CLEAN AIR, SAFE CLIMATE

# ATMOSPHERE AND CLIMATE COMPETENCE CENTER (ACCC)

RESEARCH AND INNOVATION
ECOSYSTEM
&
ACCC ROADMAP TOWARDS CLIMATE NEUTRALITY AND BEYOND
in Finland, in Europe, in internationally by 2035 / 2045

"From deep understanding to implementation of practical, sustainable solutions"

ACCC research and innovation approach represents a very 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 the 1st version (15th June.2023) 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]

1

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.

Chapters: Motivation by Kulmala, M. Lohila, A., 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 alphapetical order: Asmi, E. [2] (2.5.9), Berninger F. (chapter 2.5.3), Dal Maso M. [3] (2.2.3), Ehn, *M.* [1] *(2.3.1)*, Ezhova, E. [1] (2.3.1), Gregow H. [2] (2.2.4), Hockerstedt 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), Kangasniemi O. [3] (2.4.2), Khun 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), Lehtipalo K. [1] (2.2.4), Lintunen A. [1] (2.2.2), Mahura A. [1] (2.3.4), 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), Taipale U. [1] (2.4.3), Vakkari V. (2.5.9), Virkki S. (2.3.3), **Part III** to-be-implemented in 2023-2025.
Appendix Project portfolio: Häme, S., Lintunen, A., Lappalainen H.K (INAR), Siili T., Khun T. (FMI), Kangasniemi O. (TAU), Martikainen S., Honkonen T. (UEF)
References Alla Borisova (UH).
Managing Editor Hanna K.Lappalainen (INAR)
Editor(s) Silja Häme (INAR), Anneli Pauli (INAR), Tero Siili (FMI)
Infographs Stephany Mazon (UH), Mikko Kulmala (UH)
Photos: Juho Aalto, Pia Anttila, Lee Mauldin, Agnes Meyer-Brandis

Other materials: ACCC Flagship Reseearch and Impact Plan for 2020-2024, ACCC Mid Term report 2020-2023, ACCC Flagship proposal for 2025-2028 (submitted to Academy of Finland in June 2023).

2

_____
ACCC Research & Innovation (R&I) Ecosystem and Roadmap – a living document

Contents

3

ACCC Research & Innovation (R&I) Ecosystem and Roadmap – a living document

ACCC Research & Innovation (R&I) Ecosystem and Roadmap – a living document

ON ACCC RESEARCH AND INNOVATION ECOSYSTEM AND ROADMAP

The Atmosphere and Climate Competence Center (ACCC) is a Finnish flagship funded by Academy of Finland, at the moment for the years 2020-2024 and foreseen funding for 2025-2028. 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 will first present our multiscale research and innovation roadmap.

Furthermore we develop and present our own ACCC roadmap because:

- An integrated, holistic, realistic science based roadmap is missing, due to the lack of interdisciplinary approach
- There is clear need for more research and innovation to become globally carbon neutral and furthermore climate neutral and beyond.
- There is 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 true 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."*

SUMMARY
text-to-be-added as the 1st version of the PART II RoadmapI is ready (3 pages)

SUMMARY FOR POLICYMAKERS
text-to-be-added as the 1st version of the PART III Roadmap is ready (1 page)

FOREWORD

The Atmospheric and Climate Competence Center (ACCC) is a four-year project funded by the Academy of Finland for years 2021-2024, and a foreseen continuation for 2025-2028. It is based on 18 years as a Finnish Center of Excellence in atmospheric sciences. The partners of ACCC are Institute for Atmospheric and Earth System Reseach 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

6

and private sectors. We aim at novel research & 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 ecosystem and roadmap. 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. We will to form a living document utilising joint visions, knowledge, and efforts to establish a document in the form of an interactive e-platform. This platform can include roadmaps from our collaborators, too.

The ROADMAP to "Climate/Carbon neutral Finland and beyond" utilizes the wide spectrum of the ACCC activities such as research and innovation projects, programmes, services, applications, methods, new instruments, testbeds and pilots, knowledge exchange and science for dialogues with citizens and society at large. It also offers a toolbox to enhance the co-designing, exploration and upscaling of the current ACCC activities with stakeholders.

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 and decades. 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 (Figure 1).
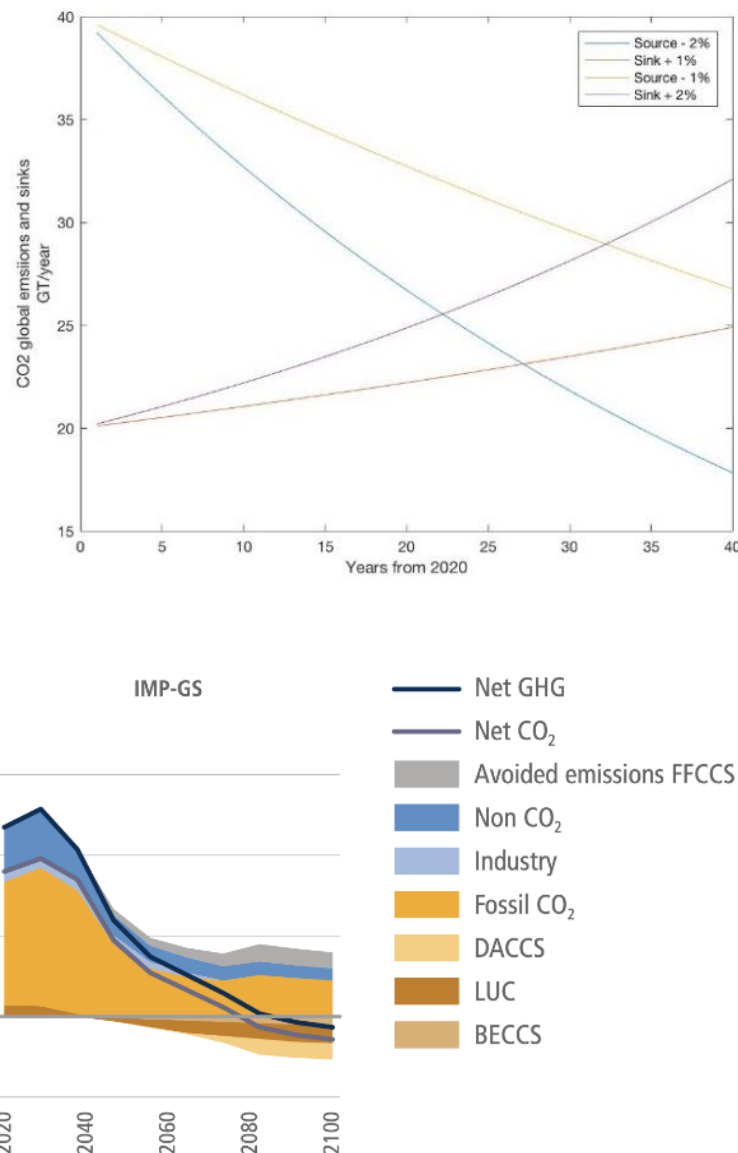
Figure 1: How many years is needed to balance global sinks and emissions? The current situation (here 2020 in x-axis, but actually it is the year when we start to reduce emissions and enhance sinks). In the case of reducing sources 2% per year and enhancing sinks 2% per year it takes 23 years to reach balance between emissions and all sinks. Note that the sinks depicted here include both natural and anthropogenic sinks, and thus the balance would not equate carbon neutrality, which is the balance between anthropogenic emissions and anthropogenic sinks." (above); The IPCC figure for the residual fossil fuel and industry emissions, carbon dioxide removal (CDR) {LUC, DACCS, BECCS}, and non-CO2

8

emissions (using AR6 GWP-100) for hold warming below 2°C with a least 67% probability (|https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_FullReport.pdf) (below).

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 of 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 being 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 ways to sequester CO_2 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 , 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 will carry 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.

Aims

The ACCC aims for the flagship term 2020-2024 /2025-2028 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

- model the behavior of these sinks and storages in the warming world and identify means to increase the biological carbon sinks and storages
- 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

- In order 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.
- 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 THE 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.
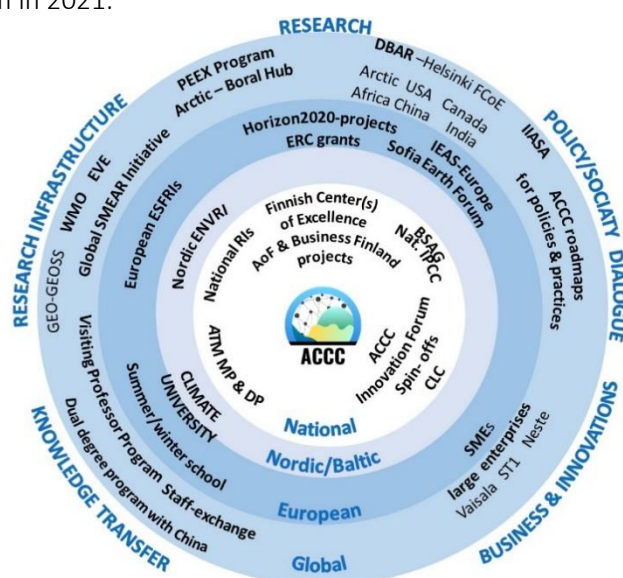
Figure 2. The main assets and collaborator frameworks of the ACCC R&I ecosystem scheme. Abbreviations in alphabetical order: **ATM MP & DP** = Master and Doctoral Programs in Atmospheric Sciences, **Arctic-Boreal Hub** = U-Arctic Thematic network, **BSAG** = Baltic Sea Action Group, **CLC** = Climate 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)

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

- business & innovation (chapter 2.5)
- international partnerships (chapter 2.6)
- society dialog (chapter 2.7)

11

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 thirteen IP tasks (Figure 3). The ACCC research programs are aimed at the quantification of the potential of the land-based climate change mitigation (RP1), understanding of the climate – air quality interactions (RP2) and on 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). "Safer Climate Initiative" (IP14). The preliminary work on IP14 and IP16 has already started in 2022. Safer Climate Initiative (IP14) has established a collaboration netwrok in Finland and organized its' first events, for example eco-limate workshop by (https://www.saferclimate.org/contact-us). For connecting stakeholders to the ACCC Roadmap (IP16) process we have, for example, organized the ACCC Innovation Forum: Kohti hiilineutraaliutta (Towards carbon neutrality) at the ThinkCorner in June 2022. (https://www.acccflagship.fi/index.php/event/save-the-date-accc-innovation-forum-towards-carbon-neutrality/).

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 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 InnovationProgrammes. 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 Academy 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 activites like projects funded by several foundations and ministires like Ministry of Education and Culture, Finland.

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,

12

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 (Chapter 2.5), boosts the use of research findings in an innovation ecosystem and enhances birth of new practical solutions and intenal 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 50 organizations (status in June 2034; see APPENDIX III LIST OF ACCC COLLABORATORS (LoC))
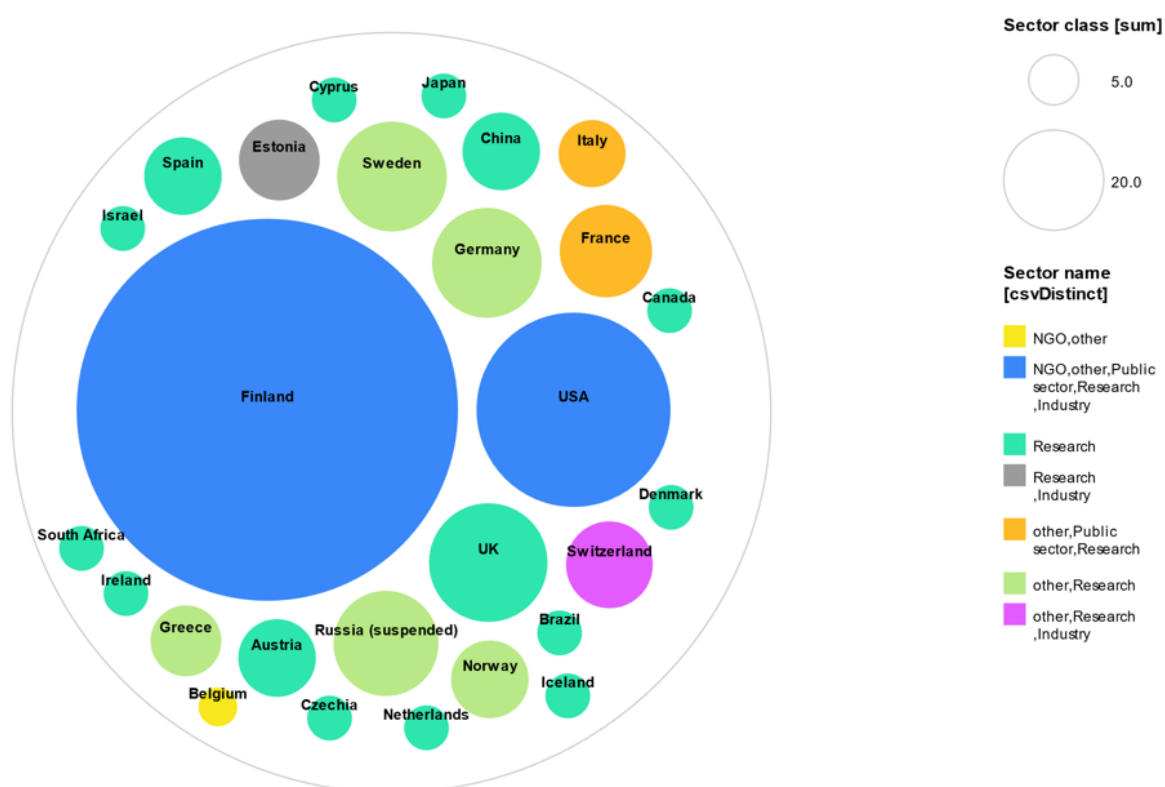
Figure 4. The ACCC stakeholders by country and sector. ACCC stakeholders by country and sectors. Circles = each circle represents a country, and the size of the circle is proportional to the number of stakeholders from that country. Color = color indicates which combination of sectors are present in that in cirlce (country). Sectors include NGOs (9), Public sector (87), Industry (160), Research (312), and other (54). 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, Sephany Mazon).

2.2 RESEARCH

2.2.1 Research overview

ACCC research programs develop methods, which can for instance be used to improve the reliability of the evaluation of the implementation of the nationally determined contributions (NDC) by verifying the estimates of the greenhouse gas emissions and sinks. In other words our measurement and modelling system can be used verifying climate impacts of different actions. 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 polices. The profound process understanding of GHGs atmospheric composition and ecosystem processes paves the way for extending the efficient land use sector mitigation activities outside the Arctic-Boreal ecosystems.

The quantification of the carbon sink & sources in the boreal forests and impact analysis of the mitigation activites is the core of ACCC activites (Photo Juho Aalto)

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 futher 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 of 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, terrestrial ecosystems have other climate effects, such as albedo, aerosol-cloud-climate (Kalliokoski et al., 2020; Kulmala et al., 2020) and water cycle effects, that feeds back to ecosystem functioning and growth. 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 (Kulmala et al., 2014; Petäjä et al., 2022). 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

Finnish Meteorological Institute at ACCC leads the work on quantifying and activating the potential of land-based climate change mitigation.

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

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.

The ACCC peatland studies carried out at the SMEAR II station in Hyytiälä contributes to the verification of land based GHG sinks & sources *(Photo*

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

- *Multi-benefit solutions to climate-smart agriculture (MULTA)*
- *Towards parcel-specific greenhouse gas calculation: new emission factors and model solutions and updatable system (LOHKO-KHK)*
- *Precise biomass information for agricultural carbon budget calculations by combining satellite and field data with ecosystem modelling (BIOHILA)*
- *From Footprints to Digital Handprints - Carbon and greenhouse gas budget of agriculture (FF2DH)*
- *Carbon and greenhouse gas balance of croplands (CROPLANT)*
- *How biodiversity impacts the ability of fields to store carbon (TWINWIN)*
- *International soil co-operation for improved visibility and impact (FIN SOIL ACTION)*
- *Solutions for reliably quantifying carbon sequestration in soil (FluCS Tool)*

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

- *Quantifying the potential of boreal peatland rewetting for climate change mitigation (SA-RESPIT)*
- *Forests on peatlands – solutions for reducing emissions and increasing of carbon sinks (MMM-TURNEE)*
- *Peatland restoration for greenhouse gas emission reduction and carbon sequestration in the Baltic Sea region (EU-LIFE Peat Carbon)*
- *Cascading carbon flow in managed forested catchments (CASCAS)*
- *The role of snowpack and soil freezing in controlling winter season wetland methane emissions (SA-WINMET)*
- *Towards high resolution atmospheric data-based greenhouse gas budgets by utilizing advances in supercomputing (GHGSUPER)*
- *Methane and soil - tree networks: Adding dimensions to greenhouse-gas studies (METNET)*
- *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)*
- *Biogeochemical and biophysical feedbacks from forest harvesting to climate change (BiBiFe)*
- *Verifying Emissions of Climate Forcers (EU-EYE-CLIMA)*
- *Mechanistic remote sensing of forest climate impacts (MONOCLE)*
- *From processes to modelling of methane emissions from trees (MEMETREE)*
- *Reducing the effects of forest management to inland waters (REFORMWATER)*
- *Kuntien mahdollisuudet käyttää maankäyttösektorin nettohiilinieluihin perustuvaa kompensointia (KUNTANIELU)*
- *Belowground Methane Turnover at a Boreal Peatland: Quantifying the Processes with in-situ Stable Isotope Methods (MIso)*
- *Drying trend in boreal peatlands - impacts and mechanisms (BorPeat)*
- *The formation and dynamics of deep soil organic matter storages (DEEP-SOM)*

16

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

Mitigation
- *Evaluating integrated spatially explicit carbon-neutrality for boreal landscapes and regions (*C-NEUT*)*
- *Managing Forests for Climate Change Mitigation (*ForClimate*)*
- *Arctic Community Resilience to Boreal Environmental change: Assessing Risks from fire and disease (*ACRoBEAR*)*
- *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
- *Sensing plant Biogenic Volatile Organic Compounds (SensBVOCs)*
- *Resolved optical ecophysiology: leaf level (REDEYE)*
- *Shrub climate sensitivity across boreal, subarctic and tundra ecosystems*
- *Phloem Ecophysiology: from Mechanistic understanding to Ecological Consequences (PhloEM EcologiC)*
- *The Hidden Role of Gases in Trees (HidRoGaT)*
- *A whole tree level approach to study source and sink limitation of tree metabolism*
- *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; Persson et al., 2022). It is commonly accepted that urgent action to avoid further deterioration of the atmosphe 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 the

contributions of 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 on the atmospheric particle concentrations and size distributions in different environments and under different meteorological conditions. We investigate the influence of primary and secondary aerosols on climate by improving the description of atmospheric aerosol formation and processes in different scale models and by improving and implementing anthropogenic emission scenarios, considering both technological advancements and systemic level changes, to these models. 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 who are involved in impact assessments: International Institute for Applied System Analysis (IIASA), Finnish Envrinmental 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 ast the Ministry of the Environment
- Universities in within and outside Europe: Beijing University of Chemical Technology (BUCT), Tsinghua University, Indian Institute of Technology (IIT) Delhi, 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*

18

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

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*)

Biogenic Volatile Organic Compounds (BVOCs) 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*)

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 NOx 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*)

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 andbehaviour. Therefore, continued effort is needed to increase the dialogue between the science community, 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 (AIforLessAuto)*
- *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)*

20

- "Locally tailored climate service for Finland" (*TAPSI*)
- *CArbon NEutral MUnicipalities 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 (SLUPSU/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)*

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)*

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)*

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

21

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 "Centre of Excellence of Inverse Modelling and Imaging" (INVERSE FINLAND, https://wiki.helsinki.fi/display/VILMA/)) (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. 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.

