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Based on the Svalbard Science Forum workshop 17–18 November 2008
at the Norwegian Institute for Air Research (NILU), Kjeller

Svalbard Science Forum

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Summary

In November 2008, Svalbard Science Forum organised a workshop with the aim to discuss future focal areas in atmosphere research in Ny-Ålesund. The result is this document that initiates an Atmosphere Research Flagship programme as part of the NySMAC science plan for Ny-Ålesund.

In Ny-Ålesund, long term measurements of several key climate parameters from the surface level up to the ozone layer have been performed for decades already. Such comprehensive data sets are available from very few sites in the Arctic and the data are continuously fed into global networks. Ny-Ålesund offers excellent conditions for scientific research, due to its accessibility and international and multidisciplinary character. For atmospheric research, Ny-Ålesund offers the possibility to perform continuous measurements both close at sea level and at 475 m of altitude within a relatively pristine environment. Also, its location under the magnetospheric cusp makes it a unique place for observing the solar wind and magnetosphere interaction on the dayside.

In order to optimally use these excellent conditions for atmospheric research and to improve cooperation within the Kongsfjorden science community, this document describes general flagship goals which include the optimal utilization of available instruments and data sets, the establishment and further development of common research infrastructures, and a programme to investigate the representativeness of measurements in Ny-Ålesund for climate change research and atmospheric process studies.

The flagship programme states the following future research priorities:

- Long term observations of key parameters concerning climate change
- Planetary boundary layer (PBL) research
- Studies and monitoring of long range transport of pollutants
- Arctic ozone layer and UV research
- Ionospheric / magnetospheric research
- Validation and synergistic analyses of satellite data

The flagship programme aims to establish a unique international long-term atmospheric monitoring and observation platform supported by all research institutions represented in Ny-Ålesund and thus to realize a supersite, allowing investigations of the complex Arctic System with a multidisciplinary approach. Interdisciplinary observations will be performed elucidating interaction processes on sea, snow and ice surfaces and the atmosphere. Special emphasis will be laid upon the impact of climate change on the Arctic environment.

Furthermore, means of better integration of atmospheric research within Ny-Ålesund, Svalbard as well as on a circumpolar level are discussed, and possibilities for interdisciplinary cooperation with other flagships are pointed out. Finally, three appendices give an overview of atmospheric stations in Ny-Ålesund, atmospheric parameters measured in Ny-Ålesund, and the atmospheric monitoring satellites in operation in 2010–2020.

Contents

1. Main features of the Atmosphere Research Flagship

1.1 Atmospheric research in Ny-Ålesund

- Several long term measurements of key climate parameters from the surface up to the ozone layer have been performed for decades already.
- Continuous measurements both from sea level to 30 m, and at 475 m altitude at the Zeppelin Mountain observatory give a unique possibility to investigate the lower atmosphere inside and outside the Planetary Boundary Layer.
- The geographical position allows studies of many aspects of the Arctic environment. For example, Ny-Ålesund is located at the junction of the warm Atlantic current with the cold Arctic basin, and the magnetospheric cusp has here its projection in the polar atmosphere.
- The geographical position also provides the possibility to measure both the pristine, clean Arctic atmosphere with minimal background values and increased pollution episodes due to long range atmospheric transport processes.
- Ny-Ålesund, with the Svalbard Rakettskytefelt, a launch site for sounding rockets (SvalRak), is the only place in the high Arctic where the entire air column from sea surface to 350 km altitude can be investigated in detail by sounding rockets.
- The interdisciplinary and truly international research activities covering a broad range of research aspects in the Arctic, act as a catalyst to spawn new scientific questions and to attract new young scientists.
- In general, Ny-Ålesund is easy accessible, has a highly developed logistical infrastructure with regular flights, a harbour, accommodation, meeting and lab facilities, and high speed Internet.

1.2 Flagship vision

- Realize a supersite to investigate the complex coupled Arctic System with a multidisciplinary approach, studying e.g. interaction processes between sea, snow and ice surfaces and the atmosphere. The motivation is to reduce uncertainties in climate forcing components and to improve climate model simulations. Multidisciplinary and comprehensive data sets, as well as interactions with other flagship programmes will be utilised.
- Establish and maintain a long-term atmospheric monitoring and observation platform supported by all research institutions represented in Ny-Ålesund.
- Enlarge the Ny-Ålesund perspective to the pan-Svalbard area by integrating it as a key element in Svalbard Integrated Arctic Earth Observing System (SIOS), and to contribute to a circum-Arctic network.

2. Introduction

Climate change occurs faster in the Arctic than elsewhere in the world and consistent signs of a general warming in the Arctic region have been observed in the last years. This is manifested in a thinning and retreating sea ice cover, and increased greenness of the tundra. However, the rate of change of different geophysical parameters of the Arctic system varies quite a lot. Ny-Ålesund is located at the northernmost point of the warm Atlantic Ocean inflow, the West Spitsbergen Current. Therefore, it has a pivotal location enabling observations of climate relevant parameters in the ocean, on land, and in the atmosphere. Additionally, atmospheric transport pathways guide pristine Arctic air masses to Ny-Ålesund, as well as pollution events originating from southerly latitudes, sometimes after extended transport times. For that reason, observations in Ny-Ålesund allow monitoring of background values of trace substances, as well as investigation of physico-chemical transformation processes of air mass characteristics.

Ny-Ålesund represents a unique site, where established international cooperation allows observation of a large number of key parameters of the Arctic system. The geographical location provides an opportunity to enhance our knowledge on the complex interactions and processes connecting different elements of this system, which in turn allows us to ameliorate parameterisation in climate models. Model reliability is often particularly poor in Arctic regions, when parameterisations used in models are based on observations at lower latitudes. Extensive long term measurements of key climate parameters are needed as basis for model upgrades.

The research stations in Ny-Ålesund offer long term observations allowing the investigation of effects of climate change and atmospheric chemical processes at one sensitive location in the high Arctic. Some of these observations are representative for a larger region, whereas others are only related to the local scale and the Kongsfjorden area. Several important measurements started already years or decades ago (e.g. stratospheric ozone investigations), or even as early as 1911 for meteorological parameters. Special emphasis and additional measurements were introduced as part of the International Polar Year (IPY) 2007/2008.

In order to understand how global climate change is reflected in local observations, two approaches are needed. Firstly, studies of atmospheric processes should be undertaken to understand physical and chemical processes in the atmosphere, on land, and in the ocean, and how these reservoirs interact at their interfaces. Secondly, it is needed to employ regional and global scale models of the ocean, ice cover, and atmosphere in order to investigate underlying physical and chemical processes and to reveal the connection between regional and global phenomena. Such atmospheric modelling efforts are conducted e.g. in the frame of international programmes like Arctic Climate Impact Assessment (ACIA), Institute of Atmospheric Science and Climate (ISAC), Intergovernmental Panel on Climate Change (IPCC), etc.

Ny-Ålesund is located at a place where the magnetospheric cusp has its projection in the polar upper atmosphere. Thus, it is a unique place for observing the solar wind and magnetosphere interaction on the dayside. Here also the high-density ionospheric plasma from lower latitudes breaks into patches, entering the polar cap by crossing the dayside auroral oval and exiting through the nightside auroal oval. These polar cap patches of high-density turbulent electron clouds give rise to scintillations of radio waves affecting communication and navigation signals. Sounding rockets from Ny-Ålesund are an unprecedented tool to investigate the underlying physics and the variability of space weather in the upper atmosphere.

Ny-Ålesund is close to the magnetic conjugate of the Zhongshan station in Antarctica. The Chinese Yellow River Station in Ny-Ålesund is equipped with the same core instrumentation as Zhongshan station, which gives unparalleled opportunities for conjugate studies, thus allowing a significant contribution to solar-terrestrial physics.

2.1 Uniqueness of Ny-Ålesund

Svalbard offers excellent opportunities for scientific research. It is easily accessible and the working conditions are exceptionally good compared to other Arctic regions. Ny-Ålesund, an old mining community, is today an international research network of primary importance and the best equipped international scientific settlement in the Arctic. Eleven countries have established permanent stations and pursue a large variety of research topics. This accumulation of a broad range of scientific activities in one place is unique in the Arctic region. Some activities are replicates, increasing their reliability, and many are supplementary providing the synergy of joint research.

Several long term measurements of key climate parameters from the surface up to the ozone layer have been performed for decades already. Their data is continuously fed into global networks like Global Atmosphere Watch (GAW) of WMO, Baseline Surface Radiation Network (BSRN), or the Network for the Detection of Atmospheric Composition Change (NDACC). Such comprehensive data sets are available from very few sites in the Arctic, making Ny-Ålesund a primary one.

Ny-Ålesund hosts laboratories and research facilities for many other research disciplines as well. This allows a unique combination of research aspects thanks to the co-location and cooperation. Examples are the link between ozone loss and marine life or the relationship between climate processes and glaciological and biological responses.

One of the important advantages of Ny-Ålesund for atmospheric research is the possibility to perform continuous measurements both close at sea level and at 475 m altitude at the Zeppelin Mountain observatory. In a monitoring and long-term perspective, it is thus possible to highlight the importance of local surface processes with respect to vertical-exchange phenomena and long-range transportation processes, as well as local deposition processes.

A general, but extremely important aspect of Ny-Ålesund’s uniqueness is its reachability with respect to its high latitude. No other place at a location of 78º North is as easily accessible as Ny-Ålesund.

2.2 The Atmosphere Research Flagship for Ny-Ålesund

In order to identify knowledge gaps and future scientific goals for atmospheric research in Ny-Ålesund, Svalbard Science Forum (SSF) invited leading researchers to a workshop at Kjeller, Norway, November 2008. The participants agreed that a systematic and coordinated flagship research program should be developed in order to effectively fill current knowledge gaps, integrate atmospheric research activities of individual institutes in Ny-Ålesund and thereby optimally use the uniqueness of Ny-Ålesund and at the same time acknowledge both its potential and limitations.

3. General flagship goals

The Atmosphere Flagship initiative for Ny-Ålesund is seeking to improve atmospheric research cooperation within the Kongsfjorden science community in several ways. The major issue is to integrate activities, many of which have been carried out isolated at the different stations until now. A first step is to spread information about available instrumentation and data sets by setting up a corresponding data base (chapter 3.1). The new Amundsen-Nobile-Climate-Change-Tower (CCT) is regarded as a central infrastructure open to international cooperation, which will foster the integration of atmospheric research (chapter 3.2).

A centralised atmospheric research laboratory, similar to the well established Marine Laboratory, would be another integrating step. A possible site is the building "Gruvebadet", located between the village, the CCT, and the Zeppelin Mountain observatory. Some atmospheric measurements in Ny-Ålesund are influenced in different ways by local orography, and regional features such as ocean currents and ice cover situation. Therefore, a major general issue is to determine how well Ny-Ålesund represents Svalbard, the region, or the Arctic in general in different atmospheric research fields (chapter 3.3).

