MODIS Atmosphere Data Products and Status

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Outline

- **MODIS atmosphere data products**
- **Physical principles behind the remote sensing of selected parameters**
- **Surface bidirectional reflectance function**
  - **Examples of recent datasets obtained in the Arctic**
  - **Progress in analysis of all acquired datasets**

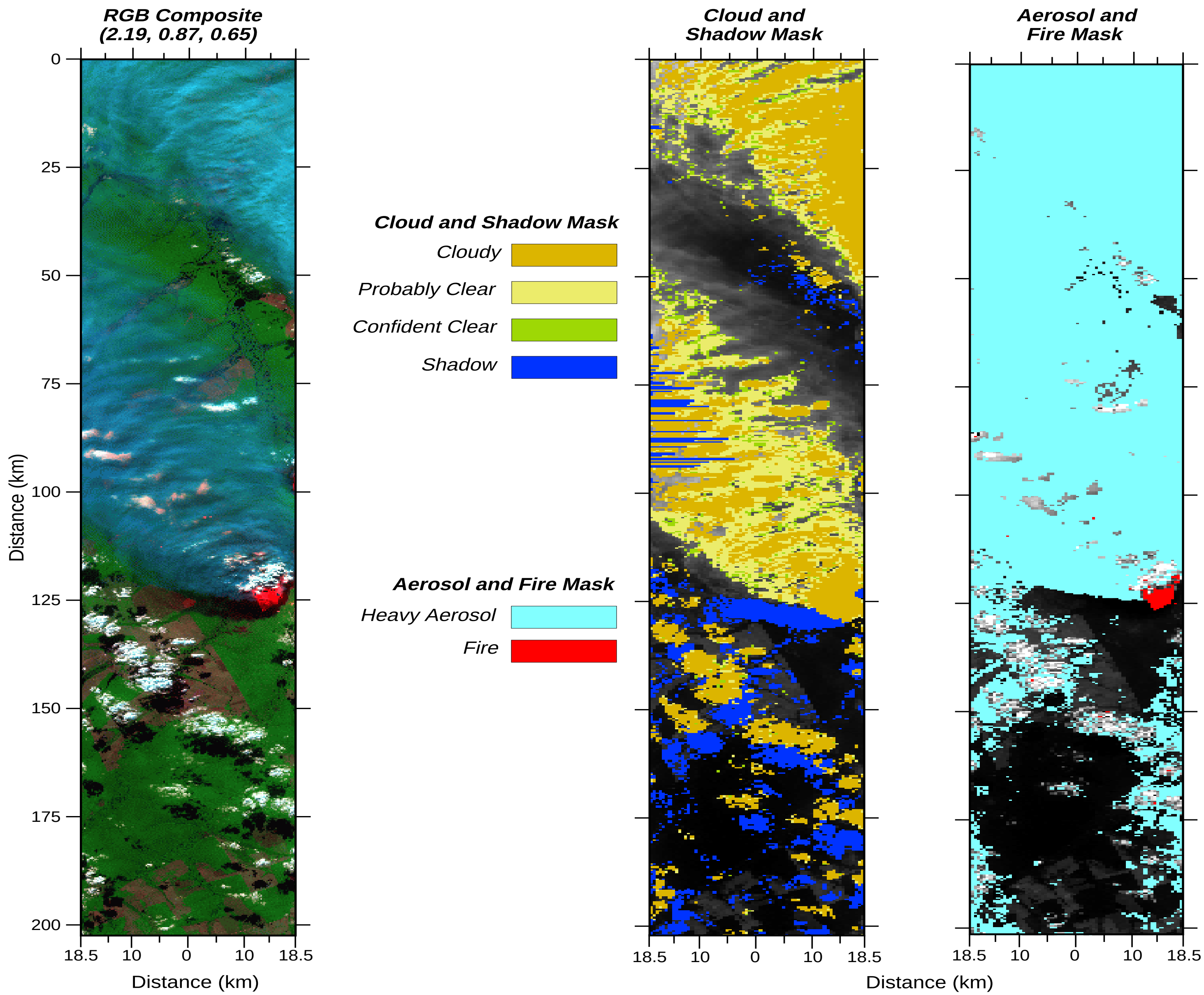
MODIS Atmosphere Products

- **Cloud mask for distinguishing clear sky from clouds**
- **Cloud radiative and microphysical properties**
  - **Cloud top pressure, temperature, and effective emissivity**
  - **Cloud optical thickness, thermodynamic phase, and effective radius**
  - **Thin cirrus reflectance in the visible**
- **Aerosol optical properties**
  - **Optical thickness over the land and ocean**
  - **Size distribution (parameters) over the ocean**
- **Atmospheric moisture and temperature gradients**
- **Column water vapor amount**
- **Gridded time-averaged (level-3) atmosphere product**
  - **Daily (1° × 1°)**
  - **8-day (1° × 1°)**
  - **Monthly (1° × 1°)**
  - **Mean, standard deviation, marginal probability density function, joint probability density functions**

Cloud Mask

- Some cloud types (viz., cirrus, low stratus, and small cumulus) are difficult to detect using visible & infrared thresholds alone
- MODIS cloud mask will use multispectral imagery to indicate whether the scene is clear, cloudy, or affected by shadows
- Cloud mask is input to rest of atmosphere, land, and ocean algorithms
- Mask will be generated at 250 m and 1 km resolutions
- Mask will use, for the first time, 17 spectral bands ranging from 0.55 - 13.93 µm (including new 1.38 µm band)
- Algorithm based on radiance thresholds in the infrared, and reflectance thresholds in the visible and near-infrared
- Mask uses different spectral tests for 10 different processing paths

	Tested		*Total Tests*	
	Daytime	*Nighttime*	*Daytime*	*Nighttime*
Ocean	*9*	*6*	**12**	**7**
Land	*6*	*4*	**9**	**5**
Snow/Ice	*4*	*4*	**6**	**4**
Coastline	*6*	*3*	**9**	**4**
Desert	*1*	*4*	**7**	**6**

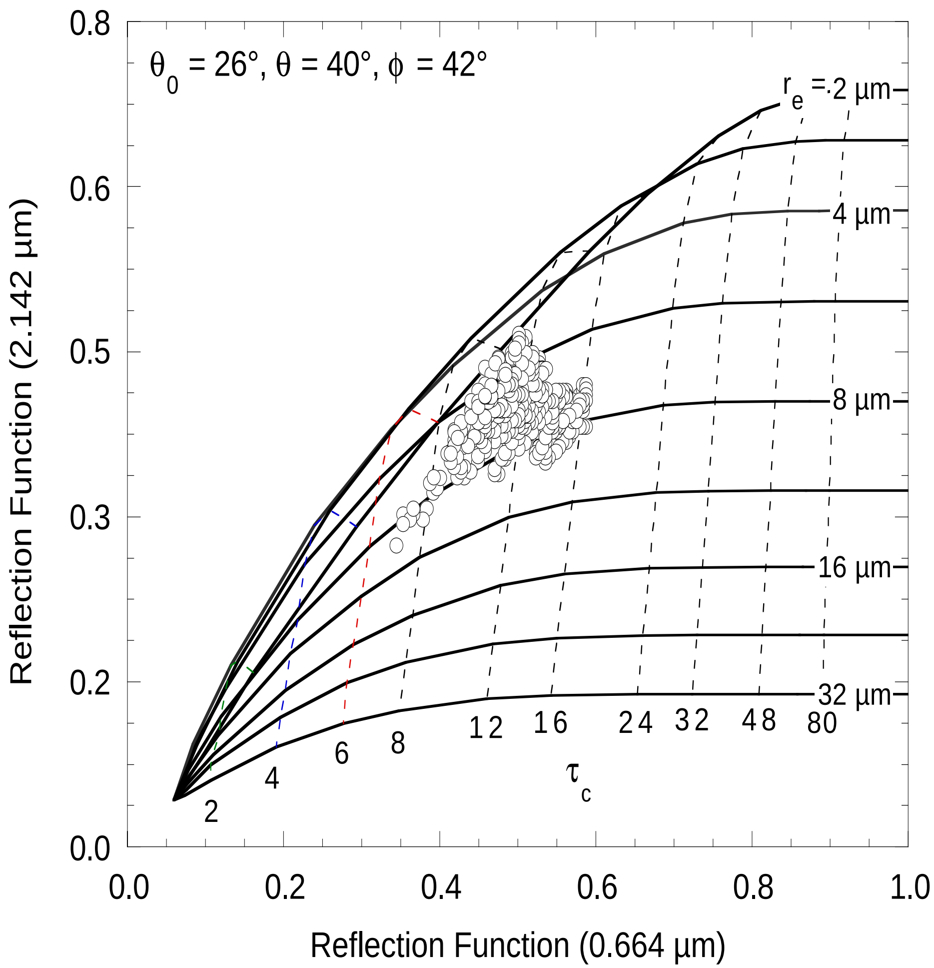

RGB Composite
(2.19, 0.87, 0.65)
Cloud and
Shadow Mask
Aerosol and
Fire Mask
Cloud and Shadow Mask
Cloudy
Probably Clear
Confident Clear
Shadow
Aerosol and Fire Mask
Heavy Aerosol
Fire
Distance (km)
0
25
50
75
100
125
150
175
200
18.5
10
0
10
18.5
Distance (km)
Distance (km)

