Sensitivity of Mediterranean convective system simulations to surface boundary conditions: the role of SST

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1 Introduction:

The role of Sea Surface Temperature (sst) on the simulation of convective system developments over western Mediterranean sea is analysed in the present work.

Traditionally the way to assign initial conditions to the surface fields has been the use of a short range forecast or a climatological value. The first solution is valid when the surface variable evolves in time along the model forecast period, but it can lead to a drift if model deficiencies (as cloud cover) are not compensated. Climatological values have been also widely used to initialise surface fields. In the short range numerical weather prediction models the sst is an stationary variable. The use of different sst fields modifies the surface forcing prescribed, varying the surface latent and sensible heat flux over the sea. Of course, the climatological solution fails in periods of climatological anomalies.

Updated fields to define the surface forcings are always better than climatological assignments, but its impact on the simulation of convective systems in the Mediterraneo depends not only on how farthe climatology is from the present sst field, but also on the synoptic environment where the convective atmospheric activity generates.

The numerical model used to study the sensitivity to initial conditions is the HIRLAM model (Kallen 1996), in which a parametrization of large scale convection Kuo type with an specific treatment of microphysical processes (Sundqvist 1989) is included. In this paper two different cases when convective systems on the western Mediterraneo developed will be presented. The first one registered the 2 of October 1990, hereafter referred as CS90, and the second happened the 11 of September 1996, hereafter referred as CS96. An experiment to find the sensitivity to surface conditions has been performed over both situations. The design of the experiments is described in section 2. The main characteristics of the data assimilation and numerical model used are there listed. In section 3 and 4 both CS90 and CS96 are described with the information available: satellite imagery, INM precipitation network data, and the results of the simulations. In section 5 some conclusions are obtained.

2 Design of the experiments

In order to assess how the sst field influences the model ability to simulate the development of convective systems on the western Mediterranean sea, two experiments differing only on how the sst is initialised has been performed over the two dates CS90 and CS96. The assimilation cycle started 24 hours before the time of the main simulation. In the reference experiment REF, the sst has been initialised with its climatological value. In the control experiment, CON, the sst field has been analysed at each assimilation step. As it has been mentioned, the HIRLAM limited area model operationally used at the INM (Diaz-Pabon 1996), has been the NWP model chosen to test the role of sst. It is a hydrostatic model with an eulerian grid point numerics. For the experiment here presented it has been run at 0.5 degrees longitude by 0.5 degrees latitude by 31 vertical levels resolution. The model domain covers the area between 15 to 65 degrees north, and from -60 to 30 degrees east. A fourth order implicit horizontal diffussion is used to prevent the energy accumulates at the smaller scales. Analysed fields of ps, T, u, v and q from ECMWF model are introduced at every time step into the area as boundary conditions.

The physics contains a parametrization for the solar and longwave radiations, a simple surface processes parametrization providing the lower boundary conditions to the first order turbulent vertical diffussion scheme. In the Sundqvist cloud parametrization the large scale convection is a Kuo type moisture convergence scheme on which the moisture suply available for generating cumulus convection, I, is the large scale convergence of moisture plus the evaporation from the surface:

$$I = -\int_0^{po} \nabla(Vq)dp + E_s$$

The first term of the equation rhs represents the convergence of moisture flux due to the dynamics, and the second term, **E** , is the moisture supply from the underlying surface due to turbulent fluxes:

$$E_s = \rho_s(\overline{wq})_s$$

The experiments here presented analyse the relative magnitude of both terms, provided a significant sensitivity to lower boundary conditions will be found when **E** is high enough in respect to the first term. The effect of varying the lower boundary contions is to change the value of the **E** term.

The HIRLAM model has its own data assimilation cycle based on a 3D multivariant Optimum Interpolation scheme for the analysis of the upper air fields(Lonnberg 1984), feeded by the information present on the short range (6 hours) forecast, and by conventional data from 3 hours time window around the nominal time of the analysis. A later step of normal modes initialization is performed. In respect to the initialization of the surface variables, and the sst specifically, the HIRLAM/INM system has its own analysis for the sea surface temperature(Navascues 1996). It is based on a Cressman succesive correction analysis method with 5 iteration cycles, and makes use of observations present on ships and buoys reports, along with the surface temperature over opened sea from ECMWF model used as pseudo observations. The analysis is also able to assimilate bogus data. This is very useful to introduce artificial gradients on specific locations.

