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

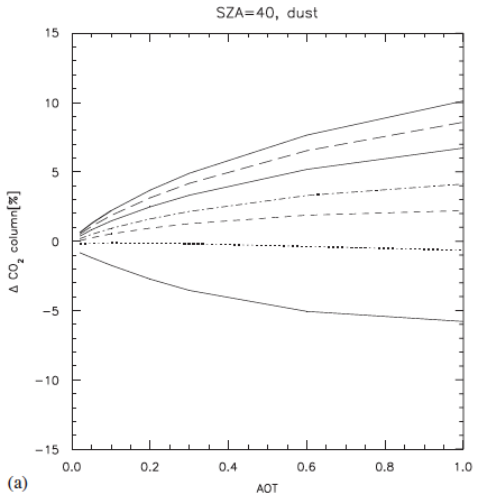
- One of the largest sources of error in space-based measurements is the scattering effect of clouds and aerosols

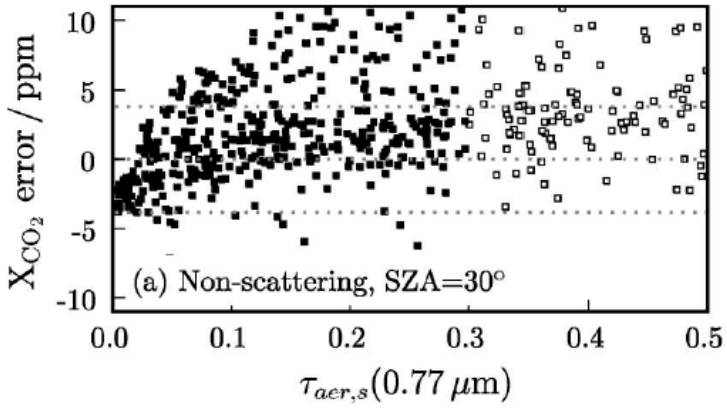
- How has this been handled in X_{CO_2} retrievals?

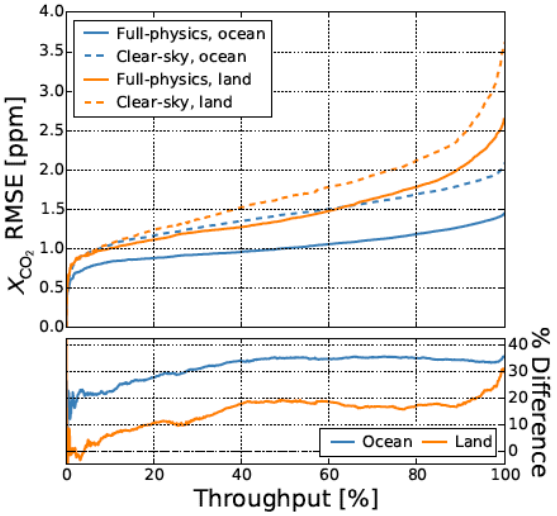
Non-scattering retrieval

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

OCO-2 B7

Complexity

- Current OCO-2 operational algorithm retrieves 8 parameters

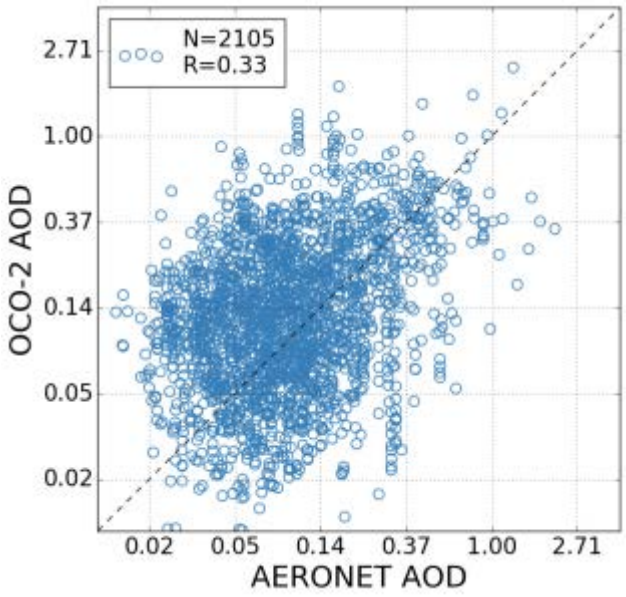
- Optical depth and height of 4 types
  - Ice cloud, water cloud, 2 aerosols from a MERRA-2 monthly climatology

