Boundary layer behavior in California's Owens Valley using the WRF-ARW model during Apr 28-30 of T-REX 2006

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1. Introduction

The Spring 2006 Terrain-induced Rotor Experiment (T-REX) provided atmospheric researchers with abundant observational data characterizing boundary layer structure and evolution in complex terrain regions. A secondary objective of the T-REX was to observe and study extended periods across California's Owens Valley during quiescent synoptic flow regimes.

The large volume of meteorological data obtained from the T-REX presented Army Research Laboratory (ARL) meteorologists with an opportunity to study conditions unique to nocturnal stable atmospheric boundary layers that develop over deep valleys. Goals of the current study are to examine: 1) nocturnal low-level jet formation and valley wind system evolution 2) surface heating/cooling evolution, including inversion layer variations 3) the two primary WRF-ARW planetary boundary layer (PBL) parameterizations at high spatial resolution.

The WRF-ARW model was run at high spatial/temporal resolutions to simulate boundary layer conditions associated with the quiescent Enhanced Observation Periods (EOP) 4 and 5 (2006 April 28-30). The interactions among inversion layer depths, near valley surface flows that intensified into nocturnal low level jets (LLJs), multi-layer wind structures above the valley, and synoptic forcing are examined using the model. Simulations using the local closure (Mellor-Yamada-Janjic) and non-local closure (Yonsei State University) WRF-ARW PBL parameterizations were executed for the cases studied.

2. ARL Modeling during T-REX 2006

Throughout the active phase of the 2006 T-REX (Mar-Apr), ARL (with support from the Army High Performance Computing Research Center) along with other various modeling groups (Naval Research Laboratory, NOAA Global Systems Division, NWS Las Vegas) generated daily mesoscale model forecasts that were placed on the EOL website (http://catalog.eol.ucar.edu/cgi-bin/trex/model/index). ARL executed the WRF-ARW in a triple nest configuration (18 km/6 km/2 km) with 40 vertical levels (to 10 mb), using NCEP GFS initial and lateral boundary conditions, and generating 48 h forecasts based daily at 1200 UTC. Subsequent to T-REX 2006, ARL than reran each case in a double nest (two-way feedback) configuration (3 km/1 km) from NCEP NAM 12 km initial and lateral boundary conditions. Again, 40 vertical levels were applied, but this time to only a top of 50 mb.

Particular focus was paid to the simulations generated during T-REX EOPs, since some of the ARL effort was supported by an ARL and Defense Threat Reduction Agency (DTRA) stable boundary layer program. Numerous statistics and graphical products have been generated by ARL for both the 2 km (and the subsequent 1 km) WRF-ARW results, and are in the process of being compiled into a publication. The EOPs 4 and 5 were selected for the current case study, due to the high fidelity 1 km results obtained previously, and due to the strong nocturnal downvalley flow patterns observed by mesonet, soundings, and profilers in the Owens Valley during that period. An example of previous 1 km surface meteorological results are shown in Figure 1, compared to Desert Research Institute mesonet observations.

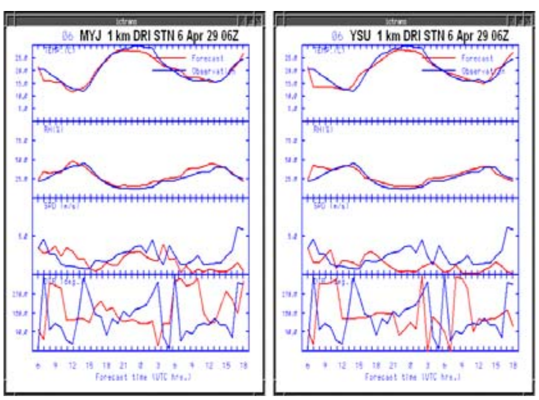

Figure 1. ARL WRF-ARW surface results compared to DRI mesonet observation site 6.

