Report #1

Many of the responses from the authors to my comments were acceptable and the revised manuscript has been better than the previous one. However, there still were some points in the revised manuscript which I think further reconsideration is necessary to be published. I also noticed several description errors in the authors response which made me a bit confused, although they were not so serious, such carefulness should be removed before the submission of revised manuscript. The followings were my concerns for the revised manuscript (Line numbers are for the revised manuscript).

- Reply: Thanks for the valuable comments. We have revised our manuscript accordingly.

- L168-174: The flow chart in Fig.2 was informative, but could you spend more word to explain why ARE bring positive (warming) response to AT (atmospheric temperature) but negative for T2m? Which level (altitude range) of the atmosphere do you consider for AT? (Within PBL or free troposphere?)

- Reply: AT represents the atmosphere within PBL as air pollutants are mainly concentrated in PBL. T2m is mostly influenced by surface forcing like sensible heat and latent heat flux. ARE cuts amount of downward shortwave radiation reaching the ground, reduces sensible heat flux, and decreases surface air temperature (Yu et al., 2006). Absorbing aerosols like black carbon and dust in the atmosphere absorb shortwave radiation and heat the atmosphere (Ding et al., 2016).

- Yu, H., Kaufman, Y. J., Chin, M., Feingold, G., Remer, L. A., Anderson, T. L., Balkanski, Y., Bellouin, N., Boucher, O., Christopher, S., DeCola, P., Kahn, R., Koch, D., Loeb, N., Reddy, M. S., Schulz, M., Takemura, T., and Zhou, M.: A review of measurement-based assessments of the aerosol direct radiative effect and forcing, Atmospheric Chemistry and Physics, 6, 613-666, 10.5194/acp-6-613-2006, 2006.

- Ding, A. J., Huang, X., Nie, W., Sun, J. N., Kerminen, V. M., Petäjä, T., Su, H., Cheng, Y. F., Yang, X. Q., Wang, M. H., Chi, X. G., Wang, J. P., Virkkula, A., Guo, W. D., Yuan, J., Wang, S. Y., Zhang, R. J., Wu, Y. F., Song, Y., Zhu, T., Zilitinkevich, S., Kulmala, M., and Fu, C. B.: Enhanced haze pollution by black carbon in megacities in China, Geophysical Research Letters, 43, 2873-2879, 10.1002/2016gl067745, 2016.

- We have revised Fig. 2 to make it clear.

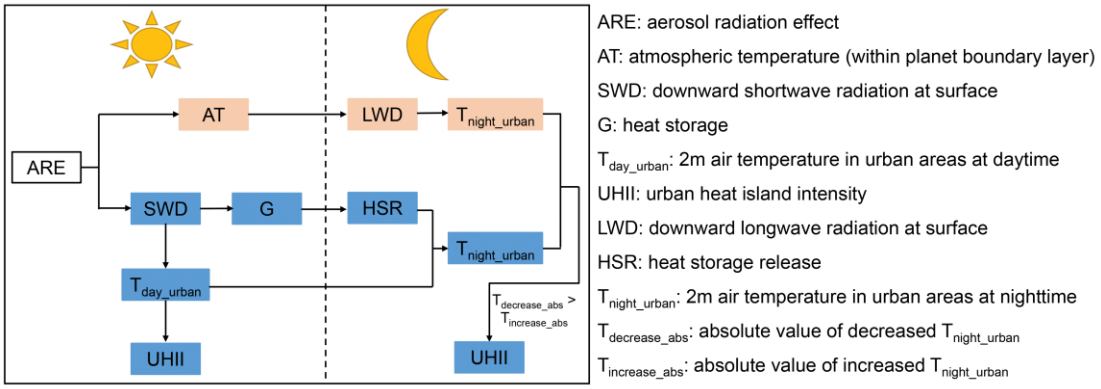

Figure 2: Flow chart shows how UHII is changed at daytime and nighttime, assuming that rural areas are not influenced by ARE. Pink boxes show increasing trend while blue ones show decreasing trend.

- L180: In the author response about the L140 of the previous manuscript, you mentioned that "We modified the expression in the manuscript to "We observe elevated UHII when northerly winds are prevalent in urban areas on polluted days (Fig. 3a, c). The mean UHIIs are 2.0 and 1.8 K at daytime and 2.9 and 2.8 K at nighttime on clean and polluted days, respectively. This is because northerly winds reduce aerosol concentrations in urban areas (Table 1). Although PM2.5 concentration in urban areas is relatively reduced, it is still high enough to keep the entire area classified as polluted", however, the revised manuscript was not modified so. Is your response correct?