Cloud Properties

- Twelve MODIS bands will be utilized to derive cloud properties
  - Visible and near-infrared bands
    - daytime retrievals of cloud optical thickness and effective radius
    - 1.6 µm band will be used to derive thermodynamic phase of clouds during the daytime (post-launch)
  - Thermal infrared bands
    - determination of cloud top properties, including cloud top altitude, cloud top temperature, and thermodynamic phase
    - thermal band at 11.03 µm will be used to make thermal emission corrections to the 3.75 µm band

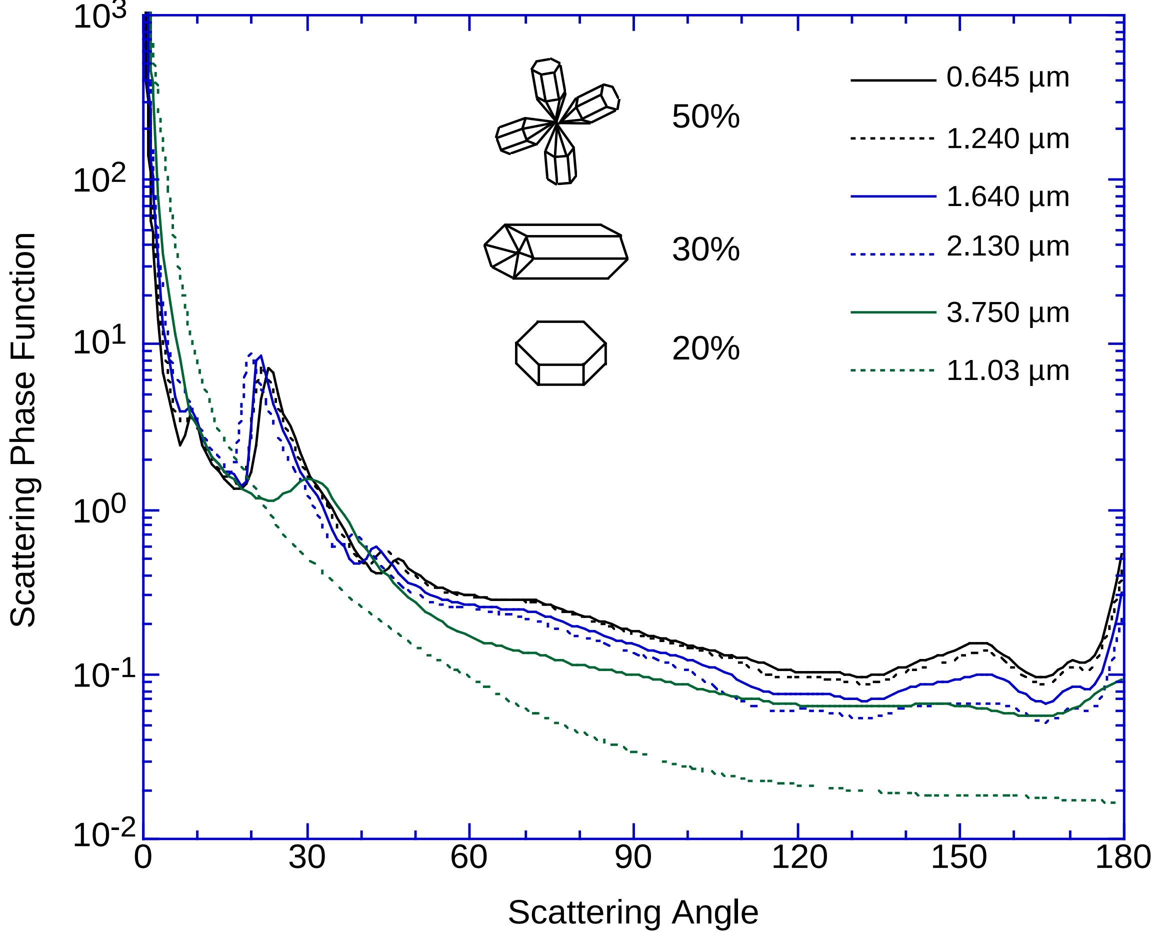
Retrieval of τ_c and r_e

- The reflection function of a nonabsorbing band (e.g., 0.66 µm) is primarily a function of optical thickness
- The reflection function of a near-infrared absorbing band (e.g., 2.14 µm) is primarily a function of effective radius
  - clouds with small drops (or ice crystals) reflect more than those with large particles
- For optically thick clouds, there is a near orthogonality in the retrieval of τ_c and r_e using a visible and near-infrared band



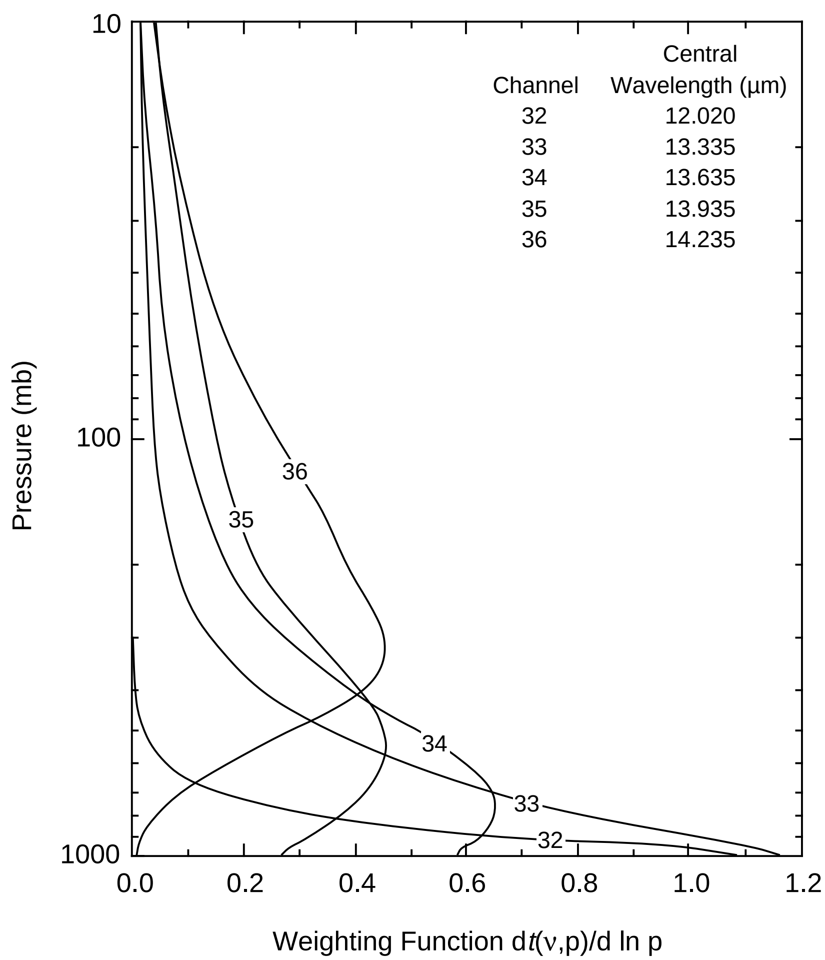
Scattering Phase Function: Ice Cloud Model

Yang and Liou (1996)



