Ice cloud retrievals using the 1.38-μm water vapor band

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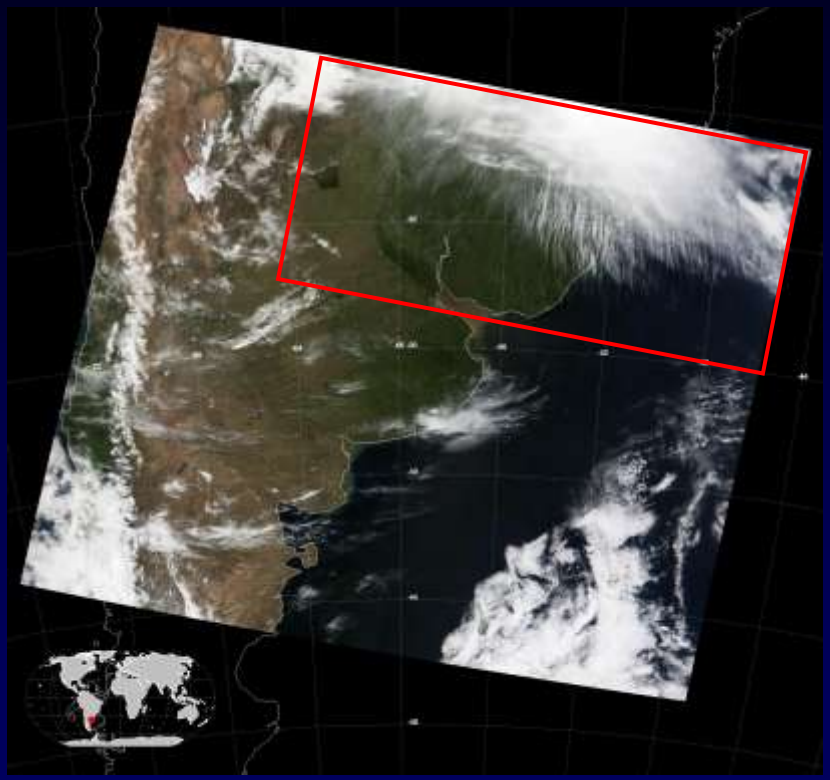
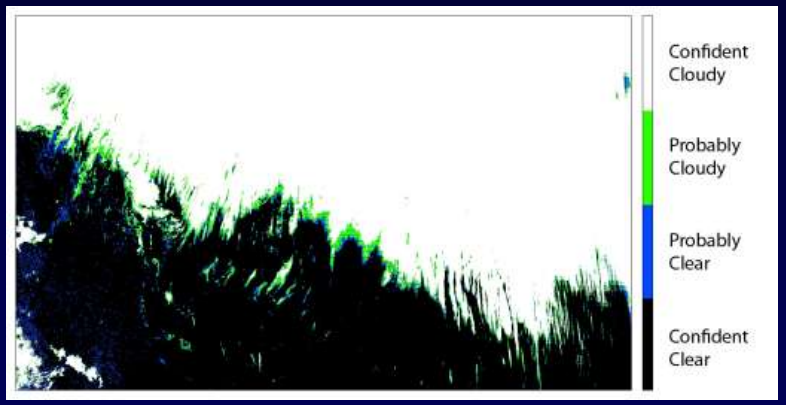
Terra MODIS: 10-21-2007



RGB (0.47-, 1.64-, 2.11-µm))

