1. BASIC DETAILS

1.1. Flagship details

Name and abbreviation of the Flagship; Atmosphere and Climate Competence Center (ACCC) **Director:** Markku Kulmala, UH; **Vice directors**: Jaana Bäck, UH, Ari Laaksonen, FMI, Annele Virtanen, UEF, Miikka Dal Maso, TAU; **Host organizations:** University of Helsinki (UH), Finnish Meteorological Institute (FMI), University of Eastern Finland (UEF), Tampere University (TAU)

The Atmosphere and Climate Competence Center (ACCC) addresses two of the most urgent global Grand Challenges: climate change and deteriorating air quality. The ACCC **vision** is safe climate and clean air. The ACCC **mission** is to i) make a significant contribution toward achieving a carbon neutral (and beyond) society in Finland, EU and globally by finding out ways to take CO_2 out from the atmosphere and reliably verify it; ii) study the dynamics of atmospheric pollution cocktail in detail and quantify the impact of reducing pollutant emissions on climate, to mitigate air pollution and sustain healthy atmosphere. The aims are defined in the original application.

2. BRIEF SUMMARY OF DEMONSTRATED SCIENTIFIC EXCELLENCE AND IMPACT

2.1. Progress during the first years of Flagship (07/2020-04/2023)

ACCC has implemented 3 Research Programs (RPs) and an Impact Program (IP) with 13 Impact Tasks (IP1-13), see Figure 2.1. The RPs are making top-level science and form the knowledge basis for the ACCC societal impact. The RPs have produced 1260 peer reviewed publications (6 in Nature and Science). ACCC has 4 Clarivate highly cited researchers (22% of all in Finland) and received 20 awards and two international positions (M. Kulmala as the Deputy Director of the Research Center of Big Data for Sustainable Development Goals (CBAS) in Beijing, China and as a Council member of The World Academy of Sciences (more RP indicators in the mid-term-report). The ACCC IP focuses on co-creation and collaboration with the stakeholders. To further build a strong ACCC ecosystem and make its activities largely known by our various stakeholders and get input from them, we organized ACCC Science Conferences in 2021 and 2022, and ACCC Impact Weeks in 2021 and 2023 with all together 3120 participants. As examples of the ACCC impact, we have 3 new start-ups, 31 new company collaborators, and we have provided statements for several national and EU policies. Below is a brief overview of the Flagship activities since the kick-off (see the mid-term report for more details).

Fig 2.1. The three Research Programs (RPs) and the Impact Program in 2020-2024.

RP1 - Quantifying and activating the potential of land-based climate change mitigation: We quantified forest carbon sinks and sources and forest management effects on them (e.g. Kalliokoski et al. 2020, Thum et al. 2020, Forsius et al. 2021), and studied climate-smart (e.g. Korkiakoski et al. 2020, 2023, Aaltonen et al. 2022, Palviainen et al. 2022, Peltomaa et al. 2022) and economically optimal (Parkatti and Tahvonen 2020) forest management practices. We also quantified greenhouse gas (GHG) balances in drained peatland forests, fens, lakes, and urban tree plantations (e.g. Miettinen et al. 2021, Zhang et al. 2021, Havu et al. 2022, Heiskanen et al. 2023), and studied how climate, increasing atmospheric CO_2 concentration and disturbances, such as forest

fires, affect boreal ecosystems (e.g. Köster et al. 2021, Zhang-Turpeinen et al. 2021, Launiainen et al. 2022, Neefjes et al. 2022, Zhang et al. 2023, Parkatti et. al. 2023). We provided evidence of the climatic cooling effect of forest-induced aerosols and clouds (e.g. Yli-Juuti et al. 2021, Petäjä et al. 2022, Kulmala et al. 2023) and developed CarbonSink+ concept (that takes into account all climate forcers, Kulmala et al. 2020) further and applied it in different ecosystems. In agricultural fields, we developed a system to estimate carbon and GHG budget (Heimsch et al. 2021, Viskari et al. 2020, 2022, Fer et al. 2021, Vira et al. 2022, Vekuri et al. 2023). We also developed a Field Observatory-service, illustrating our verification methodology with real-time online results (Nevalainen et al. 2022). And finally, we developed a top-down method for verifying national GHG estimates using cutting-edge computation together with new high-intensity satellite data on GHGs to map their sinks and sources. This method supports bottom-up national inventories and decision making (Karppinen et al. 2020, Tsuruta et al. 2023, Petrescu et al. 2023).

RP2 - Quantifying the air quality - climate interactions and their impacts: RP2 studies the origins and impacts of air pollution with the aim of identifying the best methods to minimize harmful outcomes. Findings include new information of nanocluster and secondary aerosols in urban and agricultural environments (Okuljar et al. 2021, Olin et al. 2022), influence of new particle formation, local emissions, urban morphology and particle growth on pollution in megacities and high-emission areas (Du et al. 2021, Kokkonen et al. 2021, Kulmala et al. 2021a, Hakala et al. 2022, 2023), lung-deposited surface area particulate matter metrics in low and high pollution environments (Salo et al. 2021), emissions from fuel-powered auxiliary heaters compared to exhaust emissions (Karjalainen et al. 2021), and levels and impacts of anthropogenic particle number emissions (Kontkanen et al. 2020, Olin et al. 2022). Our recent findings in Beijing, China, demonstrate the dominant role of secondary formation pathways over primary emissions in causing high aerosol particle number and mass concentrations during haze episodes (Kulmala et al. 2021a, 2022), as well as the overall important role of secondary organic aerosol formation in megacities of China (Nie et al. 2022). We prepared responses to the EU Commission questionnaires on the revision of the Ambient Air Quality Directives (2008/50/EC; 2004/107/EC), and discussed the need for integration of air quality and climate-related regulation (Kuula et al. 2022). We finalized our work on global law and policy to address emissions of short-lived climate pollutants to be published in Brill (2023; co-edited by Yamineva, Kulovesi, Recio).

RP3 – Climate change impacts and adaptation: Research was organized into three RPs instead of the originally planned two. RP3 focuses on studying how climate change affects societies and how societies can adapt to climate change. We investigated extreme weather risks, microclimate and climate change impacts on health and society (e.g. Laurila et al. 2021, Kuntsi-Reunanen 2021, Aalto et al. 2022, Votsis et al. 2021), climate adaptation in the building sector (e.g. Honkonen and Romppanen 2022) and the role of human rights in climate emergency (e.g. Savaresi and Setzer 2022). A special Issue on ACCC RP3 in the FMI Research Letter was launched in May 2022. We studied the learning of the competencies of effective climate change mitigation and adaptation in the education system (Riuttanen et al. 2021, Tolppanen et al. 2022), and published a special issue on climate adaptation law in Climate Law journal in 2022.

