EOS Direct Broadcast Real-Time Products for the National Weather Service: An Overview from Data Acquisition to Product Distribution.

Liam Gumley, Kathy Strabala, Jordan Gerth, Scott Bachmeier, Russ Dengel, Steve Dutcher, and Jerrold Robaidek.

SeaSpace 17th International Remote Sensing Conference
Mexico City
October 8-12, 2007

Space Science and Engineering Center
University of Wisconsin-Madison

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

Presentation Outline

1. Overview of EOS Direct Broadcast activities at SSEC
2. DB Processing System at SSEC
3. Creating products for the National Weather Service
4. Examples of MODIS products in AWIPS

EOS DB Reception Facility at SSEC

SeaSpace 4.4 meter antenna; operational since Jan. 2001.

Receives Terra and Aqua routinely (can receive, Oceansat, ERS-2, Radarsat).

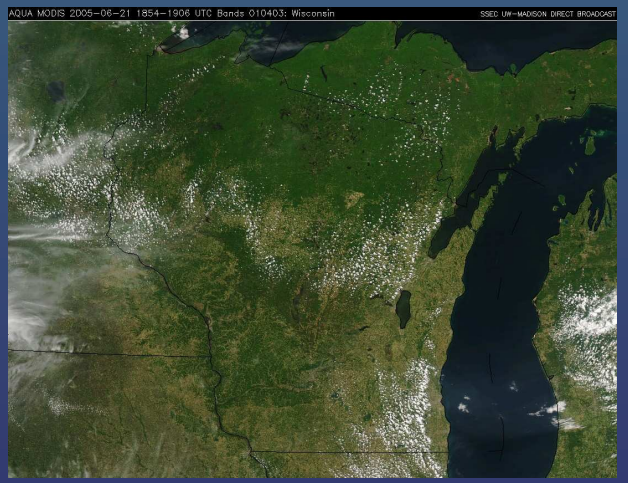
EOS Direct Broadcast Activities at SSEC

Objectives:

Routine acquisition and processing of EOS direct broadcast data. Distribution of real-time products to customers. Distribution of software for data processing.

Accomplishments:

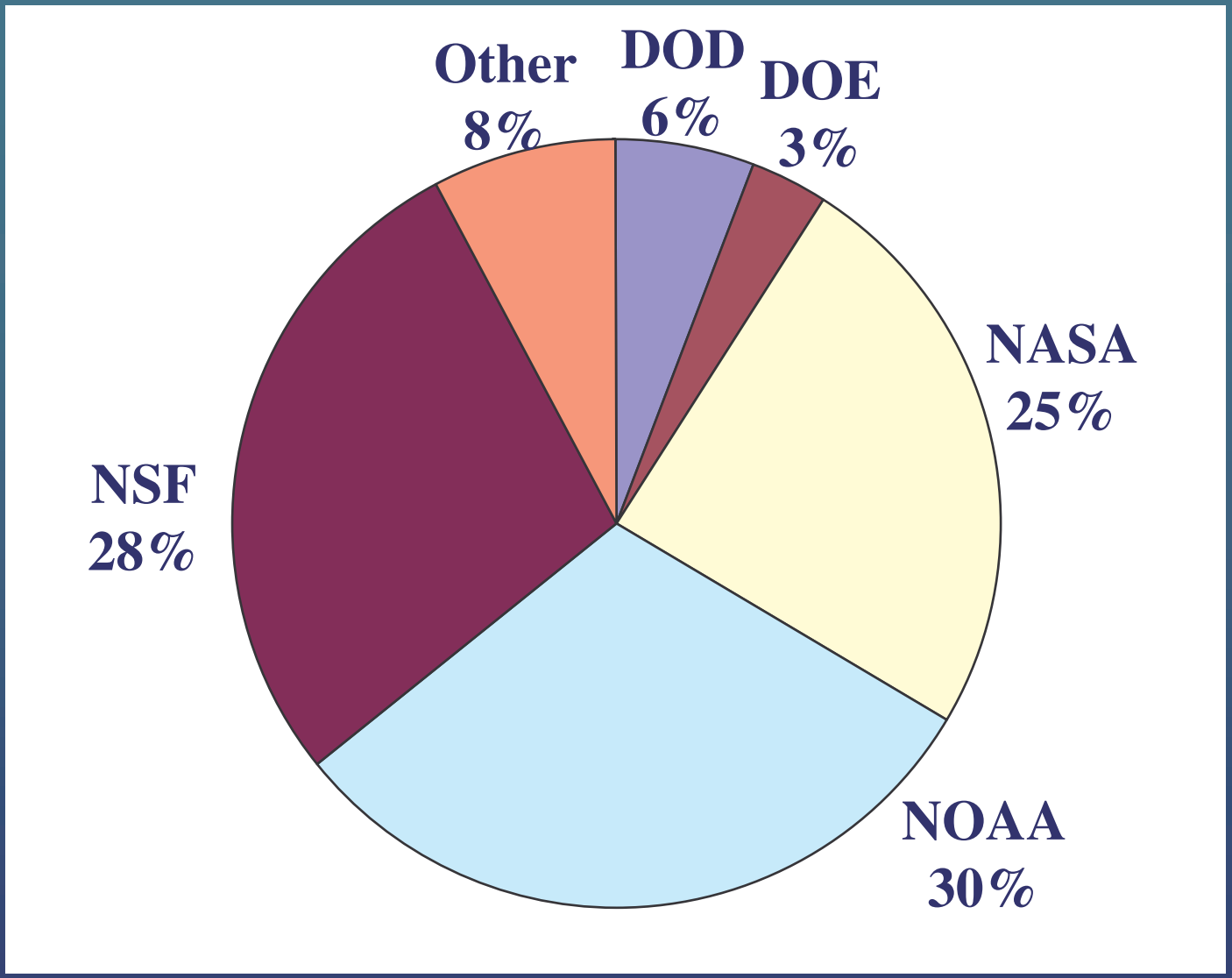
- Have acquired more than 19,500 Terra and Aqua passes.
- MODIS, AIRS, AMSR-E Level 1B data and browse images and Level 2 products, are produced automatically and made available via anonymous FTP, DODS and Web.
- IMAPP MODIS/AIRS/AMSR-E software now in use in USA, UK, Germany, Russia, Japan, China, S. Korea, Singapore, Hungary, Australia, Antarctica…



Funding: NASA, NOAA IPO

http://eosdb.ssec.wisc.edu/modisdirect/

SSEC 2006 Spending by Source: $20.6M



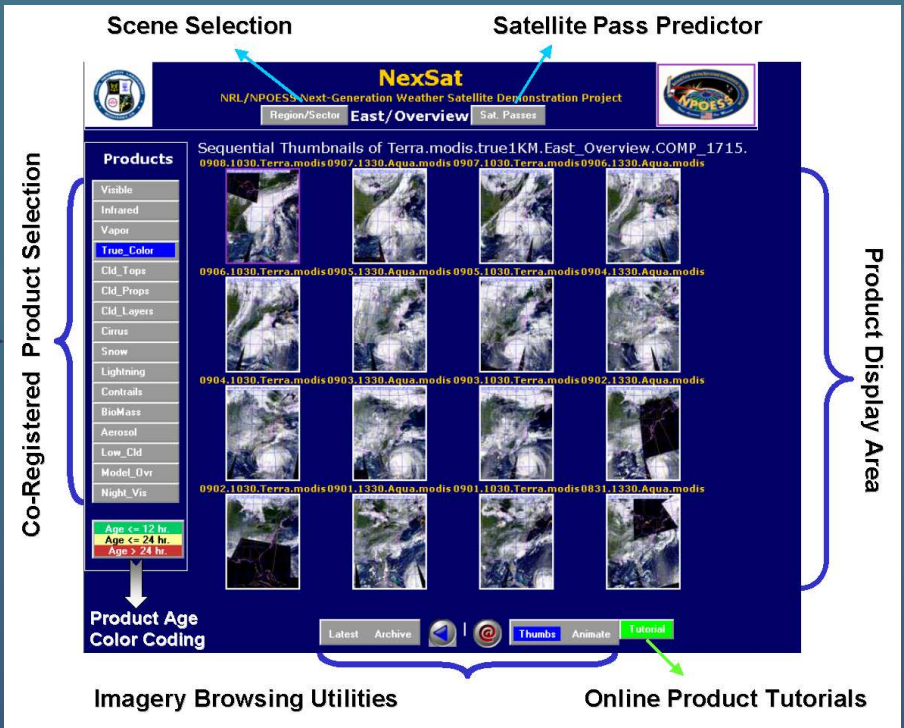
EOS DB 2007 = $965K

Major Customers for SSEC EOS DB Data

National Weather Service
Imagery for Forecasters

NRL Monterey
NexSat Website
Product Development

Canadian Ice Service
Ice Analyses



NOAA Great Lakes Environmental Research Lab
JPEG and GeoTIFF images for Great Lakes

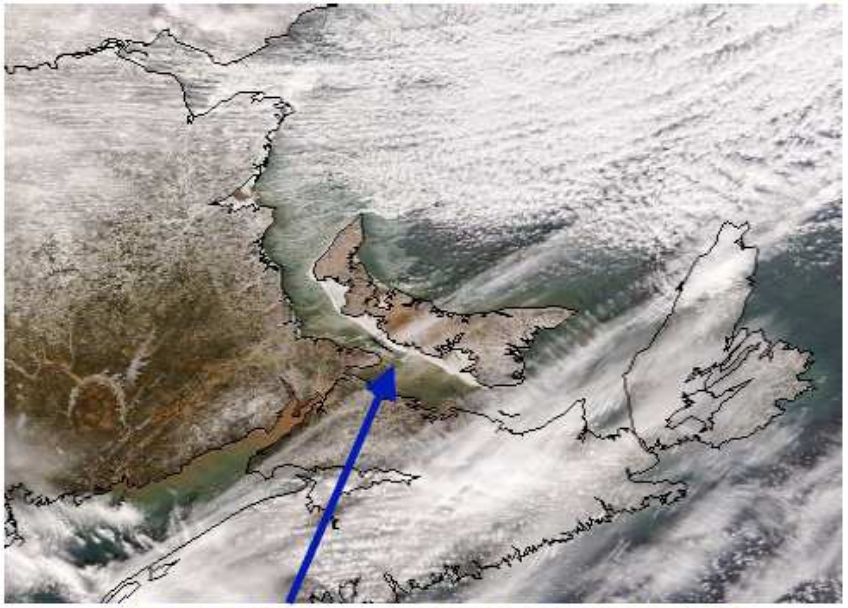
NASA/Environmental Protection Agency IDEA Project
L1B data and images for air quality forecasts

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

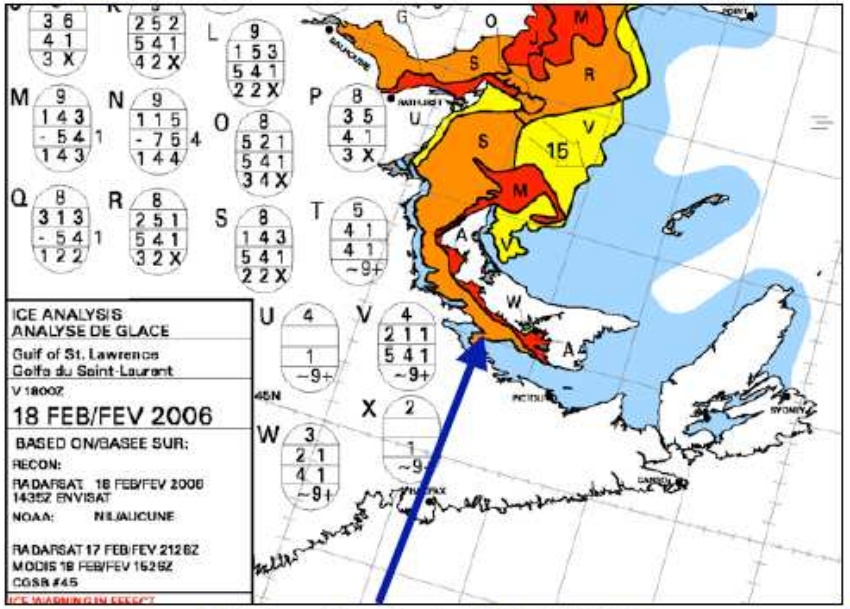
CIS data suite includes RadarSat and Envisat (SAR); AMSR, QuikScat and SSM/I (microwave); MODIS, OLS, NOAA and GOES (visible images).

- 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

NOAA Great Lakes CoastWatch

http://coastwatch.glerl.noaa.gov/

"canadian ice service" mc

Apple .Mac Amazon eBay Yahoo! News

What's New

CW Overview

AVHRR Imagery

GLSEA

Contour Maps

GOES Imagery

RADARSAT

MODIS Imagery

Ocean Color

Image Products

In Situ Data

GLFS

Statistics

JAVA GIS

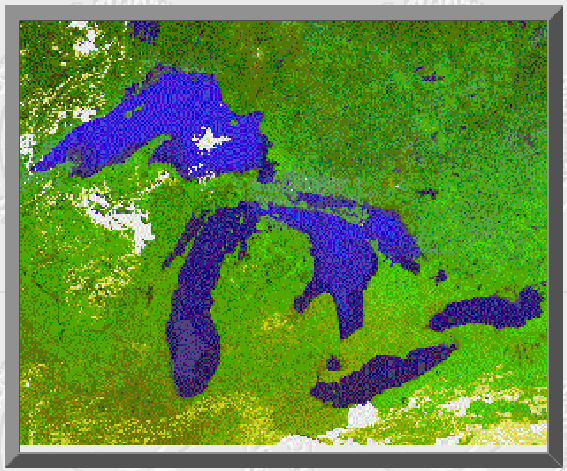
Image Archive

Software

Documentation

Validation

Welcome to the NOAA CoastWatch Great Lakes Node

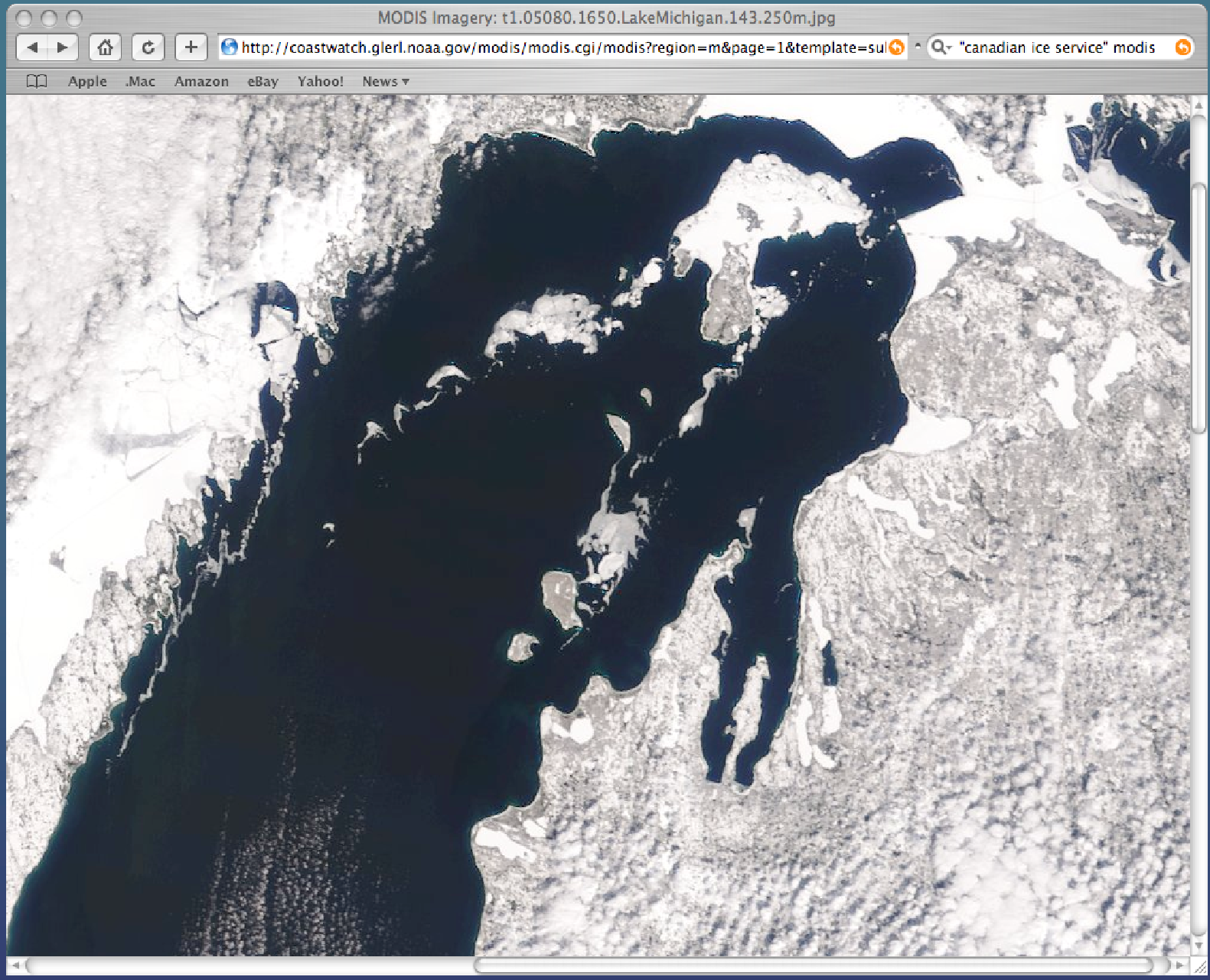


CoastWatch

Great Lakes CoastWatch Node
NOAA/Great Lakes Environmental Research Laboratory
2205 Commonwealth Blvd.
Ann Arbor, MI 48105-2945
Fax: 734-741-2055
http://coastwatch.glerl.noaa.gov

George A. Leshkevich, *Manager*

Songzhi Liu, *Operations Assistant*


MODIS Imagery: t1.05080.1650.LakeMichigan.143.250m.jpg
http://coastwatch.glerl.noaa.gov/modis/modis.cgi/modis?region=m&page=1&template=sul
"canadian ice service" modis
Apple
.Mac
Amazon
eBay
Yahoo!
News

International MODIS/AIRS Processing Package (IMAPP)

Builds upon our previous experience with
- ITPP (International TOVS Processing Package) since 1985
- IAPP (International ATOVS Processing Package) since 1998

Purpose:
- The intention in developing IMAPP for processing direct broadcast MODIS, AIRS, AMSU, AMSR-E data is to help foster the rapid improvement of retrieval algorithms and other applications of EOS data in a variety of global weather, process studies, and climate applications, just as the ITPP and IAPP have done for TOVS and ATOVS data.

Available from:

http://cimss.ssec.wisc.edu/imapp/

International MODIS/AIRS Processing Package (IMAPP)

MODIS products (developed by NASA MODIS Science Team)

- Cloud mask (MOD35), cloud properties (MOD06CT) - height, temperature, emissivity, phase
- Atmospheric profiles (MOD07) T, q, tpw, total ozone, stability
- Aerosol optical depth (MOD04)
- Sea surface temperatures
- Near-infrared water vapor

MODIS utilities

- Creating true color images tutorial
- Creating MODIS L1 product images

AIRS products (developed by NASA AIRS Science Team)

- AIRS/AMSU/HSB *(JPL L1 software)*
- AIRS Level 2 profiles: 3x3 FOV (JPL), single FOV (UW)

AMSR-E products (developed by RSS and AMSR-E Science Team)

- Rain rate, rain type
- Soil Moisture
- Snow water equivalent

IMAPP MODIS Recent Updates (August 2, 2007)

1. Pre-compiled binary code is now available to support most Linux platforms. Source code is also included in the distribution.
2. Ancillary data files are acquired automatically. The required data for each product can be automatically determined and downloaded from the IMAPP ancillary data ftp site.
3. One script now runs all of the MODIS algorithms in sequence. This includes flatfile extractions, ancillary data identification and fetching, cloud mask (MOD35), cloud top properties and cloud phase (MOD06CT), atmospheric profiles (MOD07), aerosols (MOD04), sea surface temperatures and near-infrared water vapor software packages.
4. All MODIS algorithms have been updated to NASA Collect 5, with the exception of the MOD06 Cloud Top Properties which runs 5.2 operationally.
5. User can choose either binary, HDF or both types of output formats.
6. All IDL software required to convert from binary to HDF has been removed (thanks to NASA Direct Readout Laboratory).
7. Now includes software to automatically create quick look product images (based on McIDAS-Lite).
8. Users are now required to fill out a simple registration form prior to downloading the IMAPP software.

IMAPP MODIS Product Images

Real-time product images from IMAPP MODIS are available on the Web

EOS DB Remote Sensing Workshops

- Workshop format includes:
  - Lectures on Remote Sensing Principles, Instrument Characteristics MODIS, AIRS), and Science Algorithms (e.g., Cloud Detection, Aerosol Optical Depth, Wildfire Detection)
  - Hands-on laboratory sessions where students explore and analyze MODIS and AIRS interactively
- Locations have included Italy (5+), Australia, China (2), Taiwan, Norway, South Africa

Beijing

Nanjing

Andenes

Perth

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SSEC DB Processing System Requirements

Reliable: Products must be generated 24x7x365

Consistent: Products must be available with the same format, name, content and location every day

Timely: Products must be available as soon as possible following acquisition

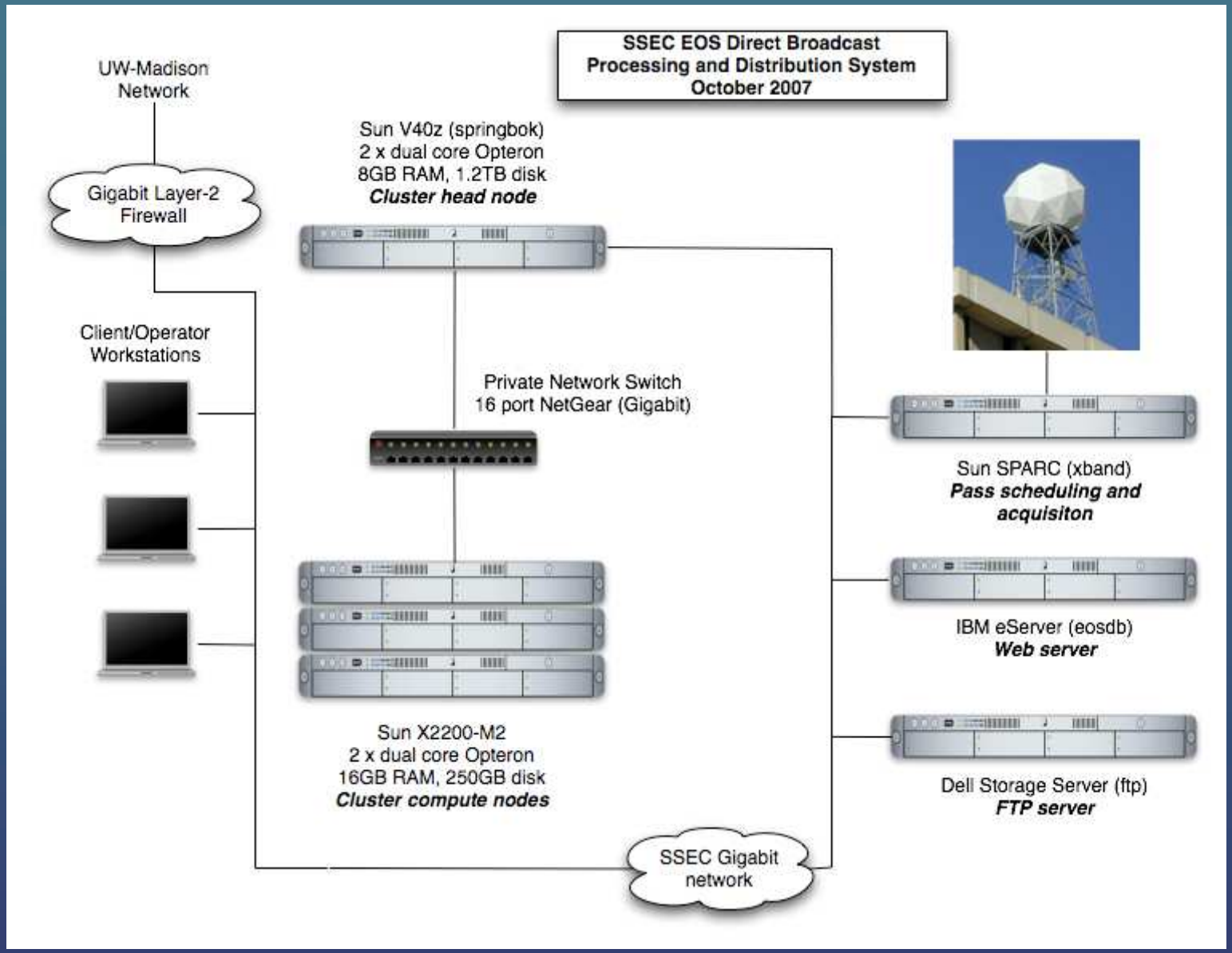
System as implemented is

(1) Maintainable by operators and developers (not a black box)

(2) Based on commodity hardware and freely available software

(3) Capable of reprocessing on demand

SSEC DB Processing System: Schematic



SSEC DB Processing System: Key Technology Decisions

Linux Cluster

- Uses commonly available hardware (Sun servers with AMD Opteron CPUs and SATA disks)
- Open source Linux cluster distribution (Rocks)
- Could be implemented on single system with multiple CPUs (system has been tested on quad core box)

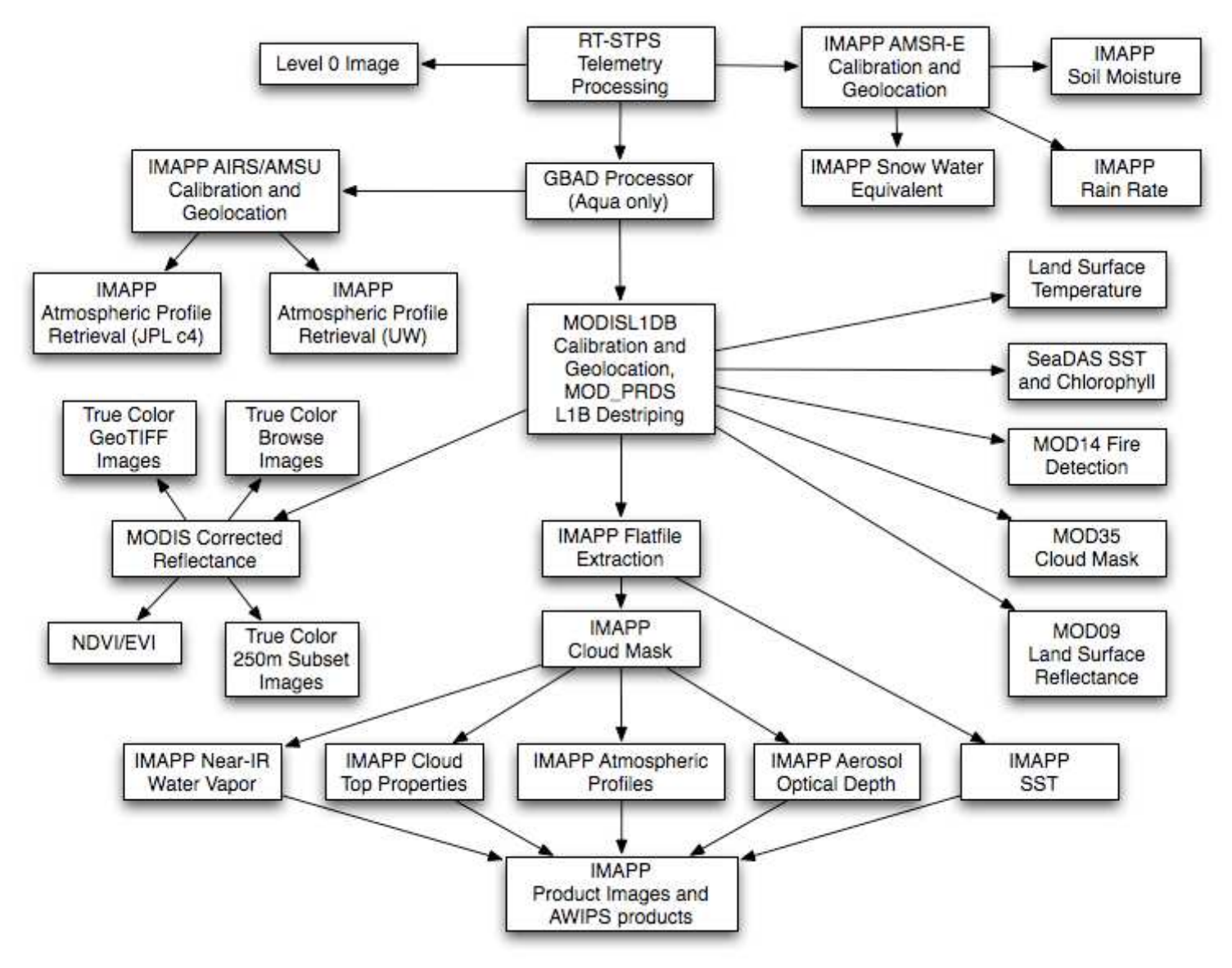
Sun Grid Engine (open source job manager)

- SGE provides a simple command line interface for submitting and managing a list of jobs. Scales from a few jobs to thousands (FIFO job scheduling).