Weighting Functions for CO_2 Slicing

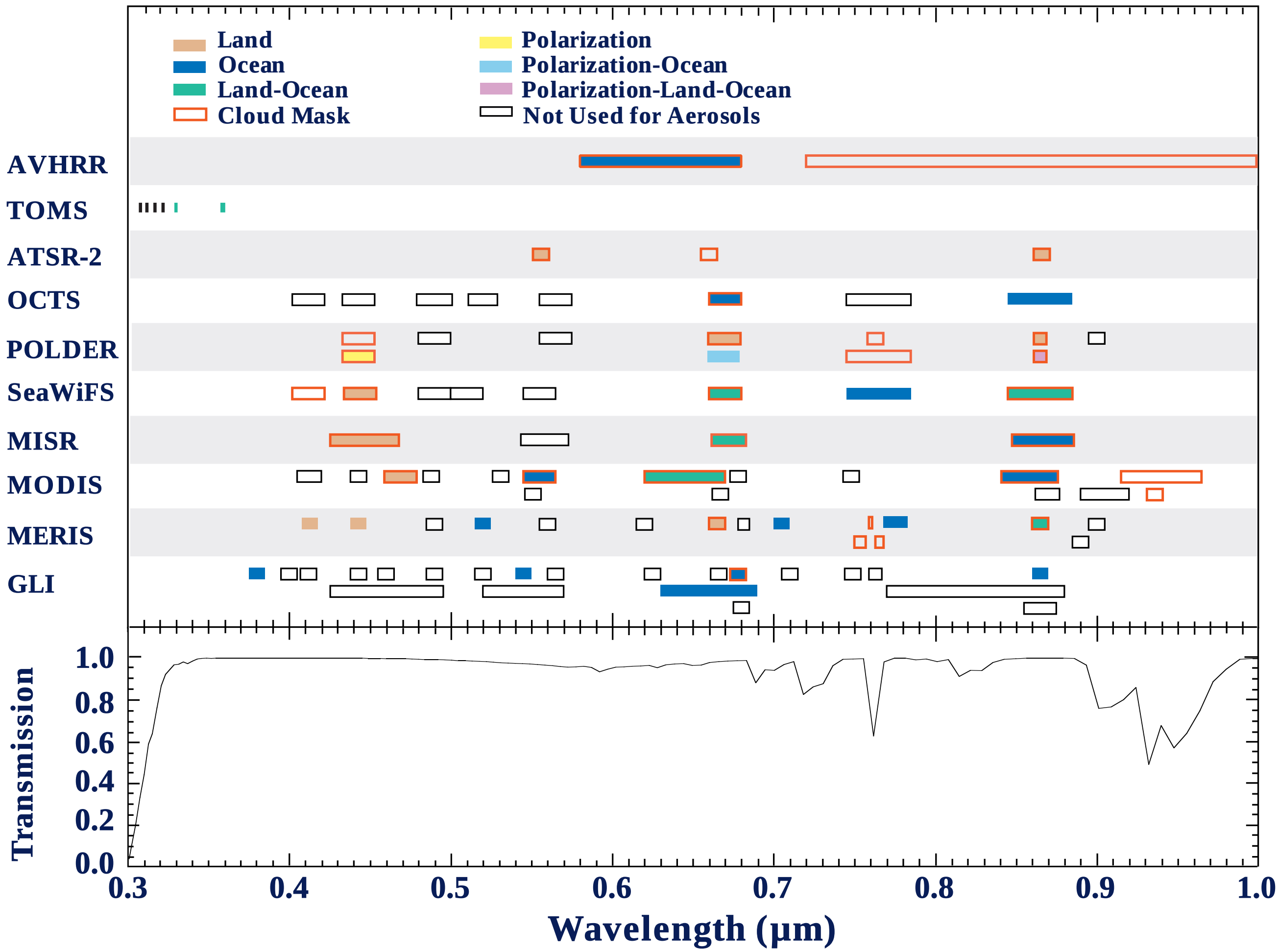
- **CO_2 slicing method**
  - **ratio of cloud forcing at two near-by wavelengths**
  - **assumes the emissivity at each wavelength is same, and cancels out in ratio of two bands**
- **The more absorbing the band, the more sensitive it is to high clouds**
  - **technique the most accurate for high and middle clouds**
- **MODIS will be the first sensor to have CO_2 slicing bands at high spatial resolution**



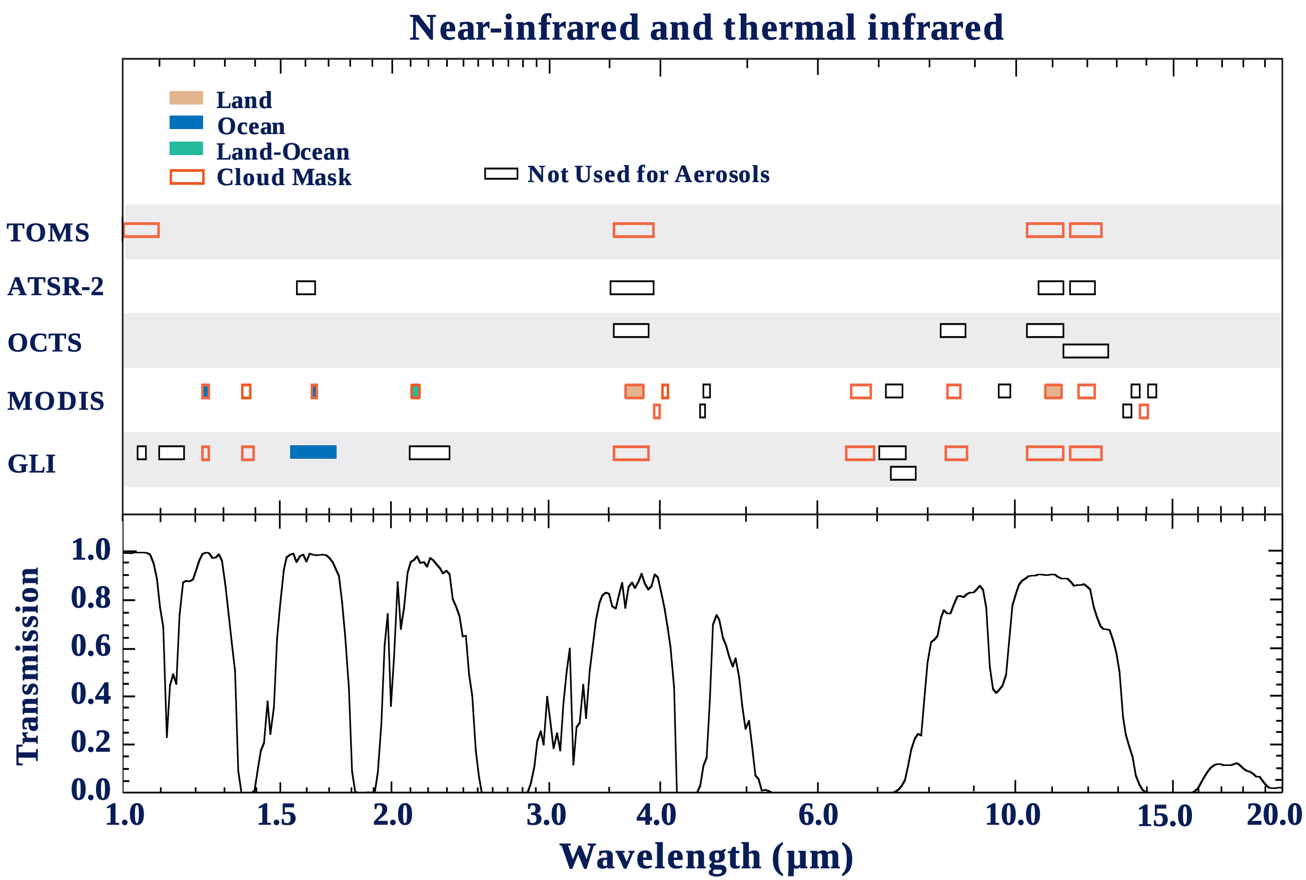
Aerosol Properties

- **Eight MODIS bands will be utilized to derive aerosol properties**
  - **0.47, 0.55, 0.65, 0.86, 1.24, 1.64, 2.13, and 3.75 µm**
  - **Ocean**
    - » **reflectance contrast between cloud-free atmosphere and ocean reflectance (dark)**
    - » **aerosol optical thickness (0.47-2.13 µm)**
    - » **size distribution characteristics (ratio between the assumed two log-normal modes, and the mean size of each mode)**
  - **Land**
    - » **dense dark vegetation and semi-arid regions determined where aerosol is most transparent (2.13 and 3.75 µm)**
    - » **contrast between Earth-atmosphere reflectance and that for dense dark vegetation surface (0.47 and 0.66 µm)**
    - » **enhanced reflectance and reduced contrast over bright surfaces (post-launch)**
    - » **aerosol optical thickness (0.47 and 0.66 µm)**

