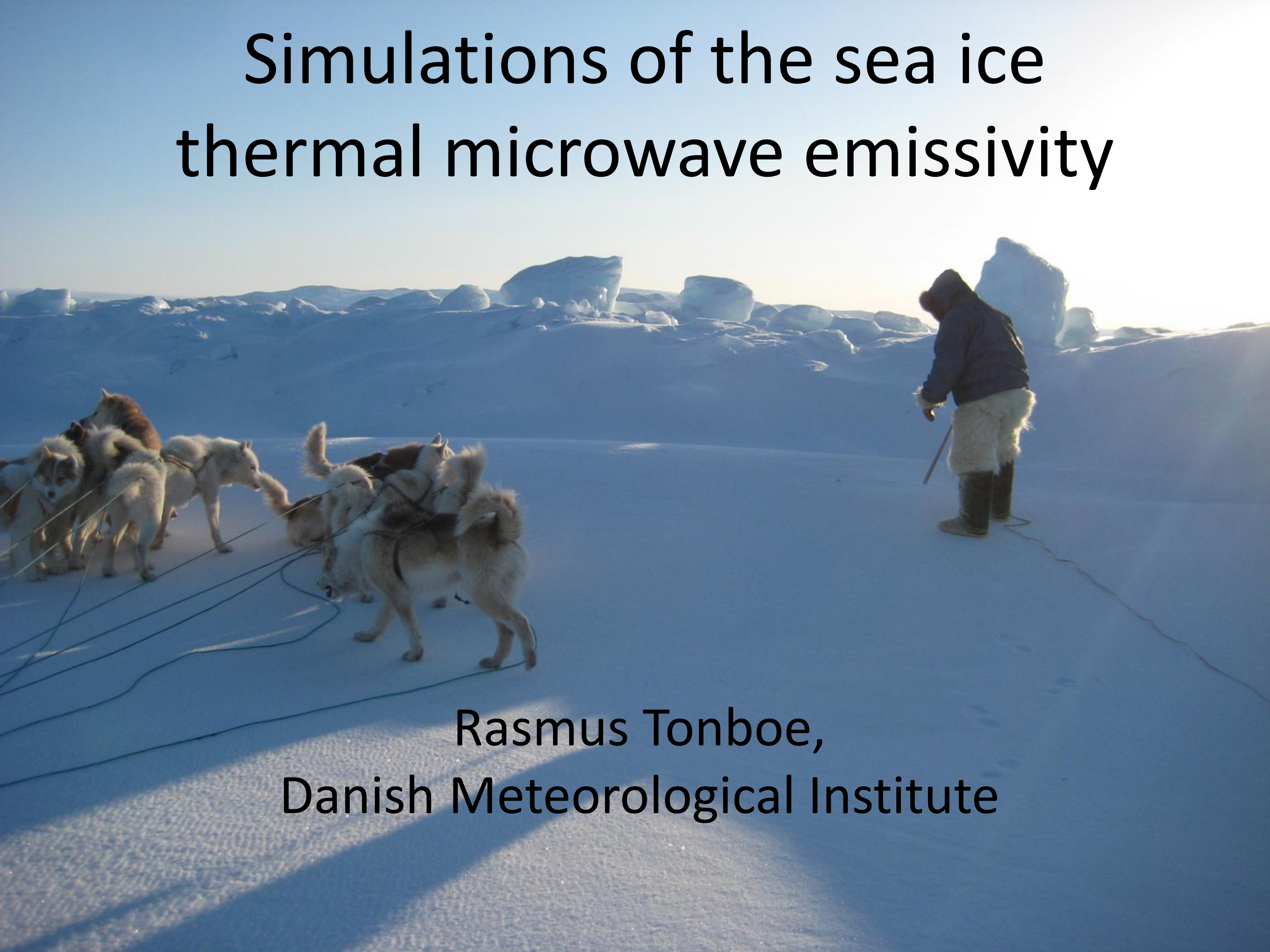
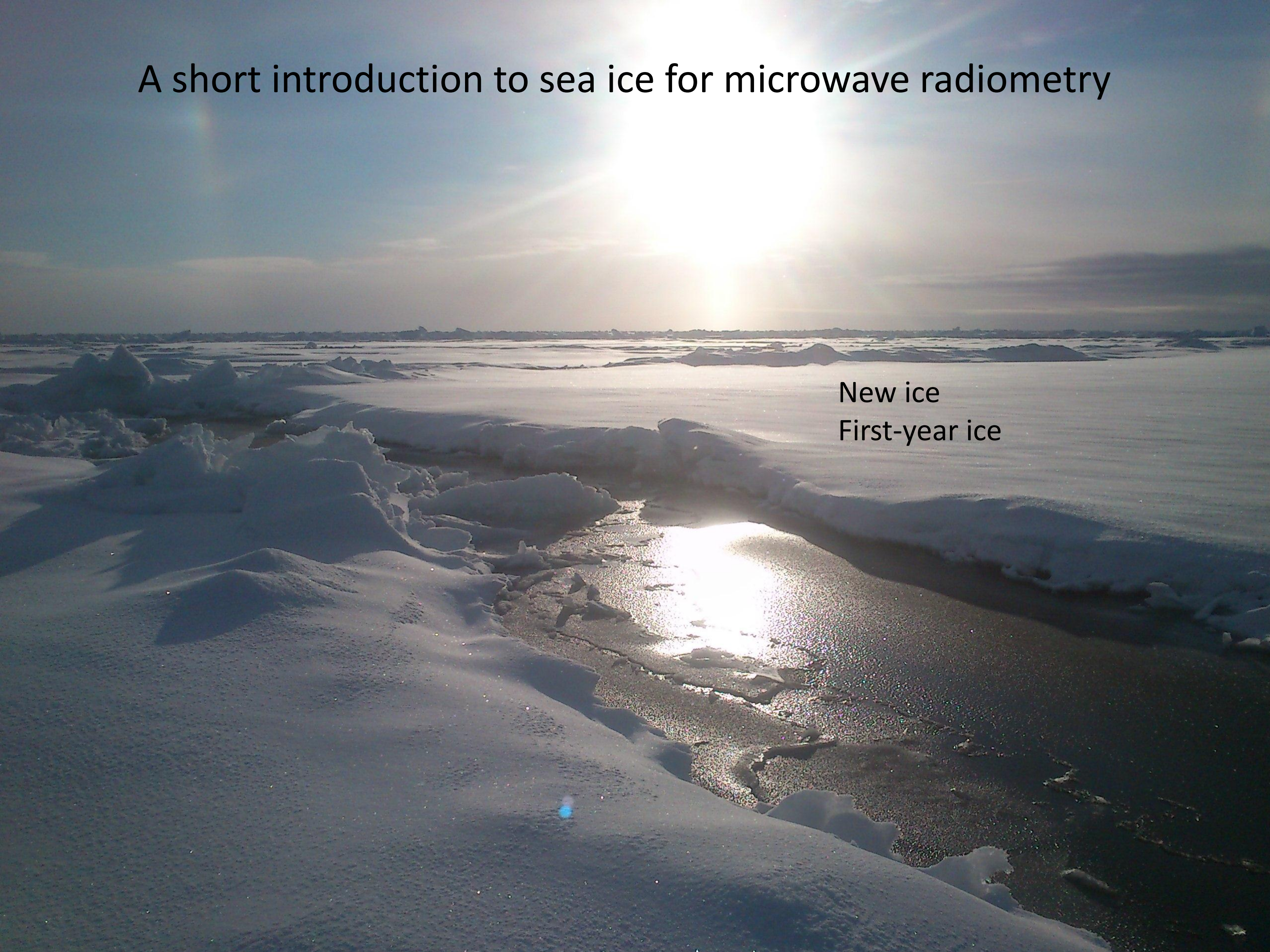
Simulations of the sea ice thermal microwave emissivity



Rasmus Tonboe,
Danish Meteorological Institute

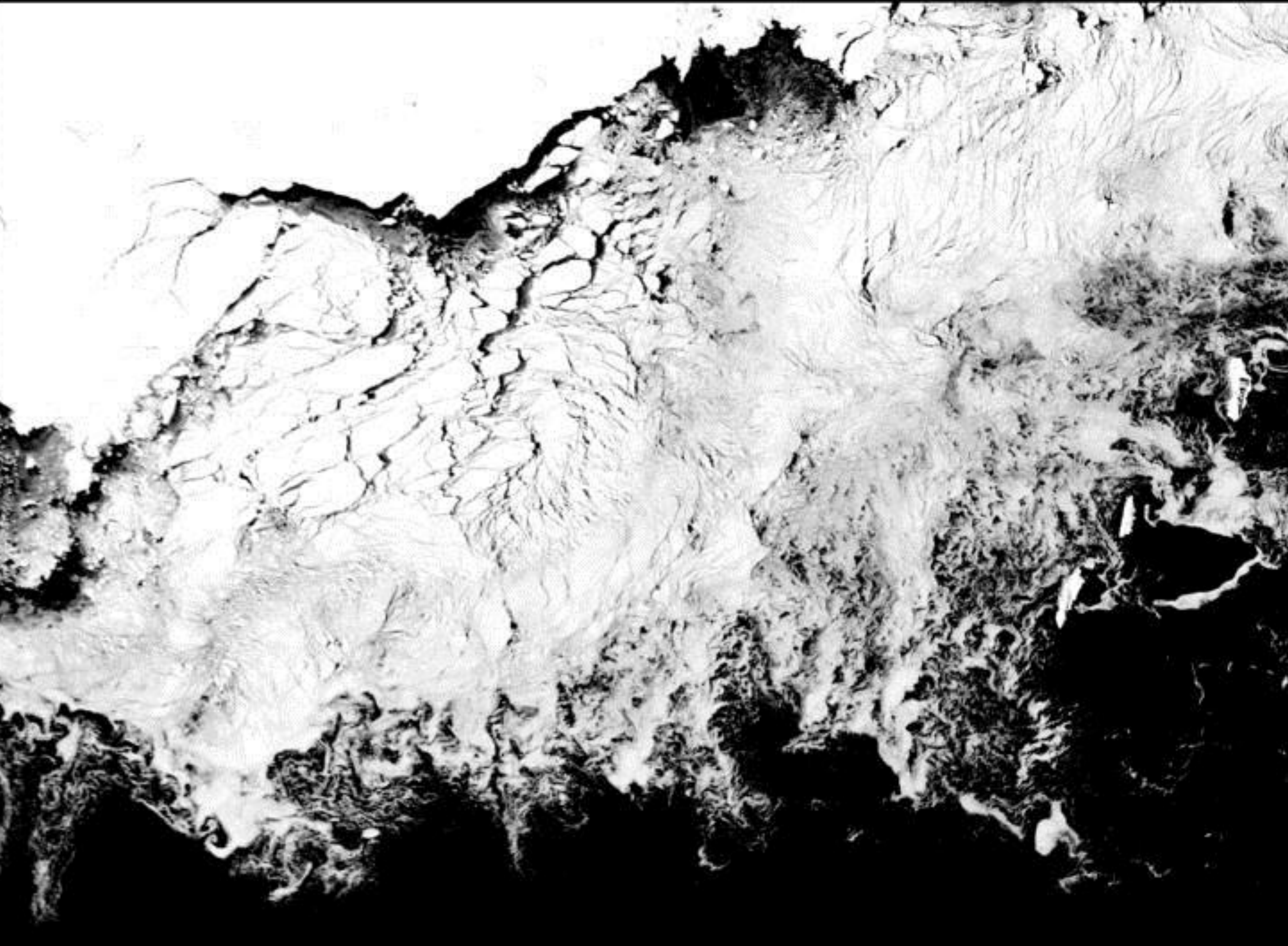
A short introduction to sea ice for microwave radiometry

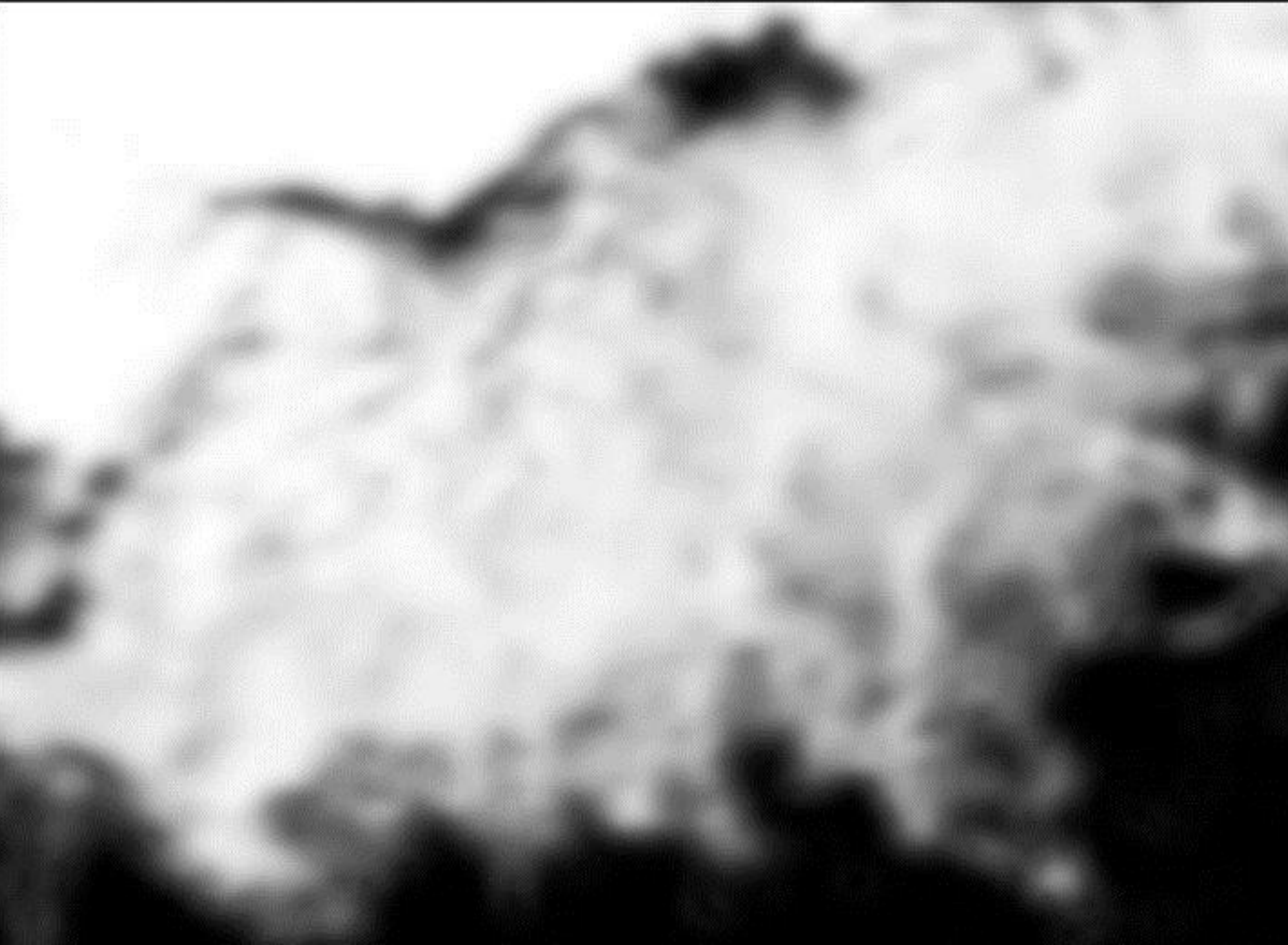



First-year ice
Ridges/ deformed ice


Multiyear ice
Melt-ponds


Refrozen meltponds





Emission modelling why and where?

