Atmospheric Composition and Climate Change: From Molecular Processes to Global Observations and Models (ACCC)

National Doctoral Programme

1 RESEARCH ENVIRONMENT AND SCIENTIFIC QUALITY OF RESEARCH

1.1 The programme's business idea

The atmosphere forms a major part of the environment to which life on Earth is sensitively responsive. Compounds in the atmosphere, such as trace gases and aerosols, are tightly connected with each other via physical, chemical, meteorological and biological processes occurring in the atmosphere and at the atmosphere-biosphere interface (see e.g. Seinfeld and Pandis, 1998). Human actions, such as emission policy, forest management and land use change, as well as various natural feedback mechanisms involving the biosphere and atmosphere, have substantial impacts on the complicated couplings between atmospheric aerosols, trace gases, air quality and climate (Brasseur and Roeckner, 2005; Arneth et al., 2009; Raes and Seinfeld, 2009). Changes in one component are directly or indirectly communicated to other via intricately linked processes, feedbacks, and teleconnections on scales from seconds to millennia. The feedbacks may be positive or negative as the interaction may have evolved as a by product to some other driving process. For example plants emit volatile organic compounds mainly to communicate with their surroundings and to tolerate stress. However, these substances are participating in atmospheric chemical reaction contributing to aerosol formation.

The world faces unprecedented global change, with the key concern of climate change. The Intergovernmental Panel on Climate Change (IPCC) has concluded that the warming of the climate system is unequivocal and it is now evident from observations of increases in global average air and ocean temperatures, melting of snow and ice and rising global average sea level (IPCC, 2007). Furthermore, the fourth assessment report of IPCC has identified aerosols, clouds and precipitation as one of the largest uncertainties in our current understanding of the climate system (IPCC, 2007). Full understanding of the interactions requires mechanistical understanding of the air chemistry and physics but also that of plant physiology. Also a large uncertainty exists in the faith of carbon cycle in the changing climate, particularly in the boreal regions. The behavior of ecosystems in transient stage may be very different from that in corresponding climate in steady state. The overall impact to climate will depend on the simultaneous changes in carbon, water and nutrient cycles and the response of current ecosystems to these. Land-use changes and ecosystem management contribute to the response as they may speed up or slow down the biodiversity change by which the ecosystems are responding to changing climate. Also our understanding of biospheric feedbacks associated with climate-induced ecosystem changes is improving, but the full accounting of their impact in climate-change modelling is far from satisfactory (Arneth et al., 2010). Thus, the current emphases in the atmospheric sciences are to describe, understand and predict the complex climate system, Earth system functioning, atmosphere-biosphere interlinks, and to develop tools and technologies to society for monitoring, prevention and mitigation of environmental risks and pressures related to climate change and air quality issues.

The atmospheric research involves several fields of science such as chemistry, physics, meteorology, biology, agricultural and forest sciences, technology, and geosciences, combining observations, experimentation and modelling. In such a framework it is crucial that observations are based on unifying theoretical framework and are carried out with various measurement techniques (including development of new devices and instrumentation) supporting each other (ground-based, airborne and satellite). Furthermore, observations should be tested against field and laboratory experiments, and process understanding be tied to theoretical and modeling development work. Great importance is

also in the ability to up-scale the small scale processes to the regional and global level phenomena and dynamics. The ACCC Doctoral Programme includes all these challenging components and brings them to the level of the student training.

The chief goal of the ACCC Doctoral Programme is to educate a next generation of top-level scientists and experts with all the necessary multidisciplinary skills to tackle the future challenges of climate change, air quality matters and environmental technologies. The supra disciplinary education will enable those experts to serve at different challenging positions in society and industry. Beside classical curriculum skills and knowledge the education on the state-of-art measurement technologies (laboratory, ground-based and remote sensing) are emphasized. The ACCC Doctoral Programme is the only effort at a national level in advanced and comprehensive climate change research education with main focus on training of students in the field of atmospheric and biogeochemical sciences covering phenomena from the nanoscale to the global level and from nanoseconds to centuries.

1.2 Research environment, research community and research infrastructures

In 2008-2009, the predecessor of the ACCC Doctoral Programme, the Graduate School in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change involved three universities (University of Helsinki, University of Kuopio, Tampere University of Technology), two research institutes (Finnish Meteorological Institute, VTT Technical Research Centre) and one private enterprise (Vaisala Oyj).

The Graduate School was very successful in combining and developing the doctoral training given in several physical, chemical, meteorological, and ecological research groups. The Graduate School had three strong backbones: an advanced research infrastructure (SMEAR stations and laboratories), a powerful researcher community (Finnish Centre of Excellence), and an existing training structure based on best practices collected from several universities in Nordic and Baltic countries (CBACCI, 2003). The investments made in the doctoral training within the Doctoral Programme have been extremely profitable. During 2008-2009, the research groups gained a lot of international interest especially from students from different countries willing to participate in the Graduate School.

The ACCC Doctoral Programme is an extension of the former Graduate School. All the scientific fields of the previous Graduate School, namely Aerosol Physics and Technology, Meteorology, Atmospheric and Analytical Chemistry, Ecosystem Ecology and Ecophysiology are represented. Since the beginning of 2010, a new component in the Doctoral Programme has been the inclusion of global observations both from ground and space platforms – Remote Sensing Technologies and Applications, and Radio Science and Engineering. The new partners include one university (Aalto University), two research institutes (Finnish Environment Institute, Finnish Geodetic Institute), and six private enterprises (Airmodus Oy, Arbonaut Oy, Beneq Oy, Helsinki Aerosol Consulting Oy, MosaicMill Oy, Space Systems Finland Oy).

The Doctoral Programme is well related and completely integrated to present research activities and supported by infrastructures presented in Figure 1.