3.1 Optimally utilise available instruments and data sets

Several stations in Ny-Ålesund have a smaller or larger array of instruments for atmospheric studies. In order to be able to fully utilise the potential of these instruments and the resulting data series, an overview of the available instruments and their properties was compiled (see appendix 3). This overview is currently administered by SSF and has complemented the gap analysis of the pan-Svalbard programme SIOS (Box 1). SIOS aims to strengthen the cooperation between the international research institutes by coordinating and complementing research infrastructure, rather than having many national replicates side by side. Ny-Ålesund has the best prerequisites to accomplish such a comprehensive instrument park within the research base and should strive to use the synergy effects of such cooperation.

Both at the Zeppelin Mountain observatory, as well as in the village, many long-time data series are being produced. These data series need to be organised and made available for the research community. Mechanisms that make it possible to share the data within the Ny-Ålesund research community should be established, without reducing the value of the data for the owner of the instruments. Such a data policy will be established within the framework of the SIOS data management. The comprehensive atmospheric data available from Ny-Ålesund should become a particular highlight of the SIOS initiative.

There is also a need to further develop the meta-database on data sets, operated by SSF (http://svalbardscienceforum.no/pages/database.htm). This database should be continuously updated with information on data collected within the atmospheric research; both for short time campaigns as well as long time series.

Box 1: Svalbard Integrated Arctic Earth Observing System (SIOS)
SIOS is a large-scale programme on the European Strategy Forum on Research Infrastructure (ESFRI) Roadmap. The preparatory phase (2010-2013) is funded by the European Union. The aim of SIOS is to develop an optimized observational infrastructure which can match advanced Earth System models with observational evidence and provide near-real-time information on Arctic change to relevant stakeholders.
During the preparatory phase, the main goal is to establish the formal framework needed to operate a geographically distributed and thematically structured multi-national research infrastructure across Svalbard and provide a research node to contribute effectively to future circum-Arctic monitoring.
Some of the sub-goals of SIOS are:

- Define the additional infrastructure needed to develop Svalbard into an Arctic Earth System observing platform, based on comprehensive science and instrument gap analysis.
- Develop a data management, accessibility, and utilization plan around a core element of the new infrastructure, the SIOS Knowledge Centre.
- Establish a practical and attractive structure which supports and encourages international access for both field campaigns and long-term cooperation through the SIOS research facilities.
- Promote and develop SIOS as an important component in global Earth System observing efforts and in international efforts to establish a Sustained Arctic Observing Network (SAON).

Read more: http://www.sios-svalbard.org/

3.2 Establish and further develop common infrastructure

During 2009 the Amundsen-Nobile-Climate-Change-Tower (CCT) was built in Ny-Ålesund and was equipped with a large suite of instruments thanks to the financial support of the Department of Earth and Environment at the Italian National Research Council (CNR). It provides a platform for groups conducting research in Ny-Ålesund in the atmospheric field, in particular flux measurements, surface albedo, and PBL studies. An agreement signed by CNR and Kings Bay A/S (KB) regulates use and maintenance of the tower and defines access rules. The tower can be used by interested research groups on the basis of a mutual Memorandum of Understanding (MoU).

In complement to this tower, it is desired to have another common facility offering lab space and basic measurement capabilities with the aim to facilitate access to Ny-Ålesund, in particular to field campaigns organised by researchers/institutions not usually operating at the site. The facility should have basic features for communication, stabilised and continuous power supply, hot and cold water, air inlets/exhausts for aerosol and gas sampling following standard recommendations (e.g. by EUSAAR), as well as instrumental maintenance by permanent staff.

The location of such a common infrastructure could be the Gruvebadet building, previously hosting several measurements from NILU, Stockholm University (SU), and National Physical Laboratory, New Dehli, India (NPL). Recently, CNR has already used the building for in situ atmospheric measurements. Gruvebadet is situated midways between Ny-Ålesund and the CCT and local influence should be minimal due to the wind regime. The location is also interesting for remote sensing since the luminous pollution from the village is drastically reduced here.

The building should offer sufficient space for routine measurements, field campaigns, as well as educational and outreach activities. A consortium set up similar to the Marine Lab could be a start for a possible organisational structure.

3.3 Investigating the representativeness of measurements in Ny-Ålesund

Svalbard is located at the northernmost tip of the West Spitsbergen Current, which carries warm, Atlantic water northwards, and just east of the Fram Strait where the largest outflow of sea ice loaded water masses from the Arctic Ocean occurs. Svalbard is also faced to the Greenland Sea, an area of deep water formation which has strong effects on the global circulation of the deep ocean current – the global conveyor belt – which in turn has a strong influence on the global climate. In the atmosphere, the largest transport of moisture to the Arctic Ocean from lower latitudes occurs in the longitude band around Svalbard. Therefore, compared with other Arctic stations as Barrow in Alaska, Alert in Canada, and Tiksi in Russia, Ny-Ålesund in Svalbard is one of the best places to perform atmospheric research. However, we still need to answer several questions concerning the representativeness of Ny-Ålesund for climate change research and atmospheric process studies:

- Ny-Ålesund is located at the coast of Kongsfjorden and close to the Zeppelin Mountain. Therefore its atmospheric condition might be affected by peculiarities of the local wind system. How much is the "flow field" perturbed by the island itself, and how strong is the local perturbation? In order to study this flow system, high resolution modelling is indispensable for clarifying the effects of orography.
- How far can we extrapolate the information collected in Ny-Ålesund into the Arctic? Ny-Ålesund, the Kongsfjorden International Research Base, has a horizontal extent, reaching from Corbel Station to Rabben Station, a vertical extent from sea level to Zeppelin Mountain observatory, 475 m a. s. l., and a temporal extent from at least the 1970s until today. This is helpful for investigations concerning the representativeness since the variability of atmospheric parameters within the Kongsfjorden area can be determined.
- Within the island of Spitsbergen, there are also scientific observation stations at Barentsburg, Longyearbyen and Hornsund, and we need to compare data from Ny-Ålesund to those measured at these stations.
- Furthermore, we should utilise mobile platforms like aircrafts, ships, ice stations and satellites for comparison to confirm the representativeness of Ny-Ålesund observations.
- We should investigate Ny-Ålesund as a "Gateway to the Arctic", with respect to the influence of the North Atlantic Ocean. Ny-Ålesund is directly influenced by the Atlantic when low pressure systems are located over western parts of Svalbard, and directly influenced by central Arctic air masses when high pressure systems overlie the west.

4. Programme topics and specific scientific goals

4.1 Current knowledge gaps

During the workshop several knowledge gaps were identified and following questions were formulated:

1. What approach should be taken to contribute to minimise the uncertainties in the current understanding of climate change, such as the huge errors encountered from aerosol-cloud interactions?
2. What are the causes for and the effects of the Arctic sea ice decline?
3. A proper platform dedicated to characterise the PBL around the sampling area needs to be developed.
4. In Ny-Ålesund, a comprehensive study of the atmospheric column from PBL to upper atmosphere is needed.
5. How much do we know about the complicated tropospheric chemistry of the region and exchange processes of minor constituents from terrestrial to atmospheric compartments?

6. How significant is the local pollution from the Ny-Ålesund village itself, i.e. our own footprint?
7. Increased knowledge about the role of long range transport of pollutants measured in Ny-Ålesund and their impact on the atmospheric processes is needed.

4.2 Monitoring

Monitoring typically refers to observations of environmental pollutants that are harmful to humans or animals by direct exposure or via the food web. A "classical" example are persistent organic pollutants (POP). As some of these compounds are banned, trends in their atmospheric concentration can show if legislative measures are effective or not. After a period of decreasing trends in POP concentrations, the last 4–5 years have shown an increasing trend, which is currently not understood.

Sometimes harmful compounds are exchanged with other compounds that are thought to be harmless. A typical example are Chlorofluorocarbons (CFC), thought to be excellent refrigerants until the components were released to the atmosphere and reached the stratosphere, where they participated in the process ozone depletion. Shortly after banning CFCs, a decrease in the atmospheric concentrations could be observed. However, replacement compounds have steadily increased at the same time. Although not toxic, these compounds are potent greenhouse gases.

Ny-Ålesund is located far from the emissions. Therefore, observations here allow for detection and determination of possible trends with a higher level of confidence than observations performed closer to the sources. A single measuring point in Ny-Ålesund will be representative for a much larger region (in particular for long-lived species) than for instance a measuring point at the European continent.

As a specific goal we acknowledge the excellent conditions for monitoring anthropogenic emissions that Ny-Ålesund exert, and we highlight this quality for further development. If a compound is considered potentially harmful, Ny-Ålesund is a very well suited location for starting a pilot monitoring program.

4.3 Long-term measurements

Long-term measurements typically refer to observations of compounds or species not necessarily toxic or directly harmful, but nevertheless with a detrimental effect on our environment or being a key player in atmospheric science. These species differ from the previous ones, because they typically have both a natural and an anthropogenic component. This means that long-term measurements are an absolute necessity if the goal is to separate the anthropogenic signal from the natural variability.

There are many examples of important tracers in this section and they range from multi-component systems such as aerosols that are characterised by size, shape, phase, chemical composition, etc. to the seemingly trivial water vapour concentration that is difficult to measure precisely.

As a specific goal we acknowledge the long-term measurements as probably one of the most important existing scientific information sources, yet they are likely the most difficult ones to find funding for. This type of data is the backbone of many other research initiatives. Hence, another specific goal is the special emphasis on coordinating and sharing these data in a way that benefits the whole scientific community of Ny-Ålesund.

4.4 Process studies

Our tools to predict the future climate are climate models. It is very important to stress that the results from these numerical simulations never will be better than the knowledge that we put into them. The scale at which we understand a phenomenon is also the scale we can use to interpret the results from these simulations.

One scale is given by the geometric grid of the model, another by the time intervals used. However, it is possible to refine these scales using parameterisations. If we understand the processes, we can simplify them and adapt their mathematical description given the numerical limitations of the climate models. Processes that need attention and improvements in models are literally endless, for every scale parameterised there is a smaller scale to challenge. This is the chaotic nature of the system Earth.

As a specific goal we acknowledge the investigation of the particular surface conditions of snow and ice as characteristic of the Polar Regions. Any of the interface regions, stratosphere-troposphere, boundary layer-free troposphere, land-atmosphere, and ocean-atmosphere, are areas where huge progress can be made by improving parameterisations. However, for the Arctic the impact of a changing ice cover is paramount. The issue of ice is not restricted to the surface, but includes also the ocean below and the atmosphere above.

In conjunction with the additional observational capability of the CCT and the extended measurements by several stations (including aircraft campaigns), important process studies focusing on heat and vapour flux from the surface throughout the atmospheric column are highlighted as another specific goal.

4.5 Climate change studies

Climate change study is a wide and general description for a specific scientific goal. It is important to emphasise that climate change normally refers to the anthropogenic perturbation of the climate or anthropogenic forcing of the climate. In addition to the forcing of the climate, climate change studies also include the effects of a changed climate and possible feedback mechanisms in the system.

Essentially, all climate forcing components listed by IPCC (2007) are observed by at least one of the institutes operating in Ny-Ålesund. One exception is the aerosol-cloud-climate interaction, due to the lack of in-situ cloud microphysical observations. Contrails are currently not a research topic in Ny-Ålesund.

The models predict that human induced climate change will be most evident in the Polar Regions. Observations show an even stronger warming and decline in ice cover than predicted by the models.

