Comparisons of Observed and Simulated Atmospheric Boundary Layer Diurnal Cycle

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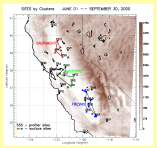
Introduction

This study is the first attempt to evaluate the performance of the NCAR/Penn State mesocale model (MM5) in simulating the summer-time lower tropospheric winds and the atmospheric boundary layer structure the Central Valley (CV) of California. About two dozen 5-day MM5 simulations are evaluated against observations obtained during the Central California Ozone Study (CCOS) in the summer of 2000. The ultimate objectives of this study are to identify the major sources of uncertainties in the MM5 simulations and to understand how uncertainties in the meteorological models affect the performance of the air quality models in this region.

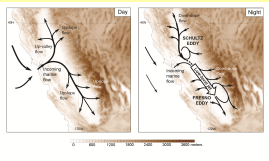
MM5 Model Setup

- MM5 Version 3.7.3
- One-way nested grids run at 36, 12 and 4-km grid spacings
- MM5 re-initialized every 5 days over the 1 June – 30 September 2000 time period; boundary and initial conditions are prescribed using the 40-km Eta analyses.
- The Eta ABL scheme, Noah LSM and the Lin et al. microphysics scheme were used on all 3 grids. The Grell convective scheme was used on the 36 and 12-km grids, no convective scheme was used on the 4-km grid.

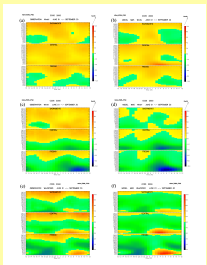
Seasonal Areal Cluster Comparison



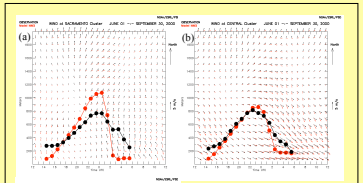
Locations of profiler sites and surface sites that are included in the three clusters used to evaluate the MM5 simulations. The profiler sites are labeled by their 3-letter identity code. Surface sites are colored dots. The Sacramento cluster is labeled in red, the Central cluster is in green and the Fresno cluster is in blue.



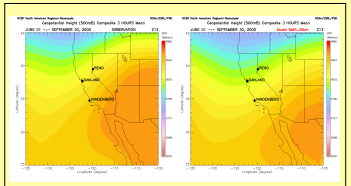
Conceptualization of the daytime and nighttime low-level wind regimes during "eddy days".



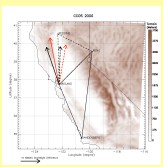
Time-height series of the seasonally-averaged diurnal cycle of the (a) profiler-observed across-valley component of the wind (b) MM5-simulated across-valley component of the wind, (c) profiler-observed along-valley component of the wind, (d) MM5-simulated along-valley component of the wind (e) profiler-observed wind speed and (f) MM5-simulated wind speed. The top panels are the average of the Sacramento cluster, the middle panels are the average of the Central cluster, and the bottom panels are the average of the Fresno cluster. Height is in m above the ground. The winds were rotated 29 degrees counterclockwise.



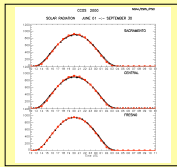
Time height series of the diurnal cycle of profiler-observed (black arrows) and model-simulated (red arrows) winds averaged over 120 days from 1 June- 30 September 2000. (a) The average wind of the sites in the Sacramento cluster, (b) the average winds of sites in the Central cluster and (c) the average winds of sites in the Fresno cluster. The black lines are the observed ABL height and the red lines are the MM5-simulated ABL height averaged over the entire time period.



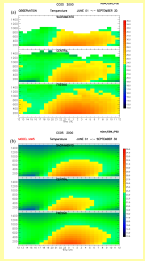
500 mb geopotential height (color contours) at 1200 UTC averaged over the entire 1 June – 30 September time period. Left panel is from North American Reanalysis (NARR), right panel is from MM5 at 36-km grid resolution.



Comparison of the observed and simulated 500-mb geopotential gradient in the San Joaquin Valley, SJV (the solid vector) as well as in the Sacramento Valley (SV) (represented by the dash vector) for both the NARR (black vectors) and the MM5 36-km simulations (red vectors)



Seasonally-averaged observed (black lines) and MM5-simulated (red lines) solar radiation (Wm^{-2}) averaged over the sites in the Sacramento cluster (top panel), the Central cluster (middle panel) and the Fresno cluster (bottom panel).

