6th National Seminar on Snow on the day of Pyry in collaboration with the COST ES1404 Action

Date: Monday, November 2, 2015, at 9.00-16.30
Place: Finnish Meteorological Institute (FMI),
Brainstorm auditorium (P-floor),
Erik Palménin aukio 1, 00560 Helsinki, Finland

Abstracts

Session A. Snow properties

Parameterization of single-scattering properties of snow

Petri Räisänen (FMI)

Snow consists of non-spherical grains of various shapes and sizes. Still, in many radiative transfer applications, single-scattering properties of snow have been based on the assumption of spherical grains. More recently, second-generation Koch fractals have been employed. While they produce a relatively flat phase function typical of deformed non-spherical particles, this is still a rather ad hoc choice. Here, angular scattering measurements for blowing snow conducted during the CLimate IMpacts of Short-Lived pollutants In the Polar region (CLIMSLIP) campaign at Ny Ålesund, Svalbard, are used to construct a reference phase function for snow. Based on this phase function, an optimized habit combination (OHC) consisting of severely rough (SR) droxtals, aggregates of SR plates and strongly distorted Koch fractals is selected. The single-scattering properties of snow are then computed for the OHC as a function of wavelength λ and snow grain volume-to-projected area equivalent radius rvp. Parameterization equations are developed for λ = 0.199–2.7 µm and rvp = 10–2000 µm, which express the single-scattering co-albedo β, the asymmetry parameter g and the phase function P11 as functions of the size parameter and the real and imaginary parts of the refractive index. The parameterizations are analytic and simple to use in radiative transfer models. Compared to the reference values computed for the OHC, the accuracy of the parameterization is very high for β and g. This is also true for the phase function parameterization, except for strongly absorbing cases (β > 0.3). Planned follow-up studies include validation against snow BRDF measurements, as well as climate model experiments.

Reference: Räisänen, P., Kokhanovsky, A., Guyot, G., Jourdan, O., and Nousiainen, T.: Parameterization of single-scattering properties of snow, The Cryosphere, 9, 1277-1301, doi:10.5194/tc-9-1277-2015, 2015.

Effects of Light Absorbing Impurities (BC/OC/dust) on Snow Properties

Meinander Outi, Pavla Dagsson Waldhauserová, Jonas Svensson, Monika Dragosics, Aki Virkkula, Jouni Peltoniemi, Heikki Lihavainen, Gerrit de Leeuw (FMI)

Climate effects of light-absorbing particles deposited on snow have been proposed to result from reduced snow albedo and increased melt (albedo feedback). We have investigated snow albedo effects linked to elemental carbon (EC), organic carbon (OC), and volcanic dust (resuspended by storms or originating from episodic volcanic eruptions) (Dagsson-Waldhauserova et al. 2015, Dragosics et al. 2015, Meinander et al. 2013, Svensson et al. 2015, Peltoniemi et al. 2015). The focus is on seasonal snow (on land at high latitudes in the Arctic) capable of reflecting the incoming solar radiation, wavelength dependently, at 300-2500 nm. Our work includes experimental work, continuous Arctic measurements, and modeling approaches. Also, a new hypothesis on density effects of light-absorbing particles is presented in Meinander et al. (2014).

Acknowledgements: Our work has been carried out in co-operation with personnel of the FMI Arctic Research Center in Sodankylä, within the Nordic Center of Excellency TRI CRAICC “Cryosphere–Atmosphere Interactions in a Changing Arctic Climate”, The Academy of Finland Centre of

Excellence in Atmospheric Science - From Molecular and Biological Processes to The Global Climate (grant no. 272041), and the Academy of Finland project “Arctic Absorbing Aerosols and Albedo of Snow” (A4) (project no. 3162).

