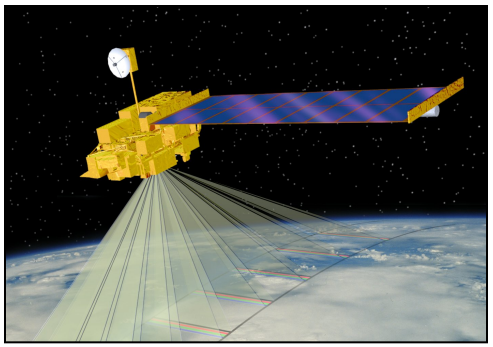
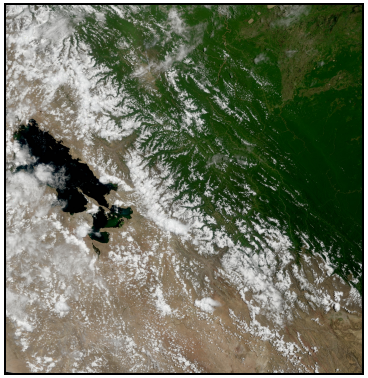
DB Product Applications

2011 WMO RA V
Citeko, Bogor, Indonesia
22 September Part 2





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

Aviation Applications Continued

- Clouds
  - Composition
  - Cloud Top Properties
  - Cloud Phase

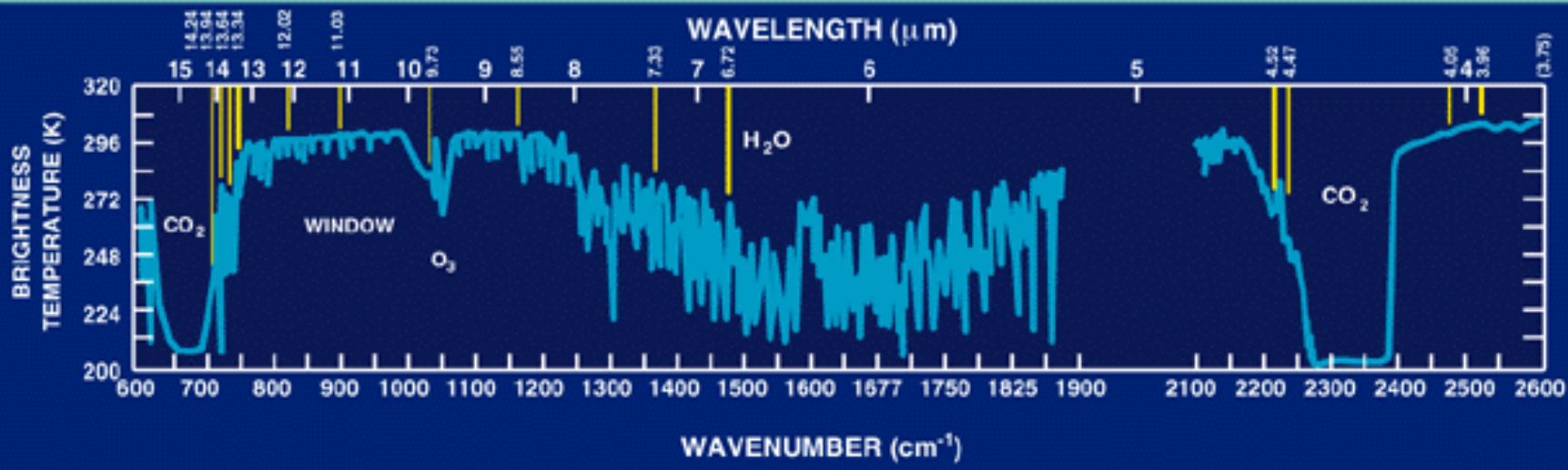
Clouds

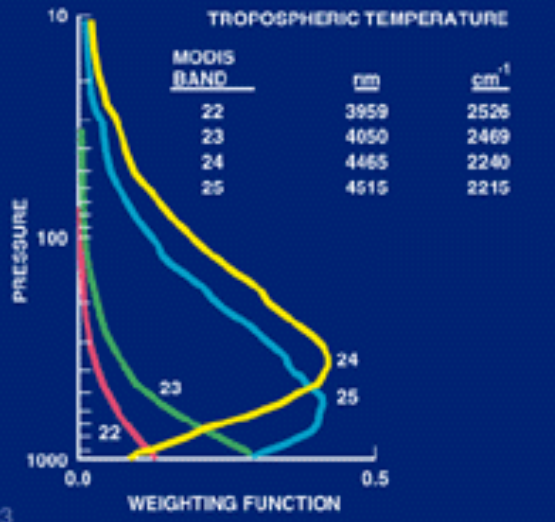
- MOD06 Cloud Product contains
  - Cloud Top Properties at 5km
    - Cloud Top Pressure, Cloud Top Temperature, Cloud Fraction, Cloud Emissivity
  - Cloud Phase at 5 km
  - Cloud Optical Properties at 1 km (Daytime only)
    - Cloud Effective Radius
    - Cloud Optical Thickness

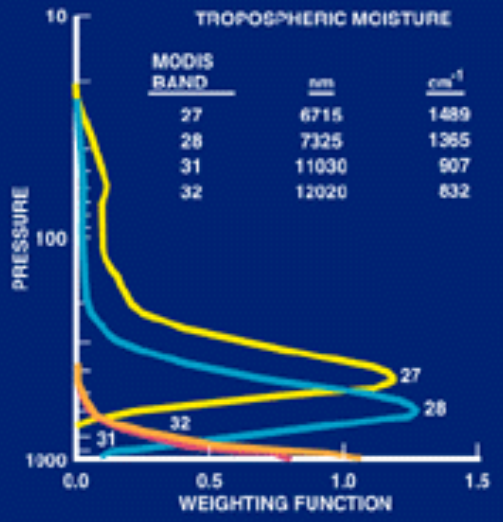
Cloud Top Property Algorithm

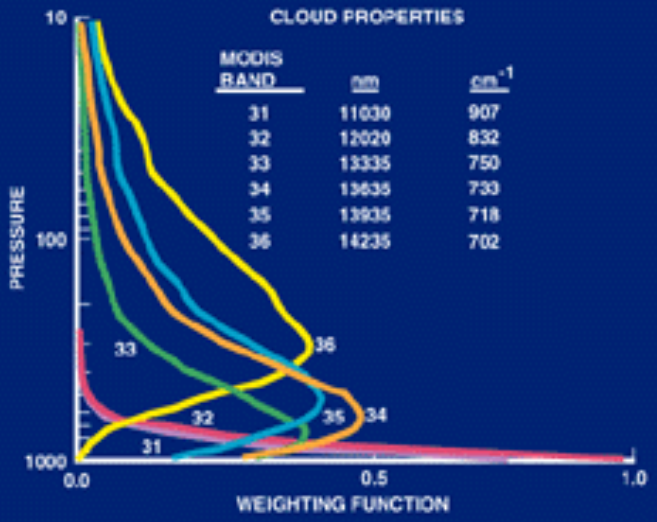
- Cloud Top Pressure, Temperature, Emissivity derived using CO_2 "slicing"
- MODIS product utilizes 4 spectral channels in the 13 – 14 μm region.
- 5x5 1 km pixel retrievals where at least 5 of the 1 km pixels are cloudy as determined by the cloud mask
- Cloud properties retrieved both day and night

ATMOSPHERE - THERMAL RADIATION





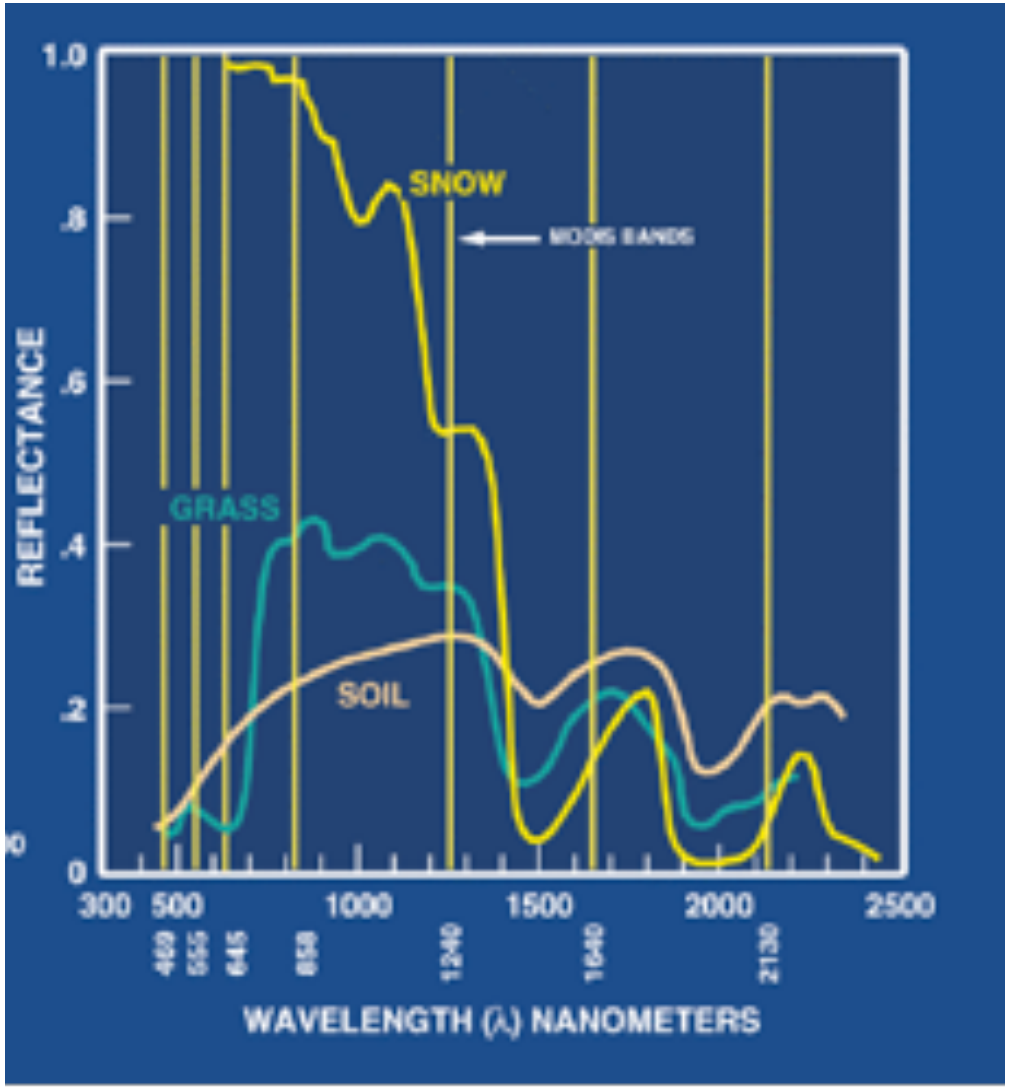




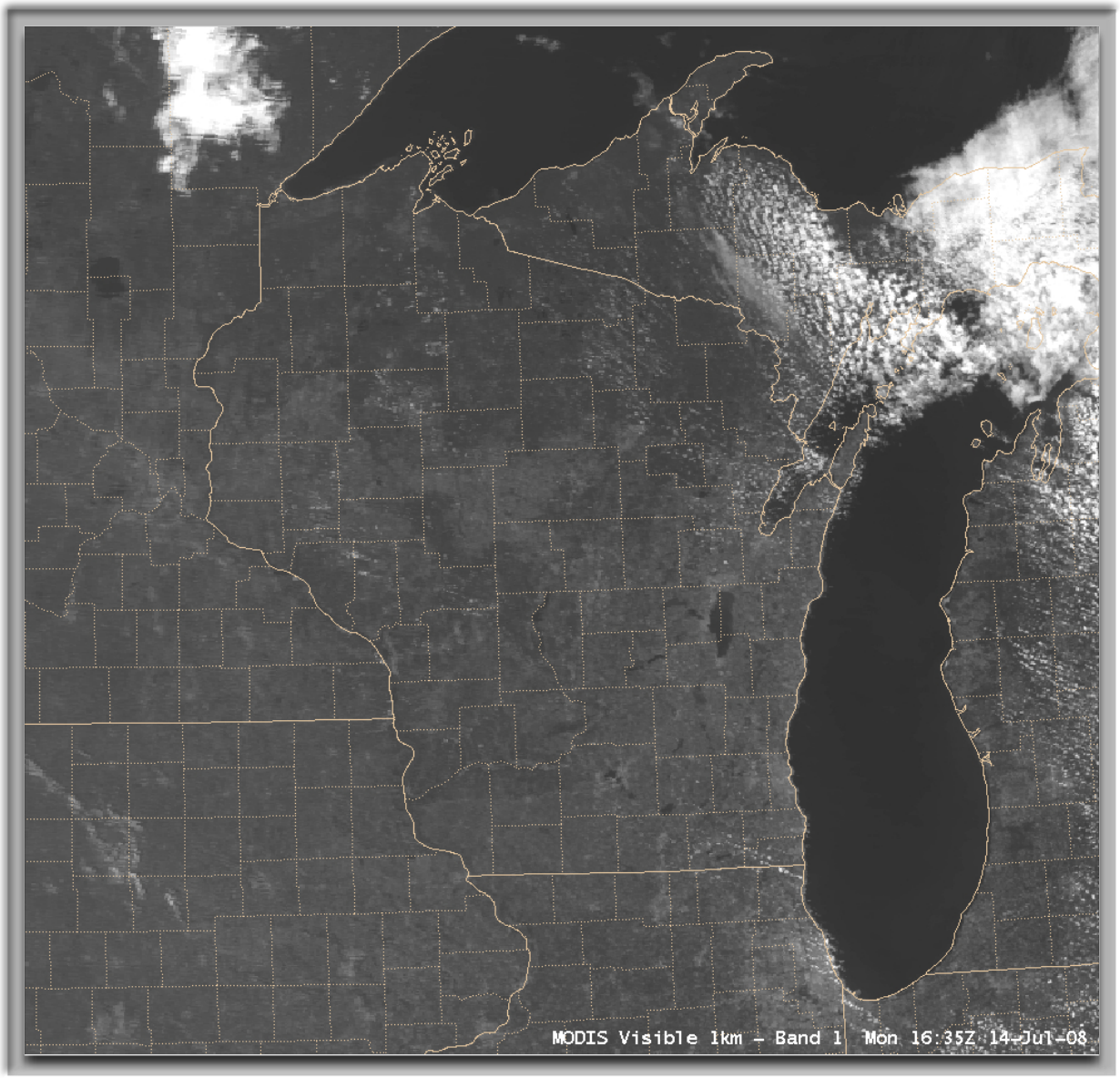
Cloud Phase

- IR Brightness Temperature Difference Product
  - Band 29 (8.6 µm) – Band 31 (11 µm)
  - Takes advantage of difference in water/ice cloud absorption in this spectral region
- Near Infrared Bands (1.6 and 2.1 µm)
- Short Wave Infrared Bands (4 µm region)

