Relationship between passive microwave observations and snow properties in Antarctica over a large range of frequencies (6 GHz – 89 GHz)

G. Picard, L. Brucker, M. Fily, L. Arnaud,
JM Barnola, O. Magand, C. Genthon

Laboratoire de Glaciologie et Géophysique de l'Environnement,
Grenoble, France

second Workshop on Remote Sensing and Modeling of Surface Properties

Toulouse, June 2009

Context

Main objective: Observe the Antarctic climate using passive microwave (window channels) + other sensors.

Motivations:
- Sparsity of ground observations in Antarctica.
- Passive Microwave: 30 years of data!
- etc...

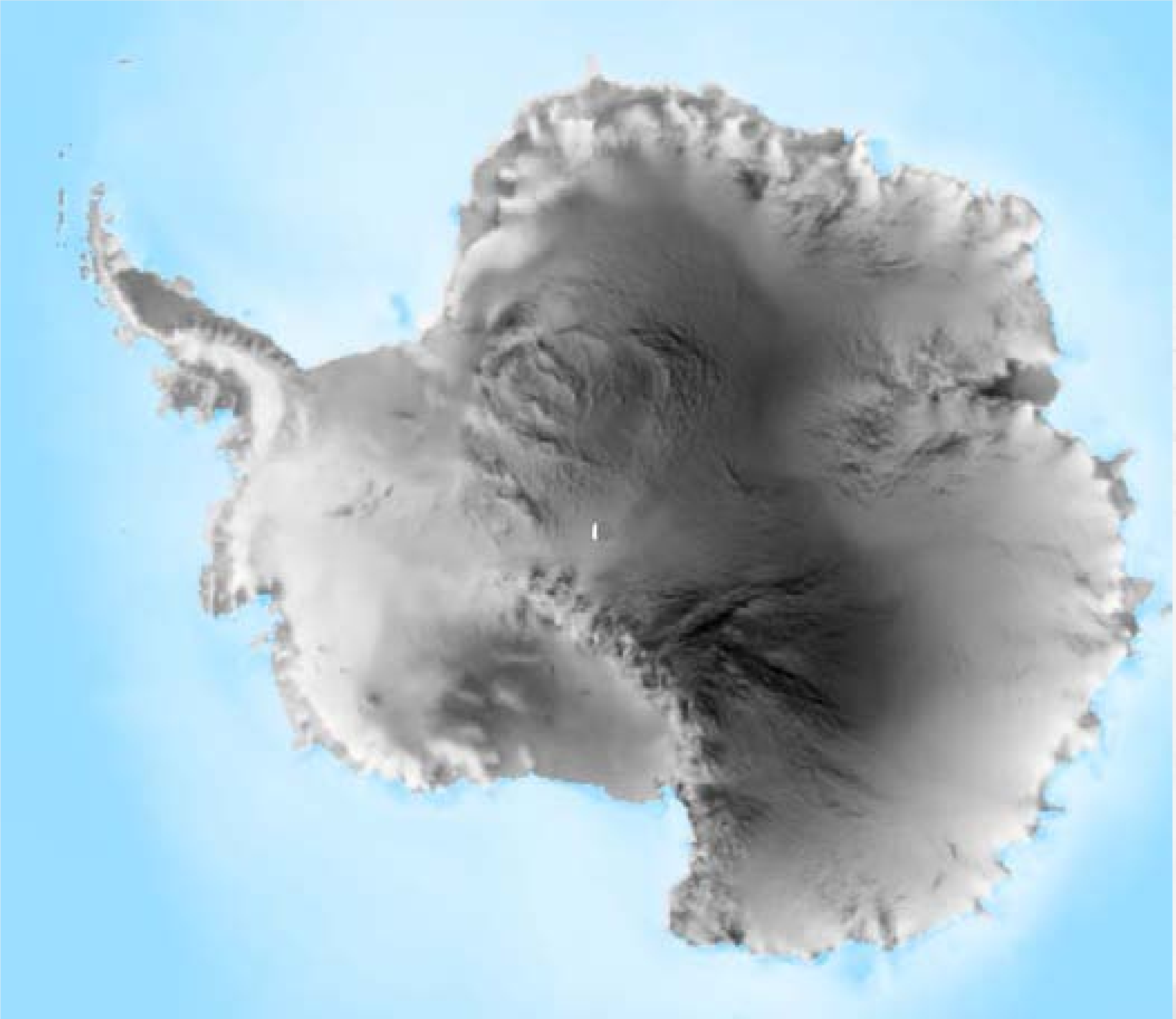
Approach:

1) Understanding the physical links between passive microwave and snow properties.
2) Invert or assimilate.

Overview of recent works - microwave perspective.

Context

Mean Tb at 36 GHz, V polarisation from AMSR-E



- *What does explain the spatial variations ?*
- *Other frequencies ?*
- *Other polarisations ?*
- *Other incidence angles ?*
- *Temporal variations ?*

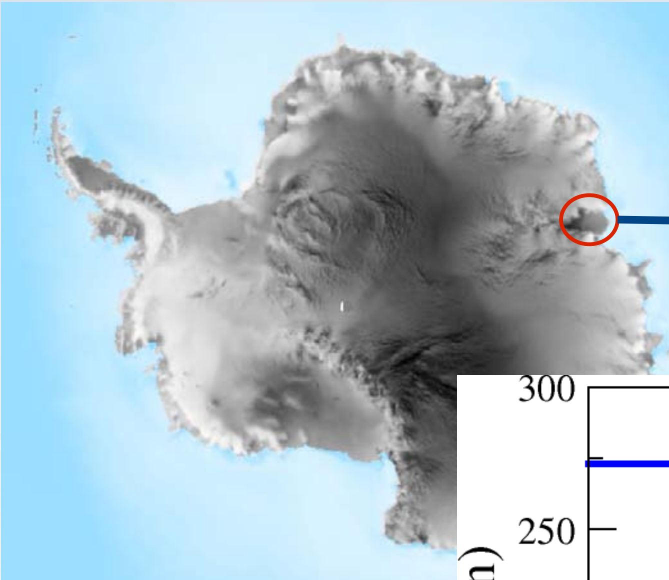
Outline

Laboratoire de Glaciologie et Géophysique de l'Environnement

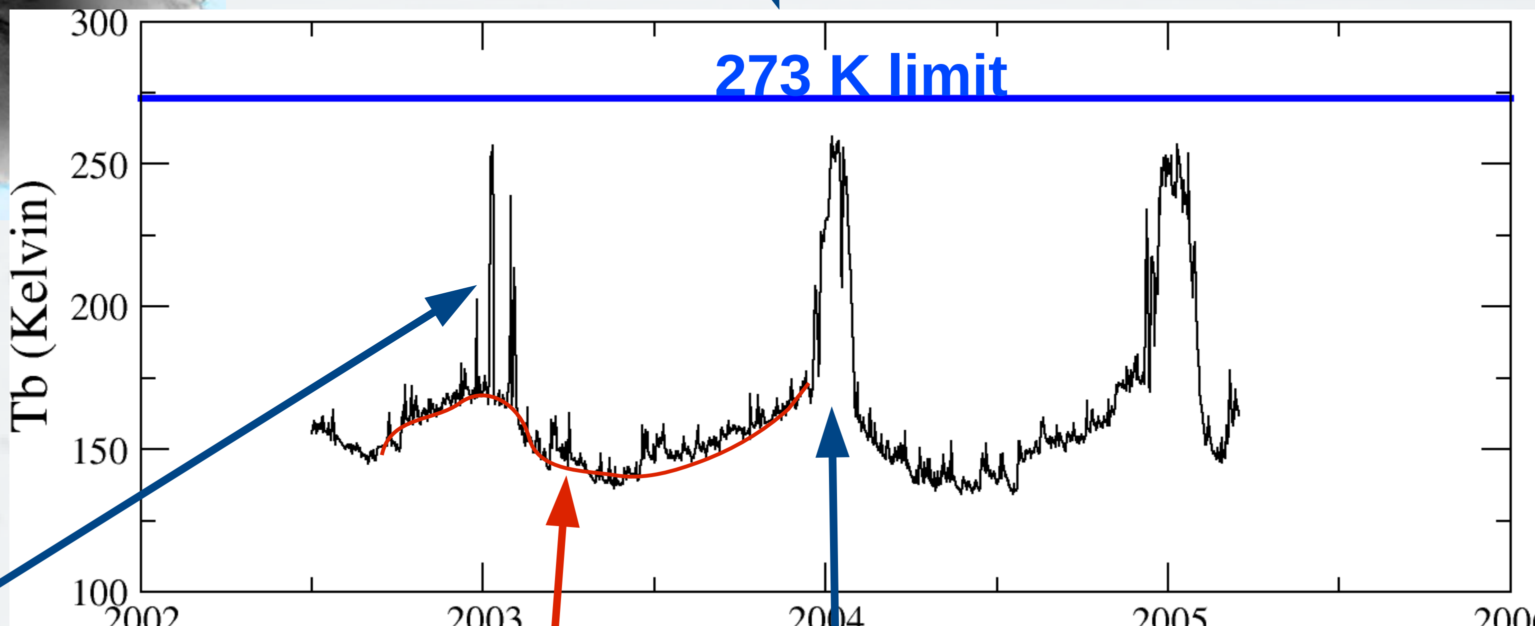
1. *Dry and wet zones.*
2. *Brightness and physical temperature variations.*
3. *Emissivity V-polarisation.*
4. *Emissivity H-polarisation.*

Dry and wet zones

Laboratoire de Glaciologie et Géophysique de l'Environnement



Timeseries of Tb at 18 GHz, H polarisation on the Amery Ice Shelf

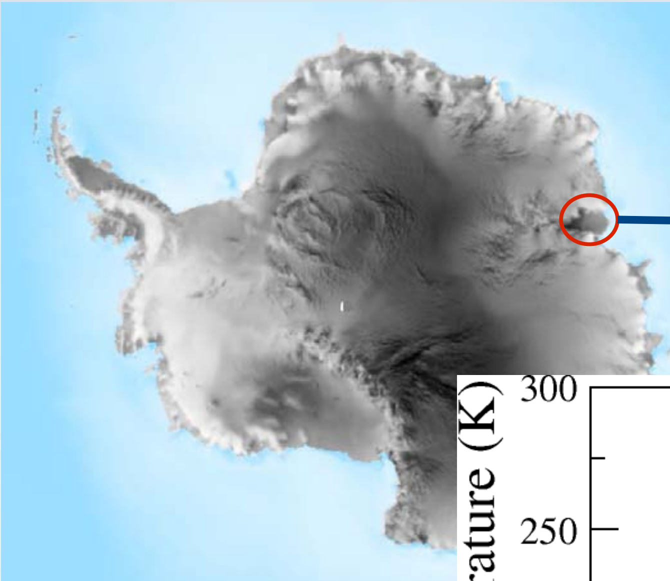


Short melt events

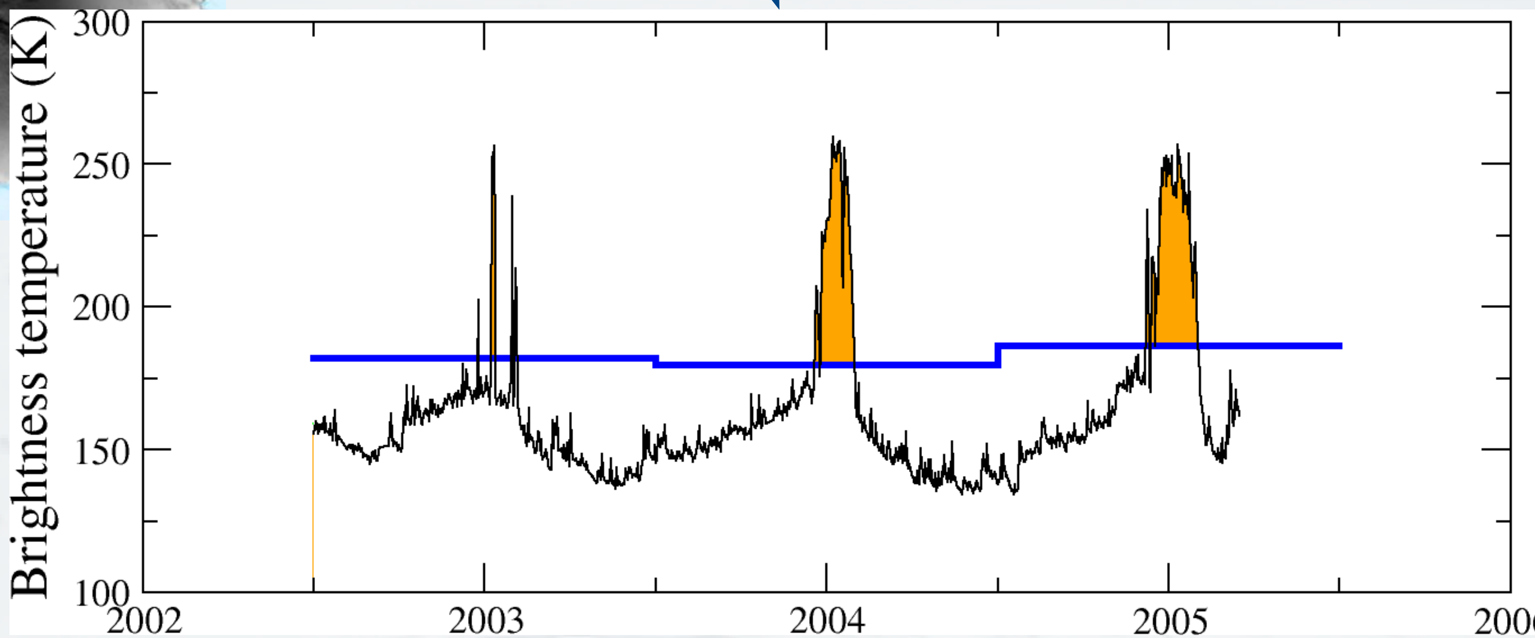
Melting season

Seasonal variations of temperature

Dry and wet zones



Timeseries of Tb at 18 GHz, H polarisation on the Amery Ice Shelf

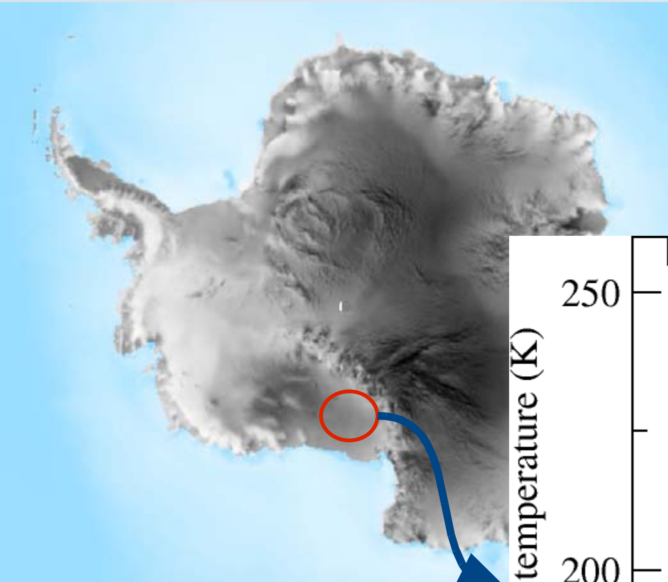


• Detection melt events for 1979 - present (up-to-date and available on the web , Picard et al. 2006, 2007, ...).

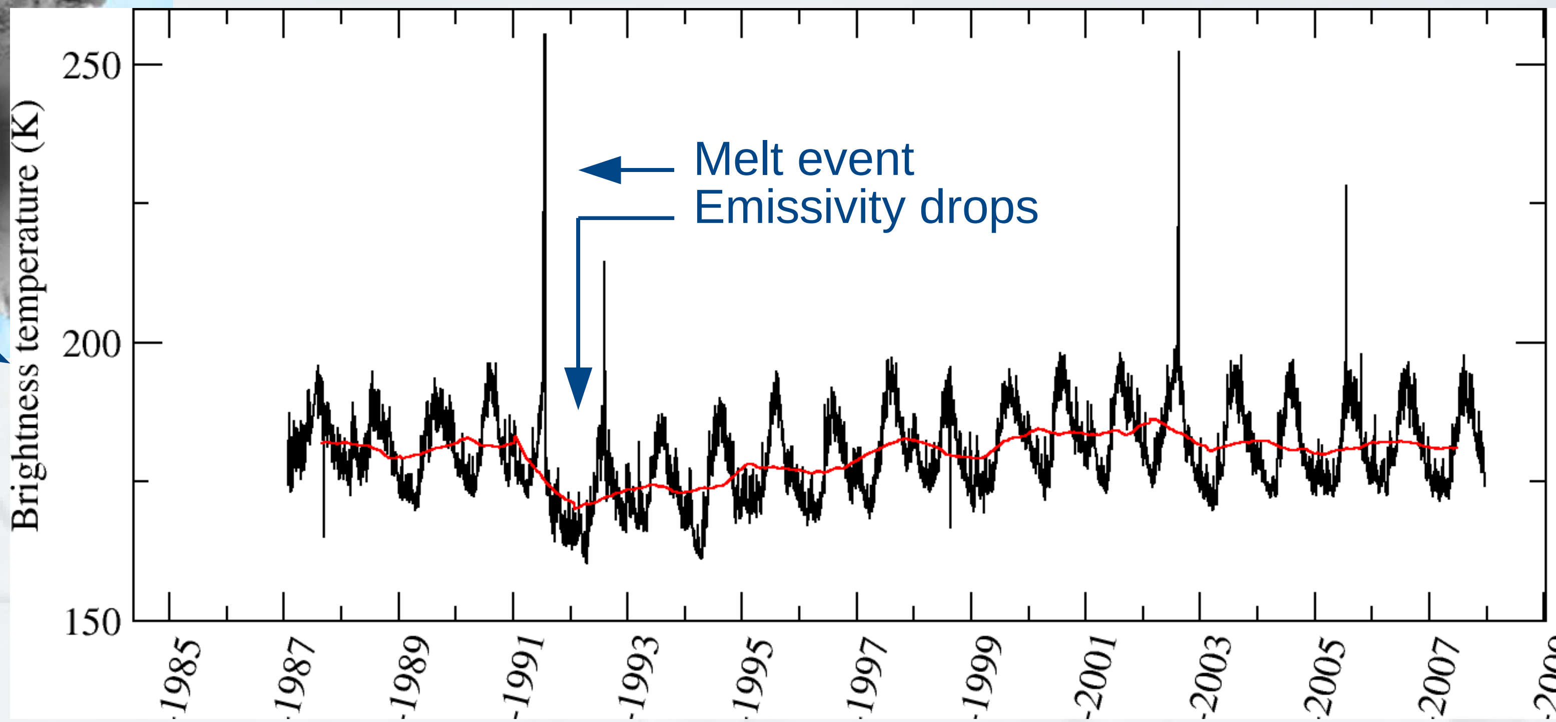
• 19 H is the best frequency/polarisation for detection.
• 37 and 89 GHz are too variable despite a better resolution.

Dry and wet zones

LGGE
Laboratoire de Glaciologie et Géophysique de l'Environnement



Timeseries of Tb at 19 GHz, H polarisation on the Ross Ice Shelf



- Melt events create refrozen layers.
- And affect durably snow emissivity at all frequencies & polarisations.

“Recovery rate” = f(snow accumulation, frequency, polarisation)

Confirmed by calculations with MEMLS - Magand et al. 2008

Dry and wet zones

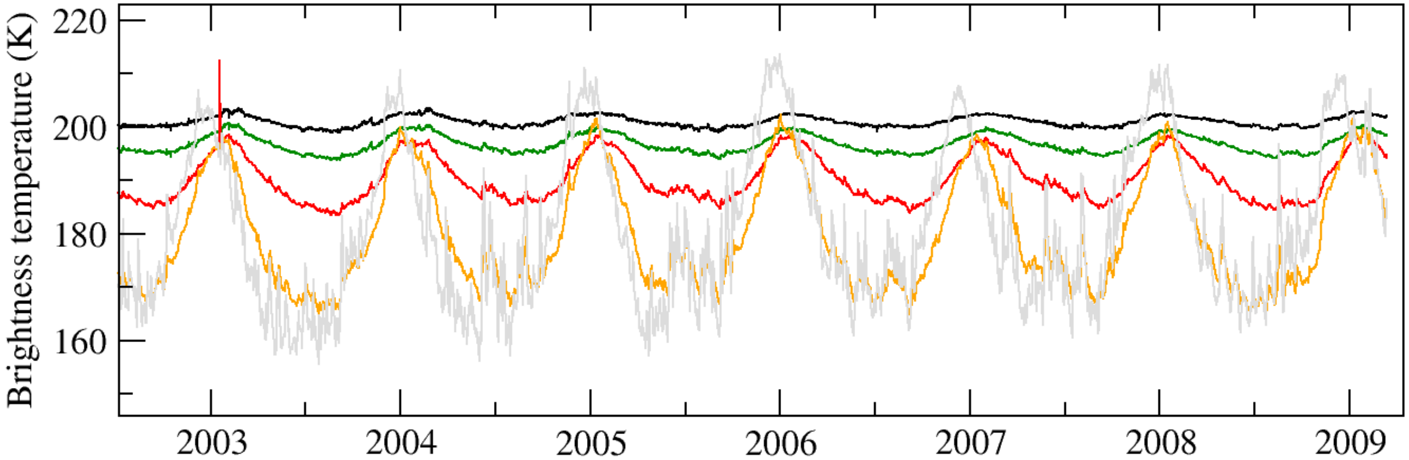
<u>Conclusion</u>: Dry / wet zones have very different microwave emission behavior.

(Very conservative dry zone)

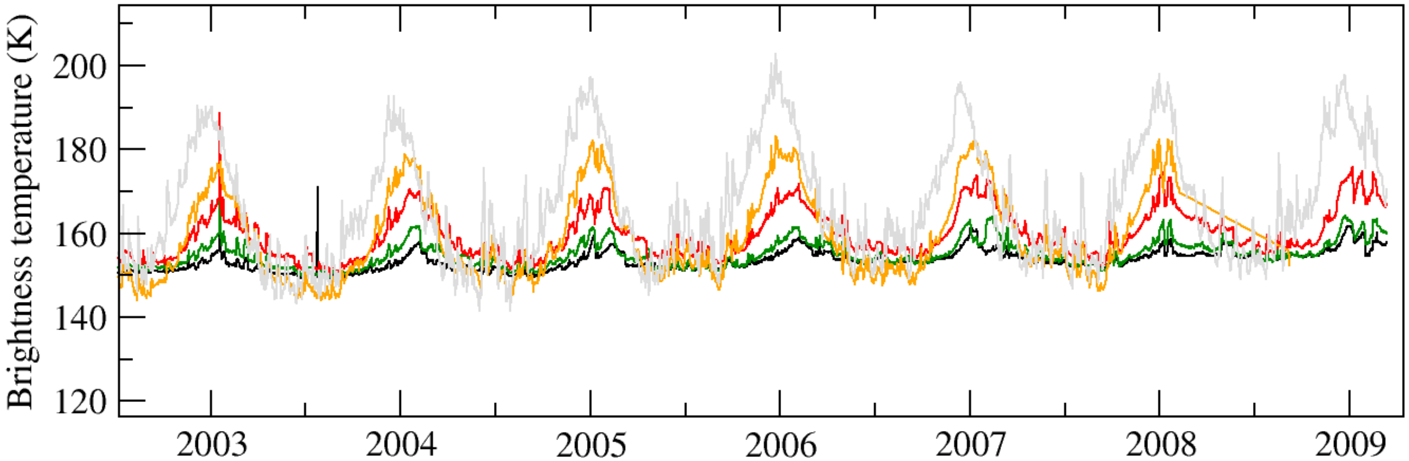
Emissivity and temperature (dry zone)

Focus on the dry zone.

AMSR at Dome C (6, 10, 18, 36, 89 GHz)



V-pol



H-pol

Dome C
Typical site + French/Italian station

Snow is transparent to microwaves
Variations look like pure variations of snow temperature.

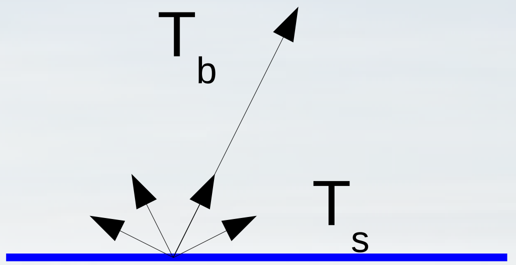
Emissivity and temperature (dry zone)

LGGE Laboratoire de Glaciologie et Géophysique de l'Environnement

What is the relevant model ?

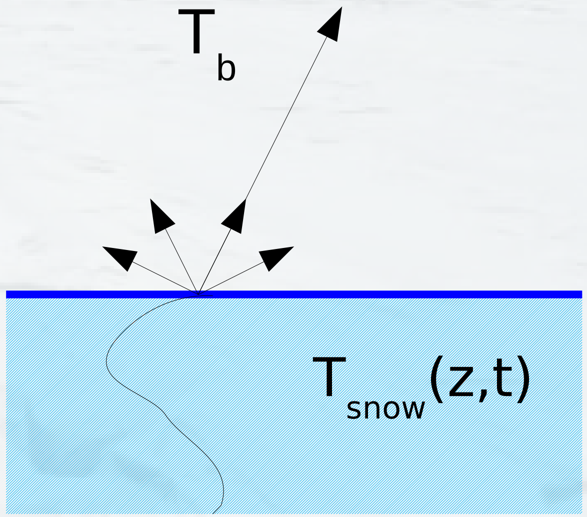
- Pure surface is inadequate (transparency)

$$Tb = \epsilon\, T_{surface}$$



- Emissivity and snow temperature.

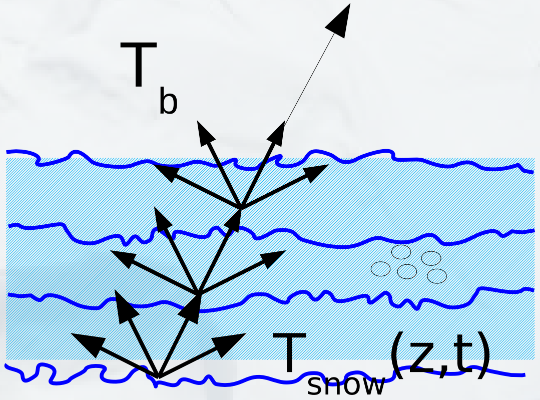
$$Tb = \epsilon \langle T_{snow(z,t)} \rangle_z$$
$$\epsilon = cste$$



- Full radiative transfer model (DMRT, MEMLS, ...)

$$T_b = RTMODEL(T_{snow}(z,t), a(z,t), \rho(z,t))$$

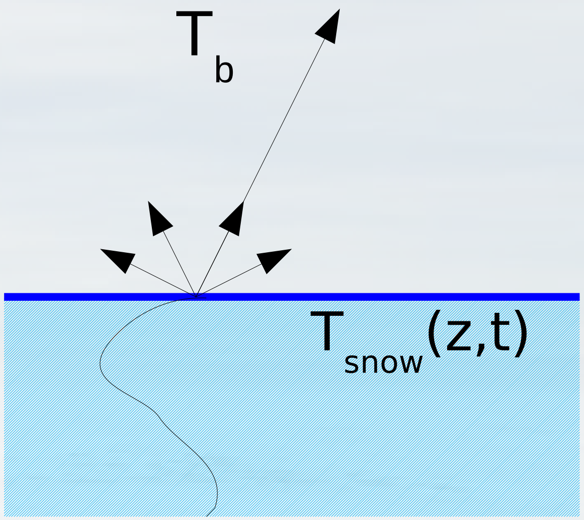
No emissivity



Emissivity and temperature (dry zone)

- In Antarctica, temporal variations of snowpack properties are slow except temperature.

$$Tb = \epsilon \langle T_{snow(z,t)} \rangle_z$$
$$\epsilon = cste$$

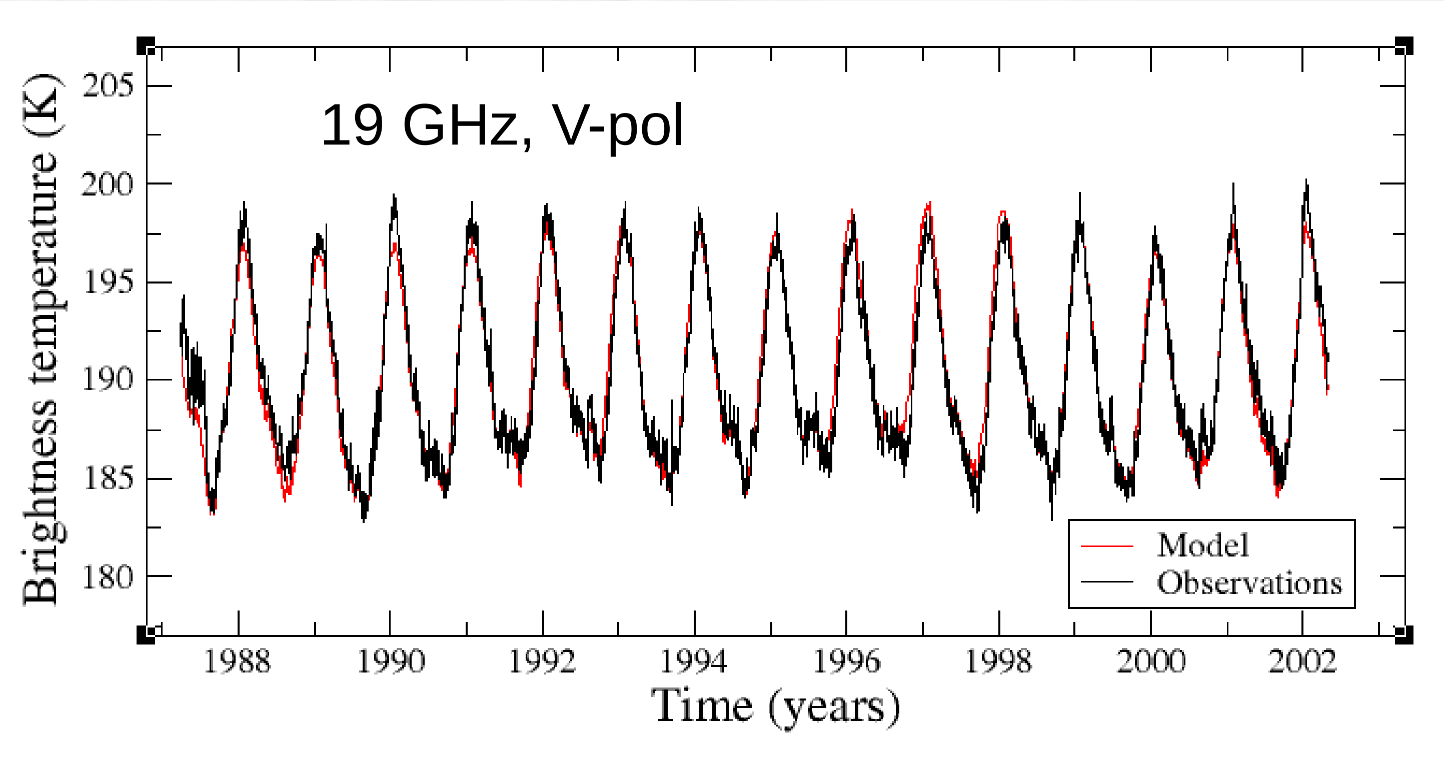


How accurate is this approximation ?

Modeling:

- Predict T_{snow} from ECWMF- ERA40 met data.
- Predict Tb from T_{snow}

Results at Dome C:

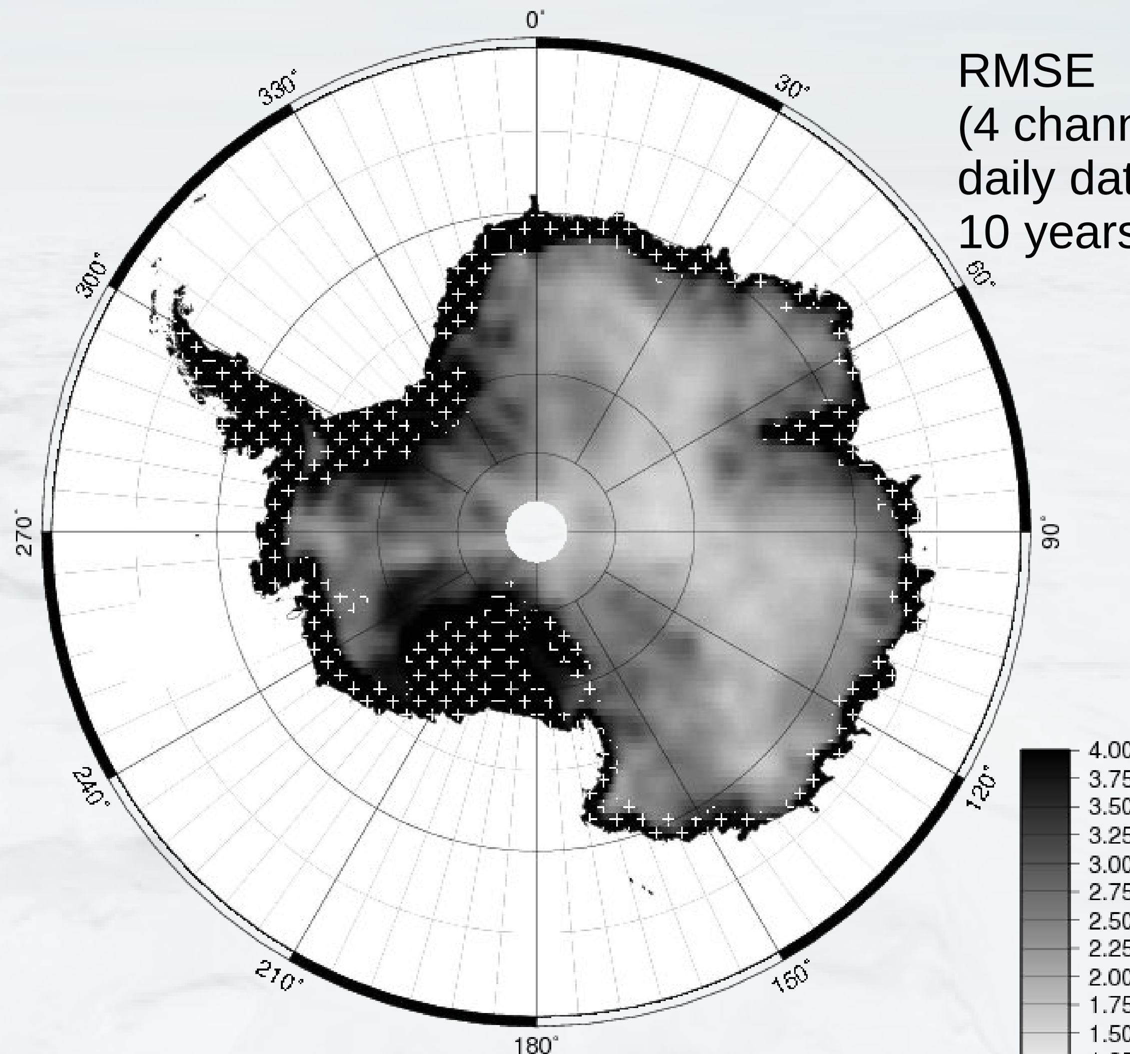


Emissivity and temperature (dry zone)

LGGE
Laboratoire de Glaciologie et Géophysique de l'Environnement

In the Antarctic dry zone, Tb time-series can be predicted with error as low as **2-5K** (RMS) even with the strong assumption of a constant emissivity and penetration depth.

RMSE
(4 channels,
daily data,
10 years)



2 important conclusions:
- Tb temporal variations are mainly snow temperature variations at 19 and 37 GHz

- Snow grain size, density, structure are fairly stable **...**

2 differents time-scales, in contrast to typical seasonal snowpacks

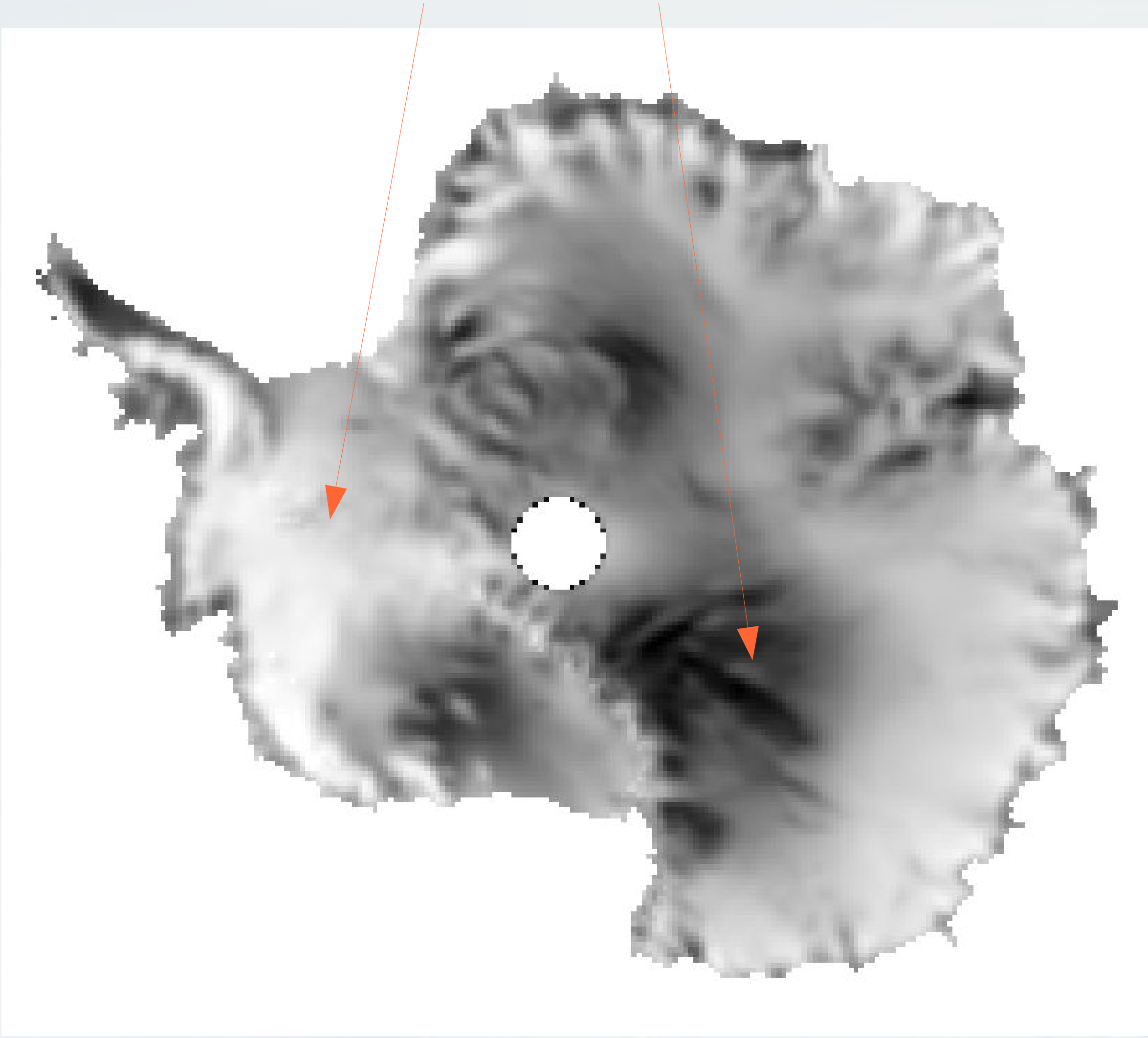
Picard et al. 2009

Emissivity (dry zone) – V pol

Laboratoire de Glaciologie et Géophysique de l'Environnement

Emissivity is constant in time (in the dry zone) but highly variable in space.

Emissivity (19 GHz, V polarisation)
varies between 0.97 and 0.65



Causes ?

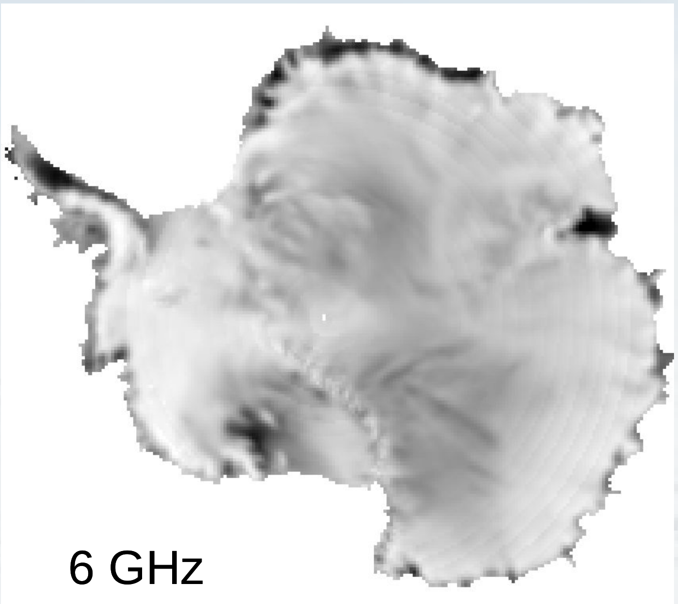
Short answer:
Mainly grain size.

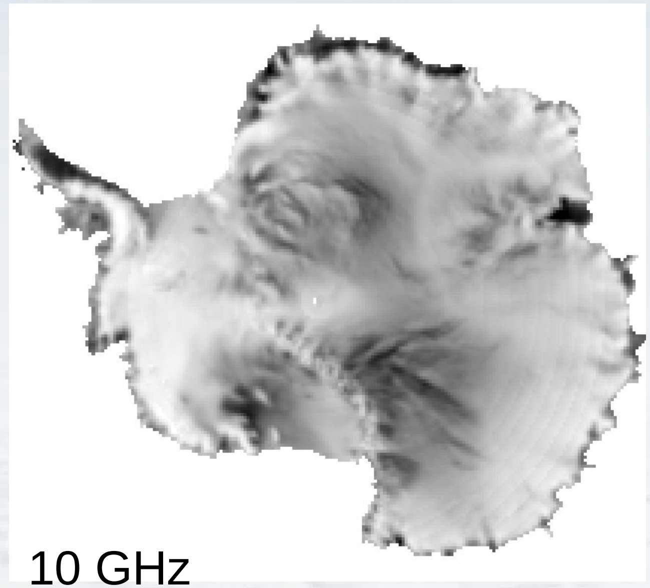
Detailed answer:
next presentation
using RT models.

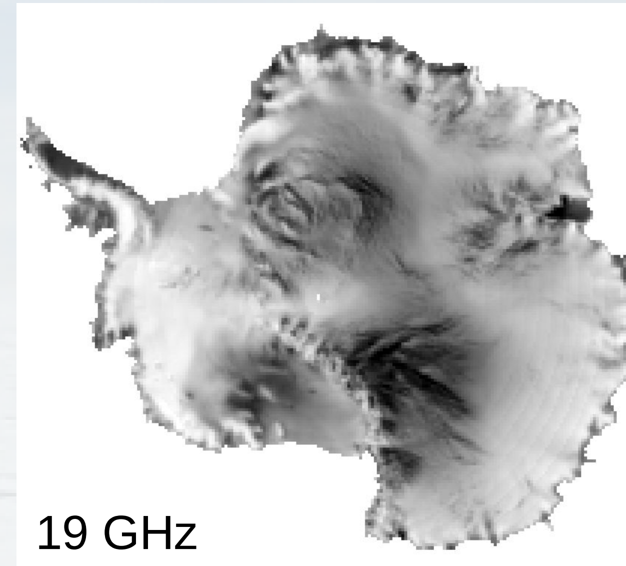
Emissivity (dry zone) – V pol

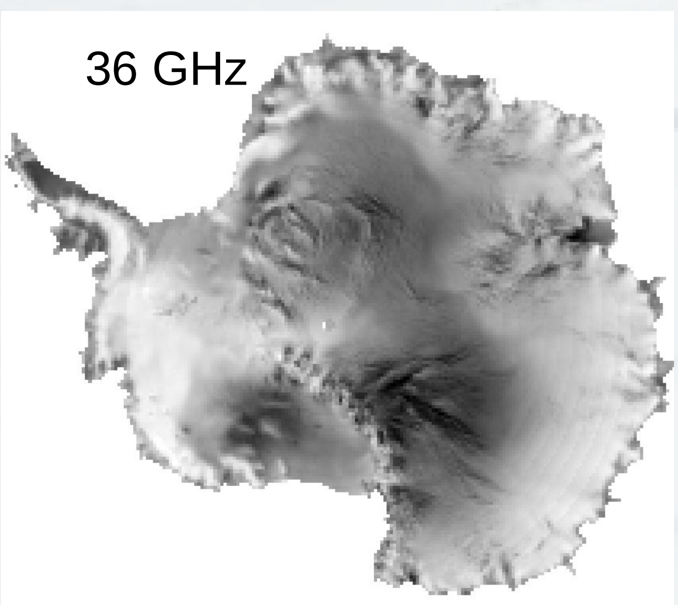
Laboratoire de Glaciologie et Géophysique de l'Environnement

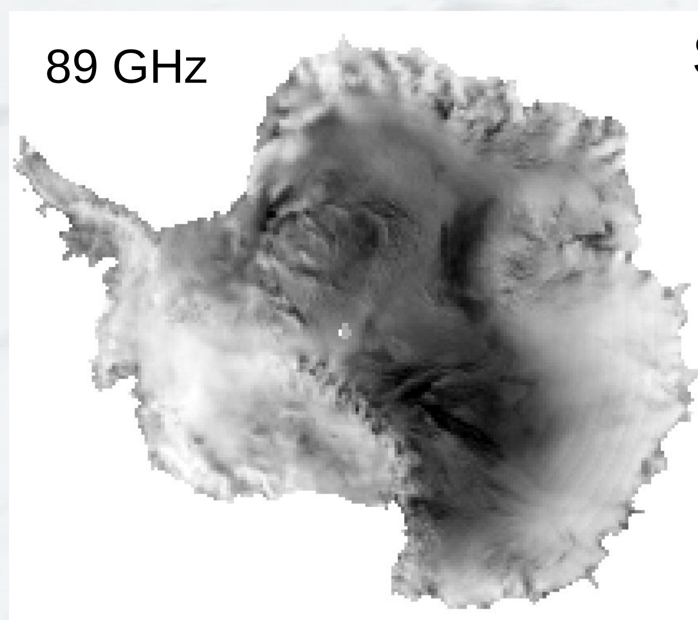
Emissivity (V polarisation) at 6 – 89 GHz.







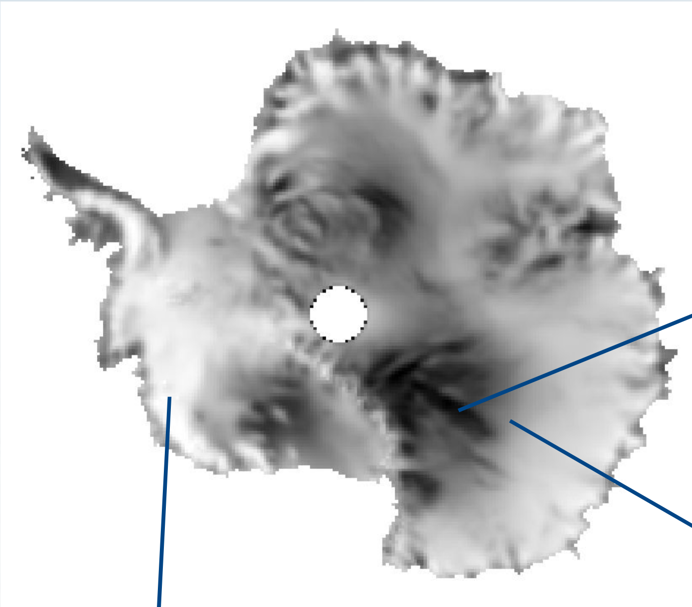




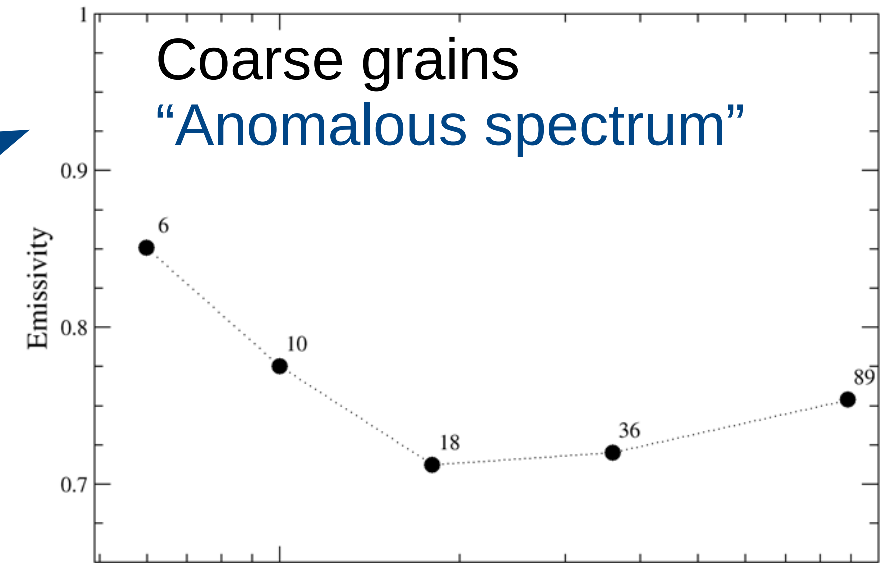
Strong correlations >0.86

GHz	6	10	18	36	89
6	1	0.96	0.93	0.91	0.86
10	0.96	1	0.99	0.94	0.85
18	0.93	0.99	1	0.96	0.87
36	0.91	0.94	0.96	1	0.97
89	0.86	0.85	0.87	0.97	1

