

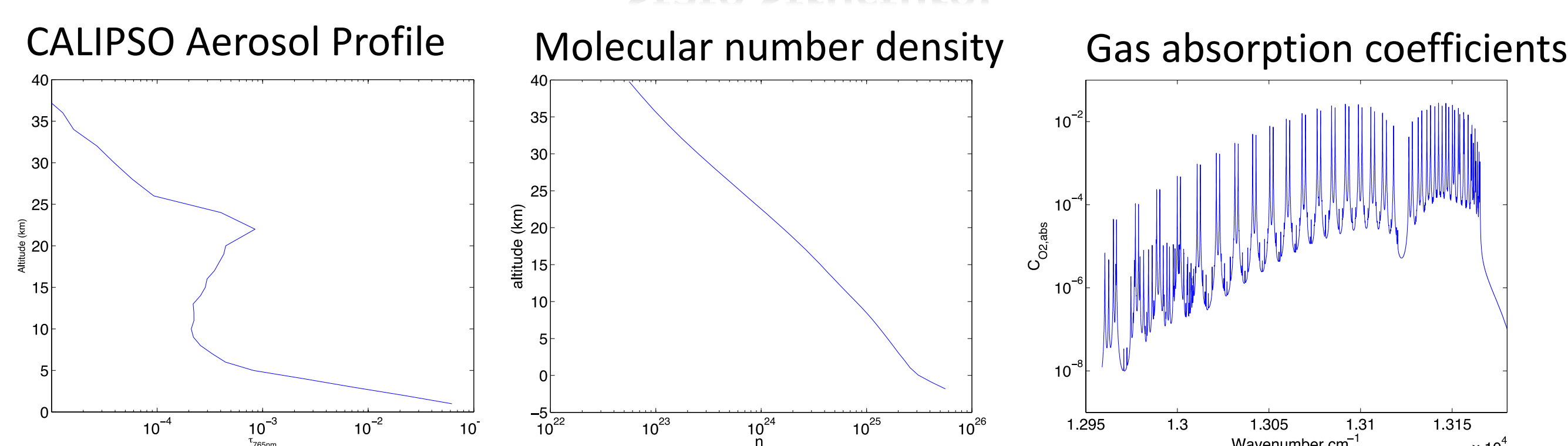
Introduction: motivation

- Aerosol absorption plays an important role in the climate by modulating atmospheric radiative forcing processes.
- Unfortunately aerosol absorption is very difficult to obtain via satellite remote sensing techniques,
- In this work we have built an algorithm to obtain aerosol absorption optical depth using both measurements from a passive oxygen A-band spectrometer and an active lidar.
- The instrument protocols for these two satellite instruments are the oxygen A-band spectrometer onboard the Orbiting Carbon Observatory (OCO-2) and the CALIOP onboard CALIPSO.
- The resultant aerosol absorption product is a valuable independent source for cross checking and validating existing aerosol absorption information, which heavily relies on AERONET products.

Methodology: main rationale

- The OCO-2 oxygen A-band, at about 765 nm, provides radiance measurements with high spectral resolving power (~20000) and high signal to noise ratio (>290).
- The CALIOP onboard CALIPSO measurements provide unique information on aerosol altitude profiles and extinction optical depths, which are used as constrains to the inversion algorithm of the OCO-2 oxygen A-band measurements.
- OCO-2 is scheduled to fly as part of the A-train constellation, a few minutes ahead of the CALIPSO satellite. This work intends to take advantage of synergies between CALIOP and OCO-2 measurements.
- The aerosol retrieval algorithm is based on Levenberg-Marquardt least squares fitting method.

