Small-scale variability of snow properties on sea ice:

From snow pits to the SnowMicroPen

Stefanie Arndt[1], Nicolas Stoll[1], Arttu Jutila[1], Stephan Paul[2]

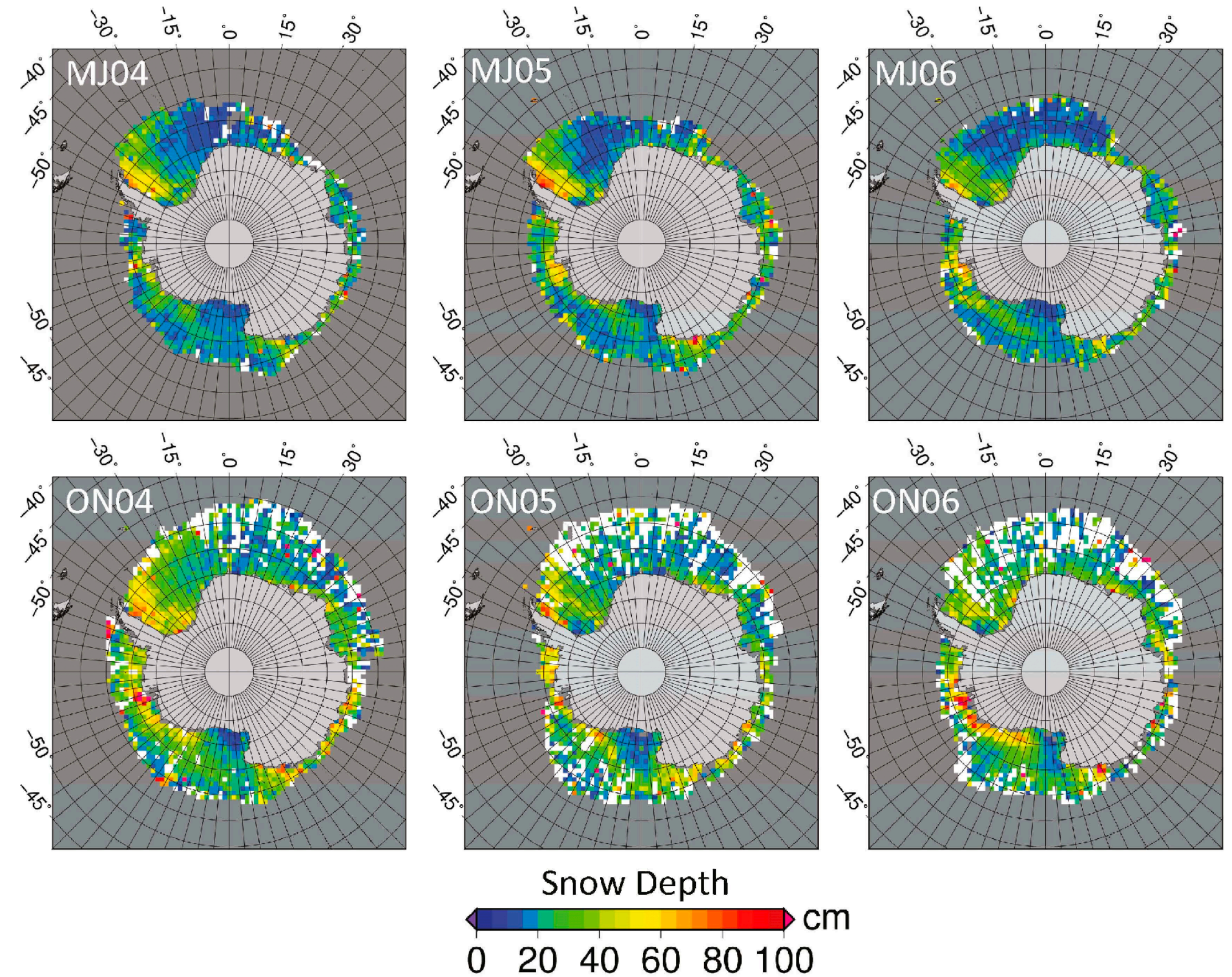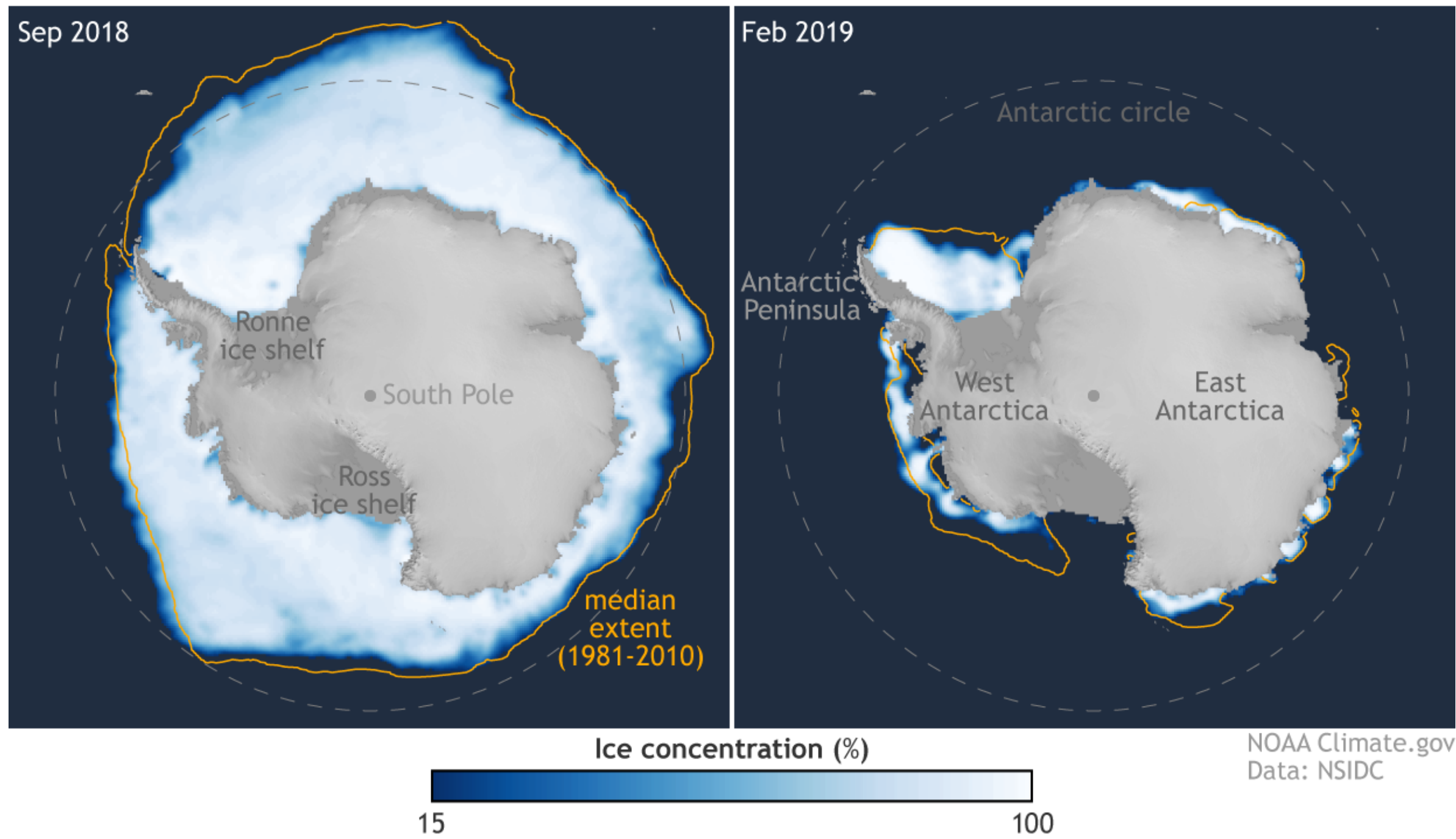[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research
[2] Ludwig-Maximilians-Universität München

HELMHOLTZ

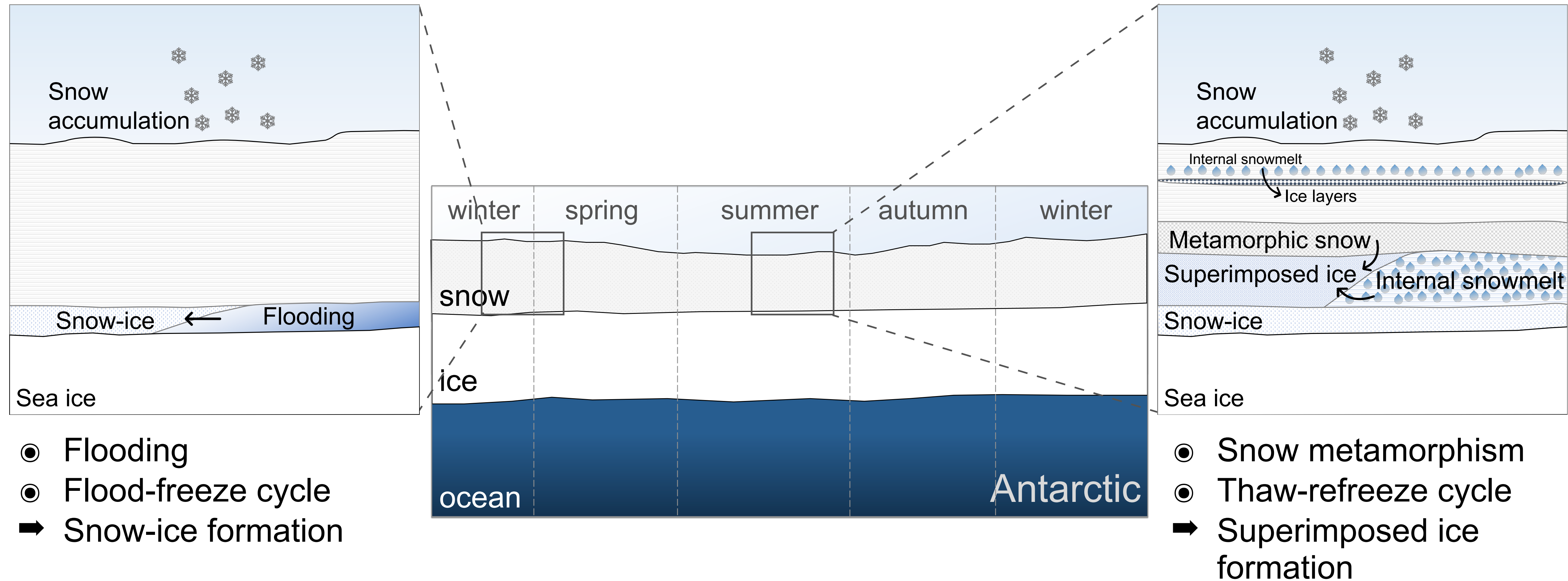# The Antarctic sea-ice and snow cover

Sea-ice maximum

Sea-ice minimum

Snow depth retrieved from ICESAT for winter (MJ) and spring (ON)
(Kern & Ozsoy-Cicek, 2016)

Temporal evolution of surface properties of Antarctic sea ice

- Flooding
- Flood-freeze cycle
➡ Snow-ice formation

- Snow metamorphism
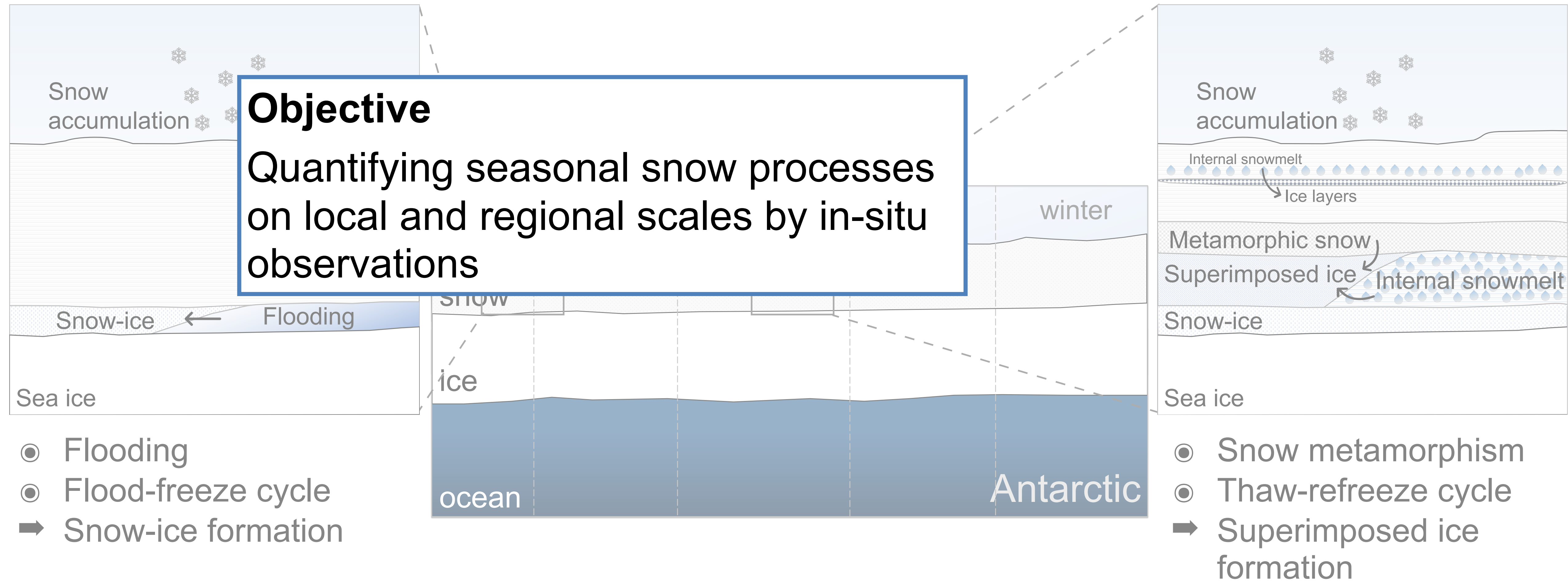- Thaw-refreeze cycle
➡ Superimposed ice formation

Temporal evolution of surface properties of Antarctic sea ice

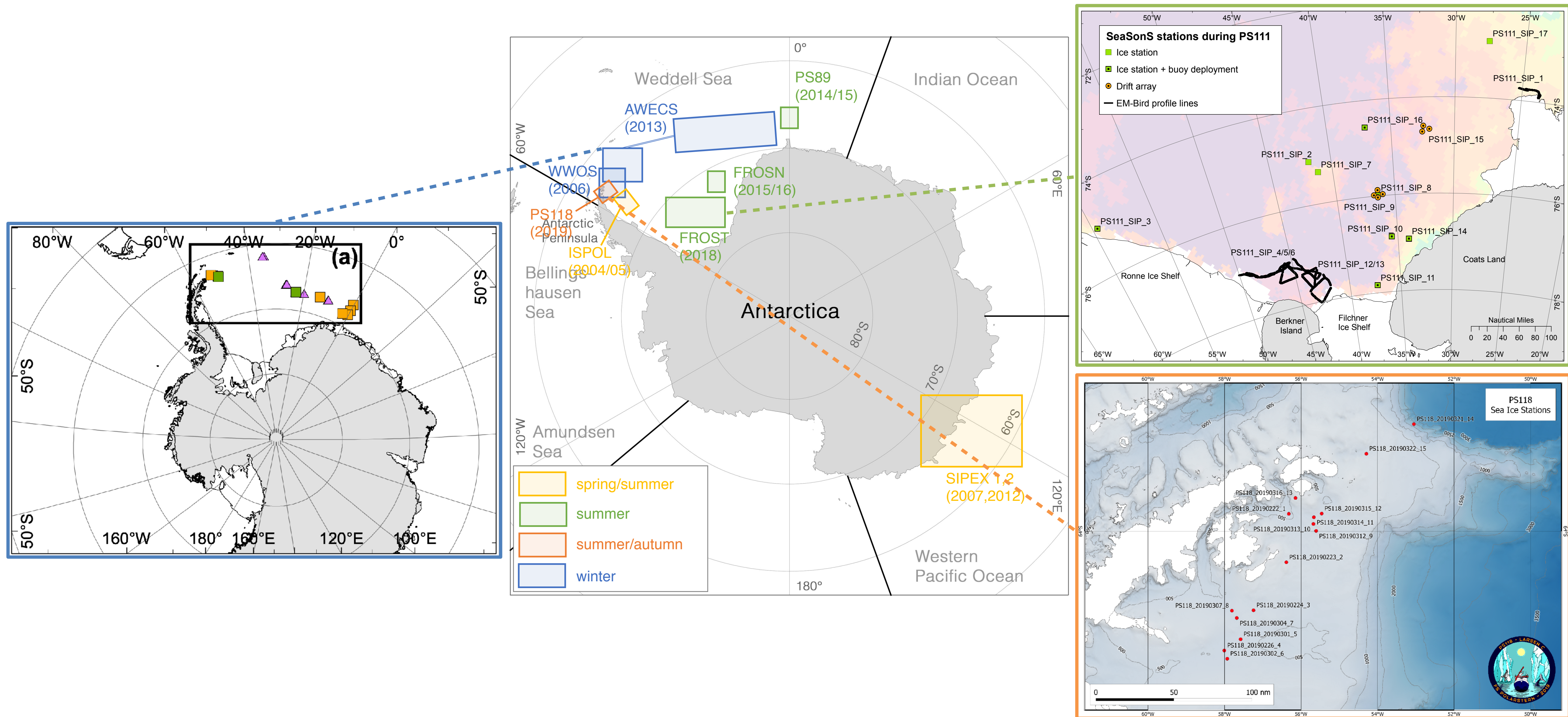**Objective**

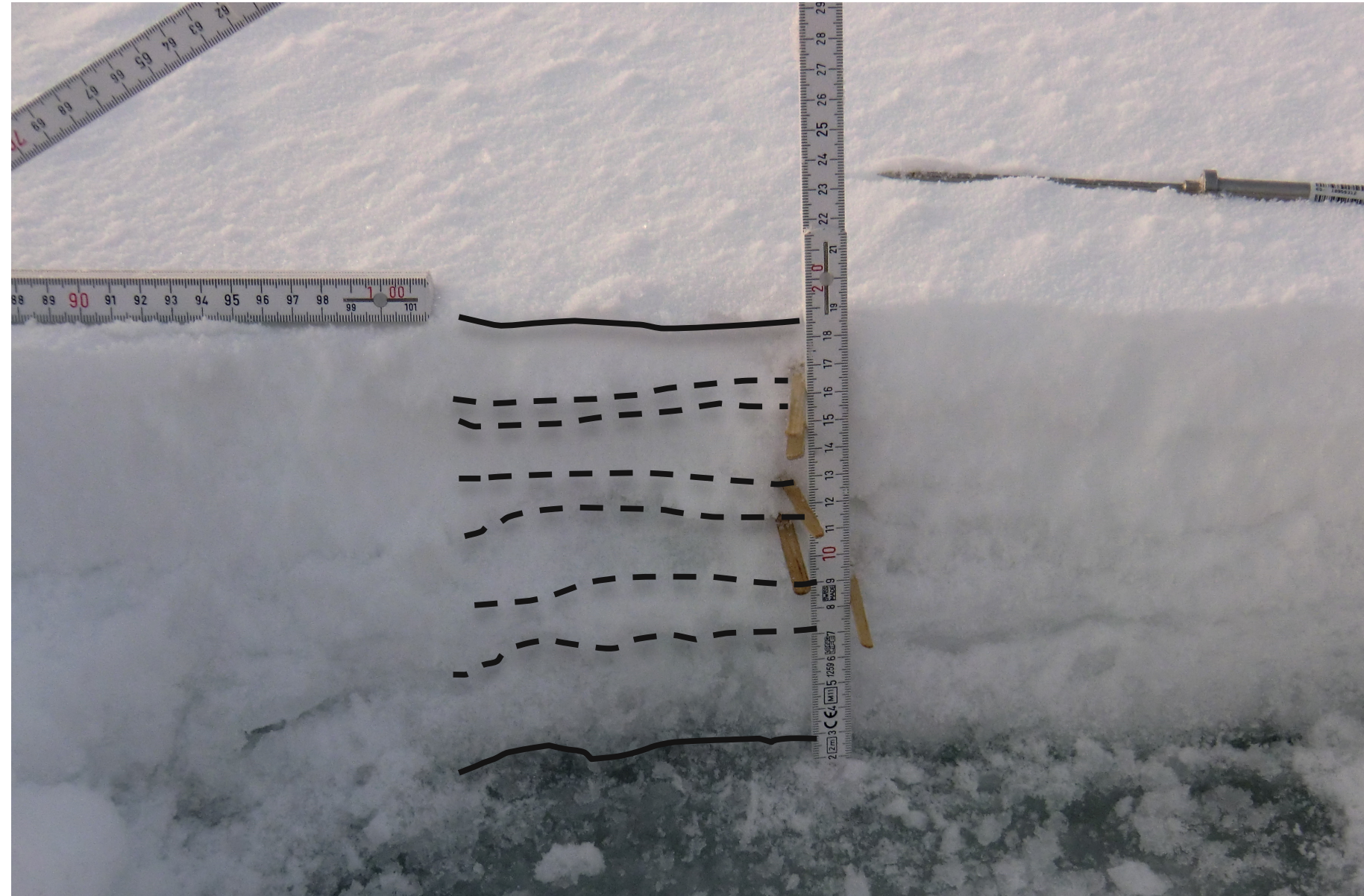Quantifying seasonal snow processes on local and regional scales by in-situ observations

Snow accumulation

Snow-ice ← Flooding

Sea ice

winter

snow

ice

ocean   Antarctic

Snow accumulation

Internal snowmelt
Ice layers

Metamorphic snow
Superimposed ice ← Internal snowmelt

Snow-ice

Sea ice

- ◉ Flooding
- ◉ Flood-freeze cycle
- ➡ Snow-ice formation

- ◉ Snow metamorphism
- ◉ Thaw-refreeze cycle
- ➡ Superimposed ice formation

AWI

HELMHOLTZ

Snow measurements throughout the Weddell Sea
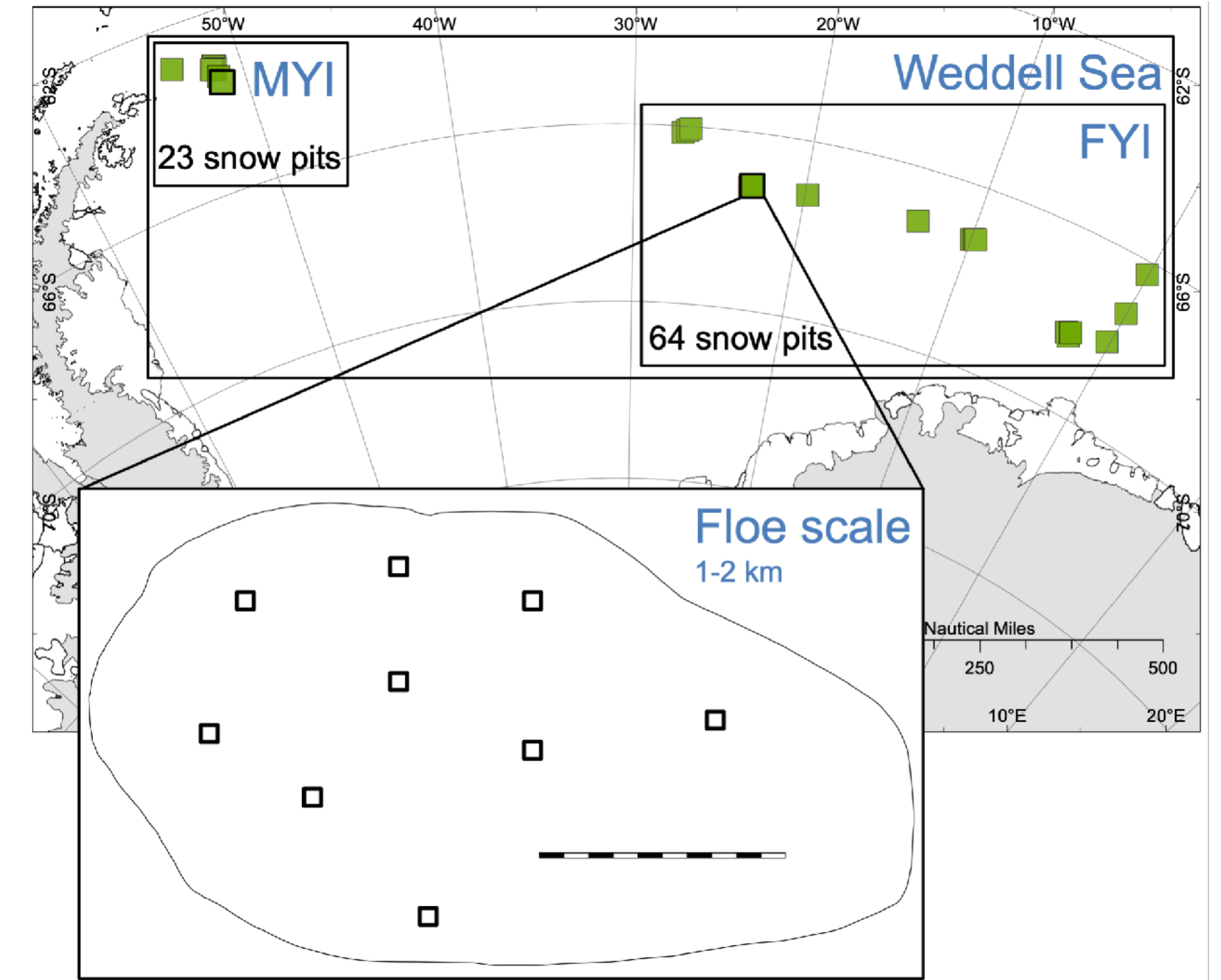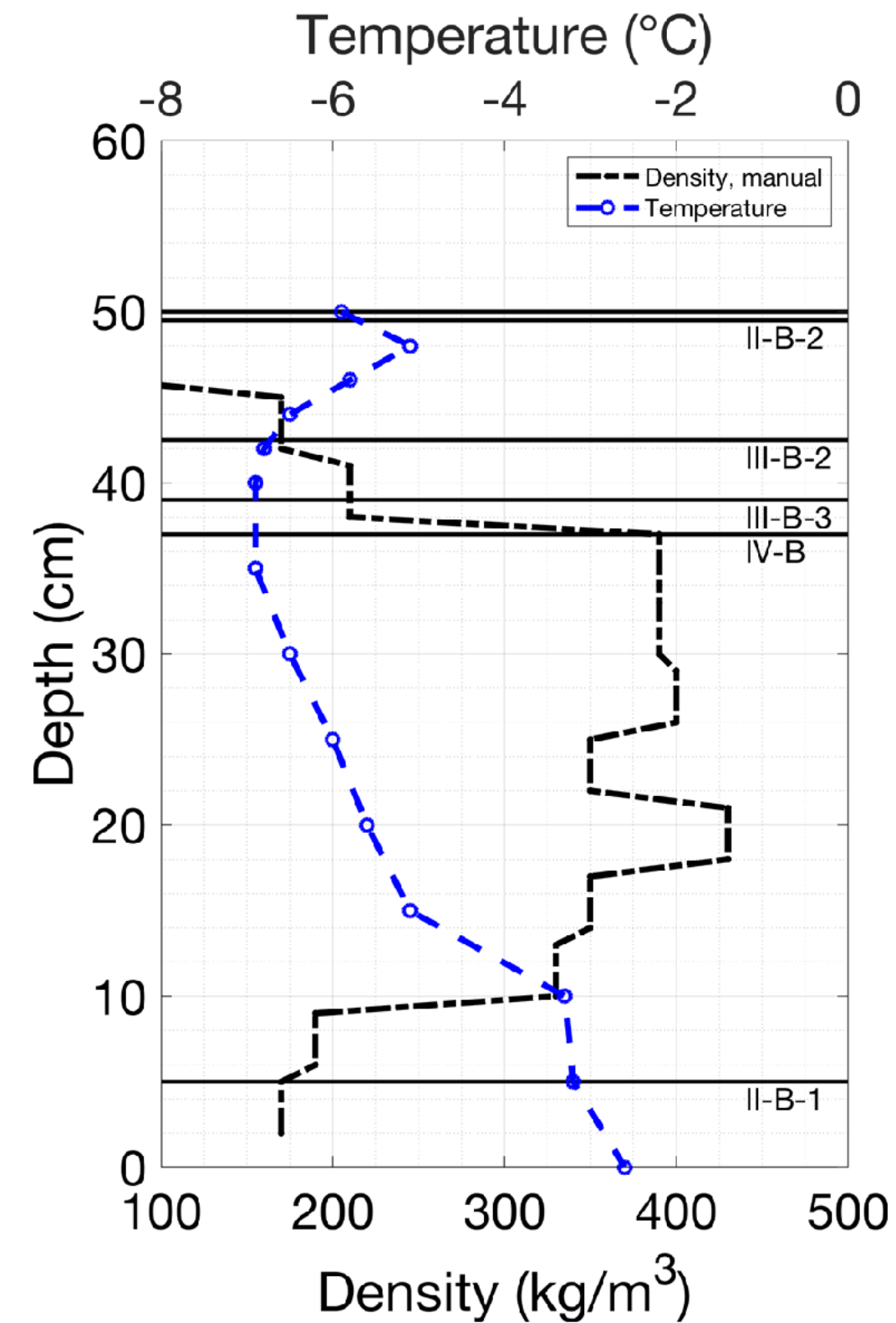
Vertical snow profiling