MOD06 Cloud Mask



MOD06 Cirrus Reflectance Flag

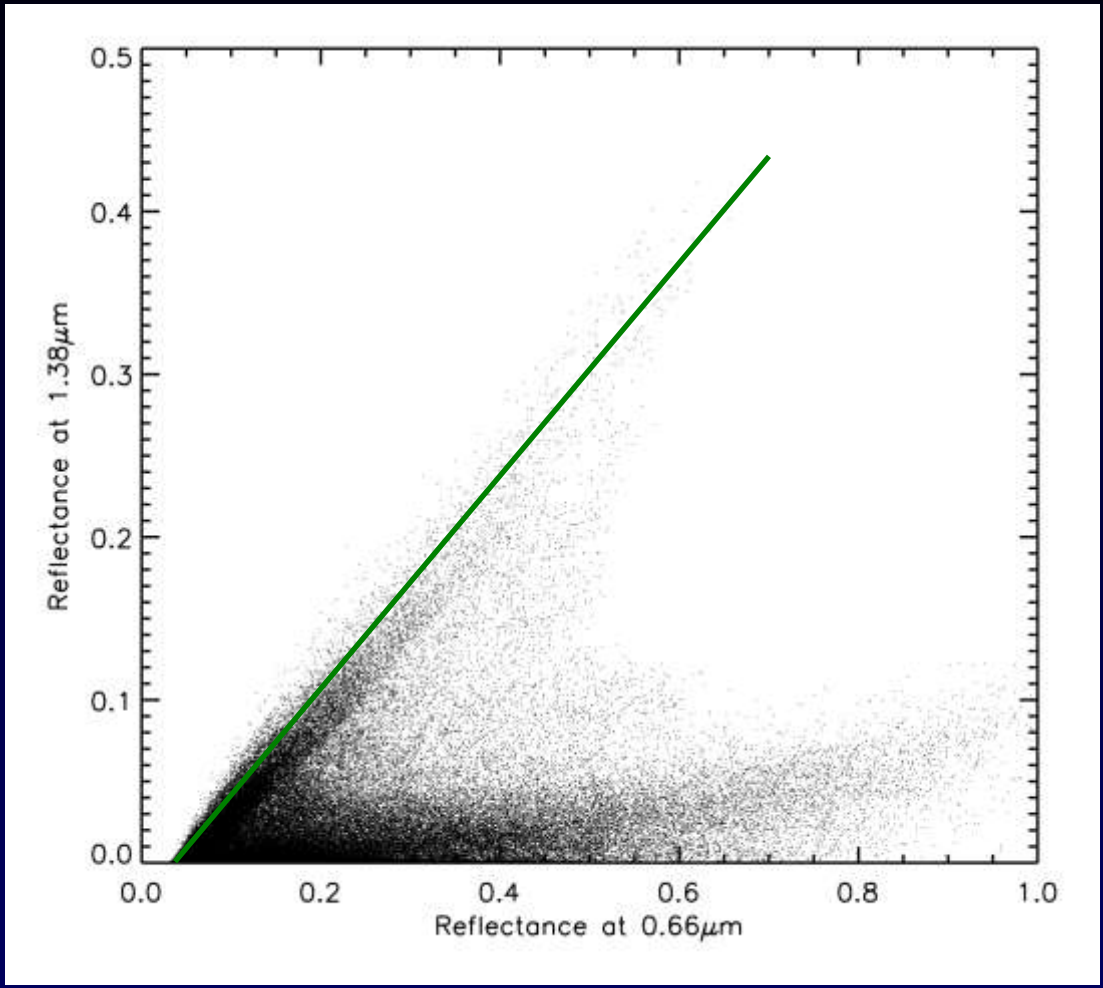
Thin Cirrus

- MOD06 cloud retrievals “miss” thin cirrus clouds (failed retrievals, no cloud mask).
- Sensitivity to thin cirrus at 1.38-μm (MODIS band 26).
  - Strong water vapor absorption band.
  - Due to high altitudes, 1.38-μm radiation not reflected by ice clouds is presumably completely absorbed in the atmosphere below ⇒ “screens” the surface.
- Caveats:
  - Up to 10% of atmospheric water vapor is located above ice clouds ⇒ non-negligible attenuation at 1.38-μm.
  - Arid atmospheres (polar regions, deserts, high-altitude locations, etc.) have insufficient below-cloud absorption at 1.38-μm ⇒ surface and low-cloud contamination.
  - Cloud microphysics affects reflectance!
- Nevertheless, 1.38-μm should be a useful compliment to the operational retrievals for thin cirrus (optical thickness).

Optical Thickness Retrievals

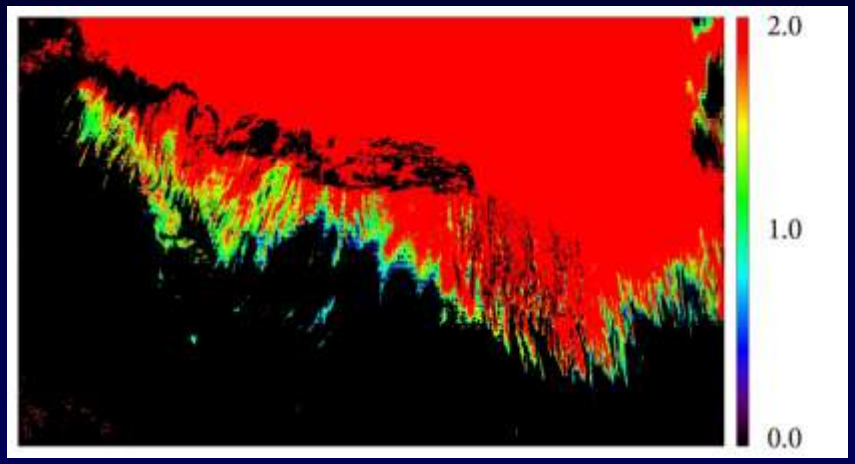
- Empirical approaches to estimating in/above cloud absorption:
  - Cirrus reflectance (Gao et al., 2003).
    - MOD06 operational product.
    - Use 1.38-µm (band 26) reflectance to remove the contribution of the surface and low clouds from 0.66-µm reflectance.
    - Can convert cirrus reflectance to cloud optical thickness (Meyer et al., 2007).
  - Can also provide an estimate of above-cloud two-way transmittance at 1.38-µm.
  - Use 0.86- and 1.24-µm as proxies for 0.66-µm.
- Pixel-level approaches:
  - Calculate above-cloud 1.38-µm two-way transmittance on a pixel-by-pixel basis.
    - Requires cloud top pressure (from MOD06) and atmospheric profile (from NCEP analyses).
    - Use correlated-k approach to estimate two-way transmittance.
    - Use MODTRAN-generated transmittance look-up library.

Aqua MODIS: 4-22-2004

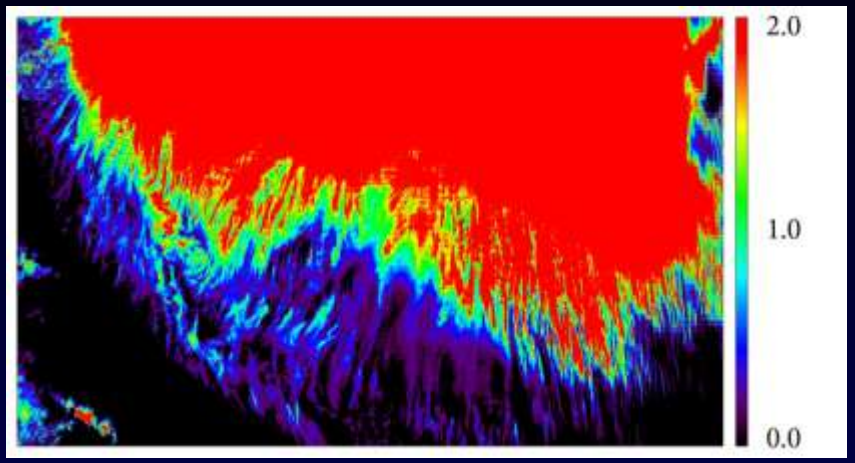


$$r_{1.38} = \Gamma r_{c,0.66}$$

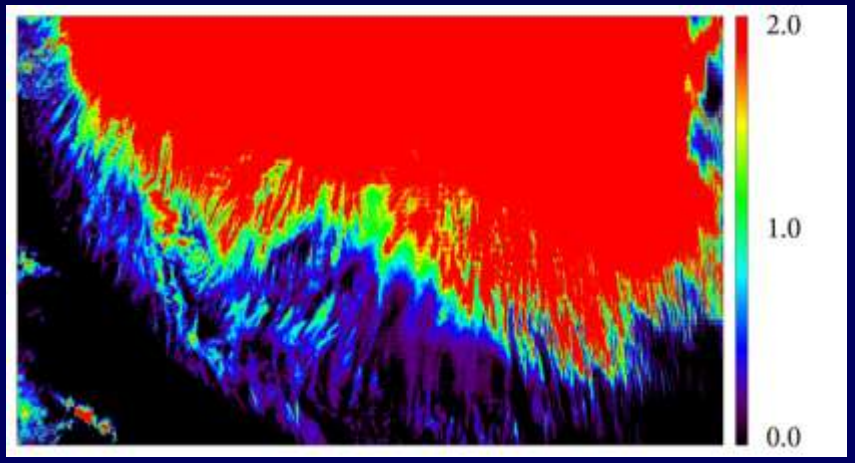
MOD06 Ice Cloud Optical Thickness

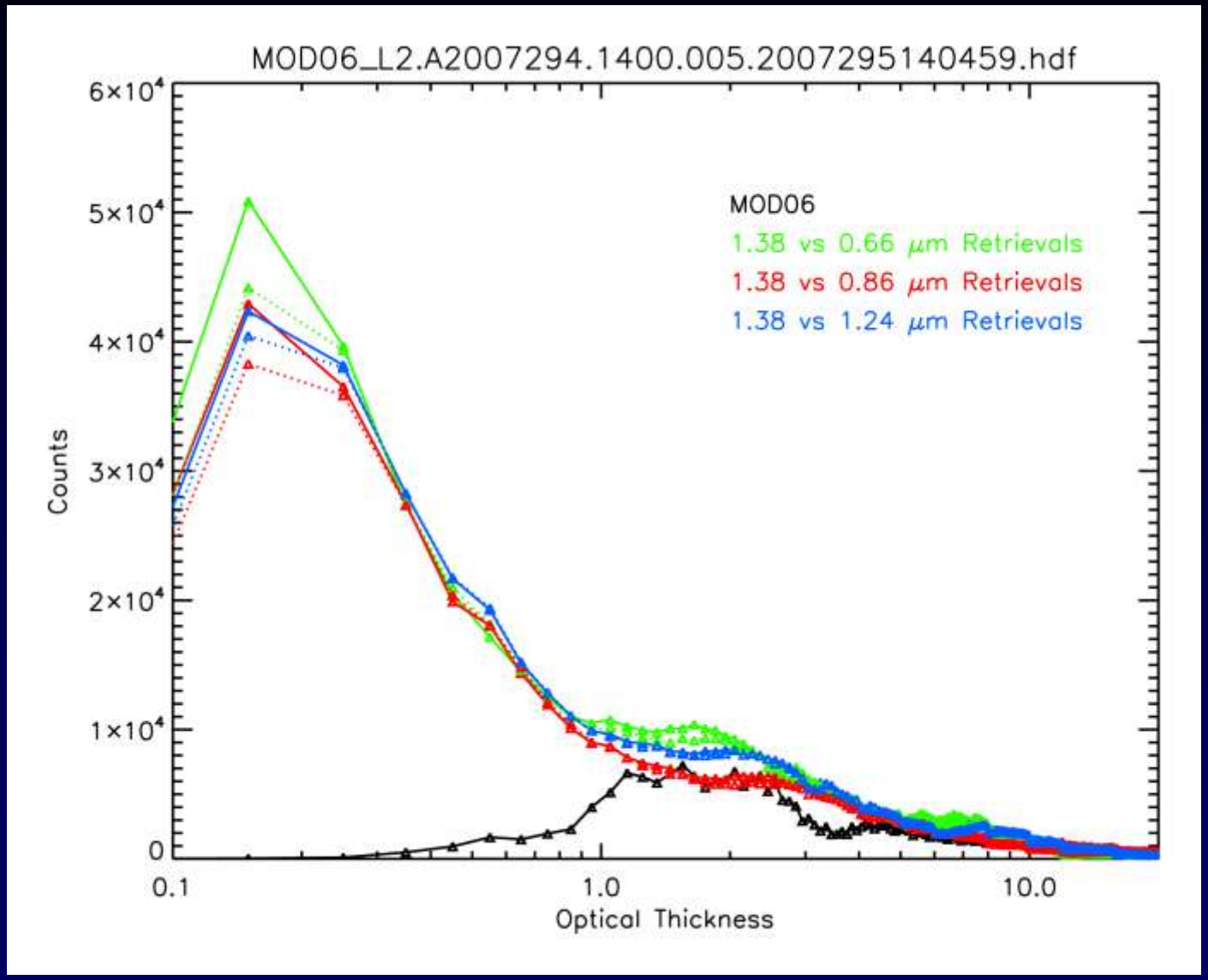


Ice Cloud Optical Thickness
Empirical: 0.66-μm Cirrus Reflectance



Ice Cloud Optical Thickness
Empirical: Corrected 1.38-μm Reflectance




MOD06_L2.A2007294.1400.005.2007295140459.hdf
MOD06
1.38 vs 0.66 μm Retrievals
1.38 vs 0.86 μm Retrievals
1.38 vs 1.24 μm Retrievals
Counts
6×10⁴
5×10⁴
4×10⁴
3×10⁴
2×10⁴
1×10⁴
0
0.1
1.0
10.0
Optical Thickness

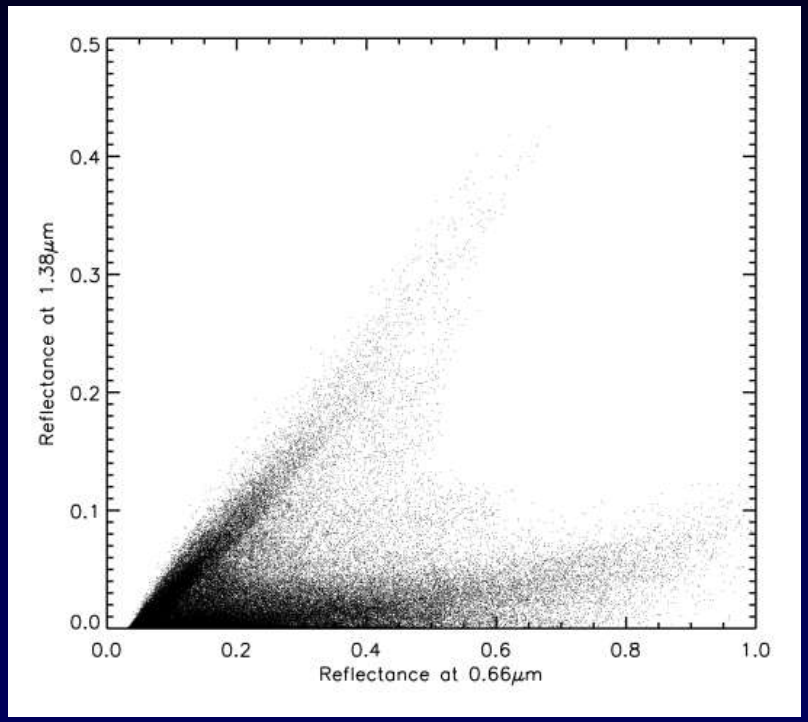
Assessment

- Forward radiative transfer calculations with DISORT.
  - ECMWF “cloudy” atmospheres (Gala Wind) - tropical ocean case.
  - Rayleigh scattering scheme (Bodhaine et al., 1999).
  - Ice cloud bulk scattering properties (MODIS Collection 5).
  - Three cloudy conditions: Single layer ice clouds, single layer water clouds, and multilayer (ice over water) clouds.
- Populate test granules.
- Two retrieval tests:
  - Current method - assume 30 μm R_e.
  - Known R_e - use exact R_e to select look-up table.
- Compare retrieved values to actual values input into DISORT.

