



# The GOES-R Fog and Low Stratus (FLS) Products: Algorithm Development and Introduction into NWS Operations

**Mike Pavolonis**  
**(NOAA/NESDIS)**

**Corey Calvert**  
**(UW-CIMSS)**

**Chad Gravelle and Scott Lindstrom**  
**(UW-CIMSS)**





# Outline



- **Definition of FLS and overview and motivation for new FLS product suite**
- **R2O timeline and lessons learned**
- **Forecaster feedback and operational impacts**
- **Next steps**

# What is FLS?

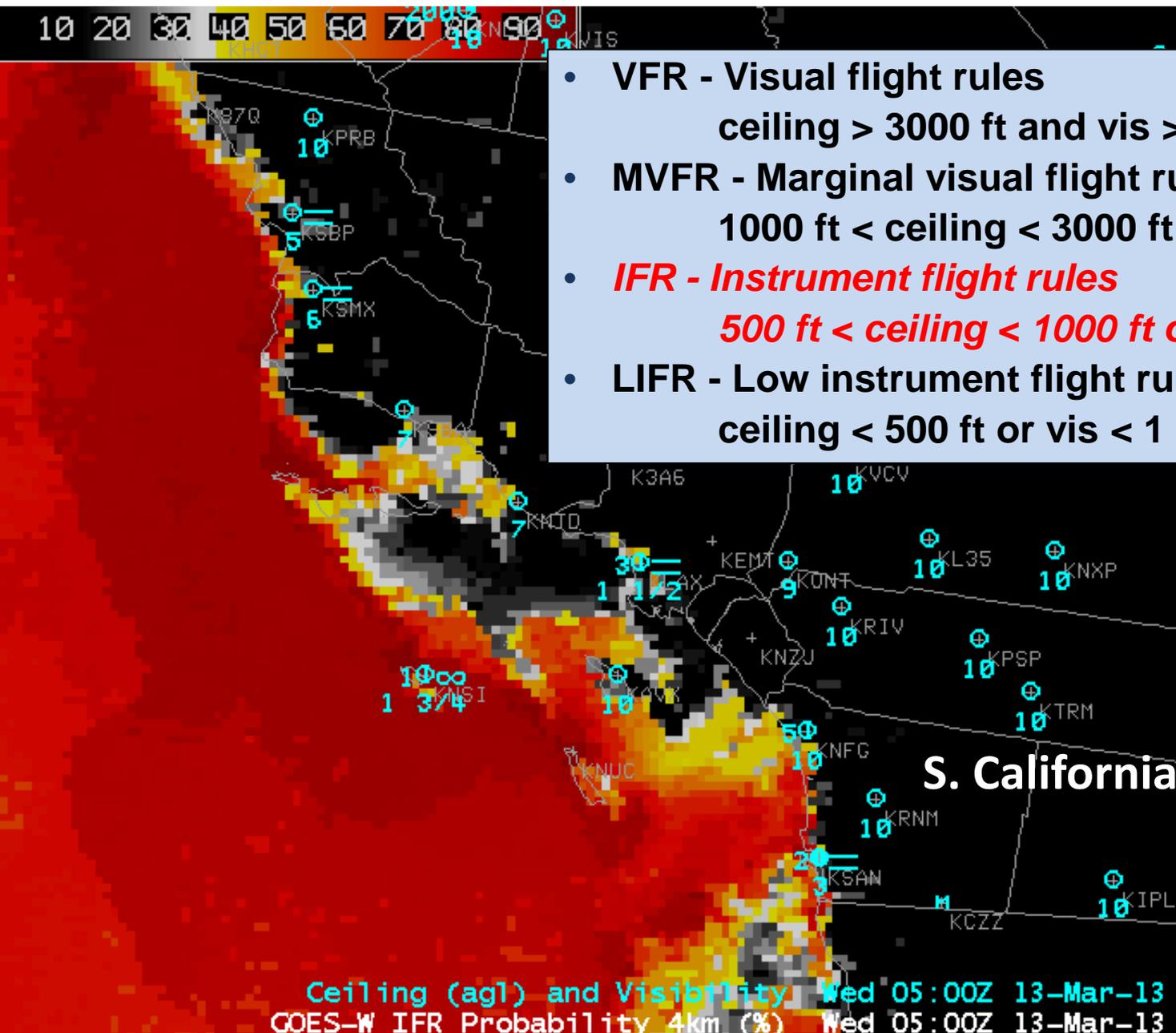
- **FLS = Fog/Low Stratus**
- **FLS is a major transportation hazard**
- **Since FLS is primarily a transportation hazard, the GOES-R definition of FLS is defined relative to aviation flight rules ceiling/surface visibility categories**

- **VFR - Visual flight rules**  
ceiling > 3000 ft and vis > 5 mi
- **MVFR - Marginal visual flight rules**  
1000 ft < ceiling < 3000 ft or 3 mi < vis < 5 mi
- **IFR - Instrument flight rules**  
500 ft < ceiling < 1000 ft or 1 mi < vis < 3 mi
- **LIFR - Low instrument flight rules**  
ceiling < 500 ft or vis < 1 mi



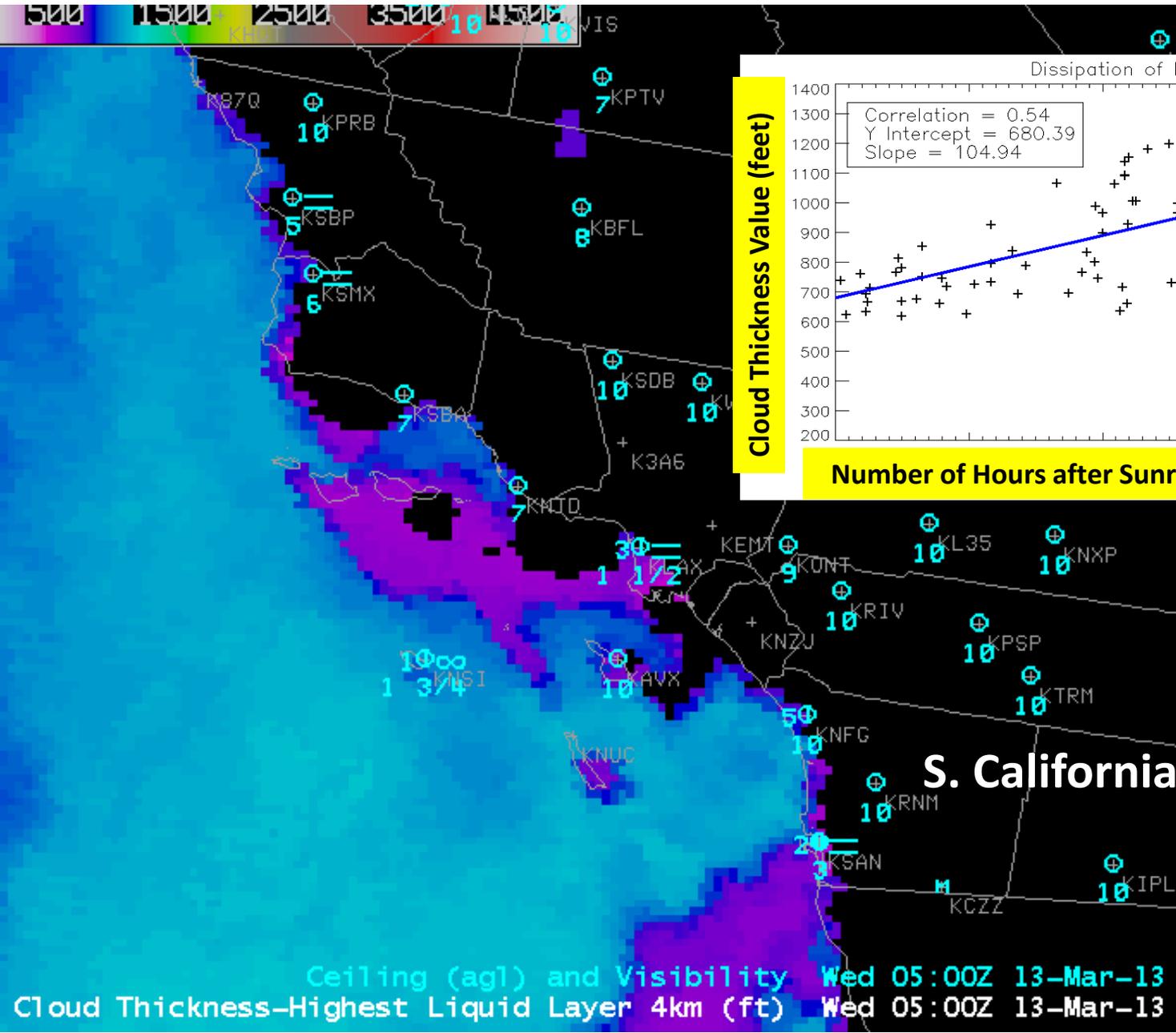


# Probability of IFR





# FLS Thickness



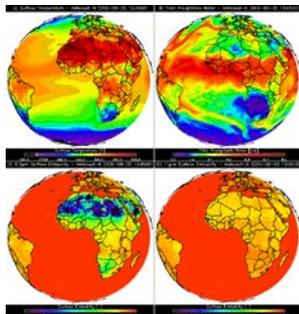
# Fused Fog/Low Cloud Detection Approach

## Satellite Data



+

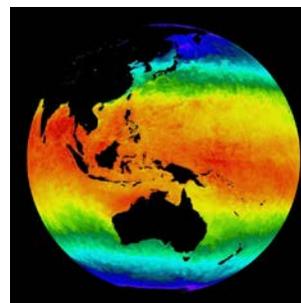
## Static Ancillary Data



- DEM
- Surface Type
- Surface Emissivity

+

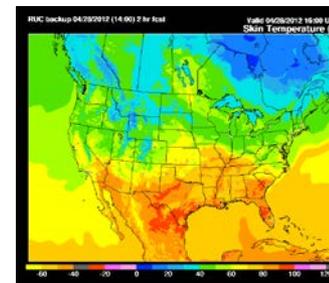
## Daily SST Data



0.25 degree OISST

+

## NWP

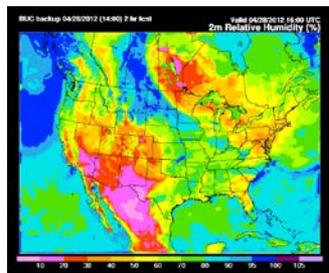


- Surface Temperature
- Profiles of T and q
- RUC/RAP (2-3 hr forecast) or GFS (12 hr forecast)

Clear Sky RTM

MVFR, IFR, and LIFR Probability

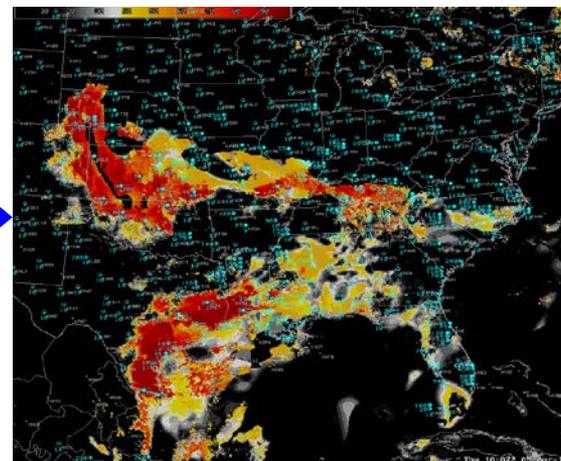
## NWP RH Profiles



- RUC/RAP (2-3 hr forecast) or GFS (12 hr forecast)

Naïve Bayesian Model

Total run time: 2 - 3 minutes



**\*\*\*IMPORTANT: Other sources of relevant data (e.g. sfc obs) influence results through the model fields**



# Motivation for Re-thinking FLS Products: Limitations of Traditional FLS Products



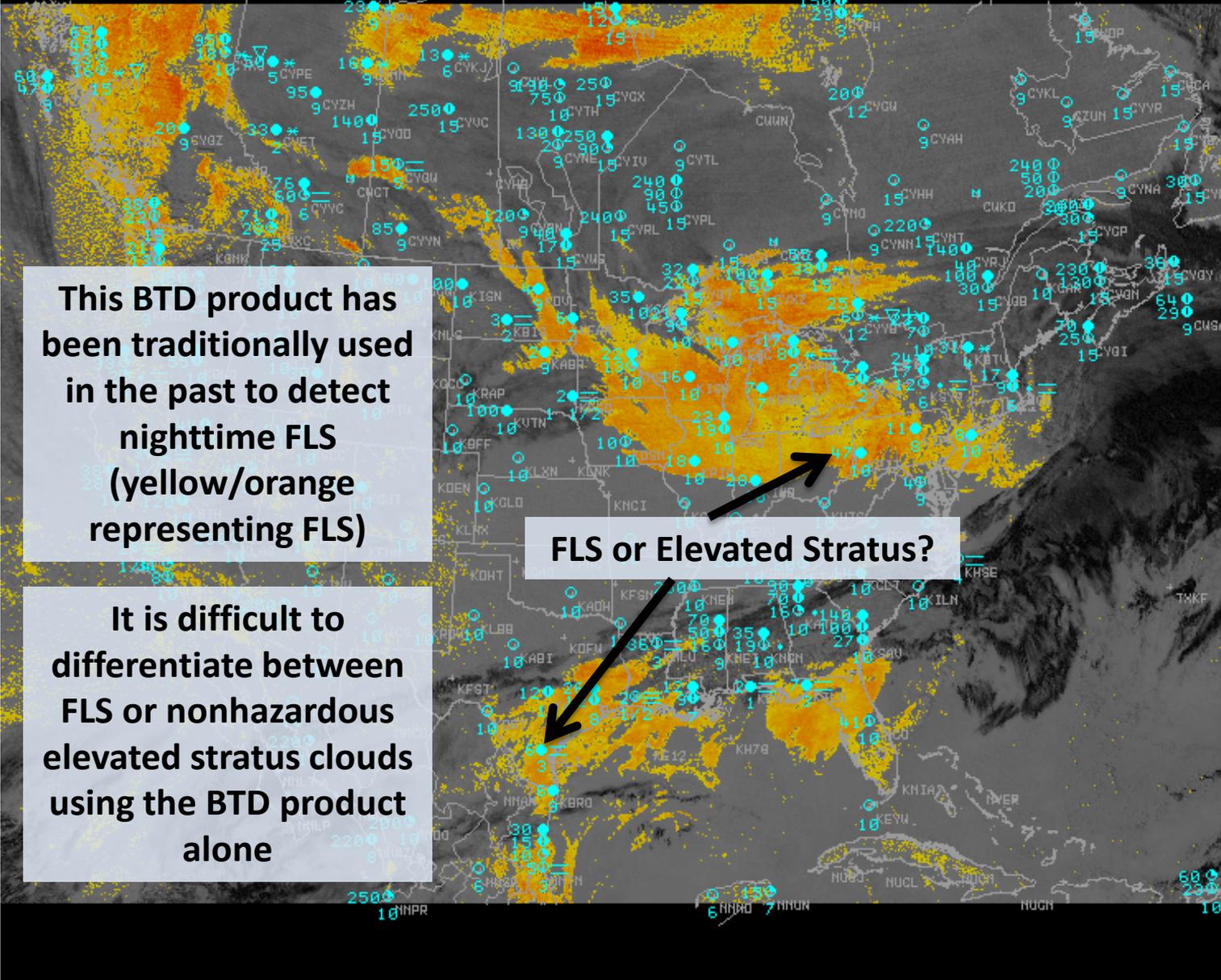


# Traditional GOES-East 11 – 3.9 $\mu\text{m}$ BTD

This BTD product has been traditionally used in the past to detect nighttime FLS (yellow/orange representing FLS)

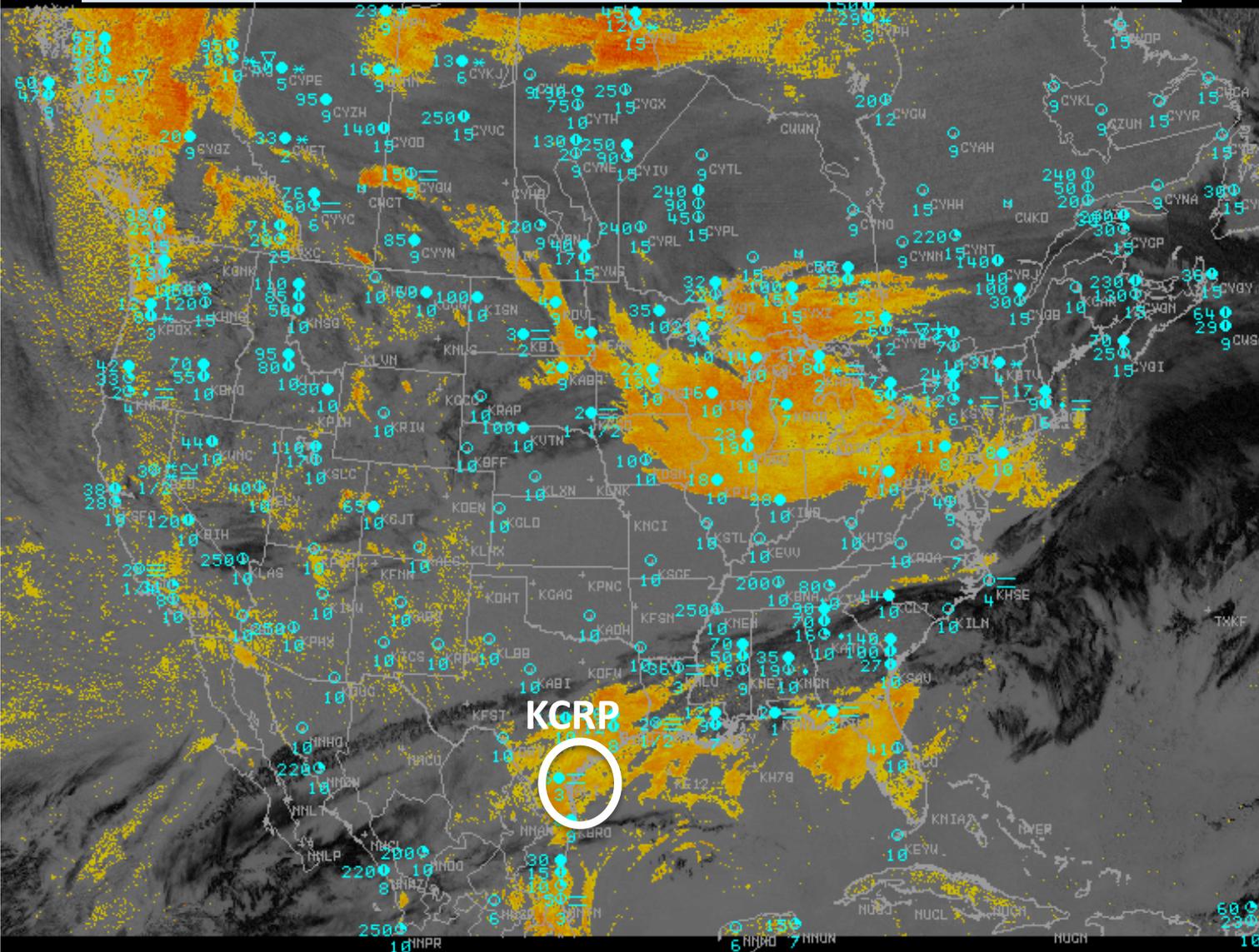
It is difficult to differentiate between FLS or nonhazardous elevated stratus clouds using the BTD product alone

FLS or Elevated Stratus?





