

Cloud Optical and Microphysical Properties: Updates for Collection 5

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- Enhancements in collection 4
- Summary of modifications and enhancements in collection 5
- Example results from tests
- Level-3 gridded products



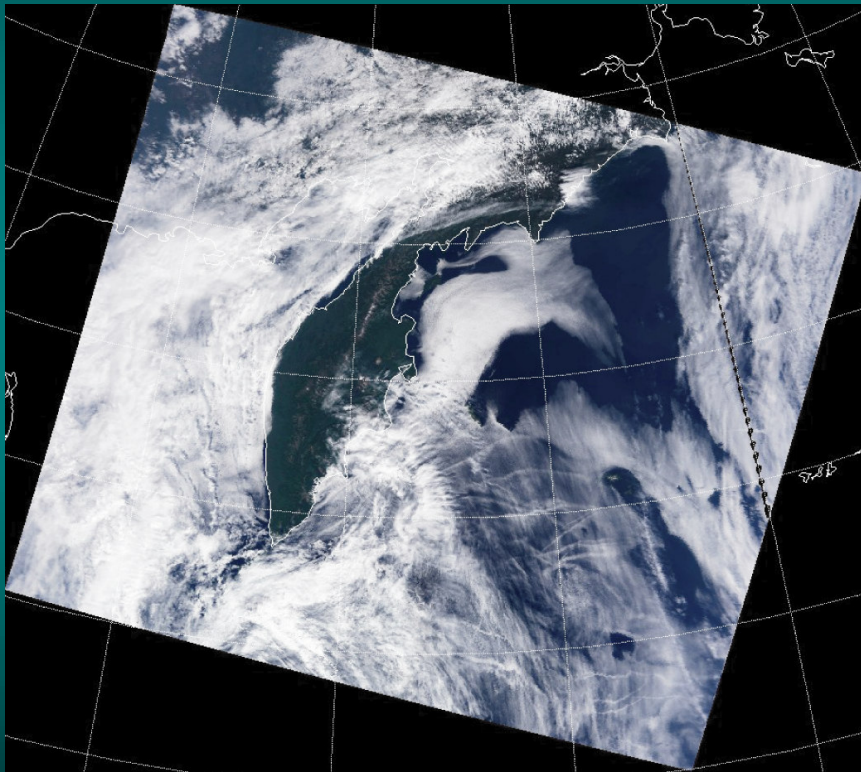
Cloud Optical & Microphysical Properties

- Pixel-level cloud product during **daytime** at **1 km**
 - Cloud optical thickness, thermodynamic phase, and effective radius
 - cloud phase determined from cloud mask tests, bispectral threshold (8.5 & 11 μm), shortwave infrared tests (1.6 and 2.1 μm), and cloud top temperature
 - surface reflectance from MODIS ecosystem and albedo products
 - solar reflectance technique using visible through midwave infrared bands
 - ✓ effective radius determined separately using 1.6, 2.1 (baseline), and 3.7 μm bands

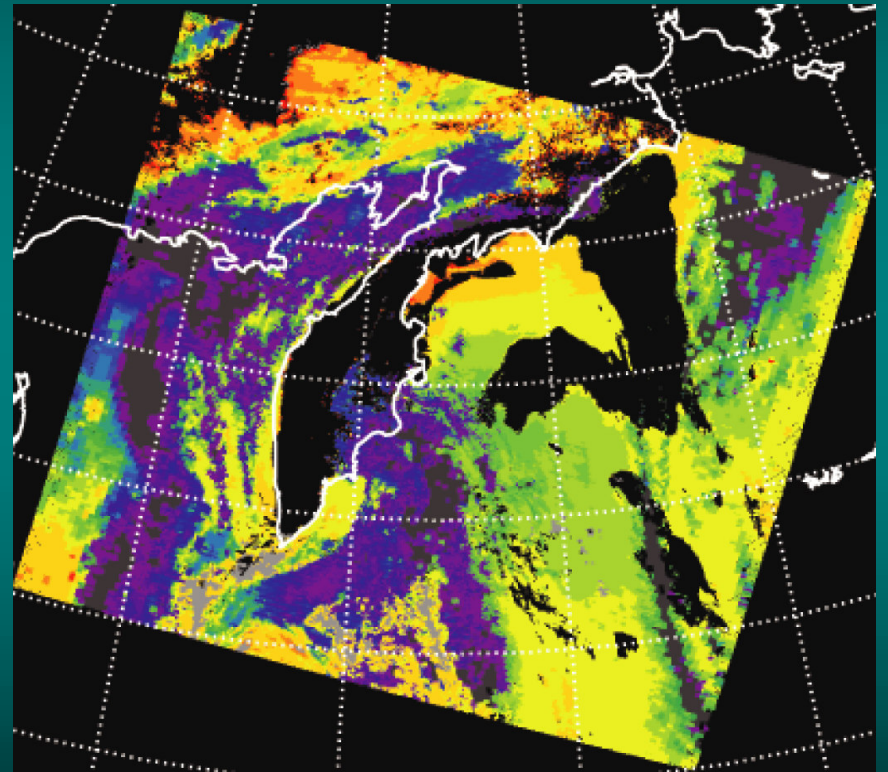
Terra/MODIS Cloud Top Pressure (W. P. Menzel - NOAA/NESDIS, Univ. Wisconsin)

Collection 4

True Color Composite (0.65, 0.56, 0.47)



Cloud Top Pressure (hPa)



Cloud Top Pressure (hPa)

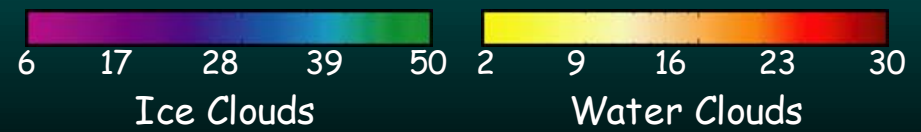
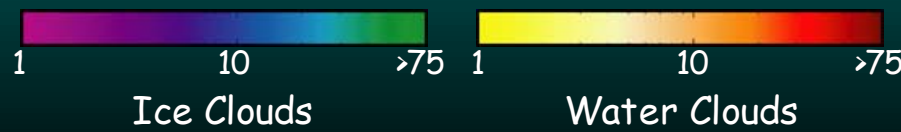
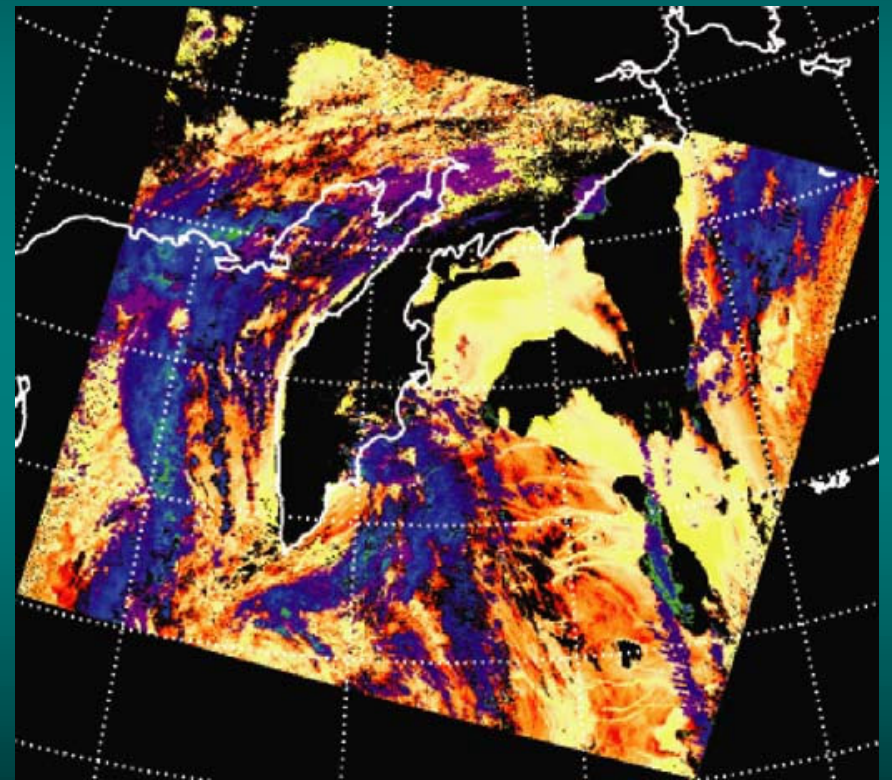
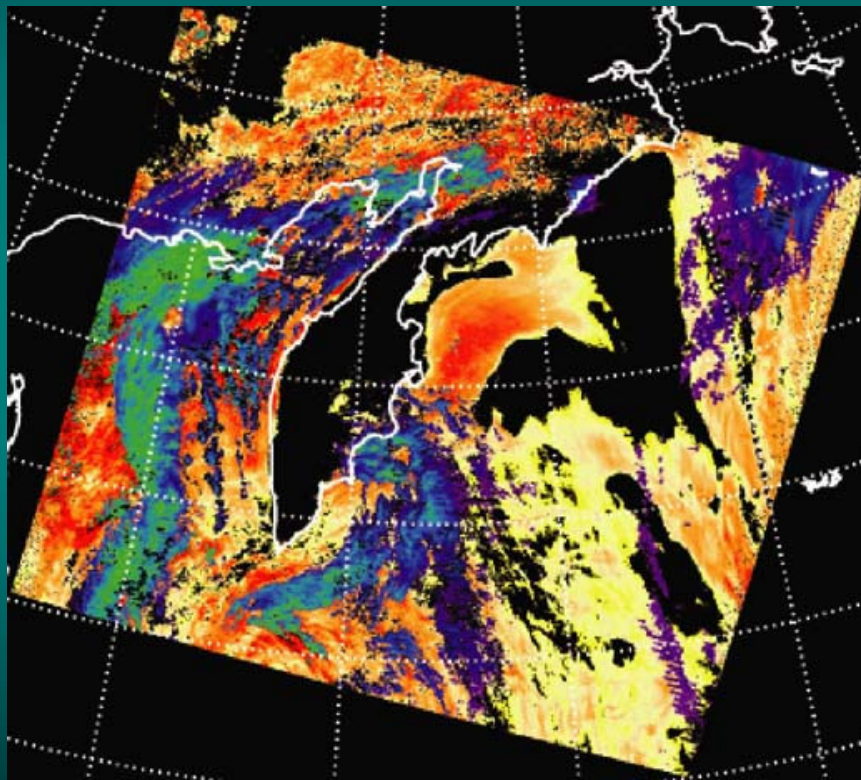
Cloud Optical Thickness and Effective Radius