References

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From cloud to precipitation: case studies of layered mixed phase cloud

Victoria Sinclair, Dmitri Moisseev, Ewan O'Connor and Tuukka Petäjä (University of Helsinki)

In Finland, a high-latitude country, the majority of precipitation is initiated by ice-phase processes which are often complex and not well represented in numerical weather prediction models. During “Biogenic Aerosols - Effects on Clouds and Climate (BAECC)”, the U.S. Department of Energy’s Atmospheric Radiation Measurement (ARM) Program deployed the ARM Mobile Facility 2 (AMF2) to Hyytiälä, Finland, for an 8-month intensive measurement campaign from February to September 2014. By combining the ground-based active remote sensing capacity of the AMF2 radars and lidar systems with extensive surface precipitation measurements and with WRF model simulations, we investigate cloud-to-precipitation processes during the cold season. In this poster we present two case studies. In the first case study a seeder-feeder type mechanism was observed whereas in the second case study the Hallett-Mossop secondary ice process was detected. The WRF simulations capture the bulk characteristics of these events well but considerable difference exist in the concentration of ice / snow particles both at the surface and at upper levels and in the amount of super-cooled liquid. These results highlight the challenge models face in correctly simulating properties of hydrometeors and thus surface precipitation rates.

Soot's effect on the natural snowpack-a series of experiments

Jonas Svensson (FMI)

Light-absorbing impurities are known to significantly affect snow and ice by lowering its albedo. Experimentally these matters have not been examined thoroughly, with very few experiments reported to date. Here we investigated the effect of soot on a natural snowpack through a series of experiments conducted (2011-2013). The changes in albedo was emphasized and monitored throughout the melting season, with some accompanying measurements of the snow properties and the light-absorbing impurities. As expected, the snow contaminated with a heavy impurity loading showed the most decrease in albedo compared to the snow with a lower impurity loading.

Session B. Snow observations and instrumentation

SORAX – Sodankylä Radiometer Experiment

Anna Kontu (FMI Arctic Research, Sodankylä, Finland)

Sodankylä Radiometer Experiment (SORAX) is the on-going microwave snow measurement campaign at the Finnish Meteorological Institute's Arctic Research Centre in Sodankylä, Finland. Its goal is to provide a data set of continuous, concurrent and co-located measurements of seasonal Arctic snowpack and freezing soil using microwave radiometers, automatic reference instruments and manual measurements. All instruments are gathered in Intensive Observation Area (IOA), a forest opening with a diameter of about 80 m in a sparse boreal pine forest on mineral soil. The opening is covered with a few centimeters of lichen and some heather. SORAX continues the data set from the previous ESA NoSREx (Nordic Snow Radar Experiment) campaign in 2009-2013. Many of the observations began already in 2009, but new parameters have been added every year.

IOA hosts a 4 m high tower, where three radiometers are installed: ESA ELBARA-II, an L-band (1.4 GHz) SMOS satellite reference radiometer, and two commercial RPG-XCH-DP radiometers, named SodRad 1 (10.65, 18.7, 21, and 36.5 GHz) and SodRad 2 (89 and 150 GHz). ELBARA-II does an elevation scan of incidence angles 30°-70° every hour, while the two SodRads perform a 2D scan of the same incidence angles over a 20° azimuth range every hour. During the winter of 2015-2016, the microwave setup will be complemented with a 1-10 GHz scatterometer (radar), which will be installed in an 8-m tower at IOA.

Numerous automatic reference measurements monitoring air, snow, soil and solar radiation are located at IOA. There are two meteorological stations, one in the opening and one in forest, with snow depth, air temperature and air humidity sensors. Soil temperature and moisture (dielectricity) are measured at 5 cm depth in the radiometer footprints, while profiles of soil temperature and moisture and snow temperature are measured outside of the footprints. In addition, a snow scale provides snow water equivalent (SWE) and a disdrometer monitors the amount and type of precipitation. IOA also hosts two optical instruments, an ASD spectrometer in a 30-m mast for monitoring of the radiance of a snow-covered forested area and an albedometer to measure incoming and reflected solar radiation.

