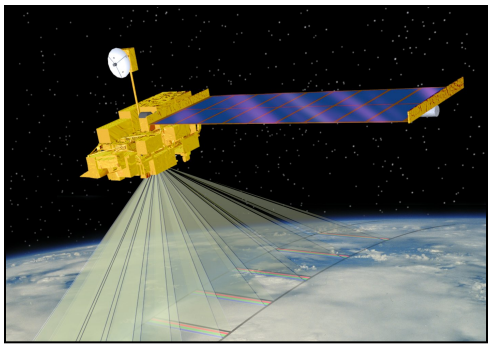
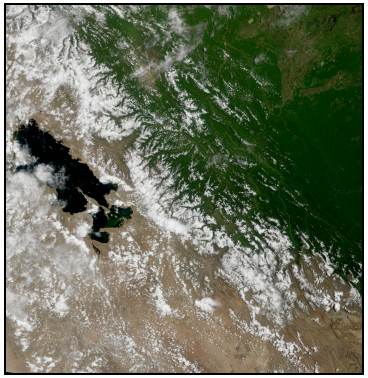
DB Product Applications

2011 IMAPP Training Workshop: Satellite Direct Broadcast for Real-Time Environmental Applications
ECNU, China
4 June 2011
Part 1



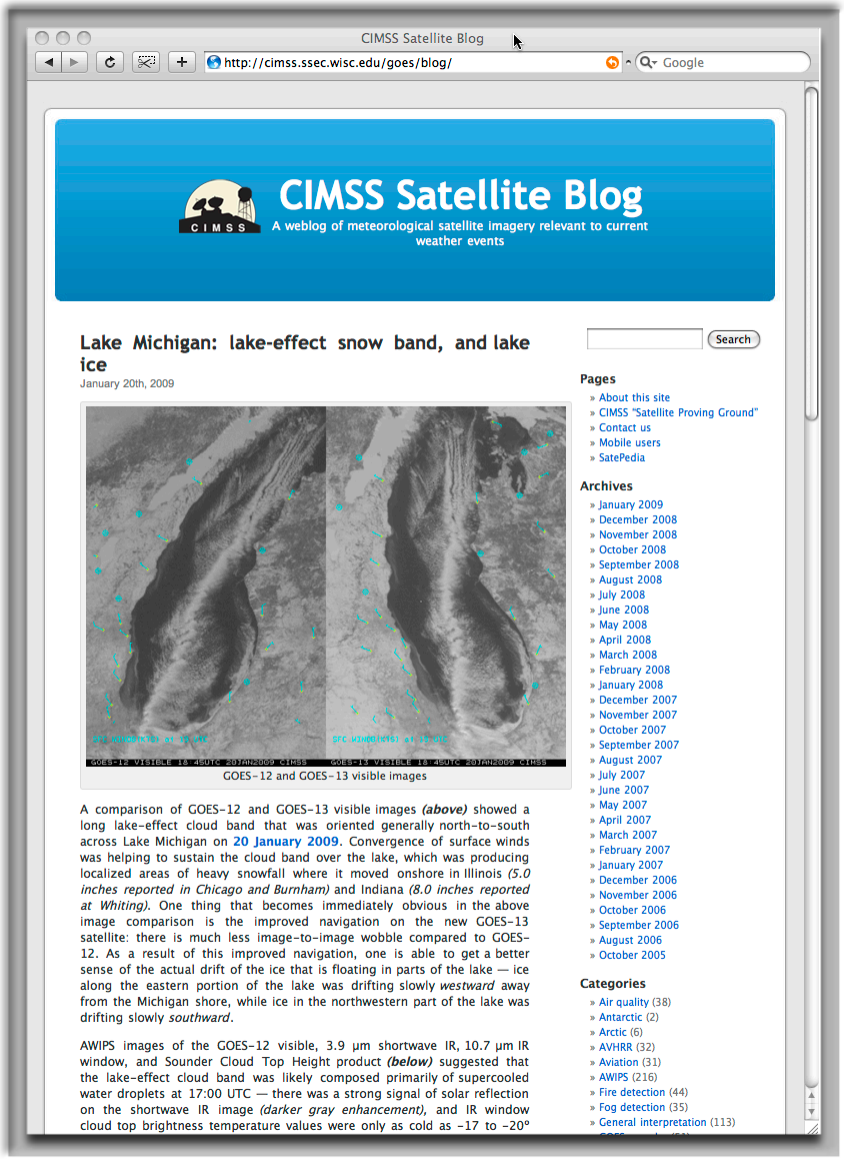


Kathleen Strabala
Cooperative Institute for Meteorological Satellite Studies
Space Science and Engineering Center
University of Wisconsin-Madison

Sources

- Publications
- Conferences and Conference Papers
- User Feedback including US National Weather Service
- CIMSS satellite blog – Scott Bachmeier
  - http://cimss.ssec.wisc.edu/goes/blog/

SSEC Satellite Blog



cimss.ssec.wisc.edu/goes/blog

MODIS DB Applications

- Huge Variety

- Weather Observation and Forecasting
  - Originally thought of as research satellite
  - Compliment to Geostationary
    - Higher Spatial Resolution (data at 250 m - 1 km, products at 250 m - 5 km)
    - Unique spectral bands (such as 1.38 µm)
    - New products (such as true color imagery)
    - Preparation for next generation of geo instruments
  - Key for forecasts is timeliness of data
    - UW provides NWS with data end to end within 1.5 hours of start of pass time.
  - Post analysis – timeliness not as important
  - Temporal coverage is limiting

MODIS DB Applications

- Public Safety and Public Interest
  - Nighttime Fog Detection
  - Snow/Ice Detection
  - Fires
  - Severe Weather
- Aviation Interest
  - Everything clouds
    - Cloud composition, Height and Temperature
  - Turbulence
  - Ash Detection
- Numerical Weather Prediction
  - IMAPP DCRAS
- Aerosols
  - Detection
  - IDEA
- Others

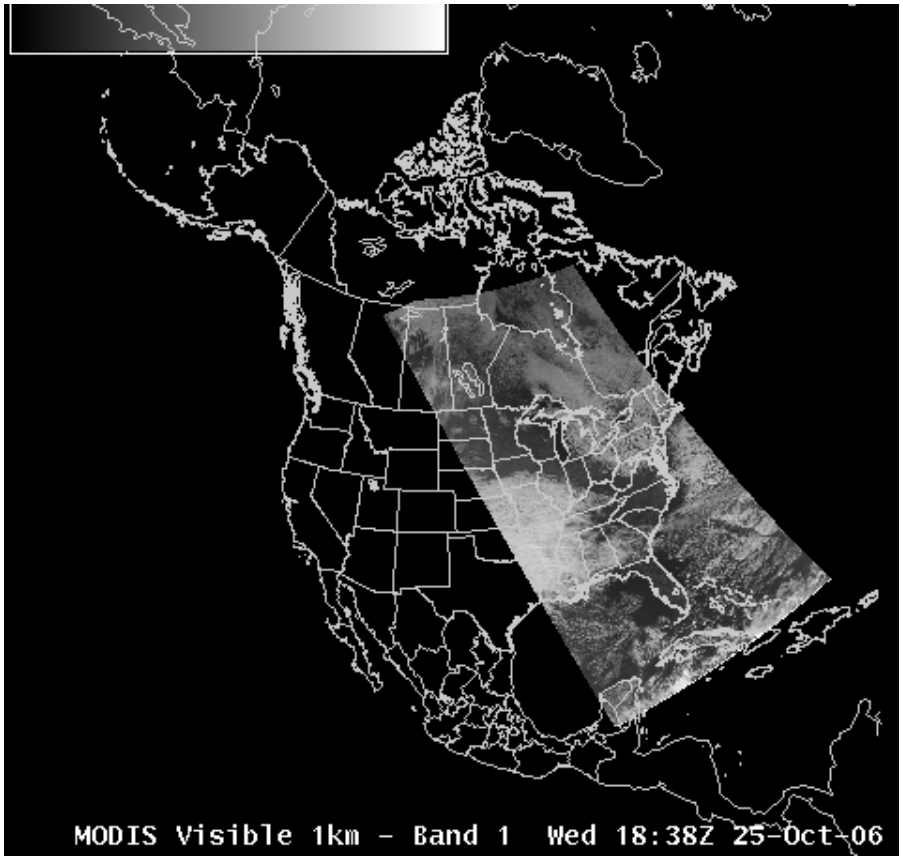
Weather and Forecasting

Complimentary to Geostationary

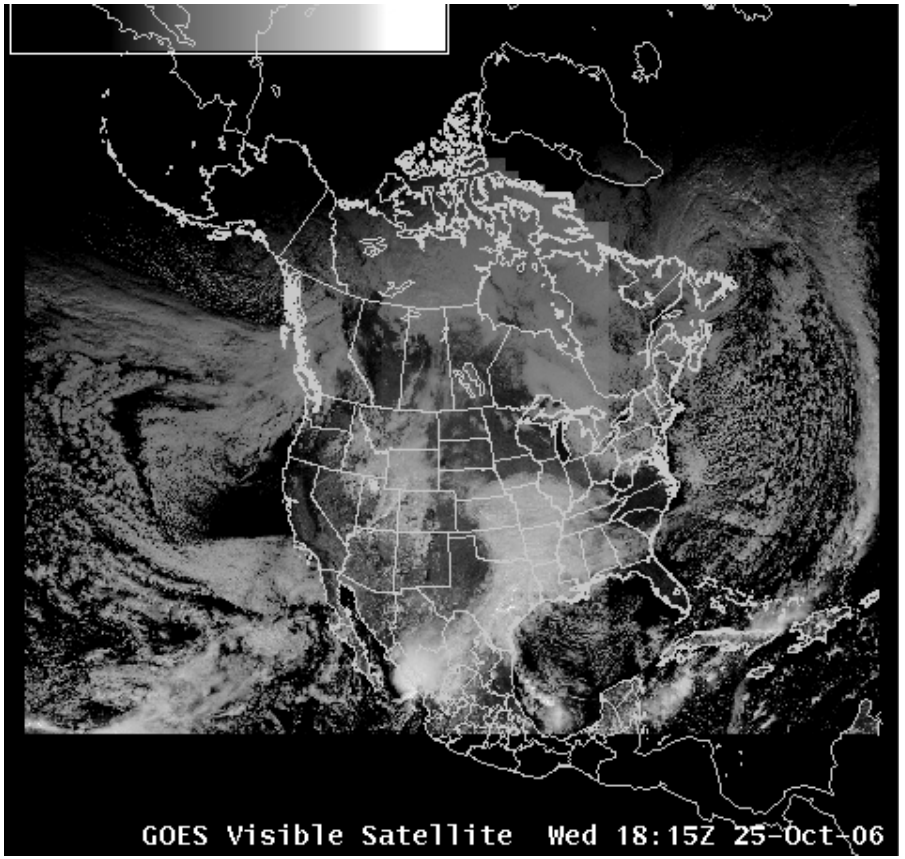
Example of Improved Spatial Resolution

MODIS Imagery in AWIPS

Band 1: Visible channel (0.6µm)



MODIS visible channel



GOES visible channel

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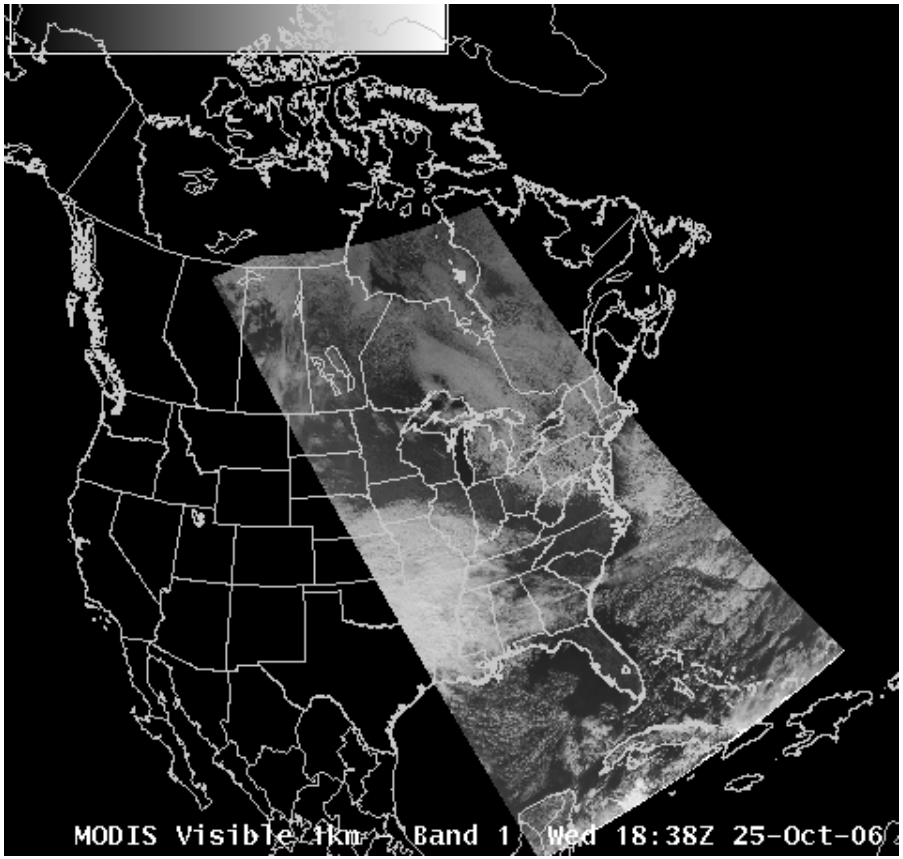
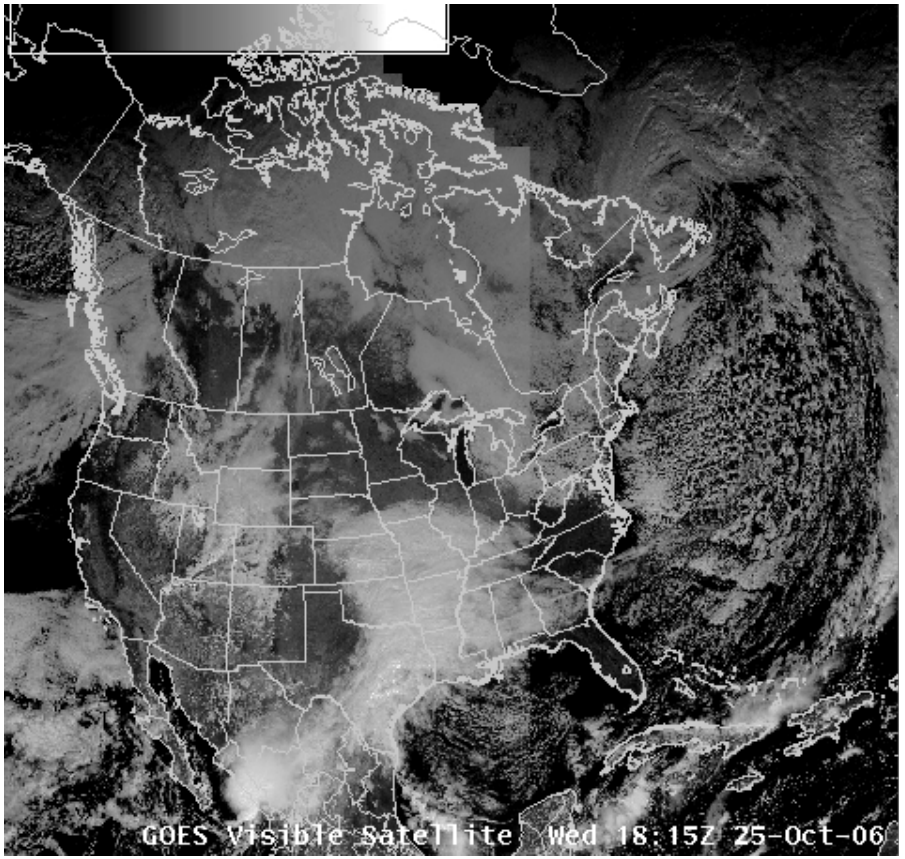


MODIS visible channel



GOES visible channel

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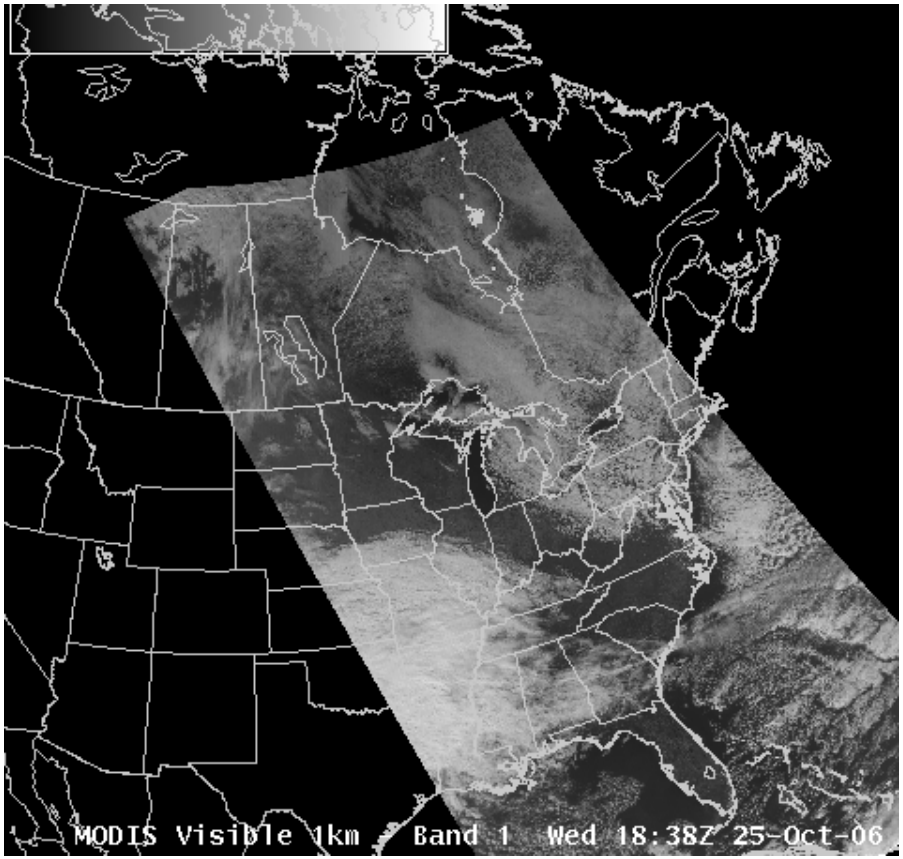

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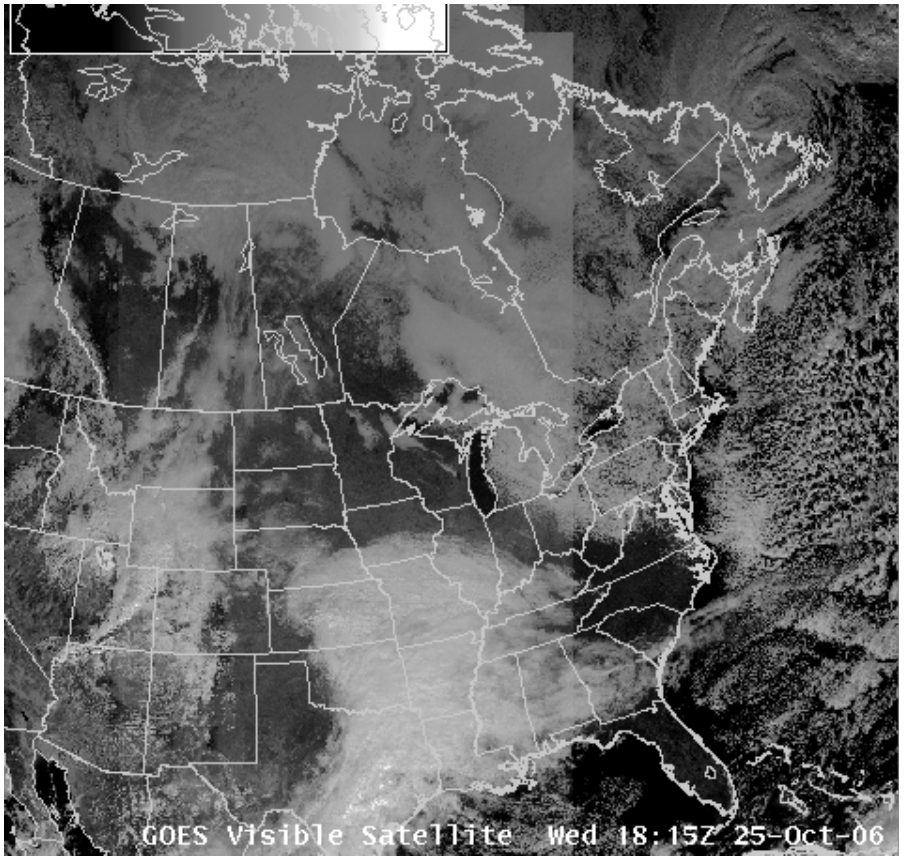

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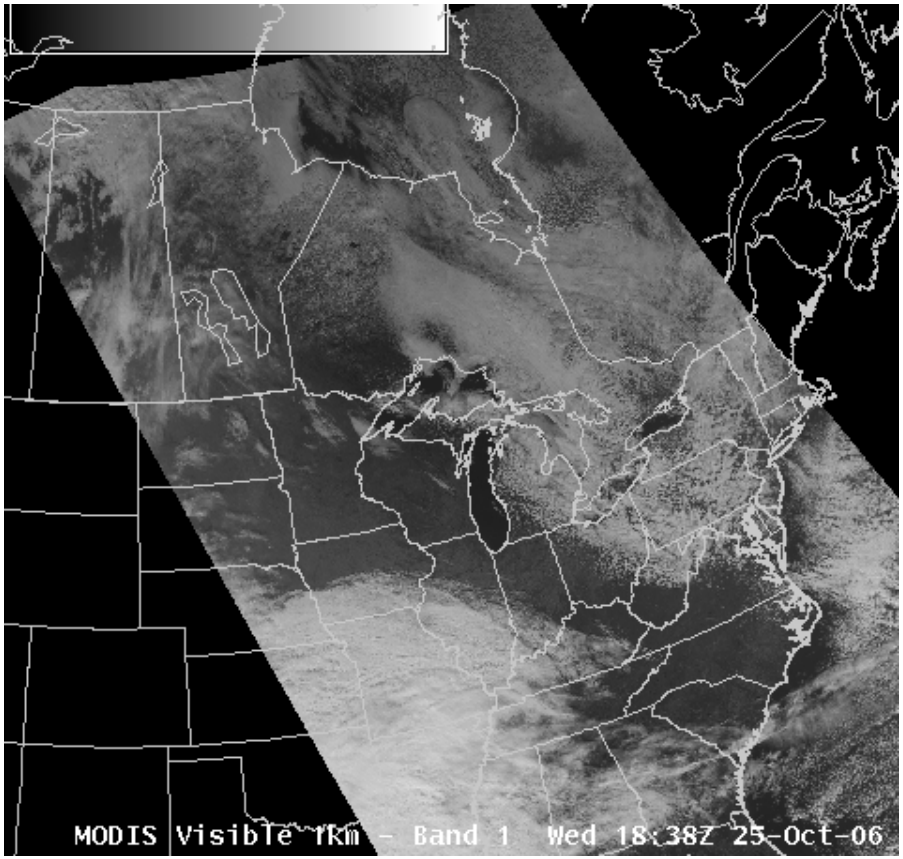

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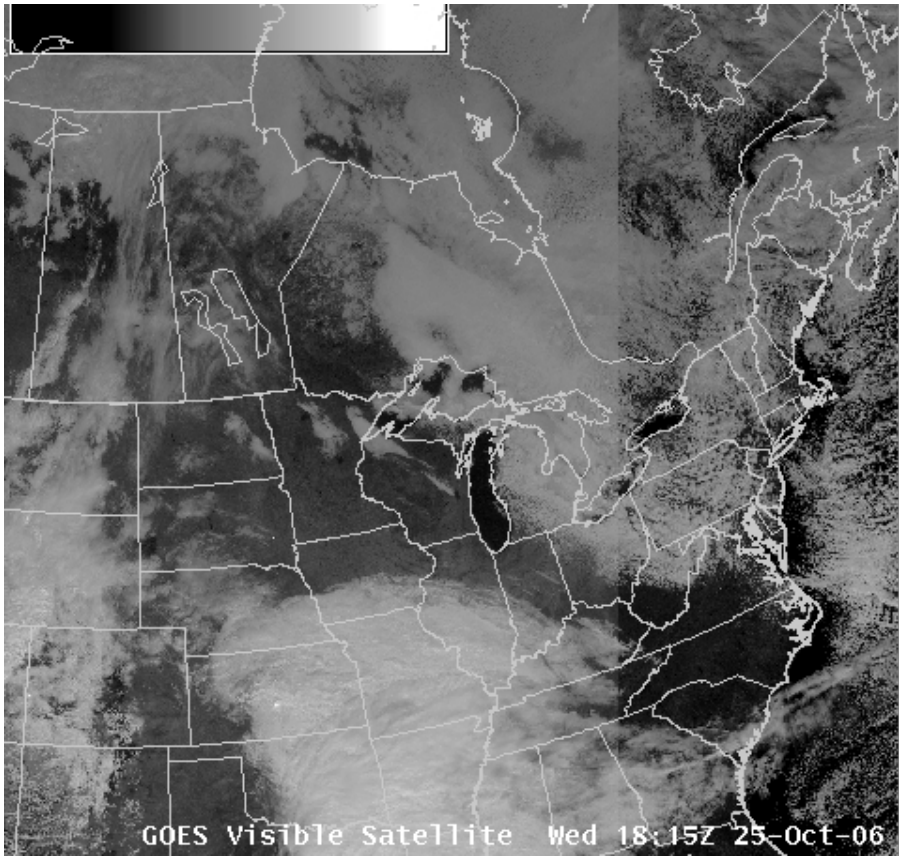

GOES visible channel

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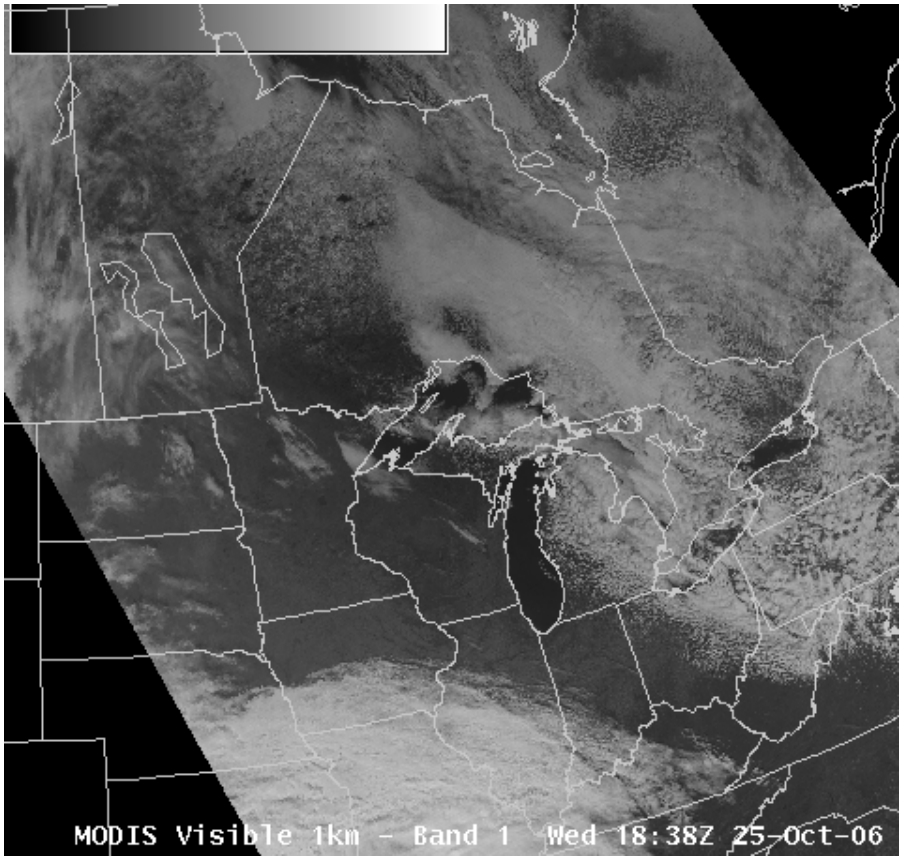
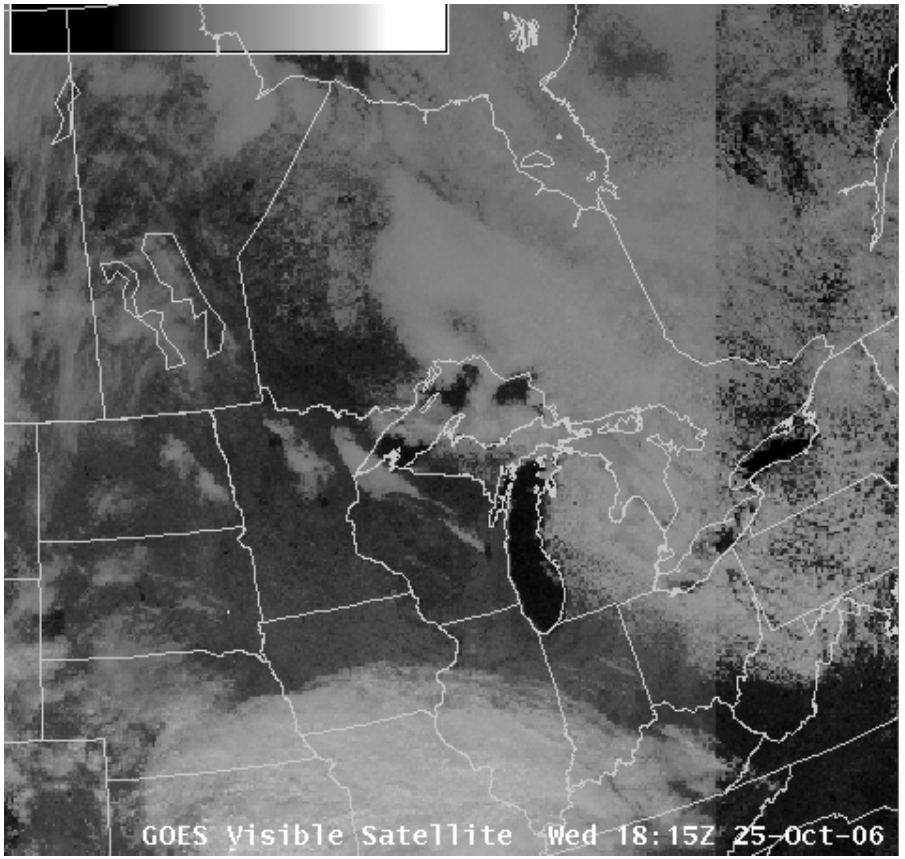


