specialized in the theory, implementation and application of inversion

methods. The objective of the INVERSE FINLAND is to create fundamentally new, efficient, and theoretically sound solutions to practical inverse problems.

2.3 RESEARCH INFRASTRUCTURE (RIs)



2.3.1 RI overview

The Research Infrastructure (RI) ecosystem of ACCC extends from the national scale to European and global scales. The RI ecosystem consists of e.g., observational networks, databases, and services that serve to produce open data for research, promote research collaboration and enhance research and innovation capacity and also function as platforms for researcher training. The RI implementation, development and operations are funded by the hosting organizations and projects (mainly by Research Council of Finland FIRI projects and EU projects).

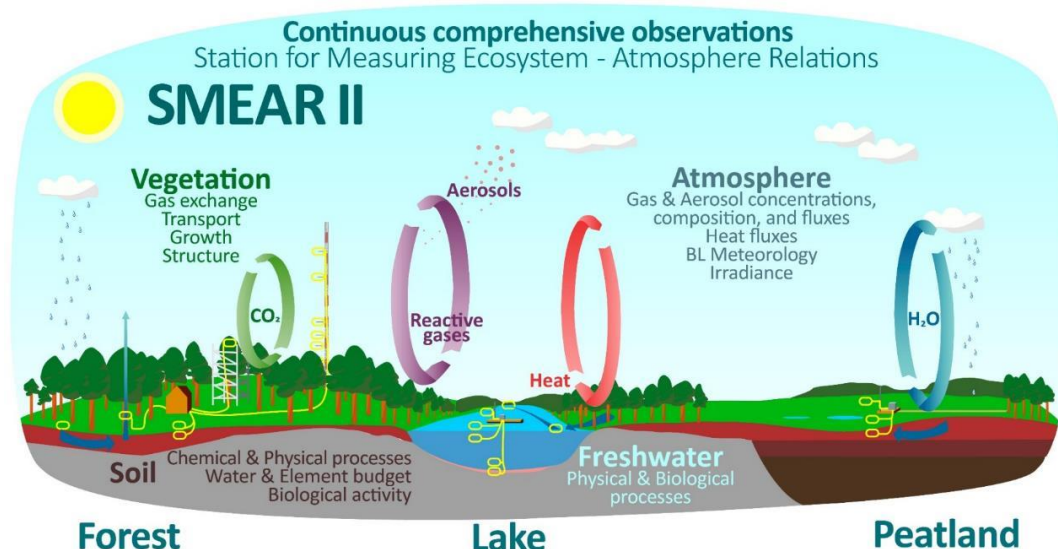
Integrated Atmospheric and Earth System Research Infrastructure (INAR RI) is the ACCC's national state-of-the-art research infrastructure (RI) providing extensive set of open high-quality long-term continuous atmosphere-ecosystem data and services supporting and enhancing research and innovation activities. The cornerstone of INAR RI is the network of advanced field stations such as Pallas-Sodankylä and the SMEAR (Station for Measuring Earth Surface – Atmosphere Relations) station network in Finland (<https://www.atm.helsinki.fi/SMEAR/index.php>). At the European level ACCC, via INAR RI, is part of several large-scale European environmental research infrastructures (ICOS, ACTRIS, eLTER, AnaEE). ACCC partners have been in the leading role in preparations of the establishment of the ICOS ERIC (est. 2015) and the ACTRIS ERIC (est. 2023). Both ICOS ERIC and ACTRIS ERIC head offices are located in Helsinki (University of Helsinki /Finnish Meteorological Institute Kumpula campus). ACCC is also actively involved in the European level collaboration of environmental RIs e.g., building FAIR services for research, innovation and society (ENVRI-FAIR), establishing comprehensive and sustainable framework for access to distributed atmospheric RIs (ATMO-ACCESS), creating a common innovation roadmap for the environmental RIs (ENVRINNOV), enhancing urban air quality monitoring and related services (RI-URBANS), and developing services to foster cutting-edge research and evidence-based policymaking to improve Europe's resilience to climate change (IRISCC).

). ACCC via INAR RI acts as an example for other European measurement stations in co-locating environmental observations, i.e., having measurements of several European level RIs at one measurement site.

These kind of coordinated and integrated observations in the atmosphere–ecosystem domain are key in helping the societies to respond and find best practices related to climate change, mitigation and adaptation, land-use change, environmental degradation and poor air quality. On a global level, ACCC is providing its expertise and support in establishment and implementation of in situ observation systems and co-operating stations outside of European borders, e.g., in polar regions, Africa, China and India. ACCC is also promoting the GlobalSMEAR (<https://www.atm.helsinki.fi/globalsmear/>) initiative towards integrated Earth observatory with a long-term vision of having a measurement network of 600-1000 observatories with high-level instrumentation carrying out observations on Earth surface - atmosphere relations: concentrations, profiles, fluxes, processes and feedbacks across disciplines.

2.3.2 National Research Infrastructures (RI)

Integrated Atmospheric and Earth System Research Infrastructure (INAR RI)



INAR RI (<https://www.helsinki.fi/en/inar/infrastructure/national-research-infrastructures>) is an umbrella RI, coordinating the distributed national nodes of European environmental research infrastructures (ICOS (<https://www.icos-cp.eu/>), ACTRIS (<https://www.actris.eu/>), eLTER (<https://elter-ri.eu/>) and AnaEE (<https://www.anaee.eu/>)). The national INAR RI sister infrastructures are ICOS-FI (<https://www.icos-finland.fi/>), ACTRIS-FI (<https://www.helsinki.fi/en/infrastructures/actris-finland>), LTER-FI (<https://www.helsinki.fi/en/networks/finnish-long-term-ecosystem-and-socio-ecological-research>) and AnaEE-FI (<https://anaee.fi/>). INAR RI is benchmarking in the integration of multidisciplinary comprehensive environmental measurements with 30 stations, several laboratories and mobile units and a data infrastructure. The mission in INAR RI is to co-locate these different environmental RIs and integrate comprehensive long-term in-situ measurements with remote sensing, experimental approach and modelling in order to quantify and predict current and future climate change impacts on ecosystem functioning, and to provide harmonized comprehensive and open big data to unravel mechanisms involved in ecosystems' responses and feedback to climate, as well as to select and test mitigation and adaptation measures. With integration of national nodes of several European environmental RIs, INAR RI is a benchmark RI in Europe, where such integration is still not actively implemented.



INAR RI has been on the national RI roadmap since 2014. Along the national RI roadmap update for 2025-2028 INAR RI was selected as one of six “Lighthouse” research infrastructures. Lighthouse status was granted to RIs that have been the most successful infrastructures in the roadmap call, and lead the way in all key infrastructure areas, such as service provision, impact, functionality and shared use. The lighthouses are showcases of and spearheads for the service offer and impact of roadmap RIs. INAR RI lighthouse received funding from RCoF for further developing the RI interoperability and capacity 2025-2029.

Each INAR RI sister RI is proceeding in different phases at European level and therefore some INAR RI components are already established while others are still under development. However, the national parts of INAR RI are in operation and delivering data. In the next years, INAR RI community continues to work towards integration of the environmental measurements, upgrade the existing observational sites and exploratory platforms to guarantee and improve the representativeness and quality of the measurements, establish new measurement sites, and develop services. In addition, INAR RI continues to be active on the European level. Outside Europe, we coordinate and support building Global SMEAR (<https://www.helsinki.fi/en/inar/infrastructure/global-smear>) station network.

Projects:

- *RCoF FIRI2021 project, INAR RI - Integrated observations for effective climate solutions in terrestrial ecosystems, 2022-2025*
- *RCoF FIRI2023 project, INAR RI – Upgrading capacities for air quality and climate actions in urban and agricultural environments, 2024-2027*
- *RCoF FIRI2024 project, INAR RI – Interoperability, co-location and capacity building, 2025-2029*

Station for Measuring Earth Surface-Atmosphere Relations (SMEAR)

Stations for Measuring Earth Surface---Atmosphere Relations (SMEAR) stations (<https://www.atm.helsinki.fi/SMEAR/index.php>) produce comprehensive, simultaneous measurements on atmosphere, Earth surface and biosphere, covering meteorology, atmospheric composition and fluxes, as well as ecosystem variables (Hari et al. 2005, Hari & Kulmala 2005). There are four SMEAR stations in Finland and the recently established new station setups called SMEAR-Agri and SMEAR-Costal-Marine operated by ACCC partner organization UH, UEF and FMI and stations also outside of Finland that UH has supported in implementation and starting of the operations (SMEAR Estonia, SORPES - Station for Observing Regional Process of Earth System station by University of Nanjing 2010 -, Beijing station by University of Chemical Technology (BUCT) 2018 -). SMEAR I station in Värriö, Eastern Lapland, owned by UH started its operations in 1991. SMEAR II station in Hyytiälä, Central Finland, owned by UH have been operating since 1995. SMEAR II station is our flagship station, the most advanced SMEAR station. SMEAR II station is carrying out measurements 24/7 on 1200 parameters on different ecosystems: a boreal forest, a wetland and lakes. SMEAR III urban measurement station (Helsinki) operated by UH and FMI started the operations in 2004. The Puijo measurement station in Kuopio, owned by UEF and FMI, joined the SMEAR network in 2009 and became the SMEAR IV station. SMEAR- Agri, owned by UH, is the newest addition to the Finnish SMEAR station network (<https://www.helsinki.fi/en/infrastructures/inar-ri-agriculture/measurement-sites>). SMEAR-Agri is an agricultural measurement station in Helsinki that started its operations in September 2021. SMEAR-Costal-Marine is part of a new “The Centre for Coastal Ecosystem and Climate Change Research” project (CoastClim <https://www.coastclim.org/>), where the SMEAR measurements in the marine environment are being developed. SmartSMEAR (<https://smear.avaa.csc.fi/>) is a data visualization and download tool for the database of continuous atmospheric, flux, soil, tree physiological and water quality measurements at SMEAR research stations

in Finland. The stations are contributing to global earth observation systems and networks such as World Meteorological Organization (WMO) – Global Atmospheric Watch (GAW), Group of Earth Observation (GEO) - The Global Earth Observation System of Systems (GEOSS), FluxNet (<https://fluxnet.org/about/>), AERONET (<https://aeronet.gsfc.nasa.gov/>) and SolRad-Net (<https://solrad-net.gsfc.nasa.gov/>), and to the European Research Infrastructures such as ICOS, ACTRIS, AnaEE and eLTER.

In Europe INAR/ACCC is setting up a new observation site at Peya site in Cyprus in collaboration with Cyprus Institute and discussion on several new ones (<https://cao.cyi.ac.cy/emme-care/>). We are also developing measurement concepts and stations in cooperation with other foreign Partners, especially in China, India and South Africa (chapter 2.5.9).

Pallas Atmosphere – Ecosystem Supersite

The Pallas Supersite consists of versatile research infrastructure for monitoring and studying the atmosphere, ecosystems and their interactions. Pallas is located 170 km north of the Arctic Circle, partly in the area of Pallas-Yllästunturi National Park (<https://en.ilmatieteenlaitos.fi/pallas-atmosphere-ecosystem-supersite>). The Finnish Meteorological Institute (FMI) has a long history of atmospheric monitoring at Pallas: the first weather station was established near Lake Pallasjärvi in 1935. The measurements of atmospheric composition were started in 1991, and the Sammallunturi station was established as a node of the Pallas–Sodankylä Global Atmosphere Watch (GAW, <https://public.wmo.int/en/programmes/global-atmosphere-watch-programme>) station in 1994. Currently, Pallas comprises one of the most important research infrastructures in Finland and in the wider circumpolar region, contributing to numerous European and global research programmes, such as GAW, ICOS (<https://www.icos-cp.eu/>), ACTRIS (<https://www.actris.eu/>) and EMEP (<https://emep.int/>).



SMEAR-Agri

SMEAR-Agri is a new platform to quantify climate and air quality impacts and mitigation potential of northern agriculture. SMEAR-Agri is located at two sites SMEAR-Agri-Viikki-grassland and the SMEAR-Agri-Haltiala-cropland in the Southern Finland. SMEAR-Agri Viikki is a permanent and long-term site. The site is constructed on the fields of Viikki Research Farm hence allowing to study the full farm climate impact. It is located on mineral clay soil, mostly under grassland. The site is constructed during summer 2021. Planned activities include micrometeorological EC system and automated chamber system for CO₂, CH₄, N₂O and H₂O, automated wireless soil measurements, measurements of crop growth and soil chemical, physical and microbial properties. Detailed maps of subsurface drainage offer many experimentation. SMEAR-Agri Haltiala is located on a sandy clay soil in agricultural cropland in northern Helsinki. Crop species at the site are varying, no-till farming/direct-seeding is used. Planned measurements include CO₂ flux, N₂O flux by eddy covariance, CH₄, N₂O, CO₂ fluxes by chambers, leaf area during the growing season and meteorological measurements. Construction of SMEAR-Agri Haltiala is ongoing and it will become a permanent, long-term site. Big questions to be solved are for example: When and in what conditions

is the field a sink or a source of carbon; What agricultural practices reinforce the sink and minimize GHG emissions?; How important is the aerosol cooling effect; Effects of seasonality year to year variability, extreme weather events on GHG fluxes.

SMEAR Coastal Tvärminne, Baltic Bridge

The Tvärminne Zoological Station (TZS), located at the entrance of the Gulf of Finland, is one of the biological research stations at the University of Helsinki. The research at the station focuses on marine/coastal biodiversity and the Baltic Sea ecosystem, monitoring the effects of anthropogenic stressors like eutrophication and climate change. The station was established already in 1902, and starting recently, the already very long marine datasets will be augmented by expanding the research at the station to atmospheric studies. The marine ecology and biogeochemistry research, together with INAR, have formed the Centre for Coastal Ecosystem and Climate Change Research (CoastClim), in order to investigate the links and feedbacks between coastal biodiversity and our climate.

The RI at TZS include a flux tower for measuring GHG exchange, to directly verify the link between the state of the marine ecosystems and the uptake and release of CO₂ and CH₄. In addition, a suite of trace gas and aerosol instrumentation have been, or are being, installed at TZS to monitor the marine impacts on VOCs as well as aerosol particles (both direct primary emissions like sea spray and secondary formation from oxidation of marine emissions), with the ultimate goal to quantify the complete climate impact of the coastal regions of the Baltic Sea.

Urban nature monitoring

We have established new platform to quantify the urban nature – climate interactions in Helsinki region. The main focuses are to quantify the net GHG exchange of diverse urban vegetation and soils, and to understand the cooling potential of different urban vegetation types against life-threatening heat waves. The main monitoring site is around the SMEAR III station and in an allotment garden in Eastern Helsinki, but observations are made over different urban vegetation types around Helsinki including meadows, lawns, and different tree species. The activities include micrometeorological flux measurements using the EC system and automated chamber system for CO₂, CH₄, N₂O and H₂O, automated sap flux and soil measurements, soil chemical and physical properties and manual shoot and chamber observations. One of the interests is to study the impact of construction (i.e. biochar, constructed soils) and management (i.e. irrigation, mowing) on GHG exchanges and well being on different vegetation types to keep up their cooling and photosynthetic potential. We also conduct BVOC emission measurement campaigns.

Health RI

Research stations SMEAR I and II were among 11 stations chosen for nationwide tick monitoring research in Finland in 2012-2018 (Sormunen et al., 2020). This data set can serve to build a spatio-temporal distribution of tick spread as a function of warming climate, and, in particular, help to foresee the dispersal of insects and pathogens to new areas along with climate change.

Besides that, INAR was actively involved in another tick-related research based on the climate data set from the European Russia (Georgiades & Ezhova et al., 2022). The deep learning methods were applied to climatic parameters, the number of tick-related hospital visits, and borreliosis incidence rates in order to predict the dynamics of tick-borne diseases in future. The study revealed an increase in the borreliosis incidence rates in the southern regions and predicted the prolongation of the tick activity season in the warming climate. However, in the north the tick activity season, according to

deep learning analysis, will remain largely the same. The difference can be attributed to the tick species' seasonal dynamics. *Ixodes ricinus*, dominating in the south, is active throughout the warm season, whereas *Ixodes persulcatus* abundant in the north, has a peak activity in late spring – early summer (e.g., Korenberg, 2000, Sormunen et al., 2020).

RI for monitoring and assessment of bioaerosols (plant pollen, fungal spores, bacteria, etc) has been recently modernized and sharply expanded by FMI in collaboration with University of Turku (UTU). It includes: (i) a long-term network of classical Hirst-type samplers (Hirst, 1952) coordinated by UTU (9 sites, Ziska et al, 2019); (ii) new bioaerosol automatic monitoring network coordinated by FMI (presently, 3 sites, Maya-Manzano et al, 2023); (iii) new bioaerosol laboratory for microbiological and molecular analysis of atmospheric DNA established in FMI (Sofiev et al, 2022); (iv) SILAM atmospheric composition model with dedicated pollen, spores, and insect-predicting modules maintained by FMI (Sofiev et al, 2012, 2017, Sofiev, 2019). Together, these infrastructure elements provide a quite comprehensive outlook of the key bioaerosols in the atmosphere, down to species and genus level, for past and future times.

Furthermore, related to the Arctic, INAR researchers investigated climatic factors influencing the anthrax outbreak of 2016 in northwest Siberia (Ezhova et al., 2021). The data set included observations from World Meteorological Organization (WMO) stations and Circumpolar Active Layer Monitoring Network (CALM) sites (Brown et al., 2000) as well as the national health monitoring data. The study revealed the importance of extreme weather events for permafrost thawing, which is considered as a trigger for the outbreak (Timofeev et al., 2019). These extreme events include heat waves and extreme snowy winters, whereas very dry summer weather could contribute to the intensification of the outbreak.

Research infrastructure ACTRIS (see more details below) is the key RI when it comes to supporting the development of the required level of understanding of sources of air pollutants that negatively affect human health. ACTRIS responds to urgent needs to develop research and most suited policies to substantially reduce air pollution across EU by providing enhanced observations but also to support technological research for reducing emissions and support development of new generations of air quality models that will more specifically address citizen's exposure to air pollution. ACTRIS data is important in investigating the health effects of particulate matter (e.g. impacts of urban air quality, air pollution of transport and industry sector). ACTRIS is used for health-related studies and health impact assessments; ACTRIS data is used for modeling the urban and regional scale of health-related atmospheric constituents. ACCC/ACTRIS-FI has had a crucial role in the development of the new EC air quality directive and has been contributing RI-URBANS EU-project, which provides guidance and service tools for EU Member states to implement the new air quality directive. These include e.g., harmonized measurements of ultrafine aerosol particles and black carbon in urban environments in all EU member states. ACTRIS-FI has supported building a platform providing up-to-date air quality information to residents, authorities and businesses in the Helsinki Metropolitan Area. ACTRIS-FI experts are also involved in collaborations investigating the air pollution sources indoor and outdoor and their impact on air quality. Regarding pandemic response, ACTRIS-FI experts have been involved in developing solutions that allow the various functions of society to continue uninterrupted and people to continue to move and live safely despite the epidemics and pandemics (project "E3 Pandemic Response and Enterprise Solutions" funded by Business Finland).

2.3.3 European Research Infrastructures (RI)

Integrated Carbon Observation System (ICOS)

ICOS (Integrated Carbon Observation System, <https://www.icos-cp.eu/>) is a European research infrastructure, which produces standardized and high-precision greenhouse gas data from close to 150 measurement stations across 14 European countries. The stations are directly supported by national funding and are called Station Networks. The stations observe greenhouse gas concentrations in the atmosphere and in oceans, as well as carbon fluxes between the atmosphere, land surface and oceans. Thus, ICOS is rooted in three domains: Atmosphere, Ecosystem and Ocean. Within each domain a Thematic Centre coordinates the observations and supports the stations. In addition to the Thematic Centres, there are Central Analytical Laboratories (CALs) that provide gas analyses and calibration gases.



ICOS operations are coordinated by ICOS ERIC, which is a specific legal entity for European RIs created by the European Commission. ICOS ERIC consists of the Head Office (<https://www.icos-cp.eu/observations/head-office>), coordinating the RI operations, and the Carbon Portal, collecting and distributing ICOS data and derived products (<https://www.icos-cp.eu/observations/carbon-portal>). In addition to coordinating, the Head Office is responsible for administration, management, and development of the RI as well as for communication. The Carbon Portal in turn acts as the platform for the observational data

and elaborated data products of the ICOS RI. It is a 'one-stop shop' for all ICOS data products, a place where ICOS data, along with ancillary data, can be openly accessed by anyone. All ICOS data available in the Carbon Portal are quality controlled by the ICOS Thematic Centres.

ICOS is a part of a diverse RI landscape. In Europe, ICOS collaborates with other European Environmental Research Infrastructures (ENVI, <https://envri.eu/research-infrastructures/>) to develop a clearer picture of the landscape, the core competences of each RI and possible cross-RI services. Internationally, ICOS participates in global initiatives such as the development of the Integrated Global Greenhouse Gas Information System (IG3IS) of the World Meteorological Organization (WMO). Furthermore, ICOS has since 2019 been an Observer organisation to the United Nations Framework Convention on Climate Change (UNFCCC). Thus, ICOS contributes to the work of the Convention and its Subsidiary Body on Scientific and Technical Advice (SBSTA) and can organise its own side-events in connection with the annual global climate negotiations (COP meetings). As an Observer also to the



Intergovernmental Panel on Climate Change (IPCC), ICOS can actively foster the participation of the ICOS community in the writing process of IPCC's various reports.

Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS)



ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure) (<https://www.actris.eu/>; <https://www.helsinki.fi/en/infrastructures/actris-finland>) is the pan-European research infrastructure producing high-quality data and information on short-lived atmospheric constituents and on the processes leading to the variability of these constituents in natural and controlled atmospheres. ACTRIS is constructed around large and comprehensive atmospheric research facilities, distributed across Europe and beyond, serving for the acquisition of reliable high-quality data to documentation the distribution and variability of aerosol, clouds and reactive trace gases in the Earth's atmosphere. Some ACTRIS atmospheric research facilities also serve to investigate processes that control the life cycle of these short-lived atmospheric constituents under ambient and controlled laboratory conditions. ACTRIS produces and disseminates quality controlled and harmonized data from both long-term observations and shorter-term, process-oriented experiments. ACTRIS data provision follows FAIR (Findable, Accessible, Interoperable, Re-usable) principles. ACTRIS data is provided by the ACTRIS Data Centre (<https://data.actris.eu/>). ACTRIS offers open access to a large portfolio of services, including training activities, physical and remote access to world-class research facilities, and tailored services, for the scientific community and other stakeholders in the public and private sectors.

ACTRIS ERIC (European Research Infrastructure Consortium) is the legal entity of ACTRIS, which coordinates and facilitates the establishment and operation of the RI. ACTRIS ERIC was established in 2023. The ACTRIS core components are the Central Facilities (CFs) and the National Facilities (NFs). ACTRIS is currently implementing its procedures and policies and setting up the facilities. Full operation of this RI is expected from 2026 onwards.

ACTRIS CFs are fundamental for ensuring that ACTRIS procedures and policies are respected and maintained. Each CF is jointly operated as a consortium of several Units in two or more countries. ACTRIS CFs are ACTRIS *Head Office*, *Data Centre* and six Topical Centres set up to respond to the scientific and technical needs of ACTRIS, each with a particular focus on either remote sensing (from the ground) or in-situ (near-surface) measurements (*Centre for Aerosol Remote Sensing*, *Centre for Cloud Remote Sensing*, *Centre for Reactive Trace Gases Remote Sensing*, *Centre for Aerosol In Situ Measurements*, *Centre for Cloud In Situ Measurements*, *Centre for Reactive Trace Gases In Situ*

Measurements). The Topical Centres support the operation of NFs and are responsible for e.g., defining procedures and tools for quality assurance and quality control of ACTRIS measurements and data, performing quality assurance and quality control of ACTRIS instruments and measurements, ensuring training and transfer of knowledge to ACTRIS operators and users, and improving measurement methodologies for aerosol, clouds and reactive trace gases. ACTRIS NFs consist of Observational Platforms (fixed ground-based measurement stations) and Exploratory Platforms (atmospheric simulation chambers, mobile platforms and laboratories), developed, managed and operated by national research performing organizations. More than 120 ACTRIS NFs are expected. These NFs will get ACTRIS label via accreditation process coordinated by ACTRIS ERIC. Finnish ACTRIS activities include hosting of the ACTRIS ERIC Head Office in Helsinki, and hosting units in ACTRIS Data Centre (FMI) and units in three Topical Centres: Centre for Aerosol In Situ Measurements (UH), Centre for Reactive Trace Gases In Situ Measurements (UH) and Centre for Cloud Remote Sensing (FMI). In addition to these European level activities, Finland has 14 measurement stations and exploratory platforms to be labelled as ACTRIS National Facilities.

Projects

- *Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS-Finland)*, <https://tiedejatutkimus.fi/fi/results/funding/26328>
- *ACTRIS Central Facilities* <https://tiedejatutkimus.fi/fi/results/funding/69277>
- *ACTRIS Implementation Project (ACTRIS IMP)* (<https://cordis.europa.eu/project/id/871115>)
- *Solutions for Sustainable Access to Atmospheric Research Facilities (ATMO-ACCESS)* <https://cordis.europa.eu/project/id/101008004>
- *Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (RI-URBANS)* <https://cordis.europa.eu/project/id/101036245>
- *Integrated Research Infrastructure Services for Climate Change risks (IRISCC)* <https://cordis.europa.eu/project/id/101131261>
- *ENVironment Research infrastructures INNOVation Roadmap (ENVRINNOV)* <https://cordis.europa.eu/project/id/101131426>
- *Cooperation and AgReements enhancing Global interOperability for Aerosol, Cloud and Trace gas research infrastructures (CARGO-ACT)* <http://cordis.europa.eu/project/id/101132093>

ACTRIS has roots in a decade-long European wide cooperation in large projects (<https://www.actris.eu/our-heritage>) and it builds on efforts such as EARLINET (https://www.earlinet.org/index.php?id=earlinet_homepage), EUSAAR/CREATE, CLOUDNET (<https://cloudnet.fmi.fi/>) and EUROCHAMP (<https://www.eurochamp.org>) (see more below). ACTRIS integrates the different projects and networks together and provides long-term sustainability for these different activities related to aerosol, clouds and trace gases measurements under ACTRIS ERIC. ACTRIS was initiated as an Integrated Initiative in 2011 building on three historical European research collaborations: EARLINET (European Aerosol Research Lidar Network, EU-FP5 and FP6 projects), EUSAAR (European Supersites for Atmospheric Aerosol Research, EU-FP6 project), CREATE (Construction, use and delivery of an European aerosol database, EU-FP5 project) and CLOUDNET (started as an EU-FP5 project for observing cloud profiles), to which a new integration of long-term trace-gas observatories was then added. The operations were pursued as part of ACTRIS-2 H2020 project in 2015-2019. The short-lived components of NDACC (Network for the Detection of Atmospheric Composition Change, <https://ndacc.larc.nasa.gov/>) are incorporated in ACTRIS. Many of the observational platforms (measurement sites) in ACTRIS are collocated with EMEP (<https://www.emep.int/>), GAW (<https://community.wmo.int/en/activity-areas/gaw>) and GRUAN (<https://www.gruan.org/>) sites, and in many cases have started observations prior to the mentioned

EU projects in quasi-independent initiatives. In addition, facilities, such as large atmospheric simulation chambers are proposed as ACTRIS National Facilities, and have been operating for years within the EUROCHAMP projects. EUROCHAMP is fully integrated into ACTRIS.

Integrated European Long-Term Ecological, critical zone and socio-ecological RI (eLTER)



eLTER (Integrated European Long-Term Ecological, critical zone and socio-ecological Research Infrastructure (<https://elter-ri.eu/>)) is a distributed pan-European research infrastructure (Nikolaidis et al. 2021, Mirtl, M., et al 2018). eLTER catalyzes scientific discovery and insights through its state-of-the-art in-situ facilities and tools, open and accessible data, collaborative working culture, transdisciplinary expertise and a demand driven portfolio of services incl. analytical tools and capacity building. eLTER RI adopts a fundamentally systemic approach to observe and analyse the human-environmental system, encompassing biological, geological, hydrological and socio-ecological perspectives and interactions. eLTER RI will be the first research infrastructure capturing and analysing holistically the integrated impacts of climate change alongside other pressures on a wide variety of European ecosystems. Ecosystem change caused by long-term pressures and short-term pulses are investigated in a nested design from the local to the continental scale.

eLTER RI will comprise of National Research Infrastructures (NRIs) and European level Central Services (CS). eLTER will offer access to Sites and Platforms as well as to long-term in-situ data (legacy data, recent Standard Observations). It will also offer data integration and analysis services including integration of diverse data into Information Clusters for each site (remote sensing, national statistics, modelling & forecasting), analytical tools and high-level data products tailored to inform policy (Pilotto, F., et al. 2020, Forsius, M., et al.2021, Segar, et al. 2022).

eLTER Central Services are expected to consist of Head Office, Service Portal and Topic Centres. The Head Office will take care of coordination of activities, outreach to wide range of stakeholders, and strategic development of the RI and collaborations with other RIs and networks. Head Office activities are currently hosted by UFZ, Germany. eLTER Service Portal will be the user-friendly access point to sites, data and the entire Service Portfolio. Topic Centres will cover different Thematic Service Areas, including Quality Assurance for Data, Modelling and Analysis Tools, Design and Interoperability,

Synthesis towards actionable knowledge and Technological Innovation & Development. The detailed description of activities of each Topic Centres is currently under discussion and the host selection process has started.

Member countries of eLTER RI will provide the national building blocks of the in-situ backbone of eLTER RI: eLTER Sites and eLTER Platforms. eLTER Sites are focal points for long-term ecosystem & critical zone observation and research which measure various environmental parameters with eLTER Standard Observation methods, while eLTER Platforms are large areas facilitating socioecological research and exemplary stakeholder engagement. All eLTER Sites will address the five categories of measurements: geosphere, hydrosphere, biosphere, socio-economic sphere, and atmosphere. Distributed site-based operations will be highly integrated and follow agreed policies. These facilities will be open for research and education via a common access scheme. eLTER is currently in Preparatory Phase finalising the design of services, structure and governance. eLTER ERIC (European Research Infrastructure Consortium) will be the legal entity of eLTER, and it is expected to be in full operation in 2026. For the eLTER projects see: eLTER Preparatory Phase Project (PPP) (<https://elter-ri.eu/elter-ppp>) and The Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research infrastructure Advanced Community project (eLTER PLUS) (<https://elter-ri.eu/elter-plus>).

Analysis and Experimentation on Ecosystems (AnaEE)

The AnaEE (Analysis and Experimentation on Ecosystems) (<https://www.anaee.eu/>) research infrastructure will help to analyze, model and predict how different ecosystems in Europe will respond to climate changes and how ecosystems can be maintained in a sustainable way. AnaEE is a research infrastructure (RI), organised as a European Research Infrastructure Consortium (ERIC) that brings together a series of state-of-the-art experimental and analytical platforms for ecosystem research throughout Europe. By linking these platforms with modelling approaches, AnaEE advances our understanding of the environmental impacts of ongoing global change and fosters adaptation and mitigation strategies for safeguarding ecosystem services and their economic and societal benefits.

In AnaEE, a series of Open-air and Enclosed experimental platforms cover major biomes and ecosystems of Europe. Compared to other continents and other European research infrastructures, AnaEE has a greater density of highly instrumented research platforms, offering opportunities for sophisticated experimental designs, high geographic resolution and state of the art instrumentation. National and transnational access (TA) is used to facilitate global change studies across natural gradients of climate. Coordinated experiments may include de novo manipulation of aquatic and/or terrestrial ecosystems, coupling of Enclosed and Open-air experimentation, and access to samples from long-term Open-air experimental platforms for assessment of biodiversity and ecosystem services, such as carbon regulation and sequestration, water quality, soil quality and associated abiotic parameters across multiple scales and in response to multiple drivers of change.

As many of the AnaEE research platforms have been operated over decades, AnaEE also offers VA (virtual access) to comprehensive background data for better long-term temporal resolution. The integrated set of AnaEE platforms, including also Analytical and Modelling platforms, provides a unique combination of opportunities for structuring European experimental research in ecosystem responses to drivers of change and will advance global change ecology significantly. This set of resources is completed by an active training, capacity building, and scientific activities program. AnaEE is established as an ERIC by the European Commission implementing decision number 2022/289 signed on February 22, 2022. AnaEE-ERIC is founded by eight countries: 7 Member countries: France, Denmark, Italy, Czech Republic, Finland, Bulgaria, Belgium being an observer, and one International Organisation (CIHEAM). France is the host country. AnaEE Finland is a national node of the European research infrastructure consortium and this node consists of 11 research platforms provided by

Natural Resources Institute Finland (Luke), University of Helsinki, University of Turku, University of Oulu and University of Eastern Finland. AnaEE Finland coordination office is managed by Luke.

Project(s)

- *Integrated SERVICES supporting a sustainable AGROecological transition (AgroServ) Community of Environmental Research Infrastructures (ENVRI)*
<https://cordis.europa.eu/project/id/101058020>

ENVRI is a community of environmental Research Infrastructures working together to observe the Earth as one system (<https://envri.eu/research-infrastructures/>). Most of the pan-European environmental RIs are currently being built and some are more mature than others. The ENVRI community is a collaborative platform where the RIs can work together, to share knowledge and to develop common solutions at all stages of RI development – in their planning, design, construction and implementation as well as operation to ensure their interoperability as well as to avoid unnecessary costs and duplication of efforts. Current ENVRI community brings together 26 European RIs that are studying different aspects of the Earth system. ACCC is part of the ENVRI community via joint projects with ACCC partner organizations (current Horizon 2020 project ENVRI-FAIR) and via ACCC partner organizations' contribution to European RIs ACTRIS, ICOS, eLTER and AnaEE.

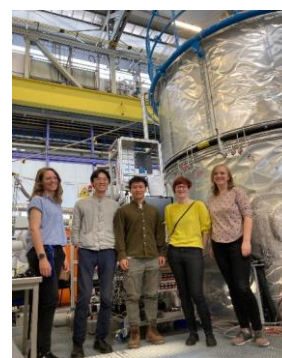
Project(s).

- *ENVironmental Research Infrastructures building Fair services Accessible for society, Innovation and Research (ENVRI-FAIR)* (<https://envri.eu/home-envri-fair/>)

2.3.4 CLOUD experiments at CERN

Three ACCC partners (INAR/HY, UEF and FMI) are part of the Cosmics Leaving Outdoor Droplets (CLOUD) collaboration, which organizes experiments at CERN (European Center for Nuclear Research) to study aerosol formation, growth and cloud processes under precisely controlled laboratory conditions in the CLOUD chamber facility (eg Kirkby et al. 2011 <https://home.cern/science/experiments/cloud>). The collaboration consists of 22 partner organizations around the world. The CLOUD collaboration has been active in developing doctoral education, especially through four successive Marie Skłodowska Curie doctoral networks (MSCA ITN & DN), out of which latest (CLOUD-DOC) started in 2022.

CLOUD has made significant advances to the understanding of aerosol formation and growth processes at molecular level, leading to many high-impact publications in Nature and Science. The CLOUD experiment has demonstrated that particle formation over continental areas generally require sulfuric acid and stabilizing compounds such as ammonia and amines (Kirkby et al. 2011; Almeida et al. 2013), while growth is mostly due to condensation of oxidized organic species (Tröstl et al. 2016; Yan et al. 2020). However, new particle formation solely from biogenic vapors released from vegetation is also possible (Kirkby et al. 2016). Over oceans, coastal areas and possibly also in polar atmospheres, particle formation from iodic acid might have a major contribution to the concentrations of particles and cloud condensation nuclei (He et al. 2011). CLOUD collaboration continues to actively organize new experiments at CERN.



INAR researchers by the CLOUD chamber at CERN (Photo Lee Mauldin).

2.3.5 Modelling RI

The ACCC's Modelling Research Infrastructure (MRI) includes a very large set of various models and access to modern computing facilities for the high performing computing (HPC). The ACCC Partners utilize models covering scales from global-, regional-, subregional-, urban- to local and micro-scales with resolutions from a



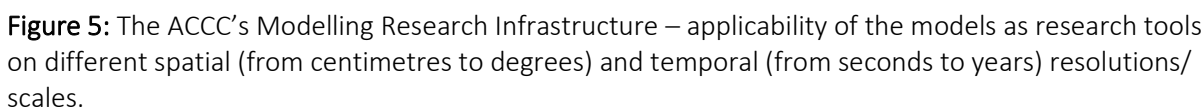
crude (in degrees, or hundreds of km, in climate simulations) to a very high resolution (a few metres, in large-eddy simulation, LES). All the Partners are actively participating in the national, regional, and international research projects, applying and further developing/ improving different models of the ACCC's MRI. Moreover, the FMI (as the national meteorological service) is also responsible for the operational numerical weather prediction (NWP) and air quality (AQ) forecasting. One of the most recent modelling approach activities is called the Earth Virtualization Engines (EVE). At the moment the in situ (data) communities are drafting the concept for the so called "Earth Virtualization Engines" (EVE) (Berlin Summit June 2023, <https://events.mpimet.mpg.de/event/59/>). The EVE is a digital infrastructure that exploits the latest advances in information technology (HPC and AI). EVE aims to operationalize a global climate prediction and information system by involving the regional RI nodes. By EVE we are able to help vulnerable communities and sectors anticipate the consequences of climate change.

In addition to own organization computing power (multi-core computers, workstations, etc. of personal usage) the ACCC Partners also utilize the Center for Science Computing (CSC; <https://www.csc.fi>) facilities and supercomputers for research projects which require extensive model simulations and usage of computational power. These are the Puhti/ Mahti (Atos BullSequana X400/ XH2000) HPCs with 682/ 1404 CPU nodes and 4.8/ 8.7 PB Lustre parallel storage. The CSC's Lumi (Cray EX) HPC (<https://www.lumi-supercomputer.eu>) is one of the three European pre-exascale supercomputers with several storage partitions (total of 117 PB of storage space). More detailed information can be found at <https://docs.csc.fi/computing/available-systems>. In addition, the European Centre for Medium-Range Weather Forecasts (ECMWF; <https://www.ecmwf.int>) provides (through the national meteorological service – the Finnish Meteorological Institute, FMI; <https://en.ilmatieteenlaitos.fi>) access to HPC facilities as well as meteorological and atmospheric composition datasets.

The ACCC Partners study, develop and apply different models as research tools ranging from micro- to global- scales covering areas of climate, air quality, ecosystem, marine, weather modelling. It provides a better scientific knowledge on interactions and feedbacks between different processes, atmospheric gaseous and particulates composition, aerosol formation and growth, air quality, clouds,

forest/ land ecosystems changes, weather, climate, etc. The ACCC MRI models and research tools (Figure 5) include the following:

- ARCA (Atmospherically Relevant Chemistry and Aerosol box model)
- MALTE-BOX (Model to predict new Aerosol formation in the Lower Troposphere box model)
- ADCHAM (kinetic multilayer model for Aerosol Dynamics, gas and particle phase chemistry in laboratory CHAMber environments)
- SOSAA (model to Simulate the concentration of Organic vapours, Sulphuric Acid and Aerosols)
- ADCHEM (2D-lagrangian model for Aerosol Dynamics, gas-phase CHEMistry and radiative transfer)
- Enviro-HIRLAM (Environment - High Resolution Limited Area Model)
- FLEXPART (FLEXible PARTicle dispersion model)
- EC-Earth (European Community Earth System Model; incl. TM5, LPG-GUESS, OpenIFS, and NEMO models)
- MPI-ESM (Max Plank Institution Earth System Model)
- NorESM (Norwegian Earth System Model)
- ESMValTool (Earth System Model Validation Tool)
- OpenIFS (Open Integrated Forecasting System)
- PALM (Parallelized Large-Eddy Simulation Model)
- FMI-ENFUSER (ENVIRONMENTAL information FUSION SERVICE)
- SILAM (System for Integrated modelling of Atmospheric composition)
- STEAM (Ship Traffic Emission Assessment Model)
- IS4FIRES (Integrated System for vegetation FIRES)
- ESCAPE (Expert System for Consequence Analysis and Preparing for Emergencies)
- FLARE (Fire plume model for Atmospheric concentrations, plume Rise and Emissions)
- HIRLAM (HIGH Resolution Limited Area Model) *) decommissioned
- HARMONIE (HIRLAM–ALADIN Research on Mesoscale Operational NWP in Euromed)
- PISCES (Pelagic Interactions Scheme for Carbon and Ecosystem Studies)
- UCLALES-SALSA (UCLA Large-Eddy Simulation Code - Sectional Aerosol module for Large-Scale Applications)
- NEMO (Nucleus for European Modelling of the Ocean)
- HBM (HIROMB-BOOS-Model: High Resolution Oceanographic Model for the Baltic sea - Baltic Operational Oceanographic System)
- WAM (WAVE Model)
- HELMI (HELSINKI Multi-category sea-Ice model).



