A new RTTOV land surface microwave emissivity tool based on a parameterization of the land surface emisssivity between 19 and 100 GHz

Filipe Aires(1), Catherine Prigent(2),
Elodie Jaumouillé(2), Frédéric Bernardo(1),
Carlos Jimenez(2), Frédérique Chevallier(3),
Roger Saunders(4), Pascal Brunel(5)

(1) LMD, Université Paris VI,
(2) Observatoire de Paris,
(3) LSCE, CEA
(4) MetOffice, UK,
(5) Meteo-France, Lannion

THE PROBLEM:

How to estimate accurate global land surface microwave emissivities between 10 and 100 GHz, for all frequencies, angles, polarizations ?

- to be used as first guess for cloud clearing procedure and assimilation of close-to-the-surface sounding channels
- to be used as first guess in Ts retrievals
- for surface background estimate in precipitation and cloud retrievals
- to simulate the responses of future instruments
- …

Models:

- difficulty to simulate the complex interaction between the radiation and the surface regardless of the surface type (bare soil, vegetation, snow…)
- require a large number of input parameters that are not always available with accuracy on a global basis

Satellite estimates: (Prigent et al. 1997) algorithm

- limited in observing conditions (frequency, incidence angle, polarization)
- require **reliable estimates of Ts** and **good cloud filtering**
- some instrument estimates have better accuracy, or want to keep independence for assimilations

A SOLUTION:

To derive a parameterization of the emissivity frequency, angular, and polarization dependence anchored on a reliable satellite-derived emissivity data base

OUTLINE

1) The method

- Estimation of the satellite-derived land surface emissivities over two months from TMI, SSM/I, and AMSU-A observations
- Analysis of their frequency, angular, and polarization dependences per surface type. Surface type specified by a clustering method applied directly on the emissivities (more flexible).
- Development of a parameterization of the emissivity frequency, angular, and polarization dependences
- Use of this parameterization, anchored on the previously calculated SSM/I emissivities at 19, 37, and 85 GHz for both polarizations at 53°

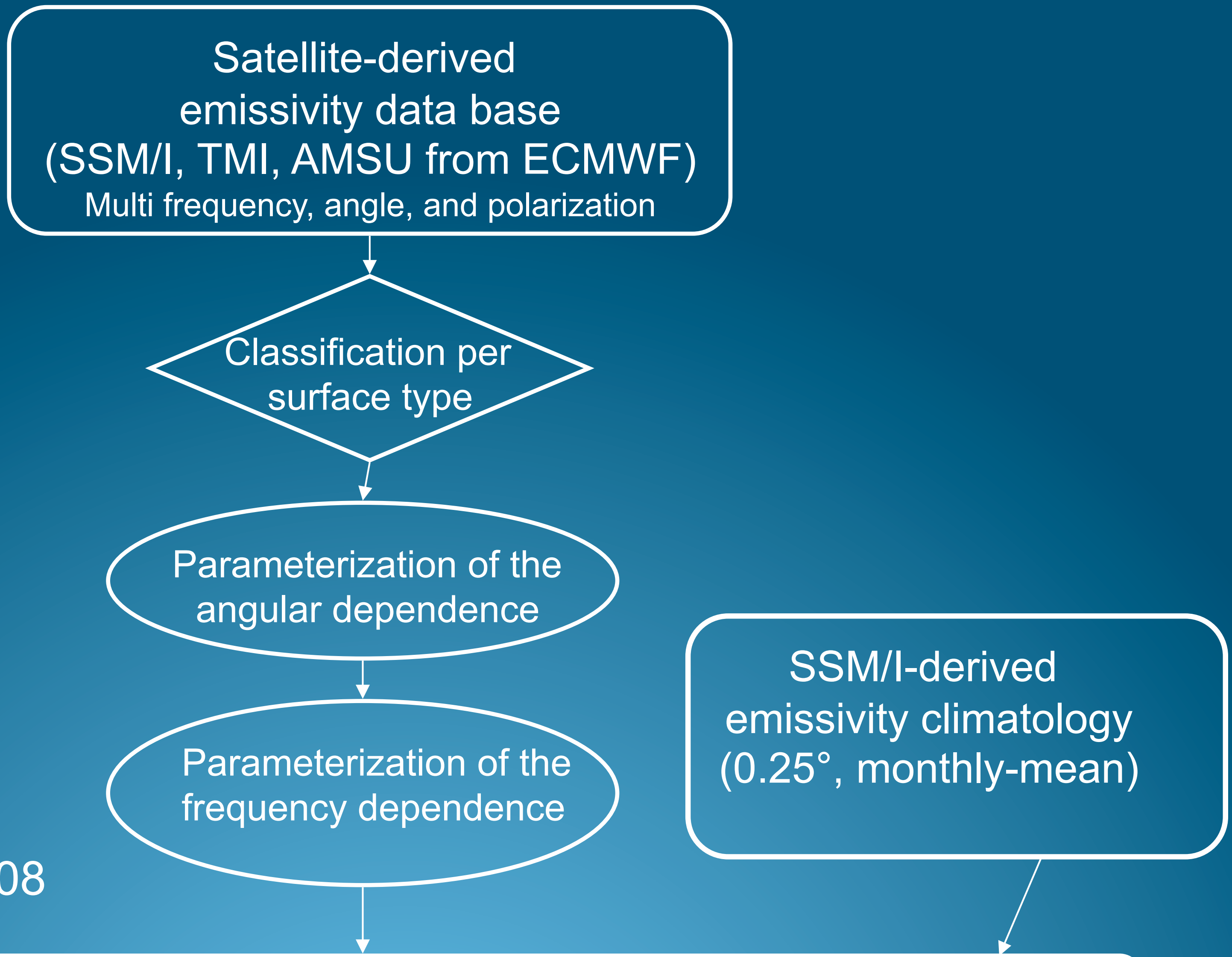
2) The results

- Emissivities comparison between satellite estimates and model outputs
- Error assessment
- RT simulations on AQUA and METOP

3) RTTOV Implementation

- Horizontal resolution
- Uncertainties

THE METHOD (1/8)



Jaumouillé et al. 2008

$$\varepsilon(lat,lon,month,freq,\ \theta,\ pol) = f(\varepsilon_{SSM/I}(lat,lon,month),\ freq,\ \theta,\ pol)$$

THE METHOD (2/8)

Emissivity calculation for different frequencies, angles, polarizations

Emissivities directly estimated from satellite observations under clear sky conditions and averaged over the month:

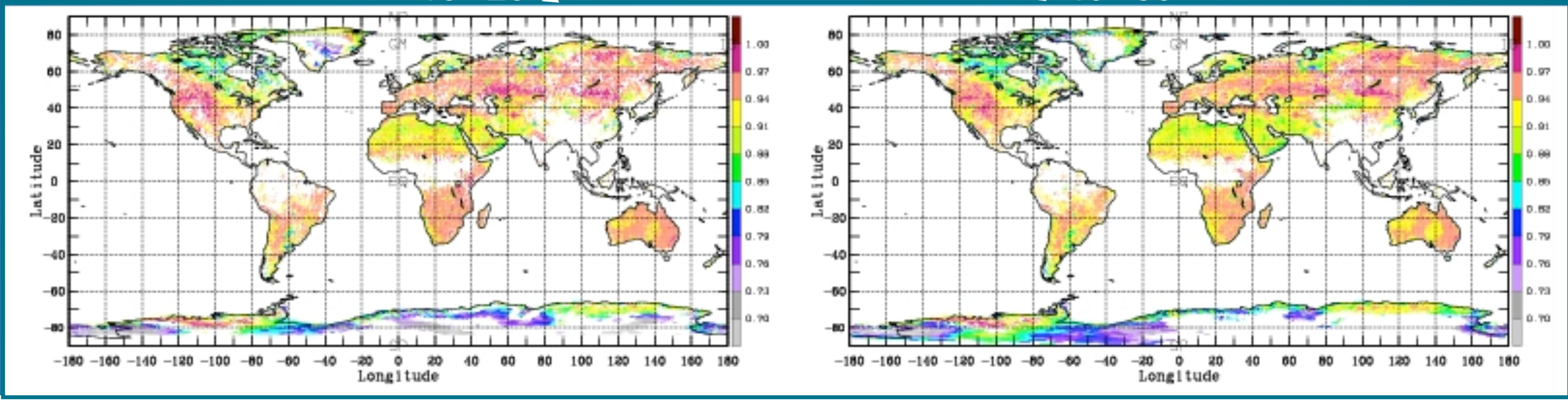
SSM/I: 19.35, 22.235, 37.0, 85.5 GHz at 53° for V and H pol. (22V only)
TMI: 10.65, 19.35, 21.3, 37.0, 85.5 GHz at 49° for V and H pol. (21V only)
AMSU-A: 23.8, 31.4, 50.3, 89.0 GHz from 0 to 55°, for a mixture of V and H pol.
Calculations performed at ECWMF (by F. Chevallier) with the methodology previously described:

- RTTOVS radiative transfer model
- atmospheric profiles, clear sky screening, and Tsurf from the ECMWF forecast