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 Academy 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 sets of open high-quality long-term continuous atmosphere-ecosystem data and services supporting and enhancing research and innovation activities. The INAR RI consists of "Station for Measuring Ecosystem–Atmosphere Relations" (SMEAR) 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 and the ACTRIS ERIC. Both ICOS ERIC and ACTRIS ERIC head offices are located in Helsinki (University of Helsinki 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) and establishing comprehensive and sustainable framework for access to distributed atmospheric RIs (ATMO-ACCESS). 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 a 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/)). 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 (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/). 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

Stations Measuring Esosystem – Armosphere Relations (SMEAR) station Finland network : SMEAR 1 sub-arctic in Värriö, SMEAR II – boreal forest (flagship) station in Hyytiälä, SMEAR III – Urban in Helsinki, SMEAR IV in Puijo. In addition, SMEAR -Costal Marine and SMEAR-Agriculture are in a pilot phase.

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) (https://www.atm.helsinki.fi/SMEAR/) and Pallas-Sodankylä GAW (Global Atmosphere Watch) (https://en.ilmatieteenlaitos.fi/pallas-atmosphere-ecosystem-supersite), 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 (https://www.helsinki.fi/en/inar/infrastructure/global-smear) station network.

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 II flagship station delivers data 24/7 on 1200 parameters on atmospheric compositiona and ecosystem processes over forest, peatland, lake in Hyytiälä. (Photo Juho Aalto)

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 Atmopsheric 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 Cypros 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 Sammaltunturi 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/).

Pallas Atmosphere-Ecosystem Supersite, located 170 km north of the Arctic Circle, is operated by Finnish Meteorlogical Institue (Photo Pia Anttila)

New opening: 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.

25
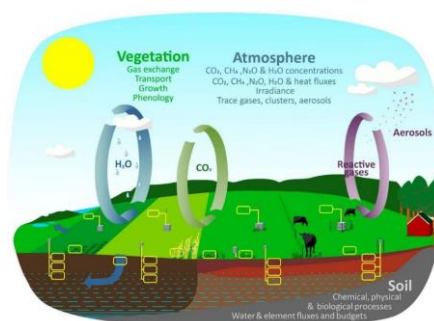
Construction of SMEAR-Agri Haltiala is ongoing and it will become a permanent, long-term site.. Big questions to be solved are for example: When and in what conditions is the field a sink or a source of carbon; What agricultural practices reinforce the sink and minimize GHG emissions ? ; How important is the aerosol cooling effect; Effects of seasonality year to year variability , extreme weather events on GHG fluxes

New opening: SMEAR Coastal Tvärminne, Baltic Bridge

The Tvärminne Zoological Station (TZS), located at the entrance of the Gulf of Finland, is one of the university's 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.

A strategic partnership in marine research between University of Helsinki (Tvärminne) and Stockholm university (Baltic Sea center), started in March 2014.

The RI at TZS include a flux tower for measuring GHG exchange, to directly verify the link between the state of the marine ecology and the uptake and release of CO_2 and CH_4. 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 marine and coastal regions of the Baltic Sea.

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

26

(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.

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 (ENVRI, 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.

SMEAR II station in Hyytiälä provides ICOS accreditated data. (Photo Juho Aalto)

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 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 stablished in 2023. The ACTRIS core components are the Central Facilities (CFs) and the National Facilities (NFs).

28

ACTRIS is currently implementing its procedures and policies and setting up the facilities. Full operation of this RI is expected from 2025 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 that will start when ACTRIS ERIC is established.

Projects

- Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS-Finland), https://akareport.aka.fi/ibi_apps/WFServlet?IBIF_ex=x_HakKuvaus2&CLICKED_ON=&HAKNRO1=328616&UILANG=en&YMISTA=AKA&TULOSTE=HTML
- ACTRIS Central Facilities https://akareport.aka.fi/ibi_apps/WFServlet?IBIF_ex=x_hakkuvaus2&CLICKED_ON=&HAKNRO1=329274&UILANG=en&TULOSTE=HTML, continues until the end of 2024
- 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

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 will be 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 eLTSER 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 eLTSER 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 coutries: 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.

31

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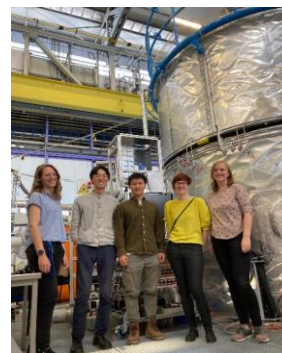
INAR researchers by the CLOUD chamber at CERN (Photo Lee Mauldin).

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 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 Finish 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).
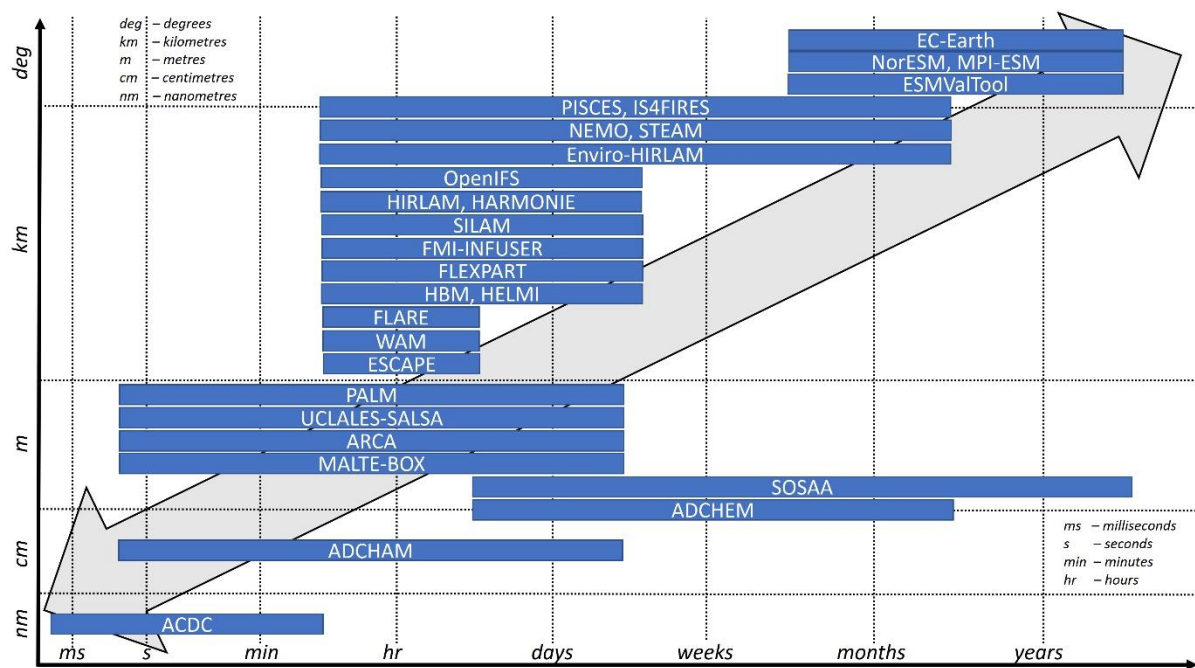
Figure 5: The ACCC's Modelling Research Infrastructure – applicability of the models as research tools on different spatial (from centimetres to degrees) and temporal (from seconds to years) resolutions/ scales.

Projects

- 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
- Finnish Climate Change Panel: Ilmastopaneeli POLKU II https://www.ilmastopaneeli.fi/en/?s=Ilmastopaneeli+POLKU+II+https://www.ilmastopaneeli.fi/en/?s=Ilmastopaneeli+POLKU+II+
- 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

34

- HERCULES - https://sites.utu.fi/hercules - HEalth, Risk and Climate change: Understanding Links between Exposure, hazards and vulnerability across spatial and temporal Scales

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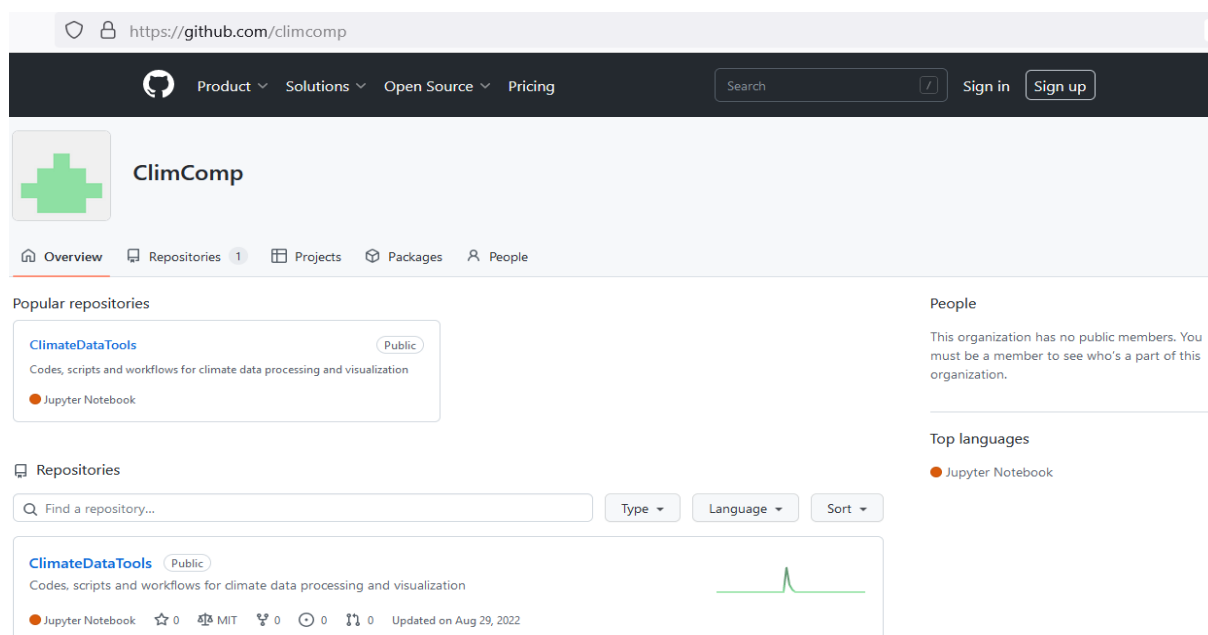
ClimComb dataportal servers as a base for the further development of the ACCC data portal.

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 masters 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 utilizes 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 (https://www.facebook.com/climatewhirl/), Carbon Tree platform (https://www.hiilipuu.fi/), Ilmasto opas (https://openilmasto-opas.fi/) and Kysyilmastosta service (https://www.kysyilmastosta.fi/).

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
> **Doctoral Programme in Atmospheric Sciences**

36

- 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/teknis-luonnontieteellinen-di-ohjelma
- **Tekniikan ja luonnontieteiden tohtoriohjelma** https://www.tuni.fi/en/study-with-us/doctoral-programme-engineering-and-natural-sciences

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 together 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

Climate University open on-line courses (INAR, ACCC Impact Task 13)

Climate University is a network of 27 Hihger 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 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). For contact laura.riuttanen(at)helsinki.fi

Pirkanmaa Climate Action Lab (INAR, ACCC Impact Task13)

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(at)helsinki.fi

Network for sustainability education by the University of Easten Finland

Network for sustainability education (https://www.kestavyysopinnot.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).

38

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. The joint institute will grant 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. The joint institute will be managed by joint committees with representatives from both universities.

The planned annual student enrollment in the bachelor's programme is 60 students in the first year, 80 in the second and 100 students per year in the following years, in the master's programme is 50 students in the first year and 80 students per year in the following years and in the doctoral programme is 10 students in the first year, 15 in the second and 25 students per year in the following years.

The curriculums of the joint programmes are planned togetherby the two universities. University of Helsinki is responsible of 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 will start 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 will allow us to continue and deepen our collaboration with Nanjing University. Via this collaboration wewill 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(at)helsinki.fi

Education projects, for details see APPENDIX Project portfolio

- CLOUD Doctoral Network (CLOUD-DOC) https://cordis.europa.eu/project/id/101073026
- ClimComp : https://blogs.helsinki.fi/climatecompetencies/about/
- Modernization of doctoral education in science and improvement of teaching, methodologies (MODEST) : https://www.emodest.eu/
- Climate change teachers' academy (CLIMADEMY) https://en.uoc.gr/announce/climademy.html
- Multilevel Local, Nation- and Regionwide Education and Training in Climate Services, Climate Change Adaptation and Mitigation (ClimEd, 2020-2023, currently on pause) http://climed.network/

2.4.3 Outreach and dissemination

Climate Whirl Arts Program

Since 2011, a dialogue between scientists and artists has been encouraged in the framework of Climate Whirl Arts Program. The Art&Science activities started after the Finnish, internationally recognised visual artist Terike Haapoja visited at the SMEAR II station in Hyytiälä. The series of artworks by the artist, inspired by the research made at the SMEAR II station, has been presented all over the world, to very different audiences, e.g., at the Venice Biennale and in several continents.

Through the art program, the dialogue between art, natural sciences and nature are made visible, and visitors to the station are involved through workshops and other activities. All in all, within the framework of the art program, science and art are combined in an interesting and unique way in the middle of a Finnish forest. In June 2023, a permanent art exhibition will open at the station. Eight artists or groups were invited to take part, and based on their proposals, the curated exhibition will take place in the surroundings of the station and in the new main building, Koto. In future, the art program will implement a program around the exhibition, dynamizing it and opening up the research made by INAR through activities that combine art and science. 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 and Finnish Arts Promoting Center. 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 Vöhyke ry (FI). (www.ilmastopyorre.fi/en @climatewhirl). For contact: ulla.taipale@helsinki.fi

FTealemetree Station (2015), designed by German artist Agnes Meyer-Brandis, is a public sculpture in the SMEAR II measurement forest. This economic forest is special because of the techno-scientific installations and a 128-meter measurement and observation tower that rises above the tops of some 60-year-old pine trees. The table enables inspiring tea and conversation sessions in the middle of the researched object, forest, itself, in the middle of the forest, in a multidisciplinary and artistic spirit. (Photo Agnes Meyer-Brandis)

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 CO_2 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

Visual layout at https://www.hiilipuu.fi/index.php/en/home/ shows in real-time the how actively Scots pine is fixing carbon at the SMEAR II station.

40

sustainable use of forests and peatlands. INAR maintains the Carbon Tree project. For contact: taina.ruuskanen(at)Helsinki.fi

Kysyilmastosta.fi

INAR Education-Team together with INAR Earth System Modelling (ESM) group have developed and implemented a social media -based approach for science outreach. Kysyilmastosta.fi service enables direct communication between citizens and researchers on climate related questions (Santala, 2019). Citizens can ask questions, and researchers answer them directly in online platform. The questions will be used for future education and research purposes: they will be analyzed for the development of climate education (Santala, 2019), and new research projects can be launched based on them (Lauri et al. 2019).
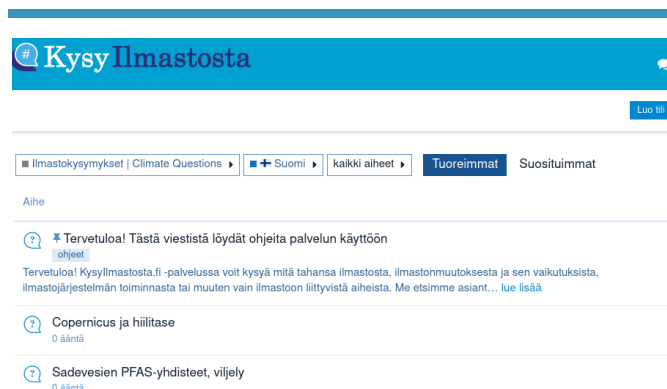
KysyIlmastosta public web service was launched in 2019.

Answers and discussion on the platform would emphasize (and link to) open-access resources of climate research documentation and data, as well as existing high-quality materials (visualizations, graphics, interactive tools). The platform necessitates activation of experts from various disciplines, including physics, chemistry, meteorology, biology as well as economics and social sciences.
The Kysyilmastosta.fi platform will include automatic clustering of topics based on question content, and this clustering is used for the interface in the front-end to ease the user in finding certain topics. Furthermore, user interactivity is increased via e.g. a voting system: users can (up)vote questions which they see most interesting. The voting system is used in assessing which questions would lead to pilot projects in climate modeling. The platform is connected to social media channels, which allows also to organize online-interviews, where a group of experts answers citizen questions in near-realtime. Twitter is used to promote and advertise the project, in order to find as wide an audience as possible to present their questions. For more information contact risto.makkonen(at)fmi.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.

ACCV 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

*Finnish Meteorlogical Institute, RP1, IP1

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 the 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 (https://carbonaction.org/fi/blogi-hiilensidonnan-todentamisjarjestelma-ja-maailman-ensimmainen-nurmipellon-hiilensidontaennuste/, Fer et al., 2021 https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.15409) represents the state-of-the-art in its field, and the basic idea is to calculate the carbon and GHG estimates for ordinary agricultural fields and farms using the model-data integration system. We use the collected data and gain knowledge to improve our models and illustrate and disseminate our verification methodology in the Field Observatory service (www.fieldobservatory.org). We collaborate with farmers and various food and technology companies. We are piloting our verification methodology in the companies' test cases (collaboration e.g., with Lantmännen and Valio) and improving the national GHG inventory system to enable more detailed field-specific estimations. Carbon Action (www.carbonaction.org), our common platform with the Baltic Sea Action Group BSAG (https://www.bsag.fi/en/home/) , is central in our work bringing together science, farmers, companies, and the public sector for hands-on collaboration (Figure 6.). Corporate participation is needed to scale carbon sequestration in farmland and for achieving Carbon Action's ambitious goals. Business is needed to implement the change in the food supply chain and communicate to consumers. Thereby we can promote more sustainable food production through cooperation.

