A European network for a harmonised monitoring of snow for the benefit of climate change scenarios, hydrology and numerical weather prediction

ESSEM COST Action ES1404

Towards a better harmonization of snow observations, modeling and data assimilation in Europe

COST Action ES1404 Harmosnow

Session: Intercomparison of measurement methods , remote sensing product and assessment of their errors

Chair: Leena Leppänen (Finnish Meteorological Institute, Finland), Nacho Lopez Moreno (Instituto Pirenaico de Ecología, Spain).

Nowadays a wide range of instruments and products are available to measure the extent, water mass, precipitation, physical and the chemical properties of snow. Comparison of these instruments is important for producing consistent observations. This session welcomes presentations about the intercomparison of methods and techniques to measure the properties of snow and assess measurement errors. These include i) manual devices to measure snow depth, water mass and liquid water content, ii) automatic instruments to measure snow depth, water mass and precipitation, iii) snow microstructure measurements, iv) measurements of the chemical composition, and v) satellite and remote sensing observations.

Session: Intercomparison of measurement methods , remote sensing product and assessment of their errors

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Oral

Seasonal snow depth derived from satellite sub-meter stereo images in Iceland

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High resolution commercial satellite stereo imagery can be used to derive near real time regional snow depth on a large to small scale. Today many commercial satellite constellations are available (World View, Pleiades) with tasking capabilities which makes this an interesting approach for water manages and hydro power operators. A near real time assessment of snow depth in seasonal snow packs as well as winter snow depth for glaciers can be obtained. By combining these snow depth estimations with in situ or modeled estimates of snow density, water storage can be estimated for hydrological model assimilation.

We use data from World View 3 taskings as well as previous ArticDEM open access data DEMs to assess the feasibility of deriving snow depth from satellite stereo imagery in selected catchments in the Icelandic highlands. Ames Stereo Pipeline (ASP) is used to match the stereo pairs with and without ground control points to generate snow depth DEMs for further analysis. Ground validation from snow depth point samples and TLS measurements are performed as well as snow pit observations of density to estimate SWE. The goal of the project is to have a scalable operational process to merge information from satellites, stations and in-situ data to reliably map snow water equivalent that can be used for decision making and data assimilation in operational context.

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Oral

Differences on snow density and snow water equivalent estimation using different snow tubes: instrumental bias, variability induced by observers and influence of snow and terrain conditions.

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Snow data collected manually is often assumed as ground truth for many applications. However the small scale variability of the snowpack and its properties, and instrument and observer induced errors add uncertainty to the data that is not easy to quantify and generally tends to be ignored. In this study, we use data from three field campaigns to better understand the variability of snow depth, snow density and snow water equivalent (SWE) and the potential errors introduced when snow data is collected by different observers using SWE tubes that are used by several research and operational institutions worldwide. The first campaign permitted us to illustrate the very high local variability of the measured snow characteristics, but it didn't provide enough data to attribute it to the natural, instrumental or observer induced error. During the second campaign we compared the variability obtained between replications at the same spot and the total variability between mean depth and density the later being higher. We also observed a noticeable variability between replications, with coefficients of variation varying between 0.005 and 0.1. It was also observed that under certain terrain conditions estimation of snow depth may add similar or even more uncertainty to SWE estimation than density estimation. No obvious instrumental bias was found. The third campaign included more measurements and the experiments were carefully designed to separate natural variability and measurement

errors. This has enabled us to identify the existence of instrumental bias that exceeded by far the natural variability and also the error induced by the observers.

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Oral

Intercomparison of snow measurement methods in Turkey

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Snow is an important aspect at mountainous areas and high latitudes in terms of water resources, agriculture, energy, tourism and indication of climate change. Turkey, with an average elevation of around 1130 meters has an important snow potential which needs careful monitoring. As a result, governmental institutes started snow measurements in 1960s using manual snow tubes. With the advancement of modern equipment, automatic methods were initiated in the early 2000s. But it was not until 2010s when the automatic SnoTel stations were extended in Turkey with cheaper sensor costs as well as more widespread telecommunication services for data transfer. Of course during this time, new sensors were also deployed measuring more detailed snow components and making them available in real-time. With the improvement of ground truth sensors, at the same time a variety of remote sensing satellites also offered state of the art for monitoring spatio-temporal changes.

In this study, snow component measurements of 11 automatic Snow Pack Analyzer (SPA) stations in Turkey are evaluated in detail for performance and satellite images (IMS and SSMI/S) are validated for representativity during the recent two snow seasons (2017 and 2018). In addition, consistency of the automatic measurements is also examined by manual snow tubes and snow pit analysis performed near some of the selected stations. The results show that in-situ and satellite measurements may be quite consistent for certain locations while large differences may be realized especially due to topography and external sources. Notable variations may also be observed even among different ground measuring methods in the vicinity for different snow seasons.

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Oral

Remote Sensing of Snow: an overview

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As a major component of the water budget in many parts of the world, snow cover constitutes the dominating element of the cryosphere in terms of spatial extent and temporal variability. Therefore, the understanding of the global water cycle demands accurate high-resolution observations of fresh water stored as snow. Additionally, snow coverage has a large impact on the radiation budget at local, regional and global scales. An accurate description of snow and sea-ice properties is of fundamental importance for improving numerical weather forecasting, and the assessment and prediction of climate change; the spatial variability of snow accumulation and depletion is also very important for determining the timing and amount of snowmelt runoff, which is fundamental for water supply. Because of the extensions and remoteness of the areas affected by snow, the available in-situ data networks are not sufficient to describe accurately the snow status at global scale and remote sensing data, acquired by satellite sensors, constitutes a unique tool for its monitoring in space and time. Space-borne sensors, operating in the optical and microwave domains, provide information on snow cover extent, snow status (wet/dry), snow water equivalent and snow depth at different resolution scales, which depend on frequency and instruments' characteristics. The aim of this presentation is to provide to the user community an overview of available remote sensing snow products, theirs reliability and limitations, and on-going initiatives to improve them in future.

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Oral

Overview of the European In-Situ Snow Measurements obtained through the Harmosnow WG1-WG2 survey.

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The working Groups 1 ("Physical Characterization of Snow Properties") and 2 ("Instrument and Method Evaluation") of the COST Action "Harmosnow" carried out a survey to obtain an updated picture of the existing variety of snow measurement practices and instrumentations in use by the European institutions. The survey collected a compilation of the measured snow properties and associated measurement techniques that are applied by the participating European countries for a large variety of applications. In this presentation we summarize the results of this survey, providing an overview on the European snow measurements that are carried out for a large variety of applications. Synthesis from the overview enables us to draw recommendations on the best measurement practices and on strategies to increase the effectiveness and the extension of the snow monitoring network.

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Oral

Retrieval of snow albedo from space and potential errors

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It is well known that the presence of snow on the ground affects the Earth's energy budget through its high albedo and thermal insulating properties, and plays an important role in the global energy balance. Thus, knowledge of snow-covered area, snow water equivalent (SWE) and/or snow depth patterns, is needed in many practical applications involving snow (e.g. for water resource forecasting and simulations of snow related interactions with weather and climate).

In 2017, five aircraft with a total of nine different sensors participated in the NASA SnowEx campaign, carrying remote sensing sensors including active and passive microwave, and active and passive optical/infrared/thermal passive sensing techniques to determine the sensitivity and accuracy of potential satellite remote sensing techniques, along with models, to measure snow under a range of forest conditions. SnowEx was conceived in order to advance our understanding of how to measure snow in forested regions and as such help improve streamflow forecasting, numerical weather forecasting, and overall understanding of the role of snow in the Water and Energy Cycle.

In this study, we will focus primarily on measurements by NASA's Cloud Absorption Radiometer (CAR) aboard the Naval Research Lab (NRL) Orion P-3C aircraft from February 16-22, 2017. The NRL P-3 flew the first science flight on February 16, based out of Colorado Springs, Colorado under clear sky. We will show results to demonstrate accurate and fast retrieval of the snow properties from CAR February 16 flight over Grand Mesa, Colorado. We will also show that airborne data can be a unique validation source for different snow models and satellite retrievals.

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Oral

Intercomparison and assessment of fractional snow cover products retrieved from optical remote sensing

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Most satellite-based snow cover provide only a "binary" map, whereby each pixel is classified as either "snow" or "not snow". The fractional snow cover, in comparison, presents significant innovation and progress. Snow fraction is needed to estimate numerous downstream characteristics of land surface as well as to land, snow, hydrology modeling and assimilation.

Creation of unbiased and consistent information on fractional snow cover is required for global studies, numerous regional and local scale applications. However currently no global products of snow fraction exist.

Our study is based on innovative analysis of remote sensing observations designed to compare performance of various algorithms and includes processing high-resolution satellite measurements provided as reference data by Landsat and/or Sentinel-2.

The recommended high resolution snow observations are excellent information not only to quantify the performance of remote sensing algorithms, but to choose the way of further algorithm improvement.

A key challenge and simultaneously advantage of proposed robust approach to processing satellite data are an opportunity to develop, implement and test algorithms using on-the-fly estimate of local reflective property modifying the calculations of snow fraction in accord to highly variable local conditions, viewing and solar geometry.

The study is designed to fulfill analysis for a broad variability of natural conditions, for a wide range of spatial and temporal scales applicable to a hierarchy of models across relevant scales.

The optimal way to derive information on fractional snow cover allows for the local variability of snow and non-snow reflective properties within a scene-specific algorithm.