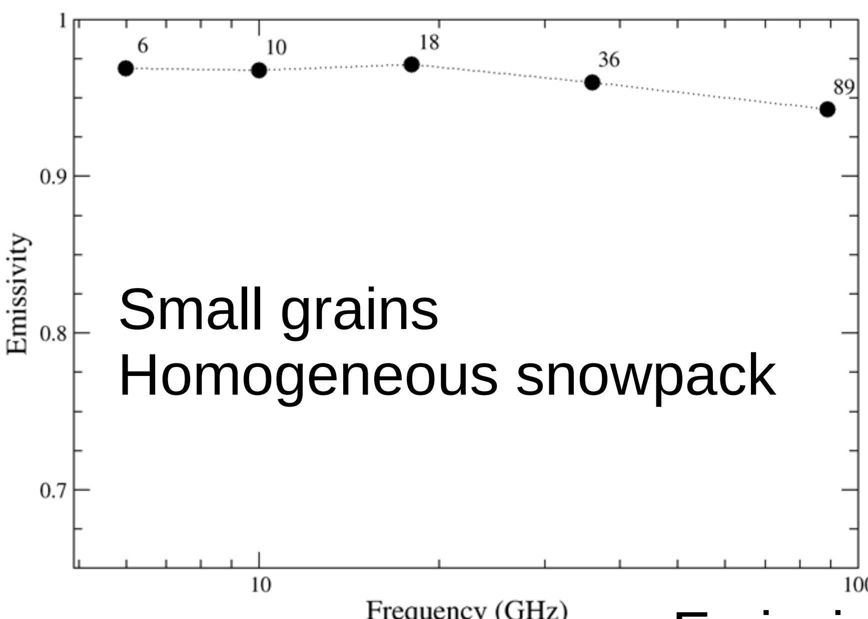
Emissivity (dry zone) – V pol



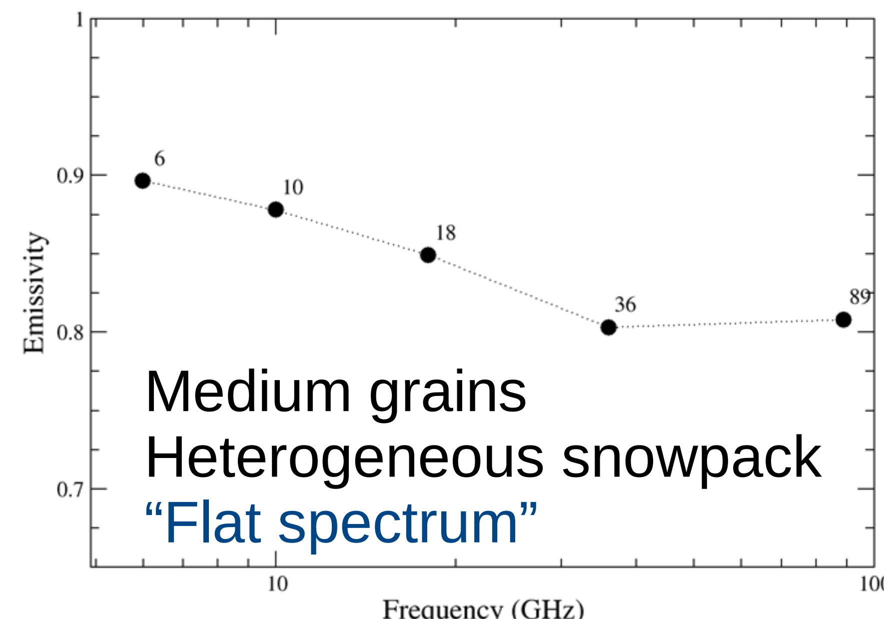
Megadune region



Marie Byrd Land



Dome C



Emissivity spectrum

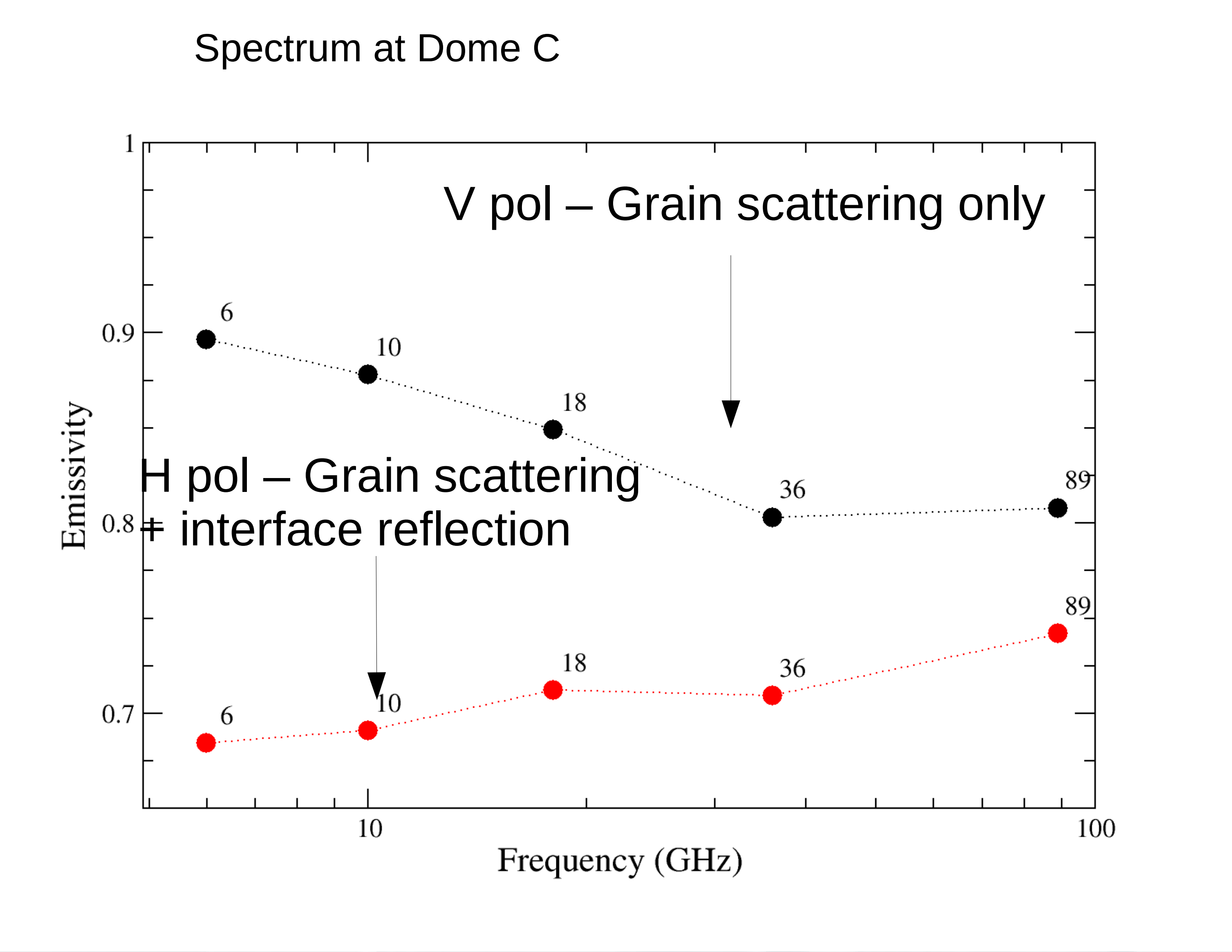
Brucker et al., 2009

Emissivity (dry zone). H pol

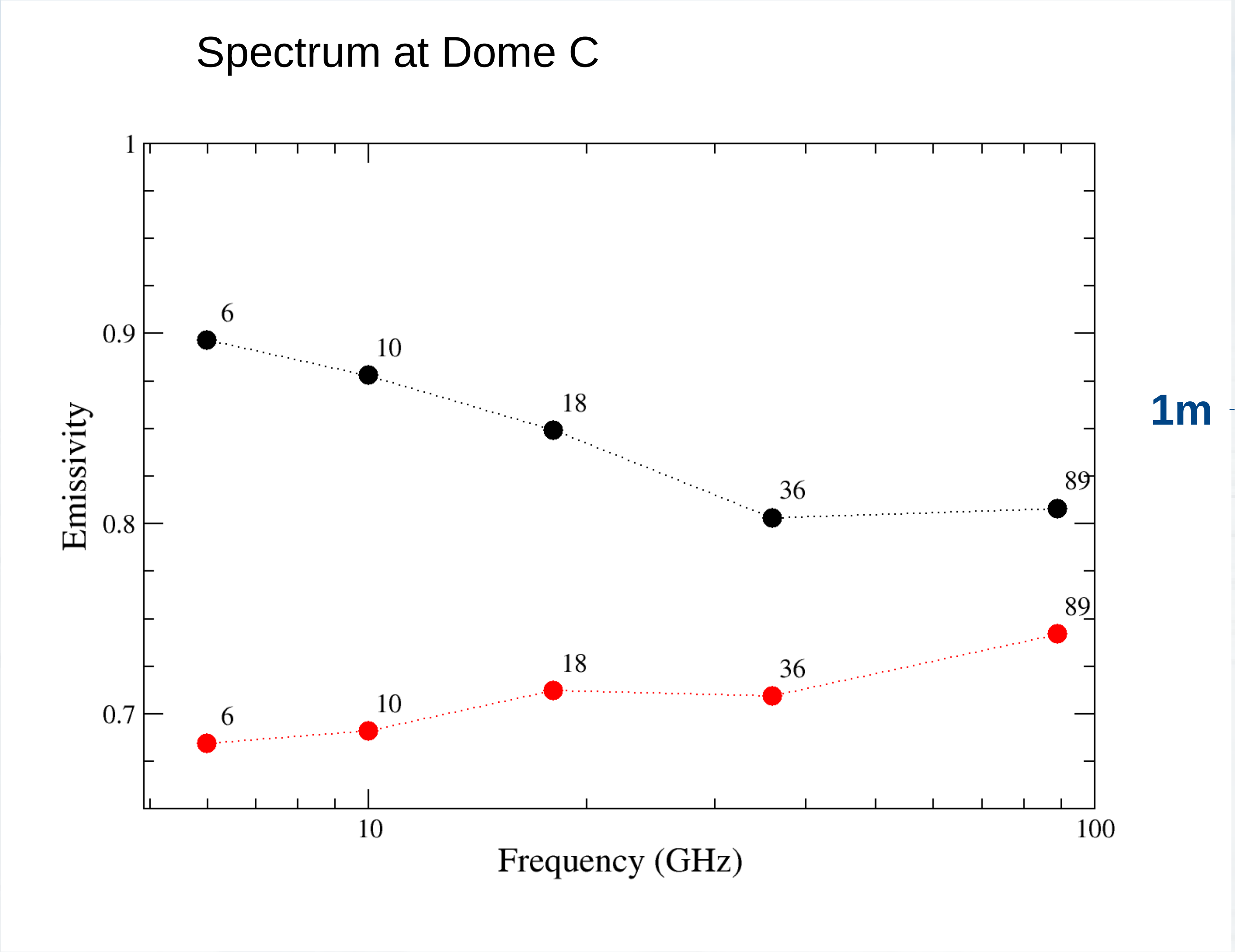
V polarisation at Brewster angle =>Moderate surface and interface effects.

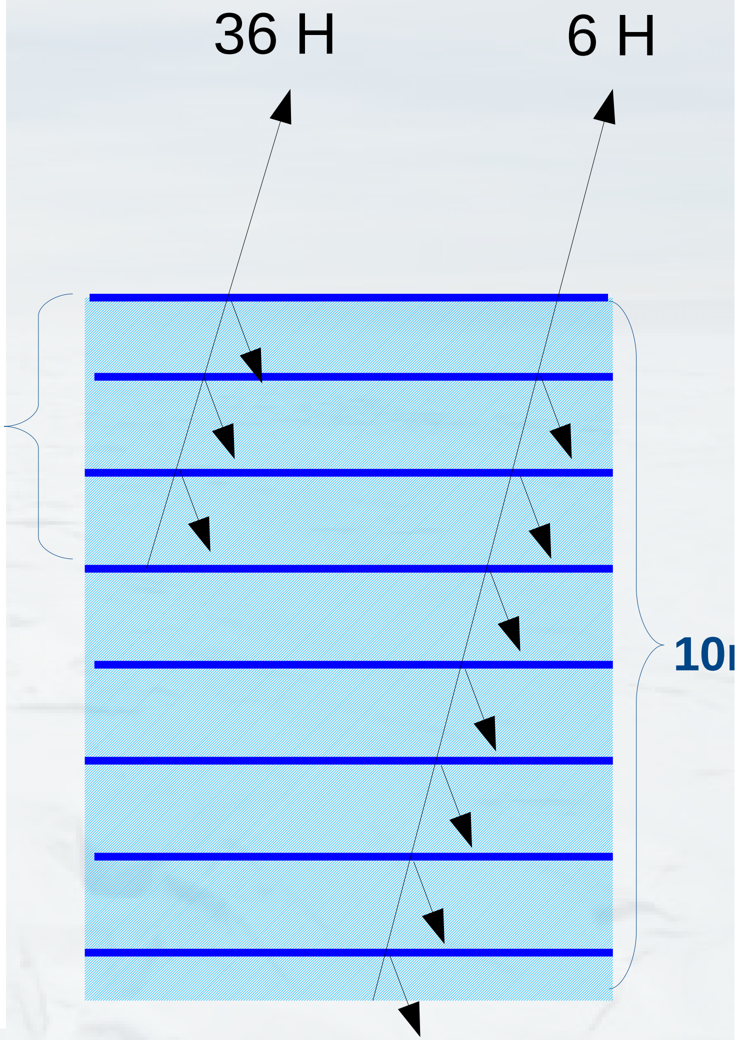
≠

H polarisation. V polarisation at <50° incidence angle.



