Aerosol First Guess Sensitivity in the ACOS X_{CO_2} Retrieval Algorithm

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Introduction

- In this work, we investigate how modifying the first guess of various aerosol parameters impacts space-based measurements of the column-averaged dry-air mole fraction of carbon dioxide (X_{CO_2}) and corresponding retrieved aerosol properties.
- Only ~1-5 pieces of aerosol information can be retrieved from Orbiting Carbon Observatory-2 (OCO-2) measurements (*Frankenberg et al.*, 2012). However, the NASA Atmospheric CO_2 Observations from Space (ACOS) algorithm (*O'Dell et al.*, 2012) retrieves 8 aerosol parameters: the height & amount of four types. Their prior distributions are shown in figure 1.
- Are there multiple valid aerosol solutions and do they significantly impact the retrieved X_{CO_2}?

ACOS B3.4 or B3.5?

- Figures 2 and 3 demonstrate that the difference in accuracy of retrieved aerosol optical depths between ACOS builds 3.4 and 3.5 is minimal.
- Other aerosol parameters are also similar between ACOS versions

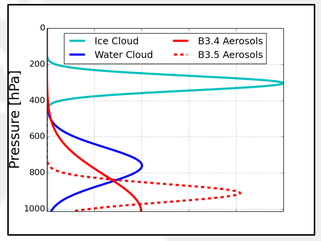


Figure 1. ACOS a priori *aerosol profiles*

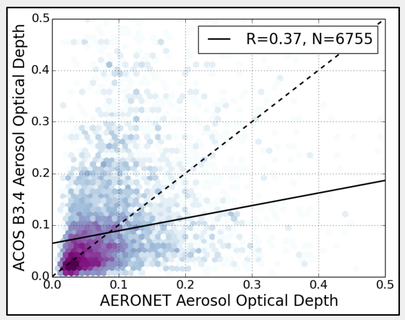


*Figure 2. AErosol RObotic NETwork (AERONET) optical depths compared to **ACOS B3.4** retrieved aerosol optical depths (N log scaled)*

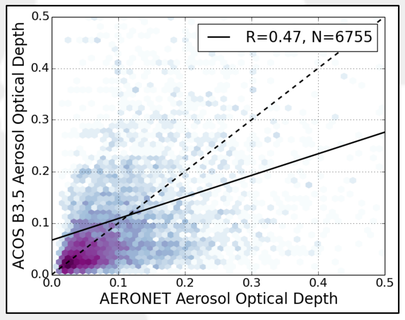


*Figure 3. AERONET optical depths compared to **ACOS B3.5** retrieved aerosol optical depths (N log scaled)*

Data & Methodology

- 12 unique simulated OCO-2 retrievals were examined in this study. The four aerosol types in ACOS B3.4 (ice cloud, water cloud, Kahn 2b, and Kahn 3b) are described by a Gaussian width and peak height along with an amount.
- Using optimal estimation (*Rogers*, 2000) to find a solution to the state vector by minimizing the cost function, we perturbed the first guess of the amount and height of all four types (8 total perturbations).
- The first guesses were 1,000 random perturbations along a Gaussian in natural log-space described by a peak at the *a priori* value and a width corresponding to the *a priori* uncertainty.

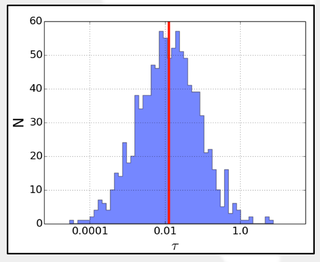


Figure 4. Ex. of the distribution of first guesses around the a prior *(red line)*

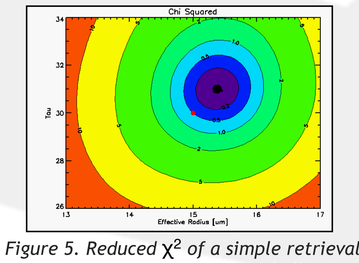


Figure 5. Reduced χ^2 of a simple retrieval where the algorithm is mostly linear

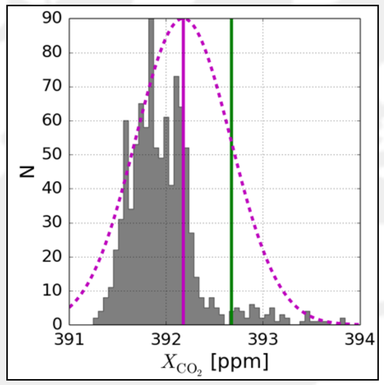


Figure 6. First Guess Case 1

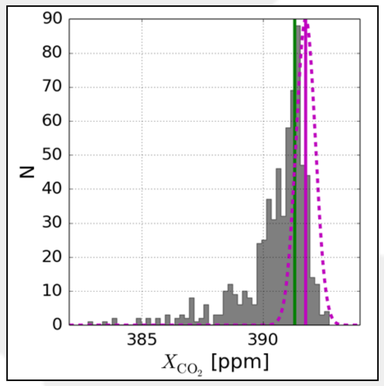


Figure 7. First Guess Case 2

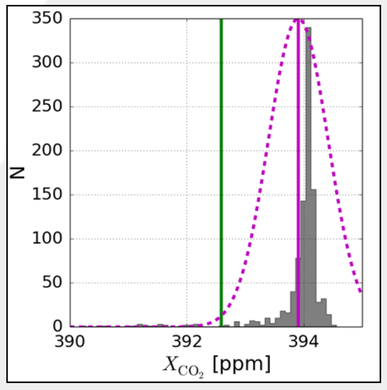
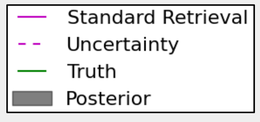


