

NASA's Earth Observing System (EOS): CIMSS Role in Observing the Atmosphere from Space & Aircraft

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- EOS goals and mission objectives
- Significant contribution of CIMSS in the 1990s and beyond
 - MODIS cloud mask, atmospheric profiles, and cloud top properties
 - AIRS land surface characteristics
 - Direct broadcast
 - Development & deployment of S-HIS
 - Contribution to development of MAS
 - Calibration of MODIS and AIRS
 - Development of light scattering properties for MODIS

QuickTime™ and a
H.264 decompressor
are needed to see this picture.

EOS Goals and Mission Objectives

Goals

- Develop an understanding of the total Earth system, and the effects of natural and human-induced changes on the global environment
- Expand scientific knowledge of the Earth system using NASA's unique capabilities from the vantage points of space, aircraft, and in situ platforms
- Disseminate information about the Earth system
- Support national and international environmental policy recommendations

Mission Objectives

- Create an integrated scientific observing system that will enable multidisciplinary study of Earth system science
- Develop a comprehensive data and information system, including a data retrieval and processing system (EOSDIS)
- Acquire and assemble a global database emphasizing remote sensing measurements from space over a decade or more
- Improve predictive models of the Earth system

MODIS Atmosphere Products developed by CIMSS

➤ Pixel-level (level-2) products

- Cloud mask for distinguishing clear sky from clouds (MOD35/MYD35)
- Cloud radiative and microphysical properties (MOD06/MYD06)
 - ✓ Cloud top pressure, temperature, and effective emissivity
- Atmospheric moisture and temperature gradients (MOD07/MYD07)
- Column water vapor amount (MOD05/MYD05)

MODIS Cloud Mask (MOD35/MYD35)

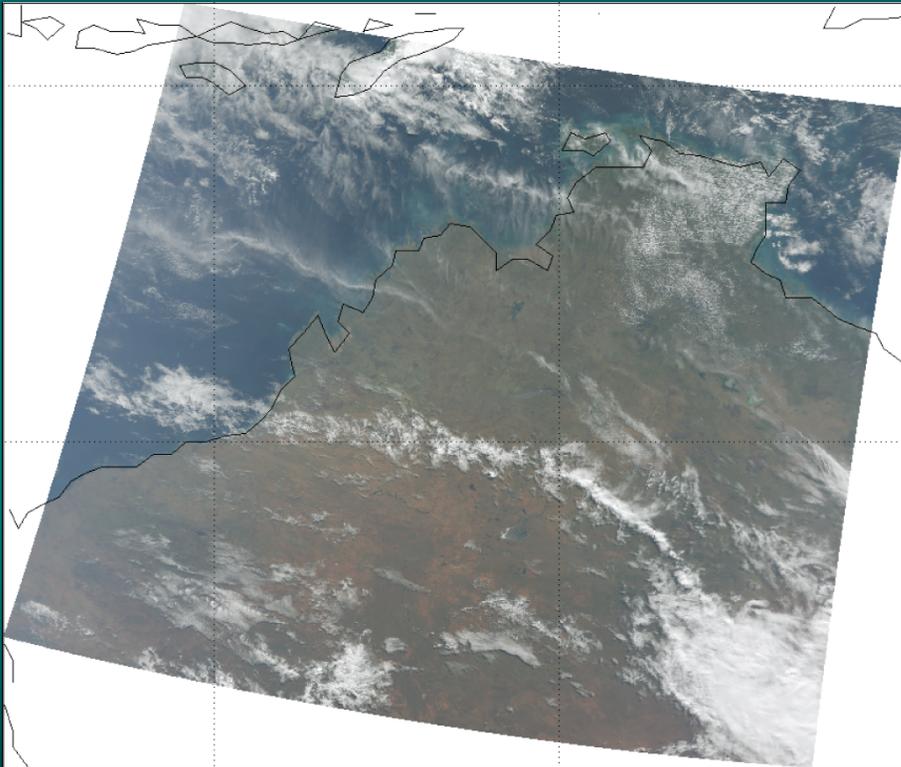
(S. A. Ackerman, W. P. Menzel, R. A. Frey, K. I. Strabala - U. Wisc.)

- MODIS cloud mask uses multispectral imagery to indicate whether the scene is clear, cloudy, or affected by shadows
- Cloud mask is input to many atmosphere and land algorithms
- Mask is generated at 250 m and 1 km resolutions
- Mask uses **20 spectral bands** ranging from 0.55-13.93 μm
 - 11 different spectral tests are performed, with different tests being conducted over each of 5 different domains (land, ocean, coast, snow, and desert)
 - Temporal consistency test is run over the oceans
 - Spatial variability is run over the oceans
- Algorithm based on radiance thresholds in the infrared, and reflectance and reflectance ratio thresholds in the visible and near-infrared
- Cloud mask consists of **48 bits of information** for each pixel, including results of individual tests and the processing path used
 - Bits 1 & 2 give combined results (confident clear, probably clear, probably cloudy, cloudy)

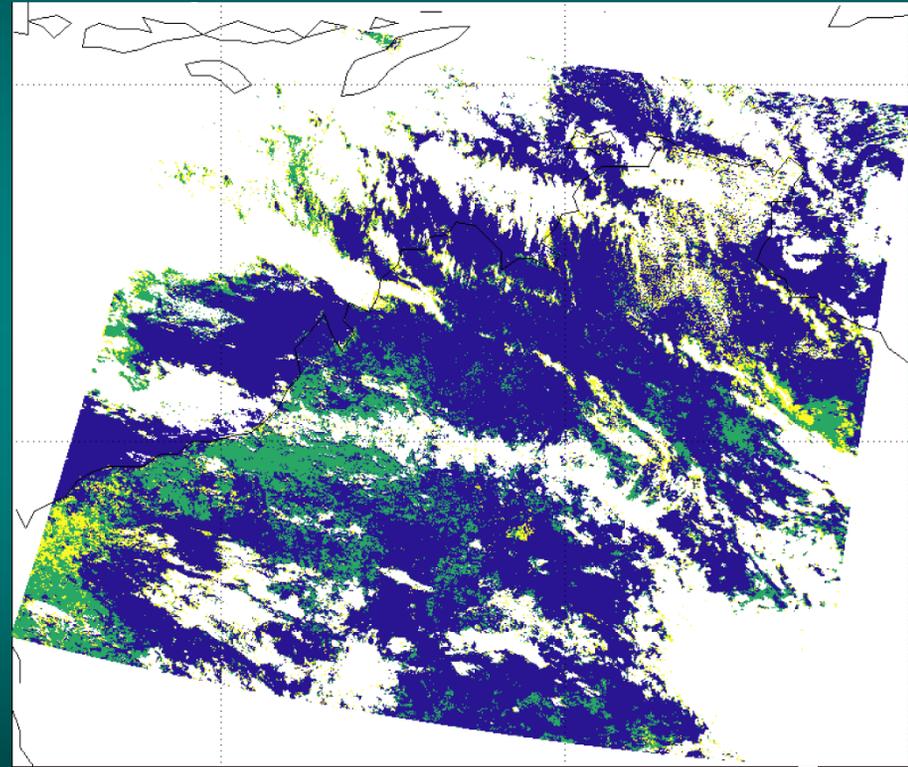
Terra/MODIS Cloud Mask

(S. A. Ackerman, W. P. Menzel - Univ. Wisconsin, NOAA/NESDIS)

True Color Composite (0.65, 0.56, 0.47)



Cloud Mask

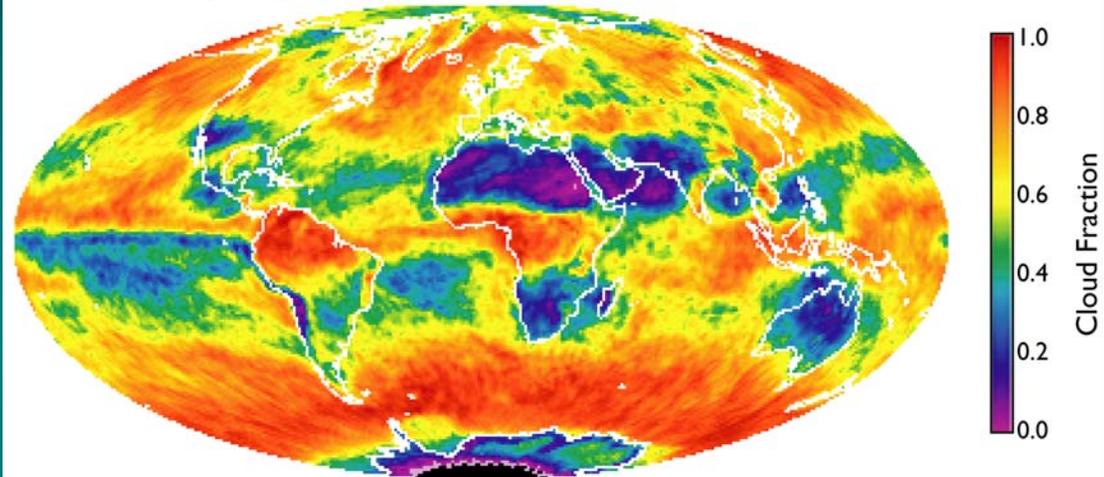


Monthly Mean Cloud Fraction during Daytime

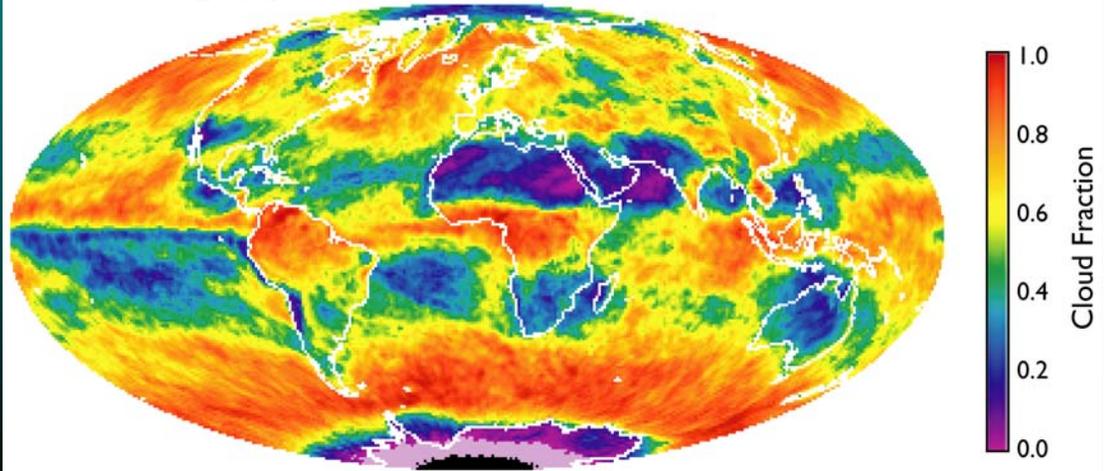
(S. A. Ackerman, W. P. Menzel, R. A. Frey, K. I. Strabala - U. Wisc.)