(M. D. King, S. Platnick - NASA GSFC)

Collection 4

Cloud Optical Thickness

Cloud Effective Radius (μm)



Aqua/MODIS Level-1B Image

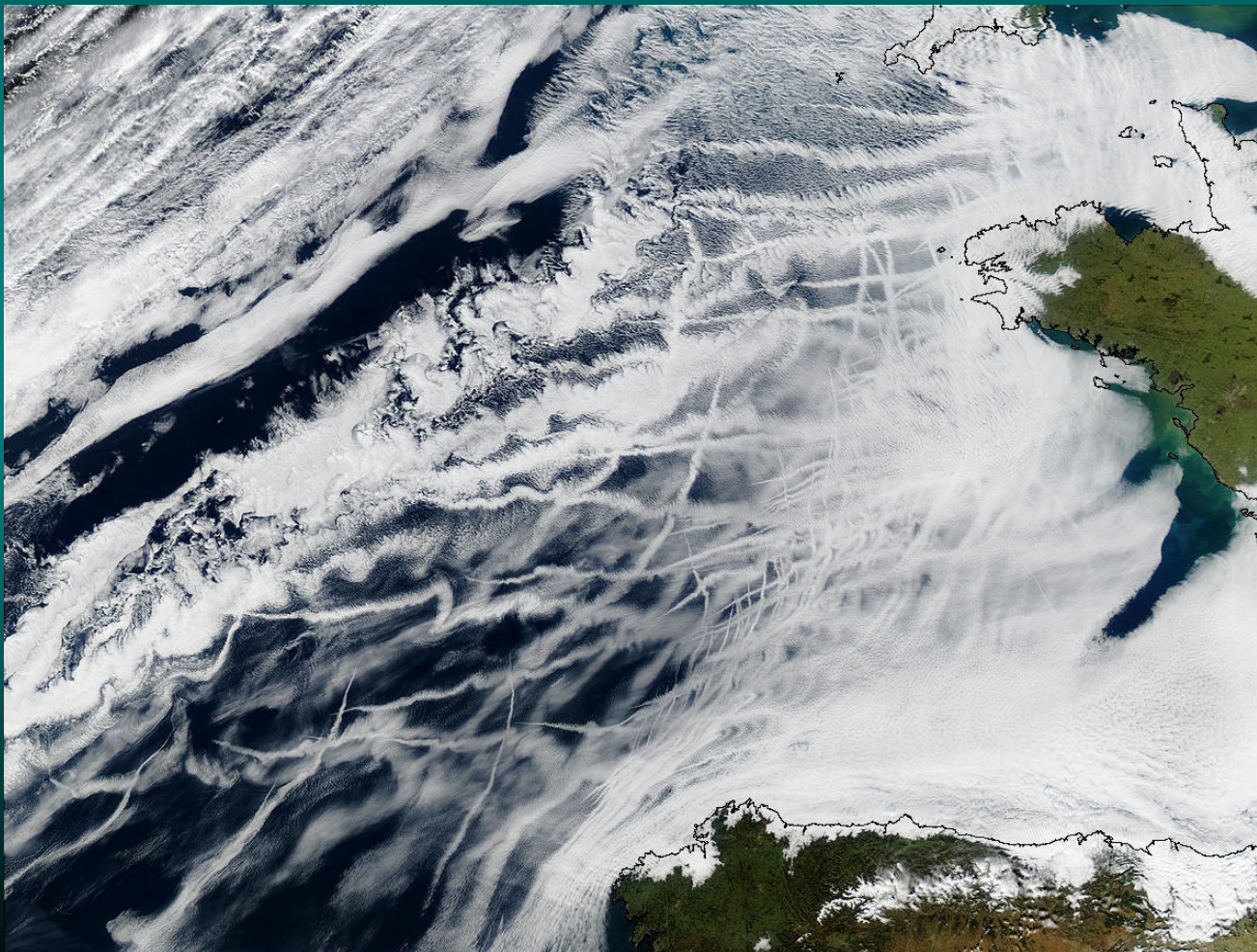
R = 0.65 μm

G = 0.56 μm

B = 0.47 μm

January 27, 2003

1340 UTC

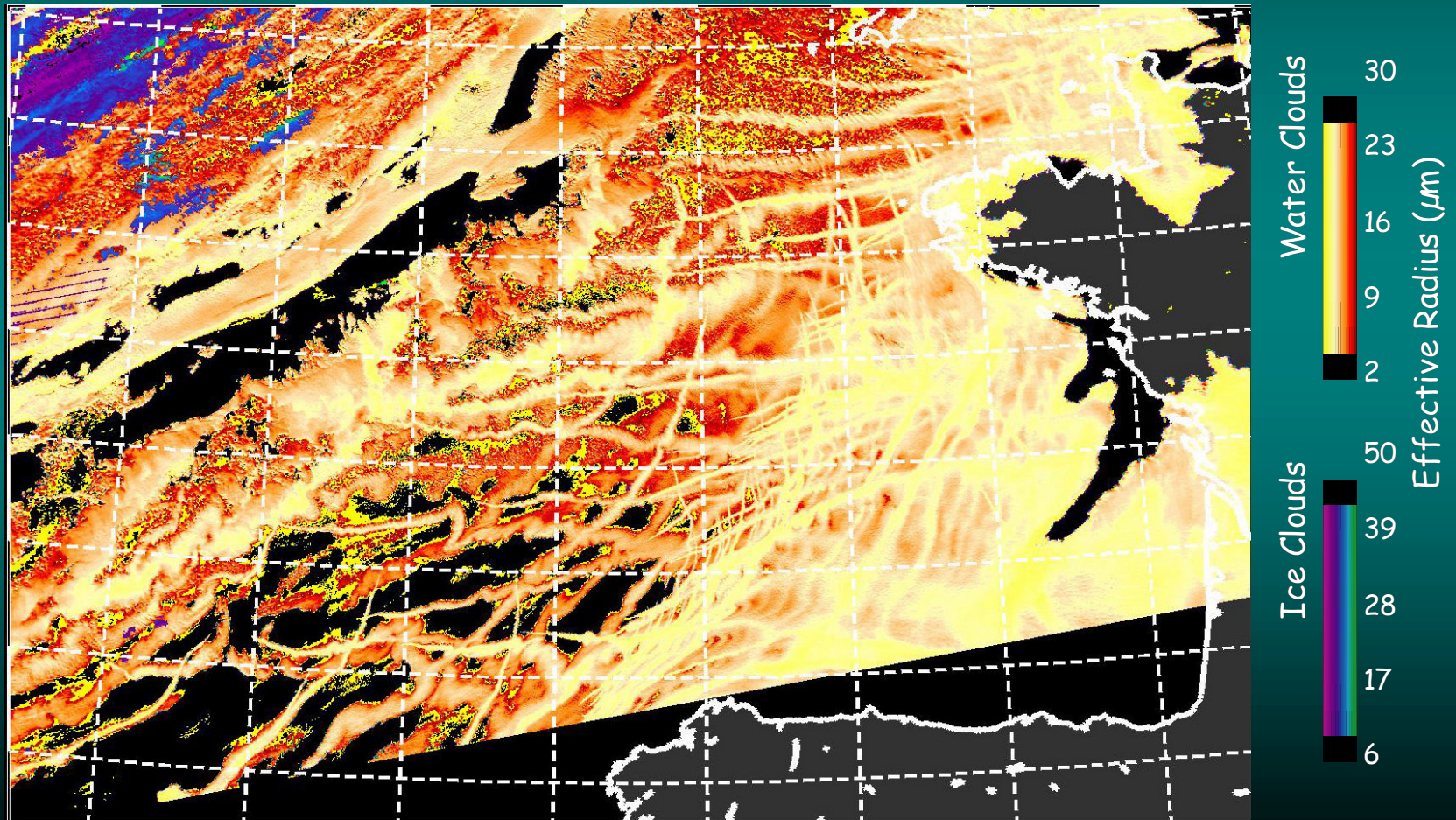


Aqua/MODIS Cloud Effective Radius

(M. D. King, S. Platnick et al. - NASA GSFC)