Parts of the ACCC Impact Program progress have been described in detail in the mid-term report as **ACCC success stories** in five topical areas with connections to RPs: i) verification of climate impacts of agriculture (**RP1 + IP1**), ii) new knowledge on black carbon (**RP2,3 + IP4,6,7**), iii) advances in mass spectrometry (**RP1,2 + IP6,7,11**), iv) improving and standardizing nanoparticle measurements (**RP1,2 + IP6,7,11**) and v) Climate University (**RP1,2,3 + IP13**).

In addition to the integrated IP success stories (IP1,4,6,7,11,13), **IP2 on nature-based climate solutions related to forestry** and **IP3 on climate neutrality of companies** have proceeded well.

As a showcase, we are developing with Natural Resources Institute Finland a synthesis model that allows forest owners to estimate in a user-friendly interface the carbon sink of their forests under different forest management and climate scenarios. We are also conducting measurements of forest carbon sinks in several cities, conducting measurements and improving modelling estimates of agricultural carbon emissions for companies to include in the lifecycle analysis of their production, and calculating carbon footprint for companies as well as carbon sink of company-owned forests. **IP5 Novel eddy technology to observe carbon sink**, a collaboration project with Vaisala was concluded in 2023, resulting in prototyping a new, cheaper CO_2 sensor for eddy covariance measurements (ref. the mid-term report). **IP8 Establishment of Climate Analytics Finland Ltd**. was successfully concluded, and the spin-off company is starting its pilot projects for carbon removal and climate impact verification. **IP9** aims to further develop ACCC R&I ecosystem and to promote ACCC results, by e.g., influencing EU regulatory processes and providing open environmental data. The name of IP9 has been **Climate – Air quality Society Forum** and is now changed to "Supporting policies and practices". ACCC partners have organized weekly ACCC office meetings, internal seminars, ACCC Newsletter, co-design-networking events, an EU Parliament visit, contributed to EU public consultation and established a database of the ACCC researchers for consultations.

IP10 Operational phase of Pan-Eurasian Experiment (PEEX), focusing on the Arctic-boreal regions, faced severe setbacks due to COVID19 and the war in Ukraine. Travelling to China is gradually returning to the pre-COVID level, but collaboration with the Russian research organizations is suspended. Despite this, 17 papers (e.g. Lappalainen et al. 2022a) have been published in the PEEX Special issue Part-II in Atmospheric Chemistry and Physics, PEEX e-Newsletters was released, and PEEX sessions at both EGU 2021-2023 and CBAS22 conferences were organized. The Arctic collaboration is framed by the University of Arctic co-operation, where ACCC (UH) leads the Arctic-Boreal Thematic network, and by the UH coordinated "Arena for the gap analysis of the existing Arctic Science Co-Operations" (Lappalainen et al. 2023) funded by the Prince Albert Foundation in Monaco. In a frame of **IP12 Science Diplomacy**, we have organized annual Sofia Earth Forums in collaboration with the Finnish Cultural Center Sofia and the Finnish Ecumenical Council (Lappalainen et al. 2022b). The ACCC (bilateral) research and education efforts with China, India, Africa, NIS countries and the Arctic science collaborations are supporting international diplomatic relations (Chapter 4, Host organization's strategic priorities and roles).

2.1.1. Self-evaluation of the Flagship activities during the first years of operation

Table 2.1.1 *Self-evaluation of the ACCC activities.*

	ACCC goals in 2020-2024	Self-evaluation of the ACCC (2020-2023)
1	"*To provide beyond state-of-the-art scientific knowledge on climate change and deteriorating air quality by quantifying carbon sink and other interlinked radiative forcers, and by quantifying non-linear processes in atmospheric pollution cocktail*"	ACCC has delivered 1260 peer reviewed papers on climate change and air quality and developed further the scientific excellence gained during the CoE in atmospheric sciences. The utilization and development of research infrastructures (SMEAR/ACTRIS/ICOS/eLTER) and international research collaboration has been the backbone of our research. ACCC has kept its timetable to meet the main goals within 8 years. See also the ACCC Scientific and Advisory Board recommendation letter attached to this application. ***High success***.
2	"*To establish an ACCC Service Portal to collect big data from comprehensive observations and multiscale models to be delivered to various stakeholders*"	The service portal initial setup is ready. The integration of the various existing data pools is in progress. Also, the connections to a modelling platform are under development. ***Medium success / in progress***.

3	*"To co-create science-based solutions for guiding the world toward climate neutrality"*	Our tailored IP tasks are at different levels of maturity (concept /service development, company spin offs) and are focused on e.g., nature-based climate solutions, climate analytics, climate neutrality, climate education. ***Medium / high success.***
4	*"To establish international and interactive atmospheric research – business innovation ecosystem in Finland"*	Our R&I ecosystem capacity and potential is huge, over 120 EU/AoF/BF projects in 2020-2024. We collaborate in national/EU/global scales. However, we need to improve the ACCC branding and intensify the collaboration with the business sector. ***Medium / high success.***

2.1.2. Identified needs/changes for achieving Flagship goals and added value generation

Table 2.1.2 *The identified ACCC needs/changes needed to achieve the goals in T2.1.1.*

1	To keep up the momentum in the scientific excellence, we need to pursue national and international **projects and grants**, carry out **Visiting Professor Program** and further improve internal communication.
2	We need to allocate **more person months** to data mining, AI and developing the ACCC e-platform and service portal. We will also better connect our different modelling scales to the portal with a user-friendly interface.
3	We need to finalize a **roadmap** "**Towards climate neutrality and beyond**" in co-design and co-operation with various stakeholders (work in progress). We need to further strengthen our cooperation with EU, USA, India, China, Global South, and NIS countries (excluding Russia) to be able to upscale the solutions.
4	We need to intensify collaboration with business sector and our **strategic partners** like Climate Leadership Coalition, Baltic Sea Action Group and The World Academy of Sciences. We need to further develop the ACCC Innovation Forum as an entry for new business partnerships and boost the innovation screening inside the ACCC community by organizing "**internal Slush events**".

3. PLAN FOR PROMOTING SCIENTIFIC EXCELLENCE AND IMPACT

ACCC implementation continues with a similar structure as in 2020-2024 with the three Research Programs and the Impact Program. However, there are some updates in the Impact Program as Impact Tasks (IP) 5 and 8 are finished and three new **IP tasks "Global South"**, "**Initiative for Safer Climate"** and "**ACCC Roadmap**" (IP14,15,16) are added to the IP.

