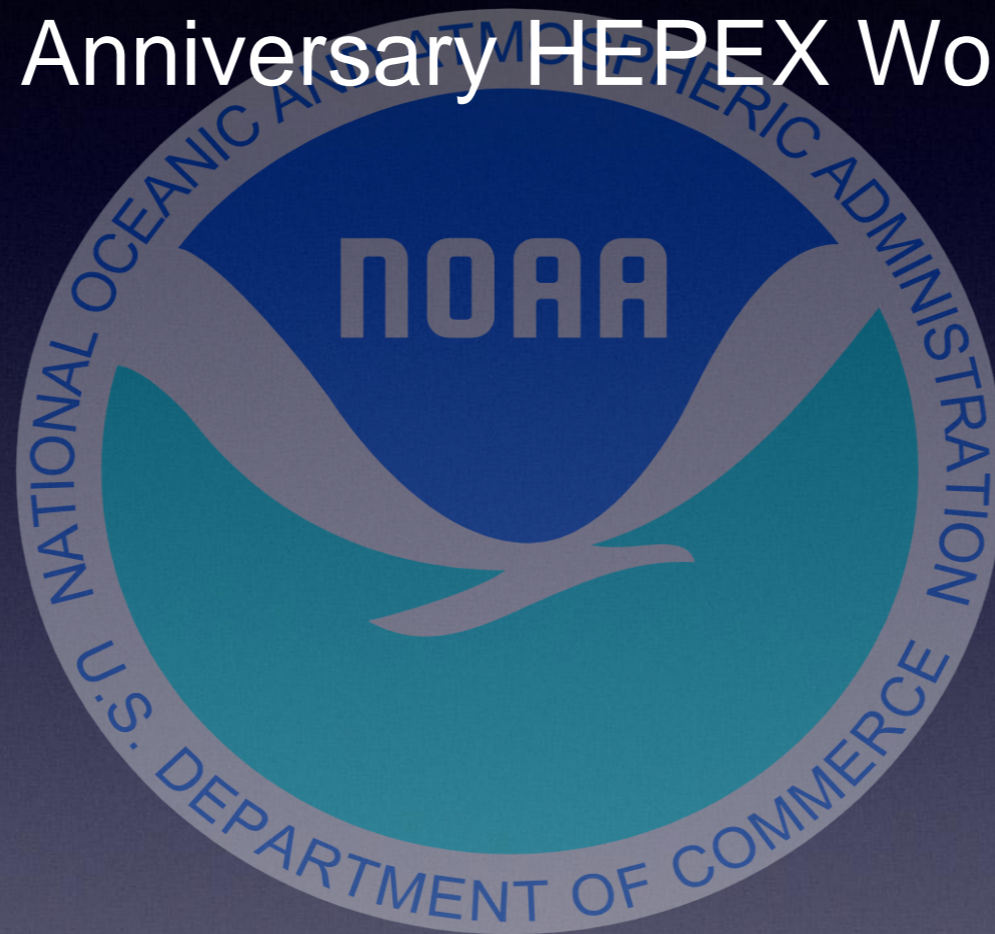


# MMEFS Operational Ensemble Hydrologic Forecasting at the Ohio River Forecast Center

10th Anniversary HEPEx Workshop



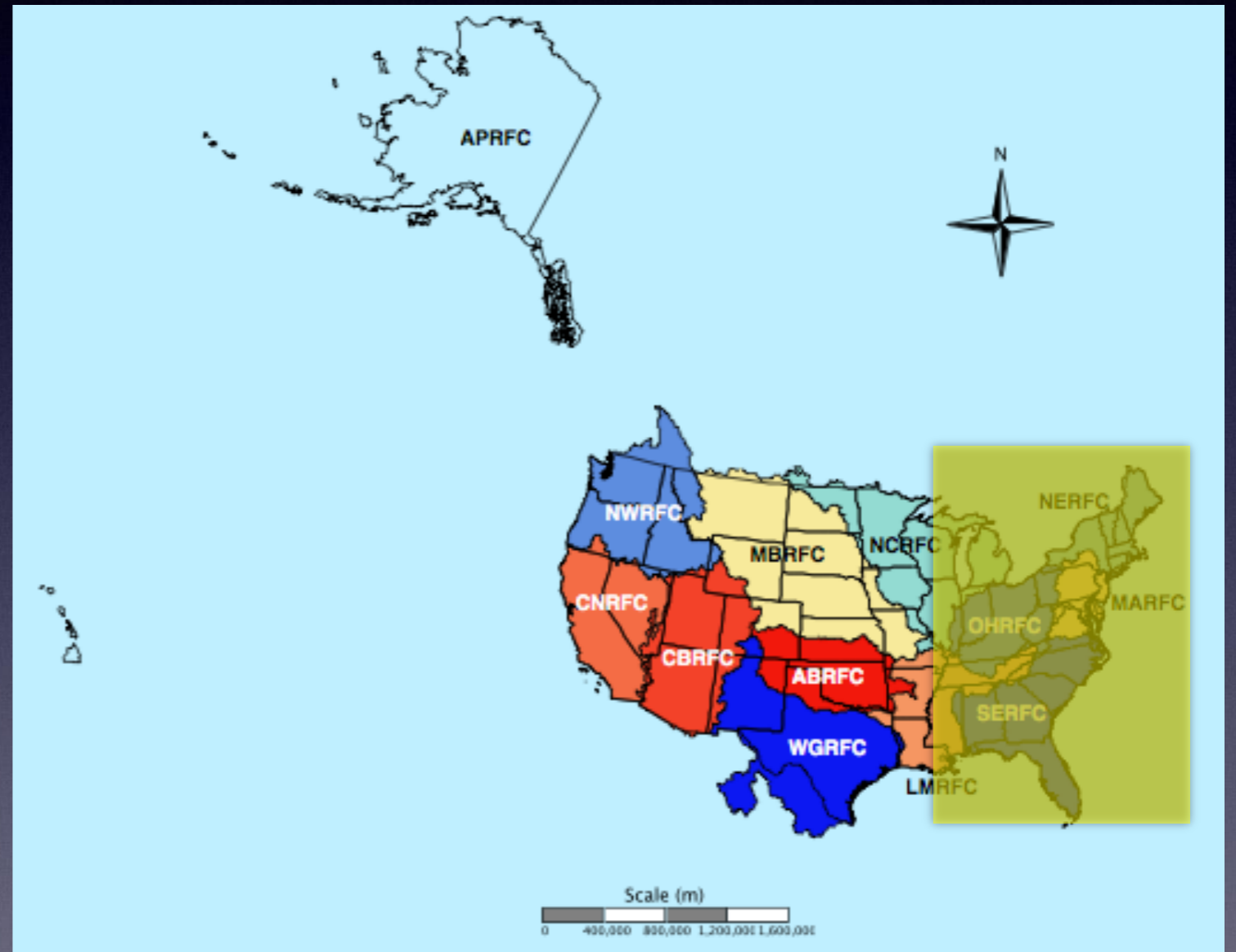
Thomas Adams

# Topics

- Introduction
- MMEFS History
- Short lead-time probabilistic streamflow forecasting with the MMEFS
- Examples
- Issues