MODIS visible channel



GOES visible channel

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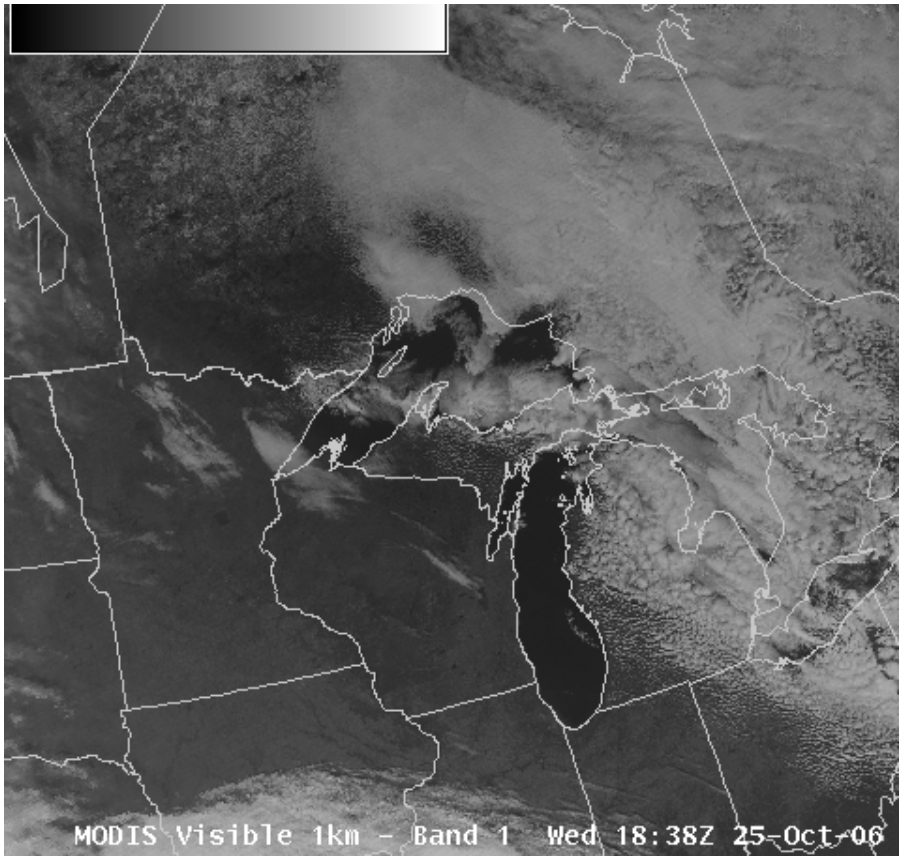
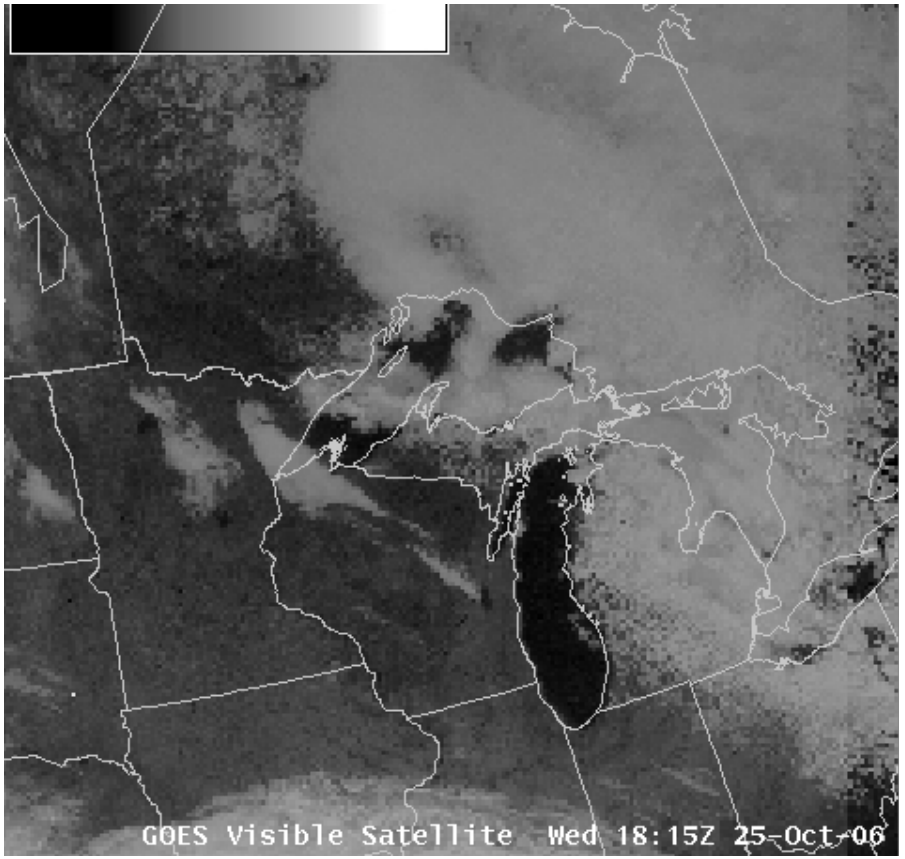


MODIS visible channel



GOES visible channel

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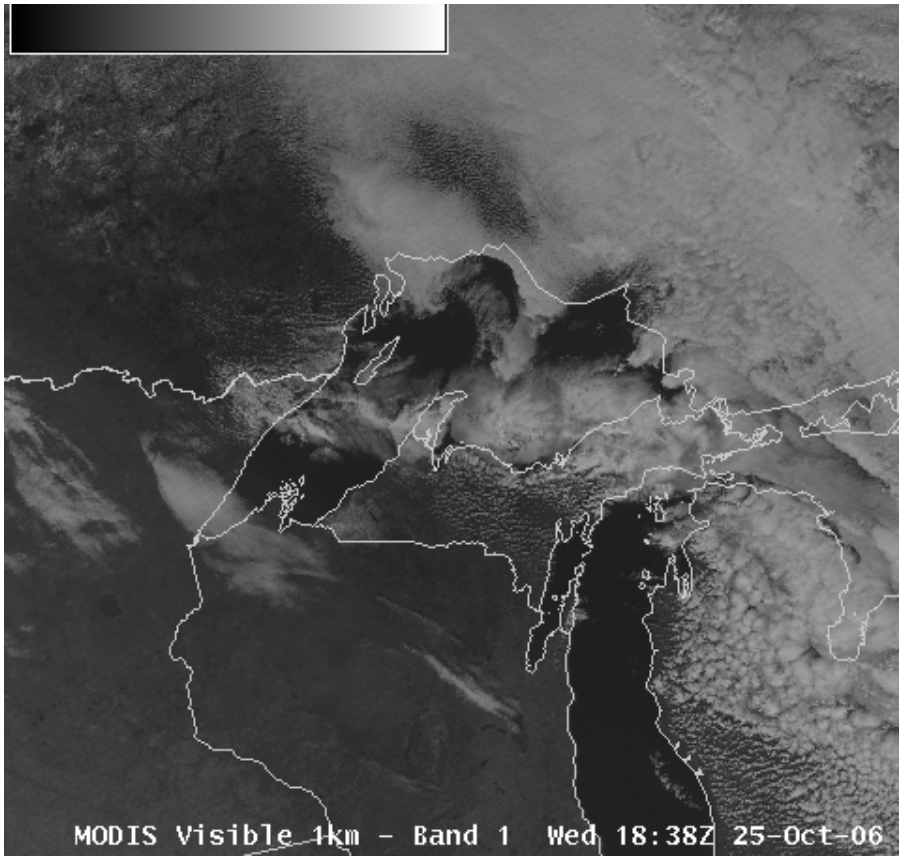
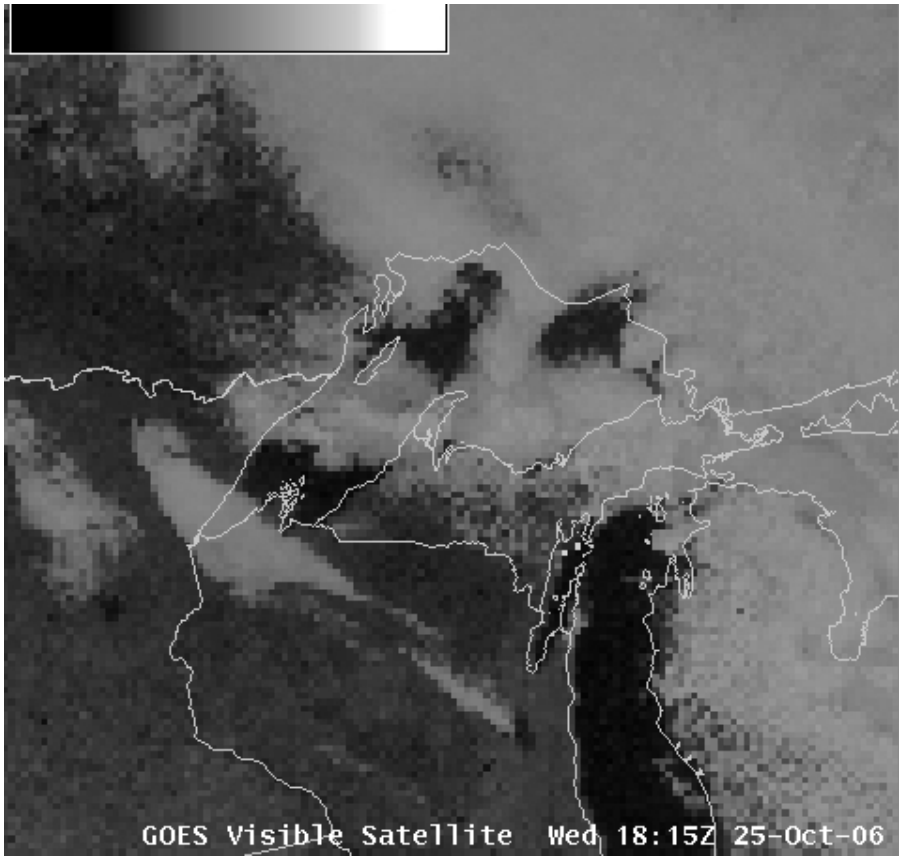


MODIS visible channel



GOES visible channel

MODIS Imagery in AWIPS

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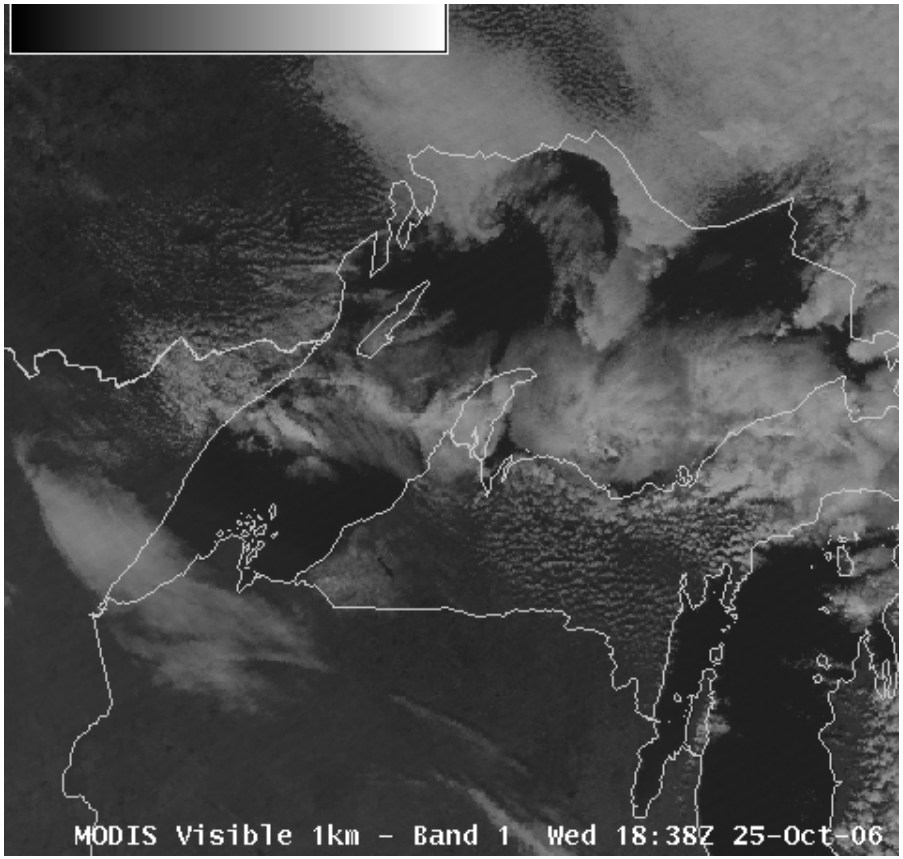
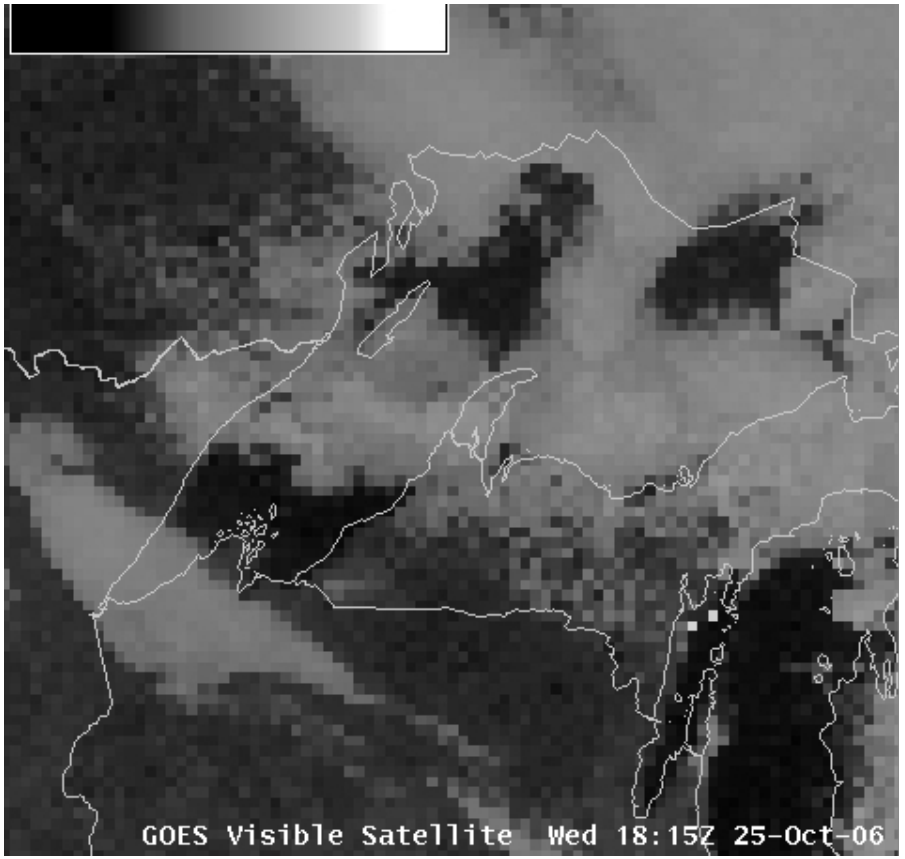
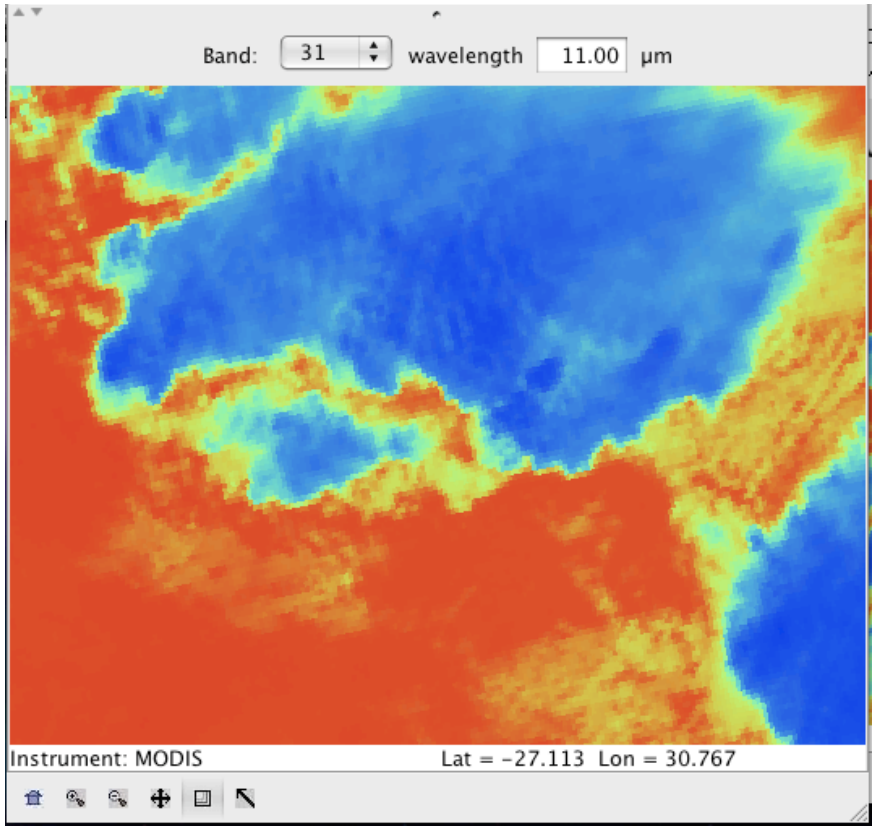


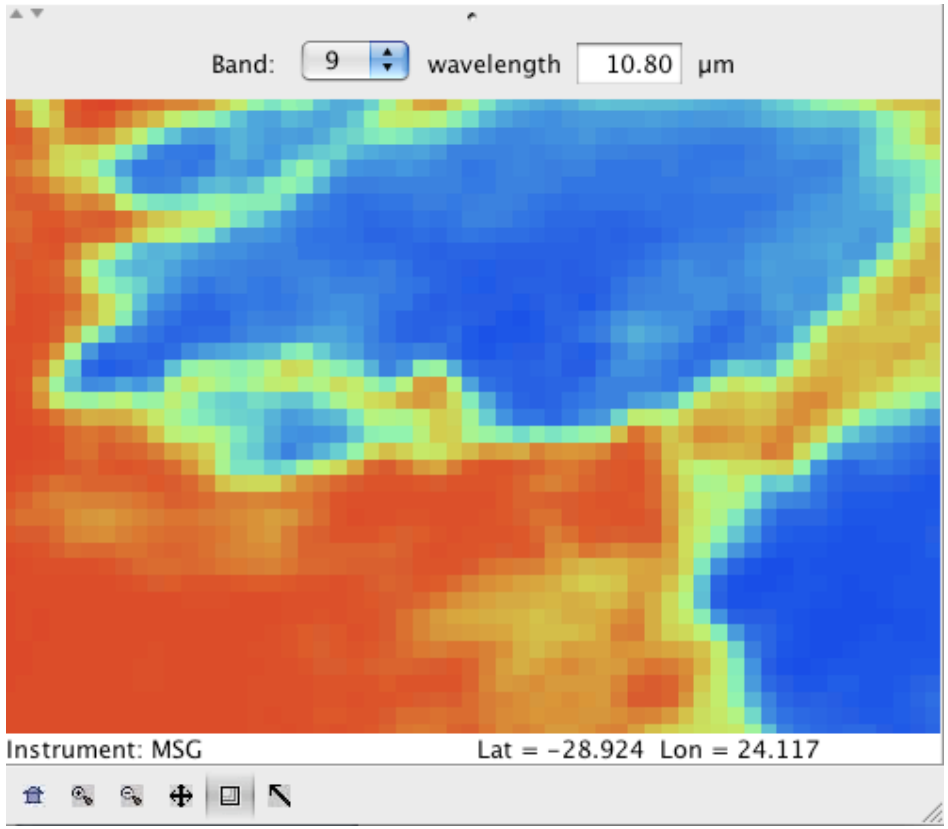
MODIS visible channel



GOES visible channel

MODIS versus SEVIRI





How Important Is Spatial Resolution?

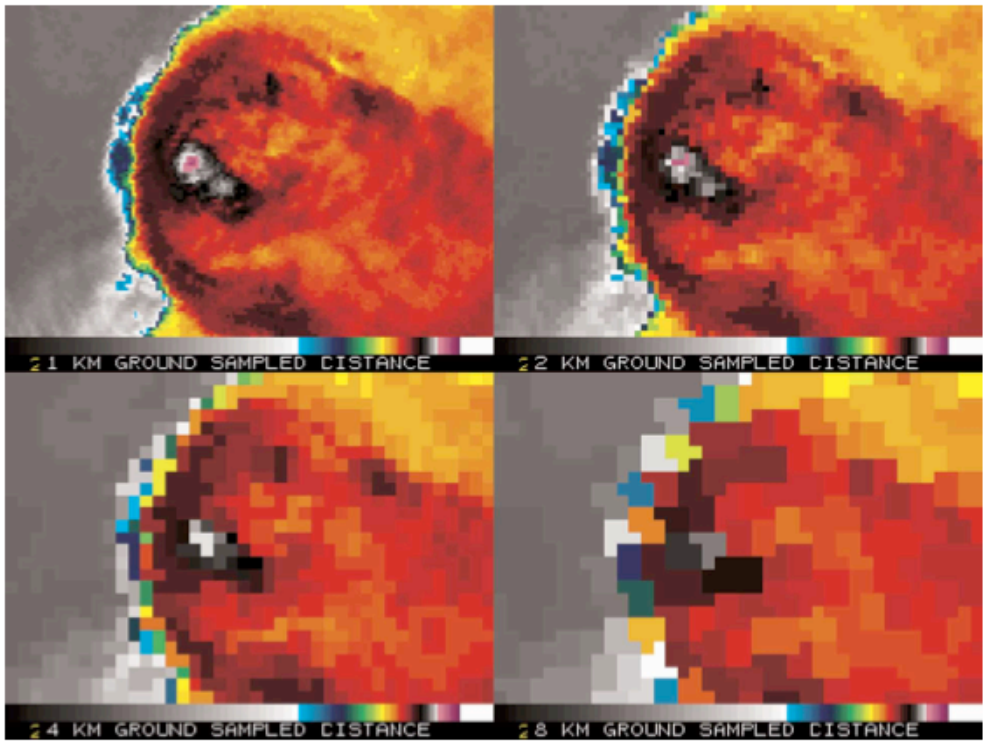


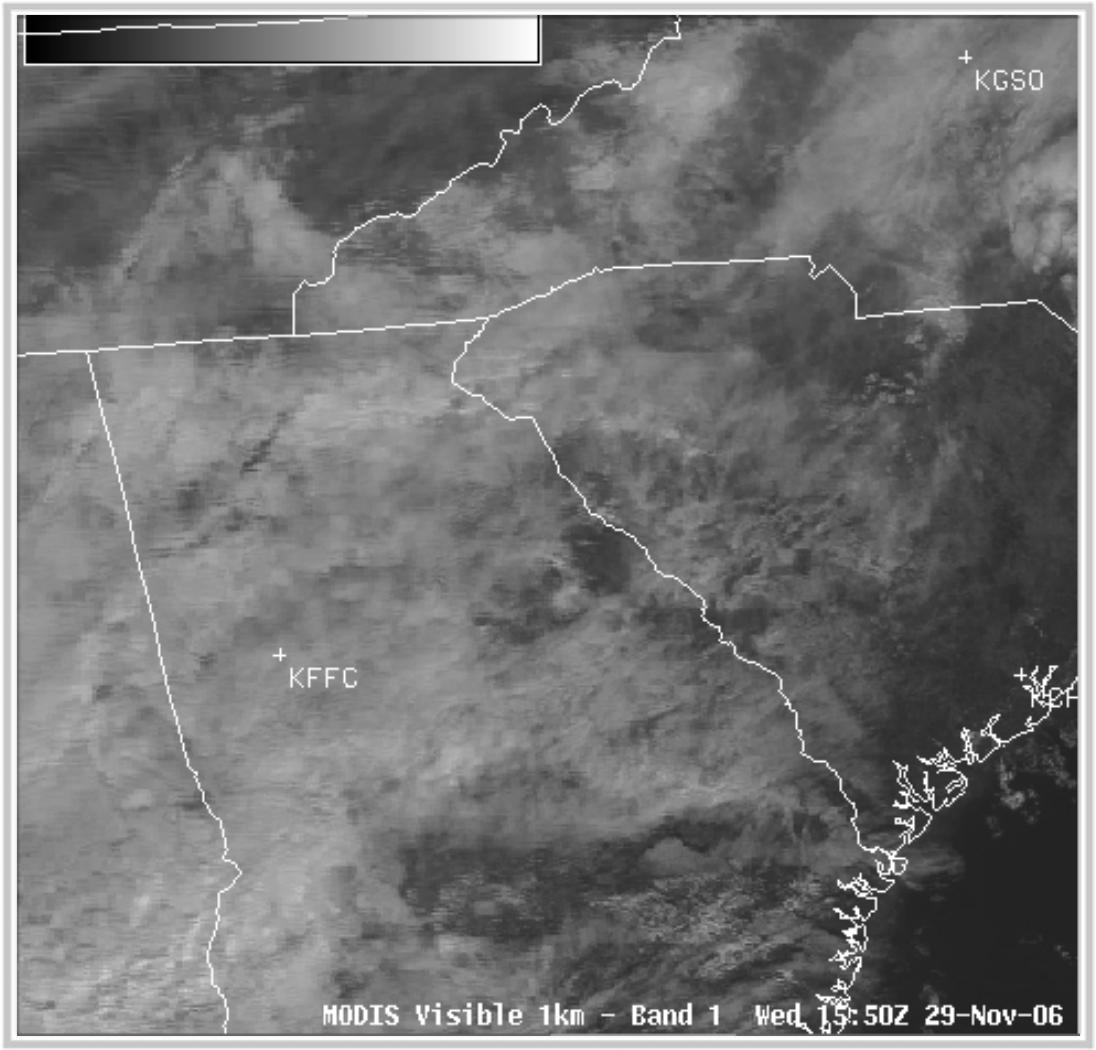
FIG. 3. Zoomed-in image of an enhanced-V feature located over northeast OK observed from enhanced LEO satellite imagery at 2218 UTC 6 May 2003 for 1-, 2-, 4-, and 8-km ground-sampled distances. The purple and white colors in the location of the updraft and overshooting top represent colder BTs, while the surrounding black and red colors represent warmer BTs.

A Quantitative Analysis of the Enhanced-V Feature in Relation to Severe Weather, Jason C. Brunner, Steven A. Ackerman, A. Scott Bachmeier, and Robert M. Rabin. Weather and Forecasting Volume 22, Issue 4 (August 2007) pp. 853–872

Example of Increased Spectral Resolution

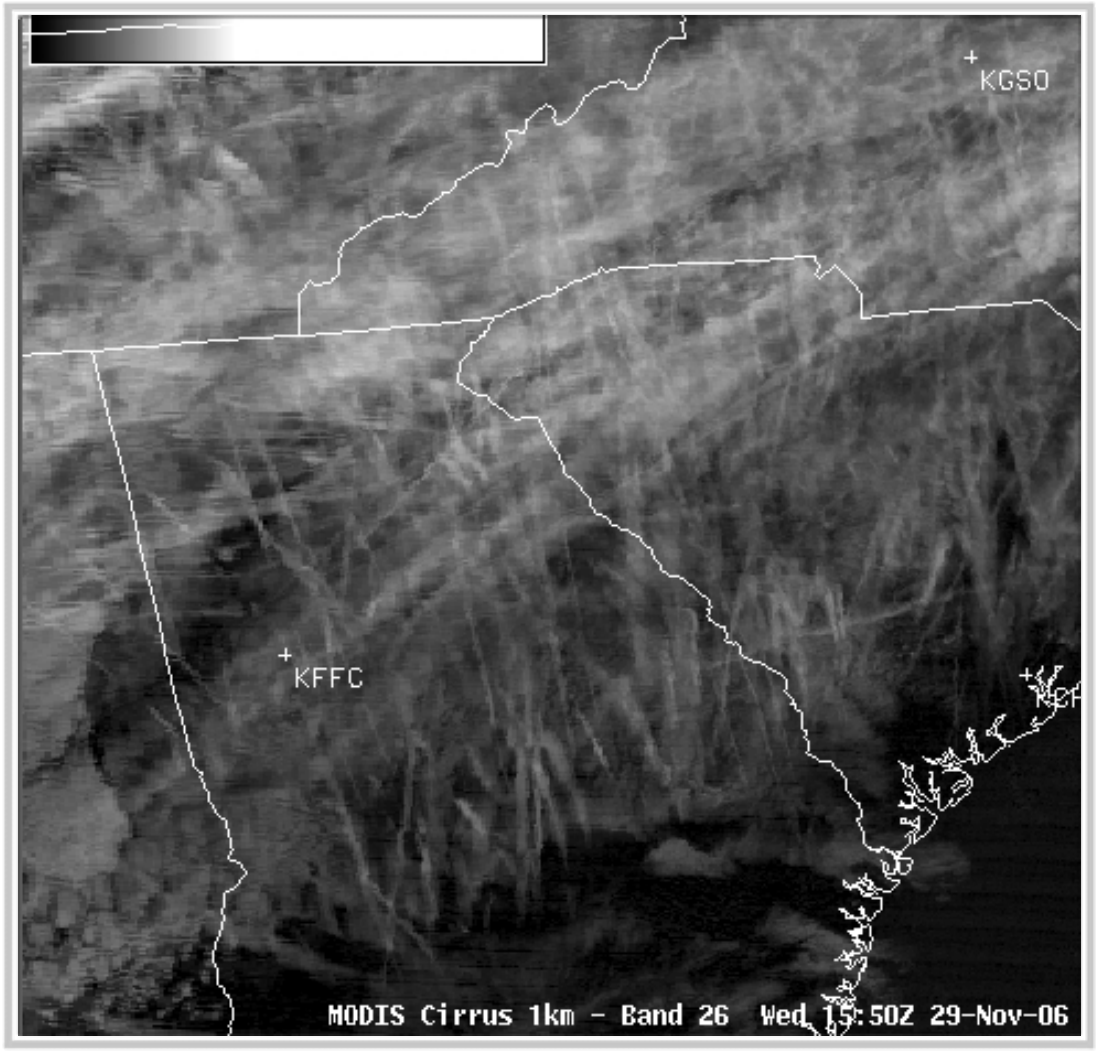
MODIS Imagery in AWIPS

Band 26: Cirrus detection (1.38 µm)



MODIS Imagery in AWIPS

Band 26: Cirrus detection (1.38 µm)

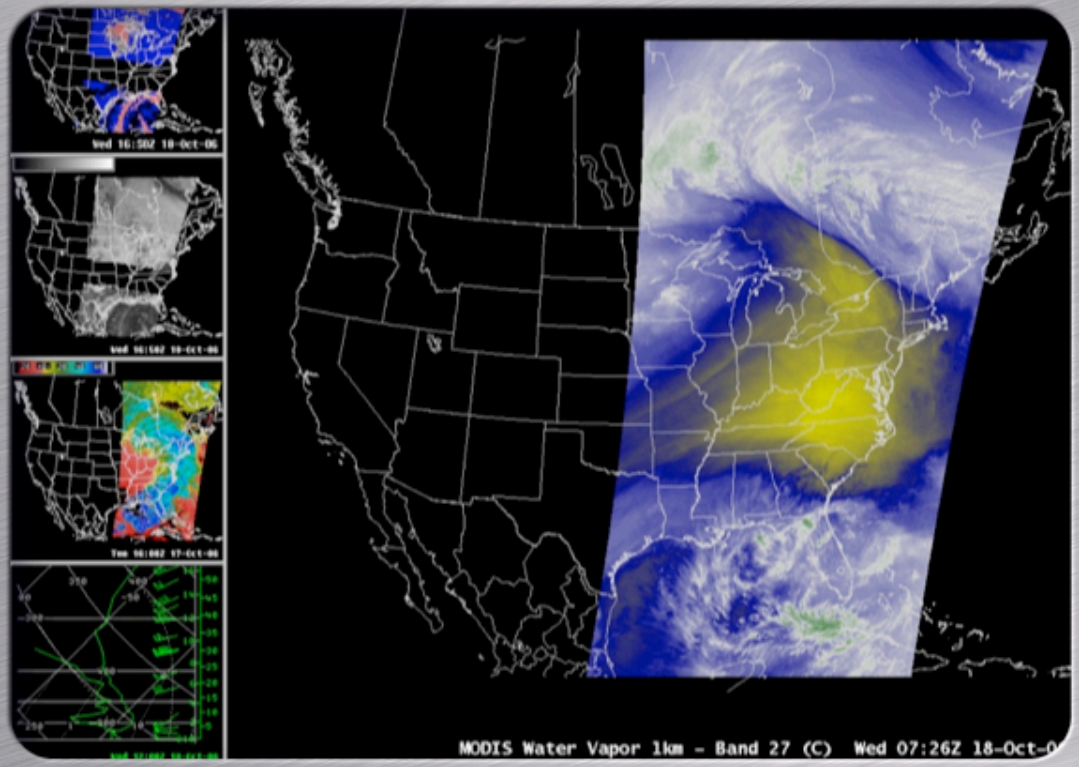


Can Polar Orbiter Data Really Be That Useful to Forecasters?

US National Weather Service

- University of Wisconsin providing Direct Broadcast MODIS products NWS in June 2006
- Reflectances and Brightness Temperatures
  - Bands 1 (.68 µm), Band 26 (1.38 µm), Band 7 (2.1 µm)
  - Band 20 (3.7 µm), Band 27 (6.7 µm), Band 31 (11 µm)
- Products
  - 1 km
    - Sea Surface Temperature, NDVI, Land Surface Temperature, Fog Product
  - 5 km
    - Cloud Top Pressure, Total Precipitable Water, Cloud Phase
- True Color 250 m Imagery

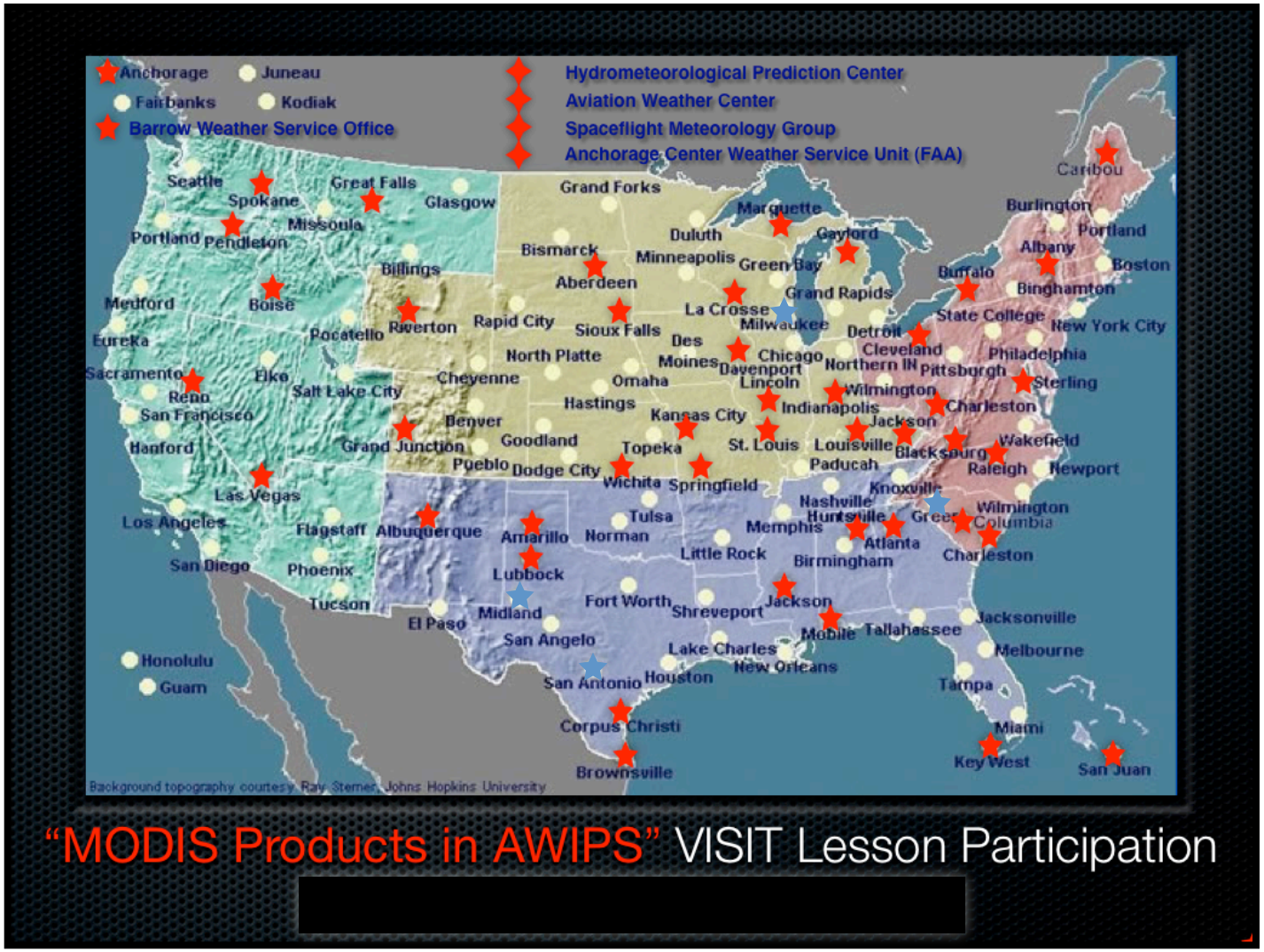
MODIS Products in AWIPS



National Weather Service • Integrated Sensor Training Professional Development Series
Virtual Institute for Satellite Integration Training

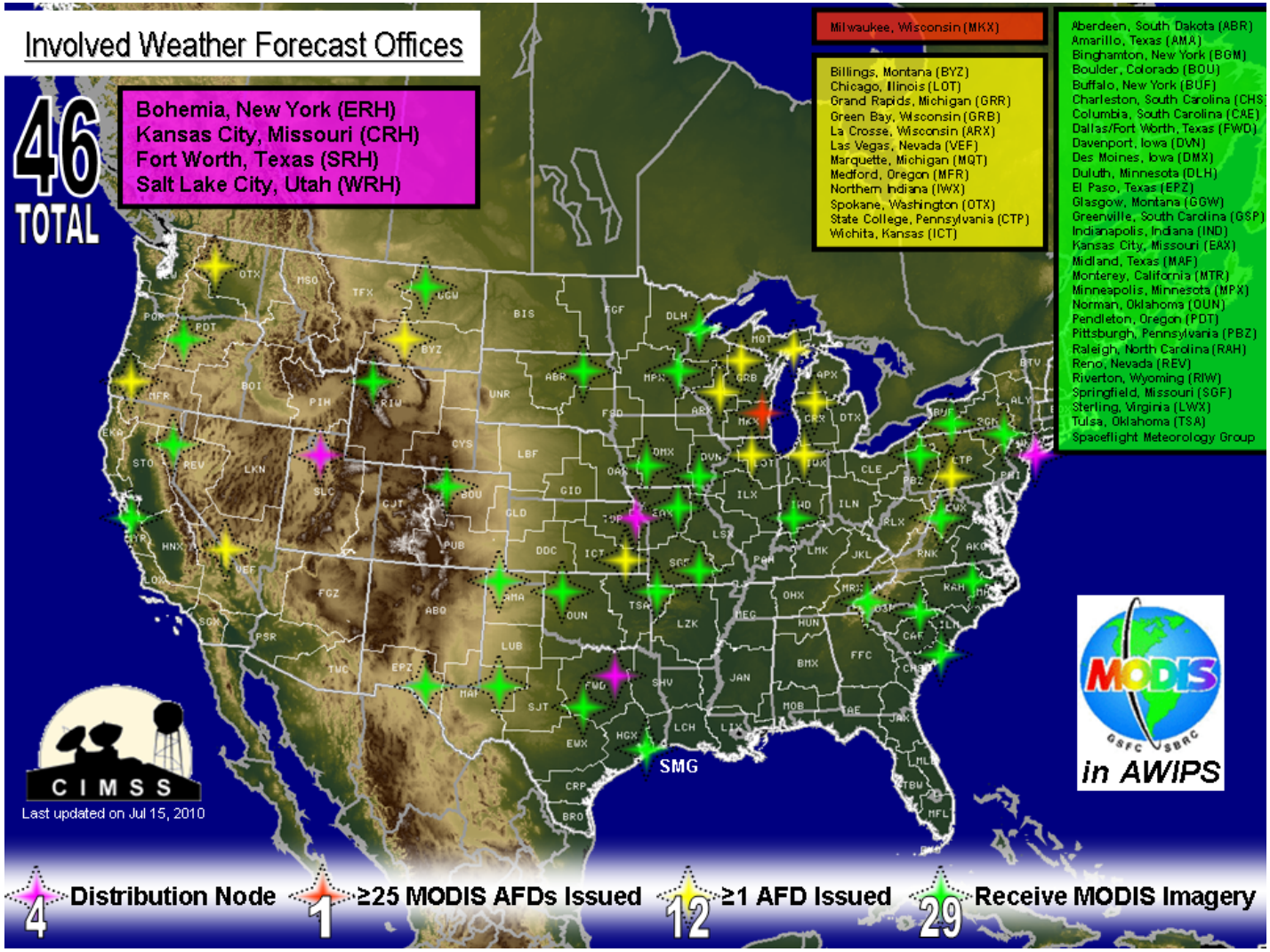
Virtual Institute for Satellite Integration Training (VISIT) lesson - offered since October 2006

MODIS Products in AWIPS

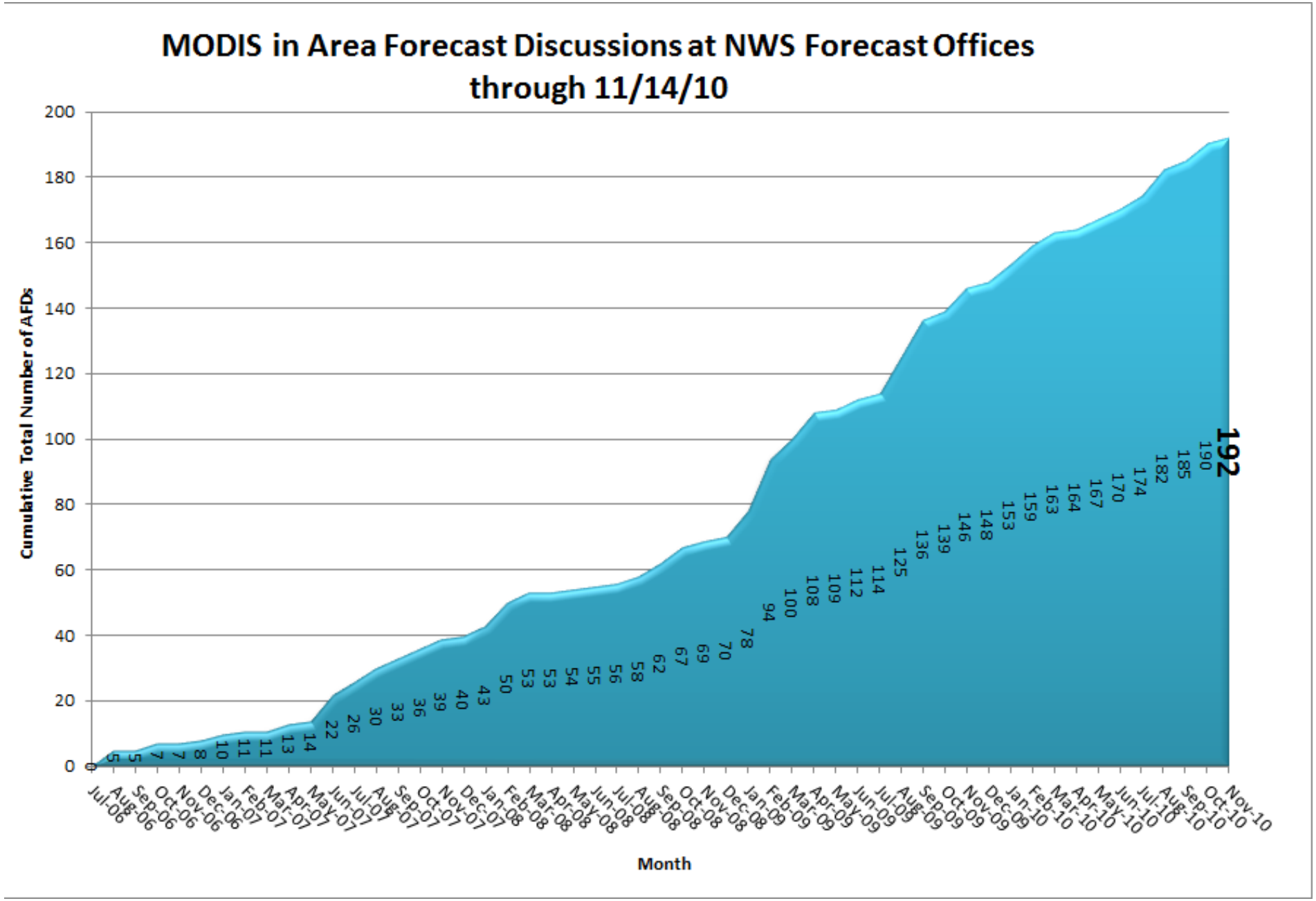


53 NWS forecast offices participating so far

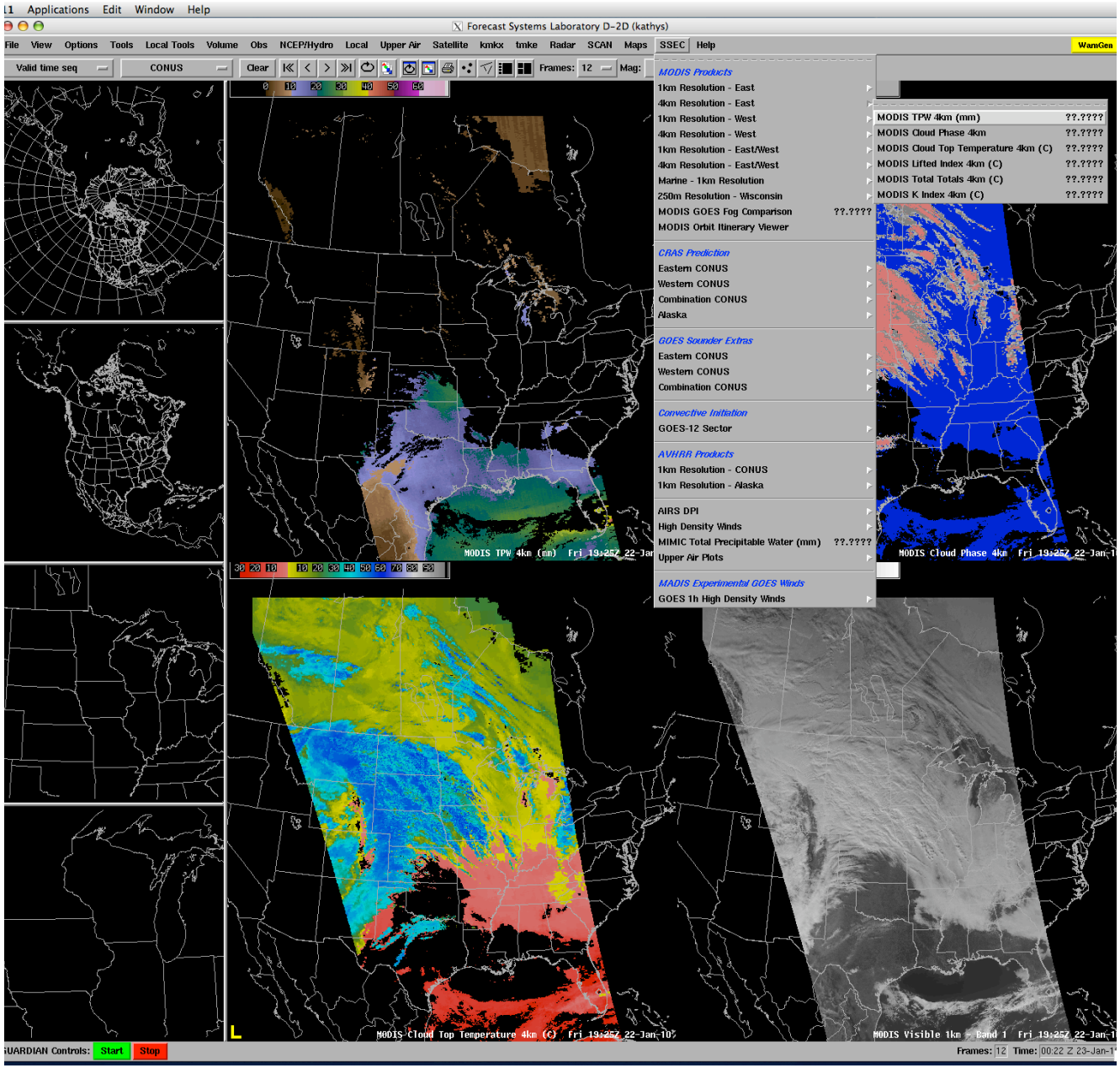
MODIS Products in AWIPS



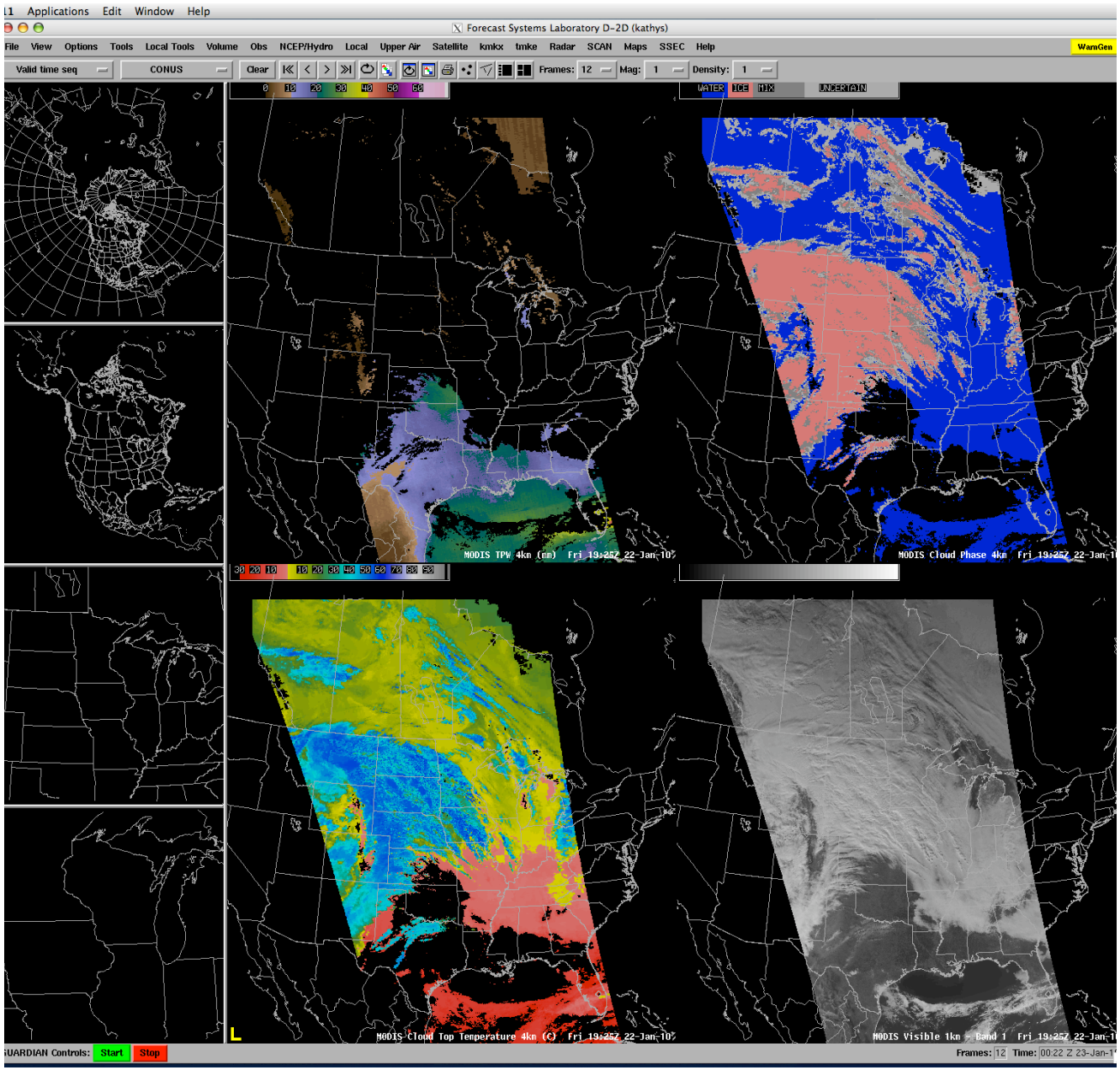
48 NWS forecast offices have added CIMSS MODIS imagery to their local AWIPS


MODIS in Area Forecast Discussions at NWS Forecast Offices through 11/14/10
Cumulative Total Number of AFDs
Month
0
20
40
60
80
100
120
140
160
180
200
0 5 5 7 7 8 10 11 11 13 14 22 26 30 33 36 39 40 43 50 53 53 54 55 56 58 62 67 69 70 78 94 100 108 109 112 114 125 136 139 146 148 153 159 163 164 167 170 174 182 185 190 192
Jul-06 Aug-06 Sep-06 Oct-06 Nov-06 Dec-06 Jan-07 Feb-07 Mar-07 Apr-07 May-07 Jun-07 Jul-07 Aug-07 Sep-07 Oct-07 Nov-07 Dec-07 Jan-08 Feb-08 Mar-08 Apr-08 May-08 Jun-08 Jul-08 Aug-08 Sep-08 Oct-08 Nov-08 Dec-08 Jan-09 Feb-09 Mar-09 Apr-09 May-09 Jun-09 Jul-09 Aug-09 Sep-09 Oct-09 Nov-09 Dec-09 Jan-10 Feb-10 Mar-10 Apr-10 May-10 Jun-10 Jul-10 Aug-10 Sep-10 Oct-10 Nov-10

MODIS Supports Operational Forecasters



MODIS Supports Operational Forecasters



MODIS Products in AWIPS

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE RENO NV
337 AM PST TUE NOV 4 2008

ANOTHER BIG STORY WITH THIS LOW HAS BEEN THE WINDS WITH MANYLOCATIONS REMAINING QUITE WINDY OVERNIGHT AS THE COLD FRONTPASSED. HIGH RES MODIS WATER VAPOR IMAGERY SHOWS GOOD MOUNTAIN WAVE ACTIVITY ALONG THE SIERRA AS THE SUPPRESSED TROPOPAUSE MOVED THROUGH OVERNIGHT. THIS UPPER FEATURE LIKELY HELPED TO DUCT STRONGER WINDS ALOFT DOWN TO THE SURFACE IN THE STABLE PRE-FRONTAL ENVIRONMENT SOUTH OF THE RENO AND TAHOE AREAS.

MODIS Products in AWIPS

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE MILWAUKEE / SULLIVAN WI
436 AM CDT WED JUL 16 2008

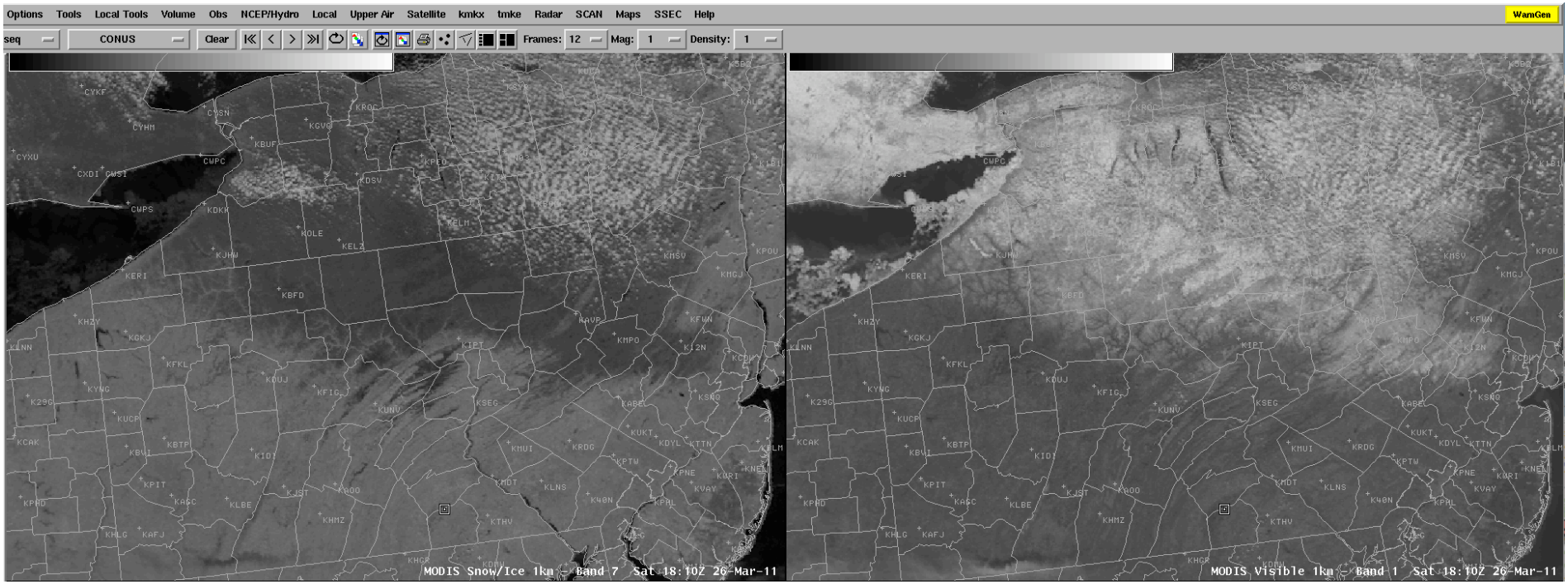
WEAK BOUNDARY VCNTY OF KMTW EXPCD TO SAG SLOWLY SOUTHWARD
THIS MORNING WITH LIGHT SOUTHWEST WINDS BECOMING NORTHEAST
AND THEN SOUTHEAST. WIND SPEEDS SHOULD BE MOSTLY LIGHT...LESS
THAN 10 KNOTS...HOWEVER BRIEF GUSTINESS POSSIBLE AS BOUNDARY
MOVES THROUGH. PER LATEST MODIS SST IMAGES...NEARSHORE HAS
WARMED SEVERAL DEGREES FROM EARLIER UPWELLING EPISODE...NOW
GENERALLY IN THE LOWER TO MIDDLE 50S. WITH INLAND DEWPOINTS
IN THE MIDDLE 60S...WILL NEED TO WATCH FOR PATCHY FOG AS WINDS
TURN ONSHORE.

MODIS has been mentioned in >200 NWS Area Forecast Discussions so far

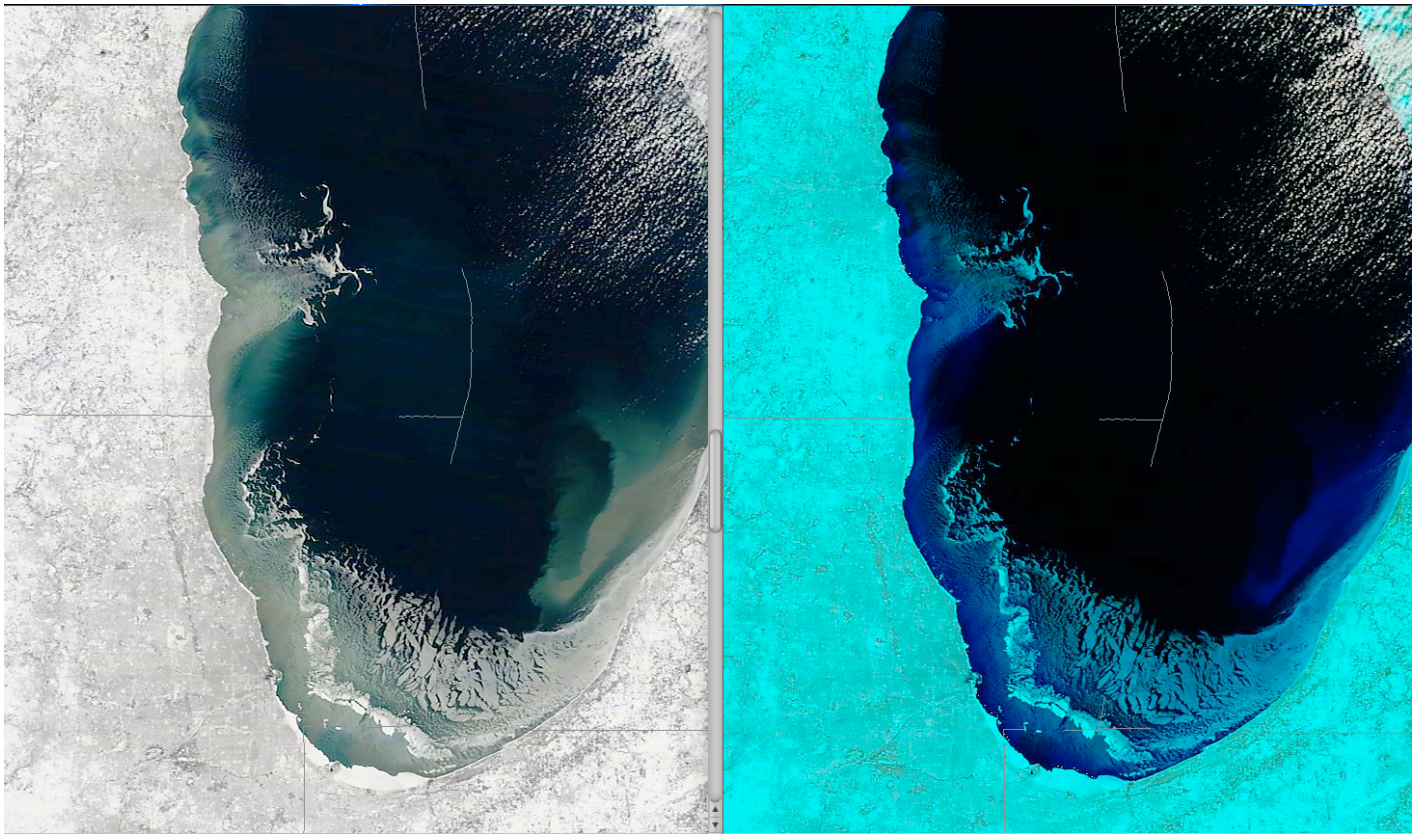
Forecasting Low Temperatures

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE STATE COLLEGE PA
442 AM EDT SUN MAR 27 2011

.SHORT TERM /6 PM THIS EVENING THROUGH 6 PM MONDAY/...ANOTHER VERY CHILLY NIGHT IN STORE FOR THE REGION WITH MINS ARND 15F BLW NORMAL. RIDGE OF HIGH PRESSURE WILL PROVIDE THE CLEARSKIES...*LGT WINDS AND DRY AIR TO ALLOW FOR GOOD RADIATIONAL COOLING. LOWS SHOULD RANGE FROM THE SINGLE DIGITS ACROSS THE SNOW COVERED N MTNS /MODIS BAND 7 IMAGERY SHOWS EXTENT OF SNOW COVER BEAUTIFULLY/*...TO ARND 20F IN THE SOUTH.



Waterway Navigation



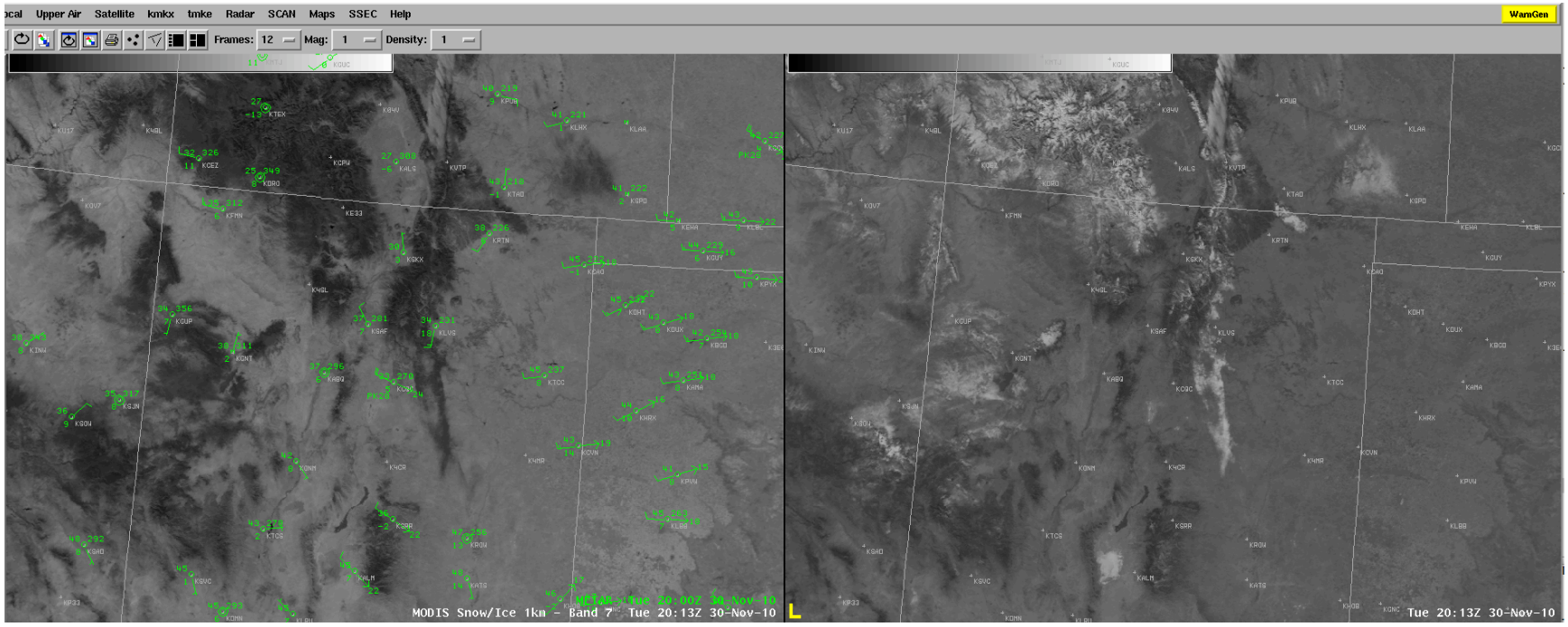
AREA FORECAST DISCUSSION NATIONAL WEATHER SERVICE MILWAUKEE/SULLIVAN WI 330 AM CST SAT FEB 5 2011

MARINE...WEST WINDS TO REMAIN BELOW SMALL CRAFT ADVISORY CRITERIA AS WEAK LOW PRESSURE MOVES INTO THE SOUTHERN LAKE MICHIGAN REGION. ***FALSE COLOR MODIS IMAGERY WHICH SHOWS ICE/SNOW VS WATER INDICATES ICE COVERAGE OVER LAKE MICHIGAN IS NOT AS EXTENSIVE AS THE VISIBLE IMAGERY WOULD SUGGEST. SOME OF THIS COULD BE SLUSHY ICE OR POSSIBLY MORE OF A TURBIDITY DIFFERENCE WITH THE PRIOR BRISKWINDS.***

Assessing Fire Danger

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE ALBUQUERQUE NM
300 AM MST WED DEC 1 2010

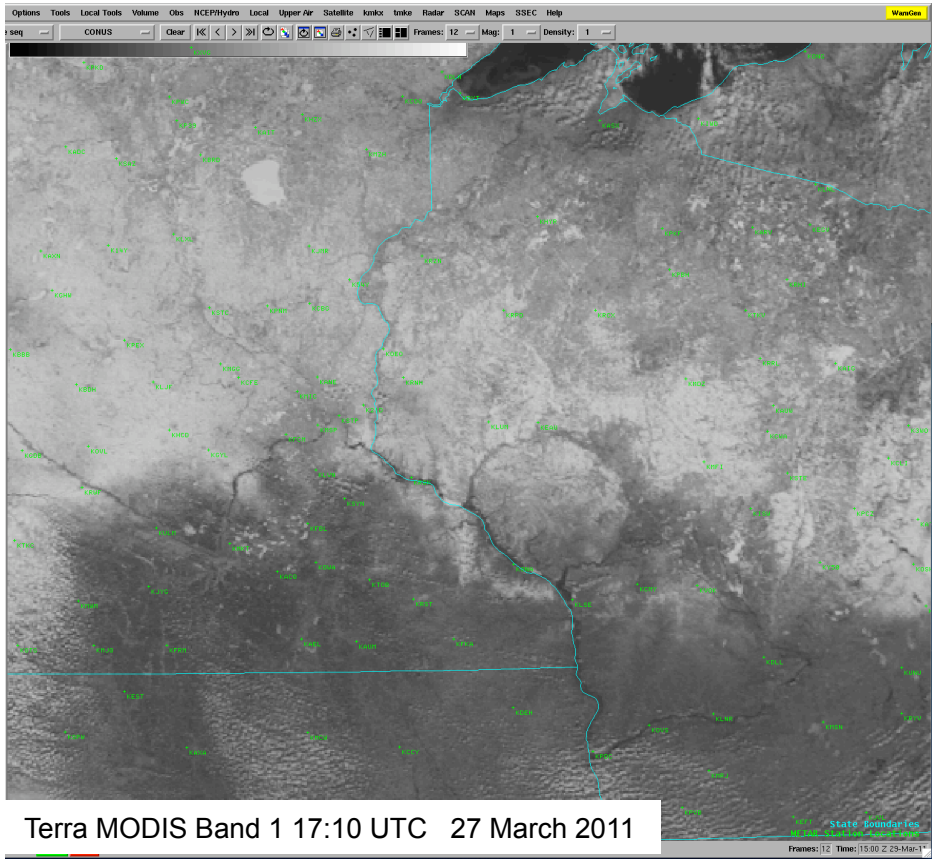
.FIRE WEATHER...ONLY MINOR CHANGES TO OVERALL FORECAST THROUGH THE WEEKEND. A 1016MB LEE TROUGH OVER THE PLAINS HAS ALLOWED WESTERLY DOWNSLOPE WINDS TO DOMINATE THE AREA...THUS TEMPS ARE MUCH WARMER AND WINDS SLIGHTLY BREEZIER. AN ISOLATED AREA OF MARGINAL CRITICAL FIRE WX CONDITIONS WILL DEVELOP BTWN CLINES CORNERS...VAUGHN...SANTA ROSA...AND LAS VEGAS BY LATE THIS MORNING HOWEVER NO FIRE WX HIGHLIGHTS WILL BE ISSUED. ***MELTING SNOWPACK EVIDENT ON THE 2013Z MODIS 1KM VISIBLE IMAGERY TUESDAY IN NEARLY THE EXACT SAME AREA WILL MITIGATE SURFACE FUEL DRYNESS.*** MIN RH VALUES WILL RANGE FROM 20-25 PCT ALONG THE COLORADO BORDER TO 10-15 PCT ACROSS THE SOUTH. VENT RATES TODAY WILL BE POOR MOST AREAS EXCEPT ALONG THE EAST SLOPES WHERE FAIR VALUES ARE EXPECTED.

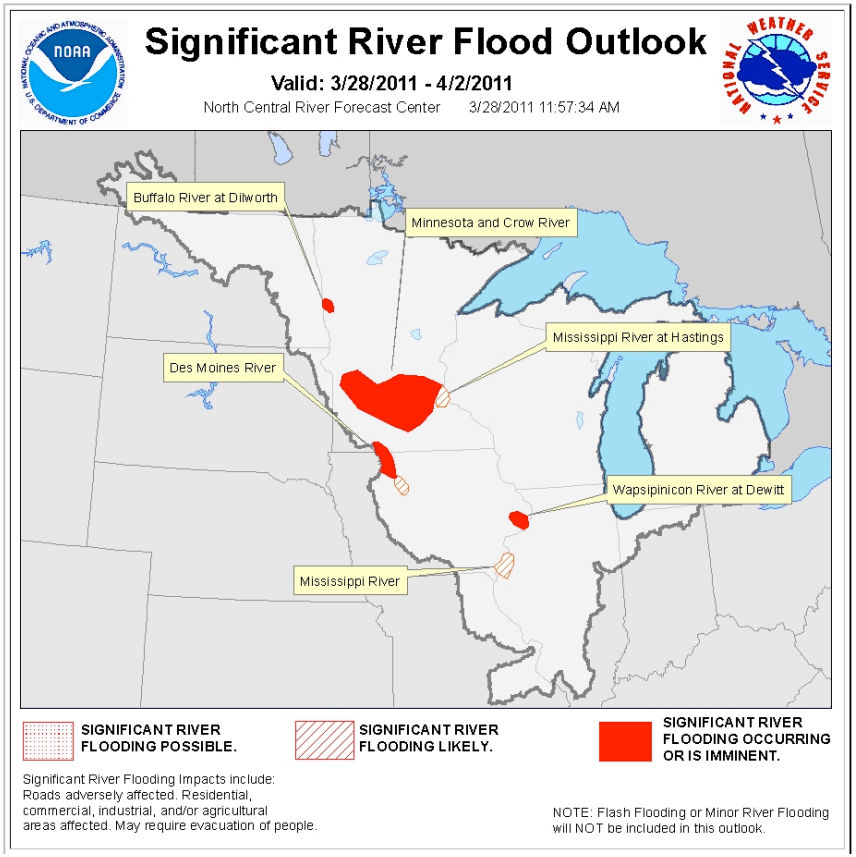


Flood Forecasting

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE TWIN CITIES/CHANHASSEN MN
422 AM CDT TUE MAR 29 2011

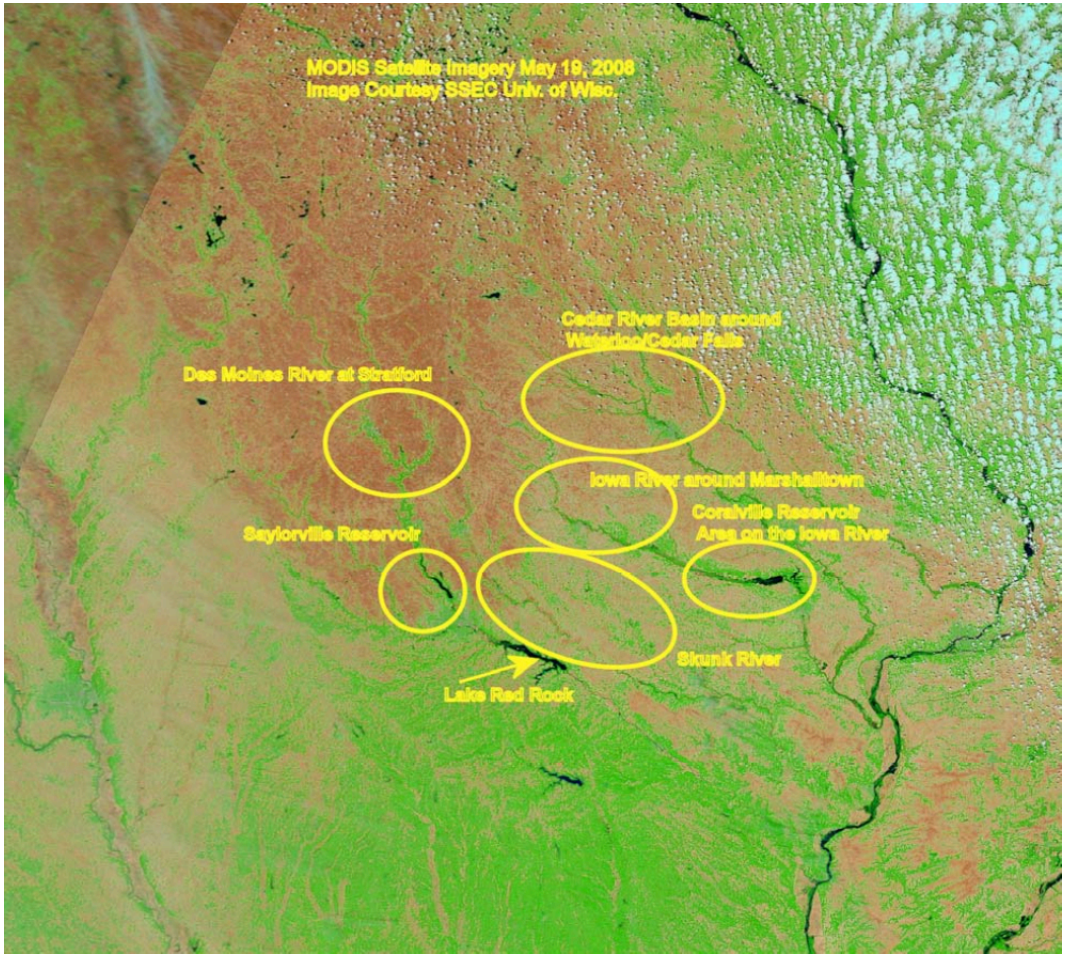
HYDROLOGY...MODIS SATELLITE PASSES OVER THE PAST COUPLE DAYS SHOW LITTLE SNOW COVER IN SOUTHERN MN...SOUTH OF THE MINNESOTA RIVER. THE EXCEPTIONIS IN THE MINNESOTA RIVER VALLEY NORTHEAST OF A LINE FROM NEW ULM TO PIPESTONE...WHERE THE EFFECT OF LAST WEEKS SNOWFALL IS STILL QUITE EVIDENT. **LATEST NOHRSC 48-HR CHANGE IN SNOW WATER EQUIVALENT SHOWS BETWEEN A TRACE AND 0.20 INCH LOSS SINCE SATURDAY ACROSS ALLOF MN AND WI...DESPITE WELL BELOW NORMAL TEMPERATURES - THE LATE MARCH SUNSHINE IS PLAYING A ROLE IN THIS SLOW MELT…**





Flooding Extent

MODIS Flooding Imagery Comparison Between May 19 and June 10, 2008 Across Iowa from NWS Des Moines



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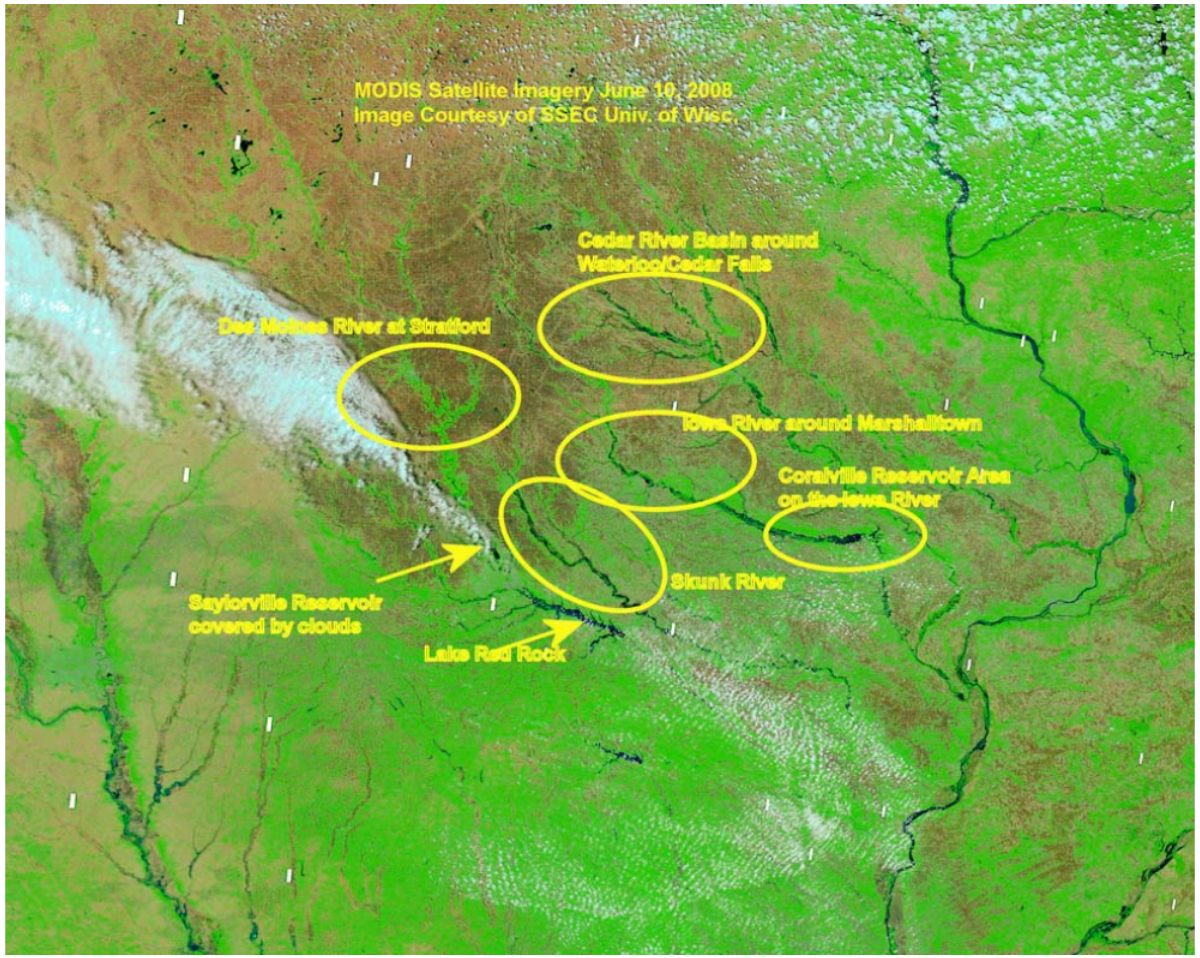
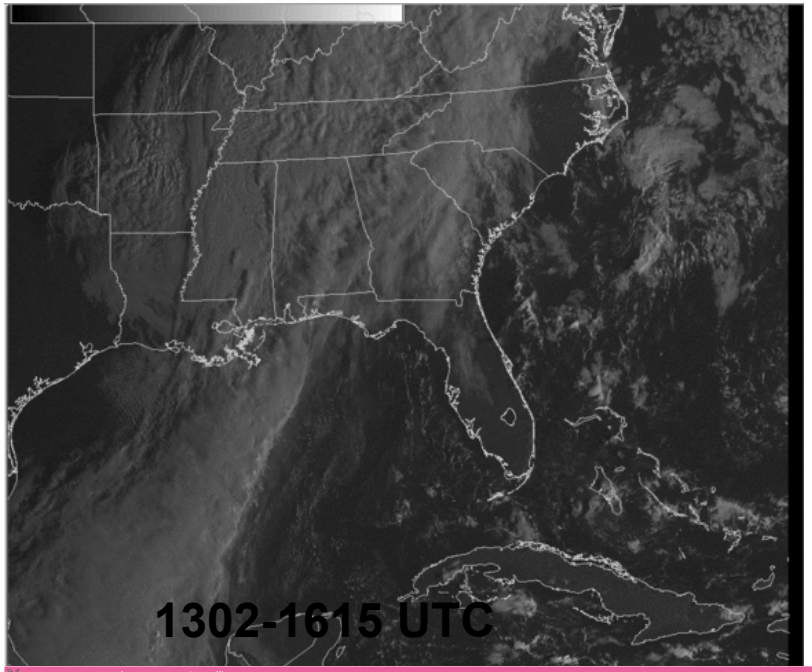
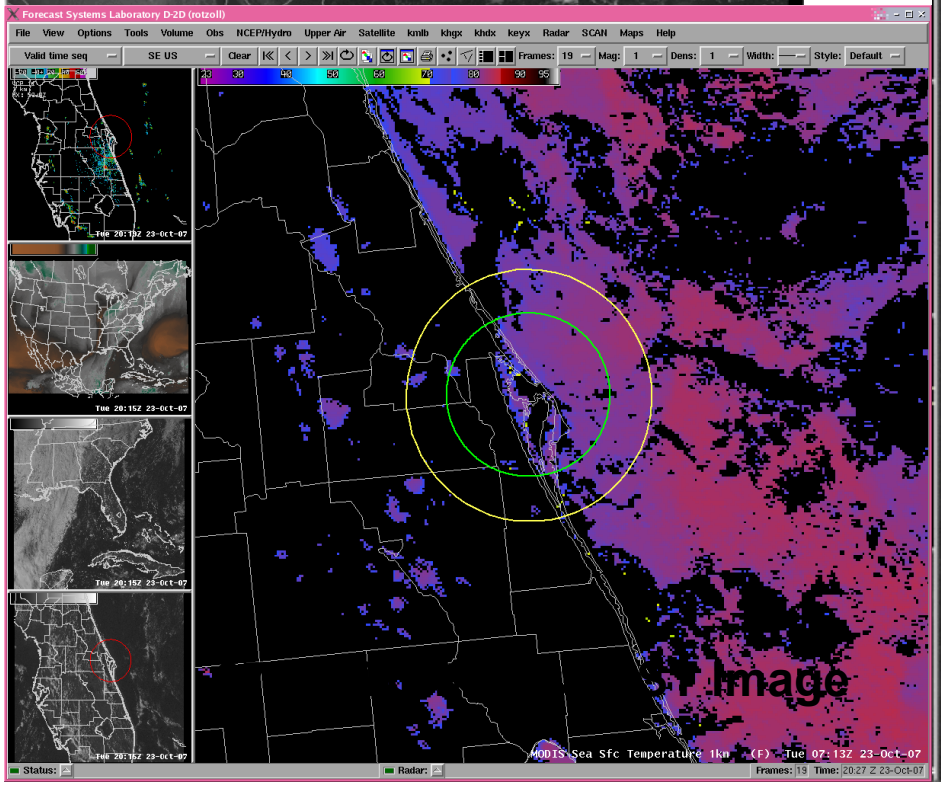
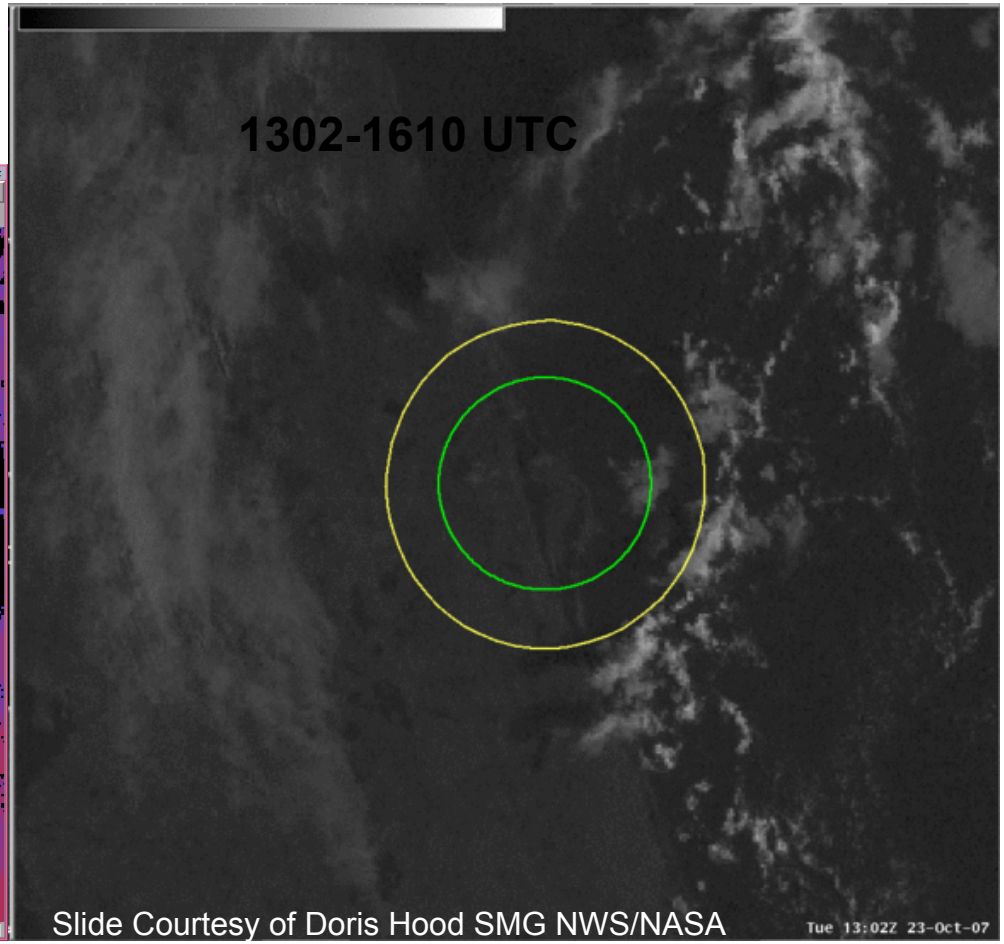


Support for Space Shuttle Launch Oct 23, 2007 1038 am CDT







How to Create Useful Products For End User

- Products that need to be cloud cleared
  - Land Surface Temperature, Simplified NDVI and EVI, IMAPP SST
  - Cloud Mask Bits must be extracted
- To remove the bow-tie effect, reprojection is required
- Some products require scaling:
  - Must use scale/add offset to unpack values

Applying Cloud Mask

- Steps to apply cloud mask:

  1). Read cloud mask

  48 bits per pixel (6 bytes)

  Bits 1-3 provide pixel cloud mask

  2). Extract bits - right justified

  Bit 0 Cloud mask determined 0=not determined

  1=determined

  Bits 1-2 Cloud mask confidence 00=cloudy

  01=uncertain

  11=probably clear

  10=confident

.

Applying Cloud Mask

3). Read other relevant bits cloud mask

1st byte contains processing path information

Bit 3	Day/Night Flag	0=Night/1=Day
Bit 4	Sun glint flag	0=Yes/1=No
Bit 5	Snow/Ice Background	0=Yes/no
Bits 6-7	Land/water Flag	00=Water
		01=Coast
		11=Desert
		10=Land

Applying Cloud Mask

4). Apply Mask:

SST – land, desert, snow/ice free, clouds (confident and probably clear)

LST – water, clouds (confident clear and probably)

NDVI - water, snow free, clouds (confident and probably clear)

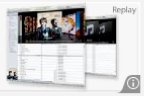
How do I do this?

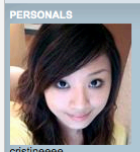
Bitwise manipulation - Programming languagues have bitwise manipulations, including unix (ibits).

Nighttime Fog Detection

Nighttime Fog Detection

- Why is This Important?
  - Low visibilities and low cloud ceilings can be hazardous to transportation operators on land, sea and air

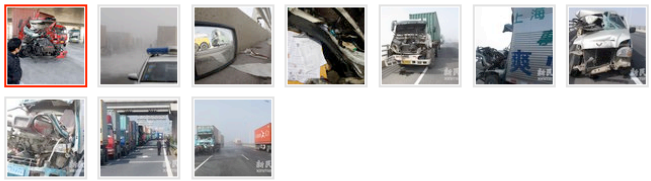




WELCOME, FRIEND!
It seems you've come to us via a web search. Please consider bookmarking us, subscribing to our RSS feed, or checking out this week's most popular stories.

27-vehicle pile up as Shanghai hit by fog, 3 dead

NEXT »



Yesterday morning at around 7am a massive pile up occurred on the Donghai Bridge connecting Shanghai to the port of Yangshan. Three people were killed and another 15 injured when a chain collision involving 27 vehicles resulted from Shanghai's worst fog in six months.

Visibility at the time of the accident was said to be less than 100 meters. Traffic resulting from the collisions eventually stretched for nearly 30 kilometers back towards Shanghai, and initially caused delays as rescue workers rushed to the scene. Helicopters were called in, but were ultimately unable to help because of the fog.

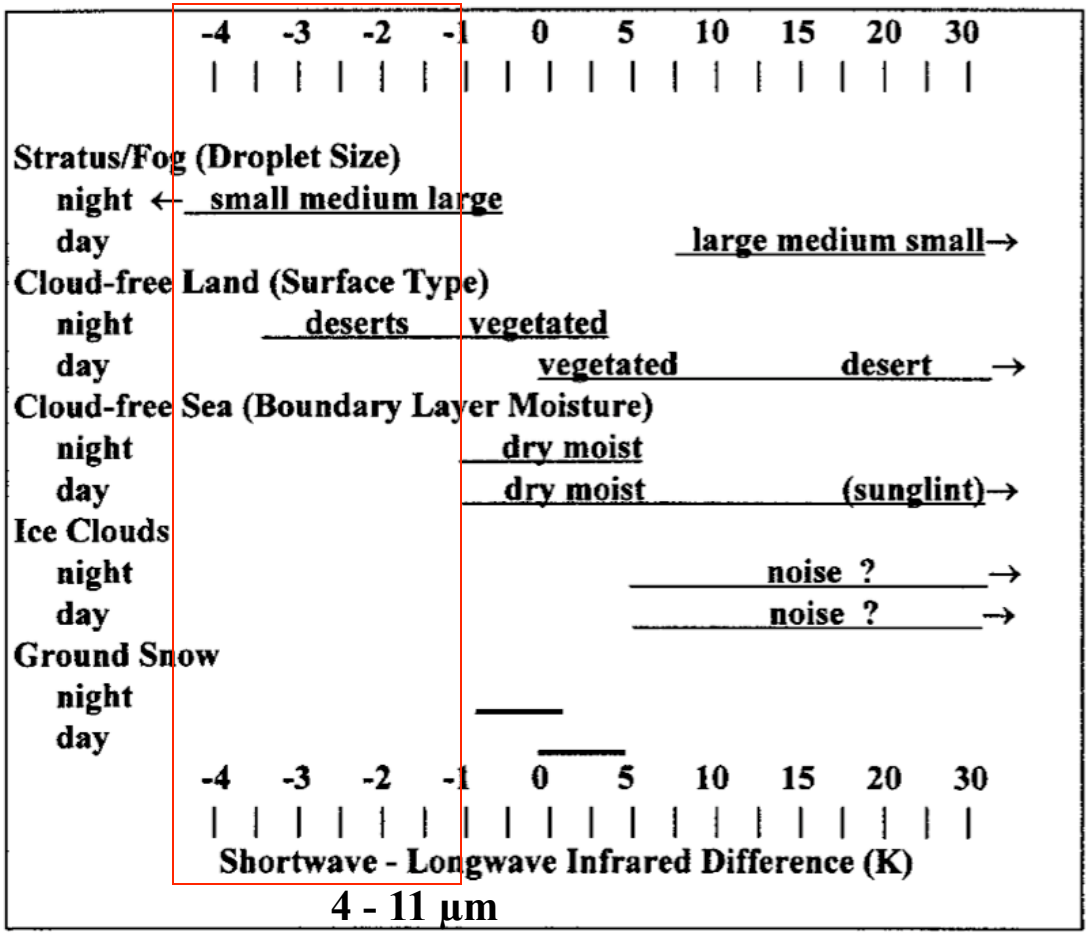
Most of the vehicles involved were container trucks. Two truck drivers and a bus driver lost their lives in the accident; the rest of the injured are in stable condition. Shanghai police had reduced speed limits on the highway to 50 km/h in anticipation of the fog the night before.

More fog is expected in the city today and tomorrow. Drive safe!