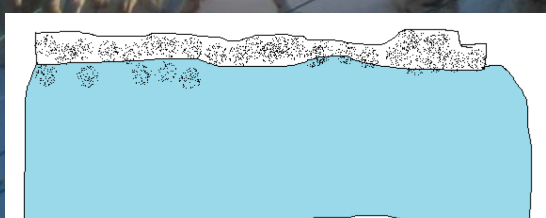
- **Estimation of uncertainties** in sea ice concentration, sea ice thickness, snow surface temperature…
- **For simplification of forward models** to reduce the computational cost or to reduce the number of free parameters.
- **Understanding limitations and ambiguities** for example between salinity, thickness and ice concentration in thin ice thickness estimation using SMOS.
- **For planning of field campaigns** which parameters to sample.
- **For use in parameter retrieval or data assimilation** for example in snow cover retrival.

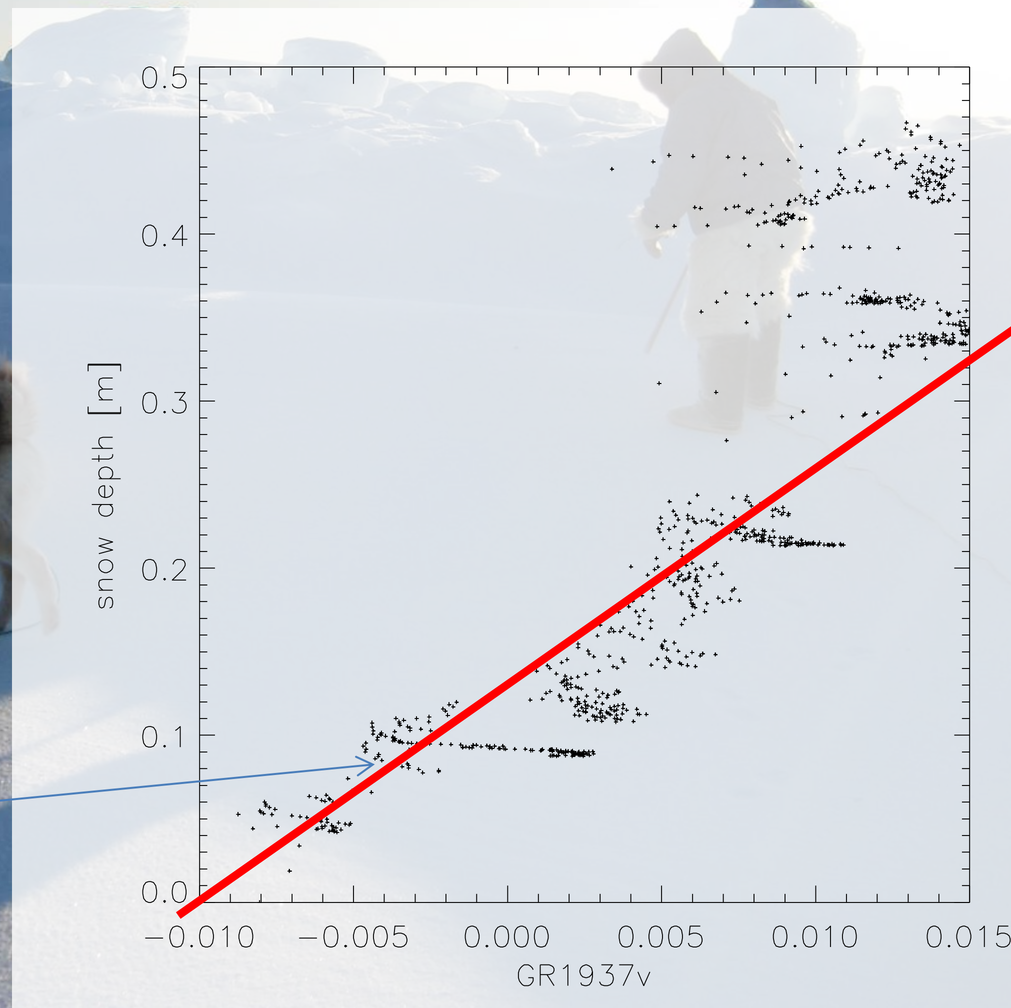
Forward emission and scattering models

- **Empirical models:** the gradient ratio snow thickness algorithm, ice concentration algorithms.
- **Semi-empirical models:** the OSISAF near 50GHz emissivity model
- **Sofisticated physical models:** for example MEMLS with multiple layers, multiple reflections, volume and surface scattering interaction.

These models are valid in the range roughly 1-100 GHz and some of these principles can also be used at higher frequencies (>100GHz). However, for ICI frequencies (183-664GHz) the emission processes are from a shallow layer at the snow surface and the models for permittivity and scattering have not been tested in this range.

The snow thickness algorithm -an empirical regression model

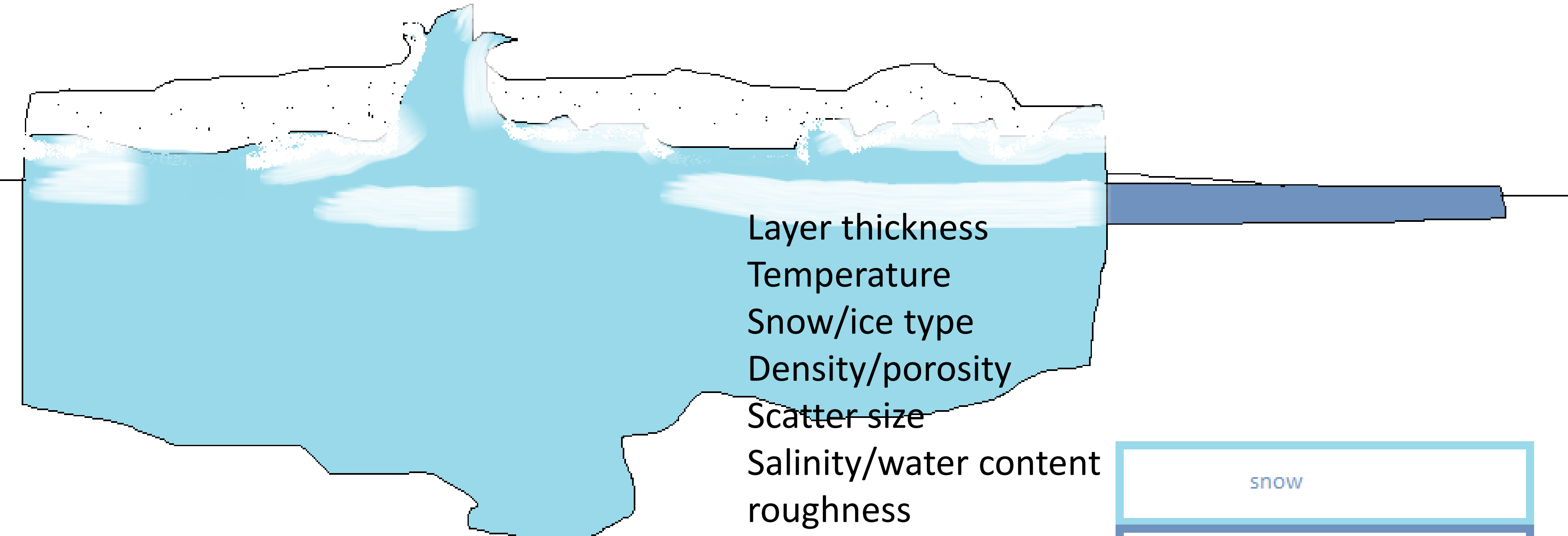




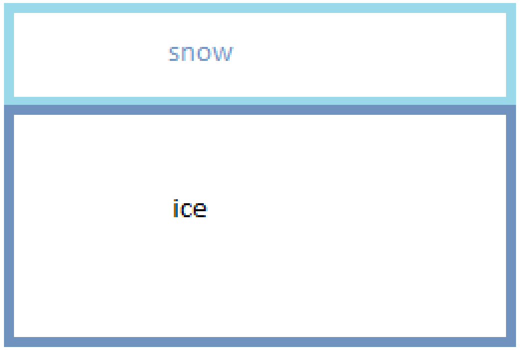
The line slope and offset are based on a particular dataset

Snow and sea ice

Sea ice concentration
Spatial distribution of e.g. roughness



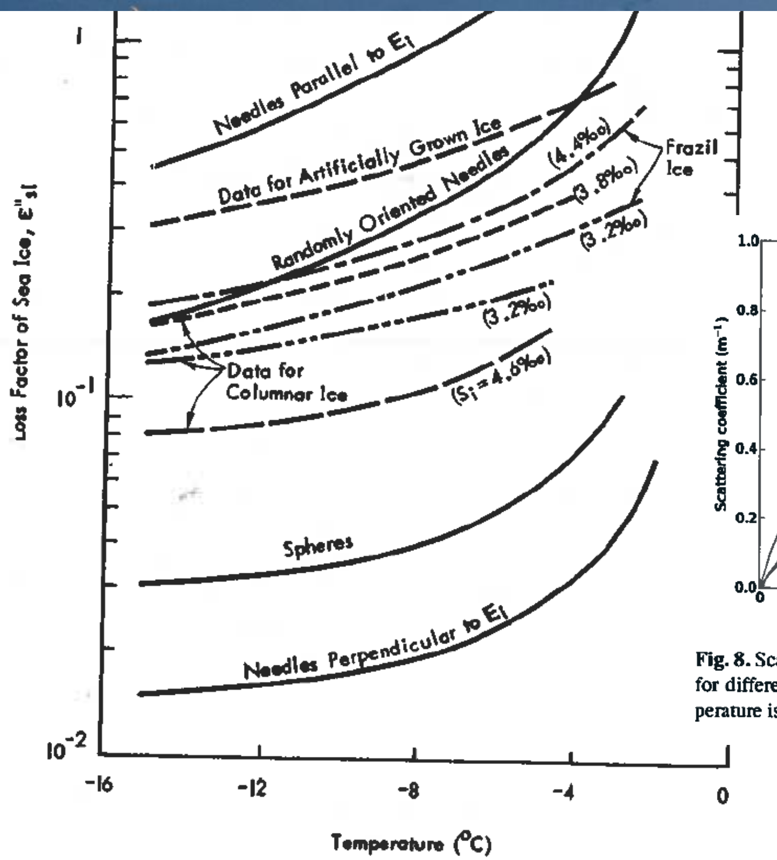
Layer thickness
Temperature
Snow/ice type
Density/porosity
Scatter size
Salinity/water content
roughness



Simplification is a necessity
-Yet we need to capture the most important processes

Assumptions, dieletric and scattering models

- Mixing and empirical models…
- DMRT(stickiness) and IBA (correlation length)…



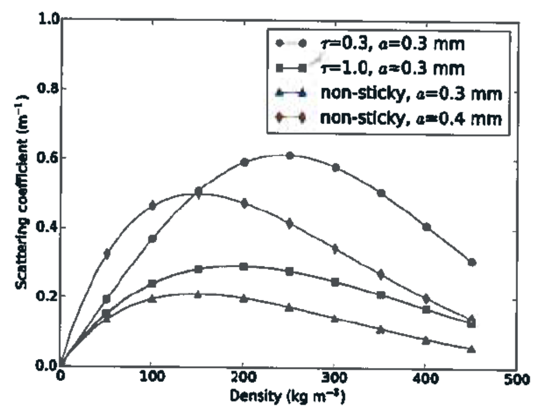


Fig. 8. Scattering coefficient at 37 GHz as a function of the density for different stickiness parameters τ and grain radius a. The temperature is 260 K.

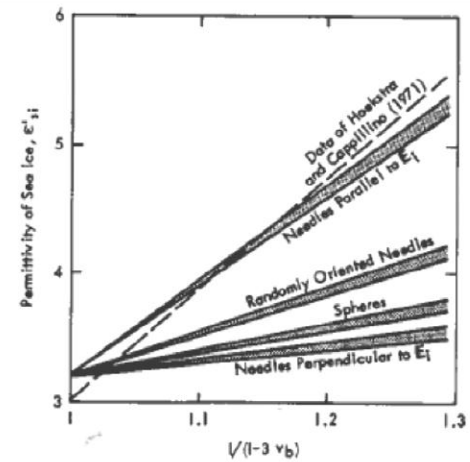


Fig. E.16 Dielectric permittivity of sea ice as a function of brine volume fraction at 9.8 GHz. The theoretical results were obtained by using salinities from 4 ‰ to 8 ‰ and ures from −3°C to −16°C (from Hallikainen, 1977).

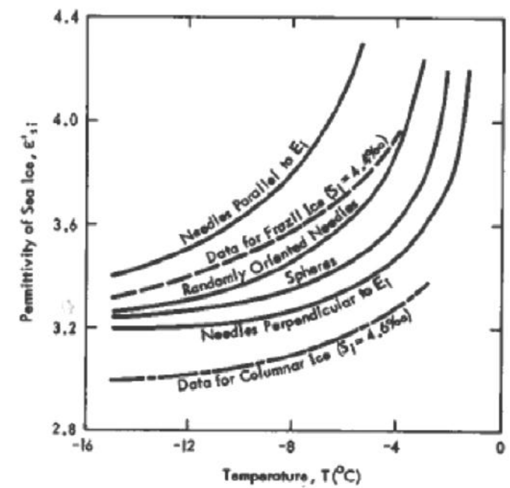


Fig. E.17 Theoretical dielectric constant of sea ice compared to experimental results for frazil ice (density 0.836) and columnar ice (density 0.896) by Vant *et al.* (1974). Frequency is 10 GHz, and salinity for theoretical calculations is 4.4 ‰ (from Hallikainen, 1977).

