Mediterranean Storms
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HEAVY RAINFALL FORECASTS IN MEDITERRANEAN SPAIN: SENSITIVITY TO MODEL INPUT DATA RESOLUTION

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ABSTRACT

The study investigates, from a statistical approach, the quality of numerical model forecasts of heavy rainfall in Mediterranean Spain as function of model input data resolution. For that purpose, 165 heavy rainfall events during the period 1984-93 are simulated with a standard mesoscale model (HIRLAM) at 0.3^0 horizontal resolution. Input data used to nest the HIRLAM model is obtained by gridding ECMWF ERA T106 spectral analysis, available at 00, 06, 12 and 18 UTC, into a mesh with 1^0, 2^0 and 3^0 resolutions. Therefore, thee sets of 165 simulations are performed by using these varied resolution input data sets, with the simulations extending from 00 to 06 UTC the next day. An additional set of simulations is considered based on the 1^0 resolution analyses except that less frequent 30-h apart boundary conditions are used. This strategy allows to assess the relative role of the small dynamical structures of the flow as compared to the action of the complex orography of the region.

The performance of the 4 sets of experiments for predicted total precipitation is evaluated for the ***whole of Mediterranean Spain*** *using the relative operating characteristic (**ROC**) curves, which combine Hit Rate and False Alarm Rate indexes. As a further refinement, the* ***subdomain spatial variability*** *is examined, and the study is particularized for* ***six major rain bearing flow regimes*** *(atlantic flow, cold front passage, southwestern disturbance aloft, southern disturbance aloft, southeastern disturbance aloft and northerly flow).*

The results show, for the considered resolution range, that there is no appreciable *improvement in model skill when higher spatial or temporal resolution data is used to nest the model. On the other hand, an accentuated spatial variability is found in the domain, with an overall tendency for better forecasts in the west and north of the region and over highlands. This is consistent with the higher ROC values obtained for Atlantic and northerly flows, as these are flow types quite influential for rainfall enhancement in the above areas.*

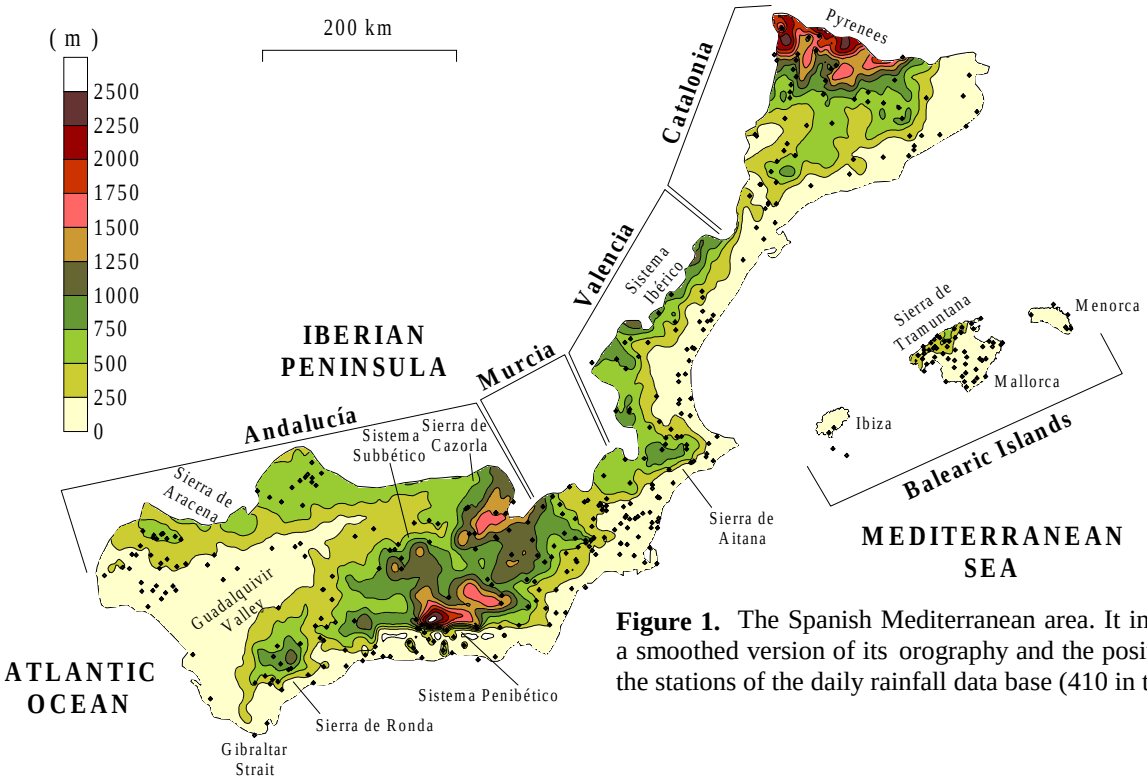


Figure 1. The Spanish Mediterranean area. It includes a smoothed version of its orography and the position of the stations of the daily rainfall data base (410 in total).