April 2003 (Collection 4)

Cloud Fraction (Terra)

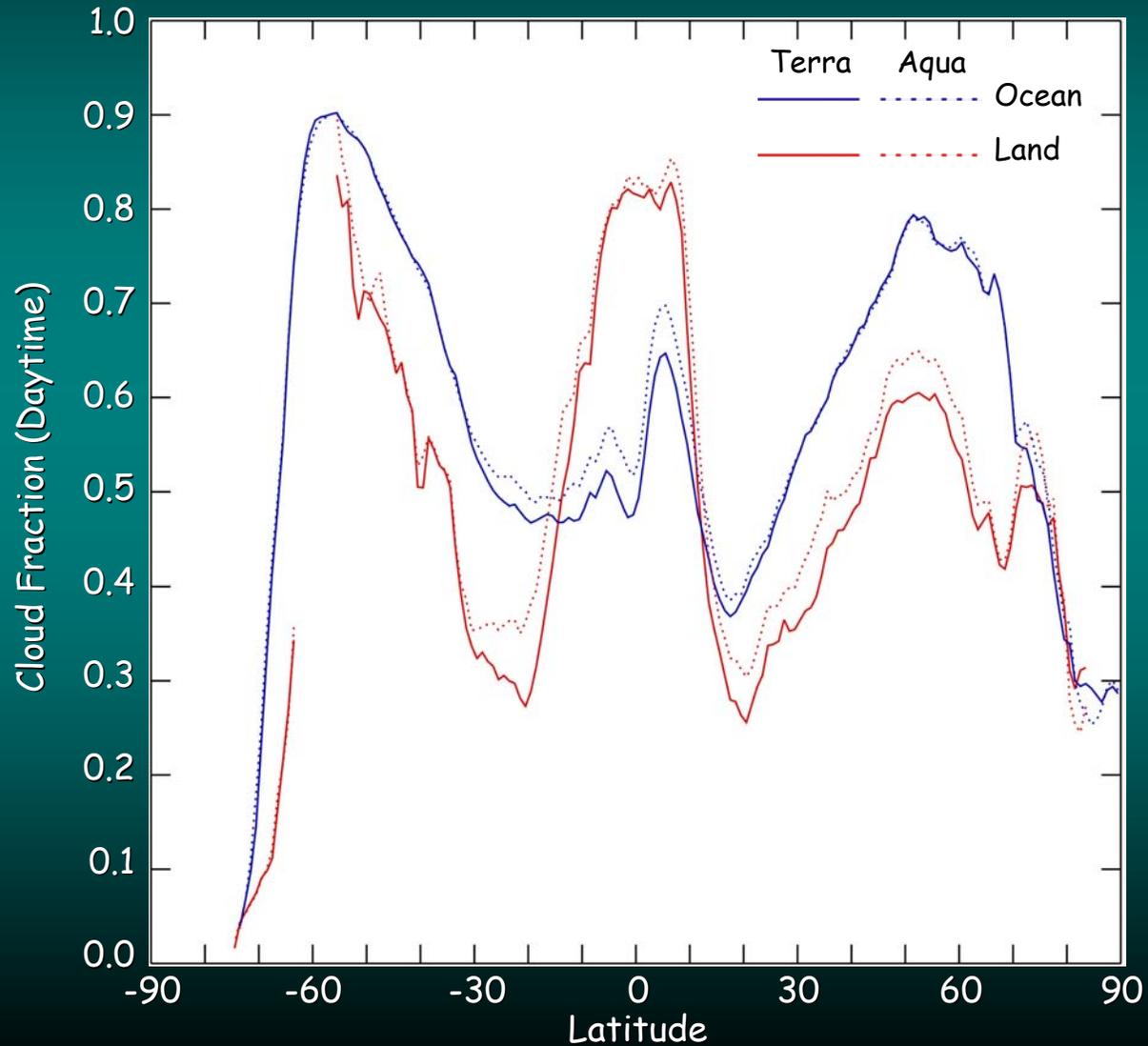


Cloud Fraction (Aqua)

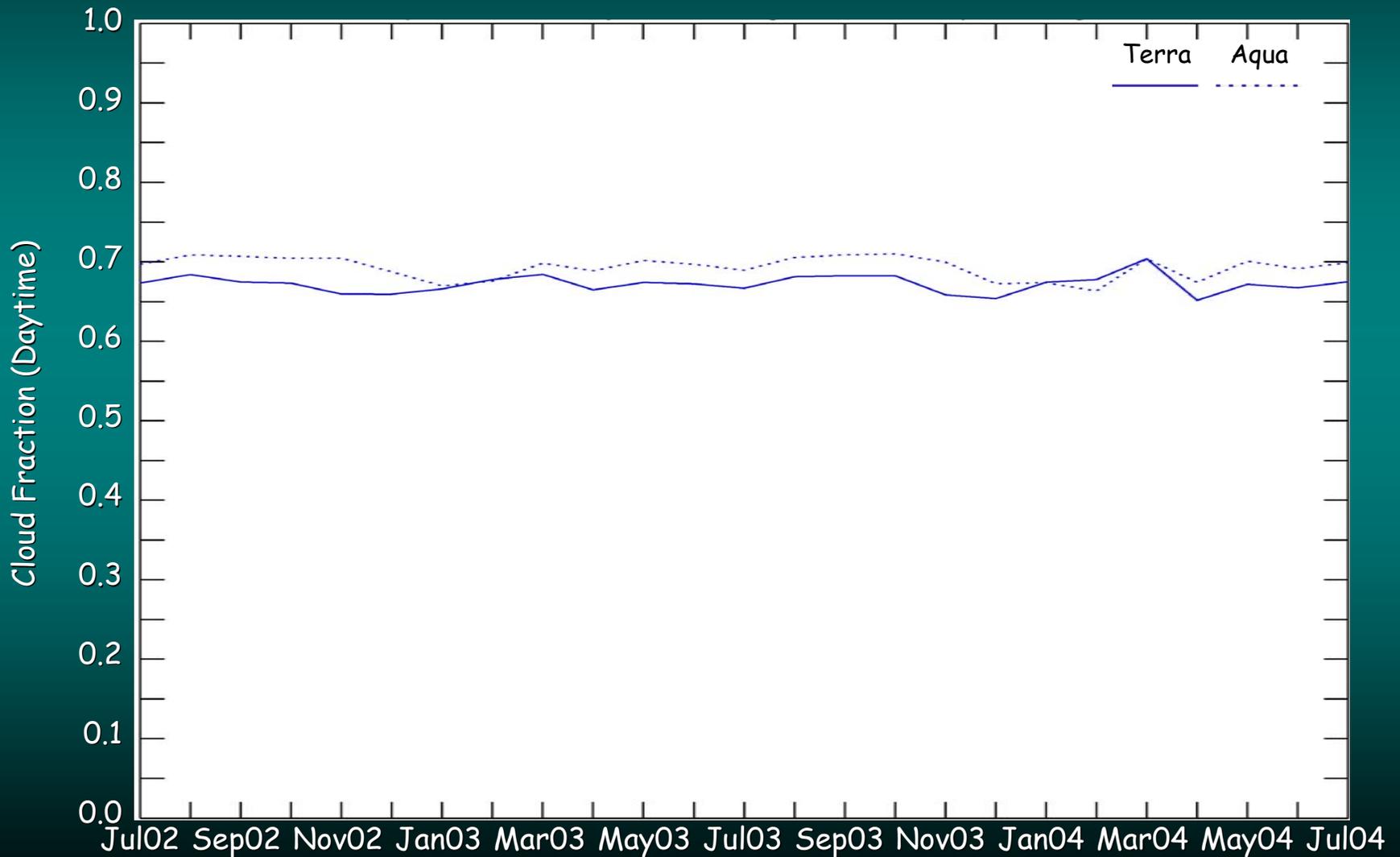


Zonal Mean Cloud Fraction during Daytime

April 2004 (Collection 4)



Time Series of Cloud Fraction during the Daytime



MODIS Top Properties (MOD06/MYD06)

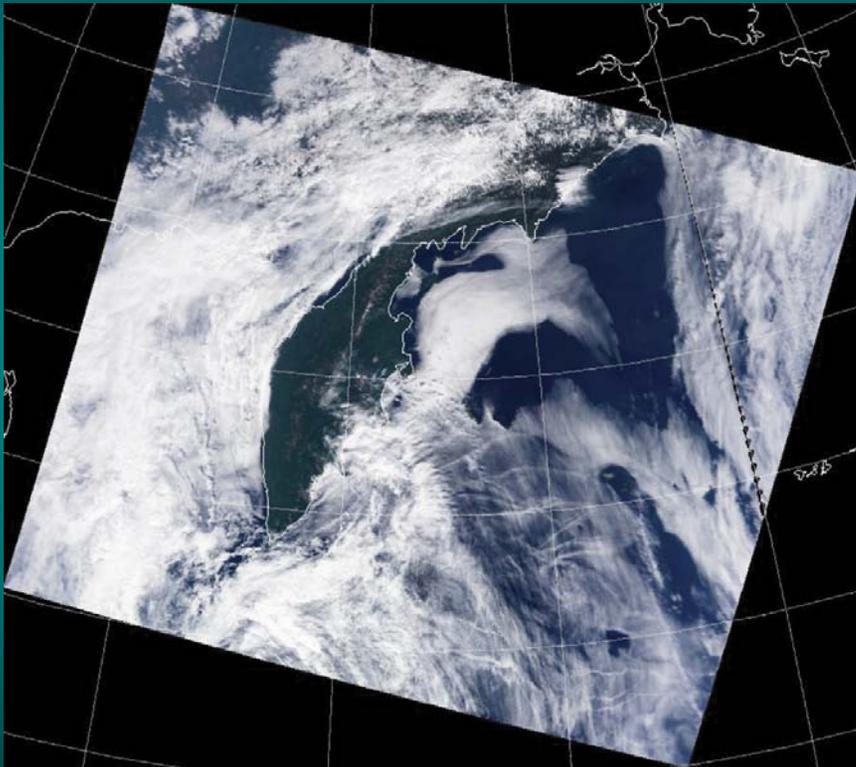
(W. P. Menzel, R. A. Frey, K. I. Strabala et al. - U. Wisconsin)