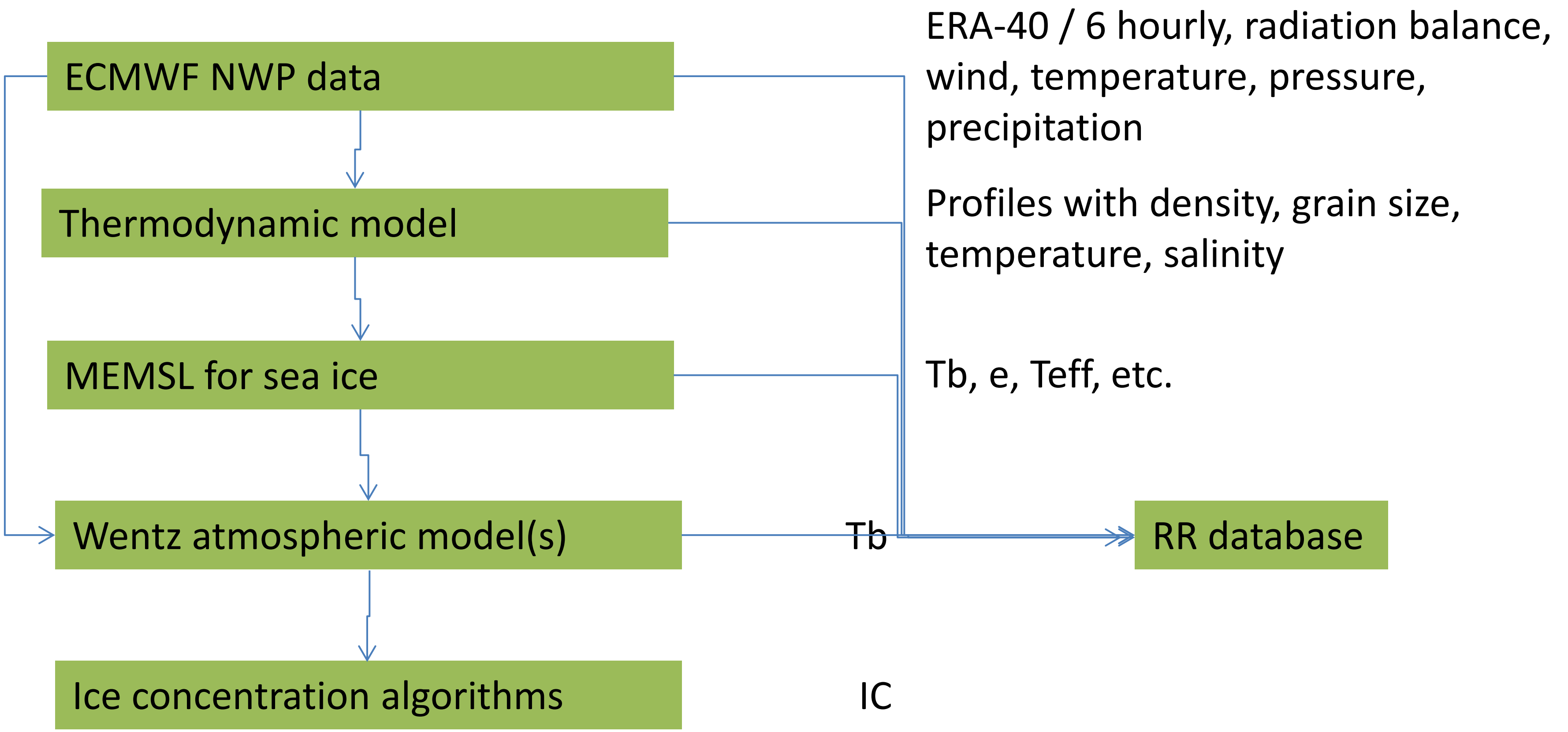
Permittivity models for sea ice

Ice type	Model type
First-year frazil ice	Randomly oriented brine needles in pure ice
First-year columnar ice	Vertically oriented brine needles in pure ice
Multiyear hummock	Any shape of air inclusions in pure ice
Pond ice	Vertically oriented brine needles and spherical air bubbles After Shokr, 1998

Second-order radiative transfer multi-layer model, MEMLS

- Physical properties include: temperature, layer thickness, density, roughness, scatter size, snow/ice type, salinity (snow wetness), viewing angle, electromagnetic frequency.
- Compute for each layer, reflectivity, loss, volume scattering, second order scattering and reflection.
- Brightness temperature, emissivity and effective temperature...
- The detailed input is a major challenge we use a thermodynamical model.

The simulated data

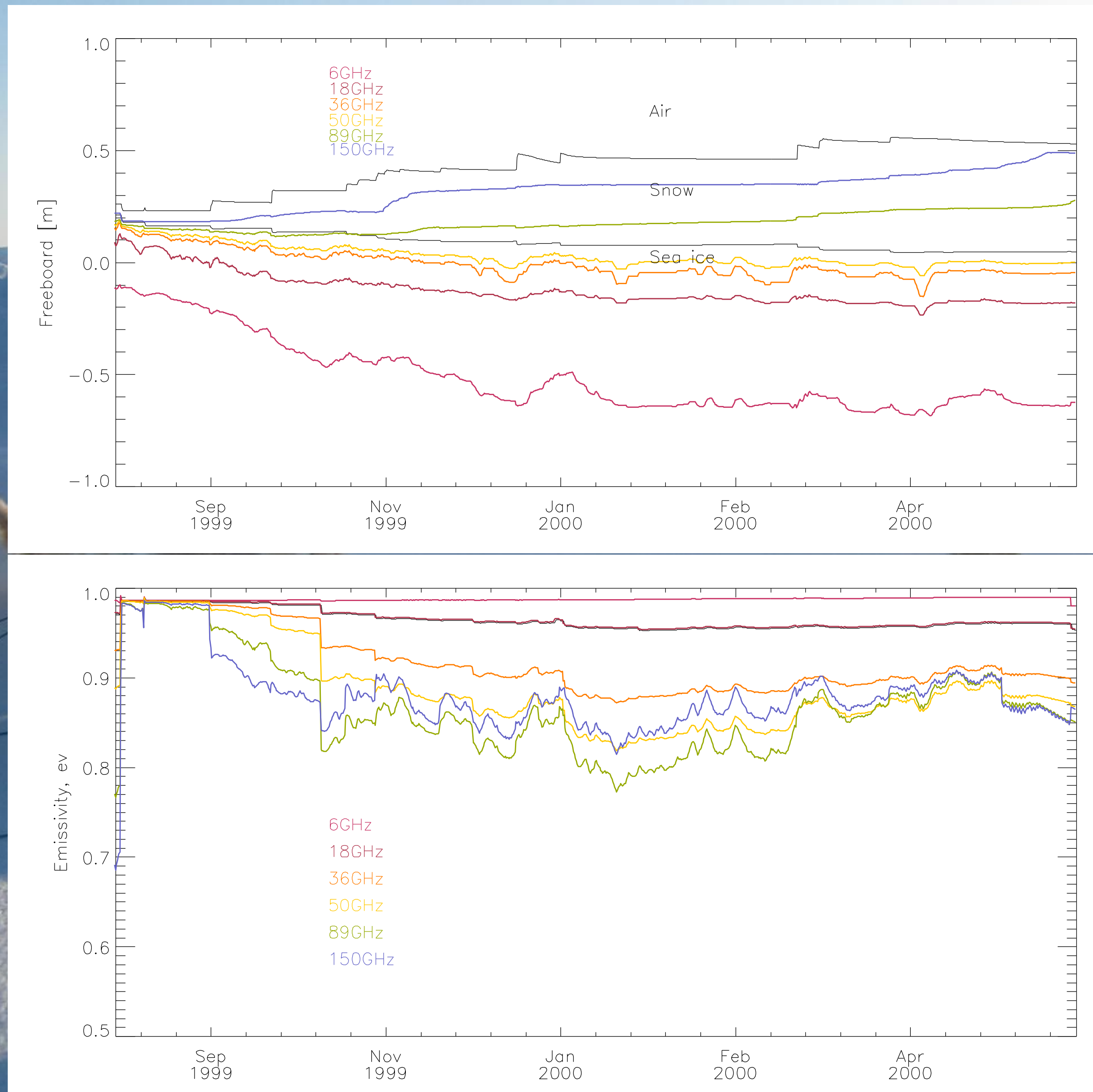


The system is described in:
Tonboe, R. T. The simulated sea ice thermal microwave emission at window and sounding frequencies. Tellus 62A, 333-344, 2010.
Tonboe, R. T., G. Dybkjær, J. L. Høyer. Simulations of the snow covered sea ice surface temperature and microwave effective temperature. Tellus 63A, 1028-1037, 2011.

