The new altimetric module in Snow Microwave Radiative Transfer Model for snow (SMRT)

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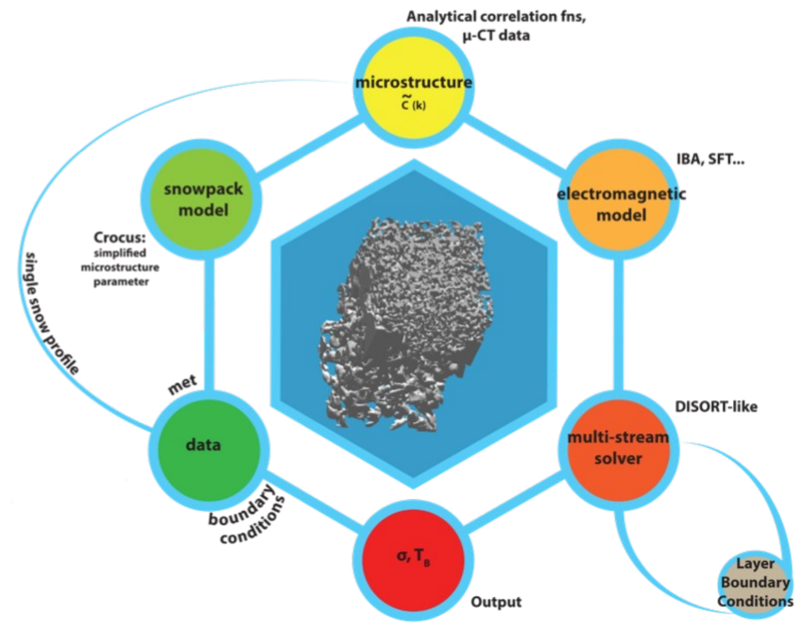
Context

SMRT origin and present status:



2015-2017:

SMRT is initiated in the MICROSNOW ESA project on snow microstructure signature in the microwaves i.e. "grain size scattering".
→ passive microwave focused.

2018:

Development of a sea-ice module. Fresh ice / lake-ice is a side product.

2019-2020:

- Development of an altimeter module in the ESA Polar Monitoring / Cristal
- First validation in Antarctica

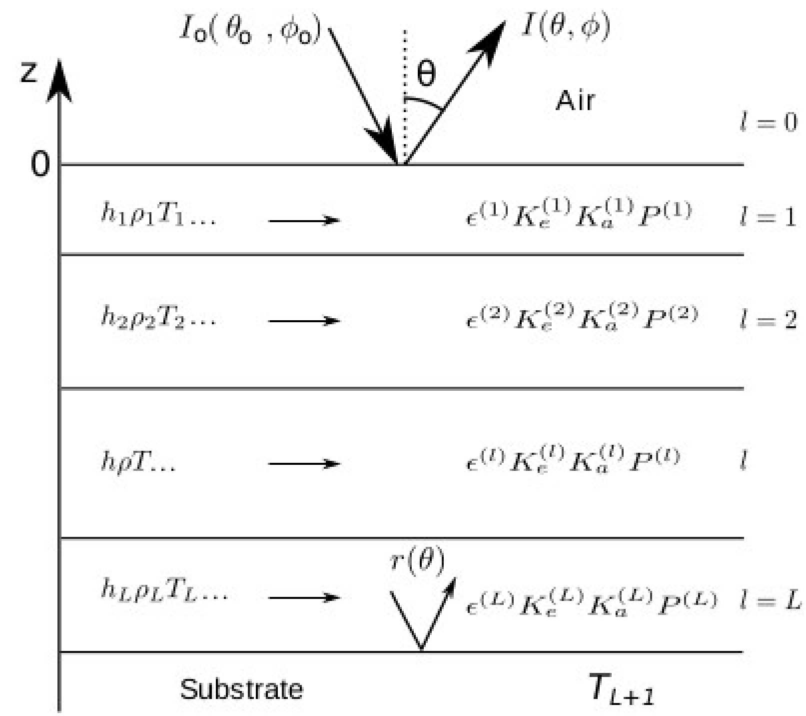
2020 - :

- LIAM (PI. C. Duguay) : validation of SMRT Altim on frozen lakes
- AKROSS (PI. M. Sandells): validation of SMRT Altim on sea-ice

Snow Microwave Radiative Transfer (SMRT)

MEMLS, HUT, DMRT-ML, DMRT-QMS are widely used passive and/or active microwave radiative transfer models for snow (not for altimetry).

The snowpack is a stack of horizontal layers



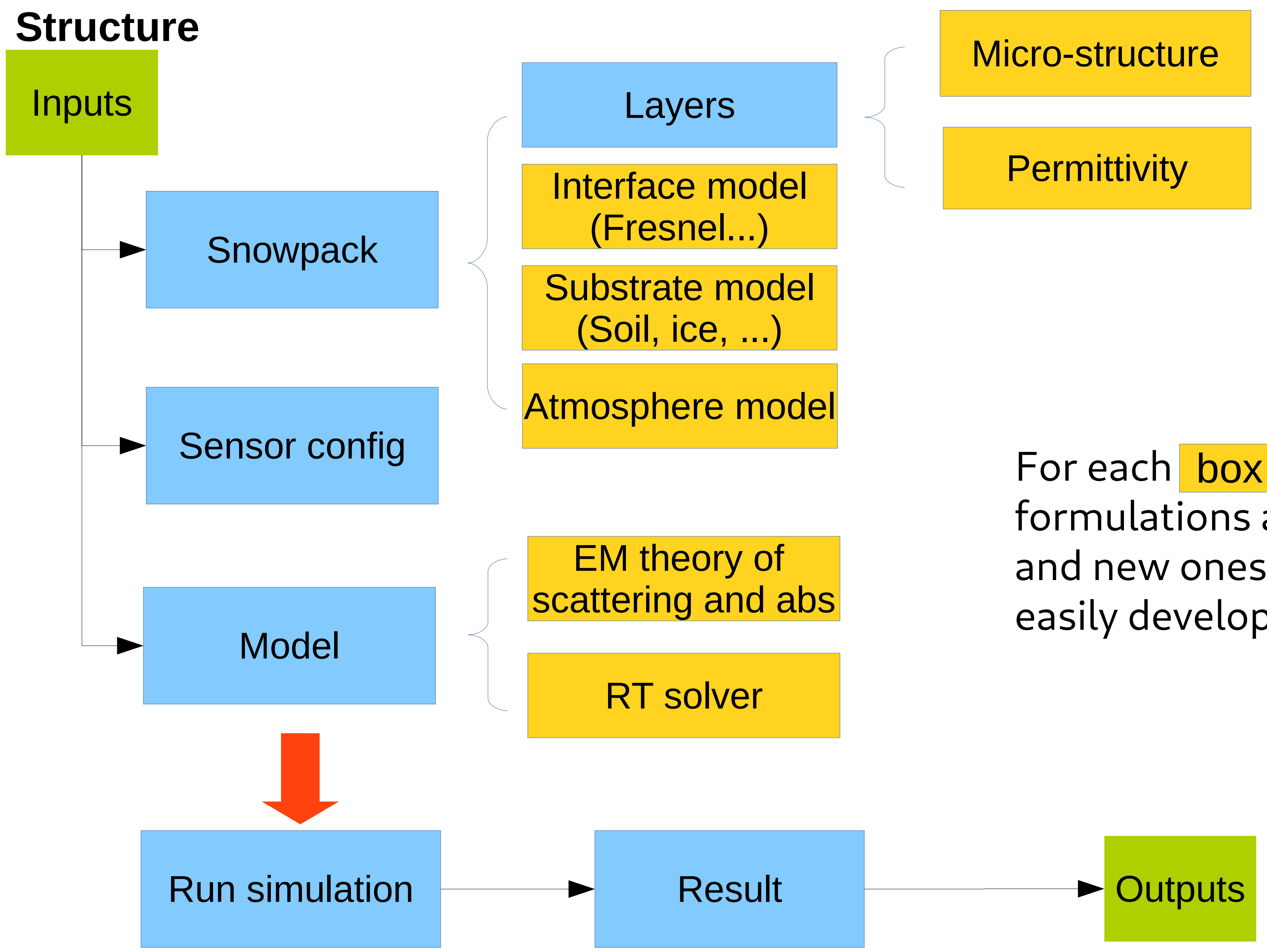
SMRT could be defined as: a new-generation passive/active microwave radiative transfer model for snow and other cold environments.

Science: a better description of the snow microstructure

Practice: It is easier to use and **easier to extend in a consistent way**

Snow Microwave Radiative Transfer (SMRT)

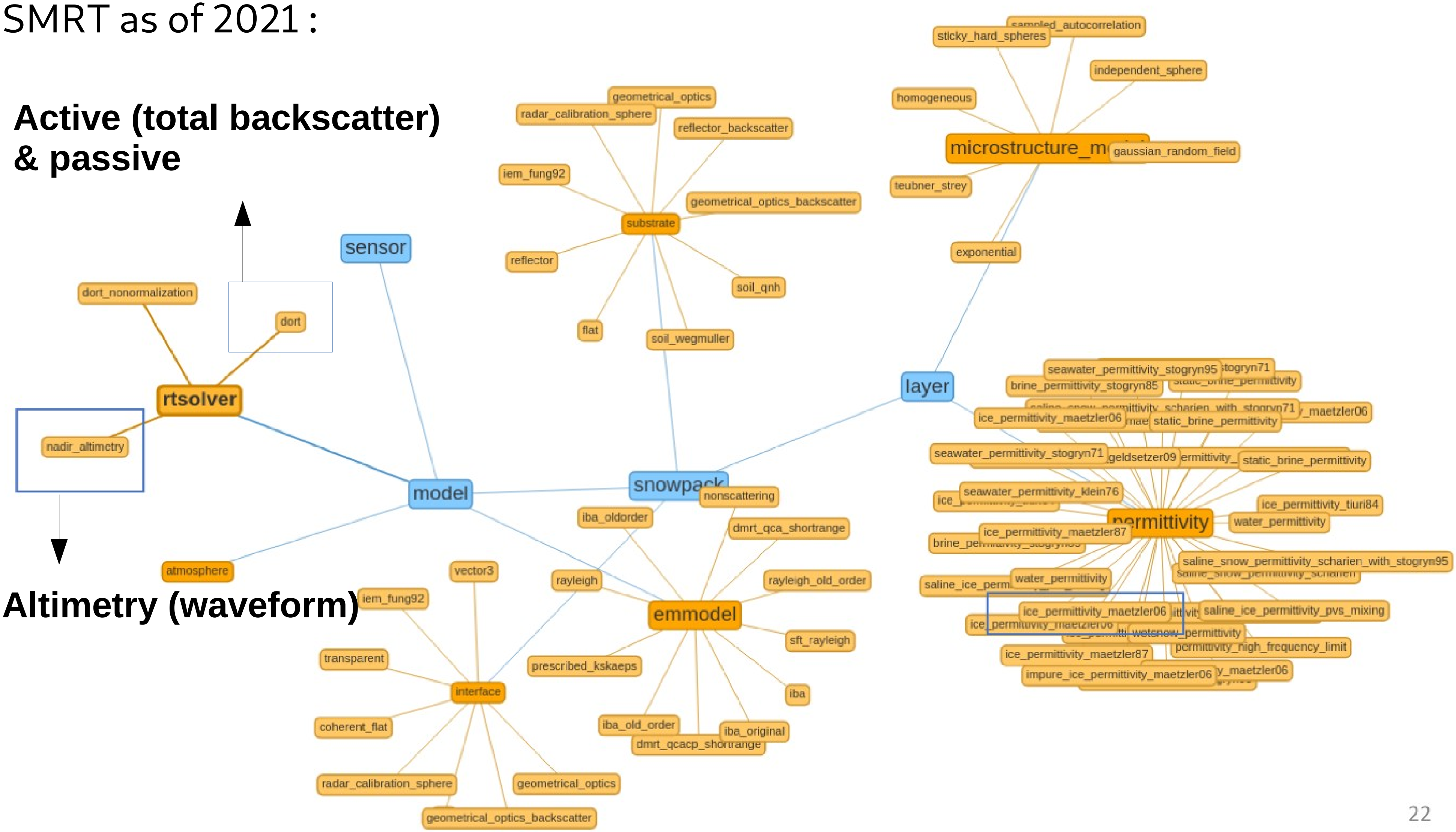
SMRT is a highly structured and modular model.



For each box many formulations are available and new ones can be easily developed

Snow Microwave Radiative Transfer (SMRT)

SMRT as of 2021 :



Some advantages of this structure:
- the altimetry module works for snow, seaice, lake ice, … and future developments
- combined passive / altimeter, total backscatter radar simulations is easy

Nadir LRM altimetry in SMRT

SMRT’s nadir altimetry model computes the waveforms in two steps:

1- compute the **vertical** profile of backscatter

Sigma = f(z)

- backscatter from the surface
- backscatter from the volume (scattering)
- backscatter from the inter-layer interfaces
- backscatter from the substrate (bottom interface)

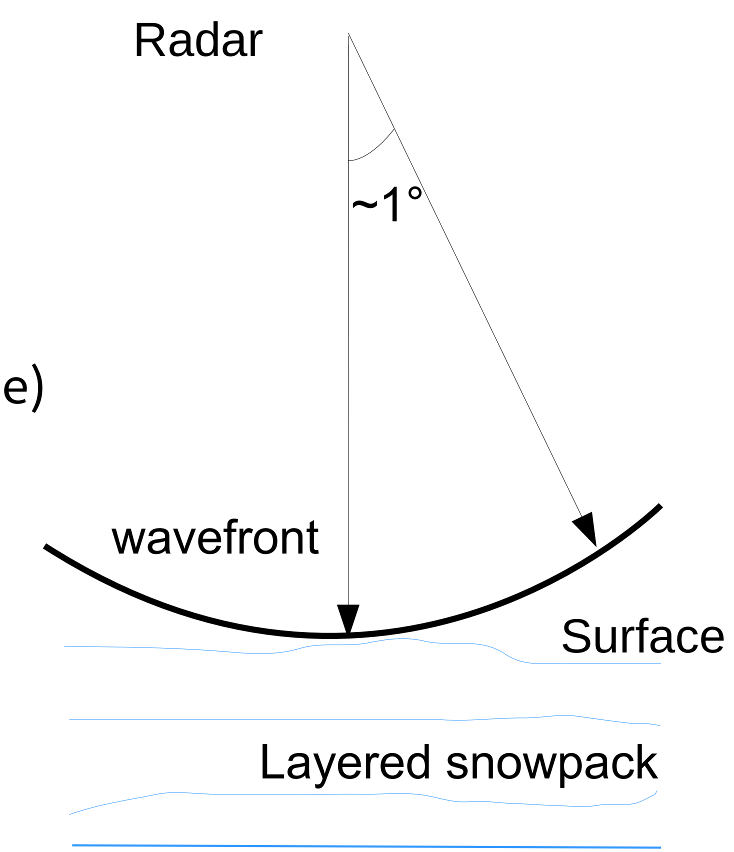
Main approx: 1st order backscatter only

2- distribute in time accounting for the **horizontal** spread/delay of the wavefront

- Brown 1977’s model → flat or tilted surface.
- « convolution with the pulse surface response »

Main approx: **LRM model**, no complex topography

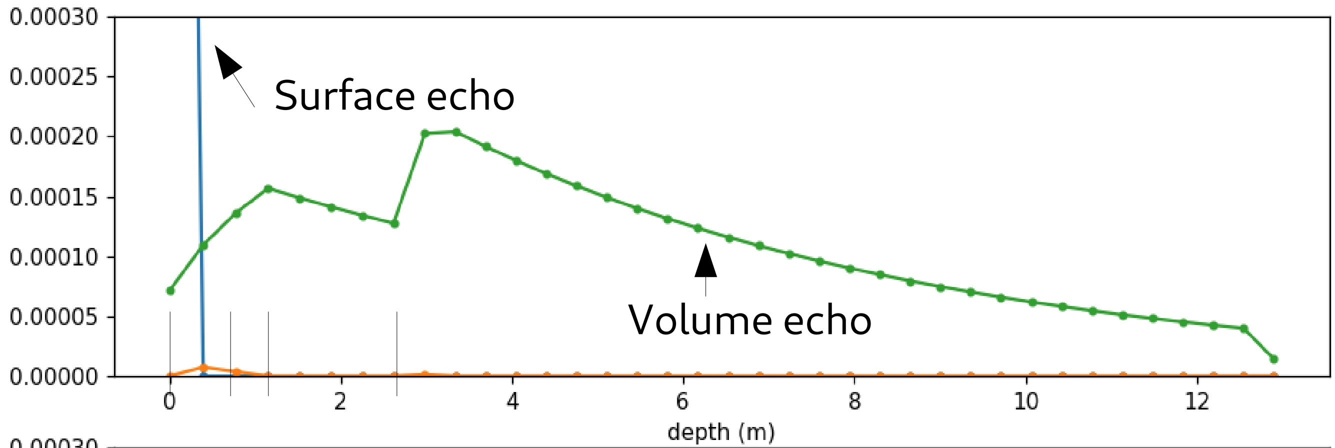
Sigma = f(t)

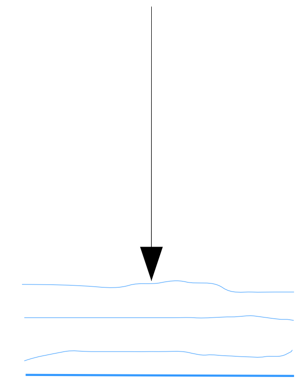


Nadir LRM altimetry in SMRT

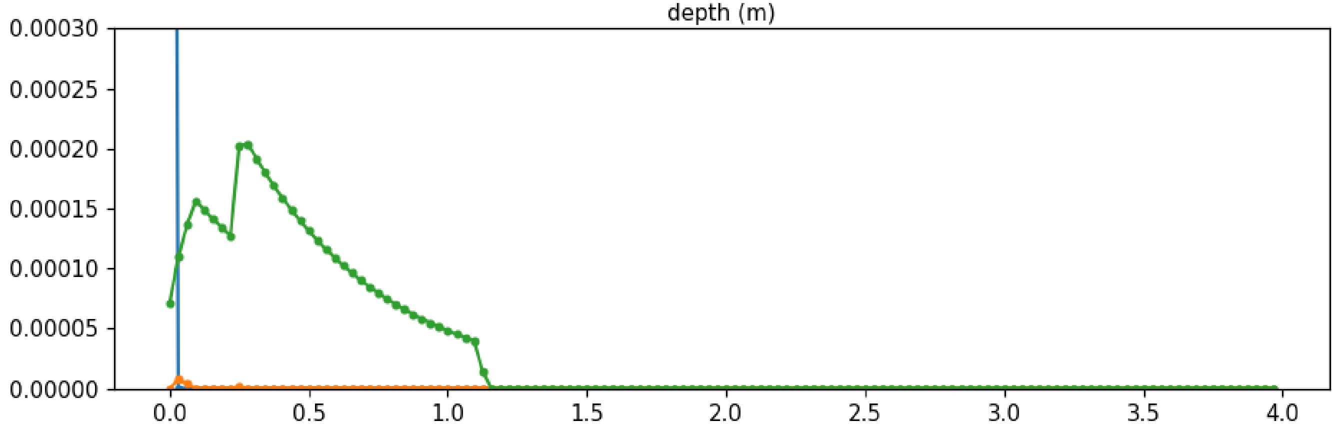
Illustrations: a snowpack with 4 layers with increasing scattering strength