3 1-2 October 1990 Case

According to the infrared METEOSAT succesive images from first hours of 2 October 90 until 12Z, a convective system started to develop and located between the mediterranean Valencia coast and Ibiza island at 12Z. The synoptic environment can be observed at the REF experiment 24 hours forecast: 300HPa geopotential height and isotachs, 500Hpa geopotential height and temperature, and 1000HPa geopotential height and 850Hpa temperature charts (figure 1). A short wave through is passing over the Iberian Peninsula with an associated jet stream at the upper levels, without any significant moisture and temperature advection at the lower troposphere pointing out to the place where the convective system developed. Precipitation registered reached up to 50 mm total amounts from 901001 at 7Z to 901002 at 7Z in the Valencia region. This period was extremely anomalous in respect to the sea surface temperature, as can be observed by looking at the climatological field used in REF experiment in comparison to the analysed one in CON experiment (figures 2a and 2b) .

The upper air forecasted fields by both REF and CON experiments are very similar. But only CON experiment is able to simulate some precipitation over the area of interest(figures 3a and 3b). The surface latent fluxes are very different in both experiments as a consequence of the sea surface forcings prescribed. The moisture convergence due to the large scale flow is weak enough to the upward turbulent flux of moisture at the surface be significant in CON experiment. In this synoptic environment the simulation of the convective system by the HIRLAM model is extremely sensitive to the specification of the lower boundary conditions.

4 10-11 September 1996 Case

Meteosat IR pictures show how from the beginning of 11 September 96 a convective system appeared between Spain and the Algerian coast, moved towards the noth and merged with other convective ystems developed in the Valencia coast. In this case the large scale flow is completely different to the CS90 case. Both REF and CON simulations show very similar 24 hours forecasted fields(figure 4): The 1000Hpa geopotential height and 850Hpa temperature chart shows a mesoscale low pressure center over western Mediterraneo and an strongly baroclinic area with warm thermal advections pointing out to the place where the CS96 developed. The 500HPa temperature and geopotential height chart shows a cut-off low over the Cadiz gulf with an cold pocket of -16 ºC over the southwest Spain. At the 300Hpa geopotential height and isotachs chart a jet stream with 50 m/s maximum wind speed is observed. Maximum precipitation amount registered by the INM stations network over the

Mediterranean coast from 960910 at 7Z to 960911 at 7Z is of the order of 200 mm. The sea surface temperature is not so far from the climatological value as at he CS90 case (figures 2c and 2d), but the synoptic forcing is much more strong. In order to strentgh the surface forcing a third experiment, called EST, has been carried out. In EST experiment bogus sst data were introduced to artificially increase the sst anomaly.

All the experiments are able to simulate the convective system development. This is because the large scale flow is determinant for it. The different specification of the surface boundaries only slightly change the precipitation pattern, giving the best results according to observations the CON experiment (figures 3c and 3d).

5 Concluding remarks

The sensitivity of heavy rain events simulation to surface forcing has been analysed with the aid of two different case studies showing that it is strongly dependent on the synoptic environment on which the convective system develops. The sst field plays a more important role on the cases with weak large scale flow, corresponding to less heavy rain events. At any case, the different sst fields modify the moisture suply available for the convection changing the forecasted precipitation pattern.

The use of different convection and turbulence parametrizations can modify the simulations here presented. It should also be kept in mind that other the surrounding orography factor is very important on the moisture convergence, so that the experiments carried out would produce different results at a higher resolution simulations.

6 Acknowledgements

The INM Climatological database department has supplied the precipitation data used to verify the experiments. The INM Analysis and Forecast techniques department has provided the information recorded on both CS90 and CS96 convective systems and gave assistance to assess the results obtained with the MaCIDAS (Man Computer Interactive Data Access System) forecasting tool.

7 References

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8 Figure Captions

Figure 1.- Synoptic environment of October 2 at 12Z, 1990. Top: Geopotential height at 1000hPa and 850hPa temperature chart. Mid page: Geopotential height and temperature at 500hPa. Bottom: Geopotential height and isotachs at 300hPa.

Figure 2.- Sea surface temperature field used in REF and CON experiments in both cases CS90 and CS96.

Figure 3.- Simulated precipitation by REF and CON experiments in CS90 and CS96.

Figure 4.- Synoptic environment of September 11 at 12Z, 1996. Top: Geopotential height at 1000hPa and 850hPa temperature chart. Mid page: Geopotential height and temperature at 500hPa. Bottom: Geopotential height and isotachs at 300hPa.

