Treatment of surface emissivity in satellit data assimilation: state-of-the-art and open issues

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METEO FRANCE
Toujours un temps d'avance

Outline

On the need for a good knowledge of emissivity

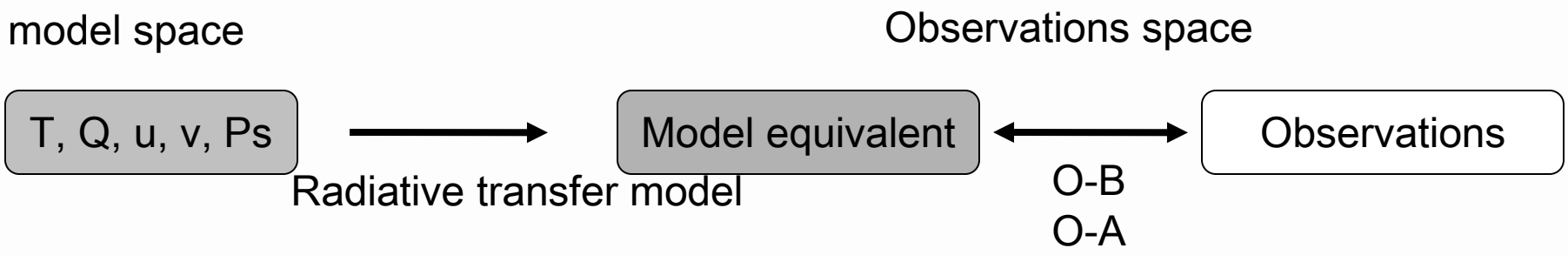
Selection of results from the RSMSP workshop

Surface emissivity modelling in the microwave spectrum

Can we use MW method for IR ?

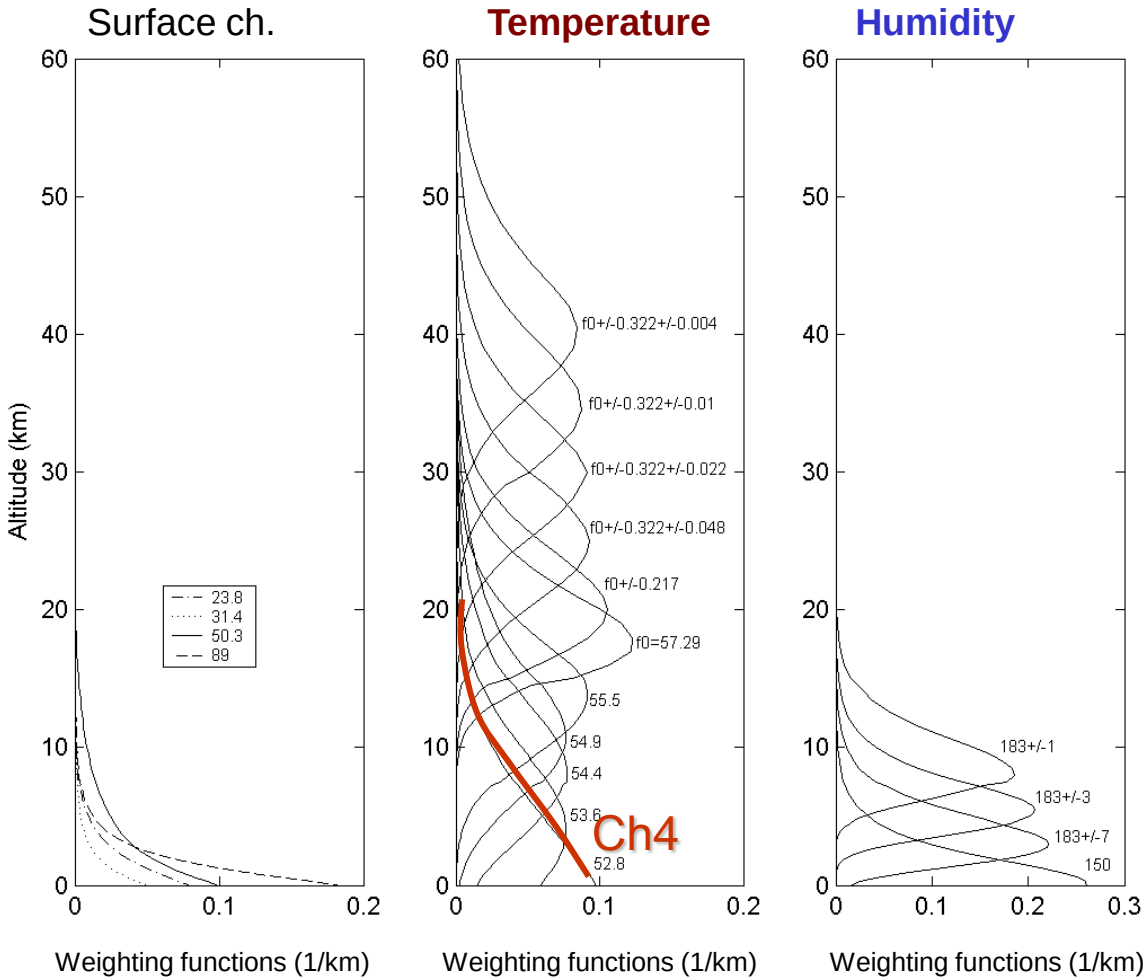
On the need for a good knowledge of emissivity

Satellites observations: Tbs (no direct measurements of T, Q)



- **Simulations of radiative transfert model**: atmospheric fields but also surface conditions
- **Data quality contrôle**: to reject cloudy/rainy data or for specific treatment in cloudy conditions
- Other conditions : bias correction, good specification of observation and model errors, ….

On the need for a good knowledge of emissivity



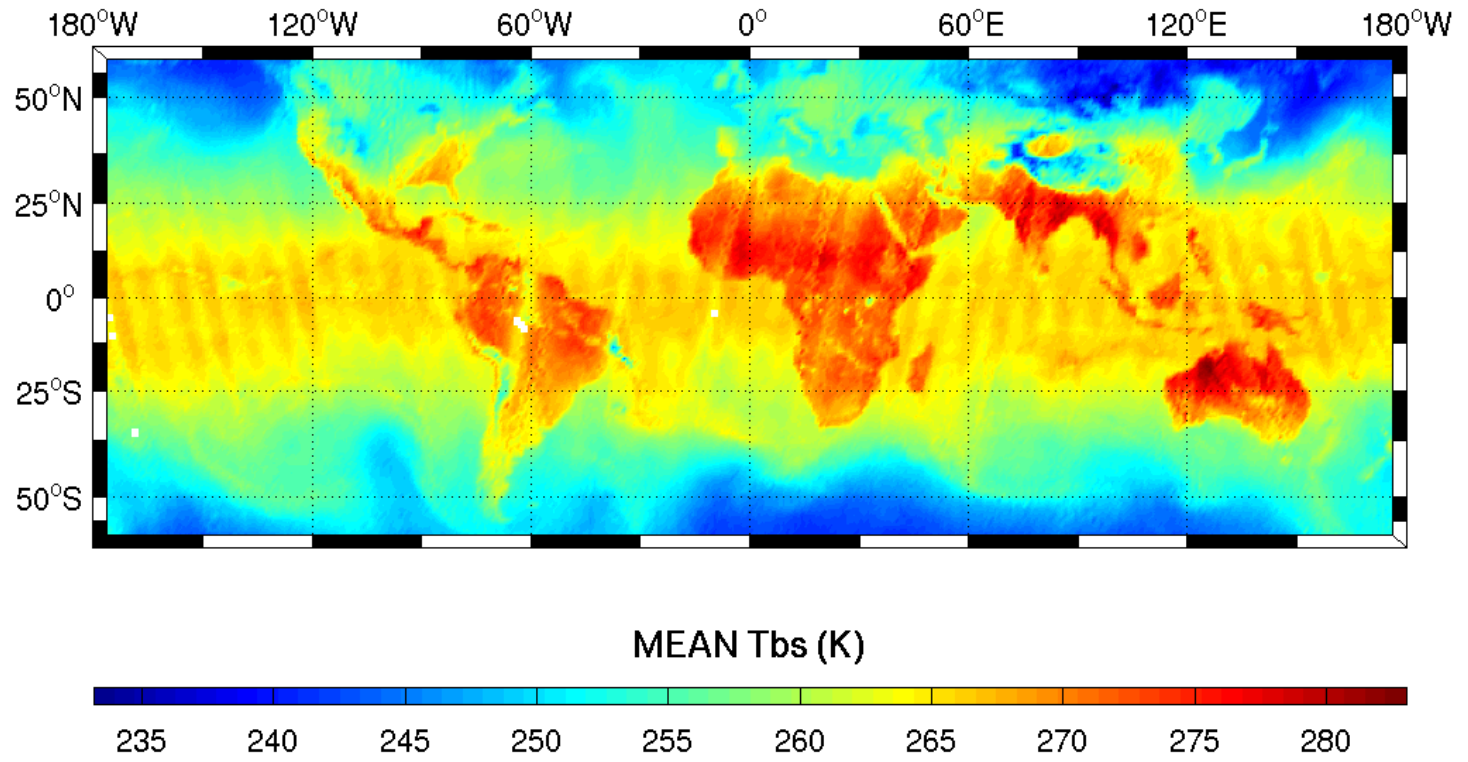
MSU-A/-B Weighting functions (standard atmosphere)

Effect of the surface

On the need for a good knowledge of emissivity

To assimilate surface sensitive channels: one should be able to separate the surface effect from the atmospheric signal

AMSU-A, ch4: 52.8 GHz, 08/04/2010



On the need for a good knowledge of emissivity

in-situ measurements

Airborne measurements

From satellites

Modeling

On the need for a good knowledge of emissivity

in-situ measurements

Airborne measurements

From satellites

Modeling

Selection of results from the RSMSP workshop

4th edition of the RSMSP (Remote Sensing and Modelling of Surface Propreties) workshop: Grenoble
14-16 March

Assimilation of surface sensitive observations: IR/MW, active/passive remote sensing, methods for handling the surface emissivity and spectral temperature; quality control issues and methodology; atmospheric variable sensitivity studies; and observation/background error specification.

Land surface assimilation schemes: State of the operational land surface modelling systems and recent developments; sensitivity studies of surface model parameters to remotely sensed data; outcomes of SMOS, GPM, SMAP missions; calibration issues, variable transforms or PDF matching techniques

Radiative transfer developments and emissivity/reflectivity models: VIS/IR/MW, all surface types, review of current available parameterization for forward modelling the surface boundary for remotely sensed data; description of available land emissivity databases/atlases (MW and IR); intercomparison/validation of physical models and retrieved emissivities (MW and IR, including land, ocean, and ice surfaces).

Retrievals of surface parameters: sea surface wind, salinity, soil moisture, canopy parameters, vegetation water content, sea-ice concentration, snow water equivalent, etc. and the resulting surface emissivity/reflectance spectra.

