Current developments on global satellite data assimilation at Météo-France

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Variational assimilation is a good algorithmic framework for an efficient use of satellite data of different kinds. Since 2000, an increasing number of satellite data has been used operationally in the global 4DVAR assimilation system, and a lot of progress has been achieved on the quality of the forecast. Figure 1 shows the weights of the various data-types in constraining the global analysis as of September 2007. The degrees of freedom for signal (DFS) indicate the importance of each observing system in the various regions. As expected the Northern mid-latitude troposphere is well covered by conventional observations (radiosondes and aircraft), while the stratospheric analysis relies primarily on brightness temperatures collected by satellite sounders.

In that respect, data from the AMSU-A, AMSU-B, HIRS, AIRS (a few channels) and SSM/I instruments are assimilated under the form of raw brightness temperatures. Very recently, ATOVS data from the European MetOp satellite have been inserted (5 September 2007). Different types of satellite winds (cloud winds or water vapour winds) are used, mainly from geostationary satellites but also including the MODIS winds over the poles (from the polar orbiting satellites NASA Eos-AQUA and TERRA). Scatterometer winds from the QuikSCAT satellite were introduced in October 2004, and complemented very recently by the ERS-2 winds (5 September 2007). It is worth highlighting the recent works and developments on the GPS applications in meteorology at Météo-France. On September 5th 2007, GPS radio-occultation measurements in the form of bending angles from 8 satellites were introduced in the global 4DVAR: 6 FORMOSAT-3/COSMIC satellites, plus GRACE-A and CHAMP. The assimilation experiments performed in Fall 2006, Spring and Summer 2007 showed a very significant impact of this new data type on the forecast skill for almost all the meteorological fields and all the expected areas, especially on the Southern Hemisphere. Figure 1 illustrates the importance of GPS radio-occultation measurements in constraining the analysis in the high southern latitudes where very few other observations with high vertical resolution are available.

Systematic biases of brightness temperatures are currently corrected using a Harris and Kelly (2001) scheme, which is based on a multiple linear regression against meteorological predictors (layer thicknesses, total column water vapour, surface temperature, etc.), beside corrections due to geometric matters (powers of the scan angle). This method was used in a static way, which needs a several-week period to train the regression. An adaptive method was developed and implemented at ECMWF (Auligné *et al.*, 2007), which introduces the coefficients of the multiple linear regression in the control variable of the 4D-VAR. As the correction is done adaptively, it does not attempt to correct model-induced biases. Another strength of the method is that conventional data (radiosondes data in particular) act as anchors when the coefficients evolve during the minimization, which prevents insidious drifts. Météo-France benefited from ECMWF developments and introduced the variational bias correction (VarBC) in ARPEGE for all AMSU-A, AMSU-B, HIRS, AIRS and SSM/I channels, in pre-operational mode. Figure 2 illustrates the positive impact of the variational bias correction on forecast RMS with respect to radiosonde geopotential measurements, especially in the stratosphere, which lasts all along the forecast range. Our future efforts in satellite data assimilation will be geared towards the implementation of this variational bias correction for all brightness temperature sounding data, the full use of the MetOp instruments (GRAS, IASI, and ASCAT), and a global increase in the number of pieces of information actually assimilated.

References:
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Auligné, T., A. P. McNally and D. Dee, 2007: "Adaptive bias correction for satellite data in a numerical weather prediction system", Q.J.R. Meteorol. Soc., 133, 631-642.