- Reply: The response was not correct because we further modified the manuscript.
- It should be "We observe elevated UHII when northerly winds are prevalent in urban areas on polluted days (Fig. 3a, c). The mean UHIIs are 2.0 and 1.8 K in daytime and 2.9 and 2.8 K in nighttime on clean and polluted days, respectively. This is associated with reduced aerosol concentrations in urban regions by northerly winds in urban areas (Table 1). From clean to polluted conditions under northerly, lower reduction in UHII by aerosols is accordingly found (Fig. 3)."

- L207: The simulated UHII in Figs. S7 and S8 should be site-based. You should clearly state it in the manuscript and the figure captions of these figures, since you described that simulated UHII is defined as area-based in chapter 2.4 (Calculation of UHII) and the case for Figs S7 and S8 is exceptions of this policy.

- Reply: We have stated that the simulated UHII in these two figures are site-based in the manuscript and the figure captions.
- Further validation of the ability of the model to simulate site-based UHII is shown in Fig. S7 and Fig. S8.
- Figure S7. Observed and simulated UHII by AF in Case_2010 in Beijing (a) and the locations of the used sites (b). Simulated UHII here is site-based.
- Figure S8. Observed and simulated UHII by AF in Case_2018 in Beijing. Observations are obtained from the stations listed in Table S1. Simulated UHII here is site-based.

- L211-212: The sentence here is not easy to understand. The "apparent" larger decreases (especially in nighttime) you mentioned here would not be UHII but delta_UHII, however the current sentence does not describe it well. Just a word "decreases" does not necessarily be understood as decrease of UHII by ARE.

- We changed the sentence to: "To better clarify the influence induced by selection of rural areas, we added Fig. S9 to show the simulated UHII calculated based on site locations and area average. Apparent difference can be found that site-based ΔUHII (difference due to ARE) decreases more than area-based UHII especially in nighttime because of lower PM2.5 concentrations in the rural sites than selected rural area.".

- L216-220: The new Fig. 4 become better than the previous one, but still difficult to properly understand what you want to mean here. In L216, your described "changes in T2m occur earlier in rural areas", but it's difficult for me to recognize such "earlier occurrence of T2m change in rural than in urban" in Fig4b and 4d. In L218-219, you also described "temperature in rural areas exhibits earlier declines in response to ARE, as indicated by ARE induced changes in T2m in Fig. 4b, d", but I could not properly recognize such "earlier decline in rural temperature" in these figures.

Furthermore, you also described "ARE results in the earlier decrease in T2m of rural areas (Fig. 4b)" in L220 as a cause of the second peak, but it's difficult for me to recognize it too. I think the multiple lines in each figure in Fig.4, which are overlapped and/or entangled each other, made it difficult to properly recognize the points you indicated in these sentences. Could you further revise Fig4 for the readers including me to recognize such points easier?

- Reply: We have added two subgraphs showing hourly changes in temperature in Fig. 4, this makes it easier to identify the earlier changes of T2m in rural areas. We have also modified Fig. 5.