- Cloud-top pressure, temperature, effective emissivity
- Retrieved for every 5 x 5 box of 1 km FOVs, when at least 5 FOVs are cloudy, day & night
- CO₂ slicing technique (5 bands, 12.0-14.2 μm)
 - retrieve p_c ; T_c from temperature profile
 - ratio of cloud forcing in 2 nearby bands
 - most accurate for high and mid-level clouds ($p_c < 700$ hPa)
- Previously applied to HIRS (NOAA POES, 20 km) and GOES sounder (~ 30 km)
- Accuracy of technique ~ 50 hPa for high clouds

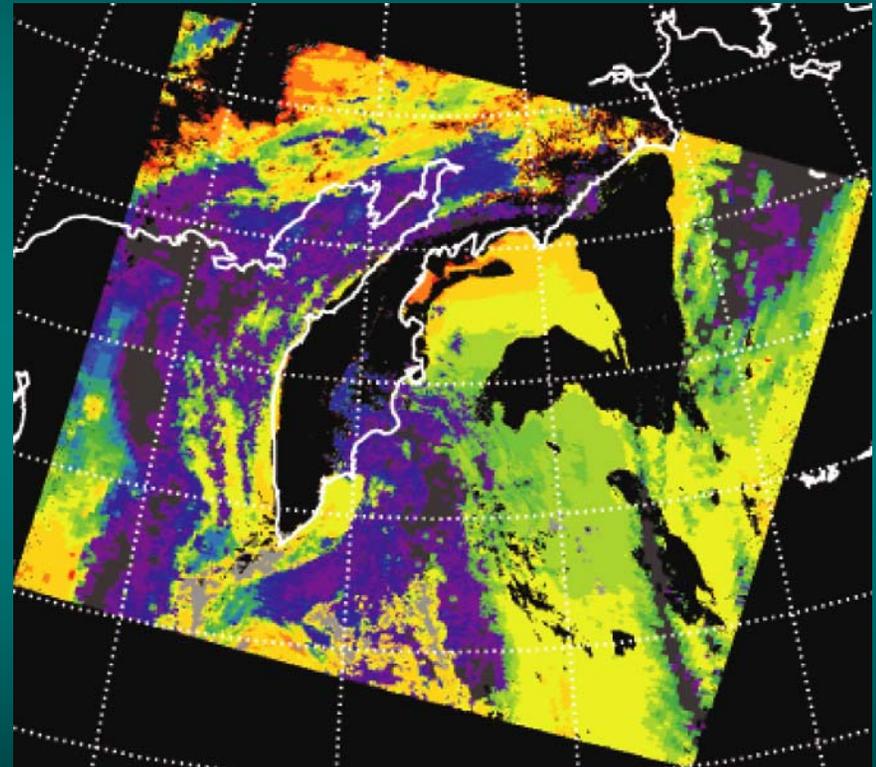
MODIS 1st satellite sensor capable of
CO₂ slicing at high spatial resolution

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

True Color Composite (0.65, 0.56, 0.47)



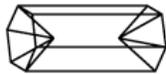
Cloud Top Pressure (hPa)



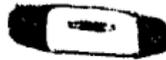
MODIS Ice Crystal Library habits/shapes

(a) Ice crystal shapes frequently observed in cirrus clouds

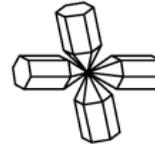
hollow column



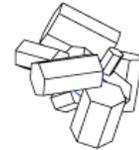
plate



bullet rosettes



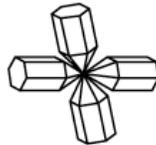
aggregates



(b) MODIS/MAS cirrus cloud microphysical model

$D < 70 \mu\text{m}$:

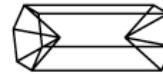
50%



+ 25%

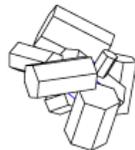


+ 25%

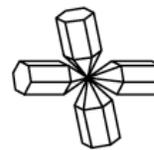


$D > 70 \mu\text{m}$:

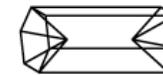
30%



+ 30%



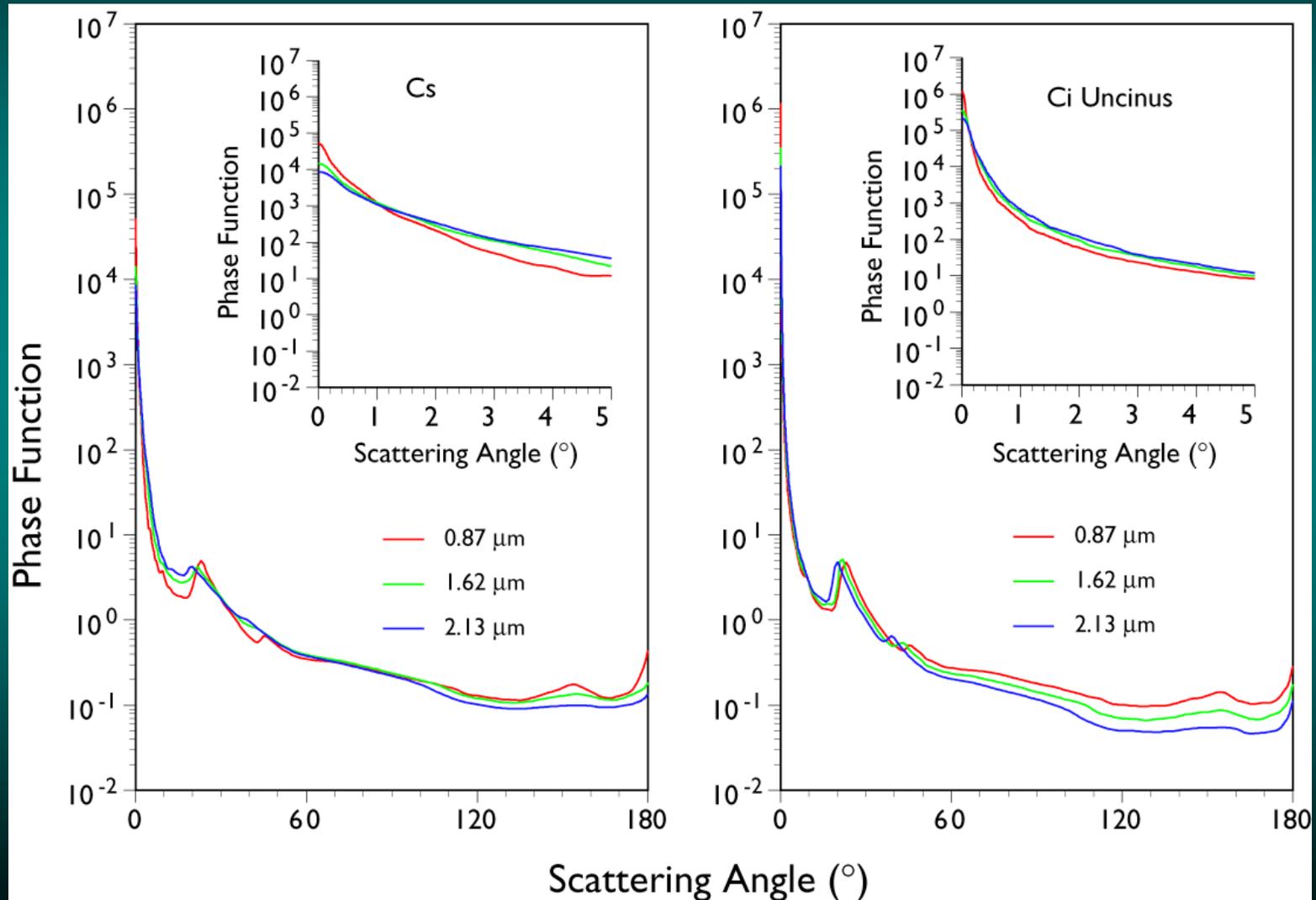
+ 20%



+ 20%



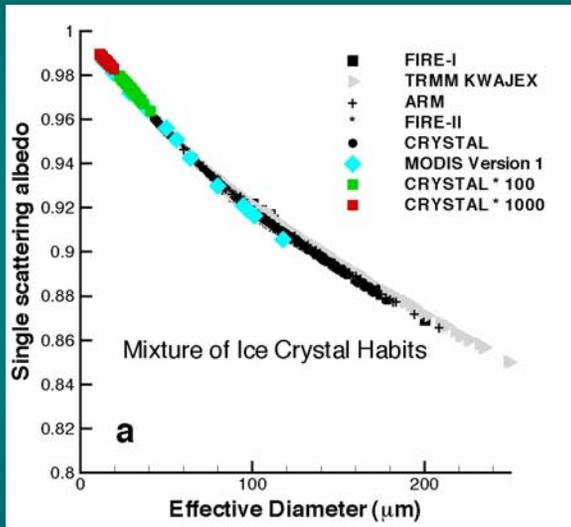
Example Ice Cloud Phase Functions (Ping Yang - FDTD + geometric optics)



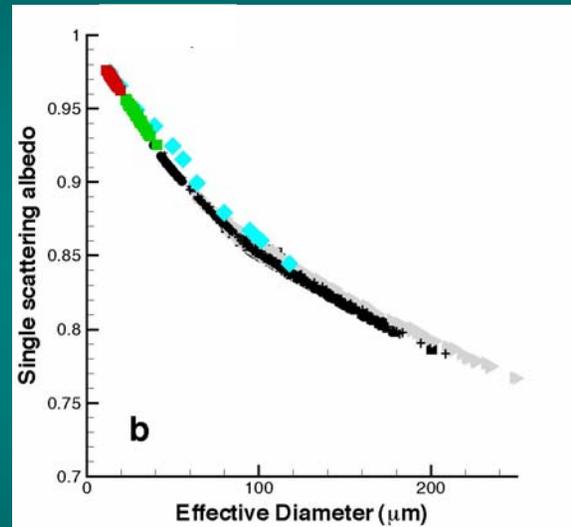
MODIS Ice Model Single Scattering Albedo

(B. A. Baum, P. Yang, A. J. Heymsfield, S. Platnick, M. D. King et al.)

