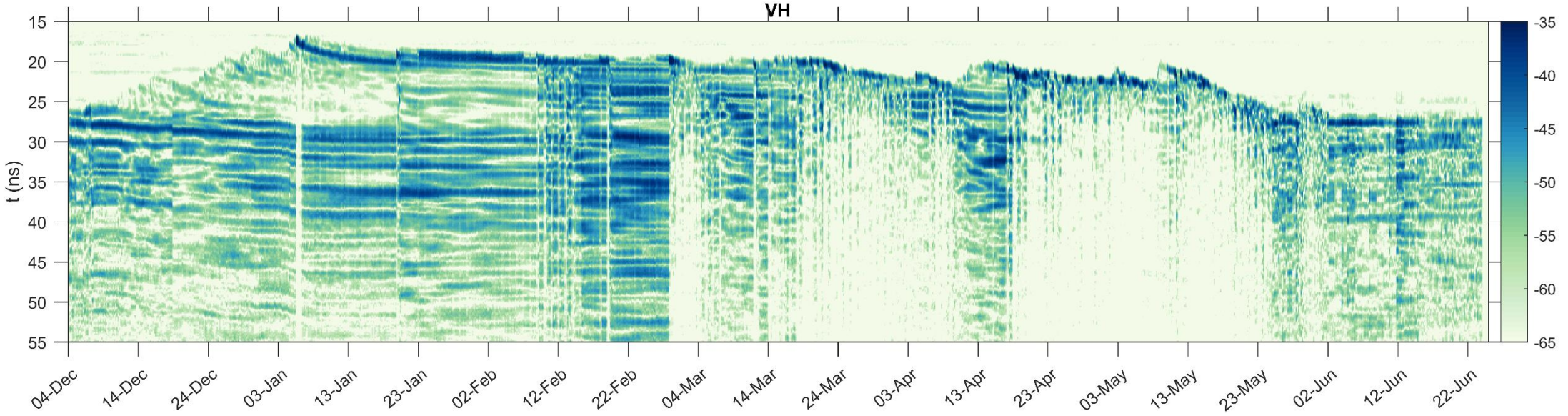
Tower based C-band measurements of an alpine snowpack

Goal:

- Understand interactions between radar waves and the snowpack
- Support Sentinel-1 snow depth retrievals (Lievens et al. 2019, 2022)

Take aways:

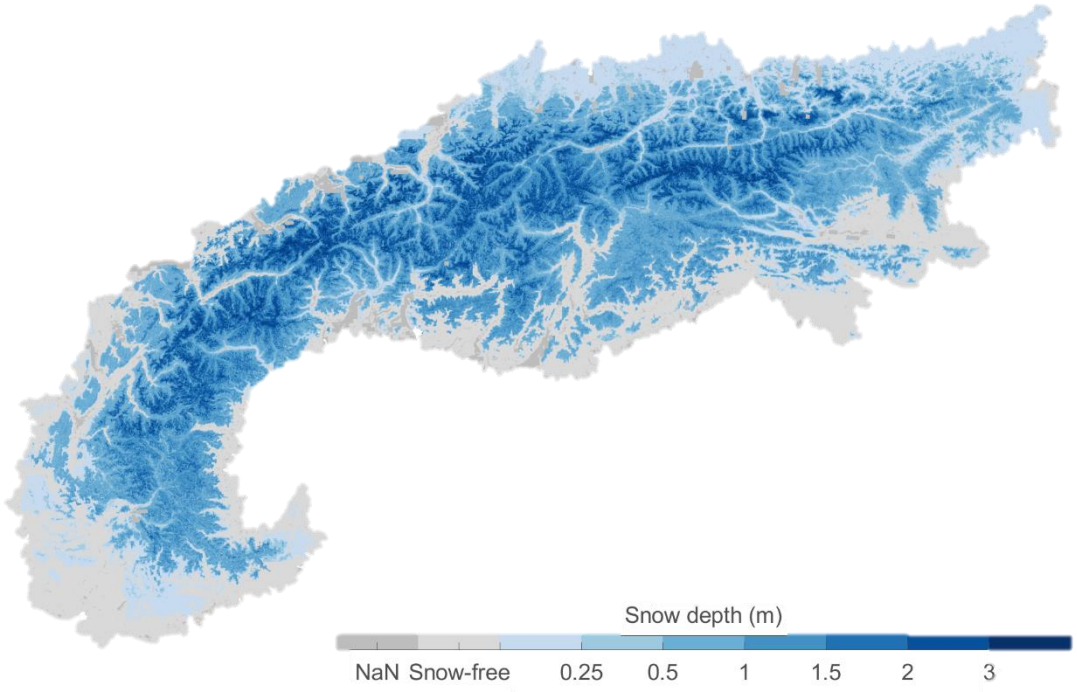
- Snow is not transparant at C-band
- Influence of wet snow & stratigraphy

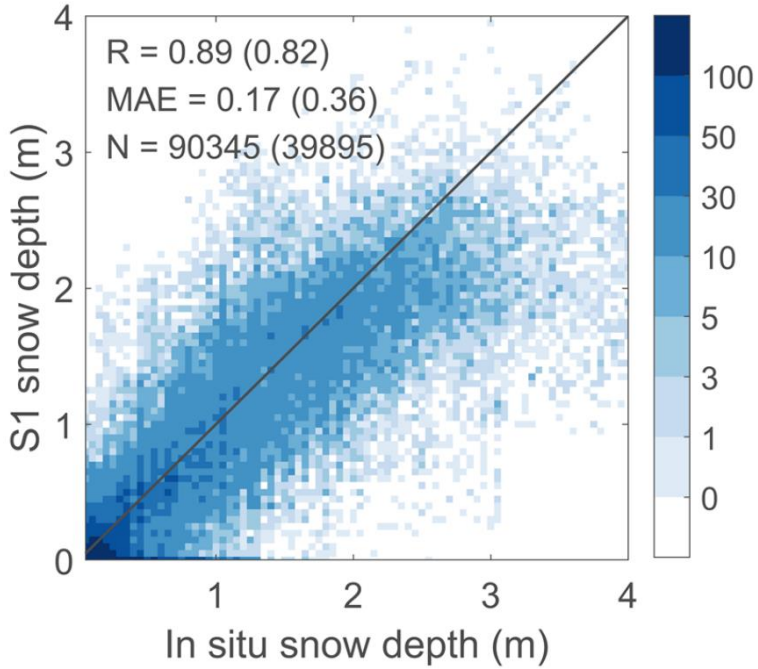


Isis Brangers, Hans-Peter Marshall, Gabrielle De Lannoy and Hans Lievens (isis.brangers@kuleuven.be)

Sentinel-1 based snow depth estimates

Resolution: <1 km spatial, ~3-6 day temporal





Scatter-plot

Time-series

Lievens et al. *Snow depth variability in the Northern Hemisphere mountains observed from space*. Nature Communications, 2019.

Lievens et al. *Sentinel-1 snow depth retrieval at sub-kilometer resolution over the European Alps*. The Cryosphere, 2022.

Good correlations with insitu SD

→ **Need to better understand physics at C-band**

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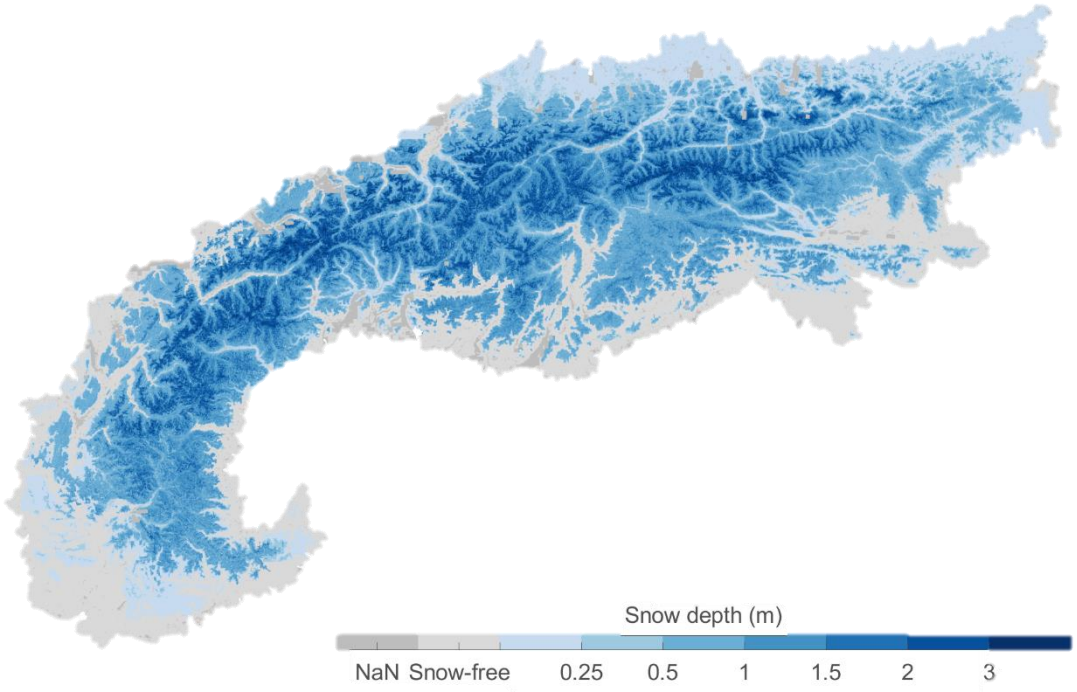

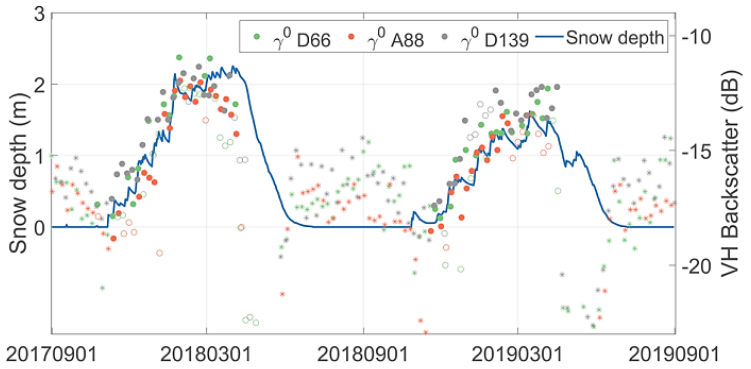

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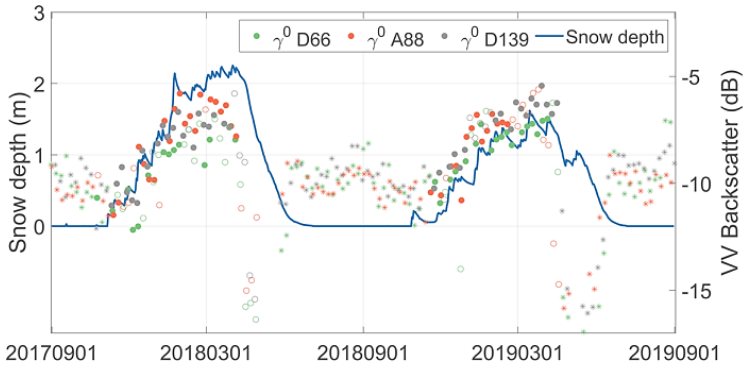

