Cloud Top Properties

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CO$_2$ Slicing: Cloud Pressure and Effective Cloud Amount

❑ CO$_2$ slicing method
– long-term operational use
– ratio of cloud signals at two near-by wavelengths
– retrieve P$_c$ and εA (product of cloud emittance ε and cloud fraction *A*)

❑ The technique is most accurate for mid- and high-level clouds

❑ Pressure related to temperature via the GDAS gridded meteorological product

❑ MODIS is the first sensor to have CO$_2$ slicing bands at high spatial resolution (1 km)

Channel	Central Wavelength (µm)
32	12.020
33	13.335
34	13.635
35	13.935
36	14.235

Pressure (mb)

10

100

1000

0.0   0.2   0.4   0.6   0.8   1.0   1.2

Weighting Function d*t*(ν,p)/d ln p

36

35

34

33

32
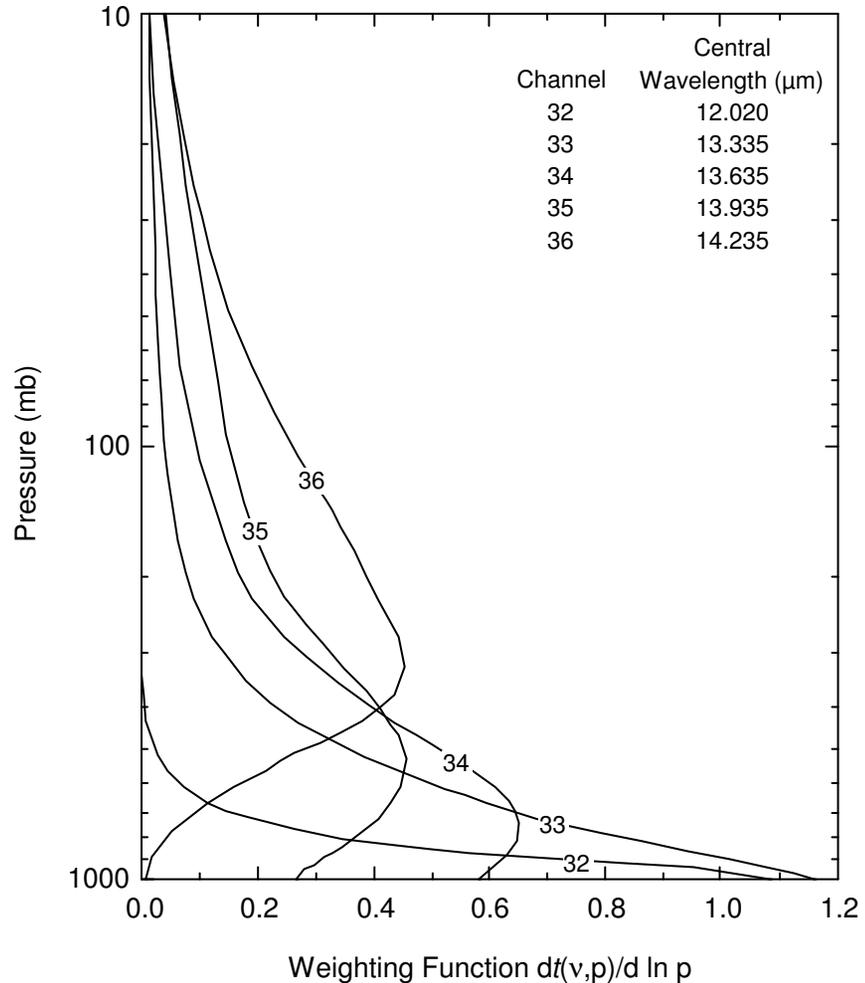
14 Jan 2003: thin high cloud
MODIS CTP too low at thin cloud edges
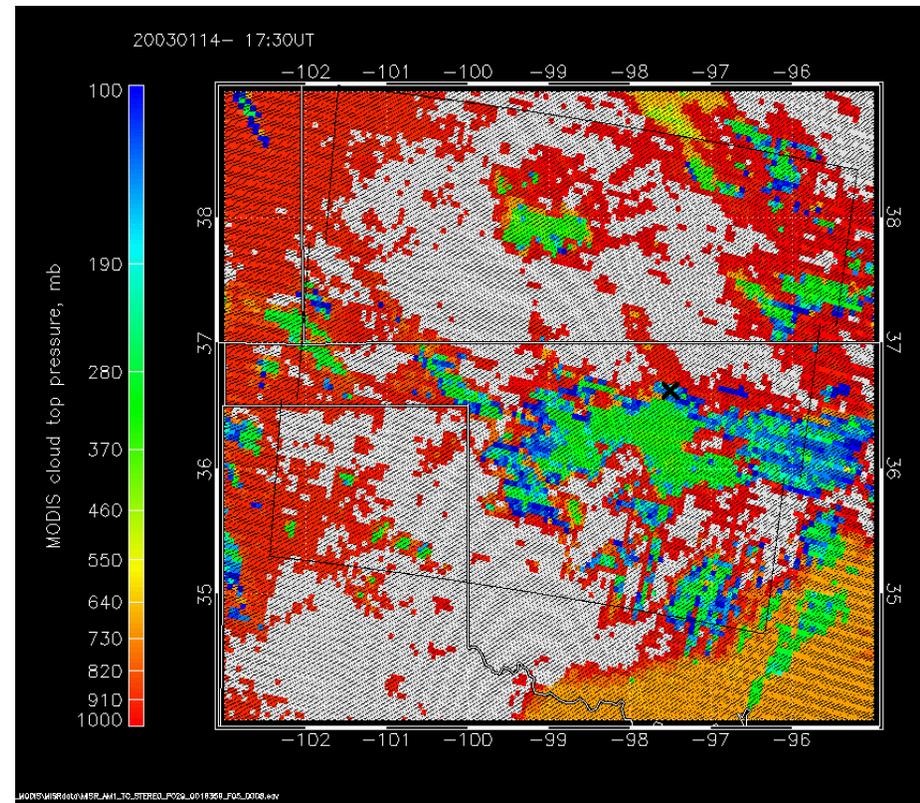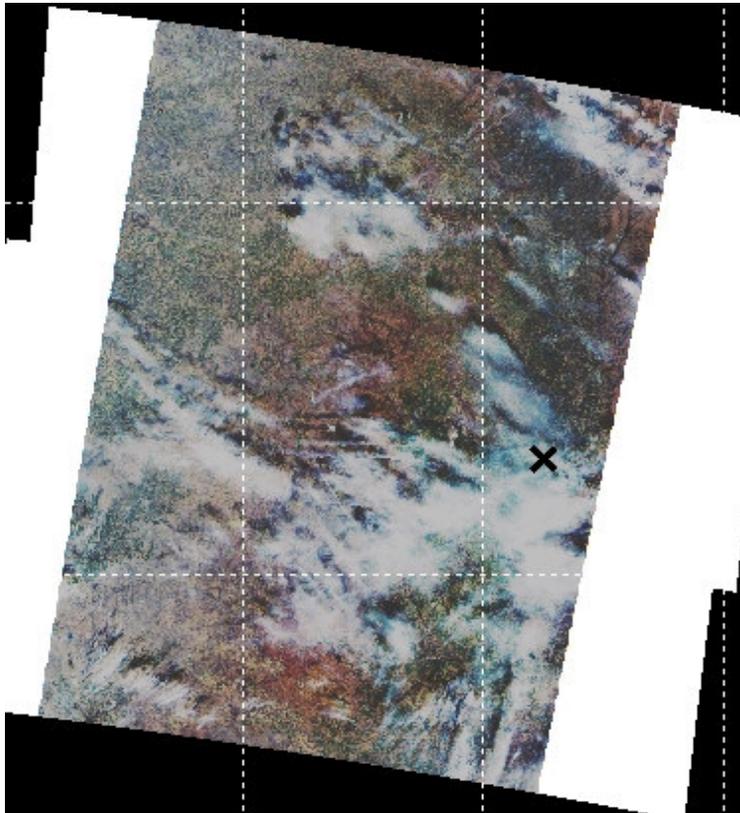
Dr. Catherine Naud, visiting CIMSS during the summer of 2003, intercompared MODIS, MISR and MERIS.
One of her findings was that in Collection 4, cloud top pressures tended to decrease near cirrus edges,
(in other words, cirrus cloud heights "curled up" at the boundaries as the clouds thinned out).

Improvements to the Algorithm for Collect 5

As a result of Catherine's work, resolution of the issue led to numerous changes.

