Ongoing developments on the use of microwave sounders and imagers at Météo-France

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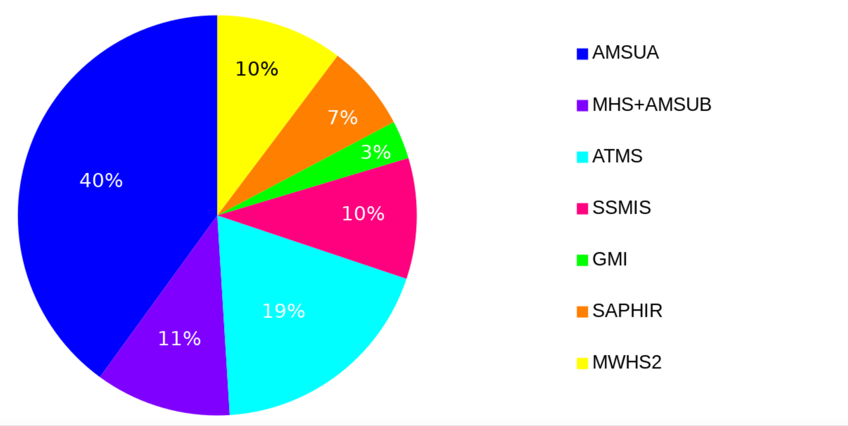
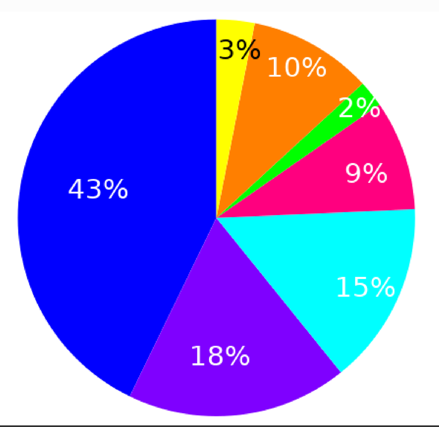
I - Overview : the use of microwave instruments in the current Météo-France parallel suite

In the global model ARPEGE (parallel suite)

Active observation number per assimilation cycle



Degree of Freedom Signal (DFS)



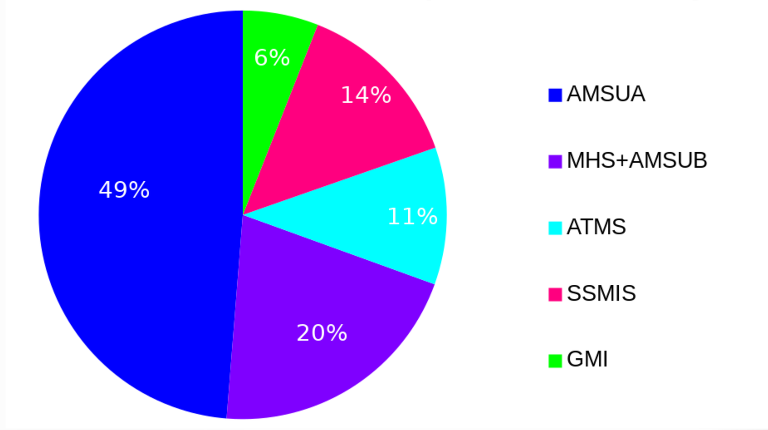
Global active obs count: 10^7

Microwave obs count: 10^6

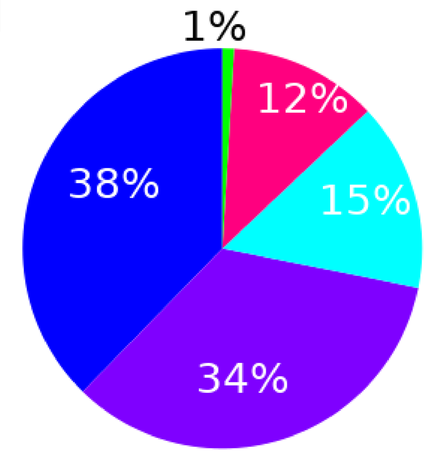
Part of Microwave sensor in global DFS: 34%

In the convective scale model AROME (parallel suite)

Active observation number per assimilation cycle



Degree of Freedom Signal (DFS)



Global active obs count: 5×10^4

Microwave obs count: 10^3

Part of Microwave sensor in global DFS: 10%

Statistics computed over 2 days (8 assimilation cycles) during the month of July of 2017 in the Météo-France global 4DVar system for ARPEGE model in the left figure, in the regional 3DVar AROME France system in the right figure. The DFS corresponds to the ability of an observation type to modify the analysis.

