Physical and chemical properties of seasonal snow in the Arctic

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1. Background

Physical properties and the chemical composition determine the behavior of snow and its role in the Arctic. Among the impurities, halogens and nitrate play important roles for processes like photochemical transformation in the snow, interaction with the atmosphere, and biological processes. Black carbon (BC) in snow has an effect on snow albedo and can change physical properties and the behavior of the snow. However, the effect of BC in snow on the albedo depends on the snowpack properties itself.

2. Chemical composition of Arctic snow (Spitzbergen)

Map around Ny-Alesund with locations for atmospheric (Zepelin and Corbel Station) and snow sampling.

- 300 snow samples around Ny-Alesund collected in March/April 2012
- Fresh and surface snow and 3 snow pits on the Kongsvegen and Austre Lovenbren glaciers
- Composition dominated by marine input
- BC measurements in the snow planned using SP2 instrument: same instrument used to measure atmospheric BC

3. Implementation of BC into snow model CROCUS

Crocus is a multi-layer physically-based snowpack model including snow metamorphism. In the standard version albedo is parameterized using three bands in the visible and near-IR range based on properties of the uppermost layer like grain size and snow age.

The radiative transfer is simulated based on the parameterization of Warren and Wiscombe (1980).

- For each layer grain size, SWE, and BC concentration is considered to simulate optical properties
- At the bottom a fixed albedo is used, at the surface the partitioning between diffuse and direct incoming solar radiation (including SZA) is taken into account

4. Observations on the Kongsvegen glacier and in Ny-Alesund

Meteorological observations between October 2011 and April 2012 from an automatic weather station installed at an altitude of ~670m on the Kongsvegen glacier. Precipitation was estimated using continuous measurements of snow height and a constant density of fresh snow of 0.85 g cm⁻³.

Chemical composition of weekly samples of precipitation collected in Ny-Alesund.

5. Results of snowpack simulations

Comparison of observed and simulated profiles in a snow pit sampled on 30 April 2012 on the Kongsvegen glacier next to AWS at 670 m altitude.

Simulated profiles obtained from combining results of snowpack modeling with CROCUS (history of accumulation) with time series of the composition of precipitation at Ny-Alesund.

Simulated profiles corrected according to different total accumulation (1079 mm on Kongsvegen vs. 315 mm at Ny-Alesund).

Large parts of the chloride profile well represented in the simulations; high bias in the simulations possibly due to percolation, low bias due to additional dry deposition.

Nitrate profile less well represented in the simulations, indicating larger impact of post-depositional processes.

6. Open issues

Combined studies of physical, chemical, and biological properties of the snow on continents and sea ice.

Very limited information on snow in Siberia.

Better understanding of the link between physical, chemical, and biological properties and processes in the snow.

Better understanding of processes at interfaces between snow and atmosphere, soil, or sea ice.

Improvement of modeling tools to address processes in the snow.

Impact of processes in the snow on air and water quality (processing of reactive species, heavy metals, POPs).

Improved representation of snow in regional models including a link to atmospheric chemistry models.

Impact of snow on biogeochemical cycles in the Arctic.

Impact of changing snow properties on permafrost stability, hydrological cycles, glacier mass balance, regional climate, and ecosystems.

References: