U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-20-019

COMBLE-Isotopic Links to Atmospheric Water's Sources (ISLAS) Snow Sampling 2020 Field Campaign Report

H Sodemann
A Seidl
A Dekhtyareva
A Johannessen

November 2020

ARM

DISCLAIMER

DOE/SC-ARM-20-019

COMBLE-Isotopic Links to Atmospheric Water's Sources (ISLAS) Snow Sampling 2020 Field Campaign Report

H Sodemann
A Dekhtyareva
A Seidl
A Johannessen
All at University of Bergen, Norway

November 2020

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acronyms and Abbreviations

AMF	ARM mobile facility
ARM	Atmospheric Radiation Measurement
COMBLE	Cold-Air Outbreaks in the Marine Boundary Layer Experiment
ERC	European Research Council
FARLAB	Facility for Advanced Isotopic Research and Monitoring of Weather, Climate and Biogeochemical Cycling
IOP	intensive operational period
ISLAS	Isotopic Links to Atmospheric Water's Sources
PI	principal investigator
PTFE	polytetrafluoroethylene
UTC	Coordinated Universal Time

Contents

Figures

1.0 Summary

Within the European Research Council (ERC)-funded project entitled Isotopic Links to Atmospheric Water's Sources (ISLAS), researchers from the University of Bergen, Norway, used the stable isotope composition of atmospheric water vapor and precipitation to obtain information about the sources and transport processes of water vapor within arctic weather systems. In particular, during cold-air outbreak conditions, evaporation and precipitation occur in close proximity within the study area. With evaporation studied at a single location (Ny-Ålesund), ISLAS researchers wanted to be able to sample the resulting precipitation at several downstream locations. The U.S. Department of Energy Atmospheric Radiation Measurement (ARM) Cold-Air Outbreaks in the Marine Boundary Layer Experiment (COMBLE) site was one of those locations, included in an entire network of precipitation sampling stations reaching from Ny-Ålesund, where water vapor isotope measurements are conducted near the surface, to Longyearbyen, Tromsø, Andenes, Ålesund, and Bergen. Daily precipitation samples, enhanced by more frequent sampling during intense operational periods (IOPs), were conducted during four weeks from 20 February to 20 March 2020. The contribution from the ARM mobile facility (AMF) observatory, deployed at ANX (Andenes, Norway) during COMBLE, was valuable to understand the spatial coherence of water isotope signals from arctic and extratropical weather systems.

The general work plan was to sample precipitation on a daily to sub-daily basis with a supplied sampling kit (Figure 1). Thereby, daily sampling lasted from 22 February to 24 March 2020. At a fixed time of day (10 UTC), samples were collected and the sampling box cleared for the next sample. Additionally, IOPs would be announced by the ISLAS principal investigator (PI). Then, ARM scientists increased sampling frequency to sub-daily. During the campaign period, two IOPs were conducted, with a total of 12 samples taken. IOP1 lasted from 27 February to 02 March 2020, and IOP2 lasted from 12 March to 14 March 2020. Solid precipitation in the box was then melted, transferred to an 8-ml glass vial, sealed, and shipped to the Facility for Advanced Isotopic Research and Monitoring of Weather, Climate and Biogeochemical Cycling (FARLAB; University of Bergen, Norway) for stable water isotope analysis. Measured stable isotope composition of precipitation samples will be related to conditions at other sampling locations and at the evaporation site to provide information about conservation of water isotope quantities.

Figure 1. Setup of the sampling equipment at Andenes near the AMF observatory on a wooden pallet, secured with rubber straps.

2.0 Results

During the campaign, the priority was daily precipitation samples at a fixed time of day. In the period from 22 February to 24 March, 23 daily samples were collected for stable water isotope analysis. Samples were collected at 10 UTC. During the entire sampling period, a high variability of precipitation phase was encountered. Most samples were recovered in the form of graupel/snow (12 samples), as rain (7 samples), and the remaining samples fell as graupel, snow, rain, or frozen rain. Precipitation amounts varied between <1 mm (26 February) and 140 mm (25 February) within the sampling box. Furthermore, higher-resolution sampling was conducted during two IOPs. During IOP1, from 27 February 10 UTC to 02 March 10 UTC, seven samples were collected, all of them as solid-phase precipitation. IOP2 ran from 12 March 10 UTC to 14 March 09 UTC, and five samples (all as graupel/snow) were collected.

Samples were processed according to FARLAB standard measurement procedures. In short, samples were transferred to 1.5-ml glass vials with rubber/PTFE septa (part #548-0907, VWR, USA). An autosampler (A0325, Picarro Inc) transferred ca. 2µl per injection into a high-precision vaporizer (A0211, Picarro Inc., USA) heated to 110°C. After blending with dry N_2 (< 5 ppm H_2O), the gas mixture was directed into the measurement cavity of a cavity-ring down spectrometer (L2140-i, Picarro Inc.) for about 7 min with a typical water concentration of 20 000 ppm. Memory effects were reduced by two times measuring a vapor mixture at a mixing ratio of 50 000 ppm, obtained from two injections of 2 µl for 5 min at the beginning of each new sample vial. Thereafter, another six injections of 2 µl per sample were measured individually as described above, and averages of the last five injections were used for further processing. Three standards were measured at the beginning and end of each batch, including a drift standard DI2 (δD: -50.72±0.73 permil, δ18O: -7.63±0.10 permil), and for calibration the laboratory standards GLW (δD: -307.79±0.75 permil, δ18O: -40.02±0.07 permil) and EVAP2 (δD: 9.52±0.65 permil, δ18O: 1.81±0.13 permil). A detailed calibration report is included with the final uploaded data set.

An overview of the measured results shows substantial day-to-day variability of the sample isotope composition (Figure 2, samples 1-17). The δ18O varied between -3.9 and -14.8 permil during the measurement period (-17.9 and -118.9 permil for δD). The d-excess showed mostly values above 10 permil, indicative of non-equilibrium fractionation during evaporation. Several daily samples showed substantially lower d-excess, likely indicating microphysical processes in and below the cloud (Graf et al. 2019).

During the higher-resolution IOP sampling periods, precipitation samples showed more moderate variability (Figure 2, samples 18-29), with increasing and decreasing depletion during the IOPs. The minimum δ18O was -12.5 permil and -12.8 permil for IOP1 (Figure 2, samples 18-24) and IOP2 (Figure 2, samples 25-29), respectively. The d-excess was clearly less variable during the two IOPs, remaining within a range of 19.5 to 32.6 permil, representative of non-equilibrium fractionation that is characteristic for cold-air outbreak conditions.

Variations in atmospheric pressure, wind speed, air temperature, and relative humidity indicate different weather events observed during the sampling period (Figure 3a, b). High variability of the isotopic composition of meteoric water samples likely reflects the shift in weather regimes and origin of the air masses arriving at the measurement site (Figure 3c, d). The mean temperature during the two IOPs (29.02-02.03 and 12.03-14.03) dropped to approximately 0°C, indicating arrival of cold-air masses (Figure 3a). According to the sampling log, the snow and graupel were the main precipitation types

during these events (green, dark blue, and light blue colors in the Figure 3d). The measured d-excess was above 20 permil for both IOPs, which indicates intense evaporation.

In forthcoming analyses, the results obtained here will be placed in relation to other samples taken along the Norwegian west coast, at Bergen, Ålesund, Tromsø, Longyearbyen, and Ny Ålesund. Particular case studies will be investigated, with the IOP sampling periods as the primary target. Lagrangian trajectory analysis will be used to investigate the air mass origin during these days. The below-cloud interaction models of Graf et al. (2019) and microphysics parametrizations, as, for example, described in Aemisegger et al. (2015), will be particularly useful to estimate the isotope signal from evaporation to cloud level contained in surface precipitation.

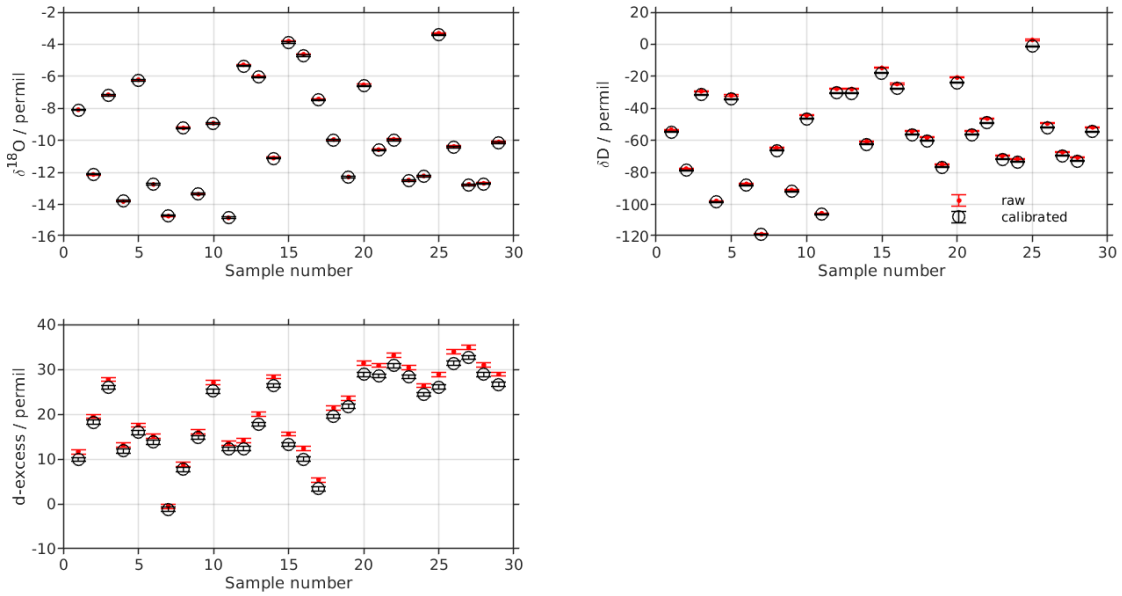

Figure 2. Overview plot of stable isotope parameters for raw and calibrated samples. (a) $\delta^{18}O$ (permil), (b) δD (permil), (c) d-excess (permil). Red symbols are raw data, black after sample calibration to VSMOW2-SLAP2 scale. Samples 1-17 are daily samples, samples 18-30 are from IOP1 and IOP2.

