Recent data assimilation activities at INM

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1. Work on the HIRLAM 3D-Var

Along the last months some assimilation activities have been carried out at INM with the HIRLAM 3D-Var system. Background error statistics have been calculated to allow the HIRLAM 3D-Var system to use the so called statistical balance background constraint with different vertical resolutions. With respect to the observation usage, some work has been performed to assimilate AMSU-A radiances within the INM operational suite, to improve the assimilation of two-meter relative humidity observations and ground based GPS Zenith Total Delay, ZTD, and to characterise error biases observed in the INM VAD data. Part of this work has allowed to introduce passively in the INM operational 3D-Var two-meter relative humidity observations, GPS ZTD data processed by eight European processing centers and INM VAD wind profiles since the end of October 2004.

1.1 Computation of background error statistics

NMC method has been used to calculate background error statistics for the statistical balance (Berre, 2000) of the HIRLAM 3D-Var system at different vertical resolutions, (40, 50 and 60 levels). The different datasets of forecast differences used are:

- FMI operational suite archived at ECMWF (RCRa) (22km, 40 levels) in late winter and early spring 2004,
- INM experiment over INM operational domain from April to June 2004 (17km, 50 levels)
- INM experiment over INM operational domain from April to June 2004 (17km, 60 levels)

The last two experiments were conducted in parallel to the operational INM suite (J.A. García-Moya, personal communication). The obtained length scales and vertical profiles of error standard deviation show to be very similar within the troposphere in the case of INM forecasts. RCRa error statistics are noisier, error standard deviations are larger and length scales longer. It has to be taken into account that this dataset contains a smaller number of cases and corresponds to a different time period. Horizontal correlation spectra show the expected behaviour in the vertical. They present some shift of energy towards the small scales when approaching low levels, with the exception of the humidity in the uppermost levels, but humidity error variance there is rather small. Vertical correlations show three dimensional isotropy, they are broader in the smaller wavenumbers and becomes sharper in the mesoscale. Cross covariances present similar features in all datasets. In particular they reproduce the link between convergent wind and mass and humidity respectively, represented in this background constraint formulation.

1.2 AMSU-A impact experiments

AMSU-A radiance data from NOAA 15 and NOAA 16 satellites are assimilated in the INM operational run (ONR: 17km degrees and 40 vertical levels) since January 2005. Previously, some work has been done. First Guess check, data selection, bias correction and data thinning followed HIRLAM Technical Report No.60. (Schyberg et al, 2003). RTTOV7 is used for radiative transfer model computations. Bias coefficients have been calculated initially from a experiment with passive AMSU-A data covering the period 10th October-11th November 2004 carried out at ECMWF in an area similar to our operational ONR, using 3 latitude bands, statistical balance background constraint and a diagonal observation error covariance matrix **R**. A second experiment with active AMSU-A (using the bias correction coefficients) was carried out to compare results to the previous passive AMSU-A experiment. There we were able to see the positive impact of assimilating AMSU-A data, especially in high and medium levels and in the longer forecast ranges.

We also studied the stability of bias correction coefficients, comparing the HIRLAM default bias correction coefficients, our bias coefficients calculated in the period (11th October-31st October 2004), our bias coefficients calculated between 12th November and 25th December 2005 and our bias coefficients calculated between 12th November 2004 and 11th January 2005 which are our operational run bias correction coefficients. This made us discard HIRLAM default coefficients and see that bias coefficients have high stability in time in the considered periods. Every month a similar comparison is scheduled in order to check bias coefficients stability and a real-time innovations monitoring system is being developed now.

1.3 GPS ZTD and two-meter reative humidity assimilation experiments

The moisture measurement from ground based GPS ZTD is an integrated moisture value instead of a profile, so, it is useful to include the two meter relative humidity (RH2m) observations from the SYNOP stations in the HIRLAM assimilation system with the aim of helping the analysis to distribute in the vertical the error in the integrated water vapour content given by the information contained in GPS ZTD observations.

The observation operator for RH2m that currently exists in the HIRLAM assimilation system was developed following Geleyn (1988). This operator has not been updated according to the development of the moasic type land surface parameterisation introduced afterwards in the HIRLAM model. On the other hand, it presents a discontinuity between the stable and unstable cases, for Richardson number Ri=0.

Along the last quarter of 2004, INM has developed a simple observation operator, the corresponding tangent linear and its adjoint, that has allowed assimilating two-meter relative humidity observations in the HIRLAM variational data assimilation system. It is based on a direct comparison of the HIRLAM relative humidity at the lowest model level against the observation at two meter in a unstable surface layer.

On the other hand, GPS ZTD observation to background error ratio has recently been estimated using the results by Stoew et al. (2005) on correlations of ZTD innovations. ZTD background error standard deviation has been obtained using the *bgos* option of the HIRLAM variational assimilation code. This procedure has allowed to tune the ZTD observation error standard deviation, which has resulted in a larger value, 18mm, than that used in previous experiments.