# Traditional GOES-East 11 – 3.9 $\mu\text{m}$ BTD



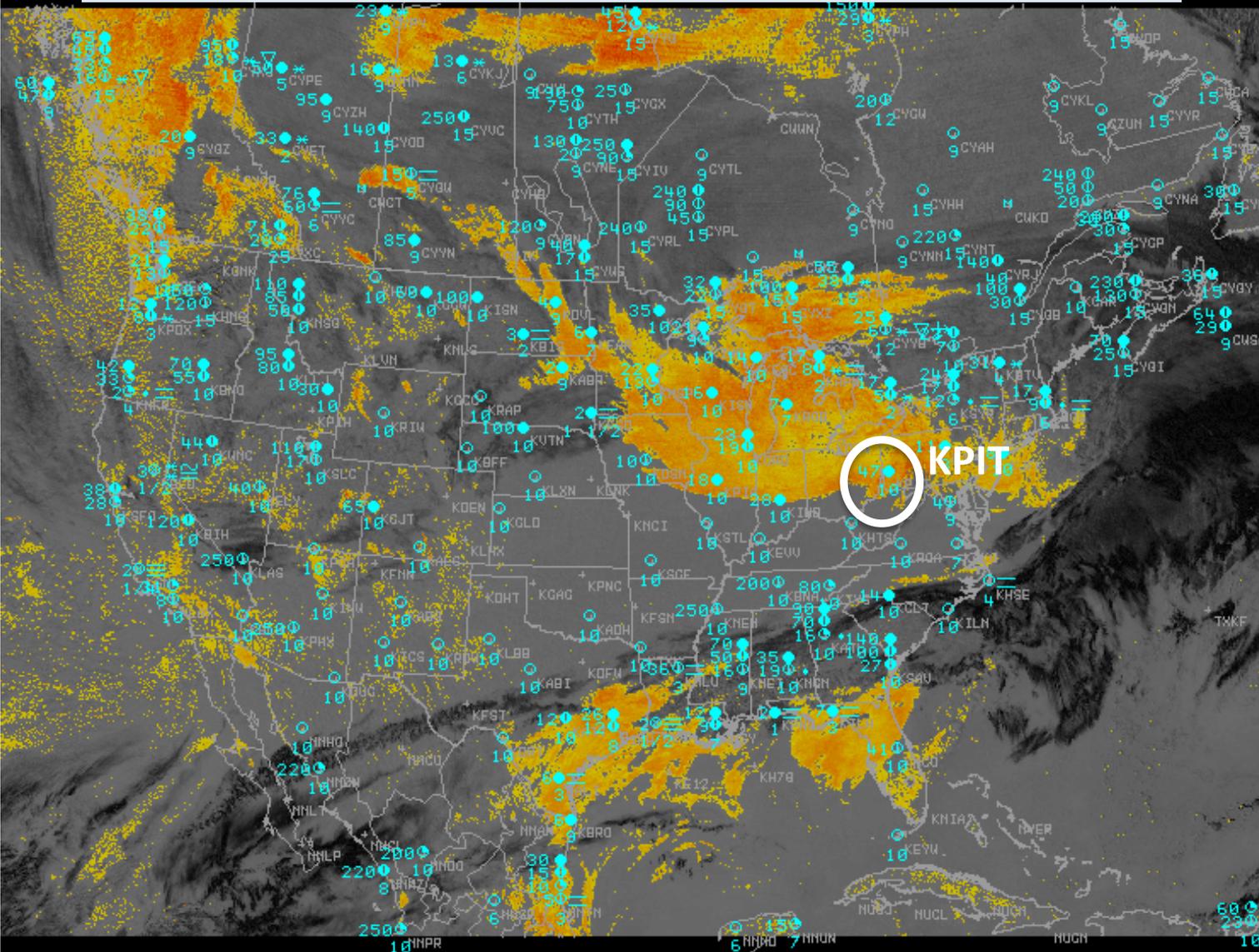
I

Ceiling (agl) and Visibility Thu 12:00Z 01-Mar-12  
GOES 11u-3.9u Satellite (counts) Thu 11:40Z 01-Mar-12





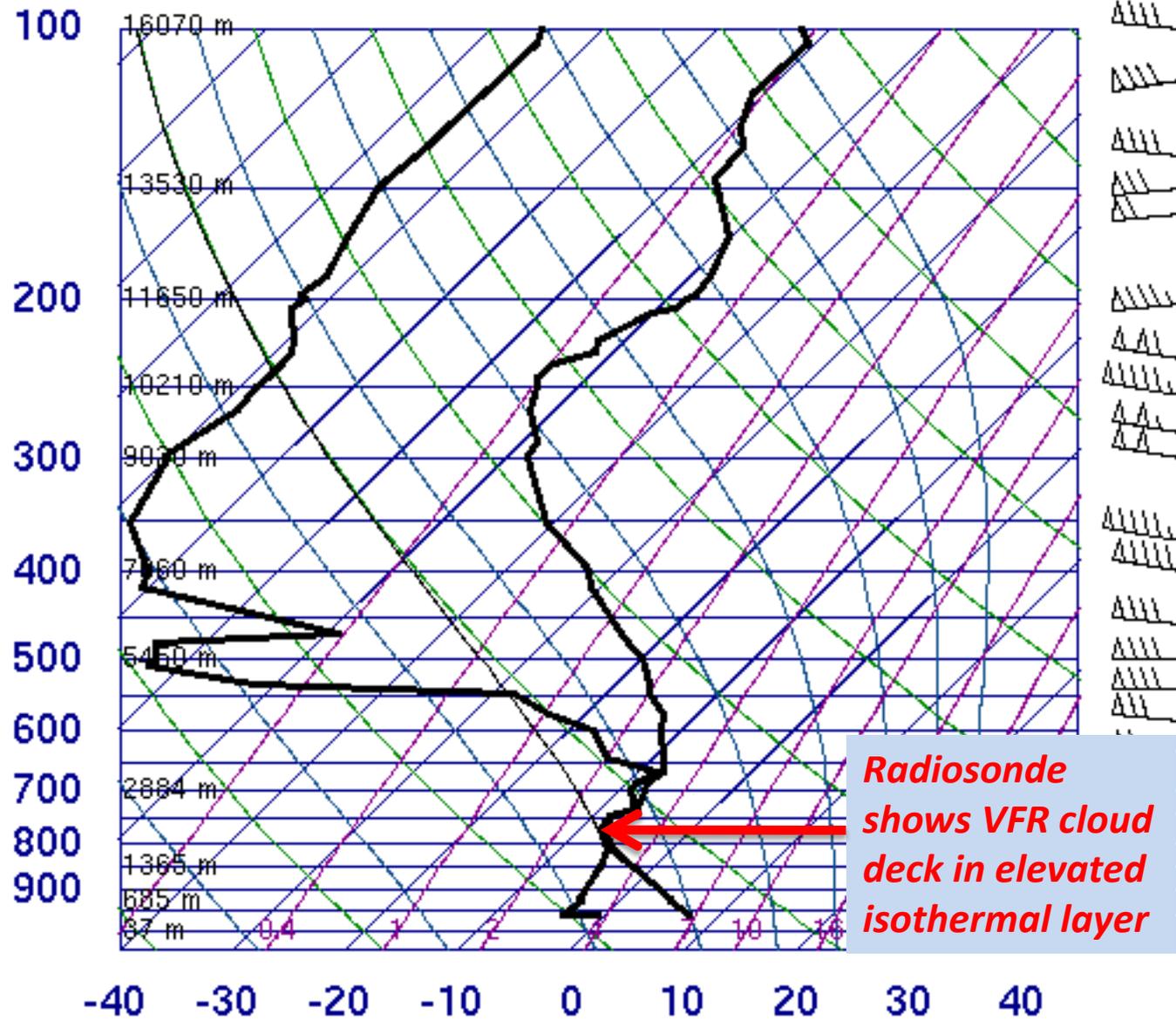
# GOES-East 11 – 3.9 μm BTD



I

Ceiling (agl) and Visibility Thu 12:00Z 01-Mar-12  
GOES 11u-3.9u Satellite (counts) Thu 11:40Z 01-Mar-12

# 72520 PIT Pittsburgh



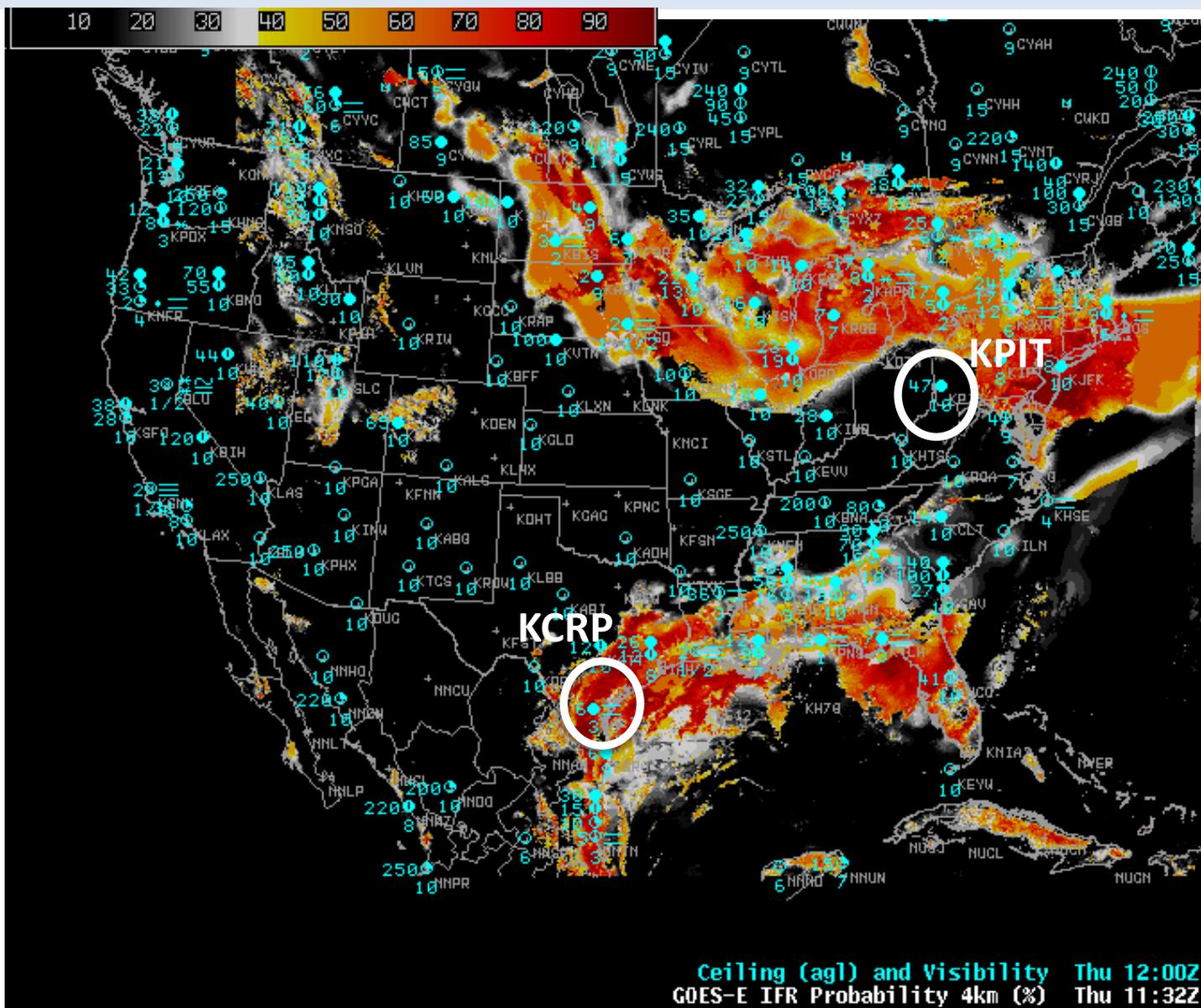
SLAT	40.53
SLON	-80.23
SELV	357.0
SHOW	13.88
LIFT	14.18
LFTV	14.12
SWET	145.9
KINX	11.80
CTOT	15.00
VTOT	18.00
TOTL	33.00
CAPE	0.00
CAPV	0.00
CINS	0.00
CINV	0.00
EQLV	-9999
EQTV	-9999
LFCT	-9999
LFCV	-9999
BRCH	0.00
BRCV	0.00
LCLT	267.6
LCLP	814.8
MLTH	283.7
MLMR	3.13
THCK	5413.
PWAT	11.07

**Radiosonde shows VFR cloud deck in elevated isothermal layer**

12Z 01 Mar 2012

University of Wyoming

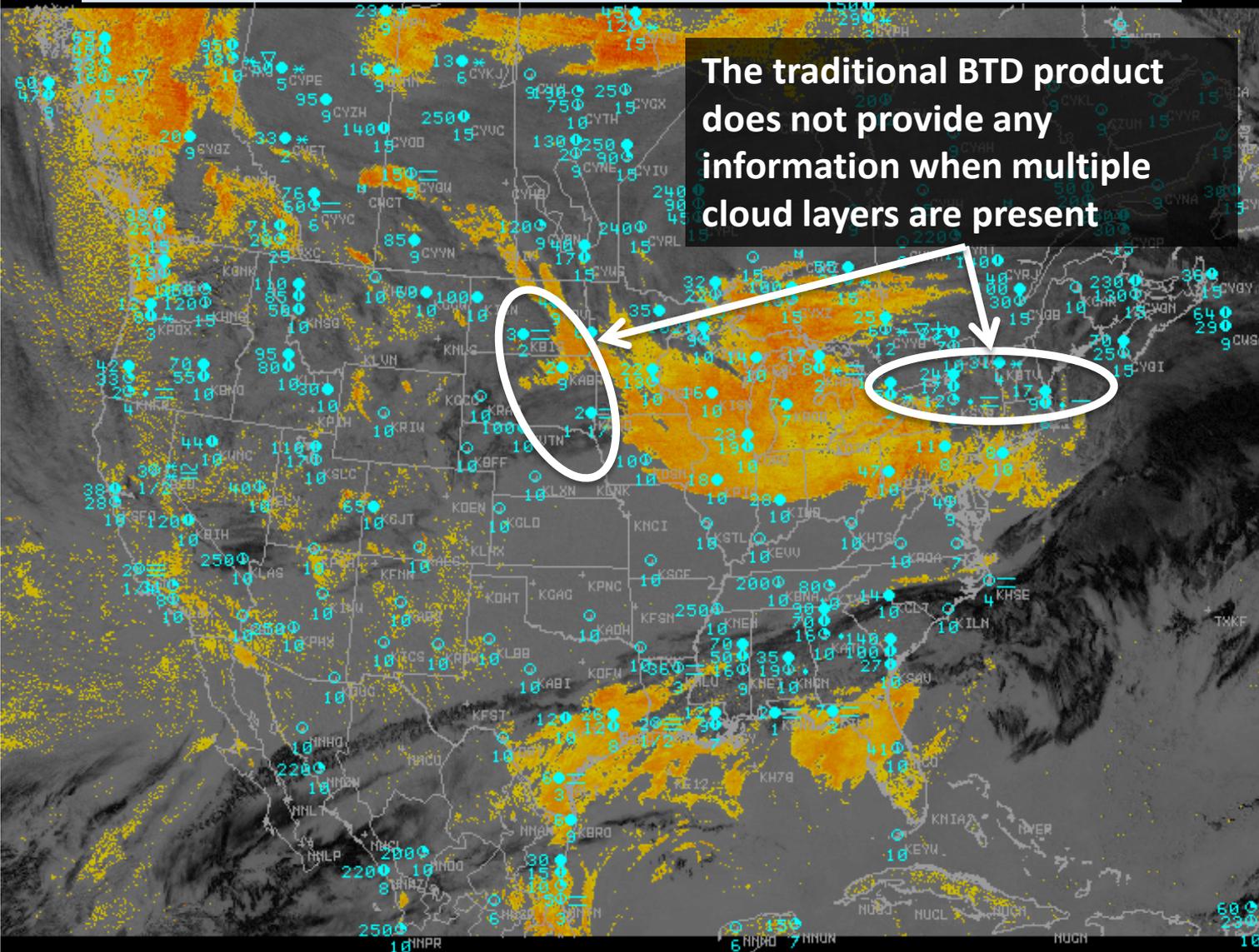
The GOES-R FLS products were developed to improve upon the traditional FLS products. *The GOES-R products are far more skilled at isolating hazardous areas of FLS.*





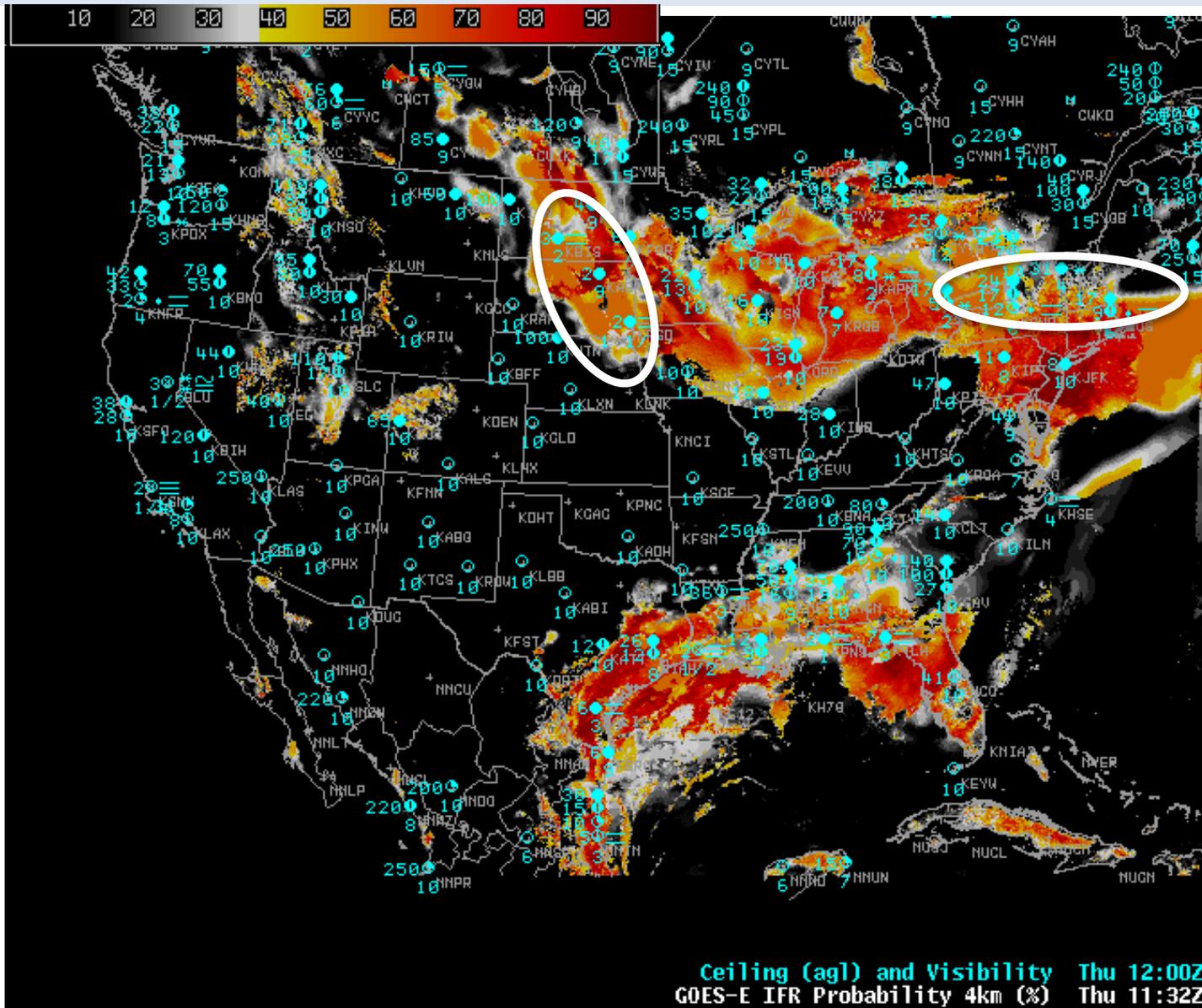
# GOES-East 11 – 3.9 μm BTDR

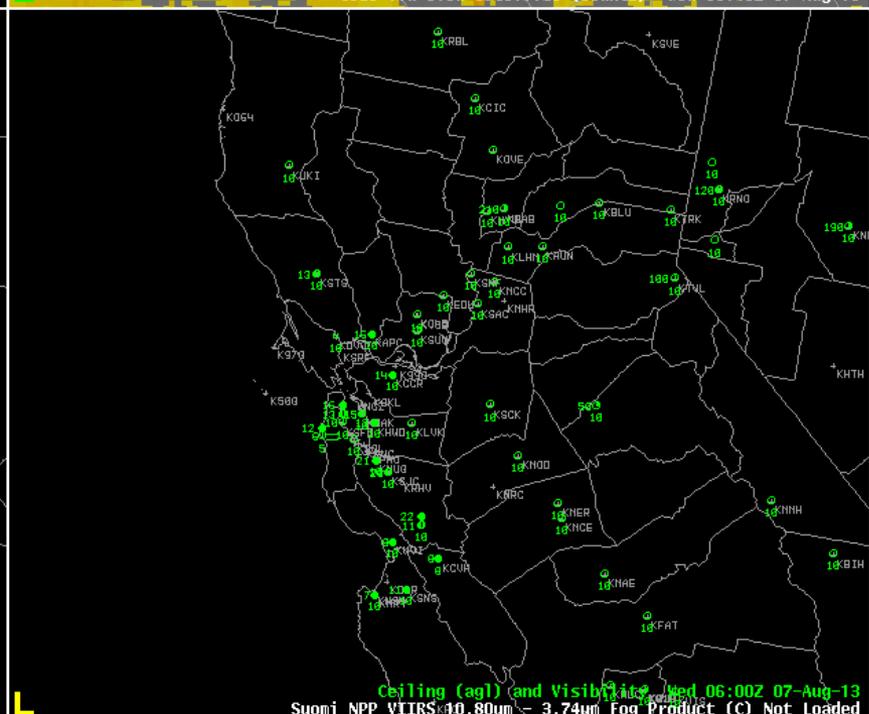
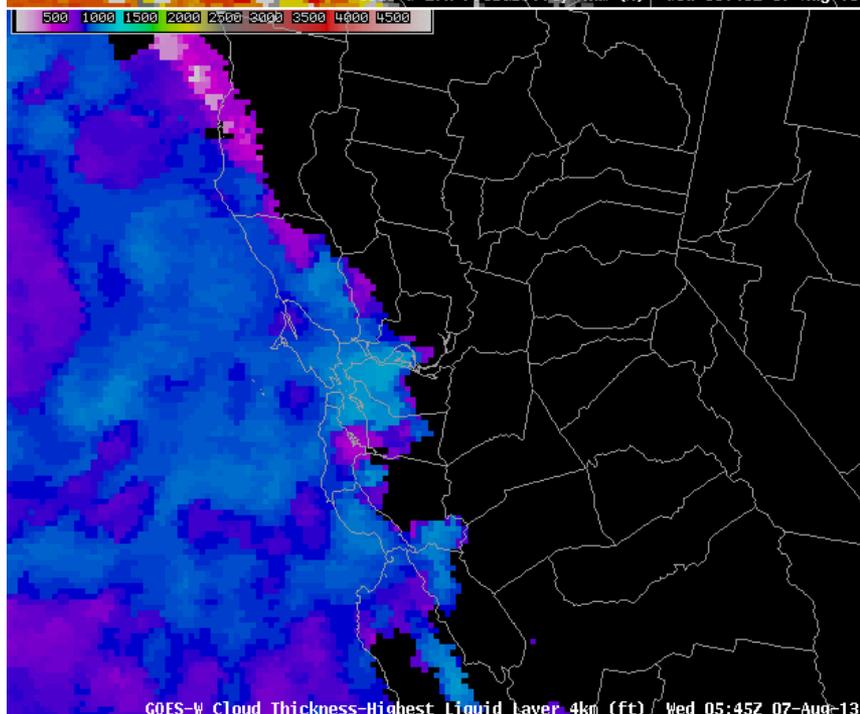
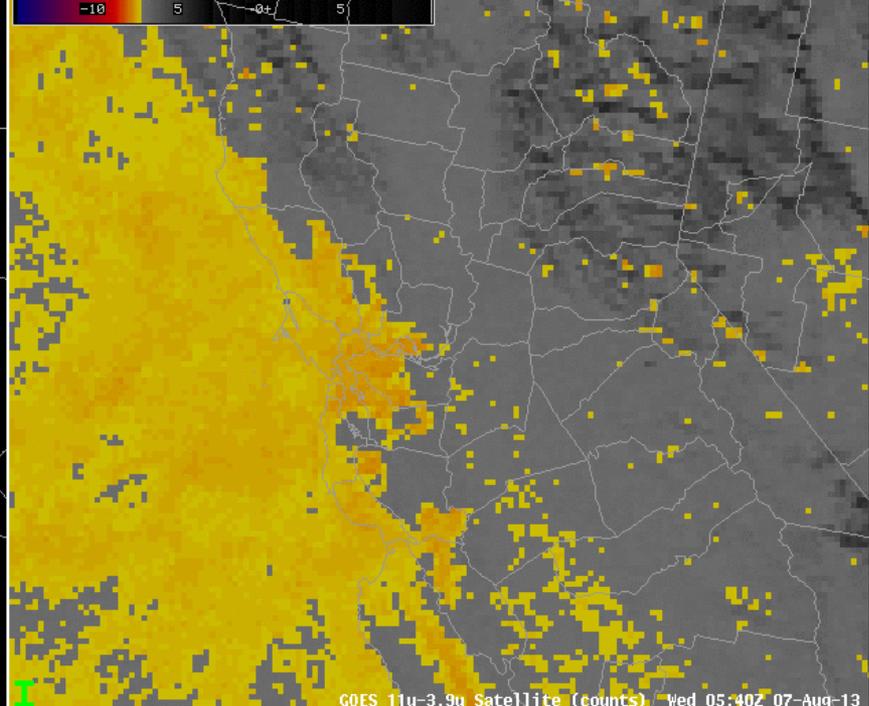
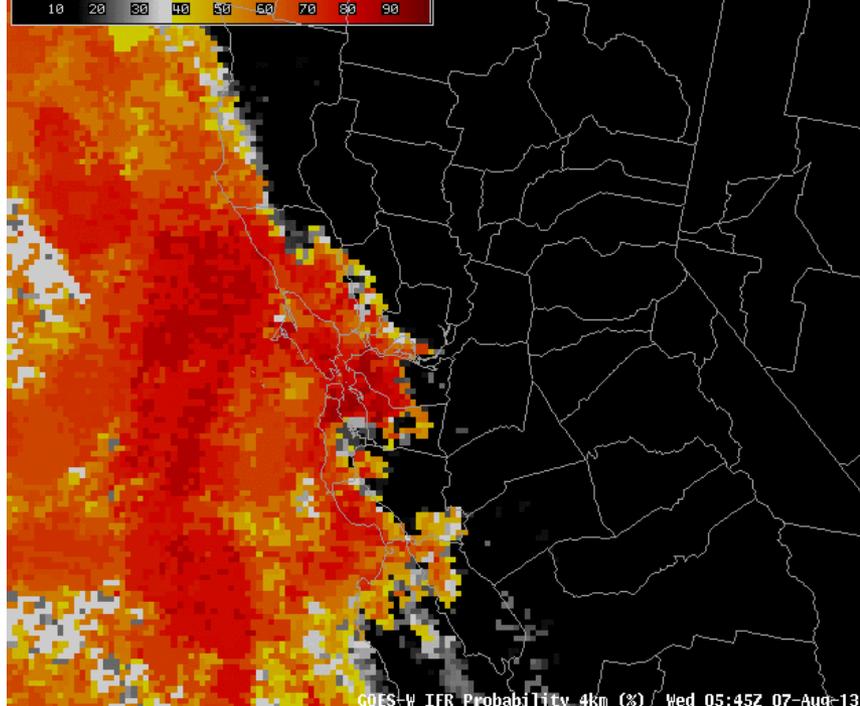
The traditional BTDR product does not provide any information when multiple cloud layers are present

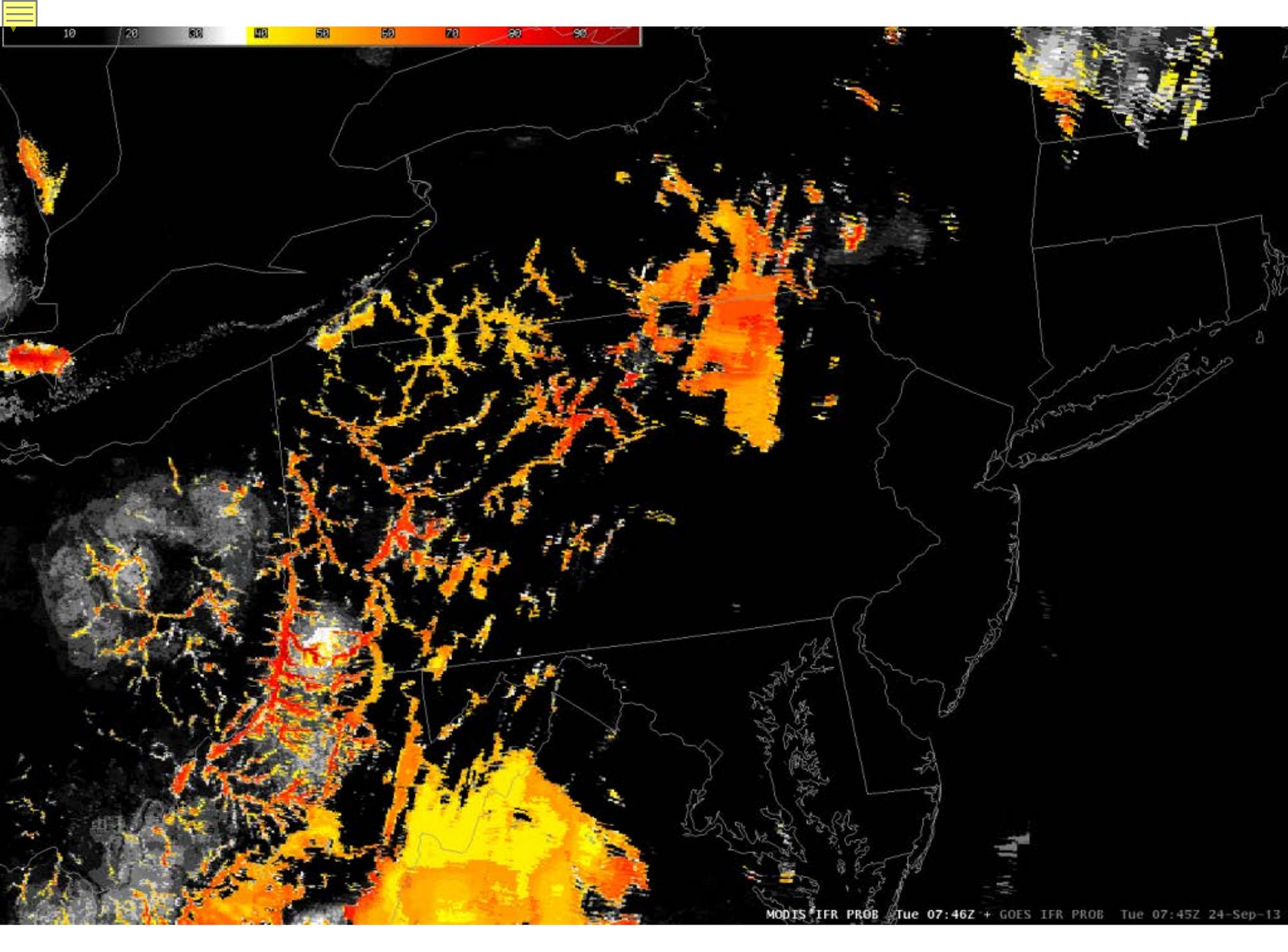


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The GOES-R FLS products were developed to improve upon the traditional FLS products. *The GOES-R products work day and night and provide information even when multiple cloud layers are present.*



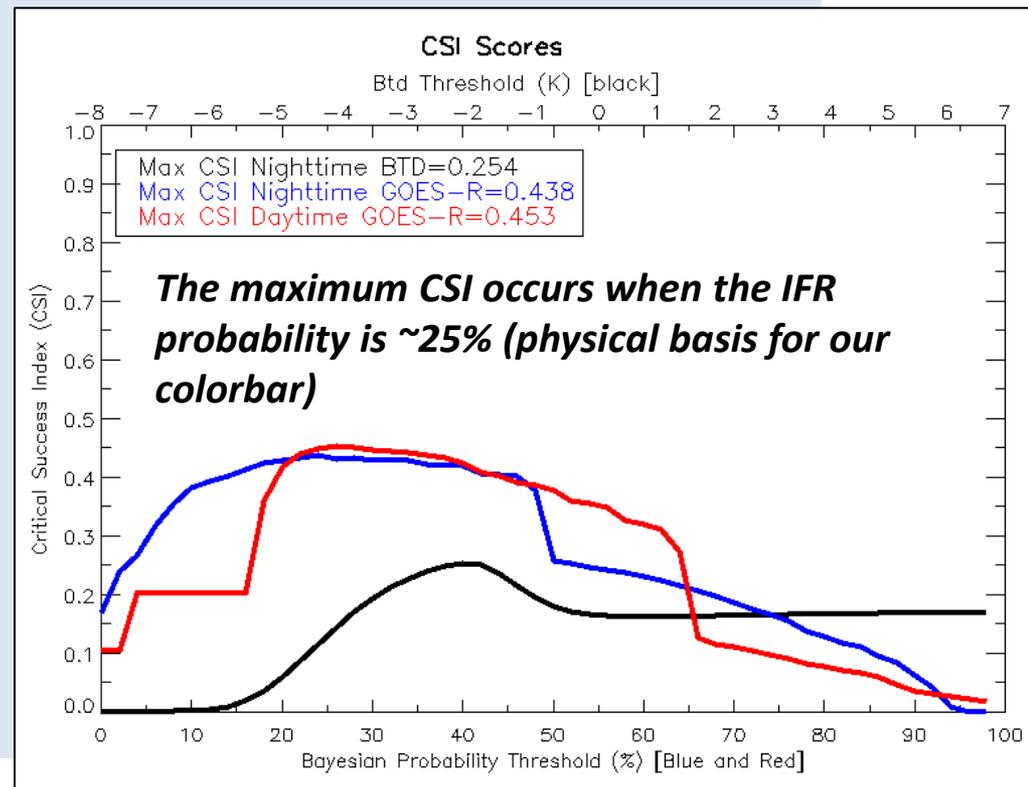




# GOES-R FLS Validation Over CONUS

- The FLS products were validated using surface observations of ceiling and visibility
- The plot below shows the Critical Success Index (CSI) of the daytime/nighttime GOES-R IFR probabilities along with the nighttime BTD product as a function of the threshold used to differentiate between FLS and non-FLS clouds

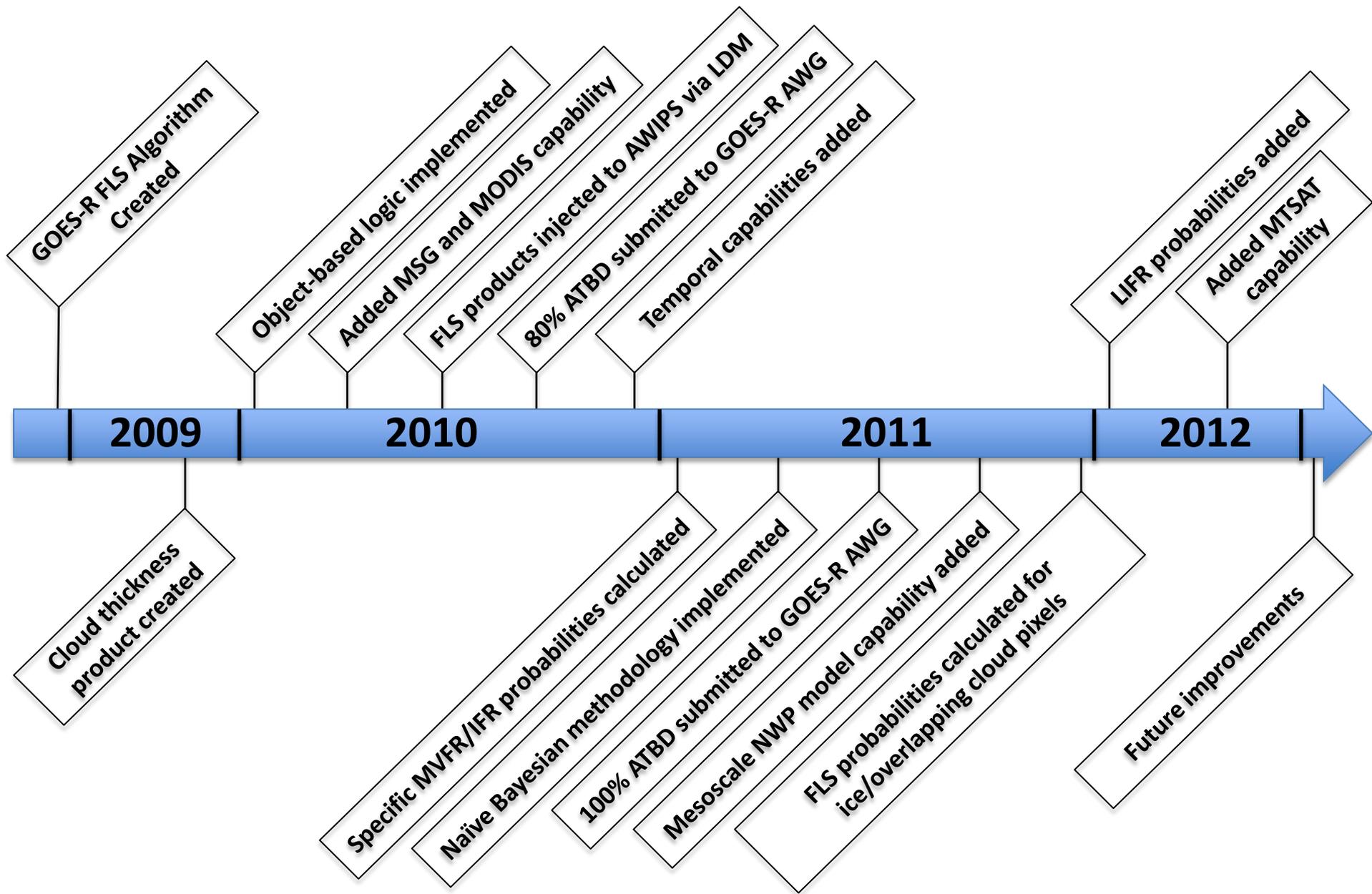
- The maximum CSI for the nighttime BTD product was calculated at 0.254
- The maximum CSI for the daytime/nighttime IFR probabilities were calculated at 0.453/0.438 respectively, nearly double that of the traditional BTD product