January 27, 2003
1340 UTC

Collection 4



MODIS Cloud Optical & Microphysical Properties

Collection 4 corrections and enhancements

- Surface reflectance database based on MODIS white-sky albedo product at 1' (~ 2 km at the equator)
 - Seasonal cycle based on sinusoidal fit poleward of 30° latitude using IGBP ecosystem classification as a proxy
- Thermodynamic phase tests drastically eliminated the high incidence of undetermined phase and enhanced the confidence in the retrieval processing path
- Fixed the large number of failed retrievals for ice clouds using 3.7 μm
 - Directly related to the 12 ice crystal models and their size relation to crystal habit—single scattering albedo is not a monotonic function of effective radius
- Smoothed transition from table lookups (small optical thickness) to asymptotic theory (large optical thickness)
 - Led to solutions with missing retrievals at $\tau_c = 13$ (water clouds) and $\tau_c = 8$ (ice clouds)
- Added new QA flags that identified failed retrievals as well as no retrieval attempted, including polar darkness

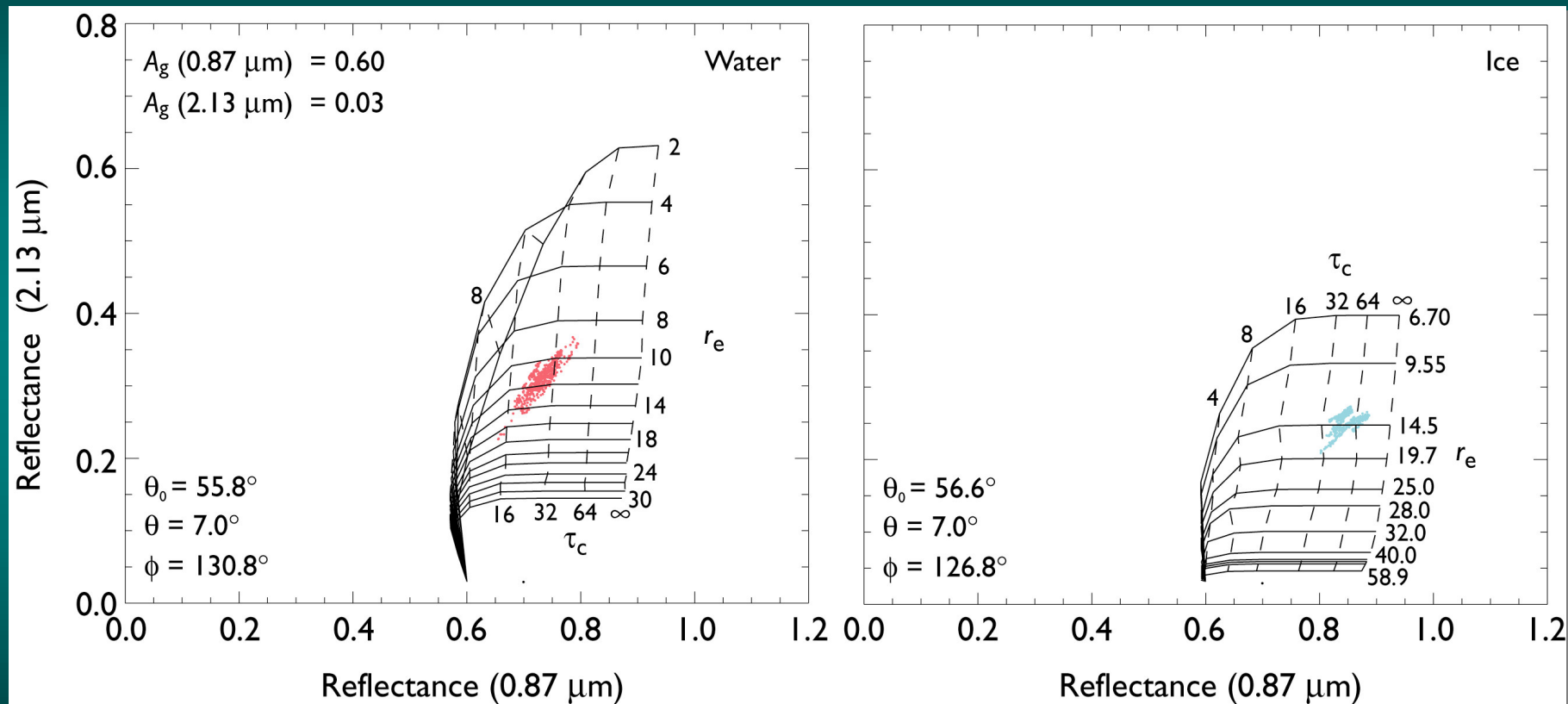
MODIS Cloud Optical & Microphysical Properties

Collection 5 corrections and enhancements

- Add a 1.6 μm vs 2.1 μm retrieval algorithm for liquid water and ice clouds over snow and sea ice surfaces and ocean surfaces
 - Additional retrieval to baseline retrieval; especially useful for water clouds over bright reflecting surfaces or when aerosol overlies marine stratocumulus clouds
- Surface reflectance database based on MODIS white-sky albedo product at 1' (~ 2 km at the equator)
 - Spatially complete spectral dataset every 16 days, based on collection 4 surface reflectance data from 2002
- Atmospheric correction
 - **Rayleigh scattering**: applied to 0.65 μm band (land only), important for thin clouds with large solar/view zenith angle combinations
 - Fixed cloud retrievals for thin clouds ($\tau_c \leq 1$)
 - **Atmospheric absorption**: transmittance lookup table
 - Water vapor above-cloud column amount primary parameter, vapor profile of minor consequence; well-mixed gases a function of p_c
 - **Ozone absorption**: applied to 0.65 μm band (land only)
 - Ozone absorption based on TOVS total ozone and Beer's Law

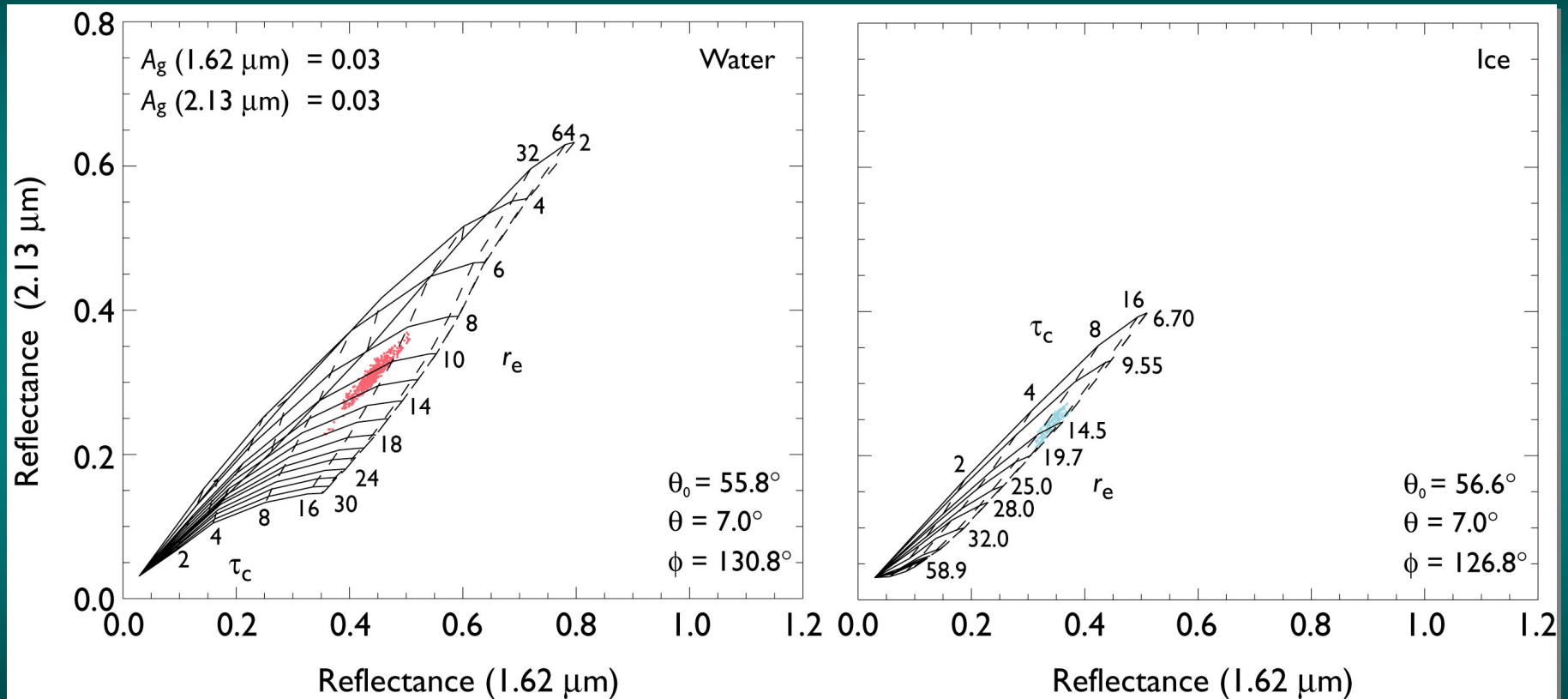
Cloud Optical & Microphysical Retrievals