Snow pits

Detailed **characterization of the snowpack**
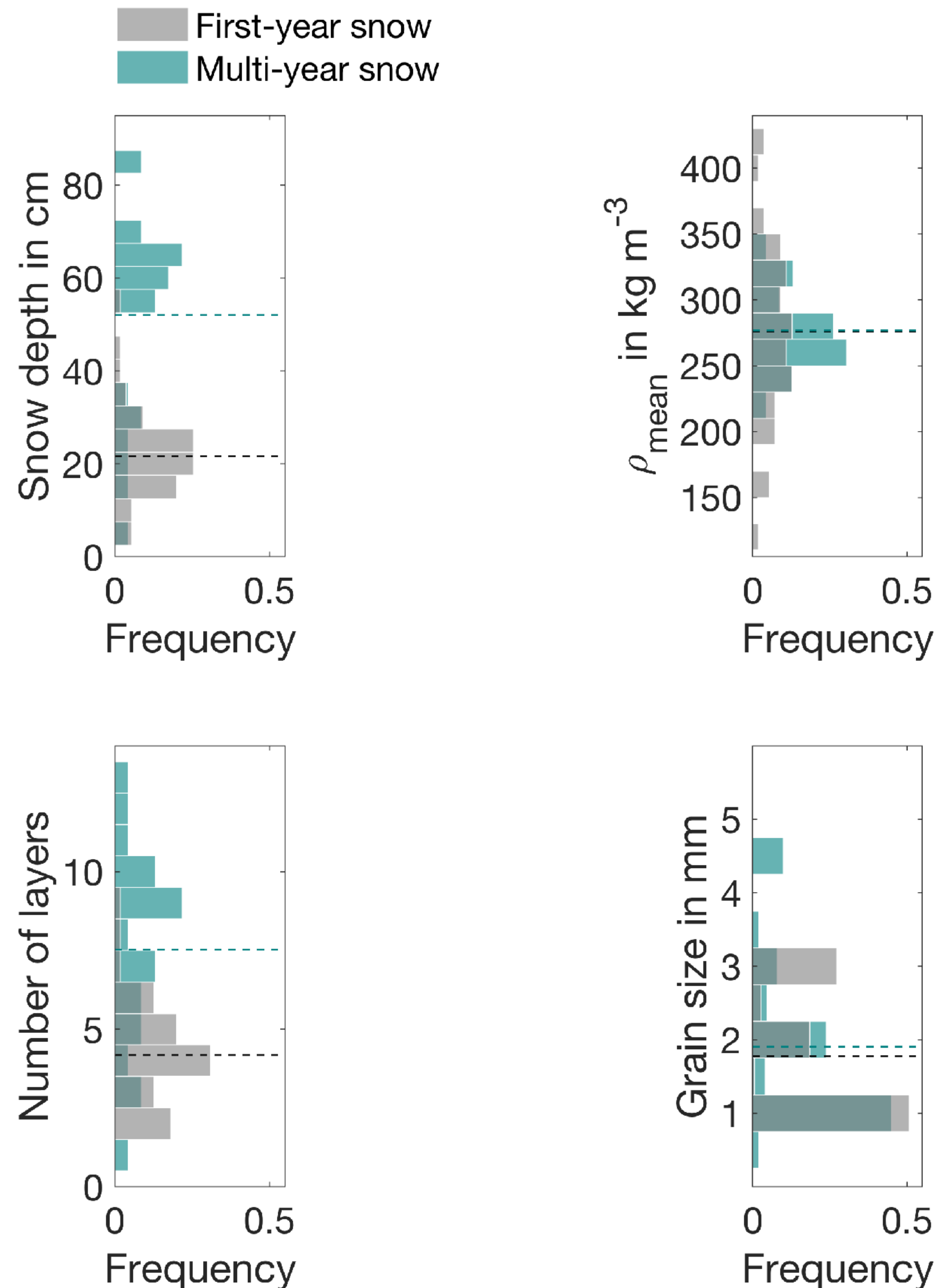
- ◉ Temperature
- ◉ Density
- ◉ Salinity
- ◉ Stratigraphy
- ◉ Liquid water content

ANT-29/6: 08 June - 12 August 2013

9 snow and ice stations
+ 15 helicopter snow stations
→ 87 sampled snow pits
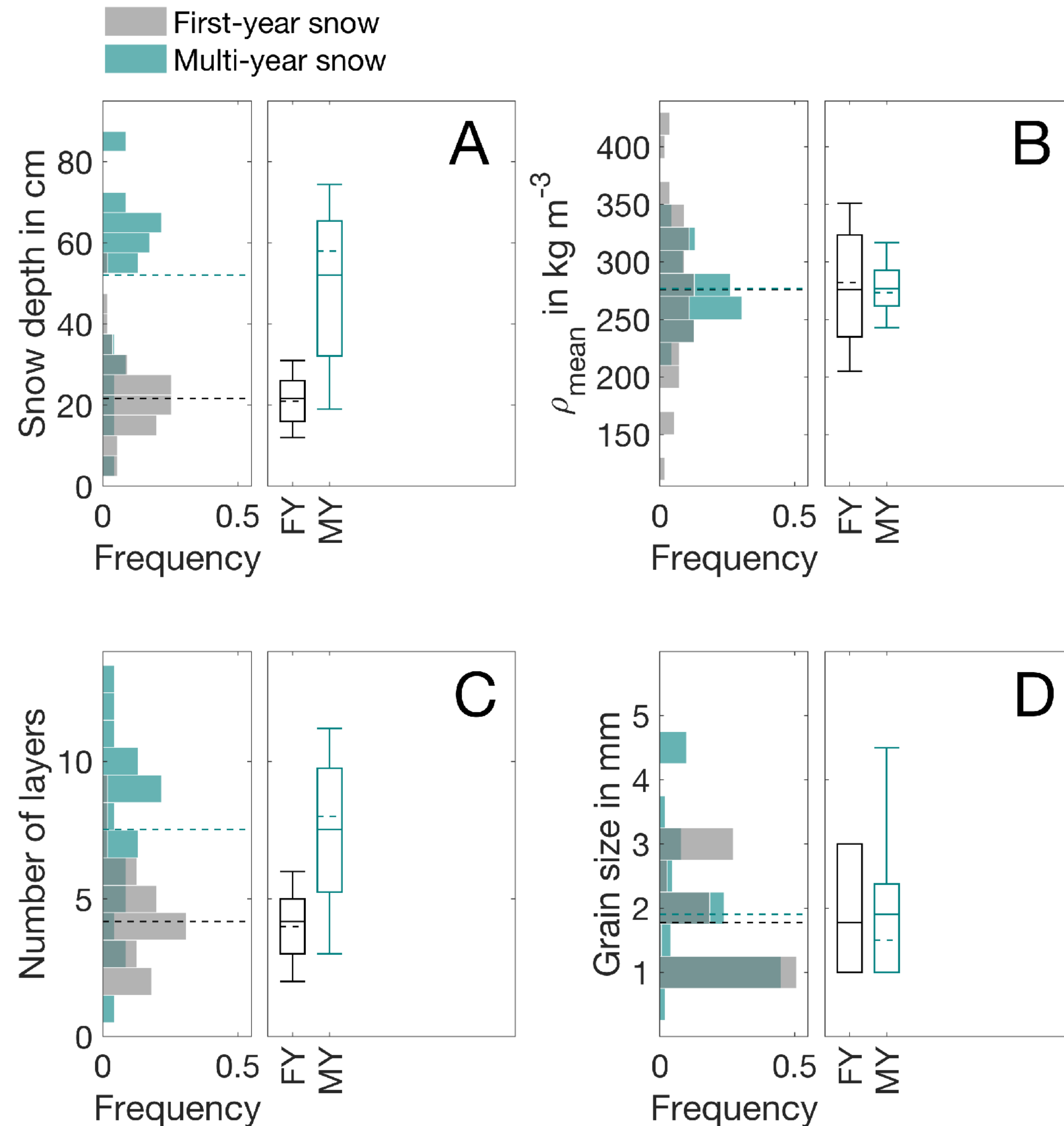
HELMHOLTZ

Regional scale: FYS vs. MYS variability

Relative standard deviations (RSD)

	FYI	**MYI**
Snow depth	0.42	0.42
Density	0.24	0.10
Number of layers	0.38	0.41
Grain size	0.49	0.61

$RSD = \dfrac{std}{mean}$: measure to quantify the variability of different quantities

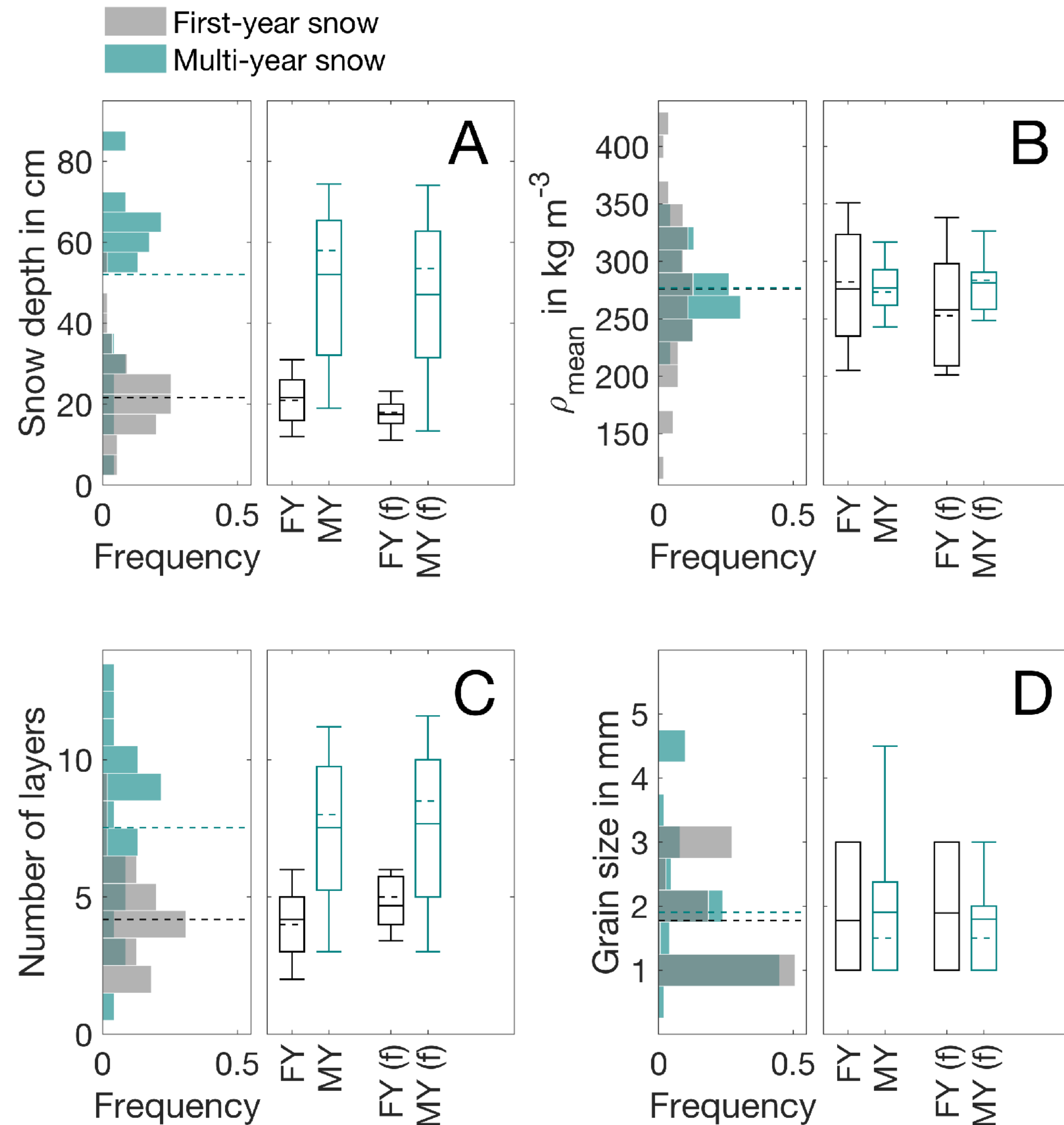◉ Snow grain size dominates the spatial snowpack variability

