Relationship between blocking activity and a heavy rain event at Southeastern Iberia

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ABSTRACT

The relationship between blocking activity and the flood of 30 January to 4 February 1993 at SE Iberia is investigated. The study of this heavy rain event emphasises the atmospheric scenario that led to thunderstorm development. In this event, the warm, moist air flow from the Mediterranean Sea, channelled by a high-over-low blocking pattern with a cold front at southeastern Iberia appears to be the main reason to help to trigger a severe weather occurrence. Conditional unstability through a deep troposphere layer and moderate to strong vertical wind shear favoured the long-lived convective structures' organisation.

1 INTRODUCTION

Southeastern Spain is occasionally subject to heavy rainfall episodes where phenomena characterised by the lack of motion associated with blocking patterns exist, i.e., when systems do not progress at all within the latitude belt of the baroclinic westerlies. Such blocking situations are frequently accompanied by extreme weather. Here, the heavy rain event of 30 January to 4 February 1993 at Segura Basin in SE Spain is analysed. This area was subjected to very heavy rain with flooding caused by repeated storms. This was a significant meteorological event not only because of the widespread property damage and numerous injuries, but also because it was an unusual winter thunderstorm (Tout and Wheeler, 1990; Wheeler, 1991) whose results were notably underestimated. It cannot be denied that SE Spain is closely monitored by forecasters because of their disastrous potential, but it is also true that the mesoscale extent of the storm makes its location and severity inherently difficult to forecast. The objective of this study is to examine the scenario that led to this severe rain event analysing both large-scale and mesoscale features.

2 DATASET

Segura Basin covers an area of some $15x10^3$ km^2 and runs to and from Southeast Iberia (Fig. 1) and a striking feature is its extreme water deficiency. This area is a relatively small one of about 150 km in width and is bounded by a coastline of about 100 km in length. The topographical features of the watershed correspond largely with hill heights. Associated with such topographical fluctuations, mesoscale convergence zones and mesoscale vortices have been documented worldwide (Parsons et al., 1990).

In this paper, a large number of stations has been selected for providing a reasonably representative precipitation dataset. The network of 180 rain gauges measuring 24-h totals (see Fig. 1) since 30 January to 4 February 1993 period was used to gain distributions of rainfall over Segura Basin. The database information is supported by daily standard level charts for surface, 500 and 300 hPa levels. On the other hand, routine radiosonde data at Murcia station were used to describe the vertical troposphere structure. From these data, standard tools of convective storm analysis such as stability indices and environmental parameters which are good indicators of convective activity were computed (Zawadzki et al., 1981; Weisman and Klemp, 1982; Droegemeier et al., 1993). The *totals-totals index* (*TTI*), the *lifted index* (*LI*) and the *K index* (*KI*) will be used as stability indices. On the other hand, the *convective available potential energy* (*CAPE*) and the *convective inhibition* (*CIN*) will be considered as indicators of convective activity because of *CAPE* is one of the most important parameters to capture moisture and conditional instability information and *CIN* is a measure of the strength of the "cap" when a stable layer or capping inversion is present.

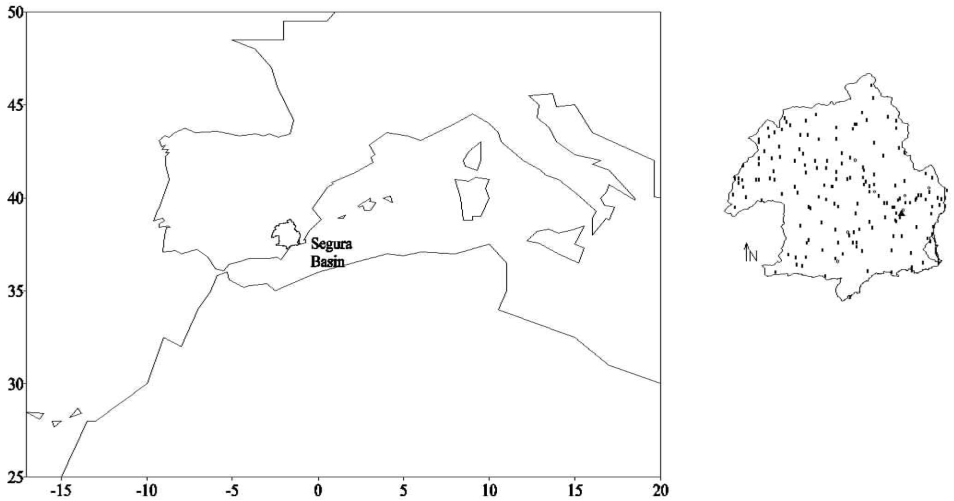

Figure 1: Location of Segura Basin in Iberian Peninsula. Precipitation gauges are shown by asterisks. Murcia radiosonde is shown by triangle.

