Assimilation of precipitation information at ECMWF

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Humidity analysis represents a large challenge for numerical weather prediction because the accuracy of the representation of the hydrological cycle in a global model depends on the accuracy and representativeness of physical parameterizations. These have to cover the response of the atmospheric moisture fields to large-scale dynamics, cloud and precipitation formation and fluxes at the surface atmosphere boundary. Beljaars (2003) assesses the ECMWF model performance with respect to the atmospheric moisture representation. The main conclusions are that too much precipitation is generated over the entire dynamic range of rain rates but that the model has a dry bias outside areas with precipitation. The precipitation-bias and its reflection in total column water vapour (TCWV) was confirmed by Marécal et al. (2002) when comparing near-surface rain estimates from satellite data and model fields as well as the atmospheric moisture required for producing the respective rainfall intensities. The clear-sky dry bias has been noted at least since the assimilation of satellite data that is almost entirely sensitive to the TCWV (Gerard and Saunders 1999) and its manifestation in the so-called tropical precipitation spin-down that is the overproduction of rain originating from the moistening of the atmosphere in the analysis. This, of course, feeds back into the large-scale dynamics through the release of latent heat.

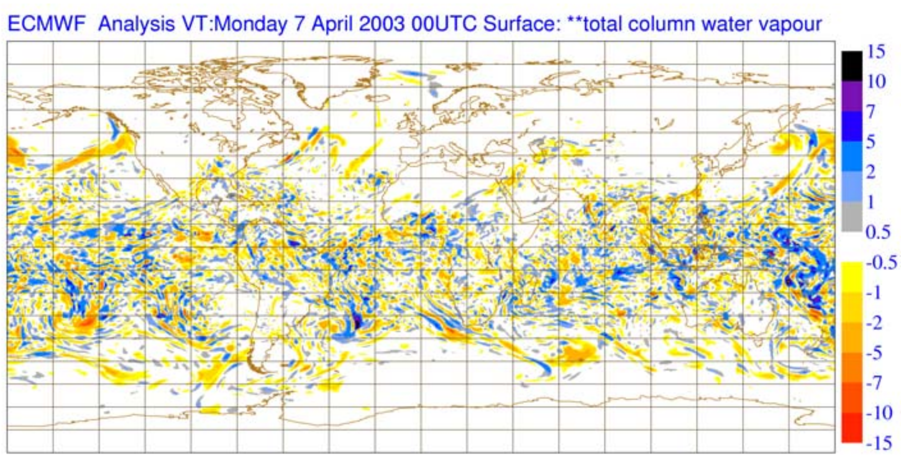

Figure 1: Difference of humidity increments between rain assimilation and control experiment (kg/m2).

Apart from improved physical parameterizations, the inclusion of observations directly related to clouds and precipitation will improve the humidity analysis - an effect that may dissipate during the forecast. At ECMWF, large efforts have been made for almost five years to prepare the assimilation of precipitation information. Marécal and Mahfouf (2000, 2002) have laid the foundation for the methodology that is likely to become operational in 2004. TCWV in rain-affected areas is estimated by a one-dimensional variational retrieval (1D-Var) that uses retrieved rain rates or microwave radiances (Moreau et al. 2003a) as observations. These TCWV 'pseudo-observations' are then assimilated like other observations in the 4D-Var system.

The intermediate 1D-Var protects the incremental 4D-Var assimilation from the strongly non-linear response of cloud and convection schemes to moisture increments as well as from the

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(weakly) non-linear relationship between radiances and water vapour / condensate (Marécal and Mahfouf 2003, Moreau et al. 2003b). All these developments required updated cloud (Tompkins and Janiskovà 2003) and convection (Lopez and Moreau 2003) schemes as well as their linearized versions in the minimization. Figure 1 shows an example of TCWV analysis increments from assimilating rain observations on April 7, 2003. While the global hydrological budget remains nearly unchanged there are large local increments that can be mainly associated with the displacement of precipitating systems. The effect of the assimilation of satellite data only between 40S-40N spreads to higher latitudes with similar increment values as observed in the Tropics. Figure 2 shows the improvement of the forecasted track of hurricane Isabel on September 15, 2003, computed from the analysis at 12 UTC.

Sensitivity studies indicate that the storm-track prediction quality highly depends on the combined effect of different observation types on humidity and dynamics. Therefore a thorough data screening is crucial for optimizing both analysis and forecast as a function of observational data and the representation of clouds and precipitation through physical parameterizations. In any case, the four-dimensional variational data assimilation system that is operated at ECMWF provides a very flexible framework for the improvement of the humidity analysis near precipitating systems.

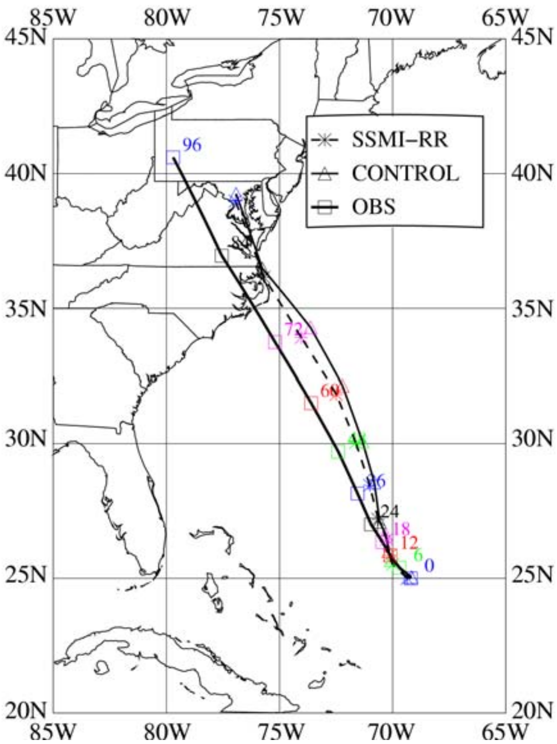

Figure 2: Hurricane Isabel track forecast on 2003/09/15.

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