3.1. Implementation plan

ACCC Research programs (RP) for years 2025-2028; deliverables, milestones and schedule

Knowledge gaps: Terrestrial ecosystems are crucial for regional and global climate neutrality targets (Friedlingstein et al. 2022), but we remain to have only partial understanding on how different land uses and management practices affect the ecosystems' carbon balance. In addition to the carbon sinks and sources, terrestrial ecosystems have other less-studied but closely interlinked climate effects, such as albedo, aerosol-cloud-climate interactions (Kalliokoski et al. 2020, Kulmala et al. 2020, Petäjä et al. 2022), and water cycle effects. Despite increasing understanding of the various interactions and feedbacks between the biosphere, atmosphere, hydrosphere and geosphere, these Earth system components are typically being studied separately. This does not allow studying the interfaces between these components, where most interactions and feedbacks occur. For example, poor knowledge on the processes occurring in the ecosystem-atmosphere interface is a major reason for still uncertain mitigation pathways like peatland restoration, afforestation, and forest and agricultural land management for increased carbon stocks (Harper et al. 2018, Kalliokoski et al. 2018, Demenois et al. 2020). RP1 focuses to overcome these gaps.

Like the Earth system components, also different environmental grand challenges are still typically being studied separately, such as the climate change and poor air quality which share the atmosphere as the route of effects. From the viewpoint of atmospheric science, the separation of the challenges is inefficient: climate change and air pollution share many of the same root

causes, and their causal chains from the initial human action to observable effects include the same compounds as well as physical and chemical processes (Fiore et al. 2012, Samset et al. 2018). Evaluating activities and emissions either based on their impact on climate, or the potential harm they cause to the health of organisms, but not both simultaneously, leads to inefficiencies in recognizing tradeoffs (e.g. sulphur emission) and synergies (e.g. black carbon). This might lead even to inefficient, costly and wrong conclusions on the impacts and the best mitigation measures. RP2 focuses to overcome these gaps.

Climate change mitigation and adaptation should be done in parallel, as outlined in IPCC AR6. Many harmful events with compound effects and partly triggered by extreme weather (e.g., droughts, wildfires, heavy rain, floods, windstorms) are projected to further intensify, occur more frequently and in larger scale in the future. Climate zones and ecosystem boundaries are projected to shift, and health and well-being impacts as well as crisis situations are expected to occur more often. Science points even to the fact that we may be crossing the planetary boundaries in the coming decades (Rockström et al. 2009). This may have fundamental and irreversible effects on e.g., security, human health, economy and biodiversity, and lead to massive migrations with major societal impacts. For society to prepare and adapt to the increased threats induced by climate change, we need to understand and quantify the risks involved at high temporal and spatial resolutions, and to develop applications that help people to understand the chain of impacts for their location, economy and well-being. Further research is needed to find solutions to climate change adaptation and how to effectively implement adaptation plans across natural and anthropogenic systems. RP3 focuses to overcome these gaps.

Expected scientific breakthroughs in land-based climate change mitigation (RP1): **R1.1** Improved estimates of GHG sources and sinks in terrestrial and aquatic ecosystems; **R1.2** Quantification of the full climate impacts of land use, land use changes and forestry (LULUCF sector), accounting for GHG balances, albedo effects, aerosol-cloud-climate and water cycle effects (CarbonSink+); **R1.3** Quantification of ecosystem responses to changing climate; **R1.4** Quantification of terrestrial feedbacks between ecosystems and atmospheric processes; **R1.5** Development of regenerative agricultural practices improving soil carbon sequestration and providing other environmental benefits; **R1.6** Development of stand and market -level forest economics that simultaneously optimize the value of wood production, carbon storage and biodiversity; **R1.7** Identification of the key limitations for increasing the terrestrial ecosystem carbon sink in the Arctic-Boreal regions.

Expected scientific breakthroughs in air quality - climate interactions and their impacts (RP2): **R2.1** Quantifying the impacts of primary aerosols, anthropogenic and biogenic secondary aerosol formation, meteorology and their non-linear interactions on air quality; **R2.2** Identifying the key pollutants triggering air quality problems in different locations, conditions and scales, including gigacity environments; **R2.3** Quantification of exhaustive aerosol emission number size distribution, enabling future emission scenarios with full consistency with IPCC GHG emissions until 2050; **R2.4** Quantitative assessment of the total (both climatic and air quality relevant) impact of transport emissions under various traffic scenarios; **R2.5** Top-down evaluation of anthropogenic and biogenic aerosol impacts on cloud droplet/ice crystal formation and Earth's radiation budget; **R2.6** Updated estimates of the feasibility and impact of stratospheric aerosol injections as means of geoengineering to slow down climate warming; **R2.7** Assessment of law and governance, and development of recommendations for integrated approaches to climate and air quality; **R2.8** Assessment of the effects of outdoor air quality on indoor air quality.

Regarding recognizing the risks society faces due to climate change and evaluating options to prepare society for the impacts of changing climate, we expect following scientific breakthroughs

(RP3): **R3.1** Prediction of extreme climate events and climate tipping points; **R3.2** Quantification of the various, interlinked impacts of climate change and air quality on high-latitude societies; **R3.3** Preparedness and multiscale outlooks for green transition; **R3.4** Establishment of a new generation of impact modelling tools to support rapid adaptation from urban to regional scale; **R3.5** Creation of continuous learning possibilities to tackle climate change and pro-actively adapt to inevitable changes; **R3.6** Establishment of preparedness tools for early warning system and health-related warning system; **R3.7** Assessment of law and governance and development of recommendations for climate adaptation at international, EU and selected national levels.

Table 3.1. *Schedule of the research programs: the* ***main deliverables*** *of the research programs are scientific publications, conference presentations and open data related to the expected scientific breakthroughs (R). Scientific breakthroughs are marked for the year when the main results are expected.* ***Milestones*** *are the successful accomplishments of the individual research projects (see the ACCC R&I ecosystem in section 4 for details) under each RP.*

Expected scientific breakthroughs	2020	2021	2022	2023	2024	**2025**	**2026**	**2027**	**2028**
Land-based climate change mitigation									
Estimates of natural C emissions and sinks							R1.3		R1.1
Other climate impacts of land use							R1.2		R1.4
Land management practices							R1.5	R1.6	R1.7
Air quality and climate interaction									
Impact assessment						R2.2	R2.4	R2.1	
Climate & emission scenarios							R2.5		R2.3
Air quality manipulations / regulations						R2.7		R2.8	R2.6
Impacts and adaptation									
Climate impact & preparedness in society						R3.1		R3.2	R3.3
Impact & preparedness tools								R3.4	R3.6
Continuous learning and governance							R3.7		R3.5

ACCC approach and main methods: To make scientific breakthroughs, we are using our comprehensive, integrated long-term field measurements from the SMEAR stations (Kulmala 2018, Kulmala et al. 2021b) and other intensively studied sites, which allows us to study the interactions between the different Earth components. We combine field measurements with targeted field and laboratory experiments, satellite observations, and multiscale modelling. As an example, atmospheric inverse modelling based on satellite data provides independent information on the carbon cycle for verification of national inventories, and we aim to provide solutions to reliably determine national emissions and removals in relevant timescales. We also utilize machine learning approaches, for example allowing highly realistic integration of economics and ecology in optimizing forest management (Malo et al. 2021, Tahvonen et al. 2022). Indeed, a holistic approach is needed to quantify the different climate impacts of terrestrial ecosystems, their interactions and feedbacks. This calls for integrated measurements, transdisciplinary collaboration and interaction with different stakeholders.

