**International Workshop**

**ATMOSPHERIC STUDIES IN THE ARCTIC**

**Contribution to the Ny-Alesund Atmosphere Flagship Programme**

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Institute of Oceanology, Polish Academy of Sciences in Sopot, Poland

(http://www.iopan.gda.pl).

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**This initiative is a joint effort of the iAREA team, the Alfred Wegener Institute and the University of Florence in cooperation with the Institute of Oceanology Polish Academy of Sciences and the Center for Polar Studies.**

**The workshop is a contribution to the Ny-Aalesund Atmosphere Flagship Programme.**

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# Book of abstracts

# The Atmosphere Flagship Programme in Ny-Ålesund, Svalbard

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Atmosphere science is a major topic of the research activities of the Ny-Ålesund International Scientific Community (NISC), which operates 13 research stations in the village of Ny-Ålesund on the west coast of Spitsbergen. Atmosphere research is one of four major components, called the Flagship Programmes, of the Science Plan for Ny-Ålesund. The Atmosphere Flagship Programme is building on several ongoing national and bilateral scientific cooperations and research programmes. The current Atmosphere Flagship initiative aims at planning and organizing joint international research activities, which shall also comprise contributions from other research locations on Svalbard, namely form Hornsund and Barentsburg, as well as from Greenland (Villum Base / Station Nord). The goal and motivation of the flagship programmes are to contribute to investigate and answer science questions, which cannot be solved by individual actions or from a single, local perspective alone.

In detail, the Atmosphere Flagship programme addresses topics like atmosphere - snow/ - sea ice / - glaciers interactions, surface and boundary layer properties, aerosol-clouds-radiation interactions, meteorological observations in a pan Svalbard network on campaign and long term scales, transport of various pollutants, stratospheric ozone, and ionospheric research. Of particular interest will be the combination of on site observations and local, regional, and global modelling work, addressing for example the representativeness of local observations. Provisions of various calibration and validation activities for observational techniques, as well as of data sets for modelling and satellite validation are additional foci.

To reach these goals, the Atmosphere Flagship Program committee organized two workshops recently, supported by the Svalbard Science Forum. The 2015 Atmosphere Research Symposium involved a large group of atmosphere researchers working in and around Ny-Ålesund, and other places on Svalbard, informing by science talks, poster sessions and discussion rounds about various ongoing research activities, as well as identifying new prioritized topics and activities for the Atmosphere Flagship Programme in the near future.

The current main research focal activities, organized in dedicated working groups of the Atmosphere Flagship initiative are these:

- Clouds and local – regional short term processes
- Long-term observations and trends in temperature, precipitation, clouds, and radiation
- Boundary layer meteorology
- Aerosols (black carbon) and snow
- Atmospheric aerosols
- Variability in surface UV irradiance and ozone column

The presentation will introduce the general flagship goals and discuss particularly the aerosol and boundary layer research topics, which are a major issue of the 2016 Sopot Atmospheric Studies in the Arctic workshop. For further information about the Atmosphere Flagship programme see: http://nysmac.npolar.no/research/flagships/atmosphere.html

# Physiochemical properties of aerosols in Arctic

**Ki-Tae Park, Sang-Jong Park, Baek-Min Kim, Taejin Choi, Young Jun Yoon**

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The overall main research objective of KOPRI aerosol research team is to address the question: will future changes of the Arctic climate induce positive or negative feedbacks with respect to DMS-aerosol-cloud interactions? To improve knowledge gaps regarding these issues, KOPRI research team has focused on the two research themes in collaboration with Stockholm University, Norwegian Polar Research Institute (NPI) and Norwegian Institute for Air research (NILU):

- Long-term observation of DMS and aerosol physics (e.g., particle distribution, cloud condensation nuclei) in Arctic atmosphere
- Examining climate feedback roles of DMS-aerosol in Arctic under global warming event

**[Expected Visit to Ny-Ålesund]**

March, 2016: 5 researchers (DMS and CCN measurements, boundary layer observation)

April, 2016: 2 researchers (DMS and CCN measurements, boundary layer observation)

# Local vs long range sources of aerosol particles upon Ny-Ålesund (Svalbard Islands): mineral chemistry and geochemical records

**B. Moroni[1], D. Cappelletti[1], S. Crocchianti[1], M. Busetto[2], M. Mazzola[2], L. Ferrero[3], S. Becagli[4], R. Traversi[4], R. Udisti[4]**

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In this study some basic aspects of individual particle analysis have been put into relationship with the geochemical signature of the aerosols in order to characterize the sources and the evolution of the aerosol particles in the PBL upon Ny-Ålesund during summer. Aerosol samplings were performed both at ground level and at different height upon the NyÅlesund polar station in June-July 2012 using a tethered balloon equipped with a cascade impactor and meteorological sensors. The samples were analyzed by ion chromatography and scanning electron microscopy coupled with energy-dispersive X-ray microanalysis (SEM-EDS).