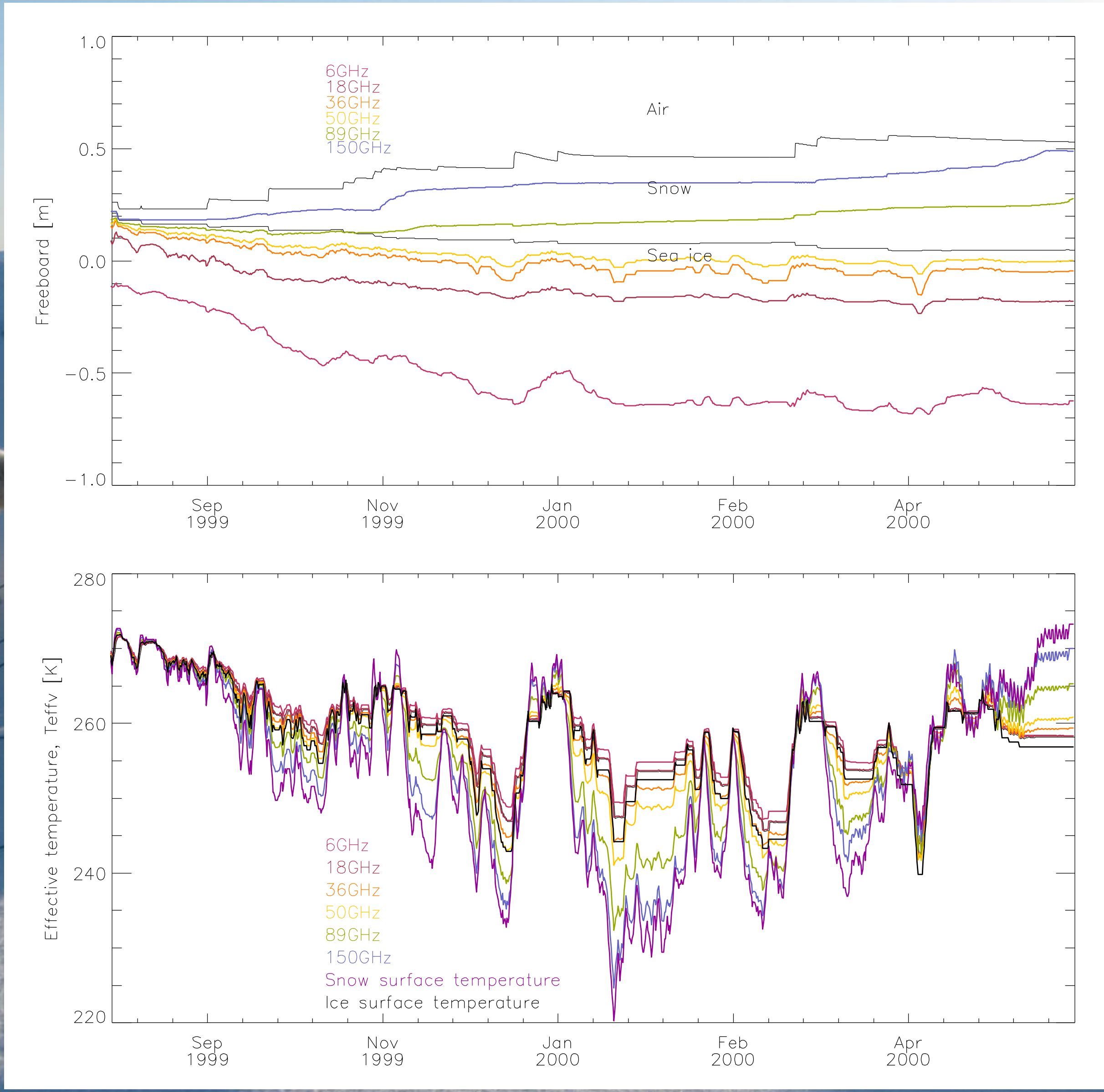
Energy and mass balance

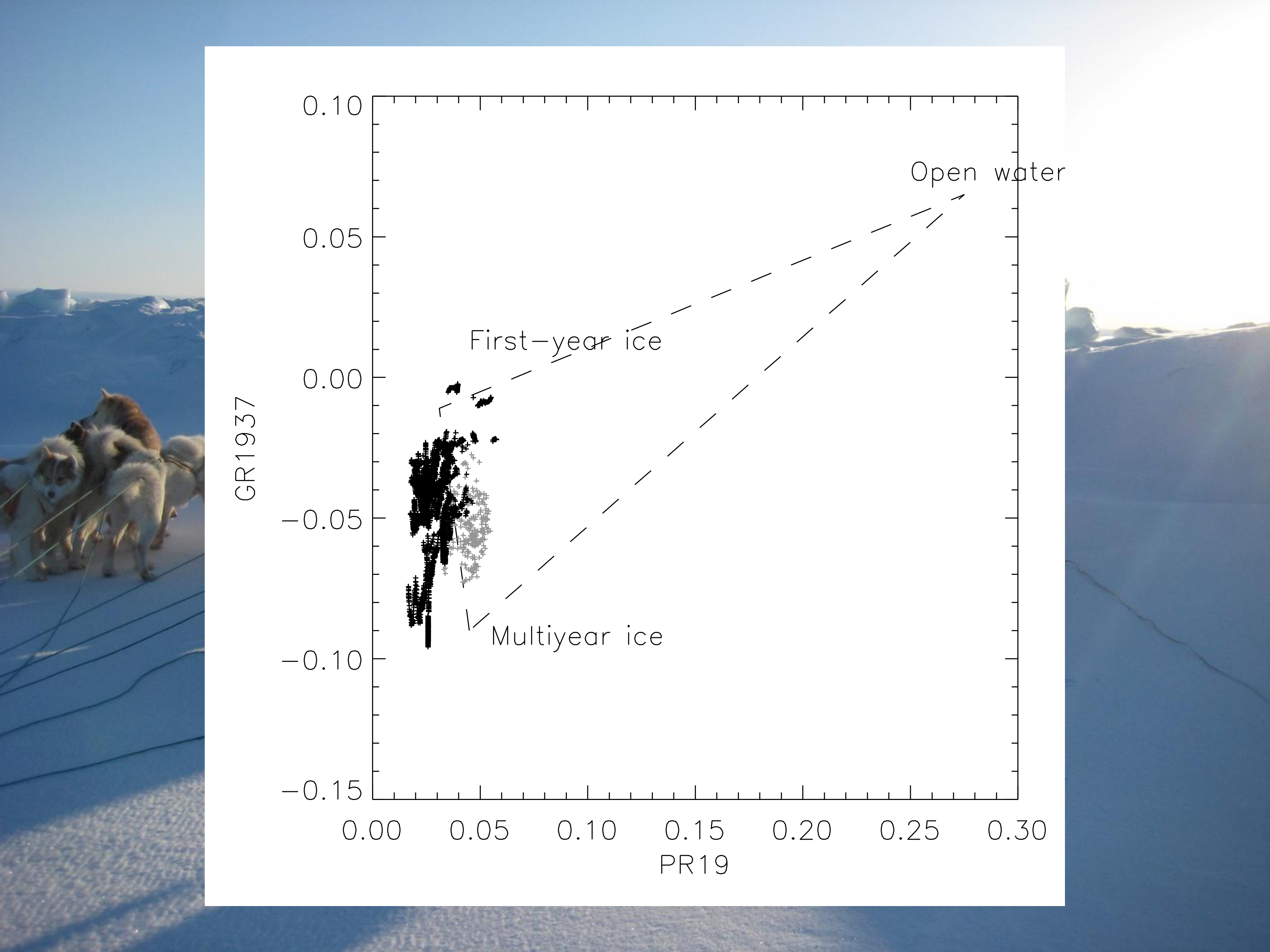
- Air temperature
- Wind speed
- Radiation balance
- Snow accumulation
- Ice growth

The microwave emissivity (6-150GHz)

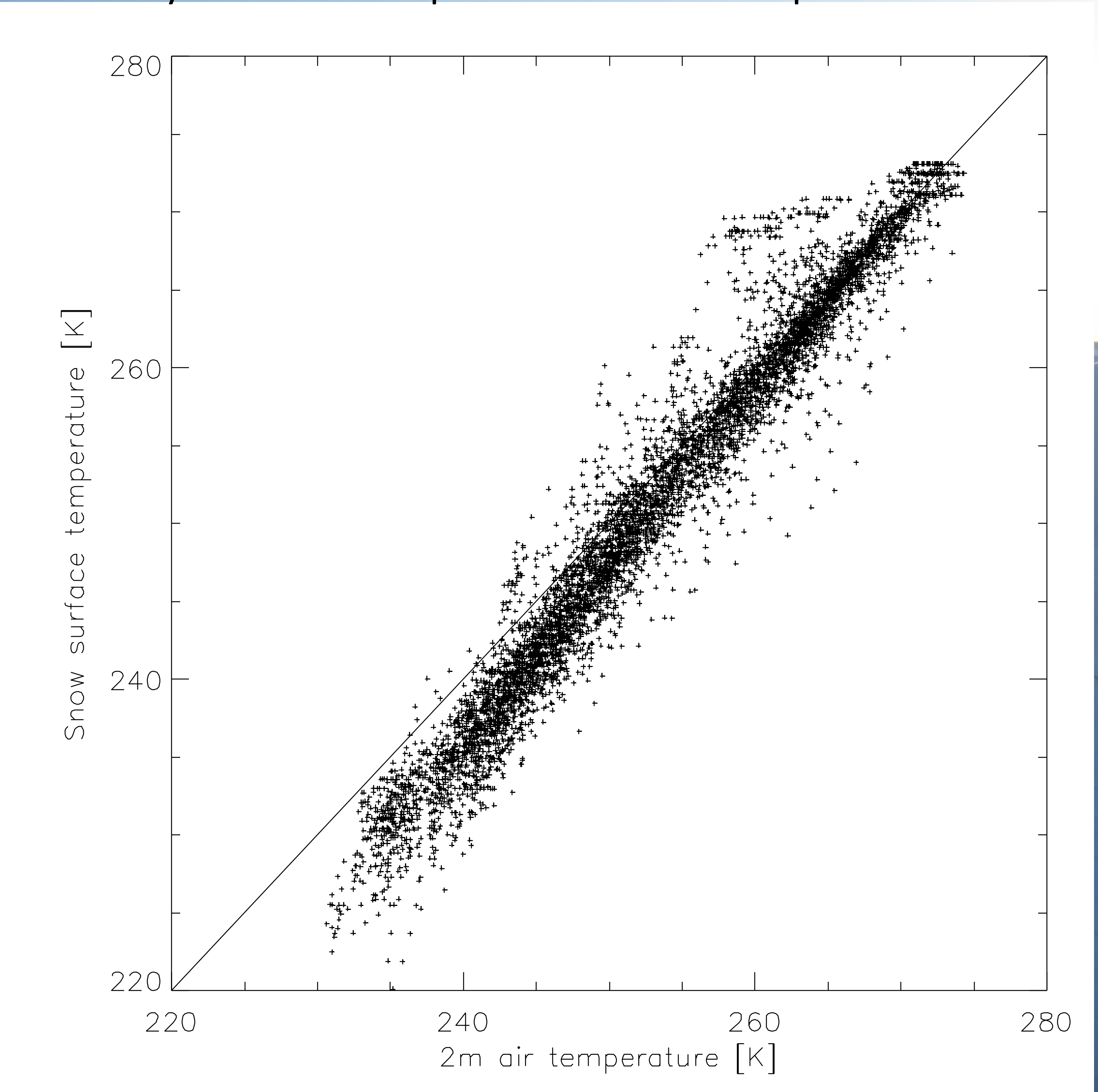


The effective temperature (6-150GHz)



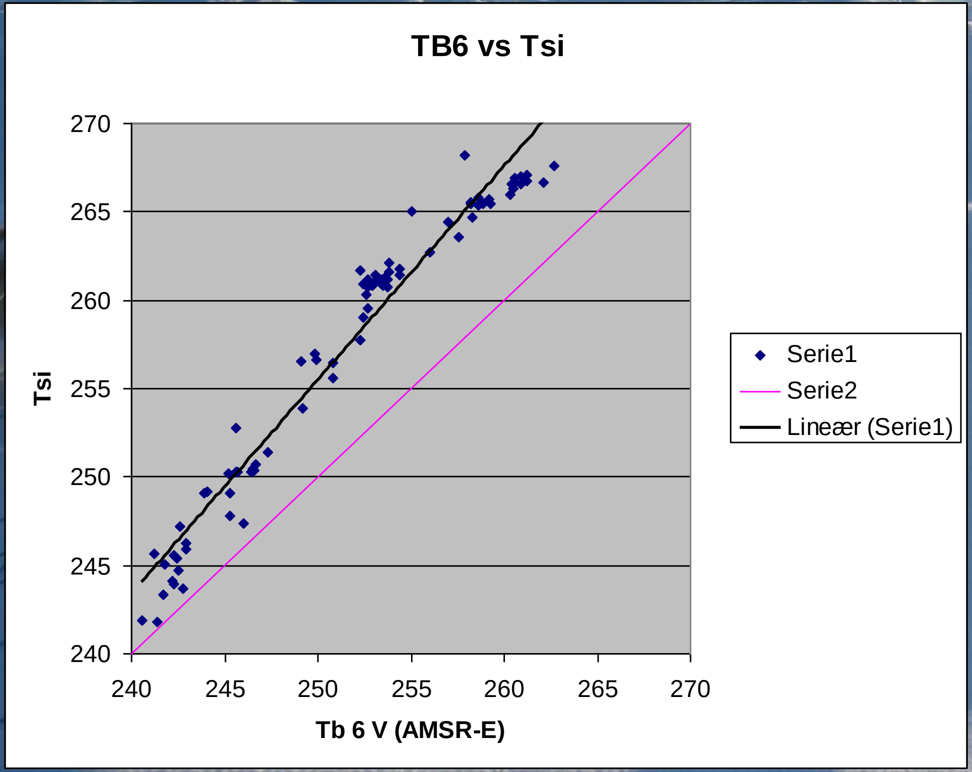

Open water
First−year ice
Multiyear ice
0.10
0.05
0.00
−0.05
−0.10
−0.15
GR1937
0.00
0.05
0.10
0.15
0.20
0.25
0.30
PR19

Multiyear ice air temperature surface temperature

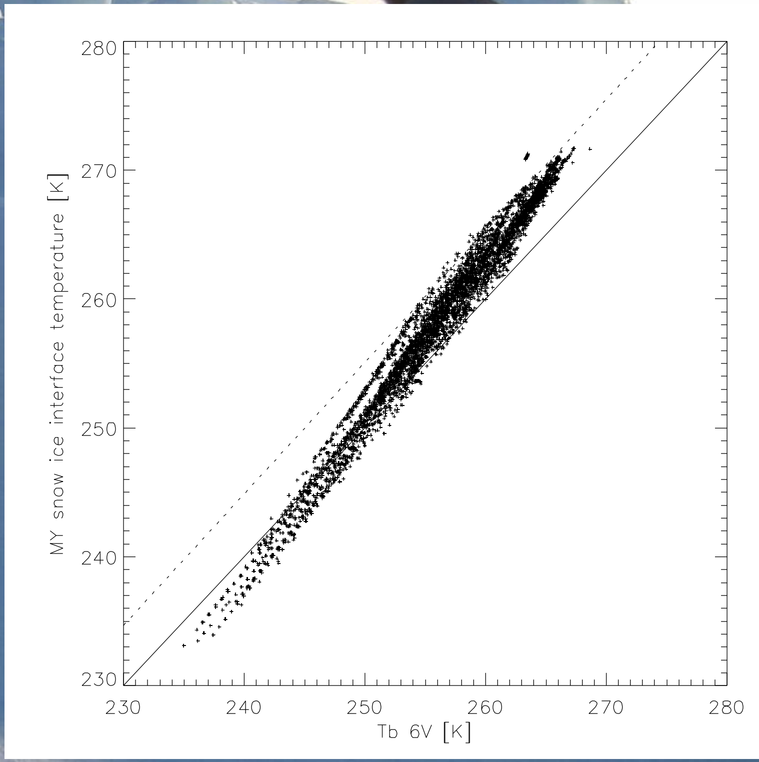


Penetration depth is a function of (ice) temperature and *vice versa*

Measurements collocated with satellite observations (from Phil Hwang)



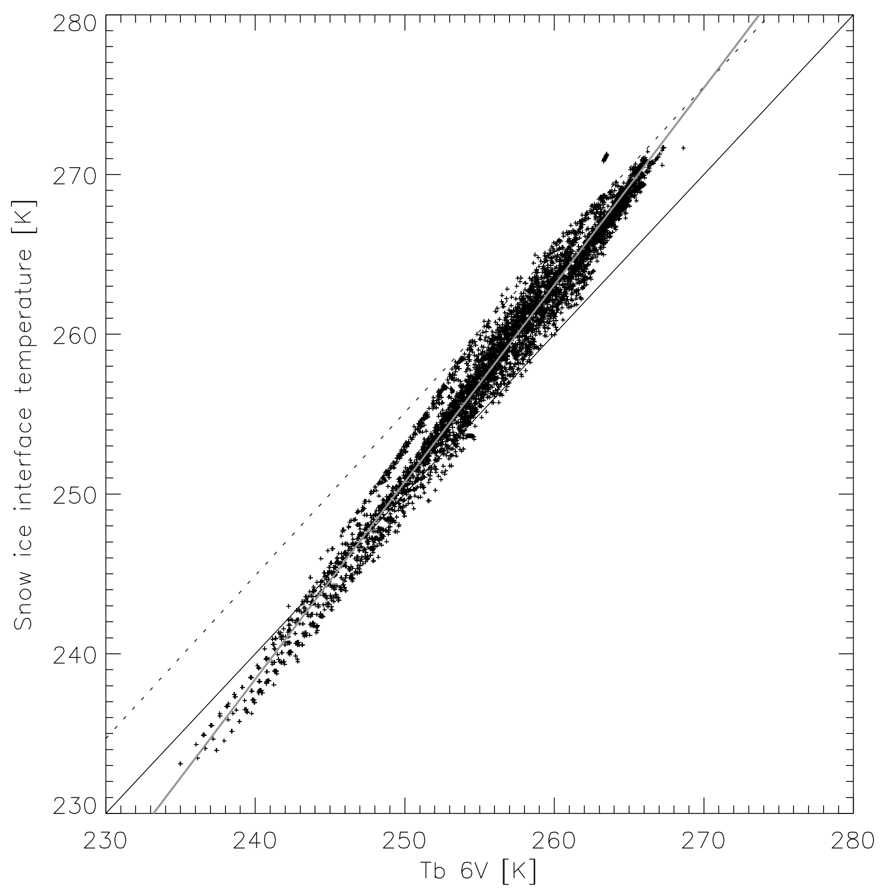
6 simulated multiyear ice profiles

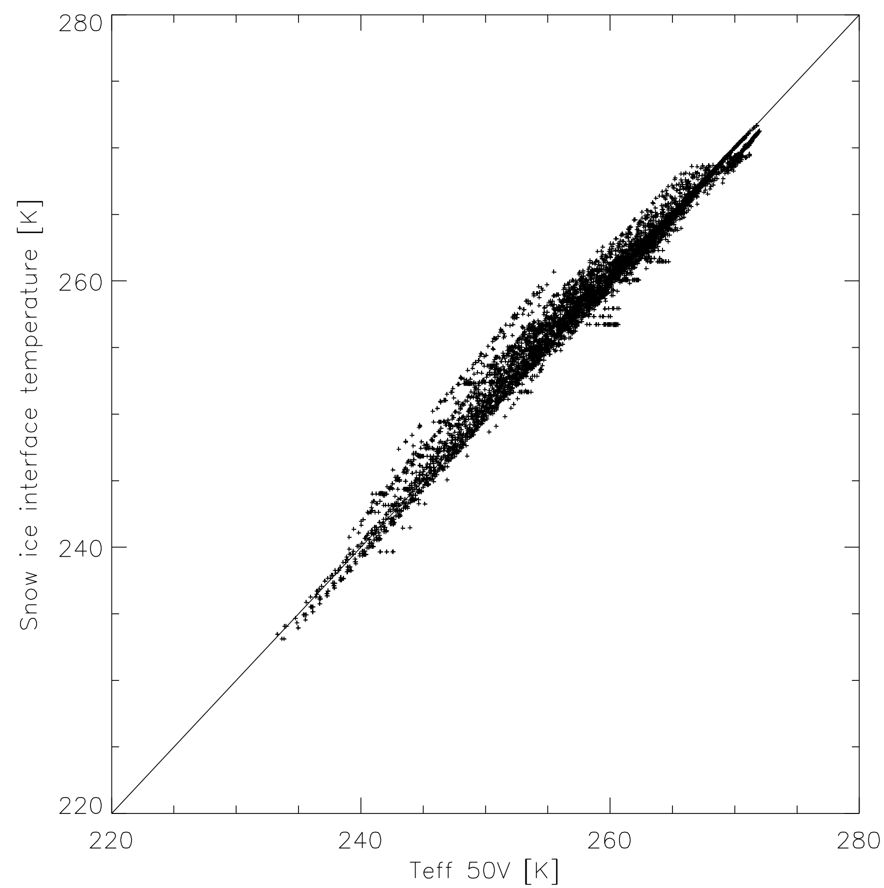


Physical temperature vs. effective temperature?

