living planet symposium

BONN
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TAKING THE PULSE
OF OUR PLANET FROM SPACE

Combination of active and passive microwave observations and radiative transfer modelling for sea ice and snow characterization

Clément Soriot, Catherine Prigent, Ghislain Picard, Frédéric Frappart

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Introduction

Microwave observations are sensitive to multiple geophysical parameters.

Can we get more information from passive microwave information about sea ice and its snow cover?

Can a sea ice or snow characterization be made from TB or σ^0 with a radiative transfer model?

Multiple microwave satellite observations, Sensitive to multiple sea ice parameters

Passive microwaves

CIMR (Copernicus Imager Microwave Radiometer)
Wide-swath conically-scanning multi-frequency microwave radiometer
(**1.4 GHz** (L-band), **6 GHz** (C-band), **10 GHz** (X-band), **18 GHz** (Ku-band), **36 GHz** (Ka-band))
Sea Ice Concentration (SIC), thin Sea Ice Thickness (SIT), Snow Depth, Sea Ice Type…

Active microwaves (scattering mode)

ASCAT on board MetOp missions is an ESA and EUMETSAT operational Earth Observer
A scatterometer at **5 GHz** (C-band), observing between 25° and 65° incidence angle
Sea Ice Type, Sea Ice Age, Surface Roughness…

How to optimize the benefit of their synergy for parameter retrievals?

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SMAP *(NASA)*

AMSR2 *(JAXA)*

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ASCAT *(already on MetOp-A, -B, C)*

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How to analyze their synergy?

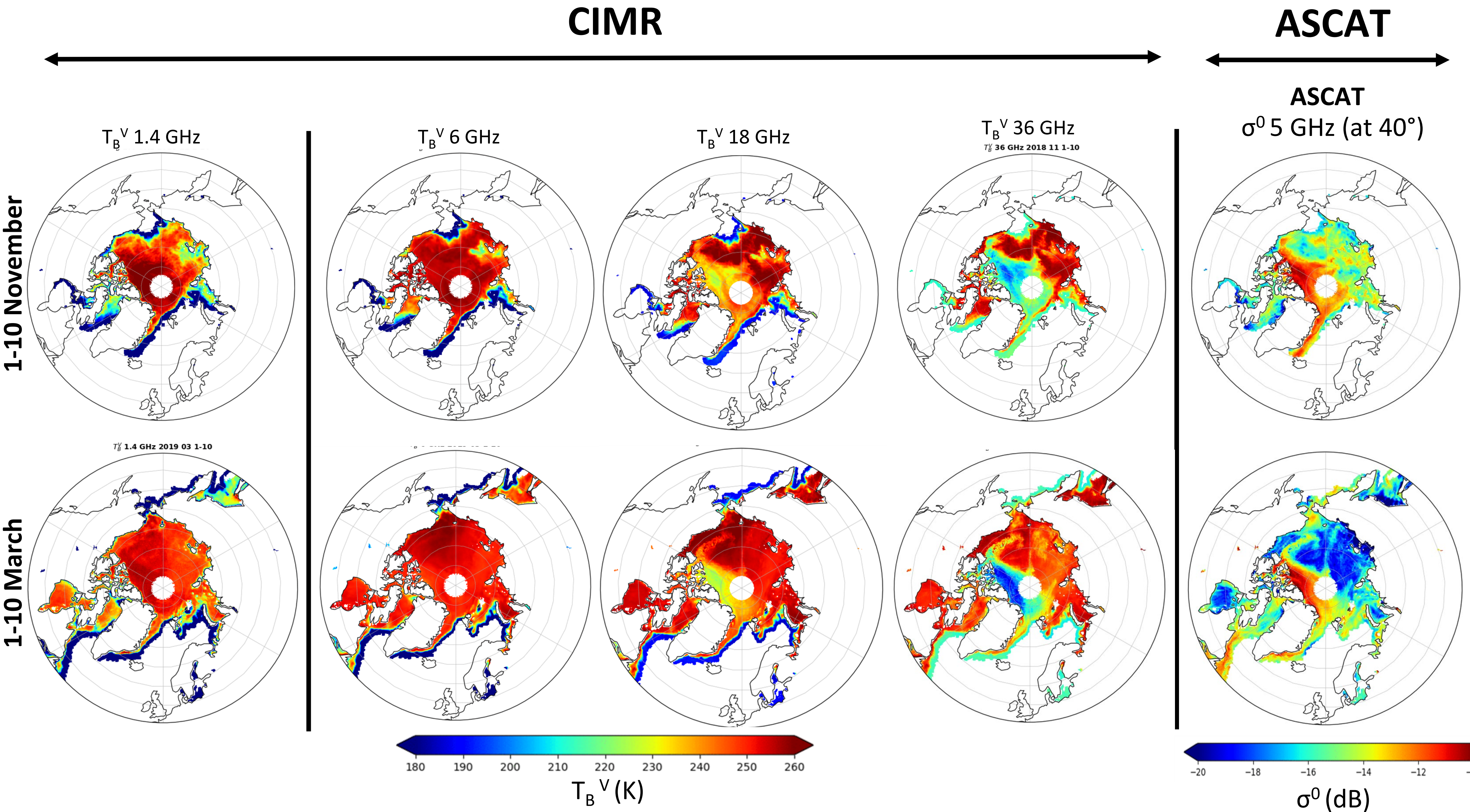
Pre-processing the satellite observations for their merging

