Status of cloudy infrared radiance assimilation at Météo-France

Vincent Guidard and Nadia Fourrié

Météo-France and CNRS, CNRM – GAME
42 avenue Coriolis, BP 45712
31057 Toulouse cédex 1

The global model ARPEGE uses a stretched grid with an horizontal resolution varying between 10 km over Europe and 65 km over the antipodes, which corresponds to a T798 truncation. The 70 vertical model levels in the σ-hybrid coordinates range from 5 Pa down to 17 m. The assimilation scheme is a 4D-Var one (Courtier et al., 1994; Rabier et al., 2000), with two loops at two different truncations: T107 for the first one and T323 for the second one. The assimilations are performed four times a day, over 6-hour time windows. The background error covariances are based on a multivariate formulation and statistics "of the day" are derived from an ensemble (Berre and Desroziers, 2010).

Four infrared sensors are assimilated in ARPEGE: HIRS (High resolution InfraRed Sounder), SEVIRI (Spinning Enhanced Visible and InfraRed Imager), AIRS (Atmospheric InfraRed Sounder) and IASI (Infrared Atmospheric Sounder Interferometer). For SEVIRI, the CSR (Clear Sky Radiance) product is assimilated. For the other three sensors, all channels which are identified as clear within the observed pixel are assimilated. The detection for HIRS is based on a selection from the CO2 channels. The detection of clear channels for AIRS and IASI is based on the McNally and Watts (2003) algorithm.

For AIRS, a CO2-slicing technique is used to retrieve the cloud top pressure and an effective cloud amount (of an equivalent single-layer cloud) in each pixel (Pangaud et al, 2009). These values are then used as inputs to the radiative transfer model and are kept constant during the minimization process. Cloudy radiances are assimilated when the retrieved cloud top pressure is between 600 and 950 hPa, whatever the effective cloud amount. There is no restriction on the channel selection in cloudy condition as our operational selection contains only channels whose weighting functions peak above 600 hPa.

The impact of assimilated these cloud-affected channels in addition to the clear ones was evaluated by Pangaud et al. (2009). A reduction of the root mean square error for the geopotential height, temperature and the wind was obtained for various forecast ranges when assimilated cloud-affected AIRS channels. It was also demonstrated that a storm track prediction was improved during a severe storm over the Mediterranean Sea.

AROME is a limited area model with a 2.5 km mesh covering mainland France. It is coupled hourly with the ARPEGE forecast on its lateral boundaries. The 60 unequally spaced vertical levels cover the troposphere with 19 levels in the first 1500 m and then more loosely in the stratosphere up to 1 hPa. AROME is a three dimensional non hydrostatic model, its dynamical core is based on the ALADIN non hydrostatic equations (Bubnova et al., 1995). The prognostic equations of the six water species (water vapour, cloud water, rain water, cloud ice crystals, snow and graupel) as well as the physical parametrizations are shared with the non hydrostatic Meso-NH Model (Lafore et al., 1998). AROME has its own 3D-VAR data assimilation scheme (Brousseau et al., 2008), based on the ALADIN France one (Fischer et al., 2005; Guidard et al., 2006). It has an incremental formulation originally introduced in the ARPEGE-IFS global data assimilation system. The increments are of the same resolution as the model. The AROME background covariances are based on the same multivariate formulation as in ALADIN-FRANCE (Berre, 2000). The operational AROME 3D-Var data assimilation system uses a 3 hour forward intermittent cycle. The analysed fields are the two components of the wind, temperature specific humidity and surface pressure. The other model fields are cycled from the previous AROME guess.

In operations, HIRS, AIRS and IASI radiances are assimilated the same way as in ARPEGE. SEVIRI raw radiances are used in AROME, and only clear channels are assimilated. The selection of SEVIRI clear channels is done for each pixel using a Cloud Type product provided by Météo-France / CMS in Lannion.

The CO2-slicing technique can be extended to IASI data, which has been evaluated. But another way is possible: as AROME provides a fine description of cloud water variables (cloud liquid water and cloud ice water, as well as a cloud fraction at each model level), one can use these cloud water profiles to fed a “cloudy” version of our operational radiative transfer model RTTOV.