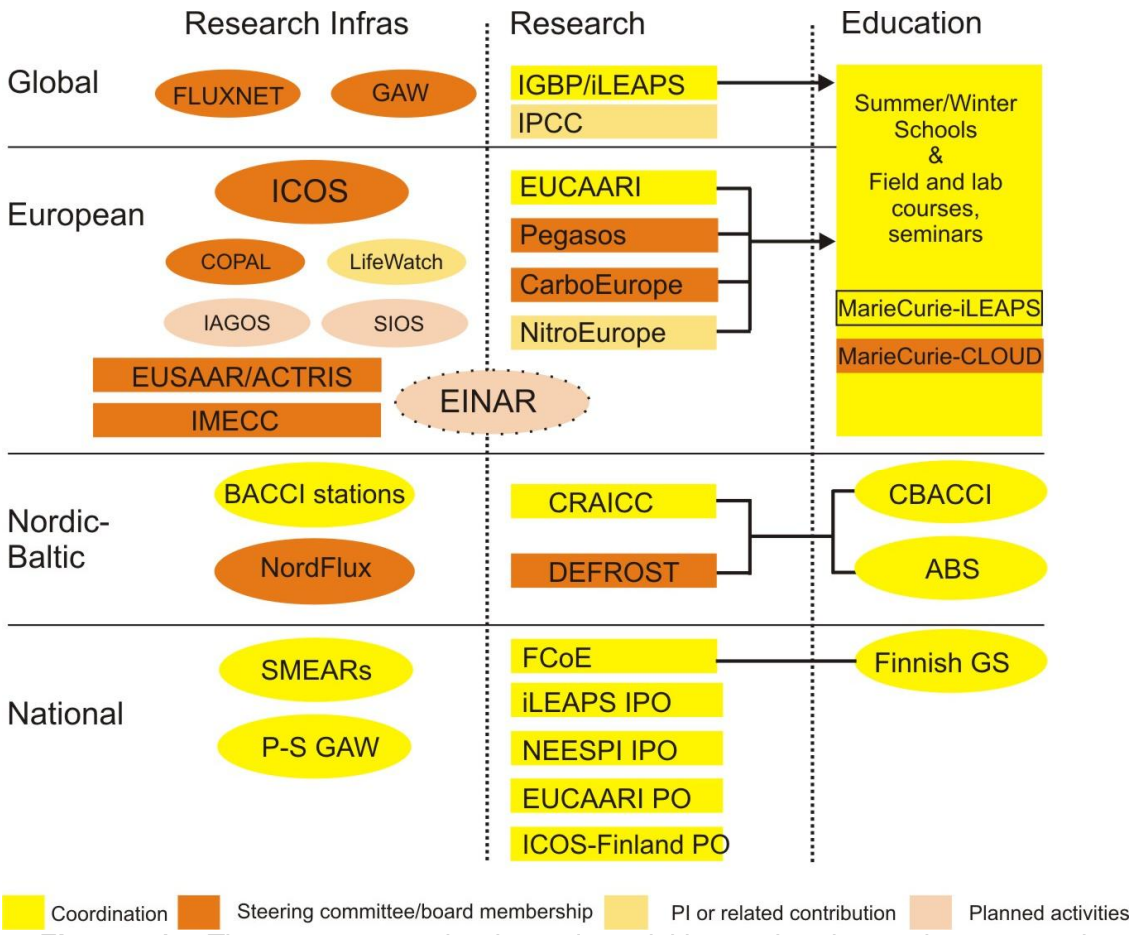

Figure 1. The current and planned activities related to the research infrastructures, major research projects and initiatives, and researcher training within the Doctoral Programme. Abbreviations: ABS=Nordic Master's Degree Programme in Atmosphere-Biosphere Studies; ACTRIS = European aerosol and atmospheric chemistry infrastructure; BACCI= Research Unit on Biosphere-Aerosol-Cloud-Climate Interactions (former Nordic Centre of Excellence); CBACCI=Nordic-Baltic Graduate School on Carbon-Biosphere-Atmosphere-Cloud-Climate Interactions; CLOUD=Cosmics Leaving OUtdoor Droplets (Marie Curie Initial Training Network); COPAL= COmmunity heavy-PAyload Long endurance Instrumented Aircraft for Tropospheric Research in Environmental and Geo-Sciences; CRAICC=Nordic Centre of Excellence on Cryosphere-Atmosphere Interactions in a Changing Arctic Climate; DEFROST=Impacts of a changing cryosphere - depicting ecosystem-climate feedbacks as affected by changes in permafrost, snow and ice distribution (Nordic Centre of Excellence); EINAR=European Institute of Atmospheric Sciences and Earth System Research; EUCAARI= European Integrated Project on Aerosol-Cloud-Climate-Air Quality Interactions; EUSAAR= European Supersites for Atmospheric Aerosol Research; FCoE=Finnish Centre of Excellence in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change; GS= Finnish Doctoral Programme ACCC (Atmospheric Composition and Climate Change: from Molecular Processes to Global Observations and Models); IAGOS= In-service Aircraft for Global Observing System; ICOS =Integrated Carbon Observation System; IGBP= International Geosphere-Biosphere Program; iLEAPS=integrated Land Ecosystem Atmosphere Processes Study; IMECC= Infrastructure for Measurements of the European Carbon Cycle; P-S GAW= Pallas-Sodankylä Global Atmosphere Watch Station; PEGASOS= Pan-European Gas-AerosSOls-climate interaction Study; SIOS= Svalbard Integrated Arctic Earth Observing System; SMEAR=Station for Measuring Ecosystem-Atmosphere Relations.

The global nature of the problems requires the use of synoptic and mesoscale tools such as satellite or airborne remote sensing to complement local ground-based measurements. The spatial continuity and temporal repeatability of remote sensing measurements provides an excellent means of quantifying and monitoring regional vegetation dynamics, plant phenology, and land use change, facilitating the analysis of the interaction between terrestrial ecosystems, atmosphere and climate. In addition to producing model input and model validation data, the variable field of view of remote sensing and optical sensors supports the upscaling, implementation and comparison of process-based vegetation models in different spatial scales (e.g. from stomata/leaf to region). Remote sensing thus confers the required global dimension to vegetation processes, which is needed to interact with global climate models.

Figure 2 shows the spatial and temporal scales of the research methodology (observations, modelling, laboratory experiments).