Retrieval space examples



Cloud Optical & Microphysical Retrievals

Retrieval space examples

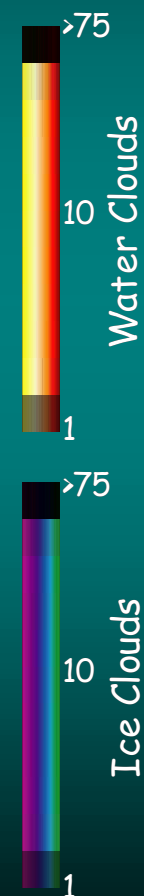
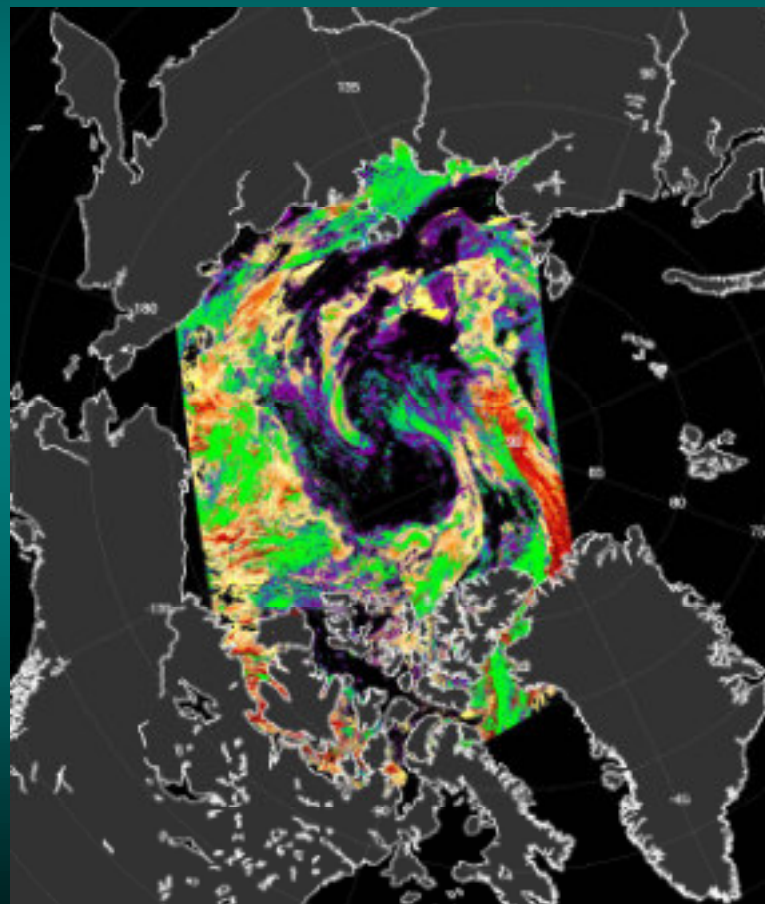
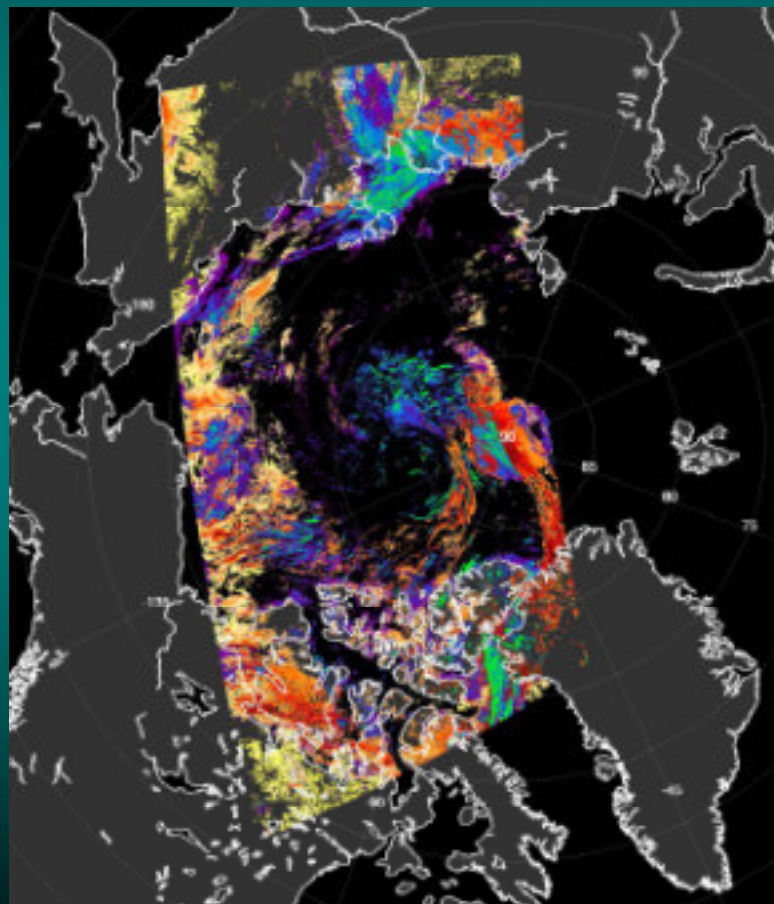


Cloud Optical Thickness in the Arctic

Collection 5

Operational Algorithm

1.6/2.1 μm Algorithm



□ Ocean/Lake □ Land

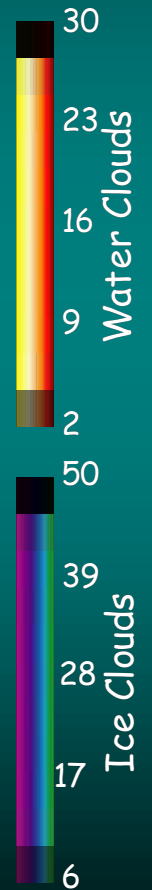
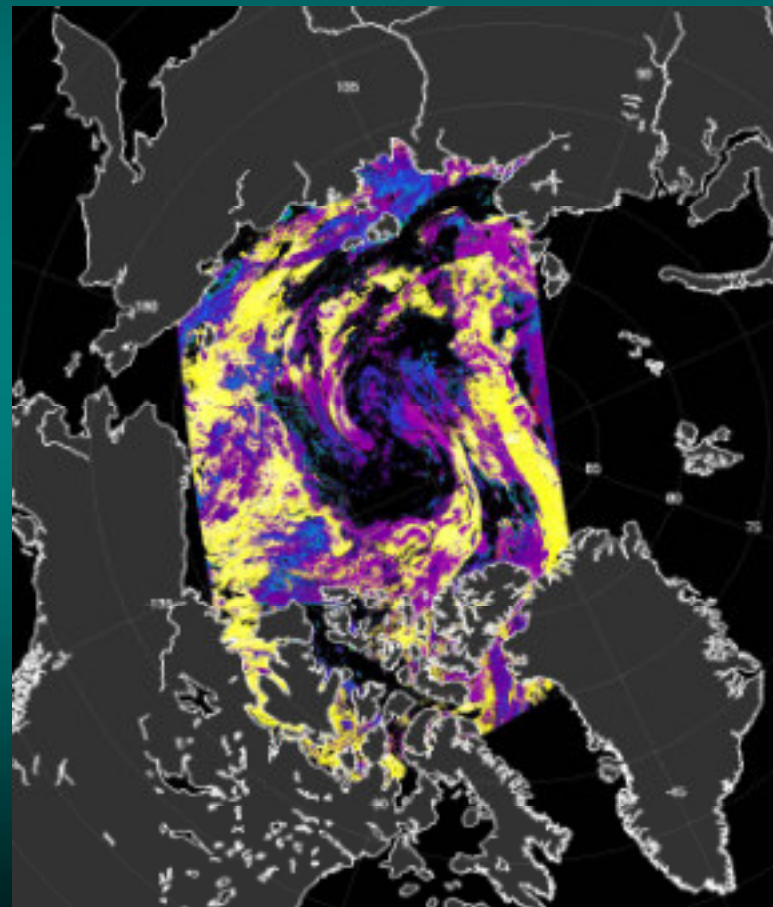
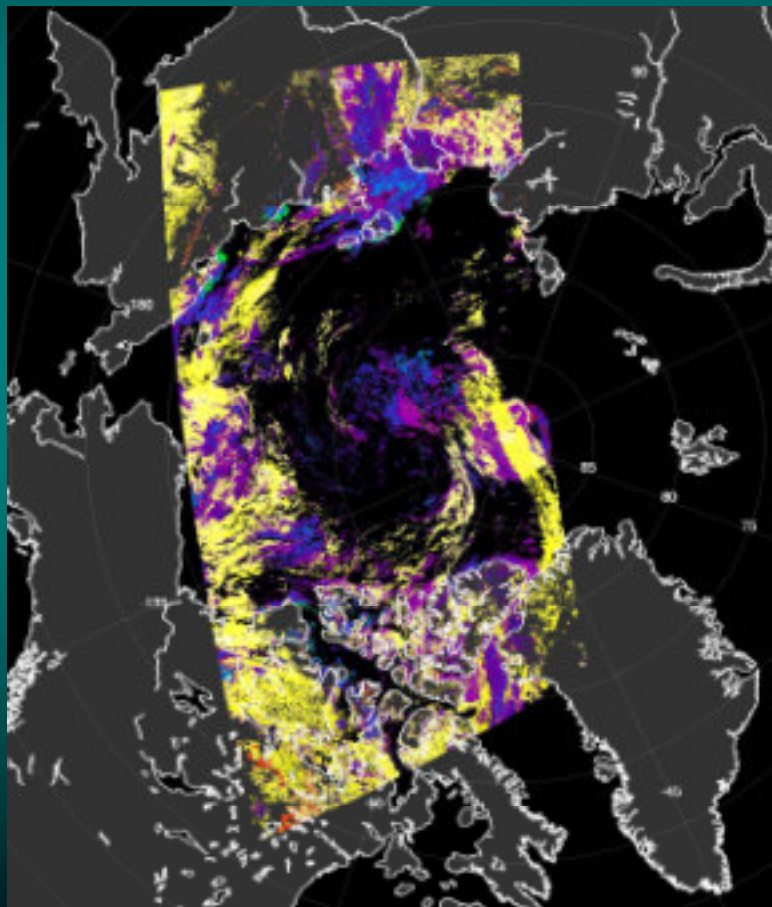
July 9, 2004