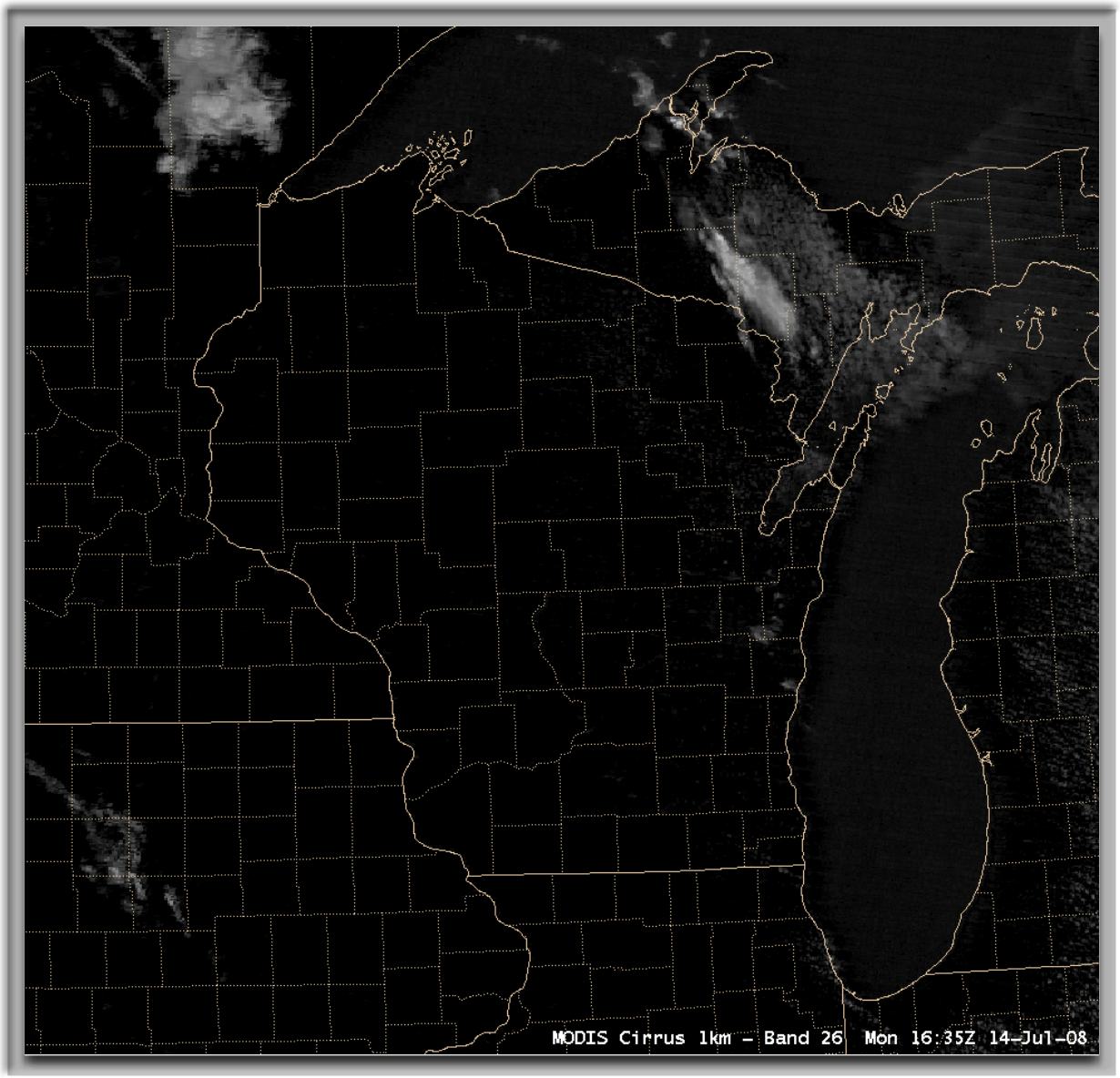
MODIS – Snow/Ice and Ice Clouds



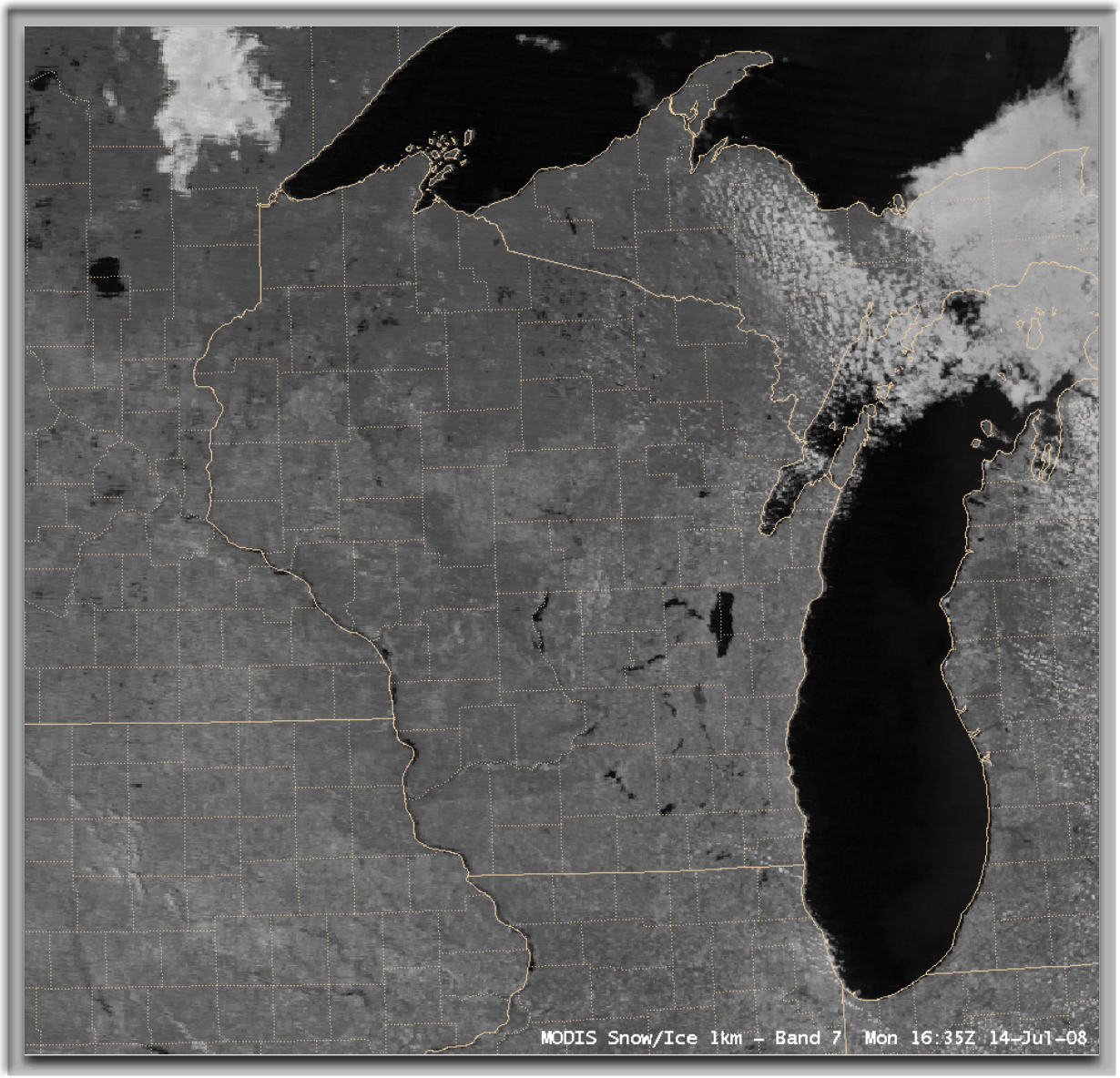
MODIS Products in AWIPS



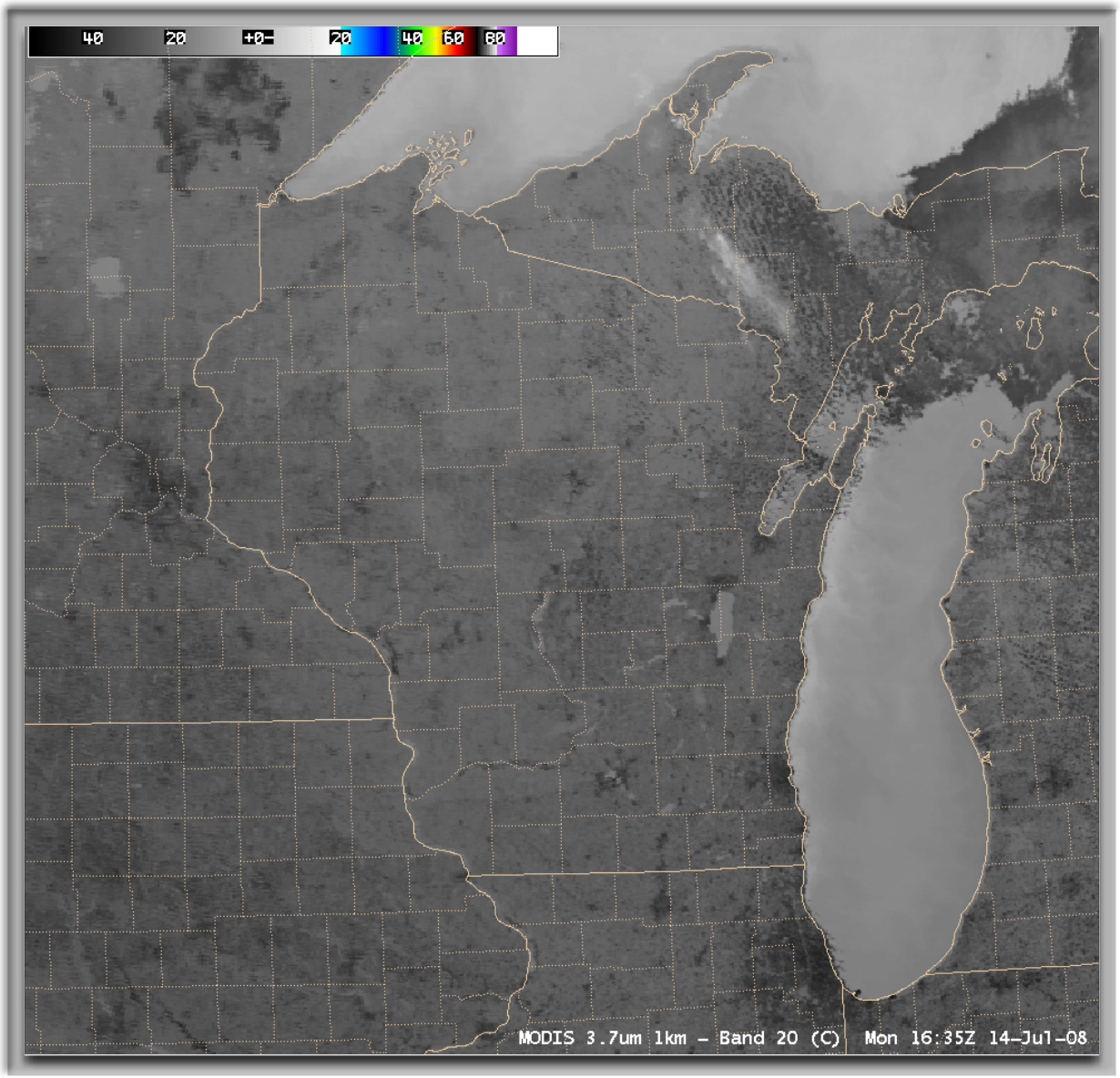
Visible (0.65 μm): 1-km resolution



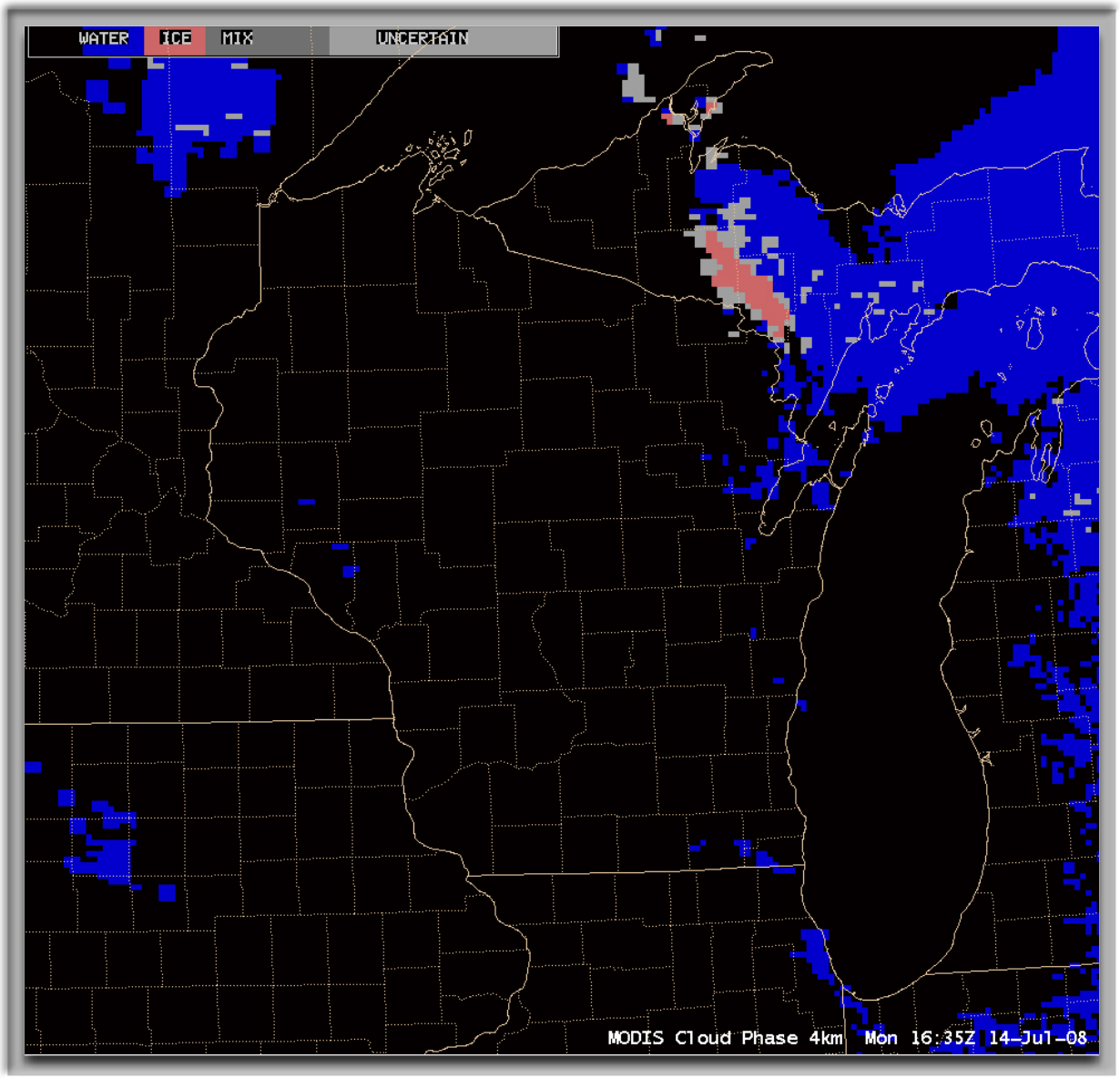
Cirrus detection (1.3 μm): 1-km resolution



Snow/ice discrimination (2.1 μm): 1-km resolution

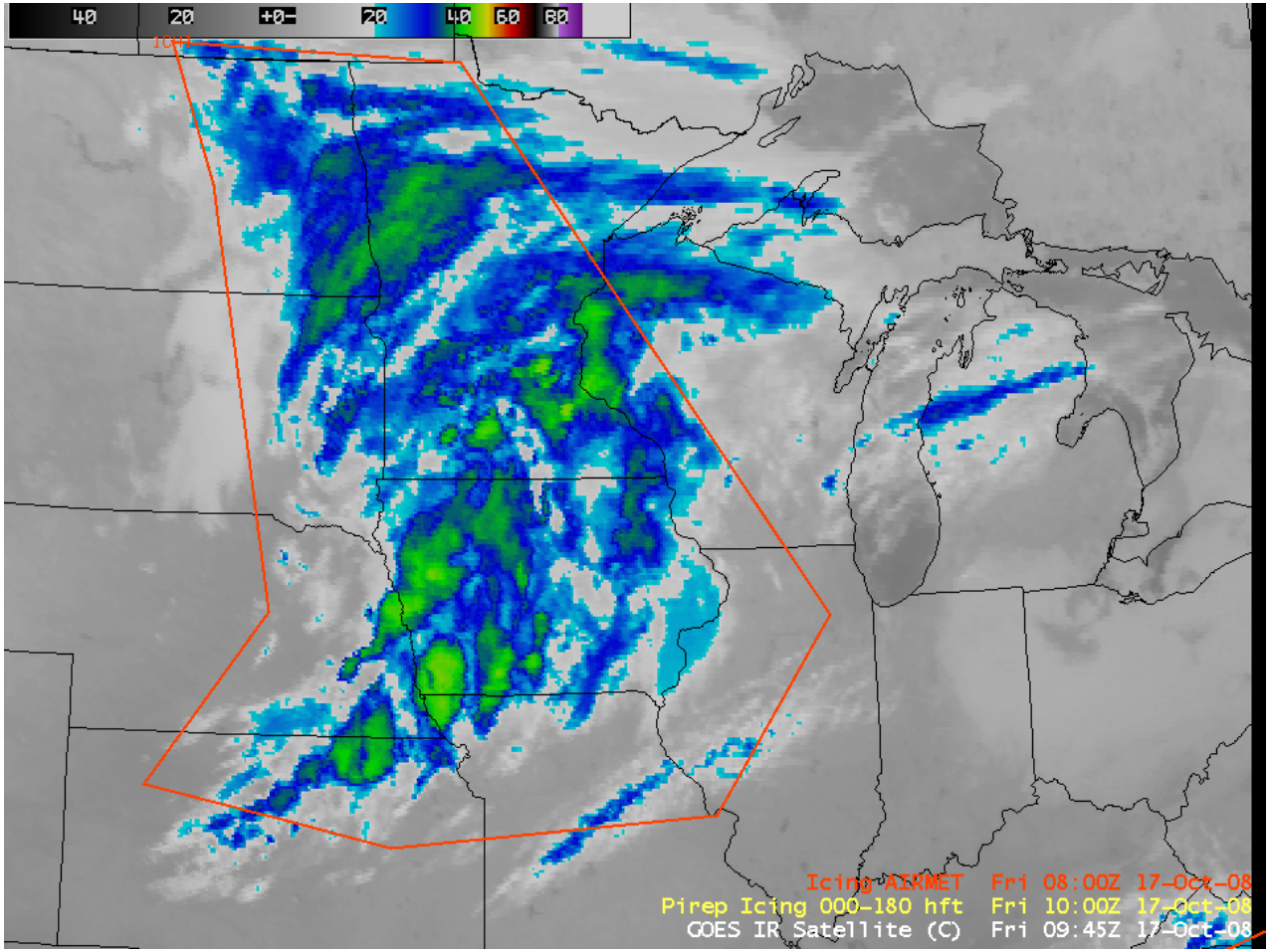


Shortwave IR (3.7 μm): 1-km resolution



Cloud Phase: 4-km resolution

Using Satellite Imagery to Help Diagnose Areas of Aircraft Icing Potential



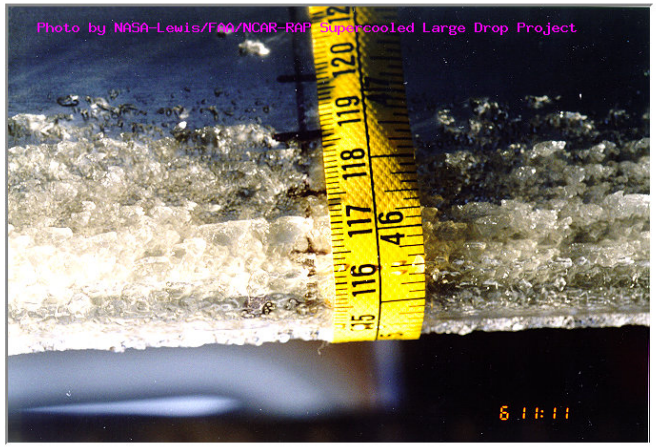
GOES IR window animation 17 October 2008

Icing

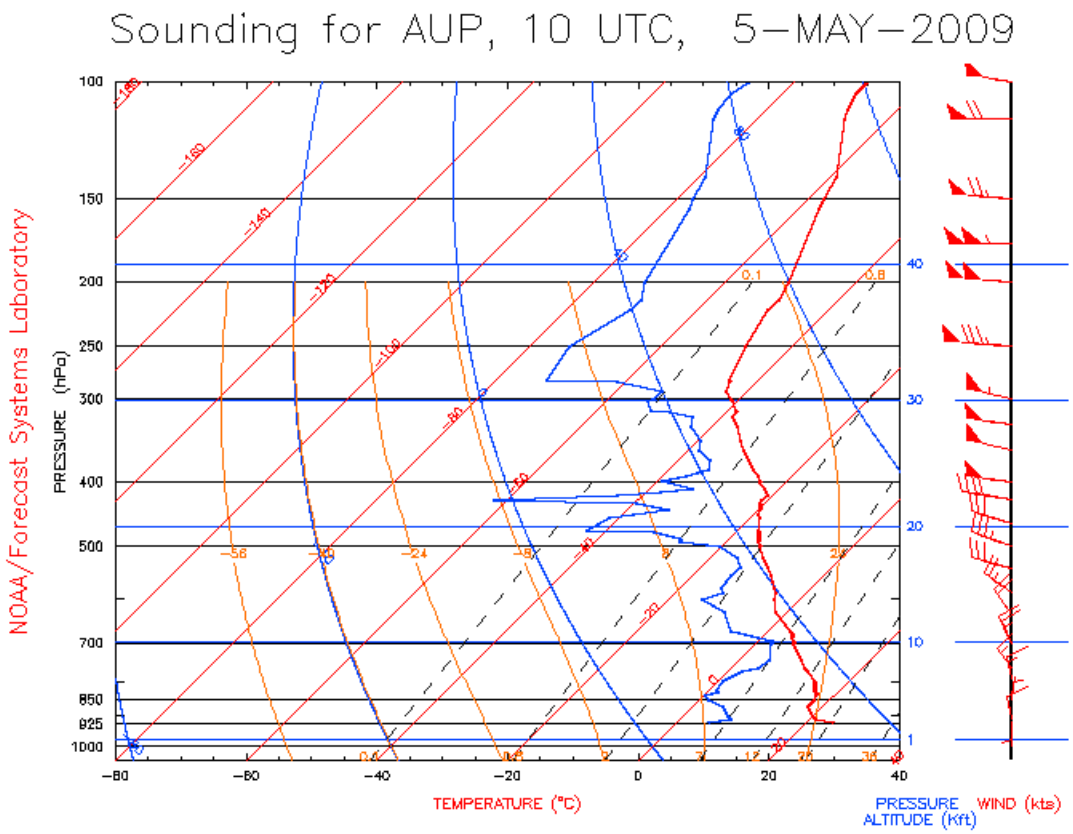
- Freezing Level
  - Altitude at which the temperature is 0 degrees C
  - Above this level the temperature is < 0 C
- Water Can Exist at Temperatures Well Below Freezing
  - Supercooled Water
- An airplane whose temperature is < freezing in this environment can accrue ice

Why is This Important?

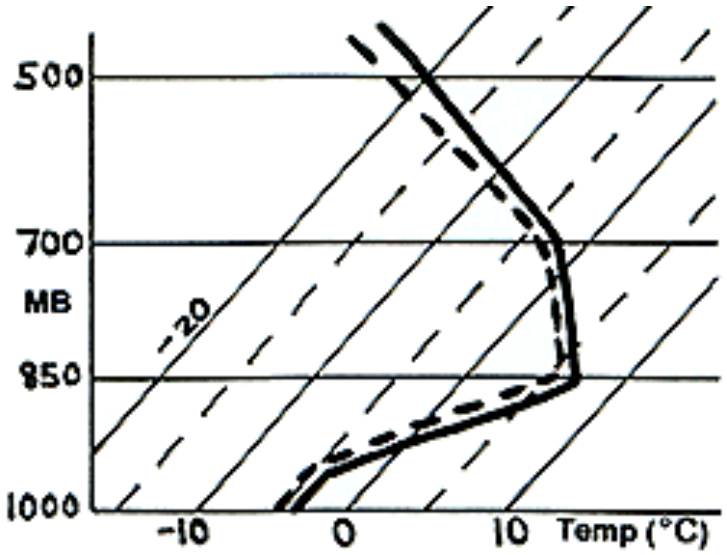
- We worry about icing because it can adversely affect the flight characteristics of an aircraft. Icing can increase drag, decrease lift, and cause control problems. The added weight of the accreted ice is generally only a factor in light aircraft.



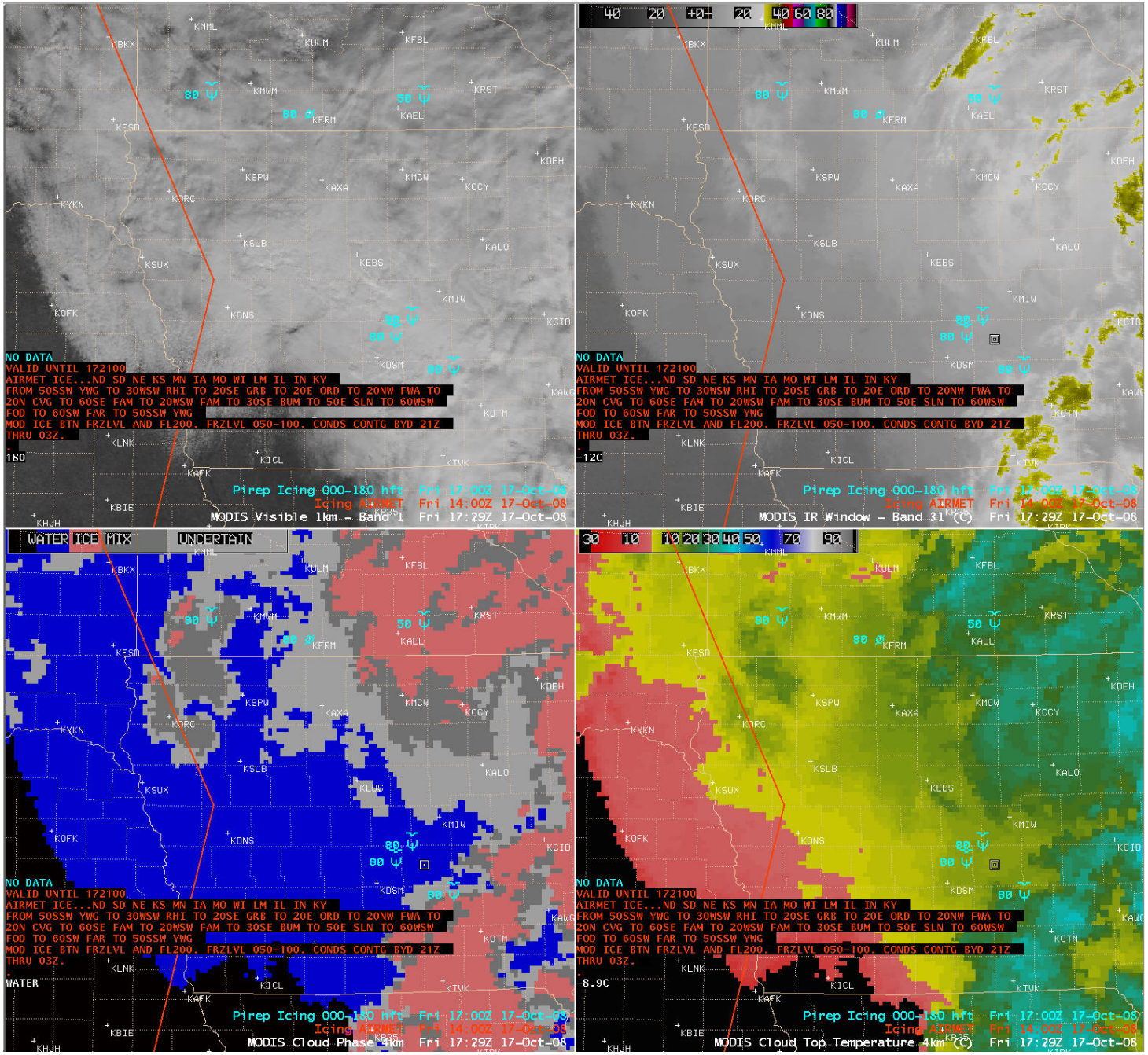
Ice Accumulation On
The Wing of a Small Aircraft
NASA


Sounding for AUP, 10 UTC, 5-MAY-2009
NOAA/Forecast Systems Laboratory
PRESSURE (hPa)
100
150
200
250
300
400
500
700
850
925
1000
-80
-60
-40
-20
0
20
40
TEMPERATURE (°C)
PRESSURE ALTITUDE (Kft)
WIND (kts)
40
30
20
10
1

Freezing Rain Sounding



- A closer view using AWIPS images of the MODIS visible channel, 11.0 µm "IR window" channel, Cloud Top Temperature (CTT) product, and Cloud Phase product at 17:29 UTC (below) indicated that much of the cloud shield along the trailing (western) edge of the shortwave over Minnesota and Iowa exhibited cloud top temperatures that were below freezing (generally in the -5 to -12º C range), but the MODIS Cloud Phase product designated those trailing edge clouds as "Water droplet" clouds (blue enhancement). Within this area of supercooled water droplet clouds were several pilot reports of icing at the 8000-foot altitude across southern Minnesota and western/central Iowa.

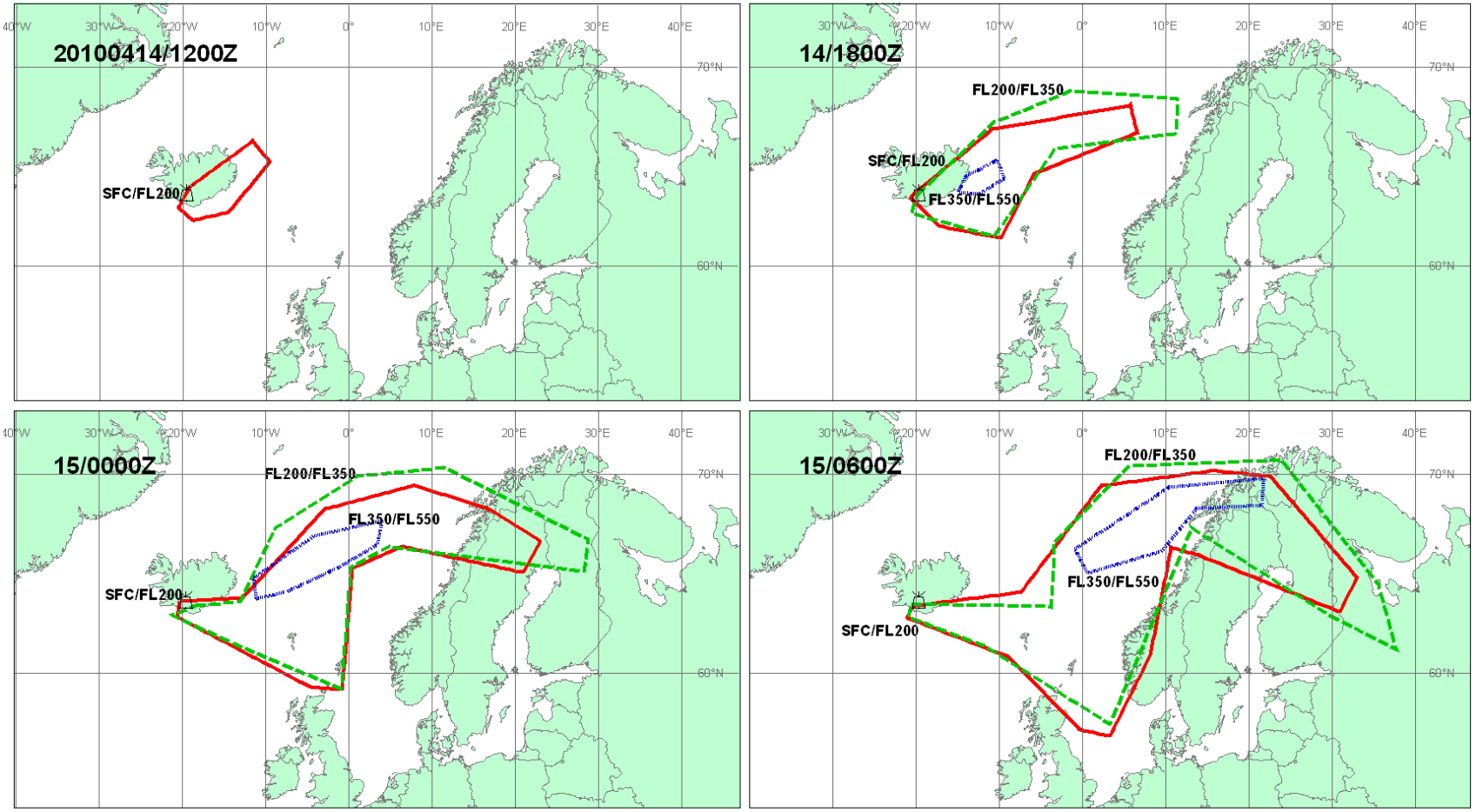

NO DATA
VALID UNTIL 172100
AIRMET ICE...ND SD NE KS MN IA MO WI LM IL IN KY
FROM 50SSW YWG TO 30WSW RHI TO 20SE GRB TO 20E ORD TO 20NW FWA TO
20N CVG TO 60SE FAM TO 20WSW FAM TO 30SE BUM TO 50E SLN TO 60WSW
FOD TO 60SW FAR TO 50SSW YWG
MOD ICE BTN FRZLVL AND FL200. FRZLVL 050-100. CONDS CONTG BYD 21Z
THRU 03Z.
180
Pirep Icing 000-180 hft Fri 17:00Z 17-Oct-08
Icing AIRMET Fri 14:00Z 17-Oct-08
MODIS Visible 1km - Band 1 Fri 17:29Z 17-Oct-08
40 20 +0+ 20 40 60 80
-12C
MODIS IR Window - Band 31 (C) Fri 17:29Z 17-Oct-08
WATER ICE MIX UNCERTAIN
WATER
MODIS Cloud Phase 4km Fri 17:29Z 17-Oct-08
30 10 10 20 30 40 50 70 90
-8.9C
MODIS Cloud Top Temperature 4km (C) Fri 17:29Z 17-Oct-08

Other Cloud Applications Too

- Identification of mature T-storms
  - Must glaciate, meaning tops of cell must be ice
- Accurate height of "thin" high clouds
  - Energy transmitted from below the cloud in the IR window. Can't get accurate level from window BT.
  - Important for pilots. Clouds mean more moisture, dry entrainment and potential for turbulence.

Ash Detection

Why is this important?