Figure 1:

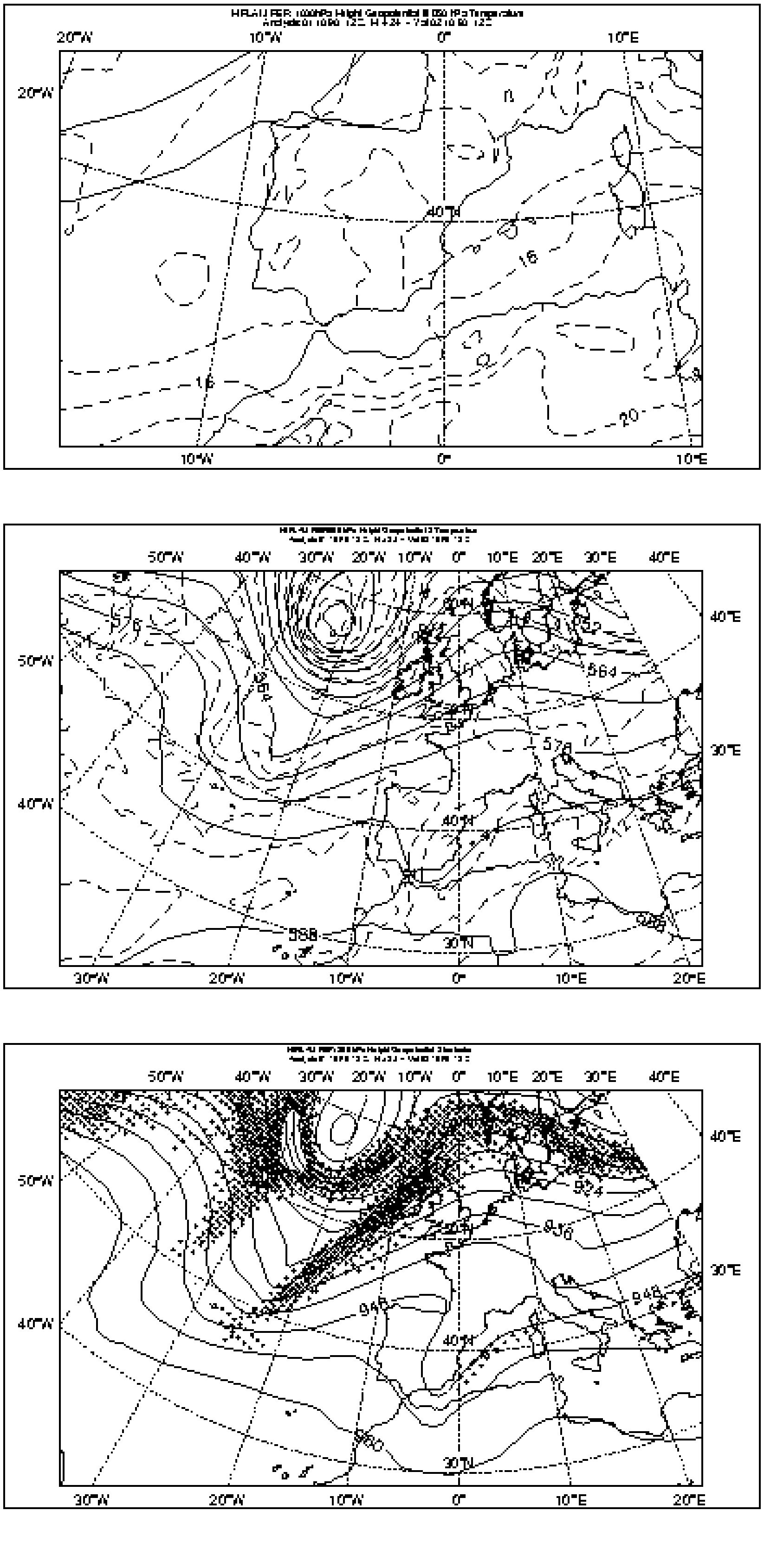
20°W
10°W
0°
10°E
40°N
16
20
50°W
40°W
30°W
20°W
30°N
576
564
552
588
936
948
960
924
40°E
30°E
20°E

Figure 2:

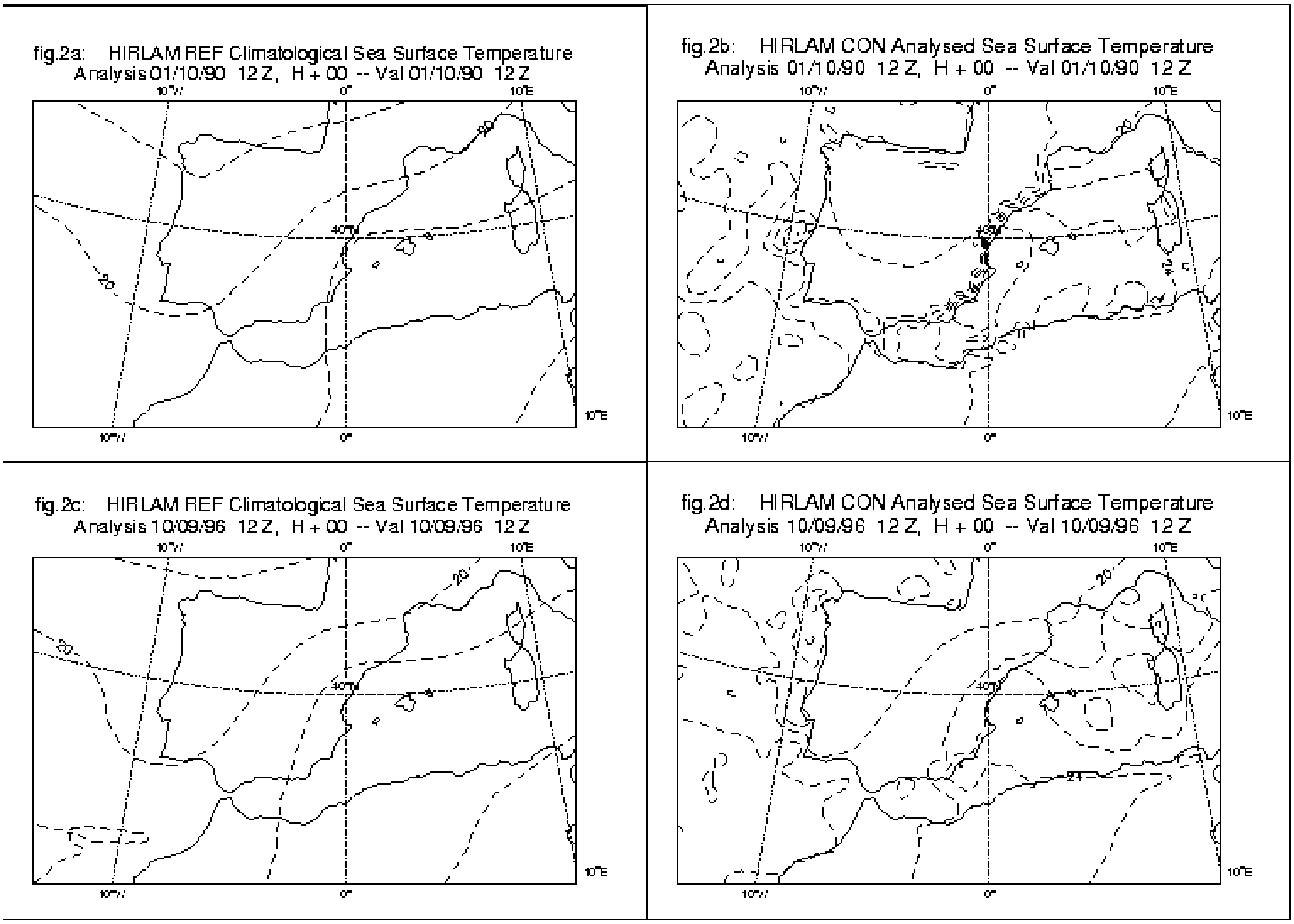
fig.2a: HIRLAM REF Climatological Sea Surface Temperature
Analysis 01/10/90 12 Z, H + 00 -- Val 01/10/90 12 Z
fig.2b: HIRLAM CON Analysed Sea Surface Temperature
Analysis 01/10/90 12 Z, H + 00 -- Val 01/10/90 12 Z
fig.2c: HIRLAM REF Climatological Sea Surface Temperature
Analysis 10/09/96 12 Z, H + 00 -- Val 10/09/96 12 Z
fig.2d: HIRLAM CON Analysed Sea Surface Temperature
Analysis 10/09/96 12 Z, H + 00 -- Val 10/09/96 12 Z

Figure 3:

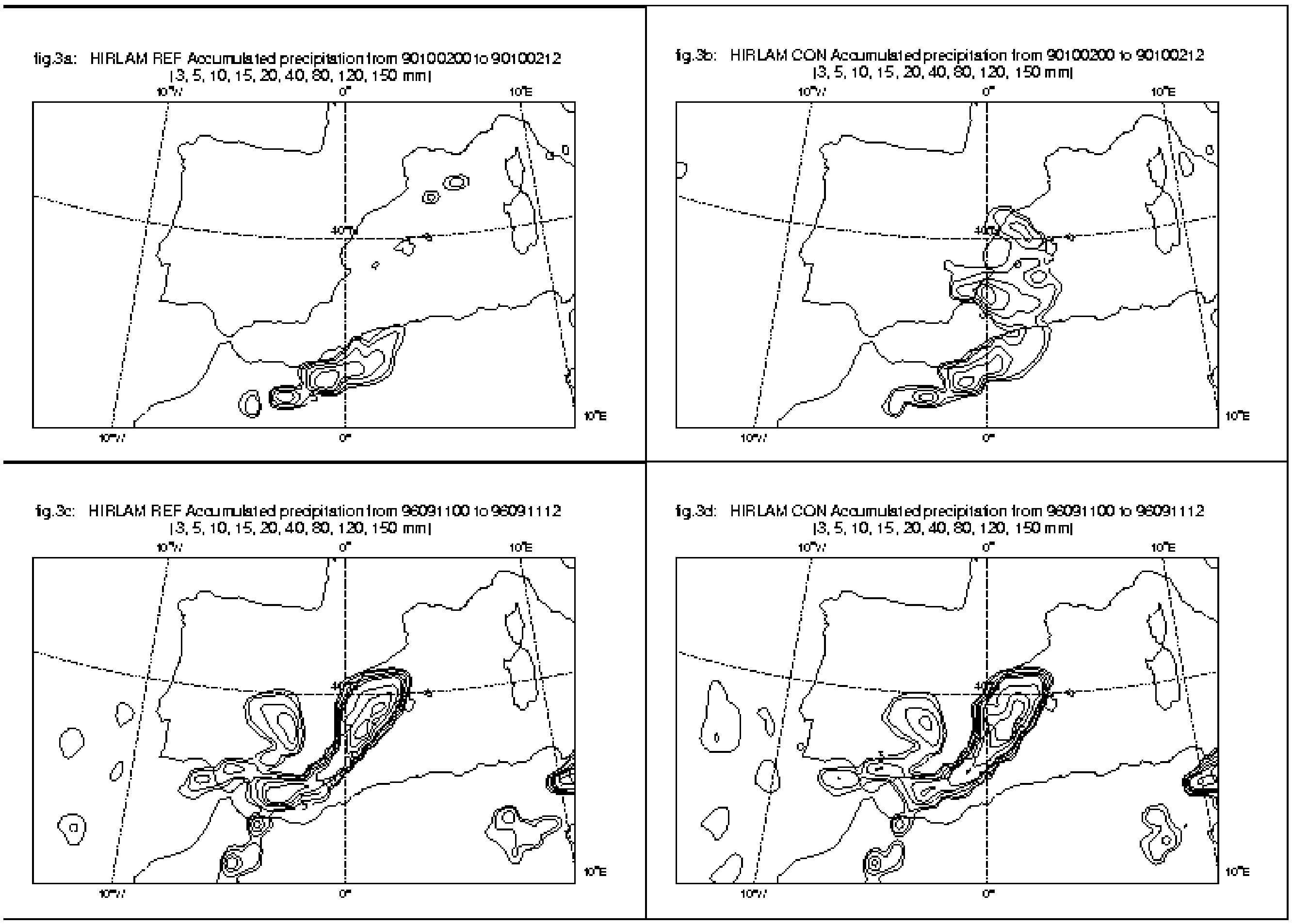

fig.3a: HIRLAM REF Accumulated precipitation from 90100200 to 90100212
[3, 5, 10, 15, 20, 40, 80, 120, 150 mm]
10°W
0°
10°E
40°N
fig.3b: HIRLAM CON Accumulated precipitation from 90100200 to 90100212
[3, 5, 10, 15, 20, 40, 80, 120, 150 mm]
fig.3c: HIRLAM REF Accumulated precipitation from 96091100 to 96091112
[3, 5, 10, 15, 20, 40, 80, 120, 150 mm]
fig.3d: HIRLAM CON Accumulated precipitation from 96091100 to 96091112
[3, 5, 10, 15, 20, 40, 80, 120, 150 mm]

Figure 4: