Modeling microwave emission at 19 and 37 GHz in Antarctica : **influence of the snow grain size**

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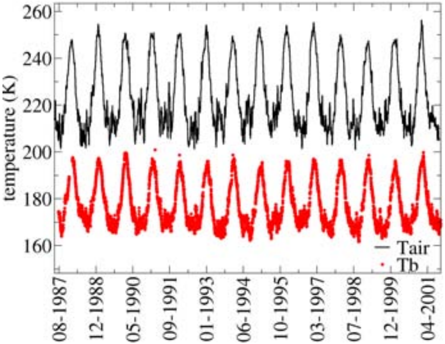
2009

Passive microwave remote sensing



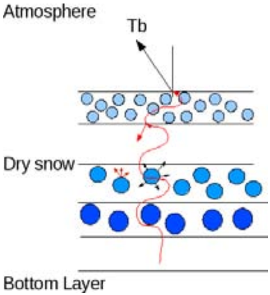
T_B depends on :

- the snow temperature profile
- the snowpack properties (grain size and density)

Objective : explain by modeling the microwave emission.

Microwave emission modeling

Dense Media Radiative Transfer theory *(Tsang and Kong, 2001)*
Multi-Layered model : **DMRT-ML**



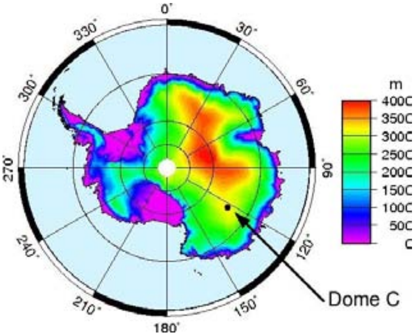
DMRT-ML is driven by vertical profiles of :

- snow temperature
- sphere radius (grain size parameter)
- snow density

Outline

1. Modeling the time series of brightness temperature **at Dome C**
2. Modeling the emissivity **at large scale in Antarctica**
3. Conclusions

Dome C, Antarctica



Dome C is on the East Antarctic Plateau (3240 m a.s.l)

Method to model $T_B(t)$ using snow measurements

3 snow property profiles :

temperature
Measured routinely since 2007 down to 21 m deep with 35 probes

density and **grain size**
Measured in Dec. 2006 in a snowpit down to 3 m deep

Snow grain size profile

Near Infrared Photography method

This approach provides microstructure measurements with a high vertical resolution *(Matzl and Schneebeli, 2006)*

near-IR Photography ⟵ − − − − − − − − − − −

↓

reflectance (ω)

↓

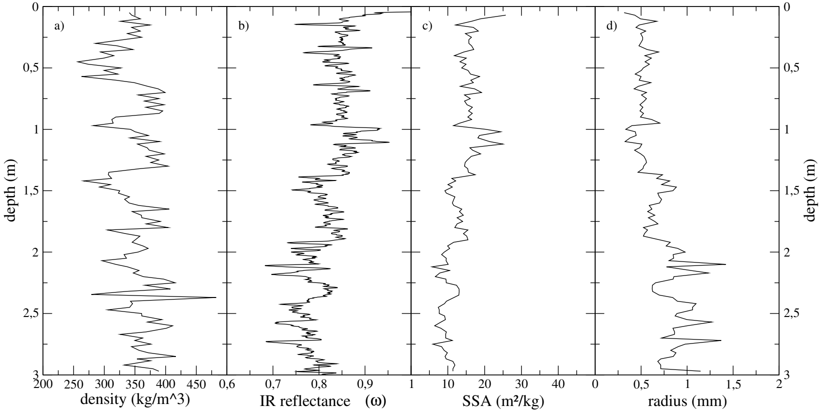
Specific Surface Area (SSA) profile
using a $\omega - SSA$ relationship *(Matzl and Schneebeli, 2006)*

↓

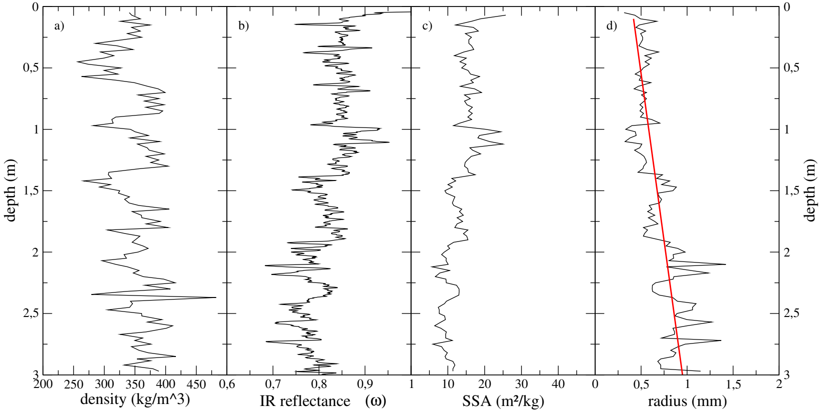
sphere radius profile

$$r_{sphere} = \frac{3}{SSA \cdot \rho_{ice}}$$

Snow property profiles at Dome C

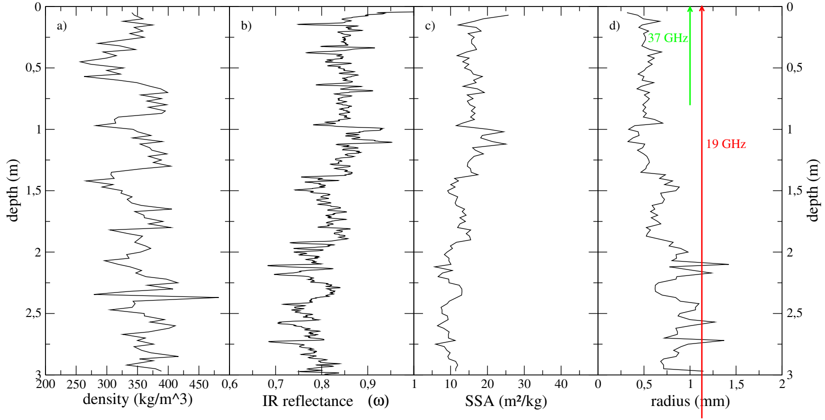


Snow property profiles at Dome C

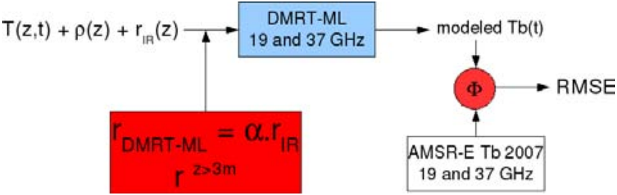


There is an increase in grain size with depth

Snow property profiles at Dome C

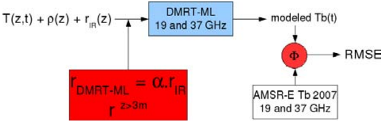


At Dome C penetration depth at 37 GHz ⇝ 0.8 m
19 GHz ⇝ 3.7 m



2 calibrated parameters : α
$r^{z>3m}$

same α and same $r^{z>3m}$ at 19 and 37 GHz



$T(z,t) + \rho(z) + r_{IR}(z)$

DMRT-ML
19 and 37 GHz

modeled Tb(t)

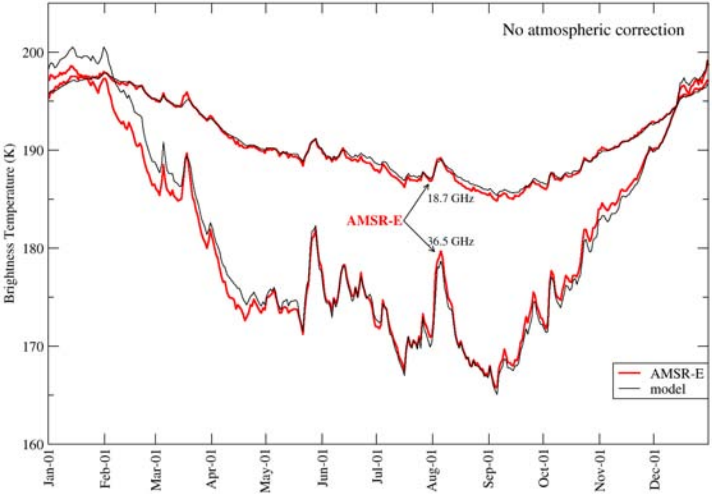
Φ

RMSE

$r_{DMRT-ML} = \alpha . r_{IR}$
$r^{z>3m}$

AMSR-E Tb 2007
19 and 37 GHz

$\alpha \simeq 2.8$
$r^{z>3m} \simeq 1.14\text{mm}$



$\text{RMSE}_{19} = 0.3\text{K}$
$\text{RMSE}_{37} = 1.3\text{K}$

$\text{RMSE} = 0.9\text{K}$

Why T_B are predicted with a low RMSE ?

- Snow properties are measured with a high vertical resolution;
- State-of-the-art model.

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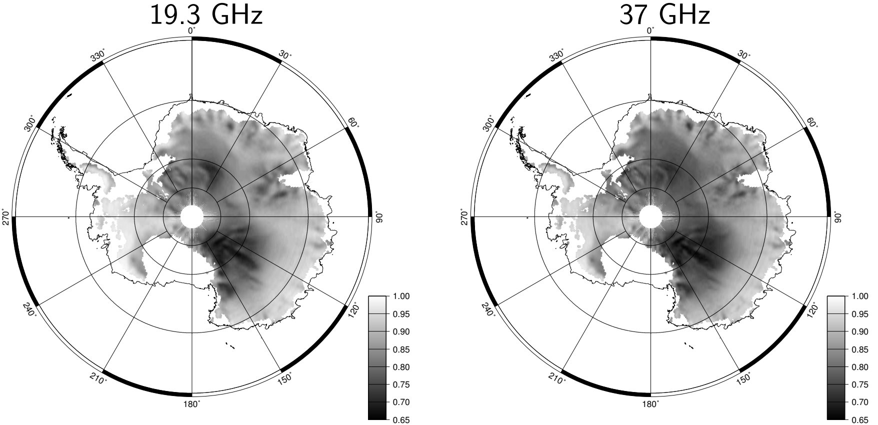
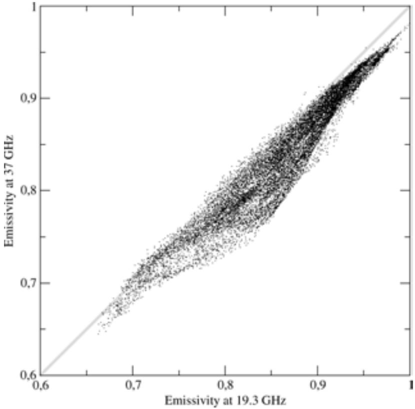
Emissivities in Antarctica derived from observations

Mean annual SSM/I emissivities in dry-snow regions



(Picard et al., 2009)

Observed emissivities in a **19-37 space**



The emissivities have close values at 19 GHz and 37 GHz

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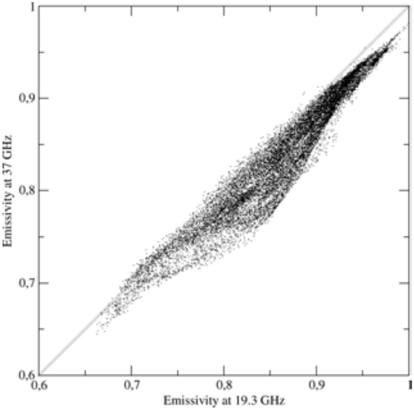
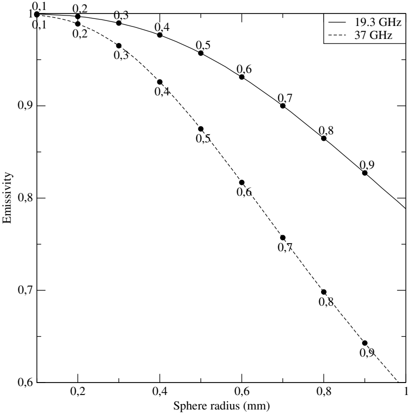


The emissivities have close values at 19 GHz and 37 GHz

Question : which snow property can explain such a distribution (spectra) of emissivity at 19 and 37 GHz ?

Homogeneous snowpack



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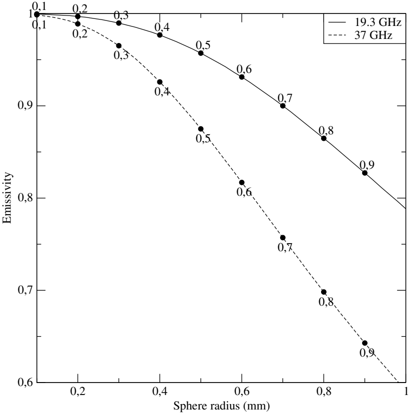

