T-REX EOPs: MESOSCALE VALLEY CIRCULATIONS AND SENSITIVITY TO SYNOPTIC CONDITIONS

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Abstract: This paper analyzes the nighttime flow dynamics and heat budget in a deep valley, California's Owens Valley, for varying synoptic conditions. Measurements from the Terrain-Induced Rotor Experiment (T-REX) reveal a pronounced valley-wind system with often non-classical flow structure. Examples include daytime down-valley winds despite clear skies and strong radiative heating, nighttime up-valley winds, or simultaneous down- and up-valley winds at different heights within the valley. Our analysis is based on the T-REX measurement data and the output of high-resolution numerical simulations using the Advanced Regional Prediction System (ARPS). Using horizontal grid resolutions of 1 km and 350 m, the model reproduces the observed event-to-event variability very well. This includes a layered structure with simultaneous down- and up-valley winds during Enhanced Observing Periods (EOPs) 1 and 2, a moderate down-valley flow during EOP 3, and strong down-valley winds during EOP 4 and 5. The analysis shows that the resulting valley wind structure and evolution is due to a subtle interaction between thermally-induced local circulations and the larger-scale synoptic forcings.

Keywords: *ICAM, boundary layer, complex terrain, turbulence, thermally-driven flows, pressure-driven channeling*

1. INTRODUCTION

Valley and slope winds are an integral part of the mountain boundary layer. On the one hand, they may strongly modify the exchange fluxes between the land surface and the free atmosphere (Weigel et al., 2007). On the other hand, they may change the turbulence structure itself and, for example, suppress the growth of the mixed layer over the valley floor (Weigel et al., 2006). They also have a large influence on the nocturnal boundary layer over complex terrain (e.g. Monti et al., 2002). While the canonical properties of these flows are by now well established (Whiteman, 1990), their interactions with the larger-scale synoptic forcings are less well understood.

Observations of the Owens Valley wind system during the recent Terrain-induced Rotors Experiment (T-REX, held 1 March - 30 April 2006, near Independence in California) revealed large differences in the valley flow structure between the 5 Enhanced Observing Periods (EOPs) despite relatively similar synoptic settings. The aim of this contribution is to use high-resolution numerical simulations of the flow in Owens Valley to investigate the mechanisms leading to the significant event-to-event variability.

2. SIMULATION SETUP

ARPS simulations were carried out for 42 hours beginning at 12 UTC on the day of the EOP. This resulted in a 11 h spin-up time. Initial and boundary conditions required to drive the 9 km run were derived from NAM analyses obtained through NOMADS. The 9 km run was then subsequently nested down to 3 km, 1 km and 350 m. Further details of the simulation setup including the land surface initialization can be found in Schmidli et al. (2007).

3. RESULTS

Table 1 summarizes some key characteristics of the EOPs including observed valley flow structure, upper-level winds, near-surface turbulence and radiation. Based on the valley flow structure, the EOPs can be devided into three distinct groups. The first group, EOP 1 and 2, was characterized by up-valley flow in the valley atmosphere. EOP 2 was characterized by a three layer structure with the mid-level up-valley flow nested between the low-level katabatic down-valley flow and an upper-level north westerly flow. In EOP 1, the up-valley flow layer was deeper and stronger, and the katabatic down-valley flow was very weak, due to the more

Table 1: EOP summary. u_{55} denotes the wind speed and direction at 5.5 km MSL, from the Independence sounding (12-14 UTC); u_{10} is the 10 m wind speed, u_* is the 5 m friction velocity, Q_{net} is the net radiation, and H is the 5 m sensible heat flux at the southern NCAR ISFF flux tower. The values from ISFF south denote nighttime averages over the period 3-13 UTC. All values are in SI units.

EOP	Date	u_{55}	u_{10}	u_*	Q_{net}	H	Comments
1	22-23 Mar	12 @ 250	0.4	0.01	-66	-12.3	up-valley flow; srf: weak down-valley flow
2	29-30 Mar	20 @ 270	1.4	0.01	-71	-11.9	three layer structure
3	18-19 Apr	5 @ 340	0.3	0.00	-67	-4.2	most classical conditions
4	28-29 Apr	9 @ 315	2.5	0.09	-92	-39.4	moderate down-valley jet
5	29-30 Apr	10 @ 280	1.4	0.04	-88	-27.7	strong down-valley jet

southerly component of the large-scale flow. The second group contains just one member, EOP 3. EOP 3 was the case with the weakest upper-level winds (typically less than 5 m/s), and it thus was the most classical EOP with regard to the evolution of the nighttime down-valley flow. The third group, EOP 4 and 5, was characterized by relatively strong down-valley flow. This can be attributed to influences from large-scale flows from northerly directions. While the skies were clear for EOP 3, 4, and 5, some high-level clouds were observed during EOP 1 and 2. The strong down-valley flow and clear skies for EOP 4 and 5 are responsible for the large surface sensible heat fluxes for these two EOPs. Weaker surface winds and some clouds result in weaker sensible heat fluxes for EOP 1 and 2. The smallest sensible heat flux is observed for EOP 3.

