

Use of SEVIRI radiances for handling of position errors in a limited-area data assimilation system



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Background

HIRLAM Data Assimilation

The HIRLAM limited-area forecasting system (Undén *et al.*, 2002) has been developed within an international cooperation, including 10 European countries. It can be applied for both deterministic for probabilistic forecasting. The deterministic upper-air data assimilation is based on a variational approach when running in probabilistic mode a hybrid ensemble/variational upper-air data assimilation is applied. The upper-air data assimilation utilizes various types of in-situ measurements, radar and satellite based remote sensing data as well as GNSS atmospheric delays. The deterministic and the probabilistic forecasting systems are set-up over two European domains as illustrated in Figure 1. The deterministic system is set up with 40 vertical levels and with a horizontal resolution of 22 kilometers. The probabilistic system is set up with 60 vertical levels and with an horizontal resolution of 10 kilometers. There are 20 ensemble members and a control run.

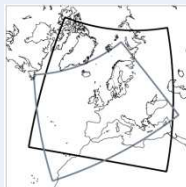


Fig. 1. Model domain of deterministic HIRLAM set-up (black frame) and of probabilistic model set-up (grey frame).

Handling of Position Errors Utilizing SEVIRI Data

Forecasting the position of localized weather phenomena such as clouds, precipitation, and fronts is a difficult task. However, these areas associated with clouds are important since this is where most of the active weather occurs. Position errors violates the additive Gaussian error model most data assimilation methods rely on. Phase errors in general are non-Gaussian and introduce bias and/or inflate the background error covariance. We propose a two step approach to handle both position errors and amplitude errors in data assimilation. First, we estimate and correct for the position error and second we estimate and correct for the amplitude error, using standard data assimilation methods. The position error handling step is based on a state-of-the-art image registration method (Sun *et al.*, 2010) and the method is adapted to both deterministic and ensemble data assimilation. The position error handling utilizes data from the SEVIRI instrument onboard the Geostationary METEOSAT satellites. We obtain data every 15 minutes with a horizontal resolution of roughly 5 kilometers over a European domain (Figure 2). Currently two infrared channels (located around 6.2 μm and 7.3 μm , respectively) are used.



Fig. 2. SEVIRI RGB image for an European scene on 20070929 1200 UTC.

Methodology and Results

Position Error Handling in Deterministic Data Assimilation

For the correction of position errors in deterministic data assimilation a two-dimensional displacement field is estimated using the background state, and high resolution radiance data from the SEVIRI instrument, as input to an optical flow algorithm. This is illustrated in Figure 3, in the case of SEVIRI radiance data from one particular channel. The displacement fields from the two channels, having sensitivities to different vertical levels of the atmosphere, are then combined to obtain a three-dimensional displacement field. The displacement field is estimated with a smoothness constraints and we introduce constraints to prevent displacement in areas of high orography and also close to the surface. The same displacement field is applied to all upper-air parameters. In order to obtain a position error corrected and balanced modified background state in the case of deterministic data assimilation, vertical profiles from the aligned model state are assimilated as pseudo observations within the traditional variational data assimilation framework. The methodology can thus be summarized as follows:

- Apply image processing to obtain displacement field and generate pseudo-observations from the position error corrected background state.
- Assimilate the pseudo-observations in a first step to obtain a balanced and position error corrected background state.
- Use this modified background state to minimize the amplitude error using a standard variational method and real observations in a second step.

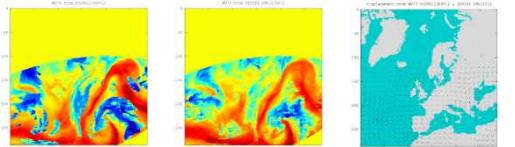


Fig. 3. Estimation of a displacement field. An example from 20090113, 12 UTC, where a low pressure system has moved too fast in the model. Blue represents low values and red represent high values. Left: Background equivalent of SEVIRI WV 073 radiance. Middle: corresponding satellite measurements. Right: Estimated displacement field.

A case study has been carried out with the deterministic system, set-up over a domain illustrated by the black frame in Figure 1, for 20090113 12 UTC. In Figure 4 verification scores of a +12h forecast launched from an initial state derived with 3-dimensional variational data assimilation (3D-Var) without and with handling of phase errors respectively, are shown. Results indicate a benefit from handling position errors.

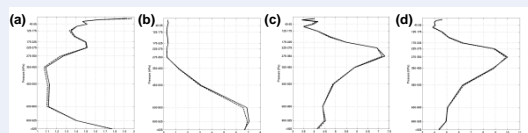


Fig. 4. Root Mean Square Error (RMSE) of +12h forecast launched from 20090113 12 UTC, for verification against radiosonde observations. Full lines are for the control standard data assimilation and dashed lines are for data assimilation including a correction of phase errors. The scores are for temperatures (a, unit:K), specific humidities (b, unit: kg/kg) and wind u-components (c, unit:m/s) and wind v-components (d, unit:m/s).

Position Error Handling in Probabilistic Data Assimilation

In the case of hybrid ensemble variational data assimilation two-dimensional displacement fields are calculated for each of the ensemble members and for the two different SEVIRI radiance channels. These are then combined to one single two-dimensional displacement field for each ensemble member by taking the average of the displacements fields of the two SEVIRI channels. These displacement fields are then used to glue together a best member field, in which the ensemble member with the smallest displacement field is used in each horizontal position. An example of such best member field is shown in Figure 3. The best member field is used to generate pseudo-observations to be assimilated within the traditional hybrid data assimilation framework to obtain a phase error corrected and balanced modified background stat. In the second second step this modified background state is used together with a full set of observations in a traditional hybrid ensemble/variational data assimilation to minimize the remaining amplitude errors. The methodology can thus be summarized:

- Apply image processing and in each location use the member state with least displacement error.
- Assimilate pseudo observations from best member model state.
- Use this modified background state to minimize the amplitude error using normal ensemble/variational data assimilation and real observations in a second step.

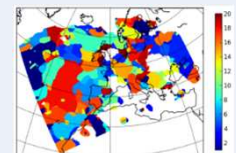


Fig. 5. Best member field derived for 20080206 00 UTC. Different colors represent different ensemble members. White represents the control member.

A case study has been carried out with the probabilistic system set-up over a domain illustrated by the gray frame in Figure 1, for 20080205 12 UTC. The verification scores of control forecasts launched from the initial states derived with the hybrid system with and without correction of position errors using the gluing approach are presented in Figure 6. The scores of the two hybrid runs are also compared with the scores of a deterministic standard 3D-Var run. In general the verification scores are better for the two hybrid runs than for the deterministic run.

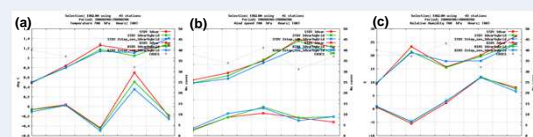


Fig. 6. Scores for verification of forecasts launched from 20080205 12 UTC against radiosonde observations. Standard deviation and bias at 700 hPa for standard 3D-Var (red), standard hybrid ensemble/3D-Var (green) and hybrid ensemble/3D-Var with correction of phase errors (blue). (a) temperatures (unit: K), (b) wind speeds (unit: m/s) and (c) relative humidities (unit: %).

References

- Sun, D., Roth, S. and Black, M. J., 2010. Secrets of Optical Flow Estimation and Their Principles. IEEE Int. Conf. on Comp. Vision & Pattern Recognition.
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