SINGLE RADIANCE OBSERVATION EXPERIMENTS
USING GLOBAL AND REGIONAL MODELS

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Abstract

According to the action (DA/NWP-15) of the ITSC-16, single observation experiments were designed with the Met Office Unified (UM) global and different regional (UM, HIRLAM, and HARMONIE) data assimilation systems. Statistical objective analysis requires the explicit specification of the observation- and background-error covariances. In this exercise, we tested the use of background error statistics, derived using different approaches: i) the largely-adopted NMC method, ii) global ensemble analyses projected forward to the short-range forecast time by the Limited Area Model itself, iii) limited-area ensemble variational assimilation and iv) limited-area ensemble variational assimilation with perturbed lateral boundary conditions. The UM (global and regional) and the HIRLAM assimilation systems were tested with background error statistics estimated using the NMC method, while all the four above cited approaches were tested with the HARMONIE regional model.

1. Introduction

The accuracy of numerical weather forecasts depends on the quality of the initial condition, which can be improved with help of a data assimilation. Meteorological data assimilation systems produce an analysis by combining observations and a prior estimate of the state of the atmosphere, which is usually provided by a previous (forecast) model run, called background or first guess [*Lorenc, 1986*]. Statistical data assimilation schemes like optimum interpolation or variational need the definition of the observation and background error statistics. These errors, by definition, are the difference between the true state of the atmosphere, which is never perfectly known, and the observations and the background, respectively. The observational errors are usually provided by instrument vendors, and eventually adjusted to account also for representativeness errors coming from the observation operator. For the estimation of the background error covariances, indirect methods have to be adopted. They can be divided in four groups, i) the observational method, which derives background-error covariances through the study of the observation minus first guess differences (called innovations, or first guess departures), assuming that the observational and the background errors are uncorrelated. In this case, the covariances between the differently located innovations can be used to compute background-error covariances if the spatial correlations of the observational error are neglected. The observational method has been used e.g. by *Hollingsworth and Lönnberg [1986]* and is effective when the observing network is dense all over the domain and can represent multi-scale errors; ii) the NMC method [*Parrish and Derber, 1992*], which assumes that differences between two forecasts initialized at different times and valid at the same time may represent the forecast error evolution. Though the background-error covariances calculated with the NMC method theoretically reflect the structure of the analysis increments rather than the data assimilation and forecast model error evolution [*Berre et al., 2006*], it has been successfully used and validated in several assimilation systems [e.g. *Rabier et al., 1998*]. It is normally applied to forecast range differences of about 24 hours, in order to have a significant error evolution. For limite-area models (LAMs), a variant of the NMC method has been proposed by *Široká et al. [2003]*, in which lateral boundary errors are neglected, and initial condition errors are approximated

as follows: they correspond to differences between respective 24 hour forecasts (without any difference in initialization time) of the high-resolution limited-area model and of the low-resolution model, which provides lateral boundary conditions; iii) ensemble assimilation methods [*Houtekamer et al., 1996*], which derive background errors applying a Monte Carlo technique, typically introducing a random perturbation in the observations and in the forecast models. Background-error covariances are then computed as covariances of the differences between the members and the ensemble mean, or alternatively from the differences between pair of members randomly chosen. *Fisher [2003]* and *Belo Pereira and Berre [2006]* successfully applied this method to a global model and found that the statistics are rather sharper than the ones computed through the NMC method, while *Berre et al. [2006]* used global ensemble analyses downscaled to a limited-area model to produce ensemble forecasts which enhanced small-scale features; iv) Extended Kalman Filter-based methods, where background-error covariances are explicitly calculated in the analysis step and propagated forward in time in the forecast step [e.g. *Ghil , 1989*]. Starting from the explicit calculation of the error covariance matrices, these methods can provide climatological error covariances from the time-averaged covariances [*Bouttier, 1996*].

The background-error covariances are important for the following reasons (*Bouttier and Courtier , 1999*): **a) spatial spreading of information** from the observation points (real observations are usually local) to a finite domain surrounding it, **b) smoothing** of the increments is important in ensuring that the analysis contains scales which are statistically compatible with the smoothness properties of the physical fields, and **c) balance properties** , which are statistical properties that link the different model variables, which is interesting for the use of observed information: observing one model variable yields information about all variables that are balanced with it.