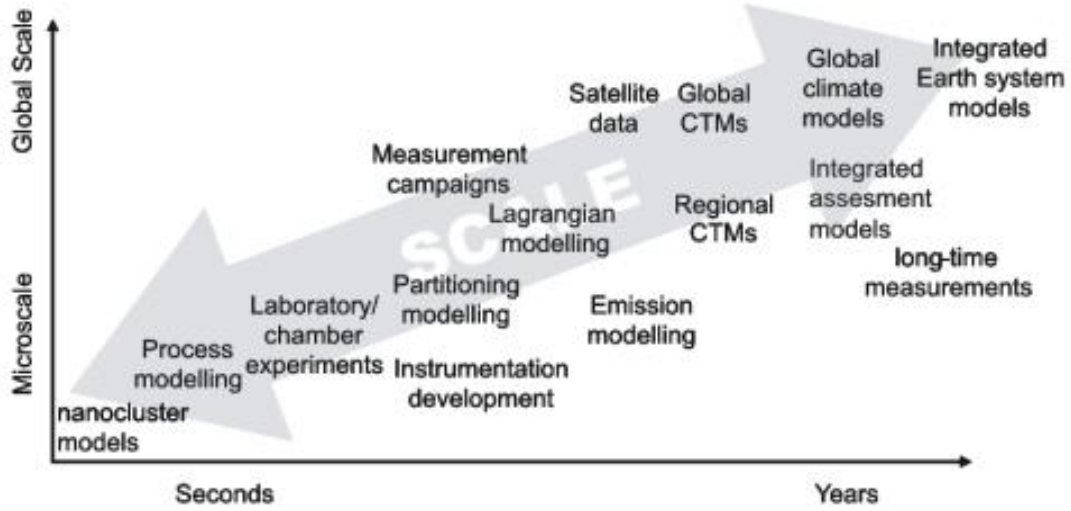

Figure 2. The temporal and spatial range of the research methods applied in the Doctoral Programme. Each partner is linked to one or more research method. The involved universities and research institutes cover a wider range of methods, whereas the private enterprises are more focused – Vaisala and Airmodus: instrumentation development; Beneq: nanocluster technology; HELAC: process modelling and laboratory experiments; Space Systems Finland: satellite technology and data processing; Arbonaut: remote sensing technology for forestry management; MosaicMill: image processing for aerial imaging.

The research topics of the Doctoral Programme include:

- Atmospheric sciences
- Aerosol and environmental physics
- Aerosol technology
- Remote sensing
- Aerosol-cloud-climate interactions
- Biosphere-atmosphere interactions
- Global climate modelling
- Atmospheric chemistry
- Land use change quantification
- Development of aerosol, remote sensing, radar, and environmental technology
- Improved positioning to improve in-situ measurements
- Ubiquitous remote sensing
- Snow and ice studies: evolution of sea ice and snow conditions

- Carbon, water, nitrogen and aerosol cycles and balances
- Air quality

The Doctoral Programme is in a strong symbiotic relationship with the Finnish Centre of Excellence in Physics, Chemistry, Biology and Meteorology of Atmospheric Composition and Climate Change. The education and knowledge transfer of the Centre of Excellence is formalized in the Doctoral Programme. On the other hand, the Doctoral Programme enhances the visibility of the Centre of Excellence internationally, especially among young researchers and students.

In the period 2012-2015, the Doctoral Programme will emphasize a conceptual approach to the research questions so that each student understands where his or her research is placed in Fig. 2, how it is related to other research topics and fields within the Doctoral Programme.

Furthermore, the experience in the organization of the joint studies within the Doctoral Programme paves way for implementing new, international joint degree programmes in Finland (e.g. Erasmus Mundus on the European level).

1.3 Links to the research activity and the profile of the units committed to the programme's operations

Atmospheric sciences are one of the focus areas in the strategies of the University of Helsinki and Finnish Meteorological Institute. Furthermore, these two partners have set a goal to establish a state-of-the-art international research centre in the atmospheric sciences and climate change in Finland. According to the strategy of the Tampere University of Technology the basis of the scientific activity of the university is in combination formed by the strong scientific and technical research and innovativeness. This realizes excellently in the programme. The Aalto University has raised multidisciplinary research as one of the focus areas in its strategy, and also noted the possibilities of the global change to emphasize the significance of research and researcher training. Forest and the environment, including climate research, is one of the focus areas of the University of Eastern Finland.

The research groups in Finland are among world-leaders in the fields represented in the Doctoral Programme. The quality of education is also excellent. The Doctoral Programme is based on research done at the host institutions, at the Finnish Center of Excellence in Physics, Chemistry, Biology, and Meteorology of Atmospheric Composition and Climate Change, within the strong and long co-operation at the Nordic level based on the former Nordic Centers of Excellence (NCoE): NCoE for Ecosystem Carbon Exchange and its Interactions with the Climate System (NECC) and NCoE for Biosphere – Aerosol – Cloud – Climate Interactions (BACCI), and the new Nordic Centres of Excellence CRAICC (Cryosphere-Atmosphere Interactions in a Changing Arctic Climate) and DEFROST (Impacts of a changing cryosphere - depicting ecosystem-climate feedbacks as affected by changes in permafrost, snow and ice distribution).

2 EDUCATION AND TRAINING

2.1 The content of the four-year doctoral training within the ACCC programme

The programme-wide training includes several annual activities: winter and summer schools, field courses, a researcher workshop, and a workshop for teachers and supervisors. The training is a combination of lectures, field measurements, computer modelling, and transferable skills. The winter and summer schools combine several topics each, and always include training on transferable skills. A key part of the annual three-day researcher workshops is a two-day seminar where the Doctoral Programme students present their recent research results, and a networking day where distinguished researchers and industry representatives are invited. The researcher workshops will provide an authentic experience

in which the research of the doctoral students is fused with their training and supervision by university, institute and industrial partners. In annual teacher and supervisor workshops, lecturers and supervisors will be trained on teaching, communication and supervising skills, including web-based teaching. The hosting of the annual events is circulated between programme partners, enabling all the students to get to know each of the Programme partners. In the organization of the joint activities, the good practices and experience from previous joint efforts, namely CBACCI (Nordic-Baltic Graduate School on Biosphere-Carbon-Aerosol-Cloud-Climate Interactions), Masters Degree Programme ABS (Atmosphere-Biosphere Studies), and Marie Curie CLOUD-ITN are fully utilized. Collaboration and co-ordination inside the Doctoral Programme involves:

- Common courses, seminars, and workshops for students, teachers and supervisors
- Common, multidisciplinary research topics with joint supervision
- Annual 3-day workshops in different research sites of the Doctoral Programme

The training modalities consist of training in scientific and technological knowledge, transferable skills and public outreach. These modalities will be organised within each host organisation, through secondments and short-term research visits, and especially via regular programme-wide training courses and workshops.

