Building A-Train synergies based on active/passive polarized observations

Optical depth retrieval for aerosols over cloud

D. Josset, F. Waquet, Y. Hu, P. Zhai, CALIPSO, POLDER and ICARE team.
Aerosol direct effect on climate

Cloudy air radiance

Clear air radiance

Albedo 0.29 +/- x?

Radiative forcing of aerosol over clouds can lead to large positive radiative forcing and is relatively unexplored (Yu et al. 2006).

Some regional in-situ observations (measurement campaign, Haywood et al.) and limited satellite data analysis (Chand et al. 2009)

→ need for observations at the global scale
→ Space observations
Aerosol direct effect: critical parameters to retrieve (simplified version of the problem)

Visible wavelength
- Backscattered fraction $\beta$
- Single scattering albedo $\omega$
- Optical Depth $\tau$
- Reflectance $\rho(\tau_N)$

Aerosols ($\tau, \beta, \omega$)

Cloud $\rho$
(Bright surface)

Ocean (dark surface)

Lidar is important for vertical structure identification. All parameters have to be determined → Focus on Aerosol Optical Depth (AOD) retrieval in this presentation.
AOD over clouds using the A-Train

• Several algorithms already exist
  – CALIPSO operational product since 2006 (aerosol lidar ratio assumption)
  – CALIPSO depolarization (Hu et al. 2007, no assumption on aerosol optical properties)
  – CALIPSO (Chand et al. 2008, based on aerosol angstrom exponent assumption)
  – PARASOL multiangle polarization (Waquet et al. 2009)
  – UV signature in passive retrievals (OMI Torres et al. 2011)

→ We are focusing our efforts on the polarization based methodologies which seem more promising in term of accurate quantification of AOD
In liquid water clouds
• Lidar ratio is almost constant (Pinnick 1983)
• Depolarization in the backscatter direction is linked only to multiple scattering.

The lidar equation can be solved unambiguously and optical depth can be retrieved with no assumptions on aerosol microphysical properties (only signal within the cloud is used). → Good consistency with MODIS and ocean surface method (not discussed here) at cloud boundaries
Independent retrieval of CALIPSO AOD directly improves knowledge of aerosol microphysics.

Lidar ratio determination accuracy increases with optical thickness.

The lidar ratio is \( \frac{1}{\omega P_{11}(\pi)} \).
Aerosol over clouds (PARASOL)

Polarization (PARASOL) allows to detect aerosol layers over clouds

A case study: 18/08/06

- Biomass burning aerosols transported over low-level clouds
- South Africa (Season of vegetation fires, Jun-Sep)

*Waquet et al., (JAS 2009)*

Polarized radiance

Longitude

Latitude

Scattering angle (°)

Polarized radiance

0.0

0.01

0.02

0.03

0.04

0.05

100

110

120

130

140

150

PARASOL AOT 865 nm

0.3

0.0
CALIPSO-PARASOL comparisons

Biomass burning aerosols

AOT PARASOL 865 nm (26072008)

AOT 532 nm

CALIPSO

(Shot to shot)

PARASOL

(→532 nm)

(Preliminary results)
CALIPSO-PARASOL comparisons

Dust case
AOT PARASOL 865 nm (26072008)

Model improvement (Waquet et al. 2011 in preparation)
accounts for
• Multiple scattering
• Non sphericity (Dubovik et al. 2006)

AOT 532 nm

Preliminary results

(CALIPSO
shot to shot)

(PARASOL
→ 532 nm)
Summary

• New largely unexplored domain for space remote sensing (extremely large positive forcing are involved). Polarization offers a major advantage (passive or active) to solve the problem

• We are building the datasets and learning about the methodologies

• Good first comparison between CALIPSO/PARASOL AOD over clouds retrievals. Encouraging but more has to be done.

Perspectives

• Important statistic of observations reachable (PARASOL swath, vertical day/night information on CALIPSO track)

• A synergetic algorithm may help for the retrieval of the other key parameters (ex: SSA), at least we should be able to determine the minimum requirements (importance of more IR wavelength in PARASOL)

• After validation, this dataset can be used to estimate radiative forcing of aerosol over clouds.