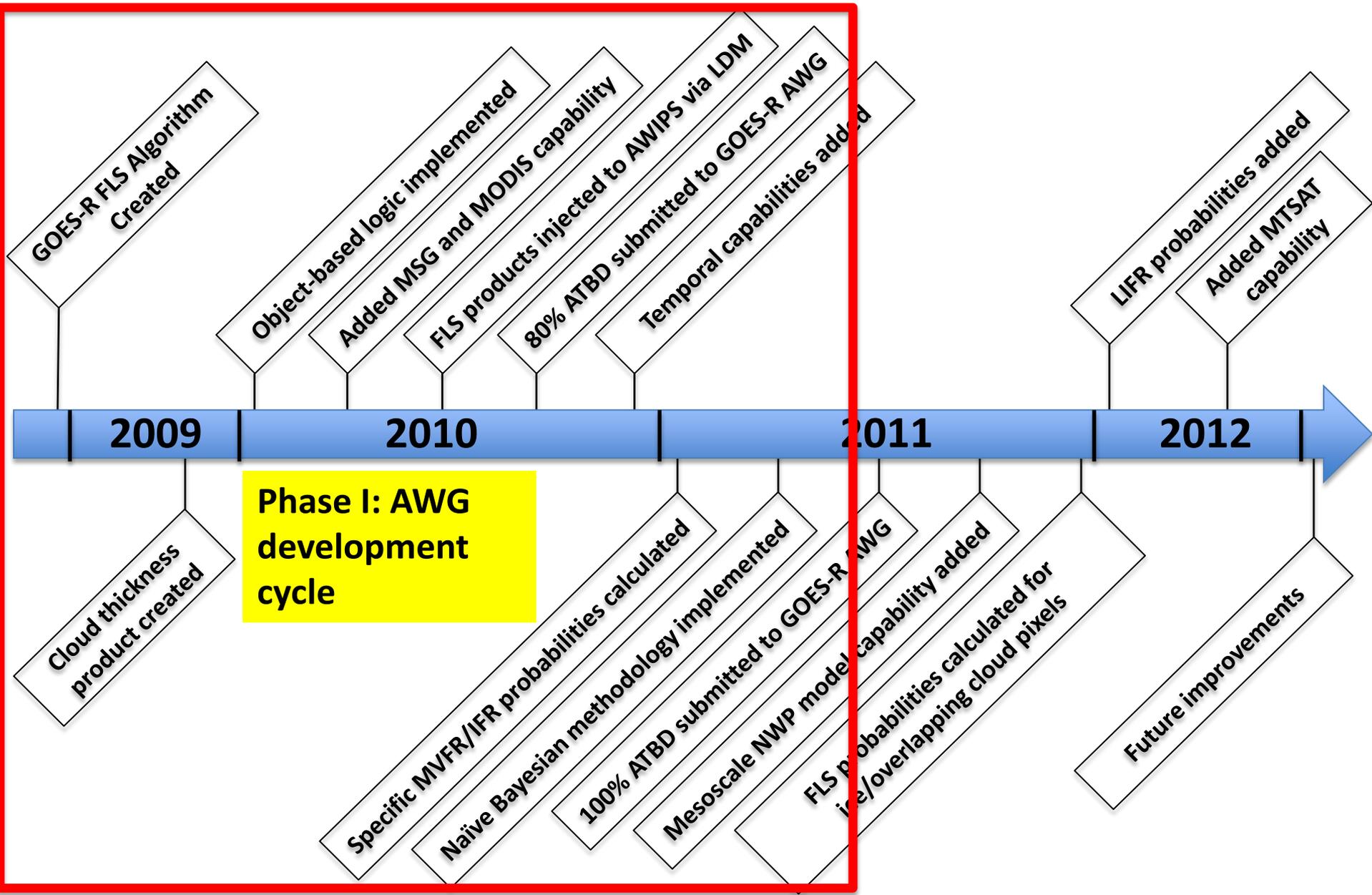
# “R20” Timeline and Lessons Learned



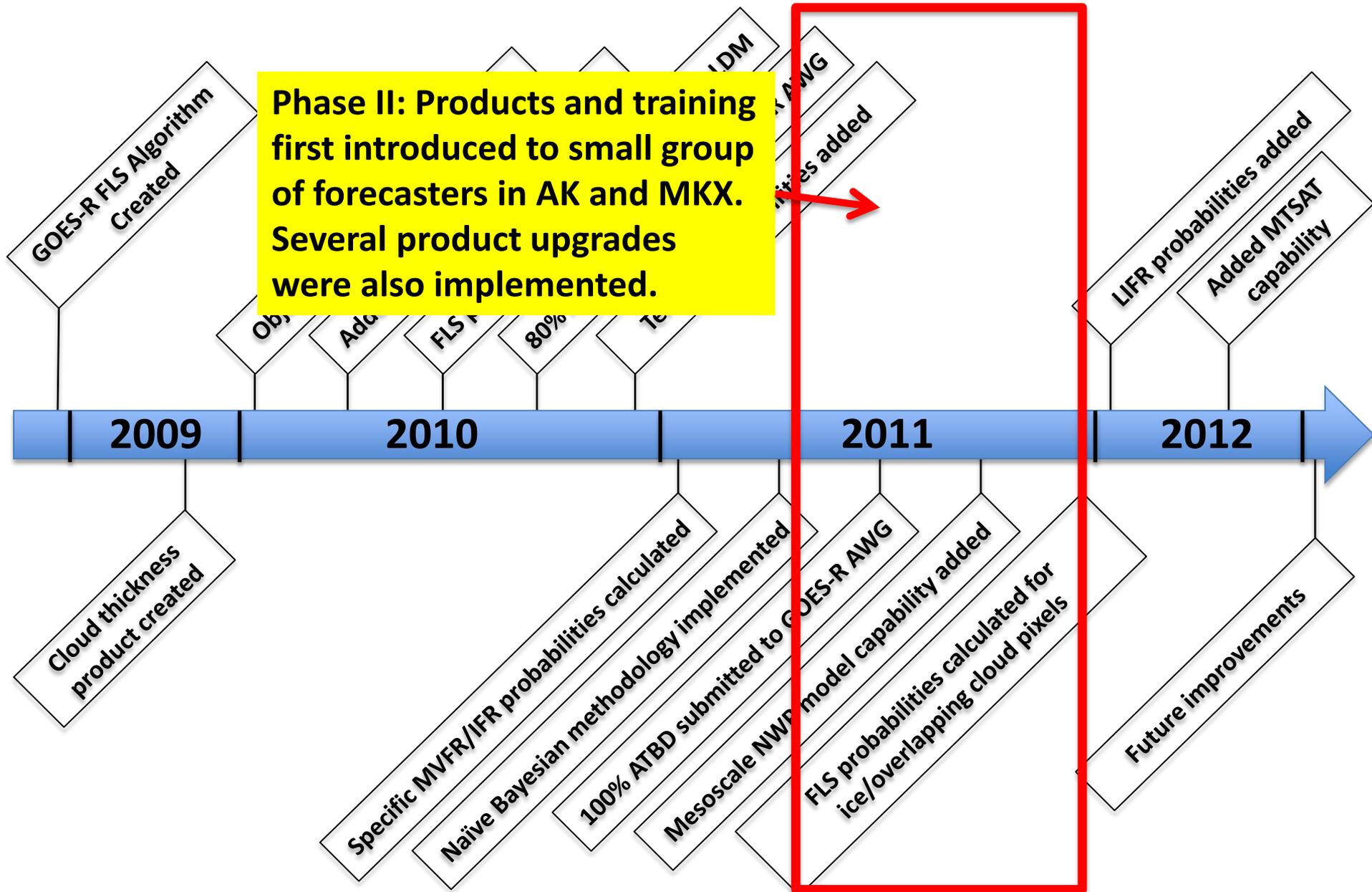
# GOES-R Fog/Low Stratus Algorithm Timeline



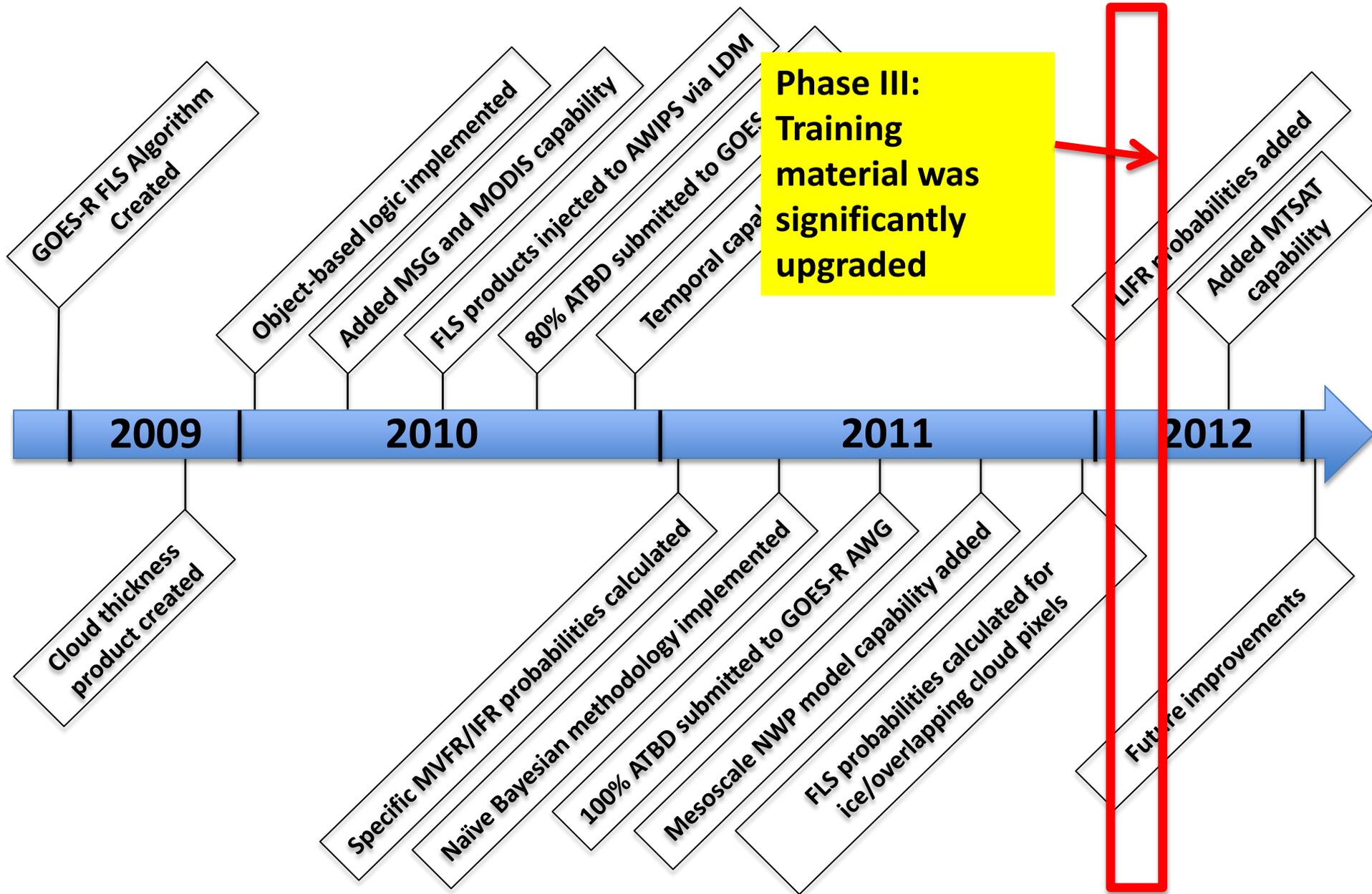
# GOES-R Fog/Low Stratus Algorithm Timeline



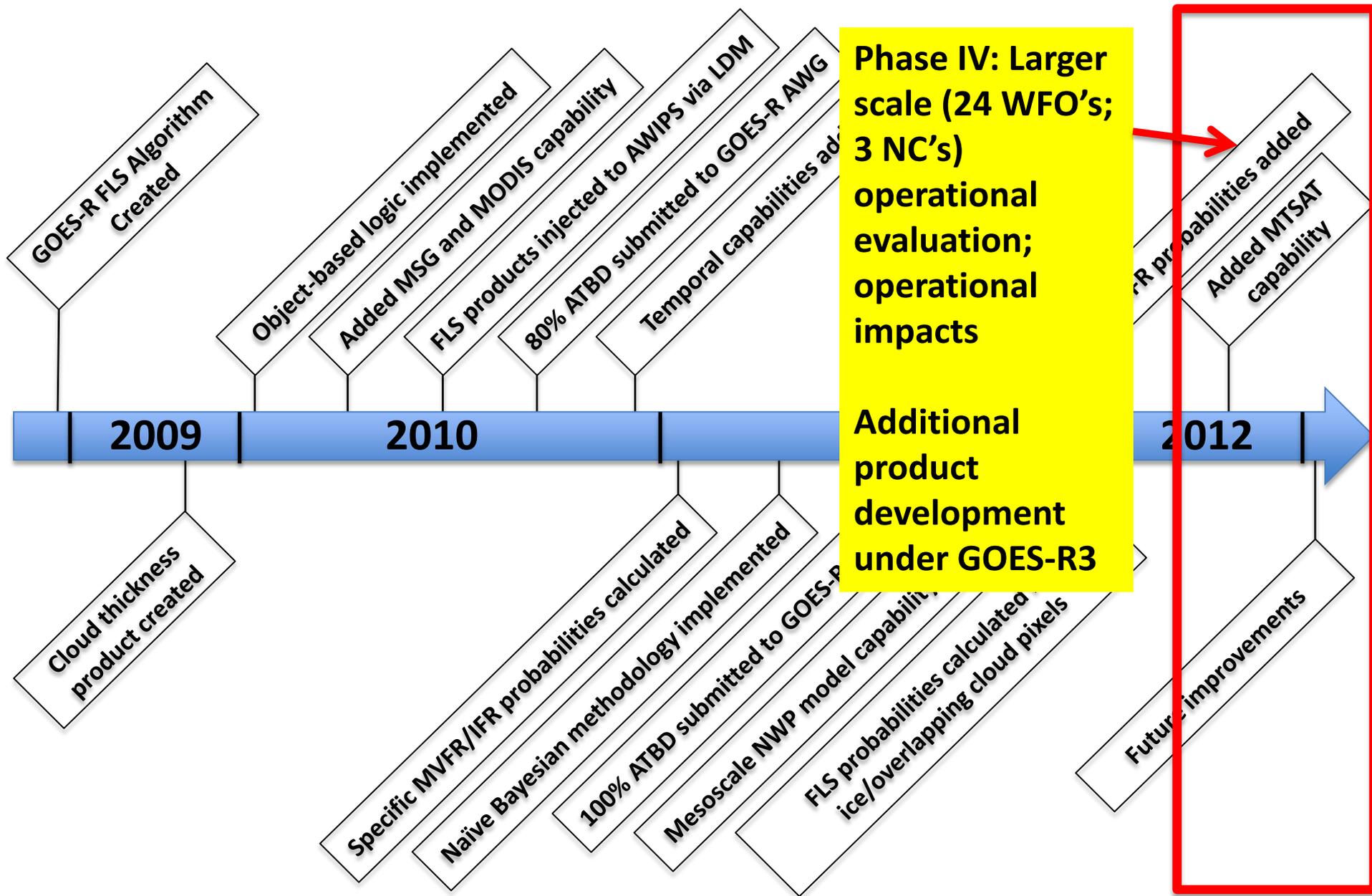
# GOES-R Fog/Low Stratus Algorithm Timeline



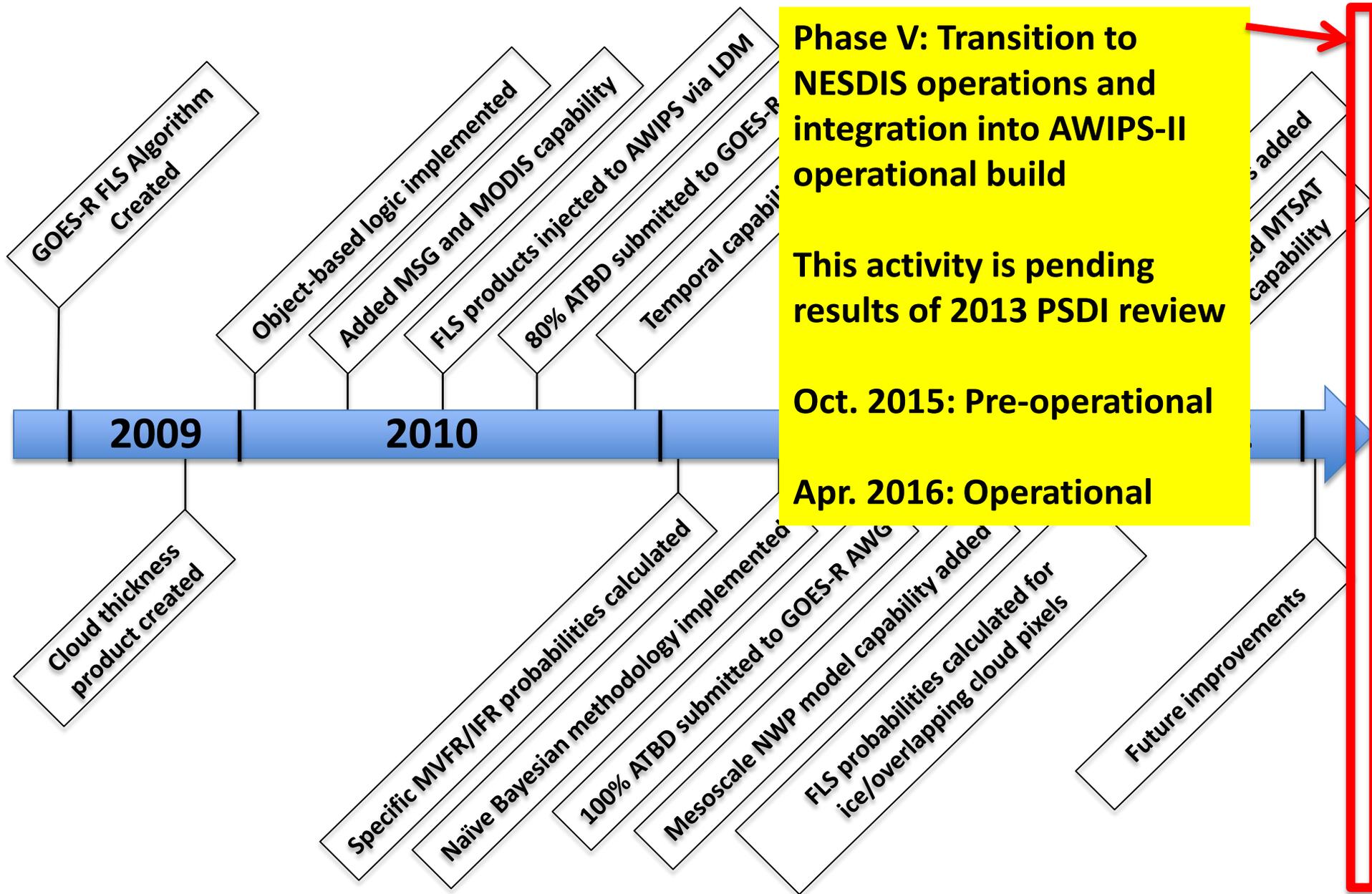
# GOES-R Fog/Low Stratus Algorithm Timeline



# GOES-R Fog/Low Stratus Algorithm Timeline



# GOES-R Fog/Low Stratus Algorithm Timeline





# Lessons Learned (so far)

- **Product naming/branding is very important**
- **SME involvement in the training process is very, very important (trainer must understand the material well enough to explain it to a non-expert in a very clear manner)**
- **Operational needs differ from region to region. Thus, the training material should contain region specific examples.**
- **Forecasters and researchers are not that different!**
- **Reliable and efficient product generation and distribution can occur outside of NESDIS operations**
- **It is important to keep training examples current**

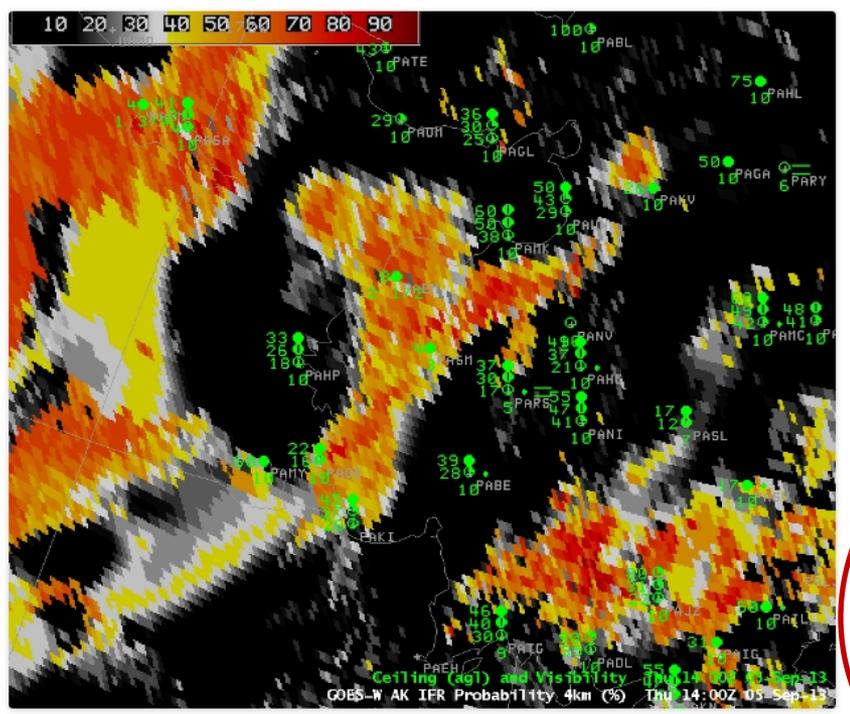
- ### Fused Fog Blog:
- New hosting site (ssec.wisc.edu)
  - Old site at 28000 hits
  - All old posts exported to new site
    - 166 total posts
  - Emails to SOOs when case is posted
  - Searchable by dates and categories