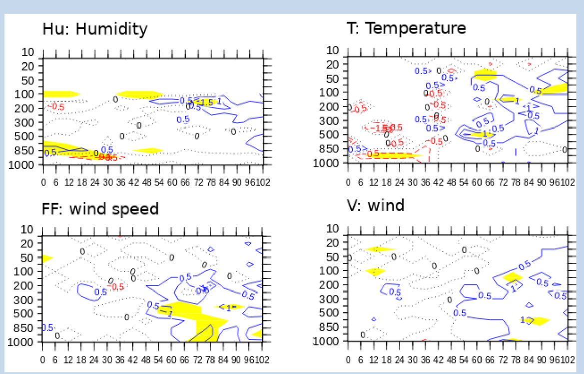
II - Use of new microwave instruments since 2015

Summary

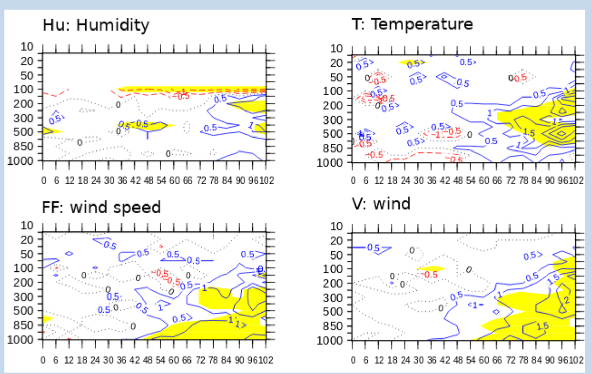
MF NWP system / Sensor	GMI - GPM	MWHS2 - FY3-C	AMSR2 – GCOM-W1	MTVZA-GY - Meteor-M
Operational (OPER)	Monitoring	None	None	None
Parallel suite (DBLE)	2 assimilated channels (183GHz)	2 assimilated channels (183GHz)	None	None
Tests ongoing for future parallel suite (TEST)	same as above	8 assimilated channels (118GHz, 183GHz)	8 assimilated channels over ocean (18GHz, 23GHz,36GHz, 89GHz)	Monitoring (18GHz, 23GHz, 36GHz, 91GHz, 183GHz)

GMI and MWHS2 experiments

OPER + GMI versus OPER



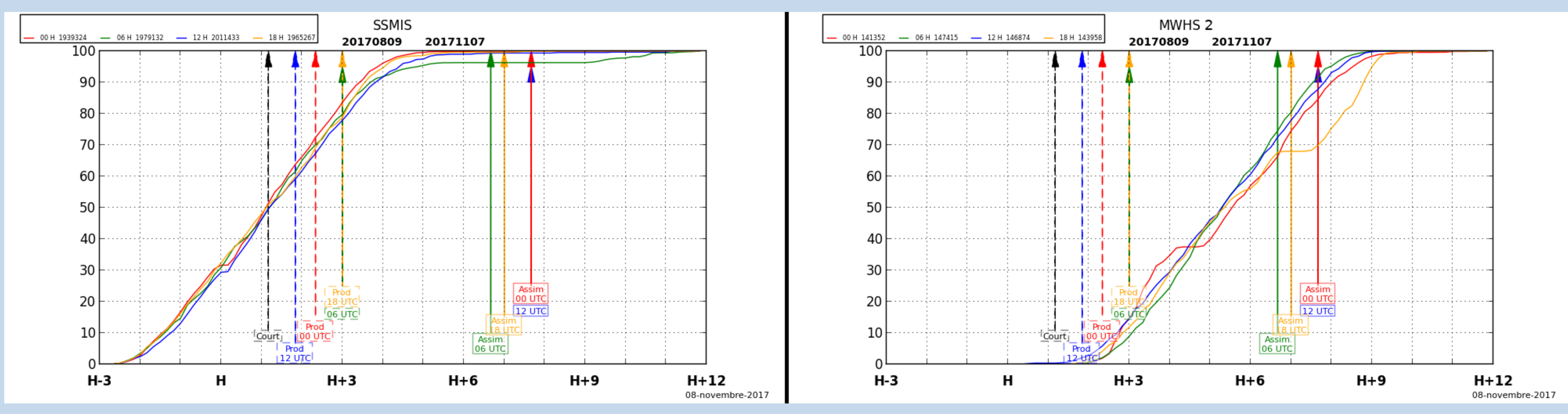
OPER + MWHS2 versus OPER



Relative Differences (%) of Root Mean Square Errors of ARPEGE Forecasts between a reference experiment and an experiment with the new observations (left GMI 183GHz channels, right figures MWHS2 183GHz channels). In the x-axis there is the forecast range, in the y axis the pressure level. The reference used is the ECMWF analysis. Scores are computed for the Europe Atlantic domain, from the January to March 2017 period. Yellow areas correspond to areas statistically significant differences at the 99% confidence level. Hu represents relative humidity.

The assimilation of GMI and MWHS2 sensors has a neutral to slightly positive on the ARPEGE 4DVar system, as we can see above. Nevertheless, the use of MWHS2 observations could be enhanced by an improved routing of the data as we see in the following figure.

Observation availability: comparison for SSMIS and MWHS2

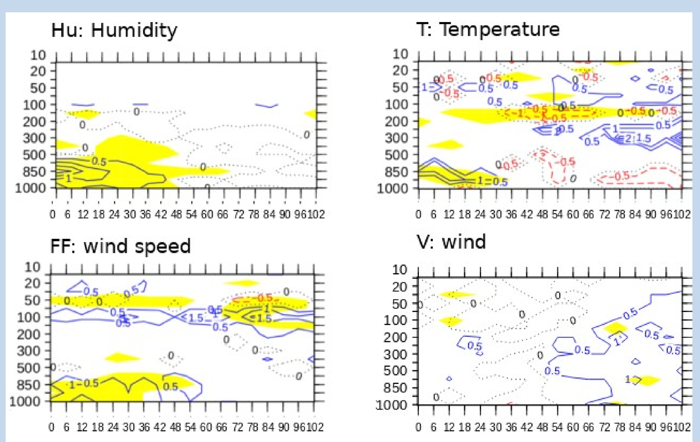


Percentage of observation availability function of time for SSMIS and MWHS2 data. Arrows represents the moment of effective run; the data received after are not used is the data assimilation. Compared to other microwave instruments (here SSMIS but it is similar for the other one), the MWHS2 observations arrive late in the Météo-France database.

AMSR2 experiments

DBLE + AMSR2 versus DBLE

The AMSR2 sensor onboard GCOM-W1 has been tested into the assimilation system over a 3-month period. The impact on the score is slightly positive, in particular in the Tropics and in the Northern hemisphere, but more neutral in the Northern hemisphere.



Scores in the Tropics from July to October 2017 with respect to ECMWF analysis. Same legend as above.

MTVZA-GY experiments

The MTVZA-GY microwave sensor will be monitored in the next parallel ARPEGE suite. It has been tested so far with some sample files. In particular, the monitoring of this instrument will permit to correct part of the biases, related to air mass-dependent biases (Upensky et al., 2016) with VarBC over a long period of time before we start the assimilation tests.

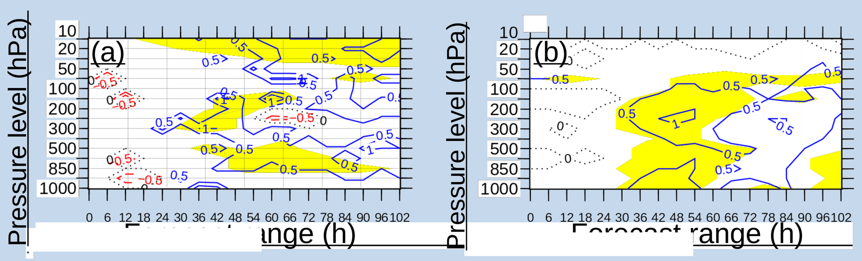
IV – Improving the quality control of SAPHIR observations using RTTOV SCATT

The SAPHIR observations are presently assimilated in clear-sky areas within the ARPEGE model (Chambon et al., 2014). Their quality control aims at screening the cloudy and rainy scenes with a FG departure check and using the RTTOV model. The channel 6 (183.31 ± 11 GHz) value is used to identify clouds in the observed scene, the following simple test allows to reject the cloudy observations:

$$|TB\_model\_clear - TB\_obs| > 5\ K$$

However, when using a clear sky radiative transfer this cloud screening introduces an asymmetry in the screening by not filtering out the cloudy scenes of the model first guess in the clear sky assimilation. The first application of the RTTOV-SCATT simulations in the ARPEGE model have thus been to improve the quality control of SAPHIR clear sky assimilation. A second test is introduced as follows to reject cloudy scenes in the model first guess:

$$|TB\_model\_clear - TB\_model\_scatt| > 5\ K$$

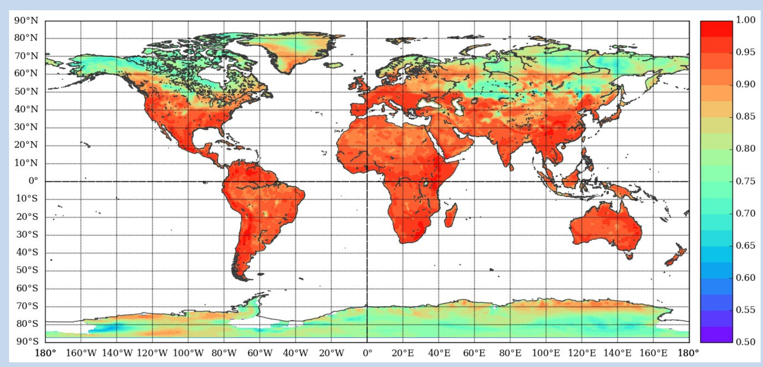


Relative Differences (%) of Root Mean Square Errors of ARPEGE Forecasts (a) Temperature and (b) winds between a reference experiment and an experiment with the improved quality control. The reference used is the ECMWF analysis. Scores are computed for the Southern Hemisphere, below 20° of latitudes, from the January to March 2017 period. Yellow areas correspond to areas statistically significant differences at the 99% confidence level.

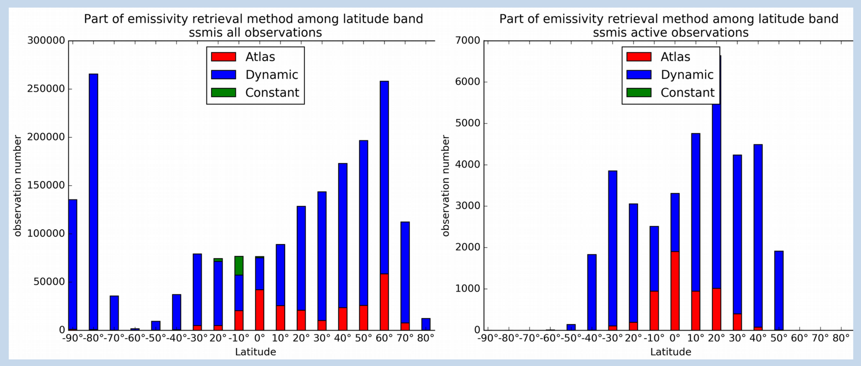
As can be seen above, the ARPEGE forecast scores are positively impacted, over a 3-month period. This will encourage us to generalize this improved quality control to other microwave sensors.

III - Monthly microwave emissivity atlases

In the ARPEGE and AROME systems, the surface emissivity is dynamically retrieved using a window channel (see Karbou et al., 2010a, 2010b). When the dynamic emissivity retrieval fails, the alternative use is to consider a climatological atlas. Currently a single atlas is used with emissivity values for several frequencies. In cases where the atlas does not provide a value (e.g. for some frequencies in some cloudy regions in the Tropics), a default constant is used. One can see on the figure below that atlas is more frequently used in the tropics than in other regions (it also true for other instruments/frequencies). One can also see the default constant value (set to 0.95) is sometimes used in the tropics: this is due to empty values in the used atlas over south America for SSMIS 91GHz channel.