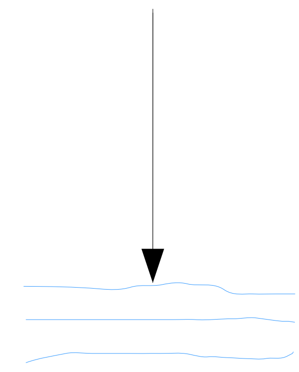
Sigma = f(z)
(vertical)



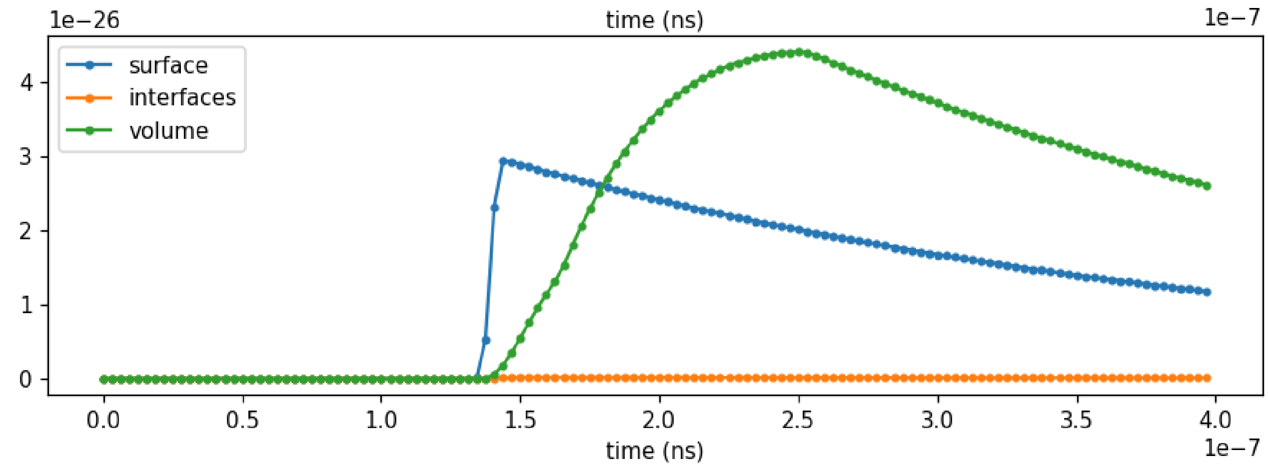


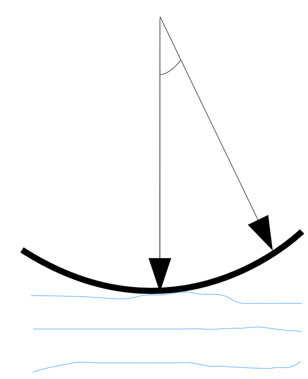
Sigma = f(t)
(vertical)





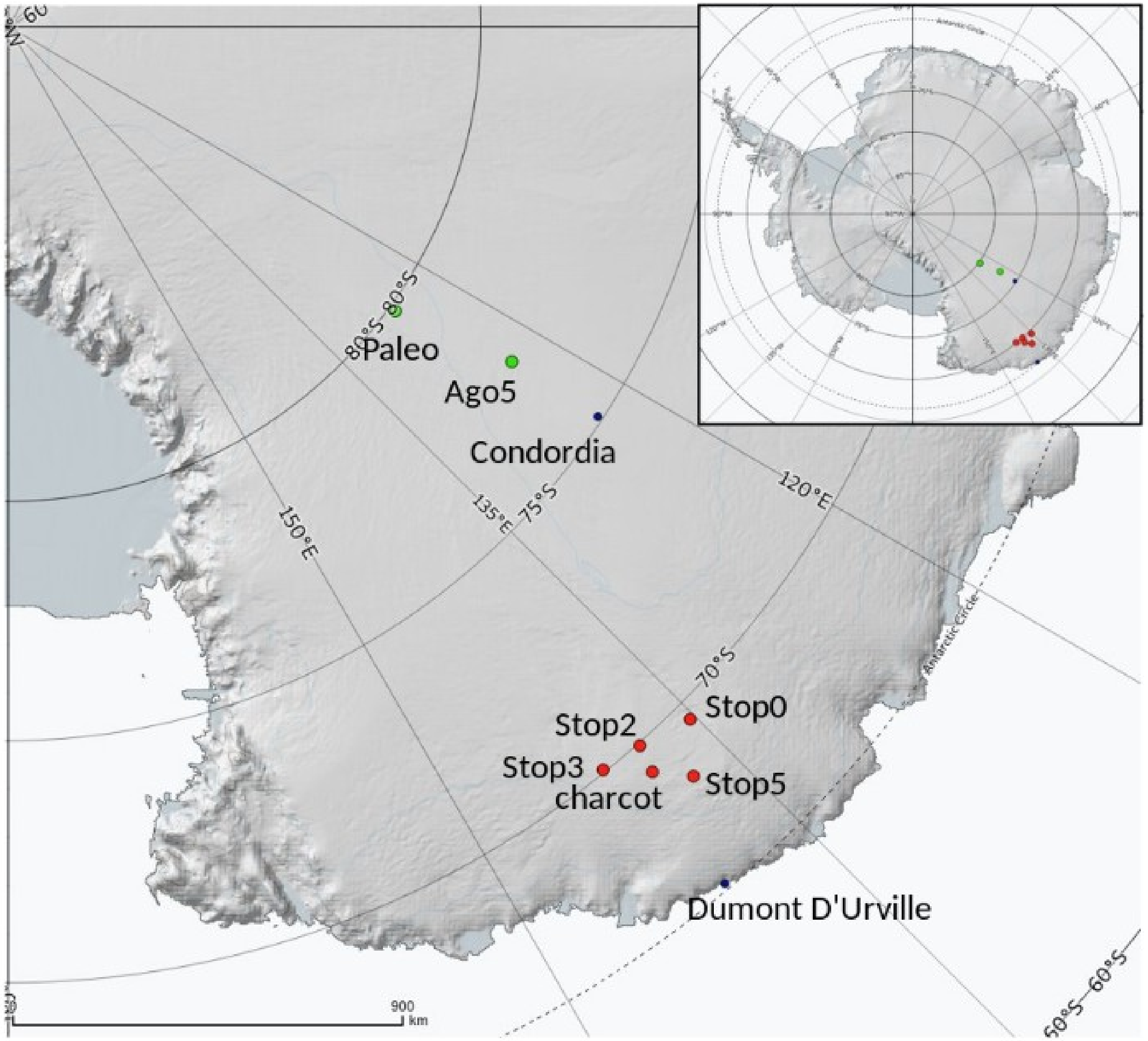
Sigma = f(t)
(vertical+
horizontal)