## GOES-R Fog Product Examples

Fog detection using GOES, Terra/Aqua or Suomi/NPP Satellite d

HOME

IFR Conditions over southwest Alaska


 Search

#### RECENT POSTS

- [IFR Conditions over southwest Alaska](#)
- [Fog over southern New England](#)
- [Northern Indiana Fog Event](#)
- [Fog on Cape Cod](#)
- [Valley Fog in Pennsylvania](#)

#### RECENT COMMENTS

#### ARCHIVES

- [September 2013](#)
- [August 2013](#)
- [July 2013](#)
- [June 2013](#)
- [May 2013](#)
- [April 2013](#)
- [March 2013](#)
- [February 2013](#)
- [January 2013](#)
- [December 2012](#)

#### CATEGORIES

- [AFD](#)
- [Alaska](#)
- [Appalachia](#)
- [AVHRR](#)
- [California](#)
- [Cloud Thickness](#)
- [Day/Night Band](#)
- [Day/Night Boundary](#)
- [Deep South](#)
- [Dissipation Time](#)
- [Emissivity](#)
- [Error Explanations](#)
- [Forecast](#)
- [Mid-Atlantic](#)
- [Midwest](#)
- [MODIS](#)
- [Multiple Cloud Layers](#)
- [New England](#)
- [Northern Plains](#)
- [Pacific Northwest](#)
- [Plains](#)
- [Rocky Mountains](#)
- [Snow](#)
- [Southeast](#)
- [Stray Light](#)
- [Suomi/NPP](#)
- [Terrain](#)
- [Texas](#)
- [Uncategorized](#)
- [Wisconsin](#)

<http://fusedfog.ssec.wisc.edu/>



# Forecaster Feedback and Operational Impacts

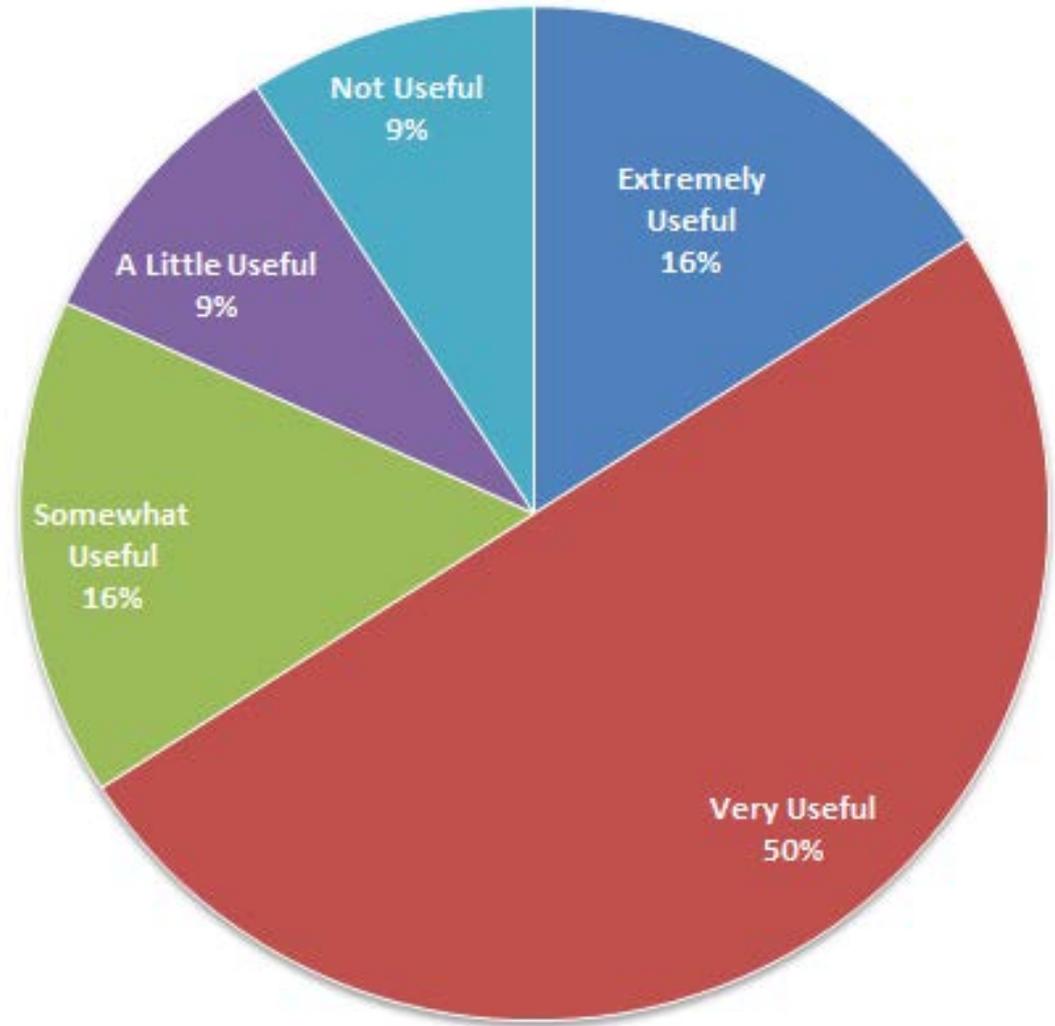


# Assessing Impacts

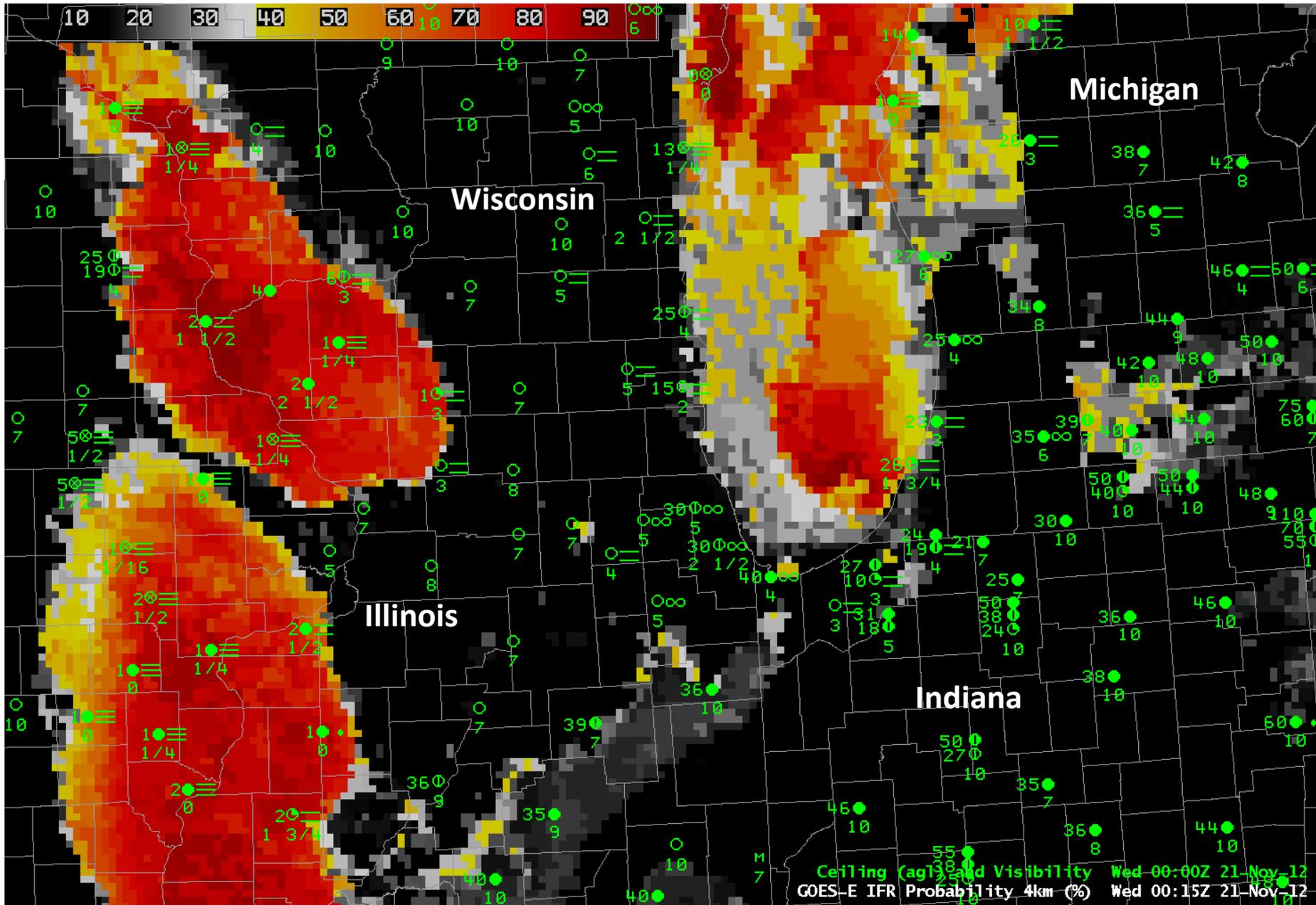
- Formal survey results indicate that the vast majority of forecasters have a very favorable opinion of the GOES-R AWG FLS products.
- The GOES-R AWG FLS products have been cited in at least 60 AFD's since March 2012.
- Several SOO's and forecasters have informed us (via email) that the GOES-R FLS products are being used on a routine basis for applications like TAF's and fog related warning/advisories.
- Social media and international activities

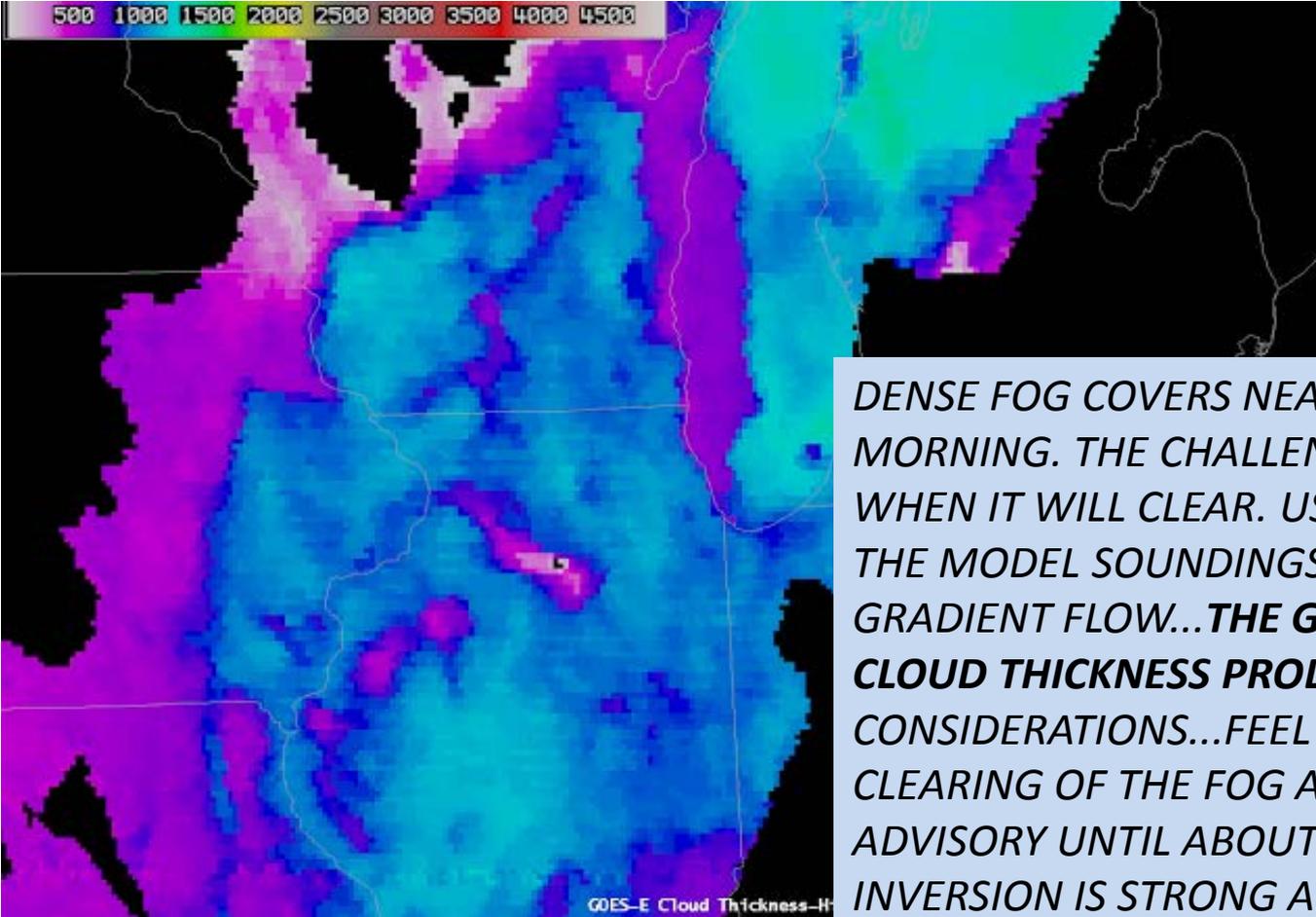
# Overall, how useful did you find the GOES-R FLS products?

**NWS Central  
Region survey  
results gathered  
by Chad Gravelle**



# FLS Development on November 21, 2012 (the day before Thanksgiving)

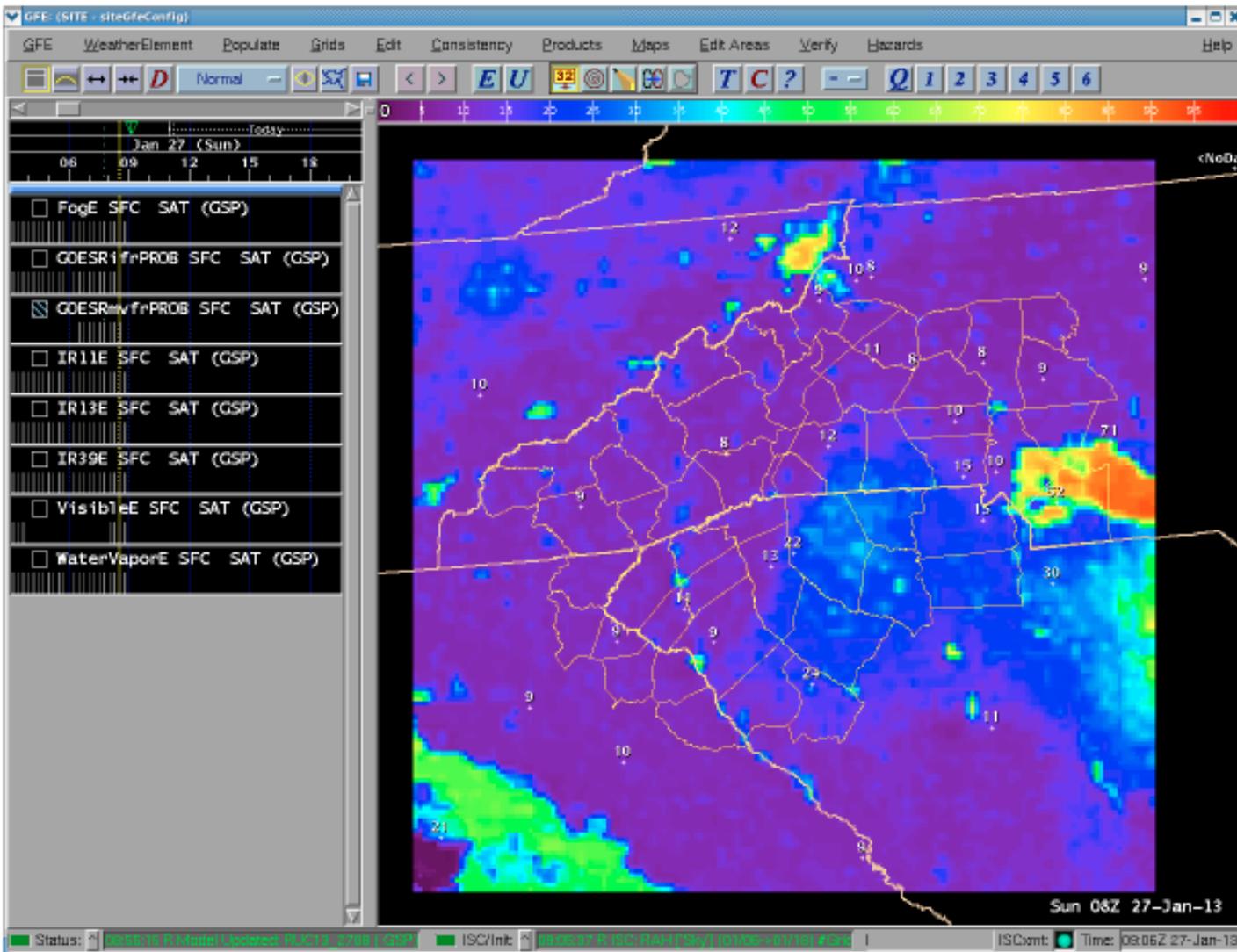




**MKX AFD on early morning of November 21, 2012**

*DENSE FOG COVERS NEARLY THE ENTIRE AREA THIS MORNING. THE CHALLENGE IS DETERMINING JUST WHEN IT WILL CLEAR. USING A COMBINATION OF THE MODEL SOUNDINGS...EXPECTED INCREASING GRADIENT FLOW...**THE GOES-R PROVING GROUND CLOUD THICKNESS PRODUCT** AND TIME OF YEAR CONSIDERATIONS...FEEL IT NECESSARY TO DELAY THE CLEARING OF THE FOG AND THE DENSE FOG ADVISORY UNTIL ABOUT 18Z. THE LOW LEVEL INVERSION IS STRONG AND IT WILL TAKE A FEW HOURS OF THAT INCREASING GRADIENT WIND TO ERODE THAT INVERSION. THE ESTIMATED DEPTH OF THE FOG IS AROUND 800-1000FT...SUGGESTING IT WILL TAKE ABOUT 3-4 HOURS AFTER SUNRISE TO CLEAR OUT. WE WERE ENDING THE DENSE FOG ADVISORY AT 10 AM AND THIS SEEMS ABOUT AN HOUR OR SO EARLY...SO WILL STRETCH IT TO NOON FOR A BIT OF A CUSHION.*

# GOES-R FLS Products in GFE Gridded Aviation Forecast Program at WFO Greenville-Spartanburg



The IFR and MVFR probabilities are now used to adjust the grids from which Terminal Area Forecasts (TAFs) are created

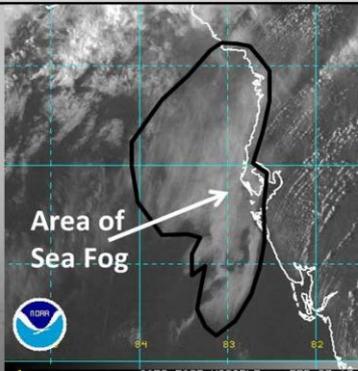
Figure 1: Satellite Weather Element Group with GOESmvfrPROB displayed

