8.2 THE RELEVANCE OF INSTABILITIES WITH HEAVY OROGRAPHIC RAINFALL DURING MAP IOP-2B

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1. INTRODUCTION

This study investigates the roles instabilities played in the initiation of the heavy orographic precipitation that occurred in the Lago Maggiore Target Area during the MAP IOP2B event, which extended from 19 to 20 September 1999. In a recent study, Lin et al. (2001) examined the orographic rainfall cases in different regions, and suggested that a conditionally or potentially unstable upstream airflow was a common ingredient for producing heavy orographic rainfall. Houze et al. (2001) reported that IOP2B was a case with low-level warm, strong and potentially unstable airstream. Lin et al. (2002, manuscript submitted to *Quart. J. Roy. Meteor. Soc.*) examined the influence of synoptic and mesoscale environments of IOP2B, and suggested that low-level flow over the southern Alpine slope tends to release the potential instability. Nevertheless, Rotunno and Ferretti (2001) suggested that strong conditional instability was produced by orographically induced differential advection of cold air in IOP2B. It appears that unstable airstream played an essential role in this heavy orographic rainfall case. It is worthwhile to learn how and in what manner the relation between instabilities and the initiation of orographic precipitation.

In considering the relevance of instabilities responsible for this heavy precipitation event, various types of instabilities, such as potential (convective) instability, conditional instability and conditional symmetric instability will be examined for this study.

2. METHODOLOGY

The use of moist instabilities on assessing precipitation events have been elaborately reviewed by Schultz and Schumacher (1999). In brief, the requirement condition for potential instability (PI) is that the equivalent potential temperature decreases with height, $\frac{\partial\theta_e}{\partial z} < 0$. Conditional instability (CI) can be diagnosed similarly to PI, except that θ_e is substituted by saturated equivalent potential temperature (θ_{es}). Conditional symmetric instability (CSI) exists when the environment lapse rate along a surface of constant absolute geostrophic momentum lies between the moist and dry adiabatic lapse rates.

Numerical simulations were performed with the grid spacing of 45/15/5 km horizontal resolutions by using the PSU/NCAR MM5 model (Dudhia 1993). The initial and boundary conditions for MAP IOP2B were initialized from the NCEP archived global analyses with 1^ox1^o resolution to the model grid point locations. A total of 45 layers in the vertical were used. The model contains 1-km resolution terrain data that was mapped to MM5. A 48-hours simulation was run from 00 UTC 19 to 00 UTC 21 September. The 45 km resolution domain covered Europe and the 5 km domain concentrated on northern Italy. The discussion in this study will focus on the 5 km horizontal resolution results.

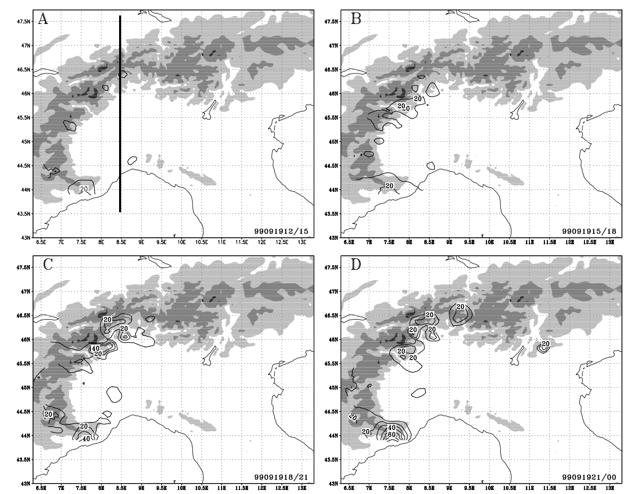

Figure 1: Analysis of the observed 3-h total accumulated rainfall (mm) over LMTA valid at (a) 11-15 UTC, (b) 15-18 UTC, (c) 18-21 UTC, and (d) 21-00 UTC, contour interval = 10 mm.

3. MESOSCALE ORGANIZATIONS

IOP2B was observed during 18-21 September 1999 when a frontal system in association with a deep trough propagated through the Alps. The time sequence of 3-h accumulated precipitation through early episodes of precipitation over LMTA is shown in Fig. 1. Light rain started at the slope of the Alps as the deep trough began moving across northern Italy. Precipitation was concentrated on southern slopes of the Alps and in the Lago Maggiore Target Area (LMTA) during the period of 12 UTC 19 to 12 UTC 20. The moist flow into the LMTA at low level was generally from the south throughout the period of precipitation.