The physical and microwave emission temperature

If it is cold, penetration is deep into something which is relatively warmer.





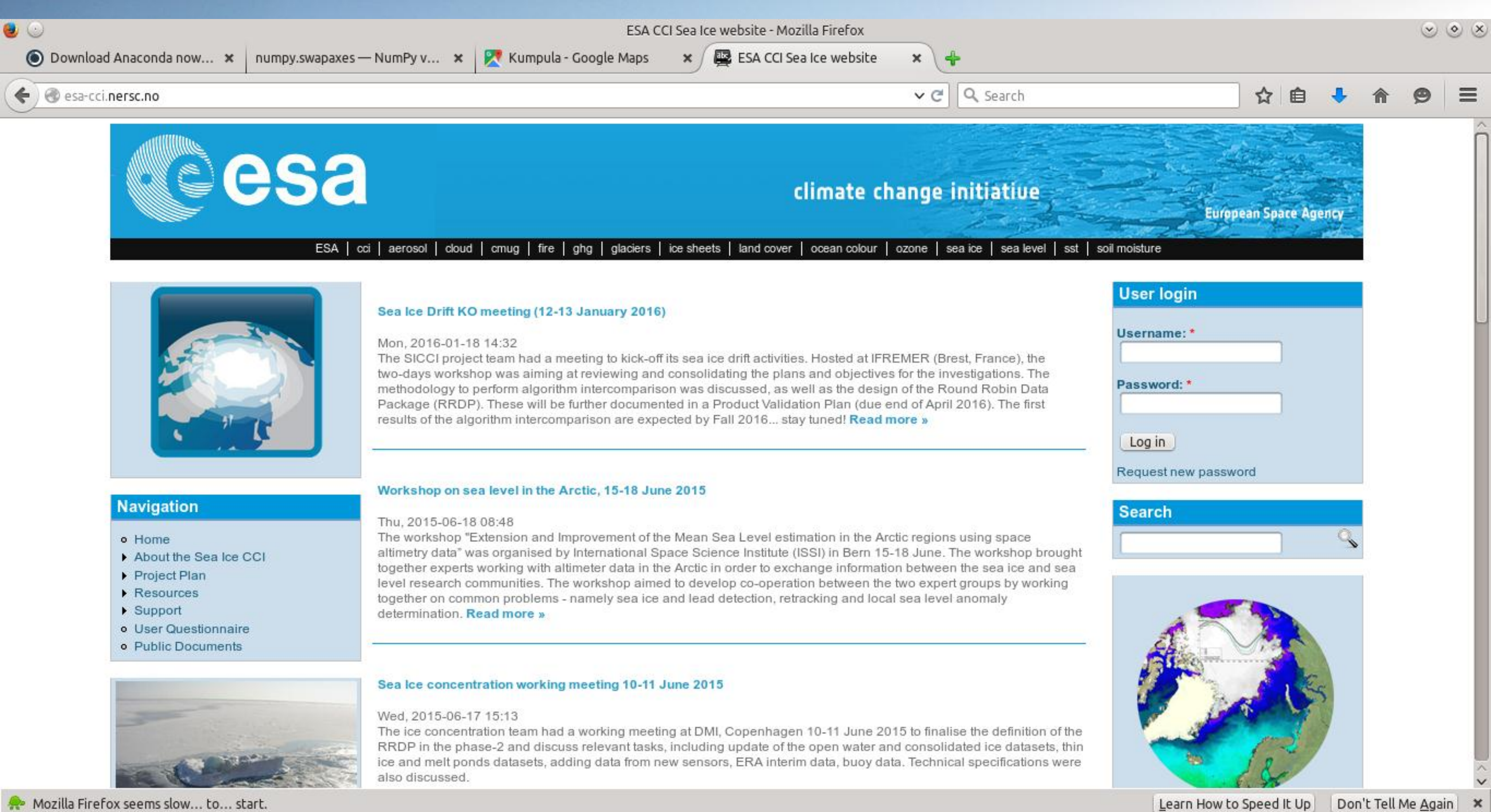
Tb 6 GHz vs. snow ice interface temperature

The 50 GHz effective temperature vs. The snow ice interface temperature

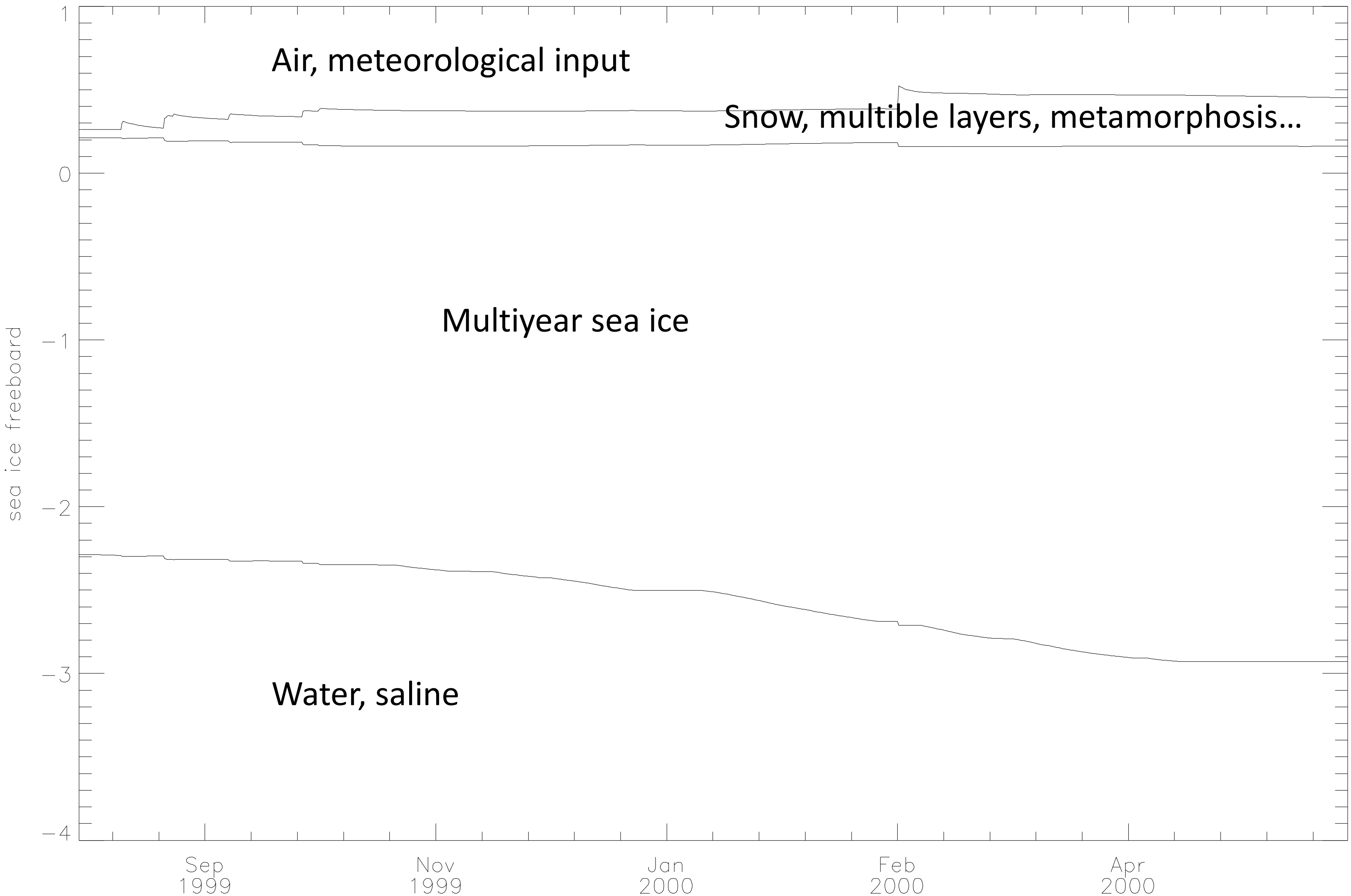
Applications

-ESA CCI Sea ice concentration algorithm evaluation

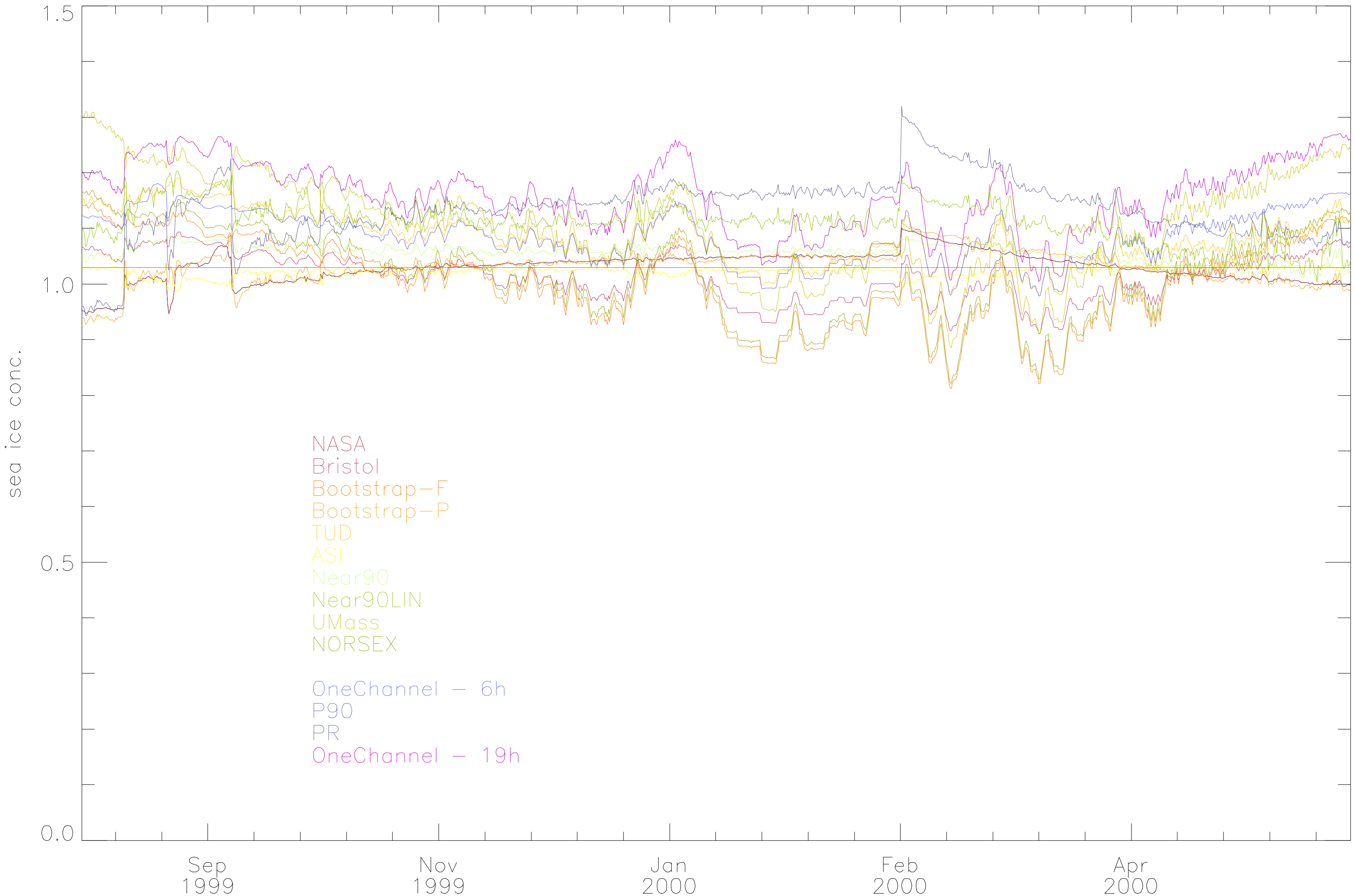
-The EUMETSAT sea ice near 50GHz emissivity product



Evaluation of sea ice concentration algorithms and methodology for building sea ice climate data: 1) low sensitivity to noise, 2) explicit reduction of noise, 3) minimization of artificial trends, 4) quantification of (residual) uncertainties.