In 2008-2009, the Doctoral Programme organized a total of 16 joint/international training courses for doctoral students.

The Doctoral Programme consortium organizes annually several training events:

- Joint summer and winter schools, field courses (see list of planned courses below and in Appendix 2)
    - 5-6 annually
- *Ad hoc* courses (courses with special emphasis on a very current research topic)
    - A few annually
- Workshops and conferences
    - Annual workshop for the Doctoral Programme
    - Annual workshop for teachers and supervisors
    - Consortium units organize ~10 other conferences and workshops annually, and participate very actively in national and international conferences and workshops
- E-learning courses
    - 2-5 annually, usually organized jointly

The specific topics of the planned summer and winter schools and field courses include:

- Formation and growth of atmospheric aerosols
- Measurements of atmospheric aerosols: aerosol physics, sampling and measurement techniques
- Aerosol-cloud-climate interactions and modelling
- Ion and aerosol dynamics
- Physics and chemistry of air pollution and their effects: field course and data analysis
- Regional and global modelling
- Field course on micrometeorology and hydrology
- Remote sensing and radar technologies
- Land use change monitoring
- Phenology and plant stress
- Arctic air pollution
- Model-data assimilation
- Carbon, water, nitrogen and aerosol cycles
- Climate politics for scientists

These schools combine core and transferable skills, but always ensuring that these skills are learned actively and kept fully relevant to the students' own research. The key transferable skills in the Doctoral Programme are (i) working in the field, (ii) atmospheric instrument technology, (iii) data analysis, (iv) computer modelling, (v) writing articles, (vi) popular science writing, (vii) presentation skills including audiovisual skills, (viii) project management, (ix) writing proposals, and (x) commercialization of scientific ideas.

The training and supervision of the Doctoral Programme is based on long-term co-operation in Atmospheric Sciences, Aerosol Physics and Technology, Ecosystem studies and Remote Sensing. The student supervision is done at research groups within the host institutions and Centres of Excellence. Each student has a main supervisor and is part of a research group with continuous contact with other students and PhD-level scientists. New multidisciplinary approaches are sought for by cross-supervising between different Doctoral Programme units. Teaching is provided both by courses at the host institutions and as joint courses on specialized topics that combine various aspects of the multidisciplinary research.

2.2 The organization of doctoral training within the programme

The ACCC Doctoral Programme has a clear structure, demonstrated by Fig. 3. The Programme is led by the Steering Committee, which includes the research group leaders of the partner universities (8 persons, chairman M. Kulmala) and research institutes (6 persons), and representatives of private enterprises (3 persons). The tasks of the Steering Committee include:

- selection of students
- decision of the joint and international courses and workshops within the Doctoral Programme
- general definitions of policy and decisions concerning the Doctoral Programme

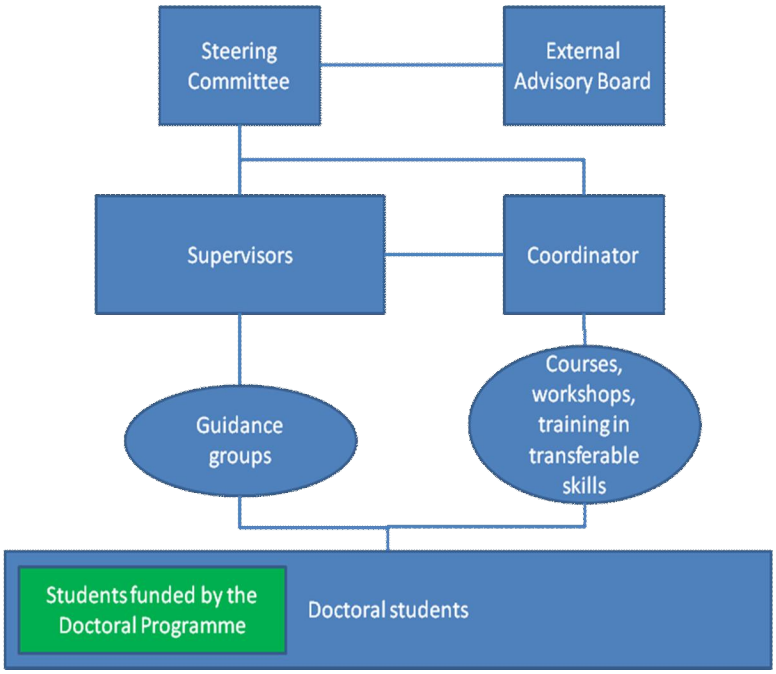

Figure 3. The structure of the ACCC Doctoral Programme. The key transferable skills given in the ACCC Programme are listed in Section 2.1.

The Doctoral Programme has a full-day coordinator. The tasks of the coordinator include:

- secretary of the Steering Committee
- preparing the student selection
- promoting the ACCC Doctoral Programme (web pages, fairs, national and international workshops and meetings)

- coordination of the international collaboration
- organizing joint and international courses, workshops and other activities within ACCC
- student feedback collection and processing
- general study guidance for the ACCC doctoral students
- keeping track of the careers of the ACCC graduates
- supporting the partners in ACCC administration
- preparing reports
- general coordination of the Doctoral Programme

The ACCC Doctoral Programme has currently 111 supervisors/teachers. Thus, the student/teacher ratio is 0.92.

The External Advisory Board, which will start in the beginning of 2012, is a new component of the Doctoral Programme. The External Advisory Board will consist of four academic experts. The initial composition of the External Advisory Board will be the following:

- Prof. Ruprecht Jaenicke, Johannes Gutenberg Universität Mainz (chairperson)
- Prof. Neil M. Donahue, Carnegie Mellon University, USA
- Prof. Pavel Kabat, Wageningen University and Research Centre, the Netherlands
- Prof. Mark Sutton, Centre for Ecology and Hydrology, Edinburgh, UK

The tasks of the External Advisory Board are described in Section 4.4.

