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MM5 simulations for air quality modeling: An application to a coastal area with complex terrain

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ABSTRACT

A series of modifications were implemented in MM5 simulation in order to account for wind along the Santa Clarita valley, a north–south running valley located in the north of Los Angeles. Due to high range mountains in the north and the east of the Los Angeles Air Basin, sea breeze entering Los Angeles exits into two directions. One branch moves toward the eastern part of the basin and the other to the north toward the Santa Clarita valley. However, the northward flow has not been examined thoroughly nor simulated successfully in the previous studies. In the present study, we proposed four modifications to trigger the flow separation. They were (1) increasing drag over the ocean, (2) increasing soil moisture content, (3) selective observational nudging, and (4) one-way nesting for the innermost domain. The Control run overpredicted near-surface wind speed over the ocean and sensible heat flux, in an urbanized area, which justifies the above 1st and 2nd modification. The Modified run provided an improvement in near-surface temperature, sensible heat flux and wind fields including southeasterly flow along the Santa Clarita valley. The improved MM5 wind field triggered a transport to the Santa Clarita valley generating a plume elongated from an urban center to the north, which did not exist in MM5 Control run. In all, the modified MM5 fields yielded better agreement in both *CO* and O_3 simulations especially in the Santa Clarita area.

1. Introduction

The complex topography and unique climate combined together with emissions from highly populated urban areas make the Los Angeles Air Basin to have among the worst air quality in the nation. Under federal law, the basin is designated as a "severe-17" nonattainment area for the 8-h ozone standard and nonattainment for $PM_{2.5}$. During the summer months, strong subsidence induced by the semi-permanent high pressure system residing over the North-eastern Pacific brings an elevated inversion to the basin. In that, cool and moist marine layer near the surface is topped by warm and dry air mass aloft, which, often, inhibits the growth of the mixing layer. In addition, light winds within the basin combined with complex terrain that separates the basin from semi-arid areas in the east and the north further limit pollutants dispersion. The annual average wind speed for year 2007 at downtown Los Angeles was 2.04 m s^{-1}. Furthermore, the region experiences more days of sunlight than any other major urban area in the United States except Phoenix, Arizona.

In terms of thermally driven local circulation, sea breeze intensifies upslope flow induced by high mountain range in the east and the north of the basin during the daytime (Fig. 1). Consequently, the highest ozone is often observed along the slopes of the surrounding mountain barriers and in the eastern basin (Ulrickson and Mass, 1990a; Boucouvala and Bornstein, 2003; Lu and Turco, 1996; Fujita et al., 2000). Yet, in detail, local transport pattern in the basin is more complex than the straightforward west–east

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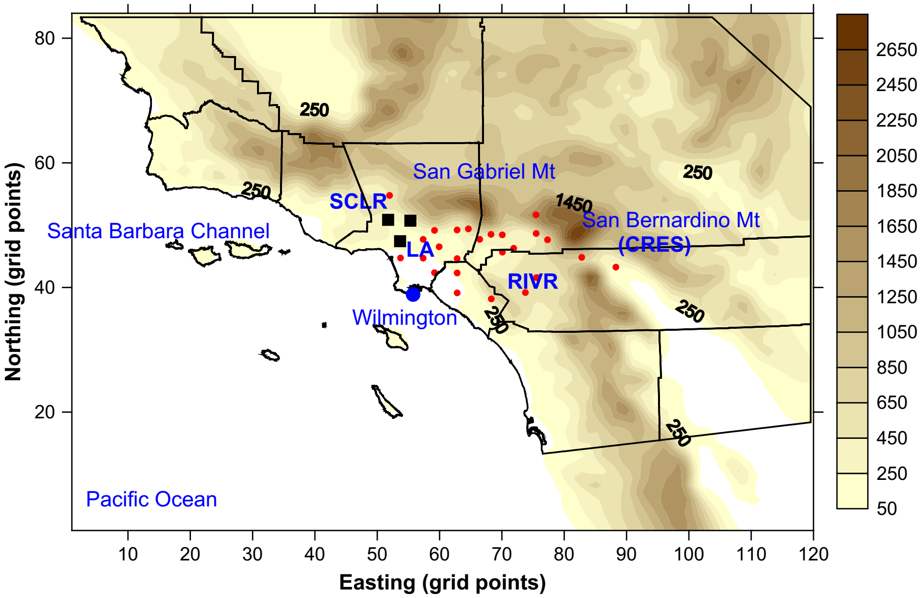

Fig. 1. Terrain height and the location of available surface monitoring stations inside the innermost MM5 domain. LA, SCLR, RIVR and CRES represent Los Angeles, Santa Clarita valley, Riverside, and Crestline, respectively. Rectangles represent three monitoring stations of which data were incorporated into data assimilation.

advection. In addition to the westerly momentum, northwest–southeast running coastal line and high terrain in the north of the basin add southerly component to the sea breeze and upslope flow. Namely, a branch of sea breeze entering the basin channels to the northeast through the Santa Clarita valley, while another exits toward the east (Fig. 2). The wind pattern presented in Fig. 2 is similar to typical summertime climatological wind streamlines constructed from wind speed and direction data collected during the period of 1950–1973 over 60 monitoring stations in the basin (South Coast Air Quality Management District, 1977). Wakimoto (1987), Douglas and Kessler (1991), and Rosenthal et al. (2003) also reported the presence of southeasterly flow in the Santa Clarita valley during morning and early afternoon period. When costal eddies such as Santa Barbara eddy circulation (Kessler and Douglas, 1991) and Catalina eddy (Wakimoto, 1987) are present, southeasterly component is often observed to intensify. However, the channeling flow occurs regardless to the existence of the coastal eddies. Evidently, on July 16, 2005 when there was no sign of a costal eddy, a pronounced double peak pattern of ozone was observed (Fig. 3). The max 1-h ozone of 173 ppb was recorded at the Santa Clarita station and secondary peak of 166 ppb was monitored at the Crestline on the day.

Ulrickson and Mass (1990b) made the first attempt to employ a full three-dimensional prognostic model to the basin, followed by many studies that applied mesoscale models to complex transport phenomena of the basin in the past. Among them, Lu and Turco (1996) used Surface Meteorology and Ozone Generation model to demonstrate the development of a vertically layered structure and

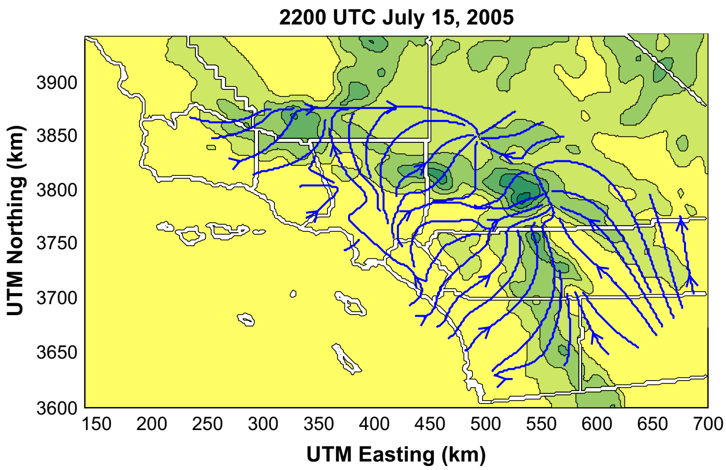

Fig. 2. Wind streamlines on 2200 UTC July 15, 2005. The streamlines were constructed from wind measurements taken at 67 stations scattered over the domain.