Improving Atmospheric Correction for Imaging Spectrometers with Iterative Fitting of Absorption by Three Phases of Water

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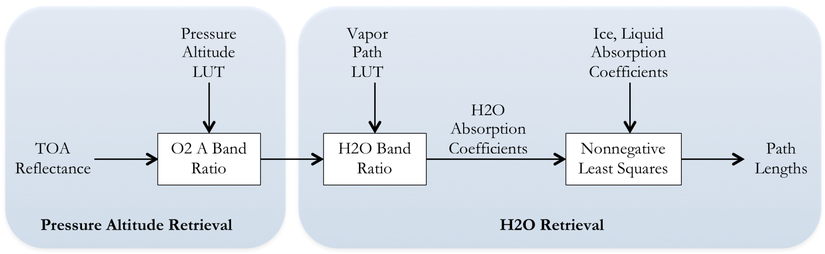
Background

Water vapor distorts ground truth reflectance spectra and must be corrected for in the top-of-atmosphere reflectance spectra using atmospheric correction algorithms. There are two methods currently in use: the band ratio method and the three phase method (diagram shown).



Both methods show inaccuracy in water vapor absorption path length calculations over certain environments, especially those that contain liquid water and/or ice.

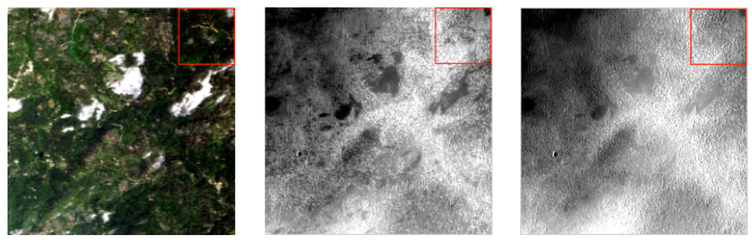


Figure 1: TOA image (left) and vapor maps using vapor paths calculated using the band ratio method (left) and three phase method (right).

Objective Find source of error, and correct for it to improve the retrieval of ground truth reflectance spectra.

Synthetic Data

- Create TOA spectra by adding known amounts of water vapor, liquid, and ice to USGS ground truth reflectance spectra.
- Apply three phase method to calculate vapor absorption path length.

Fitting 940 nm feature vs. 1140 nm feature

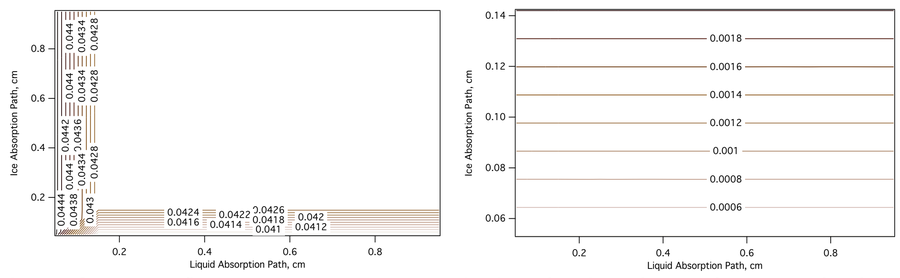


Figure 2: Error of average vapor error calculated using three phase method fitted to 940 nm vapor feature (left) and 1140 nm feature (right).

Results Fitting the 1140 nm feature is slightly better than fitting the 940 nm feature.

Changing the Initial Estimate

$$\rho_\lambda = (a + \lambda b)\exp[-\sum_j k_{j,\lambda} u_j], \quad u_j \geq 0$$

- Initial estimate needed to gather absorption coefficients, k
- In three phase method, uses calculated vapor absorption path from the band ratio method
- Band ratio method is inaccurate → inaccurate absorption coefficients → inaccurate path lengths?

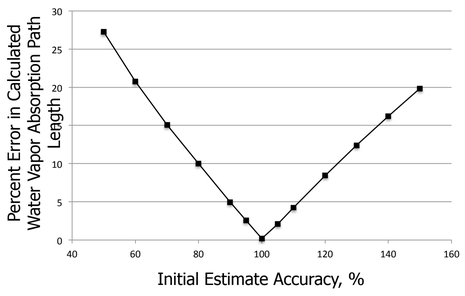
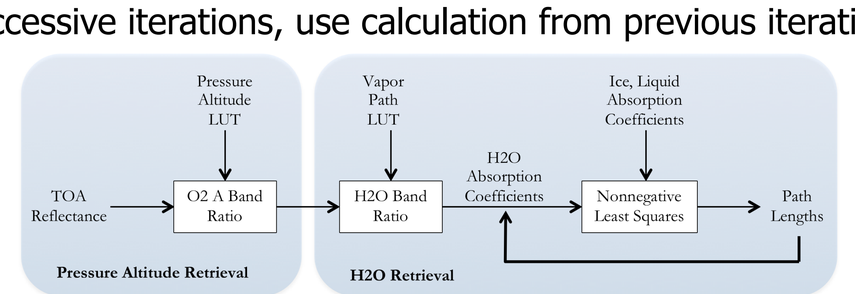


Figure 3: Percent error in calculated vapor path versus the initial accuracy in the vapor path estimate.