Non-scattering retrieval

OCO-2 B7 OCO-2 B8

Complexity

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



B7

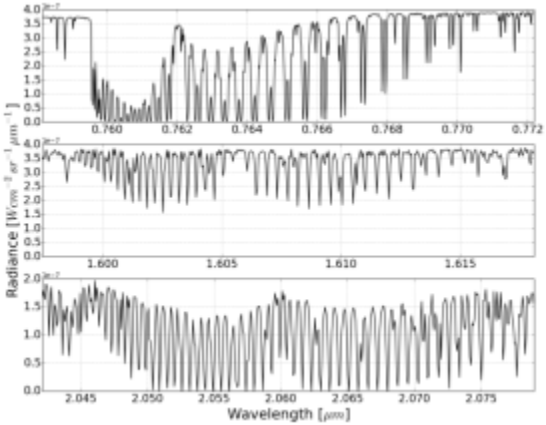
Non-scattering retrieval

OCO-2 B7 OCO-2 B8

Complexity

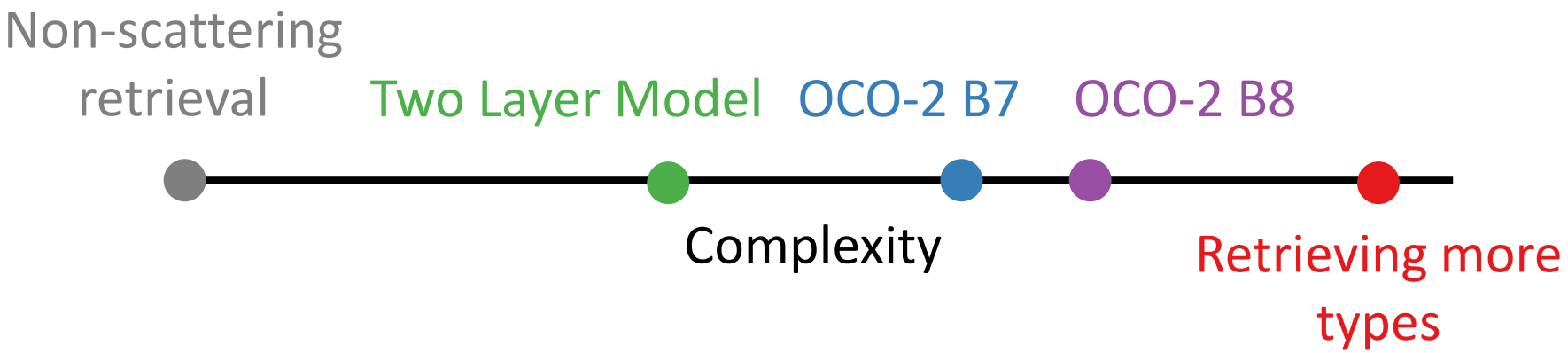
Retrieving more types

- 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



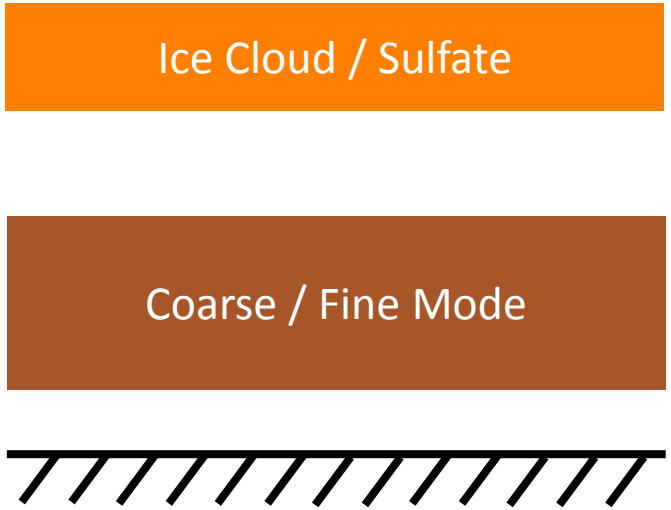
- Simple two layer model
  - Coarse and fine mode in each layer
- One lower tropospheric layer
- One upper tropospheric / stratospheric layer