For comparison purposes, emissivities also estimated from model

- Weng et al. (2001) radiative transfert model
- ECMWF forecast inputs

10°-20° AMSU-A 31.4 GHz 40°-50°



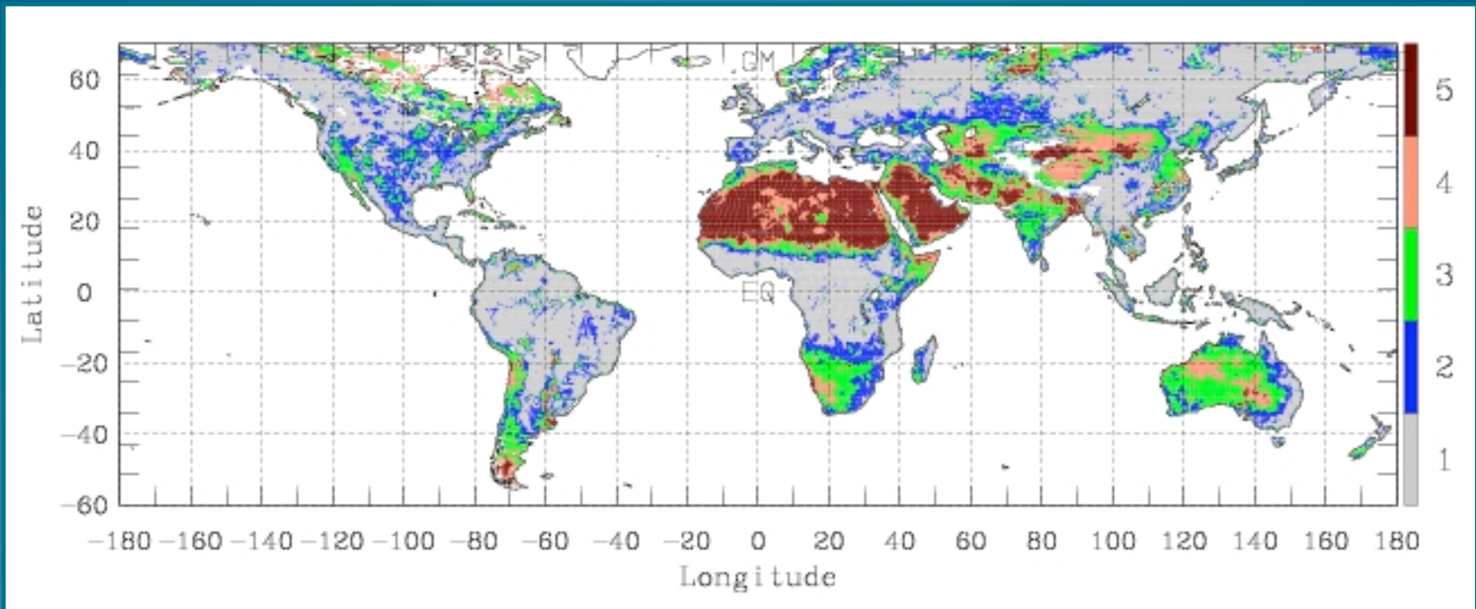
THE METHOD (3/8)

Classification of the emissivity estimates

- Data set separated in different surface types, using a clustering method applied to the SSM/I emissivity estimates.

- Five classes are isolated, from vegetated regions (class 1) to desert surfaces (class 5).

Classification for July 1992



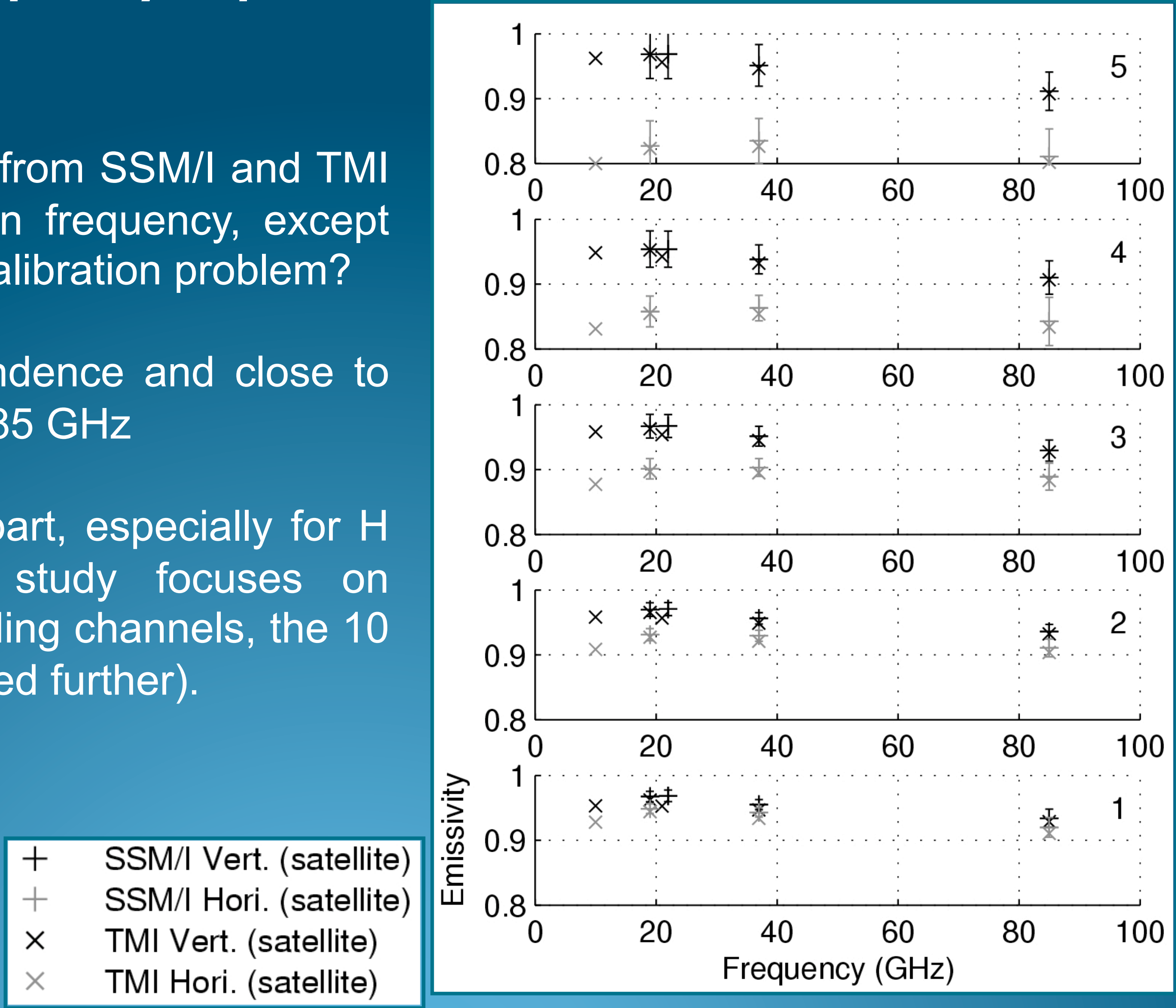
THE METHOD (4/8)

Analysis of the frequency dependence

Emissivities calculated from SSM/I and TMI very similar for a given frequency, except around 22 GHz. Inter-calibration problem?

Weak frequency dependence and close to linear between 19 and 85 GHz

The 10 GHz stands apart, especially for H polarization (as this study focuses on surface-sensitive sounding channels, the 10 GHz will not be examined further).



THE METHOD (5/8)