Validation in Antarctica

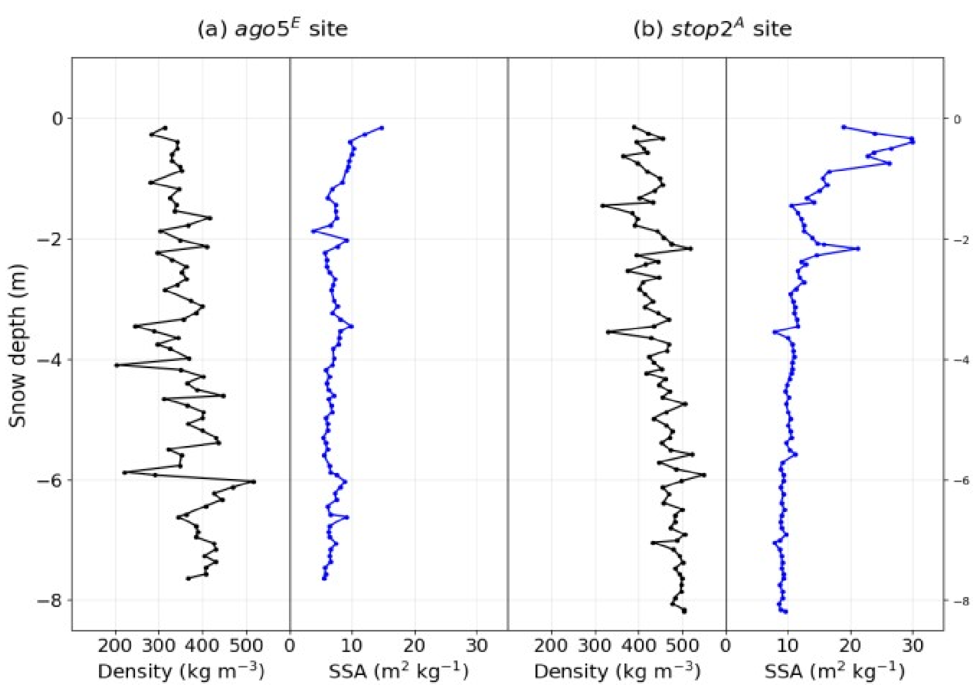
Acquisition of in-situ data during two traverses in East Antarctica (2016 and 2019) and at Concordia station

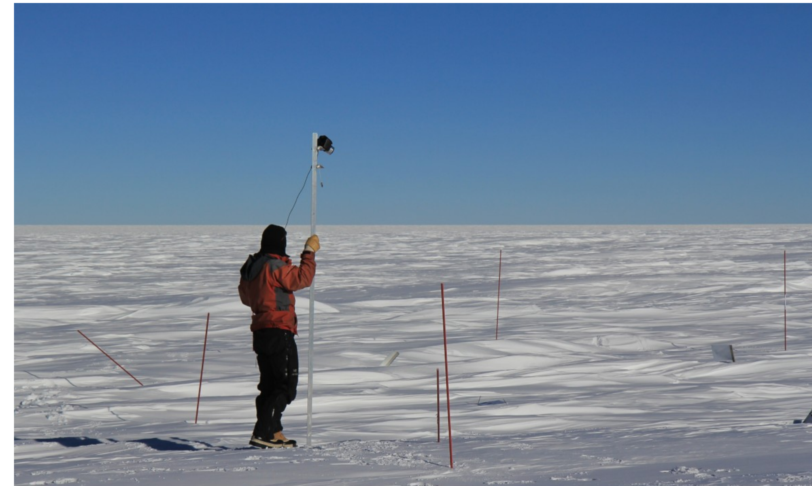


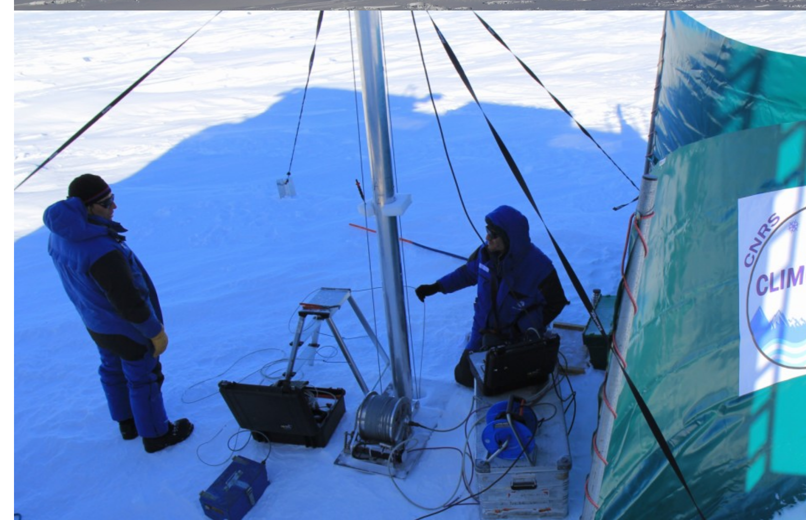
Validation in Antarctica

7 sites with high-quality measurements: slope, mean temperature, roughness (MSS), profiles of grain size and density

Name	Latitude	Longitude	Slope	σ_{surf}	T	MSS	SSA	ρ
stop5^A	-68.75	137.44	0.02	0.31	-37.2	0.03	11.6	448
charcot^A	-69.38	139.02	0.13	0.33	-37.9	0.02	12.0	433
stop0^A	-69.64	135.28	0.01	0.18	-41.1	0.02	12.4	437
stop2^A	-69.95	138.55	0.05	0.34	-40.4	0.03	12.4	449
stop3^A	-70.06	141.20	0.21	0.45	-38.9	0.05	11.5	446
ago5^E	-77.24	123.48	0.09	0.32	-54.4	0.01	7.4	361
paleo^E	-79.85	126.20	0.08	0.30	-50.5	0.01	7.7	392