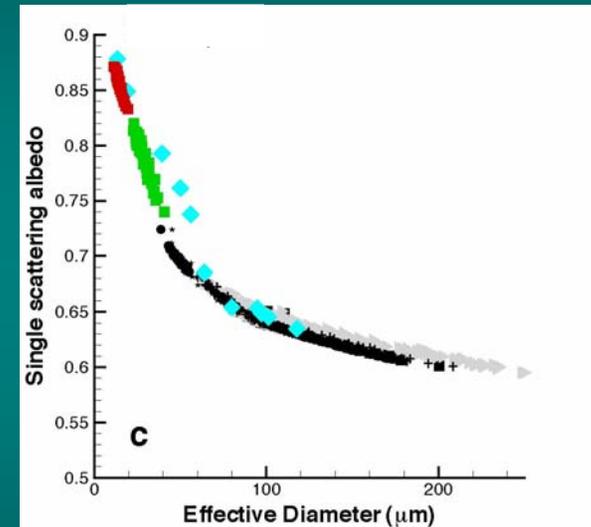
1.64 μm



2.13 μm



3.75 μm



MODIS Atmospheric Profiles Product (MOD07/MYD07)

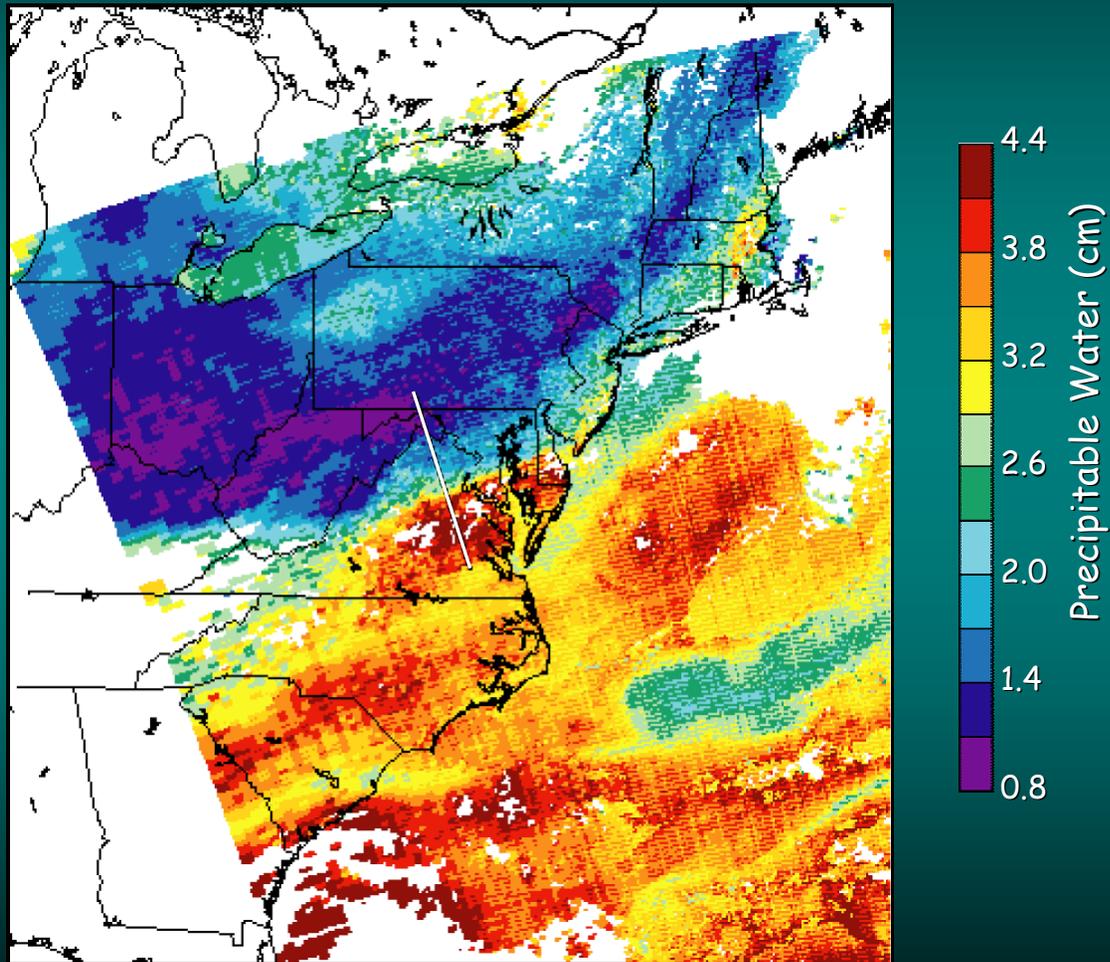
(W. P. Menzel, J. Li, S. W. Seemann - Univ. Wisconsin)

- Uses 12 spectral bands ranging from 4.47-14.24 μm
 - Statistical retrievals of atmospheric temperature, moisture layers, total precipitable water, total ozone content, and stability indices
 - Clear sky retrievals are done over land and ocean for both day and night
 - ✓ 20% of the radiances measured within a 5 x 5 field of view area (approximately 5 km) are cloud-free
 - Radiative transfer computations are performed over the MODIS bandpass characteristics where the model has 101 pressure-level vertical coordinates
 - ✓ atmospheric profile information is saved at only 20 levels
 - ✓ total precipitable water is computed by integrating over the retrieved profiles with 101 levels

Aqua/MODIS Precipitable Water

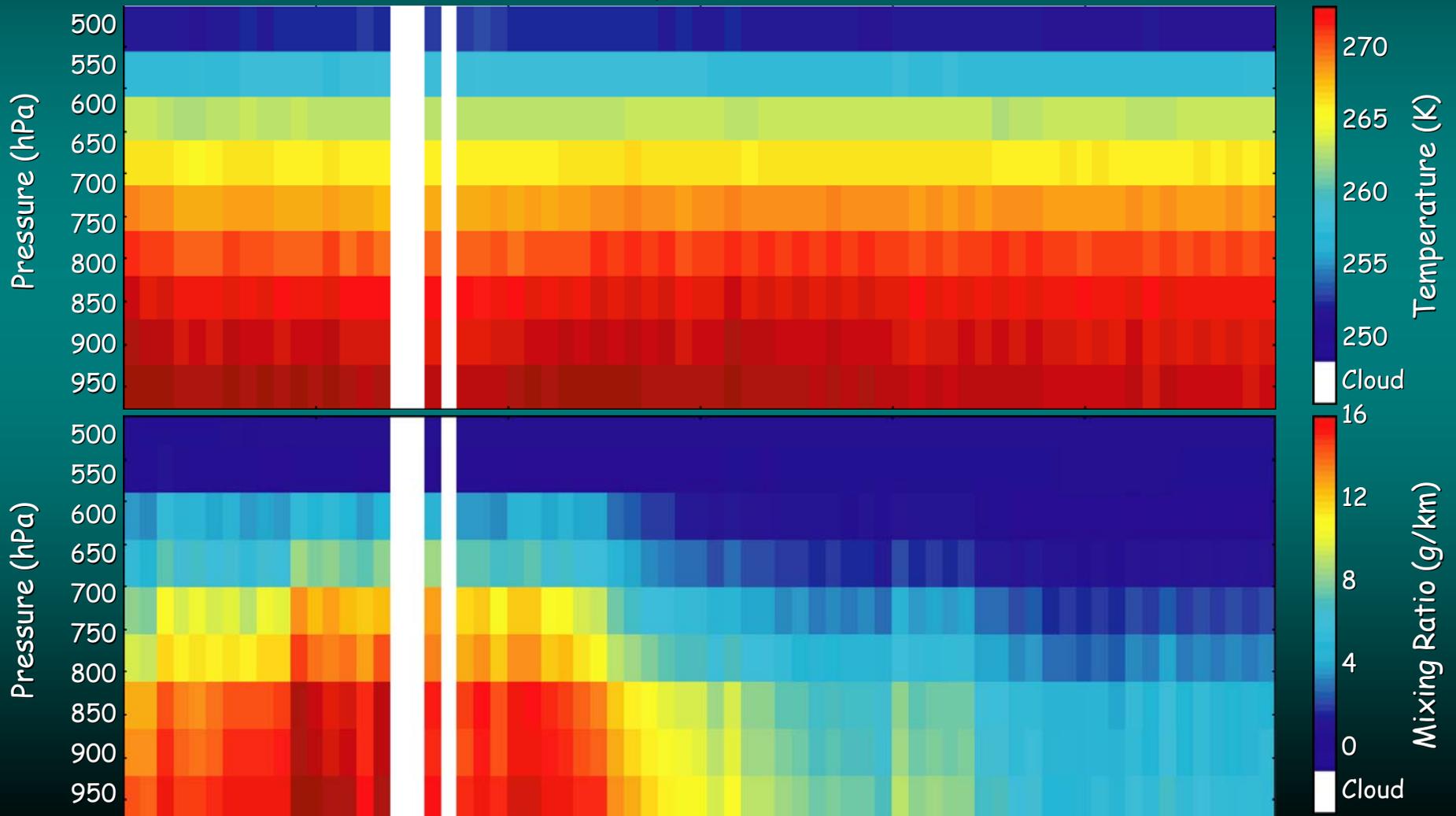
(S. W. Seemann, J. Li, W. P. Menzel - Univ. Wisconsin, NOAA)