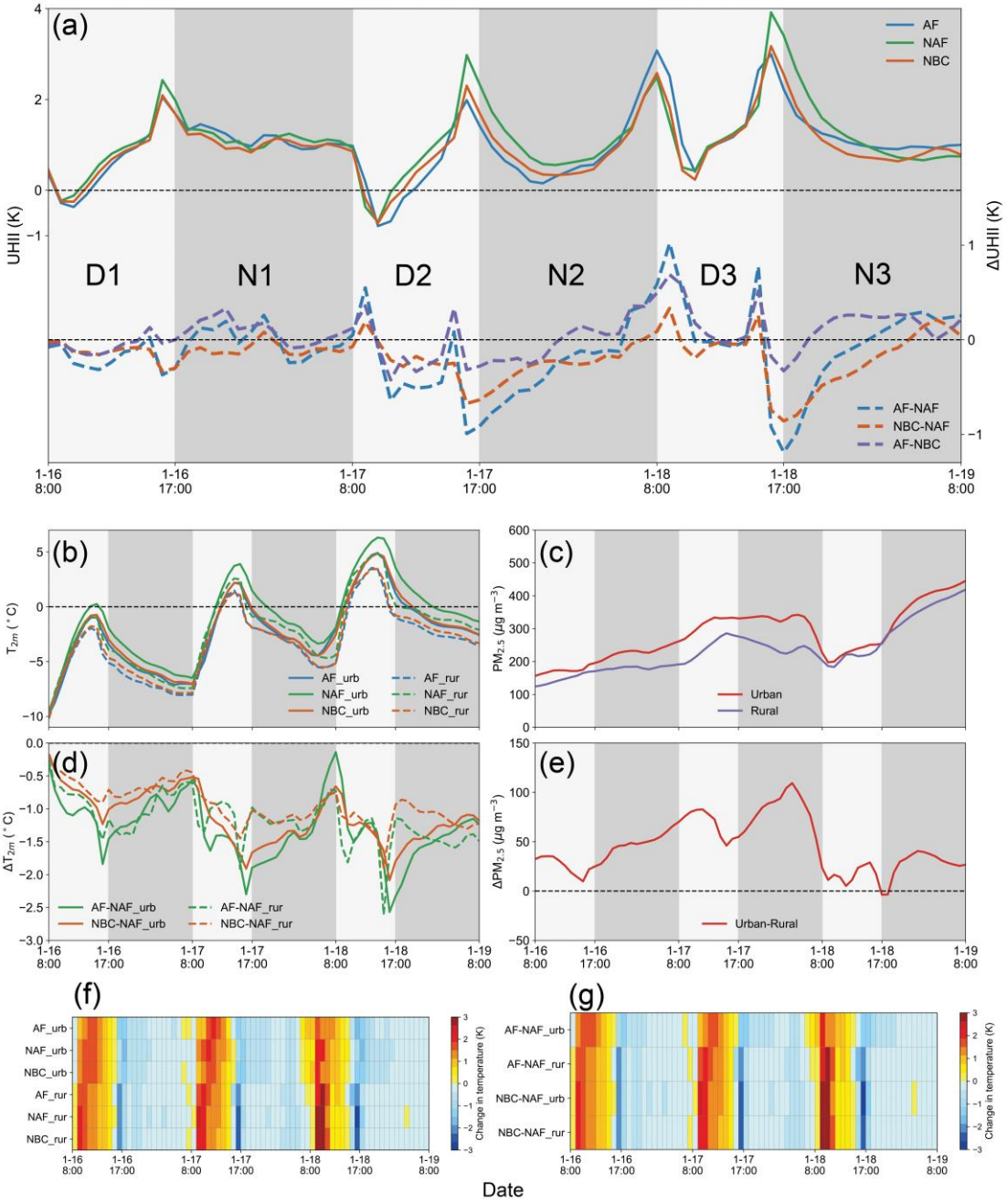

Figure 4: Variations of $UHII_{sim}$ of all cases and difference across them (a) in Case_2010. Variations of T_{2m} (b) and $\triangle T_{2m}$ (d) in urban and rural areas. Variations of $PM_{2.5}$ (c) and $\triangle PM_{2.5}$ (e) in urban and rural areas of AF case. Hourly changes in T_{2m} (f) and $\triangle T_{2m}$ (g) in urban and rural areas. AF-NAF represents the influence of ARE on UHII. NBC-NAF represents the influence

of ARE on UHII by all aerosols but BC. AF-NBC represents the influence of BC absorption on UHII.