Cloud Effective Radius in the Arctic

Collection 5

Operational Algorithm

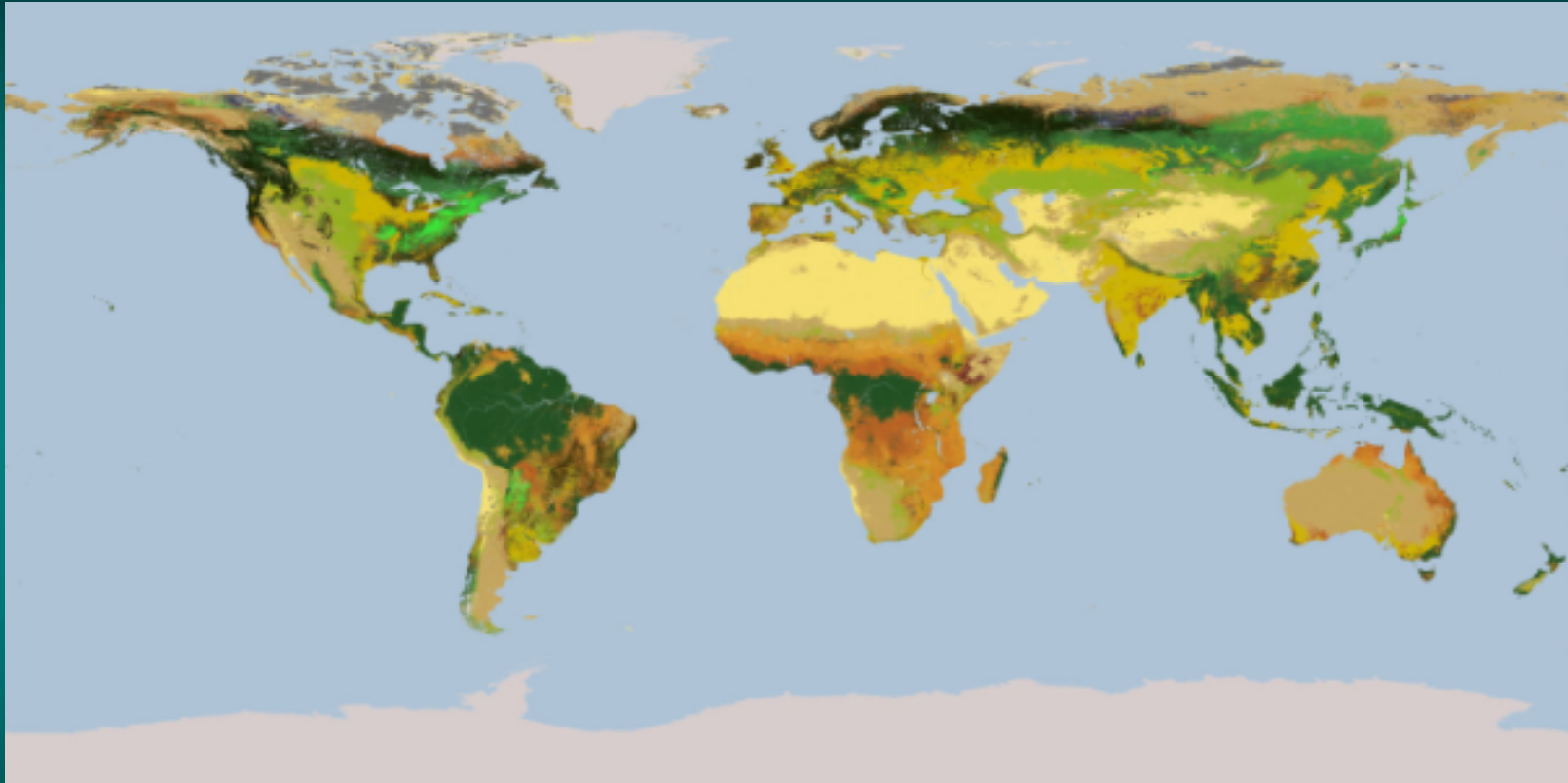
1.6/2.1 μm Algorithm



Ocean/Lake Land

July 9, 2004

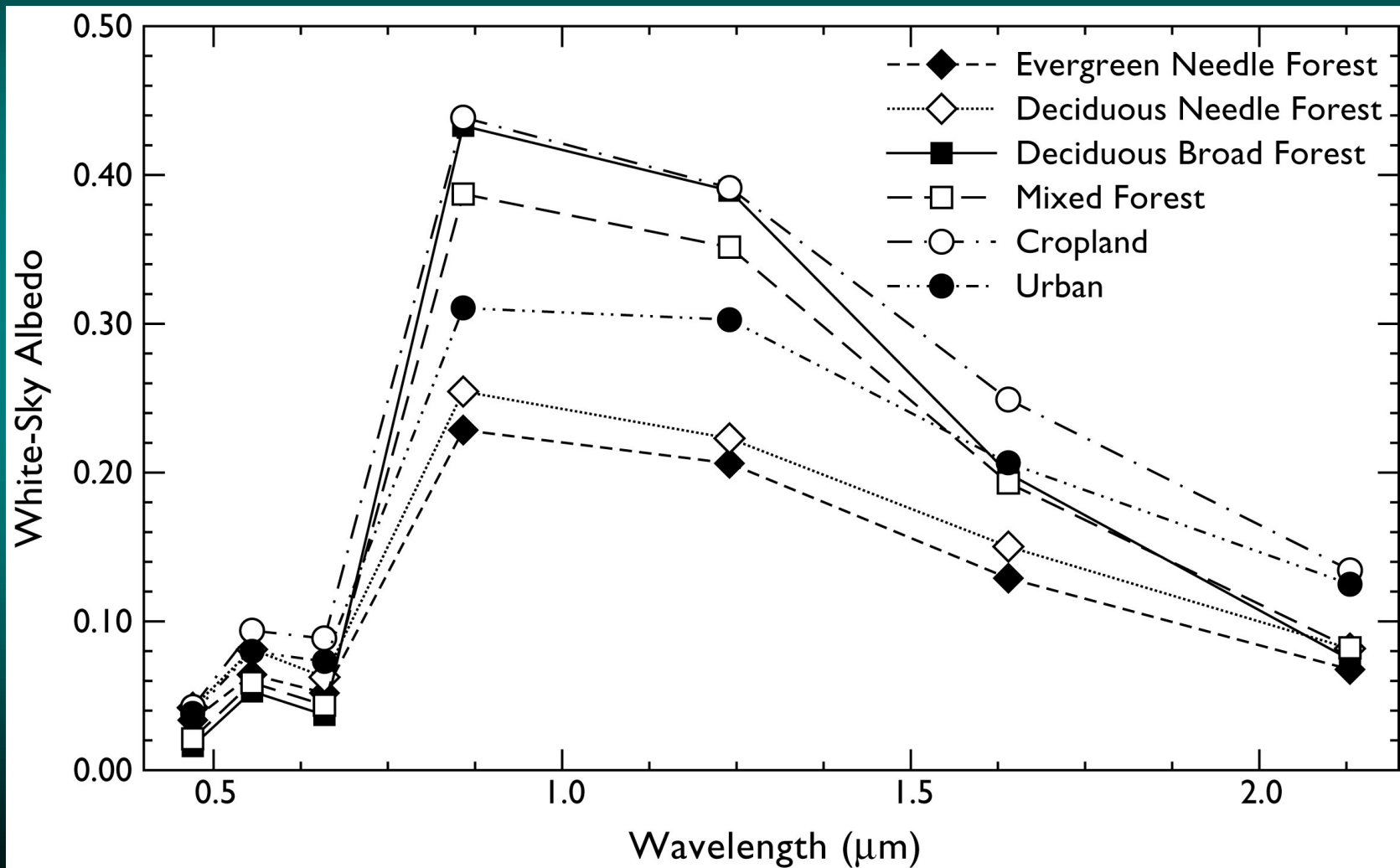
MODIS Land Cover Classification



- | | | |
|-------------------------------|-----------------------|---------------------------------|
| 0 Water | 6 Closed Shrublands | 12 Croplands |
| 1 Evergreen Needleleaf Forest | 7 Open Shrublands | 13 Urban and Built-Up |
| 2 Evergreen Broadleaf Forest | 8 Woody Savannas | 14 Cropland/Natural Veg. Mosaic |
| 3 Deciduous Needleleaf Forest | 9 Savannas | 15 Snow and Ice |
| 4 Deciduous Broadleaf Forest | 10 Grasslands | 16 Barren or Sparsely Vegetated |
| 5 Mixed Forests | 11 Permanent Wetlands | 17 Tundra |

