The assimilation of surface sensitive microwave observations over land and sea ice

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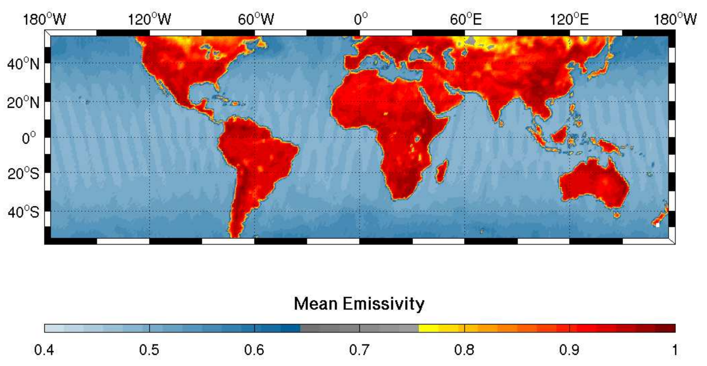
Overview: One of the major scientific challenges in numerical weather prediction is to extract useful information on the atmospheric boundary layer from remote sensing microwave observations. These data contribute increasingly to improve atmospheric analyses and therefore to improve short to medium range forecasts, but also to improve re-analyses. Better use of remote sensing data often requires appropriate representation of the surface in the models, in both emissivity and temperature. This is achieved over sea, and satellite data have a tremendous impact on the atmospheric analyses over oceans. However, over land, the surface emissivity is close to 1.0 and is highly variable and may induce biases in the forward model if its temporal and spatial variability are not well taken into account.



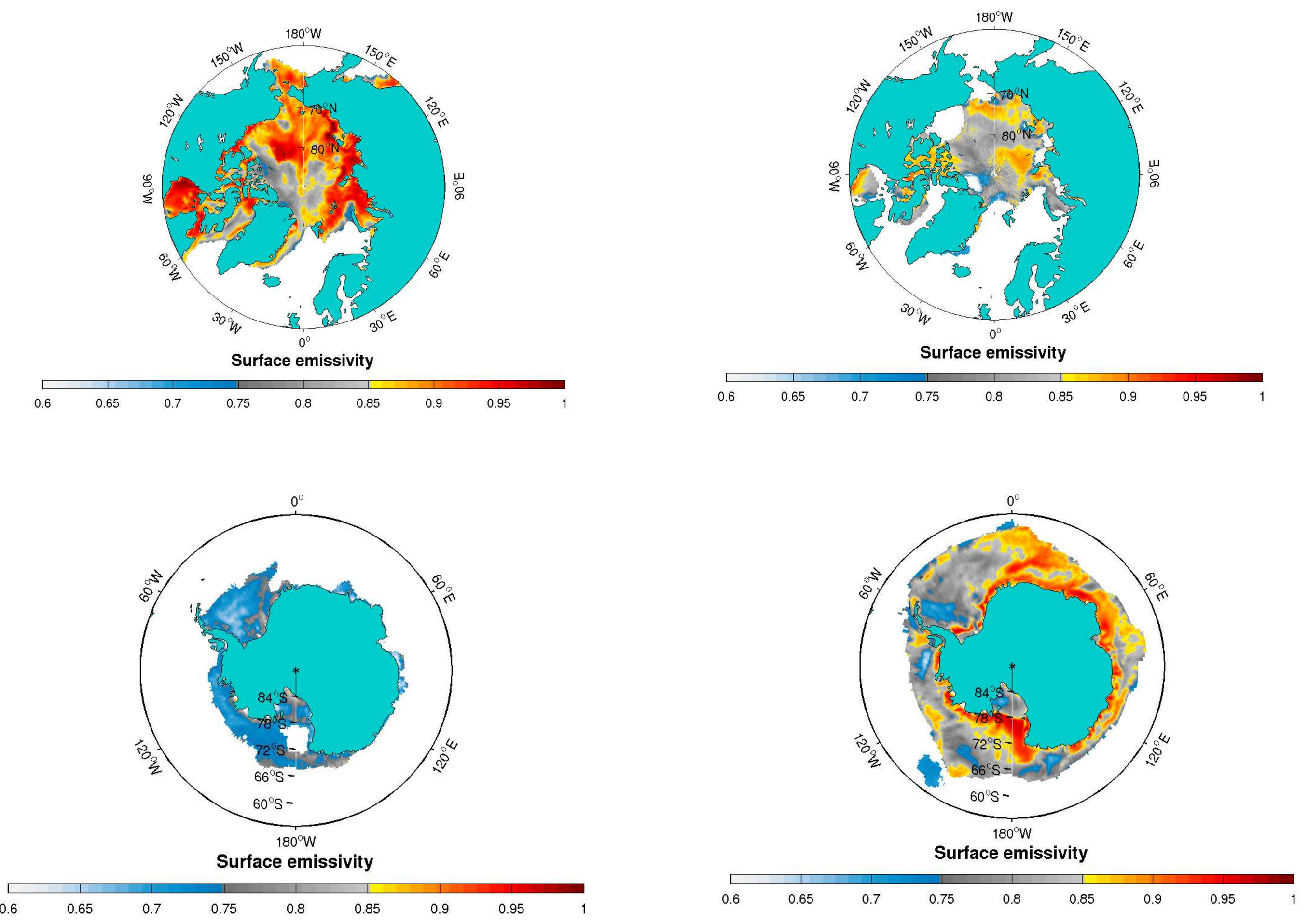
Sea emissivity ~0.5	Surface contribution to the measured signal is relatively small
Assimilation	Efficient emissivity models exist
Land emissivity ~1	Large surface contribution to the signal
Assimilation	Observations sensitive to the surface usually rejected

In such a situation, the model can not produce realistic simulations of observations sensitive to the surface and may reject many useful observations, including those not sensitive to the surface. This case concerns in particular the land and sea ice surfaces for which the surface emissivity is particularly challenging to model.

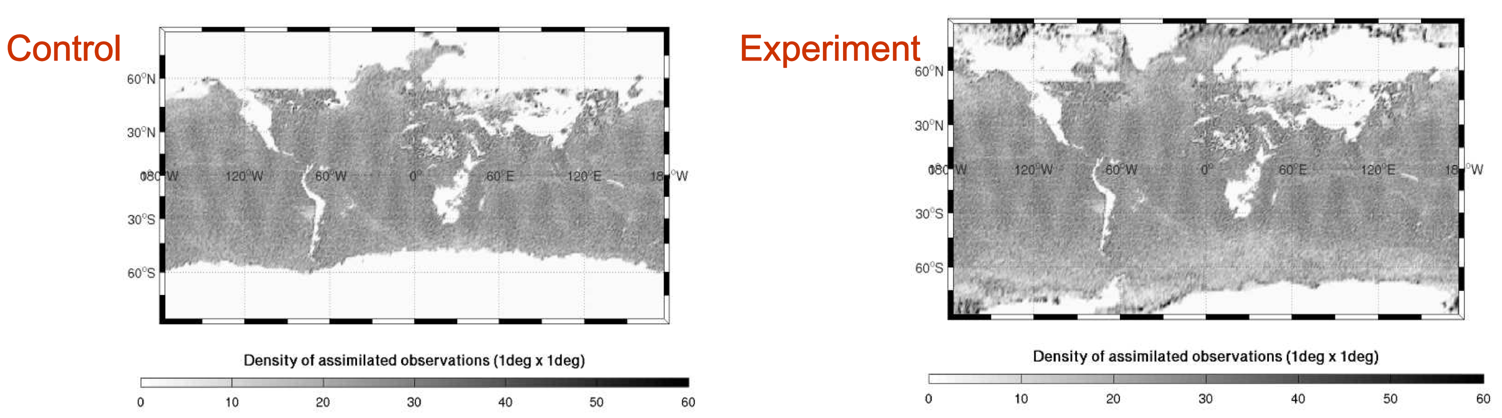
Here, we describe some of the work carried out at Météo-France for a better description of the emissivity of land and sea ice surfaces. We give details on the methodology for estimating the emissivity in the model and on its impact on the performance of the radiative transfer model used. We also expose the impact of a proper modeling of the land and sea ice emissivity in the framework of global impact studies. Two particular regions are particularly investigated: the African continent and the poles. Both areas are lacking conventional observations, and highly benefit from a better use of satellite observations.

Over sea-ice

Over sea-ice: The emissivity knowledge is also a challenging issue (see the following figures for illustrations of the emissivity variability at 89 GHz in space and time)

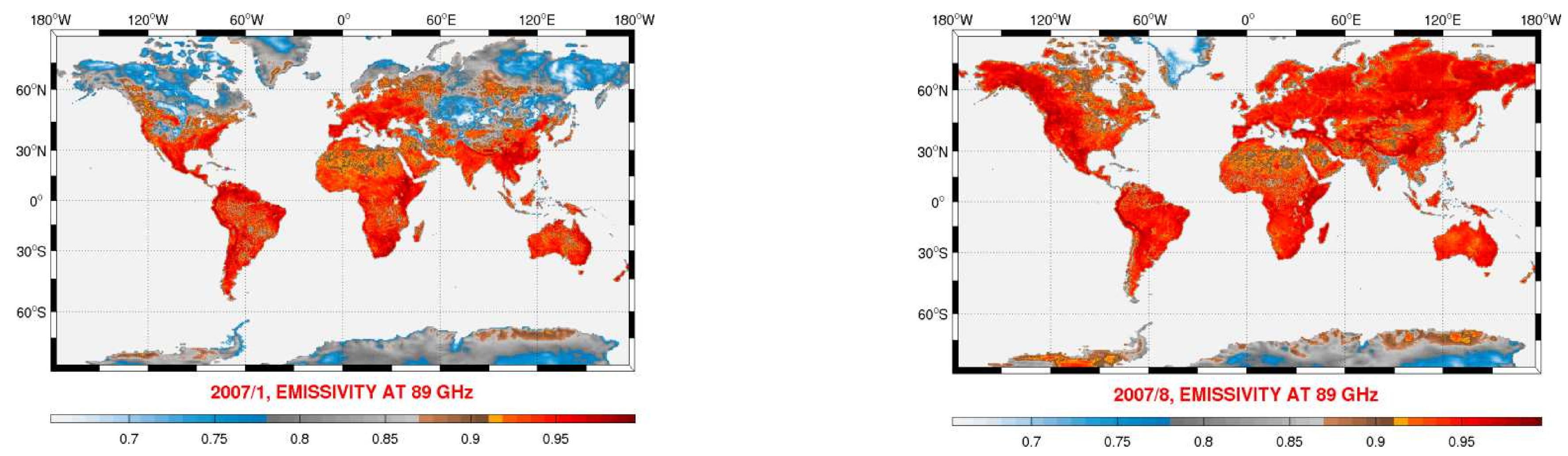


For AMSU-A, the sea-ice emissivity was estimated at 50 GHz and assigned to the remaining channels (similarly to land surfaces). For AMSU-B, a non linear combination between 89 and 150 GHz estimates was used to describe the emissivity for humidity channels. Impact studies were then run during the winter 2009-2010.



Positive impacts were noted: more data could be assimilated (see figure), resulting in better forecast scores.