Weekly manual measurements of micro- and macrostructural properties of snow with both traditional and state-of-the-art methods complete the data set. Snow layer structure is determined manually and with SnowMicroPen. Profiles of density, temperature, liquid water content, specific surface area (SSA), and optical grain size are measured at fixed intervals, while visual grain size is estimated from each layer. In addition, bulk SWE and depth are recorded.

The SORAX campaign provides an excellent data set for testing of models, e.g. microwave emission models, physical snow models, or climate models. Besides the IOA measurements described here, observations of radiation, wind, precipitation, carbon fluxes and greenhouse gas columns, among others, are available from the Arctic Research Centre.

Arctic Snow Microstructure Experiment

Leena Leppänen (FMI, Arctic Research, Sodankylä, Finland)

The Arctic Snow Microstructure Experiment (ASMEx) included ground-based microwave radiometer measurements and manual reference measurements of snow structure from the homogenous snow slabs of natural seasonal snowpack in Sodankylä, Finland. Measurements were made during two winter seasons 2014-2015. Radiometric brightness temperature observations were made with 18.7, 21.0 and 37.5 frequencies, and both vertical and horizontal polarizations. Observations were made snow upon a reflective base and an absorbing base. In the end, manual measurements of snow macro- and microstructure were performed; those measurements also studied homogeneity of the slab. Brightness temperature simulations of the two emission models, a single layer HUT snow emission model and MEMLS, were compared to observations. Accuracy of the models depended on measurement setup and used frequency. RMSE and bias were calculated; with the RMSE and bias values being smallest upon an absorbing base at vertical polarization. Simulations overestimated the brightness temperatures on absorbing base cases at horizontal polarization. At the other experimental conditions, the biases were small; with the exception of the HUT model 36.5 GHz simulation which produced an underestimation upon the reflective cases. The aim of the study is to understand better microwave extinction in snow and develop modelling of passive microwave measurements. This experiment provides an excellent framework for future research on the extinction of microwave radiation inside snow.

Can satellite-based snow products help in Quality Control of automatic in-situ snow observations in Nordic region?

Otto Hyvärinen (FMI)

There is a growing interest to automatize in-situ observations of snow observations. We examine if remotely sensed snow products can help in Quality Control (QC) of automatic in-situ snow observations. Especially interesting for QC are the changes of the snow edge, from snow-free to snow and vice versa. According to our result, satellite-based snow observations are not usable for QC in real-time applications. They might be more useful for applications of archived data when missing data because clouds etc. is easier to mitigate.

Recent developments of the H-SAF MSG/SEVIRI and Metop/AVHRR based snow extent products

Niilo Siljamo (FMI)

We describe the current status of the H-SAF MSG/SEVIRI and the global H-SAF Metop/AVHRR snow extent products with new results of the winter 2014-2015. H-SAF MSG/SEVIRI based snow extent product has been operational since 2008. Meto/AVHRR provides better resolution in polar regions where snow is an essential element of the nature. Previously, a PDU (Product Dissemination Unit, 3 minute slice of data) version of the Metop/AVHRR snow cover product has been generated for internal use in LSA SAF. Now, a global daily version of the Metop/AVHRR snow cover product has been developed.

Experience with the Campbell CS725 Snow Water Equivalent sensor at the Metsähovi Fundamental Geodetic Station, Kirkkonummi, Finland

Jaakko Mäkinen, Arttu Raja-Halli, Heikki Virtanen (Finnish Geospatial Research Institute FGI)

The Campbell CS725 SWE sensor (earlier name GMON3) is based on the attenuation of the natural gamma radiation of the rock/soil by the mass of the snow. Depending on the installation height of the downward-looking gamma sensor it integrates its SWE estimate from an area of up to 100 square meters. It has now operated in Metsähovi for two seasons (2013/4 and 2014/5), with parallel manual measurements of the SWE and snow heights. We assess the results. The immediate purpose of the SWE determination is to correct the observations of the superconducting gravimeter (SG) for the attraction of the snow mass. The sensitivity of the SG in Metsähovi corresponds to the gravitational attraction of a layer of 1 mm of water.

Session C. Snow in models

Satellite snow product assimilation in weather models

Samantha Pullen (Met Office, UK.)