Apply new forward model coefficients (LBLRTM version 7.4)

- employed new 101 pressure-level forward model (old model had 42 levels)

- changed transmittance profile characteristics significantly

- end result is that pressures are much more consistent as clouds thin out

Read in all levels of GDAS temperature and moisture profiles

- needed to rework use of GDAS for 101-level model

Reduce total number of forward model calculations for efficiency

- required for operational processing; also necessary in case we move to 1-km processing

SSTs, GDAS land surface temperatures and pressures are bilinearly interpolated

- but we still have issues over land

Improvements to the Algorithm for Collect 5

Another issue: low-level cloud pressure/temperature/height

If CO_2 slicing is not performed, and a cloud is thought to be present, then the 11-μm band is used to infer cloud top temperature/pressure assuming the cloud is opaque

Collection 4 (not yet operational forTerra, but fixed for Aqua):

- compare measured 11-μm brightness temperature to the GDAS temperature profile

Collection 5:

- account for water vapor absorption in 11-μm band using the 101-level forward model

- compare measured to calculated 11-μm radiance

- result is more accurate low-cloud assessments

Simulations of Ice and Water Phase Clouds
8.5 - 11 μm BT Differences

Ice

BTD[8.5-11 μm]

$\tau=6$

θ

20

Brightness Temperature [11 μm]

Water

BTD[8.5-11 μm]

$\tau = 20$

Brightness Temperature [11 μm]
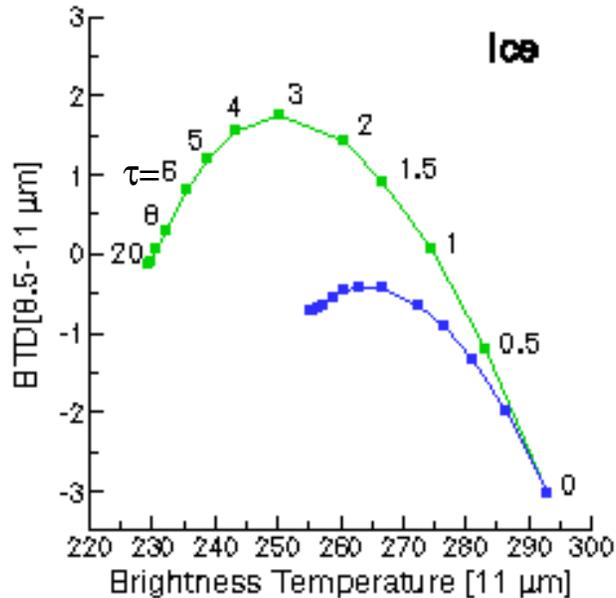
High Ice clouds

• BTD[8.5-11] > 0 over a large range of optical thicknesses τ
• T_{cld} = 228 K

Midlevel clouds

• BTD[8.5-11] values are similar (*i.e.*, negative) for both water and ice clouds
• T_{cld} = 253 K
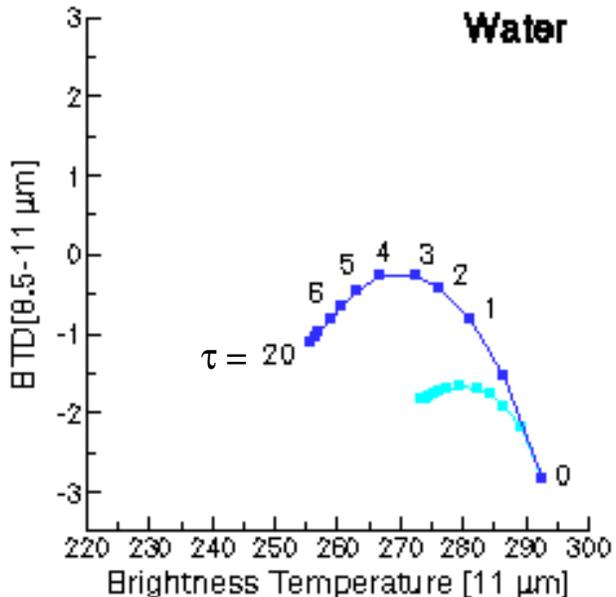
Low-level, warm clouds

• BTD[8.5-11] values always negative
• T_{cld} = 273 K

Ice: Cirrus model derived from FIRE-I in-situ data *
Water: r_e=10 μm
Angles: θ_o = 45°, θ = 20°, and ϕ = 40°
Profile: midlatitude summer

*Nasiri et al, 2001

MODIS Cloud Thermodynamic Phase
Percentage Ice and Water Cloud
05 Nov. 2000 -Daytime Only
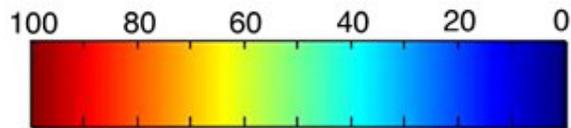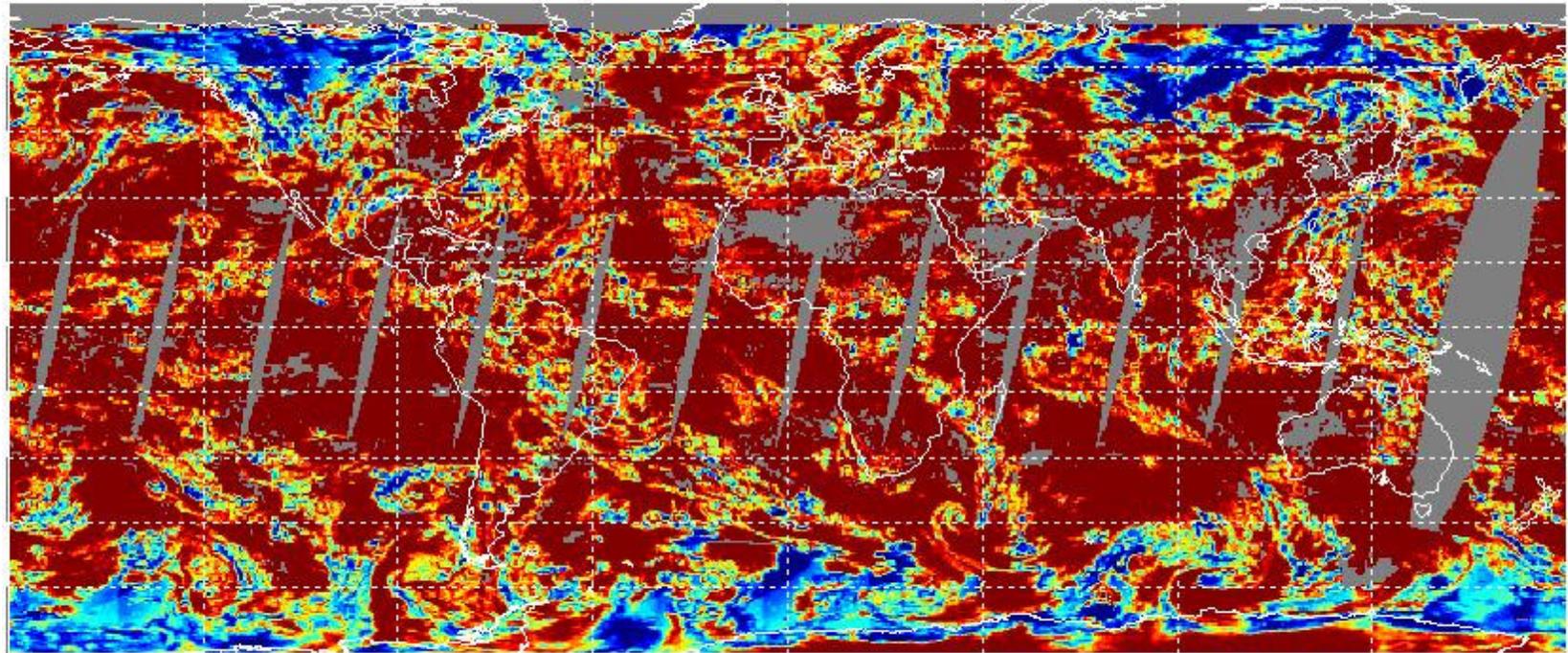
frequency of occurrence in percent (%)

