Study on limited-area short-range ensemble approaches targeted for heavy rain in Europe

Kai Sattler and Henrik Feddersen
Danish Meteorological Institute, Lyngbyvej 100, DK-2100 Copenhagen Ø
Email: ksa@dmi.dk

A common way to address the uncertainty in numerical weather prediction (NWP) is to design an ensemble, attempting to forecast the likelihood for the expected future event on basis of the best possible knowledge about the atmospheric state at the time of the forecast production. The interest of doing this with a high-resolution limited-area NWP model (LAM) has grown during the last years, and there are many different possibilities of designing a LAM ensemble. This study investigated two different approaches of creating a small LAM ensemble for rainfall prediction. They are both based on the Danish Meteorological Institute's (DMI) version of the HIgh Resolution Limited-Area Model DMI-HIRLAM, which has been configured as a doubly 1-way nested system, were the outer model receives initial as well as lateral boundary data from the ECMWF ensemble prediction system (EPS) in a 6 hour frequency. This outer model covers Europe and the North Atlantic as well as parts of North America. The inner DMI-HIRLAM model is the actual model of interest and covers Europe with a 0.1° grid. Integrations for this study were performed up to 72 hours ahead.

The first LAM ensemble is designed to represent an uncertainty in the initial condition (atmospheric state) as well as at the lateral LAM boundaries. It is created on basis of the ECMWF-EPS with 50+1 members, from which a small set of significant members is selected (selection ensemble (SE)). The significance of a member is estimated on basis of accumulated precipitation over the area of interest, which includes the river basin that may potentially experience flooding due to heavy rain. The control forecast is allways included in the selection. The selected members from the global EPS then make up the initial and boundary conditions for the members of this first LAM ensemble design. The size of the selection ensemble has been defined to be 5+1.

The second LAM ensemble tries to address model related uncertainty in the rainfall forecasts and consists of the variation of the physical representation of the condensation and convection processes within the LAM (parameterization ensemble (PE)). A similar approach has e. g. been investigated by Stensrud et al. (2000), even though with different schemes. Five parameterization schemes were available for this study:

- Stratiform condensation scheme (STC; Kållberg, 1989)
- Anthes-Kuo scheme (AKC; Kuo et al., 1974; Anthes, 1977)
- Sundquist scheme (SQS; Sundqvist, 1993)
- Tiedtke scheme (TDS; Tiedtke, 1993)
- STRACO (Sass et al., 1997)

This results in an ensemble size of 4+1, were the last member (STRACO) is identical with the control of the SE design.

The two ensemble designs SE and PE were tested on three historical heavy rain events in different European areas and of different synoptic and dynamic characteristics. The cases are the heavy rain over the Piemonte region in Northern Italy from November 1994, the strong precipitation during the end of January 1995 over the basins of the rivers Rhine and Meuse, and the heavy rain over the Odra basin in Poland/Germany/Chzech Republic in July 1997. A validation using ranked histogramms shows that both designs exhibit too little ensemble spread (not shown), the PE designs, however, shows a larger spread than the SE. Reliability diagrams for the 5 mm threshold of 24 hour accumulated rainfall between 42–66 hours forecast range are shown in Fig. 1. The two ensemble designs perform comparably well, with the PE design tending to exhibit a slightly better reliability. Both designs generally tend to overestimate higher observation frequencies at this threshold.

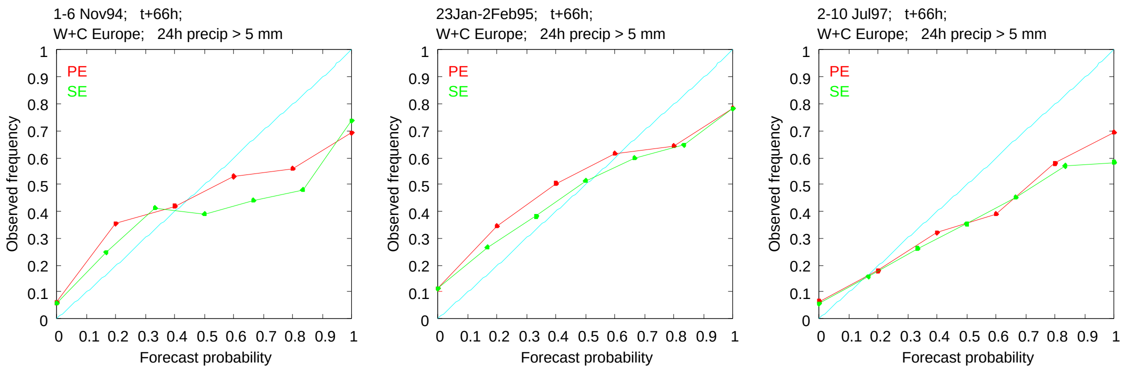

FIG. 1: Reliability diagrams for the 5 mm threshold of accumulated precipitation between 42–66 hours for the selection ensemble (green) and the parameterization ensemble (red), for the three cases of heavy rain: Piemonte case November 1994 (left), Rhine/Meuse case January 1995 (middle) and Odra case July 1997 (right).

The performance of the ensemble designs reveals to vary strongly from case to case and even on a daily basis, and a combination of both ensembles seems advantageous in many cases, but not in all. A weakness of the SE design is that the selection of the members is based on the global EPS rainfall fields only, because small scale effects as well as non-linear developments within the LAM integration are not known a priori. This may in some cases have the effect that the ensemble spread of the SE in the LAM rainfall is smaller compared to an ensemble integration of all 50+1 members with the LAM, even though this is the case in the global rainfall fields. The PE design is quite promising, as long as all schemes perform comparably well in order not to degrade the ensemble performance.

References

Anthes, R.A., 1977: A Cumulus Parameterization Scheme Utilizing a One-Dimensional Cloud Model. *Mon. Wea. Rev.*, **105**, 270–286.

Kuo, H.L., 1974: Further Studies of the Parameterization of the Influence of Cumulus Convection on Large-Scale Flow. *J. Atmos. Sci.*, **31**, 1232–1240.

Kållberg, P., 1989: *HIRLAM Forecast Model Level 1 Documentation Manual.* 77pp. Available from the Swedish Meteorological and Hydrological Institute (SMHI) Norrköping, Sweden.

Sass, B.H., 1997: Reduction of numerical noise connected to the parameterization of cloud and condensation processes in the HIRLAM model. *HIRLAM Newsletter*, **29**, 37–45. Available from the Swedish Meteorological and Hydrological Institute (SMHI) Norrköping, Sweden.

Stensrud, D.J., Bao, J.-W., Warner, T.T., 2000: Using initial condition and model physics perturbations in short-range ensembles. *Mon. Wea. Rev.*, **128**, 2077–2107.

Sundqvist, H., 1993: Inclusion of Ice Phase of Hydrometeors in Cloud Parameterization for Mesoscale and Large Scale Models. *Beitr. Phys. Atmos.*, **66**, 137–147.

Tiedtke, M., 1993: Representation of Clouds in Large-Scale Models. *Mon. Wea. Rev.*, **121**, 3040–3061.