Ensemble forecasting: status and perspectives

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Abstract: One of the main challenges for Numerical Weather Prediction is the Quantitative Precipitation Forecasting (QPF). The accurate forecast of high-impact weather still remains difficult beyond day 2 and many limited-area ensemble prediction systems have been recently developed so as to provide more reliable forecasts than achievable with a single deterministic forecast. As a consequence the calibration of ensemble precipitation forecasts has become a very demanding task, for improving the QPF, especially as an input to hydrological models. Different calibration techniques are compared: cumulative distribution function, linear regression and analogues method.

Keywords: Ensemble Prediction Systems, Quantitative Precipitation Forecasts, Calibration techniques.

1 Introduction

The first approach to the probabilistic predictions in meteorology occurred in the early seventies, the emphasis being on the study of stochastic–dynamics equations. Recently, other approaches have been developed, one of these is based on the description of the temporal evolution in the phase space of the probabilistic distribution function (PDF) of the model state vector by the Liouville equation (LE), or the Fokker–Plank equation (FPE), if model errors are taken into account through specific random forcing terms in the governing model equations (Ehrendorfer, 1994).

Actually, an approach based on LE and FPE is considered impractical in the context of forecasting forecast skill, because the high dimensionality of the state vector of realistic meteorological models and of the associated phase space (Ehrendorfer, 1994) and a finite ensemble of numerical predictions appears to be the only feasible way to predict the evolution of the atmospheric PDF beyond the range in which error growth can be prescribed by linearized dynamics. Two requirements arise: statistics of this finite ensemble should sample correctly the PDF of analysis errors and model trajectories in the phase space should be good approximations of the corresponding trajectories of the atmosphere (Molteni et al., 1996).

The idea of probabilistic weather predictions is widely accepted now: since 1992, both the National Center for Environmental Prediction (NCEP) and the European Center for Medium–Range Weather Forecast (ECMWF) have been providing weather ensemble predictions (Tracton and Kalnay, 1993 and Palmer et al., 1993).

Specifically, the ECWMF Ensemble Prediction System (EPS) has been tuned for predictions ranging from day 2 to day 15, and is based on a configuration with 50 perturbed and 1 unperturbed (i.e. starting from the ECMWF analysis, say control) members. Perturbed analyses are obtained by adding and subtracting to the operational analysis 25 orthogonal perturbations (representing the observation errors), obtained using a combination of singular vectors, computed to optimize total energy growth over a 48 hours time interval (Molteni et al., 1996). Model uncertainties are simulated by adding stochastic perturbations to the tendencies due to parameterized physical processes (Buizza et al., 1999).

2 The COSMO–LEPS Ensemble Prediction System

One of the main challenges for numerical weather prediction (NWP) is still recognized as quantitative precipitation forecasting. Computer power resources have greatly increased in the last years, thus allowing the generation of more and more sophisticated NWP models with accurate parametrization of physical processes supported by high horizontal and vertical resolution. Nevertheless, the accurate forecast of high-impact weather still remains difficult beyond day 2 and sometimes, also for shorter ranges (Tibaldi et al., 2006).

Many limited-area ensemble prediction systems have been recently developed, either in research or in operational mode, so as to address the need of detailing high-impact weather forecasts at higher and higher resolution and to provide more reliable forecasts than achievable with a single deterministic forecast. The methodology aims at combining the advantages of the probabilistic approach by global ensemble systems with the high-resolution details gained in the mesoscale integrations (Montani et al., 2011).

As far as operational implementations are concerned, the COnsortium for Small-Scale MOdelling Limited-area Ensemble Prediction System (COSMO-LEPS) is based on 16 integrations of the non–hydrostatic mesoscale model COSMO (Montani et al., 2011). In the construction of COSMO–LEPS, an algorithm selects a number of members from the ECMWF ensemble system (Marsigli et al., 2001; Molteni et al., 2001), which are used to provide both initial and boundary conditions to the integrations with the COSMO model.

3 Calibration of the Quantitative Precipitation Forecast

The calibration of precipitation forecast at high resolution is a challenging and quite new scientific issue (Hamill et al. 2008).

Fundel et al. (2009) experienced with reforecast of COSMO-LEPS (30 years) the calibration of the COSMO–LEPS precipitation over Switzerland. They carried out some sensitivity studies in order to determine the impact of the length of the reforecast period. Diomede et al. (2010), focusing the calibration work on the statistical adjustment of 24–h Quantitative Precipitation Forecasts provided by COSMO-LEPS over the Emilia–Romagna region (Northern Italy), have been used the reforecasts run by MeteoSwiss for comparing three calibration techniques: cumulative distribution function, linear regression and analogues method, based on the similarity of the forecasted precipitation fields. Two different implementations of these techniques with respect to the method used for spatial aggregation of the model grid points have been tested: calibrating functions defined either for each model grid point or for eight areas partitioning the Emilia–Romagna region. The calibration process provided a slight improvement for the reliability and skill of the COSMO-LEPS QPFs, except for the autumn season. Generally, the raw and calibrated forecasts were overconfident. Forecasts of lower precipitation events were more skilful than forecasts of higher precipitation events. The calibration functions defined for each model grid point showed higher performance. The lack of improvement related to the CDF and LR–based methods can be ascribed to the lack of a strong relationship between forecast and observed data. Results suggested that weather–regime specific correction functions should be required for improving the COSMO-LEPS QPFs.

4 Concluding remarks

It is expected the calibration of QPF could improve the skill of COSMO-LEPS forecasts, making the system more reliable and the calibrated QPF introduced as an input to hydrological models. In the future, an increase of the horizontal resolution of COSMO-LEPS will be tested. The higher resolution will likely provide more detailed forecasts for the interaction of the flow with orography and will describe with a higher degree of accuracy mesoscale–related processes and local effects. This would have a positive impact on the prediction of a number of those surface fields still nowadays strongly influenced by local effects and not always properly represented in terms of their uncertainty by mesoscale ensemble systems.

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