Toward a better modeling of surface emissivity to improve AMSU data assimilation over Antarctica

GUEDJ Stephanie, KARBOU Fatima and RABIER Florence

1. Introduction

- CONCORDIASI project :

  - To improve our understanding of the ozone depletion over Antarctica
  - To study potential interaction with lower latitudes
  - **To get more accurate NWP analyses and forecasts**

- Satellite data assimilation in NWP in polar region (Polar orbiting)

  - Choice of microwave instruments (AMSU-A & AMSU-B)
  - main features : cross-track scanning
  - Measurements : Humidity & Temperature profiles + **surface**

2. Emissivity of Antarctica

Land surface emissivity calculation

- Land surface emissivity is usually retrieved from satellite observations assuming the surface to be **flat and specular** (Prigent et al.,1997)

- Maztler (2005) has found questionable the use of this assumption for nadir viewing angles for some specific surface types

- Karbou and Prigent (2005) have shown that the specular assumption can be used for **snow-free areas**

- But can we use the specular assumption to retrieve AMSU emissivities over Antarctica ?

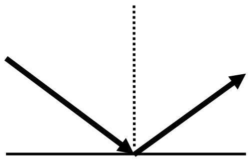
- To evaluate the effect of surface assumption on emissivity : different assumptions have been tested from **specular to lambertian**.

2. Emissivity of Antarctica

Land surface emissivity calculation

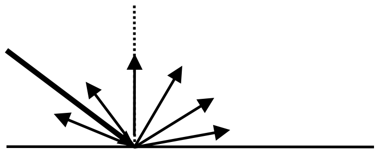
SPECULAR SURFACE

$\theta_{incident} = \theta_{reflected}$



LAMBERTIAN SURFACE

$\theta_{incident} \neq \theta_{reflected}$



$\theta_{effective}$: Average angle replacing the integration over all directions (Mätzler, 1987 and Ingold et al., 1998)

Matzler (2005) : suggest to use a specularity parameter to describe natural surface

2. Emissivity of Antarctica

Land surface emissivity calculation

5 approximations to retrieve emissivity at AMSU-A frequencies :

	Specularity Parameter
- SPECULAR	1
- LAMBERTIAN	0
- SEMI-LAMBERTIAN	0.5
- QUASI-LAMBERTIAN	0.25
- QUASI-SPECULAR	0.75

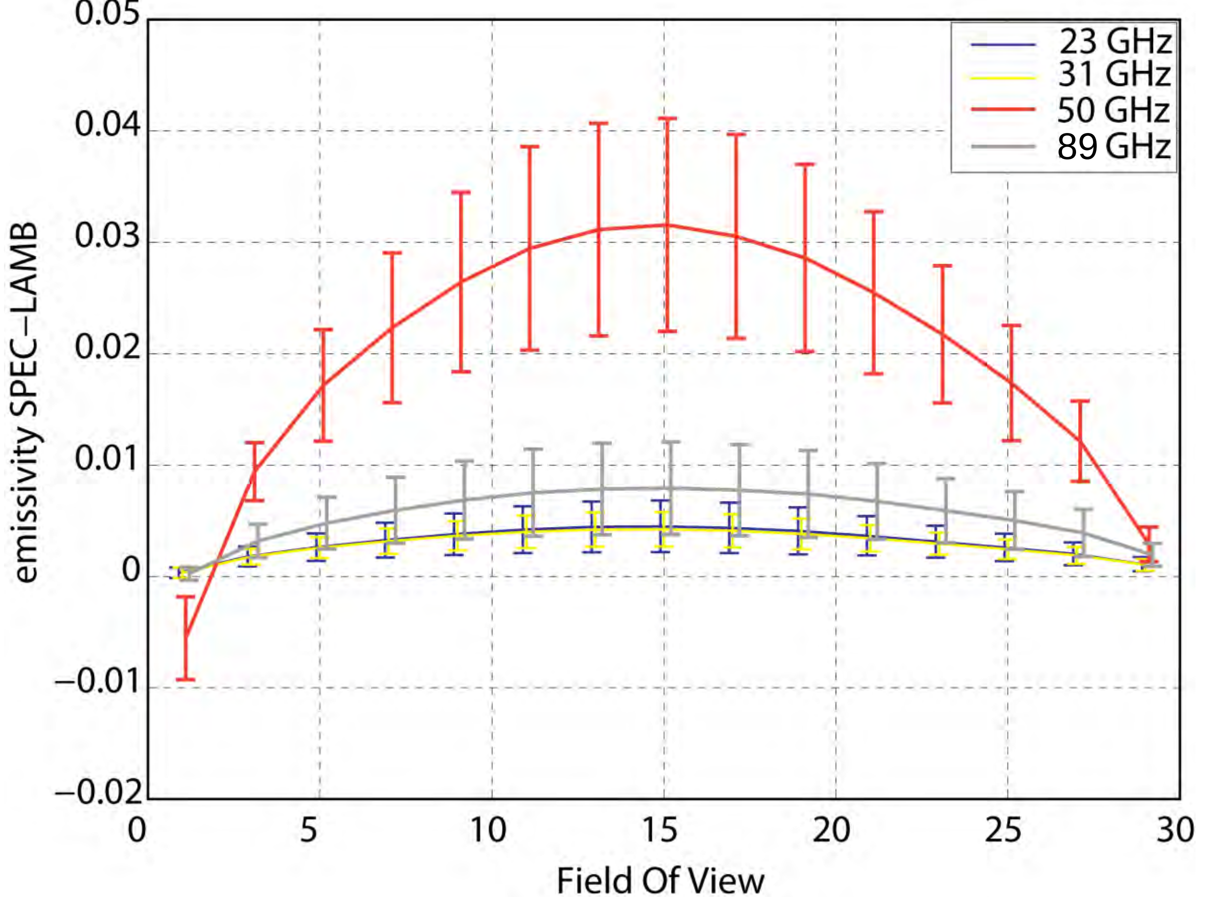
→ PERIOD : 5 approximations x 1 year

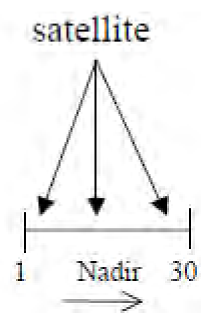
+ Comparison with the OPER2007 version : Empirical versions of models (Weng et al., 2001 and Grody, 1988)

2. Emissivity of Antarctica

Analysis of land surface emissivity

Monthly mean "ε_{SPEC} minus ε_{LAMB}" as a function of field of view positions over Antarctica for AMSU-A observations. (January 2007)



