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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Atmospheric boundary layer characteristics over the Pearl River Delta, China during summer 2006: measurement and model results" *by* S. J. Fan et al.

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We would like to thank Referee 1 for your careful reading of our manuscript and for your valuable and constructive comments. We have addressed the comments below.

Comment

This manuscript presents "Atmospheric boundary layer characteristics over the Pearl River Delta-China during summer 2006: measurement and model results". The authors discuss the well known situations of atmospheric conditions which related to the high pollution episodes. That's fine if can present good enough of the data quality and simulation results. The simulation part is quite important for this study owing to the lim-

itation of the observations. However, the authors employ the original USGS land use in their simulation. This USGS land use data set is totally outdate (nearly no urban) and has been identified by number of papers. As we know the boundary layer development is strongly related the correct atmosphere-land surface processes and even the urban canopy. This paper fails to include some most important signals in the simulation and the presentation skills still need to significantly improve.

Response

This paper reports atmospheric boundary layer (ABL) characteristics by measurements and simulations by WRF model in July 2006 over Pearl River Delta (PRD) region. We especially want to explore the detail atmospheric conditions with high pollution episodes in the summer. In fact, in order to reveal the meteorological and chemical characteristics over PRD, "Programme of Regional Integrated Experiments of Air Quality over the Pearl River Delta" (PRIDE-PRD) campaign 2004 and 2006 were conducted. The ABL measurement was a very important part in these two intensive campaigns. The characteristics of ABL in October 2004 were analyzed all by measurements. This is discussed at the second part of the Introduction and in the Experimental Section (Sections 1 and 2.1). Besides the measurements, the simulations by WRF model with high resolution were utilized to analyze the ABL features in July 2006, the local circulation can be explored with the simulations.

We agree that the correct land surface process and even the urban canopy are all essential to the boundary layer development. Many scientists (Fei Chen et al., 2011, Wang X M et al., 2009a, 2009b) have devoted to the improvement of land surface model and have pointed out the importance of land use data.

In theory, it will be better if we use the updated land use data. How much does it be improved? Does the local circulation pattern change? Li-Hui Tai (Li hui Tai et al., 2010) conducted a study to change the USGS data in WRF model with the CTCI data which is the local land use data in Taiwan. The results showed that the diurnal pattern of the

ground temperature, PBL height, latent heat flux and sensible heat flux were all the same with two sets of land use data. The maxima of all variables in daytime had a little change, but the values in nighttime were almost the same.

We agree the land use data is one of the most important parameters in the model to improve the interaction of land surface and ABL. Now in our paper, for the simulations by WRF model with USGS data were compared with the measurements, it is mostly satisfied (The 2-m temperature, the wind speed, the wind direction, the ABL height and the ABL pattern are all comparable. The local circulations are also can be explored). So, we will do another study to analyze the ABL feature with new updated land use data in the future to see how many and how much will be improved, but not this paper.

Comment

1. Abstract: The presentation is inappropriate for the abstract, parts of the contents should be moved to Introduction section.

Response

The abstract have been modified. Some sentences have been deleted or changed.

Comment

2. P4808, lin4, Abstract, “Furthermore, the modelled results also suggest that the high Air Pollutant index (API) episode was caused predominately by subsidence.” This is conclusion is inadequate, since you do not run the air quality model. Also, the sea breeze also can act the air pollutants accumulation during the sunny day as shown in Figure 2.

Response

During the whole July in 2006, there were two peaks in API (Fig. 2). One was occurred in 14 July and another was in 25 July. In our paper, we focus on the high API episode during 12-15 July, which was corresponding to the Period ÎŹ. Here, “the high Air Pollu-

tant index (API) episode” means this process, which was accompanied by the tropical cyclone “Bilis” and the subsidence were dominated the PRD region. This sentence has been changed. “Furthermore, the modeled results also suggest that the subsidence by typhoon “Bilis” had a much impact on the high Air Pollutant index (API).”

Comment

3. P4809-P4810: As mentioned in introduction section, “ There have been several investigations on the characteristics of atmospheric boundary layer (ABL) over PRD from the 1980s to 1990s (Huang and Liu, 1985; Guo, 1991; Liang et al., 1992)” : : :.” Many results pointed out that the meteorological fields were closely interacting with the chemical composition, chemical reaction process and physical optical characteristics” “Results from some model studies (Feng et al., 2007; Wu et al., 2005) also showed that most severe air pollution episodes in PRD region are very often associated with the subsidence by tropical cyclone or sea-land breeze.” What’s new in this study comparing to previous investigations?

Response

Many researches have been done on the meteorological conditions, especially the ABL features over PRD region. Some were based on the measurements and some were studied with the simulations. The resolution of measurements was almost comparatively lower but the simulations should be verified by the measurements.

