

**Tropospheric ozone maxima observed over the Arabian Sea during the
pre-monsoon
by J. Jia et al.**

Answers to referee comments, Referee #2

The authors would like to thank Referee #2 for reviewing the manuscript.

Comments:

The authors provide a detailed analysis for the variation of tropospheric ozone over Arabian Sea. They indicated that the maximum of spring time free tropospheric O₃ over AS is mainly driven by long-range transport, particularly, from India. I recommend the paper for publication after consideration of the points below.

Page 2, Line 10-12 It would be better to define the region of Arabian Sea in Figure 1. The enhancement is not very obvious. What is the reason for the 30x10 grid box line in Figure 1?

Response: The region of Arabian Sea was defined too far back (in Figure 2 as rectangle and in Page 7, Line 11). The definition is moved ahead to Page 2 Line 10-12. The sentence is now 'A tropospheric ozone maximum is observed over the Arabian Sea (AS, west side of the sub-continental India).' The caption of Figure 1 is changed to '... and (right) OMI/MLS in 2008, with bold arrows pointing to AS. The AS region is defined as 10-20 N, 60-70 E in this study and is marked with red rectangle in Fig. 2).'

The 30x10 grid box line is a default setting of the software 'pglobal'.

Page 2, Line 13-16 What is the relation between Southern Hemispheric biomass burning with enhanced TOC over Arabian Sea? I assume detailed description and citations for Southern Hemispheric biomass burning are not necessary here.

Response: The study of AS tropospheric ozone columns is inspired by averaging TOCs over long time period, when the author found four main patterns in a global scale: plumes caused by biomass burning, by the anthropogenic pollution in midlatitudes northern hemisphere, by

STE over Mediterranean, and the ozone enhancement over Arabian Sea. Plenty of studies and researches have helped us understanding the first three patterns of tropospheric ozone, while few were about the enhancement over Arabian Sea. Page 2, Line 12-18 states this motivation and aims to point out the outstanding magnitude of Arabian Sea ozone enhancement by comparing it with the other three well-known patterns. The biomass burning pattern is one of them.

The detailed citations may are not necessary, and several citations have been removed. The sentence is now '... and towards Australia (e.g., Fishman et al., 1986, 1991), 2) TOC attributed to anthropogenic sources ...'

Page 2, Line 20-21 If this phenomenon is not unique, but just a “well-known largen scale phenomenon”, why should we focus on it?

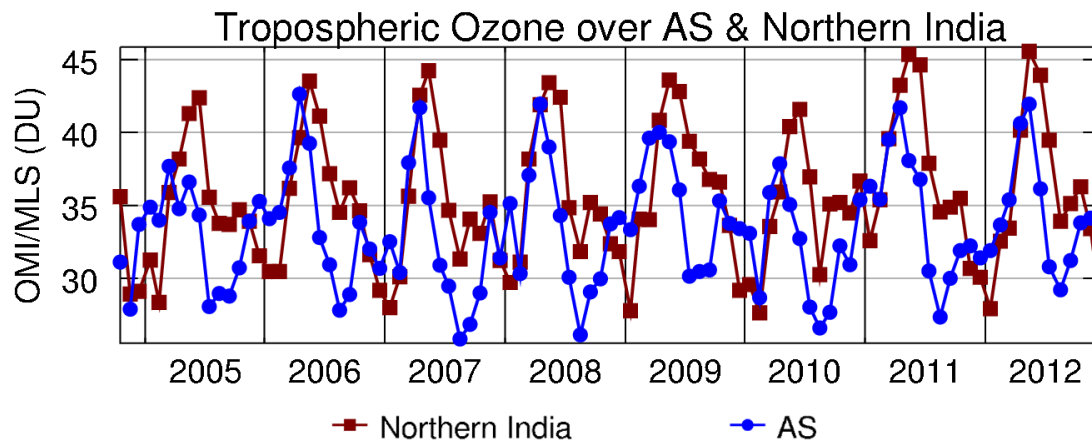
Response: The authors agree that this sentence weakened the importance of the AS ozone enhancement. The sentence is now 'Although the TOC enhancement over AS is an important global pattern of tropospheric ozone, the spring maxima in TOC are not unique over the AS representing rather a well-known large scale phenomenon in the Northern Hemisphere. '

Section 2: Is there any evaluation study for the tropospheric O3 column provided by SCIAMACHY and OMI/MLS? The TOC is highly depended on the stratosphere-troposphere separation, which could be an issue for the unpolluted area

Response: The evaluation studies for the tropospheric ozone column provided by SCIAMACHY and OMI/MLS were reported by Ebojie et al. (2014) and Ziemke et al. (2006) respectively. The monthly results for both data sets are within 5 DU comparing to ozonesonde measurements. The stratosphere-troposphere separation is operated by using tropopause height data. The tropopause height information for SCIAMACHY LNM and OMI/MLS TOC retrieval is derived from ECMWF and NCEP, respectively. The fact that different databases are used to retrieve tropopause height for SCIAMACHY and OMI/MLS is not expected to have a significant effect as tropical region has the most stable tropopause height compared to the other latitudes.

Section 4 In Figure 3, can you add a panel to show the O₃ variation over northern India? It seems that the O₃ seasonality over AS is strongly correlated with the O₃ seasonality over India (based on Figure 2). Instead of complex source analysis, I am wondering whether the variation of O₃ over AS can be simply explained by the variation of O₃ formation of India.

Response: The TOC variations over northern India and AS from OMI/MLS are shown below. Despite the similar seasonal pattern in general, the variation of ozone over AS cannot be simply explained by the variation of ozone formation of India. As discussed in the manuscript, the Northern India is a major source region for air masses over Bay of Bengal, but not for the Arabian Sea.



Section 4.3 The local chemistry production in lower troposphere is small (Figure 10), however, I am wondering whether the significant O₃ production in upper troposphere has influences on lower tropospheric O₃. Does lightning play a role in the O₃ accumulation?

Response: The HYSPLIT trajectory forward model results (Fig. 7) indicate that the air masses in upper troposphere are transported towards the Pacific Ocean rather than sinking downwards. In Page 14, Line 7-9, we also pointed out that ozone amount over ~11 km in pre-monsoon season has a zonal pattern.

We conducted limited studies on lightning influence by checking the lightning flash rate data provided from LIS/OTD (Lightning Imaging Sensor/space borne Optical Transient Detector). The lightning over AS is negligible. Lightning can play a role by influencing the source region before long range transport. Barret et al. studied lightning NO_x influence over Arabian Sea by using GEOS-Chem model. Ozone concentration at 565 hPa can decrease by 20 ppbv

1 when turning off global lightning, while it remains almost unchanged without the local light-
2 ning. These results were presented in a poster and was not published in journals in accord-
3 ance with our knowledge.

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5 *Technical comments:*

6 *Page 13, Line 11 Change Figure 6.11 to Figure 10*

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8 **Response:** Typo corrected.

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10 Besides of the comments that were given, the authors would like to clarify some contributors
11 in the acknowledgements: ‘...We acknowledge the working staffs on MACC reanalysis,
12 NCEP, and MOZART-4. ... We would like to thank Dr. Anne-Marlene Blechschmidt for her
13 help. Our gratitude goes to Prof. Christian von Savigny for giving comments during the
14 preparation of the manuscript. The authors acknowledge the North-German Supercomputing
15 Alliance (HLRN) for providing HPC resources that have contributed to the research results
16 reported in this paper’