Aerosol Properties



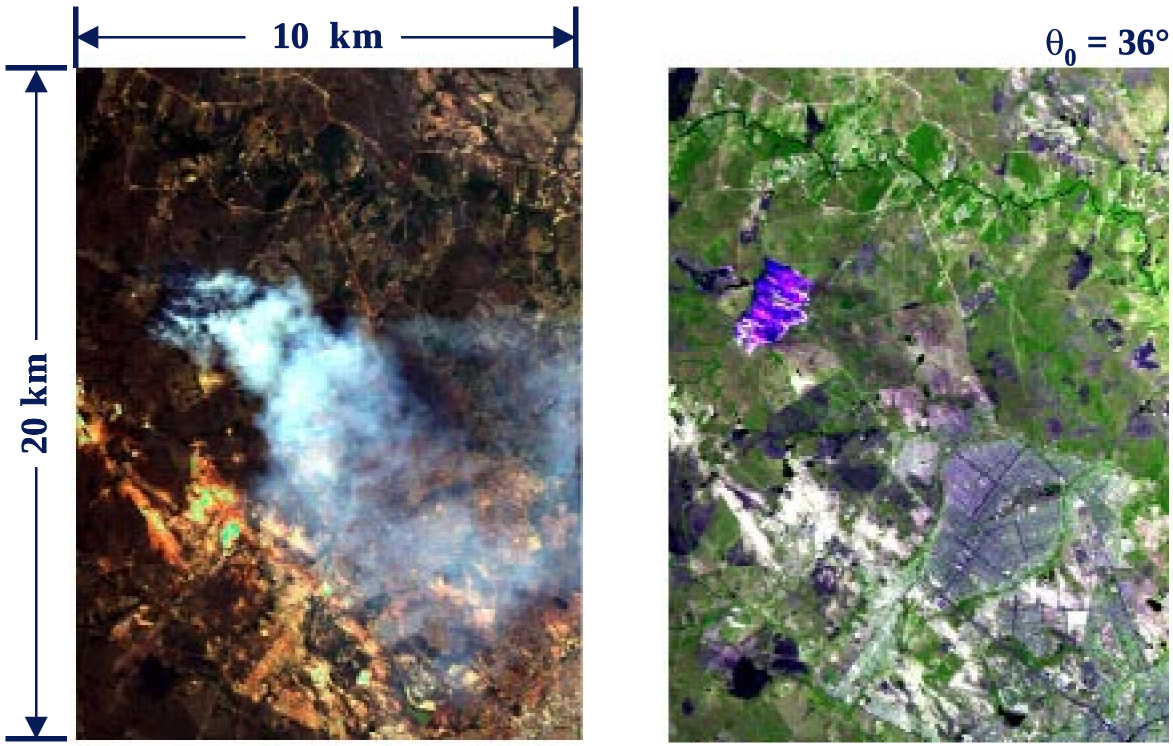
Aerosol Properties



Aerosol Effects on Reflected Solar Radiation over Land

Biomass burning
Cuiabá, Brazil (August 25, 1995)

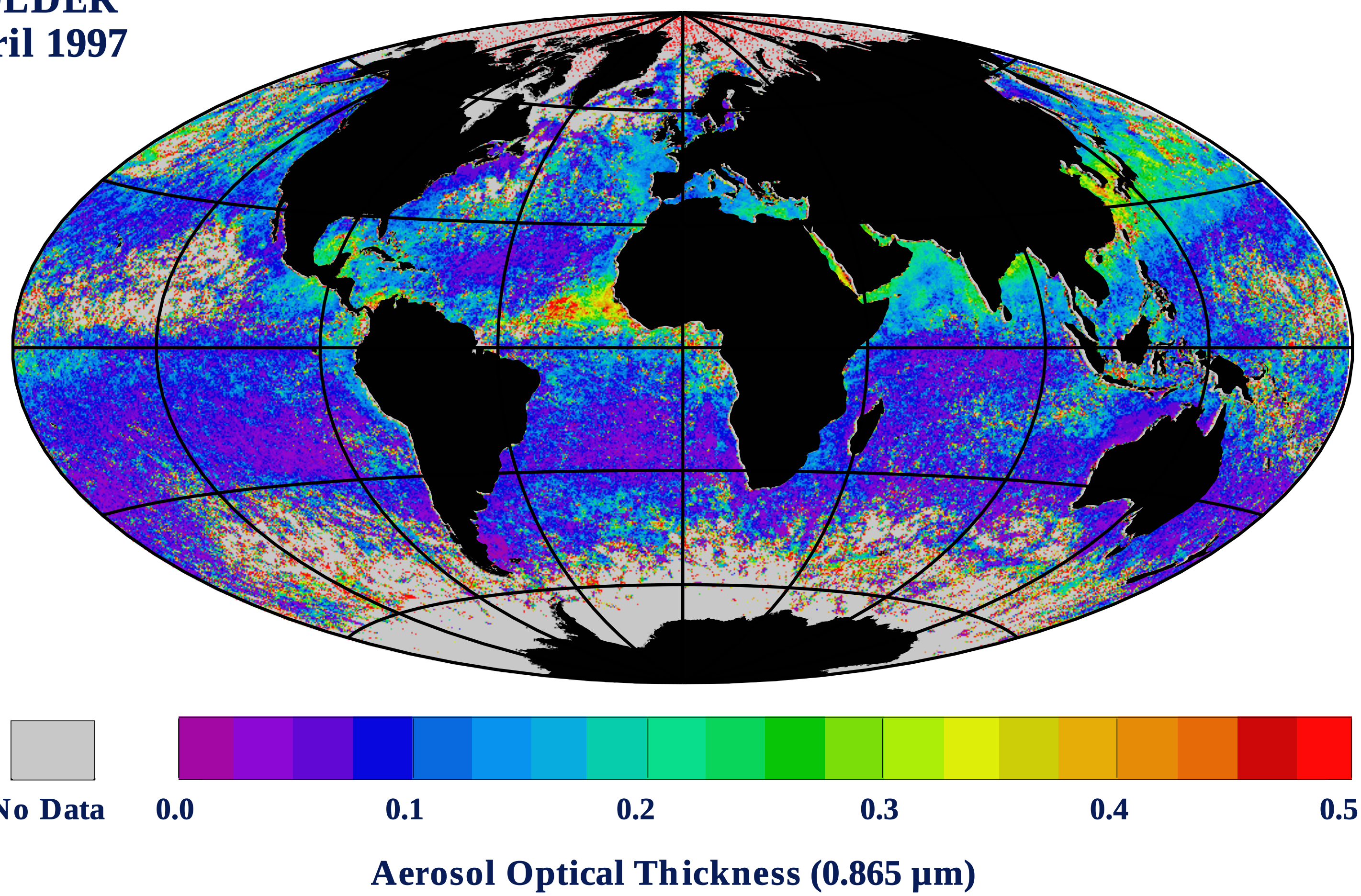
R = 0.66 µm
G = 0.55 µm
B = 0.47 µm



R = 1.65 µm
G = 1.2 µm
B = 2.1 µm

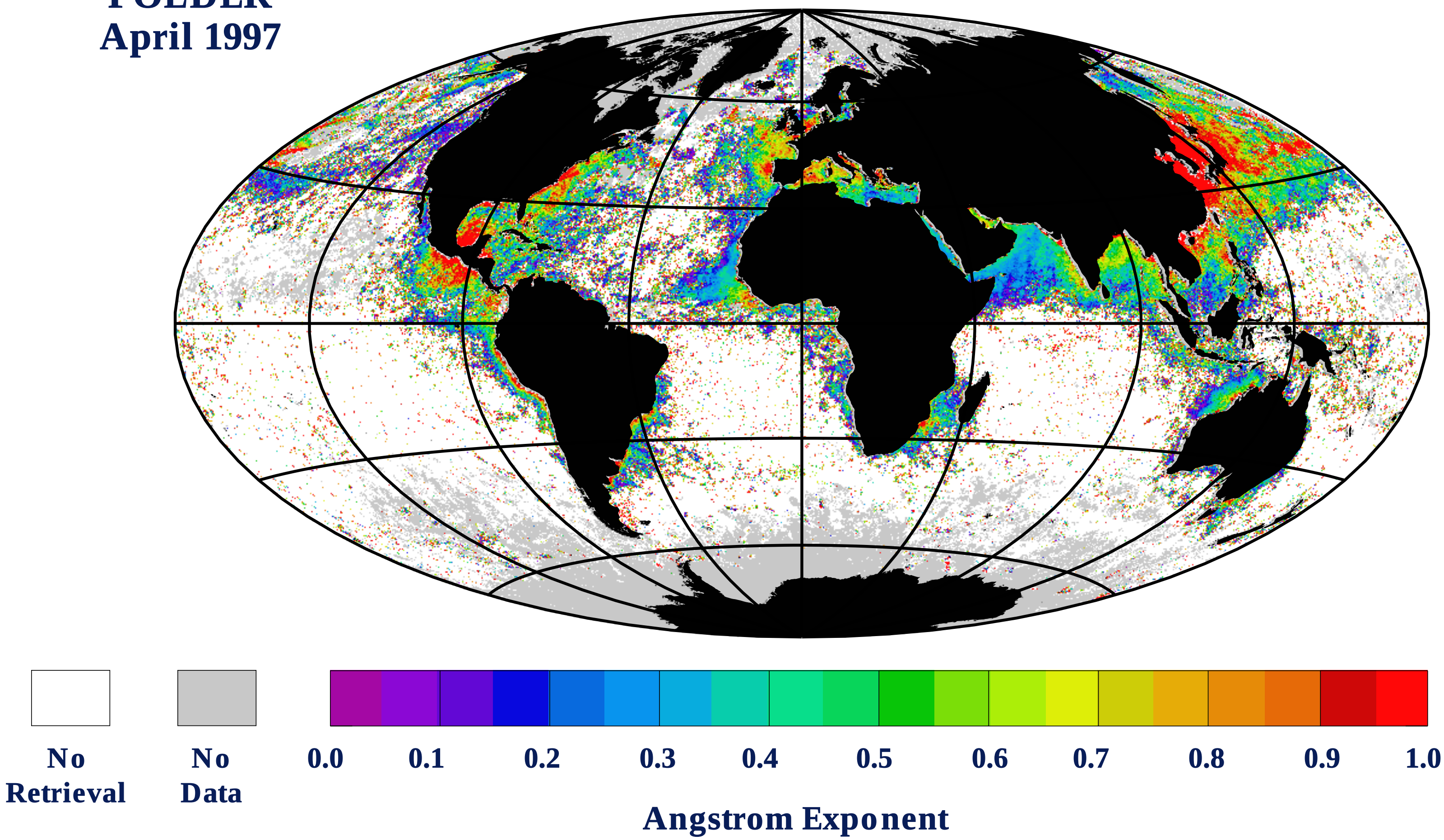
Aerosol Optical Thickness

POLDER
April 1997



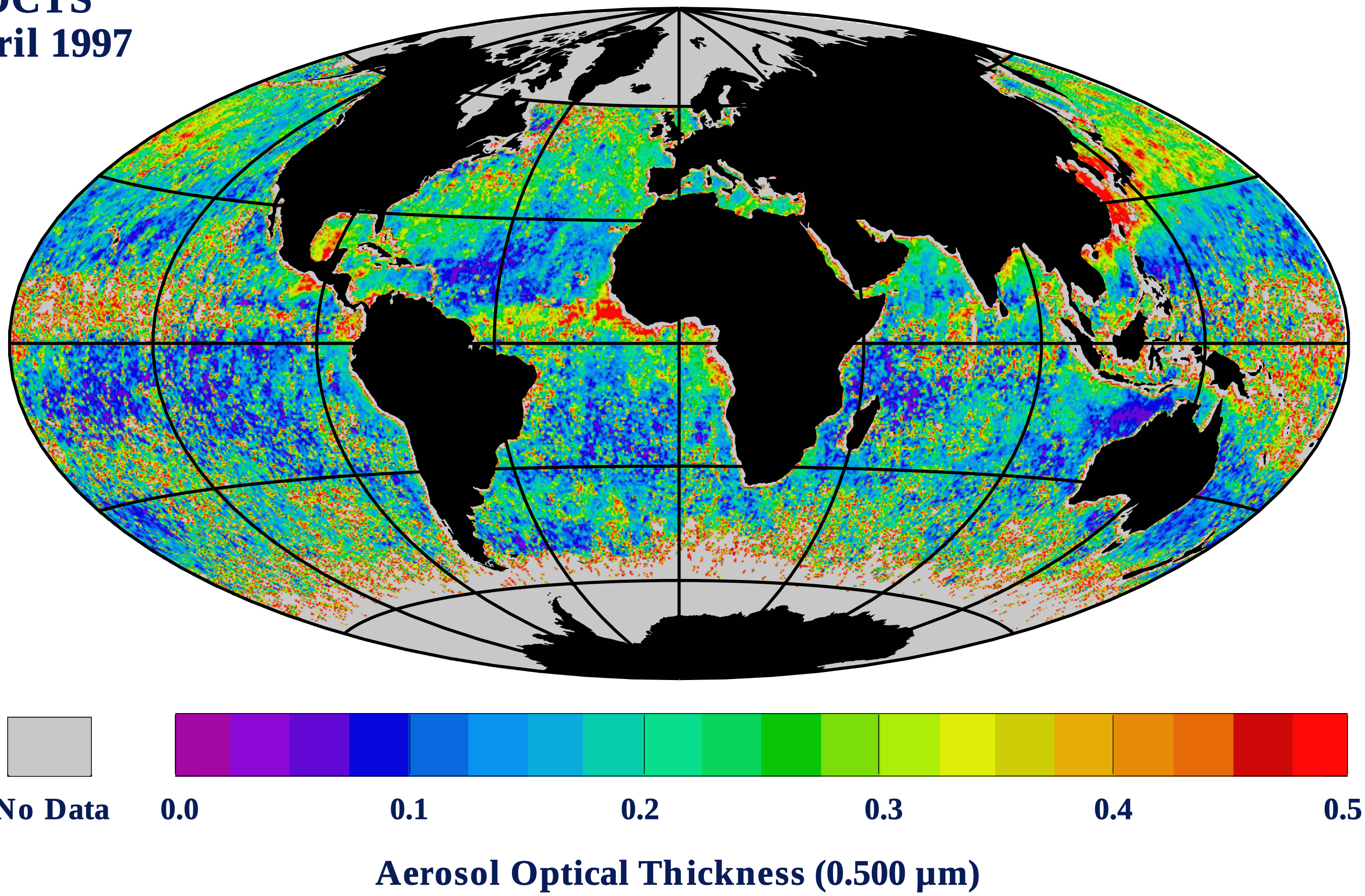
Ångström Exponent

POLDER
April 1997



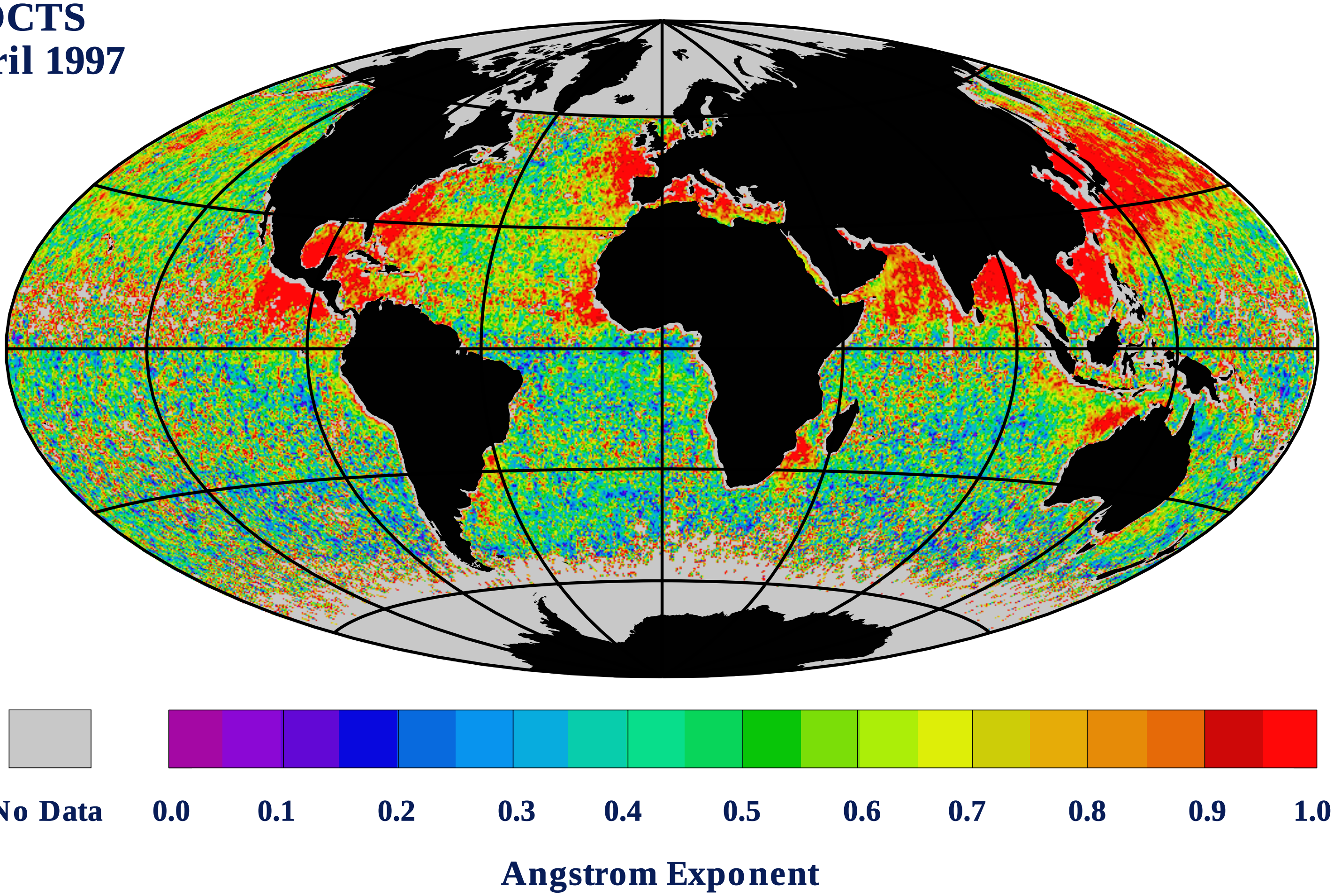
Aerosol Optical Thickness

OCTS
April 1997



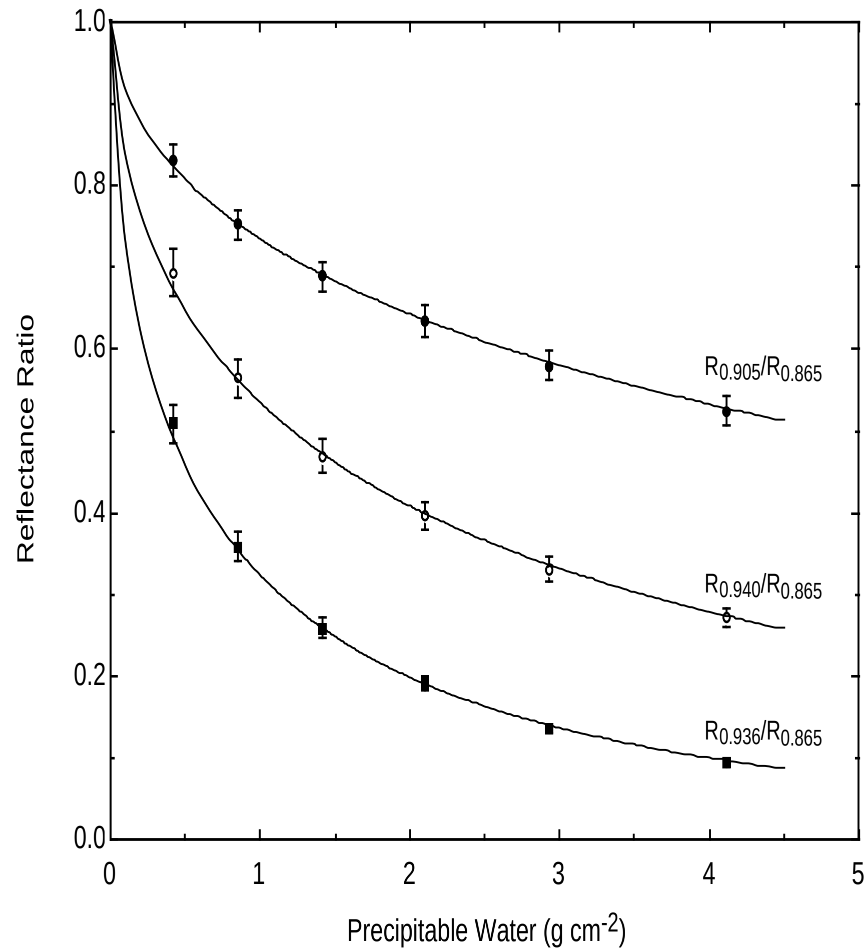
Ångström Exponent

OCTS
April 1997



Column Water Vapor Amount

- Three near-infrared bands will be used for column water vapor over reflecting surfaces (land) during the daytime
