

Impact of land surface process in MM5 over Hong Kong and Pearl River Delta

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1. INTRODUCTION

The Pearl River Delta (PRD), located in the southern part of Guangdong Province in China, is a region of 41,700 km² in size and 50 million in population. Major cities in the region include Hong Kong, Guangzhou, Shenzhen, Dongguan, Zhongshan, Foshan, and Macau. As a result of the economic reform started at the end of the 1970s, the economic and industrial growth in the PRD has been phenomenal. The region is now one of the world's largest manufacturing and industrial bases. Unfortunately, in addition to the improving economic conditions, the air quality in PRD has also deteriorated substantially in the past two decades.

To better manage the rapidly deteriorating air quality, a good understanding of the local and regional circulation, including its complex interactions between the local land-sea breeze circulation and the urban environment of the cities in PRD, is very much needed. It is generally agreed that land surface process has substantial influence on both large-scale and mesoscale circulation (Chen and Dudhia, 2001). Accurate land surface flux and forcing are very important for good simulation of the planetary boundary layer (PBL), a parameter of primary importance in air quality studies.

While there have been a number of studies on land surface processes around the world, research focused on the impact of rapid urbanization on the local and regional scale circulation is

still limited. In this study, two sets of MM5 experiments are performed to investigate the impact of different land surface characterization on land-sea-breeze circulation and urban heat island (UHI) effect over Hong Kong and PRD. The first experiment uses default MM5 surface characteristics with a simple land surface model (SLAB) (Grell, 1994), and the second one uses an up-to-date local land surface characteristics coupled with an advanced land surface model (NOAH-LSM) (Chen and Dudhia, 2001).

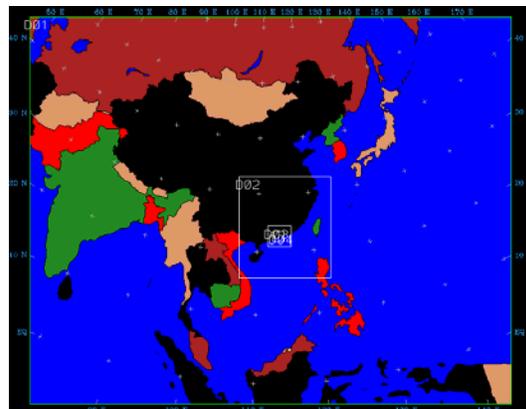


Fig.1) Domain configuration in MM5 simulations

2. MODEL DESCRIPTION

MM5 version 3.6.3 was used to study a severe air pollution episode in Hong Kong and PRD between 31 Oct 2003 and 2 Nov 2003. Figure 1 shows the domains used in this study; 4

two-way nested domains with resolution 40.5, 13.5, 4.5 and 1.5km were used. The outermost 40.5km domain covers the entire China while the innermost 1.5km domain covers Hong Kong and PRD. Thirty-five sigma-levels were used, of which thirteen were below 1km to have a finer resolution of the PBL. Grell cumulus scheme is used in domains 1 and 2, while explicit convection used in domains 3 and 4. In addition, MRF, Dudhia simple ice and RRTM schemes were applied in all domains.

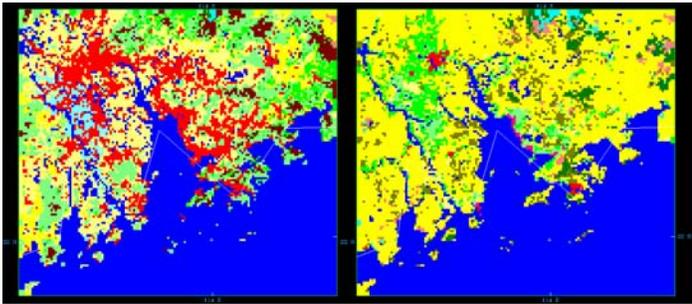


Fig.2) Landuse map of the 1.5km innermost domain: refined PRD landuse map (left), USGS 24-category landuse map (right). Urban areas are shown in red color

Two different land surface treatments were used: (1) simple land surface scheme SLAB, and (2) NOAH-LSM. For the NOAH-LSM experiment, a number of refinements were applied, including:

- 1) An up-to-date fine resolution (30m) landuse map for PRD produced by the Planning Department of the Hong Kong Government is implemented in MM5. As shown in Fig. 2, the distribution of urban area in PRD is much larger (and more realistic) than the 30s USGS landuse map created in 1994.
- 2) The green vegetation fraction in domains 1 and 2 was derived from monthly climatology value from the 0.15° resolution NOAA/NESDIS dataset. However, there would be problem caused by interpolating the NOAA/NESDIS data into our inner 1.5km domain: most of Hong Kong is interpolated to sea value (zero green vegetation) which is

unrealistic (Fig. 3). Hence, another landuse based green fraction is used in domains 3 and 4.