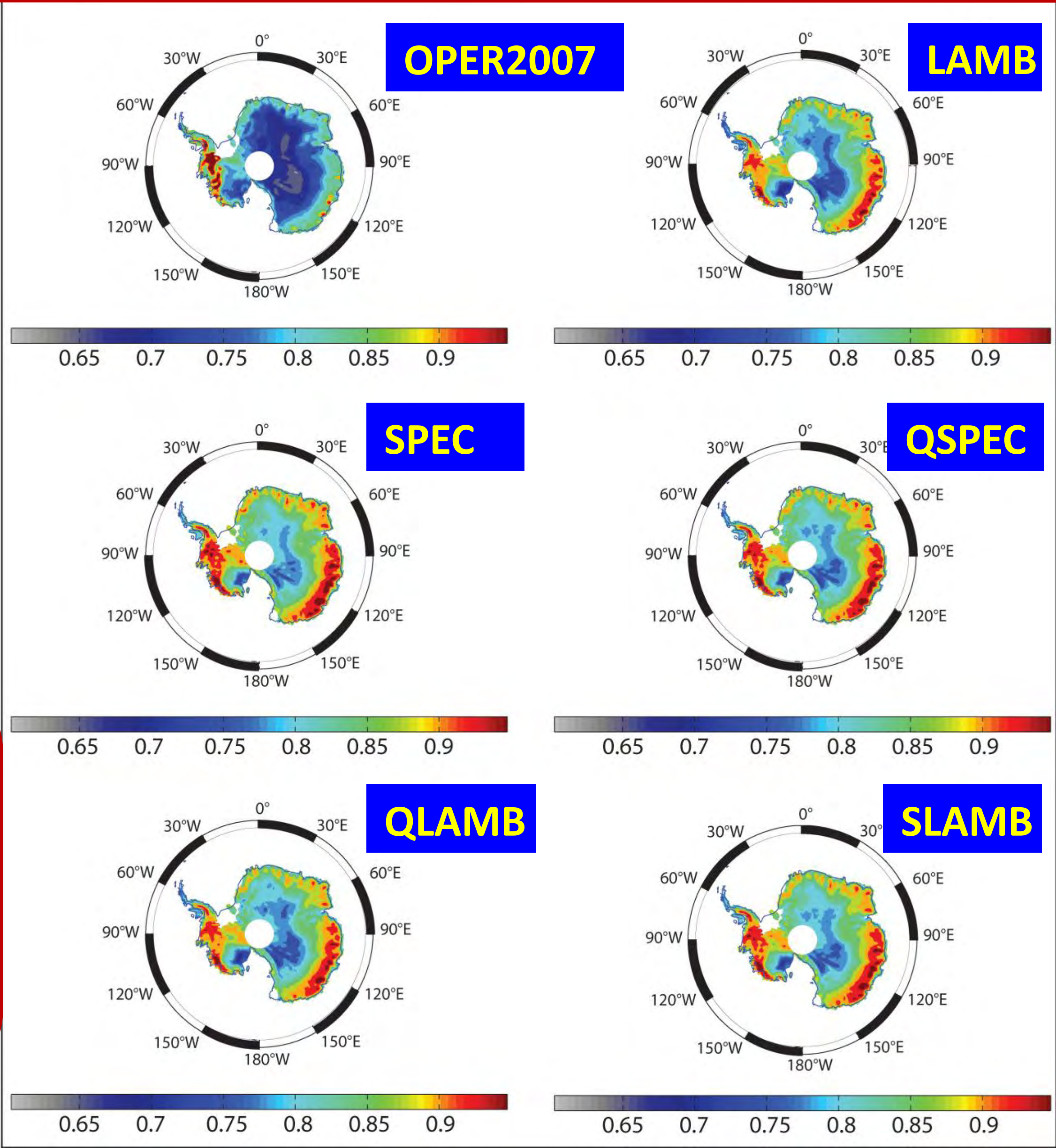


surface approximation effects are larger for AMSU-A Channel 3 especially for nadir viewing angles (up to 3%)

2. Emissivity of Antarctica

Analysis of land surface emissivity

Monthly mean emissivity maps for AMSU-A channel 3 (50 GHz) over Antarctica, for January 2007



- Emissivity is low in the centre and increases towards the coastline
- Emissivity values:
  OPER2007 < others
- Some differences between approximations

2. Emissivity of Antarctica

Analysis of land surface emissivity

- Surface approximation effects are larger for AMSU-A Channel 3
- Some differences between approximations but which one is the more realistic ?

Problem : No independant observation is available to select the best approximation

$\Rightarrow$ One Solution : Simulation of sounding brightness temperature using emissivity of channel 3 (50 GHz) as input.

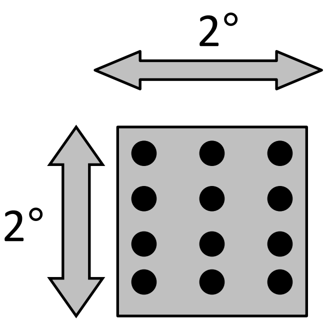
And comparison with observations

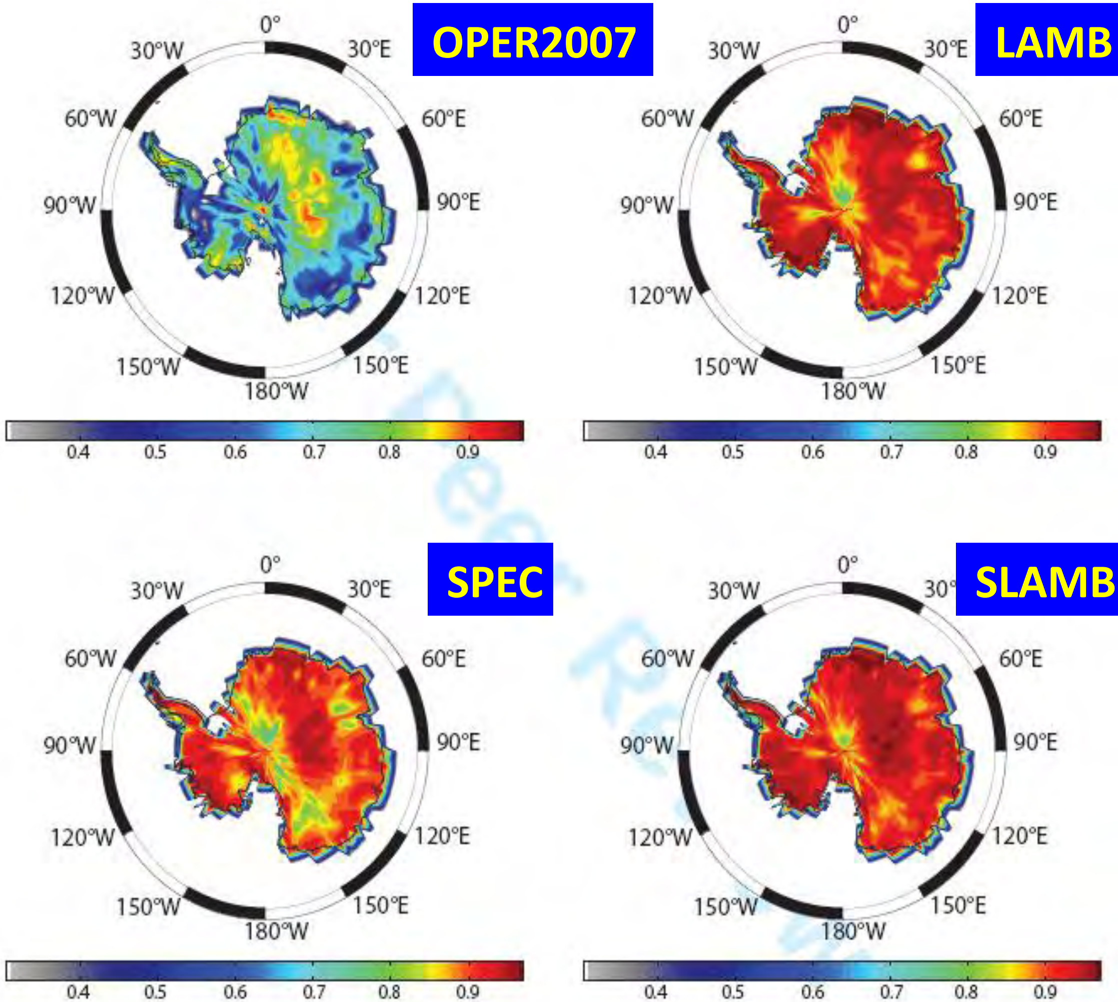
3. Evaluation of land surface emissivity