VA ADVISORY
DTG: 20100414/1200Z
VAAC: LONDON
VOLCANO:
EYJAFJALLAJOKULL
PSN: N6338 W01937
AREA: ICELAND

SUMMIT ELEV: 1666M
ADVISORY NR: 2010/001
INFO SOURCE: ICELAND MET OFFICE
AVIATION COLOUR CODE: UNKNOWN
ERUPTION DETAILS: PLUME FROM VOLCANO
REPORTED TO BE UP TO 6000M

RMK: NIL
NXT ADVISORY: 20100414/1800Z

Grimsvotn

LATEST UPDATE: 25/05/2011 - AVIATION - ICELAND - VOLCANO

Volcanic ash causes flight disruption in Germany

Germany's Hamburg and Bremen airports were forced to cancel flights on Wednesday as ash from Iceland's Grimsvotn volcano drifted across northern Europe. Authorities have warned that southwest Scandinavia could also be affected.

By News Wires (text)

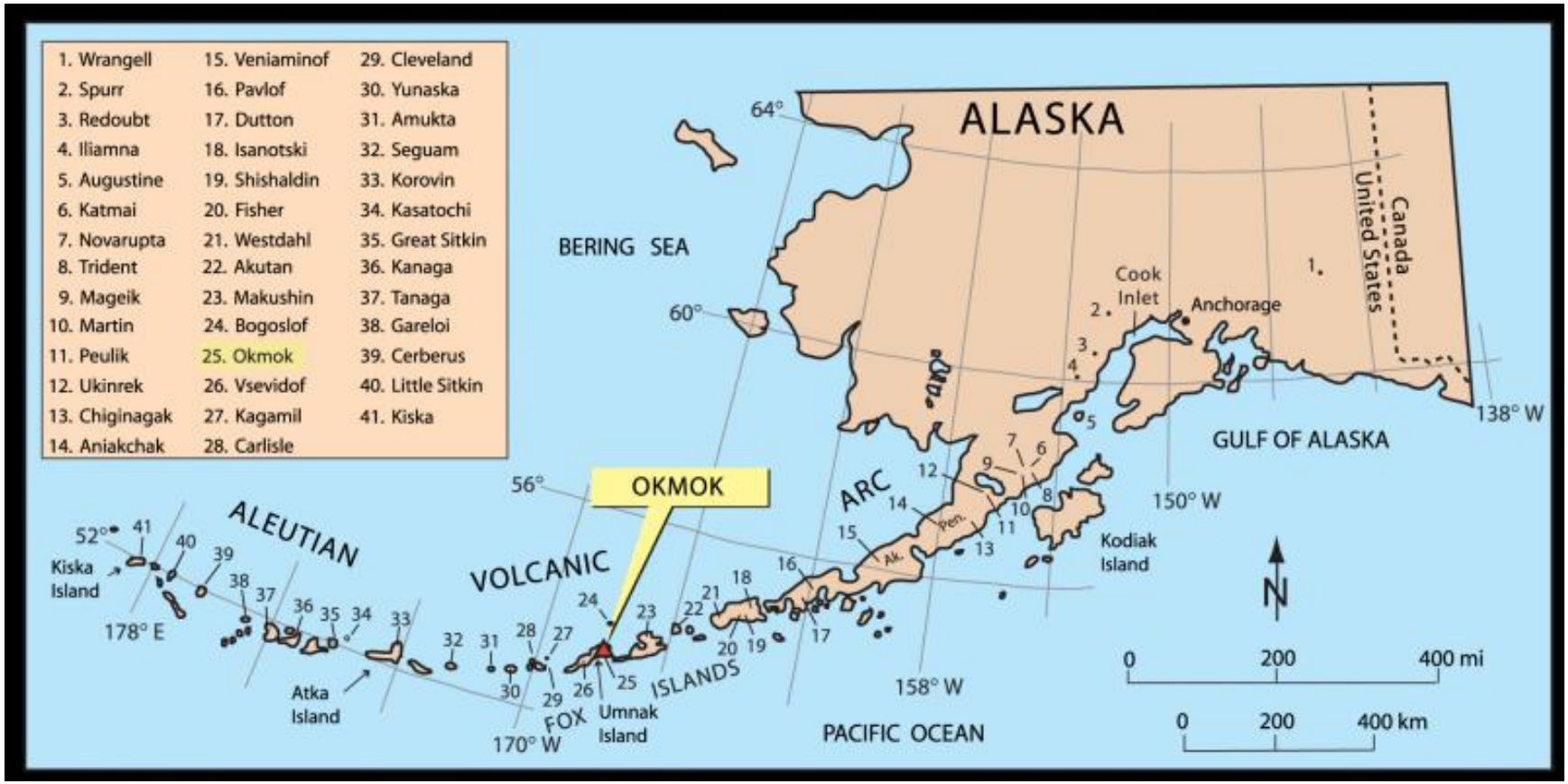
REUTERS - Two German airports halted flights on Wednesday as ash from an Icelandic volcano drifted across northern Europe, with parts of Scandinavia also facing a risk of disruption

Ash Detection

Why is this important?

- Ash particles can clog airline engines
- One such event caused a commercial airliner to make an emergency landing

Okmok Volcano

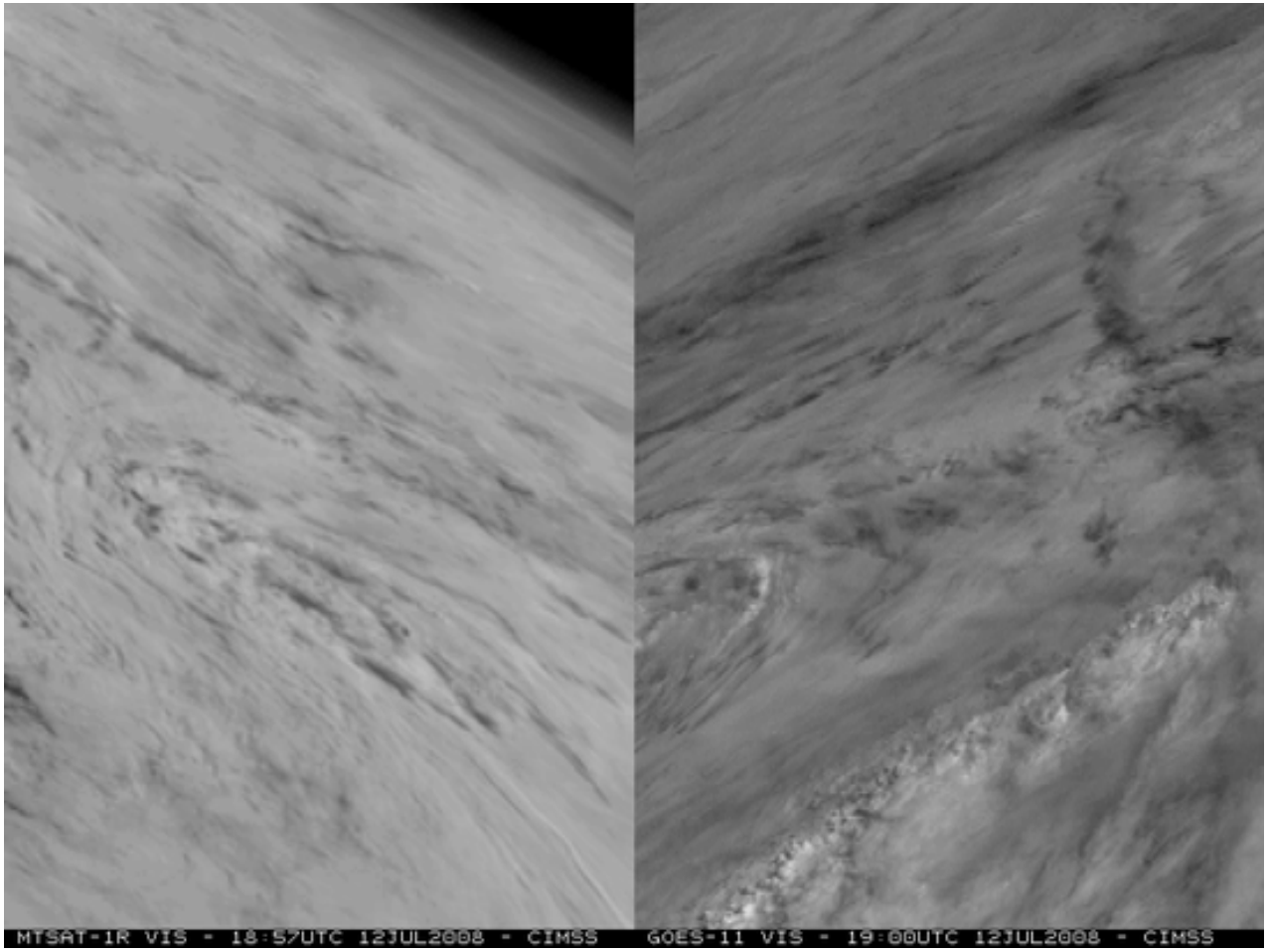


Okmok Volcano Eruption

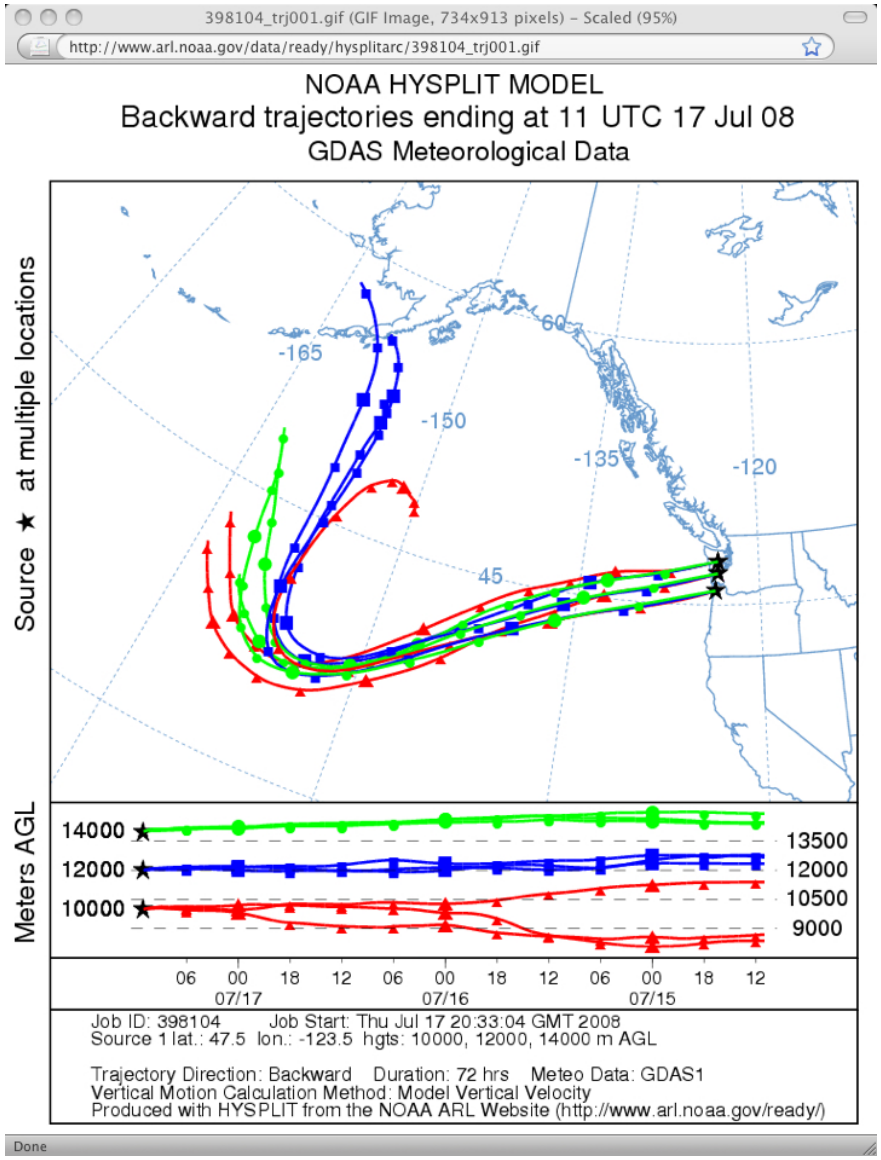
13 July 2008

Okmok Eruption

12 July 2008

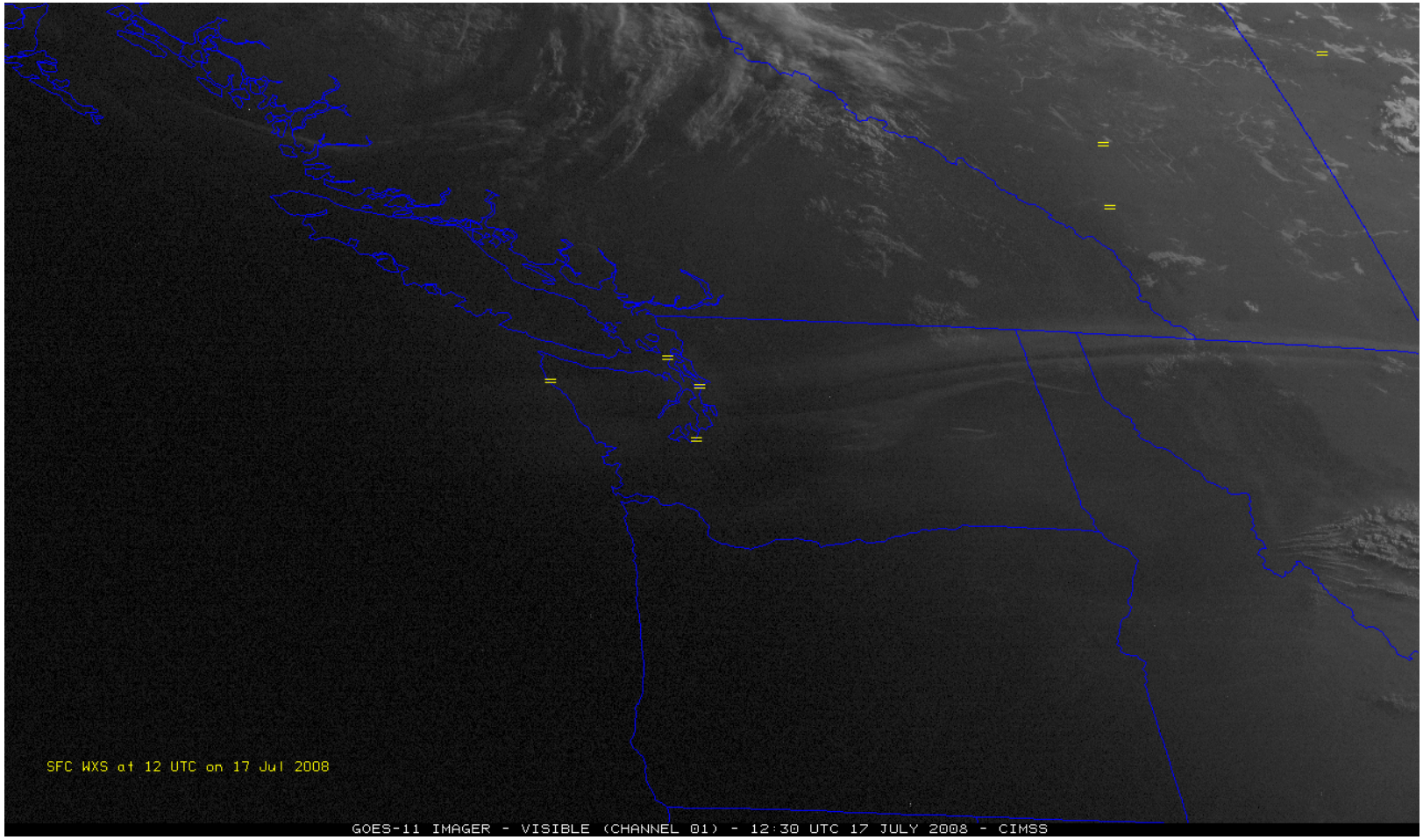


NOAA Aerosol Trajectory Model



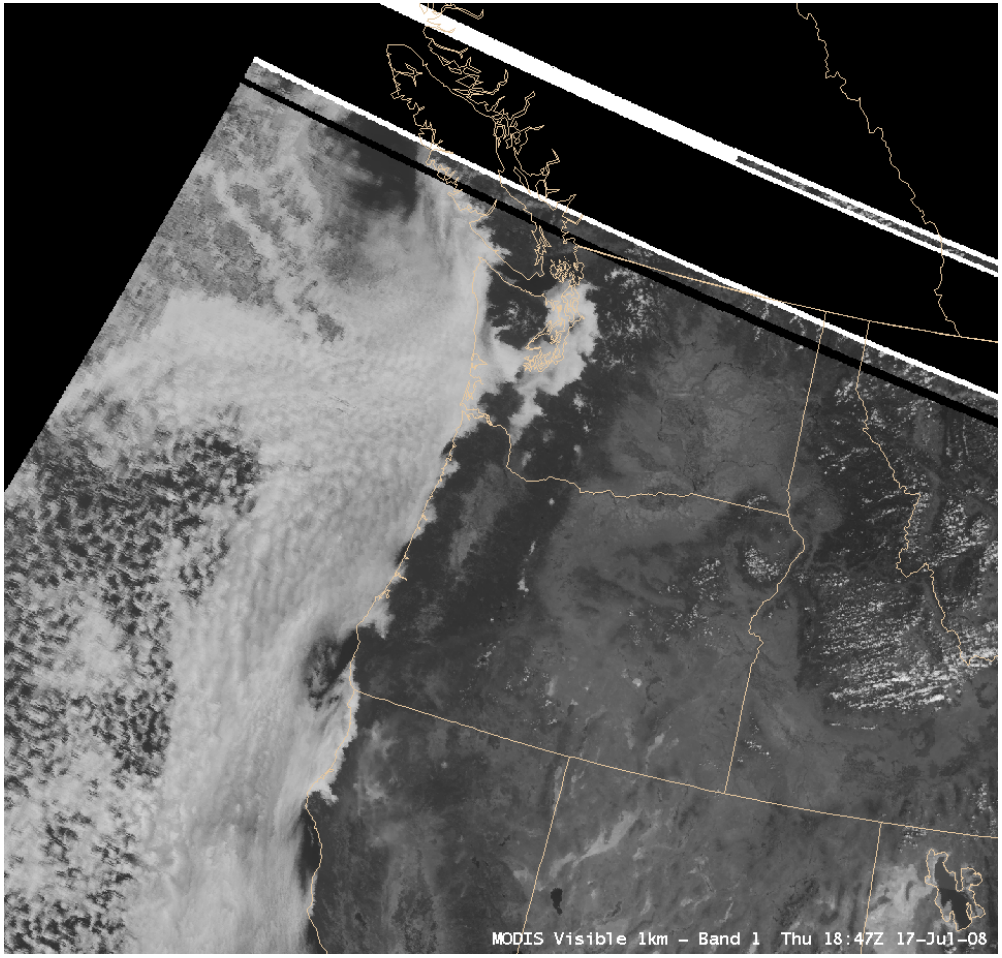
GOES Visible Image Loop

17 July 2008



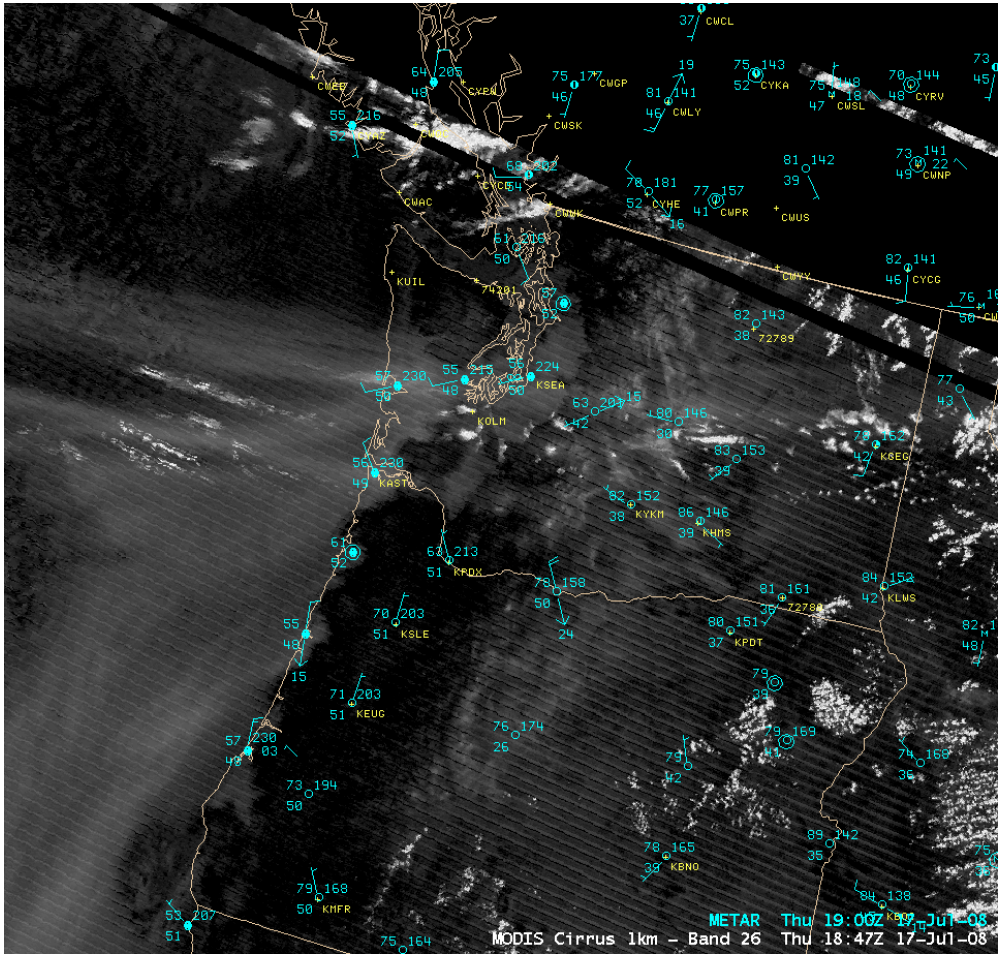
Terra MODIS Band Comparison

17 July 2008

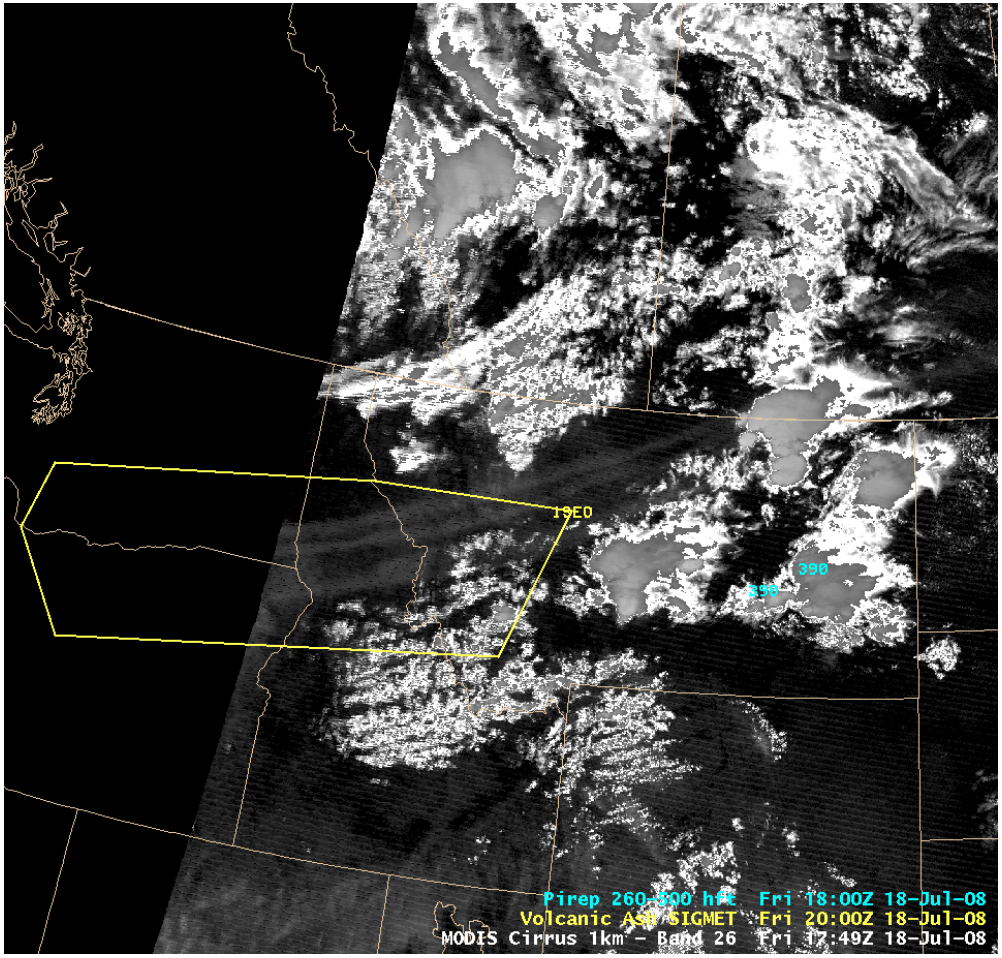


MODIS 1.38 µm Reflectances

17 July 2008



MODIS 1.38 µm Reflectances



18 July 2008

Pilot Reports

18-19 July 2008

Pilot reports (PIREPS) from aircraft encountering the Okmok volcanic plume over the northwestern and northcentral continental US on 18-19 July 2008:

DLN UA /OV DLN 270080/TM 1900/FL320/TP MD80/RM ORANGE CLOUD ASSOCIATED WITH VOLCANIC ACTIVITY. NO SMELL, CLR ABV/BLW FL320/ZLC

RDM UUA /OV DSD280030/TM 1909/FL310/TP B737/RM LGT ASH CLOUD FL320 -ZSE

PDX UUA /OV BTG180060/TM 1912/FL330/TP B738/RM FL330-310 ASH CLOUD CLR AT FL300 -ZSE

SLE UA /OV BTG180060/TM 1921/FL300/TP B733/RM BAND OF SULFER DIOXIDE WEST TO EAST FL300-340 AWC-WEBSWA

PDT UA /OV PDT/TM 1937/FL380/TP NUMEROUS/SK ORANGE HAZE/RM VOG 320-380 SMELLS THROAT IRRATATION -ZSE

PDX UUA /OV KPDX/TM 2018/FL320/TP B739/RM VERY THIN PROB ASH CLOUD VISIBLE E-W OVER PDX AND MT HOOD AT APPROX FL320 AWC-WEBASA

LWS UUA /OV MQG130050/TM 2051/FL350/TP B737/RM VOLCANIC ASH CLOUD 320-380 –ZSE

LWS UUA /OV MQG 135060/TM 2053/FL320/TP SVRL ACFT/RM VOLCANIC ASH CLOUD 320-386 CLIMBING/ DESCENDING TO AVOID ZLC

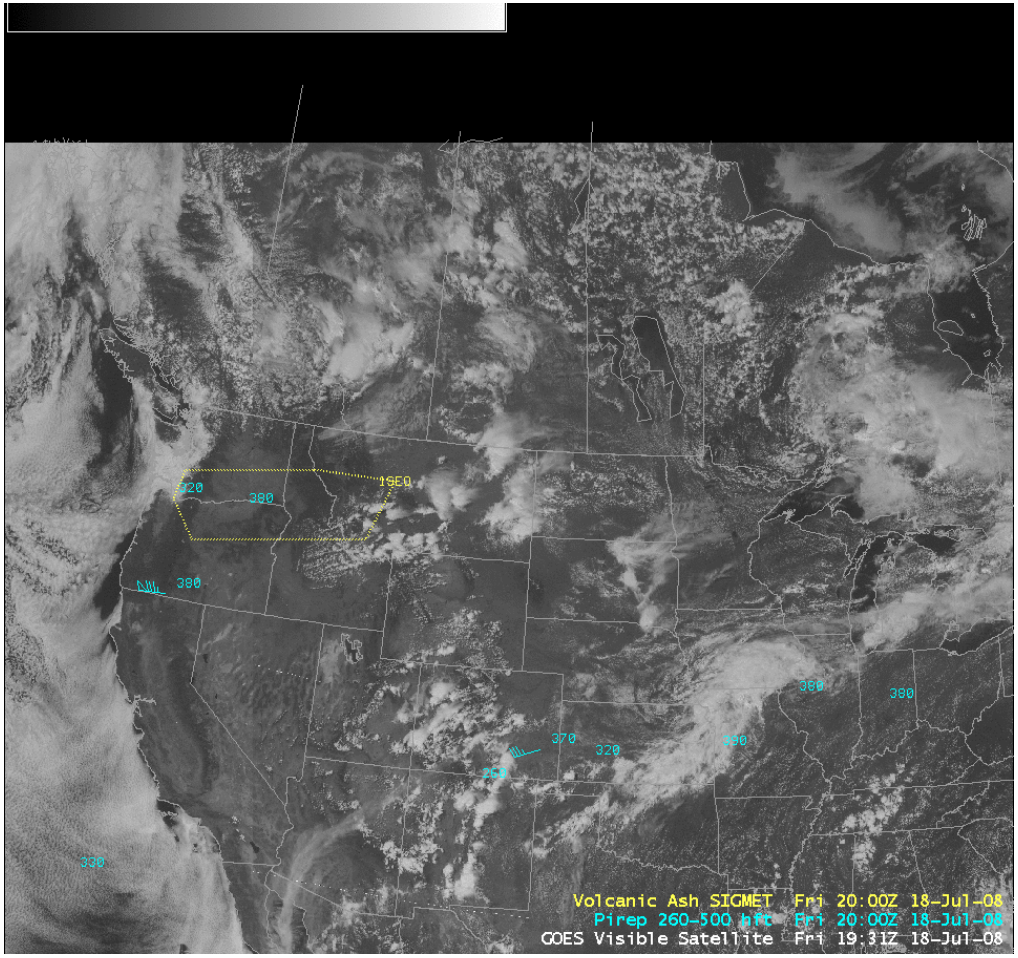
MSO UA /OV MLP143070/TM 2053/FLUNKN/TP B737/RM BAND OF CLOUDS W/ ORANGE TINT FL300-FL350 AWC-WEBSWA

PDT UA /OV PDT200020/TM 2100/FL290/TP B737/WV 275039KT/TB SMOOTH/RM ASH CLOUD APPEARS TO BE DISPERSED IN SEVERAL AREAS.MAIN CLOUD LOCATED FURTHER NORTH RUNS W-E AWC-WEBSWA

MSO UUA /OV MSO 120030/TM 2115/FL320/TP CL60/RM ASH CLOUD FL320-395 ZLC

SIGMET eventually extended

18 July 2008

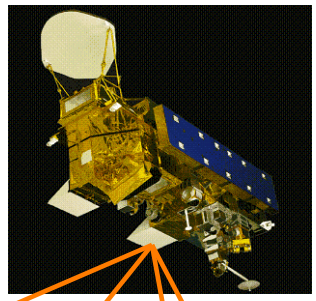


Numerical Weather Prediction

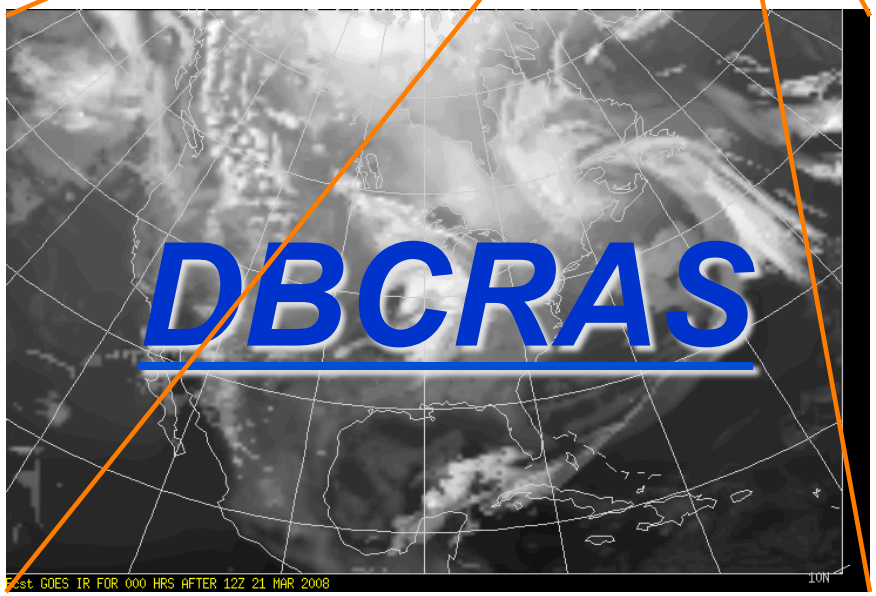
Good Grief, what is this doing here?

The Cooperative Institute for Meteorological Satellite Studies
University of Wisconsin, Madison

The Direct Broadcast Version of the CIMSS Regional Assimilation System for Global Users



Bob Aune
Advanced Satellite Products Branch,
Cooperative Research Program
Center for Satellite Applications and Research
DOC/NOAA/NESDIS



What is Numerical Weather Prediction?

- Describing the Atmosphere mathematically
  - Equations of motion
- Taking the Derivative with respect to time
  - Delta T is time step
- Need good representation of the atmosphere in 3 dimensions to start with
  - Assimilation
    - Gathering all surface observations (METARS)
    - Radiosondes – Balloon launches that provide vertical profiles of the temperature, moisture and winds
  - Satellite observations

Why should I care about DBCRAS?

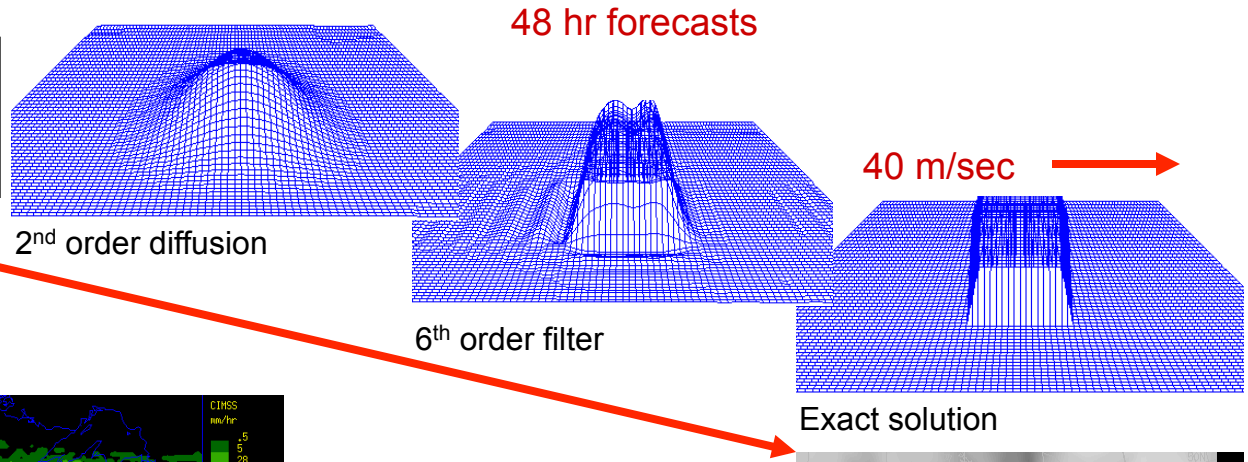
- Uses MODIS Products to improve the depiction of clouds and moisture in the initial model conditions
  - MOD07 Total Precipitable Water Vapor
  - MOD06 Cloud Top Pressure, Cloud Emissivity
- Others only assimilate satellite clear radiances
- Requires efficient and reliable internet connection
  - ≈ 500MB of ancillary data required per model run

Why should I care about DBCRAS?

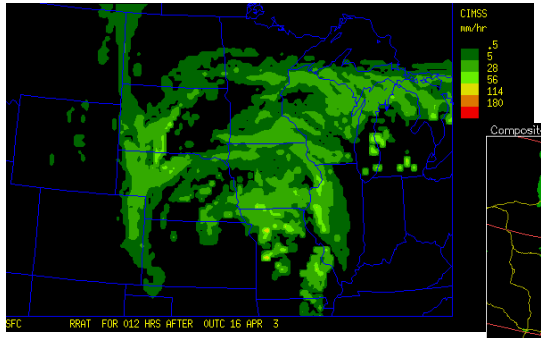
- Globally configurable (not recommended over the tropics because of projection) one time domain center set up
- Products created at 48 km resolution out to 72 hours, and a Nested grid at 16km resolution out to 48 hours
- Automatically creates forecast imagery

Improvements to CRAS Validated by GOES

Preservation of information:
- Mass conservation in advection
- Reduced gradient dissipation

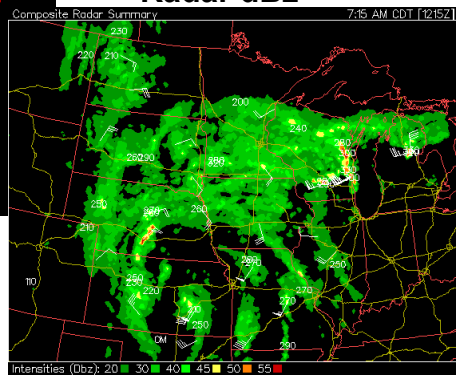


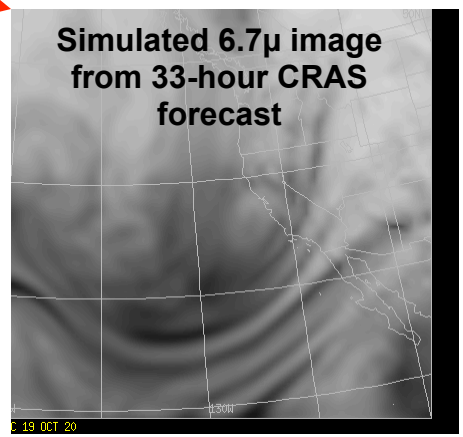
Improved physics:
- Radiative fluxes
- Moist physics



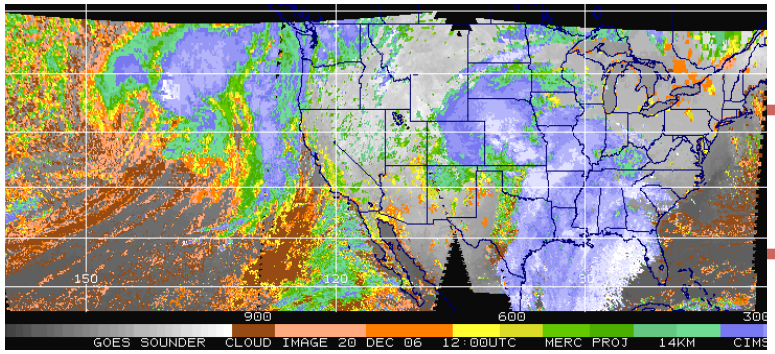
12-hour forecast rain-rate from 20 km CRAS

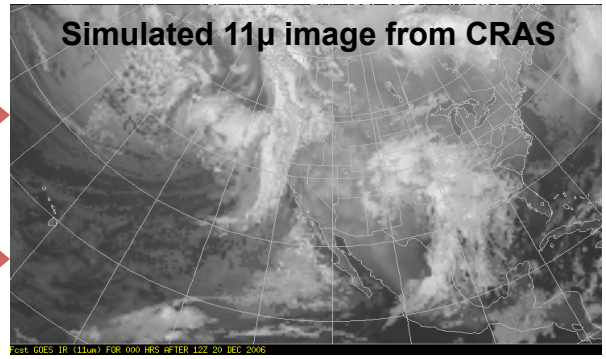
Radar dBz





Improved Initial Fields:
- Water vapor
- 3D cloud water
- Upper-level winds
- Temperature fields





Summary of improvements made to the CRAS forecast model that were validated using observations from GOES.

Year	Description of Improvement	GOES Product
1996	Initialize water vapor mixing ratio fields	Sounder 3-layer precipitable water
1998	Initialize 3D cloud fields	Sounder cloud products
1998	Precipitation parameterization	Sounder cloud products
1998	Shortwave and longwave radiative flux	Sounder skin temperature
1999	6^{th} order filter to preserve gradients	Imager water vapor
1999	Precipitation drag on vertical motion	Sounder cloud temperatures
2001	Hydrometeor advection (horizontal)	Sounder cloud products
2002	Hybrid convective parameterization	Sounder cloud products
2002	Turbulent mixing to Improve low clouds	Sounder cloud product
2004	Sub-surface soil model	Sounder skin temperature
2006	Cloud particle sedimentation	Sounder cloud products

CIMSS Regional Assimilation System - Details

Specifications

Grid: Limited area, re-locatable, Arakawa C grid
Map: Lambert conformal or polar stereographic
Resolution: Horizontal: 127km to 10km
Vertical: ~40 sigma levels, floating top
Platforms: Linux, Intel compiler
Performance: 150 minutes on a single 3.6 GHz Intel Xeon
(72hr fcst, 275x150x38 grid, dx=48 km, dt=200 sec)

Dynamics: Semi-implicit time scheme, 3rd order
Advective form - Leslie, et.al.,1985
Pseudo-non-hydrostatic, Raymond and Aune, 1998
3rd order Time filter - Raymond, 1991
6th order tangent - Raymond, 1988

Physics: Radiation – Ackerman and Stephens, 1987
Turbulence – Raymond, 1999
Precip/Clouds – modified Kessler, 1974 and Tiedke, 1993
Precip Fall rate – Kreitzberg and Perkey, 1976
Convection – Raymond and Aune, 2002

Initialization: Vertical normal mode - Bourke and McGregor, 1983

Analysis: Recursive filter - Control variables
3D variational - heights and winds, Seaman et al.,1977
1D variational - satellite radiances/retrievals

Input grids: Currently using CRAS moisture analysis merged with winds and temperatures from the NCEP GFS
Topography: USGS 2-minute surface elevation, land-water flag

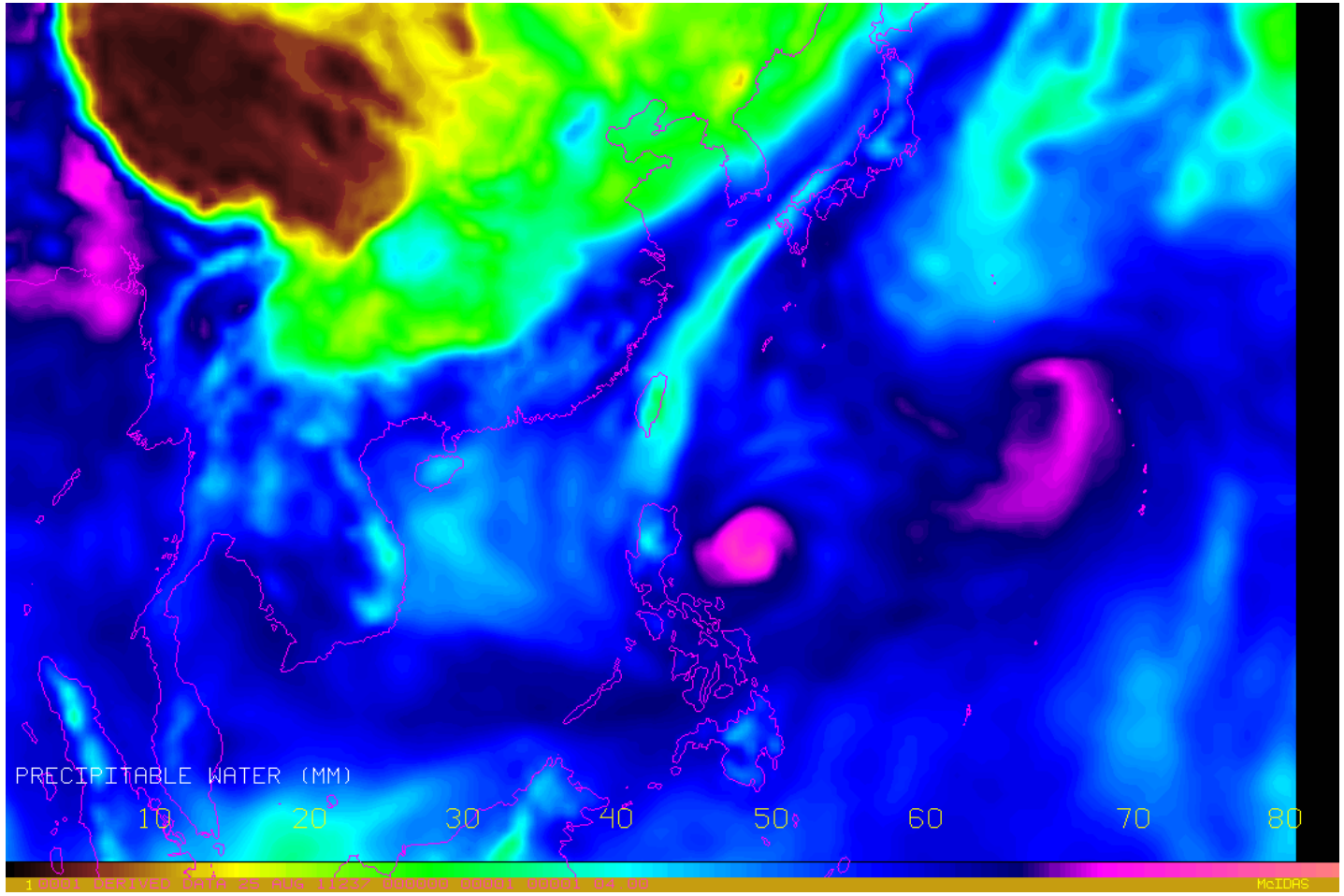
Climatology: Monthly albedo, deep-soil temperature, sub-soil moisture, sea ice, roughness, vegetative roughness, leaf-area index, greenness

Observations:
In situ: RAOBs, surface data, ACARS
GOES: 3-layer precipitable water
Cloud-top pressure and effective cloud amount, 4-layer thickness
Cloud-track and water vapor winds
Other: Gridded hourly precip, Stage II, from NCEP
SST and sea ice coverage from NESDIS

CRAS

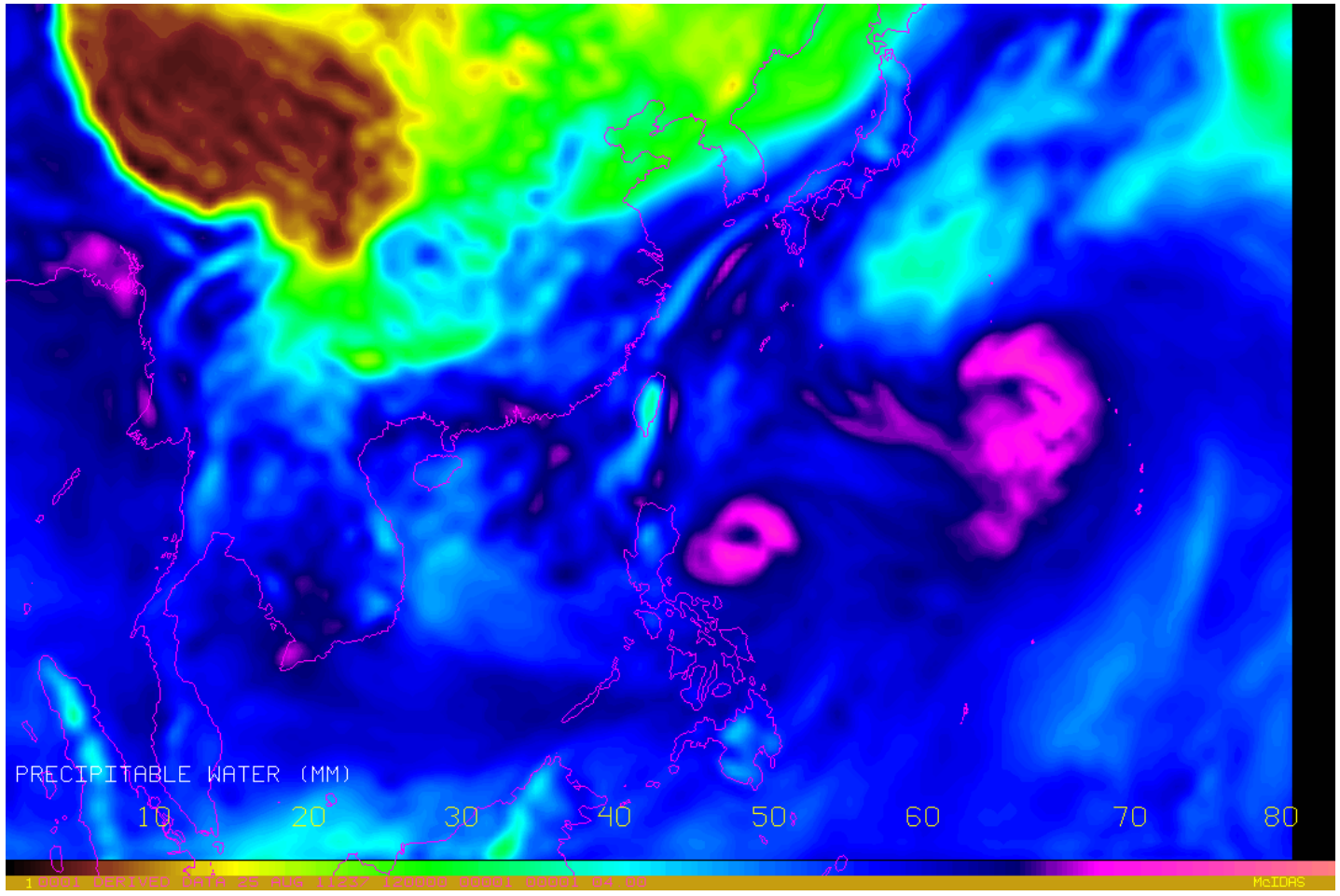
CRAS TEMPESTUS HODIE
Tomorrow's Weather Today

DBCRAS Moisture (TPW)



