Working Group 4: Aerosols (black carbon) and snow, including snow albedo feedback
Summary report for the meeting on 5 October 2016 in Kjeller, Norway

The presentations and the discussions of the workshop touched upon two different, albeit connected topics: 1. Data sets of long-term snow observations and 2. Role and the behavior of impurities in the snow.
The only snow parameter in Ny-Alesund with observational time series longer than five years appears to be the snow height. Such observations started in the village of Ny-Alesund already in the 70s by the Norwegian Meteorological Service, before being interrupted for a longer period. At present, the re-established manual snow height measurements are accompanied by multiple automatic measurements at different locations in and around Ny-Alesund. Snow water equivalent (SWE) measurements are generally rare and are still subject to major uncertainties even employing established techniques like snow pillows. Standard rain and snow gauges strongly underestimate solid precipitation and available corrections for wind influences remain to be site and instrument specific. A second site with long-term observations of snow height, SWE, and precipitation is Hornsund. Here, measurements started in the early 80s and have been performed manually. At both sites, the measurements of basic snow parameters are accompanied by measurements of albedo and stratigraphic information, which are also episodically available on the surrounding glaciers. Most of the stratigraphic observations have so far been linked to research projects and allowed the characterization of the springtime snowpack, often during the period of maximum snow height. Similar stratigraphic observations during other seasons (e.g. fall, winter, and melting period) appear to be very limited or even non-existing. The same seems to apply also for the measurement of chemical profiles in the snowpack in and around Ny-Alesund. The longest time series of continuous stratigraphic information appears to be a 60-day long sampling period with daily stratigraphic and chemical profiles obtained by the University Venice. A list of physical and chemical observations is summarized in a table with snow metadata also available at the webpage of the Atmosphere Research Flagship responding to the recommendation #1 of the working group.

The discussions allowed developing a number of recommendations by the work group:

1. The majority of the snow data is currently only accessible via the direct contact with the data owners, but not via open data bases. At least a short list of snow metadata is needed to distribute information on snow data beyond the working group and the flagship.
   Recommendation: The work group should publish a list of snow metadata (physics, chemistry, stratigraphy) on the Flagship web page. The list will be developed and verified by the members of the working group. It should be updated regularly and at least during future workshops and meetings of the work group. It should be communicated within all flagship activities and beyond.
2. The issue of a snow data base for the available observations in Ny-Alesund and Hornsund has been evoked. Different groups are working on making their data accessible via different (local) data bases.
   Recommendation: While a common snow data base would be desirable, it appears beyond a reachable goal of the working group with the currently available technical and

human resources. Moreover, it appears that the integration of the collected chemical snow data (e.g. high number of species, concentrations as function of time and depth) into a snow data base requires specific attention.

3. Manual snow height measurements are observations performed at a fixed (daily) point in time, automatic measurements generate continuous observations with short averaging periods. It has been shown that using different averaging periods of automatic measurements (e.g. 0:00 to 24:00 or 12:00 to 12:00) can introduce differences of up to several centimeters in the snow heights.
   Recommendation: To make automatic and manual snow height measurements better comparable a common averaging period for the automatic snow height measurements should be defined. It should be checked if the WMO-SPICE project issued recommendations for the averaging period. This issue should be treated at the next work group meeting.

4. Long-term, but uncorrected observations of precipitation at Ny-Alesund are available. It is well known that the observed precipitation needs to be corrected mainly in the case of solid precipitation. The corrections depend on wind speed and temperature. Some published studies are based on corrected precipitation time series. New correction functions have recently been published as a result of the WMO-SPICE project, while older correction functions specific for Ny-Alesund were published in the 90s by the Norwegian Meteorological Service. New technologies like radar have been deployed in Ny-Alesund. Similar difficulties exist for the precipitation observations at Hornsund. Here, an approach using a combination of different sensors with hydrological modeling will be applied to reduce the uncertainty in the precipitation record.
   Recommendation: The working group supports a homogeneous correction of the observed precipitation in Ny-Alesund. This correction could combine old and new corrections of the observations. The corrections should further include results of new instruments and technologies for precipitations and SWE. The final objective should be a recommended correction for precipitation time series to be used for further studies. The members of the working group may also explore if Ny-Alesund can be developed into a precipitation reference site. If successful, the approach used for the Hornsund data could be explored for Ny-Alesund.

5. Snow modeling that may be used to complement gaps in observational time series needs reliable meteorological forcing data. Some published snow modeling studies are based on such forcing data. A forcing data set for Hornsund is currently under development.
   Recommendation: The working group supports the development of homogenized forcing data for snow modeling studies. Such homogenized data sets should be developed in collaboration with the other working groups of the Atmosphere Research Flagship. Moreover, such forcing data have already been generated for published studies. Future meetings of the working group should try to attract a larger participation of the modeling community working, especially those involved in snow modeling projects at different scales.

