

An Object-Oriented Approach to Best Member Selection - Towards Adaptive Regional Ensemble Forecasting



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Introduction

Errors in regional forecasts often take the form of phase errors, where a forecasted weather system is displaced in space or time. For such errors, a direct measure of the displacement is likely to be more valuable than traditional measures, such as RMS error. Here we develop a displacement measure, with a view to using it to explore the relative importance of various sources of uncertainty in regional ensemble forecasts. The regional ensemble system currently developed at DLR builds on the COSMO-LEPS (quasi-operational at ECMWF since Nov. 02), remote sensing observations (Satellite, Radar) and a pattern recognition algorithm.

Key Questions:

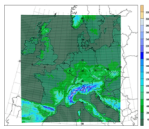
1. Does image matching provide a reasonable error measure for phase errors?
2. How does variability associated with small scale uncertainty compare with uncertainty from larger-scale environment (boundary conditions)?
3. Does increasingly strong orographic influence remove the uncertainty due to small-scale variability?

COSMO-LEPS

The limited-area ensemble prediction system COSMO-LEPS combines the global ECMWF EPS (providing initial and boundary conditions) with the high-resolution Lokal-Modell (LM). To reduce the computational effort, the LM is nested on selected members of the global ECMWF EPS. This selection is done applying a cluster analysis clustering global EPS forecasts that are similar in the target region (based on 4 variables u, v, Φ, q at 3 pressure levels 500, 700, 850 hPa) and choosing only a single representative set of boundary conditions for each cluster.

Set-up for 9 July 2002:

- 51 member ECMWF EPS T252L40 started at 00 UTC 7 July 2002
- Cluster analysis (fc +48..60h) using 10 classes
- LM $\Delta x = 7$ km with prognos. precip. and critical ice mixing ratio 2×10^{-5}
- 10 LM experiments fc +72h



Synthetic Satellite Images

Synthetic satellite imagery is generated using the fast radiative transfer model for TIROS Operational Vertical Sounder (RTTOV-7), that allows fast simulation of brightness temperatures for various satellite radiometers (e.g. Meteosat 7 MVIRI and Meteosat 8 SEVIRI).

The input variables provided by LM are

- atmospheric profiles of **temperature, specific humidity**,
- cloud properties (**cloud cover, cloud liquid water, cloud ice**),
- specific content of **snow and rain**,
- and surface properties (**skin temperature, temperature and specific humidity at 2m, land-sea mask**).

The output variables are clear and cloudy-sky radiances and brightness temperatures in IR and WV of Meteosat 7 and 8 channels of Meteosat 8. Sensitivity studies showed that a more realistic representation of clouds in LM can be achieved using the prognostic precipitation scheme (incl. precipitating snow) and a modified critical ice-mixing ratio.

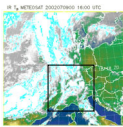
Pyramidal Image Matching

Using the model-forecast and the observed satellite image a field of displacement vectors is computed which 'morphs' the simulated image into a best match of the observed image. The stepwise procedure is as follows:

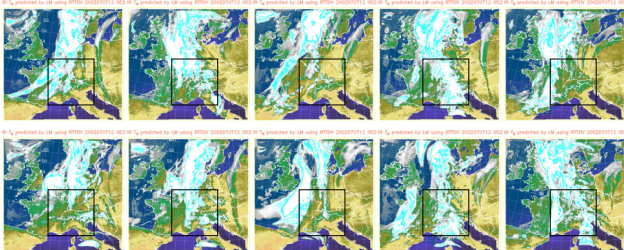
1. Choose a threshold temperature (e.g. -20°C) below which cloud structures (i.e. brightness temperatures) are matched
2. Project observed and simulated images to same grid
3. Coarse-grain both images by pixel averaging, then compute displacement vector field that minimizes total squared error in brightness temperature (rb3_4)
4. Repeat step 3 at successively finer scales
5. Displacement vector for every pixel results from the sum over all scales

The magnitude of the mean displacement vector and the quality of the final match measured by the correlation give objective measures of the quality of the forecast.