1 WHOLE OF MEDITERRANEAN SPAIN

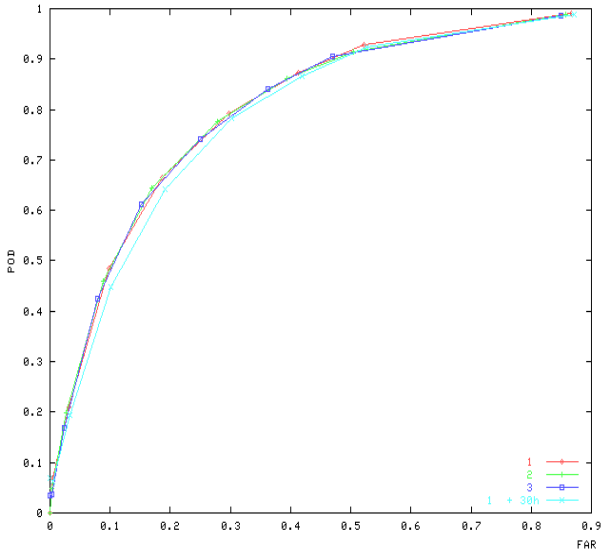
For this analysis, the 165 heavy rainfall events during the period 1984-93, defined when at least 2 % of the stations in Figure 1 registered more than 50 mm/day, are simulated with the HIRLAM model (0.3^0 grid length) nested into the ECMWF ERA T106 fields with $\mathbf{1^0}$, $\mathbf{2^0}$ and $\mathbf{3^0}$ resolutions. An additional set of simulations is considered based on the 1^0 resolution analyses except that less frequent 30-h apart boundary conditions are used ($\mathbf{1^0 + 30h}$).

The performance of the 4 sets of simulations for predicted accumulated precipitation is evaluated for all heavy rainfall days and the whole of Mediterranean Spain (408 model grid points over that domain). Observed precipitation at model grid points is derived from homogeneous and complete daily rainfall registers at 410 stations (Romero et al. 1998; Figure 1) For that purpose, the Relative Operating Characteristic (**ROC**) curves (Mason, 1982) are used. This technique is based on the Signal Detection Theory and combines False Alarm Rate (FAR) and Probability of Detection (POD). The higher the area under the ROC curve, the better is the forecast. Precipitation thresholds to construct the curves are 0, 1, 2, 4, 8, 16, 32 and 64 mm. The FAR and POD varies from values near 1 for small thresholds to 0 for the higher ones (Figure 2).

Table 1. Area values under the ROC curves

Resolution	$\mathbf{1^0}$	$\mathbf{2^0}$	$\mathbf{3^0}$	$\mathbf{1^0 + 30h}$
Area	0.817	0.816	0.814	0.804

Figure 2. ROC curves for $\mathbf{1^0}$, $\mathbf{2^0}$, $\mathbf{3^0}$ and $\mathbf{1^0 + 30h}$ experimental data sets.

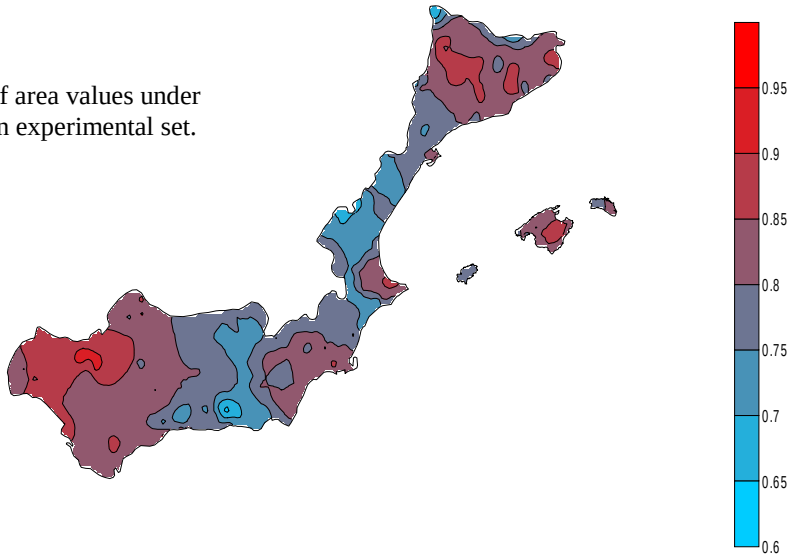


It can be noticed that no significant improvement is observed by initializating the HIRLAM model with high (in space and/or time) resolution meteorological data (Table 1).