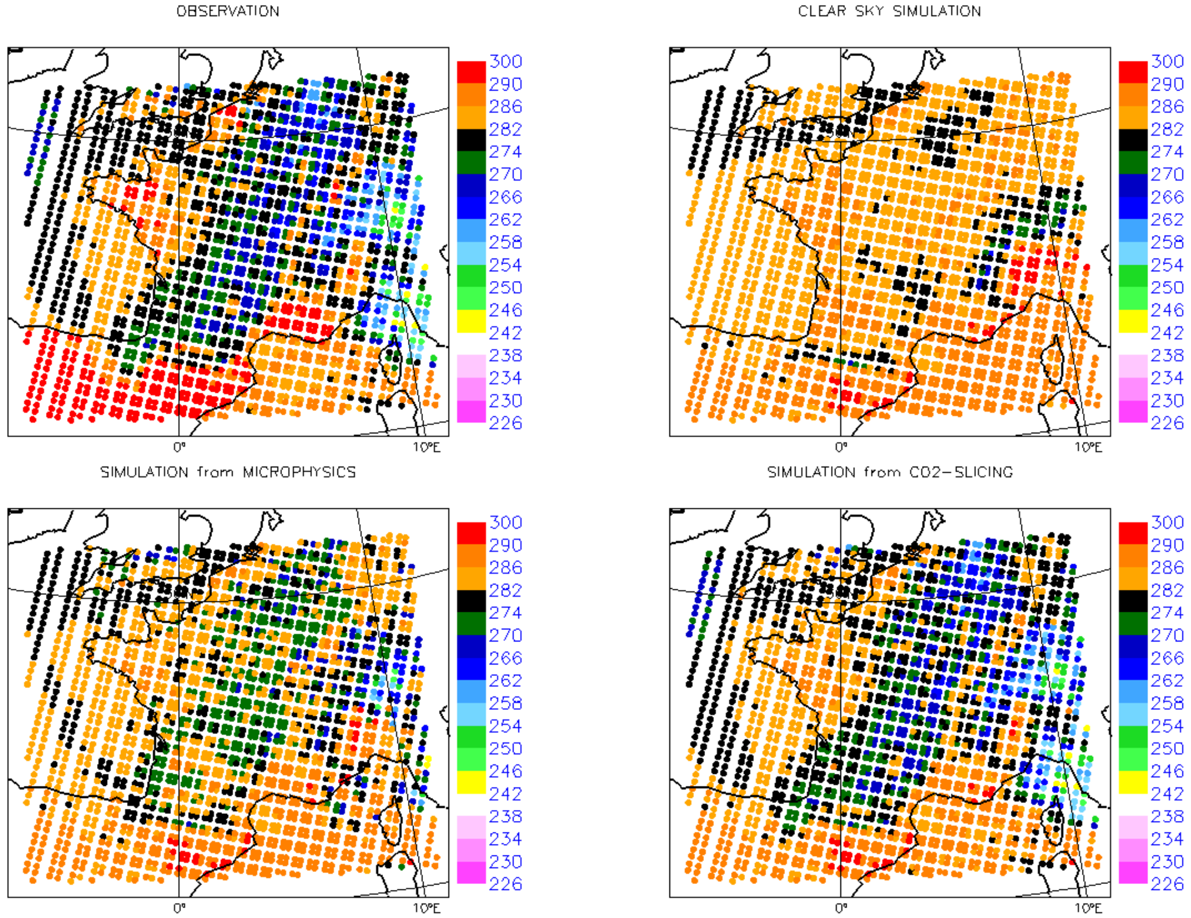

Figure 1: Observation (top left panel) and simulations when assuming clear sky conditions (top right panel), using RTTOV “cloud” with AROME cloud water profiles (bottom left panel) and using cloud top pressure and effective cloud amount from CO2-slicing (bottom right panel) for IASI surface channel #921.