September 4, 2002



Aqua/MODIS Profiles of Atmospheric Temperature and Water Vapor Mixing Ratio

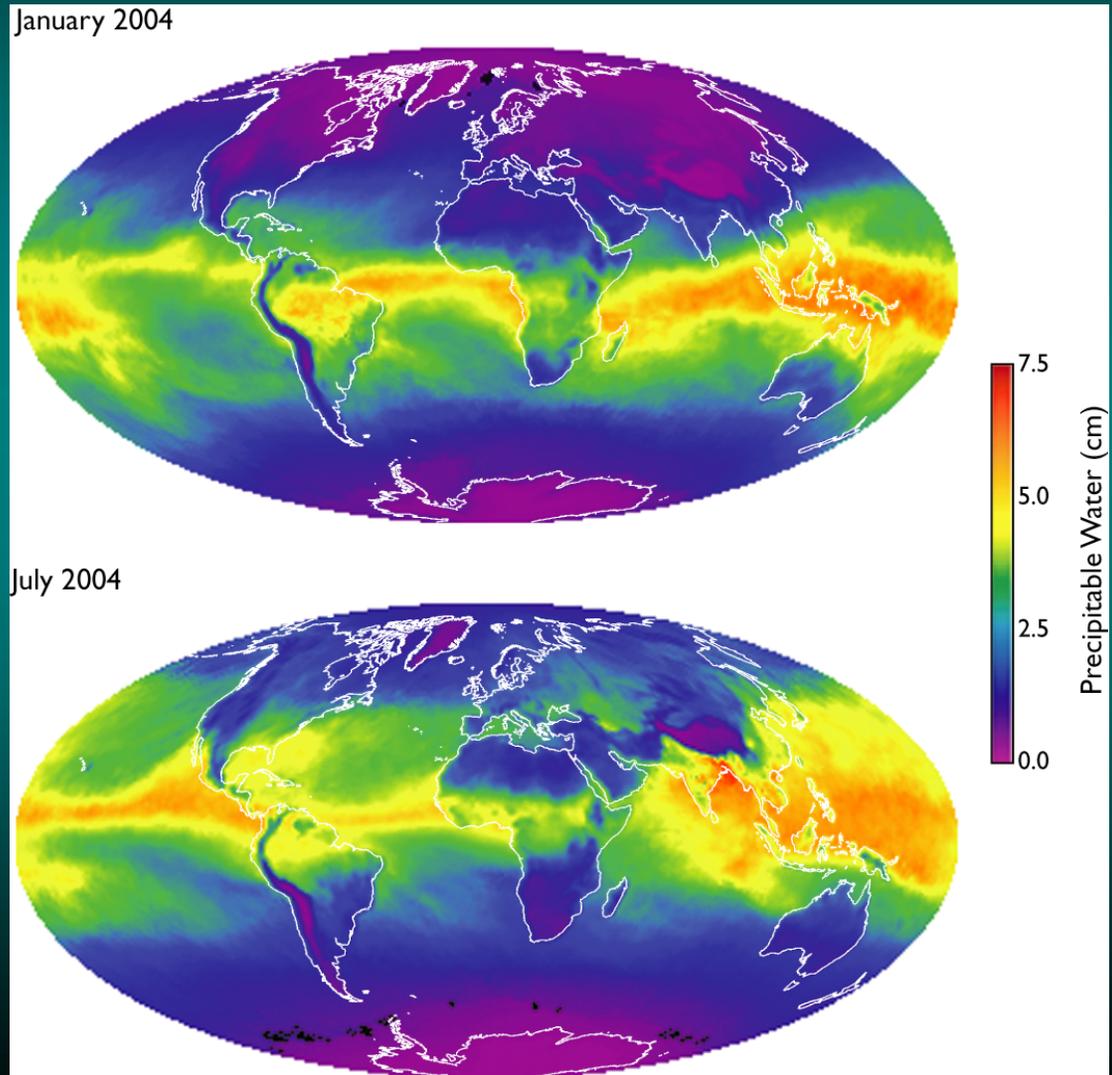
September 4, 2002



Monthly Mean Precipitable Water

(S. W. Seemann, J. Li, W. P. Menzel - Univ. Wisconsin, NOAA)

January & July 2004
(Collection 4)



MODIS Precipitable Water Product (MOD05/MYD05)

(B. C. Gao, W. P. Menzel, S. W. Seemann - NRL, Univ. Wisconsin)

➤ Near-infrared water vapor

- Uses 5 spectral bands located in and around the 0.94 μm water vapor band
- Retrievals of PW over land and over the ocean with sunglint during the daytime
- Accuracy of about 7% as compared to ground-based microwave radiometers

➤ Thermal infrared water vapor

- Uses 12 spectral bands ranging from 4.47-14.24 μm
- Algorithm consists of a statistical regression that simultaneously retrieves atmospheric profiles of temperature, water vapor, and ozone
- For dry atmospheres, MODIS overestimates the total PW, whereas for moist atmospheres MODIS underestimates PW
 - ✓ rms bias between MODIS and ground-based microwave radiometers is 4.7 mm

Terra/MODIS Level-1B Image

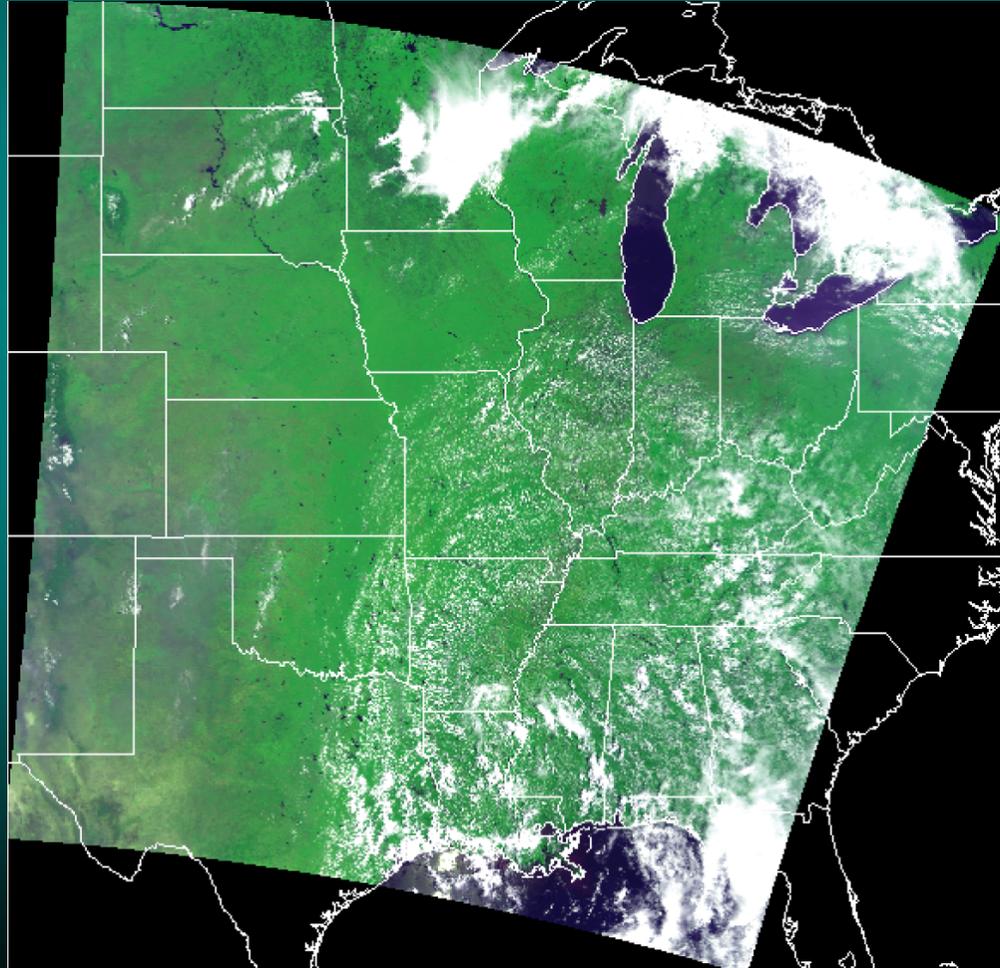
R = 0.65 μm

G = 0.86 μm

B = 0.47 μm

June 24, 2002

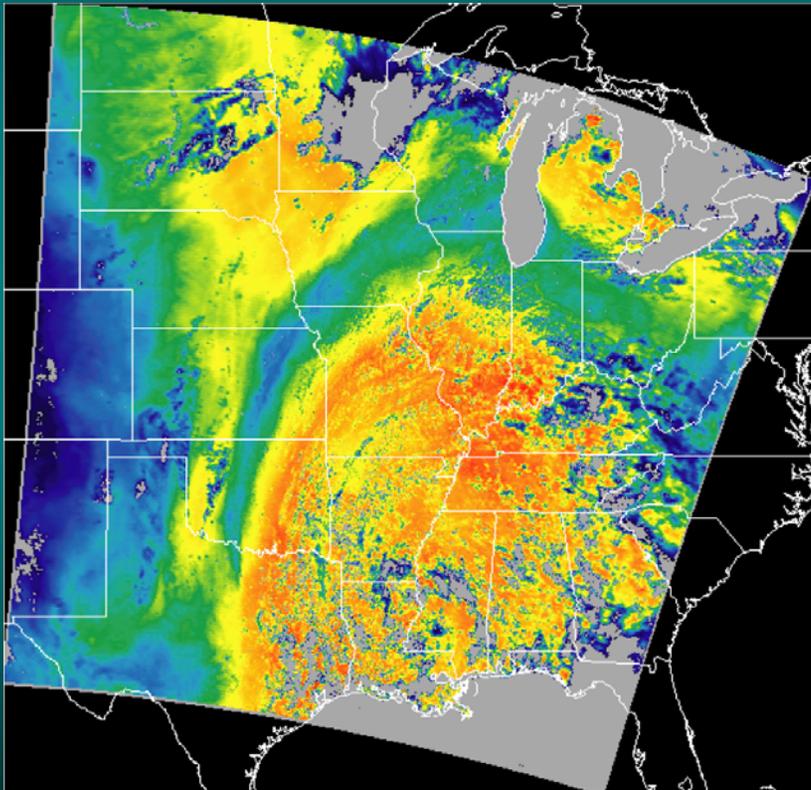
1705 UTC



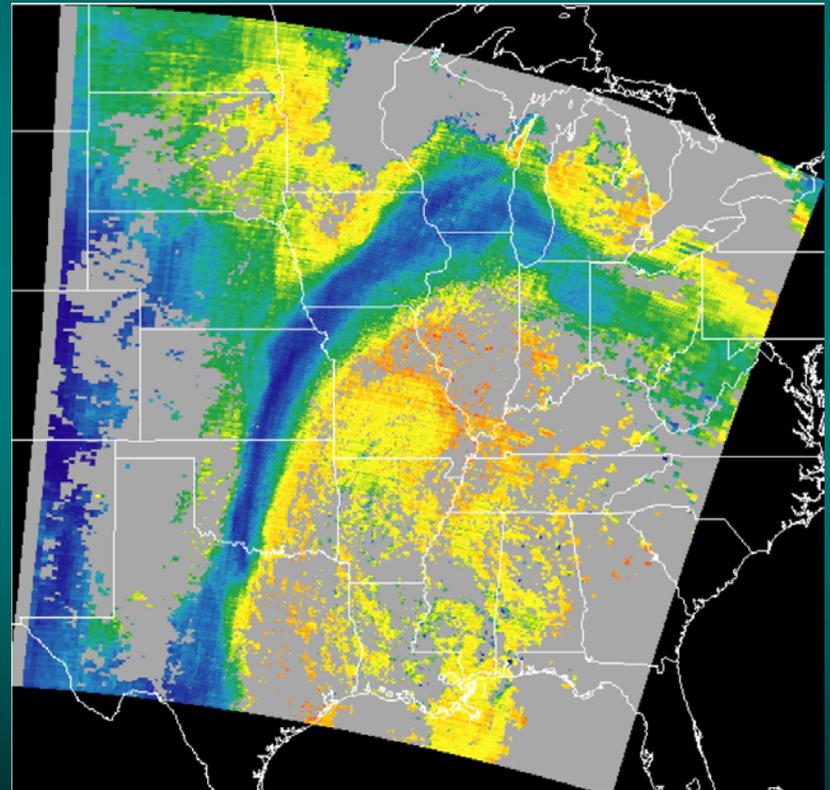
Terra/MODIS Retrievals of Precipitable Water