3 THE ANALYSIS OF THE EVENT

The large-scale environment can not only establish the setting favourable for the convection genesis but it can also supply the trigger to develop and organise the convective systems which may produce widespread rain. In the event of 30 January to 4 February 1993, the large-scale setting was characterised by a cut-off over North Africa and the transition of a ridge to closed high over Central Europe. The low was associated with a jet stream across North Africa (not shown). This situation promotes warm and cold advection downstream and upstream from the trough, respectively. The surface situation on 30 January showed the low over Gulf of Cádiz associated with a slow-moving cold front extending over South Iberia and North Africa (Fig. 2*a*). The low promoted southeasterly air flow towards Spain eastern coast. This African dry, hot flow gain huge amounts of water vapour when passing across the Mediterranean Sea. This flow was forced at low-level to ascent along the front. Therefore, the cold front constituted the trigger mechanism for intense convection. In addition, the inland topography forced new growth favouring mesoscale convergence.

On 1 February (Fig. 2*b*), it can be observed the called *high-over-low blocking pattern* which is characterised by ‘split flow’, because of the fact that the basic current split around the northern ridge-southern low system. This large-scale pattern promotes and reinforces the low-level moist, warm advection encouraged by the meridional low. In fact, the blocking pattern enhances to persist during a number of days, thereby ensuring a regular warm, moist air supply toward eastern Iberia.

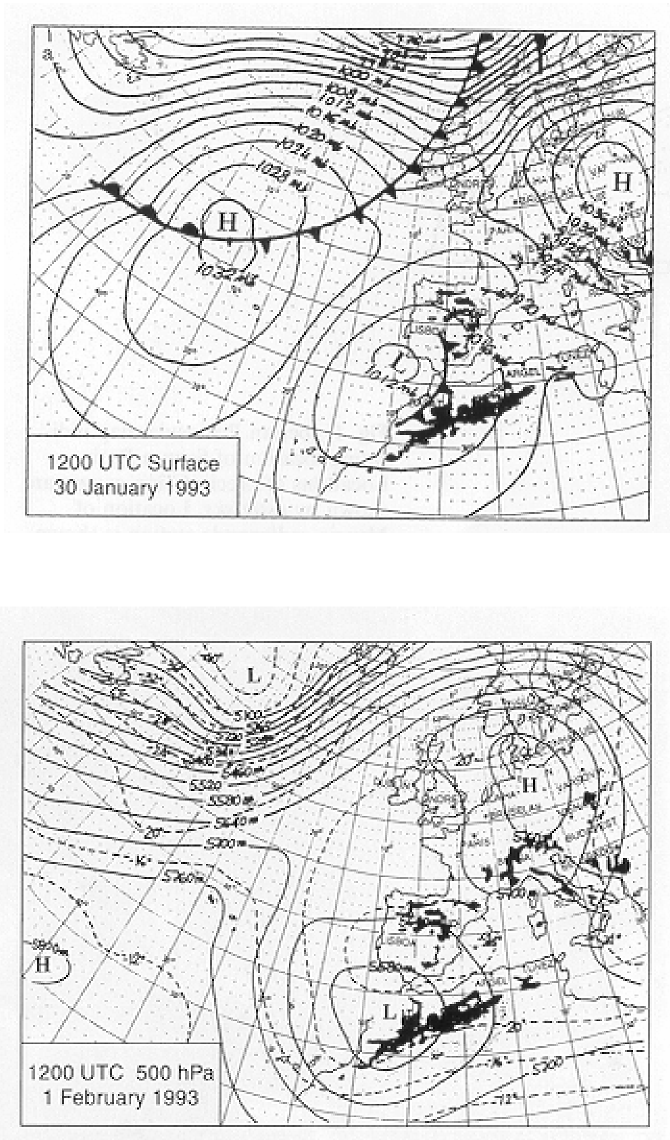

Figure 2: (a) Surface analysis on 30 January 1993 at 1200 UTC. Pressure contours every 4 hPa; (b) The 500 hPa analysis for 1 February 1993 at 1200 UTC. Height contours (solid lines) are every 60 m and temperature contours (dashed lines) are every 4ºC.