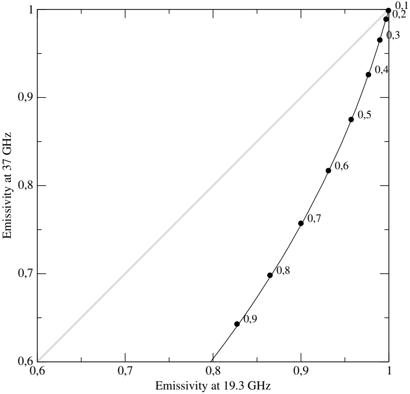

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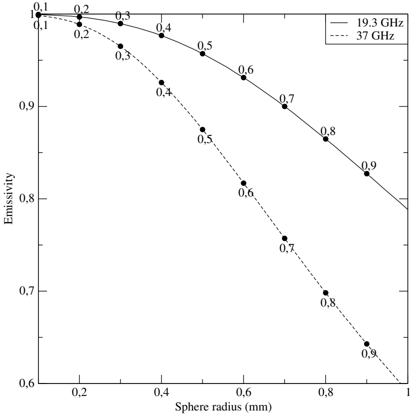

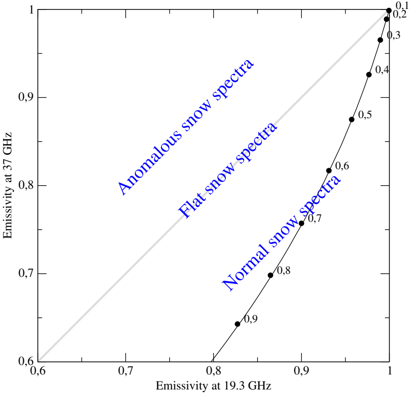

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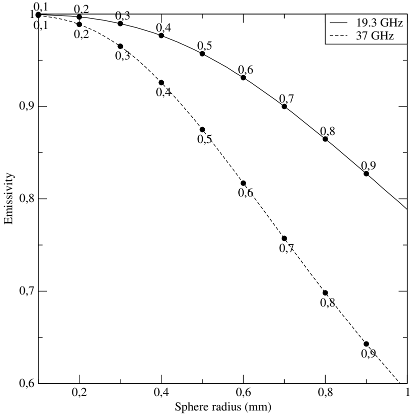

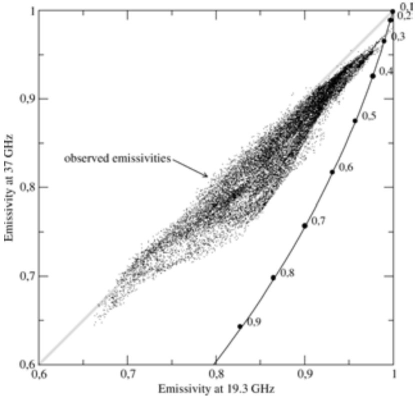

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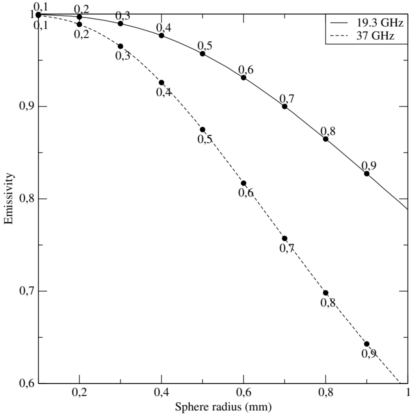
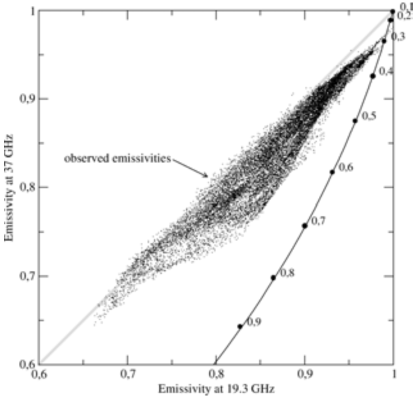




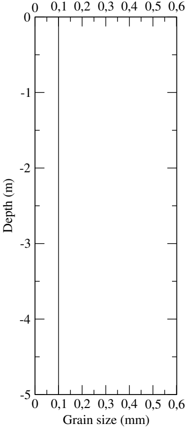
The homogeneous snowpack cannot explain simultaneously the emissivities at 19 and 37 GHz in Antarctica.