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Poster

Unmanned Air Vehicle Based Snow Depth Comparisons

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Using unmanned air vehicle (UAV) in snow studies enabled high temporal and high spatial resolutions in snow covered area (SCA) monitoring snow depth (SD) estimations. A multi-rotor UAV is used in here to get SDs over 172000 m2. UAV captured images with 80% forward and 60% side overlaps on two different (snow covered and snow free) days. Difference between digital surface models (DSMs) produced from UAV images for both days yielded SDs. UAV based SDs are compared with manual SD measurements performed on the ground concurrent with UAV flights. What this study adds to current UAV based SD literature is that, DSMs of snow covered day are obtained in two different UAV acquisitions. In the first, UAV was in continuous flight mode and in the second UAV kept its position fixed in air while images were taken. Geolocation accuracies of DSMs were compared with ground control points and found to be in ±2.5cm. Root mean square error (RMSE) of UAV derived SDs were 2.43 cm and 1.79 cm for continuous and fixed modes. Smaller RMSE in fixed acquisitions are in agreement with theoretical expectation that multi-rotor platforms may perform better than fixed-wings. SD errors reduced with increasing SDs.

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Poster

Accuracy Assessment of EUMETSAT-HSAF Fractional Snow Cover Product (H12) for 2017-2018 Snow Season in Turkey by Using Sentinel-2 MSI Data

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EUMETSAT HSAF H12 Product (Effective snow cover by VIS/IR radiometry) is based on multi-channel analysis of the AVHRR instrument onboard to NOAA and MetOp satellites. The product for flat/forested regions is generated by Finnish Meteorological Institute (FMI) and the product for mountainous areas is generated by Turkish State Meteorological Service (TSMS). Both products, thereafter, are merged at FMI. The main scope of this study is to represent the utilization of Sentinel-2 data to assess the accuracy of H12 product during 2017-2018 snow season in Turkey. Over 100 Sentinel-2 images with minimum cloud cover (i.e., <20%) are used to validate the H12 product for the 2017-2018 snow season (i.e., Dec 2017 - Apr 2018) over Turkey. Binary snow map for each Sentinel-2 image is obtained by using the algorithm developed by Hall et al. (1995). In the Sentinel-2 equivalent of this algorithm, the required condition for a pixel in a non-densely forested area to be labeled as snow is to have NDSI≥ 0.4 and band 8A reflectance > 11% and band 3 reflectance ≥ 10%. In the updated version of this algorithm, an irregular NDSI-NDVI decision region is also introduced in order to increase the accuracy for densely-forested regions (Hall et al. 1998). In order to assess the accuracy of Sentinel-2 binary snow maps obtained by both algorithms, snow depth observations from ground stations are used. Then, statistical scores of correlation coefficient and RMSE are employed to validate the H12 product and the results are represented.

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Poster

Use of satellite-based products for snow monitoring in Romania

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Snow is an important component of the Earth with high impact in the energy balance and the water cycle at high elevations in Romania. The Romanian mountainous regions (28% from the country area) are monitored by 25 in-situ sensors (16% from the total number of weather stations), due to the fact that these regions are sparsely populated and hardly accessible.

Snow monitoring is necessary for: i) weather forecasting and warning; ii) snow avalanche warnings; iii) agriculture and vegetation; iv) prediction floods due to rapid snowmelt v) water resource management.

The satellite data is used of frequent and accurate monitoring of snow properties in these regions. Satellite sensors provide the optimal way to monitor the snow layer extend and condition. The new ESA Sentinel missions provide high spatial resolution and frequent coverage (daily). The Sentinel-1 C-band SAR can be used to detect wet snow, as the backscatter drops significantly. With C-band SAR however, it is difficult to determine how wet the snow is. Optical sensors such as Sentinel-3 SLSTR on the other hand, through monitoring of the temperature and snow grain size, can be used to estimate the degree of wetness.

Within the EEA Grants, SnowBall project an approach for merging Sentinel-1 and Sentinel-3 products in a multi-temporal multi-sensor snow wetness product have been developed and validated based on in-situ measurements, for Romanian territory.

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Poster

New 21-m platform for snow and soil remote sensing observations in Sodankylä

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Ground-based instruments are vital in understanding of remote sensing observations from space. Finnish Meteorological Institute (FMI) has a long-standing program for ground-based remote sensing at the Sodankylä Arctic Space Centre. The FMI program aims at continuous (hourly to daily) observations, providing data over several seasons. FMI has operated ground-based optical spectrometers since 2006, providing observations of vegetation and ground at wavelengths relevant for studies on e.g. vegetation optical depth and snow cover. Passive microwave radiometers and several microwave radar systems have been operated since 2009, providing data for studies on snow cover and soil properties.

Past installations at have provided observations from mineral soil and wetland environments, which are typical of the Northern Boreal Forest zone. As of September 2018, a new 21-m high tower platform provides the capability to observe the forest canopy itself using the full range of instrumentation, including high frequency dual polarization radiometers (1.4, 10.65, 18.7, 21, 37 GHz), frequency scanning polarimetric radar system (1-10 GHz) and spectrometer (500-900nm). The purpose is to collect observational data on the seasonal variation of the forest cover, which in many cases distorts observations when aiming to obtain information on the ground surface, e.g. snow cover properties. The new tower installation, built as a part of the Integrated Carbon Observation System (ICOS), provides also as extensive array of automated reference measurements ranging from the carbon flux to meteorological data and forest, soil and snow cover properties.

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Poster

Cross-sensor and cross-country validation of satellite products of snow cover in Finland, Italy and Turkey

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Remote sensing represents a suited tool for the challenging monitoring of snow extent over complex topography and at large scale. However, since satellite-based observations are indirect measurements, they are generally affected by uncertainty in retrieval algorithms (Frei et al., 2012). Thus, the validation of the satellite products is of critical importance to properly assess and be aware of their accuracy when they are used for real-time operational applications.

This study addresses a cross-sensor validation comparing several satellite-based products supplying snow cover information. With the aim of further investigating the snow detection capability of satellites under different climatic and topographic conditions, the intercomparison analysis is performed over three different countries, namely Finland, Italy and Turkey.

One of the analyzed satellite-based datasets is provided by EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (HSAF). The selected product is HSAF H12, which supplies observations of the effective snow cover by VIS/IR radiometry (SN-OBS-3). The second satellite-based dataset consists of Sentinel-2A multispectral images, whose high spatial resolution is supposed to provide a reliable information on the actual snow cover extent. Lastly, MODIS FSC observations (MOD10_L2 V005) are the third analyzed dataset.

Since the reliability of satellite-based snow products is a priori unknown, this study also provides case studies assessing the consistency of remotely-sensed snow observations against high-resolution digital imagery provided by in-situ monitoring automated webcams

(Salvatori et al., 2011), which allow to overcome the impact of the presence of forest canopy affecting the satellite observations.

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Poster

Snow depth estimation using digital imagery

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Snow depth is measured traditionally by reading snow sticks on-site. Operationally, distance sensors are used to measure snow depth for decades. Depending on the sensor, calibration and maintenance at a certain level is needed for healthy observations. In the study, an easier and cheaper but reliable alternative is offered. Digital images from the cameras in measurements sites can be used to obtain snow depth information. The method proposed is using image segmentation to detect where snow surface intersects the snow sticks. For the study, images from the cameras in Solid Precipitation Intercomparison Experiment (SPICE) site in Sodankylä, Finland are used. The analyses are done for different snow sticks in different seasons, depending on the visibility of the sticks, which changes with the occasional camera movements. The results are compared with visual observations and snow depth sensor measurements. It is shown that the method provides good results even with the design of the measurement site which is not optimized for the proposed method. With this method, it is not only possible to obtain snow depth information, but also map the homogeneity of it, using low-priced instruments.

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Poster

Eddy Covariance flux measurements over lake Vanajavesi (Finland)

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The eddy covariance (EC) method is the worldwide most common technique used to assess turbulent fluxes over all types of surface. In the framework of two Short Term Scientific Mission of the COST action "A European network for a harmonized monitoring of snow for the benefit of climate change scenarios, hydrology and numerical weather prediction" (ES1404), it was feasible to have parallel EC measurements with two diferent equipments over a boreal lake during about six months, November 2015 to May 2016, including freezing and ice-free periods. Observations of surface fluxes of momentum, heat, water vapor and CO2 were made with the IRGASON Integrated Open-Path CO2/H2O Gas Analyzer and 3D Sonic Anemometer (Campbell Scientific), over lake Vanajavesi in Finland. The measurement site is located in a tip of narrow peninsula on the lake (61.133935°N; 24.259119°E), offering very good conditions for eddy covariance flux measurements. The results from the field campaign are shown in the comunication.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

Chair: Ekaterina Kurzeneva (Finnish Meteorological Institute, Finland), Carlo De Michele (Politecnico di Milano, Italy).

This session is about how snow observations are used through data assimilation techniques to improve forecasting for different applications. We welcome contributions showing reviews and perspectives in the domain of DA, inter-comparisons of techniques or progress towards standardization of the methods.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

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Oral

Snow data assimilation methods for hydrological, land surface, meteorological and climate models: Results from the COST HarmoSnow survey

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The COST Action ES1404, entitled, "A European network for a harmonised monitoring of snow for the benefit of climate change scenarious, hydrology and numerical weather prediction" (2014-2018) is aiming to coordinate efforts in Europe to harmonize approaches, validation, and methodologies of snow measurement practices, instrumentation, algorithms and data assimilation techniques. Among from other objectives the Action is dealing with following important topics: (1) Advance the application of snow data assimilation in European NWP and hydrological models and show its benefit for weather and hydrological forecasting as well as other applications, (2) Establish a validation strategy for NWP, hydrological and climate models against snow observations and advance its implementation within the European modelling communities.

The presentation reviews approaches used for assimilation of snow measurements both remote-sensing and in-situ into hydrological, land surface, meteorological and climate models. For this purpose a survey exploring the common practices of snow data assimilation in EU member states and from abroad was conducted. Results from the survey on the use of snow observation data in numerical models will be presented and the status and consequences for the future evolution of conventional snow observations from national networks and satellite products, for data assimilation and model validation will be derived.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

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Oral

Data Assimilation of Satellite Snow Products through Hydrological Modelling in Mountainous Catchments

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Assessment of sequential and variational assimilation techniques through hydrological models in mountainous catchments

Analyzing and forecasting the temporal and spatial variability of snow is important for hydrological purposes as well as for weather prediction and climatic models especially in mountainous regions. Remote sensing information has been extensively developed over the past few years including spatially distributed snow data for hydrological applications at high resolution. On the other hand, the implementation of these products in operational flow forecasting systems by means of data assimilation provides an improvement in the initial conditions of streamflow forecasts.

