Minutes from the workshop on "Integrated long –term Snow Chemistry Monitoring"

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In total 20 participants from 8 European countries (Austria, Bulgaria, Estonia, Finland, Italy, Poland, Slovenia, Sweden) participated at the workshop in order to exchange their experiences and results on snow chemistry monitoring at mountain/arctic sites. Additionally, several groups participated for an inter-comparison experiment on the sampling strategy and its impacts on the resulting ion composition (including also surface BC concentration), stable isotope content as well as snow stratigraphy of the seasonal snow cover. Finally, the participants started with discussion on the development of a protocol/guide for sampling and measurements of monitoring of chemical composition of seasonal snow under mountain/arctic conditions. According to the three main topics of the workshop, the protocol is also structured into:

- 1. Exchange of experiences on measurements of chemistry of seasonal snow on the ground

- 2. Inter-comparison experiment on snow sampling strategy for monitoring the chemical composition, stable isotope content and snow stratigraphy of seasonal snow in mountain/arctic environment
- 3. Development of the structure for a protocol/guide on measuring the snow chemistry of seasonal snow on the ground.

The participants list is added as supplemental material no. 1 (Appendix 1).

1. Exchange of experiences on snow chemistry monitoring – presentations

17 presentations were given covering, beyond others, the topics of snow sampling strategy, spatial variability of major ion composition, temporal trends in major ion concentration, ancillary information from stable isotope content, the relevance of EC/OC and dust measurements for snow chemistry and snow albedo, measurement of trace and ultra-trace elements and the relevance of forests for snow chemistry.

The list of workshop presentations is added as to the protocol as supplemental material no 2 (Appendix 2).

2. Snow chemistry inter-comparison experiment

On day three, an inter-comparison experiment was organized by the group of participants aiming at:

- to showcase different approaches of snow sampling for the purpose of snow chemistry monitoring and stable isotope measurements in snow
- to show methods to describe snow stratigraphy as ancillary information for snow chemistry monitoring
- to take samples for an inter-comparison experiment in order to quantify the impact of sampling strategy on measured values of major ion concentration, stable isotopes, EC/OC and snow water equivalent of snow cover.

The sampling was discussed in detail by the group and finally deciding to exclude the topic of laboratory inter-comparison (e.g. using standardized snow samples for round robin test) but focusing on the topic of impact of sampling technique on final ion concentration (stable isotope content).

The Institute of Chemical Technologies and Analytics (TU-Vienna, Austria) agreed to do the measurements for major ion composition of all samples and Jozef Stefan Institute (Department of Environmental Sciences) agreed to measure the stable isotopes for 18O and 2H.

In total 4 different groups performed the parallel snow sampling campaign (using their different methods and devices) and assisted by the other participants:

- Team 1: University of Graz/TU-Vienna (Austria)
- Team 2: University of Innsbruck (Austria)
- Team 3: University of Wroclaw (Poland)
- Team 4: University of Venice, University of Florence (Italy)

The general strategy is shown in the figure below. The groups worked side-by-side in one single large snow pit. The total snow depth was about 170cm of snow, with an upper dry-snow layer of ca. 90 cm thickness and a lower layer, already with clear structure of various metamorphism processes including thin ice layers near to the ground. In order to quantify the small scale spatial variability of ion deposition into the snow as an additional source for differences in the concentration values of the snow samples taken by the individual groups, it was decided, that Team 1 take parallel samples from both in the leftmost and the rightmost part of the snow pit.

Figure 1: The general concept and realization of the snow sampling inter-comparison experiment at Sonnblickbasis (from the left to the right: Team Austria1, Team Poland, Team Italy, Team Austria2 and to the right (not shown in the photograph) the location of second sampling of Team Austria 1 again.