MODIS Cloud Thermodynamic Phase
Percentage Ice and Water Cloud
05 Nov. 2000 - Nighttime Only
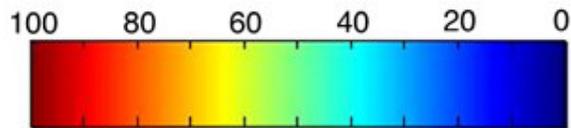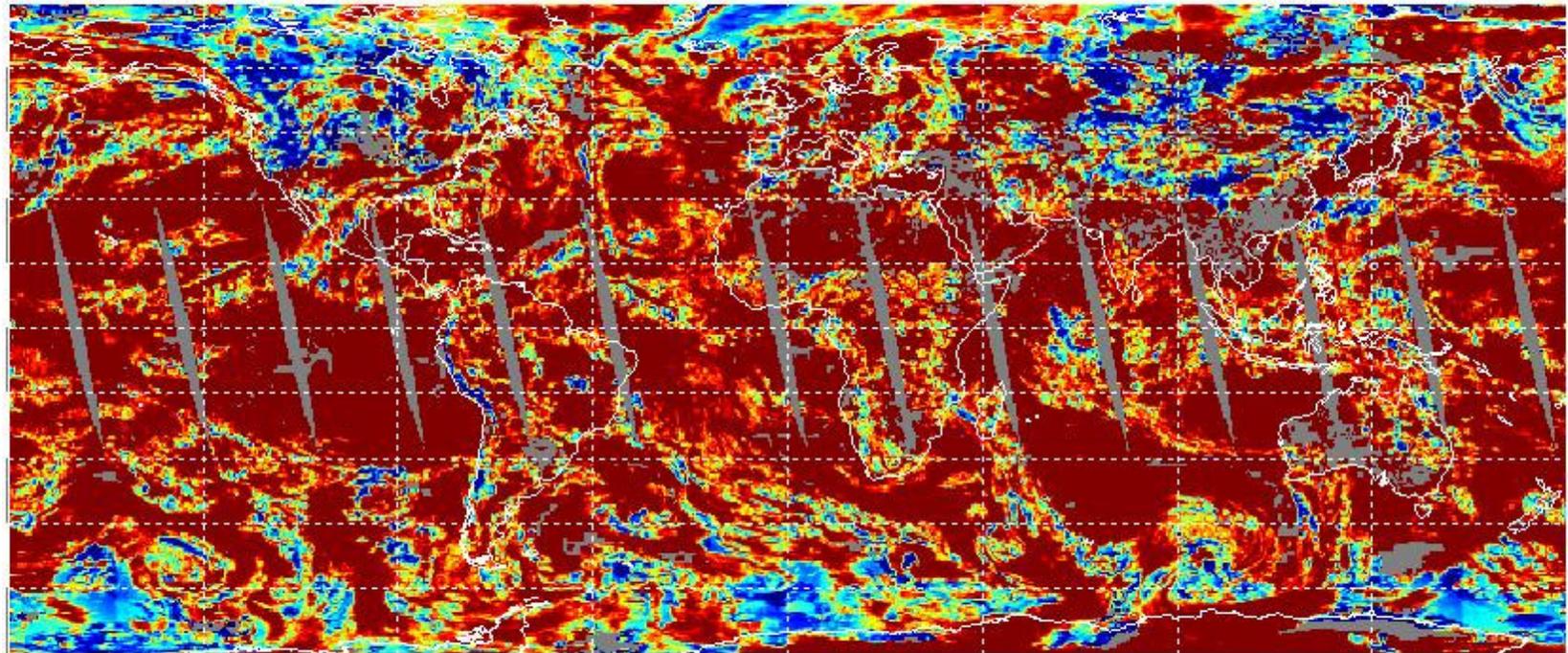
frequency of occurrence in percent (%)

MODIS Frequency of Co-occurrence
Water Phase with 253 K < T_{cld} < 268 K
05 Nov. 2000 - Daytime Only
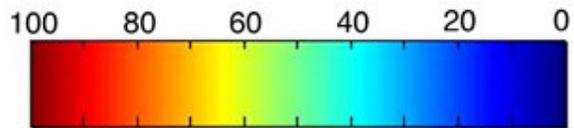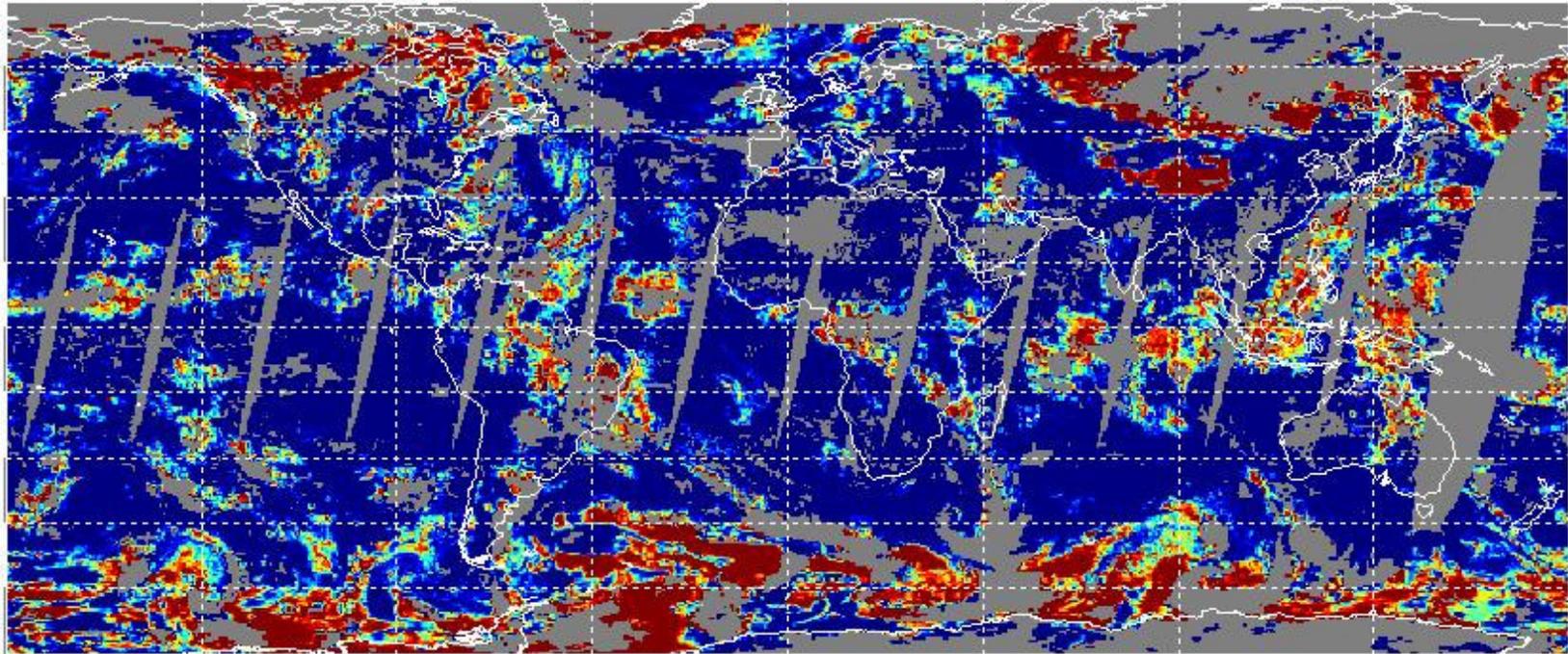
frequency of occurrence in percent (%)

MODIS Frequency of Co-occurrence
Water Phase with 253 K < T_{cld} < 268 K
05 Nov. 2000 - Nighttime Only
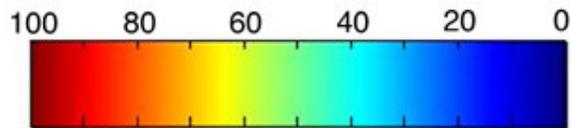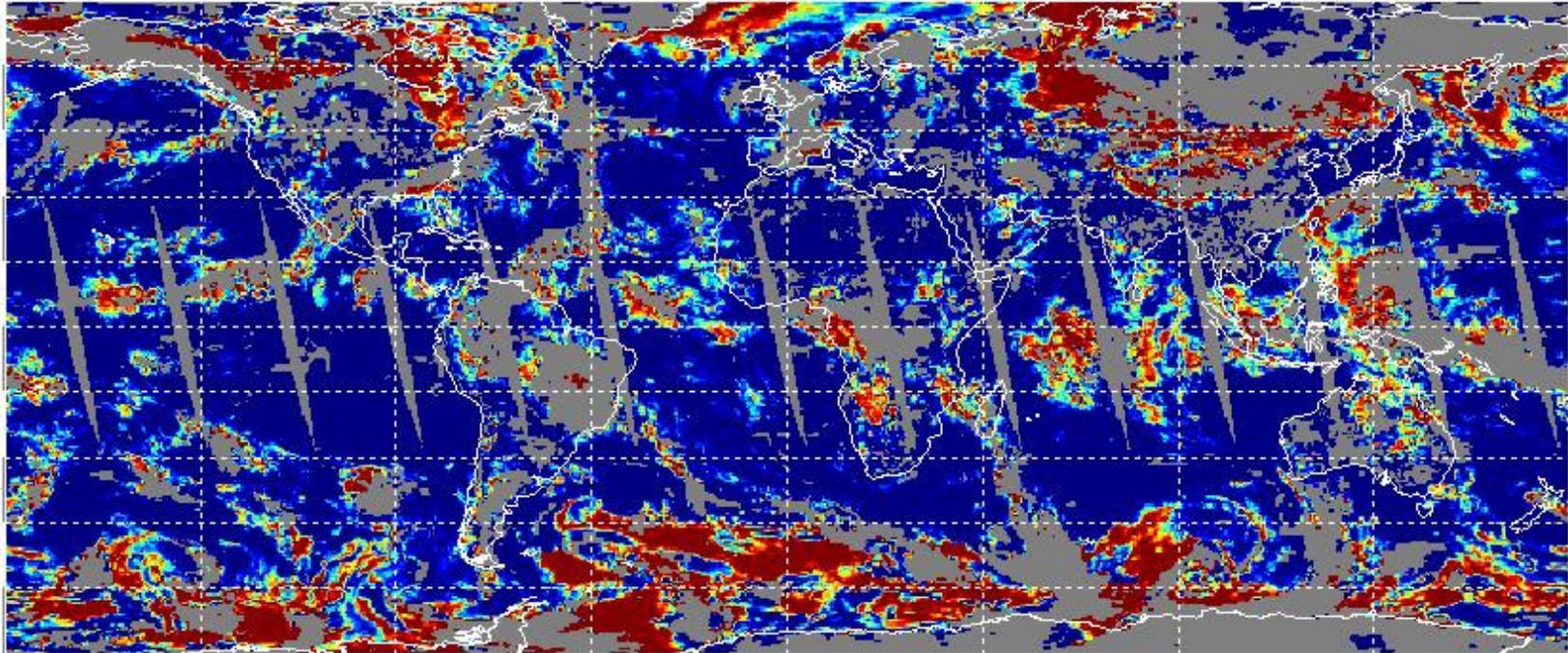
frequency of occurrence in percent (%)

