MODIS and VIIRS Data Environmental Applications: Part 2

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UPR Direct Broadcast Polar Orbiter Workshop

27 August 2016

Aviation Applications

Turbulence, Clouds

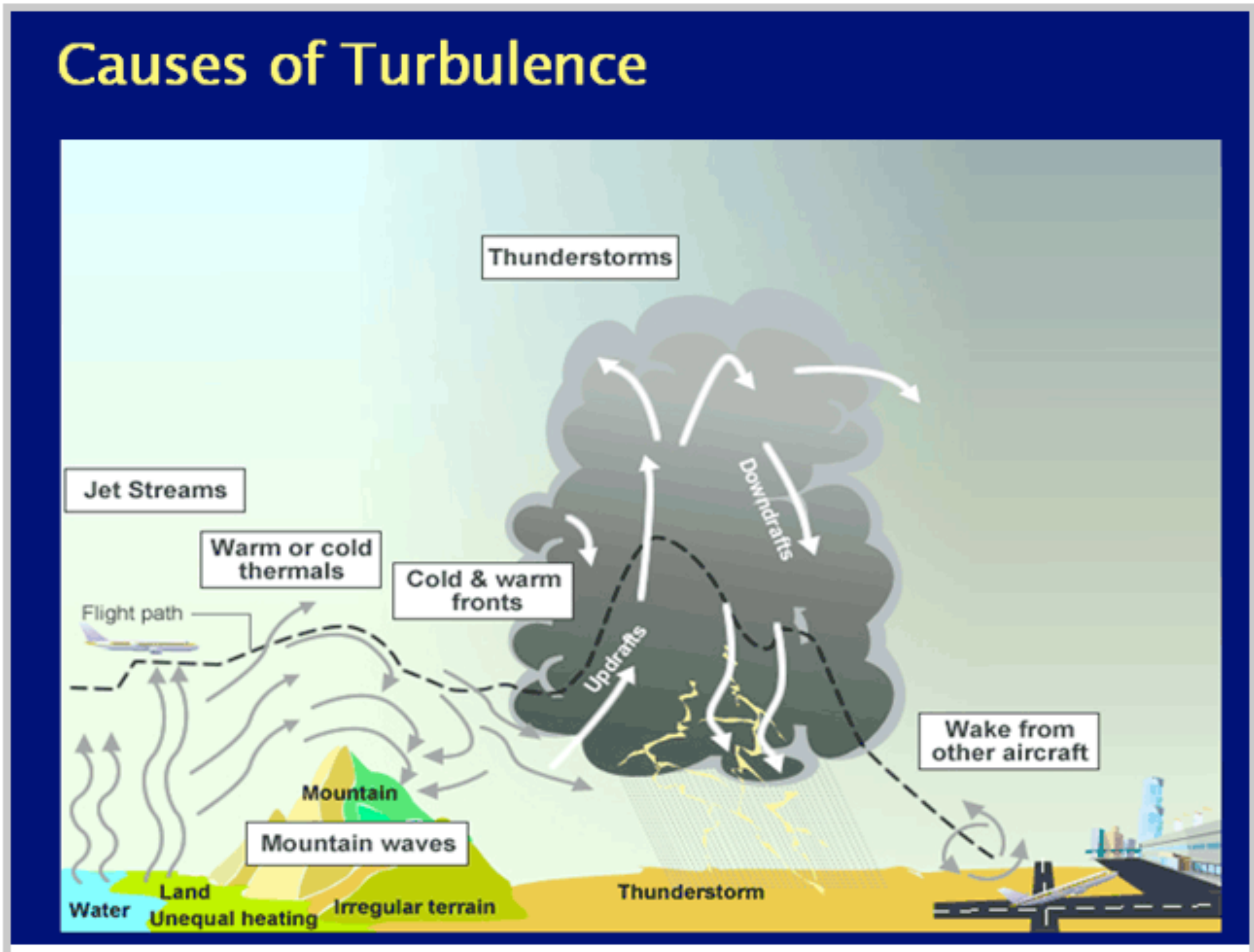
Atmospheric Turbulence

What is Turbulence?

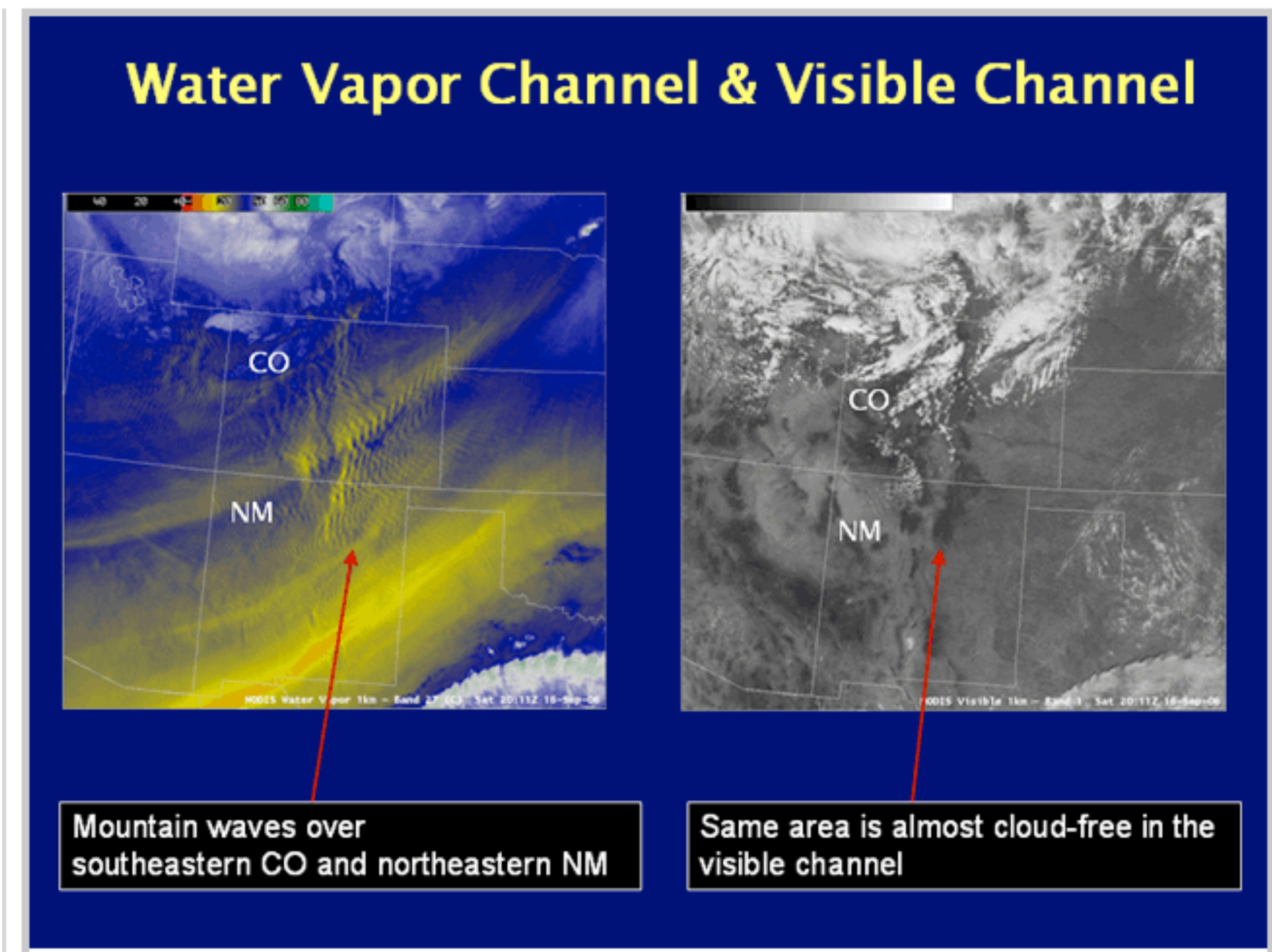
This smoke pattern shows turbulence as rapid, abrupt and chaotic changes in the speed and direction of air flow.

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

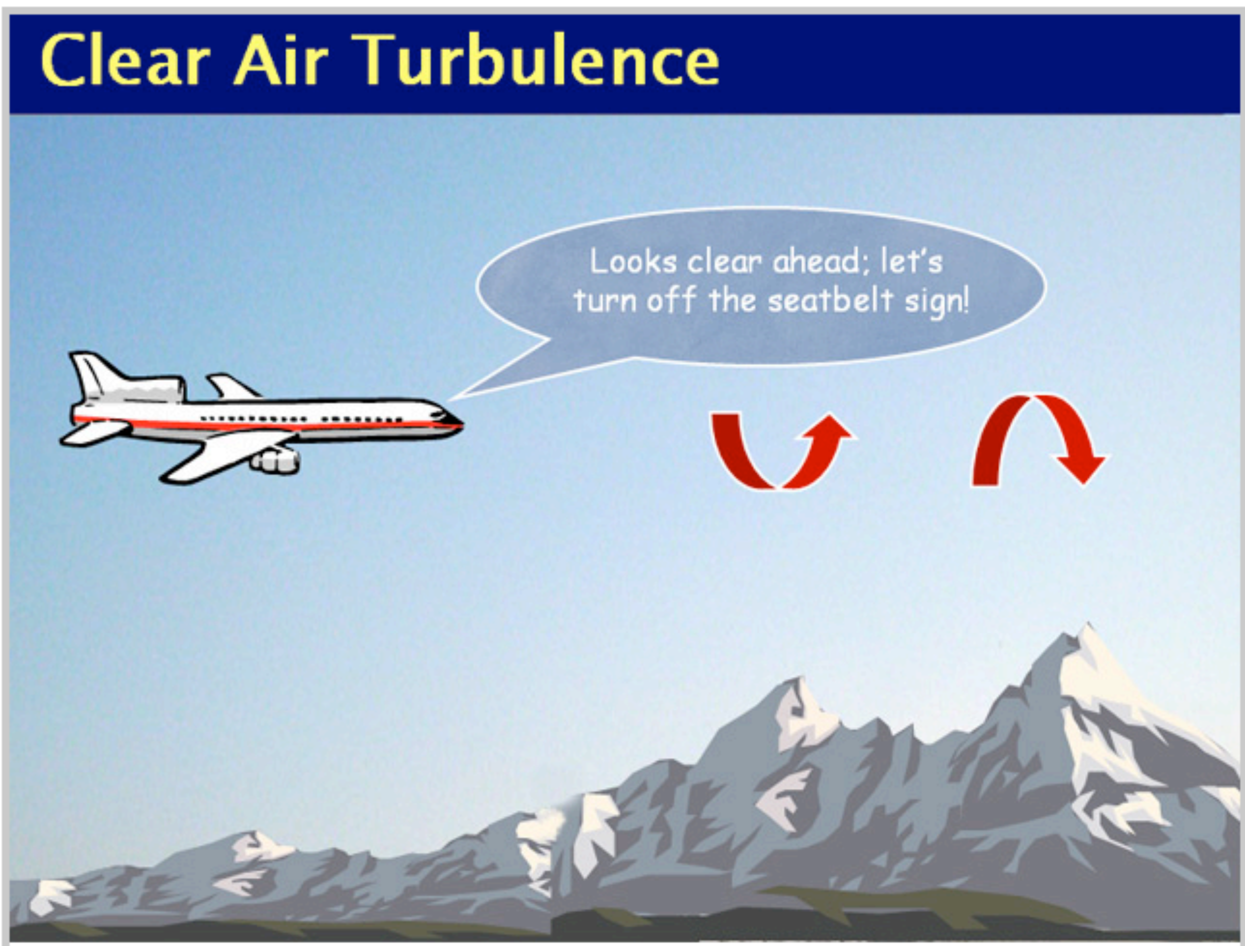
Atmospheric Turbulence



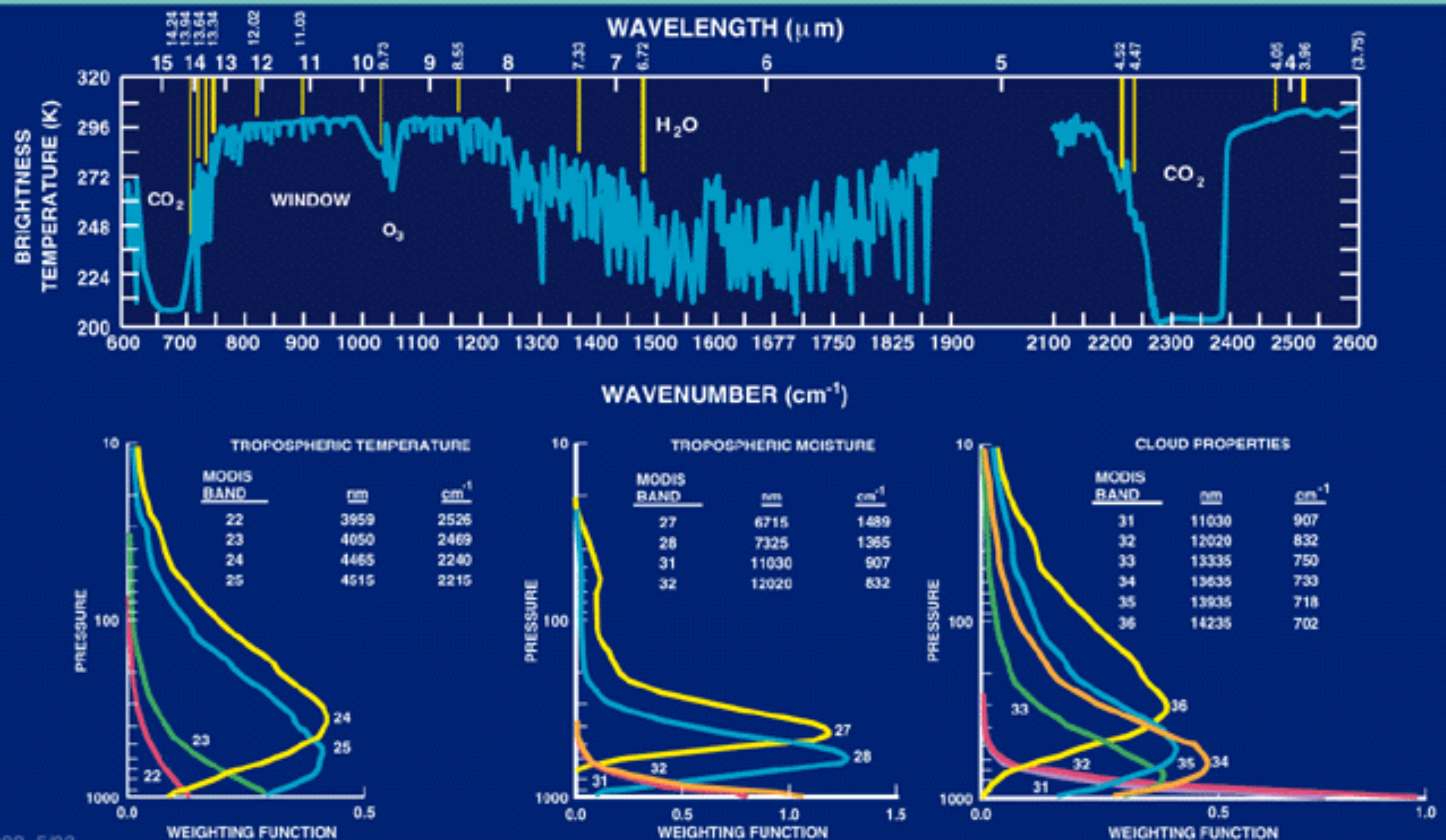
Why is 6.7 µm Important for the Detection of Turbulence?



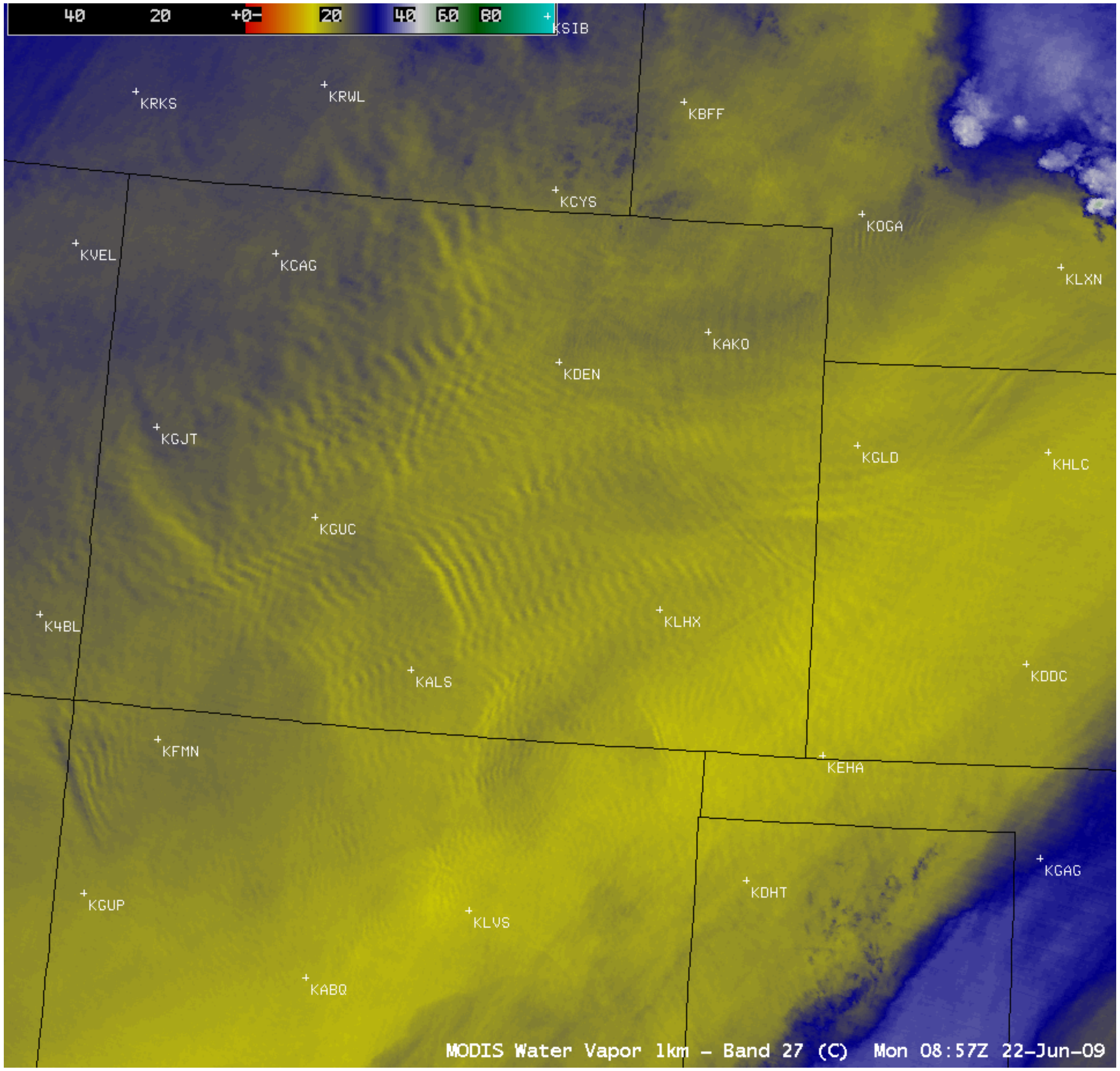
Why is This Important?



ATMOSPHERE - THERMAL RADIATION



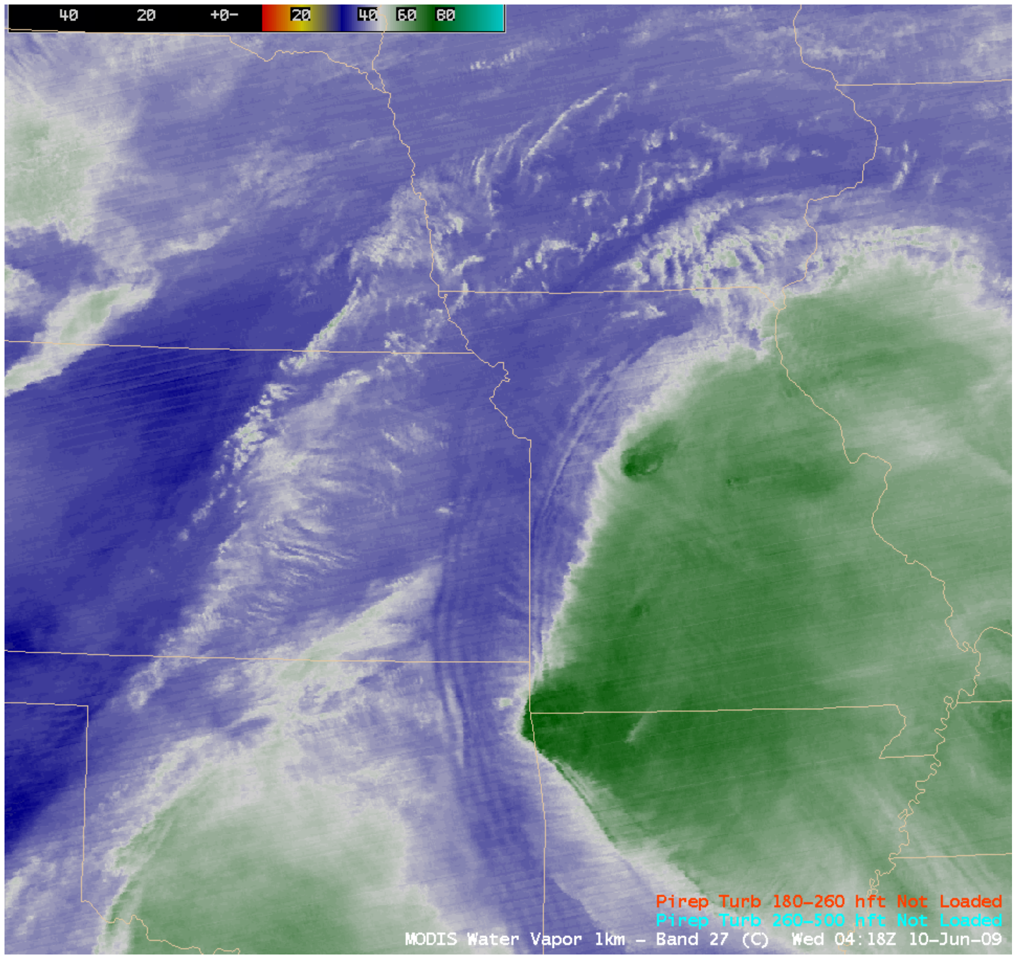
Mountain Wave Clouds in Clear Air



MODIS and GOES
08:57 UTC
22 June 2009

Turbulence Not Just from Orography

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



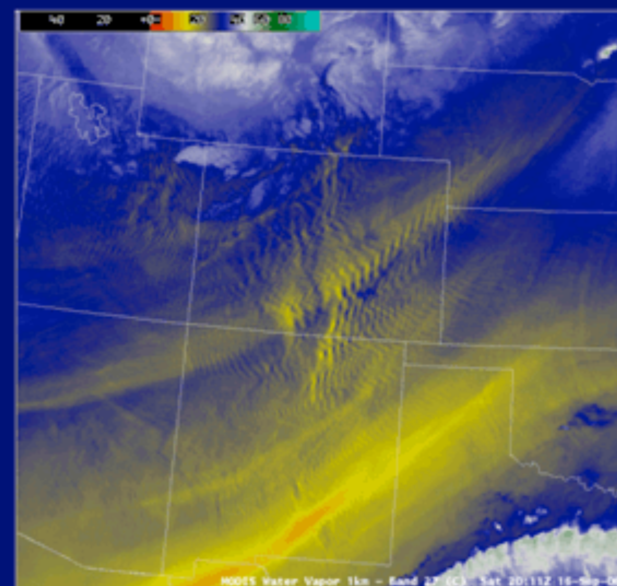
Why is 6.7 µm Important for the Detection of Turbulence?