Bash and C shell scripting languages

- Operators and developers know Bash and C shells
- Helps ensure maintainability of the system

SSEC DB Processing System: Data Flow



Software Components

NASA Direct Readout Lab: RT-STPS, GBAD processor, MOD14, MODLST, NDVI/EVI, CREFL, MOD09 (beta)

University of Dundee: EOSLZX

NASA Ocean Biology Processing Group: MODISL1DB, SeaDAS

USGS: MRTSwath

NSIDC: MS2GT

UW/JPL/RSS: IMAPP MODIS L2, IMAPP AIRS L1/L2, IMAPP AMSR-E L1/L2

UW: McIDAS-Lite, McIDAS, ADDE, MODDS, MOD35

ITTVIS: IDL

DB Processing System Script Structure

One main driver script (db_main.sh) invokes all other scripts.
Only required input is a PDS (Level 0) file. It creates the output product directory structure if it does not exist.

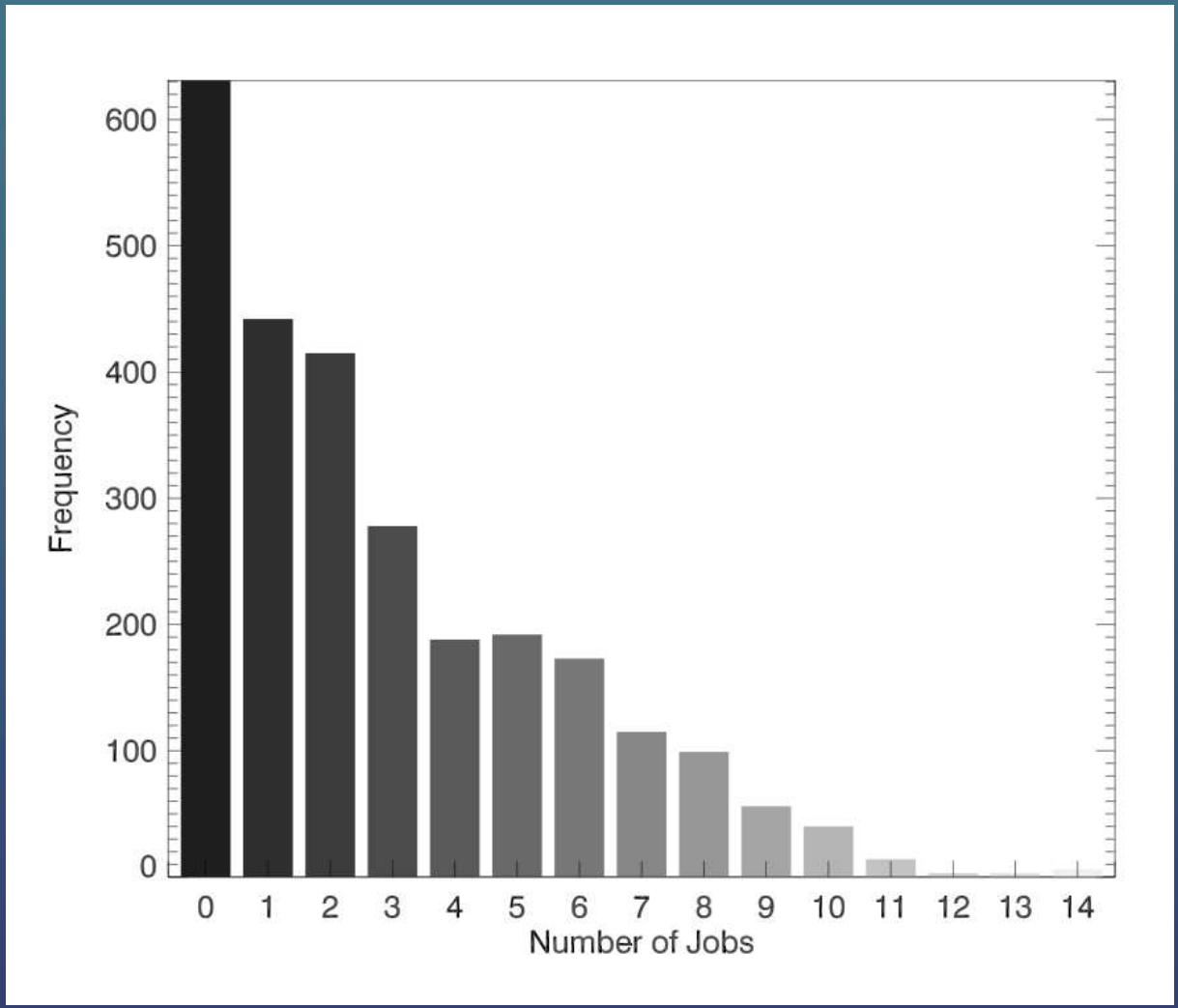
Separate MODIS, AIRS, and AMSR-R driver scripts are invoked to kick off instrument-specific jobs.

Each product generation script (e.g. modis_L1A_to_L1B.csh) is called from an SGE interface script which:

- Makes a unique directory for the job
- Copies input files from source
- Runs the algorithm
- Sends output files to online archive and distribution sites
- Saves standard input and output to log files

DB Cluster CPU Utilization

Histogram of number of active DB cluster Jobs
July 19 - October 3 2007 (10 min sampling)



DB Processing System Typical Performance

Terra pass, 2007279.1734, data time 17:35 to 17:47

- Processing started 17:49, ended 18:50 (34 separate jobs)
- Created 4 x L1B HDF (single granule), 10 x GeoTIFF, 36 x Subset JPEGS, 12 x L2 HDF products (including MOD09), 12 x L2 product images, 64 quicklook JPEGS
- 138 output files, not including AWIPS products

Aqua pass, 2007279.1915, data time 19:15 to 19:27

- Processing started 19:40, ended 20:25 (41 separate jobs)
- Created 4 x L1B HDF (single granule), 10 x GeoTIFF, 36 x Subset JPEGS, 11 x L2 HDF products (not including MOD09), 11 x L2 product images, 85 quicklook JPEGS, 18 AIRS L1B/L2 HDF (6-min granules), 6 AIRS UW L2 products, 6 AMSR-E L1B/L2 products
- 187 output files, not including AWIPS products

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MODIS Imagery Usage by NWS Forecasters

CIMSS began routine insertion into AWIPS Central Region data feed on 30 June 2006.

Current feed consists of:

- MODIS L1B Bands 1 (.86 micron), 7 (2.1 micron), 26 (1.38 micron), 20 (4.0 micron), 27 (6.7 micron) and 31 (11 micron)
- Cloud Phase, TPW, Cloud Top Temperatures, Fog, SST

Keys to success:

- Provide something better or new to forecasters (e.g., higher resolution)
- Must be delivered in a format that can be accepted by AWIPS
- Must have a person at the forecast offices to champion the data

Steve Hentz, Lead Forecaster, NWSFO MKE

About AWIPS

AWIPS

*A*dvanced

*W*eather

*I*nteractive

*P*rocessing

*S*ystem

Main AWIPS display tool is known as *D2D*

*D*isplay

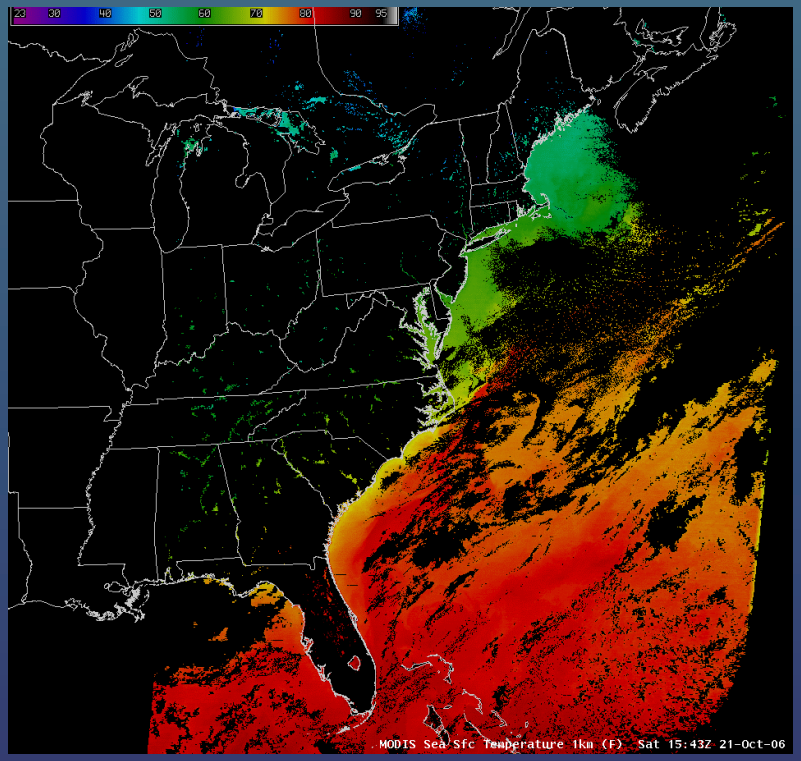
2 (Two)

*D*imensions

CIMSS/SSEC AWIPS Imagery Distribution Network

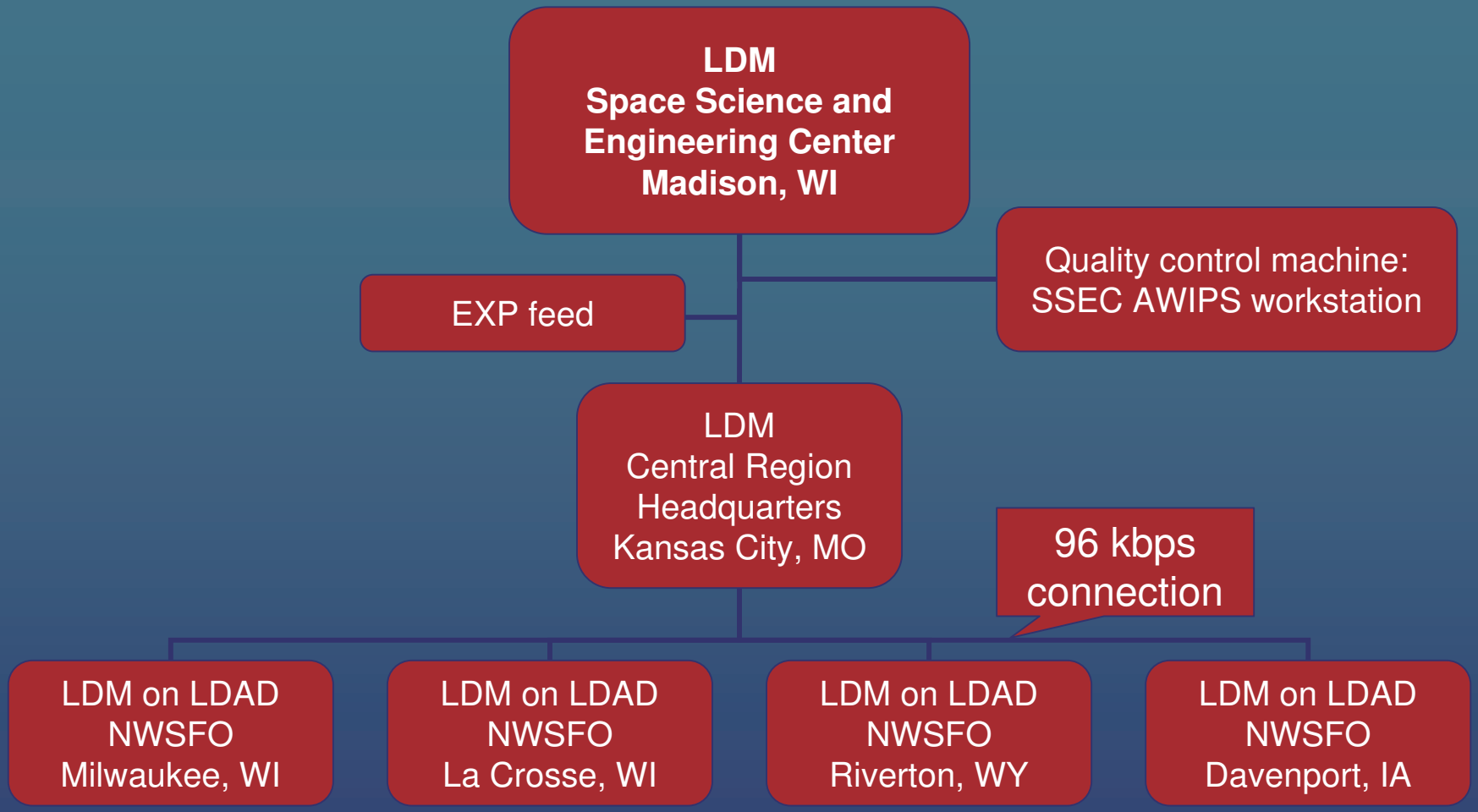
DB Products to AWIPS: Data Processing Steps

1. Reproject image and optionally cloud mask in McIDAS, write McIDAS area product
2. Fit to a predefined region used in AWIPS (eastConus, westConus)
3. Zero-fill area of NetCDF where there is no subset of the MODIS pass
4. Compress using zlib
5. Apply naming convention
6. Upload to LDM



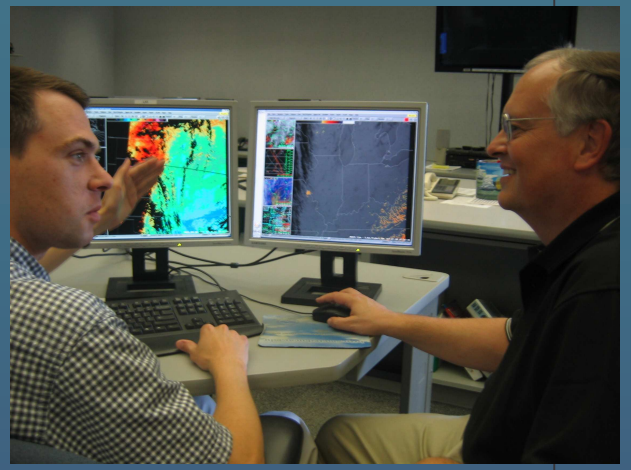
Cloud Cleared SST in AWIPS

DB Products to AWIPS: Delivery to NWS Forecast Offices



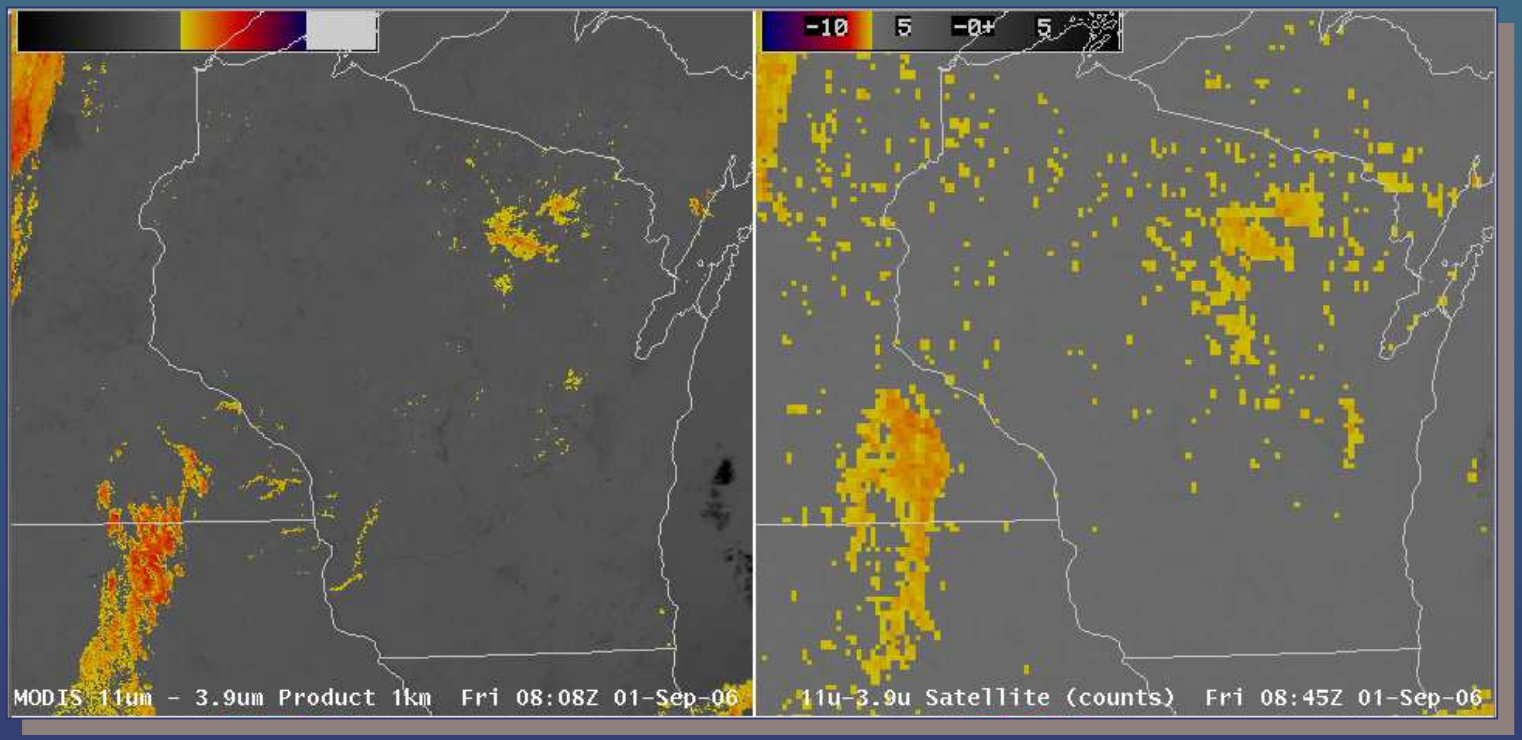
Value to NWS Forecaster

- Near-term (less than 12 hours) forecasts
  - Diagnosing heavy precipitation potential
    - Total Precipitable Water (TPW)
  - Determining precipitation type
    - Snow or freezing drizzle?
- Short-term (12 to 36 hours) forecasts
  - Areas of fog formation
  - Temperatures in lakeshore areas
- Post-event analysis
  - Temperature of significant convective cells
- Aviation
  - Small-scale orographic turbulence
- Climatology
  - Diagnosing areas of accumulated snow
  - Formation of ice on sizeable lakes and other waterways
- Marine
  - Wind shift on Great Lakes



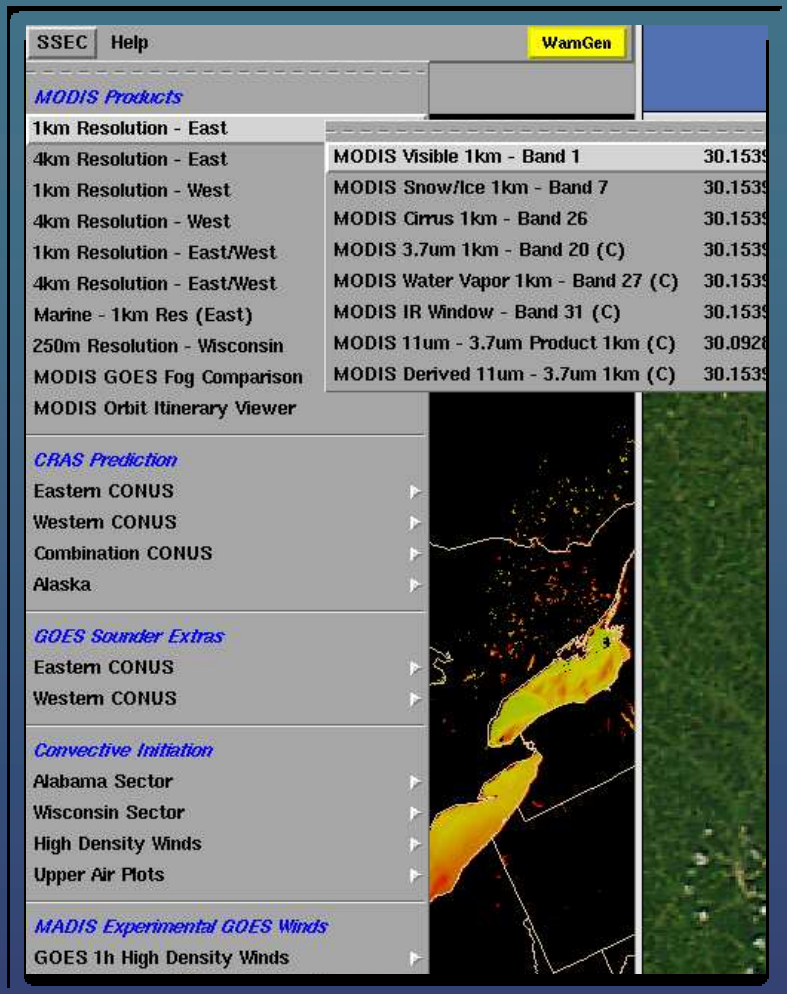
MKE Area Forecast Discussion

MAIN SHORT TERM FORECAST PROBLEM IS EAST FLOW AND MARINE LAYER INFLUENCE OVER EASTERN WISCONSIN..AND DENSE FOG POTENTIAL IN THE WEST. THINK MOST OF THE DENSE FOG WOULD BE IN THE RIVER VALLEYS...WITH A TENDENCY FOR PATCHY FOG AND SOME STRATUS AGAIN IN THE EAST WITH MORE OF A GRADIENT. MODIS 1 KM IMAGERY LAST NIGHT SHOWED THE DENSE FOG IN LONE ROCK AND BOSCOBEL WAS CONFINED TO THE IMMEDIATE WISCONSIN RIVER VALLEY..IMPORTANT INFORMATION. THE LOCAL RIVER VALLEY DENSE FOG IS NOT SEEN IN THE NORMAL 2 KM GOES.(HENTZ/MKX)



MODIS Imagery and Products in AWIPS

- Band 1 - (0.6µm) - Visible
- Band 7 - (2.1µm) - Snow/ice detection
- Band 20 - (3.7µm) - Shortwave IR
- Band 26 - (1.3µm) - Cirrus detection
- Band 27 - (6.7µm) - Water vapor
- Band 31 - (11.0µm) - IR window
- 11µm - 3.7µm - Fog/stratus product
- Total precipitable water (TPW)
- Cloud phase
- Cloud top temperature
- Sea surface temperature (SST)