Other relevant topics

Selection of results from the RSMSP workshop

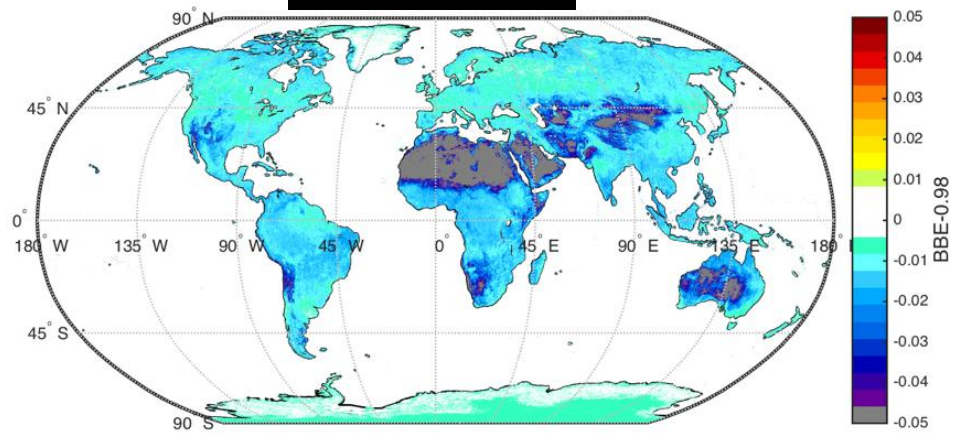
Presentation of the CAMEL database (Borbas et al. 2016)

CAMEL = **C**ombined
ASTER and
MODIS
Emissivity over
Land

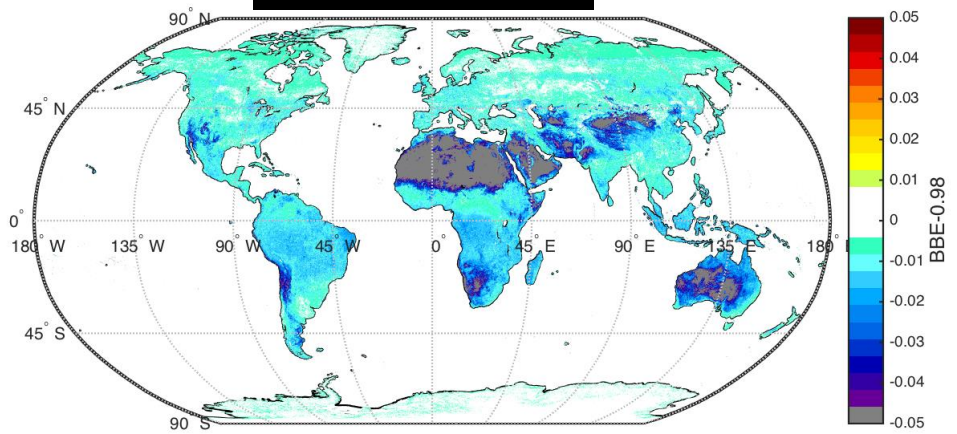
Selection of results from the RSMSP workshop

BBE – 0.980 for 8.0-13.5µm

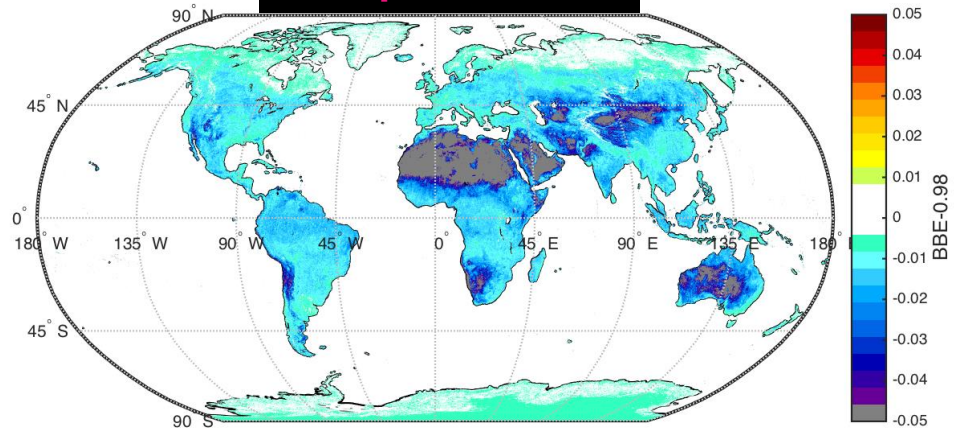
Sept 2002



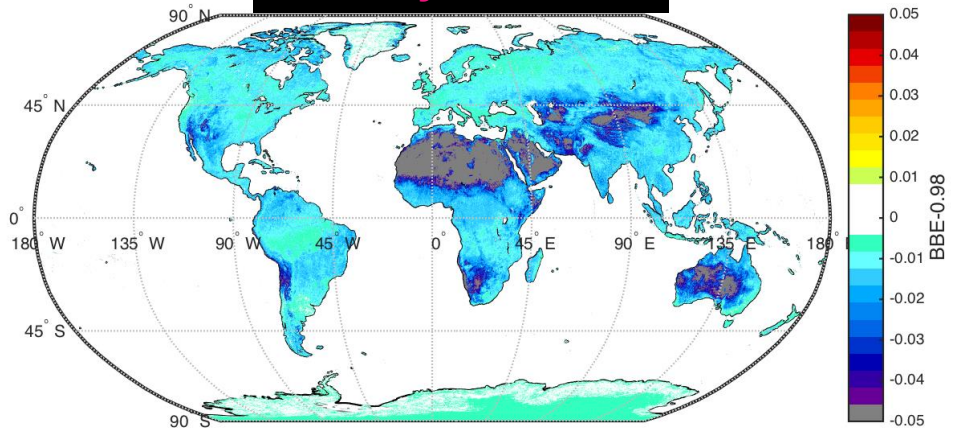
Jan 2003



Apr 2003



July 2003

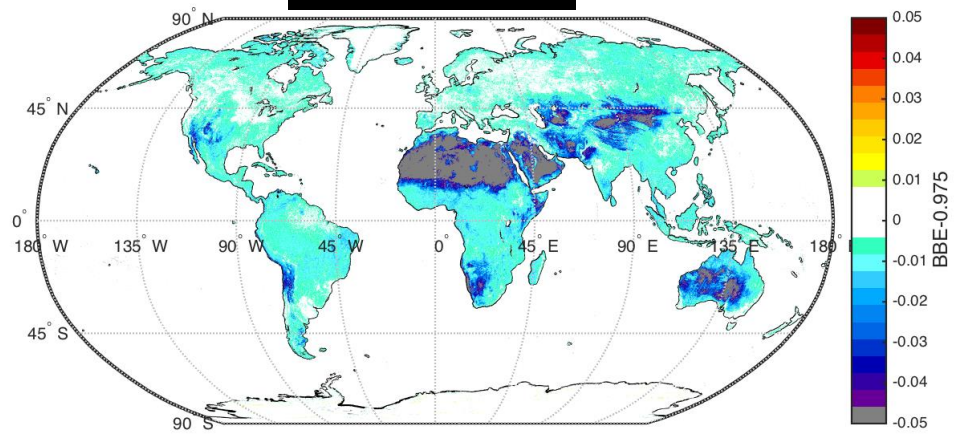


Borbas et al. 2016

Selection of results from the RSMSP workshop

BBE – 0.975 for 8.0-13.5µm

Sept 2002



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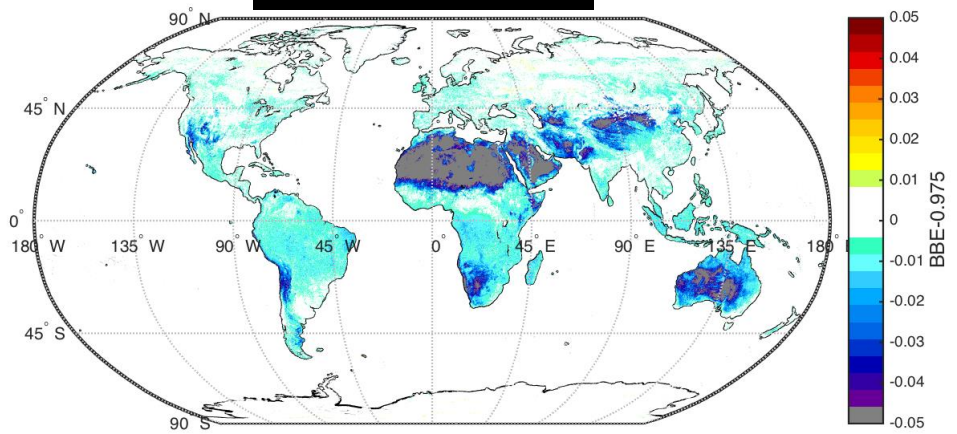

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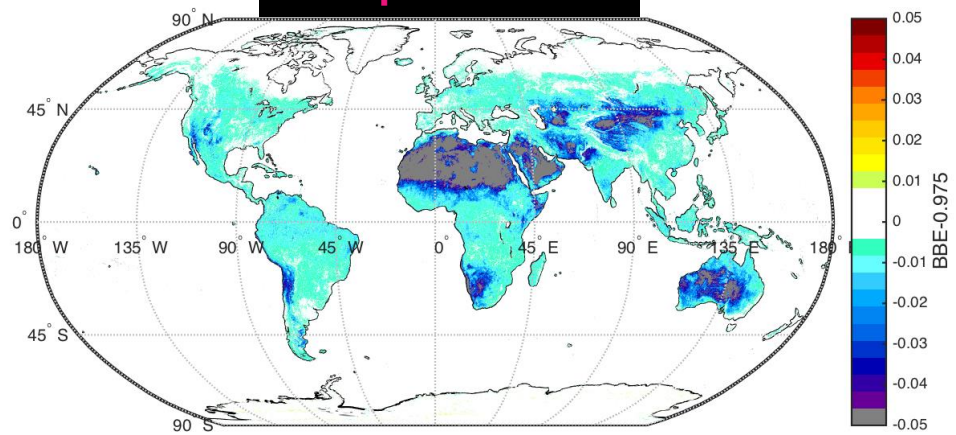

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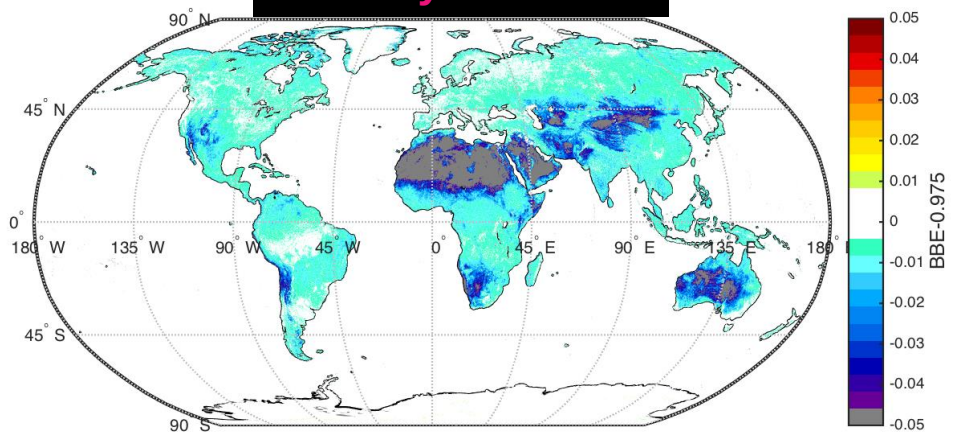

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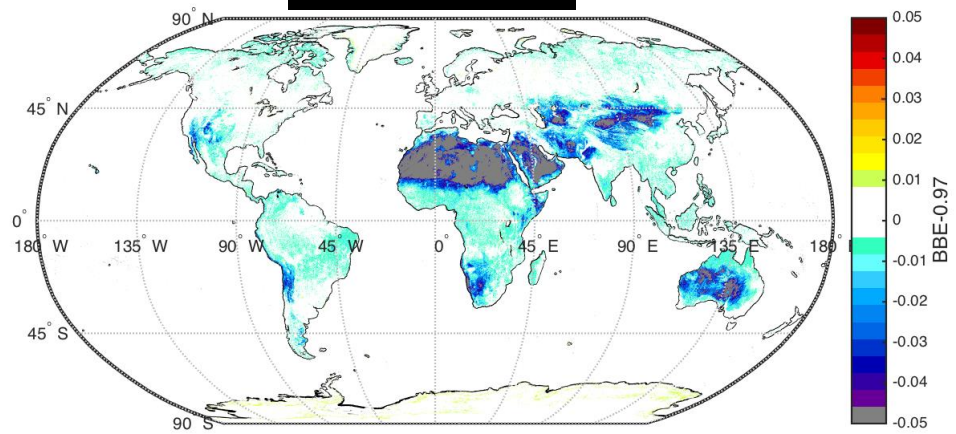
Borbas et al. 2016