Correlations between Tb_{obs} and Tb_{sim}

Maps of correlations between Tb_{obs} and Tb_{sim} of AMSU-A channel 4 (August 2007)

=> calculation of correlations in grid cell:



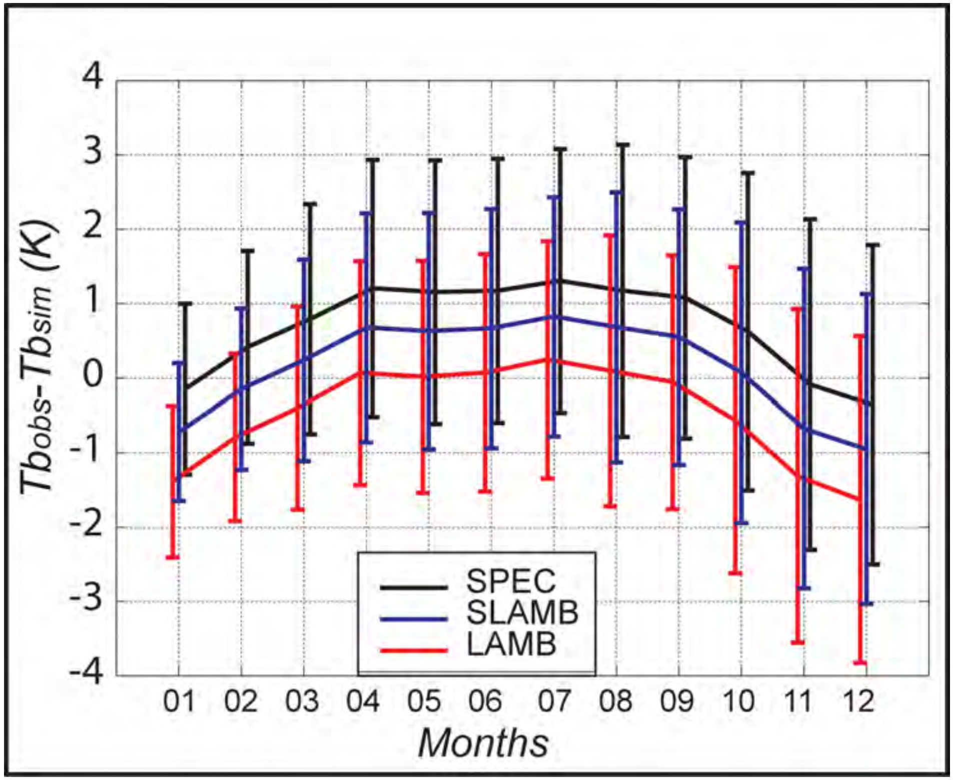


Correlations between observed and simulated Tbs have been improved by comparison to OPER2007 especially by LAMB and SLAMB

3. Evaluation of land surface emissivity

Seasonnal dependence

Mean Fg-Departures (Tb_{obs}-Tb_{sim}) of channel 4 (52 GHz) as a function of months over Antarctica.
Errorbars represent the STD



<u>Fg-Departures (K)</u>

(First-guess Departures)

=

Observations

-

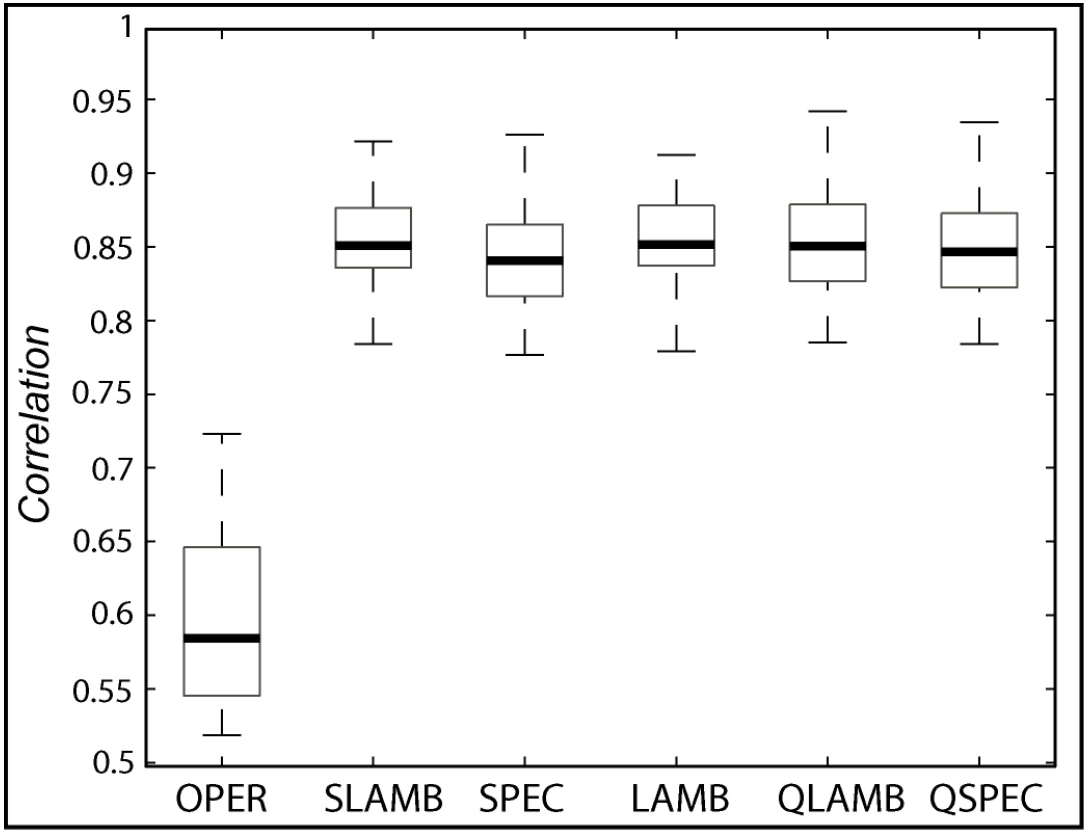
Simulations

- LAMB approximation would be more suitable during the winter period
- SLAMB or SPEC approximations could be used during summer

3. Evaluation of land surface emissivity

Distribution of correlations in 2007

Boxplot of monthly mean AMSU-A channel 4 (52 GHz) correlations between Tb_{obs} and Tb_{sim} over Antarctica



The box stretches from the lower hinge (defined as the 25th percentile) to the upper hinge (the 75th percentile) and therefore contains the middle half of the scores in the distribution. The median is shown as a line across the box.

- Correlations of all approximations seems higher than the OPER2007

4. Conclusion & future developments

- The aim of this work was to extend the use of AMSU data over Antarctica (from mid-atmosphere to surface)
- Snow surface emissivity has been calculated from 1 year of AMSU-A measurements using 5 approximations assuming the surface to be : specular (SPEC), lambertian (LAMB), and also using a specularity parameter (QLAMB, SLAMB and QSPEC)
- The LAMB approximation could be more suitable during winter and the SLAMB and SPEC approximation could be used during summer.
- Over Antarctica sea-ice surfaces, Bouchard et al. (2009) have already shown that the SPEC approximation provided satisfactory results. (Come and see her POSTER)
- SPEC, QSPEC, …. have been interfaced with RTTOV as options and can be activated in ARPEGE using logical keys as inputs : more tests are still needed before operational implementation of one of these methods (SPEC is already oper)

Come and see our poster !!

