P1.8 NOCTURNAL BOUNDARY LAYER DYNAMICS IN THE SALT LAKE BASIN DURING VTMX

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1. INTRODUCTION

During October 2000, the Department of Energy Vertical Mixing and Transport Experiment (VTMX) field experiment was held in the Salt Lake City (SLC) Basin (not shown). The SLC Basin is flanked by the Oquirrh Mountains to the west, the Wasatch Mountains to the east and north, the lower altitude transverse range to the south, and has relative low point to the northwest due to the Salt Lake. An extensive instrument array was deployed in order to better understand turbulence processes in nocturnal stable boundary layer (NSBL) (Doran et al. 2002) in this Basin where dispersion and mixing processes are influenced by a multitude of physiographic characteristics.

Our aim herein is to identify and quantify two causes of NSBL intermittent turbulence, mountain induced gravity waves and instabilities associated with vertical wind shear. Toward this goal, observations from VTMX IOP-10, 25-26 October, are analyzed and compared to numerical simulations. Tendencies from the model momentum equations are analyzed as well to further elucidate the underlying dynamics in and near the NSBL.

2. OBSERVATIONS

During the night of IOP10, a shortwave 500 mb ridge was translating eastward over the SLC Basin. The NSBL formed in the lowest 20-30m within a few hours after sunset, while just above 7-8 ms^{-1} southwesterly flow was observed across the Basin. This flow slowly increased during the night. The southwesterly flow over the Transverse Range on the south side of the Basin is strong enough to excite low amplitude mountain waves.

Figure 1 shows a time series of standard deviation of vertical velocity (σ_w) calculated from 30 minute averages of 10 Hz sonic anemometer data. The data was taken at 9.1 m at PNNL's Kennecott Slope Site, located in the southwestern part of the SLC Basin, about 12 km north of the Transverse Range (Doran et al. 2002). Obvious from the figure are several peaks in the generally increasing trend, consistent with the increasing flow over the NSBL with time. We interpret these spikes in σ_w relative to the trend, as intermittent external or internal sources of turbulence imposed upon the NSBL. For lack of a better term, we refer to these events as Apparent Turbulent Bursts (ATB). At the onset of the ATBs, σ_w increases by approximately 0.3 ms^{-1} from the minimum, and ~ 0.2 $m\ s^{-1}$ from the minimum trend line - both significant increases. Time-height plots of potential temperature derived from tethersonde measurements at this site also indicate evidence of ATBs at coincident times (not shown).

3. NUMERICAL MODELING

Model simulations are used as an aid to determine the four-dimensional evolution of these events, and to further explore the temporally and spatially complex interaction between the NSBL and overlying basin atmosphere. The mesoscale model used was the Regional Atmospheric Modeling System, (RAMS, Pielke et al. 1992).

NCEP Eta analyses were used for initialization at 1200 UTC on 25 October. Grid 1 (24 km grid spacing) encompasses the western U.S. to capture details of the synoptic evolution while the finest Grid 4 (500 m spacing) captures the immediate vicinity of the Salt Lake City Basin (where the VTMX observations were taken) as well as portions of the surrounding mountains. Vertical grid spacing on the fine grid was a constant 15 m to 360 m AGL with stretching to a maximum of 400 m above. The model was run for 24 hours, with the finest grid active during the entire night. Data from the model momentum equations were written out at every fine grid timestep (approximately 1 Hz) at 100 locations coinciding with the observational instrument array.

Shown in Figure 2 is σ_w derived from model vertical velocities using the same averaging time and at the same location as the observed values in Fig. 1. The model represents the spikes centered around 0530 and 0900 UTC quite well, but not the increasing trend seen in the observations. Although the model appears to capture the ATBs, note that the magnitude of σ_w is about an order of magnitude greater in the observations than the model. However, the 30-minute average values of vertical velocity itself *are* similar between the model and observations. We interpret this to indicate the model's failure to numerically resolve natural atmospheric processes that increase σ_w. Subgrid turbulence in this configuration of RAMS was parameterized using modified K-theory in the horizontal and a 2.5 level scheme in the vertical.

Figure 3 shows a north-south section of simulated potential temperature (θ) at 0830 UTC through the same model point as Fig. 2. The Transverse Range is seen to the south while the drop towards the Salt Lake is apparent to the north. Between these two features, tightly

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packed isentropes in the NSBL are evident, with much less stable air in the southwesterlies above. Low-amplitude waves appear north of the Transverse Range with stronger waves near the northern end of the SLC Basin. A small region of overturning isentropes at about 300 m above the surface is obvious at y = -5866 km. This corresponds to the time and location of the larger σ_w spike seen in Fig. 2. Thus it appears that this ATB is associated with some form of instability downstream from a rather low-amplitude mountain wave. Overturning θ is seen over several hours in the 15-minute model output in the vicinity of the Kennecott Slope site. These features appear to form near the site, then propagate over the site, leading to the intermittent ATB behavior.

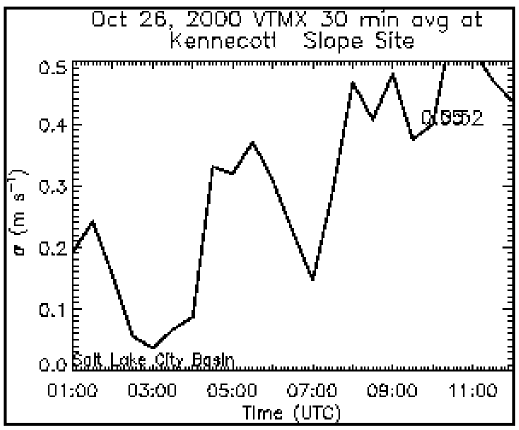

Figure 1. Vertical velocity standard deviation between 01 and 12 UTC derived from sonic anemometers at the Kennecott Slope Site during IOP-10.

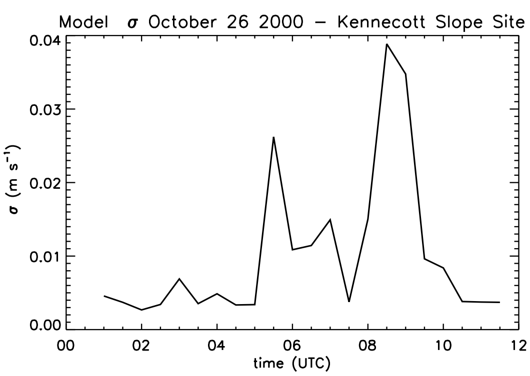

Figure 2. As in Fig. 1 except for model data.

We further investigate the underlying dynamics in Figure 4, which show time series of the east-west (*u*) component of the wind as well as components of the model Reynold's-averaged momentum equations at 8 m over the period from 01 to 12 UTC. Prior to 05 UTC, *u* is balanced by the pressure gradient and diffusion, which is characteristic of katabatic flow in numerical models. This balance is disrupted with the onset the first ATB, when advection leads to a positive *u* tendency. The katabatic-flow-like force balance is partially re-established between 06 and 07 UTC. However, once again, and more completely, that balance is disrupted after 08 UTC with the onset of the second, stronger ATB, corresponding to convective instability seen in overturning θ lines in the model output. After this time, high frequency variation is seen in *u* and its tendencies. We interpret this as NSBL flow which has become turbulent on a scale large enough to be represented by the model and remains so for approximately two hours. After 10 UTC, the flow returns to a less turbulent state and has transitioned to a near balance between advection and diffusion.

The force balance for *v* before 05 UTC differs from *u* and is characterized by a balance between positive advection and pressure gradient and negative diffusion (not shown). This indicates that earlier, weaker mixing has possibly occurred and the total flow is not purely katabatic (note that the downslope gradient at the Kennecott site is easterly so one would expect the katabatic forcing to be manifested in the u-component). Evidence for such mixing is seen in Fig. 4 between 01 and 02 UTC. Similar disruption of the force balance for *v*, as well as high frequency variability is seen in conjunction with the turbulent bursts.

4. SUMMARY AND FUTURE WORK

We have presented observations and a simulation of a apparent turbulent bursting event during VTMX IOP10. The timing of model σ_w qualitatively agrees with observations, though observed σ_w was an order of magnitude stronger than model values. The modeled ATB occurs in a region of overturning θ associated with mountain waves excited by relatively low topography in southwesterly flow. This scenario differs from what may be anticipated based on SLC Basin orientation, e.g., mountain wave activity from the north-south oriented, Oquirrh Mountains in westerly flow aloft.

Efforts are currently underway to further understand the interaction between the low-amplitude mountain wave and the NSBL. Tendencies from the model momentum equations have been presented here to elucidate the underlying dynamics of this ATB. The more fundamental understanding possible with this type of analysis we expect will ultimately lead to improved parameterizations of the NSBL, which have historically performed poorly.

5. ACKNOWLEDGMENTS

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6. REFERENCES

Doran, J.C., J.D. Fast, and J. Horel: The VTMX 2000 Campaign, *Bull. Amer. Met. Soc.,* **83,** *to appear April.*

Pielke, R.A., and collaborators1992: A comprehensive meteorological modeling system - RAMS. *Meteor. Atmos. Phys.*, **49**, 69-91.