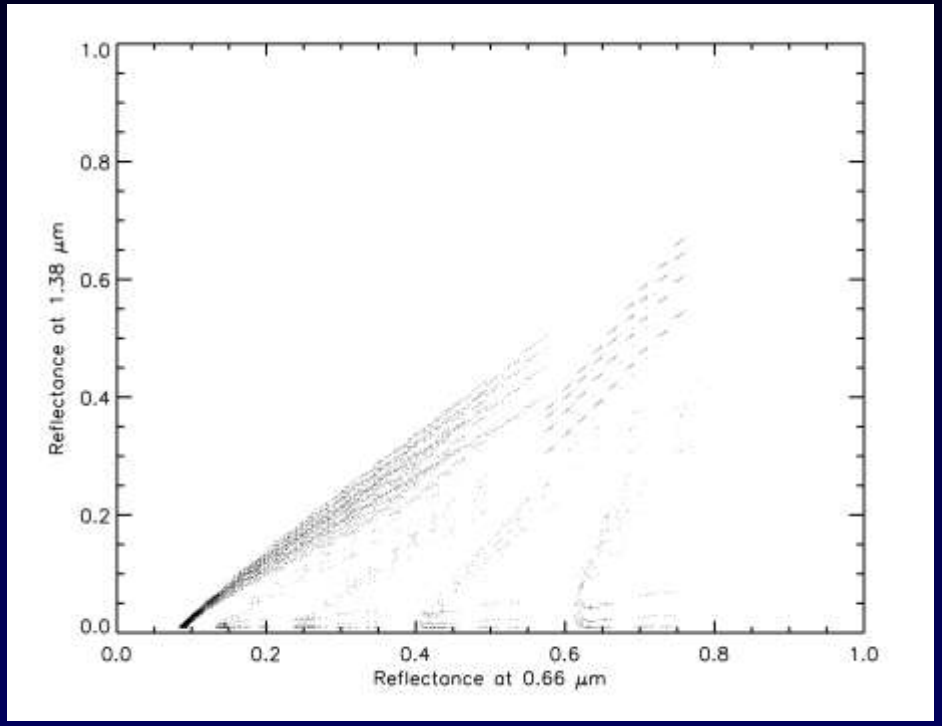
Assessment

- Scenario 1:
  - Clear sky (20%).
  - Single layer ice cloud (80%).
    - CTH between 12 and 15 km, optical thickness between 0.1 and 20, effective radius between 10 and 50 μm.
- Scenario 2:
  - Clear sky (20%).
  - Single layer ice cloud (40%).
    - CTH between 12 and 15 km, optical thickness between 0.1 and 20, effective radius between 10 and 50 μm.
  - Single layer liquid (low-level) cloud (30%).
    - CTH between 3 and 6 km, optical thickness between 2 and 20, effective radius between 4 and 20 μm.
  - Multilayer cloud (ice over liquid) (10%).
- Sun/satellite configuration:
  - Solar zenith angles between 20° and 25°, sensor zenith angles between 0° and 25°, relative azimuth equal to 155°.

