Mediterranean Storms
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STORMS IN FRONT OF THE MOUTH RIVERS IN NORTH-EASTERN COAST OF IBERIAN PENINSULA

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ABSTRACT

In general, we want to provide a first survey of the interaction of the breeze with the environment of the Mediterranean sea to form and intensify the storms, with the use of the common tools such as radar, radio sounding ,meteorological heliosyncron and geostationary satellite imagery, surface and Numerical Weather Prediction data.
In particular, we put our interest in the initiation of convective storms by convergences zones in the planetary boundary layer, like the land breeze interaction with the air over the sea in front some mouth rivers in north-eastern coast of Iberian Peninsula, with the aim to achieve a basic conceptual model which improves their nowcasting.

1 INTRODUCTION

The aim of this paper is to identify the main features, especially at low levels, of the frequently and favourite development of storms in front of the mouth rivers at nighttime in north-eastern coast of IP (Iberian Peninsula). Our interest in these convective clouds is because they are the cause of very persistent and localized rainfalls that could generate floods near the coastline. We have seen that they are one consequence of the interaction of land breeze phase with the environment. In addition, we know nowadays that the convective storms do not appear randomly distributed (*koch & Ray*, 1996). So the lower levels could determine when and where PBL (Planetary Boundary Layer) convergence zones could develop generating convection (e.g. in our case, the surroundings of mouths of the rivers) with more or less favourable synoptic (or mesoscale) conditions. In fact, there are models of NWP (Numerical Weather Prediction) that use the convergence at low levels to produce convection (e.g. *Kuo* schemes).

2 LAND AND RIVER BREEZE

We have identified that night phase of the breeze (i.e. land breeze), river breeze (*Zhong & Takle*, 1992) and katabatic winds play an important role in the storms that we want to improve its forecast, and they are determined for the characteristics of the coast. So first, we summarize the most important orographically characteristics of the north-eastern coast of IP:

1. A coastal or littoral mountain range extending south-west to north-east parallel and very near to the coastline of the Mediterranean sea (i.e. between 10-20 km), with a mean height around 400 metres.
2. A few rivers gaps through this mountain range, which we have focused in four of the most important, from north to south: Besòs, Llobregat, Francolí and Ebre.

We have found that this particular orography determines the next summarize features of the land and river breeze and katabatic winds that we could observe with the scarce data:

a. It is difficult to distinguish clearly between land breeze, local river breeze and katabatic winds, which linking up sooner o later (*Neumann*, 1951). So, we termed together as LRB (Land-River Breeze).

b. Cold air is drained from the basin of the rivers to the sea through its mountain range gaps, where these river breeze speed up and make the LRB more intense near the mouths of the rivers. The opposite effect of the gaps of the rivers with moist onshore winds could develop a flash floods around 250-300 mm at the top of their basins.

c. A apparently stronger gradient of temperature between land and sea around 2-3 k per 10 km than that reported by literature around 1 k per 20 km, because it is increased for both the cooling effect of the coastal range and a warm sea. But we could not analize the thermally induced pressure gradient because we haven't got any pressure data over the sea.

d. The onset of the LRB could be detected because of the significant change of the wind direction, without noticeable changes in the relative humidity, temperature and strength of the winds. This would occur around two or three hours later of the sunset, if there was a wind calm before. And LRB could have a thickness around 100 metres with enhancing edge which it is in accordance with other results (*Atkinson*, 1981; *Meyer*, 1971; *Schoenberger*, 1984; *Ohara et al.*, 1989).

e. The strength of the LRB is around 1-3 m/s, which is agree with the literature (*Meyer*, 1971; *Ohara et al*., 1989; *Atkinson*, 1981; *Zhong & Takle*, 1992), relativity uniform over the coast and becomes quickly quasi-stationary. It is less strong than the sea breeze phase because of it is driven primarily by mesoscale pressure gradients, which are weaker than sea breeze because there exits no low level heat source to carry it.

f. We could observe a small veering of the LRB (i.e. less than 45º) induced for Coriolis force when it flows over the sea, which is consistent with the linear theory of *Neumann* (1977).

g. The LRB blows with a predominant directions between N and NW on the coastline.

h. It seems that there are LRB all year, with a seasonality of occurrence and intensity with a maximum in winter-spring and a minimum in summer-autumn.