CIMR + SMAP 1.4 GHz T_B^V and T_B^H at 40° incidence

AMSR2 6, 10, 18, 36 GHz T_B^V and T_B^H at 55° incidence

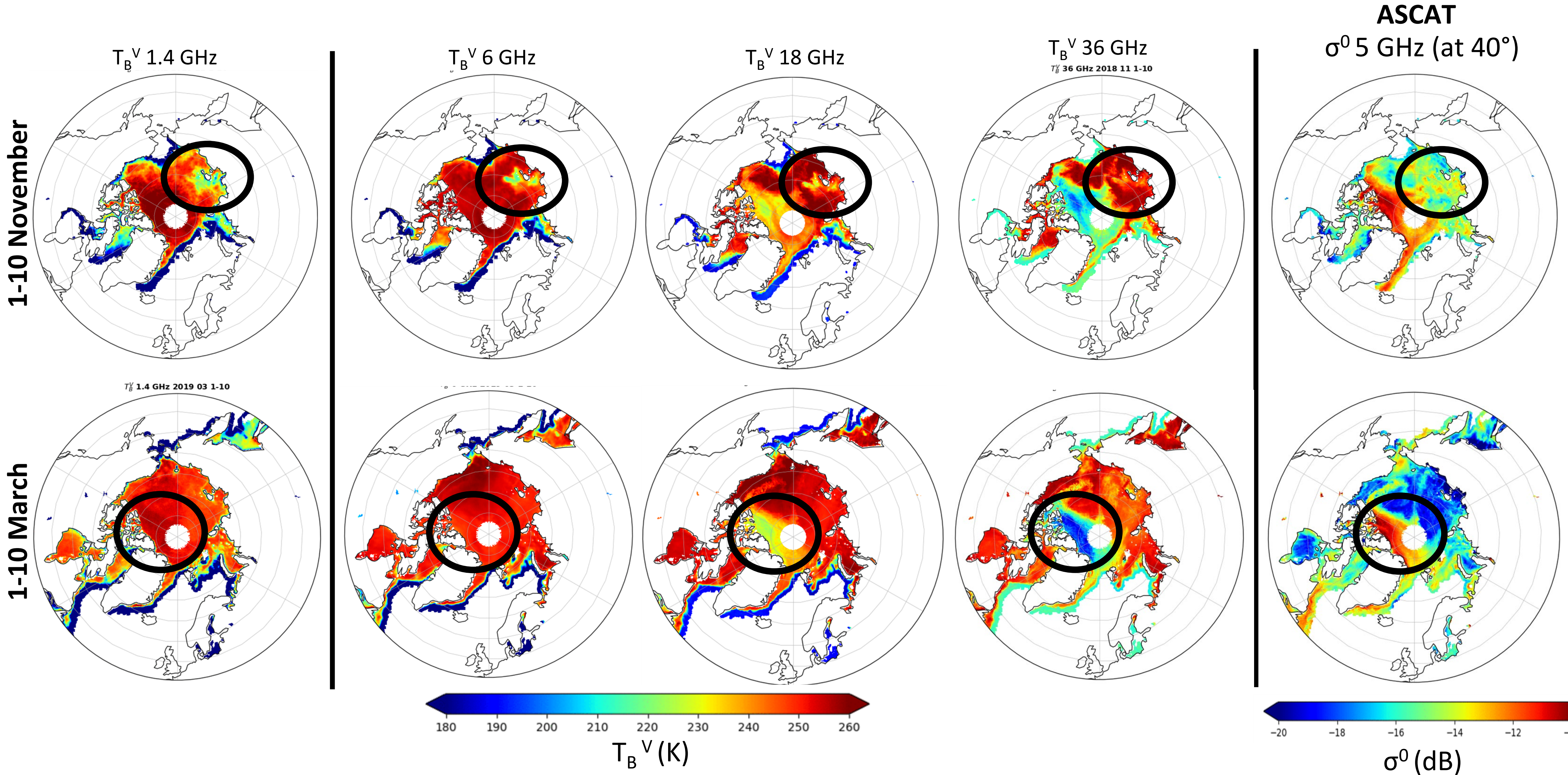
ASCAT ASCAT 5.2 GHz σ^0 interpolated at 40°

Collected over the Arctic, averaged on 10 days, and *gridded on a 12.5 km EASE grid* during the polar year 2018-2019.


CIMR
ASCAT
T_B^V 1.4 GHz
T_B^V 6 GHz
T_B^V 18 GHz
T_B^V 36 GHz
T_B^V 36 GHz 2018 11 1-10
ASCAT
σ^0 5 GHz (at 40°)
1-10 November
T_B^V 1.4 GHz 2019 03 1-10
1-10 March
180
190
200
210
220
230
240
250
260
T_B^V (K)
−20
−18
−16
−14
−12
σ^0 (dB)

CIMR

ASCAT


ASCAT
σ0 5 GHz (at 40°)
TBV 1.4 GHz
TBV 6 GHz
TBV 18 GHz
TBV 36 GHz
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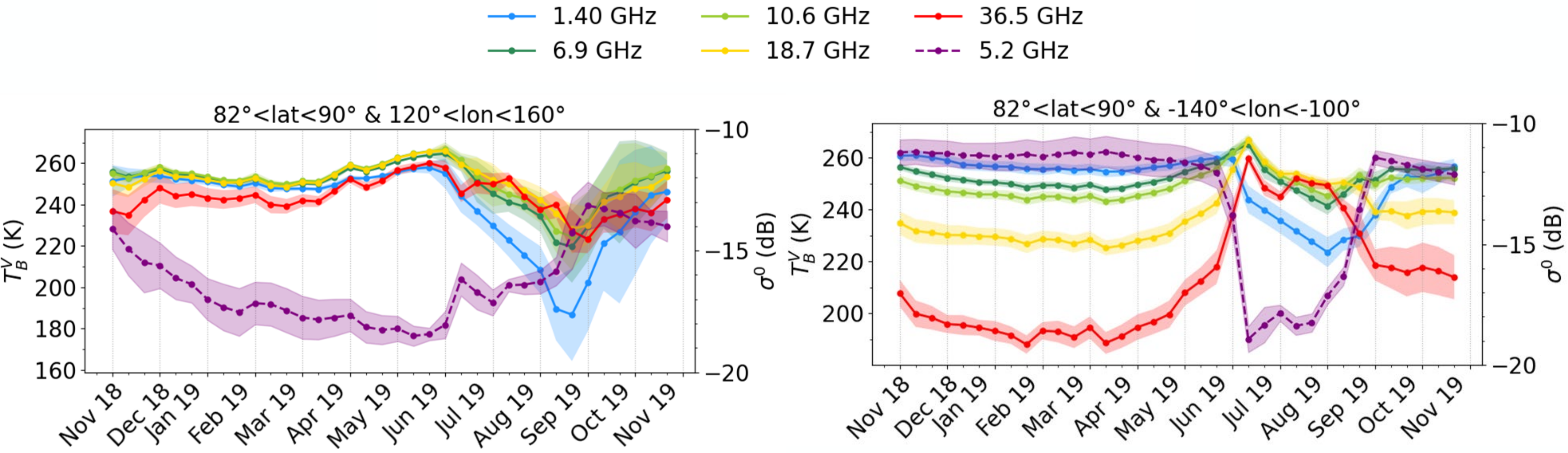
230
240
250
260
TBV (K)
−20
−18
−16
−14
−12
σ0 (dB)