Selection of results from the RSMSP workshop

BBE – 0.970 for 8.0-13.5µm

Sept 2002



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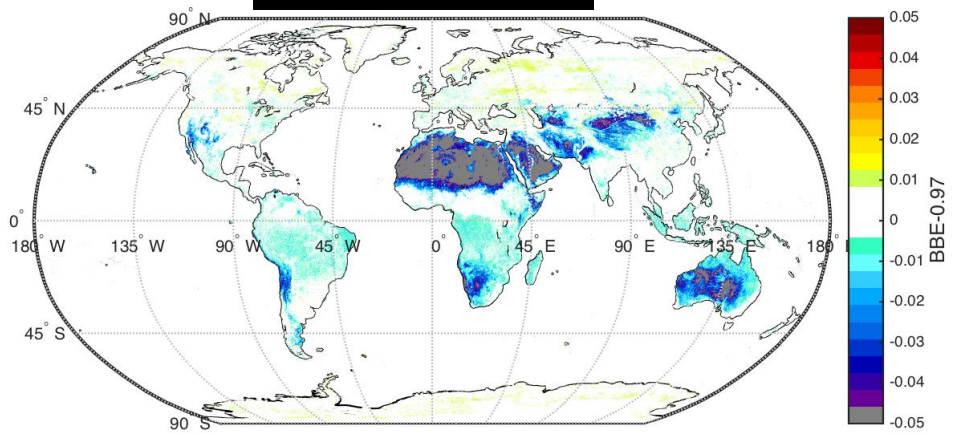

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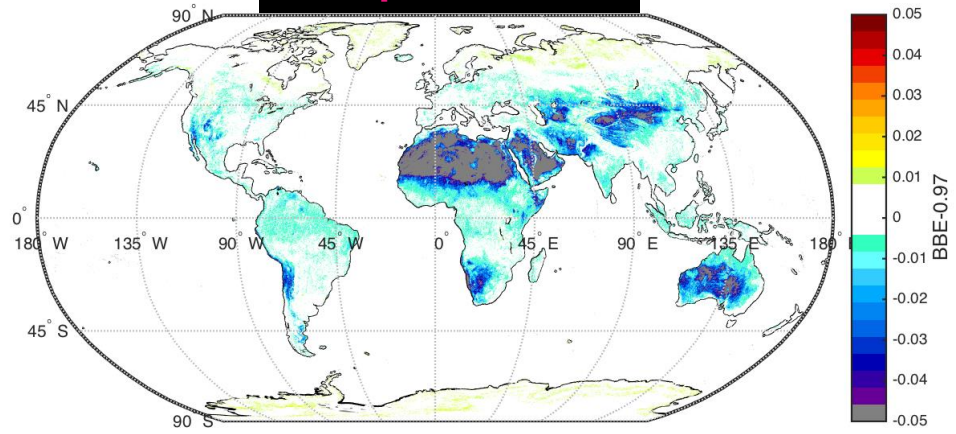

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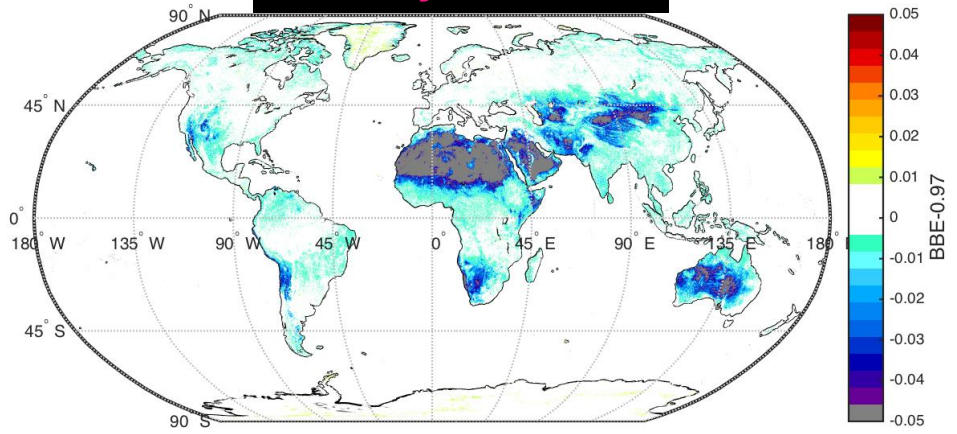
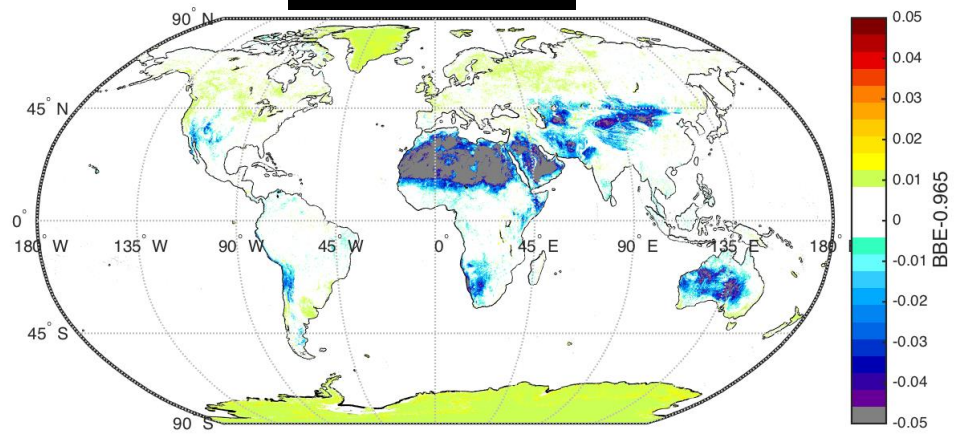


Borbas et al. 2016

Selection of results from the RSMSP workshop

BBE – 0.965 for 8.0-13.5µm

Sept 2002



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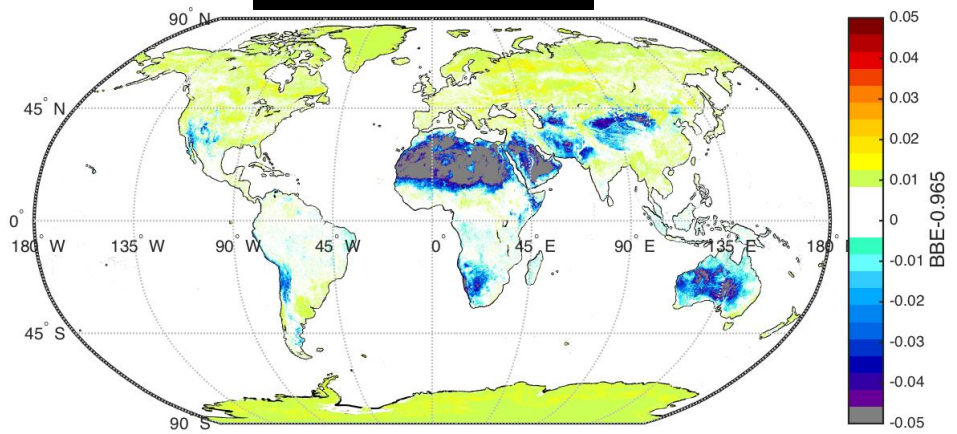

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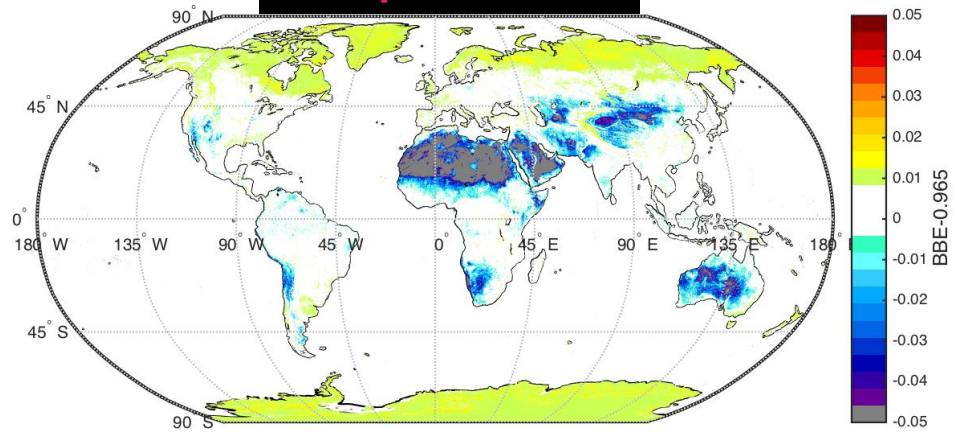

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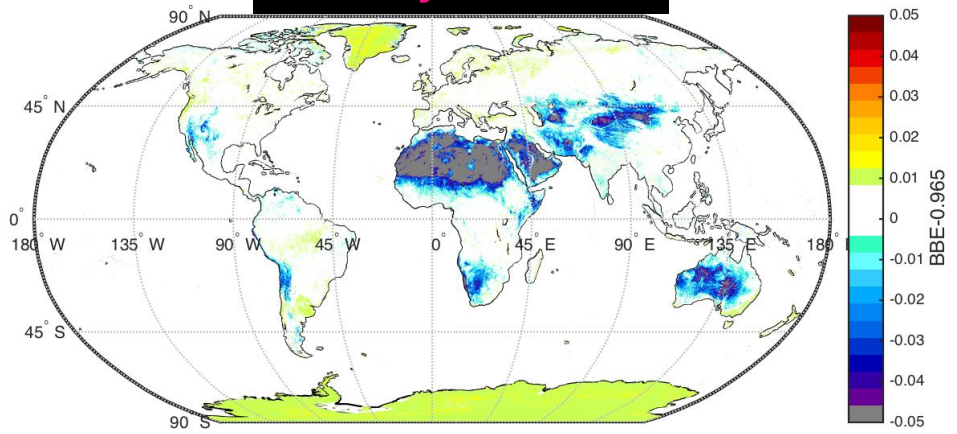

