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OBSERVATIONS AND MODELING OF THE MISTRAL WIND

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1. INTRODUCTION

The term Mistral refers to a violent wind that develops along the Rhône valley and influences the eastern Mediterranean coast of France (Fig 1). During the SOP period (9/15-11/15, 1999) of the MAP (Mesoscale Alpine Program), two Mistral events were observed. The first event occurred on 1 October (OCT01), associated with the passage of a shortwave trough in the Alpine region. The second event occurred on 6 November (NOV06), associated with the developemt of an intense north Atlantic short wave trough over the western Alps region. The MAP project was reviewed by Bougeault et al (2001).

2. OBSERVATIONS

Two aircraft, the NCAR Electra and NOAA P-3, flew a stack pattern cutting through the forecasted shear-line downstream of the French Alps (see Fig 1 for the flight track and terrain). Besides in-situ observations, Electra down-looking lidar (SABL) and P-3 belly radar provided strong returns from aerosols and ocean waves. Six dropsondes were dropped from the Electra along its first leg. Rapidscans from the Meteosat-6 standby satellite over the Alpine region had been activated by EUMETSAT. Snapshots of the whole Alpine area were taken every 5 minutes over a period of 24 hours for every IOP. Further information regarding the observation tools and data analysis algorithms can be found in Jiang et al (2002).

3. MESOSCALE MODELING

The atmospheric component of the Navy's Coupled Ocean-Atmospheric Mesoscale Prediction System (COAMPS) (Hodur 1997) was used to simulate the two mistral events. The computational domain for the present study was configured with four horizontally nested grids of 73×61, 97×97, 133×133, and 235×235 points. The corresponding horizontal spatial resolutions (Δx) are 36 km, 18 km, 6 km, and 2 km, respectively. The topographic data was taken from the U.S. Defense Mapping Agency's 100-m resolution dataset. The model domains for the third ($\Delta x = 6km$) and fourth meshes ($\Delta x = 2km$) are shown in Fig 1.

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4. MASSIF CENTRALE CLEARING LINE

Based on METEOSAT image analysis, a persistent and a well defined clearing line (MCCL) can be drawn along the lee edge of the Massif Central which was coincident for the two mistral events (Fig. 2). This clearing line (MCCL) was captured by the COAMPS model as well (not shown). Trajectory and vertical section analysis of COAMPS simulations indicated that the MCCL marked the beginning of the mistral wind acceleration. The MCCL sits over the lee-slope of Massif Centrale and dozens of kilometers away from the coastline. Hovmuller analysis shows that while some light high clouds advected through the region, the low cloud edge was persistent and almost stationary.

5. THE MISTRAL BOUNDARIES

COAMPS simulations indicated that during both mistral events, gravity wave breaking over the Mont Lozére defined the western boundary of the mistral flow, and separated the mistral from the Tramontane. The banner clouds may appear over the wake region (Fig. 3) associated with turbulent mixing of moisture from sea surface. This interpretation was consistent with the persistent cloud filaments identified during both mistral events. To the east, the mistral was bounded by a shear line, MESL (Mistral Eastern Shear Line) The existence of MESL was verified by aircraft in-situ measurement, dropsonde data (Fig 4), and Rapidscan images. Our high resolution simulations indicated that at least two mechanisms contributed to the formation of the shear-line and therefore, the primary PV banner. One mechanism is multiple gravity wave breaking as the flow ascended the complex terrain of the French Dauphene or Alpes De Provence. The other is merger of two different airmasses as proposed by Schär and Smith