Furthermore, we investigate influences of primary and secondary aerosols (from anthropogenic and biogenic sources) on climate and air quality by improving descriptions of atmospheric aerosol processes and by improving and implementing anthropogenic emission scenarios (considering both technological advancements and systemic level changes) in models of different scales. We also synthesize in-situ and remote-sensing observations with model simulations to evaluate the models, to include more detailed processes in them, and to advance air quality assessments. Using satellite observations allows expanding the analysis from point-wise observations to regional and global scales. Stratospheric aerosol injections (SAI) as a geoengineering method will be studied especially regarding how the timing and location of SAI as

well as the composition of employed aerosol compounds and/or their precursors influence the effectiveness of the SAI and occurrence of extreme weather.

To study climate change impacts and adaptation, we use climate model data combined with data from in situ and remote sensing atmospheric 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 AI-based methods and modelling tools from different disciplines. We will also quantify climate risks, which are a combination of climate hazard, exposure, and vulnerability, and will study how climate change impacts, mitigation, and adaptation affect society, infrastructure, and economy. We identify different physical, legal, and social options to climate change adaptation and mitigation. Finally, we study the legal frameworks related to air quality and climate policies and disseminate the conceptual and quantitative understanding arising from our research towards the decision makers and general public. It is important to ensure that climate law- and policymaking are conducted in the context of transparency, legitimacy, equity, and justice.

Main changes to the original plan with justifications: We have established the third research program. This was decided when ACCC was being organized. The reasoning was to highlight studying the impacts of mitigation and adaptation to climate change not only regarding terrestrial ecosystems and air quality, but also the society more broadly. Thus, planned activities and expected research results were rearranged among three research programs instead of two. Regarding methods, remote sensing and AI methods are playing a more and more important role in many research avenues in ACCC. Example of remote sensing is the use of top-down method for verifying bottom-up national carbon and GHG estimates assimilating GHGs into national inventories by atmospheric inverse modeling system tracking GHG sinks and sources. Examples of utilizing AI methods are predicting weather and climate conditions, estimating carbon sink based on ERA 5 data, and economic optimization of forest management. We have agreed also new collaborations regarding the SMEAR station network e.g., in Whistler, Canada (Nadine Borduas-Dedekind) and IIT Delhi Atmospheric Observatory, Sonipat, India (Somnath Baidya Roy).

New research openings, some of them based on SIAB feedback include: 1) Marine and coastal research (RP1). Marine research unit in FMI will be included in the flagship to extend the scope to marine systems to complete the picture of the Earth surface climate impacts and feedbacks. Also, a new SMEAR-type research station studying ecosystem-atmosphere interactions in a coastal environment has been recently established (Tvärminne). Lateral transport of carbon, nutrients and water couples the marine fluxes with terrestrial fluxes, the coastal ecosystems being the hotspots; 2) Ecosystem disturbances and climate risks (RP1). Disturbances, e.g., wildfires and flooding, as well as longer-term climate risks will be studied; 3) Geoengineering (RP1/RP2). Geoengineering solutions need to be rigorously investigated before their potential use. Without proper investigations, their use will be very risky. 4) Global shipping emissions (RP2). Especially sulfur from shipping causes impacts on local environments, climate, and health. As shipping legislation is currently being prepared, the momentum is right; 5) Indoor air quality (RP2). Especially the effects of building materials and outdoor air quality on indoor air quality will be studied; 6) Weather extremes (RP3). The frequency and severity of high impact weather extremes are increasing with changing climate. Understanding these risks and consequences to societies is increasingly needed. At the end, we will develop an extreme events service (climateguide.fi).

ACCC Impact Program (IP) for 2025-2028; **deliverables, milestones, schedule**

IP1 Carbon sequestration of agricultural land supports the implementation of climate-smart regenerative farming practices. We test the applicability of favourable farming practices from RP1

and estimate their effects using our verification method (Fer et al. 2020). We have coded this method to an IT system to operate it, show real-time results, and further develop it (Nevalainen et al. 2022). We also constantly develop our soil model Yasso used in national GHG inventories and several other modeling systems (Viskari et al. 2022). In 2025-2028, we will continue collaborating with farmers, authorities, and food and technology companies to develop practical means of applying regenerative farming practices. For example, we will use our verification method on field trials and regular fields and develop ways to improve GHG inventories, carbon footprints, and carbon offset estimates. We will prepare to evaluate bottom-up GHG inventories against independent top-down approaches (satellite data, inverse modelling). **Major Milestones**: an internationally applicable suggestion on improving national GHG inventory systems towards field-specific estimation (**M1.1 in 2026**); evaluation of our verification method in the light of international carbon removal certification schemes (**M1.2 in 2027**).

IP2 Verification of forest climate effects co-designs research projects carried out in RP1 with stakeholders and supports them in climate-smart actions with the newest scientific knowledge. Concrete examples are verification of climate impacts of specific carbon compensation actions of cities and companies and estimating the climate impact of all Finnish forests under different forest use and climate scenarios. In 2025-2028, new collaboration is foreseen with the Ministry of Environment and some Finnish forest companies. Projects in the core of IP2 are e.g., KuntaNielu-project in collaboration with cities funded by Ministry of Agriculture and Forestry, Managing Forests for Climate Change Mitigation -project funded by the AoF and Life2Taiga-project on controlled burning to restore western taiga woodlands. We will organize workshops with our stakeholders and will launch a Climate University MOOC course on Forests and climate change available online for anyone. **Major Milestones**: an open online platform to estimate the climate impact of a forest stand and a MOOC course (**M2.1 in 2025**); demonstrated use of AI methods for assessing the economically optimal forest management scenarios for simultaneous climate change mitigation, timber production and conservation of biodiversity (**M2.2 in 2027**).