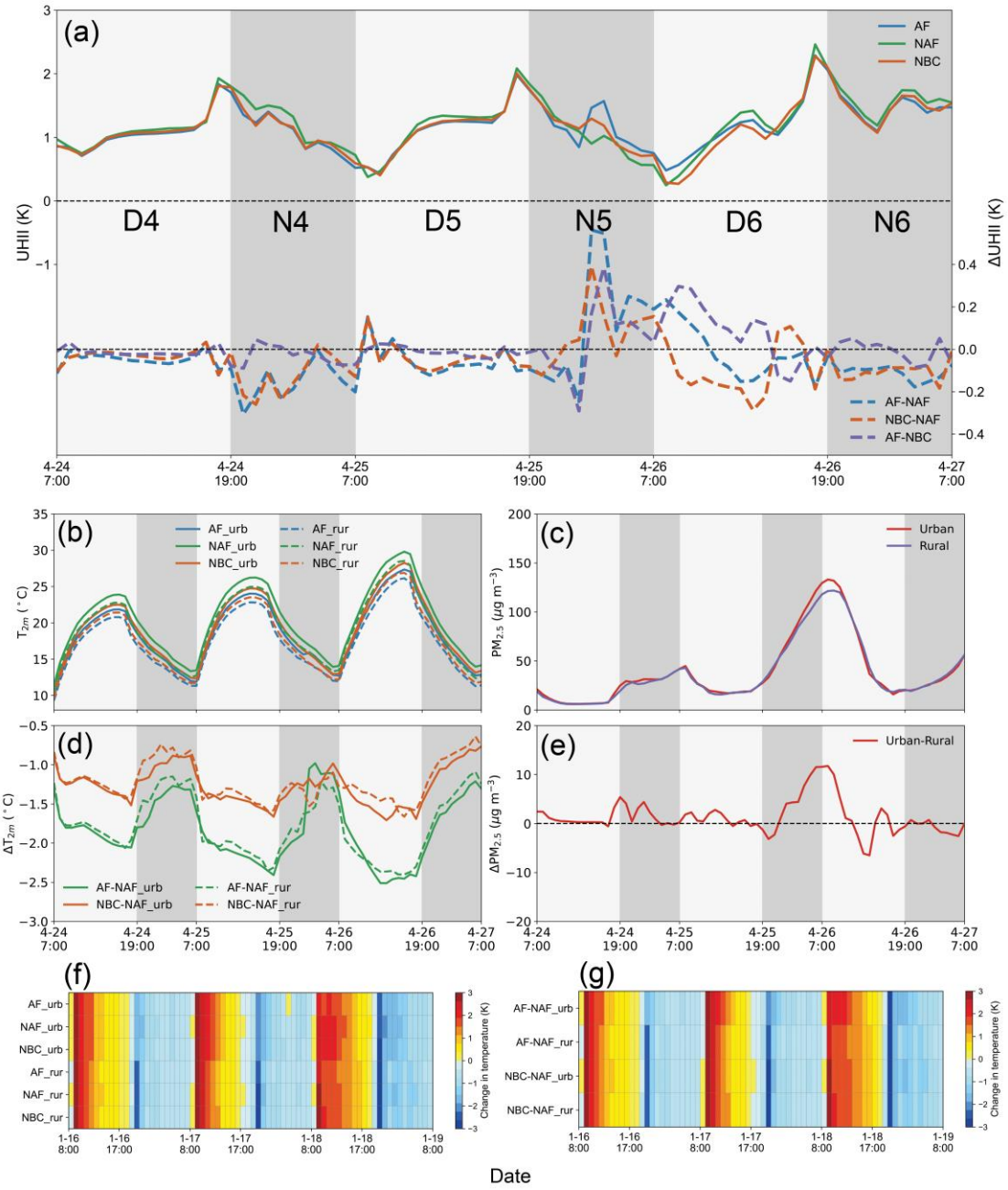

Figure 5: Same as Fig. 4 but for Case_2018.

- L22-223: You mentioned that “heat storage is smaller in daytime but reaches zero earlier than it in urban areas (Fig. S10c, d)”, but I could not see the heat storage in rural reaches zero earlier than it in urban in Fig S10, rather it reached zero later than it in urban, although the lines in Fig S10 are also hard to be distinguished each other (You should revise this figure too). If you want to mean the slower release of heat in rural than in urban, I think the heat storage in rural should reach zero LATER than it in urban.

➢ Reply: Yes, it should be later, and we have corrected it: “as suggested in Fig. S10 that heat storage is smaller in daytime but reaches zero later than it in urban areas”.

➢ We have revised the figure to make it easier to be distinguished.