- FOCI - <https://www.project-foci.eu> - Non-CO2 Forcers and their Climate, Weather, Air Quality and Health Impacts
- RI-URBANS - <https://riurbans.eu> - Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban& Industrial Area
- CRICES - <https://www.crices-h2020.eu> - Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system
- OceanNETs - <https://www.oceannets.eu> - Ocean-based Negative Emissions Technologies
- FORCeS - <https://forces-project.eu> - Constrained aerosol forcing for improved climate projections
- NextGEMS - <https://nextgems-h2020.eu> - Next Generation Earth Modelling Systems
- MOAC - Marine organic aerosol and its impacts on clouds and climate
- NETS - Negative emissions technologies
- OptiMit - Optimal role of global forests in climate change mitigation
- ClimComp - <https://blogs.helsinki.fi/climatecompetencies> - Learning of the competencies of effective climate change mitigation and adaptation in the education system
- SuCCESs - Sustainable Climate Change Mitigation Strategies in Energy-Land-Material Systems
- Magica / JPI Climate - <https://jpi-climate.eu> - Connecting Climate Knowledge for Europe
- Enviro-PEEX(Plus) - https://www.atm.helsinki.fi/peex/index.php/enviro-peex_plus - Research and development for integrated meteorology – atmospheric composition multi-scales and – processes modelling for the Pan-Eurasian EXperiment (PEEX) domain for weather, air quality and climate applications
- Enviro-PEEX(Next) - https://www.atm.helsinki.fi/peex/index.php/enviro-peex_next - Research and development for seamless modelling of meteorology – atmospheric composition on multi-scales for the Pan-Eurasian EXperiment (PEEX) domain for weather, air quality and climate applications
- PEEX-MP-at-CSC - <https://www.atm.helsinki.fi/peex/index.php/portfolio-items/mp-at-csc> - PEEX Modelling Platform research and development through CSC HPC research projectsFinnish Climate Change Panel: Ilmastopaneeli POLKU II
<https://www.ilmastopaneeli.fi/en/?s=Ilmastopaneeli+POLKU+II+https://www.ilmastopaneeli.fi/en/>

- *Finscapes* - <https://www.ilmatieteenlaitos.fi/finscapes> - Finnish Scenarios for Climate Change Research Addressing Policies, Regions and Integrated Systems
- *NICEST2* - <https://neic.no/nicest2> - Nordic Collaboration on e-Infrastructures for Earth System Modeling
- *HERCULES* - <https://sites.utu.fi/hercules> - HEalth, Risk and Climate change: Understanding Links between Exposure, hazards and vulnerability across spatial and temporal Scales
- *ClimAir* - Climate change and air contamination: Artificial Intelligence applied on the correlation between air pollutants and non-communicable respiratory diseases in Europe
- *SYLVA* - <https://sylva.bioaerosol.eu> - System for real-time monitoring of aeroallergens
- *DE_330-MF* – Destination Earth On-Demand Extremes
- *CAMS* – <https://atmosphere.copernicus.eu> - Copernicus Atmosphere Monitoring Service

2.3.6 ACCC Service Portal

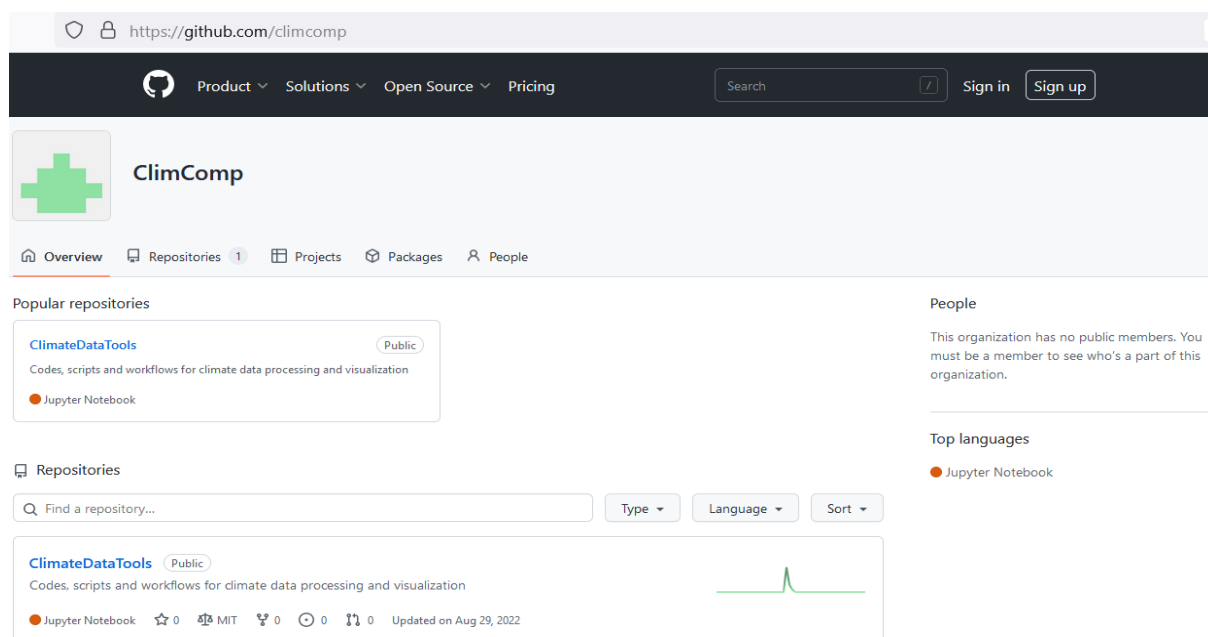
The ACCC Service Portal (www.acccflagship.fi/index.php/portal/) compiles links to ACCC data providers that include comprehensive environmental observations and multiscale models. The portal provides visualizations and data library. Own actively maintained data repositories on Research Infrastructure repositories include our research datasets, which are mainly from published articles. (<https://www.acccflagship.fi/index.php/accc-publications-table/>).

The ACCC data portal will be complemented with data portal established in ClimComp funded by the Academy of Finland. ClimComp data portal includes a gateway to tens of climate data sources worldwide with documented capabilities, focal points and limitations of these sources. In the core of ClimComp data portal are tools to ease access of Earth System and weather data. These well-documented tools consist primarily of Python notebooks providing means to access, process, visualize and analyze data. Such tools can be used in research, teaching, hackathons and can be relevant for disseminating data to general public and other stakeholders.

ACCC partners carry out several EU and ESA projects aimed at developing climate services based on in situ and remote sensing observation RIs.

Projects (see APPENDIX Project portfolio)

- *Knowledge and climate services from an African observation and Data research Infrastructure (KADI)*
- *Improving access to FORest GENetic resources Information and services for end-Users (FORGENIUS)*
- *Prototype for a Copernicus CO2 service (EU-COCO2)*
- *SpaceCasting, economic forecasting from space data (SpaceCasting)*



ClimComb dataportal servers as a base for the further development of the ACCC data portal.

2.4 CAPACITY BUILDING

2.4.1 Capacity building overview

The university partners of the ACCC (University of Helsinki, University of Tampere, University of Eastern Finland) provide education in master and doctoral programs. In addition, INAR has developed a concept of intensive courses (winter and summer schools) taking place in Hyytiälä at the SMEAR-II station. These intensive data analysis courses utilize the data pool of the SMEAR station. The MOOC education is carried out by the Climate University (<https://climateuniversity.fi/>) coordinated by INAR, and by the Network for sustainability education (<https://www.uef.fi/en/article/sustainability-studies-network-expands-already-eight-finnish-higher-education-institutions-are>) coordinated by UEF. INAR has launched a new dual degree program in collaboration with University of Nanjing. ACCC has tailored programs and platforms for the general public and schools like Climate Whirl Arts program and Periferia Art Exhibition (www.periferia.helsinki.fi), Carbon Tree platform (<https://www.hiilipuu.fi/>), Ilmastoopas (<https://www.ilmasto-opas.fi/etusivu>) <https://www.kysyilmastosta.fi/htt>, as well as a two-year Specialisation programme in climate expertise (<https://www.helsinki.fi/ilmastoasiantuntijan-erko>).

2.4.2 Education



Masters and Doctoral programs by the ACCC partners

INAR, University of Helsinki

Master's Programme in Atmospheric Sciences

- <https://www.helsinki.fi/en/degree-programmes/atmospheric-sciences-masters-programme>

Master's Programme in Forest Sciences

- <https://www.helsinki.fi/en/degree-programmes/forest-sciences-masters-programme>

Environmental Changes in Higher Latitudes (EnCHiL)

<https://enchil.net/>

Doctoral Programme in Atmospheric Sciences

- <https://www.helsinki.fi/en/admissions-and-education/apply-doctoral-programmes/doctoral-schools-and-doctoral-programmes/doctoral-school-natural-sciences/doctoral-programme-atmospheric-sciences>

Doctoral Programme in Sustainable Use of Renewable Natural Resources

- <https://www.helsinki.fi/en/admissions-and-education/apply-doctoral-programmes/doctoral-schools-and-doctoral-programmes/doctoral-school-environmental-food-and-biological-sciences/doctoral-programme-sustainable-use-renewable-natural-resources>

Masters and Doctoral programs at Faculty of Engineering and Natural Sciences, University of Tampere

- Teknis-luonnontieteellinen DI-ohjelma <https://www.tuni.fi/fi/tule-opiskelemaan/tekniis-luonnontieteellinen-di-ohjelma>
- Tekniikan ja luonnontieteiden tohtoriohjelma <https://www.tuni.fi/en/study-with-us/doctoral-programme-engineering-and-natural-sciences>

Masters and Doctoral Programs, University of Eastern Finland

- Teknillinen fysiikka, DI-ohjelma (incl. atmospheric physics study path) <https://www.uef.fi/fi/koulutus/teknillinen-fysiikka>
- Master's Degree Programme in Environmental Policy and Law <https://www.uef.fi/en/degree-programme/masters-degree-programme-in-environmental-policy-and-law>
- Joint Nordic Master Programme in Environmental Law <https://www.uef.fi/en/degree-programme/joint-nordic-master-programme-in-environmental-law>
- Metsätiede <https://www.uef.fi/fi/koulutus/metsatiede>
- Master of Science in European Forestry <https://sites.uef.fi/europeanforestry/>
- Master's Degree Programme in Forestry <https://www.uef.fi/en/degree-programme/masters-degree-programme-in-forestry-cbu>
- Master's Degree Programme in Forestry (Transatlantic Forestry) <https://www.uef.fi/en/degree-programme/masters-degree-programme-in-forestry-transatlantic-forestry>
- Master's Degree Programme in Biology of Environmental Change <https://www.uef.fi/en/degree-programme/masters-degree-programme-in-biology-of-environmental-change>
- Doctoral Programme in Science, Forestry and Technology <https://www.uef.fi/en/degree-programme/doctoral-programme-in-science-forestry-and-technology>
- Doctoral Programme of the Faculty of Social Sciences and Business Studies <https://www.uef.fi/en/degree-programme/doctoral-programme-of-the-faculty-of-social-sciences-and-business-studies>

Specialisation programme in climate expertise

Specialisation programme in climate expertise

(<https://www.helsinki.fi/en/faculty-science/teaching-and-studying/continuous-learning-and-web-based-studies/specialisation-programme-climate-expertise>) aims to answer to the increasing need for climate expertise across all sectors of society. Climate change affects all aspects of society and new competencies are required to address climate change mitigation and adaptation needs across all domains of society. This is reflected in the first round of participants who come from all field and sectors (Peltokangas et al., 2025).



The programme provides students with a strong scientific know-how in climate related issues with readiness to lead and design climate actions in practice. It is designed to be studied during a fulltime profession, it is 60 ECTS wide and lasts for two years. The studies consist of mandatory and elective courses in climate science, climate legislation and policy, as well as climate action from mitigation to adaptation. The language of instruction and completion is Finnish. 50 students are educated per programme.

Intensive courses

INAR organizes intensive courses aimed at Master's and Doctoral students on atmospheric, ecosystem and Earth system sciences. The courses are organized annually in winter, summer and autumn periods at the Hyytiälä forestry field station. The topics of the courses include:

- atmospheric processes and feedbacks
- atmosphere-biosphere interactions
- comparison of long-term time series and intensive field campaign datasets
- measurements of aerosols, trace gases and clouds
- micrometeorology and hydrology.

Topical research questions in climate change, air quality forest and soil ecology and their interactions are addressed on the courses. More theoretical teaching is provided on topics of nucleation and growth of atmospheric aerosols. In the courses students from different disciplines work together in small groups supported by the teachers and assistants. Students learn how to analyse complex multidisciplinary datasets and combine these observational data with theoretical frameworks, and how to evaluate the results and draw scientific conclusions.

The intensive courses have also been used for studying the learning of transferable skills (Ruuskanen et al., 2018). These skills include collaborative group work as well as communicating the results to others by oral and written presentations. The teachers on the winter, summer and autumn schools are from the University of Helsinki Faculty of Science and Faculty of Agriculture and Forestry, as well

as researchers from collaborating institutes within Finland and abroad. The courses gather students from Finland, other Nordic countries and internationally. Approximately 60-90 students participate in the intensive courses each year. The organization of the winter summer and autumns schools is connected with several international research infrastructures such as ACTRIS, ICOS, eLTER and PEEX.

For contact: Ilona.Ylivinkka@helsinki.fi

Climate University open on-line courses

Courses

2-5 ECTS each
50+ ECTS in total
CC-BY-SA

www.climateuniversity.fi

**CLIMATE
UNIVERSITY**

 SUSTAINABLE.NOW	 CLIMCOMMS.NOW	 SYSTEMSCHANGE.NOW
 CIRCULAR.NOW	 CLIMATE.NOW	 LUKIOLAISEN ILMASTO.NOW
 STATISTICAL TOOLS	 SOLUTIONS.NOW	 LEADERSHIP FOR SUSTAINABLE CHANGE
 BIODIVERSITY.NOW	 FORESTS AND CLIMATE	 LIVING WITH CHANGING CLIMATE

Climate University is a network of 29 Higher Education Institutions in Finland to develop and foster climate and sustainability education in higher education in Finland. The network was established by 11 higher education institutions in 2018, with support from the Ministry of Education and Culture of Finland and the Finnish Innovation Fund Sitra. The network signed cross-study agreements in December 2020 allowing all students of the network's institutions to take the Climate University courses for free from each other's curricula. Climate University published a set of nine online courses open for everyone in December 2020 (www.climateuniversity.fi). Currently, there are more than 40 course codes in the partner institutions' curricula. Every partner institution has one Climate University coordinator and one vice-coordinator, making the network impactful in communication. Climate University active topics can be read from the network blog (<https://blogs.helsinki.fi/climateuniversity/>).

In collaboration with the biodiversity education network of Finland (<https://www.biodiversityeducation.fi/>), new online course on the biodiversity topics, Biodiversity.now, was published 7th October 2022. Climate.now has been translated into Swedish and the translated version will be published in Autumn 2023. In collaboration of the ForClimate research project of the Academy of Finland, a new course on forests and climate change was published in 2025. A course on sustainable consumption was published in spring 2025 and a course on planetary health is to be published in late 2025.

Two virtual exchanges programmes have been established. Climate University for Virtual Exchanges (CLUVEX, <https://www.atm.helsinki.fi/cluvex/>) educates young people from Finland, Ukraine, Armenia and Denmark on climate change. In Una Europa Virtual Exchanges for Sustainability (UnaVEX, <https://www.atm.helsinki.fi/unavex/>) programme students from Europe and Africa co-design sustainability action together.

International collaboration has been developed with several international partners. With Una Europa European Universities Initiative, a micro-credential in sustainability, 10 ECTS, was launched in October 2022 (<https://microcredential-sustainability.una-europa.eu/>). Micro-credential consists of five MOOCs: Sustainable.now, Climate.now, Biodiversity.now, Political economy of sustainability and Sustainability and the Arts. In 2025, a new MOOC has been designed by the Universidad Complutense de Madrid on Sustainability: Social science in the face of the Anthropocene, to be added to the Micro-credential programme. Together with Atmosphere-Biosphere Studies network (ABS) a 25 ECTS online education module was developed with funding from Nordplus (2019-2022). New funding was obtained from Nordplus to continue the online pedagogy development (2022-23, with potential continuation until 2025).

For contact laura.riuttanen@helsinki.fi

Pirkanmaa Climate Action Lab

Pirkanmaa Climate Action Lab is funded by The Council of Tampere Region for a three-year period (2023-2025). Pirkanmaa climate leadership forum is established in collaboration with the Council of Tampere region, Tampere Centre for Economic Development, Transport and the Environment and Tampere diocese. Climate Action Lab connects different private and public bodies in Pirkanmaa region in order to develop solutions towards biodiversity and climate neutrality. In practice the stakeholders are immersed in the topic by hosting co-creation workshops in Hyytiälä Forestry Field Station where they can work together with the multidisciplinary climate scientists to assess climate impacts and develop novel approaches to tackle the forthcoming changes. The aim is to develop practical actions with co-development and -innovation processes. The project starts with a mapping exercise that surveys the data and information needs of the local stakeholders in Pirkanmaa. This process includes inspirational discussions between the scientists and the stakeholders.

The main body of work involves joint work in Hyytiälä, where ideas for climate solutions are first developed and then further elaborated in digital platforms, where the stakeholders are exposed to a wide variety of scientific expertise provided by the Atmosphere and Climate Competence Center. The project develops longstanding solutions to the Pirkanmaa region and enables climate resilience in the area. The infrastructures for the project are already in place. This project will expand the local relevance of the state-of-the-art climate observations performed in Hyytiälä and capitalizes on the climate expertise provided by ACCC on a regional scale. In addition, Climate Action Lab aims to improve the recognition of Hyytiälä and SMEAR II in the region.

For contact: henri.jokinen@helsinki.fi

Network for sustainability education by the University of Eastern Finland

Network for sustainability education (<https://www.kestavuysopinnot.fi/>), coordinated by the UEF, is a network for Finnish universities to offer open multidisciplinary courses for sustainability education. The network is currently formed by three founding universities (UEF, UTU, JYU) but it will expand in Autumn 2023 when new partner universities will join (probably including UHEL).

Dual-degree program between Univ. Nanjing and INAR at the Univ. Helsinki

University of Helsinki together with Nanjing University has established a joint institute and educational cooperation in atmospheric sciences (<https://nh.nju.edu.cn/en/>). The joint institute grants degrees in all levels (BSc, MSc, and PhD). In the programme the other degree will be granted by

Nanjing University and the other by University of Helsinki. The agreement to establish the joint institute was signed by the rector of University of Helsinki and president of the Nanjing University in 2021 and the first students started in autumn 2023. The joint institute is managed by joint committees with representatives from both universities (Joint Management Committee, Academic Committee, Teaching Committee and Degree Committee).

The student enrollment in the bachelor's programme was 78 students in the first year, 91 in the second and the planned intake is 100 students per year in the following years, in the master's programme intake was 34 students in the first year, 52 in the second and the planned intake is 80 students per year in the following years and in the doctoral programme the intake was 6 students in the first and second year and the planned intake is 25 students per year in the following years.

The curriculums of the joint programmes are planned together by the two universities. University of Helsinki is responsible for 1/3 of the teaching and supervision of the joint institute. The teaching will be performed as in-person teaching at the Suzhou campus of Nanjing University. The main target group of student recruitment is Chinese students. The first students started in autumn 2023.

The poor urban air quality is one of the most pressing environmental as well as health related problems in China, where urbanization and industrialization have been historically rapid and wide-ranging. Since there are around 10% of global population living in northeast China and massive emissions, the impact of this region is much larger than its geographical size. Therefore, it is crucial to educate the local people and to solve the environmental problems in this area.

The collaboration with Nanjing University and University of Helsinki started in 2009 through academic exchange and short-term visits. In 2012 we collaborated with Nanjing University in building a SMEAR type station in Nanjing (SORPES station). A Joint International Research Laboratory of Atmospheric and Earth System Sciences (JirLATEST <https://jirlatest.nju.edu.cn/mainm.htm>), was established in Nanjing in 2015.

The founding of these dual degree programmes allow us to continue and deepen our collaboration with Nanjing University. Via this collaboration we will receive high-quality and comprehensive research data from the area, which is very important in terms of climate and air quality. In addition, the collaboration will increase the international impact of University of Helsinki in general and in this geographically important region in terms of local, regional and even global air quality and climate.

For contact tom.kokkonen@helsinki.fi

Cross-institutional studies

ACCC is launching a cross-institutional initiative to support climate studies in collaboration with the University of Helsinki, Hanken School of Economics, and Aalto University. The goal is to educate high-level experts equipped with multidisciplinary skills to address complex climate challenges.

The pilot phase is planned for 2026 and will feature 10–12 climate-related courses, each enrolling approximately 20–50 students. The full study package is expected to be available starting in 2027–2028.

Courses will span a broad range of disciplines, including atmospheric sciences, forest sciences, agriculture, geography, law, economics, corporate responsibility, energy solutions, information networks, architecture, construction, automation and electrical engineering, and creative sustainability.

Contact: Katja.Lauri@helsinki.fi, Laura.Riuttanen@helsinki.fi, Matti.Vainio@helsinki.fi

Atmosphere-Biosphere Studies (ABS) network

The Atmosphere-Biosphere Studies network (ABS, <https://www.atm.helsinki.fi/abs/>) is a network of Nordic and Baltic universities on environmental education. The ABS network started by the cooperation of two Centers of Excellence, the Nordic Centre for Studies of Ecosystem Carbon Exchange, in Interaction with Climate System (NECC) and the Nordic Centre of Excellence for Studies of Biosphere-Aerosol-Cloud-Climate Interactions (BACCI). Prof. Dr Anders Lindroth from Lund University, INES and Prof. Dr Markku Kulmala from the University of Helsinki set the Research School CBAGGI to bring together top scientists in their fields.

The Research School offered a horizontal learning platform, where Bachelor, Master, and PhD students, Post-Docs, teachers, researchers, and research leaders worked together, organized and participated to courses. For Masters students, it gave an opportunity to work on their Master Thesis as part of the actual, international research projects.

The cooperation by these Centers of Excellence, funded by the NordForsk Research Programme, was active 2003-2010. From then onwards it was the ABS network, founded in 2006 and funded from the Nordplus Programme, that took the lead of the cooperation.

For contact: katja.lauri@helsinki.fi

Education projects, for details see APPENDIX Project portfolio

- *CLOUD Doctoral Network (CLOUD-DOC)*
- *Learning of the competencies of effective climate change mitigation and adaptation in the education system (ClimComp)*
- *Modernization of doctoral education in science and improvement of teaching, methodologies (MODEST)*
- *Climate change teachers' academy (CLIMADEMY)*
- *Multilevel Local, Nation- and Regionwide Education and Training in Climate Services, Climate Change Adaptation and Mitigation (ClimEd, 2020-2023, currently on pause)*
- *Una Europa Virtual Exchanges for Sustainability (UnaVEx)*
- *Climate University for Virtual Exchanges (CLUVEX)*

2.4.3 Outreach and dissemination

Climate Whirl Arts Program and Periferia Art Exhibition

Since 2012, a dialogue between scientists and artists at Hyytiälä Forest Station of University of Helsinki has been encouraged in the framework of curated ClimateWhirl Arts Program. Many artists are eager to know and understand better the current research related with the climate, forest ecosystems and the atmospheric phenomena. Through the Arts Program a dialogue with leading scientists is facilitated in the Forest Station, which is an ideal place to make artistic work in the middle of Finnish boreal nature. The art program is curated by Ulla Taipale. In June 2023, a permanent art exhibition Periferia – Forest Art Lab was opened at the Hyytiälä Forest Station. Eight artists / artistgroups were invited to take part, and based on their proposals, new artworks are on display in the surroundings of the station and in the new main building, Koto. Parallel to the art program, program of art&science activities is organised dynamizing it and opening up the research made by INAR through a combination of art and science. In April 2025 a solo exhibition “As Trees Go By” by

one of the long-term artist-in-residence, German Agnes Meyer-Brandis, was opened in important art institution, Serlachius Museum in Mänttä, Finland. The exhibition features new artworks of the artist, inspired by the forest and atmospheric sciences.

Periferia and *As Trees Go By* exhibitions have been seen by thousands of visitors, offering a new audience and visibility for the discoveries of the scientific research of INAR and ACCC mainly for non-scientific community.

The program and the future exhibition have been financed by the Kone Foundation, the Alfred Kordelin Foundation, the Pirkanmaa Fund of the Finnish Cultural Foundation, Finnish Arts Promoting Center and Serlachius Museums. The artists participating in the exhibition in alphabetical order are: Band of Weeds (FI), Terike Haapoja (FI), IC-98 (FI), Siobhan McDonald (IR), Agnes Meyer-Brandis (DE), Juhani Pallasmaa (FI), Kustaa Saksi (FI), Villi Vyöhyke ry (FI). (www.periferia.helsinki.fi, <https://serlachius.fi/en/exhibition/agnes-meyer-brandis/>, <https://www.onetreeid.de/astreesgoby/>).

For contact: ulla.taipale@helsinki.fi

Carbon Tree

Carbon Tree combines online measurements from SMEAR II station with a conceptual art and shows how a Scots pine exchanges carbon dioxide with the atmosphere. Carbon tree was initiated by forest ecologist Eija Juurola and launched in 2009 as a collaboration with internationally merited artist Terike Haapoja, who designed the concept for the carbon flow animation that intuitively shows how CO₂ is taken up and released by a single tree. In addition to seeing the present CO₂ exchange, visitor at the www.hiilipuu.fi –website can explore the past exchange or manipulate the light, temperature and environmental conditions to maximize the trees carbon uptake or to explore how warming of autumns could enhance photorespiration leading to increase in release of carbon.

The carbon tree was initiated as a co-operation between the University of Helsinki Institute for Atmospheric Research and Earth System Science (INAR) Physics and Forest Sciences and artist Terike Haapoja to promote ecologically, economically and socially sustainable use of forests and peatlands. INAR maintains the Carbon Tree project.

For contact: pauliina.schiestl-aalto@helsinki.fi

2.5 BUSINESS AND INNOVATION

2.5.1 B&I overview

ACCC multi-disciplinary research and impact activities offers great opportunities for new innovation to business and global society as a whole. There are ever increasing needs for new innovations in air quality solutions, carbon market development, verification of climate impact of certain activities etc. One key approach for the ACCC is cooperation with global auditing and accounting sector (KPMG and Deloitte). Together with global auditing companies, ACCC will search partners who are willing to build credible carbon neutrality agenda, reduce emissions and manage their climate impact also by enhancing carbon removals with verified impact and in this way improve their competitiveness, attractiveness, branding, marketing and business development. It is also important for global auditing companies to further develop their own services in areas such as climate roadmap development and evaluating and auditing climate related financial and non-financial risks and opportunities as well as wider sustainability advisory.

ACCC collaborates with the Climate Leadership Coalition (<https://clc.fi/en/>), whose member companies are developing their operations toward carbon neutrality and sustainable use of natural resources. The SITRA Climate Solutions Program has been a partner developing the climate education (IP13 Climate University). ACCC will also interact with EIT Climate-KIC (*) (<https://www.climate-kic.org/>), a European knowledge and innovation community working to accelerate the transition to a carbon neutral economy, and ECRA (<http://www.ecra-climate.eu/>), which strengthens climate research in Europe. In Finland, all ACCC partner organizations are members of Clic Innovation (<https://clicinnovation.fi/>), an open innovation cluster with the mission of creating breakthrough solutions in bioeconomy, circular economy and energy systems (ACCC application).

()EIT Climate-KIC is Europe's largest public-private partnership addressing climate change through innovation to build a net zero-carbon economy. With over 380 formal partners from across 26 countries, its mission is to catalyse systemic change for climate action through innovation in areas of human activity that have a critical impact on greenhouse gas emissions – cities, land, materials and finance – and to create climate-resilient communities. Education underpins these themes to accelerate learning and to inspire and empower the next generation of climate leaders.*

2.5.2 ACCC Innovation Forum

The interest toward climate actions in different companies in Finland, EU and globally has significantly increased in the last 24 months – a notable number of them aims to be carbon neutral as soon as possible. The ACCC Innovation Forum (launched in Dec 2021) is set to facilitate the realization and verification of this target. Innovation Forum brings together the scientific knowledge of the ACCC partners (UH, FMI, UEF, TAU) and companies of different sizes representing e.g., energy, transport, food, forestry, and auditing sectors.

ACCC Innovation Forum offers an opportunity to organize open dialogue in different forms of seminars, business visits, introduction to latest research results etc. Aim is to organize 2-4 international events / year either in Finland or abroad. We are actively developing our international contact network for innovation cooperation and we need to allocate more resources for this function from 2023 onwards. This is an important feature in ACCC activity, which increases understanding of societal and business needs and offers an opportunity to introduce ACCC innovation potential to other stakeholders.

Innovation Forum can also serve as a tool in building confidential cooperation programs between certain business interests and research institutions. Innovation Forum aims to be an easy access point of entry for many different stakeholders interested in innovation cooperation with the ACCC. ACCC supports its partners to reduce their emissions and manage their climate impact also by creating new carbon removal projects with verified impact in 2035 / 2045. We will also focus more in biodiversity issues and comprehensive climate impact analysis in coming years. The new climate impact / air quality business ecosystem forms seamless public and private partnership in Finland and will profit from ACCC scientific network in improving their competitiveness internationally.

ACCC collaborates with cities, companies and NGOs (APPENDIX: Cumulative list of the ACCC collaborators, signed Letter of Collaboration) to co-create climate solutions for the public /private sector to be carbon neutral and working towards their net zero targets. ACCC Innovation Forum provides tools verifying, in collaboration with auditing companies, the positive climate impacts of their climate actions and educate the climate competences.

2.5.3 Specific R&I clusters in ACCC

Agriculture lands and carbon sequestration

Enhancing the carbon sequestration of agricultural vegetation and soil is a crucial climate change mitigation and adaptation option. However, the applicability of this option in policymaking and companies' sustainability programs requires (i) detailed and reliable information on land ecosystems' carbon and greenhouse gas (GHG) budgets and (ii) linking these data to practical decision support systems: carbon and GHG inventories, life-cycle analyses, and carbon footprint estimates.

Our verification methodology (Fer et al., 2021, 2023) represents the state of the art in its field. The core principle is to calculate carbon and GHG estimates for ordinary agricultural fields and farms using a model–data integration system. The updated FMI MRV framework (Vira et al., 2025) is a computationally efficient, scalable platform for monitoring soil organic carbon (SOC) dynamics at parcel to national scales. The methodology integrates Sentinel-2–based gross primary productivity (GPP) estimates, reported harvest and input data, and the Yasso20 SOC model within a Bayesian data fusion framework. Daily GPP is derived from spectral indices, photosynthetically active radiation, and regression models calibrated with Eddy Covariance flux measurements. Annual net primary productivity (NPP) is then calculated and adjusted for carbon exports and imports. SOC stocks and changes are modelled using Yasso20, with minimal meteorological inputs, and uncertainty is consistently quantified. We use collected data and gained knowledge to improve our models, and to illustrate and disseminate our verification methodology in the Field Observatory -service (<https://www.fieldobservatory.org/index.php/home/>; Nevalainen et al., 2022).

We collaborate closely with farmers and various food and technology companies. We are piloting our verification methodology in corporate test cases (e.g., with HKFoods, Valio and Lantmännen) and improving the national GHG inventory system to enable more detailed, field-specific estimations. Carbon Action (<https://www.bsag.fi/en/carbon-action-en/>), our joint platform with the Baltic Sea Action Group (BSAG), is central to this work, bringing together science, farmers, companies, and the public sector for hands-on collaboration. Corporate participation is essential for scaling carbon sequestration in farmland and for achieving Carbon Action's ambitious goals. Business engagement is needed to implement changes in the food supply chain and to communicate it to consumers, thereby promoting more sustainable food production through cooperation.

A key principle is cooperation that benefits all parties. Research requires support from farmers and businesses to produce science that is implementable in practice. Conversely, the public, farmers, and businesses are highly interested in the results produced by carbon sequestration research.

FMI participates in several large national and international research consortiums covering the entire food production chain from fields to international consumers, including approaches to develop carbon removal and certification (CRCF), and auditing frameworks. Most of our ongoing and completed projects are presented on the Carbon Action project page: <https://www.bsag.fi/en/carbon-action-en-vanha/carbon-action-projects/>. The goal is to initiate systemic change towards a digitally integrated agrifood-ecosystem.

Most recently, the Agriculture's climate footprint based on field-scale assessment - AGCLIMATE project (2025–2027, funded by Business Finland) expands our work to include nitrous oxide (N₂O) monitoring and product-specific carbon footprinting. AGCLIMATE will establish a real-time openly accessible GHG measurements and develop multi-scale monitoring systems integrating SOC, N₂O fluxes, and life-cycle assessments. Demonstrations will be carried out with our research and business partners. These developments will strengthen both national GHG inventories and corporate climate strategies, while ensuring compatibility with EU carbon certification frameworks.

Through the ongoing research and innovation projects, Carbon Action and ACCC Flagship collaboration, FMI has an extensive business partner network, including major companies in the agricultural, food, retail, ICT, and electronic sectors.

For contact: Jari.liski@fmi.fi, layla.hockerstedt@fmi.fi

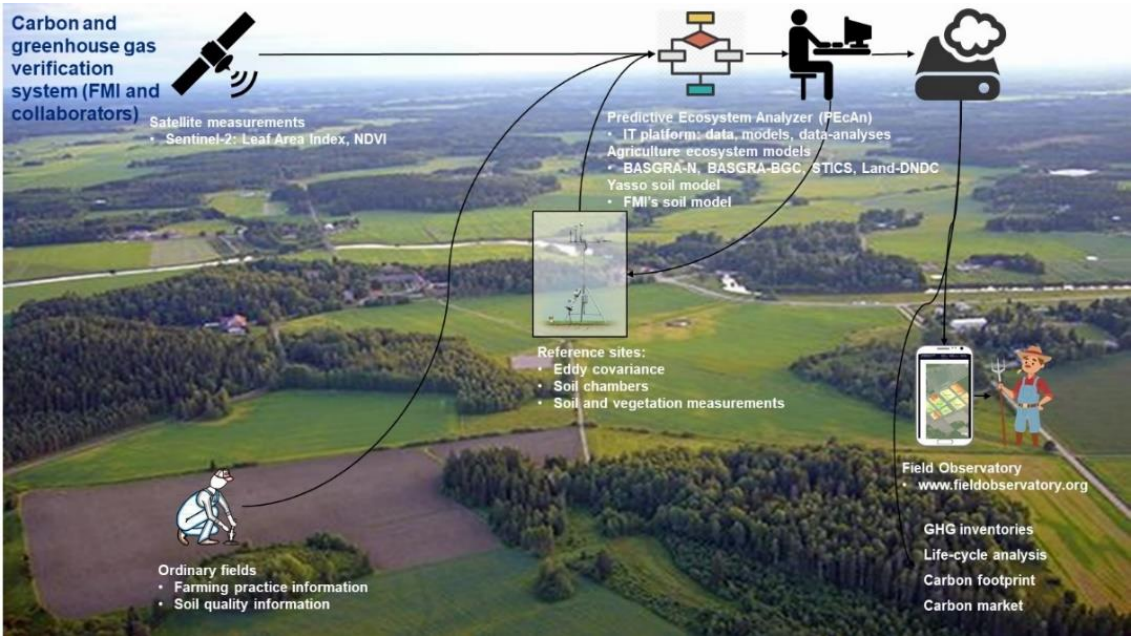


Figure 6. The observation system of agricultural lands for GHG inventories, life-cycle analysis, carbon footprints and markets. To develop this system FMI collaborates directly with many research organisations and private companies, e.g. with Valio, HKFoods, Vaisala, Hankkija, Cense Analytics, , Datasense, Lantmännen and, through projects and research platforms (Carbon Action), with many other food sector companies.

International consultancy projects by Finnish Meteorological Institute

FMI participates each year in more than 20 international consultancy projects in the field of adaption to the climate change. The projects are targeted to improve the capacities of the national hydrometeorological services to provide better weather, air quality and early-warning products and services to the respective societies.

FMI has coordinated projects and its expertise has been used in technical co-operation projects in over 100 countries around the world, including World Bank, Asian Development Bank, Green Climate Fund, Climate Risk & Early Warning Systems (CREWS), Systematic Observations Financing Facility (SOFF), European Union, World Meteorological Organisation (WMO), UNDP, UNEP, Nordic Development Fund, International Fund for Agricultural Development (IFAD) and Ministry for Foreign Affairs of Finland funded projects.

Currently FMI is implementing almost 30 development projects around the world in some 20 countries. The scope of these projects is that the beneficiary institutes will be able to produce improved and modern weather and early-warning services to their end-users, customers and stakeholders and eventually improving the resilience to the effects of the climate change in the resepective countries. The projects contribute to the development of the full hydrometeorological service value chain from observations through modeling to the actual end user products. In the core of this development work and projects is the improvement of the national early-warning systems. FMI own early warning is based on one of the most modern weather forecast and early warning

production systems in the world completely built and designed in FMI. It includes for example weather forecast workstation and forecast production system SmartMet and early warning tool for issuing and disseminating warning information in the CAP (Common Alerting Protocol) format, SmartMet Alert. This system has been implemented in multiple development projects around the world. Through the projects implemented by FMI during the recent years the improved weather and early-warning services has helped as many as 500 million people to adapt on the effects on the climate change according to Finland's Development Policy Results Report (MFA, 2022) (<https://um.fi/web/kehityspolitiikan-tulosraportti-2022/>).

For the project details see APPENDIX "Project Portfolio" (FMI PROJECTS)

Forest ecosystem services

We are partners in the Horizon Europe Eco2adapt project which includes the UEF and several Finnish small-and-medium-sized-enterprises (SME). It is an EU -China Flagship project funded under Horizon Europe with a total budget of 9 M€. In eco2adapt we will develop the Ecosystem-based Adaptation (EbA) framework, derived from Nature-Based Solutions, that harnesses biodiversity and ecosystem services to reduce vulnerability and build social-ecological resilience to climate change. We will work in Living Labs in Europe and China, located in climate hotspots, and adopt a cutting-edge Decision Theatre approach to investigate how forest managers integrate disturbance and vulnerability into decision-making. Scenarios of how disturbance affects forest dynamics and ecosystem services at a landscape scale will be derived through modelling, and in Living Labs, stakeholders will learn how their choices affect ecosystem services in neighbouring forests. We will combine interdisciplinary knowledge from scientists and stakeholders in Europe and China to understand perception and provide incentivization for adopting EbA solutions, through local capacity-building and national policy plans. Through the same Decision Theatre methodology, we will use a capacity-building approach to create and promote innovative technical, economic and governance mechanisms at a regional level. Semantic technology will be applied to create a knowledge base for hosting FAIR data and creating a SmartPhone Application (named the OneForest ToolBox) that allows users to access and add data concerning climate-resilient species, provenances, mixtures, management techniques and ecosystem services, whilst taking into account future uncertainties about climate and societal changes. We also provide a suite of cutting-edge tools to monitor vulnerability and resilience (including invasive species and above-and below- ground biodiversity), at all levels of society – from the citizen to the policymakers. By including tailored communication to all levels of society, we will reach out to a broad audience that has the capacity to cause positive change.



In addition, we coordinate the MicroEco (JPI EU- Academy project) with a total of 1.2 M€ budget. The significance of soil microbial diversity has received little attention. The reason is that the molecular methods to identify soil microbes were new, awkward to use and expensive. However, molecular tools have evolved and are now affordable. Also, nowadays, bioinformatics software is much easier to use than ten years ago. The proposed project pioneers the use of molecular biology tools to protect

and conserve the soil microbiome. The ecosystems studied in the project cover a climatic gradient from boreal to subtropical in Brazil. The project narrows critical knowledge gaps on the role of the soil microbiome (Theme1) and estimates the costs and benefits of conservation through ecosystem services (Theme 2). The project provides stakeholders with an evaluation of the importance of the soil microbiome in a conservation ecology setting. We will use tools from molecular biology and biogeochemistry to analyse the soil microbial community and its function, to understand the phylogenetic diversity of the soil community and to measure functional genes. The phylogenetic and structural analyses are then used to determine the role of the soil microbiome in the provisioning of critical ecosystem services. These are soil carbon sequestration, conservation value, soil aggregate stability and yield of commercially valuable fungi. The project uses novel methods to measure the abundance of a broad array of functional genes and tries to match long-term field data with soil microbiome data to detect red-listed species from soil DNA. The work on soil aggregate stability and the microbiome is genuinely innovative.

After the project, stakeholders in the case study regions will have information on the role of the soil microbiome for conservation. In addition, they will understand how different soil-based ecosystem services interact. As a result, they will be able to exploit tradeoffs and synergies between the ecosystem services. The project involves active engagement with local stakeholder groups and will actively disseminate its result via social media networks.

For contact: Frank.Berninger@Helsinki.fi

Advances in Mass spectrometry

(*) All partners, ACCC Success story in 2020-2024; ACCC Mid-term report

The advancement of Finland's atmospheric science community to a global leadership position in atmospheric mass spectrometry is closely tied to our collaborations with the private sector. A key was the development of a novel atmospheric-pressure-interface time-of-flight mass spectrometer (API-TOF; Tofwerk, Switzerland, and Aerodyne Research, USA). At continuing deployments to CERN's "CLOUD" atmospheric simulation chamber, API-TOF ion cluster measurements elucidate, which compounds are responsible for the first steps of new-particle formation and have thus enabled numerous landmark publications (2011-2022). Under Flagship leadership this capability has been taken to real environments around the globe, leading to discoveries of, for example, iodine-based particle formation on the Irish Atlantic coast, or acid-base clusters driving new-particle formation in Antarctica or Beijing (2016-2021). In collaboration with Air Spark, the API-TOF was deployed on a small aircraft to explore air ion compositions up to the free troposphere (2022). Since its emergence, the API-TOF has sparked the development of techniques for chemical ionization mass spectrometry (CIMS) for quantifying trace vapors. By taking advantage of the base mass spectrometer's capabilities, new levels of chemical specificity and sensitivity became possible. The development of an inlet for using nitrate ions (nitrate-CIMS) at the University of Helsinki (UH) led to a break-through in our understanding of atmospheric gas-phase oxidation chemistry. Flagship nitrate-CIMS have since been deployed around the world: from multiple European sites (forests, wetlands, cities) to Antarctica, Bolivia, the Himalaya, and China, as well as an airship and an icebreaker. A most recent publication, for instance, reports on strong particle formation involving terpenes emitted by wetlands. The nitrate-CIMS inlet triggered the formation of the spin-off company Kärsa, which develops devices for security applications such as explosives detection. In a recent study, Kärsa's multi-scheme ionization inlet enabled a Tampere University (TAU)- led team to resolve terpene oxidation mechanisms at sub-second timescales. Flagship studies involving UH, the Finnish Meteorological Institute (FMI) and the University of Eastern Finland (UEF), have used latest CIMS schemes, along with new sampling strategies, to achieve a more complete picture than ever of plant emissions and their atmospheric

impact, including ecosystem-scale fluxes via eddy covariance. As a result, for example, also larger terpenes (with 15 or even 20 carbon atoms) are increasingly found to play important roles in biosphere emissions as well as atmospheric chemistry.

Flagship efforts increasingly look at combining multiple mass spec techniques, with the goal of achieving closure across the huge diversity of organic compounds engaged in aerosol formation, also by using inlets for investigating the particle phase. At the same time, ever more capable detectors are adapted for use in our research, such as Orbitrap analyzers (in collaboration with Thermo Fisher Scientific) that offer supreme mass, and hence compositional, resolving power.

Important work has also been done to enable long-term ambient observations. In a recent UEF- and FMI-led study, long-term aerosol chemical speciation monitoring (ACSM, Aerodyne Research) was fundamental in providing direct evidence of a climate-cloud feedback mechanism via biosphere-driven aerosol. Field capabilities also enable ambitious intensive studies, such as the UEF-led FORCes campaign in 2020, which fielded 6 mass spectrometers at two stations to study aerosol-cloud interactions. Finally, collaborations with statisticians, modelers and theoreticians have been giving us an edge in (a) interpreting our increasingly complex results, and (b) understanding the intricate measurement processes themselves. Such broad, synergistic collaborations have been facilitated by the unique, large network of the ACCC Flagship.