Fog/Stratus Detection

- Simple Brightness Temperature Difference
  - 4 μm - 11 μm Brightness Temperature Difference (BTDIF)
- Takes advantage of water cloud emissivity difference between the wavelengths
  - 4 μm opaque water cloud emissivity less than 1
  - 11 μm opaque water cloud emissivity ≈ 1
  - Leads to water cloud 4 μm BT < 11 μm BT
- Simple threshold < -1 means opaque water cloud
  - BTDIF image enhancement leads to quick stratus cloud and/or fog identification (orange, red to purple)
- Nighttime only
  - Solar reflectance component can dominate 4 μm signal

4-11 micron BTDIF

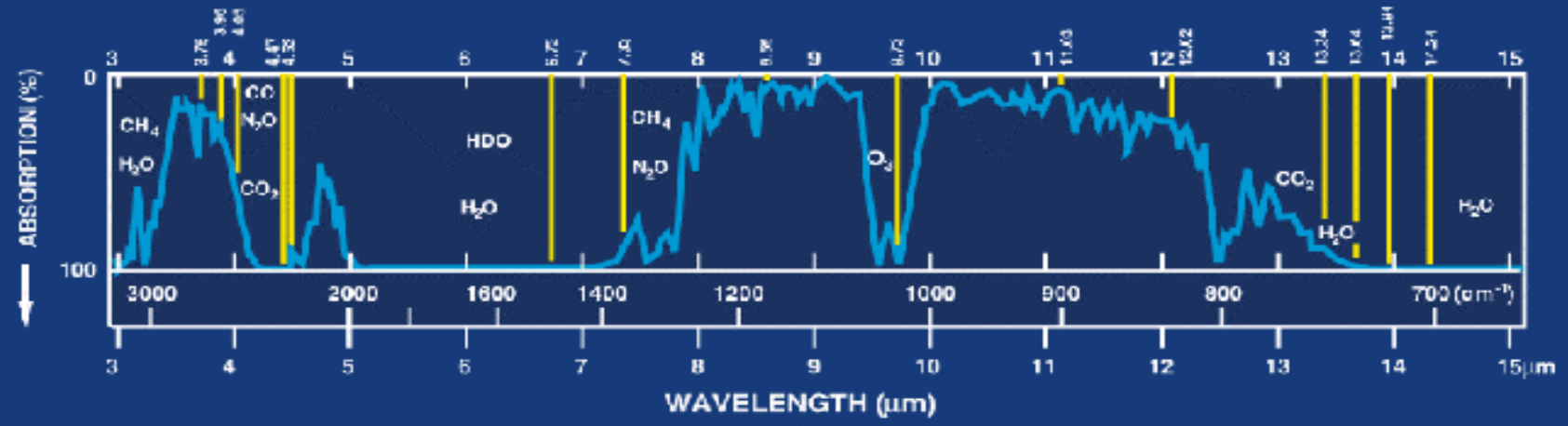


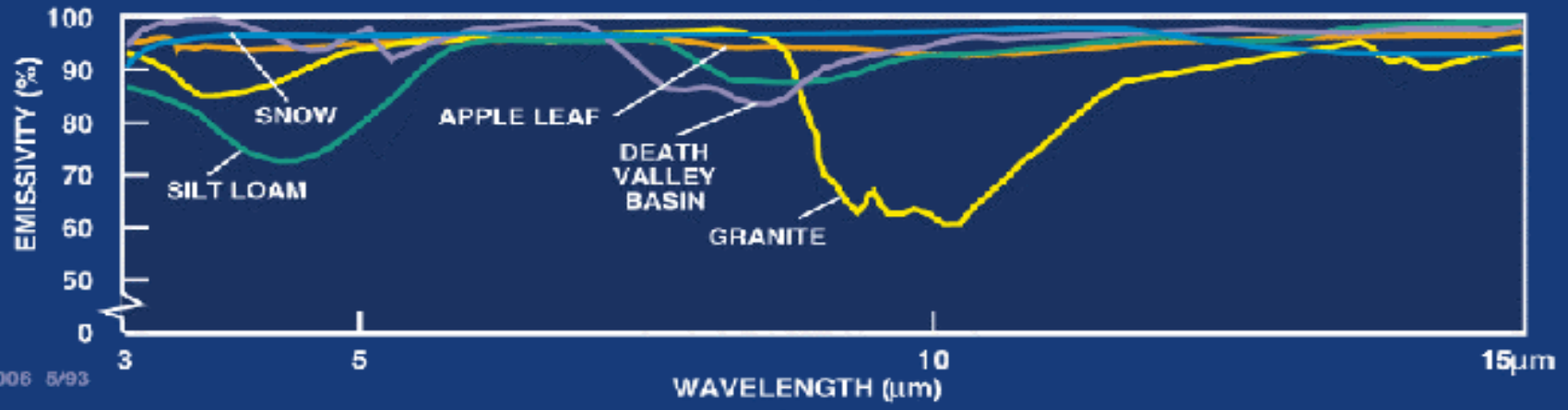
Lee, T. F., F. J. Turk, and K. Richardson, 1997: Stratus and fog products using GOES-8-9 3.9 μm data. Wea. Forecasting, 12, 664-677.

Algorithm Limitaions

- Silicate soils
  - Emissivity variations in silicate soils can cause false positives
- Higher layer clouds obscure low cloud signal
- Single detection threshold

LAND - THERMAL RADIATION



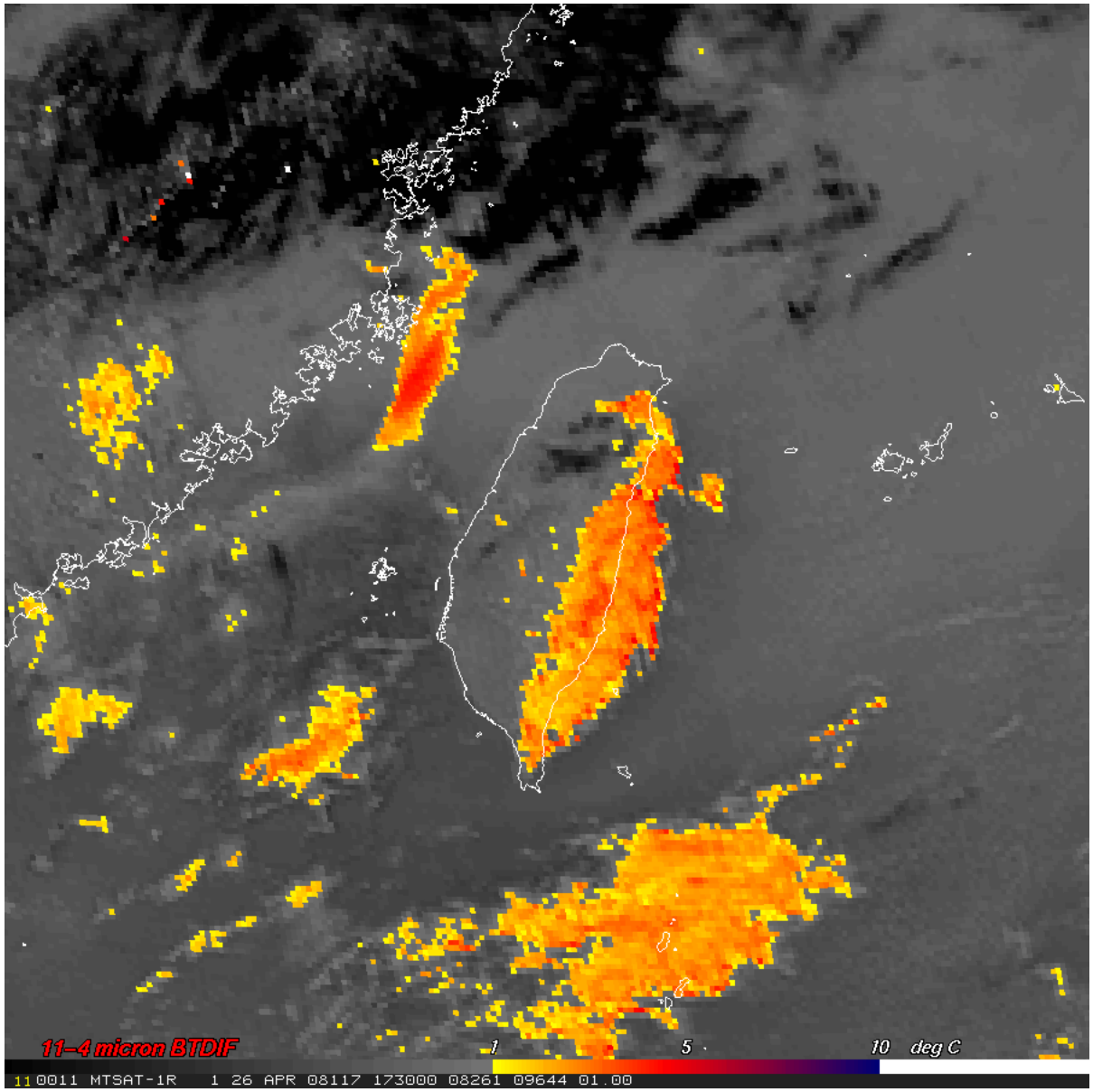


C351.006 5/93

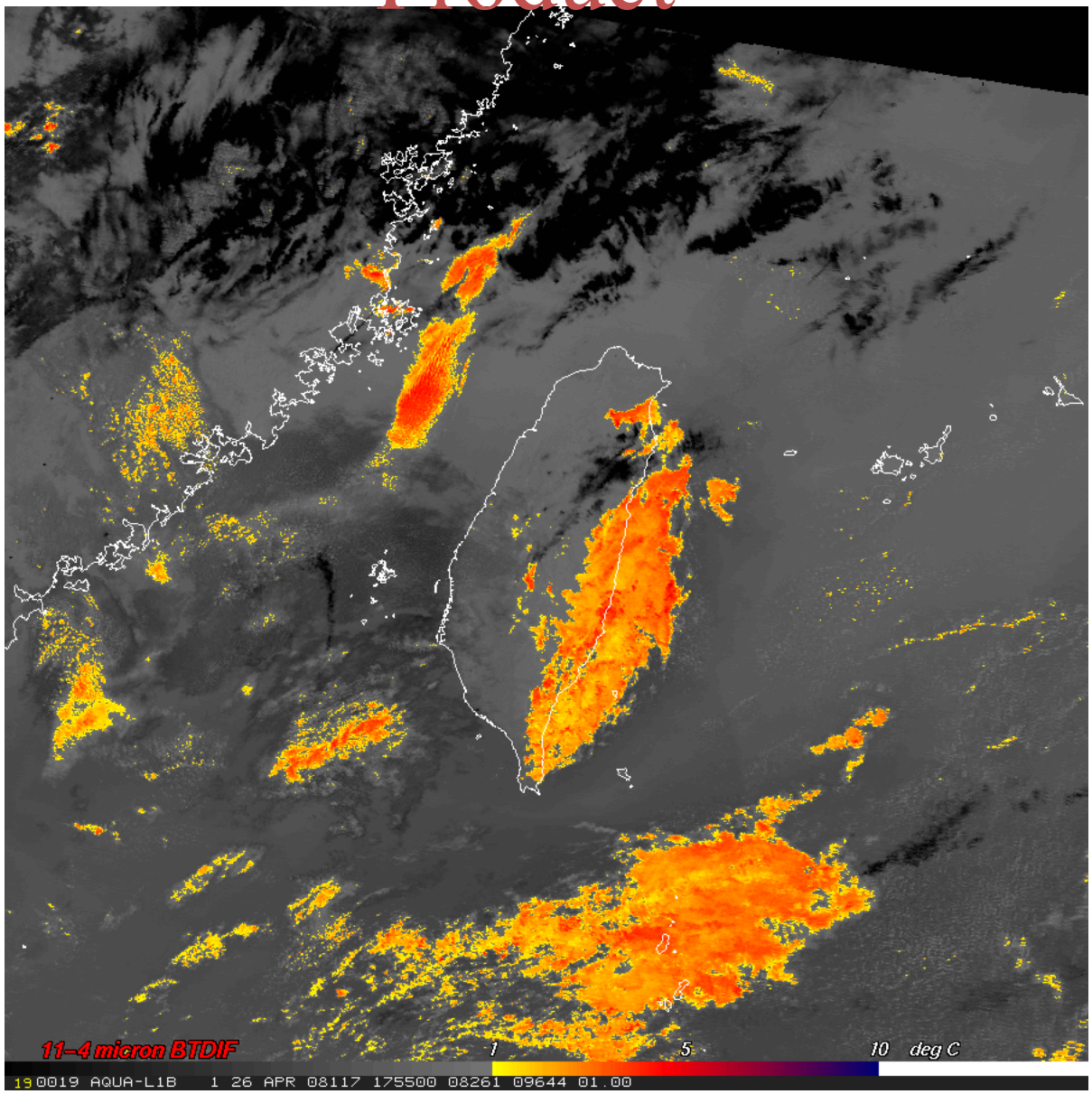
Algorithm Strengths

- Easy to implement
- Validated
  - Used by US National Weather Service for many years
- Provides nighttime information when:
  - No visible data
  - Temperatures of surface and cloud layers can be very close
- Implementation on Geo and Leo means it combines the strengths of both instruments
  - High temporal resolution of Geostationary
  - High spatial resolution of MODIS

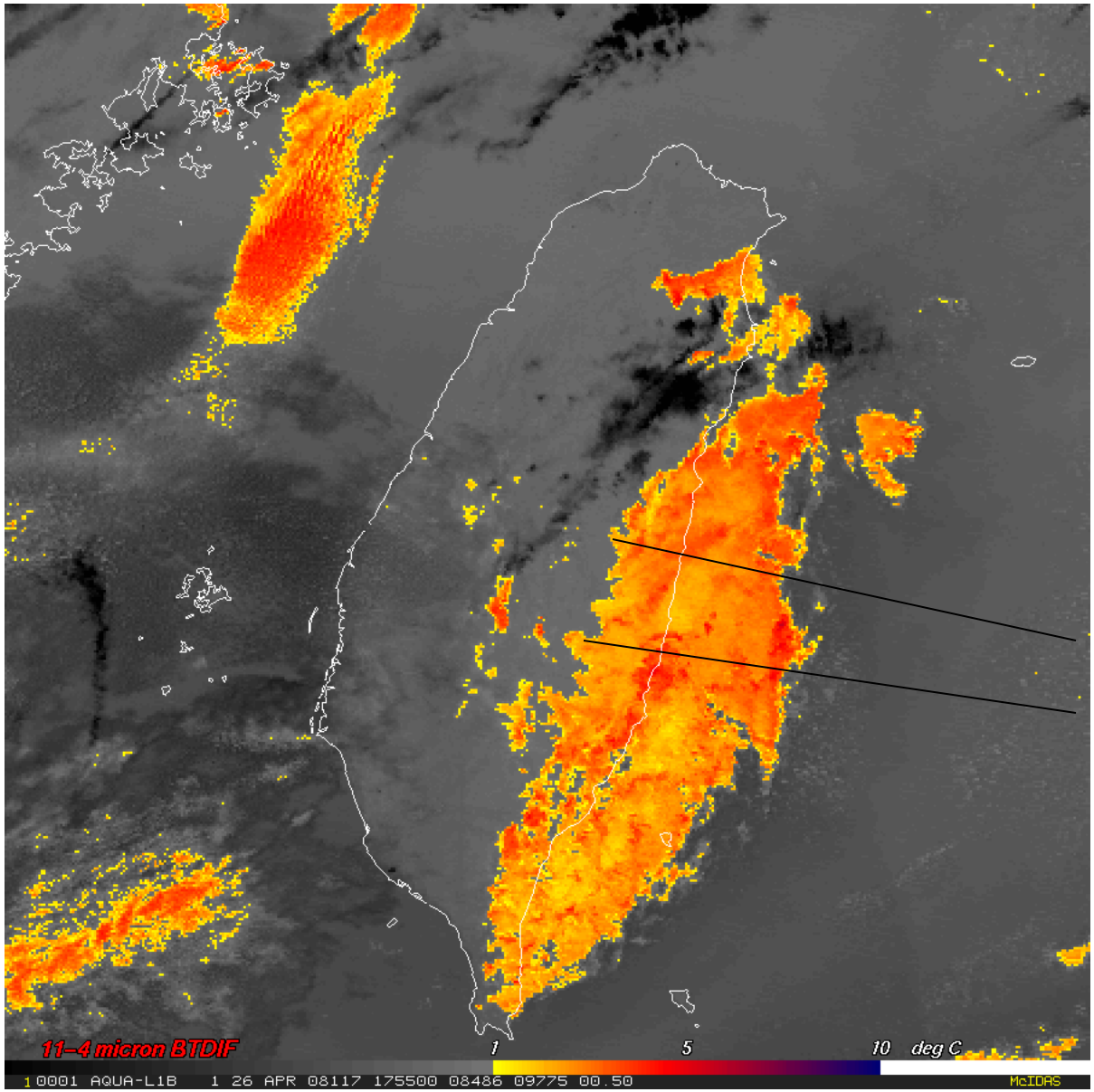
Example MTSAT Low Cloud Fog Product



Example MODIS Low Cloud Fog Product

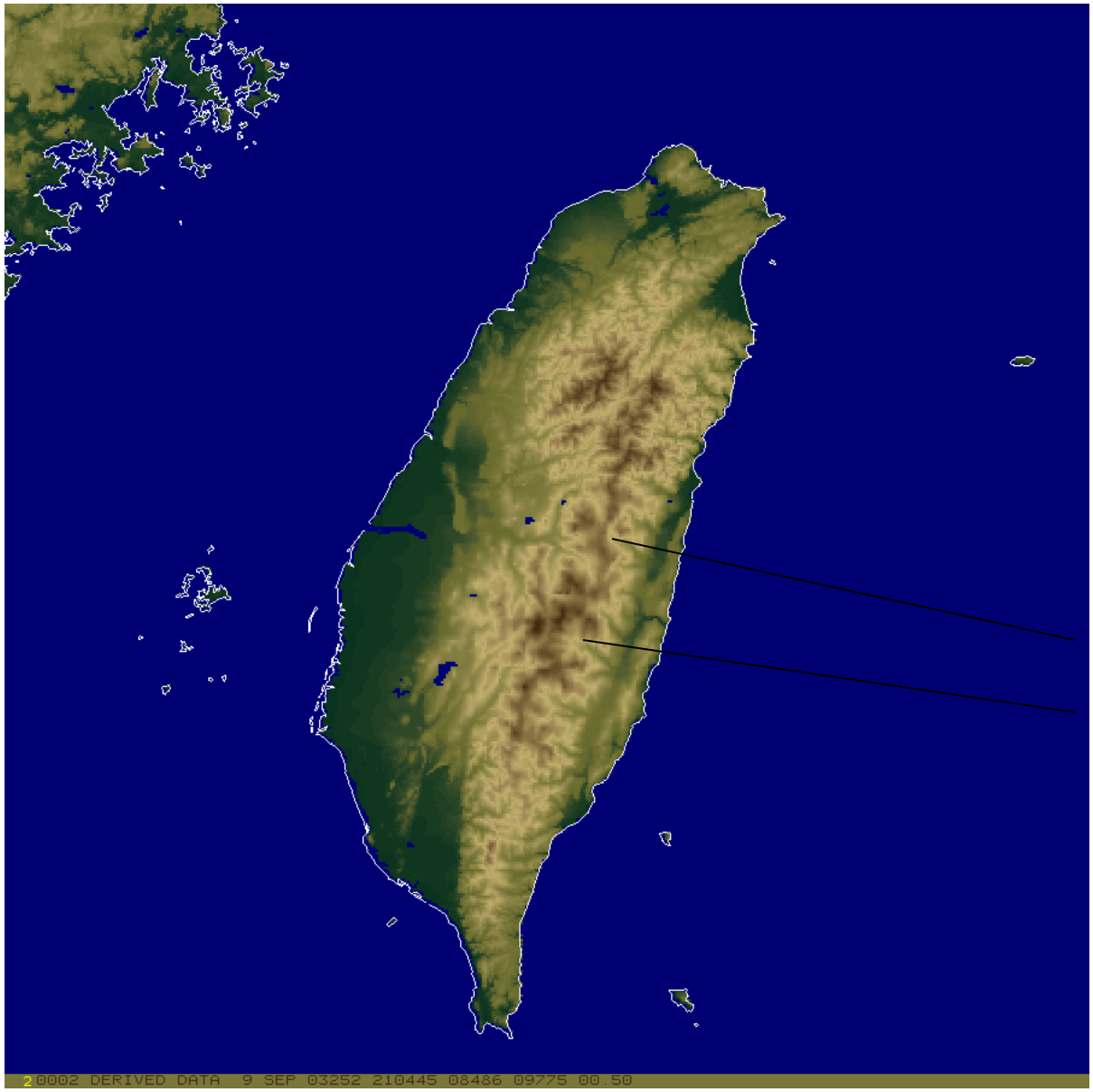


MODIS Fog and Topography



Fog entering into valleys

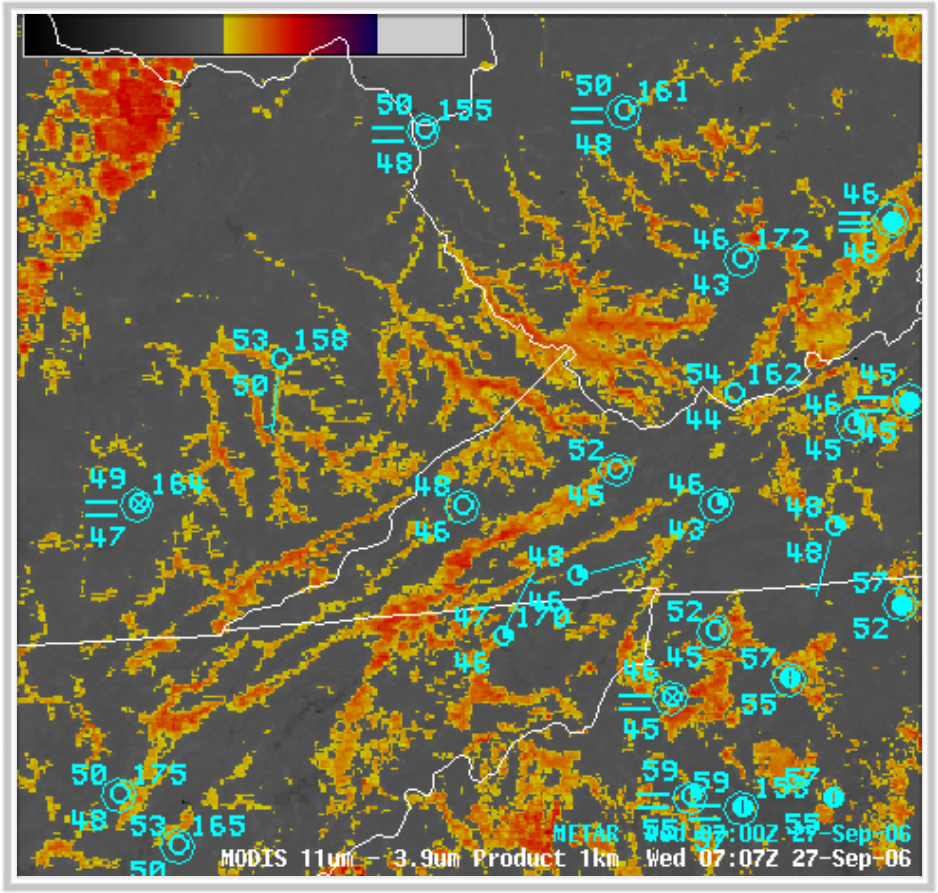
MODIS Fog and Topography



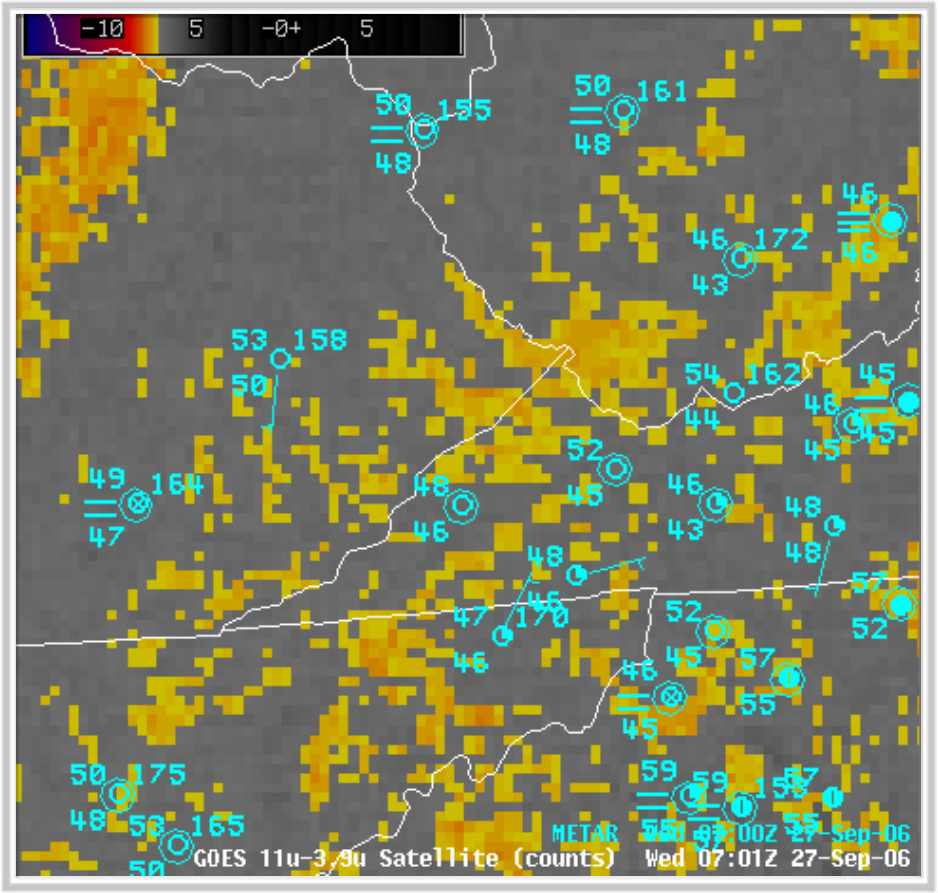
Fog entering into valleys

MODIS Imagery in AWIPS

Fog/stratus product (11.0μm - 3.7μm)



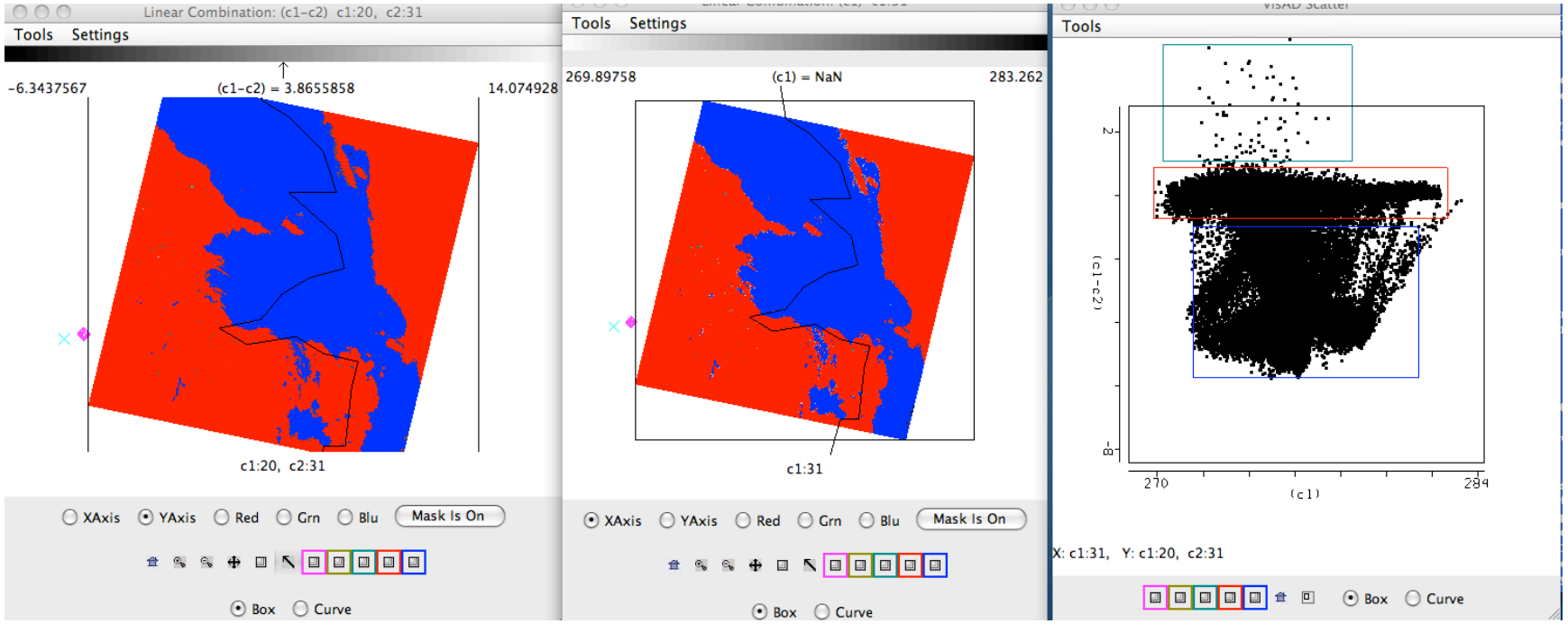
1-km MODIS



4-km GOES

Improved fog/stratus detection capability

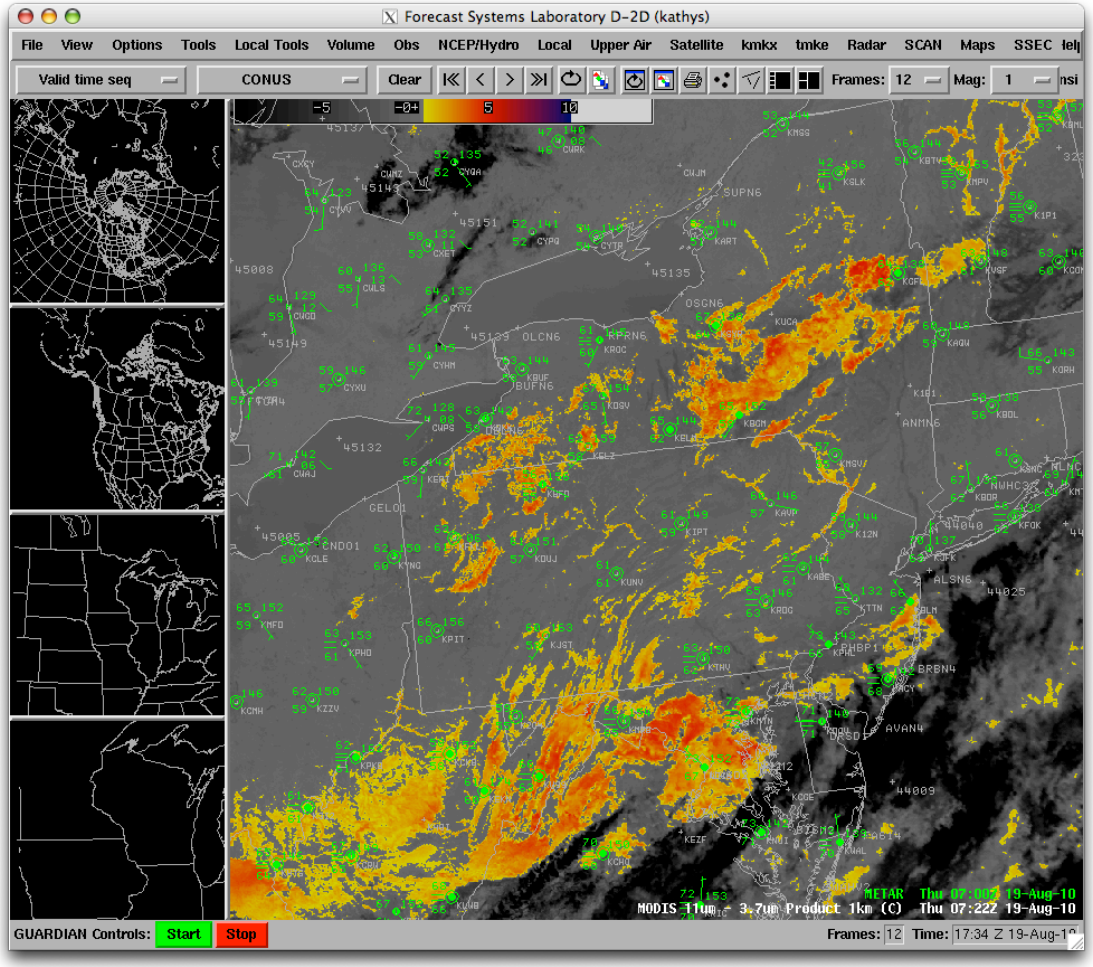
MODIS Fog Detection



Is This Product Useful?