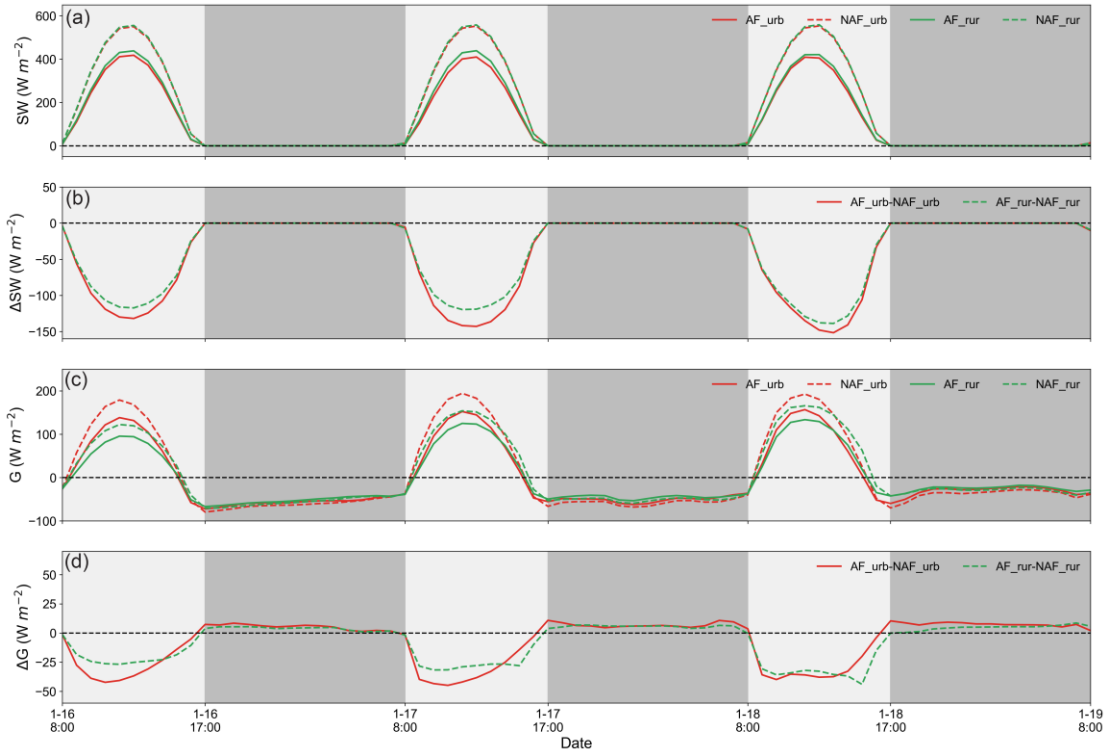

Figure S10. Variations of (a) downward shortwave radiation, (b) difference of downward shortwave radiation between AF and NAF, (c) heat storage and (d) difference in heat storage between AF and NAF in urban and rural areas in Case_2010.

- L223: I could not understand properly the causal relationship between the slower hear release and the faster decline of T2m in rural which you described here. Could you use more words to explain it clearly?

➢ Reply: Based on the theory of surface energy balance, heat storage release contributes to upward sensible heat flux at the ground which makes T2m keep on increasing after midday and decrease at a slower pace after it reaches the peak in the afternoon (Oke et al., 1992). Therefore, a slower heat storage release results in a faster decline of T2m in rural areas.

➢ Oke, T.R., Zeuner, G. and Jauregui, E.: The surface energy balance in Mexico City. Atmospheric Environment. Part B. Urban Atmosphere, 26(4), pp.433-444, 1992.

➢ We added this description in the manuscript to avoid confusion: Heat storage release contributes to upward sensible heat flux at the ground, which further increases T2m after midday and slows down the decreases after the peak in the afternoon (Oke et al., 1992).

- L225: What does “reverse the change rate of T2m” mean here? Could you describe it more precisely?

➢ Reply: We wanted to explain that ARE reduces heat storage in both rural and urban areas, under this circumstance, the smaller heat storage and slower release of heat in rural areas make T2m decrease earlier.

➢ We change the expression to “ARE reduces heat storage in both rural and urban areas, and the smaller heat storage and slower release of heat in rural areas make T2m decrease earlier,

leading to the second peak and valley."

- Fig S12: Could you add N1, N2, N3 in the figure or figure caption? Why did you use NBC-NAF, which represents the ARE by all aerosols but BC, in FigS12? If you want to show the impact of BC in this figure, you must use AF-NBC instead.

➢ Reply: We have added N1, N2, N3 in the figure and replaced NBC-NAF with AF-NBC.