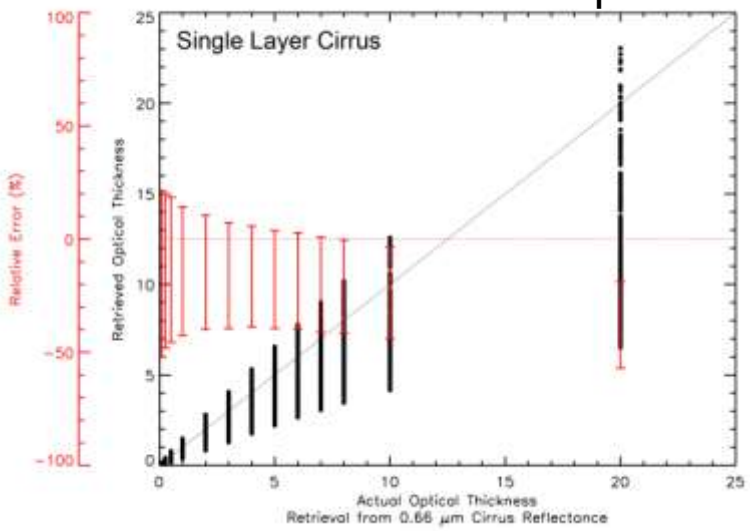
Aqua MODIS: 4-22-2004

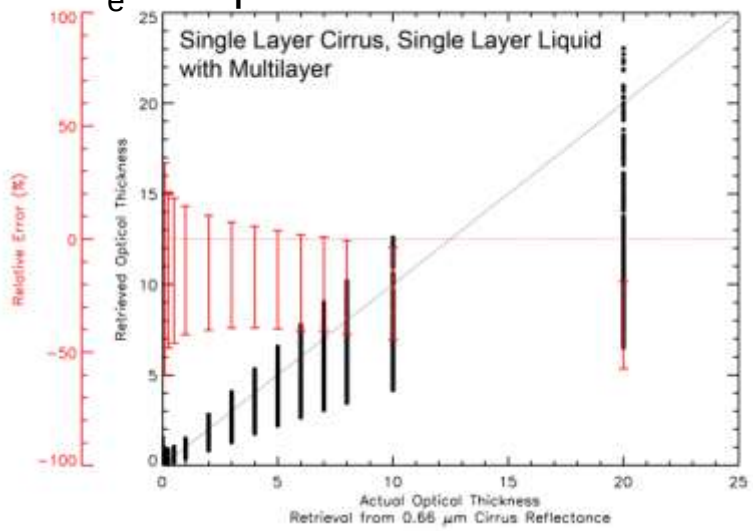


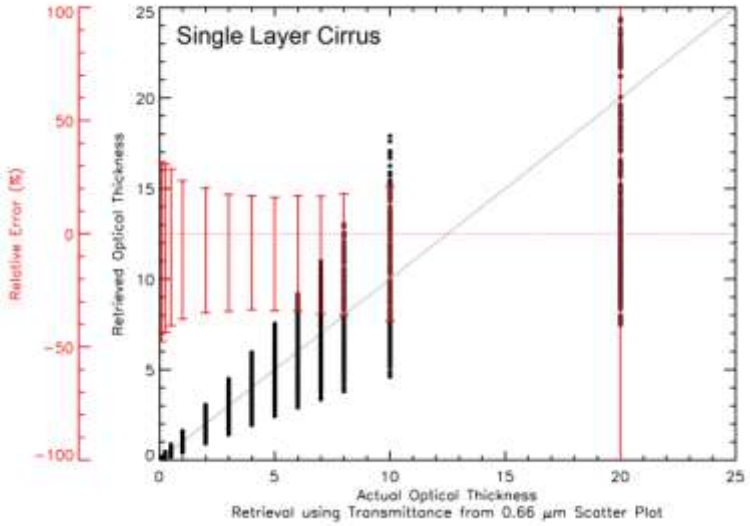
Modeled Scenario 2

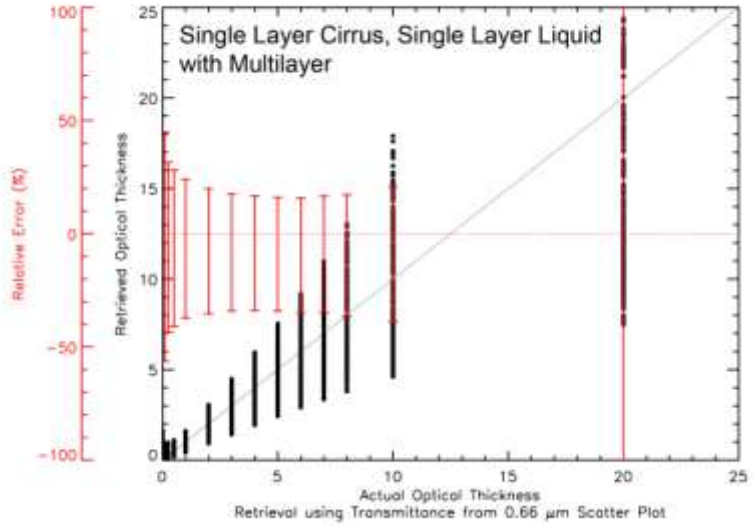


Look-up Tables for R_e= 30 µm

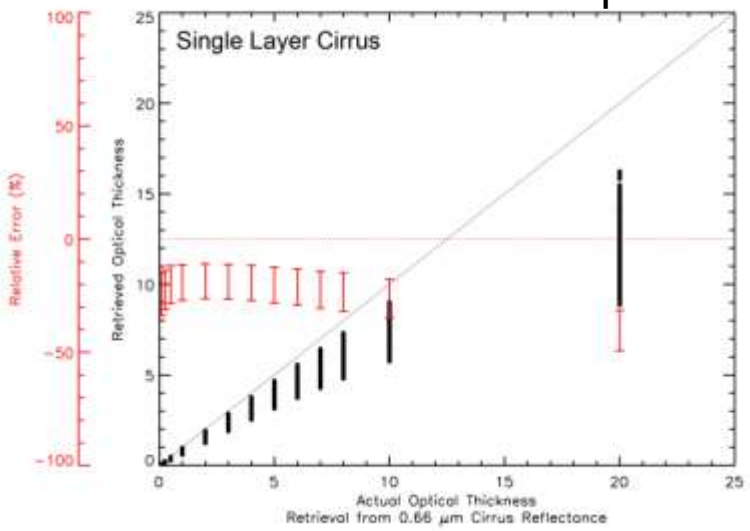


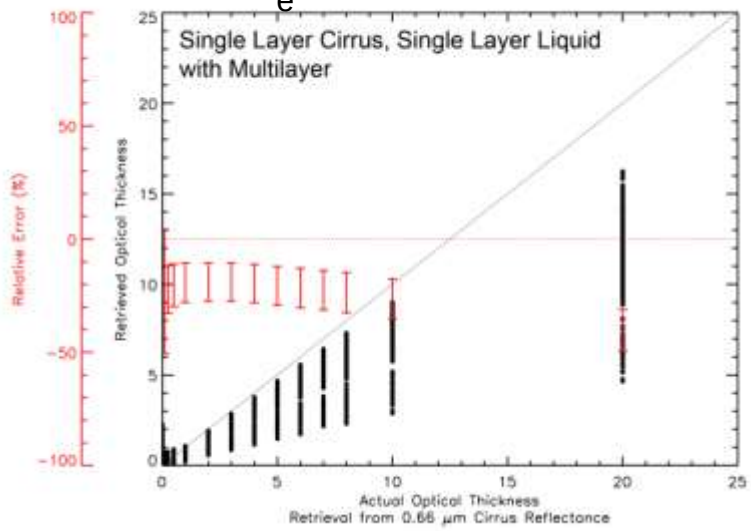


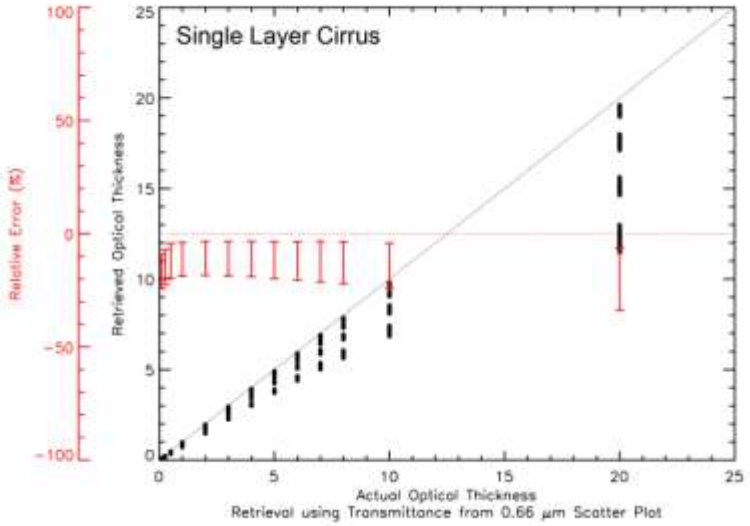