Temporal evolution of different regions

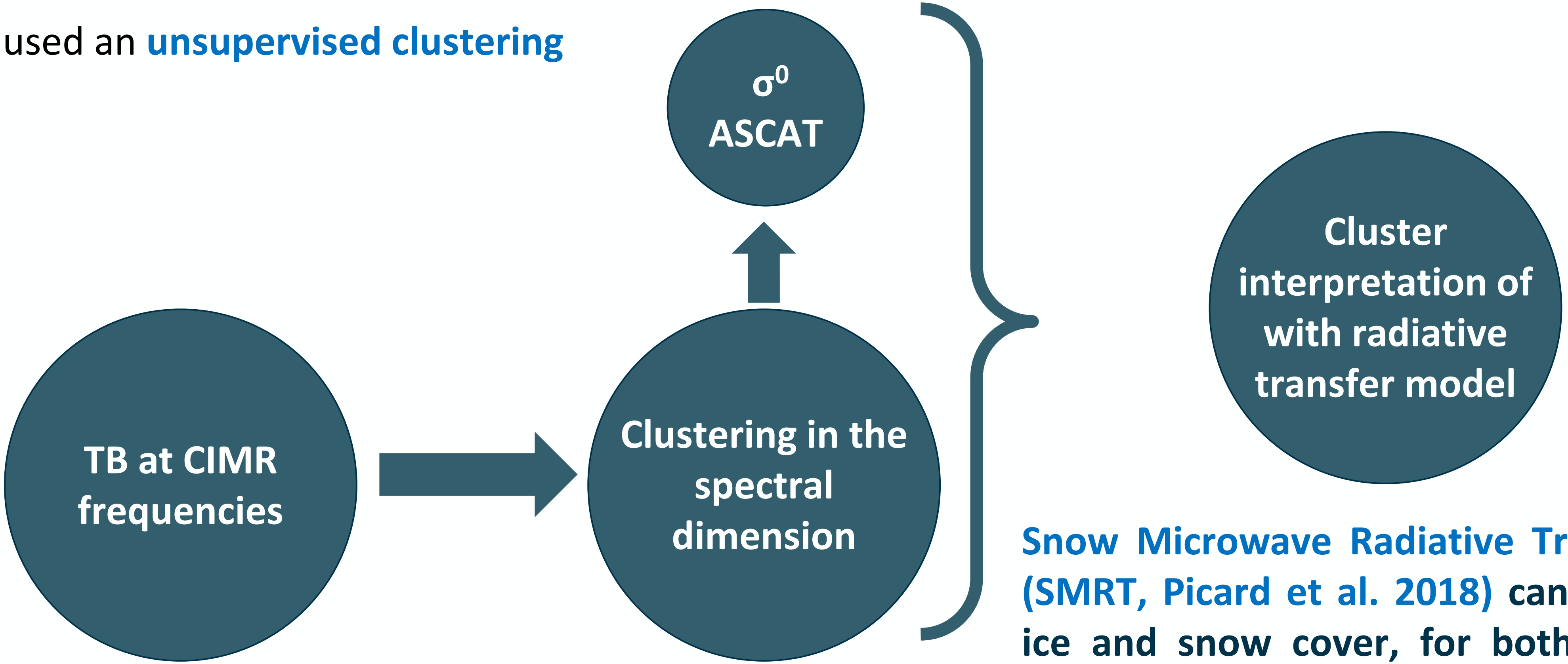
Over First Year

Over Multi Year



How to analyze their covariabilities?
How to interpret their co-variabilities?

We used an **unsupervised clustering**



σ^0 ASCAT

TB at CIMR frequencies

Clustering in the spectral dimension

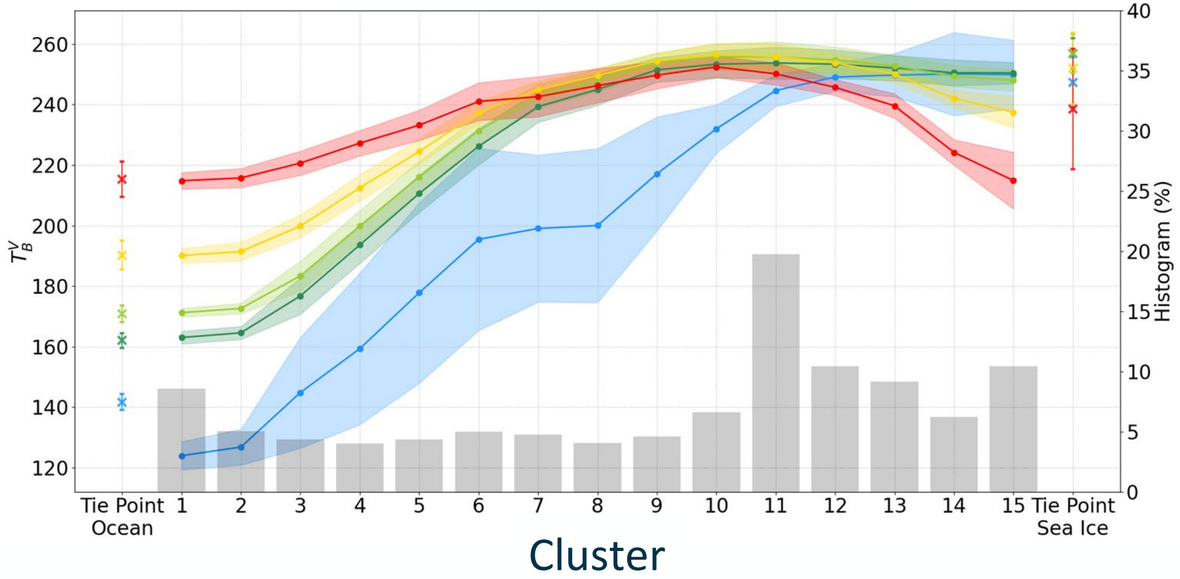
Cluster interpretation of with radiative transfer model