State Structure:



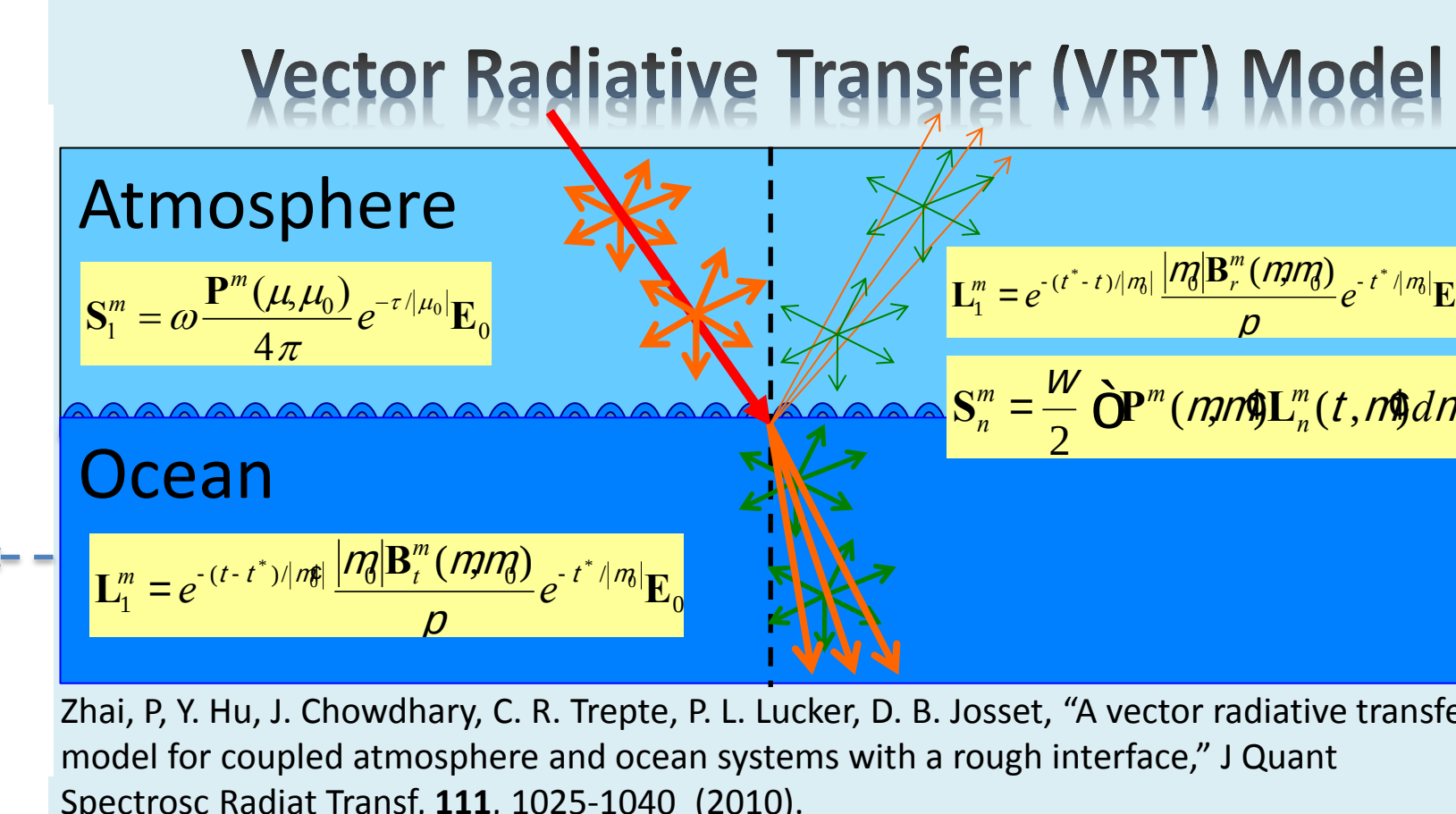