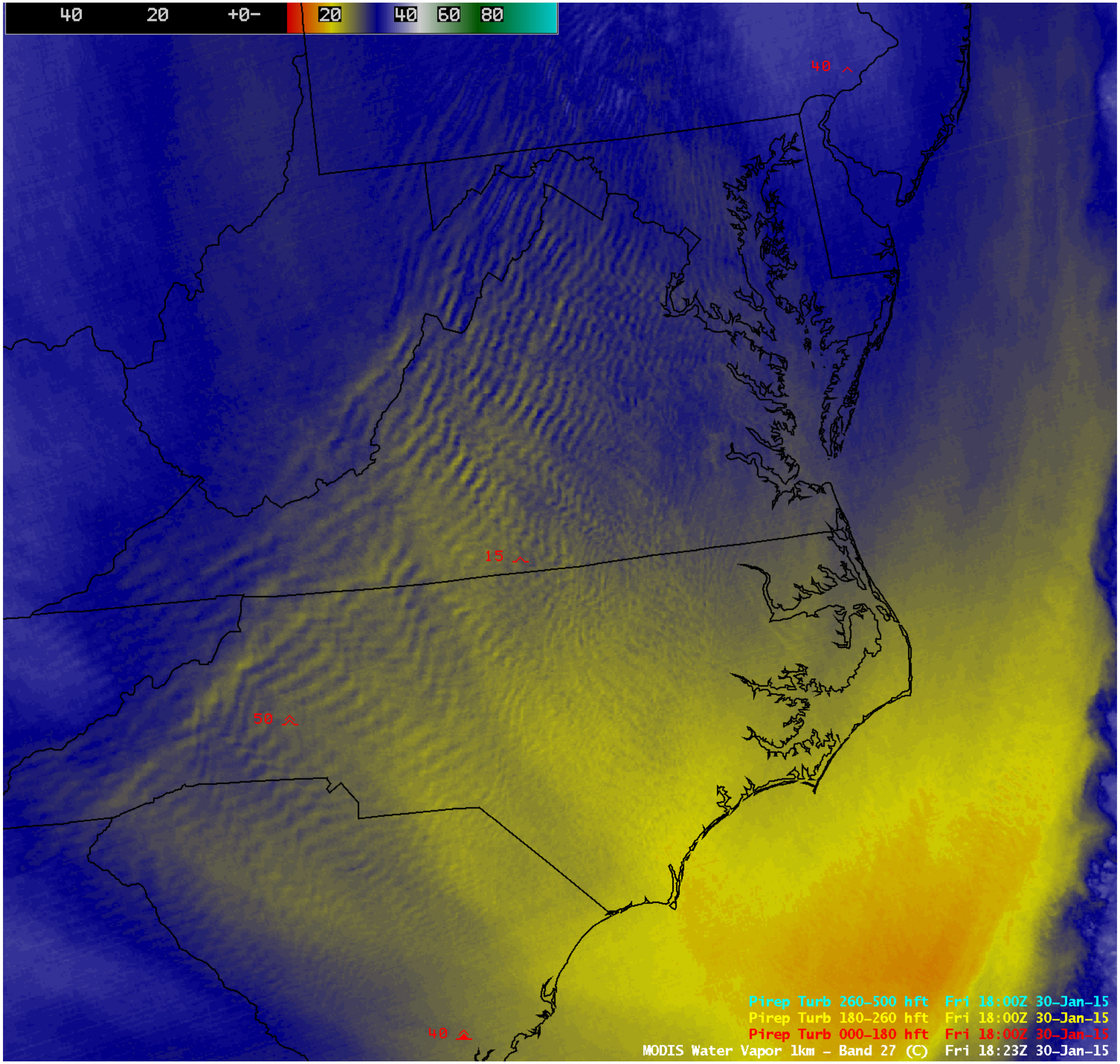
Summary

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

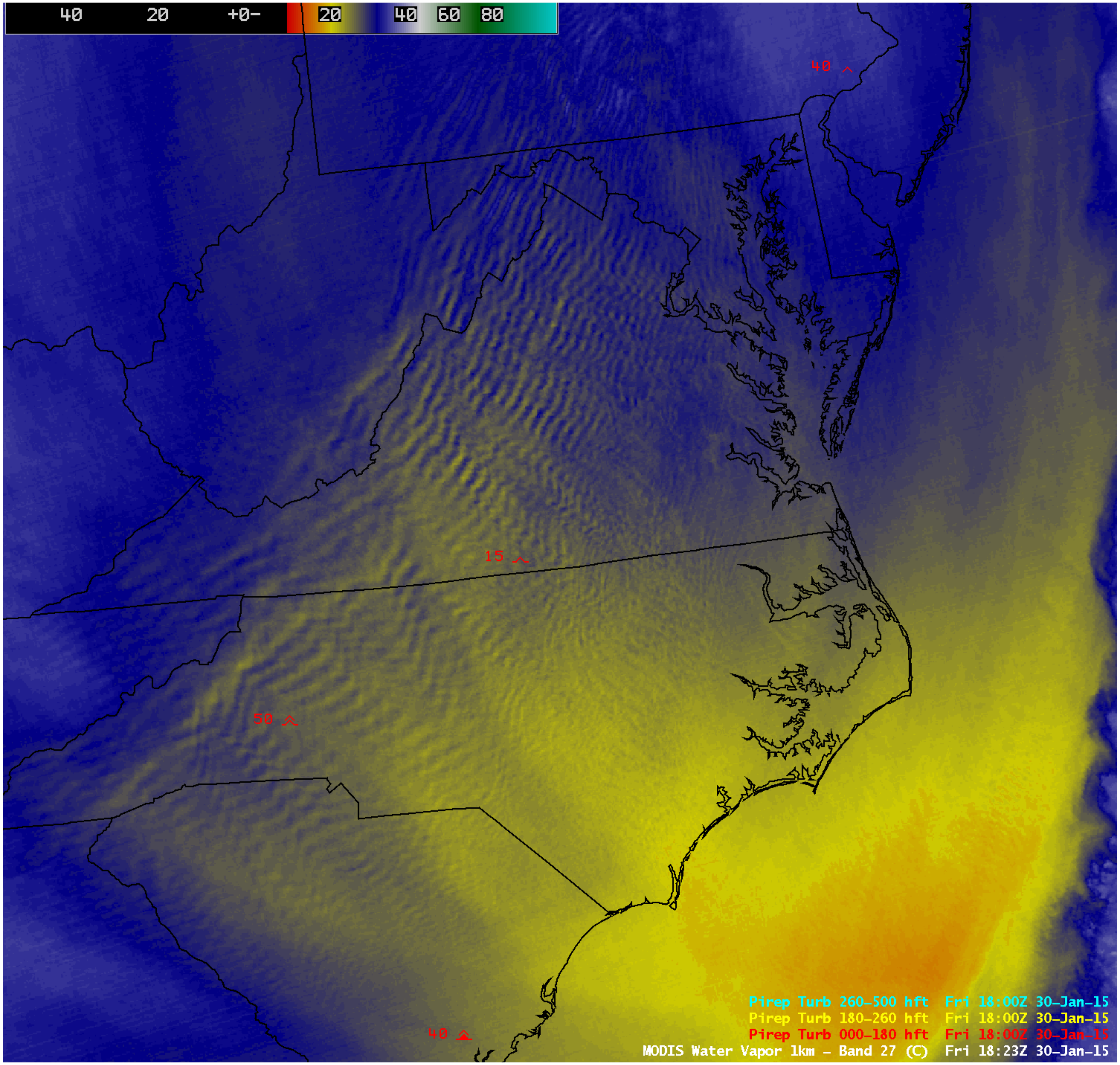
Mountain waves are one common cause of turbulence, and water vapor channel imagery has the ability to detect areas where this type of turbulence may be present.

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.





40 20 +0- 20 40 60 80
40
15
50
40
Pirep Turb 260-500 hft Fri 18:00Z 30-Jan-15
Pirep Turb 180-260 hft Fri 18:00Z 30-Jan-15
Pirep Turb 000-180 hft Fri 18:00Z 30-Jan-15
MODIS Water Vapor 1km - Band 27 (C) Fri 18:23Z 30-Jan-15


40 20 +0- 20 40 60 80
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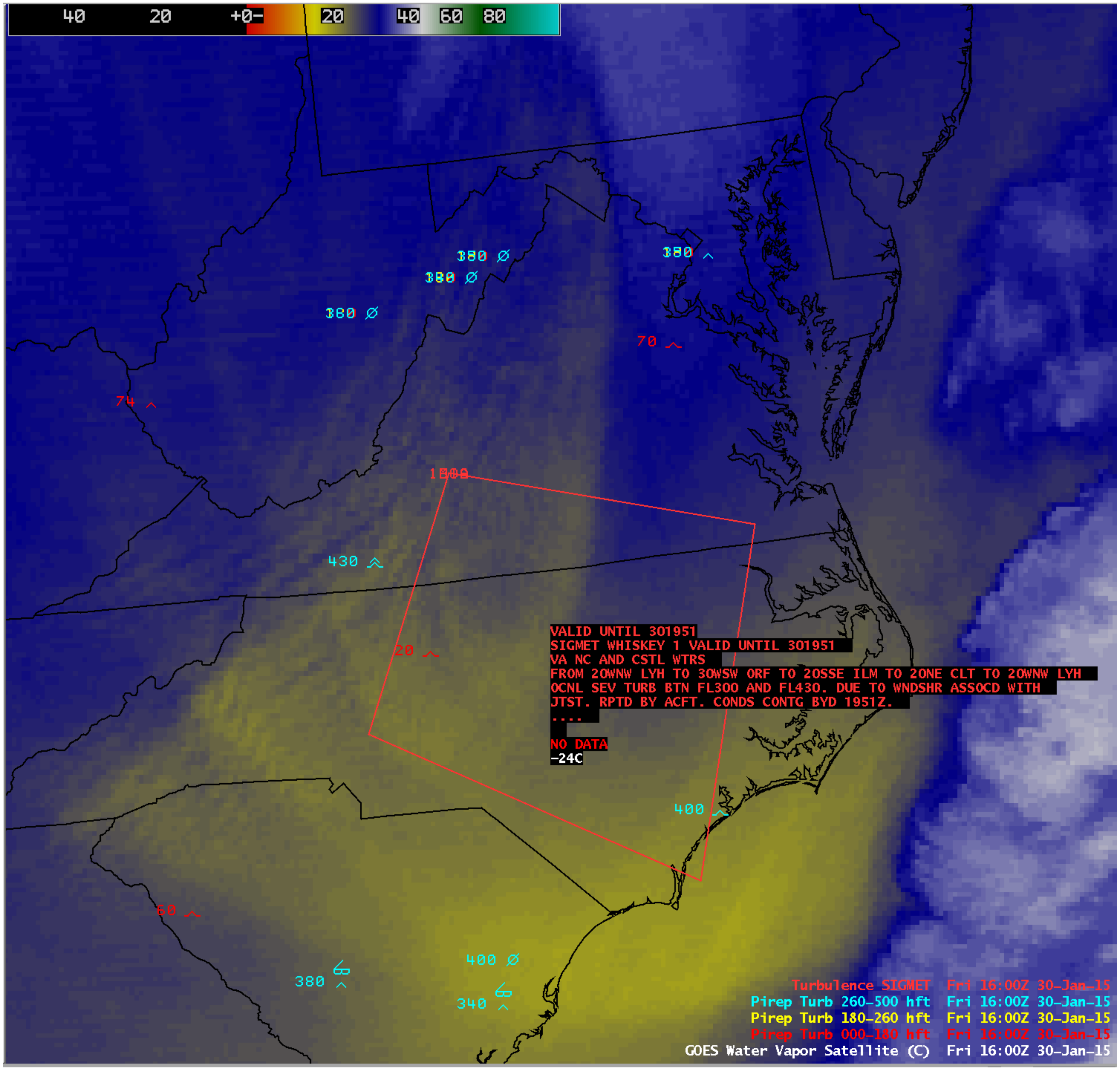
Pirep Turb 260-500 hft Fri 18:00Z 30-Jan-15
Pirep Turb 180-260 hft Fri 18:00Z 30-Jan-15
Pirep Turb 000-180 hft Fri 18:00Z 30-Jan-15
MODIS Water Vapor 1km - Band 27 (C) Fri 18:23Z 30-Jan-15



40 20 +0- 20 40 60 80
380
380
380
380
70
74
1800
430
20
VALID UNTIL 301951
SIGMET WHISKEY 1 VALID UNTIL 301951
VA NC AND CSTL WTRS
FROM 20WNW LYH TO 30WSW ORF TO 20SSE ILM TO 20NE CLT TO 20WNW LYH
OCNL SEV TURB BTN FL300 AND FL430. DUE TO WNDSHR ASSOCD WITH
JTST. RPTD BY ACFT. CONDS CONTG BYD 1951Z.
....
NO DATA
-24C
400
60
400
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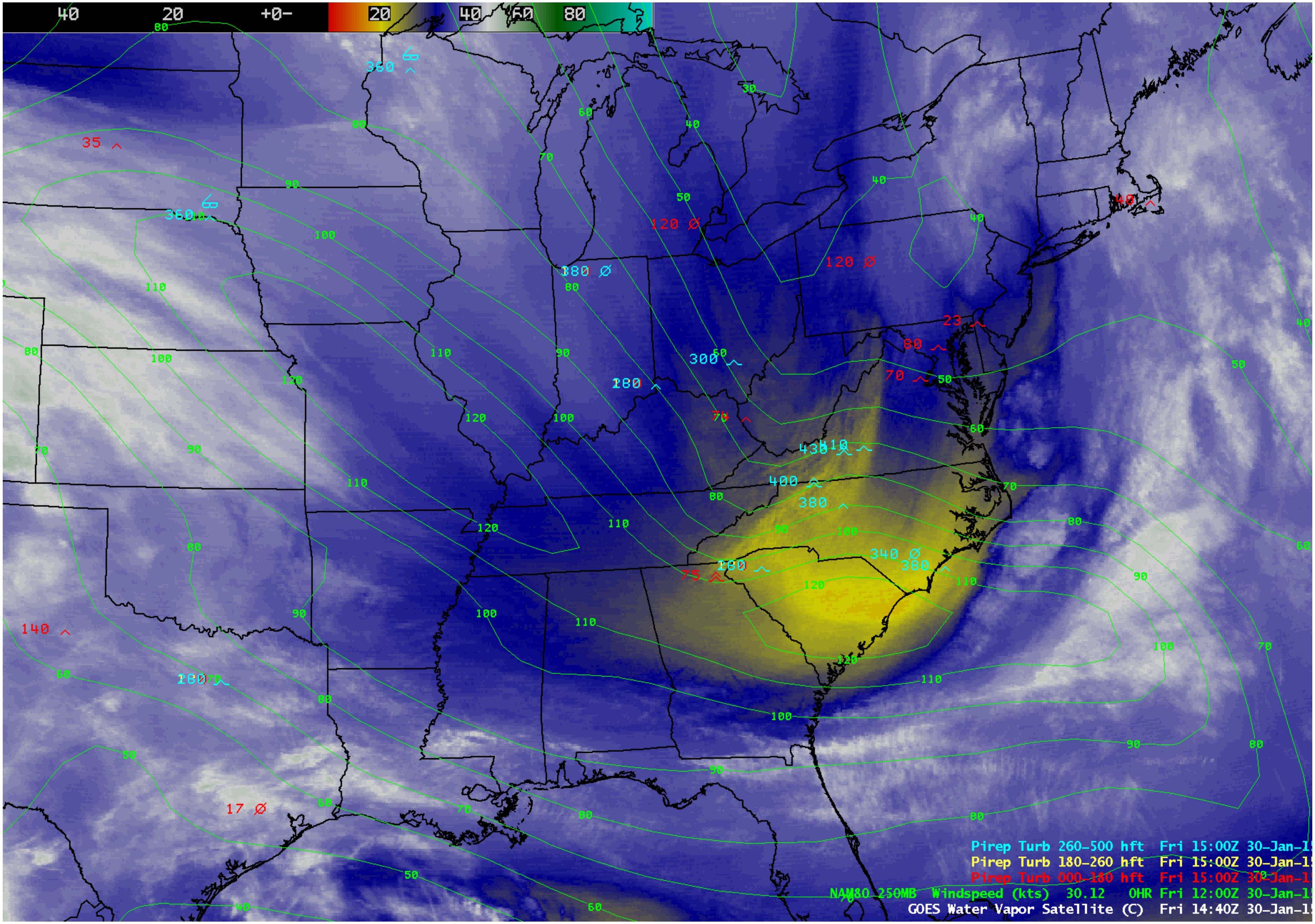
340
Turbulence SIGMET Fri 16:00Z 30-Jan-15
Pirep Turb 260-500 hft Fri 16:00Z 30-Jan-15
Pirep Turb 180-260 hft Fri 16:00Z 30-Jan-15
Pirep Turb 000-180 hft Fri 16:00Z 30-Jan-15
GOES Water Vapor Satellite (C) Fri 16:00Z 30-Jan-15


40 20 +0- 20 40 60 80
Pirep Turb 260-500 hft Fri 15:00Z 30-Jan-1
Pirep Turb 180-260 hft Fri 15:00Z 30-Jan-1
Pirep Turb 000-180 hft Fri 15:00Z 30-Jan-1
NAM80 250MB Windspeed (kts) 30.12 0HR Fri 12:00Z 30-Jan-1
GOES Water Vapor Satellite (C) Fri 14:40Z 30-Jan-1

Cloud Applications Continued

- Clouds
  - Composition
  - Cloud Top Properties
  - Cloud Phase

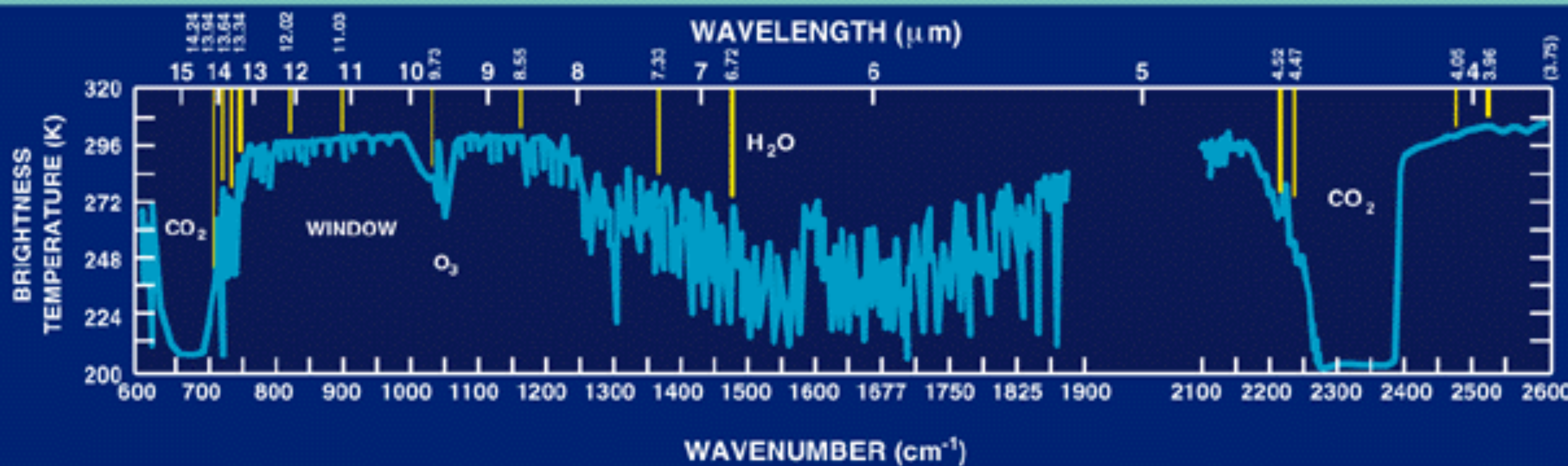
Clouds

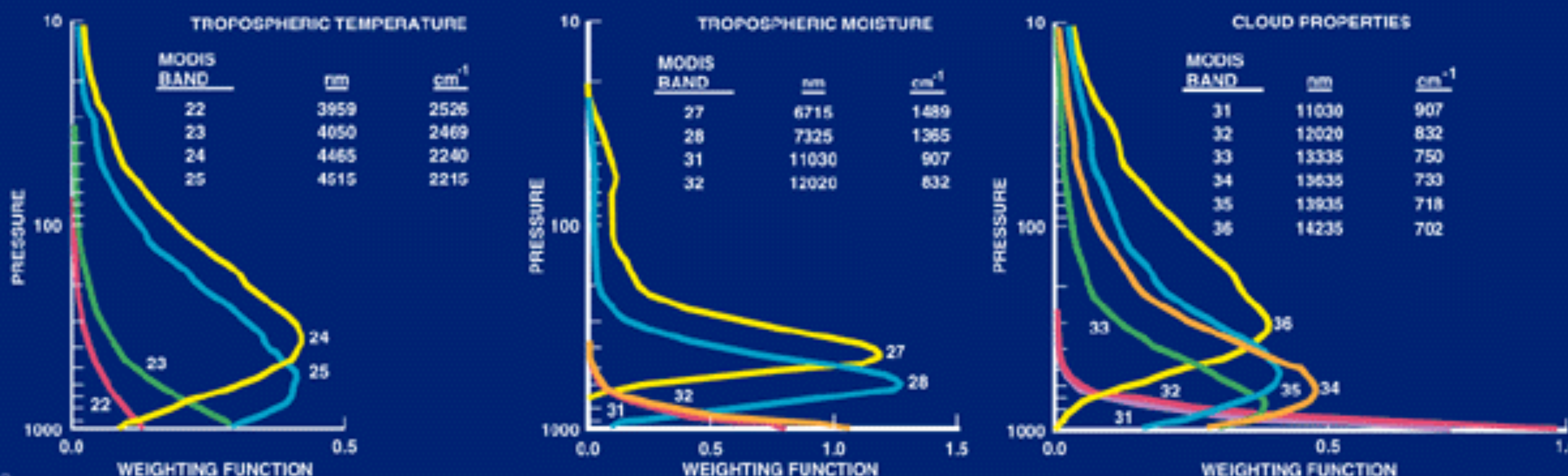
- MOD06 Cloud Product
  Example filename: a1.13214.2325.mod06ct.hdf
  - Cloud Top Properties at 5km
    - Cloud Top Pressure, Cloud Top Temperature, Cloud Fraction, Cloud Emissivity
  - Cloud Phase at 5 km
  - Cloud Optical Properties at 1 km (Daytime only)
    - Cloud Effective Radius
    - Cloud Optical 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