Processes in numerical models are inadequately represented and one of our specific goals is therefore to focus on research projects that target improvements in parameterisations of these models. This goal harmonises well with the ATMOKONG initiative described in the Kongsfjorden System Flagship.

4.6 Validation and synergistic analyses of satellite data and remote sensing

Satellite data are the only continuously available source of information over oceans and remote land areas where there are insufficient monitoring networks. Therefore the Ny-Ålesund Atmosphere Flagship has to combine data from ground-based monitoring networks with earth observation data in order to improve operational and scientific routines for performing air quality assessments.

Appendix 4 shows the list of current, approved, planned and considered satellites for monitoring and observation of the atmosphere above Svalbard from today until 2020. The 103 satellites will monitor trace gases such as ozone, aerosol properties, cloud type, cloud amount, cloud top temperature, cloud particle properties, cloud profile, liquid water, precipitation, water vapour, radiation budget, atmospheric winds and temperature fields. Marked are the 17 satellites relevant for monitoring of trace gases, and the 27 satellites relevant for monitoring of ozone.

The geographical location of Ny-Ålesund leads to a denser frequency of overpasses by polar orbiting satellites compared to locations further south. Therefore, the frequent opportunities of concurrent observations at the surface and from space make Ny-Ålesund an excellent place for the important validation and comparison studies, so called ground truthing.

4.7 Upper atmosphere

It is well known that daytime auroras (cusp auroras) are associated with strong backscatter in coherent High frequency (HF) radars (like the global SuperDARN network). The HF radio communication suffers greatly from auroral activities, but also satellite based communication and navigation systems are subject to space weather effects during solar storms.

The obvious reason for HF backscatter irregularities are decametre (~10 m) structures in the electron plasma. However, the formation mechanisms are not yet determined, not even the altitude range. Hence, it is necessary to understand the instability mechanisms that drive the electron plasma turbulence, i.e. to understand the solar wind interaction with the magnetosphere. Space weather in the high-latitude ionospheric polar atmosphere is also very important for space weather on a global scale.

As a specific scientific objective we envisage joint observation campaigns including European Incoherent Scatter Scientific Association (EISCAT), SuperDARN, rocket launching, ground based auroral observation in Longyearbyen, and satellite measurements passing overhead. With the Svalrak launch facility in Ny-Ålesund, Svalbard is the only place in the world where cusp ionospheric processes of direct coupling to the solar wind can be studied simultaneously from ground by optics and incoherent scatter radars, and in-situ by sounding rockets. For investigations of space weather processes we highlight the opportunity of comparative monitoring and analysis of the upper atmosphere observations between magnetically conjugate stations, i.e., Ny-Ålesund and Zhongshan Station, Antarctica.

5. Aspects of integration of atmospheric research

5.1 Within the Kongsfjorden International Research Base

For the community as such, programs like the EU funded LSF and ARCFAC, which aim to promote collaboration, are excellent incitements to find new partners in this work. Examples of successful cooperations specific for the atmosphere are for instance, the airborne campaigns ASTAR (Arctic Study of Tropospheric Aerosol and Radiation) in 2000, 2004, and 2007. This project involved German, Japanese, Swedish and French scientists in combining airborne and ground based measurements. Another example of a different application is the POLAR-AOD (the polar aerosol optical depth measurement network) project. Here twelve institutions from nine countries participated in a radiometer inter-comparison, which was carried out in March 2006 in Ny-Ålesund. Besides larger consortia like the examples above, it is common that two or three groups work together around a specific topic. This evolves naturally since one institute cannot cover all aspects of measurements. By exploiting the logistical opportunity of several research groups being in Ny-Ålesund, it is easy to complement each other.

5.2 Connections to other locations in Svalbard (pan-Svalbard perspective)

Hornsund

The Polish Polar Station in Hornsund was established in 1958 during the International Geophysical Year 1957–1958. Since 1978 the station is performing continuous observations in a broad range of science research, i.e. glaciology, seismology, geomagnetism, ionospheric sounding, atmospheric electricity, environmental monitoring and meteorology.

Several monitoring activities are today running parallel in Hornsund and Ny-Ålesund: UV-radiation monitoring, sunshine duration, aerosol optical thickness, and integrated water vapour content. The Hornsund meteorological station is a member of the World Meteorological Organization (WMO).

Recently a multiwavelength Elastic (3)/Raman (2) Light Detection And Ranging Radar (LIDAR) instrument for the investigation of polar aerosols and water vapour profiling has been installed at Hornsund. Comparative measurements e.g. with the LIDAR of the French-German Arctic Research Base in Ny-Ålesund (AWIPEV) are possible and should be envisaged.

Barentsburg

Barentsburg has for a long time been a key meteorological station in Western Svalbard. This station has been working since 1932. The oldest Norwegian Meteorological station in Svalbard ("Spitsbergen Radio") operated during 1912–1930, just 2.5 km south of Barentsburg. An important focus in the current flagship should be to integrate these two data series in order to utilise the unique dataset for objective and quality analysis of the observed Svalbard climate. Current activities (comparison/intercalibration of standard radiation sensors) are closely connected with joint climate analysis.

The Arctic and Antarctic Research Institute, Russia (AARI) has recently carried out joint radiation measurements in Ny-Ålesund and Barentsburg. Russian sensors for measurement of incoming global radiation are still working in Ny-Ålesund since IPY 2007/2009. Additionally, the Institute of Atmospheric Physics (Moscow) and AARI cooperate with the University of Utrecht, The Netherlands in the project "Transfer of heat, mass and impulse by katabatic winds over the glaciers" in Ny-Ålesund (2008–2019).

Longyearbyen

During the polar night, in December and January, when the sun is -10 degrees below the horizon, daytime cusp auroras can be studied by optical devices from Svalbard. There are several research stations in Svalbard performing auroral physics-related studies. The Auroral Station in Adventdalen (Nordlysstasjonen), built in 1978 as a cooperation between the Universities of Tromsø and Alaska, Fairbanks, was the first permanent station. After 30 years of operation a new optical station, the Kjell Henriksen Observatory (KHO), was built. The new observatory is located 12 km from Longyearbyen and is currently the world's largest and best equipped optical station for auroral studies. KHO provides the infrastructure we need to continue optical measurements of the aurora and airglow, and to properly maintain, service, and upgrade the instruments.

The new observatory is located close to the EISCAT Svalbard Radar (ESR). The ESR consists of two antennas; the steerable 32 m dish was built in 1996 and a 42 m field-aligned dish was added in 1999. The ESR measures several parameters related to the ionospheric plasma (electron density, electron and ion temperatures and ion velocity). The Sousy Svalbard Radar (SSR), a "mesosphere-stratosphere-troposphere" radar

(SOUSY) measures parameters related to the middle atmosphere. An ionospheric heating system (SPEAR) has also been built in the same area; it can be used for a variety of ionospheric and atmospheric investigations including the creation of artificial aurora. In addition to these facilities there are further aurora related research stations in Barentsburg and Ny-Ålesund, the latest being the Chinese Polar research station, which started operating in the 2003/2004 season.

The optical calibration laboratory at UNIS is now being used to sensitivity calibrate the instruments at KHO and the Russian station in Barentsburg. This is an initiative together with the Polar Geophysical Institute of the Russian Academy of Sciences. In addition, data from the Barentsburg station will now be available in real time through a high speed data link. The network of three optical observation sites in Svalbard (Longyearbyen, Barentsburg and Ny-Ålesund) allows auroral tomography, and due to varying meteorological conditions, increases the total amount of cloud free auroral observations.

5.3 Circumpolar and global networking

The Atmosphere research programme shall be pursued in connection to the infrastructure development as it is organised within SIOS. As a first step, this flagship programme contributes to the atmospheric sciences to the SIOS gap analysis initiative, which will formulate the research goals for the larger Svalbard region. As SIOS shall contribute to the circumpolar Sustained Arctic Observing Network (SAON), Ny-Ålesund will become more visible as an observational node. Several continuous or regular observations performed at Ny-Ålesund based stations are part of regional or global networks, e.g. the WMO networks Global Atmosphere Watch (GAW) and Baseline Surface Radiation Network (BSRN), the Network for the Detection of Atmospheric Composition Change (NDACC) and CO_2 and trace gas networks like the Total Carbon Column Observing Network (TCCON) and the Advanced Global Atmospheric Gases Experiment (AGAGE), which provide the data exchange and common data analyses platform, as well as data interpretation forums. The Zeppelin Mountain observatory is particularly contributing to the regional Arctic Monitoring and Assessment Programme (AMAP) and the European Cooperation Programme on transboundary pollution transport (EMEP).

6. Connecting to the other flagships in Ny-Ålesund

6.1 Kongsfjorden System

A Kongsfjorden Integrated Research Flagship was initiated through a workshop in March 2008. It aims at studying the Kongsfjorden ecosystem in an integrated way, building on marine biological, oceanographic, and atmospheric investigations.

The Kongsfjorden System Flagship requires the monitoring of atmospheric parameters in the inner Kongsfjorden, in order to characterise various processes at the atmosphere-ocean interface. The ATMOKONG initiative described in the flagship document summarises which particular parameters need to be provided:

1. Standard meteorology
2. Total aerosol concentration, aerosol size distribution larger than about 0.1 micrometer in diameter
3. Passive PUF sampler for water and atmosphere (OCP contaminant monitoring)
4. Trace gases by Differential Optical Absorption Spectrometer (DOAS)
5. Total deposition collector (OCP analysis)
6. Mercury-Tekran monitor
7. CH_4/CO_2 monitor
8. Halon monitor (biogenic brominated substances)
9. Wet only samplers for deposition monitoring
10. Dry only samplers for deposition monitoring

Parameters 1–7 (CO_2) are available within Ny-Ålesund, but their representativeness for the inner Kongsfjorden needs to be established. For this purpose, as a first step the comparison of these parameters with similar measurements at the Clean Air station Corbel can be conducted. At Corbel Station the following parameters have been measured since 2009:

- Meteorology
- Aerosol concentration and size distribution

Mercury measurements are performed at the Zeppelin Mountain observatory. CO_2 chamber and CO_2 (CH_4) eddy flux measurements are performed at Ny-Ålesund village and Bayelva site, respectively. These measurements shall also be conducted at Corbel, allowing for a comparison study. After such comparison studies the utilisation of Corbel and/or the compilation of the instruments at the new monitoring station can be optimised.

The results of the ATMOKONG initiative will contribute to the following research areas of the "integrated Kongsfjorden system initiative":

- Combined marine and atmospheric monitoring devices in the fjord system covering priority parameters for evaluation of inter compartmental fluxes and meteorological-station
- Combined modelling empirical investigation (fieldwork, lab-experiments) "integrated column sediment–ocean-atmosphere approach"
- (Eco)toxicological response on contaminant fluctuations (biomarkers, top-predator response)
- Identify and use marker substances and processes for quantitative estimation of transport and uptake in biological systems (e.g., particulate matter, pollutants, etc.)

6.2 Terrestrial Ecosystems

The flagship on terrestrial ecosystems focuses on multi-disciplinary studies within a framework of natural and large-scale experimental sites. Terrestrial research heavily depends on data series of abiotic factors, including precipitation, gas fluxes and input from the atmosphere into the terrestrial system. Thus one of the aims of the flagship is to improve interactions between terrestrial and atmospheric research. Likewise, the biogenic input into the atmosphere is an important issue for atmospheric research.