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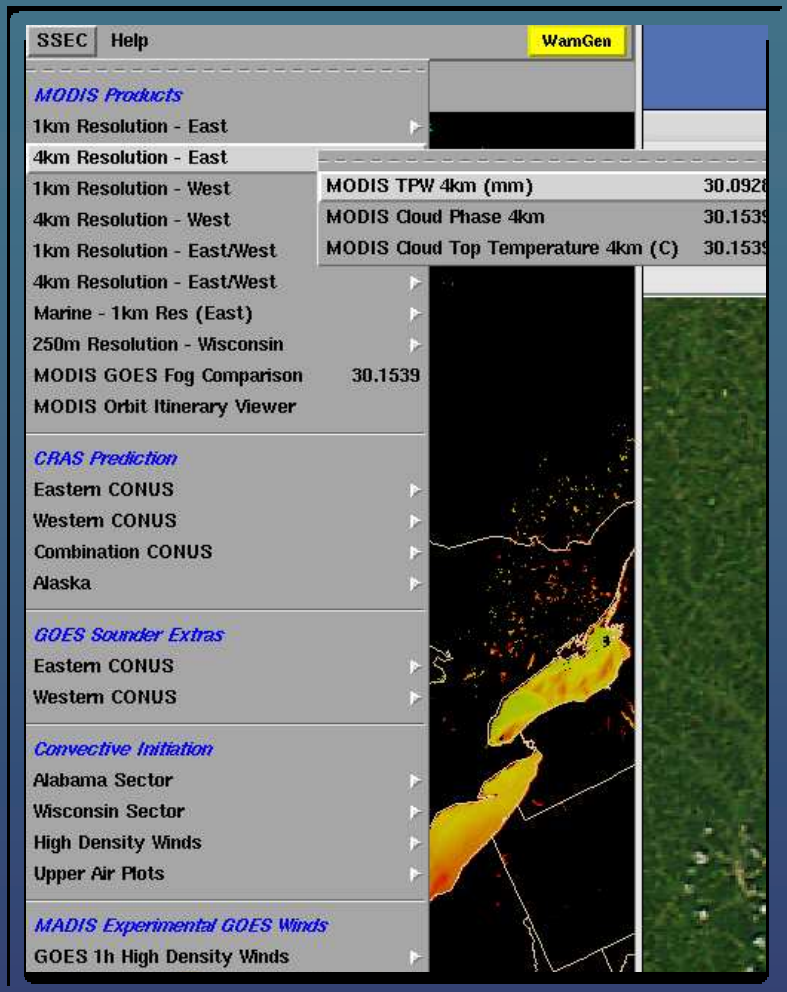

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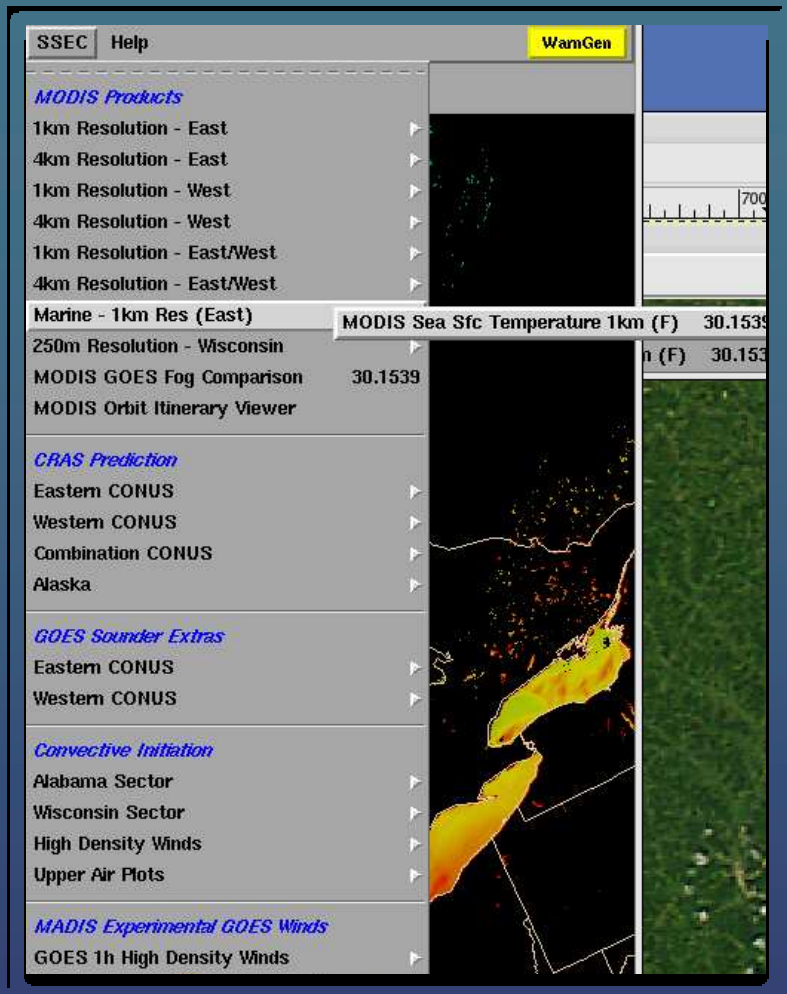

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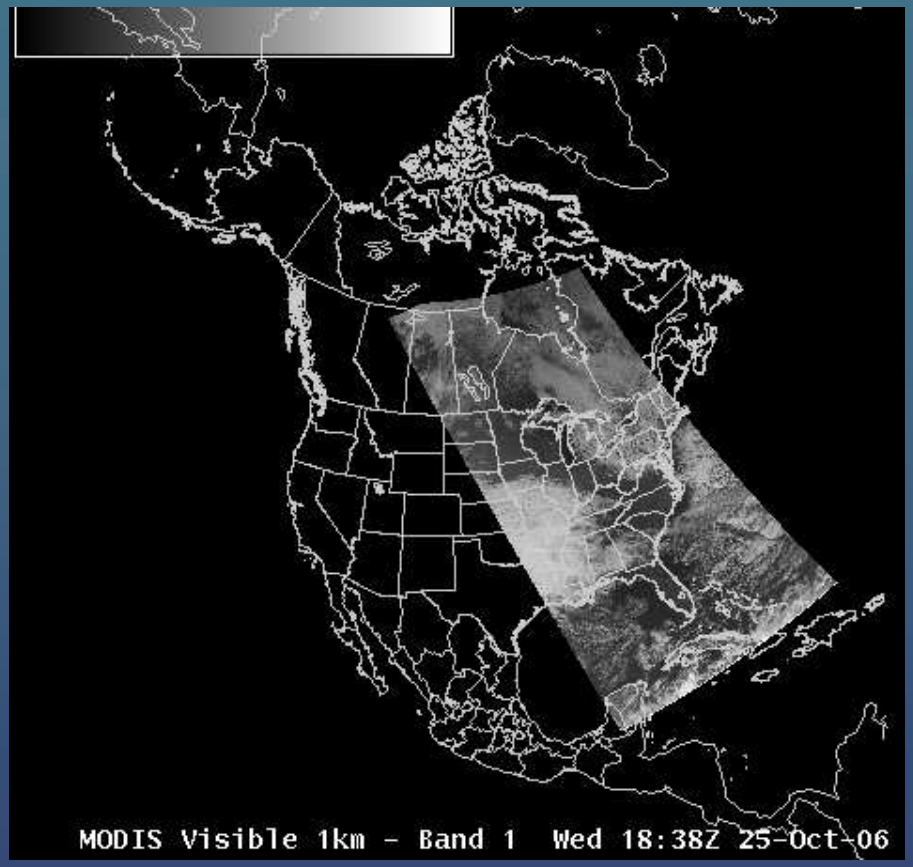
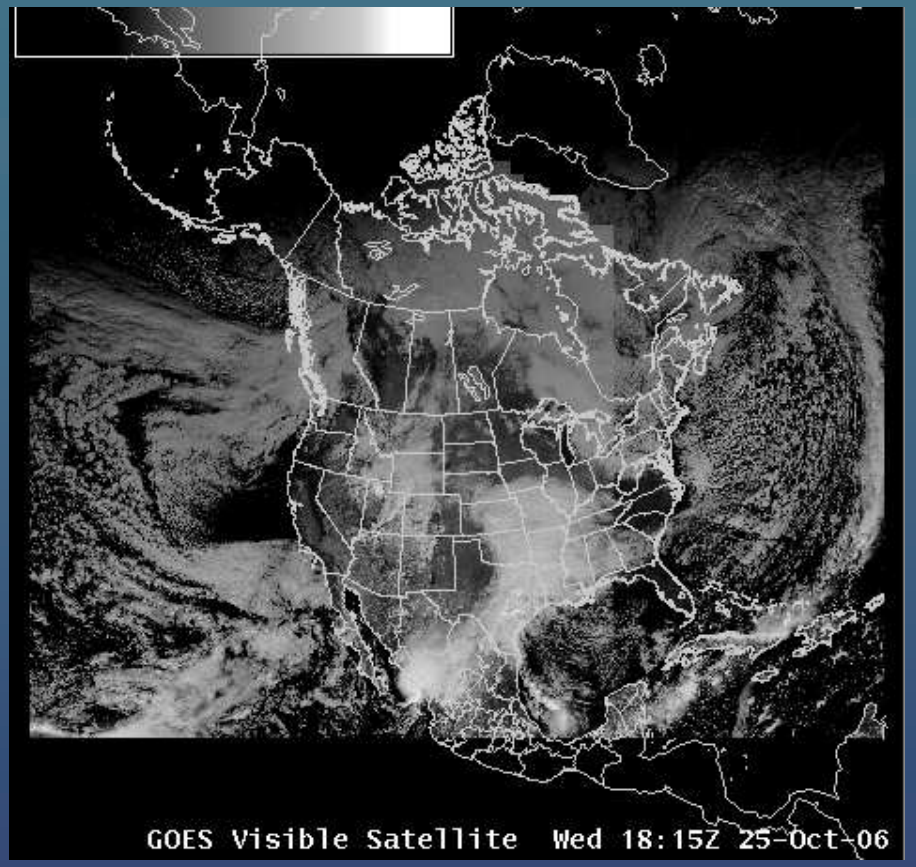
MODIS Imagery in AWIPS

Band 1: Visible channel (0.6µm)



MODIS visible channel



GOES visible channel

MODIS Imagery in AWIPS

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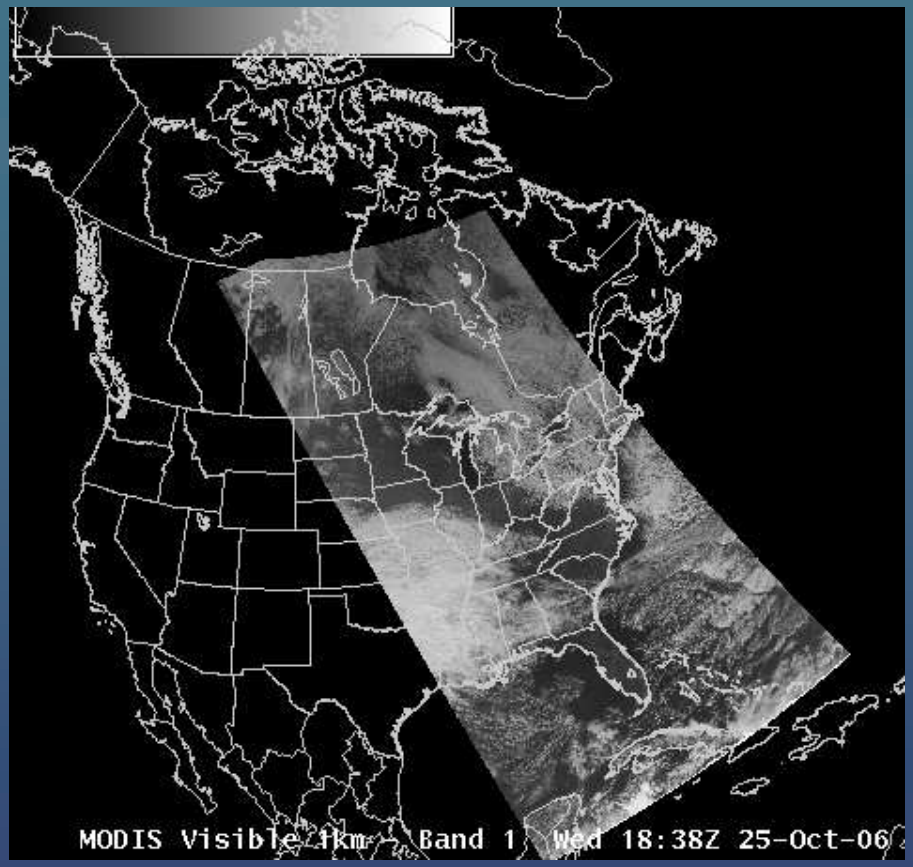
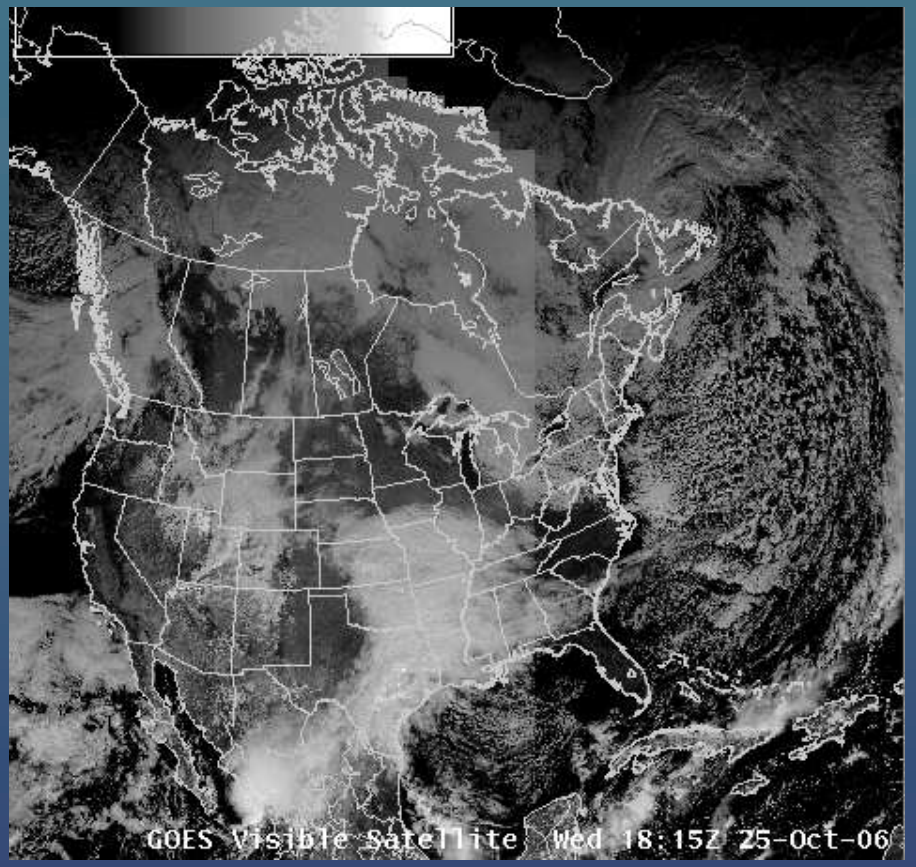


MODIS visible channel



GOES visible channel

MODIS Imagery in AWIPS

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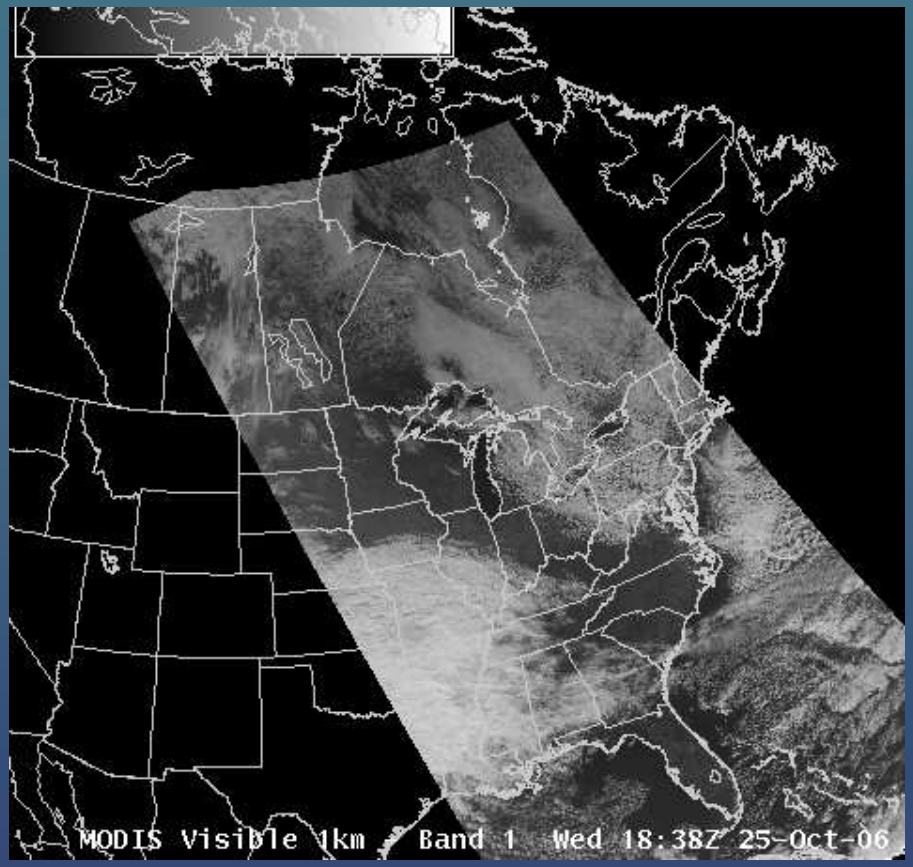
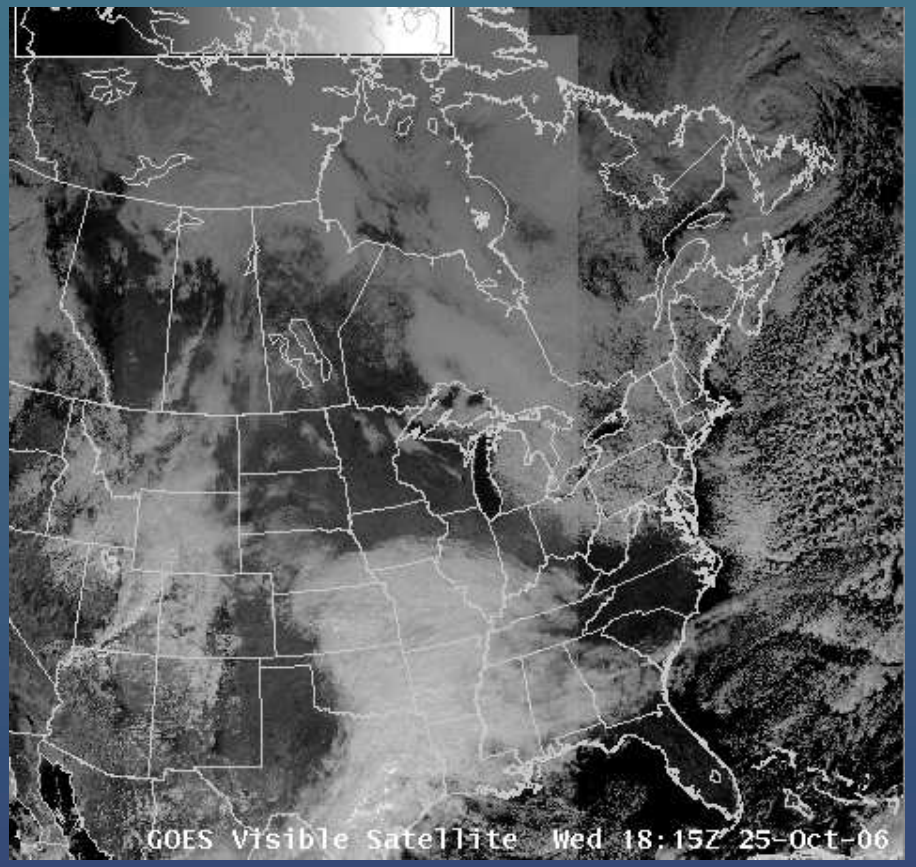


MODIS visible channel



GOES visible channel

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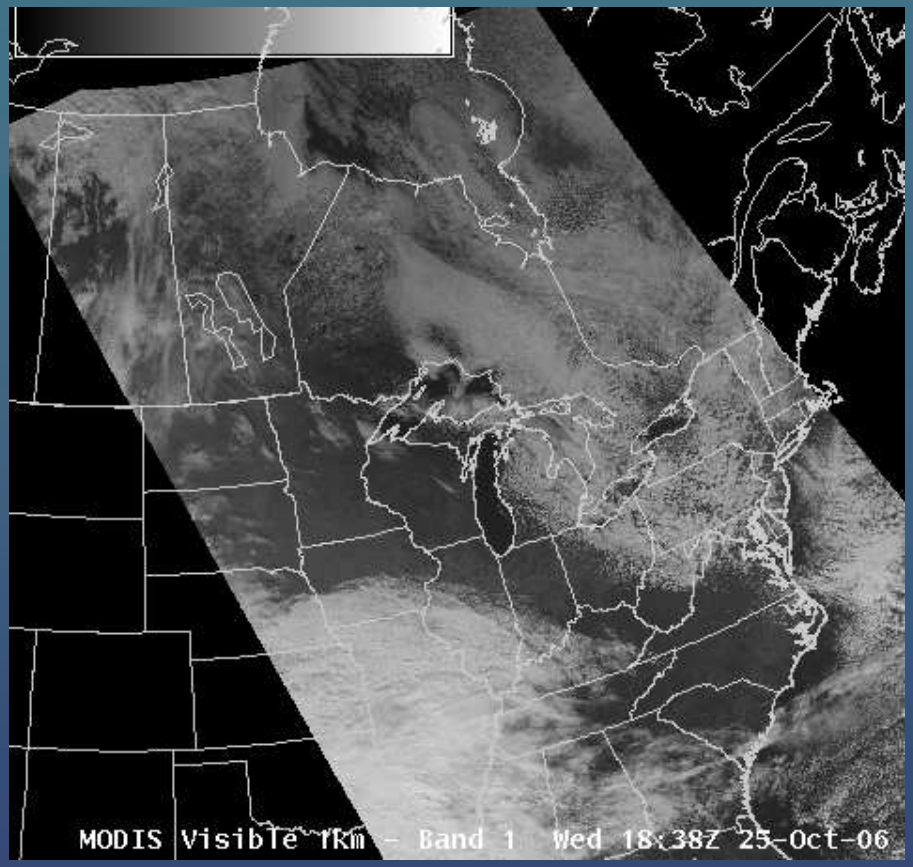
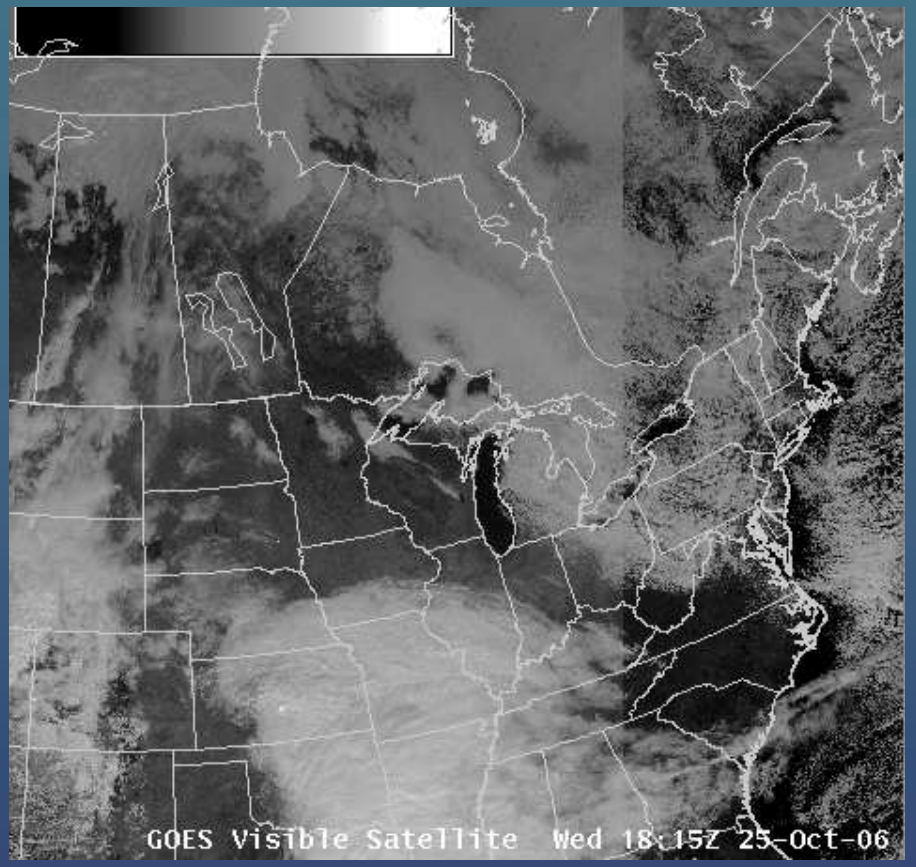