The Doctoral Programme Steering Committee meets at least twice annually and monitors teaching activities at each host institution and helps the coordinator in joint teaching efforts. The advancement of each student is monitored annually by written reports by the supervisors to ensure early identification of problems. Students other than those funded by the funds allocated by the Academy of Finland are employed through their host organizations and follow the practices at their host institutions. With regard to their graduate education, they are full members of the Programme.

The joint training is carried out by the following actions:

- Teacher workshops
    - Annually
- Inter-institutional supervision
    - Currently 40% of Doctoral Programme students
- Guidance groups
    - Each student belongs to at least one
- Horizontal learning

The summer and winter schools are usually organized jointly by two or more institutions. Typically these courses are given in the form of short courses of 1-2 weeks length involving an intensive daily programme including lectures, exercises, seminars as well as work in small groups. The course topics are related to current scientific themes. Some common courses are also offered using e-learning platforms (Moodle, Blackboard).

The courses and workshops of the Doctoral Programme are promoted among participants of other Finnish Doctoral Programmes, and students of other Finnish universities. There are connections to other Finnish Doctoral Programmes, e.g. the Doctoral Programme in Nanosciences and the Doctoral Programme in Space Sciences.

The three-day annual meetings include a workshop for all the Doctoral Programme students and a steering committee meeting. In the workshop each Doctoral Programme student presents his/her research in oral and poster sessions to an audience involving the students, supervisors and interest groups. During the annual meeting the steering committee evaluates the functions of the past year, discusses the advancement of the Doctoral

Programme students based on the supervisor reports, and decides about the implementation of the next year's activities.

Research within the Doctoral Programme includes also joint analysis of results, transfer of good practices, and benchmarking. The partners are constantly using web-based tools like Moodle and Blackboard for e-learning, and Adobe Connect Pro for distributing seminars and lectures for a wider audience. In the Doctoral Programme context, new technologies to improve and support researcher education are developed and applied (e.g. Smart-SMEAR; Junninen et al., 2009).

Each Doctoral Programme student is working with the topics listed in Section 1.2. In the beginning of doctoral studies, each student writes a study and research plan. The plans also identify the skills to be developed (the gap between the current situation and the desired outcome) and educational activities, including courses and training on transferable skills, which are needed to meet the goals in the specific time window (4 years). The personalized projects often include inter-sectoral visits and/or secondments to another partner institution. During the studies, each student participates in joint courses and workshops. The study plans are designed by recognising the research career as a whole and as a part of that, the aim is that all PhD students finish the thesis in 4 years. Also the prospects for the postdoc period and after that are taken into account.

In 2008-2009, a total of 24 doctors graduated in the Doctoral Programme. The mean period used for doctoral studies was 7.4 years, while the median was 6.5 years. These exceptionally long periods are partly explained by the fact that several graduates had extensive tasks not directly related to their research. If these persons are excluded, the mean and median values were 5.4 and 5 years, respectively. Concerning the graduated Ministry-funded students, the mean period used for doctoral studies was 4.0 years.

It is foreseen that the development of the supervision and follow-up of the Doctoral Programme students will result in a shortened doctoral study period. The general timeline of studies in the Programme is presented below:
Year 1: Summer school, winter school, courses, workshop, research
Year 2: Courses (focus on training in transferable skills), workshop, research
Year 3: Research, manuscripts, papers, workshop, seminar course
Year 4: Ph.D. thesis final papers ready, summary

2.3 Meeting the requirements of working life and career planning, mentoring

Research in atmospheric sciences concerning environmental problems, climate change, air quality, and their interactions has been improved in a determined way in Finland during the past 20 years. There have been several research programmes by the Academy of Finland and TEKES, and as a result the research groups have attained a world-leading position in these fields.

Knowledge in aerosol and environmental sciences and remote sensing techniques has become more and more important because of climate change and increase of air pollution. There is an urgent need of doctors in these fields of science. This is also reflected by the fact that each of the 24 graduates during the 2008-2009 was employed immediately after graduation by industry and commerce, Finnish universities, research institutes, or foreign universities.

The partners of the Doctoral Programme are frequently requested to provide candidates for international tasks in universities and research institutes abroad. These tasks represent an important and rapidly growing area in our fields. The appreciation of the excellence in Finnish research has led to a situation where the doctors trained here have become desirable for foreign research institutes and universities. Environmental consultancy as well

as industrial research and development tasks are becoming more important. Career planning is a solid part of the ACCC studies, and it is included in the CBACCI education structure (CBACCI, 2003). In practice the career planning is done within guidance groups and in other supervision meetings. Part of the ACCC students are involved in innovation systems and/or mentoring programmes of private enterprises.

The ACCC Programme is constantly evaluated both by self-assessment and by the External Advisory Board. When evaluating the Doctoral Programme, the following criteria are taken into account:

- Employability of graduates
  - Quality and nature of core and transferable skills
  - Universities' ability to foresee future challenges in science & society
- The graduates' ability to carry out independent, original research work
- Quality of research
  - Publications in high-impact journals
  - Number of publications
- Structured and dedicated supervision

3 COOPERATION

3.1 Cooperation with foreign doctoral programmes or corresponding programmes

The participating research groups have direct working connections to more than 80 international laboratories and have participated in more than 35 EU-projects. One example of deep and wide cooperation is the European Integrated Project on Aerosol Cloud Climate Interactions (EUCAARI) during 2006-2010. The consortium has working connections to IPCC (Intergovernmental Panel of Climate Change) and IGAC (International Global Atmospheric Chemistry) programmes. The groups are participating also a number of global observation programmes (e.g. Fluxnet and GAW), international field campaigns to investigate atmospheric aerosols, tropospheric chemistry, precipitation and cloud microphysics; and development of Earth system models (e.g. COSMOS). The Nordic Toppforskning Initiatives CRAICC (Cryosphere-Atmosphere Interactions in a Changing Arctic Climate) and DEFROST (Impacts of a changing cryosphere - depicting ecosystem-climate feedbacks from permafrost, snow and ice) will enhance Nordic doctoral training in questions related to global warming. The consortium has good connections to the European Space Agency (ESA) and NASA. Several research groups have participated in the proposal for the ESA Earth Explorer 8 mission, Polar Precipitation Mission. Fig. 1 in Section 1.2 describes the various networks and connections.

The participating research groups have an international leading position in the research area of atmospheric aerosols and many of the most visible members in the communities of biogeochemical cycles and remote sensing. Our units constantly organise international conferences, workshops, seminars, and postgraduate student courses.

Concerning international Doctoral Programmes, the Nordic-Baltic CBACCI (Biosphere - Carbon - Aerosol - Cloud - Climate Interactions) is the most important international partner. CBACCI provides doctoral students with possibilities for short and long term researcher exchange, participation in international joint graduate courses, and international networking. CBACCI is also used to disseminate best practices in local and national training programmes and research groups in the Baltic and Nordic countries. CBACCI involves universities and research institutes from Finland, Sweden, Norway, Denmark, Iceland, Estonia, Lithuania and Russia. In 2008-2009, the ACCC coordinator was involved in organizing several CBACCI events, and also participated in other international workshops related to doctoral education (Beijing, China and Moscow, Russia).

Another important partner is the global iLEAPS/IGBP network (iLEAPS = Integrated Land Ecosystem Atmosphere Processes Study, IGBP = International Geosphere Biosphere Programme). The international project office of iLEAPS is hosted by the University of Helsinki.

The Doctoral Programme is linked to European Commission FP7 Marie Curie Initial Training Networks (ITN), e.g. CLOUD-ITN, and also to a number of other EU-projects. Furthermore, the Programme partners have submitted applications for the calls for Marie Curie Initial Training Networks (iLEAPS-CC) and Erasmus Mundus Joint Doctoral Programmes (AACC – Atmospheric Aerosols and Climate Change). Currently the Doctoral Programme units are participating in more than 10 EU-projects.

3.2 Internationalisation of doctoral candidates

ACCC strongly encourages its students to participate in international activities. In 2008-2009, 93% of the Doctoral Programme students participated in at least one international course, workshop or conference, or had at least one short or long term visit abroad.

Each Doctoral Programme student has a research and postgraduate study plan, where international activities are in an important role. These include:

- conference visits including oral presentations or posters
- short laboratory visits
- international summer and winter schools
- measurement campaigns
- possible long-term visits to foreign universities or research institutes
- active participation in summer and winter schools, workshops and international conferences

The plan is carefully prepared together between the student and the supervisors, and international cooperation is implemented to support the students, their PhD work and further career plans in the best possible way.

3.3 Recruitment of foreign doctoral candidates, foreign supervisors

In 2008-2009 there were 18 foreign postgraduate students in our Doctoral Programme. Currently the number is 30. Our research groups are internationally well-known and attractive for foreign students. Furthermore, it is comparatively easy for foreigners to adjust working in our research groups, since there is an existing population of foreign students, and the main teaching and research language at our institutes is English. Finally, the participating units have recognised the importance of providing support in practical arrangements (housing, immigration etc.), and there are persons dedicated to take care of these arrangements in the research groups. The Doctoral Programme units use also special grants to attract foreign students.

Many foreign students have been recruited through international networks. The Nordic-Baltic Master's Degree Programme in Atmosphere-Biosphere Studies (ABS) is a joint programme of 10 universities in Finland, Sweden, Denmark and Estonia. The ABS programme studies give an excellent basis for postgraduate studies, and already several foreign students have continued their studies in the ACCC Doctoral Programme.

The Nordic-Baltic CBACCI Graduate School, the global iLEAPS/IGBP network as well as several EU networks and international conferences serve as good platforms for recruiting foreign students. The recruitment announcements are also posted on the Doctoral Programme website and announced using job listings in internet-based networks (FLUXNET, ESWN-JOBS, EURAXESS etc.).

The ACCC consortium has been successful to recruit internationally well-known top scientists to work in Finland. There are currently two FiDiPro professors and 18 other foreign senior scientists within the Doctoral Programme. They participate very actively in supervision, and also give courses according to the same principles as Finnish senior scientists. Furthermore, there are currently six ACCC supervisors whose affiliation is abroad. The summer and winter schools and field courses usually include visiting foreign lecturers. Furthermore, Doctoral Programme students make visits and secondments abroad in universities and research institutions, and participate actively in international courses and workshops.

3.4 National partners of the doctoral programme and forms of cooperation

From the beginning of 2010, the core of the Doctoral Programme has included four universities, four research institutes, and five private enterprises:

- University of Helsinki (Department of Physics, Department of Forest Sciences, Department of Chemistry, Department of Geography)
- University of Eastern Finland (Department of Physics and Mathematics, Department of Environmental Sciences)
- Tampere University of Technology (Department of Physics)
- Aalto University School of Science and Technology (Department of Radio Science and Engineering, Department of Surveying)
- Finnish Meteorological Institute (units in Helsinki and Kuopio)
- Finnish Geodetic Institute
- VTT Technical Research Centre of Finland
- Finland's Environmental Administration (SYKE)
- Vaisala Oyj
- Beneq Oy
- Space Systems Finland Oy
- Helsinki Aerosol Consulting Oy
- Airmodus Oy

From the beginning of 2012, two new private enterprises will be involved:

- Arbonaut Oy
- MosaicMill Oy

The Doctoral Programme is operating within the Strategic Centre for Science, Technology and Innovation in Energy and Environment, coordinated by CLEEN Ltd.

Mobility on the national level is planned on four different levels:

- mobility between Doctoral Programme sites (Helsinki-Kuopio-Tampere-Espoo)
- mobility between research fields (Ecology-Physics-Technology-Chemistry-Meteorology-Geography, in situ observations – space-based remote sensing observations)
- mobility between research methodologies (theory-modelling-experiments-observations)
- mobility between universities, research institutes and business

The mobility is carried out by organising joint courses and through researcher secondments, including private sector staff in universities or research institutes and vice versa.

Each Doctoral Programme student has a research plan including national and international mobility plan. The mobility plan includes both conference and workshop visits as well as short and long visits to domestic and foreign universities and research institutes. Part of the funds of the Doctoral Programme is used to support student visits abroad and to other institutions.