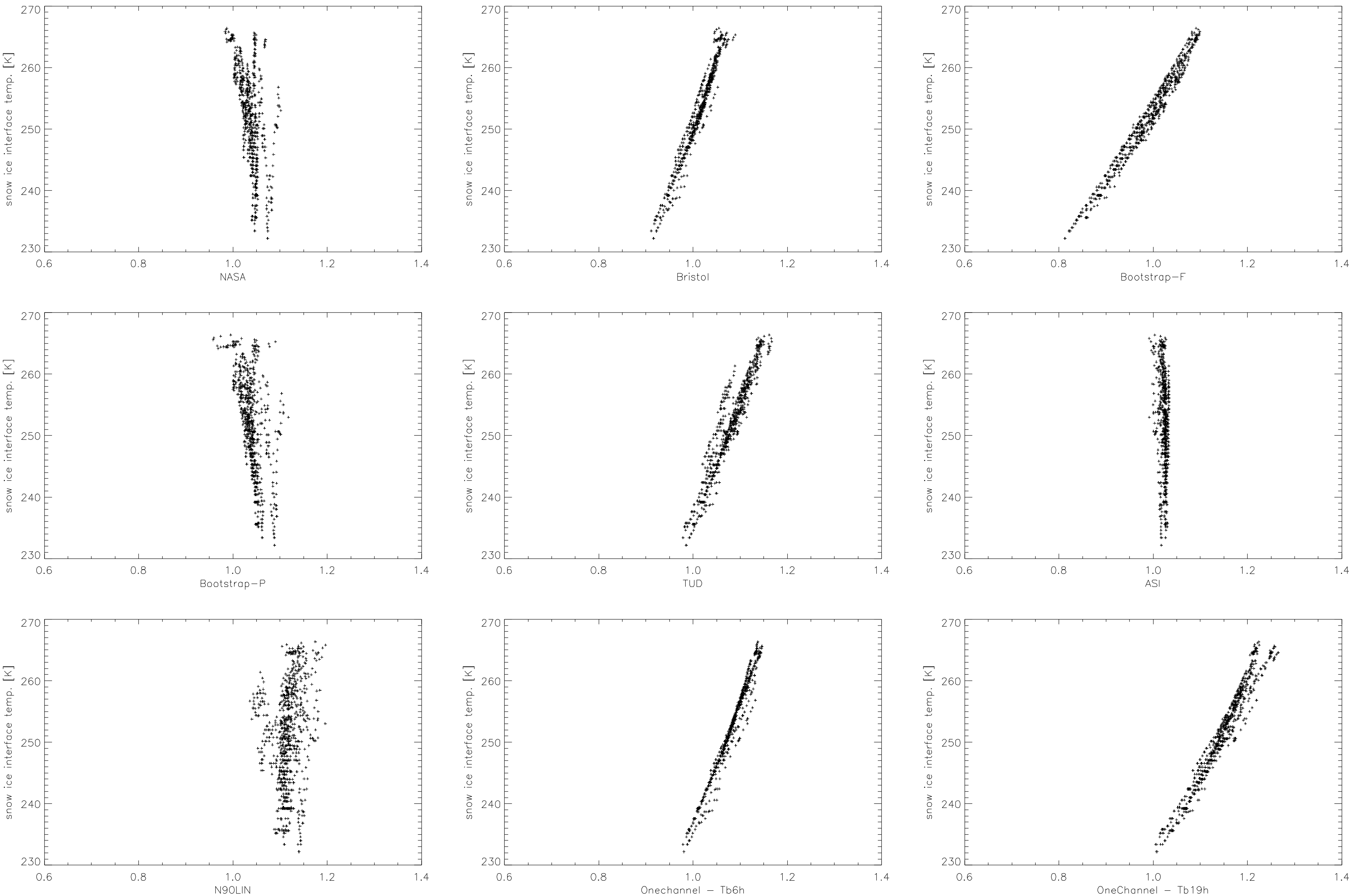


Air, meteorological input
Snow, multible layers, metamorphosis…
Multiyear sea ice
Water, saline
sea ice freeboard
1
0
−1
−2
−3
−4
Sep 1999
Nov 1999
Jan 2000
Feb 2000
Apr 2000

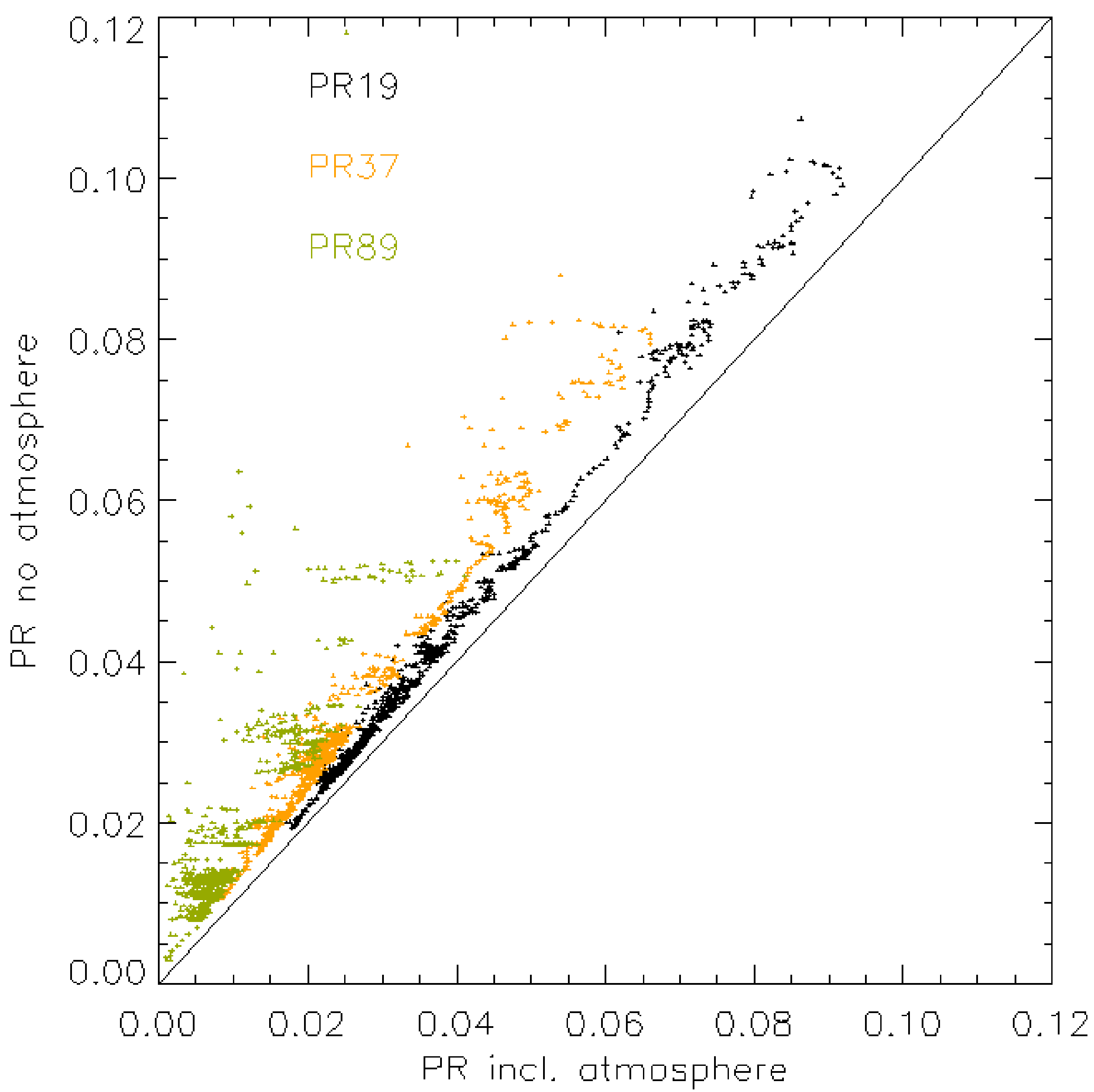


1.5
1.0
0.5
0.0
sea ice conc.
NASA
Bristol
Bootstrap−F
Bootstrap−P
TUD
ASI
Near90
Near90LIN
UMass
NORSEX
OneChannel − 6h
P90
PR
OneChannel − 19h
Sep 1999
Nov 1999
Jan 2000
Feb 2000
Apr 2000

Snow ice interface temperature vs. IC



The polarisation ratio sensitivity to the atmosphere over ice in the Ross Sea



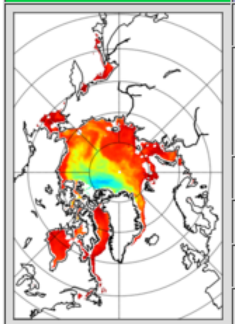
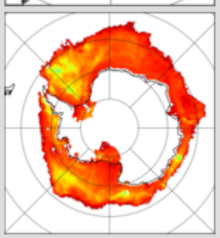
The EUMETSAT sea ice near 50GHz emissivity product

Sea Ice - Mozilla Firefox

Download Anaconda now… | numpy.swapaxes — NumPy v… | Kumpula - Google Maps | ESA CCI Sea Ice website | Sea Ice

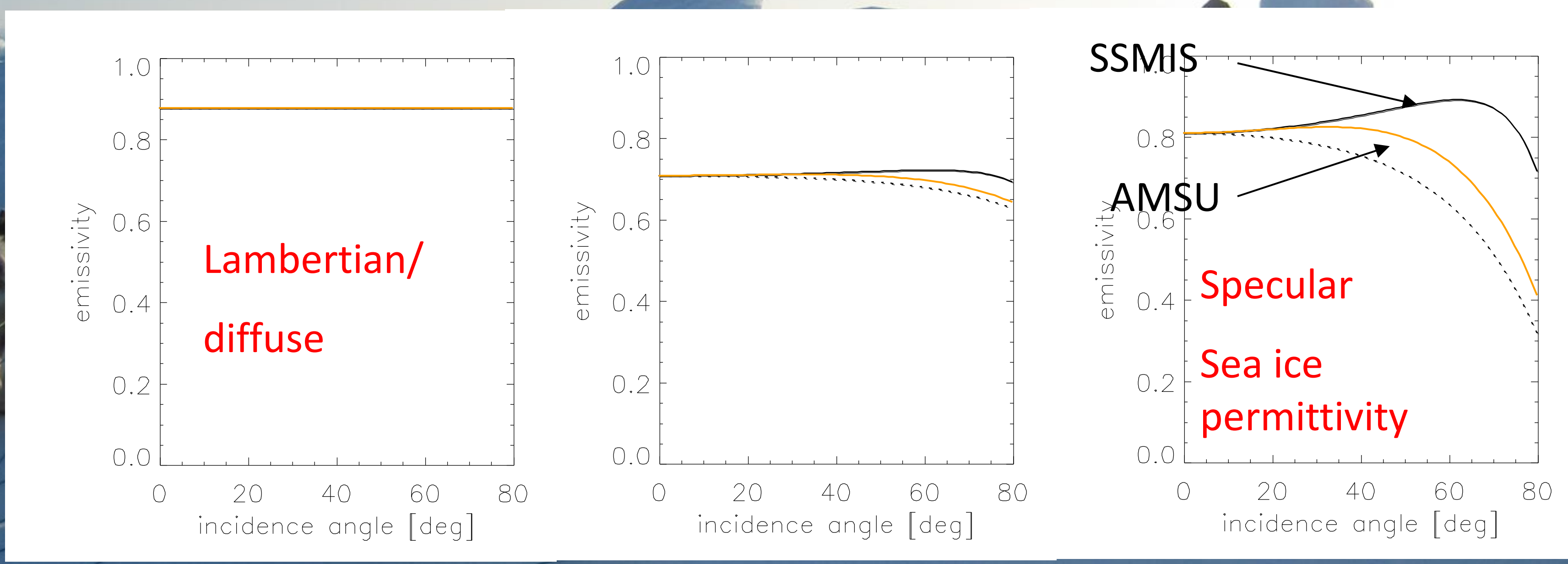
osisaf.met.no/p/ice/index.html

Search

	Remarks	*Note that during Arctic summer season (May-September) the ice type product is dubious because melting of the ice surface obscures the ice type signals.*
PRE-OPERATIONAL		**Sea Ice Emissivity**
	**Title**	**OSI-404**: The near 50GHz global sea ice emissivity
	Description	The sea ice surface emissivity is representative for the near 50 GHz channels used for temperature sounding of the atmosphere using satellite radiometers such as SSMIS and AMSU. *>> access more details*
	Data used	SSMIS brightness temperatures at 19v, 37v and 37h
	Formats	NetCDF
	NRT access	FTP (last 31 days in NetCDF)
	Archive	FTP
	**Documentation**	Product User's Manual, Validation Report, ATBD
	Links	Quicklooks NH,Quicklooks SH
	Remarks	• The emissivity is combined with the surface effective temperature, sometimes called the skin temperature, in the radiative transfer equation. Model simulations indicate that the snow-ice interface temperature or alternatively the 6 GHz brightness temperature is a closer proxy for the 50 GHz effective temperature than the snow surface or air temperature
OPERATIONAL		**Low Resolution Sea Ice Drift**
	**Title**	**OSI-405-b**: Sea Ice Motion Maps with 48 hours span, on 62.5 km Polar Stereographic Grid
	Description	The low resolution sea ice drift product from the EUMETSAT OSI SAF. Ice motion vectors with a time span of 48 hours are estimated by an advanced cross-correlation method (the Continuous MCC, CMCC) on pairs of satellite images. Several single-sensor products are available, along with a merged (multi-sensor) dataset. *>> access more details*

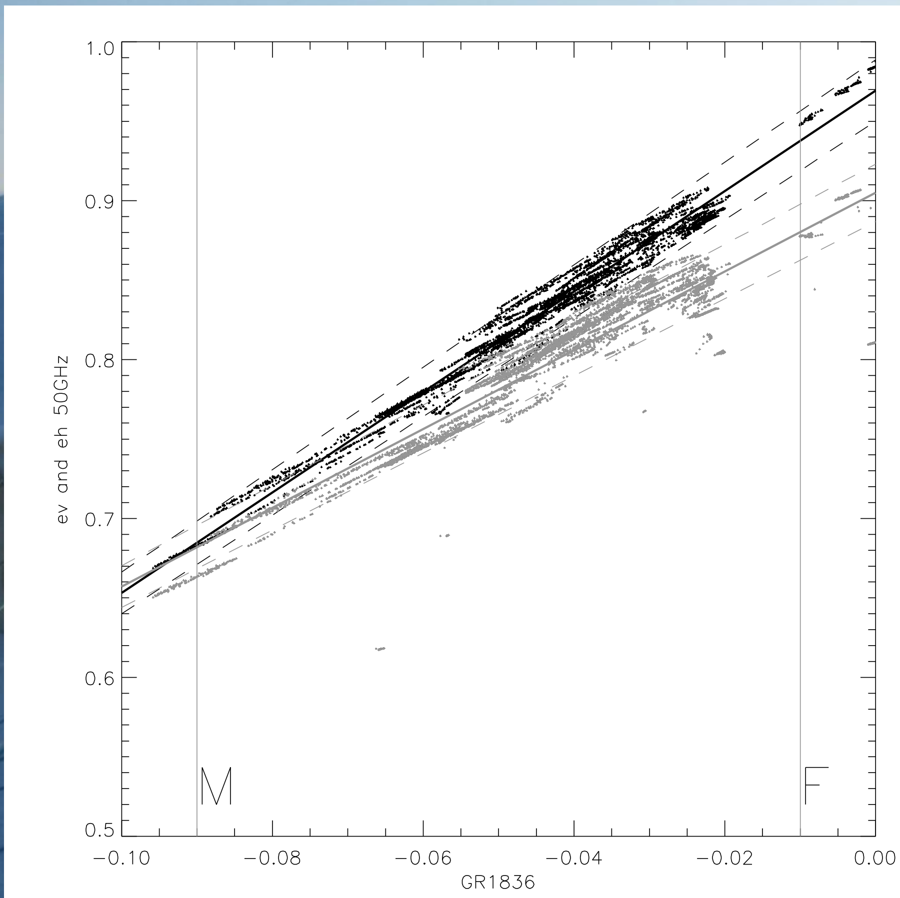
Mozilla Firefox seems slow… to… start. Learn How to Speed It Up | Don't Tell Me Again