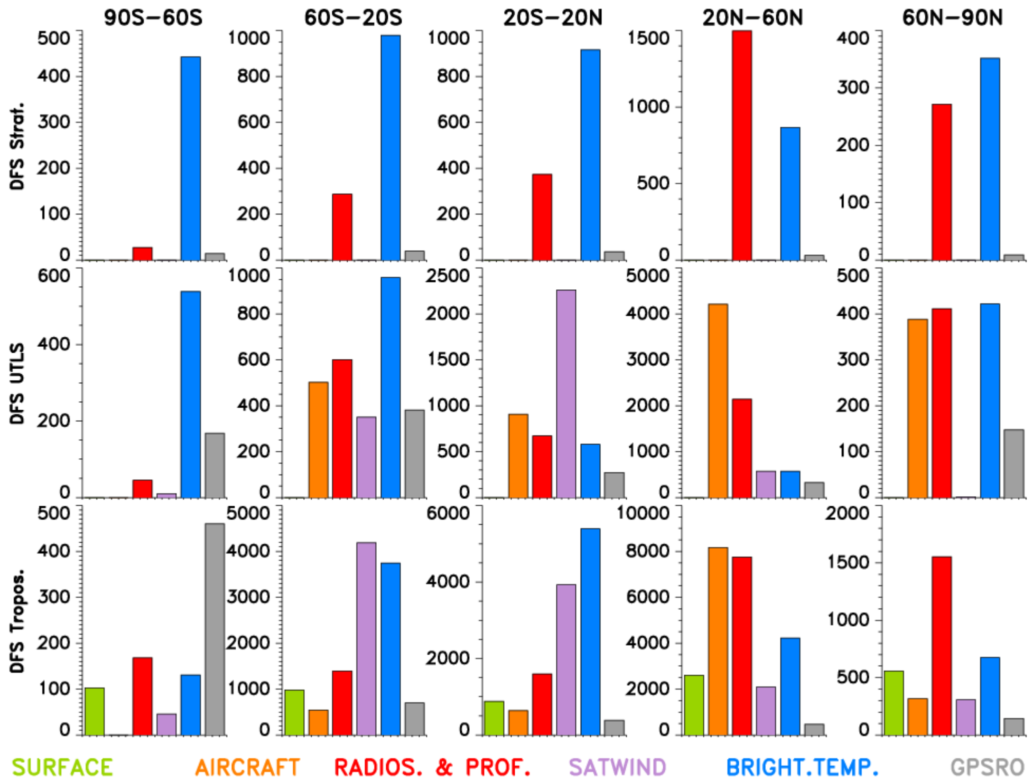

Figure 1: The numbers of degrees of freedom for signal (DFS) in the Météo-France 4DVAR analysis, as a function of observation data-type for five zonal regions and for three altitude bands (below 9 km altitude, between 9-16 km altitude, and above 16 km altitude). Note the different scales. Surface data from SYNOP, SHIP, Buoys and GPS Zenith total delays are in green, AIRCRAFT data are in orange, radiosonde and profiler data are in red, satellite winds from geostationary satellites, scatterometers and polar MODIS winds are in purple, radiance brightness temperatures from ATOVS, AIRS and SSM/I instruments are in blue, GPS radio-occultation data are in grey.

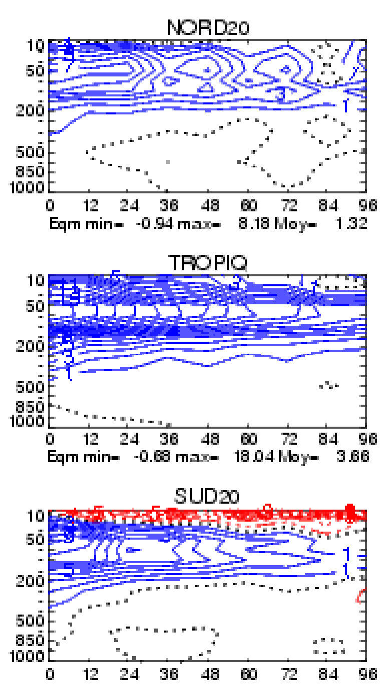

Figure 2 : RMS forecast error differences in geopotential height between the experiment using VarBC and the experiment not using VarBC, with respect to radiosonde data. RMS error differences are represented as a function of forecast range and pressure. Results are averaged over a 43 day period, in July-August 2007. Blue contours mean that VarBC improves the scores. The contour spacing is 1 m. Three areas are represented: the Northern Hemisphere (top panel), the Tropics (middle panel) and the Southern Hemisphere (bottom panel).