Snow Microwave Radiative Transfer Model (SMRT, Picard et al. 2018) can simulate sea ice and snow cover, for both passive and active microwave observations.

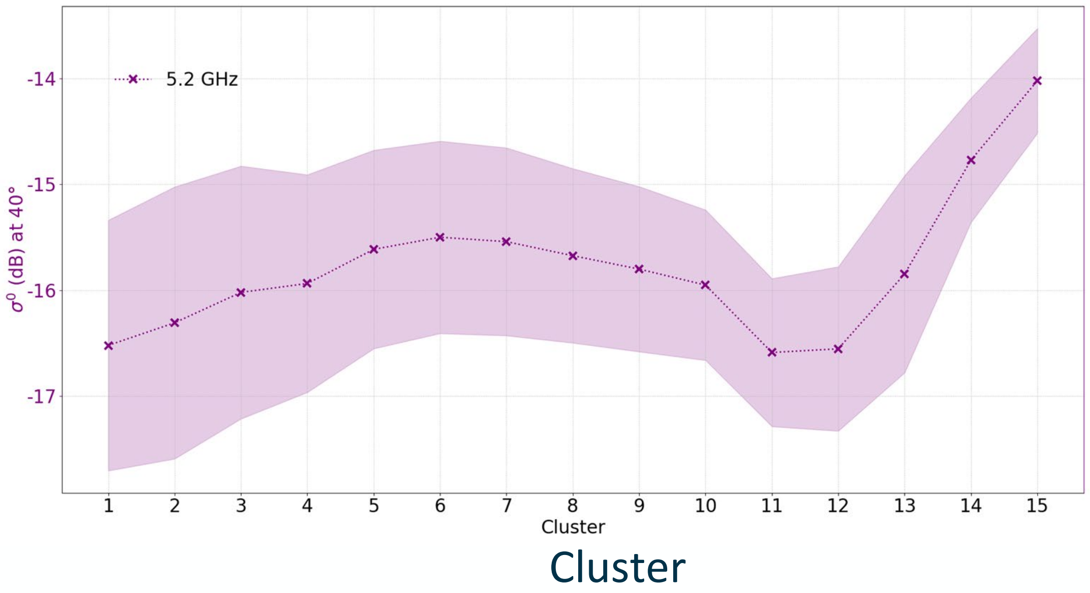
Results of the clustering

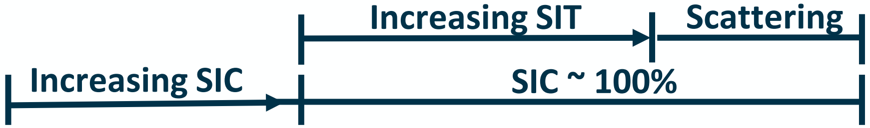
It makes it possible to analyze the co-variability of the observations, for different environmental conditions (i.e., for each cluster).

CIMR (SMAP + AMSR2) T_B^V



ASCAT σ^0 (5 GHz)





Increasing SIT

Scattering

Increasing SIC

SIC ~ 100%

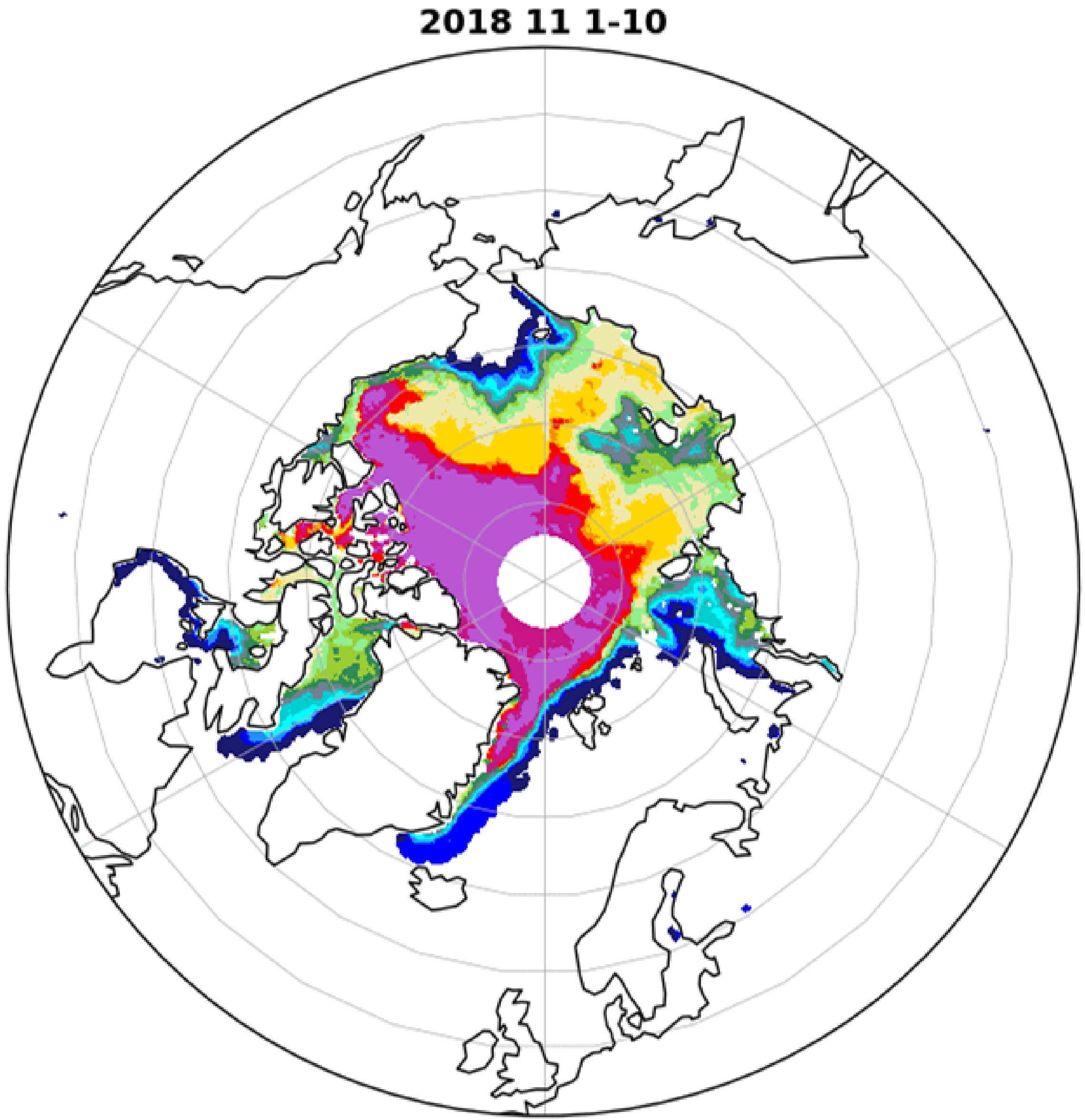
Sea Ice Concentration effects

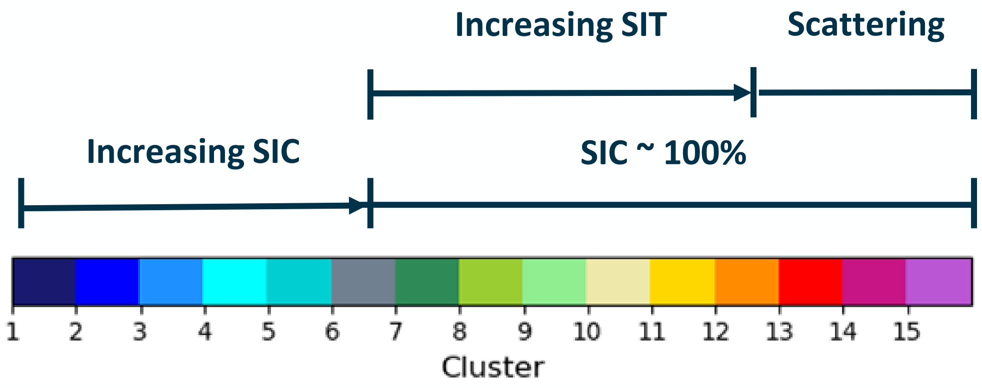
Sea Ice Thickness effects

Scattering effects

- **Snow scattering or surface scattering?**
- **Snow depth and/or ice type ?**

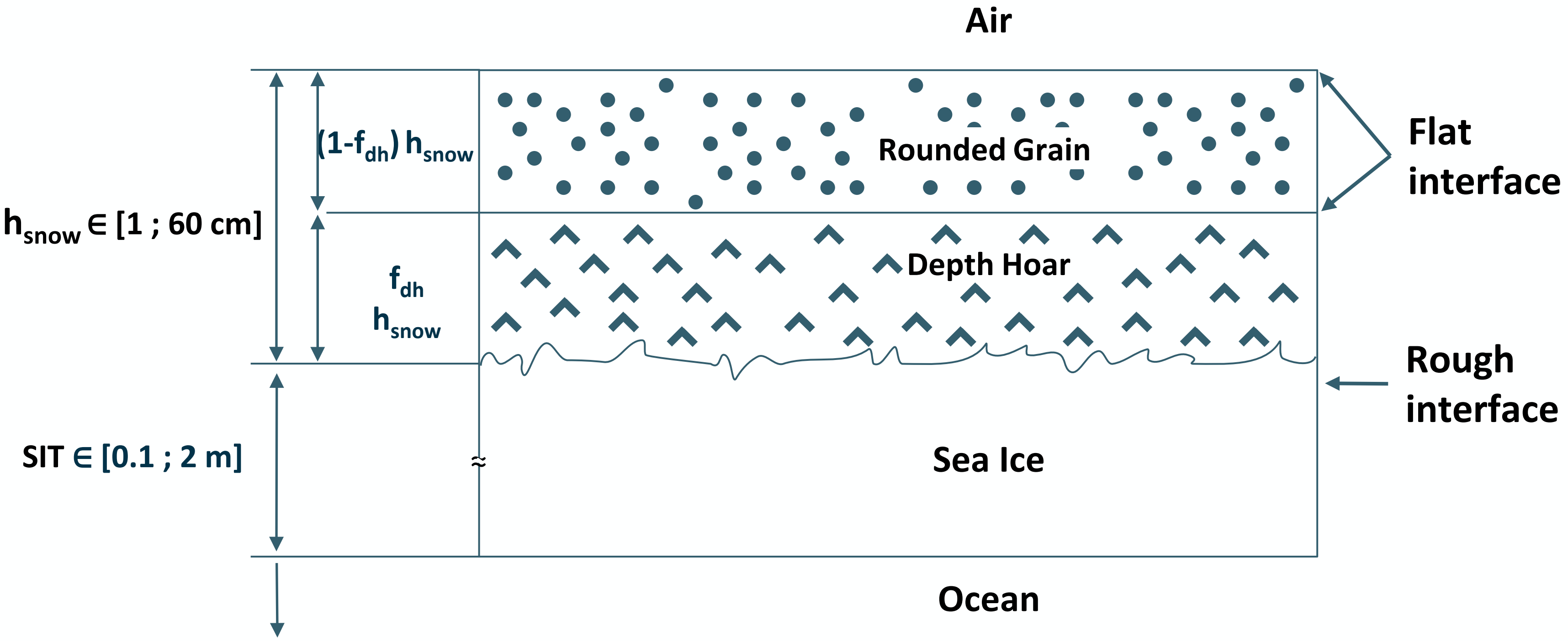
Results of the clustering





Spatially and temporally consistent clustering results (despite the fact that no temporal or spatial information is provided to the clustering)

SMRT Snowpack - Sea Ice Diagram



Air

$h_{snow} \in$ [1 ; 60 cm]

$(1-f_{dh})\ h_{snow}$

Rounded Grain

Flat interface

f_{dh} h_{snow}

Depth Hoar

Rough interface

SIT $\in$ [0.1 ; 2 m]

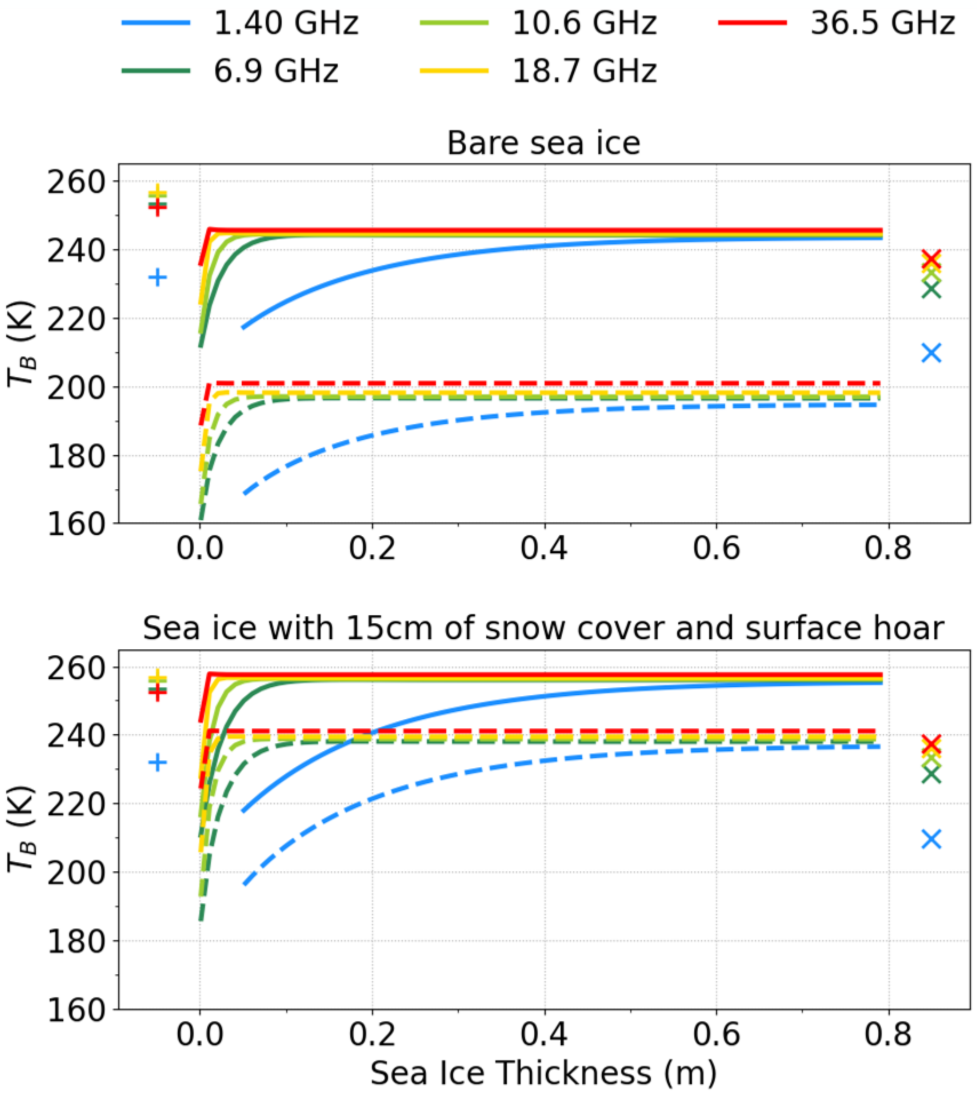
≈

Sea Ice

Ocean

Medium	Type	Parameter	Value
Snow	Wind slab	Temperature (K)	230-270
		Thickness (cm)	0.01-0.6
		Density (kg/m³)	350
		Radius of scatterers (m)	1e-4
		Stickiness	0.18
		Liquid water content	0
	Depth hoar	Temperature (K)	230-270
		Thickness (m)	0.01-0.6
		Density (kg/m³)	200
		Radius of scatterers (m)	1e-4
		Stickiness	0.1
		Liquid water content	0
Sea ice	First-year	Temperature (K)	230-270
		Thickness (m)	0.1-1
		Density (kg/m³)	0.917
		Salinity (PSU)	10
		Brine volume fraction	0.11
		Radius of scatterers (m)	1e-4
		Stickiness	0.2
	Multi-year	Temperature (K)	230-270
		Thickness (m)	1-2
		Density (kg/m³)	0.850
		Salinity (PSU)	1.4
		Brine volume fraction	0.05
		Radius of scatterers (m)	1e-4
		Stickiness	0.2
Ocean	Arctic	Temperature (K)	272
		Salinity (PSU)	30
		Thickness (m)	∞