6.3 Glacial Systems

A fourth flagship is planned on glaciology and the glacial systems of the glaciers around Ny-Ålesund. It is natural to seek connection between the atmospheric research community and the planned flagship, as topics like changing fluxes of heat, moisture, and mass into the atmosphere are important factors in glacial systems.

7. Funding needs and general requirements

Monitoring is the baseline for essentially all campaign type studies. Typically, a campaign lasts for some weeks (sometimes longer), often involving more detailed and complex measurements than those conducted in monitoring series. However, these campaigns must be put into context on a seasonal as well as interannual basis. Trends can be studied only by long-term measurements. Therefore, it must be a priority to have a long-term perspective on funding as well.

For atmospheric observations aiming to study pristine environments, it is absolutely paramount to keep the air around Ny-Ålesund as clean as possible. This involves radio and light disturbances as well as perturbations on the composition of the atmosphere. There must be a continuous discussion about the trade off of having Ny-Ålesund accessible to e.g. tourism, large VIP groups, increased research activities, and recreation for the inhabitants vs. the detrimental effects of these for the scientific programmes. The community should strive to reduce emissions as much as possible to minimise local anthropogenic impacts on the observations.

Appendix 1: List of abbreviations

a.s.l. - above sea level

AARI - Arctic and Antarctic Research Institute, St. Petersburg, Russia

ACIA - Arctic Climate Impact Assessment

AGAGE - Advanced Global Atmospheric Gases Experiment (http://agage.eas.gatech.edu/)

AMAP - Arctic Monitoring and Assessment Programme (http://www.amap.no/)

ARCFAC - The European Centre for Arctic Environmental Research (http://arcfac.npolar.no/)

ASTAR - Arctic Study of Tropospheric Aerosol and Radiation

ATMOKONG - Atmospheric monitoring in the Kongsfjorden ecosystem (chapter 3.1 in The Kongsfjorden System – a flagship programme for Ny-Ålesund, Brief Report Series 11, NP 2009)

AWI - Alfred Wegener Institute (http://www.awi.de/en/)

AWIPEV – French-German Arctic Research Base at Ny-Ålesund / Spitsbergen (http://www.awipev.eu)

BSRN - Baseline Surface Radiation Network (http://www.bsrn.awi.de/)

CCT - Amundsen-Nobile-Climate-Change-Tower (http://www.isac.cnr.it/~radiclim/CCTower/)

CFC - Chlorofluorocarbon

CH_4 - Methane

CNR-DTA - Italian National Research Council - Earth and Environment Department

CO_2 - Carbon Dioxide

DOAS - Differential Optical Absorption Spectrometer

EISCAT - European Incoherent SCATter Scientific Association (http://www.eiscat.se/)

EMEP - European Cooperation Programme on transboundary pollution transport

ESFRI - European Strategy Forum on Research Infrastructure (http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=esfri)

ESR - EISCAT Svalbard Radar

EU - European Union

EUSAAR - European Supersites for Atmospheric Aerosol Research (http://www.eusaar.net/)

GAW - Global Atmosphere Watch of WMO (http://www.wmo.int/pages/prog/arep/gaw/gaw_home_en.html)

HF - High frequency

IGFPAS - Institute of Geophysics, Polish Academy of Science

IPCC - Intergovernmental Panel on Climate Change (http://www.ipcc.ch/)

IPEV - Institut polaire français Paul Emil Victor (http://www.ipev.fr)

IPY - International Polar Year

ISAC - International Study of Arctic Change (http://www.arcticchange.org/)

ISAC - Institute of Atmospheric Science and Climate

KB - Kings Bay A/S

KHO - Kjell Henriksen Observatory (http://kho.unis.no/)

KOPRI - Korean Polar Research Institute

LIDAR Radar - Light Detection And Ranging Radar

LSF - Large Scale Facility

MoU - Memorandum of Understanding

NDACC - Network for the Detection of Atmospheric Composition Change (http://www.ndacc.org)

NILU - Norwegian Institute for Air Research

NIPR - National Institute for Polar Research

NPI - Norwegian Polar Institute

NPL - National Physical Laboratory, New Dehli, India

NSC - Norwegian Space Centre

NySMAC - Ny-Ålesund Science Managers Committee (http://www.npolar.no/nysmac/)

OPC - Optical Particle Counter

PBL - Planetary boundary layer

POLAR-AOD - the polar aerosol optical depth measurement network

POPs - Persistent Organic Pollutants

PRIC - Polar Research Institute of China

PUF - Large volume polyurethane foam sampler

RAS – Russian Academy of Science

SAON - Sustained Arctic Observing Network (http://www.arcticobserving.org/)

SIOS - Svalbard Integrated Arctic Earth Observing System (http://www.sios-svalbard.org/)

SOUSY - Sousy Svalbard Radar (SSR), a “mesosphere-stratosphere-troposphere” radar

SPEAR - Space Plasma Exploration by Active Radar

SSF - Svalbard Science Forum (http://www.svalbardscienceforum.no)

SU - Stockholm University

Super-DARN - Super Dual Auroral Radar Network

SvalRak - Svalbard Rakettskytefelt, launch site for sounding rockets

TCCON - Total Carbon Column Observing Network (http://www.tccon.caltech.edu/)

UNIS - The University Centre in Svalbard

UiO - University of Oslo

UV - Ultraviolet

WMO - World Meteorological Organization (http://www.wmo.int/pages/index_en.html)

Appendix 2: Atmospheric Research at stations in Ny-Ålesund

AWIPEV-Base (Germany, France)
Atmospheric and climate research conducted at the French-German Arctic Research Base AWIPEV is based on contributions provided mainly by the Alfred Wegener Institute (AWI) in Potsdam and Bremerhaven, the University of Bremen (Institute of Environmental Physics, IUP), the French Polar Institute Paul Emile Victor (IPEV) through the universities at Rouen and Grenoble, as well as several other universities and institutes. AWIPEV Base provides a comprehensive Atmospheric Observatory, a balloon launch facility, and a Clean Air station about 6 km away from Ny-Ålesund (Corbel-Station). In addition AWI and IPEV support atmospheric research missions in the vicinity of Svalbard by aircraft, boats, and on ice stations.

Atmosphere and climate research activities cover topics like

- Climate research by long-term observations and high resolution modelling
- Stratospheric ozone, its chemistry and relation to climate
- Short and long wave Radiation (for WMO's BSRN network)
- Aerosols and clouds
- Meteorology in the polar atmosphere, particularly in the PBL, including meteorological balloons
- Surface – atmosphere interactions, including snow/ice – atmosphere as well as permafrost soil – atmosphere interactions
- Tropospheric chemistry of Hg and ozone depletion events, and heavy metals in aerosols and precipitation

The comprehensive ground based measurements at the AWIPEV Atmospheric Observatory allow determining a complete data set for the atmospheric column from the ground (including air – soil interactions) to the stratosphere. Additionally, aircraft measurements will connect the Spitsbergen data with other measurement sites on and around the Arctic Ocean, including drifting ice stations and a circle of pan-Arctic atmospheric measurement sites.

Dasan station of Korea Polar Research Institute KOPRI (Korea)
KOPRI has launched an integrated climate research program - Research on the Composition of Polar Atmosphere and Climate Change (COMPAC) in 2006, and the following programs are running at the Dasan station under the umbrella of COMPAC.

- <u>CO2 and energy flux monitoring</u>: An eddy covariance flux system is running in the fields of the Dasan station.
- <u>CCN and DMS(g) monitoring</u>: A Cloud Condensation Nuclei (CCN) counter and gas phase Dimethylsulfide (DMS) measurements system are operating from the Zeppelin Mountain observatory.
- <u>CN monitoring from Corbel</u>: An ultrafine particle counter (CPC) is running at the Corbel station in a collaborative manner with AWIPEV.

An automatic weather system, logging wind, air temperature, air pressure, relative humidity, etc, with a time resolution of 10 minutes, has been installed on top of the Dasan station in 2005.

For the upper atmosphere research, a FT-IR (Michelson Interferometer) and a SATI (Spectral Airglow Temperature Imager) are also installed on the roof of the Dasan station, to obtain continuous mesosphere temperature data.

Dirigibile Italia (Italy)

Italian activities in Ny-Ålesund devoted to atmospheric physics and climate research are supported mainly by CNR through the Earth Environment Department (DTA) and the Polar Research Network POLARNET. Main topics covered by research activities until 2007 were ozone and UV radiation, PBL dynamics and processes, chemical fluxes at the snow - atmosphere interface, and energy budgets at the surface. Activities were based mainly on intensive field campaigns.

In 2008 a new science plan named "Climate Change Tower Integrated Project (CCT-IP)" was elaborated with the idea to place monitoring and long-term observations side by side to process study activities. Overall goals are to widen the knowledge on processes determining the energy budget at the surface, as well as along the whole atmosphere, the structure and peculiarities of the Arctic PBL, air-snow-terrain interactions, the role of pollutants/aerosols in the Arctic Environment, relationships between optical properties of the atmosphere, physical and chemical aerosol composition, and climate forcing and environmental feedbacks. The key element of the planned observational platform is the 34 m high Amundsen-Nobile Climate Change Tower (CCT). It was installed in 2009 and is located ca. 1.2 km south-east of the village. The tower permits to largely integrate Ny-Ålesund´s capability to investigate Arctic PBL, to measure and evaluate all components of the energy budget at the surface, their temporal variations, and the role played by different processes involving air, snow, ice and land (permafrost and vegetation).

During the last three years, as part of the CCT-IP programme, a large set of physico-chemical measurements was implemented inside the Gruvebadet building, a mini-LIDAR (hosted at the AWIPEV observatory) was installed, as well as a new UV radiometer (ISAC UV-RAD, hosted at Sverdrup station).

Himadri (India)

The current activity of Himadri station regarding the atmospheric science consists of carbon monoxide monitoring to study the snow-pack production of CO and its diurnal variability. The measurements were done in a campaign mode during the 1st Winter Phase Indian Arctic Expedition (3rd – 31st March, 2008) and second phase summer expedition (1st – 28th August, 2008). In addition measurements of Black carbon, aerosol number- and size distribution and surface ozone were also carried out. The measurements of the atmospheric electric field and conductivity using electric field mill and Gerdiens apparatus were also done.

Rabben Station of NIPR (Japan)

The National Institute of Polar Research (NIPR) started observations of atmospheric parameters at the Ny-Ålesund Rabben Observatory close to the air strip in 1991, based on the bi-polar standpoint with the Antarctic observation at Syowa Station (69º 00' S, 39º

35’ E). Since then, several parameters have been continuously measured at the site, such as greenhouse gases (CO_2, CH_4, N_2O, CO, SF_6 and isotopes of CO_2 and CH_4), ozone, aerosols, clouds and precipitations with support of the Norwegian Polar Institute.
Also, in-situ measurements of surface meteorology are conducted. Remote sensing of aerosols and clouds is carried out using a Micro-pulse Lidar (MPL) and sky radiometer, and in-situ measurements of aerosols were conducted using optical particle counters, integrating nephelometer, absorption photometer and several kinds of samplers.