A key principle is cooperation that benefits all parties. At first, research needs support from farmers and businesses to be able to produce science that is implementable in practice. On the other hand, the public, farmers, and businesses are interested in the results produced by the carbon sequestration research.

FMI is a part of several large (commercials) consortiums that cover the whole food production chain from fields to international consumers. For example, in the project "From Footprints to Digital Handprints (lead by HKScan, funded by Business Finland, https://www.bsag.fi/en/projects/ff2dh/) the 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, https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html). This consortium has both vertical and horizontal actors, representing business and research organizations from food, ICT, electronics, and meteorology, and climate research sectors. In BIOHILA project (https://www.bsag.fi/en/projects/biohila/, funded by the Ministry of Agriculture and Forestry), FMI is working closely with Valio and Biocode as they are Work Package (WP) leaders in the project. 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. Additionally, our new project "Digital solutions to foster climate-smart agricultural transition Digi4CSA", https://www.bsag.fi/en/projects/digi4csa/, funded by the Academy of Finland, uses Carbon Action's and ACCC Flagship's existing data streams and builds new soil carbon measurement systems and life-cycle-assessment-based carbon footprint calculations to quantify the impacts of Climate Smart Agriculture (CSA).

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(at)fmi.fi, layla.hockerstedt(at)fmi.fi
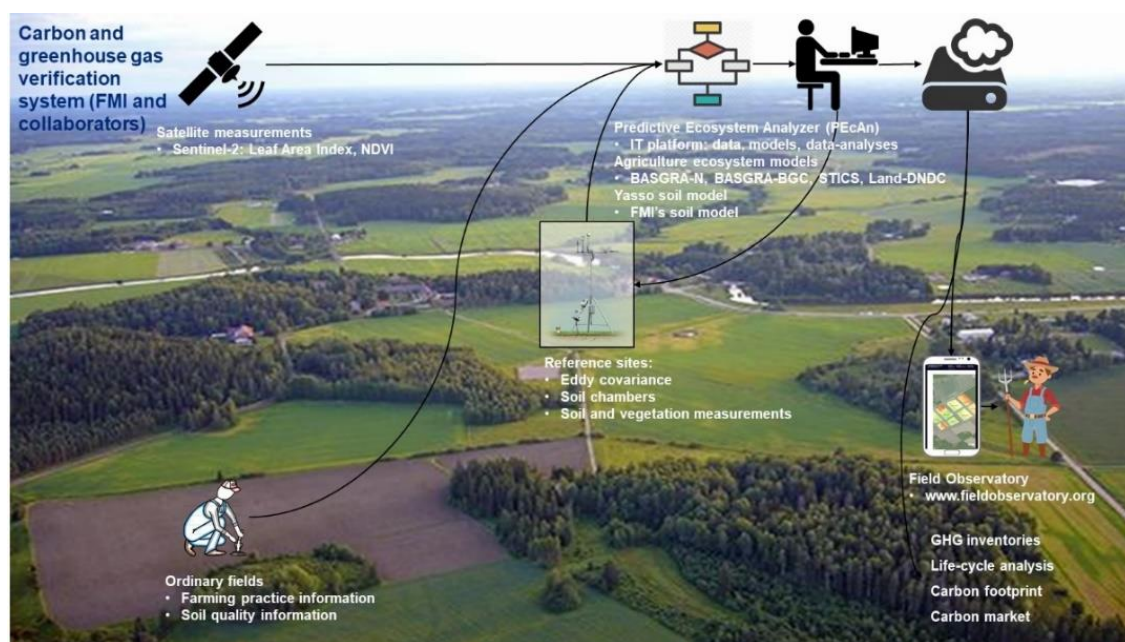
Figure 6. The observation system of agricultural lands for GHG inventories, life-cycle analysis, varbon foorprints and markets. To develop this system FMI collaborates with Valio, HKScan, Gofore, Datasense, Lantmännen, Biocode and, through projects and research platforms (Carbon Action), with S-group, Fazer, Atria, Yara, St1, Sinebrychoff, Berner, Anora, Dava foods, Nestle, Leijona catering

International consultancy projects by Finnish Meteorological Insittute

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, European Union, World Meteorological Organisation (WMO), Nordic Development Fund, International Fund for Agricultural Development (IFAD) and Ministry for Foreign Affairs of Finland funded projects.
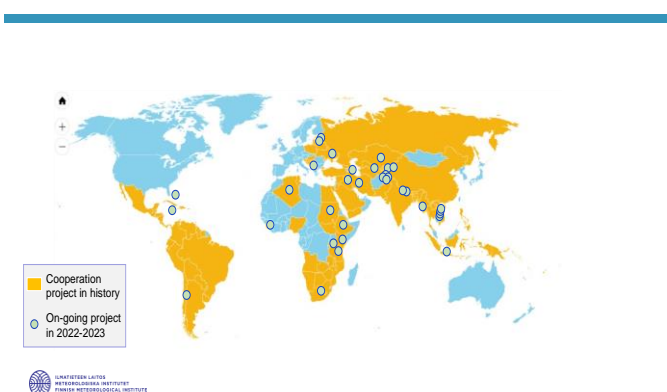
FMI international project references map, including on-going projects.

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/).

Screenshot from the Finland's Development Policy Results Report (MFA, 2022).

Forest ecosystem services

*) University of Eastern Finland, ACCC Impact Task 2

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

45

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(at)Helsinki.fi

Advances in Mass spectrometry

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

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-offlight 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.

46

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

(*) INAR, University of Helsinki, Tampere University, ACCC Success story in 2020-2024, ACCC Mid-term teport

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.

The Cluster Calibration Center (CCC) is currently in its setup phase at University of Helsinki and has started its first operations. CCC is part of the ACTRIS Centre for Aerosol In Situ Measurements (CAIS-ECAC). The aim of CCC is to standardize and validate the methods for measuring sub-10 nm particle concentration and size distribution and improve the methods to calibrate the relevant instrumentation. CCC will be central in distributing the knowledge on nanoparticle instrumentation from the ACCC into the European Research Infrastructure ACTRIS (Aerosol, Clouds and Trace Gases Research Infrastructure).

47

Air pollutants and Black Carbon (BC) footprints (TAU, ACCC Impact Task)

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(at)tuni.fi

Carbonlink classifies and categorizes carbon data. For example cars, buses, trains, flights, hotels, and services. Can be adapted to the need.

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/)

48

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/)

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 (see chapter x.x.) 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
- 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 (https://www.helsinki.fi/assets/drupal/2023-01/UH%20Arctic%20programme%202022-2030.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, singed 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-yhteistyoasiakirj/384951).

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

Pan-Eurasian Experiment (PEEX) Programme (www.atm.helsinki.fi/peex) was initiated in 2012 by the University of Helsinki INAR together with five main partners from Russia (collaboration suspended since February 2022) and China. PEEX is a multidisciplinary, multiscale bottom-up initiative focused on the effects of climate change in the Northern Eurasian Arctic and boreal environments and societies and air quality issues in China (Kulmala et al., 2015 Lappalainen et al., 2016). The PEEX program is introduced in detail in the PEEX Science Plan (Lappalainen et al., 2015, www.atm.helsinki.fi/peex/images/PEEX_Science_Plan.pdf) with specific perspectives on research questions, development needs of the environmental observation systems and education in these area. The PEEX originates from approach of the former Center of Excellence(s) (CoE), the Nordic CoE for Cryosphere Research (CRAICC) and the nine years of National CoE in Atmospheric Sciences (Boy et al. 2019 , Lintunen et al. 2023,) continued by the current approach by the ACCC flagship. The PEEX program currently covers a networks of ca 4000 researchers coming from Europe, Eastern Europe and Asia, especially form China. Over 40 official collaboration agreements with universities and research organizations have been signed. PEEX is science diplomacy in practice, when the environmental experiments, and campaigns are carried out, and when the new ground based measurement concepts and design developed in the ACCC are implemented in the Eurasian and Asian countries (Lappalainen et al., 2022).

Since 2012 PEEX collaboration has lead to scientific breakthroughs especially in understanding the land -atmosphere interactions in the pristine environments in Siberia and some of the polluted mega cities China (Kulmala ERC project). Other areas of interest have been permafrost studies (Melnikov et al. 2016, Kukkonen et al. 2020), environmental heath (Ezhova et al. 2021) and regional modelling of atmospheric pollutants (Baklanov et al.). Recent advances in the understanding of the northern Eurasian environments and of the urban air quality in China have been introduced by Lappalainen et al. (2022).

PEEX framework is motivated by research from regional to global scales, high quality RI and big data, education and training of the next generation of scientists and experts, participating processes aimed at the fast tract policy making and increasing awareness of the highly connected environmental challenges. All these aspects are needed for solving grand challenges, like climate change and air quality, and ensuring the ecosystem services. Specific bi-lateral collaboration has been carried out in the conceptual design of the ground based infrastructure, which starts with science based understanding, identification of the regional environmental challenges followed by the tailored measurement concept which would help the local authorities in their mitigation plans now and in the future (Lappalainen et al. 2018, Petäjä et al.2021, Bobylev et al. 2018, Alekseychik et al. 2016, Hari et al. 2016, Vihma et al. 2019). For contact: hanna.k.lappalainen(at)Helsinki.fi

2.6.3 Global SMEAR - Earth Observatory Initiative (ACCC Impact Task 11)

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 were 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 at 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.
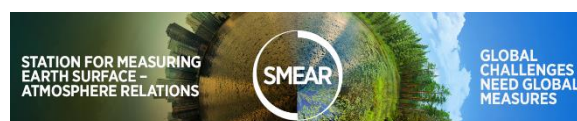
The SMEAR technical model (e.g. in-situ observation methods, instrument technology, data system, comprehensive data analysis methods) is continuously developed at the Station Measuring Ecosystem Atmosphere Relations (SMEAR) II in Hyytiälä. Today the SMEAR II serves as a prototype for the GlobalSMEAR 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 preparare 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(at)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 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

51

of Arctic is actively seeking private funding opportunities to the thematic networks https://www.uarctic.org/activities/thematic-networks/arctic-boreal-hub/. One example is the Arena for the gap analysis of the existing Arctic Science Co-Operations (AASCO, 2020–2021) funded by Prince Albert Foundation (Lappalainen et al. 2022 submitted). For contact: hanna.k.lappalainen(at)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 Tarto starts in 2023. http://dbeltroad.org/index.php?m=content&c=index&a=show&catid=99&id=658. For contact: markku.kulmala(at)helsinki.fi, hanna.k.lappalainen(at)helsinki.fi , joni.kujansuu(at)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(at)helsinki.fi, joni.kujansuu(at)helsinki.fi

Group photo of the committee members of the scientific advisory committee meeting on October 15, 2018.
https://jirlatest.nju.edu.cn/f2/15/c18607a324117/page.htm

2.6.7 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.

Future Earth Suomi (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: stephany.mazon(at)Helsinki.fi

2.6.8 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: markku.kulmala(at)Helsinki.fi

2.6.9 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). 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 is under construction. The new Beijing Haze station hosted by BUCT is the first urban mega city station based on the SMEAR concept and has been constructed in 2018-2019. 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 and Guangzhou Academy of Sciences. 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 being prepared close to Chennai on the coast of the Bay of Bengal (Fig.7). FMI have also co-conducted research expeditions (together with University oh 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 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 two international seminars related to air quality and climate in India (in 2016 and 2023), to increase local awareness and facilitating national and international networking on these topics. For contact: antti.hyvarinen@fmi.fi, rakesh.hooda@fmi.fi.

54
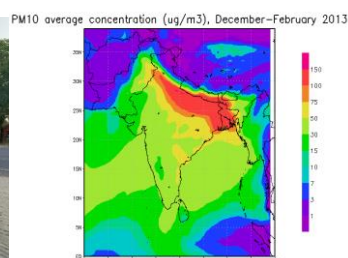
Figure 7. left: emission measurements for an Indian truck; middle: roadside measurement campaign near Delhi; right:SILAM- modeled PM_{10} concentration over India.

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(at)helsinki.fi, markku.kulmala(at)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 computional 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. 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

55

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://bolin.su.se/arctic-avenue, 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; PIs 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

Ukraine

ACCC has several projects or proposals with research organization with Ukraine framed as ""Climate science, research infrastructures and education for resilient societies" such as the ClimEd ERASMUS + project (http://climed.network/) and a new Climate University for Virtual Exhange (CLUVEX) ERASMUS+ project with partners from Finland (INAR as a coordinator), Denmark (University of Copenhagen), Ukraine (Odessa State Environmental University,   Taras Shevchenko National University of Kyiv) and Armenia (Yerevan State University). In the three year CLUVEX project we bring together 2500 students and provide them climate education. At the moment ACCC have collaboration with the following universities and organizations in Ukraine: Odessa State Environmental 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, 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".

2.7 SOCIETY DIALOGUE(S)
2.7.1 Overview

Climate change is a challenge of today's andfuture 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 tract

Minister Pekka Haavisto was one of the Invitaed Speakers in the Sofia Forum 2023 organized in Helsinki.

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 organinized in 2019 (Lappalainen et al. 2019). For contact: hanna.k.klappalainen(at)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

57

(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) For contact: hanna.k.klappalainen(at)helsinki.fi

2.7.4 Initiative for a Safer Climate (ACCC initiative)

The Initiative for a Safer Climate aims to creating new spaces for climate discussion and action at the intersection of academia and civil society. The network consists of researchers, civil society organizations, actors in the field of arts and culture, students and others. Safer Climate facilitates events, campaigns and dialogue to redefine the role of civil society in climate safety. The network was established in 2022 based on stakeholder discussions about what would be a mutually beneficial model of academia-civil society collaboration in the context of ACCC. The theme safer climate is an umbrella theme that covers multiple approaches from climate security to the concept of safer space in climate discussion. Collaborators include Helsinki Inequality Initiative (INEQ), Finnish Scouts and Guides (Partio), Ympäristöahdistuksen mieli project, Tunne ry, Mental Health Finland (Mieli ry), Think Africa and Helsinki International Movie Festival - Love and Anarchy and individual experts/artists. First joint meeting of the network was held in May 2022 and it gathered almost 40 participants from different sectors. The network organizes both internal events and events open for the general public, ranging from academic panels to family activities. Safer Climate is responsible of developing a 'science sparring' model for civil society in collaboration with multiple stakeholders, ACCC staff and University of Helsinki. The network has opened a membership/volunteer register for organizations and individuals.   For contact: rosa.rantanen(at)Helsinki.fi

2.7.5 Polar South - The World Academy of Sciences (TWAS) (IP Task 15)

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.

3 PART III ACCC ROADMAP & ACTION PLAN

The preliminary analysis of the already collected materials is in-progress. IP 16 "ACCC Roadmap" is a new impact task for the period 2025-2028.

The foreseen time for first version of publishable roadmap is October 2023

LIST OF ACRONYMS

ACCC   = The Atmosphere and Climate Competence Center
INAR   = Institute for Atmospheric and Earth System Research
UH   = University of Helsinki
TAU   = Tampere University
FMI   = The Finnish Meteorological Institute
UEF   = The University of Eastern Finland

ACTRIS   = Aerosols 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

59

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

REFERENCES

Aaltonen, H., Zhu, X., Khatun, R., Laurén, A., Palviainen, M., Könönen, M., Peltomaa, E., Berninger, F., Köster, K., Ojala, A., and Pumpanen, J.: The effects of glucose addition and water table manipulation on peat quality of drained peatland forests with different management practices, Soil Science Society of America Journal, 86, 6, 1625–1638, https://doi.org/10.1002/saj2.20419, 2022.

Alekseychik, P., Lappalainen, H.K., Petäjä, T., Zaitseva, N., Heimann, M., Laurila, T., Lihavainen, H., Asmi, E., Arshinov, M., Shevchenko, V., Makshtas, A., Dubtsov, S., Mikhailov, E., Lapshina, E., Kirpotin, S., Kurbatova, Yu., Ding, A., Guo, H., Park, S., Lavric, J. V., Reum, F., Panov, A. Prokushkin A., and Kulmala M.: Ground-based station network in Arctic and Subarctic Eurasia: an overview, Geography Environment Sustainability, 9, 2, 75-88, https://doi.org/10.15356/2071-9388_02v09_2016_06, 2016.

Almeida, J., Schobesberger, S., Kürten, A., Ortega, I.K., Kupiainen-Määttä, O., Praplan, A.P., Adamov, A., Amorim, A., Bianchi, F., Breitenlechner, M., David, A., Dommen, J., Donahue, N.M., Downard, A., Dunne, E., Duplissy, J., Ehrhart, S., Flagan, R.C., Franchin, A., Guida, R., Hakala, J., Hansel, A., Martin Heinritzi, M., Henschel, H., Jokinen, T.., Junninen, H., Kajos, M., Kangasluoma, J., Keskinen, H., Kupc, A., Kurtén, T., Kvashin, A.N., Laaksonen, A., Lehtipalo, K., Leiminger, M., Leppä, J., Loukonen, V., Makhmutov, V., Mathot, S., McGrath, M.J., Nieminen, T., Olenius, T., Onnela, A., Petäjä, T., Riccobono, F., Riipinen, I., Rissanen, M., Rondo, L., Ruuskanen, T., Santos, F.D., Sarnela, N Schallhart, S., Schnitzhofer, R., Seinfeld, J.H., Simon, M., Sipilä, M., Stozhkov, Y., Stratmann, F., Tomé, A., Tröstl, J., Tsagkogeorgas, G., Vaattovaara, P., Viisanen, Y., Virtanen, A., Vrtala, A., Wagner, P.E., Weingartner, E., Wex, H., Williamson, C., Wimmer,D., Ye, P., Yli-Juuti, T., Carslaw, K.S., Kulmala, M., Curtius, J., Baltensperger, U., Worsnop, D.R., Vehkamäki, H., and Jasper Kirkby, J.: Molecular Understanding of Sulphuric acid – amine particle nucleation in the atmosphere, Nature, 502, 359-363, https://doi.org/10.1038/nature12663, 2013.

Bobylev, S. N., Chereshnya, O. Y., Kulmala, M., Lappalainen, H. K., Petäjä, T., Solov'Eva, S. V., Tikunov, V. S., and Tynkkynen, V-P.: Indicators for digitalization of sustainable development goals in PEEX

program 2018, Geography, Environment, Sustainability, 11, 1, 145-156, https://doi.org/10.24057/2071-9388-2018-11-1-145-156, 2018.