  - 0.905, 0.936, and 0.94 µm
- Reference (nonabsorbing) bands will be compared to water vapor absorbing bands
  - 0.865 and 1.24 µm
- Uncertainties
  - 0.01 error in transmittance translates into a 2.5 % error in precipitable water
- Four thermal infrared bands will be used to derive total column water vapor under clear sky conditions using sounding techniques
  - 6.72, 7.33, 11.03, and 12.02 µm

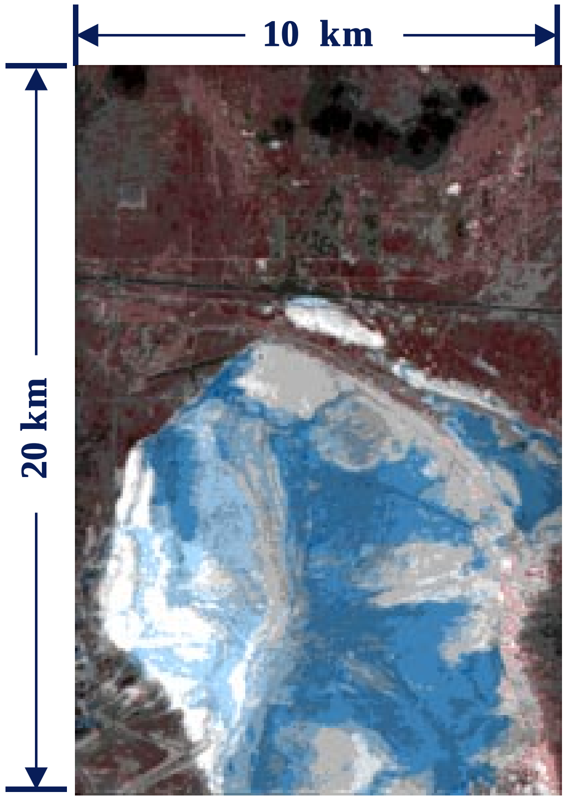


Column Water Vapor Retrieval

Green and Conel (1995)

