Meteorology (NWP community)

Overview

Numerical weather prediction (NWP) models use meteorological data from various sources. Especially remote-sensing data are required because of their high spatial and time resolution as well as their availability. The problem is with assimilation of the data to operational NWP models. Increasing resolution of NWP models require correspondingly high resolution wind and moisture data for initialisation. NWP data assimilation techniques have advanced considerably in 1990s and 2000s, with the arrival of techniques capable of extracting information from time sequences of observations (see the reviews of MacPherson et al. 2004; Sun 2005). Development of radar networking and processing around Europe makes feasible the routine operational delivery of radar information.

Data usefulness

Only digital data are expected for meteorological modelling:

- radar reflectivity volume data (3D) or ground precipitation (PseudoCAPPI, SRI),
- Doppler radar winds as volume (3D: some radial wind PPIs) or one vertical profile (VAD, VVP),
- related observation error covariance matrix.

Examples of implementations

From the perspective of assimilation of radar rainfall observations into the NWP models, two main lines of work can be identified (Berenguer and Zawadzki, 2008):

- Schemes assimilating surface rainfall measurements, mainly to constrain the profiles of temperature and specific humidity at meso-α to synoptic scales.
- Schemes assimilating volumetric reflectivity observations to constrain the rainwater mixing ratio. These models (which can include a complete description of the microphysics or simplified parameterizations) are typically run at convective scale, though some attempts have been done at larger scales as well.

Assimilation is the process of estimating meteorological conditions on a regular grid from two main sources of information: observations from disparate sources and numerical models that incorporates through mathematical equations what is known about the atmosphere. Popular and conceptually simple approach is generally referred to as “nudging” (Alberoni et al., 2003; MacPherson et al., 2004). It has been used extensively in research applications, but also in some operational systems. In this method observations are “nudged” into the model at each time step of the integration by adding an extra term to the prognostic equations, forcing the model towards the observations. The forcing term is proportional to the difference between the observed value and the model’s estimates of the observed quantity, scaled by tuneable nudging coefficients, which may depend on the relative error of the observation and the model estimate (see examples in Figs. 1, 2, and 3).

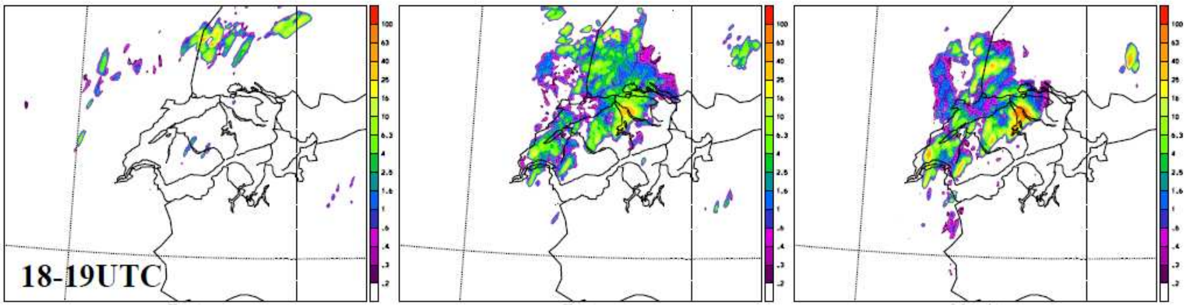

Fig. 1. Example of impact of precipitation assimilation on the 1-hour accumulated precipitation forecasts (COSMO LM model, 8 May 2003, 18-19 UTC, west of Switzerland). From the left: result without radar data, with radar data assimilated using LHN (Latent Heat Nudging) method, radar observation (Leuenberger et al., 2005).

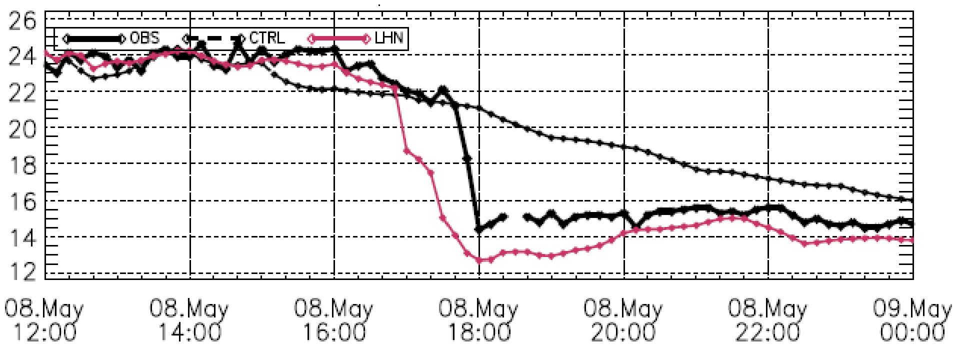

Fig. 2. Comparison of the NWP simulated temperature with observations from the Luzern (Switzerland) station. Black bold lines denote observations, black dashed lines result without radar data, and red lines with radar data assimilated using LHN (Leuenberger et al., 2005).

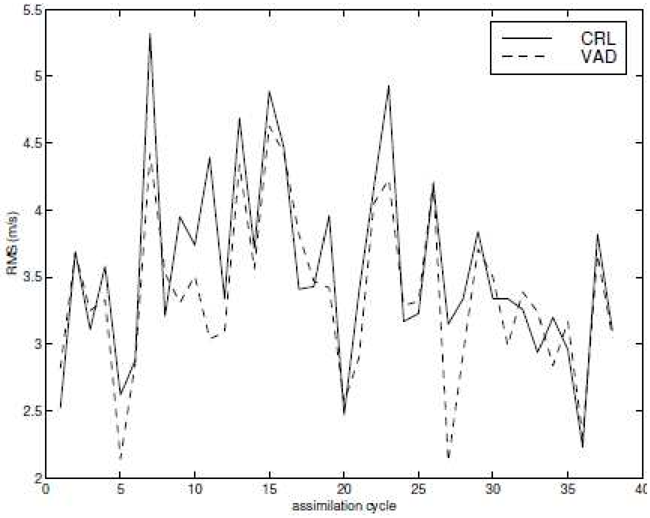

Fig. 3. Example of impact of wind data (VAD product) assimilation on the 24-hour 850 hPa wind speed forecasts (HIRLAM model). RMS (root mean square error) using conventional observations only, and conventional observations and radar VAD winds (Lindskog et al., 2002).

A new generation of assimilation schemes has been based on the variational approach. Variational assimilation provides a means of deriving the optimal analysis as combination of observations and model forecast. A key concept is that of the cost function which is a sum of terms, each measuring the distance between the model state and the available information. One term measures the distance to the observations, another the fit to the previous short-model forecast. In each term the distance is weighted by the inverse of the error covariance matrix for that information source.

4-dimensional variational assimilation (4D-Var) is run operationally among others at the European Centre for Medium Range Weather Forecasts, Meteo-France and Japan Meteorological Agency. It has also been used for a number of studies in radar data assimilation.

It has been pointed out (MacPherson et al. 2004; Sun 2005) that one important limitation of the schemes assimilating precipitation observations lies in the simplifications assumed to describe observational errors. In this framework, the present work focuses on the characterization of the observation error covariance matrix of radar rainfall estimates at ground for assimilation in mesoscale models.

Literature

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