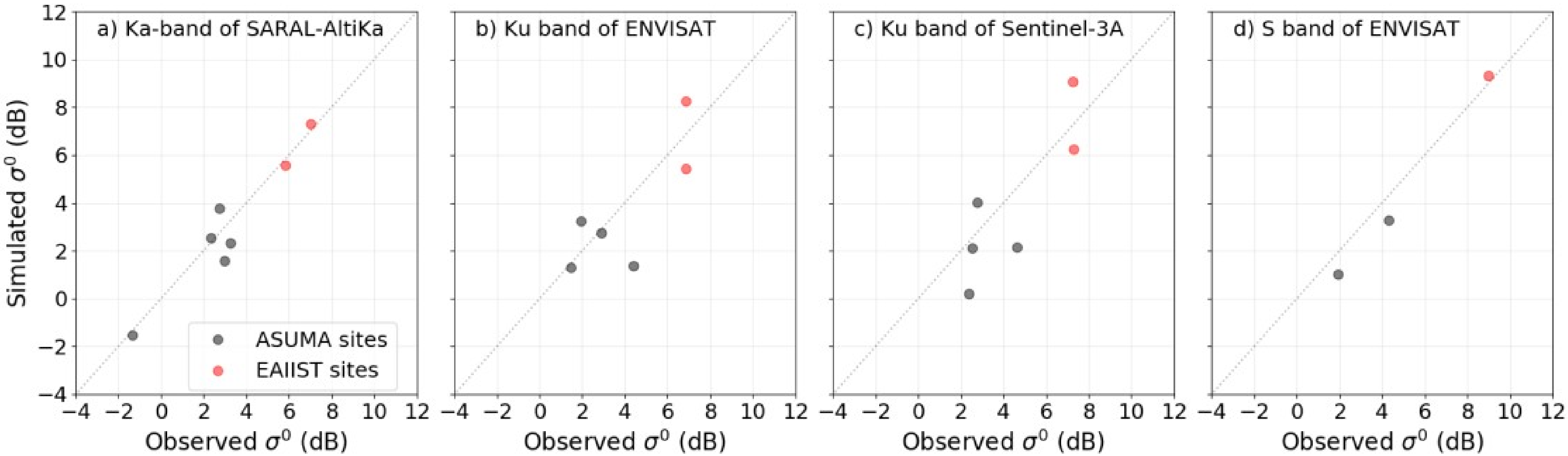




Validation in Antarctica

Results for AltiKa, ENVISAT and Sentinel 3A (LRM mode)

Total basckscatter:

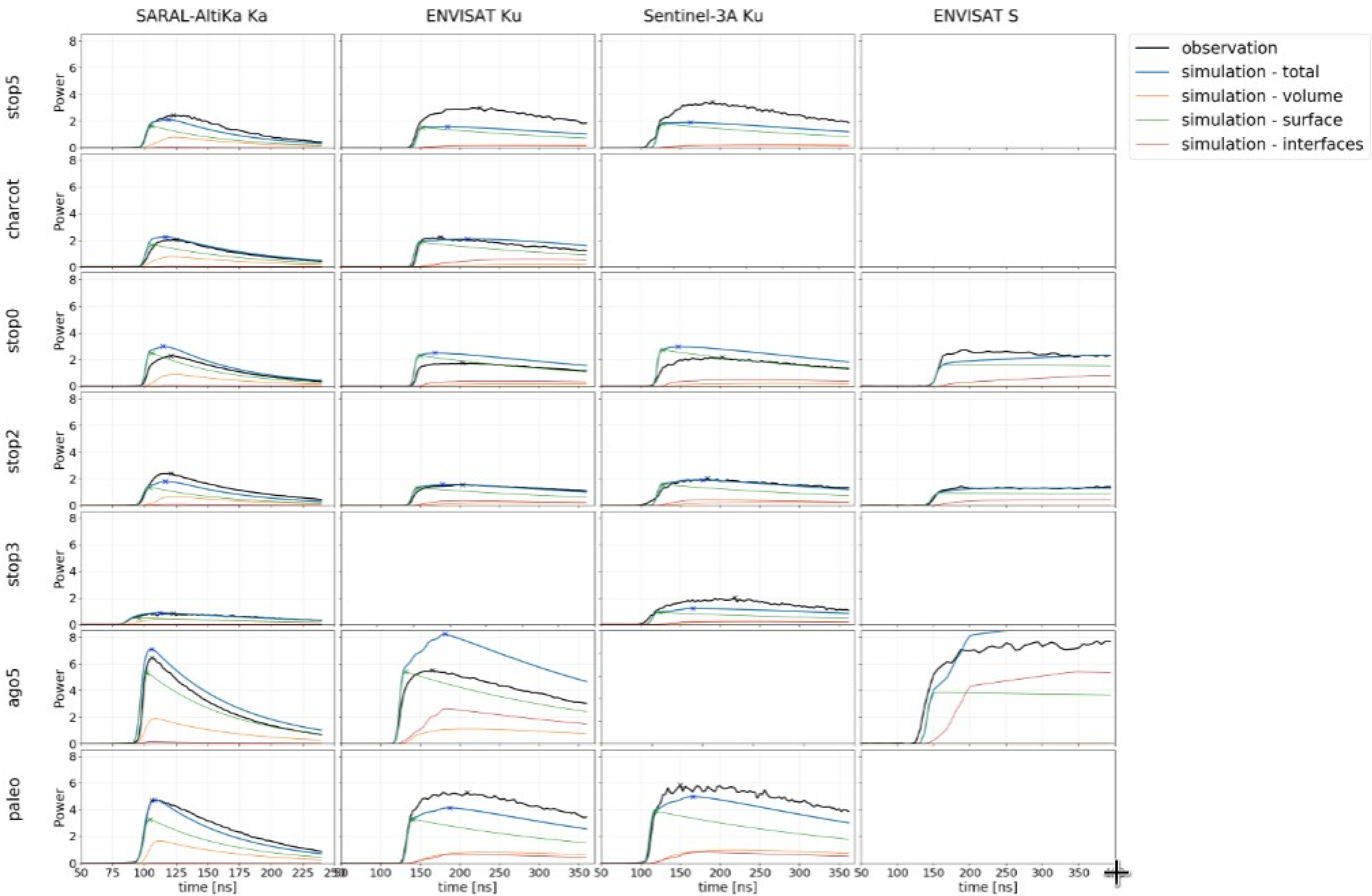


Clear increasing trend for the coastal regions to the interior

The model says:
- surface roughness is the main factor (smoother in the interior)
- grain size, density and temperature are also significant factors