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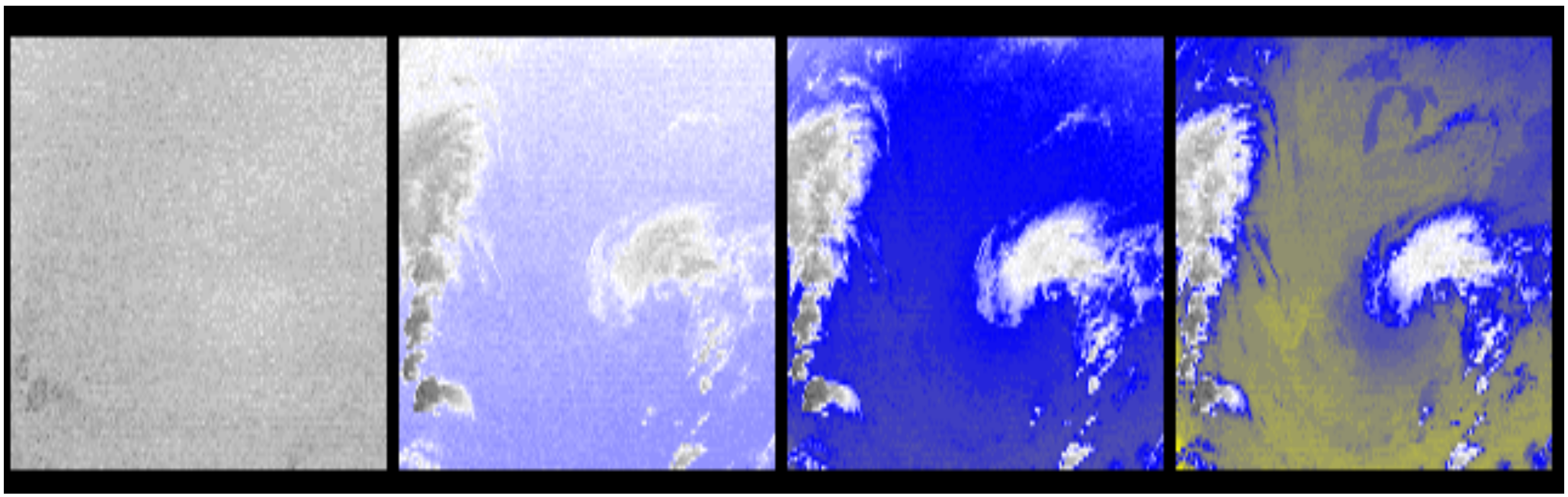
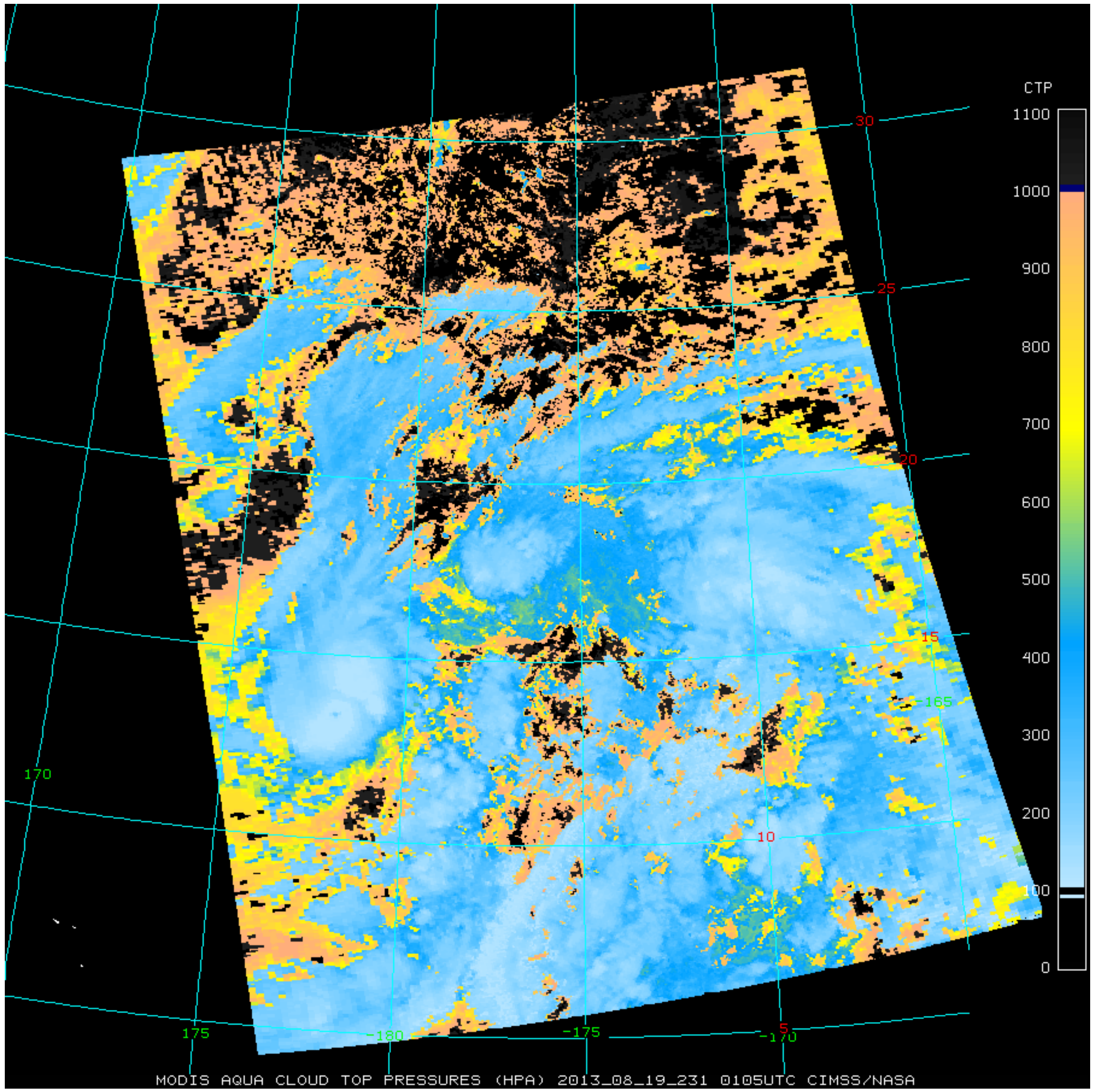
CO2 channels see to different levels in the atmosphere

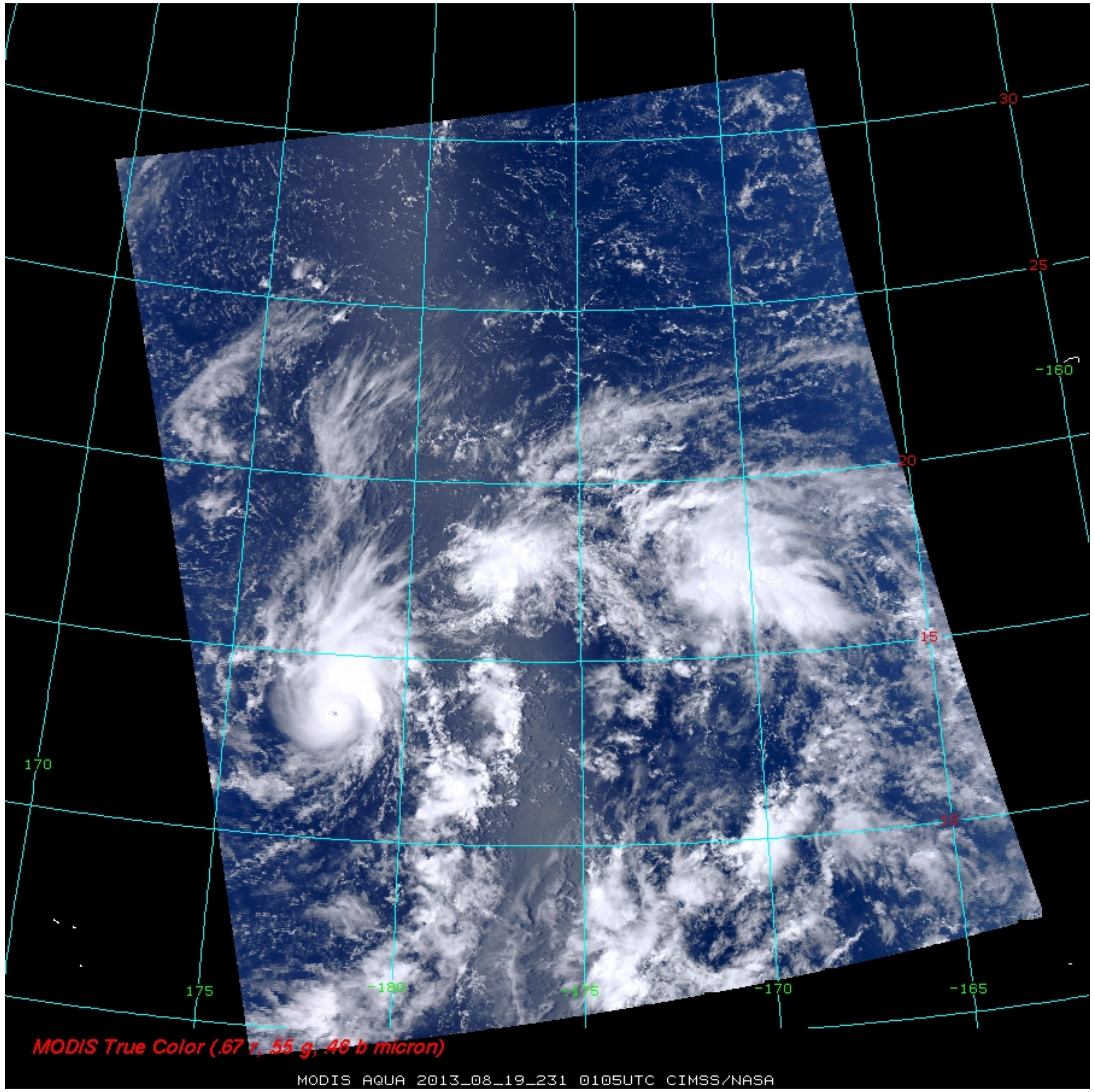


14.2 um 13.9 um 13.6 um 13.3 um

Example Cloud Top Pressure Product

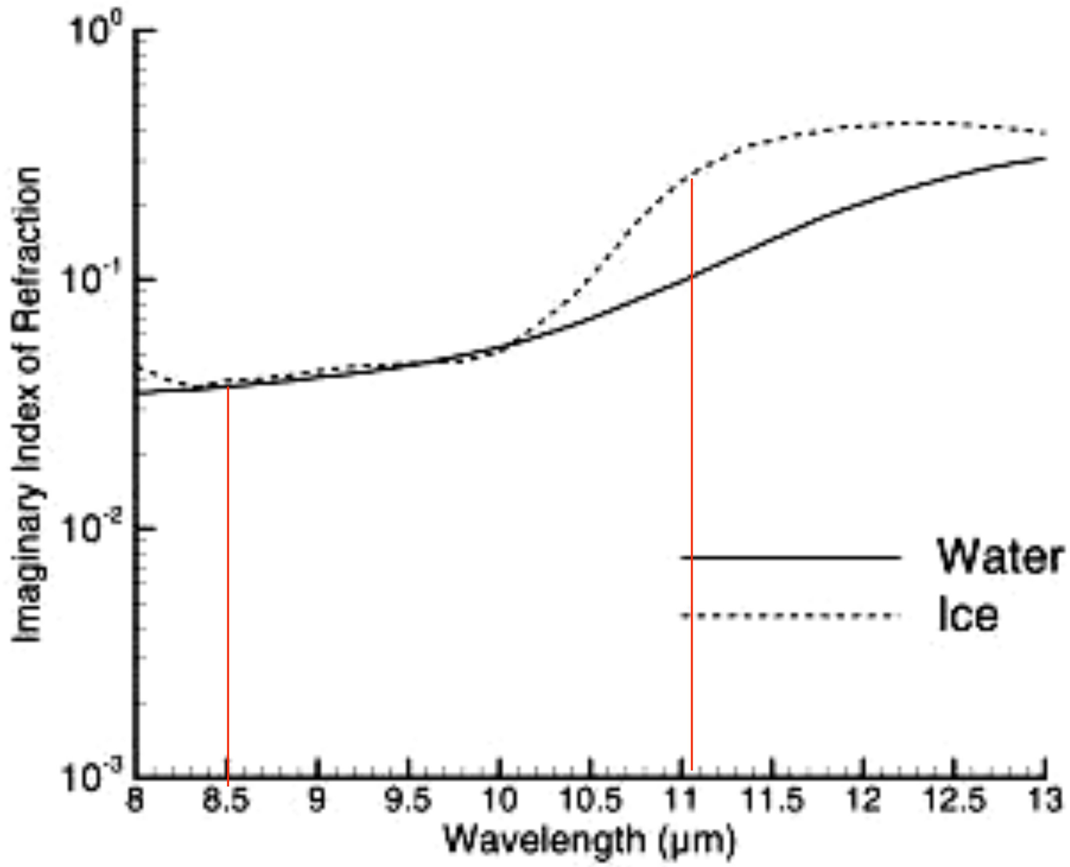


Example Cloud Top Pressure Product



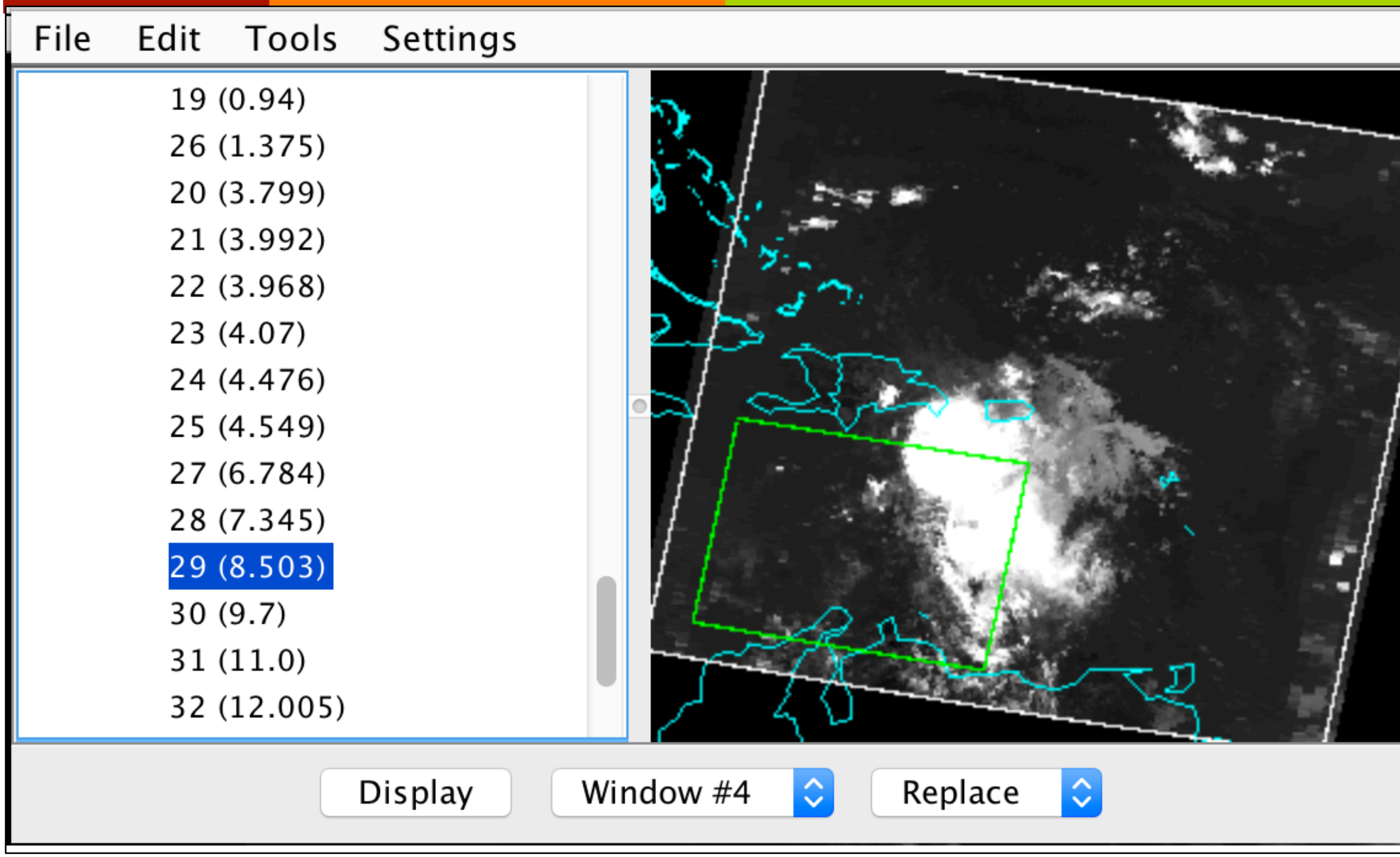
Cloud Phase

- 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)



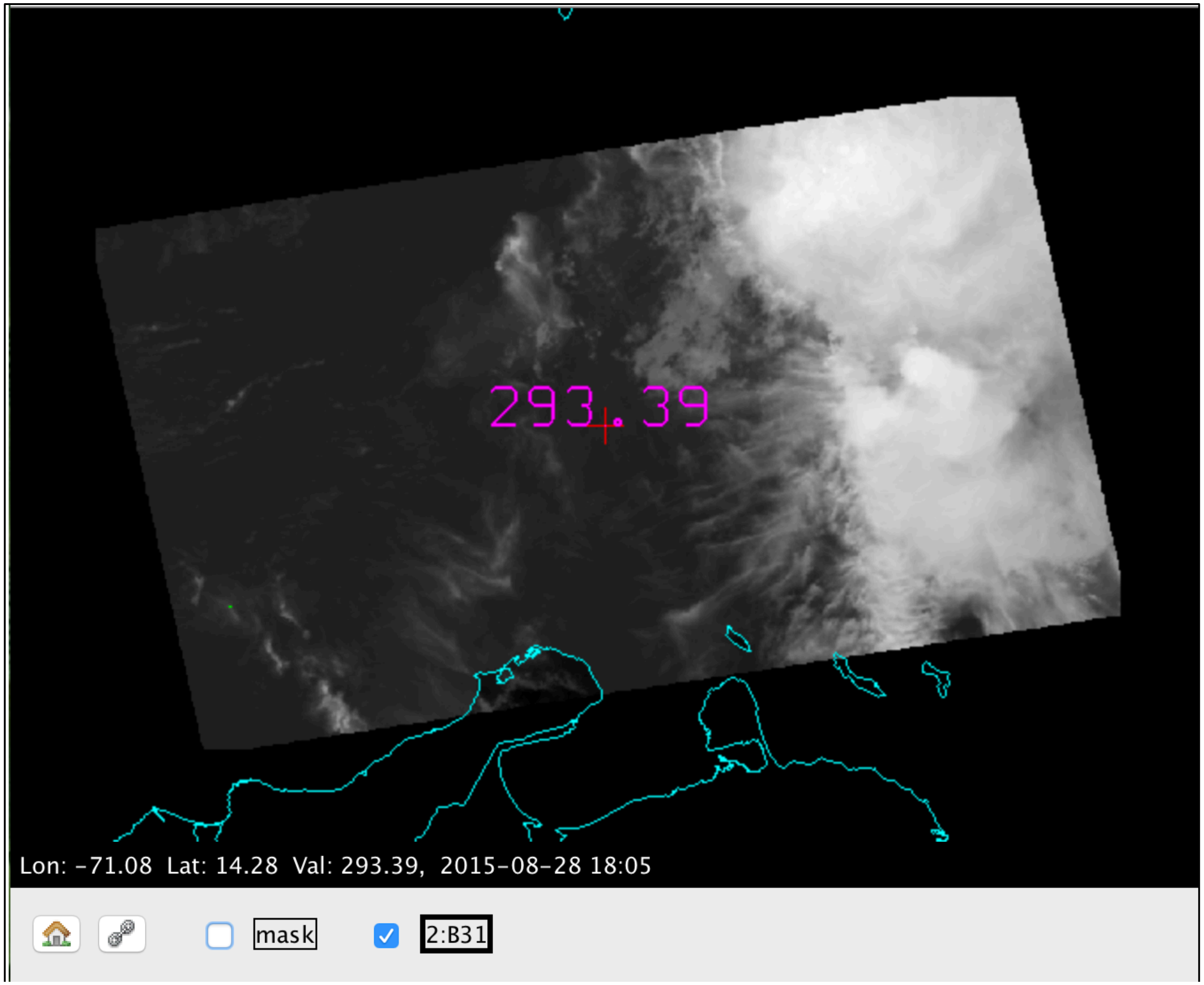
Imaginary Index of Refraction of Ice and Water 8 – 13 microns

Example of Use of Two IR Thermal Bands Tropical Storm Erika 2015

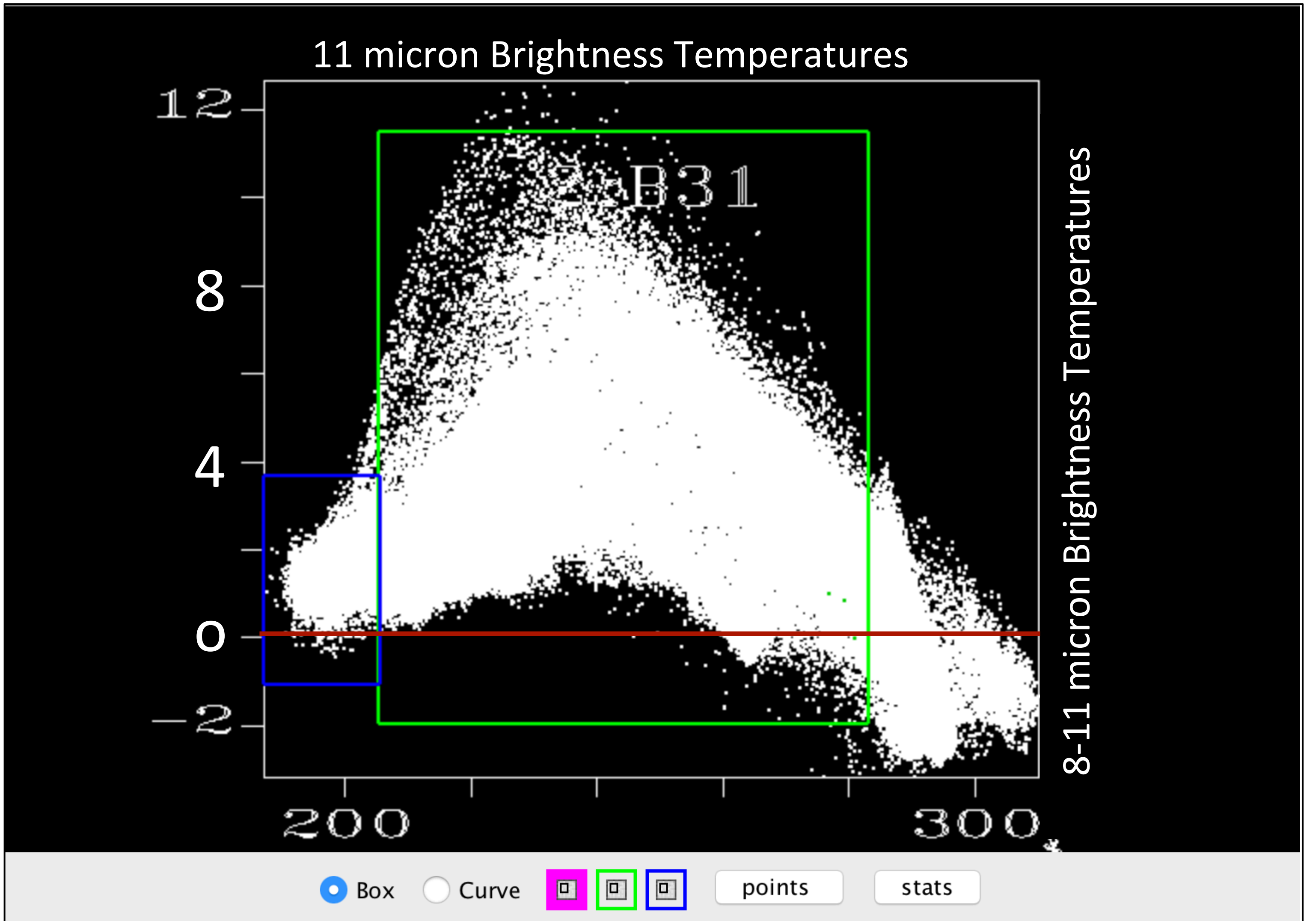


Example of Use of Two IR Thermal Bands
Tropical Storm Erika 2015

MODIS
11 micron
Brightness
Temperatures

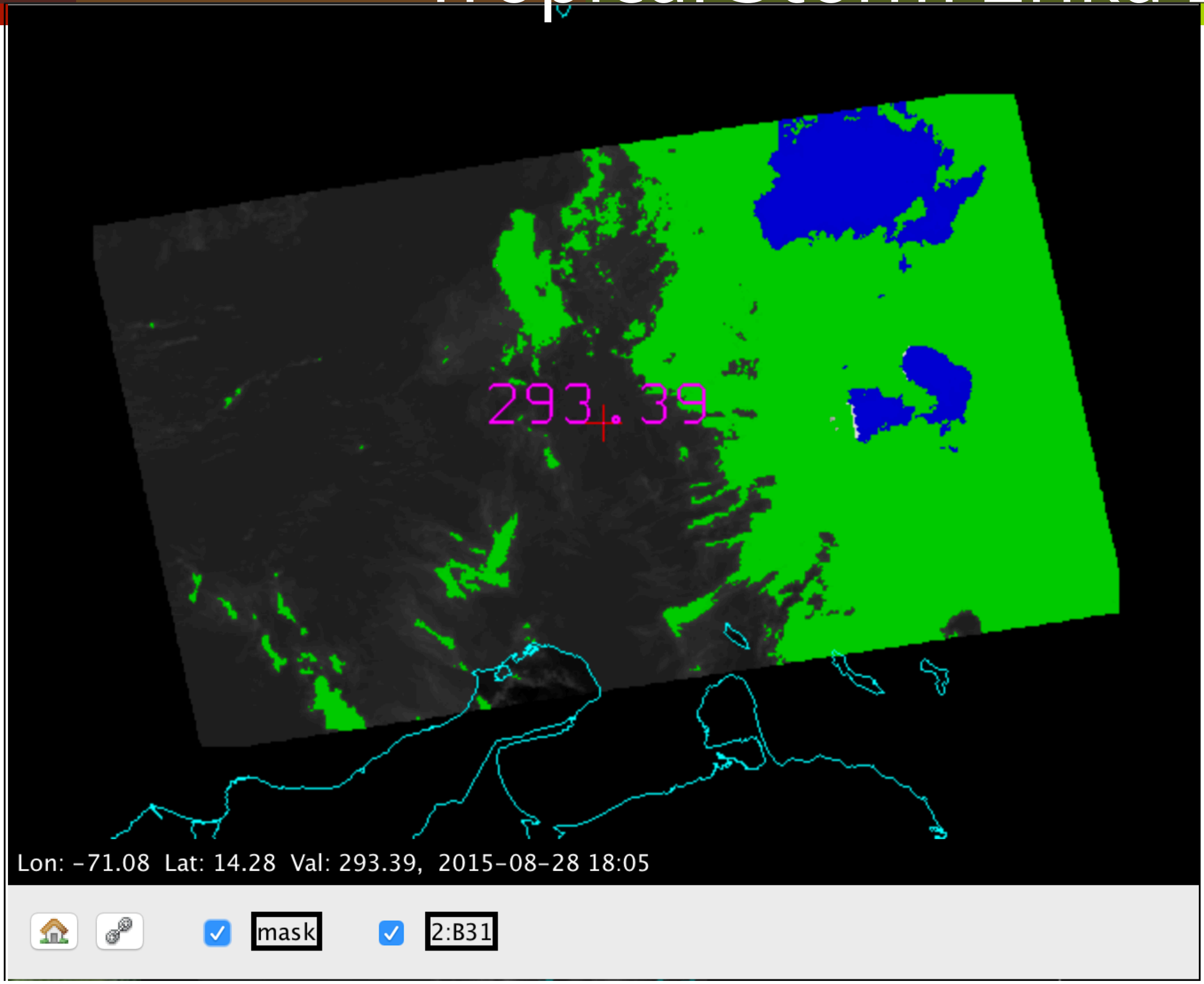


Example of Use of Two IR Thermal Bands
Tropical Storm Erika 2015



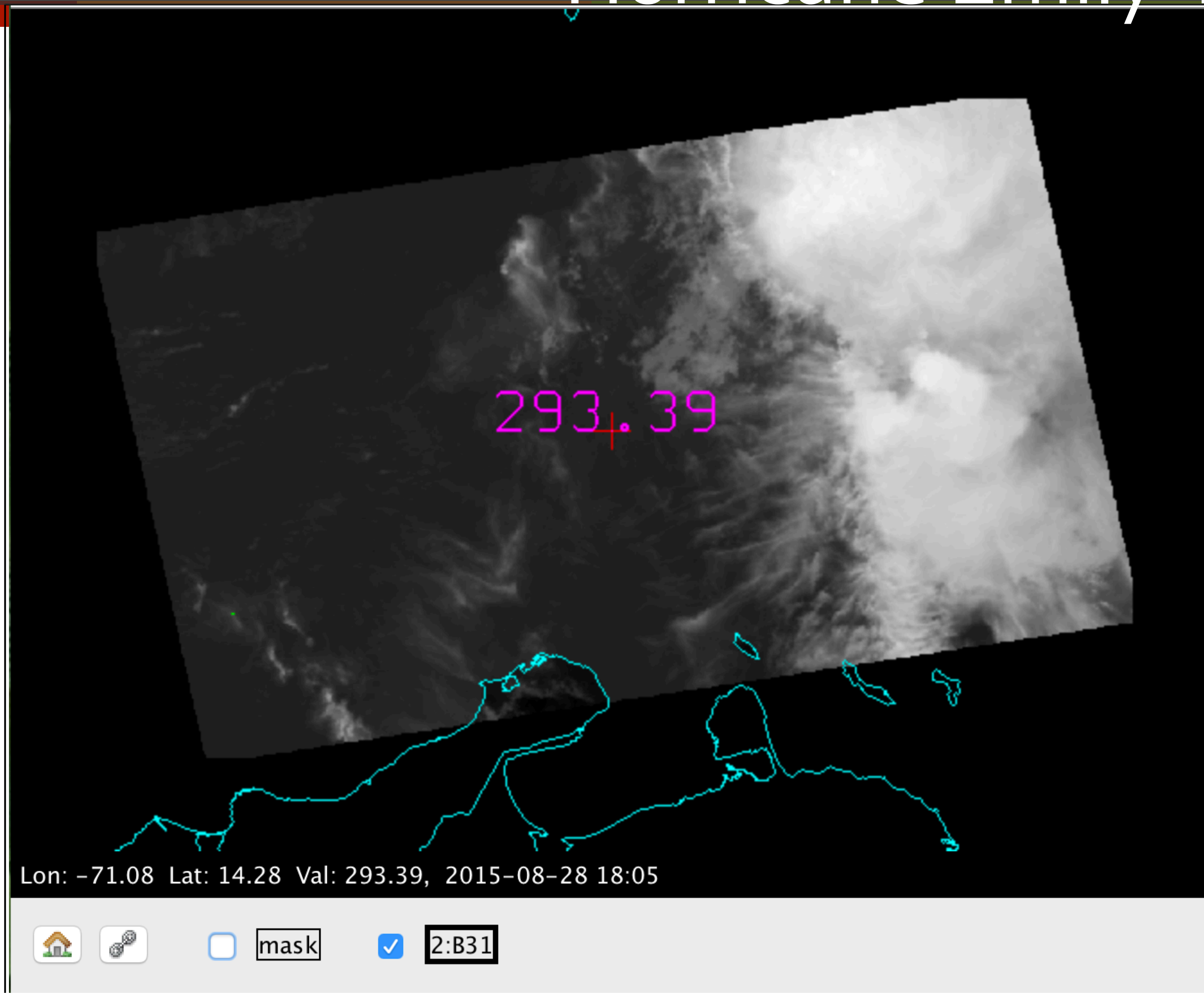
Example of Use of Two IR Thermal Bands
Tropical Storm Erika 2015

MODIS
11 micron
Brightness
Temperatures

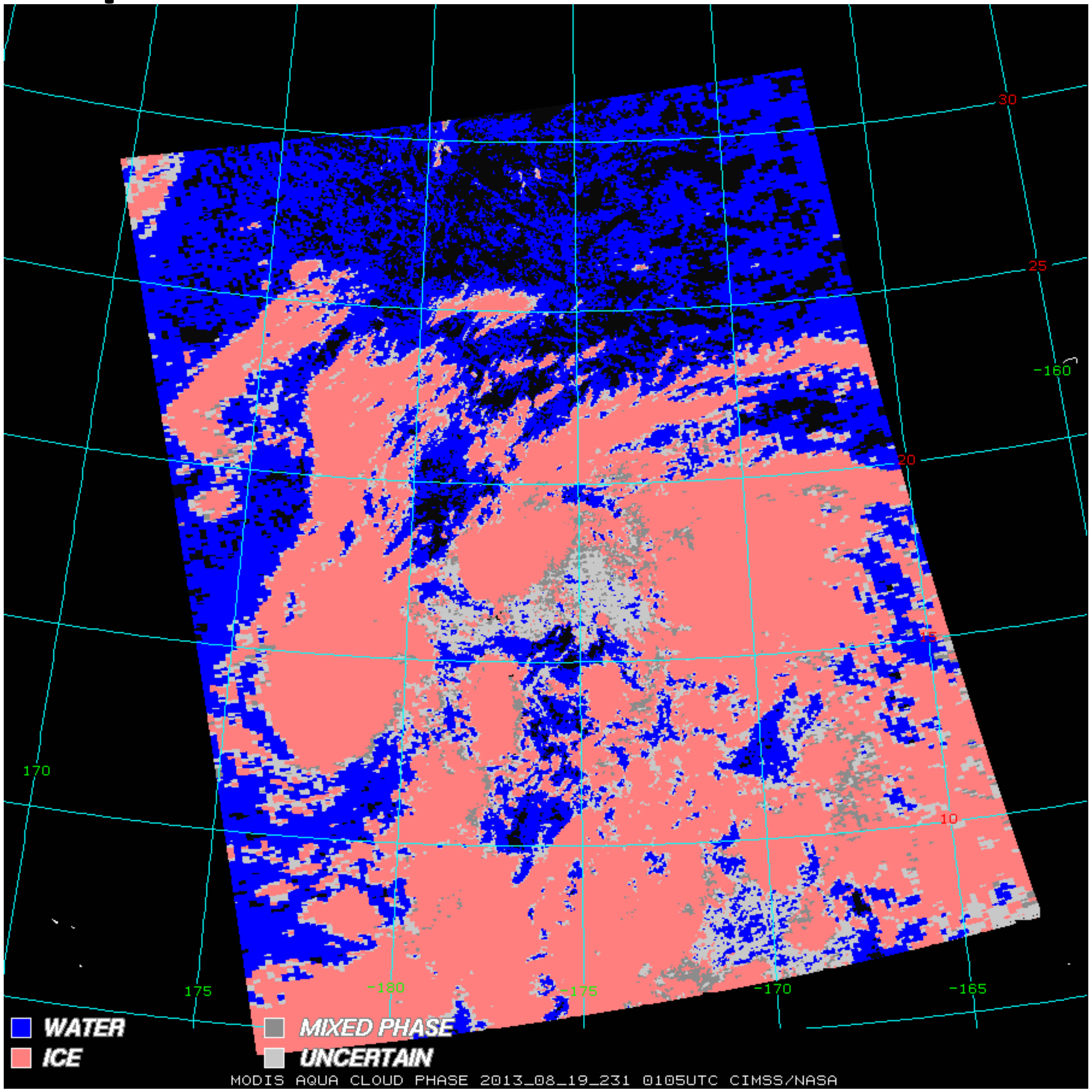


Example of Use of Two IR Thermal Bands Hurricane Emily 2015

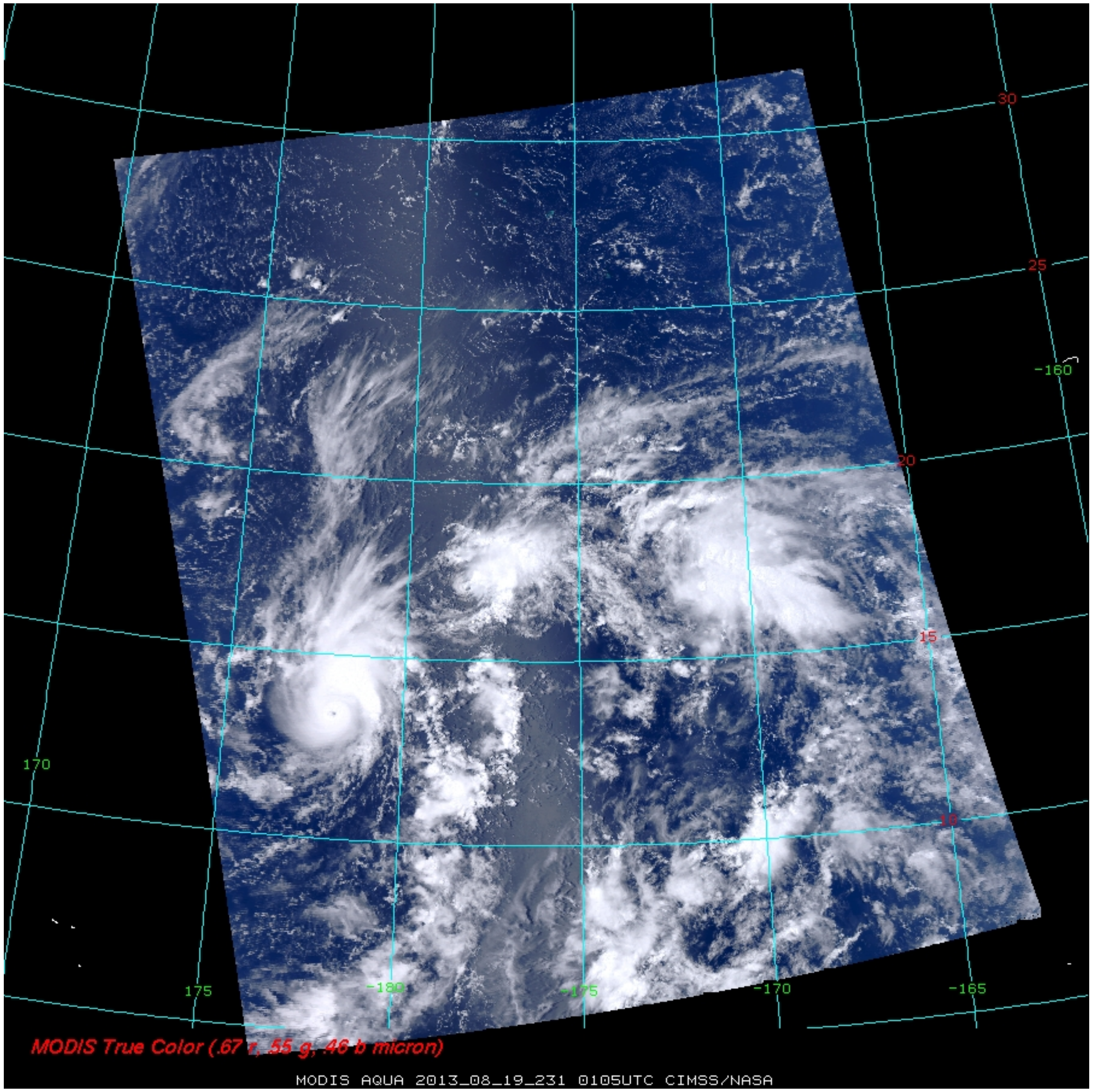
MODIS
11 micron
Brightness
Temperatures



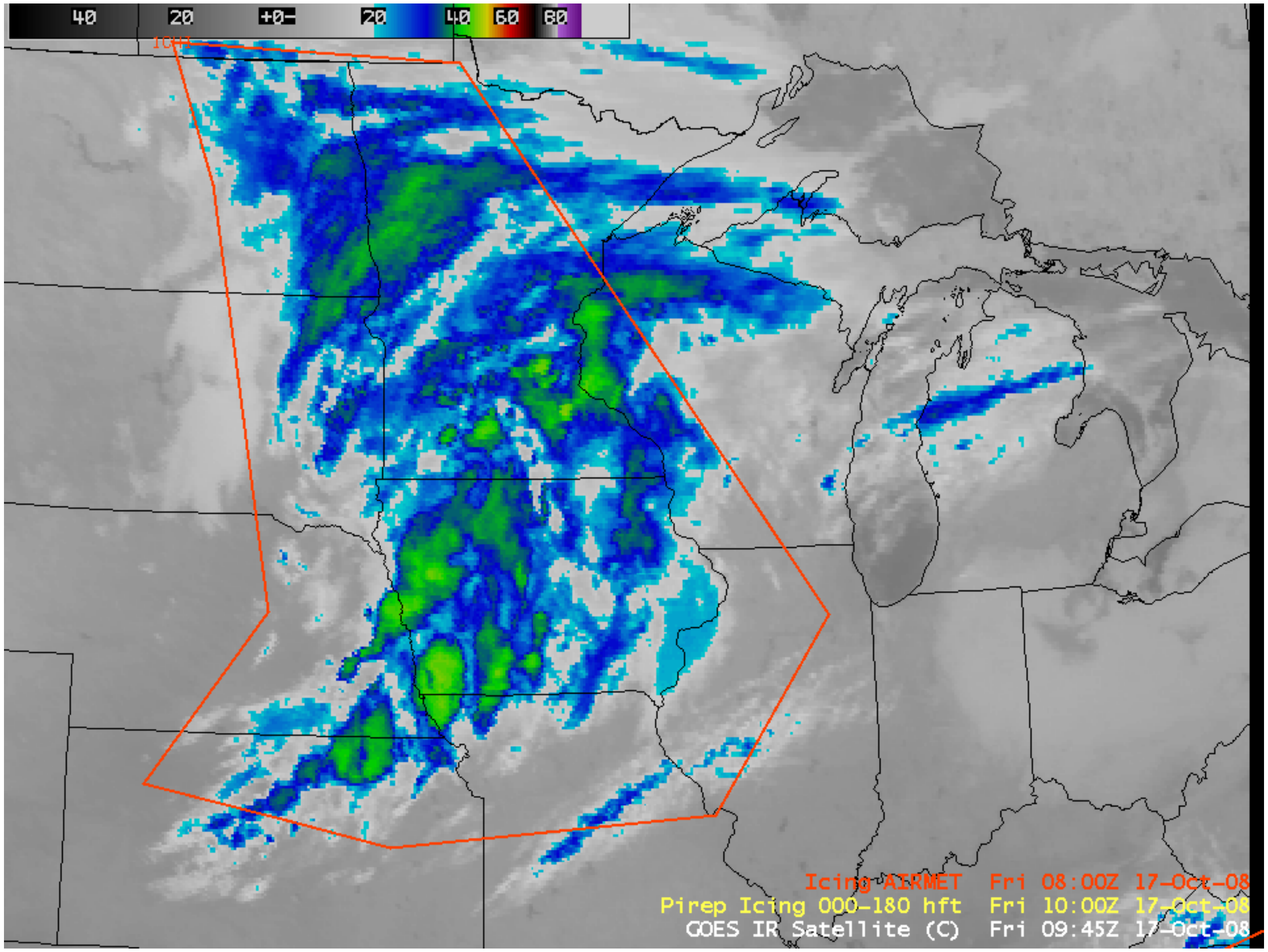
Example Cloud Phase Product



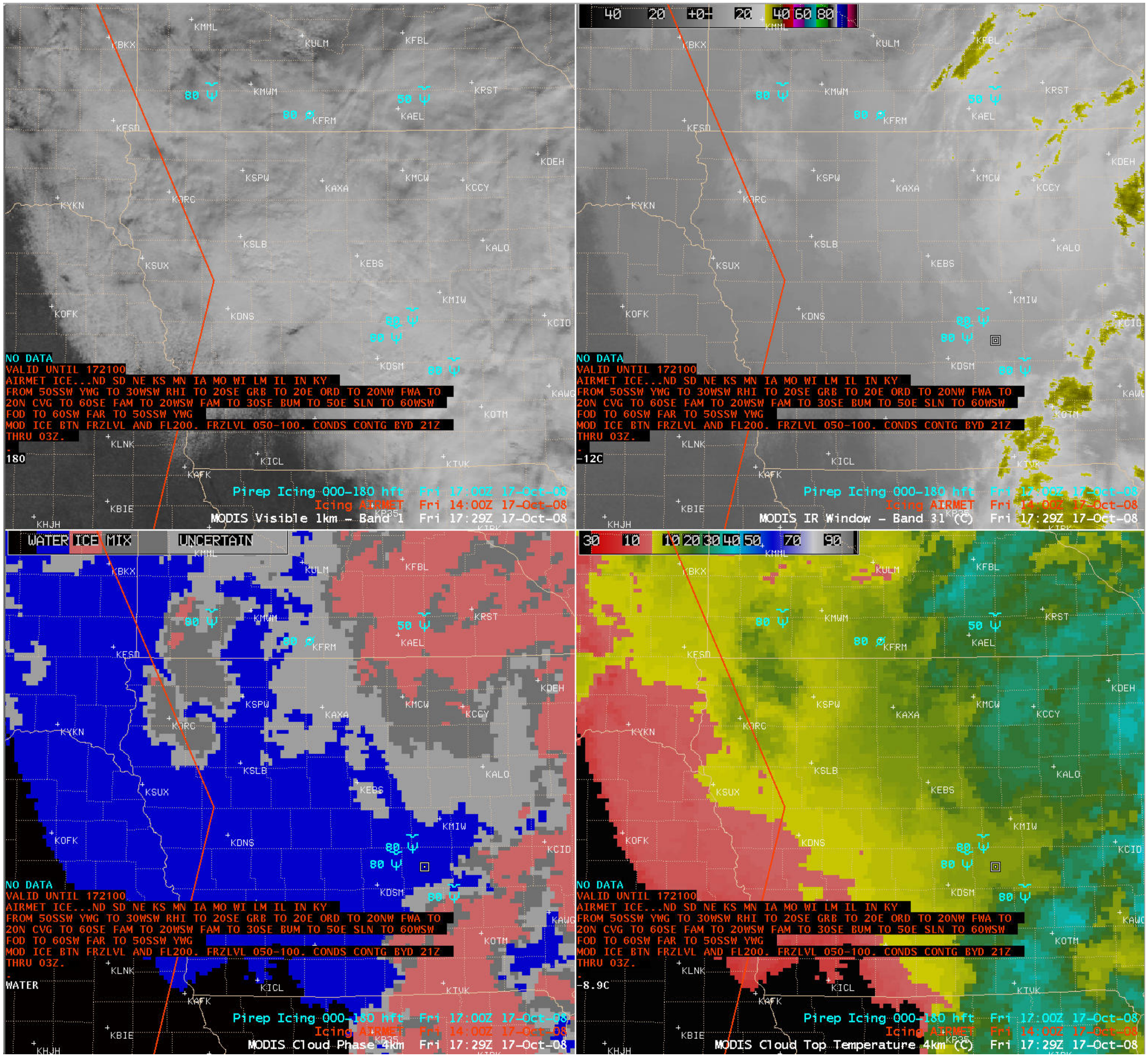
Example Cloud Top Pressure Product



Using Satellite Imagery to Help Diagnose Areas of Aircraft Icing Potential



GOES IR window animation 17 October 2008


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.
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
MODIS IR Window - Band 31 (C) Fri 17:29Z 17-Oct-08
WATER ICE MIX UNCERTAIN
MODIS Cloud Phase 4km Fri 17:29Z 17-Oct-08
MODIS Cloud Top Temperature 4km (C) Fri 17:29Z 17-Oct-08

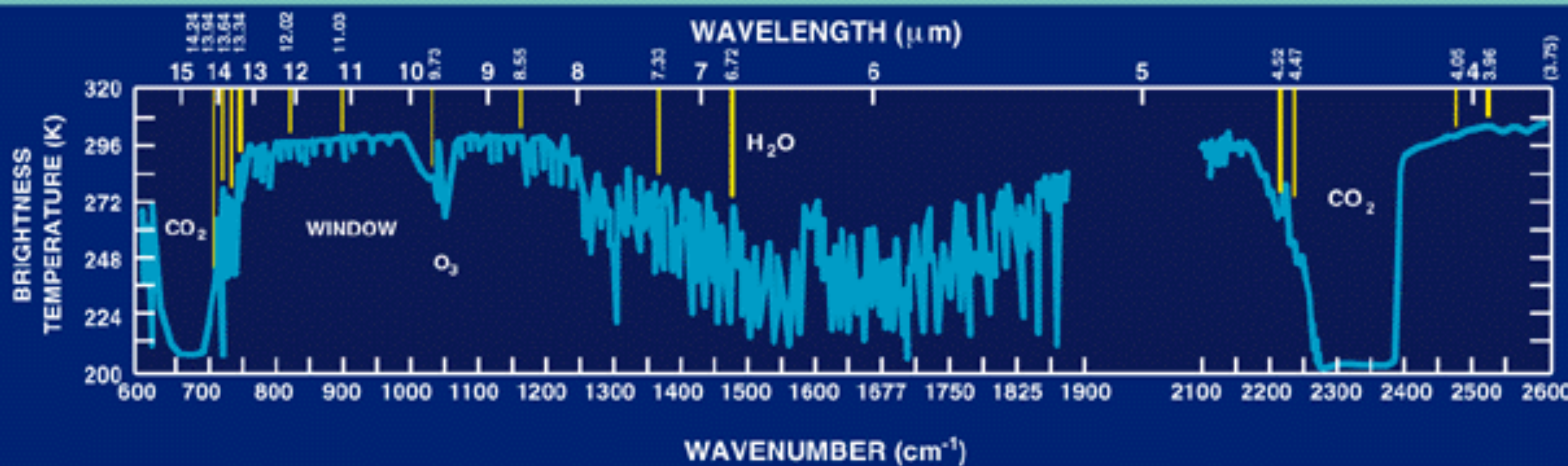
Sea Surface Temperatures

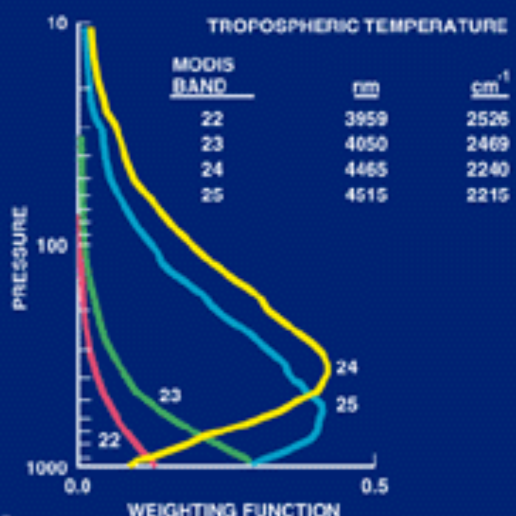
Sea Surface Temperatures

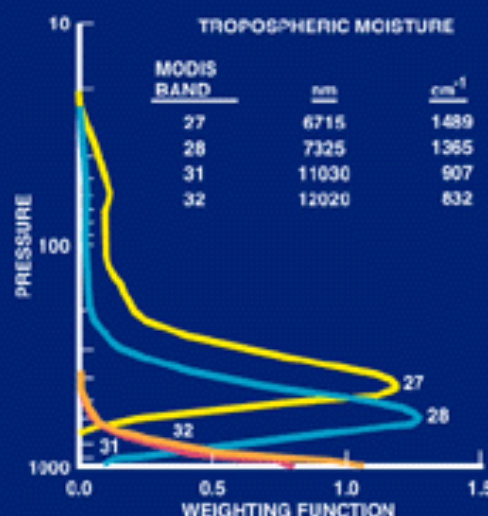
IMAPP MODIS (a1.yyddd.hhmm.mod28.hdf)
SeaDAS files (VIIRS and MODIS) (seadas in the filename)

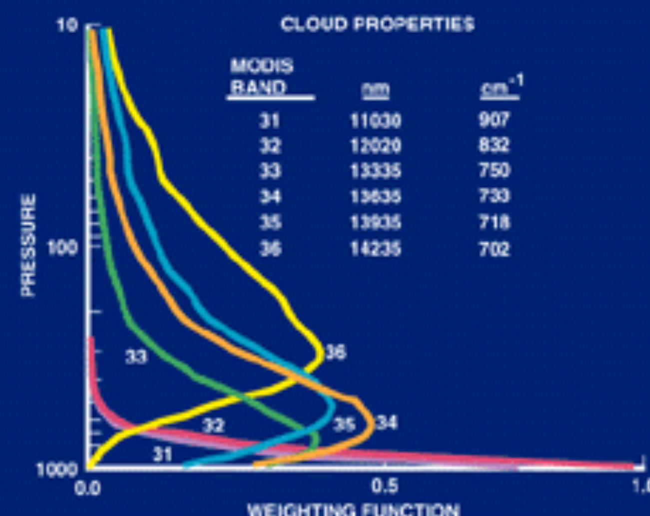
- Simple Brightness Temperature Difference Algorithm
- "Split Window" technique
- Regression between
  - 11-12 µm BTDIF (MODIS bands 31 and 32)
    (VIIRS bands 15 and 16)
  - 3.7-4.0 µm BTDIF (MODIS bands 20 and 22)
    (VIIRS bands 12 and 13)
    - Must be careful in sunglint regions because of solar contamination
  - In essence, you are trying to correct for the lowering of the observed brightness temperatures by water vapor using the BTDIF between these two window channels

ATMOSPHERE - THERMAL RADIATION









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MODIS Longwave Infrared Sea Surface Temperature (c5)

dBT <= 0.5

sst = a00 + a01*BT11 + a02*dBT*bsst + a03*dBT*(1.0/mu - 1.0)

dBT >= 0.9

sst = a10 + a11*BT11 + a12*dBT*bsst + a13*dBT*(1.0/mu - 1.0)

0.5 < dBt < 0.9

sstlo = a00 + a01*BT11 + a02*dBT*bsst + a03*dBT*(1.0/mu - 1.0)

ssthi = a10 + a11*BT11 + a12*dBT*bsst + a13*dBT*(1.0/mu - 1.0)

sst = sstlo + (dBT - 0.5)/(0.9 - 0.5)*(ssthi - sstlo)

where:

dBT = BT11 - BT12

BT11 = brightness temperature at 11 um, in deg-C

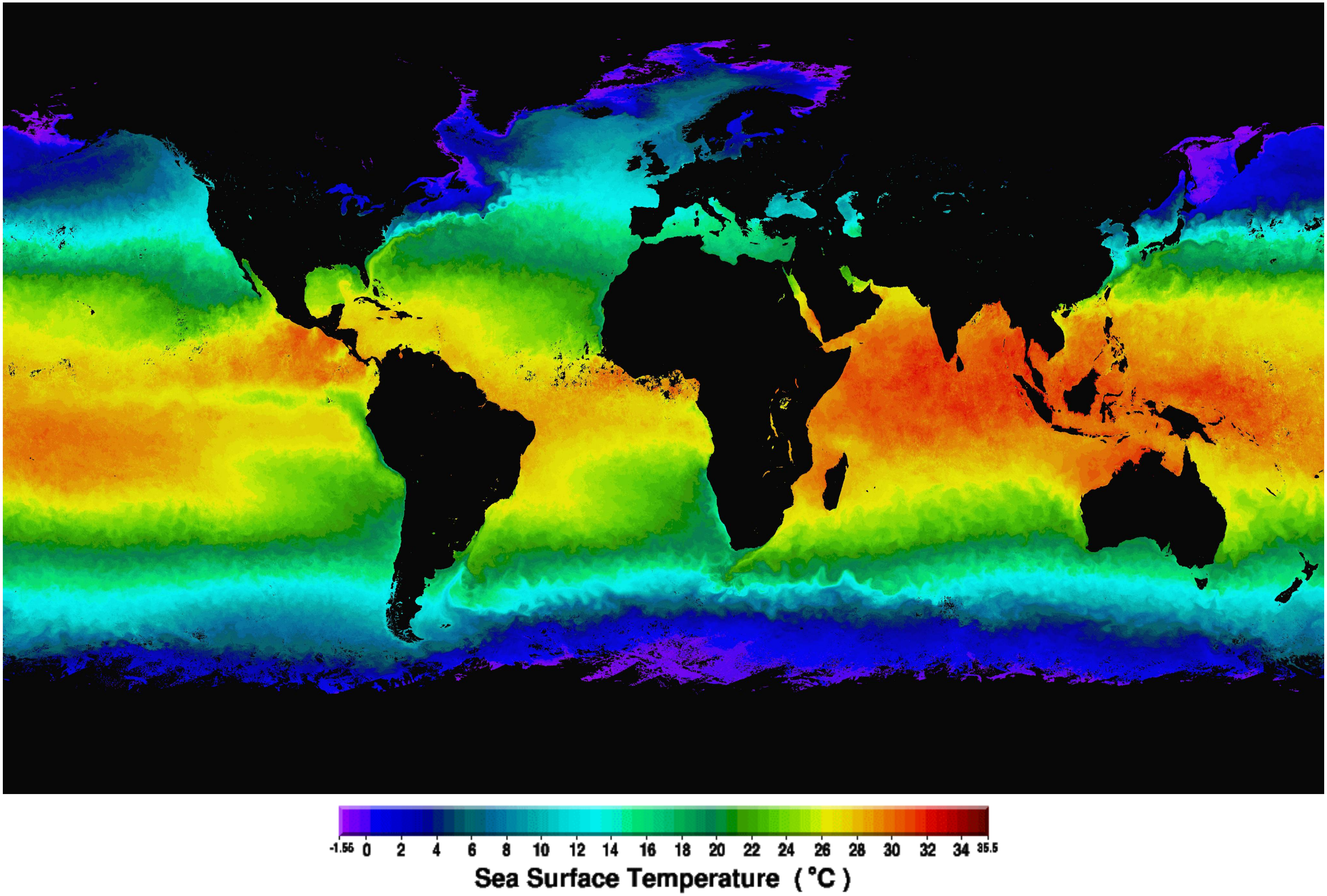
BT12 = brightness temperature at 12 um, in deg-C

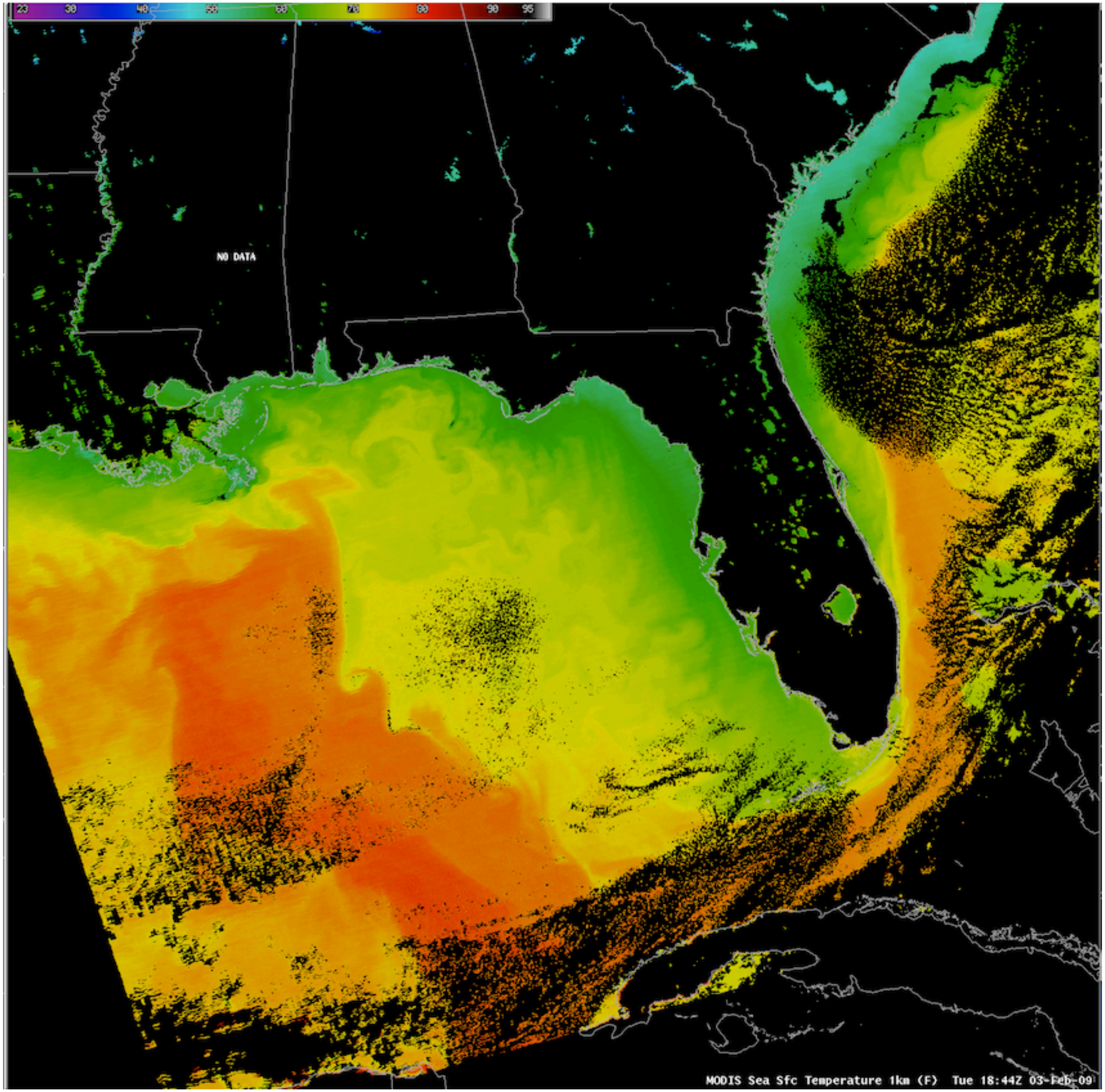
bsst = Either sst4 (if valid) or sstref (from Reynolds OISST)

mu = cosine of sensor zenith angle

a00, a01, a02, a03, a10, a11, a12, a13 derived from match-ups

Aqua MODIS Sea Surface Temperature, April 2004




23 30 40 50 60 70 80 90 95
NO DATA
MODIS Sea Sfc Temperature 1km (F) Tue 18:44Z 03-Feb-09

MODIS Sea Surface Temperature used by Forecasters

AREA FORECAST DISCUSSION...UPDATED
NATIONAL WEATHER SERVICE MILWAUKEE/SULLIVAN WI
338 AM CDT TUE MAY 31 2011

UPDATED TO ADD TODAY/TONIGHT AND AVIATION/MARINE SECTIONS

.MARINE...CLEAR MODIS IMAGE FROM MONDAY EARLY AFTN SHOWED SHALLOWER NEAR SHORE WATERS HAD WARMED INTO THE LOWER 50S...WHILE MID LAKE TEMPS REMAINED IN THE MID 40S DUE TO OVERTURNING. TIGHTENING PRESS GRADIENT THIS MORNING AND SUNSHINE WILL RESULT IN STRONG MIXING EARLY THIS MRNG. HENCE WL BUMP UP START OF SMALL CRAFT ADVY SEVERAL HOURS...AND RUN INTO THE EVE. FEW GUSTS NEAR THE SHORE MAY REACH 30-35 KNOTS LATER THIS MRNG/ EARLY AFTN.

MODIS and VIIRS DB Land Products

MODIS Land Surface Temperatures
a1.yyddd.hhss.lst.hdf

Available online at www.sciencedirect.com
ScienceDirect

Remote Sensing of Environment 106 (2007) 326–336

ELSEVIER

Remote Sensing of Environment

www.elsevier.com/locate/rse

Near-real time retrievals of land surface temperature within the MODIS Rapid Response System

A.C.T. Pinheiro [a,b,*], J. Descloitres [c], J.L. Privette [b], J. Susskind [a], L. Iredell [d], J. Schmaltz [c]

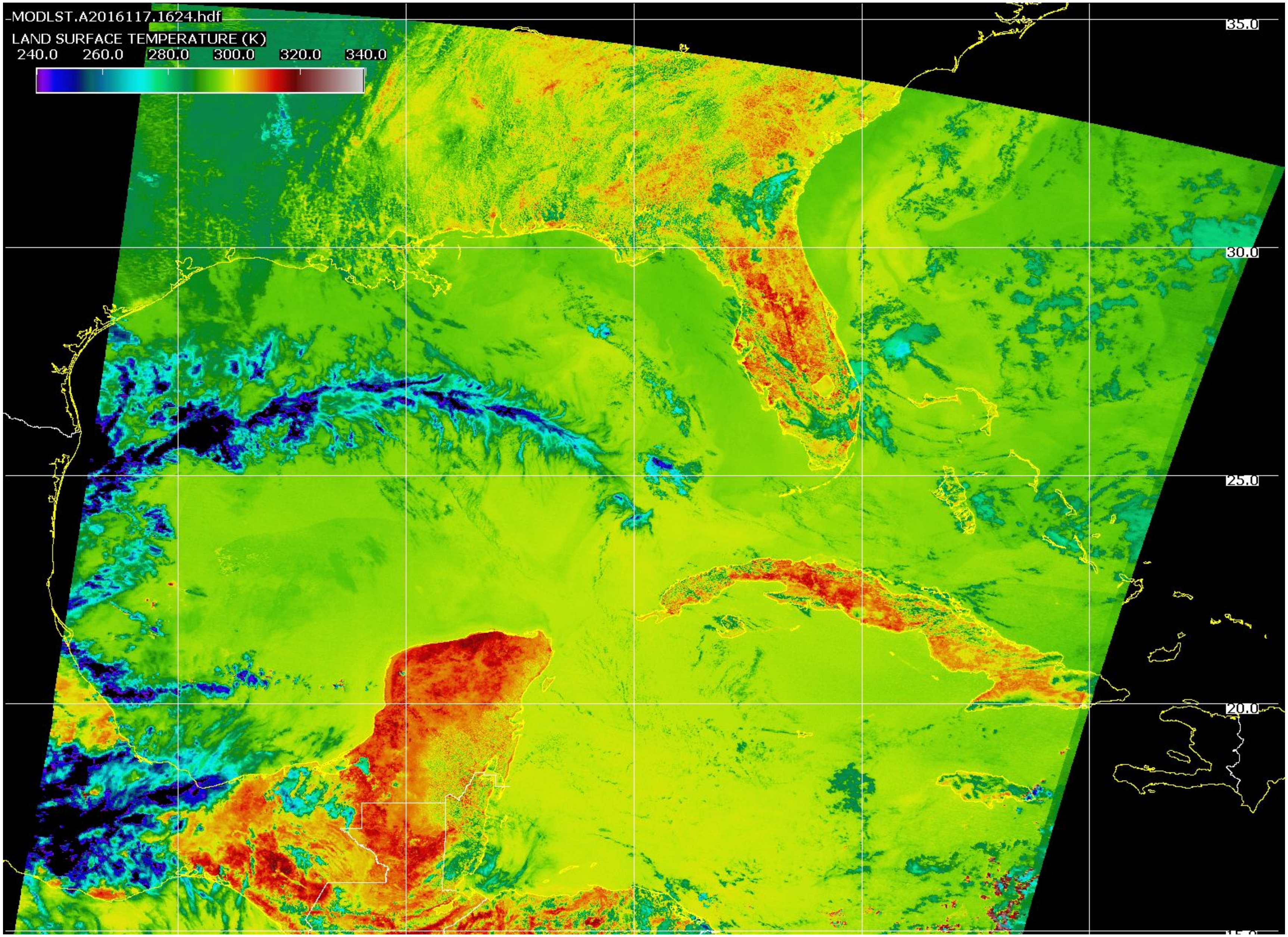
[a] *NASA Goddard Space Flight Center, Greenbelt, MD, USA*
[b] *NOAA National Climatic Data Center, Asheville, NC, USA*
[c] *Science Systems and Applications, Inc. (SSAI), NASA GSFC, Greenbelt, MD, USA*
[d] *Science Applications International Corporation (SAIC), NASA GSFC, Greenbelt, MD, USA*

Received 4 October 2005; received in revised form 31 August 2006; accepted 3 September 2006

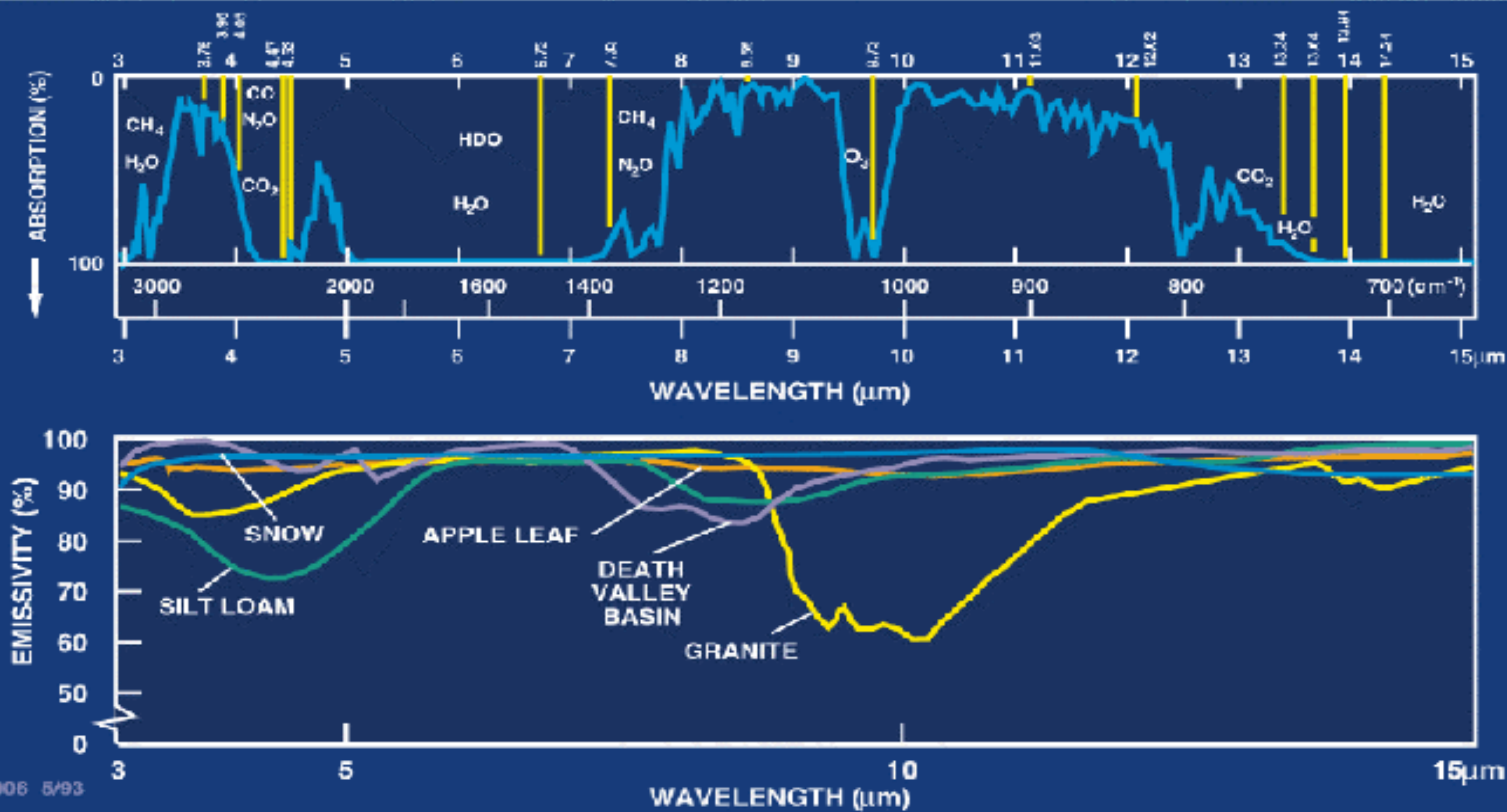
LST Technique

- Uses Split Window 11-12 micron Brightness Temperature difference to correct for water vapor
- More difficult over land because of emissivity differences
- MODIS 1 km product – not water or cloud cleared
- VIIRS product 750 m M-Band resolution
    - VLSTO*.h5

Land Surface Temperature Image



LAND - THERMAL RADIATION



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MODIS LST and buggers

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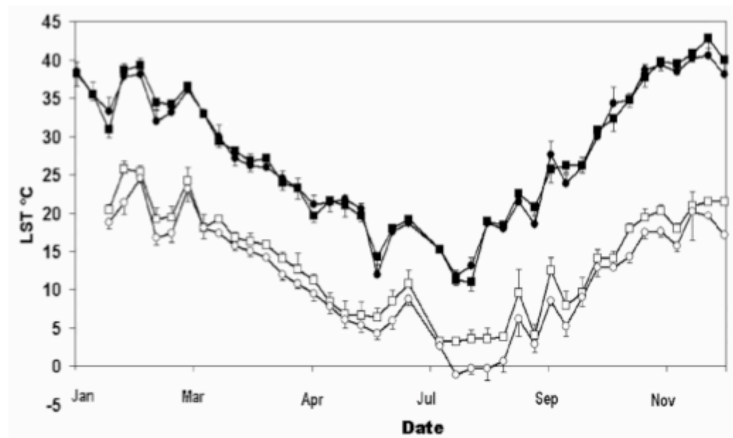


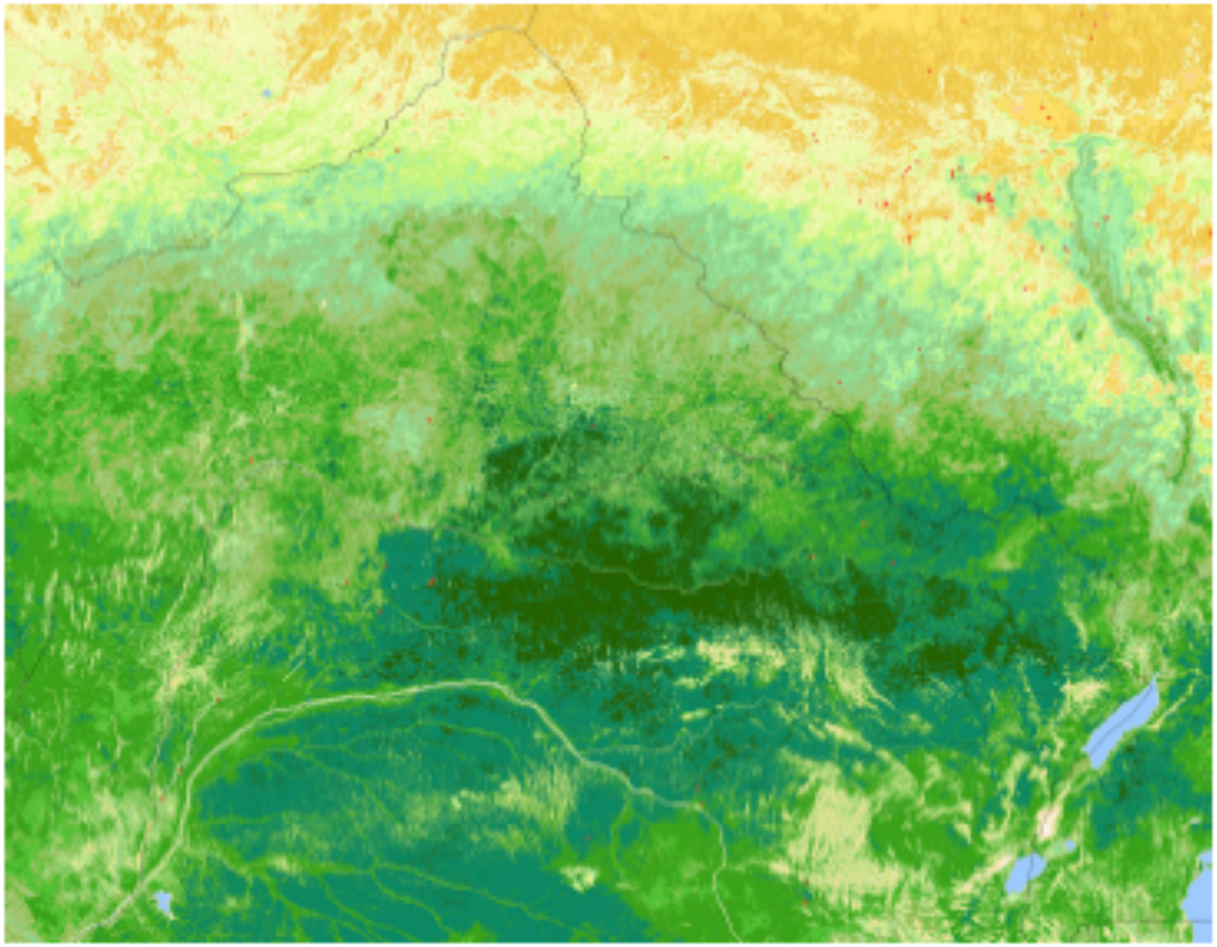
Fig. 4. Annual variation (2003) of diurnal land surface temperature (LST day) produced by the MODIS sensor (closed symbols) and LST night (open symbols) in locality groups of high (squares) and low (circles) house infestation rate. LST values are 8-d composites.

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.

Vegetation Indices

- Simple MODIS NDVI products 1km products
  - a1.16105.1726.ndvi.1000.(500,250)m.hdf
  - Created from corrected reflectances (removing Rayleigh scattering – atmosphere molecular scattering)
- VIIRS NDVI
  - Vegetation Indices (NDVI and EVI) 750 m products
    - VIVIO*.h5

Vegetation Index



Normalized Difference Vegetation Index (NDVI) image of Central Africa
http://rapidfire.sci.gsfc.nasa.gov/

Photo-Chemistry

- Light may be absorbed and participate (drive) a chemical reaction. Example: Photosynthesis in plants

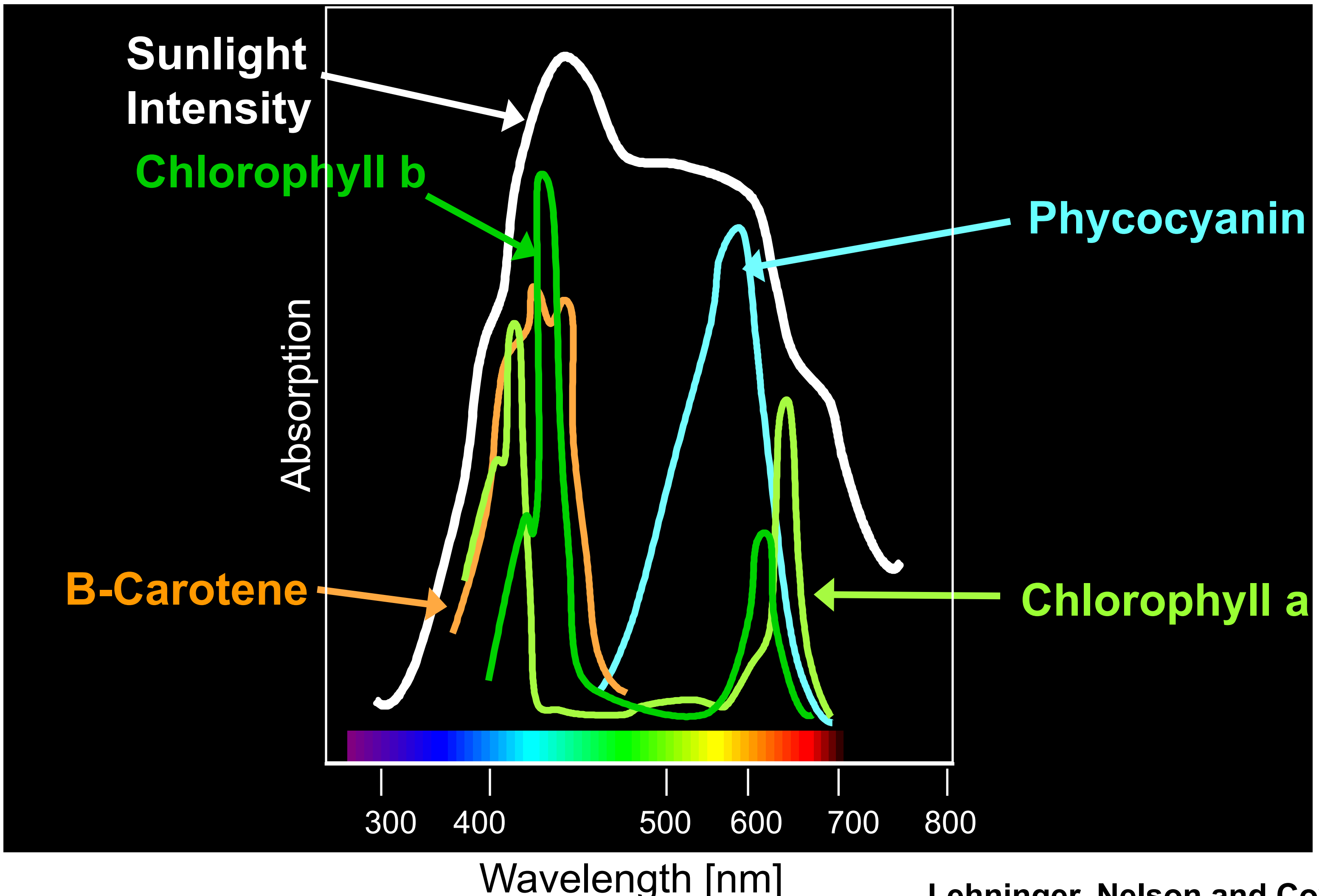
$$6CO_2 + 6H_2O + h\nu \rightarrow C_6H_{12}O_6 + 6O_2$$

- Only certain wavelengths are absorbed by some participant(s) in the reaction
- Some structure must be present to allow the reaction to occur –Chlorophyll
- Combination of chemical and structural properties of plants

Primary and secondary absorbers in plants

- Primary
  - Chlorophyll-a
  - Chlorophyll-b
- Secondary
  - Carotenoids
  - Phycobilins
  - Anthocyanins

Absorption of Visible Light by Photo-pigments



Lehninger, Nelson and Cox

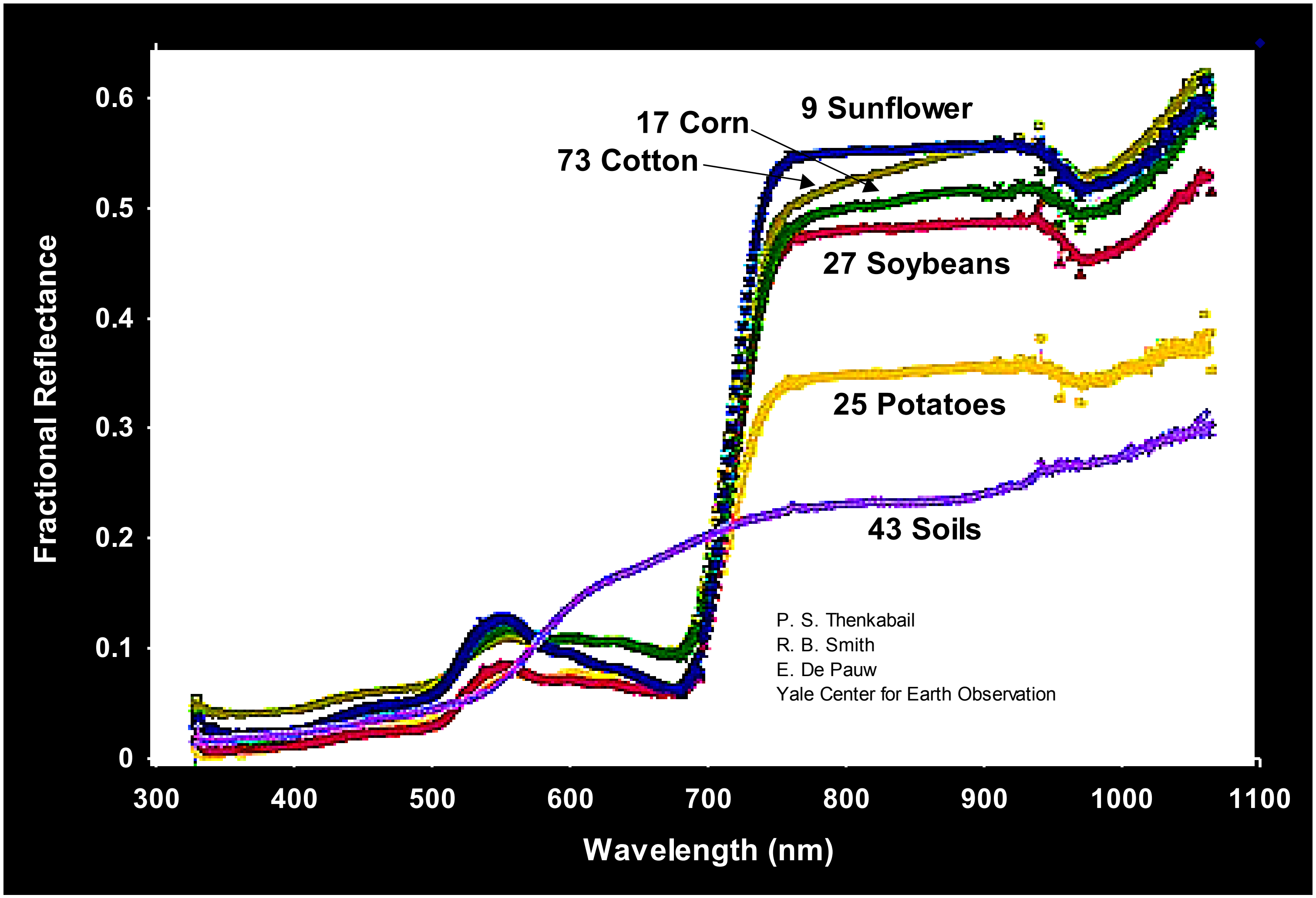
Theoretical description

VISIBLE radiation is highly absorbed by vegetation in the red (0.68 micron) and in the blue (0.47 micron). The absorption is mainly due to photosynthetically active pigments

NIR radiation is reflected and transmitted with very little absorption by vegetation

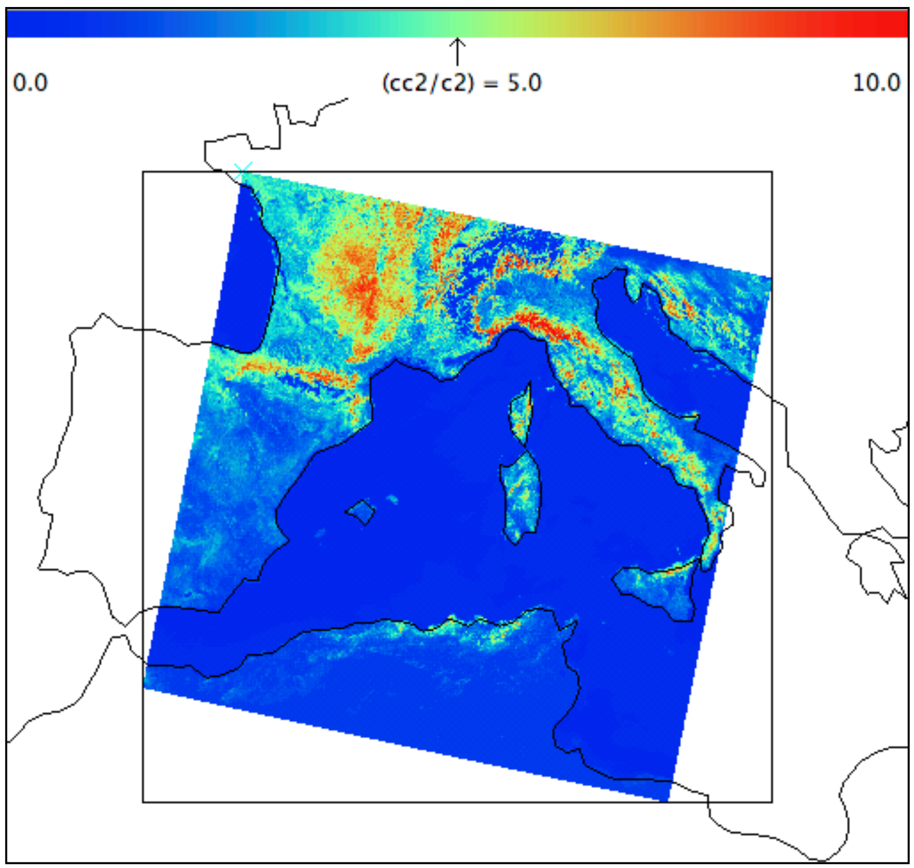
Contrast between RED and NIR responses is correlated to vegetation amount

Soil and crop reflectance



Simple Ratio (SR)

- It was the first index to be used (Jordan, 1969)
- Defined as the ratio X_{nir}/X_{red}
- For densely vegetated areas X_{red} tends to 0 and SR increases without bounds



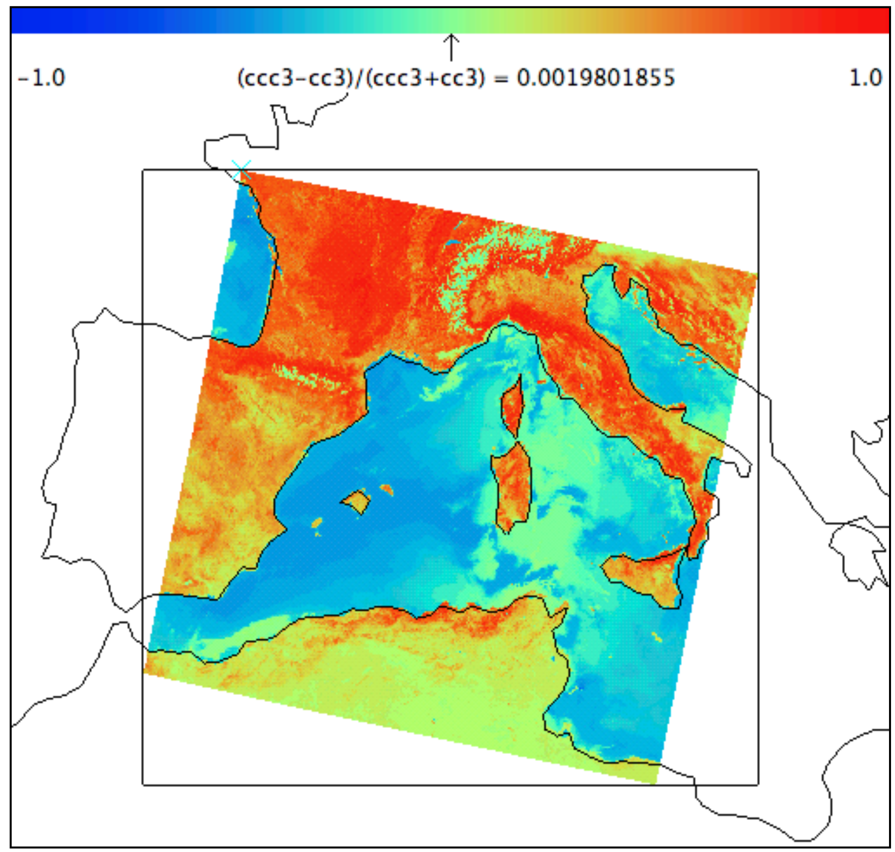
Normalized Difference Vegetation Index (NDVI)

Defined as the ratio

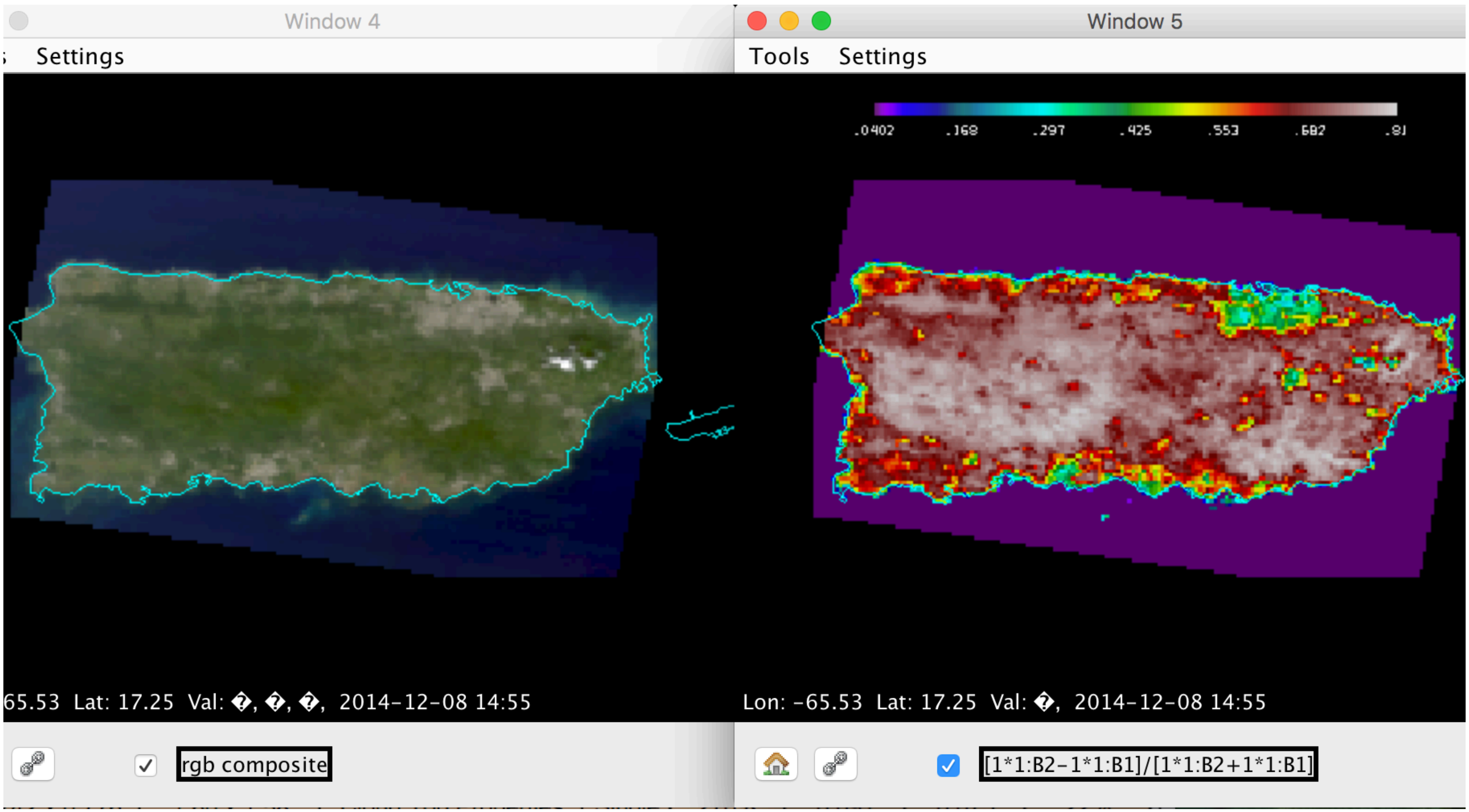
$$(X_{.86} - X_{.65})/(X_{.86} + X_{.65})$$

Correlated with:	
Plant Biomass	Crop Yield
Plant Nitrogen	Plant Dhlorophyll
Water Stress	Plant Diseases
Insect Damage	

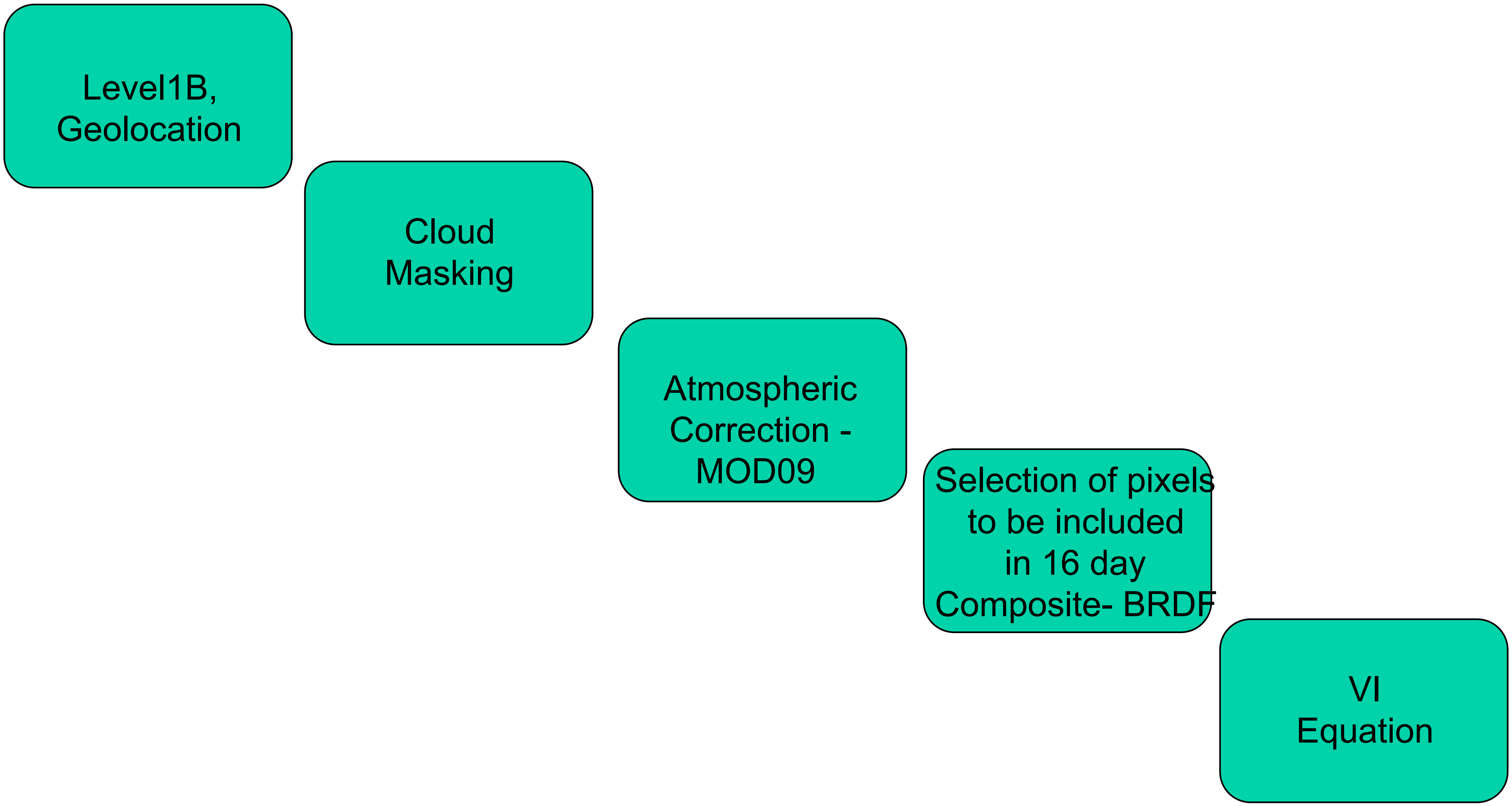
Applications:	
Vegetation Monitoring	Agricultural Activities
Drought studies	Landcover Change
Public Health Issues (mosquitos)	Climate Change Detection
Net Primary Production	Carbon Balance



RGB and NDVI product



Inputs and Processing Chain for MODIS VI Production



Using MODIS Sun Glint Patterns

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

"Mirror" reflection of sunlight off calm water.

Sun Glint

Simple example where your eye is the sensor

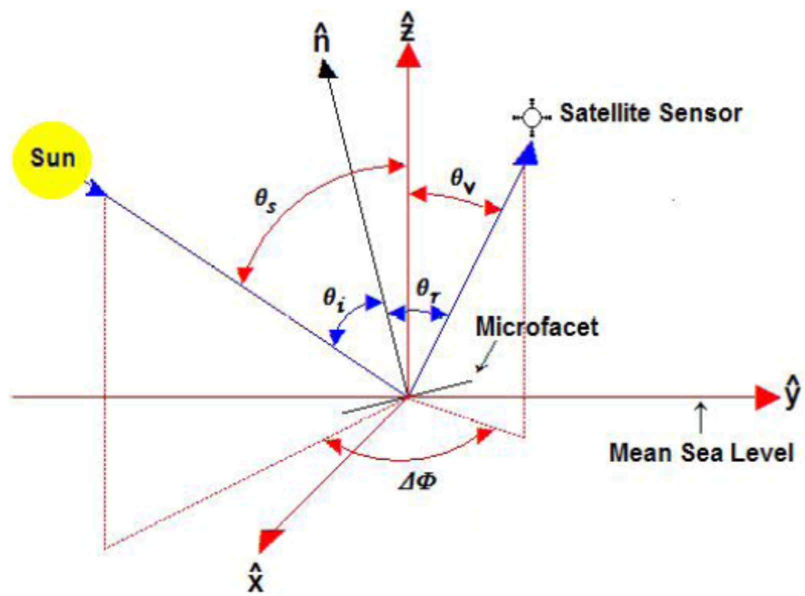
Sun Glint Ellipse Defined by: $\theta_r < 36$

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

Where θ_v = Viewing Zenith Angle

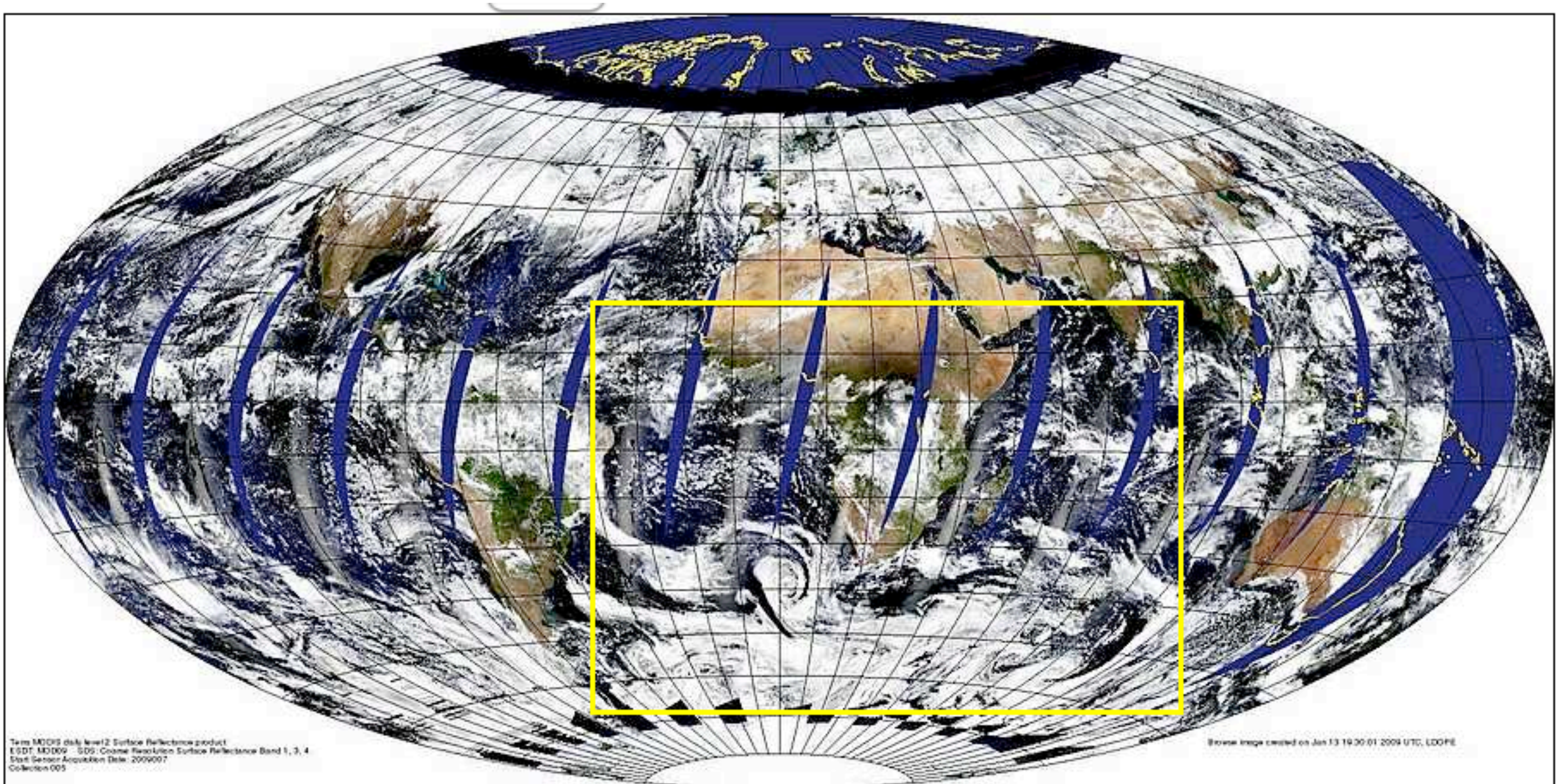
θ_s = Solar Zenith Angle

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

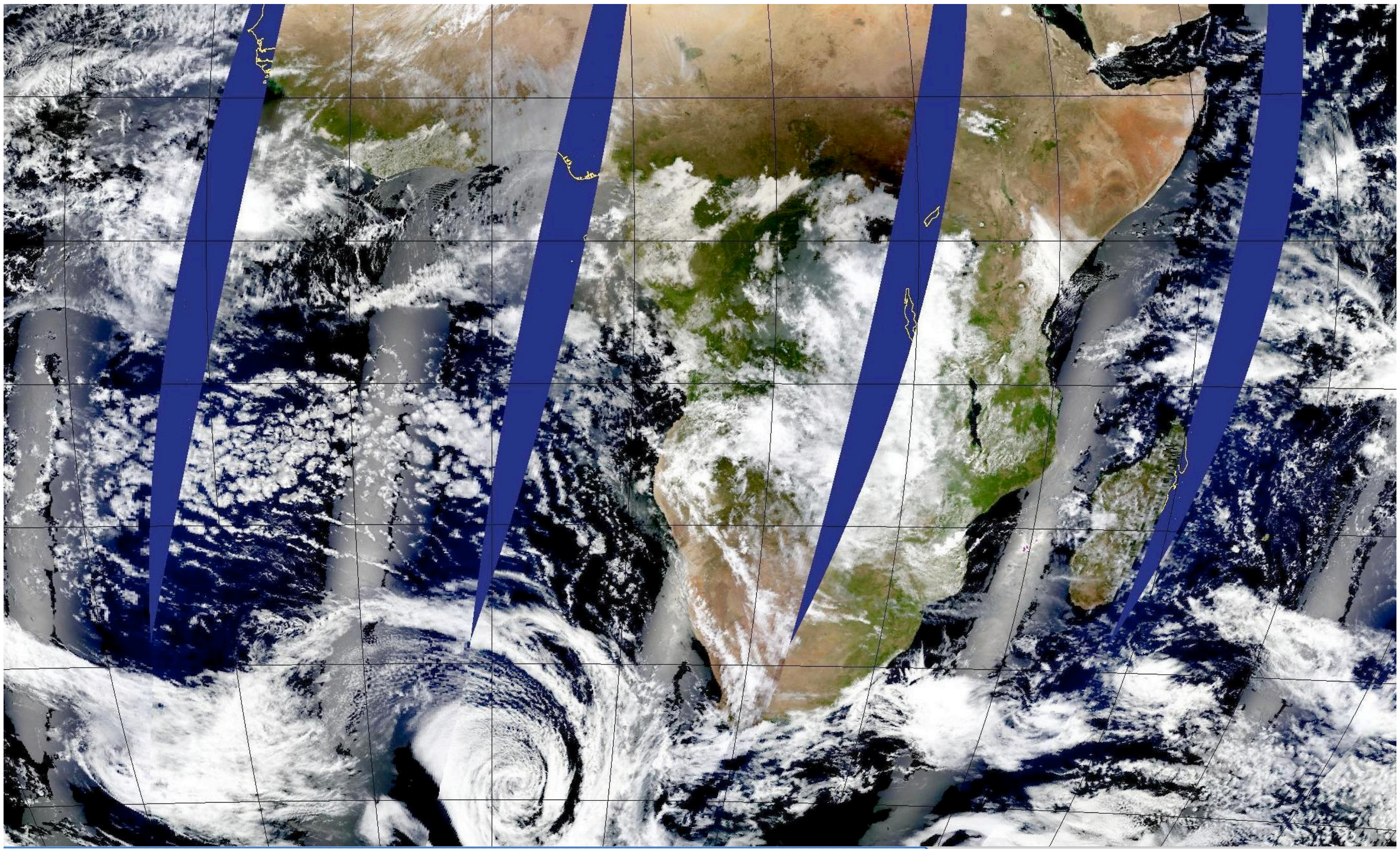


Aqua MODIS Sun Glint Example

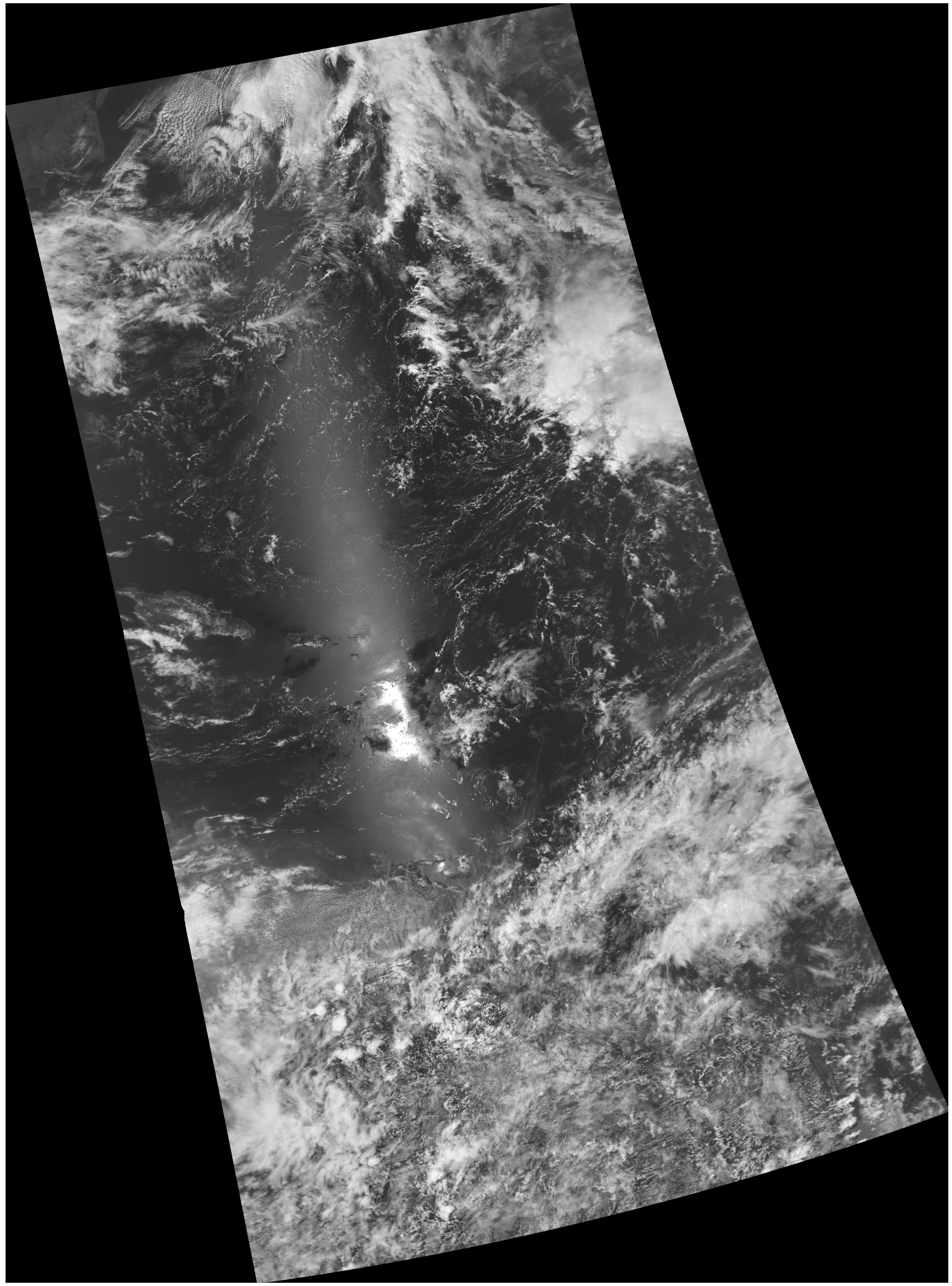
7 January 2009



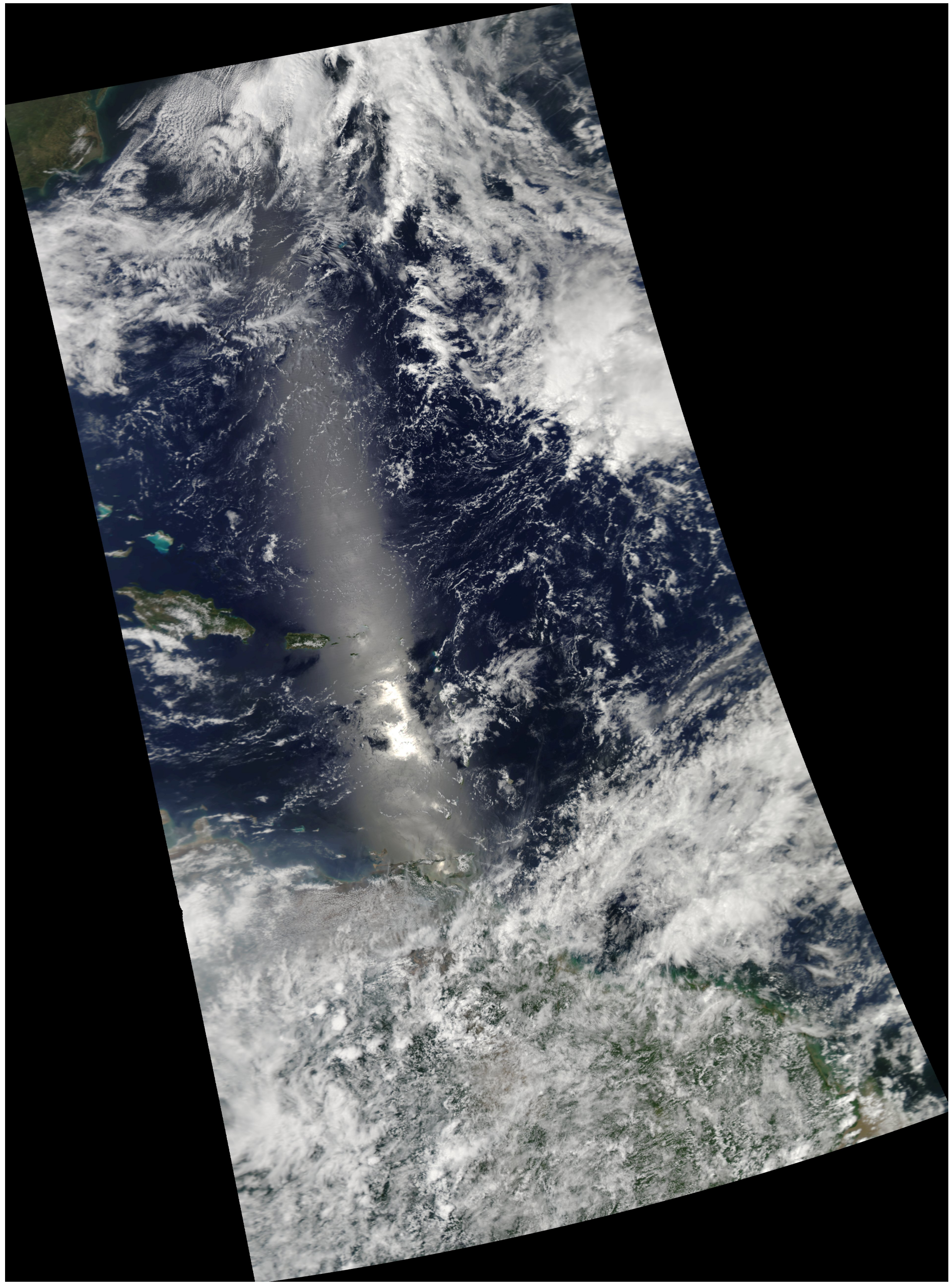
Sun Glint Patterns



MODIS Band 1
Reflectances
(.65 micron)
20160414 17:26 UTC

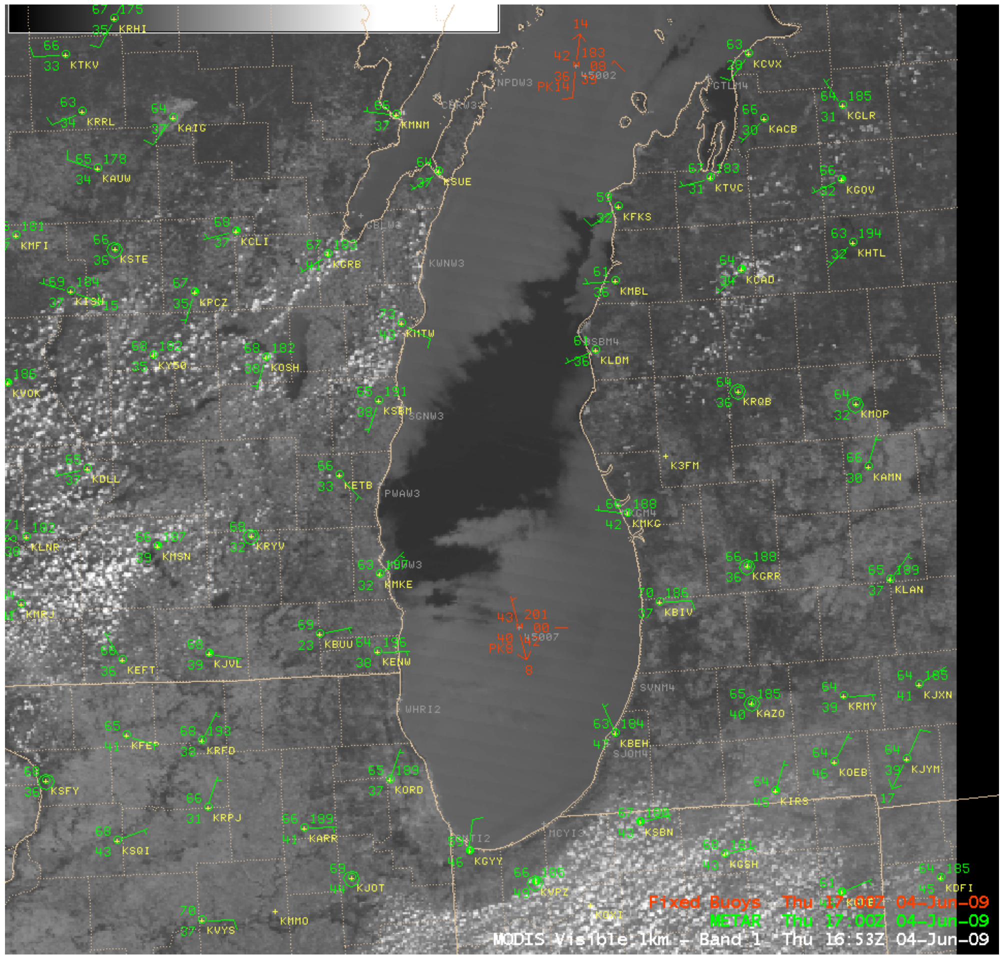


MODIS True Color Image
R: MODIS Band 1
.65 micron
G: MODIS Band 4
.55 micron
B: MODIS Band 3
.43 micron
Relfectances
20160414 17:26 UTC



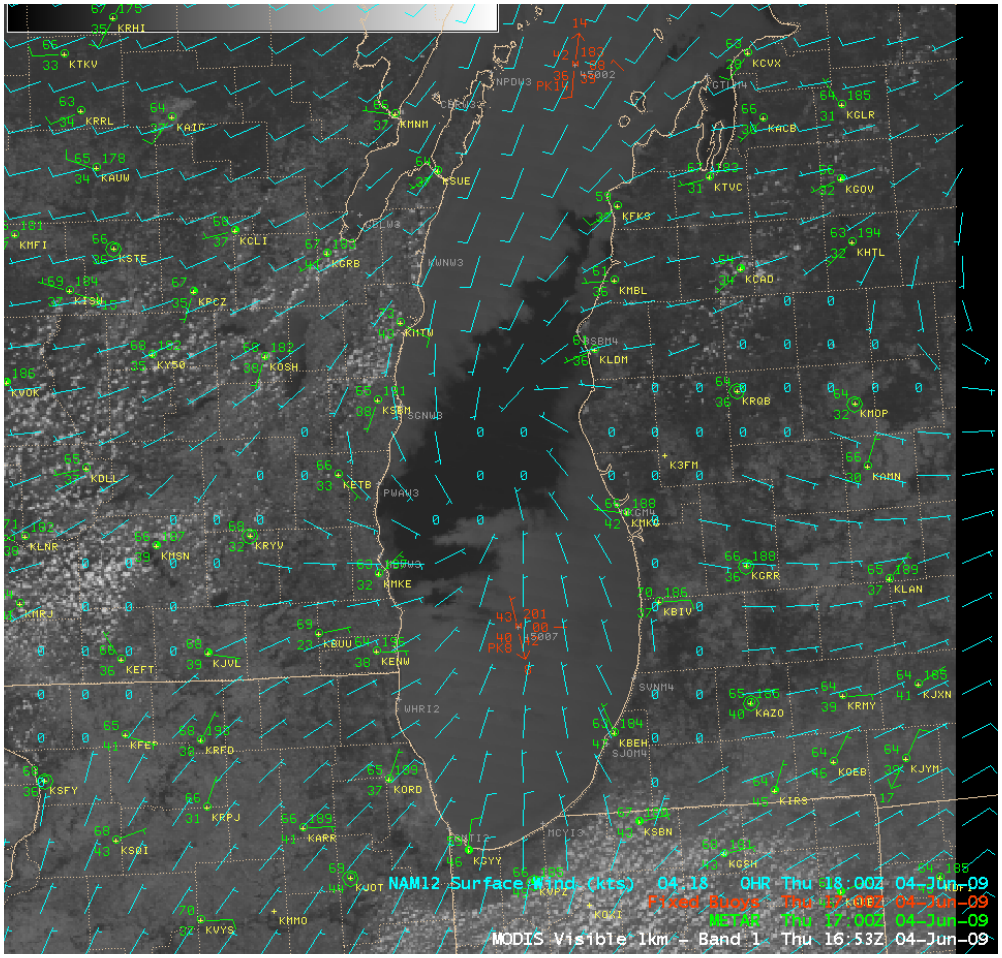
Example From Lake Michigan

4 June 2009



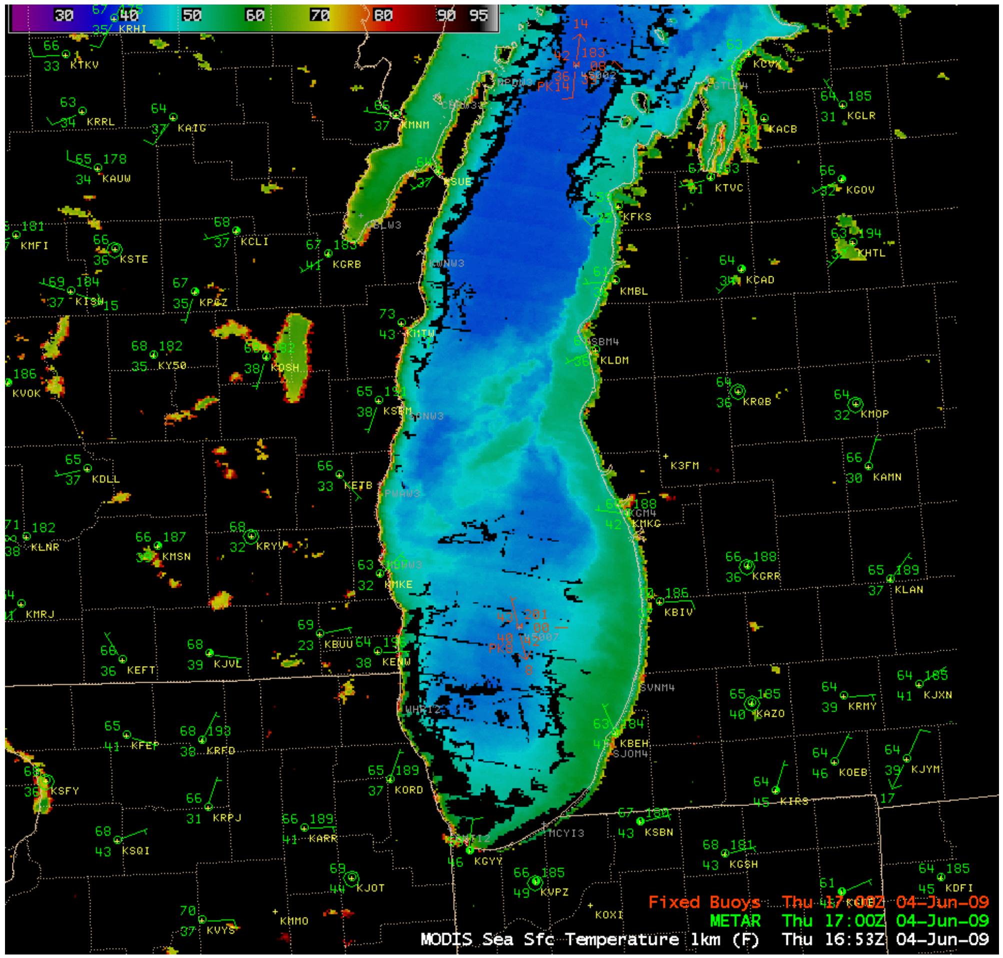
Numerical Weather Prediction

Wind analysis 18 UTC 4 June 2009



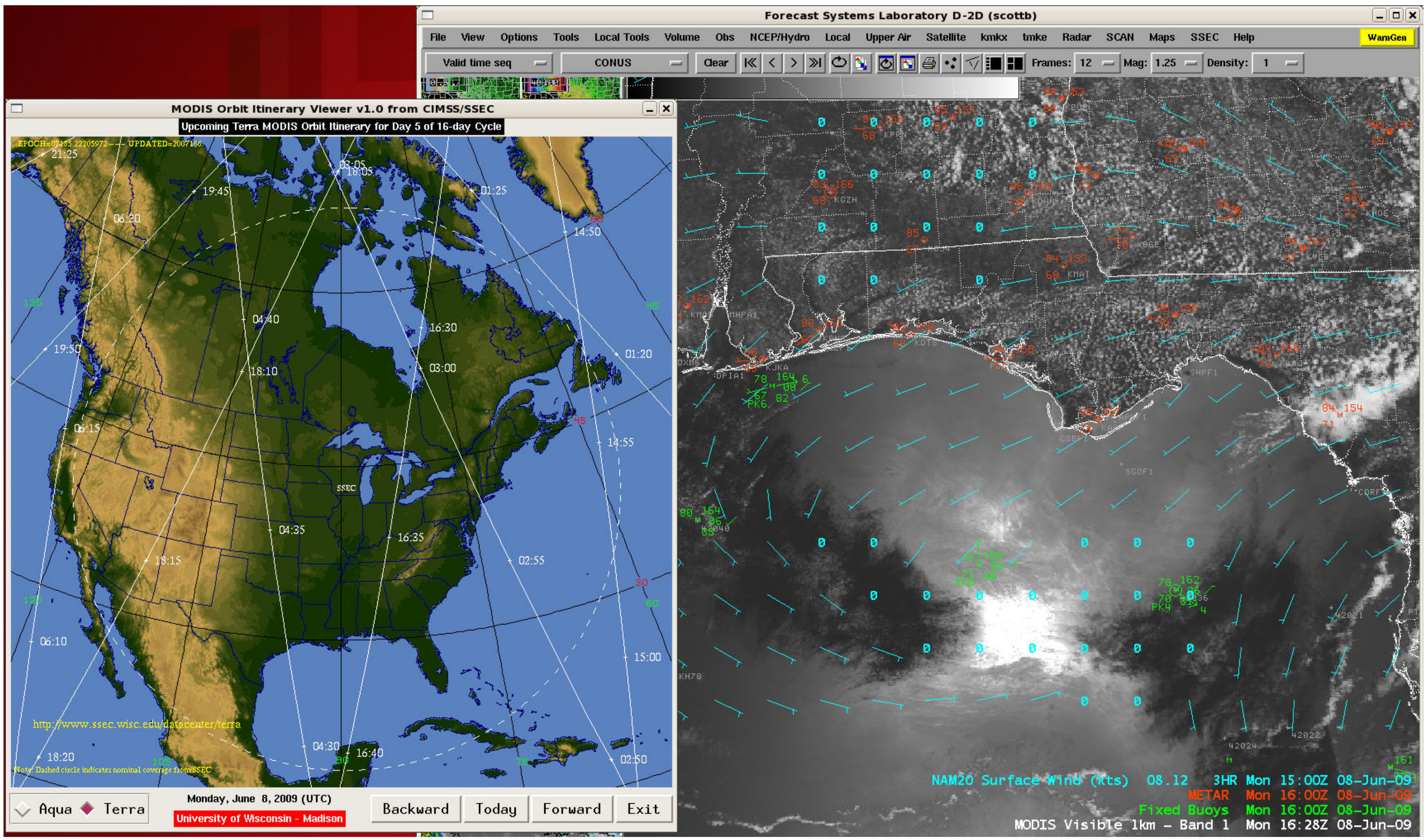
MODIS Sea Surface Temperatures

4 June 2009



MODIS Sunglint Pattern

8 June 2009



Sun Glint

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