Arndt & Paul, 2018 (JGR)

HELMHOLTZ

Regional scale: FYS vs. MYS variability

- ⊙ Snow property variability substantially higher in MYS than in FYS
- ⊙ Snow grain size dominates the spatial snowpack variability

Arndt & Paul, 2018 (JGR)
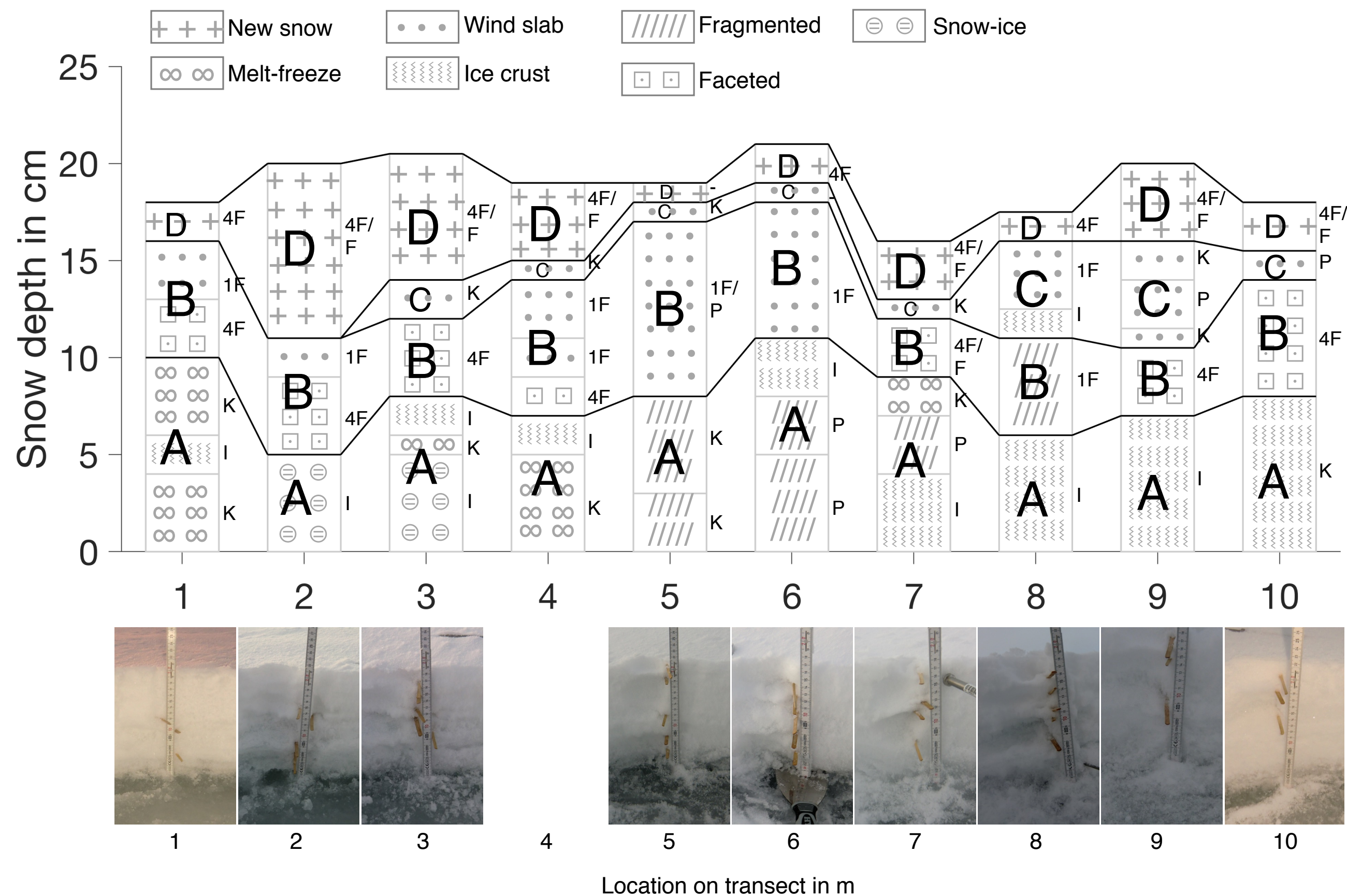
Regional vs. floe-size scale

- ⊙ Same magnitude of snow-property variability on regional and floe-size scales
- ⊙ Snow property variability substantially higher in MYS than in FYS
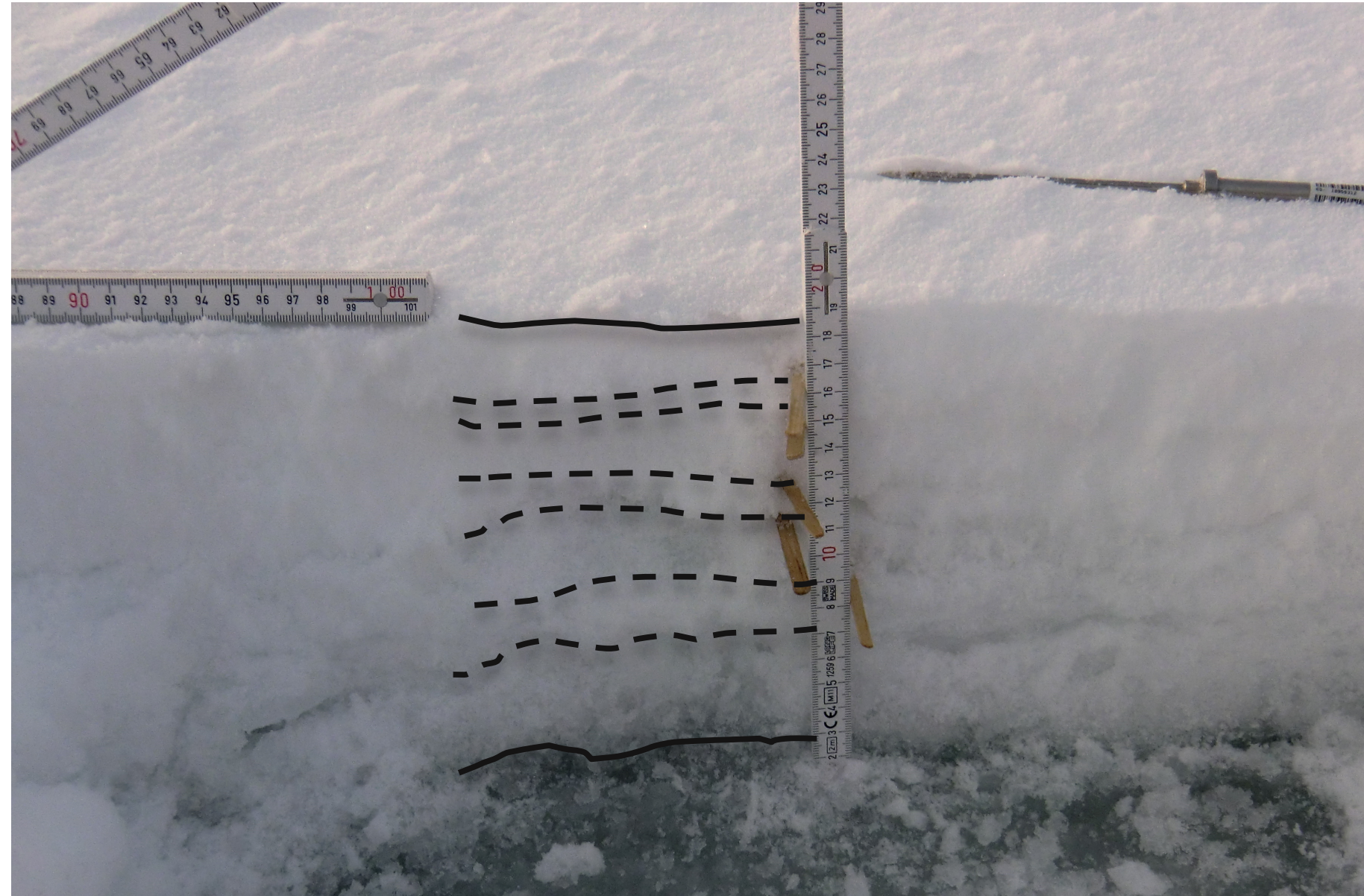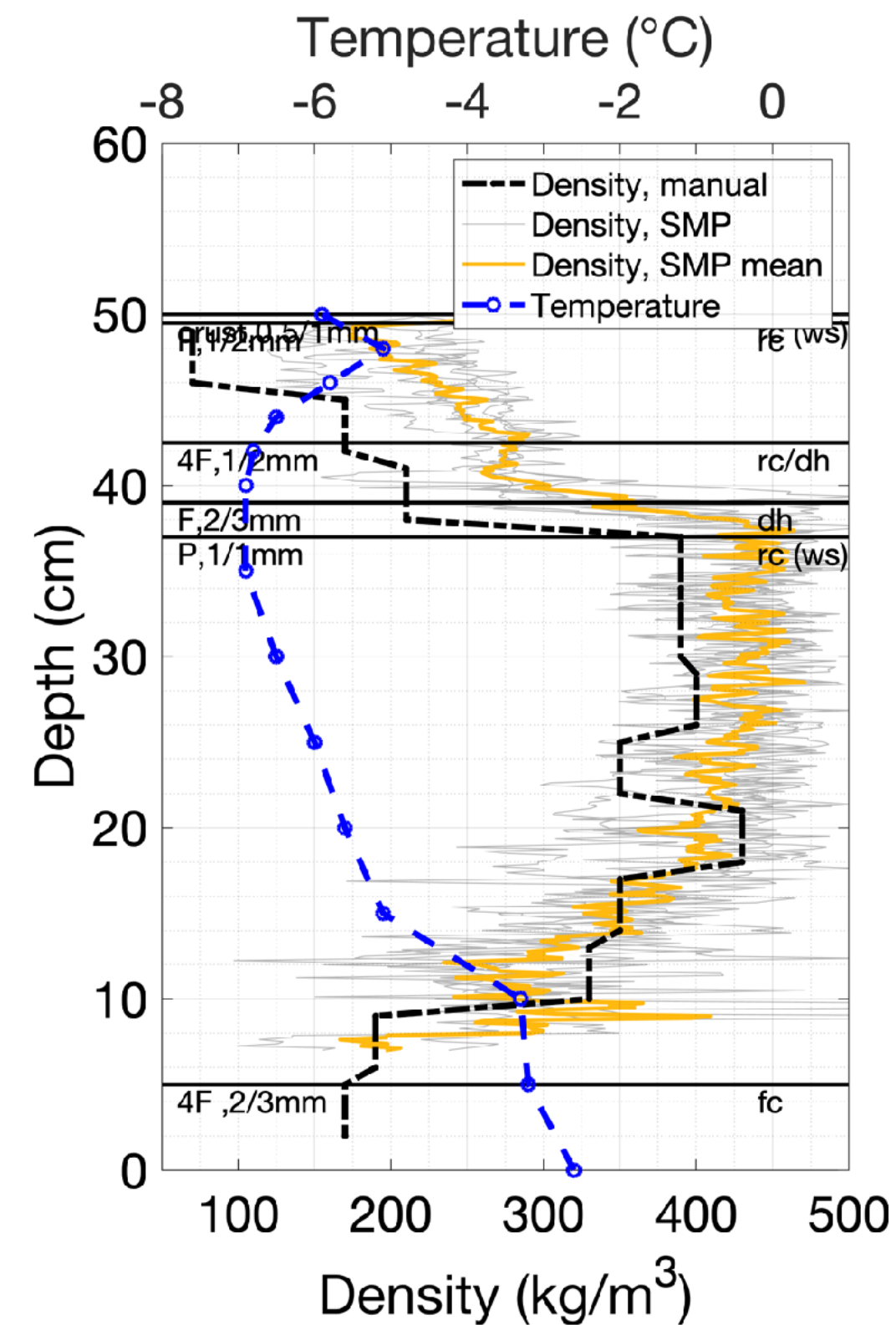- ⊙ Snow grain size dominates the spatial snowpack variability

Arndt & Paul, 2018 (JGR)

HELMHOLTZ

Small scale: Vertical layer evolution

- ◉ Small-scale snow-property variability dominated vertical extent/position of the identified layers

- ◉ Same magnitude of snow-property variability on regional and floe-size scales

- ◉ Snow property variability substantially higher in MYS than in FYS

- ◉ Snow grain size dominates the spatial snowpack variability

Arndt & Paul, 2018 (JGR)

HELMHOLTZ

Vertical snow profiling

Snow pits

Detailed **characterization of the snowpack**

- ◉ Temperature
- ◉ Density
- ◉ Salinity
- ◉ Stratigraphy
- ◉ Liquid water content

SnowMicroPen (SMP)