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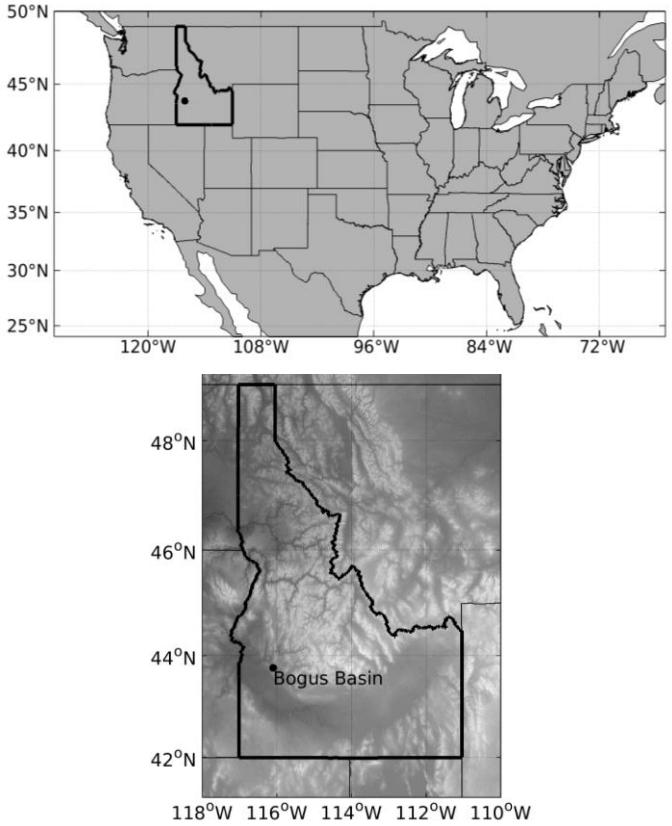
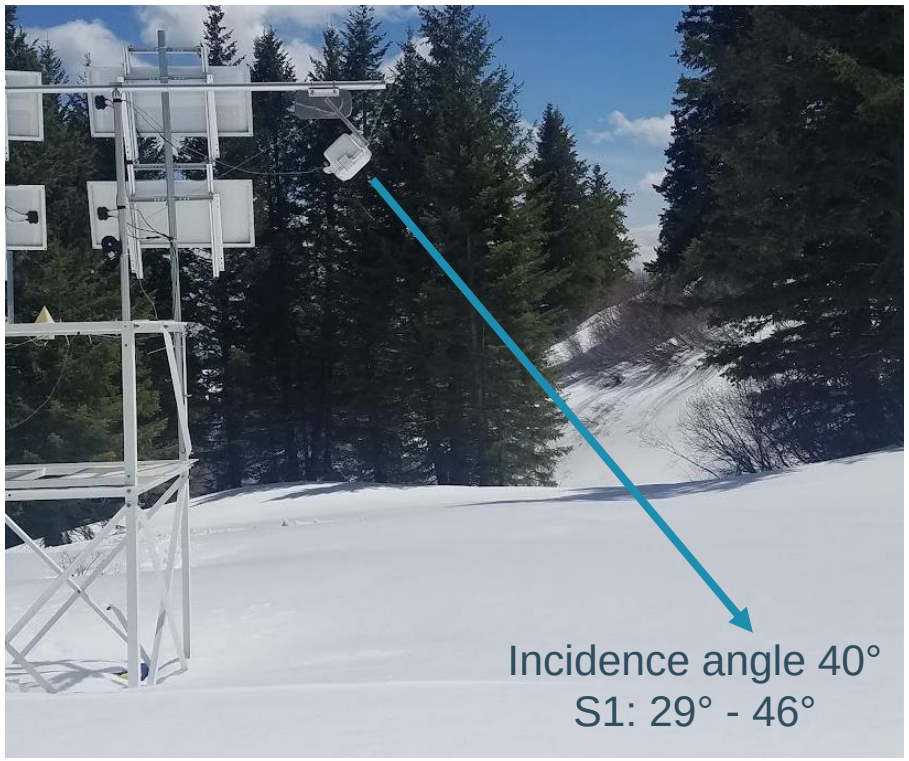


Rocky Mountains, Idaho
Elevation 1930 m

Vegetation: bushes



Median peak SWE: 650 mm
SNOTEL within 1 km

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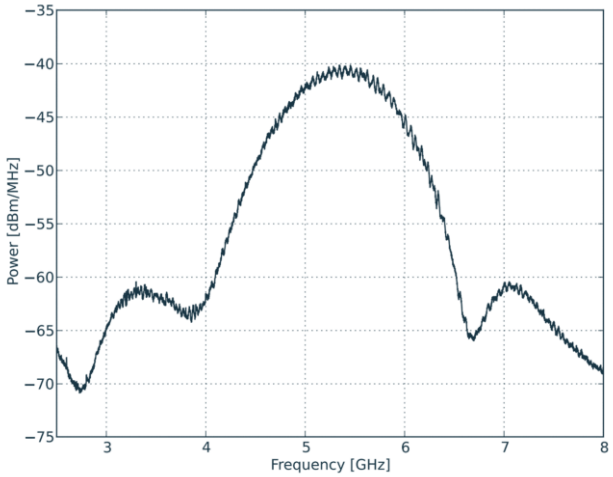
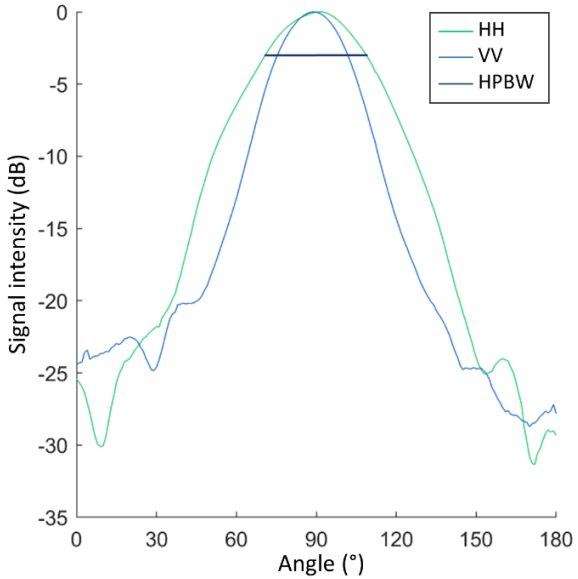
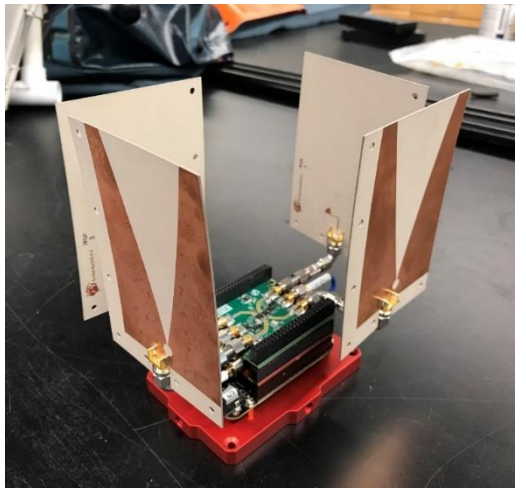
- C-band: 5.4 GHz
- 1.5 GHz bandwidth
  → high range resolution
- 40° beamwidth







- Full polarimetric (VV, HH, VH, HV)
- Pulsed radar
- Hourly measurements

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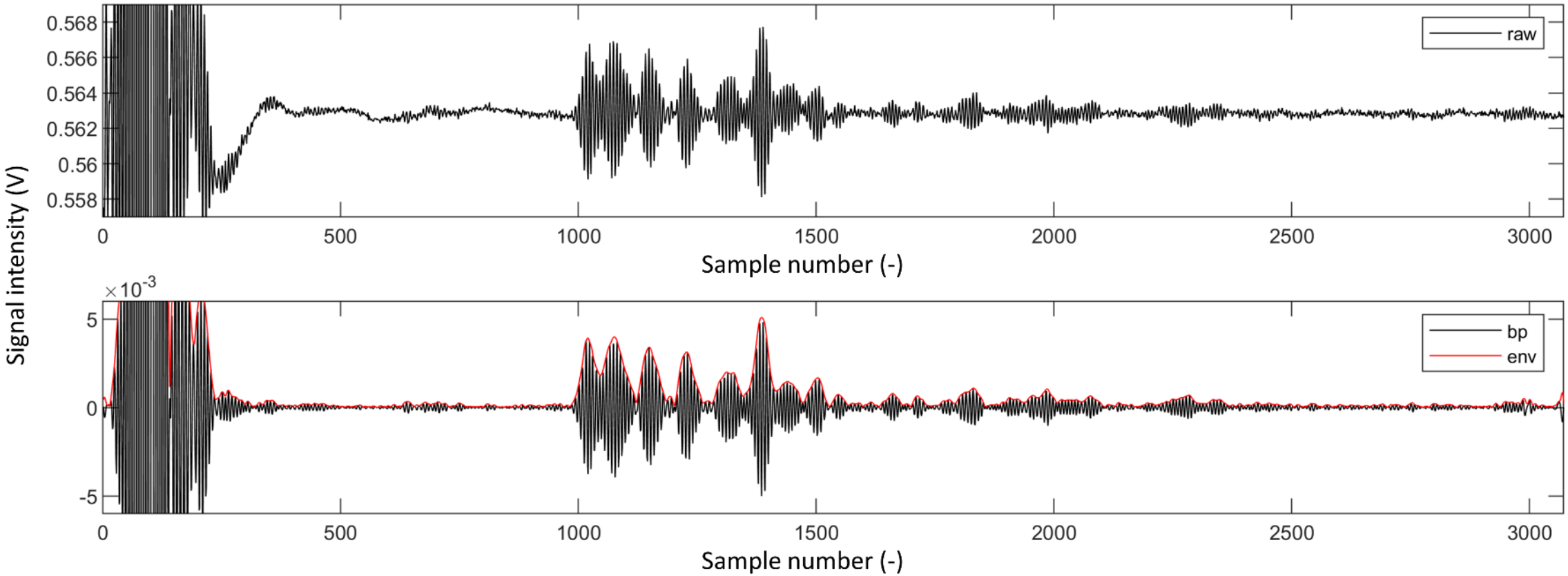

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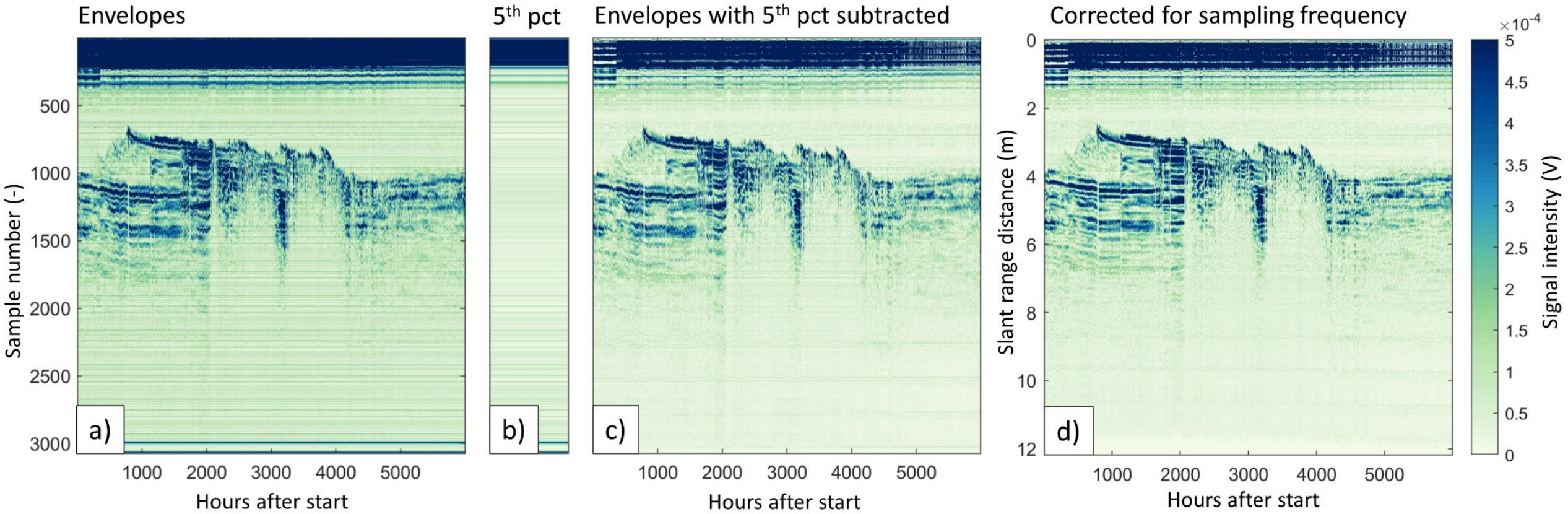

