P2.6

Low Level Flow Patterns Associated with Two Heavy Rainfall Events During MAP

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1. Introduction

The European Alps have sustained several heavy, damaging rainfall events in past years (Sénési et al., 1996; Massacand et al., 1998; Buzzi et al., 1998; Buzzi and Foschini, 2000; Fehlmann and Quadri, 2000; Tripoli et al., 2000; Lin et al., 2001). These events are characterized by an upper level trough and associated surface cyclone/front system and a low level jet (LLJ) that brings in moist air from the Mediterranean to the Alps. Tripoli et al. (2001) also found that hot African air channeled by the terrain surrounding the Mediterranean can act as an Elevated Mixed Layer (EML) and play a role in precipitation development.

For the study presented in this paper, the low level flow of two cases will be examined. These cases are from the 1999 Mesoscale Alpine Programme (MAP), specifically, IOP-2B (19 September) and IOP-8 (19 October). These two events resulted in heavy rainfall in the Lago Maggiore region but differed in characteristics in that the flow associated with IOP-2B was more unstable than the flow associated with IOP-8. The study of this paper will focus on trajectory analysis of the two events, via numerical simulations using the PSU/NCAR MM5 model. Also, terrain sensitivity tests will be performed. The simulations for IOP-2B were initialized at 0000 UTC 19 September and were 48 hours in length. Simulations for IOP-8 were initialized at 1200 UTC 19 October and were 60 hours in length. For more details of model configuration and preliminary results see Thurman et al. (2001).

2. IOP-2B

Analysis of 6 hour accumulated model rainfall indicated that the heavy rainfall started occurring in the Lago Maggiore region around 1200 UTC 20 September. Twelve back trajectories beginning at 850 hPa over the Lago Maggiore region were calculated from 1200 UTC 20 September to 0000 UTC 19 September. A trajectory of interest was trajectory 7 (Figure 1). This trajectory had origins over the Atlantic coast of Africa. An analysis of this trajectory every three hours indicated it was roughly parallel to the low level jet that had origins over the Strait of Gibralter and propagated to the southern Italian coast. The trajectory also paralleled the propagation of the rainfall from west to east and a tongue of high equivalent potential temperature (θ_e) air. This trajectory could possibly be associated with the exit region of the upper level jet and its ageostrophic circulation. Other trajectories originated in North Africa were aligned with a second tongue of high θ_e air from North Africa.

A sensitivity test was performed by smoothing the North African terrain by 75% and making a 48 hour simulation initialized at 0000 UTC 19 September. This had some affect on back trajectories from Lago Maggiore. Trajectory 7's start position had now shifted slightly west, but for the most part had followed the same path as the trajectory in the full terrain simulation. So for IOP-2B, it appears that the most pertinent low level flow was from the southwest.

In addition to comparing trajectory positions, a difference of accumulated rainfall (48 hours) between the full terrain and smoothed terrain (full-smooth) simulations revealed that smoothing the terrain caused an increase of rainfall around the Emilia-Romagna region (Figure 2).

3. IOP-8

Analysis of model rainfall revealed that for IOP-8, the heavy rains started to occur around 0600 UTC 21 October. As for IOP-2B, back trajectories were calculated from the Lago Maggiore region at 850 hPa. These trajectories were 42 hours in length. For the IOP-8 trajectories, there were two distinct parcel origins: North Africa and the area of former Yugoslavia. These distinct parcels converged over the Lago Maggiore region (Figure 3). The North African trajectories appeared to rotate around the trough that was present at the lower levels. They also were collocated with a tongue of high θ_e air from North Africa.

As for IOP-2B, the North African terrain was smoothed and the model run once more. Forty-two hour back trajectories from Lago Maggiore revealed that even reducing the African terrain affected the trajectories from former Yugoslavia. The general rainfall pattern for the IOP-8 full terrain simulation was similar in the IOP-8 smoothed simulation. A difference of accumulated rainfall (60 hours) was taken between the full terrain and smoothed terrain (full-smooth) simulations as done for the IOP-2B case. A somewhat similar pattern was found in that the smoothed North African terrain resulted in higher rainfall totals around the Emilia-Romagna region (Figure 4).