High-resolution snow penetrometer retrieving essential snow structural parameters by measuring the bonding force between snow grains
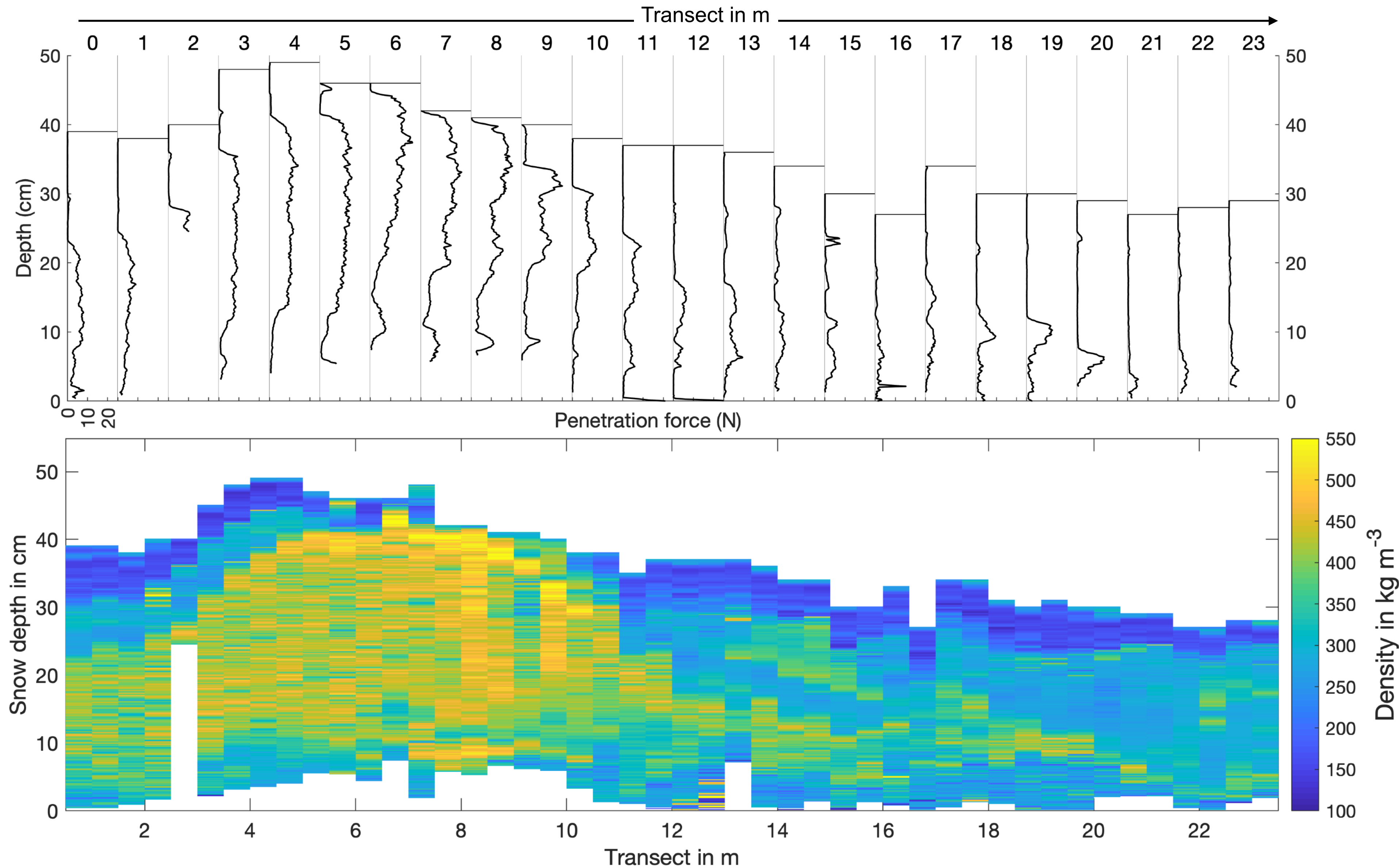
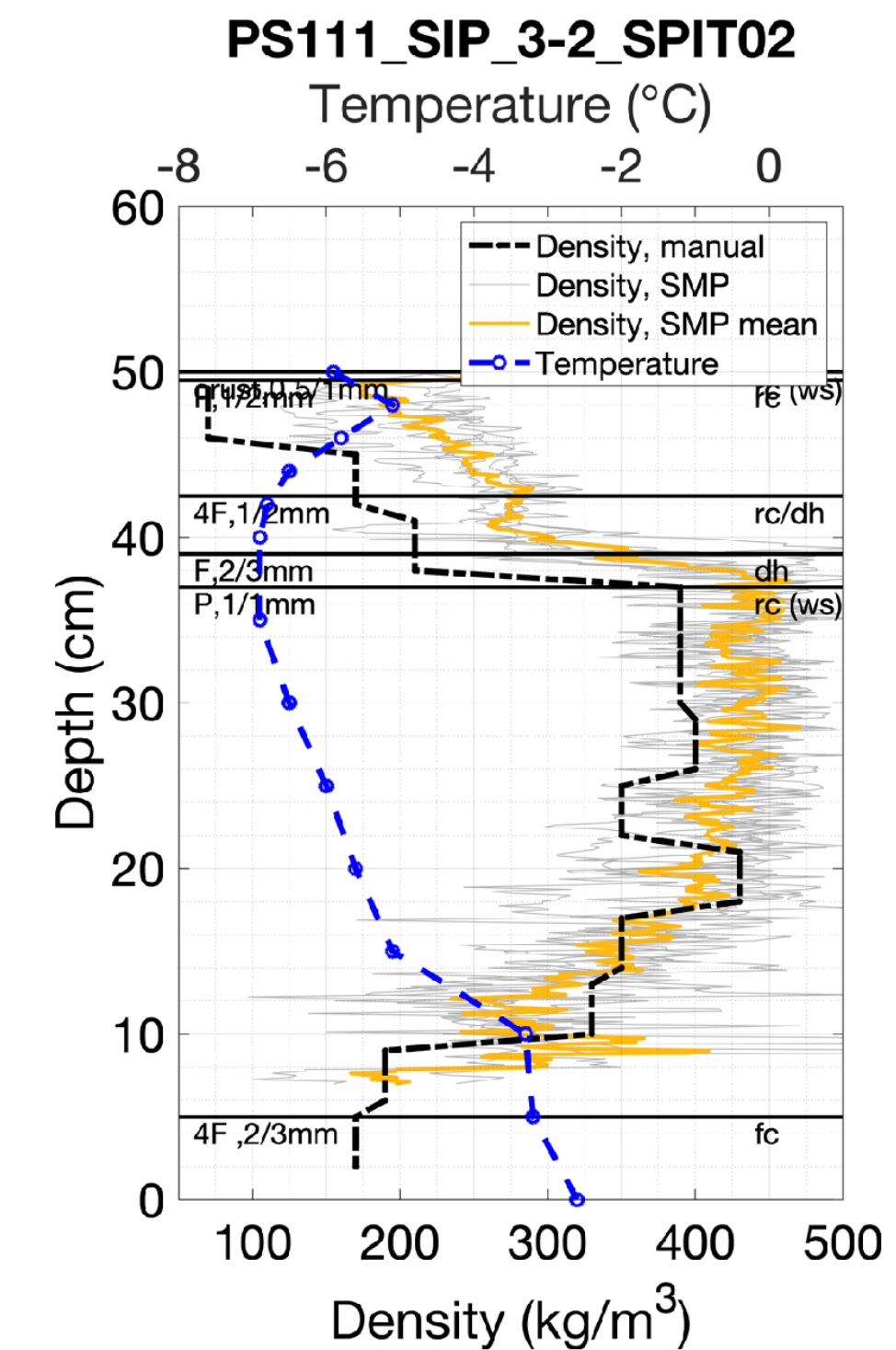- ◉ Density
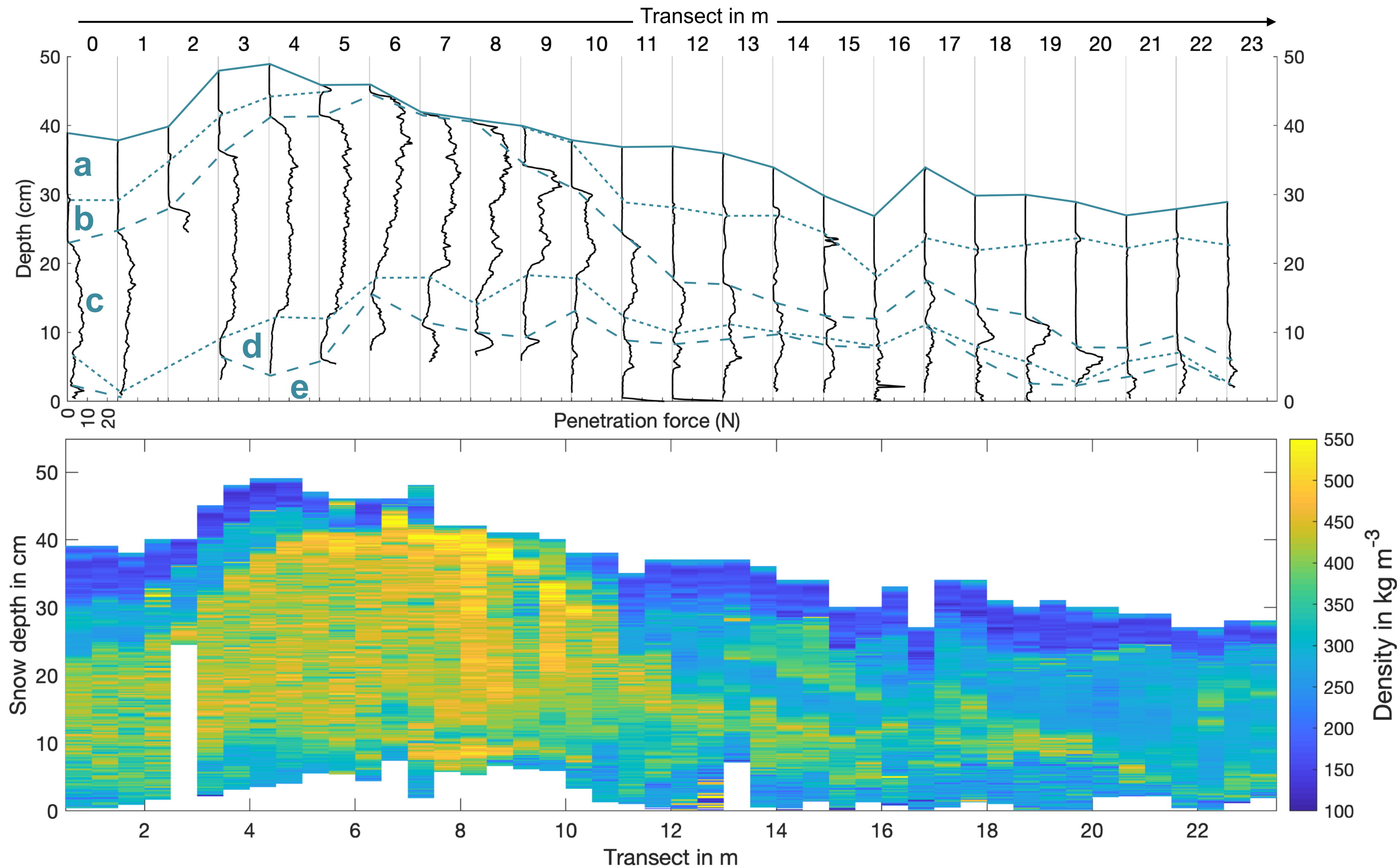- ◉ SSA