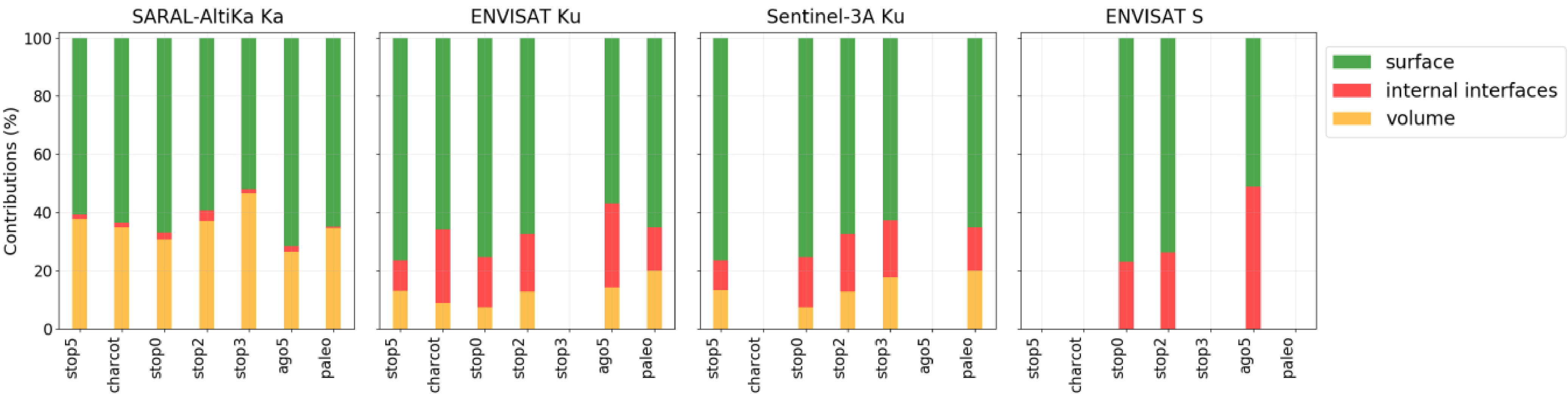
Validation in Antarctica

Waveforms:



Validation in Antarctica

Contributions of the surface, volume, inter-layer interfaces:



- The surface backscatter dominates at all the frequencies

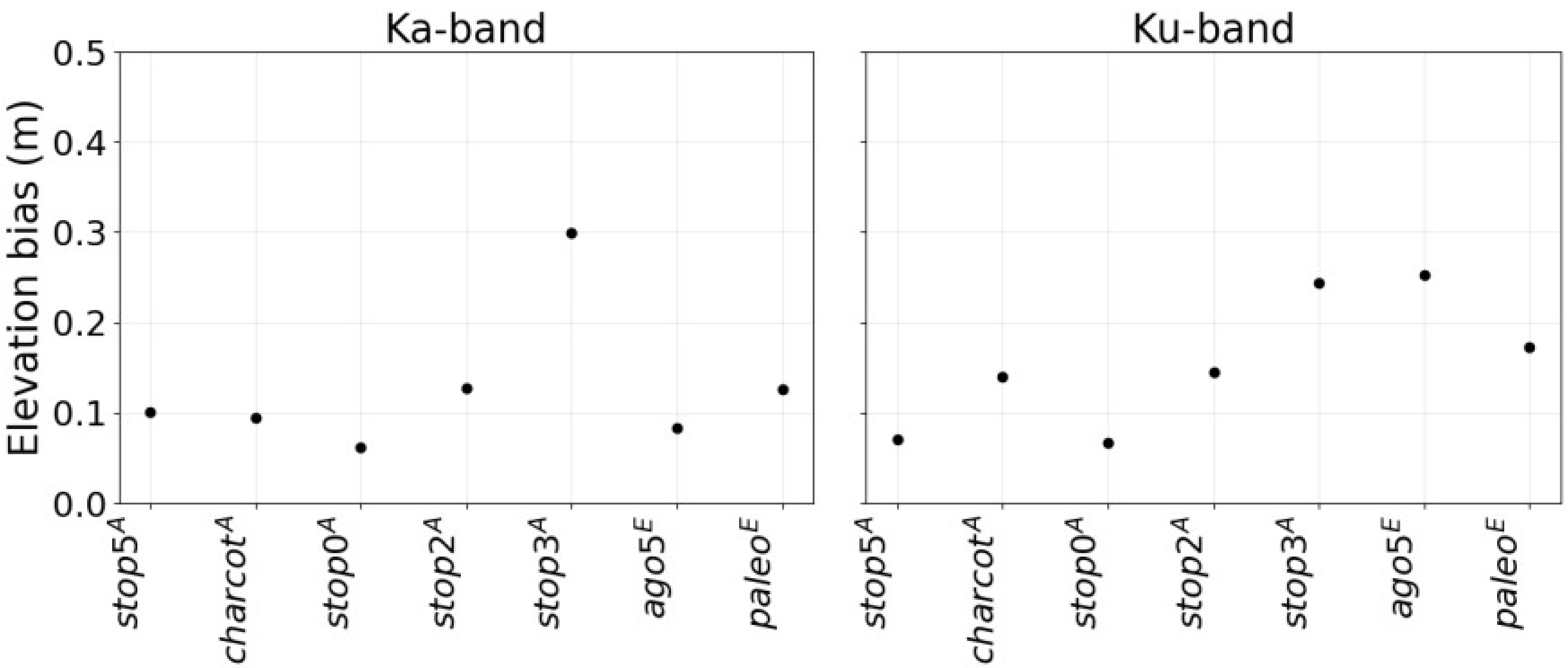
- Volume scattering is larger at Ka-band ... but penetration depth is much less than at the lower frequencies . With pd ~0.5 m, the volume echo comes very closely after the surface echo.

  - in Ku band, a *large* penetration depth but a *small* volume contribution
  - in Ka band, a *small* penetrationdepth byt a *large* volume contributuon

→ Uncertain consequences for the elevation bias.