Improving and standardizing nanoparticle measurements

Measuring aerosol particles smaller than 10 nm in diameter is important for understanding particle formation and growth processes. Ultrafine particles often dominate the aerosol number concentration in urban environments. During new particle formation or close to traffic emissions, the majority of particles can be in the sub-10 nm range. However, measuring the smallest particles is difficult due to their high diffusivity and low charging probability. Therefore, the methods for determining the sub-10 nm particle concentration and size distribution are still under development, and there is a large uncertainty in the measurements. This challenge is tackled in the ACCC at many fronts, and we have made progress on several areas related to standardizing and improving the measurements. We published the first Standard Operating Procedure (SOP) for the Airmodus Particle Size Magnifier / Nano Condensation Particle Counter (Lehtipalo et al. 2022). The aim of the SOP is to unify the procedures related to the measurements. The SOP outlines how to setup, calibrate and use the PSM/nCNC for the measurement of particle number concentration starting from 1 nm and particle size distribution between ca. 1-4 nm during field measurements. This will help in achieving comparable measurements from different sites using a PSM/nCNC. Within the Finnish Research Impact foundation project “Improved sampling of aerosol nanoparticles” we have worked on improving the sampling of sub-10 nm particles in collaboration between University of Helsinki and Airmodus Oy. As a concrete example of the project results, we have characterized the Airmodus Nanoparticle Diluter (AND) down to the particle size of 1 nm (Lampimäki et al. in preparation). AND is a sampling system designed to minimize losses for nanoparticles, allowing to dilute and dry the sample with an option to also remove all small ions.

ACTRIS Cluster Calibration Center (CCC), hosted by University of Helsinki, is part of the European ACTRIS Centre for Aerosol In Situ Measurements (CAIS-ECAC). CCC aims to test and validate the methods for measuring sub-10 nm particle concentration and size distribution and to improve the methods to calibrate the relevant instrumentation. CCC develops measurement guidelines, data tools and instrument calibration methods and practises, organizes instrument calibration and intercomparison workshops and provides training and consultancy regarding sub-10 nm particle measurements. CCC is in a central role in distributing the knowledge on nanoparticle measurements from the ACCC to the European level.



Air pollutants and Black Carbon (BC) footprints

Understanding of sources, formation paths and effects of air pollutants requires both the research of aerosol emissions and detailed investigations of atmospheric aerosols. In general, anthropogenic aerosol emissions are originated from large number of different pollution sources, such as on-road and off-road vehicles, ships, aircrafts, power plants, and residential combustion. The emitted compounds undergo atmospheric dispersion, transportation and transformation processes, and they can have impacts both on human population health and climate. The characteristics of the emissions are highly dependent on technologies used in emission sources which links the research closely with technological development done for instance in companies developing emission reduction techniques, fuels and engines. Furthermore, measurement technologies of particles and gases as well as different solutions used to protect people from air pollutants have linkages with business-related research and development.

The research of the Aerosol Physics Laboratory of TAU on aerosol emissions and their impacts on air quality, human health and climate includes several projects funded by EU, Business Finland, Finnish companies and municipalities. These projects have strong and multidisciplinary collaboration with several universities and research institutes (incl. ACCC partners, especially FMI) and, especially, with large number of companies and other stakeholders aiming to utilize the research output in their own research and development projects. One of these projects is Black Carbon Footprint (2019-2022, www.bcfootprint.com) which was a 3-year research project funded by Business Finland and Finnish companies, creating a new research-oriented business ecosystem covering actors from different areas of companies, research and authorities to obtain new in-depth knowledge about BC, measurement methods, emissions, ambient BC concentrations and their transformation during atmospheric aging. In addition to research institutes, the partners of the BC Footprint project included Vaisala Oy, Dekati Oy, Airmodus Oy, Valmet Oy, Pegasor Oy, AX-Suunnittelu, AGCO Power, and SSAB. While the BC is a pollutant and climate forcer from combustion processes, particles are emitted also from non-exhaust sources, such as vehicles brakes and tyres. These emissions and their impacts on air quality are investigated in the new NEX-EL project (Non-exhaust emissions in electrifying mining and urban environment) where several aerosol instrument related companies are included together with several actors from mining industries. In currently ongoing Future Spaces project (www.futurespace.fi/), TAU's research focuses on the effects of outdoor pollution on indoor pollutant concentrations. This project is conducted together with VTT and City of Tampere, and Finnish companies Koja Oy, A-Insinöörit, Dekati Oy, BitWise Oy, Fennia, Fidelix, and TPI Control, aiming to develop service type business related to indoor air quality. The indoor air quality is strongly linked also with TAU's research in the project Excellence in Pandemic Response and Enterprise Solutions, where several research institutes are working with more than 20 companies (www.pandemicresponse.fi).

For contact: topi.ronkko@tuni.fi

2.5.4 Spin offs and testbeds

List of Spin offs and testbeds starting from June 2020, from the onset of the ACCC are:

CarbonLINK

- CarbonLink Oy is a company founded by climate scientists from University of Helsinki. Our goal is to help organizations towards a more sustainable future. CarbonLink offers a dynamic tool for organizations to measure their carbon footprint and identify their impacts on the climate. (<https://www.carbonlink.fi/>)

Climate Analytics (ACCC Impact Task)

- Climate Analytics Finland Ltd (CAF) is a climate neutrality advisory and carbon removal verification company focusing on developing impartial carbon removal verification service for various customers. Current voluntary carbon credit systems do not offer credible option for global carbon removal market. It is necessary to impartially verify claimed carbon offsets or credits. Regulation related to this field is developing especially in Finland and in the European Union, but also elsewhere. CAF will combine relevant customer data analysis and the latest available research findings and measurements to scientifically credible modelling tools in developing independent and impartial CAF carbon removal verification as internationally scalable commercial service

Filtson Oy, Kuopio

- Filtson develops a methane removal system which reduces methane gases immediately, without intermediate processes. It can be used to slow down the greenhouse effect and reduce the release of methane into the atmosphere. (<https://filtson.fi/>)

Megasense Ltd, Helsinki

- real-time, street-level air quality and noise insights for cities, enterprises, and individuals (<https://megasense.com/>)

2.6 INTERNATIONAL INITIATIVES AND PARTNERSHIPS

2.6.1 International approach and science diplomacy

Science diplomacy aiming at scientific collaborations between countries “to address joint problems and to build constructive international partnerships for delivering effective scientific advice for policy making” has been one of the key guidelines for ACCC approach. ACCC continues (IP Task 13) this activity initiated by INAR ten years ago. The aim is to find ways to solve global Grand Challenges, particularly climate change and poor air quality in polluted megacities, and at the same time, better bridge research to international climate policy and science diplomacy processes (Lappalainen et al. 2022). INAR has introduced the Pan-Eurasian Experiment programme (2012 -



www.atm.helsinki.fi/peex) to address the environmental challenges in the Northern Eurasian and launched the GlobalSMEAR as well as hosted the European Centre of the International Eurasian Academy of Sciences (2015 -). Most recently, INAR /ACCC has coordinated the Arena for the gap analysis of the existing Arctic Science Co-Operations (AASCO, 2020–2021) to promote integrated research at the Arctic and outside the Arctic environments. (Lappalainen et al. 2022). INAR/ACCC has also joint the European Union Science Diplomacy Alliance (<https://www.science-diplomacy.eu/>)

INAR/ACCC also participates in several other international partnerships. These partnerships include:

- coordination of “Joint international research laboratory of Atmospheric and Earth System Sciences” (JirLatest) which is a long-term, bilateral RI collaboration with the University of Nanjing
- Started NJU Nanjing-Helsinki Institute with Nanjing University that is a joint education program for bachelor, master and doctoral student
- acting as one of the Center(s) of Excellence of the Digital Belt and Road (DBAR) Initiative
- coordination of the Arctic Boreal Hub, a thematic network of the University of Arctic
- INAR, as one of the “advanced partners” for the Eastern Mediterranean and Middle East – Climate and Atmosphere Research Centre (EMME-CARE).
- INAR chairs the National Committee for the Future Earth (FE) Program and participation to the FE Governing Council.

ACCC co-operates in several regions, where science diplomacy plays a role, in China, India, South-Africa, and the Arctic -Antarctic. The regional co-operation is often based on joint measurements in places where there is not enough data. The co-operation with China, India and Polar South are significant areas for making impact on global climate change and air quality policies. The importance of research and measurements in the Arctic region is increasing. The University of Helsinki has launched its Arctic Program for 2022-2030 ([UH Arctic programme 2022-2030.pdf](#))

The co-operation between all Finnish flagships and the USA research organizations and private sector actors has been boosted by a new Memorandum of Understanding (MoU) on “the cooperation in green economy and new technologies”, a MoU between State of Colorado & Government of Finland, signed in 2022 (https://finlandabroad.fi/web/usa/current-affairs/-/asset_publisher/h5w4iTUJhNne/content/coloradon-osavaltio-ja-suomi-tiivistavat-vihrean-talouden-ja-kehittyneiden-teknologioiden-kumppanuuttaan-uudella-yhteistyosiakirj/384951).

2.6.2 Pan-Eurasian Experiment (PEEX) Program (ACCC Impact Task 10)



The Pan-Eurasian Experiment (PEEX) Programme, initiated in 2012 by the University of Helsinki's Institute for Atmospheric and Earth System Research (INAR) and key partners from Russia and China, focuses on climate change impacts in the Northern Eurasian Arctic and boreal regions, as well as air quality issues in China. Due to geopolitical shifts, collaborations with Russian and Belarusian research organizations have been suspended since February 2022. Consequently, PEEX has pivoted towards strengthening research ties with countries in the Near Europe Neighborhood and Newly Independent States, resulting in the signing of, for example, 12 new Memoranda of Understanding as of April 2024.

Originating from the Nordic Centre of Excellence for Cryosphere Research and the Finnish Centre of Excellence in Atmospheric Sciences, PEEX now boasts a network of about 4,000 researchers across

Europe, Eastern Europe, and Asia, particularly emphasizing collaborations with China. With over 40 official partnership agreements, PEEX exemplifies science diplomacy in action, as environmental experiments are conducted, and new ground-based measurement concepts are implemented throughout Eurasian and Asian nations.

Since its inception, PEEX has achieved significant breakthroughs in understanding land-atmosphere interactions in Siberia and addressing pollution in China's megacities. Areas of focus include permafrost studies, environmental health, and the interactions of aerosols, gases, and boundary-layer dynamics. The program also explores regional to urban modeling of meteorological processes and pollutants. Guided by a research agenda spanning regional to global scales, PEEX emphasizes high-quality research infrastructure, big data, and the training of future scientific leaders. The framework is designed to facilitate rapid policy-making and raise awareness of critical environmental challenges. Bilateral collaborations emphasize ground-based infrastructure and tailored measurement concepts to aid local authorities in their mitigation strategies.

For contact: hanna.k.lappalainen@helsinki.fi

2.6.3 Global SMEAR - Earth Observatory Initiative



The “Station for Measuring Earth Surface – Atmosphere Relations”, the GlobalSMEAR (<https://www.atm.helsinki.fi/globalsmear/>), is a bottom-up initiative by the Institute INAR, University of Helsinki (Hari and Kulmala 2005, Hari et al. 2016, Kulmala 2018, www.atm.helsinki.fi/globalsmear). The aim of the GlobalSMEAR is to establish a global in-situ station network based on the SMEAR concept, especially, in the regions where we have significant observational gaps or other current observation capacity is under development. A global network would consist of the SMEAR flagship stations together with the different standard, flux and advanced stations (Hari et al. 2017, Kulmala 2018). The tailored SMEAR measurement concept could be applied on different land surfaces and ecosystems (forest,

peatland, agricultural land, urban), but also in marine environments (Vihma et al. 2019). The preliminary analysis of the existing ground station pool in the Arctic-Boreal region and the geographical, climatic and ecosystem representativeness of the current stations especially in Russia has been determined, the gaps are identified and tentative station network developments are proposed by Alekseychik et al. 2016. However, this approach has been suspended since February 2022.

The SMEAR technical model (e.g. in-situ observation methods, instrument technology, data system, comprehensive data analysis methods) is continuously developed at the Station Measuring Ecosystem Atmosphere Relations (SMEAR) II in Hyytiälä. Today the SMEAR II serves as a prototype for the GlobalSMEAR flagship station and represents the most advanced and comprehensive in-situ station worldwide. Currently the SMEAR II is carrying out standardized observations over 1200 parameters (including concentrations and fluxes) 24/7 on different ecosystems: boreal forest, wetland and lakes and is contributing to several European ESFRIs (ICOS for Integrated Carbon Observation System, ACTRIS for Aerosols, Clouds, and Trace gases Research Infrastructure, eLTER Integrated European Long-Term Ecosystem, Critical Zone & Socio-Ecological Research Infrastructure, AnaEE for Infrastructure for Analysis and Experimentation on Ecosystems) and Earth Observation systems and networks such as WMO GAW and GEO-GEOSS. We have developed different elements (station network concept, customer journey line, building up new stations, networking and identification of new services and end users) needed for the GlobalSMEAR implementation (Kulmala 2018). Most recent activity of the IP11 has been organizing the “Towards Global Earth Observatory” workshop in collaboration with the World Meteorological Organization (WMO) at the SMEAR-II in Hyytiälä (May 2023). The WS was to prepare the observation component to the Berlin Summit (July 3-7, 2023) Germany (<https://eve4climate.org/>), and to discuss how we can work together towards Global Earth Observatory research infrastructure (RI).



For contact: hanna.k.lappalainen@helsinki.fi, tuukka.petaja@helsinki.fi, markku.kulmala@helsinki.fi

2.6.4 Thematic Network Arctic Boreal Hub, University of Arctic

“Arctic Boreal Hub” is the University of Arctic (UArctic) thematic networks coordinated by INAR. Arctic boreal hub expands the PEEX collaboration with research organizations to USA and Canada. UArctic currently involves over 50 thematic networks representing different disciplines. The thematic networks provide collaboration “network of networks” in the Arctic research and education. Arctic Boreal hub is participating the annual University of Arctic assembly and meetings. Arctic boreal hub organizes events and distributing information e.g., newsletter to Arctic researcher network and promotes Climate University in these connections. The University of Arctic is actively seeking private funding opportunities to the thematic networks ([Thematic Network on Arctic Boreal Hub](#)). One example is the Arena for the gap analysis of the existing Arctic Science Co-Operations (AASCO, 2020–2021, 2023-2025) funded by Prince Albert Foundation (Lappalainen et al. 2022). For the further information find the AASCO White Paper(Policy Brief) by Lappalainen, H.K. and Petäjä, T. (Lead Editors) (2025) “Arena for the gap analysis of existing Arctic Science Co-Operations (AASCO), Summary of the AASCO event on February 4–5”, 2025, in Monaco, a special edition, ISBN 978-952-84-1294-6, 36 pages.

For contact: hanna.k.lappalainen@helsinki.fi



2.6.5 Digital Belt and Road – Helsinki Center of Excellence (DBAR Helsinki CoE)

Since 2018 University of Helsinki INAR has acted as a “DBAR Helsinki Center of Excellence (CoE)”. DBAR-Helsinki-CoE status bridges the INAR / ACCC research and, especially the SMEAR RI approach to the Digital Belt and Road Initiative (2018). The initiative is focused on infrastructure, trade, and economic development across the Silk Road economic region. This initiative is interested in sharing expertise, knowledge, technologies, and data to demonstrate the role of Earth observation science and technology and big Earth data applications (Guo et al. 2018). INAR / ACCC has already carried out several regional assessments of the Silk Road economic region and the needs for the environmental monitoring system (Lappalainen et al. 2018, Petäjä et al. 2021, Kulmala et al. 2021). These science based assessments introduce regional scientific questions and environmental challenges and call for the future capacity, in volume and quality, of the *in situ* observations, new data products and services based on the SMEAR concept. DBAR collaboration is concretized by specific projects and participation to annual DBAR conference and meetings. For example a new three year DBAR project titled “SmartSMEAR data platform development for the accomplishment of United Nations’ sustainable development goals (SDGs)” by INAR / ACCC in collaboration with the University of Tartu starts in 2026.

For contact: markku.kulmala@helsinki.fi, hanna.k.lappalainen@helsinki.fi, joni.kujansuu@helsinki.fi

2.6.6 Joint International Laboratory Atmospheric and Earth System Sciences (JirLATEST)

The collaboration between Nanjing University and University of Helsinki started in 2009. The collaboration included the academic exchange and short-term visits and in building a SMEAR-type station in Nanjing at 2012 (the SORPES station). The Joint international research Laboratory of Atmospheric and Earth System Sciences was established in 2015 to better bridge the research and education activities between the two universities (<https://jirlatest.nju.edu.cn/main.psp>). At the moment JirLATEST is The State Key Laboratory in China that focuses on atmospheric sciences. The laboratory develops an integrated observational platform which aims to better integration of the observations and modelling. The aim is to improve existing parameterizations and to add key processes in regional and global models (Nie et al. 2022, Ding et al., 2016a, Ding et al. 2016b).

For contact: markku.kulmala@helsinki.fi, joni.kujansuu@helsinki.fi

2.6.7 The Nanjing-Helsinki Institute in Atmospheric and Earth System Sciences, Nanjing University (NJU Nanjing-Helsinki Institute)

The Nanjing-Helsinki Institute in Atmospheric and Earth System Sciences, Nanjing University (NJU Nanjing-Helsinki Institute) was established in April 2022 through a partnership between Nanjing University and the University of Helsinki. The institute's primary objectives include developing a modern talent training system in the field of atmospheric and earth system sciences and fostering outstanding individuals with a global perspective. It also aims to cultivate talent with the potential to lead in addressing pressing global issues like climate change and sustainable development through scientific research, while contributing to local and national efforts in environmental governance, climate change mitigation, and global sustainable development.



2.6.8 Future Earth program

Future Earth is a global network that convenes researchers and scholars from all parts of the world, across different societal and academic sectors, and across the natural, social, and human sciences. Future Earth initiates and supports international collaboration between these researchers and stakeholders to identify and generate the integrated knowledge needed for successful transformations towards societies that provide good and fair lives for all within a stable and resilient Earth system (FES; Future Earth Finland) National Committee brings the global change initiative, Future Earth, to Finland. FES is working with the European network of National Committees and is directly involved in the Future Earth Assembly and Governing Council governing structure. FES aims to tackle questions on global change and sustainable development from an integrated, interdisciplinary perspective and to ensure that research is planned and produced in a close partnership with society and end-users of science in Finland. The National Committee members represent natural and social sciences, and municipalities, industry, and economic stakeholders. The secretariat of the National Committee is located at the University of Helsinki. <https://futureearthsuomi.fi/>

For contact: hanna.k.lappalainen@Helsinki.fi, Julia.karhumaa@helsinki.fi

2.6.9 Eastern Mediterranean and Middle East – Climate and Atmosphere Research Centre (EMME-CARE)

Eastern Mediterranean and Middle East – Climate and Atmosphere Research Centre (EMME-CARE) is a long-term teaming project funded by Horizon 2020 (grant no. 856612). The project started in January 2020 and is coordinated by the Cyprus Institute. The Advanced Partners are the Max Planck Institute for Chemistry (MPIC), the French Alternative Energies and Atomic Energy Commission (CEA) and the INAR at the University of Helsinki. In this project The Atmosphere and Climate Division of the Cyprus Institute has established a new CoE – the Climate and Atmosphere Research Center (CARE-C, <https://emme-care.cyi.ac.cy/projects/>).

CARE-C is focused on to carry out research on Climate Change and Air Pollution over the Eastern Mediterranean and the Middle East (EMME) region. It also motivated to identify the promising commercial research applications that contribute to the sustainable economic growth of Cyprus in a highly competitive international environment. The project also involves education and training with post-graduate degree courses on meteorology and atmospheric sciences, trainings on climate change and weather forecasting, and hands-on practice and knowledge transfer on atmospheric instrumentation.

For contact: katja.lauri@helsinki.fi

2.6.10 European bioaerosol monitoring network AutoPollen

Within the EU Horizon project SYLVA (PI: M.Sofiev, FMI), a baseline infrastructure has been developed laying down the foundation for the emerging European bioaerosol network. It is a technological contribution to the EUMETNET programme AutoPollen, which is setting up the principles and organizational structures for this network. AutoPollen and SYLVA aim at establishing a new-generation automatic European network for real-time monitoring of a multitude of biological particles, such as pollen, fungal spores, algae, some bacteria, etc. Recent extensions towards micro- and nano- plastic demonstrate the wider applications of the new monitors and technological infrastructure behind. FMI is now setting up the processing centre that will handle the AI-based processing of the raw data

collected from the devices Europe-wide (Sofiev et al, 2023). Demonstration of the network capabilities is available at the SYLVA Website <https://sylva.bioaerosol.eu>.

For contact: mihael.sofiev@fmi.fi

2.6.11 International collaboration and focus areas

China

In China, INAR research activities are coordinated as an integral part of the GlobalSMEAR approach and are connected to the analysis of the new SMEAR standardized measurements done in China. The most active partners are the Nanjing University (NJU), the Beijing University of Chemical Technology (BUCT,) and the Aerospace Information Research Institute, Chinese Academy of Sciences (AIR-CAS). The research together with NJU is carried under the “Joint international research laboratory of Atmospheric and Earth System Sciences” JirLATEST (jirlatest.nju.edu.cn/main.htm) and NJU Nanjing-Helsinki Institute (<https://nh.nju.edu.cn/en/index.htm>). INAR has published several papers together with Nanjing University based on the data from the SMEAR benchmarked station called “Station for Observing Regional Processes of the Earth System” (SORPES-NJU) (Kulmala et al. 2017, Wang et al. 2017, Petäjä et al. 2016). Presently NJU collaboration is expanding to Suzhou-city where new campus of NJU and second SORPES-NJU station are under construction. Also, NJU Nanjing-Helsinki Institute was established in April 2022 to strengthen collaboration between Nanjing University and the University of Helsinki. Students from bachelor up to doctoral level are studying dual degrees from NJU and UH. The new Beijing Haze station hosted by BUCT is the first urban mega city station based on the SMEAR concept and has been active since 2018. Station has provided important knowledge on atmospheric processes in Beijing during the corona epidemic and the first report for the Mayor of Beijing has been submitted (Du et al. 2020, Kulmala et al. 2022, Liu et al. 2022, Yan et al. 2022). The AIR-CAS / INAR collaboration is implemented in a frame of the Digital Belt and Road Program (DBAR), INAR is also hosting one of the International Centers of Excellence (ICoE) of DBAR, abbreviated the “DBAR-ICoE- Helsinki”. INAR is also promoting the PEEX approach in China under the framework of the Belt and Silk Road initiative. PEEX has published a separate PEEX Belt and Silk Road agenda, which introduces the large research questions and research infrastructures relevant to the Belt and Silk Road region (Lappalainen et al. 2018). Other major collaborators in China are Tshinghua University, Fudan University and several Chinese Academy of Sciences insitutes.

For contact: joni.kujansuu@helsinki.fi

India

A quarter of the global population lives in South Asia, and the air quality of its cities and villages is among the the worst in the world. Advances in atmospheric measurement and analysis techniques over the last few decades have drastically improved the ability to understand the sources and processes that drive air pollution and effective ways to reduce it. Unfortunately, local capacity in these state-of-art techniques is still extremely limited in South Asia. INAR and the Centre for Atmospheric Sciences, Indian Institute of Technology Delhi (IITD) are collaborating to setup an advanced atmospheric observatory in India and perform state-of-art atmospheric measurements and analysis. Cooperation between University of Helsinki (UH) and IITD is built on the foundation of the already existing MoU between a Consortium of Finnish Universities and the 23 Indian Institutes of Technology, and the MoU between IITD and UH, signed in 2022.

The FMI have been actively involved with air quality- and climate research in India since 2004. FMI’s partners include The Energy and Resources Institute (TERI, New Delhi, since 2004), the India Meteorological Department (IMD, New Delhi, since 2014), University of Hyderabad (since 2020), and

Indian Institute of Technology Madras (Chennai, since 2022). Collaboration with the partners has been project based and has been implemented under existing MoU's or collaboration agreements.

The key objectives of this collaboration are: 1) Science: Advancing air pollution science with implications for evidence-based policy to reduce air pollution in a highly polluted and populated region, with climate co-benefits. 2) Capacity building: Training researchers at the leading institute in South Asia in cutting-edge atmospheric measurement and analysis techniques. In the long-term training-the-trainers (IITD) to create a local training and capacity building hub in South Asia which will enable scientists, policymakers, civil society, and other stakeholders in the region to use state-of-art atmospheric science and technology to tackle major environmental and public health challenges. 3) Collaboration: Building and engaging a network of domestic and international stakeholders working on themes related to air quality and climate change.

FMI's activities in India have included setting up aerosol measurements in Indian Himalayan foothills (Mukteshwar 2004-2013 and Ranichauri 2015-) and in the Delhi Capital Region (Gual Pahari 2007-2010, 2016, 2019), with a new site installed close to Chennai on the coast of the Bay of Bengal (Fig.7) in 2025. FMI have also co-conducted research expeditions (together with University of Helsinki) to quantify how the amount and properties of absorbing aerosols (black carbon) is affecting the glaciers' mass balance in the Himalayas (2014-2018, 2022, 2023). In a new EU- Horizon project CryoSCOPE, new studies will be conducted at glaciers in the Kashmir region. In addition, the FMI have installed and operationalized air quality forecasting models at different spatial resolutions for the Indian region and Delhi (2020). More applied research has included understanding the effect of Indian aerosols on produced solar energy and developing solutions for improving the air quality by decreasing traffic emissions with cleaner fuels (together with TAU). Finally, the FMI have co-organized three international seminars related to air quality and climate in India (in 2016, 2023 and 2025), to increase local awareness and facilitating national and international networking on these topics.

For contact: antti.hyvarinen@fmi.fi, rakesh.hooda@fmi.fi



Figure 7. left: emission measurements for an Indian truck; middle: roadside measurement campaign near Delhi; right: SILAM- modeled PM₁₀ concentration over India.

IITD and INAR are collaborating to setup and operationalize the atmospheric observatory at IITD's Sonipat campus in the Indo-Gangetic Plain (IGP; population: 400 million). The measurement site is located 10 km northwest (upwind) of the Delhi-National Capital Territory, the world's most polluted megacity, and also acts as a gateway of pollutants from upwind locations in the middle east, Pakistan, and northern states in India. This measurement station is envisioned to become the most advanced atmospheric observatory in South Asia which will contribute to finding solutions to air pollution and climate change. In addition to collaborating on atmospheric science infrastructure development and scientific research, we are working on curriculum design and grant writing to support the teaching of intensive courses on themes related to atmospheric measurement and analysis which will be taught at this atmospheric observatory in India. Providing such training for atmospheric measurement and analysis in India will help build the capacity of air pollution science with implications for evidence-



based policy to reduce air pollution in a highly polluted and populated region, with climate co-benefits.

For contact: shahzad.gani@helsinki.fi, markku.kulmala@helsinki.fi

USA

Finland and the State of Colorado, USA are currently building cooperation in quantum technology, renewable energy and the space sector. Colorado is a national center of top research in renewable energy, cyber security and space technology, with a similar profile to Finland. Cold air expertise and similar green economy and climate goals are the unifying areas for both Finland and Colorado. There are business ecosystems of interest to Finland operating in the state, and Finnish companies are already operating in the region, but there is plenty of potential to increase cooperation.

The potential areas for the ACCC US collaboration are harmonized and comprehensive observations of the environment on the global scale. Comprehensive measurements are needed to support the green transition and to monitor and verify the environmental impacts of the implemented policies. This allows science-based decision making and a transparent society. Leverage on the excellence in atmospheric sciences in ACCC/ Finland builds on the co-location of both the ICOS and ACTRIS Head offices in Finland, the SMEAR-concept that operates all RIs in a co-located manner, data and computational services developed and operated by CSC, Technological instrument development in atmospheric and environmental sciences (e.g. Vaisala, Airmodus, Karsa), and atmospheric sciences performed within ACCC flagship with a connection to other flagships. ACCC is supporting building of comprehensive SMEAR II -Hyytiälä type of a measurement station in NYC Governor's Island in collaboration with New York Climate Exchange, Stony Brook University and other local universities (the first stage of the station development started in 2025).

For contact: tuukka.petaja@helsinki.fi

Africa

South African North-West University, University of Helsinki and the Finnish Meteorological Institute have operated a joint atmospheric research station in South Africa since July 2006 (Laakso *et al.*, 2008; Petäjä *et al.*, 2013; Vakkari *et al.*, 2013). Since May 2010 the research station has been located at Welgegund (www.welgegund.org) near North-West University campus in Potchefstroom, 100 km west of Johannesburg (Jaars *et al.*, 2014). The focus of the research is in characterising several globally significant aerosol sources such as atmospheric new particle formation, biomass burning and megacity emissions (Tiitta *et al.*, 2014; Vakkari *et al.*, 2014, 2015, 2018). Welgegund has also ecosystem measurements to facilitate studies on ecosystem – atmosphere relations (Jaars *et al.*, 2016; Räsänen *et al.*, 2017, 2020, 2022). Welgegund is the only research station in continental Africa where in-situ aerosol measurements are operated continuously, and it provides a valuable reference point for atmospheric composition in continental southern Africa (Butt *et al.*, 2016; Nieminen *et al.*, 2018; Rose *et al.*, 2021). Since 2014 the Finnish Meteorological Institute and the South African Weather Service have collaborated in aerosol particle measurements at Cape Point Global Atmospheric Watch station outside Cape Town. During the collaboration more than 15 technicians and students from different South African universities and private companies have been trained to maintain high-level atmospheric measurements for both air quality monitoring and climate research purposes. More than 20 students and several post-doctorate researchers have also participated in relevant Master level courses organized by University of Helsinki.

For contact: ville.vakkari@fmi.fi

Arctic and Antarctic



INAR conducts wide-ranging research and measurements, develops measurement concepts, techniques and data products in atmospheric, environmental and oceanic sciences for the Arctic domain. The implementation of the Arctic - boreal activities e.g. permafrost research at INAR is coordinated by the the Pan-Eurasian Experiment Program (<https://www.atm.helsinki.fi/peex> Kulmala et al., 2015, 2016; Lappalainen et al., 2016; Lappalainen et al., 2022, Kukkonen et al., 2020, Ezhova et al., 2021, Georgiades & Ezhova et al., 2022).), the GlobalSMEAR initiative

(<https://www.atm.helsinki.fi/globalsmear/index.php/global-smear>) and by the collaboration at different Arctic frameworks such as AASCO – Arctic Science Collaborations (<https://www.atm.helsinki.fi/peex/index.php/aasco/>, Lappalainen et al. 2022 submitted), Arctic Avenue (<https://www.su.se/bolin-centre-for-climate-research/about-the-centre/collaboration/arctic-avenue-1.681384> Uotila et al., 2019; Chafik et al., 2021, Tang et al., 2022), bilateral research cooperation, and participation to several international working groups (IASC, U-Arctic, SAON Data and Stations WGs, Sustainable Arctic Observation Networks (SAON) - ROADS). As importantly the research and observations carried out at the Station Measuring Ecosystem-Atmosphere Relations (SMEAR-I) station in Värriö (Eastern Lapland of Finland), in collaboration with other Arctic stations, measurement campaigns at the Arctic and Nepal Himalayas (Third Pole) and on the several research projects at the national, Nordic, European and global scales are the INAR assets in the Arctic research domain.



INAR also implements Arctic research by several ongoing projects such as (<http://www.era-planet.eu>) “Integrative and Comprehensive Understanding on Polar Environments” (iCUPE; 2017-2022; <https://www.atm.helsinki.fi/icupe/>, Petäjä et al., 2021, Noe et al., 2022), “Resilience of arctic

communities in the changing boreal environment: risk assessment of forest fires and diseases" (CRoBEAR) project, 2020-), Forest fires in the changing climate (PI T. Petäjä and E. Ezhova; Sizov & Ezhova et al. 2021), Forest fires in the changing climate (Sizov et al., 2021), Interactions between the Antarctic continental glacier and the Southern Arctic Ocean (SA, PI P. Uotila 2019-2023; Nie et al. 2022), Atmospheric Gas-to-Particle conversion (ERC, PI M. Kulmala 2017-2022) and the project on pre-industrial aerosols (ERC, F. Bianchi 2020-2024), "Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system" (CRiceS; 2021-2025; Pls R. Makkonen & J. Thomas; <https://www.crices-h2020.eu>). INAR participation to the MOSAiC expedition has provided valuable data e.g on sea ice and aerosols (Schupe et al. 2022)

For contact. hanna.k.lapppalainen@helsinki.fi, mikko.sipila@helsinki.fi, federico.bianchi@helsinki.fi, Tuukka.petaja@helsinki.fi, petteri.uotila@helsinki.fi

One of FMI key research areas are Arctic and Antarctic atmospheric and cryospheric science, focusing on topics such as dust transport and deposition at high latitudes (Meinander et al., 2022), impact of pollutants on snow and ice surface melting, reflectance and cryosphere-atmosphere interactions (Svensson et al., 2024; Ström et al., 2023) and historical carbon isotopic composition and concentration in ice cores and snow (Eckhardt et al., 2023; Ruppel et al., 2021). These were studied in project NABCEA "Novel Assessment of Black Carbon in the Eurasian Arctic " 2016-2020 and in project Black and brown carbon in atmosphere and cryosphere (BBrCaC), 2022-2025. Peat and boreal fires as a source of modern and pre-industrial carbon in the Arctic are currently studied in project Fire in the Arctic – Trends and sources of Arctic Black and Brown Carbon for targeted climate change mitigation (PeatFire, 2023-2027).

FMI also commits to long-term monitoring both in the Arctic and in Antarctic. FMI runs Pallas Atmosphere-Ecosystem Supersite in Finnish Arctic 170 km north of the Arctic Circle, forming part of the WMO Pallas-Sodankylä Global Atmospheric Watch station. FMI Arctic measurements and long historical data records from around the Arctic contribute to international efforts for resolving Arctic trends and source analysis of the key atmospheric components (e.g. Boyer et al., 2023; Backman et al., 2021; Laj et al., 2020). FMI Pallas station serves as a hub for Arctic cloud-aerosol interaction studies (Brus et al., 2025). The new project "Lifecycle of stratiform clouds in the Finnish subarctic; 4D variability of cloud microphysics and turbulence – 4Dcloud", 2025-2029, will further contribute to this understanding leveraging scientific knowledge and the state-of-the-art techniques both in-situ and remote-based.

The FMI Antarctic studies are done jointly with INAR and with several international partners, focusing on science activities and year-round monitoring at stations Dome-Concordia (collaboration with CNR, Italy), Marambio (collaboration with SMN, Argentina), south Pole (collaboration with NOAA, US) and Neymayer (collaboration with AWI, Germany). Atmospheric composition sources and connections to climate in Antarctica were studied in project Antarctic Climate Forcing Aerosol (ACFA, 2021-2024) (e.g. Asmi et al., 2018; Quelever et al., 2022; Boyer et al., 2025). The joint research was additionally acknowledged by two stipends from the Scientific Committee for Antarctic Research (SCAR). In the future Antarctic research, this long-term monitoring will be in a crucial role to understand the speed and the impact of the fast evolving climate change signals in the Antarctic.

Ukraine

ACCC has several ongoing projects (and proposals) with Universities and research organizations with Ukraine framed as "Climate science, research infrastructures and education for resilient societies" such as ERASMUS+ projects: the Multilevel Local, Nation- and Regionwide Education and Training in Climate Services, Climate Change Adaptation and Mitigation (ClimEd <http://climed.network/>) and the

Climate University for Virtual Exchanges (CLUVEX; <https://www.atm.helsinki.fi/cluvex>) with partners from Finland (INAR as a coordinator), Denmark (University of Copenhagen), Ukraine (Odessa State Environmental University/ now Mechnikov Odessa National University, Taras Shevchenko National University of Kyiv) and Armenia (Yerevan State University), and BioArt society, Finland. During 2020-2026 the ClimEd project will educate through trainings Ukrainian teachers/ researchers/ specialists/ experts in the field of climate services, climate change, and climate-dependent economic sectors. During 2023-2026 the CLUVEX project will bring together up to 2500 students and provide them climate education through the Virtual Exchange Weeks for students. At the moment ACCC have collaboration with the following universities and organizations in Ukraine: Odessa State Environmental University, Mechnikov Odessa National University, Kyiv National University of Construction & Architecture, O.M. Beketov National University of Urban Economy, Lviv Polytechnic National University, Bila Tserkva National Agrarian University, Odessa National Medical University, Taras Shevchenko National University of Kyiv, Chernivtsi National University, Ukrainian Hydrometeorological Institute, Odessa National Polytechnic University, Ukrainian Joint Meteorological and Hydrological Society, Institute of Mathematical Machines and Systems Problems, Kyiv Academic University, National Academy of Sciences of Ukraine, Ministry of Education and Science of Ukraine, and Ministry of Environmental Protection and Natural Resources of Ukraine. ACCC is also involved with a Climate KIC project coordinated by Savonia-ammattikorkeakoulu for “Roadmap for climate-oriented recovery of Ukraine”.

Baltic States

ACCC has new project “Next Generation Workforce – Empowering Young People for Improved Employment” (REOPEN, 2025-2028) with Partners from University of Helsinki, University of Latvia, Institute of Baltic Studies, Social Enterprise Estonia, and the Latvian Chamber of Commerce and Industry. The project aims to bridge the gap between education and competences needed to improve the young people’s (YP) competitiveness. The project will reopen collaboration between high education institutions (HEIs) and small/medium-sized enterprises (SMEs)/ organizations, will educate from remote areas in jointly developed training programs and provide fairly compensated smart internships as short-term mobilities (1-2 months) in Latvia, Estonia and Finland, matched to the skills and competencies of YP and actual needs of the SMEs/ organizations, thus, activating cross-border cooperation network. As a result, 300 YP from project partner countries will increase their competitiveness in the labour market – they will gain new skills during 3 training modules on soft-skills, digital and green skills, and work field-specific skills. YP will receive certificates, including official ECTS. 150 of these YP will also gain their work affiliation through practical work experience during their internships and will receive letters of reference from the hosting SMEs. As a positive side-result, the collaboration between HEIs and SMEs/ organizations will be strengthened, finding new ways and improving HEIs ability to respond more flexibly to the rapidly changing labour market skills and competencies’ demands. A cross-sectoral international collaboration network will be established, expanded and evidence-based recommendations drafted for policy and decision makers to improve the support systems for YP. entering the labour market in the long term.

For contact: hanna.k.lappalainen@Helsinki.fi, alexander.mahura@helsinki.fi

2.7 SOCIETY DIALOGUE(S)

2.7.1 Overview

Climate change is a challenge of today’s and future societies. Decisions have to be made, which urgently steer the current system first to climate-neutrality and then beyond, to “carbon negativity”. Increasing solidarity and shared responsibility are essential elements to drive sustainable and responsible policy decisions. The measures must be communicated and discussed in a way that

people can accept and internalize them. Legitimacy stems from the base that it is perceived to produce more good than bad (Lappalainen ed. 2019). ACCC is facilitating dialogues on climate change and climate neutrality, produces a science base which enables the decision-makers to take well-informed decisions. ACCC invites all actors to join this discussion by different assets.

2.7.2 Sofia Earth Forum

Sofia Earth Forum aims towards joint understanding over different boundaries to find practical solutions on Grand Challenges especially in the Northern context. The forum was established in 2016 by Academician Markku Kulmala and Metropolitan Ambrosius. Forum gathers together academic and other communities in Finland and internationally to discuss climate change research and innovation and potential solutions. The Sofia Earth Forum mission is to establish a framework of scientists and citizens to deliver a science-based message being legitimated to fast track policy making. Church has a focal role in legitimate. The Earth System Manifesto (https://www.atm.helsinki.fi/peex/images/manifesti_peex_ru_hub2.pdf) summaries the landscape *“The growing population needs more fresh water, food and energy, which will cause challenges such as climate change, declining air quality, ocean acidification, loss of biodiversity and shortages of fresh water and food supplies. Grand Challenges are the main factors controlling human well-being and the security and stability of future societies. The Grand Challenges cannot be solved separately.”* One of the major outcomes has been the forum *“Sofia Forum Suomi: Yhdessä kohti hiilineutraalia tulevaisuutta - Kannustimet, kehittäminen ja sääntely 9.–10.12.2019 Pääviestit ja pohdintoja* organized in 2019 (Lappalainen et al. 2019).

For contact: markku.kulmala@helsinki.fi

2.7.3 International Eurasian Academy of Sciences (IEAS) European Center

The host organization of the International Eurasian Academy of Sciences (IEAS) was established in 1994 as a bottom-up initiative of scientists from Europe and Asia. The aim of the Academy is to bridge scientists across different disciplines together with scholars representing culture, art and religion who are interested in solving environmental and social challenges at the Eurasian countries. IEAS academy provides a unique research network across Eurasian region to ACCC. The IEAS is organized in the branches and the research centres. The branches unite IEAS members based on scientific fields and the research centres are based on regions. The headquarters (HQ) of the IEAS European Center is in Helsinki (2012- <https://www.atm.helsinki.fi/m/ieaseurope>), the IEAS Eurasian Center is in Moscow; (collaboration suspended Feb. 2022 -), and the IEAS Asian-Pacific Center in Beijing, (<http://bj.ieaschina.org/en/index.html>).

The IEAS European Center (<https://www.atm.helsinki.fi/m/ieaseurope>) HQ in Helsinki is hosted by INAR, University of Helsinki. The IEAS Europe centre has nominated over 50 academician having academic backgrounds from atmospheric and environmental sciences to social sciences (https://www.atm.helsinki.fi/m/ieaseurope/images/IEAS_Acad_Directory_published_24Aug2021.pdf). Due war in Ukraine the IEAS activities has been suspended.

For contact: hanna.k.lappalainen@helsinki.fi

2.7.4 Initiative for a Safer Climate

Safer Climate aims to creating new spaces for climate discussion and action at the intersection of academia, civil society and arts. The network consists of researchers, civil society organizations, actors

in the field of arts and culture, students and others. Founded in 2022 as part of the ACCC, Safer Climate facilitates events, campaigns and dialogue to redefine the role of civil society in climate safety. The umbrella theme ‘safer climate’ covers multiple approaches from climate security to increasing inclusivity in climate discussion. In addition to ACCC institutions, recent collaborators include Helsinki Inequality Initiative (INEQ), Resilient and Just Systems (RESET), IHME Helsinki, Savonia University of Applied Sciences, LUOMUS – Finnish Museum of Natural History, Historians without Borders in Finland, Committee of 100 in Finland, Artists with Evidence, Tunne ry, Mental Health Finland (Mieli ry), Think Africa, Think like a Scientist, Falay Transition Design, Peace Ambassador Academy, Arizona State University Center for Science and the Imagination, UN Association of Finland, Sivi Study Center, KVS, ICAN Finland, Operaatio Arktis, The Finnish Death Studies Association, the Finnish Society for Natural Burials, Natural Resources Institute Finland (LUKE) and Helsinki International Movie Festival - Love and Anarchy as well as numerous individual experts, artists and projects. The network organizes both ACCC internal events and events open to the general public, and the network’s work has been presented in numerous international and national conferences. In 2023 and 2024, the transdisciplinary Climate Security Festival as well as the Climate & Death 2024 event gathered around a 100 participants per event from across sectors. Currently the network focus is on working with the themes of climate and security, climate and death, art-research collaboration methodologies and strengthening ACCC’s collaboration with social sciences and humanities.

