Exploring Improvements to the Aerosol Parameterization in the OCO-2 XCO₂ 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 (XCO₂) 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 data² 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) model³ 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
• XCO₂ Validation was done by comparison to the Total Carbon Column Observing Network (TCCON)⁴ and a model median validation dataset².

![MERRA-2 Monthly Climatology vs. GEOS-5 3-Hourly Aerosols](image)

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.

![Prior total AOD using the MERRA-2 climatology (top) and using the GEOS 3-hourly model (bottom)](image)

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

We see a decrease in XCO₂ 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.

![Difference in retrieved XCO₂ (top) and bias corrected XCO₂ (bottom) when using GEOS priors (note scale)](image)

Figure 4. Difference in retrieved XCO₂ (top) and bias corrected XCO₂ (bottom) when using GEOS priors (note scale)

Conclusions

• Using temporally and spatially co-located aerosol priors from GEOS resulted in small regional improvements in the retrieved XCO₂ 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 XCO₂ and XCO₂ scatter is seen, primarily in northern Africa and central Asia, where aerosol loading is often high.

Reference:


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