Preliminary evaluation of a short-range ensemble prediction system over western Mediterranean

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ABSTRACT

A generation of a short-range ensemble prediction system, based on a set of mesoscale models with different subgrid-scale physic schemes and two different initial conditions, is developed, providing flow-dependent probabilistic forecasts by means of predictive probability distributions over the Western Mediterranean. A ten members short-range ensemble forecast system has been constructed over western Mediterranean area as a result of combining two different initial conditions from global models and five different physics configurations of the non-hydrostatic Mesoscale Model (MM5, version 3). The simulations obtained from this ensemble have been investigated during October 2006 period. An overview of the mean model performance and forecast variability, together with an evaluation of the ensemble accuracy, by means of comparison between the ensemble system and observations is provided. Calculations of the ensemble probability distribution functions for precipitation are displayed, providing explicit information on ensemble forecast uncertainty and constituting one of the major advantages of the ensemble methods over deterministic forecasting. The quality and value of precipitation forecasts have been evaluated against Spanish Climatic Network. The verification scores exhibit hopeful results encouraging the extension of this preliminary research to other verification periods and studying cases.

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1. Introduction

A technique currently used to tackle the problem of weather predictability is Ensemble Weather Forecasting. A prediction system based on this technique is named an Ensemble Prediction System (EPS). An EPS Produces multiple weather forecasts by iterating forward random perturbations of a best estimate of initial conditions (Leith, 1974; Toth et al., 2001).

Over the Western Mediterranean, a generation of a short-range ensemble prediction system, based on a set of mesoscale models with different subgrid-scale physic schemes and two different initial conditions, is developed. A ten members short-range ensemble forecast system has been constructed over western Mediterranean area as a result of combining two different initial conditions from global models and five different physics configurations of the non-hydrostatic Mesoscale Model (MM5, version 3). The ensemble simulations have been investigated during a 2-weeks precipitation period of October 2006. The quality and value of precipitation forecasts have been evaluated against Spanish Climatic Network.

Comparisons between the ensemble system and observations provide an overview of the mean model performance and forecast variability besides an evaluation of the ensemble accuracy. Calculations of the ensemble probability distribution functions for precipitation are displayed, providing explicit information on ensemble forecast uncertainty and constituting one of the major advantages of the ensemble methods over deterministic forecasting.

2. The Short-Range Ensemble Prediction System

The non-hydrostatic Mesoscale Model (MM5, version 3), developed by the Pennsylvania State University-National Center of Atmospheric Research (Anthes and Warner, 1978; Grell et al., 1994) has been chosen to be used in this study. In this paper, five combinations of the MM5 parameterization and two initial boundary conditions (Table 1) have been selected to generate a short-range EPS.

All the ensemble members use a terrain following σ-coordinate system with 30 vertical levels, being vertical resolution enhanced in the lower troposphere in order to get a more accurately representation of boundary layer processes. The spatial domain, which comprises the whole Iberian Peninsula as well as the most western side of the Mediterranean basin, is covered with a 30-km horizontal grid spacing in the coarse domain and 10-km for the fine domain (Figure 1).

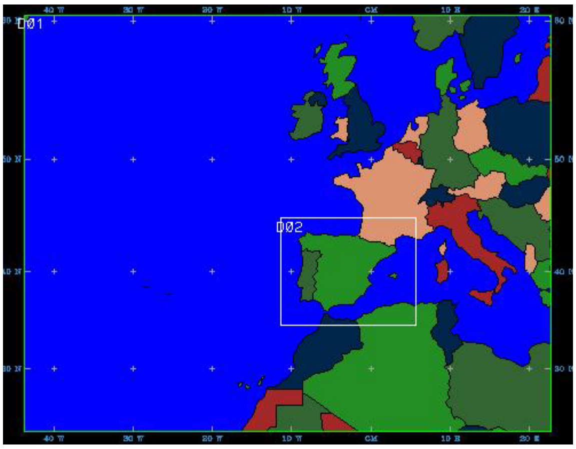


Figure 1: Geographic coverage of the MM5 short-range ensemble simulations.

Depending on the model member, time step has been chosen from 35 s till 240 s. Two different data have been used to generate the ensemble members: the IFS-ECMWF data (0.5º x 0.5º grid spacing, 21 isobaric vertical levels) and NCEP analysis and forecasts (1.0º x 1.0º grid spacing, 26 isobaric vertical levels) were used as initial and boundary conditions. The period was simulated by means of a daily single run (starting at 00 UTC) of each ensemble member with a 36-hour forecast horizon. Thus, area, output runs and forecast length were selected in order to avoid boundary conditions effects, maintaining, at the same time, the capability of generating probabilities (Warner et al., 1997). Physical uncertainties were incorporated into the ensemble by using different physical parameterization schemes, which are already incorporated in the MM5 parameterization sets. Details of the physics used to build up the two sets of 5 different ensemble members are listed in Table 1.

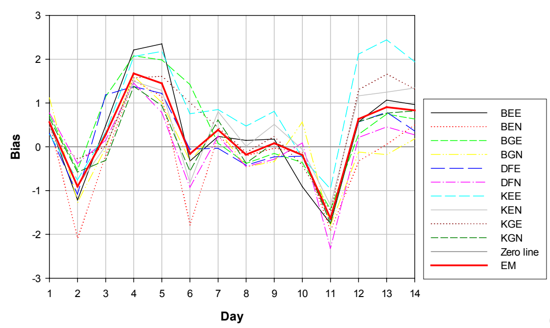
NAME	CUMULUS (ICUPA)	PBL(IPLTYP)	MICROPHYSICS (IMPHYS)	RADIATION (IFRAD)	LAND SURFACE (ISOIL)
DFE	Grell(3)	MRF(5)	SIMPLE ICE (4)	CLOUD(2)	5 LAYER(1)
BEE	Betts-Miller(7)	MYJ (4)	REISNER(7)	RRTM(4)	NOAH(2)
BGE	Betts-Miller(7)	MYJ (4)	REISNER(7)	RRTM(4)	NOAH(2)
KEE	Kain-Fritsch(6)	GAYNO-SHEMAN(5)	GODDARD(6)	RRTM(4)	5 LAYER(1)
KGE	Kain-Fritsch(6)	GAYNO-SHEMAN(5)	GODDARD(6)	RRTM(4)	5 LAYER(1)
DFN	Grell(3)	MRF(5)	SIMPLE ICE (4)	CLOUD(2)	5 LAYER(1)
BEN	Betts-Miller(7)	MYJ (4)	REISNER(7)	RRTM(4)	NOAH(2)
BGN	Betts-Miller(7)	MYJ (4)	REISNER(7)	RRTM(4)	NOAH(2)
KEN	Kain-Fritsch(6)	GAYNO-SHEMAN(5)	GODDARD(6)	RRTM(4)	5 LAYER(1)
KGN	Kain-Fritsch(6)	GAYNO-SHEMAN(5)	GODDARD(6)	RRTM(4)	5 LAYER(1)

Table 1: Combinations of the MM5 parameterizations selected to generate the short-range ensemble prediction system.

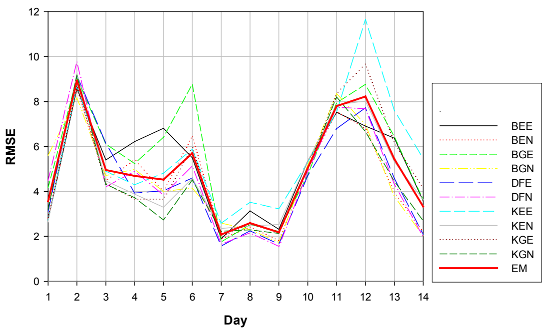
The different model configurations chosen to create the physics ensemble are built changing both convection and planetary boundary layer parameterization schemes, generating plausible and realistic solutions to the predictability problem.

3. Results

This work shows the performance of the simulations obtained from the 10-members ensemble for a 2-weeks period of October 2006 for the fine domain. Throughout the event simulation period, bias and rmse results (Figure 2a and b) show differences between the behaviors of the diverse ensemble members. Both ensemble mean and most of the ensemble members, exhibit large departures in early and final stages of the period, which indicate that some rainfall overprediction exists. However, during the central part of the period nearly zero evolution both in the bias and the rmse can be noticed.



(a)



(b)

Figure 2: Temporal evolution of BIAS (a) and RMSE (b) for each ensemble member and ensemble mean.

The relationship between root mean squared error (rmse) and spread of the ensemble mean is close to the ideal diagonal with a correlation value of 0.80. The whole period shows a spread value shorter than the ensemble mean error, indicating an under-dispersive behavior. This situation is coherent with the idea that the low-spread period are essentially more predictable that high-spread events which are basically less predictable.

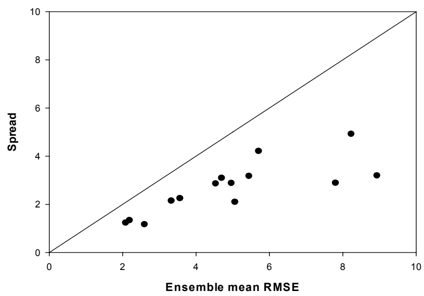


Figure 3: Scatter diagram of the ensemble RMSE (mm) and the ensemble spread (mm) for daily precipitation, showing in continuous line the ideal diagonal.

The Verification Rank Histogram or Talagrand distribution is the histogram of frequencies of the rank of the observed data within the forecast ensemble (Talagrand et al., 1997). A good EPS should have a uniform distribution. Otherwise, non-uniform shapes may indicate under/overdispersion and bias.