The development of an operational 50 GHz emissivity model for EUMETSAT

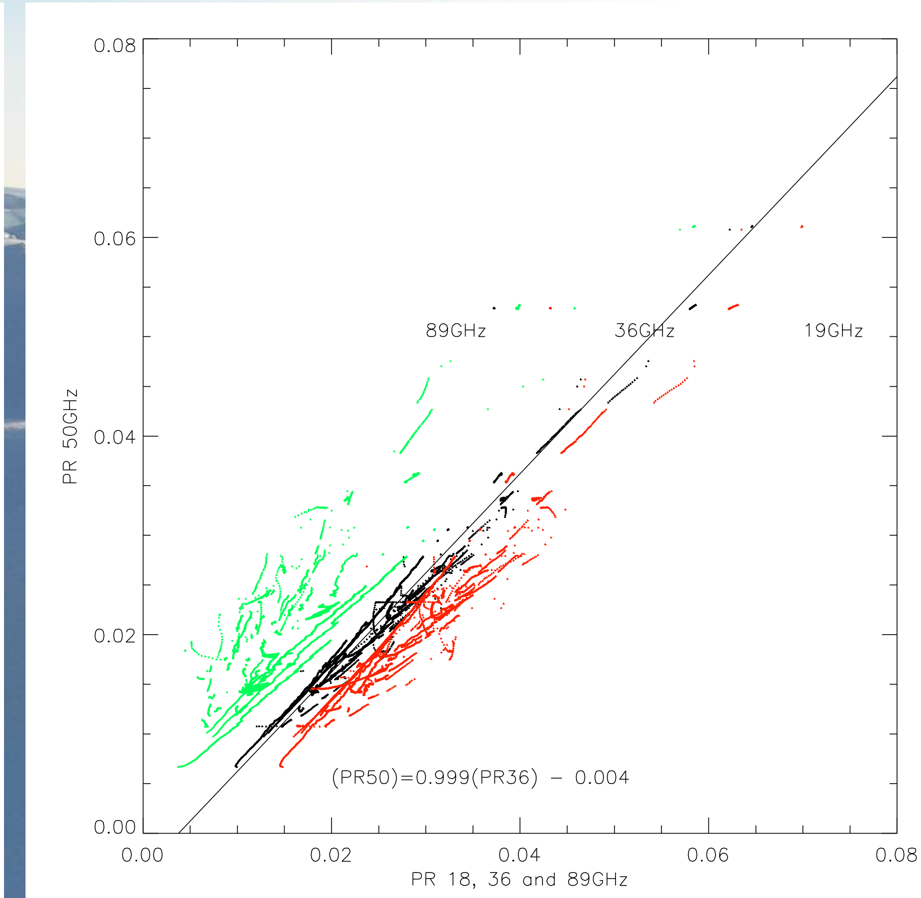


The model parameter R and S simulated relationships

$$e(\theta)=S(1-Rr(\theta))$$



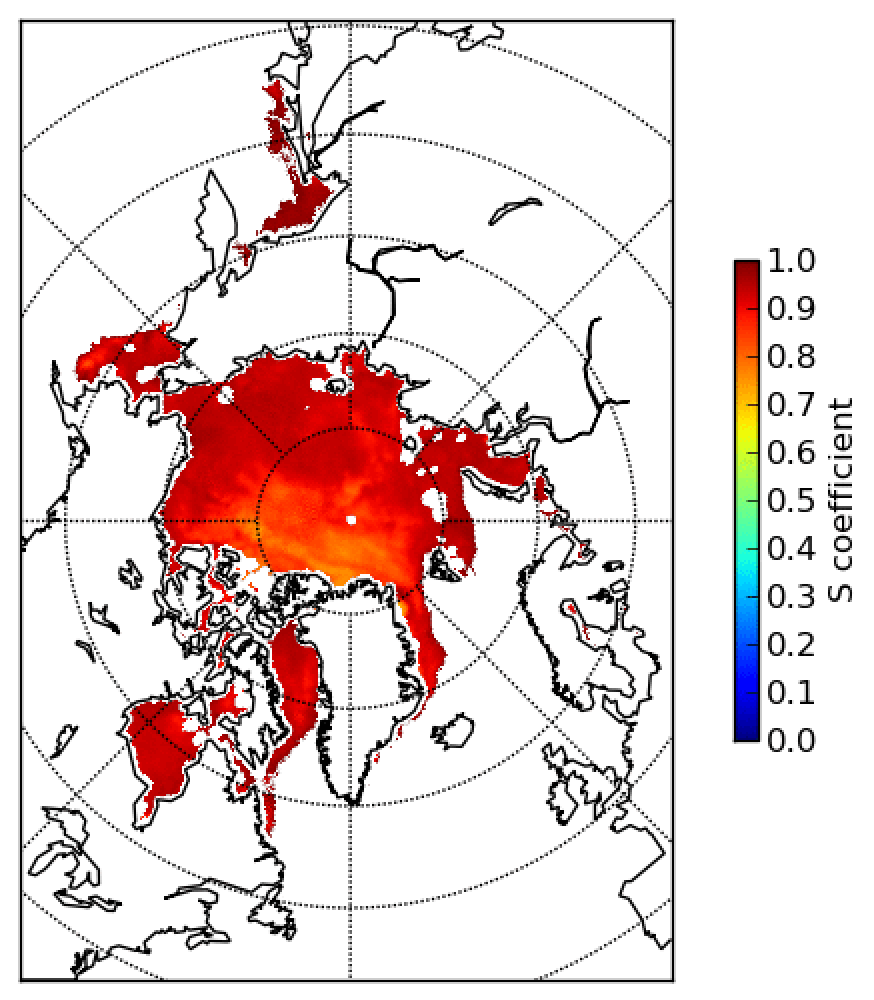
The 50 GHz emissivity as a function of the 18/36 GHz spectral gradient



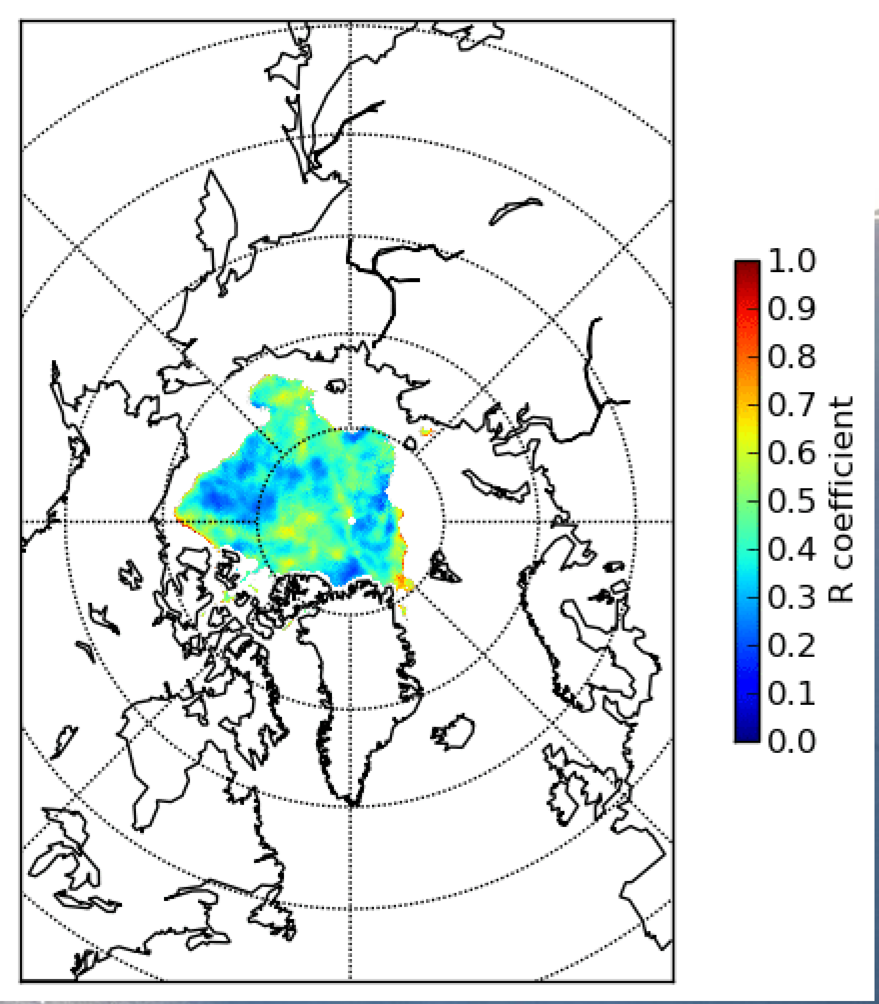
The 50 GHz polarisation as a function of the 18, 36 and 89GHz polarisation.

