Atmospheric
Chemistry
and Physics
Discussions

Interactive comment on "Long-term Variations in Ozone Levels in the Troposphere and Lower Stratosphere over Beijing: Observations and Model Simulations" *by* Yuli Zhang et al.

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Thanks for all the comments and suggestions. We already added the significance and error estimates. The criteria to define time periods in Fig. 6 are consistent with the time intervals in Fig. 3 and Fig. 4 in which sudden decrease is defined as the period in which the most significant decrease in Gaussian-weighted deseasonalized ozone was observed. The periods of sudden decrease are different in different altitudes, so the time intervals in Fig. 6 are different in different altitudes. In this paper, we focused on the changes of ozone trend which mainly caused by the change of emission and the sudden decrease in 2011-2012 which is largely related to the transport from

stratosphere. The other meteorological reason such as ENSO and tropopause might also related to ozone variation as we discussed in the conclusion section. However, they are not the main points of this paper and less important than emission and stratospheric transport. There may be many other meteorological factors like jet and tropical widening, but obviously it is impossible for anyone to investigate all of them in one single paper. We would like to deeper dive on other mechanisms in the future. As for the key finding of this paper, we think the dataset itself, the trends it revealed and the sudden decrease are the most innovative parts. Based on the only long-term observed ozonesonde data in North China Plain, we revealed the very interesting changes in tropospheric and lower-stratospheric ozone. We use NO2 form OMI to show the influence of precursor on the change of trend, and we use CLaMS model to show the influence of stratospheric transport on the sudden decrease of ozone in 2011-2012. All of these make this paper an interesting and relatively complete story which we don't agree to call it "coarse". Does a good paper must contain complicated methods or revealed all possible mechanisms? We have carefully revised the manuscript according to these suggestions. Our point-to-point responses are listed below:

Major comments: As I said the data record is interesting, but the analysis is more than coarse. The authors should at least provide some statistical valid metrics for the significance of trends. 1) There are no significance or error estimates of the 'trends' (the authors state, that the the time series is too short for this, which is weird, since the focus of the paper is on trends)

Reply: we already added the significance and error estimates in the previous version of our paper.

2) The selection of time intervals to calculate trends seems arbitrary and different in different altitudes. Criteria are not clear and seem to differ (Fig. 6).

Reply: the selection of time intervals to calculate trends is indeed different in different altitudes (Fig. 6.). But the criteria are not arbitrary, they are consistent with the time

intervals in Fig. 3 and Fig. 4 in which sudden decrease is defined as the period in which the most significant decrease in Gaussian-weighted deseasonalized ozone was observed. The periods of sudden decrease are different in different altitudes, so the time intervals in Fig. 6 are different in different altitudes. We gave a clearer description in Fig. 6.

3) They should also explain more clearly the role of meteorology when interpreting the seasonally resolved trends in the free troposphere (note that the whole manuscript does not contain any mentioning of the monsoon, convection, tropopause, jets).

Reply: after the analysis of the long-term trends and the sudden decrease of ozone. We gave the seasonal trends to show in which seasons the significant changes of ozone are observed. In this part, we think that the precursors are the most important factors for the ozone in the troposphere-dominated range, and the transport greatly affects the ozone in the stratosphere-dominated range. It doesn't mean that we can exclude the meteorological reasons such as monsoon, convection, tropopause and jets. They are not the key points of this paper and less important than precursors and transport. Actually, we mentioned ENSO and tropopause in the discussion and conclusions section. There may be many other meteorological factors which affect variation of ozone, but obviously it is impossible for anyone to investigate all of them in one single paper.

4) They use the CLAMS model, which has no tropospheric chemistry to compare ozone (as mentioned correctly by the authors). How do the authors exclude potential changes of tropospheric ozone sources, circulation changes and long-range transport, which could potentially also lead to different variability and trends? The fact that an incomplete model sometimes agrees with observations, does not automatically exclude other processes, which are not included in the model, to explain the observed ozone tendencies.

Reply: CLaMS is not used to simulate tropospheric ozone and to compare with

ozonesonde. We want to isolate and quantify the long-term trends caused by transport from the stratosphere and by tropospheric chemistry. There is no tropospheric chemistry in CLaMS which you think it is an incomplete model. However, it is the specialty makes it a very qualified model for this work (to isolate and quantify the trends caused by transport and by tropospheric chemistry). We did not exclude potential changes of tropospheric ozone sources, circulation changes, long-range transport and other unknown reasons, but they are not the key points of this paper. No paper can completely include all factors, especially some of them are still unknown. For this paper, we revealed the trends and the sudden decrease of ozone based on the rare ozonesonde dataset, and we found these changes in ozone are related to NO2 and transport. So far, it is a complete and interesting story. Other mechanisms can be investigated deeper and more complete in future works.

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2019-1145/acp-2019-1145-AC4-supplement.pdf