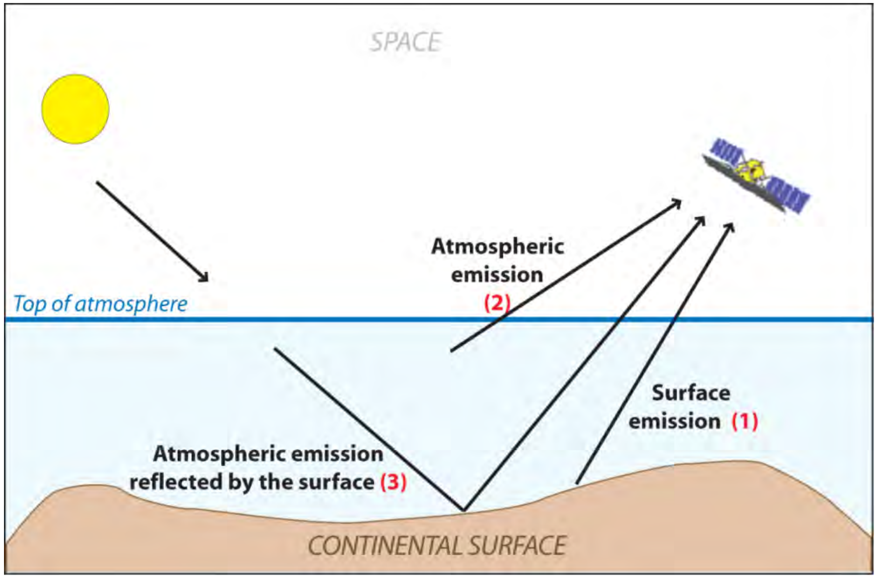
Thank YOU

2. Emissivity of Antarctica

Land surface emissivity calculation

<u>Hypothesis</u>: - The surface is usually supposed to be flat and specular (METHOD 1)
- Surface skin temperature = Surface temperature
- No volume scattering and non-scattering plane-parallel atmosphere

$$Tb(\theta) = \underbrace{(T_{skin} \times \varepsilon(\theta) \times \Gamma)}_{(1)} + \underbrace{T_{\uparrow}(\theta)}_{(2)} + \underbrace{(T_{\downarrow}(\theta) \times (1-\varepsilon) \times \Gamma)}_{(3)}$$



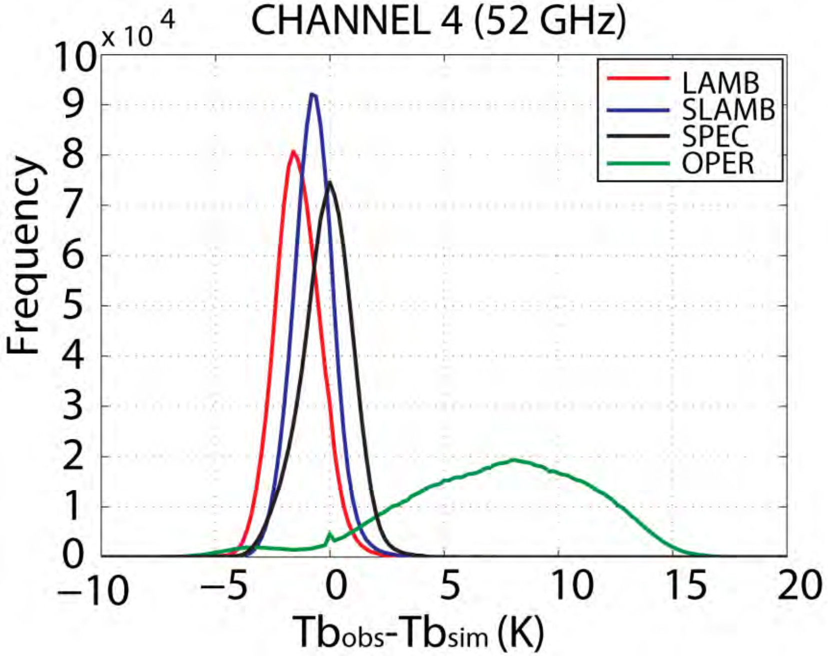
Outputs of RTTOV model:
T, Q short-range forecasts or radiosondes or reanalyses

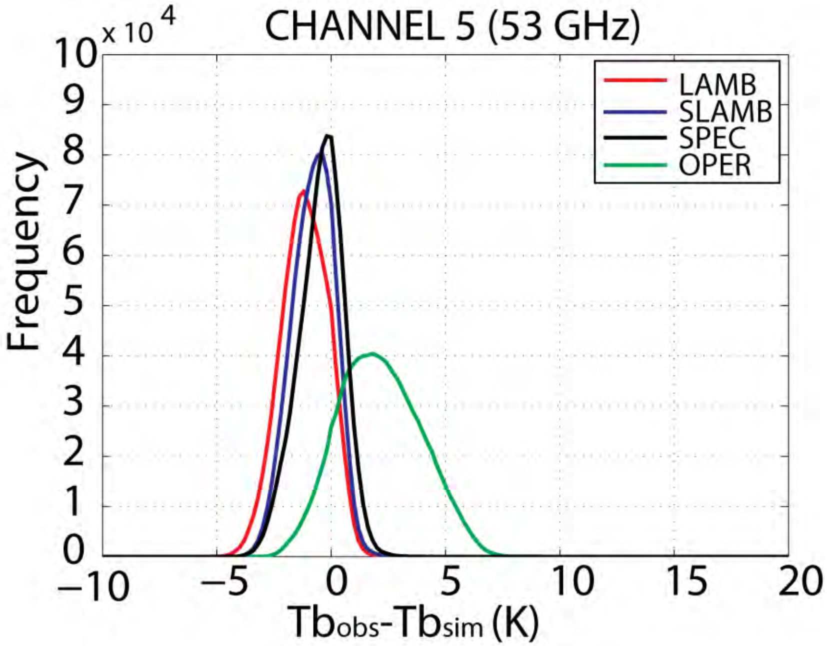
$$\varepsilon(\theta) = \frac{Tb(\theta) - T_{\uparrow}(\theta) - T_{\downarrow}(\theta) \times \Gamma}{(T_{skin} - T_{\downarrow}(\theta)) \times \Gamma}$$

The surface assumption is applied to the T↓ component.
For very rough surfaces, a lambertian reflection can also be supposed …

Distribution of Fg-Departures

Fg-Departures (Tb_{obs} - Tb_{sim}) histograms of AMSU-A channel 4 and 5
January 2007