Surface Albedo

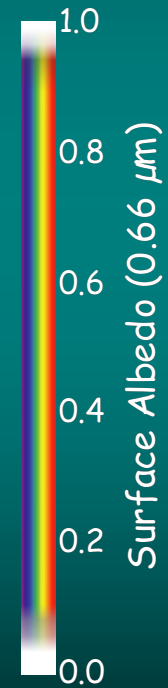
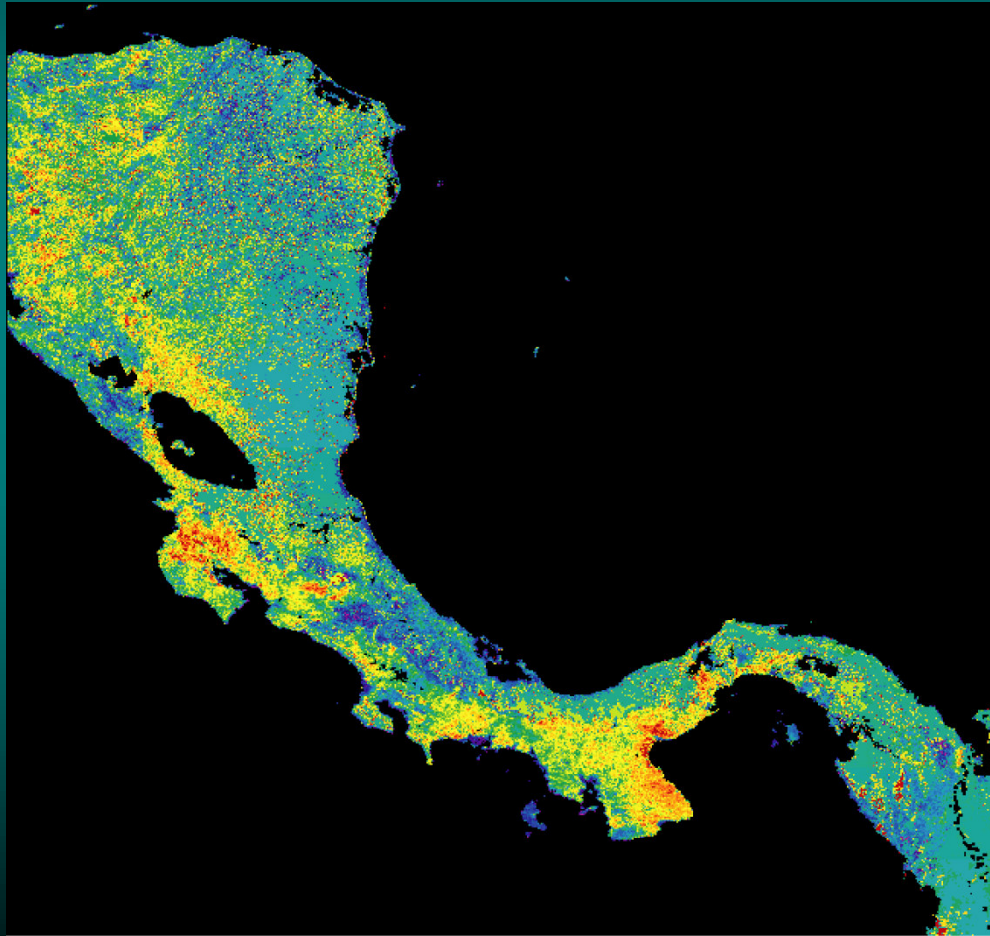
Ecosystem + MOD43 (Strahler, Schaaf et al.) aggregation



Surface Albedo of Central America

July 12-27, 2001

Collection 3



MODIS Cloud Optical & Microphysical Properties

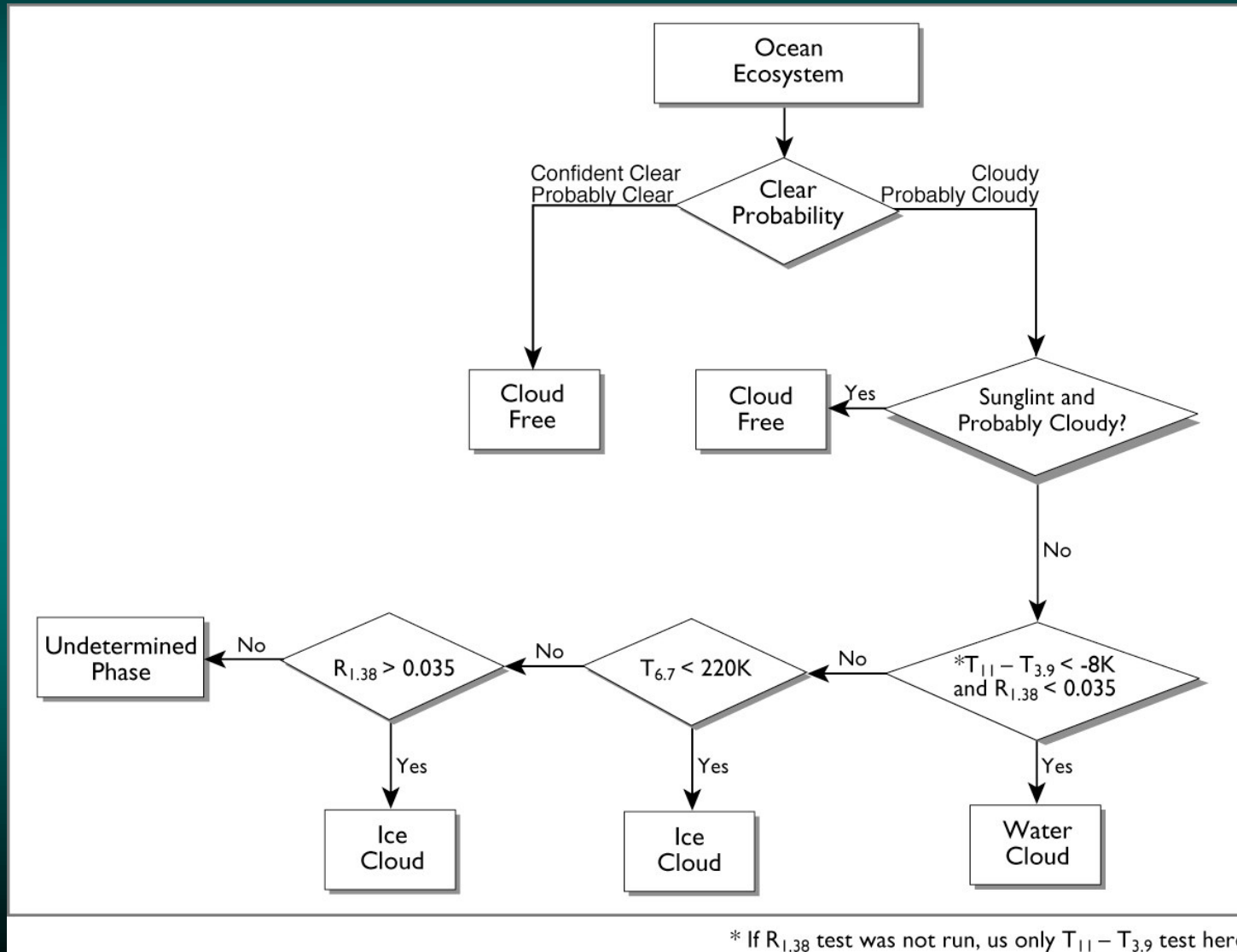
Collection 5 corrections and enhancements

- Implement uncertainty of cloud optical thickness and effective radius
 - Uncertainty based on model sensitivities and surface albedo, calibration, and atmospheric transmission uncertainties
- Implement algorithm to determine the presence of multi-layer clouds
- Retrieval produces a 'fill value' when the adjacent pixel is 'clear,' thereby eliminating small τ_c , large r_e retrievals around the edge of broken clouds
- If reflectance saturates at $0.86 \mu\text{m}$, switch to $0.65 \mu\text{m}$ for retrieval
 - If $\tau_c > 100$ and indeterminate, still retrieve r_e , which is well determined for large R_{vis}