This short note reports single radiance observation experiments performed with different regional (using HIRLAM, HARMONIE and UM) and global (UM) data assimilation systems. Features derived using different assimilation techniques (3D- and 4D-VAR), as well as background-error statistics derived using different estimation techniques are presented. The single observation experiments were conducted with two single microwave radiances (channel 7 (54.94 GHz) from AMSU-A and channel 4 (183.31 ± 3.00 GHz) from the AMSU-B instruments). The "synthetic" radiance measurements were situated at 0 degree longitude and 60 degree north latitude. In order to have similar meteorological situation, the experiments were performed at the same time for all the participating models. Here, we report some example from the results. More detailed report will be posted on the ITSC web page.

2. Using the HARMONIE/Norway regional model

The HARMONIE/Norway regional model runs in experimental mode at the Norwegian Meteorological Institute. The assimilation system, based on the ALADIN model, includes a surface Optimal Interpolation scheme to update soil moisture content and skin temperature fields, an upper-air spectral three-dimensional variational assimilation to analyse wind, temperature, specific humidity and surface pressure fields. The resolution of the model is 11 Km in both x- and y-direction and the vertical discretization consists of 60 eta levels up to 0.2 hPa. The domain of the model is shown on the figure below (Fig. 1).

The tested background error statistics were derived via: **NMC:** NMC method; **GDE:** downloaded global ECMWF ensemble fields; **LPB:** LAM ensemble using perturbed lateral boundary conditions (LBCs); **LUB/LAM:** LAM ensemble using unperturbed LBCs (this part of the results is not shown here, see the ITSC web page for more details).
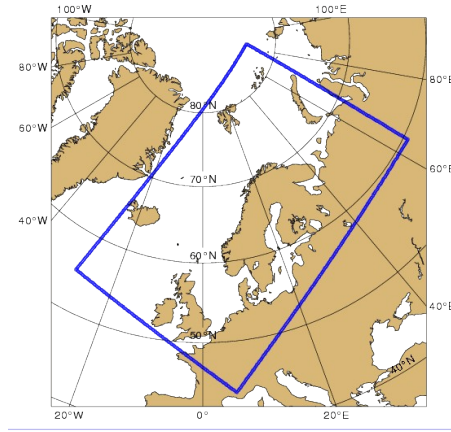
Figure 1: The domain extension of the HARMONIE/Norway model.
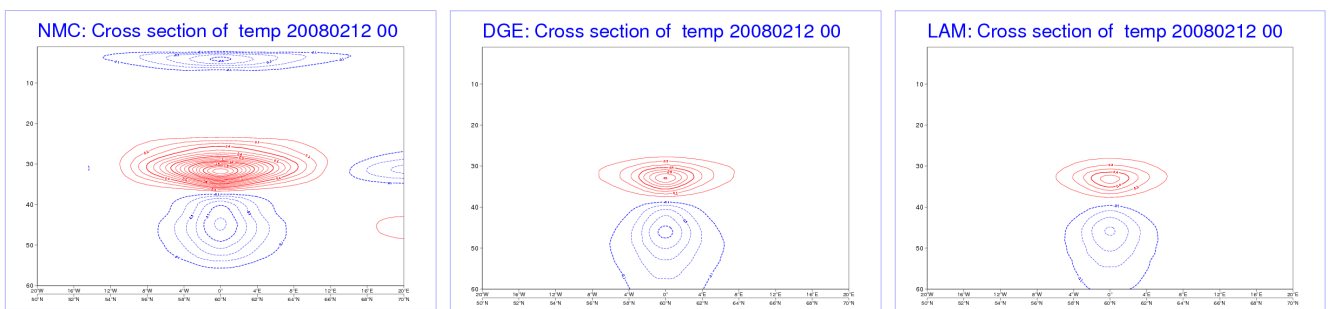

Figure 2: Single AMSU-A channel 7 observation: temperature increment using background error statistics, estimated via the NMC (left) and downscaled fields from global ensemble (middle), and the LAM ensemble with perturbed LBCs.