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Radar equation

$$\sigma_0 = \frac{P_{rec}}{P_{tr}} R^4 \frac{(4\pi)^3}{G_{rec} G_{tr} \lambda^2} \frac{1}{A}$$

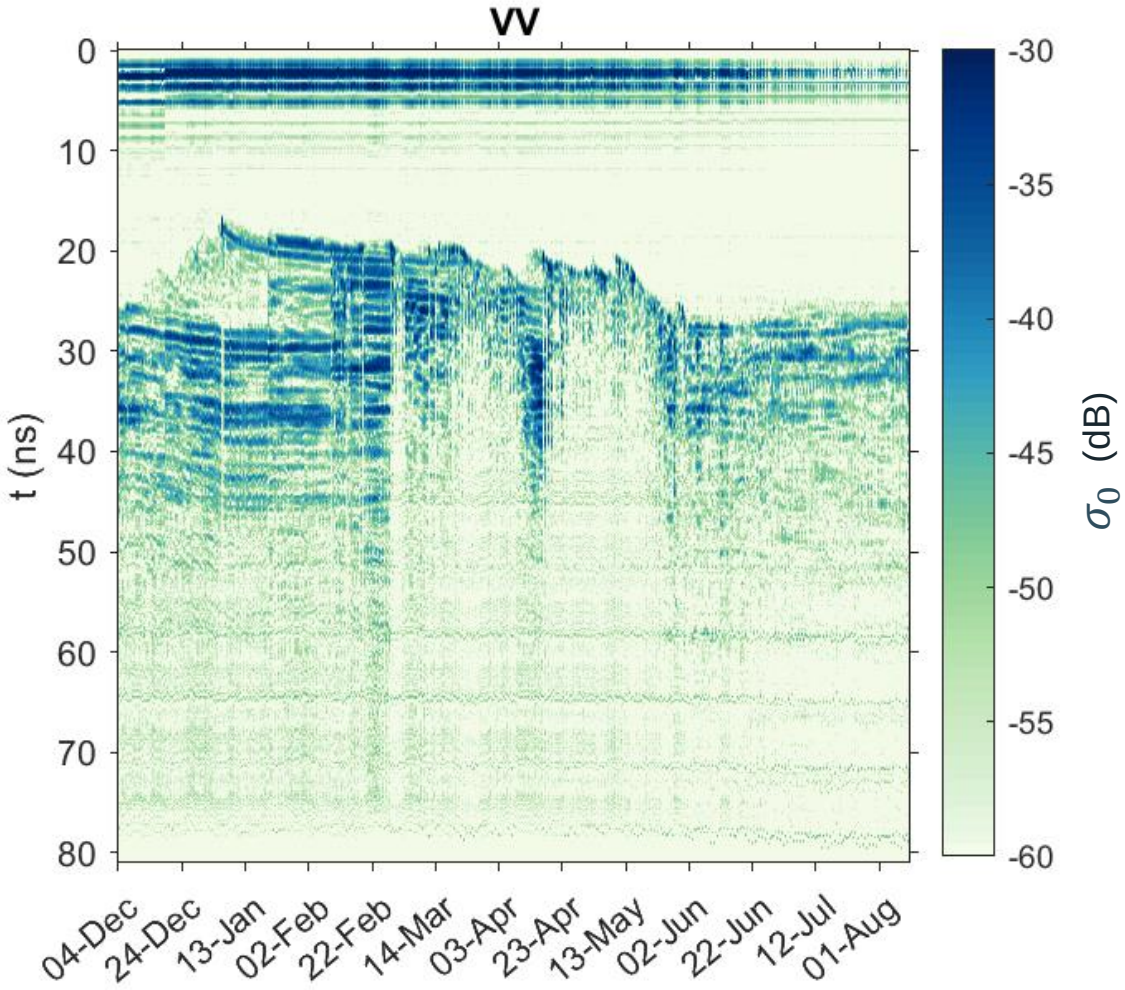
With footprint area A expanding with distance from the radar

$$A = \pi \left(R \tan \frac{\mathrm{HPBW}}{2}\right)^2$$

Aggregating constants:

$$\sigma_0 = P_{rec} R^2 k$$

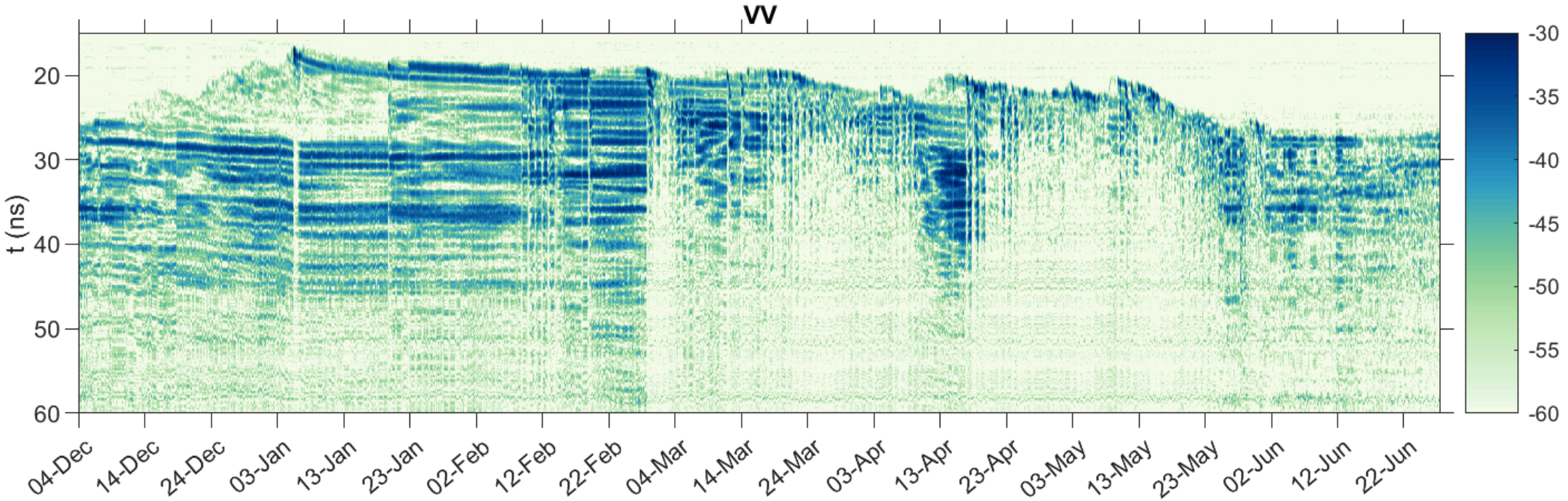
$$E_{rec}{}^2$$



VV

HH

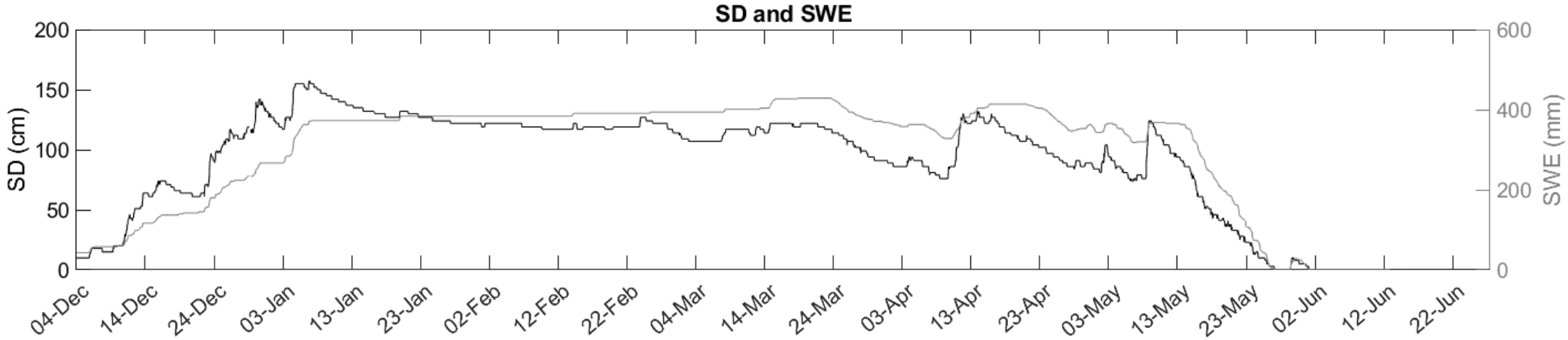
VH



Snow

T air

Soil



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VV

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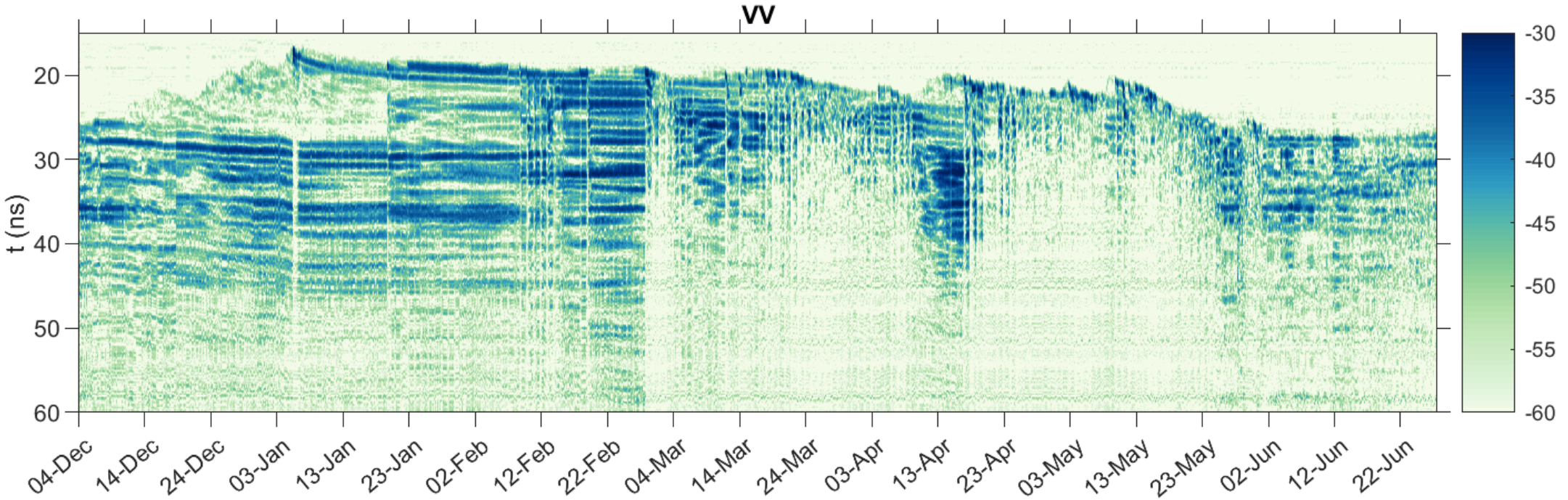
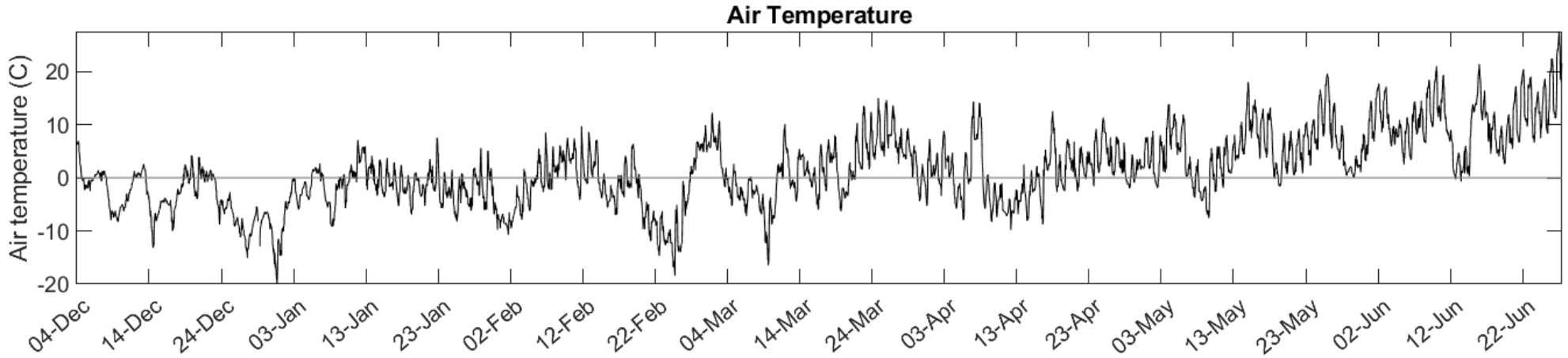


Snow

T air

Soil



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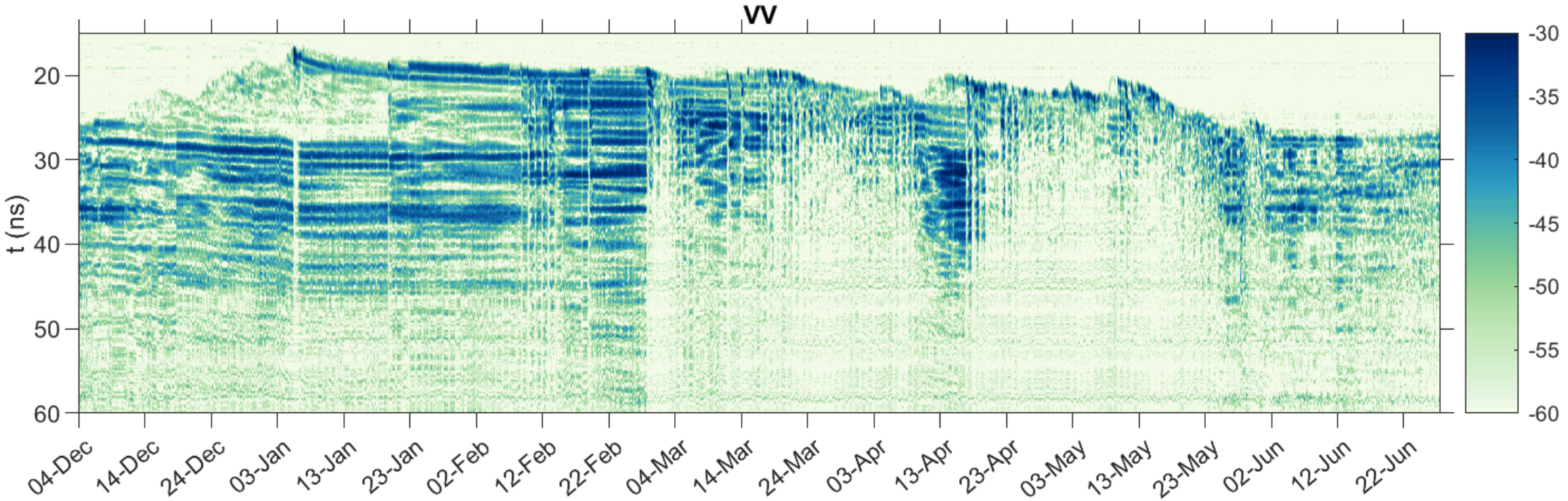

Snow

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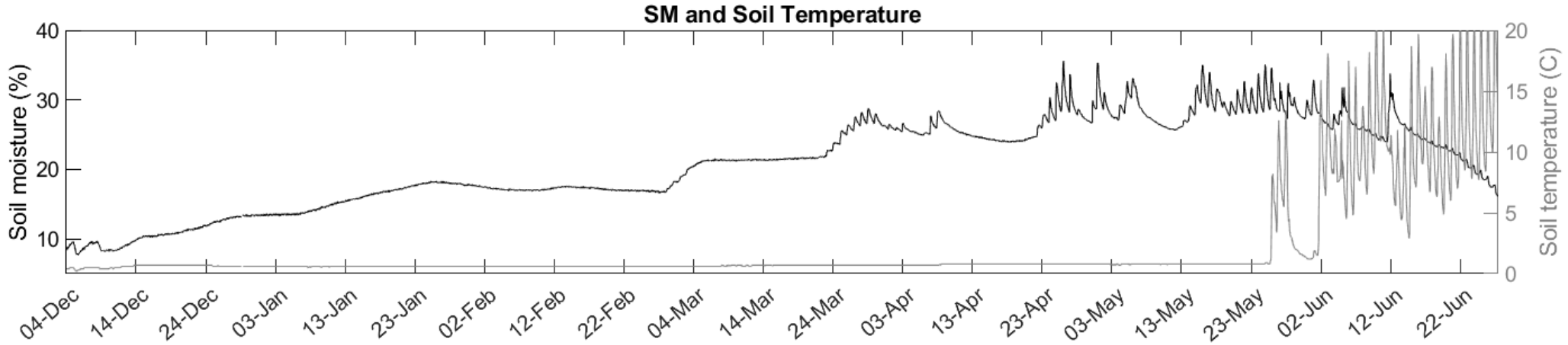
Soil



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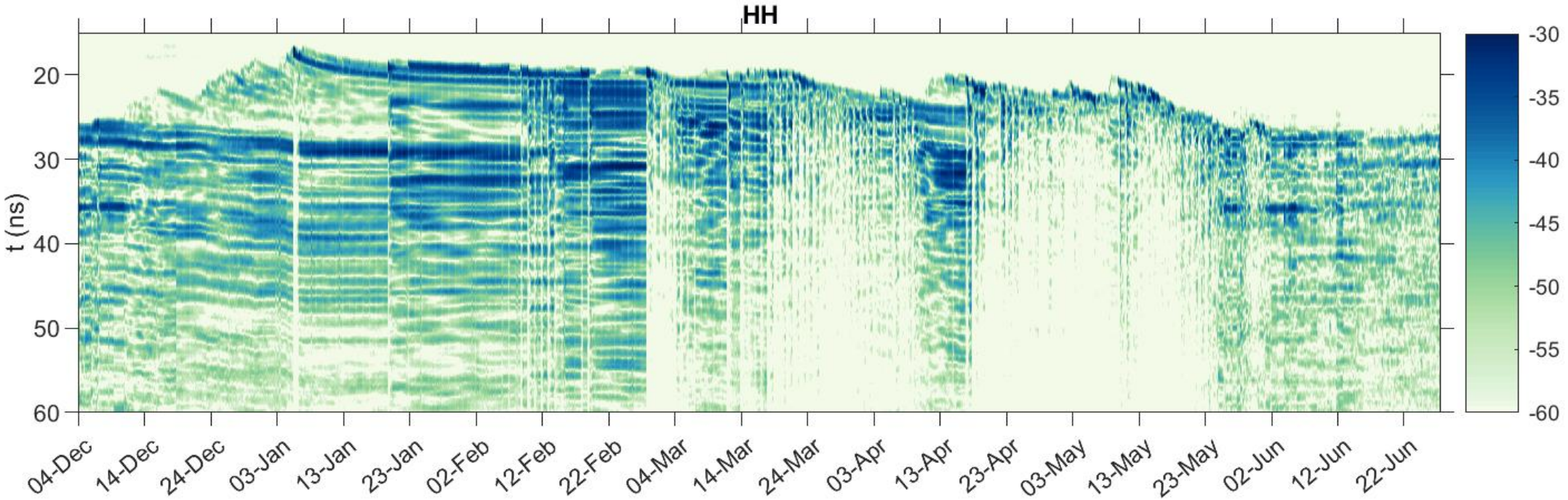
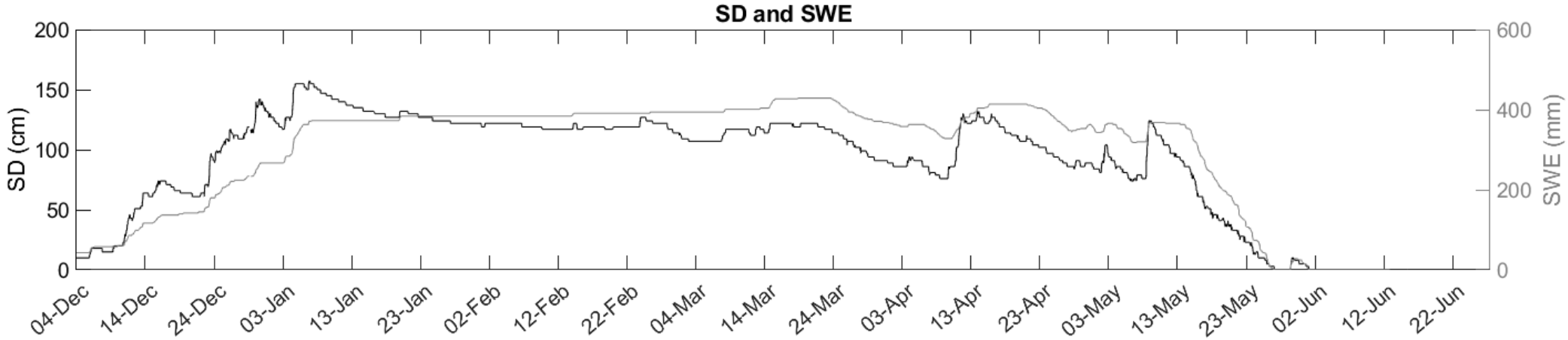


Snow

T air

Soil



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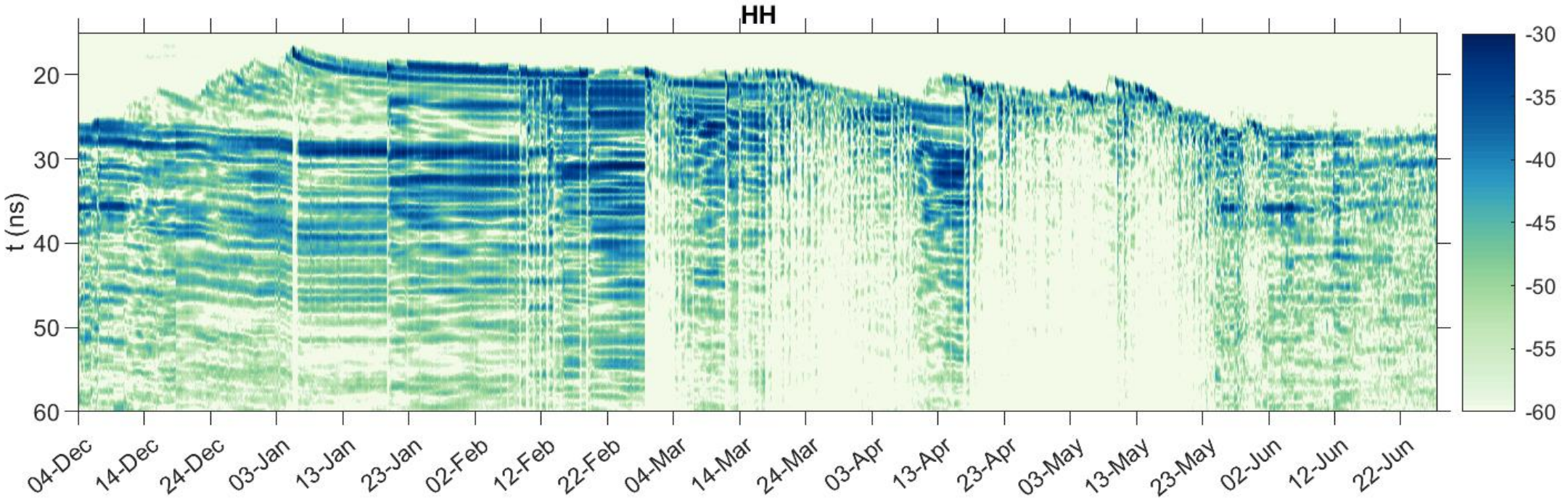
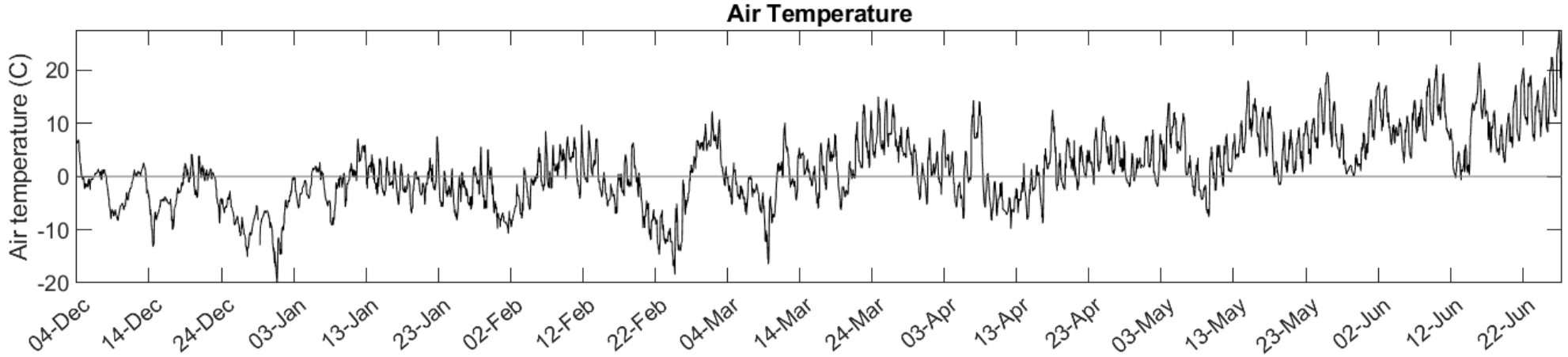