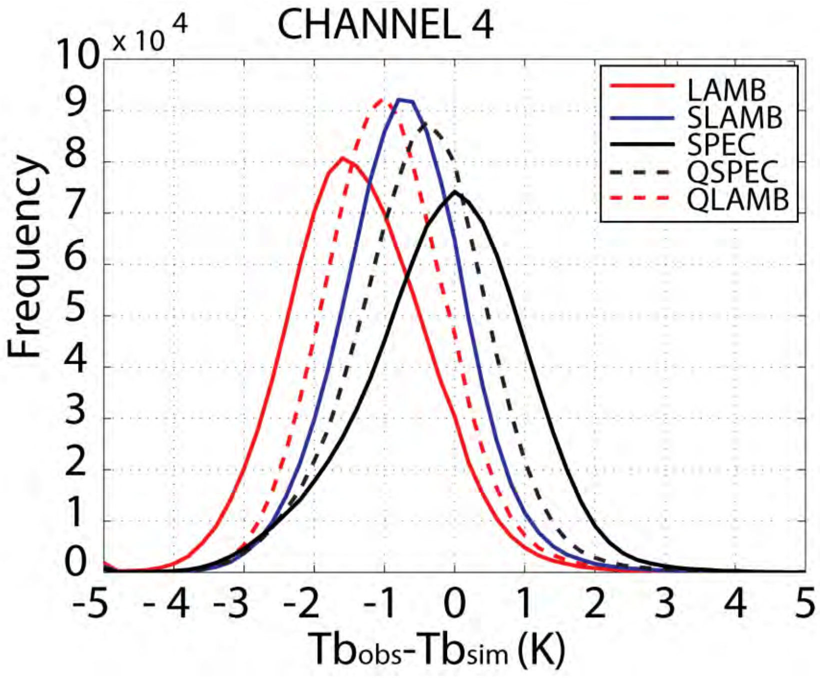


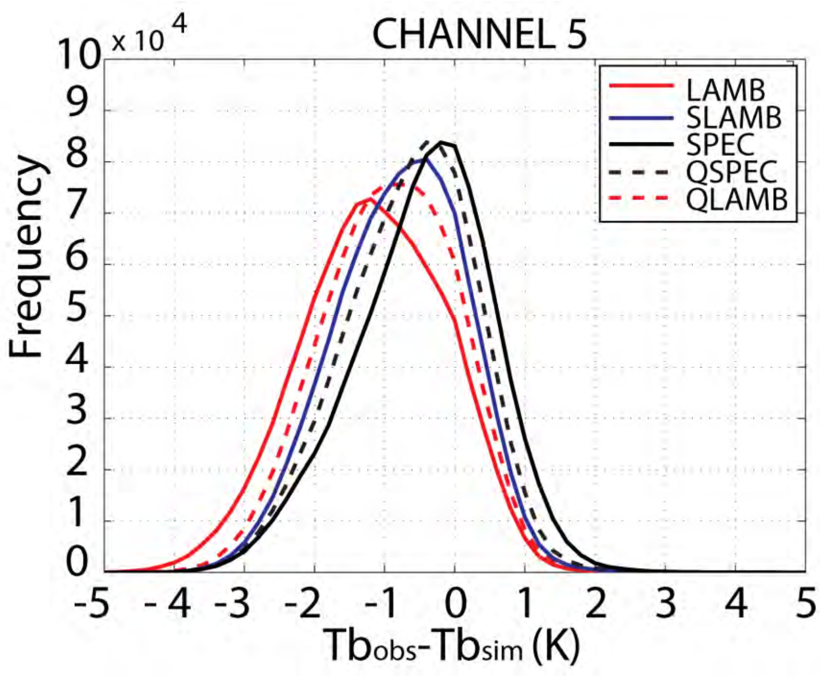


- Each approximation have significantly been improve by comparison to the OPER
- Channel 4 : SLAMB shows the lowest STD and SPEC presents the lowest bias
-Channel 5: Best result to SPEC approach