IP3 Verification of carbon neutrality and compensation of emissions for different private companies main goal in 2025-2028 is to make science-based impact verification for companies' carbon neutrality projects. The need for new standards will be explored and preparative work of defining them will be continued according to the latest scientific protocols and working methods. IP3 continues collaboration (started in 2022) with an auditing company KPMG and the carbon compensation company Maanvaalija Oy. More national and international companies are expected to be interested in creating credible and verified carbon neutrality projects in different natural environments while EU regulation is developing from 2023-2024 onwards. IP3 is linked to ongoing EU activities like projects "CSRD and future Carbon Removal and Greenwashing regulation" and Finnish national regulation and policies, especially Government plan 2023-2027. **Major Milestones (IP3)**: Start concrete cooperation with Governors Island project in New York City (**M3.1 in 2025**); 10 new national and international carbon neutrality and climate impact pilot projects with private companies and business ecosystems (**M3.2 in 2027**).

IP4 Climate neutral and resilient cities and health supports Finnish cities and communities to achieve better preparedness for climate change impacts and in achieving climate neutrality. IP4 co-designs on new solutions and scientific findings with the communities. In 2020-2023, this dialogue was facilitated through a range of interactive projects with communities and research institutes and by organised topical seminar series "Climate Neutral and Resilient Cities". The seminar series will continue with 3-4 seminars per year during 2025-2028. IP4 is divided into sub-topics focusing on climate neutrality and adaptation in urban planning, predictability and impacts of climate events, urban climate simulations, climate change impacts on health, and

tourism industry. These goals are supported by several ongoing projects (see the ACCC R&I Ecosystem document) and the FMI-internal TAPSI project that develops new climate services providing high resolution climate information at city scale in Finland. **Major Milestones (IP4):** Involve a large number of Finnish cities in the academic-stakeholder dialogue through "Climate Neutral and Resilient Cities" seminar series and other activities (**M4.1 in 2025**); start joint projects with >10 new Finnish cities to support climate neutrality and resilience (**M4.2 in 2027**).

IP6 Novel technology for comprehensive atmospheric observations continues active interaction with collaborators and seeks for potential new technology developments within the ACCC in 2025-2028. The main collaborators are instrument (Vaisala, Karsa, Airmodus, Pegasor and Dekati) and auditing companies (Deloitte, KMPG). New collaboration is foreseen with ACTRIS and WMO. There are many ongoing projects in the ACCC on technology development, such as the "Non-exhaust emissions in electrifying mining and urban environment" (Business Finland), "Particle emission prevention and impact: from real-world emissions of traffic to secondary PM of urban air" (EU), "Excellence in Pandemic Response and Enterprise Solutions" (Business Finland), "Research Infrastructures Services Reinforcing Air Quality Monitoring Capacities in European Urban & Industrial AreaS" (EU) and the ACTRIS Cluster Calibration Center at University of Helsinki. **Major milestones (IP6**): Research/Innovation program on measurement technologies prepared with ACCC stakeholders and submitted to relevant call(s) of Business Finland / Horizon Europe (**M6.1 in 2025**); joint measurement campaign on air quality in Gigacity areas organized by ACCC partners and opened for collaborative experiments with ACCC stakeholders (**M6.2 in 2026**).

IP7 Solving air pollution cocktail and finding ways to improve air quality produces quantified information to authorities and decision makers on the formation mechanisms of air pollution. The efficacy of different actions to reduce harmful pollution are estimated together with the impacts of these actions on climate. This allows to set well-targeted air quality and climate related regulations, and the private sector to be able to verify the impacts of their business. The produced information is crucial for policy makers, companies and other stake holders for evaluating the impacts of the regulations. IP7 collaborates with several ongoing Horizon2020 projects. In 2025-2028, new collaborators will be cities (specifically megacities), Helsinki Region Environmental Services (HSY), ACTRIS and companies building instruments monitoring atmospheric composition. IP7 has international stakeholders in China, India and South Africa, where poor air quality remains a critical challenge to society. **Major Milestones (IP7):** Module for emitted particle number size distribution from anthropogenic emissions implemented to GAINSv6a/FRES (global/national) (**M7.1 in 2025**); international workshop from deep understanding to practical solutions aiming to improve air quality (**M7.1 in 2026**).

IP9 Supporting policies and practices promotes ACCC results, by e.g., influencing EU regulatory processes and providing open environmental data. In 2025-2028, we will i) improve our capability to influence future regulatory processes and EU research and innovation programmes, ii) develop ACCC service portal and complement it with portal established in AoF ClimComp-project including a gateway to various Earth System and weather data with means to process, visualize and analyze the data, and iii) intensify collaboration with the Climate Leadership Coalition aiming to identify new relevant private sector collaborators. To increase the awareness and dialogue between the scientific community, stakeholders and the public, we organize annually ACCC Impact Week, ACCC Science Conference and Innovation Forum -events, and start in 2024 "innovation screening" in collaboration with the UH Fundraising Team. We also work on improving climate science communication through various channels (e.g., climateguide.fi) and develop new climate services. **Major Milestones (IP9):** ACCC service portal in operation (**M9.1 in 2025**); relevant connections to the EU institutions as well as to the Finnish authorities preparing

EU policies established and active contribution processes to main climate regulation instruments accomplished (**M9.2 in 2026**).

IP10 Operational phase of Pan-Eurasian Experiment (PEEX)'s main milestones for 2025-2028 are to strengthen the PEEX activities in the Arctic context and with China and renewing the network with the Newly Independent States. As an example, we have utilized satellite data to support air quality analysis, training and capacity building in Azerbaijan, Kyrgyzstan and Ukraine. PEEX will continue synthesizing and upscaling the outcomes of joint research and education projects and will develop RI in the NIS countries together with IP11, IP13 and the WMO Global campus. PEEX is involved in several projects supporting research and education in Ukraine, such as a Climate KIC project Roadmaps-for-Ukraine with Savonia University of Applied Sciences. The Arctic collaboration is framed by the University of Arctic and the AASCO-2 -project. PEEX activities also include publishing PEEX Special issue Part-II in ACP journal, publishing the PEEX e-Newsletter and organizing PEEX sessions at science conferences like EGU, CBAS, UArctic, Arctic Circle). **Major Milestones (IP10):** PEEX network renewed by 2028 with > new 10 MoUs signed (**M10.1 in 2027**); AASCO-2- Arctic science collaboration successfully completed (**M10.2 in 2025**).