For contact: rosa.rantanen@helsinki.fi

2.7.5 Polar South - The World Academy of Sciences (TWAS)

The World Academy of Sciences (TWAS) is a network working to advance science in the developing countries. The council of TWAS is responsible for supervising academy affairs (M. Kulmala is a council member in 2023-2026). This enables new ACCC coordinated activities in Global South and educating doctoral students in atmospheric sciences from each country from Global South. The idea is that the new PhDs would be climate change experts in the administrations in their home countries and would enhance e.g., the open data availability their countries (see IP11 Global Observatory). Satellite data is playing an increasingly large role in supporting climate actions in global south; FMI has recently started ICI project with Rwanda, Kenya and Tanzania to support their resilience and monitoring of climate and air quality. Also submitted ERASMUS+ Virtual Exchange for UnaEuropa, coordinated by UH, with university partners from Democratic Republic of the Congo, Kenya, and South Africa has synergy with this task.

For contact: markku.kulmala@Helsinki.fi

LIST OF ACRONYMS

ACCC	= <i>The Atmosphere and Climate Competence Center</i>
INAR	= <i>Institute for Atmospheric and Earth System Research</i>
UH	= <i>University of Helsinki</i>
TAU	= <i>Tampere University</i>
FMI	= <i>The Finnish Meteorological Institute</i>
UEF	= <i>The University of Eastern Finland</i>
ACTRIS	= Aerosol, Clouds and Trace gases Research Infrastructure
ACTRIS-FI	= ACTRIS (see above) Finland
AMAP	= Arctic Monitoring and Assessment Program
AnaEE	= Infrastructure for Analysis and Experimentation on Ecosystems
Arctic-Boreal Hub	= U-Arctic Thematic network led by ACCC
ATM MP & DP	= Master and Doctoral Programs in Atmospheric Sciences I
BSAG	= Baltic Sea Action Group
CAF	= Climate Analytics Finland Ltd.
CAP	= Common Alerting Protocol
CAS	= Chinese Academy of Sciences
CBACCCI	= Carbon-Biosphere-Aerosol-Cloud-Climate Interactions a Nordic graduate school
Nordic	
CERN	= European Organisation for Nuclear Research
CLC	= Climate Leadership Coalition
CODATA	= The Committee on Data for Science and Technology
Copernicus	= EU's Earth Observation Programme
CRAICC	= Cryosphere-atmosphere interactions in a changing Arctic climate (a NCoE lead by ACCC)
CSA	= Climate Smart Agriculture
DBAR	= Digital Belt And Road
DIMECC	= Digital Internet Materials & Engineering Co-Creation
EASAC	= European Academies Science Advisory Council
EEA	= European Environment Agency
EFI	= European Forest Institute
eLTER	= European Long-term Ecosystem Research
EMME-CARE	= Eastern Mediterranean and Middle East – Climate and Atmosphere Research
Centre	
ENVRI	= Network for Nordic Atmospheric and Earth System Science
EOSC	= European Open Science Cloud
ERC-grants	= European Research Council grants
ERMES	= European Research on Mobile Emission Sources
ESA	= European Space Agency
ETC-ACM	= European Topic Centre for Air Pollution and Climate Change Mitigation
EVE	= the Earth Virtualization Engines
EU DGs	= European Union Directorate Generals in e.g. Environment Education and Culture and Climate Action
EUDAT	= European Data Infrastructure
FE European Alliance	= Future Earth European Alliance
FES	= Future Earth Finland Nat.
GAW	= Global Atmospheric Watch
GEO-GEOSS	= Global Earth Observation System of Systems
GlobalSMEAR	= Global Observatory on Atmosphere-Earth system interactions
ICOS	= Integrated Carbon Observation System
ICOS-FI	= ICOS (see above) Finland



IEAS	= International Eurasian Academy of Sciences
IFAD	= International Fund for Agricultural Development
IIASA	= International Institute for Applied Systems Analysis
ILTER	= International Long-Term Ecosystem Research
IPCC	= Intergovernmental Panel on Climate Change
LULUCF	= Land use, Land-use change and Forestry
MC-CLOUD-TRAIN	= Marie Curie H2020 Initial Training Network for CLOUD experiment at CERN
INAR Ecosyst.	= INAR Ecosystems research infrastructure
NASA	= National Aeronautics and Space Administration
Nat. CP	= National Climate-change Panel
NCoE	= Nordic Centers of Excellence
NMR	= the Nordic council of Ministers
Nordic Univ. Hub	= Nordic University Hub in Atmospheric and Earth System Sciences
PEEX	= Pan-Eurasian Experiment
RGS	= Russian Geographical Society
UNECE TFEIP	= Task Force on Emission Inventories and Projections
UNFCCC	= United Nations Framework Convention on Climate Change
WMO	= World Meteorological Organization

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APPENDIX I ACCC RESOURCES

Cumulative information starting from 2020 - :

ACCC Visiting Professors Program

Doug Worsnop (INAR UH) (2007 -)
 Paolo Laj (INAR UH)
 Ram Oren (INAR UH)
 Sari Palmroth (2023 -)
 Roddy Dewar (INAR UH)
 Chandrasekaran Venkatachalam (INAR UH, FMI)
 Leonidas Ntziachristos (TAU)
 Aleksander Baklanov (INAR UH)
 Jingqiu Mao (INAR UH)

ACCC Professors in Practice

Anneli Pauli (INAR UH)
 Jouni Keronen (INAR UH)

Staff exchange

APPENDIX II PROJECT PORTFOLIO

NOTE: This list included projects > 500.000 euros total budget funded by Research Council of Finland, Business Finland, private foundations and Horizon 2020 programs. This is not the full list of all projects carried out by the ACCC partner organizations.

Atmosphere and Climate Competence Center (ACCC)

PIs /directors: Markku Kulmala, University of Helsinki (director); Jaana Bäck University of Helsinki (vice director); Ari Laaksonen, FM; Miikka Dal Maso, Tampere University; Annele Virtanen, University of Eastern Finland
 Funding: Academy of Finland, Flagship Program
 Partners: INAR UH, FMI, TAU, UEF
 Active: 1.7.2020-30.4.2023
 Website: <https://www.acccflagship.fi>

The Atmosphere and Climate Competence Center (ACCC) is a one of the Academy of Finland funded projects of the Flagship program^(*). ACCC will help Finland, EU and ultimately the whole world in reaching the Paris climate target and in mitigation and adaptation to climate change by providing sustainable, cost-effective and science-based solutions. We will quantify and activate the potential for climate change mitigation through carbon sequestration in forests and soils, and quantify the air quality-climate interactions and impacts to mitigate air pollution and sustain healthy atmosphere and to quantify the impact of reducing pollutant emissions on climate. The active interaction between the interdisciplinary ACCC and the policy makers and public / private sector facilitates effective climate policies, mitigation and adaptation plans from national to international scales. The company collaboration boosts new practical solutions e.g. new atmospheric measurement instruments, climate – air quality analysis services and improved verification services for auditing sector.

(*) The Academy of Finland's Flagship Programme is an instrument that supports high-quality research and increases the economic and societal impact emerging from the research. The Finnish Flagships represent an effective mix of close cooperation with business and society, adaptability and a strong commitment from host organisations. www.aka.fi/en/research-funding/programmes-and-other-funding-schemes/flagship-programme/.

RESEARCH PROJECTS

PROJECTS CONTRIBUTING POTENTIAL OF LAND-BASED CC MITIGATION (RP1)

Carbon balance, sequestration in agriculture lands

Multi-benefit solutions to climate-smart agriculture (MULTA)

PI(s): Jari Liski (coordinator), Finnish Meteorological Institute (jari.liski@fmi.fi); Annalea Lohila (annalea.lohila@helsinki.fi), Jussi Heinonsalo (jussi.heinonsalo@helsinki.fi), University of Helsinki

Funding: Academy of Finland, Strategic Research Council

Active: 1.6.2019-28.2.2023; 1.9.2022-31.8.2025

Partners:

Website: <https://carbonaction.org/en/en-stn-multa/>

Food system is facing a huge challenge. It should contribute significantly to the mitigation of climate change while producing healthy food sustainably for a growing population. Farming causes the majority of climate impacts in the food system. Sequestering atmospheric carbon to the soil is a great opportunity for the food system to address the climate crisis. Climate-smart agriculture offers also many other benefits. It improves productivity, enhances soil health, and increases biodiversity, resiliency, food quality and retention of nutrients and water. To this end, we i) design climate-smart agricultural solutions beneficial to food system, ii) test their application in farm scale, iii) develop a verification system for the carbon sequestration and iv) develop economic measures and policies implement the solutions in Finland and abroad. We utilize co-design and interaction with farmers, companies and policy-makers to drive systemic change in our food system.

Towards parcel-specific greenhouse gas calculation: new emission factors and model solutions and updatable system (LOHKO-KHK)

PI: Jari Liski (jari.liski@fmi.fi), FMI; Maarit Liimatainen (maarit.liimatainen@luke.fi), LUKE

Funding: The Ministry of Agriculture and Forestry as part of the 'Catch the carbon' programme

Active: 1.1.2022–31.10.2024

Partners:

Website: <https://carbonaction.org/en/lohko-khk-2/>

The current Finnish greenhouse gas inventory calculates plant residues entering the soil and the soil emissions roughly using a south-north distribution based on crop yield statistics and livestock numbers. It does not consider the impact of cultivation operations in detail. Life cycle analyses do not currently have well-established practices for estimating soil emissions from the manufacture of products. In most cases, soil emissions and removals have not been taken into account at all. The calculation of climate impacts related to the carbon market emphasizes the need for field-specific information. The main goal of the project is to develop a system for Finnish field-specific greenhouse gas accounting. The work is divided into five closely connected and partially iterative phases. 1. compile measurement data and form an overall picture of the impact of different soil types and

cultivation practices on the greenhouse gas balances of field plots and the quality and coverage of data through data analysis; 2. the development of statistical and simulation models for the carbon sequestration and greenhouse gas emissions of farming systems through measurements; 3. integrate measurement data, improved models, and model inputs into the information and calculation system and calculate field-specific greenhouse gas data with this system; 4. developing methods for integrating improved greenhouse gas data into practical accounting systems; and 5. develop a policy to update the greenhouse gas calculation of fields in the future as new information accumulates. The project promotes the “transition to climate-resilient agriculture, forestry and other land use” (LULUCF), as the methods developed in the project can estimate greenhouse gas sequestration and emissions per plot and take into account the impact of farming activities in this calculation. Such a calculation will make it possible to plan agricultural climate measures in more detail, monitor the effects, and develop control measures.

Precise biomass information for agricultural carbon budget calculations by combining satellite and field data with ecosystem modelling (BIOHILA)

PI: Jari Liski (jari.liski@fmi.fi), FMI; Iivari Kunttu (iivari.kunttu@hamk.fi), HAMK; Ernesto Hartikainen (ernesto.hartikainen@biocode.io), Biocode Ltd; Juha Nousiainen (juha.nousiainen@valio.fi), Valio Ltd

Funding: The Ministry of Agriculture and Forestry as part of the 'Catch the carbon' - programme

Active: 1.4.2022–31.10.2023

Partners:

Website: <https://carbonaction.org/en/biohila-2/>

The main objectives of the project are to develop a method for producing accurate information on field biomass and to use this information and method in agricultural carbon balance accounting, public and private sector climate work, and food production operations. The project will create a method for estimating, mapping and modeling field biomass, which is linked to key decision-making and operational accounting applications used for agricultural climate solutions: greenhouse gas inventory and scenario systems, and carbon offsets and food carbon footprint calculators. This method is suitable for field-specific and farm-specific carbon balance calculations and can provide information on the annual growth trend of biomass and carbon balance at the field-level using satellite images.

From Footprints to Digital Handprints - Carbon and greenhouse gas budget of agriculture (FF2DH)

PI: Jari Liski (jari.liski@fmi.fi), FMI

Funding: Business Finland

Active: 1.4.2022–30.3.2025

Partners:

Website: <https://www.bsag.fi/hankkeet/ff2dh/>

The development of Smart Environmental Handprints of Finnish food products, services and processes and how to turn handprints visible and commercially beneficial in global markets. This project is a part of a large From Footprints to Digital Handprints consortium and covers the whole food production chain from fields to international consumers. Consortium level aim is to start the systemic level change towards the transformation of Finnish food sector to a digitally integrated agrifood ecosystem. Main studies of this consortium include solutions for interoperable agrifood data-infrastructure, especially compatibility to European structures (Gaia-X). In addition, end to end systems architecture creation, verification, and requirements management are part of the consortium's work. This consortium has both vertical and horizontal actors, representing business and research organizations from food, ICT, electronics, and meteorology, and climate research sectors.

Carbon and greenhouse gas balance of croplands (CROPLANT)

PI: Jari Liski (jari.liski@fmi.fi), FMI
 Funding: Lantmännens Research Foundation and Lantmännens
 Active: 1.7.2022-30.9.2024
 Partners: Lantmännens, Finnish Meteorological Institute and Häme University of Applied Sciences
 Website:

The role of carbon sequestration is extremely important in modern agriculture. In general, there is a need to improve carbon sequestration. A combination of different methods, including different measurements on the fields, soil measurements, satellite data, and finally, modeling, are needed. In this project, all these elements are used. The studies will be conducted on LM Agro's experimental farm in Hauho, Finland, and on five ordinary farms in Finland. The farms are in southern Finland and belong to the Climate and Nature -program.

How biodiversity impacts the ability of fields to store carbon (TWINWIN)

PI: Jari Liski (jari.liski@fmi.fi), Finnish Meteorological Institute; Jussi Heinonsalo (jussi.heinonsalo@helsinki.fi), University of Helsinki; Laura Höijer (laura.hojer@bsag.fi), BSAG
 Funding: Maj and Tor Nessling Foundation
 Active: Phase I 2019-2021, phase II 2021-2023 (1.6.2019-31.5.2023)
 Partners: Finnish Meteorological Institute, University of Helsinki, University of Zürich, BSAG
 Website: <https://carbonaction.org/en/twinwin-project/>

Biodiversity may increase carbon sequestration to agricultural soils in many ways. Diverse vegetation assimilate atmospheric CO₂ efficiently and roots and root exudates transport C into different depths in soil. Plant diversity support diverse microbial communities that induces stable soil C formation. Increased soil organic matter content is essential for soil fertility and culturability and as a positive feedback, improved plant growth increases CO₂ assimilation and flow to soil. Modern agriculture where monocultures and chemical plant protection (e.g. herbicides, pesticides) are common has caused a decline in biodiversity in agricultural ecosystems. Currently, it is not well known how the increased plant diversity affect plant production and C sequestration. The aim of the project is to investigate how much agricultural soil C sequestration can be increased by increasing plant diversity. In particular, we are interested in understanding which diversity-related processes are essential for soil C accumulation. Biodiversity impacts on soil C sequestration will be investigated using field and greenhouse experiments and the most important factors will be included in the models that describe soil C cycling. In addition to the scientific work, a special emphasis is put in the outreach and communication. In the first phase of the project, in 2019-2021, an ambitious field experiment was established to Viikki, and the research work, including various measurements and modeling, got off to a great start. In the second phase of the project, in 2021-2023, the research will be extended from plants and microbes to soil animals. The biodiversity impact mechanisms identified in the project will be used to improve soil carbon model Yasso. This will help to address the ecological sustainability of agriculture more holistically.

International soil co-operation for improved visibility and impact (FIN SOIL ACTION)

PI: Elisa Vainio (elisa.vainio@bsag.fi), BSAG; Laura Höijer (laura.hojer@bsag.fi), BSAG; Annalea Lohila (annalea.lohila@fmi.fi), FMI
 Funding: Ministry of Agriculture and Forestry as part of the 'Catch the carbon' -programme
 Active: 1.4.2021-30.9.2023
 Partners: Baltic Sea Action Group (BSAG) and Finnish Meteorological Institute (FMI)

Website: <https://carbonaction.org/en/project-international-soil-co-operation-for-improved-visibility-and-impact-fin-soil-action/>

The main goal of the project is to strengthen the impact and visibility of Finnish soil know-how, the networking of experts in the field nationally and internationally, and co-operation with key international networks. The project builds strongly on existing national and international networks, projects, and events – raising awareness of these, building cooperation and synergies, new opportunities, funding opportunities, and impact. As a result of the project, Finland's and Carbon Action's cooperation with the 4/1000 initiative in particular will be intensified. The most visible is the 4/1000 Northern Europe event to be held in 2023, together with the 4/1000 initiative. Finland takes its place as a pioneer in promoting carbon sequestration in agricultural land, and at the same time strongly promotes the international networking of Finnish researchers and other actors. Through events and other activities, the project will promote solutions for the promotion of Monitoring, Reporting and Verification (MRV) work, carbon market mechanisms, user-friendly tools for carbon sequestration monitoring, regenerative soil management, soil monitoring, certification, climate solutions for peatlands and citizen participation. The project also promotes the coordination of biodiversity and climate measures. BSAG is responsible for project management, coordination, communication, event organization and participation, and interaction. The Finnish Meteorological Institute is responsible for scientific co-operation and co-ordination with the 4/1000 initiative. EJP SOIL program / EJP SOIL National Hub is a key collaborator.

Solutions for reliably quantifying carbon sequestration in soil (FluCS Tool)

PI: Henriikka Vekuri (henriikka.vekuri@fmi.fi), FMI
Funding: Maj and Tor Nessling Foundation
Active: 2020-2023
Partners:
Website: <https://carbonaction.org/en/flucs-tool-project/>

Direct measurement of the changes in soil carbon stock is slow, laborious and expensive and has significant uncertainties due to large background stocks and high spatial variability. An alternative is to infer the soil carbon stock change from measurements of the gaseous carbon fluxes (carbon dioxide and methane) between ecosystems and the atmosphere. The main objective of this work is to develop a multi-purpose tool for estimating the uncertainty in long-term greenhouse gas flux measurements and annual carbon balances, which could be used for a variety of ecosystems when estimating their climatic impact and finding solutions suitable for their unique environmental challenges. The end product of the project will substantially improve the reliability and comparability of carbon sequestration estimates.

Towards climate positive agriculture: The contribution of new particle formation to the climate impact of agriculture (CARBON+)

PI: Markku Kulmala (markku.kulmala@helsinki.fi), UH; Janne Rinne (janne.rinne@helsinki.fi; Luke); Jari Liski (jari.liski@fmi.fi; FMI)
Funding: Business Finland and involved companies
Active: 2025-2027
Partners: Valio, Atria, HKFoods, Fazer, Aired, Climate Analytics Finland, Airmodus, Gasmet Technologies Oy, MegaSense

In this project, we build a holistic understanding of the contribution of food production to global climate. In the holistic approach, not only the climate-warming greenhouse gas emissions from various fields, farming systems and animal shelters are considered, but also the climate-cooling

formation of atmospheric aerosol particles is accounted for. We increase the process understanding of aerosol particle formation in agriculture and identify crops and livestock that maximize the positive climate impacts of agriculture. By increasing our understanding of the atmospheric aerosol formation processes in these systems, we can model aerosol particle production also outside the fields measured in the project. With this research we verify the more comprehensive and probably less negative climate impacts of agriculture, which is an essential part of the food industry's value chain and life cycle assessment. The development of climate-neutral agriculture and food industry is a huge asset in the global market and increases the competitiveness of Finland's agriculture and food industry. The project increases exports related to the food system from many angles. Research organizations in the project are the University of Helsinki (UH), Natural Resources Institute Finland and the Finnish Meteorological Institute. Company partners include Valio, Atria, HKFoods and Fazer from the food sector, Gasmot, Airmodus, Megasense and Airel from equipment manufacturers and Climate Analytics Finland from the climate impact verification sector.

Carbon balance in forests and peatlands

The Centre of Excellence in Peatlands, Climate Change and Restoration

PI (s): Eeva-Stiina Tuittila (UEF), Tuula Aalto (FMI), Annalea Lohila (FMI), Miina Rautiainen (Aalto University), Minna Välimäki (HU)
 Funding: The Research Council of Finland
 Active: 2026-2033
 Partners: UEF, FMI, AALTO, HU
 Website:

The Centre of Excellence in Peatlands, Climate Change and Restoration studies the ongoing change in northern peatlands: how climate change impacts their biodiversity and climate response, and how upcoming large-scale restoration in Finland and elsewhere in Europe will affect them. We will also provide support for informed decisions on restoration if the impacts on biodiversity and climate conflict. The research combines long time series, paleoecology, remote sensing, experimental ecological research, modeling, and disaggregative decision support methods in a novel and original way. The research will be carried out as a joint project of researchers operating at the Universities of Eastern Finland, Helsinki, and Aalto and the Finnish Meteorological Institute, and in close cooperation with leading international researchers and stakeholders. The CoE will educate new experts to solve problems that require multidisciplinary understanding, such as those related to the future of peatlands.

Quantifying the potential of boreal peatland rewetting for climate change mitigation (SA-RESPEAT)

PI: Coord Kari Minkkinen /UHEL, FMI PI Mika Aurela, 2021-2025
 Funding: Academy of Finland
 Active: 2021-2025
 Partners:
 Website:

Assess the possibilities for climate change mitigation of rewetting forestry-drained peatlands in boreal zone.

Forests on peatlands – solutions for reducing emissions and increasing of carbon sinks (MMM-TURNEE)

PI: Annalea Lohila, Tuula Aalto (tuula.aalto@fmi.fi), FMI
 Funding:

Active: 2021-2023
 Partners:
 Website:

The main goal of the project is to estimate the potential of mitigating emissions and increasing the CO2 sinks by managing fertile forestry-drained peatlands and cutaway peatlands in Finland.

Peatland restoration for greenhouse gas emission reduction and carbon sequestration in the Baltic Sea region (EU-LIFE Peat Carbon)

PI: Tuula Aalto (tuula.aalto@fmi.fi), FMI
 Funding: EU
 Active: 2022-2027
 Partners: Univ. Latvia (CR Mara Pakalne)
 Website:

The project aims to successfully implement climate change mitigation (CCM) measures in raised bogs in Latvia and Finland. To stop continual degradation and release of carbon emissions from these bogs, dams in drainage ditches along the bog perimeters will be constructed. The water-soaked earth will allow vegetation to regrow in degraded areas and prevent carbon from being released from the peat. An important aspect of the project is the utilization of innovative methods, including the creation of an ecosystem model based on remote sensing and monitoring results. Through these innovative methods, resulting changes in the hydrology, vegetation and greenhouse gas (GHG) emissions can be supervised closely. Monitoring also provides and contributes to knowledge on decreasing GHG emissions that can later be accessed by policy-makers and the general public. Knowledge sharing events hosted by Germany and Denmark at the end of the project to educate politicians, experts and the public will promote the results of the project and the importance of peatlands in carbon emission reduction.

Cascading carbon flow in managed forested catchments (CASCAS)

PI: Marjo Palviainen, University of Helsinki (marjo.palviainen@helsinki.fi); Jukka Pumpanen, University of Eastern Finland (jukka.pumpanen@uef.fi)
 Funding: Academy of Finland
 Active: 1.9.2019-31.8.2023
 Partners:
 Website: <https://www.helsinki.fi/en/projects/cascading-carbon-flow-managed-forested-catchments>

In Nordic countries, a large part of the forests are growing on peatland soils, and their utilization will increase in the future because renewable energy sources such as biomass are increasingly being used as a replacement of fossil fuels to decrease the C emissions heating the atmosphere which causes also pressure on water quality due to the risk of releasing large amounts of organic matter to runoff and drainage. The aim of this study is to reveal the effect of forest management practices on peatland on dissolved organic matter load and quality and their subsequent effects on GHG emissions in inland waters. We will study these mechanisms using state-of-the art isotope techniques and water quality measurements and construct a model for estimating the effects of different forest management operations on water quality and GHG emissions and give recommendations on less invasive and more environmentally and climatically friendly forest management options in peatland forests.

The role of snowpack and soil freezing in controlling winter season wetland methane emissions (SA-WINMET)

PI: Tuula Aalto (tuula.aalto@fmi.fi), FMI

Funding:
Active: 2022-2026
Partners:
Website: <https://space.fmi.fi/2022/09/14/winmet-project-monitors-wintertime-methane-fluxes-from-wetlands/>

The northern high latitudes have seen increases of mean air temperatures well above the globally documented average, manifested by reductions in snow cover and changes in soil freezing. The wetland methane emissions are closely connected to those changes, however thorough examination of the role of snowpack and soil freezing in controlling the emissions is missing. In this project we will apply versatile field and satellite measurements to study wetland snow and soil properties and greenhouse gas exchange together with atmospheric methane observations. These observations will be used to develop models to further explain the role of the biophysical drivers of the methane emissions and to estimate the regional winter season methane emissions. The aim of the project is to use these diverse methods together to quantify the winter season methane emissions from northern latitude wetlands and to determine the role of snow accumulation and soil freezing in slowing down the emissions.

Towards high resolution atmospheric data-based greenhouse gas budgets by utilizing advances in supercomputing (GHGSUPER)

PI: Tuula Aalto (tuula.aalto@fmi.fi), FMI
Funding:
Active: 2022-2024
Partners:
Website:

Developments in HPC open new research possibilities and bring policy-relevant information concerning use of atmospheric data in greenhouse gas budgeting in support of national inventories. The project will employ new HPC resources for utilizing satellite greenhouse gas observations in atmospheric inverse modelling of GHG emissions and removals, and solutions for enhancing the performance of the models in spatial and temporal domains as well as producing computationally more effective model systems. Increasing quantities of satellite data need to be assimilated in an efficient way in GHG models while retaining the essential information content of the data. The project increases the readiness level for future high intensity satellite observations by developing methods to assimilate high resolution data into inverse models. New HPC resources will be employed for estimating CO₂ and CH₄ fluxes and their uncertainties by atmospheric inverse modelling in nationally relevant scales.

Methane and soil - tree networks: Adding dimensions to greenhouse-gas studies (METNET)

PI: Maarit Raivonen, University of Helsinki (maarit.raivonen@helsinki.fi); Ari Laurén, University of Eastern Finland (ari.lauren@uef.fi)
Funding: Academy of Finland
Active: 1.9.2019-31.8.2023
Partners:
Website: <https://researchportal.helsinki.fi/en/projects/methane-and-soil-tree-networks-adding-dimensions-to-greenhouse-ga>
<https://uefconnect.uef.fi/en/group/metnet-methane-and-soil-tree-networks-adding-dimensions-to-greenhouse-gas-studies/>

Peatlands are a major source of methane (CH₄) globally. Lack of a simulation model describing CH₄ transport from peat through trees to atmosphere is a key bottle neck in assessing the global

importance of tree mediated CH₄ emissions. An innovative method for computing CH₄ production, consumption and transport will be constructed by combining cutting-edge X-ray tomography, network science and simulation techniques. Three dimensional pore systems of tropical, temperate and boreal peats and methane conducting tree tissues will be imaged using X-ray tomography; and used to create networks of interconnected pipes. Process-based methane computation will be done in this domain. Controlled laboratory manipulation experiments and field experiments are used in developing and validating the simulation model. Flexible and general network modelling approach has not yet been applied within greenhouse gas modelling. It has potential to profoundly renew the ecosystem modelling paradigm and research.

Using remote sensing observations together with a novel terrestrial biosphere model to understand global carbon and nitrogen cycles (RESEMON)

PI: Tea Thum (tea.thum@fmi.fi), FMI
Funding: Academy of Finland
Active: 09/2020 - 12/2025
Partners:
Website: <https://teathum.com/resemon/>

Include sun-induced chlorophyll fluorescence in the terrestrial biosphere model QUINCY and evaluate and improve QUINCY's leaf chlorophyll formulation. This work will improve linkages between using remote sensing observations and modelling, aiming to better understanding of global carbon and nitrogen cycles.

Fiducial Reference Measurements for Greenhouse Gases (FRM4GHG)

PI: Rigel Kivi (rigel.kivi@fmi.fi), FMI
Funding: European Space Agency
Active: 10/2021 – 10/2025
Partners: University of Bremen, Royal Belgian Institute for Space Aeronomy, Finnish Meteorological Institute, Karlsruhe Institute of Technology, Rijksuniversiteit Groningen, Rutherford Appleton Laboratory, University of Wollongong
Website: <https://frm4ghg.aeronomie.be/>
Improving the quality of GHG measurements and implementing new methods

Upgrading knowledge and solutions to fast-track wetland restoration across Europe (EU-WETHORIZONS)

PI: FMI PI Annalea Lohila, 2022-2025
Funding: EU
Active: 2022-2025
Partners: CR Aarhus University (Claudia Nielsen)
Website: <https://www.ymner.com/en/funded-projects/wet-horizons-upgrading-knowledge-and-solutions-to-fast-track-wetland-restoration-across-europe>

WET HORIZONS is a Horizon Europe project that will provide the critical flying start for the challenge of enhancing wetland restoration using a holistic approach. It will boost crucial wetland knowledge and develop sound tools and approaches for fast-tracking large scale restoration action. Despite the efforts of previous projects addressing wetlands restoration, there are still relevant gaps in knowledge due to a lack of wetland data availability and harmonization of the existing information. The project will improve the current data from pristine, drained and rewetted peatlands, floodplains and coastal wetlands; model the effects of typical restoration measures under variable conditions; and analyse the potential socioeconomic impacts. This will enable us to choose the best pathways in wetland restoration minimizing trade-offs, including hotspot priority lists where the ecological and biodiversity

benefits are greatest with minimum investment. WET HORIZONS will involve citizen science for data collection and will develop digital tools for upscaling wetland restoration including an app for the visualization of wetland status and a Decision Support System (DSS) for policymakers. The results will be available in open-access repositories to maximize their use and outreach.

Biogeochemical and biophysical feedbacks from forest harvesting to climate change (BiBiFe)

PI: Jaana Bäck (coordinator) (jaana.back@helsinki.fi), Veli-Matti Kerminen (veli-matti.kerminen@helsinki.fi), University of Helsinki; Mika Aurela (mika.aurela@fmi.fi), FMI

Funding: Academy of Finland

Active: 1.9.2019-31.8.2023

Partners:

Website: <https://www.luke.fi/en/projects/bibife>

Forests are crucial in addressing the climate change not only through bioenergy, but also by the exchange of greenhouse gases in forests, and by maintaining the effective carbon sinks and stocks for removing CO₂ and keeping it away from the atmosphere. Further, many previously unaccounted biophysical feedbacks make reliable accounting of the role of forests very challenging. Adapting forest management to mitigate climate change is a multidisciplinary task, and responds to an urgent societal need for advising the forest and climate policies with solid scientific knowledge. The project aims to quantify the impacts of forest management on climate relevant feedback processes. By thinning a mineral and two organic forest sites, we change the ratio between biogeochemical and biophysical impacts at the stand level. By analysing the full climate impact of the managements, we are able to produce policy-relevant advice on management-climate feedbacks and climate-smart forestry.

Verifying Emissions of Climate Forcers (EU-EYE-CLIMA)

PI: Tuula Aalto (tuula.aalto@fmi.fi), FMI

Funding: EU

Active: 2023-2026

Partners: NILU

Website: <https://cordis.europa.eu/project/id/101081395>

The Global Stocktake, and the success of the Paris Agreement, hinges on the information nations provide about their emissions through National Greenhouse Gas Inventories (NGHGs). Current methodologies laid-out by the IPCC for reporting emissions are generally built around the use of statistical data and emission factors. Although they are designed to be transparent, they can have significant uncertainties owing to incomplete or inaccurate information. The 2019 refinement of the IPCC Guidelines highlights the need for independent verification of NGHGs especially using atmospheric observations. However, the technical complexity and the hitherto limited resolving power of atmospheric constraints makes it challenging for NGHGI compilers to adopt this type of verification. EYE-CLIMA will address this need for independent verification by developing observation-based methods (using both satellite remote sensing and ground-based observations) to a level of readiness where they can be used to determine emissions at national and sub-national scales and for verification of NGHGs. The methodology involves using process-based and data-driven models to simulate GHG fluxes, first without atmospheric observations, then these fluxes are then combined with models of atmospheric transport and chemistry to assimilate atmospheric observations, which are used to correct the first flux estimates. Through engagement with stakeholders, i.e. NGHGI compilers, EYE-CLIMA, will develop flux data products for CO₂ (LULUCF sector), CH₄, N₂O, and emissions data of F-gases (SF₆, HFC-23, HFC-143a, HFC-125, HFC-134a, HFC-32) and black carbon (BC), which will be tailored to their needs. The fluxes will be attributed to natural versus anthropogenic sources, and for the latter, to source sectors that can be compared with groups of

IPCC sectors in NGHGs. The methodology for the atmospheric inversions and how to use these for verification of NGHGs will be described in best practice guidelines.

Effects of wintertime physiology of trees on forest carbon sequestration in changing climate

PI: Anna Lintunen, University of Helsinki (anna.lintunen@helsinki.fi)
 Funding: University of Helsinki research grant
 Active: 1.1.2020-31.12.2023
 Partners:
 Website: <https://researchportal.helsinki.fi/en/projects/effects-of-wintertime-physiology-of-trees-on-forest-carbon-seques>

Knowledge of wintertime and early spring photosynthesis, tree water and carbohydrate relations, water and nutrient uptake capacity, timing of bud burst, freezing processes and their consequences for trees, and especially the effect of changing environment on these processes remains poor. This can also be seen in the current carbon models that fail to estimate the springtime photosynthesis and gross primary production especially in the boreal coniferous forests. The overarching objective of this project is to characterize the wintertime tree physiology and phenology in current and future climatic conditions and their effects on tree performance and growth at high latitudes.

Mechanistic remote sensing of forest climate impacts (MONOCLE)

PI: Jon Atherton, University of Helsinki (jon.atherton@helsinki.fi)
 Funding: Academy of Finland research fellow
 Active: 2022-2027
 Partners:
 Website:

The project investigates how climate impacts on forests reflect on remote sensing data and how this information scales from the leaf to the satellite pixel.

From processes to modelling of methane emissions from trees (MEMETREE)

PI: Mari Pihlatie, University of Helsinki (mari.pihlatie@helsinki.fi)
 Funding: EU, ERC
 Active: 1.10.2021 - 30.09.2024
 Partners:
 Website: <https://cordis.europa.eu/project/id/757695>

Atmospheric concentration of the strong greenhouse gas methane (CH₄) is rising with an increased annual growth rate. Biosphere has an important role in the global CH₄ budget, but high uncertainties remain in the strength of its different sink and source components. Among the natural sources, the contribution of vegetation to the global CH₄ budget is the least well understood. Role of trees to the CH₄ budget of forest ecosystems has long been overlooked due to the perception that trees do not play a role in the CH₄ dynamics. Methanogenic Archaea were long considered as the sole CH₄ producing organisms, while new findings of aerobic CH₄ production in terrestrial vegetation and in fungi show our incomplete understanding of the CH₄ cycling processes. Enclosure measurements from trees reveal that trees can emit CH₄ and may substantially contribute to the net CH₄ exchange of forests. The main aim of MEMETRE project is to raise the process-based understanding of CH₄ exchange in boreal and temperate forests to the level where we can construct a sound process model for the soil-tree-atmosphere CH₄ exchange. We will achieve this by novel laboratory and field experiment focusing on newly identified processes, quantifying CH₄ fluxes, seasonal and daily variability and drivers of CH₄ at leaf-level, tree and ecosystem level. We use novel CH₄ flux measurement techniques to identify the roles of fungal and methanogenic production and transport

mechanisms to the CH₄ emission from trees, and we synthesize the experimental work to build a process model including CH₄ exchange processes within trees and the soil, transport of CH₄ between the soil and the trees, and transport of CH₄ within the trees. The project will revolutionize our understanding of CH₄ flux dynamics in forest ecosystems. It will significantly narrow down the high uncertainties in boreal and temperate forests for their contribution to the global CH₄ budget.

Reducing the effects of forest management to inland waters (REFORMWATER)

PI: Jukka Pumpanen, University of Eastern Finland (jukka.pumpanen@uef.fi); Marjo Palviainen, University of Helsinki (marjo.palviainen@helsinki.fi)

Funding:

Active: 01.04.2019 - 30.06.2023

Partners:

Website: <https://www.helsinki.fi/en/projects/reducing-effects-forest-management-inland-waters>

As the demand for wood and renewable energy sources is increasing, there is an ongoing pressure to use the large timber stock on drained peatlands. This has consequences on inland water quality. The aim of this study is to quantify the effects of current management practices (harvesting and subsequent ditch network maintenance) on peatland forests on the transport of dissolved organic matter to aquatic systems and consequent greenhouse gas emissions. We will also study alternative forest management techniques such as continuous cover forestry to reduce the DOM load to inland waters. We will test the potential of biochar to decrease the DOM and nutrient load on aquatic systems. Finally, we develop state-of-the art process-modelling techniques for assessing the effects of forest management practices on water quality in peatland-dominated catchments, and for optimizing the production in such a way that enables wood production while keeping the adverse environmental impacts to a minimum.

Kuntien mahdollisuudet käyttää maankäyttösektorin nettohiilinieluihin perustuvaa kompensointia (KUNTANIELU)

PI: Anna Lintunen (partner PI), University of Helsinki (anna.lintunen@helsinki.fi); Markku Kulmala (markku.kulmala@helsinki.fi), University of Helsinki

Funding: Ministry of Agriculture and Forestry Catch the Carbon

Active: 1.4.2022-30.9.2024

Partners: SYKE (leads), LUKE and the cities of Turku, Espoo, Lahti and Joensuu

Website: <https://mmm.fi/-/kuntien-mahdollisuudet-kayttaa-maankayttosektorin-nettohiilinieluihin-perustuvaa-kompensointia>

In KuntaNielu project, we investigate the possibilities of municipalities to use compensation based on net carbon sinks of the land use sector. The project is led by SYKE and the other partners are LUKE and the cities of Turku, Espoo, Lahti and Joensuu. The project aims to create conditions for municipalities to strengthen the net sink of the land use sector and to create a basis for compensation activities at the municipal level, with which the municipality can move towards carbon neutrality.

Quantifying carbon sink, CarbonSink+ and their interaction with air quality

PI: Markku Kulmala, University of Helsinki (markku.kulmala@helsinki.fi)

Funding: Jane and Aatos Erkko Foundation

Active: 1.1.2020-31.12.2022

Partners: -

Website: -

In this project, we aim to create novel understanding, reduce the scientific uncertainties and support creating solutions related to climate change and air quality. In more detail, our objectives are to i) reduce the uncertainty of the remaining carbon budget significantly (by a factor of 2-8), ii) to quantify the potential of land-based climate mitigation by finding ways to increase carbon sinks and stocks as well as CarbonSink+ in boreal ecosystems, iii) to quantify air-quality-climate interactions in pristine and polluted regions, and iv) to assess climate change impacts and support adaptation by providing better climate projections and services. This will help society reach the Paris climate targets, and adapt to climate change

Belowground Methane Turnover at a Boreal Peatland: Quantifying the Processes with in situ Stable Isotope Methods (MISO)

PI: Xuefei Li, University of Helsinki (xuefei.z.li@helsinki.fi)

Funding: Academy of Finland

Active: 1.9.2020-31.8.2023

Partners:

Website: <https://researchportal.helsinki.fi/en/projects/belowground-methane-turnover-at-a-boreal-peatland-quantifying-the>

Methane (CH₄) is a greenhouse gas which has strong climate-warming effect. Substantial amount of CH₄ is emitted from peatlands every year. Currently the estimation of peatland CH₄ emission remains uncertain. In this project, for the first time we propose a systematic study targeting the major CH₄ turnover processes (CH₄ production, consumption and transport). These belowground processes will be examined continuously with a novel automatic measuring system and will be traced using isotope labels too. The results will then be used to improve a CH₄ model. The model prediction will be compared with the observed CH₄ emission. This research will be conducted mostly at Siikaneva wetland station located in Ruovesi, Finland. The outcome of this project will help towards a better estimation of CH₄ emission in Finland and abroad.

Drying trend in boreal peatlands - impacts and mechanisms (BorPeat)

PI: Eeva-Stiina Tuittila, University of Eastern Finland (eeva-stiina.tuittila@uef.fi)

Funding:

Active: 1.9.2020-31.8.2024 (extended 31.3.2026)

Partners:

Website:

The response of terrestrial ecosystems to climate change is a key uncertainty. The response of northern peatlands has a high impact because they store a third of the global soil organic carbon reserves and act as net sources of CH₄. Vegetation of arctic peatlands has changed as a result of thawing permafrost and their greenhouse gas (GHG) dynamics have drastically altered. Recent studies on boreal peatlands indicate a drying trend in their vegetation composition but the response varies between peatland types. We aim to assess if the drying trend is a widespread phenomenon and also detectable in the GHG dynamics, and identify underlying mechanisms behind the ongoing change. We use a long-term experimental site in Finland, and a suite of EC sites in Finland, Sweden and Canada with the longest records of pristine boreal peatland GHG fluxes.

The formation and dynamics of deep soil organic matter storages (DEEP-SOM)

PI: Jussi Heinonsalo, University of Helsinki (jussi.heinonsalo@helsinki.fi)

Funding: Academy of Finland

Active: 2021-2025

Partners:

Website: <https://carbonaction.org/en/projects/deep-som/>



Soil organic matter (SOM) forms one of the largest C pools globally. Recently, manipulation of SOM pools through different management practices has become one of the most tempting alternatives for climate change mitigation due the large potential and low unit cost. The aim of the project is to investigate how SOM in deeper soil layers (below 30 cm) is affected by the roots of living plants and how stabile C pools are formed. The great novelty of this research is that our project focuses on deeper soil layers and combines factors that play a critical role in SOM stabilization: soil physical properties (mineral-associated and particulate fractions), presence of plant roots as a resource for C inputs, microbiology and biomarkers, and characterization of SOM based on its resistance to thermal decomposition and nutrient stoichiometry. The data produced improves future model predictions and verification of C sequestration as climate change mitigation tool.

Novel soil management practices - key for sustainable bioeconomy and climate change mitigation (SOMPA)

PI: Maarit Raivonen, University of Helsinki (maarit.raivonen@helsinki.fi); Kati Kulovesi, University of Eastern Finland (kati.kulovesi@uef.fi)
Funding: Academy of Finland
Active: 1.1.2021-31.12.2023
Partners:
Website: <https://projects.luke.fi/sompa/en/>

Finland has an ambitious target to be carbon neutral by 2035, which means that climate change mitigation actions need to be implemented in all sectors including agriculture and forestry. Currently, peat soils of croplands and forests are largest sources of GHG emissions on land-use sector in Finland. This project will develop ecologically and economically sustainable climate change mitigation methods for forest and cropland on peat soil. We will produce new scientific knowledge on drivers for the soil CH₄ and CO₂ emissions on peat soils and on cost-efficient and ecologically sustainable means to mitigate the emissions. We will provide methods that encourage land owners to apply the optimal mitigation measures in practice. The methods to be developed by this consortium will help Finland to reach the carbon neutrality target.