Snow

T air

Soil



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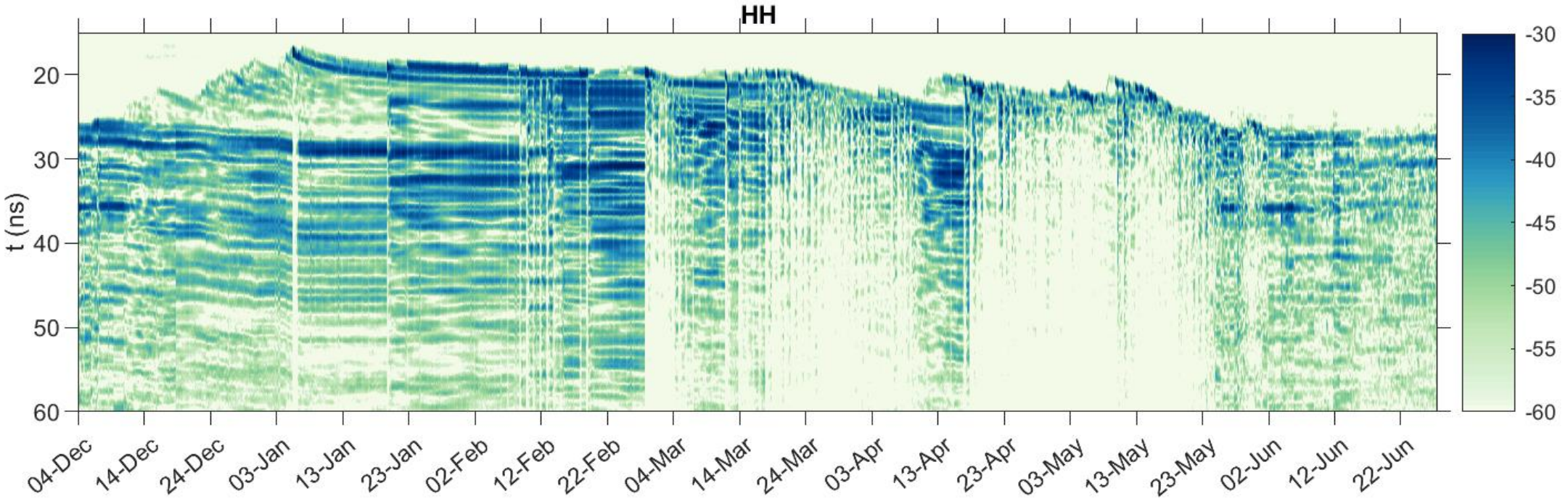

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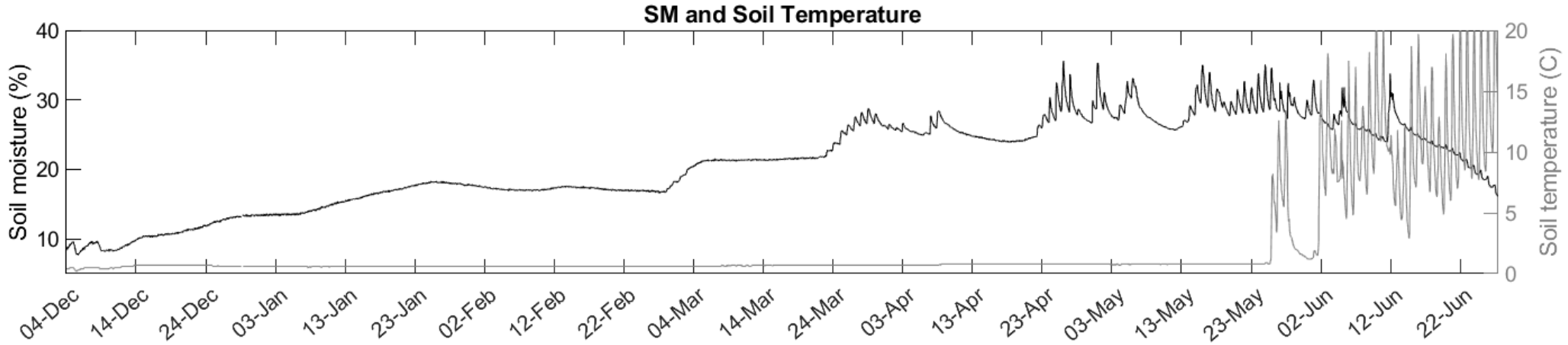

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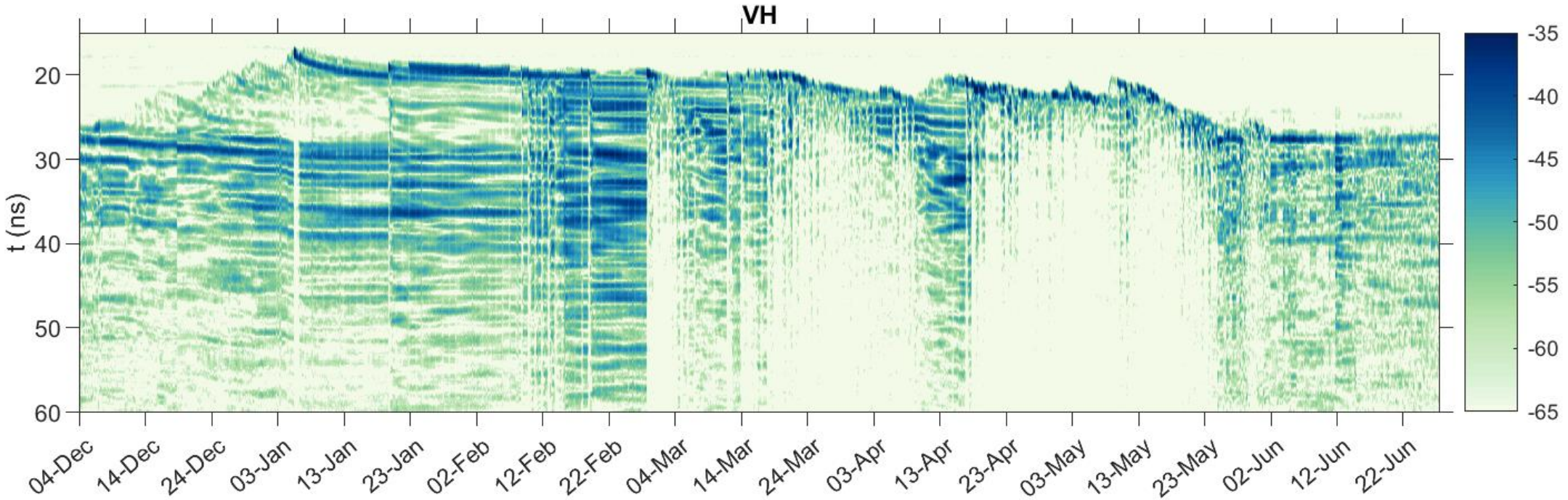

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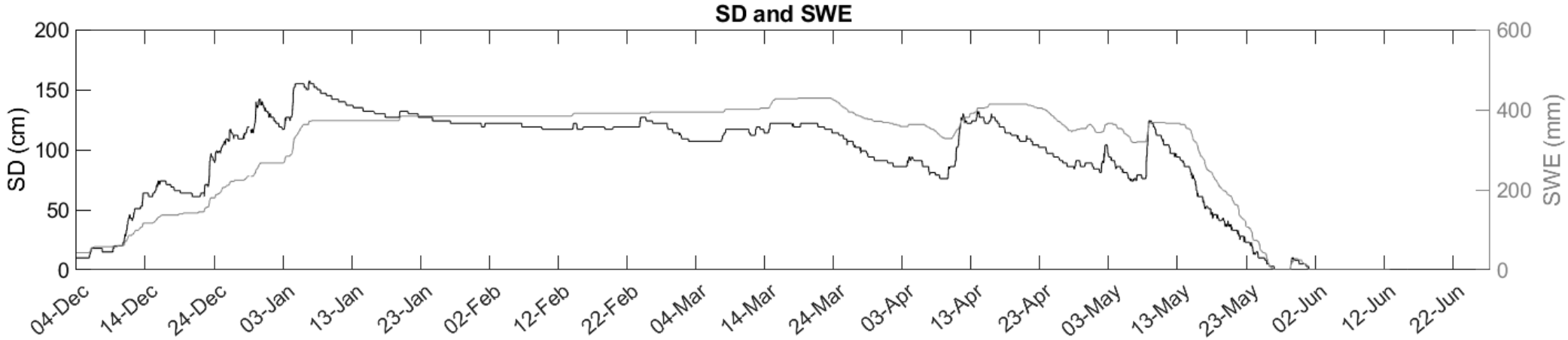

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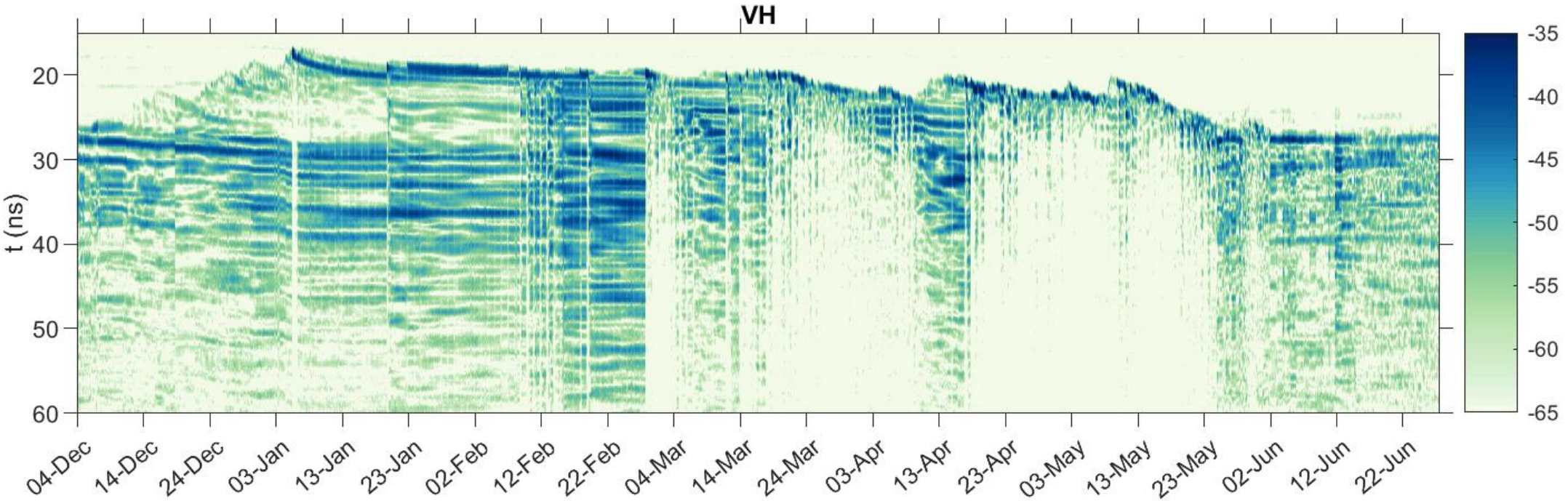