IP11 Towards global observatory. In 2025-2028, we will integrate the SMEAR concept to the World Meteorological Organization (WMO) activities and contribute as in-situ observation component to the Earth Virtualization Engines (EVE). The main strategic collaborators are WMO, Integrated Carbon Observation System (ICOS), Aerosol, Clouds and Trace Gases RI (ACTRIS), European long-term ecosystem RI (eLTER), Institute for Applied System Analysis, Digital Belt & Road Program, University of Nanjing and Vaisala Ltd. IP11 is linked with several ongoing research and RI projects, and we will link the SmartSMEAR data platform to the DBAR Data Center. Also, the new ACCC IP Global South (**IP15$_{new}$**) provides an opportunity to use the SMEAR II station as the main education RI platform and, thus, facilitates the implementation of the SMEAR concept to the Global South. **Major Milestones (IP11**): "Towards Global Earth Observatory" White Paper published (**M11.1 in 2024**); integrated Global Observatory established together with various stakeholders (**M11.2 in 2025**).

IP12 Science diplomacy. In 2025-2028, ACCC will continue organizing the annual Sofia Forum (part of the ACCC Impact Week) that gathers different sectors of the society, including politicians, business representatives, NGOs and churches to discuss grand challenges. Next, ACCC plans to take more proactive role in some international forums. As an example, ACCC has recently been in contact with the Vatican's climate program "Vatican Dicastery for Promoting Integral Human Development" to seek collaboration. Science diplomacy continues to be an integral part of the ACCC research collaboration carried out in China, India, NIS countries and in the Arctic region. **Major Milestones (IP12):** Joint activities with Vatican (**M12.1 in 2025**); organization of Sofia Earth Forum (**M12.2 in 2025, 2026, 2027**).

IP13 Climate University's new strategy for 2023-2027 aims at being a brave forerunner in educating active sustainability makers for the society and business. We not only teach but also study the learning of the competencies of effective climate change mitigation and adaptation in the education system (AoF ClimComp) and develop teacher education on climate change (Erasmus+ Teachers Climate Change Academy 2022-2025). New initiatives are Pirkanmaa Climate Action Lab launched in 2023 in collaboration with the Council of Tampere Region and other regional stakeholders and Climate Expert Specialization Education starting in 2024 in collaboration with Climate University network, Climate Leadership Coalition and Technology Industries Finland. IP13 also has other ongoing projects, such as Una Europa Micro-Credential in Sustainability in collaboration with European Universities Alliance, and Climate University for Virtual Exchanges (Erasmus+ project) with partners from Ukraine, Armenia and Denmark. **Major**

Milestones (IP13): Climate expert specialization education starts (**M13.1 in 2024**); all Higher Education Institutions in Finland are part of Climate University network (**M13.2 in 2027**).

IP14$_{new}$ Safer Climate is a new IP task complimenting the existing impact tasks and RP3 by strengthening collaboration with civil society, humanities and social sciences networks as well as climate security experts. The impact task is building on the Initiative for a Safer Climate network, established in 2022. In 2025-2028, Safer Climate aims 1) to grow ACCC's ecosystem and impact within civil society in national, EU and global levels; 2) to further create new transdisciplinary, creative spaces for science-based climate discussion and action at the intersection of research, civil society and art; 3) to produce research-based dialogue, publications and events related to civil society's role in climate security. Together with collaborators, we aim to pilot a community-based approach to climate awareness, emphasizing resilience, preparedness and participation. **Major Milestones (IP14):** Establishing a recurring climate security festival as an international and cross-sectoral forum to discuss/create solutions to climate change related security risks (**M14.1 in 2025**); co-designing a Roadmap to a Safer Climate, emphasizing collaboration between research and civil society (see also IP16) (**M14.2 in 2027**).

IP15$_{new}$ Global South is a new IP task. 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. **Major Milestones (IP15):** TWAS education program established and coordinated by ACCC (**M15.1 in 2025**); first educated doctors from the program (**M15.2 in 2027**).

IP16$_{new}$ ACCC Roadmap. There is a need for an integrated, holistic roadmap to further enhance interdisciplinary approach. ACCC roadmap is built bottom-up to integrate and upscale ACCC research and impact and present this in a living document. The ACCC will deliver a roadmap at the following time windows: Finland carbon neutral in 2035, Europe carbon neutral in 2045 and Global carbon neutrality and beyond by 2055. The landscape analysis for the roadmap bases on the ACCC Impact Week invited presentations. **Major Milestones (IP16):** 1st full version of the roadmap ready (**M16.1 in 2025**); roadmap widely co-designed and communicated with stakeholders in Finland and internationally (**M16.2 in 2027**).

Main changes to the original plan with justifications of the Impact Program (IP): The IP is built on Impact Tasks with different aims (strategical, service development, technical, capacity building, upscaling) and maturity levels, involving different stakeholders (public, private sector, NGOs and civil society). We add new tasks to the IP as some previous ones are completed. New IP tasks for the 2025-2028 are "Safe Climate Initiative" (IP14$_{new}$), "Global South" (IP15$_{new}$) and "ACCC Roadmap" (IP16$_{new}$). We also changed the name of IP9 to "Supporting policies and practices".

Risk management and mitigation: The foreseen risks introduced in the ACCC proposal for 2020-2024 also apply for the 2025-2028 period. The most important risks considering the large volume of the ACCC relate to inadequate communication between different disciplines / ACCC programs and lack of interoperability between the various scientific approaches and methods. To support

synergies and coherence within the ACCC, we are continuously developing new practices in coordinating activities and to strengthen internal communication. An unexpected risk is the geopolitical situation caused by the war in Ukraine. To manage and mitigate this risk, we have paused all collaborations and activities with Russia and made strategic changes especially in the PEEX collaborations and activities (IP10). None of the risks identified in the beginning of the flagship period have been realized. But many lessons have been learnt, and we are constantly developing our processes especially in internal and external communication, coordination and how to support the R&I ecosystem development.

Strategy beyond the Flagship term and expected outcomes: Our mission by 2028 is to be a world-leading, interdisciplinary atmosphere and climate competence center enabling an innovative use of scientific results in planning and implementing the climate and air quality policies and governance. By 2028 we will be in an active interaction with the policy makers, private sector and civil society including relevant NGOs. We have provided relevant and timely science-based knowledge, methods and services related to climate change and air quality. We have especially succeeded to find nature-based solutions to harvest CO_2 from the atmosphere and reliably verify the uptake. By 2028, ACCC will also have institutionalized its community with around 900 academic and technical experts working on climate and air quality research and impact to continue under the Finnish Atmospheric Science Network (established in 2013, contract renewed in 2020). In addition to the joint ACCC Flagship, the network shares a large number of national and international research projects and has a joint research infrastructure INAR RI recognised at the Finnish RI Roadmap. The partners have also brought the head offices of ICOS ERIC and ACTRIS ERIC to Finland with joint efforts. By 2028, we foresee that the ACCC's top-level research and innovation network will have produced significant impacts and new climate services in various fields of the society and upscaled its' research and innovation ecosystem to be a major player also in an international context. This guarantees a successful continuation of the network also in the future and to produce new knowledge for Finland to be carbon neutral by 2035.