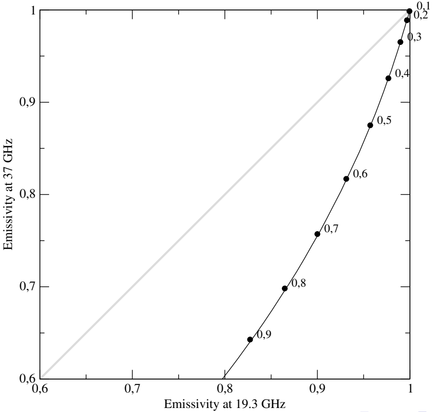
Heterogeneous snowpack

with a linear increase in snow grain size with depth

To increase the snow grain size with depth :

$$r(z) = r_{near\ surf} + Q \cdot z$$





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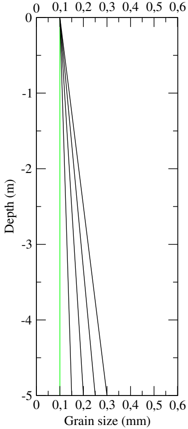

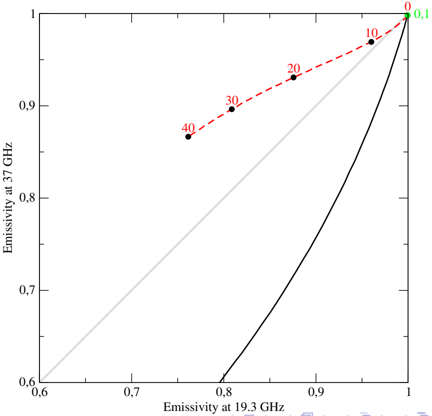

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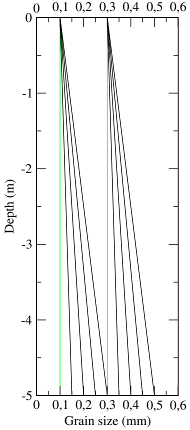

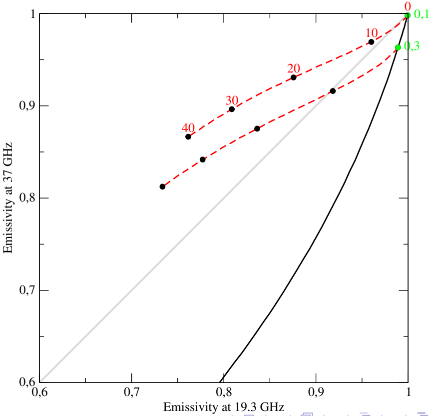

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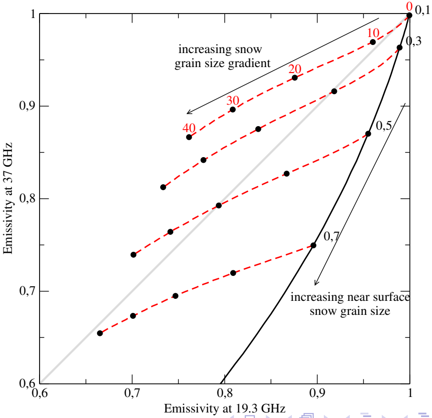


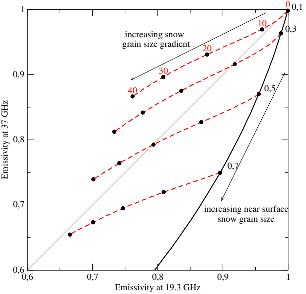
Heterogeneous snowpack

with a linear increase in snow grain size with depth

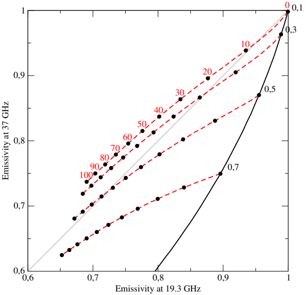
To increase the snow grain size with depth :

$$r^n(z) = r^n_{near\ surf} + Q_n \cdot z$$

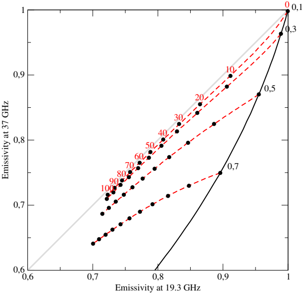
n=1



n=2



n=3



n=3 cannot explain anomalous snow spectra

Heterogeneous snowpack

with a linear increase in snow grain size with depth

To increase the snow grain size with depth :

