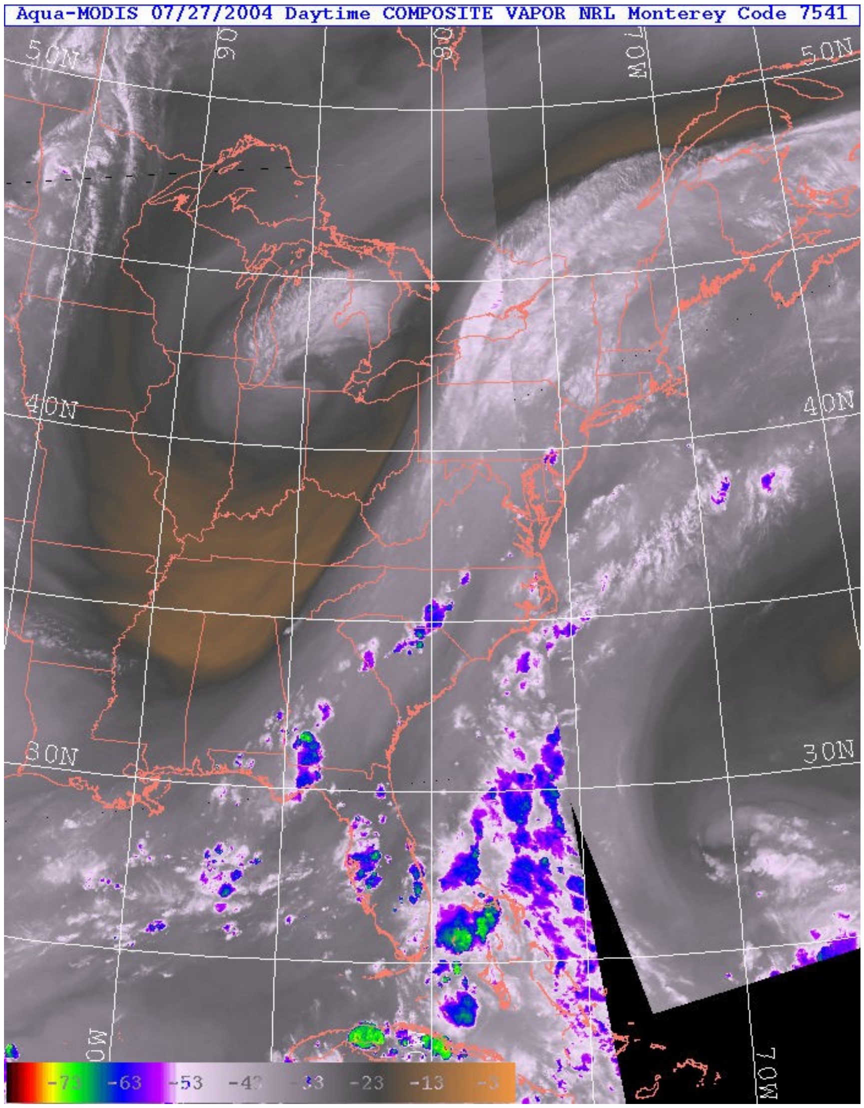
Satellite Product Tutorials:

Water Vapor Imagery



Above: A water vapor channel image from the MODIS sensor over the eastern continental United States (CONUS) on July 27, 2004 during a daytime composite. Two adjacent MODIS passes have been stitched together to capture the upper-level water vapor illustrating an influx of moisture from the Gulf of Mexico and offshore Florida up along the US east coast. Drier air aloft is seen digging past the Great Lakes and into the Mississippi River region with an associated trough.

Why We're Interested…

Accurately mapping the three-dimensional distribution of moisture is critical to understanding both the short term potential for cloud and rain development as well as predicting medium to long range (3-14 days) weather evolution. Unfortunately our ability to determine the horizontal and vertical moisture fields on the space and time scales required is poor compared to our current needs. Thus, both geostationary and polar orbiter data sets are merged to fill in the data cube.

Geostationary water vapor measurements provide the high temporal sampling and synoptic views, which enable us to detect large scale moisture changes within the atmosphere's upper levels. However, spatial resolution from GOES-EAST/WEST is ~ 8-km at nadir and degrades as one moves away from the sub satellite point, whether east/west or north/south. Therefore, GOES water vapor resolutions over CONUS range from ~ 9-18-km.

The MODIS sensor is on the Aqua and Terra polar orbiter spacecraft that fly at an altitude of 705 km, well below the 35,780 km for geostationary platforms. Thus, MODIS water vapor resolution is much improved, (1-km at nadir) and degrades to 4-5 km near the swath edge.

How This Enhancement is Created…

The brightness temperatures (Tbs) observed by MODIS are calibrated and displayed here using a table that associates varying colors with Tbs. Dry air permits the sensor to view deeper into the atmosphere, thus measuring upwelling radiances lower and warmer in value. Conversely, moist air blocks the sensor from viewing below and radiates at higher altitudes and thus colder values.

How to Interpret…

The MODIS water vapor imagery is representative of moisture within a broad upper-level layer. The altitude range varies from ~ 250 –600 mb, with peak weighting near 450 mb. The altitude will be typically higher when moist values are present and towards the low end of the range when the atmosphere is dry. The 6.7 um channel is not a window channel and thus one rarely sees the earth's surface except on occasions when very dry air exists over high mountainous regions.

The MODIS water vapor imagery has been color coded to enable users to quickly identify areas of larger moisture. Areas with large moisture values are typically represented by active convection, which has transported large water vapor values aloft. The Tbs at these heights are lower and are represented by blue, green, yellow, red and brown colors in the Figure with the rain cells offshore Florida. Note how the color code gives the appearance of clouds when modest water vapor values are encountered in Figure 1 along the eastern US seaboard.

Low water vapor values are displayed in several gray shades as noted over the Mid-West and map the upper-level trough digging into the Mississippi River states. The trough is lifting out the moisture along the east coast and very moist values will soon be replaced with much drier air and weather.

What to look for:

Concentrated areas of very cold brightness temperatures signifying large water vapor values that may be associated with rain, thunderstorms and other severe weather. Warm Tbs or dry areas occur in regions of sinking air typically found within high pressure regions (anticyclones -ridges) while cold Tbs and moist values are dominant in areas of low pressure (cyclonic flow) where storms often prevail.

What to watch out for:

Moisture aloft may correlate poorly with moisture at lower-levels or with the total amount of water vapor throughout the atmospheric column. An upper-level cloud deck may overlie a completely dry region below and thus not be representative of the weather we experience on the surface.

The color scale does not always permit the user to adequately discern the complete water vapor structure for a given range of values. For instance, the color table has been purposely selected to enhance areas where rain is likely to occur, but this has been accomplished while sacrificing low moisture ranges. In Figure 1, the upper Midwest and Great Lakes region has a deep upper-level trough with some apparent eddy-like features. However, considerable detail in local structure is lost since these "warm Tbs and low moisture" values are spread over a gray scale range that generically does well, but may have problems at any given time.

Other Considerations: The MODIS data CONUS composites take multiple hours to complete and thus moisture features will move during the compositing timeframe. Fast moving moisture will create distorted seams near the edges of composited MODIS swaths.

Looking Toward the NPOESS Era…

The measurements required for mapping upper-level water vapor via the imagery shown here will become available operationally during the NPOESS era using the Visible Infrared Imaging Radiometer Suite (VIIRS). It is currently envisioned that the third NPOESS spacecraft (C3) will carry a VIIRS sensor containing the 6.7 um channel. With a three-satellite constellation, NPOESS-VIIRS will provide roughly 4-hour refresh over the United States. The high spatial resolution (370 meters, or just under ¼ mile "boxes") will enable detailed depiction of water vapor patterns to supplement the higher time refresh information (but coarser spatial resolution) to be offered from the next-generation geostationary operational environmental satellite series, GOES-R. For more information on NPOESS, please visit: http://www.ipo.noaa.gov/

Did You Know…?

Atmospheric water vapor values can change very rapidly due to convergence of low-level moisture that is brought aloft by vigorous convection and thunderstorms. Thunderstorm timescales of 30-60 minutes can rapidly transport huge water vapor amounts aloft. Much of the water vapor will condense and fall out of clouds as raindrops, while significant amounts can be spread over hundreds and even thousands of kms via cirrus anvils.

Want to Learn More?

COMET® Program NPOESS Education and Training Series:
Water vapor: http://www.comet.ucar.edu/class/satmet/wv_lec.html
NPOESS Program: http://meted.ucar.edu/npoess/cunningham/index.htm

Science Papers:

Key, J., D. Santek, C.S. Velden, N. Bormann, J.-N. Thepaut, L.P. Riishojgaard, Y. Zhu, and W.P. Menzel, 2003: Cloud-drift and Water Vapor Winds in the Polar Regions from MODIS. *IEEE Trans. Geosci. Remote Sens.*, **41**, 482-492.

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King, M. D., W. P.Menzel, Y. J. Kaufman, D. Tanré, B.-C. Gao, S. Platnick, S. A. Ackerman, L. A. Remer, R. Pincus, and P. A. Hubanks, 2002: Cloud, Aerosol and Water Vapor Properties from MODIS: Preliminary Results from Terra. Accepted by IEEE Transactions on Geoscience and Remote Sensing, Aqua Special Issue.

Soden, B. J., and F. P. Bretherton, 1993: Upper tropospheric relative humidity from the GOES 6.7 μm channel: Method and climatology for July 1987. *Journal of Geophysical Research*, 98, 16669.

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