MODIS Daytime Cloud Overlap Technique

Assumption: At most 2 cloud layers in data array

For a 200x200 pixel (1km resolution) array of MODIS data:

- Identify clear pixels from MODIS cloud mask

- Identify unambiguous ice pixels and water pixels from the 8.5- and 11-μm bispectral cloud phase technique

- Classify unambiguous ice/water pixels as belonging to the higher/lower cloud layer

- Classify remaining pixels as overlapped

Stagger the pixel array over the image so that each pixel is analyzed multiple times (away from the granule borders)

MAS data from single-layered cirrus and water phase clouds
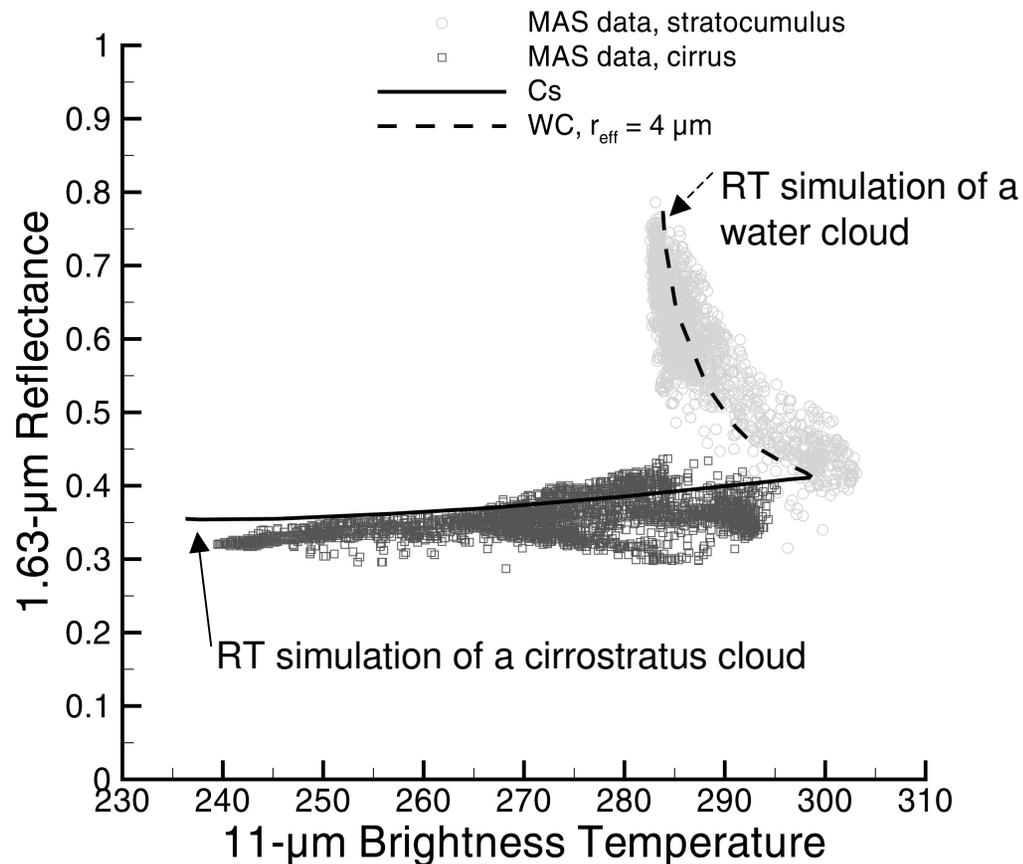
From Baum and Spinhirne (2000), Figure 2a

- 1.6 µm reflectance varies as a function of optical thickness more for water clouds than ice clouds

- 11 µm BT varies as a function of optical thickness more for ice clouds than for water clouds

MAS data from cirrus overlying water phase cloud
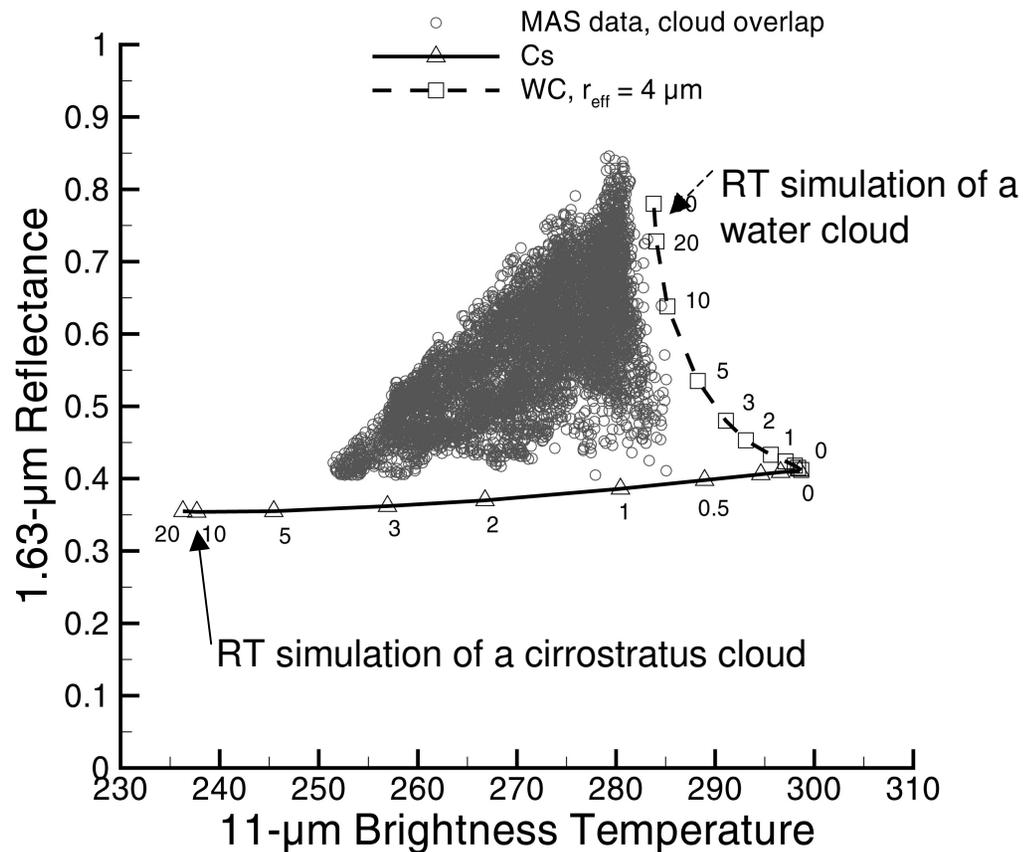
- MAS data from overlap region falls between single layer water and cirrus cloud data in R[1.63 μm] and BT[11 μm] space

From Baum and Spinhirne (2000), Figure 2b

200 by 200 pixels of MODIS Data from 15 Oct. 2000 at 1725Z

RGB (0.65, 1.63, 11 (flipped) micron)

11 micron BT Clear, High Cloud, and Low Cloud Pixels

11 micron BT (K)

1.6 μm Reflectance

11 μm BT (K)
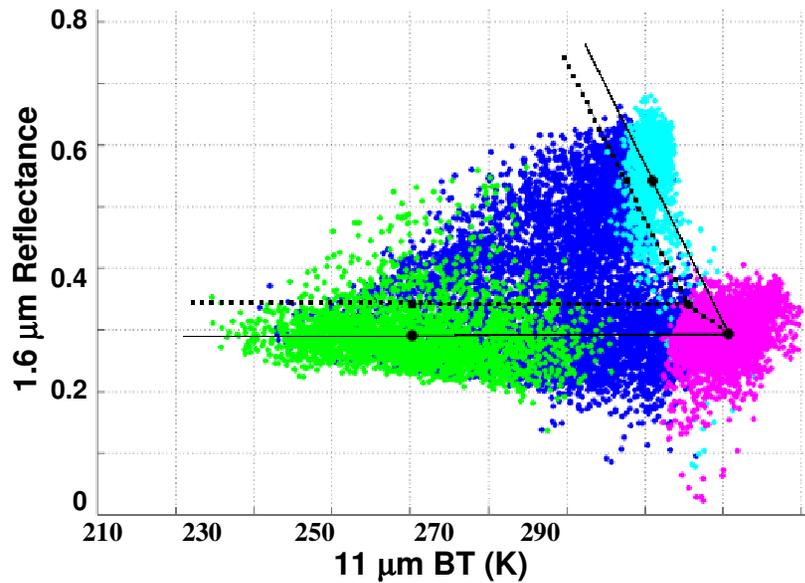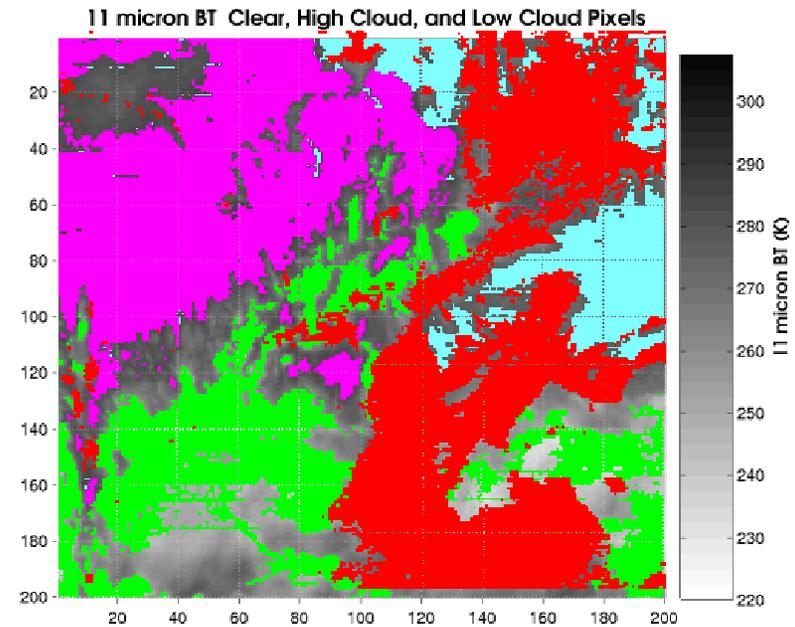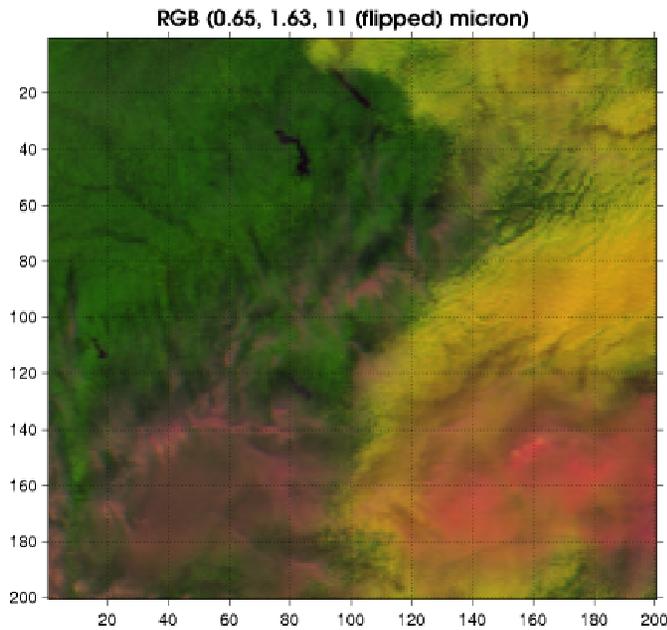
■ Water Cloud (from MODIS Phase)
■ Ice Cloud (from MODIS Phase)
■ Clear (from MODIS Cloud Mask)
■ Other (to be determined)

Recent Research

Greg McGarragh has been producing the following products using MODIS Direct Broadcast at 1 km resolution for the past year

    a. Daytime multilayered cloud identification

    b. Cloud phase

    c. Cloud top pressure and effective cloud amount

Note: The products are greatly improved by incorporating the CIMSS destriping software on all IR bands.

The multilayered cloud and IR cloud phase are being incorporated in the DB operational software, and will eventually go into DAAC operational code

MODIS Terra Over Western U.S. on 6 July 2004 - 1842 UTC

RGB: Bands 1, 7, 31(flipped)

Pressure (hPa)
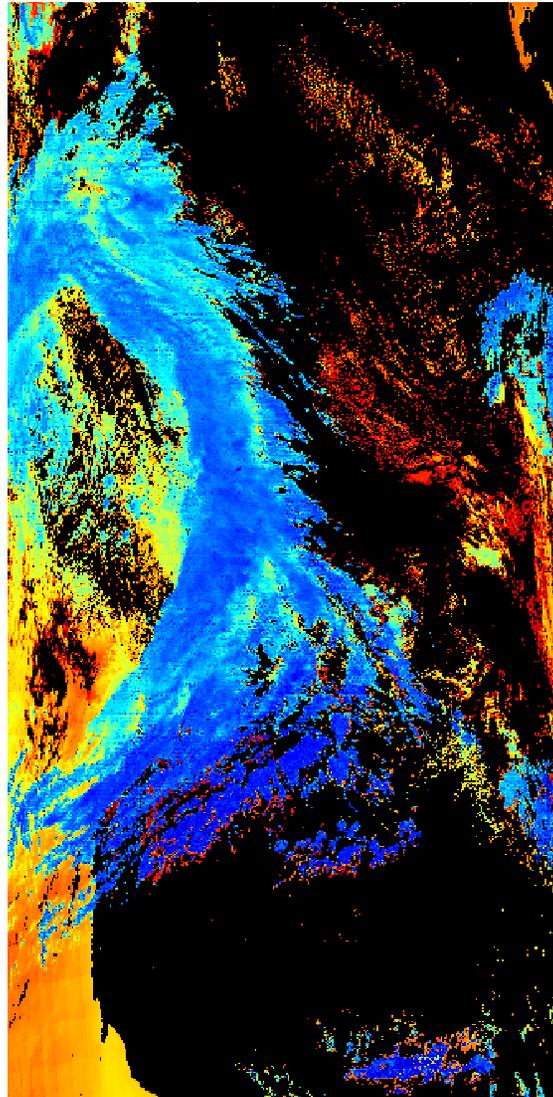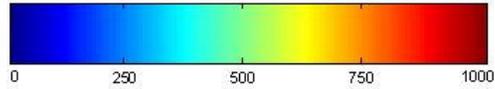
Effective Cloud Amount

MODIS Terra Over Western U.S. on 6 July 2004 - 1842 UTC
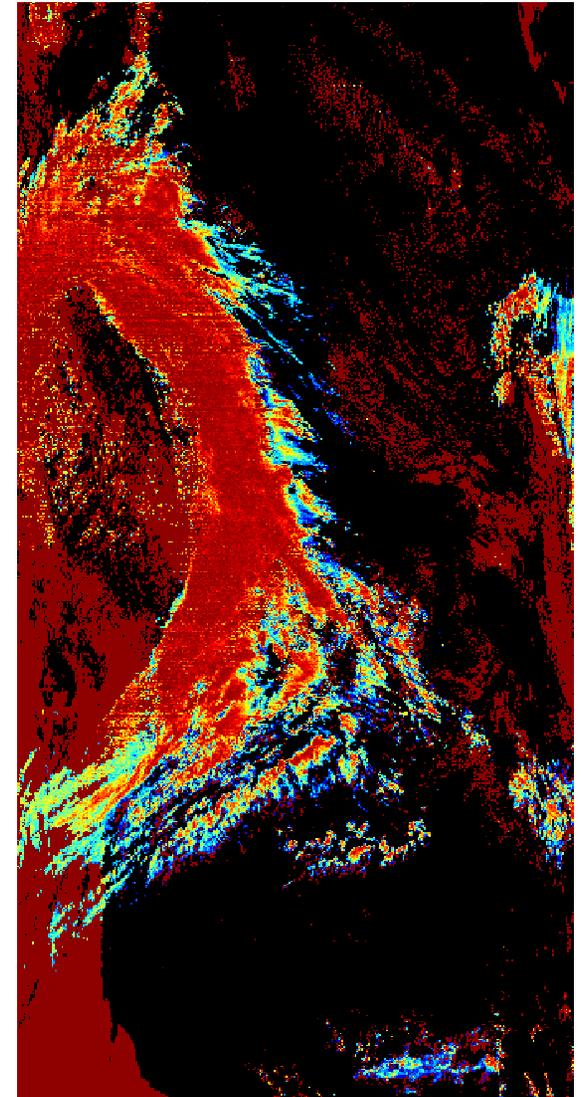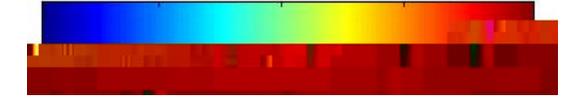
MODIS Terra Over Western U.S. on 6 July 2004 - 1842 UTC

Pressure (hPa)
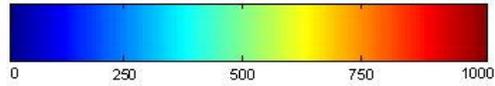
Percentage of the time a pixel is classified as having multilayerd clouds (each pixel is tested up to 256 times)

MODIS Terra Over Western U.S. on 6 July 2004 - 1842 UTC
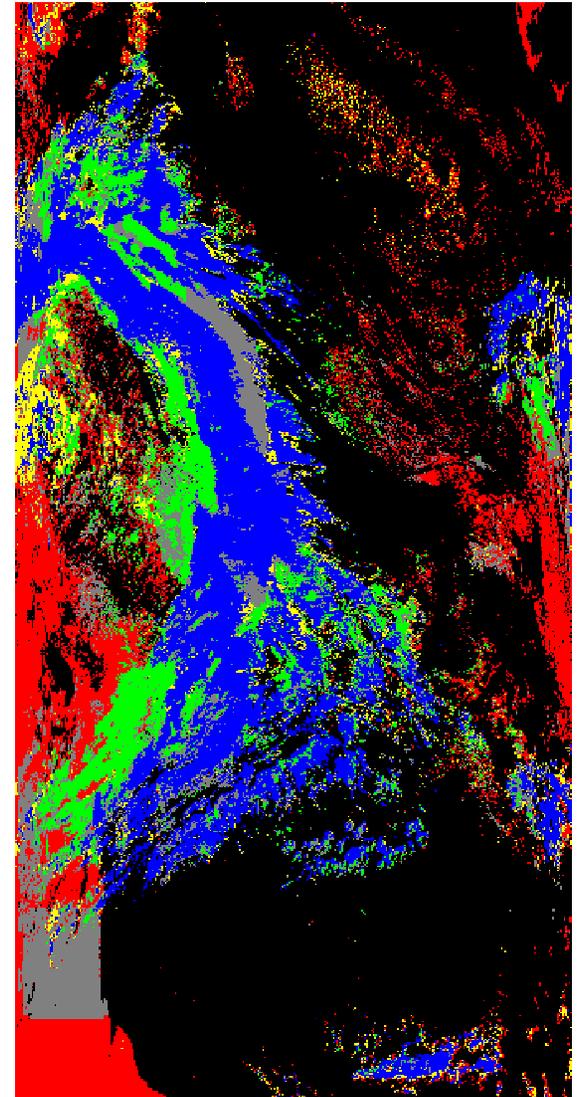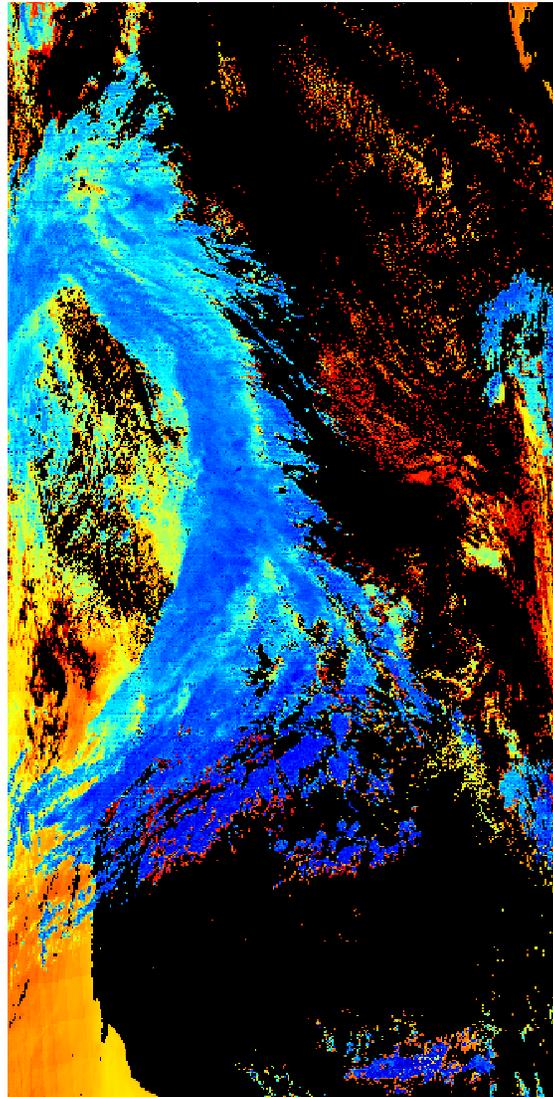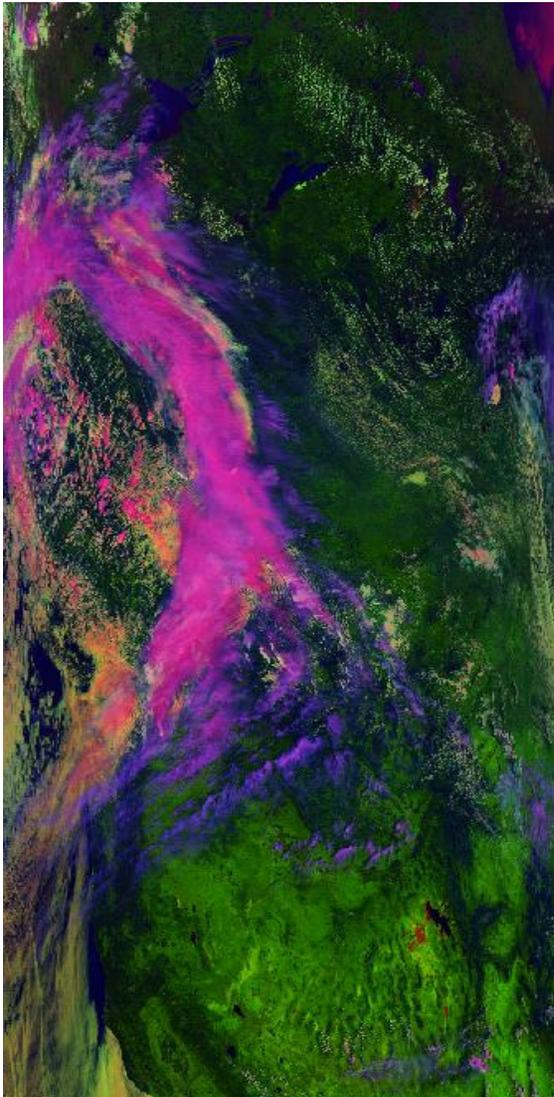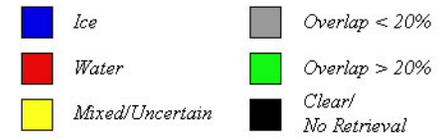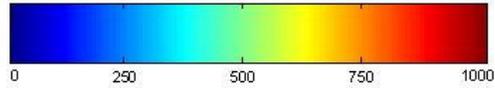
April 1-8, 2003
8-day composite
Aqua

Frequency of
CTP < 440 hPa
& $\varepsilon A < 0.5$
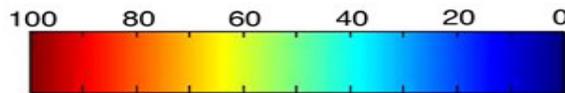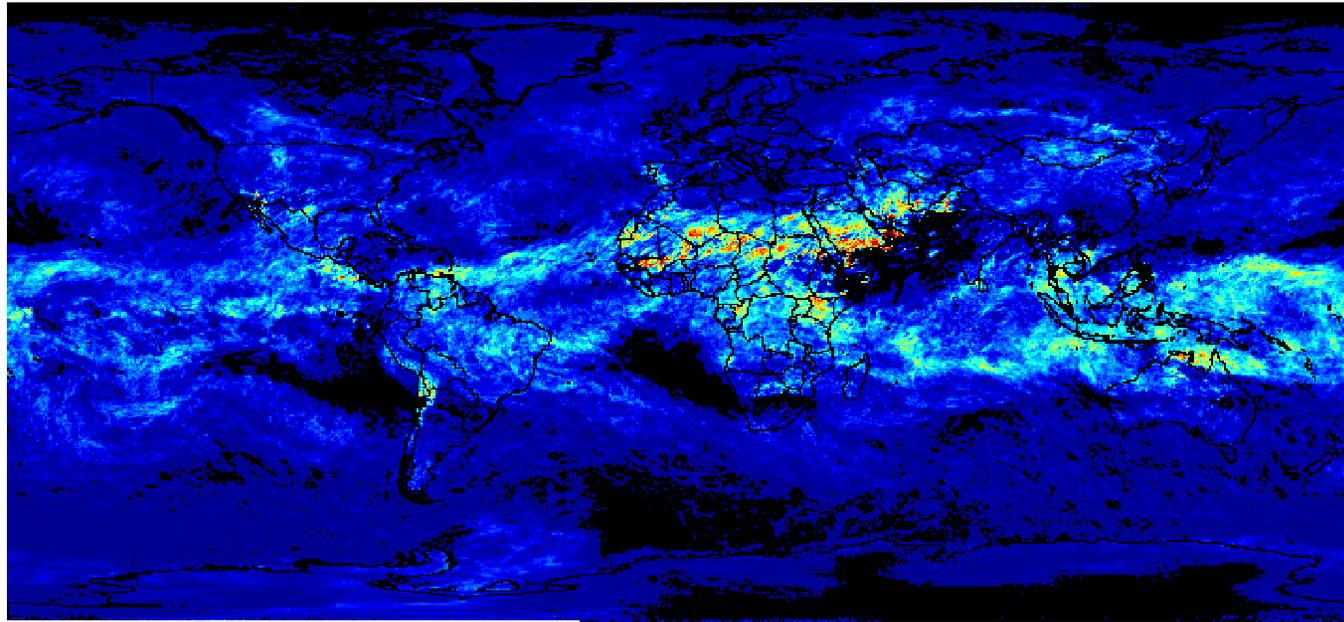
frequency of occurrence in percent (%)