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4. THE SIMULATION RESULTS

The spatial and temporal rainfall distributions were realistically simulated by the model. It appears that the rain was initiated over the windward slopes during the period of 12 UTC 19 to 00 UTC 20. Fig. 2 shows the areas conducive to PI and CI on a N-S cross section (see Fig. 1a). These results suggest that both PI and CI might co-existed upstream of southern Alpine slopes and LMTA. Examination of CSI indicates that it is unlikely the slantwise convection occurred under these conditions, because the release of PI or CI would dominate the release of CSI (e.g., Nicosia and Grumm 1999).

The parcel trajectory analyses along a N-S cross section indicated that vertical motion below 1.5 km was very strong and varied significantly horizontally upstream of LMTA (Fig. 3). Above 1.5 km, however, the parcel trajectories clearly suggested that the layer-lifting initiated the convective clouds, which may have produced light rain over the southern Alpine slopes from 12Z September 19 to 00Z September 20. This implies that PI may play a significant role in initiating the convection. In addition, the simulated convective available potential energy (CAPE) was lower than 50 J/kg during that time, which downplayed the importance of CI in the initiation of the convection.

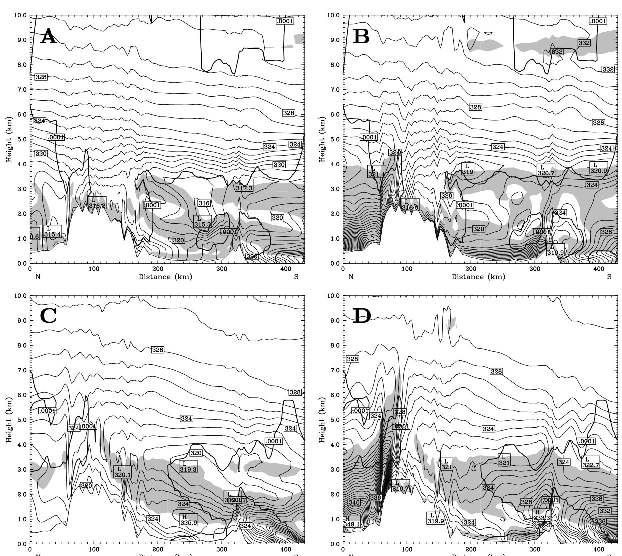

Figure 2: Potential instability fields (shaded) along cross section (see Fig. 1a) valid at (a) 12 UTC 19, (c) 00 UTC 20, and conditional instability (shaded) valid at (b) 12 UTC 19, (d) 00 UTC 20. The cloud regions are denoted by heavy lines for $q_v > 0.0001$ g kg^{-1}.

5. CONCLUSIONS

In this study we have simulated and analyzed the heavy orographic rainfall that developed during MAP IOP2B, and hoped to uncover the possible initiation mechanism for the convection. The model performed adequately in reproducing the orographic precipitation. The impinging moist low-level jet was not substantially blocked by barriers but flowed over the Alps. The simulation results suggest that the areas conducive to PI and CI are similar when the impinging airstream is near saturation.

The parcel trajectories reveal that ascent is very strong near the surface, which could be induced by the convergence in the concave region. The parcel trajectories suggest that layer lifting could be responsible for the initiation of deep, moist convection. In addition, CAPE is rarely correlated with heaviest precipitation, based on previous studies. This also implies that CI might not play an essential role in the initiation of the convection. The conditional symmetric instability may not be a necessary condition for initiating the deep convection, especially when gravitational instability dominated.

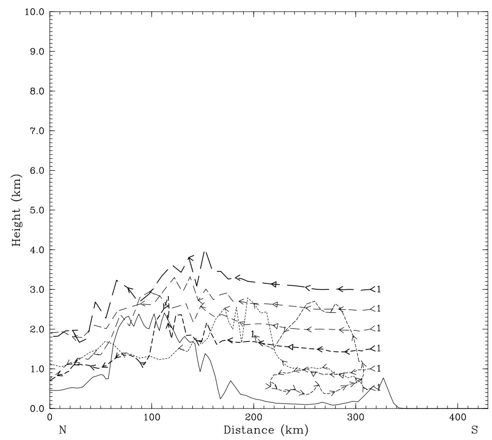

Figure 3: Parcel trajectories along cross section (see Fig. 1a), starting from 0.5 km to 3 km, with 0.5 km interval.

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