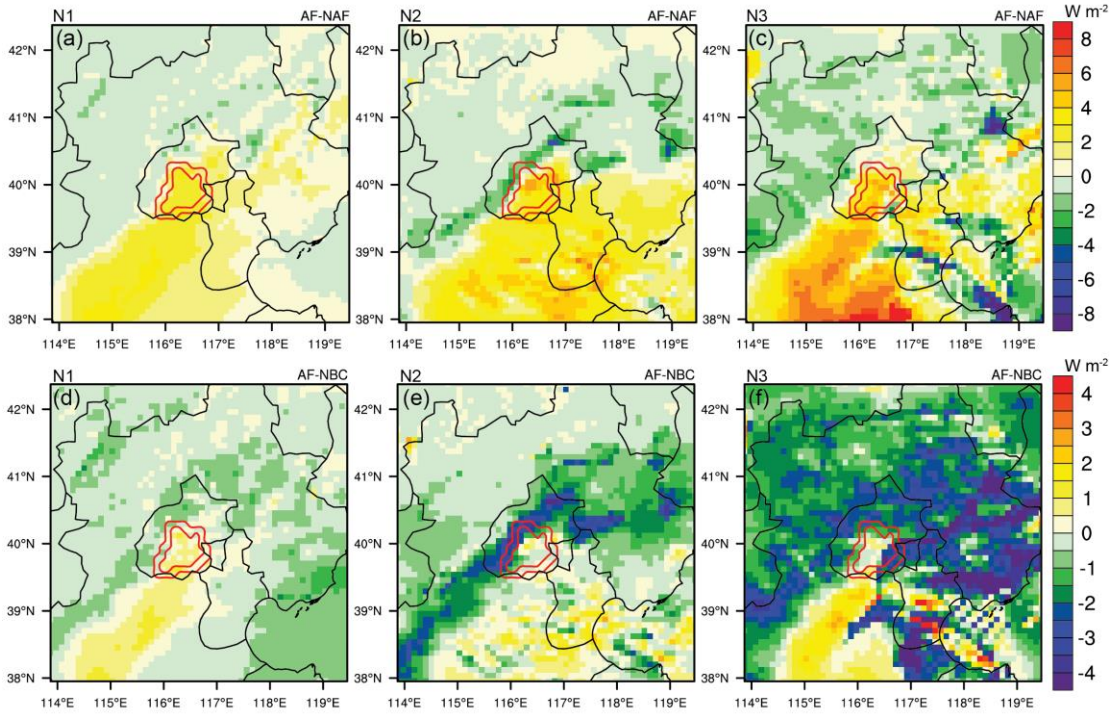

Figure S12. Simulated difference in downward longwave radiation between AF and NAF (first row), AF and NBC (second row) at nighttime in Case_2010. The areas within the inner red line are urban areas. The areas between the two red lines are rural areas having the same size as the urban areas.

- L242: You described that "the impacts of aerosols on UHII are mainly generated by modified downward longwave radiation in nighttime", but from delta_UHII shown in Fig4a, I could not agree with it. The delta _UHII clearly shows large impact of aerosol on UHII in daytime. Could you discuss more about it here?

➢ Reply: Yes, Fig 4a clearly shows large impacts of aerosol on UHII in daytime. This sentence means modified downward longwave radiation is the main process that is influenced by aerosols in nighttime to generate impacts on UHII.

➢ To avoid confusion, we changed the sentence to: The impacts of aerosols on UHII in nighttime are mainly generated by modified downward longwave radiation.

- L243: Could you describe more precisely about what does "thermal difference of the atmosphere" mean?

➢ Reply: "Thermal difference of the atmosphere" means thermal difference between urban atmosphere and rural atmosphere. We changed it to UHII to avoid misunderstanding.

- L248: N6 should be N5

➢ Reply: We have changed N6 to N5.

Report #2

1. Line 43: Is UHI or UHII commonly calculated as the temperature difference between a city and surrounding rural areas?

- Reply: Yes. A UHI is an urban or metropolitan area that is significantly warmer than its surrounding rural areas, therefore, the temperature difference between a city and surrounding rural areas is often used to quantify the intensity of UHI (Oke, 1973; Deilami et al., 2018).
- Oke, T. R.: City size and the urban heat island, Atmospheric Environment (1967), 7, 769-779, 10.1016/0004-6981(73)90140-6, 1973.
- Deilami, K., Kamruzzaman, M., and Liu, Y.: Urban heat island effect: A systematic review of spatio-temporal factors, data, methods, and mitigation measures, International Journal of Applied Earth Observation and Geoinformation, 67, 30-42, 10.1016/j.jag.2017.12.009, 2018.

2. Line 88: Were the 2010 and 2018 MODIS land cover data used for the 2010 and 2018 simulations, respectively? Which year's MODIS land cover data were shown in Fig. S1?

- Reply: Yes, we used 2010 and 2018 MODIS land cover data for the 2010 and 2018 simulations, respectively, as we stated in Section 2.2 that "We introduced the Moderate Resolution Imaging Spectroradiometer (MODIS) land cover data in 2010 and 2018 into simulations to better capture the spatial distribution of different land use types (Fig. S1)."
- We revised Fig. S1 to show land cover in both 2010 and 2018.