3. The Met Office experiments

3.1 Using the Met Office North Atlantic European (NAE) Model

The NAE model is a limited area model covering the area shown in Figure 3. The model horizontal resolution is 12 km and there are 38 levels in the vertical, extending up to an altitude of 35 km. The dynamical core is non-hydrostatic and a 4D-Var assimilation scheme is employed to produce analyses every six hours. Global error covariances are used with modified horizontal length scales.
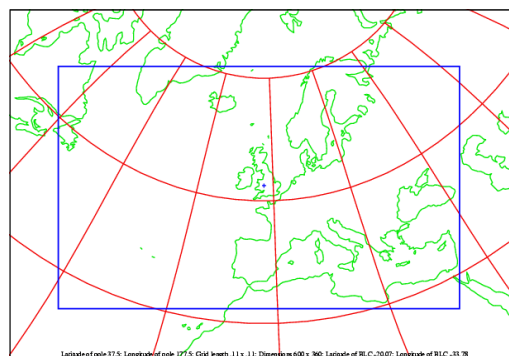

Figure 3: The domain extension of the Met Office NAE regional model
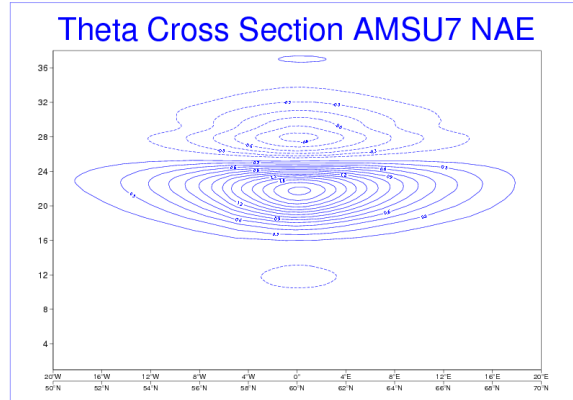
Figure 4: Single AMSU-A channel 7 radiance experiment with the NAE model. Temperature increment with background error statistics rescaled from the global one and estimated via the NMC method.

3.2. Using the Met Office Global Model

The model horizontal resolution is 25 km. The same vertical level set is used as in the NAE domain. Assimilation scheme is also 4D-Var with error covariances derived via the NMC method. There are 70 levels in the vertical extending up to an altitude of 80 km.
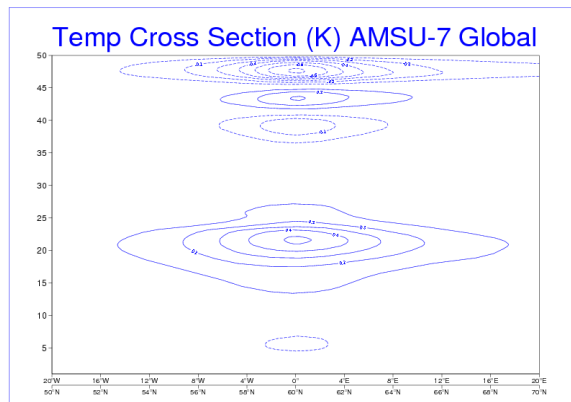

Figure 5: Single AMSU-A channel 7 radiance experiment with the global UM model. Temperature increment with background error statistics estimated via the NMC method.

4. The SMHI experiments

4.1 Using the HIRLAM C22 regional model

The HIRLAM model grid is expressed in rotated lat/lon coordinates. **C22** has 22 km horizontal resolution and 40 vertical levels up to 10 hPa. In these experiments 3D-Var was used. The background errors statistics were calculated using the NMC method and statistical balance (Figs. 6 & 7).
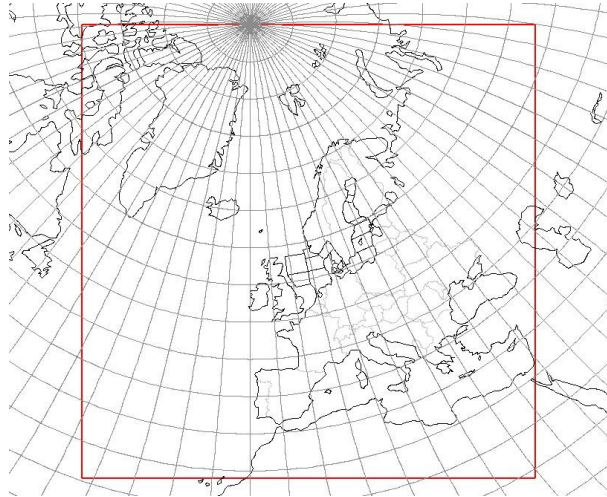
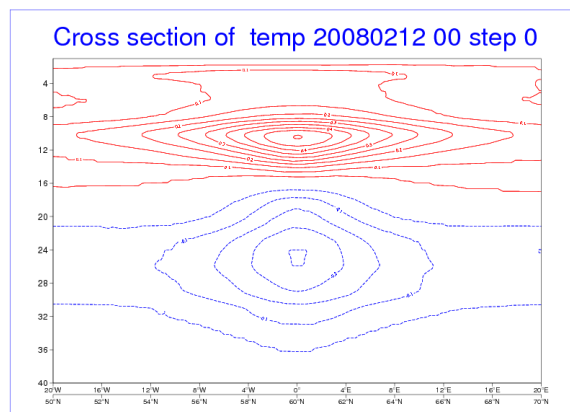*Figure 6: The domain extension of the HIRLAM C22 regional model.*