3. Latest WRF-ARW Model Configuration for EOP 4/5 Case Study

In order to better simulate the significant diurnal flow features in the Owens Valley throughout EOPs 4-5, the WRF-ARW was run in a triple (one-way) nesting configuration of 4 km, 1 km, and 250 m grid spacing. Horizontal dimensions of 121x121 were used for each nest (Figure 2). In the vertical dimension, 50 levels and a top of 50 mb were used. In order to simulate the entire EOP 4 and 5 periods, a 51h forecast period was selected spanning 1800 UTC Apr 28- 2100 UTC Apr 30. No data assimilation was used, and NCEP NAM 12 km gridded fields provided the initial and lateral boundary conditions for the outer nest. Additionally, two simulations were run to compare differences in PBL schemes- one using Yonsei State University (YSU) and the other Mellor-Yamada-Janjic (MYJ). The other namelist physics remained fixed between the simulations, and are listed in Table 1.

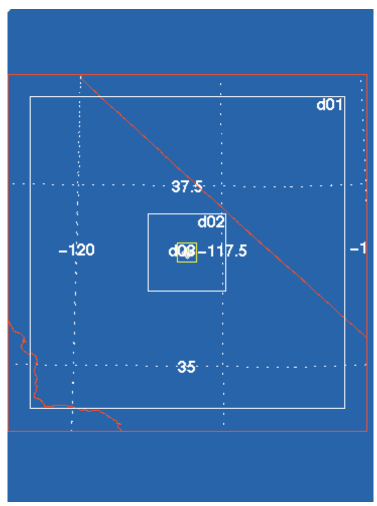

Figure 2. ARL WRF-ARW nest configuration for EOP 4/5 high resolution model runs.

4. Discussion

ARL has completed a pair of high resolution simulations of the period spanning EOPs 4 and 5 of T-REX 2006, encompassing 51 h between 1800 UTC Apr 28- 2100 UTC Apr 30. Initial ARL concentration has been on analysis of results

WRF-ARW Namelist Options
Lin microphysics
No cumulus parameterization
Dudhia short wave radiation
RRTM long wave radiation
NOAH land surface model
conventional terrain averaging in WRFSI
Runge-Kutte 3rd order dynamics
Diff_opt=1 (2nd order diffusion on coordinate surfaces)
Km_opt=4 (horizontal Smagorinsky 1st order closure)
5th order horizontal advection of momentum & scalars
3rd order vertical advection of momentum and scalars

Table 1. Options selected in namelist for ARL's WRF-ARW high resolution EOP 4/5 model run.

from the 1 km (second) nest, although some attention has also been paid to both the outer (4 km) and inner (250 m) nest outputs. The simulations differed only in that one used the YSU PBL namelist option, while the other the MYJ.

Using a variety of free public-domain graphical display packages, plots for both simulations and all WRF-ARW nests continue to be generated, examining features both at the surface and aloft. These include detailed cross sectional analyses, both zonal and meridional. In addition, numerous special observations collected during the 2006 T-REX (surface mesonet, wind profiler, soundings, etc) are being collected and processed for use in verifying the results of the model simulations and for producing comparisons.

Most of the observational comparisons for the EOP 4/5 high resolution runs are still in the process of being generated at ARL, and are not shown in this paper. Initial subjective findings do seem to show that both model PBL options (YSU and MYJ) generally reproduced, although with differences, the diurnal flow evolution of EOPs 4 and 5, particularly the downvalley flows and low-level jet structure (20-30 knots) observed at night and in the early morning hours just above the valley floor (Figures 3-8). Continued focus will be on the differences in downvalley flow evolution between the YSU and MYJ runs (particularly in the early evening transition hours) and on the general overall structure of the wind and thermodynamic fields both near and well above the Owens Valley floor.

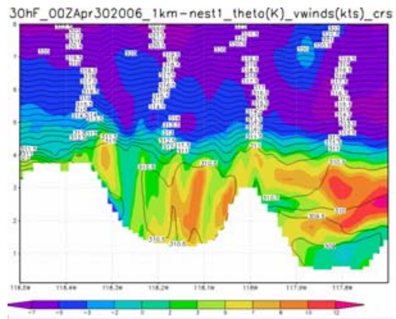

Figure 3. Zonal cross section across 36.81 deg N, valid 2006 Apr 30 00 UTC after 30 h, with blue/purple representing northerly v-wind component (WRF-ARW 1 km nest 2- MYJ option)

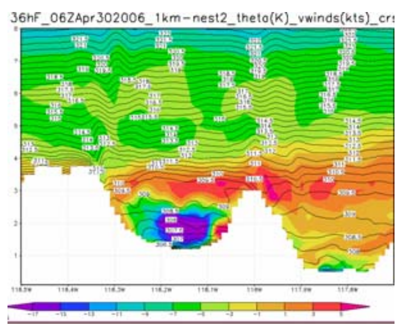

Figure 4. Same as Fig 3, but valid 2006 Apr 30 06 UTC after 36 h.