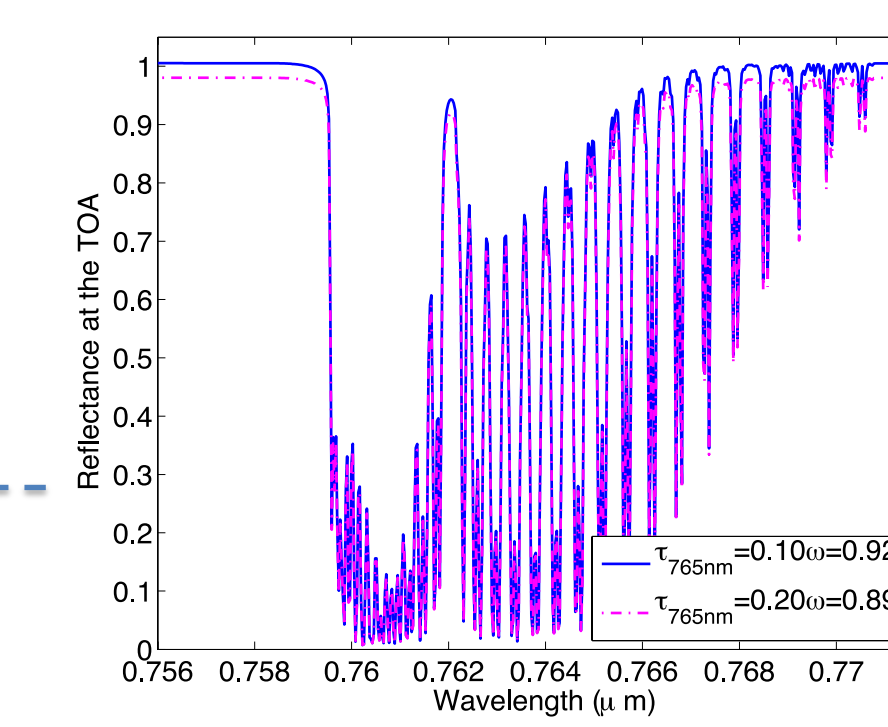