2 SUBDOMAIN SPATIAL VARIABILITY

The performance of the 4 sets of simulations is regionally evaluated by computing the ROC curves for each of the 408 model grid points over Mediterranean Spain (see Figure 3 for the 1^0 resolution set).

Figure 3. Spatial distribution of area values under ROC curves for the $\mathbf{1^0}$ resolution experimental set.



Results show that there are not important differences among the 4 sets of simulations. The model shows higher skill over Catalonia, central and western Andalucía, the Balearics and some areas of the Southeast. These regions are principally affected by Atlantic flows (central and western Andalucía), northerly flows (in Catalonia and Balearic Islands) and cold front passage. On the contrary, model skill is relatively low over eastern Andalucía and northern Valencia, where the effect of easterly flows and southwestern disturbances aloft is very important.

3 MAJOR RAIN FLOW REGIMES

Finally, the performance of the forecast system (in this case only for 1^0 input data resolution) is particularized for six rain bearing flow regimes that affect Mediterranean Spain (Romero et al. 1999; Sotillo et al. 2002). The 165 heavy rainfall days are then subdivided as belonging to one of the following flows types:

Atlantic flow (**A**), 53; cold front passage (**C**),11; southwestern disturbance aloft (**SW**), 31; southern disturbance aloft (**S**), 30; southeastern disturbance aloft (**SE**), 19; and finally northerly flow (**N**), 21.

Table 2. Area values under the ROC curves for the six major rain bearing flow regimes.

A	C	SW	S	SE	N
0.816	0.836	0.802	0.835	0.739	0.835

Figure 4. ROC curves for the six major rain bearing flow regimes.