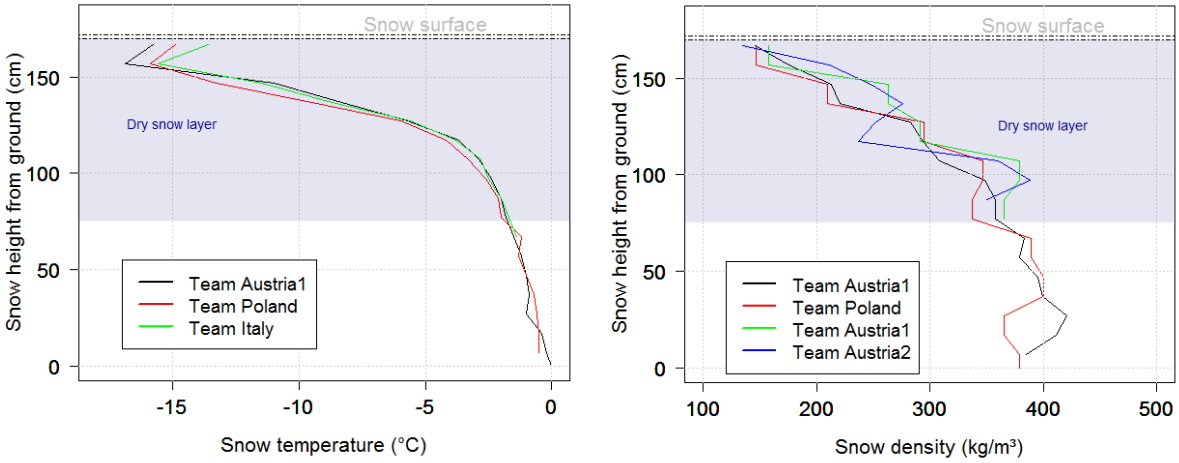


Figure 2: Preliminary results of snow temperature and snow density measurements in the snow pit of the inter-comparison experiment at Sonnblickbasis. Snow samples for chemical analysis and stable isotope measurements were taken from the uppermost dry snow layer only.

First results of the inter-comparison for physical snow parameters (snow temperature and snow density) were discussed at the workshop and are shown in Figure 2. Taking into account the small scale variability of snow temperature and snow density, the inter-comparison shows rather high agreement between the measurements of the individual groups.

Samples for chemical analysis from the 4 teams (Austria1, Poland, Italy, Austria2) were immediately stored in a freezer at the base station of Sonnblick Observatory and were transported to TU Vienna by A. Kasper on last day of the workshop. TU-Vienna will prepare (melt) the snow samples and split for further analysis (IC and stable isotopes).

Additionally, 2 groups (Outi Meinander, FMI and Silvia Becagli, U-Florence) worked on sampling of surface snow for EC/OC analysis (see photographs below).

Figure 3: Samling of surface snow for EC/OC analysis (right) and filtering of samples (left)

3. Discussion on outline for a protocol on snow-chemistry monitoring

The participants started with general discussion on the need for a protocol/guide on snow chemistry measurements for seasonal snow and its potential relevance and added value for research community. From a survey of already existing protocols/guides on snow chemistry monitoring two such protocols were identified:

1) J.C. Gallet, M.P. Bjorkman, C. Larose, B. Luks, T. Martma and C. Zdanowicz (Eds). 2018. Protocols and recommendations for the measurement of snow physical properties, and sampling of snow for black carbon, water isotopes, major ions and microorganisms, Kortrapport / Brief Report no. 046, Norwegian Polar Institute
2) George P. Ingersoll, Don Campbell, M. Alisa Mast, David W. Clow, Leora Nanus, and Brent Frakes. 2009. Snowpack Chemistry Monitoring Protocol for the Rocky Mountain Network; Narrative and Standard Operating Procedures. United States Geological Service (USGS). Administrative Report

On the one hand side these two protocols are clearly focused on instructions for snow chemistry monitoring and, consequently cover a rather similar topic as the planned COST harmosnow protocol/guide. However, on the other hand side, these two existing protocols have a particular focus coming from either the study region or the underlying program. Thus the participants of the workshop agreed that a more general protocol/guide would a great benefit for research community in particular for the following reasons:

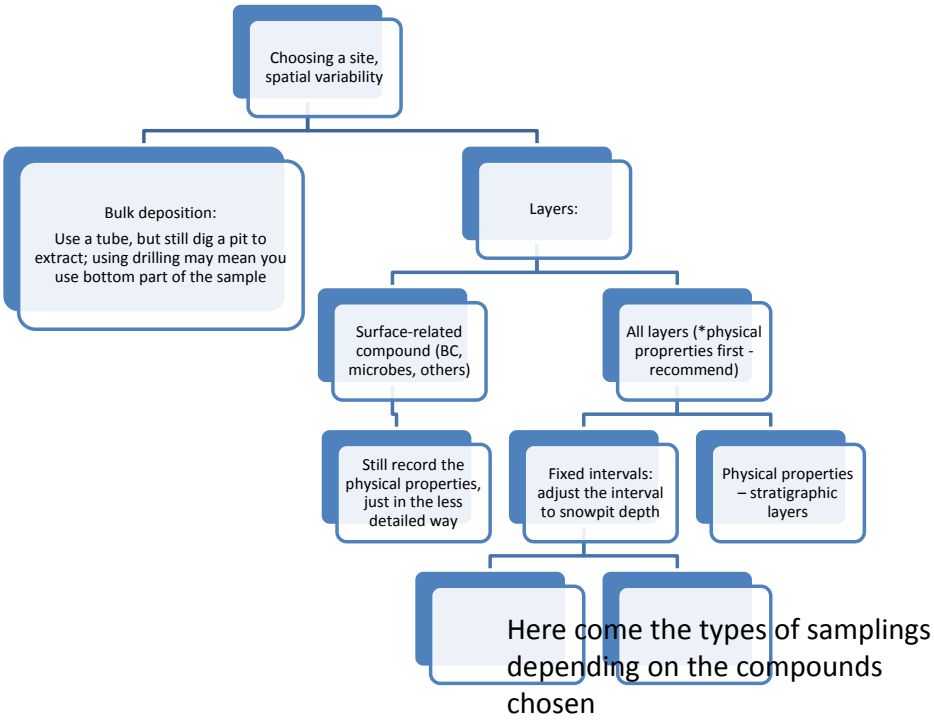
- Documentation of methods including their uncertainty
- Investigating trends in space and time (e.g. from different sites worldwide)
- Introduction to snow chemistry measurements for beginners

Obviously, such protocol/guide could be of large benefit for researchers starting with a program on snow chemistry monitoring.

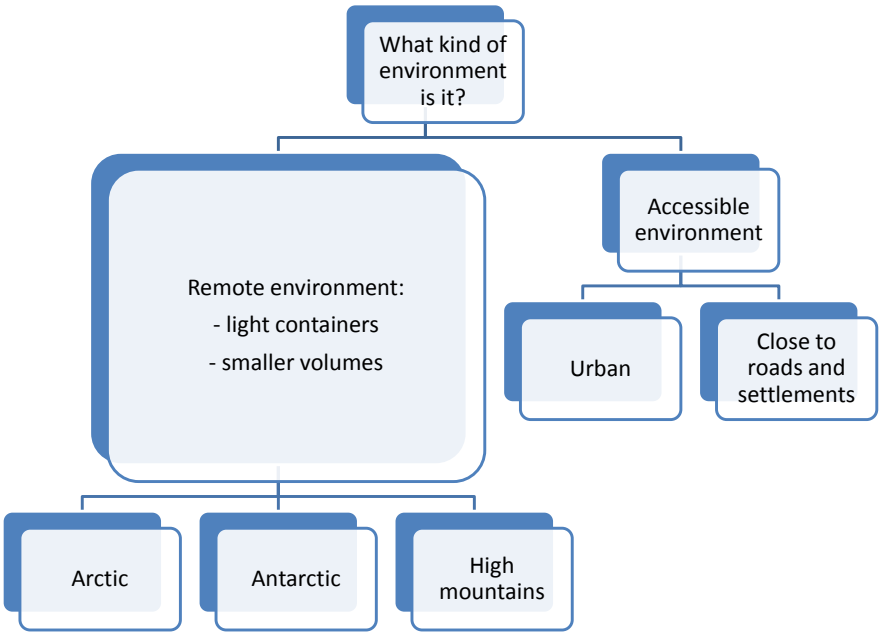
However, the participants agreed also that the field of snow chemistry investigations is rather broad and that a protocol/guide could not describe all potential methods for snow chemistry measurements (in particular if it comes to measurements of trace elements with extreme low concentration values requiring ultra-clean measurement conditions). Consequently, the purpose of a protocol/guide should be for measurement of atmospheric deposition/concentration of major ions as well as the investigation of spatiotemporal changes and trends.

In a next step an outline and structure of the protocol/guide was developed based on a concept of decision trees (several examples developed at the workshop are given below):