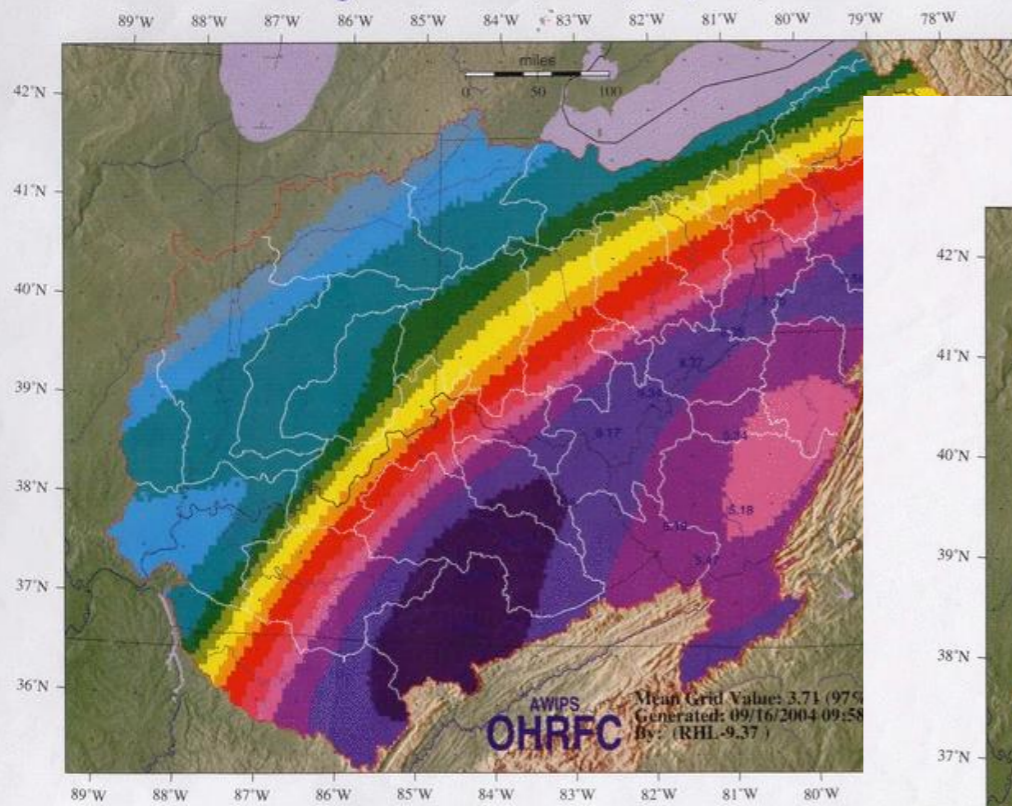
# Introduction

- 13 River Forecast Centers
- All RFCs use the *Delft-FEWS* based *Community Hydrologic Prediction System* (CHPS)
- MMEFS: OHRFC, NERFC, MARFC, SERFC
- 288 OHRFC forecast points

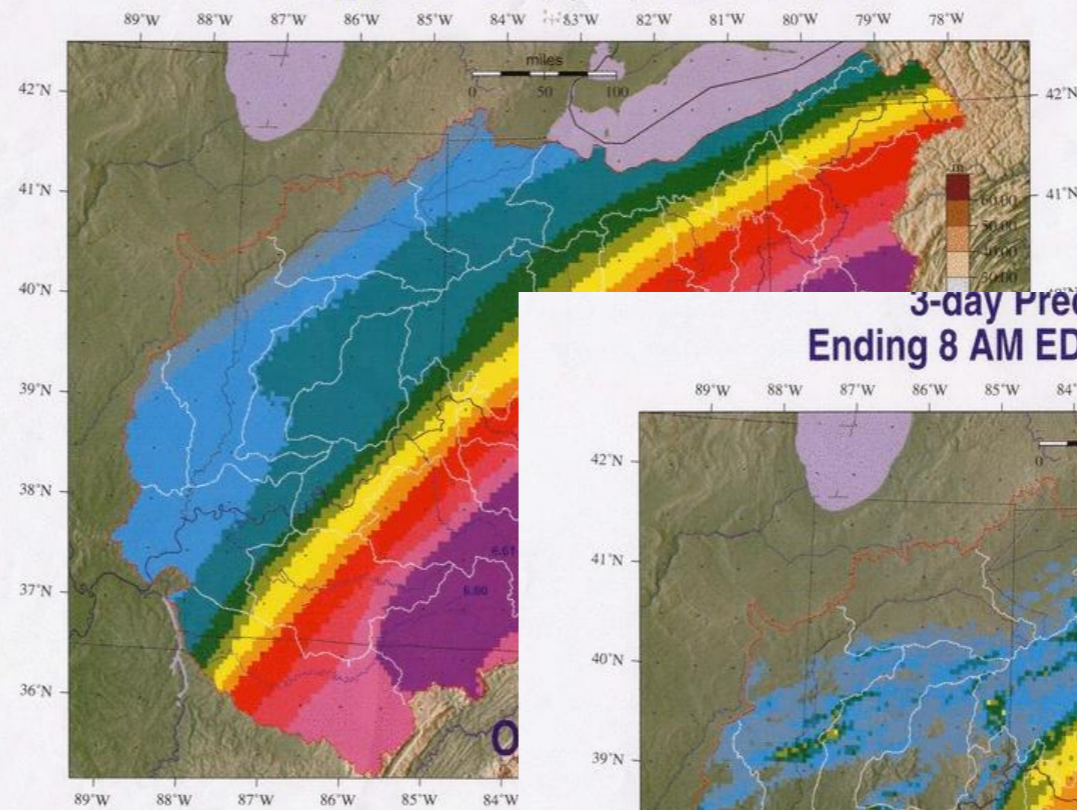


# Precipitation Forecasting — Quantitative Precipitation Forecast (QPF)

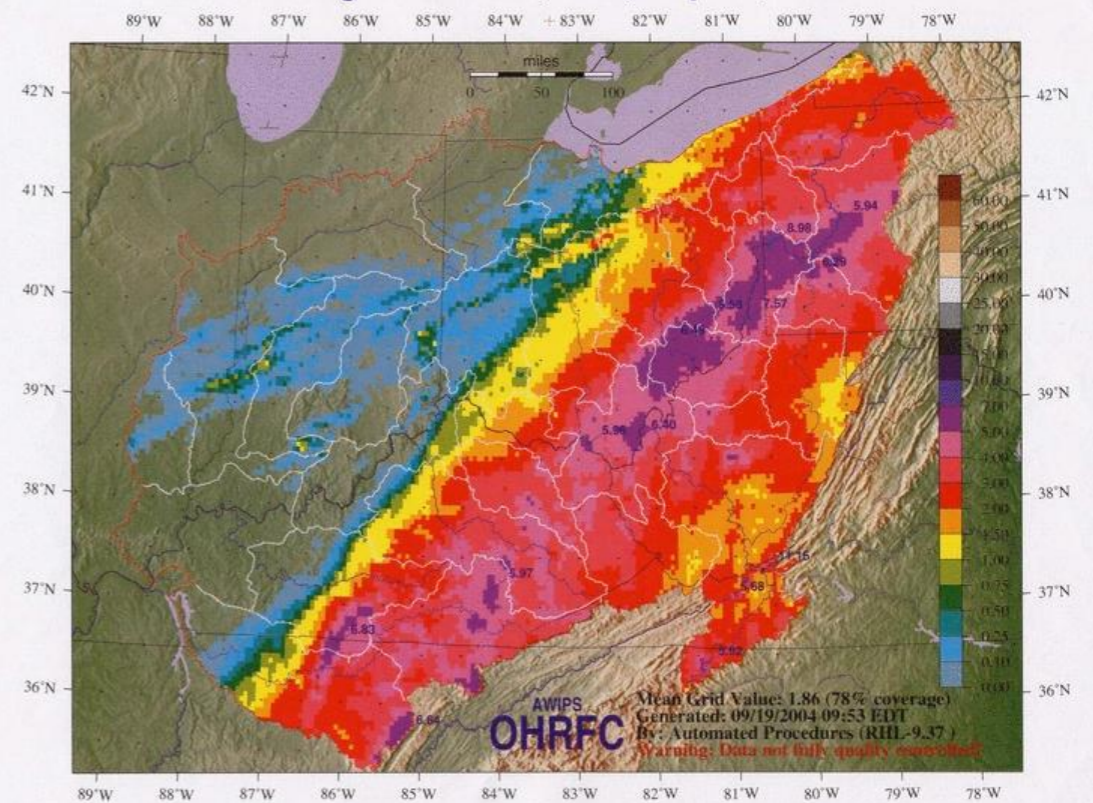
72-hr Forecast Areal-Avg Precipitation (HPC)  
Ending 8 AM EDT, Sun, Sep 19, 2004



72-hr Forecast Areal-Avg Precipitation (NAS)  
Ending 8 AM EDT, Sun, Sep 19, 2004



3-day Precipitation Total  
Ending 8 AM EDT, Sun, Sep 19, 2004



Hurricane Ivan

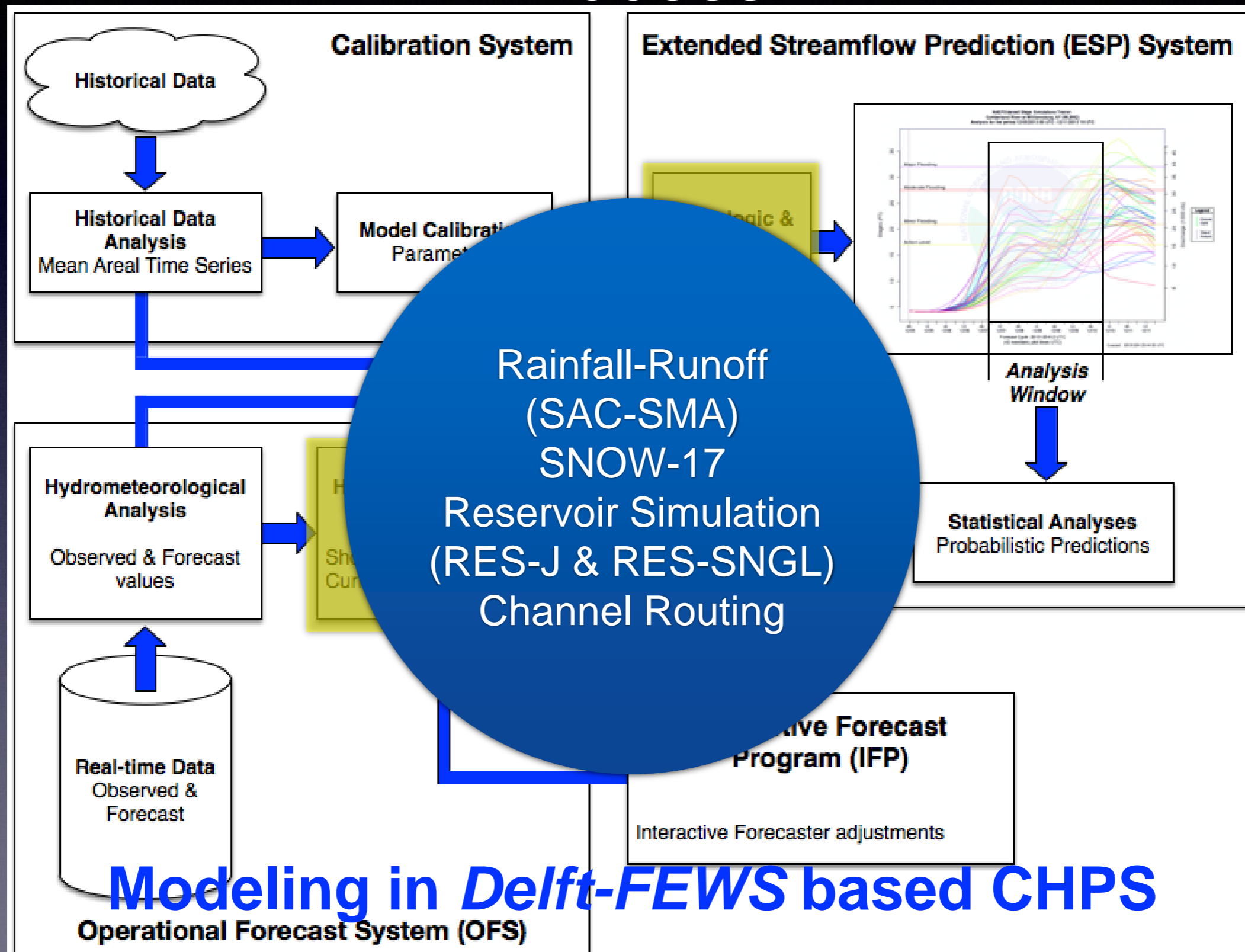
# Short Lead-time Ensemble Hydrologic Forecasting