3 FOCUSED CONVERGENCE AT LOW LEVELS

The LRB acts as a small SCF (Shallow Cold Front) (*Neumann*, 1951; *Meyer*, 1971) or cool density current (*Shoenberger*, 1984) when it arrives over the Mediterranean sea. We have observed that it exist, for example, the case of the night between the days 18 and 19 July 2002 that we show in the Figure 1. With a synoptic situation of the weak barometric gradient at surface and stability in the PBL, we could see a typical LRB circulation that develops nocturnal cumulus humilis into the sea (around 20-30 km) that marks where is the SCF as shown by *Meyer* (1971).

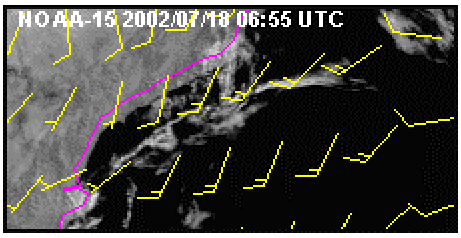


Figure 1. Imagery of visible channel 2 of NOAA-15 at 06:55 UTC of 18 July 2002 and winds plotted from the analysis of NWP INM-HIRLAM 0'2º (06:00 UTC). We can see a thin line of cumulus which are generated for the convergence of the LRB and onshore wind. Other clouds are cirrus. The NWP only shows the onshore wind.

But, because the LRB isn't autoconvective, we could observe another necessary feature for the convergence at low levels, a synoptic or mesoscale wind that flows from the sea to the coast against the SCF. Usually this wind has particular conditions of the mass air that lies over the Mediterranean sea under the influence of it (*Jansà*, 1997). It is very moist and warm, as a result of that it is less dense. This increases the discontinuity between both air masses at very low levels in the nocturnal or SBL (Stable Boundary Layer). For continuity the less dense air has to lift over the denser air, and it may arrive very quickly to its LCL (Lifted Condensation Level) and develops convective cells. Usually these recurrent storms have the next main features:

1. Persistence of the precipitation.
2. Localized phenomenon.
3. Intense rainfalls.

This is because of there is a focused convergence that occurs near or over the mouth of the river at the same place, where the convection appears again and again, and they last a lot of hours. And this, of course, could produce intense rainfalls over the ground and floods. Sometimes these storms appear a few kilometres into the sea and its consequences are less important for humans. In the next Table 1 we summarize two selected episodes and its precipitation from local pluviometer network to illustrate the mouth rivers storms.

Date LRB (dd/mm/yy)	Mesoscale features	Mouths of rivers	Convection Movement	Period * (UTC)	Wind (m/s)	Rain gauge (mm)	Light-ning	Convec-tion type
11-12/09/02	Light instability. Warm advection at low levels. Low pressure gradient over IP.	Besòs	Stationary	20:54 + 4 hours	5 on. No ava	27.8 Barce-lona in 10'	2 -	Warm
		Llobregat	Stationary	22:44 + 6 hours	2'5 ons. 2'5 offs.	75 Castell. 67 Begues	60 - 5 +	Warm / Cold
		Francolí	Slowly to seaward.	02:30 + 4 hours	No ava.	35 Tarrago-na	>100 -	Cold
21/08/02	Instability in SE of IP. Low 1012 in IP.	Ebre	Slowly to seaward.	01:10 + 4 hours	1'2 offs. 8 ons.	No avalaible	27 - 1 +	Cold

Table 1. Main characteristics of convective storms of the cases selected and discussed in this study (Offs: offshore or LRB wind; Ons: onshore wind; No ava: data no avalaible; + and -: positive and negative lightning; * period with the radar reflectivity).

This is one of the four categories of recurrent convergences zones over sea in north-eastern IP that we had recognized in a previous study (*Pascual & Callado*, 2002), which was based in those proposed by *Koch* and *Ray* (1997). We termed it as Interaction between Land Breeze and Wind Onshore.

With the aim to show focused convergences, we have selected two clearly cases which the lifted air could destroy the inversion of SBL and arrived at its LFC. In these cases, there were likely shear instability and turbulence, with a thicker edge, i.e. LRB head (*Ohara et al.*, 1989; *Meyer*, 1971).

3.1 Besòs, Llobregat and Francolí case

In the Table 1 we can see the features of one triple case for these three rivers (11 and 12 September 2002) and in Figure 2 we can recognize and analyse the main elements for the convergence in Besòs and Llobregat mouths by Doppler radar imagery:

a. There were apparent convergent radial winds, the onshore one and the offshore one (2 and -6 m/s near A).
b. This circulation was very persistent (4-6 hours, Table 1).
c. The cloud tops were very low at the Besòs mouth (less than 3 km in B with warm precipitation process).
d. Raingauge measures showed a intense rain in spite of relatively low reflectivity (27 mm/10'; 34 dBz near B).