Decision 1: Choosing a site and deciding for depth=time resolution of sampling



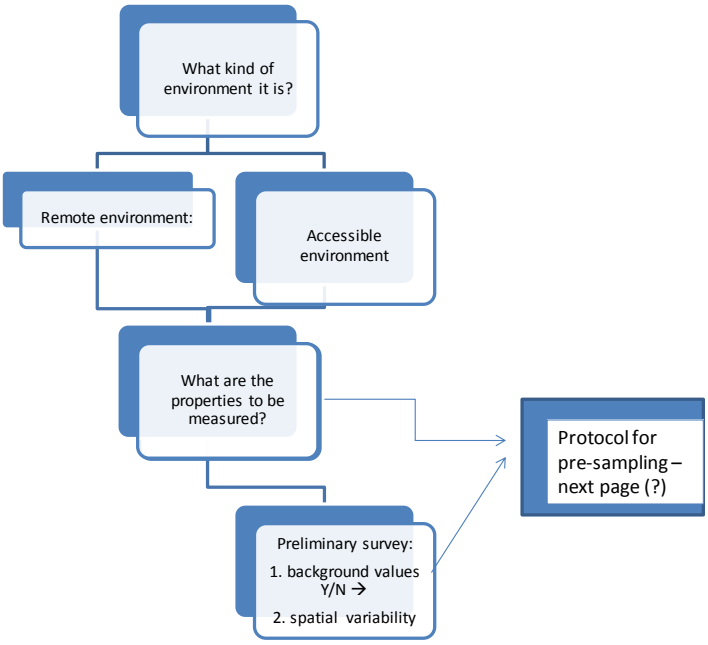
Decision 2: Decision on logistics (logistics decision tree):



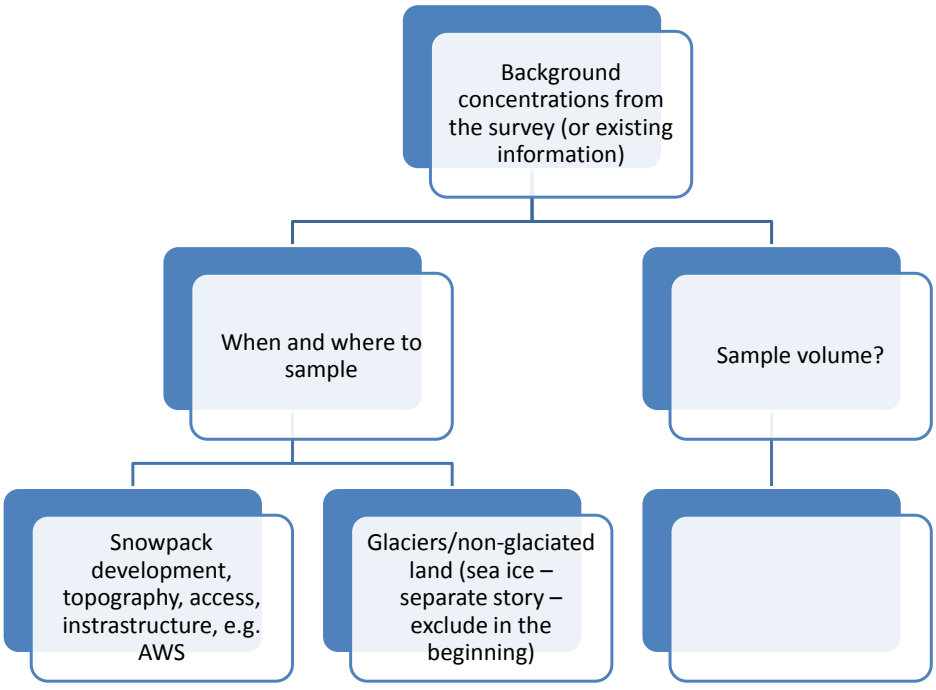
*if you plan to work in a restricted area, e.g. national park, make sure you obtain permission well in advance

Decision 2: Decision on logistics (logistics decision tree, variant 2):

Or a list of considerations how to prepare your preliminary sampling



Decision 3: Decision on ????



Draft structure for the protocol/guide on snow chemistry monitoring:

1. Scope of the protocol/guide
   The aim of the sampling/monitoring is for measuring atmospheric deposition either in the time or space domain or both. This includes also the measurements of ancillary information. Aim of the protocol is not to describe measuring pure and ultra-pure trace elements.
2. Choosing site and temporal resolution of sampling
3. Results from previous studies on spatial variability of major ion deposition and stable isotopes in snow
4. How to take snow samples from snow cover
   4.1 bulk sampling
   4.2 single layers sampling
   4.3 surface snow sampling
5. Measuring OC/EC of surface snow
6. Measuring snow micro biology
7. Measuring physical properties of the snow
8. Measuring trace elements in the snow cover
9. Measuring stable isotopes of the snow cover
10. Ancillary observations in the field
11. Quality assurance of measured data
12. Archiving of data

Task assignment:

Wolfgang Schöner – physical properties

Otti Meinander – BC

Christian Zdanowicz – spatial variability

Birgit Sattler / Cathrine Larose – microbiology

Ulrike Nickus – major ions

Tonu Martma / Polona Vreca – stable isotopes

Andrea Spolaor – trace elements

Supplemental material:

Annex 1: List of workshop presentations

Annex 2: Participants list

Annex 3: List of used devices for snow sampling