- Goal: to generate short lead-time (Days 1 to 7) probabilistic hydrologic forecasts — focused on *flood forecasting*
- Errors in predicting precipitation (in particular), temperature, & other meteorological variables... leads to hydrologic forecast uncertainty
- The hydrologic forecast uncertainty must be quantified and passed on to the public & decision makers
- Use NWP & hydrologic models to objectively quantify forecast uncertainty

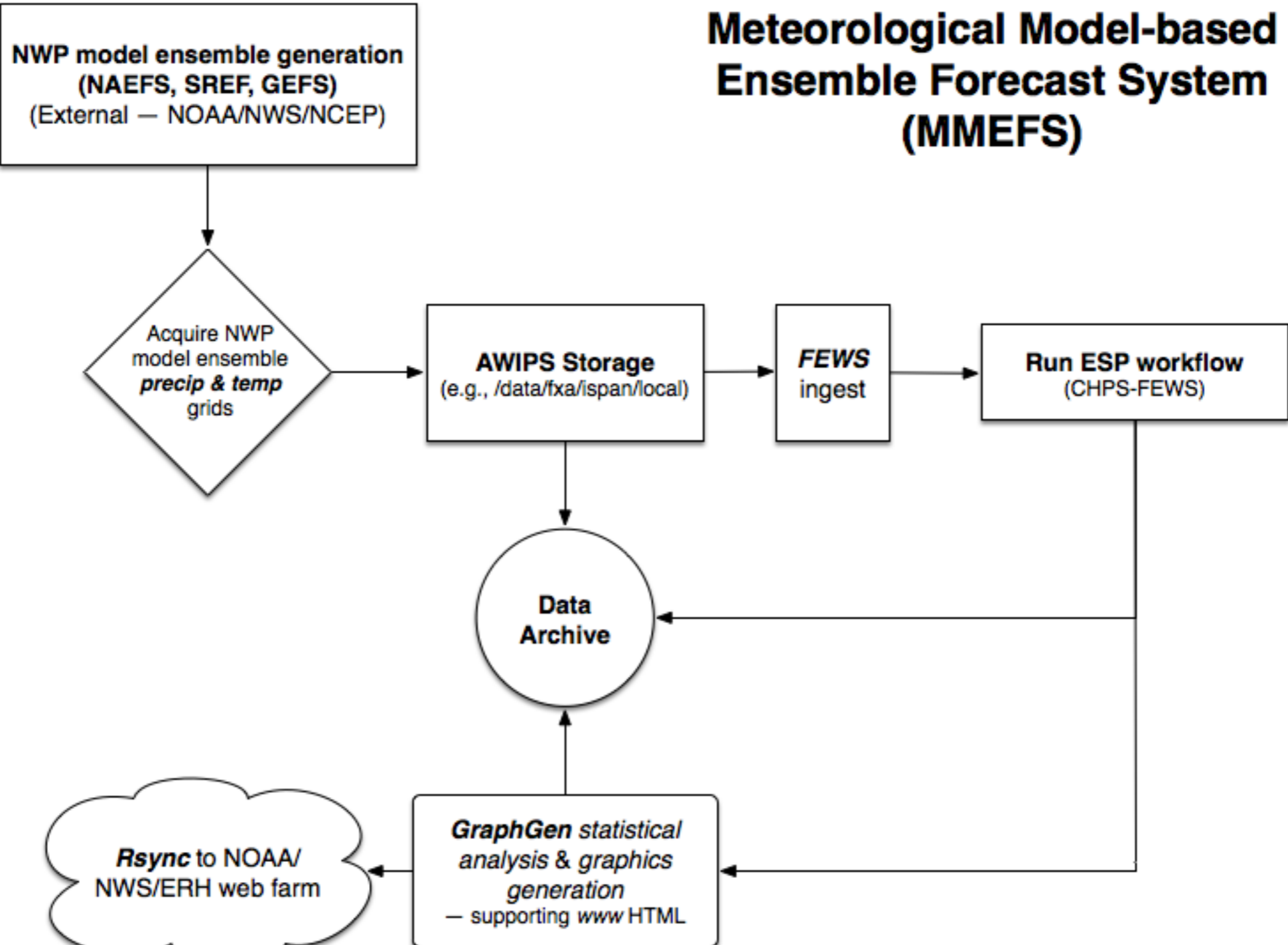
# History

- GENS — 2007, developed at NERFC by Rob Shedd
- GENS customized to run at OHRFC — Tom Adams (late 2007)
- Generalized & optimized at MARFC by Joe Ostrowski: MMEFS (2008)