3.5 Describe the cooperation and contacts with society at large (incl. business and industry etc.) and how this promotes the cooperation.

The education given in the Doctoral Programme serves the society and industry in several ways. The importance of the global climate change has emerged new regulations, creating the business a need for adaptation. Further on, new technologies have to be constantly developed and implemented.

The co-operation with several industrial enterprises already exists, and the core of the Doctoral Programme involves seven private enterprises (Airmodus Oy, Arbonaut Oy, Beneq Oy, Helsinki Aerosol Consulting Oy, MosaicMill Oy, Space Systems Finland Oy, Vaisala Oyj). Two of these companies (HELAC, Airmodus) are spin-off companies started by current or past Doctoral Programme students. The aim is to enhance our co-operation with several other private companies, e.g. Nokia Oyj, Dekati Oy, and Genano Oy in Finland, Airel Ltd in Estonia, and Aerodyne Research Inc. in the USA. Furthermore, there are several small and medium-sized enterprises involved in the co-operation. The American working ideas related to research enterprises will be applied in the Finnish conditions, particularly in co-operation with FiDiPro Professors, Dr. D. R. Worsnop and Dr. V. Chandrasekar. Prof. Worsnop is the vice president of Aerodyne Research, Inc., and the director of the Center for Aerosol and Cloud Chemistry. Prof. Chandrasekar is a deputy director and director of research of National Science Foundation (NSF) Engineering Research Center for Collaborative Adaptive Sensing of Atmosphere (CASA). The CASA ERC project has strong industrial partnership program including companies such as Raytheon, ITT and IBM. The center aims to develop and utilize ground breaking, innovative and transformative environment monitoring system. This kind of highly innovative companies will enhance the innovation networks and chains in Finland.

The Doctoral Programme does not aim only for student-time collaboration. The goal is to educate people with adequate training for the future challenges of the society. A specific aim is to enhance the settling on the private sector after obtaining the PhD degree. There are students from universities, research institutes as well as private companies in the various training events of the Doctoral Programme. Part of the Doctoral Programme students will be involved in the innovation systems of private enterprises.

4 QUALITY OF OPERATIONS

4.1 Organization of administration and operations

The partners in the program are shown by a shell-shaped structure shown in Figure 4.

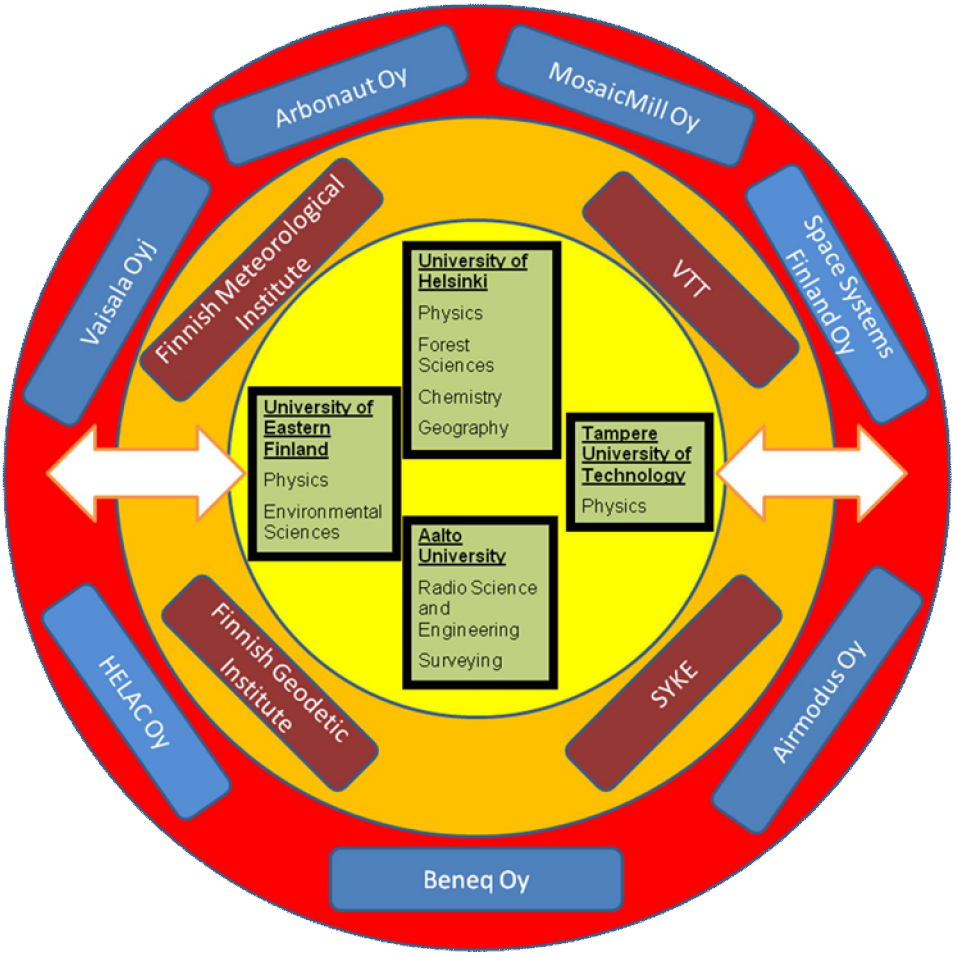

Figure 4. The current composition of the ACCC Doctoral Programme.

In Fig. 4, the four universities are in the core – all the Doctoral Programme students are enrolled as doctoral students in one of these four universities, and also the majority of the ACCC students (77% in 2008-2009) are being employed by one of these universities. The universities are also responsible in providing the required formal training (including courses and transferable skills). The four participating research institutes are placed in the middle shell. In 2008-2009, 23% of the ACCC students were employed by these research institutes. The research institutes are strongly connected with the universities – there are common guidance groups, joint research projects, and joint professors and other senior staff members. The seven private enterprises are in the outermost shell. They operate with issues related to the research questions within the Doctoral Programme, but each of them has a more specific focus (e.g. instrument development). The enterprises are full members of the ACCC consortium, they participate actively in the Doctoral Programme, and they have strong connections with both the universities and research institutes involved.

