

1 **Response to referee comments on “Spatial distribution and temporal trend of ozone pollution**
2 **in China observed with the OMI satellite instrument, 2005–2017”**

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4 We thank the referees for their careful reading of the manuscript and the valuable comments. This
5 document is organized as follows: the Referee’s comments are in *italic*, our responses are in plain
6 text, and all the revisions in the manuscript are shown in blue. The line numbers in this document
7 refer to the updated manuscript.

8
9 **Referee 3**

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11 *This paper explored the capability of OMI ozone columns to represent the surface O₃. I feel the*
12 *satellite data is over-interpreted based on the evidence provided in the paper. However, I do believe*
13 *it will be big news if substantial improvements are made to prove that the conclusion is solid.*

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15 **Response.** We thank the reviewer for raising so many good points, which have significantly
16 improved our work. Now we have a new Figure 4 showing that OMI 850-400 retrievals have limited
17 skill in predicting the daily ozone variability in the north and we only predict the trends of ozone
18 pollution in southern China (south of 34°N). We have new in-situ observations to validate the trends
19 inferred from the OMI, which are shown in Figure 6. And we have revised the title.

20 **New title.** Ability of the OMI satellite instrument to observe surface ozone pollution in China:
21 application to 2005-2017 ozone trends

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24 General comments:

25 *1. The sensitivity of OMI O₃ to the lower troposphere is very low. I feel that is the reason why no*
26 *quantitative comparison to surface observations has so far been done. I’m wondering is there any*
27 *improvements that have been made to make the quantitative comparison robust? Why does not the*
28 *quantitative comparison work for other regions, but work for China?*

29 **Response.** We now explain this better in the Introduction.

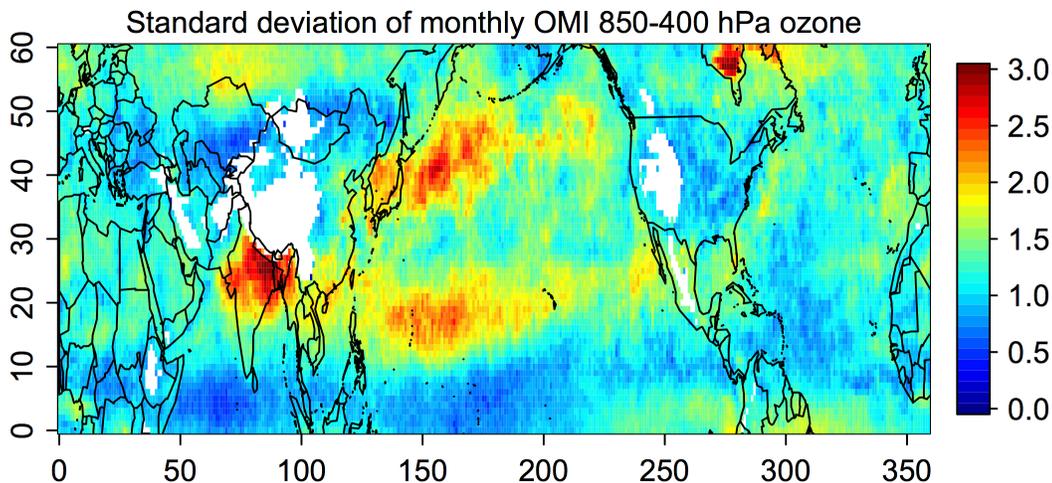
30 **P2L23.** However, no quantitative comparison of the satellite data to surface observations has so far been done.
31 Surface ozone network data are available in the US and Europe but levels are generally too low to enable
32 statistically meaningful validation. Ozone levels in China are much higher (Lu et al., 2018). The high density
33 of the MEE network, combined with vertical profile information from ozonesondes and aircraft, provides a
34 unique opportunity for evaluating quantitatively the ability of OMI to observe ozone pollution.

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36 *2. The robustness of the residual. How large is the temporal and spatial variations of the*
37 *background? Is it likely that such variations bring significant uncertainties to the subtraction?*

38 **Response.** Thanks for making this good point. We have tested different approaches to correct the
39 background and the results are consistent with what have presented in the paper. In the text, we make
40 it simple by saying this.