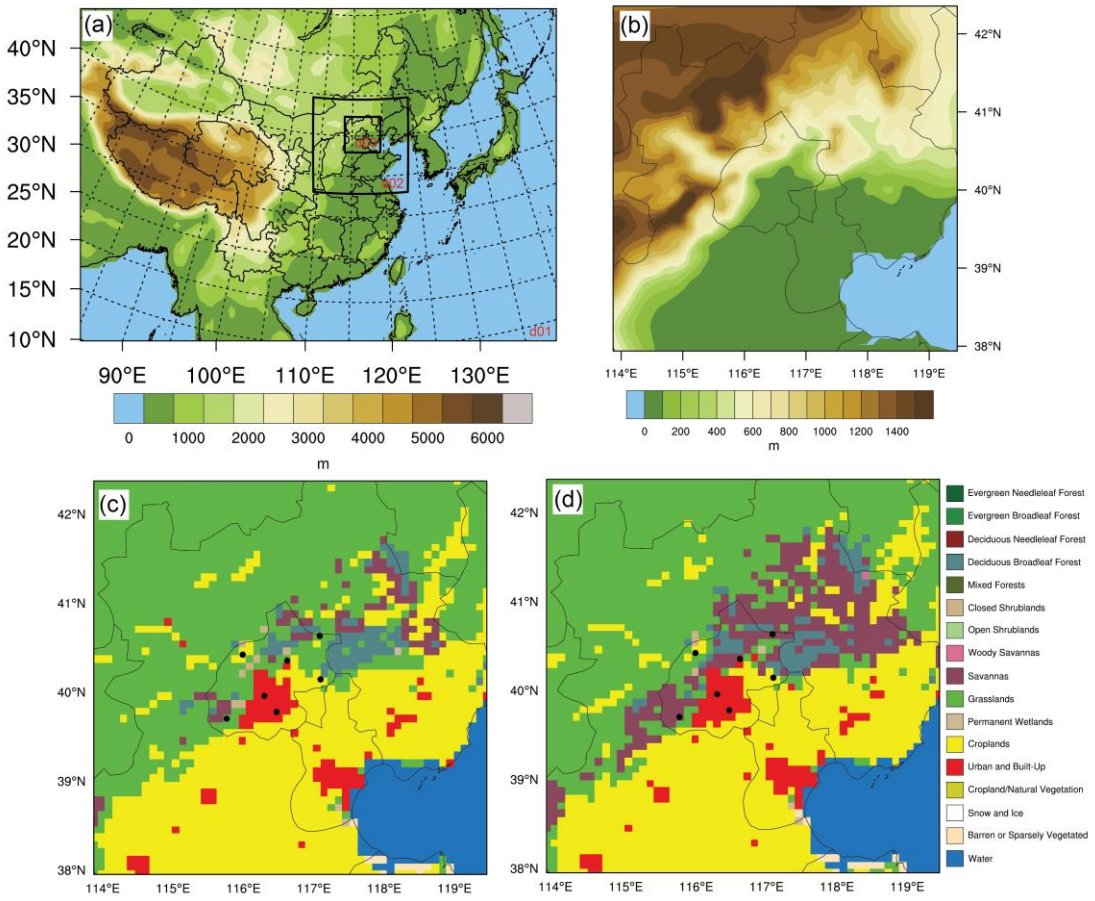

Figure S1. WRF-Chem domain configuration with terrain height (a), terrain height of the innermost domain (b), land use categories of the innermost domain of Case_2010 (c) and

Case_2018 (d) (Black dots in b represent locations of automatic weather stations).

3. Line 129: the study period should end on April 27, 2018.

- Reply: We have changed it.

4. Line 151: Please change it to "…rural stations were classified as the polluted ones of urban stations …".

- Reply: We have changed it.

5. Line 173: What process does it refer to in the sentence "…smaller than that by the process during daytime." Please clarify.

- Reply: The process refers to the decreased daytime temperature and heat storage release. We have changed the expression to "The increase of UHII due to strengthened longwave radiation process is smaller than the decrease of UHII caused by reduced temperature and heat storage release during daytime (see difference between Fig. 1b, c, e and f)".

6. Line 185: the logic and Fig. S4 indicates that ARE-induced enhanced longwave radiation reduces the weakening (instead of weakens as described in the manuscript) of UHII in nighttime.

