La neige du Svalbard

Hans-Werner Jacobi, Jean-Pierre Dedieu, Paul Tudes, Olivier Champagne, Olga Zolina

IGE, Univ. Grenoble Alpes/CNRS/INRAE/IRD/Grenoble INP, Grenoble, France

Anna Wendleder

German Aerospace Center (DLR), Oberpfaffenhofen-Weßling, Germany

Eric Bernard

Laboratoire ThéMa, CNRS/University of Franche-Comté, Besançon, France

Jean-Michel Friedt

FEMTO-ST, CNRS/University of Franche-Comté, Besançon, France

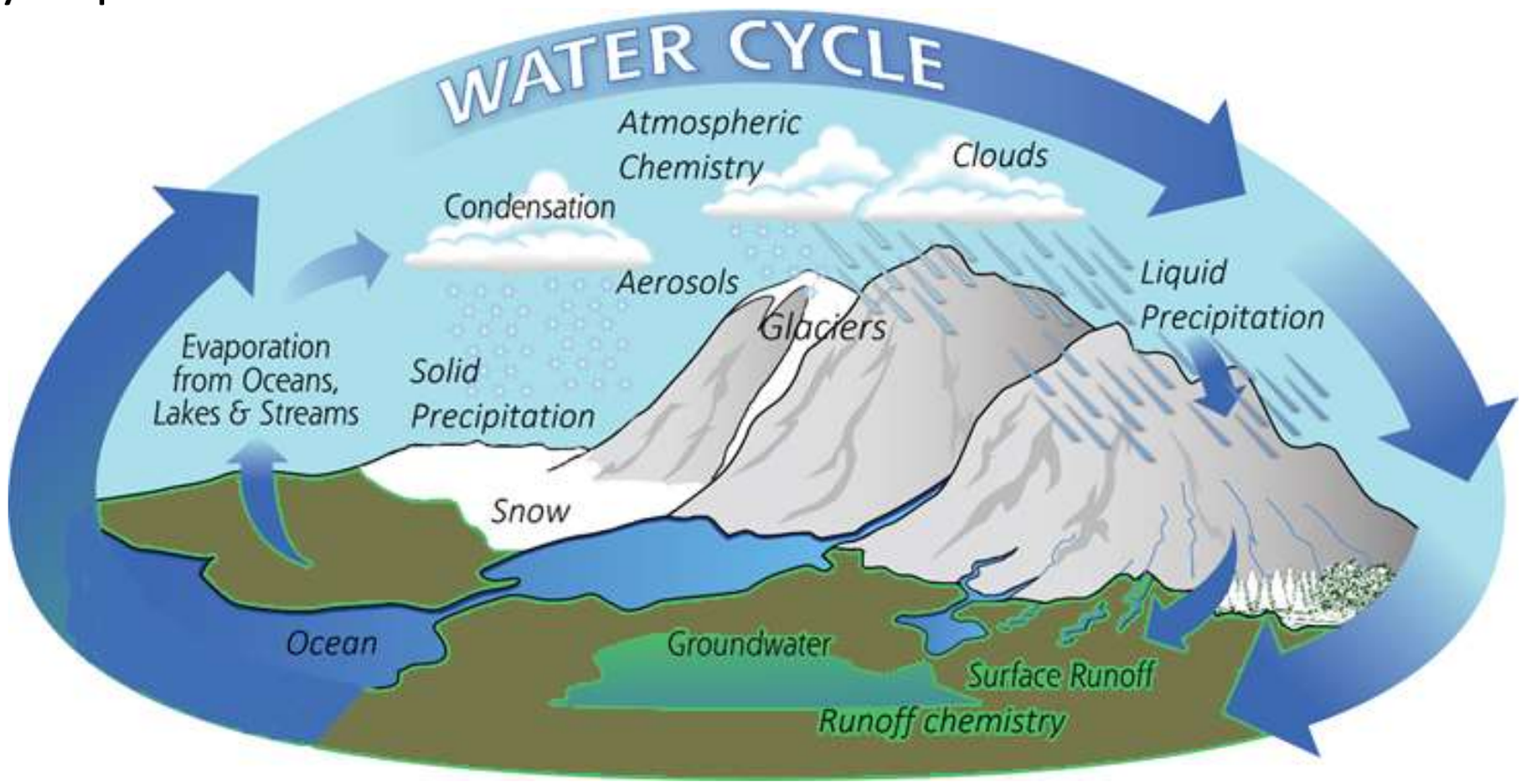
Overwintering personnel of the *AWIPEV & Sverdrup Station of the Norwegian Polar Institute*

Atelier Neige, 22/03/2024

ARCSNOW: Snow-atmosphere interactions and deposition in the Arctic

The objectives of ARCSNOW are

- to understand changes in the water cycle in the Arctic
- to study biogeochemical cycles in the Arctic
- to quantify wet and dry deposition in the Arctic

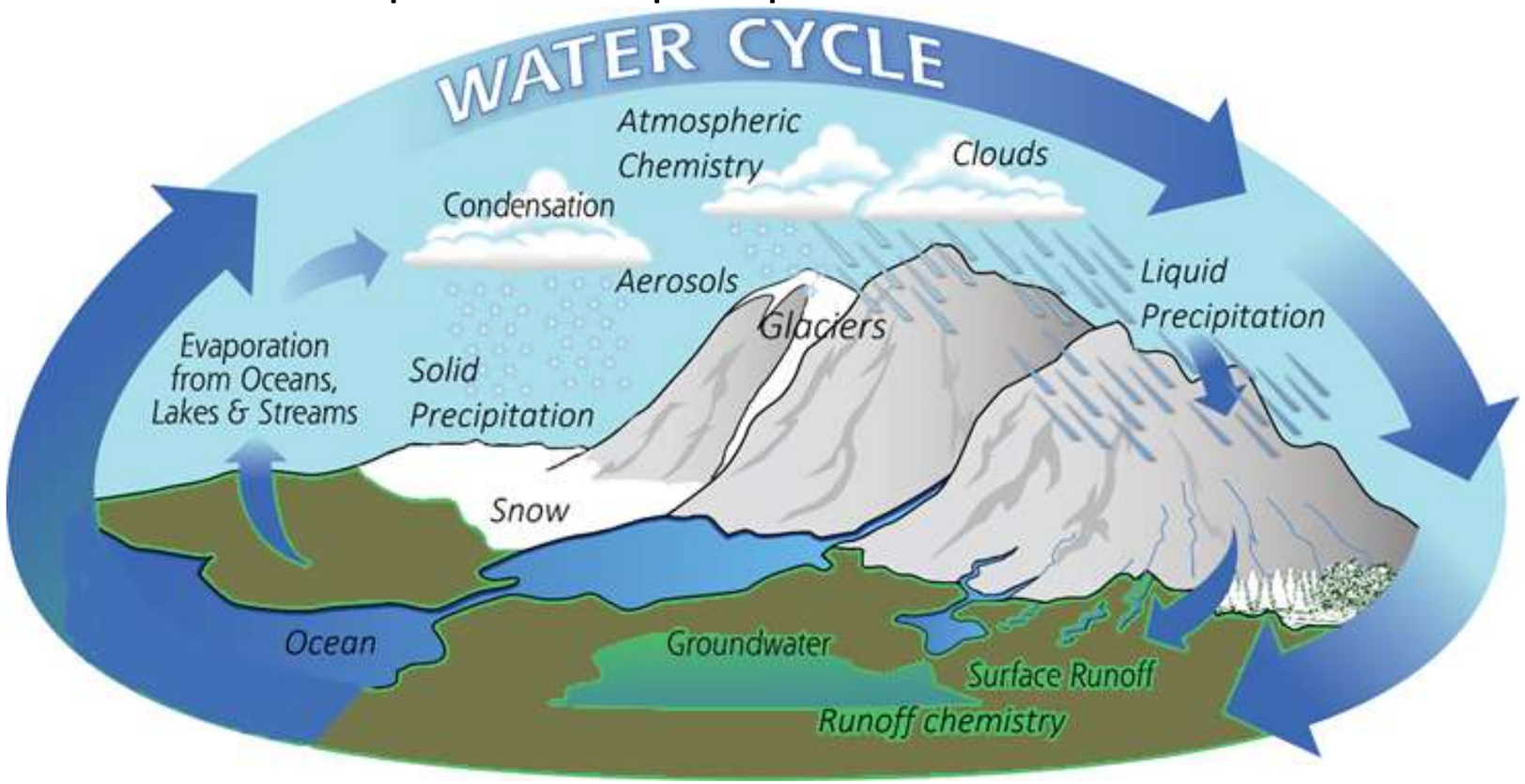


Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Snow-atmosphere interactions and deposition in the Arctic

ARCSNOW includes

- **year-round observations** of precipitation and snow
- the determination of snowpack properties and their spatial variability
- the determination of the chemical composition of precipitation and snow



Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Snow-atmosphere interactions and deposition in the Arctic

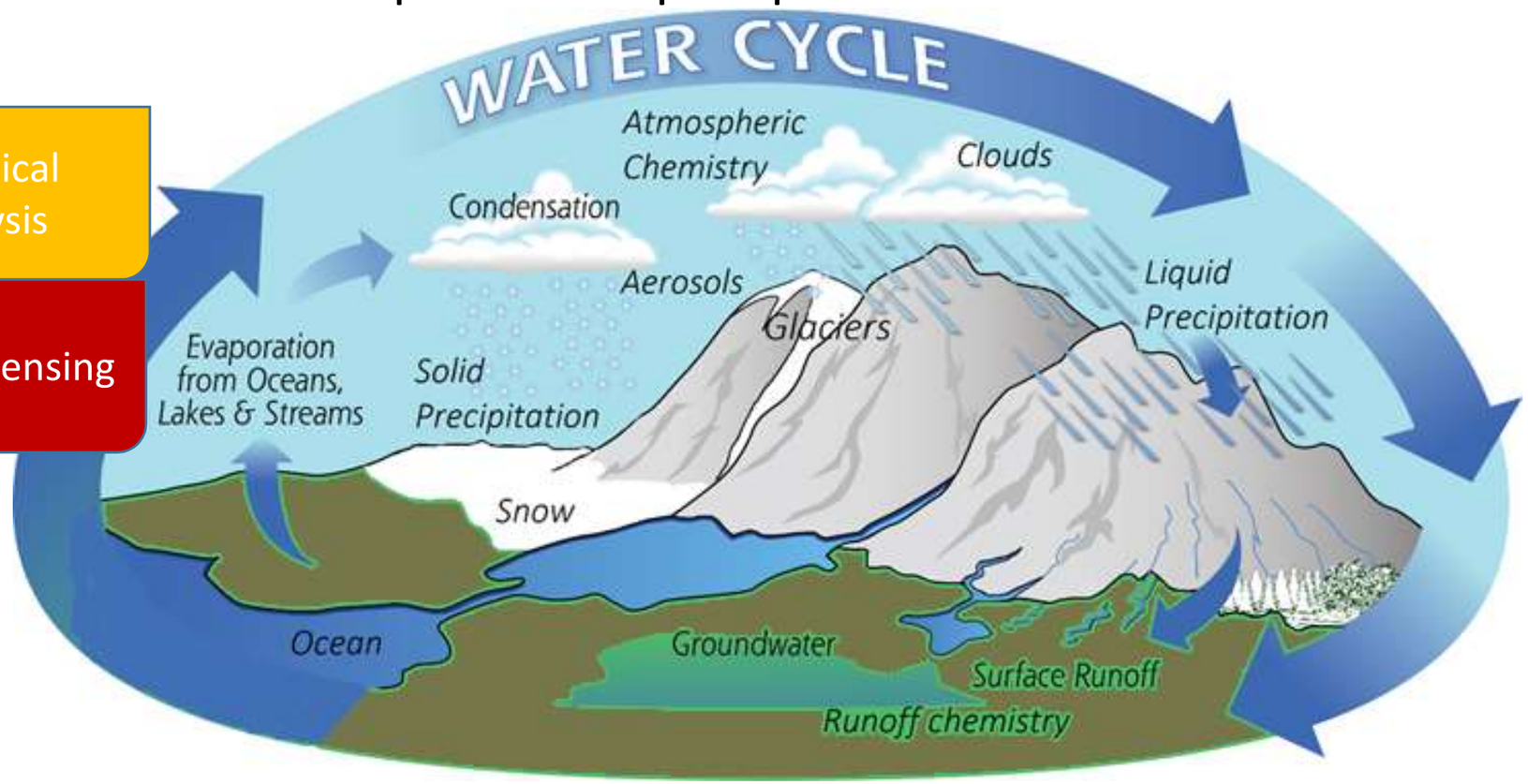
ARCSNOW includes

- year-round observations of precipitation and snow
- the determination of snowpack properties and their spatial variability
- the determination of the chemical composition of precipitation and snow

Field measurements and sampling

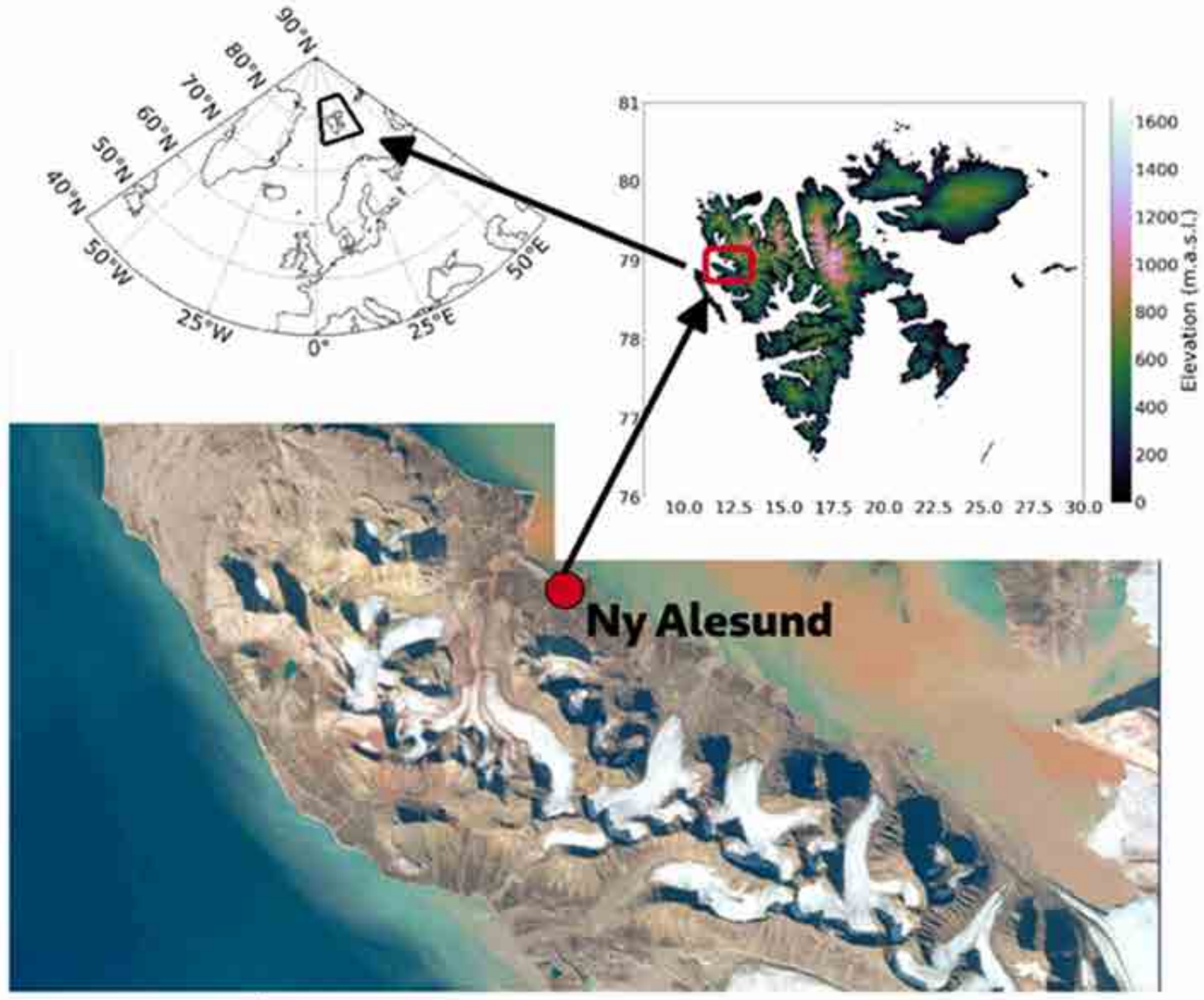
Chemical analysis

Remote sensing



Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Observations at Ny-Alesund, Svalbard



Champagne et al., *J.Hydromet.*, in press 2024

Institute of Environmental Geosciences, Grenoble, France

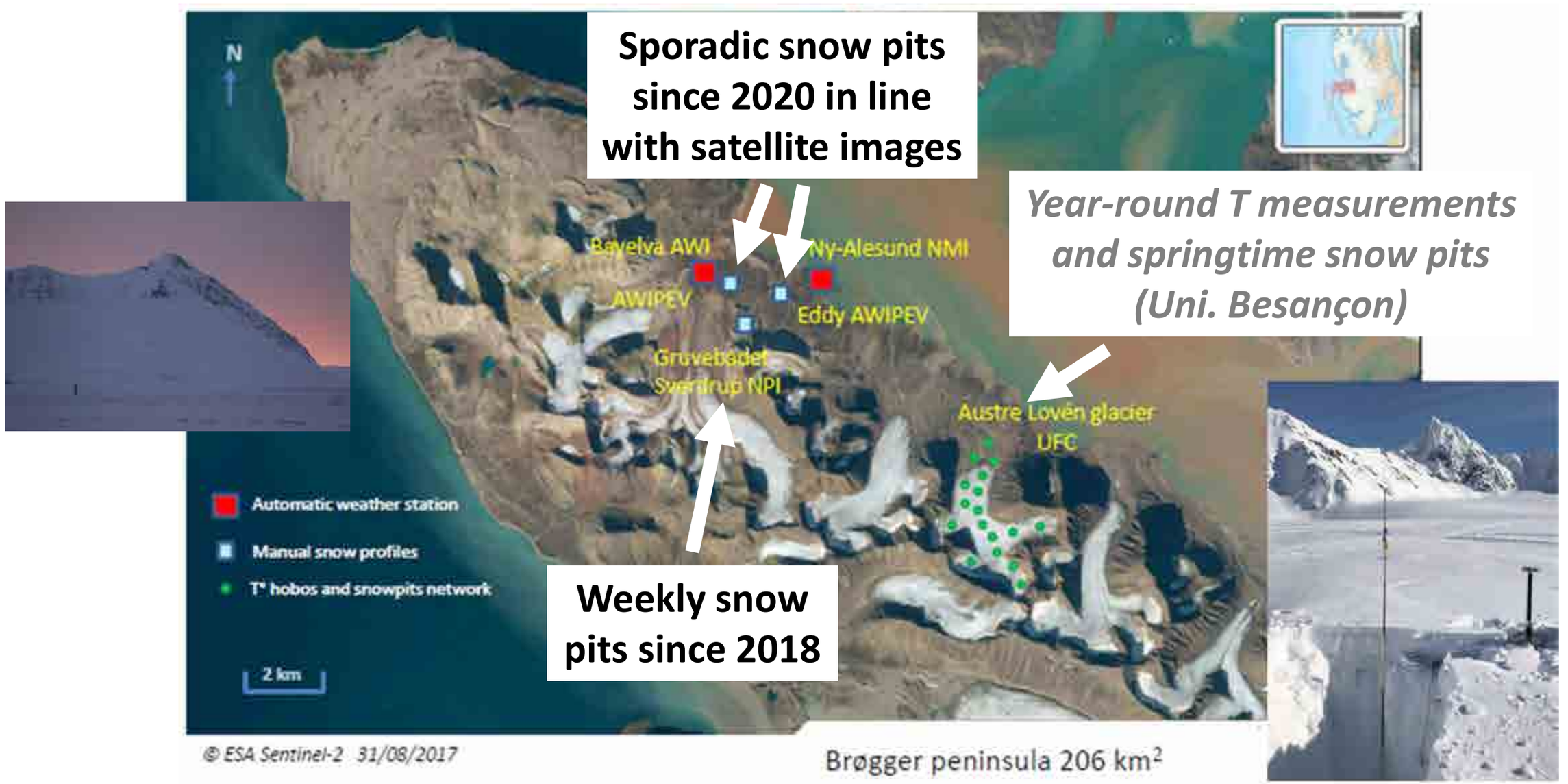
ARCSNOW: Observations at Ny-Alesund, Svalbard

Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Observations at Ny-Alesund, Svalbard

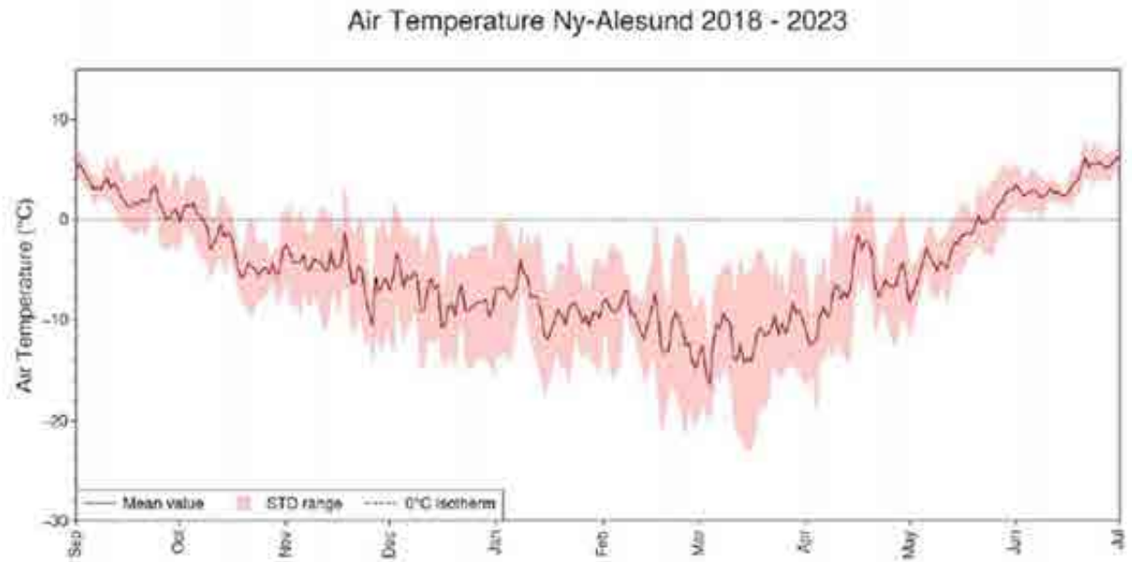
Institute of Environmental Geosciences, Grenoble, France

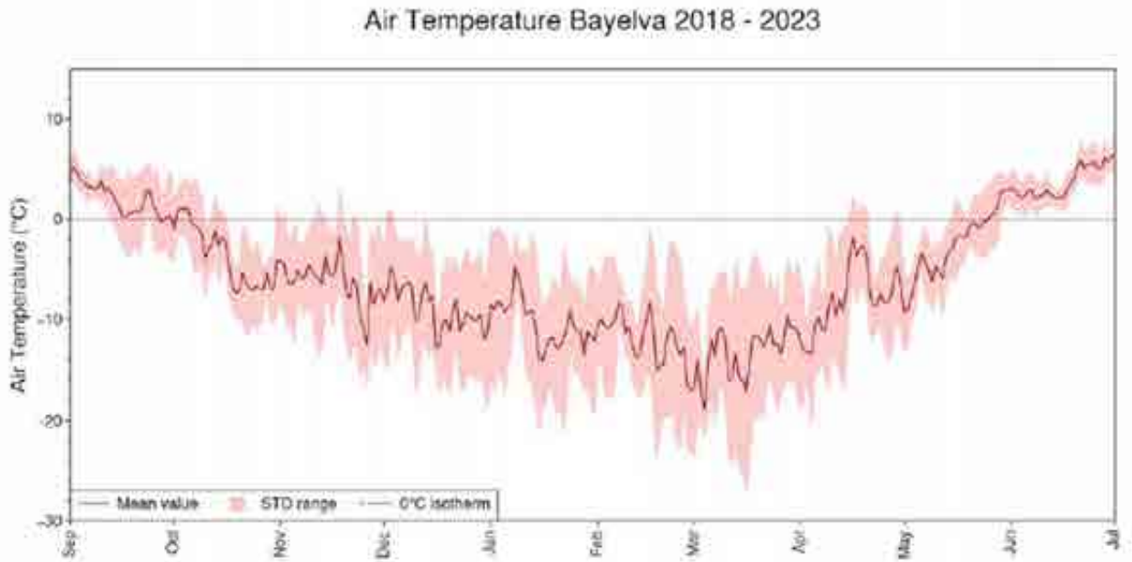
ARCSNOW: Observations at Ny-Alesund, Svalbard