Despite the availability of a large number of satellite-derived observations of snow characteristics, such products are not widely assimilated in NWP models. This presentation will begin with a brief overview of the current situation, describing the particular requirements of snow products for assimilation into NWP systems, what is currently used and the future direction of snow data assimilation in the NWP community. This overview will be followed by a presentation of work at the Met Office towards the use of a satellite-derived snow cover product in the high resolution UK forecasting model.

At the Met Office, a snow assimilation scheme is under development for implementation in the UK forecasting model. Both ground station snow depth reports and satellite-derived snow cover data will be used to produce an improved analysis of model snow extent and amount. Assessment of the snow cover product from the EUMETSAT H-SAF suggests that it would be a suitable source of UK snow cover data in the

new assimilation scheme. This presentation will describe the assessment of the H-SAF snow cover product for potential assimilation over the UK, and introduce the new assimilation scheme under development.
The lack of widespread persistent snowy conditions in the UK makes validation of observational and model snow data hard. Validation of satellite-derived snow cover data depends upon there being sufficient ground station reports, and cloud-free satellite observations for meaningful analysis. Validation must, therefore, be performed using data from exceptionally snowy winters. The UK experienced two episodes of severe winter weather between late November and late December 2010. Significant snowfalls on both occasions, and persistently low temperatures, led to much of the UK spending considerable time under lying snow, making this a particularly useful study period for assessment of modelled and observed snow in the UK.
For evaluation of the H-SAF snow cover product, comparisons of snow presence have been performed between the H-SAF product, short-range forecast fields of snow amount from the UK NWP model, and ground-based observations of snow from the UK Synoptic network, during December 2010. Representation of snow cover compared well between satellite product and model, with an overall rate of agreement of over 80%. Both temporally and spatially averaged comparison rates were examined in order to identify any features relating to particular weather conditions or geography. An estimate of the relative accuracies of the remotely sensed and modelled snow cover was found by comparing both datasets with a common set of ground-based snow observations. Rates of agreement with ground station observations were very high for both datasets, but the H-SAF product performed better overall, with an agreement rate of over 89%. These results, along with qualitative studies of the snow cover in each dataset on individual days, indicate the added value that the H-SAF data could provide by assimilation into the forecasting model.

Modelling snow water equivalent and thickness in Watershed Simulation and Forecasting System at SYKE

Vesa Kolhinen (Finnish Environment Institute SYKE)

Reliable estimates of snow water equivalent are essential for discharge and flood forecasts. The snow model [B. Vehviläinen] in Watershed Simulation and Forecasting System (WSFS) is used to simulate snow water equivalent and thickness, needed for the discharge forecasts especially during spring time. Recently a physically more correct description of snow thickness has been added into WSFS.
Snow model uses meteorological observations as an input: density of new snow is obtained from precipitation and air temperature. Compaction and thickness of total snow pack are then calculated using temperature and snow density. This leads to change of retention capacity and change of liquid and solid water amounts, which are then evaluated for the total snow pack. As a result, snow water equivalent, thickness and density are obtained.
The free parameters of the model have been calibrated using measurements at snow lines and precipitation stations. Currently the model simulates snow both for open and forest areas, but in the future different forest types can be included as well.
An energy balance model, which calculates the heat flux affecting on the snow pack, is also being implemented into WSFS. This model utilizes short and long wave radiation, sensible and latent heat fluxes, and due to physically more correct method, it is expected to give better description of snow melt especially during the spring time, than currently used degree-day method.
Additionally, a completely new ground frost model has been added into WSFS. It utilizes a thermodynamical model, where all head will be used for melting of freezing ground soil. Parameters of the model are calibrated using frost measurements from several observation points. As the observations are from various forest types (open, forest, swamp), the model simulates the same forest types.
New snow and ground frost model are being tested and will be taken into operational use in near future. Currently we do utilize them in snow and ground frost maps, available from www-site www.ymparisto.fi.