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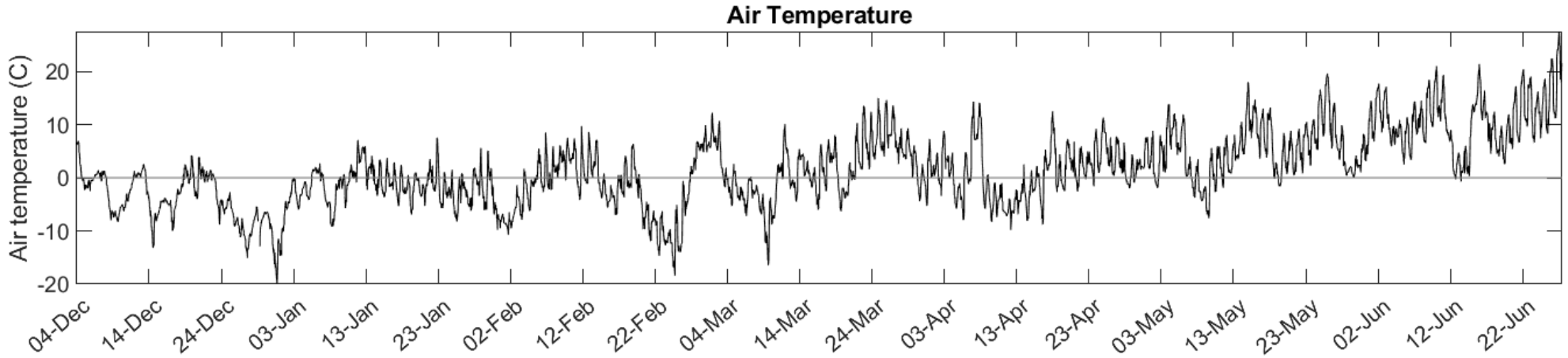

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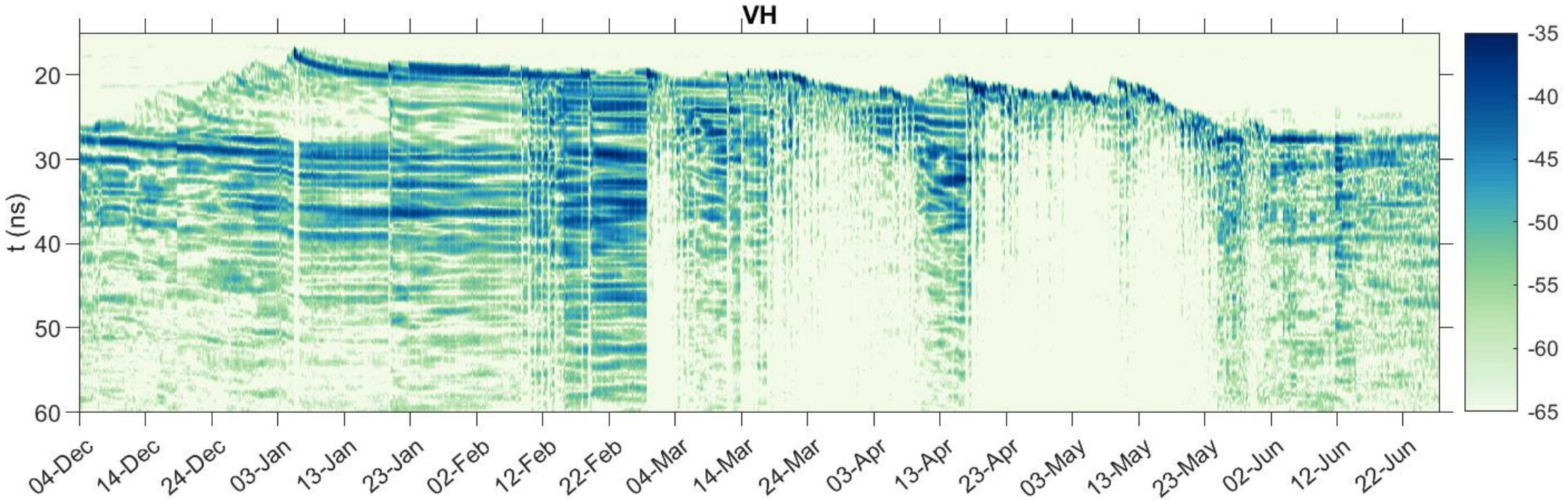

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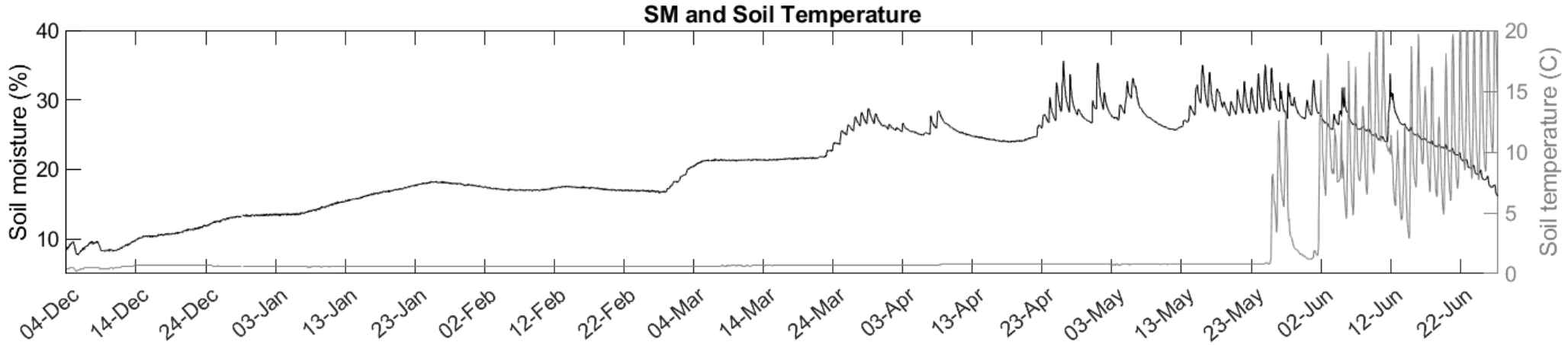

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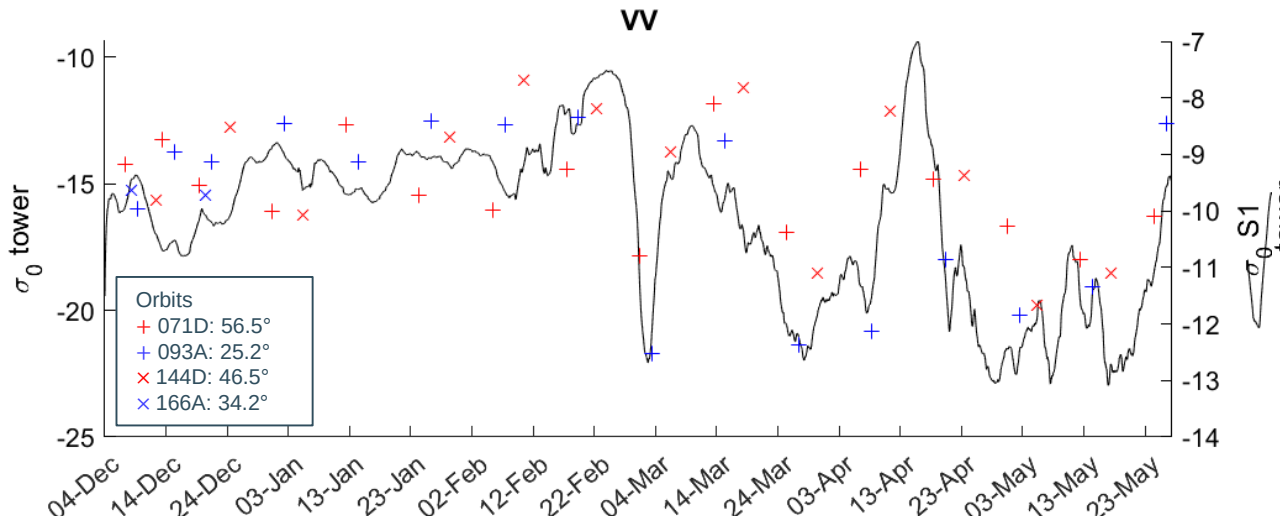