3.2. Consideration of responsible science

As in the ACCC proposal for 2020-2024, we are committed to (i) FAIR principles, (ii) strategy to promote open science globally, (iii) ethical research promoting integrity and deterring misconduct, (iv) support the SDGs from the UN Agenda 2030 apply for the next ACCC period. Furthermore, we monitor, report, follow and reduce (e.g., virtual meetings, encouraging vegetarian options) the carbon footprint in all our activities.

4. ECOSYSTEM AND ORGANISATION

4.1. Description of ecosystem and organization

ACCC Research and Impact (R&I) ecosystem consists of 622 collaborative organizations from different public and private sectors, including academic organizations, governmental partners, companies, ministries, churches, NGOs, cities and various networks or coalitions, including EU research infrastructures. Newly established ACTRIS ERIC in Helsinki and active connections to ICOS ERIC and eLTER RI solidifies the ACCC synergy with the European RI ESFRI process and highlights our role in European RI integration. *The collaboration framework is presented in detail in the ACCC R&I Ecosystem document (http://www.acccflagship.fi/files/ACCC_R&I_Ecosystem.pdf).* The ACCC community itself comprises of ca. 700 academics working in the four partner organizations on atmospheric research and impact. The names of the Principal Investigators (PIs) and Impact coordinators are listed in the 1st ACCC proposal.

Externally funded projects are crucial for the ACCC R&I ecosystem. "Portfolio" of the ongoing projects includes projects funded mostly by the Academy of Finland, Business Finland, private

foundations, European Union Horizon 2020 and European Space Agency. The number of projects with > 500.000 euros total budget, (all of them includes large number of project partners) in each topical research area per research program (RP) are:

- **RP1 land-based climate solutions**: carbon balance and sequestration in agriculture (8 projects), carbon balance and climate mitigation in forests, peatlands and lakes (28), ecosystem processes and tree ecophysiology (6)
- **RP2 climate - AQ interactions:** climate modelling (4 projects), weather modelling (2), atmospheric chemistry, volatile organic compounds and aerosols (10), air quality, health and traffic (5), ocean studies (2), nitrogen studies (4), greenhouse gases and improving the satellite retrievals (3)
- **RP3 CC impacts & adaptation:** Climate change impacts and adaptation (19 projects), green transition (5), climate law (4)

In the ACCC R&I ecosystem, we have three Centres of Excellence (CoE) funded by the Academy of Finland. "*Virtual laboratory for molecular level atmospheric transformations*" (UH, TAU, UEF) aims to generate a virtual laboratory composed of digital twins of real-life instruments commonly used to study the state of the atmospheric environment. This virtual laboratory approach resolves the processes controlling ambient new particle formation and growth under various experimental conditions relevant to Earth's atmosphere. "*CoE in Tree Biology*" (UH) studies carbon sequestration in trees at molecular level and its potential improvement to mitigate climate change. Understanding of the carbon sink in trees at molecular level is still relatively superficial compared to many other aspects of this complex problem and the CoE aims to shed light on this. "*CoE of Inverse Modelling and Imaging*" (UH, FMI, TAU) is specialized in the theory, implementation and application of inversion methods. The objective of the CoE is to create fundamentally new, efficient, and theoretically sound solutions to practical inverse problems.

The ACCC R&I ecosystem components to meet global grand challenges, with focus on climate change and air quality are: (i) excellent science – quality, critical mass and interdisciplinary **research**, (ii) world-class **research infrastructures** (RIs) – an integrated network of RIs, (iii) **knowledge transfer** for capacity building, education and training, (iv) **business and innovation** and (v) **policy/society dialogue** (Fig. 4.1.1). ACCC works at several scales: **national** (e.g. business collaboration with SMEs and large enterprises, climate and air quality policy with ministries, education with schools and universities, climate-smart solutions with cities, climate actions with civil society), **Nordic** (e.g. Nordforsk funded projects), **European** (e.g. Horizon2020 and ERC projects, European RIs, European Commission consultations), and **global** (e.g. Climate University and GlobalSMEAR upscaling, targeted research activities in China, India, USA, Canada, Arctic, Africa). ACCC PIs and Impact Coordinators (ICs) have many "positions of trust" in national and international bodies and working groups such as the Finnish Climate Change Panel, TWAS and WMO Scientific Advisory panel (see the mid-term report for details).

The strong collaboration network of more than 600 academic stakeholders in and outside of Finland has been built during the former CoE in Atmospheric sciences (2002-2020). In 2025-2028, the ACCC is further expanding the collaboration outside the academic communities aimed at becoming a strong actor in climate policymaking e.g. European Commission public consultations (IP9 Supporting policies and practices) and civil society climate action ($IP14_{new}$).

Host organisation's strategic priorities and roles: As previously, research and collaboration within the ACCC is based on the strategies of the ACCC partners UH, FMI, UEF and TAU. ACCC supports the governmental strategy to deepen cooperation between the universities and the sectorial research institutes. The strategic priorities of the organizations and their links to those of ACCC are regularly monitored and discussed in the ACCC Steering Board, where rectors of all

three partner universities and the Director General from the FMI are members. Clear evidence for positioning of ACCC in the core of the host organizations' strategies is the important role of ACCC partners in the profiling areas selected by the three universities over the years. In 2022, ACCC partners in UH and UEF were in the core of the universities' profiling area proposals (AoF Profi 7).