Emissivity (dry zone). H pol

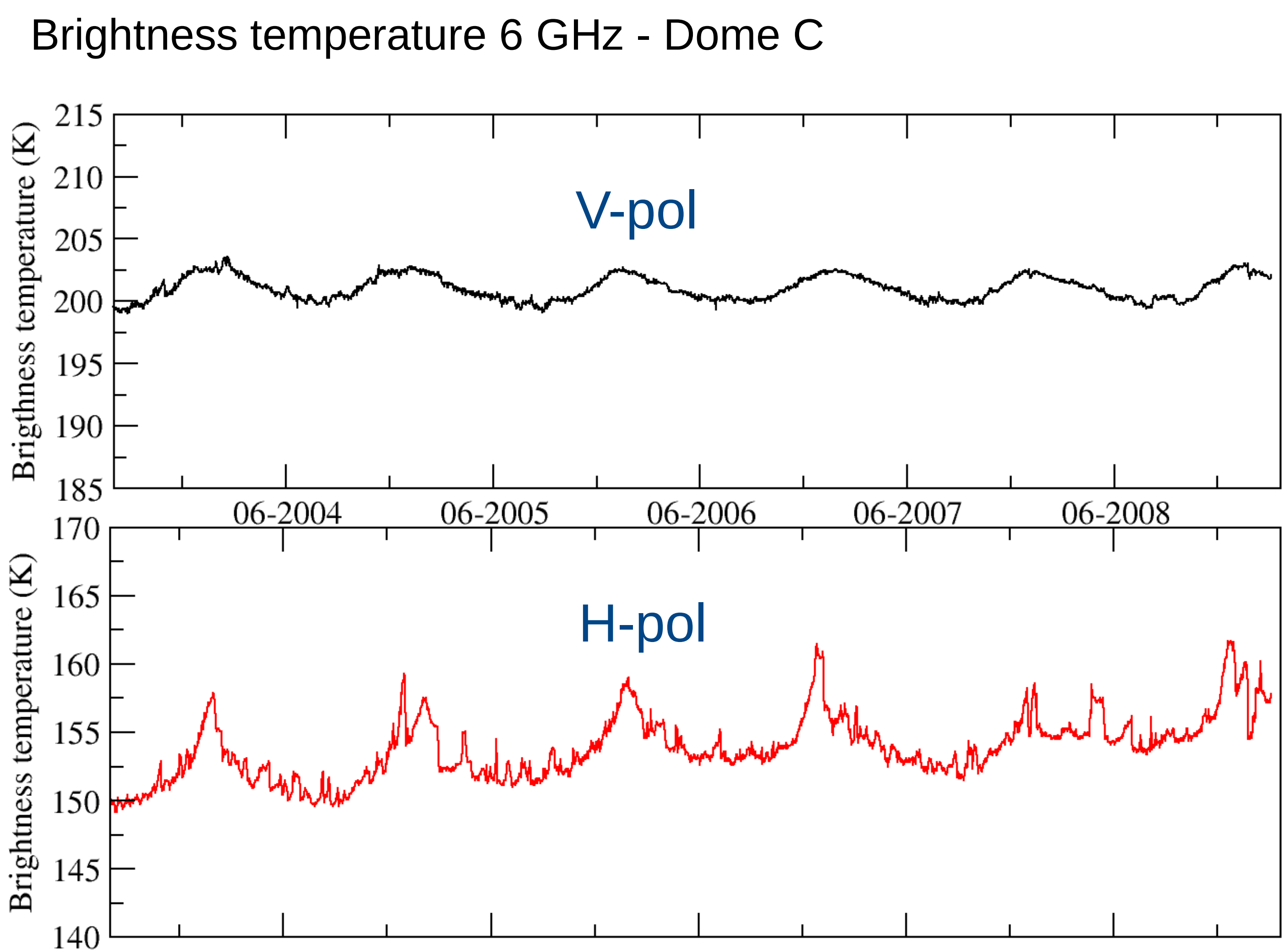




Confirmed by DMRT calculation at 37 GHz using measured 2cm-resolution density profile.
New density profiles down to 10 m are needed (to be measured next austral season) for 19 GHz and lower frequencies.

Emissivity (dry zone). H pol

Influence of temporal variations in surface.



Variations of density, surface roughness, ... ? caused by wind, snowfall, ... ?

Work in progress...

Summary

Laboratoire de Glaciologie et Géophysique de l'Environnement

What we have learned and
what remains to do ?

Dry zone - Wet zone

Dynamic mainly driven by
snow temperature profile

Melt events
Ice layers

V-polarisation
at ~50°

H-polarisation

Other
polarisations
(windsat)

Grain size.
Profile of grain size

Interfaces
+
Surface

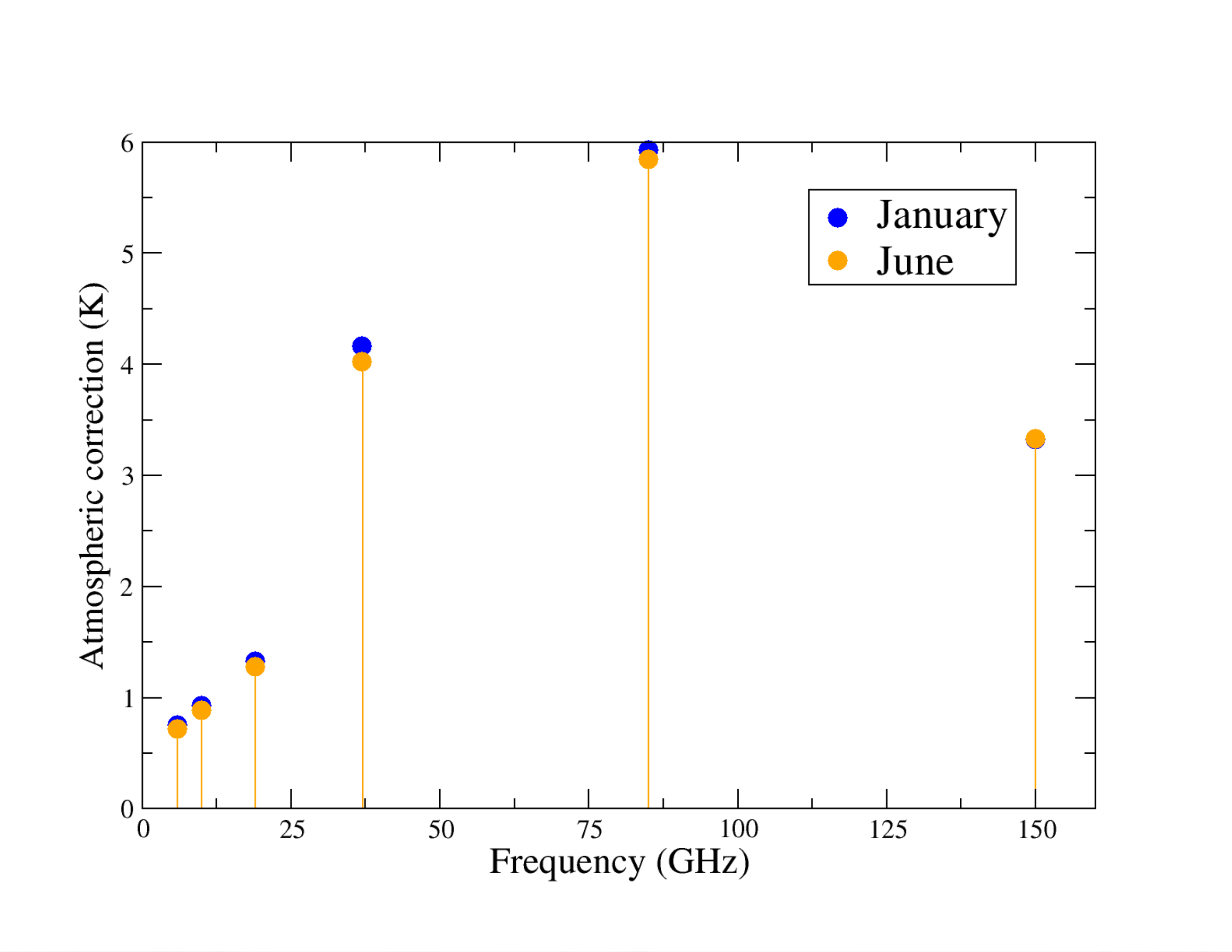
Dynamic secondly
driven
by surface
changes
?

Other topics to address:

- L-band SMOS
- 150 GHz
- Azimuth variations

Emissivity (dry zone) – V pol

Atmosphere ?



RTTOV
Typical conditions
over the Plateau

- Correction for the atmosphere ~ 1 to 6 K : Weak but not negligible.
- <u>Constant correction</u>

Larger and more variable in the coastal regions