Concerning the importance of snowmelt in spite of the limited availability of data in the mountainous Eastern Turkey, incorporating different DA techniques is very crucial in the runoff predictions over the region. The work includes implementation of sequential and variational techniques through a previously calibrated conceptual hydrological model to assimilate remotely sensed snow covered area (SCA) and observed streamflow data. Sequential techniques have been commonly applied to hydrological processes however their application over snow dominated catchments with additional snow observations is rather limited. On the other hand, variational techniques relying on optimization algorithms have been seldom used. Therefore, exhaustive comparisons of these methods are one of the essential tasks in hydrological applications. Data assimilation results show a progress in the lead time performance of streamflow forecasts by using perfect forecast data beside an improvement in the forecast skill of modelled snow states.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

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Oral

Snow data assimilation at Deutscher Wetterdienst

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Snow data assimilation (DA) is an essential part of the surface analysis in Numerical Weather Prediction (NWP). The applied methods differ across the NWP centers from simple interpolation methods (i.e. Cressman) to modern DA methods as Ensemble Kalman Filter approaches. In addition configurations for observation window, temporal update, and observation database lead to large spread in the different analyses. The relative simple methods widely used compared to their atmospheric counterparts, an increasing data volume as the availability of new observation types require the innovation of code which, at DWD and other institutes, has been developed in the early 1980's. This needs a revision of all parts of the snow DA system. Within Cost action Harmosnow tools are developed and knowledge has been shared, to assess the present status of Snow data assimilation systems in Europe and potential sources for future developments. The talk will give an overview about the Snow DA scheme at DWD in comparison to others and plans on future developments. It covers scientific challenges and addresses practical aspects as well.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

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Poster

The value of satellite retrieved snow cover images to assess water resources and the theoretical hydropower potential in ungauged mountain catchments

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The estimation of water resources in ungauged areas is of major importance to develop adequate and sustainable water management strategies. Hydrological modelling can provide a powerful tool to assimilate hydro-meteorological data and estimate the total amount of water resources available from ungauged areas. Complementary, remotely sensed snow cover images provide important information on the snow cover area in inaccessible mountain areas. In this study, the conceptual lumped Hydrologiska Byråns Vattenbalansavdelning model (HBV) is used to estimate the total amount of snow, ice and rainfall runoff in two ungauged areas in north-eastern Iceland (Leirdalshraun, a 274 km2 area above 595 m asl and Heljardalsfjöll, a 946 km2 area above 235 m asl) that could potentially be used for hydropower production. The model parameters were determined using a multiple dataset calibration (MDC) relying on one year of satellite derived snow cover images and discharge data of gauged sub-catchments. Runoff from the ungauged area potentially used for hydropower exploitation was estimated using the parameter sets of the gauged sub-catchments. Snow cover in the ungauged areas as well as discharge in the gauged sub-catchments were validated over a 10 year validation period, revealing a robust simulation of snow melt in the entire area. The results reveal that the total amount of snow-melt, ice-melt and rainfall runoff available in Leirdalshraun and Heljardalsfjöll amounts up to ~690 M m3 a-1 and ~1190 M m3 a-1, respectively. The theoretical potential energy of these water resources would account for up to 1.9 TWh a-1, revealing a tremendous hydropower potential if the water could be collected in respective reservoirs and be deviated to turbines at sea-level. While the results are only valid for the specific case study, the presented modelling approach can be applied to any remote mountain area dominated by snow melt runoff.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

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Poster

Towards a ensemble simulation system for snowpack state with assimilation of satellite data

Marie Dumont[(1)], Jesus Revuelto[(1)], Bertrand Cluzet[(1)], Matthieu Lafaysse[(1)], Emmanuel Cosme[(2)], François Tuzet[(1)]

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Uncertainties of meteorological forcing and shortcomings in the modelling of snow physical processes, when accumulated on time along a snow season, could produce large deviations in the simulations from real snowpack state. An efficient way to mitigate such uncertainties is to use ensemble simulations that account for errors in both meteorological forcings and snow models. However such ensemble simulations often results in large uncertainties regarding the present and future snowpack states that needs to be reduce for an efficient snowpack reanalysis or forecast.

A promising way to reduce such uncertainties is to combine the use of snow observations and ensemble snow simulations. Satellite data, on the contrary to in situ measurements, offers the possibility of monitor the snow evolution over large areas. In addition, optical sensors such as MODIS, VIIRS and Sentinel-2, provides images with an adequate time and spatial resolution to survey the snowpack in mountainous areas.

In this study, we present the preliminary results of an ensemble snowpack simulations system with assimilation of optical satellite date over part of the French Alps and we quantify the potential impact of assimilating MODIS surface reflectance on snow depth and snow water equivalent simulations in several simulations configurations : punctual, semi-distributed and fully distributed at 250 m spatial resolution.

Session: Snow data assimilation methods in NWP, hydrology, and other disciplines

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Poster

The effect of varying weights in multi-objective calibration on model performance and time stability of model parameters

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Rainfall-runoff models traditionally use only runoff observation for their calibration. Using more data in calibration strategy may help to improve the model consistency and also to better constrain model parameters. The objective of this paper is to assess the effects of varying weights (ws) in multi-objective calibration on snow and runoff model performance and time stability of hydrologic model parameters. This study is carried out by a lumped conceptual r-r model (the TUW model). This model was calibrated separately for two periods (i.e., 1981-1990 and 2001-2010) that are characterized by high climatic variability. Several parametrizations of the TUW model between runoff (ws = 1) and snow (ws = 0) were taken. This methodology was tested for two large groups of Austrian catchments (i.e., catchments with a dominant snow and soil moisture regime) that were delineated by a parameter sensitive study. The results show that the runoff model performance is almost intensive to a large range (i.e., from 0 to 0.97) of snow weight. On the contrary, the snow model performance has a tendency to linearly increase with increasing snow weight. This relationship is similar in different time periods (i.e., 1981–1990 and 2001–2010).

An assessment of the effect of different weight combinations on model parameters in different climatic periods show that the values of the model parameters are clearly related to the weights and also to the climatic conditions of the calibration period.

Session: Session on Representation of errors in NWP, hydrological and climate models

Chair: Vera Potopová (Czech University of Life Sciences Prague, Czech Republic), Martin Lange (Deutscher Wetterdienst, Germany).

In this session we welcome contributions that address topics related to different aspects on errors and the impact in data assimilation systems with respect to numerical weather prediction, hydrology and other disciplines. The session also cover aspects on snow observations in climate models and crop growth models. The focus of the session is on snow data assimilation, but more common topics related to this special field are also welcome.

Session: Session on Representation of errors in NWP, hydrological and climate models

Oral

The application of snow observations in agrometeorological models

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The role of snow schemes of different complexity (single-bulk-layer snow scheme and/or multilayer version) coupled with the climate models has been a topic of research in the climatological and agrometeorological communities. Simulation of the snow-water balance in cropping systems is an essential tool, not only to monitor water status, but also to find ways in which soil water and irrigation water can be used more efficiently. The crop models calculate expected growth and development based on equations that describe how a crop, as a community of plants, responds to soil and weather conditions. Input snow data in crop model offers simulating the winter survival of perennial crops as well as annual water cycling in agricultural soils. The information about snow cover presence/absence is essential for estimating potential frost damage to winter crops. Although crop growth models are very sophisticated software, algorithms for estimating the occurrence and influence of snow cover are not always included. The intended improvements can exploit snow data information leading to more precise simulations in the crop models and soil moisture simulations resulting more precise crop yield forecasts.

Session: Session on Representation of errors in NWP, hydrological and climate models

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Oral

Comparison of statistical downscaling methods of satellite-based snow water equivalent product

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Snow water equivalent (SWE) is one of the most important indicators in spring flood forecasting and flood warning. The information on SWE can be obtained from the in situ measurements or microwave satellite instrument observations. However, remote sensing products based on the passive microwave sensor information have a coarse resolution (around 25 km) and it is not sufficient for regional applications. In this study we tried to downscale 0.25° x 0.25° HSAF (EUMETSAT Support to Operational Hydrology and Water Management) SWE product (SN OBS 4 - H13). The main aim was to downscaled HSAF SWE product to the higher resolution, 0.05° x 0.05°, using multiple linear regression analysis and artificial neural networks. The statistical relationship between SWE and different environmental parameters such as topography, land cover type and daily minimum temperature were determined in the area of the Baltic States for the period from 2012 to 2018. Our results show, that downscaled SWE product, produced using artificial neural network had a higher agreement with in situ SWE (RMSE = 7.3, bias = -0.3) than the one generated with the linear regression model (RMSE = 7.8, bias = -1.1). Although downscaling with neural network provided better overall results, the accuracy was poor in the areas with shallow snow. Results indicate that downscaling of satellite-based SWE with the neural networks has a potential, but is limited by the accuracy of the original product.

Session: Session on Representation of errors in NWP, hydrological and climate models

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Oral

Error statistics in Data Assimilation for NWP: perspectives for snow

Ekaterina Kurzeneva[(1)], Margarita Choulga[(2)], Laura Rontu[(1)]
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(2) European Centre for Medium Range-Weather Forecasts (ECMWF), RG2 9AX Reading, UK

All methods of Data Assimilation rely on the statistics of errors, both errors of observations and of the background. For error statistics, usually the mean error, the error variance and error covariances are used. Error covariances are often modeled using Gaussian approximation of autocorrelation functions. Often in DA systems for NWP all these statistics are considered as ad-hoc parameters. They are tuned depending on the size of an atmospheric model grid and density of the observational network, whereas they should be connected with the real statistical properties of the physical fields and reflect the reality.

