

## Chemical evolution of the surface and subsurface Svalbard annual snow

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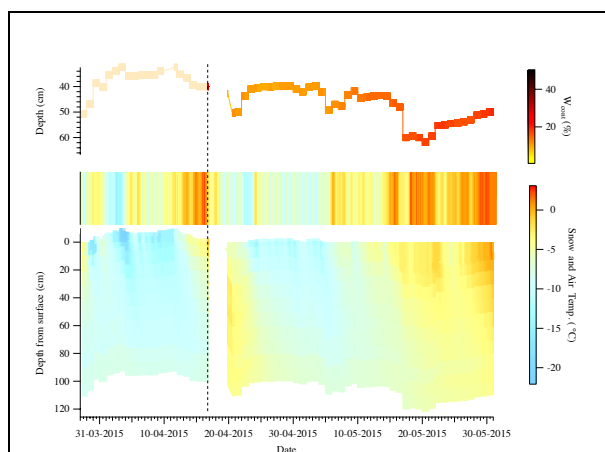
### Abstract

Understanding and monitoring the evolution of annual snow is an important aspect of cryosphere research. Changes in physical properties such as hardness, presence of melt layers, or the shape and size of crystals can completely modify the robustness, propriety and quality of the snow. Evaluating these changes can inform the study and prediction of avalanches. The annual snow layer is an extremely dynamic portion of the cryosphere and can be defined as the snow accumulated on the ground during the year, from September to April. The characteristics of the annual snow strata can influence the access to food, particularly for animals that rely on food sources below the snow strata (Kohler et al. 2004). From a chemical point of view, snow depositions during the winter are a sink for an impressive amount of chemical compounds (natural and anthropogenic) and elements trapped in the snow layers. Particularly, compounds and elements that can be photo-activated accumulate during the winter and can be re-emitted in the atmosphere, taking part in numerous geochemical and biological cycles (Björkman et al. 2013) during the spring. However, elements that can be photo-activated are not the only ones to be released from the annual snow strata. During the melting phase, all elements and compounds that are still present in the snow can be released in the melting water (Bogdal et al. 2010), accumulate in the ground or be discharged in the sea, affecting biological productivity or, in the case of anthropogenic compounds, causing a spotted contamination of the surrounding environment.

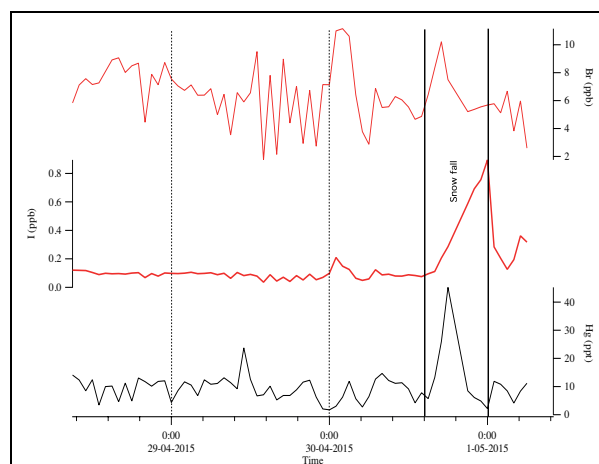
Two experiments were performed to evaluate the changes in the chemical composition of surface and subsurface annual snow. An in-depth investigation of the evolution of the first meter of the annual snow layer, with daily resolution, was conducted in the glacier of Austre Brøggerbreen, Svalbard, between the 27<sup>th</sup> of March and the 31<sup>st</sup> of May, in concomitance with the start of the melting phase (Spolaor et al. 2016). The present monitoring study mainly aimed to evaluate changes in the thermal profile and liquid water content (LWC) during the formation of a new ice layer (Figure 1) as well as the re-allocation of the total dissolved salts (TDS) and, more in detailed, the specific ionic compound as Na<sup>+</sup>, Br<sup>-</sup>, NO<sub>3</sub><sup>-</sup>, Cl<sup>-</sup>, Ca<sup>2+</sup>, Mg<sup>2+</sup> ect. In addition, and to corroborate the previous experiment, three additionally experiments were performed, two at high temporal resolution between the 29<sup>th</sup> April and 1<sup>st</sup> of May 2015 (Figure 2) and between the 7<sup>th</sup> and the 10<sup>th</sup> of April 2016, and one sampling the surface snow (15 cm) with daily resolution between the 1<sup>st</sup> of April to the 30<sup>th</sup> of June 2014. The first high-resolution experiment were performed during the midnight sun season while the second ones when the night and day cycle was still present. In both

experiments a surface samples have been collect every 1-hour for 3 consecutive days, with the aimed to study the effect of the solar radiation, snow deposition events and meteorological conditions in the chemical surface snow composition and evolution.

Preliminary results suggest a clear effect of the meteorological condition on the chemical and physical evolution of the annual snow layer, particularly, the rain event occurred between the 16<sup>th</sup> and the 17<sup>th</sup> of April 2015, have completely modify the structure of the annual snow. Results from the high-resolution experiments seem suggest that an effect of the light induced reaction in not negligible in the surface snow (first 3 cm). This light induced surface processes become more evident when night and day cycle is present. Studying the evolution of surface and subsurface snow in the Austre Brøggerbreen glacier from a physical and chemical point of view required a multidisciplinary approach involving several kinds of research expertise, such as snow physics, chemistry, atmospheric chemistry and technology development. In particular, our experiments contributed to understanding the evolution of the snow's physical and chemical proprieties as a function of temperature and the presence of liquid water as well the meteorological conditions. The results obtained may be relevant to future evaluations of the interaction between snow, atmosphere and the post-depositional processes that re-emit specific elements and compounds, including anthropogenic contaminant; also they may be of help when evaluating the re-allocation of ionic species during the melting phase in the context of a paleoclimatic reconstruction based on an ice core sampled from a glacier affected by summer melting.



**Figure 1:** Monitoring the thermal profile and the presence of liquid water in the first metre of the annual snow in the Austre Brøggerbreen glacier. The panel above show the Liquid water content ( $W_{cont}$  %) at 50 cm depth, the air and snow temperature at different depth between the 1<sup>st</sup> of April to the 31<sup>st</sup> of May 2015.



**Figure 2:** Surface snow high resolution sampling (1 hour) at the Gruvenbadet site. The surface snow (3 cm) have been sampled and analyzed for a large number of elements and compounds (in this case only iodine, bromine and mercury are shown). The results obtained have been compared with meteorological data including the amount of snow fall, wind direction and incoming solar radiation

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