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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Anthropogenic forcing of shift in precipitation in Eastern China in late 1970s" *by* T. Wang et al.

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Response to the comments on "Anthropogenic forcing of shift in precipitation in Eastern China in late 1970s" of referee 3

Review's comments for the paper (acp-2013-48) "Anthropogenic forcing of shift in precipitation in Eastern China in late 1970s" General comments By using coupled ocean-atmosphere general circulation model ensemble simulations with different external forcing, this paper attempts to attribute the anomalous precipitation pattern experienced over East Asia during the second half of the 20th century which is characterized by a dipole pattern with increased rainfall in the middle and lower reaches of the Yangtze River Valley and decreased rainfall in northern China. The manuscript concludes that

this dipole structure of precipitation anomalies is mainly caused by the combined effect of increasing global greenhouse gases and regional aerosol emissions over China. The paper further argues that the increasing greenhouse gases induce tropical warming and a westward shift of the western Pacific subtropical high, leading to more precipitation in southern China. At the same time the aerosol cooling effect over land contributes to a reduced summer land–sea thermal contrast and therefore to a weakened East Asian summer monsoon and to drought in northern China. Consequently, an anomalous precipitation pattern starts to emerge in eastern China. The results are interesting and worth of publication after addressing the following questions.

Specific comments

1. The model simulation in response to all forcing (ALL150) shows a dipole pattern of precipitation anomalies over East Asia, similar to that based on observations occurred during the second half of the 20th century. However, the sum of the response to natural forcing (NAT150) and that to anthropogenic forcing (ANT150) does not reproduce the precipitation pattern seen in all forcing experiment. The reviewer likes to see more understanding and comments on this nonlinear behavior in the model.

Response to the comment 1: Please see the Response to comment 3 shown below. Thanks very much!

2. The paper argues that the increasing greenhouse gases induce tropical warming and a westward shift of the western Pacific subtropical high, leading to more precipitation in southern China. At the same time the aerosol cooling effect over land contributes to a reduced summer land–sea thermal contrast and therefore to a weakened East Asian summer monsoon and to drought in northern China. However, there are no enough evidences in the paper to support these statements since there are no experiments performed to assess the separate roles of increasing greenhouse gases and of increasing aerosols.

Response to the comment 2: We agree on this point. Due to lacking of only-aerosols

ensemble, it is hard to examine the climatic effects of the aerosols. In the revised manuscript, we used the responses of land to the strong convection and increased precipitation, as you suggested, to explain the slightly cooling and less pronounced warming over eastern China in ALL150 and ANT150. At the same time, we pointed out that the surface cooling effects of anthropogenic aerosols could also contribute to them (please see P14, L15-32, P15, L1-3 in the revised manuscript).

3. The paper claimed that ANT150 simulated the weakened EASM and associated the anomalous precipitation pattern. But various figures shown in the paper do not support this conclusion. Therefore, the conclusion that anthropogenic forcing is responsible for the observed precipitation changes experienced during the second half of the 20th century is not justified.

Response to the comment 3: We agree on your point. In the revised manuscript, we added more analysis on the anomalous precipitation pattern and associated climate changes. We think the present analysis is enough to support the close relationship between anthropogenic forcings and the interdecadal shift in precipitation over eastern China in the late 1970s. As follows: Fig. 7 and Fig. 8 show the earlier happened (about 5 years) anomalous precipitation pattern (increased precipitation over the YRV whereas decreased precipitation over the NC). Fig. 10d and Fig. 11b show the westward shift of the western Pacific subtropical high (WPSH) in the ANT150. Fig. 12d shows the strong warming over the Indian Ocean and South China Sea. Fig. 14d and Fig. 15b show the southward displacement of East Asia westerly jet (EAJ). In the Fig 18d, the cyclonic wind anomalies over the southern part of eastern China imply a strong convection, which is a key factor to enhance precipitation there. Fig. 19d shows a weak warming over eastern China surrounded by strong warming ocean. In fact, the ANT150 simulated an earlier happened climate shift compared to ALL150. In the revised manuscript, changes in the Indian Ocean SST is crucial, and acts as a bridge to link the anthropogenic forcings and East Asian climate. Through warming the Indian Ocean SST, the anthropogenic forcings lead to the westward shift of the WPSH and

