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MULTI-SCALE FLOW INTERACTIONS IN COMPLEX TERRAIN

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1. INTRODUCTION

In Northern New Mexico, the Rio Grande basin is an area where meteorological influences can combine with anthropogenic and natural sources to create poor air quality. As development and population increases in this region, the potential for increased air quality problems exist. North of Santa Fe, the Espanola basin is a relatively wide and flat section of the Rio Grande basin, just upstream of the steep, narrow White Rock Canyon (Figure 1). The Pajarito Plateau is located on the eastern flank of the Jemez Mountains that manifest the west side of the Rio Grande Valley, where the river runs roughly north-northeast to south-southwest through White Rock Canyon.

In general, atmospheric observations are limited in this area and little is known of the flows and vertical transport and mixing that exist under stable atmospheric conditions with the potential to affect the air quality. However, on the Pajarito Plateau, a network of surface meteorological stations has been routinely maintained by Los Alamos National Laboratory (Baars, et al., 1998). This network includes five instrumented towers, within an approximately 10 km by 15 km area. The towers stand from 23 m to 92 m tall, with multiple wind measurement heights. Investigation of the station records indicates that the wind fields can be quite complicated and may be the result of interactions of thermally and/or dynamically driven flows of many scales (Bowen, 1990 and Bowen, et al., 2000).

Slope flows are often found on the plateau during the morning and evening transition times, but it is not unusual to find wind directions that are inconsistent with slope flows at some or all of the stations. It has been speculated that valley circulations, as well as synoptically driven winds, interact with the slope flows, but the mesonet measurements alone, with no measurements in the remainder of the valley, were not sufficient to investigate this hypothesis thoroughly.

Thus, during October of 1995, supplemental meteorological instrumentation was placed in the Rio Grande basin to study the complex interaction of thermally and dynamically driven air flow in the area. A sodar was added near the 92 m tower and a radar wind profiler was placed in the Rio Grande Valley, near the river (where the elevation of the stream flow gage is 1673 m MSL) and just east of the plateau and north of White Rock Canyon. Measurements were also added at the top of Pajarito Mountain (at 3195 m MSL), west of the plateau, and across the valley, on top of Tesuque Peak in the Sangre de Cristo Mountains (at 3691 m MSL). Two surface stations were also added to the north-facing slopes of Pajarito Mountain.

This paper presents observations from October 1995 and results of numerical simulations of this area. This study addresses two science questions. 1) What is the nature of the interaction of terrain-induced flows with cold air in basins and with flows of different scales? and 2) How do large-scale weather patterns affect these interactions? By addressing these questions, we hope to better understand the vertical motions and transport processes in the basin.

2. THE OBSERVATIONS OF OCTOBER 1995

Examination of wind observations reveals that, on relatively synoptically quiet nights, the winds on the slopes of Pajarito Mountain tend to flow down the slope, through the night. Likewise, in Los Alamos Canyon, one of a number of narrow canyons that cut through the plateau from west to east, winds were consistently down valley, beginning just after sunset and lasting through the night.

The other stations on the plateau typically have downslope flows early in the evening, but these flows are not maintained until morning. Sometimes the winds on the plateau turn clockwise through the night. This is consistent with the conceptual interaction of slope and valley flows, where westerly slope flows, off of the Jemez mountains and the Pajarito Plateau, are found just after sunset. As the night progresses, the winds turn through northwesterly and northerly, as the slope flows give way to down valley flow in the Rio Grande basin. After sunrise, the flows on the plateau turn through northeasterly and then easterly, in the morning transition. However, on a significant number of nights, the wind directions at one or two of the mesonet towers can be very different from the other towers, indicating circulation on the plateau other than what would be

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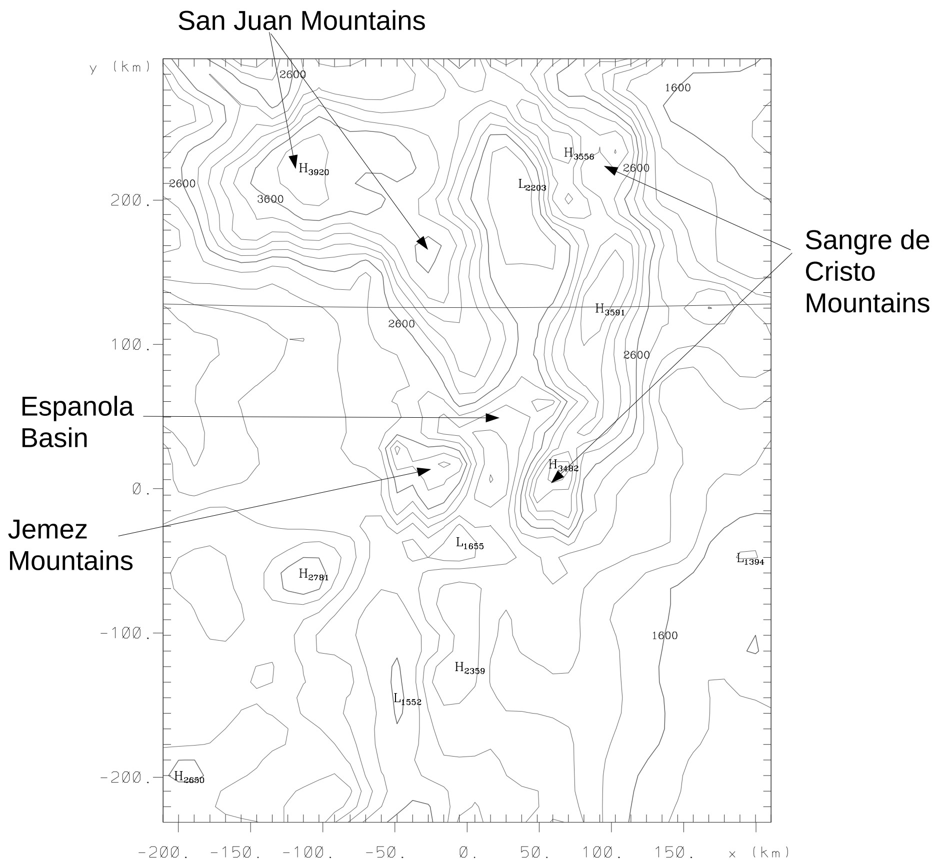

Figure 1. Topography of the upper Rio Grande basin, as represented on RAMS grid 1. Contour intervals are 200 m.

expected from the conceptual interaction of the slope and valley flows.

Data from the profiler, in the valley, indicate that the up valley flows from the previous day, can remain in the basin well into the night. At the lowest profiler measurement heights (about 100 m AGL), winds switch to down valley sometimes as late as a few hours before sunrise.

Wind directions at the stations on the two mountain peaks appear to align with the synoptic winds at night, but show some indications of influence by the local, thermally-driven flows during the day and during the transition times, especially on Pajarito Mountain.

3. MODEL SIMULATIONS

To add additional insight into the nature of the flows in this portion of the Rio Grande basin, we are simulating them with the Regional Atmospheric Modeling System (RAMS) model (Pielke, et al., 1992). Five nested grids are used, in order to simulate regional to local scale flows, with horizontal grid spacings from 10.8 km to 75 m. Vertical grid spacing near the surface is 60 m. The simulation begins at 0000 UTC 23 October 1995 and runs through 1800 UTC 25 October. Synoptic weather conditions during this time period were relatively undisturbed. At 1200 UTC on 23 October, an upper-level trough was to the east of the region and 500 mb winds decreased from 44 m/s to 15 m/s by 1200 UTC on the 24th. A weak short wave moved through the area as the upper-level flow became more zonal. At the surface, high pressure, centered to the northwest of the region, remained in place for these three days, weakening somewhat from 1028 mb to 1022 mb.

Preliminary results from the simulations indicate that the model tends to recreate the downslope flows early in the evening, but the down valley flow in the Los Alamos canyon is not as stable of a feature as found in the observations. Figure 2 shows the winds at 30 m above the surface on grid 3, roughly two hours after sunset. Early evening westerly flows extend down the slope and up the other side of the Rio Grande basin (Figure 3). With time, downslope flows also develop on the east side of the basin. The model runs agree with the profiler observations, where down valley winds in the Rio Grande basin develop later in the night.

The model captures the morning transition period relatively well, when easterly flow tends to dominate the stations on the plateau. However, the changing winds through the night were not as well simulated by RAMS.

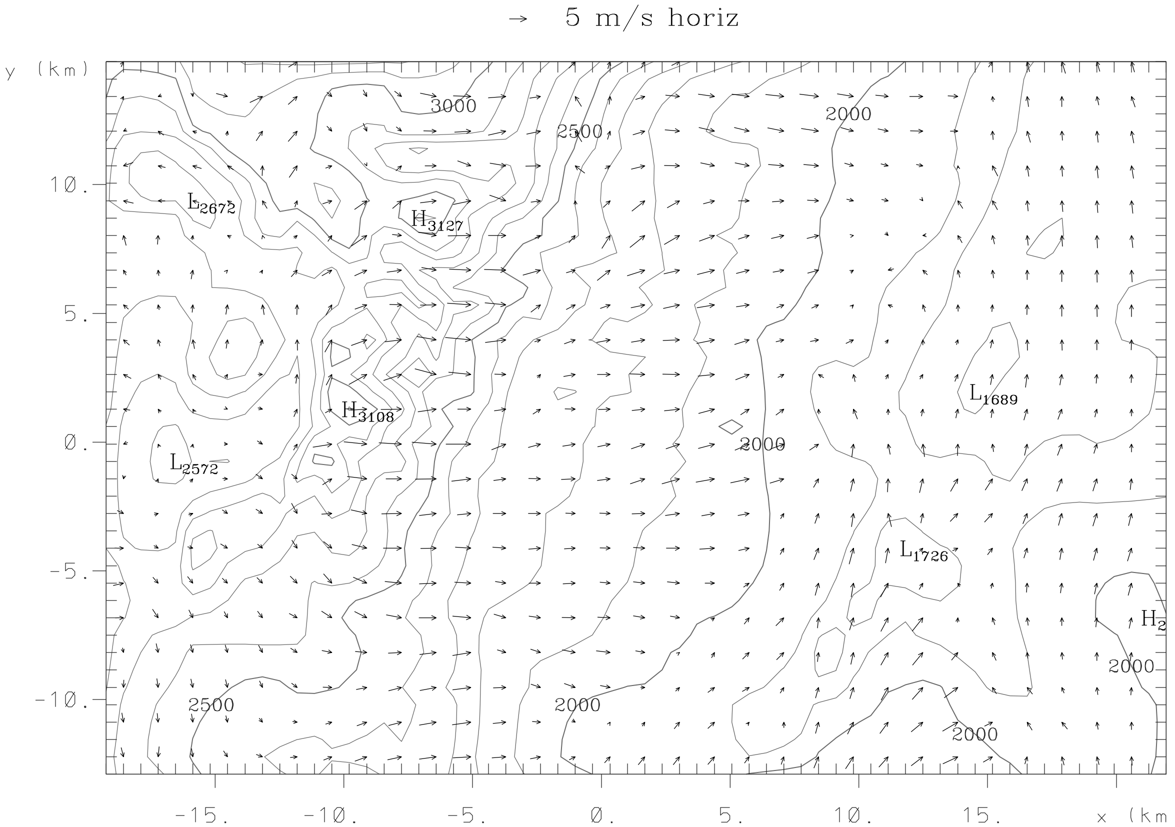

Figure 2. Horizontal winds and topography (contour interval is 100 m) on grid 3 of the RAMS simulation at 0200 UTC on 24 October 1995.

Gravity waves are found to influence the model vertical motions in the basin, especially above the tops of the Jemez and Sangre de Cristo Mountains (Figure 3). Model wind fields also indicate that the synoptic winds sometimes flow around the Jemez Mountains. This is particularly evident early in the simulation, when northwest flow diverts around the Jemez, resulting in lower wind speeds and easterly wind directions over parts of the plateau.

4. ACKNOWLEDGMENTS

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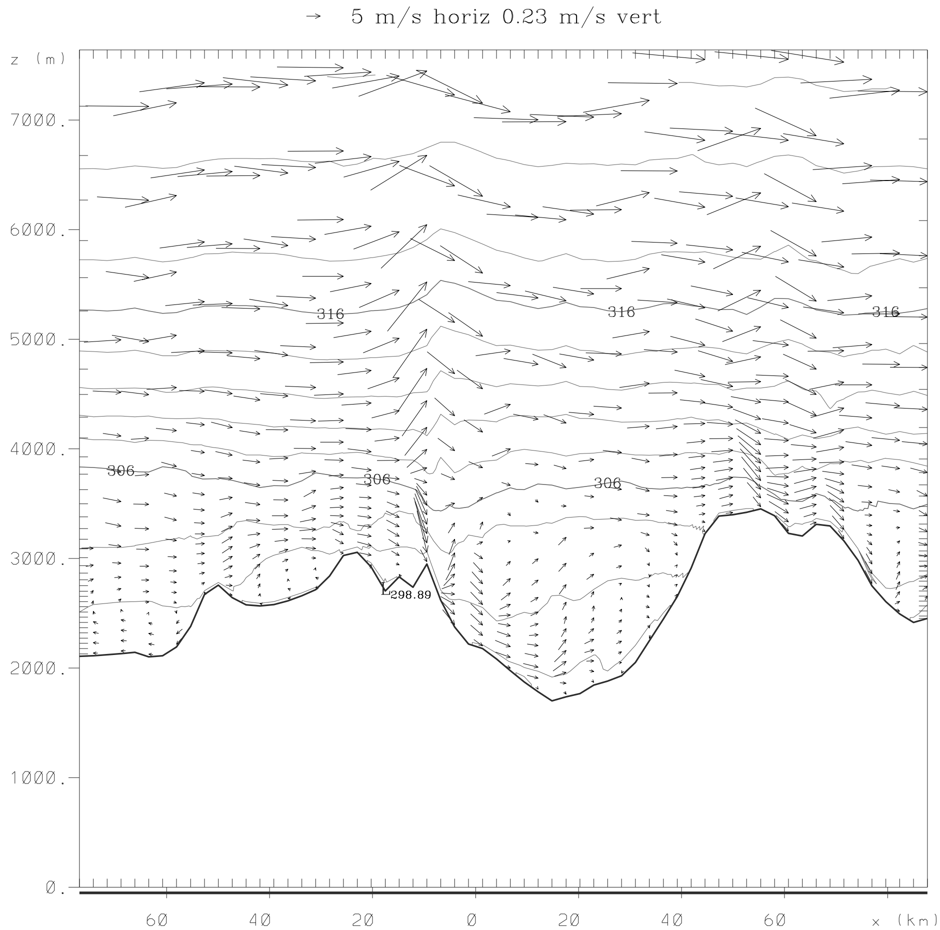

Figure 3. Horizontal and vertical winds and potential temperature (contour interval is 2 degrees K) on grid 2 of the RAMS simulation at 0200 UTC on 24 October 1995.