Emissivity estimation: The emissivity is calculated for each microwave sensor using observed brightness temperatures from a well selected window channel: Ch3 (50.3 GHz) for AMSU-A and Ch1 (89 GHz) for AMSU-B (Karbou et al. 2006). For emissivity computation, short-range forecasts of air temperature, humidity and surface temperature are also used (inputs to the radiative transfer model RTTOV). Below are examples of mean surface emissivities obtained for January (right) and August (left) at 89 GHz

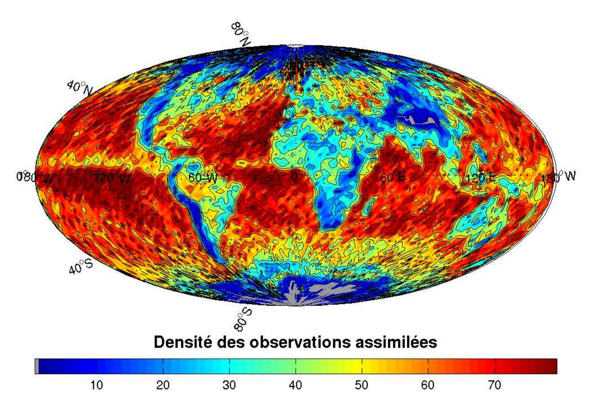


One can notice the very high spatial and temporal variability of the emissivity

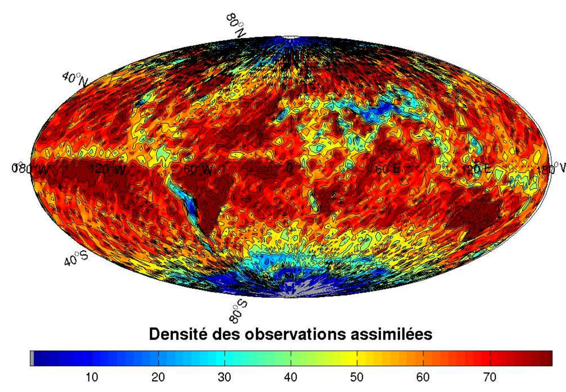
Assimilation of AMSU observations over land surfaces

Assimilation of AMSU observations over land surfaces: The new land emissivity model was implemented in the French assimilation system and several impact studies were conducted in order to study its impact. The studies were conducted in two stages: first, the impact of the emissivity model was studied without changing any other parameters of the system (ie assimilating only the channels that are not sensitive to the surface) and then the assimilation of observations sensitive to the surface was tested.
The assimilation studies were conducted during the Summer 2006.

(a) Impact on sounding channels:



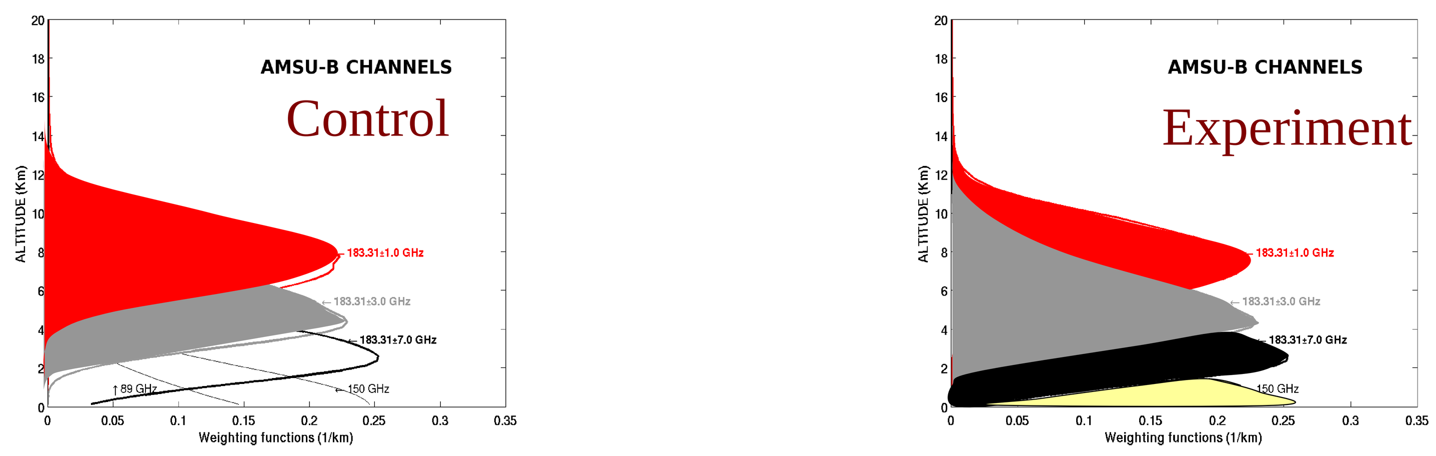
Density of AMSU-A observations being assimilated, before (left) and after (right) the implementation of the emissivity computation