Validation in Antarctica

Elevation bias simulations:



- same order of magnitude at Ku and Ka bands

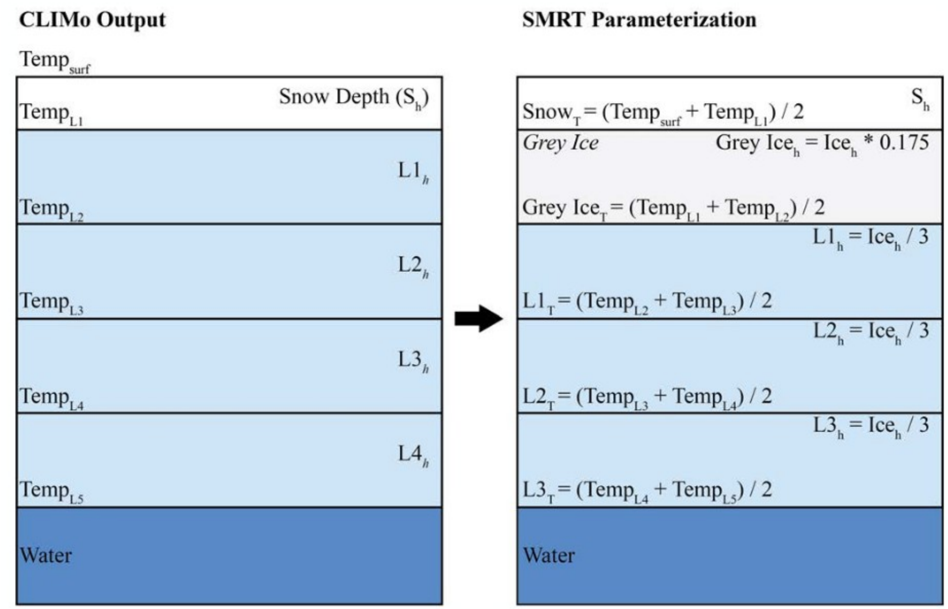
- the bias does not depend on the same factors at both bands (roughness, grains, ...)

First results on frozen lakes

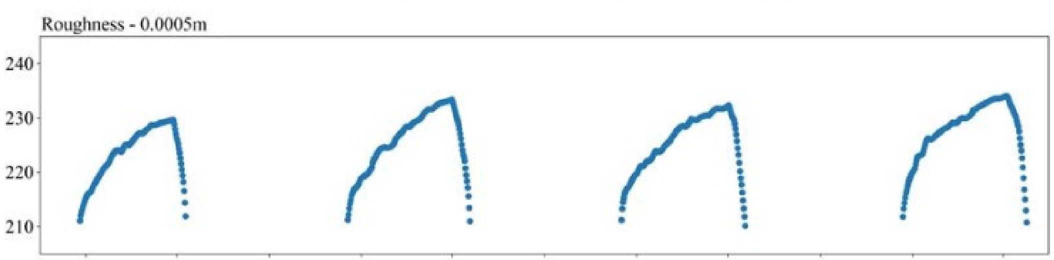
Ongoing ESA LIAM project
(PI Claude Duguay, U. Waterloo)

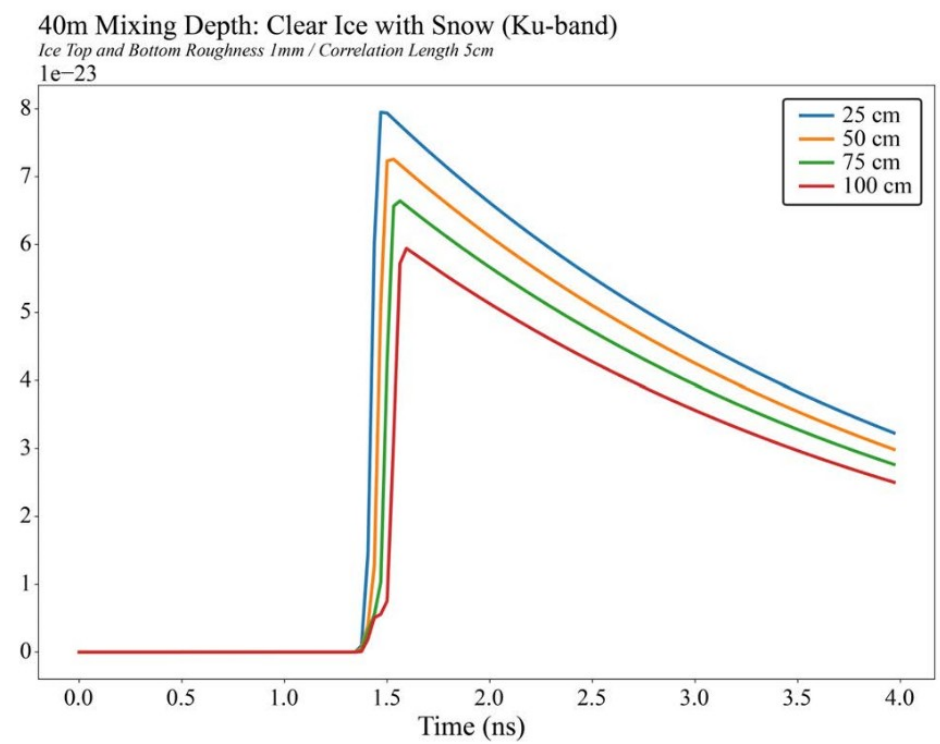
Coupling between the thermodynamical model CLIMo with SMRT. Work by J. Murfit (PhD student)

- predict ice and snow state as a function of time
- nadir simulation of T_B
- nadir simulation of total backscatter
- first simulations of waveforms



18.7 GHz TB Simulations (2005-2009)





SMRT allows consistent multi-sensor simulations → asset to develop smarter retrieval algorithms

A few points to conclude...

- A new altimeter model for snow, sea-ice, frozen lakes, ...

Radar altimeter waveform simulations in Antarctica with the Snow Microwave Radiative Transfer Model (SMRT)

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in press

- SMRT has been coupled with a more advanced altimeter simulator: AltiDop (J. Aublanc, P. Thibault, CLS, Toulouse). It takes into account REMA (8m DEM in Antarctica).

- Validation on sea-ice is ongoing. ESA AKROSS (M. Sandells, U. Northumbria)

Future works:

- implement retrackers in SMRT → investigate elevation bias

- implement SAR and others altimetric modes → Cryosat, Cristal

SMRT is open-source: http://github.com/smrt-model/smrt
Welcome to use it, welcome to improve it !