Figure 8. First Guess Case 3



Results

- 3 of the 12 cases are described below

Case 1 (figure 6)

- Most first guess perturbation X_{CO_2} values are within the posterior error of the standard retrieval
- >1ppm spread simply from perturbing the aerosol first guesses
- Should theoretically only find one solution if there were a single χ^2 minimum (like the example in figure 5)

Case 2 (figure 7)

- The true X_{CO_2} is near the standard retrieval, which is also the peak of the 1,000 cases.
- Significant spread in retrieved X_{CO_2}

Case 3 (figure 8)

- Large positive bias in the retrieved X_{CO_2} values relative to the truth
- The truth is essentially outside the confidence bounds which indicates an underestimation of the posterior X_{CO_2} error
- Some first guess perturbations retrieve X_{CO_2} values closer to the truth (around 392.6 ppm)

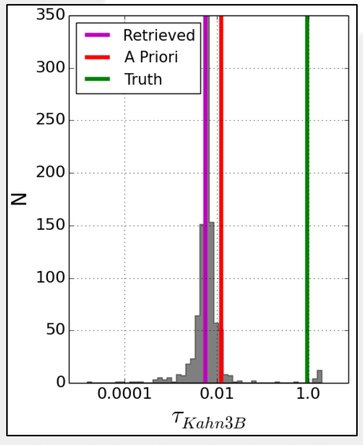


Figure 9. First Guess Case 3 Kahn 3b optical depth distribution

Aerosol Distribution

- Figure 9 shows the retrieved Kahn 3b distribution for case 3. Most of the perturbations find a low aerosol optical depth solution while a small population manages to find optical depths much closer to the true value of ~1.0. Figure 10 shows that these populations are in regions of lower χ^2.
- Indicative of non-linearity in the aerosol scheme

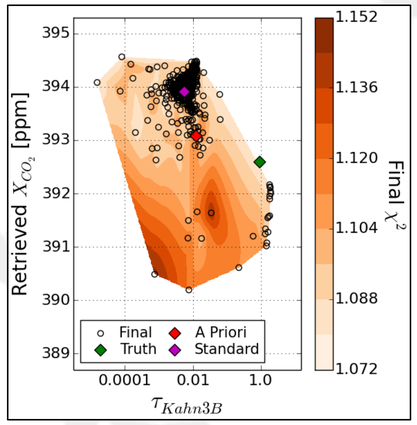


Figure 10. Case 3 Kahn 3b optical depths vs. the retrieved X_{CO_2} with corresponding χ^2 values

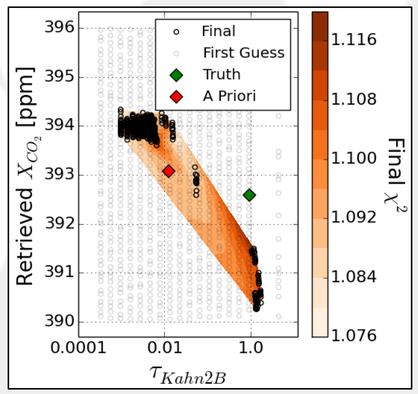


Figure 11. Kahn 2b optical depths vs. the retrieved X_{CO_2} with corresponding χ^2 values

Aerosol Distribution

- Figure 11 shows a different test where only the X_{CO_2} and Kahn 2b optical depth were perturbed
- Figure 12 shows a case where two distinct optical depth populations are being retrieved.
- Both examples are evidence of non-linearity in the retrieval algorithm

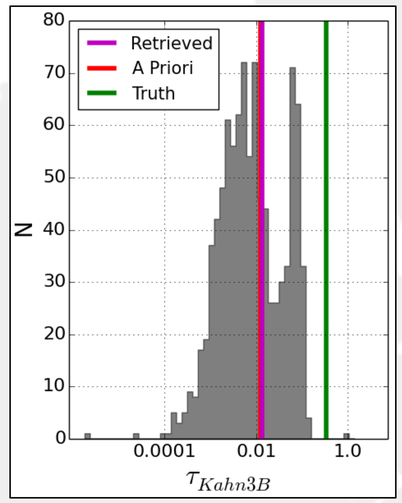


Figure 12. First Guess Kahn 3b optical depth distribution

Conclusions

- The ACOS X_{CO_2} retrieval algorithm, when applied to simulated OCO-2 radiances, is highly sensitive to the first guess of aerosol parameters.
- Perturbing the first guess of aerosol heights and amounts often results in unacceptably high variations in the retrieved X_{CO_2}, which indicates non-linearity in the retrieval algorithm.
- More information is likely needed to help constrain the aerosol solutions such as additional measurements from other A-Train satellites including MODIS and CALIPSO. Other solutions including changing the scheme's complexity or *a priori* information.

References

Frankenberg et al.: Aerosol information content analysis of multi-angle high spectral resolution measurements and its benefit for high accuracy greenhouse gas retrievals, Atmospheric Measurement Techniques, 5, 1809-1821, doi:10.5194/amt-5-1809-2012, 2012.

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Acknowledgements. I would like to thank Christopher W. O'Dell for his mentorship and guidance on this project.

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