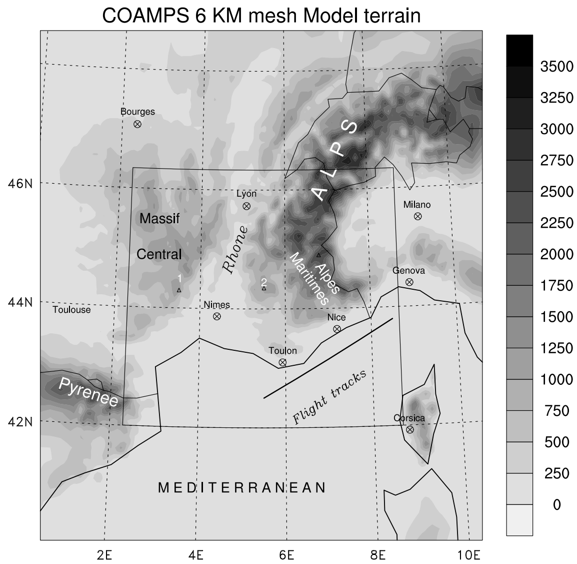

Figure 1: COAMPS 6km and 2km mesh computational domain terrain field and geographical locations of interest. Research aircraft flight track is marked.

(1993).

6. CONCLUSIONS

In the literature, the mistral has been often referred to as a "gap wind", a "fall wind", or a wind developed down the Rhône valley. This study suggested that the mistral wind can be partly described by the above terms, but none of them accurately capture the full range of mistral dynamics. For example, for the October 1 case, a large portion of the mistral flow actually ascends and passes over the Massif Central, and the term "fall wind" is more accurate in that sense. When the term "gap wind" is used, the channeling effect is emphasized. Our study implies that the mistral is deep enough to override some of the terrain and wide enough for the Coriolis force to be important. Flow turning into Rhône valley may be largely under the influence of Coriolis force. Therefore, to some degree, the term "gap wind" may be misleading considering it is often used to refer flow forced into a channel by pressure gradient force. Nevertheless, the blocking near Lyon was important for both mistral events. For low level air,

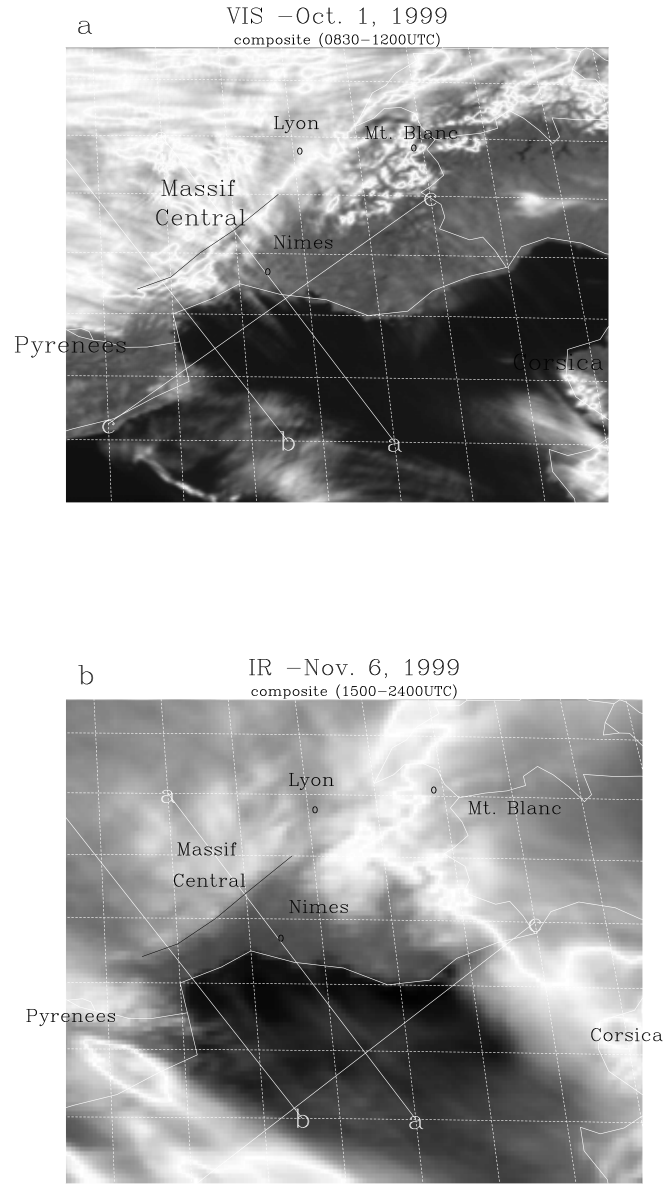

Figure 2: Composite images for a) 0830-1200UTC, October 1, 1999. b) 1500-2400 UTC, November, 6. The MCCL is indicated by a thin solid line and three white lines, aa, bb, cc are marked for Hovmüller diagrams.