# KTBW routinely utilizes the GOES-R AWG FLS products, including during high impact events

**Weather-Ready Nation**  
National Oceanic and Atmospheric Administration

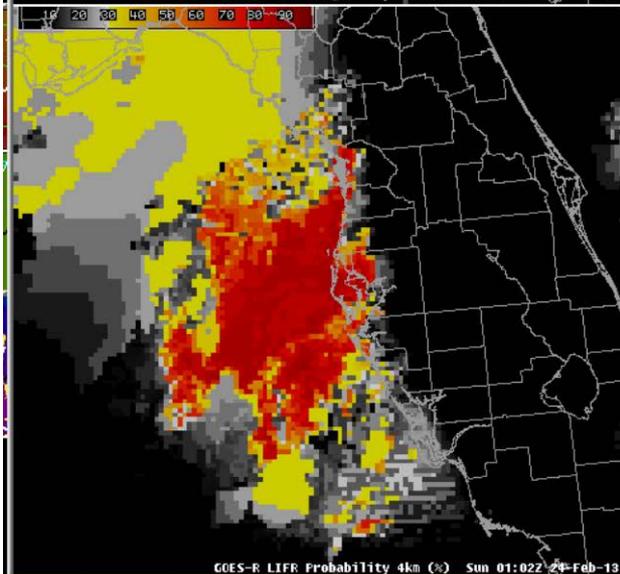
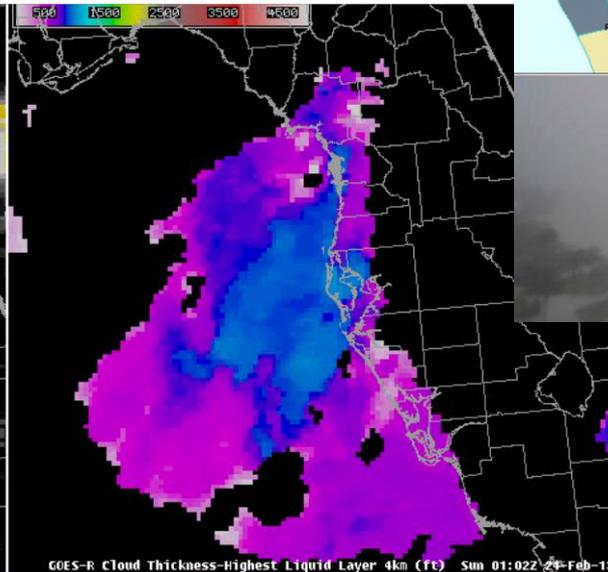
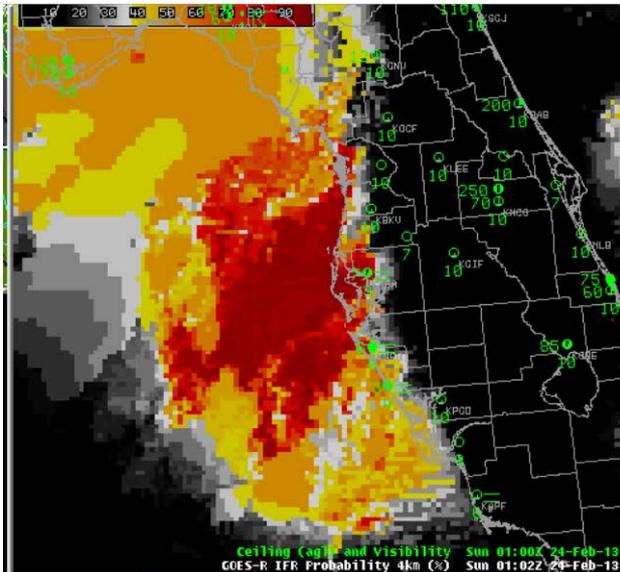


**Dense Fog Advisory Rest of The Afternoon Through Tonight**



Area of Sea Fog

St Pete Beach

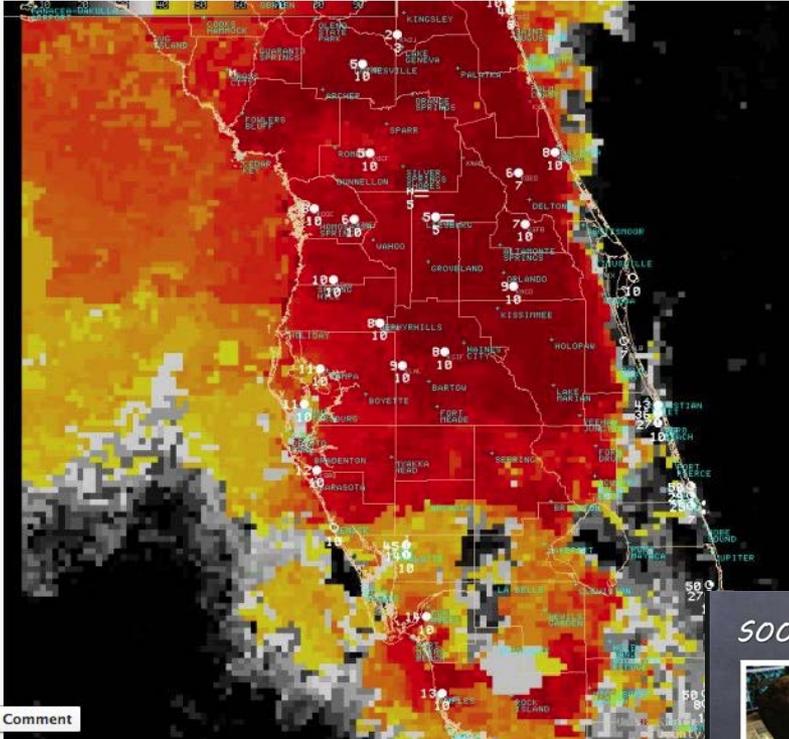


The forecasters at KTBW (WFO Tampa Bay, FL) used the GOES-R fog/low stratus products to brief the U.S. Coast Guard (USCG) during a fog event in the NE Gulf of Mexico in early February 2013. Through coordination with the NWS and other agencies, restrictions were put in place to keep large vessels either in port or anchored at sea until the fog lifted. The GOES-R IFR and LIFR probability products were very helpful in identifying the extent of the hazardous areas so that navigation restrictions could be confined to only necessary areas. At the end of the briefing the USCG Commander Omar told the forecasters at KTBW, "Great weather information and thank you for providing us support on the call."

# WFO Tampa Bay

## Timeline Photos

Back to Album · US National Weather Service Tampa Bay Florida's Photos · US National Weather Service Tampa Bay Florida's Page Previous · Next



Like Comment

**US National Weather Service Tampa Bay Florida**  
 Low clouds developing tonight will keep temperatures cooler along the Nature Coast and even into the Tampa Bay area later today.  
 Like · Comment · Share · December 14, 2012

17 people like this.  
 2 shares

**Judy Ann Smith Dunleavy** I want sunshine and warm weather  
 December 14, 2012 at 8:43am via mobile · Like

Write a comment...

Album: Timeline Photo  
 Shared with: Pub

Open Photo Viewer  
 Download  
 Mark as Spam  
 Report/Remove Tag

# GOES-R AWG FLS products and NWS social media



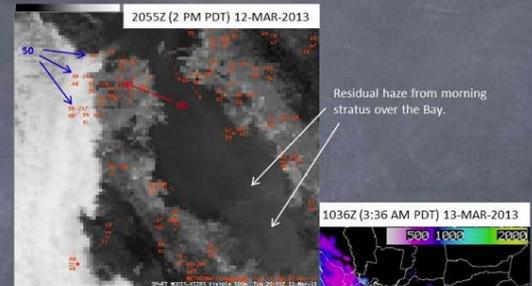
# WFO Monterrey

## 500 Snippet



By Dr Warren Blier  
 Science and Operations  
 Officer (500)

## Marine Stratus, small-scale temperature contrasts and some new satellite imagery



**US National Weather Service San Francisco Bay Area/Monterrey California**  
 Like This Page · 23 hours ago

500 Snippet March 13, 2013

Even during quiescent periods of mild and dry weather, the complex topography of our forecast area results in some interesting small-scale variations in weather conditions. The first figure shows a 500-m resolution visible satellite image centered on San Francisco and the San Mateo Peninsula from 1:55 pm PDT yesterday afternoon, taken by the VIIRS scanning radiometer ...See More

Like · Comment · Share

13 people like this.  
 2 shares

**Sirf Muse Cool.** We have micro-climates right on our one acre property. The front side is forested while the back is a South sloping meadow. The back is often 10-20° warmer/hotter than the front. Right now the front thermometer is reading 70° and back one is read... See More  
 22 hours ago · Like · e3 1

**Dick G. Lord** Ris rery interstening  
 22 hours ago · Like

Write a comment...

# Next Steps

- Generate GOES-R FLS products using VIIRS (coming soon!)
- Reduce differences between daytime and nighttime results
- Merge LEO and GEO capabilities (e.g. use high spatial resolution VIIRS FLS probability as *a priori* probability in GOES classifier)
- Incorporate morphometric characterization of landforms into classifier (this should allow for more accurate and detailed depiction of smaller scale valley fogs and local variability in cloud base)
- Develop 1 - 3 hour *prognostic* IFR and LIFR probability products
- Develop fog formation alerting capability
- Integrate results with GPS applications



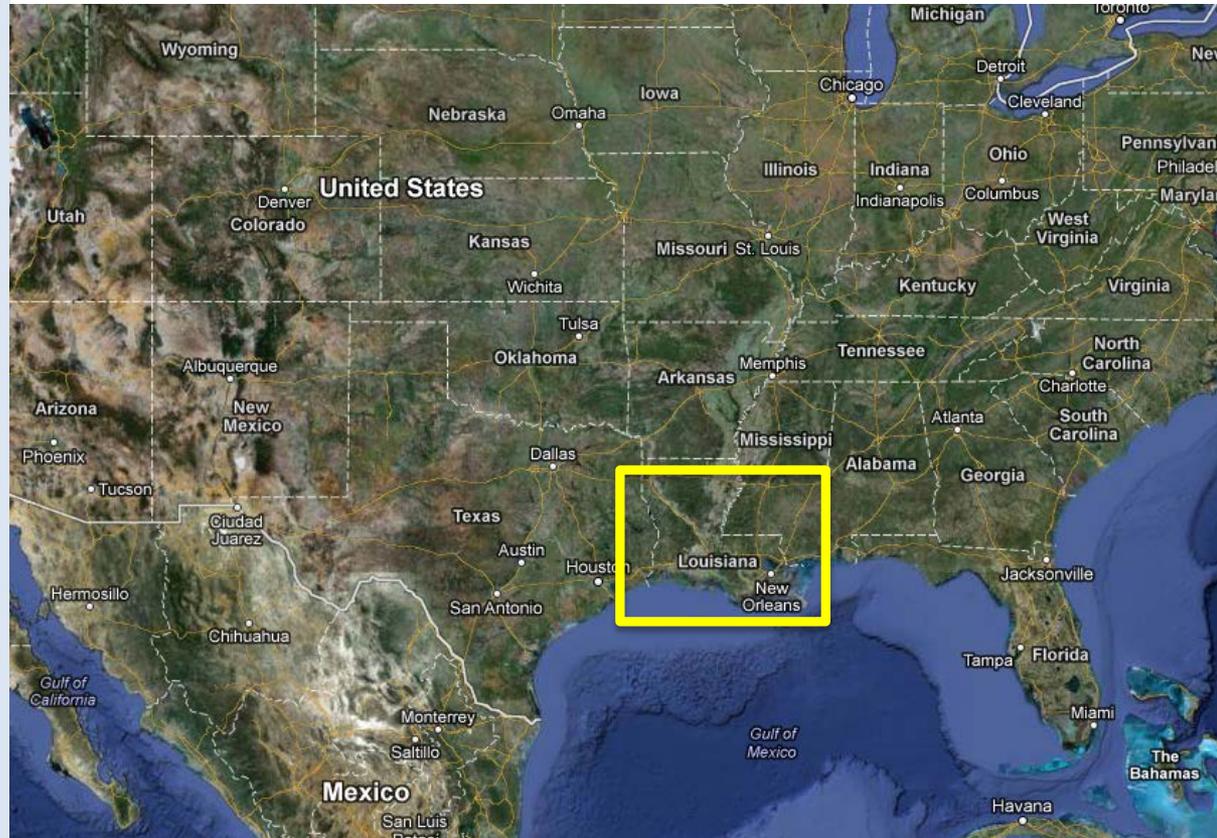
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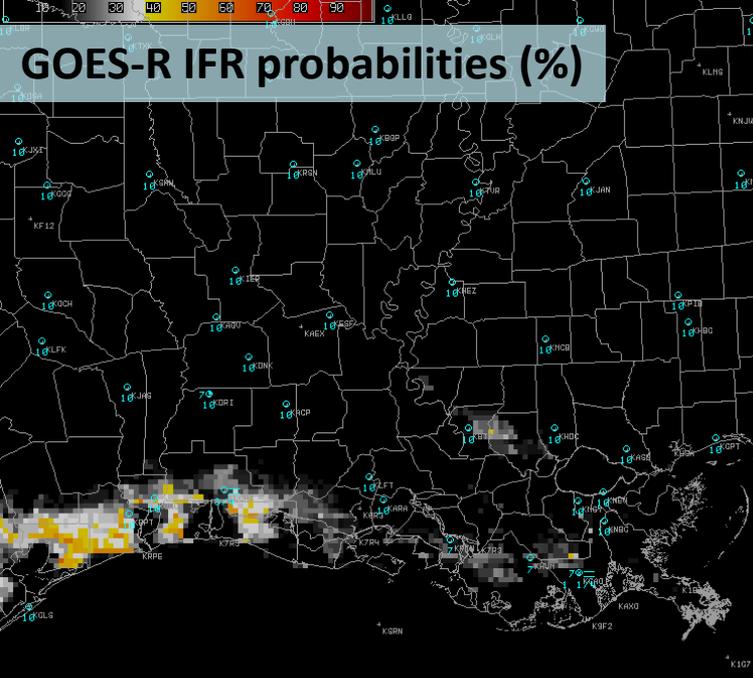


# Prototype GOES-R Fog Alerting Capability

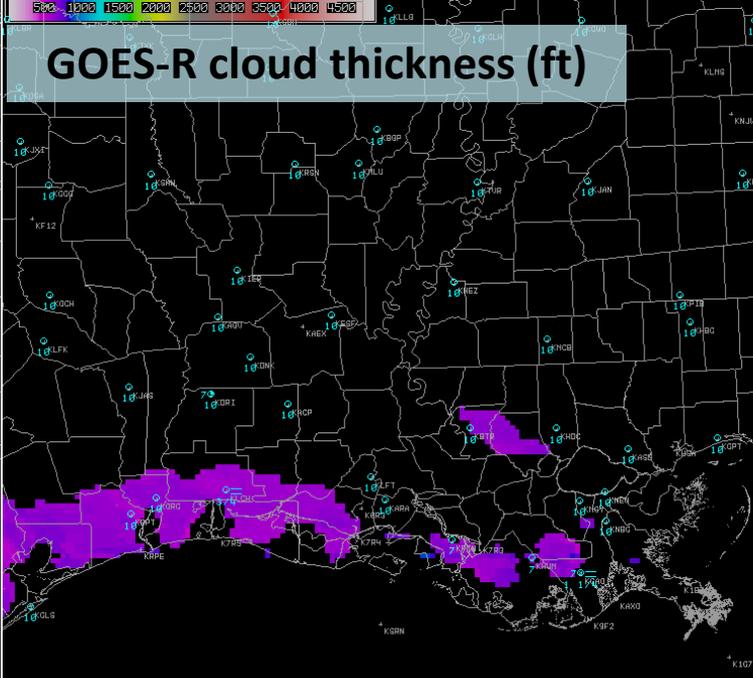
- Shallow fog formed across southern Louisiana on March 6, 2012.
- Prototype GOES-R fog alerting product triggered an alarm indicating the likely development of fog at 7:45 UTC
- AFD was posted by NWS in St. Charles at 10:31 UTC with first mention of shallow, localized fog formation
- Updated AFD was posted at 11:33 UTC with mention of fog as an aviation hazard
- The heritage fog product never produced a coherent signal



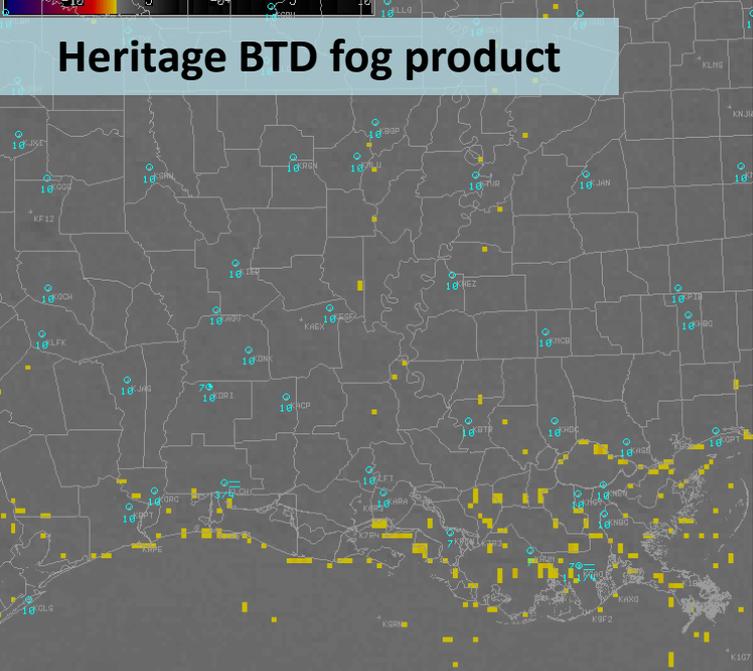
**The traditional BTD product has difficulty discerning areas of fog throughout entire event**



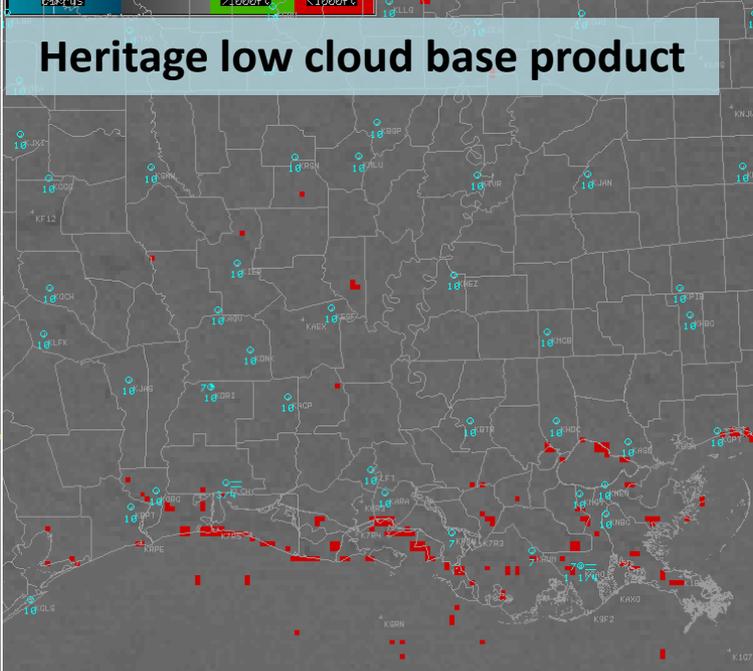
Ceiling (agl) and Visibility Tue 06:00Z 06-Mar-12  
 GOES-E IFR Probability 4km (%) Tue 05:45Z 06-Mar-12



Ceiling (agl) and Visibility Tue 06:00Z 06-Mar-12  
 GOES-E Cloud Thickness-Highest Liquid Layer 4km (ft) Tue 05:45Z 06-Mar-12

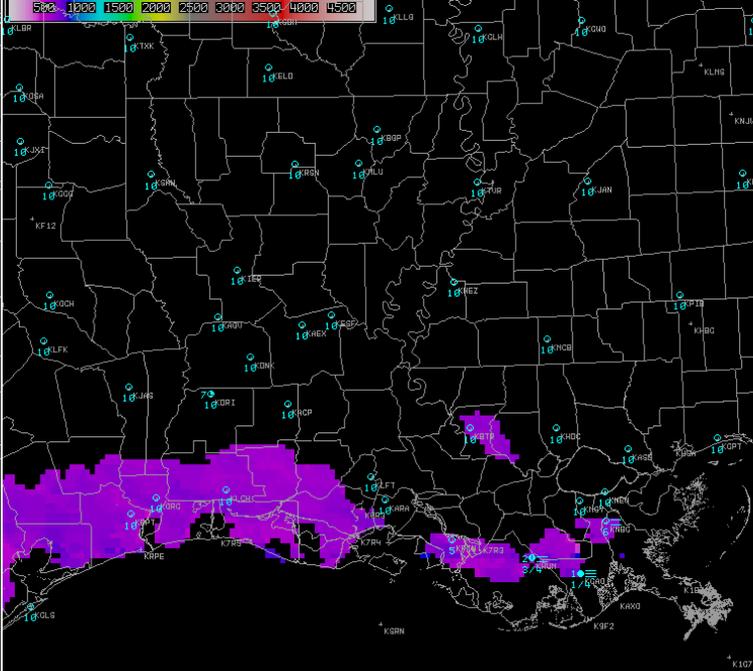
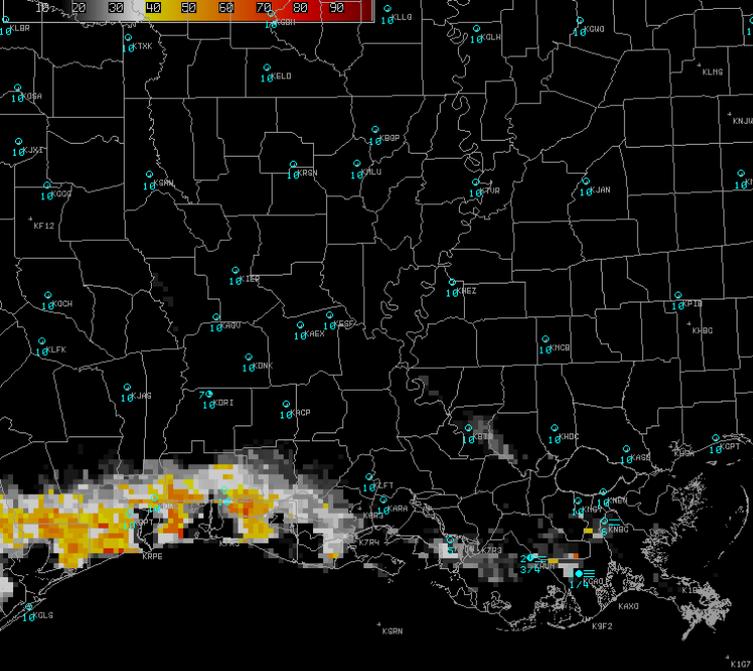