Figure 3 displays the 3-day back-trajectories on 1000, 850 and 500 hPa pressure levels at Murcia up to 31 January. It should be noted that the source of air in the middle and upper troposphere is North Atlantic arriving at Segura Basin after giving long way round about North Africa. In contrast, at the lower troposphere, on the 1000 hPa level, moist air masses from the inner Mediterranean Sea arrived at. The short-run but warm airmass associated with the 850 hPa back-trajectory is usually sufficient for the boundary layer to be laden with moisture as well and allow for the increased amount of potential instability to be ensured over SE-Spain.

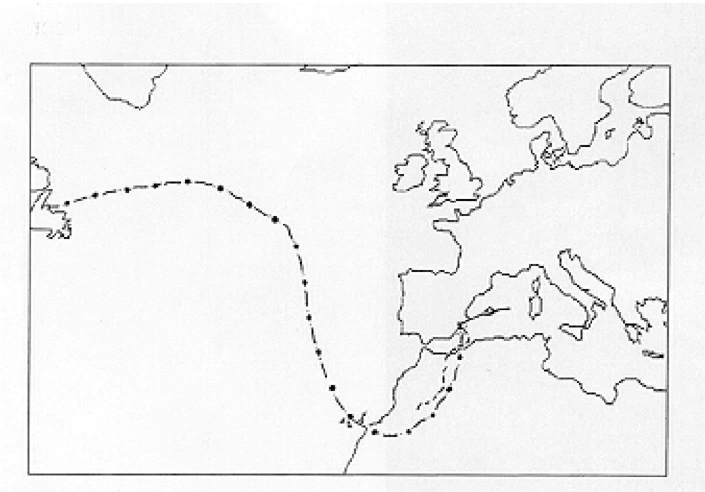

Figure 3: Three-day back-trajectories on 1000 hPa (solid line), 850 hPa (dashed line) and 500 hPa (dashed-dotted line) pressure levels at Murcia station up to 31 January 1993.

Figure 4 (top) shows the IR satellite image for 1 February 1993. It can be observed the clouds organised in a band-like pattern along the southeasterly wind flow. Downwind at SE Spain the contrast between the warm surface and the colder cloud tops result more evident due to the clouds grow in depth and the cloud-top temperatures decrease. On the next day (Fig. 4 bottom), the IR image showed brighter bands of clouds lying along the low-level wind flow with darker, warmer (thinner clouds) areas outside.