- Cooperative project between the OHRFC, NERFC & MARFC, with assistance from the NWS/National Centers for Environmental Prediction (NCEP) and NWS/ERH
- Officially a NOAA/NWS/ER Experimental Product in 2010
  - Beginning of review period by Customer Advisory Board
- SERFC joined in 2010
- Moved from ESPADP based graphics to R based graphics (Fall 2011)
- Google Maps public webpage interface
- Was NWSRFS ESP based, now runs in CHPS-FEWS — significant code eliminated
- Became operation January 2013
- Graphics generation from R to NWS GraphGen — more code eliminated

# NOAA/NWS Hydrologic Modeling Process



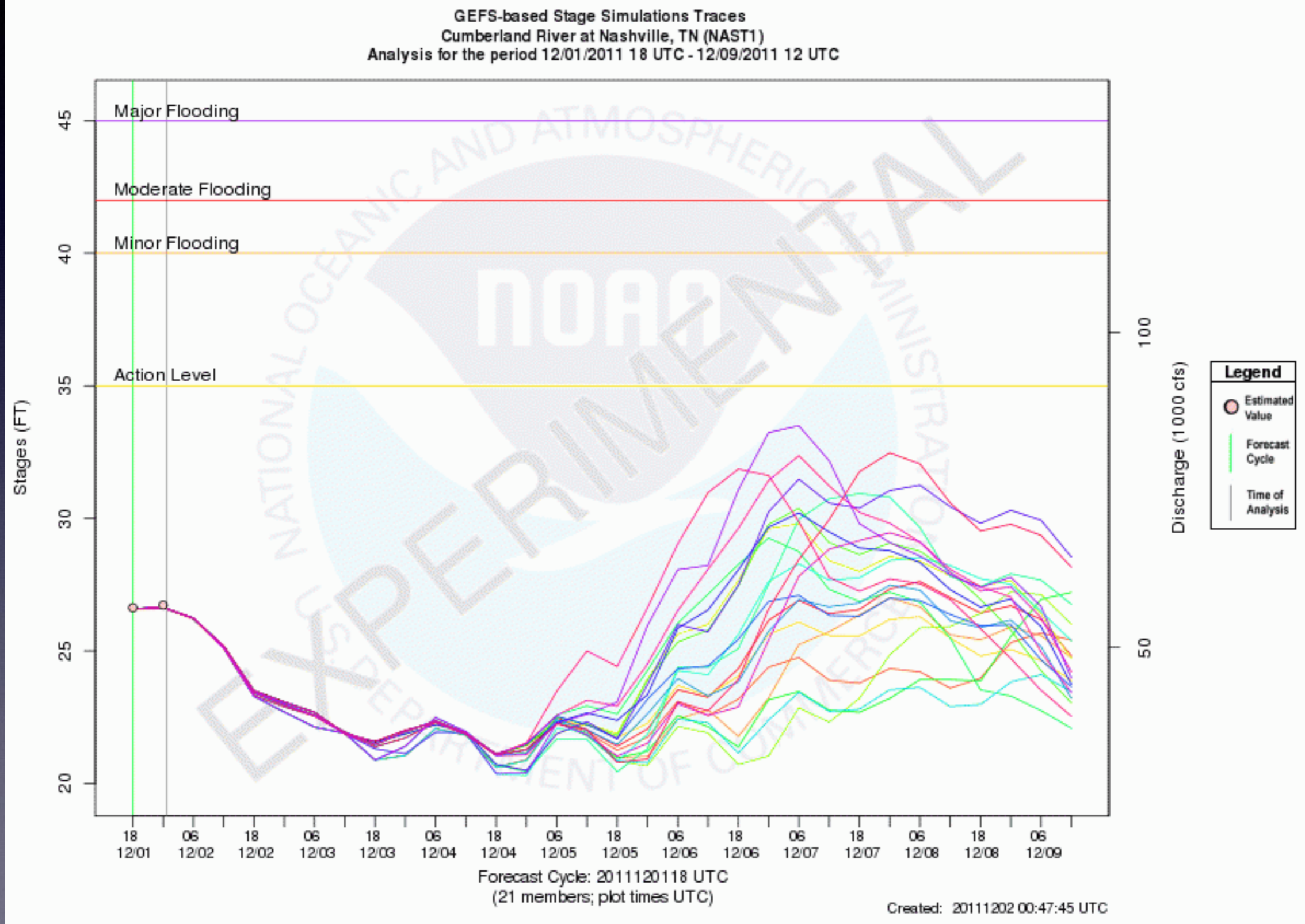
# Meteorological Model-based Ensemble Forecast System (MMEFS)