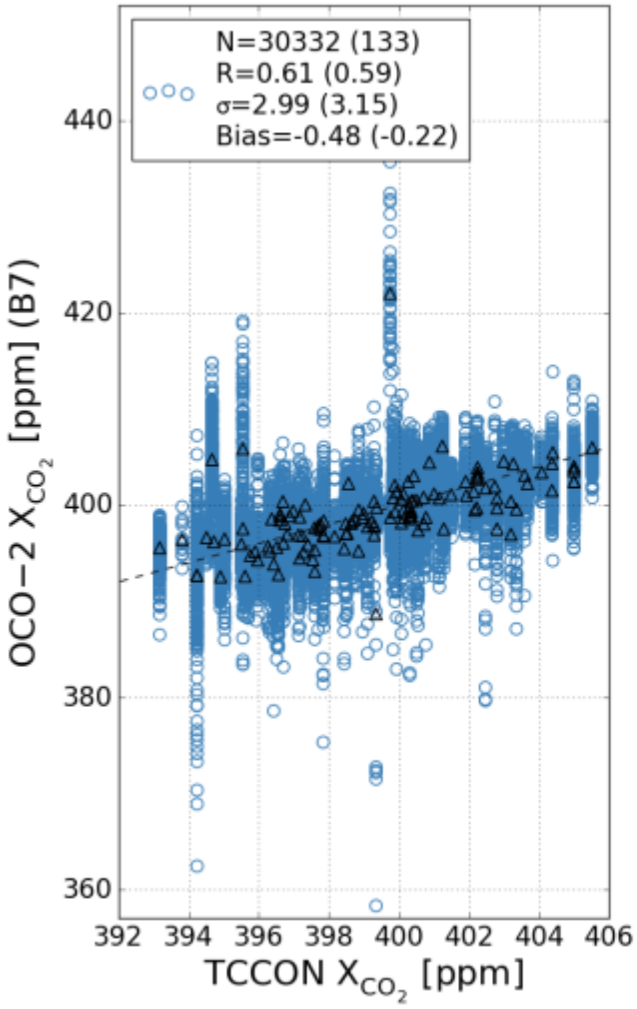
- Retrieve a mix of coarse (e.g. dust) and fine (e.g. sulfate) mode particles in the lower layer

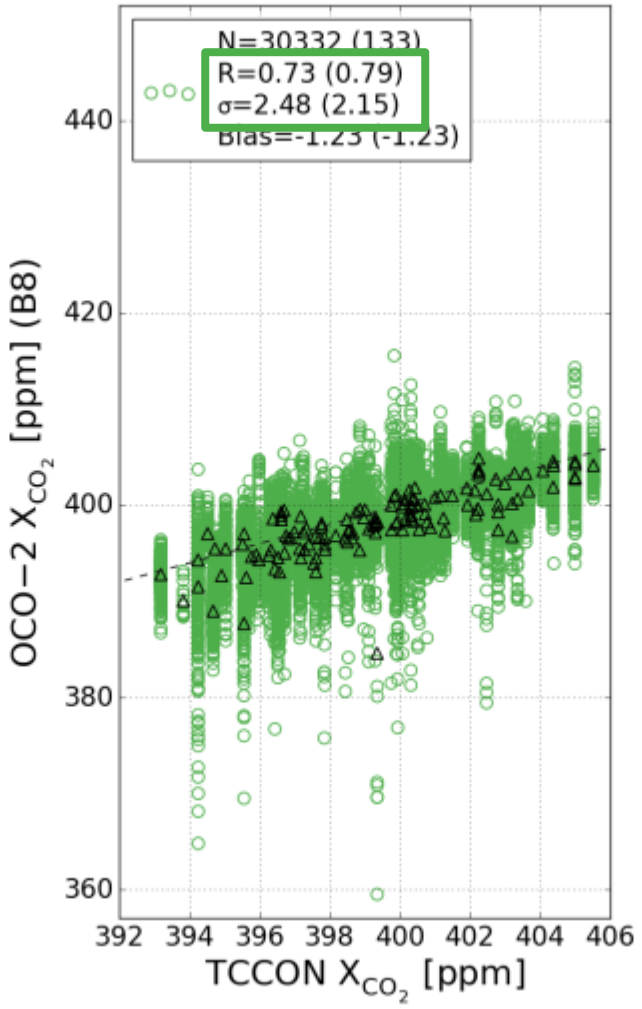
- Retrieve a mix of ice cloud (cirrus) and stratospheric aerosol (sulfate) in the upper layer

