Atmos. Chem. Phys. Discuss., 12, C6172–C6178, 2012
www.atmos-chem-phys-discuss.net/12/C6172/2012/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Tropospheric column ozone: matching individual profiles from Aura OMI and TES with a chemistry-transport model" *by* Q. Tang and M. J. Prather

Anonymous Referee #3

Received and published: 24 August 2012

This study uses the CTM as a transfer standard to conduct a three-way comparison of CTM, OMI, and TES tropospheric column ozone and evaluate the effect of a priori on retrievals. It demonstrates that the use of relatively noise free CTM can improve the validation of measurement precision much better than direct comparison and also reveals some weakness in CTM and both OMI/TES observations. This paper is generally well written and organized. It makes important contributions to the validation of tropospheric ozone column and is suitable for publication on ACP. However, more references could be cited to help interpret the results e.g., those with respect to wave-1 pattern, enhanced ozone over the South Atlantic (not just limited to lower troposphere and not just due to biomass burning), the sensitivity of OMI to capture the wave-1 pattern. As

pointed out by reviewer 2, Zhang et al., 2010 is cited but not cited for its main work, which provides a theoretical framework to use the CTM as the transfer standard to compare observation with similarly coarse and yet different vertical resolution by using OMI and TES ozone (focus on ozone at 500 hPa). The figures could be improved by adding several panels. Some of the discussions are not clear. The abstract/conclusion emphasizes that OMI and TES biases are within a few percent, but it should be clearly stated that this is for monthly zonal mean biases as there are large monthly mean biases at many places. Overall, I recommend this paper to be published on ACP after addressing the following specific comments.

Specific comments

1. In Abstract, add "zonal" between "monthly" and "mean OMI-TES" on L18 and add "zonal" before "OMI TCO" in line 19.

2. P16063, L10, Zhang et al., 2010 should be cited as it also provided a theoretical framework of using a CTM as a transfer platform to compare OMI and TES retrievals.

3. P16064, L20, Levelt et al., 2006 is a better reference for OMI.

4. P16066, L9-10, I agree with reviewer 1 that this sentence is difficult to understand. I suggest changing it to "Given the limited DOFS (vertical sensitivity) in the troposphere, their integrated TCO is less dependent on the a priori information than ozone at individual tropospheric layers due to the removal of smoothing errors between tropospheric layers in the integrated TCO, and thus we do not adjust the retrievals due to AK differences in the direct OMI-TES comparison."

5. In Figure 1 caption, please define the mean biases (i.e., y-axis variable minus x-axis variable) although it is defined in the text.

6. In Figures 1 and 2, it would be very useful to add another panel by comparing CTM TCO vs. TES* TCO, which can help the readers understand the CTM vs. OMI/TES comparison with the same a priori (e.g., understand the sentences on P16068, L1-7).

7. P16067, L5, I agree with the reviewer 1 that the conjecture of "larger TCO variations over NH mid-latitudes in summer . . ." can be checked from model simulations. In addition, the retrieval sensitivity for OMI decreases due to the increase of solar zenith angle and the retrieval sensitivity for TES might also decrease due to the decrease of temperature, which can also cause the reduction of standard deviations.

8. P16067, L2, is the statement of large TES TCO measurement noise based on the figure/table, which is not clear, or based on some references? Please make it clear or give some references. From Fig. 1 (a) and (c), the model-TES standard deviation is actually smaller than the model-OMI standard deviation.

9. P16067, L24-25, to accurately understand why the model-observation correlation is much larger than OMI-TES correlation, you need to start from the definitions of the quantities:

Model TCO (Xm) with OMI averaging kernels: Xm,omi' = Xa + Aomi (Xm-Xa) OMI TCO: Xomi' = Xa + Aomi(Xt-Xa) + Bomi + Eomi Where Xt is true TCO, Bomi is OMI TCO bias and Eomi is OMI TCO noise Xm,omi'-Xomi' = Aomi(Xm-Xt) – Bomi – Eomi Xm-Xt is the model error

Model TCO with TES averaging kernels: Xm,tes' = Xa + Ates (Xm-Xa) TES TCO: Xtes' = Xa + Ates(Xt-Xa) + Btes + Etes Xm,tes'-Xtes' = Ates(Xm-Xt) – Btes - Etes

OMI TCO: Xomi' = Xa + Aomi(Xt-Xa) + Bomi + Eomi TES TCO: Xtes' = Xa + Ates (Xt-Xa) + Btes + Etes Xomi'-Xtes' = (Aomi-Ates)(Xt-Xa) + Bomi + Eomi – Btes - Etes

The noise free in CTM makes the standard deviation of model-observation differences (either Eomi or Etes) much smaller than that of OMI-TES differences (both Eomi and Etes). If neglecting B and E and assume Xm = Xt, then model-observation correlation is 1 while OMI-TES correlation is not 1 due to retrieval sensitivity differences (Aomi-Ates)(Xt-Xa). Therefore, the larger model-observation correlation is not only due to the generally uncorrelated nature of OMI and TES measurement noise but also due

to the OMI/TES retrieval sensitivity differences and the relatively small model error. It mentions that "noise . . . is larger than the model error." But I don't think it is clear from these equations about whether OMI or TES noise is larger than model error. Please clarify it.

10. P16068, L7, "CTM-TES" should be "CTM-TES*".

11. P16068, L23, the sentence "only part of which can be due to the a priori" is not clear to me. How a priori explains why model-observation correlation is larger as the same a priori is used in both retrievals and model TCO processed with retrieval averaging kernels? The reasons should be similar to those at middle latitudes.

12. P16068, L26-27, does not TES also report surface pressure less than 700 hPa for these high terrain regions?

13. P16069, L8, as reviewer 1 also suggested, it would be better to elaborate this rather than based on personal communication. It is well known that the TCO derived using tropospheric ozone residual methods from TOMS/OMI total ozone minus stratospheric column ozone can capture the wave-1 in the tropics, low ozone in the Pacific and high ozone (not limited to lower tropospheric ozone only but also in the middle and upper troposphere as seen from Figure 4 of Thompson et al., 2003, not just due to biomass burning but a combination of biomass burning, lighting and dynamics as shown in Martin et al., 2002) over the Atlantic (e.g., references as early as Fishman and Larsen, 1987 to recent references like Ziemke et al., 2006 and Schoeberl et al., 2007). The wave-1 pattern, originating from total ozone, suggests that UV retrievals even with a few wavelengths like the TOMS algorithm have the sensitivity to see the wave-1 pattern. Ozone profile algorithm, which uses many more wavelengths, ideally should have more sensitivity to better capture this pattern. The papers by Liu et al. (2005, 2006, 2010) using a similar ozone profile retrieval algorithm (also with zonal mean a priori) clearly show ozone profile retrievals from GOME and OMI can clearly captures the wave-1 pattern: from as low as 10 DU over the Pacific to as high as 60 DU over the Atlantic.

However, the retrievals need to fit the measurements in the 310-340 nm to better than 0.2-0.3% to extract useful tropospheric ozone information. Therefore, the inability to capture wavel-1 pattern in the operational OMI product is an algorithm specific issue rather than the OMI/UV's limitation.

14. P16069, last paragraph, according to Zhang et al. (2010), a better approach to evaluate the true OMI and TES biases than OMI-TES or OMI-TES* is the CTM method by using CTM as transform standard (equation 13 of Zhang et al., 2010), i.e., the differences between CTM-OMI and CTM-TES*. I suggest adding a panel for CTM-TES* and a panel for (CTM-OMI) minus (CTM –TES*).

15. P16072, L10, I think that near uniform zonal bands of OMI TCO in both the tropics (without the well-known wave-1 pattern) and mid-latitude with jumps makes it not suitable to derive longitudinal and latitudinal dependent TCO climatology.

16. P16072, L17, I suggest changing "implying large single profile noise in each observation" to "due to the inclusion of both OMI and TES profile noise" according to comment 9.

17. P16072, L18-19, see comment 9, it is not clear to me about why OMI/TES TCO noise is larger than model uncertainties.

18. P16072, L21, Do you mean "this level of noise" as sigma*(OMI-TES*) in those tables? Please make it clear in the text. In supplement tables, how is sigma*(OMI-TES*) calculated? Do you calculate the sigma(OMI-TES*) for each 5x5 box and then take the average of all boxes within the given latitude bands or do you take the root mean square of sigma(OMI-TES*) in all boxes? Please make it clear in the Table S1 footnote. According to the tables the noise is mostly 2-4 DU except for S4 and S8 (3-5 DU). I think that this combined noise of 2-4 DU is very small for single OMI and TES measurements. What is the single measurement requirement to detect tropospheric folds or stratospheric intrusion, whose signal I think can be much larger than 2-4 DU?

19. P16073, L24-25, since the small OMI/TES biases refer to the zonal mean biases, it is good to make it clear in these conclusive statements. I suggest adding "zonal mean" before "OMI". It says "OMI and TES agree within a few percent and imply that OMI TCO bias is at most a few Dobson units". Note that 1 DU is about 3% based on global average TCO of $\sim$30 DU. According to the supplement tables, the OMI-TES* bias is typically within 3 DU. I suggest changing it to "zonal mean OMI and TES typically agree within 5-10% and imply zonal mean OMI TCO bias is at most a few DU" and making similar changes in the abstract.

20. P16074, L2, I suggest changing "two instruments" to "two instruments/algorithms" to reflect that it is due to both instrument and algorithm differences.

References

Fishman, J., and J. C. Larsen (1987), Distribution of total ozone and stratospheric ozone in the tropics: Implications for the distribution of tropospheric ozone, J. Geophys. Res., 92, 6627-6634.

Levelt, P. F., et al. (2006), Science Objectives of the Ozone Monitoring Instrument, IEEE Trans. Geosci. Remote Sens., 44, 1199-1208.

Liu, X., P. K. Bhartia, K. Chance, R. J. D. Spurr, and T. P. Kurosu (2010), Ozone profile retrievals from the Ozone Monitoring Instrument, Atmos. Chem. Phys., 10, 2521-2537.

Liu, X., et al. (2006), First directly retrieved global distribution of tropospheric column ozone from GOME: Comparison with the GEOS-CHEM model, J. Geophys. Res., 111, D02308, doi:10.1029/2005JD006564.

Liu, X., et al. (2005), Ozone profile and tropospheric ozone retrievals from Global Ozone Monitoring Experiment: Algorithm description and validation, J. Geophys. Res., 110, D20307, doi:10.1029/2005JD006240.

Martin, R. V., et al. (2002), Interpretation of TOMS observations of tropical tropospheric ozone with a global model and in-situ observations, J. Geophys. Res., 107, 4351, doi:

10.1029/2001JD001480.

Schoeberl, M. R., et al. (2007), A trajectory-based estimate of the tropospheric ozone column using the residual method, J. Geophys. Res., 112, D24S49, doi: 10.1029/2007JD008773.

Thompson, A. M., et al., Southern Hemisphere Additional Ozonesondes (SHADOZ) 1998–2000 tropical ozone climatology, 2, Tropospheric variability and the zonal wave-one, J. Geophys. Res., 108(D2), 8241, doi:10.1029/2002JD002241, 2003.

Zhang, L., et al. (2010), Intercomparison methods for satellite measurements of atmospheric composition: application to tropospheric ozone from TES and OMI, Atmos. Chem. Phys., 10, 4725-4739.

Ziemke, J. R., et al. (2006), Tropospheric ozone determined from Aura OMI and MLS: Evaluation of measurements and comparison with the Global Modeling Initiative's Chemical Transport Model, J. Geophys. Res., 111, D19303, doi: 10.1029/2006JD007089.

Interactive comment on Atmos. Chem. Phys. Discuss., 12, 16061, 2012.