Collection 5 minor modifications

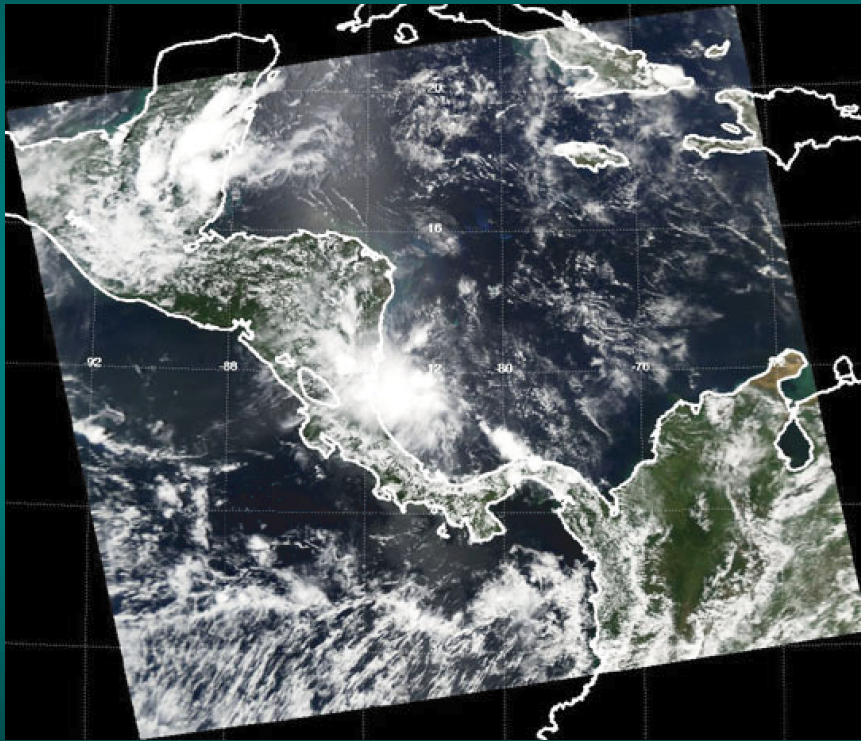
- Add separate SDS in file for thermodynamic phase (Cloud_Phase_Optical_Properties)
- Set maximum solar zenith angle of cloud optical property retrievals to 81.4°
 - There was previously a difference between day/night for cloud mask and cloud optical properties
- Set ice water density to 0.93 g cm^{-3}
 - This affects the ice water path computation
- Read the detector quality flag and uncertainty index in level-1b file to determine whether pixel is a good candidate for cloud retrieval (e.g., $1.6 \mu\text{m}$ channels on Aqua)

Cloud Mask Tests over an Ocean Ecosystem

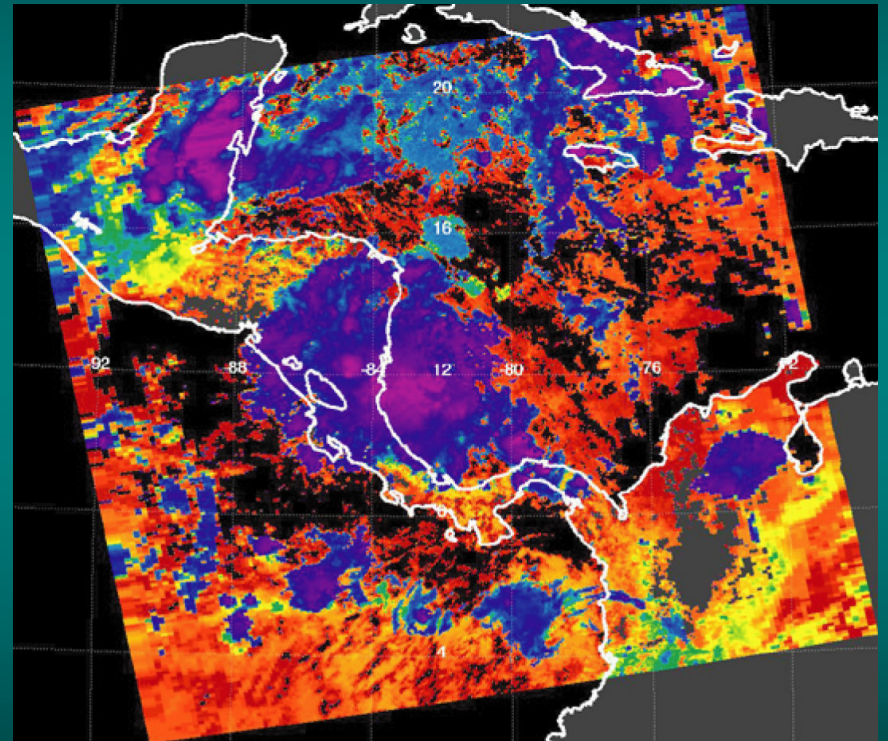


Aqua/MODIS Cloud Top Pressure (W. P. Menzel - NOAA/NESDIS, Univ. Wisconsin)

True Color Composite (0.65, 0.56, 0.47)



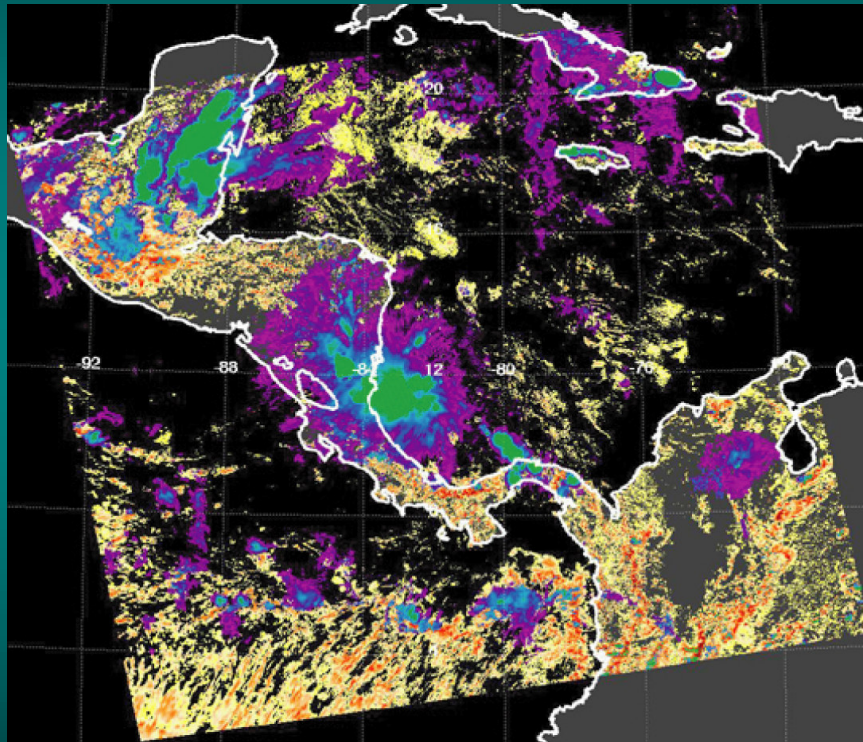
Cloud Top Pressure (hPa)



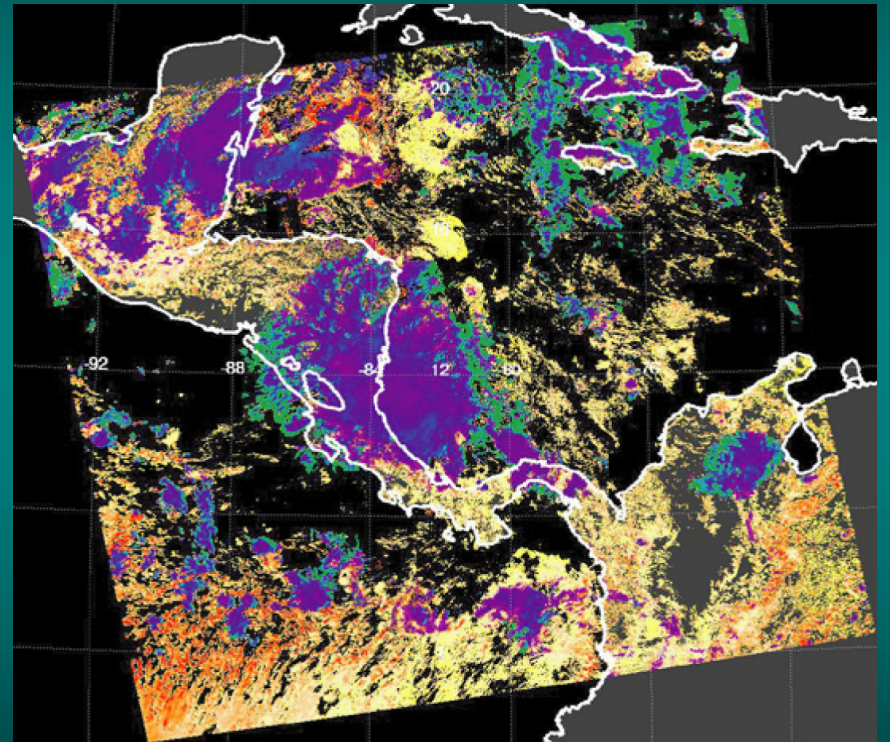
Cloud Optical Thickness and Effective Radius

(M. D. King, S. Platnick - NASA GSFC)

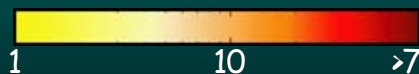
Cloud Optical Thickness



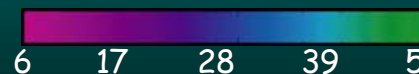
Cloud Effective Radius (μm)



Ice Clouds



Water Clouds



Ice Clouds



Water Clouds

MODIS Cloud Optical & Microphysical Properties

Collection 5 additional enhancements under study

- Sunlint screening and filtering
 - Sunlint screening from cloud mask eliminates many clouds in the tropics that we would like to retrieve
- SWIR thresholds in cloud phase decision tree are based on ratios of 1.6 and 2.1 μm to 0.65 μm for all ecosystems
 - The thresholds should vary by surface type and perhaps geographic region
- Heavy aerosol detection
 - Spatial variability tests being explored to eliminate dust that is being falsely identified as clouds over both ocean and land
- Replacement of forward libraries for ice clouds
- Integration of GMAO temperature and water vapor fields into ancillary input
 - Currently we are using NCEP data