Boy, M., Thomson, E. S., Acosta Navarro, J.-C., Arnalds, O., Batchvarova, E., Bäck, J., Berninger, F., Bilde, M., Dagsson-Waldhauserova, P., Castarède, D., Dalirian, M., de Leeuw, G., Dragosics, M., Duplissy, E.-M., Duplissy, J., Ekman, A. M. L., Fang, K., Gallet, J.-C., Glasius, M., Gryning, S.-E., Grythe, H., Hansson, H.-C., Hansson, M., Isaksson, E., Iversen, T., Jonsdottir, I., Kasurinen, V., Kirkevåg, A., Korhola, A., Krejci, R., Kristjansson, J. E., Lappalainen, H. K., Lauri, A., Leppäranta, M., Lihavainen, H., Makkonen, R., Massling, A., Meinander, O., Nilsson, E. D., Olafsson, H., Pettersson, J. B. C., Prisle, N. L., Riipinen, I., Roldin, P., Ruppel, M., Salter, M., Sand, M., Seland, Ø., Seppä, H., Skov, H., Soares, J., Stohl, A., Ström, J., Svensson, J., Swietlicki, E., Tabakova, K., Thorsteinsson, T., Virkkula, A., Weyhenmeyer, G. A., Wu, Y., Zieger, P., and Kulmala, M.: Interactions between the atmosphere, cryosphere and ecosystems at northern high latitudes, Atmos. Chem. Phys., 19, 2015-2061, https://doi.org/10.5194/acp-19-2015-2019, 2019.

Brown, J., Hinkel, K.M., and Nelson, F.E.: The Circumpolar Active Layer Monitoring (CALM) program: historical perspectives and initial results, Polar Geography, 24 (3), 165-258, 2000.

Butt, E.W., Rap, A., Schmidt, A., Scott, C.E., Pringle, K.J., Reddington, C.L., Richards, N.A.D., Woodhouse, M.T., Ramirez-Villegas, J., Yang, H., Vakkari, V., Stone, E.A., Rupakheti, M., Praveen, P. S., van Zyl, P. G., Beukes, J. P., Josipovic, M., Mitchell, E.J.S., Sallu, S.M., Forster P.M., and Spracklen, D.V.: The impact of residential combustion emissions on atmospheric aerosol, human health, and climate, Atmos. Chem. Phys. 16, 873–905, 2016.

Chafik, L., Århthun, M., Langehaug, H., and Uotila, P.: Decadal propagation of thermohaline pulses in the Arctic Ocean, Abstract from Workshop: Multi-annual to Decadal Climate Predictability in the North Atlantic-Arctic Sector, Copenhagen, Denmark, https://drive.google.com/drive/folders/1f9FjCHAljwTUT3BGhfw7Dm5XR76GbuTP?usp=sharing, 2021.

COM(2020)21, European Green Deal Investment Plan, Brussels, 14.1.2020, https://www.eumonitor.eu/9353000/1/j9vvik7m1c3gyxp/vl5bgbajymzx, 2020.

Dal Maso et al., 2022 tba

Demenois, J., Torquebiau, E., Arnoult, M.H., Eglin, T., Masse, D., Assouma, M.H., Blanfort, V., Chenu, C., Chapuis-Lardy, L., Medoc, J.-M., and Sall, S.N.: Barriers and Strategies to Boost Soil Carbon Sequestration in Agriculture, Front. Sustain. Food Syst. 4, 37, https://doi.org/10.3389/fsufs.2020.00037, 2020.

Ding A., Nie, W., Huang, X., Chi, X., Sun, J., Kerminen, V.-M., Xu, Z., Guo, W., Petaja, T., Yang, X., Kulmala, M., and Fu, C.: Long-term observation of air pollution-weather/climate interactions at the SORPES station: a review and outlook, Front. Environ. Sci. Eng.,10 (5), 15, https://doi.org/10.1007/s11783-016-0877-3, 2016.

Ding, A., Huang, X., Nie, W., Sun, J., Kerminen, V.-M., Petaja, T., Su, H., Cheng, Y., Yang, X., Wang, M., Chi, X., Wang, J., Virkkula, A., Guo, W., Yuan, J., Wang, S., Zhang, R., Wu, Y., Song, Y., Zhu, T., Zilitinkevich, S., Kulmala, M., and Fu, C.:Enhanced haze pollution by black carbon in megacities in China, Geophys. Res. Lett., 43, 6, 2873-2879, https://doi.org/10.1002/2016GL067745, 2016.

Du, W., Dada, L., Zhao, J., Chen, X., Dällenbach, K., Xie, C., Wang, W., He, Y., Cai, J., Yao, L., Zhang, Y., Wang, Q., Xu, W., Wang, Y., Tang, G., Cheng, X., Kokkonen, T. V., Zhou, W., Yan, C., Chu, B., Zha, Q., Hakala, S., Kurppa, M., Järvi, L., Liu, Y., Li, Z., Ge, M., Fu, P., Nie, W., Bianchi, F., Petäjä, T., Paasonen, P., Wang, Z., Worsnop, D.R., Kerminen, V.-M., Kulmala, M., and Sun, Y.: A 3D study on the amplification of regional haze and particle growth by local emissions, npj Clim Atmos Sci, 4(1), 4, https://doi.org/10.1038/s41612-020-00156-5, 2021.

Du, W., Cai, J., Zheng, F., Yan, C., Zhou, Y., Guo, Y., Chu, B., Yao, L., Heikkinen, L., Fan, X., Wang, Y., Cai, R., Hakala, S., Chan, T., Kontkanen, J., Tuovinen, S., Petäjä, T., Kangasluoma, J., Bianchi, F., and Kulmala, M.: Influence of Aerosol Chemical Composition on Condensation Sink Efficiency and New Particle Formation in Beijing, Environmental Science & Technology Letters, 9, https//doi.org/10.1021/acs.estlett.2c00159, 2022.

61

Ezhova, E., Orlov, D., Suhonen, E., Kaverin, D., Mahura, A., Gennadinik, V., Kukkonen, I., Drozdov, D., Lappalainen, H.K., Melnikov, V., Petäjä, T., Kerminen, V.-M., Zilitinkevich, S., Malkhasova, S.M., Christensen, T., and Kulmala, M: Climatic factors influencing the Anthrax outbreak of 2016 in Siberia, Russia, EcoHealth, 18, 217–228, https://doi.org/10.1007/s10393-021-01549-5, 2021.

Fer, I., Gardella, A. K., Shiklomanov, A.N., Campbell, E.E., Cowdery, E.M., De Kauwe, M.G., Desai A, Duveneck MJ, Fisher JB, Haynes KD, Hoffman FM, Johnston MR, Kooper R, LeBauer DS, Mantooth, J., Parton, W.J., Poulter, B., Quaife, T., Raiho, A., Schaefer, K., Serbin, S.P., Simkins, J., Wilcox, K.R., Viskari, T., Dietze, M.C.: Beyond ecosystem modeling: A roadmap to community cyberinfrastructure for ecological data-model integration, Glob Change Biol., 27, 13– 26, https://doi.org/10.1111/gcb.15409, 2021.

Fiore et al., 2012 tba

Fiore, A.M., V. Naik, D.V. Spracklen, A. Steiner, N. Unger, M. Prather, D. Bergmann, P.J. Cameron-Smith, I. Cionni, W.J. Collins, S. Dalsoren, V. Eyring, G.A. Folberth, P. Ginoux, L.W. Horowitz, B. Josse, J.F. Lamarque, I.A. MacKenzie, T. Nagashima, F.M. O'Connor, M. Righi, S.T. Rumbold, D.T. Shindell, R.B. Skeie, K. Sudo, S. Szopa, T. Takemura, and G. Zeng: Global air quality and climate. Chem. Soc. Rev., 41, 6663-6683, https://doi.org/10.1039/c2cs35095e, 2012.

Forsius, M., Kujala, H., Minunno, F., Holmberg, M., Leikola, N., Mikkonen, N., Autio, I., Paunu, V.-V., Tanhuanpää, T., Hurskainen, P., Mäyrä, J., Kivinen, S., Keski-Saari, S., Kosenius, A.-K., Kuusela, S., Virkkala, R., Viinikka, A., Vihervaara, P., Akujarvi, A., Bäck, J., Karvosenoja, N., Kumpula, T., Kuzmin, A., Mäkelä, A., Moilanen, A., Ollikainen, M., Pekkonen, M., Peltoniemi, M., Poikolainen, L., Rankinen, K., Rasilo, T., Tuominen, S., Valkama, J., Vanhala, P., and Heikkinen, R.K.: Developing a spatially explicit modelling and evaluation framework for integrated carbon sequestration and biodiversity conservation: application in southern Finland, The Science of the Total Environment 775, 145847, https://doi.org/10.1016/j.scitotenv.2021.145847, 2021.

Forsius, M., Posch, M., Holmberg, M., Vuorenmaa, J., Kleemola, S., Augustaitis, A., Beudert, B., Bochenek, W., Clarke, N., de Wit, H.A., Dirnböck, T., Frey, J., Grandin, U., Hakola, H., Kobler, J., Krám, P., Lindroos, A.-J., Löfgren, S., Pecka, T., Rönnback, P., Skotak, K., Szpikowski, J., Ukonmaanaho, L., Valinia, S., and Váňa, M.: Assessing critical load exceedances and ecosystem impacts of anthropogenic nitrogen and sulphur deposition at unmanaged forested catchments in Europe, Science of the total environment, 753, 141791, https://doi.org/10.1016/j.scitotenv.2020.141791, 2021.

Friedlingstein, P., Jones, M. W., O'Sullivan, M., Andrew, R. M., Bakker, D. C. E., Hauck, J., Le Quéré, C., Peters, G. P., Peters, W., Pongratz, J., Sitch, S., Canadell, J. G., Ciais, P., Jackson, R. B., Alin, S. R., Anthoni, P., Bates, N. R., Becker, M., Bellouin, N., Bopp, L., Chau, T. T. T., Chevallier, F., Chini, L. P., Cronin, M., Currie, K. I., Decharme, B., Djeutchouang, L. M., Dou, X., Evans, W., Feely, R. A., Feng, L., Gasser, T., Gilfillan, D., Gkritzalis, T., Grassi, G., Gregor, L., Gruber, N., Gürses, Ö., Harris, I., Houghton, R. A., Hurtt, G. C., Iida, Y., Ilyina, T., Luijkx, I. T., Jain, A., Jones, S. D., Kato, E., Kennedy, D., Klein Goldewijk, K., Knauer, J., Korsbakken, J. I., Körtzinger, A., Landschützer, P., Lauvset, S. K., Lefèvre, N., Lienert, S., Liu, J., Marland, G., McGuire, P. C., Melton, J. R., Munro, D. R., Nabel, J. E. M. S., Nakaoka, S.-I., Niwa, Y., Ono, T., Pierrot, D., Poulter, B., Rehder, G., Resplandy, L., Robertson, E., Rödenbeck, C., Rosan, T. M., Schwinger, J., Schwingshackl, C., Séférian, R., Sutton, A. J., Sweeney, C., Tanhua, T., Tans, P. P., Tian, H., Tilbrook, B., Tubiello, F., van der Werf, G. R., Vuichard, N., Wada, C., Wanninkhof, R., Watson, A. J., Willis, D., Wiltshire, A. J., Yuan, W., Yue, C., Yue, X., Zaehle, S., and Zeng, J.: Global Carbon Budget 2021, Earth Syst. Sci. Data, 14, 1917–2005, https://doi.org/10.5194/essd-14-1917-2022, 2022.

Georgiades, P., Ezhova, E., Räty, M., Orlov, D., Kulmala, M., Lelieveld, J., Malkhazova, S., Erguler, K., and Petäjä, T.: The impact of climatic factors on tick-related hospital visits and borreliosis incidence rates in European Russia, PLOS ONE, 17(7), e0269846, https://doi.org/10.1371/journal.pone.0269846, 2022.

Griscom, B.W., Adams, J., Ellis, P.W., and Fargione, J.: Natural Climate Solutions, Proc. Natl. Acad. Sci. USA, 114, 11645-11650, https://doi.org/10.1073/pnas.1710465114, 2017.

Griscom, B.W, Busch, J., Cook-Patton, S.-C., Ellis, P.W., Funk, J., Leavitt, S.M., Lomax, G., Turner, W.R., Chapman, M., Engelmann, J., Gurwick, N.P., Landis, E., Lawrence, D., Malhi, Y., Schindler Murray, L., Navarrete, D., Roe, S., Scull, S., Smith, P., Streck, C., Walker, W.S., and Worthington, T.: National mitigation potential from natural climate solutions in the tropics, Phil. Trans. R. Soc. B 375: 20190126, http://dx.doi.org/10.1098/rstb.2019.0126, 2020.

Guo, H., Qiu, Y., Menenti, M. Chen, F., Uhlir, P., Zhang, L., van Genderen, J., Liang, D., Ishwaran, N., Zhu, L., Liu, J.,: The Digital Belt and Road program in support of regional sustainability, International Journal of Digital Earth, 11:7, 657–669, https://doi.org/10.1080/17538947.2018.1471790, 2018.

Hakala, S., Vakkari, V., Bianchi, F., Dada, L, Deng, C., Dällenbach, K., Fu, Y., Jiang, J., Kangasluoma, J., Kujansuu, J., Liu, Y., Petäjä, T., Wang, L., Yan, C., Kulmala, M., and Paasonen, P.: Observed coupling between air mass history, secondary growth of nucleation mode particles and aerosol pollution levels in Beijing. Environ. Sci. Atmos. 2, 146-164, https://doi.org/10.1039/d1ea00089f, 2022.

Hari, P. and Kulmala, M.: Station for Measuring Ecosystem-Atmosphere Relations (SMEAR II), Boreal Environment Research, 10(5), 315-322, ISSN 1239-6095, 2005.

Hari, P.K.J., Petäjä, T.T., Bäck, J.K., Kerminen, V-M., Lappalainen, H.K., Vihma, T., Laurila, T., Viisanen, Y., Vesala, T.V., and Kulmala, M.T.: Conceptual design of a measurement network of the global change, Atmospheric Chemistry and Physics, 16, 1017-1028, https://doi.org/10.5194/acp-16-1017-2016, 2016.

Harper, A.B., Powell, T., Cox, P.M., Hous, J., Huntingford, C., Lenton, T.M., Sitch, S., Burke, E., Chadburn, S.E., Collins, W.J., Comyn-Platt, E., Daioglou, V., Doelman, J.C., Hayman, G., Robertson, E., van Vuuren, D., Wiltshire, A., Webber, C.P., Bastos, A., Boysen, L., Ciais, P., Devaraju, N., Jain, A.J., Krause, A., Poulter, B., and Shu, S.: Land-use emissions play a critical role in land-based mitigation for Paris climate targets, Nat. Commun., 9, 2938, https://doi.org/10.1038/s41467-018-05340-z, 2018.

Havu, M., Kulmala, L., Kolari, P., Vesala, T., Riikonen, A., and Järvi, L.: Carbon sequestration potential of street tree plantings in Helsinki. Biogeosciences 19, 8, 2121-2143, https://doi.org/10.5194/bg-19-2121-2022, 2022.

He, X-C., Tham, Y.J., Dada, L., Wang, M., Stolzenburg, D., Iyer, S., Shen, J., Rörup, B., Rissanen, M., Schobesberger, S., Baalbaki, R., Jokinen, T., Sarnela, N., Beck, L.J., Bianchi, F., Chu, B., Duplissy, J., Hansel, A., Junninen, H., Lehtipalo, K., Petäjä, T., Thakur, R.C., Kulmala, M., Kerminen, V.-M., Kurten, T., Worsnop, D.R., Sipilä, M., Kangasluoma, J., Kemppainen, D., Laitinen, T., Wang, Y., Wu, Y., Yan, C., Zha, Q., and Zhou, P.: Role of iodine oxoacids in atmospheric aerosol nucleation. Science 371, 589-595, https://doi.org/10.1126/science.abe0298, 2021.

Heiskanen, L., Tuovinen, J-P., Räsänen, A., Virtanen, T., Juutinen, S., Lohila, A., Penttilä, T., Linkosalmi, M., Mikola, J., Laurila, T., and Aurela, M.: Carbon dioxide and methane exchange of a patterned subarctic fen during two contrasting growing seasons. Biogeosciences, 18(3), 873–896, https://doi.org/10.5194/bg-18-873-2021, 2021.

Heiskanen, L., Tuovinen, J.-P., Räsänen, A., Virtanen, T., Juutinen, S., Vekuri, H., Lohila, A., Mikola, J., and Aurela, M.:-Meteorological responses of carbon dioxide and methane fluxes in the terrestrial and aquatic ecosystems of a subarctic landscape. Biogeosciences 20, 545, https://doi.org/10.5194/bg-20-545-2023, 2023.

IPCC: Climate Change 2013: The Physical Science Basis. Working group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change, edited by: Stocker, T.F, Qin, D., Plattner, G.-K., Tignor, M.M.B., Allen, S.K., Boschung, J., Nauels, A., Xia, Y., Bex, V., and Midgley, P.M., Cambridge University Press, ISBN 978-92-9169-138-8, 2013.Jaars, K., Beukes, J. P., van Zyl, P. G., Venter, A. D., Josipovic, M., Pienaar, J. J., Vakkari, V., Aaltonen, H., Laakso, H., Kulmala, M., Tiitta, P., Guenther, A., Hellen, H., Laakso, L., and Hakola, H.: Ambient aromatic hydrocarbon measurements at Welgegund, South Africa. Atmos. Chem. Phys. 14(13), 7075-7089. https://doi.org/10.5194/acp-14-7075-2014, 2014.

Jaars, K., van Zyl, P. G., Beukes, J. P., Hellen, H., Vakkari, V., Josipovic, M., Venter, A. D., Räsänen, M., Knoetze, L., Cilliers, D.P., Siebert, S.J., Kulmala, M., Rinne, J., Guenther, A., Laakso, L., and Hakola, H.: Measurements of biogenic volatile organic compounds at a grazed savannah grassland agricultural landscape in South Africa, Atmos. Chem. Phys. 16, 15665–15688, https://doi.org/10.5194/acp-16-15665-2016, 2016.

Kalliokoski T., Makela, A., Fronzek, S., Minunno, F., and Peltoniemi, M.: Decomposing sources of uncertainty in climate change projections of boreal forest primary production, Agric. For. Meteorol., 262, 192–205, https://doi.org/10.1016/j.agrformet.2018.06.030, 2018.

Kalliokoski, T., Bäck, J., Boy, M., Kulmala, M., Kuusinen, N., Mäkelä, A., Minkinen, K., Minunno, F., Paasonen, P, Peltoniemi, M., Taipale, D., Valsta, L., Vanhatalo, A., Zhou, L., Zhou, P., and Berninger, F.: Mitigation Impact of Different Harvest Scenarios of Finnish Forests rhat Account for Albedo, Aerosols, and Trade-Offs of Carbon Sequestration and Avoided Emissions, Frontiers in Forests and Global Change 3, 562044, https://doi.org/10.3389/ffgc.2020.562044, 2020.

