ANALYSIS OF THE 12-13 NOVEMBER 2004 HEAVY RAINFALL EVENT OVER SOUTHERN ITALY

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Abstract: During 12-13 November heavy rainfall affected Ionian regions of Southern Italy causing local floods with relevant impacts on human activities. Rain gauges data showed a non uniform distribution of precipitation with values exceeding 200 mm per day over two different localized areas.
Both observational data and the MM5 model results were combined in order to investigate main mesoscale processes and features leading to the event.
The synoptic setting, similarly to heavy rainfall episodes in other Mediterranean regions, was characterized by a slow-moving trough exhibiting cut-off circulation; during 12 and 13 November, the cut-off low moved eastward contributing to onset a low-level jet (LLJ). As revealed by the numerical mesoscale analysis, the convectively unstable LLJ interacted with orography resulting in an important factor contributing to rainfall formation.

Keywords: *heavy rainfall, low-level jet, MM5*

1. INTRODUCTION

Several heavy rainfall episodes occur, mainly in autumn, on different regions of the Mediterranean Basin: during this season high sea surface temperature and upper-level disturbances approaching the Basin create favourable conditions under which various mesoscale uplifting mechanisms can lead to deep moist convection (Homar et al., 2002). Slow moving upper level trough, sometimes associated with cut-off circulation, can contribute to the onset of low-level flow advecting warm and moist air that, interacting with orography, can generate heavy precipitation (Doswell et al., 1998); also, orography can deviate and intensify the low-level flow leading to the formation of convergence zones often associated with heavy rainfall (Buzzi et al., 2000).

Heavy rainfall hit Ionian regions of Southern Italy during 12-13 November 2004. Rain gauges data showed a non-uniform distribution of precipitation: on 12 November, about 250 mm were recorded over the northernmost coastal area of the Ionian Sea; on 13 November, about 200 mm were recorded over the central zone of Salentine Peninsula (Fig. 1).

In this study, we combined observations and numerical data obtained using the PSU/NCAR MM5 model, to identify main synoptic and mesoscale ingredients conducive to the heavy rainfall episode.

2. SYNOPTIC ENVIRONMENT AND OBSERVATIONS

At 12 UTC 11 Nov, a day prior to the examined period, a cut-off low embedded in a pre-existing wide and positively-tilted upper-level trough was located over Western Mediterranean. At surface, the Azore high over the Eastern Atlantic, and a weaker anticyclone over Eastern Europe, surrounded a wide area of relatively low pressure values covering North-West Africa and the Central-Western Mediterranean. On the eastern bound of this area, a south-easterly low-level flow existed. In subsequent hours, the cut-off low moved south-westward while, over Eastern Mediterranean, a ridge developed; the enhanced pressure gradient intensified the pre-existing south-easterly flow generating a LLJ that entered Mediterranean from Libya. At the same time, the cut-off low interacted with a low-level thermal anomaly in the lee of Atlas Mountains where, during first hours of 12 Nov, a shallow surface vortex started to build up (Horvath et al., 2006).

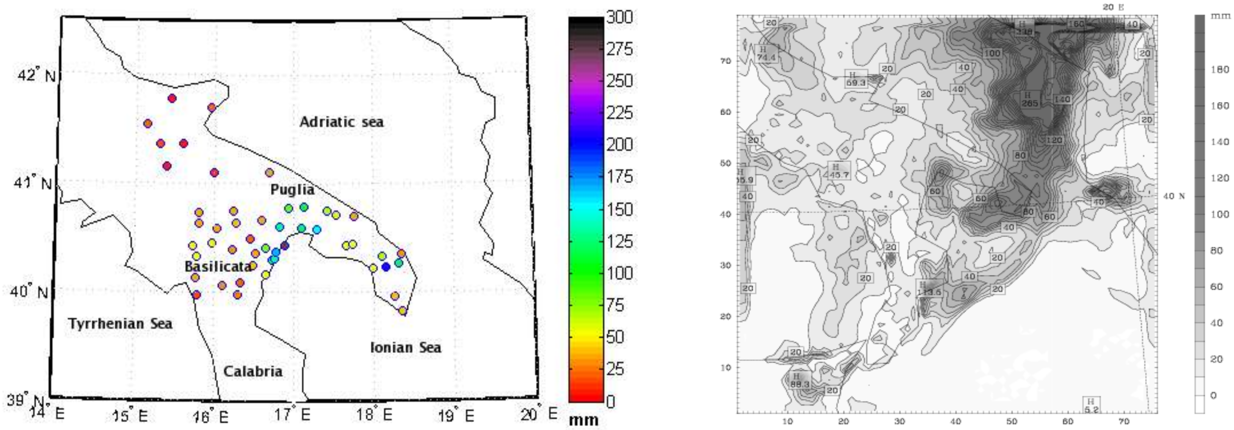

Figure 1: Accumulated observed (left) and simulated (right) rainfall (mm) during 12-13 November.