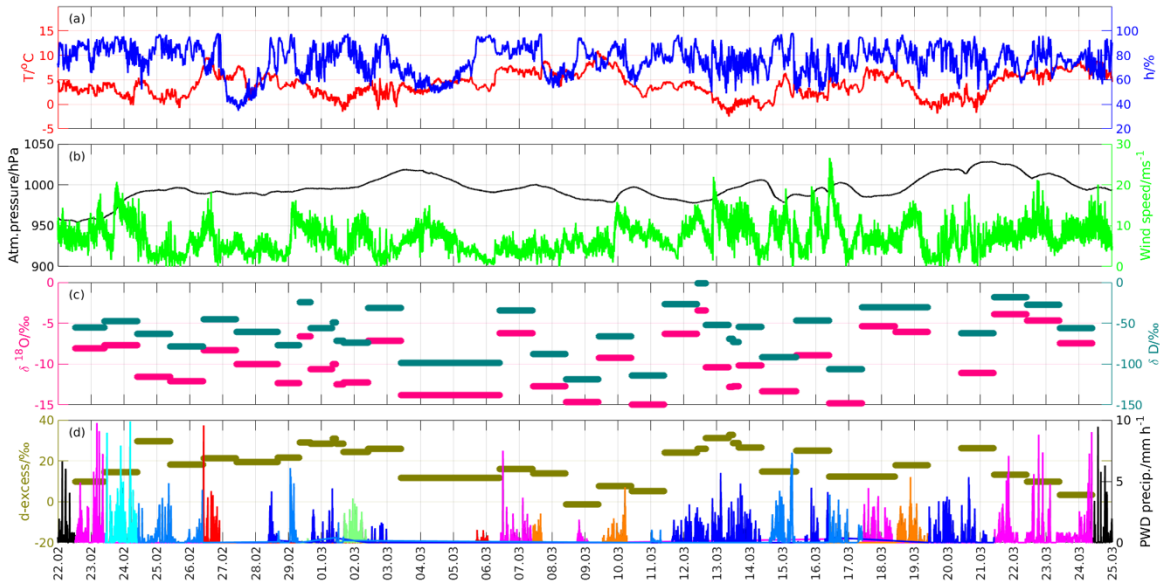

Figure 3. Time series of observations in Andenes between 00 UTC 22 February and 00 UTC 25 March 2020. (a) Local temperature (T; red) and relative humidity (h; blue) measured by the COMBLE meteorological station. (b) Atmospheric pressure (black) and wind speed (green). (c) The isotopic composition of precipitation samples: δ18O (magenta) and δD (light blue). (d) Same as in (c), but for d-excess (light brown) and sample type based on campaign log (unclassified [black], rain[magenta], sleet [red]; frozen rain [orange], graupel [green], snow [light blue], graupel/snow [dark blue], ice [cyan]). The mean precipitation rate for different sample types obtained from a present weather detector is shown in the right axis.

3.0 Publications and References

Aemisegger, F, JK Spiegel, S Pfahl, H Sodemann, W Eugster, and H Wernli. 2015. "Isotope meteorology of cold front passages: A case study combining observations and modeling." *Geophysical Research Letters* 42(13): 5652–5660, https://doi.org/10.1002/2015GL063988

Atmospheric Radiation Measurement (ARM) user facility. 2019, updated hourly. Surface Meteorological Instrumentation (MET). 2020-02-01 to 2020-04-01, ARM Mobile Facility (ANX) Andenes, Norway; AMF1 (main site for COMBLE) (M1). Compiled by J. Kyrouac and D. Holdridge. ARM Data Center. Data set accessed 2020-11-03 at http://dx.doi.org/10.5439/1025220

Graf, P, H Wernli, S Pfahl, and H Sodemann. 2019. "A new interpretative framework for below-cloud effects on stable water isotopes in vapour and rain." *Atmospheric Chemistry and Physics* 19(2): 747–765, https://doi.org/10.5194/acp-19-747-2019

ISLAS2020 field campaign and data report. 2020. Geophysical Institute, University of Bergen, Norway, unpublished report.

www.arm.gov

U.S. DEPARTMENT OF
ENERGY

Office of Science