~~Kalliokoski, T., Mäkelä, A., Fronzek, S., Minunno, F. and Peltoniemi, M.: Decomposing sources of uncertainty in climate change projections of boreal forest primary production. Agricul. For. Meteorol. 262, 192-205, https://doi.org/10.1016/j.agrformet.2018.06.030, 2018.~~

Karjalainen, P.; Nikka, M.; Olin, M.; Martikainen, S.; Rostedt, A.; Arffman, A.; and Mikkonen, S.: Fuel-Operated Auxiliary Heaters Are a Major Additional Source of Vehicular Particulate Emissions in Cold Regions. Atmosphere 2021, 12, 1105. https://doi.org/10.3390/atmos12091105, 2021.

Karjalainen, P., Teinilä, K., Kuittinen, N., Aakko-Saksa, P., Bloss, M., Vesala, H., Pettinen, R., Saarikoski, S., Jalkanen, J-P., and Timonen, H.: Real-world particle emissions and secondary aerosol formation from a diesel oxidation catalyst and scrubber equipped ship operating with two fuels in a SECA area, Environmental pollution, 292, 118278, https://doi.org/10.1016/j.envpol.2021.118278, 2021.

Kirkby, J., Curtius, J., Almeida, J., Dunne, E., Duplissy, J., Ehrhart, S., Franchin, A., Gagné, S., Ickes, L., Kürten, A., Kupc, A., Metzger, A., Riccobono, F., Rondo, L., Schobesberger, S., Tsagkogeorgas, G., Wimmer, D., Amorim, A., Bianchi, F., and Kulmala, M.: Role of sulphuric acid, ammonia and galactic cosmic rays in atmospheric aerosol nucleation. Nature. 476. 429-33, https://doi.org/10.1038/nature10343, 2011.

Kirkby, J., Duplissy, J., Sengupta, K., Frege, C., Gordon, H., Williamson, C., Heinritzi, M., Simon, M., Yan, C., Almeida, J., Tröstl, J., Nieminen, T., Ortega, I., Wagner, R., Adamov, A., Amorim, A., Bernhammer, A.-K., Bianchi, F., Breitenlechner, M., and Curtius, J.: Ion-induced nucleation of pure biogenic particles, Nature, 533, 521-526, https://doi.org/10.1038/nature17953, 2016.

Kokkonen, T., Xie, Y., Paasonen, P., Gani, S., Jiang, L., Wang, B., Zhou, D., Qin, W., Nie, W., Kerminen, V-M., Petäjä, T., Sun, J., Kulmala, M., and Ding, A.: The effect of urban morphological characteristics on the spatial variation of PM2.5 air quality in downtown Nanjing. Environmental science: Atmospheres, 1(7), 481-497, https://doi.org/10.1039/D1EA00035G, 2021.

Kontkanen, J., Deng, C., Fu, Y., Dada, L., Zhou, Y., Cai, J., Dällenbach, K., Hakala, S., Kokkonen, T., Lin, Z., Liu, Y., Wang, Y., Yan, C., Petäjä, T., Jiang, J., Kulmala, M., and Paasonen, P.: Size-resolved particle number emissions in Beijing determined from measured particle size distributions. Atmospheric Chemistry and Physics, 20(19), 11329-11348, https://doi.org/10.5194/acp-20-11329-2020, 2020.

Korenberg E.I.: Seasonal population dynamics of Ixodes ticks and tick-borne encephalitis virus, Exp. Appl. Acarol. 24. 665–681, https://doi.org/10.1023/A:1010798518261, 2000.

Korkiakoski, M., Ojanen, P., Penttila, T., Minkkinen, K., Sarkkola, S., Rainne, J., Laurila, T., and Lohila, A.: Impact of partial harvest on CH4 and N2O balances of a drained boreal peatland forest. Agricultural and Forest Meteorology, 295, 108168, https://doi.org/10.1016/j.agrformet.2020.108168, 2020.

Kriegler, E., Luderer, G., Bauer, N., Baumstark, L., Fujimori, S., Popp, A., Rogelj, J., Strefler, J., and van Vuuren, D.P.: Pathways limiting warming to 1.5°C: a tale of turning around in no time? Phil Trans R Soc A, 376, 20160457, https://doi.org/10.1098/rsta.2016.0457, 2018.

Kukkonen, I., Suhonen, E., Ezhova, E., Lappalainen, H., Gennadinik, V., Ponomareva, O., Gravis, A., Miles, V., Kulmala, M., Melnikov, V., and Drozdov, D.: Observations and modelling of ground temperature evolution in the discontinuous permafrost zone in Nadym, north-west Siberia, Permafrost and Periglacial Processes, 31(2), 264-280, https://doi.org/10.1002/ppp.2040, 2020.

Kulmala, M., Nieminen, T., Nikandrova, A., Lehtipalo, K., Manninen, H. E., Kajos, M.K., Kolari, P., Lauri, A., Petäjä, T., Krejci, R., Hansson, H.-C., Swietlicki, E., Lindroth, A., Christensen, T.R., Arneth, A., Hari, P., Bäck, J., Vesala, T., and Kerminen, V.-M.: CO2-induced terrestrial climate feedback mechanism: From carbon sink to aerosol source and back, Boreal Env. Res. 19, Suppl. B: 122-131, ISSN 1797-2469 (online), 2014.

Kulmala, M.: Atmospheric chemistry: China's choking cocktail, Nature, 526, 497–499, https://doi.org/10.1038/526497a, 2015.

Kulmala, M., Lappalainen, H. K., Petaja, T., Kurten, T., Kerminen, V. -M., Viisanen, Y., Hari, P., Sorvari, S., Back, J., Bondur, V., Kasimov, N., Kotlyakov, V., Matvienko, G., Baklanov, A., Guo, H. D., Ding, A., Hansson, H. -C., and Zilitinkevich, S.: Introduction: The Pan-Eurasian Experiment (PEEX) - multidisciplinary, multiscale and multicomponent research and capacity-building initiative, Atmospheric Chemistry and Physics, 15(22), 13085-13096, https://doi.org/10.5194/acp-15-13085-2015, 2015.

Kulmala, M., Lappalainen, H.K., Petäjä, T., Kerminen, V-M., Viisanen, Y., Matvienko, G., Melnikov, V., Baklanov, A., Bondur, V., Kasimov, N., and Zilitinkevich, S.: Pan-Eurasian Experiment (PEEX) Program: Grand Challenges in the Arctic-boreal context. J. Geography Environment Sustainability, No 2, 5-18, https://doi.org/10.15356/2071-9388_02v09_2016_01, 2016.

Kulmala, M., Kerminen, V-M., Petäjä, T., Ding, A. J., and Wang, L.: Atmospheric gas-to-particle conversion: why NPF events are observed in megacities? Faraday Discussions, 200, 271-288. https://doi.org/10.1039/c6fd00257a, 2017.

Kulmala, M.: Build a global Earth observatory, Nature 553, 21-23, https://doi.org/10.1038/d41586-017-08967-y, 2018.

Kulmala, M., Dada, L., Daellenbach, K.R., Yan, C., Stolzenburg, D., Kontkanen, J., Ezhova, E., Hakala, S., Tuovinen, S., Kokkonen, T., Kurppa, M., Cai, R., Zhou, Y., Yin, R., Baalbaki, R., Chan, T., Chu, B., Deng, C., Fu, Y., Ge, M., He, H., Heikkinen, L., Junninen, H., Liu, Y., Lu, Y., Nie, W., Rusanen, A., Vakkari, V., Wang, Y., Yang, G., Yao, L., Zheng, J., Kujansuu, J., Kangasluoma, J., Petäjä, T., Paasonen, P., Järvi, L., Worsnop, D., Ding, A., Liu, Y., Wang, L., Jiang, J., Bianchi F., and Kerminen, V.-M.: Is reducing new particle formation a plausible solution to mitigate particulate air pollution in Beijing and other Chinese megacities? Faraday Discuss., 2021,226, 334-347, https://doi.org/10.1039/D0FD00078G, 2020.

Kulmala M., Ezhova E., Kalliokoski T., Noe S., Vesala T., Lohila A., Liski J., Makkonen R., Bäck J., Petäjä, T., and Kerminen, V.-M.: CarbonSink+ — Accounting for multiple climate feedbacks from forests, Boreal Env. Res. 25, 145-159, http://hdl.handle.net/10138/325225, 2020.

Kulmala, M., Stolzenburg, D., Dada, L., Cai, R., Kontkanen, J., Yan, C., Kangasluoma, J., Ahonen, L., Gonzalez-Carracedo, L., Sulo, J., Tuovinen, S. O. L., Deng, C., Li, Y., Lehtipalo, K., Lehtinen, K. E. J., Petäjä, T., Winkler, P. M., Jiang, J., and Kerminen, V-M.: Towards a concentration closure of sub-6 nm aerosol particles and sub-3 nm atmospheric clusters, Journal of Aerosol Science, 159, 105878, https://doi.org/10.1016/j.jaerosci.2021.105878, 2021.

Kulmala, M., Kokkonen, T. V., Pekkanen, J., Paatero, S., Petäjä, T., Kerminen, V.-M., and Ding, A.: Opinion: Gigacity – a source of problems or the new way to sustainable development, Atmos. Chem. Phys., 21, 8313–8322, https://doi.org/10.5194/acp-21-8313-2021, 2021.

Kulmala, M, Lintunen, A., Ylivinkka, I., Mukkala, J., Rantanen, R., Kujansuu, J., Petäjä, T., and Lappalainen, H. K.: Atmospheric and ecosystem big data providing key contributions in reaching United Nations' sustainable development goals, Big Earth Data, 5, 3, 277-305, https://doi.org/10.1080/20964471.2021.1936943, 2021.

Kulmala, M., Cai, R., Stolzenburg, D., Zhou, Y., Dada, L., Guo, Y., Yan, C., Petäjä, T., Jiang, J., and Kerminen, V.-M.: The contribution of new particle formation and subsequent growth to haze

65

formation, Environmental Science: Atmospheres, 2, 3, 352-361, https://doi.org/10.1039/d1ea00096a, 2022

Kuntsi-Reunanen, 2021 tba

Kuula, J., Friman, M., Helin, A., Niemi, J., Aurela, M., Timonen, H., and Saarikoski, S.: Utilization of scattering and absorption-based particulate matter sensors in the environment impacted by residential wood combustion, Journal of Aerosol Science, 150, 105671, https://doi.org/10.1016/j.jaerosci.2020.105671, 2020.

Kuula et al. 2022 tba

Köster E., Pumpanen J., Palviainen M., Zhou X. and Köster K.: Effect of biochar amendment on the properties of growing media and and growth of containerized Norway spruce, Scots pine, and silver birch, seedlings, Canadian Journal of Forest Research, 51,1, 31-40, https://doi.org/10.1139/cjfr-2019-0399, 2021.

Köster K., Aaltonen H., Berninger F., Heinonsalo J., Köster E., Ribeiro-Kumara C., Sun H., Tedersoo L., Zhou X. and Pumpanen J. 2021. Impacts of wildfire on soil microbiome in Boreal environments. Current Opinion in Environmental Science & Health. 22, 100258, https://doi.org/10.1016/j.coesh.2021.100258, 2021.

Laakso, L., Laakso, H. , Aalto, P.P. , Keronen, P., Petäjä, T., Nieminen, T., Pohja, T., Siivola, E., Kulmala, M., Kgabi, N., Molefe, M., Mabaso, D., Phalatse, D., Pienaar K., and Kerminen, V.-M.: Basic characteristics of atmospheric particles, trace gases and meteorology in a relatively clean Southern African Savannah environment, Atmos. Chem. Phys. 8, 4823–4839, https://doi.org/10.5194/acp-8-4823-2008, 2008.

Lappalainen, H. K., Kulmala, M., and Zilitinkevich, S. (Eds.): Pan Eurasian Experiment (PEEX) Science Plan, available at: https://www.atm.helsinki.fi/peex/ (last access: 26 January 2022), ISBN 978-951-51-0587-5 (printed), ISBN 978-951-51-0588-2 (online), 2015.

Lappalainen, H. K., Kerminen, V.-M., Petäjä, T., Kurten, T., Baklanov, A., Shvidenko, A., Bäck, J., Vihma, T., Alekseychik, P., Andreae, M. O., Arnold, S. R., Arshinov, M., Asmi, E., Belan, B., Bobylev, L., Chalov, S., Cheng, Y., Chubarova, N., de Leeuw, G., Ding, A., Dobrolyubov, S., Dubtsov, S., Dyukarev, E., Elansky, N., Eleftheriadis, K., Esau, I., Filatov, N., Flint, M., Fu, C., Glezer, O., Gliko, A., Heimann, M., Holtslag, A. A. M., Hõrrak, U., Janhunen, J., Juhola, S., Järvi, L., Järvinen, H., Kanukhina, A., Konstantinov, P., Kotlyakov, V., Kieloaho, A.-J., Komarov, A. S., Kujansuu, J., Kukkonen, I., Duplissy, E.-M., Laaksonen, A., Laurila, T., Lihavainen, H., Lisitzin, A., Mahura, A., Makshtas, A., Mareev, E., Mazon, S., Matishov, D., Melnikov, V., Mikhailov, E., Moisseev, D., Nigmatulin, R., Noe, S. M., Ojala, A., Pihlatie, M., Popovicheva, O., Pumpanen, J., Regerand, T., Repina, I., Shcherbinin, A., Shevchenko, V., Sipilä, M., Skorokhod, A., Spracklen, D. V., Su, H., Subetto, D. A., Sun, J., Terzhevik, A. Y., Timofeyev, Y., Troitskaya, Y., Tynkkynen, V.-P., Kharuk, V. I., Zaytseva, N., Zhang, J., Viisanen, Y., Vesala, T., Hari, P., Hansson, H. C., Matvienko, G. G., Kasimov, N. S., Guo, H., Bondur, V., Zilitinkevich, S., & Kulmala, M.: Pan-Eurasian Experiment (PEEX): towards a holistic understanding of the feedbacks and interactions in the land–atmosphere–ocean–society continuum in the northern Eurasian region. Atmos. Chem. Phys., 16, 14421–14461, https://doi.org/10.5194/acp-16-14421-2016, 2016.

Lappalainen, H. K., Kulmala, M., Kujansuu, J., Petäjä, T., Mahura, A., de Leeuw, G., Zilitinkevich, S., Juustila, M., Kerminen, V. M., Bornstein, B., and Jiahua, Z.: The Silk Road agenda of the Pan-Eurasian Experiment (PEEX) program, Big Earth Data, 2, 8–35, https://doi.org/10.1080/20964471.2018.1437704, 2018.

Lappalainen (ed.) Sofia Forum Suomi: Yhdessä kohti hiilineutraalia tulevaisuutta - Kannustimet, kehittäminen ja sääntely 9.–10.12.2019 Pääviestit ja pohdintoja sisältää keskustelun tulokset" Suomen Ekumeenisen Neuvoston julkaisuja CXIII, ISBN 978-952-9529-76-6 (nid.), ISBN 978-952-9529-77-3 (PDF), 2019.

Lappalainen, H. K., Petäjä, T., Vihma, T., Räisänen, J., Baklanov, A., Chalov, S., Esau, I., Ezhova, E., Leppäranta, M., Pozdnyakov, D., Pumpanen, J., Andreae, M. O., Arshinov, M., Asmi, E., Bai, J., Bashmachnikov, I., Belan, B., Bianchi, F., Biskaborn, B., Boy, M., Bäck, J., Cheng, B., Chubarova, N.,

Duplissy, J., Dyukarev, E., Eleftheriadis, K., Forsius, M., Heimann, M., Juhola, S., Konovalov, V., Konovalov, I., Konstantinov, P., Köster, K., Lapshina, E., Lintunen, A., Mahura, A., Makkonen, R., Malkhazova, S., Mammarella, I., Mammola, S., Buenrostro Mazon, S., Meinander, O., Mikhailov, E., Miles, V., Myslenkov, S., Orlov, D., Paris, J.-D., Pirazzini, R., Popovicheva, O., Pulliainen, J., Rautiainen, K., Sachs, T., Shevchenko, V., Skorokhod, A., Stohl, A., Suhonen, E., Thomson, E. S., Tsidilina, M., Tynkkynen, V.-P., Uotila, P., Virkkula, A., Voropay, N., Wolf, T., Yasunaka, S., Zhang, J., Qiu, Y., Ding, A., Guo, H., Bondur, V., Kasimov, N., Zilitinkevich, S., Kerminen, V.-M., and Kulmala, M.: Overview: Recent advances in the understanding of the northern Eurasian environments and of the urban air quality in China – a PanEurasian Experiment (PEEX) programme perspective, Atmos. Chem. Phys., 22, 4413–4469, https://doi.org/10.5194/acp-22-4413-2022, 2022.

Lappalainen, H.K, Petäjä, T., Lintunen, A., and Kulmala, M.: Institute for Atmospheric and Earth System Research (INAR): Showcases for making science diplomacy. Polar Record, 58, E15, https://doi.org/10.1017/S0032247421000760, 2022.

Lappalainen et al. (2022) "Arctic science collaborations – the AASCO-project calls for a holistic system understanding of the Arctic environmental system for well-targeted policy actions" submitted to Environmental Sciences and Policy (submitted)

Launiainen, S., Katul, G. G., Leppa, K., Kolari, P., Aslan, T., Gronholm, T., Korhonen, L., Mammarella, I., and Vesala, T.: Does growing atmospheric CO2 explain increasing carbon sink in a boreal coniferous forest? Global Change Biology, 28(9), 2910-2929, https://doi.org/10.1111/gcb.16117, 2022.

Laurila, T. K., Gregow, H., Corner, J. S., and Sinclair, V.: Characteristics of extratropical cyclones and precursors to windstorms in northern Europe. Weather and Climate Dynamics, 2(4), 1111-1130. https://doi.org/10.5194/wcd-2-1111-2021, 2021.

Laurila, T. K., Sinclair, V. A., and Gregow, H.: Climatology, variability, and trends in near-surface wind speeds over the North Atlantic and Europe during 1979-2018 based on ERA5, International Journal of Climatology, 41(4), 2253-2278, https://doi.org/10.1002/joc.6957, 2021.

Laurila, T., Lintunen, A., Okuljar, M. (Eds.): Proceedings of the Atmosphere and Climate Competence Center (ACCC) Research Flagship and Finnish Atmospheric Science Network Conference 2021 Report Series in Aerosol Science, 245 (2021), SBN 978-952-7276-71-6 (PDF), ISSN 0784-3496, http://www.faar.fi/ 307 (pp), 2021.