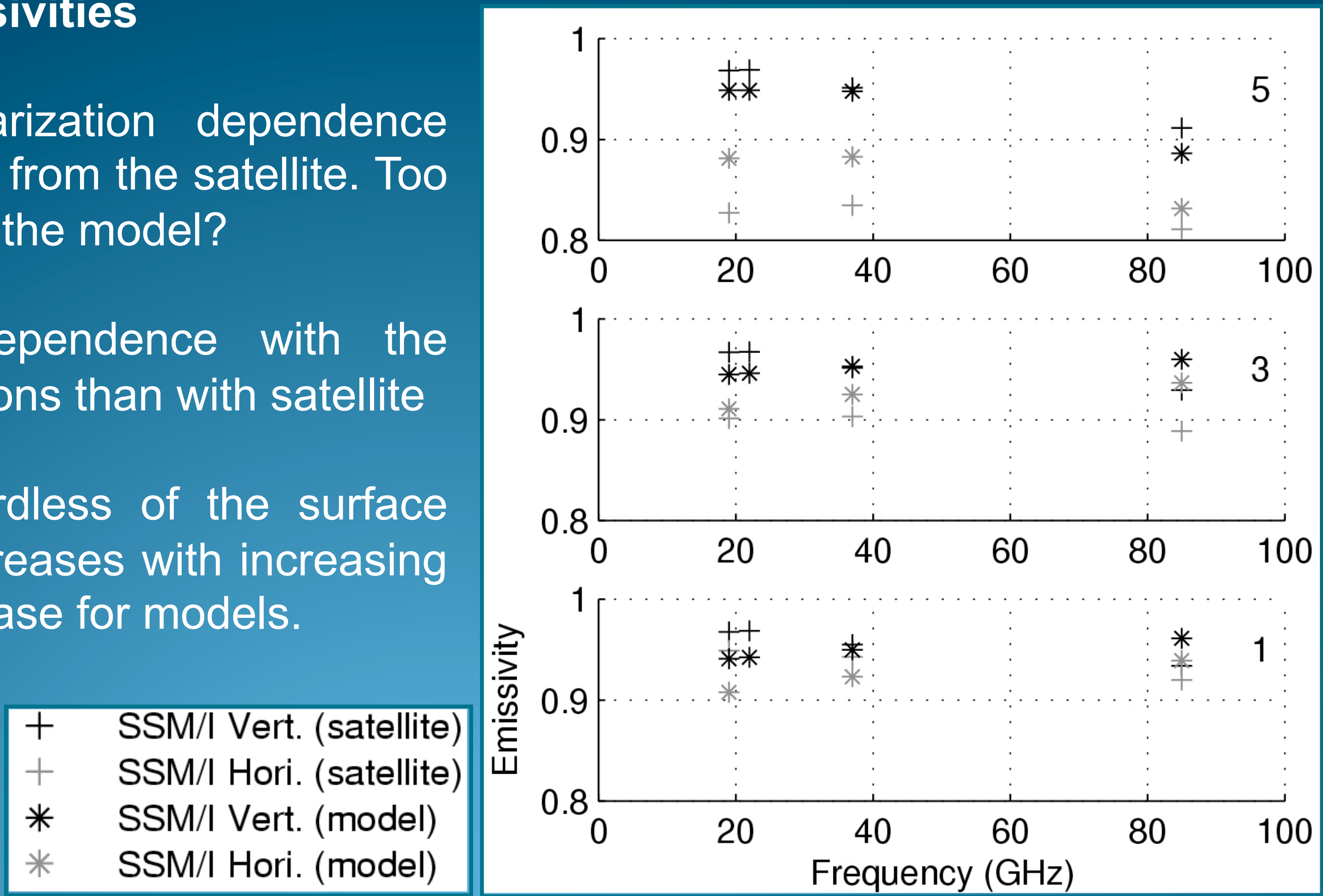
Analysis of the frequency dependence

Comparison between satellite-derived and modeled emissivities

Much smaller polarization dependence from the model than from the satellite. Too much ‘roughness’ in the model?

Less frequency dependence with the model over arid regions than with satellite

With satellite, regardless of the surface type, emissivity decreases with increasing frequency. Not the case for models.

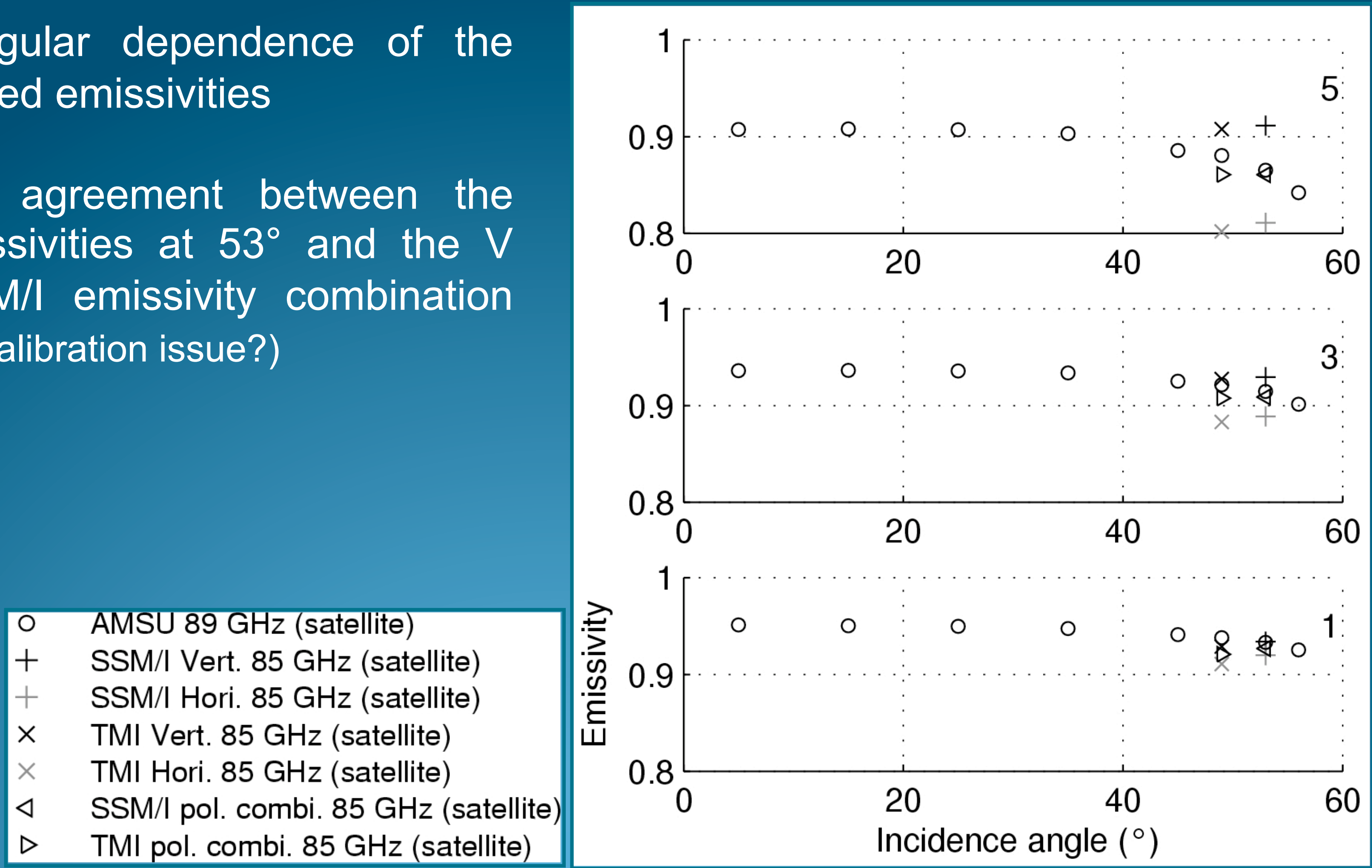


THE METHOD (6/8)

Analysis of the angular dependence

Smooth angular dependence of the AMSU derived emissivities

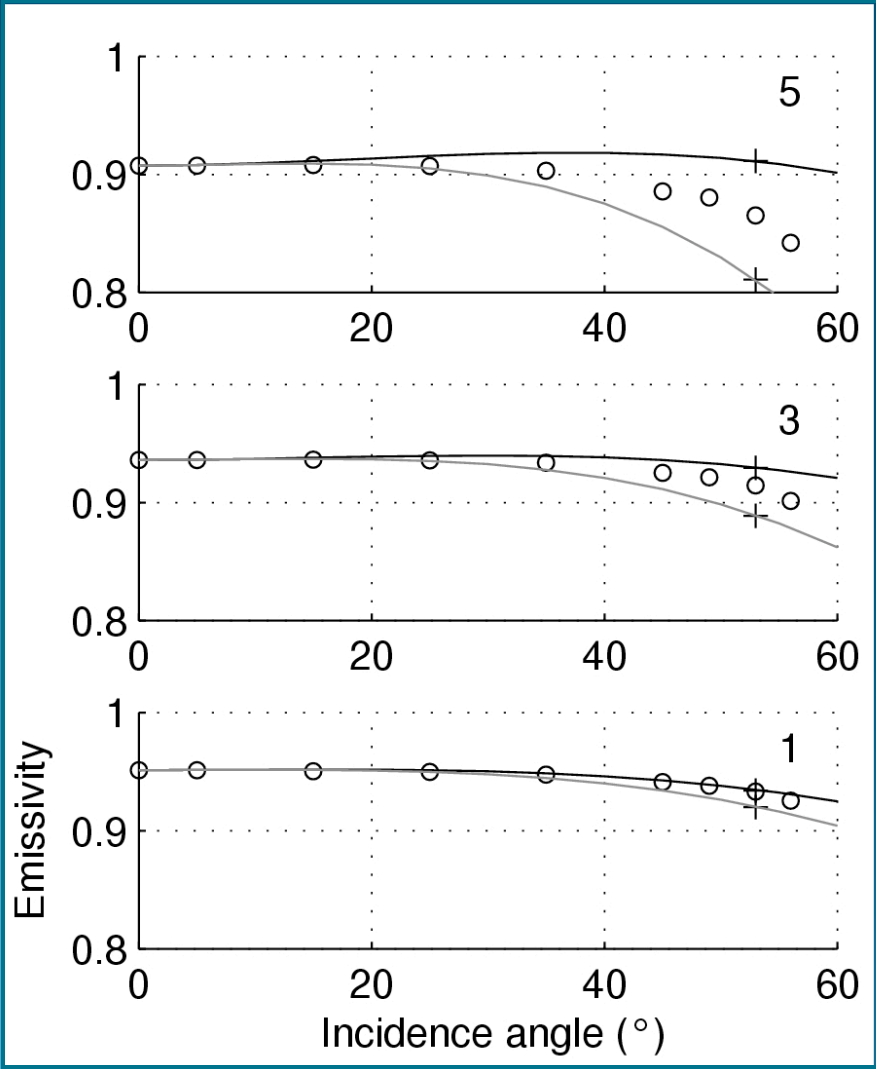
Very good agreement between the AMSU emissivities at 53° and the V and H SSM/I emissivity combination (with TMI, a calibration issue?)

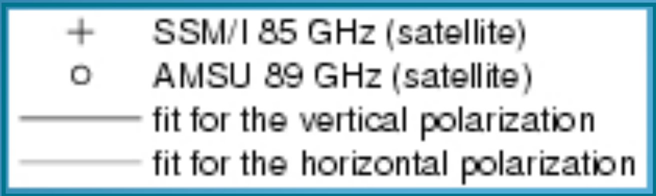


THE METHOD (7/8)

Analysis of the angular dependence

To describe the emissivity angular dependence, derivation of a polynomial function that fits both the SSM/I and AMSU derived estimates, for each surface type.