- Operational Fog Detection System was Installed at the Taiwan Central Weather Bureau in November 2009

Recent AFD using MODIS

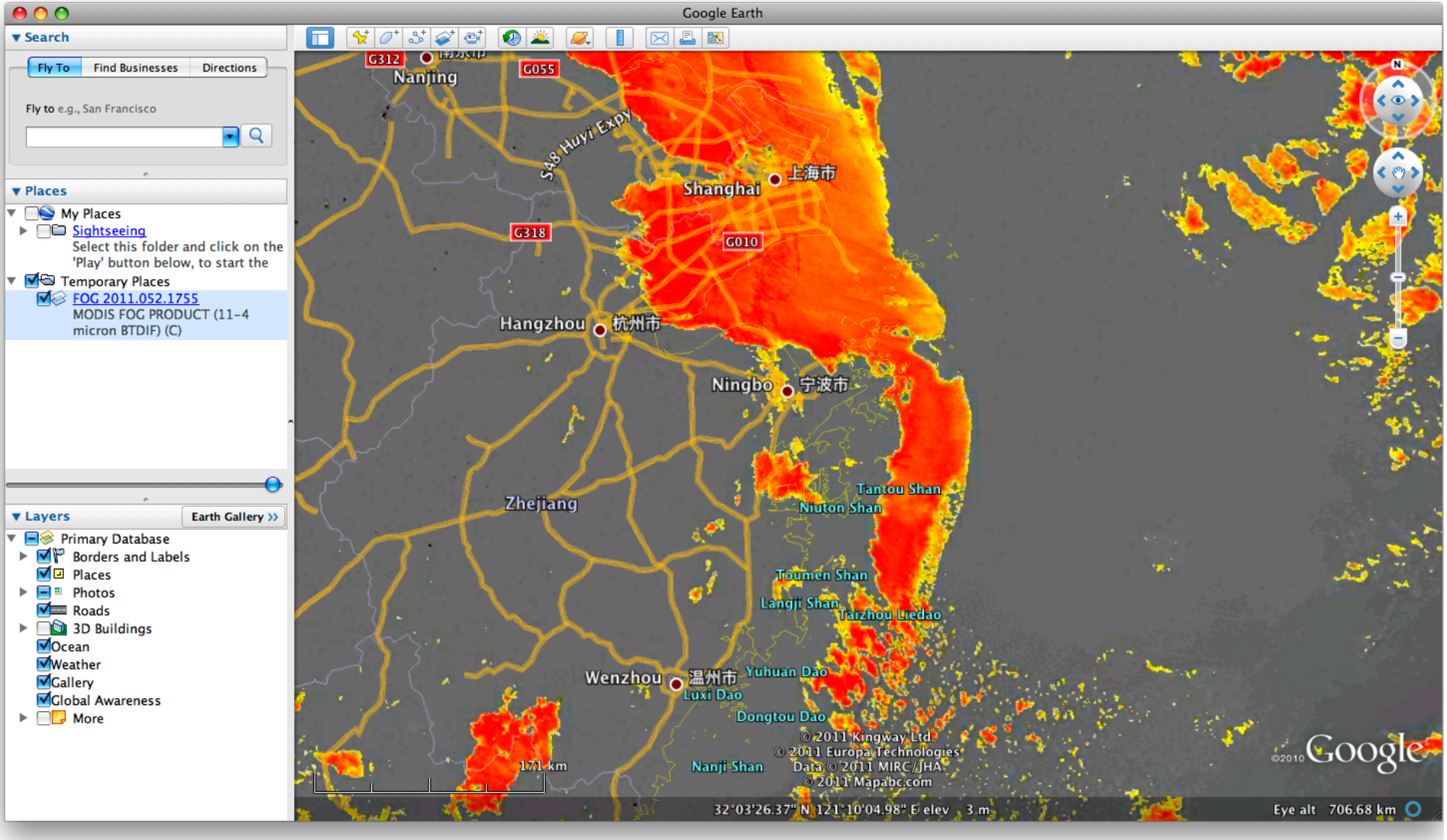


AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE
STATE COLLEGE PA
522 AM EDT THU AUG 19 2010.

SYNOPSIS...A WEAK FRONT COLD FRONT WILL PUSH THROUGH PENNSYLVANIA LATE TONIGHT AND FRIDAY. HIGH PRESSURE WILL BUILD OVER THE STATE LATE FRIDAY AND SATURDAY. COLD FRONTS ARE LIKELY TO AFFECT THE AREA LATE SUNDAY AND AGAIN AROUND NEXT WEDNESDAY.

NEAR TERM /UNTIL 6 PM THIS EVENING/...***EARLY MORNING MODIS 11-3.78UM IMAGERY SHOWING PATCHY VALLEY FOG ACROSS CENTRAL PA***...WHILE FOG A BIT MORE WIDESPREAD ACROSS THE S TIER...WHERE RAIN FELL YESTERDAY. LATEST 3KM HRRR AND LAMPGUIDANCE BOTH SUGGEST FOG WILL BURN OFF IN MOST LOCATIONS BY13-14Z.

Fog Product in Google Earth



References

- Chaurasia, S., Sathiyamoorthy, V., Paul Shukla, B., Simon, B., Joshi, P. C. and Pal, P. K. (2011), Night time fog detection using MODIS data over Northern India. Meteorological Applications, 18: n/a.doi: 10.1002/met.248

- Ellrod, Gary P. and A. Scott Bachmeier, 2003: Inter-comparison of GOES and MODIS Imagery in the Analysis of Fog and Stratus, 12 Conference on Satellite Meteorology and Oceanography, P1.15, Long Beach California.

- Eyre, J. R., J. L. Brownscombe, and R. J. Allam, 1984: Detection of fog at night using Advanced Very High Resolution Radiometer (AVHRR) imagery. Meteorological Magazine, 113, 266-275.

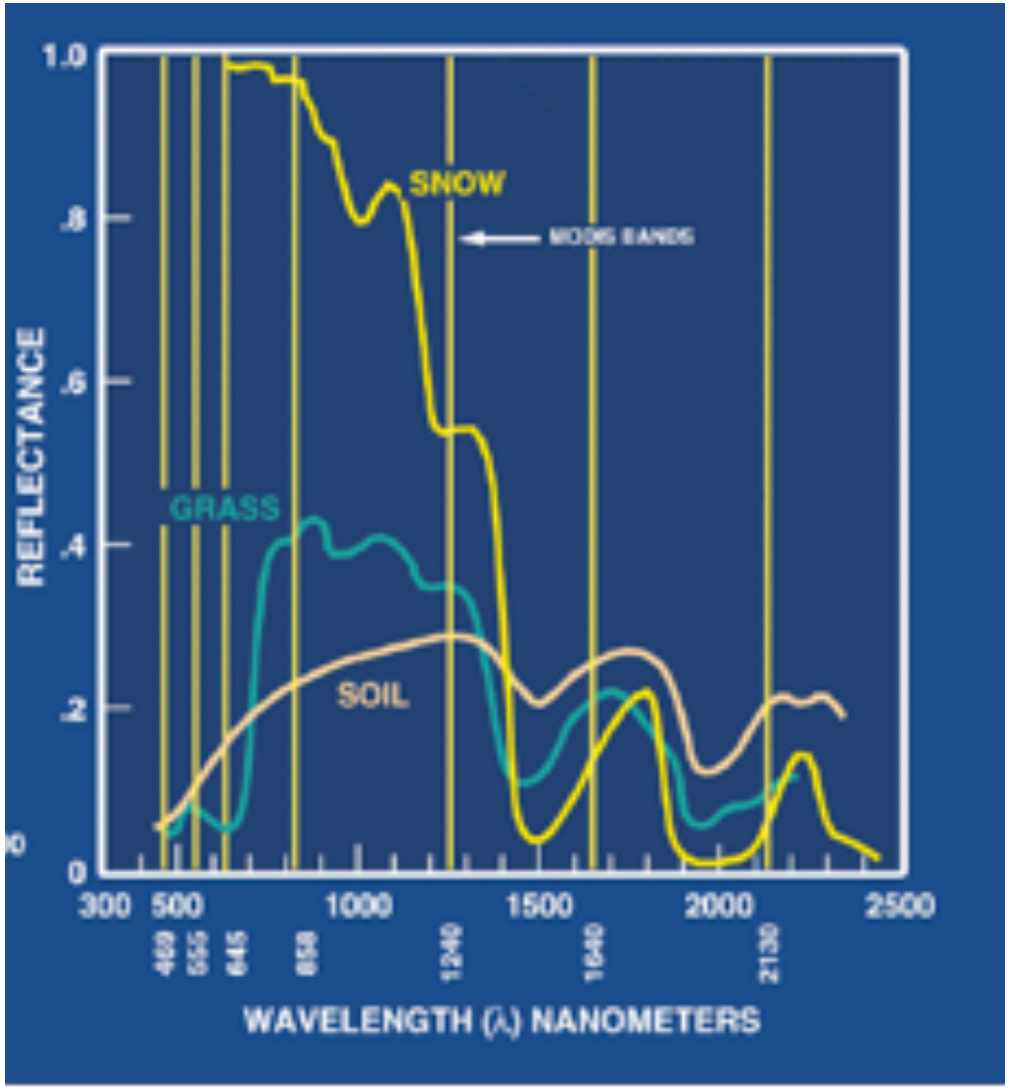
Snow and Ice Detection

Snow and Ice Detection

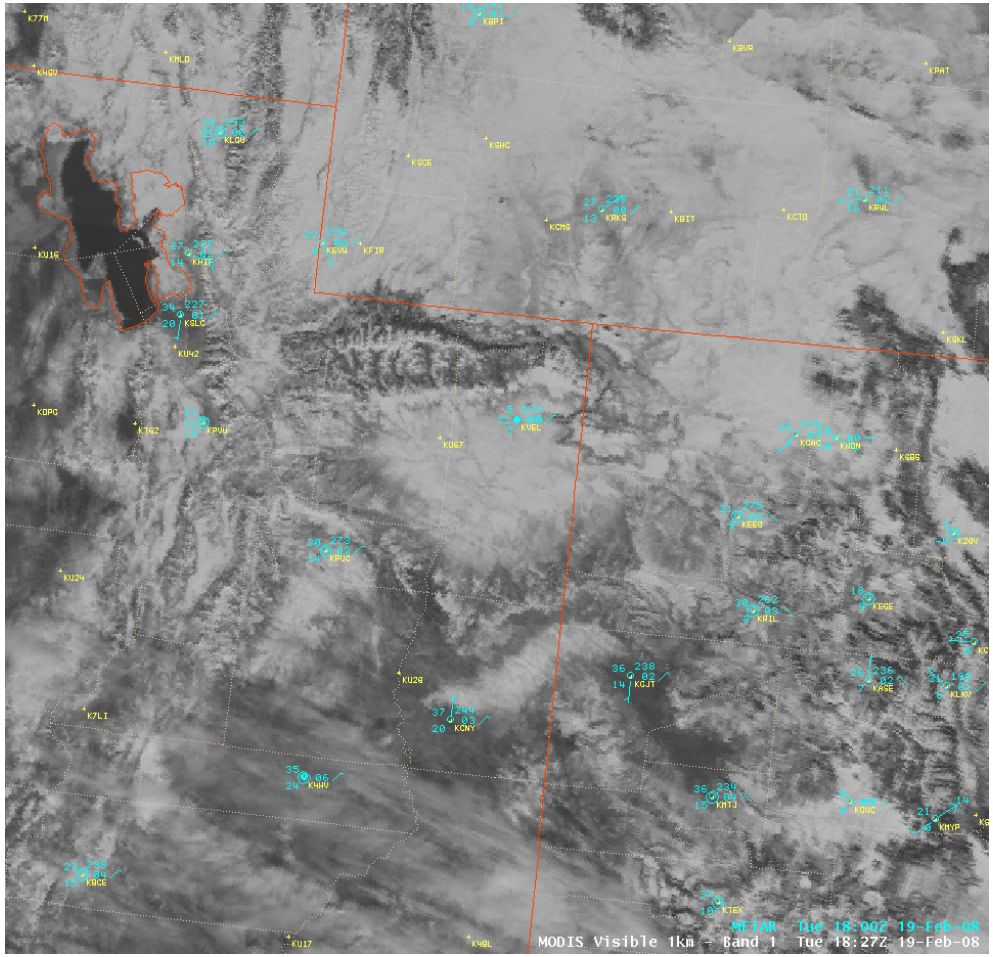
- Take advantage of change of absorption properties of snow and ice in visible and near-infrared region
- Normalized Difference Snow Index (NDSI)
  - similar to the normalized-difference vegetation index (NDVI)
  - Snow has strong visible reflectance but absorbs strongly in the short-wave IR
    - Band 4 (.56 µm) – Band 6 (1.6 µm) (or 7 -2.1µm for Aqua)

    - Band 4 (.56 µm) + Band 6 (1.6 µm) (or 7 - 2.1µm for Aqua)
  - Hall DK, Riggs GA, Salomonson VV. 1995. Development of methods for mapping global snow cover using Moderate Resolution Imaging Spectroradiometer (MODIS) data. *Remote Sensing of Environment* ***54: 127 – 140.***

MODIS – Snow/Ice and Ice Clouds



Discriminating Ice from Clouds

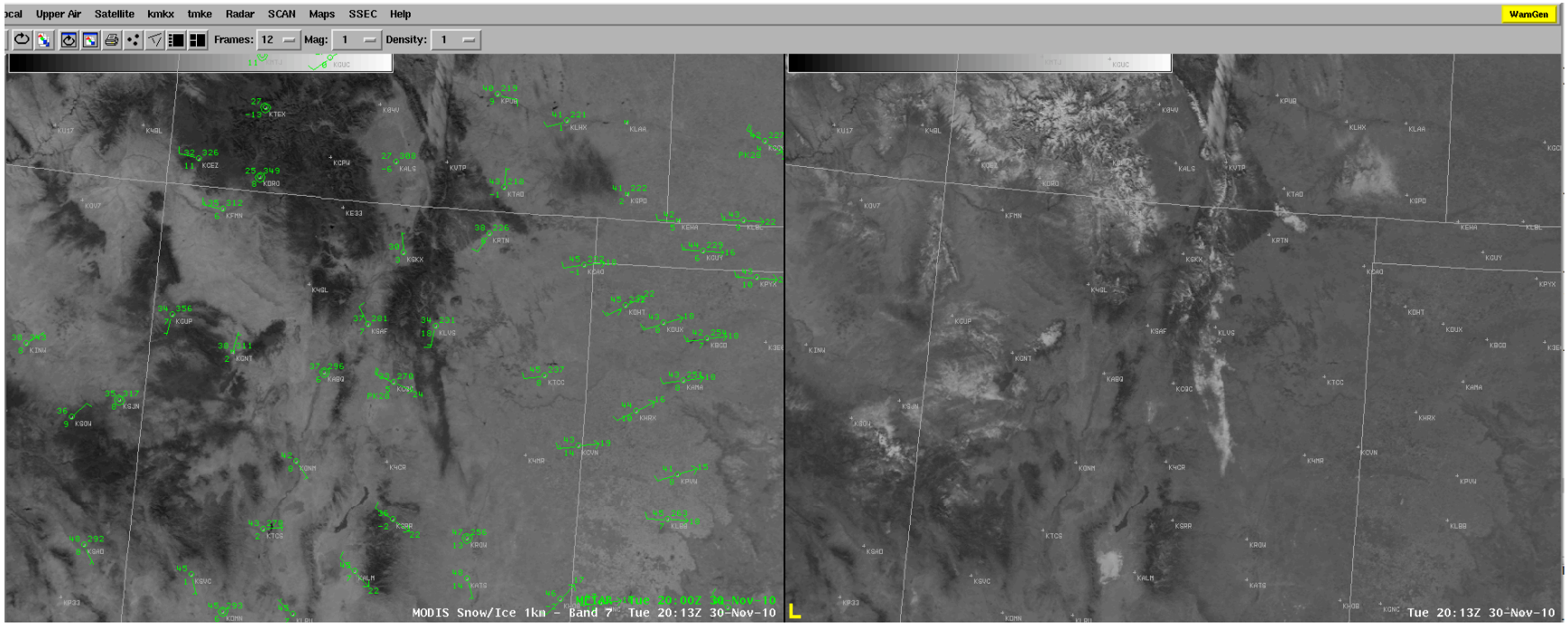


Why is this important?

Assessing Fire Danger

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE ALBUQUERQUE NM
300 AM MST WED DEC 1 2010

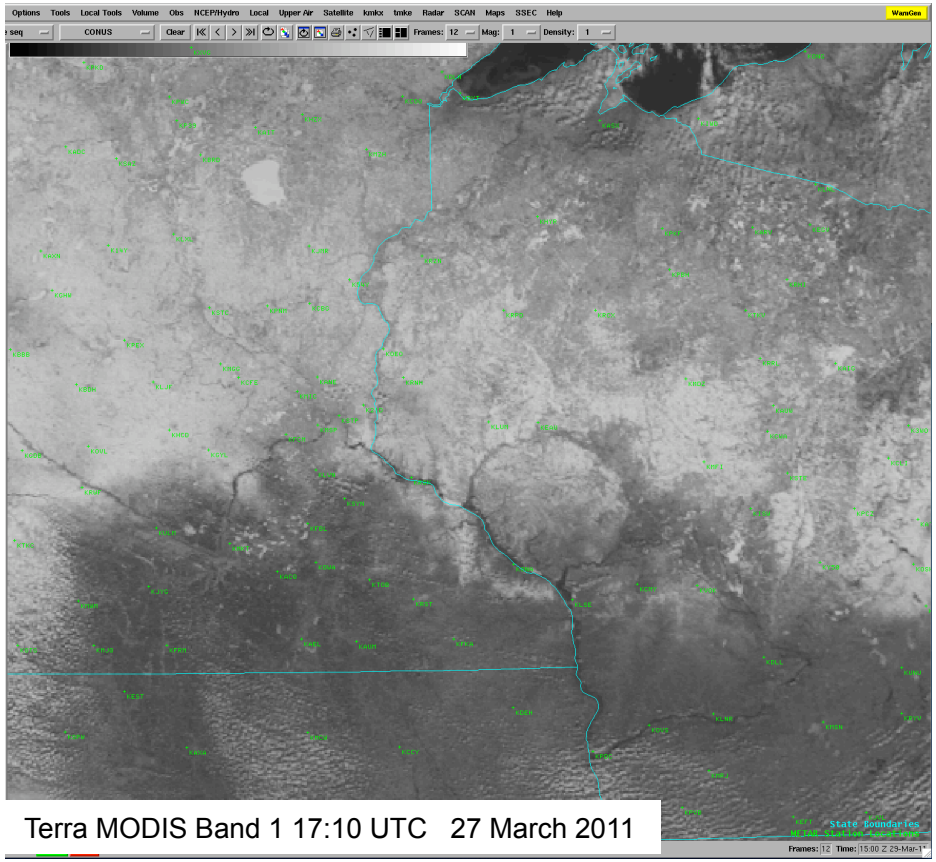
.FIRE WEATHER...ONLY MINOR CHANGES TO OVERALL FORECAST THROUGH THE WEEKEND. A 1016MB LEE TROUGH OVER THE PLAINS HAS ALLOWED WESTERLY DOWNSLOPE WINDS TO DOMINATE THE AREA...THUS TEMPS ARE MUCH WARMER AND WINDS SLIGHTLY BREEZIER. AN ISOLATED AREA OF MARGINAL CRITICAL FIRE WX CONDITIONS WILL DEVELOP BTWN CLINES CORNERS...VAUGHN...SANTA ROSA...AND LAS VEGAS BY LATE THIS MORNING HOWEVER NO FIRE WX HIGHLIGHTS WILL BE ISSUED. ***MELTING SNOWPACK EVIDENT ON THE 2013Z MODIS 1KM VISIBLE IMAGERY TUESDAY IN NEARLY THE EXACT SAME AREA WILL MITIGATE SURFACE FUEL DRYNESS.*** MIN RH VALUES WILL RANGE FROM 20-25 PCT ALONG THE COLORADO BORDER TO 10-15 PCT ACROSS THE SOUTH. VENT RATES TODAY WILL BE POOR MOST AREAS EXCEPT ALONG THE EAST SLOPES WHERE FAIR VALUES ARE EXPECTED.

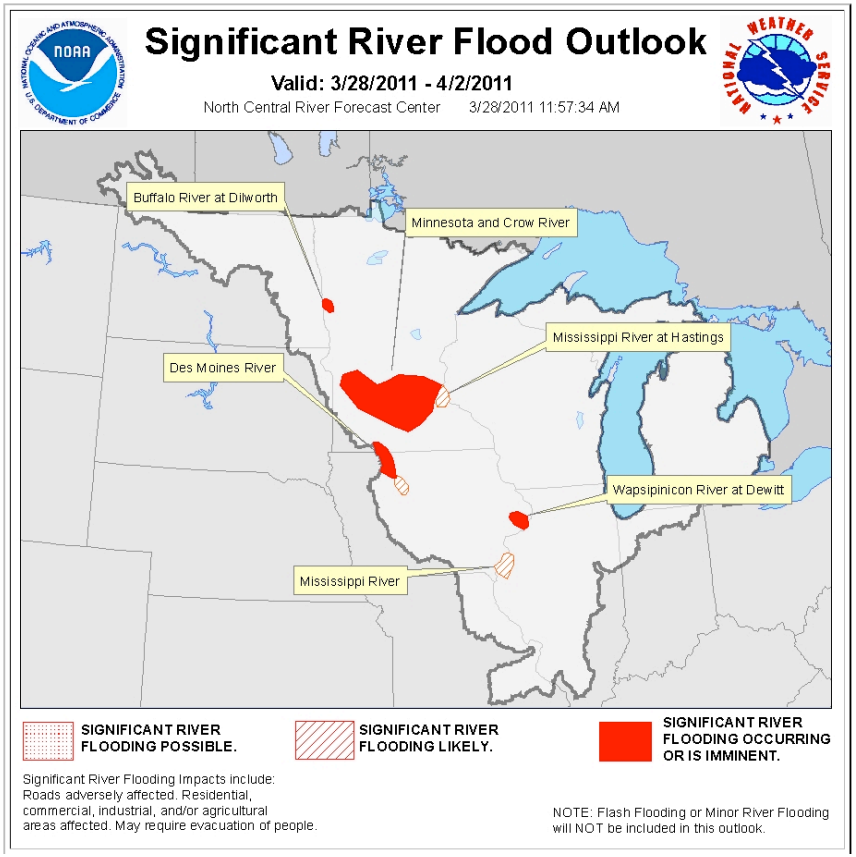


Flood Forecasting

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE TWIN CITIES/CHANHASSEN MN
422 AM CDT TUE MAR 29 2011

HYDROLOGY...MODIS SATELLITE PASSES OVER THE PAST COUPLE DAYS SHOW LITTLE SNOW COVER IN SOUTHERN MN...SOUTH OF THE MINNESOTA RIVER. THE EXCEPTIONIS IN THE MINNESOTA RIVER VALLEY NORTHEAST OF A LINE FROM NEW ULM TO PIPESTONE...WHERE THE EFFECT OF LAST WEEKS SNOWFALL IS STILL QUITE EVIDENT. **LATEST NOHRSC 48-HR CHANGE IN SNOW WATER EQUIVALENT SHOWS BETWEEN A TRACE AND 0.20 INCH LOSS SINCE SATURDAY ACROSS ALLOF MN AND WI...DESPITE WELL BELOW NORMAL TEMPERATURES - THE LATE MARCH SUNSHINE IS PLAYING A ROLE IN THIS SLOW MELT…**



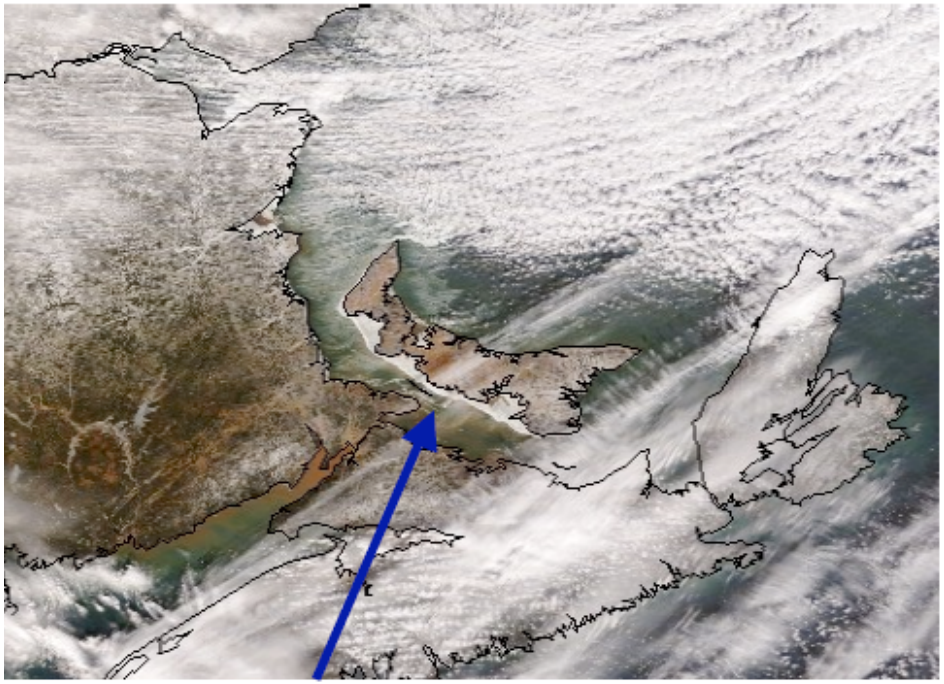


Canadian Ice Service integrates MODIS into operational data stream for ice monitoring

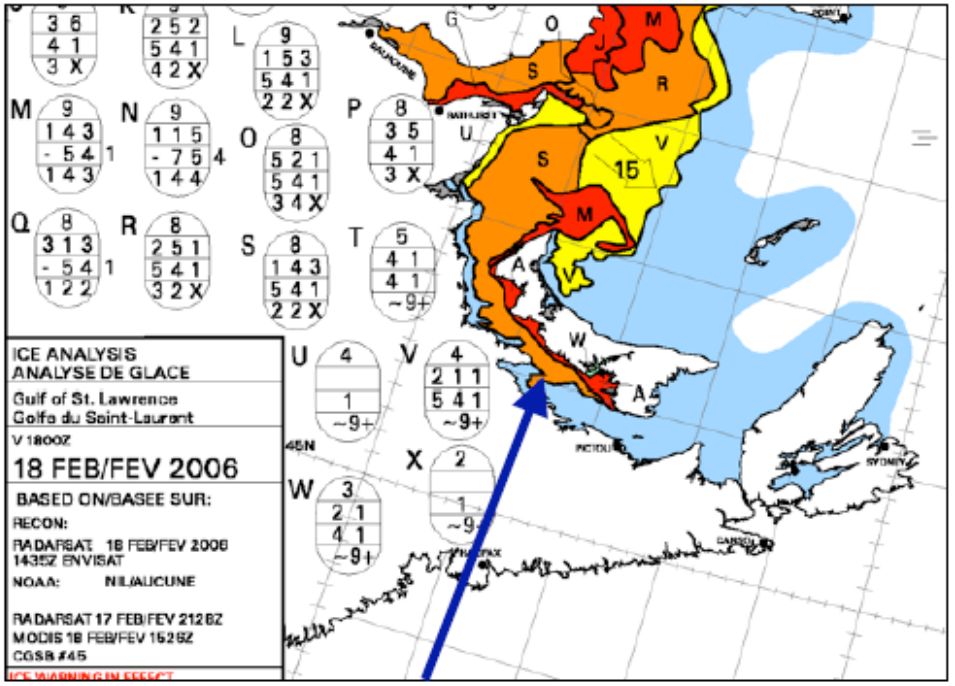
CIS data suite includes RadarSat and Envisat (SAR); AMSR, QuikScat and SSM/I (microwave); MODIS, OLS, NOAA and GOES (visible images).

- MODIS supplements SAR data in clear sky conditions.
- 250 meter resolution true color GeoTIFF images are obtained daily from SSEC for Great Lakes, Hudson Bay, Labrador coast, and Gulf of St. Lawrence.

MODIS helps to define ice boundary along southern Prince Edward Island



MODIS DB image 2006/02/18 15:26 UTC



CIS Ice Analysis 2006/02/18

Severe Weather

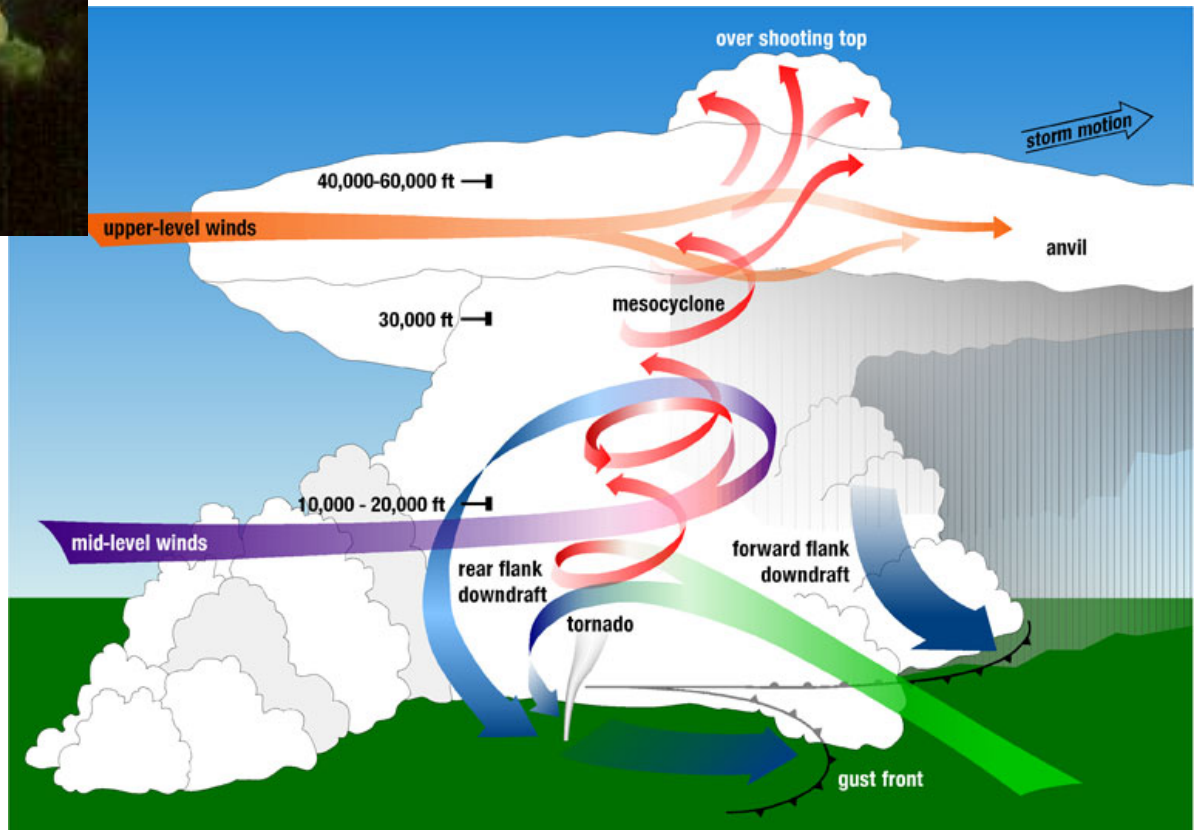
Extreme Winds, Thunderstorms, Rainfall, Hail

Thunderstorms

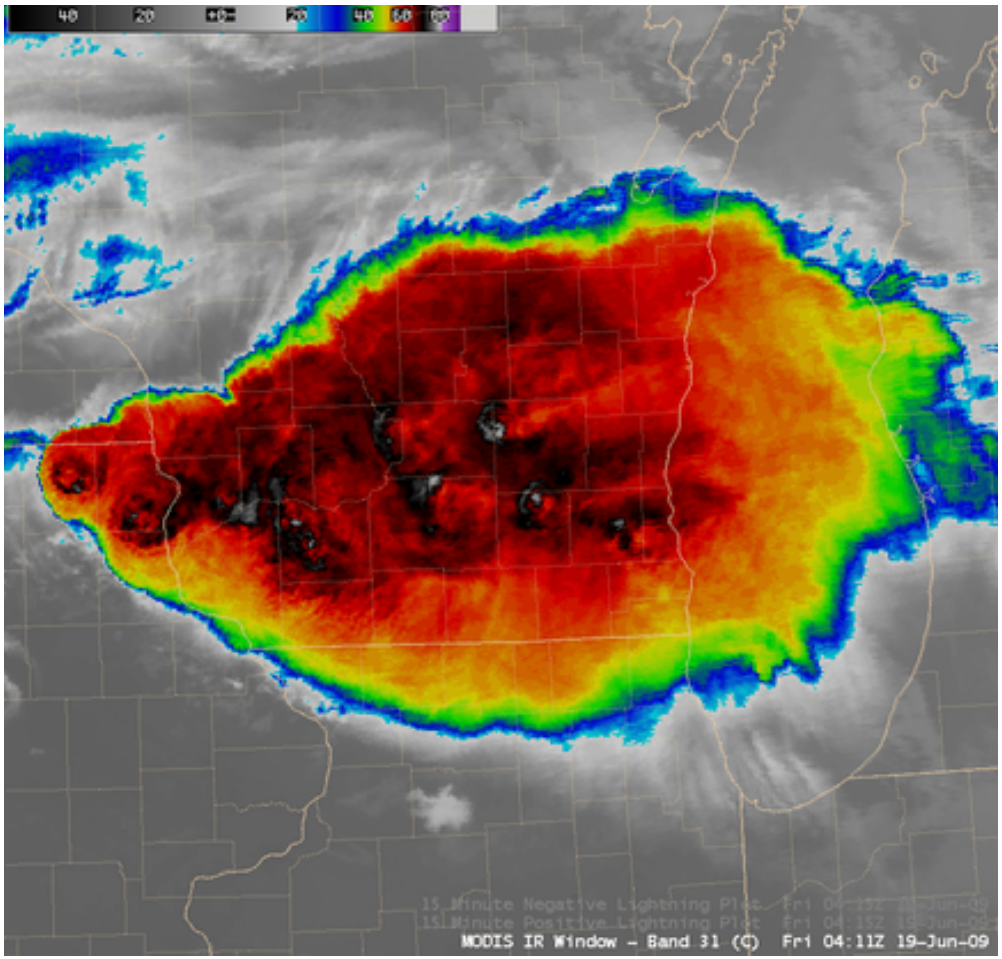
- Characteristics of Severe Weather as Observed from Satellite
  - Overshooting Tops
  - Gravity Wave Generation

Overshooting Top

A dome-like protrusion above a thunderstorm anvil, representing a very strong updraft and hence a higher potential for severe weather with that storm. A persistent and/or large overshooting top often is present on a supercell.



