Interactive comment on “The Contributions to the Explosive Growth of PM2.5 Mass due to Aerosols-Radiation Feedback and Further Decrease in Turbulent Diffusion during a Red-alert Heavy Haze in JING-JIN-JI in China” by Hong Wang et al.

Anonymous Referee #3 Received and published: 1 August 2018

This paper deals with the effect of “aerosols-radiation feedback” and “decrease in turbulent diffusion” to “the Explosive growth of PM2.5 mass” in Jing-Jin-Ji area, northern China. Numerical experiments are carried out for three runs, the first run absents “Aerosols-Radiation Feedback”, the second run is with normal Aerosols-Radiation Feedback, and the third run is with reduced Turbulent Diffusion in addition. A one week haze event is modeled. Results of these runs, one by one, show improvement to reproduce the observed results.

Response:

We would like to heartily thank the reviewer for his serious review on our work and the valuable comments. We carefully considered comments of the reviewer and revised the paper accordingly, one by one of the following:

My major concern and suggestion:

Comment 1) This paper proposes a sensitive test on factors that influence the model result. But in the paper, results are directly presented, no middle results or any more supporting materials. Therefore, the conclusions are not convinced.

Response:

Thank the reviewer for this important comment, the model description GRPAES_CUACE including dynamic, physical and chemical processes is given in section 2.1. The parameterizing schemes and chemical mechanism used in this study and the related references are summarized in new Table 1 in the revised paper.

CAUCE, two-way coupling and the DC calculation and PBL scheme are closely related with the aim of this study, so a brief introduction of this is given in section 2.1 (line 107-126) and the references are also added in the revised manuscript.

The modeled meteorology factors of wind speed, temperature (figure 3) and etc, downward shortwave fluxes due to AF and DTD (figure 5), and AOD and SSA (table 4) are analyzed and compared with observation to support the conclusions in the revised manuscript.

Comment 2) Reducing DC may lead the meteorological model running unrealistically. Details about the change of wind field etc. need to be displayed.

Response:

In our model, The DC is calculated in PBL scheme and it is passed into the chemical module (as DC_chem) to calculate the turbulence diffusion process of chemical tracers including gas and particles matter (PM). In our sensitive test, only DC_chem is reduced by 80% in the chemical module as a local variables but this change of DC was not changed in dynamic and other physics processed outside the CAUCE module. So, the turbulence diffusion process in PBL and wind in dynamic frame were not changed by the DTD sensitive experiment. The text line 162-178 is rewritten to explain this and the explanation of the three experiments. The explanation of the experiments set in table 2 is also corrected in the revised manuscript.

PBL meteorology background (figure 2) and wind and temperature changing (figure 3) are added to introduce and validate the meteorology condition of the haze episode in the revised manuscript.

Comment 3) Need description: synoptic background/weather condition for this haze event.

Response:

Figure 2 is added in the revised manuscript to show the geopotential height, wind and temperature at 500, 700, 850, 900, 950, 1000hPa to study the synoptic background and weather condition for this haze event.

Comment 4) Details of the model are needed, particularly the parts of lower atmosphere, levels, PBL scheme, surface model, radiation, aerosol absorption, etc.

Response:

The brief introduction of model dynamic, information of horizontal and vertical coordinates, physical package including PBL scheme, surface model, radiation etc. and chemical schemes, and the mechanism of aerosols direct and indirect mechanism are introduced in section 2.1 (line 84-106) and are also summarized in new Table 1 in the revised manuscript.

The introduction of two-way coupling including aerosols mixing method is also added in line 107-117 and the related references are also added in the revised manuscript.

Modeled aerosols optical depth (AOD) and single scattering albedo (SSA) representing the aerosol absorption are evaluated in the revised manuscript (table 4 and the related discussion)

Comment 5) PBL is mentioned as a crucial part in the paper, but no information about PBL is illustrated.

Response:

The introduction of DC calculation and PBL scheme and related references are added in line 118-126 in the revised manuscript.