HiiliNielu+ metsät

PI: Markku Kulmala, UH (markku.kulmala@helsinki.fi); Lauri Mehtätalo, Luke (lauri.mehtatalo@luke.fi); Annalea Lohila, FMI (annalea.lohila@fmi.fi)
Funding: Ministry of Agriculture and Forestry
Active: 2025-2026
Partners: UH, Luke, FMI
Website:

The aim of the study is to measure local aerosol particle production in different forest types and combine new measurement data with forest carbon sink calculations. The measurements will be carried out and the collected data will be analyzed in 2025-2026. Based on the analysis, a first version of a conceptual model will be built to link aerosol formation to carbon sink calculations.

Forests, tree ecophysiology

Sensing plant Biogenic Volatile Organic Compounds (SensBVOCs)

PI: Chao Zhang (chao.x.zhang@helsinki.fi), University of Helsinki
Funding: Academy of Finland post-doc
Active: 2021-2024
Partners:

Website:

The project investigates and models the spectral expression of BVOC emissions and their dynamics.

Resolved optical ecophysiology: leaf level (REDEYE)

PI: Albert Porcar-Castell (joan.porcar@helsinki.fi), University of Helsinki

Funding: Academy of Finland

Active: 2022-2026

Partners:

Website:

The project develops and implements novel protocols combining gas exchange, spectral reflectance and fluorescence to resolve and model the regulation of photosynthesis in situ.

Shrub climate sensitivity across boreal, subarctic and tundra ecosystems

PI: Anna Lintunen (anna.lintunen@helsinki.fi), University of Helsinki

Funding: Collaboration program between the university of Helsinki and university of Edinburgh

Active: 1.1.2021-31.12.2024

Partners: University of Edinburgh

Website: <https://researchportal.helsinki.fi/fi/projects/shrub-climate-sensitivity-across-boreal-subarctic-and-tundra-ecos>

In this project, we study the physiological responses of shrubs to environmental changes in tundra, sub-arctic and boreal ecosystems. This knowledge informs Earth system models to improve future projections of climate change impacts in high latitudes particularly across latitudes from the boreal forest to Arctic tundra.

Phloem Ecophysiology: from Mechanistic understanding to Ecological Consequences (PhloEM EcologiC)

PI: Yann Salmon (yann.salmon@helsinki.fi), University of Helsinki

Funding: Academy of Finland

Active: 1.9.2019-31.08.2024

Partners:

Website: <https://researchportal.helsinki.fi/fi/projects/phloem-ecophysiology-from-mechanistic-understanding-to-ecological>

PhloEM EcologiC focus on the mechanistic understanding of carbon and water transport through trees and how they are regulated. Phloem transport is central to plant ecology, and theories to explain it date from 1930. However, these theory need to be confronted to experimental data, a challenging task due to the sensitivity of the phloem tissue. Our objectives are to understand the processes driving phloem transport in trees and test their ecological consequences in terms of species distribution, coexistence and survival to drought. We will use experimental, both in controlled and field conditions, and statistical approaches to address these questions. The research will be conducted mostly at the University of Helsinki and at a research station in Hyytiälä, with additional collaboration in Australia, Europe and (sub)tropical regions. This project outcome will help improve forest management practices in Finland and abroad, particularly in regions exposed to extreme climatic events.

The Hidden Role of Gases in Trees (HidRoGaT)

PI: Timo Vesala (timo.vesala@helsinki.fi) (coordinator), Teemu Hölttä (teemu.holtta@helsinki.fi), University of Helsinki; Ari Laurén (ari.lauren@uef.fi), University of Eastern Finland

Funding: Academy of Finland
 Active: 1.9.2021-31.8.2025
 Partners:
 Website: <https://www.research.fi/en/results/funding/34233>

Trees transport water (sap) through vessels in their stems, under tension. Drought may lead to embolism, where gas fills the vessels and water can no longer be transported. Nanobubbles, recently discovered in sap, may contribute to embolism, but also play a crucial role in the movement of gases within plants. We will develop a tissue network model and a coarser tree model, in which the transport physics, and production and consumption of different gases, are described. Networks created from X-ray tomography images of tree cross-sections will be used as the basis of the tissue level model. Gas concentrations and stem effluxes will be measured to test and parameterise the models. Molecular simulations assess the stability of nanobubbles, and their dynamic behaviour in trees. These simulations will communicate with the tissue and whole tree models. The project will provide a holistic understanding on the role of gases in tree physiological processes.

A whole tree level approach to study source and sink limitation of tree metabolism

PI: Teemu Hölttä (teemu.holtta@helsinki.fi), University of Helsinki
 Funding: Academy of Finland
 Active: 2019-2023
 Partners:
 Website:

The project will study the dependency of tree water use, CO₂ assimilation, growth and respiration on environmental conditions and the internal water and carbon status of a tree. A method of measuring and monitoring minute changes in whole stem and xylem diameter will be applied and developed further to quantify tree water and carbon status in terms of water content, water potential, turgor pressure, osmotic pressure and soil and xylem hydraulic conductance. Measurements will be conducted mainly with pine trees at the SMEAR II in Hyytiälä and the results will be compared with pine trees in much drier conditions in Israel. A whole tree level mechanistic theoretical framework will be used to model tree function and the interconnections between different processes. In addition, the found dependencies for the different processes will be implemented to a structural functional model LIGNUM, as well as in earth system models.

The role of bark in tree survival under drought stress (ROBAST)

PI: Anna Lintunen (anna.lintunen@helsinki.fi), University of Helsinki
 Funding: Academy of Finland Research Fellow
 Active: 1.9.2023-31.8.2027
 Partners:
 Website:

In recent years, cases of widespread forest mortality have been recorded worldwide. Our current understanding still cannot explain why some trees die and some survive, and variation and changes in bark conductance is a plausible hypothesis that I test here. We will study the role of bark in tree survival in dry conditions when stomata are closed due to active regulation thus minimizing foliage water loss and photosynthesis, but water loss through bark and bark photosynthesis continue. We use a unique combination of field and laboratory experiments on bark structure and function and their plasticity to climatic conditions and combine the measurements with modelling of tree hydraulics, regional tree mortality and land-surface modelling to allow improved estimates of species performance and survival in future climate scenarios. The results help us to better understand forest resilience and the integrity of forest carbon sinks in changing climate.

Mitigation

Evaluating integrated spatially explicit carbon-neutrality for boreal landscapes and regions (C-NEUT)

PI: Mika Aurela (mika.aurela@fmi.fi), FMI
 Funding:
 Active: 2022-2024
 Partners: SYKE (Martin Forsius)
 Website: <https://research.fi/en/results/funding/68682>

The challenges posed by climate change, biodiversity loss and harmful land-use are deeply interconnected. The overall objective of the project is to provide top-class spatially explicit information on the potential for reaching carbon-neutrality in boreal landscapes and regions, considering sustainability issues. Advanced modelling and remote sensing techniques are developed and utilized. Both anthropogenic and land-use based greenhouse gas (GHG) emissions are evaluated. Data from top-class research sites is used. The policy-relevant aim is to provide detailed spatial, scenario-based information at different scales for key end-users (e.g. communities, provinces, ministries). This information can be used for e.g. regional land-use and energy strategy planning/management, and sustainability assessment.

Managing Forests for Climate Change Mitigation (ForClimate)

PI: Markku Kulmala (markku.kulmala@helsinki.fi) - coordinator, Anna Lintunen (anna.lintunen@helsinki.fi), Annikki Mäkelä (annikki.makela@helsinki.fi), University of Helsinki; Annalea Lohila (annalea.lohila@fmi.fi), FMI
 Funding: Academy of Finland
 Active: 1.1.2022-31.12.2024
 Partners: Natural Resources Institute Finland and the Finnish Meteorological Institute
 Website: <https://www.atm.helsinki.fi/forclimate/>

The aim of the project is to resolve efficient forest management strategies to strengthen the ability of forests to mitigate climate change. We analyze the impacts of forest management and changing climate on forest carbon sink and radiative forcing by combining comprehensive long-term data sets on boreal forests and the atmosphere with diverse forest growth modelling. We develop a synthesis model MottiC+ and a stand simulation tool available online for public use. The model will allow assessing forest-atmosphere interactions in different management and climate scenarios at various scales accounting not only for carbon sink, but also other forest climate impacts (other GHG's, albedo and aerosols). We will also produce an open online MOOC course on forest use and climate impacts. The interdisciplinary consortium includes scientists from the University of Helsinki, the Natural Resources Institute Finland and the Finnish Meteorological Institute as well as forest sector collaborators.

Arctic Community Resilience to Boreal Environmental change: Assessing Risks from fire and disease (ACRoBEAR)

PI: Tuukka Petäjä, University of Helsinki (tuukka.petaja@helsinki.fi)
 Funding: Academy of Finland
 Active: 1.1.2020-31.12.2023
 Partners:
 Website: <https://cocarbon.fi/en/>

Despite the Arctic being the most rapidly warming area on Earth, so far no estimates exist of how the extensive changes in temperature and precipitation have already led to changes in fire-related air

quality risk and climate-related disease risk to northern community health. Moreover, there is little knowledge of how climatic, social and governance factors combine, and likely result in different approaches to resilience and mitigation scenarios across different regions of the northern high latitudes. This project aims to address these knowledge deficiencies to produce robust pan-Arctic predictions of fire air quality and climate-related disease risk under future climate and development scenarios, based on new knowledge of both underlying science and community perceptions and understanding.

Quantifying the potential of boreal peatland rewetting for climate change mitigation (RESPEAT)

PI: Kari Minkkinen (kari.minkkinen@helsinki.fi), Maarit Raivonen (maarit.raivonen@helsinki.fi), University of Helsinki; Mika Aurela (mika.aurela@fmi.fi), FMI

Funding: Academy of Finland

Active: 1.9.2021-31.8.2025

Partners:

Website: <https://researchportal.helsinki.fi/en/projects/quantifying-the-potential-of-boreal-peatland-rewetting-for-climat>

Northern peatlands have accumulated unproportionally high amount of atmospheric C, which is largely lost back to the atmosphere when peatlands are drained for forestry. Rewetting peatlands has thus a very large mitigation potential for climate change. However, the impacts of other greenhouse gases like methane, and changes in biophysical factors like albedo, should be considered when planning mitigation operations in peatlands. However, empirical data on the impact of rewetting on climate affecting variables is still scarce. We will study those aspects. We will collect new data from rewetted peatlands, and use previously collected data from several intensively studied peatlands in Finland. In addition, we will test and improve existing process based models of carbon and greenhouse gas dynamics in peatlands, and produce a synthesis of the climate change mitigation potential of restoring Finnish peatlands, applicable to other northern peatlands as well.

Impact of Nanoplastics Pollution on aquatic and atmospheric Environments (NaPue)

PI: Monica Passananti (monica.passananti@helsinki.fi), University of Helsinki

Funding: EU, ERC

Active: 1.9.2021-31.8.2026

Partners:

Website: <https://cordis.europa.eu/project/id/948666>

NaPue (Impact of Nanoplastics Pollution on aquatic and atmospheric Environments) is an ERC project. When it comes to environmental protection, one of the greatest concerns is plastic pollution. Plastics have made their way to the most remote regions of our planet, polluting even the air we breathe. As plastics degrade, they can produce tiny particles called nanoplastics. The NaPue project will investigate the presence of nanoplastics and how they affect different environments. Moreover, it will explain how they disrupt various natural processes and how their effects vary compared to larger plastics. The ultimate goal is to better assess the environmental impact of nanoplastics while helping to develop strategies to safeguard against pollution.

Wetland restoration for the future (ALFAWETLANDS)

PI: Tuula Aalto (tuula.aalto@fmi.fi), FMI

Funding: EU

Active: 2022-2026

Partners: LUKE

Website: <https://www.luke.fi/en/projects/alfawetlands>

The ultimate goal of ALFAWETLANDS is to improve the geospatial knowledge base of wetlands, to evaluate pathways of wetland restoration that incorporate a co-creation process and to provide information and indicators for sustainability to maximise climate change mitigation, biodiversity and other benefits. The cross-cutting theme is climate change mitigation, which at the same time supports biodiversity and is socially just and rewarding

Arena for the gap analysis of the existing Arctic Science Co-Operations (AASCO-2)

PI: hanna.k.lappalainen@helsinki.fi
 Funding: Prince Albert II of Monaco Foundation
 Partners: The Sustained Arctic Observing Networks Initiating Group, The Silk Road Economic Belt and the 21st Century Maritime Silk Road, SIOS, The Fletcher School, The University of the Arctic, The Global Atmosphere Watch (GAW) Programme
 Active: 2023-2025
 Website: <https://www.atm.helsinki.fi/peex/index.php/aasco/>

The “Arena for the gap analysis of the existing Arctic Science Co-Operations” (AASCO) project, 2023-2025, is a continuation and extension for the AASCO project funded by the Prince Albert Foundation in 2020-2022 (N°2858). The AASCO process is focused on the understanding the land-ocean-atmosphere feedback and interactions taking place in Arctic-boreal context and region under changing climate. In the previous project we focused on the understanding the land-ocean-atmosphere feedback and interactions taking place in Arctic-boreal context, a region under changing climate. We analysed the Arctic-boreal research gaps, the problems that have not been answered by any of the existing studies or research in this field.

AASCO-2 project in 2023-2025 aims to meet following issues and challenges:

- to further connect and consolidate the existing research communities interested in the feedback analysis: the current academic communities in the field of Arctic ocean, ecosystem and atmospheric research are still working quite separately. In order to find solutions to climate change we need to have also a cross disciplinary, integrative and holistic vision, implementation
- to communicate with different stakeholders, e.g. European Commission, on research funding in this field: we need to bring up the relevance of the holistic approach to the research funders more actively.
- to ensure the open data availability in the Arctic under changing geopolitical situation and bring together different actors providing data for the feedback analysis: data gap due to suspended collaboration with Russia and to find a way forward with data availability in the Arctic region is one of the most urgent questions

Using nuclear observations to improve climate research and GHG emission estimates (NUCLIM)

PI: Markku.Kulmala@helsinki.fi
 Funding: Euratom Research and Training Programme
 Partners: INES TEC (Portugal), Ilmatieteen laitos (Finland), Institutul National De Cercetare-Dezvoltare Pentru Fizica Si Inginerie, Nucleara-Horia Hulubei (Romania), Physikalisch-Technische Bundesanstalt (Germany), Universidade Dos Acores (Portugal), Fundacao Gaspar Frutuoso (Portugal), University Of Galway (Ireland), Helsingin Yliopisto (Finland), Uniwersytet Lodzki (Poland), Npl Management Limited (United Kingdom), University Of Bristol (United Kingdom)
 Active: 01/09/2024 – 31/08/2028
 Website: <https://www.nuclim.eu/home>



Radon is a unique atmospheric tracer. High-quality direct and indirect measurements of radon concentration can advance climate science, radiation protection and nuclear surveillance. These observations will provide a precise baseline for European greenhouse gas (GHG) levels and assist in environmental studies. The EU-funded NUCLIM project aims to investigate the influence of terrestrial factors on air masses, measure pollution events and explore the impact of natural planktonic communities on GHG emissions. Additionally, it will analyse marine boundary layer clouds and aerosols, and study wet deposition and meteorological processes affecting ambient gamma dose rates for nuclear surveillance networks.

Holistic infrastructure for knowledge on land-use sector carbon sinks and emissions tracking (HIKET)

PI: Markku Kulmala, University of Helsinki (markku.kulmala@helsinki.fi); Research Director: Tuomo Kalliokoski, University of Helsinki (tuomo.kalliokoski@helsinki.fi); Jari Liski, Head of Division, Finnish Meteorological Institute (jari.liski@fmi.fi) Anne Tolvanen, Programme Director, Natural Resources Institute Finland (Luke) (anne.tolvanen@luke.fi)

Funding: The Prime Minister's Office

Active: 25.8.2025 - 31.12.2027

Partners: Finnish Meteorological Institute (FMI), Natural Resources Institute Finland (Luke)

Website: <https://www.helsinki.fi/hiket>

Holistic infrastructure for knowledge on land-use sector carbon sinks and emissions tracking (HIKET) is a joint project of the University of Helsinki, the Finnish Meteorological Institute, and the Natural Resources Institute Finland funded by the Prime Minister's Office. Its main objective is to improve understanding of carbon flows and stocks in the land use sector, as well as reduce the uncertainties related to carbon balance estimates. HIKET brings together measurements, models, and open data to strengthen cross-organizational collaboration and to build a more robust knowledge base for monitoring carbon fluxes and data-informed decision-making.

PROJECTS CONTRIBUTING THE AQ – CLIMATE INTERACTIONS (RP2)

Climate modelling

Constrained aerosol forcing for improved climate projections (FORCeS)

PIs: Tuomo Nieminen (tuomo.nieminen@helsinki.fi), University of Helsinki; Annele Virtanen (annele.virtanen@uef.fi), UEF

Funding: EU

Active: 1.10.2019-31.3.2024

Partners:

Website: <https://forces-project.eu/> <https://cordis.europa.eu/project/id/821205>

FORCeS (Constrained aerosol forcing for improved climate projections) is a EU-funded project where European scientists will come together to study the magnitude of aerosol radiative forcing caused by anthropogenic emissions. Understanding the role of aerosols and aerosol-cloud reciprocal action is instrumental for policymakers involved in the Paris Agreement. There is currently a level of uncertainty that needs to be cleared up as there is a comprehension gap between processes and pattern implementation on the climate scale. The FORCeS project aims to detect essential processes that influence aerosol radiative forcing and study data related to aerosols and clouds' impacts on

climate during recent decades. The project will organise workshops among leading European climate scientists and climate specialists aiming to improve European climate models.

Climate relevant interactions and feedbacks: the key role of sea ice and snow in the polar and global climate system (CRices)

PIs: Risto Makkonen (risto.makkonen@fmi.fi), FMI (project coordinator); Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki

Funding: EU

Active: 1.9.2021-31.8.2025

Partners:

Website: <https://cordis.europa.eu/project/id/101003826> <https://en.ilmatieteenlaitos.fi/press-release/7Hl5wqSzMeJvUizgtMZgTb>

Climate and Earth system models (ESMs) are key tools for projecting future climate change; however, these models have significant shortcomings regarding their descriptions of polar ocean-ice/snow-atmosphere interactions, limiting their effectiveness. The EU-funded CRiceS (Climate relevant interactions and feedbacks: the key role of sea ice and snow in the polar and global climate system) project will increase understanding of how rapid sea ice decline is interlinked with physical and chemical changes in the polar oceans and atmosphere. Consortium members will quantify the controlling chemical, biogeochemical and physical processes/interactions within the coupled ocean-ice/snow-atmosphere system through a comprehensive analysis of new and emerging in-situ and satellite observations. CRiceS will improve process, regional and climate models / ESMs to deliver improved quantification of feedback mechanisms within the Earth system.

GreenFeedBack

PI: Ivan Mammarella (ivan.mammarella@helsinki.fi), University of Helsinki

Funding: EU

Active: 1.7.2022-30.6.2026

Partners:

Website:

The ambition of GreenFeedBack is to enhance knowledge of the GHG dynamics in the ecosystems and link GHG in terrestrial, freshwater and marine ecosystems to provide a solid basis for estimation of regional and global climate feedback processes taking human pressure on ecosystems into account. GreenFeedBack will study the processes in sensitive terrestrial, freshwater, coastal and marine areas of which some are hypothesized to be tipping elements in the climate system. Thus, the primary focus will be on high latitude terrestrial and freshwater systems, marine shelves and ocean areas and thereby advance the process-based representation of ecosystems in Earth System Models (ESM). The analysis will involve co-design between scientists and stakeholders. We will use data from the ICOS and ACTRIS stations in Europe and the GIOS, GEM and SMEAR network in Greenland and Finland as well as data from dedicated field and laboratory studies. The enhanced knowledge will be used to improve descriptions of the GHG processes for implementation in ecosystem models and ESMs. Hence, GreenFeedBack will improve and apply ecosystem- and Earth System models to advance our understanding of GHGs effect on climate variability over different time horizons.

Non-CO2 forcers and their climate, weather, air quality and health impacts (FOCI)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki

Funding: EU

Active: 1.9.2022-31.8.2026

Partners:
 Website:

The FOCI (non-CO2 Forcers and their Climate, weather, air quality and health Impacts) project aims at improving our knowledge of individual and cumulative contribution of non-CO2 radiative forcers and their precursors. Specifically, FOCI targets those species where there is the greatest of uncertainty in determining their impact on climate change and the associated influence on weather patterns (e.g., atmospheric and ocean circulation and extreme weather events), air pollution episodes and health impacts. Our integrated observational and modelling analysis will focus on the radiative forcing properties of PM2.5/PM10, CCN and their components (e.g., POA, SOA, BC/EC, SIA, dust), O3 (and its precursors NOx, VOCs, SO2, CO), CH4, and N2O in the wider context of the warming potential of all key GHGs. 24 European Research Institutions including experimentalists and modelers are involved in the FOCI project to assess the impact of key radiative forcers on the climate system

Weather modelling

Unifying Numerical Weather Prediction and Precise Orbit Determination of Global Navigation Satellite Systems

PI: Heikki Järvinen (heikki.jarvinen@helsinki.fi), University of Helsinki
 Funding:
 Active: 1.9.2020-31.8.2024
 Partners:
 Website: <https://researchportal.helsinki.fi/en/projects/academy-of-finland-unifying-numerical-weather-prediction-and-prec>

We are surrounded by digital services in our daily life, such as telecommunication and mobile navigation. We are quite used to the idea that these services are accurate and reliable. In fact, this is due to a lot of very interesting science that keeps advancing. In this research, we are particularly interested in the Earth's atmosphere and the way it disturbs the propagation of navigation satellite signals - yes, the very signals your mobile device receives in order to determine your position on a digital map. Our aim is to drastically improve the knowledge how these atmospheric disturbances affect the accuracy of satellite navigation systems. Interestingly, we can at the same time improve the accuracy of weather forecasts. This may sound odd, but is possible because weather-of-the-day is coupled to the accuracy we know the navigation satellite orbits - knowing one improves the knowledge of the other.

Quantifying controls on the intensity, variability and impacts of extreme European STORMS

PI: Victoria Sinclair (victoria.sinclair@helsinki.fi), University of Helsinki
 Funding: EU
 Active: 1.9.2021-31.8.2025
 Partners:
 Website: <https://researchportal.helsinki.fi/en/projects/quantifying-controls-on-the-intensity-variability-and-impacts-of->

Large-scale mid-latitude storms are studied as their strong winds and heavy rain can cause damage, injuries and even death. Our understanding of what controls the strength and impacts of these storms is incomplete and because of this we have little confidence in how these storms and their impacts will change in the future. We use a numerical model, OpenIFS, to simulate thousands of idealized storms, each of which develops in a different environment. We systematically change the environment (e.g., mean temperature) by varying many variables at once as this is what climate models predict will happen in the future. The strength of the storms is measured by meteorological variables and in

terms of impacts. We also use reanalysis data to relate these results to real, observed storms. Teaching material and tools to assist weather forecasters are also created. The research is performed in INAR at the University of Helsinki.

Atmospheric chemistry, BVOCs and aerosols

Satellites supporting air quality monitoring in Finland, projects 1 and 2

PI: Anu-Maija Sundström (anu-maija.sundstrom@fmi.fi), FMI
 Funding: Finnish Ministry of Environment
 Active: 2019-2020 (project 1), 2020-2021 (project 2)
 Partners:
 Website:

The first project considered an overview of the operational satellite observations that could be used to support air quality monitoring in Finland. The study was published in the Finnish Meteorological Institute report series (Report 2020:01). In the second project satellite observations were used as a part of the Finnish national air quality assessment for the European Commission.

Processes in organic aerosol particles in the boreal environment (PROBE)

PI: Mikael Ehn, University of Helsinki (Mikael.ehn@helsinki.fi)
 Funding: Academy of Finland
 Active: 1.9.2018-31.8.2023
 Partners:
 Website: <https://researchportal.helsinki.fi/en/projects/processes-in-organic-aerosol-particles-in-the-boreal-environment>

The largest uncertainty in climate predictions stems from small, yet ubiquitous, particles in the atmosphere. These aerosol particles have a cooling effect on climate while also deteriorating air quality causing an estimated 4 million premature deaths yearly. Organic aerosol (OA), the most important contributor to atmospheric aerosols, forms when volatile emissions, from biogenic or anthropogenic sources, are oxidized in the atmosphere to form less volatile, condensable species. However, there is an increasing amount of evidence that particle phase processing (PPP) can further alter the molecular structure, and thus properties, of OA. This PPP will be systematically studied in PROBE, using advanced mass spectrometry. Our approach will be to first identify under which conditions PPP seems to most important, subsequently targeting these systems for further, more detailed, studies to infer mechanistic insights into the specific reaction pathways.

Chasing pre-industrial aerosols, ERC project (CHAPAs)

PI: Federico Bianchi, University of Helsinki (federico.bianchi@helsinki.fi)
 Funding: EU
 Active: 1.1.2020-31.12.2024
 Partners:
 Website: <https://cordis.europa.eu/project/id/850614/results>

Models are critical to testing hypotheses and predicting outcomes. Models of climate change attempt to explain past events and predict future ones using data related to man-made and natural climate drivers. Aerosol particles result from both human activity and natural emissions. Significant uncertainty exists regarding their net effect on climate. One way to distinguish them is to look at pre-industrial environments when only natural aerosol emissions were present. The CHAPAs project is studying aerosols in pristine environments like the Arctic and Siberia as a proxy. Environmental measurements and laboratory experiments will help scientists quantify the ways in which new aerosol

particles form and grow, pointing to pre-industrial aerosol nucleation mechanisms that could enhance the accuracy of climate models.

Deep into abyss: resolving the charger ions

PI: Juha Kangasluoma, University of Helsinki (juha.kangasluoma@helsinki.fi)
 Funding: Academy of Finland
 Active: 1.9.2019-31.8.2023
 Partners:
 Website:

This project studies the properties of the small ions generated by radioactive decay or x-ray ionization of air, and their use in charging aerosol particles. Variations in the charger ion properties affect the particle size distributions measurements, which have not been addressed before. This project advances the particle size distribution measurement techniques, and increases our understanding on ion-particle interactions.

Molecular understanding on the aerosol formation in the high Arctic

PI: Tuukka Petäjä, University of Helsinki (tuukka.petaja@helsinki.fi)
 Funding: Academy of Finland, MOSAiC
 Active: 1.9.2020-31.8.2024
 Partners:
 Website: <https://mosaic-expedition.org/>

The climate and environment in the Arctic are changing faster than anywhere else on this planet. Complex feedback mechanisms in the Arctic atmosphere-ocean systems are not very well understood. In this project we will resolve mechanisms and to quantify the relevance and contribution of different secondary particle formation pathways in the aerosol number and Cloud Condensation Nuclei (CCN) load in the Arctic region and particularly over ice covered and open ocean environments over different seasons and meteorological and oceanic conditions. In order to reach our challenging goals, we will utilize and merge all the relevant data collected from Multidisciplinary drifting Observatory for the Study of Arctic Climate (MOSAiC) and two complementary stationary sites in the Arctic, at Ny Ålesund, Svalbard and at Villum, Greenland.

Antarctic Climate Forcing Aerosol (ACFA)

PI: Mikko Sipilä, University of Helsinki (mikko.sipila@helsinki.fi); Aki Virkkula, FMI (aki.virkkula@fmi.fi)
 Funding: Academy of Finland
 Active: 11.1.2021-31.12.2024
 Partners:
 Website: <https://research.fi/en/results/funding/33735>

The project deals with the climate-forcing properties of Antarctic aerosols, atmospheric processing and long-range transport of aerosols, as well as the interaction of aerosols with radiation and clouds. Three major topics will be investigated: 1) the relative contribution of different cloud condensation nuclei (CCN) sources in the total CCN budget in representative parts of Antarctica, 2) the nature, source and relative contribution of different ice nucleating particles (INPs) in Antarctic clouds, and 3) estimation of the contribution of long-range transported aerosol to scattering, absorption and CCN and INPs at representative parts of Antarctica. The project contains an intensive campaign at the Finnish station Aboa in Queen Maud Land 130 km from the open sea, another at the Argentinian Marambio, a sea-level site in the Antarctic Peninsula and analyses of longterm data from Marambio and the high-altitude site Concordia, a French-Italian site on the East Antarctic plateau.



Importance of aqueous phase processing of organic aerosols in Boreal areas (AquBor)

PI: Annele Virtanen, University of Eastern Finland (annele.virtanen@uef.fi)
 Funding:
 Active: 1.9.2018-31.8.2024
 Partners:
 Website:

In this project we will ambitiously study in both laboratory and real atmospheric conditions how the interactions of OA with water vapour, both at sub- and supersaturation conditions, change the particle composition and the most atmospherically relevant properties of the particles. This is vital to understand the evolution of OA in the atmosphere. We will specifically concentrated on environments typical for Boreal area. We will utilize an extensive set of existing online mass spectrometer techniques and other state of the art instrumentation as well as develop new methodology to achieve the ultimate goal of the study: the first comprehensive parameterization applicable in global climate models to describe changes in OA mass, composition and properties due to the aqueous phase processing both in sub saturation and in-cloud conditions.

Rate estimation and uncertainty quantification of aerosol microphysical processes

PI: Kari Lehtinen, University of Eastern Finland (kari.lehtinen@uef.fi)
 Funding:
 Active: 1.9.2020-31.8.2024
 Partners:
 Website:

The IPCC recognizes aerosol effects as the main uncertainties in the estimation of anthropogenic radiative forcing. Some of this is caused by the fact that the processes at the initial stages of new particle formation (NPF) in the atmosphere are still poorly understood. The last decade has been a huge leap forward in NPF research mainly due to fast instrument development. Nevertheless, the analysis of NPF event dynamics is typically still primitive: NPF is typically identified 'by eye' and analyzed using oversimplified balance equation and/or regression methods. We aim to deliver NPF event analysis methodology, with which partly subjective human analysis is replaced with statistical inverse mathematics methods. The improved process understanding, rigorous quantification of uncertainties in addition to rates and a re-analysis of existing data will improve parameterizations of the different microphysical processes when estimating their effect on climate and human health.

Grow or die: new particle growth in the polluted environments

PI: Runlong Cai, University of Helsinki (runlong.kai@helsinki.fi)
 Funding:
 Active: 1.9.2020-31.8.2023
 Partners:
 Website:

This project aims to resolve how the newly formed particles grow in the presence of a high background aerosol concentration. Particle growth rate and the background aerosol concentration determine the survival and growth of new particles to stable sizes and their impacts on the global climate and local air quality. This project will be mainly based on the data acquired in both laboratory and long-term field studies conducted at University and Helsinki and Beijing, respectively. We will use aerosol and cluster dynamic models in data interpretation. The effect of background aerosol concentration and role of various chemical compounds at different stages of particle growth will be

quantified. Our results will reveal the fate of new particles under high background aerosol concentrations and their impacts on climate and air quality, especially in polluted environments.

Soil reactive emissions from boreal forests: impact of soil properties and effects on atmospheric chemistry (SOREMI)

PI: Arnaud Praplan (arnaud.praplan@fmi.fi), Finnish Meteorological Institute
 Funding:
 Active: 1.9.2022 - 31.8.2026
 Partners: Finnish Meteorological Institute (FMI) and the Natural Resources Institute Finland (Luke)
 Website:

Boreal forest soils emit various VOCs to the atmosphere. These reactive compounds affect ozone and secondary aerosol formation. However, they are poorly characterized and their influence on atmospheric chemistry is not well understood. This consortium project of the Finnish Meteorological Institute (FMI) and the Natural Resources Institute Finland (Luke) will improve methods to analyse these yet unknown VOCs, measure the composition and amounts of their emissions from different types of nitrogen-limited forest soils, and study in the laboratory the effects of wetting/drying and thawing/freezing on these soil emissions, as well as their aerosol formation potential. Field measurements will be performed in long-term, well-documented field experiments that make it possible to find out the response of these organic emissions to soil properties and, for instance, to tree species in the stand and harvesting intensity.

Health effects and associated socio-economic costs of increasing temperatures and wildfires - A global assessment (HEATCOST)

PI: Mikhail Sofiev (mikhail.sofiev@fmi.fi), Finnish Meteorological Institute
 Funding: Academy of Finland
 Active: 1.1.2020 – 31.12.2023
 Partners:
 Website:

HEATCOST capitalizes on the H2020 project EXHAUSTION, which quantifies cardiopulmonary health effects from climate change in Europe. HEATCOST will expand to global scale and quantify health risks attributable to heat and air pollution (with a particular focus on air pollution from wildfires) in main world regions under selected climate scenarios and socioeconomic pathways. The research is co-designed with stakeholder partners engaged in development and implementation of adaptation measures. HEATCOST will increase synergies between teams across partner countries and stakeholder organizations, fostering a new climate and environmental health knowledge platform based on a transdisciplinary and end-user focused approach.

The role of multiphase emissions and new particle formation on haze and cloud condensation nuclei in India

PI: Antti Hyvärinen (antti.hyvarinen@fmi.fi), Finnish Meteorological Institute
 Funding: Academy of Finland
 Active: 1.9.2024 – 31.8.2028
 Partners: University of Helsinki, IIT Madras, IIT Delhi, University of Hyderabad
 Website:

The main objective of this study is to comprehend the interaction and feedbacks between new particle formation, air quality, and climate in India. This will be achieved through comprehensive long-

term observations and modeling of atmospheric composition and air quality. Measurements are conducted at two sites, Sonipat in North India and Chennai in South Peninsular India, allowing us to explore the atmospheric pollution issue under different emission sources and meteorological conditions. The project aims to address air pollution challenges in India while enhancing our understanding of the associated climate effects.

Black and Brown Carbon in the Atmosphere and the Cryosphere (BBrCAC)

PI: Aki Virkkula, Finnish Meteorological Institute (aki.virkkula@fmi.fi)
 Funding:
 Active: 1.10.2021 - 30.09.2025
 Partners:
 Website:

The contributions of black and brown carbon (BC and BrC) to the radiative forcing of climate will be estimated in Finland and in a wider boreal context. The contributions of BC and BrC to light absorption in the uv-vis wavelength range in urban and background aerosols, aerosol emissions from different fuels, and snow will be measured. Aerosols will be measured in Helsinki and Lapland and in aging-chamber experiments in Kuopio. Long-term (60 years) filter samples, snow collected in Finnish Lapland, Svalbard, Siberia and the Alps and a 300-year time series of ice from Svalbard will be analyzed for BC and BrC concentrations and absorption spectra. Fossil fuel and biomass burning contributions will be estimated by carbon isotope analyses. Emission inventories will be updated to include BrC by using measured BC and BrC emission factors and used for updating emission scenarios and estimating the radiative forcing of BC and BrC in selected scenarios for the period 2020-2100.

Vegetation Fires and Smoke Pollution Warning and Advisory System for Europe (VFSP-WASE)

PI: Mikhail Sofiev, Finnish Meteorological Institute (firstname.lastname@fmi.fi)
 Funding: Finnish Research Council
 Active: 1.1.2024-31.12.2025
 Partners:
 Website: <https://vfsp-wase.fmi.fi>

Vegetation fires is one of the top-level concerns related to climate change. They can severely damage environment, reduce biodiversity, and have a highly detrimental effect on society by destroying property and taking lives. Fires are also one of the largest sources of particulate matter and toxic gases impacting regional air quality, human health, and environment over large areas.

Recognizing the necessity of collective international efforts and concerted actions, a group of experts (including the PI of this proposal) came up with a suggestion of a global network of Vegetation Fires and Smoke Pollution Warning Advisory Centers (VFSP-WAC) under the WMO Global Atmospheric Watch (GAW) programme. The overall goal of the current proposal is to combine the cutting-edge research of ACCC flagship with Finnish and European expertise and lay down the scientific and operational foundation for the Vegetation Fire and Smoke Pollution Warning and Advisory System for Europe, VFSP-WASE. This system will eventually become the scientific and infrastructural foundation of the European node of global VFSP-WAC network.

The system will build upon the ACCC flagship results

- Fire-related research consolidated in Integrated System for wildland fires (IS4FIRES, <http://is4fires.fmi.fi>)
- Research and applications studying the atmospheric release and dispersion of fire smoke with the System for integrated modeLLing of Atmospheric coMposition (SILAM, <http://silam.fmi.fi>) integrated with IS4FIRES
- New insights in the atmospheric aerosol processes obtained within ACCC, which will be brought to SILAM-IS4FIRES improving its representation of the fire-induced aerosols
- New insights in fire and fire smoke predictions from Horizon EXHAUSTION and Academy of Finland HEATCOST (PI: M.Sofiev) projects, which benefited from and contributed to ACCC.
- The novelty of the VFSP-WASE approach:

- VFSP-WASE will, for the first time, construct an ensemble of fire and fire smoke forecasting combining the IS4FIRES-SILAM predictions with data from other European/global fire information systems
- VFSP-WASE will combine scientific and operational-service components and maintain links with the WMO GAW resources;
- VFSP-WASE will be tailored to diversity of European environment and very different fire regimes and climate-change effects around the continent.
- VFSP-WASE is based on science-to-society approach: advances fire research and uses its outcome for services for society.

Biogenic Volatile Organic Compounds (BVOCs), bioaerosols, and peatland

Quantifying missing pieces of the boreal BVOC budget: exchange of BVOCs in boreal peatlands and implications for the formation of secondary organic aerosols

PI: Aino Korrensalo, University of Eastern Finland (aino.korresalo@uef.fi)

Funding:

Active: 1.10.2021 - 30.09.2024

Partners:

Website:

Biogenic volatile organic compounds (BVOC) cool down global climate by participating in the formation of secondary organic aerosols (SOA), that indirectly increase cloud albedo. BVOCs released by boreal soil and vegetation impact the climate both at the boreal and arctic regions. Although up to 28% of boreal zone is covered by peatlands, BVOCs released from these ecosystems are poorly known. This study will quantify for the first time how BVOCs produced in the peat are oxidized before reaching the atmosphere and participate there in SOA formation. Climate change is predicted to increase the cover of arboreal plants in peatlands. By comparing peatland ecosystems naturally dominated by sedges or arboreal species this study will give foresight on the impacts of current and changing peatland vegetation on BVOC release. The results of this study will enable accounting for peatlands in the process models and thus improve the accuracy of their predictions about the cooling impact of BVOCs.

Sesquiterpene emissions and their impact on atmospheric chemistry (SEIAC)

PI: Simon Schallhart (simon.schallhart@fmi.fi), Finnish Meteorological Institute

Funding:

Active: 1.9.2019-31.3.2023

Partners:

Website:

In this project we will study a group of very fast reacting gases in the atmosphere, the sesquiterpenes,. They are known to be emitted by branches of boreal trees and we want to know what happens to them in the atmosphere and how important they are for the air chemistry, and the formation and growth of aerosol particles. Therefore, we will measure how much the whole forest (soil, understory and trees) emits. This will tell us the regional impact of these emissions. Additional we will measure the individual sesquiterpene concentrations and total amount of reactive gases in the forest air. From these measurements we can calculate, how important sesquiterpenes are for the atmospheric chemistry. In a second step we will measure the reaction rates of individual sesquiterpenes and oxidize them in a chamber, which shows us the oxidation products of the individual sesquiterpenes and their potential to form and grow aerosol.

A SYstem for reaL-time obserVation of Aeroallergens (SYLVA)

PI: Mikhail Sofiev (mikhail.sofiev@fmi.fi), Finnish Meteorological Institute
 Funding: EU Horizon Europe
 Active: 1.1.2023 – 31.12.2026
 Partners: UTU
 Website: <https://sylva.bioaerosol.eu>

Primary biological aerosols (bioaerosols: mainly pollen and fungal spores, but also bacteria and viruses) released into the air by plants, fungi, and other biota, are strongly impacted by climate change. Simultaneously, they also directly affect the climate through interactions with clouds and precipitation. Many bioaerosols, especially pollen and some fungal spores, have allergenic effect on humans. Such aeroallergens affect over 80 million Europeans, reducing their quality of life and costing well over €50 billion/year.

Information on bioaerosols is also vital for agriculture and forestry, where timely data about plant development, abundance of pathogens and parasites, as well as invasive species, are necessary for precision-agriculture and knowledge-based technologies. The demand for timely, free, and objective information is currently not met.

The overall goal of SYLVA is:

To achieve a radical improvement and fill gaps in temporal resolution, timeliness, coverage, and availability of information about aeroallergens and other bioaerosols. SYLVA technological innovations will be accompanied with new infrastructure, distribution and exploitation pathways, and links with stakeholders to ensure technology uptake and sustainability beyond the lifetime of the project.

To achieve this goal, the project will:

- Develop cutting-edge bioaerosol monitoring technologies
- Extend bioaerosol monitoring data infrastructure and software accessibility, ensuring open-source publication and integration into the European environmental observing system
- Validate the operational maturity and added-value of bioaerosol monitoring technology through Demonstration Pilots in three European regions
- Maximise impact and ensure the long-term sustainability by demonstrating SYLVA innovations to key stakeholders related to climate, health, agriculture, silviculture, and the environment
- Ensure the long-term sustainability of bioaerosol technology and infrastructure across Europe

Towards an overarching understanding of fungal spore dispersion across scales: combining eDNA and flow cytometry with integrated atmospheric modelling for bioaerosol and biodiversity monitoring (SPORELIFE)

PI: Mikhail Sofiev (mikhail.sofiev@fmi.fi), Finnish Meteorological Institute
 Funding: Academy of Finland
 Active: 1.9.2023 – 31.8.2027
 Partners: SYKE, UTU
 Website:

The overall aim of SPORELIFE is to leap forwards in scientific understanding of airborne spore dispersion and factors determining spatiotemporal patterns in fungal community composition in the air. We aim at a (semi-)mechanistic numerical representation of processes controlling spore preparation, release, and atmospheric transport, simultaneously developing the methods of their observation and modelling. As a crucial application, we will assess the feasibility of using airborne eDNA and flow cytometry to fungal biodiversity monitoring at different scales.