The organization of activities, and the roles of the Steering Committee and the coordinator are described in Section 2.1.

4.2 Application and selection processes, evaluation criteria and the implementation of the evaluation

The open, international doctoral student selection is prepared biannually by the Steering Committee together with the Programme coordinator. The application must include personal information of the applicant, a letter of motivation, an initial research plan, a statement by the supervisor in master studies, and a copy of the master's degree certificate including the transcript of studies.

The Coordinator prepares the applications for SC, which ranks the applications according to the following guidelines:

- suitability of master's degree studies
- grades in master's degree studies
- number and quality of publications (peer reviewed journals, peer reviewed conference papers)
- other scientific and technological merits
- initial research plan
- supervisors' statements

The top applicants will be interviewed. Special attention is paid to equality issues in the interview and in the student selection generally. The aim is that there is a minimum representation of 40% of each gender on each application round. Currently there is a rather good balance between genders (47% of all ACCC students and 50% of students in the positions funded by the Ministry of Educaton are female).

The rules for the ranking are transparent, and are clearly communicated through the Doctoral Programme webpage to anyone interested in applying.

The number of applicants in the previous application rounds:

Year	Total	Selected
2005	92	5
2006	91	3
2009	102	12

4.3 Supervision and monitoring arrangements

Each Doctoral Programme student has at least two, but usually three supervisors, including at least one senior scientist who is internationally recognized. Furthermore, at least one of the supervisors is working in a very close scientific collaboration with the student. The ACCC Programme has currently 111 docent-level supervisors, out of which 47 are professors.

Each doctoral student has participated and will participate also in one or two guidance groups. A guidance group typically consists of 5-8 students and 2-3 supervisors. The group meets every second week. In the group meetings the students report their progress, which is then discussed. Also senior scientist will give general and detailed comments and feedback to students. During 2008-2009 altogether 13 guidance groups were operating. Currently more than 40% of the ACCC students have supervisors from at least two partner institutes.

The Steering Committee follows the progress of the doctoral students continuously, and may suggest supervision rearrangements if needed. Each student has a right to contact the Steering Committee anytime if he/she feels that the supervision is insufficient or inadequate. The supervisors have the right to contact the Steering Committee if they feel that the student's research work is not progressing as planned. The Steering Committee is committed to act promptly to solve the possible problems brought up by ACCC students or supervisors.

The supervisors for individual students have been and will be selected according to a) needs of students, b) the research needs, and c) the capacity and experience of the supervisor.

4.4 Good practices applied within the programme

Students of the programme serve as a valuable source of criticism and new ideas of developing the programme. Guidance groups provided to us a common, permanent, well-working feedback system, which has been and will be used. Furthermore, the Doctoral Programme will arrange an annual 2-day workshop for the teachers and supervisors to

further improve their skills to advise students. The meetings include discussions e.g. on quality assurance and self-assessment in teaching and supervision, intercultural supervision and education, and ethics in science.

The general guidelines and good practices within the Doctoral Programme include:

- Maintenance, development and dissemination of best practices
- Open and transparent recruitment policy
- Active participation on the national and international policy and education system development
- Use of external evaluation
- Continuation of commitment on all levels (students, postdocs, senior scientists, professors)

Internal evaluation is carried out on different levels. During each classroom course, summer and winter school and workshop, student feedback is collected. The feedback is processed by the Coordinator after each event, and collected in a database. The Steering Committee discusses the feedback on an annual basis, and implements the improvements in the annual plan of activities.

The Doctoral Programme follows the Standards and Guidelines for Quality Assurance in the European Higher Education Area (www.enqa.eu).

The Programme has also an External Advisory Board (EAB), which plays the major role in the external evaluation. EAB members participate in the annual workshop, and give direct feedback to the ACCC students and the Steering Committee. Furthermore, EAB prepares evaluation reports on a regular basis. The reports include suggestions for improvements in the current practices.

4.5 Structure, partners, and the division of labour between different partners

Our doctoral programme is part of wide national and international environment including research infrastuctures, research projects and knowledge transfer projects (see Figure 1). The financial support of the participating universities and research institutes is significant, several millions Euros per year. They also participate in developing it actively via a) updating infrastructures, b) participating new challenging projects, and c) developing educational tools further. Joint infrastructures and a joint Doctoral Programme support Universities and vice versa.

Fig. 4 in Section 4.1 shows the partners of the programme. The formal education is given by the universities. The research is performed in universities and research institutes. The companies will provide recent, challenging application to basic research and provide also current connections to industry.

Fig. 5 shows the CBACCI education structure, which is a leading education idea behind the Doctoral Programme. The research career is seen as a whole, steps from one level to the next take place smoothly and with strong peer support and interaction between different levels.

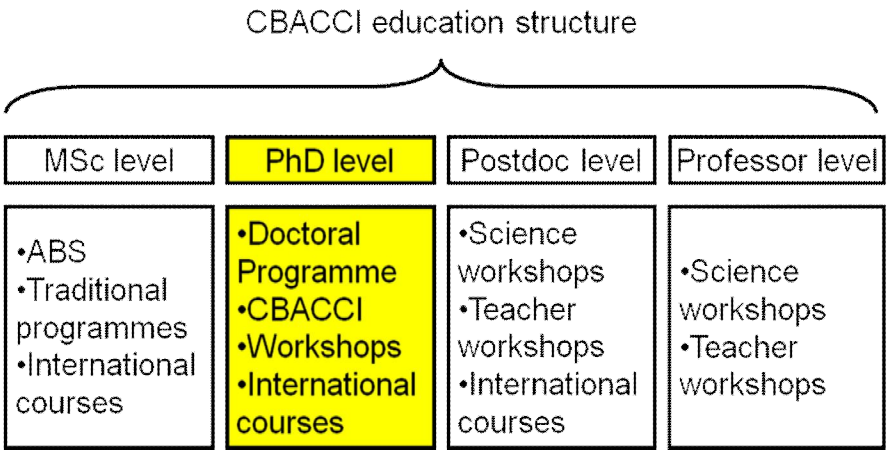

Figure 5. The CBACCI education structure.

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