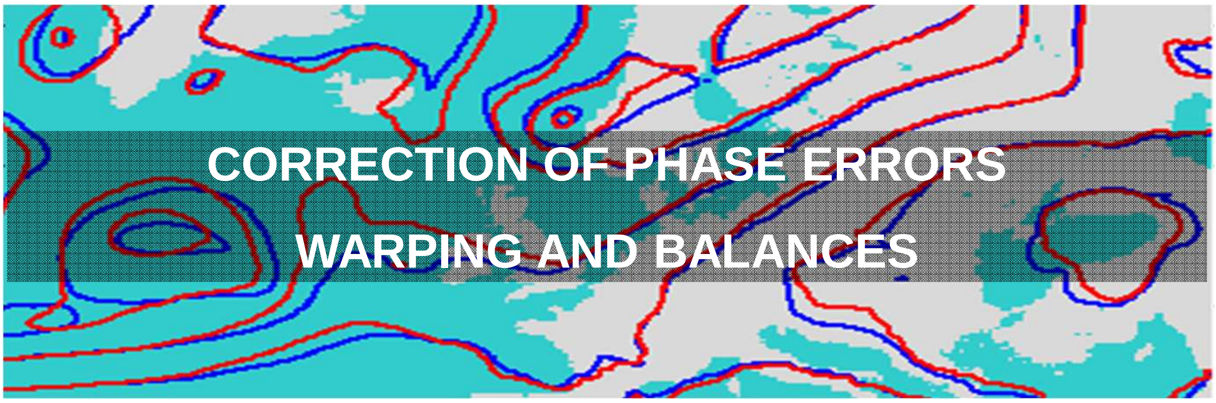

CORRECTION OF PHASE ERRORS WARPING AND BALANCES

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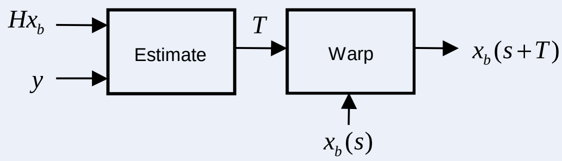
Background

Phase errors

Techniques traditionally utilized in meteorological data assimilation are based on the assumption that the error distributions of the observations and the background field are additive and with a Gaussian distribution. Sometimes, however the errors are non-additive. It is well known that phase errors in the background field are associated with non-additive errors. We propose a two step procedure for handling of both additive and non-additive types of errors in the data assimilation procedure:

1. Minimize non-additive errors by applying a warping technique to correct phase errors in the background field.
2. Minimize additive errors by applying standard 3D-Var data assimilation utilizing the phase-corrected background state.



Balances

Application of the warping technique introduce imbalances in the phase corrected background state. These imbalances cannot be removed by a incremental digital filter and introduces noisy spurious adjustment processes through gravity waves. The imbalances could be handled by a full digital filter initialization, but then there is a risk to remove also relevant information provided by the observations. In the present study we are investigating an improved handling of balances in the warping step. The warped field is introduced as pseudo-observations and used to modify the original background field in a full-scale data assimilation with HIRLAM variational data assimilation and its balance constraint. The resulting field is then used as background field in the following standard 3D-Var, when a full set of observations are assimilated.

Selecting a case study

A large number of HIRLAM C22 (domain shown by Fig 1) + 12 hours forecasts were compared with analyses valid at the same time. A case with large forecast phase errors was identified (Fig 2) - the 12 hours forecast valid at 20090113 12 UTC. A series of parallel data assimilation experiments was carried out for 20090113 12 UTC. In the reference experiment the 12 h forecast launched from 20090113 00 UTC was used as background state and in the rest of the experiments various warping approaches to handle the phase errors in the background state were investigated.

Results

Experimental Design

Here the results from three different runs are presented: CONTROL: No warping before standard 3D-Var. WARP: Warping before standard 3D-Var. PSEUDO: Originating points of displacement fields were introduced as pseudo-observations in 'arrival' grid-points. The pseudo observations are assimilated to phase-correct background state before standard 3D-Var. Pseudo-observations for (u.v,T,q) from all horizontal grid-points where the length of displacement fields are larger than a threshold (and not too high orography) are assimilated (Fig 3). The functionality of the warping and application of a balance constraint are demonstrated through detailed inspection of the background state of and through calculation of objective verification scores for forecast skill.

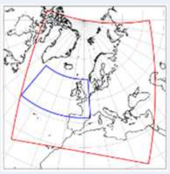


Fig 1. Model area (red) and verification area (blue) where phase errors are large..

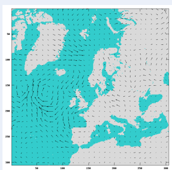


Fig. 2. Estimated phase errors for the 12 hour forecast from 20090113:00 UTC.

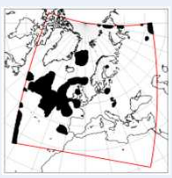
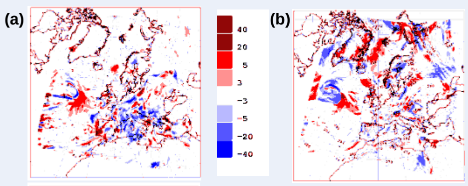


Fig. 3. Areas with large displacement vectors and no high orography.

Warping modifications of background state

Shown (Fig 4) are the temperature errors close to 950 hPa for the + 12 h forecast when verified against the corresponding analysis and how the warping technique is used to correct the phase errors over the Atlantic, East of Great Britain. The PSEUDO experiment results in a much more balanced background state and analysis than WARP (not shown).



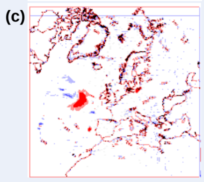


Fig. 4. Temperature errors (a) for the 12 h forecast when verified against the corresponding analysis and temperature modifications to the phase error affected background state in the WARP (b) and PSEUDO (c) experiment. Vertical level is around 950 hPa and unit is Kelvin times 10.

Forecast verification scores

The potential of the warping based phase corrections to result also in improved forecasts in the Atlantic region has been investigated. Verification of 6 hours forecasts after application of data assimilation and incremental digital filter initialization are presented in Table 1. Root Mean Square (RMS) Errors of 6 hours forecasts for verification against the HIRLAM C22 analysis at 20090113 18 UTC, averaged over the area represented by a blue frame in Fig 1. The scores are for the model variables surface pressure, u, v, T and q at model levels 30 (~855 hPa) and 40 (~1009 hPa). When WARP and PSEUDO produce better scores than CONTROL they are marked green and cases when the scores are worse are marked red. Results from applying the warping together with the balance constraint through pseudo observations are encouraging.

Table 1: Forecast verification scores (RMS).

	CONTROL	WARP	PSEUDO
Surf. Pres. (Pa)	186.017	134.991	177.766
T lev 40 (K)	0.554	0. 555	0.548
T lev 30 (K)	0.912	0.959	0.851
Q lev 40 (kg/kg)	0.000577	0.000393	0.000342
Q lev 30 (kg/kg)	0.000341	0.000551	0.000507
U lev 40 (m/s)	2.560	2.210	2.425
U lev 30 (m/s)	2.933	2.646	2.858
V lev 40 (m/s)	2.309	2.151	2.102
V lev 30 (m/s)	2.484	2.479	2.358

Future developments

Future work will focus on warping studies with real data from the SEVIRI instrument onboard Meteosat. These studies will be associated with developments aiming at an optimal strategy of handling the fact that observations and model data represent different scales. In addition an alternative approach for handling of phase errors will be investigated. This approach will be based on a particle filter idea.

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