Founded on these ground-based observations, a number of other experiments and measurement campaigns have been performed using a combination of platforms. For instance, information about the vertical distribution of aerosols and its role for the radiation budget were obtained by airborne observations using aircrafts together with balloon borne observations were linked to the ground based measurements. Another example of combining different platforms are the overpass experiments for ground validation of the ICESat (Ice, Cloud and land Elevation Satellite)/ GLAS (Geoscience Laser Altimeter System) atmospheric measurements performed in 2003 and 2004.

University of Oslo (Norway)

The University of Oslo has carried out daytime auroral measurements from Ny-Ålesund every winter since 1982. The emphasis of the research has been to explore solar terrestrial interactions in the upper atmosphere, with particular emphasis on the coupling between the magnetised solar wind plasma and the earth magnetosphere-ionosphere system. The basic research on plasma physical problems has a wide range of applicability also in astrophysics. In December 2008, the first sounding rocket in the ICI-series (Investigation of Cusp Irregularities) was launched to investigate instability processes in relation to auroral activities giving rise to problems for radio communication and satellite navigation signals. This is an important element of ionospheric space situation awareness for the region.

Andøya Rocket Range – SvalRak (Norway)

Ny-Ålesund hosts a rocket launch facility –SvalRak – for launching sounding rockets into the polar ionosphere. SvalRak is operated by Andøya Rocket Range (ARS) on a campaign basis. FRISK (Forsknings-Raketter for Innovasjon, Sikkerhet og Klima), an initiative to increase the number of sounding rockets launched both from Andøya and SvalRak, is being worked on by several research groups in Norway. There is an ongoing collaboration between FFI and IAP to study the mesosphere by sounding rockets.

Yellow River Station (China)

The Polar Research Institute of China (PRIC) conducts observation of aurora since 2003. The observing system consists of three wavelengths at 557.7, 630.0, 427.8 nm, respectively, for the simultaneous monitoring of aurora at Yellow River Station, Ny-Ålesund, at a temporal resolution of 10 seconds. The imaging riometer which observes the cosmic radio noise variation at the frequency of 38.2 MHz was renovated in 2008 at Yellow River Station. The imaging riometer was originally run by Nagoya University, and was taken over by PRIC in 2004. The auroral observation is a routine mission in winter, which is committed each year from the middle of October to the beginning of March the following year. The imaging riometer restarted its routine observation in

2009. It has its counterpart imaging riometer at Zhongshan Station, Antarctica, forming a conjugate pair of observations at the cusp latitude in both hemispheres. The routine automatic GPS ionospheric scintillation/TEC system has been running since 2007 and records ionospheric scintillation parameters such as S4 index, phase index and TEC etc., simultaneously.

Since 2007, the Chinese Academy of Meteorological Sciences has carried out a boundary layer physical process research project. Single particle black carbon measurements over the tundra of Ny-Ålesund have been undertaken since 2010. Based on gradient data of two layers of temperature, humidity, and wind, with radiation and turbulent data the surface processes are analysed by the Bulk transfer and eddy-covariance methods. The mass and the mixing state of individual black carbon (BC) particle are measured using Single Particle Soot Photometer (SP2) instruments based on the laser-induced incandescence (LII) technique during the summer campaign.

Sverdrup station and Zeppelin Mountain observatory (Norway, Sweden)

The Sverdrup station is the basis for many field expeditions taking place by personnel from NPI, but often other institutes and universities begin their scientific field work there, too. Also non-scientific excursions by journalists and visits by dignitaries will be connected to the Sverdrup station.

Meteorological observations as part of the WMO network are conducted three times per day. The longest running time series (start in 1974) of broad band radiation measurements in Ny-Ålesund are conducted on the tundra near the station. The broadband observations were recently complemented with Ramses sensors for spectral albedo measurements of the snow surface. These observations are performed in connection to surface snow sampling conducted in the area. The snow is melted and analysed for Black Carbon. The Sverdrup station is also base for a number of photospectrometric measurements and radiation measurements by NILU and NPI. Weekly precipitation samples for chemical analysis by NILU have been collected at the station since 1974.

The Zeppelin Mountain observatory is owned and operated by the NPI, but besides snow sampling there are currently no monitoring activities by NPI. The scientific work at the Zeppelin Mountain observatory is organised by NILU. Stockholm University is the other main partner with a permanent lab at the station. Several other institutes are collaborating with shorter or longer visits, for instance University of Bergen, FMI, University of Heidelberg, KOPRI.

NILU has been monitoring a wide range of air pollutants and trace gases at Zeppelin Mountain observatory over the past twenty years, including heavy metals, acidic compounds, main inorganic compounds, persistant organic pollutants (PCB, pesticides etc.) and non-CO2 greenhouse gases.

Stockholm University focuses on aerosol physic-chemical properties, such as the number size distribution, optical properties, and carbon partitioning (OC/EC). Since the end of the 1980's Stockholm University has performed continuous measurements of CO_2. In collaboration with NOAA and NPI, weekly flask samples have been collected and sent to NOAA to be analysed.

As complement to the measurements at the Zeppelin Mountain observatory and in order to monitor the near-field environment, NPI, NILU and SU perform measurements of some key parameters in the middle of Ny-Ålesund since July 2008 (NILU-container). These parameters include Black Carbon in air, number density of particles, particle inorganic chemistry, SO_2, NOx, CO, BTEX and local meteorology.

Appendix 3: Overview of atmospheric parameters measured in Ny-Ålesund

The information in this table has been updated in January 2011. SSF maintains a dynamic copy of this list and aims to update it regularily.

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Web site
Images of 557.7 and 630.0 nm emissions (4-6 fpm, wide FOV)	AllSky Imager, Image intensified (operated since 1988)	10 sec	2 wave band, 557.7 nm & 630.0 nm, routine operation each winter	Sverdrup Station	Via contact person	Univ. in Oslo
Images of 557.7 and 630.0 nm emissions (4-6 fpm, wide FOV)	AllSky Imager, EMCCD (operated since 2010)	5 sec	2 wave band, 557.7 nm & 630.0 nm, routine operation each winter	Sverdrup Station	Via contact person	Univ. in Oslo
Intensity of 2 auroral lines along the meridian (20 s)	Meridian scanning photometer (operated since 1997)	15 sec	Routine observation each winter	Sverdrup Station	Via contact person	Univ. in Oslo
Ionospheric Total Electron Content	GPS receiver (operated since 2009)	1 min	Routine observation all year round	Sverdrup Station	Via contact person	Univ. in Oslo
Mesospheric temperature (OH layer)	FTIR spectrometer (operated since 2002)			Dasan Station		KOPRI

All-sky aurora imagers	3-wave length all-sky aurora image system (Data available since 2003)	10 sec	3 wave bands at 557.7nm, 630.0nm & 427.8nm respectively, routine observation in winter each year	78.9N, 11.9E	Via contact person	PRIC / Prof. Yang Huigen
Ionospheric absoption at 38.2MHz	Imaging reometer (upgraded in 2009)	1 sec	38.2MHz, routine observation all year round	78.9N, 11.9E	Via contact person	PRIC / Prof. Hu Hongqiao
Ionospheric scintillation S4 index, ionospheric total electron content (TEC)	GSV4004 ionospheric scitillation and TEC monitor	1 min	Routine observation all year round	78.9N, 11.9E		Inst. of Geology and Geophysics, CAS/Ning Baiqi (Dr.); China Research Inst. of Radiowave Propagation (CRIRP)/ Prof. Zhen Weimin; http://space.iggcas.ac.cn
Ionospheric total electron content (TEC)				Sverdrup Station		Univ. Wales, Aberystwyth
Particle counter	CPC - 3776		Once per month	Corbel	Open access on request	KOPRI / Dr. Young Jun Yoon
Particle counter	CPC - TSI 3010		Once per month	Corbel	Open access on request	IPEV
Meteorological parameters (temperature, humidity, wind direction & speed)	Automated weather station, Sky pyranometer	Aver. 1/ h	Once per month	Corbel	Open access on request	IPEV

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
Meteorological parameters (temperature, humidity, wind direction & speed)	Automated weather station	Aver. 1/ h		Ostrelooven-brean	Open access on request	IPEV
Temperature (2m)	PT100	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Temperature (10m)	PT100	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Rel. humidity 1 (2m)	Vaisala HMP 229	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Rel. humidity 2 (2m)	Vaisala HMP 230	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Wind (2m)	Thiess wind transmitter	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Wind (10m)	Thiess wind transmitter	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Pressure (station level)	Paroscientific DigiQuarz	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Cloud high	Vaisala Laser Ceilograph LD-40	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Sunshine duration	Haenni Solar 111	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Global radiation	Kipp&Zonen CM11 Pyranometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Reflex radiation	Kipp&Zonen CM11 Pyranometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350

Diffuse radiation	Kipp&Zonen CM11 Pyranometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Direct radiation	Eppley Pyrheliometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Global radiation (red glass filter)	Kipp&Zonen CM11 Pyranometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Global radiation (orange glass filter)	Kipp&Zonen CM11 Pyranometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Long wave radiation (incoming)	Eppley Precision infrared Radiometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Long wave radiation (outgoing)	Eppley Precision infrared Radiometer	1 min	Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
UV radiation	Eppley UV Radiometer		Continuous	78.925N/11.95E (11m)	Access with time lag	AWI/Marion Maturilli Ris_ID: 2350
Radiosounding data	Vaisala RS92	1/day	Continuous	78.925N/11.95E (11m)	Open access	AWI/Marion Maturilli Ris_ID: 1118
Ozonesounding data	Vaisala ECC Ozone sonde	1 or 2/week	Continuous	78.925N/11.95E (11m)	Open access	AWI/Marion Maturilli Ris_ID: 1118
AOD	Sunphotometer SP1A	1 min	During polar day & clear sky available	78.925N/11.95E (11m)	Access with time lag	AWI/Andreas Herber Ris_ID: 2353
AOD	Starphotometer SPST1	1 h	During polar night & clear sky available	78.925N/11.95E (20m)		AWI/Andreas Herber Ris_ID: 2353
Ozone total column	MAX-DOAS UV/vis	2/day	Feb to Oct	AWIPEV atmospheric observatory	Access with time lag	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock http://www.ndsc.ncep.noaa.gov/data/
NO2 total column	MAX-DOAS UV/vis	2/day	Feb to Oct	AWIPEV atmospheric observatory	Access with time lag	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock http://www.ndsc.ncep.noaa.gov/data/

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
BrO differential slant column	MAX-DOAS UV/vis	2/day	Feb to Oct, only when 90° SZA available	AWIPEV atmospheric observatory	Access with time lag; available on request, will be uploaded to GEOMON data centre	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock
OClO differential slant column	MAX-DOAS UV/vis	2/day	Feb to Oct, only for chlorine activation in the stratosphere	AWIPEV atmospheric observatory	Access with time lag; available on request, will be uploaded to GEOMON data centre	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock
Tropospheric NO2 profiles	MAX-DOAS UV/vis	1 h	Feb to Oct	AWIPEV atmospheric observatory (ground to 3 km)	Access with time lag; available on request, will be uploaded to GEOMON data centre	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock
Tropospheric BrO column	MAX-DOAS UV/vis	1 h	Feb to Oct	AWIPEV atmospheric observatory	Access with time lag; available on request, will be uploaded to GEOMON data centre	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock

Tropospheric IO column	MAX-DOAS UV/vis	1 h	Feb to Oct	AWIPEV atmospheric observatory	Access with time lag; available on request, will be uploaded to GEOMON data centre	Institute of Environmental Physics, Univ. Bremen, Folkard Wittrock
O3	Microwave	1 h	Continuous	AWIPEV atmospheric observatory (20m)	Access with time lag; via NDSC, ENVISAT webpage or contact person	Univ. Bremen, Mathias Palm RiS_ID: 390
H2O	Microwave	1 day	Continuous	AWIPEV atmospheric observatory (20m)	Access with time lag	Univ. Bremen, Mathias Palm RiS_ID: 390
O3, H2O	FTIR	1 h	During polar night & moon light	AWIPEV atmospheric observatory (20m)	Access with time lag; via contact person	Univ. Bremen, Mathias Palm RiS_ID: 2198
Constant: O2, N2; long lived: CO2, N2O, CH4; troposphere: C2H2, C2H6, CH2O, CO, HCN, COS, H2O; stratosphere: O3, HCl, HF, HNO3, NO2, NO	FTIR	1 h	Dep. on solar light	AWIPEV atmospheric observatory (20m)	Access with time lag; via contact person	Univ. Bremen, Mathias Palm RiS_ID: 2198
OH temperature	FTIR	6 h	Continous during polar night	AWIPEV atmospheric observatory (20m)	Not yet (under development)	Univ. Bremen, Mathias Palm RiS_ID: 3330

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
Spectral solar UV irradiance	Until 2009: isiUV mulitchannel spectroradiometer; since 2009: Bentham scanning UV spectroradiometer	Until 2009: 1/10 min; since 2009: 4/h	During daylight conditions from March to October	AWIPEV atmospheric observatory (20m)	On request; once NDACC certified, available via NDACC data base	AWI Bremerhaven/Otto Schrems RiS_ID: 468
Heavy metals in size separated aerosols	Ground aerosol sampler	1 week	Continuous	AWIPEV atmospheric observatory (20m)		AWI/Michael Kriews
Heavy metals in total deposition samples	Total deposition sampler	2-14 days	Continuous	AWIPEV atmospheric observatory (20m)		AWI/Michael Kriews
Heavy metals in precipitation samples	Wet only sampler	1 week	Continuous	AWIPEV atmospheric observatory (20m)		AWI/Michael Kriews
Soil temperature, soil moisture	TDR-System plus temperature sensors	1 h	Continuous	78.925N/11.95E (11m); Tundra-NP station	Access with time lag	AWI Potsdam, Julia Boike, Konstanze Piel RiS_ID: 2950 www.awi.de/en/go/sparc

Air temperature (2m), air humidity, windspeed, wind direction, radiation_global, radiation_longwave, radiation_netto, snowheight, precipitation, soil temperature, soil moisture	TDR-System plus standard climate station compounds	1 h	Continuous	78.87N/15.56E (25,1m); Bayelva station	Access with time lag	AWI Potsdam, Julia Boike, Konstanze Piel RiS_ID: 2950 www.awi.de/en/go/sparc
Sensible and latent heat flux, CO2 fluxes, three dimensional windspeed/-direction, snowheight, airtemperature	Eddy-Covariance Station with open path gas analyzer	2/h	Continuous	78.87N/15.56E (17,5m); Eddy Covariance station	Access with time lag	AWI Potsdam, Julia Boike, Konstanze Piel RiS_ID: 2950 www.awi.de/en/go/sparc
Carbon monoxide (CO)	APMA-370 - Horiba, Germany	5 min	Measurement period: 3rd - 31st March, 2008 - 28 days & 1st -26th August, 2008 - 25 days	Himadri station & Gruvebadet	Data with PI	Dr.B.C. Arya, NPL, New Delhi, India (bcarya@nplindia.org)
Aerosol number-size distribution (>0.3 micron - 20.0 micron)	Grimm 1.108 - Grimm, Germany	5 min	Measurement period: 3rd - 31st March, 2008 - 28 days & 1st -26th August, 2008 - 25 days	Himadri station & Gruvebadet	Data with PI	Dr.B.C. Arya, NPL, New Delhi, India (bcarya@nplindia.org)

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
Black Carbon (BC)	AE 42-7-ER-MC - Magee Scientific, USA	5 min	Measurement period: 3rd - 31st March, 2008 - 28 days	Himadri station	Data with PI	Dr.B.C. Arya, NPL, New Delhi, India (bcarya@nplindia.org)
Surface Ozone	APOA-370 - Horiba, Germany	5 min	Measurement period: 1st - 26th August, 2008 - 25 days	Gruvebadet building	Data with PI	Dr.B.C. Arya, NPL, New Delhi, India (bcarya@nplindia.org)
UV fluxes in the spectral range 300-380 nm - Ozone content - Erithemal/DNA dose rate	UV-RAD ISAC radiometer equipeed with 7 very narrow channels (1 nm FWHM) (300 nm, 306 nm, 310 m, 314 nm, 325 nm, 338 nm, 364 nm)	< 2 min	24 hours	10 m asl (Sverdrup station)	Open access on request	CNR-ISAC/Boyan Petkov (b.petkov@isac.cnr.it); www.isac.cnr.it/~radiclim/CCTower
Ozone Content - UV spectra	Brewer No. 050	30 min	24 hours	10 m asl (Sverdrup station)	Open access on request	CNR, Inst. of Acoustic "O.M. Corbino"/Claudio Rafanelli (c.rafanelli@idac.rm.cnr.it)
Particle backscatter coefficient - particle depolarization ratio	Miniaturized 532 nm elastic backscattering & depolarization lidar MULID	10 min/ profile	Continuous since 2010 (previously: 2 profiles/ day)	AWIPEV atmospheric observatory (20m)	Open access on request	CNR-ISAC/Luca Diliberto (l.diliberto@isac.cnr.it) www.isac.cnr.it/~radiclim/CCTower

Backscatter profile, cloud base height, aerosol extinction profile	Micro-pulse lidar / NASA upgraded SESI Model (laser wavelength: 523.5nm, maximum height: 60km, range resolution: 30m)	1 min	Continuous	AWIPEV atmospheric observatory (20m)	Since March 2002	NIPR/Masataka Shiobara; NASA MPL-net (http://mplnet.gsfc.nasa.gov)
Greenhouse gases' concentrations and isotope ratios	Air Sampling	Weekly	Weekly	Rabben (40m asl)	For cooperative research	NIPR/Shinji Morimoto
Aerosol optical thickness, Angstrom parameter, aerosol size distribution	Sky-radiometer / Prede POM-02 (11 channels between 315 - 2200nm; aerosol analysis available for 400, 500, 675, 870 & 1020 nm)	10 min, nominal	Continuous	Rabben (40m asl)	Since March 2000	NIPR/Masataka Shiobara
Whole sky image, cloud fraction	All sky camera / Prede PSV-100 (3-color CCD camera)	10 min	Continuous	Rabben (40m asl)	Since March 2005	NIPR/Masataka Shiobara
Cloud vertical profile and precipitation	Vertical pointing radar	1 sec	Until 2005	Rabben		NIPR/M.Wada (wada@nipr.ac.jp)
Vertical profile of aerosol backscattering coefficient and depolarization	Lidar/ 532nm and 1064nm	15 min	Every winter season	Rabben/ 2-30km		Fukuoka Univ. and Nagoya Univ./Koichi Shiraish
Aerosol size distribution (0.3-7.0 um)	Balloon borne optical particle counter/ LD (780nm) side scatering	90 min/ profile	1-3 times/ winter season	Rabben/ 2-30km		Fukuoka Univ./Masahsiko Hayashi

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
PSC properties	Low-resolution FTIR (0.2 cm-1)	~20 min	Few times/ day when sky is clear; campaign based (3 winters from 2008/2009); Dec-March	AWIPEV atmospheric observatory (20m)	On request	Nat. Inst. for Envir. Studies, Japan/Hideaki Nakajima
Hg (Mercury) elemental	Tekran 2537A	5 min	All year	Zeppelin 475 m	Access with time lag	NILU, Pfaffhuber
Particulate heavy metals (As, Cd, Co, Cr, Cu, Pb, Mn, Ni, V, Zn)	Filter sampling	3/week	All year	Zeppelin 475 m	Access with time lag	NILU, Aas
Particulate and gaseous nitrogen compounds (HNO_3/NO_3^-, NH_4^+/NH_3)	Filter sampling	24 h	All year	Zeppelin 475 m	Access with time lag	NILU, Aas
Particulate and gaseous sulphur compounds (SO_2, SO_4^{2-})	Filter sampling	24 h	All year	Zeppelin 475 m	Access with time lag	NILU, Aas
Inorganic Particle Bound (Na+, K+, Ca2+, Mg2+, Cl-)	Filter sampling	24 h	All year	Zeppelin 475 m	Access with time lag	NILU, Aas
Methane CH_4	GC/FID	15 min	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Nitrous oxide N_2O	GC/ECD	15 min	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
CFC's (5)	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre

HCFC's (3)	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
HFC's (3)	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Chlorinated trace gases (6)	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Methyl Bromide	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Methyl Iodide	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Perfluorinated trace gases (CF4, C2F6)	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Halones (H-1211, H-1301)	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
SF_6	GC/MS	2 h	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Hydrogen H_2	GC	20 min	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
CO	GC	20 min	All year	Zeppelin 475 m	Access with time lag	NILU, Myhre
Tropospheric ozone	Monitor	5 min	All year	Zeppelin 475 m	Access with time lag	NILU, Aas
PCB (33 compounds)	HiVol filter sampler	2/week	All year	Zeppelin 475 m	Access with time lag	NILU, Breivik
Pesticides	HiVol filter sampler	2/week	All year	Zeppelin 475 m	Access with time lag	NILU, Breivik

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
Brominated flame retardents (18 compounds)	HiVol filter sampler	Weekly	All year	Zeppelin 475 m	Access with time lag	NILU, Breivik
PAH (polyaromatic hydrocarbons, 40 compounds)	HiVol filter sampler	2/week	All year	Zeppelin 475 m	Access with time lag	NILU, Manø
Perfluorinated Alkylated Substances	HiVol filter sampler	2/week	All year	Zeppelin 475 m	Access with time lag	NILU, Breivik
NOx, NO2	Monitor	5 min	All year	Nordpolhotellet	Open access	NILU, Bäcklund
SO2	Monitor	5 min	All year	Nordpolhotellet	Open access	NILU, Bäcklund
BTEX	GC/PID	15 min	All year	Nordpolhotellet	Restricted	NILU, Hermansen
Precipitation (pH, conductivity, SO42-, Na+, K+, Ca2+, Mg2+, Cl-, NO3-, NH4+)	Rain sampler	Weekly	All year	Sverdrup station	Access with time lag	NILU, Aas
AOD Aerosol Optical Depth	PFR Sun photometer	1 min	Apr - Sep	Sverdrup station	Access with time lag	NILU, Stebel
UV - irradiation	NILU-UV	1 min	Apr - Sep	Sverdrup station	Access with time lag	NILU, Stebel
CO2	NDIR - Li-COR	Continously	All year	Zeppelin 475 m	Access with time lag	ITM - SU
Particle number concentration	CPC - TSI 3010	1 h	All year	Zeppelin 475 m	Access with time lag	ITM - SU
Particle size distribution	DMPS OPC	1 h	All year	Zeppelin 475 m	Access with time lag	ITM - SU