Severe Thunderstorm Example 1

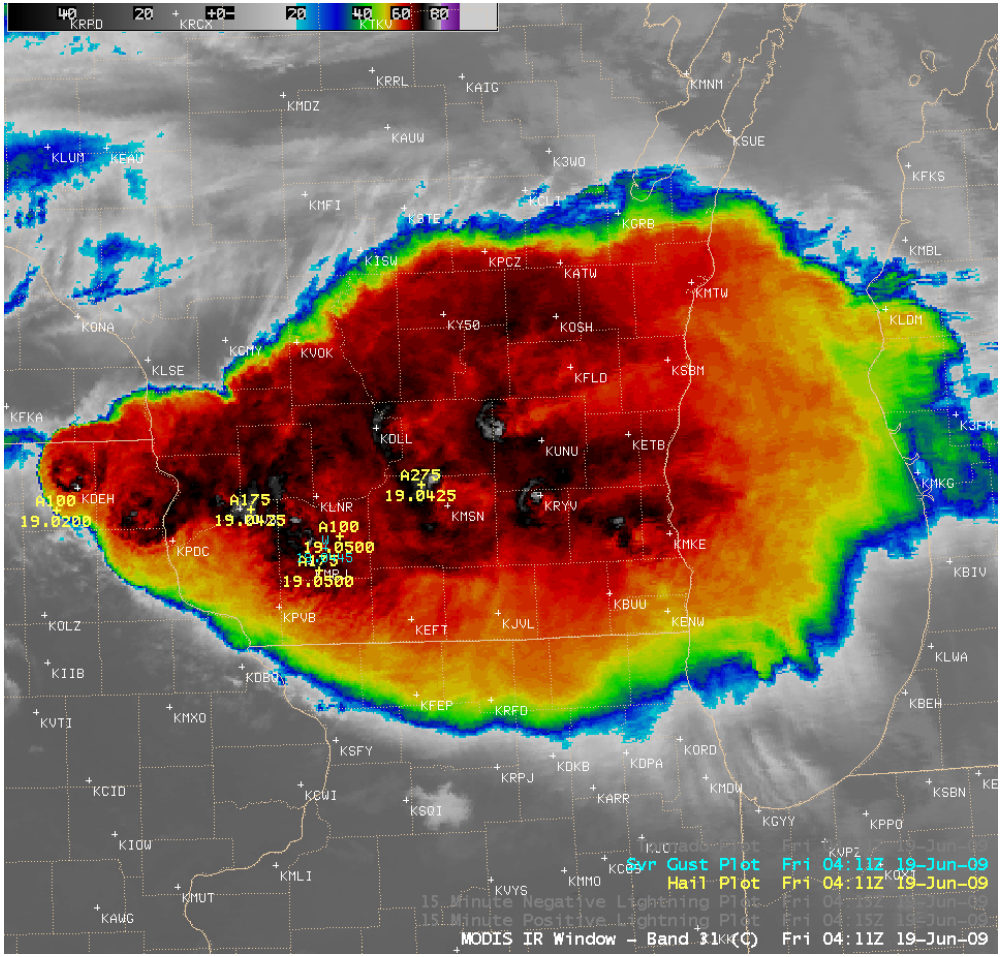


Including Lightning Detection

04:11 UTC
19 June 2009

During the 15-minute interval ending at 04:15 UTC this storm produced over 900 lightning strikes

Severe Thunderstorm Example 1

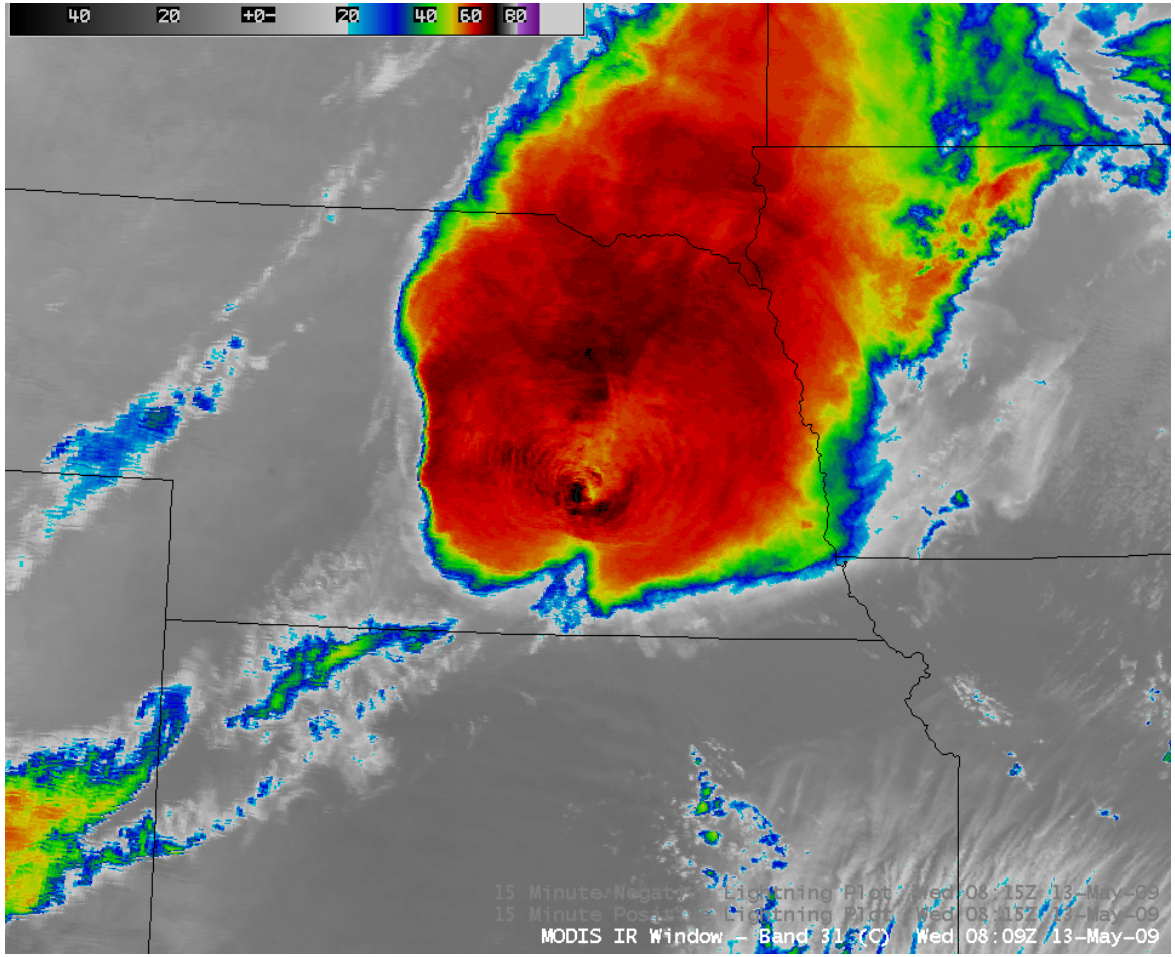


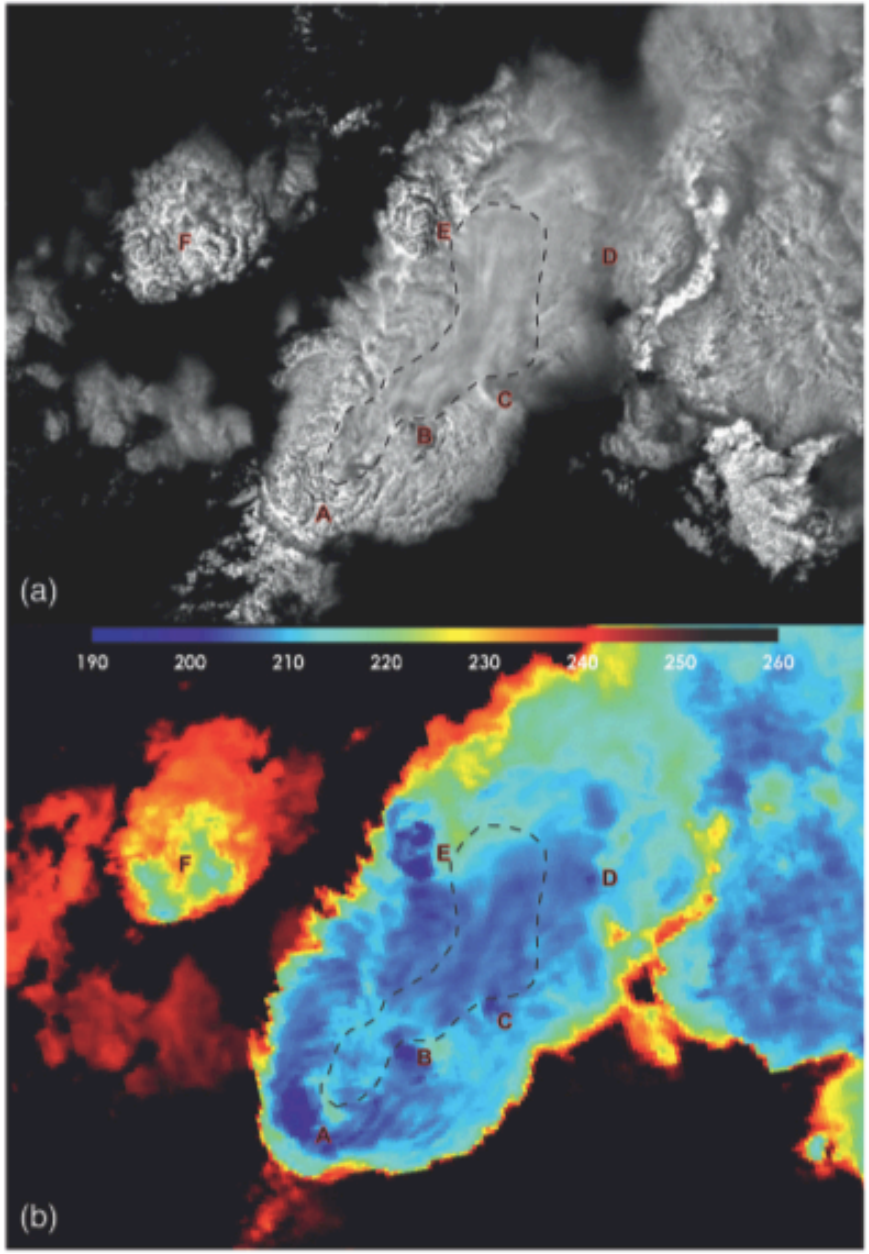
Including Severe Winds and Hail Reports
04:11 UTC
19 June 2009

During the 15-minute interval ending at 04:15 UTC this storm produced over 900 lightning strikes

Severe Thunderstorm Case 2

Including
Lightning
and Hail
Reports
13 May 2009

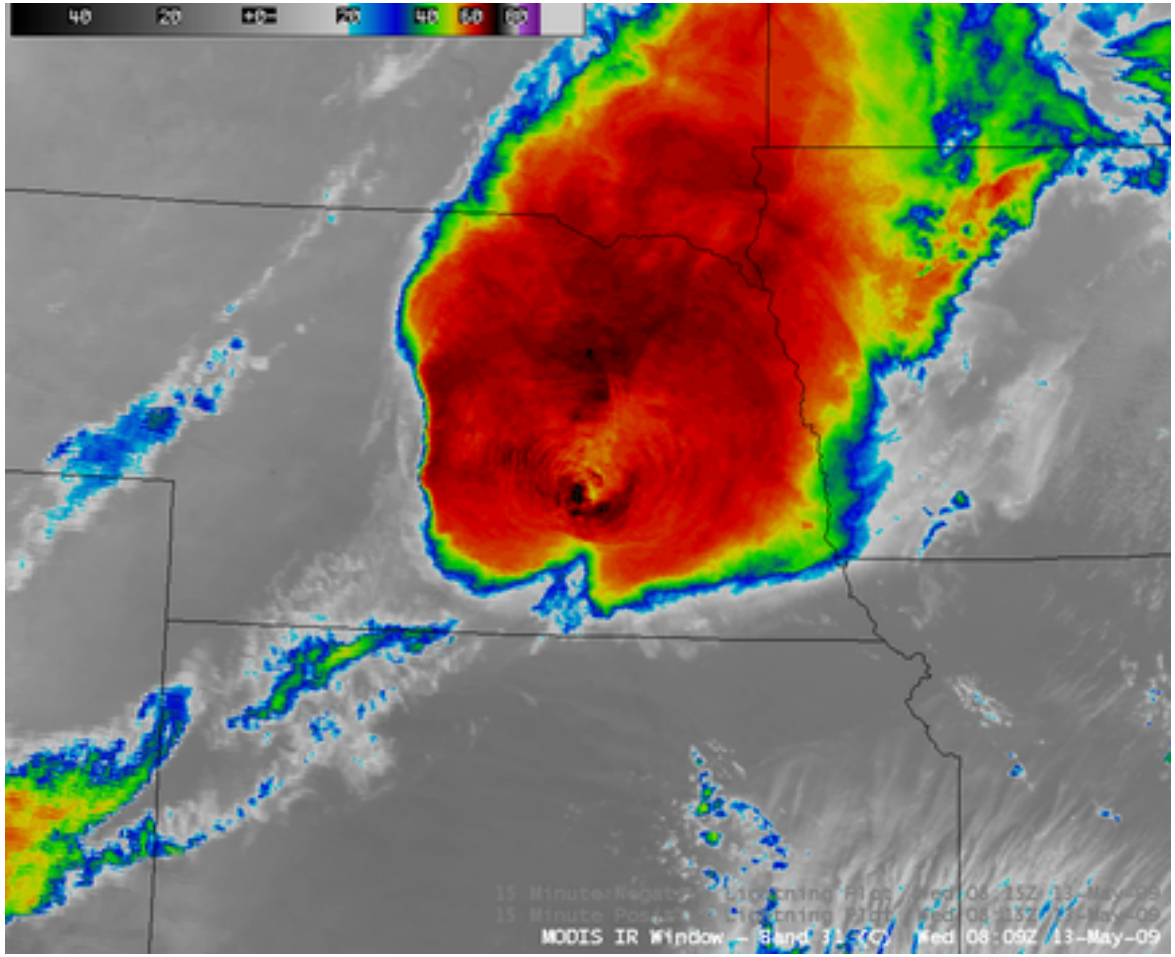




Bedka, K., Brunner, J., Dworak, Feltz, W., Otkin, J. and T. Greenwald: 2010. Objective Satellite-Based Detection of Overshooting Tops Using Infrared Window Channel Brightness Temperature Gradients, Journal of Applied Meteorology and Climatology, Vol. 49, pp. 181-202.

Severe Thunderstorm Case 2

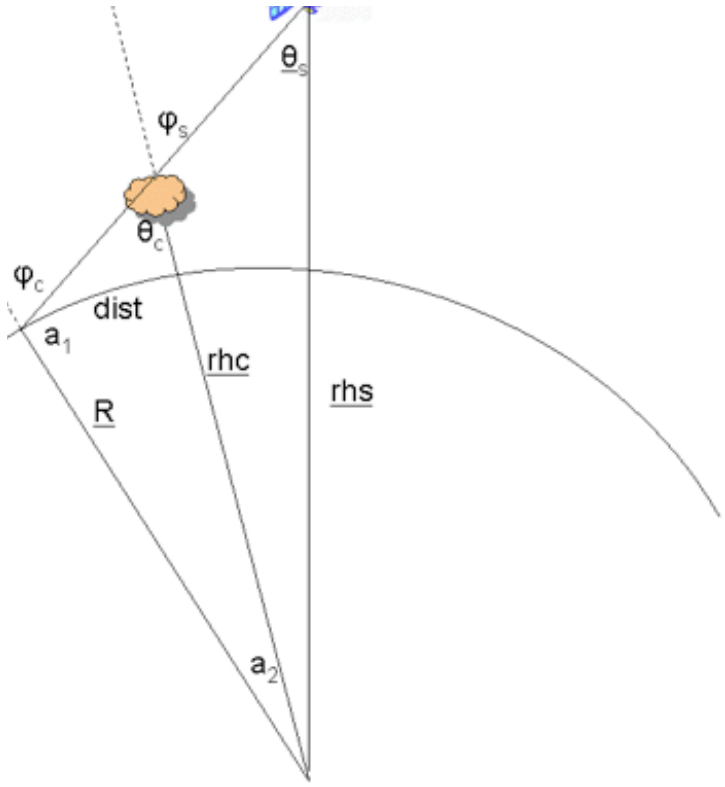
Comparison
MODIS
versus
GOES
13 May 2009



Parallax

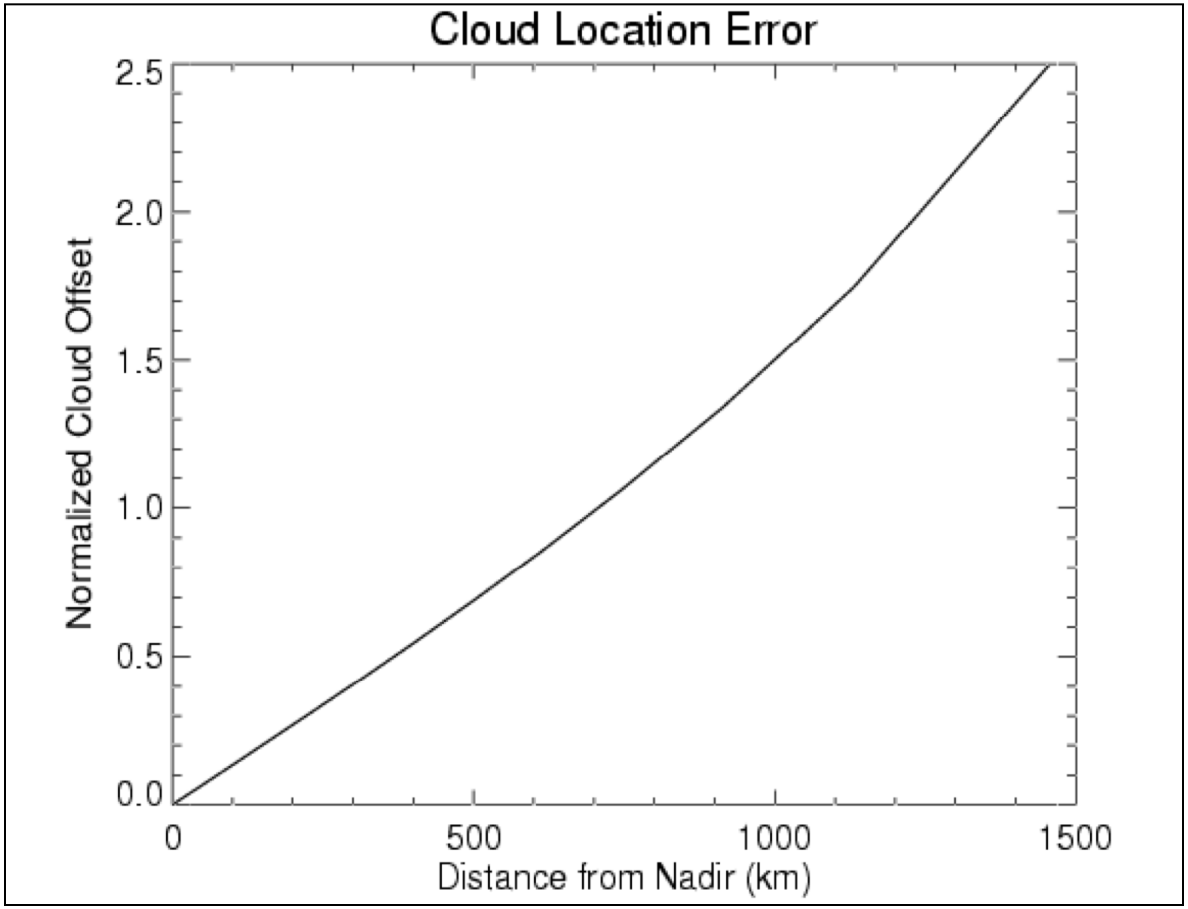
- The apparent displacement of a feature above ground that results from non-nadir viewing angles.
- Fortunately, there has been shown to be a relationship between cloud displacement, cloud height and distance from nadir
- Cloud top pressure (hPa) is part of the MOD06 product, and cloud height will be a part of the collect 6 product

Schematic Diagram of the Geometry used in Parallax Correction



e distance from earth's center
distance from earth's center
adius
viewing angle from satellite nadir
position viewing angle from cloud nadir
zenith angle from cloud
enith angle from ground
km) of cloud ground position

Estimating Parallax Error
Dave Santek



So if you have a cloud at a pixel that was 1000 km from nadir, the parallax correction would be 1.5 x the height of the cloud. Ex: 4 km x 1.5 = 6 km 10 km x 1.5=15 km

Aviation Applications

Turbulence, Clouds, Ash Detection

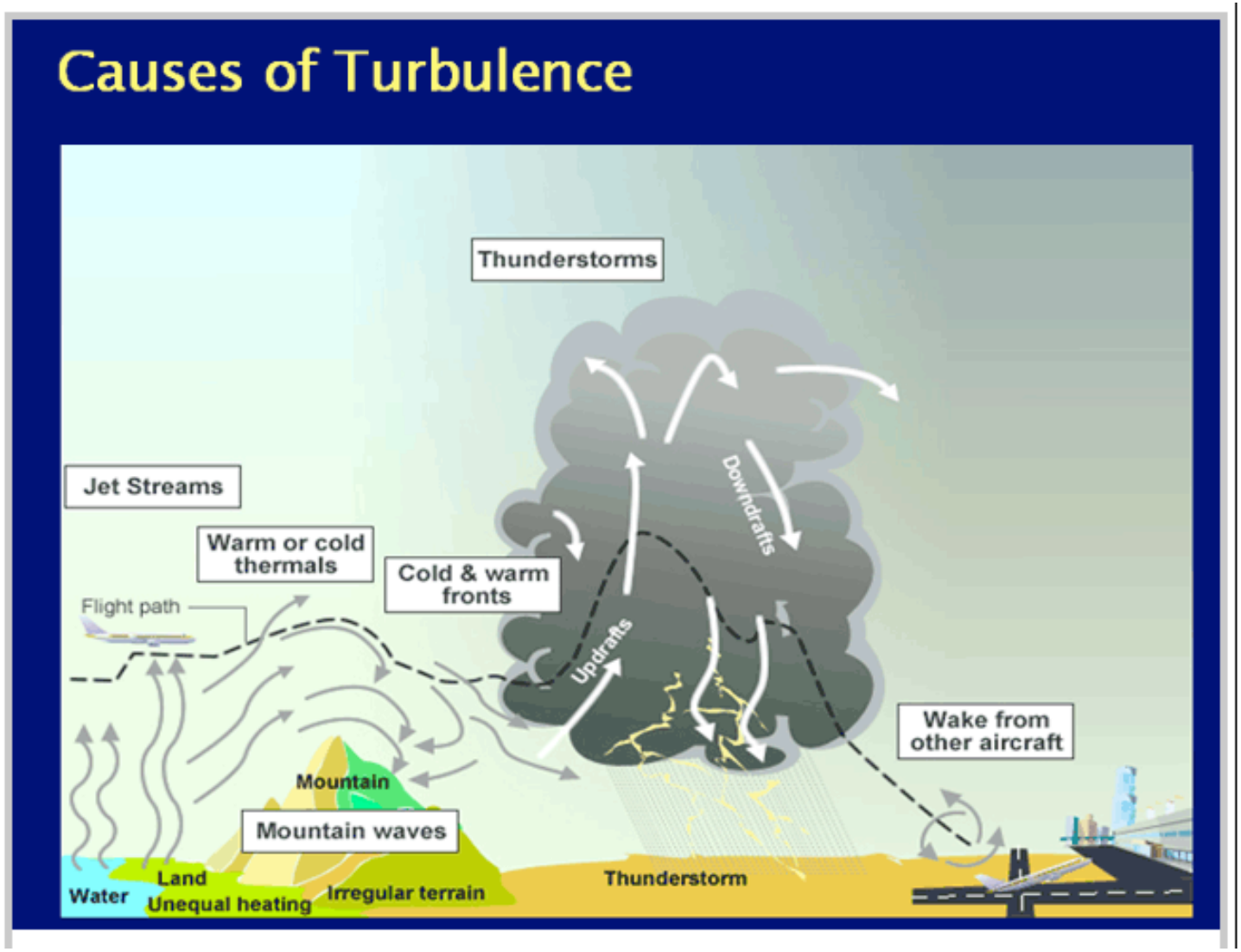
Atmospheric Turbulence

What is Turbulence?

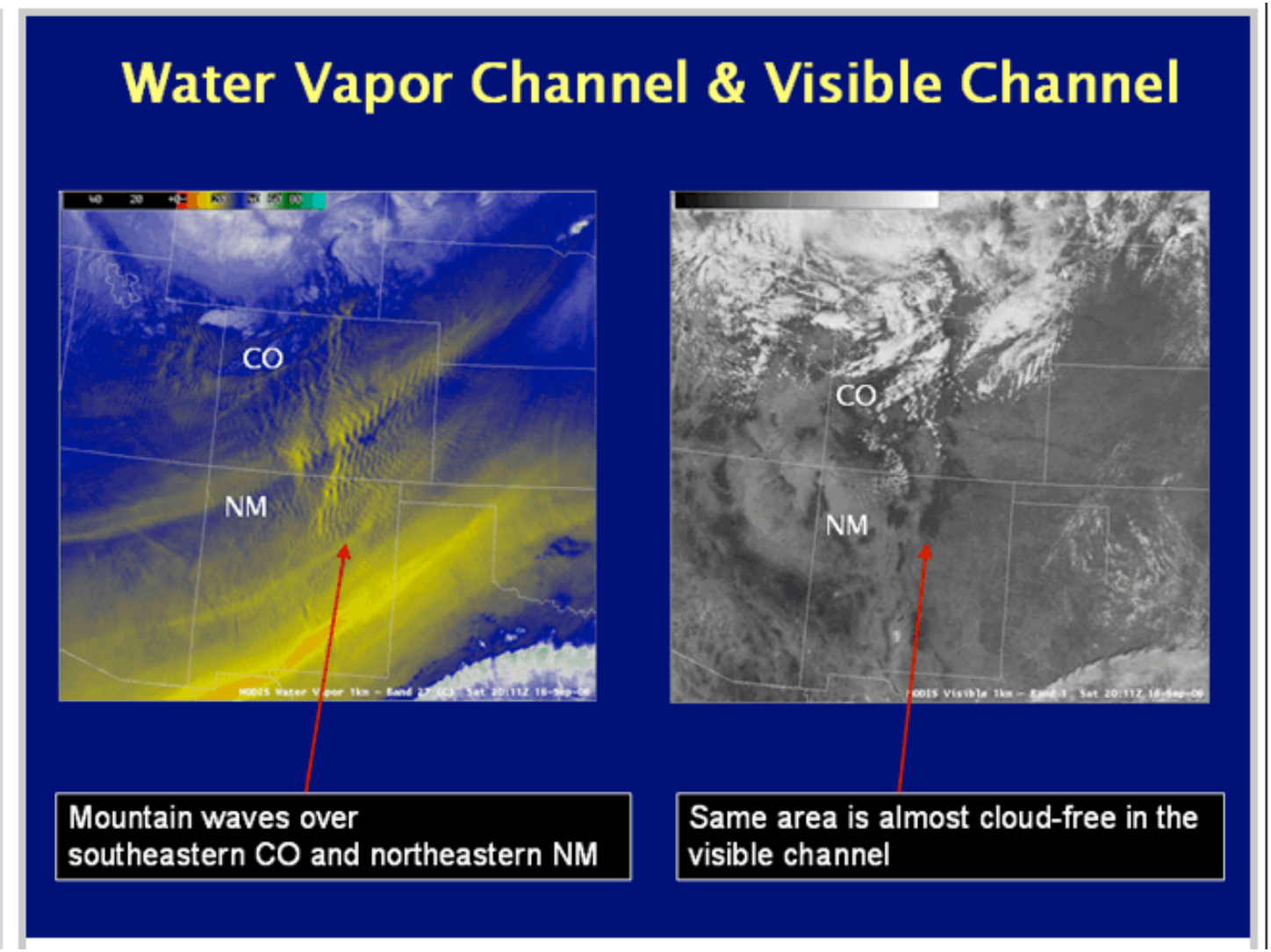
This smoke pattern shows turbulence as rapid, abrupt and chaotic changes in the speed and direction of air flow.

Colored smoke is used to show “wake turbulence” generated by an aircraft upon take-off or landing.