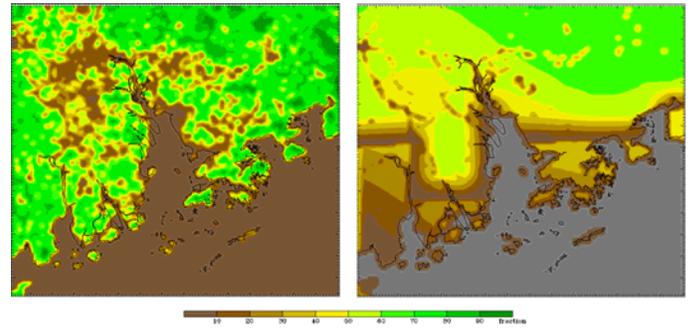


Fig.3) Green vegetation fraction map: landuse based (left), interpolation from 0.15° NOAA/NESDIS (right)

- 3) Enhancements to urban landuse in NOAH-LSM (Liu, 2004) have also been applied. They included: a) increasing the roughness length; b) reducing the surface albedo; c) using a larger volumetric heat capacity; d) increasing the value of soil thermal conductivity; e) reducing the green vegetation fraction and increasing minimum canopy resistance to decrease evaporation.
- 4) Modifications of MRF PBL scheme (Liu, 2004) which uses better methods for computation of free convection turbulence, PBL height, and surface heat flux.

The MM5 runs were initialized using the 1°x1° NCEP Final Analysis (FNL) data as first guess field. Observations available on the Global Telecommunication System (GTS) were incorporated in MM5 initial conditions through the program LITTLE_R. Soil parameters including soil moisture, soil temperature, soil water content, etc. were initialized using the 47km resolution AGRMET data. To avoid interpolation problems similar to those found in green vegetation, a value of 0.3m³/m³, which was consistent with AGRMET data, of soil moisture and soil water are assigned to each grid in domains 3 and 4 rather than direct interpolation from the source AGRMET data. For urban landuse, soil moisture was assigned as 0.1m³/m³.

3. RESULTS AND DISCUSSION

Two sets of MM5 simulations with different land surface treatments were initialized at 8 am 31 Oct 2003. The observed winds at a number of automatic weather stations at 2pm on 31 Oct 2003 in Hong Kong are plotted in Fig. 4, and corresponding surface wind fields forecasted in the two experiments, NOAH-LSM and default MM5, were plotted in Figs. 5 and 6, respectively. Figure 4 shows a weak background easterly wind over Hong Kong and the local circulation was dominated by a sea breeze circulation. This feature was very well simulated in the refined NOAH-LSM run (Fig. 5), but it was not well defined in the default MM5 simulation (Fig. 6).

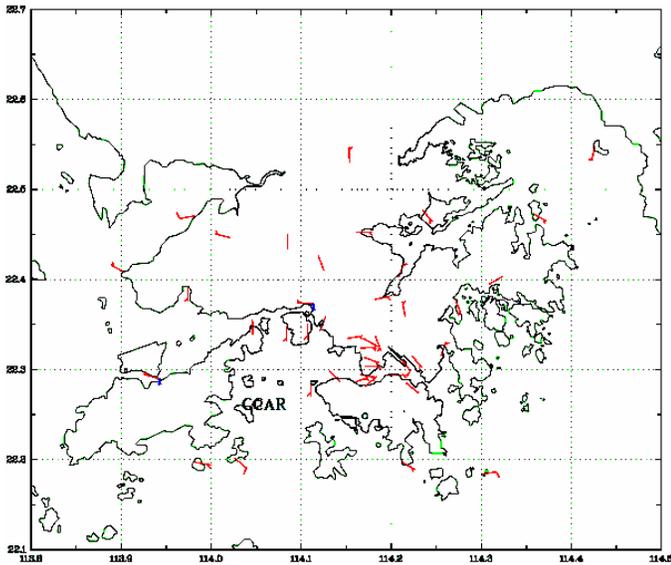


Fig.4) Observational surface winds at 2pm 31Oct, 2003

In addition to capturing the land-sea circulation around the coastal areas, the urban heat island effect over HK and PRD was also well simulated in the NOAH-LSM run. Figure 7 shows the time-series plot of observed (solid line) and forecasted (dotted line) two meter temperature averaged for 9 rural stations (triangles) and 17 urban stations (circles) over Hong Kong. Average surface temperature at urban areas was found to be warmer than that of rural areas by about 1 to 2 degrees. To study the energy balance, the simulated sensible heat flux at 5pm and

the simulated latent heat flux at 1pm were shown in Figs. 8 and 9, respectively. The large thermal capacity in urban area resulted in positive sensible heat flux in late afternoon while the lower soil moisture and reduced evaporation lead a lower latent heat flux during day time.