SMP transects during austral summer 2018

In total:
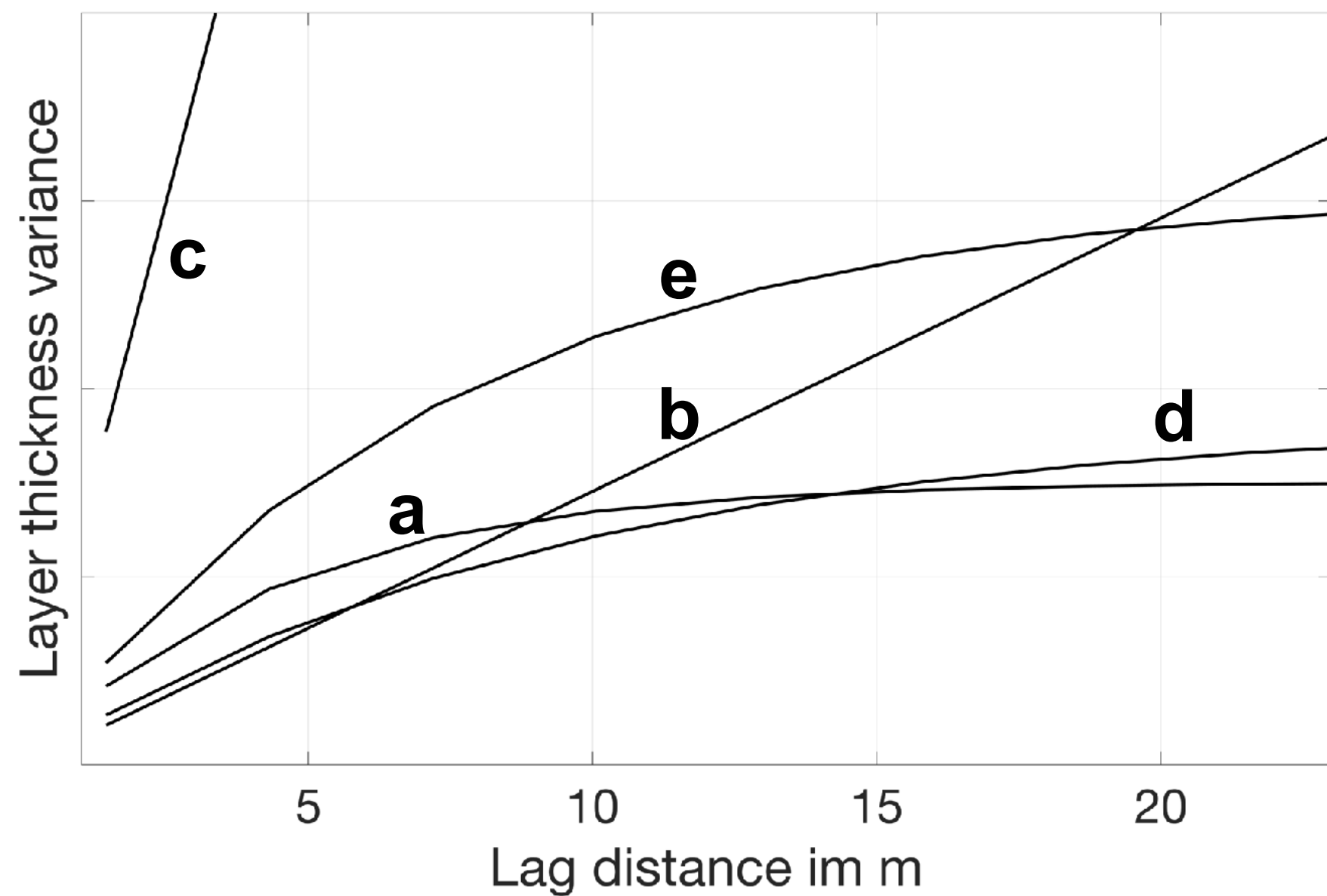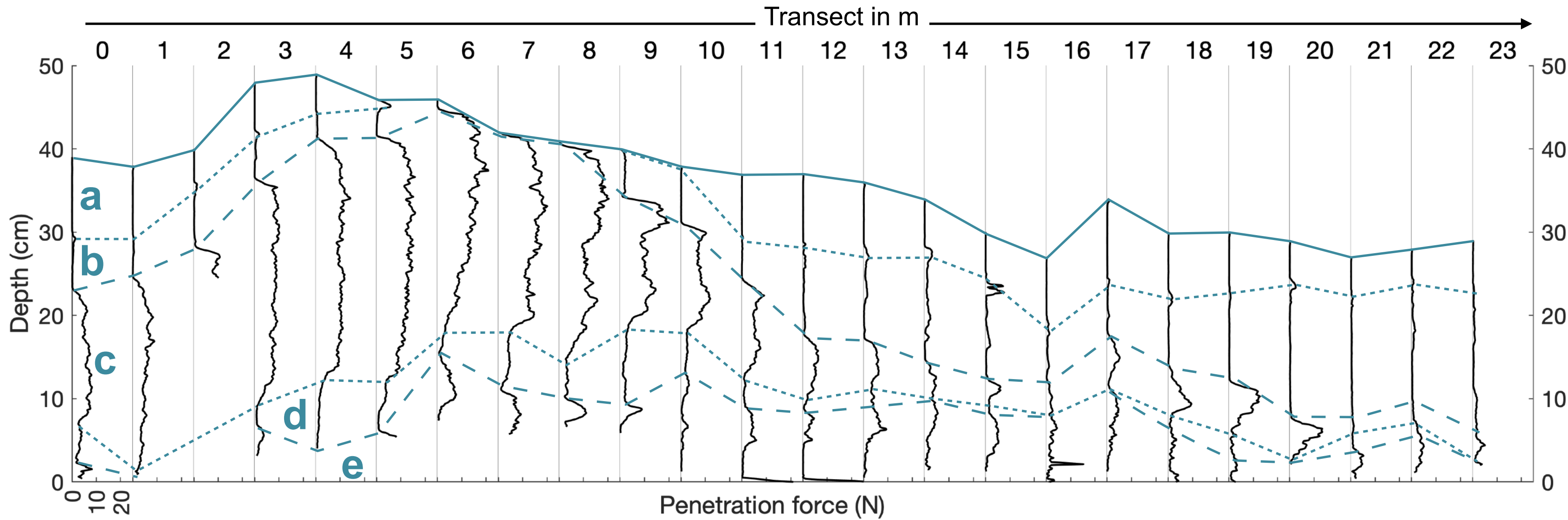- 6 SMP transect lines
- 13 snow pits co-located with SMP measurements

SMP transects during austral summer 2018
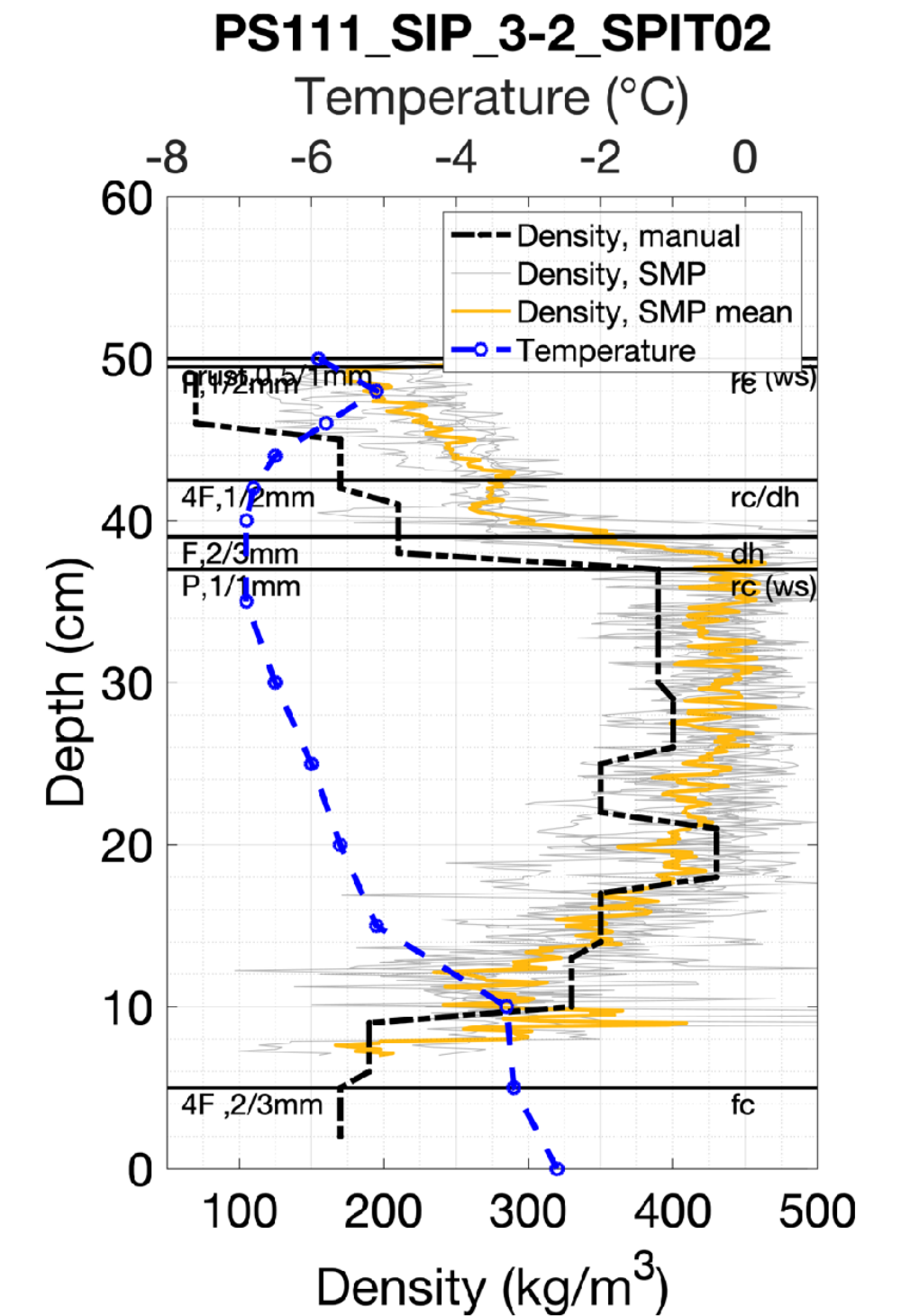
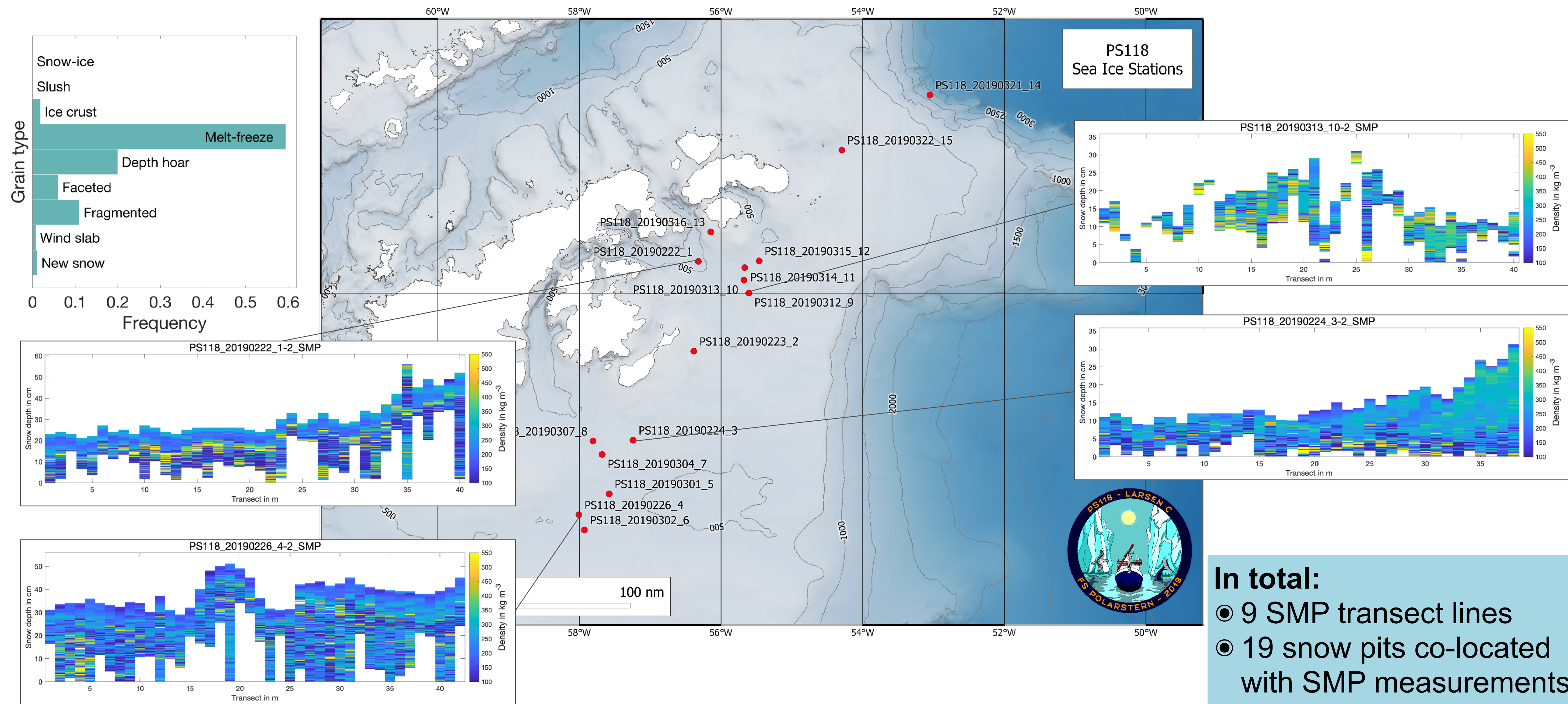# SMP transects during austral summer 2018