Liu, Y., Zhan, J., Zheng, F., Song, B., Zhang, Y., Ma, W., Hua, C., Xie, J., Bao, X., Yan, C., Bianchi, F., Petäjä, T., Ding, A., Song, Y., He, H., and Kulmala, M.: Dust emission reduction enhanced gas-to-particle conversion of ammonia in the North China Plain, Nature Communications, 13, 6887, https://doi.org/10.1038/s41467-022-34733-4, 2022.

Melnikov, V., Gennadinik. V., Kulmala, M., Lappalainen, K. H., Petäjä , P. and Zilitinkevich, S.: Cryosphere: a kingdom of anomalies and diversity, Atmos. Chem. Phys., 18, 6535-6542, https://doi.org/doi.org/10.5194/acp-18-6535-2018, 2018.

Miettinen, J., Carlier, S., Häme, L., Mäkelä, A., Minunno, F., Penttilä, J., Pisl, J., Rasinmäki, J., Rauste, Y., Seitsonen, L., Tian, X., and Häme, T.: Demonstration of large area forest volume and primary production estimation approach based on Sentinel-2 imagery and process based ecosystem modelling, International Journal of Remote Sensing, 42:24, 9467-9489, https://doi.org/10.1080/01431161.2021.1998715, 2021.

Mirtl, M., Borer, E.T., Djukic, I., Forsius, M., Haubold, H., Hugo, W., Jourdan, J., Lindenmayer, D., McDowell, W.H., Muraoka, H., Orenstein, D.E., Pauw, J.C., Peterseil, J., Shibata, H., Wohner, C., Yu, X., and Haase, P.: Genesis, goals and achievements of Long-Term Ecological Research at the global scale: A critical review of ILTER and future directions. Science of the Total Environment 626: 1439-1462, https://doi.org/10.1016/j.scitotenv.2017.12.001, 2018.

Neefjes, I., Laapas, M., Liu, Y., Médus, E., Miettunen, E., Ahonen, L., Quéléver, L., Aalto, J., Bäck, J., Kerminen, V-M., Lamplahti, J., Luoma, K., Mäki, M., Mammarella, I., Petäjä, T., Räty, M., Sarnela, N., Ylivinkka, I., Hakala, S., Kulmala, M., Nieminen, T., and Lintunen, A: 25 years of atmospheric and

ecosystem measurements in a boreal forest — Seasonal variation and responses to warm and dry years. Boreal Environment Research 27, 1, ISSN 1797-2469 (online), 2022.

Nevalainen, O., Niemitalo, O., Fer, I., Juntunen, A., Mattila, T., Koskela, O., Kukkamäki, J., Höckerstedt, L., Mäkelä, L., Jarva, P., Heimsch, L., Vekuri, H., Kulmala, L., Stam, Å., Kuusela, O., Gerin, S., Viskari, T., Vira, J., Hyväluoma, J., Tuovinen, J.-P., Lohila, A., Laurila, T., Heinonsalo, J., Aalto, T., Kunttu, I., and Liski, J.: Towards agricultural soil carbon monitoring, reporting, and verification through the Field Observatory Network (FiON). Geoscientific Instrumentation, Methods and Data Systems, https://doi.org/10.5194/gi-11-93-2022, 2022

Nie, W., Yan, C., Huang, D., Wang, Z., Liu, Y., Qiao, X., Guo, Y., Tian, L., Zheng, P., Xu, Z., Li, Y., Xu, Z., Qi, X., Sun, P., Wang, J., Zheng, F., Li, X., Yin, R., Dallenbach, K., Ding, A.: Secondary organic aerosol formed by condensing anthropogenic vapours over China's megacities, Nature Geoscience, 15, 1-7, https://doi.org/10.1038/s41561-022-00922-5, 2022.

Nie, Y., Uotila, P., Cheng, B., Massonnet, F., Kimura, N., Cipollone, A., and Lv, X.: Southern Ocean sea ice concentration budgets of five ocean-sea ice reanalyses. Clim. Dyn., 59, 3265-3285, https://doi.org/10.1007/s00382-022-06260-x, 2022.

Nieminen, T., Kerminen, V.-M., Petäjä, T., Aalto, P. P., Arshinov, M., Asmi, E., Baltensperger, U., Beddows, D. C. S., Beukes, J. P., Collins, D., Ding, A., Harrison, R. M., Henzing, B., Hooda, R., Hu, M., Hõrrak, U., Kivekäs, N., Komsaare, K., Krejci, R., Kristensson, A., Laakso, L., Laaksonen, A., Leaitch, W. R., Lihavainen, H., Mihalopoulos, N., Németh, Z., Nie, W., O'Dowd, C., Salma, I., Sellegri, K., Svenningsson, B., Swietlicki, E., Tunved, P., Ulevicius, V., Vakkari, V., Vana, M., Wiedensohler, A., Wu, Z., Virtanen, A., and Kulmala, M.: Global analysis of continental boundary layer new particle formation based on long-term measurements, Atmos. Chem. Phys., 18, 14737–14756, https://doi.org/10.5194/acp-18-14737-2018, 2018.

Nikolaidis N, Orenstein, D., Choler, Ph., Bäck, J., Barov, B., Brown, M., Dirnböck, Th., Gaillardet, J., Haubold, H., Rennie, S., Watkins, J., Kaukolehto, M., and Mirtl M.: eLTER RI Strategic Plan. Deliverable D1.1 EU Horizon 2020 eLTER PPP Project, Grant agreement No. 871126, https://elter-ri.eu/storage/app/uploads/public/62c/e9d/a42/62ce9da42ce55823718157.pdf, 2021

Noe, S.M., Tabakova, K., Mahura, A., Lappalainen, H.K., Kosmale, M., Heilimo, J., Salzano, R., Santoro, M., Salvatori, R., Spolaor, A., Cairns, W., Barbante, C., Pankratov, F., Humbert, A., Sonke, J.E., Law, K.S., Onishi, T., Paris, J.-D., Skov, H., Massling, A., Dommergue, A., Arshinov, M., Davydov, D., Belan, B., Petäjä, T.: Arctic observations and sustainable development goals – Contributions and examples from ERA-PLANET iCUPE data, Environmental Science & Policy, 132, 323-336, ISSN 1462-9011, https://doi.org/10.1016/j.envsci.2022.02.034, 2022.

OECD, The Economic Consequences of Outdoor Air Pollution, OECD Publishing, Paris, ISBN: 9789264257474, 2016.

Okuljar, M., Kuuluvainen, H., Kontkanen, J., Garmash, O., Olin, M., Niemi, J. V., Timonen, H., Kangasluoma, J., Tham, Y. J., Baalbaki, R., Sipilä, M., Salo, L., Lintusaari, H., Portin, H., Teinilä, K., Aurela, M., Dal Maso, M., Rönkkö, T., Petäjä, T., and Paasonen, P.: Measurement report: The influence of traffic and new particle formation on the size distribution of 1–800 nm particles in Helsinki – a street canyon and an urban background station comparison. Atmospheric Chemistry and Physics, 21(13), 9931–9953, https://doi.org/10.5194/acp-21-9931-2021, 2021.

Olin, M., Kuuluvainen, H., Aurela, M., Kalliokoski, J., Kuittinen, N., Isotalo, M., Timonen, H. J., Niemi, J. V., Rönkkö, T., and Dal Maso, M.: Traffic-originated nanocluster emission exceeds H2SO4-driven photochemical new particle formation in an urban area, Atmos. Chem. Phys., 20, 1–13, https://doi.org/10.5194/acp-20-1-2020, 2020.

Olin M., Patoulias D., Kuuluvainen H., Niemi J.V., Rönkkö T., Pandis S.N., Riipinen I., and Dal Maso M.: Contribution of traffic-originated nanoparticle emissions to regional and local aerosol levels, Atmospheric Chemistry and Physics, https://doi.org/10.5194/acp-22-1131-2022, 2022.

Ovaska, A. and Männistö, E. (Eds.): Abstract Book of the ACCC & Finnish Atmospheric Science Network Conference 2022, 21.11. – 22.11.2022 Tampere, Report Series in Aerosol Science N:o 257 (2022). ISBN 978-952-7276-93-8, ISSN 2814-4236, http://www.faar.fi/, 317 pp., 2022.

Palviainen, M., Aaltonen, H., Laurén, A., Köster, K., Berninger, F., Ojala, A., and Pumpanen, J.: Biochar amendment increases tree growth in nutrient-poor, young Scots pine stands in Finland. Forest Ecology and Management 474, 118362, https://doi.org/10.1016/j.foreco.2020.118362, 2020.

Palviainen M., Peltomaa E., Laurén A., Kinnunen N., Ojala A., Berninger F., Zhu X., and Pumpanen J.: Water quality and the biodegradability of dissolved organic carbon in drained boreal peatland under different forest harvesting intensities. Science of the Total Environment, 806, https://doi.org/10.1016/j.scitotenv.2021.150919, 2022.

Pan Eurasian Experiment (PEEX) Science Plan. Editors Lappalainen H.K., Kulmala M. and S. Zilitinkevich. Copyright © 2015 WEB: www.atm.helsinki.fi/peex, ISBN 978-951-51-0587-5 (printed), ISBN 978-951-51-0588-2 (online)

Parkatti V.-P. and Tahvonen, O.: Optimizing continuous cover and rotation forestry in mixed-species boreal forests, Can. J. For. Res., 50, 11, https://cdnsciencepub.com/doi/10.1139/cjfr-2020-0056, 2020.

Peltomaa, E., Könönen, M., Palviainen, M., Laurén, A., Zhu, X., Kinnunen, N., Aaltonen, H., Ojala, A., and Pumpanen, J.: Impact of Forest Harvesting Intensity and Water Table on Biodegradability of Dissolved Organic Carbon in Boreal Peat in an Incubation Experiment. Forests, 13(4), 599, https://doi.org/10.3390/f13040599, 2022.

Persson et al., 2022 tba

Petäjä, T., V. Vakkari, T. Pohja, T. Nieminen, H. Laakso, P.P. Aalto, P. Keronen, E. Siivola, V.-M. Kerminen, M. Kulmala and Laakso, L.: Transportable Aerosol Characterization Trailer with Trace Gas Chemistry: Design, Instruments and Verification, Aerosol Air Qual. Res. 13, 421–435, https://doi.org/10.4209/aaqr.2012.08.0207, 2013.

Petaja T. Jarvi, L., Kerminen, V.-M., Ding, A. J., Sun, J. N., Nie, W., Kujansuu, J., Virkkula, A., Yang, X. Q., Fu, C. B., Zilitinkevich, S., and Kulmala, M.: Enhanced air pollution via aerosol-boundary layer feedback in China, Scientific Reports 6, https://doi.org/10.1038/srep18998, 2016.

Petäjä, T., Duplissy, E.-M., Tabakova, K., Schmale, J., Altstädter, B., Ancellet, G., Arshinov, M., Balin, Y., Baltensperger, U., Bange, J., Beamish, A., Belan, B., Berchet, A., Bossi, R., Cairns, W. R. L., Ebinghaus, R., El Haddad, I., Ferreira-Araujo, B., Franck, A., Huang, L., Hyvärinen, A., Humbert, A., Kalogridis, A.-C., Konstantinov, P., Lampert, A., MacLeod, M., Magand, O., Mahura, A., Marelle, L., Masloboev, V., Moisseev, D., Moschos, V., Neckel, N., Onishi, T., Osterwalder, S., Ovaska, A., Paasonen, P., Panchenko, M., Pankratov, F., Pernov, J. B., Platis, A., Popovicheva, O., Raut, J.-C., Riandet, A., Sachs, T., Salvatori, R., Salzano, R., Schröder, L., Schön, M., Shevchenko, V., Skov, H., Sonke, J. E., Spolaor, A., Stathopoulos, V. K., Strahlendorff, M., Thomas, J. L., Vitale, V., Vratolis, S., Barbante, C., Chabrillat, S., Dommergue, A., Eleftheriadis, K., Heilimo, J., Law, K. S., Massling, A., Noe, S. M., Paris, J.-D., Prévôt, A. S. H., Riipinen, I., Wehner, B., Xie, Z., and Lappalainen, H. K.: Overview: Integrative and Comprehensive Understanding on Polar Environments (iCUPE) – concept and initial results. Atmos. Chem. Phys., 20, 8551–8592, https://doi.org/10.5194/acp-20-8551-2020, 2020.

Petäjä, T., Ganzei, K. S., Lappalainen, H. K., Tabakova, K., Makkonen, R., Räisänen, J., Chalov, S., Kulmala, M., Zilitinkevich, S., Baklanov, P. Y., Shakirov, R. B., Mishina, N. V., Egidarev, E. G. & Kondrat'ev, I. I.: Research agenda for the Russian Far East and utilization of multi-platform now and for the future. https://doi.org/10.1080/17538947.2020.1826589, 2021.

Petäjä, T., Tabakova, K., Manninen, A., Ezhova, E., O'Connor, E., Moisseev, D., Sinclair, V., Backman, J., Levula, J., Luoma, K., Virkkula, A., Paramonov, M., Räty, M., Äijälä, M., Heikkinen, L., Ehn, M., Sipilä, M., Yli-Juuti, T., Virtanen, A., Ritsche, M., Hickmon, N., Pulik, G., Rosenfeld, D., Worsnop, D., Bäck, J, Kulmala, M., and Kerminen, V-M.: Influence of biogenic emissions from boreal forests on aerosol-cloud interactions. Nature Geoscience 15, 42. https://doi.org/10.1038/s41561-021-00876-0, 2022.

Pilotto, F., Kühn, I., Adrian, R., Alber, R., Alignier, A., Andrews, C., Bäck, J., Barbaro, L., Beaumont, D., Beenaerts, N., Benham, S., Boukal, D. S., Bretagnolle, V., Camatti, E., Canullo, R., Cardoso, P. G., Ens, B. J., Everaert, G., Evtimova, V., Feuchtmayr, H., Garcia-Gonzalez, R., Gomez Garcia, D., Grandin, U., Gutowski, J.M., Hadar, L., Halada, L., Halassy, M., Hummel, H., Huttunen, K-L.,

Jaroszewicz, B., Jensen, T.C., Kalivoda, H., Schmidt, I.K., Kroencke, I., Leinonen, R., Martinho, F., Meesenburg, H., Meyer, J., Minerbi, S., Monteith, D., Nikolov, B.P., Oro, D., Ozolins, D., Padedda, B.M., Pallett, D., Pansera, M., Pardal, M.A., Petriccione, B., Pipan, T., Poeyry, J., Schaefer, S.M., Schaub, M., Schneider, S.C., Skuja, A., Soetaert, K., Springe, G., Stanchev, R., Stockan, J.A., Stoll, S., Sundqvist, L., Thimonier, A., Van Hoey, G., Van Ryckegem, G., Visser, M.E., Vorhauser, S., and Haase, P.: Meta-analysis of multidecadal biodiversity trends in Europe, Nature Communications, 11(1), 3486, https://doi.org/10.1038/s41467-020-17171-y, 2020.

Post, E., Forchhammer, M., Bret-Harte, M, Callaghan, T., Christensen, T.R., Elberling, B., Fox, A., Gilg, O., Hik, D., Høye, T.T., Ims, R.A., Jeppesen, E., Klein, D.R., Madsen, J., McGuire, A.d., Rysgaard, S., Schindler, D.e., Stirling, I., Tamstorf, M.P., Tyler, N.J.C., Van der Wal, R., Welker, J., Wookey, P.A., Schmidt, N.M., and Aastrup,P.: Ecological Dynamics Across the Arctic Associated With Recent Climate Change, science, 325(5946), 1355-8, https://doi.org/10.1126/science.1173113, 2009.

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S. III, Lambin, E., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H., Nykvist, B., De Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S, Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D. , Richardson, K., Crutzen, P., and Foley, J.: Planetary boundaries: Exploring the safe operating space for humanity. Ecol. Soc., 14, 2, 32, https://www.ecologyandsociety.org/vol14/iss2/art32/, 2009.

Roe, S., Streck, C., Obersteiner, M., Frank, S., Griscom, B., Drouet, L., Fricko, O., Gusti, M., Harris, N., Hasegawa,T., Hausfather, Z., Havlík, P., House, J., Nabuurs, G-J-., Popp, A., Sanz Sánchez, M.J., Sanderman, J., Smith, P., Stehfest, E., and Lawrence, D.: Contribution of the land sector to a 1.5 °C world. Nat. Clim. Chang. 9, 817–828, https://doi.org/10.1038/s41558-019-0591-9, 2019.Rose, C., M. Collaud Coen, E. Andrews, Y. Lin, I. Bossert, C. Lund Myhre, T. Tuch, A. Wiedensohler, M. Fiebig, P. Aalto, A. Alastuey, E. Alonso-Blanco, M. Andrade, B. Artíñano, T. Arsov, U. Baltensperger, S. Bastian, O. Bath, J.P. Beukes, B.T. Brem, N. Bukowiecki, J.A. Casquero-Vera, S. Conil, K. Eleftheriadis, O. Favez, H. Flentje, M.I. Gini, F.J. Gómez-Moreno, M. Gysel-Beer, A.G. Hallar, I. Kalapov, N. Kalivitis, A. Kasper-Giebl, M. Keywood, J.E. Kim, S.-W. Kim, A. Kristensson, M. Kulmala, H. Lihavainen, N.-H. Lin, H. Lyamani, A. Marinoni, S. Martins Dos Santos, O.L. Mayol-Bracero, F. Meinhardt, M. Merkel, J.-M. Metzger, N. Mihalopoulos, J. Ondracek, M. Pandolfi, N. Pérez, T. Petäjä, J.-E. Petit, D. Picard, J.-M. Pichon, V. Pont, J.-P. Putaud, F. Reisen, K. Sellegri, S. Sharma, G. Schauer, P. Sheridan, J.P. Sherman, A. Schwerin, R. Sohmer, M. Sorribas, J. Sun, P. Tulet, V. Vakkari, P.G. van Zyl, F. Velarde, P. Villani, S. Vratolis, Z. Wagner, S.-H. Wang, K. Weinhold, R. Weller, M. Yela, V. Zdimal and P. Laj : Seasonality of the particle number concentration and size distribution: a global analysis retrieved from the network of Global Atmosphere Watch (GAW) near-surface observatories, Atmos. Chem. Phys. 21, 17185–17223, https://doi.org/10.5194/acp-21-17185-2021, 2021.

Ruuhela, R., Hyvärinen, O., and Jylhä, K.: Regional Assessment of Temperature-Related Mortality in Finland. Int. J. Environ. Res. Public Health, 15, 406. https://doi.org/10.3390/ijerph15030406, 2018.