Ceiling (agl) and Visibility Tue 06:00Z 06-Mar-12  
 GOES 11u-3.9u Satellite (counts) Tue 05:40Z 06-Mar-12



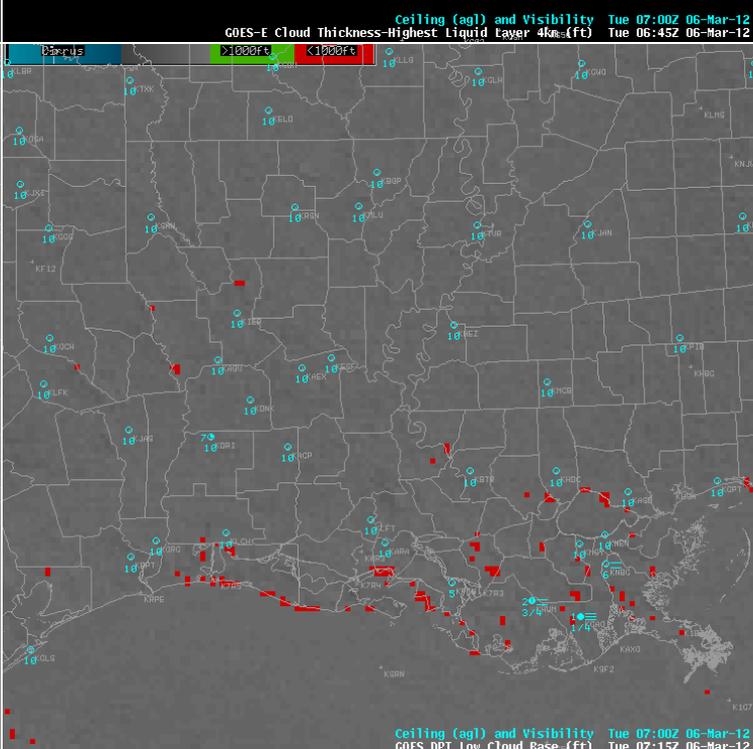
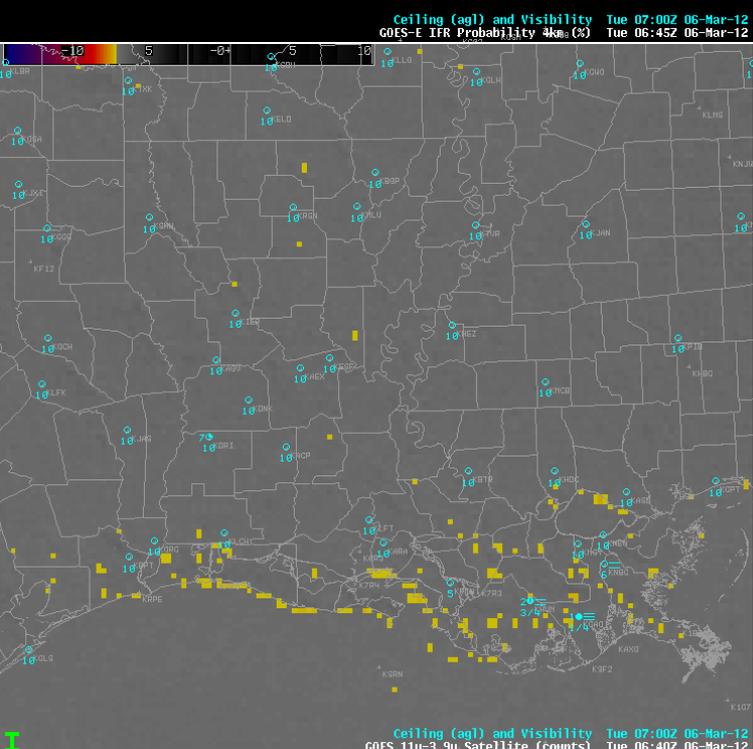
Ceiling (agl) and Visibility Tue 06:00Z 06-Mar-12  
 GOES DPI Low Cloud Base (ft) Tue 06:15Z 06-Mar-12

**3/6/2012  
 05:45 UTC**



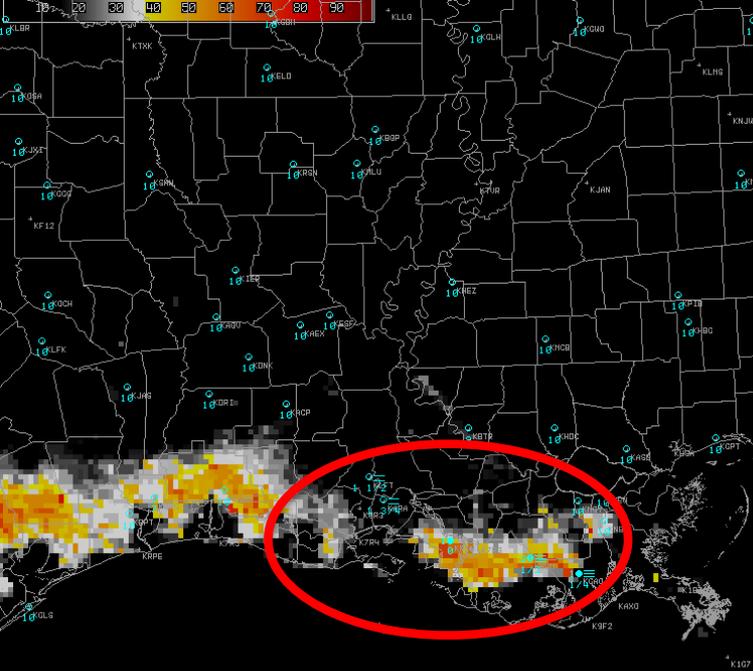
**GOES-R IFR probabilities start increasing over S. Louisiana**

**GOES-R cloud thickness product indicates any fog present is shallow**

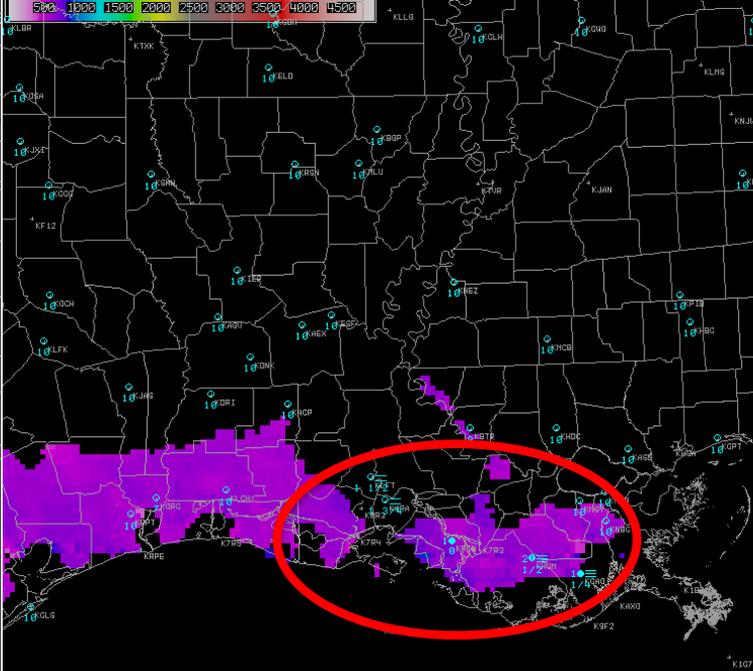


**Traditional fog products appear noisy with no discernable signal**

**3/6/2012  
06:45 UTC**

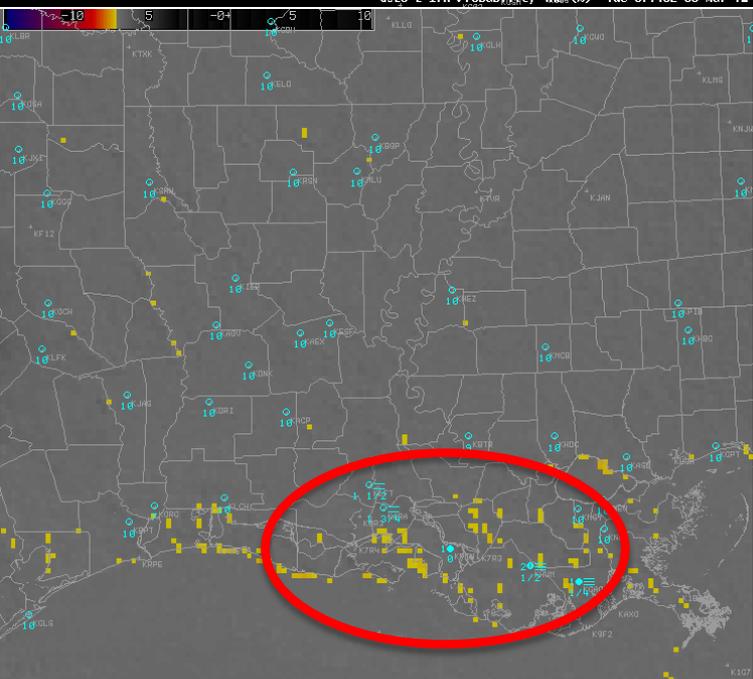


Ceiling (agl) and Visibility Tue 08:00Z 06-Mar-12  
 GOES-E IFR Probability 4km (ft) Tue 07:45Z 06-Mar-12

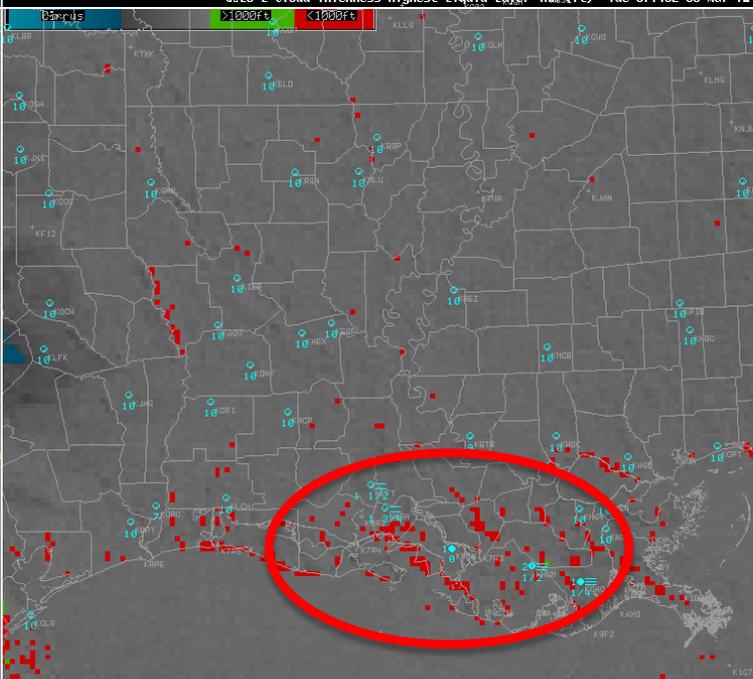


Ceiling (agl) and Visibility Tue 08:00Z 06-Mar-12  
 GOES-E Cloud Thickness-Highest Liquid Layer 4km (ft) Tue 07:45Z 06-Mar-12

Several surface stations indicate ceiling and visibilities meeting IFR criteria (see circled area)



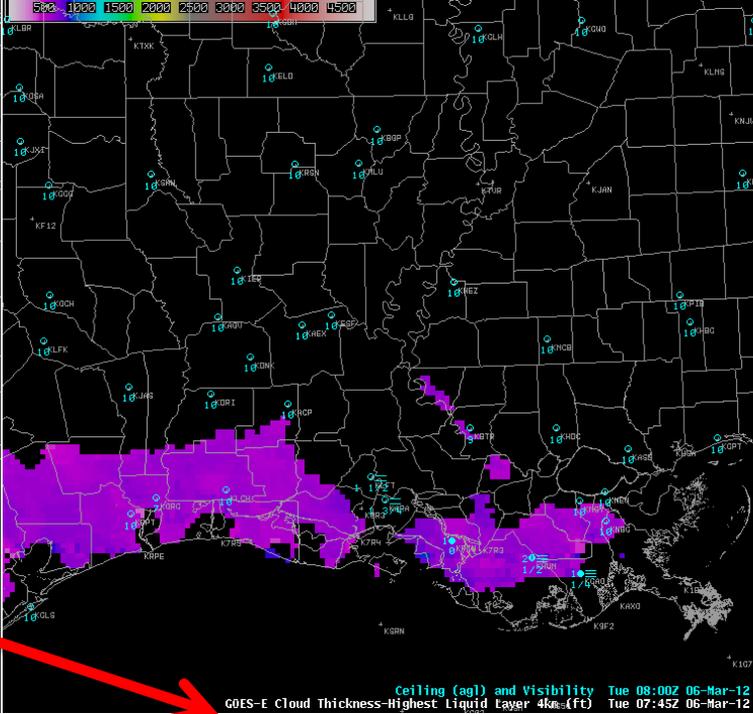
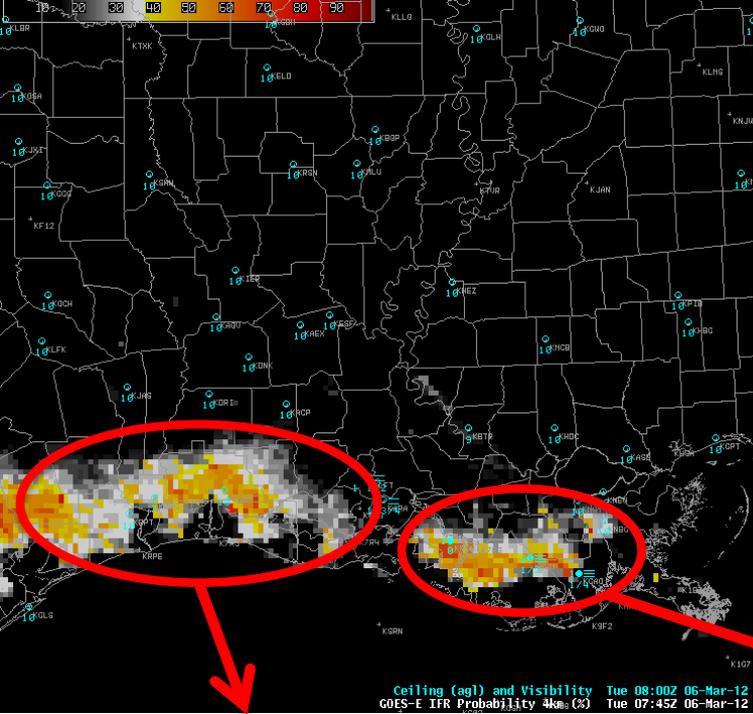
Ceiling (agl) and Visibility Tue 08:00Z 06-Mar-12  
 GOES 11u-3.9u Satellite (counts) Tue 07:40Z 06-Mar-12



Ceiling (agl) and Visibility Tue 08:00Z 06-Mar-12  
 GOES DPI Low Cloud Base (ft) Tue 08:15Z 06-Mar-12

Traditional fog products appear noisy with no discernable signal

3/6/2012  
 07:45 UTC



**GOES-R fog alerting product produced alarms for both Lake Charles (LCH) and New Orleans/Baton Rouge (LIX) WFO's warning of fog development**

GUARDIAN Pop-up Message Window

\*\*\*\*\* POSSIBLE FOG DEVELOPING IN CWA (LCH) \*\*\*\*\*

Satellite: GOES-13  
Date and Time: March 6, 2012 07:45:00 GMT

Counties/Parishes where fog may be developing include:  
Louisiana:  
> Vermilion, Acadia, Jefferson Davis, Allen, Beauregard, Calcasieu, Cameron  
Texas:  
> Jasper, Newton, Tyler, Hardin, Orange, Jefferson

FLS Object Statistics:  
> Median IFR Probability = 41.0%  
> Max IFR Probability = 91.3%  
> Median LIFR Probability = 22.8%  
> Max LIFR Probability = 86.0%  
> Number of Satellite Pixels = 1145  
> Geographic Area = 18320.0 km^2

Show Log Acknowledge Last Acknowledge All (1)... Close

GUARDIAN Pop-up Message Window

\*\*\*\*\* POSSIBLE FOG DEVELOPING IN CWA (LIX) \*\*\*\*\*

Satellite: GOES-13  
Date and Time: March 6, 2012 07:45:00 GMT

Counties/Parishes where fog may be developing include:  
Louisiana:  
> St. Mary, St. Martin, Assumption, Terrebonne, Lafourche, St. Charles, Jefferson, Orleans, St. Bernard, Plaquemines

FLS Object Statistics:  
> Median IFR Probability = 43.2%  
> Max IFR Probability = 82.5%  
> Median LIFR Probability = 24.4%  
> Max LIFR Probability = 71.4%  
> Number of Satellite Pixels = 140  
> Geographic Area = 2240.0 km^2

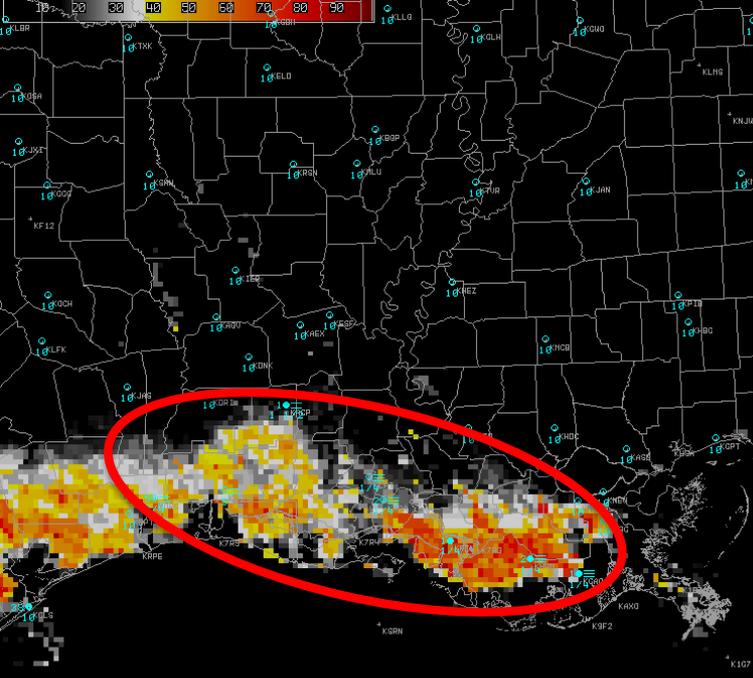
Show Log Acknowledge Last Acknowledge All (1)... Close