Rogers Dry Lake

R = 0.66 µm
G = 0.55 µm
B = 0.47 µm

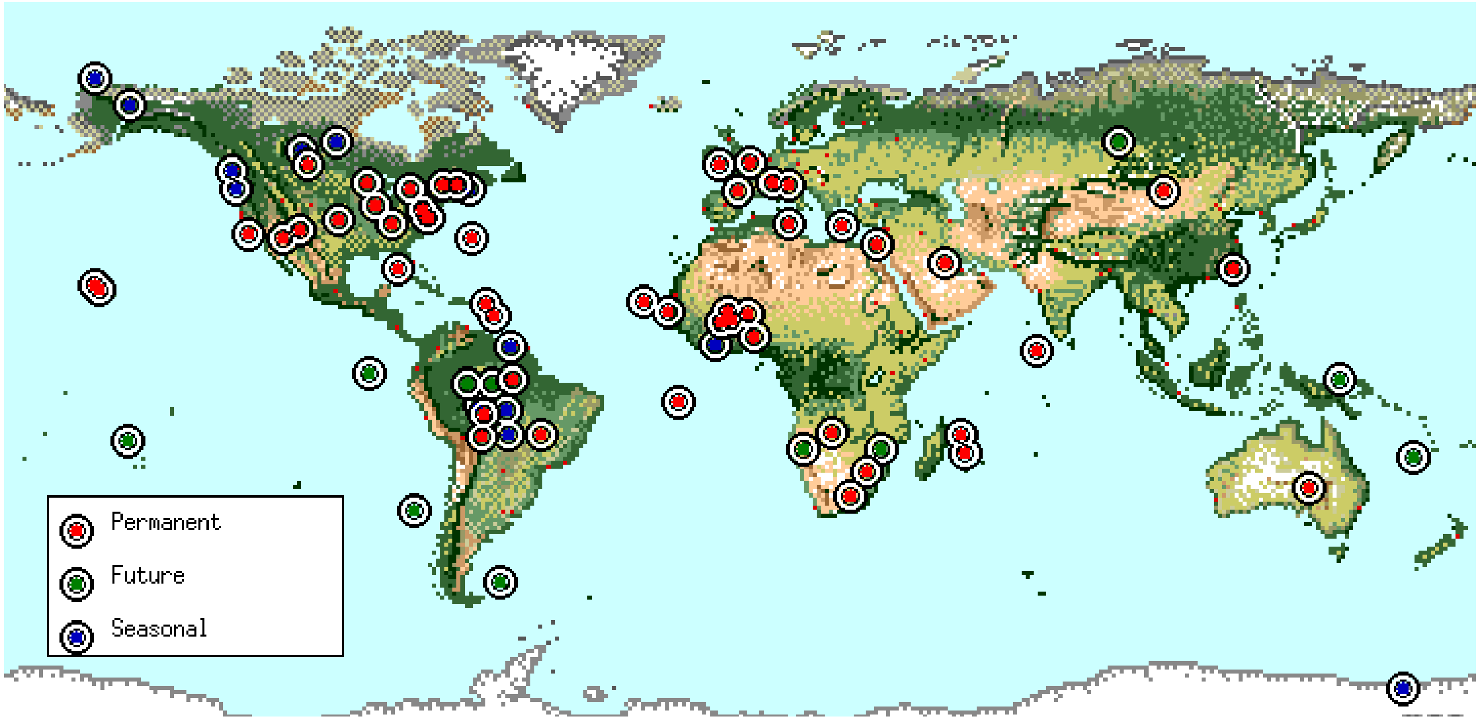


θ_0 = 36°

Black = 1.2 cm
White = 1.5 cm

June 1999 AERONET (Aerosol Robotic Network)

- **Automatic recording and transmitting Sun/Sky Photometers**
- **Data Base: Aerosol optical thickness, size distribution, phase function & precipitable water**
- **Collaborative: NASA – instruments/sites and centralized calibration & database**
  Non-NASA – instruments/sites

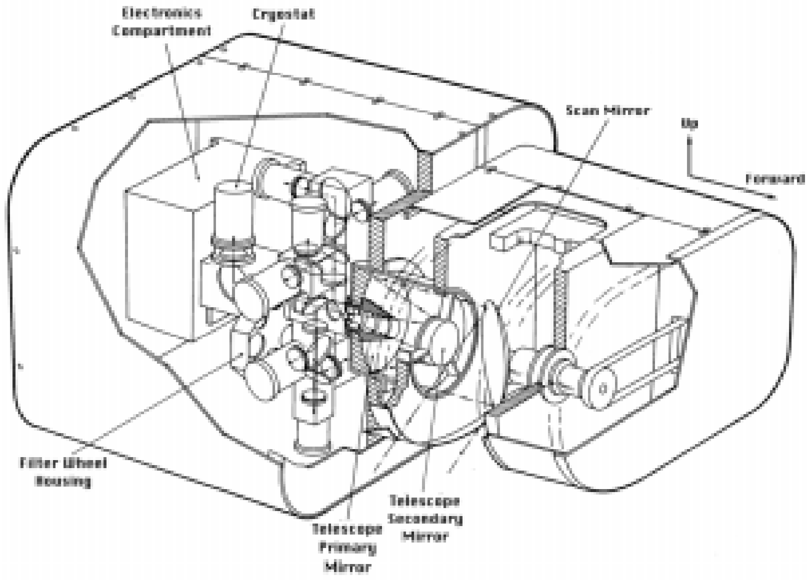


MODIS Atmosphere Status

- **MODIS Software**
  - **All PGEs have been delivered and accepted, with the exception of the level-3 ‘weekly’ product**
    - **This weekly product is a new addition, but is virtually identical with the monthly product - expected in January 1999**
- **Documentation**
  - **All 6 ATBDs developed by the MODIS atmosphere group have been updated and delivered to the EOS Project Science Office**
  - **Validation Plan currently being updated to include the following new features**
    - **Input from investigations selected through the validation NRA**
    - **Recent plans for SAFARI 2000 field campaign in southern Africa in August-September 2000**
    - **Extended planning through 2004 (current plan ends at December 2000)**
    - **Updated launch status of AM-1 and PM-1**

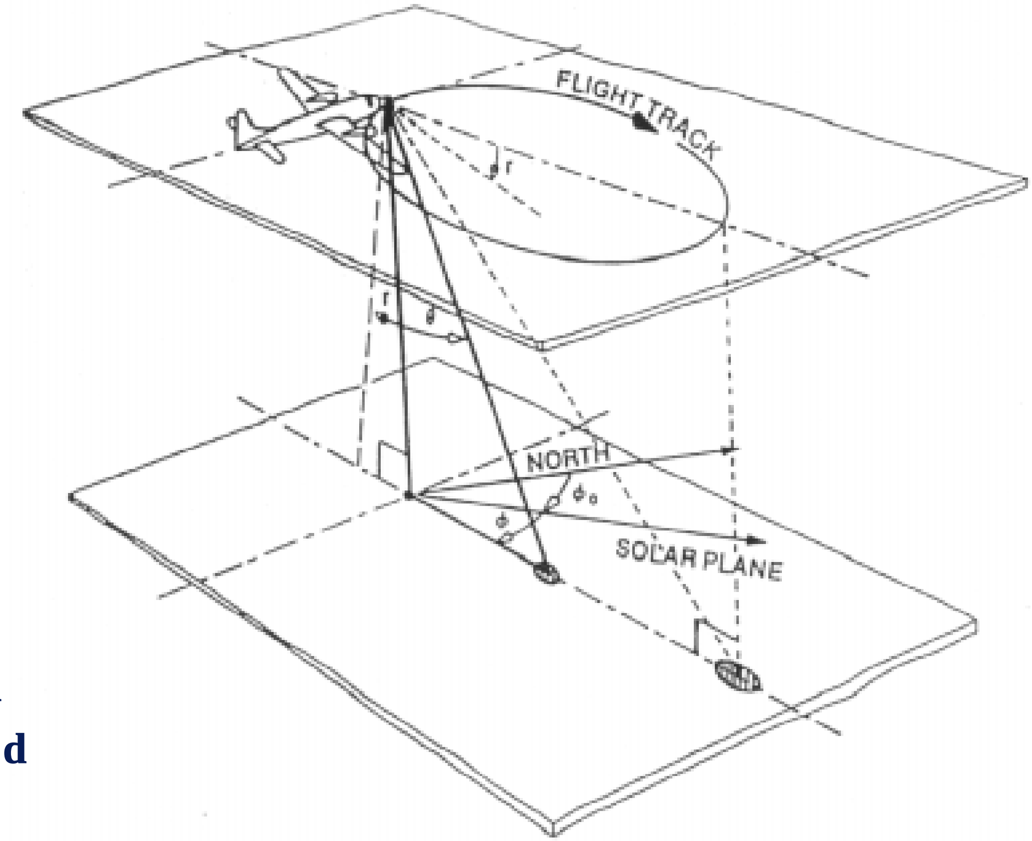
Cloud Absorption Radiometer

- **Goddard Space Flight Center**
  - **developed in 1982-1983**
- **University of Washington**
  - **integrated & flown in 1984 (B-23)**
  - **principal data from 1987-97 (C-131A)**
  - **flights after 1998 (CV-580)**
- **Sensor Characteristics**
  - **13 spectral bands ranging from 0.30 to 2.29 µm**
  - **scan ±95° from horizon on right-hand side of aircraft**
  - **field of view 17.5 mrad (1°)**
  - **scan rate 1.67 Hz (100 rpm)**
  - **data system 8 channels @ 10 bit**
  - **395 pixels in scan line**
  - **4% reflectance calibration accuracy**