Ruuskanen, T., Vehkamäki, H., Riuttanen, L., and Lauri, A.: An Exploratory Study of the Learning of Transferable Skills in a Research-Oriented Intensive Course in Atmospheric Sciences. Sustainability, 10, 1385, https://doi.org/10.3390/su10051385, 2018.

Räsänen, M., Aurela, M., Vakkari, V., Beukes, J. P., Tuovinen, J.-P., Van Zyl, P. G., Josipovic, M., Venter, A. D., Jaars, K., Siebert, S. J., Laurila, T., Rinne, J., and Laakso, L.: Carbon balance of a grazed savanna grassland ecosystem in South Africa, Biogeosciences 14, 1039–1054. https://doi.org/10.5194/bg-14-1039-2017, 2017.

Räsänen, M., Merbold, L., Vakkari, V., Aurela, M., Laakso, L., Beukes, J.P., Van Zyl, P.G., Josipovic, M., Feig, G., Pellikka, P., Rinne, J,. and Katul, G.G.: Root-zone soil moisture variability across African savannas: From pulsed rainfall to land-cover switches, Ecohydrology 13, e2213, https://doi.org/10.1002/eco.2213, 2020.

Räsänen, M., Aurela, M., Vakkari, V., Beukes, J.P., Tuovinen, J-P., van Zyl, P.G., Josipovic, M., Siebert, S.J., Laurila, T., Kulmala, M., Laakso, L., Rinne, J., Oren, R., and Katul, G.: The effect of rainfall

amount and timing on annual transpiration in a grazed savanna grassland, Hydrol. Earth Syst. Sci. 26, 5773–5791. https://doi.org/10.5194/hess-26-5773-2022, 2022.

Salo L., Hyvärinen A., Jalava P., Teinilä K., Hooda R.K., Datta A., Saarikoski S., Lintusaari H., Lepistö T., Martikainen S., Rostedt A., Sharma V.P., Rahman M.H., Subudhi S., Asmi E., Niemi J.V., Lihavainen H., Lal B., Keskinen J., Kuuluvainen H., Timonen H., and Rönkkö T.: The characteristics and size of lung-depositing particles vary significantly between high and low pollution traffic environments, Atmospheric Environment, 255, https://doi.org/10.1016/j.atmosenv.2021.118421, 2021.

Salo L., Rönkkö T., Saarikoski S., Teinilä K., Kuula J., Alanen J., Arffman A., Timonen H., and Keskinen J.: Concentrations and size distributions of particle lung-deposited surface area (LDSA) in an underground mine, Aerosol and Air Quality Research, 21, 8, https://doi.org/10.4209/aaqr.200660, 2021.

Samset, B.H., Sand, M., Smith, C. J., Bauer, S.E., Forster, P.M.., J. S. Fuglestvedt, S. Osprey, C.-F. Schleussner : Climate Impacts From a Removal of Anthropogenic Aerosol Emissions, https://doi.org/10.1002/2017GL076079, 2018.

Santala and Makkonen, 2019 tba

Santala et al. 2019 tba

Segar, J., Pereira, H.M., Baeten, L., Bernhardt-Römermann, M., De Frenne, P., Fernández, N., Gilliam, F.S., Lenoir, J., Ortmann-Ajkai, A., Verheyen, K., Waller, D., Telekim B., Brunet, J., Chudomelová, M., Decocq, G., Dirnböck, T., Hédl, R., Heinken, T., Jaroszewicz, B., Kopecký, M., Macek, M., Máliš , F., Naaf, T., Orczewska, A., Reczynska, K., Schmidt, W., Šebesta, J., Stachurska-Swakoń, A., Standovár, T., Swierkosz, K., Vild, O., Wulf, M., and Staude, I.R.: () Divergent roles of herbivory in eutrophying forests, Nature Communications 13, 7837, https://doi.org/10.1038/s41467-022-35282-6, 2022.

Shupe, M.D., Rex, M., Blomquist, B., Persson, O.G., Schmale, J., Uttal, T., Althausen, D., Boyer, M., Brasseur, Z., Brooks, I.M., Jokinen, T., Laurila, T., Petaja, T., Pirazzini, R., and Quelever, L.:. Overview of the MOSAiC Expedition – Atmosphere, Elementa, 10, 1, 00060, https://doi.org/10.1525/elementa.2021.00060, 2022.

Sizov, O., Ezhova, E., Tsymbarovich, P., Soromotin, A., Prihod'ko, N., Petäjä, T., Zilitinkevich, S., Kulmala, M., Bäck, J., and Köster, K.: Fire and vegetation dynamics in northwest Siberia during the last 60 years based on high-resolution remote sensing. Biogeosciences, 18, 207–228. https://doi.org/10.5194/bg-18-207-2021, 2021.

Sormunen, J. J., Andersson, T., Aspi, J., Bäck, J., Cederberg, T., Haavisto, N., Halonen, H., Hänninen, J., Inkinen, J., Kulha, N., Laaksonen, M., Loehr, J., Mäkelä, S., Mäkinen, K., Norkko, J., Paavola, R., Pajala, P., Petäjä, T., Puisto, A., .Sippola, E., Snickars, M., Sundell, J., Tanski, N., Uotila, A., Vesilahti, E.-M., Vesterinen, E.J., Vuorenmaa, S., Ylönen, H., Ylönen, J., and Klemola, T.: Monitoring of ticks and tickborne pathogens through a nationwide research station network in Finland, Ticks and Tickborne Diseases, 11(5), 101449, https://doi.org/10.1016/j.ttbdis.2020.101449, 2020.

Sofiev, M.: On possibilities of assimilation of near-real-time pollen data by atmospheric composition models, Aerobiologia 1. https://doi.org/10.1007/s10453-019-09583-1, 2019.

Sofiev, M., Ritenberga, O., Albertini, R., Arteta, J., Belmonte, J., Bonini, M., Celenk, S., Damialis, A., Douros, J., Elbern, H., Friese, E., Galan, C., Gilles, O., Hrga, I., Kouznetsov, R., Krajsek, K., Plu, M., Prank, M., Robertson, L., Steensen, B.M., Thibaudon, M., Segers, A., Stepanovich, B., Valdebenito, A.M., Vira, J., and Vokou, D.: Multi - model ensemble simulations of olive pollen distribution in Europe in 2014, Atmospheric Chemistry and Physics 17, 12341–12360, https://doi.org/10.5194/acp-17-12341-2017, 2017.

Sofiev, M., Siljamo, P., Ranta, H., Linkosalo, T., Jaeger, S., Rasmussen, A., Rantio-Lehtimaki, A., Severova, E., and Kukkonen, J.: A numerical model of birch pollen emission and dispersion in the atmosphere. Description of the emission module. International journal of biometeorology 57, 54–58. https://doi.org/10.1007/s00484-012-0532-z, 2012.

Sofiev, M., Sofieva, S., Palamarchuk, J., Šaulienė, I., Kadantsev, E., Atanasova, N., Fatahi, Y., Kouznetsov, R., Kuula, J., Noreikaite, A., Peltonen, M., Pihlajamäki, T., Saarto, A., Svirskaite, J., Toiviainen, L., Tyuryakov, S., Šukienė, L., Asmi, E., Bamford, D., Hyvärinen, A.-P., and Karppinen, A.:

ACCC Research & Innovation (R&I) Ecosystem and Roadmap – a living document

Bioaerosols in the atmosphere at two sites in Northern Europe in spring 2021: Outline of an experimental campaign. Environmental Research 214, 113798, https://doi.org/10.1016/j.envres.2022.113798, 2022.

Tahvonen, O., Rämö, J., and Mönkkönen, M.: Economics of mixed-species forestry with ecosystem services, Canadian Journal of Forest Research, 49(10), 1219-1232, https://doi.org/10.1139/cjfr-2018-0514б, 2019.

Tang, J., Zhou., P., Miller, P., Schurgers, G., Gustafson, A., Makkonen, R., Fu, Y., and Rinnan, R.: High latitude vegetation changes will determine future plant volatile impacts on atmospheric organic aerosols, submitted to Nature Communications, Preprint from Research Square, https://doi.org/10.21203/rs.3.rs-1143422/v1, 2022.

Thum, T., Nabel, J. E. M. S., Tsuruta, A., Aalto, T., Dlugokencky, E. J., Liski, J., Luijkx, I. T., Markkanen, T., Pongratz, J., Yoshida, Y., and Zaehle, S.: Evaluating two soil carbon models within the global land surface model JSBACH using surface and spaceborne observations of atmospheric CO2, Biogeosciences, 17, 5721–5743, https://doi.org/10.5194/bg-17-5721-2020, 2020.

Tiitta, P., Vakkari, V., Croteau, P., Beukes, J. P., van Zyl, P. G., Josipovic, M., Venter, A. D., Jaars, K., Pienaar, J. J., Ng, N. L., Canagaratna, M. R., Jayne, J. T., Kerminen, V. -M., Kokkola, H., Kulmala, M., Laaksonen, A., Worsnop, D. R., and Laakso, L.: Chemical composition, main sources and temporal variability of PM1 aerosols in southern African grassland. Atmospheric Chemistry and Physics, 14(4), 1909-1927, https://doi.org/10.5194/acp-14-1909-2014, 2014.

Timofeev, V., Bahtejeva, I., Mironova, R., Titareva, G., Lev, I., Christiany, D., Borzilov, A., Bogun, A., Vergnaud G.: Insights from Bacillus anthracis strains isolated from permafrost in the tundra zone of Russia. PLoS One, 14(5), e0209140, https://doi.org/10.1371/journal.pone.0209140, 2019.

Tuomenvirta, H., Gregow, H., Harjanne, A., Luhtala, S., Mäkelä, A., Pilli-Sihvola, K., Juhola, S., Hilden, M., Peltonen-Sainio, P., Miettinen, I.T., and Halonen, M.: Identifying Policy Actions Supporting Weather-Related Risk Management and Climate Change Adaptation in Finland, Sustainability, 11, 13, 3661, https://doi.org/10.3390/su11133661, 2019.

Tröstl, J., Chuang, W., Gordon, H., Heinritzi, M., Yan, C., Molteni, U., Ahlm, L., Frege, C., Bianchi, F., Wagner, R., Simon, M., Lehtipalo, K., Williamson, C., Craven, J., Duplissy, J., damov, A., Almeida, J., Bernhammer, A.-K., Breitenlechner, M., Baltensperger, U.: The role of low- volatility organic compounds in initial particle growth in the atmosphere, *Nature*, 533, 527-531, https://doi.org/10.1038/nature18271, 2016.

UNEP, Nations Environment Programme (2016): The Adaptation Finance Gap Report 2016, Nairobi, Kenya, https://wedocs.unep.org/20.500.11822/32865, 2016.

Uotila, P., H. Goosse, K. Haines, M. Chevallier, A. Barthélemy, C. Bricaud, J. Carton, N. Fučkar, G. Garric, D. Iovino, F. Kauker, M. Korhonen, V. S. Lien, M. Marnela, F. Massonnet, D. Mignac, K. A. Peterson, R. Sadikni, L. Shi, S. Tietsche, T. Toyoda, J. Xie, and Z. Zhang: An assessment of ten ocean reanalyses in the polar regions, Clim. Dyn., doi:10.1007/s00382-018-4242-z, 2019.

Vakkari, V., Beukes, J. P., Laakso, H., Mabaso, D., Pienaar, J. J., Kulmala, M., and Laakso, L.: Long-term observations of aerosol size distributions in semi-clean and polluted savannah in South Africa. Atmospheric Chemistry and Physics, 13(4), 1751-1770, https://doi.org/10.5194/acp-13-1751-2013, 2013.

Vakkari, V., Kerminen, V.-M., Beukes, J.P., Tiitta, P., van Zyl, P.G., Josipovic, M., Venter, A.D., Jaars, K. Worsnop, D.R., Kulmala, M., and Laakso, L.: Rapid changes in biomass burning aerosols by atmospheric oxidation, Geophys. Res. Lett. 41, 2644–2651, https://doi.org/10.1002/2014GL059396, 2014.

Vakkari, V., Tiitta, P., Jaars, K., Croteau, P., Beukes, J.P., Josipovic, M. Kerminen, V.-M., Kulmala, M.,Venter, A.D., van Zyl, P.G., Worsnop, D.R., and Laakso, L.: Re-evaluating the contribution of sulfuric acid and the origin of organic compounds in atmospheric nanoparticle growth, Geophys. Res. Lett. 42, 10486–10493, https://doi.org/10.1002/2015GL066459, 2015.

72

Vakkari, V., Beukes, J. P., Dal Maso, M., Aurela, M., Josipovic, M., and van Zyl, P.G.: Major secondary aerosol formation in southern African open biomass burning plumes, Nature Geosci. 11, 580–583, 10.1038/s41561-018-0170-0, 2018.

van Asselt, H., Huitema, D., and Jordan, A.: Global Climate Governance after Paris: Setting the Stage for Experimentation? In B. Turnheim, P. Kivimaa, and F. Berkhout (Eds.), Innovating Climate Governance: Moving beyond Experiments (pp. 27-46). Cambridge University Press. https://doi.org/10.1017/9781108277679.003, 2018.

Vihma, T., Uotila, P., Sandven, S., Pozdnyakov, D., Makshtas, A., Pelyasov, A., Pirazzini, R., Danielsen, F., Chalov, S., Lappalainen, H. K., Ivanov, V., Frolov, I., Albin, A., Cheng, B., Dobrolyubov, S., Arkhipkin, V., Myslenkov, S., Petäjä, T., and Kulmala, M.: Towards an advanced observation system for the marine Arctic in the framework of the Pan-Eurasian Experiment (PEEX), Atmos. Chem. Phys., 19, 1941–1970, https://doi.org/10.5194/acp-19-1941-2019, 2019.

Viskari, T., Pusa, J., Fer, I., Repo, A., Vira, J., and Liski, J.: Calibrating the soil organic carbon model Yasso20 with multiple datasets, Geosci. Model Dev., 15, 1735–1752, https://doi.org/10.5194/gmd-15-1735-2022, 2022.

Votsis A., Ruuhela R., and Gregow H.,: The socio-spatial patterns of heat stress exposure in Helsinki on two hot days of 2018 and 2019, FMI's Climate Bulletin: Research Letters, 3(1), 22–24, https://doi.org/10.35614/ISSN-2341-6408-IK-2021-08-RL, 2021.

Votsis, A.: Utilizing a 73elular automaton model to explore the influence of coastal flood adaptation strategies on Helsinki's urbanization patterns, Comp. Env. Urban Syst., 64, 344–355, https://doi.org/10.1016/j.compenvurbsys.2017.04.005, 2017.

Wang, J., Zhao, B., Wang, S., Yang, F., Xing, J., Morawska, L., Ding, A., Kulmala, M., Kerminen,V.-M., Kujansuu, J., Wang, Z., Ding, D., Zhang, X., Wang, H., Tian, M., Petaja, T., Jiang, J., and Hao, J.: Particulate matter pollution over China and the effects of control policies, Science of the Total Environment 584, 426-447, https://doi.org/10.1016/j.scitotenv.2017.01.027, 2017.

Wu, R., Dai, H., Geng, Y., Xie, Y., Masui, T., Liu, Z., Qian, Y.: Economic Impacts from PM2.5 Pollution-Related Health Effects: A Case Study in Shanghai, Environ Sci Technol 51, 5035-5042, https://doi.org/10.1021/acs.est.7b00026, 2017.

Yamineva, Y. and Kulovesi, K.: Keeping the Arctic White: The Legal and Governance Landscape for Reducing Short-Lived Climate Pollutants in the Arctic Region Transnat. Env. Law, 7, 201-227, https://doi.org/10.1017/S2047102517000401, 2018.

Yan, C., Nie, W., Vogel, A. L., Dada, Lehtipalo, K., Stolzenburg, D., Wagner, R., Rissanen, M.P., Xiao, M., Ahonen, L., Fischer, L., Rose, C., Bianchi, F., Gordon, H., Simon, M., Heinritzi, M., Garmash, O., Roldin, P., Dias, A., Ye, P., Hofbauer, V., Amorim, A., Bauer, P.S., Bergen, A., Bernhammer, A.-K., Breitenlechner, M., Brilke, S., Buchholz, A., Buenrostro Mazon, S., Canagaratna, M.R., Chen, X., Ding, A., Dommen, J., Draper, D.C., Duplissy, J., Frege, C., Heyn,C., Guida,R., Hakala, J., Heikkinen, L., Hoyle, C.R., Jokinen, T., Kangasluoma, J., Kirkby, J., Kontkanen, J., Kürten, A., Lawler, M.J., Mai, H., Mathot, S., Mauldin, R. L. III, , Molteni, U.,Nichman, L., Nieminen, T., Nowak, J., Ojdanic, A., Onnela, A., Pajunoja, A., Petäjä, T., Piel, F., Quéléver,L.L.J., Sarnela, N., Schallhart, S., Sengupta, K., Sipilä, M.,Tomé, A., Tröstl, J., Väisänen, O., Wagner, A.C., Ylisirniö, A., Zha, Q., Baltensperger, U.,Carslaw, K.S., Curtius, J., Flagan, R.C., Hansel, A.,Riipinen, I., Smith,J.N., Virtanen, A., Winkler, P.M., Donahue, N.M.,Kerminen, V.-M., Kulmala, M., Ehn, M., and Worsnop, D.R.: Size-dependent influence of NOx on the growth rates of organic aerosol particles. Sci. Adv. 6, 22, eaay4945, https://www.science.org/doi/10.1126/sciadv.aay4945, 2020.

Yan, C., Shen, Y., Stolzenburg, D., Dada, L., Qi, X., Hakala, S., Sundström, A-M., Guo, Y., Lipponen, A., Kokkonen, T., Kontkanen, J., Cai, R., Cai, J., Chan, T., Chen, L., Chu, B., Deng, C., Du, W., Fan, X., and Kulmala, M.: The effect of COVID-19 restrictions on atmospheric new particle formation in Beijing, Atmospheric Chemistry and Physics discussion, https://doi.org/10.5194/acp-2021-1079, 2022.

Yao, L., Garmash, O., Bianchi, F., Zheng, J., Yan, C., Kontkanen, J., Junninen, H., Mazon, S.B., Ehn, M., Paasonen, P., Sipilä, M., Wang, M., Wang, X., Xiao, S., Chen, H., Lu, Y., Zhang, B., Wang, D., Fu, Q.,

Geng, F., Li, L., Wang, H., Qiao, L., Yang, X., Chen, J., Kerminen, V.M., Petäjä, T., Worsnop, D.R., Kulmala, M., and Wang, L.: Atmospheric new particle formation from sulfuric acid and amines in a Chinese megacity, Science 361(6399), 278-281, https://doi.org/10.1126/science.aao4839, 2018.