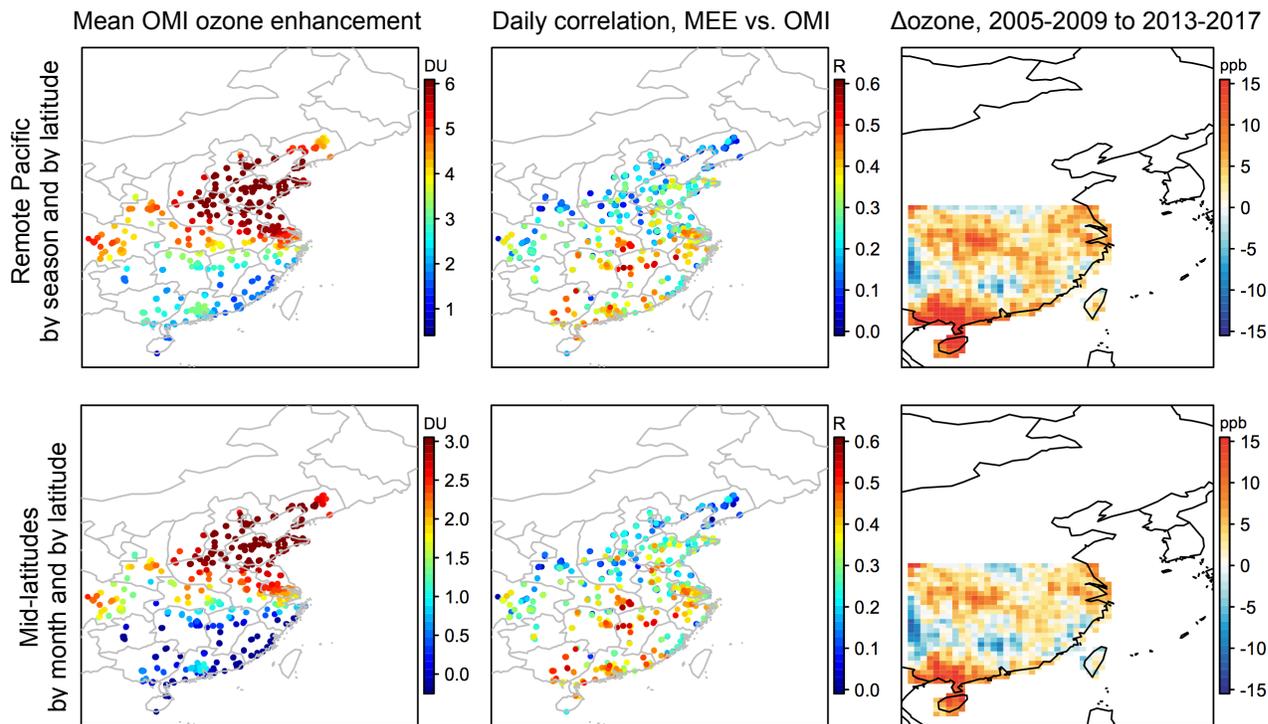
41 **P4L1.** We examined different spatial and temporal averaging domains for the North Pacific background and
42 found little effect on the residual.

43 The uncertainty related to the background correction can be found in these two figures.



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Figure SX. Standard deviation of monthly OMI 850-400 hPa ozone during 2005-2017 summers.



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Figure SX. The mean ozone enhancement (left panel), daily correlation of OMI and MEE ozone (mid panel), and the OMI inferred changes of mean ozone concentrations from 2005-2009 to 2013-2017 using different approaches correcting the OMI drift. In the top panel, we subtract the monthly mean Pacific background (150°E-150°W) for the corresponding latitude and season. In the bottom panel, we subtract the monthly mean mid-latitude ozone for the corresponding latitude and month.

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3. The correlation between MEE and OMI. The correlation seems to be related with the dependence of O₃ on latitude. I suggest additional analysis here to prove that is not the case.

Response. We are not sure if the reviewer is referring to Figure 1f here. In Figure 1f, the correlation

58 is higher in the south and lower in the north. This is because in the northern China, OMI 850-400 hPa
59 ozone has lower sensitivity in the boundary layer, more likely to be influenced by the upper
60 tropospheric ozone variability and stratosphere-troposphere exchange. We have added new
61 discussion in the text.

62 P6 L27. We find that the low correlation of OMI with boundary layer ozone in the northern
63 ozonesonde data is due not only to the low DOFS but also to a large variability of ozone in the
64 upper troposphere. Figure 4 (left panel) shows the standard deviation of daily OMI 400-200 hPa
65 ozone during 2005-2017 summers, indicating that upper tropospheric ozone has much higher
66 variability in the north ($> 34^{\circ}\text{N}$) than in the south. This is related to the location of the jet stream
67 and more active stratospheric influence (Hayashida et al., 2015). Figure 4 (right panel) displays the
68 vertical profiles of ozone standard deviations for the five ozonesonde sites. For the two sites north
69 of 34°N , the ozone variability becomes very large above 8 km. Since the OMI 850-400 hPa
70 retrieval also contains information from above 400 hPa, this upper tropospheric variability causes a
71 large amount of noise that masks the signal from boundary layer variability. For the three sites
72 south of 34°N , the ozone variability in the boundary layer is much higher than in the free
73 troposphere and the upper tropospheric ozone variability still remains low even above 8 km. In the
74 rest of this paper we focus our attention on ozone episodes and the long-term trends in southern
75 China (south of 34°N).

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77 If the reviewer refers to Figure 1d, we now make it clear that we have corrected the background that
78 is dependent on latitudes.

79 P3 L23. To remove this gradient and also any long-term uniform drift in the data, we subtract the monthly
80 mean Pacific background (150°E - 150°W) for the corresponding latitude and month

81 P4 L22. After subtracting the North Pacific background for the corresponding latitude in month, we obtain the
82 OMI ozone enhancements shown in Figure 1d.

83 P4 L23. The spatial correlation coefficient between the OMI ozone enhancements and the MEE surface
84 network is $R = 0.73$ over eastern China. The correlation is driven in part by the latitudinal gradient but also by
85 the enhancements in the large megacity clusters identified as rectangles in Figure 1b. Thus the correlation
86 coefficient is $R = 0.55$ for the 26 - 34°N latitude band including YRD, SCB, and Wuhan.

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89 *Specific comments:*

90 1. *“We exclude outliers with over 35 Dobson Units (DU) at 850- 400 hPa (>99th percentile in*
91 *eastern China) and exclude July 2011 when the retrievals are anomalously high.” Please give the*
92 *reference to the exclusion. Otherwise, please quantify the influence of the exclusion.*

93 **Response.** Thanks for pointing this out. We delete this because we don’t use the July 2011 data and
94 not excluding the extremely high data has little effect on our result.

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96 2. *“We see that high-ozone episodes in the 950-850 hPa sonde data are systematically associated*
97 *with high OMI values, though the converse does not always hold.” Additional explanation for the*
98 *reason is expected.*

99 **Response.** Thanks. Now we say

100 P6L4. We see that high-ozone episodes in the 950-850 hPa sonde data are systematically associated with high
101 OMI values, though the converse does not always hold because free tropospheric enhancements affecting OMI

102 can also occur.

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