Improving Downslope Wind Forecasts in a Mountainous Region: Assessing Uncertainty in High-Resolution Modeling over the Las Vegas Forecast Zone

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Goals

•Investigate structure and evolution of ABL over complex terrain through measurements and modeling.

•Evaluate performance of WRF parameterizations for the ABL over complex topography during both active and quiescent conditions.

Motivation

Understanding the evolution and structure of the atmospheric boundary layer (ABL) poses a significant challenge for existing capabilities to predict its structure and its effect on dispersion of Chemical, Biological, Radiological, and Nuclear (CBRN) materials as well as severe weather conditions. Predictions are limited by model grids, parameterizations of the sub-grid processes, and energy balance as well as the complexity of terrain and land forms. This study is a basic research effort to address the fundamental understanding of the ABL through measurements, modeling, and theoretical analyses. The research focuses on the evaluating of parameterizations for the ABL in operational forecast models such as the Weather Research and Forecasting (WRF) model. Two cases will be discussed which cover a range of atmospheric stabilities. Stable and very stable cases are represented in valley drainage flow cases in the Owens Valley, CA. Downslope wind events in Las Vegas represent more unstable cases.

Las Vegas - Downslope wind events

Downslope wind events occur seasonally across the Sierra Nevada Range and remain difficult to forecast timing, duration, and intensity. Two events were studied in an effort to develop a more suitable model configuration of the current operational mesoscale model used by the Las Vegas NWS Forecast Office.

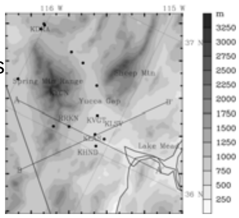

Figure 1: Nested 1 km grid showing Las Vegas area topography, stations for model verification, and cross-sections used to analyze model results.

All Stations (20)				
	Temperature		Wind Speed	
Model Run ID	Mean Bias	RMSE	Mean Bias	RMSE
YSU 60 levels	-2.24	2.51	3.83	5.70
QSNE 61 levels	-2.44	2.65	0.48	4.21
YSU 61 levels	-2.18	2.46	1.47	4.12
MYJ 61 levels	-2.57	2.83	0.63	4.09
YSU 137 levels	0.09	1.87	3.63	5.70
Valley Stations (16)				
	Temperature		Wind Speed	
Model Run ID	Mean Bias	RMSE	Mean Bias	RMSE
YSU 60 levels	-2.17	2.46	2.74	4.73
QSNE 61 levels	-2.44	2.65	-0.27	4.14
YSU 61 levels	-2.09	2.37	0.68	3.98
MYJ 61 levels	-2.57	2.83	-0.05	4.05
YSU 137 levels	0.29	1.89	2.71	4.76
Mountain Stations (4)				
	Temperature		Wind Speed	
Model Run ID	Mean Bias	RMSE	Mean Bias	RMSE
YSU 60 levels	-2.50	2.70	7.92	9.33
QSNE 61 levels	-2.46	2.66	3.31	5.97
YSU 61 levels	-2.56	2.80	4.44	6.11
MYJ 61 levels	-2.59	2.82	3.20	5.79
YSU 137 levels	-0.73	1.79	7.11	9.22

Table 1: Statistics calculated from WRF output and station observations show a dependence on ABL scheme and vertical resolution. Non-local closure (YSU) produced most accurate forecast with high resolution configuration (YSU61, 20 levels in lowest 2 km), especially at valley stations. However, further model validation is required over a range of atmospheric stabilities.

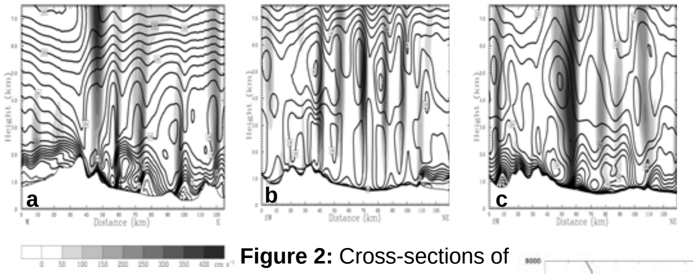

Figure 2: Cross-sections of vertical velocity (shaded) and horizontal wind (contours) valid (a) 12 UTC 15 April 2008, (b) 00 UTC and (c) 12 UTC 4 October 2009 reveal gravity waves trapped below ABL temperature inversion cause surface gustiness and lee rotors (a).