6. “Arctic” test data including snow properties would have a wide range of applications in snow modeling and calibration/validation activities. Such test data are under development for the Hornsund site.

Recommendation: The working group supports the development of homogenized open-access data sets to test and validate models (snow and others). Such homogenized data sets should not be limited to snow, but should also consider the entire atmosphere-snow system and include standard meteorological parameters, surface exchange fluxes or permafrost. The development of such data sets requires the cooperation with and involvement of the different working groups of the Atmosphere Research Flagship and beyond (e.g. Glaciology Research Flagship). The development of such data sets for Ny-Alesund can profit from the experience currently generated using the Hornsund data.

7. Chemical information is based on analysis performed in different laboratories using different methods on site (Hornsund, Barentsburg) or after shipment to home laboratories. An inter comparison of the methods and techniques is needed and is the objective of an ongoing project distributing snow samples to different laboratories and analyzing for BC, major ions, and isotopes. Results of this inter comparison are expected in summer 2017.
   Recommendation: The working group supports the snow inter comparison project and will review the results during its next meeting.

Snow metadata collected after the meeting of the working group 4, on 5 October 2016 in Kjeller, Norway

Location	Station	Parameter	Method	Frequency + Period	Data access	Contact
Physics						
Hornsund	Hornsund	Snow height	Manually	Daily, 1982 - today	Via Contact	Tomas Wawrzyniak, tomasz@igf.edu.pl
Hornsund	Hornsund	Precipitation	Manually	Daily, 1982 - today	Via Contact	Tomas Wawrzyniak, tomasz@igf.edu.pl
Hornsund	Hornsund	SWE	Manually	Daily, 1982 - today	Via Contact	Tomas Wawrzyniak, tomasz@igf.edu.pl
Hornsund	Fuklebekken	Snow height	Manually	Weekly, 2013 - today	Via Contact	Tomas Wawrzyniak, tomasz@igf.edu.pl
Hornsund	300 point measurements	Snow height	Manually	Annually, 2013 - today	Via Contact	Tomas Wawrzyniak, tomasz@igf.edu.pl
Hornsund	50 point measurements	SWE	Manually	Annually, 2013 - today	Via Contact	Tomas Wawrzyniak, tomasz@igf.edu.pl
Brøggerhalvøya	300 point measurements	Snow height	Manually	Annually, 2001 - today	Via Contact	Jean-Charles Gallet, jc@npolar.no
Brøggerhalvøya	300 point measurements	Grounded ice	Manually	Annually, 2001 - today	Via Contact	Jean-Charles Gallet, jc@npolar.no
Ny-Alesund	Village	Snow height	Manually	1974 – 1976; 2008 - today	eklima	Mareile Wolff, mareilew@met.no
Ny-Alesund	Met. field	Snow height	Automatic	1998 – 2006	Via Contact	Mareile Wolff, mareilew@met.no
Ny-Alesund	Met. field	Snow height	Automatic	2011 – today	Via Contact	Marion Maturilli, marion.maturilli@awi.de
Ny-Alesund	Eddy Station	Snow height	Automatic	2013 – today	Via Contact	Marion Maturilli, marion.maturilli@awi.de
Ny-Alesund	Bayelva	Snow height	Automatic	1998 – today	Via Contact; PANGEA	Julia Boike, Julia.boike@awi.de
Ny-Alesund	Bayelva	Photographs	Automatic	?	PANGEA	Julia Boike, Julia.boike@awi.de
Ny-Alesund	CCT	Snow height	Automatic	2009 – today	Via Contact	Angelo Viola, a.viola@isac.cnr.it
Ny-Alesund	CCT	Spectral reflectance	Automatic	Hourly, 2009 – today	Via Contact	Angelo Viola, a.viola@isac.cnr.it
Ny-Alesund	CCT	Photographs	Automatic	?	Via Contact	Angelo Viola, a.viola@isac.cnr.it