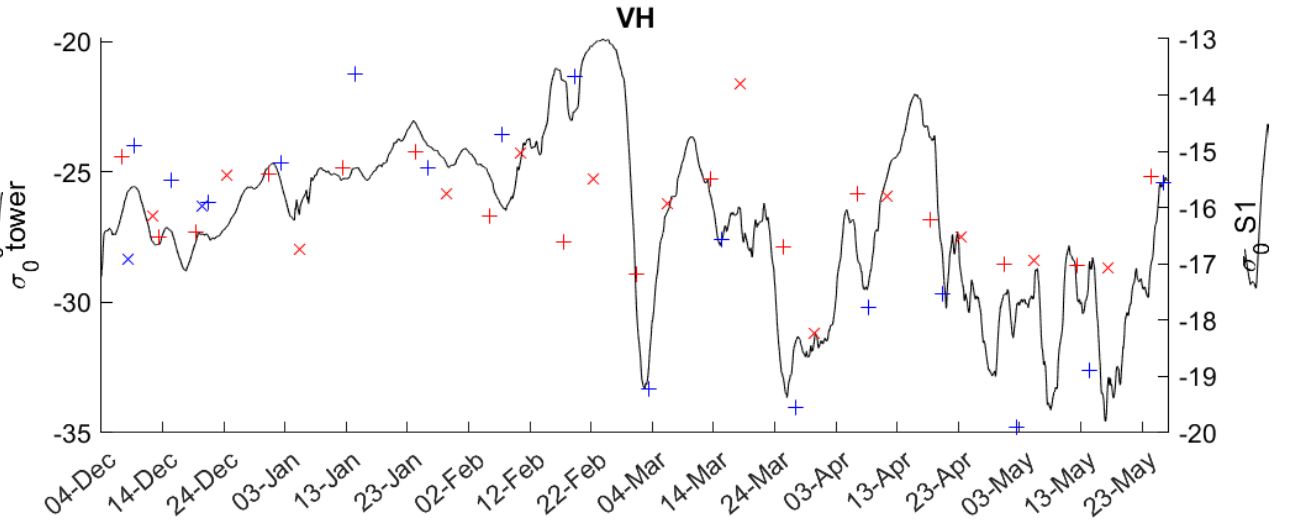

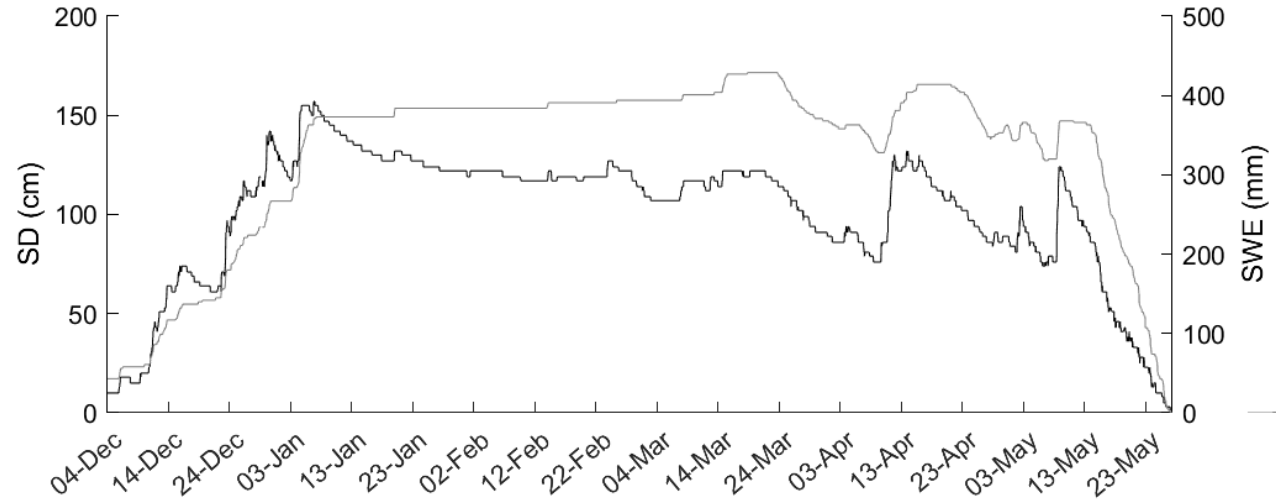

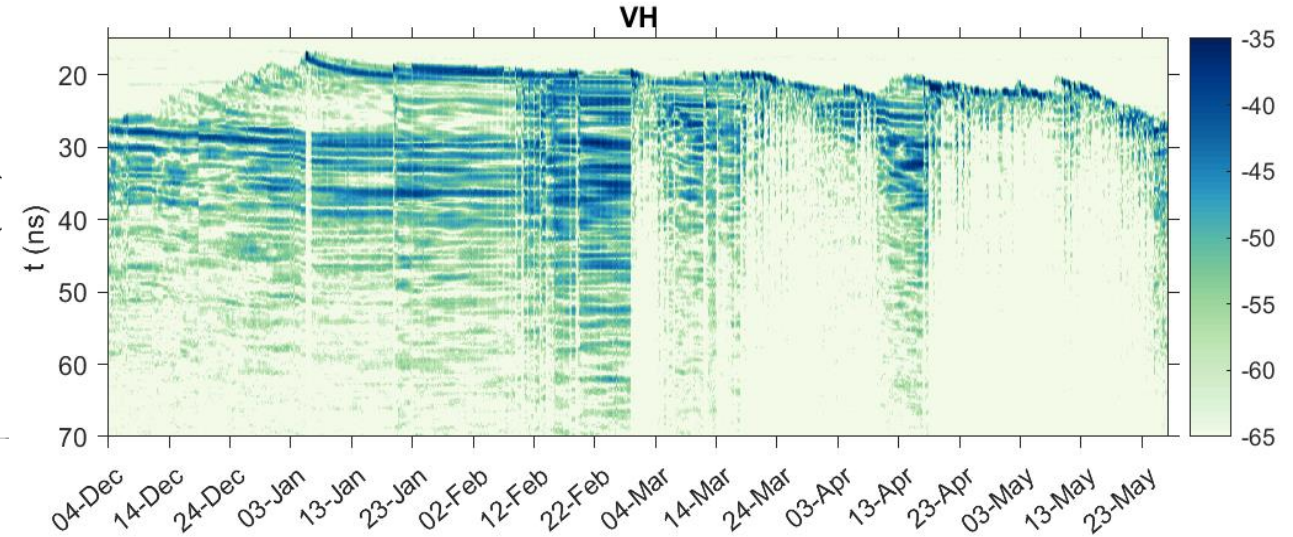

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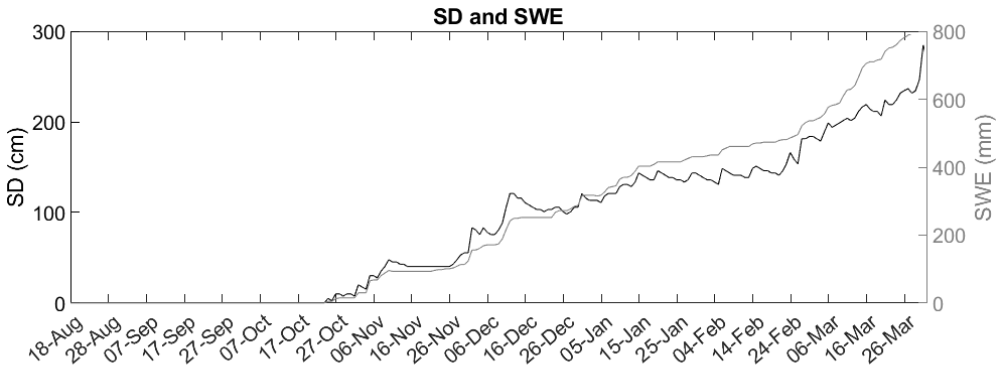
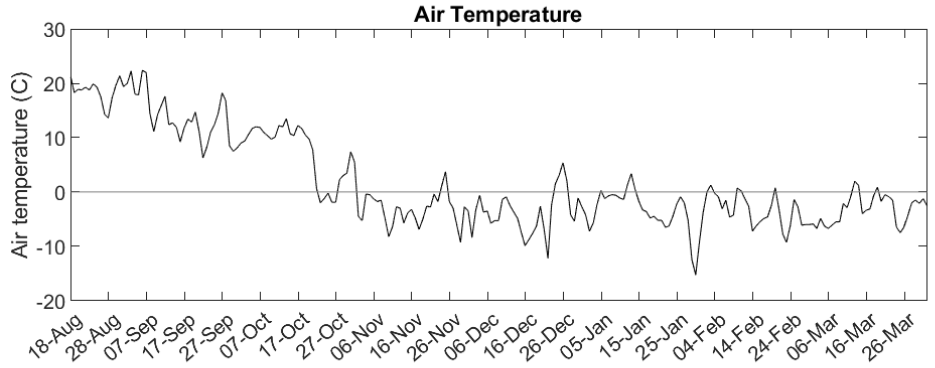
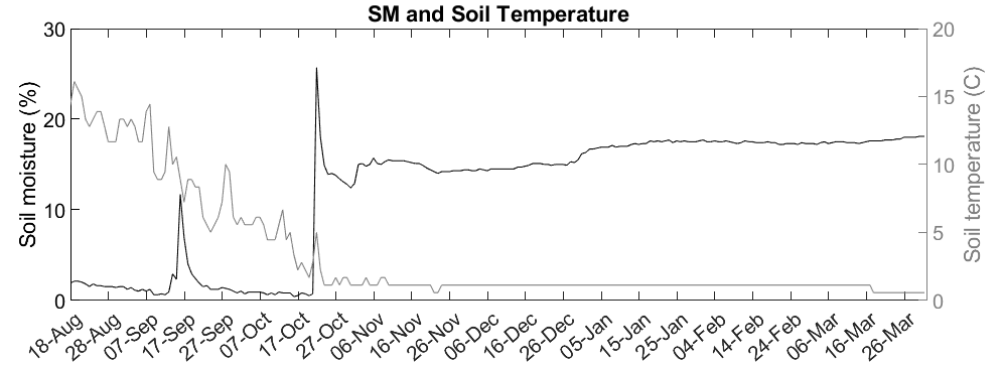
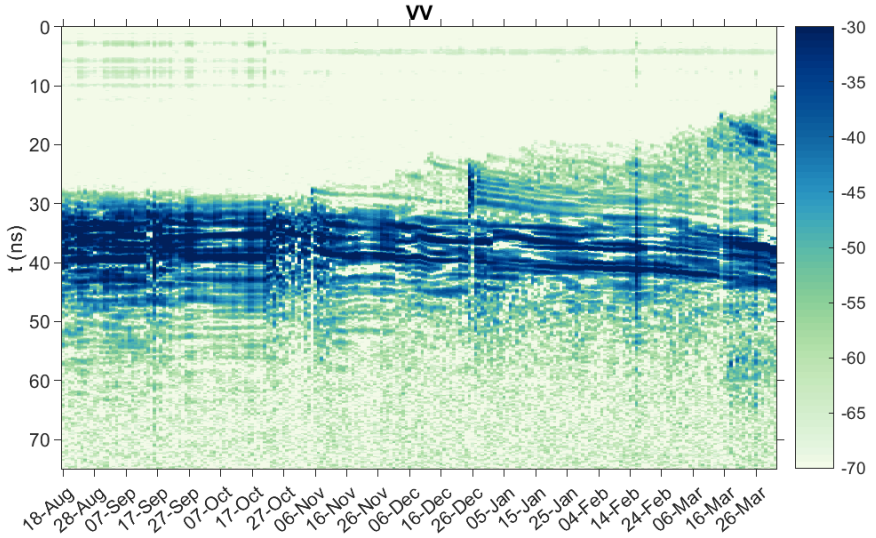
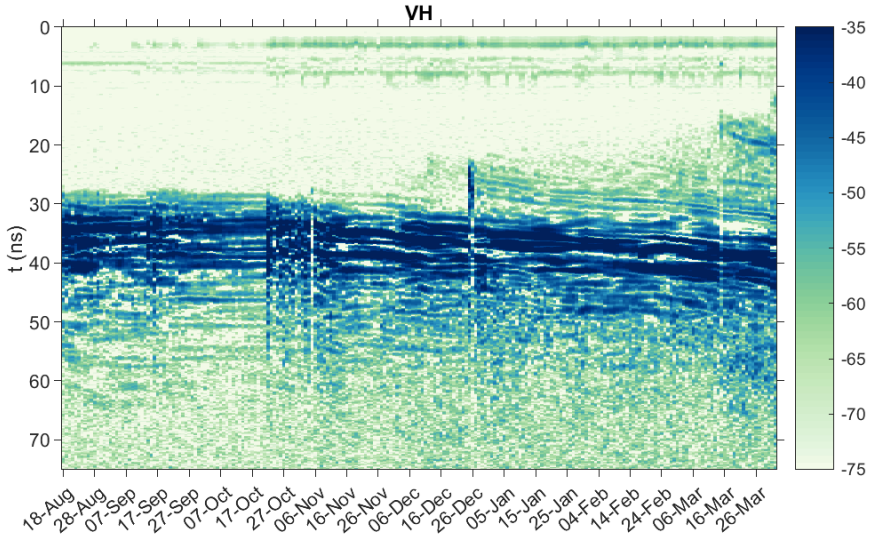








2022-2023



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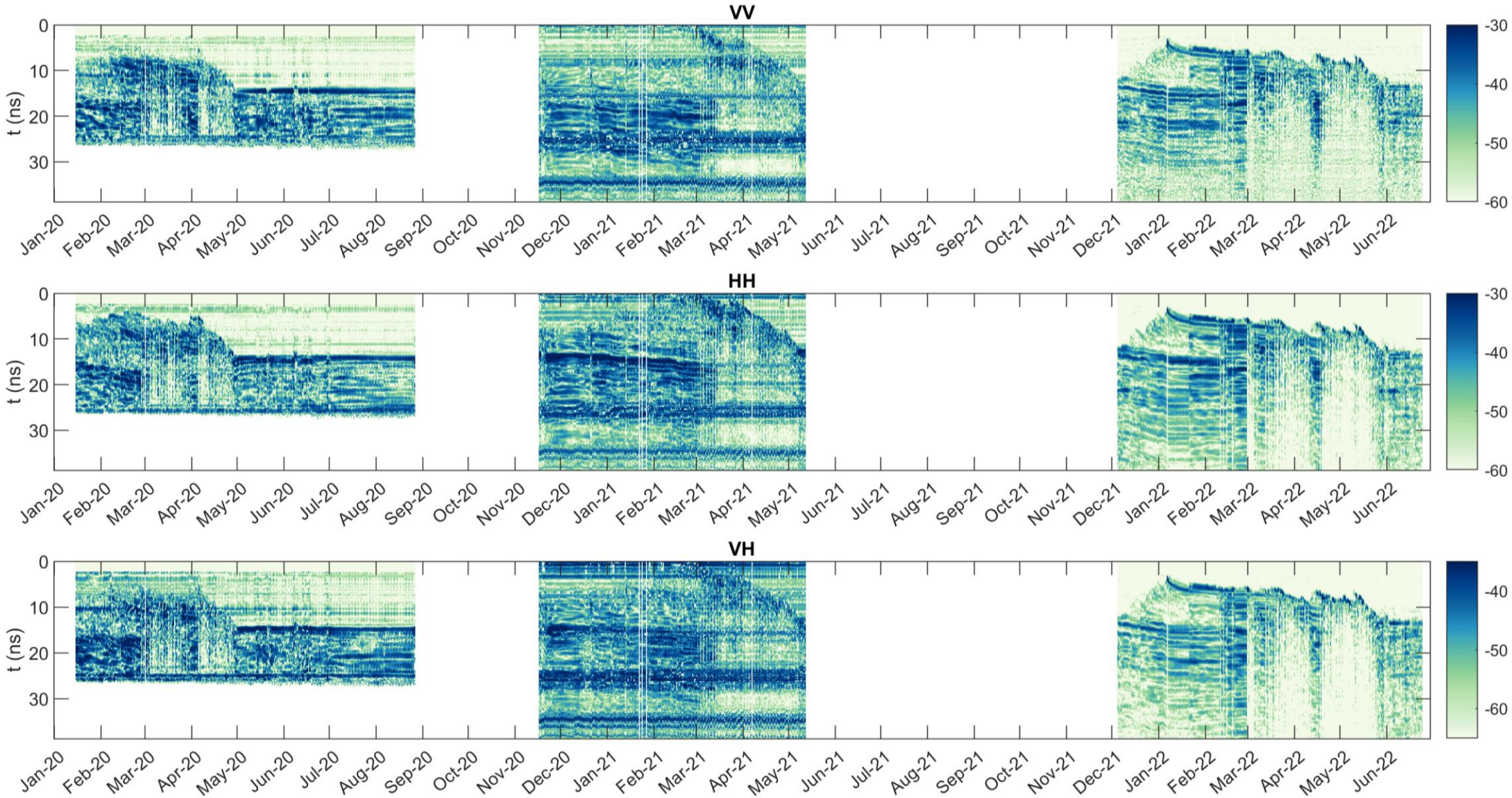