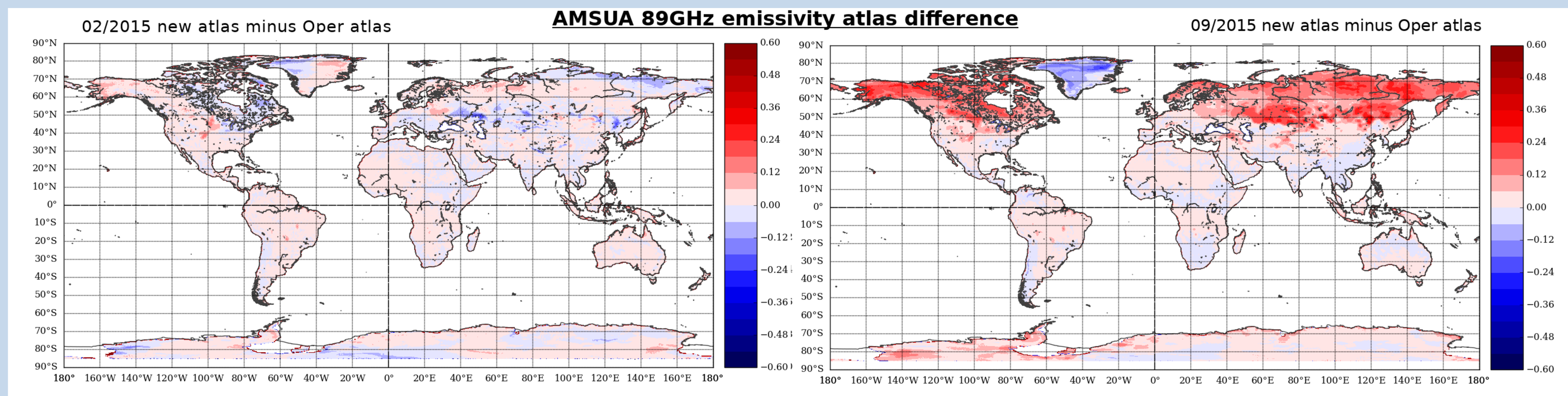


Emissivity atlas for AMSUA 89GHz used in Météo-France NWP operational models for low zenith angle (1). Computed over several months in 2005, 2006 and 2007



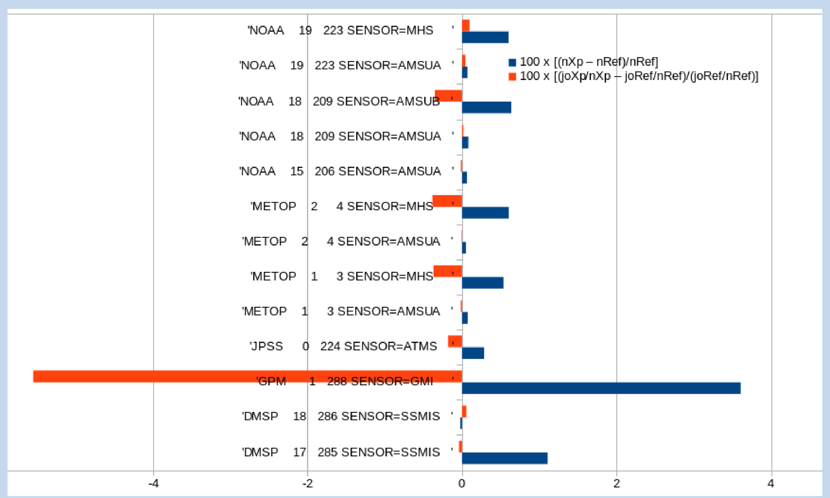
Number of cases for which either atlas or dynamic emissivity or default constant is used for SSMIS (left figure : all observations, right figure: only active observations) channel 183GHz +/- 3GHz. One day of 4DVar (4 assimilation cycles)

Some of the latest emissivity atlases computed by Fatima Karbou (https://www.nwpsaf.eu) have been tested with the ARPEGE 4D-Var system. One specificity of these atlases is that one can take into account the seasonal variability (see example below showing differences between February and September) of surface emissivity by changing of atlas every month.

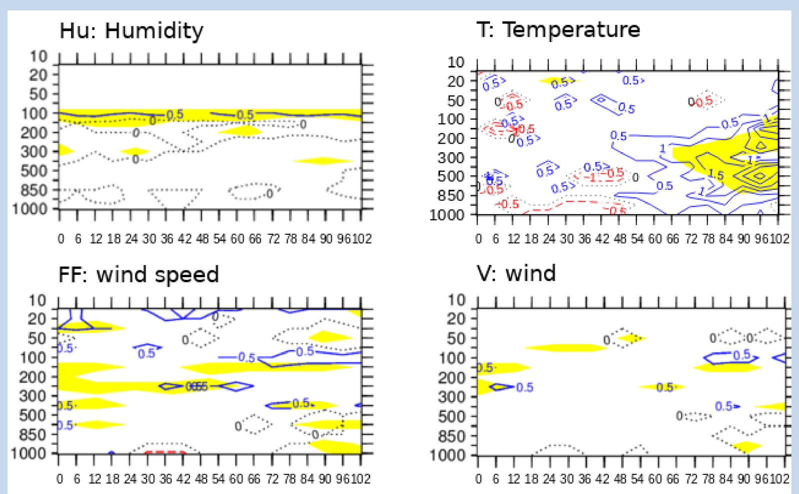


Differences between AMSUA 89GHz monthly new atlas (February at the left, September for the right) and the one used in operations. One can see the large differences over Canada, Russia and Greenland).