In the presentation, the theoretical basis for calculation of error statistics from spatially distributed observational network is outlined. The positive example is given for the observations of the water temperature over lakes. The error variance, the structure and autocorrelation functions are calculated using archives of Finnish Environmental Institute (SYKE). Perspectives to apply this techniques for snow observations are discussed.

Session: Session on Representation of errors in NWP, hydrological and climate models

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Poster

Assessing Spatio-temporal snow cover patterns in a mountainous Mediterranean watershed using conceptual modelling and remote sensing

Cenk Donmez(1), Suha Berberoglu(1), Ahmet Cilek(1)
(1) Cukurova University, Landscape Architecture Department, Adana, Turkey

The important role of snow in catchment hydrology and its vulnerability towards projected future climate warming require detaield knowledge about prevailing snow cover patterns. Severe changes in snow pack characteristics may arise due to climate change and lead to environmental consequences. Hence, predicting and understanding the spatial variability of snow-related dynamics plays an important role as important resources for the water supplies as the main income source and driving force of local development of many regions. The snow cover patterns in subcatchment scale are analysed by incorporating the hydrological modelling system JAMS and MODIS remote sensing data in the study. Wide range of spatial and time series data sets including land cover, soils, geology and meteorological information are used as main model entities. 8-day MODIS composites (MOD10A2 and MYD10A2) for 2005-2006 season are used also as remotely sensed images. A stronger snow cover information with longer endurance defined by the model than shown by MODIS data. The study concludes with the remarks on the potential contribution of recent developments such as distributed snow modelling and use of remote sensing data to improve our understanding water cycle. Addressing the model results, specific strategic benchmarks were recommended to manage the snow-water at the subcatchment level to address present issues and projected adaptation needs for better water management.

Session: Session on Representation of errors in NWP, hydrological and climate models

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Poster

Numerical simulation of snow formation using bin microphysics scheme

István Geresdi[(1)], Lulin Xue[(2)], Noémi Sarkadi[(1)], Roy Rasmussen[(2)]
(1) University of Pécs, Faculty of Sciences, Pécs, Hungary
(2) National Center for Atmospheric Research, Boulder, Colorado, USA

The versatility of shape and density of snowflakes makes the numerical simulation of their formation and growth rather difficult. Our size resolving numerical model is able to track the evolution of snowflakes without any arbitrary assumption about the size distribution of snow particles. Besides the number concentration and mass in each bin the riming fraction, or the fraction of melted water are the prognostic variables. Because this scheme is computational burden it cannot be applied in operational weather forecast, but it is an efficient tool in the research projects. Current version of the model describes how snow can be formed by riming and aggregation of pristine ice crystal; furthermore their growth by vapor diffusion and melting are also simulated. The scheme has been implemented into the WRF mesoscale numerical model, which allows the numerical simulation of the interaction between cloud dynamics and microphysics.

One of the potential applications is to study the impact of artificial ice nuclei on the precipitation formation. Current presentation will show the results about numerical simulation of a real case. During the Wyoming Weather Modification Pilot Program AgI particles were released by ground base generators. The efficiency of seeding was investigated by comparison of simulated surface precipitations for both seeded and control cases.

Session: Harmonization strategies across international organizations and other activities

Chair: Patricia De Rosnay (European Centre for Medium Range-Weather Forecasts, United Kingdom), Ali Nadir Arslan (Finnish Meteorological Institute, Finland).

This session will discuss common synergies and interactions on harmonization of snow measurements within existing international initiatives and programmes with the contributions of the COST Action on HARMOSNOW. We will also discuss on how to move forward to harmonized snow observation in the future for both in-situ and satellite measurements.

Session: Harmonization strategies across international organizations and other activities

Oral

European Space Agency snow activities

Tania Casal[1], Malcolm Davidson[1], Dirk Schuettemeyer[1], Thorsten Fehr[1], Michael Kern[1]
(1) European Space Agency (ESA) ESTEC, EOP-SMS, Noordwijk, The Netherlands

In the framework of its Earth Observation Programmes the European Space Agency (ESA) carries out ground based and airborne campaigns to support geophysical algorithm development, calibration/validation, simulation of future spaceborne Earth observation missions, and applications development related to cryosphere, land, oceans, atmosphere and solid Earth.

ESA has conducted over 162 airborne and ground measurements campaigns since 1981 and snow has had an important role in several of them. ESA campaigns have been addressing many of the questions related to snow still arising today. Examples are the SnowSum experiment designed to ultimately relate the precipitation over the Greenland Ice Sheet with the actual snow depth, to the scatterometer tower based SnowLab winter campaigns in the Swiss Alps, and several scientific activities addressing many different snow questions such as SnowPEX, SCADAS, SnowConcepts and S34Sci Land Snow.

Future missions such as the next Copernicus High Priority Candidate Missions, in particular the Copernicus Imaging Microwave radiometer (CIMR), the Copernicus L-Band SAR mission (ROSE-L) and the Copernicus Polar Ice and snow Topography mission (Polar Ice Topo) all acknowledge the need to deliver parameters on snow in particular SWE , total snow area, and snow depth among others. Snow also became one of the new Essential Climate Variables (ECVs) in the ESA Climate Initiative + which began in 2018 and will continue till 2024.

This presentation will give an overview of the various activities that ESA is conducting in relation to snow and show the ESA investment into advancing our knowledge of snow measurements from space in particularly with a view on future cryospheric missions.

Session: Harmonization strategies across international organizations and other activities

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Oral

Global Cryosphere Watch (GCW) Snow Watch activities for improved data reporting and exchange.

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In this talk we present the GCW Snow Watch activities related to snow reporting on the Global Telecommunication System (GTS) and the HARMOSNOW COST action contribution. Following Snow Watch initiatives and its interaction with the HARMOSNOW COST action members, the WMO Executive Council EC-69 approved resolution 7.1 on international exchange of snow data in May 2017. This is a major achievement of Snow Watch. The European Centre for Medium-Range Weather Forecasts (ECMWF) developed in 2018, following a similar initiative, a new BUFR template for reporting Snow Water Equivalent (SWE). It was submitted to and approved by the WMO Inter-Programme Expert Team on Codes Maintenance (IPET-CM). Snow water equivalent, which corresponds to the model snow mass prognostic variables, is starting to be available from a few networks and is potentially very relevant for assimilation in NWP systems. Finally we discuss perspectives to further improve snow reporting for operational applications.

Session: Harmonization strategies across international organizations and other activities

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Oral

HarmoSnow and Global Cryosphere Watch – Common goals and aspects

Charles Fierz[(1)], Giovanni Macelloni[(2)], Rodica Nitu[(3)], Samantha Pullen[(4)], Patricia de Rosnay[(5)], Wolfgang Schöner[(6)]

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(2) CNR, Institute of Applied Physics "Nello Carrara" (IFAC), Sesto Fiorentino, Italy
(3) WMO Global Cryosphere Watch, Geneva, Switzerland
(4) Met Office, Exeter, UK
(5) European Centre for Medium Range-Weather Forecasts, Reading, UK
(6) University of Graz, Department of Geography, Graz, Austria

Several bodies coordinate research and modeling of the cryosphere or its components, but up to now no international mechanism has existed that supports all key cryospheric in-situ and remote sensing observations, including measurement best practices, data exchange and quality management as well as network interoperability. In 2011, the World Meteorological Organization (WMO) launched the Global Cryosphere Watch (GCW) initiative with exactly these goals in mind. Many of the latter are also at the heart of the COST Action HarmoSnow. In this presentation we will focus on common aspects of both initiatives and how they benefit each other regarding snow observations. In particular, we will highlight measurement guidelines for snow, operational networks as well as (near) real time exchange of snow measurements through the WMO Global Telecommunication System (GTS).

Session: Harmonization strategies across international organizations and other activities

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Poster

Harmonization of remote sensing observation on snow fraction to fill a gap in snow products.

Igor Appel[1]
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The current status of estimating subpixel fractional snow cover on the basis of remote sensing observations is a matter of significant concern. Currently, no validated global snow fraction products exists though it is an important component of land surface and hydrologic models. Estimation of fractional snow covering up to 40% of land in the Northern Hemisphere is not a low priority task because this information is critically important to many downstream atmosphere and land products retrieved from remote sensing as well as to a wide variety of hydrologic and meteorologic models.

The significance of the fractional snow product has been confirmed by the decisions made by ESA and the Japan Aerospace Exploration Agency (JAXA) to estimate snow fraction using optical observations from Sentinel-3 and the Global Change Observation Mission —Climate (GCOM-C) respectively

The algorithms under consideration to retrieve snow fraction are noticeably different. The intercomparison of the results provided by variable algorithms needs to be considered as an essential stage in their assessment and thorough validation is required at the earliest possible stages of algorithm development.

Available preliminary results demonstrate that improved harmonization is achievable on the basis of allowing for the local variability of snow and non-snow reflective properties within a scene-specific algorithm.

Collaboration between researchers with experiences supplementing each other can be a very promising way to tackle the problem of optimizing fractional snow algorithm development. Such collaboration should be considered as a key recommendation for developing snow product algorithms and other related activities.

Session: Actions and methods for training snow scientists and observers

Chair: David Christian Finger (Reykjavik University, Iceland), Martin Schneebeli (WSL Institute for Snow and Avalanche Research SLF, Switzerland).

The training in measuring snow properties is extremely important to obtain data of high quality. As the measurement methods require either somewhat subjective classification skills and / or very specific measurement techniques, initiatives to train these competencies have internationally been promoted at different levels and operational contexts. Training in data assimilation and on complex modeling is another important topics. We are looking for examples of teaching snow science to different communities.