blocking created a cold air pool near Lyon. Cold air leaked into the Rhône valley and joined the mistral. For air at a higher level, blocking built up high pressure around Lyon. The perturbation pressure gradient may cancel the large scale pressure gradient and allow air to turn under the influence of the rotation of the earth.

We found that gravity wave breaking over the Mont Lozére defined the western boundary of the mistral flow, and separated the mistral from the Tramontane. The banner clouds (MLBC) may appear over the wake region associated with turbulent mixing of moisture from sea surface. To the east of the mistral wind, a well defined shearline separated the strong mistral flow from relatively calm wake flow.

6. ACKNOWLEDGMENTS

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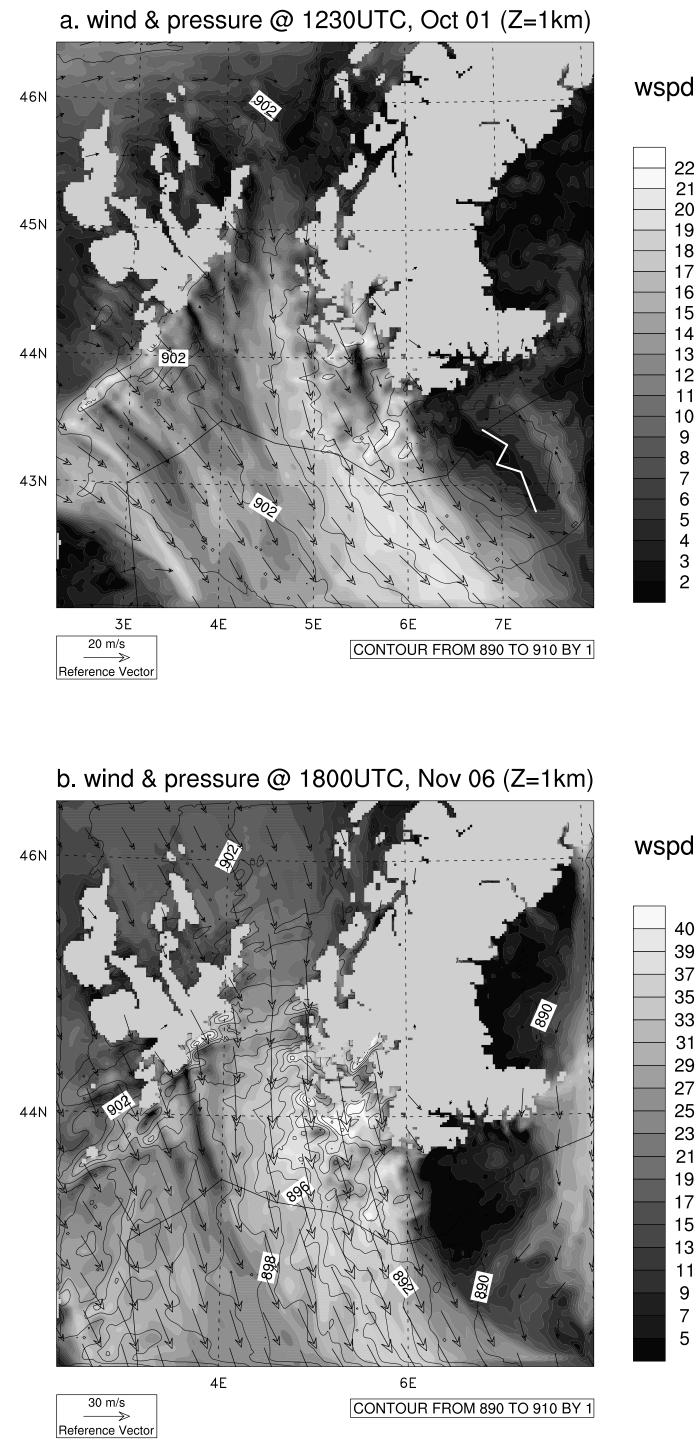

Figure 3: Snapshots of wind and pressure at Z=1km from COAMPS simulations. Pressure is contoured and wind-speed is in gray scale. Arrows are wind vectors. a) 1230UTC, October 1. The white line indicates the MESL detected by NOAA P-3 Belly Radar (see text); b) 1800UTC November 6.

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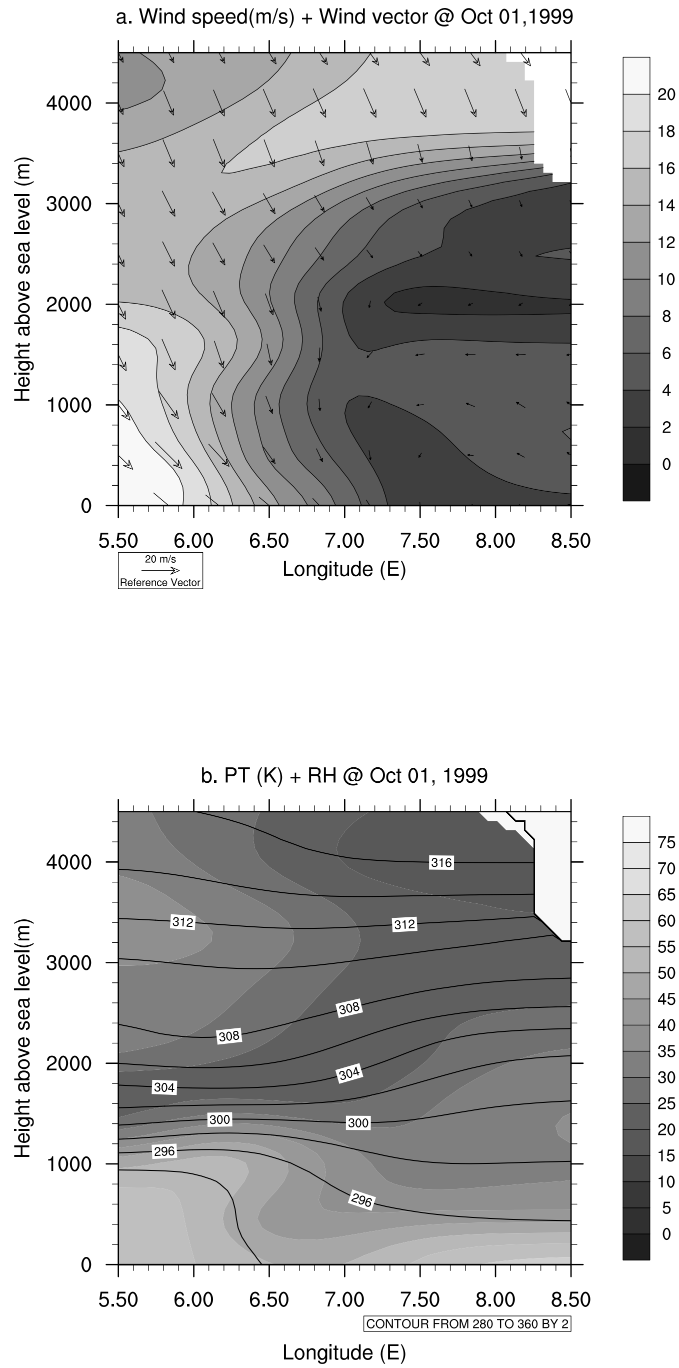

Figure 4: The vertical section along the flight track (see Fig 1) for the first mistral derived from objective analysis of dropsonde data. a) horizontal wind vector and wind-speed (m/s, in gray scale); b) potential temperature is contoured and relative humidity is in gray scale.