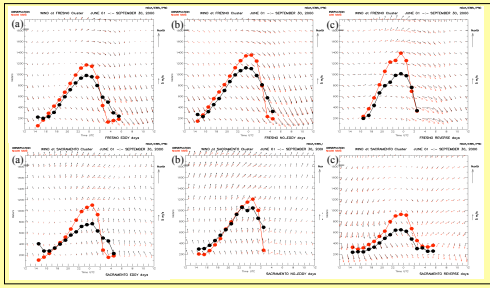


Time-height series of the seasonally averaged diurnal cycle of virtual temperature averaged from (a) profiler-observations and (b) the MM5 simulations. The top panels are averaged over the Sacramento cluster, the middle panels are averaged over the Central cluster and the bottom panel is averaged over the Fresno cluster.

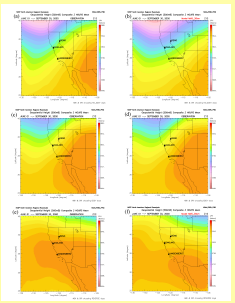
These results strongly suggest that errors in the simulated winds and ABL evolution are closely associated with the biases in the simulated synoptic pressure field and the Bowen ratio of the surface fluxes.

Eddy/No-Eddy/Reverse Day Regime Comparison

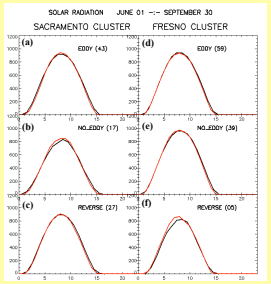
Eddy days are defined as those when the Fresno/Schultz eddy occurs in the Southern/Northern Central Valley, while no-eddy days are define as those when no eddies can be identified in the Central Valley. The reverse days are those when the incoming flow through the San Francisco Bay area ceases.



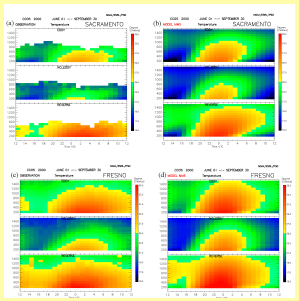
Time height series of the diurnal cycle of profiler-observed (black arrows) and MM5-simulated winds (red arrows) averaged over the days categorized by (a) eddy days, (b) no eddy days and (c) reverse days. The top row is the winds averaged over the Fresno cluster, the bottom row is the winds averaged over the Sacramento cluster.



Composite mean of 500 mb geopotential heights (m) at 1200 UTC from NARR (left panels) and from the MM5 36-km simulations (right panels). (a) and (b) are on eddy days; (c) and (d) are from no-eddy days; (e) and (f) are from reverse days.



Observed (black lines) and MM5-simulated (red lines) solar radiation (Wm^{-2}) averaged over the sites in the Sacramento cluster on (a) eddy days in the SV (b) no-eddy days in the SV (c) reverse days in the SV; averaged over the Fresno cluster on (d) eddy days in the SJV, (e) no-eddy days in the SJV and (f) reverse days in the SJV.



Time-height series of the seasonally averaged diurnal cycle of virtual temperature. (a) The profile-observed virtual temperature averaged over the Sacramento cluster. The top panel is on eddy days, middle panel is on no-eddy days and bottom panel is on reverse days. (b) same as (a) except the temperature is the MM5-simulated virtual temperature. (c) Same as (a) except the profile-observed virtual temperature is averaged over the Fresno cluster (d) is the same as (b) except the MM5-simulated virtual temperature is averaged over the Fresno cluster. Height is in m above the ground.

Summary and Conclusions

The main conclusions that can be drawn from this evaluation of season-long 5-day simulations of the NCAR/Penn State mesoscale model in California's Central Valley using observations taken during the CCOS 2000 experiment are:

1. The accuracy of the simulated low-level winds varies in the CV. Overall the simulated low-level winds are more accurate in the southern part of the CV than in the northern. There are noticeable biases in the simulated wind speed and direction. These biases are consistent with the biases in the observed and simulated large-scale, upper level flows, indicating that the errors in the simulated upper-level winds and forcing are a major source of the errors in the simulated low-level winds.

2. The simulated maximum heights of the daytime ABL are higher than observed, particularly in the northern and southern CV. Examination of the bias with the CCOS observations strongly suggests that this bias is not only associated with the large-scale, upper level biases, but also linked to differences in the surface heat fluxes as indicated by the diurnal bias in the simulated low-level temperature.

3. There appears to be a bias in the simulated ratio of the surface sensible heat flux to latent flux (i.e., the Bowen ratio), as revealed by the bias in the simulated low-level temperature. This bias strongly indicates that the soil moisture in the model is lower than in reality, reflecting errors in the initial soil conditions.