Session: Actions and methods for training snow scientists and observers

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Oral

Field Measurements for Snow Science in North America: Programs and Training

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(4) Geosciences, Boise State University, Boise, ID, USA

Several decades ago there were few programs in North America that trained students to make high-quality, fundamental snowpack measurements in support of science or operational programs. Students gained knowledge and skills working with advisors or other practitioners in a mentoring relationship. This presentation focuses on three current training venues for snow scientists.

On-site training for major field campaigns. The NASA Cold Land Processes Experiment (CLPX) (2002-2004), and SnowEx17 provided intensive training for field personnel at the beginning of campaign exercises. These training sessions consisted of small-group, in situ demonstrations of tools and techniques, with discussion of standard techniques, likely problems, and pragmatic solutions. Outcome from the training based on post-campaign data QA/QC indicated that this training was less effective than we hoped.

NASA/CUAHSI Snow School. In 2014 another community effort initiated a three-day intensive field school for basic snowpack measurements. The school was targeted to modelers and remote sensing scientists that use physical snowpack measurements, but do not collect field data themselves, and to field scientists and technicians who collect field data in support of science.

College-level snow science programs. Many college and university programs teach one or more courses related to snow, often in the context of hydrology, and more rarely, with an avalanche focus. Colorado Mountain College (CMC) in Leadville, Colorado has started a new two-year program that gives students background and training to begin working directly in an avalanche related research or industry position, or as a technician in any setting where snowpack properties need to be quantified in a scientific manner.

Session: Actions and methods for training snow scientists and observers

Oral

Experiences from the Snow Science Winter Schools

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(3) Univ. Grenoble Alpes, Université de Toulouse, Météo-France, CNRS, CNRM, Centre d'Etudes de la Neige, Grenoble, France

Snow science is changing from semi-quantitative, mostly observing and classifying, science towards more a quantitative, instrument-based, science. Comparing the most recent version of the International Classification for Snow (Fierz et al., 2009) to the first one (Anonymous, 1954) an increase in detail can be found, but the standard methods of observations did not change. However, the past twenty years showed a massive change in investigating snow properties by increasingly more complex methods. Recognizing in a broad community that the three-dimensional structure of snow must be considered for explaining the physical properties, a number of new technologies to measure density, specific surface area, anisotropy and stratigraphy have been developed. The Snow Science Winter Schools started in 2015 in Sodankylä, Finland, with exactly this goal to enable students to learn and use these new techniques. Interestingly, the structural and stratigraphic complexity of snowpack is still best explored in the traditional way. The newer methods, often of a more abstract nature, are often hard to understand in their use and power.

Anonymous (1954). The International classification for snow (1954th-08–01 ed.). Division of Building Research, National Research Council Canada. Retrieved from https://nparc.nrc-cnrc.gc.ca/eng/view/accepted/?id=0bfbbca8-9356-4ecf-bcac-3733a26eb2fa

Fierz, C., Armstrong, R. L., Durand, Y., Etchevers, P., Greene, E., Mcclung, D. M., … Sokratov, S. A. (2009). The international classification for seasonal snow on the ground. IHP-VII Technical Documents in Hydrology N°83, IACS Contribution N°1. Paris: UNESCO-IHP, Paris. Retrieved from http://www.cryosphericsciences.org/outcomes/snowClassification/snowclass_2009-11-23-tagged-highres.pdf

Session: Actions and methods for training snow scientists and observers

Poster

Colorado Mountain College Avalanche Science Program, a college-level training program for avalanche safety workers

Kelly Elder(1), Roger Coit(2), Ethan Greene(3), Rebecca Hodgetts(3), Brian Lazar(3), John MacKinnon(2), Blase Reardon(3)

(1) Rocky Mountain Research Station, US Forest Service, Fort Collins, CO, USA

(2) Colorado Mountain College, Leadville, CO, USA

(3) Colorado Avalanche Information Center, Boulder, CO, USA

In the fall of 2017 the CMC Timberline Campus launched a new technical education certificate program for people that want to work in the avalanche safety industry. The Avalanche Science Program (ASP) is a two-year curriculum that includes 12 courses, 22 credit hours, 500 instructor contact hours. Students visit the Colorado Mountain College (CMC), Leadville campus for three 6- to 8-day sessions each, over two winters. The remaining coursework is completed simultaneously, primarily as online hybrid classes with lectures and group work conducted in 'live' virtual classrooms. The program is the first of its kind in North America and offers aspiring and experienced avalanche workers a formal, college-level educational program with instruction in snow and avalanche science, data collection, meteorology, forecasting, rescue, and operations.

The program is structured to facilitate a high field-to-classroom time ratio, high instructor-to-student ratios, and includes field internships. While the on-campus sessions take advantage of the location in the Colorado Rockies for field studies, the online aspect allows students to engage in the program from almost any geographical location. The first student cohort for the 2017/2018 academic year included many students simultaneously working in the ski industry and residing as far as 2000 km from the Leadville campus. Students will graduate from the program with significant exposure to the latest in industry practices across a spectrum of operational applications and will be job-ready, possessing a core set of technical skills, risk management awareness, and fundamental knowledge in snow science.

Session: Actions and methods for training snow scientists and observers

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Poster

The X-Snow project: citizen science for homogenizing snow measurements

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Despite quantities such as snow water equivalent, snow depth and density are routinely used for water management and recreational purposes over the northeast portion of the United States, measurements of snow properties are still sparse. To fill this gap, in January 2018 we have started the X- Snow project, a crowd-sourced effort to perform snow measurements, as well as analyze and distribute snow data for scientific research. The project aims at homogenizing citizen-science measurements with state-of-the-art techniques, including hyperspectral remote sensing and in-situ observations in conjunction with structure-from-motion snow depth estimates, with the goals of educating the public about the importance of snow and teaches how to properly perform snow measurements. One of the aspects that we have been evaluating concerns the production of a smartphone app to enable citizen scientists to upload their data to a public repository. To encourage participants to use the app and improve their skills to perform 'proper' measurements, we plan to use a rating system. A first time user will be assigned to a "novice" category. To increase the expert level, a user can undergo training and take tests through the app to verify their knowledge. A user's expert level can also increase after they make many measurements that are not removed by the automatic quality control system. In this presentation, I will show our preliminary results from the X-snow 2018 experiment and our plans for the incoming snow season.

Session: Actions and methods for training snow scientists and observers

Poster

Snow Microwave Radiative Transfer (SMRT) model - Training the community

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The Snow Microwave Radiative Transfer (SMRT) model has been developed in the framework of the ESA project "Microstructural origin of electromagnetic signatures in microwave remote sensing of snow" starting in 2015. The model computes the thermal emission and backscatter model of snowpack in the microwave domain. SMRT was specifically tailored to unify and compare different descriptions of the snow microstructure found in existing microwave models and allows inclusion of new microstructure models. After accomplishing this initial, highly specific goal, it rapidly appeared that the design and implementation choices made for SMRT were more versatile and suitable for a wider community of users, especially beginners. In particular, thanks to the Python programming language – featuring readability and offering a large set of modern tools for the documentation and graphing, SMRT is easy to learn and to use for both simple calculations as well as for complex workflows. The model is distributed following open-source principles via github and comprehensively documented via its own website.

Towards establishing SMRT as a "community model", the authors organized a 3 day training in February 2018 at Lautaret pass in France. This event was sponsored by COST Harmosnow ES1404, ESA and OSUG@2020 and hosted 25 participants. The training included short lessons and practicals on various aspects of SMRT comprising e.g: introduction , radiative transfer, scattering theories, microstructure, soil and substrates under the snowpack, development rules and strategies. Practicals were entirely based on the jupyter notebook tool, which allows rapid programming and highly interactive testing even for users not experienced in Python. The notebooks for the training are open-source and also available on github.

This poster illustrates this event.

Session: Actions and methods for training snow scientists and observers

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Poster

Training on snow & atmosphere science in Master at Université Grenoble Alpes: the Lautaret pass field work week

Ghislain Picard[(1)], Didier Voisin[(1)], Emmanuel Lemeur[(1)]
(1) UGA, CNRS, Institut des Géosciences de l'Environnement (IGE), UMR 5001, 38041 Grenoble, France

The master of Earth Science and Environment in Grenoble proposes 6 study paths. The "Atmosphere, Climate and Terrestrial surface" path (called ACSC in French) trains undergraduate students in the field of climate science and more specifically on the cryosphere, atmosphere, water cycle, ocean, etc.

In this master, we propose a 6-day field trip at the Lautaret Pass, 2000 m.a.s.l at about 1h30 from Grenoble in a great scenic mountainous place. The trip takes place at the end of February or early March every year. The topics addressed include snow metamorphism, snow thermal regime, surface energy budget, snow depth distribution, atmospheric ozone, micro-meteorology. Beyond the traditional stratigraphy in snow pits, a significant part of the time is devoted to the use of cutting edge instruments and devices such as Ground Penetrating Radar (GPR), Differential GPS, optical spectrometer, automatic meteorological station, etc. The acquired data are then analyzed and post-processed during the evenings and after the week using Python numerical tools, QGIS Geographical Information Software, and GPR specific software so as to produce scientific reliable results. The students work in group of 3 and are truly active during the full week.

This field trip is open to about 20 students (up to a maximum of 24) which includes all the ACSC students (compulsory) whose number oscillate from 13 to 18 depending on the year. A few seats are therefore open for external / international students.

Session: Recommendations on measurement methods and instrumentation

Chair: Ladislav Holko (Slovak Academy of Sciences, Slovakia), Charles Fierz (WSL Institute for Snow and Avalanche Research SLF, Switzerland).

Measurement or indirect assessment of snow characteristics comprise of a variety of approaches which are applied by different groups or institutes around the world in slightly different ways. This results in differences that limit the comparability of these measurements and indirect assessments . This session welcomes efforts of standardization of the measurement protocols, recommendations on the use of instruments and other methods of acquisition of snow characteristics and homogenization of the imperfect observations. Operational and research applications at any scales (point measurements in snow pits or at meteorological stations, snow transects, satellite images, etc.) are welcome.