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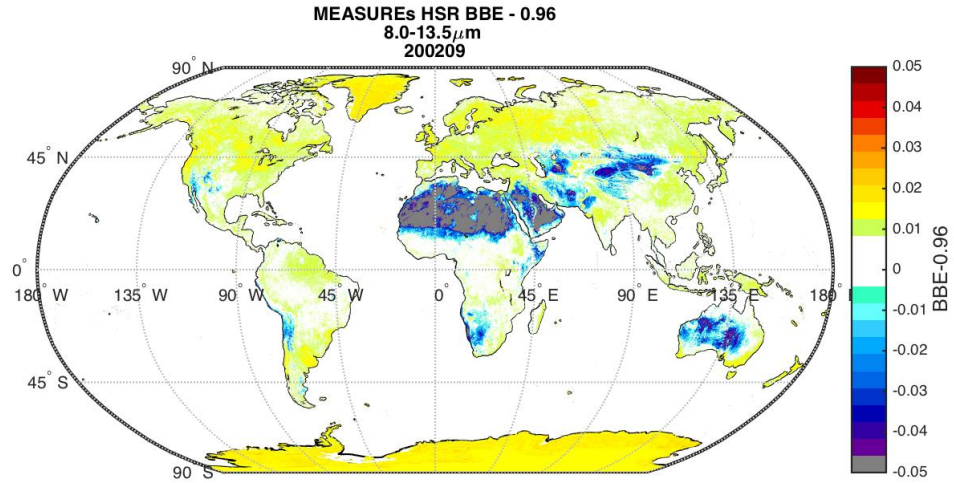
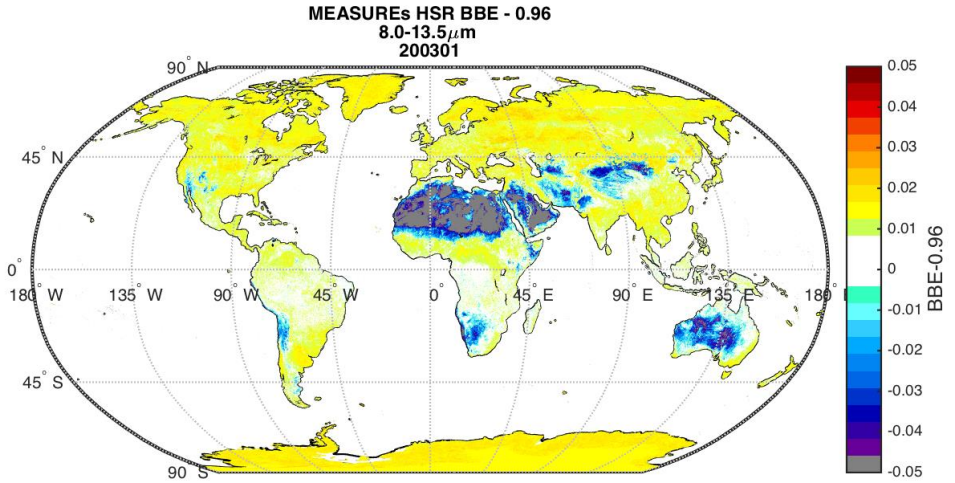
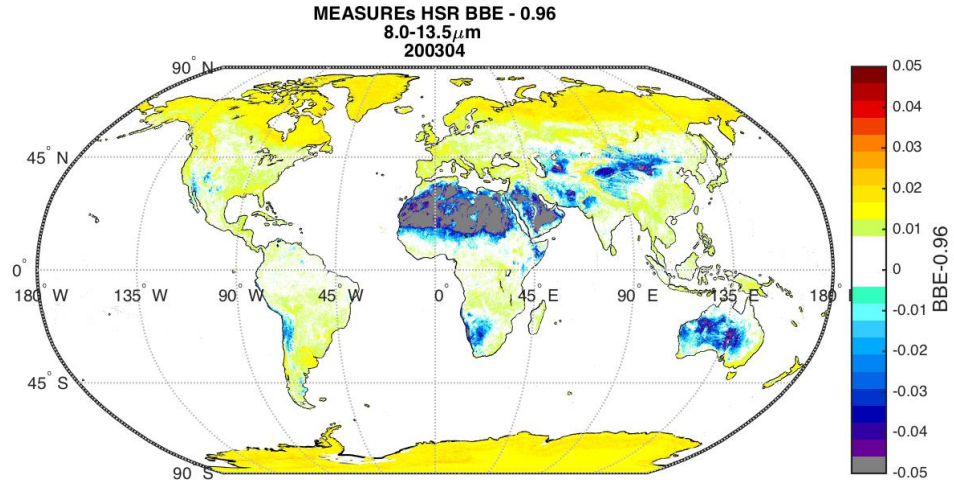
Borbas et al. 2016

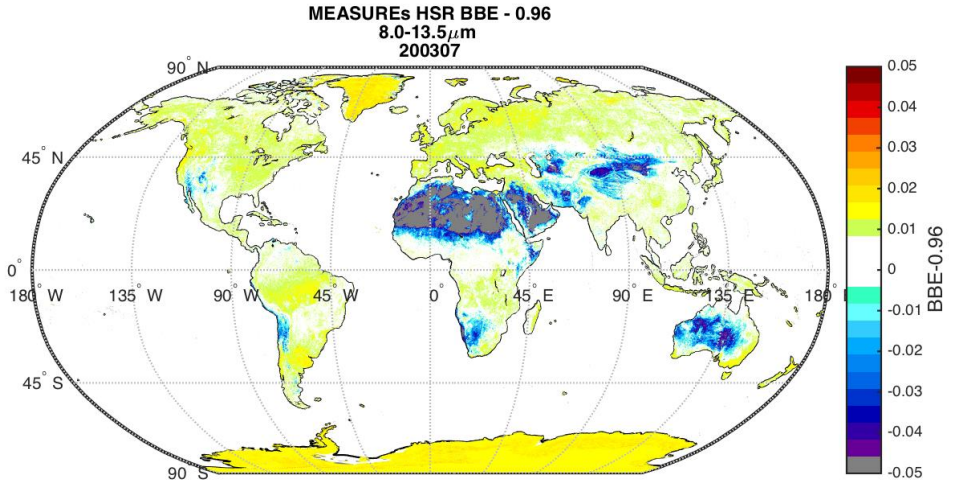
Selection of results from the RSMSP workshop

BBE – 0.960 for 8.0-13.5µm









Borbas et al. 2016

Development of a Dynamic Infrared Land Surface Emissivity Atlas based on IASI Retrievals at the Met-Office (Gray et al. 2016)

NRT atlas
- up-to-date information
- short term variability

• assimilation surface sensitive IR channels over land for NWP (FG for 1dvar)

• apply to other IR instruments such as SEVIRI

• improve Tskin accuracy

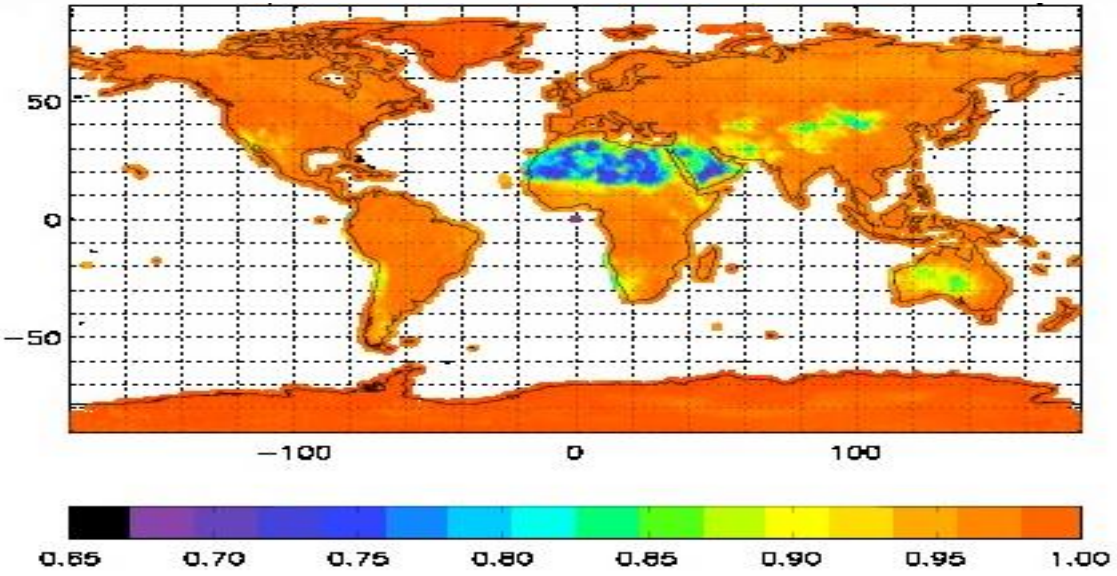
Development of a Dynamic Infrared Land Surface Emissivity Atlas based on IASI Retrievals at the Met-Office (Gray et al. 2016)

1dvar Retrieval of Emissivity

- $\varepsilon(\lambda)$ retrievals from estimation of PC coefficients in 1dvar
- high dimensional data set reconstructed from PC set of reduced dimensionality
- skin temperature, cloud top pressure and cloud fraction also retrieved

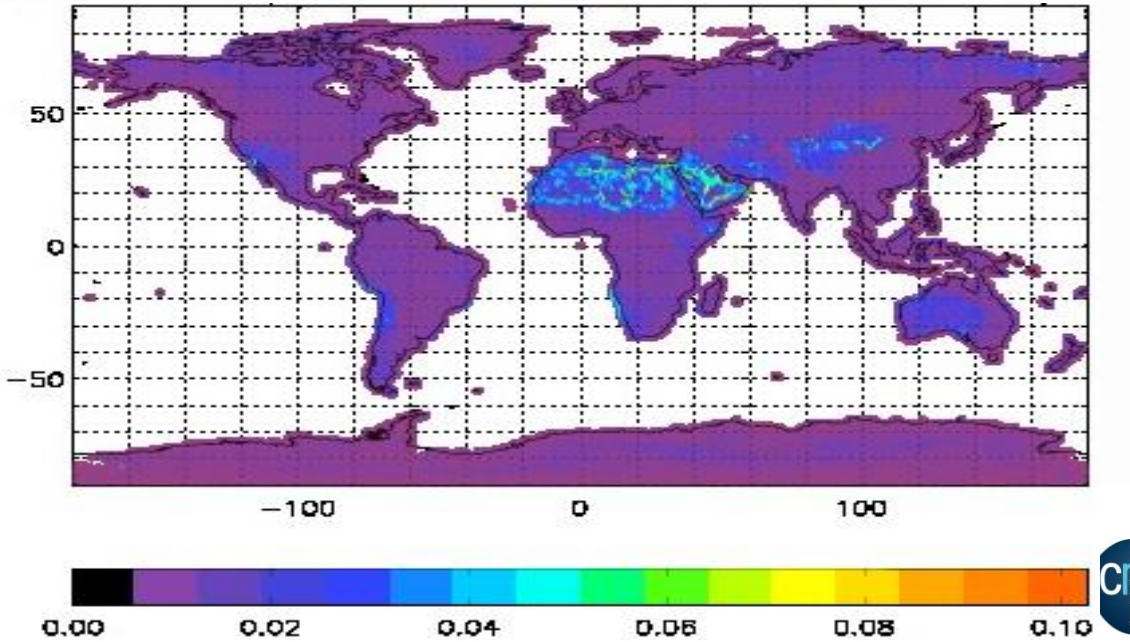
Selection of results from the RSMSP workshop

Atlas construction IASI chan.1884 (8.96μm)



Emissivity

Gray et al. 2016



$\sigma_{emissivity}$

Selection of results from the RSMSP workshop

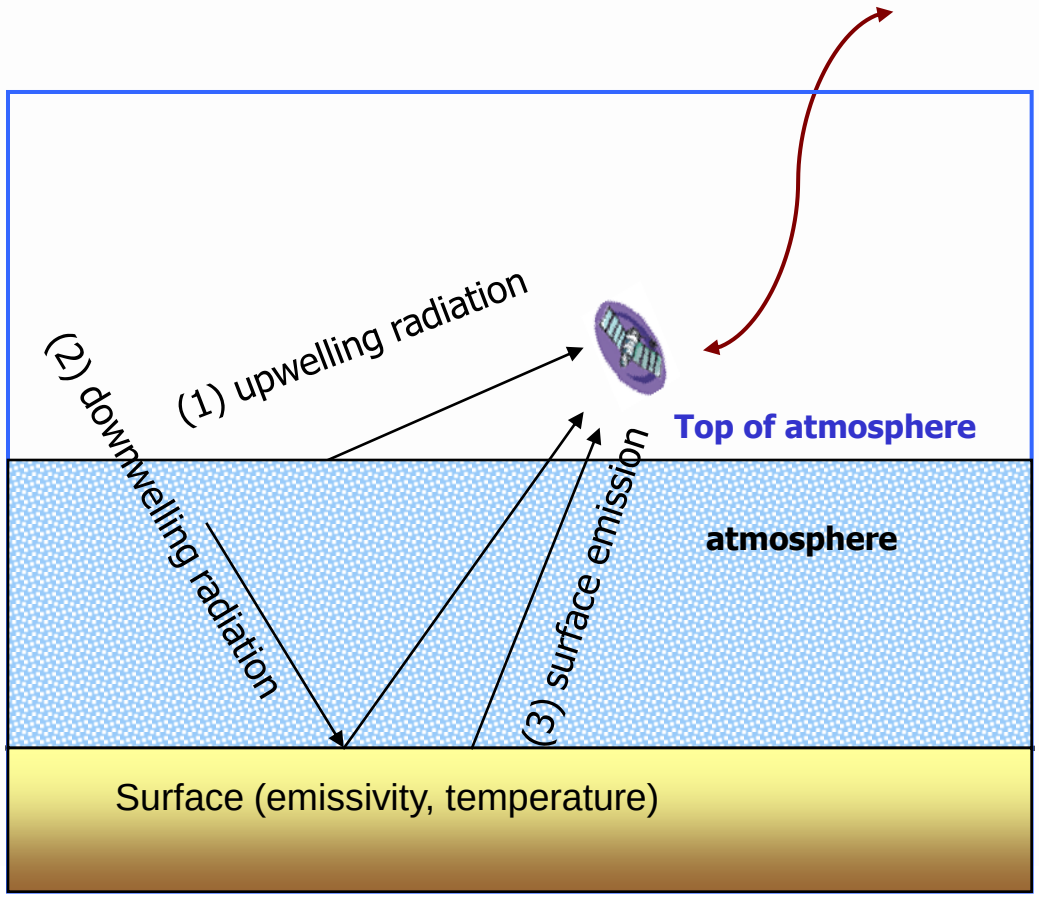
Jan 2013

Trials of IASI surface sensitive observation assimilation over land (Boukachaba et al. 2016, next talk)