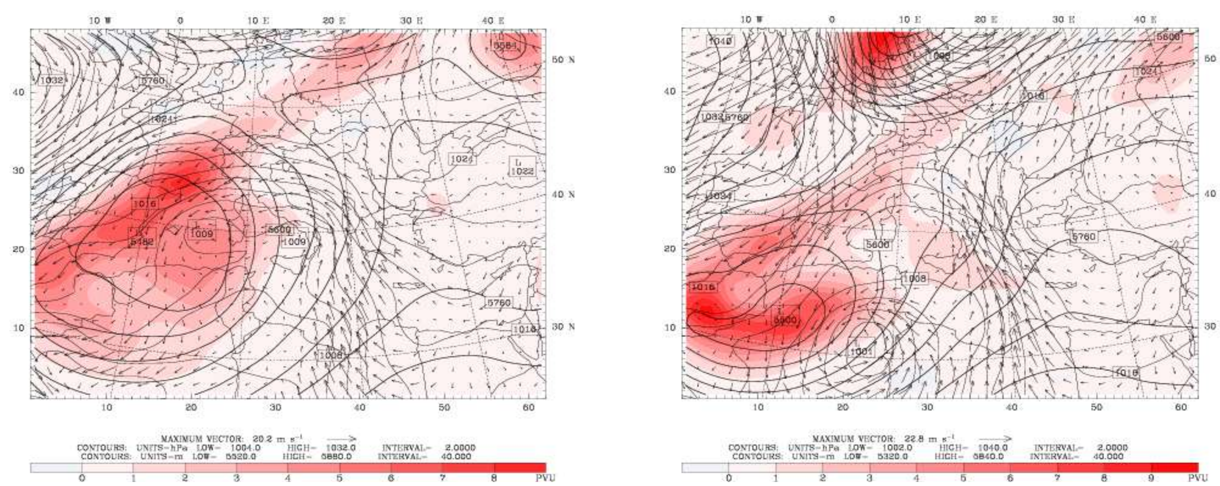

Figure 2: ECMWF analysis interpolated on the MM5 67.5 Km domain: 500 hPa heights (solid line, 40 m interval), 300 hPa Ertel's potential vorticity (shaded, 1 PVU = 10^{-6} K m^2 kg^{-1} s^{-1}), sea level pressure (thin line, 2 hPa interval) and 925 hPa winds at 00 UTC 12 Nov (left), at 00 UTC 13 Nov (right).

A first period of heavy rainfall hit localized coastal areas facing northernmost part of the Ionian Sea; two precipitation maxima were recorded around 17 UTC and 23 UTC 12 Nov, the latter producing about 100 mm in a 2-hour period. At the same time, available rain gauge data, even sparse, showed weaker precipitation (< 10 mm h^{-1}) over surrounding regions. The Brindisi sounding at 00 UTC 13 Nov showed saturated mid-level air (700-500 hPa) overcoming a potentially unstable surface layer (1000 – 870 hPa), indicating, together with a wind intensity maximum of about 31 m s^{-1} at 875 hPa, the presence of the warm and moist south-easterly LLJ;

twelve hours before, the atmosphere over the same sounding location was conditionally unstable.

By 00 UTC 13 nov, the 500 hPa cut-off low started to move eastward; at surface, the Azore high intensified and extended eastwards; the low-level vortex, deepening between Tunisia and Lybia, shifted towards the Mediterranean. A short-wave trough, with associated 300 hPa potential vorticity region (2 PVU), approached Southern Italy (Fig. 2); it moved north-westward along the trough-ridge boundary and 6 hours later it reached the Adriatic Sea. In this period, precipitation shifted eastward and reduced: rainfall producing more than 10 mm per hour were registered over the northern portion of Salento. Later, precipitation affected the central portion of Salentine peninsula persisting for several hours: two peaks of about 40 mm h^{-1} were observed at around 09 UTC and 15 UTC 13 Nov. On 12 UTC 13 Nov, the low-level cyclone approached the Mediterranean; the induced circulation substituted the LLJ and weak rainfall were recorded during the evening of 13 Nov.

3. MESOSCALE FEATURES

We used the MM5 model to simulate the heavy rainfall event. The model is initialized at 12 UTC 11 Nov with ECMWF analysis data; boundary and initial conditions are updated every 6 hours. Three two-way nested domains with 67.5, 22.5 and 7.5 km grid resolution respectively, and 25 unequally spaced vertical levels are used. We adopted the Kain-Fritsch cumulus parametrization scheme on outer and intermediate domains and the Grell scheme on the innermost domain. Mixed-phase microphysics parametrization scheme is used to represent moist processes, the MRF scheme to parametrize the planetary boundary layer processes.

