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Enhancement in secondary particulate matter production due to mountain trapping

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ABSTRACT

As China's largest economic development zone, the Pearl River Delta (PRD) is subject to particulate matter (PM) and visibility deterioration problems. Due to high PM concentration, haze days impacting ambient visibility have occurred frequently in this region. Besides visibility impairment, PM pollution also causes a negative impact on public health. These negative impacts have heightened the need to improve our understanding of the PM pollution of the PRD region. One major cause of the PRD pollution problem is cold front passages in the winter; however, the mechanism of pollution formation stays unclear. In this study, the Comprehensive Air Quality Model (CAMx) is utilized to investigate the detailed PM production and transport mechanisms in the PRD.

Simulated concentrations of $PM_{2.5}$ species, which have a good correlation with observation, show that sulfate and nitrate are the dominant pollutants among different $PM_{2.5}$ species. Before the cold front passage a large amount of gas-phase and particle-phase pollutants are transported to the mountainous regions in the north of the PRD, and become trapped by the terrain. Over the mountain regions, cloud driven by upwelling flow promotes aqueous-phase reactions including oxidations of PM precursors such as SO_2 and NO_2. By this process, production of secondary PM is enhanced. When the cold front continues to advance further south, PM is transported to the PRD cities, and suppressed into a thin layer near the ground by a low planetary boundary layer (PBL). Thus high PM concentration episodes take place in the PRD cities.

After examining production and transportation pathways, this study presents that the complex terrain configuration would block pollutant dispersion, provide cloudy environment, and advance secondary PM production. Previous studies have pointed out that pollution emitted from outside this region largely influences the air quality in the PRD; however, this study shows that pollutants from the outside could be originated from the PRD and transported back resulting in significant increase of secondary PM concentration, and provides new insight into PM production and transport mechanism in the PRD.

1. Introduction

As China's largest economic development zone, the Pearl River Delta region (PRD, location shown in Fig. 1b) suffers from particulate matter (PM) pollution. (Wang, 2003; Chan

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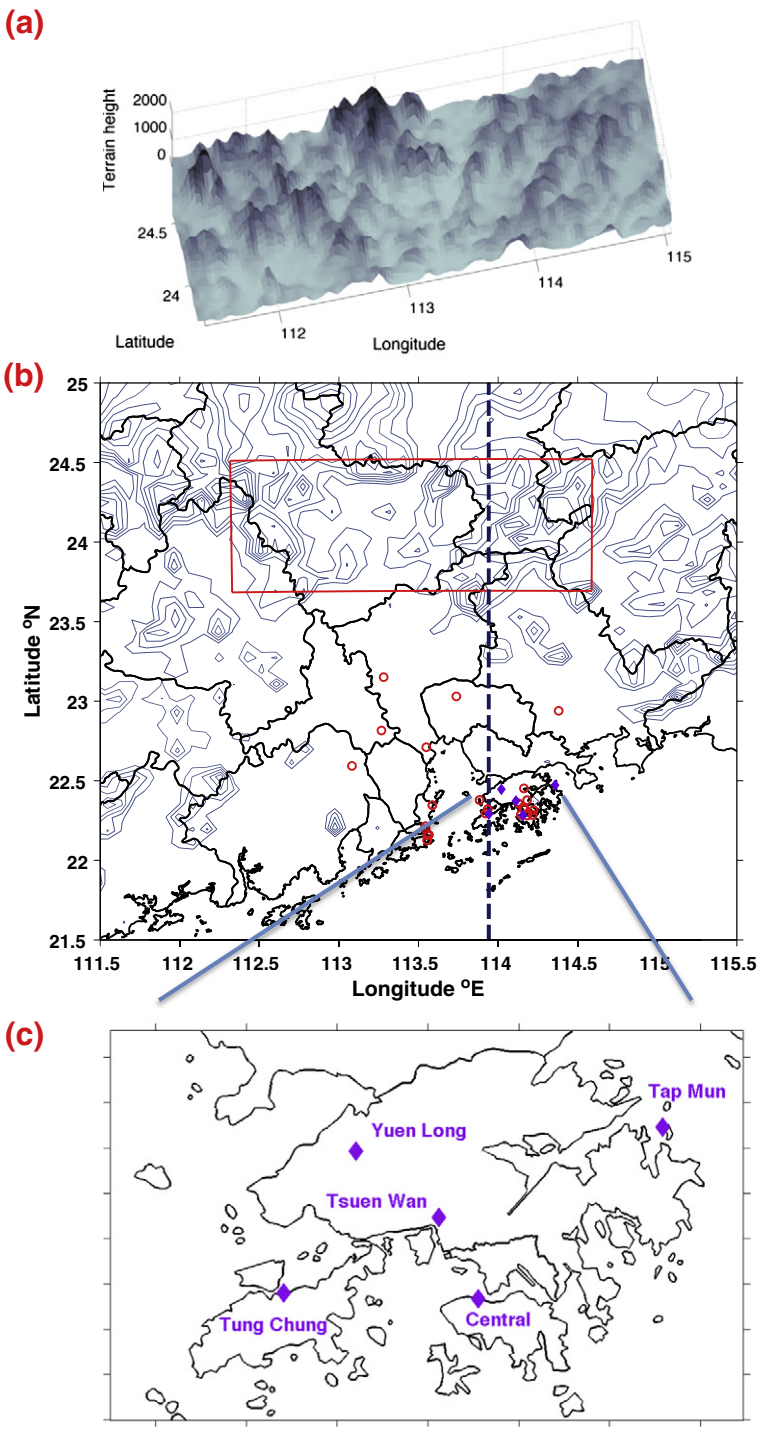

Fig. 1. PRD region map. The purple diamonds show the locations of the $PM_{2.5}$ monitoring stations under study (Tung Chung, Yuen Long, Tsuen Wan, Central and Tap Mun, from west to east). The red circles refer to the PM_{10} monitoring stations. The red box shows the mountain region in the northern PRD, and the morphology is also indicated. The dashed blue line represents the position of a vertical cross-section analyzed in a later section, and the gray lines are contours indicating terrain height, starting from 200 m at intervals of 100 m.

and Yao, 2008; Kwok et al., 2010). Haze days due to high PM concentration, have occurred frequently in this region (Huang and Yu, 2008; Tan et al., 2009; HKO, 2013). Besides deterioration of visibility, PM pollution also causes a negative impact on residential health. Tie et al. (2009) report that in PRD region, PM abundance is associated with the mortality of lung cancer. In a later study on the health impact of air pollution, it is identified that in the PRD region exposure to PM and gaseous pollutants