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Reply on RC1

Xiangde Xu et al.

Author comment on ""Warm cover": precursory strong signals for haze pollution hidden in the middle troposphere" by Xiangde Xu et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2020-1140-AC1, 2021

Major comments:

1. For the introduction, we have adjusted it as required and added new content.

"1 Introduction

In China, mainly over the region east of 100°E and south of 40°N (Tie et al., 2009), $PM_{2.5}$ (particulate matter with an aerodynamic diameter equal to or less than 2.5 μm) has become the primary air pollutant (Wang, et al., 2017). Therefore□in September 2013, the Chinese government launched the China's first air pollution control action plan – 'The Airborne Pollution Prevention and Control Action Plan (2013-2017)' (State Council of the People's Republic of China, 2013). By 2017, 64% of China's cities are still suffering from the air pollution, especially Beijing-Tianjin-Hebei region and surrounding areas (Wang et al., 2019; Miao et al., 2019). Then, in July 2018, the Chinese government launched the second three-year action plan for air pollution control, the "blue sky defense plan", which demonstrates China's firm determination and new measures for air pollution control (State Council of the People's Republic of China, 2018). After the implementation of air pollution control action plans, the air quality in many regions and cities in China has been significantly improved.

Anthropogenic pollutant emissions and unfavorable meteorological conditions are commonly regarded as two key factors for haze pollution(Ding and Liu, 2014; Yim et al., 2014; Zhang et al., 2015). Air pollutants mainly come from the surface emission sources, and most of the pollutants are transported from the surface to the atmosphere through the atmospheric boundary layer (ABL) (Quan et al., 2020). Structural characteristics of ABL are the key meteorological conditions which influences the formation and maintenance of heavy pollution episodes (Wang et al., 2015; Cheng et al., 2016; Wang et al., 2016; Tang et al., 2016; Wang et al., 2019).

Most of the previous studies focused on exploring the impact on the heavy air pollution in Eastern China (EC) for the meteorological conditions in ABL. However, the thermodynamic and dynamic structures of troposphere can affect the meteorological conditions in ABL (Cai et al., 2020). The convection and diffusion in the ABL were suppressed by a relatively stable structure of 'warm cover' in the middle troposphere, leading to the ABL height decreases, which were favourable for the formation and persistence of heavily polluted weather (Quan et al.,2013; Wang et al.,2015; Cai et al.,

2020).

This study investigated whether the thermodynamic structure of the troposphere and its intensity changes can be used as a "strong warning signal" for the changes of $PM_{2.5}$ concentration in heavily polluted weathers, and whether this strong signal exists in the time scales of seasonal, interannual and interdecadal. In order to explore the interaction between the free troposphere and the ABL and the impact on the heavy air pollution in Eastern China (EC), this study extended the meteorological conditions for heavy air pollution from the boundary layer to the middle troposphere. We identify a precursory 'strong signals' hidden in the free troposphere for frequent haze pollution in winter in EC. **"**

2. Meteorological conditions in February 2014 were worse than that in January 2013. In February 2014□a rarely persistent air pollution weather process occurred in central and eastern China, this process had caused severe air pollution in more than 50 cities, with an impact area of 2.07 million square kilometers. Among the 25 regional ultra-long pollution events (≥6 days) during the winters of 2012–2018, the 'most serious' pollution events during February 18–27 was long lasting, contained heavy pollution, produced low visibility, and had a broad impact on northern China. In the Beijing area during February 20–26, the regional average $PM_{2.5}$ concentration was continued to exceed the 'most-serious' pollution level, and with a peak value of up to 456 μg m^{-3}.

3. Due to the limited space of the article, some quantitative analysis will be given in the future, such as the contribution of each meteorological element to polluted weather. This study focused on exploring whether the thermodynamic structure of the troposphere and its intensity changes can be used as a "strong warning signal" for the changes of $PM_{2.5}$ concentration in heavily polluted weathers, and whether this strong signal exists in the time scales of seasonal, interannual and interdecadal.

Minor comments:

- **Line 26: "In addition to".** We have adjusted it as required.

- **Line 43: Delete "with excessive concentrations of $PM_{2.5}$".** We have adjusted it as required.

- **Line 87: the North China Plain. Please check it throughout the manuscript.** We have removed it.

- **Line 88-89: Change to "for the long-lasting and heavy haze pollution". This statement needs to be rephrased. "sulfur-dioxide pollutants" is not appropriate.** We have adjusted it as required.

- **Line 98: What do you mean by "long heavy air pollution "?** We have adjusted it as required, "persistent heavy air pollution".

- **The labels in the contour plot in Fig.3-4 are overlaid and need to be optimized.** We have adjusted it as required.

- **All the abbreviations should be defined for the first time. Please check throughout the article.** We have adjusted it as required.

Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2020-1140/acp-2020-1140-AC1-supplement.zip