Surface emissivity modeling in the microwave

Emissivity estimation using the radiative transfer equation

Under several assumptions



$$Tb = \overbrace{\varepsilon.Ts.\tau}^{(3)} + \overbrace{(1-\varepsilon).\tau.T(\downarrow)}^{(2)} + \overbrace{T(\uparrow)}^{(1)}$$

Ill posed problem : uncertainties about the surface and the atmosphere

==> radiative transfer model (RTTOV) +
T/Q profiles (short range forecasts, analyses, reanalyses) +
Ts (IR retrievals /short-range forecasts, analyses)

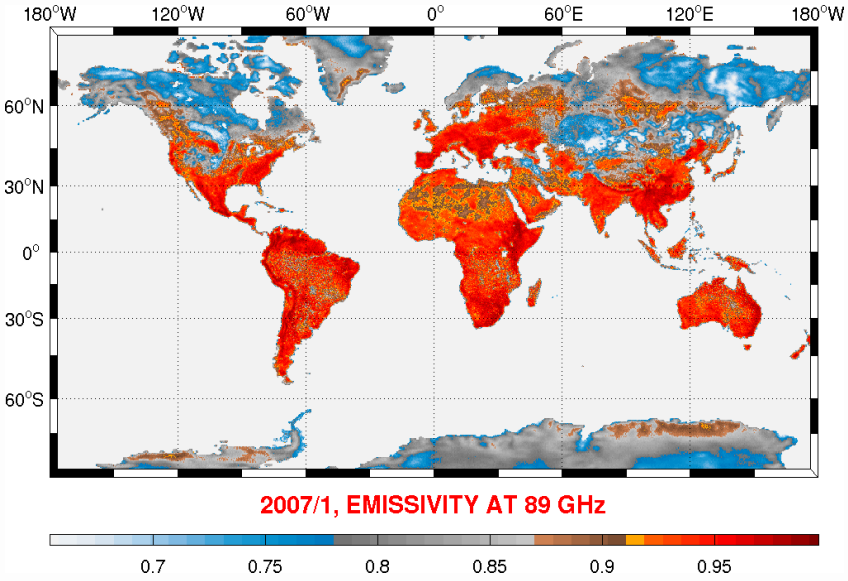
Emissivity estimation:

$$\varepsilon = \frac{Tb - T(\uparrow) - T(\downarrow) \times \tau}{\tau \times (Ts - T(\downarrow))}$$

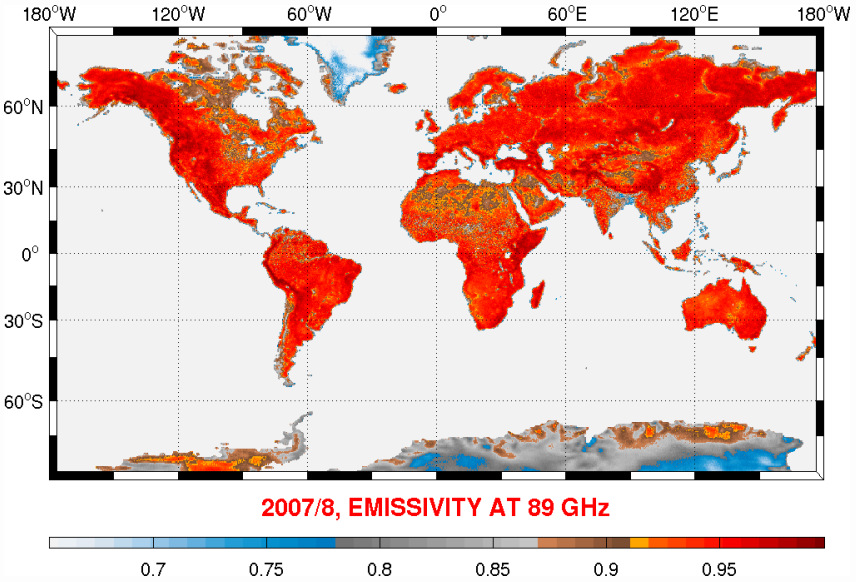
Surface emissivity modeling in the microwave

Emissivity highly variable: surface types, in time, frequency, observation angle …

January



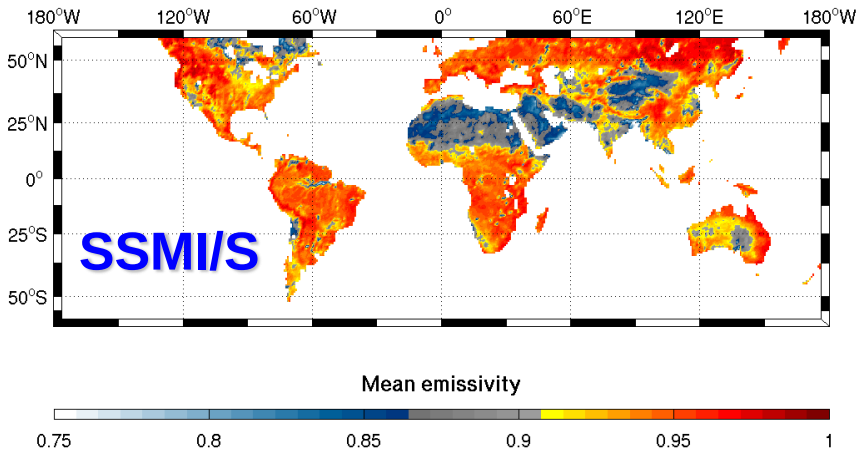
August

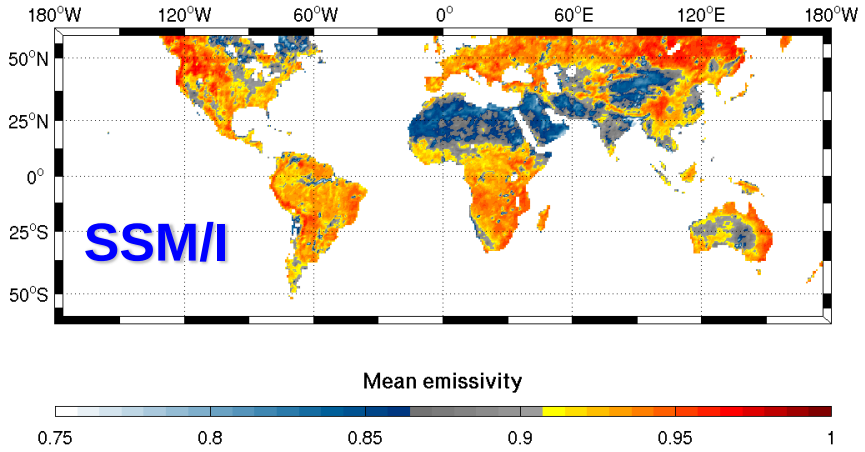


AMSU-A 89 GHz

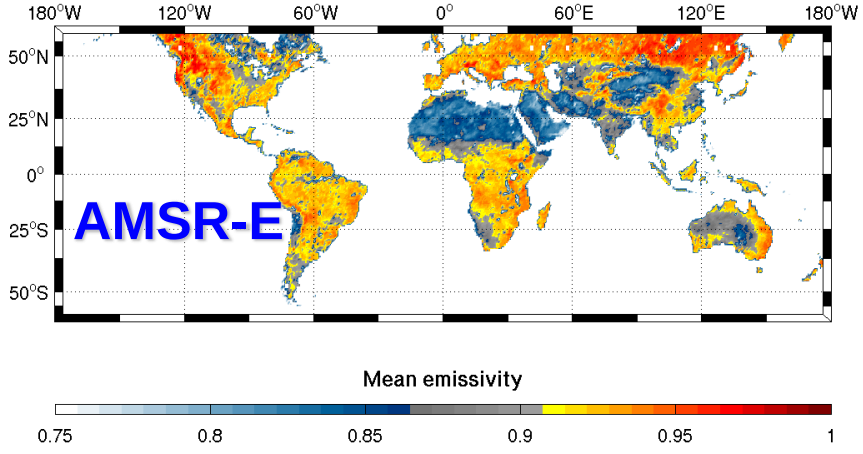
Surface emissivity modeling in the microwave

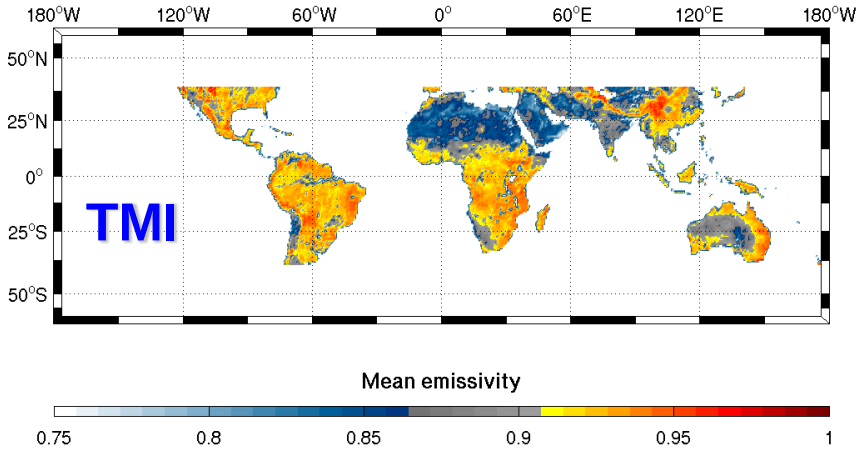
Emissivity is highly variable: surface types, time-space, frequency, observation angle …





37 GHz, horizontale polar. August





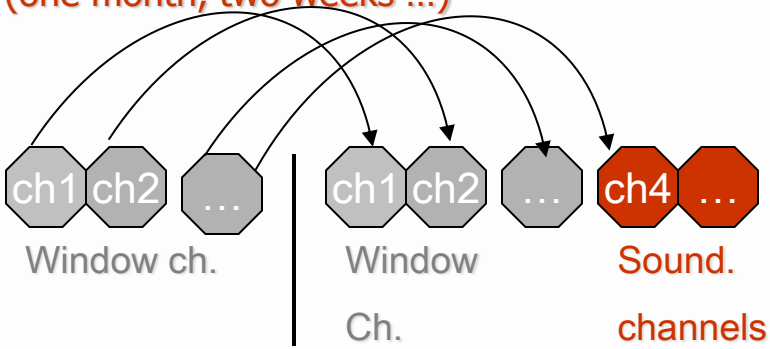
Surface emissivity modeling in the microwave

Assimilation of surface sensitive channels over land

New emissivity parametrisation: based on satellite emissivity estimates

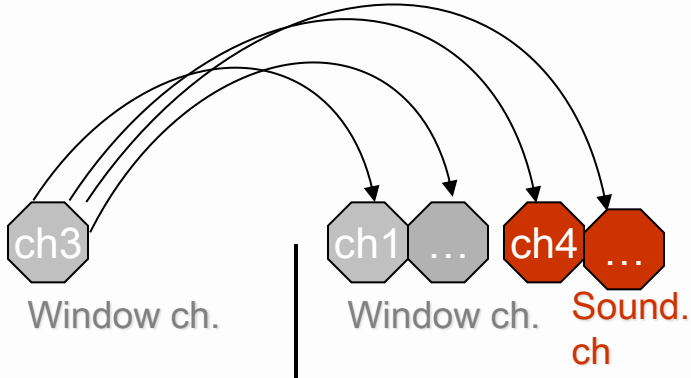
Two possible strategies: « statical » or « dynamical »

Emissivity climatologies from window channels (one month, two weeks ...)