Gridded Level-3 Joint Atmosphere Products

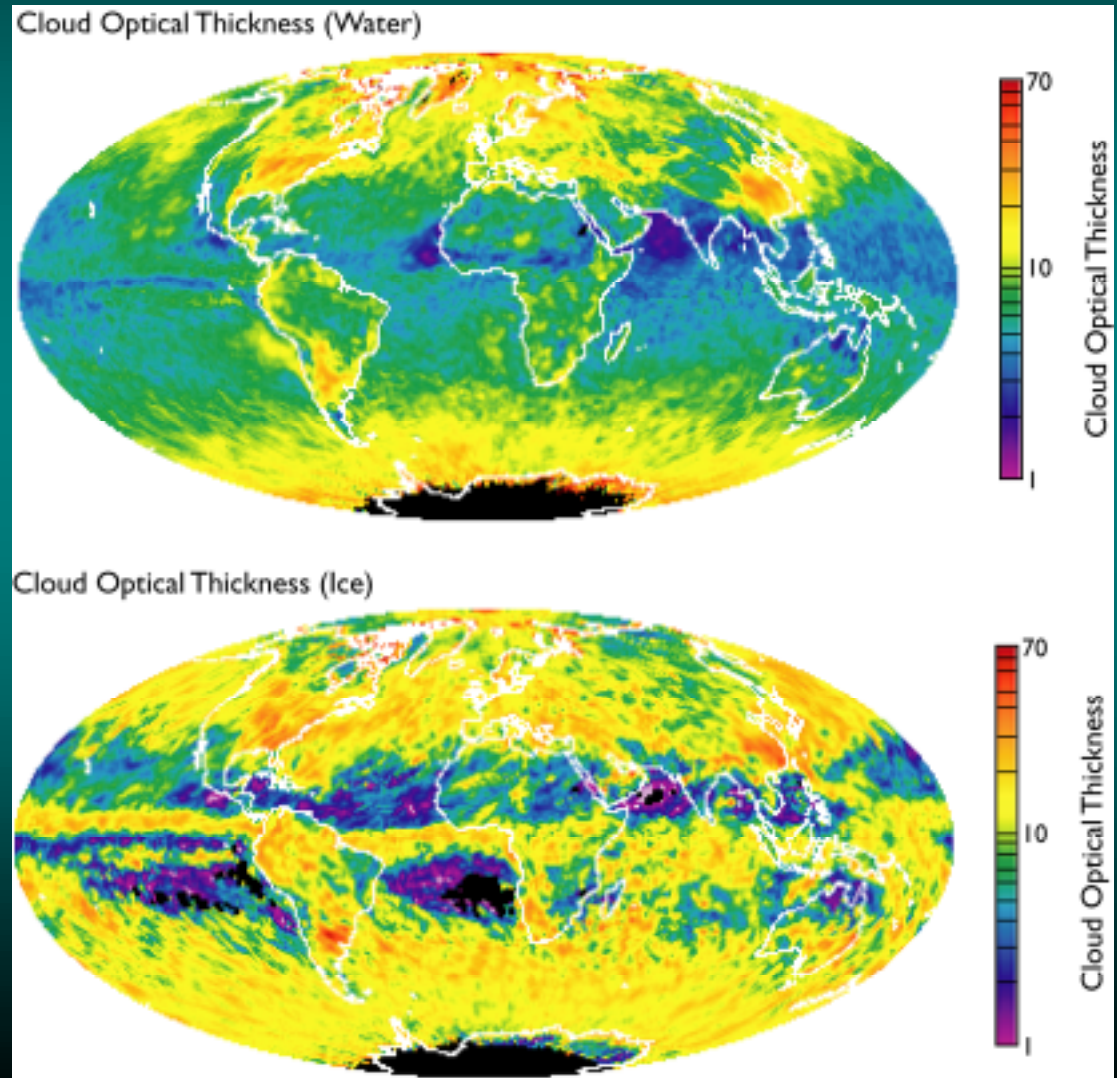
(M. D. King, S. Platnick, P. A. Hubanks)

- Daily, 8-day, and monthly products (474.8, 883.2, 883.2 MB)
- $1^\circ \times 1^\circ$ equal angle grid
- Mean, standard deviation, marginal probability density function, joint probability density functions

Monthly Mean Cloud Optical Thickness

(M. D. King, S. Platnick et al. - NASA GSFC)

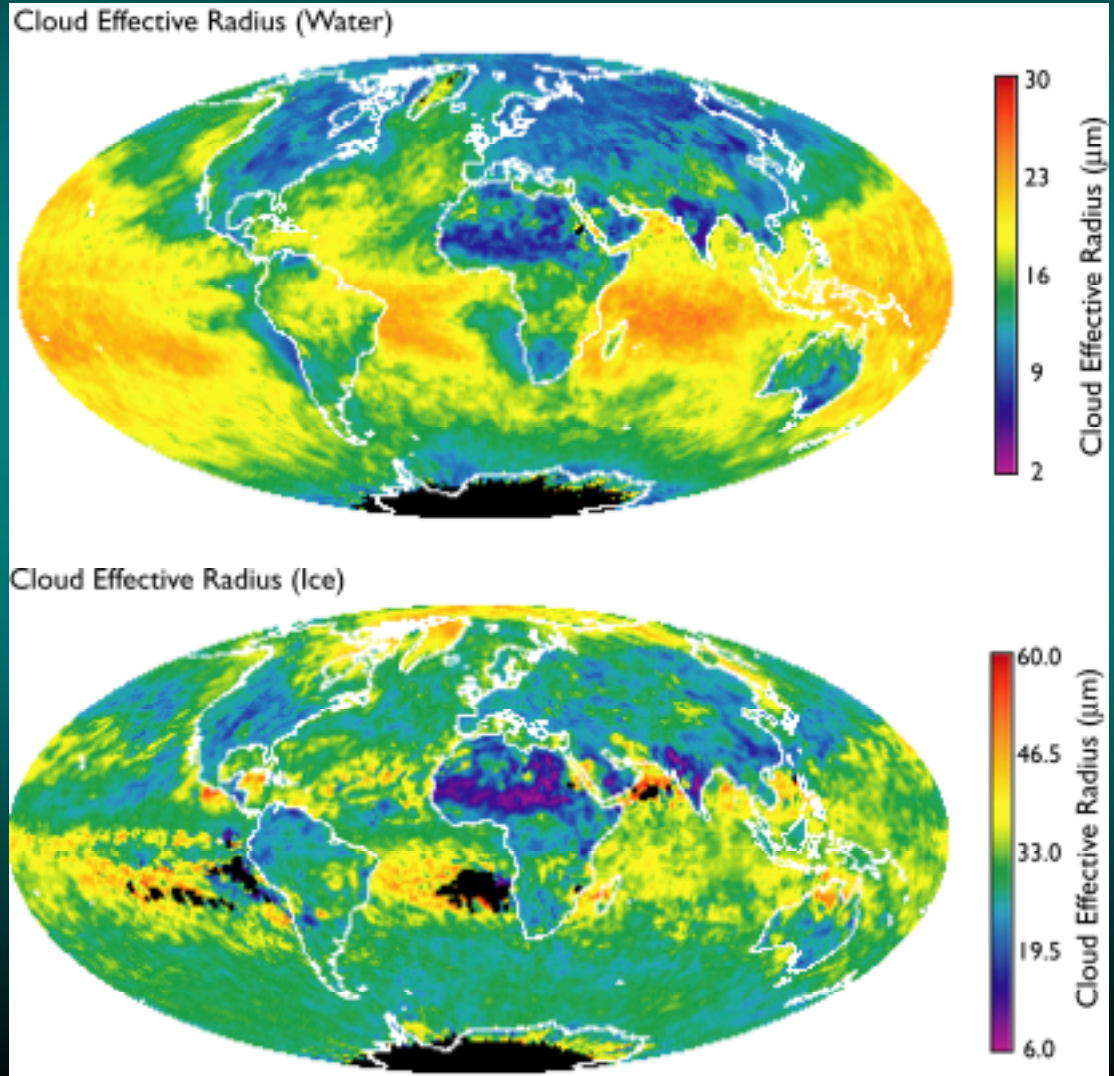
April 2003 (Collection 4)



Monthly Mean Cloud Effective Radius

(M. D. King, S. Platnick et al. - NASA GSFC)

April 2003 (Collection 4)



Summary of MODIS Atmosphere Products

- **Collection 4** reprocessing complete for Aqua; Terra and Aqua forward stream near real-time
- Image Production for Web site
 - 228 MB of images produced every day
 - Terra & Aqua
 - Level-1B daytime granules
 - Level-3 daily, eight-day, and monthly products
 - Level-3 high resolution daily product (10 km)
- Storage
 - 131 GB of disk space used to date
 - 1.9 million files
- Access metrics for 2002
 - 5,508,924 hits
 - 63,635 visits
 - 144 GB of data transferred
- **Collection 5** enhancements and reprocessing to begin ~January 1, 2005