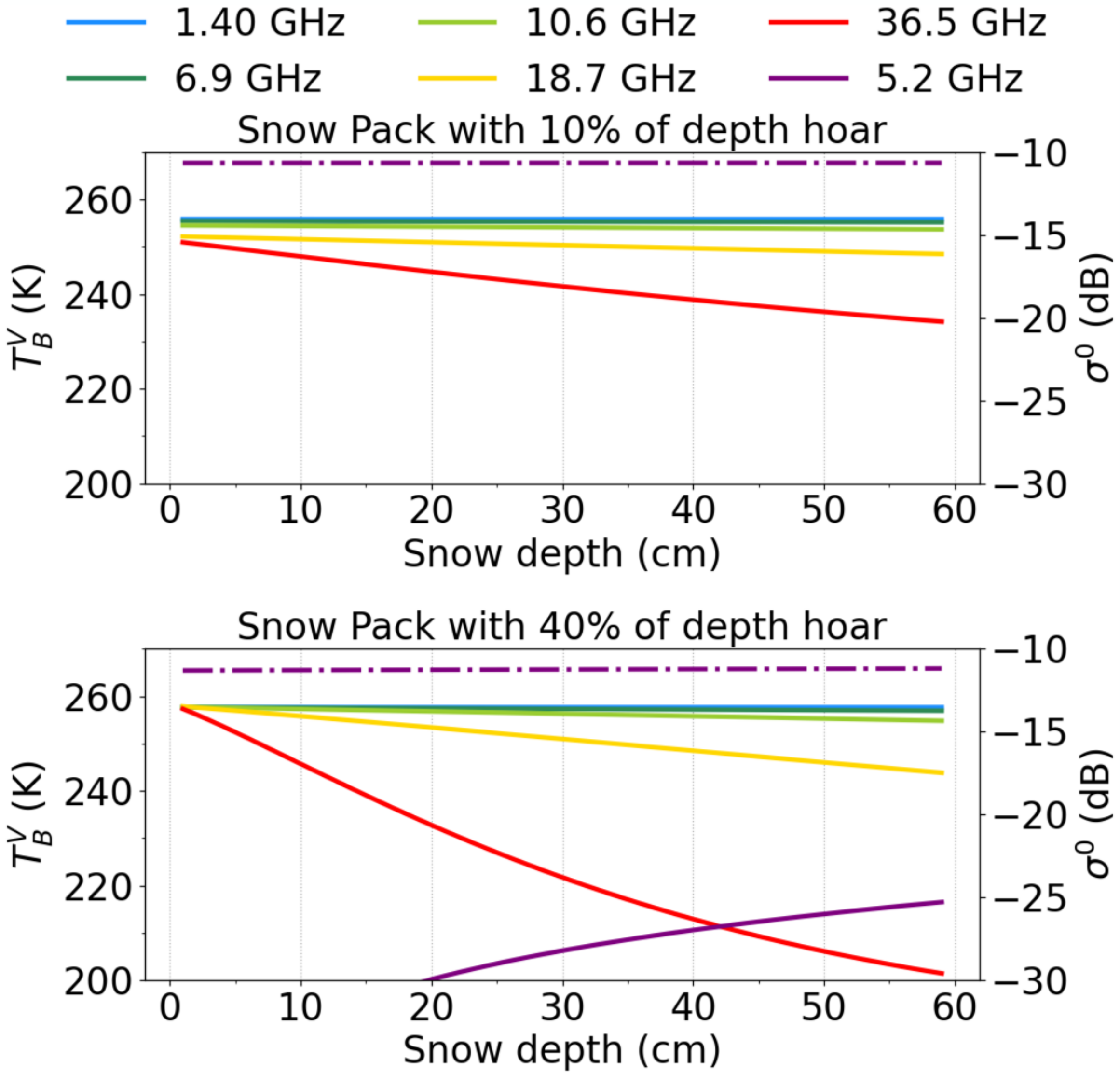
Simulation of the sensitivity to the ice thickness with SMRT



SMRT model can simulate the influence of ice thickness on the signals in agreement with the classification for all observations and their co-variabilities :

- **Sensitivity of the 1.4 GHz for the thin ice (<0.5m)**
- **Good agreements with observations**
- **With a shallow layer of snow and a surface hoar, ΔV-H is reduced and match the observations**

Simulation of the scattering signals with SMRT (Snow? Depth hoar ? Surface roughness? Multi-year ice / First-year ice?)