THE METHOD (8/8)

How the algorithm works:

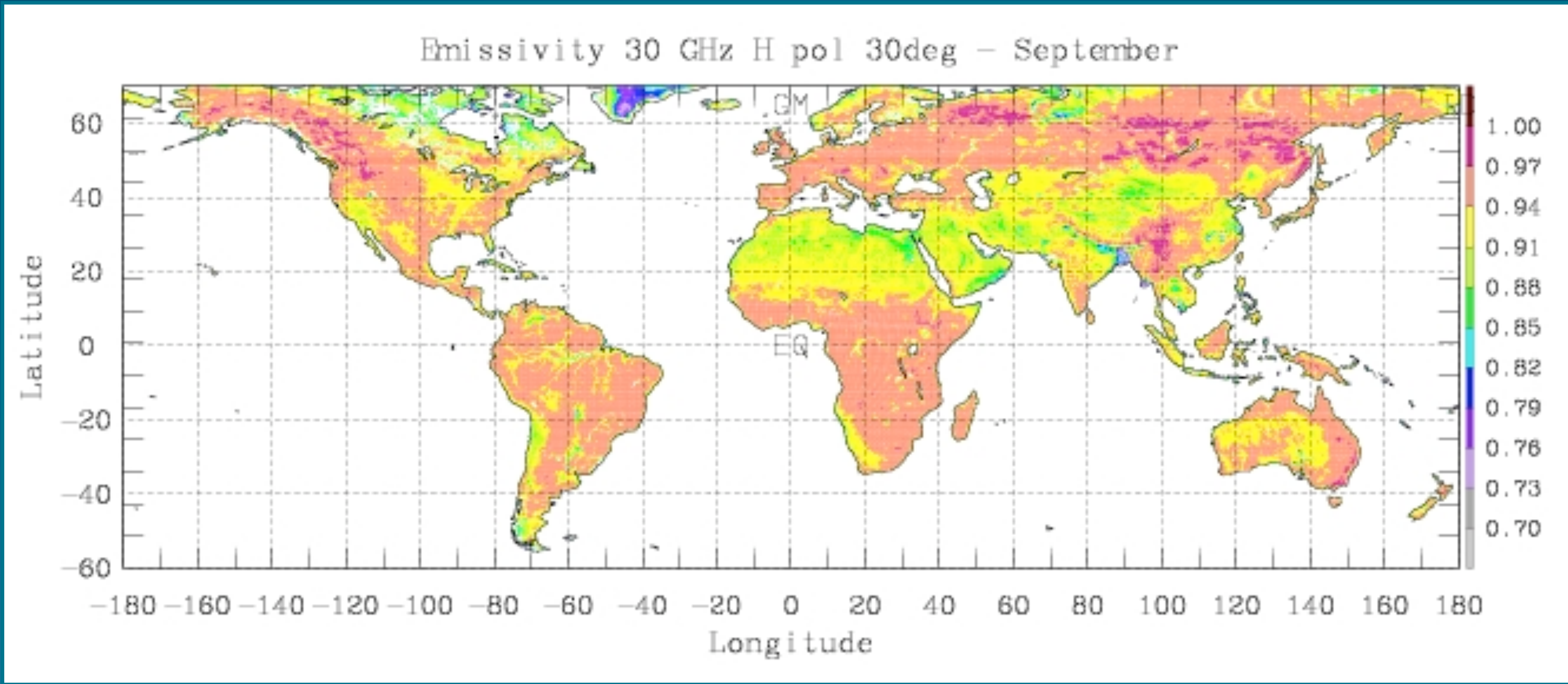
1) Selection by the user of
   - -a location on the Earth (lat, lon)
   - -a month
   - -a frequency, incidence angle, polarization

2) Search for the SSM/I emissivities in the climatological data base for that location and month.

3) Apply the frequency and angular parameterization to derive the emissivity for the observing conditions selected by the user (frequency, angle, and polarization).

THE RESULTS (1/8)

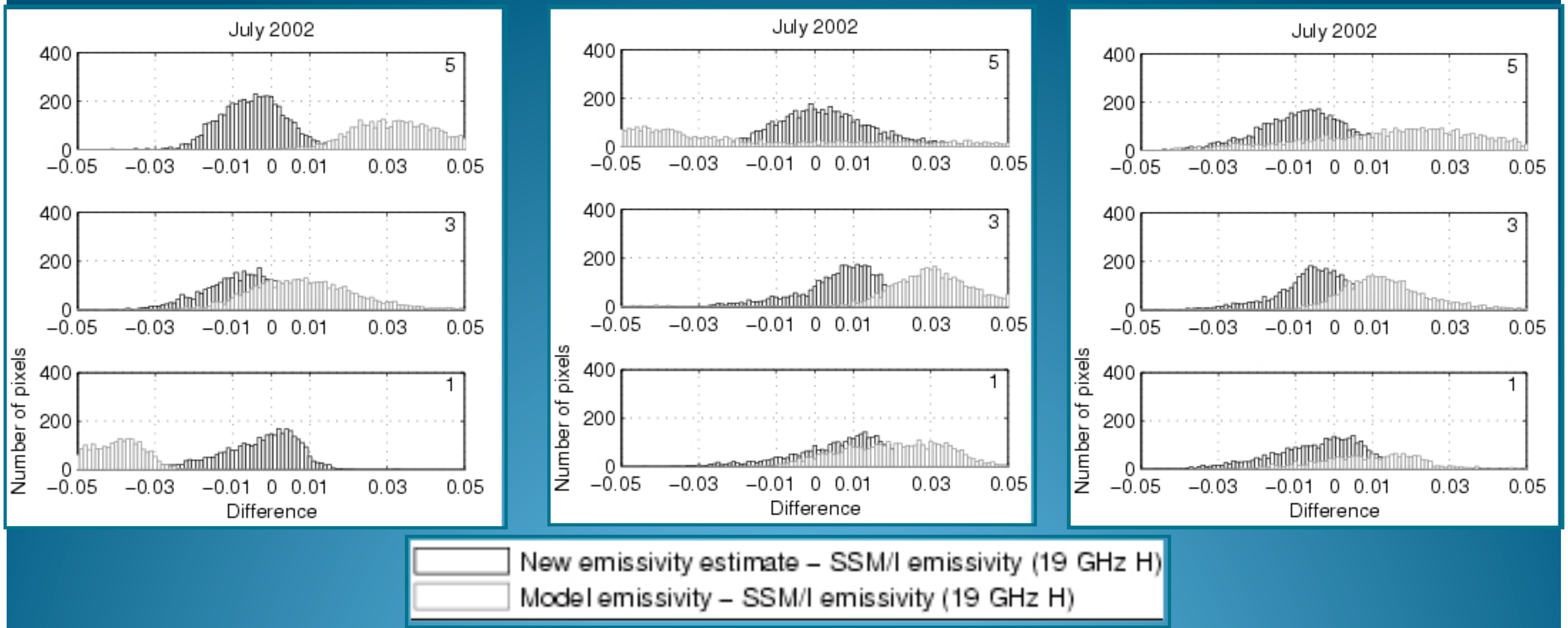
Global map of the estimated emissivity at 30 GHz, 30° incidence and horizontal polarization in September



THE RESULTS (2/8)

Histograms of the errors

SSM/I 19GHz H (53°) **AMSU 31.4GHz (5°)** **SSM/I 85GHz V (53°)**

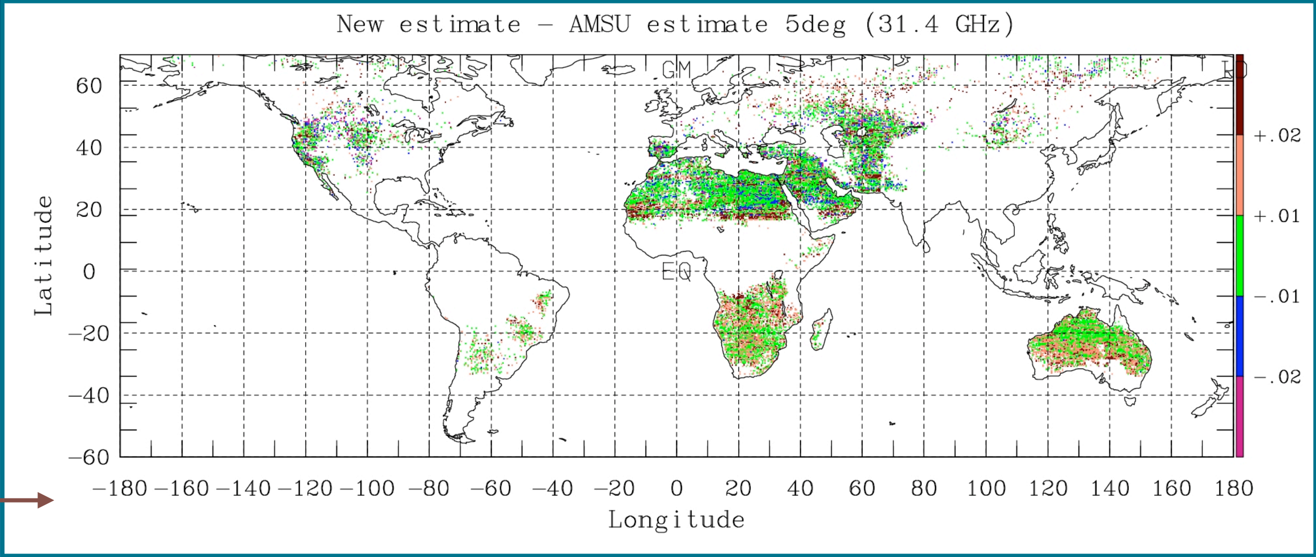


THE RESULTS (3/8)