southward displacement of EAJ, which ultimately led to enhanced water vapor transport and summer precipitation over the YRV region. At the same period, the surface cooling effects from the stronger convection, higher precipitation and rapidly increasing anthropogenic aerosols lead to the negative temperature anomalies over the eastern China. It is in stark contrast with the surrounding warming ocean caused by the increased greenhouse gases, resulting in reduced land–sea thermal contrasts. By the cooperation of the westward shifted WPSH, the southward shifted EAJ and reduced land–sea thermal contrasts, the EASM weakened and the summer precipitation deceases over the NC. During the late 20th century, the natural forcings plays an opposite role in regulating the changes in WPSH (Fig. 11c) and EAJ (Fig. 15b), and lead to an enhanced southerly wind over eastern China (Fig. 18e) and associated precipitation (Fig. 5e and Fig. 6). The natural forcings postpone the anthropogenic agents forced climate changes in eastern China, making ALL150 well coincide with the observations (more detail can be seen in the revised manuscript). AT the beginning, the response of the Indian Ocean SST to the anthropogenic heat and natural cooling is likely linear. And then, the displacements of the WPSH and EAJ are the responses of them to the Indian Ocean SST. In this process, the internal variability of the climate system is also involved, thus showing a nonlinear process. Therefore, the ALL WPSH is not equal to the sum of ANT150 WPSH and NAT150 WPSH. So is for the precipitation, it is the final results of multi factors.

4. Lines 4-7 on page 7. “the negative-positive-negative precipitation anomalies do appear in ANT150, implying linkages between the anthropogenic forcing agents and the change in the observed precipitation”. The pattern shown in figure 5d is very different from either Figure 5a or Figure 5c, and therefore does not support that observed pattern is anthropogenic related. Meanwhile, it seems that the sum of figure 5d and figure 5e is very different from figure 5c. The reviewer likes authors to make comments on this nonlinearity and clarify their attribution statements.

Response to the comment 4: Please see the Response to comment 3 above. Thanks

very much!

5. On page 7. Figure 6 shows negative trend in both the NC and YRV regions in ANT150 experiment. Correlation with observations in the YRV is also negative. The running trends in the NC and YRV shown in figure 7b in the last 50 years show a similarity to those in figure 7a, but figure 7c does not. Therefore, figures 5, 6, and 7 do not support your attribution statement that the IVSP in late 1970s is likely controlled by anthropogenic factors.

Response to the comment 5: In the revised manuscript, we put the original Fig. 7b and Fig. 7c together. Fig. 8a in the revised manuscript actually suggests an earlier (about 5 years) happened precipitation shift in ANT150 compared to ALL150. The corresponding pattern is shown in Fig. 8b. Together with the analysis on the WPSH, EAJ, circulation and surface anomalies, this similar shift in precipitation and associated climate changes indicate that IVSP in late 1970s is likely controlled by anthropogenic factors. More detail can be seen in the revised manuscript.

6. Line 24-26 on page 8. The pattern of circulation anomalies over East Asia and Northwestern Pacific shown in Figure 9d is not similar to either figure 9a or figure 9c, and therefore does not support your statement that the observed climatic features were partly captured by ANT150.

Response to the comment 6: In the ANT150, the similar climate shift happened during the period of 1953-1990. Therefore, we used this period as parallel analysis in the revised manuscript (please see the Fig. 18). In Fig. 18d, ANT150 simulates weakened summer monsoon circulation over Southeast Asia and South Asia. At the same time, ANT150 simulates cyclonic wind anomalies over southern part of eastern China, which is a direct reason to increase precipitation there. These changes are very similar to ALL150. The significant southerly wind anomalies over North China are possibly caused by the much stronger warming over the northern of China (Fig. 19d). The differences imply that the regulating from natural forcings is also very important for well

reproducing the past climate changes.