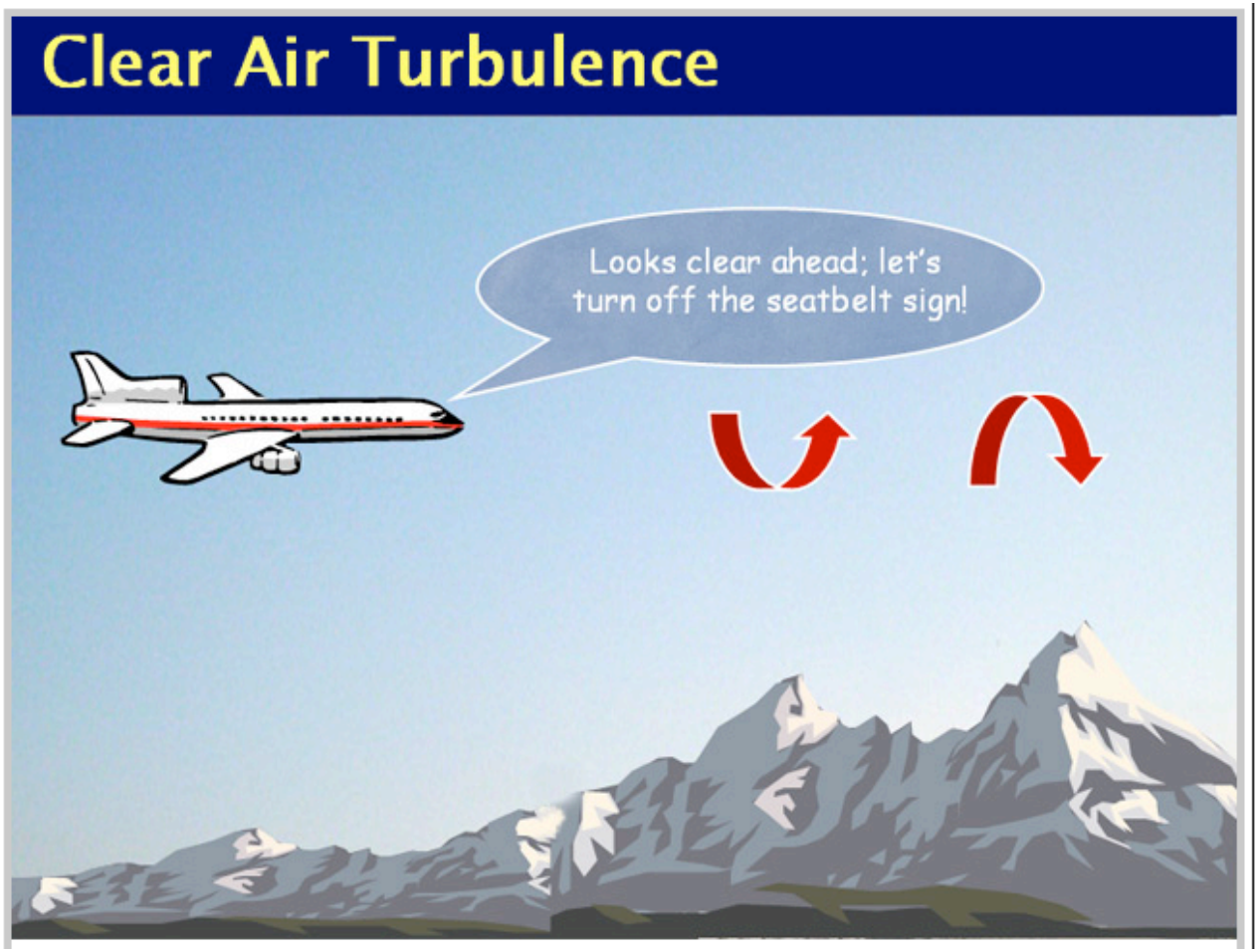
Atmospheric Turbulence



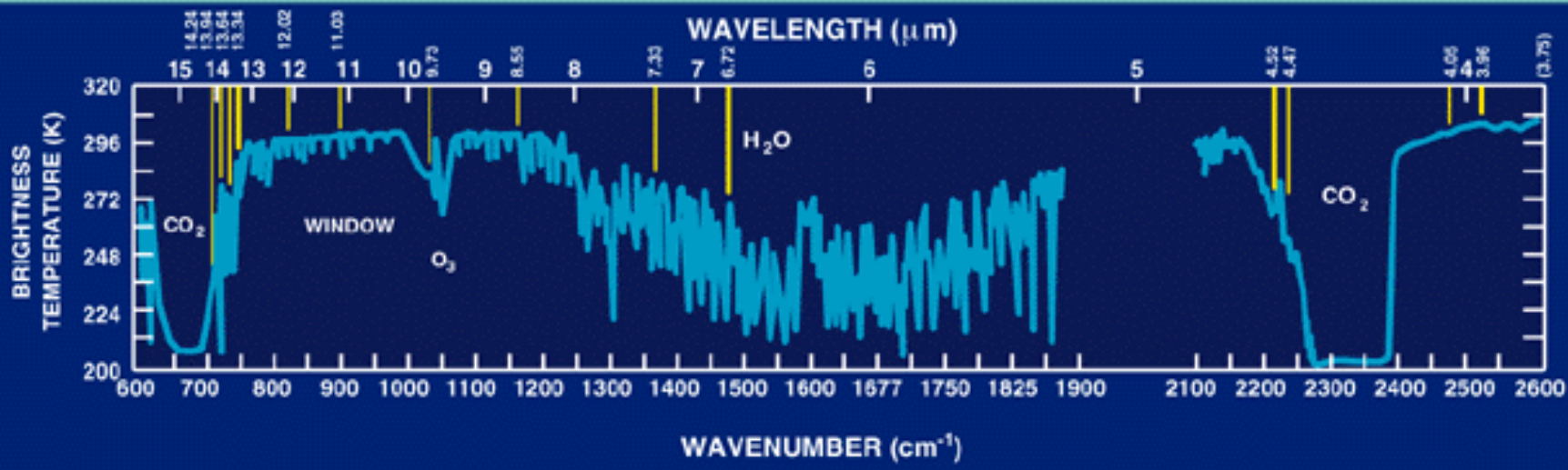
Why is 6.7 µm Important for the Detection of Turbulence?

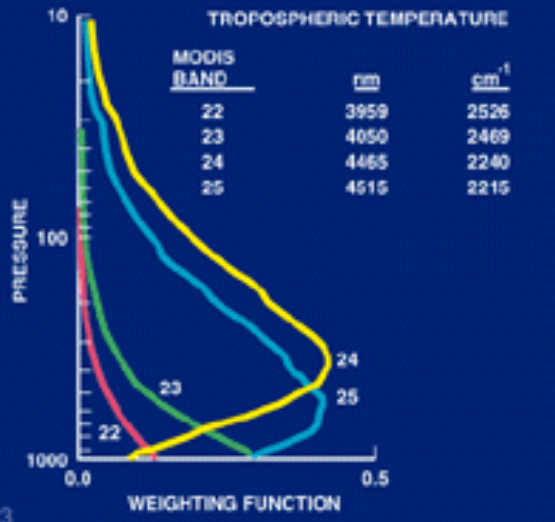


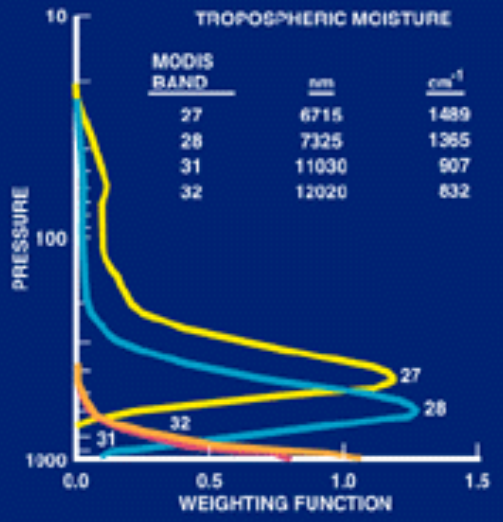
Why is This Important?

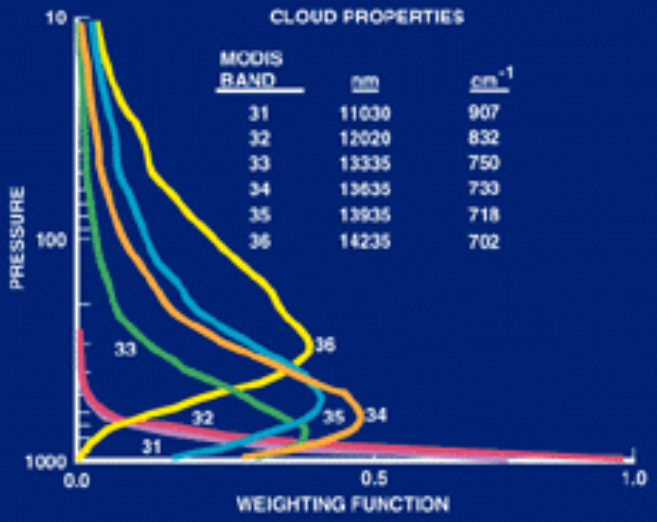


ATMOSPHERE - THERMAL RADIATION

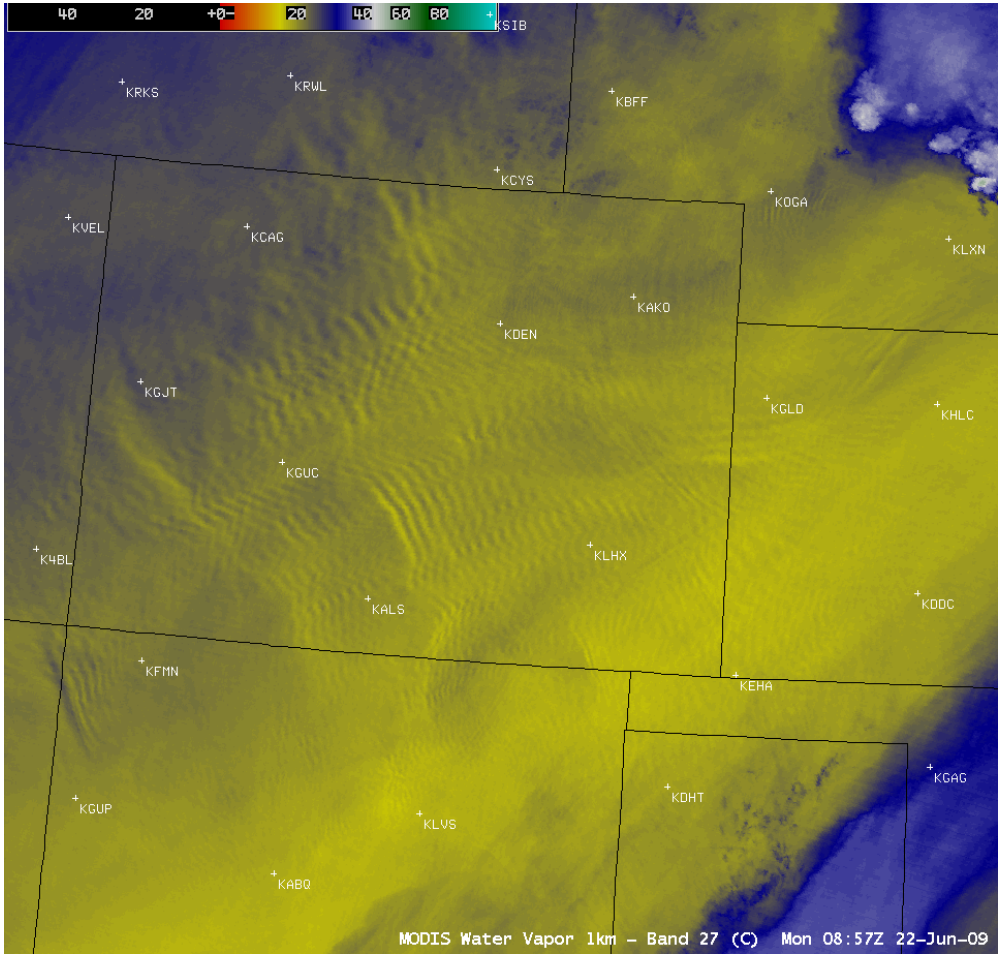






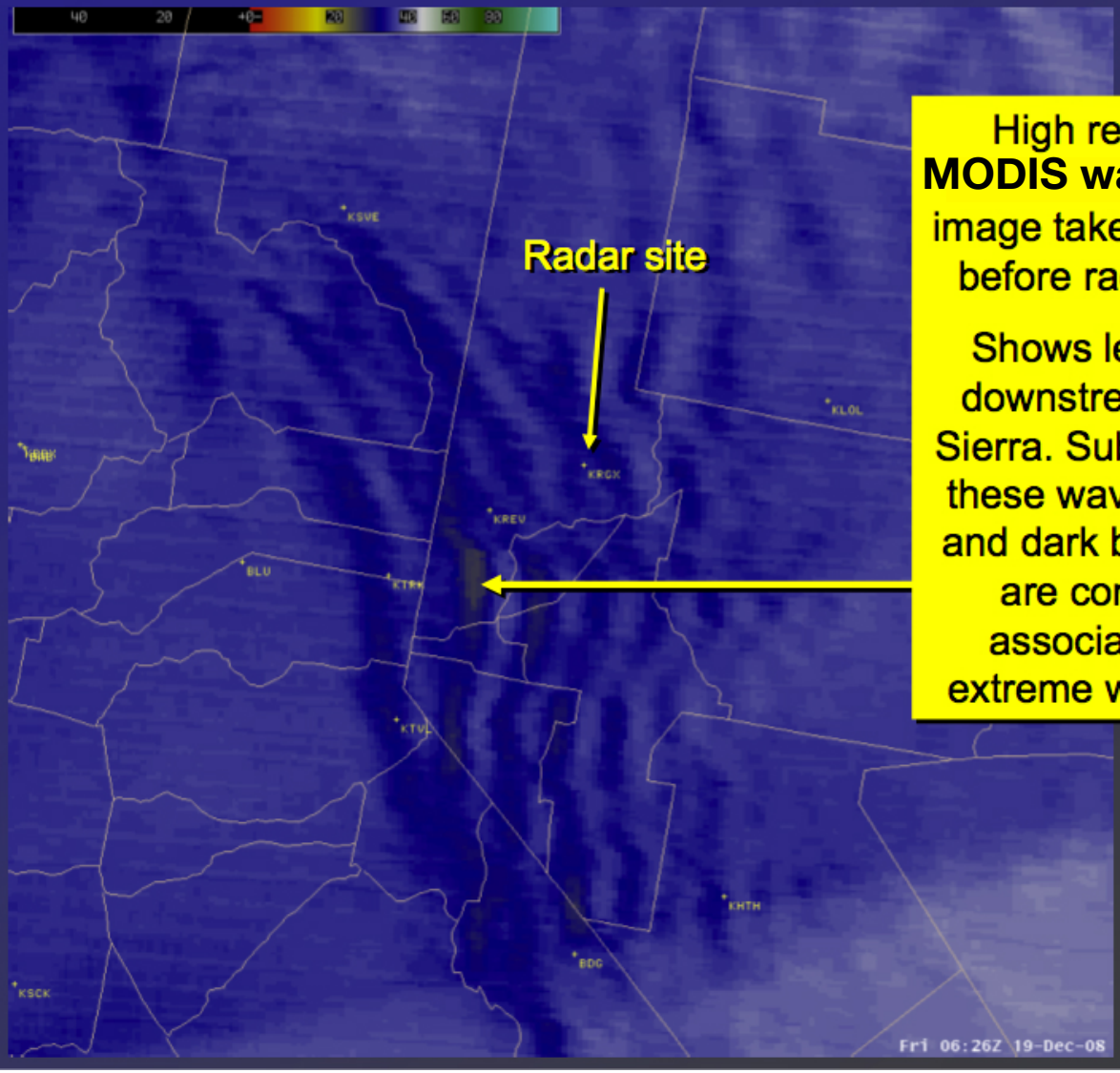


Mountain Wave Clouds in Clear Air



MODIS and
GOES
08:57 UTC
22 June 2009

Lee Waves



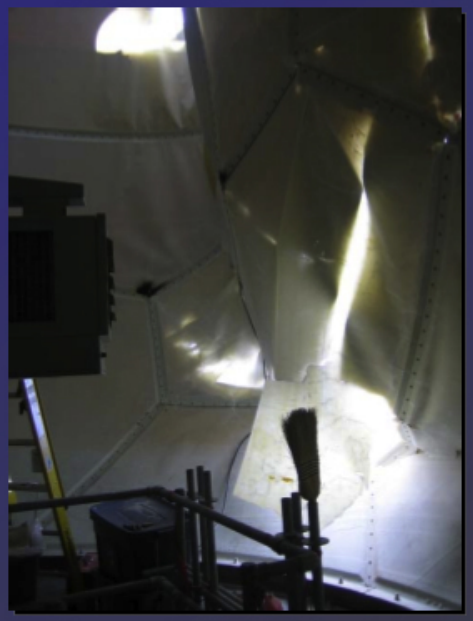
High resolution **MODIS water vapor** image taken ~4 hours before radar failed.

Shows lee waves downstream of the Sierra. Subsidence in these waves (yellow and dark blue areas) are commonly associated with extreme wind gusts.

(credit: NWS forecast office, Reno NV)

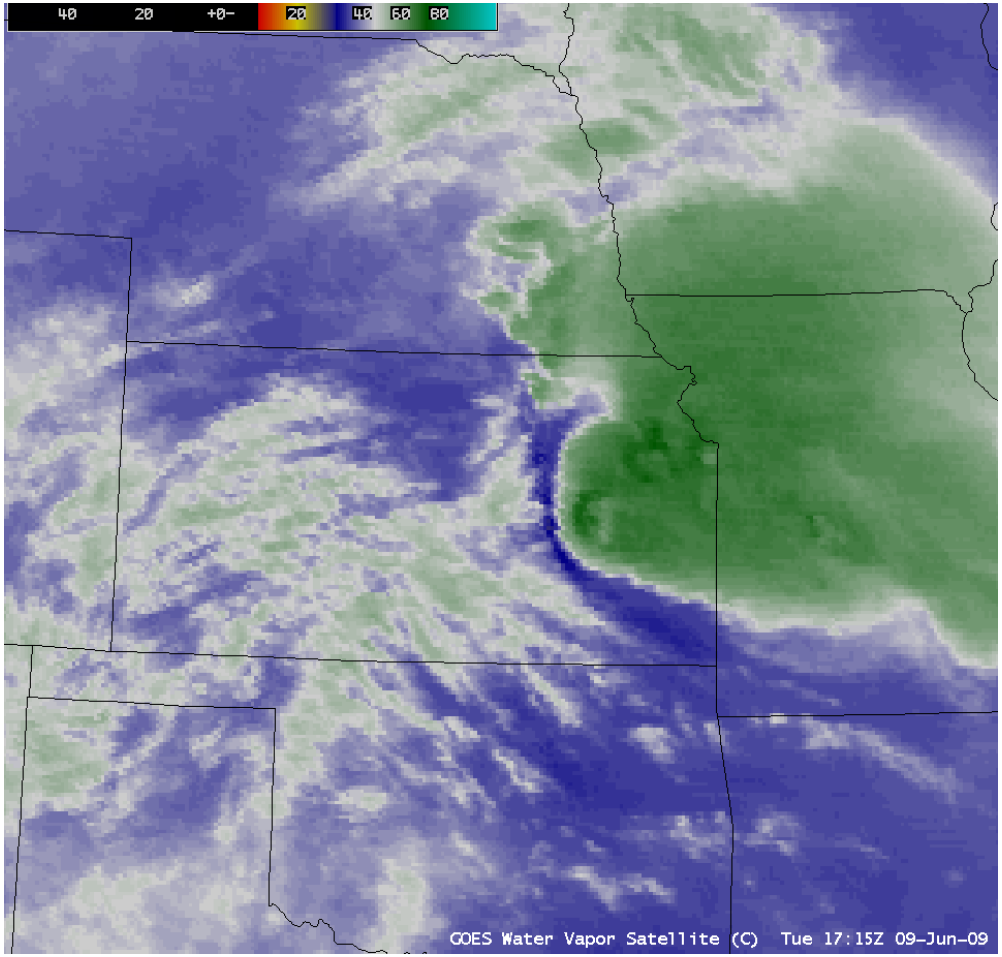
Photos

Photos taken by NWS Reno electronics team, on first visit to radar after dome failure (19 Dec.).



(credit: NWS forecast office, Reno NV)

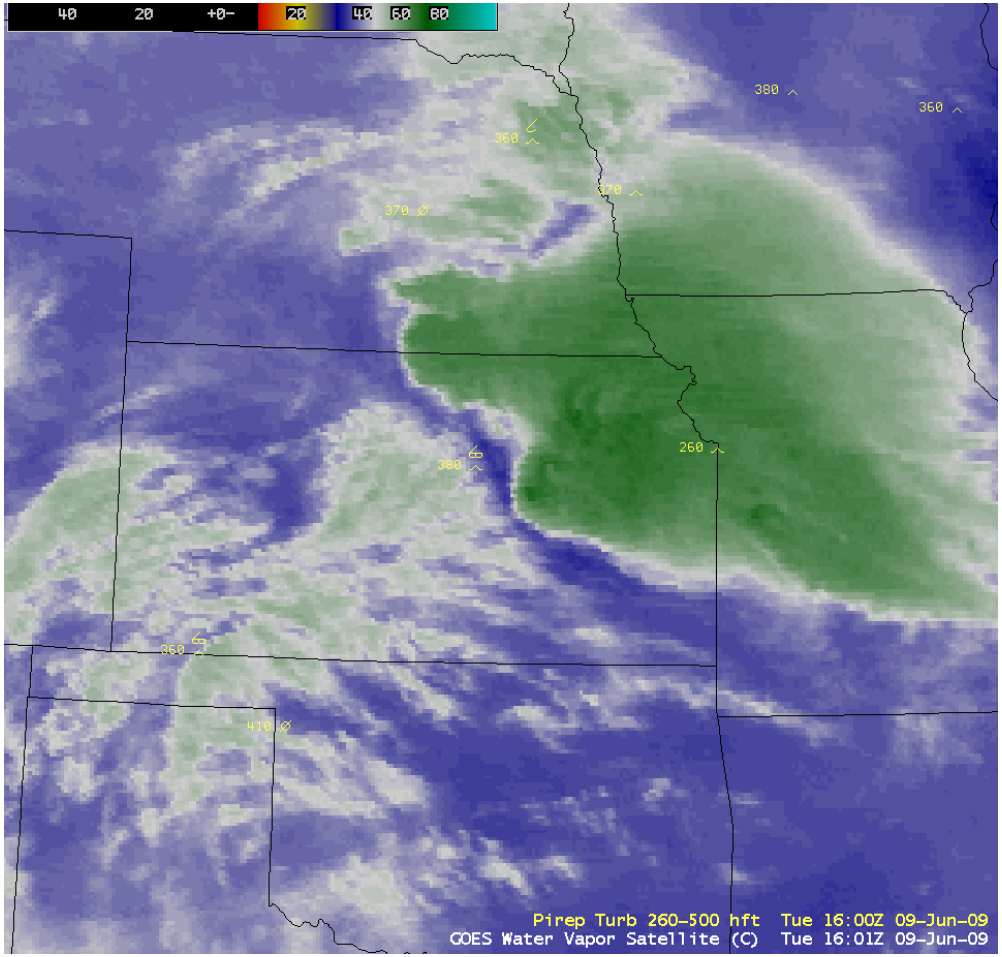
Turbulence Not Just from Orography



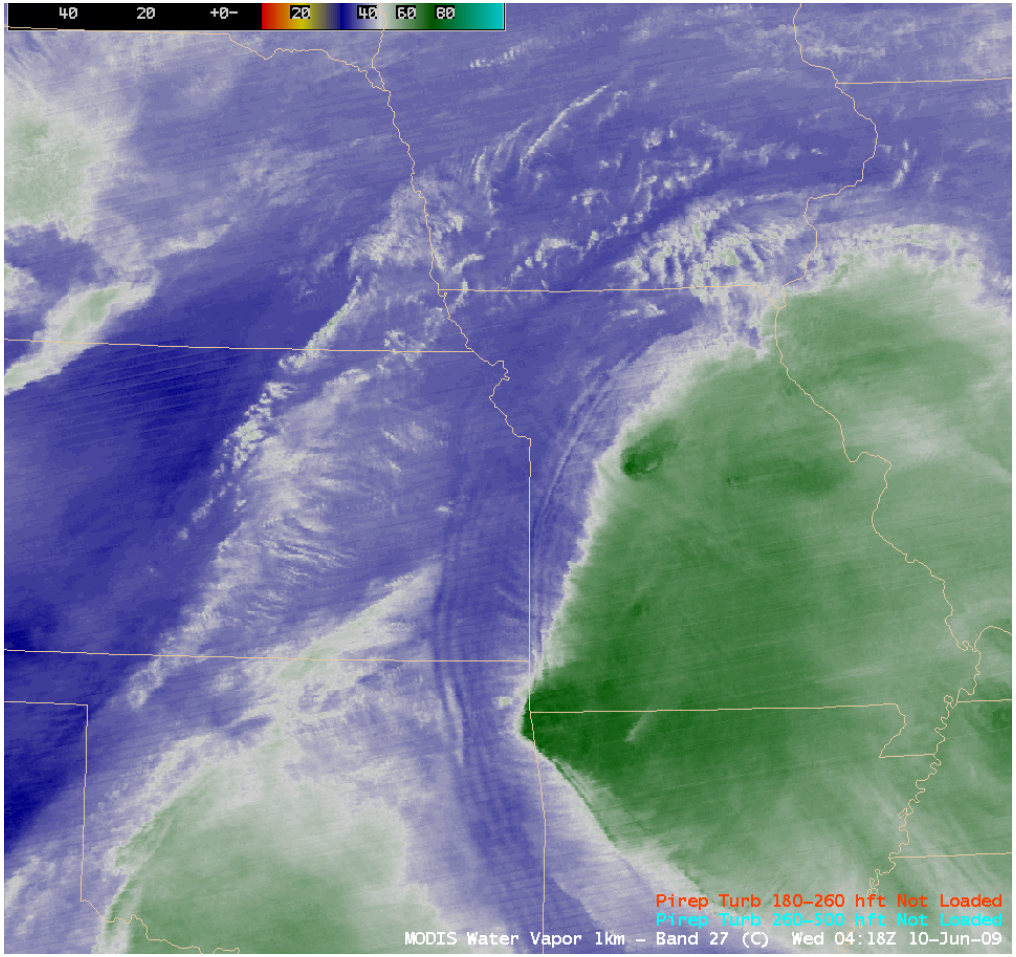
MODIS 6.7μm
Water Vapor
Band
17:15 UTC
9 June 2009

Pilot Reports of Turbulence

GOES 6.5μm
Water Vapor
Band
16:00 UTC
9 June 2009



Turbulence Not Just from Orography



MODIS 6.7 μm
Water Vapor
Band
04:18 UTC
10 June 2009

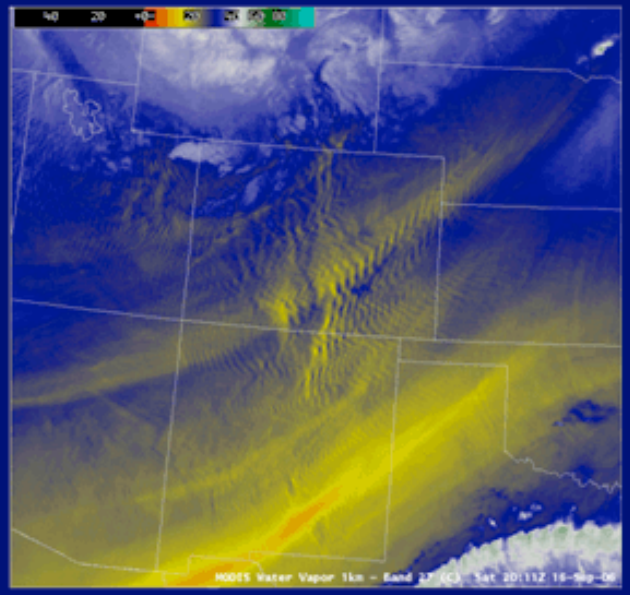
Why is 6.7 µm Important for the Detection of Turbulence?

Summary

Turbulence is a significant hazard to aviation, and satellite imagery can sometimes be a helpful tool in turbulence detection.

Mountain waves are one common cause of turbulence, and water vapor channel imagery has the ability to detect areas where this type of turbulence may be present.

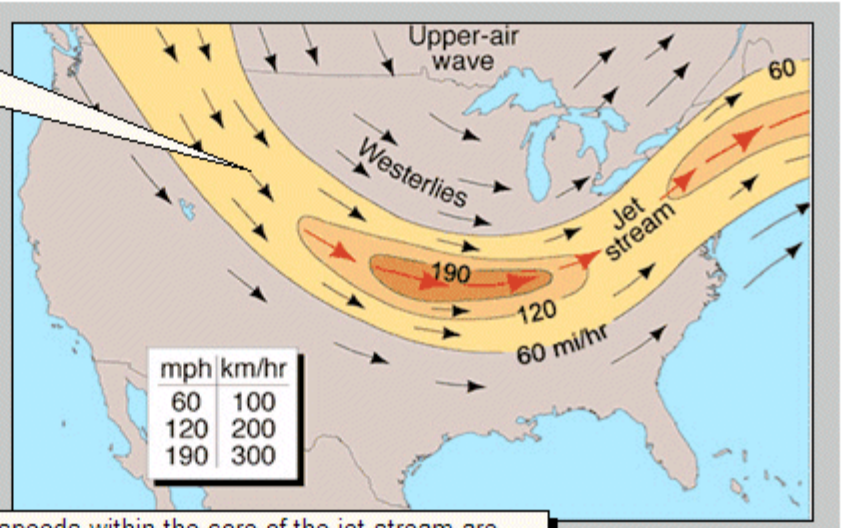
The typical "herringbone" signature of mountain waves often occurs in clear (cloud-free) air, making the water vapor channel the only tool for accurate turbulence detection in those cases.



More With Water Vapor

What is the Jet Stream?

The jet stream is a high velocity current of air found in the upper levels of the atmosphere. Generally seen at altitudes of 6-12 miles above the Earth's surface, this fast-moving "river of air" can be several hundred miles in width, but is only about 1-2 miles deep.



mph	km/hr
60	100
120	200
190	300

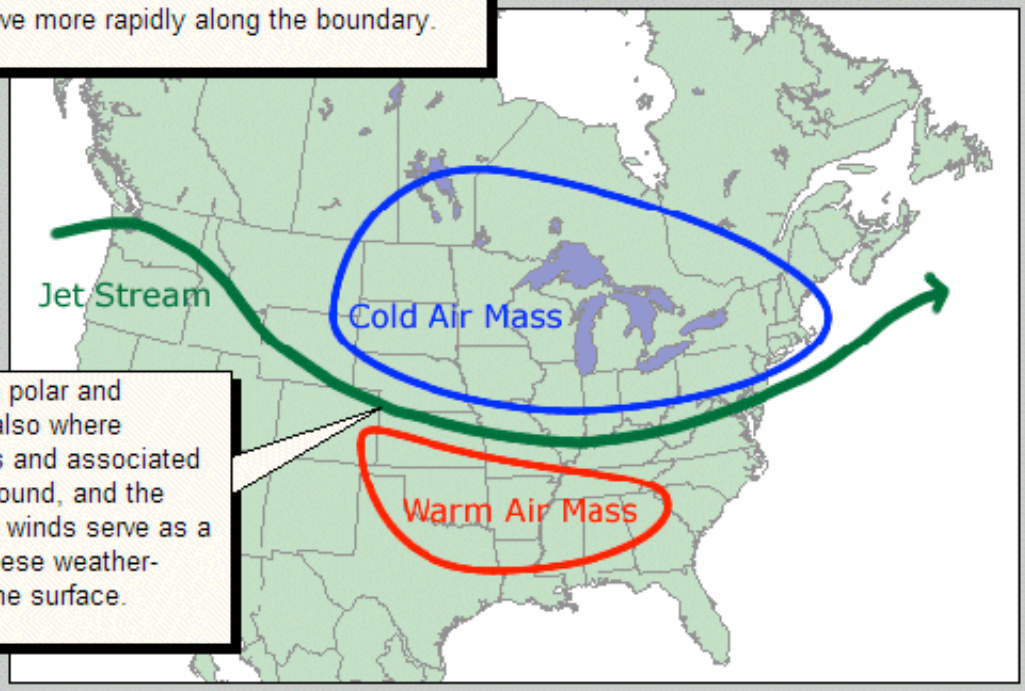
Wind Speeds within the Jet Stream

Wind speeds within the core of the jet stream are often greater than 150 mph, but can occasionaly reach speeds exceeding 300 mph (maximum wind speeds within the jet core have been reported as high as 400 mph!). The strongest wind speeds are not continuous along the jet stream, but rather are focused within embedded velocity maxima known as "jet streaks". Multiple jet streaks are often present along the axis of a jet stream as it circles the Earth.

Jet Stream and Water Vapor

What creates the Jet Stream?

Jet streams are generated by strong temperature contrasts in the upper atmosphere, between cold polar air masses and warm tropical air masses. This temperature difference induces a large pressure difference between the two air masses, which then forces the air to move more rapidly along the boundary.



Impact on Weather

This boundary between polar and tropical air masses is also where surface frontal systems and associated precipitation are often found, and the high altitude jet stream winds serve as a "steering current" for these weather-producing features at the surface.

Atmospheric Turbulence