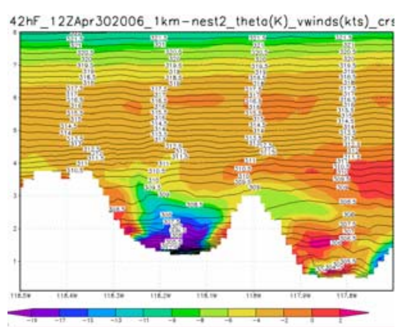

Figure 5. Same as Fig 3, but valid 2006 Apr 30 12 UTC after 42 h.

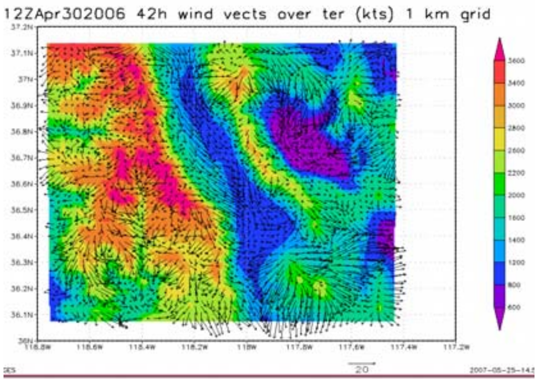

Figure 6 . Surface 10 magl wind vectors (kts) plotted over shaded terrain (m), valid 2006 Apr 30 12 UTC after 42 h (WRF-ARW 1 km nest 2- MYJ option).

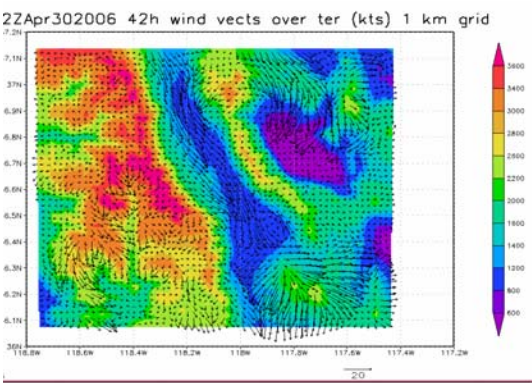

Figure 7. Same as Fig 6, but for YSU.

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5. Acknowledgements

The authors would like to thank both the Army's Major Shared Resource Center and the Army High Performance Computing Research Center (including Network Computing Services, Inc) for the use of their high performance computers. They would also like to thank Dr. Jim Doyle (NRL), Dr. Tina-Katopodes-Chow (U. California-Berkeley), Dr. Juerg Schmidli and Dr. Jimy Dudhia (NCAR), and Dr. Steve Koch (NOAA GSD) for their useful suggestions and ideas.

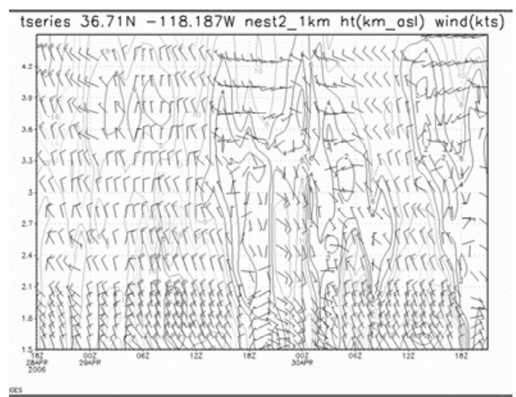

Figure 8. Time/height series of winds (kts) near Independence , CA (WRF-ARW 1km nest 2- MYJ option) with height axis in km asl.