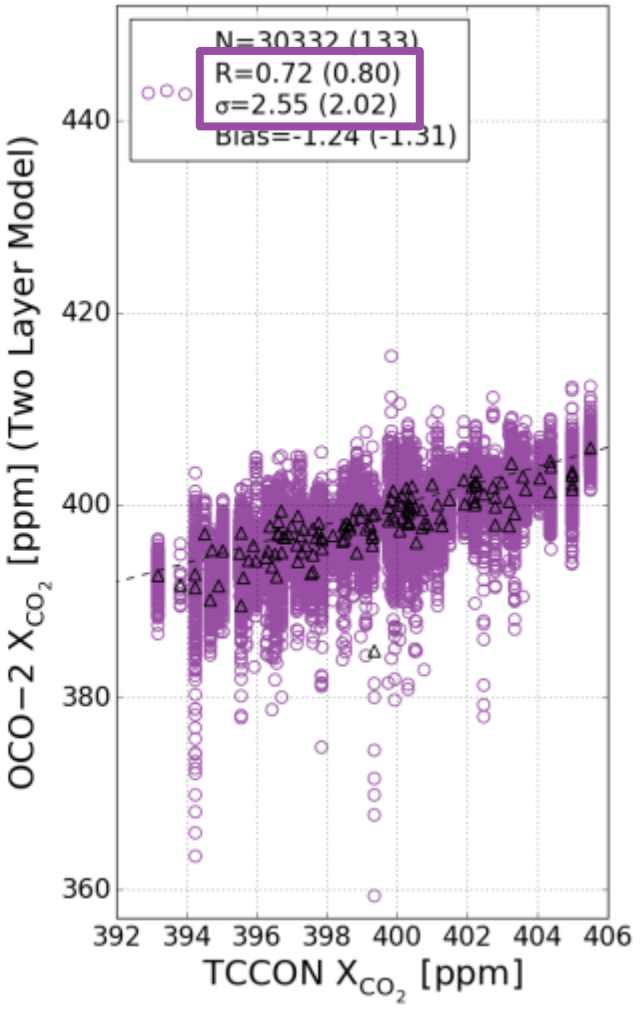
- Use more intelligent priors (GEOS-5 FP-IT 3-hourly)