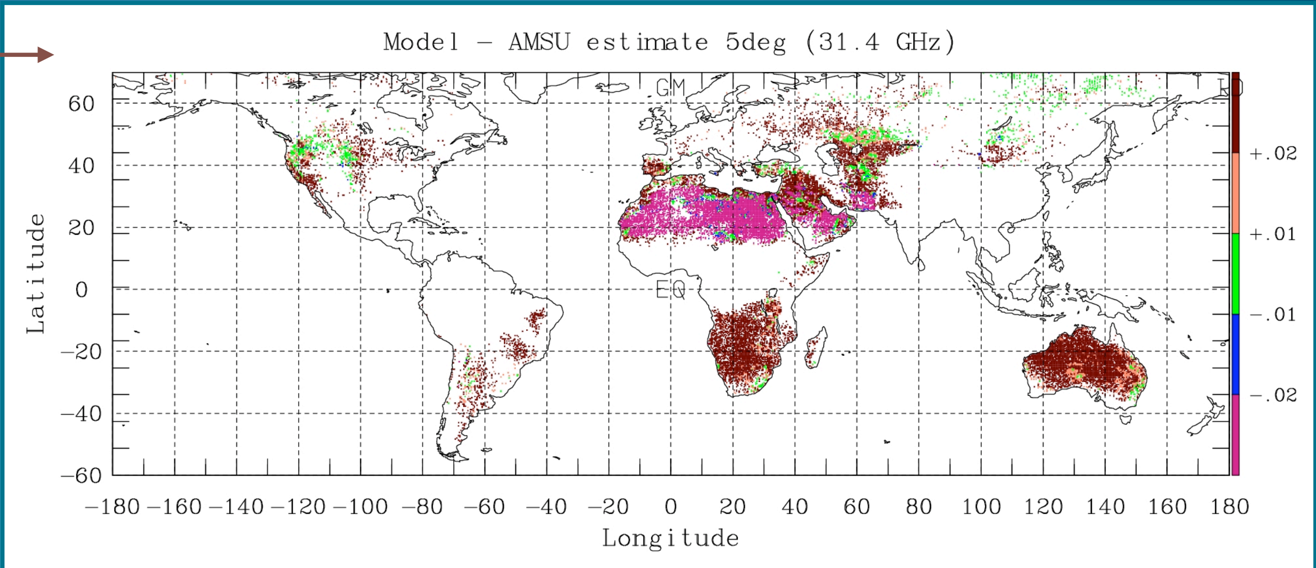
Map of the errors

Example at 31.4 GHz at 5° incidence angle

New estimate - AMSU derived estimate



Model - AMSU derived estimate



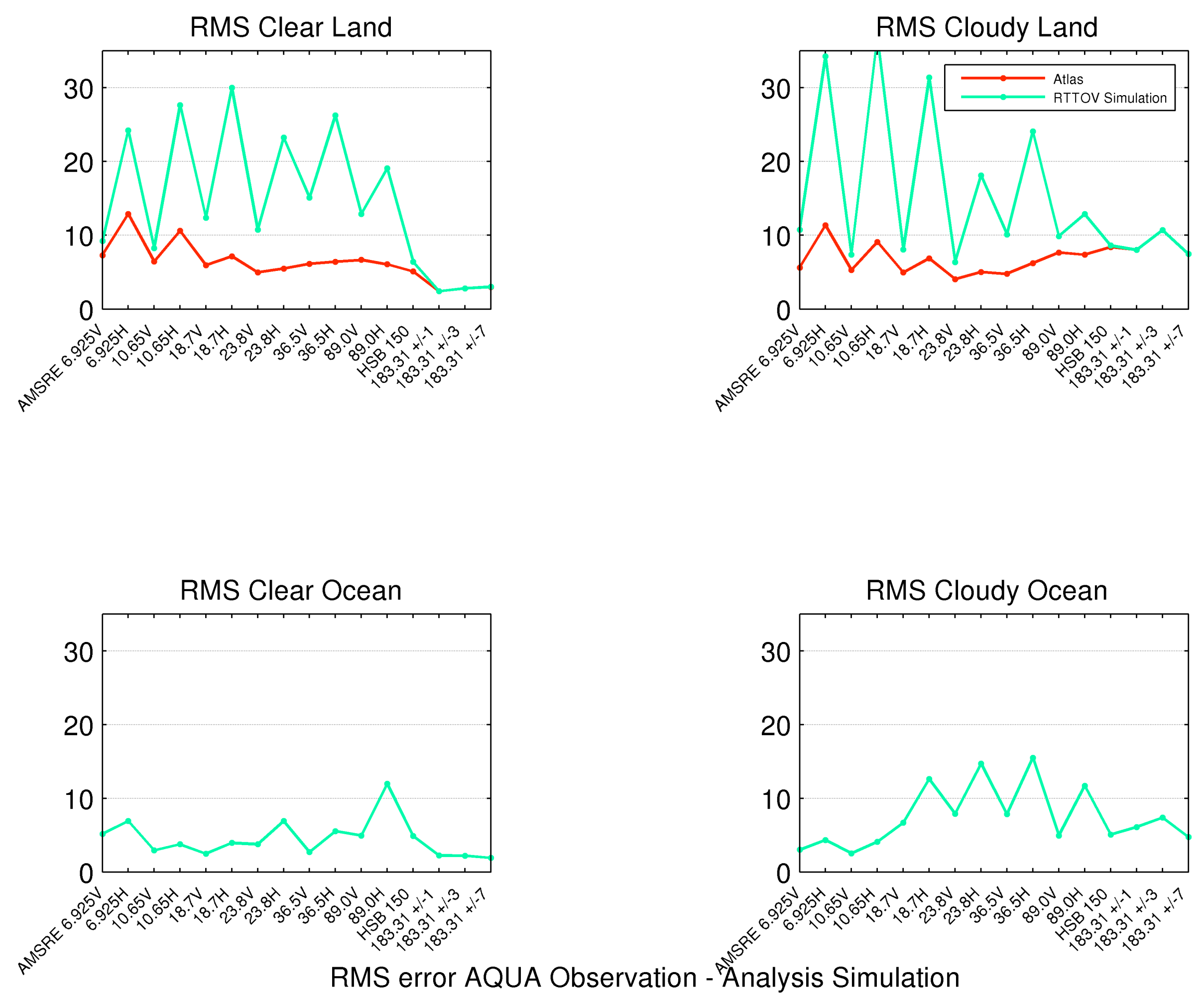
- Quality of the input parameters in the model?
- Ability of the model to represent the complexity of the radiation / surface interaction

THE RESULTS (4/8)

Coincidence between:

- **BT simulations:**
  - **ECMWF analysis**
  - **& RTTOV simulations**
- **BT observations**
  - **Aqua (AMSR-E & HSB)**

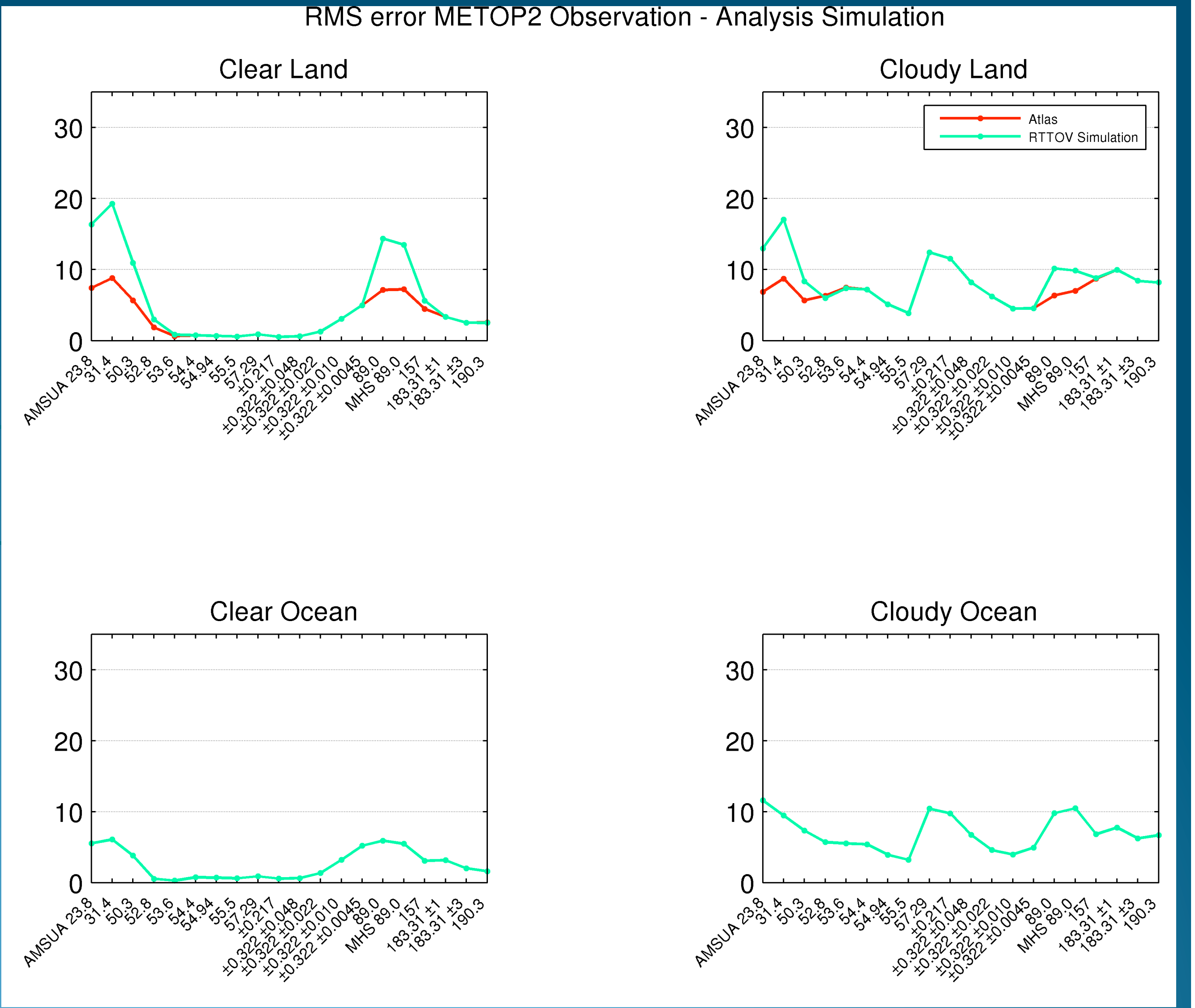
➔RMS errors with and without the emissivities



THE RESULTS (5/8)

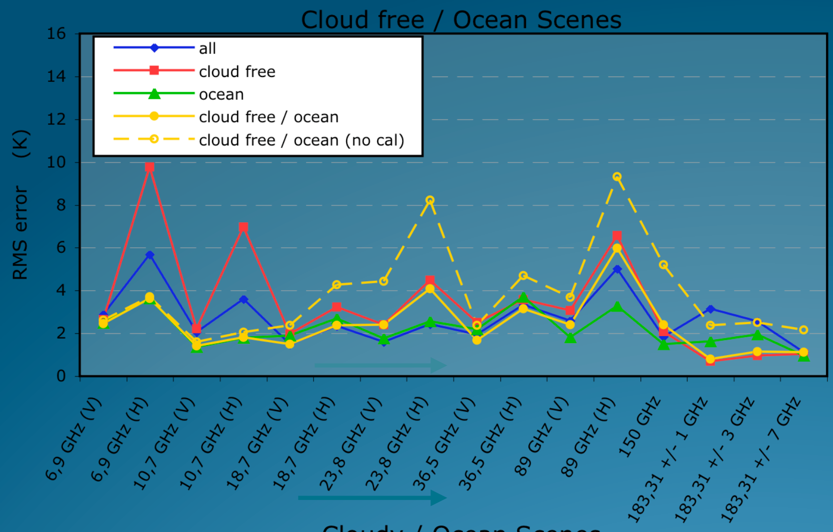
Similar experiment

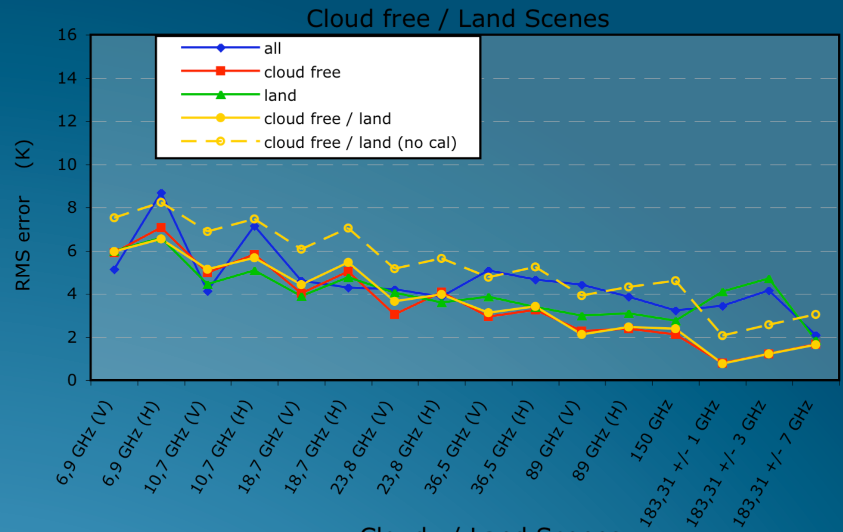
with BT observations from METOP:
AMSU-A & MHS

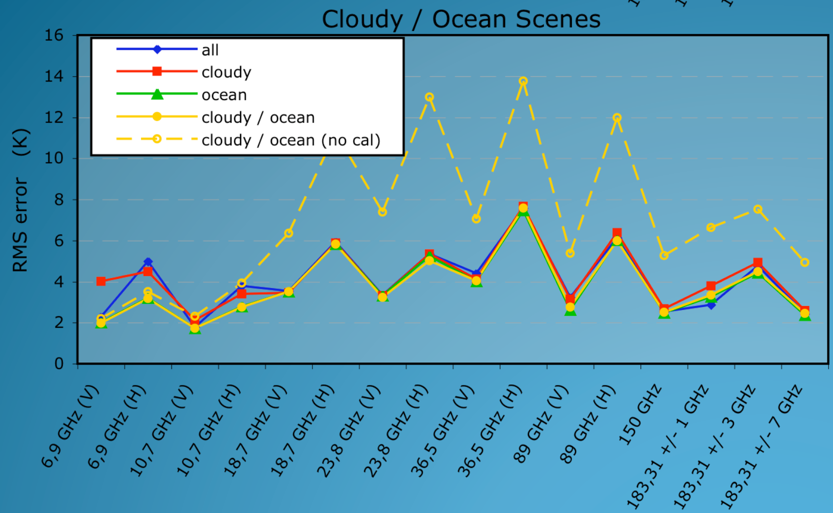


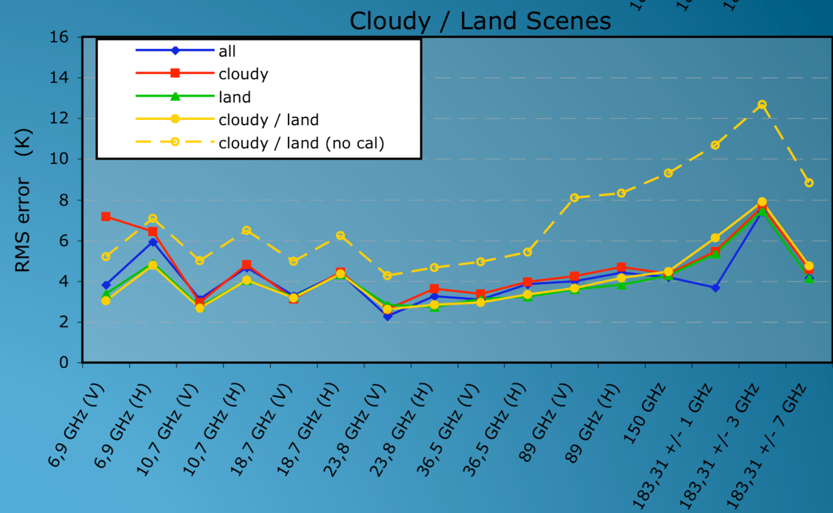
THE RESULTS (6/8)

If added to a calibration procedure: land/sea, clear/non precipitating situations can be simulated/inverted/assim.
➔ ex: Megha-Tropiques water vapour retrievals