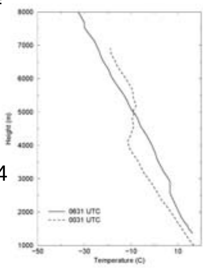

Figure 3: AMDAR temperature profiles from KLAS 4 October 2009 suggest that inversion heights tend to dictate event intensity in addition to low level mean winds and upstream atmospheric stability.

Owens Valley - Drainage flows

Stable atmospheric conditions were observed in Owens Valley, CA during Enhanced Observing Periods (EOPs) of the Terrain Induced Rotor Experiment (T-REX) in 2006. This discussion will focus on the ability of WRF to simulate drainage valley and slope flows and the evolution of the nocturnal boundary layer within the valley.

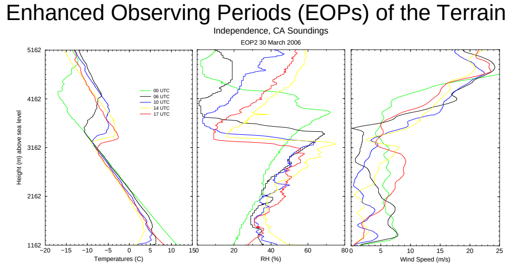

Figure 4: Temperature (°C), RH(%), and wind speed (m/s) profiles, from Independence, CA valid 30 March 2006, have been used as indicators of ABL structure (i.e. surface and residual layers) and evolution.

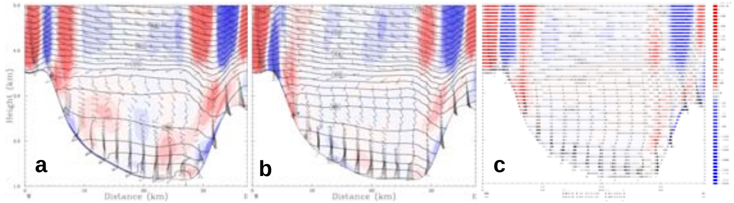

Figure 5: Cross-sections of model horizontal wind (barbs), virtual potential temperature (contours) and vertical velocity (shaded) across Owens Valley valid (a) 06 UTC, (b) 10 UTC, (c) 14 UTC 30 March 2006 show layered flows following the ABL structure of indicators in Fig. 4. Slope and valley winds are found within the surface layer, while channeled flow dominates the residual layer, and westerly synoptic flow is in the free atmosphere.

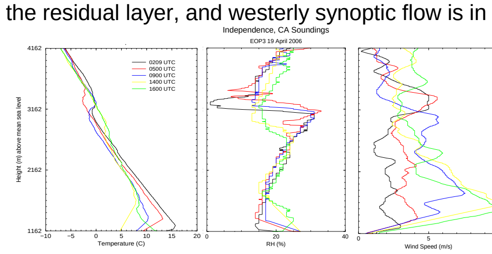

Figure 6: As in Fig. 4, valid 19 April 2006. Profiles display shallower and more stable ABL has formed.

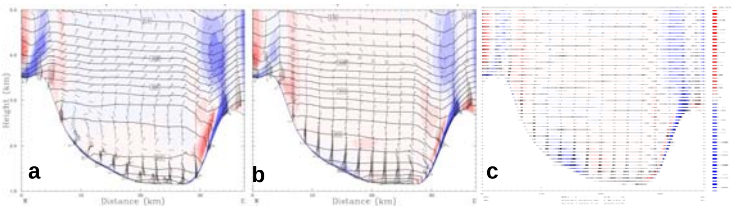

Figure 7: Same as Fig. 5. Valid (a) 06 UTC, (b) 09 UTC, and (c) 14 UTC 19 April 2006. Model has difficulty with very stable ABL, surface flow diverges from observations.

Conclusions

Measurements show ABL structure and evolution well, but few sites are located over terrain making it difficult to verify model results. Model resolution, especially in the vertical, is essential to modeling the ABL, however, terrain relief is a limiting factor. Model parameterizations appear reasonable over terrain, generating slope flows during stable conditions without explicitly resolving them. Current surface layer parameterizations appear unable to replicate very stable ABL. More than just a simple microphysics scheme is needed even in relatively dry environment. Further model evaluations of stable ABL conditions are necessary.

Acknowledgements

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