- Retrieve optical depth and height of Gaussian layers

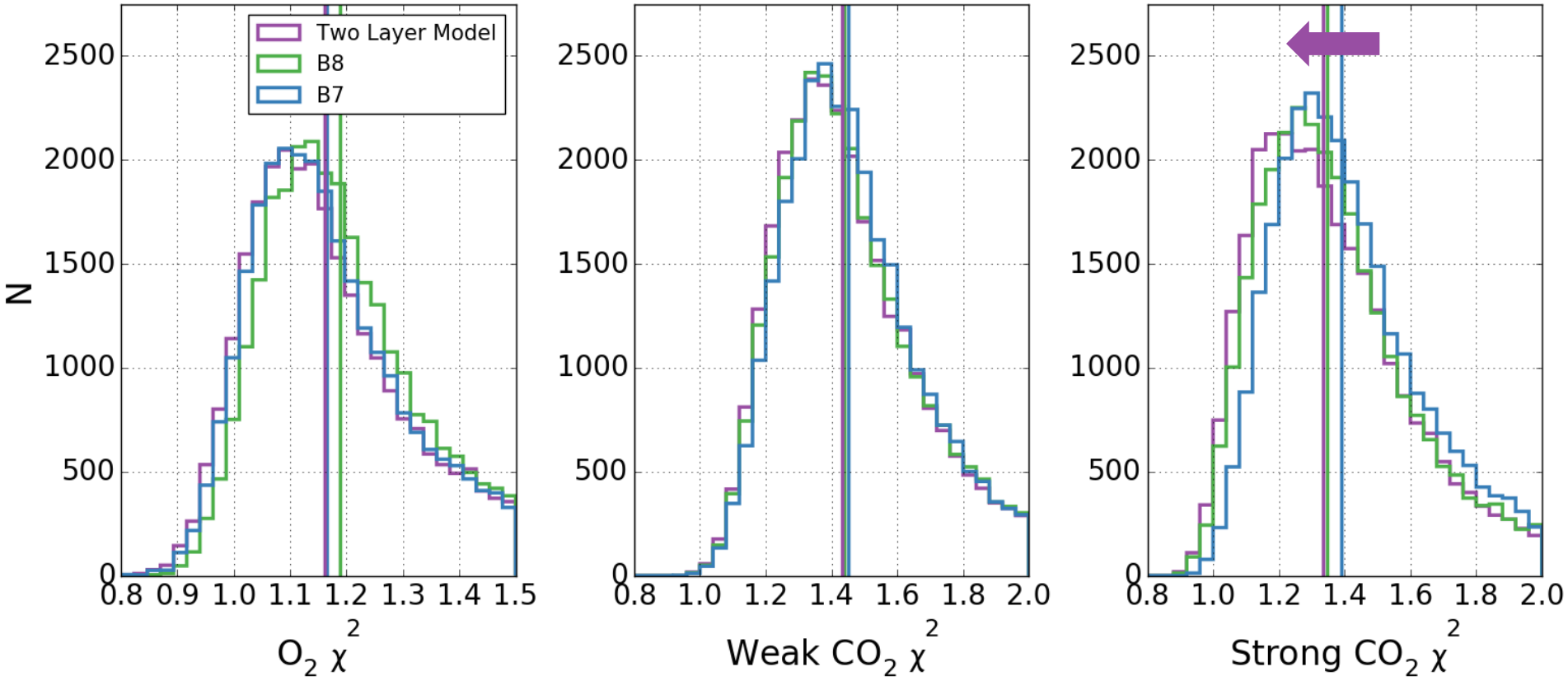








- Similar correlation, slight improvement in overpass-mean scatter



- Slightly better fit to the radiances

Conclusions