The results show the main contribution of long range over local/regional transported particles and sediments in the aerosols in the period of interest. Amongst the long range sources a main contribution was represented by Siberian local soils and regional wildfires which provided typical particles (metal oxides, calcareous grains) and ion species ($nssK^+$, $nssSO_4^{2-}$ and $Cl^-$) to the aerosols. Amongst the local sources, and apart from the sea which provided a huge amount of marine salt, a main contribution was represented by the fly ash emitted by the cruise ships whose stacks can be considered elevated continuous point sources of fly ash in the air.

The amounts of the particulate fraction in the samples was found to be definitely low compared with their amounts in spring [1]. If we consider the very low amounts of fine loose soils, the permanent snow cover in many areas and the high levels of soil moisture especially in summer time, all preventing particle resuspension, this fact underlines the low impact of the local sources on dust production upon Ny-Ålesund all over the year.

Another aspect which results from aerosol particle characterization is the clear stratification of the Planetary Boundary Layer upon Ny-Ålesund. This typical feature, which has been already documented in spring on the same site [1], is quite effective also in summertime despite the higher potential of local dust production and the lower atmospheric stability characterizing this period.

Studies are now in progress in order to characterize in more detail the natural (soil) and anthropogenic (pollutant) atmospheric particles upon Ny-Alesund during summer. Activities on ground include the survey and sampling of local dust sources (rock and soil outcrops) and suspended atmospheric particles (airborne dust) over them. The results are expected to provide a better estimation of the impact of particulate matter on the aerosol

properties upon Ny-Ålesund. In addition, they would be very useful to monitor the effect of activities of the polar station on the surrounding environment and the quality of data collected over there.

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# Aerosol-cloud interaction: Direct observations of activated aerosol particles using Counterflow Virtual Impactor (CVI) at Zeppelin station, Ny Ålesund

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From November 2015, Counterflow Virtual Impactor is operational at Zeppelin station, Ny Ålesund. With CVI it is possible to sample and analyze cloud residual particles in real-time. Cloud residual particles are aerosol particles, which has been activated into cloud droplets and ice crystals. By letting the clouds engulf the station we can study the cloud microphysical properties in-situ, while comparing with other pertinent cloud properties obtained through international collaboration at the Ny-Ålesund research village, Svalbard (78 deg. N.). Example of these are aerosol properties, cloud geometry, and radiative properties. To place a CVI on the ground is a very cost effective approach in comparison to using an airborne platform, and it allows us to obtain data covering many aspects of the cloud on a seasonal and annual basis. Ultimately, this project will lead to new knowledge about the processes controlling cloud properties in the Arctic and lead to new numerical formulations of aerosol-cloud interaction to be used in Earth system models. During the workshop we would like to present for the first results of direct observations of the cloud residual microphysical properties in the Arctic during winter.

# Optical properties of biomass burning originated aerosols measured during July 2015 over the European Arctic

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In this presentation the authors describe a biomass burning episode from summer 2015 and its consequences for aerosol load over the European Arctic. The wild fires, analyzed by the authors, occurred in central Canada between late June and early July 2015. According to Global News Canada 2015 is one of the worst years in last 5 years in terms of a number of forest fires. As a result of these fire outbreaks biomass burning aerosols reached such remote areas as Spitsbergen, and even northern Europe, where the authors observed and measured the properties of those aerosols. With southerly winds the pollution and aerosols were advected into the Arctic region and travelled vast distances causing, temporary, however, significant in numbers, distortion of radiative budget.

In the low stratosphere a shallow aerosol layer existed at least 4 weeks. We found extremely high value of AOD measured in Ny-Alesund and Hornsund as well as in the Northern Scandinavia (in Andenes) during that time. Although the presented data do not include final calibration and final cloud screening, which may remove the highest values of AOD, the retrieved values are very high and consistent between lidars and photometers. For example the long-term mean AOD in Hornsund station at 500 nm is about 0.08 (between March and September) and 0.09 in Andenes (between March and October) and during this event AOD exceed the value 1.0 in Spitsbergen and 0.7 in Andenes.

**Acknowledgements**

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# The July 2015 biomass burning aerosol from lidar perspective

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During July 2015 very pronounced forest fire aerosol from Canada were observed above different sites in Svalbard. The AOD at visible wavelengths reached values of 1 which is 5 times more than a strong Arctic haze event.