Particle light absorption	DMA - soot photometer	1 h	All year	Zeppelin 475 m	Access with time lag	ITM - SU
Particle light scattering	Nephelometer - TSI 3563, 3 wl	1 h	All year	Zeppelin 475 m	Access with time lag	ITM - SU
Organic and elemental carbon	Filter sampling/thermo-optical analysis	Weekly	All year	Zeppelin 475 m	Access with time lag	ITM - SU
Cloud Condensation Nuclei concentration	CCN counter (DMT)	30 min/1 SS cycle	Continuous	Zeppelin station	Access with time lag	KOPRI/ Young Jun YOON/ yjyoon@kopri.re.kr
CO2 flux (mg/m2/s)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Sensible heat flux (W/m2)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Latent heat flux (W/m2)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Momentum flux (kg/m/s2)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Wind speed (m/s)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
Wind direction (Deg)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
T (DegC)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
H2O (g/m3)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
CO2 (mg/m3)	Eddy Covariance System: 3-D sonic anemometer (CSAT3, CampbellSci) + Opne path gas analyzer (LI7500, LICOR)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
RSDN (W/m2)	Net radiometer (CNR1, Kipp & Zonen)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
RLDN (W/m2)	Net radiometer (CNR1, Kipp & Zonen)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr

RSUP (W/m2)	Net radiometer (CNR1, Kipp & Zonen)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
RLUP (W/m2)	Net radiometer (CNR1, Kipp & Zonen)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Rn (W/m2)	Net radiometer (CNR1, Kipp & Zonen)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
T_soil (DegC)	TCAV (CampbellSci)	30 min	Continuous	78°55.408' N/ 11°55.927' E (-0.1 m)	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Soil water content (m3/m3)	CS616-L (CampbellSci)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Soil heat flux (W/m2)	Soil heat flux plate (HFP01, CampbellSci)	30 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
T_ground (DegC)	Baroo-Diver Thermister with Environ Mon.	1 h	Continuous	78°55.408' N/ 11°55.927' E -0.25/0.5/1 m	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Wind speed (m/s) & Wind direction (Deg)	2-D Sonic anemometer (FT702LM, FT Technologies, Ltd)	10 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
T_air (DegC)	HMP45C (Vaisala)	10 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
RH (%)	HMP45C (Vaisala)	10 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
P (hPa)	PTB100 (Vaisala)	10 min	Continuous	78°55.408' N/ 11°55.927' E	Access with time lag	KOPRI/Dr. Taejin Choi/ ctjin@kopri.re.kr
Turbulent fluxes of moisture, momentum, temperature	KH-20 fast hygrometer, Gill sonic anemometer	1 min	Continuous	Amundsen-Nobile CCTower (~ 50 m a.s.l.)	Open access on request	CNR-ISAC/Angelo Viola (a.viola@isac.cnr.it); www.isac.cnr.it/~radiclim/CCTower
Snow height	Campbell Snow level SR50	1 min	Continuous	Amundsen-Nobile CCTower (~ 50 m a.s.l.)	Open access on request	CNR-ISAC/Christian Lanconelli (c.lanconelli@isac.cnr.it); www.isac.cnr.it/~radiclim/CCTower
Thermal flux into snow	Flux plate HFp01	1 min	Continuous	Amundsen-Nobile CCTower (~ 50 m a.s.l.)	Open access on request	CNR-IBIMET/Marianna Nardino (m.nardino@ibimet.cnr.it); www.isac.cnr.it/~radiclim/CCTower

Snow temperature gradient	2 pt100 at 2 different levels (3W-Half Bridge)	1 min	Continuous	Amundsen-Nobile CCTower (~ 50 m a.s.l.)	Open access on request	CNR-IBIMET/Marianna Nardino (m.nardino@ibimet.cnr.it); www.isac.cnr.it/~radiclim/CCTower
Snow/soil skin temperature	IR sensor	1 min	Continuous	Amundsen-Nobile CCTower (~ 50 m a.s.l.)	Open access on request	CNR-ISAC/Christian Lanconelli (c.lanconelli@isac.cnr.it); www.isac.cnr.it/~radiclim/CCTower
Aerosol size distribution in the range 3 - 20000 nm	TSI 3034 Scanning Mobility particle sizer (SMPS) and TSI 3321 Aerodynamic Particle Sizer (APS)	1 min	Continuous from mid-March to mid-Sept (based on field campaigns)	Gruvebadet (~30 m a.s.l.)	Open access on request	Florence University/Roberto Udisti (roberto.udisti@unifi.it); www.isac.cnr.it/~radiclim/CCTower
Aerosol absorption coefficient at 440, 550, 870 nm	PSAP absorption photometer (3 wavelengths)	1 min	Continuous from mid-March to mid-Sept (based on field campaigns)	Gruvebadet (~30 m a.s.l.)	Open access on request	CNR-ISAC/Mauro Mazzola (m.mazzola@isac.cnr.it); www.isac.cnr.it/~radiclim/CCTower
Aerosol scattering coefficient at 532 nm	M903 Radiance Research nephelometer	1 min	Continuous from mid-March to mid-Sept (based on field campaigns)	Gruvebadet (~30 m a.s.l.)	Open access on request	CNR-ISAC/Mauro Mazzola (m.mazzola@isac.cnr.it); www.isac.cnr.it/~radiclim/CCTower

Derived parameter	Instrument/System	Time resolution	Frequency of operation	Location/ Altitude	Availability	Contact/RiS ID/ Website
Aerosol chemical composition (integral and size-segregated)	Aerosol sampling systems (single stage, multistage, 2 DLPI 12 stages DEKATI)	1-4-7 days	Continuous from mid-March to mid-Sept (based on field campaigns)	Gruvebadet (~30 m a.s.l.)	Open access on request with time lag	Florence University/Roberto Udisti (roberto.udisti@unifi.it); www.isac.cnr.it/~radiclim/CCTower
Aerosol concentration in the range 5 600 nm	TSI ultrafine counter particle	1 min	Continuous from mid-March to mid-Sept (based on field campaigns)	Gruvebadet (~30 m a.s.l.)	Open access on request	Florence University/Roberto Udisti (roberto.udisti@unifi.it); www.isac.cnr.it/~radiclim/CCTower

Appendix 4: List of atmospheric monitoring satellites in operation 2010–2020

Satellite Mission	Agency	Period	Trace gases (excl. ozone)	Ozone	Aerosols	Cloud type, amount & temp.	Cloud particle (prop. & profile)	Liquid water & precipitation	Atmospheric humidity fields	Radiation budget	Atmospheric winds	Atmospheric temp. fields
ACE (planned)	NASA	2020-2023			X	X	X	X		X		X
ACRIMSAT	NASA	1999-2011								X		
ACSENDS (planned)	NASA	2020-2023	X									X
ADM-Aeolos	ESA	2012-2015			X	X	X				X	
Aqua	NASA	2002-2011	X	X	X	X	X	X	X	X		X
Aura	NASA	2004-2011	X	X	X	X	X		X			X
CALIPSO	NASA/CNES	2006-2011	X		X	X					X	
CBERS-3	CRESDA/INPE	2010-2013				X						
CBERS-4	CRESDA/INPE	2014-2017				X						
CHAMP	DLR	2000-2011							X			X
CLARREO-1 (planned)	NASA	2017-2020							X	X		X
CLARREO-2 (planned)	NASA/NOAA	2019-2022			X				X	X		X
CLARREO-3 (planned)	NASA	2020-20203										X
CLARREO-4 (planned)	NASA	2020-2023			X				X	X		X
CloudSat	NASA	2006-2012				X	X	X		X		X
D/F Climate Mission (planned)	DLR/CNES	2014-2017	X									
Deimos-1	DMI	2009-2014								X		
DMSP F-14	NOAA	1997-2011				X		X	X			X
DMSP F-15	NOAA	1999-2013				X	X	X	X			
DMSP F-16	NOAA	2003-2011				X		X	X			X
DMSP F-17	NOAA	2006-2018				X		X	X			X
DMSP F-18	NOAA	2009-2014				X		X	X			X

Appendix 4 continued

Satellite Mission	Agency	Period	Trace gases (excl. ozone)	Ozone	Aerosols	Cloud type, amount & temp.	Cloud particle (prop. & profile)	Liquid water & precipitation	Atmospheric humidity fields	Radiation budget	Atmospheric winds	Atmospheric temp. fields
DMSP F-19	NOAA	2012-2017				X		X	X			X
DMSP F-20	NOAA	2014-2019				X		X	X			X
EarthCARE	ESA	2013-2016			X	X	X			X		X
EnMAP	DLR	2014-2019			X							
Envisat	ESA	2002-2013	X	X	X	X	X			X		X
ERS-2	ESA	1995-2011	X	X	X	X			X	X		
FORMOSAT-2	NSPO	2004-2011				X						
FY-1D	NRSCC/CMA	2002-2011			X	X				X		
FY-3A	NRSCC/CMA	2008-2011	X	X		X	X	X	X	X		X
FY-3B	NRSCC/CMA	2010-2012	X	X		X	X	X	X	X		X
FY-3C	NRSCC/CMA	2012-2016	X	X		X	X	X	X	X		X
FY-3D	NRSCC/CMA	2014-2018	X	X		X	X	X	X	X		X
FY-3E (planned)	NRSCC/CMA	2016-2020	X	X		X	X	X	X	X		X
FY-3F (planned)	NRSCC/CMA	2018-2022	X	X		X	X	X	X	X	X	X
FY-3G (planned)	NRSCC/CMA	2020-2024	X	X		X	X	X	X	X	X	X
GCOM-C1	JAXA	2014-2019			X	X			X			
GCOM-C2	JAXA	2018-2023			X	X			X			
GCOM-W1	JAXA	2012-2017					X	X	X			
GCOM-W2	JAXA	2016-2021					X	X	X			
GCOM-W3	JAXA	2020-2025					X	X	X			
Glory	NASA	2010-2015			X		X					
GOSAT	JAXA/MOE (Japan)/NIES (Japan)	2009-2014	X									
HJ-1A	CAST	2008-2011				X				X		
HY-2A	NSOAS/CAST	2010-2011							X			
HyspIRI (planned)	NASA	2020-2023								X		

Appendix 4 continued

Satellite Mission	Agency	Period	Trace gases (excl. ozone)	Ozone	Aerosols	Cloud type, amount & temp.	Cloud particle (prop. & profile)	Liquid water & precipitation	Atmospheric humidity fields	Radiation budget	Atmospheric winds	Atmospheric temp. fields
ICESat-II (planned)	NASA	2015-2020			X	X	X					
Ikonos-2	GeoEye	1999-2011				X						
Ingenio	CDTI/ESA	2014-2021	X						X			
ISTAG (planned)	ISRO	2015-2020		X								
JPSS-1	NOAA/EUMETSAT/ NASA	2015-2023	X		X	X	X	X	X	X		X
JPSS-2	NOAA/EUMETSAT/ NASA	2018-2026	X	X	X	X	X	X	X	X	X	X
Landsat-5	USGS/NASA	1984-2012				X						
Landsat-7	USGS/NASA	1999-2012				X						
LDCM	NASA/USGS	2012-2017				X				X		
MAPSAR	INPE	2015-2019							X			
Meteor-M N1	Roscosmos/ Roshydromet	2009-2014	X	X	X	X	X	X	X	X		X
Meteor-M N2	Roscosmos/ Roshydromet	2011-2016	X	X	X	X	X	X	X	X		X
Meteor-M N3	Roscosmos/ Roshydromet	2012-2017	X	X					X	X		X
Meteor-MP N1 (planned)	Roscosmos/ Roshydromet	2014-2019	X	X	X	X	X	X	X	X		X
Meteor-MP N2 (planned)	Roscosmos/ Roshydromet	2016-2021	X	X	X	X	X	X	X	X		X
Meteor-MP N3 (planned)	Roscosmos/ Roshydromet	2016-2021	X	X	X	X	X	X	X	X		X
MetOp-A	EUMETSAT	2006-2012	X	X	X	X	X	X	X	X		X
MetOp-B	EUMETSAT	2012-2017	X	X		X	X	X	X	X		X
MetOp-C	EUMETSAT	2016-2021	X	X	X	X	X	X	X	X		X
MIOSAT	ASI	2013-2016	X		X	X						
MTG-I1	EUMETSAT/ESA	2016-2025		X	X	X	X	X	X	X	X	X

Appendix 4 continued

Satellite Mission	Agency	Period	Trace gases (excl. ozone)	Ozone	Aerosols	Cloud type, amount & temp.	Cloud particle (prop. & profile)	Liquid water & precipitation	Atmospheric humidity fields	Radiation budget	Atmospheric winds	Atmospheric temp. fields
MTG-S1	EUMETSAT/ESA	2018-2027							■		■	■
NMP-EO	NASA	200-2011								■		
NOAA-15	NOAA	1998-2011	■	■	■	■		■	■	■	■	■
NOAA-16	NOAA	2000-2012	■	■	■	■	■	■	■	■	■	■
NOAA-17	NOAA	2002-2014	■	■	■	■	■	■	■	■	■	■
NOAA-18	NOAA	2005-2015	■	■	■	■	■	■	■	■		■
NOAA-N´	NOAA	2009-2016	■	■	■	■	■	■	■	■		■
NPOESS-4	NOAA	2020-2027		■								
NPP	NASA/NOAA/DoD	2011-2016	■	■	■	■	■	■	■	■	■	■
OCEANSAT-1	ISRO	1999-2011			■			■			■	
OCEANSAT-2	ISRO	2008-2014			■							■
OCEANSAT-3 (planned)	ISRO	2014-2019			■							
OCO	NASA	2008-2010	■									
OCO-2 (planned)	NASA	2013-2016	■									
Odin	SNSB/CNES/CSA/ TEKES	2001-2012	■		■				■			■
PACE (planned)	NASA	2018-2021			■							
PARASOL	CNES	2004-2011			■	■						
PICARD	CNES	2010-2011								■		
PRISMA	ASI	2012-2017			■							
PROBA	ESA	2001-2012			■					■		■
RapidEye	DLR	2008-2015				■						
RESOURCESAT (planned)	ISRO	2014-2019										■
SAC-C	CONAE	2000-2012			■				■	■		■
SAC-D/Aquarius	CONAE/NASA	2010-2015							■			■
SAGE-III (planned)	NASA	2014-2019	■									
SARAL	CNES/ISRO	2011-2013							■			

Appendix 4 continued

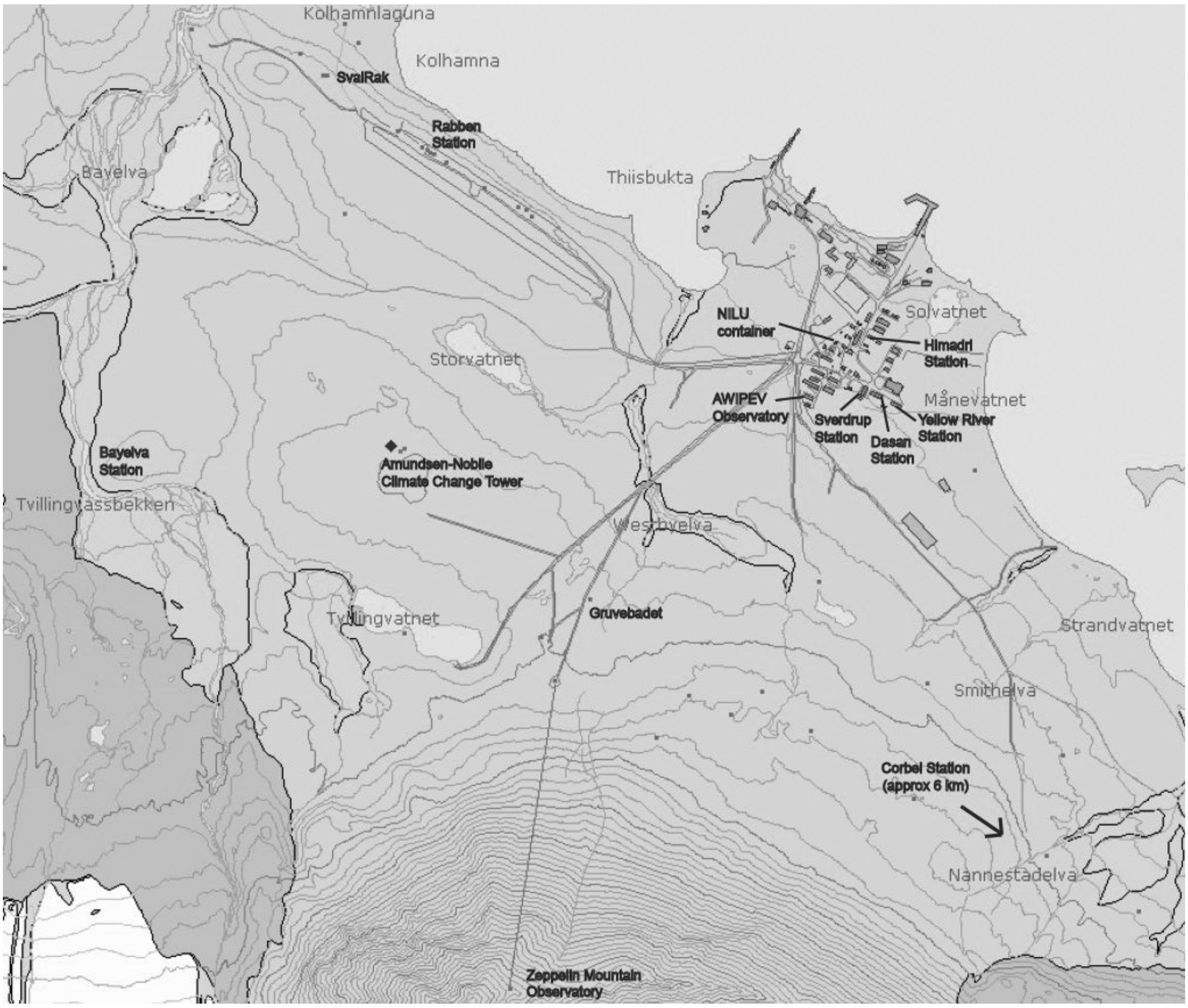
Satellite Mission	Agency	Period	Trace gases (excl. ozone)	Ozone	Aerosols	Cloud type, amount & temp.	Cloud particle (prop. & profile)	Liquid water & precipitation	Atmospheric humidity fields	Radiation budget	Atmospheric winds	Atmospheric temp. fields
SCISAT-1	CSA	2003-2013	■	■	■		■				■	■
Sentinel-2A	ESA/EC	2013-2020								■		
Sentinel-2B	ESA/EC	2014-2022								■		
Sentinel-2C (planned)	ESA/EC	2020-2027								■		
Sentinel-3A	ESA/EC	2013-2010			■	■	■		■	■		■
Sentinel-3B	ESA/EC	2014-2022			■	■	■		■	■		■
Sentinel-3C (planned)	ESA/EC	2020-2027			■	■	■		■	■		■
Sentinel-5	ESA/EC	2019-2026	■	■	■	■		■	■		■	■
Sentinel-5 precursor	ESA	2014-2020	■	■	■	■			■			
SumbandilaSat	CSIR/Uni of Stellenbosh	2009-2014			■							■
Terra	NASA	1999-2011	■	■	■	■	■		■	■	■	■
TerraSAR-X	DLR	2007-2012							■			■
TIMED	NASA	2001-2011		■								
TopSat	BNSC	2005-2011								■		
UK-DMC	UKSA	2003-2010								■		

Agency Acronym	Agency	Country
ASI	Agenzia Spaziale Italiana	Italy
BNSC	British National Space Agency	UK
CAST	Chinese Academy of Space Technology	China
CDTI	Centro para el Desarrollo Tecnologico Industrial	Spain
CMA	China Meteorological Administration	China
CNES	Centre National d'Etudes Spatiales	France
CONAE	Comision Nacional de Actividades	Argentina
CRESDA	China Center for Resources Satellite Data and Application	China
CSA	Canadian Space Agency	Canada
CSIRO	Commonwealth Scientific and Industrial Research Organisation	Australia

Appendix 4 continued

Agency Acronym	Agency	Country
DLR	Deutsche Zentrum für Luft – und Raumfahrt/ German Aerospace Center	Germany
DMI	Danish Meteorological Institute	Denmark
DoD	U.S. Departement of Defense	U.S.A.
DRDC	Defence Research and Development Canada	Canada
EC	European Commission	E.U. M.S.
ESA	European Space Agency	ESA M.S.
EUMETSAT	European Organization for the Exploitation of Metereological Satellites	M.S.
GeoEye	GeoEye Inc.	U.S.A.
INPE	Instituto Nacional de Pesquisas Espaciais	Brazil
ISRO	Indian Space Research Organization	India
JAXA	Japan Aerospace Exploration Agency	Japan
MOE	Ministry of the Environment	Japan
NASA	National Aeronautics and Space Administration	U.S.A.
NIES	National Institute for Environmental Studies	Japan
NOAA	National Oceanic and Atmospheric Administration	U.S.A.
NRSCC	National Remote Sensing Centre of China	China
NSOAS	National Satellite Ocean Application Service	China
NSPO	National Space Organization	China
Roscosmos	Russian Federal Space Agency	Russia
Roshydromet	Russian Federal Service for Hydrometeorology and Environmental Monitoring	Russia
SNSB	Swedish National Space Board	Sweden
TEKES	Finnish National Technology Agency	Finland
UKSA	UK Space Agency	UK
Uni. of Stellenbosh	University of Stellenbosh	South Africa
USGS	United States Geological Survey	U.S.A.

Appendix 5: Map of locations mentioned in the text



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