The model parameters, S, R

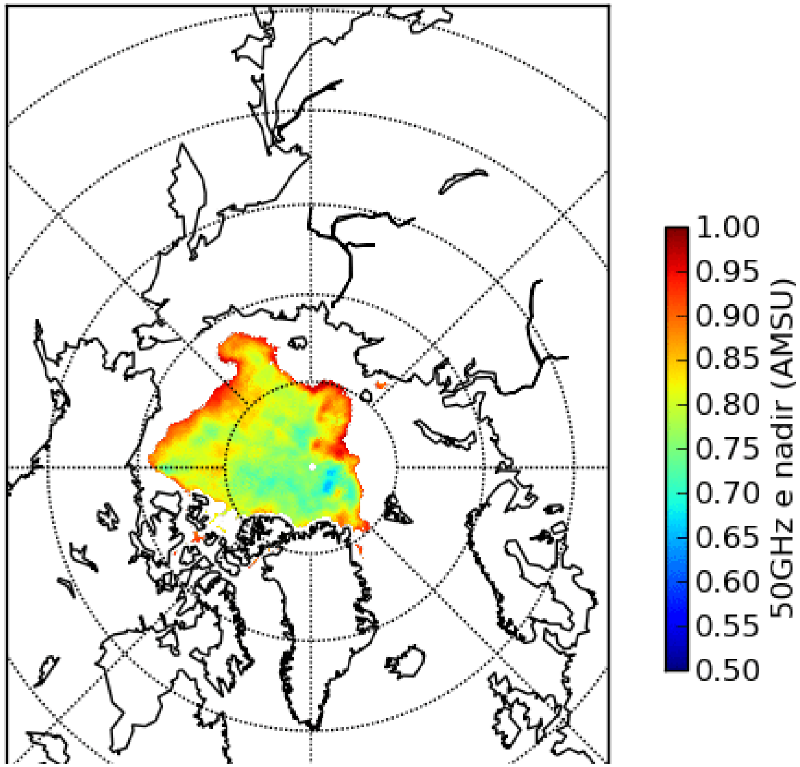
The S-factor, magnitude



The R-factor, the polarisation, R=0 diffuse, R=1 specular

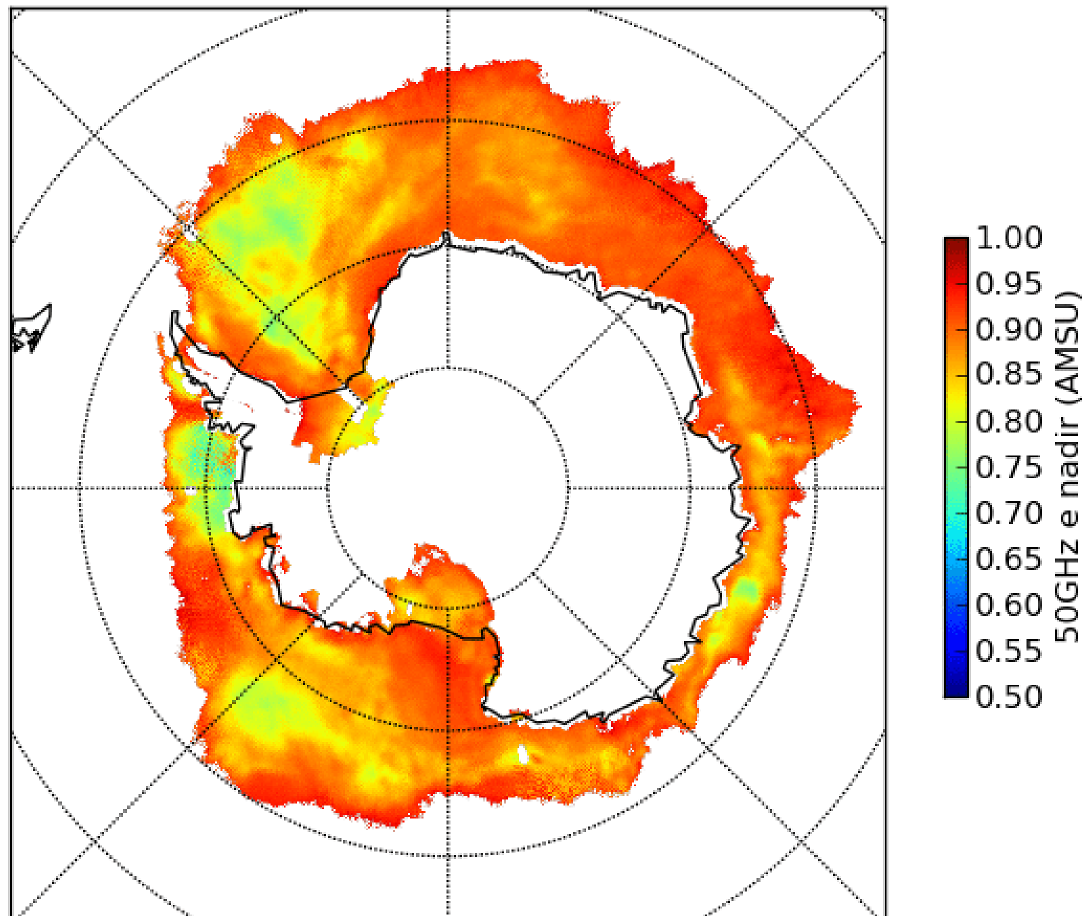


The emissivity



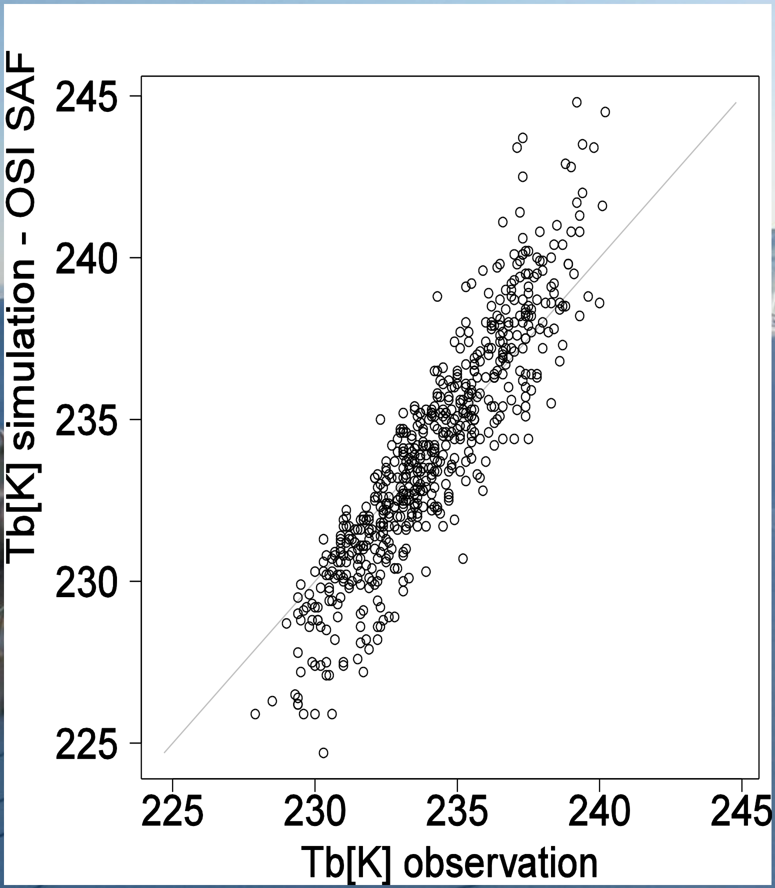
Arctic 50 GHz sea ice nadir emissivity

Antarctic 50 GHz sea ice nadir emissivity

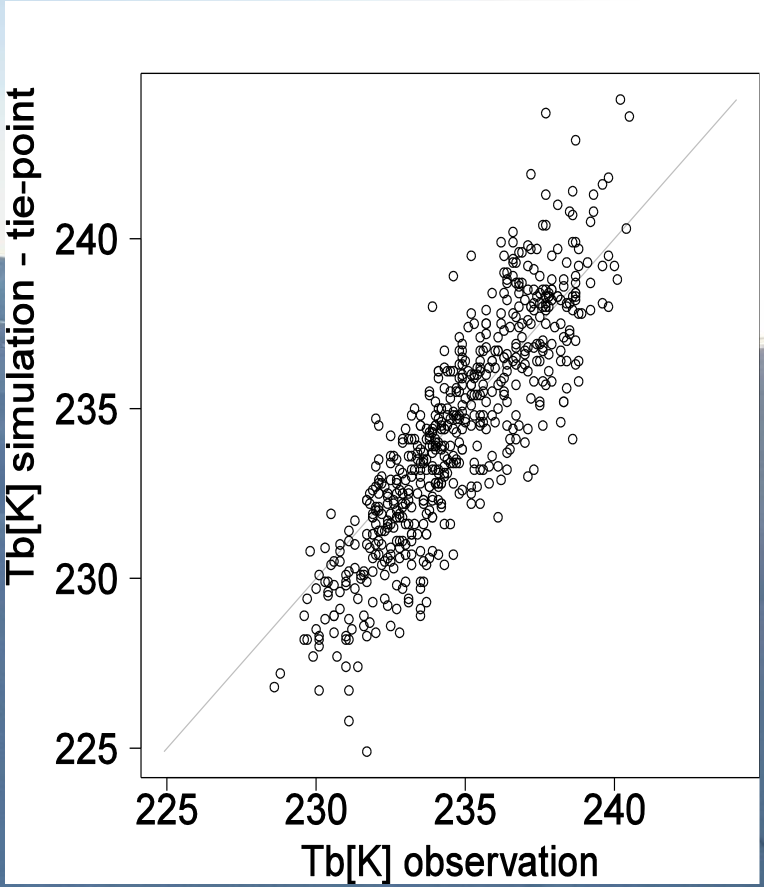


Depth hoar above ice surface
Lincoln Sea 2006

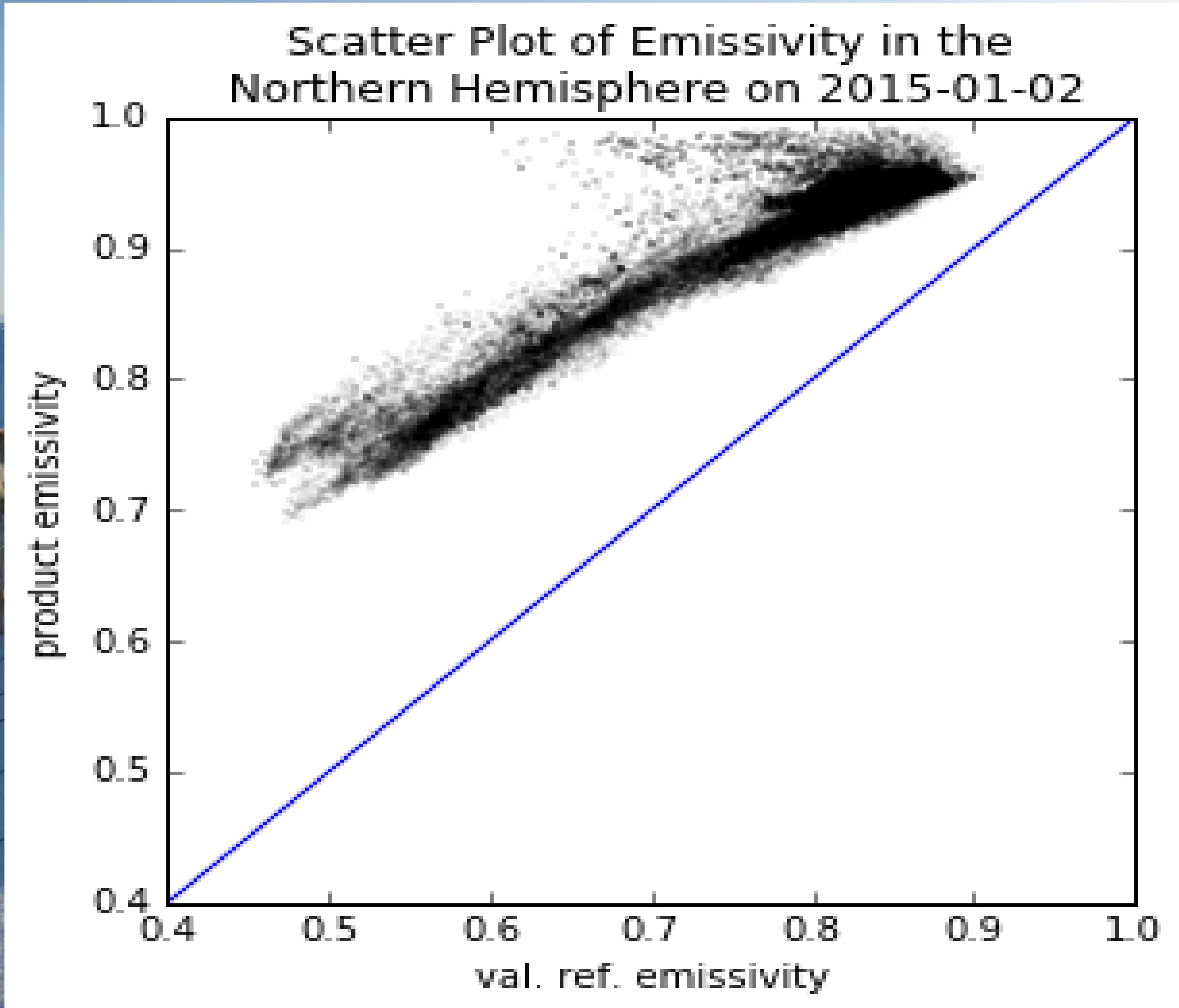
Simulated and observed Tb using RTTOV and HIRLAM atmospheric profiles



The simulated, using the OSI SAF model, and observed Tb's at NOAA 15- AMSU A channel 4 (52.8GHz). STD: 1.54K

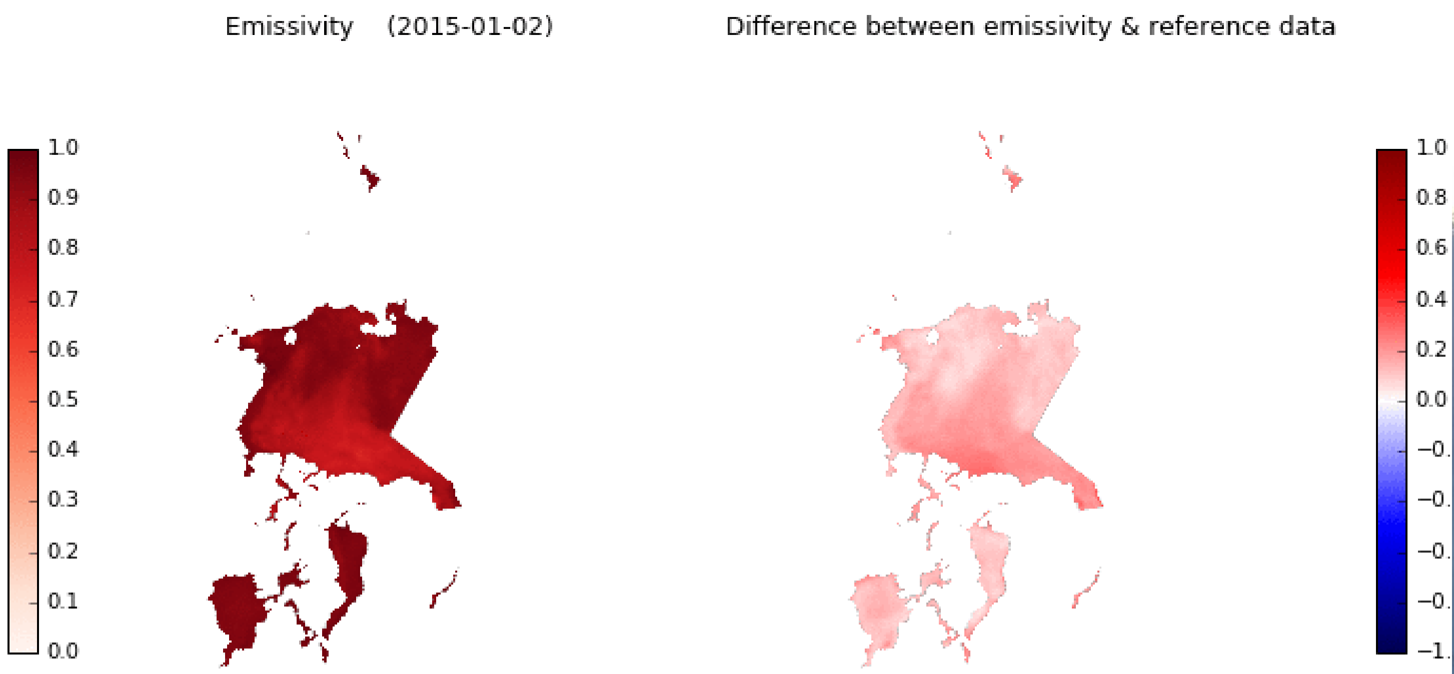


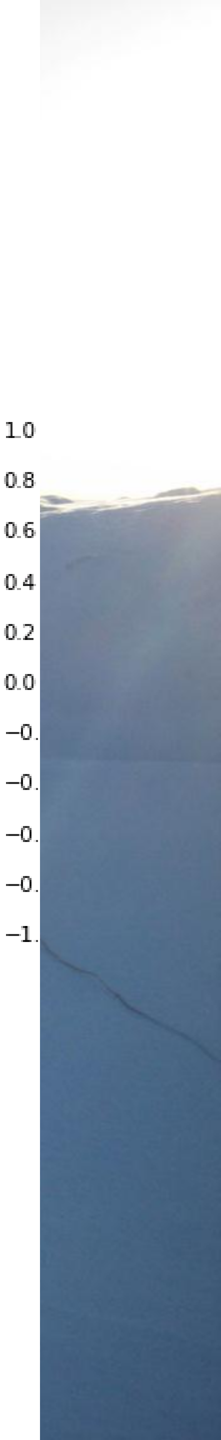
The simulated, using the tie-point model, and the NOAA 15 AMSU A channel 4 (52.8GHz). STD 1.76K



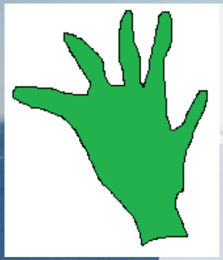
Scatter Plot of Emissivity in the
Northern Hemisphere on 2015-01-02
product emissivity
val. ref. emissivity
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Comparison – ongoing…





Forward models for ice and snow



On the one hand, there are ways forward: detailed input multilayer microwave emission models can simulate realistic signatures and variability. Semi-empirical models can simulate signatures at selected frequencies without prior knowledge of the snow and ice.

On the other hand, 1)one or two layer models suitable for OE and assimilation with bulk snow and ice parameters does not capture the measured signatures with realistic physical input, and 2) the valid range (spectral) of emissivity models is limited.