SMP transects during austral summer 2018

Length scales of layer thickness variability

a (rc, soft)   : 4 m
b (dh, soft) : >> 23 m
c (rc, hard) : > 23 m
d (rc, soft)   : 9 m
e (fc, soft)   : 7 m
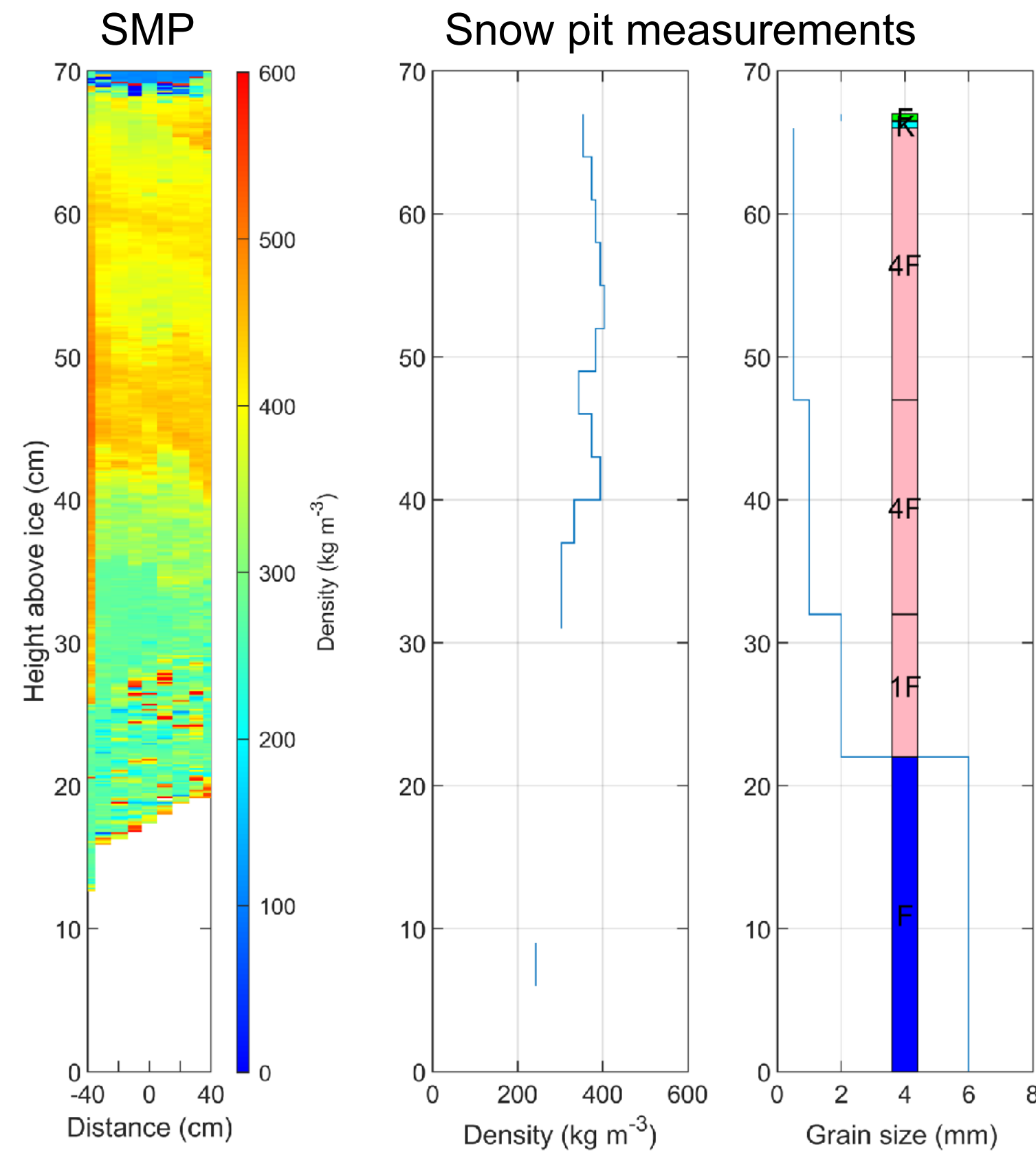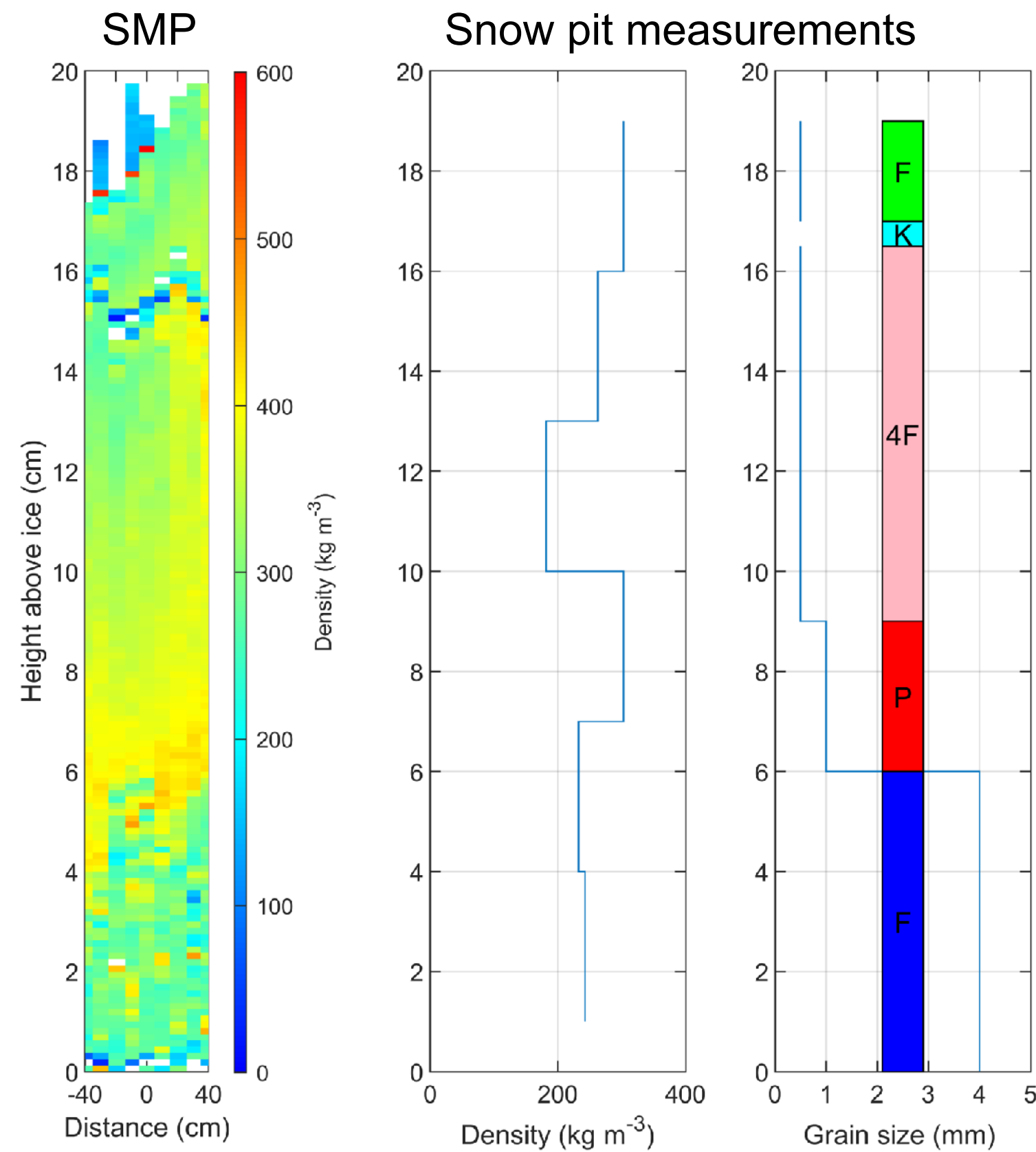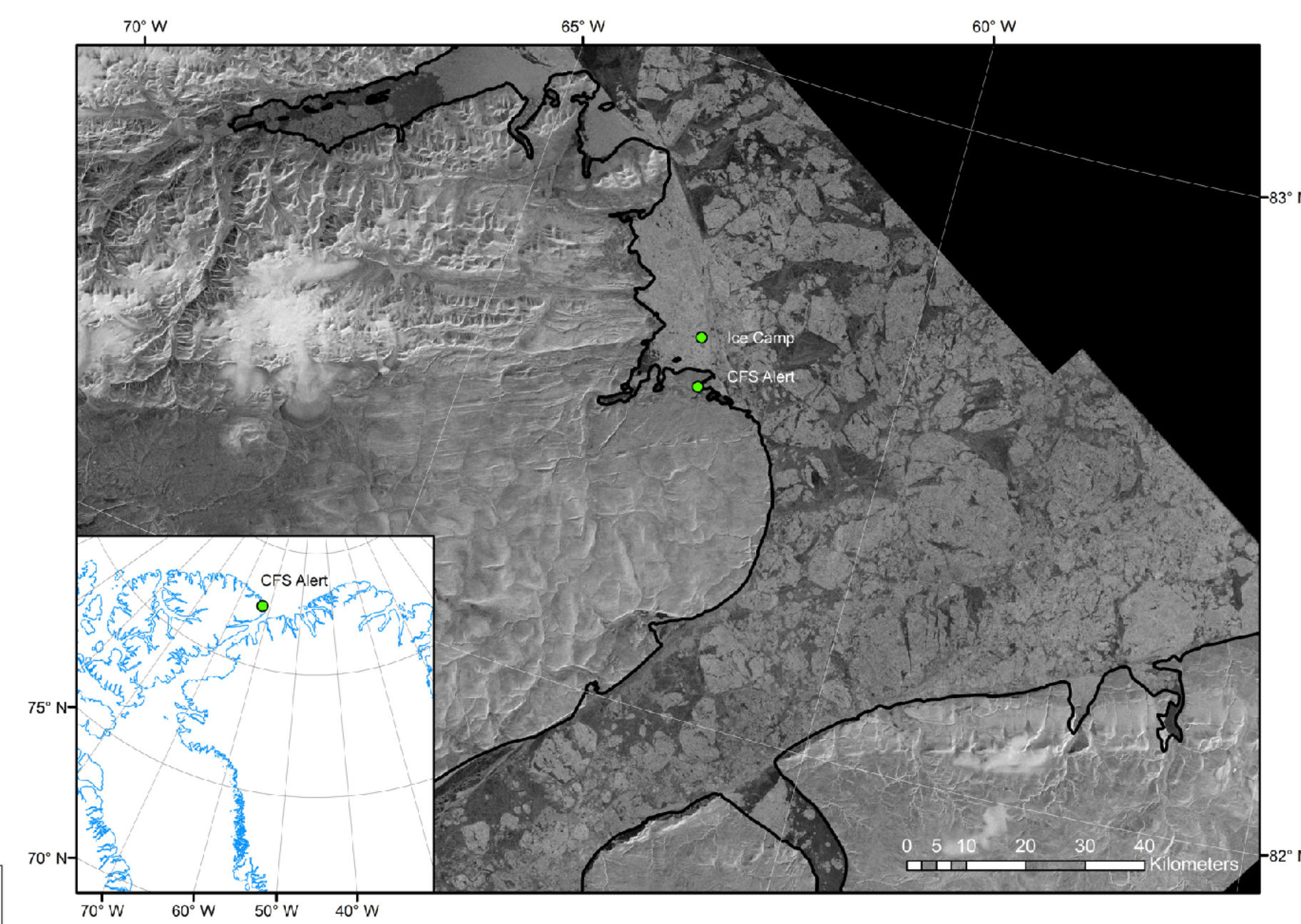
SMP transects during austral summer/autumn 2019

In total:
- 9 SMP transect lines
- 19 snow pits co-located with SMP measurements

And on Arctic sea ice?

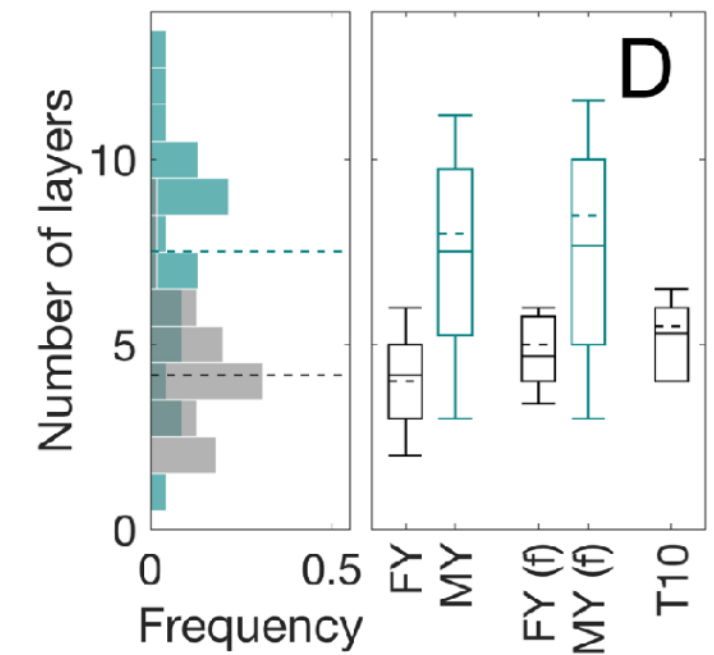Ellesmere Island (Alert), Canada (spring 2018)

In total:
- ⊙ 1 long SMP transect line
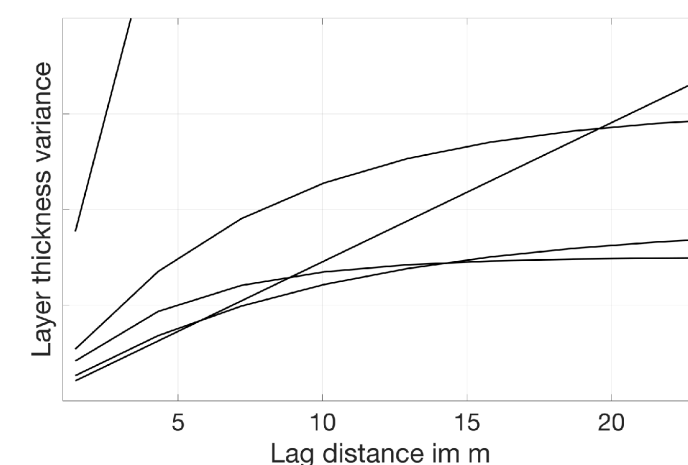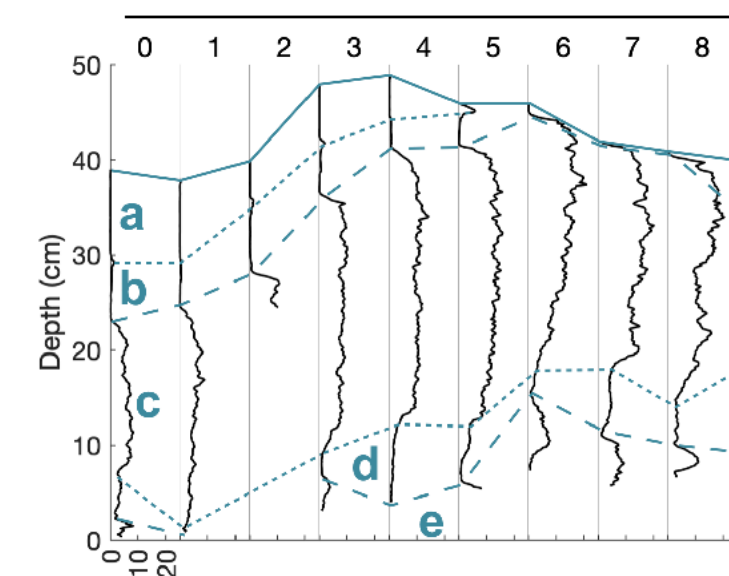- ⊙ 9 snow pits co-located with SMP measurements

HELMHOLTZ

Take home message

- ◉ We **CAN** qualitatively describe snow properties and their variability on different spatial scales