The numerical simulation captures the evolution of the LLJ revealing its mesoscale features. At 00 UTC 12 Nov, the cut-off low aloft Western Mediterranean moved south-westward and a ridge developed over Eastern Mediterranean; the related, surface high pressure area expanded to the west enhancing pressure gradient over the Libyan region centred on 30° N, 20° E. As a result, the pre-existing south-easterly flow intensified giving rise to a LLJ. Moving northward, the warm and dry air coming from Sahara gained moisture over the sea; horizontal wind shift and a convergence area developed ahead of the jet. The analysis of the highest resolution domain results reveals that the LLJ was characterized by high θ_e values (up to 332 °K), resulting in a potentially unstable layer when approaching the Ionian Calabria coast on 15 UTC 12 Nov. The airstream was partially blocked and subsequently forced to move north-eastward: convergence ahead intensified and the high θ_e airstream remained over the Ionian basin, only partially reaching the Tyrrhenian; furthermore, the LLJ area narrowed when entering Southern Adriatic where a simulated wind speed maximum started to appear on 17 UTC 12 Nov. At midtropospheric levels, moist air, embedded in the broad cyclonic circulation, reached Southern Calabria at 07 UTC 12 Nov; a moisture maximum developed ahead of intensive southerly currents that veered south-westerly when the cyclone, developing over North Africa, approached the Ionian region.

The small number of observations does not allow a detailed comparison between simulated and observed precipitation, especially above the sea, but, even if the model underestimates the amounts of the localized observed rainfall peaks and shows a time shift, the precipitation pattern is acceptably well reproduced (Fig. 1). Heavy rainfall mainly hit Ionian coastal zones exposed to southern flow; in accordance with observed data, a wide area of lighter precipitation was reproduced downstream of Calabria region. The south-easterly LLJ impinged on Calabria coast until 08 UTC 13 Nov; during this period a convergence zone persisted upslope of central Calabria orography. According to model outputs, convective cells produced over this area during 12 Nov were advected, within midtropospheric southerly currents, towards northernmost tip of Ionian where intensified. The simulated rainfall maximum over Salento (about 130 mm) is due to persisting rainfall: the model shows a convergence line, in coincidence of precipitation, related to a surface boundary with the LLJ impinging on lower θ_e air downstream (Fig. 3). This mechanism was also responsible for initiating residual precipitation affecting a small area on the eastern coast of Salento, during 13 Nov.

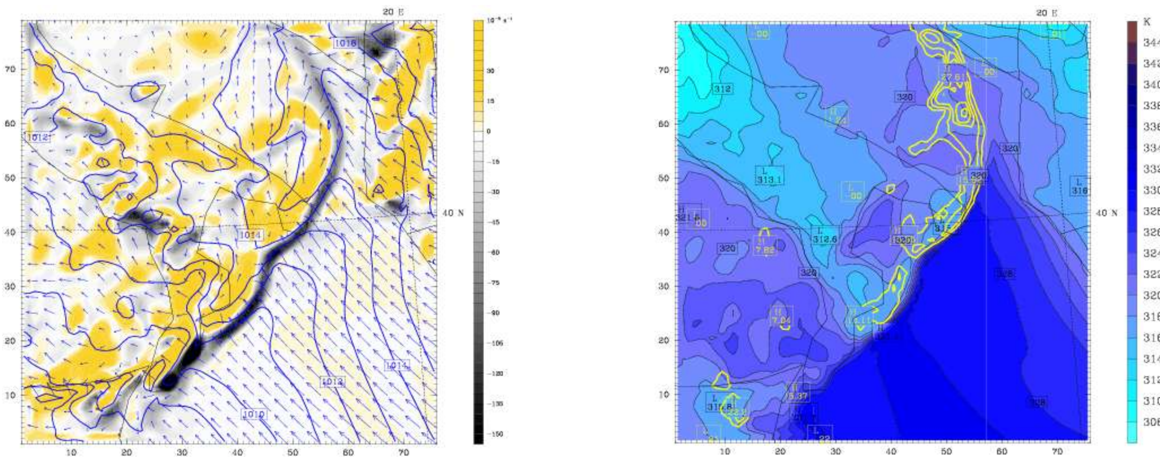

Figure 3: Left: 1000 hPa convergence field (shaded, 5 x 10^{-5} x s^{-1} interval), sea level pressure (contour, 1 hPa interval) and winds (maximum wind speed vector of about 18 m s^{-1}) at 22 UTC 12 Nov. Right: 1000 hPa θ_e (shaded, 2 °K interval), 1-hour accumulated rainfall(yellow contour, mm), surface wind at 22 UTC 12 Nov.

4. CONCLUSIONS

In this study, we exploited observed and numerical data to identify main synoptic and mesoscale ingredients leading to a heavy rainfall event occurred over Southern Italy. We found that the synoptic setting was characterized by a slow-moving trough exhibiting cut-off circulation, downstream of which heavy rainfall occurred; the position and persistence of the trough caused advection of warm and moist air at low-levels. The subsequent cut-off eastward shift enhanced the south-easterly flow giving rise to a convectively unstable LLJ. The LLJ affected the focus area throughout the rainfall period continually supplying moisture. Moreover, it was partially blocked and deflected by the complex topography of the Ionian area, contributing to produce unequally (in space and time) precipitation distributed over the Ionian region.

Further development of this work will be related to the implementation of additional numerical experiments in order to investigate the influence of synoptic and mesoscale features, and their multiscale interactions.

Acknowledgements: *the authors are grateful to the following company and institutions for providing precipitation data: SMA Industria s.p.a., A.R.P.A.B. - Servizio Idrografico e Mareografico, and Aeronauitca Militare. The work of K. Horvath was supported by the Ministry of Science, Technology and Sports of Republic of Croatia under project number 0004001.*

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