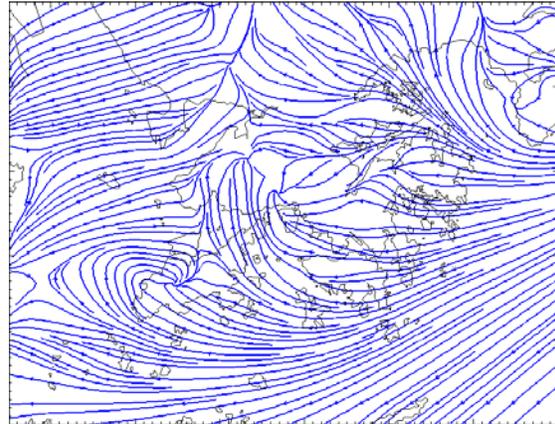


Fig.5) NOAH-LSM MM5 six hrs forecast surface streamlines valid at local time 2pm 31Oct, 2003



Fig.6) Default MM5 six hrs forecast surface streamlines valid at local time 2pm 31Oct, 2003

Our preliminary results show that many of the local meteorological features can be well captured by the refined NOAH-LSM experiment. Further analyses will be performed to study the effect of land surface process on the evolution of the PBL over PRD and Hong Kong.

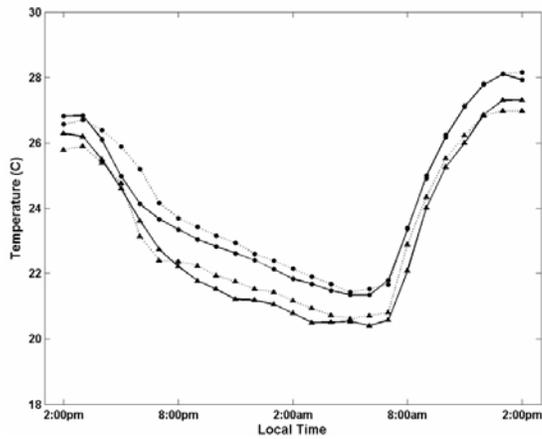


Fig.7) Time series of surface temperature over Hong Kong from 31Oct to 1Nov, 2003: Observational data (solid line), 6 to 30 hrs MM5 forecast (dotted line) average for 17 urban stations (●), 9 rural stations (▲)

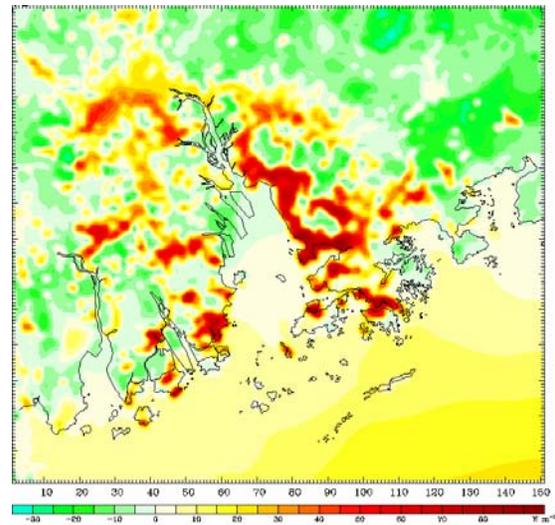


Fig.8) Surface sensible heat flux valid at local time 5pm

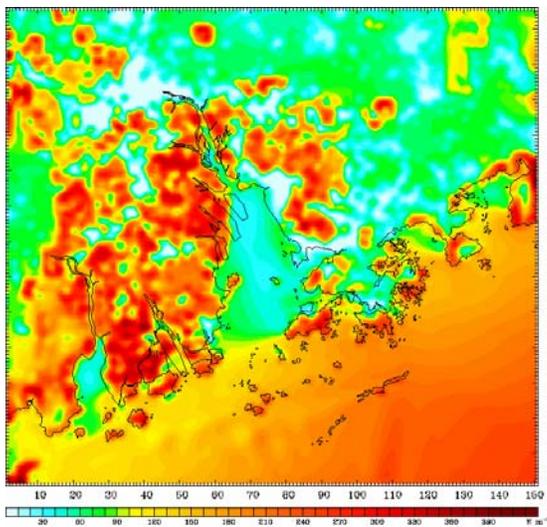


Fig.9) Surface latent heat flux valid at local time 1pm

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