Acknowledgements: This work has been contributed by Paula Havu and Panu Juntunen

B. Vehviläinen: Snow cover models in operational watershed forecasting, Publications of Water and Environment Research Institute 11/1992, ISBN 951-47-5712-2, ISSN 0783-9472

Surface mass balance modelling and velocity inversion for Midtre Lovenbreen

Ilona Välisuo (FMI)

Current estimates on the surface mass balance of glaciers rely on in-situ observations and remote observations of the surface elevation changes of the glacier. Both methods have disadvantages: in-situ stake measurements have usually limited in spatial coverage and remote altimetry only captures the height changes without information on the dynamic changes of the glacier. We present a new approach of combining surface elevation data (digital elevation models), stake measurement of flow velocity and full-stokes glacier modelling in order to obtain a high resolution spatial pattern of the surface mass balance a the glacier. In situ measurements of mass balance will be used for validation. The study is done for Midtre Lovénbreen, a small valley glacier in Ny-Ålesund, Svalbard, because of the long time series of observations available.

Session D. Snow and climate

Future changes in mean and extreme snowfall in Northern Europe, as simulated by the ENSEMBLES RCMs

Jouni Räisänen (University of Helsinki)

Changes in snowfall in northern Europe (55-71°N, 5-35°E) are analyzed from 12 regional model simulations of 21st century climate from the ENSEMBLES project. As an ensemble mean, the models suggest a decrease in the winter total snowfall nearly everywhere in the domain. In the middle of the winter, however, snowfall generally increases in the coldest areas. The borderline between increasing and decreasing snowfall typically coincides with the -11ºC isotherm in baseline (1980-2010) monthly mean temperature. High extremes of daily snowfall remain nearly unchanged, except for decreases in the mildest areas, where snowfall as a whole becomes much less common. This suggests that societies in the Nordic countries will need to maintain their capacity to cope with heavy snowfall even in the future, despite the expected warming of winter climate.

This research is reported in more detail in Räisänen (2015).

Reference:

Räisänen, J., 2015: 21st century changes in snowfall climate in Northern Europe in ENSEMBLES regional climate models. *Climate Dynamics*, doi: 10.1007/s00382-015-2587-0.

Multimodel estimates of the changes in the Baltic Sea ice cover during the present century

Anna Luomaranta et al. (FMI)

We estimate the future decreases in the annual maximum ice extent (MIB) and the 30-year mean values of maximum fast ice thickness in the Baltic Sea by 2090. The results are based on observations and the output of 28 global climate model simulations from the CMIP5 project. Two greenhouse gas scenarios are used: RCP4.5 and RCP8.5. The MIB was estimated using a statistical procedure, and the mean maximum fast ice thickness was calculated using Stefan's law. The results were calculated for the multi-model mean and separately for individual models.

The MIB is projected to decrease according to both scenarios. According to RCP8.5, only mild ice winters (ice extent < 115 000 km^2) occur from the 2060s onwards. In RCP4.5, average ice winters (ice extent between 115 000 km^2 and 230 000 km^2) may still occur in the 2080s. The average maximum fast ice thickness was estimated only in coastal sea areas. In RCP4.5, the southern and southwestern parts of the Baltic Sea become ice-free in a typical winter by the end of the century. In 2081-2090, the largest thickness, locally more than 60 cm, is found in the Bay of Bothnia. In RCP8.5 in 2081-2090, ice occurs mainly in the Bay of Bothnia only.

The uncertainties caused by differences in climate models, unknown future emissions and inaccuracies in the calculation methods are quite large. Despite these uncertainties, our robust finding is that the Baltic Sea is very unlikely to become totally ice-free during the 21st century.