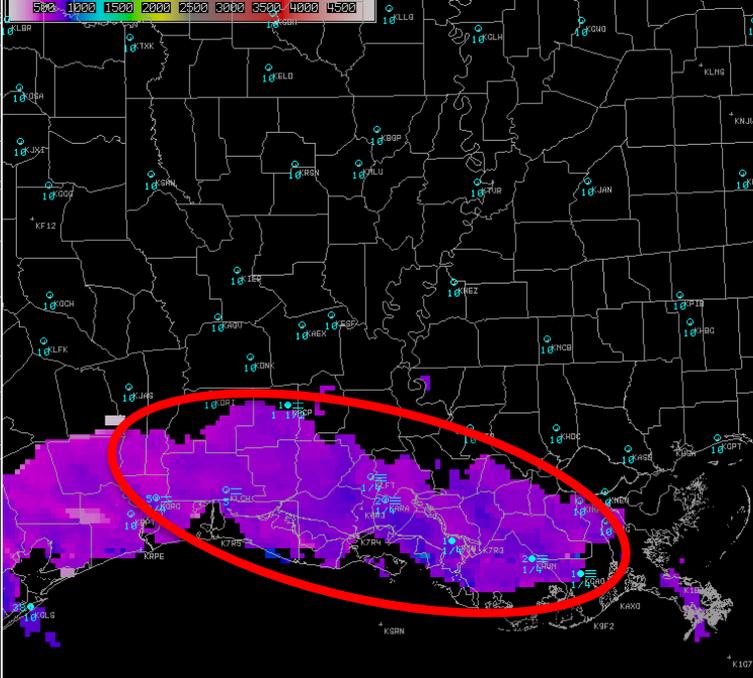
Map of local WFO's and corresponding CWA's



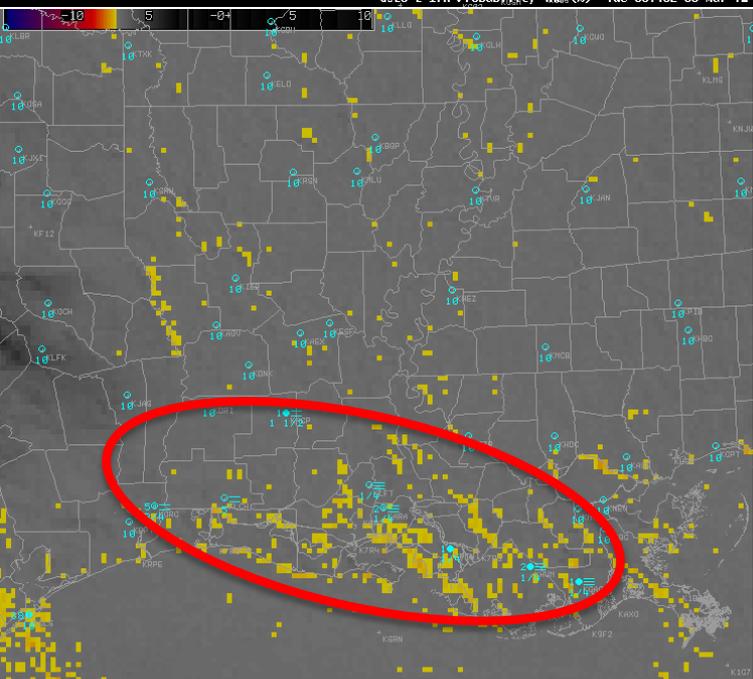
**3/6/2012  
07:45 UTC**



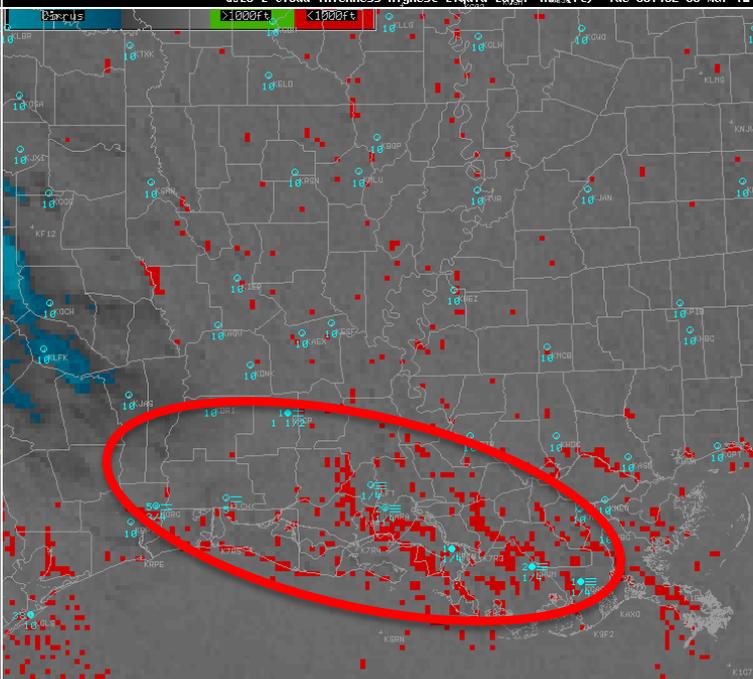
Ceiling (agl) and Visibility Tue 09:00Z 06-Mar-12  
GOES-E IFR Probability 4km (fc) Tue 08:45Z 06-Mar-12



Ceiling (agl) and Visibility Tue 09:00Z 06-Mar-12  
GOES-E Cloud Thickness-Highest Liquid Layer 4km (fc) Tue 08:45Z 06-Mar-12



Ceiling (agl) and Visibility Tue 09:00Z 06-Mar-12  
GOES 11u-3.9u Satellite (counts) Tue 08:40Z 06-Mar-12

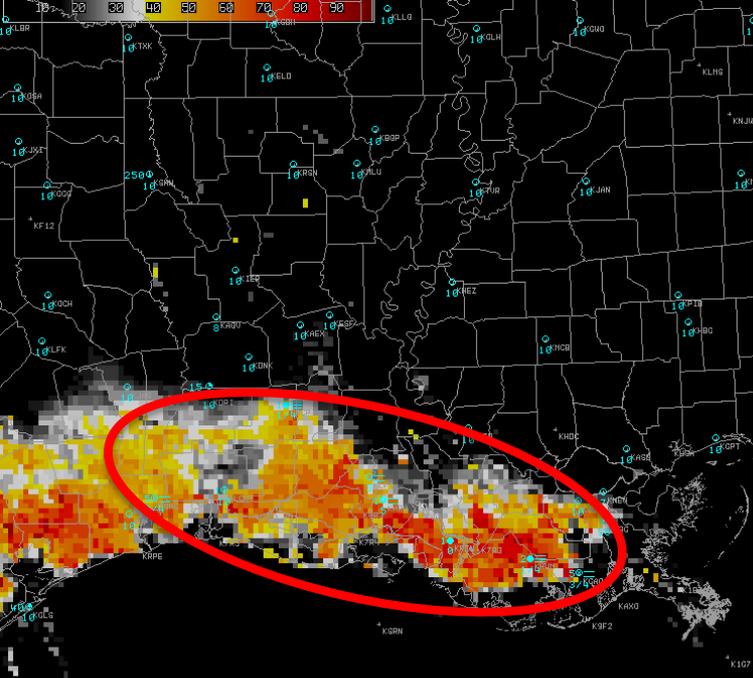


Ceiling (agl) and Visibility Tue 09:00Z 06-Mar-12  
GOES DPI Low Cloud Base (fc) Tue 09:15Z 06-Mar-12

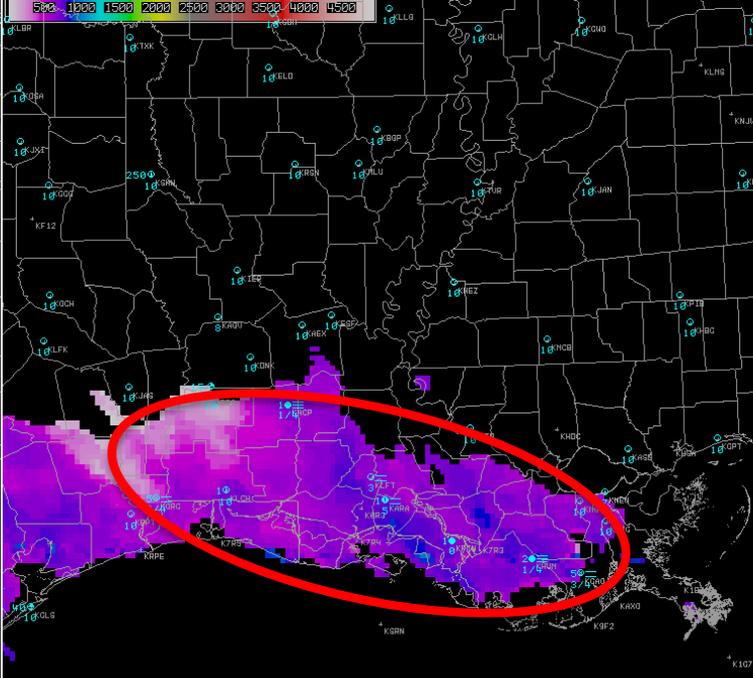
Several surface stations indicate ceiling and visibilities meeting IFR criteria (see circled area)

Traditional fog products appear noisy with no discernable signal

3/6/2012  
08:45 UTC

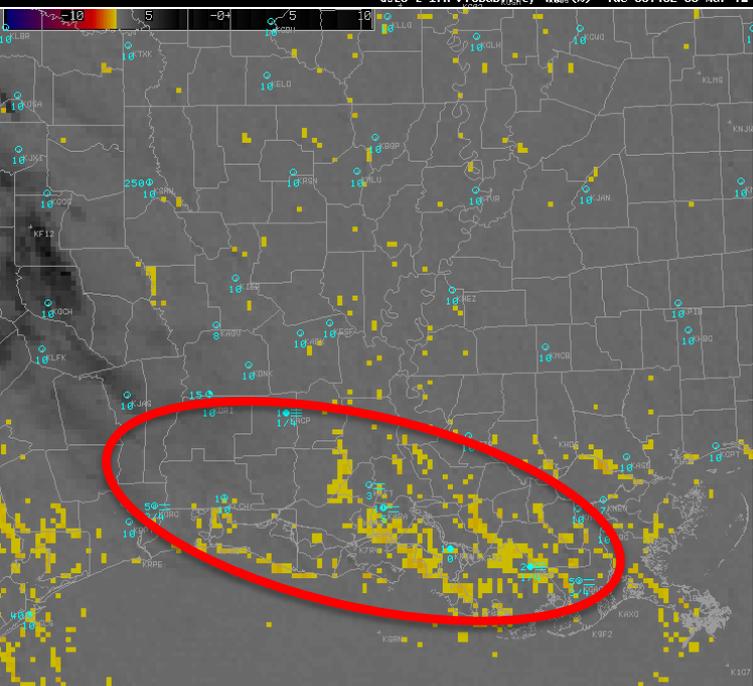


Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES-E IFR Probability 4km (fc) Tue 09:45Z 06-Mar-12

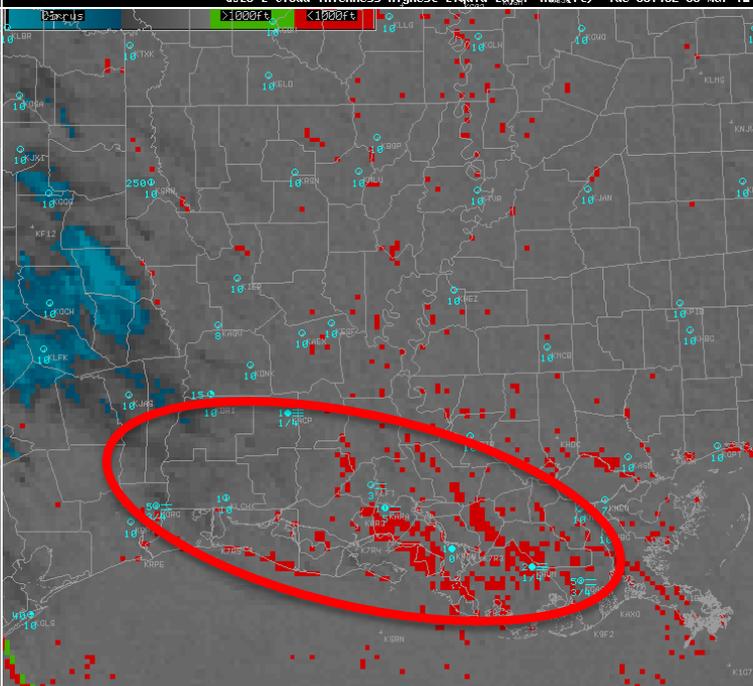


Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES-E Cloud Thickness-highest Liquid Layer 4km (fc) Tue 09:45Z 06-Mar-12

Several surface stations indicate ceiling and visibilities meeting IFR criteria (see circled area)



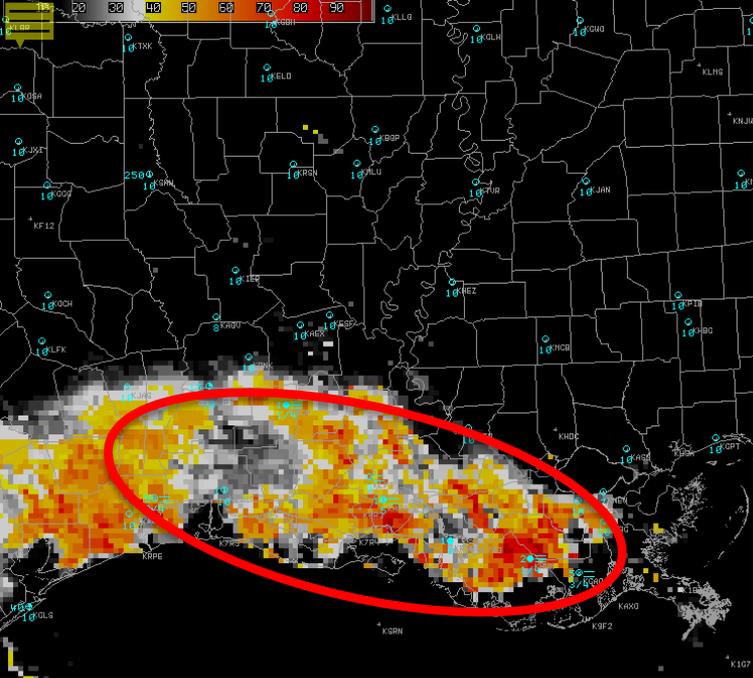
Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES 11u-3.9u Satellite (counts) Tue 09:40Z 06-Mar-12



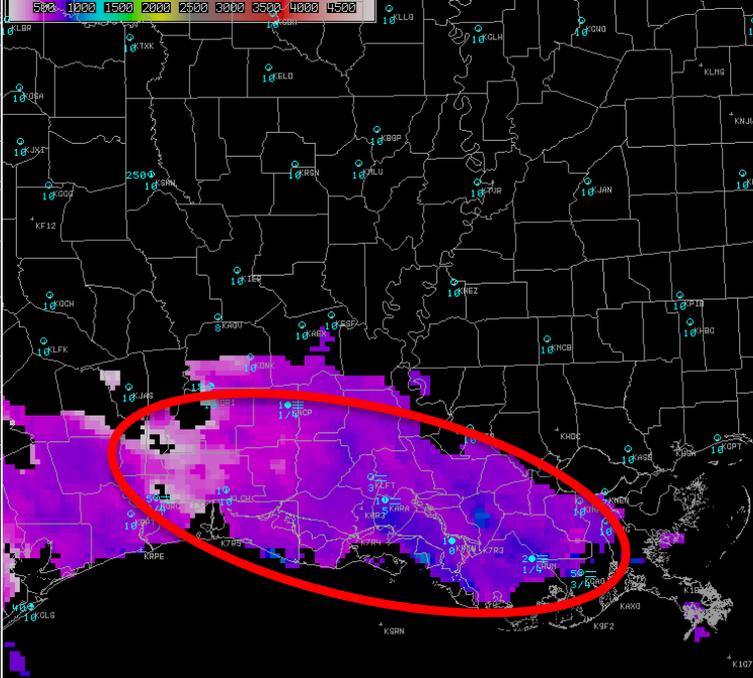
Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES DPI Low Cloud Base (fc) Tue 10:15Z 06-Mar-12

Traditional fog products appear noisy with no discernable signal

3/6/2012  
09:45 UTC

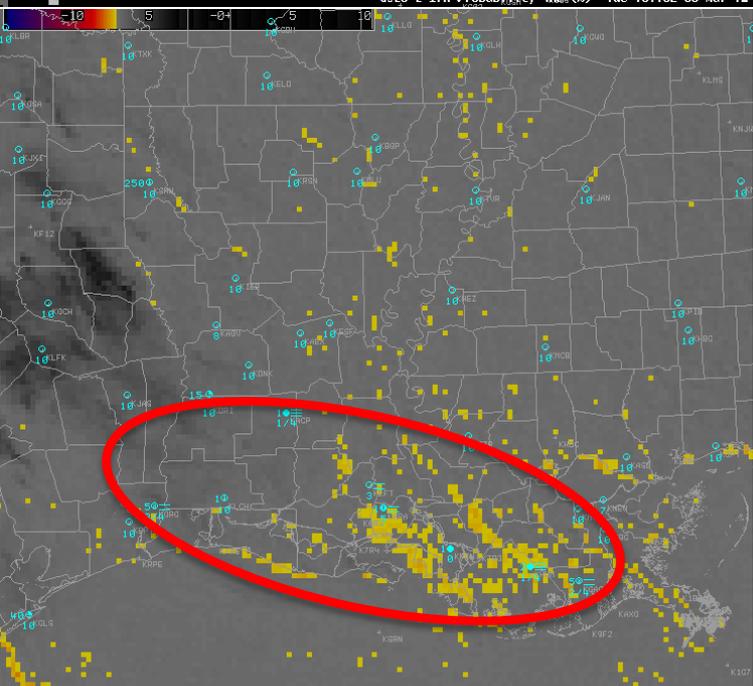


Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES-E IFR Probability 4km (%) Tue 10:15Z 06-Mar-12

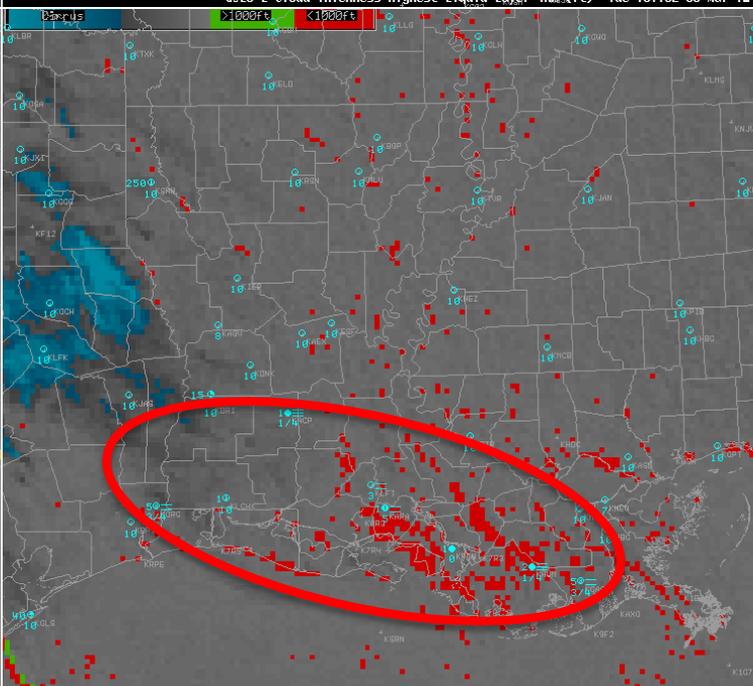


Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES-E Cloud Thickness-Highest Liquid Layer 4km (ft) Tue 10:15Z 06-Mar-12

Several surface stations indicate ceiling and visibilities meeting IFR criteria (see circled area)



Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES 11u-3.9u Satellite (counts) Tue 10:10Z 06-Mar-12



Ceiling (agl) and Visibility Tue 10:00Z 06-Mar-12  
GOES DPI Low Cloud Base (ft) Tue 10:15Z 06-Mar-12

Traditional fog products appear noisy with no discernable signal

3/6/2012  
10:15 UTC

# Next Steps

- Generate GOES-R FLS products using VIIRS (coming soon!)
- Reduce differences between daytime and nighttime results
- Merge LEO and GEO capabilities (e.g. use high spatial resolution VIIRS FLS probability as *a priori* probability in GOES classifier)
- Incorporate morphometric characterization of landforms into classifier (this should allow for more accurate and detailed depiction of smaller scale valley fogs and local variability in cloud base)
- Develop 1 - 3 hour *prognostic* IFR and LIFR probability products
- Develop fog formation alerting capability
- [Integrate results with GPS applications](#)