In Figure 1, one can first notice a difference between the three simulations and the observations over land (Spain and French Riviera). Indeed, the simulated brightness temperatures are smaller than the observations in the clear-sky regions of the domain over land, but not over sea. This raises the question of land surface temperature simulation in the short range AROME forecast. It ensues that cloudy patterns are unequally simulated when using RTTOV "cloud", whereas simulations from the CO2-slicing retrieval are much more realistic. Despite a good horizontal location of the cloud liquid water content in AROME (not shown), the vertical extension is not wide enough as depicted in Figure 2. Which explains why the simulations from AROME microphysics using RTTOV "cloud" are warmer than IASI observations.

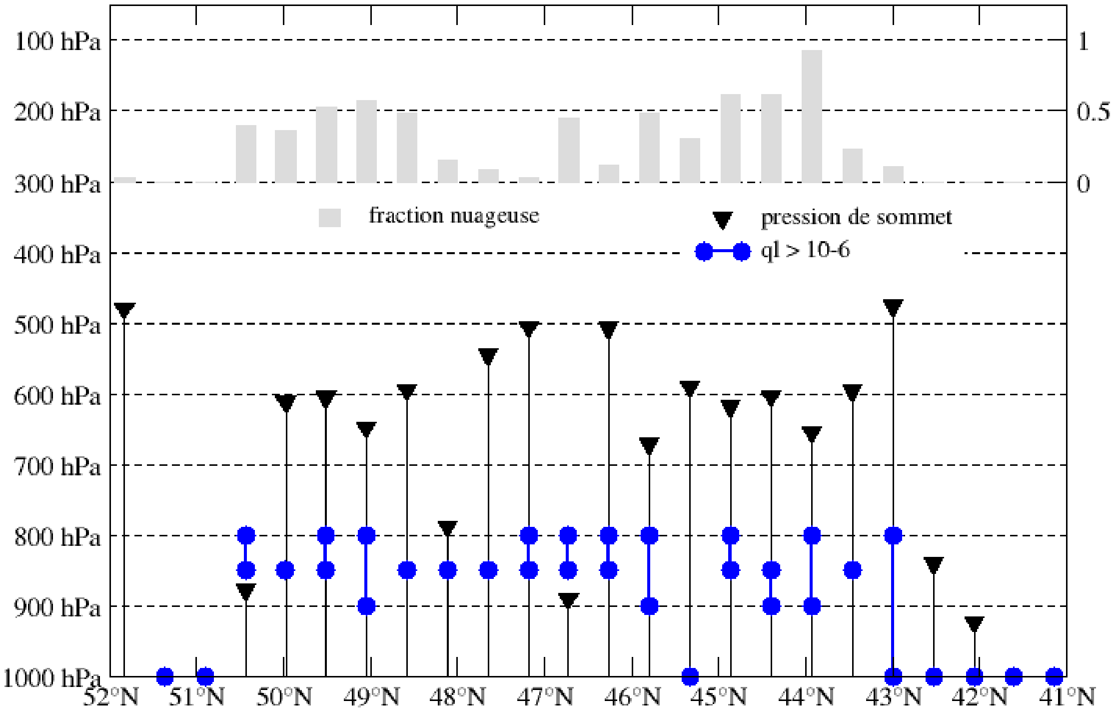

Figure 2: Vertical cross section from (52N, 3E) to (41N, 0E) of AROME cloud liquid water (vertical extension in blue), compared to cloud top pressures (black triangles) and effective cloud amounts (grey bars) retrieved from the CO2-slicing technique.

As a conclusion from this comparison between several approaches, several issues can be raised. The single-layer cloud approach assumed in our implementation of the CO2-slicing technique is an easy one but complex multiple-layer cases exist; furthermore, there is no feedback during the assimilation on cloud water variables. If cloud water profiles are jointly used with the RTTOV "cloud" radiative transfer model, one may be aware that problems in the forecast of land surface temperature will affect the simulations, as they do in clear sky conditions. Moreover, horizontal interpolations from model cloud water variable forecasts may be tricky (in the forward model, but also in the tangent linear and adjoint models). The description of both the observation errors and the background errors has to be accurate enough to enable an appropriate feedback on the cloud water variables of the AROME model.

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