Frequency of
multilayered
cloud detection
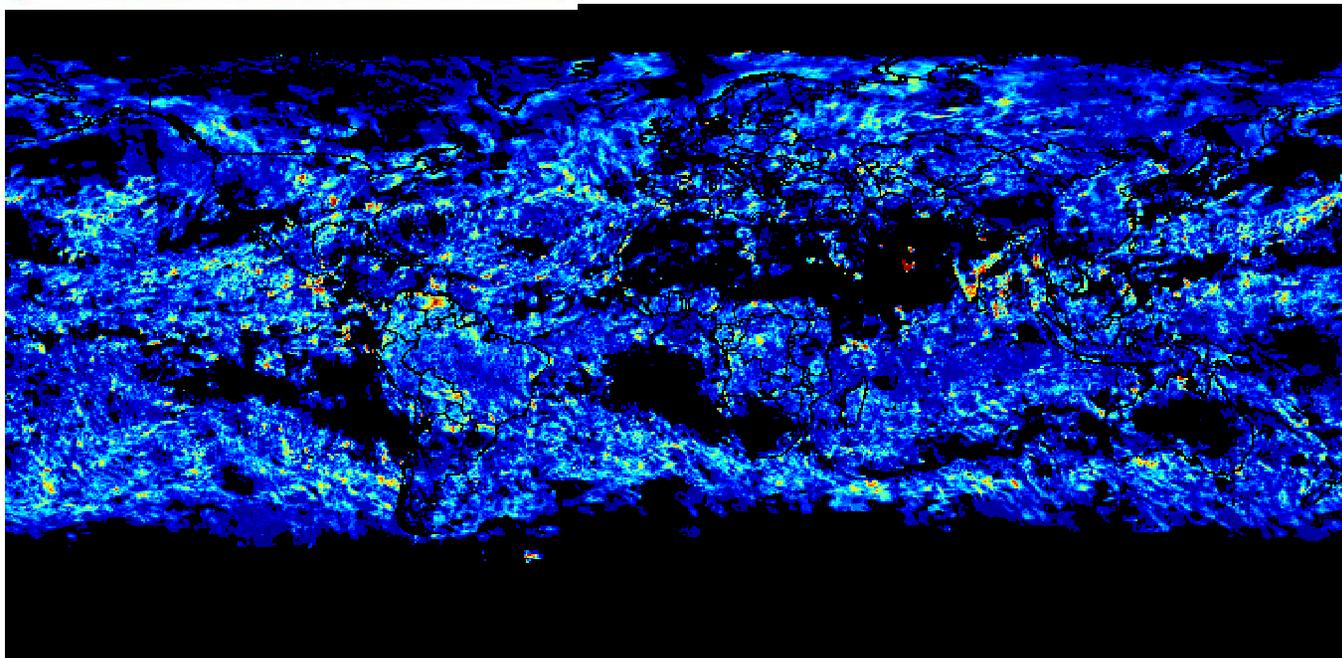
MODIS Aqua, April 1-8, 2003
Multilayered clouds: breakdown by IR-derived phase
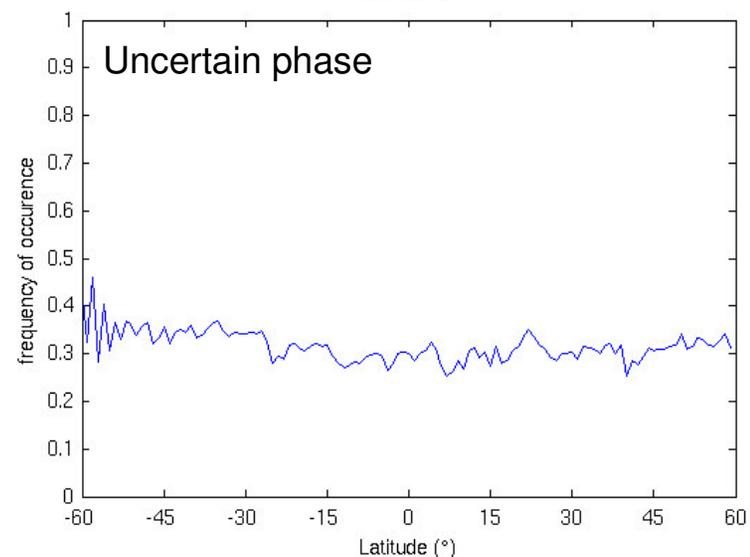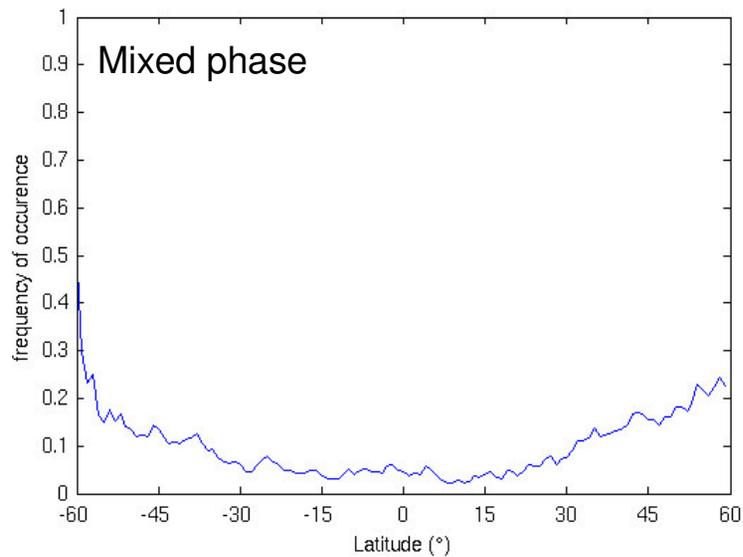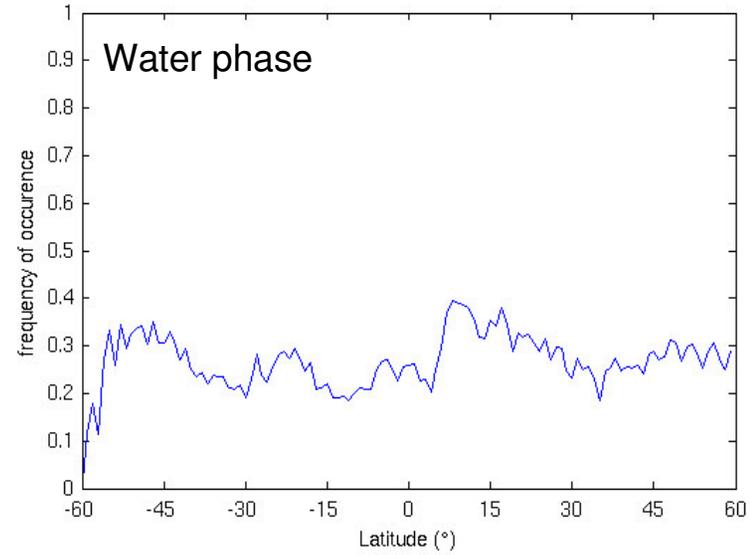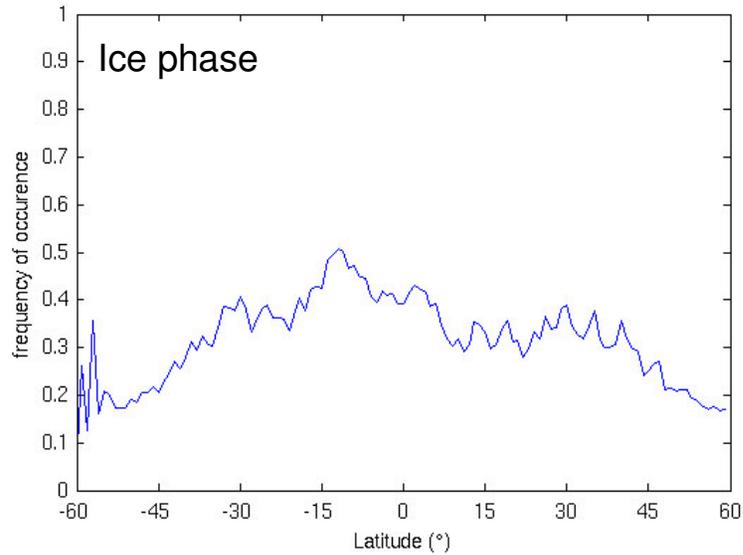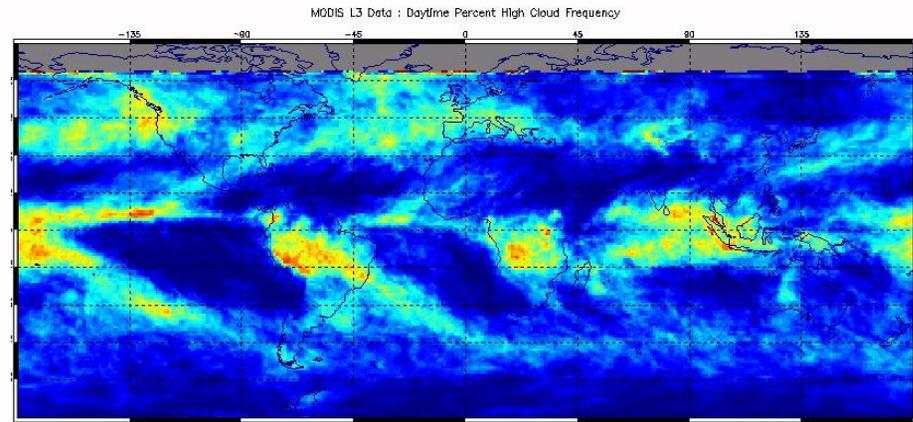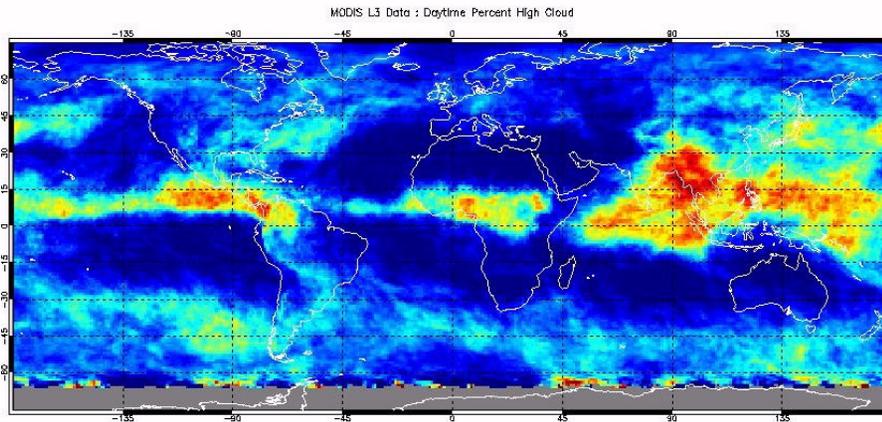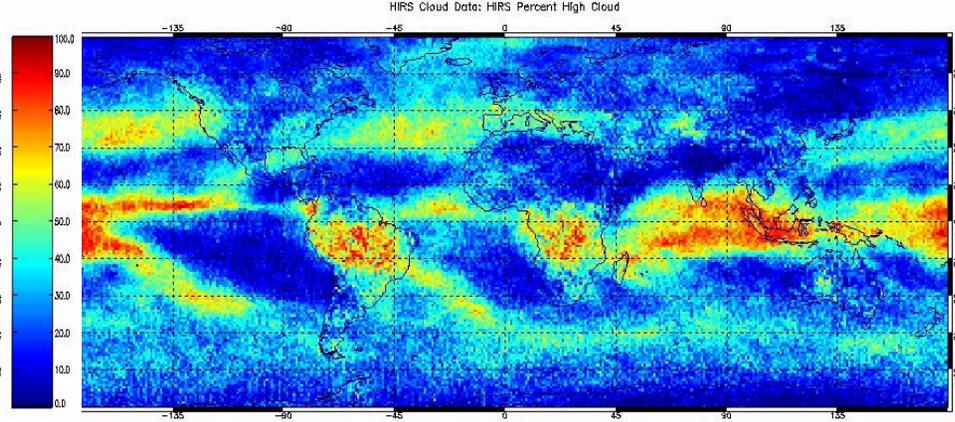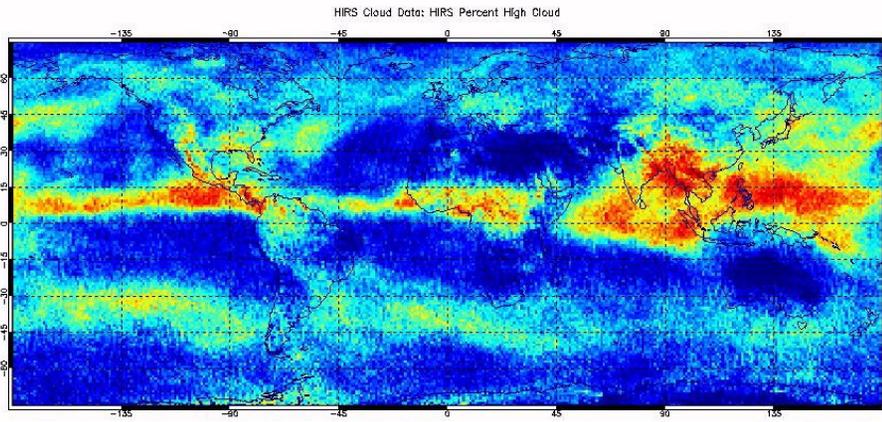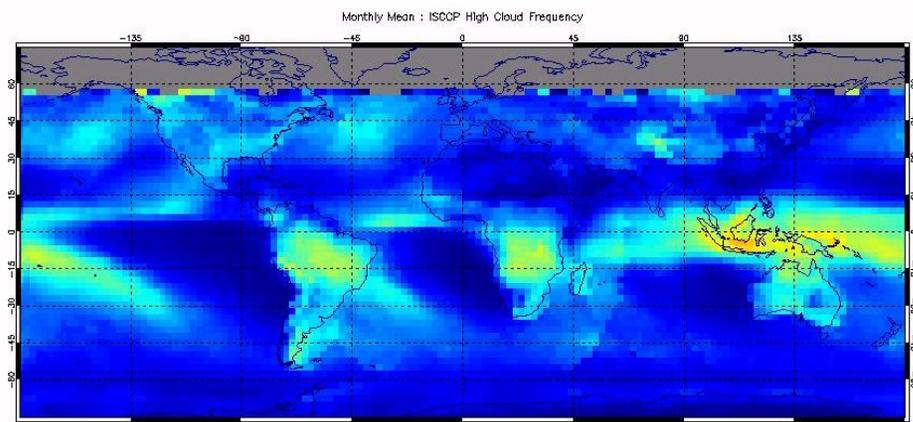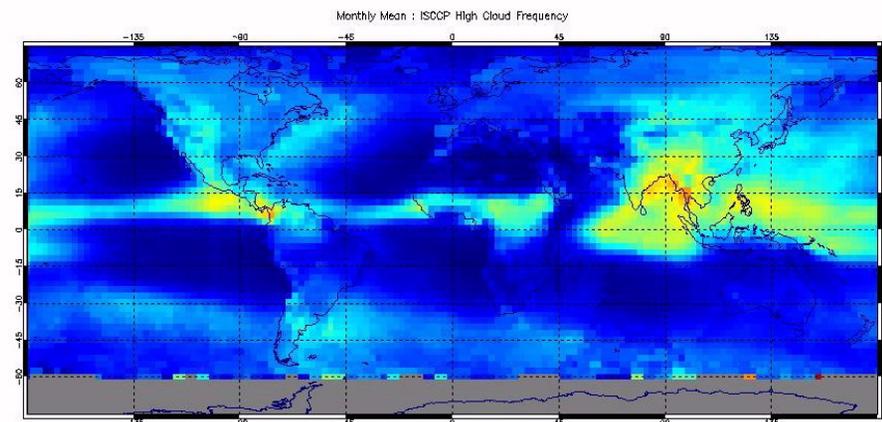
ISCCP (top), HIRS (mid), & MODIS (bot) for July (left) & Dec (right) 2002

Summary of Improvements to the CTP for Collect 5

1) Apply new forward model coefficients (LBLRTM version 7.4)

2) Read in all levels of GDAS temperature and moisture profiles

3) Reduce total number of forward model calculations for efficiency

4) SSTs, GDAS land surface temperatures and pressures are bi-linearly interpolated

5) Apply simple land vs. water surface emissivity correction

6) Account for water vapor absorption in window band calculations

7) Reduced Aqua noise thresholds (allowable clear vs. cloudy radiance differences)

8) Employ UW-Madison de-striping algorithm for L1b input radiances