Convection in Bavaria on 9 July 2002, 16 UTC



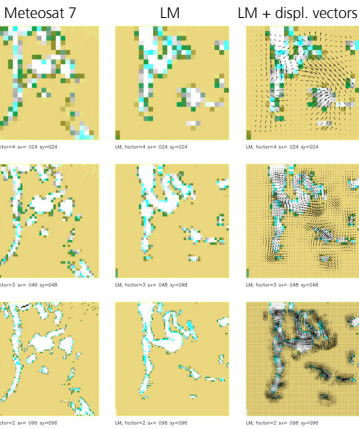
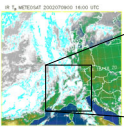
Visual intercomparison of the observed IR Meteosat 7 (left) and the model-forecast synthetic IR images of each representative member of all 10 clusters (fc +52h; below). While most of the clusters capture the synoptic scale cloud pattern there are large differences (i.e. spread) in the pre-frontal convection ahead the cold front in the Alpine region (black square).



Rank	1	2	3	4	5	6	7	8	9	10
population	3	2	4	1	5	7	6	8	9	10
subjective	2	10	4	7	9	1	5	6	8	3
displacement	4	9	2	10	7	6	1	8	3	5

Rank of clusters ordered by population (member per cluster), visual inspection of 8 scientists (subjective) and weighted displacement (see Fig. (c) at fc +52h in lower box). The image matching agrees reasonably well with human rank.

Pyramidal Image Matching of Member 7



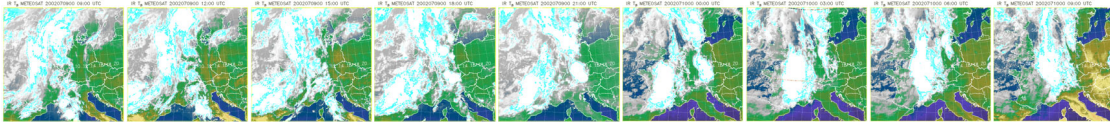
Set-up:

- same projection
- same subdomain 128×128 LM gridpoints (black square)
- $BT < -20^{\circ}\text{C}$ only
- coarse-grain (5x5 LM GP per pixel element; upper line)
- LM coarse-grain superimposed with displacement vectors in the actual verification domain (gridpoints common in Meteosat and LM; right row)
- successively finer grain

Results (from left to right): Meteosat 7 observed cloud structures, original LM clouds superimposed with total displacement vector field and matched cloud structures.

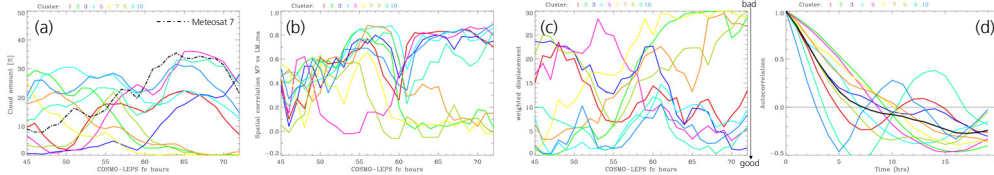
Timeseries

3 hourly Meteosat 7 observed IR images from 9 July 9 UTC until 10 July 9 UTC



Quality Measures:

The weighted mean displacement (c) combines 3 quality measures: the ratio of cloud occurrence (a), the correlation of observed Meteosat and matched LM cloud structures (b) and the mean displacement (all evaluated in the subdomain). The persistence of the quality of individual members is about 6 hours (d).



Outlook

- Introduction of small-scale perturbations to spawn new members; discard bad members (the adaptive component)
- Apply Latent Heat Nudging only in best members (within DAQUA project)
- Apply feature tracking algorithm
- Investigation of further cases with different orographic forcing (e.g. MAP, CSIP, COPS)