June 24, 2002
1705 UTC

Near-Infrared PW



Thermal Infrared PW

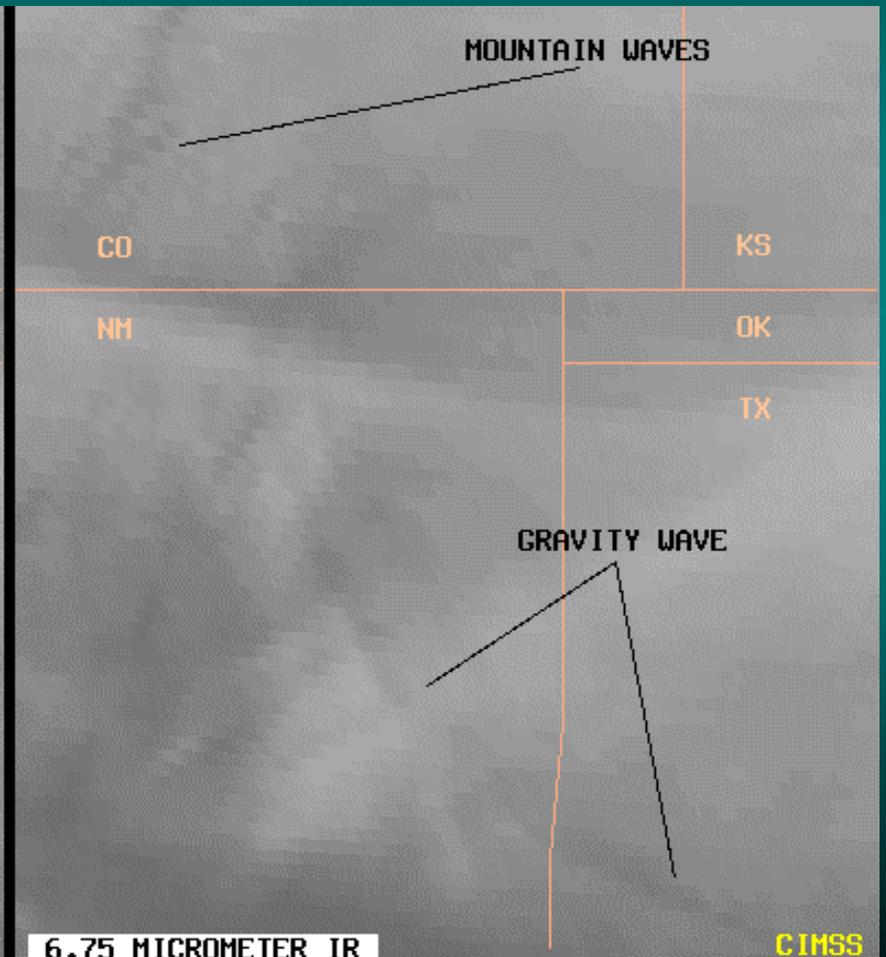
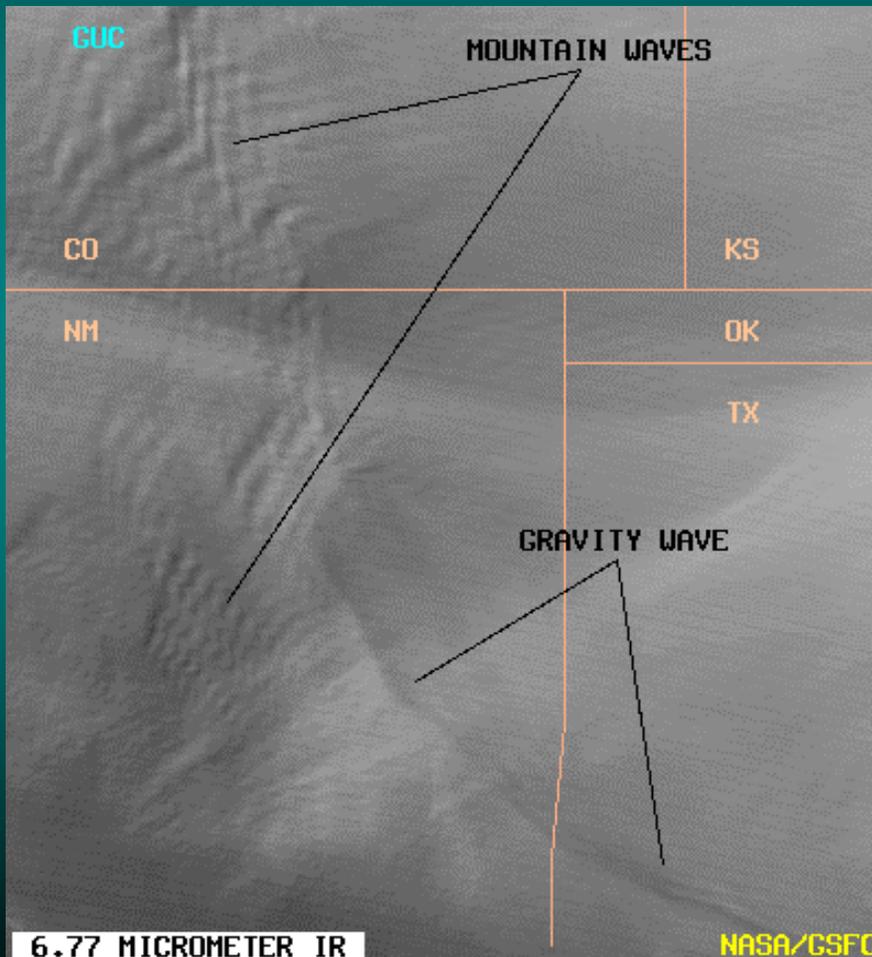


Water Vapor (cm)

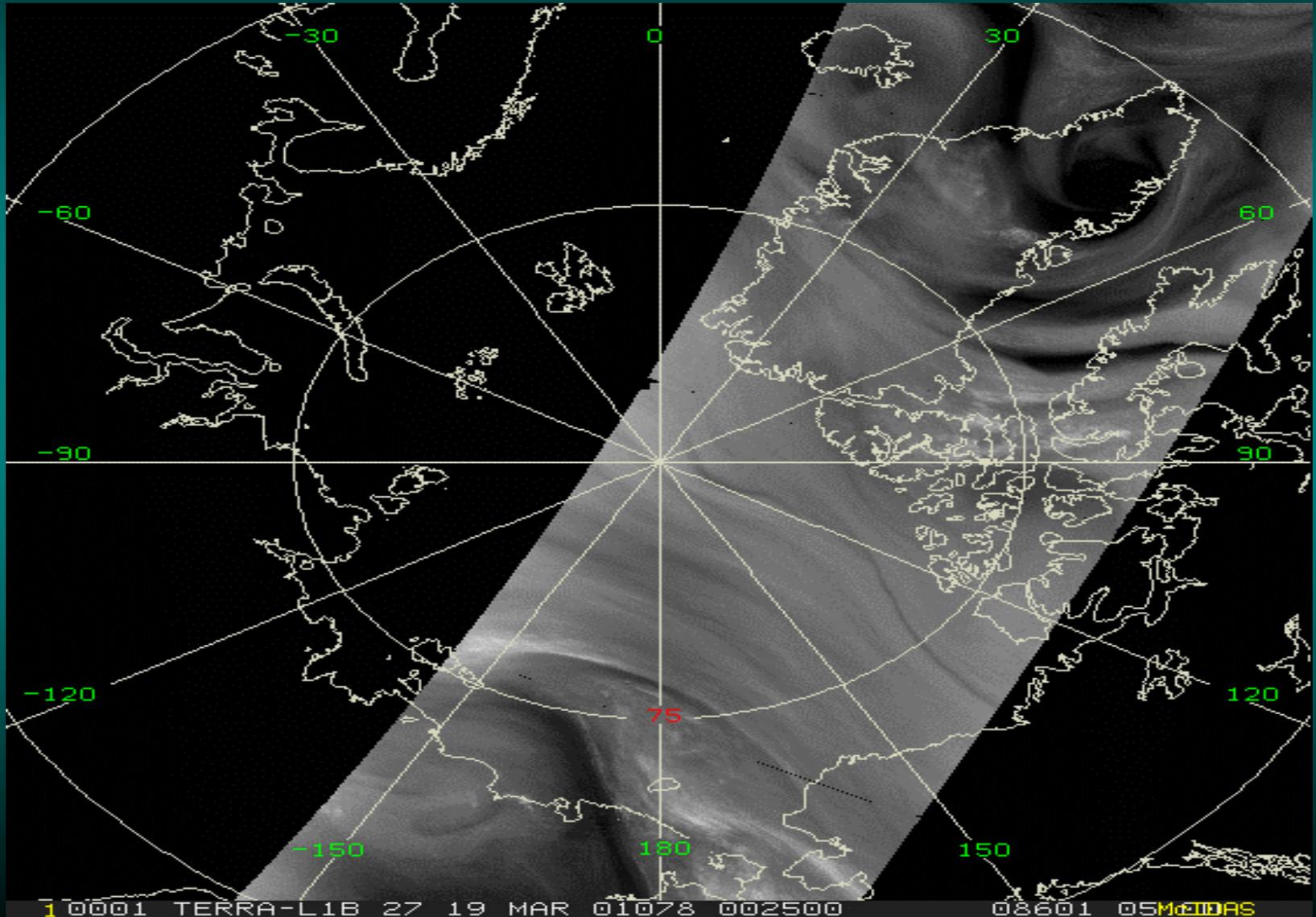
MODIS Reveals Atmospheric Moisture Details As Never Seen Before

MODIS Water Vapor (1 km)

GOES-8 Water Vapor (4 x 8 km)