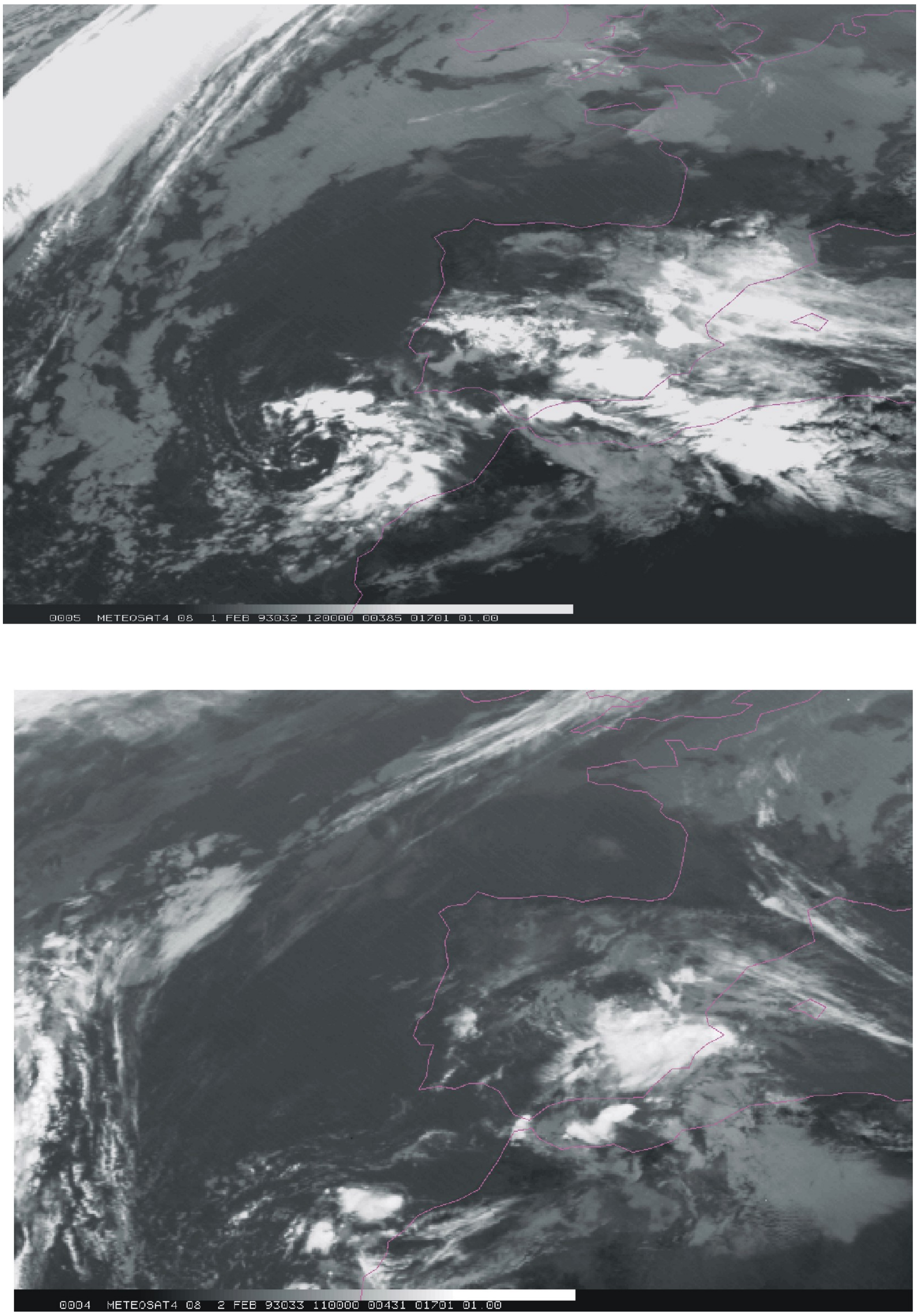

Figure 4: Meteosat infrared image for: (top) 1 February 1993 at 1200 UTC; (bottom) 2 February 1993 at 1100 UTC.

According to Doswell et al. (1985), large-scale processes may play a fundamental role in the modification of the local thermodynamic environment. In this event, local conditions changed dramatically from stability to extreme unstability. In fact, the subsynoptic conditions at the first of the episode showed high-based cloudiness on 29 January at Murcia station. For this date to 31 January, the values of both *TTI* and *LI* stability indices varied from 27 and 14 to 49 and zero, respectively, indicating increasing potential for convective storms. On 31 January (Fig. 5 left), the conditional instability is noted associated with differential temperature and moisture advection. Furthermore, a shallow surface-based, nearly adiabatic layer characterised by easterly flows carrying warm and moist air off Mediterranean Sea is noticeable. This layer is separated from a dry, cold layer above by a relatively stable layer. On 30 and 31 January scattered outbreaks of rainfall, by far 20 mm day^{-1}, were gauged at the most of watershed (Fig. 6*a* and Fig. *6b*). Moreover, the wind shear is non-unidirectional as displayed in the Fig. 5 (left) which shows the wind shear vector veering with height.