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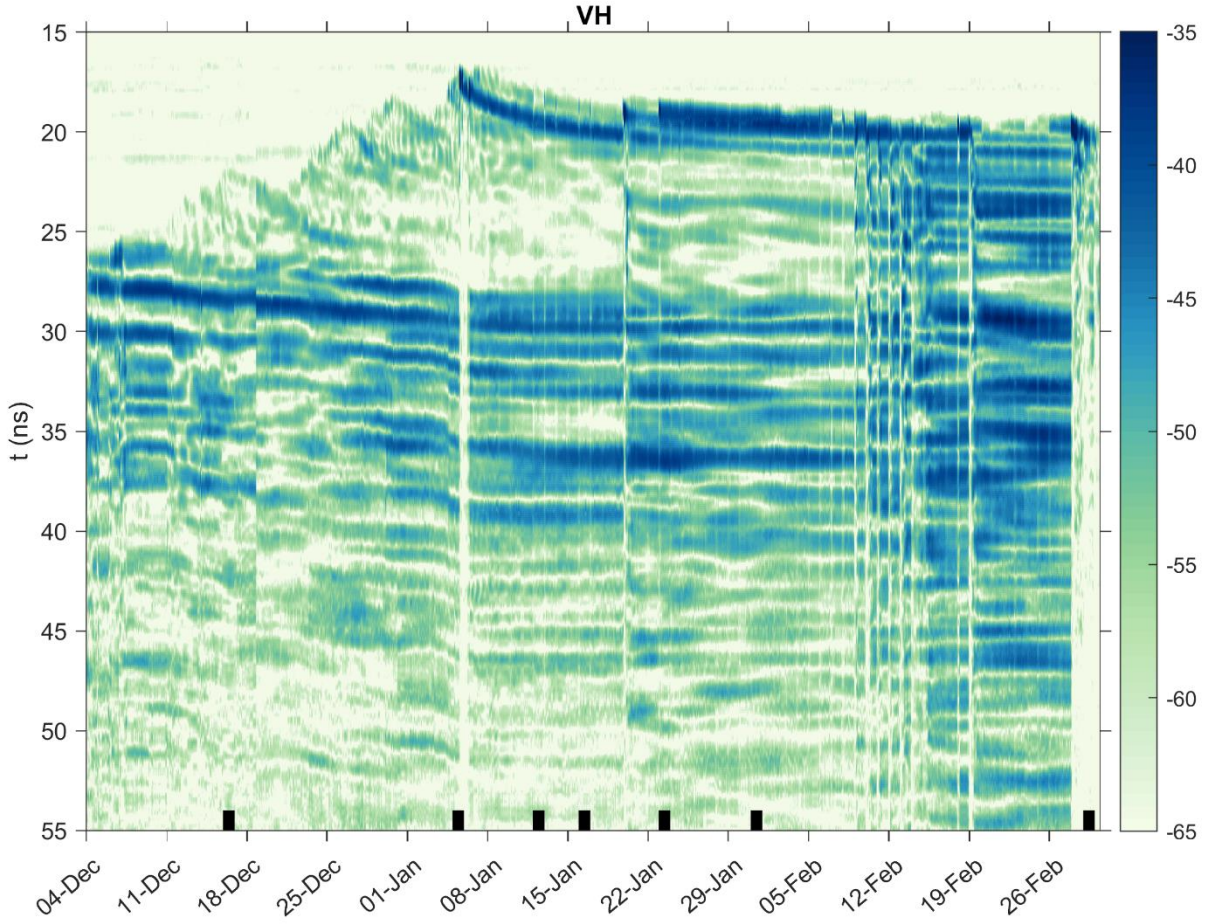
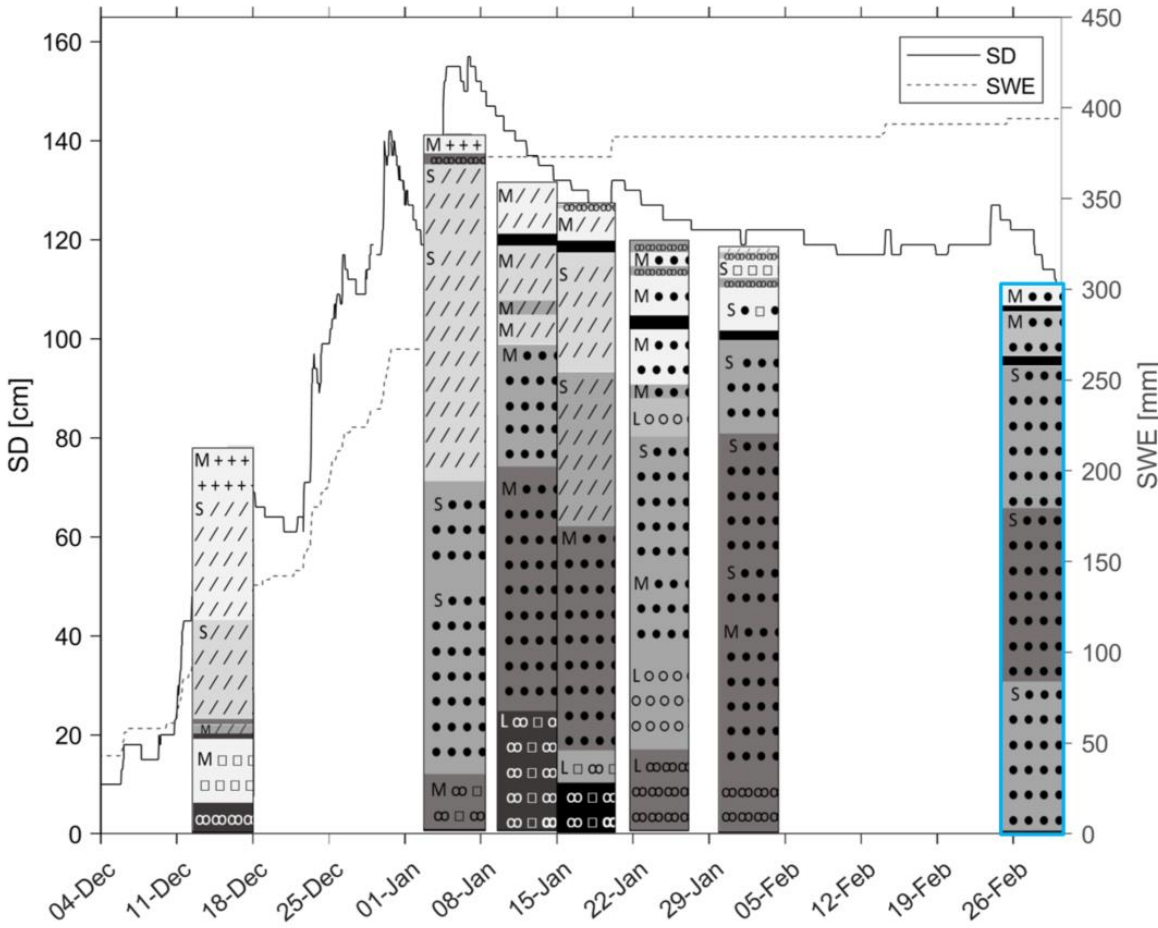
Impact of stratigraphy

Considerable impact from
- Melt freeze cycles
- Ice layers / crusts
- Liquid water





Graintypes:
+ : Fresh
/ : Decomp.
● : Rounds
○ ∞ : Melt forms
□ : Facets

Grainsizes:
S : <1 mm
M : 1-2 mm
L : >2 mm

Fist
4 Fingers
1 Finger
Pencil
Knife
Ice

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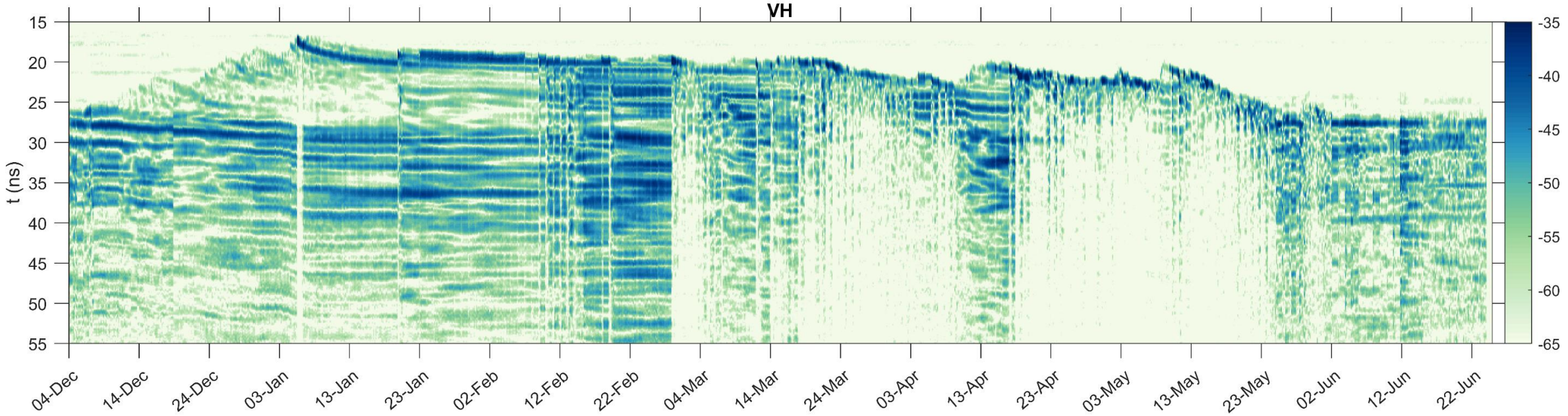

Suggested contributions:

- Air-snow interface:
  - Low/medium reflection for dry snow
  - High reflection in case of wet snow or strong scattering layer (ice/crust) at top
- Wet snow
  - Scattering only at top of snowpack
- Snow-ground interface
  - High if signal not obstructed by wet snow
- Higher order interactions (return partly after main ground reflection)
  - Low to high, seems to become more strong during the snow season
- Volume scattering
  - Low/medium for dry snow (hard to distinguish from snow layer interface scattering)
- Snow layer interface scattering
  - High for interfaces with crusts
  - Low/medium for less contrasting layers

→ Melt-freeze cycles and contrasting layers dominate dry snow signal

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