- Reply: Yes. We have corrected it.

7. Fig. 6: suggest adding the location of Beijing in the map (e.g., in panels g, h, i), just as done in Fig. S11 and S12, since Fig. 6 is the only map shown in the main part of the manuscript.

- Reply: This figure contained the location of Beijing, but it was not clear. We have revised Fig. 6 to make them clear.

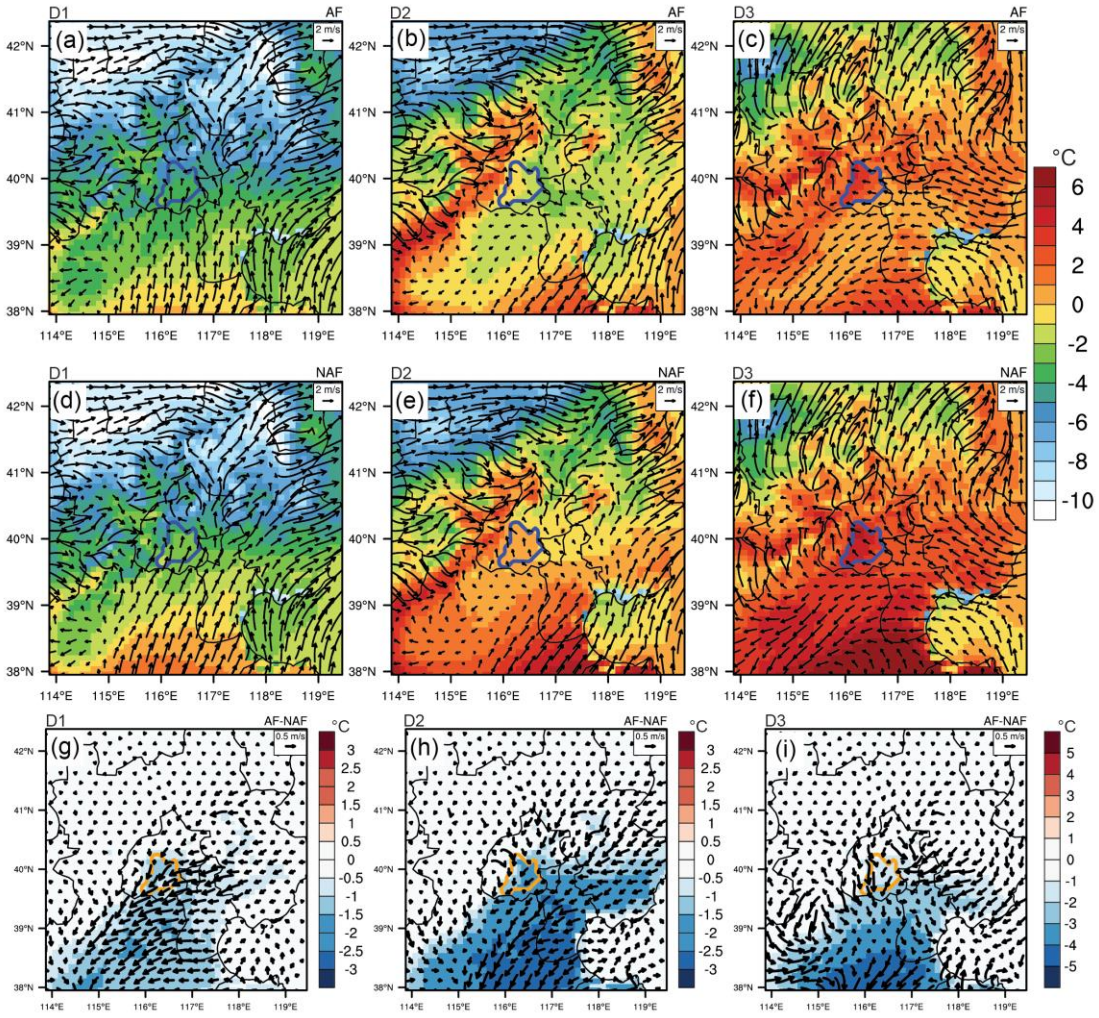

Figure 6: Simulated 2m air temperature and 10m wind field in AF (first row), NAF (second row) and differences between AF and NAF (third row) on D1 (first column), D2 (second column), and D3 (third column). The areas within the blue (a-f) and orange (g-i) line are urban areas of Beijing.