The impact of the assimilation of near surface humidity observations added to the rest of conventional observations, including GPS ZTD observations, has been studied through a series of parallel experiments carried out over one month long in spring 2004. Model precipitation over Spain shows for this period an improvement due to assimilation of new humidity information (ZTD or RH2m or ZTD+RH2m) in cases of moderate or heavy rainfall. Very small impact in verification scores of relative humidity (against radiosonde observations) has been found. However, a positive impact in RH2m due to assimilation of RH2m observations has been obtained.

1.4 Errors and quality control of INM VAD data

INM VAD data have been introduced passively through the HIRLAM 3D-Var system in two different experiments covering respectively the whole October 2002 and most of June 2004. The comparison against the HIRLAM model has allowed to identify the existence in the fall season, at 00 and 06 UTC, of persistent northerly wind in radar data associated with radar wind speeds (faster than HIRLAM model) of the order of 10 m/s. In the summer period, radar data shows a much better agreement to closest radiosonde. The observed features are very similar to those reported by several authors about the contamination of VAD winds by biological flying objects, especially migration birds in the U.S., as e.g. Gauthreaux et al.,1998, Collins, 2001 . According to Collins, up to a 40% of nighttime VAD data over the U.S. in spring is contaminated by birds migration and is rejected by the NCEP quality control procedure designed for this purpose. In order to filter them from the analysis we have followed the NCEP strategy, consisting on removing VAD winds which v-component of the wind increment exceeds some threshold in magnitude, from the south in spring and from the north in the fall. So, we have introduced an appropiate routine to quality control winds influenced by bird migration in the screening part of the HIRLAM 3D-Var system. Additionally we have used VAD and co-located radiosonde wind innovations to tune the VAD error standard deviation, *sigmao*, with a diurnal dependence. For that purpose, the assumed wind background error has been estimated using the *bgos* option included in the HIRLAM 3D-Var system, and wind observation error values for radiosonde assigned in *obsproc* step have been used. These has produced VAD *sigmao* values ranging between 4-7 m/s at night.

The new quality control and *sigmao* values have been tested in a parallel run assimilating VAD data over the whole month October 2002. The objective verification of HIRLAM forecasts has shown a positive impact of assimilating VAD data especially over France, but also over Spain in humidity and wind in the shorter forecast ranges (up to H+24). Model precipitation has been verified using the high resolution INM Climate stations network reduced to the model resolution (22km). The assimilation of VAD data seems to improve the model precipitation in cases of moderate rainfall according to the obtained standard verification scores like ETS and TSS. This is also visible in separate case studies.

VAD wind profiles are passive in the INM operational suite since the end of October 2004. A recent analysis of these data, similar to that performed over October 2002 and June 2004, has shown similar features in the autumn 2004 and still more pronounced in spring 2005, but in this case southerly instead northerly winds. This seems to confirm that birds migration is seriously affecting night VAD data both in the fall and spring.

2. Soil moisture assimilation, results of ELDAS experiments

This work has been carried out in the context of the ELDAS project (European Land Data Assimilation System, see http://www.knmi.nl/samenw/eldas) (Van der Hurk et al., 2002), which is supported by the European Union in the context of the Fifth Framework Program. ELDAS was designed to develop a general data assimilation system for estimating soil moisture fields on the continental (European) scale, and to evaluate the impact of these fields in meteorological and hydrological applications. Moreover, a set of accurate databases of precipitation, radiation and surface heating rates at high spatial and temporal resolution were created.

The INM has participated in the project to asses the impact of the ELDAS generated soil moisture fields, provided by the ARPEGE global model, when applied to the soil water content initialization in the HIRLAM simulations (see Parodi et al., 2005). Three different soil moisture assimilation schemes have been compared using the operational HIRLAM model along the growing period from June to November 2000. Three experiments were done using the same HIRLAM system set-up, and differing only in the soil moisture assimilation algorithm,

- CNTRL experiment made use of the sequential assimilation installed in the HIRLAM reference system.
- ELD experiment imported daily (at 0UTC) soil water content produced by ARPEGE with a 24 hours variational assimilation procedure and further corrected using ELDAS analysed precipitation.
- VAR experiment made use of a 6 hours variational soil moisture assimilation within HIRLAM.

Important modifications were introduced in the HIRLAM system to approach the land surface scheme formulation of the ARPEGE and HIRLAM models. ISBA surface scheme without tiling structure and ECOCLIMAP as physiographic database are common modifications to the three experiments. In the case of VAR experiment, the soil variational assimilation code developed in Météo-France (Balsamo et al., 2004) has been implemented in the HIRLAM system. This last experiment was run over a reduced time period to be tested against the ELD parent experiment.

Soil water content shows noticeable differences between the three experiments. CNTRL presents the larger analysis increments. The total amount of soil water content added by the analysis step in all experiments is of the same order of magnitude that other terms in the soil water balance. The verification of screen level parameters does not show, in general, a clear improvement of any soil moisture assimilation method. In order to asses the impact of different soil moisture initialization methods, the systematic differences in analysed soil moisture, and predicted surface temperature, two-meter relative humidity and temperature have been calculated. It is observed that the largest differences in near surface parameters appear over southern Europe. Some features have become evident, as the lack of sensitivity of two-meter temperature and humidity to the big differences in soil moisture observed along the coast, indicating the dominant role there of sea breeze local circulations.

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