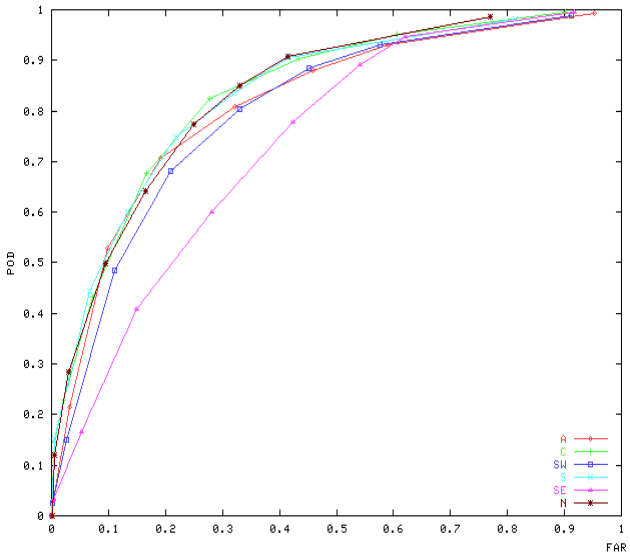
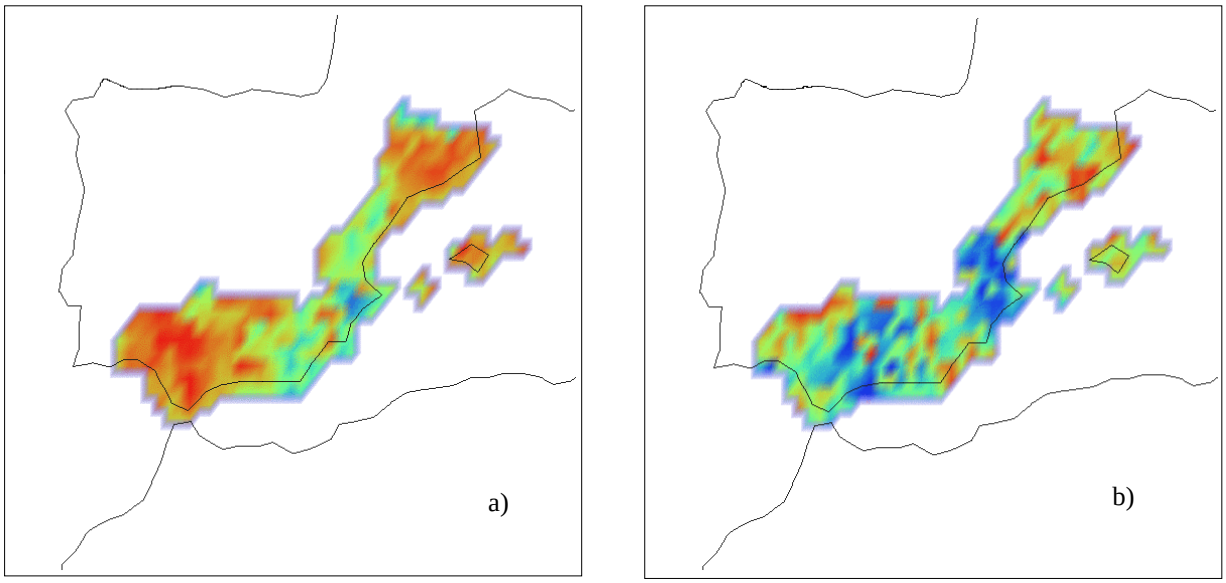
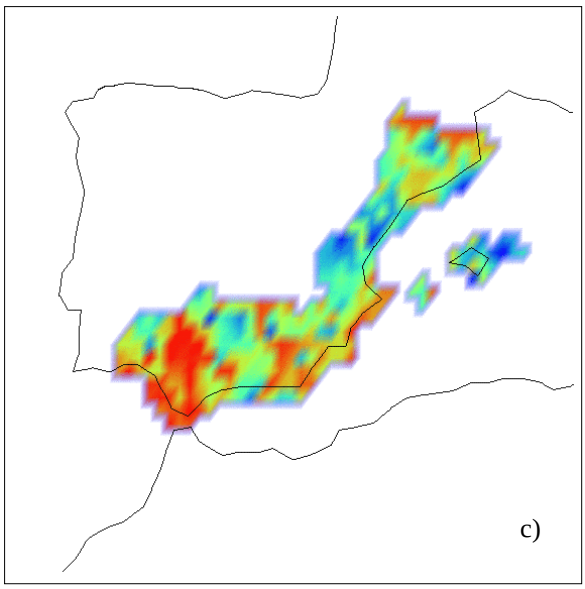
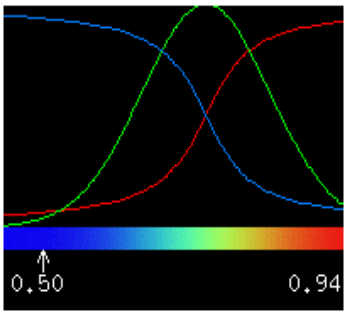


Figure 5. Spatial distribution of area values under ROC curves for some of the major rain bearing flow regimes: (a) Atlantic flow and cold front passage; (b) Southeastern disturbance aloft; (c) Northerly flow.







Results are summarized in Figures 4 and 5 and Table 2. It can be observed that for Atlantic flows and cold fronts crossing the Iberian Peninsula, the forecast skill is better over Catalonia, western Andalucía and the Balearic Islands. Similar results are obtained for southwestern and southern lows. For these regimes, the model exhibits the worst performance over areas of Valencia and the Southeast (Figure 5a).

On the other hand, with southeastern disturbances aloft the predictability is generally lower than for other regimes (Table 2; Figure 5b). Northerly flows appear to offer a good model skill for all areas except the Balearic Islands and most of Valencia (Table 2; Figure 5c).

4 CONCLUSION

The study has shown that for the considered resolution range (1^0-3^0) there is no appreciable improvement in model skill when higher spatial or temporal resolution data is used to nest the mesoscale model. This suggests that the role of the orography for the heavy precipitation control overcomes the dynamical action induced by subsynoptic features embedded in the circulation.

On the other hand, an accentuated spatial variability is found in the domain, with an overall tendency for better forecasts in the west and north of the region and over highlands. This is consistent with the higher ROC area values that have been obtained for Atlantic and northerly flows, as these are flow types quite influential for rainfall enhancement in the above areas. For pure Mediterranean flow regimes (particularly, southeastern disturbances aloft) the predictability is generally worse, implying that rainfall forecasts over the east facing lands of Mediterranean Spain are more critical.

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