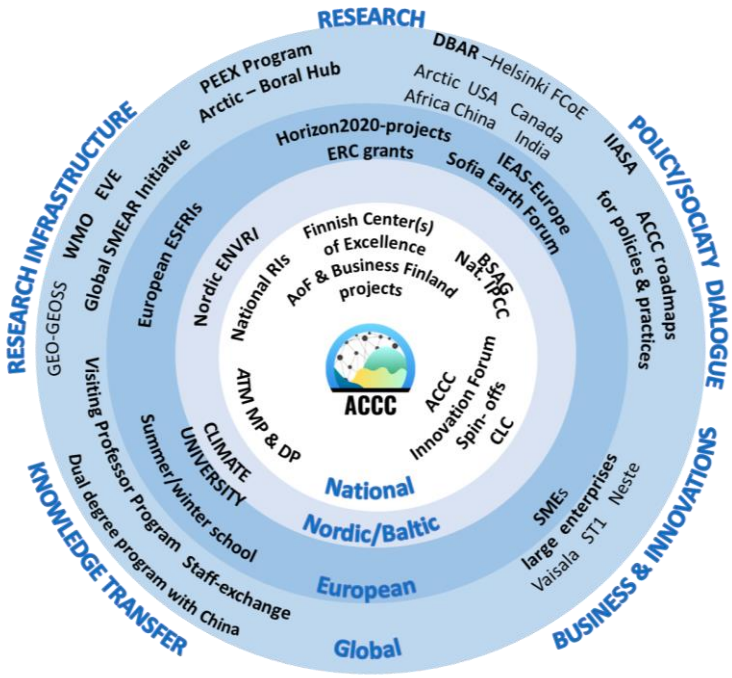

Fig. 4.1.1 *The main assets and collaborator frameworks of the ACCC R&I ecosystem scheme. Abbreviations in alphabetical order:* ***ATM MP & DP*** *= Master and Doctoral Programs in Atmospheric Sciences,* ***Arctic-Boreal Hub*** *= U-Arctic Thematic network,* ***BSAG*** *= Baltic Sea Action Group,* ***CLC*** *= 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.*

Flagship management and administrative structures: The ACCC administrative bodies are the Steering Board (rectors/directors of UH, FMI, UEF, TAU), Directorate (ACCC director and vice-directors, Research and Impact coordinators), Virtual office (Directorate + Research coordinators from all organizations), Plenary meetings (ACCC PI researchers) and the Scientific & Impact Advisory Board (SIAB). Two new ACCC representatives, Prof. Tuukka Petäjä (M) from UH and Director Hannele Korhonen (F) from FMI have been invited as Directorate Members for the period 2025-2028 to strengthen the group with two merited and dedicated research and impact experts from the ACCC. SIAB consists of members that represent ACCC key stakeholders (The Finnish Innovation Fund SITRA, WMO, ICOS ERIC, Cargotec Ltd., KPMG, Climate Leadership Coalition, Universities of California, Crete and Århus and DBAR/CBAS, Ministry of the Environment, and Finnish Climate Panel). In 2024, ACCC will invite A. Jalkala, Chief Strategy Officer (Vaisala Ltd.) as a new member in the SIAB. T. Kaskinen, as a new CLC CEO will be replacing the former CEO J. Keronen (retired) in SIAB. To support implementation and high international scientific level of the RPs, ACCC carries out a Visiting Professor Program, and to support implementation of the IP, ACCC has two Professors of Practice (A. Pauli and J. Keronen) and a Policy Expert (S. Paatero) employed. The Virtual office is the most important day-to-day management body with its' weekly meetings.

Key collaborators and their roles: In 2020, ACCC identified 45 key collaborators (signed Letters of Commitments, LoC, listed in the 1st ACCC proposal), which represent public and private sectors, European research structures, NGOs and other associations. The new LoCs signed during the 1st ACCC period are: The Guides and Scouts of Finland, Natural Resources Institute Finland, University of Tartu, Estonian University of Life Sciences, Football Association of Finland, Think

Africa, MetsäGroup, Actuarial Society of Finland and the European Science Diplomacy Alliance (copies of singed LoC attached). The protocol with new collaborators is that ACCC will first sign the LoC with a new collaborator, and then the collaboration will be implemented in new R&I projects, field campaigns, test beds, joint events and/or invited presentations depending on the collaborator's domain. The business collaboration is under non-disclosure agreements (NDA).

Innovation orientation of the ecosystem and planned actions to increase its' appeal: ACCC innovation and business potential builds on nature-based climate solutions (IP1, 2, 3, 4), climate analytical services (IP3 and concluded IP8), instrument technology (IP6, 7 and concluded IP5) and climate education (IP13,15), PEEX (IP10), Global Observatory (IP11), supporting policies and practices including roadmaps (IP9,14,16) and science diplomacy (IP12) to upscale new innovations to international scales. In 2025-2028, the specific geographical focus areas are Arctic (multidisciplinary science collaboration), China (deepen the existing collaboration, air quality monitoring, PhD education), India (air quality monitoring), USA (instrument technology, climate analytics services), Canada (SMEAR type station development), Global South (education, TWAS) and Ukraine (air quality monitoring, education, training). To keep up this momentum and attention of the international research community, we aim to submit several R&I projects to Business Finland and Horizon Europe calls. ACCC continues organizing Impact weeks, Innovation Forum events and participate in international forums to attract new relevant collaborators especially outside academics. We will carry out the ACCC ecosystem innovation screening and develop specific ACCC themes (such as "indoor air quality") together with the university fundraising teams for private funders. We deepen the already established collaboration with companies in different IP:s, for example, air quality company collaboration with Valmet, Vaisala, Dekati and Airmodus in IP7.

Identified needs for changes and strategy for the development of the ecosystem: The strategic aim of ACCC is that the eight-year time window of a flagship program enables the consolidation and strengthening of our R&I ecosystem to become recognized as one of the world leaders in our field. This aim is built on intensifying collaboration with the numerous stakeholders that have committed to the collaboration and made joint plans with the ACCC during the first years of the flagship, developing data, verification, air quality and extreme weather services to support different actors in the society to mitigate and adapt to climate change, preparing policy briefs in coordinated manner to impact national and EU policies, preparing the ACCC roadmap towards climate neutrality in co-design and co-operation with our various stakeholders, applying new European Research Council Grant(s) and other large international projects, benchmarking cutting edge markets for ACCC (new R&I collaboration openings in the USA) and deepening the collaboration with China (e.g., dual-degree program between Univ. Nanjing and INAR-UH) and India (the Centre for Atmospheric Sciences, Indian Institute of Technology Delhi (IITD)). The war in Ukraine was a serious setback in our collaboration with Russia (IP10, IP11). Due to the suspension of all cooperation with Russia, the work of the PEEX network is being renewed. Safer Climate Initiative ($IP14_{new}$) will continue establishing better involvement of the various NGOs to climate action, Global-South ($IP15_{new}$) will expand the geographical area of the ACCC activities to global south and especially Africa and the ACCC Roadmap ($IP16_{new}$) will channel the ACCC know-how impact to carbon neutrality goals of public / private sector. We also carry out as a part of ACCC Innovation Forum the "innovation screening" of all ACCC projects to boost the company spin offs and patents inside the ACCC and it' national community and deliver policy briefs to speed our impact on regulation policies.

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