Air Quality, health and traffic

Autoxidation of Anthropogenic Volatile Organic Compounds (AVOC) as a Source of Urban Air Pollution (ADAPT)

PI: Matti Rissanen, Tampere University (matti.rissanen@tuni.fi)
 Funding: EU
 Active: 1.2.2021–31.1.2026
 Partners:
 Website: <https://cordis.europa.eu/project/id/101002728>

The organic compounds produced by combustion and other man-made activities are detrimental for the atmosphere. Gas-phase oxidation reactions, mediated by peroxy radicals (RO₂), open the pathways to remove these organic pollutants. Oxidation also results in the formation of particulate matter, aerosols, that influence the atmosphere. Recently, functionalised RO₂ were found to undergo autoxidation processes, allowing for rapid ambient aerosol formation. This previous work revealed how the abundant biogenic hydrocarbons autoxidise, yet the mechanisms enabling autoxidation of anthropogenic volatile hydrocarbons (AVOCs) remain unknown. The EU-funded ADAPT project will combine innovative mass spectrometric detection methods, empowered by theoretical calculations, to decipher the mechanism of AVOC autoxidation. The findings will contribute to air quality management and the design of cleaner fuels and engines.

Transport derived ultrafines and the brain effects (TUBE)

PI: Topi Rönkkö, Tampere University (topi.ronkko@tuni.fi)
 Funding: EU
 Active: 1.5.2019–30.4.2023
 Partners:
 Website: <https://cordis.europa.eu/project/id/814978>

Air pollutants have long been known to cause respiratory and cardiovascular diseases. However, recent evidence indicates an association between polluted air and neurological disorders such as Alzheimer's disease. To investigate this observation further, the EU-funded TUBE project is bringing together experts from various disciplines. The aim is to study the inflammatory, cytotoxic and genotoxic impact of ultrafine particles in exhaust aerosol, generated from different types of traffic. Using both in vitro models and epidemiological data, researchers will give emphasis to the neurotoxic and brain health effects of traffic-generated particles, paving the way for novel risk assessment strategies.

Shipping Contributions to Inland Pollution Push for the Enforcement of Regulations (SCIPPER)

PI: Jorma Keskinen (jorma.keskine@tuni.fi); Miikka Dal Maso (miikka.dalmaso@tuni.fi), Tampere University
 Funding:
 Active: 1.5.2019–31.1.2023
 Partners:
 Website: <https://www.scipper-project.eu/>

Ships produce high emissions of nitrogen, sulphur oxides and particulate matter. Most of these occur close to shore, significantly degrading air-quality in coastal areas. In a global regulatory effort to reduce SO_x emissions, a maximum 0.5 % fuel sulphur content is enforced. In this context, it is important to monitor emissions of vessels during their normal operation. The EU-funded SCIPPER project deploys next-generation measurement techniques to monitor emissions. It conducts real-world experimental campaigns with vessels in EU ports. The project aims to provide evidence on the performance and capacity of different techniques for shipping emissions monitoring and regulation enforcement. It also works to assess the impacts of shipping emissions on air quality under different regulatory enforcement scenarios.

Emission Factors of Primary Particles, Secondary Particulate Matter and NO_x for the Passenger Car Fleet in Finland (EFFi)

PI: Panu Karjalainen, Tampere University (panu.karjalainen@tuni.fi)
 Funding:
 Active: 1.9.2019–31.8.2022
 Partners:
 Website: <https://www.tuni.fi/en/research/effi-emission-factors-primary-particles-secondary-particulate-matter-and-nox-passenger-car>

The current vehicle fleet in Finland is a mixture of new and old engine technologies with the mean age of a passenger car being about 11 years. Vehicles currently operating have passed the new vehicle standards in terms of regulated pollutants of the year of manufacture. However, we do not know whether emissions have increased due to usage. Also it is unknown, how big source of gaseous emissions as well as primary and secondary particles each vehicle type is. The information of real-world emissions is collected from new measurements for hundreds vehicles representing Finnish fleet especially by chasing them with a mobile laboratory van or by measuring directly from the tailpipe with a portable measurement system. As a result, a new emission dataset is created consisting of various branches of tailpipe emissions.

CouSCOUS - Sustainable urban development emerging from the merger of cutting-edge Climate, Social and Computer Sciences

PI: Leena Järvi, University of Helsinki (leena.jarvi@helsinki.fi)
 Funding: Academy of Finland
 Active: 1.9.2020-31.8.2024
 Partners:
 Website: <https://researchportal.helsinki.fi/en/projects/sustainable-urban-development-emerging-from-the-merger-of-cutting>

In the fight against climate change and coping with the pressures arising from urbanisation cities worldwide make solutions in urban structure modifying pollutant emissions and local air quality. The consortium answers to the possible challenges on air quality by helping cities to plan climate healthy future urban areas, considering future traffic flows and population structures. CouSCOUS combines the fields of artificial intelligence, atmospheric and social sciences in a way that has not been done in this extent before and therefore advances the state of scientific research in all disciplines involved and provides decision makers and city planners globally with novel relevant information and tools for creating future sustainable cities. Consortia will utilize various detailed data sources, from grid-level population data to climate and traffic data and analyses them. The consortia will work tightly both together as well as in co-operation with relevant stakeholders.

Ocean studies

Polar Regions in the Earth System (PolarRES)

PI: Petteri Uotila (petteri.uotila@helsinki.fi), University of Helsinki
 Funding: EU
 Active: 1.9.2021-31.8.2025
 Partners:
 Website: <https://polarres.eu/>
<https://cordis.europa.eu/project/id/101003826>



The Polar regions in a global context are poorly understood, hindering efforts at mitigating and adapting to climate change impacts. The EU-funded PolarRES (Polar Regions in the Earth System) project will provide fresh insights into key local-regional scale physical and chemical processes for atmosphere-ocean-ice interactions in the Arctic and Antarctic, the projected changes in the global circulation and their impacts on the environment and society. Consortium members will apply regional climate models (RCMs) to investigate the influence of projected changes in the global circulation on the climate of the Arctic and Antarctic. They will combine high-resolution simulations from state-of-the-art RCMs and next-generation fully coupled RCMs with a comprehensive range of existing and novel observations, including satellite images from relevant projects funded by the ESA Earth Observation Programme.

The impact of Antarctic Ice Sheet - Southern Ocean interactions on marine ice sheet stability and ocean circulation (COLD)

PI: Petteri Uotila (petteri.uotila@helsinki.fi), University of Helsinki
 Funding: Academy of Finland
 Active: 1.9.2019-31.8.2023
 Partners:
 Website:

The Antarctic Ice Sheet has the potential to cause tens of metres of sea level rise if climate warming continues unchecked. It has already started to lose mass, contributing to increases in global sea level. The main causes are complex networks of interacting processes involving the deformation of ice, sliding of ice over its bedrock, and nearby ocean circulation. Our consortium brings together leading Finnish glaciologists, oceanographers and computer scientists to simulate these networks of interactions. We aim to better understand the main controls on Antarctica's contribution to sea level rise, understand how ice - ocean interactions may impact on larger scale ocean circulation patterns, and improve our ability to predict how much sea level rise to expect over the next century.

Nitrogen studies

A combined experiment and modelling approach to quantify the nitrous oxide budget of permafrost regions (N-PERM)

PI: Christina Biasi (christina.biasi@uef.fi), UEF; Ivan Mammarella (ivan.mammarella@helsinki.fi), University of Helsinki
 Funding: Academy of Finland
 Active: 1.9.2021-31.8.2025
 Partners:
 Website: <https://research.fi/en/results/funding/34193>

The project N-PERM aims at advancing our understanding on nitrous oxide (N₂O) dynamics and budget in permafrost regions including Arctic and Alpine soils. We will achieve this goal by establishing continuous and long term N₂O flux measurements at a permafrost-peatland, by using process-based models to simulate N₂O fluxes and estimate future responses of Arctic ecosystem to climate change. Additionally, we will apply machine learning tools to the new and comprehensive datasets to deliver annual N₂O budgets, upscaled to the northern permafrost regions. The work will improve our knowledge on permafrost climate feedbacks under present and warmer climatic conditions and helps to clarify the role of northern permafrost regions in the global N cycle in present and future.

Microbial mechanisms regulating N₂O metabolism in above-ground vegetation - significant northern N₂O sink?

PI: Henri Siljanen (henri.siljanen@uef.fi), UEF
 Funding:
 Active: 01.09.2021 - 31.08.2026
 Partners:
 Website:

Nitrous oxide (N₂O) reduction to dinitrogen, is the last step of complete denitrification. Thus, it is globally significant and indispensable component of the nitrogen cycle. There are certain vegetation species in the Boreal region that have the ability to consume atmospheric N₂O. Therefore, they have great potential for capturing N₂O from the atmosphere and mitigating climate change. However, little is known about N₂O-consuming microbes in these environments, even though their climatic potential may be high. Proposed study will examine N₂O consuming communities in these environments. The project generates novel ideas and methodologies for sustainable forest and peatland management, as well as technologies for N₂O capture.

Emissions of reactive nitrogen gases (HONO and NO) from northern peatlands - Unraveling the nitrogen cycle in northern soils under changing climate (ERNO)

PI: Marja Maljanen (marja.maljanen@uef.fi), UEF
 Funding:
 Active: 01.09.2022 - 31.08.2026
 Partners:
 Website: <https://www.acccflagship.fi/index.php/2022/10/21/erno-project-will-be-studying-emissions-of-reactive-nitrogen-gases-hono-and-no-from-northern-peatlands-under-changing-climate/>

This study is unravelling the role of northern peatlands as source of reactive nitrogen gases, nitrous acid (HONO) and nitric oxide (NO). Both gases play a significant role in the atmospheric chemistry, HONO as a source of cleaning agent hydroxyl radical and NO regulates ozone and nitrate radical formation. The production pathways of these gases from soils are poorly known, however they are emitted in nitrogen cycle processes similarly as greenhouse gas nitrous oxide. Northern peatlands are large storages not only of carbon but also nitrogen and therefore they are potential sources of these nitrogen gases. Here we will study deeply the processes and factors affecting the emissions of HONO and NO along a peatland gradient within the boreal to subarctic and arctic zones, including permafrost-affected peatlands. Our results will be used to upscale HONO and NO emissions to regional level and to validate atmospheric and emission models of these reactive gases from northern peatlands.

Fate of nitrogen released from thawing permafrost: from microbial transformations to gaseous losses (Thaw-N)

PI: Maija Marushchak (Maija.marushchak@uef.fi), UEF
 Funding:
 Active: 01.09.2022-31.08.2027
 Partners:

According to recent reports from the Arctic, part of the long-term-stable nitrogen stocks in permafrost-affected soils are on the move. We are observing changes in vegetation growth and composition, increased nitrogen export to waterbodies, as well as increased release of the strong greenhouse gas nitrous oxide. Thaw-N project digs into the reasons behind these changes by studying the pools and fate of nitrogen in permafrost soils. In the multidisciplinary study conducted at the University of Eastern Finland and several collaborating institutes, we will investigate the amount, quality, microbial transformation processes and atmospheric release of permafrost N and compared to the seasonally thawing active layer. We use modern stable isotope techniques to resolve the

complete N cycle, and combine this process information with advanced microbial studies. The results of Thaw-N will represent a leap forward in understanding the fate of permafrost N after thaw, and its climatic consequences.

Greenhouse gases and improving the satellite retrievals

Methane in the Arctic in support of Arctic Methane and Permafrost Challenge (AMPAC) (MethaneCAMP)

PI: Johanna Tamminen (johanna.tamminen@fmi.fi), FMI

Funding: ESA

Active: 04/2022 – 03/2024

Partners:

Website:

The purpose of this project is to support the recently launched ESA-NASA community initiative on Arctic Methane and Permafrost Challenge (AMPAC). In MethaneCAMP our aim is to assess and validate capabilities of the current satellite instruments in measuring Arctic and high latitude methane. Based on the findings our aim is to improve the satellite retrievals and demonstrate the potential of satellites in monitoring long term trends, in detecting methane emission hot-spots and in improving inverse modelling of methane at high northern latitudes.

Study on Improved Glint Retrieval for CO₂M (SNOWITE)

PI: Hannakaisa Lindqvist (hannakaisa.lindqvist @fmi.fi), FMI

Funding: ESA

Active: 1.3.2021–1.12.2022

Partners: Consortium is led by FMI and participated by Finnish Geospatial Research Institute and University of Leicester

Website:

The SNOWITE project aims to assess the expected radiance levels of CO₂M glint-mode observations over water and snow-covered surfaces. This included the concept of a feasibility study for making greenhouse gas retrievals over snow. The aim is also to introduce and evaluate improvements to greenhouse gas satellite observations. The project also contributes to the advancement of satellite validation at high latitudes in the form of AirCore profile measurements and a collective analysis using high-latitude ground-based reference data.

Urban challenge of CO₂ observing satellites: From aerosol scattering towards verifying CO₂ emission reductions from space (CitySpot)

PI: Hannakaisa Lindqvist (hannakaisa.lindqvist @fmi.fi), FMI

Funding: Academy of Finland

Active: 1.9.2020–31.8.2024

Partners:

Website:

Deriving CO₂ emissions from satellite CO₂ observations of polluted atmospheres over cities and other urban areas is a demanding challenge. In this project, we answer this challenge by 1) developing space-based CO₂ observations over urban areas and 2) applying advanced plume modelling tools to derive emission signatures. First, we will ingest aerosol information from existing aerosol satellite data from e.g. MODIS and CALIPSO, and realistic optical models. Both radiative transfer simulations and measurements by the Orbiting Carbon Observatory -2 (OCO-2) and OCO-3 are used in the development. For the atmospheric transport and diffusion of localised plumes, we employ Lagrangian

modelling, and derive emissions based on OCO-2, OCO-3, and possibly TanSat CO₂ data. We collect the emission signatures into an open database and compare them against reported emissions. In addition, we estimate the aerosol-induced errors in the total column CO₂ and quantify their effect on the derived emissions. The project aims to significantly progress our ability to monitor human emissions from space, and thus help support the goals of the Paris Agreement.

Plastic-derived emerging aerosol pollutants from fires PLASTER

PI: Panu Karjalainen (panu.karjalainen@tuni.fi), Tampere University
 Funding: Reserach Council of Finland
 Active: 1.9.2025-31.8.2029
 Partners: University of Eastern Finland, Tampere University
 Website: -

Plastic-derived emerging organic pollutants (PEOP), including micro- and nanoplastics and specific chemicals, pose global threats to ecosystems and human health. The overall picture of these emerging pollutants is limited, as measurement methods are still evolving to accurately trace their abundance in the environment. This research hypothesizes that incomplete burning of plastics, such as accidental fires and residential burning of waste, is a major source of PEOP into the atmosphere and significantly influences ambient air respiratory and endocrine toxicity. PLASTER aims at assessing how plastic burning influences particulate matter and specifically PEOP in atmosphere, and their health-related toxicological properties. We will carry out comprehensive laboratory and field studies and utilize novel chemical analysis methods and biological models to establish databases of emissions from plastic fires and their toxicities, and improved methodologies for monitoring of PEOP in air.

Project name - MEAPS

PI: Panu Karjalainen (panu.karjalainen@tuni.fi), Tampere University
 Funding: Reserach Council of Finland
 Active: 1.9.2023-31.8.2027
 Partners: Tampere University
 Website: -

Transportation emissions are one of the major causes for global warming and bad air quality. MEAPS develops new measurement techniques to quantify realistic estimates of gaseous and particulate phase emissions from several vehicle categories. Moreover, project focuses on better nanoparticle sampling and detection from road traffic and non-road mobile machinery system renewal, the role of renewable fuels, and the potential effects of these. Especially, the assessment of the direct and indirect climatic effects as well as air quality impact of aerosols originating from transport requires detailed information of the nature of emission development. Project combines an expertise ranging from construction new instruments, understanding the emission factors from single vehicles, and parameterization of experimental results for further use. This approach can provide new understanding how different vehicle development scenarios will affect our future.

REALCHEM – Real-world emission Experiments and comprehensive Assessment of Low-carbon fuels: towards Clean Hard-to-Electrify transport Modes

PI: Miikka Dal Maso (miikka.dalmaso@tuni.fi), Tampere University
 Funding: EU, Horizon Europe Grant Agreement No. 101192395
 Active: 1.2.2025-30.11.2028
 Partners: TAU (Coordinator), VTT (FI), IVL (SE), HEREON (DE), AUTH (GR), IEM (CZ), FMI (FI), ONERA (FR), SAFRAN (FR), Polis Network (BE), Danaos (GR), Region Skåne (SE)
 Website: <https://realchemproject.eu/>

The REALCHEM project aims to promote a clean and climate-friendly transport system by studying emissions from low carbon fuels in hard-to-electrify (HtE) transport sectors, including aviation, shipping, and heavy-duty on-road and non-road mobile machinery. The project will observe emissions from various fuels and engines under real-life conditions, model their effects on air quality and human health, and focus on the most important new technologies. REALCHEM will use a large amount of pre-existing data on both low-carbon and fossil fuels, and conduct novel experimental work in all three HtE transport modes. The aim is to produce guidance and technology packages for cleaner transport in terms of health effects and climate impacts. The data will be organized into a low-carbon fuel emission database, which will help REALCHEM generate new knowledge and identify the most efficient new fuels and technologies. The project has three main objectives: 1) Produce robust, comprehensive, and actionable scientific data on the characteristics of emissions from low-carbon fuels in the Hard-to-Electrify transport modes. 2) Understand the effect of introducing low-carbon fuels to the developing technology matrix on human health, climate, and the environment: 3) Help technology developers and users to understand the emission formation and reduce the harmful pollution from engines using low-carbon fuels.

Understanding the Non-CO₂ Impacts of DeCarbonised Aviation - UNIC

PI: Topi Rönkkö (topi.ronkko@tuni.fi), Tampere University
 Funding: EU, Horizon Europe Grant Agreement No. 101192598
 Active: 1.2.2025-31.1.2029
 Partners: Onera (Coordinator), TAU (FI), Pegasor (FI), Cardiff University (FI), ENV-ISA (ES), Univ. Reading (UK), ZHAW(CH), SMHI (SE), Manchester University (UK), CNRC (CA), Univ. Helsinki (FI)
 Website: <https://unic-project.com/>

UNIC combines innovative in-flight and ground-based emissions measurement methods, advanced lab-scale experiments, and cutting-edge modelling. Aviation contributes approximately 3-4% of the total anthropogenic radiative forcing on the atmosphere. Up to two-thirds of that impact are estimated to originate from emissions other than that of carbon dioxide, also known as non-CO₂ emissions, such as nitrous oxides (NO_x), water vapor (H₂O), and particulate matter (PM). Some non-CO₂ emissions play a key role in the formation of both persistent condensation trails (contrails) and contrail-induced cirrus clouds, which are currently thought to contribute the largest share of aviation's non-CO₂ effect on climate. Despite this, the exact mechanisms through which non-CO₂ emissions have this impact still involves significant uncertainties. To reduce these and advance towards a more complete understanding of aviation climate impacts, UNIC will bring together innovative in-flight and ground-based emissions measurement methods, advanced lab-scale experiments, and cutting-edge modelling to advance the scientific understanding of real-world emissions from aircraft at cruise altitude and the role these play in contrail and contrail-cloud formation, as well as aerosol-cloud interactions.

Global trends in IAQ: Novel technologies, Competence and Business - GIANT

PI: Topi Rönkkö (topi.ronkko@tuni.fi), Tampere University
 Funding: Business Finland
 Active: 1.1.2024-31.12.2026
 Partners: Tampere University, Finnish Meteorological Institute, VTT, University of Helsinki, University of Eastern Finland, Dekati, Airmodus, Gasera, HSY, AirO, ISEC, Lamit, Halton, Genano, Entos, Realin, Smartwatcher, Pegasor, Cervi, LIFAair, Terveysilma, Tamlink, City of Helsinki, City of Vantaa, City of Tampere
 Website: <https://www.giant-iaq.fi>



Air pollution is known to have extensive health impacts and recent World Health Organization recommendations state it is important to build capacity and start systematic measurements of ultrafine particles and black carbon in addition to existing air quality parameters in both indoor and outdoor environments. The GIANT project aims to scientifically understand indoor aerosol phenomena, indoor and outdoor sources of pollutants, and their impact on indoor air quality and health. The project also seeks possibilities for advanced indoor air quality monitoring and exposure mitigation strategies. The focus of the project is specifically on understanding the role of new emerging pollutants, such as ultrafine particles, black carbon, volatile organic compounds, and secondary aerosols.

PAREMPI

PI: Topi Rönkkö (topi.ronkko@tuni.fi), Tampere University
 Funding: European Union, Horizon Europe
 Active: 1.1.2023-31.12.2025
 Partners: VTT, Tampere University, Finnish Meteorological Institute, Lund University, BOSMAL, ONERA, IEM CAS, Magellan Circle
 Website: <https://parempi.eu/>

Air pollution is the cause of millions of premature deaths worldwide. The adverse health effects are projected to be prevented especially by reducing harmful fine particulate matter (PM_{2.5}) emissions that adversely affects air quality and is strongly linked to the premature deaths caused by air pollution. Transportation is crucial in the worldwide distribution of food, materials, energy and more. However, all transport sectors are substantial emitters of air pollutants. The PAREMPI project will reveal the contribution of the secondary aerosols (SecA) from transport sources to ambient PM_{2.5} levels via increased understanding of precursors and their atmospheric reactions. The project aims to study the contribution of transport sectors' precursor exhaust emissions on Secondary Aerosols (SecA) as well as quantities and composition of formed secondary PM_{2.5}, particularly in winter conditions. The tools developed in the project include the novel digital software (ePMI module) developed for quantification of the SecA from precursor emissions, estimation of external costs based on the health impact of PM_{2.5} originating from transport sources and evaluation of robust emission measurement systems for measurements in real-driving conditions and monitoring of SecA emissions.

Aerosurf – The aerosol interaction surface area size distribution: the impact of parameter uncertainty on atmospheric aerosol process rates and air quality metrics

PI: Miikka Dal Maso (miikka.dalmaso@tuni.fi), Tampere University
 Funding: EU, Horizon Europe Grant Agreement No. 101192598
 Active: 1.9.2023-31.8.2027
 Partners: TAU
 Website: N/A

The project AeroSurf is a theoretical and laboratory study of a key quantity governing atmospheric aerosol processes: the aerosol surface interaction area (SIA) and its size distribution. Our starting point is that the proper quantification of SIA is essential for determining secondary aerosol formation rates in the laboratory and field, and for predicting survival rates of newly formed particles; it also determines instrumental response rates of sensor-type instruments, and it is also an important as a potential health-relevance metric. Despite its importance, there are many factors in its determination in which we rely on strong assumptions that are subject to significant uncertainties. AeroSurf tests these assumptions for atmospherically relevant aerosols and reduce uncertainties, with the aim of better understanding the role of SIA and its size distribution in atmospheric processes and urban air quality. AeroSurf addresses this problem theoretically by combining existing data, descriptions, and

parameterisations of complex-shaped particulates, their observable parameters such as effective density, mass-mobility relationship and black carbon content, and existing multi-instrumental datasets to provide a more comprehensive methodology for computation of atmospheric aerosol surface interaction area for condensation, coagulation, and ion uptake. As a result of AeroSurf, we will greatly reduce uncertainties in the determination of a key process-governing parameter in of atmospheric aerosols, and take an important step towards its reliable quantification and use as an air quality metric.

ROSES

PI: Topi Rönkkö (topi.ronkko@tuni.fi), Tampere University
 Funding: Research Council of Finland
 Active: 1.9.2024-31.8.2028
 Partners: Tampere University, University of Eastern Finland (coordinator)
 Website: -

Air pollution is a well-known cause of adverse health effects in human respiratory system and other organs. Especially ultrafine particles (UFP) and their component, black carbon (BC) are emerging as highly important for health and environment as stated by WHO. Oxidative stress is a key mechanism in the human adverse health effects, and NRF2 is a key factor in those effects. It is, however, not clear what are the actual reasons for the adverse effects, and therefore systematic approach to study the UFP compositions in a highly controllable manner is needed. Moreover, air pollution monitoring would need easy and robust ways of detecting the potential for adverse effects from air samples. In this highly multidisciplinary project between University of Eastern Finland and Tampere University, we systematically study the role of different compositions (metals, organic compounds) on adverse effects. The project contributes to a major societal challenge of UFP exposure in cities worldwide.

Non-exhaust emissions in electrifying mining and urban environment -NEX-EL

PI: Topi Rönkkö (topi.ronkko@tuni.fi), Tampere University
 Funding: Business Finland
 Active: 1.3.2023-28.2.2026
 Partners: VTT, Tampere University, Finnish Meteorological Institute, University of Oulu, Sandvik Mining and Rock Solutions, Dekati, Forcit, Helsinki Region Environmental Services, Ramboll Finland, Airmodus, Pegasor, Outokumpu Chrome, Tapojärvi, Satel
 Website: <https://nixel.fi/>

Electrification is advancing in both urban traffic and mining operations, causing the role of non-exhaust emissions to increase when exhaust emissions decrease. The Nex-El project aids industry and companies in minimizing non-exhaust emissions from roads and mines, enabling sustainable operations and supporting development of new products. Reducing health effects of non-exhaust emissions on workers in mines and citizens in urban areas will increase their healthy living years. Finnish companies are investing on electrification and need solutions to meet anticipated standards for air quality, emissions and non-exhaust emissions as well as to secure overall do-no-significant-harm principles. The NEX-EL project will examine the emission sources and properties of non-exhaust particles in mines and street environments (for example brake and tyre dust) as well as in laboratory tests. For the mine, an unique air quality model, using measured data, will be developed. The purpose of this model is utilization of air quality information in the operation of mine, e.g. in optimization energy efficiency of ventilation.

Next Generation AI Researchers for Air Quality Excellence (NextAIRE)

PI: Tareq.Hussein@helsinki.fi

Funding: European Commission Joint Research Centre
 Partners:
 Active: 01/09/2025 - 31/08/2028
 Website: <https://cordis.europa.eu/project/id/101217310>

Under the framework of the EU's Air Quality Directive and the Zero Pollution Action Plan, air quality remains under close scrutiny, particularly in urban areas where pollution levels frequently exceed recommended limits. Although renewable energy innovations and green solutions have contributed to emission reductions and improved sustainability, challenges in achieving clean air persist. The EU-funded NextAIRE project will enhance interoperability, advance expertise and improve the geographical and cross-sectoral circulation of European R&I specialists in air quality monitoring. This includes experts in IoT, machine learning, hardware and environmental science. Focusing on widening countries, the project will collaborate with 16 partners to utilise training methodologies that advance air quality monitoring solutions and increase the number of experts and specialists in the field.

An autonomous, real-time monitoring system to measure air quality, noise, and traffic at construction sites (IDEALSENS)

PI: Juha Kangasluoma (juha.kangasluoma@helsinki.fi), Petri Koskinen, Martha Arbayani Zaidan
 Funding: Business Finland
 Partners: Microsoft Finland
 Active: 01/01/2025 - 31/08/2026
 Website: <https://www.helsinki.fi/en/researchgroups/intelligent-environmental-monitoring-and-analytics/projects>

IdealSens aims to develop an autonomous, real-time monitoring system to measure air quality, noise, and traffic at construction sites. Our goal is to help cities and construction companies ensure regulatory compliance, improve public health, and drive sustainability.

PROJECTS CONTRIBUTING CC IMPACTS AND ADAPTATION (RP3)

Artificial Intelligence for Urban Low-Emission Autonomous Traffic (AlforLessAuto)

PI: Leena Järvi, University of Helsinki (leena.jarvi@helsinki.fi)
 Funding: Academy of Finland
 Active: 1.1.2022-31.12.2024
 Partners:
 Website:

At present, road transport contributes a significant amount to the total carbon dioxide (CO₂) emissions in the EU. AlforLEssAuto brings together atmospheric and computer scientists, and traffic engineers in active dialogue with municipal stakeholders with the ultimate aim to understand how autonomous electrified traffic should be organized during the transition period in order to reduce carbon emissions. This is achieved by building a framework of computational modelling tools to evaluate the CO₂ emissions originating from electrified automated vehicles, and by developing artificial intelligence based control from vehicle-level to city-center wide traffic-level in which CO₂ emissions are minimized. Such multidisciplinary approach has not been done to this extent before and thus AlforLEssAuto advances the state of scientific research in all disciplines involved and the novel combination will certainly lead to new, scientifically and societally, important breakthroughs.

CLIMAt risk and vulnerability Assessment framework and toolboX (CLIMAAX)

PI: Thomas Kühn (thomas.kuhn@fmi.fi), FMI
 Funding: EU
 Active: 1.1.2023 – 31.01.2027
 Partners:
 Website:

Many European regions and communities have limited experience and resources to integrate available local and global data, models, and concepts into a context-specific Climate Risk Assessment (CRA). For an authoritative CRA, local data and evidence need to be integrated with established pan-European reference data and scenarios. CLIMAAX will provide substantial financial, analytical and practical support to regions and communities to develop and improve their CRAs by a number of activities. CLIMAAX will deliver (a) a standardized CRA framework CRA built on current community experience and best-practices, (b) a Toolbox with data, models and utilities to provide access to European and global open data archives integrated with local data and procedures, (c) five European pilot regional CRAs to shape the framework and toolset, (d) financial support for at least 50 regions to execute a context-specific CRA, (e) CRA guidance material and online helpdesk for other European regions, and (f) a proposal to upscale results into the future operationalization of the regional CRA support function.

The main target groups are regional authorities, community organizations (sectoral stakeholder organizations, NGOs, citizen networks) and Civil Protection Agencies focusing on climate risk management and emergency response. The project will engage a large Community of Practice to co-create the framework and toolbox and co-define the financial support application and monitoring criteria.

Finnish Scenarios for Climate Change Research Addressing Policies, Regions and Integrated Systems (FINSCAPES)

PI: Timothy Carter (timothy.carter@syke.fi), Syke; Taru Palosuo (taru.palosuo@luke.fi), Luke; Kirsti Jylhä (kirsti.jylha@fmi.fi), FMI
 Funding: Academy of Finland
 Active: 1.2.2021-30.11.2024
 Partners: Finnish Environment Institute (Syke); Natural Resources Institute Finland (Luke); Finnish Meteorological Institute (FMI)
 Website: <https://www.syke.fi/projects/finscapes>, <https://www.ilmatieteenlaitos.fi/finscapes>

The FINSCAPES project aims to develop new integrated scenarios of socioeconomic and climate change during the 21st century for use in climate change research and policy making in Finland. In close collaboration with stakeholders of key societally relevant systems, it co-produces national and regional socioeconomic narratives as extensions of global shared socioeconomic pathways (SSPs). Using recent global climate model simulation results, a set of national and regional future climate projections will be prepared, with new analysis on extreme weather and compound events and preparation of climate and impact storylines. Narratives and climate projections are combined into integrated, system-wide SSP-based scenarios for Finnish sub-regions and nationally. Design, development and application of the scenarios are demonstrated in case studies of relevance for research and policy. Emphasis is placed on effective dissemination of project outcomes at regional, national and international level.

Heat and health in the changing climate (HEATCLIM)

PI: Timo Lanki (timo.lanki@uef.fi), UEF; Sakari Karvonen (sakari.karvonen@thl.fi), THL; Risto Kosonen (risto.kosonen@aalto.fi), Aalto; Kirsti Jylhä (kirsti.jylha@fmi.fi), FMI
 Funding: Academy of Finland
 Active: 1.1.2020-31.12.2023

Partners: University of Eastern Finland. Department of Environmental and Biological Sciences (UEF); Finnish Institute for Health and Welfare (THL); Aalto University (Aalto); Finnish Meteorological Institute (FMI)

Website: <https://sites.uef.fi/heatclim/>, <https://www.ilmatieteenlaitos.fi/heatclim>

Climate change is increasing summer-time temperatures and risk of heat waves. Exposure to excess heat is associated with increased morbidity and mortality especially among vulnerable population groups. The project produces new scientific information on the health effects of high temperatures and societal and other factors related to heat vulnerability. The project also evaluates technological solutions to reduce exposure to heat. The main role of FMI is to improve climate projections and sub-seasonal forecasts of heat waves. Finally, the project provides an estimate of the burden of disease, as well as related economic costs, caused by heat in Finland in different climate, societal and adaptation scenarios. Project makes use of health and other types of register data, but also includes field measurements. The results of the project can be used as guidance on societally acceptable and economically efficient adaptation measures to reduce population vulnerability to heat in Finland.

DestinE climate digital twin

PI: Sami Niemelä (CATS) (sami.niemela@fmi.fi), FMI Anders Lindfors (DEODE) (anders.lindfors@fmi.fi)

Funding: EU

Active: 1.09.2022-30.04.2024

Partners: CATS leader Centre for Scientific Computing (Finland), 12 other partner organisations (incl. FMI); DEODE Leader Meteo France, 27 other partner organisations (incl. FMI)

Website: <https://digital-strategy.ec.europa.eu/en/policies/destination-earth>

Destination Earth (DestinE), a European Commission flagship initiative for a sustainable future Image of the Earth from space representing Destination Earth. The Destination Earth (DestinE) is a flagship initiative of the European Commission to develop a highly accurate digital model of the Earth on a global scale. This model will monitor, simulate and predict the interaction between natural phenomena and human activities. It will contribute to achieving the objectives of the twin transition, green and digital as part of the European Commission's Green Deal and Digital Strategy. FMI participates in two projects: Climate Adaptation Digital Twin (CATS), On-demand Extremes Digital Twin (DEODE).

Adaptation Means of Reindeer Husbandry (CLIMINI)

PI: Hilppa Gregow (hilppa.gregow@fmi.fi), Heikki Tuomenvirta (heikki.tuomenvirta@fmi.fi), FMI

Funding: EU (European Regional Development Fund, ERDF)

Active: 1.3.2020-30.10.2023

Partners: Arctic Centre of University of Lapland, Finnish Meteorological Institute, Natural Resources Institute Finland

Website: <https://www.arcticcentre.org/FI/climini/climini-EN>

Adaptation to changing climate is continuous and developing. Reindeer herders and reindeer husbandry have to be prepared for both unexpected weather phenomena, which may take place next week, or in longer term, as slower changes. The aim of the CLIMINI project is to (i) produce a synthesis based on available knowledge about the impacts of climate change on reindeer husbandry of Finland, as well as its adaptation to climate change, (ii) recommendations for measures for reindeer husbandry to minimize the harmful and utilize potential benefits of climate change, and (iii) root

operational models for adaptation (“Best practices”) into the practical herding work for example through education and guidance of the livelihood.

Exposure to heat and air pollution in EUrope – cardiopulmonary impacts and benefits of mitigation and adaptation (EXHAUSTION)

PI: Antti-Pekka Hyvärinen (antti.hyvarinen@fmi.fi), Ari Karppinen (ari.karppinen@fmi.fi), Jaakko Kukkonen (jaakko.kukkonen@fmi.fi), FMI

Funding: EU Horizon 2020

Active: 1.06.2019-31.01.2024

Partners: Center for International Climate Research, Aarhus University, London School of Hygiene and Tropical Medicine, University of Oslo, Finnish Meteorological Institute, Draxis Environmental Technologies, Norwegian Institute of Public health, Info Design Lab, Helmholtz Zentrum München, University of Porto, D EP Lazio, Luxembourg Institute of socio-economic research, Meteo Romania

Website: <https://www.exhaustion.eu/>

Extreme heat and wildland fires are identified as key climate risks in Europe. The two risks are interlinked, as the risk of wildland fires increases during periods of extreme heat and decreasing precipitation. Extreme heat increases the death and disease rates for cardiopulmonary disease (CPD). Wildland fires cause intense air pollution in the form of fine particulate matter (PM_{2.5}) and ozone (O₃). These are the two major air pollutants threatening human health in Europe, and their main health effects are related to CPD. Episodes of extreme temperatures and extreme levels of PM_{2.5} and O₃ are likely to occur simultaneously and could occur more often, last longer, and become more intense in a warming world. EXHAUSTION will establish exposure projections for extreme heat and air pollution based on the most updated and advanced climate modeling efforts. EXHAUSTION has access to unique retrospective health registries on CPD mortality and morbidity in Northern, Central, and Southern European settings. In addition, EXHAUSTION draws upon a large time-series data base in a multi-country observational study. These data enable us to derive novel exposure-response relationships for heat, air pollution, and CPD. By combining the exposure projections and the exposure-response relationships, EXHAUSTION quantifies the future exacerbation of CPD in European settings and attributes the change in CPD mortality to a changing climate. EXHAUSTION will develop innovative adaptation strategies informed by epidemiological evidence, and address major inequity issues by identifying how age, sex, and indicators of socio-economic status (SES) predict probability for CPD caused by extreme heat and air pollution. EXHAUSTION will model socio-economic cost estimates for the response in CPD, and identify and validate possible adaptation strategies. Cost estimates, including projected health co-benefits of future adaptive measures and greenhouse gas (GHG) mitigation measures will be established.

Vector-borne diseases and climate change in finland: mapping, modelling, mitigation (VECLIMIT)

PI: Hilppa Gregow (hilppa.gregow@fmi.fi), FMI

Funding: Academy of Finland

Active: 1.1.2020-31.12.2023

Partners: University of Helsinki, Finnish Meteorological Institute, Natural Resources Institute Finland, University of Turku, University of Jyväskylä, National Institute for Health and Welfare, Finnish Food Authority

Website: <https://www.helsinki.fi/en/projects/veclimit>

Vector-borne diseases (VBD) are posing an increasing threat to humans. Quantifying this risk is complicated as it arises from the interplay between multiple hosts, vector and pathogen species and the environment, including changing climate. This consortium (partners from Universities of Helsinki, Jyväskylä and Turku, Luke, NIHW, FFA and FMI) aims to estimate and predict these risks in relation to climate change in Finland. This will be achieved by integrating existing long-term human disease

incidence data with data on host communities and environment using modern analyses tools, empirical field studies and modelling. The ultimate goal is to better quantify environmental and societal factors that drive VBD and provide essential information for intervention strategies. The main focus is on tick-borne diseases (Lyme borreliosis and tick-borne encephalitis), but the concepts and methods developed can be used in studying other VBDs affected by climate change.

Individuals, communities and municipalities mitigating climate change by carbon smart green space (CO-CARBON)

PI: Leena Järvi, University of Helsinki (leena.jarvi@helsinki.fi); Liisa Kulmala, FMI (liisa.kulmala@fmi.fi)
 Funding: Academy of Finland
 Active: 1.10.2020-30.9.2023
 Partners: University of Helsinki, Aalto University, and Häme University of Applied Sciences.
 Website: <https://research.aalto.fi/en/projects/artificial-intelligence-for-urban-low-emission-autonomous-traffic-2>

Urban green spaces are seen as one potential method to mitigate climate change and its impacts on society. Vegetation and soil store atmospheric carbon, modify local climate and stormwater cycling and impact human well-being. The aim of CO-CARBON is to quantify the carbon storage of green spaces at different urban scales using novel measurements and process-based models at the same time when accounting for other socio-ecological factors, and support practical operations for the multiple planning and management needs of carbon-smart green spaces. The aim is to have carbon-smart green spaces to become a well-recognized part of urban transition at different societal levels. CO-CARBON will bring together atmospheric, soil and social scientists with landscape designers, urban planners, businesses, governmental and national bodies and residents. The project is done at the University of Helsinki, Aalto University, Finnish Meteorological Institute and Häme University of Applied Sciences.

MARine and WEather events in the changing CLimate as potential external hazards to nuclear safety (MAWECLI)

PI: Ulpu Leijala (ulpu.leijala@fmi.fi)
 Funding: The National Nuclear Waste Management Fund
 Active: 1.2.2023-31.12.2025
 Partners: Finnish Meteorological Institute (FMI)
 Website:

The goal is to improve reliability of estimates about the likelihood of extreme single and joint events in the changing climate. The research material and methods include the newest available meteorological data, physical and statistical modeling and extreme value analysis. We share expertise and utilise synergies among scientists from various disciplines. The results include estimates of the frequency and magnitude of high wind gusts, future sea-effect snowfall, most hazardous geomagnetic storms, and joint effect of intense snowfall and high wind speeds. We also make multi hazard assessment for convective storms, meteotsunamis and lightning, and produce improved estimates on coastal flooding risks, extreme air temperature, and worst-case flooding events caused by cyclones.

Piloting Innovative Insurance for Adaptation (PIISA)

PI: Hilppa Gregow (hilppa.gregow@fmi.fi), FMI
 Funding: EU
 Active: 1.6.2023 - 31.5.2026
 Partners:
 Website:

PIISA will develop and test a collection of weather and climate risk insurance products, with special reference to (1) cities and citizens' well-being, (2) agriculture, and (3) forests and forestry. PIISA will co-create innovative climate services for managing immediate, mid-term and long-term risks regarding nature-based solutions (NBS) and carbon capture. PIISA will also investigate the current and future distribution and magnitude of extremes, relevant to all the awareness raising pilots that it will organize with various target groups. PIISA contributes to the weather and climate change adaptation research and work in EU regions and communities. The Finnish Meteorological Institute is responsible coordinator of the project.

Urban green space solutions in carbon neutral cities (CarboCity)

PI: Leena Järvi, University of Helsinki (leena.jarvi@helsinki.fi); Liisa Kulmala, FMI (liisa.kulmala@fmi.fi)
Funding: Academy of Finland
Active: 1.9.2019-31.8.2024
Partners:
Website: <https://researchportal.helsinki.fi/en/projects/urban-green-space-solutions-in-carbon-neutral-cities>

Cities worldwide aim to reduce their carbon emissions to the atmosphere and turn themselves carbon neutral in the forthcoming years. One attractive possibility is to maximize carbon sink to urban green space but there is a lack of research based information on how effective natural urban carbon sinks can act in present and future climates. This knowledge gap is partly due to lack of detailed ecophysiological research in cities and appropriate models that can account for the complex land use and microclimate in urban areas. CarboCity will answer to these needs and provide such a model by studying special characteristics of urban natural sinks and sources and by quantifying the natural carbon flows and storages in cities located at different climates (Helsinki, London, Minneapolis, Beijing and São Paulo). It provides us detailed information on the impact of soil and vegetation on urban carbon cycle and finds optimal planning solutions for maximising carbon sink in the future.

Validated Local Risk Actionable Data for Adaptation (VALORADA)

PI: Thomas Kühn (thomas.kuhn@fmi.fi), FMI
Funding: EU
Active: 1.6.2023-31.5.2026
Partners:
Website:

VALORADA's vision is to empower European regions and cities to steer the upcoming societal transformation towards sustainable and climate-resilient development through their own actions. VALORADA's mission is to enable the merging of local knowledge with climate and non-climate data by means of co-developed data manipulation tools and climate data. VALORADA will increase the use of available climate information in regional and local administrations by co-designing climate-data services which grant "climate value" to locally sourced data sets in regions and communities. The project will run for three years (2023-2026), and the total budget of the project is 3 M€, whereof the FM's share is 315k€. 14 partners are participating in the project. Further information: Thomas Kühn (Climate Change and Future Cities).

Water-based solutions for carbon storage, people and wilderness (WaterLANDS)

PI: Eeva-Stiina Tuittila, University of Eastern Finland (eeva-stiina.tuittila@uef.fi)
Funding: EU Horizon 2020 Green Deal Call 7.1
Active: 01.12.2021-30.11.2026

Partners: 32 partners from 14 countries
 Website: <https://waterlands.eu/project-overview/>

WaterLANDS will contribute to the restoration of wetland sites across Europe which have been damaged by human activity and is laying the foundations for protection across larger areas.