MODIS visible channel



GOES visible channel

MODIS Imagery in AWIPS

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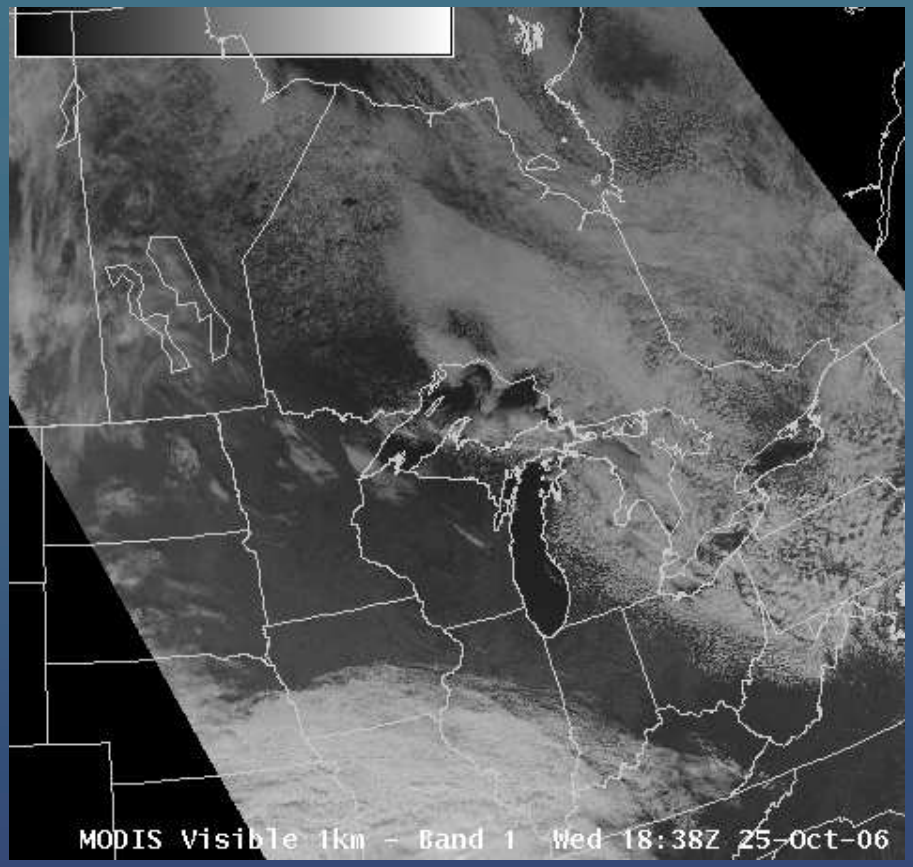
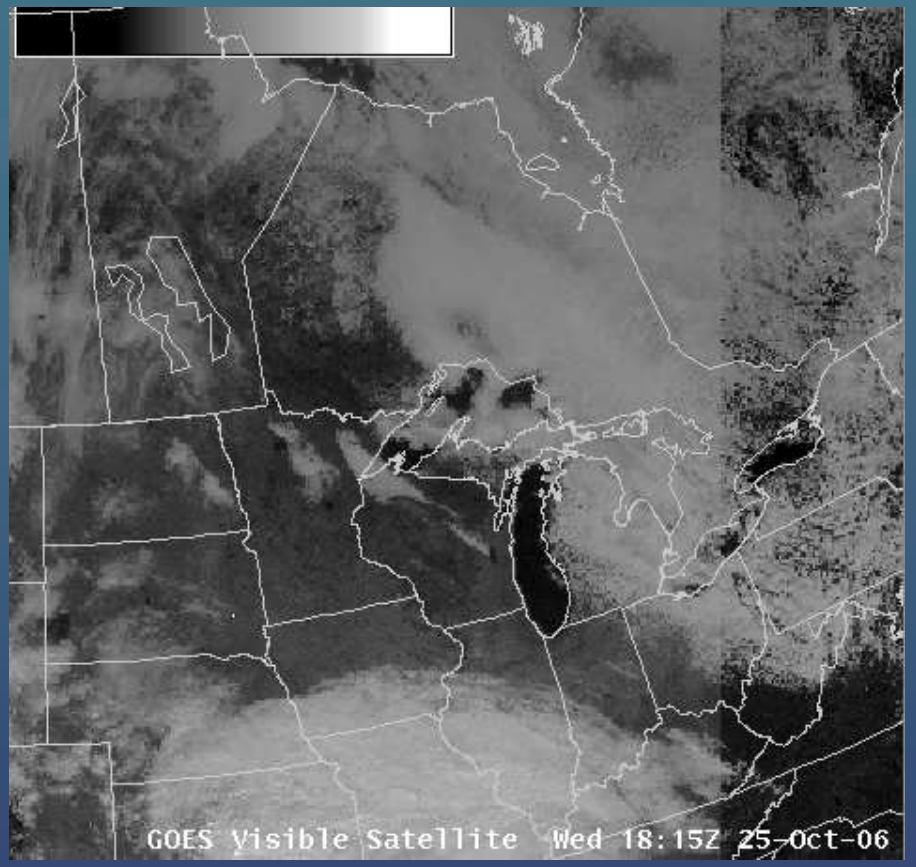


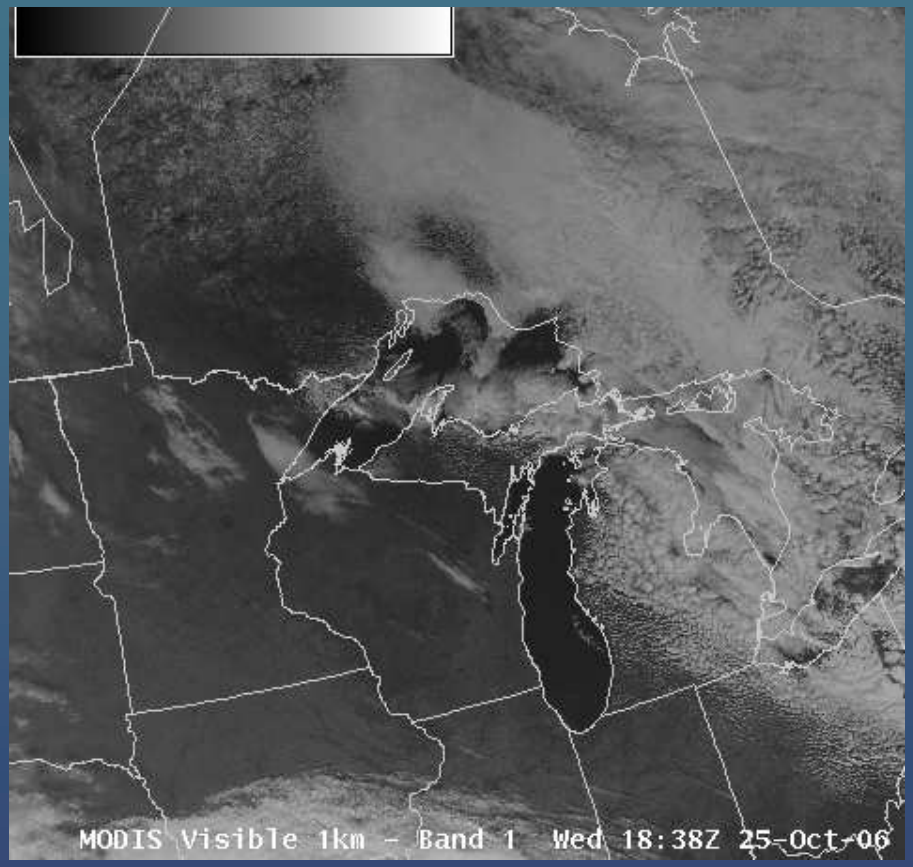
MODIS visible channel



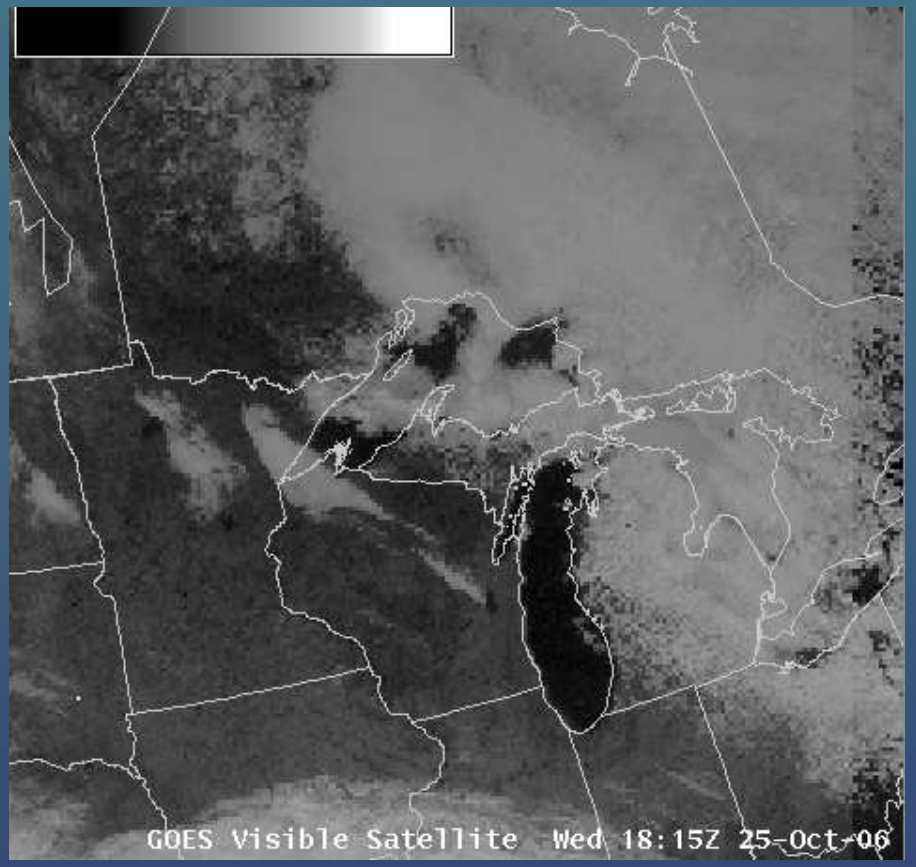
GOES visible channel

MODIS Imagery in AWIPS

Band 1: Visible channel (0.6µm)



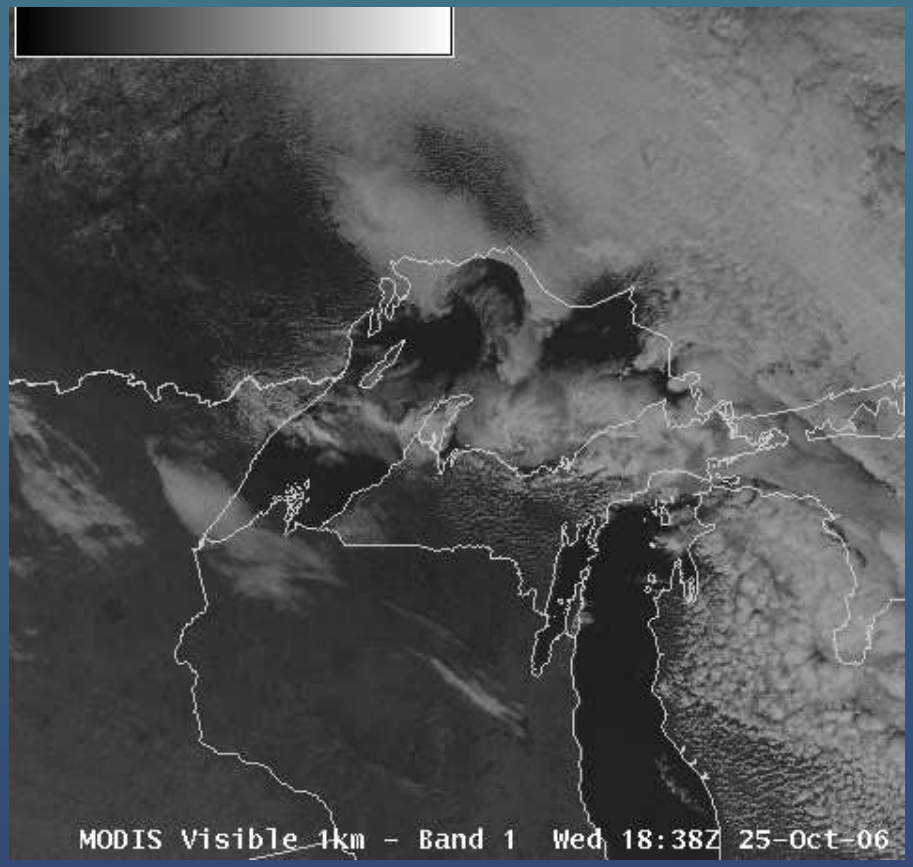
MODIS visible channel



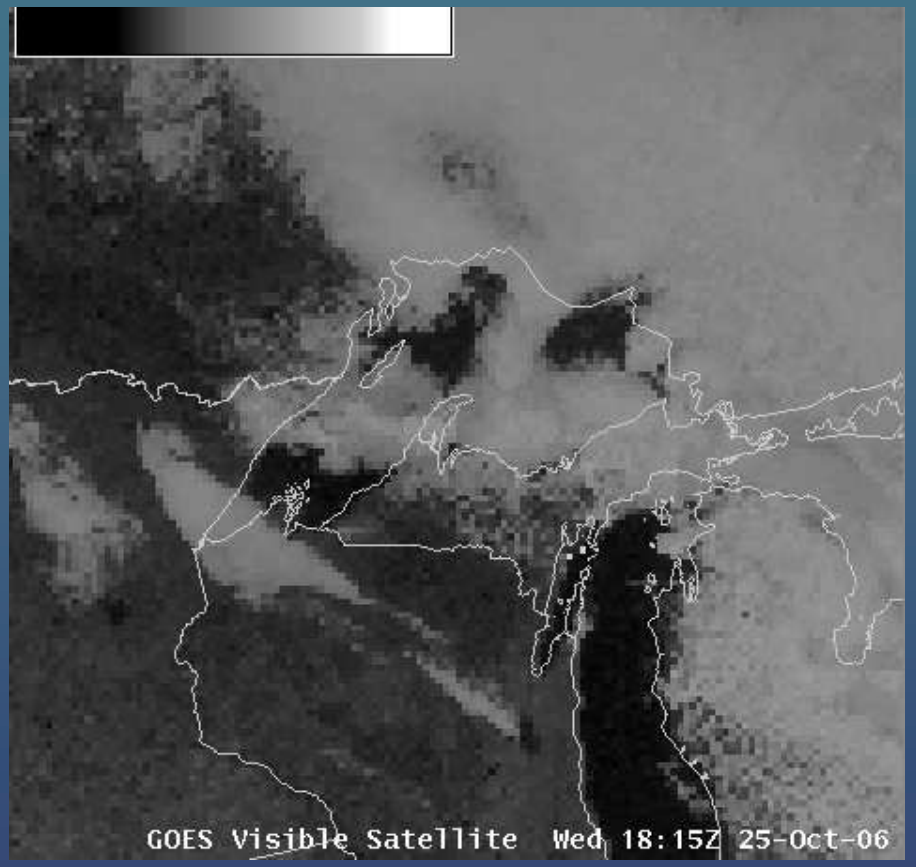
GOES visible channel

MODIS Imagery in AWIPS

Band 1: Visible channel (0.6µm)



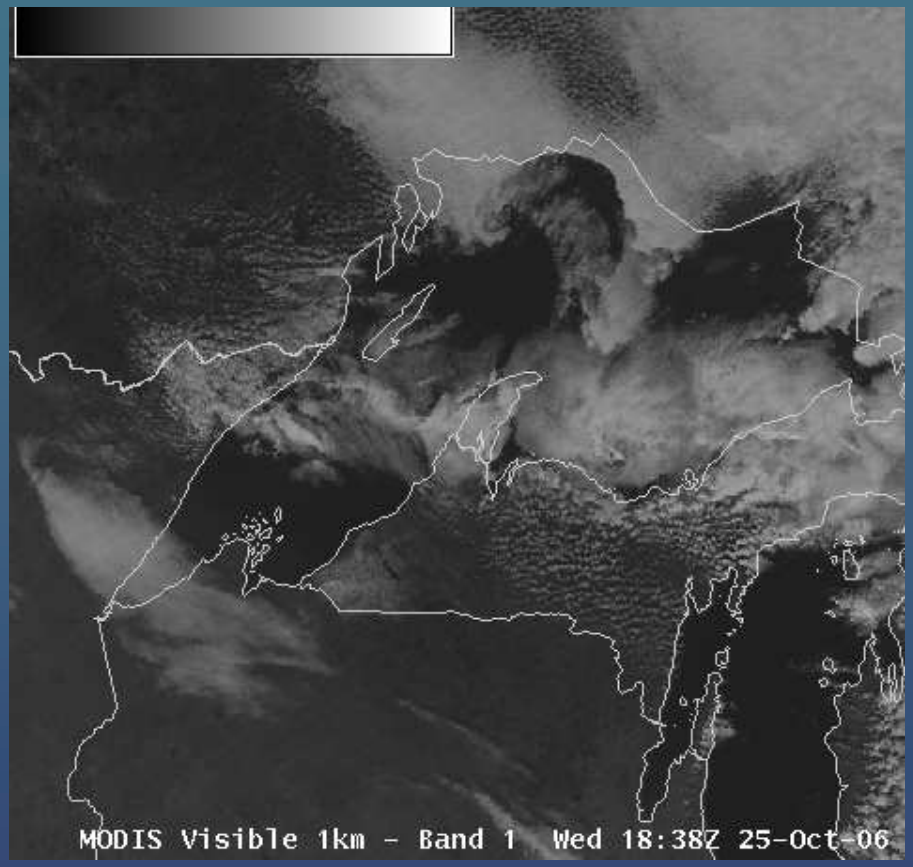
MODIS visible channel



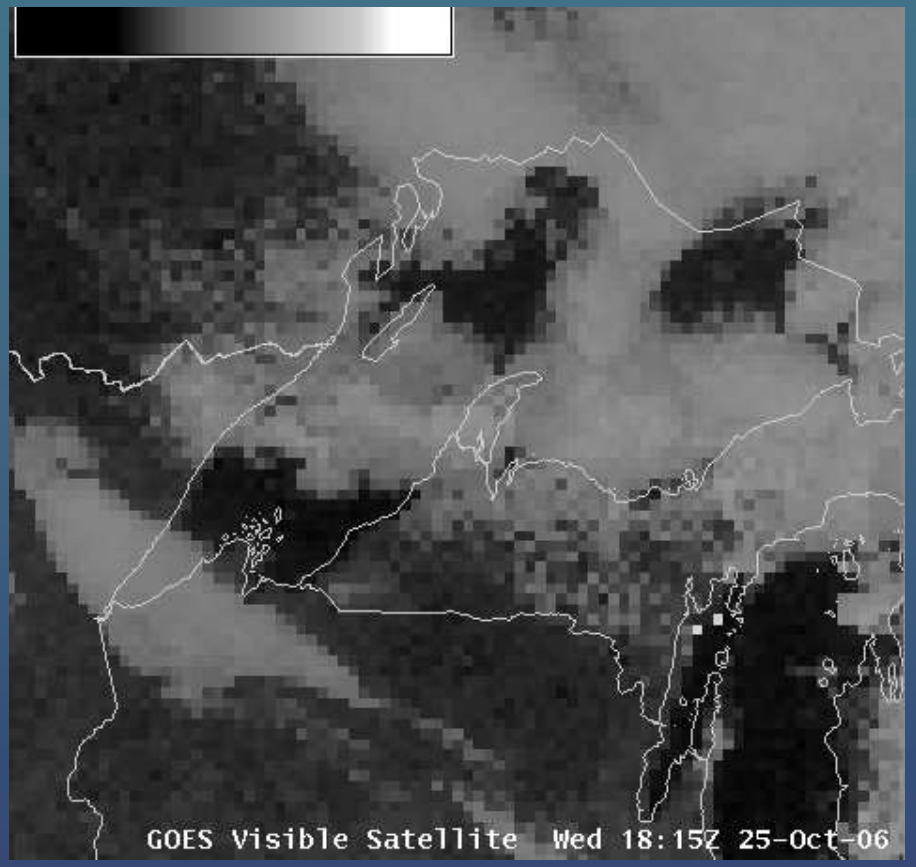
GOES visible channel

MODIS Imagery in AWIPS

Band 1: Visible channel (0.6µm)



MODIS visible channel



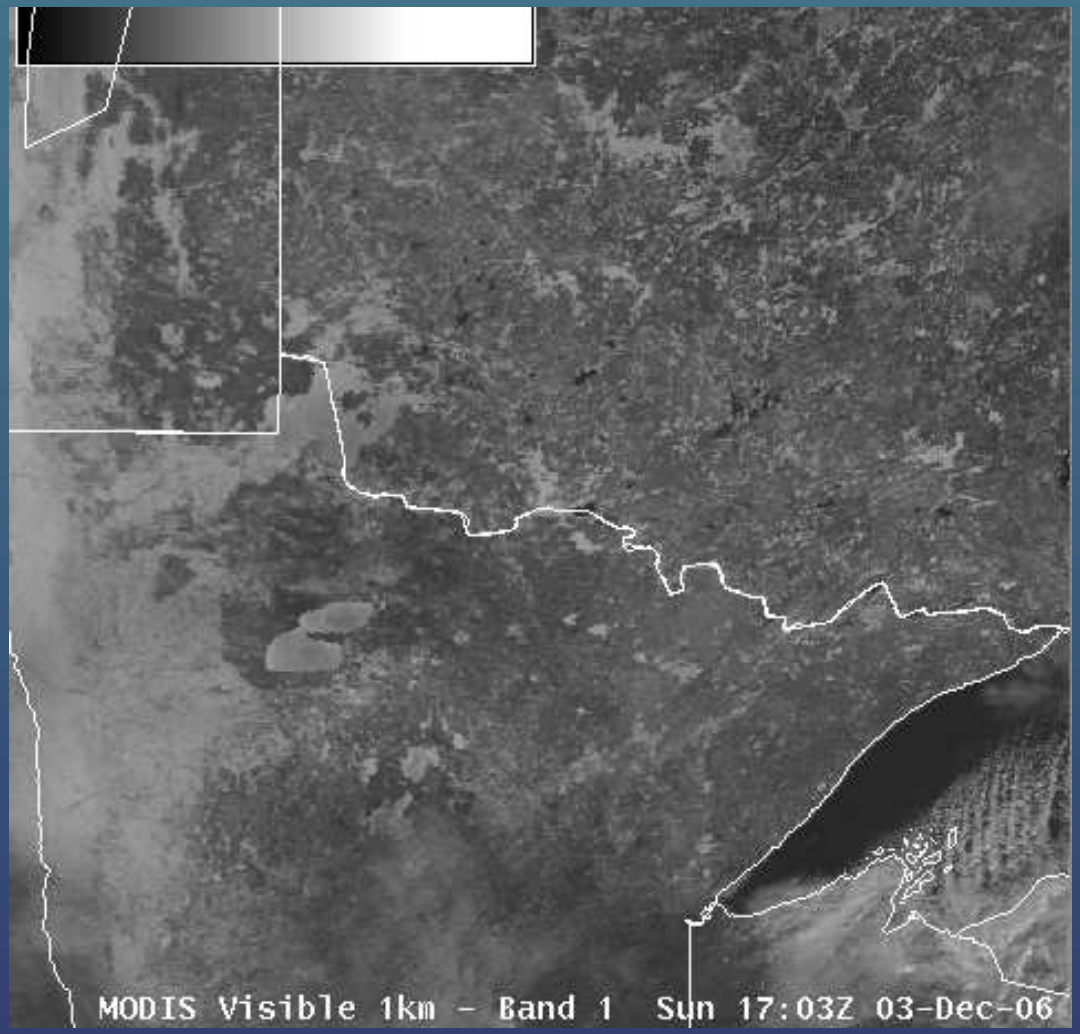
GOES visible channel

MODIS Imagery in AWIPS

Band 1: Visible channel (0.6µm)

MODIS Imagery in AWIPS

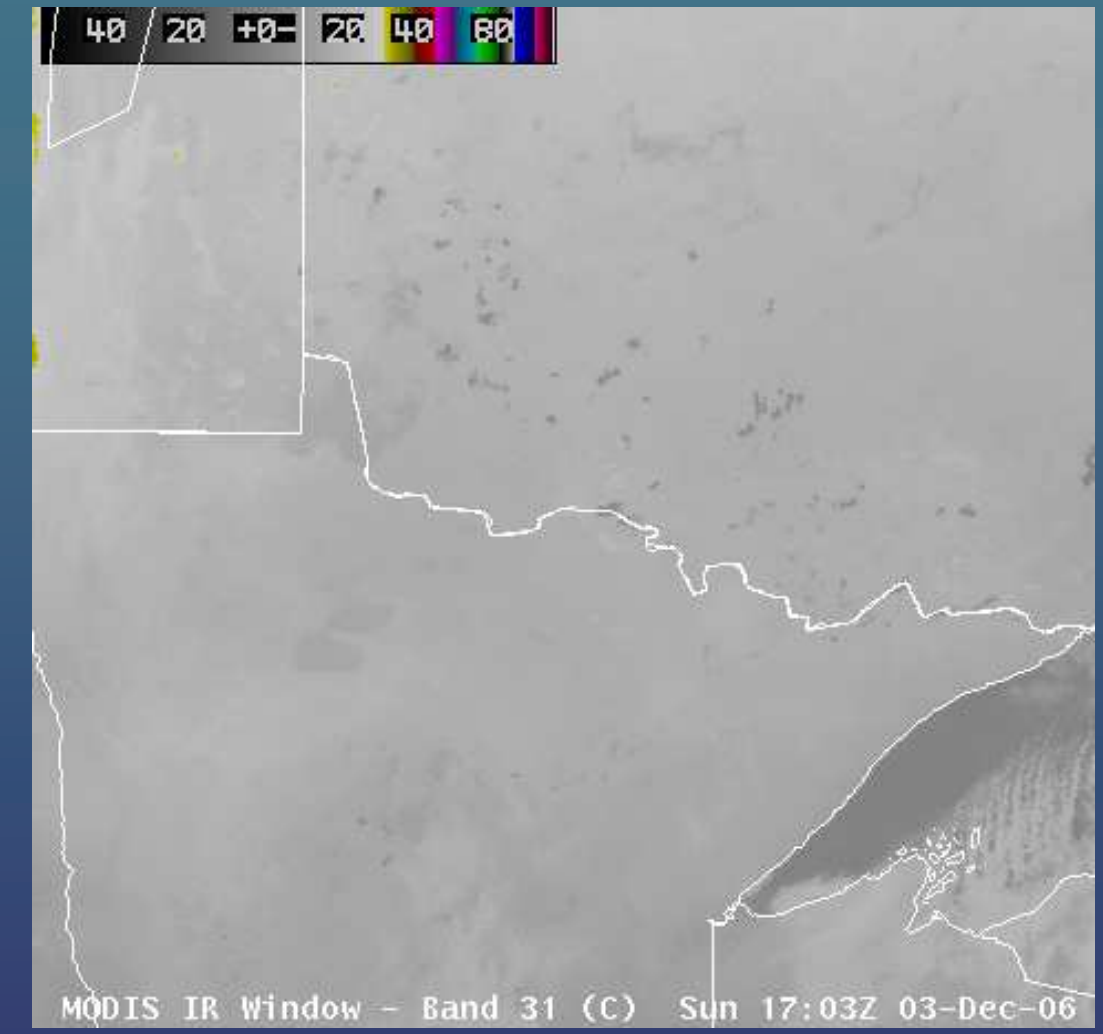
Band 7: Snow/Ice channel (2.1µm)



Snow/ice vs. supercooled water cloud discrimination

MODIS Imagery in AWIPS

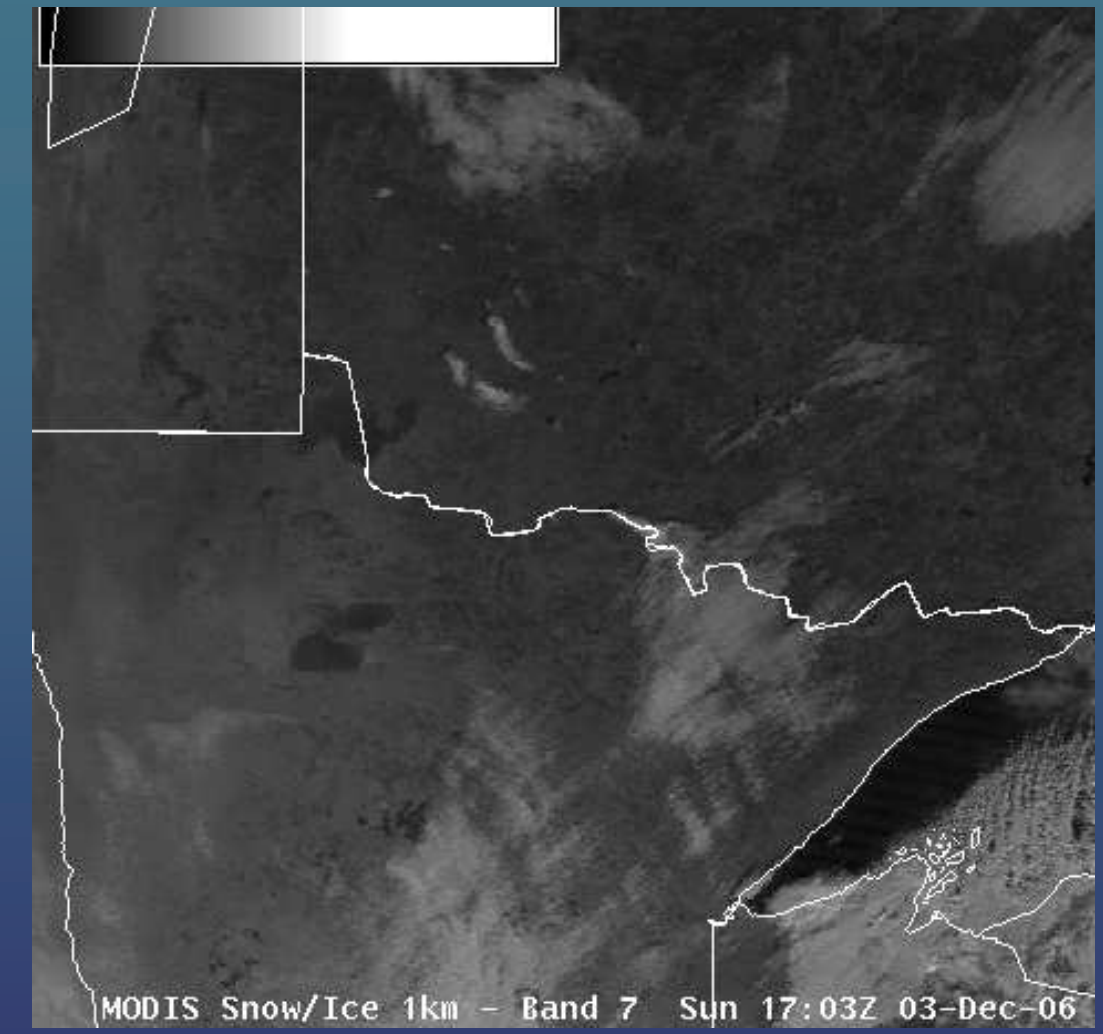
Band 7: Snow/Ice channel (2.1µm)



Snow/ice vs. supercooled water cloud discrimination

MODIS Imagery in AWIPS

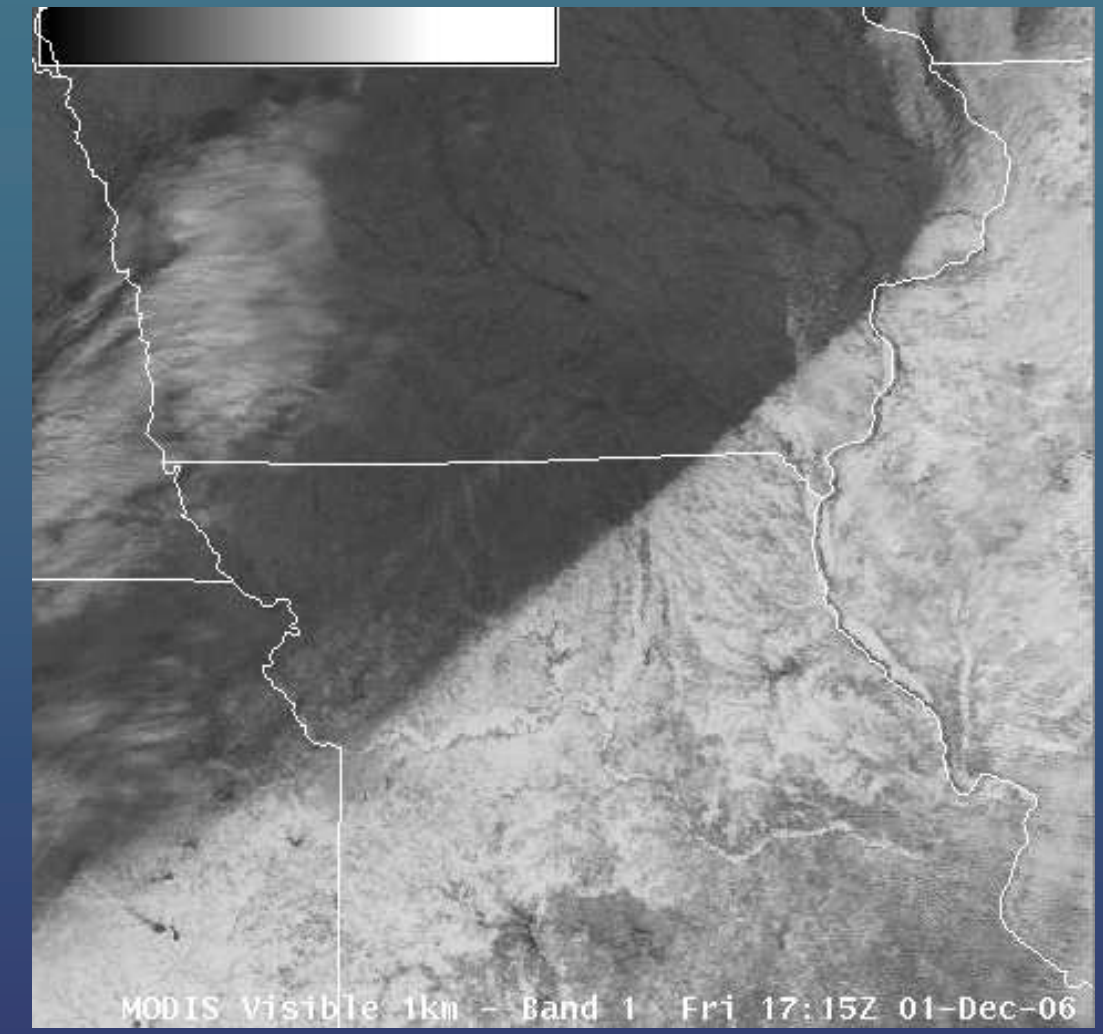
Band 7: Snow/Ice channel (2.1µm)



Snow/ice vs. supercooled water cloud discrimination

MODIS Imagery in AWIPS

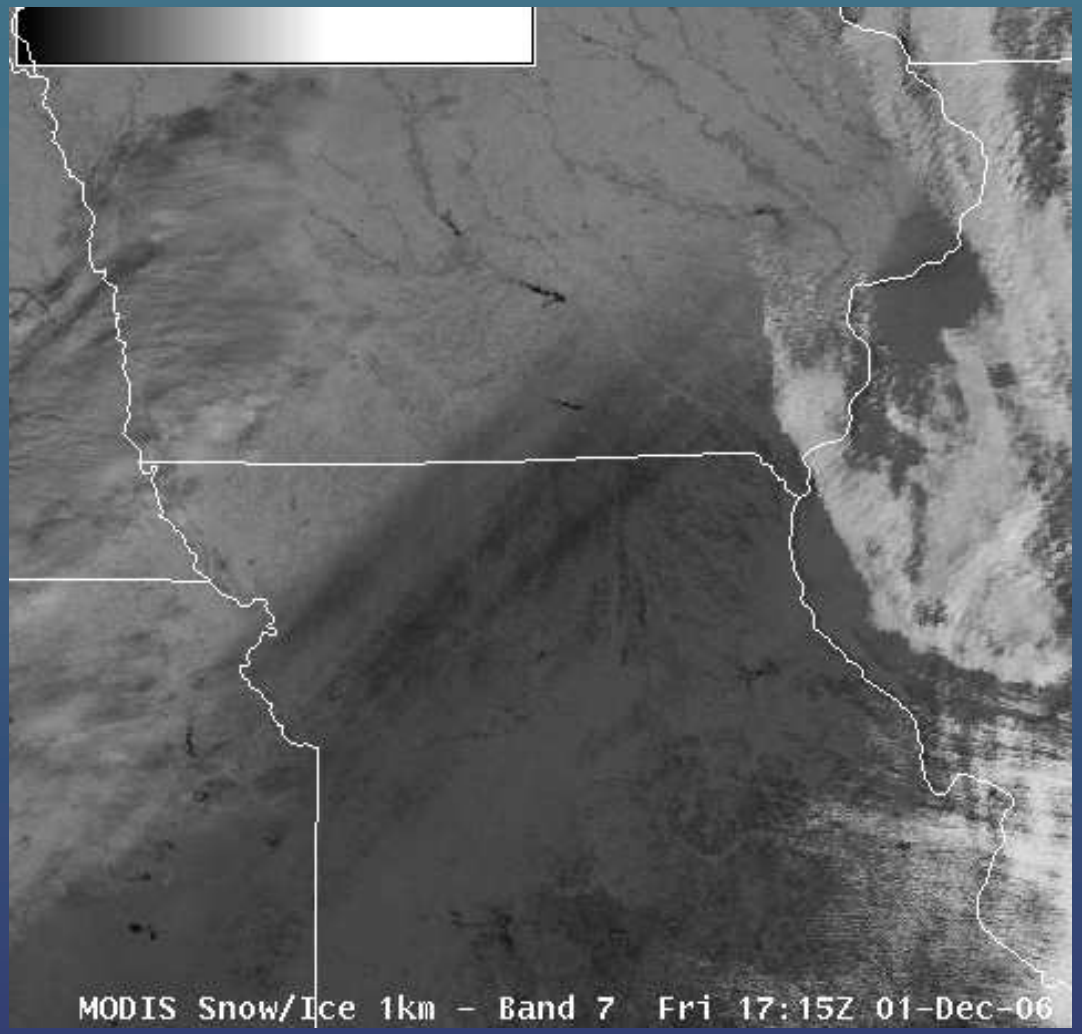
Band 7: Snow/Ice channel (2.1µm)



Snow/ice vs. supercooled water cloud discrimination

MODIS Imagery in AWIPS

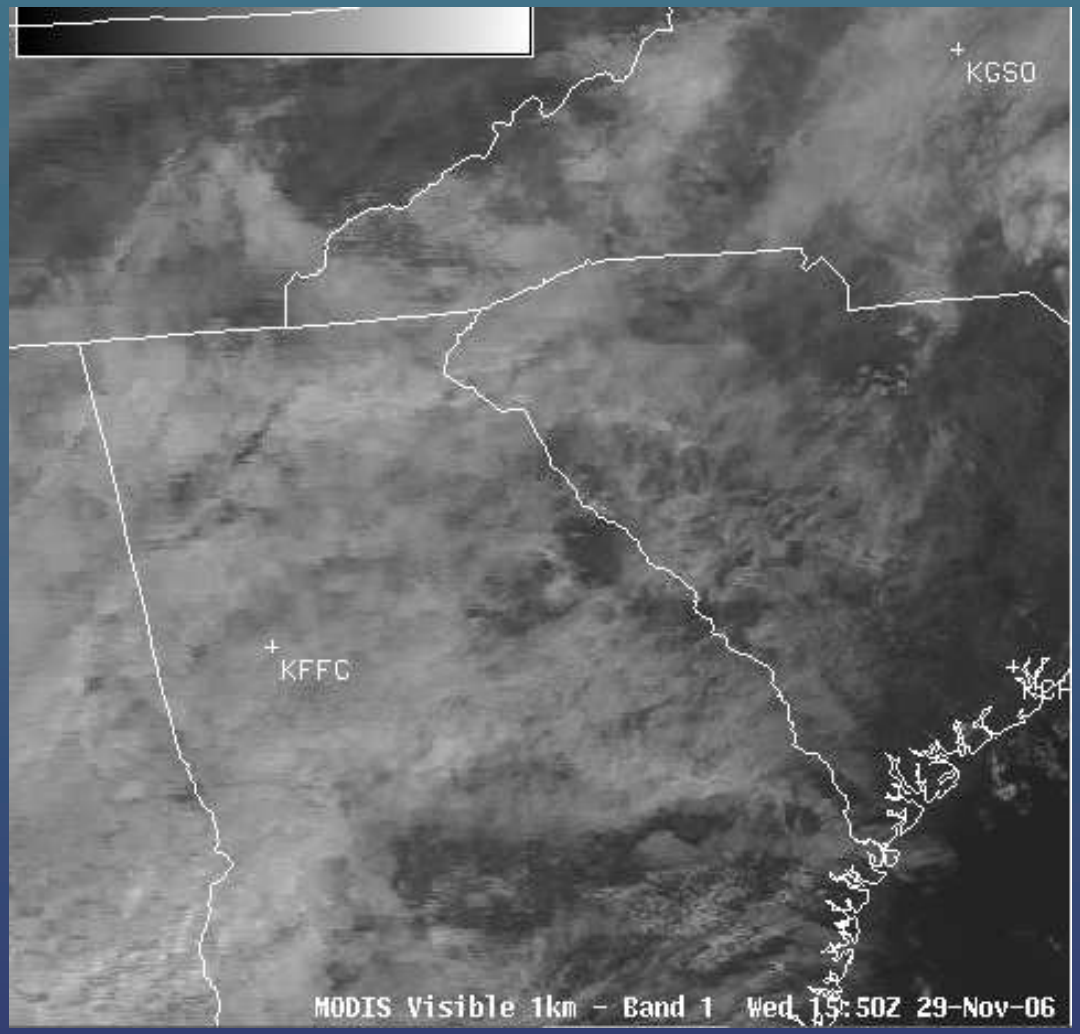
Band 7: Snow/Ice channel (2.1µm)



Snow/ice vs. supercooled water cloud discrimination

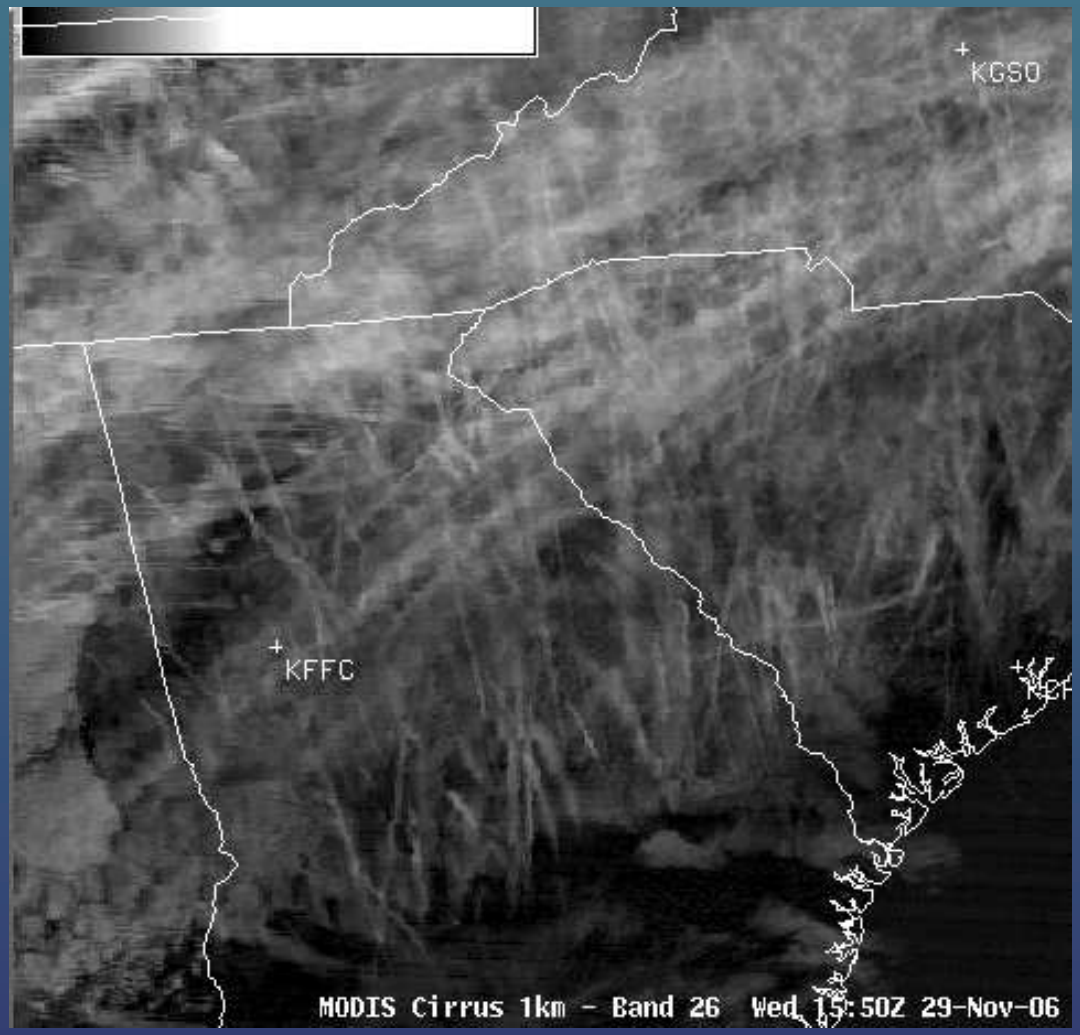
MODIS Imagery in AWIPS

Band 26: Cirrus detection (1.3µm)



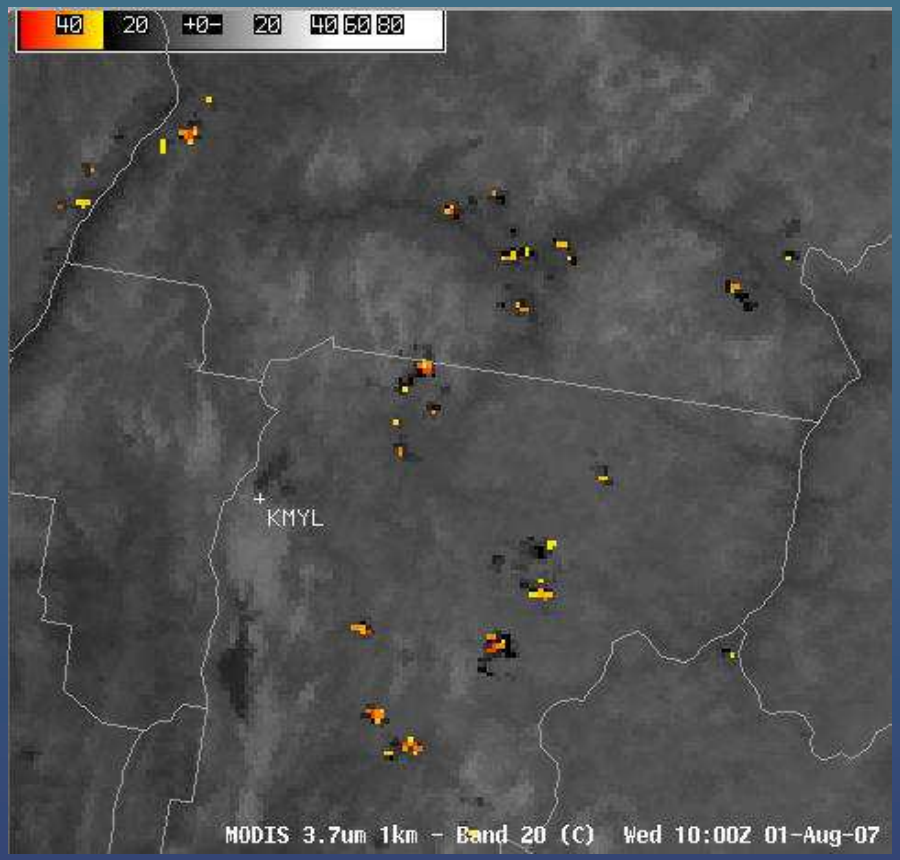
MODIS Imagery in AWIPS

Band 26: Cirrus detection (1.3µm)

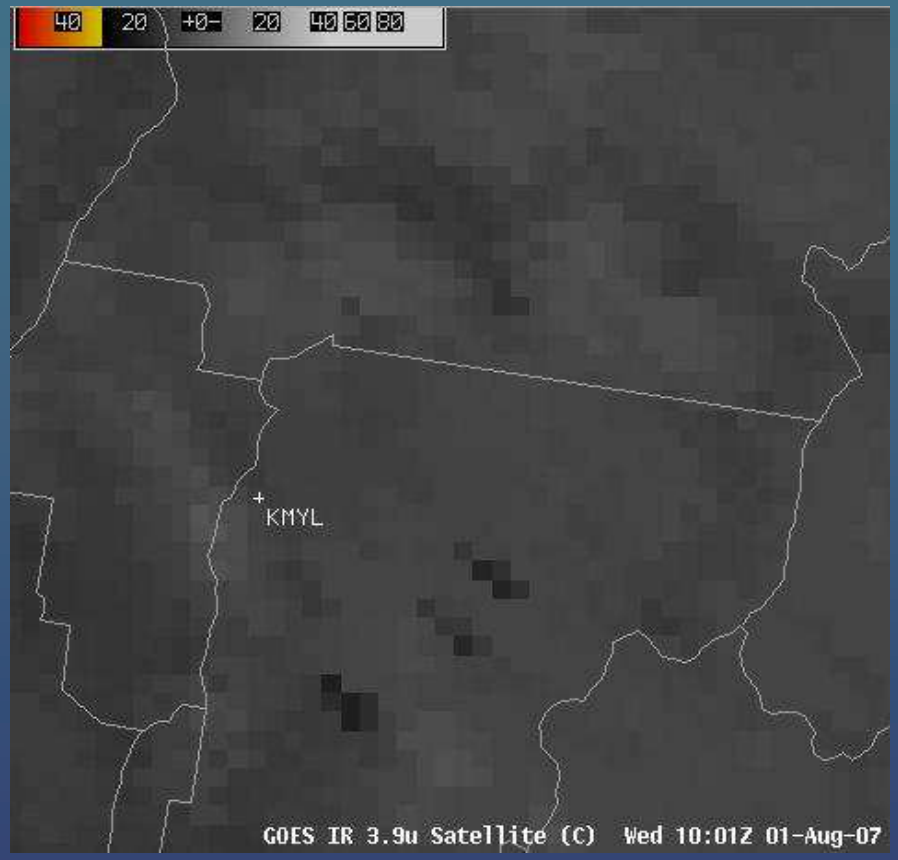


MODIS Imagery in AWIPS

Band 20: Shortwave IR (3.7µm)



1-km MODIS

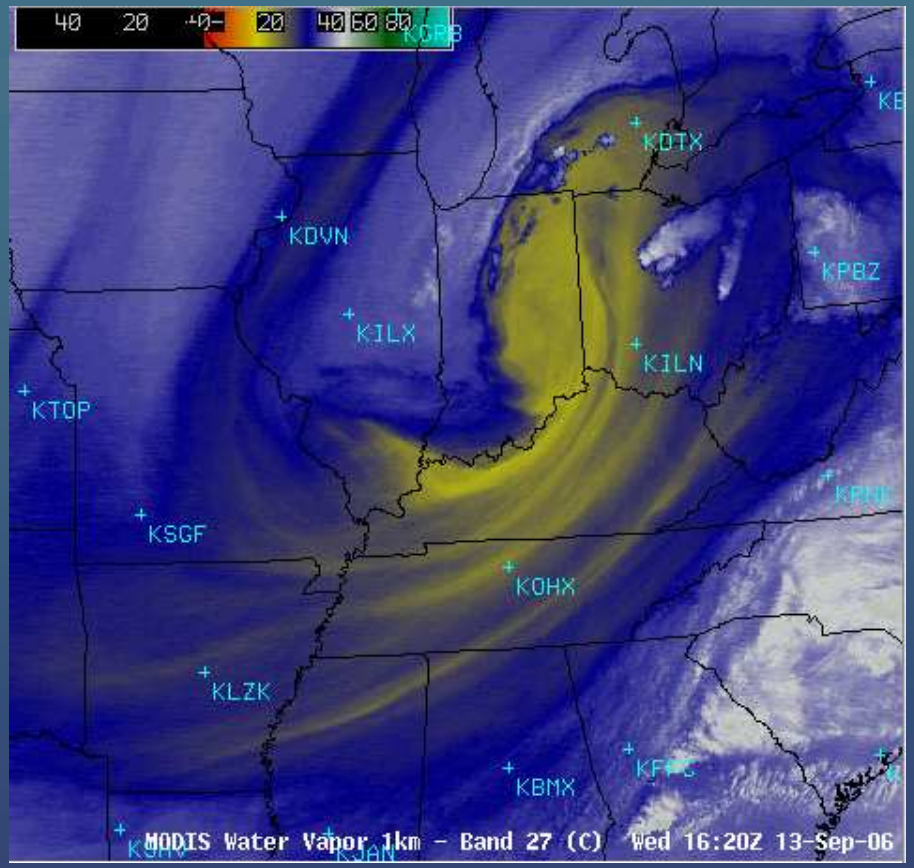


4-km GOES

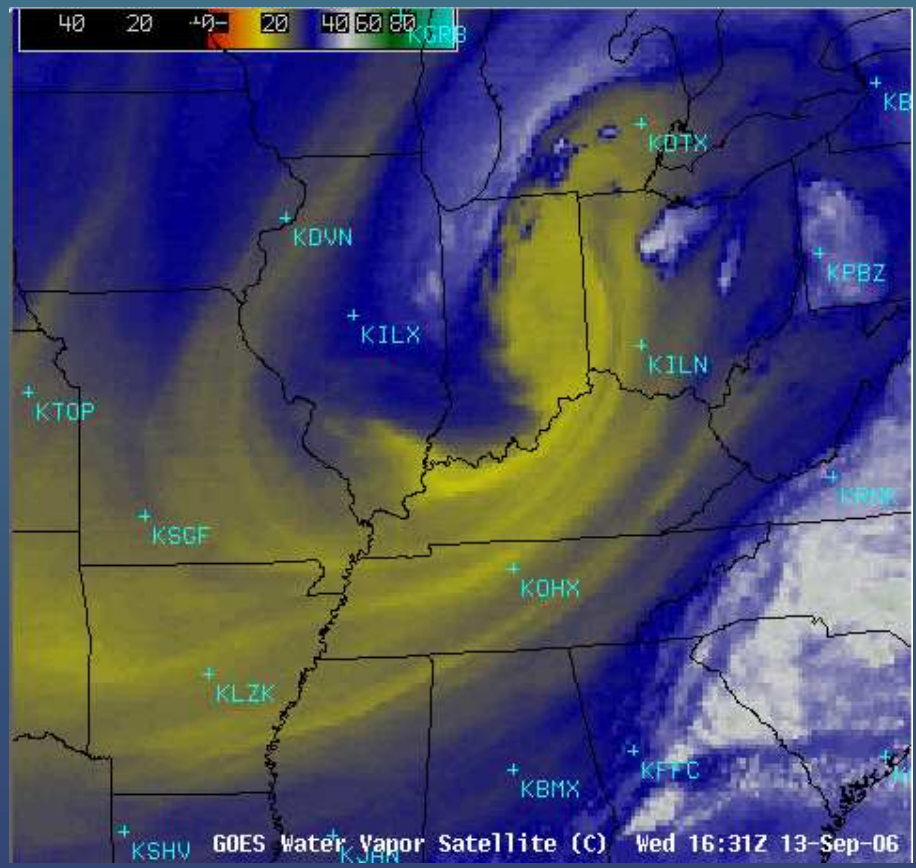
Improved fire detection capability

MODIS Imagery in AWIPS

Band 27: Water vapor (6.7µm)



1-km MODIS

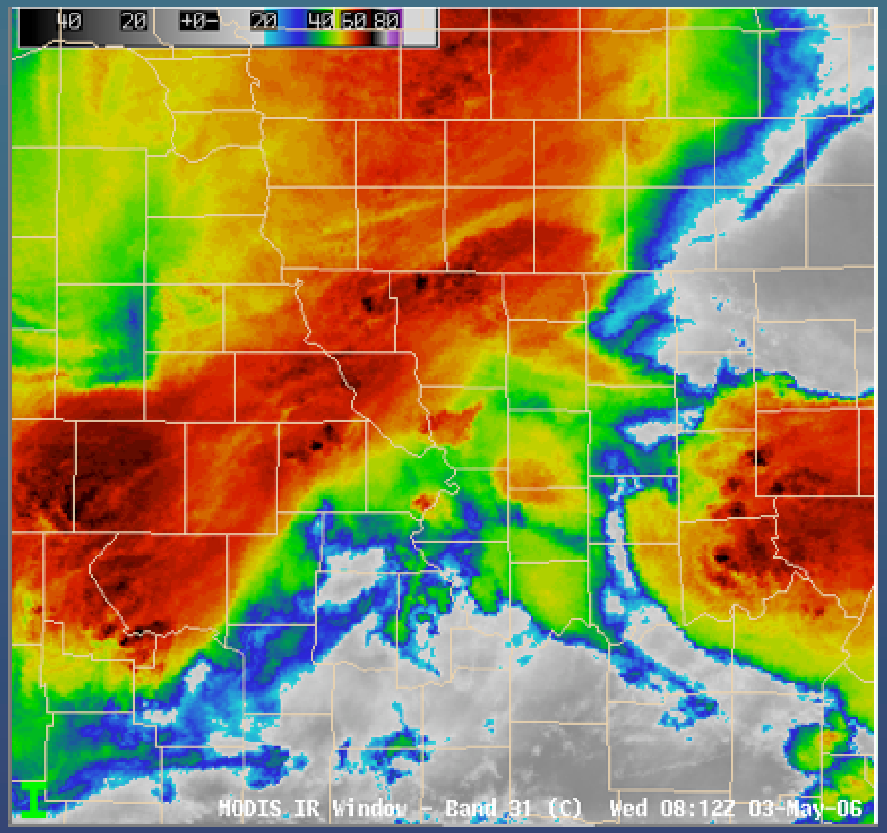


4-km GOES

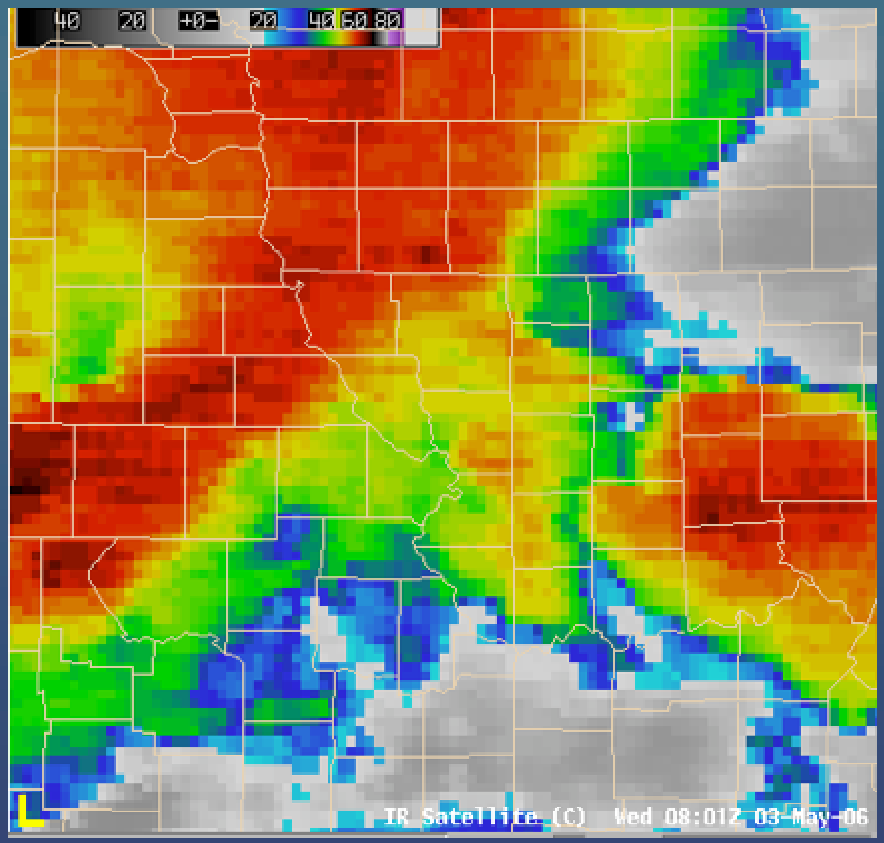
Improved feature identification (jet streaks, turbulence, etc)

MODIS Imagery in AWIPS

Band 31: IR window (11.0µm)



1-km MODIS

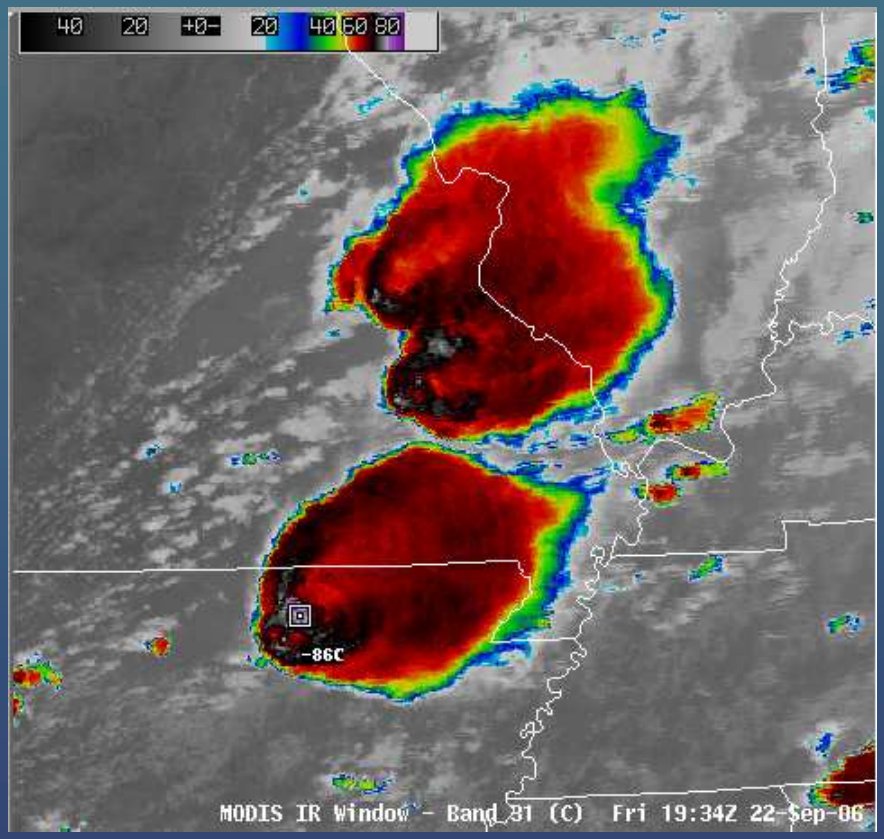


4-km GOES

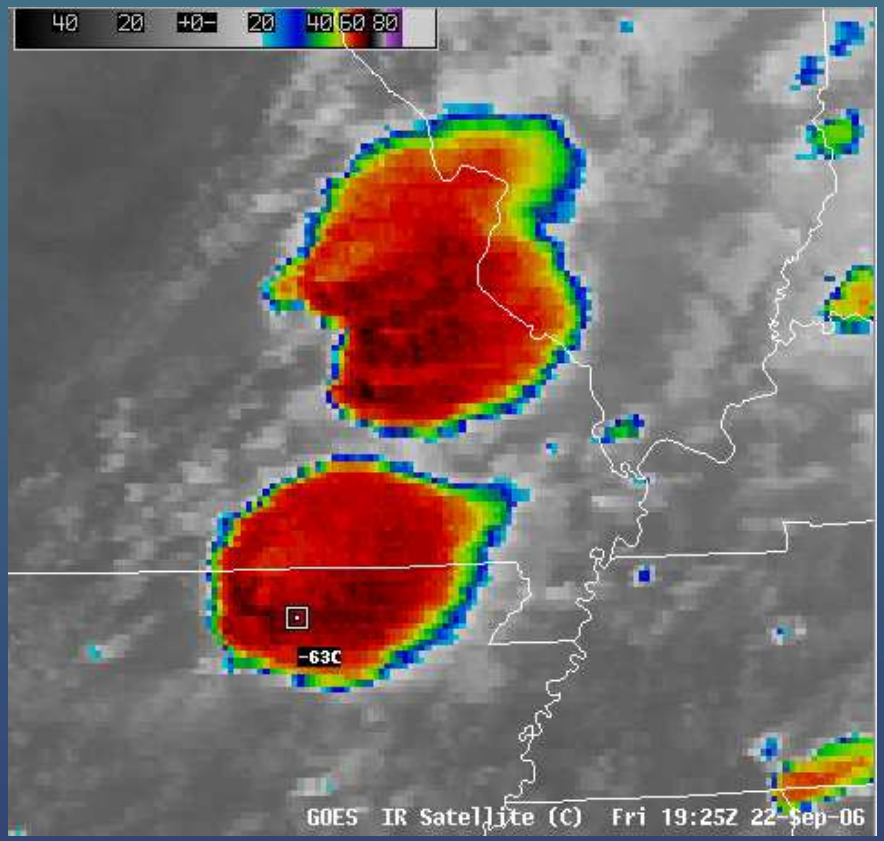
Improved feature identification (overshooting tops, enhanced-v)

MODIS Imagery in AWIPS

Band 31: IR window (11.0µm)



1-km MODIS

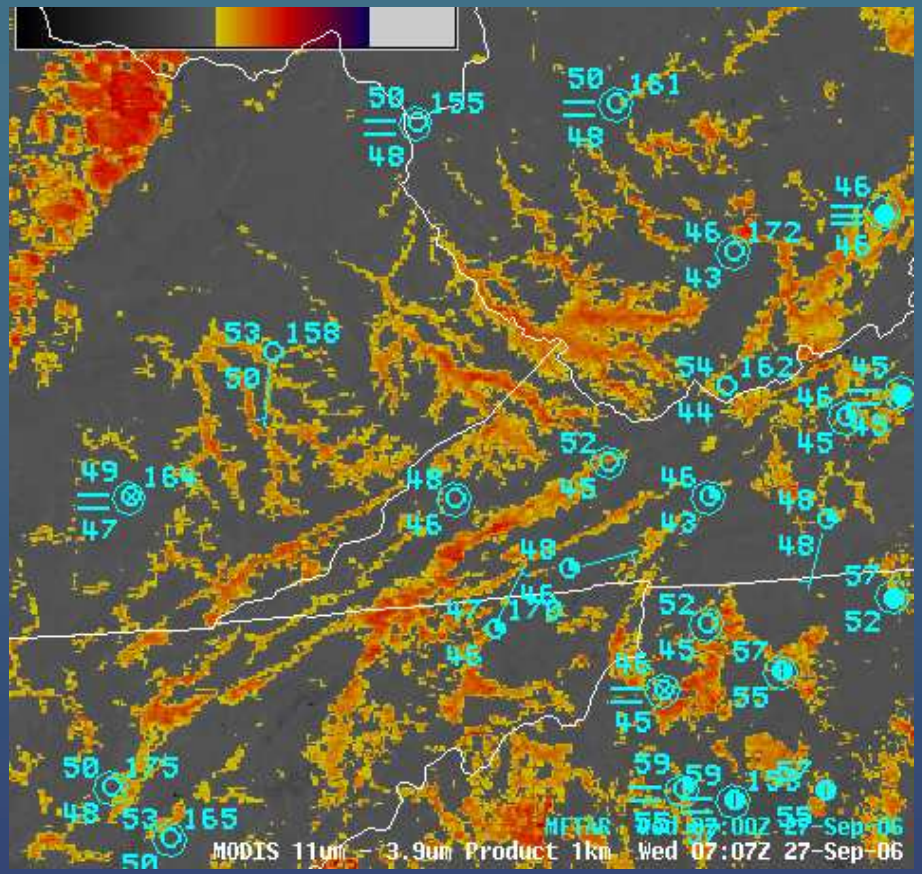


4-km GOES

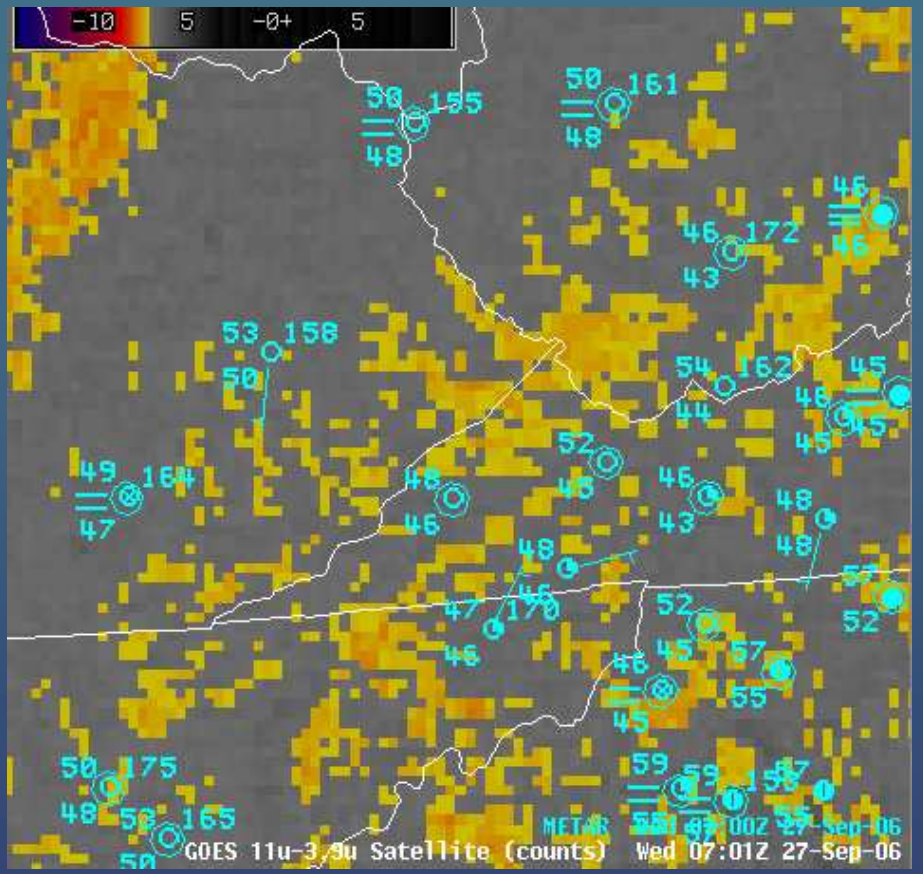
Improved feature identification (overshooting tops, enhanced-v)

MODIS Imagery in AWIPS

Fog/stratus product (11.0µm - 3.7µm)



1-km MODIS

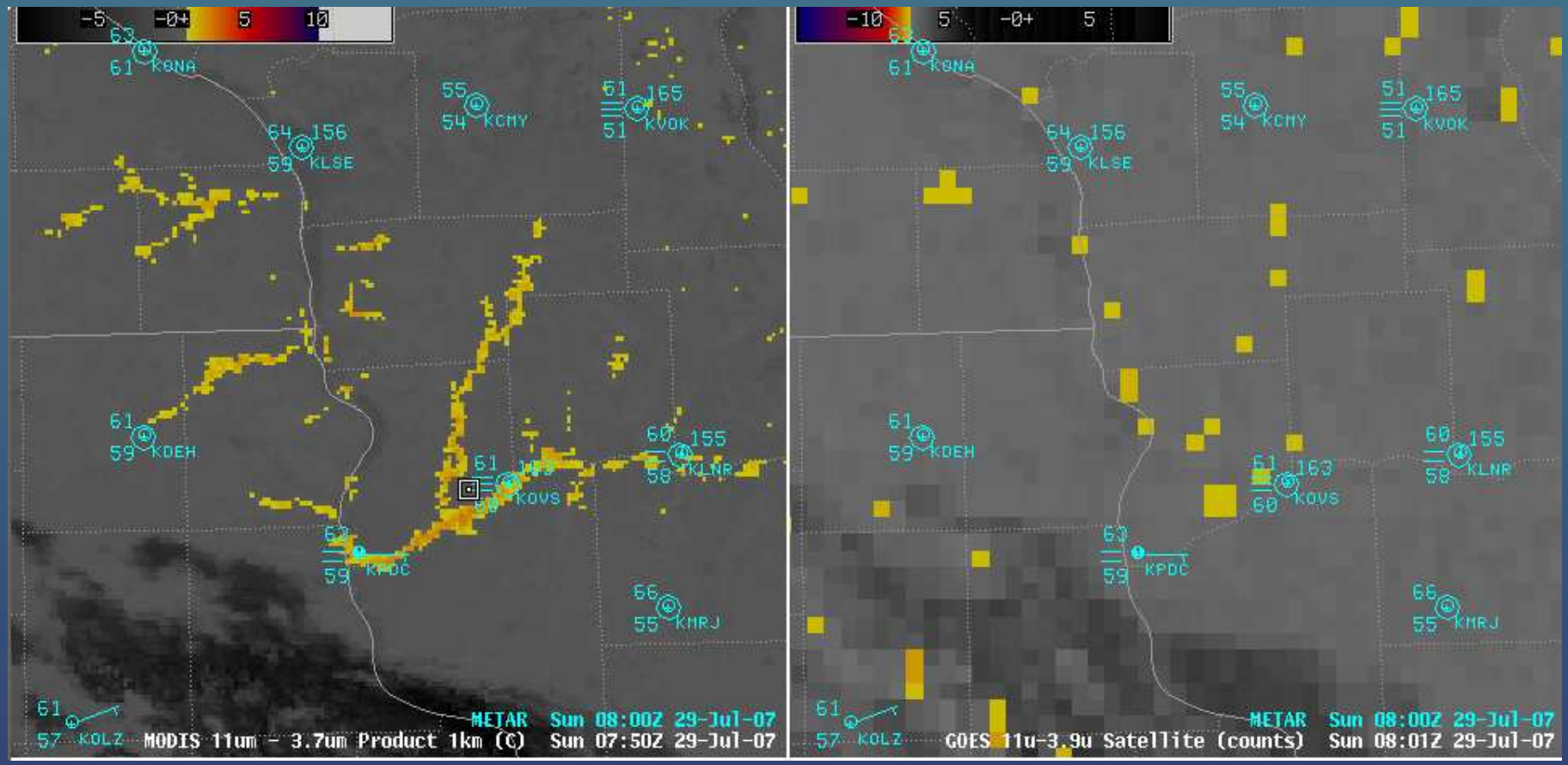


4-km GOES

Improved fog/stratus detection capability

MODIS Imagery in AWIPS

Fog/stratus product (11.0µm - 3.7µm)



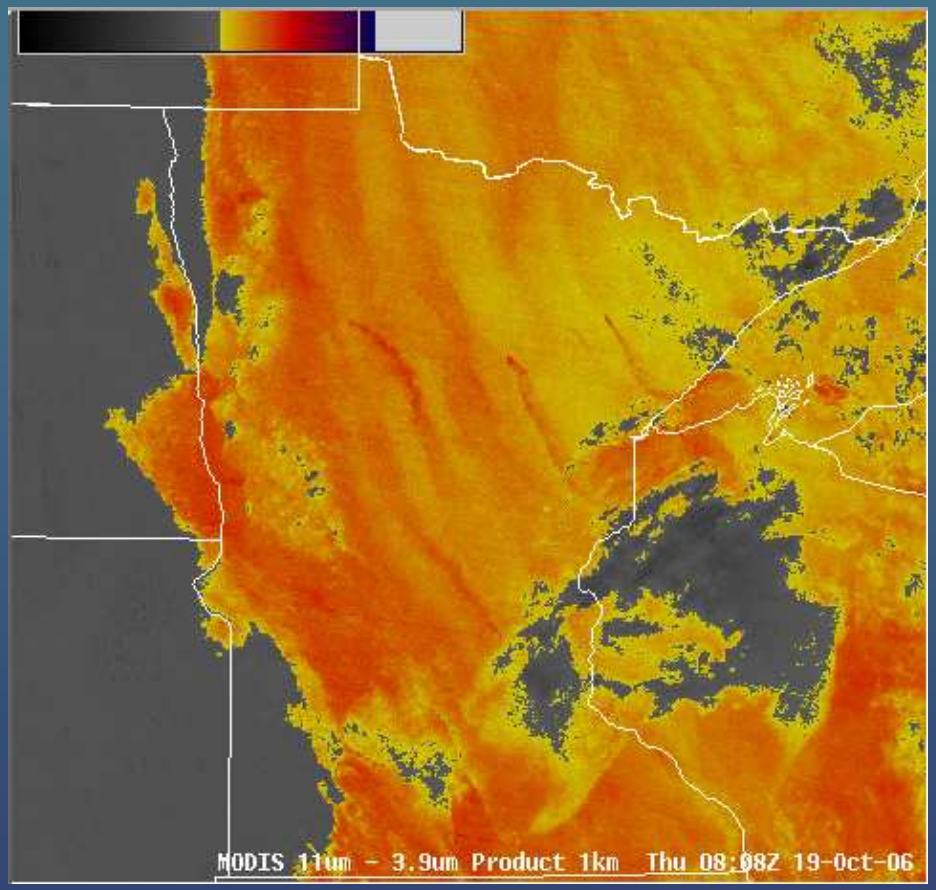
1-km MODIS

4-km GOES

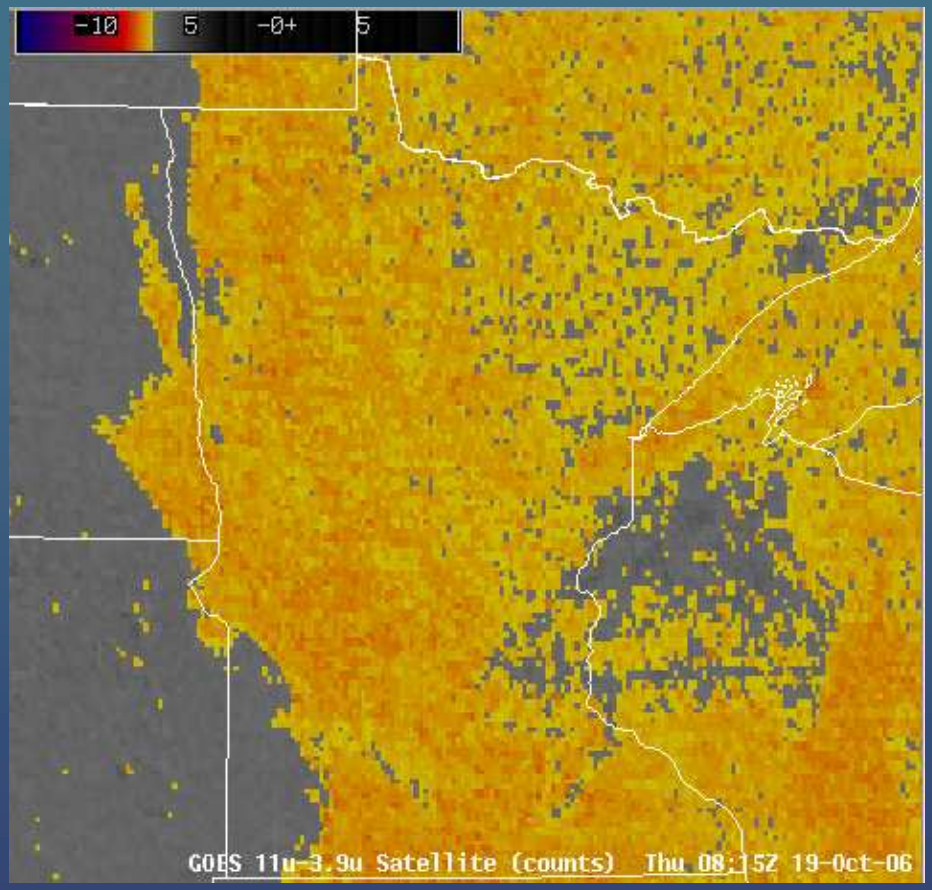
Improved fog/stratus detection capability

MODIS Imagery in AWIPS

Fog/stratus product (11.0µm - 3.7µm)



1-km MODIS

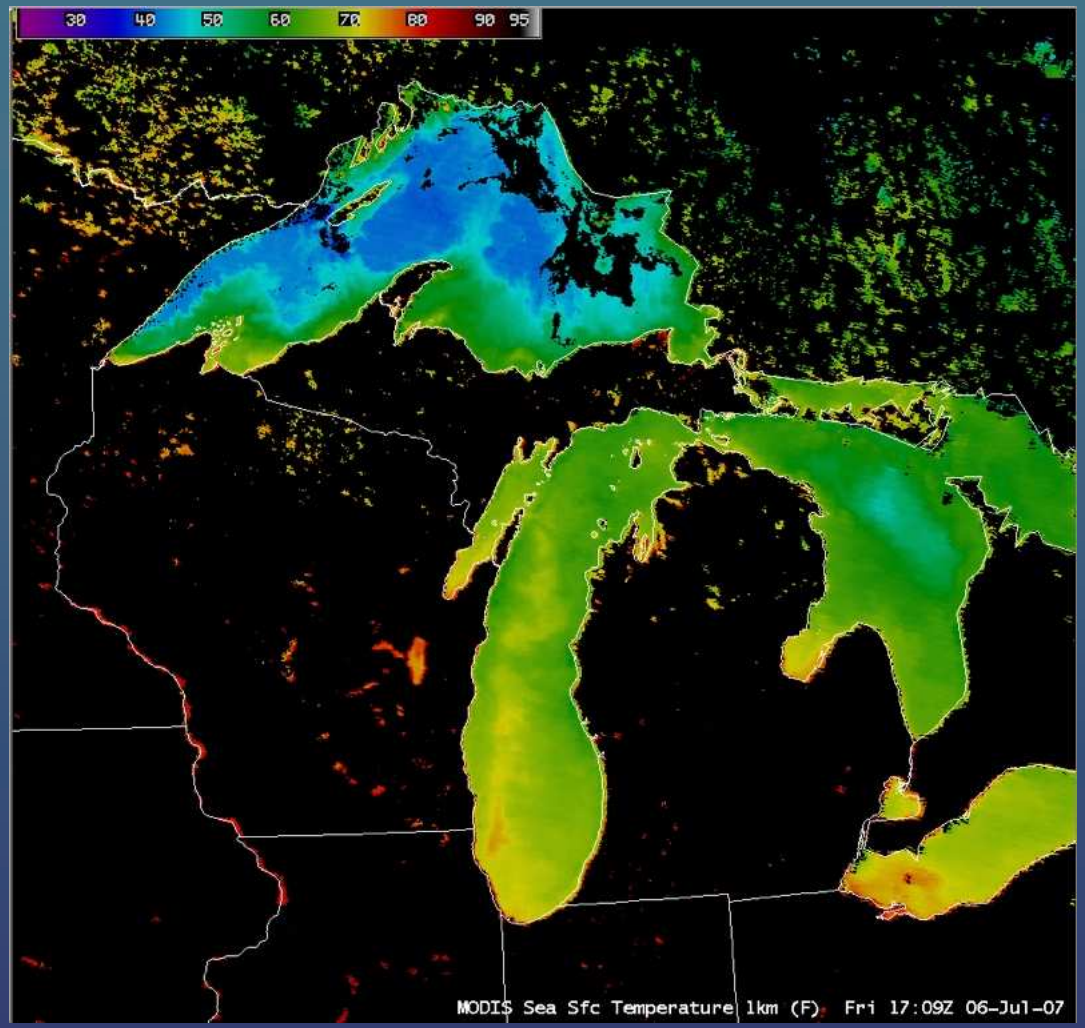


4-km GOES

Improved fog/stratus detection capability

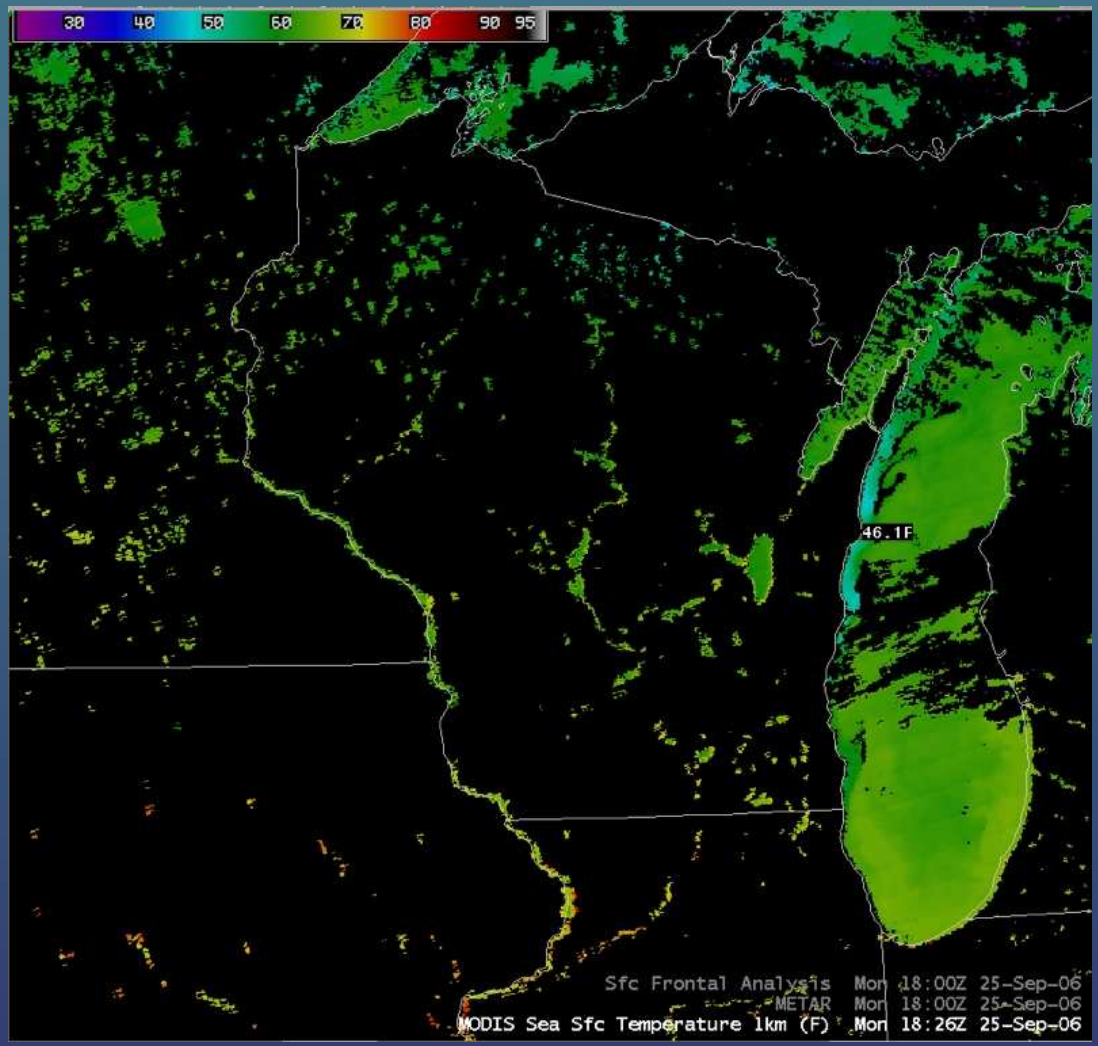
MODIS Imagery in AWIPS

Sea surface temperature



MODIS Imagery in AWIPS

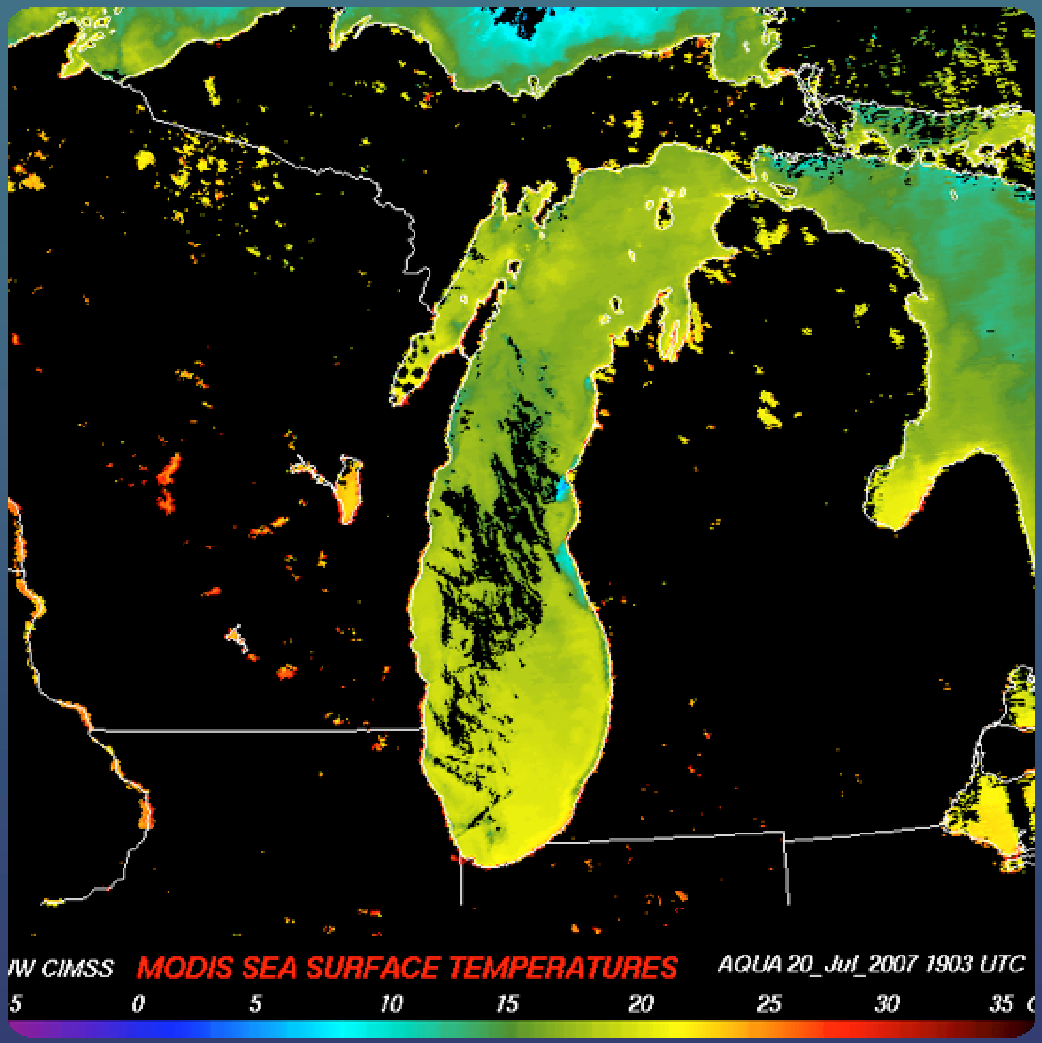
Sea surface temperature



Identify areas of upwelling

MODIS Imagery in AWIPS

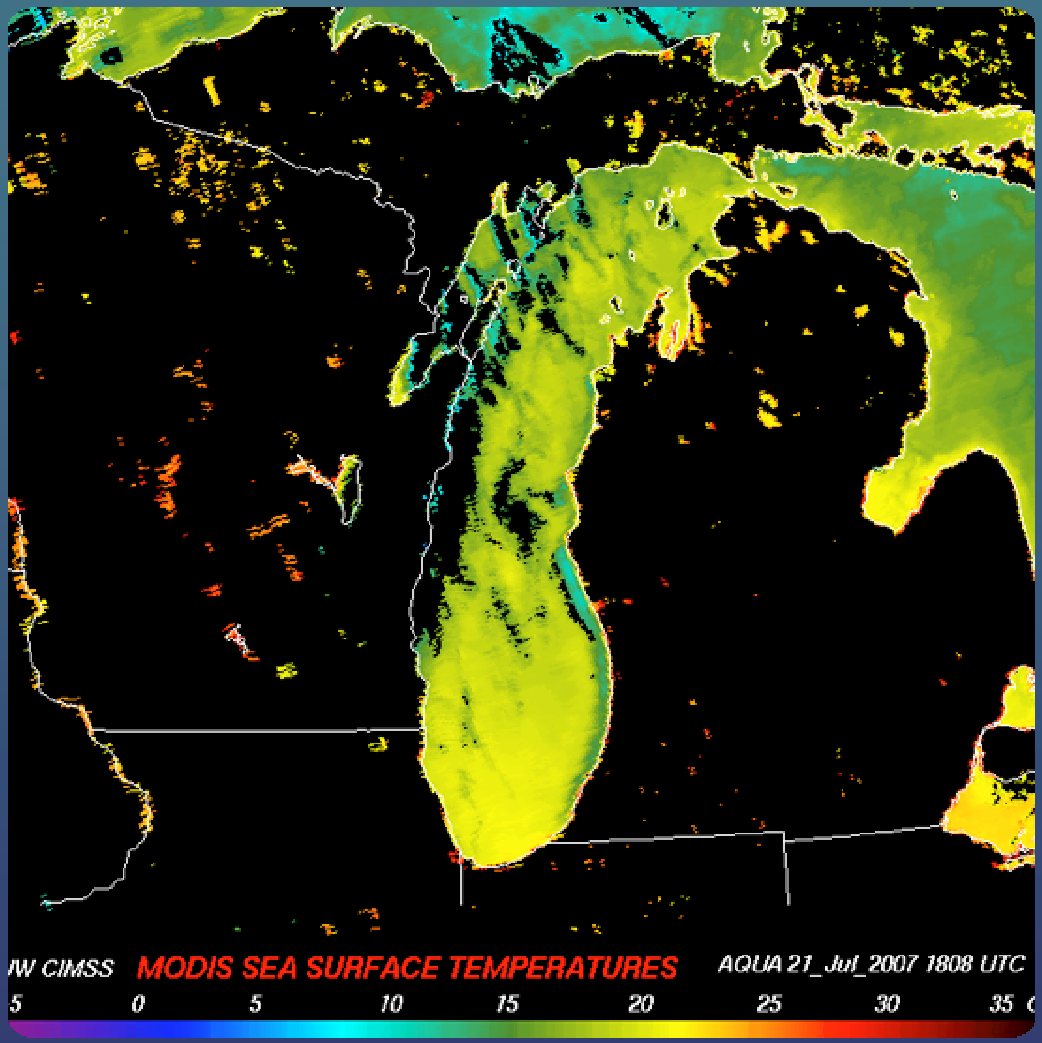
Sea surface temperature



Identify areas of rapid SST increase

MODIS Imagery in AWIPS

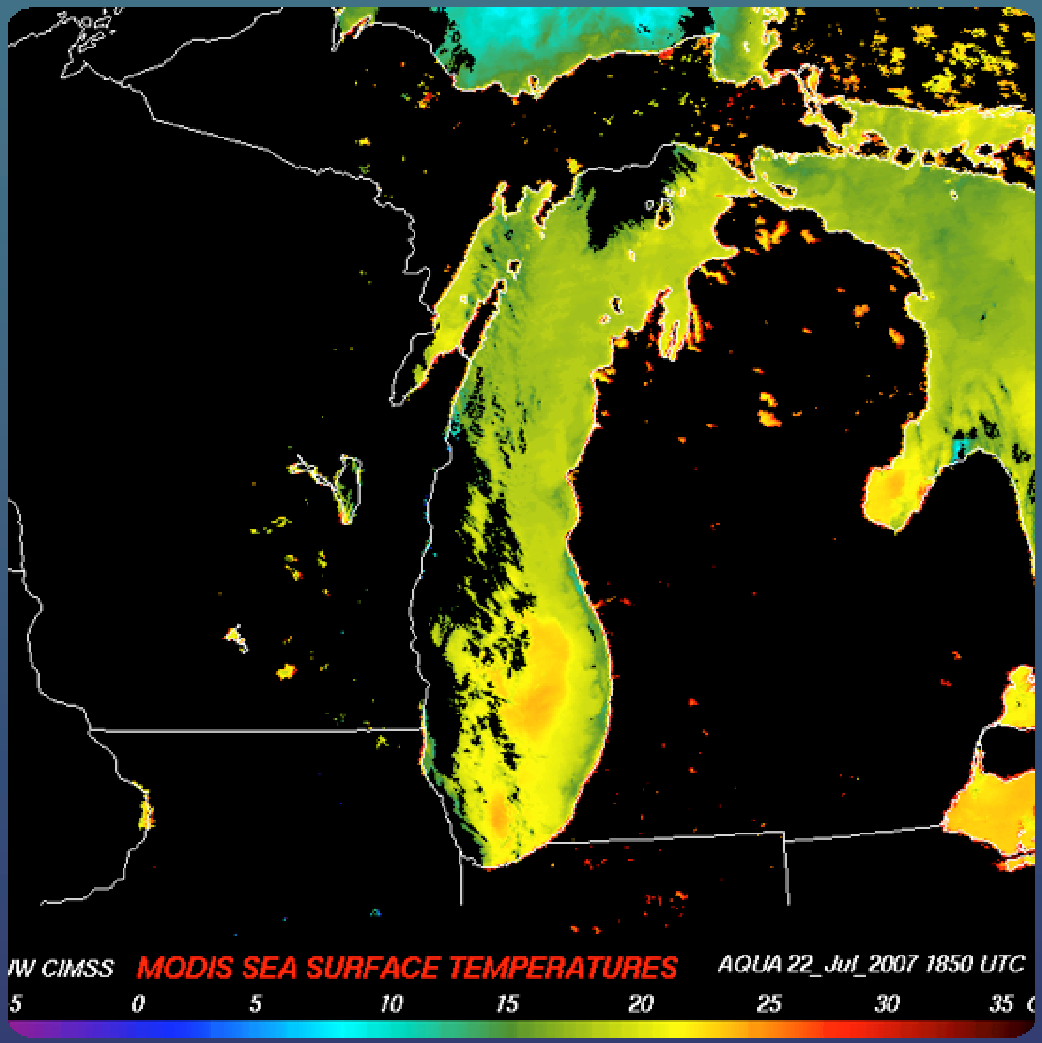
Sea surface temperature



Identify areas of rapid SST increase

MODIS Imagery in AWIPS

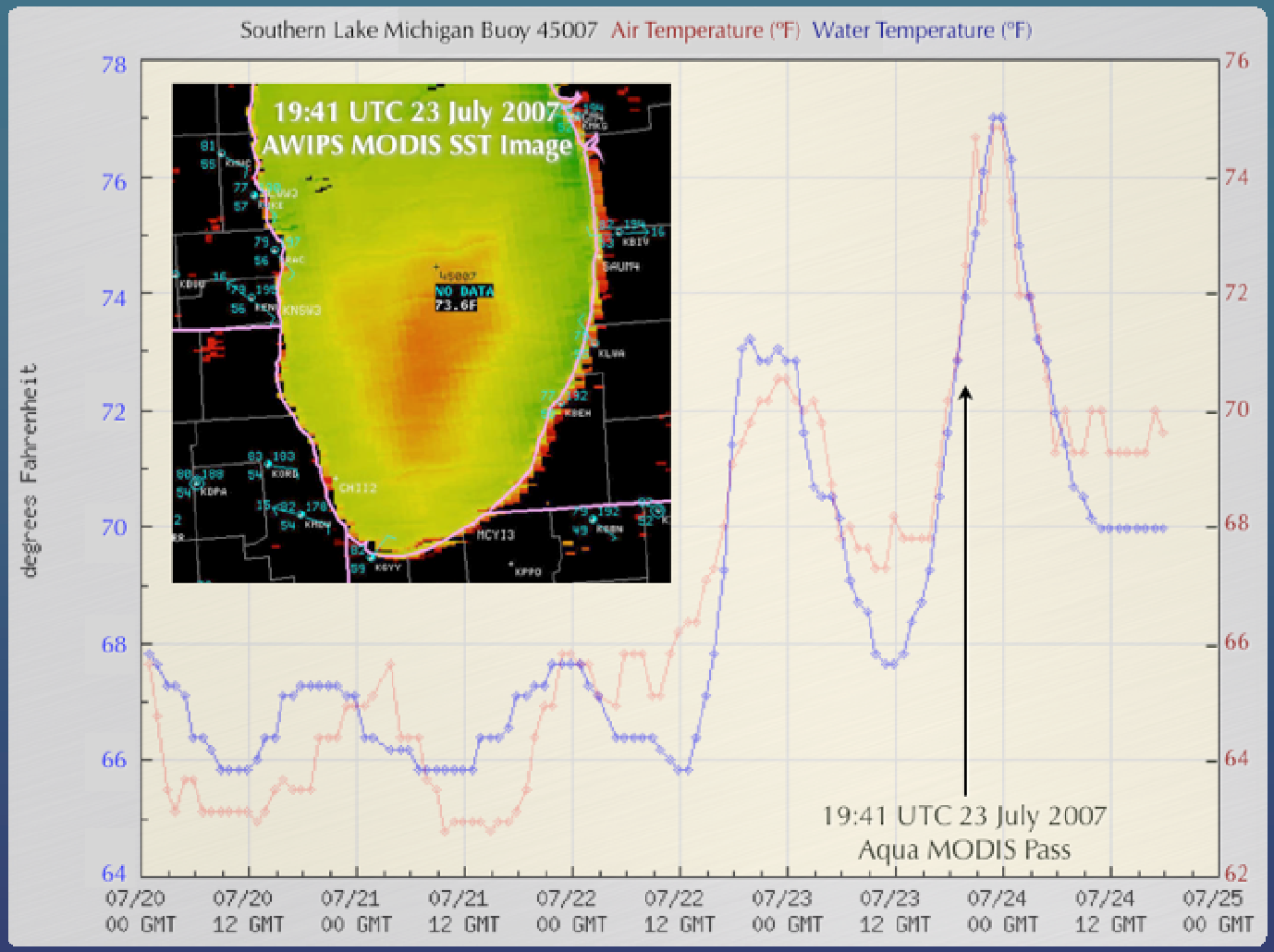
Sea surface temperature



Identify areas of rapid SST increase

MODIS Imagery in AWIPS

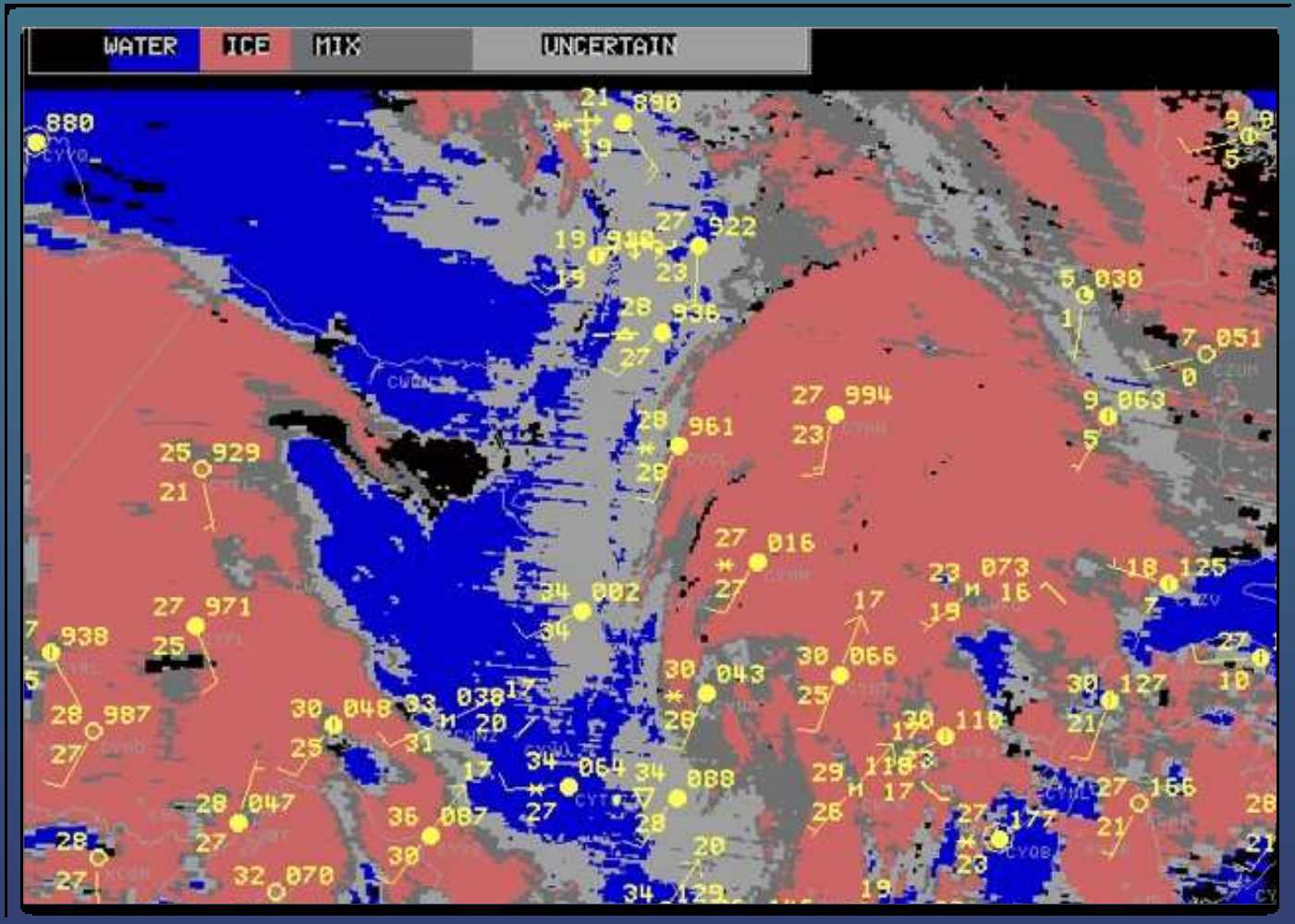
Sea surface temperature



Identify areas of rapid SST increase

MODIS Imagery in AWIPS

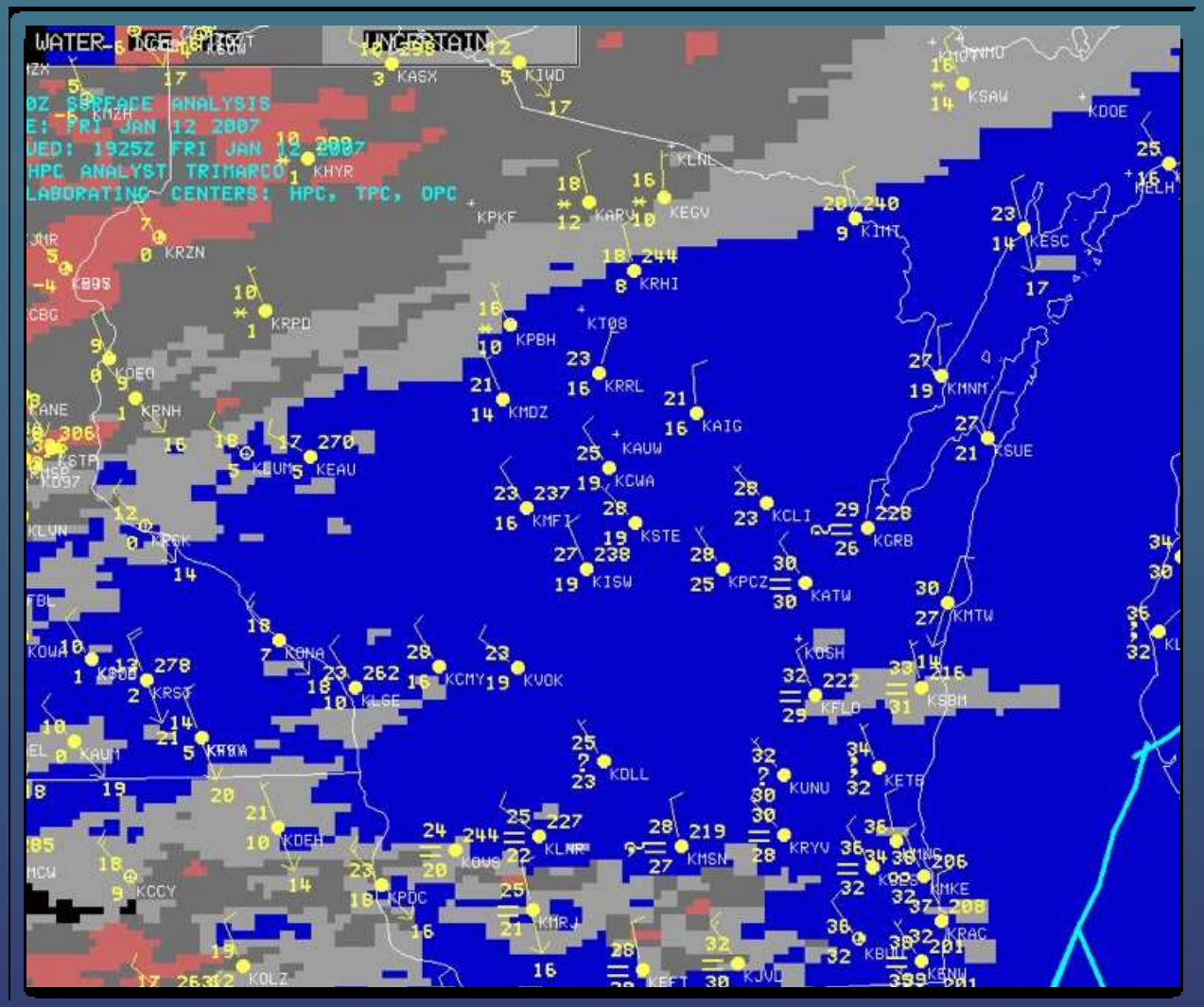
Cloud phase product



Can aid in the *precipitation type* forecast problem

MODIS Imagery in AWIPS

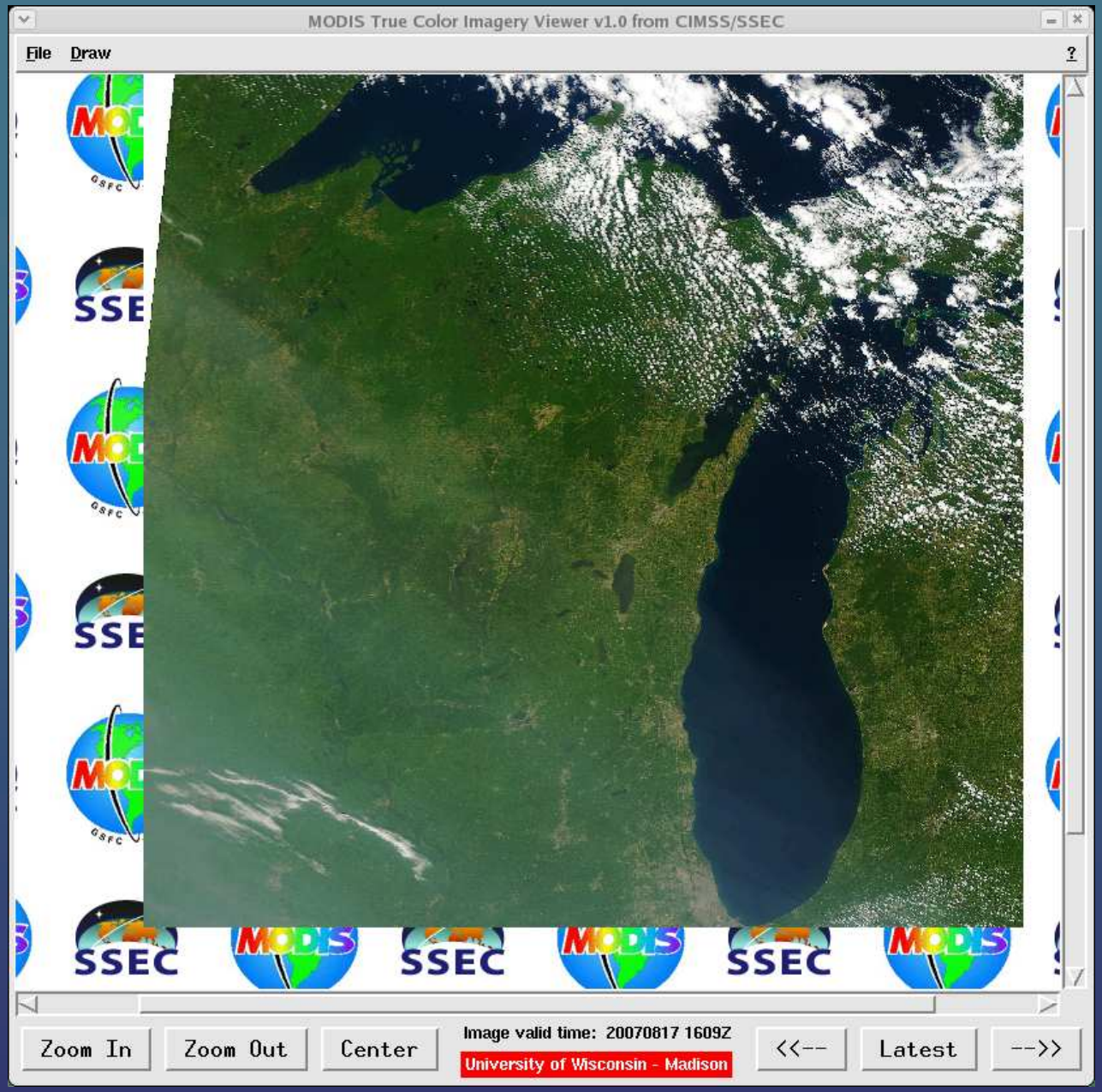
Cloud phase product



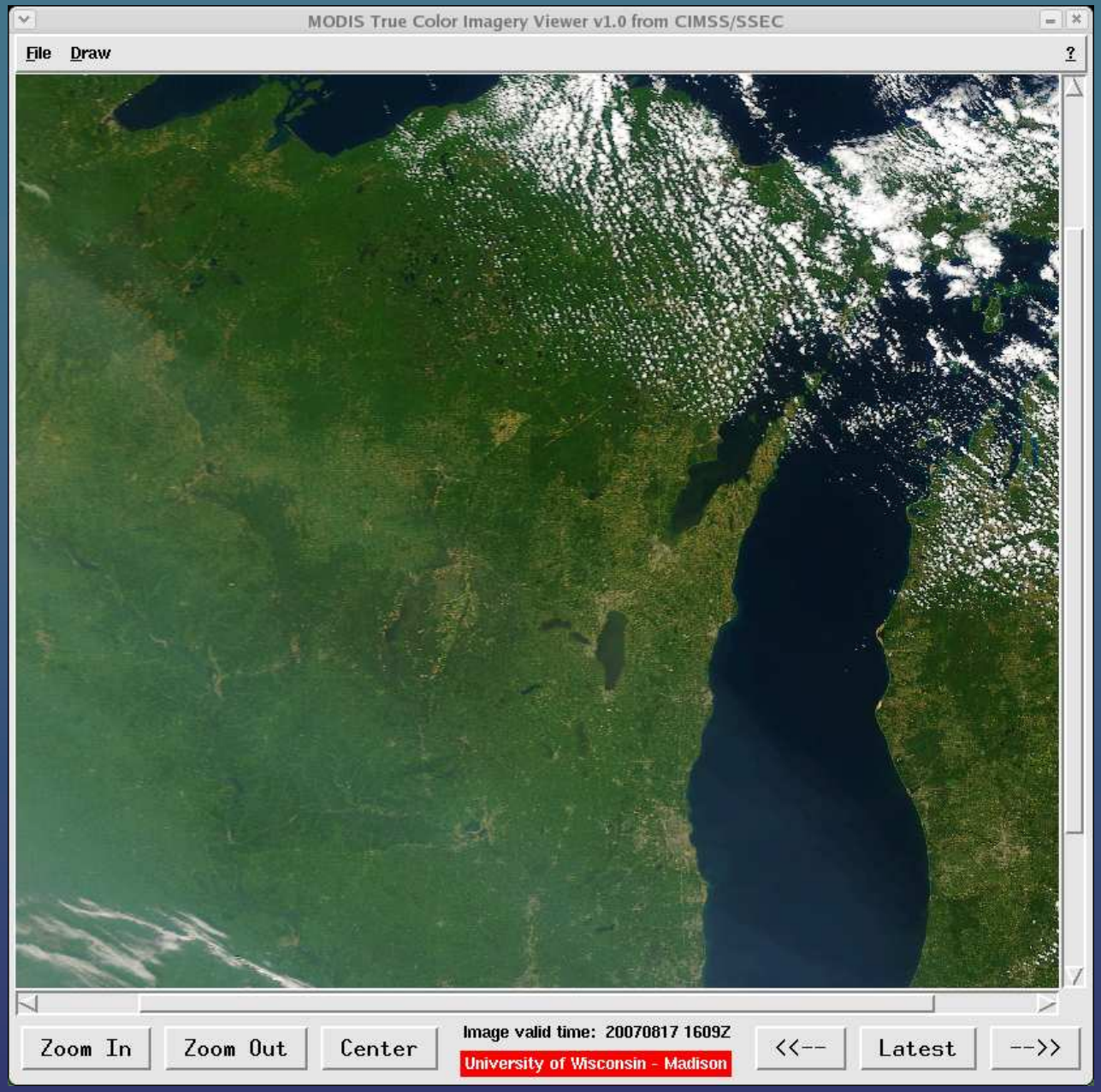
Can aid in the *precipitation type* forecast problem

MODIS True Color Imagery Viewer

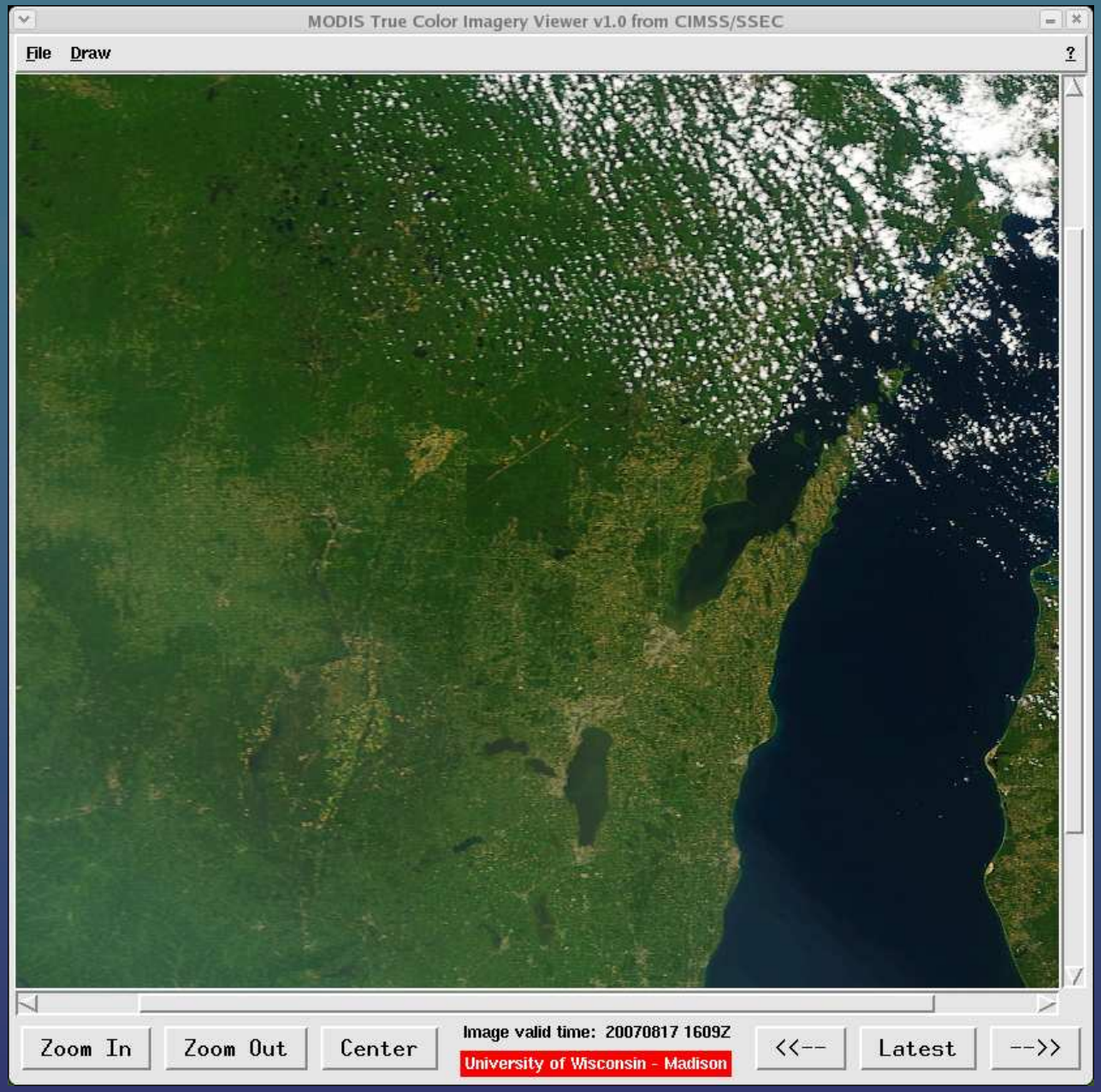
MODIS True Color Imagery Viewer



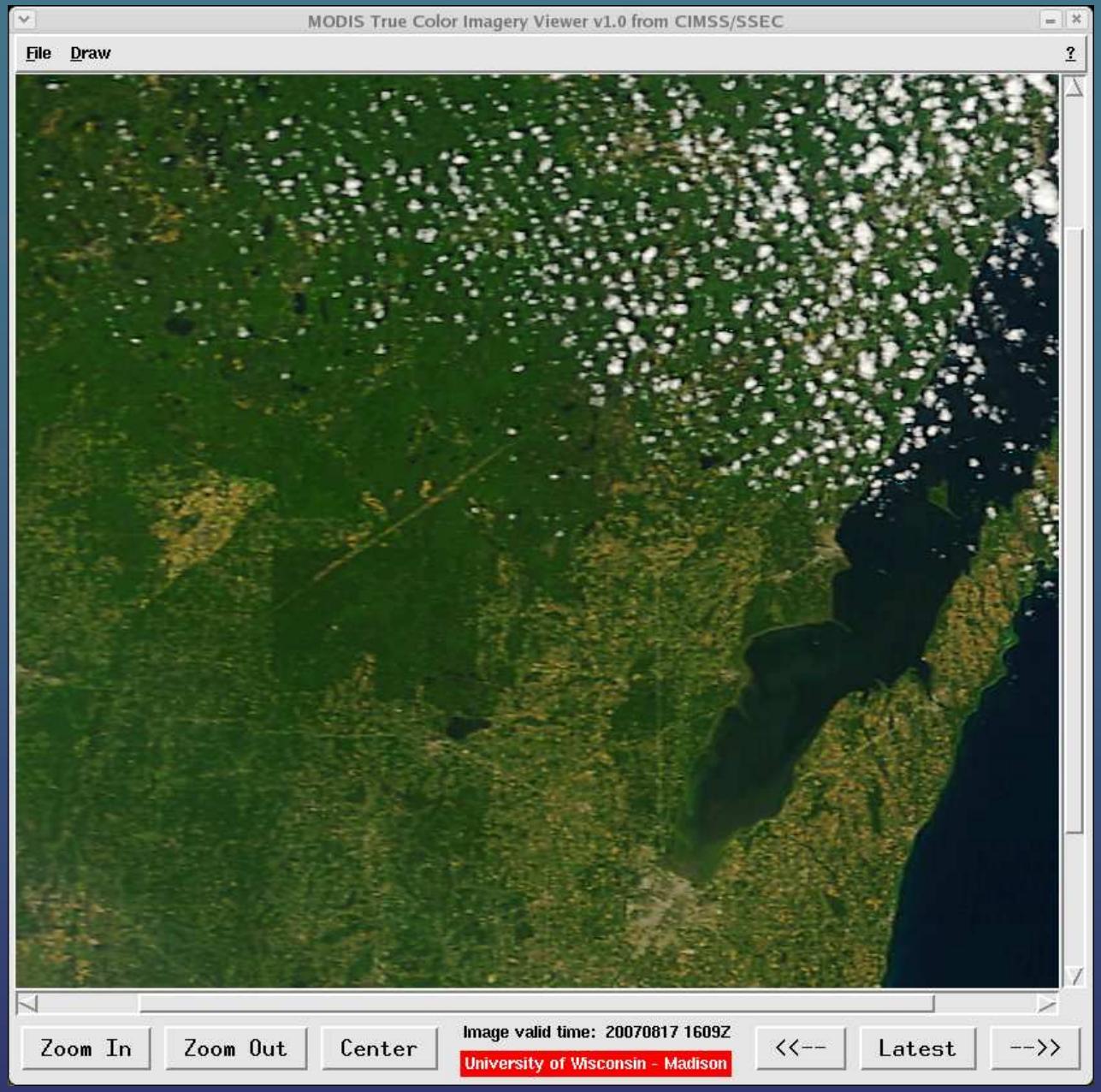
MODIS True Color Imagery Viewer



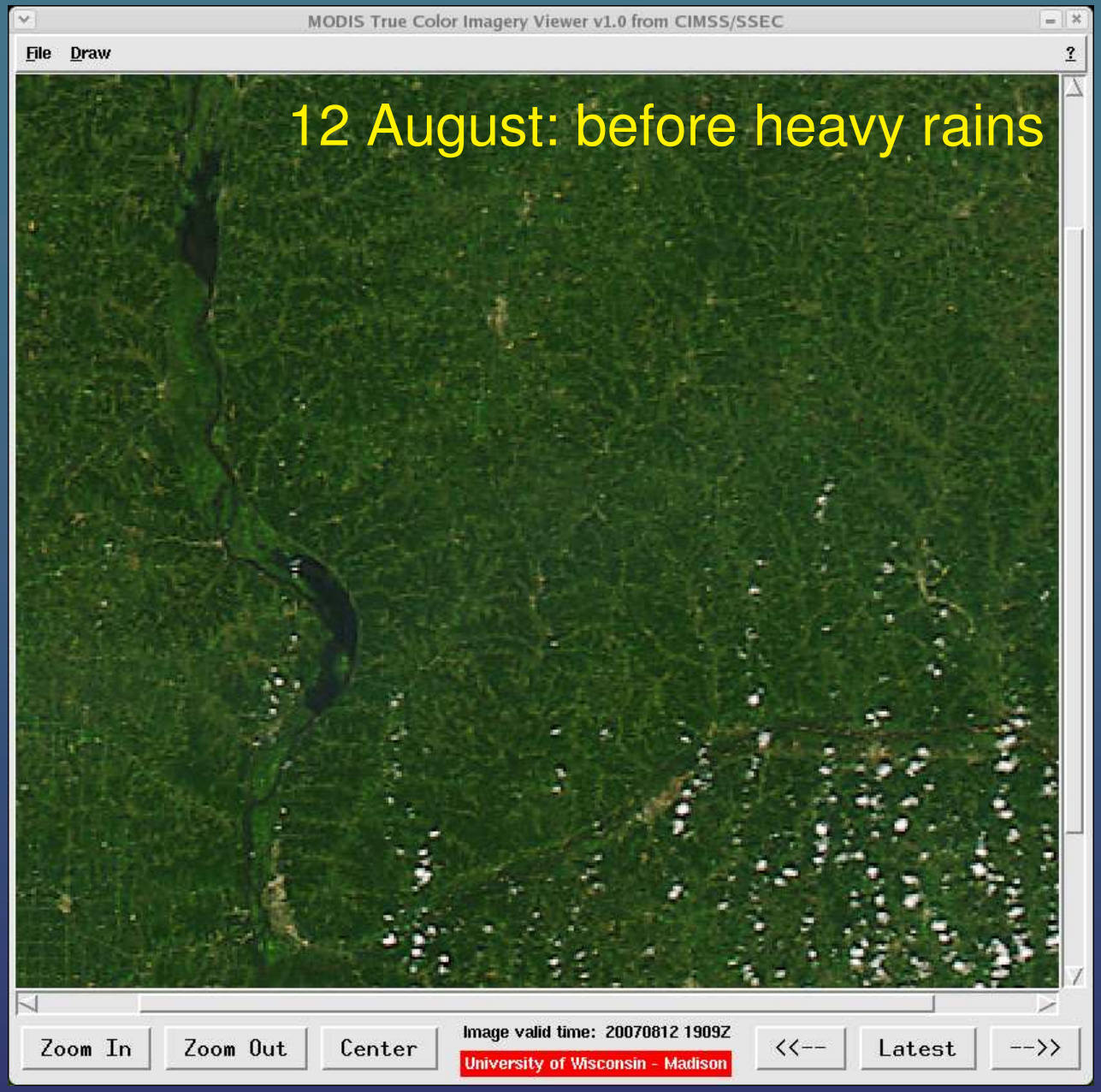
MODIS True Color Imagery Viewer



MODIS True Color Imagery Viewer



MODIS True Color Imagery Viewer



MODIS True Color Imagery Viewer

MODIS Imagery in AWIPS: Pros and Cons

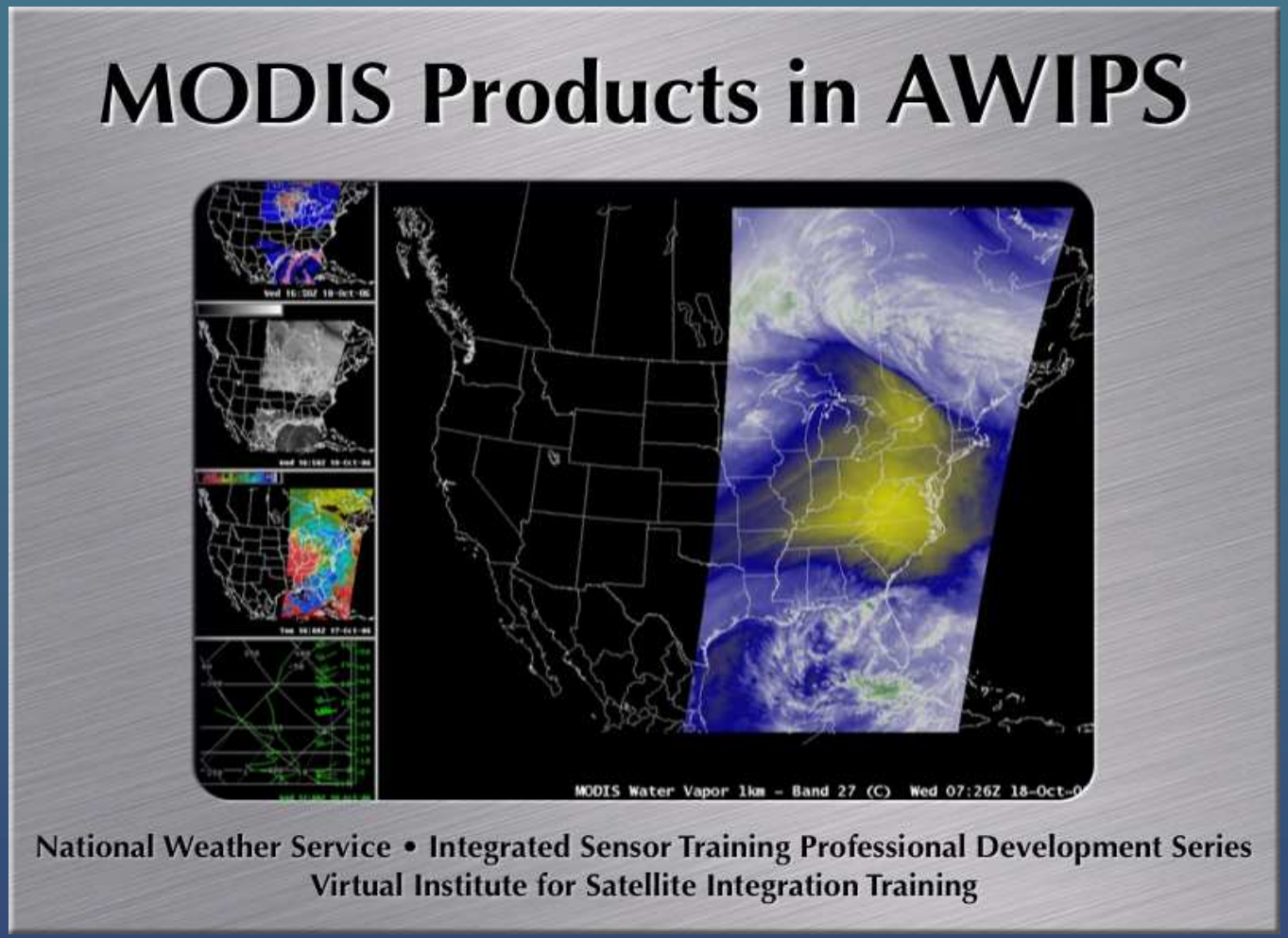
Pros:

- New satellite channels and products not yet available on GOES; prepares forecasters for what will be available in the GOES-R era
- Better spatial resolution than comparable GOES channels
- MODIS imagery does not suffer resolution degradation when viewed at large scales (N. Hemisphere, North American, CONUS)
- Minimal parallax error

Cons:

- Polar orbit: inconsistent coverage (overpass time and geometry)
- Data latency: 15-45 minutes for individual 1km channels, 30-75 minutes for 4km products

For more information, see the VISIT lesson



http://cimss.ssec.wisc.edu/goes/visit/modis.html