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Atmospheric Measurement Techniques Discussions

Interactive comment on "Limb–nadir matching using non-coincident NO_2 observations: Proof of concept and the OMI-minus-OSIRIS prototype product" *by* Cristen Adams et al.

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We thank you for your comments, which have helped to improve our manuscript. Below we address the recommended changes point-by-point.

Comments

1) The motivation for using non-coincident measurements should be made more clear in the introduction. It appears that the main motivation is application for future geostationary missions where coincident limb measurements will not be available for most nadir observations. The current paragraph on this feels buried toward the end of the introduction section – it took me time to figure out the motivation for this difficult tech-

nique. The motivation could be made even more relevant by a brief discussion of the power of geostationary observations for NO2 measurements and the associated science they (and by extension this method) will help enable.

We have reorganized the introduction as recommended. The first two paragraphs now read:

"Nadir satellite instruments can measure daily global maps of tropospheric nitrogen dioxide (NO2), which, at the surface, is a pollutant linked to smog and acid rain. Tropospheric NO2 was first successfully retrieved from the Global Ozone Monitoring Experiment (GOME) (Burrows et al., 1999), and has since also been measured by the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) (Bovensmann et al., 1999), Ozone Monitoring Instrument (OMI) (Levelt et al., 2006) and GOME 2 (Callies et al., 2000) nadir-viewing instruments. The next generation of nadir instruments will be on geostationary platforms such as the Tropospheric Emissions: Monitoring of Pollution (TEMPO) (Chance et al., 2013; Zoogman et al., 2014), Sentinel-4 (Ingmann et al., 2012), and Geostationary Environmental Monitoring Spectrometer (GEMS) (Kim, 2012). These instruments will measure air pollution at much higher spatial and temporal resolution, allowing for the study of the diurnal cycle of emissions and chemistry at a sub-urban scale.

High concentrations of NO2 are found in the stratosphere, where NO2 has a large seasonal and diurnal variability due to photochemistry, and, in some case, due to dynamics as well (e.g., Dirksen et al., 2011). Therefore retrievals for tropospheric NO2 from nadir instruments typically rely on extrapolation or assimilation approaches to determine the stratospheric contribution to NO2. A correct and unbiased removal of stratospheric NO2 is a major challenge and represents a significant source of uncertainty in tropospheric NO2 retrieval products. In this proof-of-concept study, we investigate the possibility of retrieving tropospheric NO2 by matching non-coincident measurements from limb-viewing satellite instruments with nadir-viewing instruments. Similar techniques could be applied to future geostationary missions, which will take measurements across a range of local times."

2) Due to the pivotal role played by the model in translating the non-coincident measurements it would be beneficial to have a brief discussion of the model's validation, particularly when using the monthly and climatological inputs used.

We have added the following text to Sect. 2.3:

"Validation of individual profiles from the box model, constrained in an analogous manner, was performed using MkIV balloon measurements (Brohede et al., 2008). Additional, albeit indirect, verification of the model's ability to adjust from one LST to another can be seen in the numerous satellite NO2 validation studies for which this approach has been used, including the original OSIRIS NO2 work (Brohede et al., 2007), ACE-FTS NO2 (Kerzenmacher et al., 2008), as well as what is provided in Appendix A."

3) As the model scaling factors are applied to each vertical layer from the Osiris retrieval, how does the vertical resolution of Osiris effect the corrected stratospheric column? How much would the result differ with different vertical grids?

The scaling factors tend to vary with a length scale of $\sim$5 km, and so the 2 km vertical resolution of OSIRIS and the 2 km grid on which the scaling factors are calculated are sufficient to capture this. A particular OSIRIS point represents an average number density over 2 km, integrated over the finer vertical scale variability that it cannot resolve. Since we are interested in the number density integrated over the entire stratosphere, the OSIRIS resolution is also sufficient. Only once the scaling factor grid spacing is increased to something like 5 km would an additional error be introduced.

4) The Osiris data were temporally averaged over 3-day windows to gain better spatial coverage. How would this be changed or effect application of this method to geostationary nadir measurements?

If this exact method was applied to future geostationary missions, the selection of the averaging window would depend on the limb instrument being used. If the limb in-

strument had a similar spatial/temporal coverage to OSIRIS, then a 3-day averaging window provides a good balance between data coverage and resolution. If the limb instrument had a different sampling pattern, then perhaps a different temporal/spatial averaging would be better. Additionally, further validation would be required, since LST adjustments would be required for each hour of geostationary measurements.

The methodology used here is intended for proof-of-concept. If limb-nadir matching was applied to future missions in an operational analysis, it would likely use a more sophisticated matching method, such as assimilation in a chemical transport model.

Tables and Figures:

Table 1: Since the correction factors are from a previous publication it's not clear that this is a necessary inclusion.

These results are not explicitly shown by Marchenko and therefore we have kept the table. We have changed the table caption to "are based on the results of Marchenko et al., 2015" to reflect this.

Figure 9: As the colorbar ranges are close (as opposed to being different by an order of magnitude) I would recommend the same range for all the panels for more accurate visual comparisons.

The colorbar ranges were chosen so that the similarity between the features in the OSIRIS and OMI datasets could be seen easily, despite the offset between the OSIRIS and OMI VCDs. When the same colorbar is used for all figures, it is difficult to see these similarities because of the bias between the OSIRIS and OMI datasets (see Fig. 1 at the bottom of this response). Therefore, we have elected to keep the different colorbars.

Figure 12: This figure is very hard to parse since the symbols overlap each other much of the time. I'm not sure the best way to fix, perhaps smaller symbols?

The figure has been replaced so that symbols are smaller and there is less overlap between symbols.

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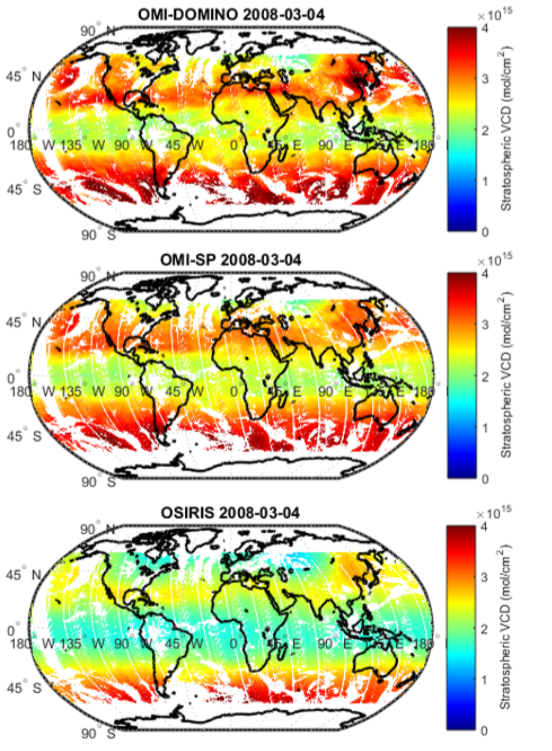

Fig. 1.