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Atmospheric Measurement Techniques Discussions

Interactive comment on "Assessing remote polarimetric measurements sensitivities to aerosol emissions using the GEOS-Chem adjoint model" *by* B. S. Meland et al.

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Specific Comments

1) Response: That is correct; these sensitivities represent the percent change in the reflectance for some percent change in the aerosol properties. We have added an additional paragraph at the end of Section 4.1 to clarify this and to present our reasoning in utilizing the normalized sensitivities throughout this work.

2) Response: Roughly 700 total pixels were used in the case of the wide-swath gird and about 70 were used for the narrow swath grid. The wide and narrow swatch grids

were generated by sub-sampling of the MODIS grid as discussed in the beginning of Sec. 3. After these grids were generated, pixels were removed from these subsampled grids based on quality control tests as well as cloud screening. We have clarified that these pixel were removed in the text in Sec. 3.

We are in full agreement that the use of higher resolution grids (more data points) would result in both better spatial coverage and in more statistically robust results. Ideally, we would have preferred to use the entire MODIS grid to represent our wide-swath grid. However, we were limited to using these more sparsely populated grids by the computational time requirements of the model used in this work. A complete radiative transfer calculation is required for each pixel in these grids. For example, a calculation using all available pixels ($\sim$25,000) from a single MODIS granule would take approximately 50 days using our current model. As our calculations utilize approximately 100 MODIS granules for the two week period, these calculations quickly become prohibitively long.

3) Response: We have examined a number of the individual wide-swath grids, such as the single grid depicted in Figure 3, which were used in this study (i.e. one observation time). For an individual grid, there will be a more even spatial distribution of the pixels (those that were not removed by the quality checks). In those cases, we did see that sensitivities did tend to be higher for larger azimuthal angles. We suspect this effect may be due to two factors, the angular dependence of the single aerosol light scattering properties (phase function and polarization profile) and the increase in path length for the more extreme azimuthal angles. As the path length increases, the interaction between incident solar radiation and the aerosols within that path will increase resulting in a higher sensitivity to the aerosol properties. Comments have been added to Section 4.2 to explain this azimuthal dependence.

We do concur that in the statement "it is primarily due to the dependence of the Stokes parameters on viewing geometry", the word primarily may be inappropriate in this case. Since the sensitivities to aerosol concentrations of a given species are normalized by the concentration of that species, we do not expect the sensitivities to show a spatial

dependence that correlates with the concentrations of that species. However, upon further thought on this question, we believe it may be possible that there is a dependence on the concentrations of the other aerosol species. For example, we see an increase in the concentrations of OCPI on the eastern coast of the U.S., but a smaller relative increase in the concentrations in BCPI concentrations. The TOA reflectance sensitivity to BCPI concentrations may therefore be masked or enhanced by spatial dependence of the OCPI concentrations. We have added comments in Section 4.2 to allow for this possibility.

4) Response: The normalized sensitivities reflect the impact of percent changes to existing emissions used in the GEOS-Chem model. Therefore some aspects of the different spatial patterns reflect differences in the spatial patterns of the emissions. For example, NH3 emissions are very high in India, while SO2 emissions are high in China, which explains the differences in the locations of the emissions sensitivities in Asia.

For the case of the high sensitivities to NH3 emissions over eastern Africa, we saw that the NH3 emissions in this region were of comparable magnitude during this season as emissions over the U.S. In addition, SO2 emissions over eastern Africa were negligible for the time period examined in this work. Therefore, the only secondary aerosol being formed in this region would be ammonium nitrate. In this case, the GEOS-Chem model is then particularly sensitive to NH3 emissions from that region. Text has been added to the manuscript to explain this feature.

5) Response: It appears as though there is a similarity in the spatial dependence of these ratios to that of the surface reflectivities (see Figure 2). The surface reflectivities are much lower on the east coast, particularly in the SE. However, the surface reflectivities are similarly low on the NE coast of the US where we are not seeing these low values of the ratios consistently. To further examine this, we have run a series of radiative transfer and adjoint calculations where the surface reflectivities were held at a constant value of 0.1 over the US. We then generated ratios of the sensitivities of the polarized reflectance to emissions, E/R (dR_p)/dE, with variable surface reflectance to

the sensitivities where the surface reflectance was held constant (See attached Response Figure 1). The largest changes in the polarized reflectance sensitivities to emissions are seen only on the east coast (the sensitivities increase with increasing reflectance there) and not the west coast. Similar results were seen for the sensitivities of the radiant reflectance to black carbon emissions, though the radiant sensitivities to the other species were more uniform (See attached Response Figure 2).

It is also possible that sensitivities near these coastal regions could also be effected by the higher relative humidities in those areas during the time period of these calculations (See attached Response Figure 3). Higher RH values will result in changes to the aerosol optical properties and therefore sensitivities. We have added comments to section 4.3 to explain these lower values.

Technical Comments

1) Response: The reviewer is correct; biomass burning emissions did come from the GFED v2 inventory. This has been corrected in the text.

2) Response: You are correct. This term should be the effective radius. Also, the use of the standard deviation of the aerosol size distribution, sigma, was changed to the variance in an earlier iteration of the manuscript and we missed changing this term. These terms have now both been corrected on page 5456 of the manuscript as well as in the Appendix. I have also corrected a typo in Figure 4. The plot in the first column of the middle row should be the normalized sensitivities of the reflectance with respect to the variance, ν, not the standard deviation, σ, of the aerosol size distribution.

3) Response: The emissions inventories used by GEOS-Chem provide sulfur emissions primarily in terms of SO2 (although a small fraction is indeed treated as direct SO4 emissions). Most of the sulfate aerosol, SO4, is then later formed through the oxidation of SO2 to sulfuric acid then partitioning from the gas phase to the aerosol phase. The sensitivities presented in the first panel of Figure 5 are actually in terms of SO2 emissions so that is not a typo. This is discussed, along with the equivalent

treatment for ammonium, in the beginning of Sec. 4.3.

4) Response: This is correct. The values inset in Figures 6-9 are the scaling factors for those sensitivities. We have clarified this in the captions for those figures.

5) Response: In Figures 8 and 9, we are plotting the normalized sensitivities of radiant reflectance to aerosol emissions, E/R_I (dR_I)/dE. In other words the percent change in the TOA reflectance for some percent change in emissions. For regions where the emissions are zero, this value will also be zero and given a white color indicator using the colorbar we chose to display these sensitivities. Using the adjoint of the GEOS-Chem model, we are calculating these sensitivities to emissions for all grid cells at once. There are no grid cells that have no data points in those figures, just values very close to zero in the case of low emissions or small values of (dR_I)/dE. We have added comments to the beginning of Sec. 4.3 to clarify this.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 5447, 2013.

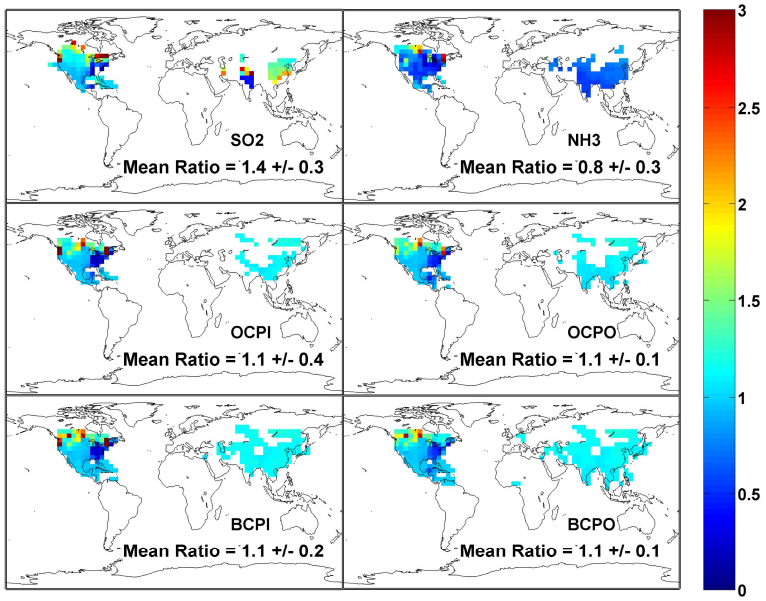

Fig. 1. Response Figure 1

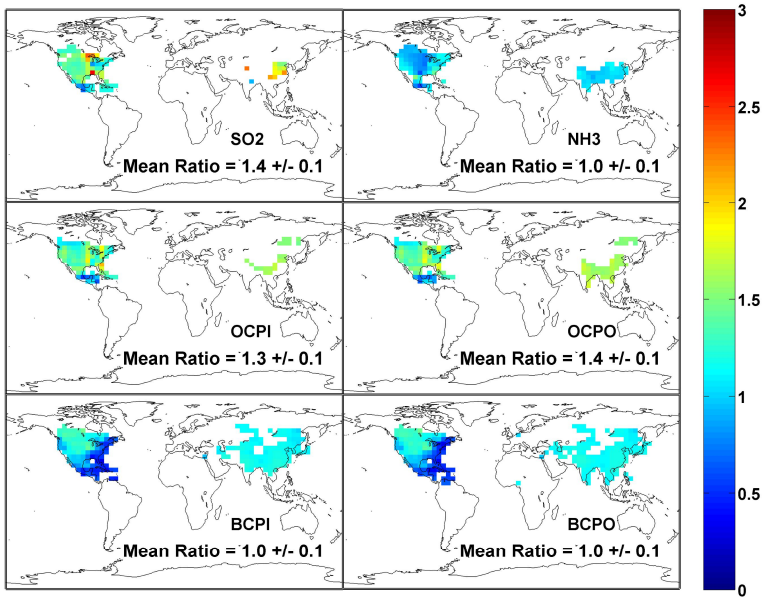

Fig. 2. Response Figure 3

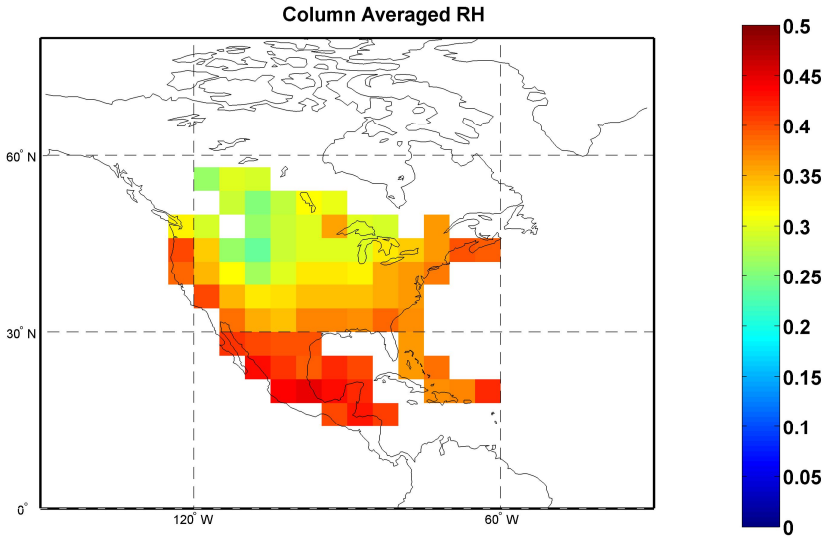

Fig. 3. Response Figure 3