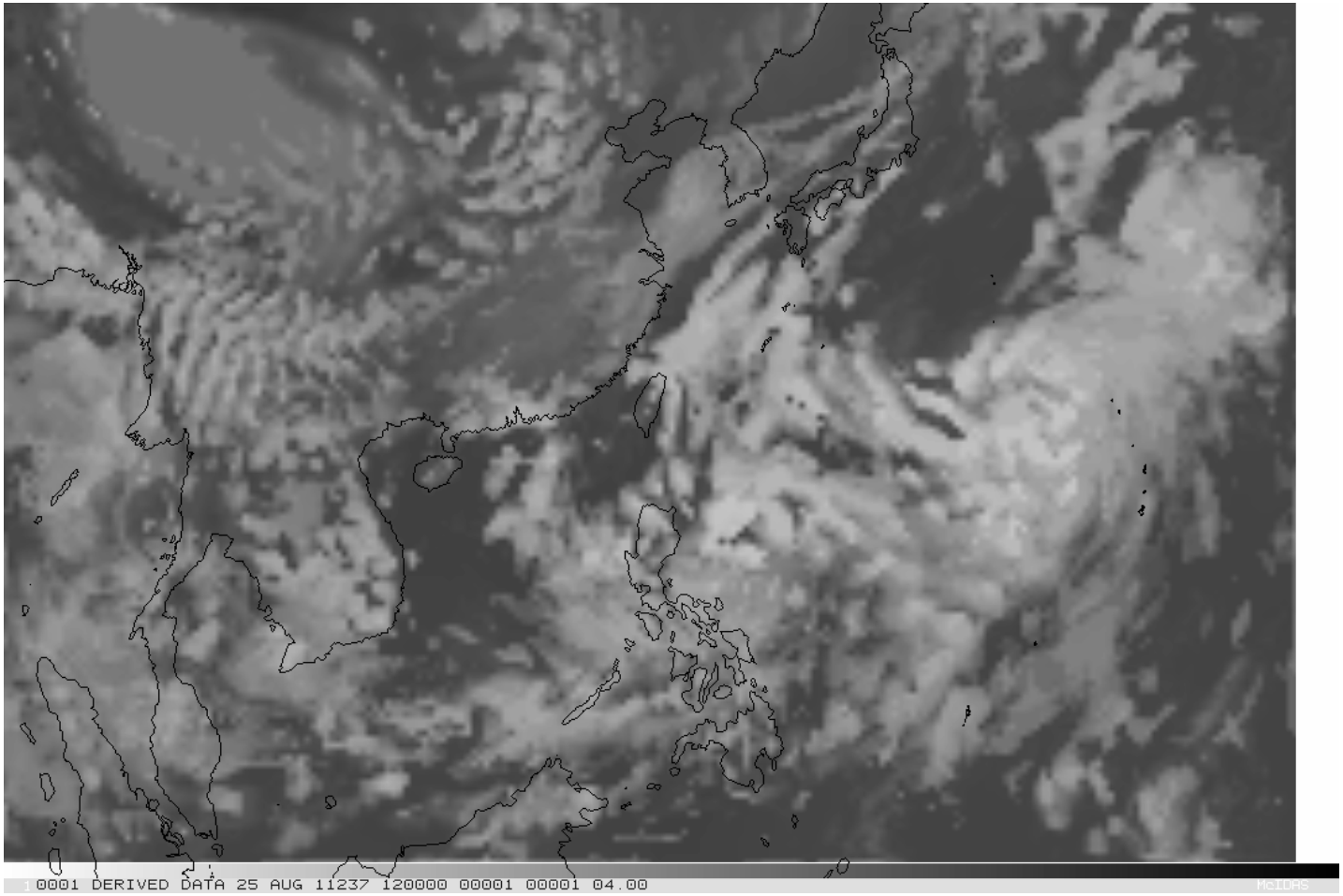
DBCRAS 12 hour Pre-forecast Total Precipitable Water Vapor 00 UTC 25 August 2011

DBCRAS Moisture (TPW)



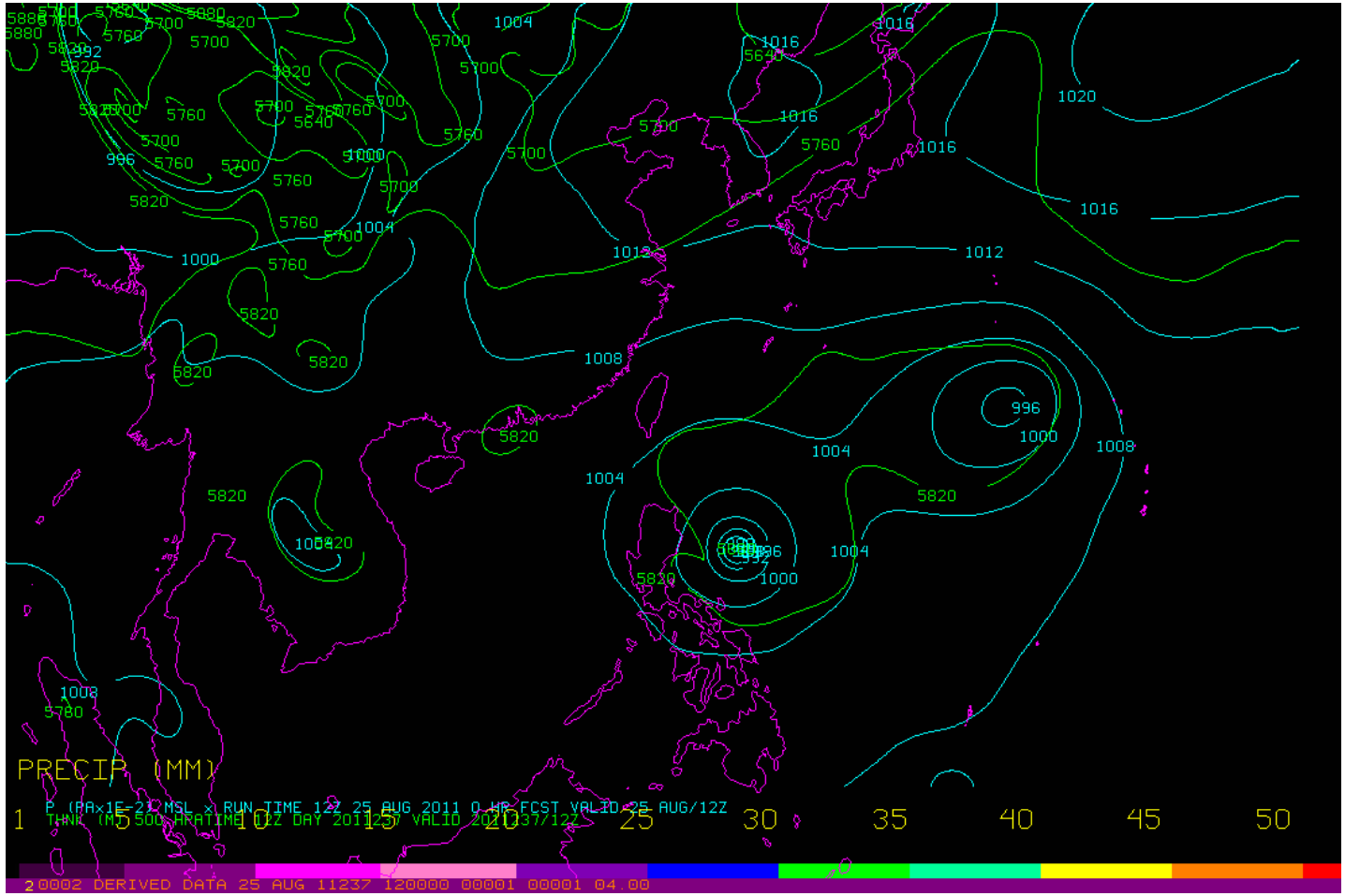
DBCRAS 72 hour Forecast Total Precipitable Water Vapor 12 UTC 10 April 2011

DBCRAS IR Window



DBCRAS 72 hour Forecast 11 μm Brightness Temperatures 12 UTC 25 August 2011

DBCRAS Sea Level Pressure, Precipitation



DBCRAS 72 hour Forecast SLP, Precipitation 12 UTC 25 August 2011

Applications

- Weather Forecasting
  - CRAS is used by some US Forecasters in the US
  - DBCRAS was installed at Taiwan Central Weather Bureau in November 2008
- Fire hazard
- Others?

References

- Bayler, G., R. M. Aune and W. H. Raymond, 2000: NWP cloud initialization using GOES sounder data and improved modeling of nonprecipitating clouds. Mon. Wea. Rev. 128, 3911-3920.
- Raymond, W. H., and R. M. Aune, 1998: Improved precipitation forecasts using parameterized feedbacks in a hydrostatic forecast model. Mon. Wea. Rev., 126, 693-710.
- Raymond, W. H., 1999: Non-local turbulent mixing based on convective adjustment concepts (NTAC). Bound-layer Meteor, 92, 263-291.

How accurate is the CRAS model?

AREA FORECAST DISCUSSION
NATIONAL WEATHER SERVICE TWIN CITIES/CHANHASSEN MN
224 PM CDT WED OCT 29 2008

.DISCUSSION...

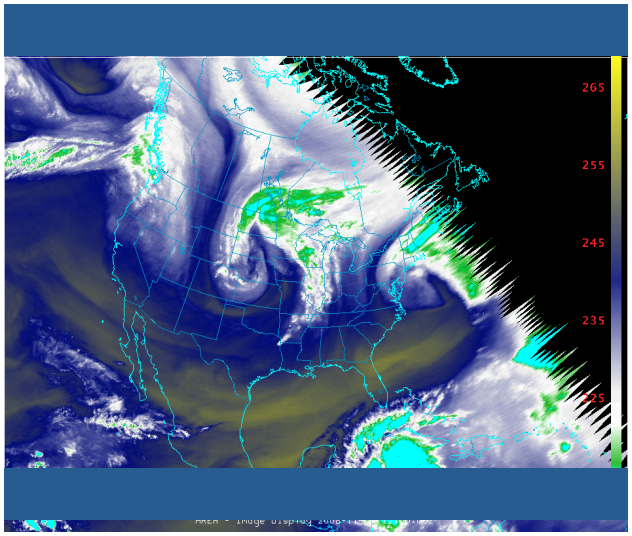
NEXT COLD FRONT EXPECTED TO COME THROUGH DRY...WITH LIMITED MOISTURE...LITTLE CLOUD WILL BE ASSOCIATED...AS INDICATED BY MODEL BUFKIT TIME/HGT OVERVIEWS AND CRAS IR SATELLITE FCST. SOME CONCERN HOW FAR SOUTH CURRENT STRONG LOOKING SHORT WAVE MOVING THROUGH MT/ID/WY REGION. MODELS DIVE THIS FEATURE FAR ENOUGH SOUTH TO LIMIT THREAT OF SIGNIFICANT CLOUDS OVER THE CWA. FRONT SHOULD EXIT TO THE SOUTHEAST OF THE AREA BY FRIDAY MORNING. SHOULD SEE SOME MARGINAL COOLING BEHIND THIS FRONT. AGREE WITH MAV GUIDANCE NUMBERS FOR THE MOST PART.

How accurate is the CRAS model??

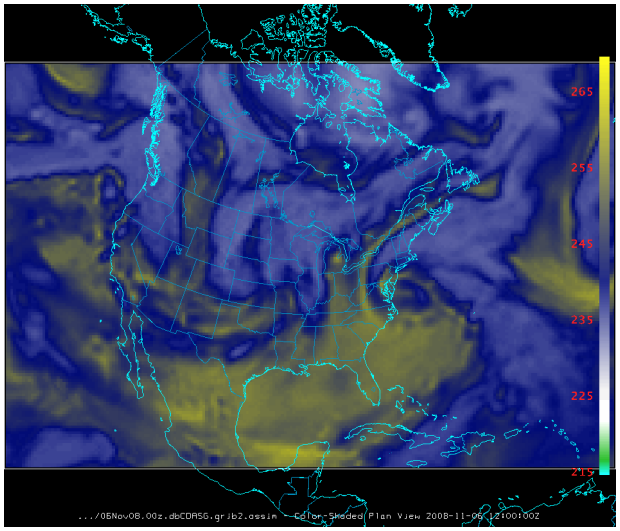
Comparison from 5 November 2008

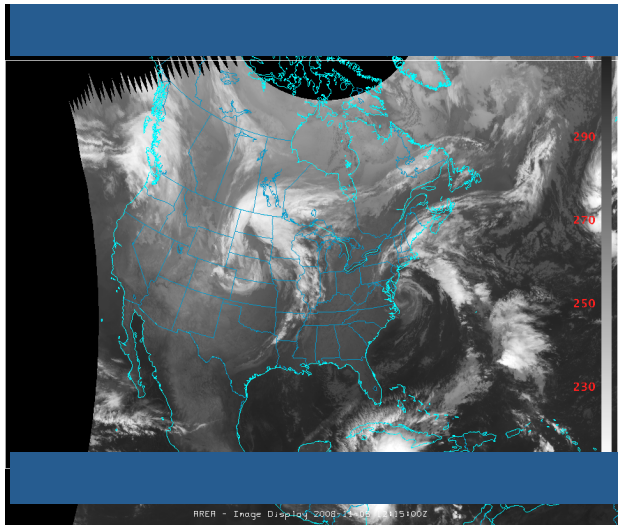
GOES Observations

CRAS 12 Hour forecast

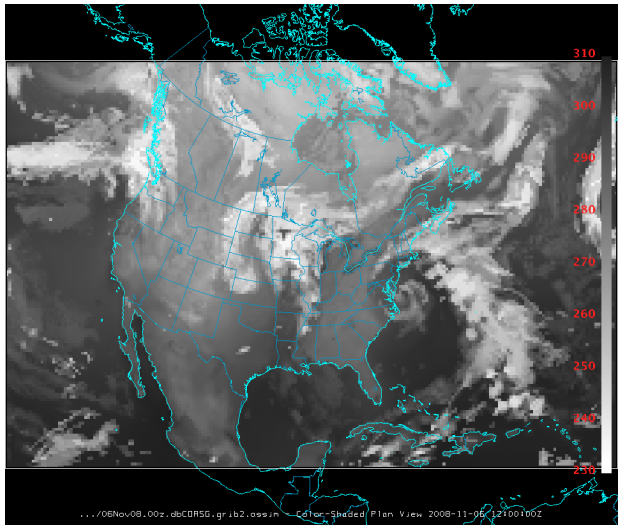


6.7 micron (CRAS no Clouds)

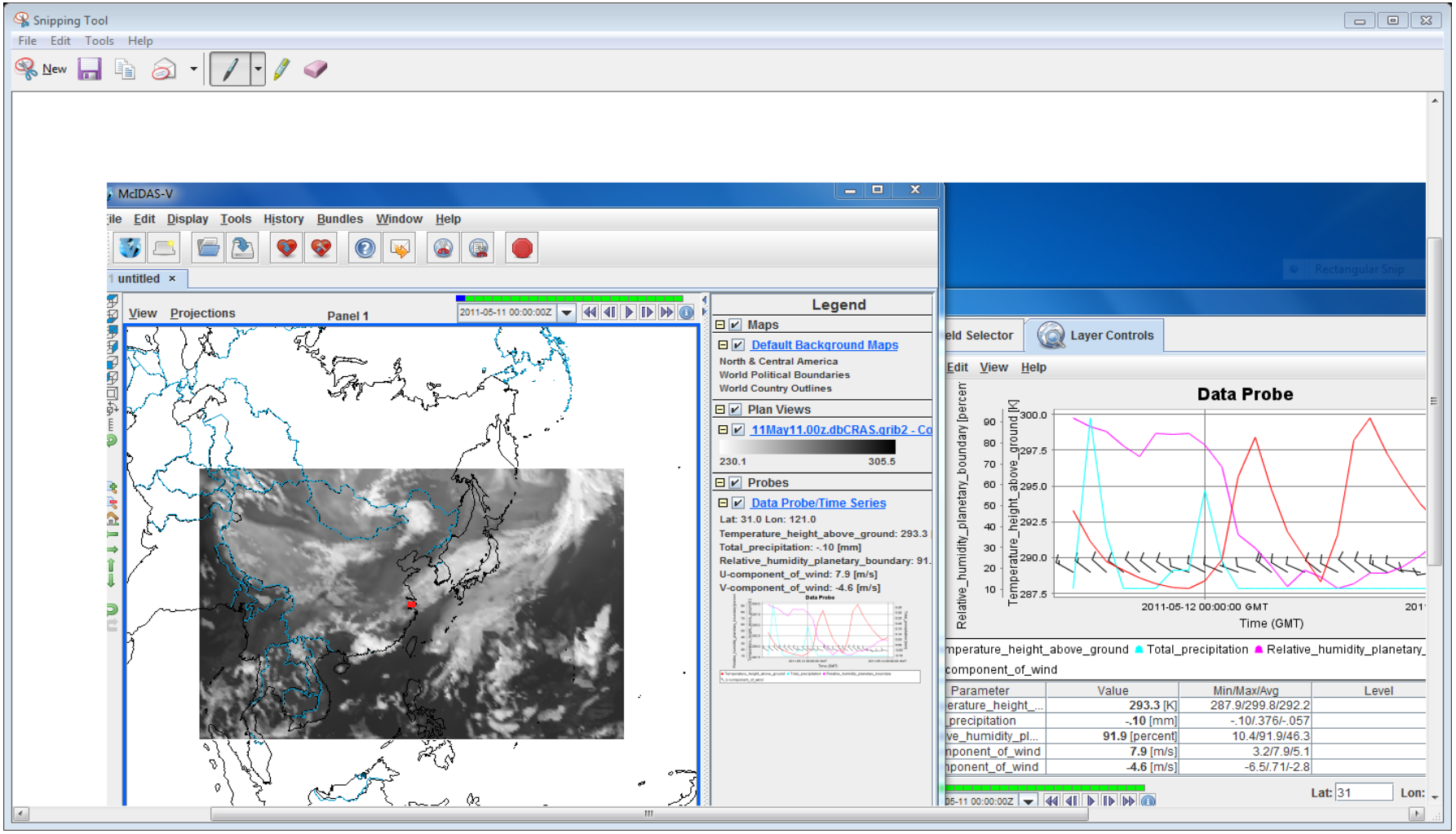




11 micron



Examining DBCRAS Output



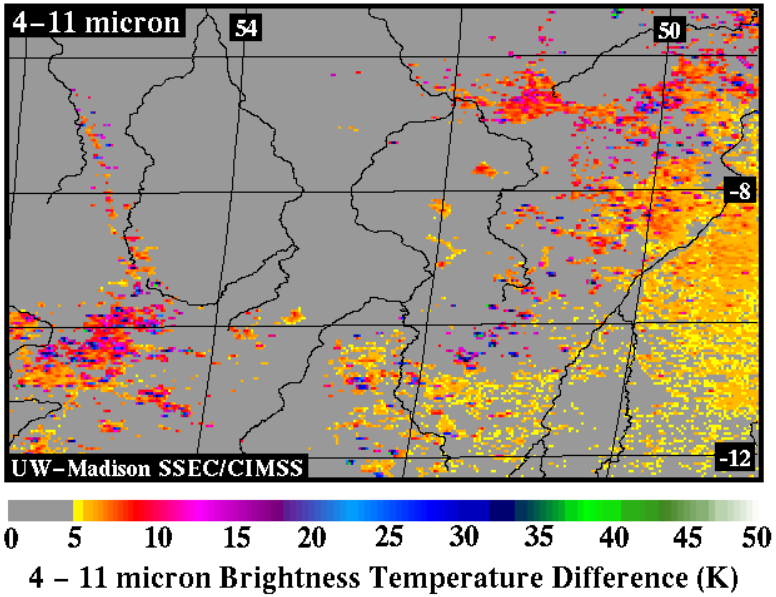
Fires

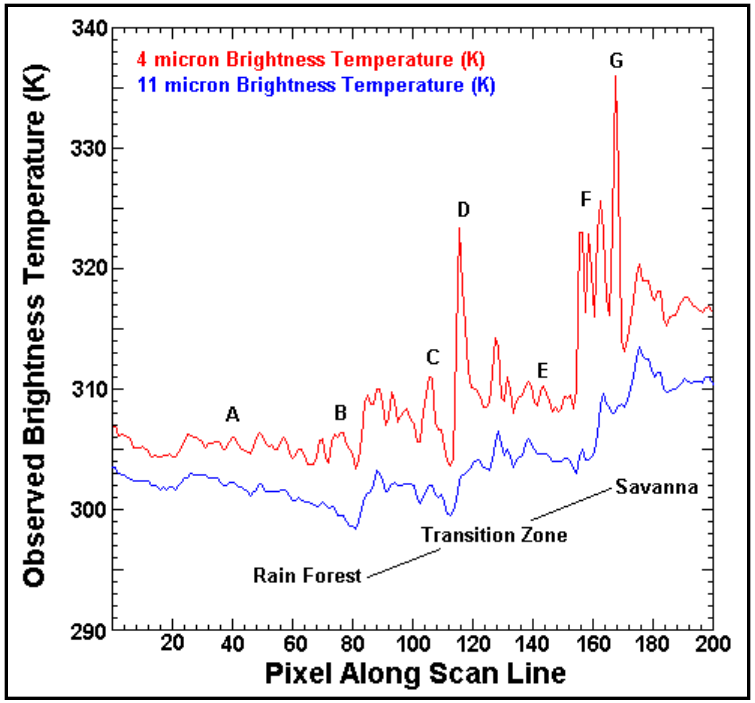
MODIS Fire Product

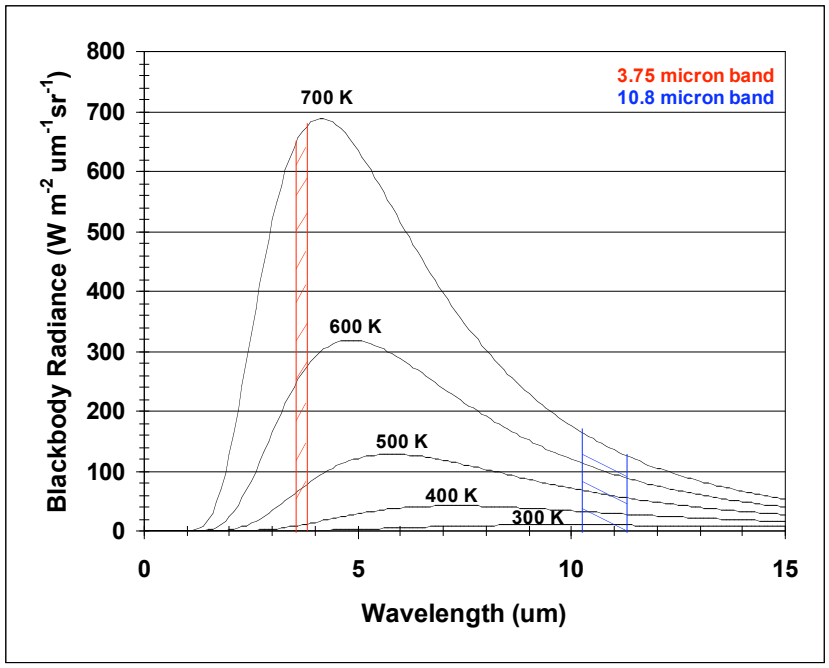
Louis Giglio Chris Justice

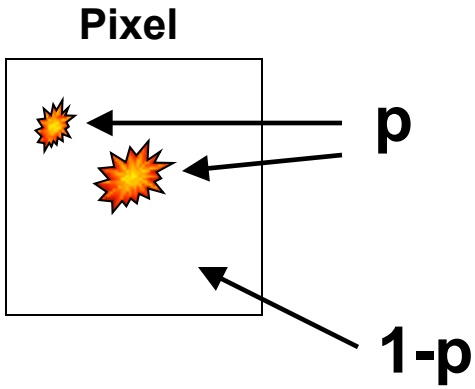
- Based upon the Temperature Sensitivity difference between 4 and 11 microns
- Contextual Fire Detection Algorithm
  - Infrared static Brightness Temperature thresholds
  - Dynamic thresholds compare pixel to surrounding background

How are Meteorological Satellites Used to Monitor Fires?









$$B_4(T_4) = pB_4(T_{fire}) + (1-p)B_4(T_{bg})$$

$$B_{11}(T_{11}) = pB_{11}(T_{fire}) + (1-p)B_{11}(T_{bg})$$

MOD14 Key Output Parameters

1km resolution

- fire_mask 8 bit unsigned integer
  - 0 missing input data
  - 3 water
  - 4 cloud
  - 5 non-fire
  - 6 unknown
  - 7 fire (low confidence)
  - 8 fire (nominal confidence)
  - 9 fire (high confidence)
- Line and element of fire pixel
- Latitude and longitude of fire pixel
- Fire pixel confidence (one value for each fire detected per scene)

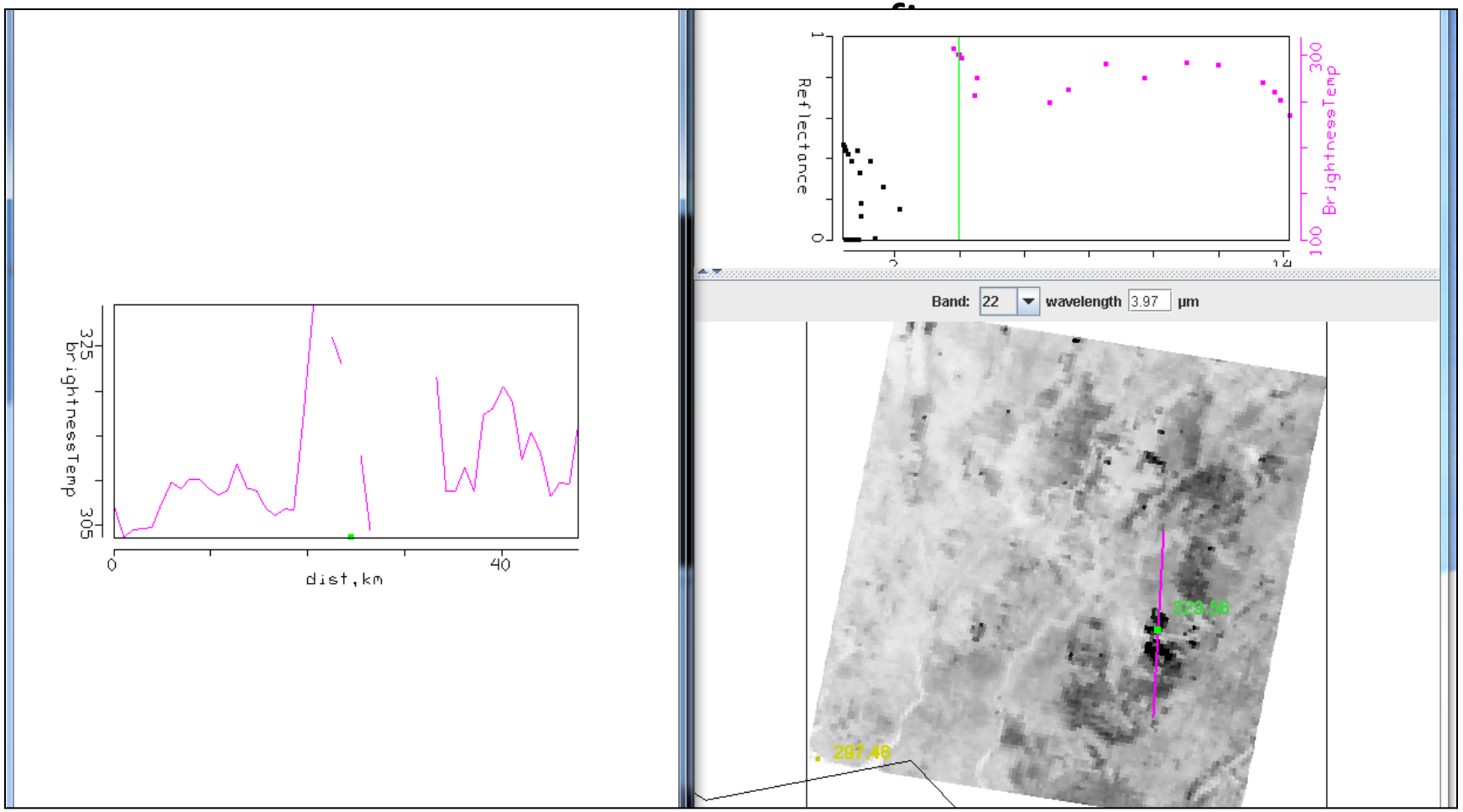
Algorithm Description

- MODIS bands 21 and 22 (3.99 micron)
  - Band 22 saturates at 331 K
  - Band 21 "fire channel" saturates at ~ 500 K
    - 12 bit range broader – less sensitive
    - The calibration of B21 uses fixed calibration coefficients and not using the scan-by-scan onboard black body (more noise)
    - So use Band 22 unless it is saturated
- MODIS band 31 (11 micron)
  - Saturates at ~ 400 K for Terra
  - Saturates at ~ 340 K for Aqua

Algorithm Description (cont.)

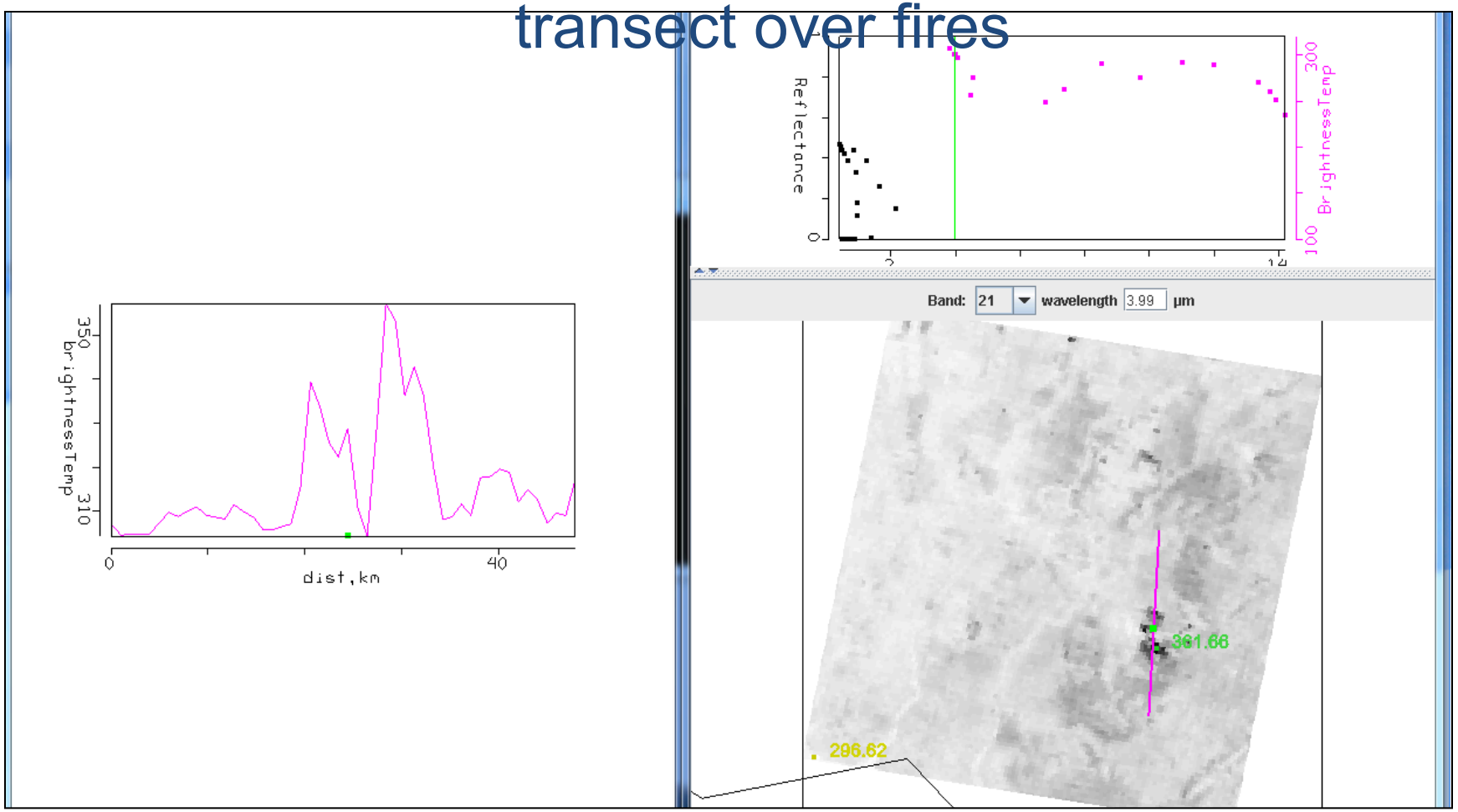
Aqua MODIS true color image 18 April 2003 12:45 UTC

MODIS Terra Band 22 (3.99 µm)



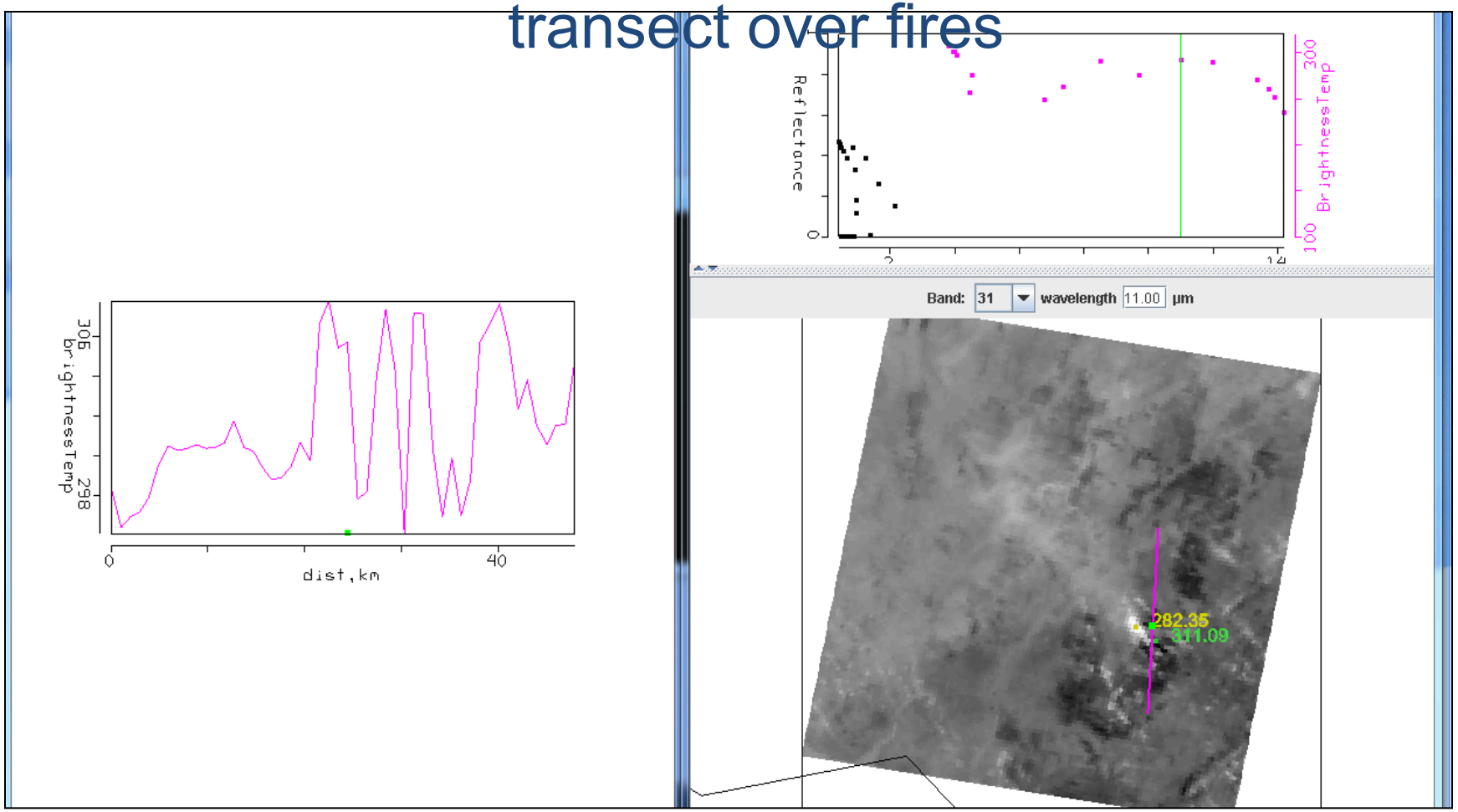
MODIS Terra Band 21 (3.99 μm)

transect over fires



MODIS Terra Band 31 (11 μm)

transect over fires



Algorithm Description (cont.)

- Potential Fire Pixel identified
  - BT4 > 310 K (~37 C)
  - BT4-11 > 10 K
  - .86 micron reflectance < .3
- Otherwise flagged as non-fire pixel

Screening Potential Fire Pixels

(1) BT4 > 360 K (~87 C)

Contextual Tests: Performed on as many as 21 x 21 box surrounding potential fire pixel to separate out from background

(2) $BT4-11 > \overline{BT4-11} + 3.5\partial_{BT4-11}$

(3) $BT4-11 > \overline{BT4-11} + 6K$

(4) $BT4 > \overline{BT4} + 3\partial_{BT4}$

(5) $BT11 > \overline{BT11} + \partial_{BT11} - 4K$

(6) $\partial'_4 > 5K$

Where δ is the Mean Absolute Difference (MAD):

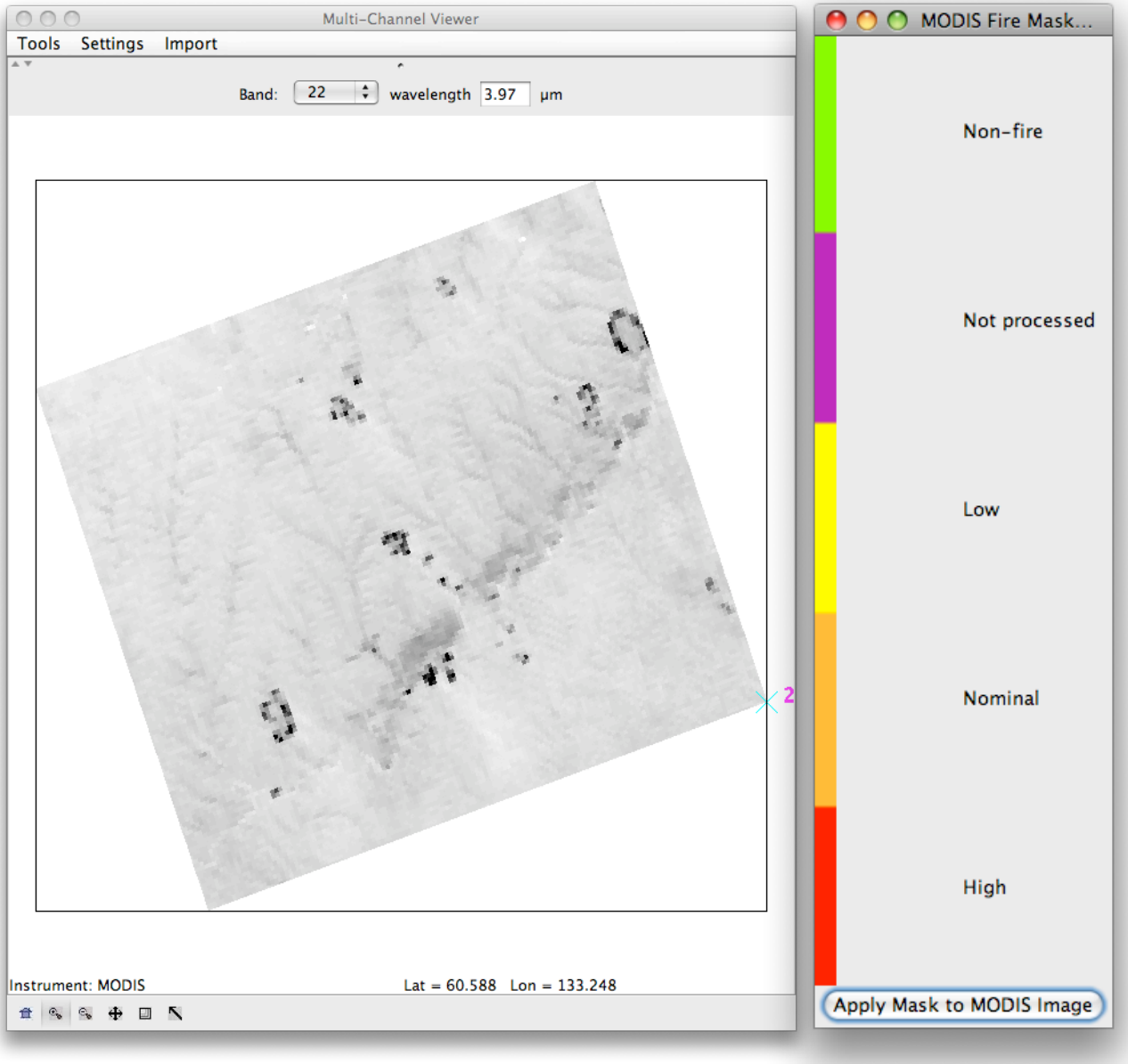
$$\text{MAD} = \frac{1}{N}\sum_i |x_i - \bar{x}|$$

Problem Areas

- If there are many fires – hard to get representative background temperature in max 21x21 pixel region
- Sunglint – Affects 4 micron band radiance
- Transition areas – contextual tests pick up boundaries
- Coastal areas – need really good geolocation so no mixed pixels are included
- Clouds – BT4-11 large over water and thick ice cloud

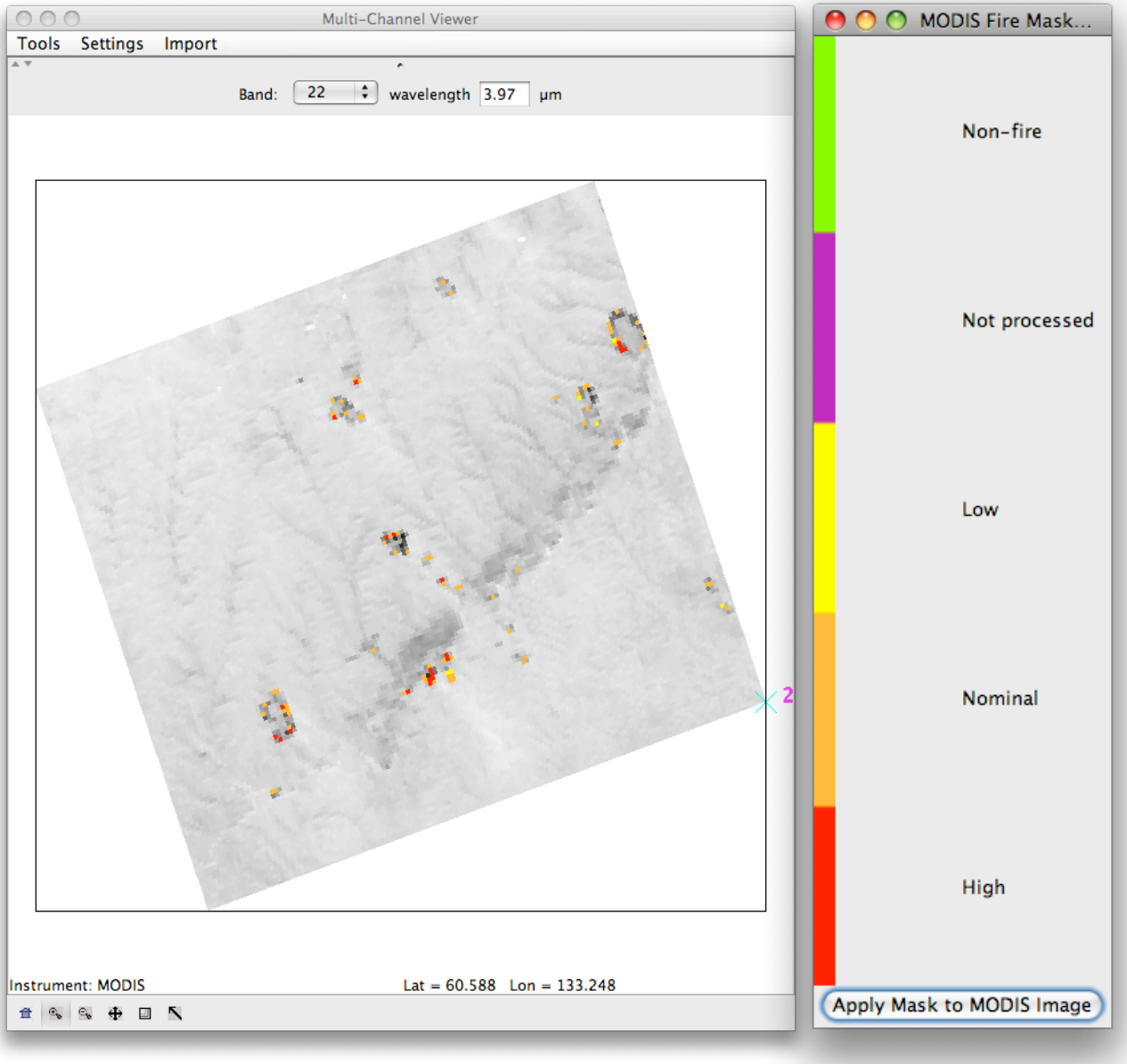
MODIS Fire Product

11 May 2011
03:40 UTC
Aqua MODIS



MODIS Fire Product

11 May 2011
03:40 UTC
Aqua MODIS



Fire Detection

AREA FORECAST DISCUSSION

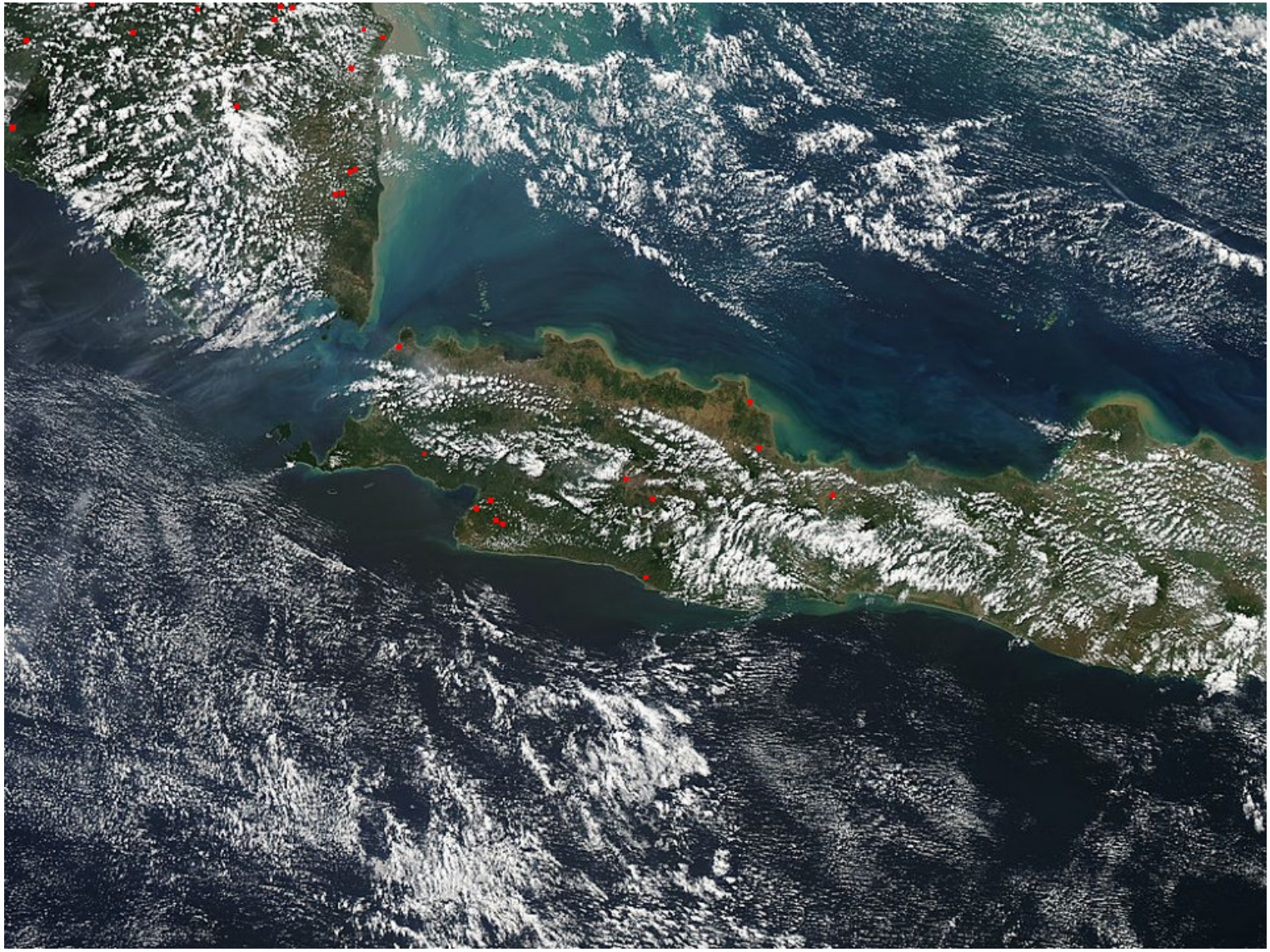
NATIONAL WEATHER SERVICE LUBBOCK TX

315 PM CDT MON APR 11 2011

.FIRE WEATHER...*GOES 3.9 MICRON AND MODIS/POES 3.7 MICRON SATELLITE IMAGES SHOW ONLY ONE FIRE START SO FAR THIS AFTERNOON ALONG THE KENT/SCURRY COUNTY LINE. GOOD NEWS IS THAT THEY ARE NOT SHOWING ANY LARGE FLARE-UPS ON THE SWENSON/STONEWALL AND KING COUNTY FIRE.* DECREASING WIND SPEEDS WILL ALSO HELP WITH ANY CONTINUED FIREFIGHTING EFFORTS THROUGH TONIGHT. BY LATE TOMORROW MORNING...CONDITIONS CONTINUE TO LOOK MARGINAL TOMORROW FOR MEETING RED FLAG CRITERIA...BUT SOUTH WIND OF 15 TO 25 MPH AND RH VALUES BETWEEN 10 TO 15 PERCENT WILL RESULT IN AT LEAST AN INCREASED FIRE DANGER OVER THE REGION. WILL HOLD ONTO THE FIRE WEATHER WATCH FOR ANOTHER COUPLE OF SHIFTS TO MAKE SURE THE FORECAST REMAINS CONSISTENT IN THE COMPUTER MODELS FOR TOMORROW.

- Due to wildfires, the NWS WFO in Lubbock, Texas, is using the AWIPS alerting system, GUARDIAN, to inform forecasters of each new MODIS and AVHRR shortwave IR image that arrives.

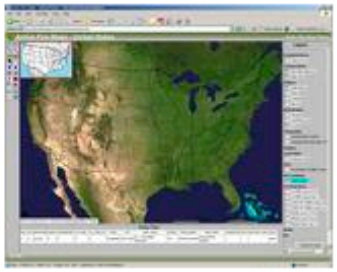
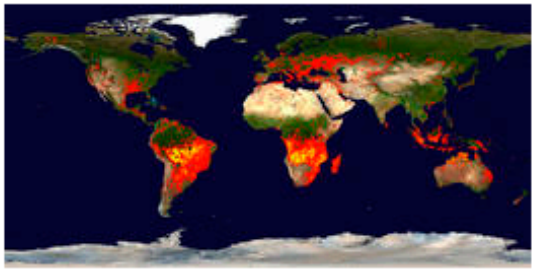
Active Fires



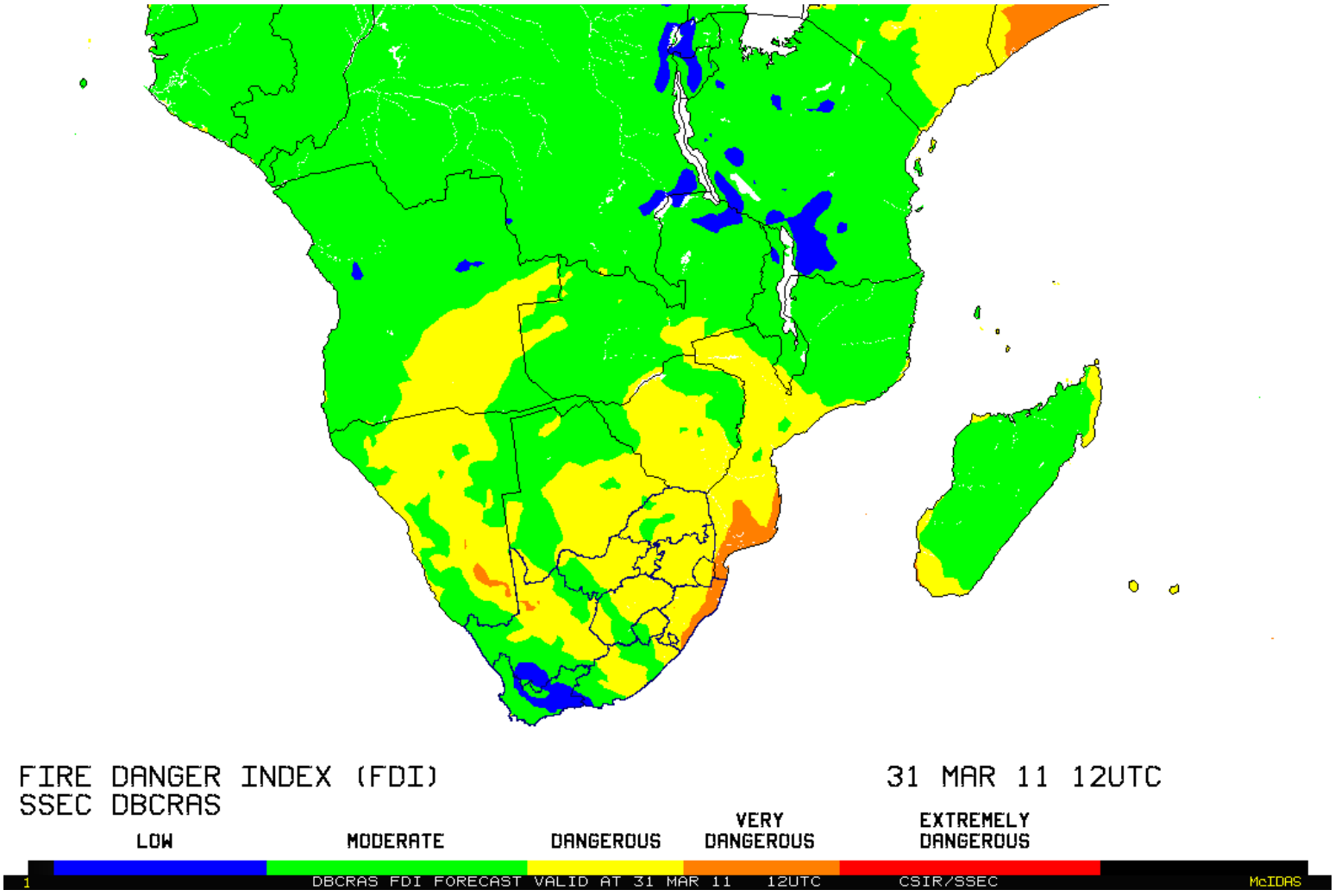
2011/08/01 Aqua MODIS

MODIS Fire Detection Applications

MODIS Fire Detection Applications

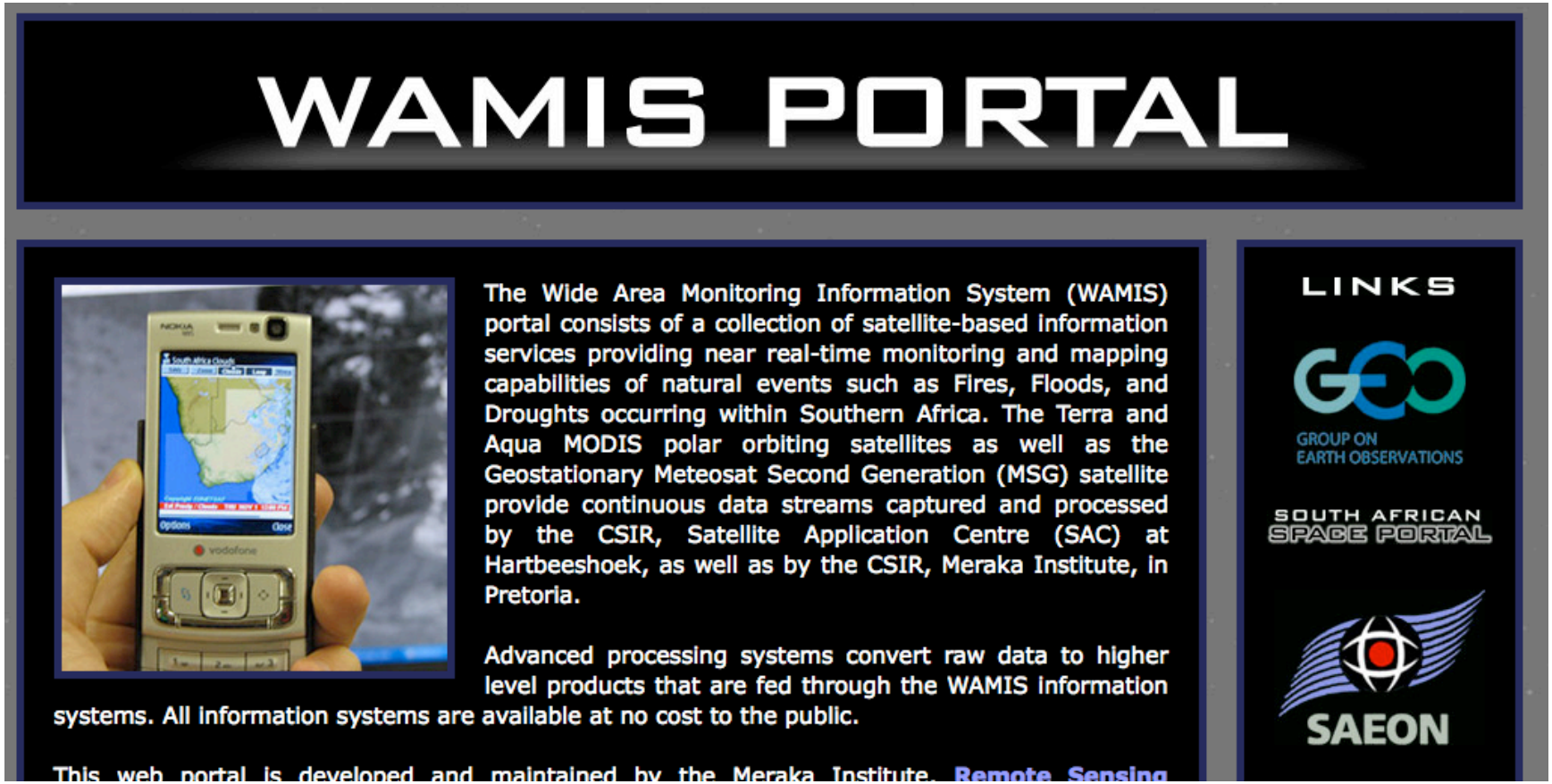
FIRMS Web Fire Mapper	Active Fire Maps	Global Fire Maps
		
The Fire Information for Resource Management System (FIRMS) at the University of Maryland integrates remote sensing and GIS technologies to deliver global MODIS hotspot/fire locations to natural resource managers and other stakeholders around the World. **+ Read more and access data**	The USFS's Remote Sensing Applications Center generates regional maps for the US fire managers using the active fire locations provided by the MODIS Rapid Response System, and also makes them available through an interactive ArcIMS interface over the conterminous United States, Alaska, and Canada. **+ Read more and access data**	Global 10-day fire maps are generated using the MODIS Rapid Response fire locations to represent the current fire activity across the world. **+ Read more** **+ Fire location data**
Natural Hazards	**Applications**	

Forecasting Fire Potential over South Africa sing DBCRAS CSIR Meraka Institute



Global Applications

http://www.wamis.co.za/



Other Applications

MODIS LST and buggers

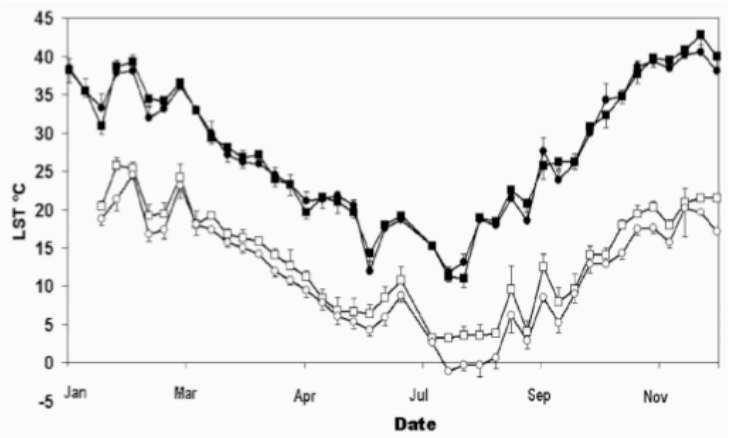


Fig. 4. Annual variation (2003) of diurnal land surface temperature (LST day) produced by the MODIS sensor (closed symbols) and LST night (open symbols) in locality groups of high (squares) and low (circles) house infestation rate. LST values are 8-d composites.

Reference: X. Porcasi, , S. S. Catala, H. Hrellac, M. C. Scavuzzo, D. E. Gorla, 2006: Infestation of Rural Houses by Triatoma Infestans (Hemiptera: Reduviidae) in Southern Area of Gran Chaco in Argentina, J. Med. Entomol. 43(5): 1060-1067.

Using MODIS Sun Glint Patterns

- What is sun glint?
- Application
  - Identifying regions of calm waters
  - Relationship of calm waters and sea surface temperatures
  - Oil spill locations

"Mirror" reflection of sunlight off calm water.

Sun Glint

Simple example where your eye is the sensor

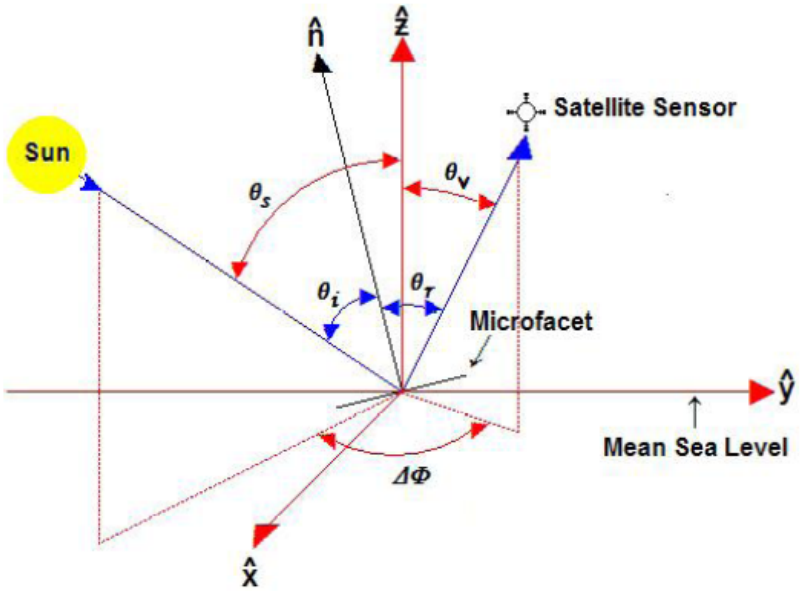
Sun Glint Ellipse Defined by: $\theta_r < 36$

$\cos \theta_r = \sin \theta_v \cos \theta_s \cos \Delta\Phi + \sin \theta_v \cos \theta_s$

Where θ_v = Viewing Zenith Angle

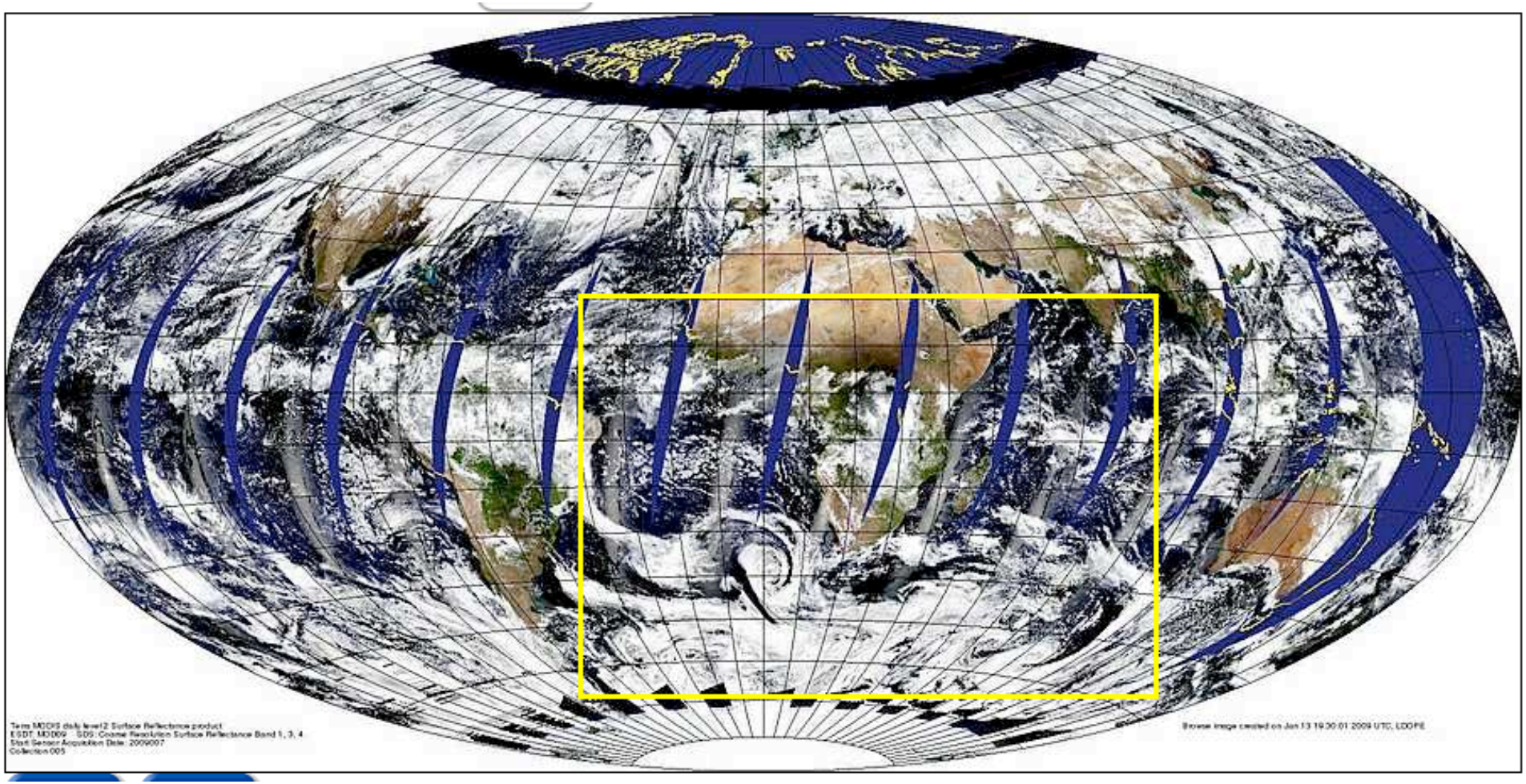
θ_s = Solar Zenith Angle

$\Delta\Phi$ = Relative Angle – difference between the Solar and Viewing azimuth angles.

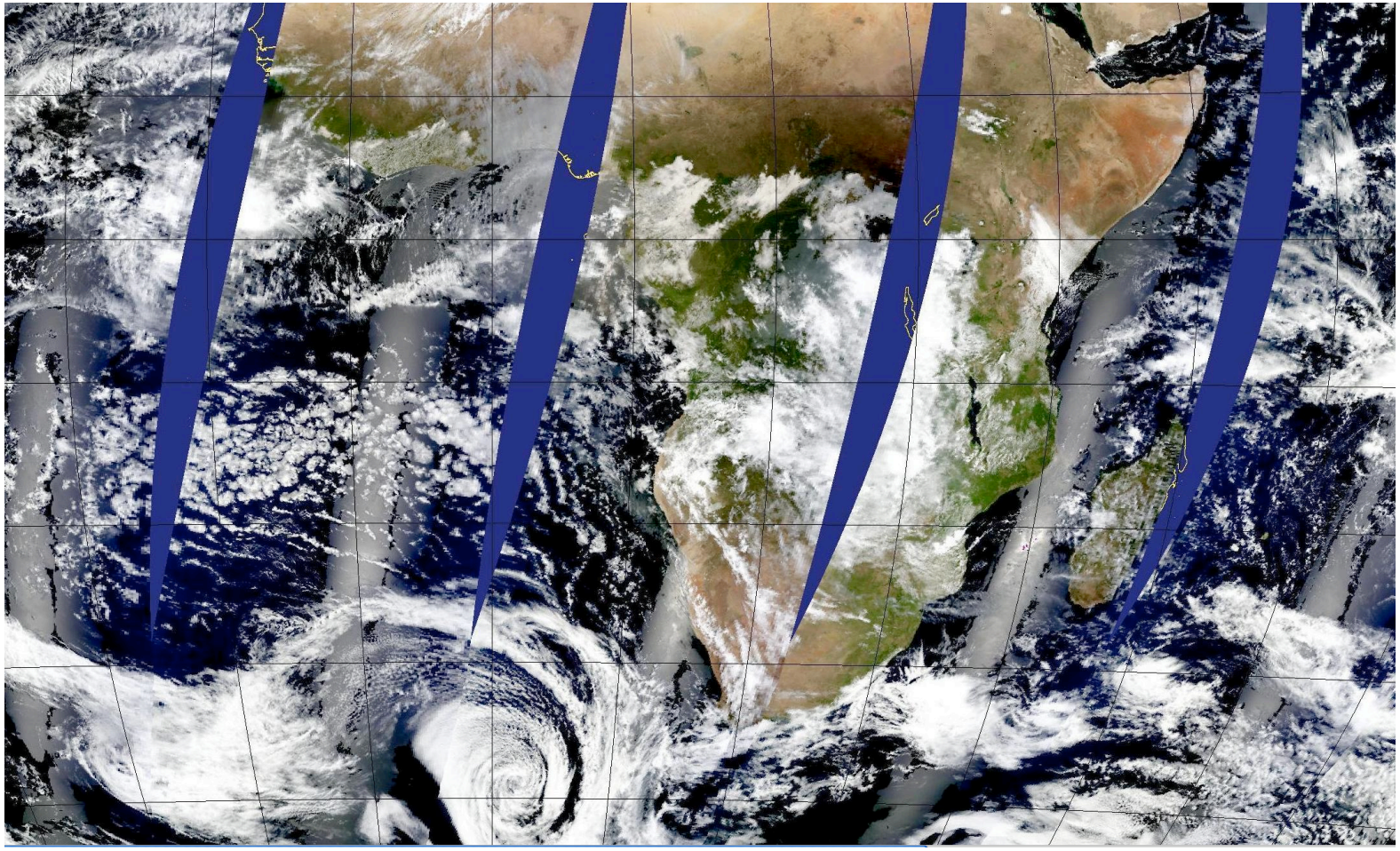


Aqua MODIS Sun Glint Example

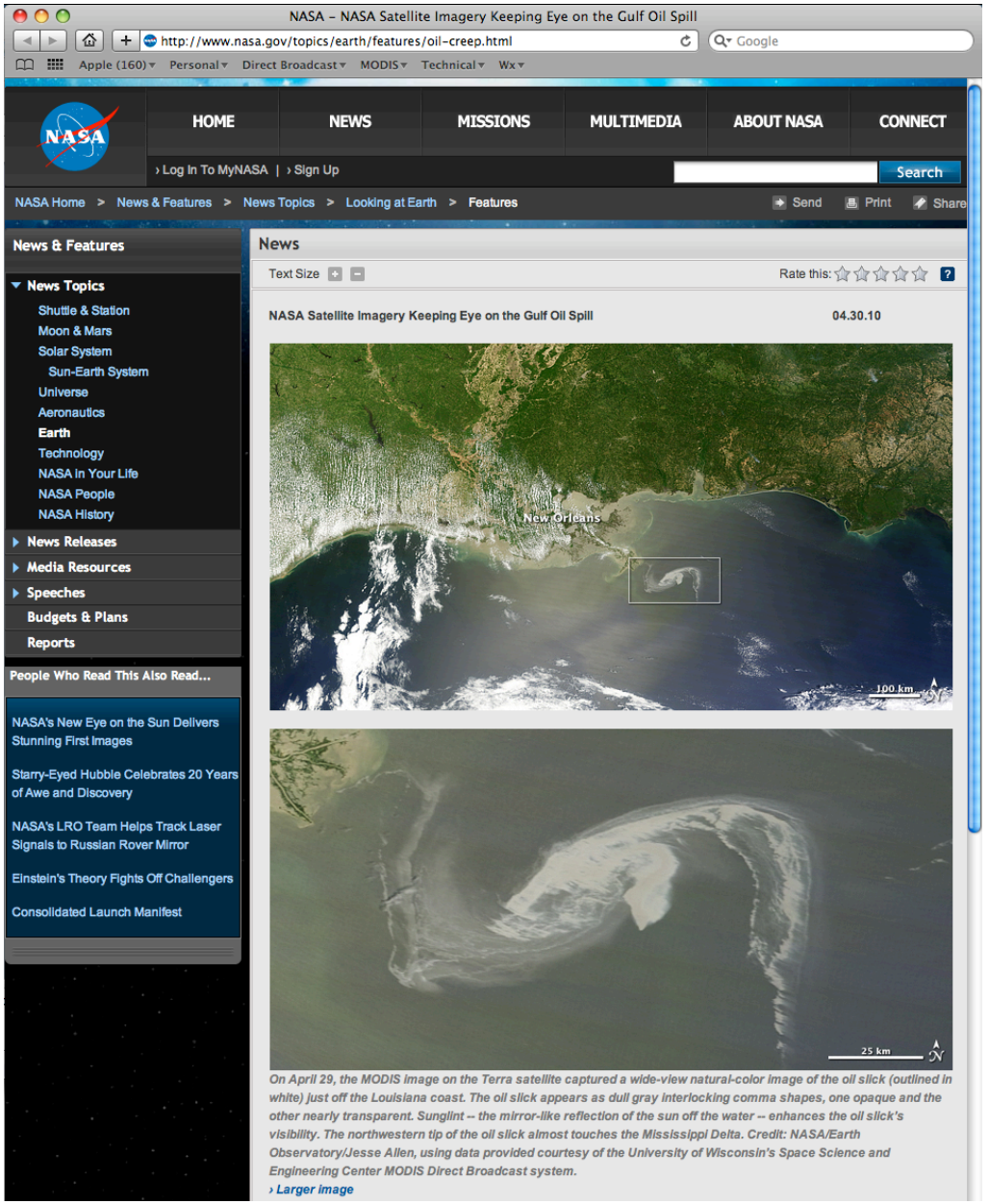
7 January 2009



Sun Glint Patterns



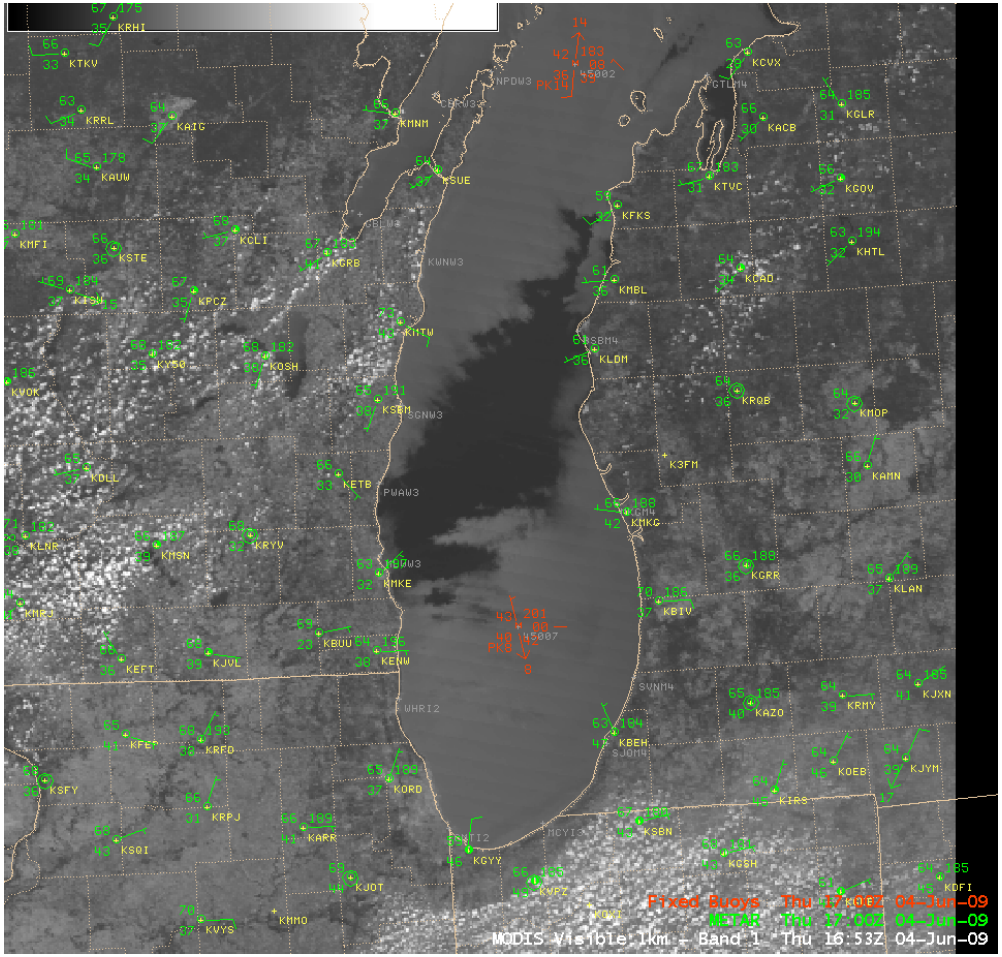
NASA Feature Article



http://www.nasa.gov/topics/earth/features/oil-creep.html

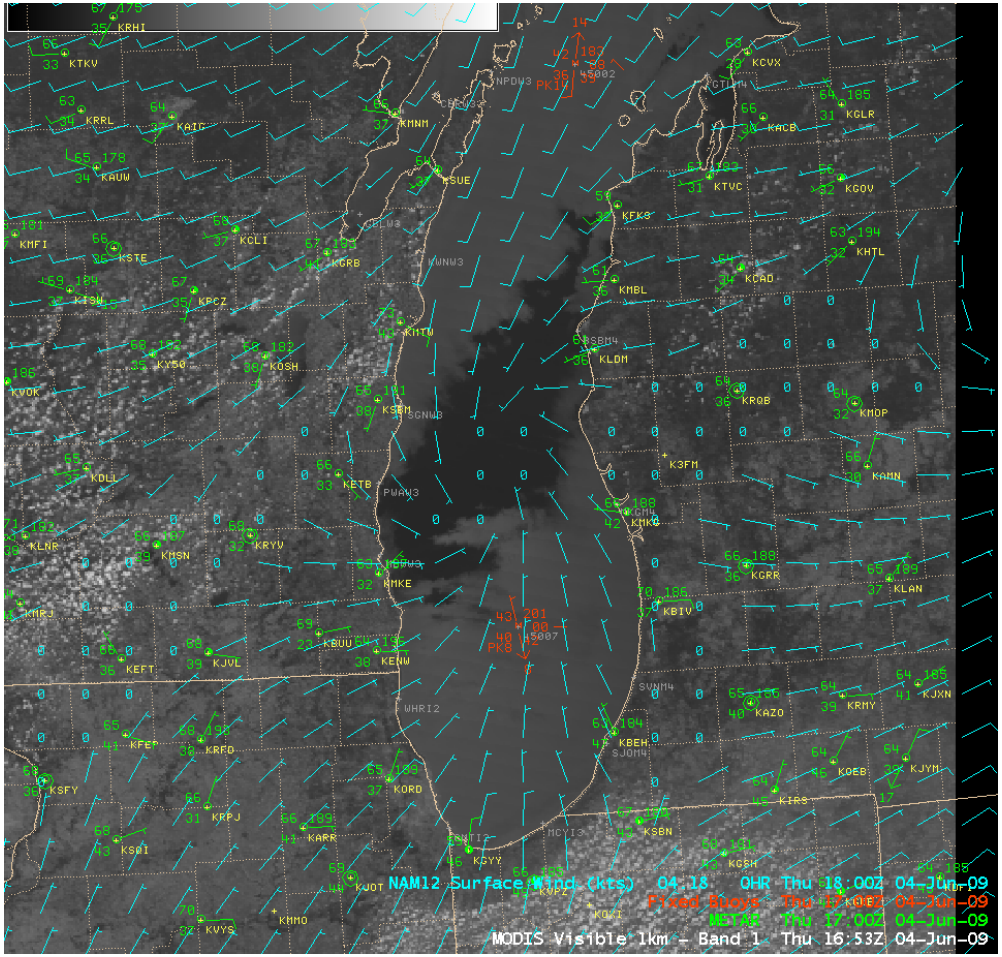
Example From Lake Michigan

4 June 2009



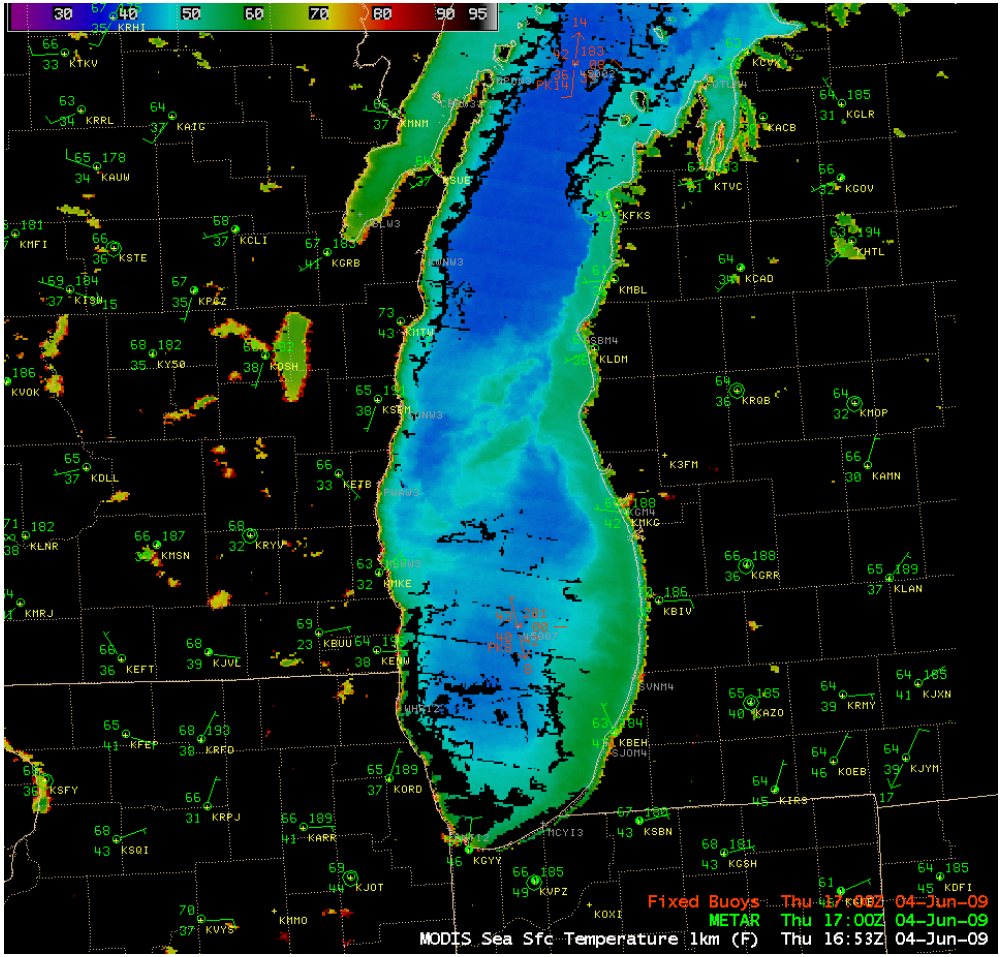
Numerical Weather Prediction

Wind analysis 18 UTC 4 June 2009

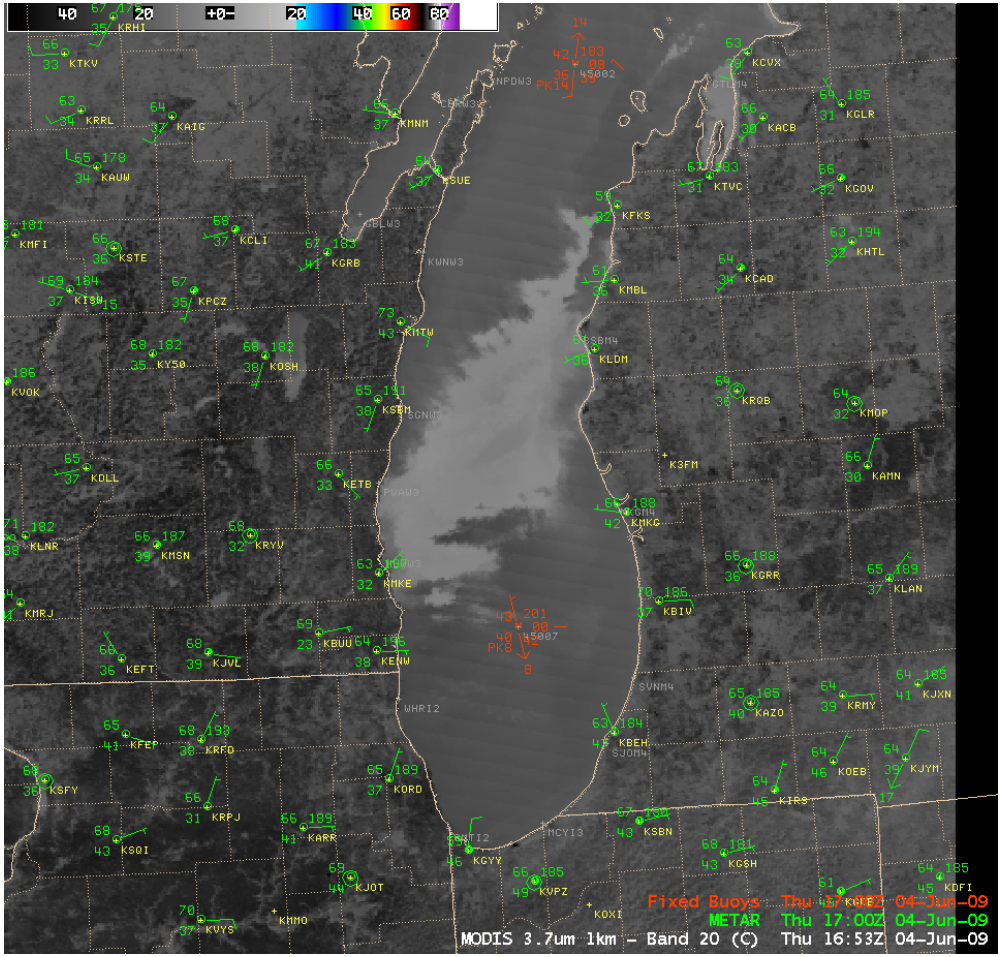


MODIS Sea Surface Temperatures

4 June 2009

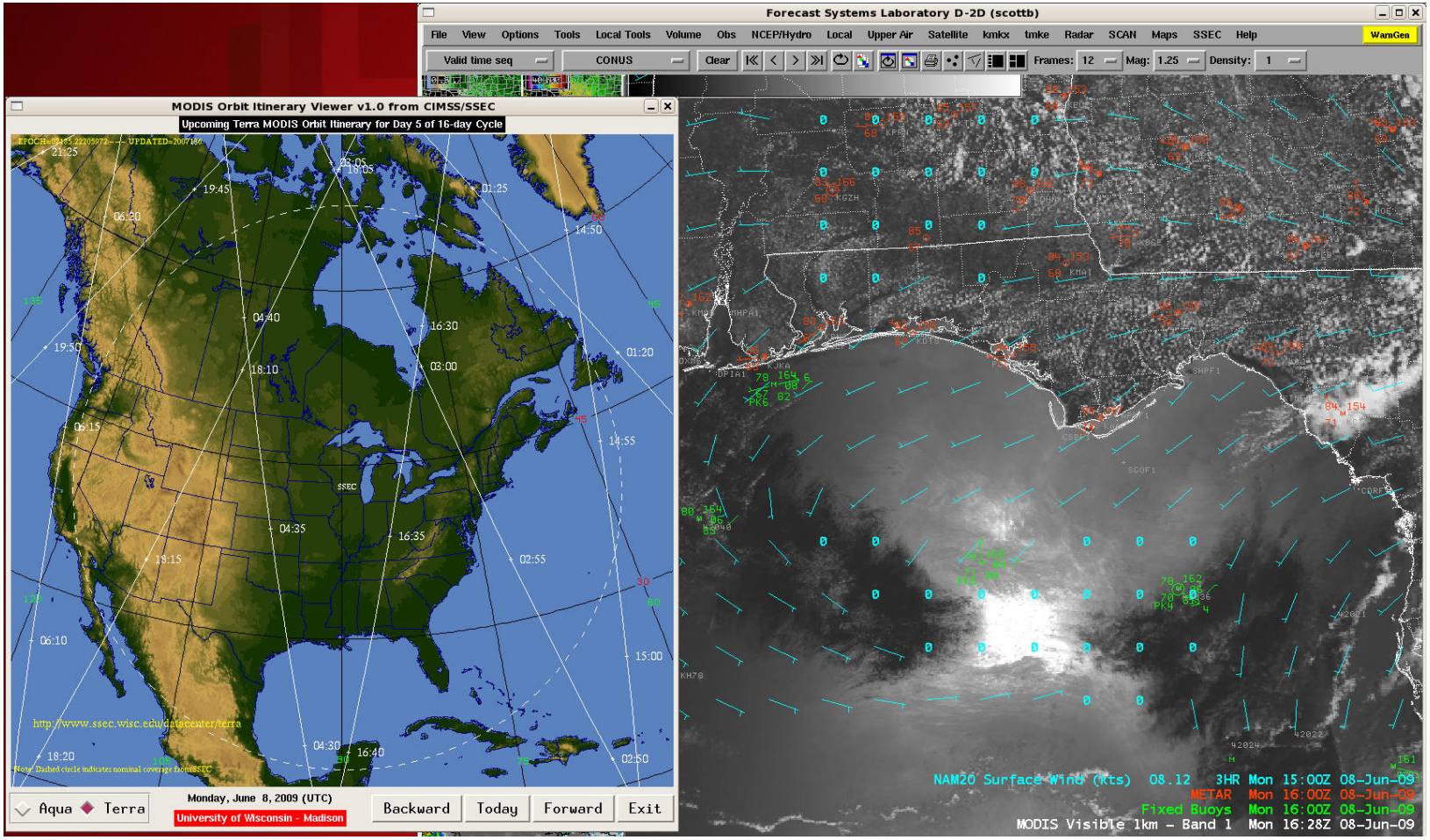


MODIS 4 µm Brightness Temperatures



MODIS Sunglint Pattern

8 June 2009



MODIS Polar Wind Vectors can be derived automatically

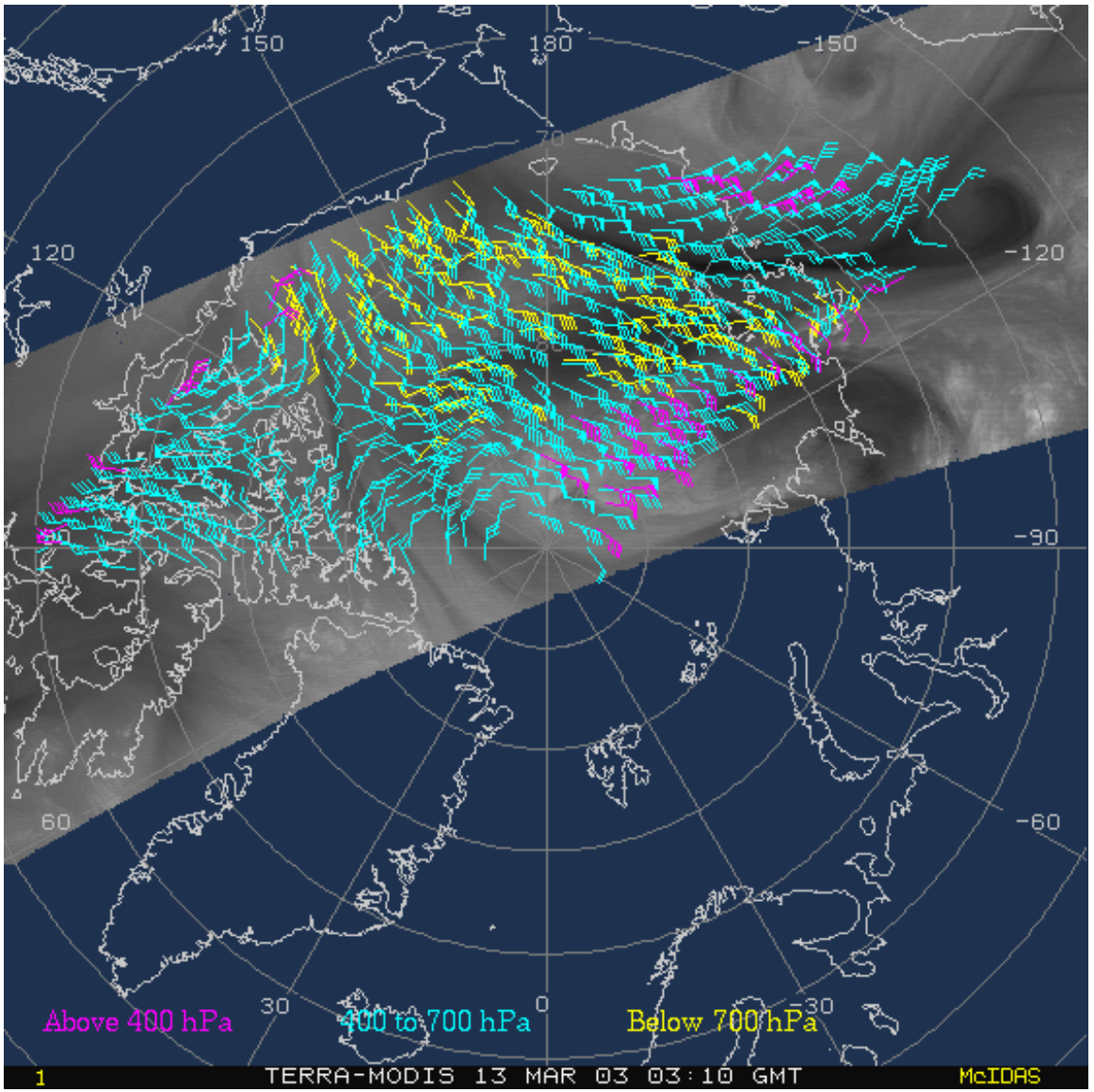
Jeff Key, Chris Velden, Dave Santek

Wind vectors are generated using automatic feature tracking software developed for GOES.

6.7 μm heights are assigned based on forecast atmospheric profile.

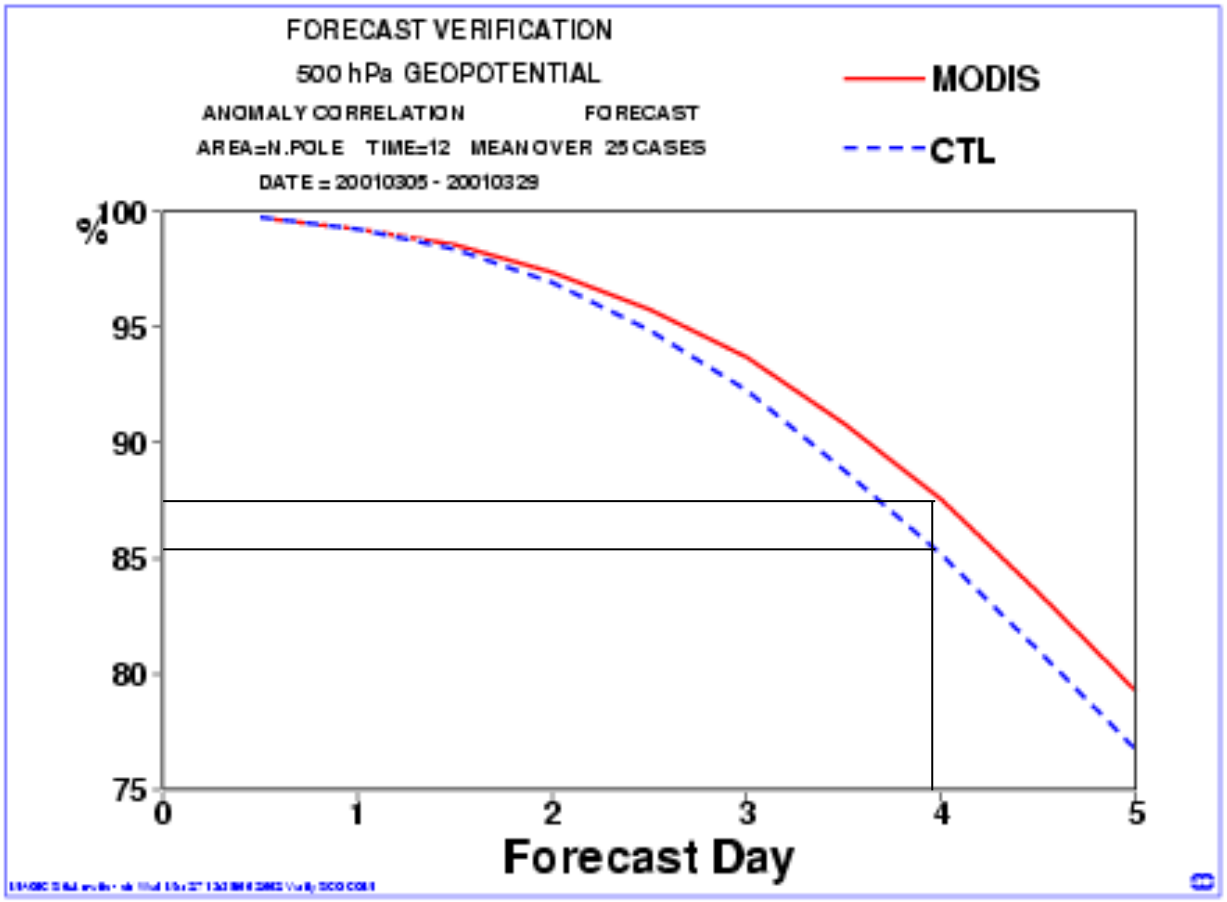
11.0 μm heights are assigned based on window brightness temperature or CO2 cloud height.

Winds are automatically quality controlled.



Terra MODIS 6.7 μm (band 27) 2003/03/13

Positive impact on forecast demonstrated by ECMWF



NWP Centers using MODIS Polar Winds Operationally:

ECMWF, GMAO, JMA, CMC, FNMOC, UKMO, DWD, NCEP/EMC

Key, J. R., D. Santek, C. S. Velden, N. Bormann, J.-N. Thépaut, L. P. Riishojgaard, Y. Zhu, and W. P. Menzel, 2003. Cloud-Drift and Water Vapor Winds in the Polar Regions from MODIS. *IEEE Transactions on Geoscience and Remote Sensing, 41, 482-492.*