7. Lines 3-6 on page 9. This statement is very confusing. The tripole structure of observed SAT anomalies with cooling in the middle might indicate that the cooling is the response of land surface to enhanced convection since it is expected that enhanced convection reflects more shortwave radiation. Meanwhile enhanced precipitation enhances surface evaporative cooling. Both processes might be responsible for the cooling. It is not convincing that this anomalous temperature distribution causes a weakened EASM.

Response to the comment 7: We agree on this point and modify accordingly. Please see Page 14, Line 12-32, Page 15 Line 1-7 in the revised manuscript. Thanks very much for this comment and suggestion. In the revised manuscript, we attribute the weakened EASM to the cooperation of the westward shifted WPSH, the southward displaced EAJ and the reduced land-sea thermal contrast.

8. Lines 20-22 on page 9. The lack of cooling in ANT150 shown in Figure 10d does not support your comments that the slight cooling in ALL150 over eastern China is most likely attributed to the cooling effect of increased anthropogenic sulphate aerosols there.

Response to the comment 8: We agree on this point. The present model results cannot support the conclusion that the slightly cooling over eastern China in ALL150 is caused by aerosols, particularly when we lack of an only aerosols simulation. In the revised manuscript, we attribute these cooling and less pronounced warming over eastern China partly to the natural forcing (i.e. volcanoes), and partly to the responses of land surface to enhanced precipitation (surface evaporative cooling) and convection (reflecting more shortwave radiation) as your suggestion. At the same time, we also point out that the cooling effects from anthropogenic aerosols are not negligible either, which could contribute to these cooling or less pronounced warming in ALL150 and ANT150. The detail analysis please see P14,L12-32. Thank you for this comment.

9. Lines 24-28 on page 9. There are no evidences to support these statements.

Response to the comment 9: please see the response to comment 8.

10. Unless you can justify your attribution statement about the role of the anthropogenic forcing in observed precipitation changes, further analysis about the changes in the subtropical high does not help much.

Response to the comment 10: In the revised manuscript, we connect multi factors of the East Asian summer monsoon system to the external forcings via changes in the Indian Ocean SST, and address the final response of the summer precipitation to the anthropogenic forcings and associated climate changes. Thanks for this comment.

11. Lines 12-19 on page 11. These conclusions are not justified.

Response to the comment 11: In the revised manuscript, based on the present analysis, we conclude as follows (Page 15, Line 9-28): "The model results presented here, together with observations, suggest that anthropogenic forcings are most likely the prime drivers for the IVSP over eastern China in late 1970s. The increased greenhouse gas concentrations induced Indian Ocean warming causing a westward shift of the WPSH and a southward displacement of the EAJ, which ultimately led to enhanced water vapor transport and summer precipitation over the YRV region. At the same period, the surface cooling effects from the stronger convection, higher precipitation and rapidly increasing anthropogenic aerosols lead to the negative temperature anomalies over eastern China. It is in stark contrast with the surrounding warming ocean caused by the increased greenhouse gases, resulting in reduced land–sea thermal contrasts. By the cooperation of the westward shifted WPSH, the southward shifted EAJ and reduced land–sea thermal contrasts, the EASM weakened and the summer precipitation deceases over the NC. Consequently, the IVSP started to emerge in eastern China since the late 1970s. This study highlights the dominant roles of anthropogenic forcings in the interdecadal changes of the East Asian climate during the second half of the 20th century. In addition, the external natural forcing plays an opposite role to the

anthropogenic forcing in regulating the changes in WPSH and EAJ and mitigating the surrounding ocean warming of the eastern China, and postpones the anthropogenic forced IVSP and associated climate changes in eastern China in ALL150 during the second half of the 20th century. This is likely the reason why ALL150 compares so well with the observations."

Technical corrections Figure 2 caption. Shall the unit of aerosol burden being mg m-2 Response: Modify accordingly. Thanks very much for this correction.

Interactive comment on Atmos. Chem. Phys. Discuss., 13, 11997, 2013.