Aerosol Parameterization in Space-Based $X_{CO_2}$ Retrievals

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• Carbon community wants accurate, non-biased OCO-2 $X_{CO_2}$ measurements

• One of the largest sources of error in space-based measurements is the scattering effect of clouds and aerosols

• How has this been handled in $X_{CO_2}$ retrievals?
Complexity

- Ignoring clouds and aerosols proved ineffective \(^1\)

\(^1\) O’Brien and Rayner, 2002; Aben et al., 2007; Butz et al., 2009; Nelson et al., 2016
• Thus, methods of adding one or more scattering particles were developed\(^2\)

• Try to retrieve information about amount, optical properties, and/or location in the atmosphere

\(^2\)Butz et al., 2009; Yokota et al., 2009; Crisp et al., 2010; Reuter et al., 2013; Parker et al., 2011
Non-scattering retrieval

Current OCO-2 operational algorithm retrieves 8 parameters:

- Optical depth and height of 4 types
  - Ice cloud, water cloud, 2 aerosols from a MERRA-2 monthly climatology
Complexity

Non-scattering retrieval

OCO-2 B7  OCO-2 B8

- Latest non-operational algorithm (B8) retrieves 9 parameters
- B7 + stratospheric aerosol (+ other changes)
- Retrieved AOD has always compared poorly to AERONET

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Non-scattering retrieval

OCO-2 B7  OCO-2 B8

Complexity

Retrieving more types

• Tests retrieving additional types not promising

• More information than in the radiances\(^3\)
  – 2-5 degrees of freedom for aerosols

• Idea: can we do better if we use a simpler aerosol parameterization with intelligent priors?

\(^3\)Frankenberg et al., 2012
Non-scattering retrieval

Two Layer Model

- Simple two layer model
  - Coarse and fine mode in each layer
- One lower tropospheric layer
- One upper tropospheric / stratospheric layer

OCO-2 B7

OCO-2 B8

Complexity

Retrieving more types
• Retrieve a mix of coarse (e.g. dust) and fine (e.g. sulfate) mode particles in the lower layer

• Retrieve a mix of ice cloud (cirrus) and stratospheric aerosol (sulfate) in the upper layer

• Use more intelligent priors (GEOS-5 FP-IT 3-hourly)

• Retrieve optical depth and height of Gaussian layers
• Similar correlation, slight improvement in overpass-mean scatter
• Slightly better fit to the radiances
Conclusions

• Simple but realistic two layer aerosol model shows promise

• Potential benefits of a simpler aerosol model:
  – More interpretable aerosol results
  – Better convergence -> more measurements!
  – Less non-linearity (fewer state vector elements)
Next Steps

• Customized filtering and bias correction

• Dependence on optical properties of coarse and fine mode particles

• Implement GEOS-5 vertical aerosol information as a priori
Backup Slides
• 32,176 soundings co-located w/ TCCON and AERONET to within 1°, +/- 30 min.
• 136 overpasses over 14 locations