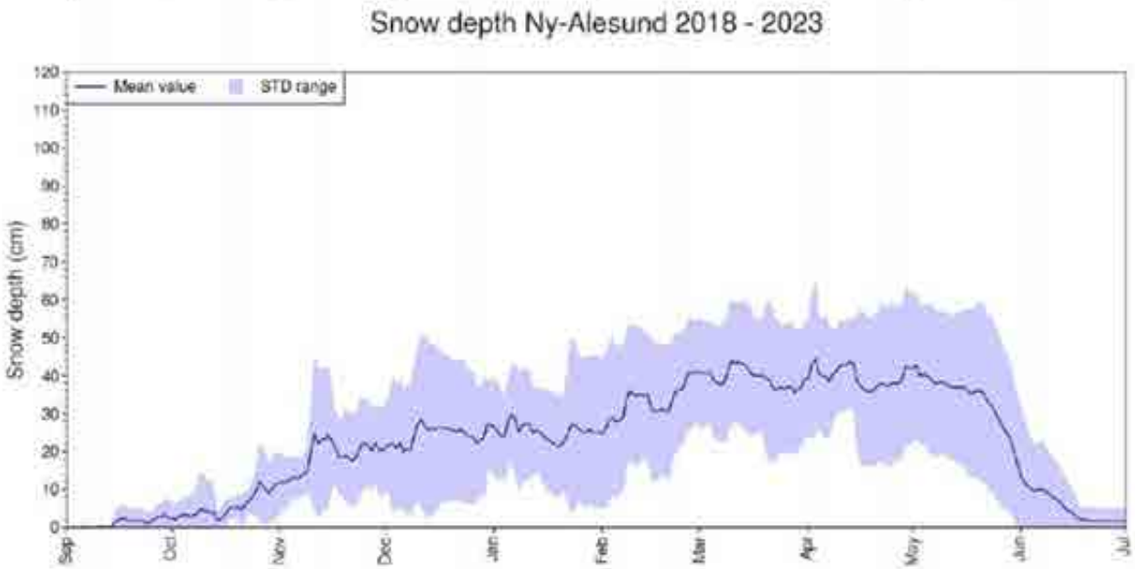


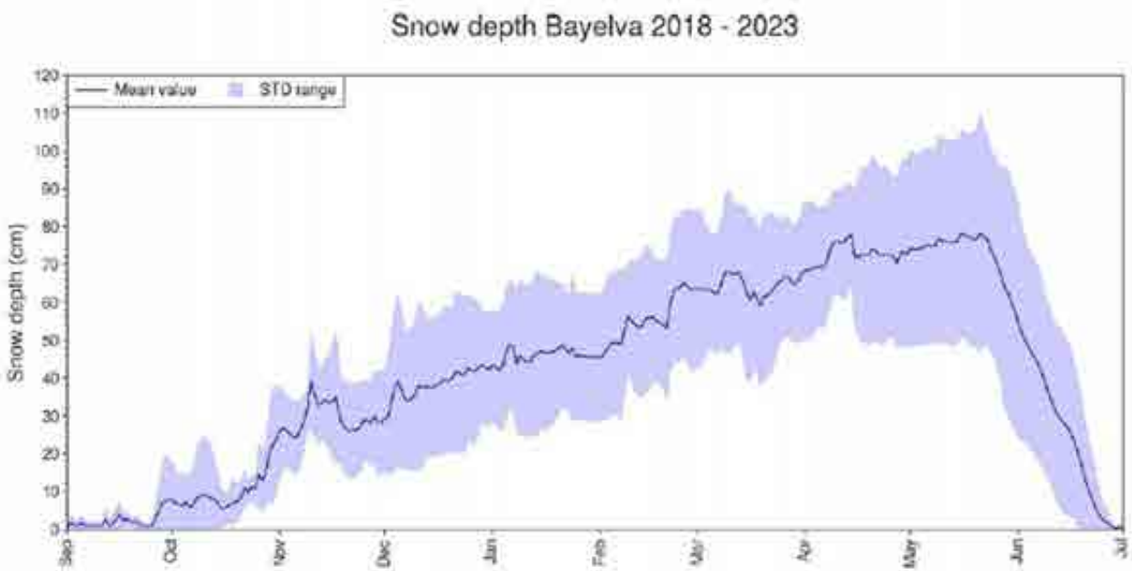
Institute of Environmental Geosciences, Grenoble, France

Observations at Ny-Alesund and Bayelva: Temperature and snow depth 2018-2023



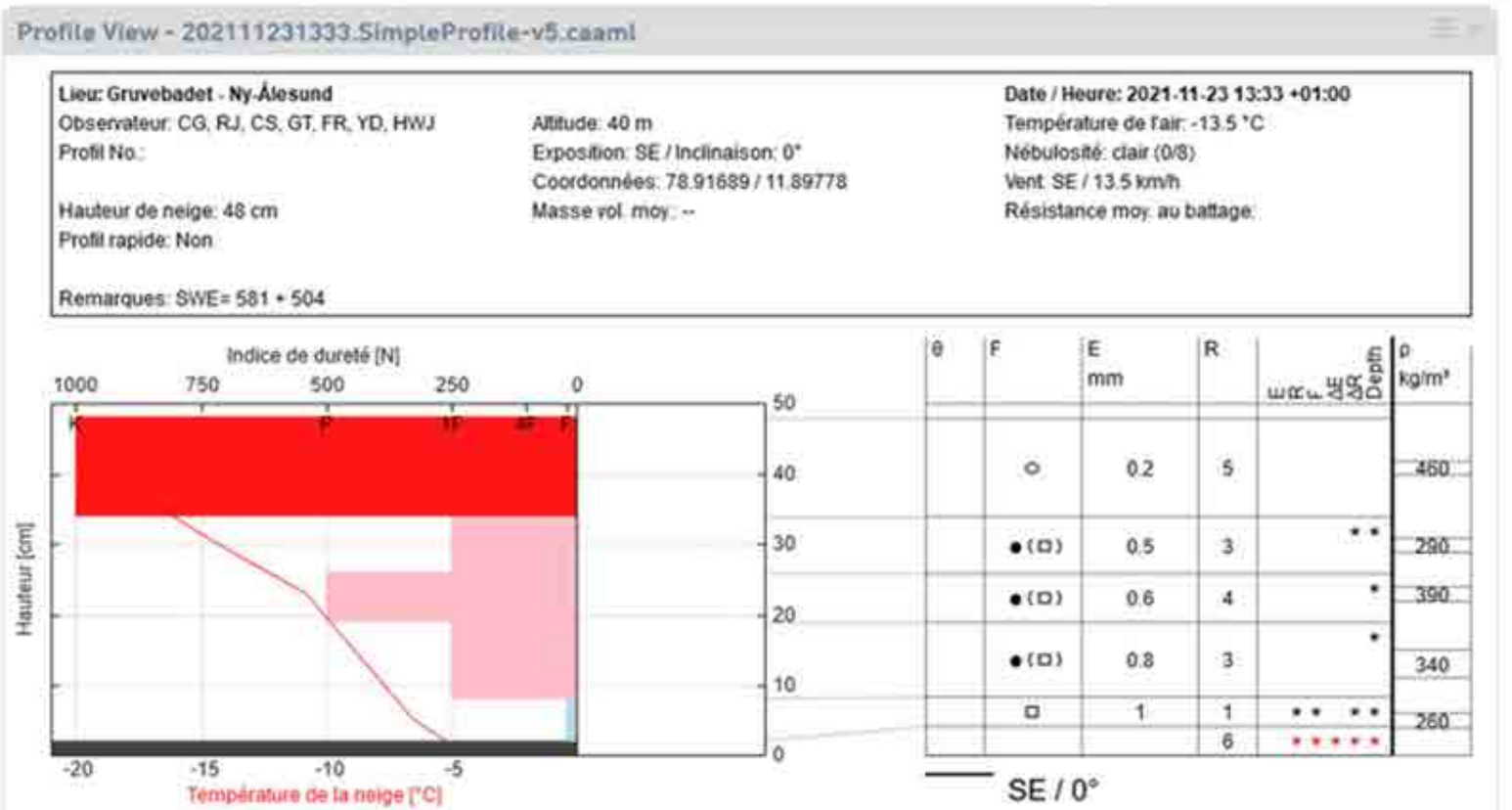






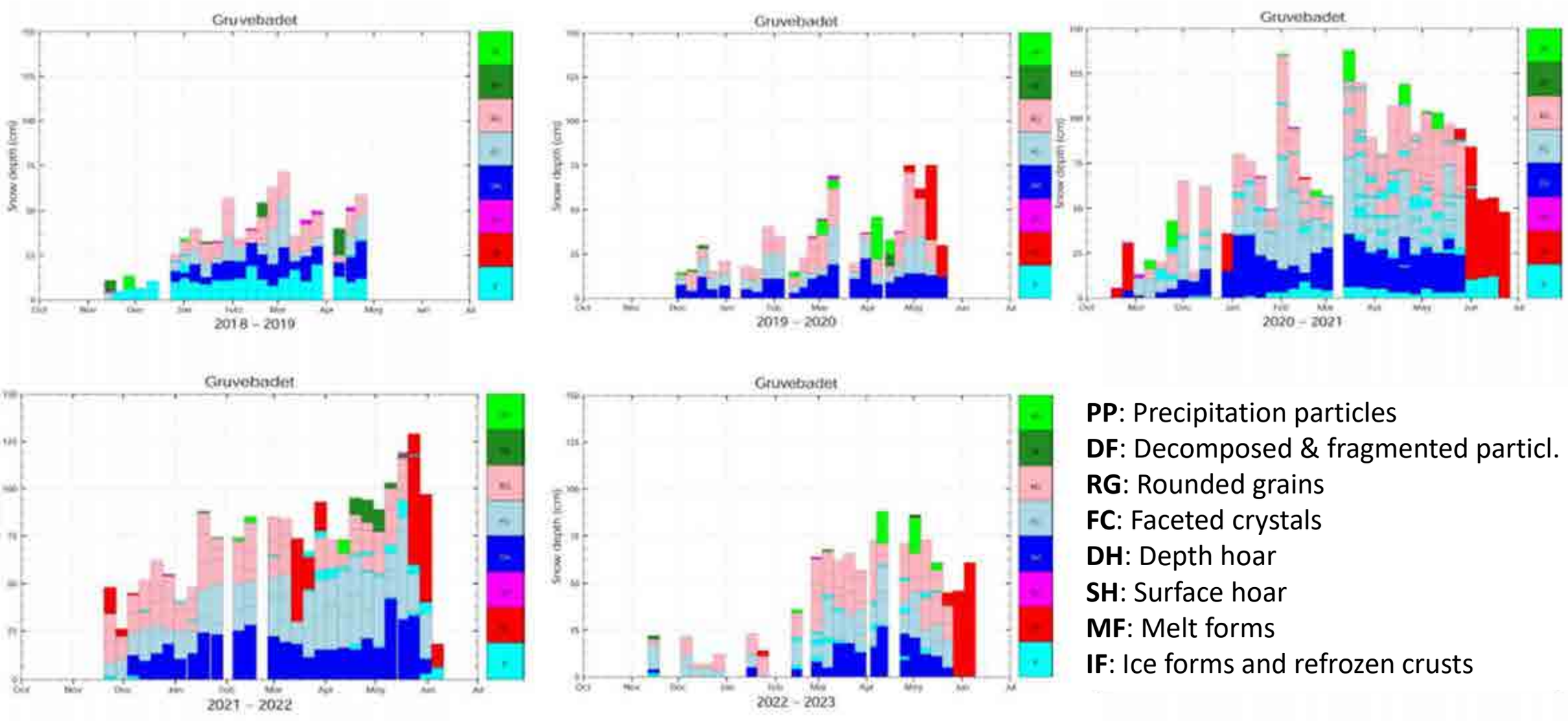
Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Weekly snow pits at Gruvebadet



Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: High annual variability at Gruvebadet

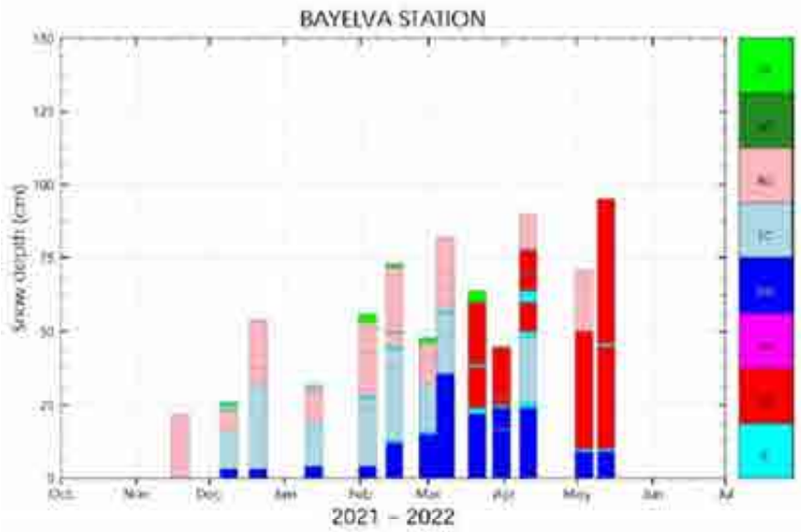


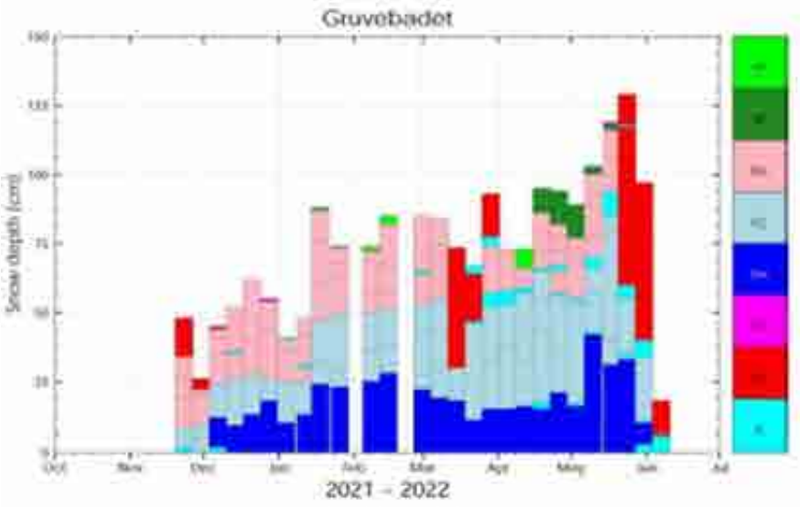
PP: Precipitation particles
DF: Decomposed & fragmented particl.
RG: Rounded grains
FC: Faceted crystals
DH: Depth hoar
SH: Surface hoar
MF: Melt forms
IF: Ice forms and refrozen crusts

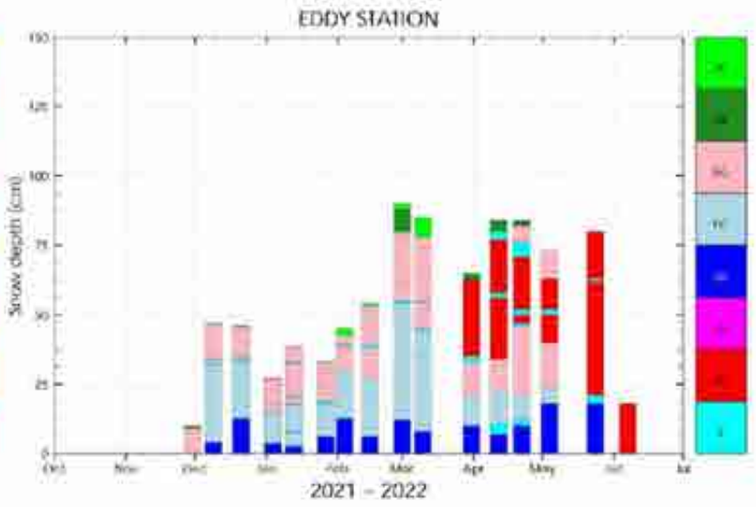
Institute of Environmental Geosciences, Grenoble, France

according to Fierz et al., 2009

ARCSNOW: High spatial variability





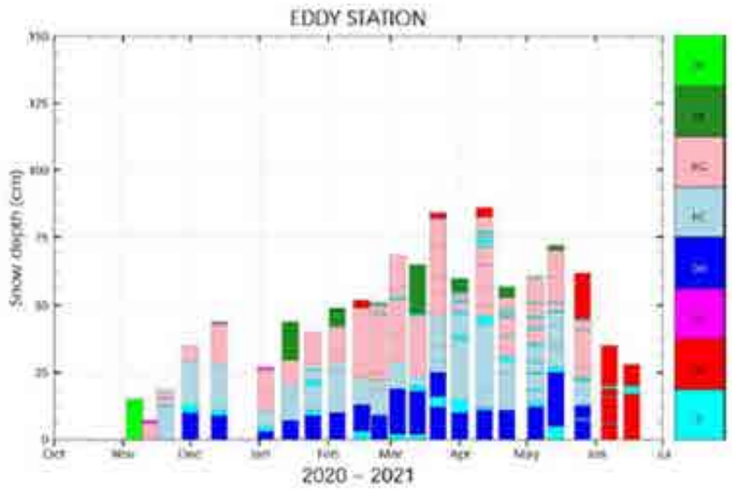


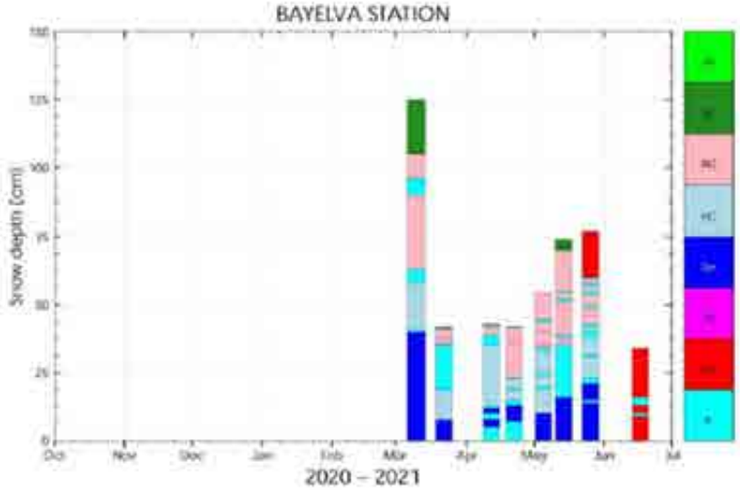
PP: Precipitation particles
DF: Decomposed & fragmented particl.
RG: Rounded grains
FC: Faceted crystals
DH: Depth hoar
SH: Surface hoar
MF: Melt forms
IF: Ice forms and refrozen crusts

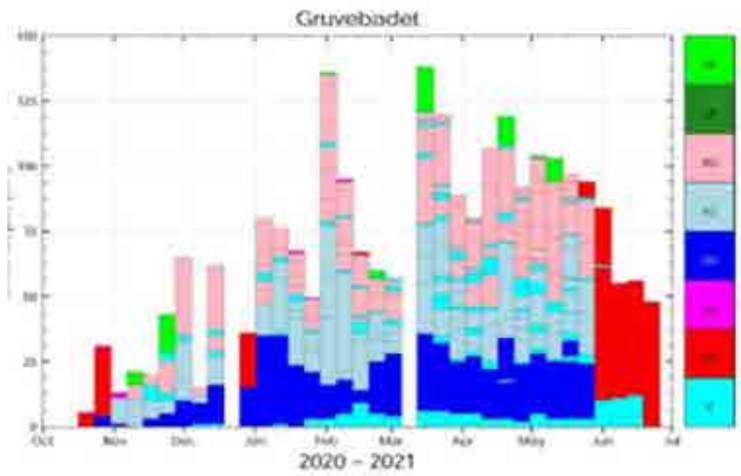
according to Fierz et al., 2009

Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: High spatial variability





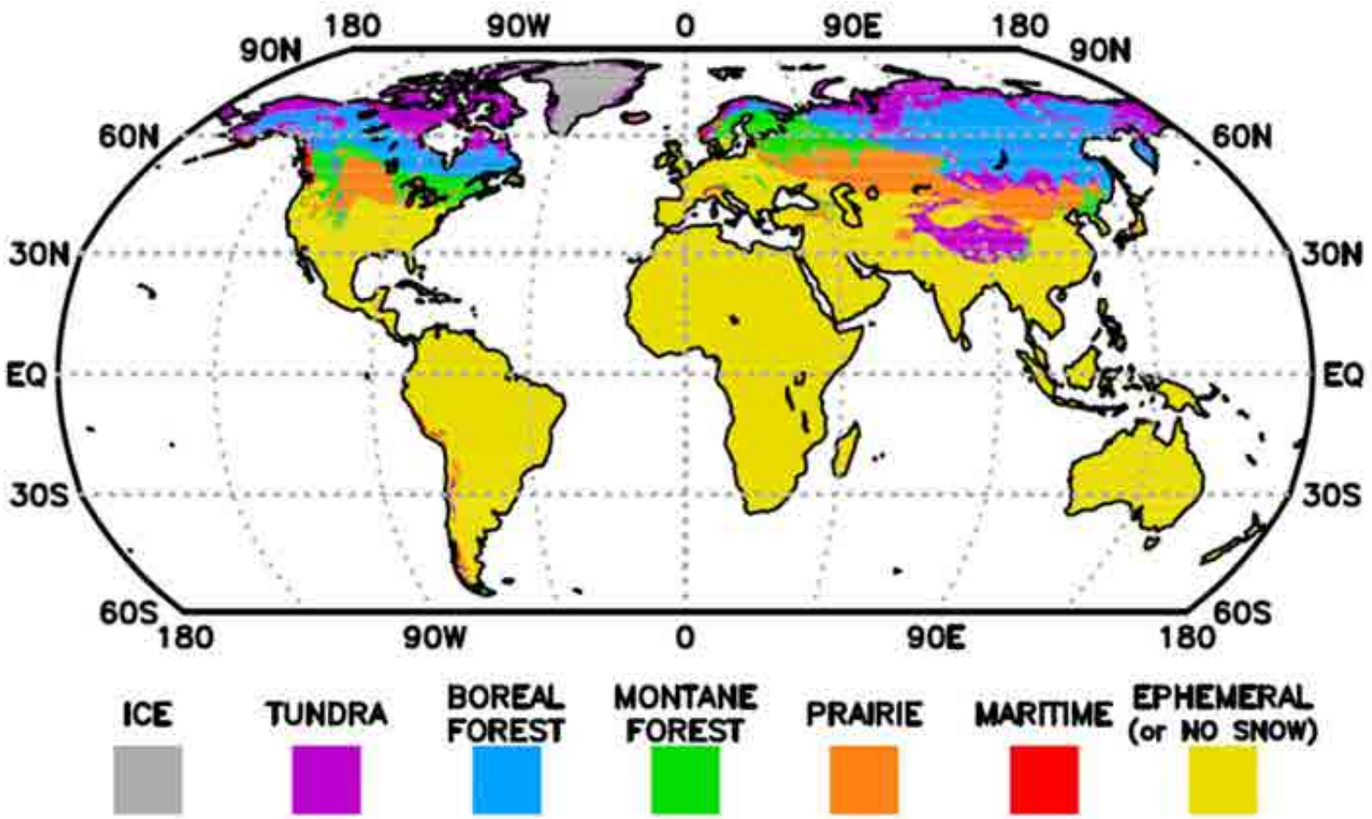


PP: Precipitation particles
DF: Decomposed & fragmented particl.
RG: Rounded grains
FC: Faceted crystals
DH: Depth hoar
SH: Surface hoar
MF: Melt forms
IF: Ice forms and refrozen crusts

