Anonymous Referee #2

This paper investigated the dynamics of urban boundary layer (UBL) in Beijing during a severe air pollution episode (1–4 December 2016) and interactions between UBL and surface energy balance (SEB). Although the topic of this paper fits the scope of ACP, the major drawback lies on the rather isolated analyses: how synoptic conditions, surface energy balance and urban boundary layer evolution interact with each other is not elaborated. Moreover, the feedbacks between these processes are not well summarized, which are expected to appear in the conclusion but unfortunately not. Also, given the context of this work being a megacity, urban signatures involved in the urban SEB and PBL dynamics (e.g., anthropogenic emissions, urban morphology, etc.) are largely missing in relevant discussions.

That being said, the separate analyses of synoptic conditions, SEB characteristics and UBL development are sound with detailed descriptions and appropriate comments on relevant studies. As such, this paper does show potential for publication after the above concerns are well addressed in a revised form.

Responses: We thank the reviewer for the overall positive assessment of the paper and for the constructive and valuable suggestions.

1) In our case, air quality was getting worse with decreasing wind speed. Such weak wind is negative to the turbulence transport, which means large heat will be stored in the urban canopy, resulting in the weak UBL evolution. Detailed description can be found in Line 255-259, Line 415-435, Line 463-466, Line 472-474, Line 511-525 and Line 624-647 in the revised paper. Moreover, a sketch map, Fig R2 (Fig. 12 in the revised paper) with some discussion have been added in section 3.4 in the revised paper to describe the interaction between the synoptic conditions (pressure, wind, temperature, relative humidity, etc.), surface energy balance and urban boundary layer evolution, and the interactions between the aerosol pollutants and UBL structure.

2) We totally agree with the reviewer that the urban signatures involved in the urban SEB and PBL dynamics (e.g., anthropogenic emissions, urban morphology, etc.) are significant for Beijing (and other megacities). Anthropogenic heat flux (Q_F) is an important component of the surface energy budget in urban areas. Unfortunately, Q_F is difficult to estimate due to the absence of accurate energy consumption and traffic flow data, and they often carry

considerable uncertainty (Sun et al., 2017). Therefore $G - Q_F = R_n - H - LE$ (also suggested by one of anonymous reviewers for this paper) has been analyzed in the revised paper. Besides, urban morphology plays an important role in the SEB and PBL dynamics, however, limited to the detail urban morphology information of Beijing, only the fact that large fraction of the impervious urban surfaces leads to the large urban heat capacity was discussed in the paper (Line 447-451). It should be pointed out that our focus here is on the difference of the heat storage characteristics between clean and polluted days. Was the Q_F, an additional energy source, not changed during different days in a short term, the large $(G - Q_F)/R_n$ would imply that more heat is stored in the urban canopy, compared with other term. We found that heat storage ratios during three polluted daytimes was larger mainly as a result of the reduced *Rn* (caused by the aerosol cooling force), and weaker wind, which contributing to the weaker development of the CBL, compared to the clean daytime. The more detailed discussion has been added in Line 438-451.

Reference:

Sun, T., Kotthaus, S., Li, D., Ward, H.C., Gao, Z., Ni, G.-H., Grimmond, C.S.B.: Attribution and mitigation of heat wave-induced urban heat storage change. Environ. Res. Lett. 12, 114007, 10.1088/1748-9326/aa922a, 2017.

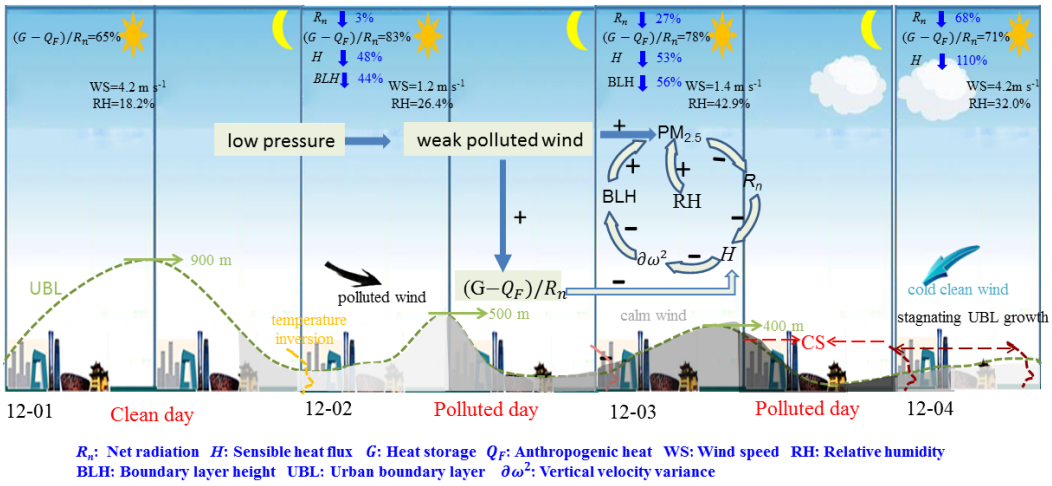

Fig. R2 (Fig. 12 in the revised paper): Schematic diagrams of the roles of synoptic conditions, surface energy budget in the development of UBL, and the two-way feedback between UBL structure and accumulation of $PM_{2.5}$ during 1–4 December 2016, the values of meteorological elements averaged in noon hours (1200–1400 LST).

Specific comments:

L253–255: This is not well justified: Traffic emission might not be increased as commuters may be less during weekends than weekdays.

Responses: This sentence has been removed.

L442: It would be good to comment on the possible impacts of anthropogenic heat on the estimates of urban heat storage.

Responses: We thank the reviewer's valuable suggestion. The more detailed discussion has been added in Line 477-484.

L503: the physical meaning of RSCS gradient is better to be provided.

Responses: Thanks for this comment. The meaning of the RSCS has been added in the revised manuscript (Line 543-547).

Figures 2, 4, 5 and 6: corresponding dates should be explicitly annotated

below the x-axes for better legibility.

Responses: As suggested, all these figures have been revised. Thanks.