Ny-Alesund	Met. field	SWE	Automatic	Hourly, 2010 - today	Via Contact	Heidi Bache Stranden, hrb@nve.no
Ny-Alesund	Met. field	Spectral albedo	Automatic	Hourly, 2012 – today	Via Contact	Masataka Shiobara, shio@nipr.ac.jp
Woodfjorden	?? point measurements	Spectral albedo	Manually	2013	Via Contact	Alia Khan, alia.khan@colorado.edu
Longyearbyen	?? point measurements	Spectral albedo	Manually	2013, 2015, 2016	Via Contact	Alia Khan, alia.khan@colorado.edu
Ny-Alesund	?? point measurements	Spectral albedo	Manually	2016	Via Contact	Alia Khan, alia.khan@colorado.edu
Stratigraphy						
Brøggerhalvøya	?? point measurements	Stratigraphy	Manually	Annually, 2015 - today	Via Contact	Jean-Charles Gallet, jc@npolar.no
Kongsvegen	5 point measurements	Stratigraphy	Manually	Annually, 2010 - 2012	Via Contact	Friedrich Obleitner, friedrich.obleitner@uibk.ac.at
Midre Lovenbreen	1 point measurements	Stratigraphy	Manually	Annually, 2010 - 2012	Via Contact	Friedrich Obleitner, friedrich.obleitner@uibk.ac.at
Austre Broggerbreen	1 point measurements	Stratigraphy	Manually	Annually, 2010 - 2012	Via Contact	Friedrich Obleitner, friedrich.obleitner@uibk.ac.at
Ny-Alesund	Bird cliff	Stratigraphy	Manually	Annually, 2010 - 2012	Via Contact	Friedrich Obleitner, friedrich.obleitner@uibk.ac.at
Ny-Alesund	Bayelva	Stratigraphy	Manually	Bi-annually, 1998 – today	Via Contact	Julia Boike, Julia.boike@awi.de
Ny-Alesund	3 point measurements (glaciers)	Stratigraphy	Manually	Annually, 2011 - 2015	Via Contact	Andrea Spolaor, andrea.spolaor@unive.it
Ny-Alesund	5 point measurements (glaciers)	Stratigraphy	Manually	Annually, 2016 - today	Via Contact	Andrea Spolaor, andrea.spolaor@unive.it
Austre Broggerbreen	60 point measurements	Stratigraphy	Manually	2014	Via Contact	Andrea Spolaor, andrea.spolaor@unive.it
Kongsvegen	1 point measurements	Stratigraphy	Manually	2012	Via Contact	Hans-Werner Jacobi, Hans-Werner.Jacobi@univ-grenobble-alpes.fr
Austre Lovenbreen	1 point measurements	Stratigraphy	Manually	2012	Via Contact	Hans-Werner Jacobi, Hans-Werner.Jacobi@univ-grenobble-alpes.fr
Ny-Alesund	Gruvebadet, 5 point measurements	Stratigraphy	Manually	2014	Via Contact	Hans-Werner Jacobi, Hans-Werner.Jacobi@univ-grenobble-alpes.fr
Chemistry						

Ny-Alesund	Met. field	EC, 0 – 5 cm	Manually	April 2013	Via Contact	Masataka Shiobara, shio@nipr.ac.jp
Ny-Alesund	3 point measurements (glaciers)	Chemical profiles (metals, ions, organics)	Manually	Annually, 2011 - 2015	Via Contact	Andrea Spolaor, andrea.spolaor@unive.it
Ny-Alesund	5 point measurements (glaciers)	Chemical profiles (metals, ions, organics)	Manually	Annually, 2016 - today	Via Contact	Andrea Spolaor, andrea.spolaor@unive.it
Broggerbreen	?? point measurements	BC, 0 – 5 cm	Manually	Anually, 2007 - today	Via Contact	Jean-Charles Gallet, jc@npolar.no
Woodfjorden	?? point measurements	rBC, eBC	Manually	2013	Via Contact	Alia Khan, alia.khan@colorado.edu
Longyearbyen	?? point measurements	rBC, eBC	Manually	2013, 2015, 2016	Via Contact	Alia Khan, alia.khan@colorado.edu
Ny-Alesund	?? point measurements	rBC, eBC	Manually	2016	Via Contact	Alia Khan, alia.khan@colorado.edu
Austre Broggerbreen	60 point measurements	Chemical profiles (metals, ions, organics)	Manually	2014	Via Contact	Andrea Spolaor, andrea.spolaor@unive.it
Kongsvegen	1 point measurements	Chemical profiles (ions, rBC)	Manually	2012	Via Contact	Hans-Werner Jacobi, Hans-Werner.Jacobi@univ-grenobble-alpes.fr
Austre Lovenbreen	1 point measurements	Chemical profiles (ions, rBC)	Manually	2012	Via Contact	Hans-Werner Jacobi, Hans-Werner.Jacobi@univ-grenobble-alpes.fr
Ny-Alesund	Gruvebadet, 5 point measurements	Chemical profiles (ions, rBC)	Manually	2014	Via Contact	Hans-Werner Jacobi, Hans-Werner.Jacobi@univ-grenobble-alpes.fr