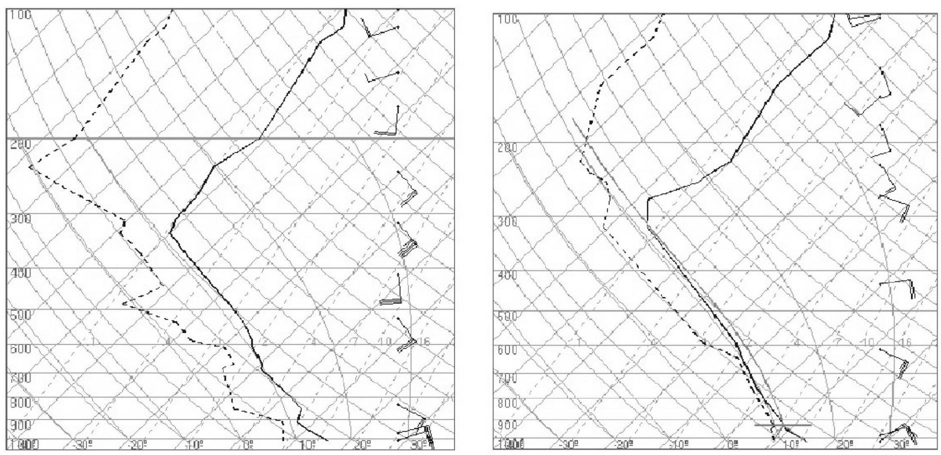

Figure 5: Skew *T*-log*p* plot of Murcia sounding at 1200 UTC on: (left) 31 January; (right) 1 February 1993. Solid line is the temperature plot (ºC); dashed line is the dewpoint plot (ºC); wind barbs are in knots.

The 1200 UTC sounding on 1 February (Fig. 5 right) is representative of the so-called *tropical sounding* (McCaul, 1987). A deep moist layer up to about 9 km above ground level without a stable layer can be observed. The lapse rate is less than dry adiabatic but greater than moist adiabatic, i.e., the sounding is conditionally unstable. In fact, the *TTI*, *LI* and *KI* values of 57, -2 and 29, respectively, suggest an increase of convection probability at Segura Basin. Without a capping inversion, but with a deep moist layer, there is then the possibility of widespread convection. In fact, daily precipitation became organised west of Basin with a maximum of up to 50 mm or so to the northwest as it can be seen in Fig. *6c*.

Substantial negative buoyancy (*CIN*) must often be overcome before a rising parcel reaches its level of free convection. High values of *CIN* are conducive to conditions of lower-level channelling of the easterly warm, moist flow towards SE Spain. In our case, *CIN* values decreased from 1331 J kg^{-1} on 29 January to nearly zero on 1 February. Simultaneously, some but weaker increases in *CAPE* were observed. As a result, a strong lifting had been needed to initiate deep convection. In addition to large-scale parameters, vertical wind shear became a critical control over the maintenance of deep, precipitating convection. In fact, computed vertical wind shear values between 10 and 20 m s^{-1} became in this case throughout the storm period. Yet, wind shear did have a moderate strength so as to promote suited conditions to organise a long-lived convective structure.

Figure 6: Isohyets of daily rainfall (mm) over Segura Basin for: (a) 30 January; (b) 31 January; (c) 1 February; (d) 2 February; (e) 3 February and (f) 4 February 1993. Study domain is mapped at 1:850000 scale.

Local atmosphere conditions during the later part of the event were analogous to those previously described on 1 February, and so widespread convective activity throughout the Segura Basin continued up to 4 February also resulting in heavy rains spreading out over much of the Segura Basin's area (Fig. 6*d-f*). Here, the maximum precipitation shifted eastward approaching to the coastline with exceptional amounts of rainfall about 150 mm day^{-1} or so.

At the end of the storm period, on 5 February 1993, both large-scale and subsynoptic conditions were no longer indicative of storm development with no significant rainfall amounts and no well-organised patterns.

4 SUMMARY

The study of the heavy rainfall episode (30 January-4 February 1993) at SE Spain has been focused on a meteorological analysis of this event by analysing its large-scale and subsynoptic features to illustrate a conceptual framework for understanding the processes leading to intense convection at this area. Such events are a typical autumntime phenomenon at SE Spain. However, this case was a significant weather event not only because of being a hazard, but also because it was an unusual winter storm which was inherently more difficult to forecast.

The contribution from large-scale conditions was crucial to the explosive development. A large-scale critical control was the cut-off over North Africa and the transition of the ridge over Central Europe to a closed high establishing a high-over-low blocking pattern. This pattern promotes and reinforces the low-level moist, warm advection encouraged by the meridional low. The channelling effect meant that there was continuing destabilisation of the atmosphere. The upper trough acted, together with the proximity of a cold front to southeastern Iberia, to induce mass ascent and therefore, release of conditional instability and subsequently severe weather.

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