according to Fierz et al., 2009

Institute of Environmental Geosciences, Grenoble, France

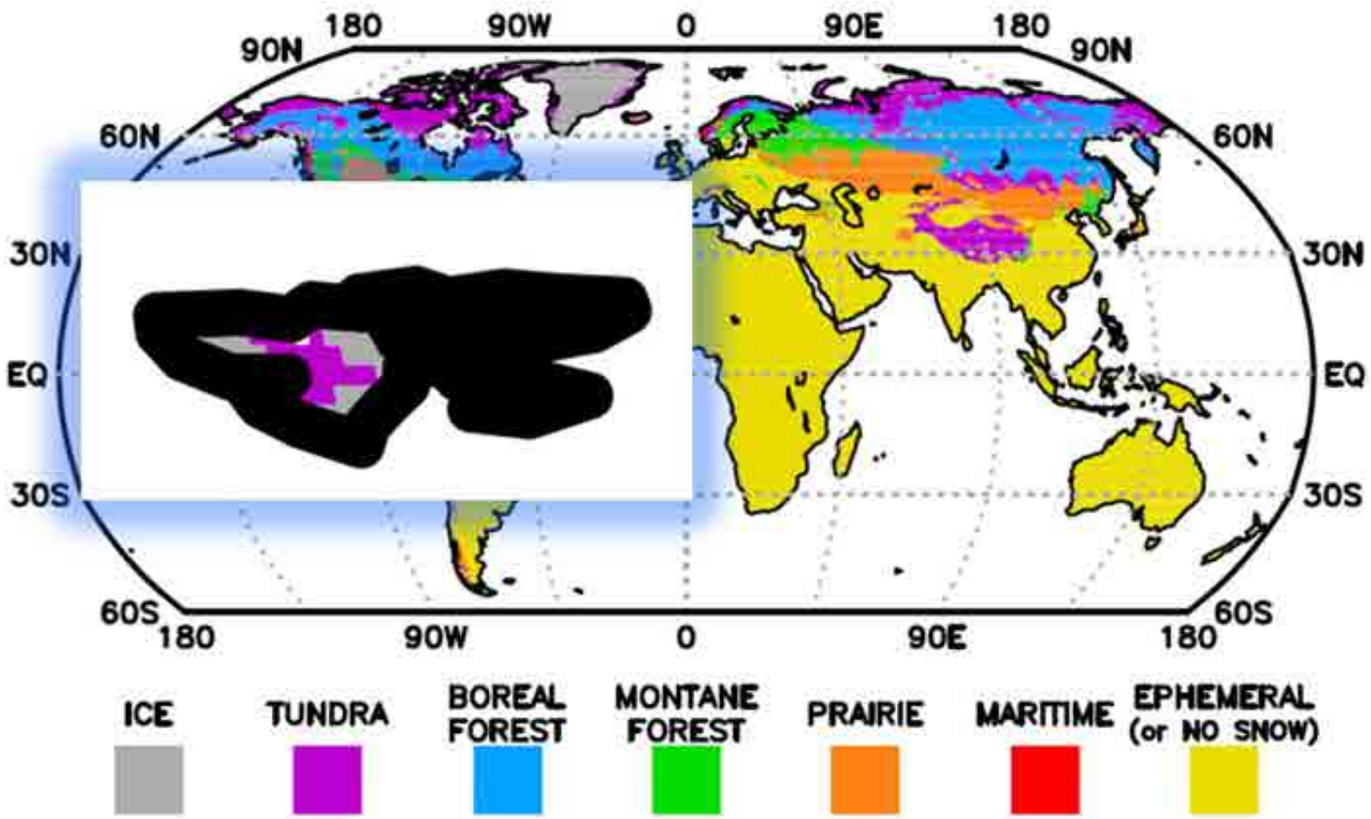
What class of snow at Ny-Alesund to expect?



Institute of Environmental Geosciences, Grenoble, France

Sturm & Liston, J.Hydromet. 2021

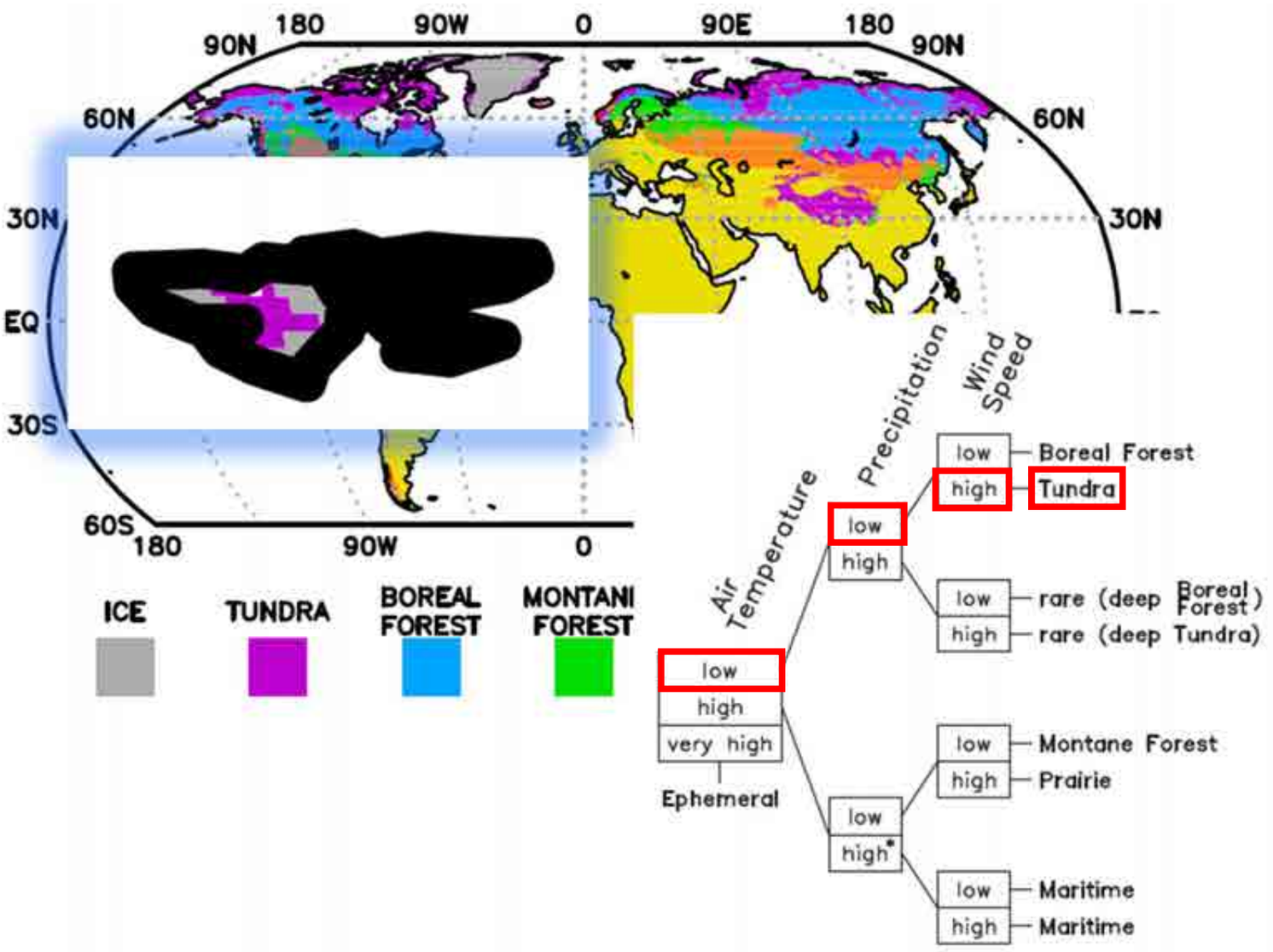
What class of snow at Ny-Alesund to expect?

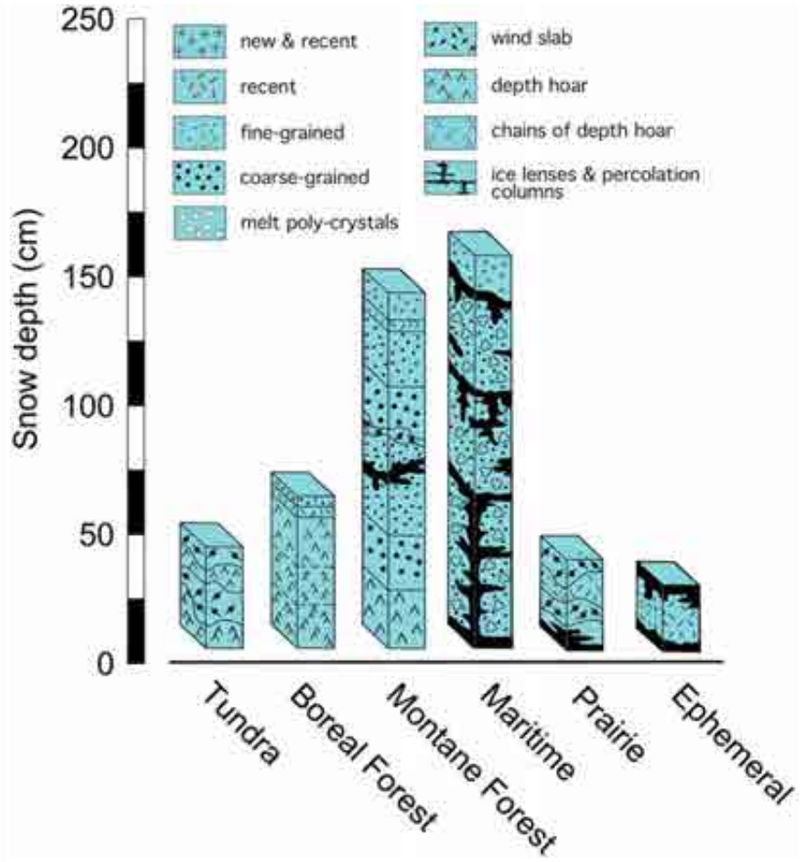


Institute of Environmental Geosciences, Grenoble, France

Sturm & Liston, J.Hydromet. 2021

What class of snow at Ny-Alesund to expect?

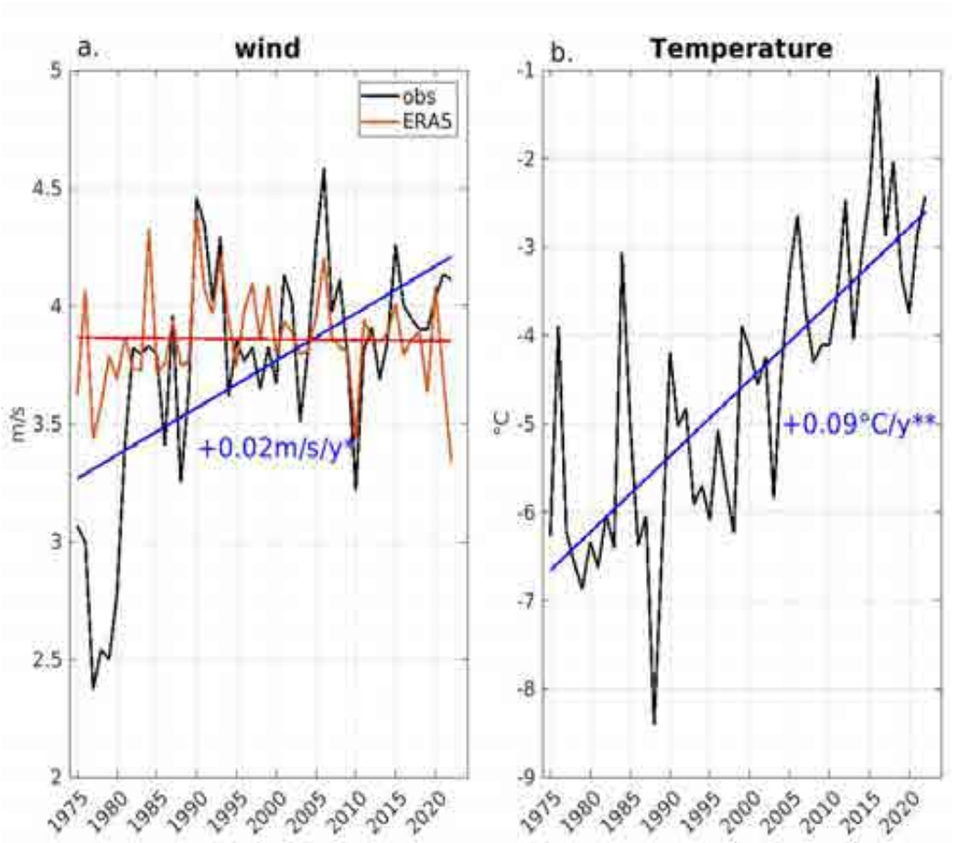


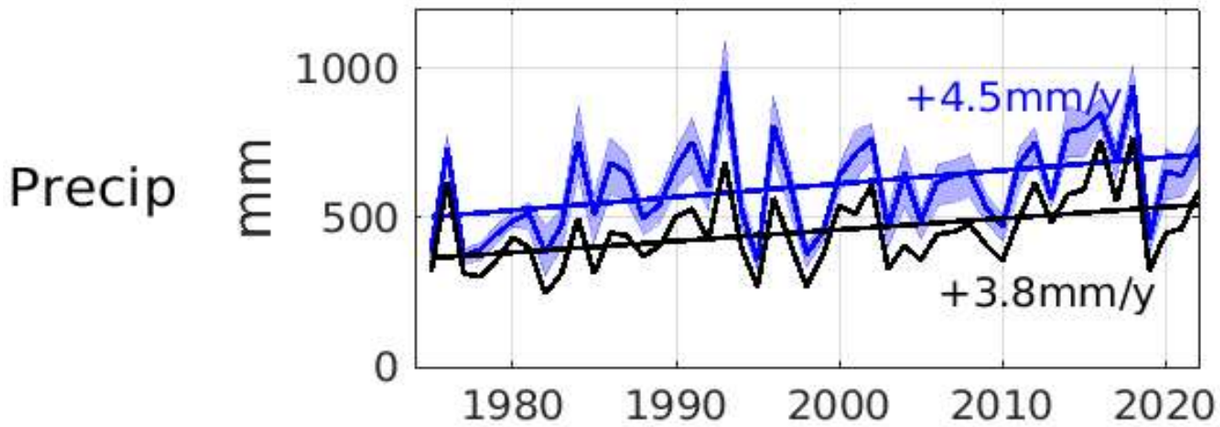


Institute of Environmental Geosciences, Grenoble, France

Sturm & Liston, *J.Hydromet.* 2021

Strong changes in the last 48 years at Ny-Alesund



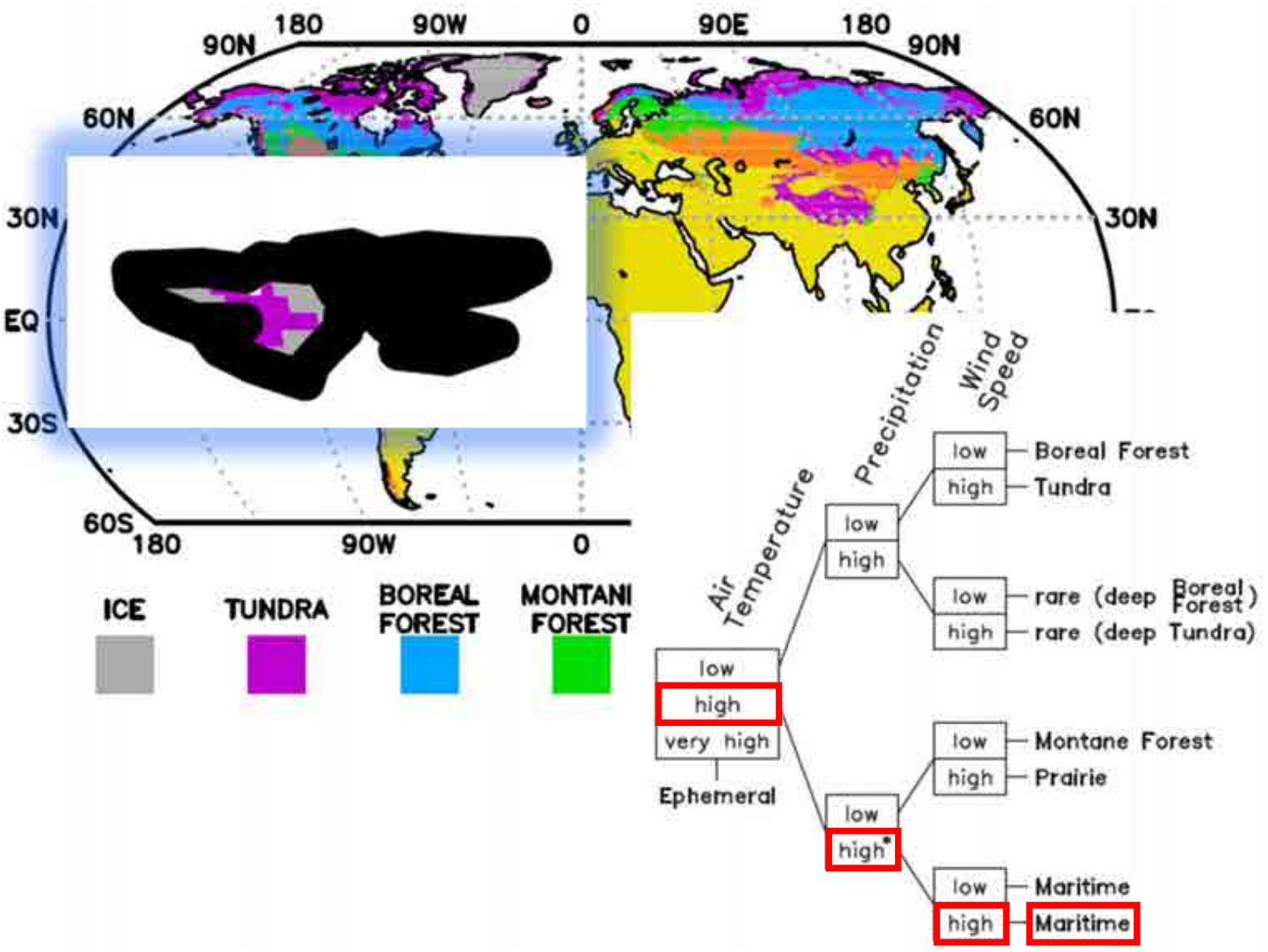


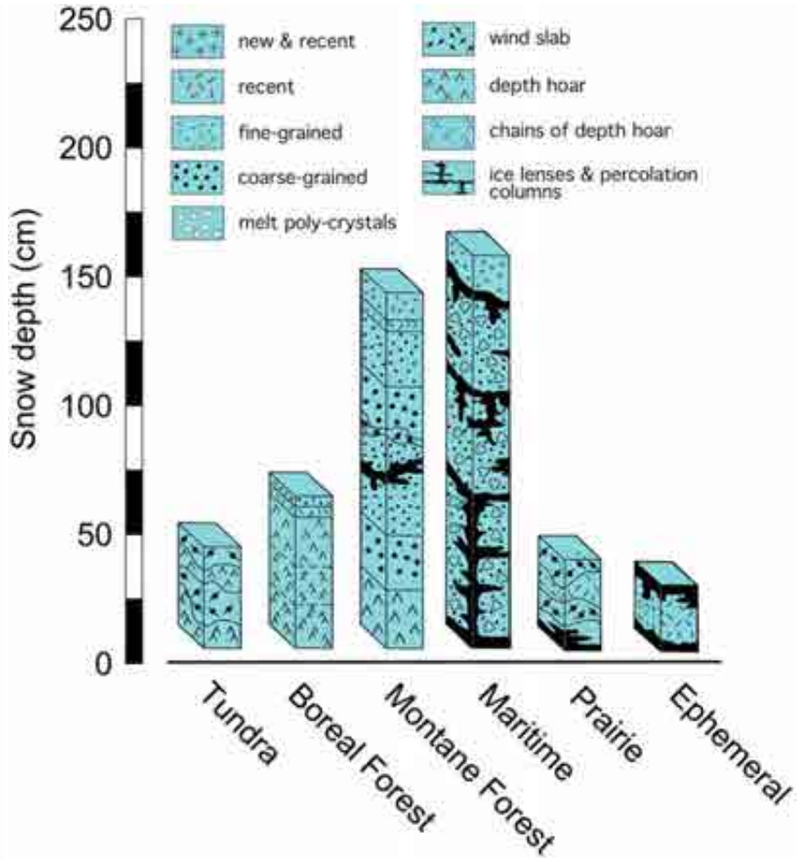
	Trend 1975 – 2022	Increase
Wind speed – Observations	+0,02 m s^{-1} per year	~1 m s^{-1}
Wind speed – ERA 5	**No trend**	**0**
Temperature	**+0,09 °C per year**	**+4,3 °C**
Precipitation	**+4,5 mm per year**	**+220 mm**

Champagne et al., *J.Hydromet.*, in press 2024

Institute of Environmental Geosciences, Grenoble, France

What class of snow at Ny-Alesund to expect?

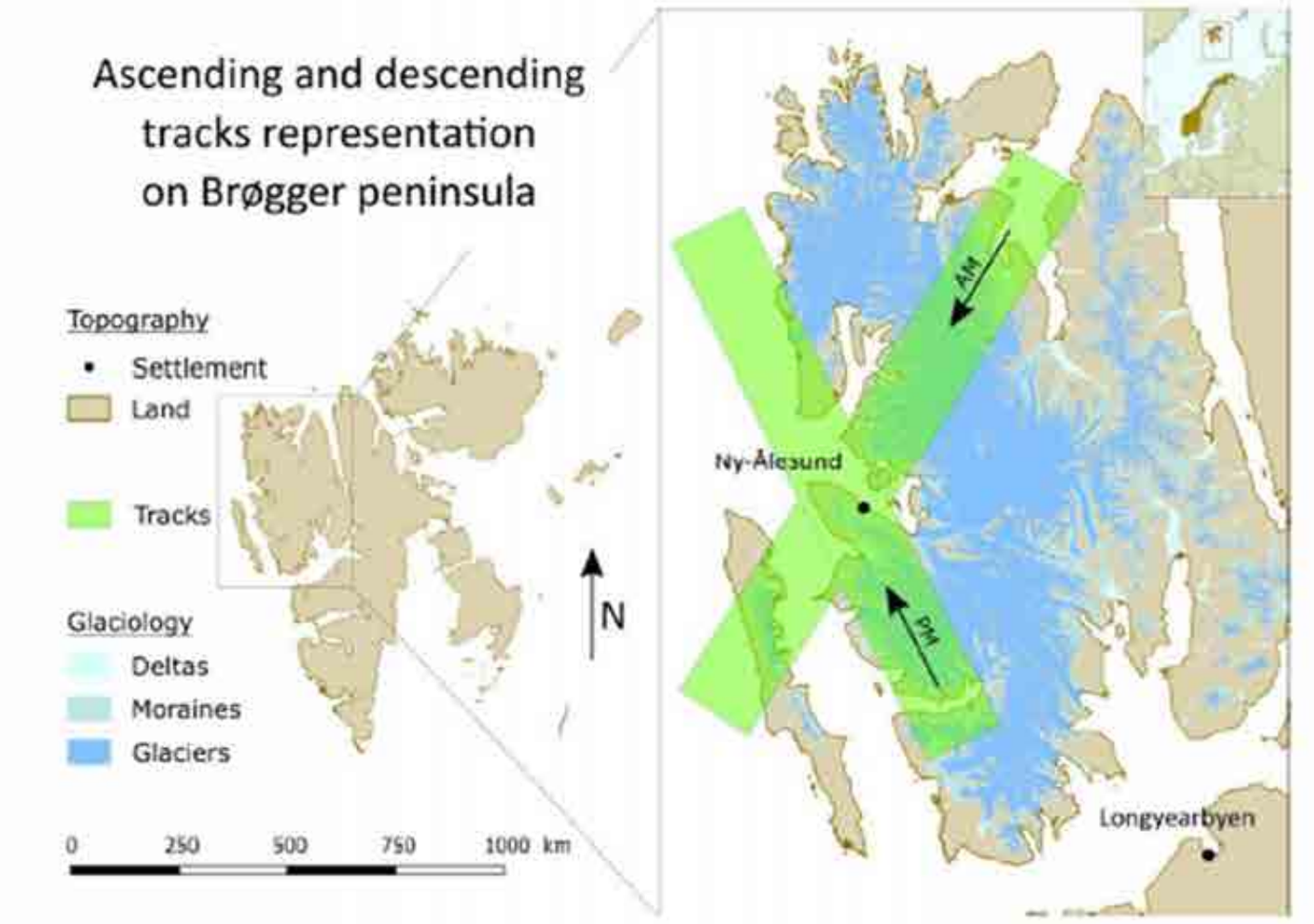




Institute of Environmental Geosciences, Grenoble, France

Sturm & Liston, *J.Hydromet.* 2021

ARCSNOW: Use remote sensing techniques to address the spatial variability of snow properties



Satellite TerraSAR-X (DLR)

- regular SAR Images since September 2018
- 36h pairwise orbits : over path at 06:30 and 15:40 UTC
- 11-day cycle
- X-band = 3.1 cm (9.6 GHz)
- 5-m resolution

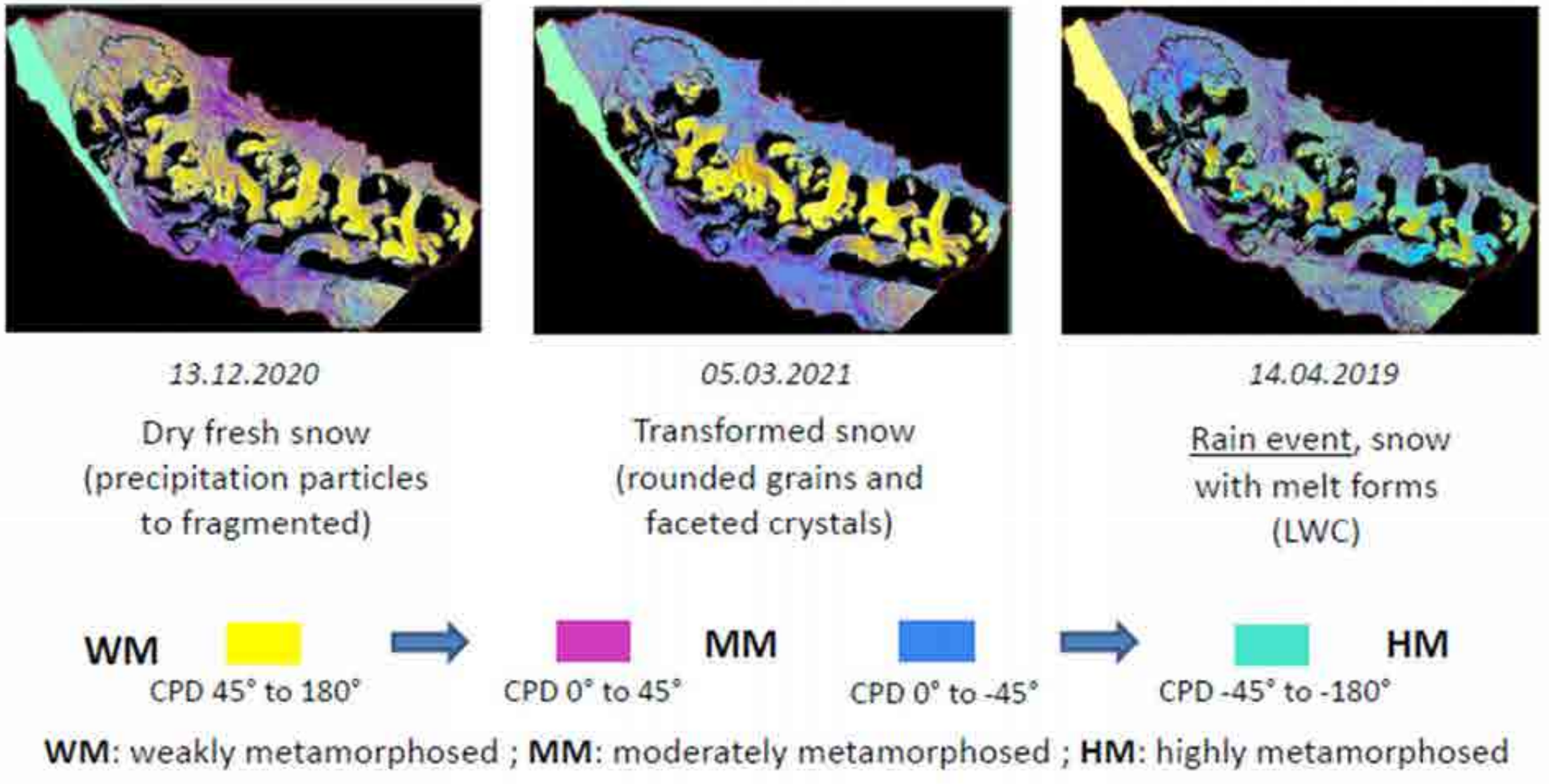
Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Mapping of snow metamorphism at a regional scale

Cross-polar difference: polarimetric SAR method to determine the degree of snow metamorphism from dry (positive °) to transformed (negative °)

Three representative cases of snow metamorphism

(all areas are covered by snow ; terrestrial black: slopes > 25°= SAR shadow mask)

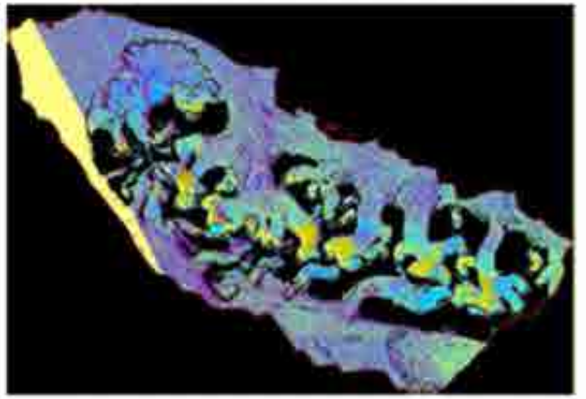


Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Mapping of snow metamorphism at a regional scale

Cro ee of snow metamorphism
°)

31/01/2024
c/o Mathilde Carbonnel



14.04.2019

Rain event, snow with melt forms (LWC)

WM: weakly metamorphosed ; **MM**: moderately metamorphosed ; **HM**: highly metamorphosed

Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Characterization of rain-on-snow (ROS) events at Ny-Alesund

Institute of Environmental Geosciences, Grenoble, France

Sensors design and ROS events

Sensor	Radarsat Constellation Mission (RCM)	TerraSAR-X (TSX)
Band	C	X
Frequency (GHz)	5.4	9.6
Wavelength (cm)	5.6	3.1
Repeat cycle (day)	4	11
Resolution (m)	5 (CP) & 9 (QP)	5
Incidence Angle (°)	33 to 43	36 to 39
Acquisition mode	Quad-Pol & Comp-Pol (SLC)	Dual-Pol HH VV (SLC)

Liquid precipitation at Ny-Alesund

ROS dates	P (mm)	RCM	TSX
05 - 10/02/2017	75	/	X
13 - 14/01/2018	64	/	X
27/02/2018	45	/	X
17 - 18/04/2019	43	/	X
03 - 04/01/2021	27	/	X
15 - 16/03/2022	63	X	/
02 - 03/12/2022	53	X	/
22 - 24/05/2023	42	X	X

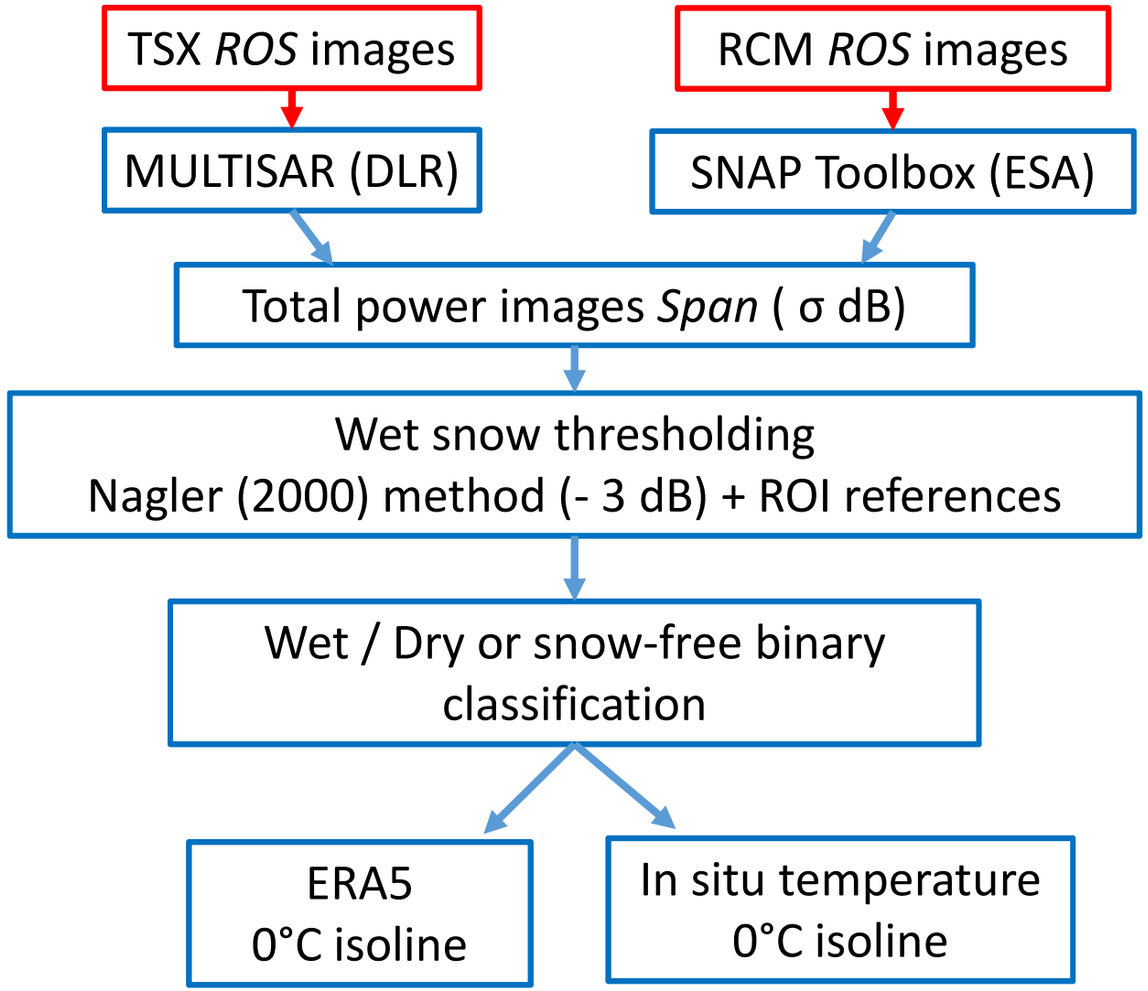
ARCSNOW: Workflow for SAR data processing

PRE-PROCESSING
(radio- & geometric correction)

MASTER IMAGES
for dry snow
(*13/12/20, 01/01/22, 06/02/22*)

OUTPUT PRODUCTS
(mapping)

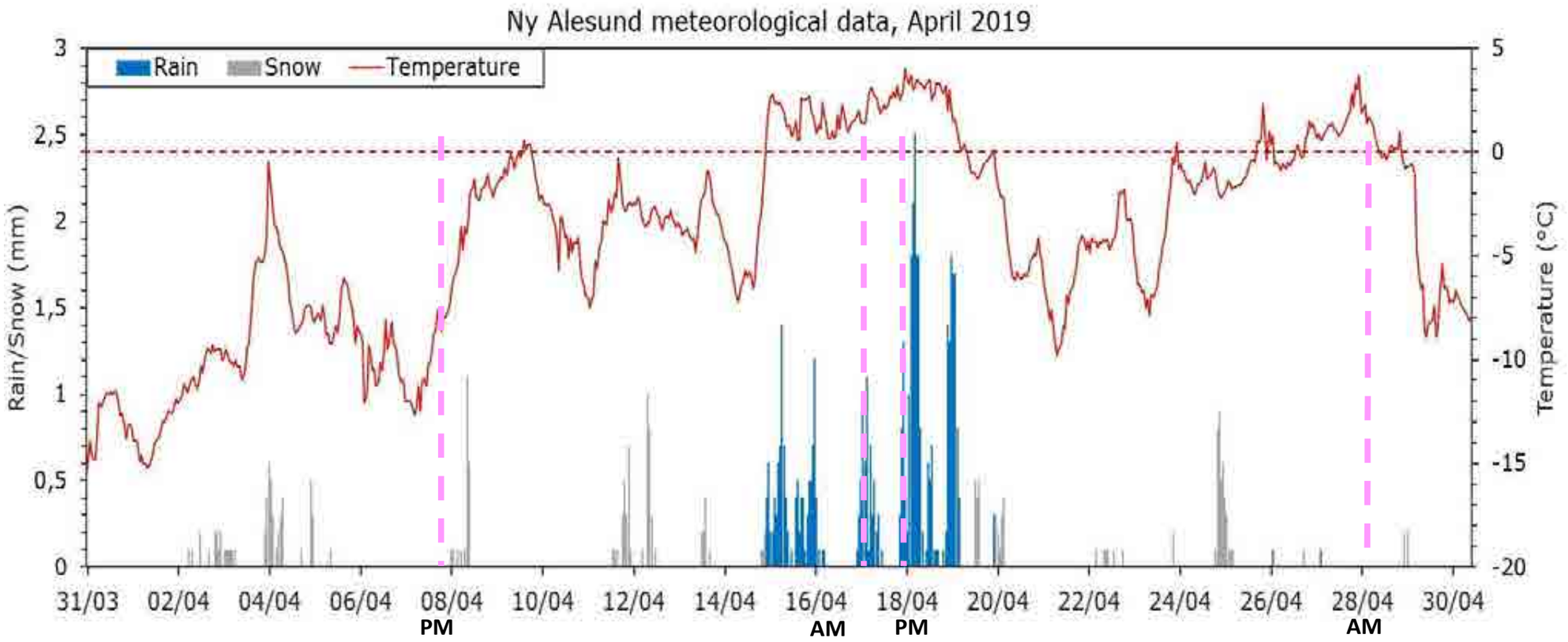
VALIDATION



Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: ROS event characterization using TerraSAR-X

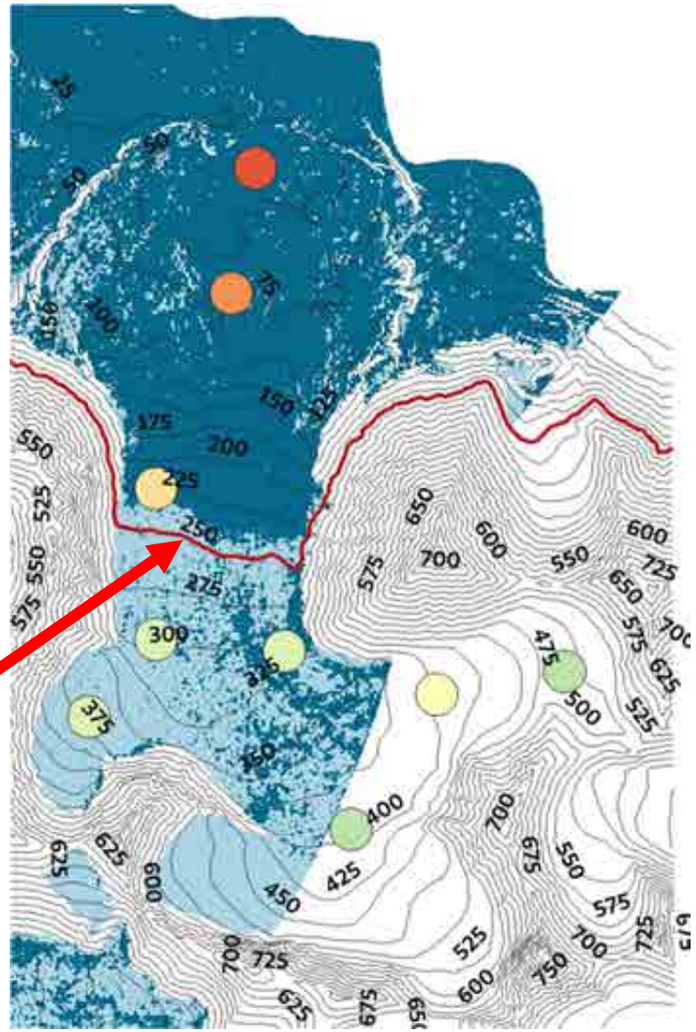
Example of 17 - 18/04/2019 event (P = 43.1 mm, T_{max} = 4.6 °C)

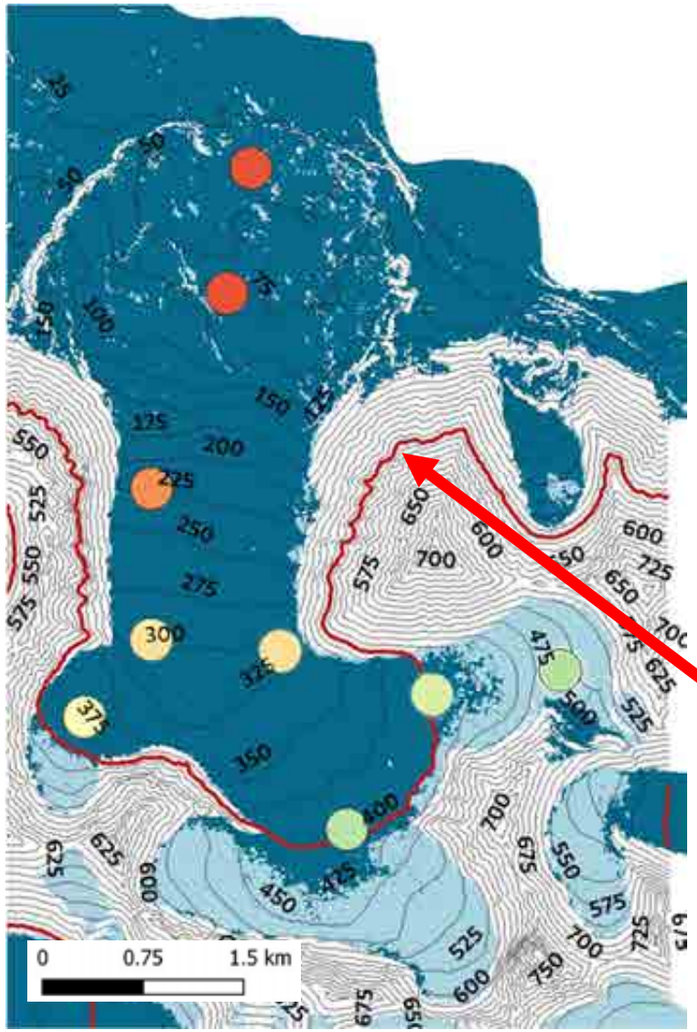


TerraSAR-X
registration date and mode

Institute of Environmental Geosciences, Grenoble, France

ARCSNOW: Development of the ROS event on the Austre Lovénbren





250 m

400 m

17 April 2019

18 April 2019

In situ temperature in °C

- 2 - 3
- 1.5 - 2
- 1 - 1.5
- 0.5 - 1
- 0 - 0.5
- -0.5 - 0
- -1 - -0.5
- -1.5 - -1
- -2 - -1.5
- -3 - -2

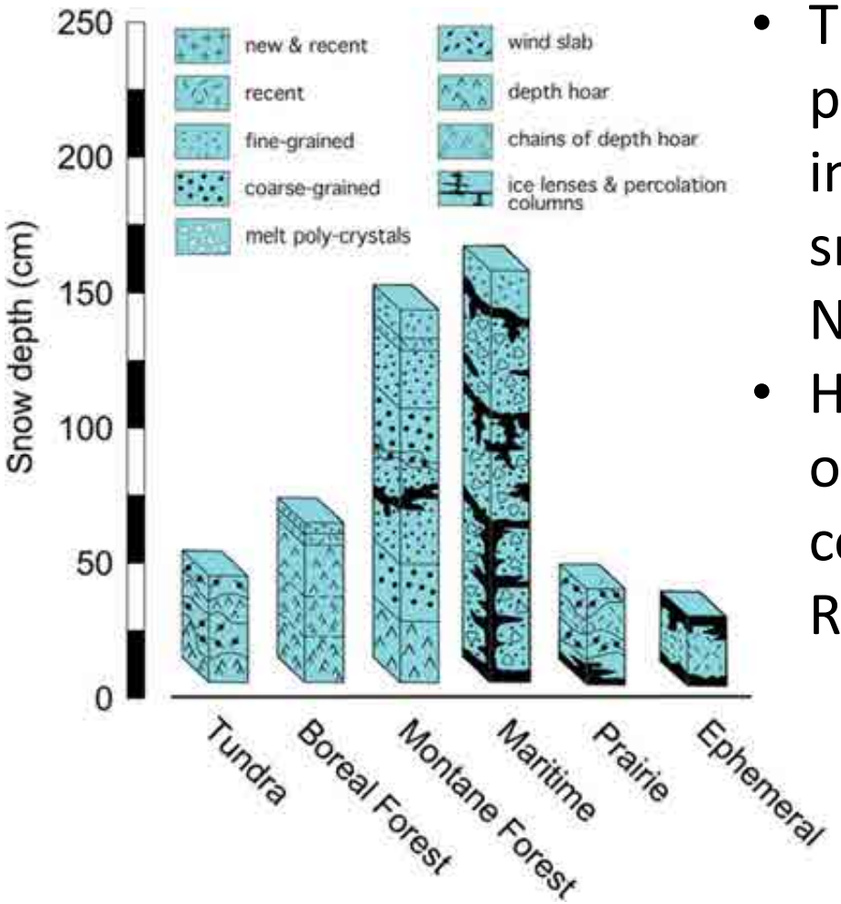
ERA5 0°C isoline

No SAR data (layover mask)

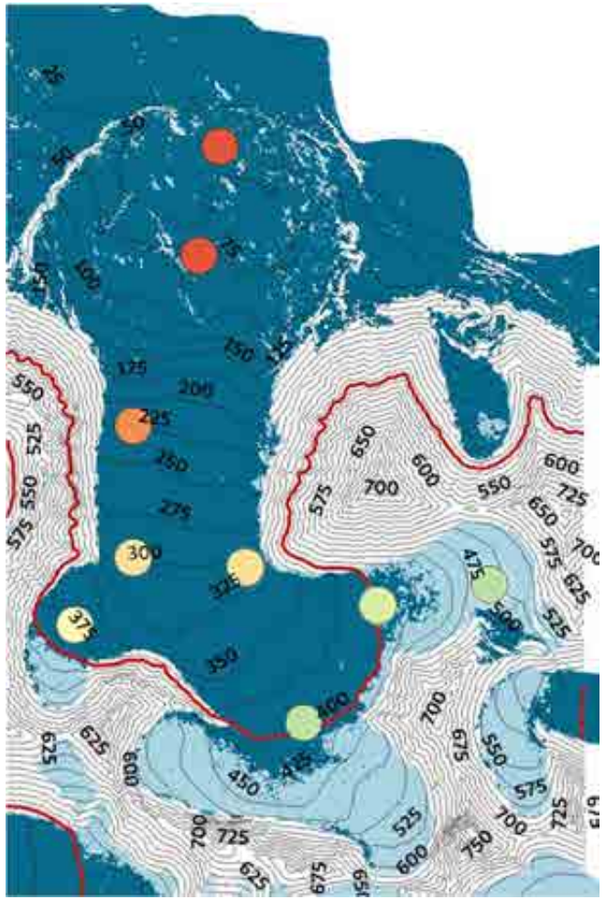
Institute of Environmental Geosciences, Grenoble, France

Conclusions

- The changes in Ny-Alesund (as well as in the Arctic!) have been very strong (temperature, precipitation) leading to a very strong impact on snow properties.



- The variability of the snowpack properties is very high (documented in detail since 2016). A typical tundra snowpack sometimes still forms at Ny-Alesund.
- However, properties of a snowpack of a warmer climate are more common (melt forms, ice layers, ROS).
  - High resolution data can be used to characterize ROS events, i.e. identify regions not impacted by ROS.



Institute of Environmental Geosciences, Grenoble, France