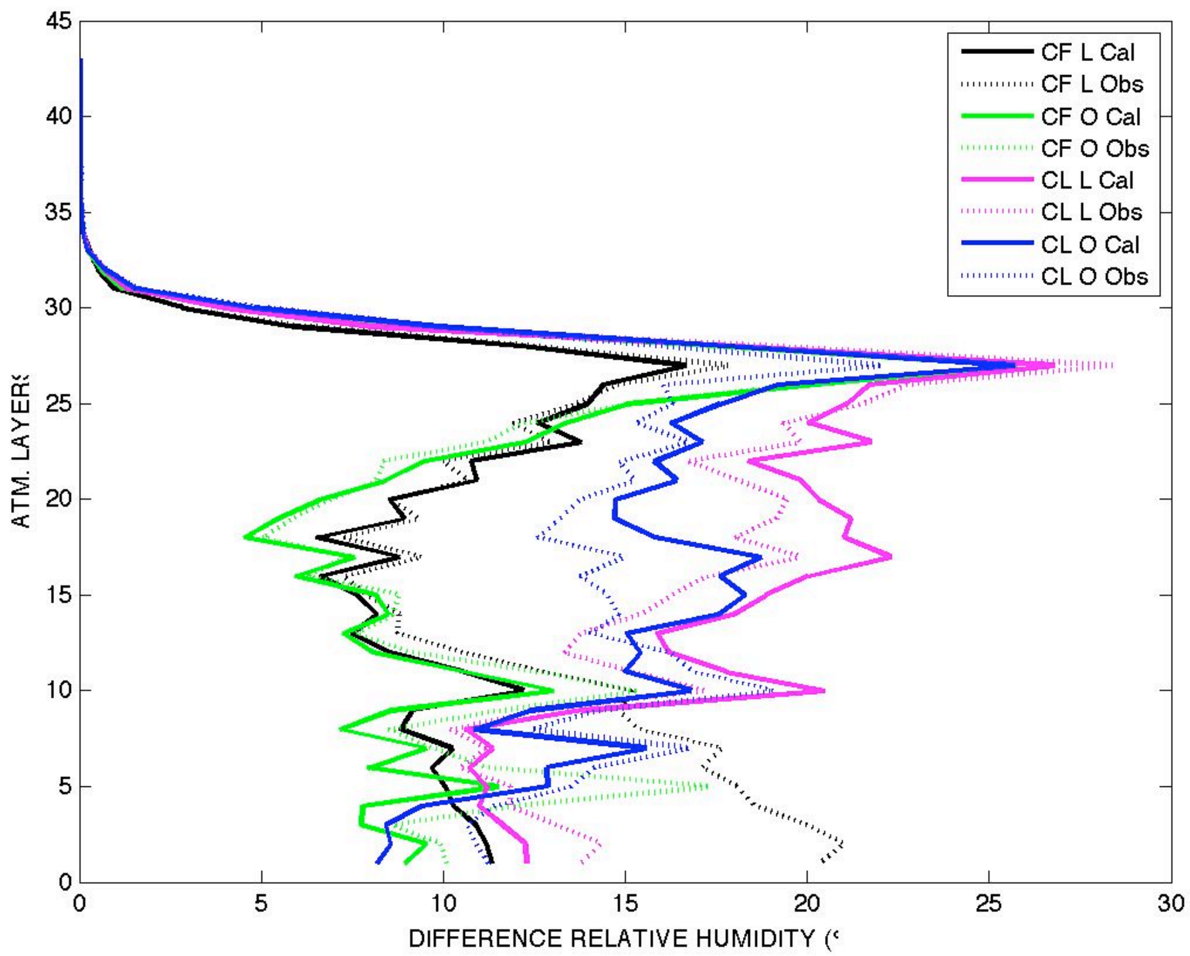


THE RESULTS (7/8) : WV retrieval from MT

Megha-Tropiques
- **Saphir (amsu-B)**
- **Madras**

Simultaneous retrieval of:
- **WV**
- **TCWV**
- **Ts**
- **Emissivity**

Similar results for land and ocean!



THE RESULTS (8/8) : validation on TB-space

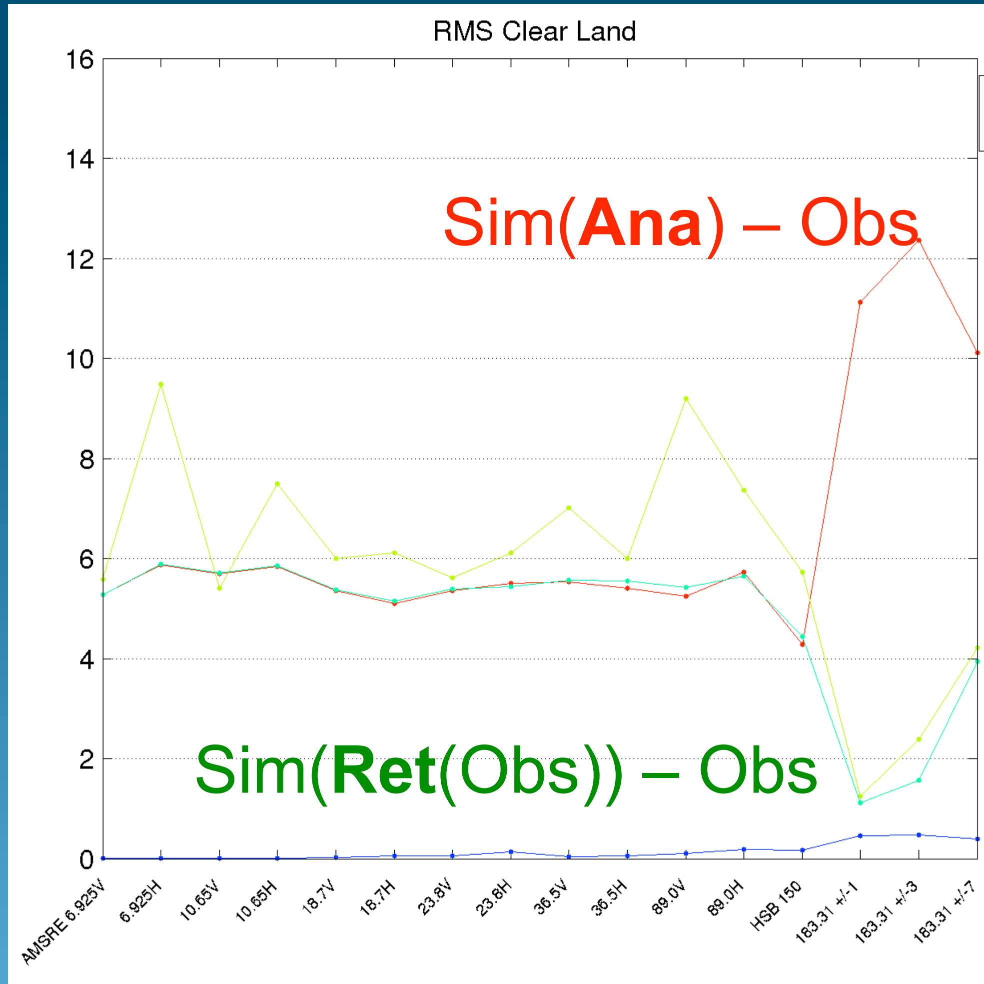
Simultaneous retrieval of:

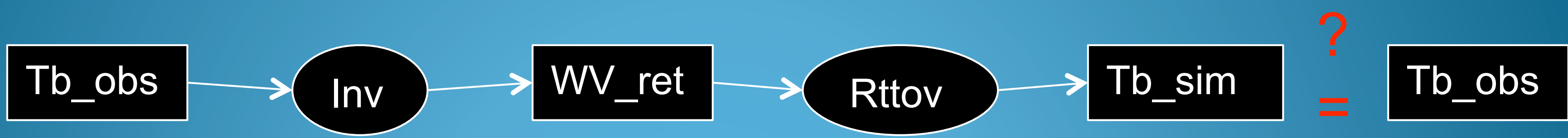
- **WV profile**
- **TCWV**
- **Ts**
- **Emissivity**

then RT simulations

Rk: It is very efficient to perform simultaneous retrieval of Ts and emis (Aires et al. 2001) using the emis atlas as a FG and an a priori Ts:

Much improvements on WV sensitive channels





RTTOV IMPLEMENTATION

The interpolator tool can work on any horizontal resolution

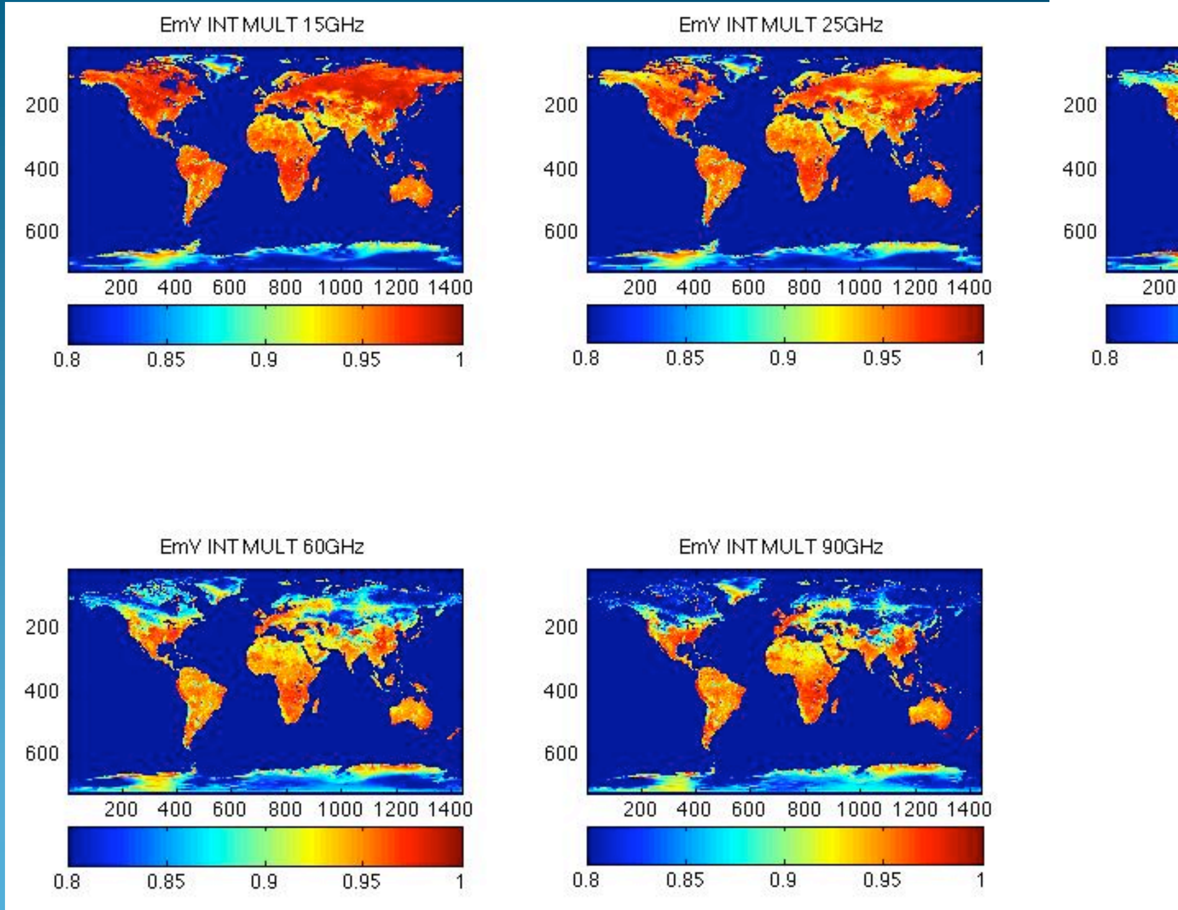
Nominal resolution of 0.25 equal-area and monthly

Provide Covariance matrix of the uncertainties

In Fortran 90

Different practical configur.