4. Summary and Conclusions

Trajectory analysis of two rainfall events in the Italian Alps revealed some similarities and differences. For IOP-2B, all back trajectories calculated from the Lago Maggiore region of Italy had origins in North Africa or just west of Africa. Reducing the North African terrain by 75% resulted in shifting the trajectories' origins and also a shift in the rainfall pattern over the Italian Alps.

Trajectory analysis for IOP-8 revealed two differing parcel origins: Africa and the former Yugoslavia. Parcels originating in the cooler more stable Yugoslavia converged with air parcels from warmer North Africa. Reducing the North African terrain affected the parcels originating in North Africa, as well as the parcels from the Yugoslavian area.

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When comparing the accumulated rainfall between the full terrain and reduced terrain simulations, a similar pattern to IOP-2B was found.

So, it can be said that North African terrain does have an affect on rainfall distribution in the Alps for both IOP-2B and IOP-8. For IOP-2B, it appears to be a result of a broad warm south-southwesterly flow from Africa impinging on the Alps. For IOP-8, it appears to be a case of two differing air masses converging over the Alps, leading to rainfall development.

Future work will include more sensitivity tests, including terrain smoothing of Corsica and Sardinia to see if there is a channeling affect on the airflow, as seen in Tripoli et al.(2000) and manipulation of sea surface temperatures to see the effects of the Mediterranean Sea. Also, more analysis linking low level flow with upper level flow patterns will be performed.

5. Acknowledgements

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6. References

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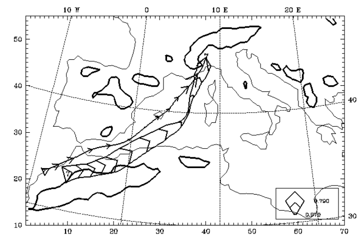

Figure 1. Full terrain (arrows) and smoothed terrain (ribbon) 36 hour back trajectories for IOP-2B. Trajectories are for trajectory 7. 1 km terrain is shown by bold contours.

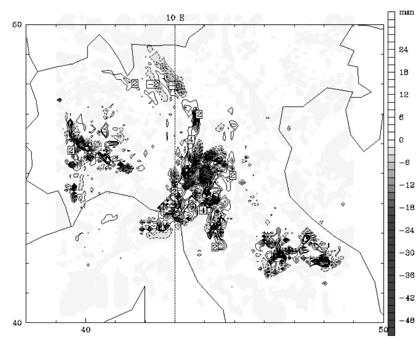

Figure 2. 48 hour accumulated rainfall differences (mm) for full terrain – smooth terrain rainfall. Shaded areas are negative.

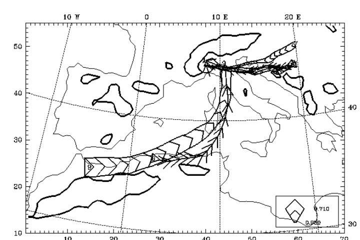

Figure 3. As for Figure 1, except for IOP-8 and 42 hour back trajectories.

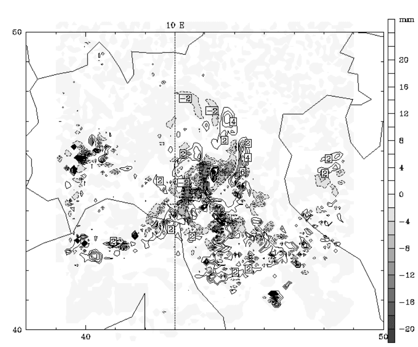

Figure 4. As for Figure 2, except for IOP-8 and 60 hour rainfall totals.