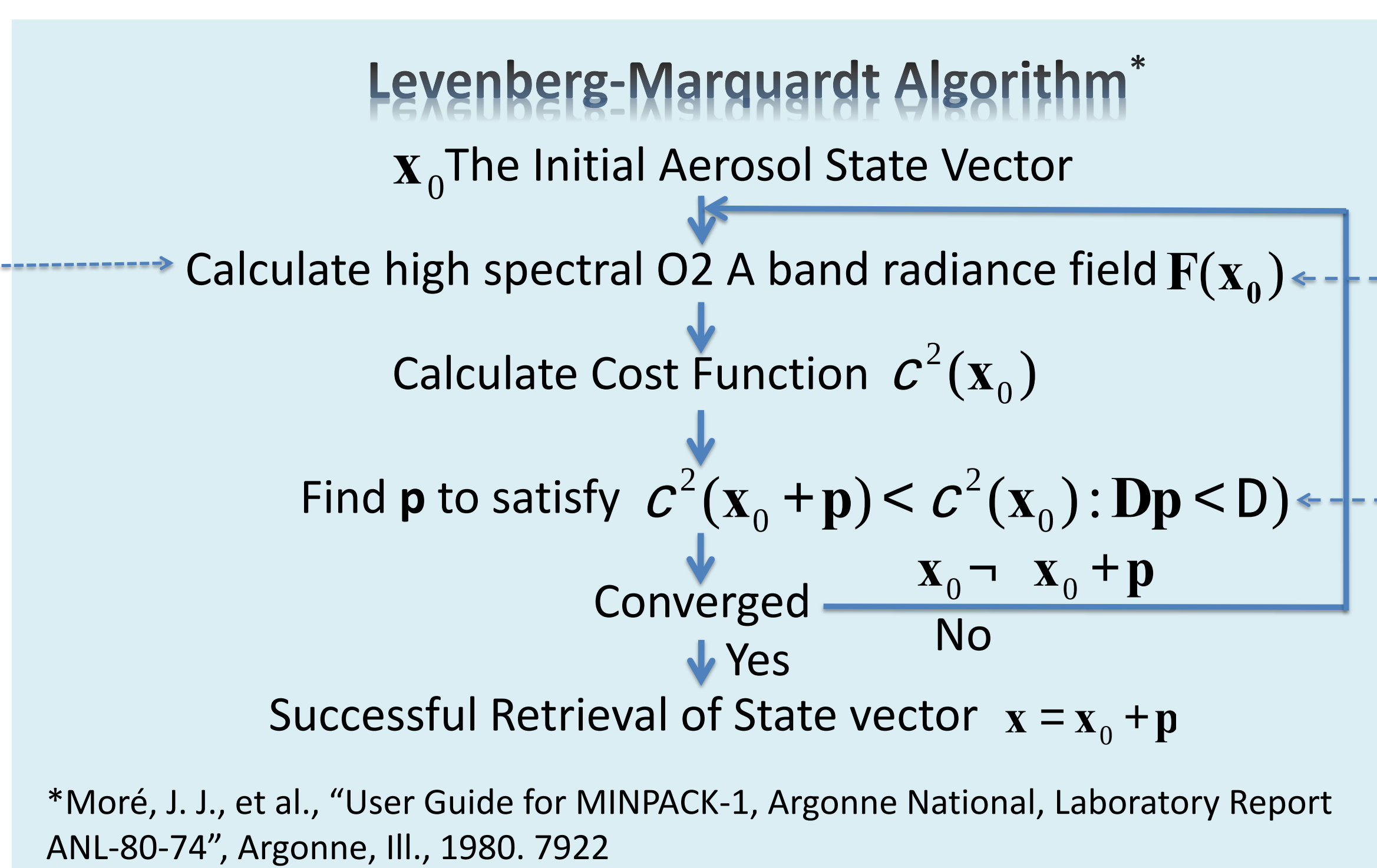
Bimodal Aerosol Model

$$N(r) = \frac{1}{\sqrt{2\pi}} \frac{N_i}{\ln s_{gr}} \exp \left\{ -\frac{(\ln r - \ln r_{gr})^2}{2 \ln^2 s_{gr}} \right\}$$

$$t = t_a + t_r \quad \nu = \frac{t_{scat,a} + t_{scat,r}}{t_{ext,a} + t_{ext,r}} \quad \mathbf{p} = \frac{t_{scat,a} \mathbf{p}_a + t_{scat,r} \mathbf{p}_r}{t_{scat,a} + t_{scat,r}}$$

The gas absorption coefficients are calculated from the ABSCO JPL look-up table.

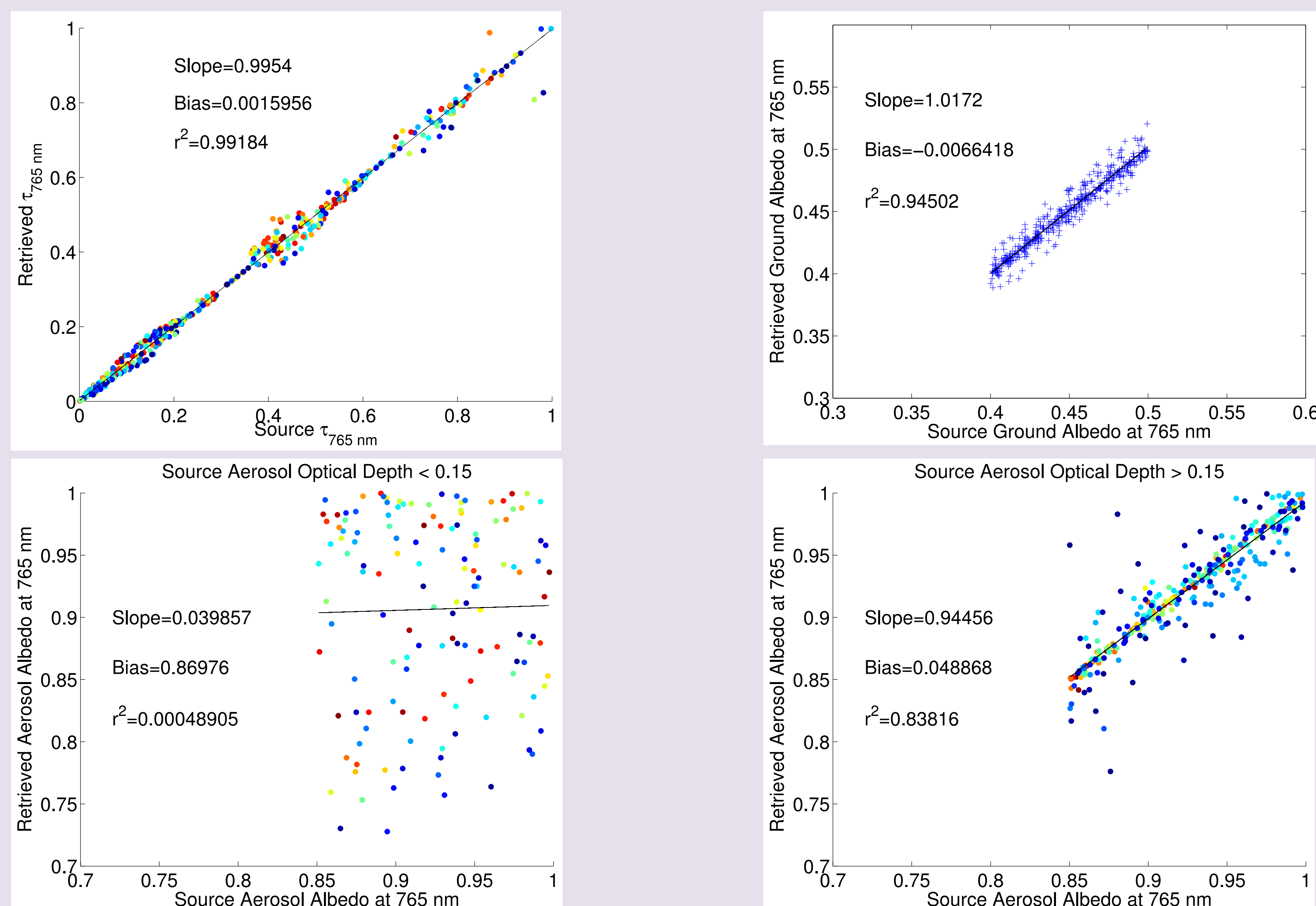
Aerosol Retrieval Algorithm Flowchart



$$C^2 = (F(\mathbf{x}) - \mathbf{y})^T S_e^{-1} (F(\mathbf{x}) - \mathbf{y}) + (\mathbf{x} - \mathbf{x}_a)^T S_a^{-1} (\mathbf{x} - \mathbf{x}_a)$$

F(x) is the forward model.
x is the state vector: aerosol optical depth, single scattering albedo, ground reflection albedo;
S_e is the measurement error covariance matrix;
S_a is the a priori covariance matrix;
x_a is the a priori state.