- Simple but realistic two layer aerosol model shows promise

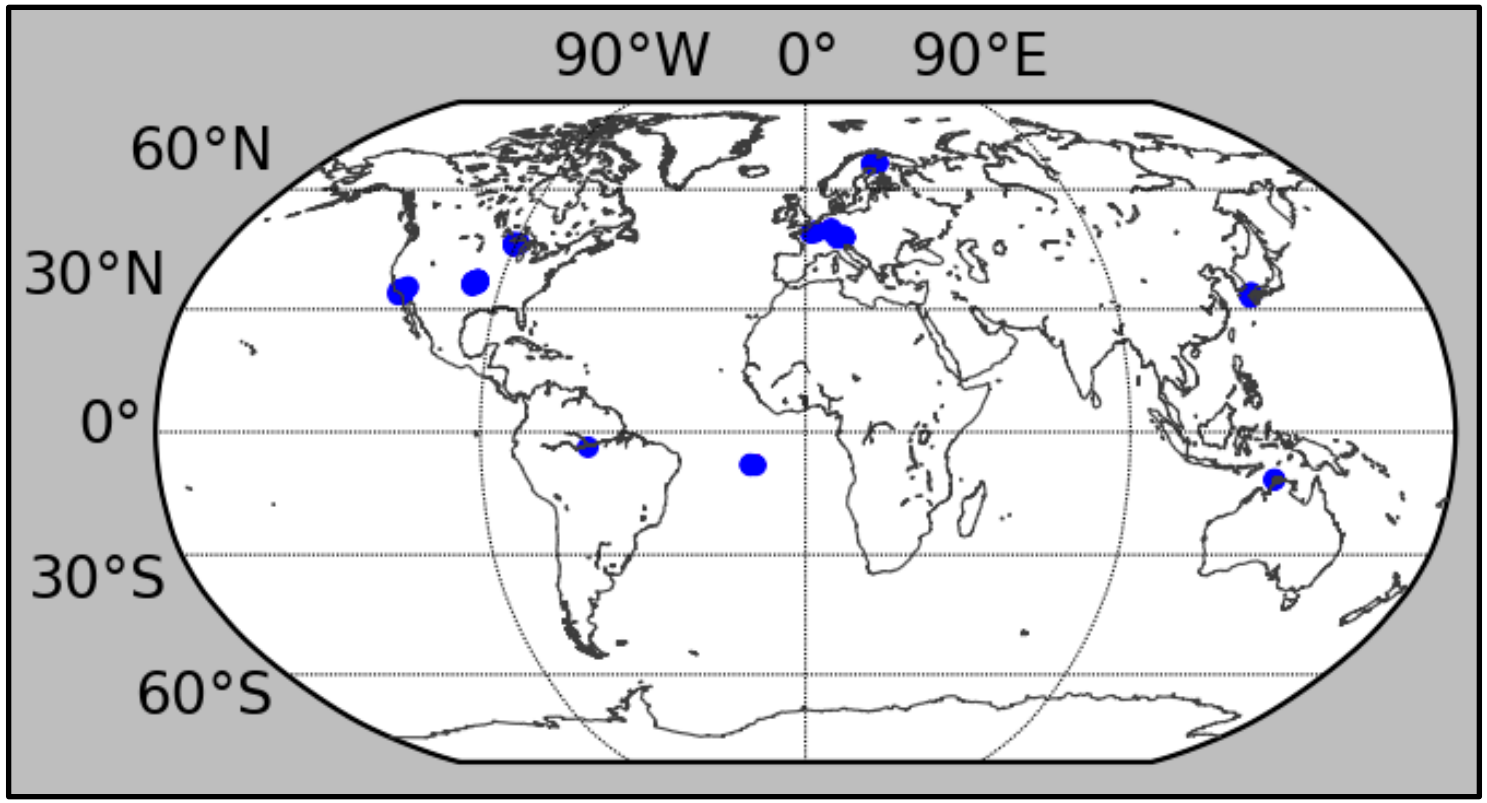
- Potential benefits of a simpler aerosol model:
  - More interpretable aerosol results
  - Better convergence -> more measurements!
  - Less non-linearity (fewer state vector elements)