As a result we identify the convergence and a warm precipitation. It is interesting to notice that in a first phase the precipitation process in Llobregat mouth area is warm, but later it changes to cold one, as we can diagnose from radar imagery and lightning data. Finally it results in a little flood because its persistence (6 hours).

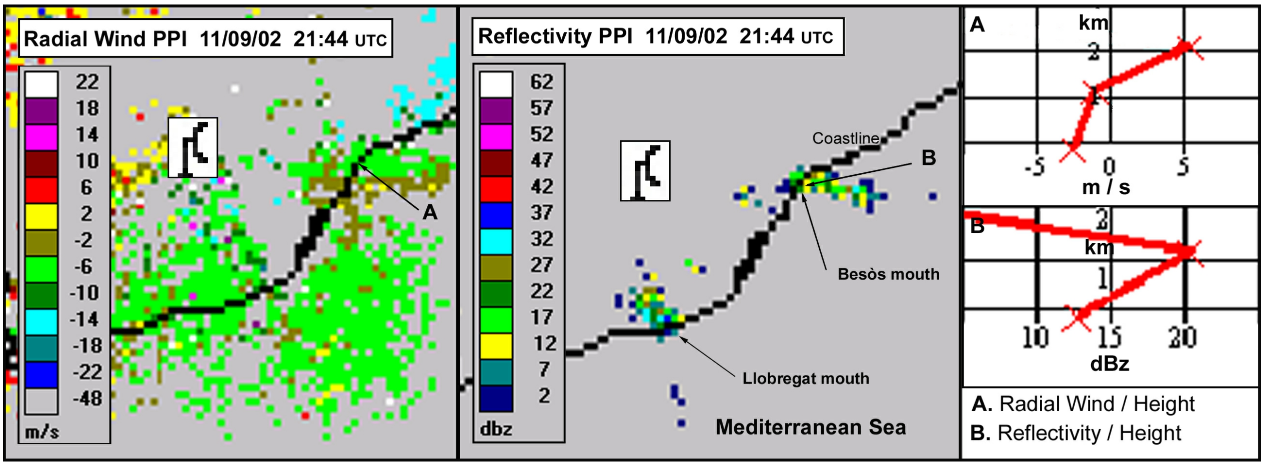


Figure 2. Radial wind and reflectivity imageries of C-band Doppler radar with a resolution of 1.1 km x 1.1 km. And verticals profiles to 29 km from the radar in the mouth of Besòs.

3.2 Ebre case (21 August 2002)

This is another example of a recurrent convergence in a mouth, but with the particularity that the Ebre basin is greater than Besòs, Llobregat and Francolí rivers and the interaction between the synoptic winds and the orography produces a regional wind along the valley (Cierzo) that could act as offshore wind. The existence of this regional wind implies two consequences: 1) There are a high frequency of convergences and 2) sometimes it is difficult to identify the role of the LRB in these convergences.

3.3 Another cases

We have selected two clearly cases to show the generation of rainfall inland from a simple convergence at low levels but there are more complex cases where probably the LRB could enhance the convection development. One of these situations is the autoconvective Catalonian-Balearic Convergence Zone (CBCZ) which could generate an onshore wind by an anticyclonic vorticity centre associated with the western shear line of Tramontane regional wind (*Jansà*, 1997). Sometimes the CBCZ can develop stratiform cloudiness with embedded convection near the mouths of the rivers (e.g. Besòs River). Another situation, which is another of the four recurrent convergences zones that we have mentioned before, is the Prefrontal Troughs (lee trough) in which the LRB could play some role enhancing locally convergence offshore (*Pascual & Callado*, 2002).

4 CONCLUSIONS

The main feature of the development of showers near of the mouth of rivers at night is the focused convergence zones in the Planetary Boundary Layer between the land-river breeze (i.e. offshore winds) and synoptic or mesoscale Mediterranean moist wind blowing over the sea toward the coast (i.e. onshore wind). These convergence zones are very small and focused because the special orography of north-eastern coast of the Iberian Peninsula. They are more intense where there are a river gap in the coastal range because the land-river breeze can flow and accelerate trough it.