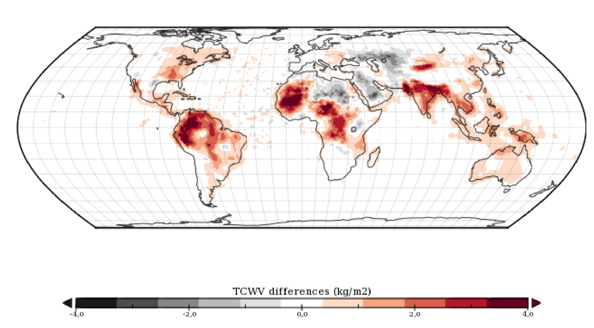
The emissivity change was found to be positive for sounding channels. In particular, large improvements in the radiative transfer model performance in terms of bias/std of "departures from first-guess" were noted (Karbou et al. 2010a). An increase of the number of assimilated data was also noticed (see the accompanying figure for results from AMSU-A channel 7, sensitive to temperature ~ 10 km)

(a) Impact of surface sensitive observations:

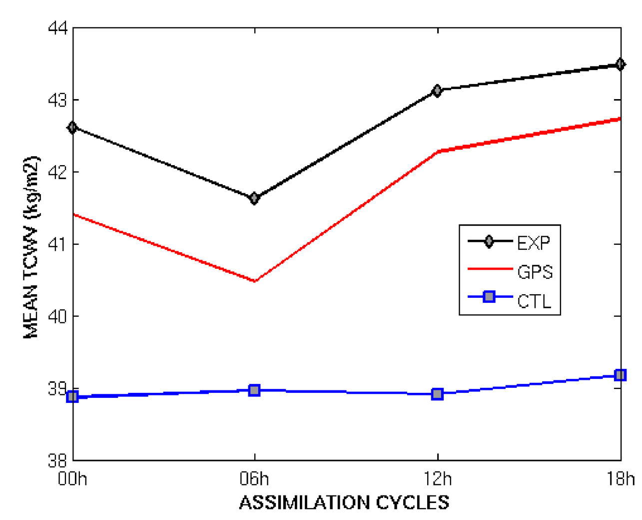
With the assimilation, for the first time, of surface sensitive observations from AMSU-A and AMSU-B over land surfaces.



The assimilation of these observations impacts key parameters of the water cycle. An important change of the analyzed atmospheric fields and of the precipitation forecasts over the Tropics has been noted. Our experiment emphasizes the atmosphere moistening in India, South America and in West Africa together with a drying over Arabia and North-East Africa. The humidity change not only concerns the surface but also many levels of the atmosphere, up to 500 hPa. The humidity change was successfully evaluated using independent GPS[1] data. The changes result in a better-organized African monsoon with a stronger ITCZ[2]. Forecast errors were reduced over the Tropics leading to significant forecast improvements at higher latitudes at 48h and 72h ranges (Karbou et al. 2010b).



Legend of the figures: (left) Mean Total Column Water Vapour (TCWV) differences (experiment minus control) during August 2006. Negative (positive) values indicate that the control assimilation is more moist (dry) than the experiment. (right) Diurnal cycle of TCWV near TIMBUKTU (MALI) estimated using GPS measurements and using analyses from CTL and from EXP assimilation experiments. Statistics are for 45 days (from 01/08/2006 to 14/09/2006)



[1] Global Positioning System
[2] Inter Tropical Convergence Zone

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