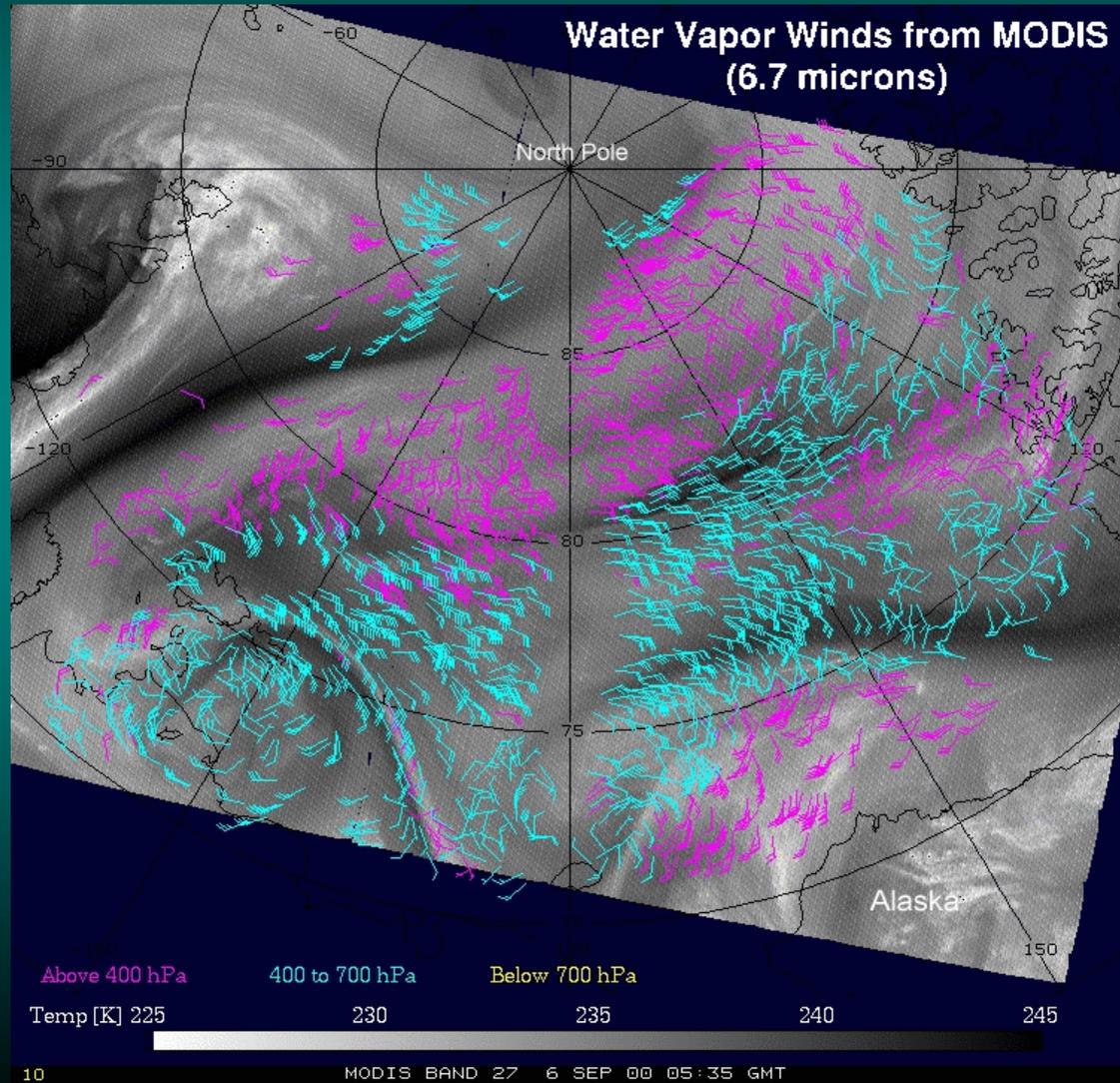


Every 100 Minutes MODIS Covers the Polar Regions

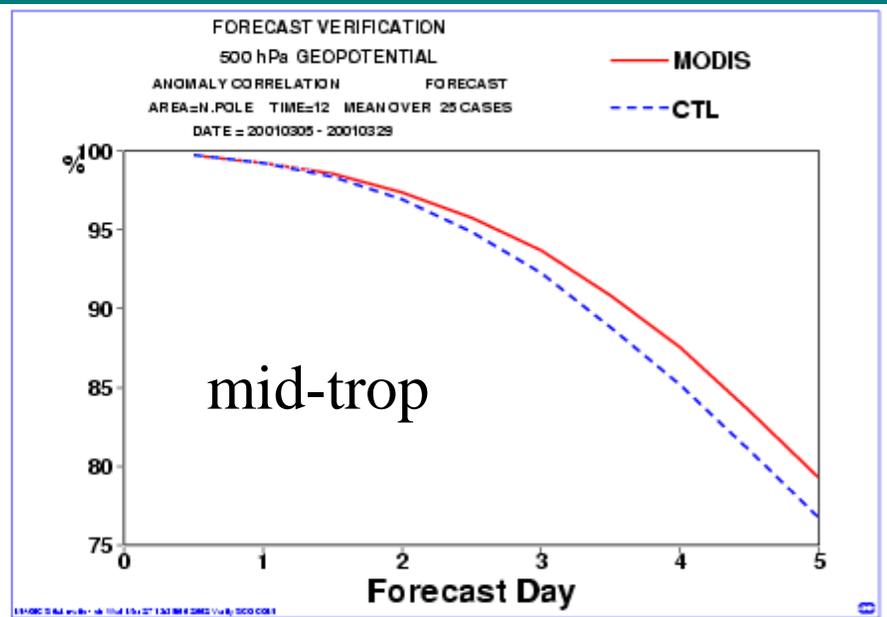
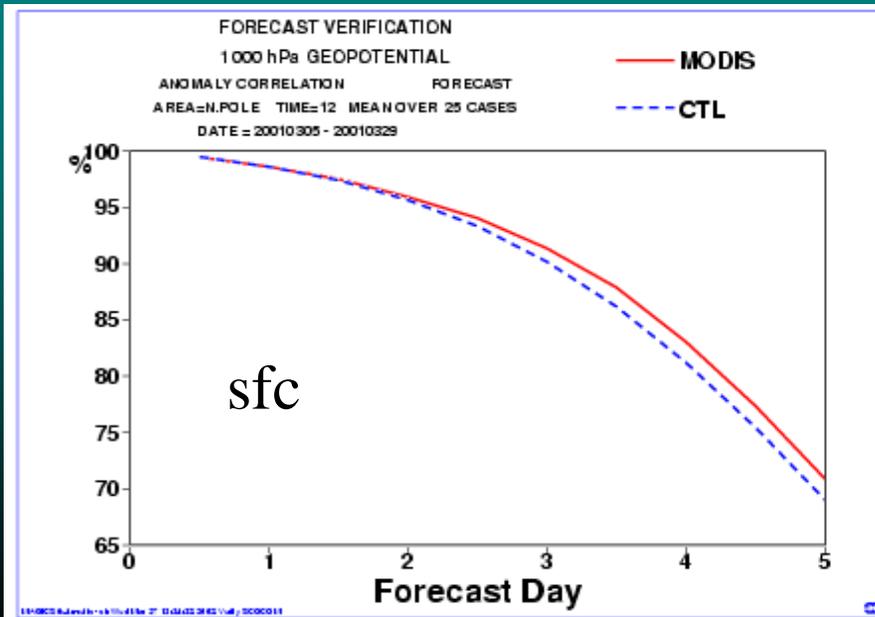
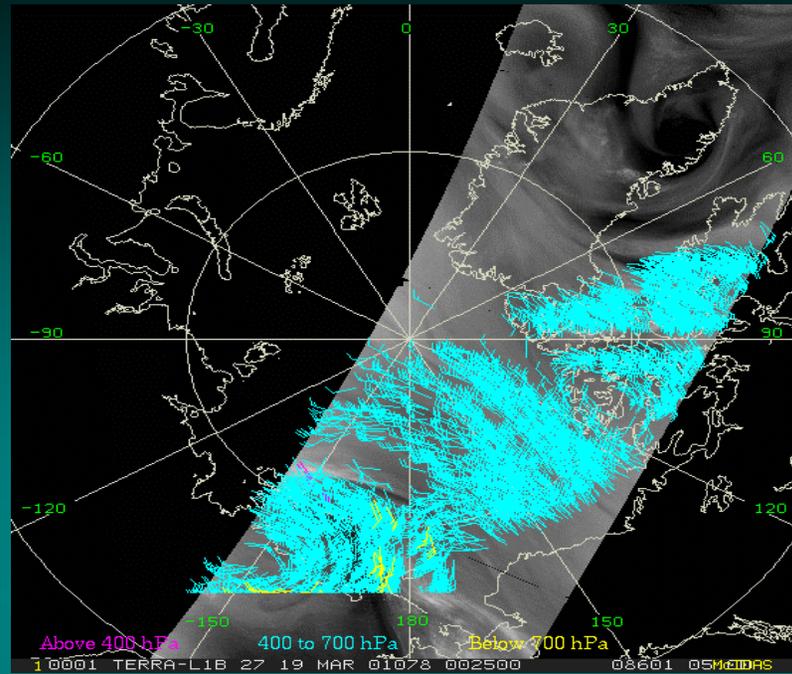


Winds from MODIS: An Arctic Example

Cloud Tracked Winds
Water Vapor Winds



Winds improve Weather Forecast



MODIS Airborne Simulator (MAS)

(M. D. King, W. P. Menzel, C. C. Moeller et al. - GSFC, Univ. Wisc.)

➤ Platform

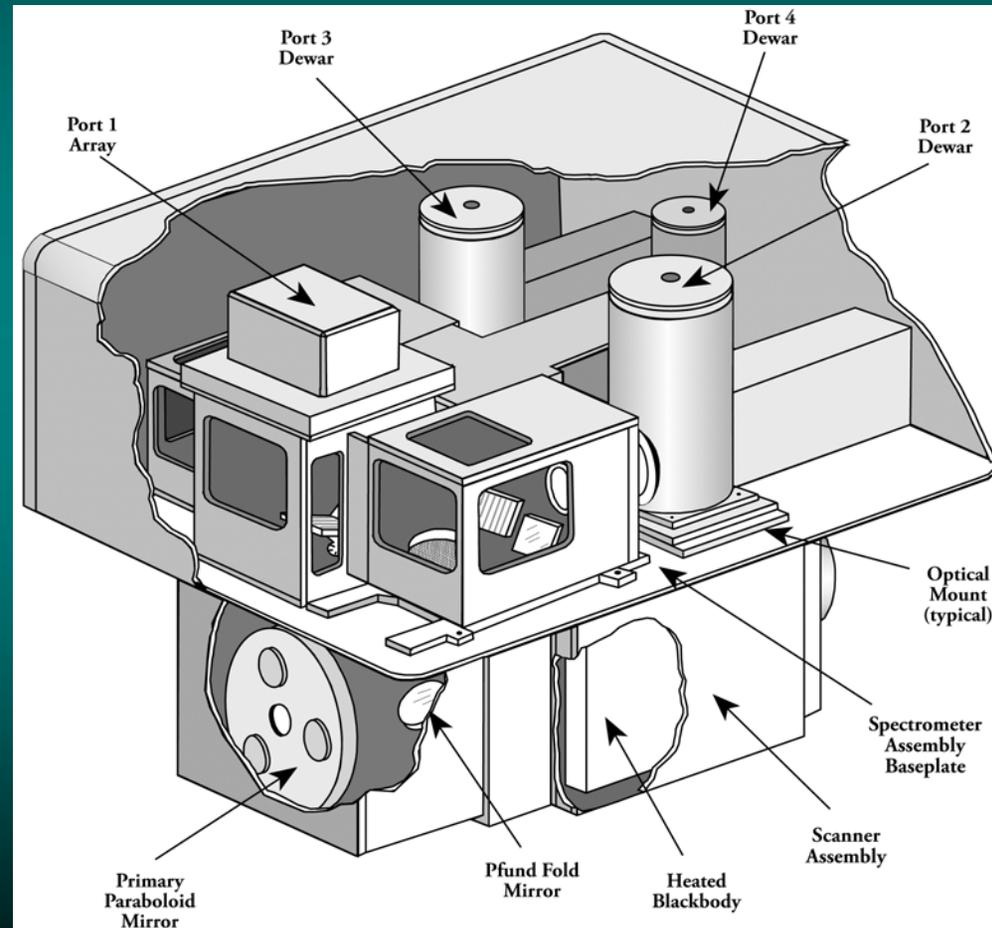
- ER-2

➤ Altitude

- 20 km (nominal)