- Take into account the emissivity change with obs. angle (AMSU)
- Uncertainties if the surface conditions change (rain, snow, …)
- Very useful to estimate the Ts

Estimate the emissivity using one window channel for every atmos. And surface situation



- choose the best window channel (the most sensitive to the surface or the closest channel, in frequency, to sounding channels ?)
- With this method, we account for the angular dependence of the emissivity and for any change in the surface condition

Météo-France: Dynamical approach for emissivity

ECMWF : Dynamical + dynamical atlas (Krzeminski et al. 2008)

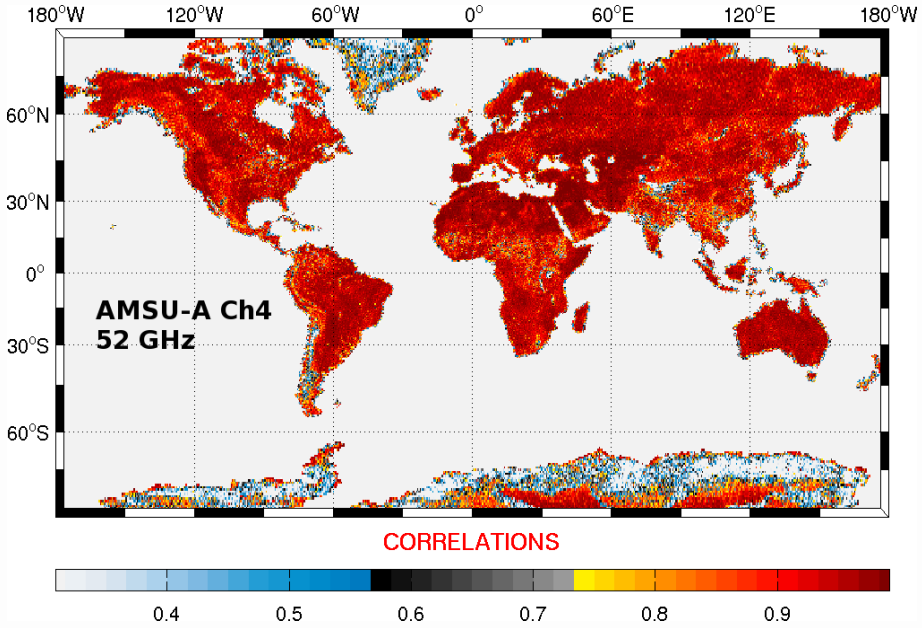
Met-Office: CNRM atlases + 1D-Var analysis of skin temperature (Gray et al. 2016)

Surface emissivity modeling in the microwave

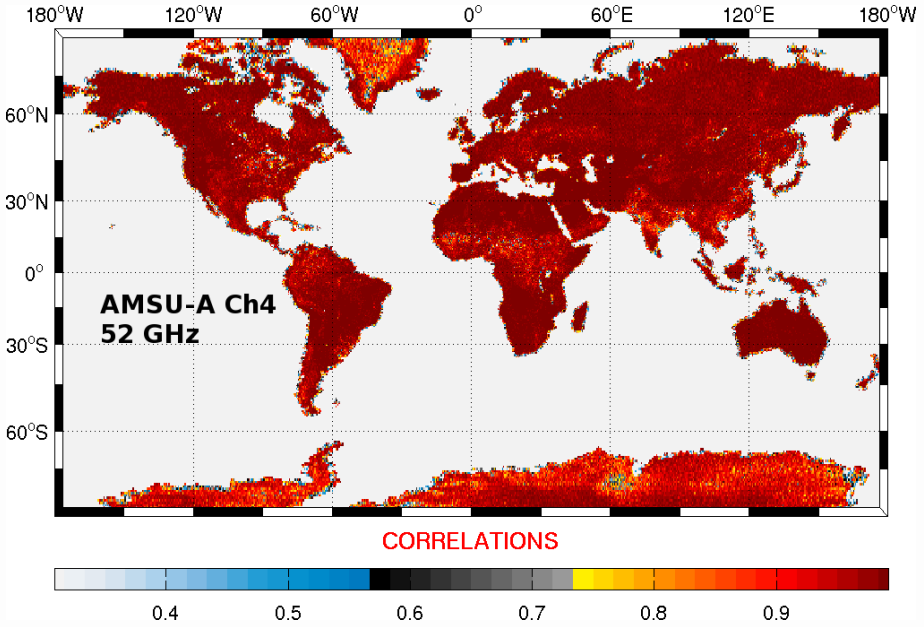
Assimilation of surface sensitive channels over land

Correlations between Obs and RTTOV Sim., AMSU-A ch4 (Temp. Sounding), August

CTL

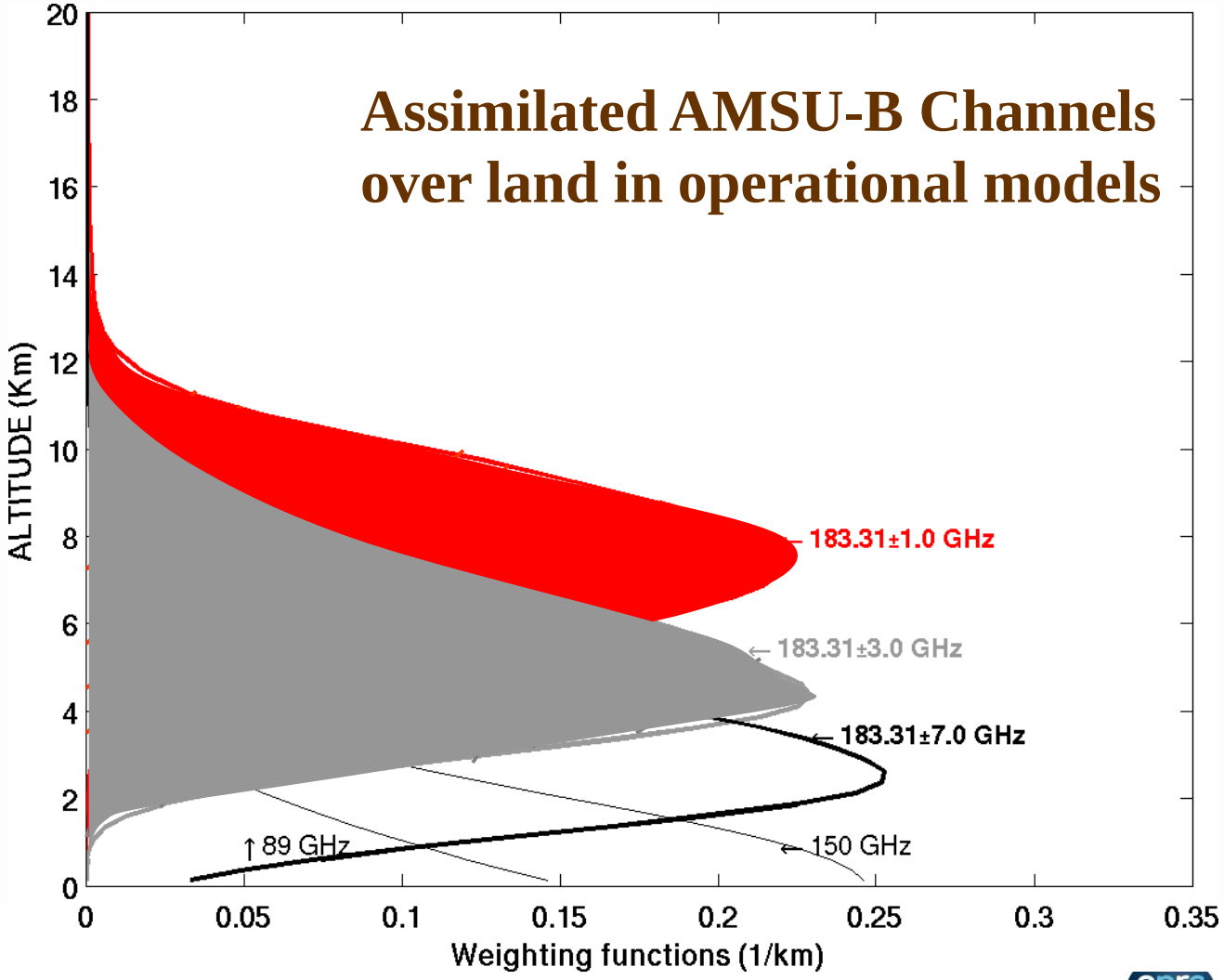


CTL + dynamical emis.



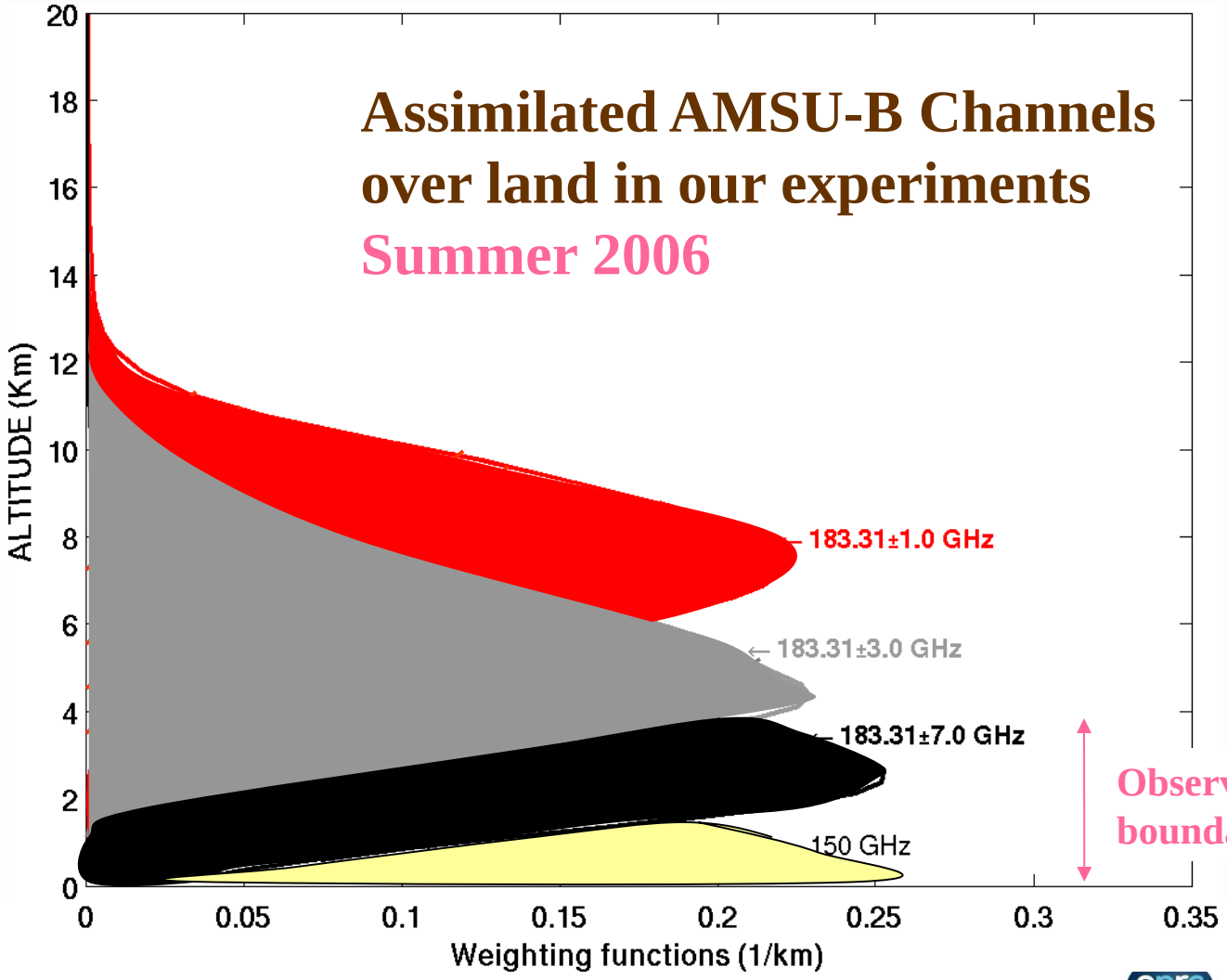
Surface emissivity modeling in the microwave

Assimilation of surface sensitive channels over land



Surface emissivity modeling in the microwave

Assimilation of surface sensitive channels over land



Surface emissivity modeling in the microwave

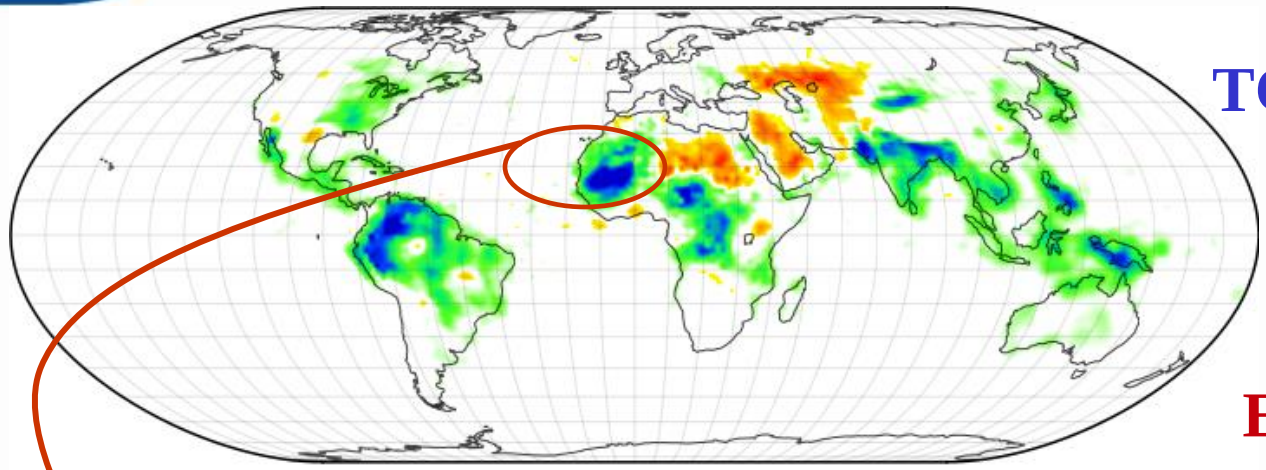
Assimilation of surface sensitive channels over land

Main results when AMSU surface channels are assimilated in the Météo-France 4D-Var:

- Forecast errors with respect to radiosondes and ECMWF analyses
- Impact on analysis of humidity, evaluation against independent GPS measurements from AMMA network

Surface emissivity modeling in the microwave

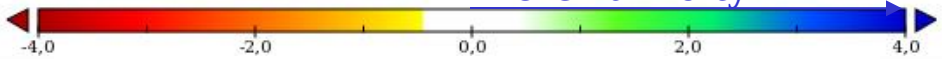
Assimilation of surface sensitive channels over land

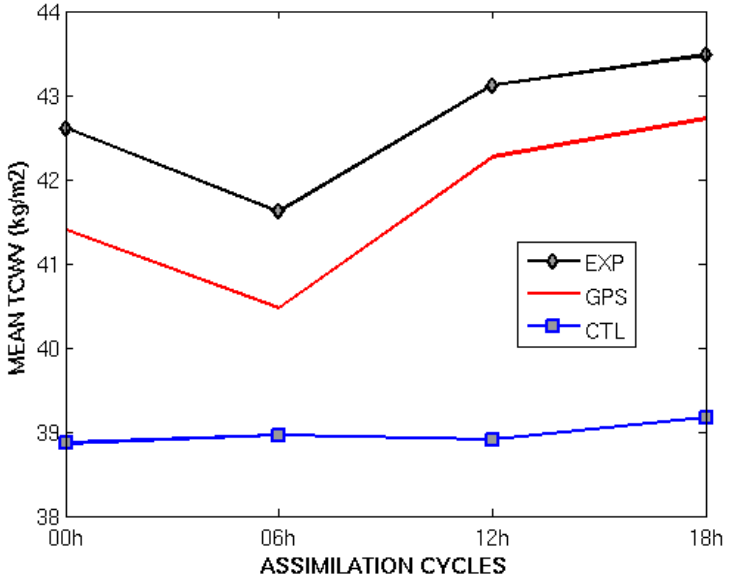


TCWV (EXP-CTL)

Evaluation against GPS measurements

More humidity in EXP

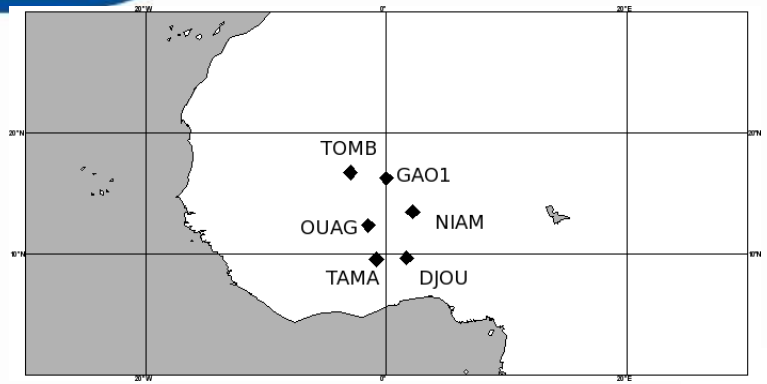




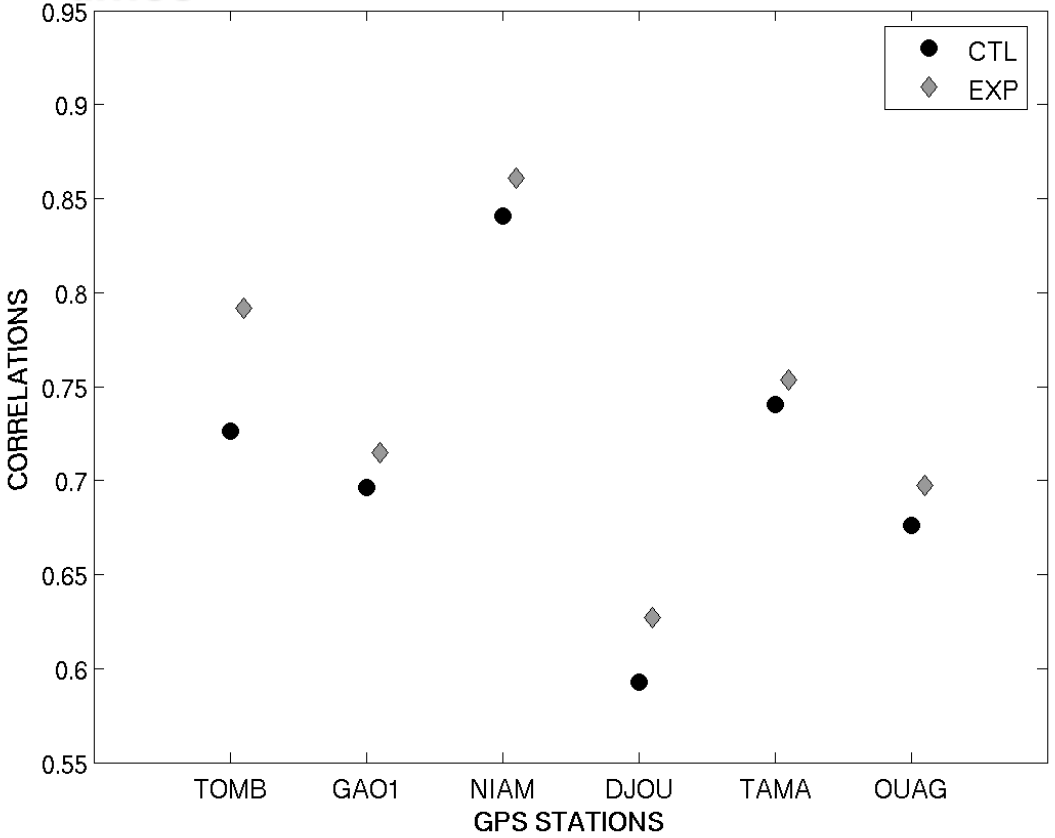
TCWV diurnal cycle, Timbuktu (MALI)

Surface emissivity modeling in the microwave

Assimilation of surface sensitive channels over land

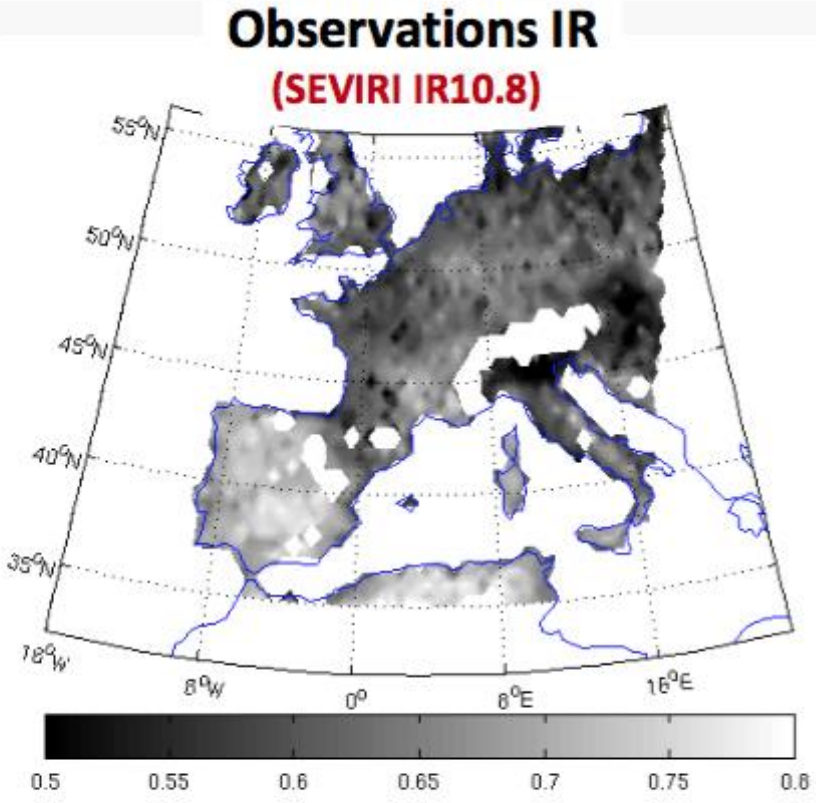


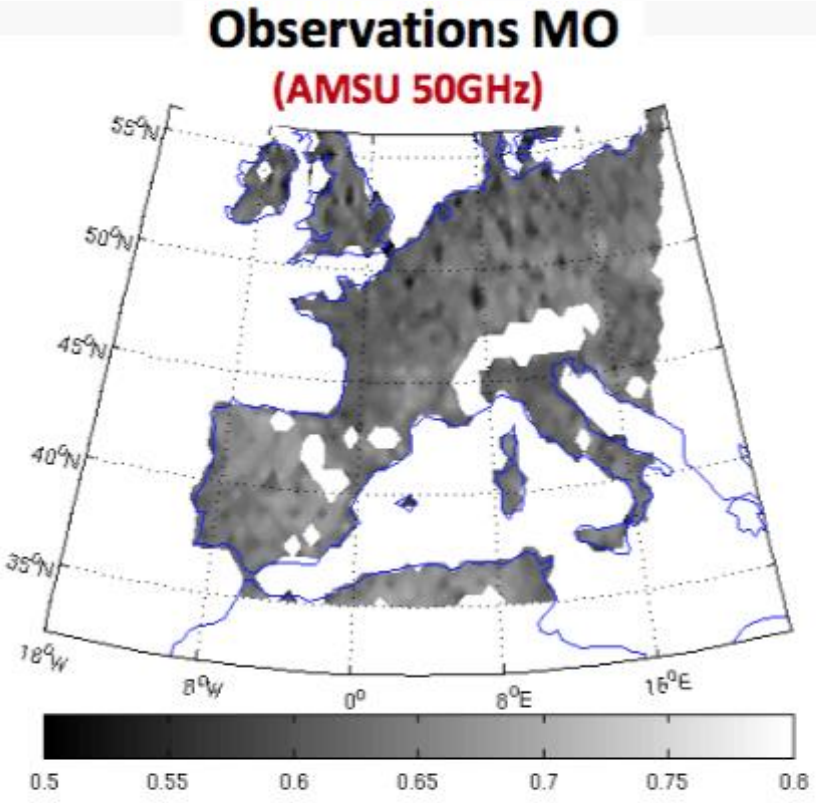
Correlations with GPS, 45 days, synoptic times