For this reason it is hypothesized that all different aerosol measuring systems should have seen the same aerosol type, regardless of their location on Svalbard. Hence this event is an excellent example for an aerosol closure study and it can be learnt how well results of different instruments agree on the derived aerosol properties. Possible deviations might be explained by interactions with the boundary layer and orography.

Moreover, due to the high number concentration, this event had a clear impact on radiation, which is worth to be analyzed in detail.

During the workshop these topics might be discussed with the aim on a second paper (1: use this event for a closure study, 2: estimate direct aerosol forcing)

To stimulate such a discussion results from KARL lidar, radiosonde and BSRN are presented. From the extinction and backscatter coefficients an index of refraction and a size distribution is estimated. It will be discussed to what extend the derived aerosol properties depend on the relative humidity.

# Morphochemical characteristics and mixing state of individual carbonaceous particles from the Canadian biomass burning event of July 2015 at Ny-Ålesund (Svalbard Islands)

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Wildfires pose a serious question on climate change in the Arctic as a source of particles which are able to modulate the net radiative forcing and the albedo properties of the exposed surfaces [1]. As the impact of wildfires is expected to rapidly increase with time due to global warming, better knowledge of the intrinsic properties of the constituent particles of biomass burning aerosols is essential to improve the climate change models. As an example, here we report the results of individual particle characterization of an aerosol sample from the Canadian wildfire of July 2015 collected at Ny-Ålesund during the last summer campaign.

Wildfires developed in Western Canada all the summer with highest levels from the end of June to the end of July. At Ny-Alesund the long range transported biomass burning particles mostly impacted from 10 to 15 of July following the movement of air masses. On July 13 an aerosol sample was collected at the Gruvebadet station, near Ny-Ålesund, using a DEKATI 12-stage low pressure cascade impactor (cut-off from 30 nm up to 10 mm) operating with 25mm polycarbonate filters. Individual particle analyses were performed on the filters by scanning electron microscopy coupled with image analysis, 3D surface reconstruction and energy-dispersive X-ray microanalysis (SEM-EDS). Continuous measurements of particle size distribution (SMPS and APS) and optical properties (PSAP and Nephelometer) were also recorded at Gruvebadet during the event.

Different types of carbonaceous particles were evidenced, along with large amounts of chloride and nitrate individual particles and aggregates. Among the carbonaceous particles, tar balls [2] are the most widespread particle type, followed by partly coated and embedded particles, and a very few bare particles. Each particle type shows a typical size range and morphology and a distinct grain boundary complexity.

Results of analyses are very similar to those found in the case of freshly emitted wildfires developed at much lower latitudes in summer [3, 4]. In particular, the presence of two distinct types of tar balls, dark and bright, identified based on the secondary electron signal, has been put into relationship with a different degree of oxidation of the particle's surface and, thus, to a different degree of surface reactivity. The results, however, are also very different from those found in the case of freshly emitted wildfires developed at high latitudes in the same period [5]. This fact points to the complexity and intrinsic variability of biomass burning products depending on their sources, the geographical location of forested areas, the time and the mode of the transport from the source regions. All these factors can dramatically influence the physico-chemical evolution of particles during the long range

transport till the final properties at the measurement site. Therefore correct evaluation of the state of mixing of carbonaceous particles is a very important target for the future studies in the Arctic system.

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# Sulfate source apportionment in the Ny Ålesund (Svalbard Islands) Arctic aerosol

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Daily PM10 aerosol samples were collected at the Gruvebadet observatory, Ny Ålesund (Svalbard Islands), during the spring-summer 2014 Italian Arctic Campaign. A total of 136 samples were analysed for ion (inorganic anions and cations, selected organic anions) composition aiming to evaluate the seasonal pattern of sulfate, as a key component of the Arctic haze. Ionic balances indicated a strong sulfate seasonality with mean spring concentration about 1.5 times higher than measured in summer. The spring and summer aerosol was almost neutral, indicating that ammonia was the major neutralizing agent for atmospheric acidic species. The linear regression between sulfate from potential acidic sources (non-sea salt sulfate and non-crustal sulfate) and ammonium indicated that the mean sulfate/ammonium ratio was intermediate between semi- (NH4HSO4) and complete ((NH4)2SO4) neutralization. By using sea-salt sodium as sea-spray marker, non-sea-salt calcium as crustal marker and methanesulphonic acid as biogenic marker, a detailed source apportionment for sulfate was carried out. The anthropic input (calculated as the differences between total sulfate and the sum of sea-salt, crustal and biogenic contributes) was found to be the most relevant contribution to the sulphate budget in the Ny Ålesund aerosol in summer and, especially, in spring. In this last season, crustal, sea-salt, biogenic and anthropic sources accounted for 3.3%, 12.0%, 11.5% and 74.8%, respectively.

