Exploring Improvements to the Aerosol Parameterization in the OCO-2 X_{CO_2} Retrieval Algorithm

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Introduction

- The **scattering effects of clouds and aerosols** are one of the primary sources of error when making space-based measurements of carbon dioxide
- Here, we attempt to **enhance both the accuracy and precision** of Orbiting Carbon Observatory-2 (OCO-2) retrievals of column-averaged dry-air mole fraction of carbon dioxide (X_{CO_2}) **by using better-informed aerosol priors** from the Goddard Earth Observing System Model (GEOS)
- This work, described in detail by Nelson et al. (2019)[1] and furthered here, will likely be incorporated into OCO-2 B10

Data & Methods

- Primarily B8 and B9 OCO-2 data[2] was used for this analysis
- OCO-2 uses optimal estimation to solve for several cloud/aerosol properties, including the aerosol optical depth (AOD) of two tropospheric types (two of the red curve in Fig. 1)
- **Aerosol priors were taken from the GEOS-5 Forward Processing for Instrument Teams (FP-IT) model**[3] 3-hourly output instead of a Modern-Era Retrospective analysis for Research and Applications, Version 2 (MERRA-2) monthly climatology
- The **uncertainty** on the two GEOS AOD priors was set to **25% of B9**, reflecting higher confidence that the priors are more realistic
- X_{CO_2} Validation was done by comparison to the Total Carbon Column Observing Network (TCCON)[4] and a model median validation dataset[2].

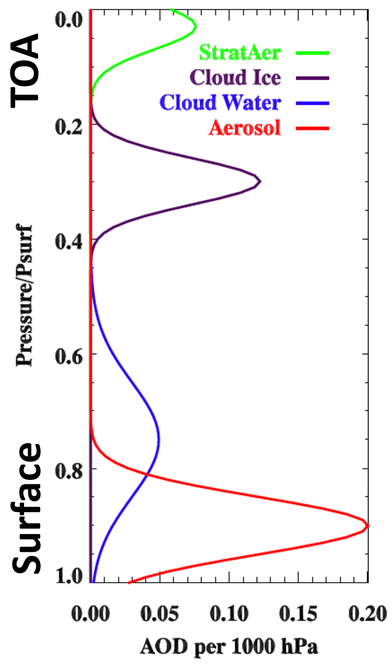
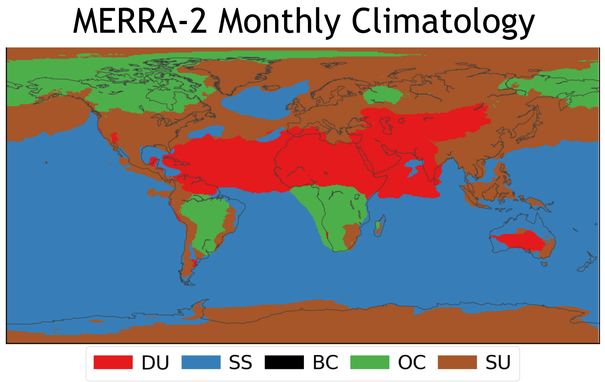


Figure 1. Prior Gaussian shapes, figure courtesy of Chris O'Dell

MERRA-2 Monthly Climatology



GEOS-5 3-Hourly Aerosols

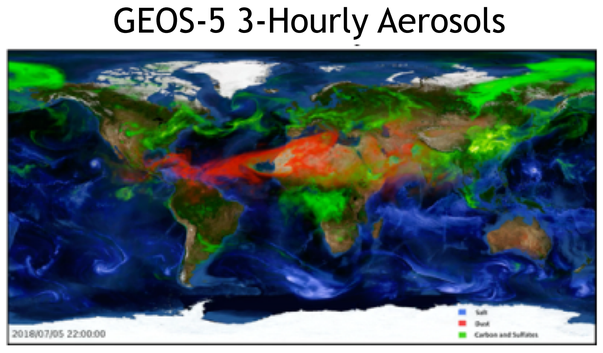
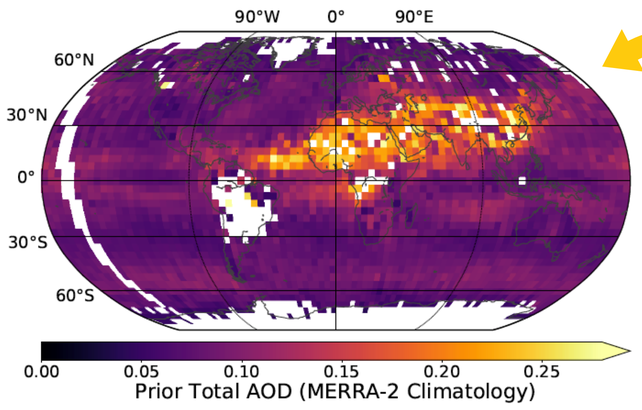


Figure 2. Example of the monthly climatology vs. the 3-hourly product



The prior AOD from the MERRA-2 climatology was too large in many regions because it was not filtered to represent the clear scenes that OCO-2 typically measures

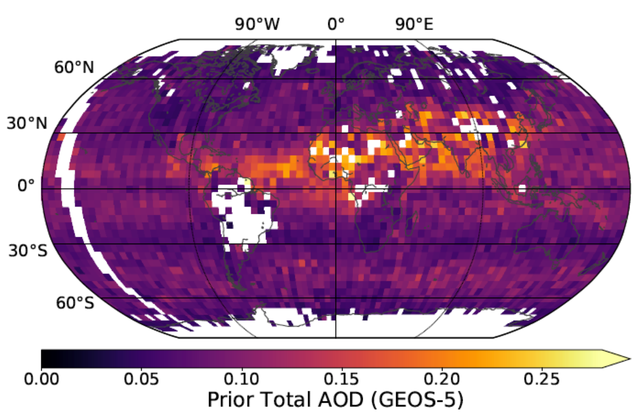


Figure 3. Prior total AOD using the MERRA-2 climatology (top) and using the GEOS 3-hourly model (bottom)

We see a decrease in X_{CO_2} of more than 1 ppm in certain regions with the updated aerosol scheme

This decrease is around 0.3 ppm when the B9 bias correction is applied, with some scatter at high latitudes

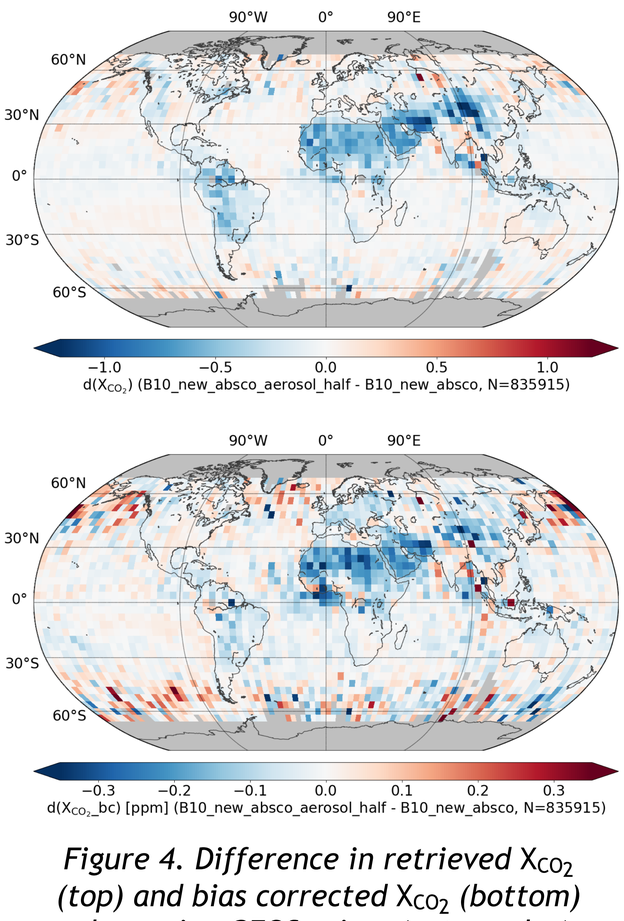


Figure 4. Difference in retrieved X_{CO_2} (top) and bias corrected X_{CO_2} (bottom) when using GEOS priors (note scales)