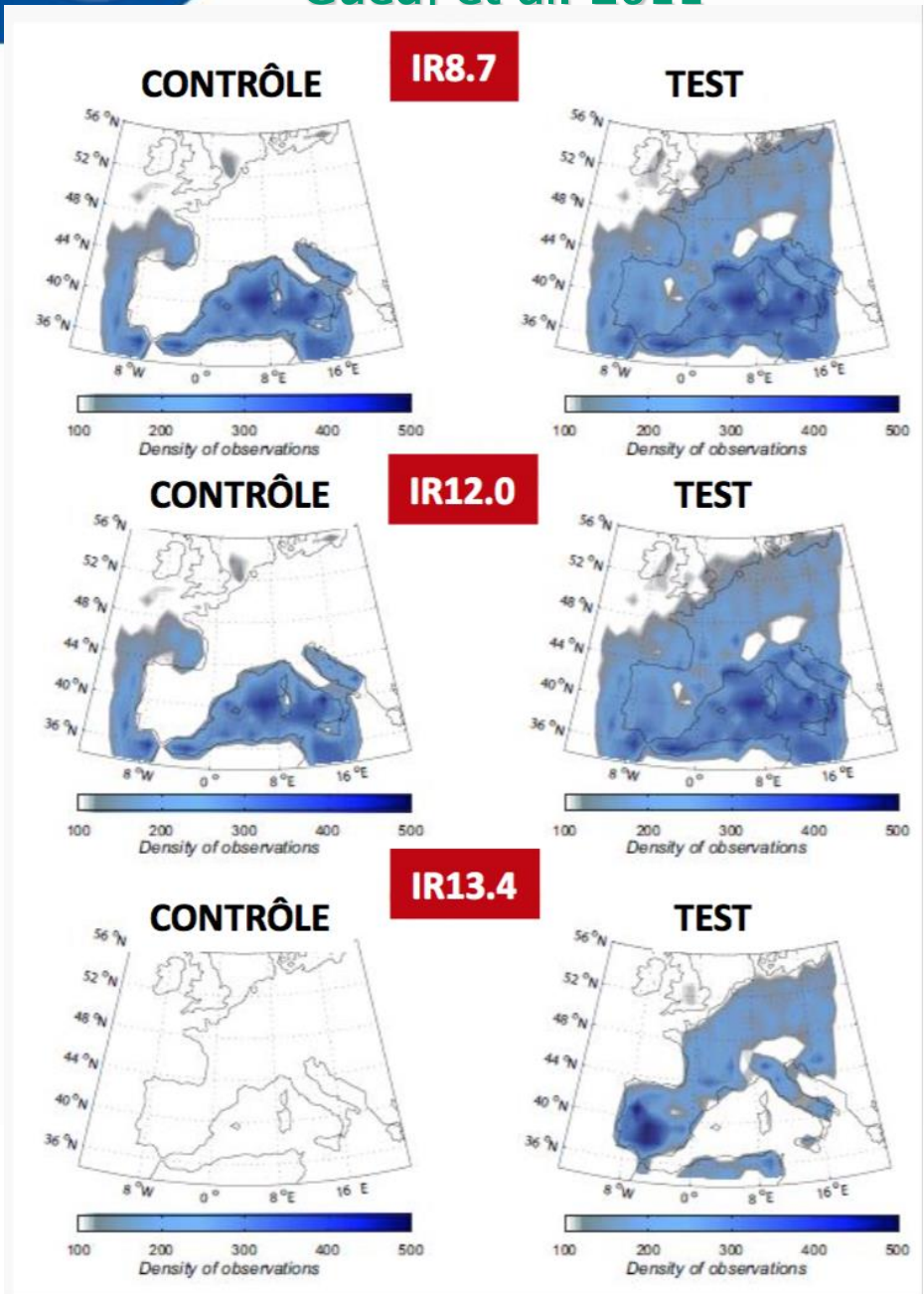
Can we use MW methods for IR ?

Similar mean atmospheric transmission but different sensitivity to clouds !





Can we use MW methods for IR ?
Guedi et al. 2011

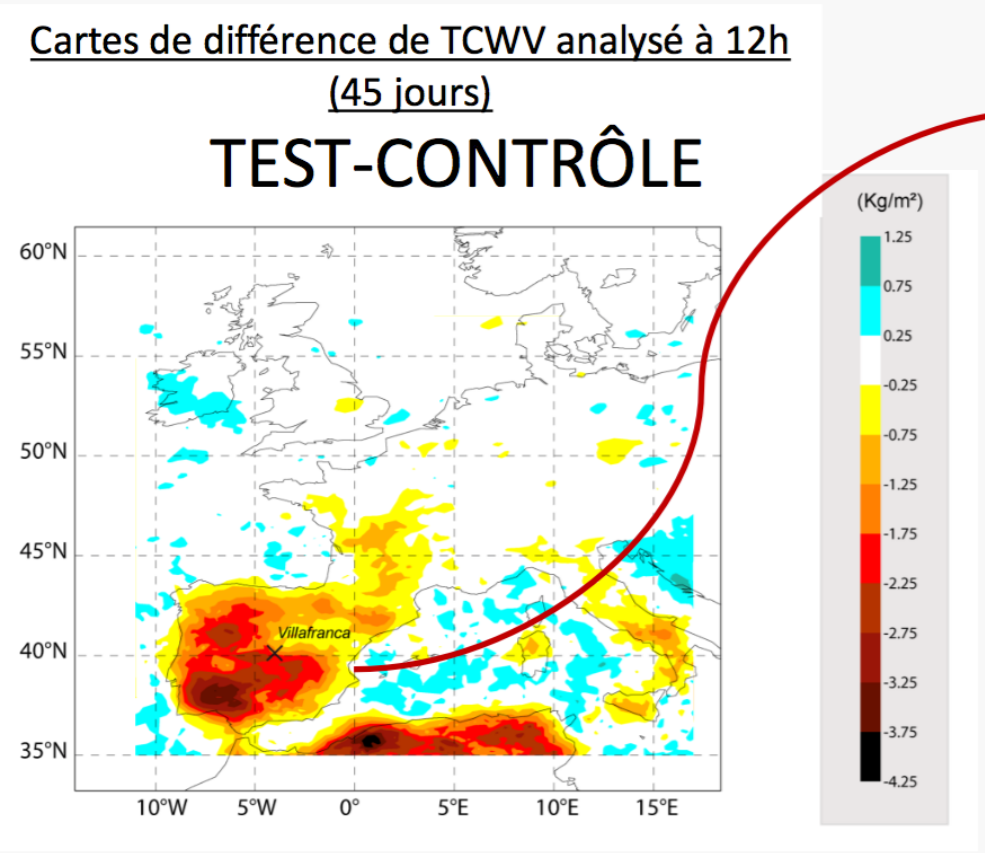


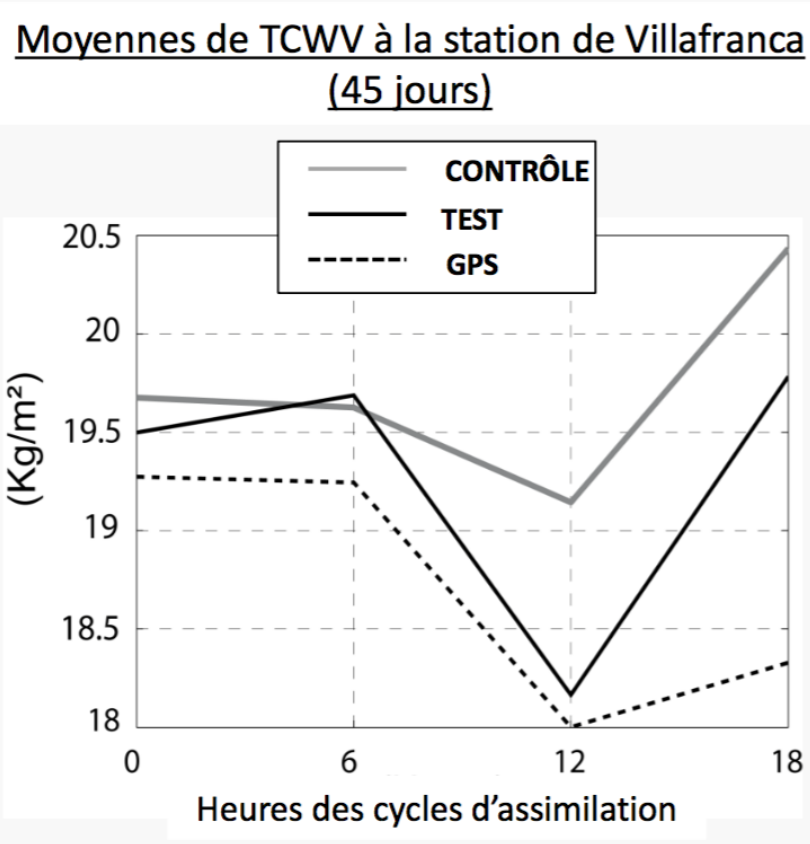
- Control: Surface temperature from the NWP model; Cte emissivity (0.98)

- Test: emissivity from the LAND-SAF + Surface temperature retrieval

Can we use MW methods for IR ?
Guedj et al. 2011

- Control: Surface temperature from the NWP model; Cte emissivity (0.98)
- Test: emissivity from the LAND-SAF + Surface temperature retrieval





Conclusions

• Surface emissivity can be estimated at global scale using data from several instruments

• A good representation of land surface emissivity motivated assimilation studies to assimilate low level humidity observations (usually blacklisted)

• The assimilation of these channels:

- Positive impact in scores wrt radiosondes, ECMWF analyses
- Large impact on humidity analysis (& temp., wind) over the Tropics: low to mid-levels
- TCWV Change evaluated against independent GPS measurements
- Assimilation extended to sea ice surfaces with positives impacts in analyses and forecasts

Conclusions

• Surface emissivity can be estimated at global scale using data from several instruments (IR)

• Assimilation trials with SEVIRI observations over land (Guedj et al. 2011)

• Ongoing studies towards a better use of IASI observations over land (Anais Vincensini thesis (2013), Talk of Niama Boukachaba)

• More results in Karbou et al. 2010a-b (Weather and Forecasting), in Gerard et al. 2011 (IEEE-TGRS), Guedj et al. (2010-2011), Karbou et al. 2014 (MWR)

Conclusions

Operational upgrades at Météo-France:

- July 2008: « dynamical land emissivity model »
- April 2010: *Assimilation of AMSU surface sensitive observations over land*
- November 2010: *emissivity model for sea-ice and assim. of AMSU data*
- *2012: Assimilation of IR surface channels from SEVIRI*

CNRM Land emissivity database: available for use for the scientific community (2006-to present, http://www.cnrm-game.fr/spip.php?rubrique203)

MW and IR emissivity climatology is available via RTTOV-11 package


Thank you for your attention
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Toujours un temps d'avance