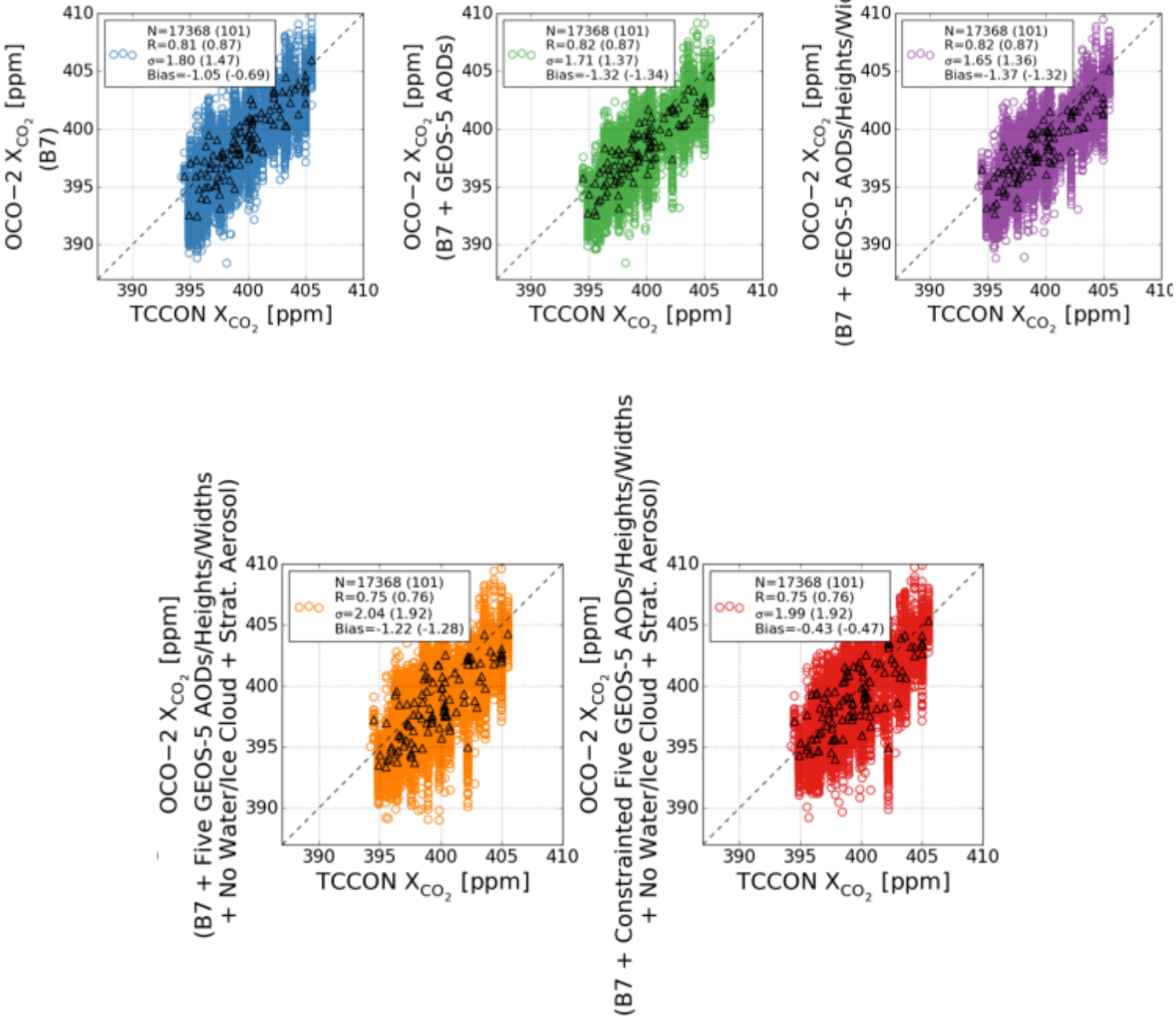
Next Steps

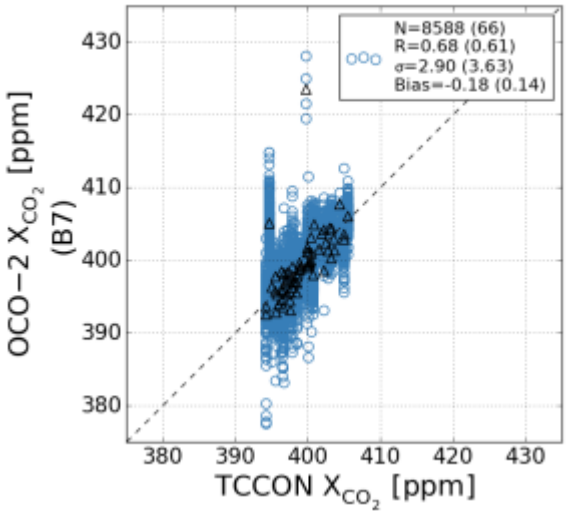
- Customized filtering and bias correction
- Dependence on optical properties of coarse and fine mode particles
- Implement GEOS-5 vertical aerosol information as a priori

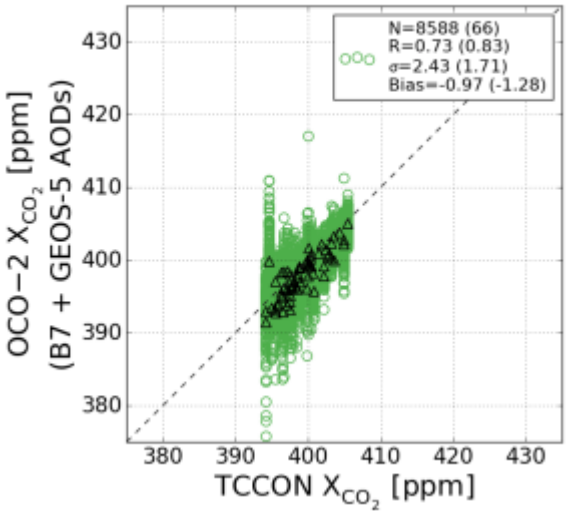
Backup Slides

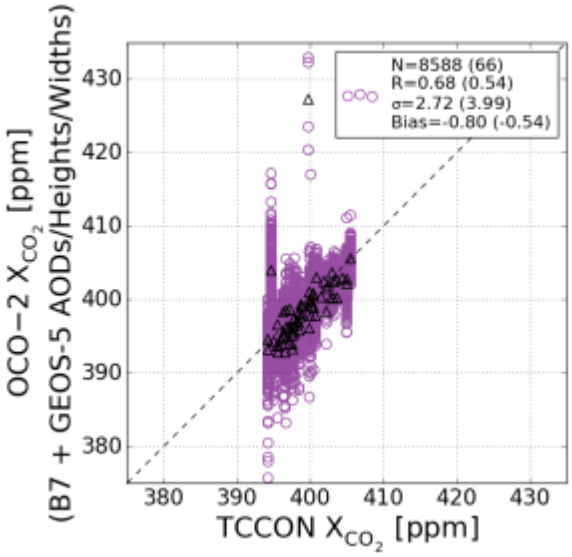
- 32,176 soundings co-located w/ TCCON and AERONET to within 1°, +/- 30 min.
- 136 overpasses over 14 locations

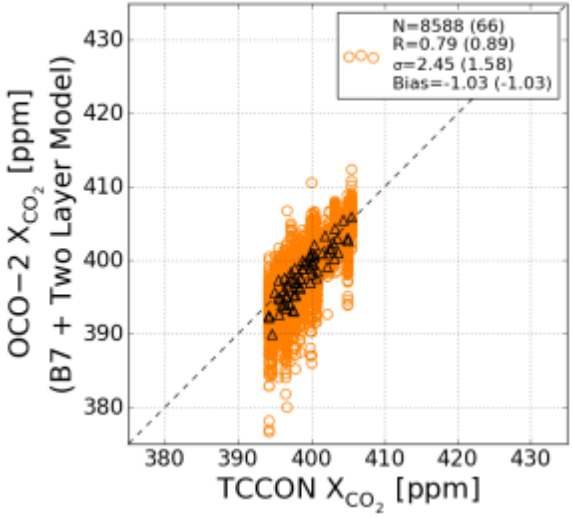



N=17368 (101)
R=0.81 (0.87)
σ=1.80 (1.47)
Bias=-1.05 (-0.69)
OCO−2 X$_{CO_2}$ [ppm] (B7)
TCCON X$_{CO_2}$ [ppm]
N=17368 (101)
R=0.82 (0.87)
σ=1.71 (1.37)
Bias=-1.32 (-1.34)
OCO−2 X$_{CO_2}$ [ppm] (B7 + GEOS-5 AODs)
TCCON X$_{CO_2}$ [ppm]
N=17368 (101)
R=0.82 (0.87)
σ=1.65 (1.36)
Bias=-1.37 (-1.32)
OCO−2 X$_{CO_2}$ [ppm] (B7 + GEOS-5 AODs/Heights/Widths)
TCCON X$_{CO_2}$ [ppm]
N=17368 (101)
R=0.75 (0.76)
σ=2.04 (1.92)
Bias=-1.22 (-1.28)
OCO−2 X$_{CO_2}$ [ppm] (B7 + Five GEOS-5 AODs/Heights/Widths + No Water/Ice Cloud + Strat. Aerosol)
TCCON X$_{CO_2}$ [ppm]
N=17368 (101)
R=0.75 (0.76)
σ=1.99 (1.92)
Bias=-0.43 (-0.47)
OCO−2 X$_{CO_2}$ [ppm] (B7 + Constrainted Five GEOS-5 AODs/Heights/Widths + No Water/Ice Cloud + Strat. Aerosol)
TCCON X$_{CO_2}$ [ppm]


N=8588 (66)
R=0.68 (0.61)
σ=2.90 (3.63)
Bias=-0.18 (0.14)
OCO−2 X_{CO_2} [ppm] (B7)
TCCON X_{CO_2} [ppm]
380
390
400
410
420
430


N=8588 (66)
R=0.73 (0.83)
σ=2.43 (1.71)
Bias=-0.97 (-1.28)
OCO−2 X_{CO_2} [ppm] (B7 + GEOS-5 AODs)
TCCON X_{CO_2} [ppm]
380
390
400
410
420
430


N=8588 (66)
R=0.68 (0.54)
σ=2.72 (3.99)
Bias=-0.80 (-0.54)
OCO−2 X_{CO_2} [ppm] (B7 + GEOS-5 AODs/Heights/Widths)
TCCON X_{CO_2} [ppm]
380
390
400
410
420
430


N=8588 (66)
R=0.79 (0.89)
σ=2.45 (1.58)
Bias=-1.03 (-1.03)
OCO−2 X_{CO_2} [ppm] (B7 + Two Layer Model)
TCCON X_{CO_2} [ppm]
380
390
400
410
420
430