The PBL meteorology background at 900, 950, 1000 hPa (figure 2) is also added in the revised manuscript. Figure 3 including PBL wind and temperature is added in the revised manuscript. Figure 7 also showed the vertical structure of observation and modeled temperature, which included the information of PBL inversion.

Other points:

Comment 1) ”Jing-Jin-Ji”, not to be “JING-Jin-Ji” etc. different forms.

Response:

"JING-JIN-JI" and "JING-Jin_Ji" are all replaced by "Jing-Jin-Ji" in the revised manuscript.

Comment 2) Too many abbreviates, and their combination, hard to read the text; There are only 3 experiment runs, number them as Run 1~3, may be clearer.

Response:

"EXP1, EXP2 and EXP3" are used to replace the "EXP_bk, EXP_td_af, and EXP_td20_af" in the text, table and figures in the revised manuscript

Comment 3) Page 4, line 70-72:"One is that aerosols radiation feedback (AF) is not calculated online in the model run. AF can restrain turbulence by cooling surface and PBL while heating the atmosphere above it", Result of AF is mostly determined by absorbing aerosols, and by their vertical distribution.

Response:

This description is not accurate enough and it is revised as "AF may restrain turbulence by cooling surface and PBL while heating the atmosphere above it when aerosols with certain absorption characteristics concentrated in PBL" in the manuscript.

Comment 4) Page 4, line 77: "A Red-alert Heavy Haze occurred on 15 to 17 December", 15-23 Dec.

Response:

"15-17 Dec" is corrected as "15 to 23" in this line.

Comment 5) Page 4, Section 2.1, the model GRAPES_CUACE need to be introduced more detail, as well the setup of the simulations.

Response:

The detailed introduction of model GRAPES_CUACE is added in the section 2.1 including the related test and an added Table 1 including model dynamic frame and physical package in the revised manuscript; Section 2.4 Experiments Design (line 169-185) and table 2 are rewritten to introduce the setup of the simulations.

Comment 6) Page 5, Section 2.2, just lists the air pollutants, not relevant information crucial to this paper is given.

Response:

Line 107-110 in section 2.2 is revised to introduction the emission data in the revised manuscript and table 2 is added to list all VOCs emission used.

Comment 7) Page 5-6, Section 2.4, too simple in description. Table1, repeated, but still too simple.

Response:

Section 2.4 (line 169-185) and table 2 are rewritten to display the setup of the simulations in the revised manuscript.

Comment 8) Page6, line131:"which is named as the explosive growth (EG)", this is the first time mentions "explosive growth". Nothing is known what is the cause of EG: chemistry, transport, or accumulation of air pollutant?

Response:

From 00UTC on 17 to 00UTC 20 21 December, PM2.5 increased sharply and most of the study area reached the PM2.5 peaks of 400-600 ug/m3 rapidly during this period, which is named as the explosive growth (EG) stage (EGS) of $PM_{2.5}$.

The cause of EG involves in several aspects such as meteorology, aerosols radiation feedback, chemistry, and transport etc. In this work, diffusion process of meteorology impacts and aerosols feedbacks were mainly discussed and regarded to contribute greatly to the $PM_{2.5}$ EG. This is the main aim in section 3. A short paragraph is added in section 3 to explain this.

Comment 9) Page 6, Section 3.1, only PM2.5 is investigated. What about its source: primary or secondary? What about other pollutants? And their effect on $PM_{2.5}$ concentration?

Response:

Yes, there are many elements affecting PM2.5, such as emission, primary or secondary, gases and so on, but our study title is "The Contributions to the Explosive Growth of $PM_{2.5}$ Mass…….". If we focus on the reason for the explosive growth of $PM_{2.5}$, the atmosphere stable condition (turbulence diffusion) and the key elements what may result in distinct changes of it (AF) are the most important because the effects of primary or secondary aerosols and gas on $PM_{2.5}$ concentration does not changes so greatly from clear day to $PM_{2.5}$ EG stage during severe episode.