- ◉ … but we **CAN NOT** quantify length scale variabilities of snow properties on a floe-scale
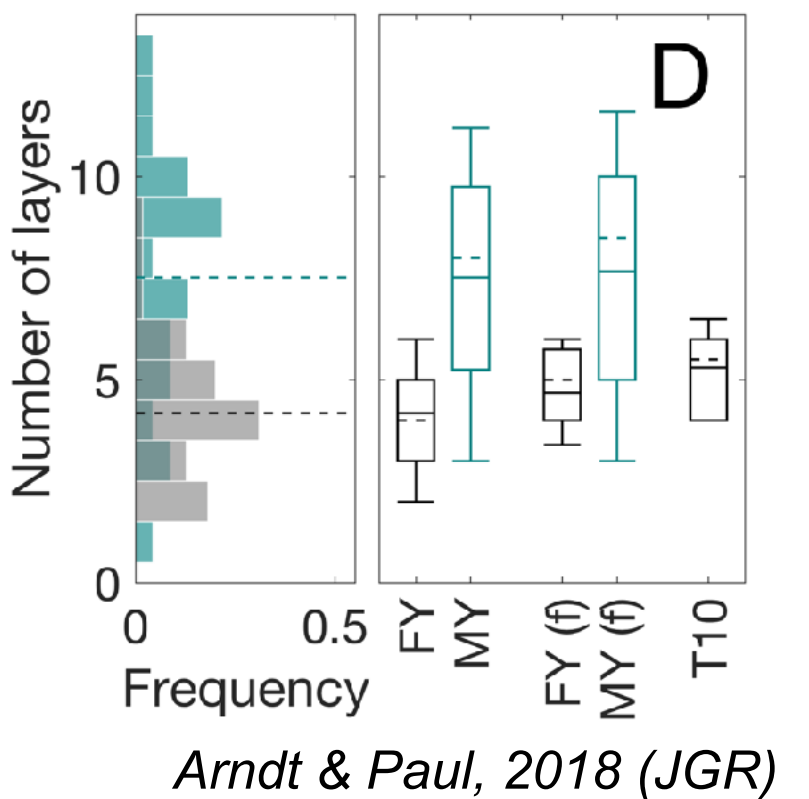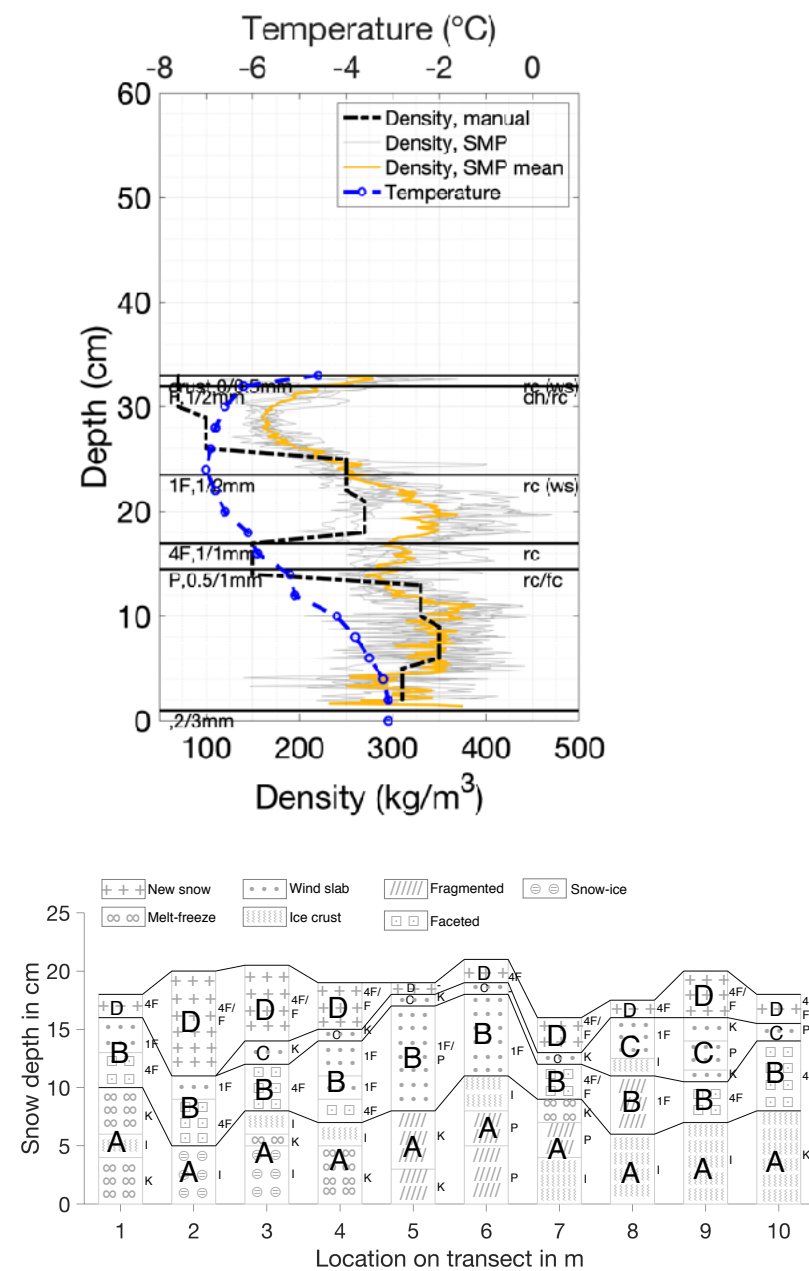 (from, e.g., SMP measurements)

… can't we?

HELMHOLTZ

Spatiotemporal scales of Antarctic snowpack variabilities

Local/Floe scale
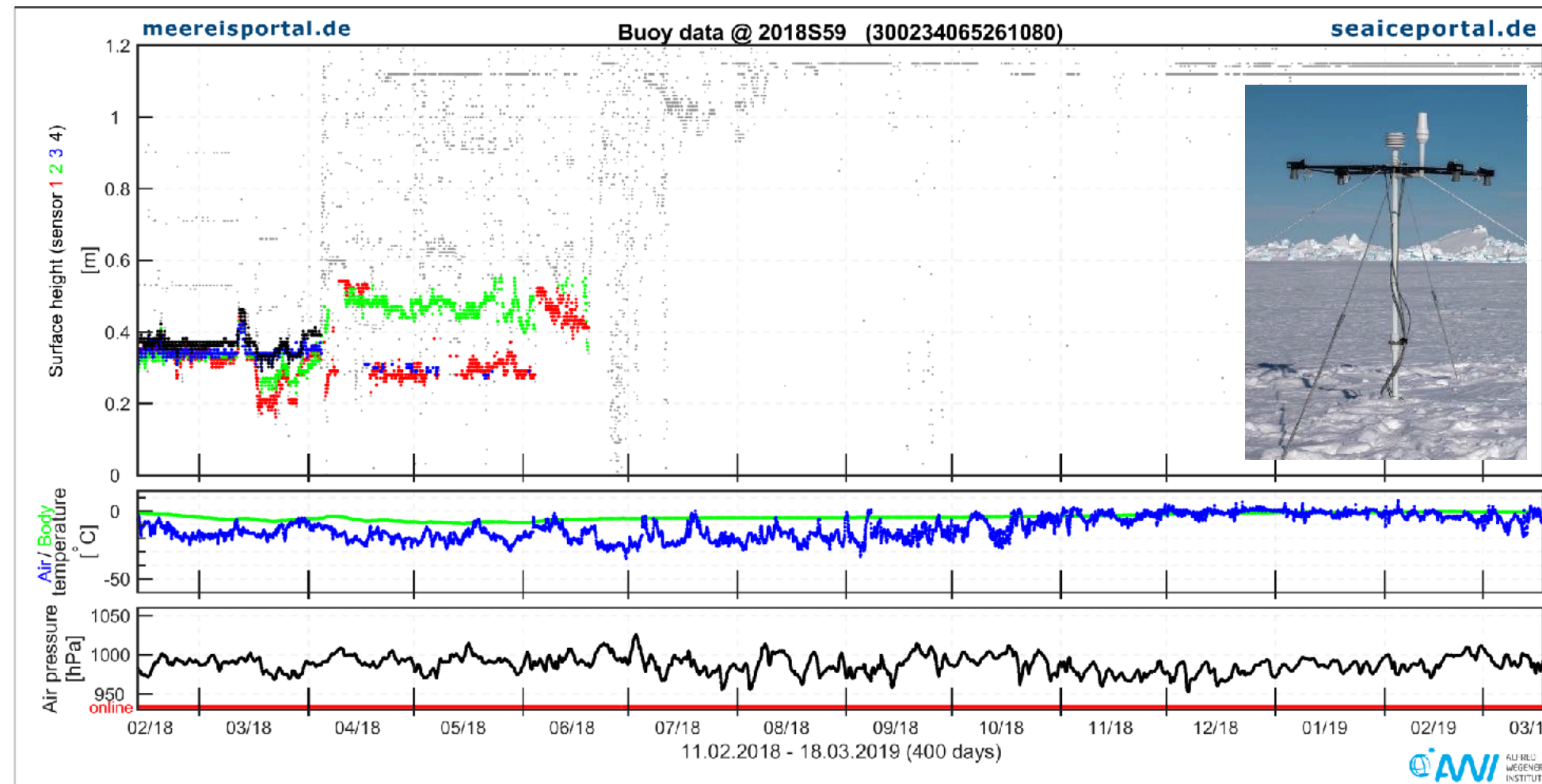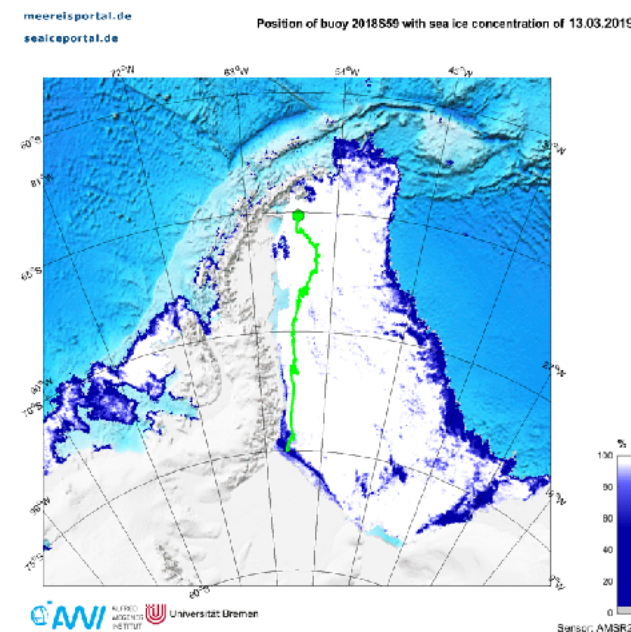
Arndt & Paul, 2018 (JGR)

Temporal evolution of local snow processes

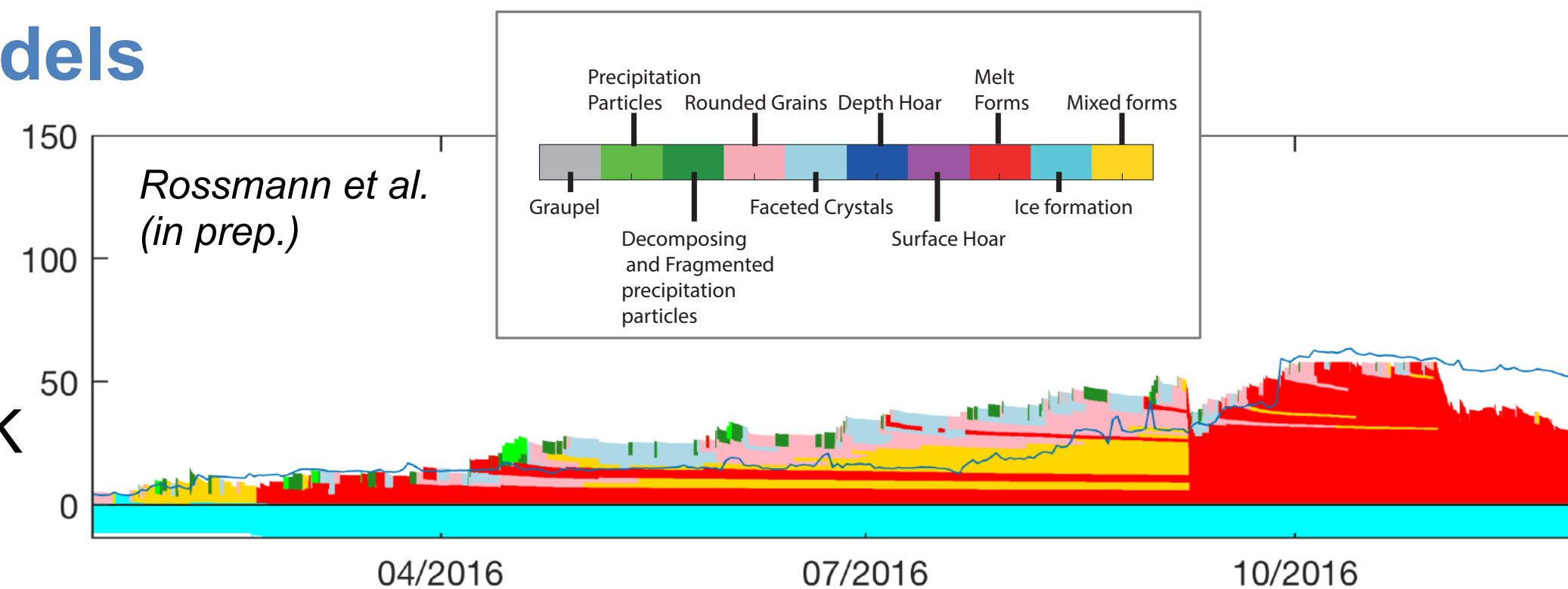### Autonomous ice-tethered platforms

Snow Buoys

Seasonal evolution of snow accumulation rates

1-D snow models

Temporal processes in the snowpack from snow models as, e.g., SNOWPACK

Rossmann et al. (in prep.)

Global scale

Arndt et al., 2016 (JGR)

Arndt & Haas (in review)

DFG SPP 1158: **SnowCast** (2019-2022)

HELMHOLTZ