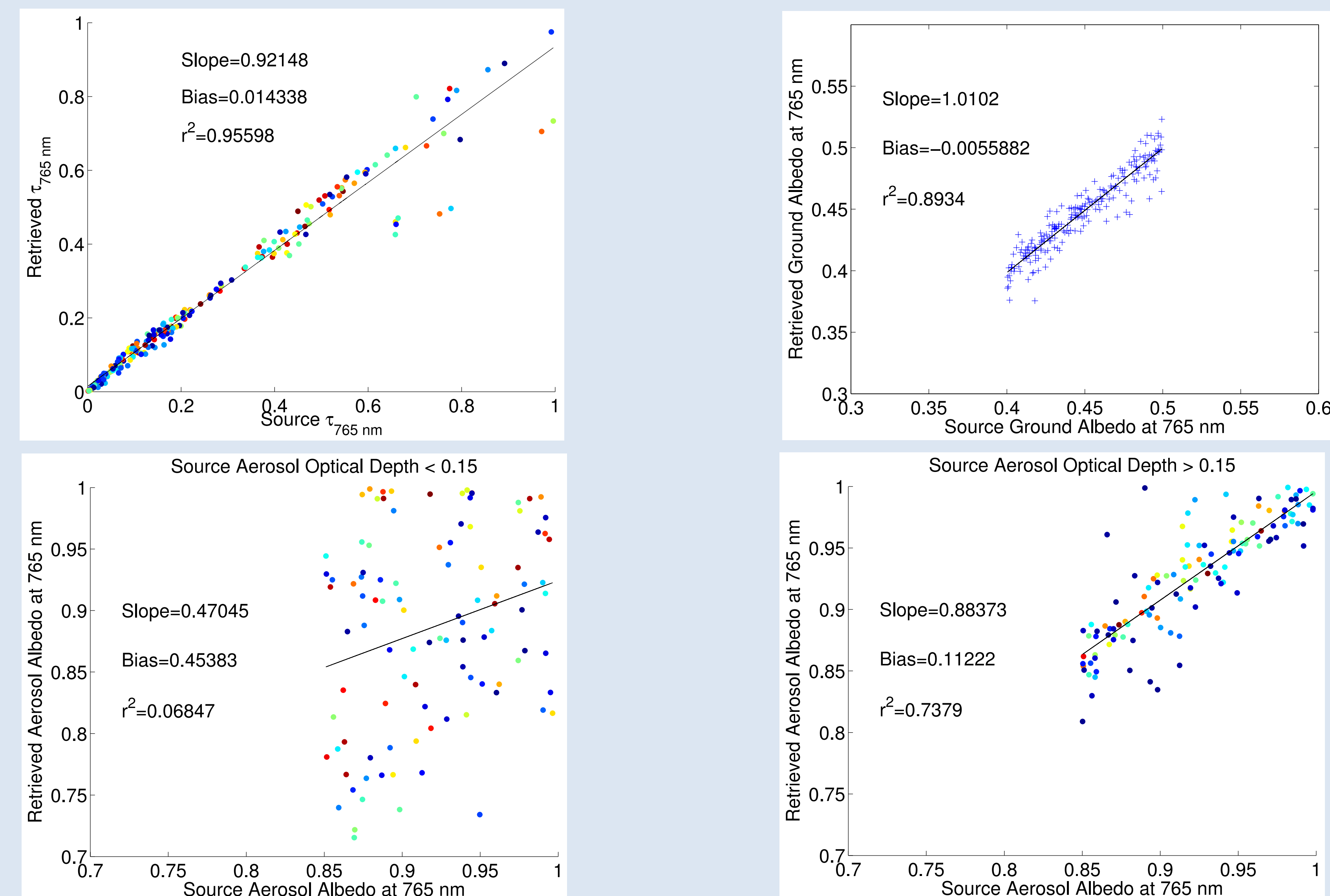
Results: based on synthetic data, assuming aerosol model is known.



Conclusion if aerosol model is known :

- The optical depth retrieval is highly accurate with the r² of 0.99;
- The ground albedo retrieval is also very good in the statistical point of view;
- If the aerosol optical depth is smaller than 0.15, the aerosol single scattering albedo retrieval performance is poor.
- If the aerosol optical depth is larger than 0.15, the aerosol single scattering albedo retrieval performance is promising.

Results: based on synthetic data, assuming aerosol model is unknown.



Conclusion if aerosol model is unknown :

- The optical depth retrieval is still accurate with the r² of 0.96;
- The ground albedo retrieval is degraded but correlation is still good;
- The aerosol single scattering albedo for the cases with the aerosol optical depth larger than 0.15 is retrievable and meaningful with a correlation coefficient r² of 0.74.
- In real scenario, the aerosol model can be estimated based on CALIOP measurement (depolarization ratio, color ratio, etc.), which will help the retrieval algorithm.