Comment 10) Page 7, Section 3.2, directly presents result of temperature profile, no logic description about the relation of AF and inversion strengthening. No qualitative and quantitative assessment on question if the result is right or correct.

Response:

Figure 6 in the revised mancuscription is the vertical profiles of temperature changing due to aerosols feedback and it offered the qualitative and quantitative cause of the results of temperature inversion changing in Figure 7, line 158-177 is the explanation how the radiative cooling/heating rates due to aerosols resulted in the temperature inversion in figure 7 and offered quantitative temperature changes during CS and EG stage. Figure 7 displayed the observational and modeled temperature profiles and showed their obvious corrections by AF comparing with observation.

Anyway, we guess the reviewer want to know how the vertical profiles of temperature changing due to aerosols (figure 6) is calculated, so the detailed description of model introduction in section 2.1 is added to explain how the DT/dt_aero is calculated and impacts on model thermodynamics and then dynamic and physics.

Comment 11) Page 8, Section 3.3, the text is very difficult to read through since too many abbreviates.

Response:

The abbreviates "EGS， DC_bk, DC_td_af, DC_td20_af, $PM_{2.5}$_bk, $PM_{2.5}$_td_af, $PM_{2.5}$_td20_af" are deleted and only the abbreviates "EXP1, EXP2, and EXP3" are remained in the revised manuscript.

Comment 12) Page 9, line 220-221: " significant decrease in turbulent diffusion on PM2.5 during EGS and DC_td_af was as low as 14m2/s on 20 December, which decreased about 50% comparing with DC_bk.", this sentence need to clarify. And "DC was 14m2/s", in where? What level? What time? Day or night?

Response:

This paragraph is corrected as "PBL DC at noon of EXP2 was as low as 14m^2/s on 20 December, which decreased about 50% comparing with that of EXP1. PBL DC at noon of EXP2 on haze day was only about 20% of that on clear day. The PBL DCat noon……"

Comment 13) Page 10, line 245: "...we name it as 'turbulent intermittent"', What do you mean the 'turbulent intermittent'? Does 'turbulent intermittent' really mean lower diffusion coefficient or mixing rate?

Response:

When the turbulence diffusion processes is extreme weak and near zero turbulence, it is name "turbulent intermittent", in this study, when DC value is less than 4 to 6 m^2/s, we consider it is near zero the turbulence diffusion named it as "turbulent intermittent".

A brief explanation is added in this line in the revised mancusript.

Comment 14) Page 10, line 253-254: "for the deficient description of extreme weak turbulent diffusion by PBL scheme in atmospheric models, are studied by analysing the changes of...", nothing about the PBL scheme is presented in this paper.

Response:

The introduction of DC calculation and PBL scheme and related references are added in line 118-126 in the revised manuscript.

Comment 15) in Table 1, "retaining 20% (reducing 80%) of normal turbulent diffusion", How to do this? Reducing the value at all the model domain?

Response:

The 80% reduction in turbulent diffusion coefficient (DC) is implemented in the chemical tracers (gas and particles) in the chemical module CUCAE. DC outside the CAUCE is not changed in the other parts of the model. Yes, The 80% reduction is applied to all simulated domain, but JING-JIN-JI region is mainly discussed in this study.

The solar radiation is the major cause of turbulence diffusion and PBLH diurnal changing during daytime. The observation study showed that the direct solar radiation on severe haze days is reduced 89% comparing with clear day in Beijing during the same period with this study (the following figure if from the result by Zhong, J.T., et al., 2018). The 80% reduction of turbulence diffusion is mainly according to this study. This reason is also added in section 2.4, Line 162-178; The wind speed changing (also an indicator of turbulence diffusion) from clear to haze days is added (figure 3 in the revised manuscript) in the revised paper, which also support the supposing of 80% reduction of DC.

Comment 16) in Figure 5, the DC, at what position? What level/height?

Response:

The vertical level information of DC is added in the caption of figure 5