# Size distribution and chemical characterization of aerosol collected in Ny Ålesund (Svalbard Islands) during a biomass burning event in Canada (July 2015)

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Since aerosol composition and dimensions play a fundamental role in the radiative budget of the planet influencing its total albedo, such huge particulate production events as wildfires represent a significant contribution to this forcing factor. The physical properties and the chemical characterization of the aerosol coming from biomass burning events can provide a better understanding of their effects on the climate.

The 2015 spring-summer aerosol sampling campaign in Ny Ålesund provided the opportunity to study the chemical composition and the size distribution of the particulate originated by the many Canadian wildfire events occurred during summer 2015, which significantly affected the particulate reaching Ny Ålesund between 9 and 15 of July.

In the observatory of Gruvebadet, daily samples of PM10 were collected on Teflon and quartz filters, whereas 4 and 12-stage impactor samples on polycarbonate have a 4-day resolution. Thanks to the measurements performed by Ion Chromatography, ICP-MS and Thermo-Optical Analyzer, we have available a broad data set of ionic composition, metal content (including Rare Earth Elements) and Elemental and Organic carbon content, to characterize the long-range biomass burning particulate. In addition, size distribution data of the particles were collected in the same laboratory through two particle counter devices (APS and SMPS, 10-minute resolution), yielding a high resolution analysis particle concentration between 10 nm and 20 μm (106 channels).

The size distribution shows a very high and stable concentration of particles in the range 0.5 - 1.0 μm during the occurrence of the whole event, whereas smaller particles peak mainly between 50 and 250 nm with some discontinuities.

High and simultaneous concentration of non sea salt - potassium and oxalate, which can be taken as markers for biomass burning, are present in conjunction with the high number of particles in the fine and accumulation mode, revealing the long range sources of the aerosol reaching Ny Ålesund, which is also supported by the large abundance of sulfate and ammonium, unusual during summertime.

# Arctic Amplification AC3 – a new German Transregional Collaborative Research Centre – Contributions from the AWIPEV Research Base in Ny-Alesund, Svalbard

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The German Research Association (Deutsche Forschungsgemeinschaft, DFG) is funding a new Transregional Collaborative Research Centre to address a major question of Climate Change: Why is the Arctic warming much faster than the global mean? What are the reasons for this Arctic Amplification? The Alfred Wegener Institute, together with the Universities of Bremen and Cologne, will substantially increase their research work at the joint French-German Arctic Research Base AWIPEV in Ny-Aalesund, Svalbard as a contribution to this research initiative. Building on previous, multi-year observations, they will in particular intensify the observations of aerosols and clouds, their interactions and radiative effects, the atmospheric water vapour content and its isotopic composition, as well as observations of trace gases and the complete meteorological profile.

A major contribution will be the installation of a new cloud radar to observe cloud properties and structures in high temporal, and vertical resolution. The radar is scheduled for installation by the University of Cologne during spring 2016.

The project will characterize the thermodynamic structure, clouds, aerosols, trace gases and radiative effects in the Ny-Aalesund atmospheric column. The combined analysis of aerosols, water vapour, and cloud parameters will also allow investigating the impact of transport from mid-latitudes. The observations are closely connected to model studies, which describe the atmospheric Ny-Aalesund column. The combination of cloud radar measurements, passive microwave radiometry, and lidar profiling will allow investigating the interaction of different aerosol types with clouds and their respective properties.

The observations in Ny-Aalesund will be combined with intensive ship based and air borne observations during a dedicated campaign in early summer 2017. One particular research focus of this combination will be the assessment of the representativeness of observations in Ny-Aalesund and their usability for regional modelling.

The workshop contribution will present the AC3 project goals for Ny-Aalesund, and the ongoing and planned observations and campaign activities, in particular for the 2016 season and beyond.

Information about the AC3 project will be posted at www.ac3-tr.de and www.awipev.eu

# Breeze circulation in Svalbard fjords: Kongsfjorden and Hornsund

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We analyze data series (1992-2013) of wind measurements from meteorological stations in Ny-Ålesund and Hornsund in Svalbard and compared them to surface layer winds from the NCEP/NCAR reanalysis. Large discrepancies between the local wind direction and directions of wind compatible with analysis of the pressure fields are found. Most winds blow along the main axes of the fjords and the Easterly direction is preferred for most directions of large scale wind field. One of the most important factors controlling directions of local wind in the Svalbard fjords is the temperature difference between the neighboring glaciers and surface sea temperatures of open waters warmed by the West Spitsbergen current. We explain it as breeze circulation. The lowest probability of breeze events during the summer, when this difference of temperature is smallest supports this interpretation. A Monte Carlo analysis of breeze probabilities reject the null hypothesis of independent breeze events in both fjords. Therefore we posit the breeze occurrence are largely controlled by mesoscale circulation.