Session: Recommendations on measurement methods and instrumentation

Oral

Ground Measurements for Field Campaigns: Parameters, Priorities and Problems

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Measurement techniques for physical parameters of the snowpack have developed over the last century based on scientific and operational needs. Many of the standard techniques vary by region, country, and continent and by situational need or skills of the collector. Many of the standard techniques were developed for archaic needs that do not necessarily provide the appropriate data for recent developments in modeling or remote sensing retrievals. An assessment of parameters and the techniques for measuring them is given in the context of difficulty and uncertainty in the measurements.

Session: Recommendations on measurement methods and instrumentation

Oral

Overview of in situ snow albedo measurements

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The Harmosnow workshop "In situ snow albedo measurements: toward a snow albedo intercomparison experiment" was organized with the purpose of reaching an overview on the state-of-art of the broadband and spectral snow albedo measurements.

In situ measurement of snow albedo is challenging due to the high number of artifacts that may affect the observations. These artifacts can be instrumental (e.g. thermal dependence of the sensor's sensitivity, light collector that deviates from the ideal hemispherical view), environmental (e.g. uneven or tilted snow surface, shadows or reflections from the surroundings), or due to the installation set-up (e.g. obstruction in the field of view of the sensors, shadow). Although the procedures for the use and installation of the broadband radiometers are well established and standardized, their application over snow-covered areas is often unachievable due to logistic and environmental constrains. Hence, very few radiation stations around the word measure snow broadband albedo, and even less measure snow spectral albedo. Indeed, there are very few commercial all-weather spectro-radiometers that measure in the wavelength range between 350 and 1100 nm, and none that measure beyond 1100 nm. Presently, the spectral radiometers do not have common measurement protocols, and their calibration has yet to be fully resolved.

The workshop was arranged to identify the technical and operational challenges in broadband and spectral snow albedo measurements, to develop a measurement protocol adaptable to the various measuring conditions, and to provide recommendations/guidelines on the calibration and characterization of the instruments. We present here the main outcomes of the workshop.

Session: Recommendations on measurement methods and instrumentation

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Oral

Snow chemistry of seasonal snow cover – effort towards a guideline for environmental monitoring purposes

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(3) Technical University of Vienna, Institute of Chemical Technologies and Analytics, Austria;
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Standardization of measurements is an important topic within the cryosphere research and is currently a core issue of the WMO Global Cryosphere Watch (GCW). Whereas the development of best practices for GCW, in its first stage, focus on physical properties of the snow, there is an emerging interest to have similar guideline for chemical properties of the snow, too. Using the opportunity of the COST-Harmosnow project to support such activity, a workshop was held in Austria in February 2018 with two major aims, (i) to do an inter-comparison experiment of different sampling techniques for snow chemistry measurements (including water stable isotopes (SI) and black carbon (BC)) and (ii) to initiate the development of a guideline for chemical properties of the seasonal snow cover. In this presentation we will show results of the inter-comparison experiment for the example of physical snow properties, ion composition, SI and BC. The results from the inter-comparison (taking also previous inter-comparison studies into account) serve as the basis in order to present the general concept and status of the guideline. Very recently, also a cooperation with the IASC Cryosphere WG was established to develop the guideline as a joint effort.

Session: Recommendations on measurement methods and instrumentation

Poster

Snow measurements in Republic of Macedonia

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Snow measurements in Republic of Macedonia, like all other meteorological elements, are carried out in the frames of the meteorological station network, operated by the Hydrometeorological Service of Republic of Macedonia.

Our measurements of snow macrophysical parameters include snow presence, snow depth, snow water equivalent, and snow density. These describe the bulk characteristics of the whole snowpack or of a snow layer, and they are the primary snow properties that are needed for most operational applications. We also have measurements for some parameters characterizing precipitating and suspended snow, such as the height of new snow, which is measured regularly and precipitation intensity, measured at some measuring site, but flux of drifting/blowing snow and particle size distribution is not measured at all.

Spatial distribution of the precipitation in Macedonia is irregular because of the complex orography, which impacts the pluviograph regime through the months, seasons and years. Spatial irregularity is manifesting through altitude, geographical longitude and latitude. There is a significant necessity for further research and application in various sectors (water and energy management, agriculture, tourism etc.)

The regional and sub regional cooperation towards the harmonized monitoring of snow is necessary and beneficial for the whole region. The need for an interdisciplinary approach to resolve the current snow measurement and modeling limitations can improve climate change scenarios, hydrology, and numerical weather prediction as well.

Session: Recommendations on measurement methods and instrumentation

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Poster

Evaporation over ice/snow surfaces and lakes: eddy covariance measurements in Antarctica.

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Perspectives of an Eddy Covariance (EC) method to be apply to assess evaporation and CO2 fluxes over ice/snow covered surfaces and lakes is discussed. The specifics of the data post processing procedure for the Integrated 3-D sonic anemometer and CO2 and H2O open-path gas analyzer (Igrason) are suggested. The results for two field experiments in the Schirmaher oasis (East Antarctica) and the Evora region (Portugal) are presented to report the outputs from the short term scientific mission "Eddy Covariance flux measurements over ice/snow land surface and lakes" (08.10-27.10.2018) funded by the Snow COST action.

Session: Recommendations on measurement methods and instrumentation

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Poster

Measurement of Snow at Hungarian Meteorological Service and a Short Review of Snow Climate in Hungary

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Regular meteorological measurements in Hungary carried out by instruments started in 1717. The predecessor organization of the current Hungarian Meteorological Service was founded in 1870. This institution has been responsible for meteorological measurements in the country.

There are nearly 300 AWSs in Hungary now measuring precipitation continuously, in winter the water mass of snow. In addition 460 voluntary observers measure precipitation by Hellmann-type raingauge once a day in the morning and snow depth, if any. Depth of snow is determined by snow measuring staff providing a representative average. Water equivalent of fresh snow is measured after melting the snow. Snow density is measured at 12 stations manually, if the snow depth exceeds 3 cm. We also have short-term experience with automatic snow measuring instruments.

Winter snow is important part of our climate system. Long-term tendencies of snow days, periods with snow-cover and other characteristics are prepared to feature snow climate in Hungary.

Session: Recommendations on measurement methods and instrumentation

Poster

Modelling snow water equivalent in the coastal zone of Hornsund fiord

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Snow water equivalent characterizes the hydrological significance of snow cover. Despite this fact, snow water equivalent (swe) measurements are scarce. Measuring swe is time-consuming thus alternative methods for snow water equivalent estimation are needed. A reliable method for swe estimation could save a lot of effort by sampling only snow depths instead of bulk density and would allow evaluation of hydrological models when only snow depth measurements are available.

We present a method for estimation of snow water equivalent in Hornsund coastal zone using daily snow depth observations. Set of regression models was optimized and calibrated for consecutive stages of snowpack accumulation and ablation. The dataset of manual observations of snow depth and swe at Hornsund meteorological station (WMO 01003) covering 1982-2018 period was used for assessing parameters of each model. Dataset was divided into sets with varying snow depth – snow water equivalent dependencies. Models were calibrated and then validated on part of datasets that were not used for calibration. The proposed approach for estimation of snow water equivalent gave very promising results, with the coefficient of determination higher than 0.9 for both calibration and validation therefore that proposed method could be extended to other Arctic sites where snow water equivalent measurements are rare.

Session: Snow observation reporting and dissemination

Chair: Samantha Pullen (Met Office, United Kingdom), Giovanni Macelloni (IFAC, Italy).

Observations of snow properties are of vital importance for use by a wide range of applications including operational services and research applications. To fully exploit these valuable observational data there must be a harmonised approach to observation reporting practices, data formats and dissemination. The data must be freely available with a timeliness that satisfies user requirements. In this session we welcome contributions that address topics related to harmonised approaches to observations of snowpack properties and initiatives to make these observations available and useable by the international community for operational and research purposes. Possible topics include (but are not restricted to): harmonised reporting practice, regional in situ observation networks, snow data exchange, Data formats for snow observations, Observation-model interfaces — e.g. observation processing methods and software for standardising uptake of observations into models, archives of observations of snow properties

Session: Snow observation reporting and dissemination

Oral

Automatic snow measuring stations network in CHMI

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Automatic snow station is a measuring mechanism, which can in real time measure and record the snow water equivalent (SWE) and the total snow depth (SD). The SWE is in the CHMI network of automatic snow stations measured by principle of hydrostatic pressure in closed pillow. The pillow is filled up with mixture of antifreeze liquid and water and inside the pillow there are usually two pressure sensors. The snow depth is measured by ultrasonic or laser sensors which are attached on the vertical standpipe. The first 2 pillows were installed in 2006 in the climatological station Desná – Souš in the Jizerské hory Mts. In 2009 the original number of 4 testing stations was gradually expended and in these days there is a network of 16 automatic stations (pillows which can measure SWE and SD). The network of pillows was complete by 10 stations which can measure only SD. Prospectively (in the year 2020) there will be the final number of 53 stations in the whole area of the Czech Republic. Data from snow pillows are important input for every week evaluation of water reserve in the snow cover (necessary for water management). They are also important for a control of manual snow measuring in the CHMI standard station network and also for the validation of model which can calculate the SWE for the whole area of the Czech Republic using climatological data from the CHMI standard stations network.