Figure 7: Single AMSU-A channel 7 radiance experiment with the HIRLAM C22 model. Temperature increment with background error statistics estimated via the NMC method.

4.2 Using the HARMONIE/Sweden regional model

In this exercise we used the HARMONIE 4D-Var assimilation system, which is under development and based mainly on the ALADIN model. The resolution of the model is 5.5 km in both x- and y-directions and with 60 vertical levels up to 10 hPa (Fig. 9).
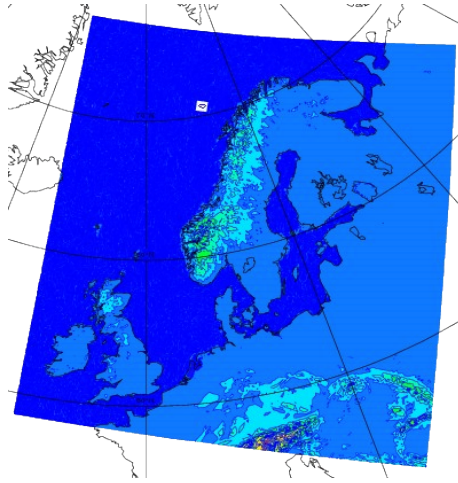
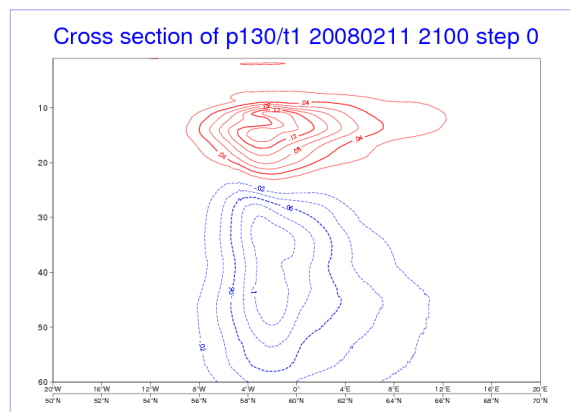*Figure 8: The domain extension of the HARMONIE/Sweden regional model.*

Figure 9: Single AMSU-A channel 7 radiance experiment with the HARMONIE/Sweden model. Temperature increment with background error statistics estimated using ensemble and downscaling technique.

4. Concluding remarks

Single radiance experiments were performed at different centres (Met Office, SMHI, and Met.no) under the same meteorological conditions and for the same place and time. The channel 7 (54.94 GHz) from AMSU-A and the channel 4 (183.31 ± 3.00 GHz) from the AMSU-B instruments were chosen. Three- and four-dimensional variational assimilation techniques were applied. Different background error statistics, estimated via different techniques (NMC and variants of ensemble), were used. Single radiance experiments showed broader increment spread with the NMC-derived background error statistics than with the ensemble-based ones. The applied rescaling (from global to regional or from larger LAM domain with coarser horizontal resolution to smaller domain with higher horizontal resolution) techniques (with the NAE and HIRLAM C22) showed that the size (the spread of information) of the increment remains the same. Using the ensemble-based statistics, the results via downscaling technique showed broader spread, while the statistics derived via LAM ensemble showed more local spread of information. See *Storto and Randriamampianina [2010]*, for more details about the use the ensemble technique to derive background error statistics for LAM data assimilation system.

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