Available upon request

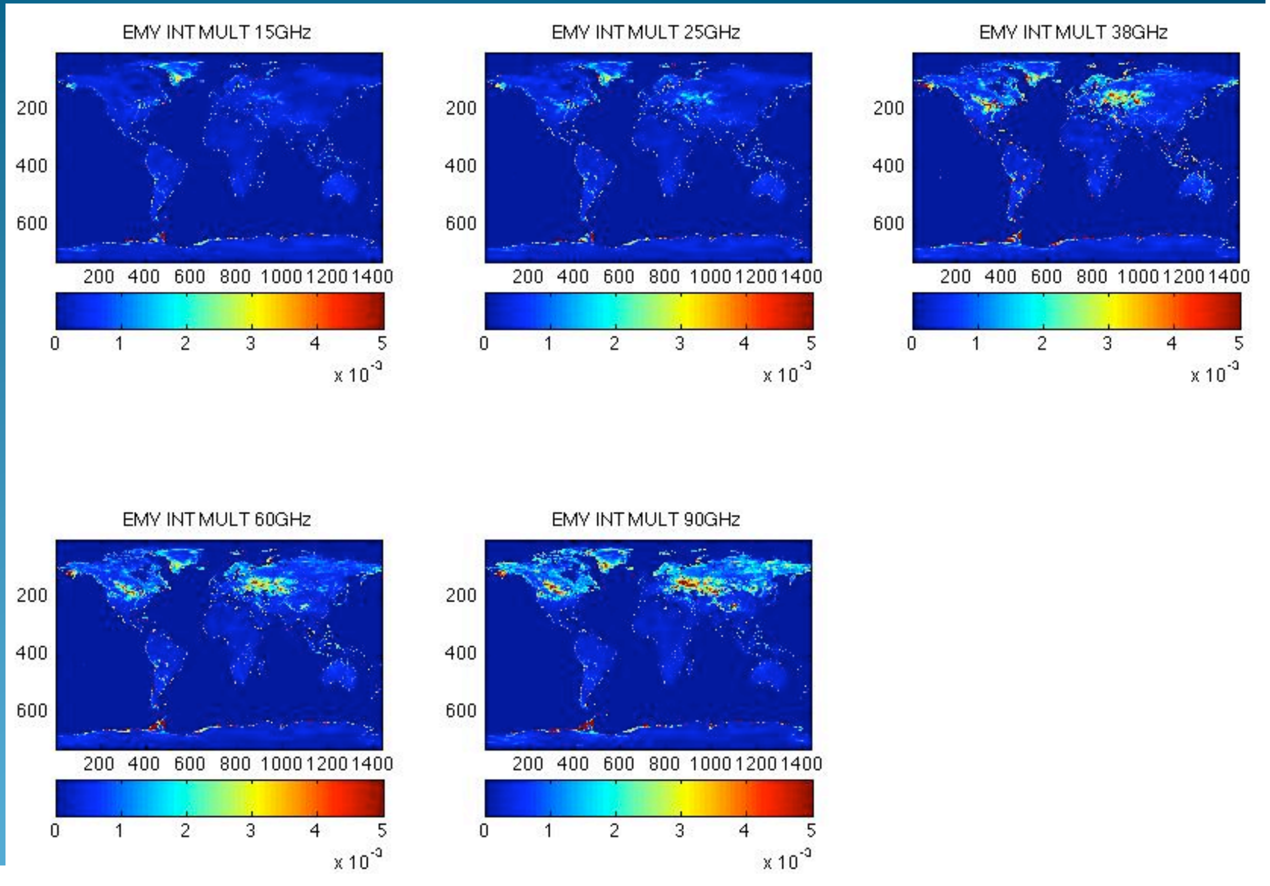


RTTOV IMPLEMENTATION: UNCERTAINTIES

Original SSM/I atlas possess 7×7 covariance matrix of uncertainties = C
➔ each location, 0.25°×0.25°, monthly
From statistics: identical correlations structure inside each of 10 surface classes, but different standard deviations.

Each emissivity input is a linear combination of the SSM/I emissivities so uncertainty on new estimates is N(0,F^t • C • F)

Important for assimilation purpose

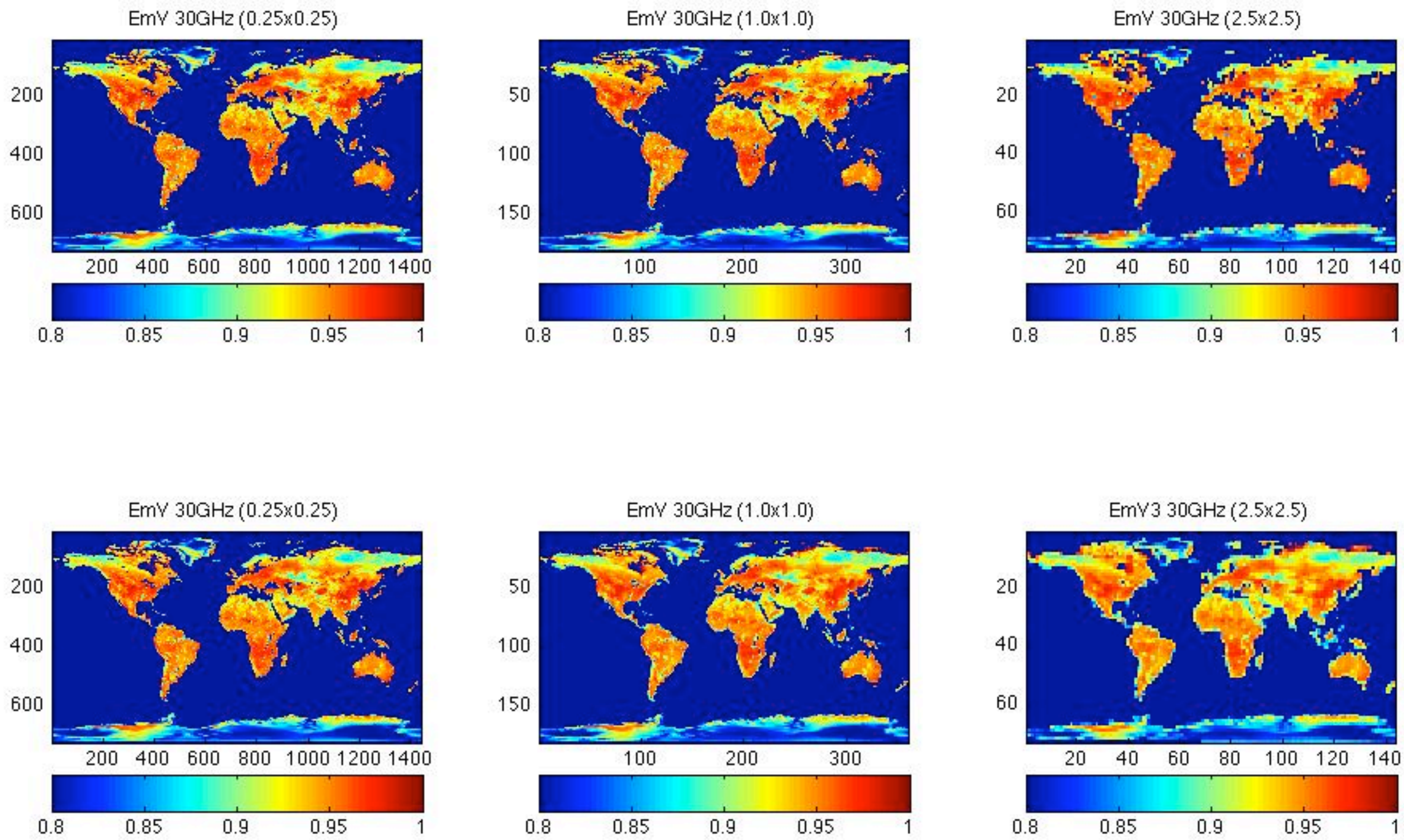


RTTOV IMPLEMENTATION: HORIZONTAL RESOLUTION

The interpolator tool can be used at any horizontal resolution

Unique original pixel

Multiple original pixel



CONCLUSION

A method developed to estimate global microwave emissivities in the 19-90 GHz range (potentially higher frequency), for all incidence angles and both orthogonal polarizations. It is anchored to a monthly-mean emissivity climatology derived from SSM/I observations over a decade.

- to be used as first guess for cloud clearing procedure and assimilation of close-to-the-surface sounding channels
- to be used as first guess in Ts retrievals
- for surface background estimate in precipitation and cloud retrievals
- to simulate the responses of future instruments

Comparisons performed with model outputs

Impact on RT simulations for AQUA (AMSRE/HSB) and METOP (ASMUA/MHS) show strong positive impact: recommend the use of emis atlas and Ts a priori FGs and then simultaneous retrieval or assimilation.

RTTOV implementation (Fortran90+Atlas) available upon request