Results
A lot of the error comes from inaccuracy in the initial estimate of the vapor absorption path.

Iterative Method

- Iterate over three phase fitting method.
- For first iteration, use band ratio calculation.
- For successive iterations, use calculation from previous iteration.



Results

Synthetic Data

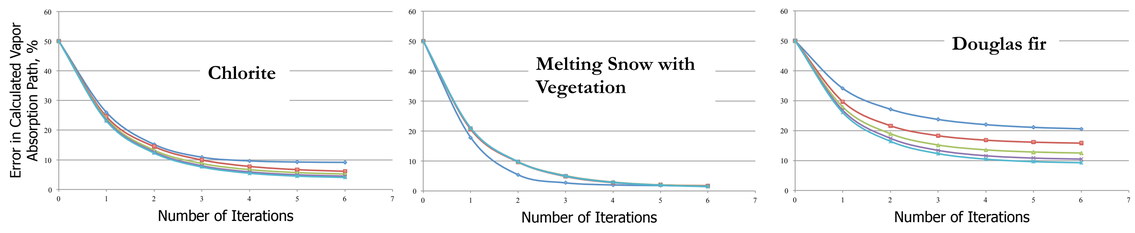


Figure 4: Vapor path error after n iterations for various environments, all starting with a 50% overestimate.

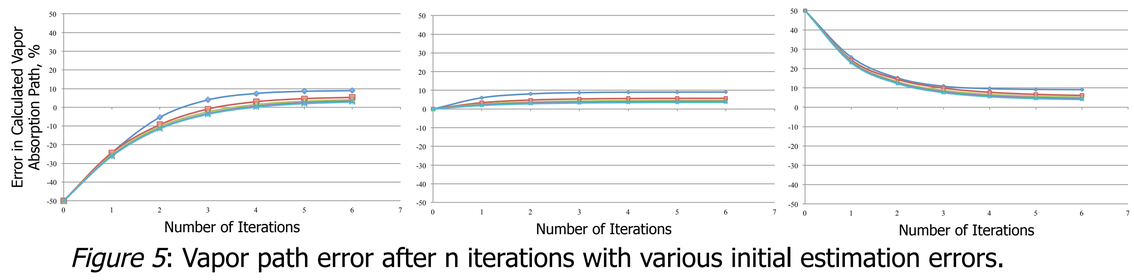
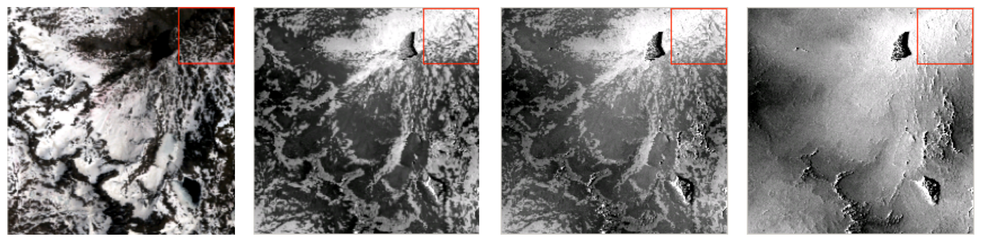


Figure 5: Vapor path error after n iterations with various initial estimation errors.

AVIRIS Data

City and Cropland

Snow-Covered Mountain



Vegetated Area

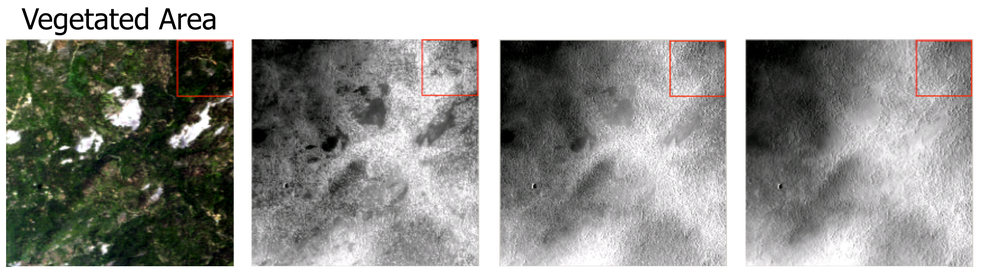


Figure 6: RGB top-of-atmosphere images (left) and vapor maps (from left to right: band ratio method, three phase method, iterative method). Vapor maps should show little interference from ground features.

Conclusion

- The iterative method is the most accurate water vapor correction method to date.
- Using multiple iterations of the three phase method, it removes bias caused by the band ratio calculations.
- It demonstrates improved accuracy over vegetated and snow-covered areas.
- The iterative method is currently installed in the AVIRIS-NG data pipeline.

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