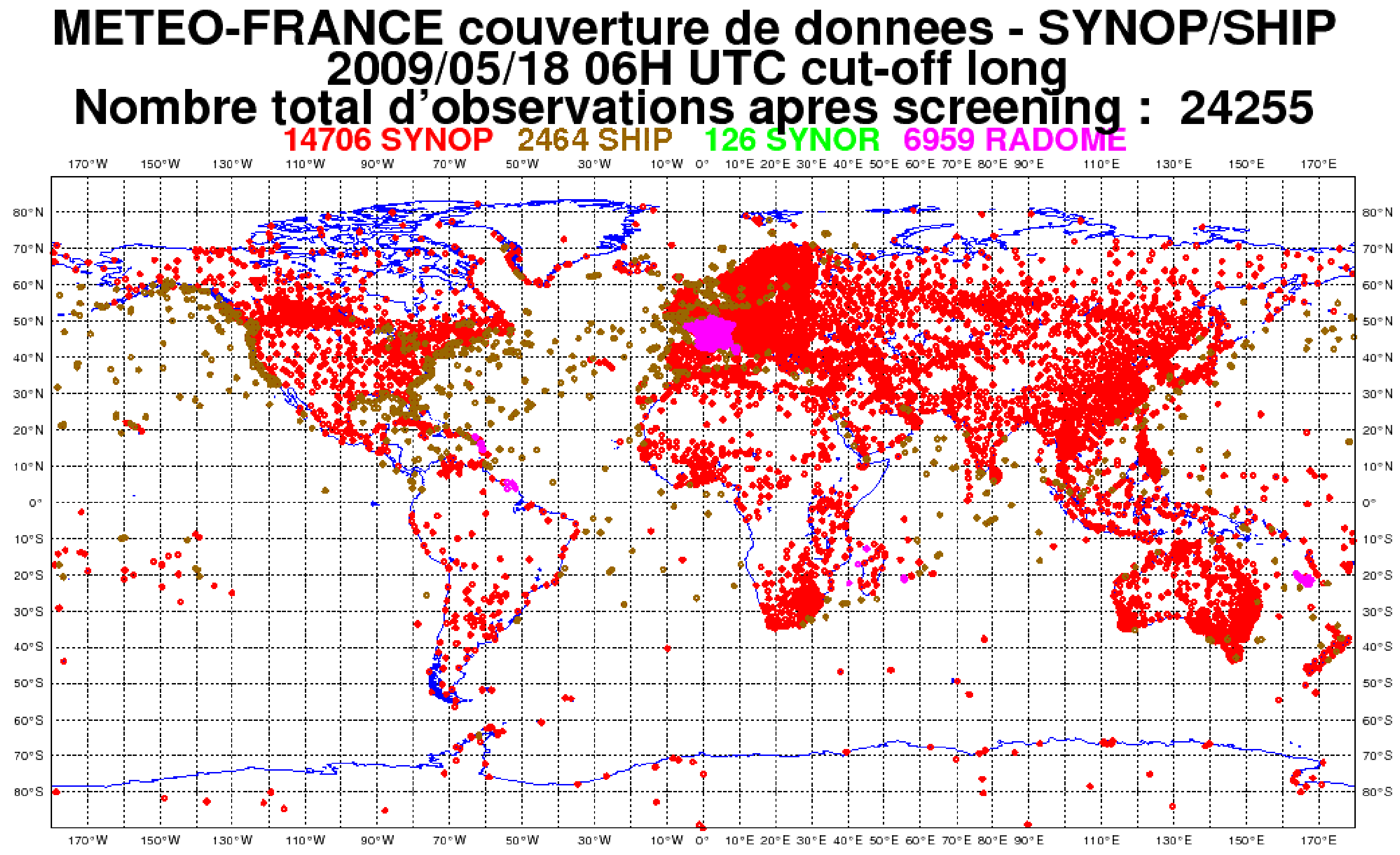
Distribution of Fg-Departures

Fg-Departures (Tbobs - Tbsim) histograms of AMSU-A channel 4 and 5
January 2007

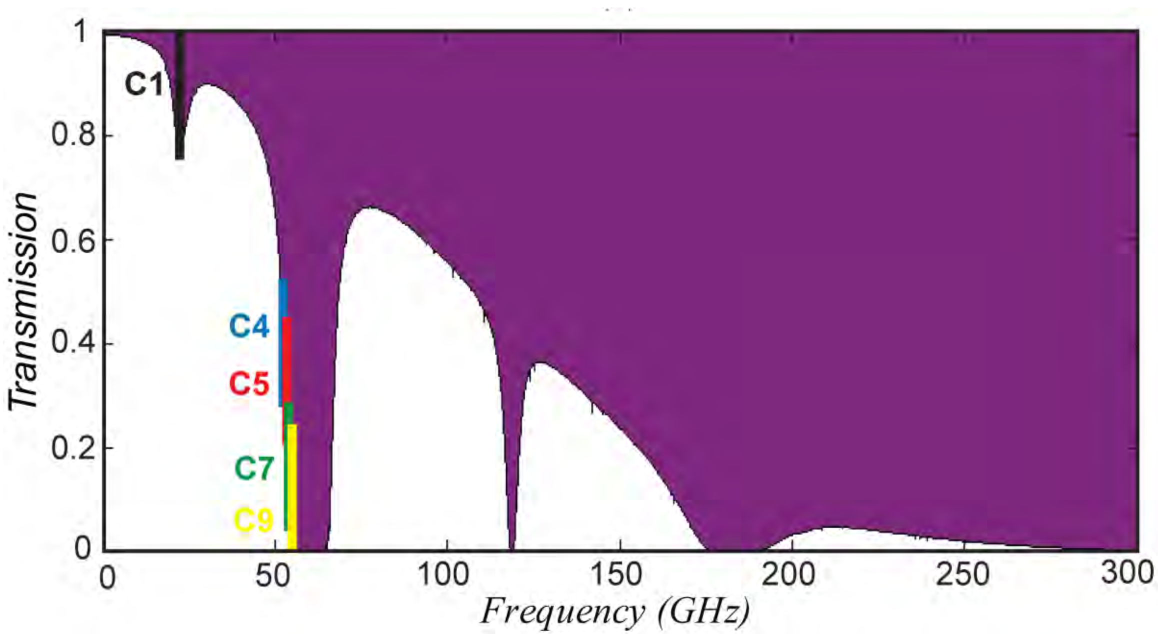




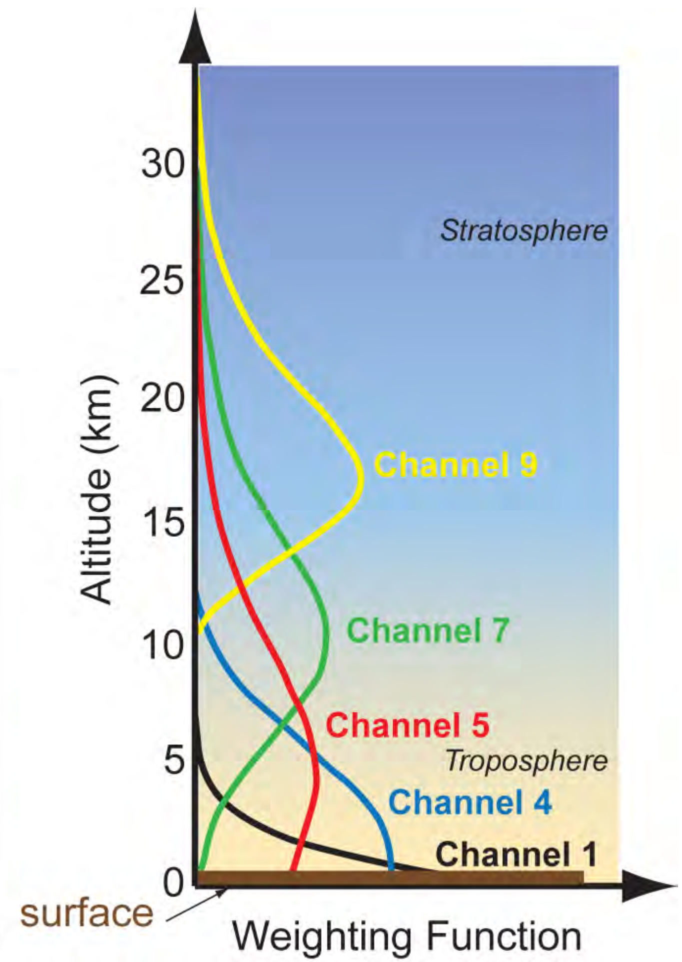
MOTIVATIONS



Lack of *in-situ* observations to well constrain the NWP models over ANTARCTICA



Transmission
Frequency (GHz)
0
0.2
0.4
0.6
0.8
1
0
50
100
150
200
250
300
C1
C4
C5
C7
C9



Altitude (km)
Weighting Function
0
5
10
15
20
25
30
Stratosphere
Troposphere
Channel 9
Channel 7
Channel 5
Channel 4
Channel 1
surface

$$Tb(\theta) = (T_{skin} \times \varepsilon(\theta) \times \Gamma) + T_{\uparrow}(\theta) + (T_{\downarrow}(\theta) \times (1-\varepsilon) \times \Gamma)$$

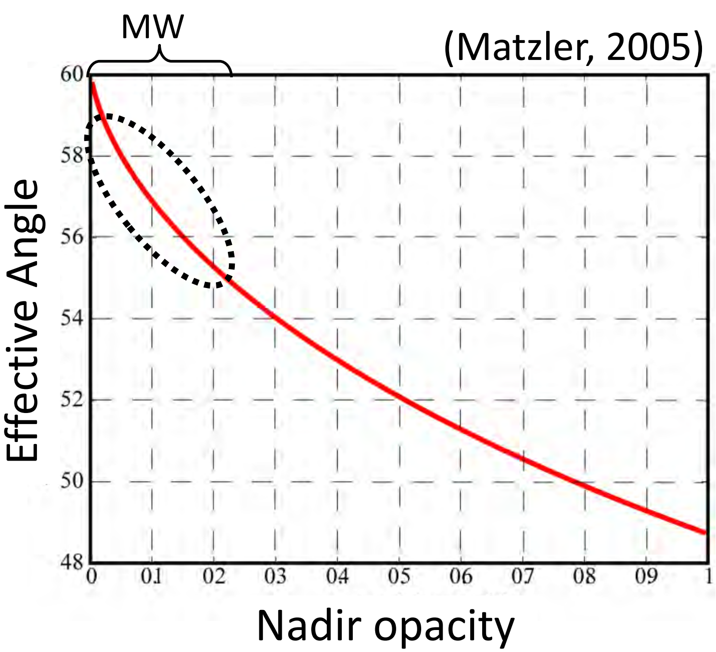
$$\varepsilon(\theta) = (Tb(\theta) - T_{\uparrow}(\theta) - T_{\downarrow}(\theta) \times \Gamma)/((T_{skin} - T_{\downarrow}(\theta)) \times \Gamma)$$

$$T_{\downarrow}(\theta) = \int_{H}^{0} T(z)\alpha(z) e^{\frac{-\tau(z,0)}{\cos(\theta)}} dz$$

SPEC

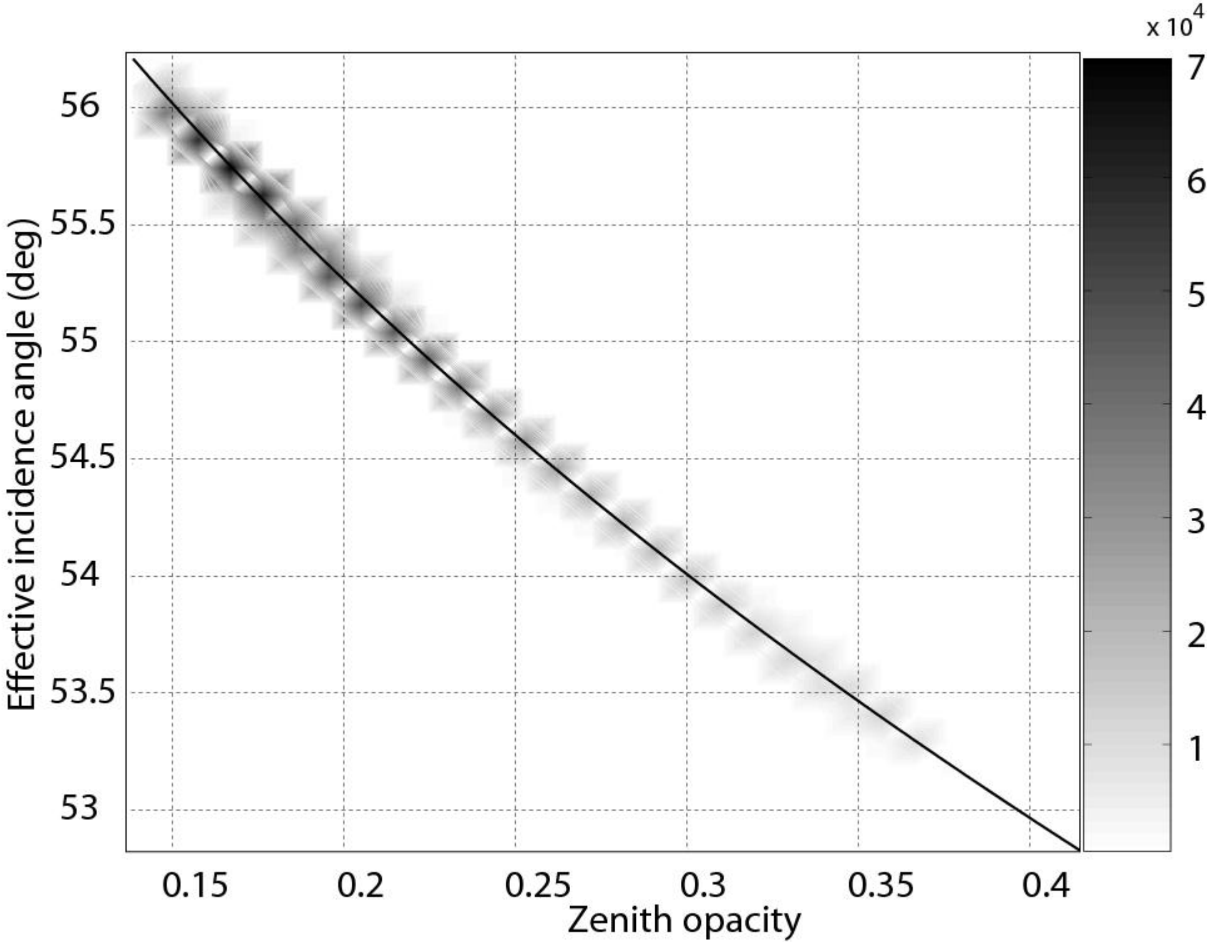
$$T_{\downarrow}(\theta) = \int_{0}^{\pi/2} 2\cos(\theta)\sin(\theta)\left(\int_{H}^{0} T(z)\alpha(z) e^{\frac{-\tau(z,0)}{\cos(\theta)}} dz\right) d\theta$$

LAMB



$$\theta_{eff} = \arccos\left(\frac{-\tau}{\ln(2xE_3(\tau))}\right)$$

$$T_{\downarrow}(\theta) = sT^{\downarrow}_{SPEC} + (1-s)T^{\downarrow}_{LAMB}$$

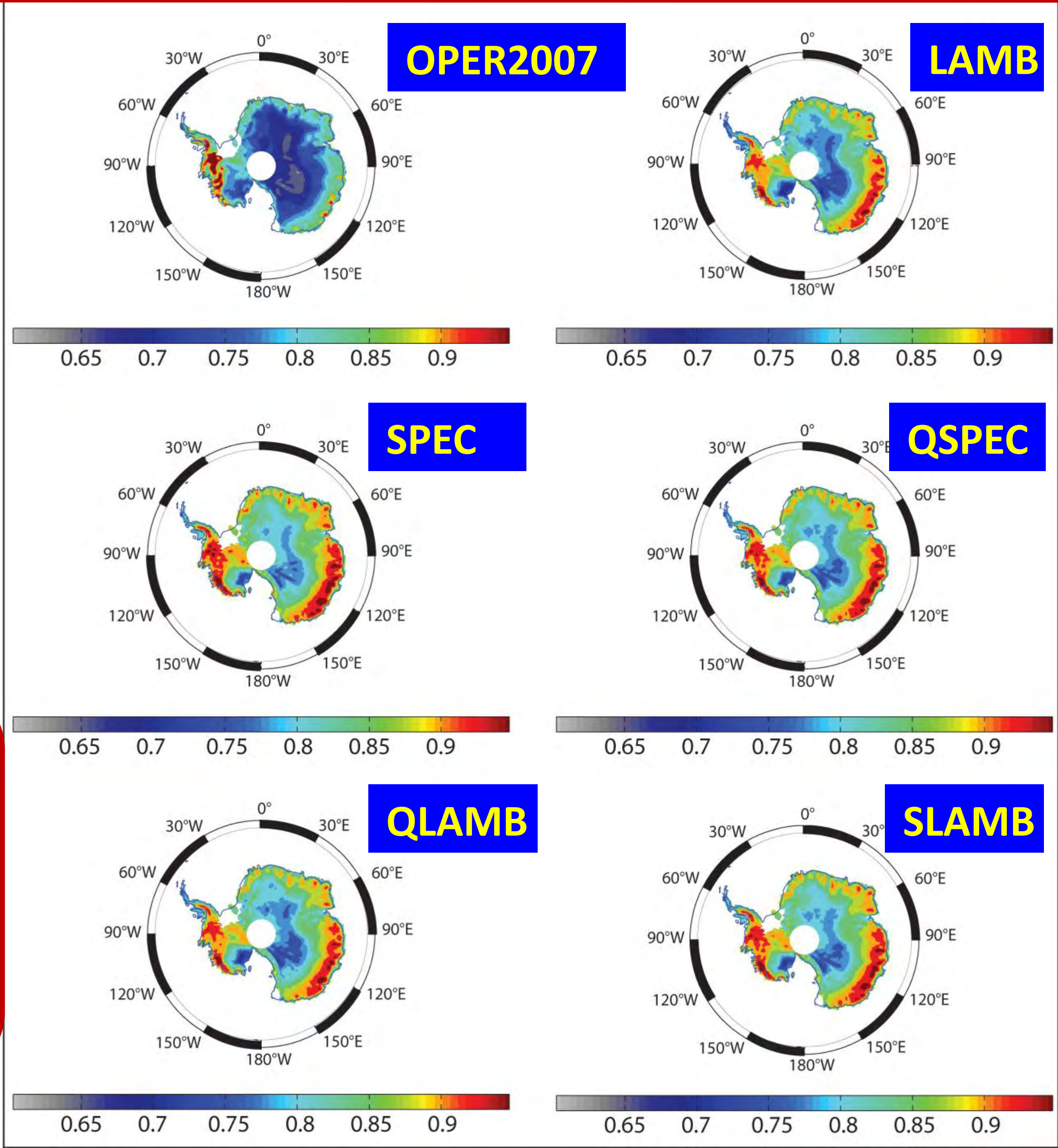


x 10^4
7
6
5
4
3
2
1
56
55.5
55
54.5
54
53.5
53
Effective incidence angle (deg)
0.15
0.2
0.25
0.3
0.35
0.4
Zenith opacity