# Seasonal and long-term variability of atmospheric circulation over Svalbard in the light of manual catalogue of circulation types

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Defined as three-dimensional, large-scale movement of the air, atmospheric circulation is an important factor triggering the accumulation of aerosols within the Arctic. Air pressure patterns have been proved to determine the type and amount of aerosols transported into the Artic (Stone et al. 2014). This finding was established by describing the air circulation around the quasi-persistent centres of action at days with the high aerosols concentration over the Arctic or its specific locations thus being qualitative assessment.

Classification of circulation types (Niedźwiedź 2015) used in this presentation to describe the climatology and long-term changes in atmospheric circulation over Spitsbergen can be used for quantitative assessment of the relations between the direction of air advection, types of pressure system and aerosols concentration over Spitsbergen. The catalogue was created manually on the base of synoptic charts (00 UTC or 12 UTC). It consist of 21 model circulation types depicted by the direction of air advection (e.g. N – northern advection, NE – north-eastern advection) and the type of baric centre (c- cyclonic, a - anticyclonic). One of the model circulation types were attributed to each day since December 1950. The catalogue is constantly updated. The classification of circulation types was proved to be the useful means for the research of the relation between atmospheric circulation and various climate elements (e.g. air temperature, precipitation, wind speed, weather types) and the chemical composition of precipitation, however, it has never been used for quantitative analysis of aerosols accumulation in the Arctic.

Annual frequency of circulation types over the Spitsbergen indicates the clear dominance of the air advection from the eastern sector, particularly from NE and E directions. In winter, when the Arctic is most polluted the air is usually inflowing from the NE, E and SE directions when Spitsbergen is under an influence of low pressure system (circulation types NEc, Ec and SEc). Such behavior was not found in case of the anticyclonic types with the analogues air advection. The further research could be into the analysis of relations between both occurrence and concentration of aerosols for particular circulation types.

# Atmospheric boundary layer, turbulence, and cloud observation to enhance climate prediction capabilities

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KOPRI launches a 4-yr research project (2016.01.-2019.12) to better understand Arctic boundary layer (BL) and cloud with final aim of better climate prediction system. We plan to establish infra-structure to measure vertical profiles of wind, temperature, and moisture continuously. In addition, field campaigns to carry out in-situ cloud/aerosol observation are planned during the project. KOPRI team recognizes that active cooperation with other research teams such as Germany, Italy, Norway, Japan, India can maximize our scientific outcomes. To enhance our knowledge about the Arctic BL and cloud, our new project will integrate observation and modeling as follows:

- *Observation*; Establish infrastructure for observing Arctic cloud and boundary layer based on Ny-Ålesund (but not limited to)
- *Modeling*; Develop the Arctic–mid-latitude regional weather and global climate prediction system

**[Expected Visit to Ny-Ålesund]**

March, 2016: 5 researchers (DMS and CCN measurements, boundary layer observation)

April, 2016: 2 researchers (DMS and CCN measurements, boundary layer observation)

# Chemistry of snow cover and acidic snowfall during a season with high level air pollution at Hansbreen glacier, Spitsbergen

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In early May 2006 was observed a high pollution in the Arctic. Those anthropogenic haze was a typical rapid transport of BB aerosols (smoke) from agricultural fires in Eastern Europe to the Arctic. We want to present the results from chemical analysis of fresh snowfall, and how the hydrochemical processes and the transformation of atmospheric precipitation and deposits impact on the atmospheric boundary layer.

The chemical properties of precipitation and snow cover have been monitored at the Hornsund Polish Polar Station, Spitsbergen. The chemistry of fresh snow and the properties of snow cover were monitored in the altitudinal profile of the Hansbreen Glacier. Meteorological data from the cost and from the glacier helped to examine in detail the impact of atmospheric processes on the snow cover contamination. The episode with extremely acid precipitation was recognised in snow cover analysed in spring 2006. A source area of pollution and type of synoptic situation which enhanced transfer of pollution to the European Arctic were identified.

# Comparison of the aerosol single scattering properties during iAREA campaigns in 2014 and 2015

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In 2014 and 2015 two iAREA (Impact of Absorbing Aerosol in the European Arctic) campaigns were carried out over spring season in Ny-Alesund, Spitsbergen. The main issue of the measurements was to retrieve single scattering properties of the aerosols characterizing polar atmosphere during Arctic Haze season. To achieve that, we used a variety of instruments consisting of: Nephelometer 3563, Photo-acoustics Extinctiometer, Microtops II Sun Photometer, particle counters system SMPS + APS and Aethalometer AE31. In addition, the micro AE51 and HandiLaz particle counter as well as radiosonde were attached to a tethered balloon, also vertical profiles were provided by AWI Aerosol Raman Lidar KARL and Near-range Aerosol Raman lidar (NARLa). During both campaigns a few event days were detected, mostly being characterized by sea spray advections. During the speech author will provide a brief comparison between the spring conditions measured in 2014 and 2015 with a special emphasis put on the characterization of the event days, the similarities of both campaigns and some long-term changes occurring in the last two decades in Arctic basing on climatological data from Zeppelin Station.