Session: Snow observation reporting and dissemination

Oral

3D-snow mapping, a comparison of methods leading to a standardized measurement and post processing protocol

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In the last decade new technologies such as LIDAR (Light Detection and Ranging) and SfM-(Structure from Motion) photogrammetry allowed researchers and engineers to complete spatial snow depth mapping in high resolution and high accuracy. However, different carriers of the surveying instruments e.g. terrestrial, mobile, airborne, or spaceborne and different types of instruments having very different technical specifications resulted in a variety of quality in the provided results. The resultant resolutions and inaccuracies are not always discussed or mentioned, but are of great importance for the applicant. This presentation aims to first define the different important parameters of the instruments and the measurement methodology and shows in a second step via results of comparative research advances and limitations of each single method. A standardized measurement protocol is hereby discussed (e.g. to provide reproducibility test results) as well as recommendations on the use of instruments. The final goal is to provide examples for a harmonized reporting practice and snow depth maps data exchange solutions defining data formats that should be used for archiving and exchange. These data formats already incorporate the uptake of the data into models such as physical snow pack or avalanche dynamic models.

Session: Snow observation reporting and dissemination

Oral

Insights of the European Snow Booklet

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The “European Snow Booklet” (ESB) is a book of reference for snow measurements that is produced in the framework of the European Cooperation in Science and Technology (COST) Action ES1404 “HarmoSnow”. The ESB is a unique collection of information about current operational snow observations in the European countries and what methods are used to perform basic measurements of snow on the ground: snow depth (HS), presence of snow on the ground (PSG), depth of snowfall (HN) and water equivalent of the snow cover (SWE). Numerous institutions of 38 European countries provided detailed information on their operational snow measurement networks. Similarities and differences between the countries, that are, the number of stations, the spatial and altitudinal station distribution, or the methods applied are pointed out, indirectly showing the relevance of snow for each country. The ESB will therefore improve the awareness of both the scientific community and operational services dealing with snow measurements, as well as of the general public with regards to different basic snow measurement methods applied in each European country. Further, this inventory shows the importance to distribute national snow depth observations over WMO’s Global Telecommunication System (GTS). Currently A wealth of operational snow depth observations are performed in nation-wide networks in most European countries, while the national weather services report only few observations via GTS. Difficulties and inconsistencies between national snow observations and those reported via GTS are described and problems between national and global reporting systems are discussed. Thus the ESB aims at a better knowledge transfer within a large network of researchers and practitioners from all parts of Europe.

Session: Snow observation reporting and dissemination

Oral

Enhancing data quality and data publication with the MeteoIO library.

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The MeteoIO library has been designed as a meteorological data pre-processing library for numerical models. It was designed to read data from a variety of sources, standardize it into a unique representation (parameter naming and units) as well as filter, correct, resample and spatially interpolate it according to the end user’s configuration. After ten years of development, it has moved from being a simple library to a data preparation Swiss army knife. It can be used outside of numerical models to build standalone operational applications such as monitoring the data quality from a measurement network or converting disparate measurements data sets into a common format.

This latter application is developed, for example, for the needs of the World Meteorological Organization's Global Cryosphere Watch (GCW) which is an international mechanism for supporting all key cryospheric in-situ and remote sensing observations. A majority of the measuring stations are operated by universities and research organizations, which are not familiar with the WMO metadata and data exchange mechanisms and do not have the resources to adopt them. The MeteoIO library offers a way to prepare the data for publication on the GCW data-portal by reading the measurements in their native format as they are generated by the organization in charge of the station, performing data filtering, filling data gaps (all according to the configuration performed by the local organization) and writing out the data in a standardized format and schema, according to WMO recommendations (based on the NetCDF common data model and the CF convention).

Another example of such an operational application is PROSNOW, funded from the European Union's Horizon 2020 research and innovation programme, that needs to integrate measured data with snow cover modeled outputs and weather forecasts systems to optimize snow management in Alpine ski resorts. The MeteoIO library then acts as the glue between the measured data, the climatic forecasts systems and the snow models to transparently exchange data and prepare the data to be suitable for numerical models consuming this data.

The MeteoIO library is released under an Open Source license and is available at https://models.slf.ch/p/meteoio .

Session: Snow observation reporting and dissemination

Poster

Expeditionary measurements of snow in the Jizerské hory Mountains and the Giant Mountains in the Czech Republic between 1983 and 2018 as a means of obtaining extreme seasonal snow data.

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Measurements were needed as supplementary information on the regular measurement of the CHMI station network for calculations of seasonal maximum values of snow water equivalent and snow depth and for the improvement of terrestrial modelling data for surface data processing. The time for measurements is depended on seasonal maximum of snow water equivalent which comes true mostly during March. Expeditionary manual measurements which are realized mostly in the mountain regions are still needed.

The methods of measurement and the apparatus used are described. The result is a long-term comparison of seasonal values in individual locations. Without this measurement, it would be difficult to estimate the characteristics of the snow in topographically rugged terrain. The widening of the network of automatic snow stations in the rare occurrence of manual stations would improve the estimation of snow conditions for hydrological and meteorological purpose. The automatic snow stations help to get data in real time. Data from expeditionary measurements are stored in standard CHMI database just as the data from regular station network of CHMI.

Session: Snow observation reporting and dissemination

Poster

Interactive snow profile edition with niViz

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The niViz software has been designed to visualize snow profiles and timeseries of profiles within a web browser, either online or offline. This applies to both measured and simulated data, based around the CAAML snow profile standard based on Fierz et al., 2009. A new module has been developed to create or edit snow profiles interactively. This module allows editing all properties present into the CAAML standard: metadata (including weather conditions, surface conditions, and observer/station/profile ID); stratigraphy with all possible grain shapes subclasses, wetness and hardness as well as optional comments for each layer; multiple profiles of temperature, density, liquid water content, specific surface area (SSA), ram resistance or snow micropenetrometer profiles that all can be imported from CSV files; stability information (as various stability tests, from classical compression to propagation saw tests). Thanks to the standardized nature of CAAML, the generated profiles can then be exchanged between the many worldwide institutions supporting the standard.

This Javascript library and application is available under an Open Source license (GNU affero General Public License) at https://models.slf.ch/p/niviz thanks to the funding provided by an international consortium of more than ten institutions.

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Session: Snow observation reporting and dissemination

Poster

Snow melt and light-absorbing impurities of soot and dust in Iceland and Finland

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Soot particles on snow/ice absorb solar irradiance and accelerate the melt of snowpacks and glaciers via the snow albedo feedback mechanism (Bond et al. 2013). Deposited light-absorbing aerosols, such as soot, can also decrease the water-holding capacity of melting dirty snow, resulting in decrease in snow density, i.e., 'the density effect' (Meinander et al. 2014, Skiles & Painter 2017). In order to quantify the effects of absorbing material on snow and define its contribution to climate change, we have conducted a series of dedicated bidirectional reflectance measurements (Meinander et al. 2014, Peltoniemi et al. 2015 and Svensson et al. 2016), where chimney soot, volcanic sand, and glaciogenic silt were deposited on snow in the selected test sites in Finland in a controlled way. Also, our results on Icelandic volcanic ash (Dragosics et al. 2016) have showed that Eyjafjällajokull ash with grain size smaller than 500 µm insulate the ice below at a thickness of 9-15 mm (called as 'critical thickness'). For the 90 µm grain size, the insulation thickness was found to be13 mm. The maximum melt occurred at thickness of 1mm for the larger particles, and at the thickness of < 1-2 mm for the smaller particles (called as 'effective thickness'). Earlier, similar threshold dust layer thickness values have been given for Mt St Helens (1980) ash, and Hekla (1947) tephra, but our results were the first ones reported for the Eyjafjällajokull ash. Our findings have been independently repeated and confirmed by Möller et al. (2016). In Iceland, the dust layers in the nature can be from mm scale up to tens of meters. Our results, including most recent field work in Iceland, suggests that the roles of soot and dust in snow melt and albedo changes need to be included in the various snow melt approaches.

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Session: Intercomparison of snow models and future of snow modeling across disciplines

Chair: Marie Dumont (French National Centre for Scientific Research, France), Jürgen Helmert (Deutscher Wetterdienst, Germany).

Continuous estimates of the snow state from numerical model predictions are still limited by uncertainties in meteorological forcing data and model structural problems for snow processes in land surface models. Three major classes of snowpack models are employed for various applications: single-layer snow models, schemes of intermediate complexity, and detailed snowpack models, which differ in the description and the parameterization of the properties inside the snowpack and the related processes. The choice of the model complexity level is generally guided by the foreseen application. For instance, in the case of avalanche hazards forecasting, a detailed description of the the snowpack physical properties is required and thus a multi-layer model is to be preferred. This session aims to review existing snow models used in numerical weather prediction and climate models, hydrology, and for the avalanche hazards forecasting. We are interested to identify possibilities to harmonize approaches for the parameterization of snow processes in snow models of different complexity and we look forward to contributions addressing these topics.

Session: Intercomparison of snow models and future of snow modeling across disciplines

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Oral

ESM-SnowMIP: Concept, first results and plans

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ESM-SnowMIP is an international coordinated modelling effort to evaluate current snow schemes against local and global observations in a wide variety of settings, including snow schemes that are included in Earth System Models. The project aims at identifying crucial processes and snow characteristics that need to be improved in snow models in the context of local- and global-scale modeling. A further objective of ESM-SnowMIP is to better quantify snow-related feedbacks in the Earth system. ESM-SnowMIP is tightly linked to the Land Surface, Snow and Soil Moisture Model Intercomparison Project, which in turn is part of the 6th phase of the Coupled Model Intercomparison Project (CMIP6). I present and discuss some initial results from the intercomparison of site-scale multi-year simulations.