Reference:

Luomaranta, Anna et al. 2014: Multimodel estimates of the changes in the Baltic Sea ice cover during the present century. Tellus A, 66, 22617, http://dx.doi.org/10.3402/tellusa.v66.22617

Session E. Living with snow and ice

Ground frost variation in Finland

Mirjam Orvomaa (Finnish Environment Institute SYKE)

Ground frost has been measured by the Finnish Environment Institute and its prior organizations at some locations since the 1920's, and a more extensive network has been monitored since the 1950's. The present network consists of circa 40 ground frost stations that are situated across the country, and represent a variety of climatic conditions in different soil, forest and mire terrains. These stations, together with the ground frost observations made at the groundwater monitoring sites, and the small catchments areas monitoring sites form a combined ground frost monitoring network that consists of circa 700 measuring sites.

Ground frost has been measured by different methods throughout the 20th century. Methylene blue tubes replaced other methods in the 1970's and have been used exclusively since then because the results it produces are more comparable than those obtained with previous methods. Observations are made during the winter time every 6th, 16th an 26th day of the month. Moreover this, the observations are denser when ground frost is thawing. The ground frost stations measurements represent results from naturally occurring ground frost and snow cover.

Snow depth and the frost sum are the major factors effecting frost depth. The freezing and thawing is affected by the soil type, soil moisture, groundwater levels, and the terrain in general. The regional variations of snow depth can differ tremendously, which is explained by the above listed factors and by the timing of snowfall versus the starting period of frost weather. This study presents the regional variations of ground frost at six regionally representative monitoring sites during the past thirty to sixty years. In short, the southwestern and coastal regions of Finland often have more ground frost than the eastern and northern regions due to differences in snowfall periods. Ground frost penetrates deeper without an isolating snow cover.

Depending on the geographical location, the period of ground frost occurrence varies between four to eight months, which is relatively long in European perspective. The maximum ground frost depths are generally registered in the southern and central parts of the country in February- March and in the northern parts in late March. The thickness of ground frost can vary between 0- 200cm. The thawing rate is dependant on how spring proceeds yearly.

The winters in Finland are anticipated to become substantially milder during this century and thus snow cover will become thinner especially in the southern and central parts of the country (Veijalainen et al., 2012). These factors amongst others will affect ground frost thickness and occurrence in the future. The changes in the depth and occurrence periods of ground frost during the past fifty years help predict the effects of climate change in the future. The assets and constraints of the decrease or disappearance of ground frost is also discussed in this study.

Reference

Veijalainen, N., Jakkila, J. Nurmi, T. Vehviläinen, B., Marttunen M. Aaltonen, J., 2012. Suomen vesivarat ja ilmastonmuutos – vaikutukset ja muutoksiin sopeutuminen. WaterAdapt projektin loppuraportti. Finnish Environment 16/2012.

Citizen science in collecting snow observations – high schoolers as field researchers

Atte Harjanne, Achim Drebs, Niilo Siljamo (FMI)

Citizen science offers chances to gather observations and ideas and process data cost-efficiently while simultaneously increasing the outreach of the research through science education. Realizing this opportunity, Finnish Meteorological Institute (FMI) has carried out a project combining citizen science with science education in co-operation with volunteering secondary schools in 2014-2015. One of the focal topics in the project was snow research, and high schoolers collected observations on snow depth and snow coverage.

Advancements in automated and remote observation technologies have provided new tools to measure snow conditions, but challenges remain. The whole range of characteristics snow and snow cover can have is easier to observe by humans than by existing equipment. However, observations are typically necessary from large geographic areas and remote locations, making the human effort a potential bottleneck in the observation process. Snow research is thus an ideal topic for citizen science, since simple layman measurements can be used to gather the data.

In FMI's science education project the high school students were instructed to measure snow depth and snow cover. Snow depth measurements were conducted with a self-made measurement stick through a five step measurement process to address the variations in the local environment. Snow cover observations were done visually on a ten point scale complemented with a photo from the observation spot. FMI researchers advised in the choice of observation locations, but the measurements were done independently by the students or together with the teachers.

The project showed that the high schoolers were able to produce quality measurements and support the collection of snow observation archives and the development of satellite-based snow observations. The usefulness was however limited because of the relatively small number of participating students. There is however clear potential for a more large scale data collection and online instructions were produced to help in future undertakings. Development of a citizen science snow observation mobile application was also started.