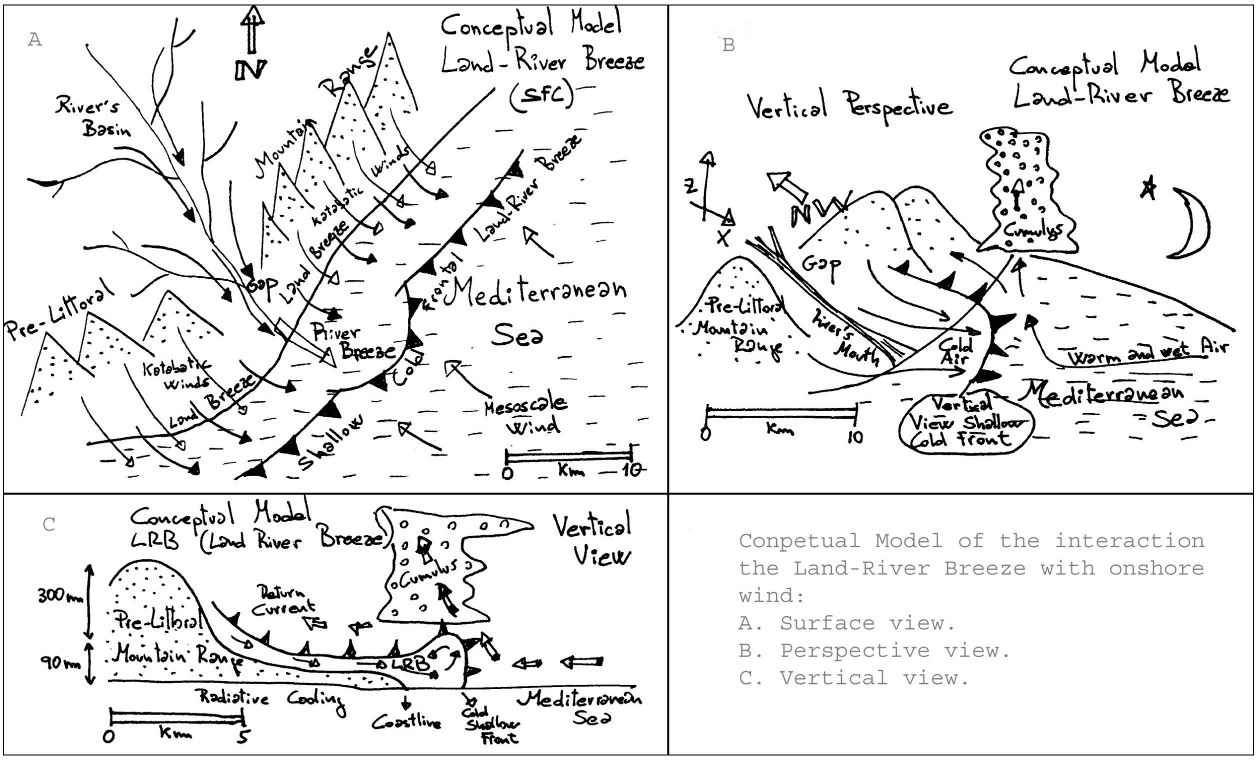
The offshore wind acts like a shallow cold front. The onshore flux supplies moist air near to saturation and with the special characteristics of the Mediterranean air mass. This air is forced to overrun and lift the offshore wind where they strike, and it could arrive with a small upward at its lifting condensation level, crossing the inversion of the stable nocturnal boundary layer and arriving at its level of free convection, as well. This upward movement can generate two types of very localized and persistent rainfalls: a typical mid-latitudes thunderstorm (i.e. cold precipitation or Findeisen-Bergeron precipitation process) or/and a like tropical shower without lightning (i.e. warm precipitation or collision-coalescence precipitation process).

As a driving mechanism we have found the next three main conditions to produce these focused convergences near the mouth rivers:

a. A weak pressure gradient in cloudless at night which permits easier the land-river breezes formation.
b. A moist wind blowing inland from Mediterranean sea.
c. A neutral or low stability in the nocturnal boundary layer.

If the low levels winds achieve these three special conditions, they could trigger showers and thunderstorms, which could also show a great persistence at the same place.

With these features we would have enough knowledge to improve the nowcasting of convection in front of the mouth rivers. With this aim we present in the Figure 3 a possible basic conceptual model of Land-River Breeze.



Conpetual Model of the interaction the Land-River Breeze with onshore wind:
A. Surface view.
B. Perspective view.
C. Vertical view.

Figure 3. Three points of view of the conceptual model of the LRB when blowing onshore wind at night.

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