The difference in valley flow structure between the three groups and the skill of the numerical model to reproduce the case-to-case variability is illustrated in Fig. 1. The figure depicts time-height plots of wind and potential temperature for an up-valley flow case (EOP 2), the most undisturbed case (EOP 3), and the case with the strongest down-valley flow (EOP 5). It can be seen that the model nicely reproduces the case-to-case variability; the three layer structure for EOP 2, the late-night maximum in wind speed for EOP 3, and the deep layer of strong down-valley flow for EOP 5. A closer look at the individual cases reveals also some significant differences between the observations and the model. Larger differences are found for EOP 2 and EOP 3, for which the model seems to simulate a too localized down-valley jet. This is likely due to the underestimation of turbulent mixing in the model. Note that the present results are for the default setup with a constant soil moisture saturation ratio of 20% on the 1 km domain. An even better match with the observations can be obtained by improving the soil moisture initialization. This is, however, not so relevant for the present purpose of analyzing the case-to-case variability.

The mechanisms leading to this strongly varying response of the valley flow and its sensitivity to the large-scale synoptic forcing will be analyzed.

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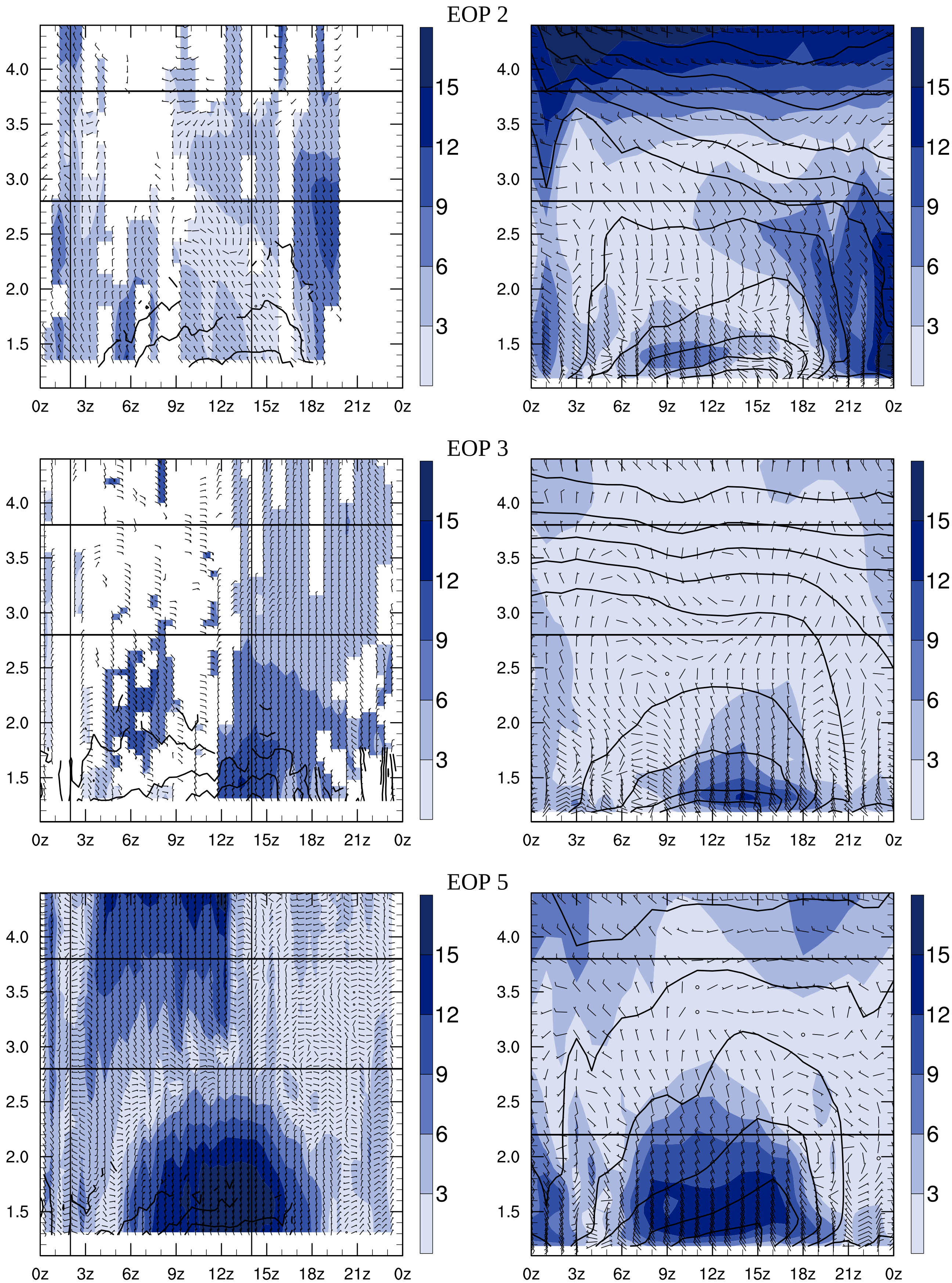

Figure 1: Time-height plot of wind direction (barbs), wind velocity (color) and potential temperature (contour lines) at the MISS Manzanar site for the wind profiler (left panels) and the model simulation (right panels). Note that the high wind speeds above 3 km for EOP 5 are due to bird echos.