# Retrieval of aerosol single-scattering profiles based on synergy of in-situ and remote sensing techniques during iAREA campaign in Ny-Alesund

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In this study we present a new method to retrieve vertical profile of aerosol single-scattering properties based on synergy of different measurement techniques. Presented results are based on the iAREA (Impact of absorbing aerosols on radiative forcing in the European Arctic) campaigns which took place in the Ny-Alesund in spring of 2015. Our methodology used in-situ observation of black carbon concentration and absorption coefficient by the micro-aethalometer AE-51 mounted onboard of the tethered balloon as well as the remote sensing measurements made by sun photometer and lidar systems. The active remote sensing equipment includes KARL Raman lidar and near-range aerosol Raman lidar (NARLa). In case of KARL lidar the overlap range (about 800 m) limits retrieval of the aerosol extinction coefficient nearly the surface. In case of the NARLs system the aerosol optical properties can be retrieved from about 200 m above the surface. Due to the tethered balloon observation of black carbon concentration we retrieved aerosol optical properties between 200 and 1500 m a.g.l. The AE-51 micro-aethalometer reports the black carbon concentration deposited on the quartz filter which can be use to estimate the aerosol absorption coefficients. Conversion of black carbon concentration to the aerosol absorption coefficient is complicated due to light multiple scattering between filter and aerosol layer. To reduce this effect we applied correction for filter loading and multiple scattering effects based on comparison with PAX device. From minimization we retrieved profiles of: aerosol extinction coefficient, aerosol single scattering albedo, and aerosol absorption coefficient based on the Klett-Fernald-Sasano and Raman method.

The research leading to these results has received funding from the Polish-Norwegian Research Programme operated by the National Centre for Research and Development under the Norwegian Financial Mechanism 2009-2014 in the frame of Project Contract No Pol-Nor/196911/38/2013.

# AGAP: an Atmospheric Gondola for Aerosol Profiling

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A novel airborne gondola has been developed to profile the Arctic boundary layer exploiting a tethered balloon system. A number of aerosol instrumentation have been customized and deployed in the gondola for two test campaigns conducted in Ny-Ålesund in September 2014 and April-May 2015. The performances of the instrumental setup have been characterized and will be described. An illustration of the main results and a discussion of the main phenomenology will be also presented. Briefly, the tethered balloon systems demonstrates the capability of successfully lifting up to 15 kg of scientific payload, featuring a power autonomy of about 3 hours of continuous measurements with 1 battery. We demonstrates for the first time on a tethered balloon the capability of measuring at the same time aerosol light scattering, absorption coefficients and size distribution, which is very promising for deducing the aerosol optical properties as a function of height along the probed atmospheric column.

The field campaign will be repeated during spring 2016, probably in April for at least three weeks but with the possibility to extend to May, in order to complement the measurements performed by other groups. A possible improvement in the payload will be the implementation of a miniaturized particle soot absorption photometer (PSAP) in place of or together with the micro-aethalometer.. We would like also to perform particles sampling on filter during some of the balloon launches.

# Aerosol optical properties in the atmospheric surface layer observed during iAREA2014 campaign on Spitsbergen

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The aim of this paper is to distinguish classes of aerosols optical properties observed during Arctic Haze season 2014 on Spitsbergen and to characterize these classes with respect to aerosol chemical composition, predominating advection direction (air mass trajectory), meteorological conditions and time during a day. During iAREA2014 campaign that took place on Svalbard between 15th of Mar and 4th of May 2014, measurements of aerosol scattering coefficients (total and backward) and absorption coefficient were performed. The scattering coefficients were measured with the integrating nephelometer model 3563 (TSI). The absorption coefficient was directly measured with photoacoustic extinctiometers (Droplet Measurement Technologies company). It was also retrieved from simultaneous measurements of the scattering coefficients and transmittance of aerosol accumulated on a filter (aethalometer AE31, Magee Scientific Company). Six-day backward trajectories of the air inflowing at 500 m over the stations during optical measurements were computed by means of the HYSPLIT model (Draxler et al., 2003). Based on the measured scattering and absorption coefficients we calculated backward to total scattering coefficient ratio and single scattering albedo for wavelength □=550 nm and Ångström exponent of the extinction coefficient for wavelengths □=450 nm and □=700 nm. These properties characterize aerosol type, not aerosol concentration. An application of non-hierarchical cluster analysis (k-mean method) to these aerosol optical properties allowed us to distinguish classes of atmospheric aerosol over Spitsbergen during Arctic Haze season.

# Primary production, sea ice melting, and biogenic aerosol in the Arctic

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This study examines the time evolution of methanesulfonic acid (MSA, arising from the atmospheric oxidation of the biogenic dimethylsulfide, DMS) in the Arctic atmospheric aerosol and its relationship with satellite-derived chlorophyll a (Chl), and primary production (PP), also as a function of sea ice melting (SIM) and ice free area in the marginal ice zone (IF-MIZ) extension in these Artic regions.

Aerosol samples (PM10) are collected over the period 2010-2015 at two Arctic sites, Ny Ålesund (78.9°N, 11.9°E), Svalbard islands, and Thule Air Base (76.5°N, 68.8°W), Greenland, and have been analysed for MSA content by ion chromatography. PP is calculated by means of a bio-optical, physiologically based, semi-analytical model in the potential source areas located in the surrounding oceanic regions (Barents and Greenland Seas for Ny Ålesund, and Baffin Bay for Thule). In general, MSA shows a better correlation with PP rather than with Chl. In particular, in the Barents Sea next to Ny Ålesund a significant correlation is obtained during the spring and summer periods between MSA and PP in spring. Conversely, the linear regression MSA – PP in the Greenland Sea is significant only during the summer period. At Thule, we find a significant correlation between MSA and PP over the entire spring/summer period. The differences in the slopes of the MSA-PP correlation are due to taxonomic differences in the phytoplanktonic assemblages. Indeed, DMS emission in Barents and Buffin Bay is mainly related to the MIZ diatoms that are prolific producers of DMS, whereas in the Greenland Sea the DMS peak is related to an offshore pelagic bloom, where low-DMS producer species are present. The correlations between MSA and PP joint to meteorological analysis show that source intensity plays a dominant role in controlling the concentration of MSA, but transport processes may affect the degree of correlation between the two parameters. For instance, in May 2010 frequent advection of air from the Barents Seas (caused by a particular synoptical condition likely related to the strong negative phase of the Arctic Oscillation) determined anomalous large concentrations of MSA at Ny Ålesund.

The most important outcome is the good correlation between MSA and SIM and between MSA and IF-MIZ. Such relationships are calculated by combining the data sets from the two sites and suggest that PP is related to sea ice melting and to the extension of marginal sea ice areas, and that these factors are the main drivers for MSA concentrations at the considered Arctic sites.

# Size distribution and ion composition of aerosol collected at Ny Ålesund in the spring-summer field campaign 2013

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During the 2013 Arctic campaign, direct measurements and size-segregated samplings of atmospheric aerosol were carried out from March to September at the Gruvebadet observatory in Ny Ålesund (Svalbard Islands). Continuous size distribution measurements (104 size classes) were performed both in the nano- (TSI-SMPS system) and micro-metric (TSI-APS device) range with 10-minute resolution. Aerosol sampling was performed on a daily basis (PM10 fraction) and with a 4-day resolution (4-stage cascade impactor). Aerosol samples were analyzed by a three-Ion Chromatograph system, after extraction in ultra-sonic bath, in order to determine the ion composition (inorganic cations and anions, selected organic anions).

As concerning the particle size distribution, a pronounced difference between early and late spring can be noticed, with a larger occurrence of particles belonging to the 100 – 300 nm range in early spring and to the 20 - 50 nm range in late spring (as visible in the plots from SMPS measurements).

Such a pattern is consistent with the dominance of the Arctic Haze processes active in early spring and a mix of long-range transport and local new particle production starting in late spring.

Regarding the seasonal pattern of natural and anthropic chemical markers, one can observe that sea spray aerosol is evenly distributed along all the sampling period with a size distribution mostly peaking between 1.0 and 10 μm. Anthropic sulfate dominates the spring aerosol load (Arctic Haze), both in acidic form (H2SO4) and in partially or totally neutralized ammonium salts. Biogenic contributions, marked by methanesulfonic acid, are relatively relevant in late spring-early summer and are almost completely distributed in the finest aerosol fraction (<1.0 μm).

A back-trajectory analysis was performed for specific deposition events, in order to depict transport processes and possible source areas of the aerosol reaching Ny Ålesund.

# Results from a closure experiment between Lidar and tetherd balloon measurements in Ny-Ålesund

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Aerosols properties (i.e. size distribution, chemical composition, Black Carbon fraction) and their load along the air column influence the climate forcing (IPCC, 2013; Corrigan et al., 2008).

A closure experiment was conducted over Ny-Ålesund comparing optical properties derived from Lidar measurements and calculated from aerosol vertical profiles measured using a tethered balloon platform.

Vertical aerosol profiles were measured using a tethered balloon (helium-filled) balloon fitted with a miniaturized electrical nanoparticle detector (miniDiSC); an Optical Particle Counter (OPC GRIMM *1.107*; 31 size classes between 0.25 to 32 μm); a novel micro-Aethalometer (AE51, Magee Scientific); a miniaturized cascade impactor (Sioutas SKC with 2 impaction stages: <1 μm, >1 μm); a meteorological station (Vaisala Tethersonde TTS 111). Data used for the closure experiment were collected on 26$^{th}$ April 2011. The aerosol optical properties along vertical profiles were calculated using the Mie theory applied to the OPC aerosol size distribution that was previously corrected using the aerosol refractive index obtained by AERONET (Hornsund site) and then log-normally interpolated.

Lidar measurements were performed by the Alfred-Wegener-Institut (AWI) using the the Koldewey Aerosol Raman Lidar (KARL); KARL is a Nd:YAG based Raman lidar which measures the elastically backscattered light in three wavelengths (355nm, 532nm and 1064 nm) as well as the N2 shifted lines from the 2nd and 3rd harmonic (Hofmann et al., 2009). The main lidar data used during the closure experiment was the backscattering coefficient obteined in the Field of View of the Lidar telescope.

The results (i.e. aerosol phase function) were first validated with AERONET data finding a good reproduction of the aerosol phase function. Backscattering coefficients from balloon and lidar were compared. Figure 1 reports an example of the closure experiment. Altitude ($H_s$) is normalized at the planetary boundary layer height where $H_s$=0 ($H_s$=-1 at ground). As reported in Figure 1, there is a good agreement for what concern the shape of the aerosol optical properties obtained by lidar and balloon measurements. For what concern the

absolute values, lidar data showed backscattering coefficient values about 2-3 times higher at 355 and 532 nm while there was 1:1 agreement for 1064 nm.

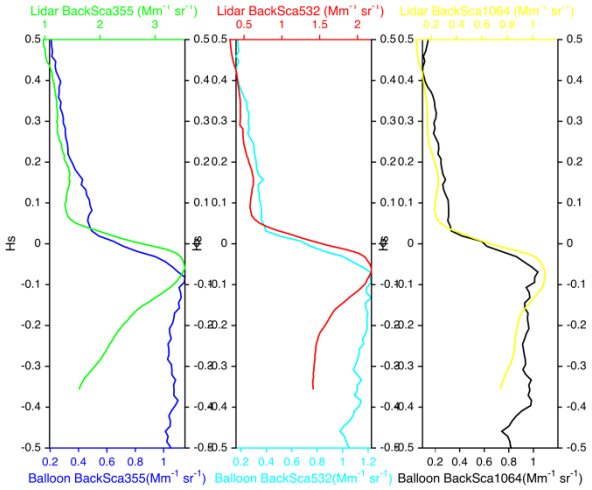


Figure 1. A vertical profile of backscattering coefficient obtained by lidar and balloon data at: 355, 532 and 1064 nm.

Corrigan et al. (2008). Atmos. Chem. Phys., 8, 737–747.
IPCC: Climate Change 2013.

# The atmospheric boundary layer characteristics observed at the Climate Change Tower in Ny Alesund, status and perspective

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The Amundsen-Nobile Climate Change Tower (CCT) is an important the scientific platform operating in Ny-Ålesund Svalbard. The CCT is equipped with a set of meteorological sensors installed ad different height to provide continuous measurements of the atmospheric parameters that affect the climate and its variability. Main meteorological parameters observed during the 6 years of measurements since November 2009 are presented to describe the thermodynamic characteristic of the lower layers of the atmosphere .

Even if the time series are not long enough for climatological studies, useful assumptions can be made for analysis concerning turbulence studies for example for testing similarity predictions and address some questions for quasi neutral, convective and stable atmospheric boundary layer in the Arctic. An attempt to answer to questions about the transition from dynamic to free convection for the CBL, the recognition of the structure of the SBL ( traditional and up-side down ) as well as the evaluation of the Von Karman constant in the quasi- neutral conditions is given.

The analysis shown is based on the uses four conventional Young anemometers and Vaisala thermo-hygrometers, alternate at lower levels, by two lined up Gill sonic anemometers, installed on the CCT. Integration of such analysis with other observations and techniques, and as remote sensing , is planned, to extend the vertical profiling at higher level and contribute to the comprehension of phenomena that link the atmospheric boundary layer the other components of the Arctic climate system.