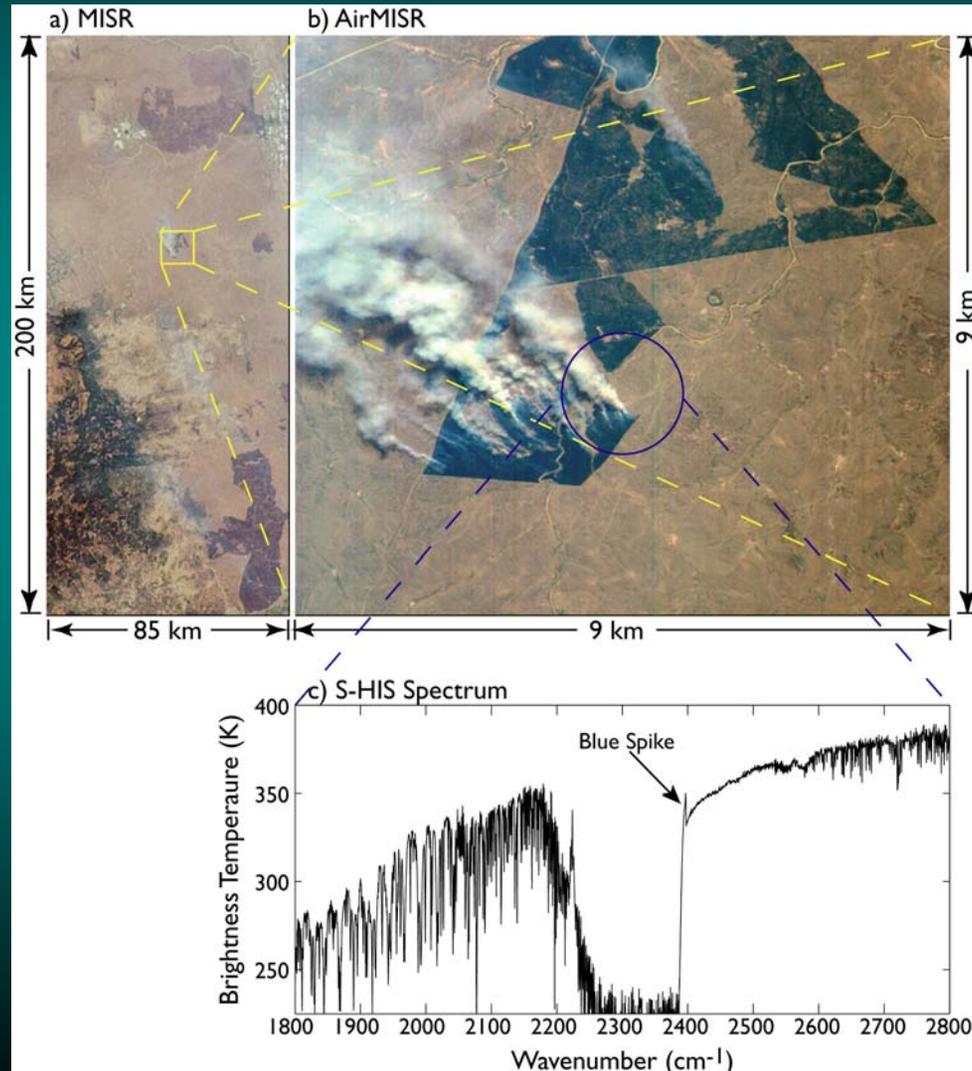
➤ Sensor Characteristics

- 50 spectral bands ranging from 0.55 to 14.2 μm
- cross-track scan mirror with ~ 40 km swath width (scan $\pm 43^\circ$)
- instantaneous field of view 2.5 mrad
- scan rate 6.25 Hz
- 16 bits per channel
- 716 pixels in scan line
- calibration
 - » integrating sphere on ground
 - » Two on-board temperature controlled blackbodies



MISR, AirMISR, and S-HIS Observations (H. E. Revercomb - Univ. Wisc.)

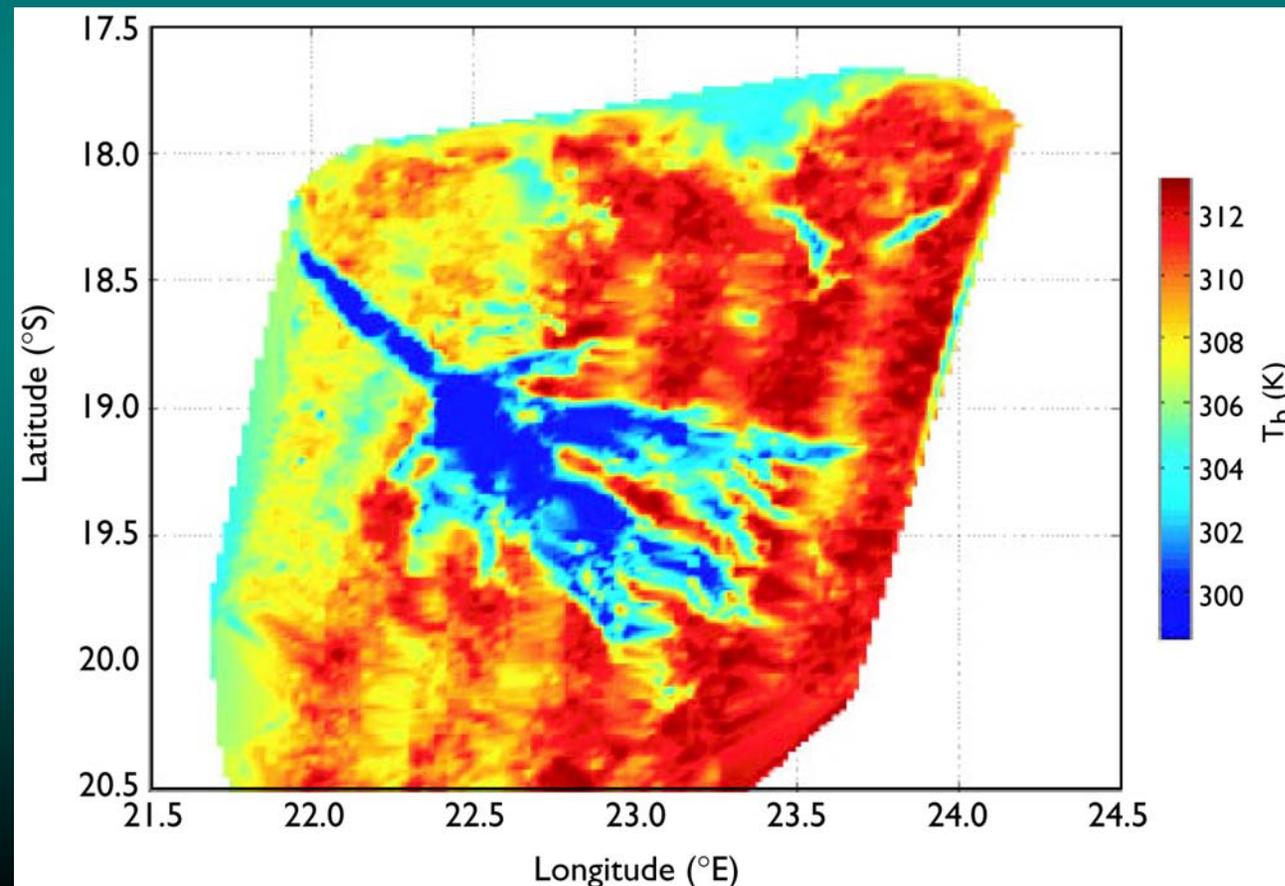
Timbavati Fire



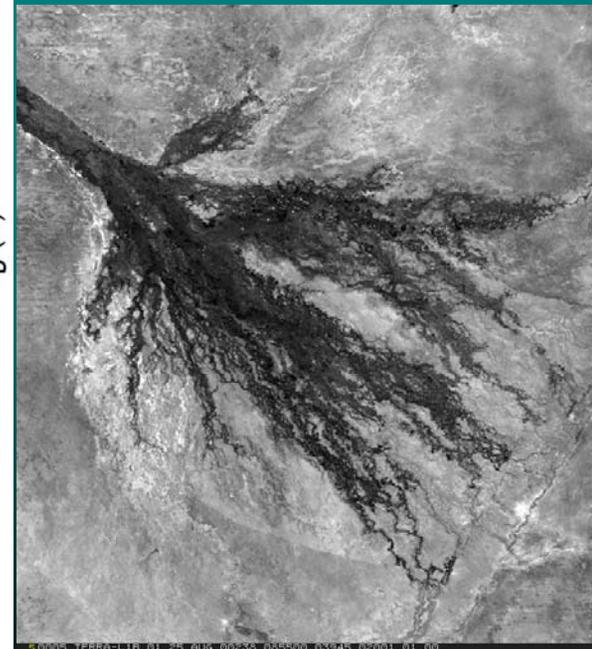
MODIS and S-HIS Observations (H. E. Revercomb - Univ. Wisc.)

Okavango Delta, Botswana
August 27, 2000

Scanning HIS: 2 km footprints
 T_b (980-985 cm^{-1})



MODIS: 250 m
0.65 μm



King et al. (2003)

Summary

- CIMSS personnel have collaborated on numerous algorithms for MODIS
- New algorithms for detecting winds in polar regions have been developed and assimilated in numerous centers for medium range weather forecasting
- Direct broadcast development has allowed some 100 ground receiving stations worldwide to have access to timely data processing algorithms
- Airborne sensors have been developed for algorithm development as well as validation activities (MAS and S-HIS)
- The MODIS cloud mask algorithm has also been developed and applied to MAS data as well as to Midori II/GLI data