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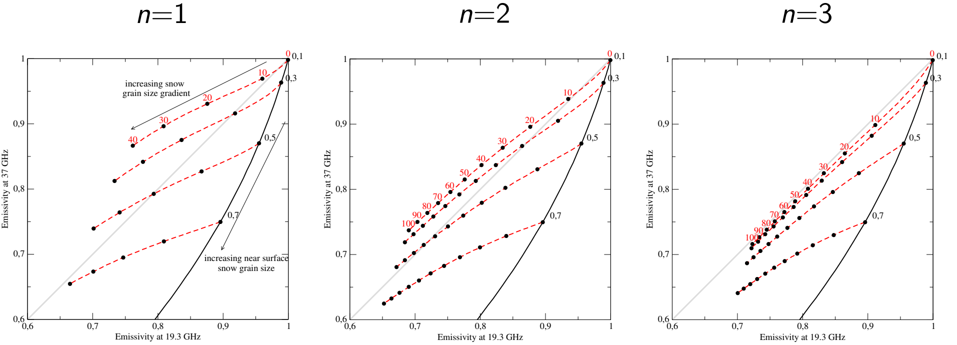


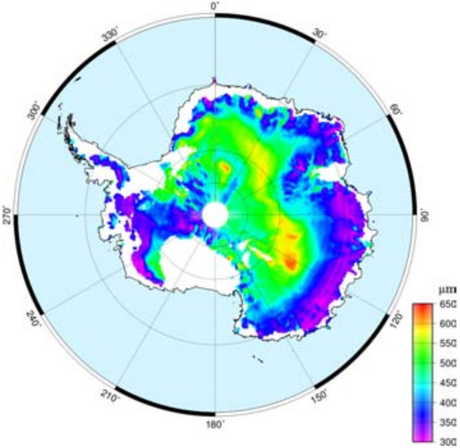
n=1 n=2 n=3

$$\boxed{\{e_{19},\quad e_{37}\} \Longrightarrow \{r_{near\ surf},\quad Q_n\}}$$

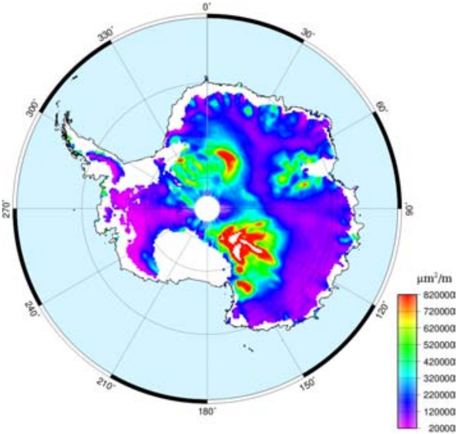
Retrieved snow grain profile parameters

$$\{e_{19},\quad e_{37}\} \Longrightarrow \{r_{near\ \ surf},\quad Q_n\}$$

$r_{near\ \ surf}$



Q_n for n=2

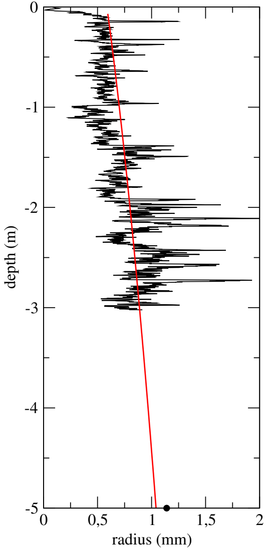


Validations

- *in situ* measurements acquired along traverses
- IR photographs at Dome C
- climate models

- grain size retrieved by visible and infrared satellite sensors (POLDER, ATSR-2, Landsat and MODIS)

Validation at Dome C



Grain size derived from :
- IR photography
- inversion of the emissivities

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CONCLUSIONS

- An increase in snow grain size with depth was measured by IR photography;
- With a calibrated α and $r^{z>3m}$, $T_B(t)$ are accurately explained, RMSE$<$1K;
- Emissivities modeled with a homogeneous snowpack cannot predict the flat spectra of observed emissivities
  $\Longrightarrow$ **the snow grain size must increase with depth**;
- Considering a simple grain growth relationship and $\{e_{19}, \ e_{37}\}$, it is possible to retrieve $\{r_{near\ surf}, \ Q_n\}$;
- Our retrievals were validated.

FUTURE WORKS

- Explain the horizontal polarization;
- New measure of snow properties.

Acknowledgements

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