Session: Intercomparison of snow models and future of snow modeling across disciplines

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Oral

Impacts of meteorological data elevation coverage on a hydrologic model for mountainous watersheds

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A hydrologic modelling procedure for poorly gauged watersheds is developed in this study using the UBC watershed model and limited meteorological information. The impact of elevation coverage on precipitation and temperature measurements is investigated on the accuracy of hydrological modeling at mountainous watersheds in different river basins located in Canada, Cyprus and Pakistan. Catchments from cold, temperate, continental and semiarid climate zones are included to demonstrate the developed procedure for modelling daily streamflow and subsequent snow accumulation and melting. A simplified energy budget approach, which is based on daily maximum and minimum temperature and can account for forested and open areas, aspect and latitude, is used in the UBC watershed model for the estimation of the snowmelt and glacier melt. Then, the best structure identified with the UBC model is used and compared with an regional uncalibrated model derived form a universal set of parameters for water allocation and flow routing, precipitation gradients estimated from the available annual precipitation data as well as from regional information on the distribution of orographic precipitation. The results show that the performance of the UBC model is largely affected by the quality and the representativeness of meteorological data rather than their elevation coverage and when limited streamflow measurements are available, the regional uncalibrated UBC model is considered a successful substitute method over the conventional calibration/validation procedure.

Session: Intercomparison of snow models and future of snow modeling across disciplines

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Oral

Modeling and operational forecast of hazardous wet snow load at the Hungarian Meteorological Service

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Since 2009, when a devastating wet snow accretion damaged several hundreds of electricity transmission poles and wires in southwestern Hungary comprehensive research has been carried out at the Hungarian Meteorological Service (OMSZ). The risks of wet snow load on transmission networks have long been known (Ju et al., 1899), but the physical properties of snow crystals, the development of the snow sleeves on wires and the integration of all of these processes into NWP models are still an active research topic. During our work the Admirat accretion model (2008) was used to calculate the cylindrical wet snow load on wires in combination with sticking efficiency (ß) by Nygaard et al. (2013). Based on long-term (1965-2016) meteorological observations and statistics the density of the snow sleeve was considered as constant 300 kg m-3. The input parameters from NWP models (ECMWF, AROME, WRF, ALADIN, MEANDER nowcasting system) are 2 m temperature, wet-bulb temperature, precipitation and 10 m wind speed. In order to determine the precipitation type we used empirical methods, like 850/1000 hPa relative topography (Hirsch, 2008), long-term statistics (Fövényi, 2001), and model microphysics as well. Wet snow formation needs special circumstances, precisely a narrow 2 m temperature interval close to 0 °C (between – 0.5 °C and +2 °C), so the results strongly depends on the precision of the NWP model input parameters. Reasonably, the probabilistic approach is also recommended, thus, promising experimental ensemble forecasts have been run with ECMWF-ENS, AROME-ENS and ALADIN-ENS (Simon et al., 2018). Since 2013, wet snow load forecasts have been available during the operational work at the OMSZ. The wet snow load forecasts can be visualised by HAWK3 visualisation system developed at the OMSZ and the hazard level of wet snow load is harmonized with the operational warning system (Somfalvi-Tóth et al., 2015), so customers can be informed in detail about the severity of an oncoming wet snow event.

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Session: Intercomparison of snow models and future of snow modeling across disciplines

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Oral

A multi-layer snow cover model for numerical weather prediction and climate models

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The seasonal snow cover strongly influences boundary layer processes such as turbulence and radiation. Therefore, knowledge of the current state of the snow cover on the ground is of paramount importance for numerical weather prediction (NWP) and climate models. This is especially true since the horizontal resolution (up to 1 km) of NWP models strongly increased in recent years. Currently, most NWP models use simplified – typically one snow layer – snow cover schemes, which are in general not capable to simulate snow cover formation, evolution and melt with adequate accuracy. Within the framework of the COSMO consortium (Consortium for Small-scale Modelling) we are developing a new multi-layer snow cover module for the regional weather forecasting and climate model COSMO and the global model ICON (Icosahedral Nonhydrostatic). The snow cover model consists of six snow layers with increasing but constant thickness for the upper part (top 29 cm) of the snow cover and a variable amount of snow layers (minimum = 2) in the lower part of the snow cover. Preliminary results indicated an improvement of the snow surface temperature with only minor effects on the near surface air temperatures, when compared to the single layer counterpart at the location of a network of high-alpine weather stations.

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Oral

Snow modelling : current status and future avenue

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Modelling the state and physical properties of the snow cover has a number of crucial applications, such as avalanche hazard forecasting, water resource management to meet both human and hydropower needs, as well as ecological, meteorological and climate studies. The time evolution of the snowpack depends on the mass and energy exchange through its boundaries and on the internal processes occurring within the snowpack. A snow model is a computer code that describes the physical behaviour of the snowpack in a simplified manner. A large variety of snow models exists, with various degrees of complexity ranging from simple degree day models to more sophisticated detailed multilayer snowpack models, used e.g. for avalanche forecasting.

With this multitude of models to choose from, decisions must be made based on the most appropriate level of complexity for a given application. During the recent years, there have been efforts to inter-compare and unify snow modelling e.g. by developing multi-physics ensemble models that include parametrizations from different original snow models. Another on-going attempt aims at a renewal of snow modelling in order to bridge the gap between our knowledge in snow physics and the limited capabilities of detailed snow models that were developed decades ago. Such a project aims at a snow model that can be modular and detailed enough for the wide range of applications for which snow evolution is critical. This ambitious goal requires to balance the requirements imposed by the desired numerical robustness and by the desired flexibility to facilitate modularity.

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Oral

Evaluation of Point Based Snowpack Modeling for SNOTEL Sites in Turkey

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Snowmelt runoff in the mountainous eastern part of Turkey is of great importance as it constitutes 60–70% in volume of the total yearly runoff during spring and early summer months. Therefore, determining the amount and timing of snowmelt is of utmost value in order to use the water resources of the country in an optimal manner. Considering the difficulties experienced in measuring the snowpack on land and the problem of spatial representation of point measurements, snowpack modeling has a key role in terms of monitoring and forecasting the properties of snowpack.

In this study; snowpack components, such as height of snow (HS), snow water equivalent (SWE) and snow density (ρsnow), measured at some of the SNOTEL stations in Turkey are evaluated with a snowpack model. Conceptual snowpack model SNOW-17, which has a common usage in the literature, is chosen in this framework. In addition, snow components at some of these stations are validated using manual snow tube and snow pit measurements.

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Poster

Comparison of 50-year return period wet snow loads based on weather station data between 1965-1990 and 1991-2016 in Hungary

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Most members of modern society are exposed to electricity supply, so power outage can result in extensive damage to property. To prevent regular system failures transmission line designers have to take into account different weather situations dangerous to overhead wires and poles, such as extreme ice, snow or wind loads. In this study we focus on a phenomenon named wet snow developing amongst specific air stratification conditions. National (MSZ 151-8:2002; MSZ 151-1:2004), European (CENELEC) (EN 50341-1:2012) and international standards (ISO12494) contain the guidelines how to calculate the cylindrical accretion of wet snow on transmission wires. Following these standards together with the latest results in wet snow modeling (Nygaard et al., 2013, Lacavalla et al., 2015) and the statistical method of Peak-over-threshold (POT) (Coles, 2001) the 50-year return period wet snow load has been calculated based on 12 weather station data for the periods of 1965-1990 and 1991-2016.

The aim of this study is on the one hand to investigate the exposure to wet snow in different parts of Hungary, on the other hand the 50-year long dataset allows us to reveal the long-term changes in frequency and intensity of wet snow loads.

In ISO12494 (2001) 10 ice classes are determined ranging from R1 (0.5 kg/m) to R10 (> 50 kg/m) also using the method of 50-year return period. In this study the weather stations have been classified into these ice classes. The results calculated from the data of 1965-1990 show, that 6 out of 12 stations belonged to R4 (2.8 kg/m) and R5 (5 kg/m) ice classes, 4 stations belonged to R3 (1.6 kg/m), while 2 stations belonged to R1 (0.5 kg/m) and R2 (0.9 kg/m). By comparison the 50-year return period wet snow loads calculated from the data of 1991-2016 have changed. Recently, only 3 out of 12 stations belong to R4 and R5 ice classes, 3 stations belong to R3, 3 stations belong to R1 and R2, while the ice class of Siófok has risen into R6 (8.9 kg/m) considering as a more exposed area to significant wet snow load.

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Poster

MWDiEM, a new tool to model the granular nature of snow avalanches

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MWDiEM is a new open-source, discrete element model based numerical tool, that is able to effectively model the dynamics of polyhedral and spherical granular particles. The tool is especially aimed at geological mass-waste applications where the fluid content of the flow is none or negligible, e.g. rock avalanches, boulder falls, dry sand, gravel and debris slides, dry debris flows and snow avalanches. The model is prepared for GIS implementation; includes possible entrainment and erosion of the particles; the use of different basal topographies and obstacles in the path of the movement is implemented and different slide initiation/slope failure methods are realized, like vibrations or forced breakup of a block of mass. The simulations give us the opportunity to look inside the dynamics of avalanches, including flow velocities, shear rates, segregation patterns and to explain any unexpected run-out zone geometries, providing a useful tool in the future for both scientist and avalanche professionals.

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Poster

Digital mapping of wind deposited snow in the Low Tatras, Slovakia

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A submodule of AvalMap, a snowpack model developed by the author, models snow redistribution by wind to incorporate it in the final avalanche danger maps it produces. As a first step 10 minute wind measurements are averaged as vectors to get one speed, direction and duration value at each timestep in AvalMap. These values are then modified by a factor based on macro (general shape of the mountain and distance from ridge) and micro terrain features (curvature, slope and aspect-wind direction ratio) to spatially distribute the point data. Then, as a second step snow transport is calculated based on the ratio of shear velocity (from logarithmic wind profile), to threshold shear velocity. Next, the flux, the potential carrying capacity of the wind is calculated, which is also based on shear and threshold shear velocity. Difference of the fluxes is then determined for each pixel from the direction of the wind, to derive the amount of snow that could actually be carried away or deposited. Sublimation and densification in the carried snow are also considered. The amount of snow actually transported depends on the temperature, height and density of the available snow layers. By putting these all together we determine the spatial distribution of wind deposited snow by considering the deposition areas indicated by the difference of the fluxes, the distance from the ridges and the time the air spends at each pixel by the given wind speed as well.