Data assimilation results from the implementation of monthly surface emissivity atlases



Mean relative difference (%) for observation number and normalized first guess departures between test (parallel suite with monthly atlases: xp), and parallel suite (ref). Statistics are computed from 10 July to 10 October (almost 365 assimilation cycles).



Scores in the tropics from July to October 2017. Same variables as in part II.

The figures above show that the use of the new monthly atlases within the parallel suite have a relatively positive impact on the number of assimilated microwave observations, and on the first guess departure for some sensors. The most important impact is on GMI as indeed the choice was made for this sensor to retrieve emissivity from the 166 GHz channel, with which the retrieval often fails in the Tropics or differs too much from the climatological atlas. The forecast scores of the new atlases appears to be slightly positive, especially in the Tropics.

V – Others developments

Band correction RTTOV coefficients for microwave instruments

The latest version of coefficients made available by the RTTOV team, taking into account band corrections have been tested with the 4D-Var ARPEGE. The impact of this modification seems to be neutral onto the ARPEGE forecasts.

Increase MW thinning ratio

The current horizontal thinning of microwave observations is of 140km. We have been experimenting an improved thinning of 100km which would correspond to the same one used for IASI observations. The preliminary results, over a 3-month period, modifying the thinning of MHS, SAPHIR, ATMS and SSMIS are neutral as they seem positive in the Northern hemisphere but negative in the Southern hemisphere.

Using South America DbNet RARS data for the short cutoff

In Meteo-France NWP system, the longest ARPEGE forecasts are initialized with an analysis with a quite short cut-off in order to make them available to forecasters as early as possible. In order to increase the number of observations used within the analyses used for these long forecasts, the satellite data gathered through the DbNet RARS network are tested. We have added the microwave data provided by the RARS sub centers 10 (Cachoeira Paulista), 11 (Cuiaba), 12 (Brasilia). The use of these RARS data leads to an increase of the number of observations considered in the screening process (resp. in the minimisation): ATMS +15% (resp. +0,6 % used effectively in the minimisation), AMSUA +4% (+0,5%) , AMSUB +2,3% (+0,4%). Nevertheless, the impact on forecast scores appears to be neutral.

Conclusion and perspectives

Microwave observations contribute to roughly 30% of the total DFS of the ARPEGE global system, bringing important information on temperature and humidity. In the context of a continuously evolving observing system (e.g. loss of some instruments), it is important to keep studying the impacts of new instruments to ensure the resilience of the system. The next instruments for which one plan to start studies in the near future are MWHS-2 and MWTS-2 onboard FY3-D, ATMS onboard JPSS-1 and MTVZA-GY onboard Meteor-M N2-1.

References:
Chambon, P., Meunier, L. F., Guillaume, F., Piriou, J. M., Roca, R., & Mahfouf, J. F. (2015). Investigating the impact of the water-vapour sounding observations from SAPHIR on board Megha-Tropiques for the ARPEGE global model. QJRMS, 141(690), 1769-1779.
Karbou, F et al. 2010a, Global 4D-Var assimilation and forecast experiments using AMSU observations over land. Part-I: Impact of various land surface emissivity parameterizations, Weather and Forecasting, 25, 5-19.
Karbou, F et al. 2010b, Global 4D-Var assimilation and forecast experiments using AMSU observations over land. Part II: Impact of assimilating surface sensitive channels on the African Monsoon during AMMA, Weather and Forecasting, 25, 20-36.
Upensky et al. 2016, An initial assessment of microwave imager/sounder MTVZA-GY data from Meteor-M N2 satellite https://cimss.ssec.wisc.edu/itwg/itsc/itsc20/papers/1_05_uspensky_paper.pdf

Links:
DBNet page on WMO website: http://www.wmo.int/pages/prog/sat/documents/DBNet_Network-status-and-plans-2017-04.pdf
Météo-France external monitoring website: http://www.meteo.fr/special/minisites/monitoring/menu.html

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