Biosphere Laboratory of Eastern Finland (BioLab)

PI: Eeva-Stiina Tuittila, University of Eastern Finland (eeva-stiina.tuittila@uef.fi)
 Funding: Research Council of Finland
 Active: 01.01.2023-31.12.2025
 Partners: GTK
 Website: <https://uefconnect.uef.fi/en/biosphere-laboratory-of-eastern-finland/>

The new biosphere laboratory brings together research on the carbon cycle and plant stress of northern ecosystems. Its aim is to promote the bioeconomy, which is especially important in Eastern Finland, and to support the adaptation of agriculture and forestry to climate change.

The Biosphere Laboratory consists of three modules:

1. An experimental laboratory that is located on the university campus and enables experimental research in controlled conditions
2. A mobile field measurement laboratory that enables a broad spatial dimension of the research and rapid reaction to disturbances such as forest fires and insect damage
3. A data management module that supports efficient data transfer, storage, and research visualization.

Locally tailored climate service for Finland (TAPSI).

PI: Hilppa Gregow, Finnish Meteorological Institute (hilppa.gregow@fmi.fi)
 Funding:
 Active: 1.1.2023 -- 31.12.2024 (will continue also after)
 Partners:
 Website:

The aim of TAPSI is to develop interactive high-resolution climate services for risks and opportunities and improve adaptation to climate change in Finland. TAPSI focuses e.g. on thunderstorm, heatwave and slippery condition risks in climatic scales. Also, a new urban measurement network in Helsinki, Tampere, Oulu and Rovaniemi will be created to be able to monitor, e.g., the urban and health related risks more closely in near real time.

CRYOsphere Science Concluding in new Observations and Productive Exploitation (CryoSCOPE)

PI: Rakesh Hooda (FMI)
 Funding: EU
 Active: 2025-2029
 Partners:
 Website: <https://cryoscope-project.eu/>

The CryoSCOPE project addresses challenges related to evolving land ice, snow, and permafrost, excelling in comprehensive in situ and remote sensing observations of the atmosphere, aerosols, cryosphere, and hydrology. CryoSCOPE aims to demonstrate excellence across the entire value chain by: Providing advanced observations of the CAH system in globally significant "cold spots," including the Indian Himalayas, the Alps, Iceland, Northern Scandinavia, and Svalbard. Integrating observation-

constrained modeling, spanning from detailed process models to Earth System Models (ESMs), enhancing our understanding of physical and chemical processes of the CAH system. Generating new knowledge on cryosphere-ecosystem changes in targeted regions and globally, enabling predictions of the impacts of climate change and related drivers across seasonal to long-term time scales. Developing societally impactful services and solutions to bolster resilience against the changes occurring at various time scales. The overarching scientific objective of CryoSCOPE is to understand and quantify physical and chemical processes of the CAH system in diverse landscapes and found the intricate interplay among different processes. This encompasses examining how these interactions are represented within regional process-based models and global ESMs, and predicting their susceptibility to climate change impacts.

DestinE climate digital twin (stage 2)

PI: Sami Niemelä (CATS) (sami.niemela@fmi.fi), FMI Anders Lindfors (DEODE) (anders.lindfors@fmi.fi)
Funding: EU
Active: 01.05.2024-06.06.2026
Partners: CATS leader Centre for Scientific Computing (Finland), 12 other partner organisations (incl. FMI); DEODE Leader Meteo France, 27 other partner organisations (incl. FMI)
Website: <https://digital-strategy.ec.europa.eu/en/policies/destination-earth>

Destination Earth (DestinE), a European Commission flagship initiative for a sustainable future Image of the Earth from space representing Destination Earth. The Destination Earth (DestinE) is a flagship initiative of the European Commission to develop a highly accurate digital model of the Earth on a global scale. This model will monitor, simulate and predict the interaction between natural phenomena and human activities. It will contribute to achieving the objectives of the twin transition, green and digital as part of the European Commission's Green Deal and Digital Strategy. FMI participates in two projects: Climate Adaptation Digital Twin (CATS), On-demand Extremes Digital Twin (DEODE). Stage 3 is currently in preparation.

ILMOS Uusimaa

PI: Anna Luomaranta (anna.luomaranta@fmi.fi)
Funding:
Active: 01.10.2025 - 31.05.2027
Partners: FMI
Website:

The ILMOS project supports climate adaptation planning in the Uusimaa region by producing high-resolution climate data, assessing socio-economic impacts, and developing narrative-based communication tools. The climate data will be derived from state-of-the-art gridded observational datasets covering past climate conditions in Finland, as well as the latest global and regional climate model outputs (e.g., EURO-CORDEX, CMIP6). These data will be used to create a series of narrative-based "climate stories" that translate scientific results into relatable accounts of climate change impacts, tailored to different local contexts and stakeholder perspectives. To better understand urban microclimates, ILMOS applies machine learning to integrate climate model data, local measurements, and non-climatic geospatial data. This approach enables the study of how built environments and blue-green infrastructure influence local climate conditions in Finnish cities. The resulting high-resolution microclimate data will support an evaluation of the economic and social implications of adaptation measures, including both tangible benefits and intangible ones.

Insights into Future Extreme Windstorms: Dynamics and Impacts (WIND-IMPACT)

PI: victoria.sinclair@helsinki.fi
 Funding: Research Council of Finland
 Partners: University of Helsinki (coordinator) and FMI
 Active: 01/09/2025 - 31/08/2029
 Website: <https://researchportal.helsinki.fi/en/projects/insights-into-future-extreme-windstorms-dynamics-and-impacts/>

In this project we investigate how climate change affects the characteristics of windstorms in northern Europe by using projections from a digital twin of Earth at unprecedented kilometre-scale resolution. We also develop machine learning based models to predict the impact of these storms on the electrical grid and apply these tools to quantify the future risks of windstorms to the electricity network. Additionally, we estimate the future socio-economic losses from windstorms and explore the potential of economic mechanisms to mitigate their impacts.

Green transition

Towards Carbon Neutral Municipalities and Regions (CANEMURE)

PI:
 Funding: EU
 Active: 2018-31.10.2024
 Partners:
 Website:

The aim of the project is to promote smart low-carbon transport, increase the production of decentralised renewable energy and improve the energy efficiency of buildings. In addition, support is provided for climate sustainable urban planning processes and conditions created for low-carbon production and consumption. The project also promotes the implementation of climate strategy in agriculture and forestry, especially in peatlands.

The Canemure consortium consists of 21 partners and 15 co-financiers, and is coordinated by the Finnish Environment Institute SYKE. The total budget for the project is 15.3 million euros funded by the EU Life programme. The Canemure-project includes 13 sub-projects carried out by 15 different project beneficiaries, each producing concrete actions and results for climate change mitigation and adaptation.

Facing system change together: Citizen deliberation in informed and just climate transitions (FACTOR)

PI: Maija Setälä (maiset@utu.fi), UTU; Anna Luomaranta (anna.luomaranta@fmi.fi), FMI; Heli Saarikoski, SYKE; Katriina Soini, Luke; Simo Kyllönen, HY
 Funding: Academy of Finland
 Active: 01.02.2021 - 31.12.2024
 Partners:
 Website: <https://sites.utu.fi/factor/>

FACTOR explores how citizen deliberation can facilitate just and informed climate transition. FACTOR analyses various obstacles for an agreement regarding climate justice, including individual biases and misperceptions, and how deliberative processes can potentially counteract these obstacles. FACTOR organises deliberative mini-publics in order to help citizens and policy makers make informed and balanced judgments regarding climate transitions. Deliberations are organised both at the regional and the national level. At the national level the project will develop the ways in which climate information is presented at the Climateguide.fi portal. FACTOR conducts surveys and interviews as well as field experiments to gauge the effects of deliberative citizen participation among policy

makers and the public at large. FACTOR is led by the University of Turku. The Finnish Meteorological Institute is responsible for the scientific co-operation and coordination of the WP3.

Pilot Application in Urban Landscapes - Towards integrated city observatories for greenhouse gases (PAUL)

PI: Leena Järvi (leena.jarvi@helsinki.fi), University of Helsinki
 Funding: EU
 Active: 1.10.2021-31.12.2025
 Partners:
 Website: <https://www.icos-cp.eu/projects/icos-cities-project>,
<https://cordis.europa.eu/project/id/101037319>

Cities are emission hotspots and play an important role in emission reduction efforts. Observing and verifying greenhouse gas emissions from densely populated urban areas is essential. The EU-funded project PAUL (Pilot Application in Urban Landscapes - Towards integrated city observatories for greenhouse gases) – ICOS cities will develop and evaluate innovative greenhouse gas measurement technologies and observatories. The aim is to provide unique data sets feeding diverse models and scientific studies, while testing the feasibility of modelling approaches in various areas. Moreover, the project will help cities execute their climate action goals by providing data on fossil fuel emissions from urban areas. Pilots will be conducted in Munich, Paris and Zurich. For increased impact, 12 other European cities are included in the city network.

Assessing Sectoral Perspectives on Climate Transitions to support the Global Stocktake and subsequent NDCs (NDC Aspects)

PI: Harro van Asselt (harro.vanasselt@uef.fi), University of Eastern Finland
 Funding: EU Horizon 2020
 Active: 1.8.2021-31.7.2024
 Partners: 12 academic institutions and SMEs
 Website: <http://www.ndc-aspects.eu>

The overarching objective of NDC ASPECTS is to provide cutting-edge analysis and robust scientific evidence in support of the 2023 Global Stocktake under the Paris Agreement and related efforts by countries to up-grade existing NDCs up to 2030, prepare new NDCs of highest possible ambition for the period beyond 2030 and effectively implement these NDCs. NDC ASPECTS will approach this issue with a focus on policy and governance perspectives, complemented by insights from quantitative modelling.

The European Green Deal: Governing the EU's Transition towards Climate Neutrality and Sustainability, EU – Jean Monnet Network project (GreenDeal-NET)

PI: Sebastian Oberthür (sebastian.oberthur@uef.fi), University of Eastern Finland
 Funding: EU Jean Monnet Network
 Active: 2022-2025
 Partners: 11 universities
 Website: <https://cim.unitn.it/gd-net/general-overview>

The network provides a platform for collaboration and exchange on European climate and sustainability governance, with a view to (a) collect, share, discuss and advance relevant academic research/ teaching and (b) actively foster engagement and debate with policymakers and the broader public.

Leaving No One Lost in Transition: Citizens and the Legitimacy of Finland's Transition to a Carbon Neutral Welfare State (2035legitimacy.fi)

PI: Kati Kulovesi (kati.kulovesi@uef.fi), University of Eastern Finland
 Funding: Academy of Finland
 Active: 01.10.2020 - 30.09.2023/2026
 Partners: FMI; Univ. of Helsinki; Univ. of Jyväskylä; SYKE
 Website: <https://2035legitimacy.fi/>

Finland's goals of being carbon neutral by 2035 is ambitious but achievable, and research is emerging concerning economic and technological options to implement them. However, the social and legitimacy dimensions of the carbon neutrality target have received much less attention. The 2035Legitimacy project is designed to address this important gap. The project builds on the assumption that the societal transformation needed to achieve the 2035 carbon neutrality goal cannot be imposed on a democratic society; it requires widespread social support. The project will rely on multidisciplinary collaboration to study the legitimacy of Finland's 2035 carbon neutrality transition and opportunities to address related challenges, especially from the perspective of private citizens. The project engages an extensive network of interaction partners and stakeholders representing state and municipal authorities, as well as academic, industry, labor and civil society organizations.

Strengthening democratic governance for climate transitions (RETOOL)

PI: Annalisa Savaresi (annalisa.savaresi@uef.fi), University of Eastern Finland
 Funding: Horizon Europe
 Active: 1.2.2024-31.1.2027
 Partners: Vrije Universiteit Brussel (VUB), Università di Trento, Ghent University, University of Natural Resources and Life Sciences, Vienna (BOKU), University of Eastern Finland, HOLISTIC, DD Foundation and The London School of Economics and Political Science (LSE)
 Website: <https://retoolproject.eu/>

The RETOOL project aims to advance our understanding of how to address the twin challenges of responding to the climate imperative while strengthening and reinvigorating democratic governance. The project studies how diverse types of institutions across European democracies—including parliaments, executives, courts, climate advisory bodies, citizens' assemblies & mobilisation by activists—are evolving and innovating to respond to the climate crisis.

Climate law

Investment, Infrastructure, Innovation and sector Integration: TRAnsformative policies for a ClimaTe-neutral European Union (4I-TRACTION)

PI: Kati Kulovesi (kati.kulovesi@uef.fi), University of Eastern Finland
 Funding: EU Horizon2020
 Active: 1.8.2021-31.7.2024
 Partners: 8 academic institutions and non-profit organisations
 Website: <https://www.4i-traction.eu/>

The TRACTIIION project sets out what transformative climate policy means for the EU, leading to a set of policy pathways and an overarching governance framework for climate neutrality. Based on a stocktake of existing climate policies and their performance, it spells out how the current EU policy mix will need to evolve in the 2020s to set course for achieving the long-term objectives. The analysis

will be structured around four cross-cutting challenges - fostering pervasive innovation, shifting investment and finance, rolling out the infrastructure for a climate-neutral economy, and integrating solutions across different sectors, recognising that a systemic transformation will need to go beyond the current, predominantly sectoral policy approaches. The analysis will incorporate scientific insights and policies from outside the EU and examine how the EU's efforts interact with those of other key countries. To receive input, provide feedback and validate conclusions, the project will closely engage with a broad set of stakeholders.

Transformative Transparency? Assessing the Effects of Reporting and Review in the International Climate Change Regime (TRANSCLIM)

PI: Harro van Asselt (harro.vanasselt@uef.fi), University of Eastern Finland
 Funding: Academy of Finland
 Active: 1.9.2020-31.8.2024
 Partners: Finnish Institute of International Affairs
 Website: <https://sites.uef.fi/cceel/transclim/>

Transparency, in the form of reporting by states and the review of reports by international bodies, can strengthen accountability and effectiveness in global governance. However, theoretical assumptions on the effects of reporting and review are yet to be tested for one of the most pressing challenges of our age: climate change. TRANSCLIM, a joint project by UEF Law School and the Finnish Institute of International Affairs, offers multidisciplinary perspectives on the effects of transparency arrangements in the international climate regime. Combining legal analysis with political science research and country studies, the project explores the different effects of reporting and review for various actors, including states, non-state actors, and international organisations. By doing so, the project contributes to transparency studies as well as the implementation of the transparency framework of the Paris Agreement on climate change.

Achieving High-Integrity Voluntary Climate Action (ACHIEVE)

PI: Lauri Peterson (lauri.peterson@uef.fi), University of Eastern Finland
 Funding: Horizon Europe
 Active: 1.1.2024-31.12.2027
 Partners: NewClimate Institute for Climate Policy and Global Sustainability (NCI); Ministry of Infrastructure and Water Management (PBL) Netherlands; Öko-Institute – Institute for Applied Ecology (OEKO); E3-Modeling (E3M); Tropical Agricultural Research and Higher Education Center (CATIE); Stockholm University; University of Oxford; HOLISTIC; World Wildlife Fund for Nature (WWF); CDP Europe
 Website: <https://sites.uef.fi/cceel/achieve/>

The ACHIEVE research initiative seeks to enhance and expand voluntary climate efforts to advance the global goal of achieving a net-zero society by 2050. The project's objectives encompass:

1. Generate insights on the effectiveness and reliability of voluntary climate actions, including the use of carbon credits.
2. Evaluate the authenticity and consequences of voluntary climate actions.
3. Examine how mutually beneficial interactions can occur between policies, regulations, and high-integrity voluntary climate initiatives.
4. Leverage scientific discoveries to facilitate the expansion of high-integrity voluntary actions.

Voluntary carbon offsetting in (climate) action: Perception coalitions, representations, and regulation (OFFCORR)

PI: Kateryna Holzer (kateryna.holzer@uef.fi), University of Eastern Finland
 Funding: Research Council of Finland

Active: 1.9.2023-31.8.2027
 Partners: Finnish Meteorological Institute (FMI)
 Website:

Voluntary carbon offsetting grows fast but is criticized and under-regulated. OFFCORR produces in-depth understanding on how citizens, organisations and experts make sense of offsetting, how it is practiced, how it is connected to other climate actions, and what kinds of regulation and governance are needed. OFFCORR studies offsetting as part of sustainability transformations, from grass-root level to market actors and legislation, using social psychology, political science and law. Together we will design, collect, and analyse interviews and surveys. The results provide a holistic picture of various levels of arguments and views regarding offsetting. OFFCORR will develop both novel scientific understanding and regulatory and market recommendations for policy makers and market actors for a more holistic, legitimate and effective voluntary carbon offsetting. OFFCORR will engage a variety of stakeholders to make future-oriented strategies to manage tensions regarding offsetting.

Science-based legal pathways to reduce black carbon emissions in the EU and China. Towards integrated climate – air quality approaches (ClimAirPathways)

PI: Yulia Yamineva (yulia.yamineva@uef.fi), University of Eastern Finland and Thomas Kühn (thomas.kuhn@fmi.fi), Finnish Meteorological Institute
 Funding: Research Council of Finland
 Active: 1.9.2023-31.8.2027
 Partners: University of Helsinki; FMI
 Website: <https://sites.uef.fi/cceel/climairpathways/>

The main aim of the project is to develop pathways to reduce black carbon emissions in the EU and China through integrated approaches to climate change and air pollution. Climate change and air pollution are two of the most important challenges to public health and sustainability, closely linked both in terms of emission sources and impacts. These two problems are often addressed in a fragmented, siloed manner, and there is no sufficient understanding of what explains such policy disintegration and how to develop and diffuse effective legal rules to achieve co-benefits for climate and air quality. One example is reducing emissions of short-lived climate pollutants, including black carbon, which contributes to air pollution and climate change. To develop pathways to reduce black carbon emissions, the project is organised into three work packages (WPs) – one with a socio-legal focus (WP1, “Law & Governance”), drawing on policy integration and norm diffusion studies; one focused on climate modelling (WP2, “Scientific Modelling”) and a third package to coordinate between them and synthesise findings (WP3, “Synthesis & Coordination”). The long-term contribution of ClimAirPathways is the advancement of problem-oriented, interdisciplinary research for better policy coherence and sustainable development. In doing so, the project draws on insights and expertise gained under two previous projects on short-lived climate pollutants at CCEEL, ClimaSlow (European Research Council, 2017-2022) and Keeping the Arctic White (Academy of Finland 2015-2018).

Regulatory Cooperation on Carbon Standards (RECOSTA)

PI: Kateryna Holzer (kateryna.holzer@uef.fi), University of Eastern Finland
 Funding: UEF
 Active: 2022-2025
 Partners: University of Groningen, the World Trade Institute (WTI) at the University of Bern, and the Trade and Environment Division of the World Trade Organization.
 Website: <https://sites.uef.fi/cceel/recosta/>

Different levels of carbon restrictions undermine competitiveness of producers from countries with strict carbon standards and relocate emissions to countries with lax standards. International regulatory cooperation can prevent this through establishing common rules for carbon standard setting, carbon footprint measurement and certification, as well as common rules for the use of trade-related carbon restrictions, including carbon import duties and border carbon adjustments. RECOSTA examines regulatory cooperation arrangements in a transnational setting looking into two layers: state-to-state (in the WTO, the UNFCCC, free trade agreements and sectoral agreements) and also at the public-private level, including the possibility of engagement of private voluntary certification schemes in the implementation of mandatory technical regulations enacted by states. RECOSTA strives to understand when, where and how trade-driven regulatory cooperation on carbon standards takes place. It also elaborates essential elements of effective regulatory cooperation on carbon standards and provides recommendations to regulators and policymakers on feasible avenues and working mechanisms of such regulatory cooperation. By developing building blocks for international regulatory cooperation, RECOSTA also addresses the problems of inconsistency and low quality of carbon standards and, consequently, their lack of credibility among consumers, high costs of compliance for companies, trade tensions they cause and low effectiveness of these measures as emissions reduction tools.

Climate adaptation law

PI: Yulia Yamineva (yulia.yamineva@uef.fi)
Participants: Yulia Yamineva (yulia.yamineva@uef.fi), Tuula Honkonen (tuula.honkonen@uef.fi); Raihanatul Jannat (raihanatul.jannat@uef.fi)
Funding: ACCC

The goal is to improve our understanding of the emerging law on climate adaptation at international, transnational, national and subnational levels, including its contents, characteristics and (legal) consequences. The research will analyse: the emergence of international and transnational norms relating to climate adaptation, their origins, characteristics, and effects; potential of law to address transboundary adaptation risks; interactions with other sub-fields of climate law, and with other branches of law, such as international environmental law and international disaster law; how legal approaches to climate adaptation taken at the national or subnational level converge or diverge in terms of principles, contents, and institutions; the potential for litigation to drive developments in adaptation law; barriers to effective use of law to promote adaptation and to the development of climate adaptation law as a discrete sub-field.

Resilient forest value chains – enhancing resilience through natural and socio-economic responses (RESONATE)

PI: Annikki Mäkelä (annikki.makela@helsinki.fi), University of Helsinki
Funding:
Active: 2021-2024
Partners:
Website:

Climate change poses a major challenge for European forests, demonstrated by recent extreme events and forest disturbances of unprecedented intensity. As climate change continues, adverse impacts on the stability and production capacity of European forests could undermine the role of forests and the forest-based sector as a central pillar of the European Green Deal. To mitigate increasing disturbance risks, more effort is needed in prevention, particularly by improving the resilience of European forests and associated value chains. Forest owners need better guidance in adapting the management of their forests to coping with climate-induced forest disturbances and changes in functioning. Similarly, the forest-based sector will require substantial innovation capacity

to respond to changes in profitability, unpredictable wood flows, and a gradual change in tree species. There is an urgent need to improve the scientific understanding on how resilience of Europe's forests and forest value chains can be improved. RESONATE aims to guide decision-making towards enhancing resilience of forests and forest value chains in response to four resilience challenges: i) changing suitability of tree species due to climate change; ii) increased risks of forest disturbances; iii) changing societal demand on forest products and ecosystem services; iv) biodiversity decline. With an integrated resilience and vulnerability assessment, RESONATE investigates how past and current site factors and management affect forest system resilience in different forest types and management systems across Europe. Based on scenario analysis, foresight studies with active stakeholder engagement, and policy analysis, future-oriented response strategies to enhance forest and forest value chain resilience will be elaborated. RESONATE further highlights and balances trade-offs in decision making and delivers user-oriented recommendations and decision support with tools including, e.g., a Resilience Dashboard.

Climate change and Health: Adapting to Mental, Physical and Societal challenges (CHAMPS)

PI: At FMI Reija Ruuhela (reija.ruuhela@fmi.fi)
 Funding: Academy of Finland, Climate change and health programme (CLIHE)
 Active: 01.01.2020–31.12.2024
 Partners: Finnish Institute for Health and Welfare (THL, coordinator), Finnish Environment Institute (SYKE), Finnish Meteorological Institute (FMI), University of Eastern Finland and University of Helsinki
 Website: <https://thl.fi/en/research-and-development/research-and-projects/climate-change-and-health-adapting-to-mental-physical-and-societal-challenges-champs->

The project will extend understanding of climate change impacts beyond direct health effects to the wider societal costs. It examines relationships between weather variables and health using, e.g., information on hospital admissions, sickness absences and mortality. Novel results are anticipated on the impacts of solar radiation and its spectrum on seasonal mental health, relevant to other high-latitude regions in changing climate as well. Furthermore, we relate health impacts of weather and climate to information on socioeconomic, demographic and health status and project future health impacts using alternative climate change, socioeconomic and adaptation scenarios. With stakeholders we identify appropriate adaptation responses in the context of broader policy goals.

Smart Land Use Policy for Sustainable urbanization (SmartLand)

PI: Seppo Junnila, Aalto University
 Funding: Academy of Finland, Strategic Research Council (STEER program)
 Active: 06/2019–08/2025
 Partners: Aalto University (coordinator), Finnish Meteorological Institute, University of Helsinki, University of Turku
 Website: <https://smartland.fi/>, <https://en.ilmatieteenlaitos.fi/smartland>

The consortium helps to identify and develop effective land-use policies focusing on alleviating the following urban problems: 1) housing availability and affordability, 2) socioeconomic segregation of neighborhoods, and 3) carbon emission and energy use in cities. Land use policies are defined broadly, the instrument studied within the project are various, ranging from more traditional command and control policies to economic instruments (incentives structures) and information-based instruments. The research will identify existing and completely novel policies that effectively steer sustainable urbanisation considering all the three above-mentioned challenges and their interconnectedness. The consortium will also study and further develop these policies and their implementation in co-operation with the key stakeholders in the field of land use planning and development. Also, research-based long-term scenarios are utilised in co-creating processes.



EDUCATION

Learning of the competencies of effective climate change mitigation and adaptation in the education system (ClimComp)

PI: Markku Kulmala, University of Helsinki
 Funding: Research Council of Finland
 Active: 2021–11/2024
 Partners: University of Helsinki (coordinator), Finnish Meteorological Institute
 Website: <https://blogs.helsinki.fi/climatecompetencies/>

In this study, we examine what are the competencies needed in the society to efficiently mitigate and adapt to climate change and how these competencies are learned and taught throughout the education system. Climate expertise is urgently needed in all sectors of the society. We propose that in active collaboration with the state-of-art research, education system as well as society, optimal learning moments are created and climate competencies are learned. In collaboration with atmospheric scientists, climate modellers, educational scientists and psychologists we study optimal learning moments in project-based learning, research-practice partnership as well as online learning environments among youth. As a result, we propose systemic changes to the education system to better teach and learn the climate competencies and develop new tools for youth to learn climate change competencies.

CENTER(S) OF EXCELLENCE

Center of Excellence in Tree Biology

PI: Teemu Hölttä, University of Helsinki (teemu.holtt@helsinki.fi)
 Funding:
 Active: 2022-2029
 Partners:
 Website: www.helsinki.fi/en/researchgroups/centre-of-excellence-in-tree-biology

The CoE studies how genes control the carbon sink effect of trees. Forest trees have a key role as sinks for the atmospheric greenhouse gas, carbon dioxide (CO₂). Trees take up the CO₂ through narrow openings in their leaves (called stomata). After fixing the CO₂ in their green chloroplasts to form carbohydrates (or sugars), these compounds are then transported through a conductive tissue (phloem) to the trunk of the tree where they provide building blocks for the plant biomass. A specific stem cell system (cambium) orchestrates the underlying radial growth. The researchers will first dissect the process in the source (leaf), transport (phloem) and sink (cambium) segments. Finally, they will integrate this information at a whole tree level by combining various disciplines of plant science to analyse how forest tree individuals vary in their capacity to fix CO₂. The researchers will also use the information to breed trees that act as more efficient carbon sinks.

Virtual laboratory for molecular level atmospheric transformations (VILMA)

PI: Hanna Vehkamäki (coordinator) (hanna.vehkamaki@helsinki.fi), Juha Kangasluoma (juha.kangasluoma@helsinki.fi), Mikko Sipilä (mikko.sipila@helsinki.fi), Theo Kurten (teo.kurten@helsinki.fi), University of Helsinki; Kari Lehtinen (kari.lehtinen@uef.fi), Siegfried Schobesberger (siegfried.schobesberger@uef.fi), University of Eastern Finland; Matti Rissanen (matti.rissanen@tuni.fi), Tampere University
 Funding: Academy of Finland, Centre of Excellence
 Active: 2022-2029
 Partners:

Website: <https://wiki.helsinki.fi/display/VILMA>

Understanding the formation of atmospheric aerosol is vital as they help to cool the climate, but also cause increased mortality through bad air quality. A key problem in predicting aerosol formation is the huge number of compounds, reactions and processes involved, as well as the complexity of the participating compounds. We will solve these challenges by combining atmospheric and computer science to construct a virtual laboratory for atmospheric aerosol formation, interactively integrating experimental and theoretical state-of-the-art methods from the fields of chemistry, physics and artificial intelligence. This will allow us to tackle many unsolved problems in atmospheric science, for example the reactions responsible for the formation and growth of organic nanoparticles. Outreach – tailored versions of our virtual laboratory will also provide schoolchildren and the general public with insights not only into atmospheric science, but also into the scientific process more generally.

<https://wiki.helsinki.fi/display/VILMA>

The Centre of Excellence of Inverse Modelling and Imaging is internationally recognized as the world's leading unit in the field

PI: Professor Matti Lassas (Univ. of Helsinki); the vice-directors research professor Johanna Tamminen (Finnish Meteorological Institute), professor Mikko Kaasalainen (Univ. of Tampere).

Funding: Academy of Finland, Centre of Excellence

Active: 2022-2029

Partners: University of Helsinki, Department of Mathematics and Statistics, Inverse Problems Group, Aalto University, Department of Mathematics and Systems Analysis, Inverse Problems Research Group, University of Eastern Finland, Department of Applied Physics, Computational Physics and Inverse Problems Research, Finnish Meteorological Institute, Earth Observation Research, Greenhouse Gases and Satellite Methods, University of Jyväskylä, Department of Mathematics and Statistics, Inverse Problems Research Group, LUT University, Department of Mathematics and Physics, Inverse Problems, University of Oulu, Department of Mathematical Sciences, Inverse Problems Research Group, Tampere University, Department of Mathematics, Inverse Problems Group

Website:

It specializes in the theory, implementation and application of inversion methods. The objective is to create fundamentally new, efficient, and theoretically sound solutions to practical inverse problems, especially in following application areas: Medical imaging, Geophysics and space research, Remote sensing and modelling in environmental and climate research.

Eastern Mediterranean and Middle East – Climate and Atmosphere Research Centre (EMME-CARE)

PI: Markku Kulmala, University of Helsinki (markku.kulmala@helsinki.fi)

Funding: EU, Teaming

Active: 1.9.2019-31.8.2026

Partners: CR Cyprus Institute (Cyl), Max Planck Institute for Chemistry (MPIC), the French Alternative Energies and Atomic Energy Commission (CEA)

Website: <https://emme-care.cyi.ac.cy/>

The Eastern Mediterranean and Middle East regions face long-standing political and social problems. This is exacerbated by climate change effects such as air pollution, droughts, water shortages, high temperatures and desert dust. Human life is heavily affected and increase migration is seen. The Cyprus Institute (Cyl) has extensive experience in climate and atmospheric studies. The EU-funded EMME-CARE (Eastern Mediterranean and Middle East – Climate and Atmosphere Research Centre)

project aims to upgrade the Climate Division of Cyl to a Centre of Excellence (CoE) in the entire region. It will integrate experimental research and environmental data to elaborate proposals for the public health, agricultural and energy sectors. The CoE will work to generate solutions for society and will also serve as a knowledge hub.

RESEARCH INFRASTRUCTURES (RIS)

National RI

Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS-Finland)

PI: Markku Kulmala (markku.kulmala@helsinki.fi), University of Helsinki; Annele Virtanen (annele.virtanen@uef.fi), University of Eastern Finland; Jorma Keskinen (jorma.keskinen@tufi.fi), Tampere University

Funding: Research Council of Finland, FIRI (FIRI2019)

Active: 1.1.2020-31.12.2024

Partners: University of Helsinki, University of Eastern Finland, Tampere University

Website: <https://www2.helsinki.fi/en/infrastructures/actris-finland>; <https://www.actris.eu>

Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) is a highly distributed research infrastructure that aims to secure long-term atmospheric research done at a European level, and provide tools to tackle socio-economic challenges including air quality and climate change. ACTRIS-Finland (ACTRIS-FI), consisting of 14 research facilities, is a significant part of INAR RI and one of the cornerstones of European ACTRIS. ACTRIS is currently moving to implementation phase and it's expected to become fully operational in 2025. During the implementation phase the instrumentation of ACTRIS-FI facilities, 5 observational sites and 5 exploratory platforms (such as simulation chambers, laboratory and instrumented mobile van), will be upgraded to fulfill ACTRIS technical requirements and to provide optimal set of ACTRIS measurements. After the upgrading, ACTRIS-FI facilities shall be labelled as ACTRIS National Facilities to become officially part of the European ACTRIS. This FIRI project enables the needed instrument upgrading of ACTRIS-FI facilities (owned by University of Helsinki, University of Eastern Finland and Tampere University) and support the work of personnel to perform needed ACTRIS implementation activities such as instrument installations and quality assurance, and ACTRIS labelling process at the national level.

Integrated Atmospheric and Earth System Research Infrastructure (INAR RI) - Integrated observations for effective climate solutions in terrestrial ecosystems

PI: Markku Kulmala (markku.kulmala@helsinki.fi), University of Helsinki; Hannele Hakola (hannele.hakola@fmi.fi), FMI; Kari Lehtinen (kari.lehtinen@uef.fi), University of Eastern Finland; Jorma Keskinen (jorma.keskinen@tufi.fi), Tampere University

Funding: Research Council of Finland, FIRI (FIRI2021)

Active: 1.1.2022-31.12.2025

Partners: University of Helsinki, Finnish Meteorological Institute, University of Eastern Finland, Tampere University

Website: <https://www2.helsinki.fi/en/inar-institute-for-atmospheric-and-earth-system-research/infrastructure/national-research-infrastructure>

INAR RI is an umbrella RI, coordinating the distributed national nodes of European environmental research infrastructures (ICOS, ACTRIS, eLTER and AnaEE). INAR RI is benchmarking in the integration of multidisciplinary comprehensive environmental measurements with 30 stations, several laboratories and mobile units and two data infrastructures. This project shall upgrade the existing RI, build new INAR RI facilities and develop services e.g. related to data management and access provision to help the society to answer questions related to sustainability, climate change, and

environment degradation. This FIRI project strongly supports the national goals of carbon neutrality by having a special focus on improving the RI for better quantifying carbon sinks and related climate effects.

INAR RI belongs to the national RI roadmap 2021-2024. INAR RI acts as an umbrella research infrastructure, taking care of the implementation and national coordination of the ESFRI (European Strategy Forum on Research Infrastructures) infrastructures in the environmental domain in Finland: ICOS (Integrated Carbon Observation System), ACTRIS (Aerosol, Clouds, and Trace gases Research Infrastructure), eLTER (Integrated European Long-Term Ecosystem, Critical Zone & Socio-Ecological Research Infrastructure) and AnaEE (Infrastructure for Analysis and Experimentation on Ecosystems). The national INAR RI sister infrastructures are ICOS-FI, ACTRIS-FI, LTER-FI and AnaEE-FI. The mission in INAR RI is to co-locate these different environmental RIs and ingrate comprehensive long-term in-situ measurements with remote sensing, experimental approach and modelling in order to quantify and predict current and future climate change impacts on ecosystem functioning, and to provide harmonized comprehensive and open big data to unravel mechanisms involved in ecosystems' responses and feedback to climate, as well as to select and test mitigation and adaptation measures. With integration of national nodes of several ESFRIs, INAR RI is a benchmark RI in Europe, where such integration is still not actively implemented. The INAR RI facilities currently include 30 sites (17 co-located), several laboratories and mobile units and 2 data infrastructures. The cornerstones of INAR RI are the highly instrumented core stations like the SMEAR stations (Stations for Measuring Earth Surface—Atmosphere Relations) and Pallas-Sodankylä GAW (Global Atmosphere Watch), which provide co-location of measurements for the four environmental ESFRIs. Each INAR RI sister RI is proceeding in different phases at European level and therefore some INAR RI components are already established while others are still under development. However, the national parts of INAR RI are in operation and delivering data. In the next years, INAR RI community continues to work towards integration of the environmental measurements, upgrade the existing observational sites and exploratory platforms to guarantee and improve the representativeness and quality of the measurements, establish new measurement sites, and develop services. In addition, INAR RI continues to be active on the European level. Outside Europe, we coordinate and support building Global SMEAR station network.

Integrated Atmospheric and Earth System Research Infrastructure (INAR RI) – Upgrading capacities for air quality and climate actions in urban and agricultural environments

PI: Tuukka Petäjä (Tuukka.petaja@helsinki.fi), University of Helsinki, Antti Hyvärinen (antti.hyvarinen@fmi.fi), FMI; Annele Virtanen (annele.virtanen@uef.fi), University of Eastern Finland; Miikka Dal Maso (miikka.dalmaso@tuni.fi), Tampere University

Funding: Research Council of Finland, FIRI (FIRI2023)

Active: 1.1.2024-31.12.2027

Partners: University of Helsinki, Finnish Meteorological Institute, University of Eastern Finland, Tampere University

Website: <https://www.helsinki.fi/en/inar/infrastructure>

INAR RI is an umbrella RI, coordinating the distributed national nodes of European environmental research infrastructures (ICOS, ACTRIS, eLTER and AnaEE). INAR RI is benchmarking in the integration of multidisciplinary comprehensive environmental measurements with 30 stations, several laboratories and mobile units and two data infrastructures. This project shall upgrade the existing RI with a focus on the urban and agricultural environments and develop services to help the society to answer questions related to air quality and climate change. This project strongly supports the national goal of carbon neutrality by providing missing information regarding urban and agricultural emissions allowing us to assess the full air quality and climate impacts and feedbacks related to agricultural activities and urban greenery.

Integrated Atmospheric and Earth System Research Infrastructure (INAR RI) – Interoperability, co-location and capacity building

PI: Tuukka Petäjä (Tuukka.petaja@helsinki.fi), University of Helsinki, Antti Hyvärinen (antti.hyvarinen@fmi.fi), FMI; Annele Virtanen (annele.virtanen@uef.fi), University of Eastern Finland; Miikka Dal Maso (miikka.dalmaso@tuni.fi), Tampere University
Funding: Research Council of Finland, FIRI (FIRI2024)
Active: 1.1.2025-31.12.2029
Partners: University of Helsinki, Finnish Meteorological Institute, University of Eastern Finland, Tampere University
Website: <https://www.helsinki.fi/en/inar/infrastructure>

INAR RI is an umbrella RI, coordinating the distributed national nodes of European environmental research infrastructures (ICOS, ACTRIS, eLTER and AnaEE). INAR RI is benchmarking in the integration of multidisciplinary comprehensive environmental measurements with 30 stations, several laboratories and mobile units and two data infrastructures. This project shall upgrade the existing RI with a focus on the urban and agricultural environments and develop services to help the society to answer questions related to air quality and climate change. INAR RI is the key data and service provider for the top-level Earth system research and development activities performed e.g., within ACCC research and impact Flagship and the environmental ESFRI communities and hence, has a crucial impact on research, development and innovation. In this project INAR RI will further develop and strengthen its integration e.g., via streamlining the data flows and further development of the data portal. INAR RI will develop its research facilities to guarantee and improve the representativeness and quality of the measurements, ensure that they fulfill the European level technical requirements and continue addressing the scientifically and socially relevant topics in climate change, air quality and biodiversity loss in different environments. This funding is related to the RI lighthouse status that INAR RI received in early 2025.

European Research Infrastructures (RI) projects

In situ RI

ACTRIS Central Facilities

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki
Funding: Research Council of Finland, FIRI (FIRI2019)
Active: 1.1.2020-31.12.2024
Partners: University of Helsinki
Website: <https://www2.helsinki.fi/en/infrastructures/actris-finland>
<https://www.actris.eu/>

Atmospheric processes are increasingly in the focus of many societal and environmental challenges, such as poor air quality and climate change. The Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) is a pan-European research infrastructure aiming to secure long-term and extensive atmospheric research done at national and European level, and providing tools to tackle these challenges. The research based on ACTRIS will positively impact on e.g. human health, climate resilience, protection from environmental hazards, and visibility. ACTRIS consists of an extensive network of National Facilities (observational sites and exploratory platforms), and Central Facilities: Data Centre, six Topical Centres and Head Office. The leadership of ACTRIS is in Finland; ACTRIS Head Office (HO) and the statutory seat of ACTRIS ERIC will be in Helsinki. The HO coordinates the research infrastructure at the European level. HO shall coordinate and promote ACTRIS services, promote technology development and innovations, handle internal and external communication and cooperation, operate the legal entity, and ensure the strategic development and sustainability of

ACTRIS. In addition to HO, Finland (University of Helsinki, UH) will also host units of the following two Topical Centres; Centre for Aerosol In Situ Measurements and Centre for Reactive Trace Gases In Situ Measurements. ACTRIS Topical Centres maintain the high-quality observations done within ACTRIS and develop novel instrumentation to be deployed within the pan-European RI. This project provides elemental support in setting up ACTRIS ERIC Head Office and in securing the operations of the HO and of the two UH facilities. The broad participation of Finland in ACTRIS activities is significant and further promotes the international leadership in atmospheric sciences that Finland has already achieved.

ACTRIS Central Facilities

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki
 Funding: Research Council of Finland, FIRI (FIRI2024)
 Active: 1.1.2025-31.12.2027
 Partners: University of Helsinki
 Website: <https://www.actris.eu/> <https://www2.helsinki.fi/en/infrastructures/actris-finland>

Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS) is a pan-European research infrastructure aiming to secure long-term atmospheric research and providing tools to tackle socio-economic challenges such as air quality and climate change. ACTRIS consists of extensive network of National Facilities, Data Centre and Topical Centres. ACTRIS ERIC was established in April 2023 with the statutory seat and Head Office in Finland. Finland also contributes to ACTRIS Topical Centres and ACTRIS Data Centre by leading four Units: on measurements of sub-10 nm aerosol particles and aerosol precursor vapours, cloud remote sensing and data curation. Finland hosts several state-of-the-art observational and exploratory facilities. ACTRIS provides access to atmospheric data, research possibilities at the facilities, instrument calibration and development, and education to a vast community of users; scientists, policymakers, public and private sector. This project supports the implementation and operation of ACTRIS ERIC Head Office in Finland and University of Helsinki Topical Centre Units (for measurements of sub-10 nm aerosol particles and aerosol precursor vapours).

ACTRIS Implementation Project (ACTRIS IMP)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki
 Funding: EU Horizon 2020
 Active: 1.1.2020-31.12.2023
 Partners:
 Website: <https://www.actris.eu/how-are-we-funded>;
<https://cordis.europa.eu/project/id/871115>

ACTRIS IMP (Aerosol, Clouds and Trace Gases Research Infrastructure Implementation Project) is a EU Horizon 2020 Coordination and Support Section project supporting the implementation of ACTRIS. The project is coordinated by Finnish Meteorological Institute and University of Helsinki is a project partner and co-coordinator. ACTRIS IMP builds on the achievements of the previous successful EU Horizon 2020 project ACTRIS PPP (ACTRIS Preparatory Phase Project) 2017-2019 and on the scientific and technical deliveries of the ACTRIS-2 and EUROCHAMP-2020 EU Horizon 2020 projects. The ACTRIS IMP project will elevate ACTRIS to a new level of maturity and will set the required coordinated structures for coherent implementation actions, to be performed at both the national and European level. The overarching objective of ACTRIS IMP is to coordinate and accomplish the actions required for implementing a globally recognised long-term sustainable research infrastructure with operational services by 2025.

