Multi-Sensor Retrieval of Aerosol Properties

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Problem Statement

Current status of aerosol remote sensing

- Retrieval of aerosol properties from space has been attempted thus far using radiances, either at multiple wavelengths (e.g., as obtained by the MODIS instrument) or multiple viewing angles (e.g., as obtained from the MISR instrument)
  - The POLDER instrument, which included a polarimeter, flew briefly and demonstrated the use of polarization as an additional data input
- Inversion to obtain aerosol optical depth, aerosol type, and some indication of aerosol size requires *a priori* assumptions of a limited number of aerosol models
- The model space is searched to find the closest match to observations

Upcoming improvements

- New measurement strategies have been proposed for the near future that will make available new data to help constrain inversions
- We use the example of instruments planned for the "A-Train" to discuss the improvements that can be expected via multi-sensor aerosol retrievals

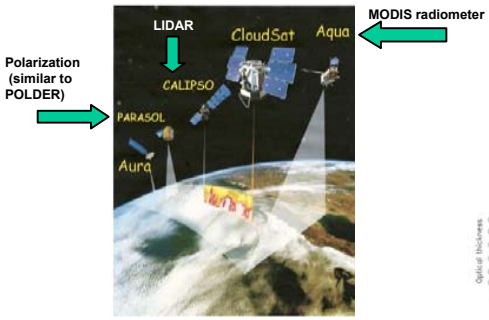


Fig. 1. The concept of the A-Train constellation and it members.

Publications

Reports and journal articles

- On the capability of polarization to infer aerosol optical thickness over land (extensive quarterly report to GC/AR, July 2002)
- Study of the A-band spectrum in order to improve aerosol retrievals (extensive quarterly report to CG/AR, September 2002)
- Simulation of the APS capability to retrieve aerosol optical properties (proposal to NPOESS, December 2002)
- A multi-sensor retrieval of absorbing aerosol optical parameters (to be submitted January 2004 to a special issue on aerosol remote sensing in *Journal of Geophysical Research*)

Conferences and Workshops

- Polarization capability to infer small ice cloud and aerosol optical thickness over land (Presentation at the CALIPSO workshop, 2002)
- Capability of polarization measurements to infer aerosol optical properties (Poster at the NPOESS workshop, 2002)
- Effect of the presence of sub-visible cirrus cloud on the aerosol retrieval (Poster at the EGS, 2003)
- Capability of high resolution A-band measurements to infer the aerosol single scattering albedo (Poster at the EGS, 2003)

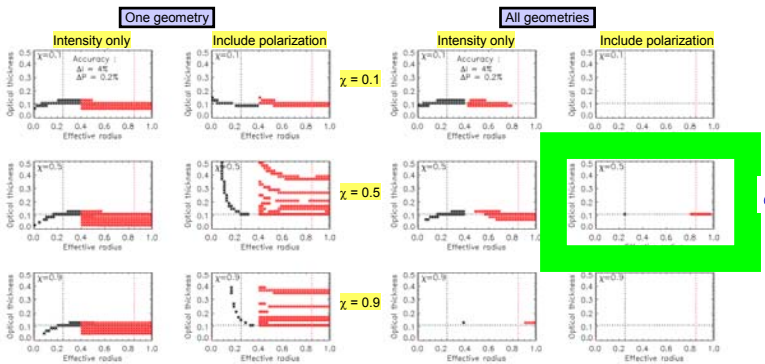
Polarization and Multiple Viewing Angles

Modeling multi-viewing and single viewing retrieval of aerosol optical depth and effective radius for a bimodal size distribution (m, known)

- A bimodal aerosol size distribution of known refractive index and optical depth was assumed and radiances computed
  - $\chi = 0.5$ (equal contributions to radiances from both modes) was assumed
  - $\tau = 0.1$ for each mode; $r_{e1} = 0.25$ µm; $r_{e2} = 0.85$ µm
- Inversions were performed for one geometry with and without polarization data, and for multiple viewing geometries with and without polarization data
- All possible combinations of aerosol size distribution and optical depth that pass the instrument accuracy criteria were plotted as a function of the (unknown) value of χ
  - Indicates why current inversions need to be constrained with *a priori* choices of allowed aerosol models

Conclusions

- Addition of multiple viewing geometries reduces the solution space even if only intensity is used in the retrieval
  - Impossible to determine which value of χ is most appropriate without additional assumptions
- Adding polarization to the multiple viewing geometries results in
  - NO possible solutions for incorrect values of χ
  - A UNIQUE solution for the small mode aerosol r_e and τ
  - LIMITED potential solutions for the large mode (note that large particles do not polarize light significantly, so the addition of polarization measurements is not as helpful as for the small mode)



BLACK = small mode solutions; **RED** = large mode solutions

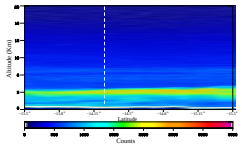
Summary

- ***Polarization can be useful information for improving aerosol retrievals (especially over land and for small particles)***
- ***Still need alternate method for removal of thin cirrus contamination***
- ***Multiple viewing angles are important for reducing uncertainty of retrievals***
- ***LIDAR is useful for retrieval of aerosol absorption properties, since these inversions are sensitive to layer altitude***
- ***We are developing a generalized framework to ingest multi-sensor data that shows great promise for improved aerosol retrievals***

Multi-Sensor Retrieval Methodology

Method to assimilate different kind of measurements to retrieve absorbing aerosol properties

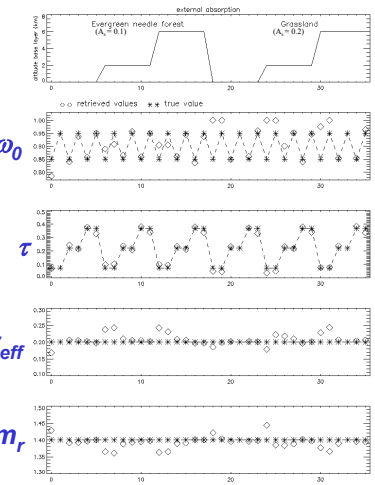
- Absorption properties of aerosols are generally unknown, but affect LIDAR and other retrievals
  - Can absorption be deduced from an expanded suite of measurements?



Example data snapshot from LITE (arbitrary units)

Concept

- From LITE (LIDAR-in-space) data that gives and example vertical profiles of aerosol extinction, build realistic radiances as a multi-viewing polarimeter and high resolution spectrometer would measure them from space
  - High-resolution spectrometer used to remove thin cirrus that can contaminate the aerosol retrieval (not discussed here; see references)
- Use the synergy between the polarimeter, spectrometer, and LIDAR data to **simultaneously** retrieve τ *(optical depth),* ω_0 *(single-scattering albedo),* r_{eff} *(effective radius)* and m_r
  - e.g., use the LIDAR return to develop vertical profile of aerosol extinction, based on properties retrieved from other sensors; adjust vertical profile as solution is converged on
  - The retrieval algorithm uses a Bayesian statistical approach formulated in an optimal estimation theory. An iterative conjugate gradient method is then used to minimize the cost function.



Description of cases: Variations in layer height and underlying surface albedo

Retrieved single-scatter albedo (stars are true value, open diamonds are retrievals)
- retrievals poorest at low τ (next panel)

Retrieved optical depth
- retrievals always good - errors are less than 10%

Retrieved effective radius
- retrievals improve as τ and layer height increase

Retrieved real part of refractive index
- retrievals improve as τ and layer height increase