Yli-Juuti, T., Mielonen, T., Heikkinen, L., Arola, A., Ehn, M., Isokääntä, S., Keskinen, H-M., Kulmala, M., Laakso, A., Lipponen, A., Luoma, K., Mikkonen, S., Nieminen, T., Paasonen, P., Petäjä, T., Romakkaniemi, S., Tonttila, J., Kokkola, H., and Virtanen, A.: Significance of the organic aerosol driven climate feedback in the boreal area, Nature Communications, 12, 1, 5637, https://doi.org/10.1038/s41467-021-25850-7, 2021.

Zhang, G., Jing, S., Xu, W., Gao, Y., Yan, C., Liang, L., Huang, C., and Wang, H.: Simultaneous observation of atmospheric peroxyacetyl nitrate and ozone in the megacity of Shanghai, China: Regional transport and thermal decomposition, Environmental Pollution, 274, 116570, https://doi.org/10.1016/j.envpol.2021.116570, 2021.

Zhang, H., Tuittila, E-S., Korrensalo, A., Laine, A. M., Uljas, S., Welti, N., Kerttula, J., Maljanen, M., Elliott, D., Vesala, T., and Lohila, A.: Methane production and oxidation potentials along a fen-bog gradient from southern boreal to subarctic peatlands in Finland, Global Change Biology, 27(18), 4449-4464, https://doi.org/10.1111/gcb.15740, 2021.

Zhang, Y., Jyske, T., Pumpanen, J., Hölttä, T., Gao, Q., Berninger, F., & Duan, B. (2021). Adaptation of Abies fargesii var. faxoniana (Rehder et E.H. Wilson) Tang S Liu seedlings to high altitude in a subalpine forest in southwestern China with special reference to phloem and xylem traits, Annals of Forest Science, 78, 85, https://doi.org/10.1007/s13595-021-01095-8, 2021.

Zhang-Turpeinen, H., Kivimäenpää, M., Berninger, F., Köster, K., Zhao, P., Zhou, X., and Pumpanen, J.: Age-related response of forest floor biogenic volatile organic compound fluxes to boreal forest succession after wildfires. Agricultural and Forest Meteorology 308-309, 108584 https://doi.org/10.1016/j.agrformet.2021.108584, 2021.

Ziska, L.H., Makra, L., Harry, S.K., Bruffaerts, N., Hendrickx, M., Coates, F., Saarto, A., Thibaudon, M., Oliver, G., Damialis, A., Charalampopoulos, A., Vokou, D., Heiđmarsson, S., Guđjohnsen, E., Bonini, M., Oh, J.-W., Sullivan, K., Ford, L., Brooks, G.D., Myszkowska, D., Severova, E., Gehrig, R., Ramón, G.D., Beggs, P.J., Knowlton, K., and Crimmins, A.R.: Temperature-related changes in airborne allergenic pollen abundance and seasonality across the northern hemisphere: a retrospective data analysis, The Lancet Planetary Health 3, e124–e131, https://doi.org/10.1016/S2542-5196(19)30015-4, 2019.

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)

ACCC Professors in Practice
Anneli Pauli (INAR UH)
Jouni Keronen (INAR UN)

Staff exchange

APPENDIX II PROJECT PORTFOLIO

NOTE: This list included projects > 500.000 euros total budget finded by Academy of Finland, Business Finland, private foundations and Horizon 2020 programs. This is not the full list of all projects carried out by the ACCC parner 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(at)fmi.fi); Annalea Lohila (annalea.lohila(at)Helsinki.fi), Jussi Heinonsalo (jussi.heinosalo(at)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(at)fmi.fi), FMI; Maarit Liimatainen (maarit.liimatainen(at)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-

76

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(at)fmi.fi), FMI; Iivari Kunttu (iivari.kunttu(at)hamk.fi), HAMK; Ernesto Hartikainen (ernesto.hartikainen(at)biocode.io), Biocode Ltd; Juha Nousiainen (juha.nousiainen(at)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(at)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(at)fmi.fi), FMI

Funding: Lantmännen Research Foundation and Lantmännen

Active: 1.7.2022-30.9.2024

Partners: Lantmännen, 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(at)fmi.fi), Finnish Meteorological Institute; Jussi Heinonsalo (jussi.heinonsalo(at)helsinki.fi), University of Helsinki; Laura Höijer (laura.hoijer(at)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 CO_2 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 CO_2 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(at)bsag.fi), BSAG; Laura Höijer (laura.hoijer(at)bsag.fi), BSAG; Annalea Lohila (annalea.lohila(at)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

78

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(at)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.

Carbon balance in forests and 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
FundingAcademy 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(at)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 CO_2 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(at)fmi.fi), FMI
FundingEU
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(at)helsinki.fi); Jukka Pumpanen, University of Eastern Finland (jukka.pumpanen(at)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(at)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(at)fmi.fi), FMI
Funding
Active: 2022-2024

80

Partners:
Website:

Developments in HPC open new research possibilities and bring policy-relevant information concerning use of atmospheric data ingreenhouse 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 CO_2 and CH_4 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(at)helsinki.fi); Ari Laurén, University of Eastern Finland (ari.lauren(at)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 (CH_4) globally. Lack of a simulation model describing CH_4 transport from peat through trees to atmosphere is a key bottle neck in assessing the global importance of tree mediated CH_4 emissions. An innovative method for computing CH_4 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(at)fmi.fi), FMI
FundingAcademy 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(at)fmi.fi), FMI
FundingEuropean 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
FundingEU
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 datafrom 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 inwetland 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(at)helsinki.fi), Veli-Matti Kerminen (veli-matti.kerminen(at)helsinki.fi), University of Helsinki; Mika Aurela (mika.aurela(at)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(at)fmi.fi), FMI
FundingEU
Active: 2023-2026
Partners: NILU

82

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 (NGHGIs). 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 NGHGIs 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 NGHGIs. 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 NGHGIs. The methodology for the atmospheric inversions and how to use these for verification of NGHGIs 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(at)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(at)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(at)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(at)uef.fi); Marjo Palviainen, University of Helsinki (marjo.palviainen(at)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 techiques 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(at)helsinki.fi); Markku Kulmala (markku.kulmaka(at)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(at)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(at)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(at)uef.fi)
Funding:
Active: 1.9.2020-31.8.2024
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

85

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(at)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(at)helsinki.fi); Kati Kulovesi, University of Eastern Finland (kati.kulovesi(at)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 CH_4 and CO_2 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.

Forests, tree ecophysiology

Sensing plant Biogenic Volatile Organic Compounds (SensBVOCs)

PI: Chao Zhang (chao.x.zhang(at)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(at)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(at)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(at)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(at)helsinki.fi)   (coordinator),   Teemu   Hölttä (teemu.holtta(at)helsinki.fi), University of Helsinki; Ari Laurén (ari.lauren(at)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(at)helsinki.fi), University of Helsinki
Funding: Academy of Finland
Active: 2019-2023
Partners:
Website:

The project will study the dependency of tree water use, CO_2 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(at)helsinki.fi), University of Helsinki
Funding: Academy of Finland Research Fellow
Active: 1.9.2023-31.8.2027
Partners:
Website:

n 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(at)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((at)helsinki.fi) - coordinator, Anna Lintunen (anna.lintunen(at)helsinki.fi), Annikki Mäkelä (annikki.makela(at)helsinki.fi), University of Helsinki; Annalea Lohila (annalea.lohila(at)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(at)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(at)helsinki.fi), Maarit Raivonen (maarit.raivonen(at)helsinki.fi), University of Helsinki; Mika Aurela (mika.aurela(at)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(at)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(at)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

Projects contributing the AQ – climate interactions (RP2)

Climate modelling

Constrained aerosol forcing for improved climate projections (FORCeS)
PIs: Tuomo Nieminen (tuomo.nieminen(at)helsinki.fi), University of Helsinki; Annele Virtanen (annele.virtanen(at)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(at)fmi.fi), FMI (project coordinator); Tuukka Petäjä (tuukka.petaja(at)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(at)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(at)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.järvinen(at)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(at)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(at)fmi.fi), FMI
FundingFinnish 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(at)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(at)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.

93

Deep into abyss: resolving the charger ions

PI: Juha Kangasluoma, University of Helsinki (juha.kangasluoma(at)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(at)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(at)helsinki.fi); Aki Virkkula, FMI (aki.virkula(at)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(at)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(at)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(at)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(at)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(at)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.

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(at)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.

Biogenic Volatile Organic Compounds (BVOCs) 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(at)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(at)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.

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(at)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(at)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(at)tuni.fi); Miikka Dal Maso (miikka.dalmaso(at)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 SOx 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 NOx for the Passenger Car Fleet in Finland (EFFi)
PI: Panu Karjalainen, Tampere University (panu.karjalainen(at)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(at)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 is 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(at)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(at)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(at)uef.fi),   UEF;   Ivan   Mammarella (ivan.mammarella(at)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(at)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(at)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(at)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(at)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 (at)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 (at)fmi.fi), FMI
FundingAcademy of Finland
Active: 1.9.2020–31.8.2024
Partners:
Website:

Deriving CO_2 emissions from satellite CO_2 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 CO_2 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 CO_2 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 CO_2 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.

Title to be added

PI: Yulia Yamineva (yulia.yamineva(at)uef.fi), UEF
Funding: ACCC
Active: 2020–2024
Partners:
Website

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. Currently these two problems are 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. This research provides a comprehensive, theoretically grounded

account mapping, untangling and explaining the climate - air quality nexus at global level and in the selected jurisdictions (EU, China). The research goes beyond traditional doctrinal analysis of norms ('law in books') and instead considers law as a policy process ('law in context'), drawing on sociolegal and policy integration scholarship.

Projects contributing cc impacts and adaptation (RP3)

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

PI: Leena Järvi, University of Helsinki (leena.jarvi(at)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 (CO_2) emissions in the EU. AIforLEssAuto 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 CO_2 emissions originating from electrified automated vehicles, and by developing artificial intelligence based control from vehicle-level to city-center wide traffic-level in which CO_2 emissions are minimized. Such multidisciplinary approach has not been done to this extent before and thus AIforLEssAuto advances the state of scientific research in all disciplines involved and the novel combination will certainly lead to new, scientifically and societally, important breakthroughs.

CLIMAte risk and vulnerability Assessment framework and toolboX (CLIMAAX)

PI: Thomas Kühn (thomas.kuhn(at)fmi.fi), FMI
Funding: EU
Active: 1.1.2023 – 31.12.2026
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(at)syke.fi), Syke; Taru Palosuo (taru.palosuo(at)luke.fi), Luke; Kirsti Jylhä (kirsti.jylha(at)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(at)uef.fi), UEF; Sakari Karvonen (sakari.karvonen(at)thl.fi), THL; Risto Kosonen (risto.kosonen(at)aalto.fi), Aalto; Kirsti Jylhä (kirsti.jylha(at)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(at)fmi.fi), FMI Anders Lindfors (DEODE) (anders.lindfors(at)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(at)fmi.fi),, Heikki Tuomenvirta (heikki. tuomenvirta(at)fmi.fi), FMI
Funding:	EU (European Regional Development Fund, ERDF)
Active:	1.3.2020-30.106.2023
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(at)fmi.fi), Ari Karppinen (ari.karppinen(at)fmi.fi), Jaakko Kukkonen (jaakko.kukkonen(at)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 (PM2.5) 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 PM2.5 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(at)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(at)helsinki.fi); Liisa Kulmala, FMI (liisa.kulmala(at)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(at)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(at)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(at)helsinki.fi); Liisa Kulmala, FMI (liisa.kulmala(at)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 Paolo). 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(at)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(at)uef.fi)
Funding: EU Horizon 2020 Green Deal Call 7.1
Active:
Partners:
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.

Locally tailored climate service for Finland (TAPSI).

PI: Hilppa Gregow, Finnish Meteorological Institute (hilppa.gregow(at)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.

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(at)utu.fi), UTU; Anna Luomaranta (anna.luomaranta(at)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(at)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(at)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. http://www.ndc-aspects.eu

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(at)uef.fi), University of Eastern Finland
Funding: EU Jean Monnet Network
Active: 2022-2025
Partners: 11 universities
Website: https://cjm.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(at)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.

Climate law

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

PI: Kati Kulovesi (kati.kulovesi(at)uef.fi), University of Eastern Finland

110

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(at)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.

Climate adaptation law
PI   Yulia Yamineva (yulia.yamineva(at)uef.fi)
Participants: Yulia Yamineva (yulia.yamineva(at)uef.fi), Tuula Honkonen (tuula.honkonen(at)uef.fi); Raihanatul Jannat (raihanatul.jannat(at)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

111

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(at)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(at)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/web/thlfi-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.

Center(s) of Excellence

Center of Excellence in Tree Biology

PI: Teemu Hölttä, University of Helsinki (teemu.holtta(at)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 (CO_2). Trees take up the CO_2 through narrow openings in their leaves (called stomata). After fixing the CO_2 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 CO_2. 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(at)helsinki.fi), Juha Kangasluoma (juha.kangasluoma(at)helsinki.fi), Mikko Sipilä (mikko.sipila(at)helsinki.fi), Theo Kurten (teo.kurten(at)helsinki.fi), University of Helsinki; Kari Lehtinen (kari.lehtinen(at)uef.fi), Siegfried Schobesberger (siegfried.schobesberger(at)uef.fi), University of Eastern Finland; Matti Rissanen (matti.rissanen(at)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

113

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(at)helsinki.fi)
Funding: EU, Teaming
Active: 1.9.2019-31.8.2026
Partners: CR Cyprus Institute (CyI), 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 (CyI) 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 CyI 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.

114

Research Infrastructures (RIs)

National RI

Integrated Atmospheric and Earth System Research Infrastructure (INAR) RI

PI:	Markku Kulmala (markku.kulmala(at)helsinki.fi), University of Helsinki: Hannele Hakola (hannele.hakola(at)fmi.fi), FMI; Kari Lehtinen (kari.lehtinen(at)uef.fi), University of Eastern Finland; Jorma Keskinen (jorma.keskinen(at)tufi.fi), Tampere University
Funding:	Academy of Finland, Finnish Research Infrastructure (FIRI)
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-infrastructures

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.

115

European Research Infrastructures (RI) projects
In situ RI
Aerosol, Clouds and Trace Gases Research Infrastructure (ACTRIS-Finland)
PI: Markku Kulmala (markku.kulmala(at)helsinki.fi), University of Helsinki; Annele Virtanen (annele.virtanen(at)uef.fi), University of Eastern Finland; Jorma Keskinen (jorma.keskinen(at)tufi.fi), Tampere University
Funding: Academy of Finland Finnish Research Infrastructure (FIRI)
Active: 1.1.2020-31.12.2024
Partners:
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. https://www2.helsinki.fi/en/infrastructures/actris-finland; https://www.actris.eu

ACTRIS Central Facilities
PI: Tuukka Petäjä (tuukka.petaja(at)helsinki.fi), University of Helsinki
Funding: Academy of Finland Finnish Research Infrastructure (FIRI)
Active: 1.1.2020-31.12.2024
Partners:
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

116

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 Implementation Project (ACTRIS IMP)

PI: Tuukka Petäjä (tuukka.petaja(at)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(at)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(at)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).

Next Generation Earth Modelling Systems (NextGEMS)

PI: Heikki Järvinen (heikki.järvinen(at)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 (at) 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 Botanics, 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.

Service RI
Knowledge and climate services from an African observation and Data research Infrastructure (KADI)

PI: Tuukka Petäjä (tuukka.petaja(at)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 CO_2. 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(at)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 CO_2 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 CO_2 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(at)fmi.fi), FMI
FundingBusiness Finland / SpaceCasting Co-Creation project led by University of Vaasa
Active: 10/2022 - 03/2023

119

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.

Station for Measuring Earth Surface-Atmosphere Relations (SMEAR)

PI: Tuukka Petäjä (tuukka.petaja(at)helsinki.fi) - director, 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, Bejing 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(at)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.

CAPACITY BUILDING

Climate University
CR: Laura Riuttanen (laura.riutanen(at)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 Higer 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).

121

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(at)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 interdisiplinarity, 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(at)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., https://www.acccflagship.fi/index.php/2022/09/26/meet-the-climademy-project/

CLOUD Doctoral Network (CLOUD-DOC)

ACCC Research & Innovation (R&I) Ecosystem and Roadmap – a living document

PI:	Markku Kulmala (markku.kulmala(at)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(at)helsinki.fi), University of Helsinki; Svyatoslav Tyuryakov (svyatoslav.tyuryakov(at)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).

APPENDIX III LIST OF ACCC COLLABORATORS (LoC)

List of collaborators with singed ACCC – letter of Commitment (LoC), status June 2023

No	Name	Type		
		Private sector	Public sector	Other Org
1	ACTRIS - European RI for Aerosol, Clouds and Trace Gases			
2	Airmodus Ltd.	1		
3	Actuarial Society of Finland	1		
4	Baltic Sea Action Group (BSAG)			1
5	City of Helsinki		1	
6	City of Kuopio		1	
7	City of Vantaa		1	
8	Claned Ltd.	1		
9	Climate Leadership Coalition (CLC)			1
10	Digital Belt and Road – AirCAS, China		1	
11	Dekati Ltd.	1		
12	Deloitte Ltd.	1		
13	Eastern Lapland Federation of Municipalities		1	
14	eLTER - European long-term ecosystem research			
15	Estonian University of Life Sciences		1	
16	European Science Diplomacy (EU SciDip) Alliance			1
17	Finnair	1		
18	Football Association of Finland			1
19	Future Earth			1
20	Helsinki Institute of Sustainability Science (HELSUS)		1	
21	HINKU - Carbon Neutral Municipalities			1
22	ICOS-ERIC Integrated Cabon Observation System			
23	IIASA- International Institute for Applied Systems Analysis		1	
24	Karsa Ltd.	1		
25	KPMG - global network of firms for audit services	1		
26	Kuopion Energia	1		
27	MetsäGroup	1		
28	Ministy of Transport & Communication		1	
29	Moscow State University		0	
30	Natural Resources Institute Finland (Luke)		1	
31	Neste	1		
32	Nanjing University, China		1	
33	Partioaitta Ltd.	1		
34	Pegasor Ltd.	1		
35	Russian Academy of Sciences, Russia			0
36	S-Group	1		
37	The Finnish Innovation Fund Sitra			1
38	The Guides and Scouts of Finland (SuomenPartio)			1
39	Think Africa			1
40	Traficom		1	
41	Solita	1		
42	ST1	1		
43	Finnish Environmental Institute (SYKE)		1	
44	University of Tartu		1	
45	UPM	1		
46	Useless	1		
47	Vaisala	1		
48	Valio	1		
49	World Meteorological Organization (WMO)			1
50	Wärtsilä	1		
	Total number	**21**	**14**	**10**

on pause