Solutions for Sustainable Access to Atmospheric Research Facilities (ATMO-ACCESS)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki
 Funding: EU Horizon 2020

Active: 1.04.2021-31.03.2025
 Partners: Finnish ACTRIS and ICOS sites and platforms: SMEAR II, KASC (Kuopio Atmospheric Simulation Chambers) and Finland combined mobile laboratory; all ACCC partner institutes
 Website: <https://www.atmo-access.eu/>; <https://www.actris.eu/how-are-we-funded>; <https://cordis.europa.eu/project/id/101008004>

ATMO-ACCESS (Solutions for Sustainable Access to Atmospheric Research Facilities) is a EU Horizon 2020 project to develop a new framework for providing access to distributed atmospheric research infrastructures. The project will assist in the creation of a durable, sustainable framework that allows easy access to different atmospheric RIs via virtual tools and cloud services. ATMO-ACCESS opens physical and remote access to 43 operational European atmospheric research facilities, including ground-based observation stations, simulation chambers, but also mobile facilities and central laboratories that are fundamental elements in distributed RIs. These facilities include Finnish ACTRIS and ICOS sites and platforms: SMEAR II, KASC (Kuopio Atmospheric Simulation Chambers) and Finland combined mobile laboratory. All ACCC partner institutes are ATMO-ACCESS project partners.

Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS (RI-URBANS)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi) - co-coordinator, University of Helsinki
 Funding: EU Horizon 2020
 Active: 1.10.2021-30.09.2025
 Partners: Finnish Meteorological Institute
 Website: <https://riurbans.eu/>; <https://cordis.europa.eu/project/id/101036245>

RI-URBANS (Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS) is a EU Horizon 2020 project to demonstrate how advanced service tools from atmospheric research infrastructures can be adapted to tackle air quality challenges and societal needs in urban and industrial areas. University of Helsinki is the project co-coordinator and Finnish Meteorological Institute is a partner in the project. The project will provide enhanced air quality observations for advanced air quality policy assessment by developing synergies between Air Quality Monitoring Networks (AQMNs) and RIs in the atmospheric domain. This will increase the capacity of AQMNs to evaluate, predict and support urban air pollution restriction policies. Combining science and technology, RI-URBANS will implement five pilot service tools in nine European cities (incl. Helsinki).

Modelling RI

Next Generation Earth Modelling Systems (NextGEMS)

PI: Heikki Järvinen (heikki.jarvinen@helsinki.fi), University of Helsinki
 Funding: EU Horizon 2020
 Active: 1.9.2021-31.8.2025
 Partners:
 Website: <https://digital-strategy.ec.europa.eu/en/policies/destination-earth/>; <https://nextgems-h2020.eu/>; <https://www.esiwace.eu/>; <https://www.lumi-supercomputer.eu/>

UH participates in EU's Destination Earth (DestinE) initiative aiming at developing a Climate Adaptation Digital Twin – a highly accurate digital replica of the planet Earth – to support adaptation to climate change. On a wider scale, DestinE contributes to the EU Commission's Green Deal and Digital Strategy. UH also participates in the EU H2020 project NextGEMS () where the scientific development of the Digital Twin models takes place. In addition, UH is a member of the EU Horizon

Europe Centre of Excellence in Simulation of Weather and Climate in Europe which essentially aims at enabling to unleash the full potential of the new exa-scale super-computers, such as LUMI in Finland, for running the Digital Twin models.

A SYstem for Real-Time ObserVation of Aeroallergens (SYLVA)

PI: Mikhail Sofiev (mikhail.sofiev @ fmi.fi), Finnish Meteorological Institute
 Funding: EU Horizon 2022
 Active: 1.1.2023-31.12.2026
 Partners: Finnish Meteorological Institute; EUMETNET; Technical University of Munich, Centre of Allergy and Environment; University of Cordoba, Departament of Botany, Ecology and Vegetation Physiology; NILU Norwegian Institute for air research; University of Vilnius, Siauliai Academy; University of Turku; Helmut Hund Wetzlar GMBH; CNR Consiglio Nazionale delle Ricerche; BioSense, Research and Development Institute for IT in Biosystems; MeteoSwiss Federal Office of Meteorology and Climatology; Swisens
 Website: <https://sylva.bioaerosol.eu/>

The overall goal of SYLVA is to achieve a radical improvement and fill gaps in temporal resolution, timeliness, coverage, and availability of information about aeroallergens and other bioaerosols, which are important indicators and modulators of climate change, affect human and plant health, and play a vital role in ecosystems. SYLVA technological innovations will be accompanied with new infrastructure, distribution and exploitation pathways, and links with stakeholders to ensure technology uptake and sustainability beyond the lifetime of the project.

Digital Twin of Earth system for Cryosphere, Land surface and related interactions (TerraDT)

PI: Markku Kulmala (markku.kulmala@helsinki.fi), University of Helsinki
 Funding: Horizon Europe
 Active: 1.1.2025-31.12.2028
 Partners: University of Helsinki, Finnish Meteorological Institute, University of Eastern Finland
 Website: <https://terradt.eu/>; <https://cordis.europa.eu/project/id/101187992>

TerraDT (Digital Twin of Earth system for Cryosphere, Land surface and related interactions) enhances the capabilities of the EU's Destination Earth (DestinE). TerraDT develops new digital twin components describing land ice, sea ice, aerosols and land surface more accurately than before.

Service RI

Knowledge and climate services from an African observation and Data research Infrastructure (KADI)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki
 Funding: EU
 Active: 1.9.2022-31.8.2025
 Partners:
 Website: <https://cordis.europa.eu/project/id/101058525>

The project KADI "Knowledge and climate services from an African observation and Data research Infrastructure" aims to provide concepts for developing the best available science and science-based services in Africa that are needed to sharpen our common action on climate change as outlined in the Paris Agreement and the UN Sustainable Development Goals, in particular SDG 13 'Take urgent action to combat climate change and its impacts'. The concepts to be provided aim at improving the knowledge base on climate change in Africa and developing the tools to combat the negative consequences of it. This basic objective shall be achieved by a consortium that combines partners from Africa and Europe but also combines diverse experiences, backgrounds and viewpoints. The

common goal is to provide a comprehensive concept that supports the important societal role of research outlined above by co-designing research capacities for climate change observation with societal demands and expectations, in our case called ‘climate services’ and to pave the way for their implementation.

Improving access to FORest GENetic resources Information and services for end-Users (FORGENIUS)

PI: Teemu Hölttä (teemu.holtta@helsinki.fi), University of Helsinki
 Funding: EU (H2020)
 Active: 2021-2025
 Partners:
 Website: <https://www.forgenius.eu/>

European nations have been increasingly concerned with georeferenced information on the conservation of forest genetic resources. This is imperative as forests provide essential societal services, covering approximately a third of the European continent, sequestering 719 million tonnes of CO₂. They also provide jobs to over 3 million people, generating revenue for 16 million forest owners. The EU-funded FORGENIUS project aims to develop methods and tools for greater insight into the characteristics and the value of forest genetic resources accessions presently existing in 35 European countries. The project will create novel services for users within and outside the conservation communities and will significantly increase and improve data quantity and quality in the European forest genetic resources information system.

Prototype for a Copernicus CO₂ service (EU-COCO₂)

PI: Johanna Tamminen (johanna.tamminen@fmi.fi), FMI
 Funding: EU
 Active: 2021-2023
 Partners: CR ECWMF (Richard Engelen)
 Website: <https://coco2-project.eu/>

The CoCO₂ project will build the prototype systems for a European Monitoring and Verification Support capacity for anthropogenic CO₂ emissions by bringing together expertise, existing capacities and innovative ideas from European and international players. The CoCO₂ project will deliver the prototype systems for a new European anthropogenic CO₂ emissions monitoring and verification support capacity that can be implemented within the Copernicus programme as one of its service elements.

SpaceCasting, economic forecasting from space data (SpaceCasting)

PI: Johanna Tamminen (johanna.tamminen@fmi.fi), FMI
 Funding: Business Finland / SpaceCasting Co-Creation project led by University of Vaasa
 Active: 10/2022 - 03/2023
 Partners:
 Website:

This project aims to combine the knowledge of artificial intelligence, industry, economics, and remote sensing experts to model economic processes and use remote sensing data to create new indicators that provide information on analytical entities such as industries or individual companies in a faster cycle than traditional information sources.

Cooperation and AgReements enhancing Global interOperability for Aerosol, Cloud and Trace gas research infrastructures (CARGO-ACT)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki

Funding: Horizon Europe
 Active: 1.3.2024-28.2.2027
 Partners: University of Helsinki, Finnish Meteorological Institute
 Website: <https://www.cargo-act.eu/>; <http://cordis.europa.eu/project/id/101132093>

CARGO-ACT (Cooperation and AgReements enhancing Global interOperability for Aerosol, Cloud and Trace gas research infrastructures) aims to deliver a roadmap for sustainable global cooperation between key organisations around the globe to provide all users, in the scientific community and beyond, with the best possible services for accessing and using information from monitoring climate- and air quality-relevant properties of aerosol, clouds and trace gases in the atmosphere.

Integrated Research Infrastructure Services for Climate Change risks (IRISCC)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi) University of Helsinki
 Funding: Horizon Europe
 Active: 1.4.2024-30.09.2028
 Partners: University of Helsinki and Finnish Meteorological Institute are project partners and University of Eastern Finland is a linked third party
 Website: <https://www.iriscc.eu/>; <https://cordis.europa.eu/project/id/101131261>

IRISCC (Integrated Research Infrastructure Services for Climate Change risks) a Horizon Europe project providing scientific and knowledge services to foster cutting-edge research and evidence-based policymaking to improve Europe's resilience to climate change. IRISCC ensures a “one-stop-shop” for various user communities on climate change risk related RI services by setting up a dedicated catalogue of services and related access management system both for granting transnational (onsite and remote) and offering virtual access. IRISCC is a consortium of diverse and complementary leading research infrastructures covering disciplines from natural sciences to social sciences. University of Helsinki and Finnish Meteorological Institute are project partners and University of Eastern Finland is a linked third party.

Station for Measuring Earth Surface-Atmosphere Relations (SMEAR)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi), University of Helsinki
 Funding:
 Active:
 Partners:
 Website: <https://smear.avaa.csc.fi/>

Stations for Measuring Earth Surface--Atmosphere Relations (SMEAR) stations produce comprehensive, simultaneous measurements on atmosphere, Earth surface and biosphere, covering meteorology, atmospheric composition and fluxes, as well as ecosystem variables. There are five SMEAR stations in Finland (SMEAR I-IV and SMEAR-Agri) owned by ACCC partner organization UH, UEF and FMI and stations also outside of Finland that UH has supported in implementation and starting of the operations (SMEAR Estonia, Beijing Haze, Cyros station by the EMME-CARE Teaming project). SMEAR I station in Värriö, Eastern Lapland, owned by UH started its operations in 1991. SMEAR II station in Hyytiälä, Central Finland, owned by UH have been operating since 1995. SMEAR II station is our flagship station, the most advanced SMEAR station. SMEAR II station is carrying out measurements 24/7 on 1200 parameters on different ecosystems: boreal forest, wetland and lakes. SMEAR III urban measurement station (Helsinki) owned by UH and FMI started the operations in 2004. The Puijo measurement station in Kuopio, owned by UEF and FMI, joined the SMEAR network in 2009 and became the SMEAR IV station. SMEAR-Agri, owned by UH, is the newest addition to Finnish SMEAR station network. SMEAR-Agri is an agricultural measurement station in Helsinki that started its

operations in September 2021. SMEAR stations provide open access and open data. SmartSMEAR (<https://smear.avaa.csc.fi/>) is a data visualization and download tool for the database of continuous atmospheric, flux, soil, tree physiological and water quality measurements at Finnish SMEAR research stations. The Finnish SMEAR stations are contributing to global earth observation systems and networks such as WMO GAW, GEO-GEOSS, FluxNet, AERONET and SolRad-Net, and to the European Research Infrastructures such as ICOS, ACTRIS, AnaEE and eLTER.

Community of Environmental Research Infrastructures (ENVRI)

ENVRI is a community of environmental Research Infrastructures working together to observe the Earth as one system. Most of the pan-European environmental RIs are currently being built and some are more mature than others. The ENVRI community is a collaborative platform where the RIs can work together, to share knowledge and to develop common solutions at all stages of RI development – in their planning, design, construction and implementation as well as operation to ensure their interoperability as well as to avoid unnecessary costs and duplication of efforts. Current ENVRI community brings together 26 European RIs that are studying different aspects of the Earth system. ACCC is part of the ENVRI community via joint projects with ACCC partner organizations (current Horizon 2020 project ENVRI-FAIR) and via ACCC partner organizations' contribution to European RIs ACTRIS, ICOS, eLTER and AnaEE.

ENVIRONMENTAL RESEARCH INFRASTRUCTURES BUILDING FAIR SERVICES ACCESSIBLE FOR SOCIETY, INNOVATION AND RESEARCH (ENVRI-FAIR)

PI: NN (n.n@helsinki.fi, University of Helsinki)
 Funding: EU Horizon 2020
 Active: 01.01.2019-30.06.2023
 Partners: Finnish Meteorological Institute
 Website: <https://envri.eu/home-envri-fair/>; <https://cordis.europa.eu/project/id/824068>

ENVRI FAIR (ENVIRONMENTAL RESEARCH INFRASTRUCTURES BUILDING FAIR SERVICES ACCESSIBLE FOR SOCIETY, INNOVATION AND RESEARCH) is a EU Horizon 2020 project to advance the findability, accessibility, interoperability and reusability (FAIRness) of the digital assets, such as research data and services, and connect them to the emerging European Open Science Cloud. ENVRI-FAIR targets the development and implementation of a technical and policy framework to overcome discipline boundaries within the ENVRI community. Cross-discipline harmonisation and standardisation, together with the implementation of joint data management and access structures, will facilitate truly interdisciplinary Earth system science that is fundamental to addressing today's environmental challenges. University of Helsinki and Finnish Meteorological Institute are project partners.

ENVIRONMENT RESEARCH INFRASTRUCTURES INNOVATION ROADMAP (ENVRINNOV)

PI: Tuukka Petäjä (tuukka.petaja@helsinki.fi, University of Helsinki)
 Funding: Horizon Europe
 Active: 01.01.2024-31.12.2026
 Partners: University of Helsinki
 Website: <https://cordis.europa.eu/project/id/101131426/de>

ENVRINNOV (ENVIRONMENT RESEARCH INFRASTRUCTURES INNOVATION ROADMAP) is Horizon Europe project to co-design, test, and validate a common innovation roadmap for environmental research infrastructures. This strategic guide will enable the establishment and operation of an ENVRI Innovation Hub (EIH), fostering the development of cutting-edge technologies and services to respond to environmental threats. University of Helsinki is a project partner.

CAPACITY BUILDING

Climate University

CR: Laura Riuttanen (laura.riutanen@helsinki.fi, University of Helsinki)
 Funding: Ministry of Education and Culture of Finland, the Finnish Innovation Fund Sitra, ACCC
 Active: 01.01.2019-30.06.2023
 Partners: 27 Higher Education Institutions in Finland
 Website: <https://climateuniversity.fi/>; <https://blogs.helsinki.fi/climateuniversity/>

Climate University is a network of 27 Higher Education Institutions in Finland to develop and foster climate and sustainability education in higher education in Finland. The network was established by 11 higher education institutions in 2018, with support from the Ministry of Education and Culture of Finland and the Finnish Innovation Fund Sitra. Network signed cross-study agreements in December 2020 allowing all students of the network's institutions to take the Climate University courses for free from each other's curricula. Climate University published a set of nine online courses open for everyone in December 2020 (www.climateuniversity.fi). Currently, there is more than 40 course codes in the partner institutions' curricula. Every partner institution has one Climate University coordinator and one vice-coordinator, making the network impactful in communication. Climate University coordinators and teachers meet annually – next meeting to be held 2.-3.11.2022 in Tampere, with support of ACCC funding. Climate University active topics can be read from the network blog (<https://blogs.helsinki.fi/climateuniversity/>).

In collaboration with the Biodiversity education network of Finland (<https://www.biodiversityeducation.fi/>), new online course on the biodiversity topics, Biodiversity.now, was published 7th October 2022. Climate.now has been translated into Swedish and the translated version is to be published in Autumn 2022. In collaboration of the ForClimate research project of the Academy of Finland, a new course on forests and climate change is to be planned.

International collaboration has been developed with several international partners. With Una Europa European Universities Initiative, a micro-credential in sustainability, 10 ECTS, was launched in October 2022 (<https://microcredential-sustainability.una-europa.eu/>). Micro-credential consists of five MOOCs: Sustainable.now, Climate.now, Biodiversity.now, Political economy of sustainability and Sustainability and the Arts. Together with Atmosphere-Biosphere Studies network (ABS) a 25 ECTS online education module was developed with funding from Nordplus (2019-2022). New funding was obtained from Nordplus to continue the online pedagogy development (2022-23, with potential continuation until 2025).

Pirkanmaa climate leadership forum was established in collaboration with the Council of Tampere region, Tampere Centre for Economic Development, Transport and the Environment and Tampere diocese, and three workshops were held: 19.1.2021 online, 10.6.2021 virtually from Hyytiälä and 20.4.2022 eventually in Hyytiälä, to invite city, municipality and church leaders to share visions on climate leadership of the region. Research was conducted during the forum, to frame regional climate leadership competencies.

Modernization of doctoral education in science and improvement of teaching, methodologies (MODEST)

PI: Timo Vesala (timo.vesala@helsinki.fi, University of Helsinki)
 Funding: Ministry of Education and Culture of Finland and the Finnish Innovation Fund Sitra; ACCC
 Active: 15.11.2018-15.11.2022
 Partners:
 Website: <https://www.emodest.eu/index.php>

MODEST project aims at modernization of doctoral education in Science in Partner Countries (PCs) incl. European countries and Armenia, Belarus (currently suspended), and Russia (currently suspended). Wider project objective is “To enhance cooperation capacities of Higher educational institutions of Partner Countries in the field of Doctoral Studies within European Higher Education Area (EHEA) and European Research Area (ERA)” and specific objectives include 1) the improvement of quality and employability of doctoral graduates of PC higher education institutes (HEIs) by modernizing doctoral education towards interdisciplinarity, internationalisation, enhancing mobility and using new teaching methodologies; 2) the organization of special training sessions for academic and administrative staff of HEIs in PCs; 3) the improvement of up-skills of research and educational staff by retraining them on new teaching methods and create modern learning and research environment based on student centered approach, competence-based program development; 4) improvement of structure and internal capacities of services of doctoral education and research by setting up Doctoral Training Centers in PC HEIs; and 5) the establishment of a professional network using modern ICT tools.

Climate change teachers’ academy (CLIMADEMY)

PI: Laura Riuttanen (laura.riutanen@helsinki.fi, University of Helsinki)
 Funding: EU
 Active: 1.6.2022-31.5.2025
 Partners: 11 Erasmus+ Teacher Academies in Finland, Germany, Greece and Italy, will be open for new members
 Website: <https://www.acccflagship.fi/index.php/2022/09/26/meet-the-climademy-project/>

The Erasmus+ Teacher Academies is a new flagship action of the 2021-2027 Erasmus+ programme that aims to create partnerships of teacher’s education and training providers across Europe in order to develop the European and international dimensions of teacher’s education, contributing to the achievement of the objectives of the European Education Area. The first 11 Erasmus+ Teacher Academies have been launched as of summer 2022 to support teachers with learning opportunities and to develop teacher’s education. Among them, the CLIMate change teachers’ acaDEMY (CLIMADEMY) aims to create a European network to offer a comprehensive program where teachers will interact and learn how to educate the next generation of European citizens on climate change issues. CLIMADEMY. The consortium consists of four EU countries (Finland, Germany, Greece and Italy) and once operationally established, it will be open to new members.,

CLOUD Doctoral Network (CLOUD-DOC)

PI: Markku Kulmala (markku.kulmala@helsinki.fi), University of Helsinki
 Funding: EU
 Active: 1.9.2022-31.8.2026
 Partners: 12 institutions across Europe (10 EU-funded)
 Website: <https://cordis.europa.eu/project/id/101073026>

CLOUD-DOC establishes a network of early-stage researchers (ESRs, all PhD students) at 12 institutions across Europe (10 EU-funded). The role of aerosol nucleation for atmospheric aerosol, clouds and climate is investigated. The focus of investigations will be to study under well-controlled laboratory conditions the oxidation chemistry, aerosol nucleation and growth processes that are responsible for aerosol particle formation in cold regions of the atmosphere (a) Arctic environments, b) the upper troposphere above the Asian monsoon region, c) the upper troposphere above tropical rain forests, and d) the Southern Ocean). The major research activity of the network will be two sets of joint experiments carried out at the CLOUD aerosol chamber at CERN to which all ESRs contribute. At the CLOUD chamber nucleation experiments are performed at an unprecedented level of precision

and completeness using highly innovative instrumentation. A well-structured research and training plan is set up for every ESR as well as a comprehensive, quality-controlled supervision. A high-quality PhD training is arranged. The ESRs are brought together for network training events such as summer schools and workshops for integral data analysis. Courses by world-leading experts are taught spanning from general atmospheric aerosol chemistry and physics to specialized sessions including the role of aerosol for clouds, climate and also health. The summer schools and workshops are specifically tailored to the needs of the trainees. Transferable skills training includes courses on scientific writing, presentation skills, interaction with media, entrepreneurship, IPR, management, gender dimension and diversity in science, and good scientific conduct. There are partners from the private sector closely integrated in the action. <https://cordis.europa.eu/project/id/101073026>

Multilevel Local, Nation- and Regionwide Education and Training in Climate Services, Climate Change Adaptation and Mitigation (ClimEd, 2020-2023, currently on pause)

PI: Hanna K. Lappalainen (hanna.k.lappalainen@helsinki.fi), University of Helsinki;
Svyatoslav Tyuryakov (svyatoslav.tyuryakov@fmi.fi), FMI
Funding: Erasmus+
Active: 2020-2023, currently on pause
Partners:
Website: <http://climed.network/>

Erasmus+ Programme for Capacity Building in the Field of Higher Education Action project. The ClimEd project is aimed at development of competency-based curricula for continuous comprehensive training of specialists in the field of climate services in Ukraine, as well as the initiation and development of additional education in climate change for decision-makers, experts in climate-dependent economic sectors and the general public, which contribute to stabilization of the national economy in the face of climate change and its adaptation to the upcoming climate change. The regional priority is the modernisation of curriculum by developing new and innovative courses and methodologies in the subject areas as defined (Environment).

Climate University for Virtual Exchanges (CLUVEX)

PI: Hanna K. Lappalainen (hanna.k.lappalainen@helsinki.fi), University of Helsinki
Funding: Erasmus+
Active: 2023-2026
Partners: University of Helsinki (Finland), Odessa I.I. Mechnikov National University (1.6.2024-, replaced by Odessa State Environmental University due to merging, Ukraine), Taras Shevchenko National University of Kyiv (Ukraine), Yerevan State University (Armenia), University of Copenhagen (Denmark) and BioArt Society (Finland)
Website: <https://www.atm.helsinki.fi/cluvex/>

CLUVEX main aim is to bridge students from European and Neighbourhood East universities and to engage them with climate competences e.g., ideas of adaptation and mitigation to climate change and the green agenda together with interdisciplinary/ green/ soft skills. CLUVEX main activities are the interactive on-line courses including traditional education materials in a way that students, professors and teaching assistants will work together in small groups. The VE will take place in small groups discussing specific topics of climate change.

Project builds on atmospheric sciences research and existing virtual on-line platform called "Climate University" developed and hosted by the University of Helsinki (coordinator). The Climate University has been already piloted since 2018 in 25 higher education institutions in Finland. VE activities will be integrated into interactive Climate University higher education e-courses involving 2500 higher education participants. Project novelty is that the art & science partner BioArt Society will introduce

artistic perspectives on how contemporary art aims to contribute to the public climate change discourse in the form of VE lectures and creative exercises.

Project will be implemented on a 50% basis so that half of participants come from universities of Denmark and Finland e.g., European universities and the other half from Ukraine and Armenia universities (as Neighbourhood East countries). All the partners bring their technical tools together with pedagogical expertise for designing new VE interaction between students.

Una Europa Virtual Exchanges for Sustainability (UnaVEx)

PI: Hanna K. Lappalainen (hanna.k.lappalainen@helsinki.fi), University of Helsinki
 Funding: Erasmus+
 Active: 2024-2027
 Partners: University of Helsinki (Finland, Coordinator), Alma Mater Studiorum - Universita di Bologna (Italy), Katholieke Universiteit Leuven (Belgium), University of Johannesburg (South Africa), University of Nairobi (Kenya), Universite de Kinshasa (Democratic Republic of the Congo). Associated Partners: Una Europa (Belgium), Universite Paris I Pantheon-Sorbonne (France), Universidad Complutense de Madrid (Spain), University College Dublin (Ireland), Freie Universitaet Berlin (Germany), Universiteit Leiden (Netherlands) and Uniwersytet Jagiellonski (Poland)
 Website: <https://www.atm.helsinki.fi/unavex/>

UnaVEx is a 3-year ERASMUS+ project (2024—2027) funded by European Union where high education institutions from Europe and Sub-Sahara Africa from Una Europa—African partnership, co-design and implement transversal and intercultural virtual exchange, on line workshops, for every student interested in global sustainability education, without physical mobility. UnaVEx is about co-designing and implementing international, interdisciplinary and intercultural online bridge between European and African students for sustainability education.

INTERNATIONAL CONCULTANSY PROJECTS BY FINNNISH METEOROLOGICAL INSTITUTE

UFIM-ICI

PIs/Project Manager(s): Anne Hirsikko, Matti Eerikäinen
 Funding (source): 2.35 MEUR (Ministry for Foreign Affairs of Finland).
 Active: 1 Jan 2022-31 Dec 2025
 Partners/clients: Finnish Meteorological Institute (FMI), Ukrainian Hydrometeorological Center (UHMC)
 Website: N/A

The target is for UHMC to have increased capacity to generate affective and timely weather and climate services and early warnings. This is achieved by improving weather observation capabilities nationally and regionally, improving the automated weather and early warning service production and by improving national and regional weather data and service delivery and enhancing UHMC visibility. The activities for the project are:

- Development of automated meteorological and agrometeorological observation capacity: acquisition and installation of new stations
- Creating a master plan for future modernization of UHMC
- Development of weather forecast and warning services: installing of SmartMet forecast and service production system and SmartMet Alert warning system
- Development of weather forecast data quality: assessing UHMC capabilities to run WRF, benchmarking FMI modelling system and training of future UHMC experts

- Development of customer-oriented weather service production process in national, regional and community levels: development of new products piloted on customers. Installation of free mobile phone SmartMet license and development of weather information web-portal
- Development of UHMC quality management process
- Enhancing the visibility and cooperative contribution of UHMC in Ukraine with neighbouring countries

FINKERAT-ICI

PIs/Project Manager(s):	Anne Hirsikko, Alessandro Chiariello
Funding (source):	2.5 MEUR (Ministry for Foreign Affairs of Finland)
Active:	1 Jan 2022-31 Dec 2025
Partners/clients:	Finnish Meteorological Institute (FMI), Kenya Meteorological Department (KMD), Rwanda Meteorology Agency MeteoRwanda, Tanzania Meteorological Authority (TMA)
Website:	N/A

The project aim is to strengthen the regional scale meteorological capacity in East-Africa by improving the agencies capability to independently use and maintain new meteorological information sources and systems to better deliver weather, climate and early warning services for different stakeholders and end-users. The project will also improve the capacity of partner agencies to engage with national agencies or NGOs to develop weather, climate and early warning services for vulnerable communities in their countries.The activities for the project are:

- Training workshop with WMO on standard international protocol for dissemination of weather warnings
- Co-development of the warning dissemination process to a common platform
- Training workshop on NWP
- NWP workshop with East African Community task force
- Development of NWP operational manual for WRF
- Installation of SmartMet and SmartMetAlert system
- Training to operate and configure SmartMet
- Training of WRF model management and operations including data assimilation and model verification
- Development of weather, climate and early warning products to be disseminated to end-users.
- Training of communities to enhance uptake of services.
- Expert workshops on topics such as remote sensing, air quality monitoring, calibration services
- Assistance in developing national master plans.
- Piloting new technologies

FMI-Uzhydromet Meteorology Project (FUME-ICI)

PIs/Project Manager(s):	Julia Warley
Funding (source):	2.0 MEUR (Ministry for Foreign Affairs of Finland)
Active:	1 Jan 2022-31 Dec 2025
Partners/clients:	Finnish Meteorological Institute (FMI), Uzhydromet
Website:	N/A

The project outcome is to improve Uzhydromet’s capacity to generate effective and timely weather and climate services and early warnings and to increase the quality and outreach of local meteorological services to support the development of the Uzbek society in different socio-economic sectors and regions. Activities have been done in the central office in Tashkent but also at the six regional offices to improve the capacity nation-wide. Local aspects were included also in developing

early warning systems on community level and piloting this in one community. The activities for the project are:

- Development of the national and regional severe weather observation capabilities with a feasibility study and plan of establishing a regional lightning detection network
- Development of one integrated data collection and management system
- Training in modern observation and data management systems as well as a study visit to Finland for benchmarking and to familiarize with FMI solution.
- Improving air quality monitoring and management and piloting new sensor technology.
- Assessing current systems and developing a Master Plan for future modernization of the hydro-meteorological and air quality infrastructure in Uzbekistan.
- Installing of weather forecast and service provision software SmartMet in central site and regional offices.
- Training to operate delivered software.
- Installing SmartMet Alert a system for early warning service provision.
- Development of early warning system in community level with at least one pilot community
- Improve capacity of Uzhydromet regional training centre with new course offering and piloting these
- Development of quality management process
- A high-level seminar on climate change issues

Improving meteorological observation infrastructure and forecasting capabilities of the National Meteorology Agency (NMA) to minimize the impact of frequent weather hazards (Ethiopia-PIF)

PIs/Project Manager(s):	Marilla Visuri, Matti Eerikäinen
Funding (source):	0.74 MEUR (Finnish Public Sector Investment Facility)
Active:	1 Jun 2021-31 Dec 2024
Partners/clients:	Finnish Meteorological Institute (FMI), Ethiopian Meteorological Institute (EMI), Vaisala Ltd
Website:	N/A

The main goal of the project is to increase the meteorological observation density with modern real-time observations. The project aim is to be sustainable and to permanently increase the capacity of EMI. The project is a complete modernization project of the EMI and the project includes in Ethiopia installation of three new weather radars and modernization of one existing radar, installation of a lightning detection network, installation of supplementary Air Quality Network in Addis Ababa and related data integration and management system. FMI provides the SmartMet forecaster workstation and forecast production system, with SmartAlert Early Warning software to improve the forecast services and Early Warning Services in Ethiopia. Moreover the FMI project activities includes installation of SmartMet verify verification software tool for monitoring and developing the forecast data quality. The Project includes also a significant capacity building component including training of the staff of the EMI in forecasting of severe weather and dissemination of early warnings, training in aviation weather forecasting and utilization of weather radar data in forecasting process, communicating of early warnings and weather forecasts to large audiences and numerical weather prediction and model verification.

- Installation and modernization of observation and forecast production systems.
- Training workshops by FMI experts:
 - Early Warning Systems,
 - Lightning Detection,
 - Radar data
 - Weather forecasting

- Aviation weather forecasting
- Numerical weather prediction
- Forecast verification
- Planning, equipping and putting into operation modern meteorological weather forecast and Early Warning Production and Dissemination System
- Project Management

FINTAJ ICI Project – FMI-Tajikhydromet Meteorology Project (FINTAJ III)

PIs/Project Manager(s): Julia Warley
 Funding (source): 1.0 MEUR (Ministry for Foreign Affairs of Finland)
 Active: 1 Mar 2022-30 Jun 2026
 Partners/clients: Finnish Meteorological Institute (FMI), Tajikhydromet
 Website: N/A

The project target is improved capacity of Tajikhydromet to deliver air quality, weather and early warning services and conduct glacier monitoring. The outcome can be divided to three thematic sections that are:

1. Development of weather forecast and early warning services including community level considerations and development of customer-oriented weather forecast production process
2. Strengthening glacier and climate change studies and awareness
3. Enhancing air quality monitoring and forecasting

The activities for the project are:

- Installation of a local Numerical Weather Prediction model
- Installation and modernization of observation and forecast production system including automatic warning features.
- Implementation of a mobile application for weather and early warning dissemination
- Comprehensive training package on system utilization and development for the IT staff and forecasters
- Development of early warning system in community level with at least one pilot community
- Continuation of glacier survey expeditions
- Joint research to study atmosphere-glacier interactions
- Expert support on Climate Change issues
- Enhancing the air quality monitoring system
- Implementing of air quality modelling and forecasting system in Tajikistan
- Quantifying the contribution of different emission sources to the pollution levels in Dushanbe (source apportionment study)
- Expert support for air quality management and awareness rising.

FINKMET ICI Project- Finnish-Kyrgyzstan Meteorology Project Extension Phase (FINKMET III)

PIs/Project Manager(s): Julia Warley
 Funding (source): 1.0 MEUR (Ministry for Foreign Affairs of Finland)
 Active: 1 Mar 2022-30 Jun 2026
 Partners/clients: Finnish Meteorological Institute (FMI), Kyrgyzhydromet
 Website: N/A

FINKMET III Project builds on the foundation laid in previous projects “Finnish-Kyrgyz Meteorology Project (FINKMET)” I and II. Many of the activities continue the work from these projects and expands the capabilities with new tools and expertise. Key results are:

1. Improved weather forecast and early warning services for Kyrgys Society.
 - a) Development of national weather modelling and post-processing capabilities.
 - b) Development of weather forecast and warning services of Kyrgyzhydromet.
 - c) Development of customer oriented weather forecast production process.
 - d) Development of early warning system in community level.
2. Improved capacity to perform glacier and snow monitoring and research.
 - a) Continuation of glacier survey expeditions.
 - b) Joint research to study atmosphere-glacier interactions.
 - c) A high-level seminar on climate change issues.
3. Enhancement of air quality monitoring and modelling capacity and support for air quality management.
 - a) Enhancing the air quality monitoring system.
 - b) Implementation of air quality modelling and forecasting system in Kyrgyzstan.
 - c) Quantifying the contribution of different emission sources to the pollution levels in Bishkek (source apportionment study).
 - d) Expert support for air quality management and awareness rising.

Enhancing BMKG Capacity on Climate, Weather and Air Quality Forecast and Weather Warnings to Better Serve the Indonesian Society (Indonesia ICI- INDFIN)

PIs/Project Manager(s): Edith Rodriguez, Harri Pietarila
 Funding (source): 0.5 MEUR (Ministry for Foreign Affairs of Finland)
 Active: 1 Jan 2022-31 Dec 2025
 Partners/clients: Finnish Meteorological Institute (FMI), BMKG Indonesia
 Website: N/A

BMKG: Meteorology, Climatology, and Geophysical Agency (Indonesian: Badan Meteorologi, Klimatologi, dan Geofisika).

The outcome of the INDFIN project is improving BMKG capacity to deliver weather and air quality prediction and warnings, including the aviation weather needs. Improving the weather forecast and implementing an air quality model will enrich BMKG's capacity and the Indonesian government to address better the current climate, environment, health and national security challenges. The project aims to increase the quality and outreach of services of BMKG to support the development of Indonesian society in different socio-economic sectors.

The project has three different components:

- Enhance BMKG capacity for weather forecasting and early warnings by development of local Numerical Weather Prediction (NWP)
- Develop an operational Air Quality forecast for Indonesia by implementing the System for Integrated modelling of Atmospheric composition (SILAM) in BMKG.
- Improvement of the Aviation operation and safety by improving BMKG capacity in observation instrumentation maintenance (especially radars) and development of data management, data processing and data analysis process chain.

The activities to achieve the outcome are:

1. Enhance BMKG capacity for weather forecasting and early warnings.
 - a) Development of local Numerical Weather Prediction (NWP) focusing on setting parametrisation, data assimilation and the possibility of an alternative global model
 - b) Improvement of NWP verification methods
 - c) NWP performance validation using global model input.
 - d) Exploring new weather and early warning service provision to stakeholders, customers and general public.
 - e) Support in generating revenue from weather services provision.

2. Development of an operational Air Quality forecast for Indonesia
 - a) Implementation of System for Integrated modelling of Atmospheric composition (SILAM) in BMKG
 - b) Tune SILAM for Indonesia needs using the available AQ data and the NWP model as input for SILAM
 - c) Implement specific SILAM routines for forest fire events.
3. Improvement of the Aviation operation and safety
 - a) Improve capacity building on the instrumentation maintenance plan, special focus on radars.
 - b) Support BMKG experts in data storage and data processing Quality Assurance (QA) and Quality Control (QC) of the data.
 - c) Boost BMKG capacity building on data analysis, special focus on radars.
 - d) Support the development of a roadmap for aviation operation and safety.

Ukraine-Finland institutional cooperation in Air Quality monitoring (UFAIR ICI)

PIs/Project Manager(s): Jenni Latikka, Harri Pietarila
 Funding (source): 2.0 MEUR (Ministry for Foreign Affairs of Finland)
 Active: 1 Nov 2023-31 Jul 2028
 Partners/clients: Finnish Meteorological Institute (FMI), Ministry of Environmental Protection and Natural Resources (MEPNR), Ukrainian Hydrometeorological Center (UHMC)
 Website: N/A

Project description not available.

Moldova EU-Twinning

PIs/Project Manager(s): Katja Loven, Harri Pietarila, Maija Peltola
 Funding (source): 2.0 MEUR (EU)
 Active: 1 Aug 2023-31 Aug 2026
 Partners/clients: Finnish Meteorological Institute (FMI), Moldova (organisation TBC)
 Website: N/A

Project description not available.

Information and Communication Technologies (ICT) system for the LEPL National Environmental Agency

PIs/Project Manager(s): Ljubov Liman, Matti Eerikäinen
 Funding (source): 0.58 MEUR (N/A)
 Active: 1 Mar 2024-31 Aug 2026
 Partners/clients: Finnish Meteorological Institute (FMI), NEA (Georgia)
 Website: N/A

Project description not available.

Arena for the gap analysis of the existing Arctic Science Co-Operations (AASCO-2)

PI: hanna.k.lappalainen@helsinki.fi
 Funding: Prince Albert II of Monaco Foundation
 Partners: The Sustained Arctic Observing Networks Initiating Group, The Silk Road Economic Belt and the 21st Century Maritime Silk Road, SIOS, The Fletcher School, The University of the Arctic, The Global Atmosphere Watch (GAW) Programme
 Active: 2023-2025
 Website: <https://www.atm.helsinki.fi/peex/index.php/aasco/>

The “Arena for the gap analysis of the existing Arctic Science Co-Operations” (AASCO) project, 2023-2025, is a continuation and extension for the AASCO project funded by the Prince Albert Foundation in 2020-2022 (N°2858). The AASCO process is focused on the understanding the land-ocean-atmosphere feedback and interactions taking place in Arctic-boreal context and region under changing climate. In the previous project we focused on the understanding the land-ocean-atmosphere feedback and interactions taking place in Arctic-boreal context, a region under changing climate. We analysed the Arctic-boreal research gaps, the problems that have not been answered by any of the existing studies or research in this field.

AASCO-2 project in 2023-2025 aims to meet following issues and challenges:

- to further connect and consolidate the existing research communities interested in the feedback analysis: the current academic communities in the field of Arctic ocean, ecosystem and atmospheric research are still working quite separately. In order to find solutions to climate change we need to have also a cross disciplinary, integrative and holistic vision, implementation
- to communicate with different stakeholders, e.g. European Commission, on research funding in this field: we need to bring up the relevance of the holistic approach to the research funders more actively.
- to ensure the open data availability in the Arctic under changing geopolitical situation and bring together different actors providing data for the feedback analysis: data gap due to suspended collaboration with Russia and to find a way forward with data availability in the Arctic region is one of the most urgent questions

Specialisation programme in climate expertise (IlmastoERKO)

PI: Taina.Ruuskanen@helsinki.fi
Funding: Technology Industries of Finland Centennial Foundation, University of Helsinki
Partners:
Active: 2024-
Website: <https://www.helsinki.fi/fi/matemaattis-luonnontieteellinen-tiedekunta/opetus-ja-opiskelu/jatkuva-oppiminen-ja-verkko-opinnot/ilmastoasiantuntijan-erikoistumiskoulutus>

IlmastoERKO was established to respond to the societal need for climate education (Siponen et al., 2024) and its goal is to raise the level of climate knowledge throughout Finland over time. The two-year, 60-credit training is completed alongside work and addresses climate change as both a natural science and a social phenomenon. It is the first specialization training at the Faculty of Mathematics and Natural Sciences of the University of Helsinki, the pilot of which began in March 2024.

APPENDIX III LIST OF ACCC COLLABORATORS (LoC)

List of collaborators with signed ACCC – letter of Commitment (LoC), status October 2025

ACTRIS – Aerosol, Clouds and Trace Gases Research Infrastructure
 Actuarial Society of Finland
 Airmodus Ltd.
 Baltic Sea Action Group (BSAG)
 City of Helsinki
 City of Kuopio
 City of Vantaa
 Claned Ltd.
 Climate Leadership Coalition (CLC)
 Consulate General of Finland, New York
 Dekati Ltd.
 Deloitte Ltd.
 Digital Belt and Road – AirCAS, China
 Eastern Lapland Federation of Municipalities
 eLTER – Integrated European Long-Term Ecosystem, critical zone and socio-ecological Research
 Estonian University of Life Sciences
 European Science Diplomacy (EU SciDip) Alliance
 Finnair
 Finnish Environmental Institute (SYKE)
 Football Association of Finland
 Future Earth
 Helsinki Institute of Sustainability Science (HELSUS)
 HINKU – Carbon Neutral Municipalities
 ICOS-ERIC Integrated Carbon Observation System
 IIASA – International Institute for Applied Systems Analysis
 Karsa Ltd.
 KPMG – global network of firms for audit services
 Kuopion Energia
 MetsäGroup
 Ministry of Transport and Communication
 Moscow State University, Russia (suspended)
 Nanjing University, China
 Natural Resources Institute Finland (Luke)
 Neste
 Operaatio Arktis
 Partioaitta Ltd.
 Pegasor Ltd.
 Russian Academy of Sciences, Russia (suspended)
 S-Group
 Solita
 ST1
 The Finnish Innovation Fund Sitra
 The Guides and Scouts of Finland (Suomen Partio)
 Think Africa
 Traficom
 University of Tartu
 UPM



Useless
Vaisala
Valio
World Meteorological Organization (WMO)
Wärtsilä