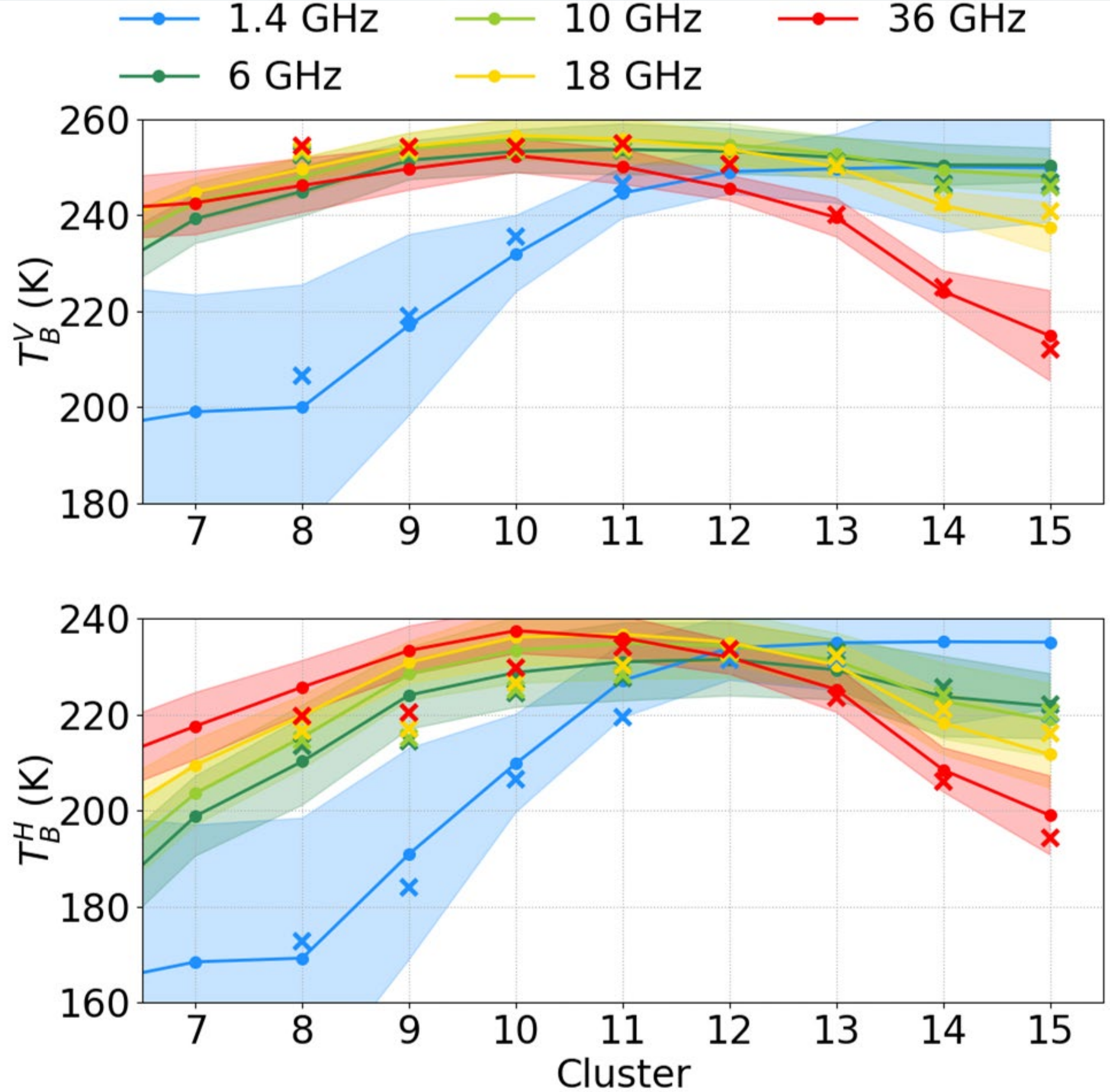
- **Snow layer with regular small grain cannot scatter the signals at 18 and 36 GHz, as much as observed.**
- **Presence of depth hoar over MY ice and not over FY ice can explain the observed difference.**
- **The scattering observed on the σ^0 not related to the snow nor to the depth hoar, but to surface roughness at the ice snow interface.**

Evaluation of SMRT over Sea Ice

With SMRT, we are able to:

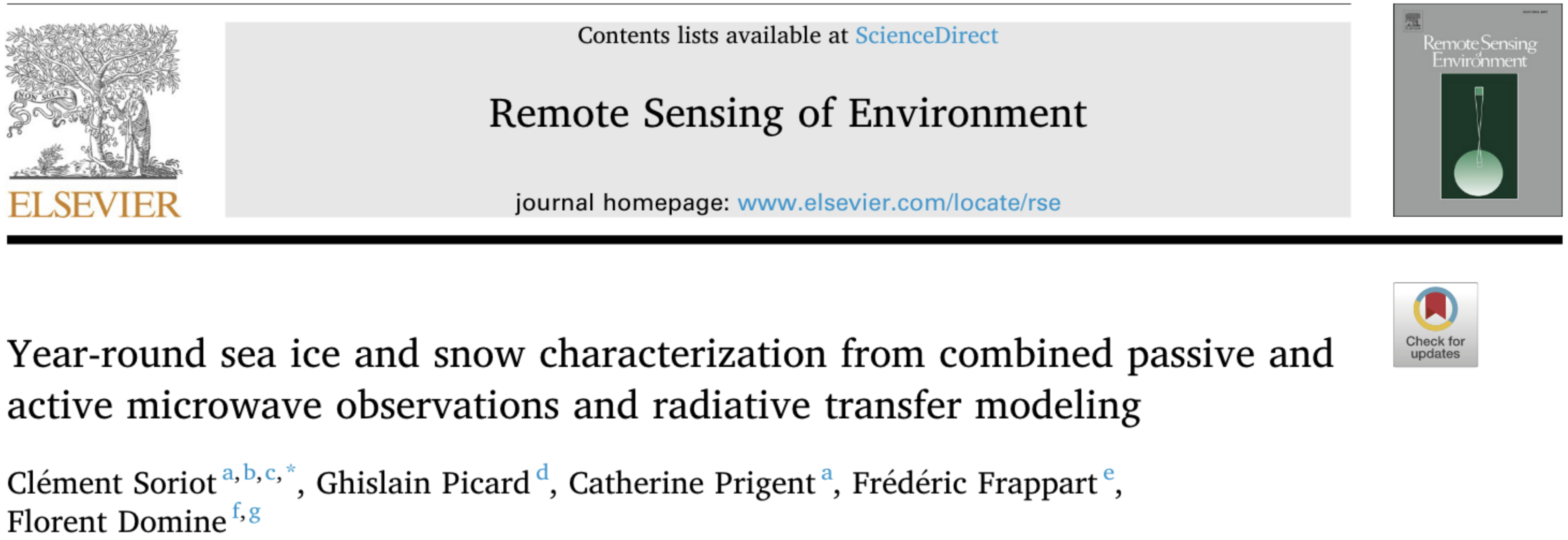
- **Simulate the effect of SIT**
- **Give physical reason to the scattering signatures**
    - **Due to depth hoar (18-36 GHz)**
    - **Due to surface roughness (σ^0)**
- **Reproduce behaviors highlighted by the classification**

Simultaneously for all the CIMR frequencies at V and H polarization



Take home message

- **There are synergies to be exploited between CIMR and ASCAT.**
- **Passive microwave observation at CIMR frequencies can tell a lot about sea ice and its snow cover**
- **Realistic simulations with consistent physical interpretations of the microwave signal have been obtained with SMRT**
- **Snow microstructure has more impact on brightness temperature than snow depth**



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Year-round sea ice and snow characterization from combined passive and active microwave observations and radiative transfer modeling

Clément Soriot[a,b,c,*], Ghislain Picard[d], Catherine Prigent[a], Frédéric Frappart[e], Florent Domine[f,g]