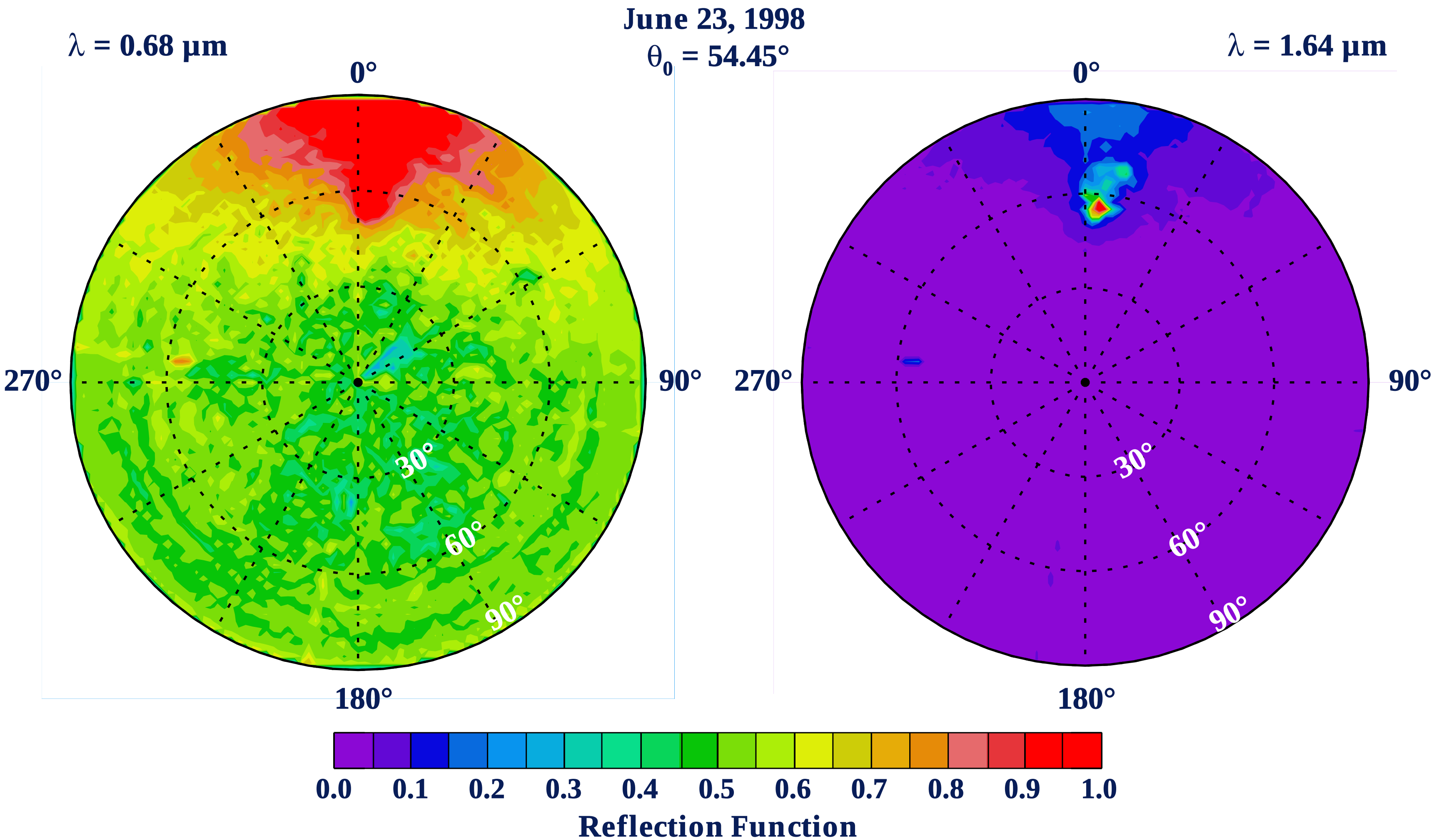


Bidirectional Reflectance Measurements

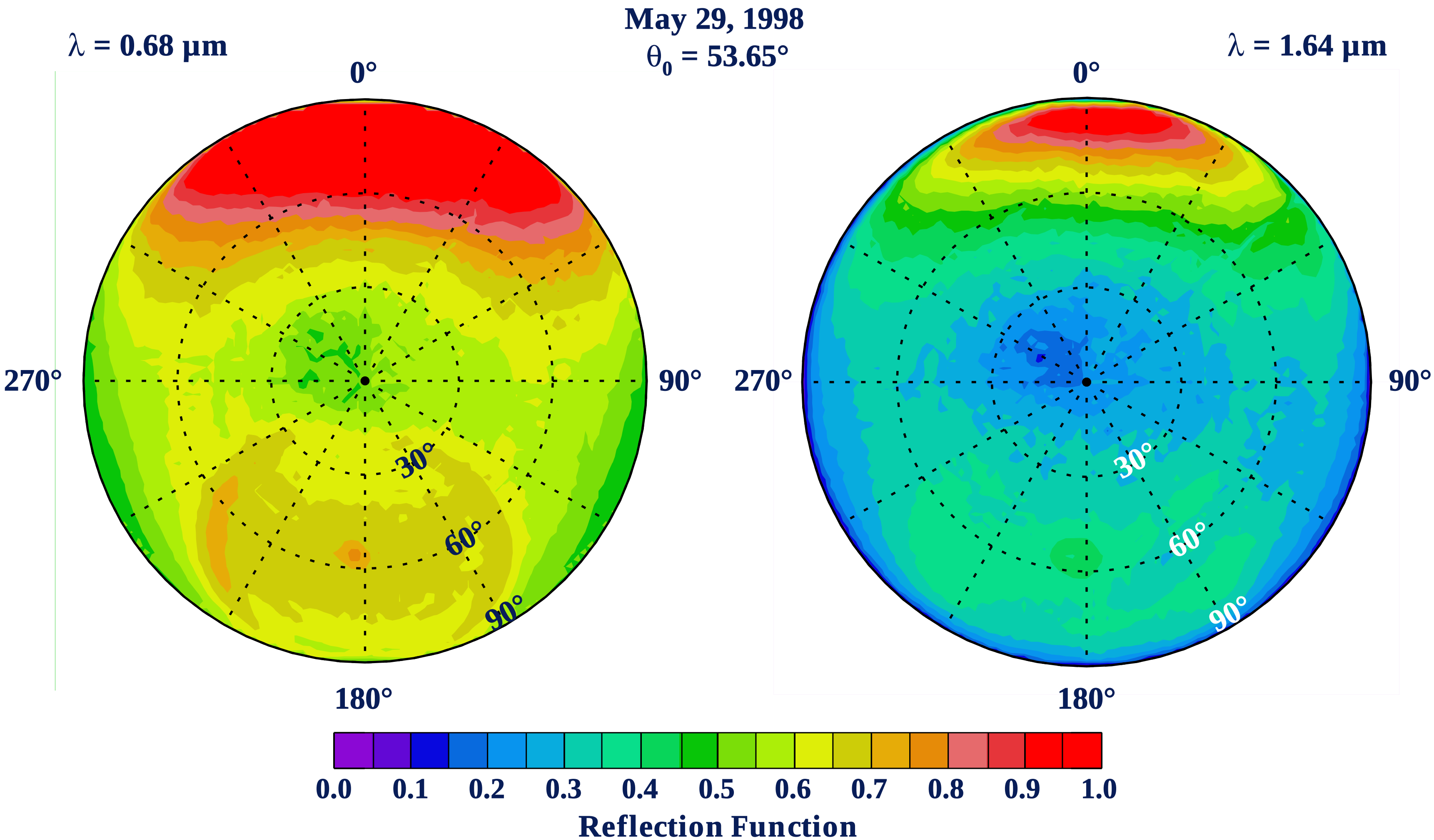
- Roll: ~20°
- Time: ~2 min
- Speed: ~80 m s^{-1}
- Height: ~600 m
- Diameter: ~3 km
- Resolution
  - 10 m (nadir)
  - 270 m (θ = 80°)
- Channels
  - 7 continuously sampled: 0.30 (0.75), 0.47 (0.51), 0.67, 0.87, 1.04, 1.22, and 1.27 µm
  - 2 filter wheel channels used for BRDF measurements (1.64 & 2.20 µm)



Bidirectional Reflectance—Sea Ice



Bidirectional Reflectance—Arctic Stratus



Summary

- Surface bidirectional reflectance measurements acquired under the following conditions
  - Cerrado and dense forest (Brazil)
  - Dense smoke layers over forest (Brazil)
  - Snow over tundra and open tundra (Alaska)
  - Fast, first year, and multi-year sea ice (Alaska)
  - Ocean with sun glint (Persian Gulf, Atlantic Ocean, Strait of Juan de Fuca)
  - Great dismal swamp (Virginia)
  - Desert (Saudi Arabia)
  - Oil Fire Smoke (Kuwait)
  - Water and ice clouds (various)