2. Emissivity of Antarctica

b. Land surface emissivity analysis (2)

Monthly mean emissivity maps for AMSU-A channel 3 (50 GHz) over Antarctica, for January 2007

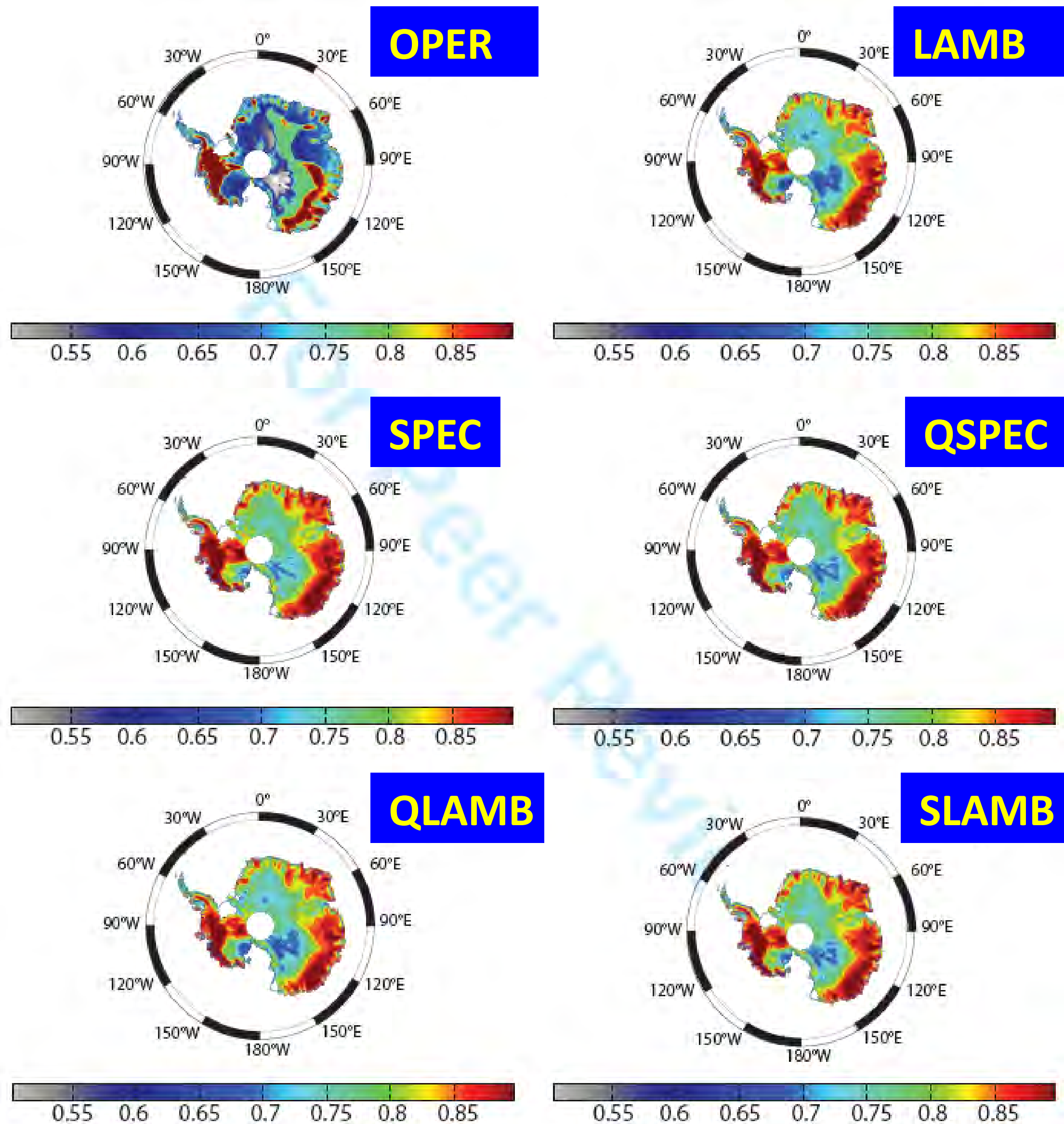


- **Emissivity is low in the centre and increases towards the coastline**
- **Emissivity values:**
  OPER2007 < others
- **Some differences between approximations**

Monthly mean emissivity maps for AMSU-A channel 3 (50 GHz) over Antarctica, for August 2007

OPER : Empirical scheme
(*Weng et al., 2001*)

app.	SPEC	LAMB
SLAMB	50%	50%
QLAMB	30%	70%
QSPEC	70%	30%



2. Emissivity of Antarctica

Land surface emissivity calculation

METHOD 1: SPECULAR

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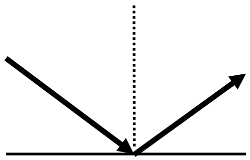

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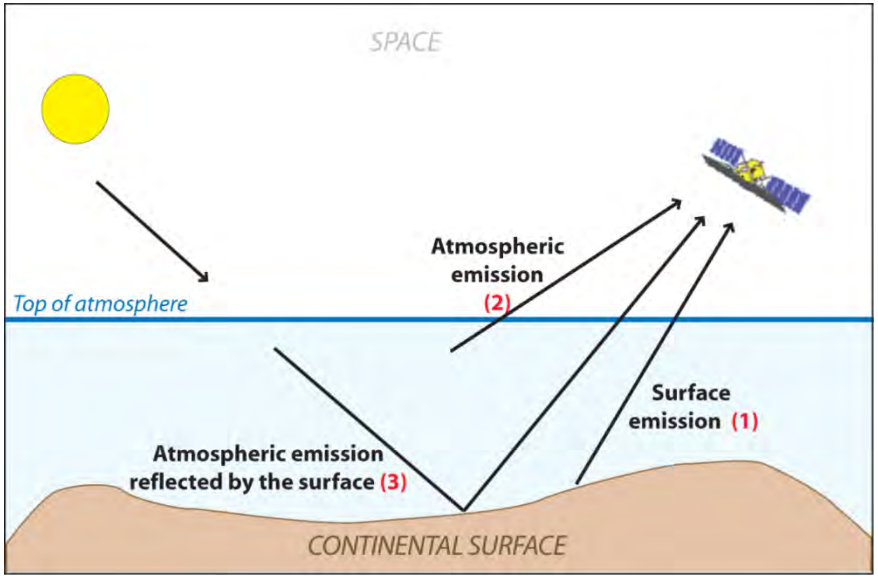

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