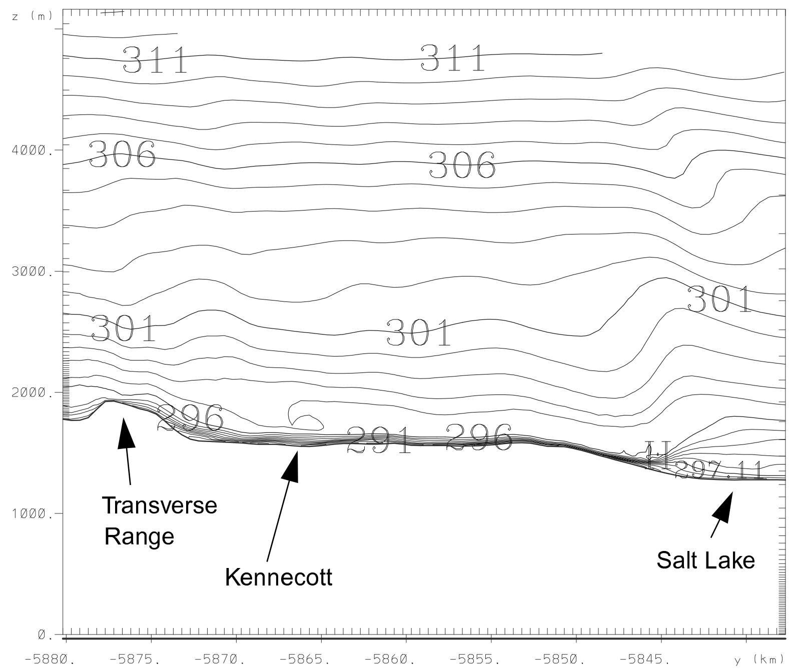

Figure 3. North-south section of simulated potential temperature (1K interval) at 0830 UTC through the Kennecott Slope Site.

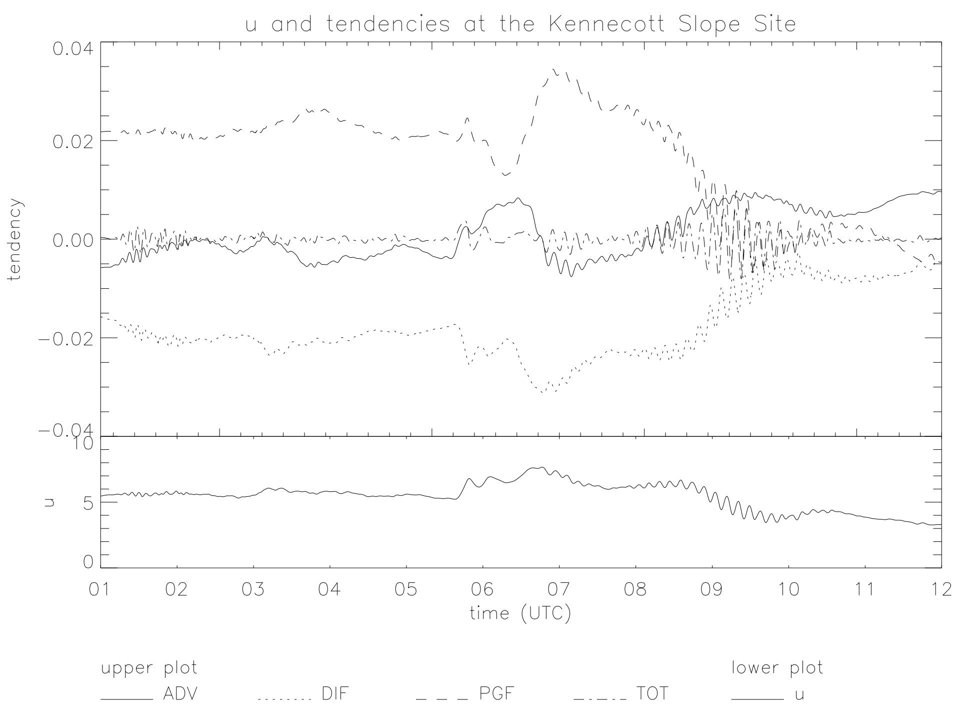

Figure 4. Time series of simulated a) u and b) v, flow (lower sub-panel) and tendencies from the model momentum equations (top sub-panel) between 00 and 12 UTC during IOP-10 at 7.5 m AGL at the Kennecott Slope Site.