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Comparison of three different methods of perturbing the potential vorticity field in mesoscale forecasts of Mediterranean heavy precipitation events: PV-gradient, PV-adjoint and PV-satellite

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Heavy precipitation events occur regularly in the western Mediterranean region. These events often have a high impact on the society due to economic and personal losses. The improvement of the mesoscale numerical forecasts of these events can be used to prevent or minimize their impact on the society. In previous studies, two ensemble prediction systems (EPSs) based on perturbing the model initial and boundary conditions were developed and tested for a collection of high-impact MEDEX cyclonic episodes. These EPSs perturb the initial and boundary potential vorticity (PV) field through a PV inversion algorithm. This technique ensures modifications of all the meteorological fields without compromising the mass-wind balance. One EPS introduces the perturbations along the zones of the three-dimensional PV structure presenting the local most intense values and gradients of the field (a semi-objective choice, *PV-gradient*), while the other perturbs the PV field over the MM5 adjoint model calculated sensitivity zones (an objective method, *PV-adjoint*). The PV perturbations are set from a PV error climatology (PVEC) that characterizes typical PV errors in the ECMWF forecasts, both in intensity and displacement. This intensity and displacement perturbation of the PV field is chosen randomly, while its location is given by the perturbation zones defined in each ensemble generation method.

Encouraged by the good results obtained by these two EPSs that perturb the PV field, a new approach based on a manual perturbation of the PV field has been tested and compared with the previous results. This technique uses the satellite water vapor (WV) observations to guide the correction of initial PV structures. The correction of the PV field intents to improve the match between the PV distribution and the WV image, taking advantage of the relation between dark and bright features of WV images and PV anomalies, under some assumptions. Afterwards, the PV inversion algorithm is applied to run a forecast with the corresponding perturbed initial state (*PV-satellite*).

The non hydrostatic MM5 mesoscale model has been used to run all forecasts. The simulations are performed for a two-day period with a 22.5 km resolution domain (Domain 1 in *http://mm5forecasts.uib.es*) nested in the ECMWF large-scale forecast fields. The MEDEX cyclone of 10 June 2000, also known as the Montserrat Case, is a suitable testbed to compare the performance of each ensemble and the PV-satellite method. This case is characterized by an Atlantic upper-level trough and low-level cold front which generated a stationary mesoscale cyclone over the Spanish Mediterranean coast, advecting warm and moist air toward Catalonia from the Mediterranean Sea. The consequences of the resulting mesoscale convective system were 6-h accumulated rainfall amounts of 180 mm with estimated material losses to exceed 65 million euros by media.

The performace of both ensemble forecasting systems and PV-satellite technique for our case study is evaluated through the verification of the rainfall field. Since the EPSs are probabilistic forecasts and the PV-satellite is deterministic, their comparison is done using the individual ensemble members. Therefore the verification procedure uses deterministic scores, like the ROC curve, the Taylor diagram or the Q-Q plot. These scores cover the different quality attributes of the forecast such as reliability, resolution, uncertainty and sharpness. The results show that the PV-satellite technique performance lies within the performance range obtained by both ensembles; it is even better than the non-perturbed ensemble member. Thus, perturbing randomly using the PV error climatology and introducing the perturbations in the zones given by each EPS captures the mismatch between PV and WV fields better than manual perturbations made by an expert forecaster, at least for this case study.