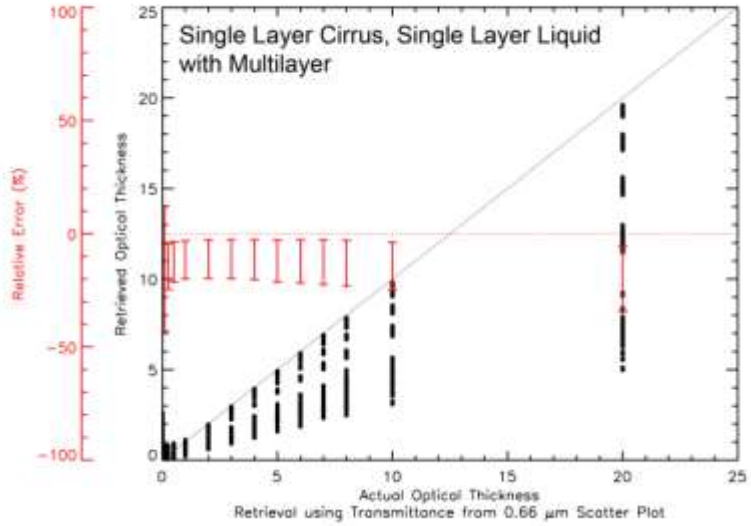


Look-up Tables with Exact R_e



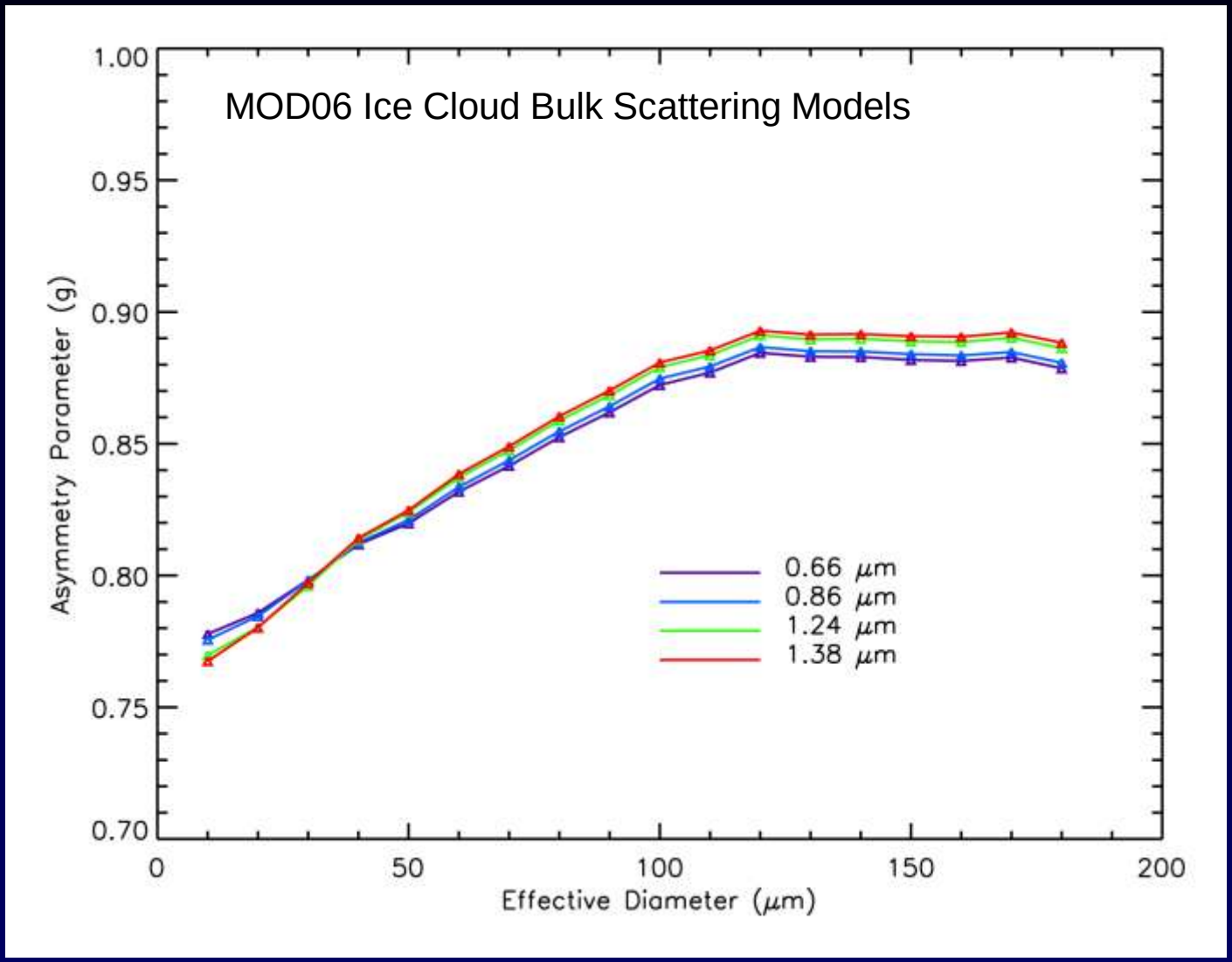


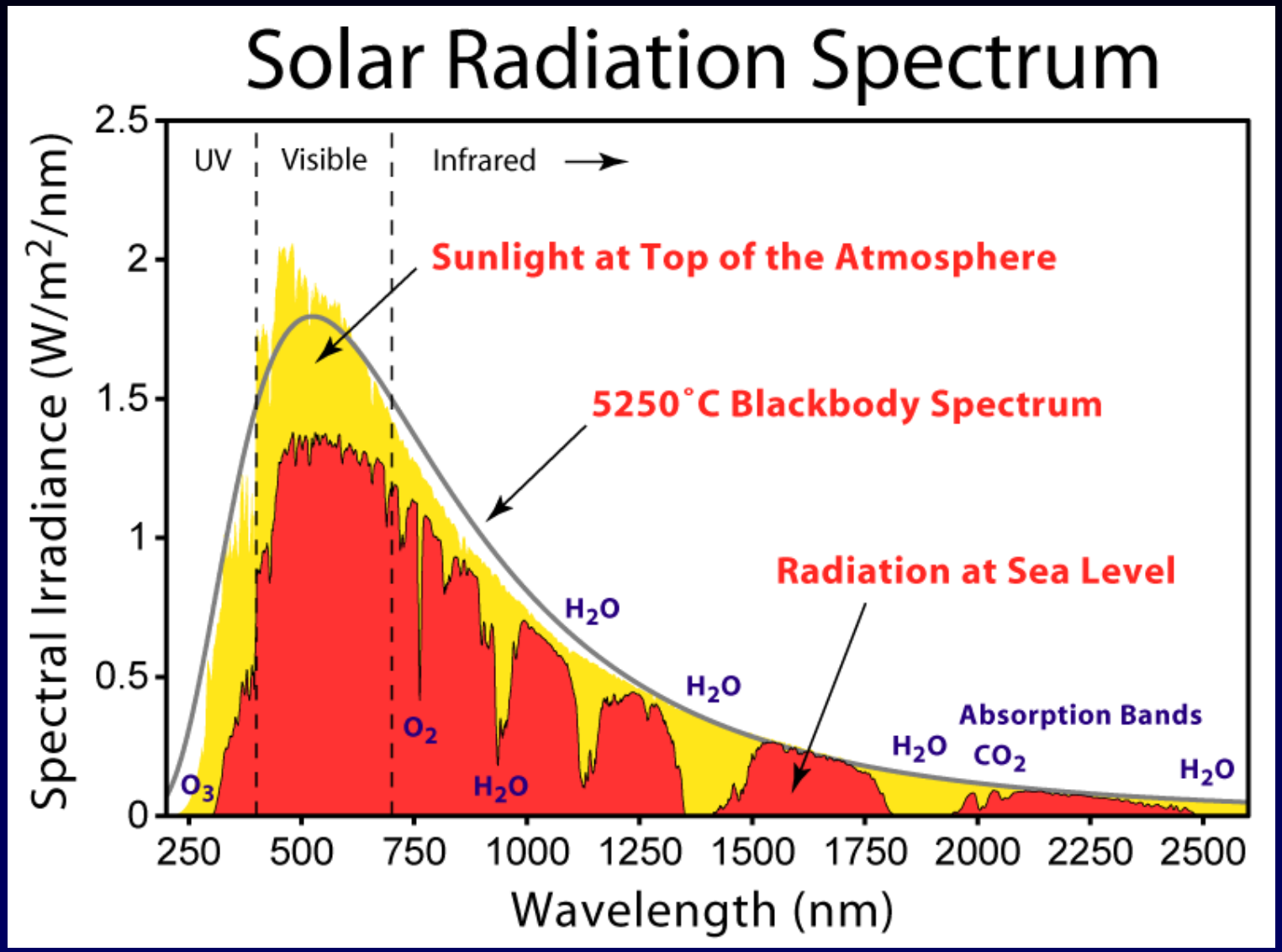




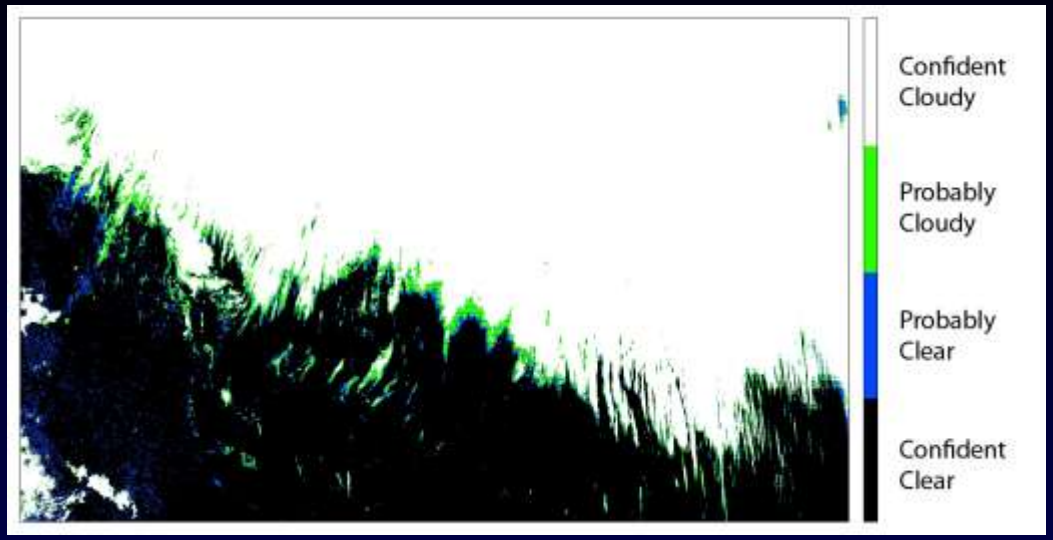
What Next?

- Evaluate confidence in “real world” retrievals.
  - Continue forward modeling.
  - Determine 1.38-µm contamination.
    - Beta scheme for a contamination “flag.”
- Include an uncertainty analysis.
- Determine the situations and band combinations that give the “best” result.
- Incorporate thin cirrus retrieval into MOD06 Collection 6.


MOD06 Ice Cloud Bulk Scattering Models
Asymmetry Parameter (g)
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0
50
100
150
200
Effective Diameter (μm)
0.66 μm
0.86 μm
1.24 μm
1.38 μm


Solar Radiation Spectrum
Spectral Irradiance (W/m²/nm)
2.5
2
1.5
1
0.5
0
UV
Visible
Infrared
Sunlight at Top of the Atmosphere
5250˚C Blackbody Spectrum
Radiation at Sea Level
H2O
H2O
O2
O3
H2O
Absorption Bands
H2O
CO2
H2O
250
500
750
1000
1250
1500
1750
2000
2250
2500
Wavelength (nm)

MOD06 Cloud Mask



MOD06 Cirrus Reflectance Flag