In our paper, these two kinds of data were used. At first all kinds of sounding measurements during PRIDE-PRD campaign 2006 were utilized to explore the basic characteristics of ABL over PRD, and then the simulations by WRF mesoscale model with high resolution were used to analyze the detailed temperature and wind structure and the local circulation. As one part of PRIDE-PRD campaign 2006, the meteorological results provided by this study can be used for other studies in PRD July intensive campaign to understanding the main ABL features in this time of year. Additionally, no other detailed study of this region on the ABL features has been performed at this time of

year.

Comment

4. P4812-4813: There were two periods of high temperature weather from 12–14 July and 23–25 July, corresponding to strong tropical cyclone“Bilis” and typhoon “Kaemi”, respectively” How do you classify the period”12-15” is typhoon process and the period”20-23” is sunny day period? What is major reason you are according to for the classification?

Response

From the weather charts during 20-22 July, it can be seen that the tropical storm “kaemi” was far away from PRD region. After 23 July, “Kaemi” moved into the east of 130°E and the PRD region was influenced by the typhoon. The measured temperature increased from 23 July and reached the maximum in 25 July. The precipitation by typhoon “kaemi” occurred during 25-27 July. In 12 July, the strong tropical storm “Bilis” located between 120°E and 130°E. The whole PRD region was under the influence of “Bilis”. The maximum measured temperature occurred in 14 July. The precipitation by “Bilis” occurred from 15 to 17 July. So we classified the period “20-23” was the sunny day period. The periods “12-15” and “23-25” were the typhoon processes.

Comment

5. P4811: It seems to me the significant different between this study and other studies is the model resolution. (P4811, line 1-5).

Response

As stated in our paper, a lot of researches pointed out that the high resolution forecast was a key task for further progress in NWP model development (P4811, line 5-8). In this study, the local scale meteorological conditions could not be captured by 50 km and 10 km resolution meteorological model. Fine-scale (at a resolution of 1 km) meteorological (WRF) results demonstrated a successful simulation in ABL and reasonable agreement

with the available observations.

Comment

6. P4814:” The original USGS 24-category land cover data was employed.” As we all know the boundary layer development is strongly associated with land-surface processes and even the urban canopy. The correct land use classification is quite important for modeling study about the near surface air temperature and boundary layer development. There are number of papers discussing about the land use of the original USGS in the model is totally outdate. There are nearly no urban in the USGS land use data set. How can you convince the reader that USGS land use in your model is good enough to study this issue?

Response

The simulations in our paper were compared with the measurements in various fields, such as the surface observations in many meteorological stations, the horizontal wind fields, the vertical temperature and wind profiles by sounding measurements, the hourly 2-m temperature, 10-m wind speed and wind direction, the ABL structure and height by lidar and so on. In all, the simulations were moderate satisfied. The main ABL features were be captured by the simulations. But model failed to describe the ABL height in nighttime.

The ABL height in nighttime calculated by WRF model seemed much lower than the actual values. It also can be seen in other study (Li hui Tai et al., 2010), the ABL height in nighttime by WRF model was still much lower even when the land use data has been improved. Studies by XM Wang (2009b) also pointed out that the calculated nighttime ABL height by WRF model increased 50-100m when they modified the land use data over PRD region. So we think, besides the land use data, the PBL parameterization scheme, the initial and boundary conditions, the vertical resolution in PBL, and the land surface model are all important to the simulations. According to the results in this study, how to improve the simulations, including the ABL height in nighttime and the

simulations in rainy days, we will continue to study in the future.

Comment

7. P 4816: “It should be noted in Table 1 that except for the wind speed in period II, the average simulated wind direction, wind speed and temperature in three periods are all close to the observations. “ It does not make sense only to present the 2-m absolute value to examine the model performance. I suggest you need to calculate the difference below the boundary layer (at least 1 km) since this paper is to discuss the atmospheric boundary layer characteristics. More important, the absolute values seem not large but those differences occupied significant percentage comparing to the mean value. For example, the RMSE for wind speed is as high as about 56% of mean simulation for Period I and period III.

Response

Limited to the observations, the vertical wind profile at Panyu station and the temperature profile at Qianyuan station on 14 July and 21 July were compared with the simulations (Fig.8 and Fig.9). The results showed that the vertical wind and temperature structure were captured well by WRF model.

In Table 1 that except for the wind speed in rainy days, the average simulated wind direction, wind speed and temperature in three periods are all close to the observations, especially the simulated temperature in period I and period III, with the correlation coefficient reaching 0.72 and 0.91, respectively. For wind speed and wind directions in three periods, the correlation coefficients are all over 0.4. The values of MB, MAGE, RMSE, and FAE indicated the model overestimated the wind fields in most of the time. In all, the simulated temperature fields were better than the wind fields. The simulations in wind speed and wind direction need to be improved in the future study.

Comment

8. Figure 6, According to the simulation results at different stations, the boundary

layer development heights are quite different. Actually, the boundary high is significant related to land surface. How can you compare boundary layer measurement by lidar in Hongkong with your simulation results? Do you think the lidar measurement in Hongkong can represent the boundary layer in whole PRD ?

