Remote Sensing of the Radiative and Microphysical Properties of Cirrus Clouds during TC$^4$ with the MODIS Airborne Simulator

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- Provide the MODIS Airborne Simulator for the NASA ER-2 aircraft
  - Multispectral imagery from 0.47 to 14.3 µm
    ✓ Serves as customized ‘MODIS’ sensor for support of other instruments onboard the aircraft
- MAS retrievals
  - Cloud optical properties during the daytime
    ✓ Cloud thermodynamic phase, cloud optical thickness, effective radius
    ✓ Estimate of multilayer clouds
  - Cloud top properties both day and night
    ✓ Cloud top pressure, temperature, and effective emissivity
- MODIS retrievals
  - Provide cloud properties from MODIS to compare with MAS retrievals
- Validation and intercomparisons
  - Cloud thermodynamic phase, cloud top pressure, and multilayer clouds (CALIPSO)
NASA ER-2 Aircraft
TC⁴ Configuration

- Cloud Physics Lidar (CPL)
- Cloud Radar System (CRS)
- ER-2 Doppler Radar (EDOP)
- Q-bay & E-bay: Advanced Microwave Precipitation Radiometer (AMPR), SSFR, & Blackbody IR
- Solar Spectral Flux Radiometer (SSFR)
- Conical Scanning Sub-mm Imaging Radiometer (CoSSIR)
- MODIS Airborne Simulator (MAS)
- Scanning HIS
MODIS Airborne Simulator

- **Platform**
  - ER-2
    - 20 km (nominal)

- **Sensor Characteristics**
  - 50 spectral bands ranging from 0.47 to 14.3 $\mu$m
  - Scan $\pm 43^\circ$
    - Swath width of ~40 km
  - Instantaneous field-of-view 2.5 mrad
    - 50 m at nadir
  - 16 bits per channel
  - 1.72 GB hr$^{-1}$
  - 716 pixels in scan line

- **Calibration**
  - Integrating sphere on ground
  - Two on-board temperature controlled blackbodies
MAS Cloud Optical & Microphysical Properties  
(M. D. King, S. Platnick et al. – NASA GSFC)

- **Pixel-level cloud product during **daytime at 50 m
  - Daytime defined as $\theta_0 < 81.4^\circ$ to be consistent with cloud mask

- **Critical input**
  - Cloud mask: to retrieve or not to retrieve?
  - Cloud thermodynamic phase: liquid water or ice libraries?
    - Continuous spectra in 1.6 and 2.1 $\mu$m region permits multiple algorithms to be used to test cloud thermodynamic phase

- **Atmospheric correction**
  - Requires cloud top pressure
    - MODIS CO$_2$ slicing algorithm recently ported to MAS processing
  - Ancillary information regarding atmospheric moisture & temperature (e.g., NCEP)

- **Surface albedo** for land
  - Uses spatially filled surface albedo product derived from MODIS Collection 4
Cloud Optical & Microphysical Retrievals

Retrieval space examples

Liquid water cloud
Sea ice surface

Ice cloud
Sea ice surface

Based on Nakajima and King (1990) algorithm
Cloud Retrievals in FIRE ACE
July 12-27, 2001

- Cloud Mask
- Thermodynamic phase
  - Liquid water vs ice
- Cloud top altitude
  - not shown
- Optical thickness
- Effective radius
Central America Surface Albedo from MODIS
July 12-27, 2001
Terra and Aqua Goals & Objectives

- Provide measurements of the effects of clouds, aerosols, and greenhouse gases on the Earth’s total energy balance
  - Cloud mask and determination of the presence of clouds
  - Cloud top properties (height/pressure, temperature)
  - Cloud optical and microphysical properties
    ✓ Liquid water vs ice phase
    ✓ Cloud optical thickness, effective radius, and integrated water path
Aqua’s Orbit

- Altitude of 705 km
- Near-polar, sun-synchronous, orbiting the Earth every 98.8 minutes, crossing the equator going north at 1:30 p.m. and going south at 1:30 a.m.
Aqua/MODIS True Color and Cloud Top Pressure
(W. P. Menzel, R. A. Frey – University of Wisconsin)

True Color Composite (0.65, 0.56, 0.47)

Cloud Top Pressure (hPa)

July 18, 2003
Cloud Optical Thickness and Effective Radius
(M. D. King, S. Platnick – NASA GSFC)

Cloud Optical Thickness

Cloud Effective Radius (µm)

Ice Clouds

Water Clouds

Ice Clouds

Water Clouds

July 18, 2003
MAS Derived Products
(M. D. King, S. Platnick et al. – NASA GSFC)

- Imagery of clouds and surface properties in support of other investigators
  - High spatial resolution with a swath width of approximately 40 km
- Pixel-level cloud product during **daytime at 50 m**
  - Cloud mask
  - Cloud thermodynamic phase
  - Indication of single layer or multilayer clouds
  - Cloud top pressure and temperature
  - Cloud optical thickness, effective radius, and integrated water path
Satellite Validation Goals

- Provide high resolution cloud retrievals to enable examination of subpixel cloud retrievals from MODIS
- Compare cloud top height and multilayer cloud detection with CALIPSO
  - Multilayer cloud detection algorithm during daytime only
- Intercompare thermodynamic phase determination from MAS and MODIS with
  - CALIPSO and POLDER during the daytime
  - CPL during daytime on any flight, including those coordinated with Terra
- Intercompare cloud top altitude from MAS and MODIS with OMI’s cloud top height algorithms during the daytime
Science Goals and Satellite Coordination

- Establish confidence in thin cirrus and multilayer cloud detection from MODIS during the **daytime**
  - Intercomparisons with MAS and CPL on ER-2
  - Intercomparisons with POLDER on PARASOL and CALIOP on CALIPSO

- Establish accuracy of cloud top altitude algorithm
  - Compare MAS and MODIS retrievals with CALIOP, CPL, and OMI

- Satellite coordination
  - Aqua, CALIPSO, CloudSat, and Aura/OMI during the **daytime**
  - Terra (MODIS and MISR) during the **daytime**

- Flights at night are of far less value for the objectives of this investigation
NASA ER-2 High Altitude Research Aircraft