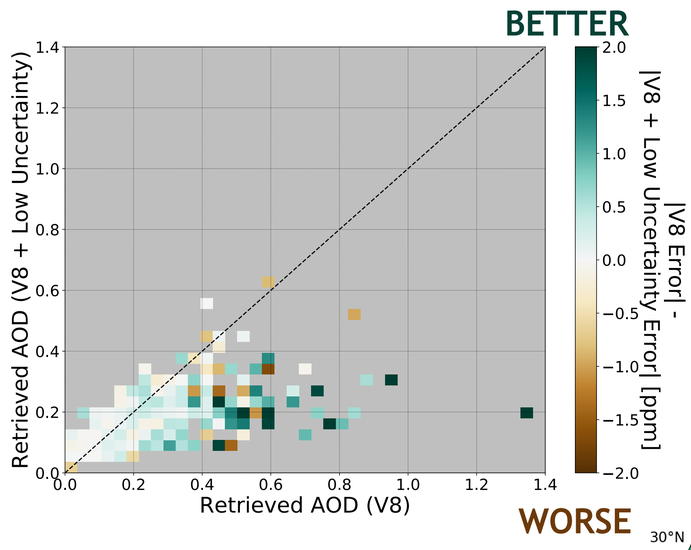
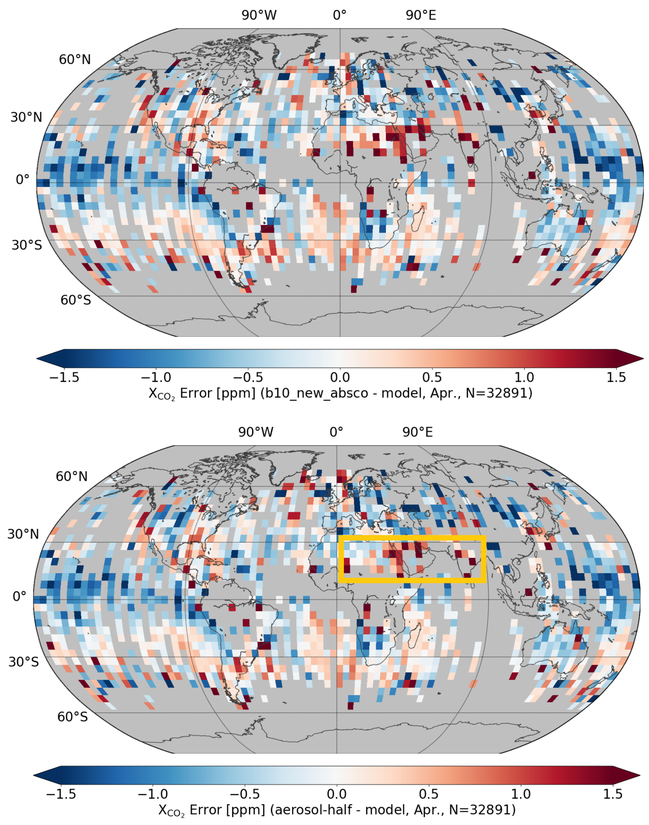


Figure 5. Retrieved AOD (B8) vs. retrieved AOD for B8 with lower (25%) prior uncertainty on the tropospheric AODs for northern Africa and central Asia

Here we can see the removal of high biased X_{CO_2} measurements when using the updated GEOS aerosol scheme



In this region, for example, the bias in X_{CO_2} against a model median validation dataset was reduced from +0.66 ppm to +0.30 ppm

Figure 7. X_{CO_2} error using climatological aerosol priors (top) and using GEOS aerosols (bottom) for the month of April