Response

In Fig.6, the simulated ABL heights during three periods in July 2006 at different stations were compared. It was very apparent there were three kinds of pattern for the diurnal of ABL. The simulated diurnal variation of ABL height in subsidence days and sunny days were all more obvious than those in rainy days. In rainy days, the change of ABL height was instantaneous, the ABL changed quickly from the stable regime to the convection regime. Besides these simulated results, measurements need to be found to verify these three kinds of pattern. So, we used the Hongkong lidar signals for only Hongkong has lidar signals in July 2006. Hongkong is situated in the south of PRD. In July, Hongkong was also affected by the same meteorological background fields of PRD. The lidar measurement in Hongkong can represent the boundary layer main features of PRD in July 2006.

It was very inspiring that the observations by lidar in Hongkong also showed that there were obvious diurnal changes of ABL height in subsidence days and sunny days. In the rainy days, the diurnal variation was not apparent. That is to say, though there have differences in ABL at various stations, but the main ABL patterns in subsidence days, rainy days and sunny days were very clear.

Comment

9. Also, for the lidar detection, it still has about 500m height during night time but simulation results are almost zero. The authors explain that it was caused by the MRF high resolution planetary boundary layer parameterization scheme used in the model. This reviewer think this simulation does not including correct land use, couple detail atmosphere-land surface process model and even the urban canopy model will be

other important reasons. The model simulation is an important part for this study. The author should including those important modules.

Response

Yes, The ABL height in nighttime calculated by WRF model seemed much lower than the actual values. The model failed to describe the ABL height in nighttime. The simulations much underestimated these values not only in this study, but also in other study even with the update land use data (Li hui Tai et al., 2010). Studies by XM Wang (2009b) also pointed out that the calculated nighttime ABL height by WRF model increased 50-100m when they updated the land use data over PRD region. Besides the land use data, the PBL parameterization scheme, the initial and boundary conditions, the vertical resolution in PBL, the land surface model and many other uncertain errors by computation are all important to the simulations. We will study the simulated ABL height in nighttime by WRF model in the future,

Comment

10. P.4822, What is" the aforementioned stations were all controlled by west" ? There are lots of similar sentences, Please check the whole article by native English speaker.

Response

It will be improved.

Comment

11. P4821, Why "at Xinken station, located in the Pearl River Estuary, the winds were from the south. It was obviously influenced by the sea breeze." " It does not make sense, the sea breeze prevailing at 20, 00LST according to your explanation. At 0800LST and 1400 LST, the wind directions are mostly easterly and your explanation is "The winds at Xinken station changed to the west, it was also affected by the sea-land breeze(P 4821, line 21-22)" If so, why simulation wind direction is same at 0800LST and 1400LST ? Furthermore, the simulation wind direction is significant different from

the observation at 14 00LST.

Response

The actual wind is the combine of the large scale wind (background wind) and the small scale wind by local circulation. In Fig10a and b, at that time, the tropical cyclone "Bilis" still had not made landfall, the distance between "Bilis" and PRD region was far. The average wind speed at Guangzhou on 12 July was 1.54ms-1. Under the small background system wind fields, the local circulation is essential to various stations. Different from Fig. 10a and b, the tropical cyclone "Bilis" had already made landfall in Fig.10c and d, PRD regions were deeply influenced by "Bilis". The average wind speed at Guangzhou in 14 July was 3.46ms-1. The winds at various stations in PRD tend to be similar under such background system wind fields. That's why the simulation wind direction is same at 0800LST and 1400LST. The wind speed and directions still need to be improved in the future study.

Comment

12. This study including three type of simulation, why just discuss in detail during the period of 12-14 July ? and, How can you conclude the results say" The features of ABL under three kinds of weather: subsidence days, rainy days and sunny days: : :: : :, The results show that the model can reproduce the meteorological fields well" on page 4824. I do not think so, because the rainy day period your simulation is quite far from observation (table 1)

Response

The two API peaks in July 2006 were also caused by the subsidence motion from tropical cyclones. So we especially focused on the ABL characteristics in PRD from 12–15 July, the detail synoptic situation and simulations during this period were analyzed in the paper. We agree the reviewer's point. The simulations in rainy days were not very well. So the sentence on page 4824 changed to "The results show that the model can

reproduce the meteorological fields moderate well."

Comment

13. How can you conclude "The differences are induced by the local effects in PRD areas, such as sea-land breeze effects, urban heat island effects and mountain valley effects." I think you even do not include the correct land use in the model simulation.

Response

The local circulation can be captured not only in this case, but also in other cases by WRF model. The sea-land breeze circulation over PRD region has been simulated with high resolution mesoscale model WRF or MM5 with USGS land use data in many researches (Lin et al., 2001, Chen et al., 2009). The coastlines in PRD, the urban land use in Guangzhou city and the topography in Nanling Mountain are all described by USGS data. The basic local circulations can be simulated by WRF model. It is expected that more detail features of local circulations can be captured with update land use data in the future.

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