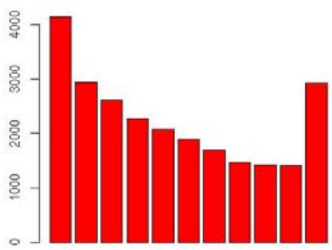


Figure 4: Talagrand diagram defined by the 10 ordered ensemble members at each grid points.

In this work, the Talagrand indicates some underdispersion by the EPS, i.e., the verifying observation falls outside the envelope forecasts generated by the ensemble members. Moreover, the asymmetric shape suggests a bias behaviour.

The ensemble spread gives a measure of the quality of the ensemble forecasts and the spread spatial configuration can be considered as a prediction of the spatial distribution of the actual error. Thus, the spread can provide information on the uncertainty of the ensemble forecast. Figure 5 shows similar spatial precipitation distribution of the ensemble mean versus the observed precipitation averaged over the period. Maximum ensemble spread centers are coincident with maxima rainfall areas.

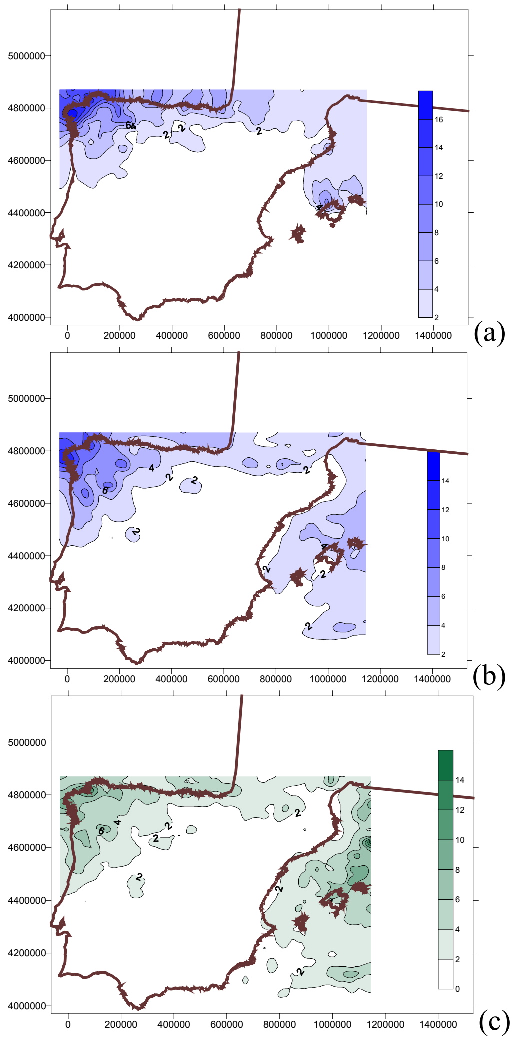
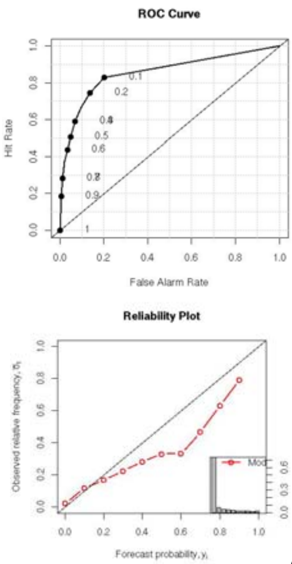


Figure 5: Spatial distribution of (a) daily mean observed precipitation, (b) daily mean of ensemble forecasted precipitation, (c) daily mean of ensemble spread.



(a)
(b)

Figure 6: (a) ROC Curve precipitation; (b) Reliability diagram, over 5mm/24h.

The ROC (Figure 6a) is considered a measure of potential utility, measuring ability of the forecast in discriminating between two alternative outcomes. Although the Talagrand (Figure 4) shows some bias, the good ROC curve indicates usefulness of the forecasting system.

The reliability diagram (Figure 6b) shows a good agreement between forecast probability and the mean observed frequency, except for certain forecast probability vales ranging about 50% due to some undersampling effect as it can also noted in the sharpness diagram.

4. Conclusions

- The ensemble mean provides the best forecast compared with any ensemble member.

- The created short-range ensemble has high spread-skill correlation values for daily precipitation and is affected by underdispersion.

- The EPS is underdispersive as the Talagrand shows, indicating that the generated envelope forecasts are not including the verifying observation.

- Mean spatial rainfall distributions obtained from the ensemble system show similar patterns with the largest accumulated rainfall values settling down over the same areas than mean observed precipitation.

- On a daily basis, mean precipitation and the mean spread of the ensemble shows similarity between maximum ensemble spread nuclei and maxima rainfall areas.

The ROC and reliability diagrams show the potential utility of the system. Here, both schemes display a good EPS performance.

The verification scores exhibit hopeful results encouraging the extension of this preliminary research to other verification periods and studying cases and the possible inclusion of new members using WRF-NMM and WRF-ARW models.

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