Fig. 5 demonstrates that, over northern Africa and central Asia, X_{CO_2} improvement is, in part, due to the lower AOD prior uncertainty alone

The reduction in bias occurs where large AODs were previously retrieved

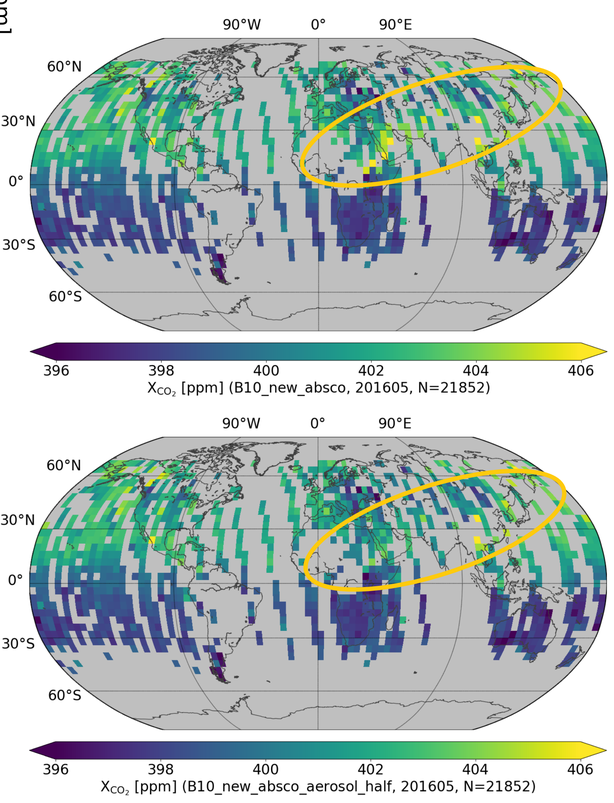


Figure 6. Retrieved X_{CO_2} using climatological aerosols (top) and GEOS aerosols (bottom) for May 2016

Aerosol scheme	Surface	Raw σ [ppm]	Postfiltered σ [ppm]	Postfiltered +bias correction σ [ppm]
Climatology	Land	2.82	2.00	**1.21**
GEOS	Land	2.75	1.88	**1.19**
Climatology	Ocean	1.54	1.03	**0.86**
GEOS	Ocean	1.57	1.04	**0.85**

Table 1. Global validation statistics against TCCON

Conclusions

- Using temporally and spatially co-located aerosol priors from GEOS resulted in **small regional improvements in the retrieved X_{CO_2} from OCO-2**. This is because:
  - The retrieval starts from a smaller, more representative AOD prior
  - The prior uncertainty is reduced to prevent unrealistically large AODs from being retrieved
- The global error statistics against both TCCON (Table 1) and the model median validation dataset (not shown) are similar with and without the updated aerosol priors
- A reduction in high biased X_{CO_2} and X_{CO_2} scatter is seen, primarily in northern Africa and central Asia, where aerosol loading is often high

References

- 1 – Nelson, R. R. et al.: The impact of improved aerosol priors on near-infrared measurements of carbon dioxide, Atmos. Meas. Tech., 12, 1495-1512, doi:10.5194/amt-12-1495-2019, 2019.
- 2 – O'Dell, C. W. et al.: Improved retrievals of carbon dioxide from Orbiting Carbon Observatory-2 with the version 8 ACOS algorithm, Atmos. Meas. Tech., 11, 6539-6576, doi:10.5194/amt-11-6539-2018, 2018.
- 3 - Rienecker, M. M. et al.: The GEOS-5 Data Assimilation System-Documentation of Versions 5.0.1, 5.1.0, and 5.2.0, Tech. rep., NASA Goddard Space Flight Center, Greenbelt, MD, 2008.
- 4 - Wunch, D. et al.: The Total Carbon Column Observing Network, Philosophical Transactions of the Royal Society A, 369, 2087-2112, doi:10.1098/rsta.2010.0240, 2011.

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