AWIPS-2 Environment

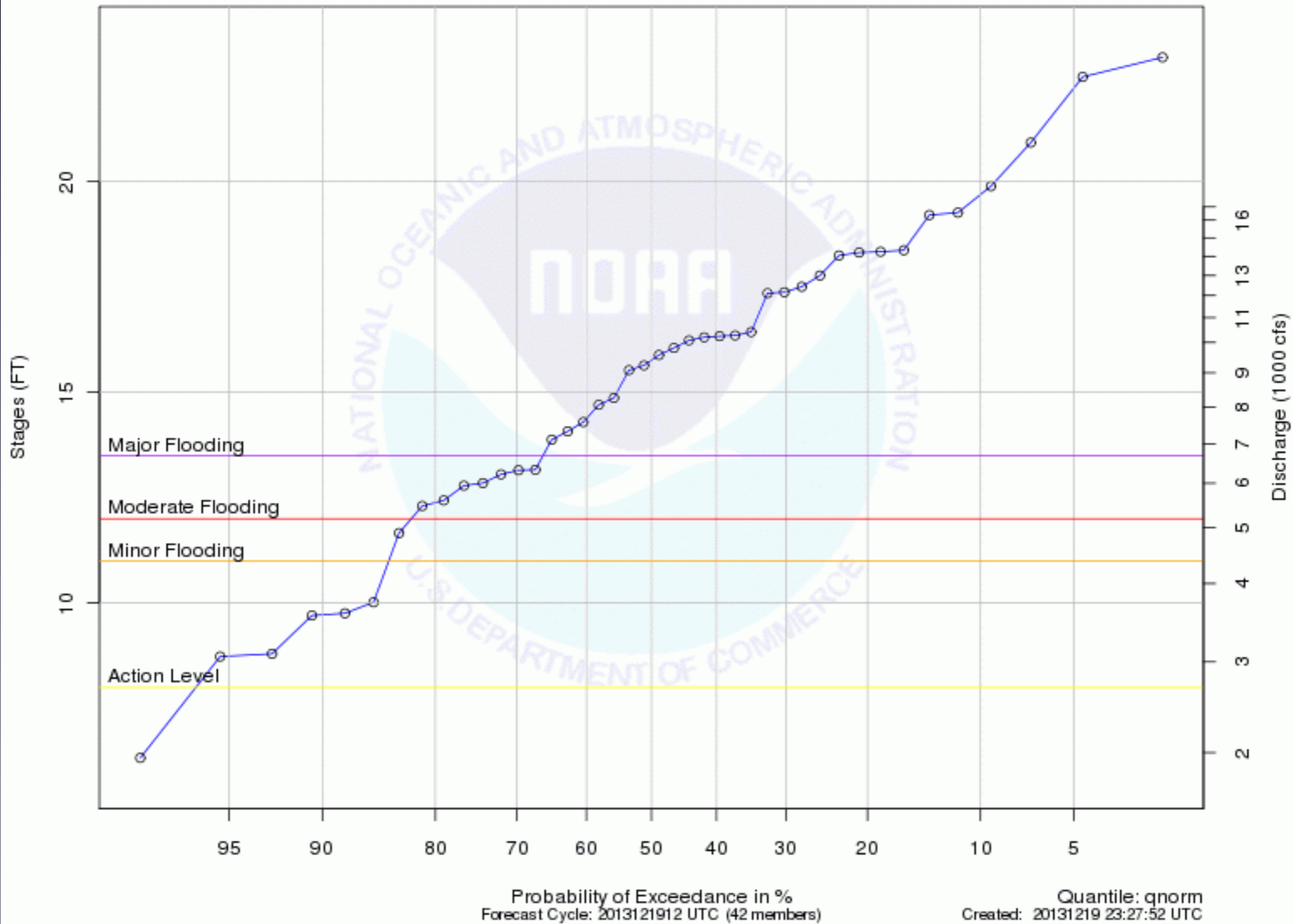


# Nashville, TN GEFS Example

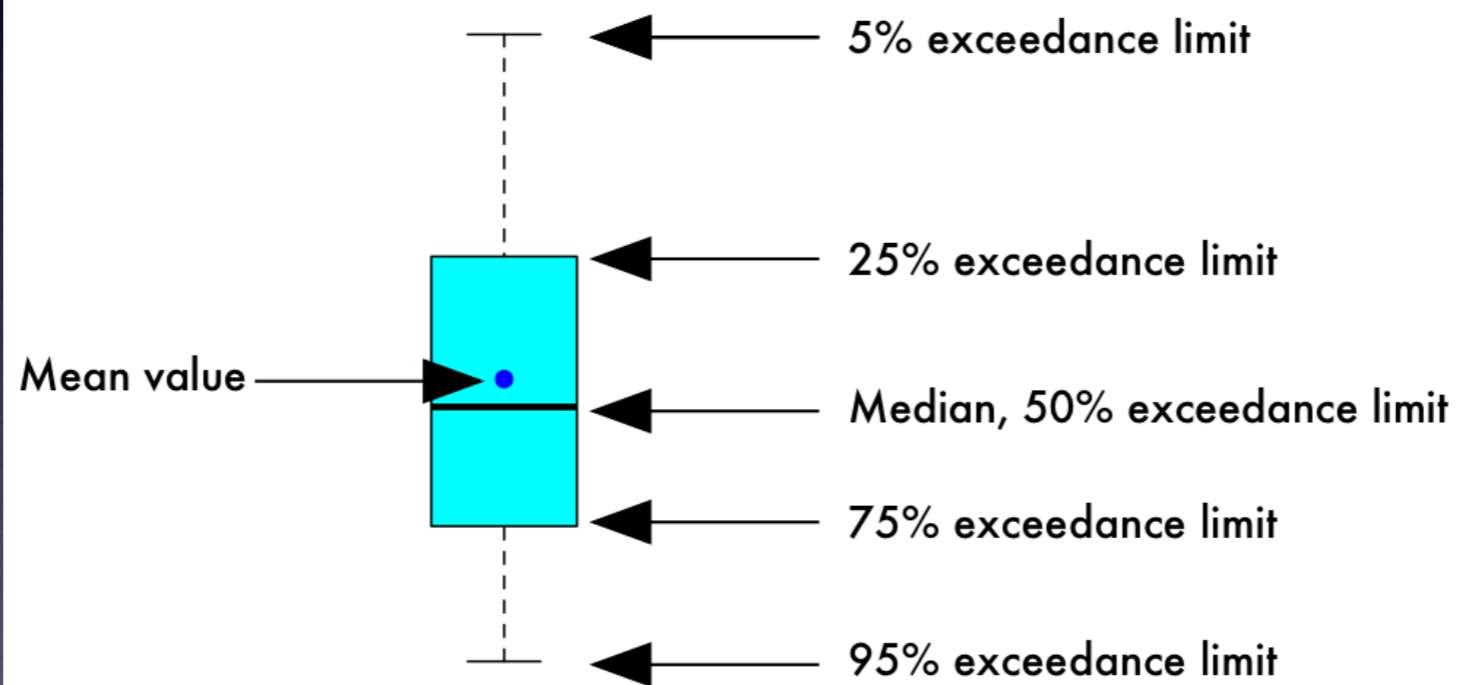


# Probability of Exceedance

NAEFS-based Stage Simulations Probability of Exceedance Plot  
Blanchard River at Findlay, OH (FDYO1)  
Analysis for the period 12/20/2013 00UTC - 12/26/2013 12UTC

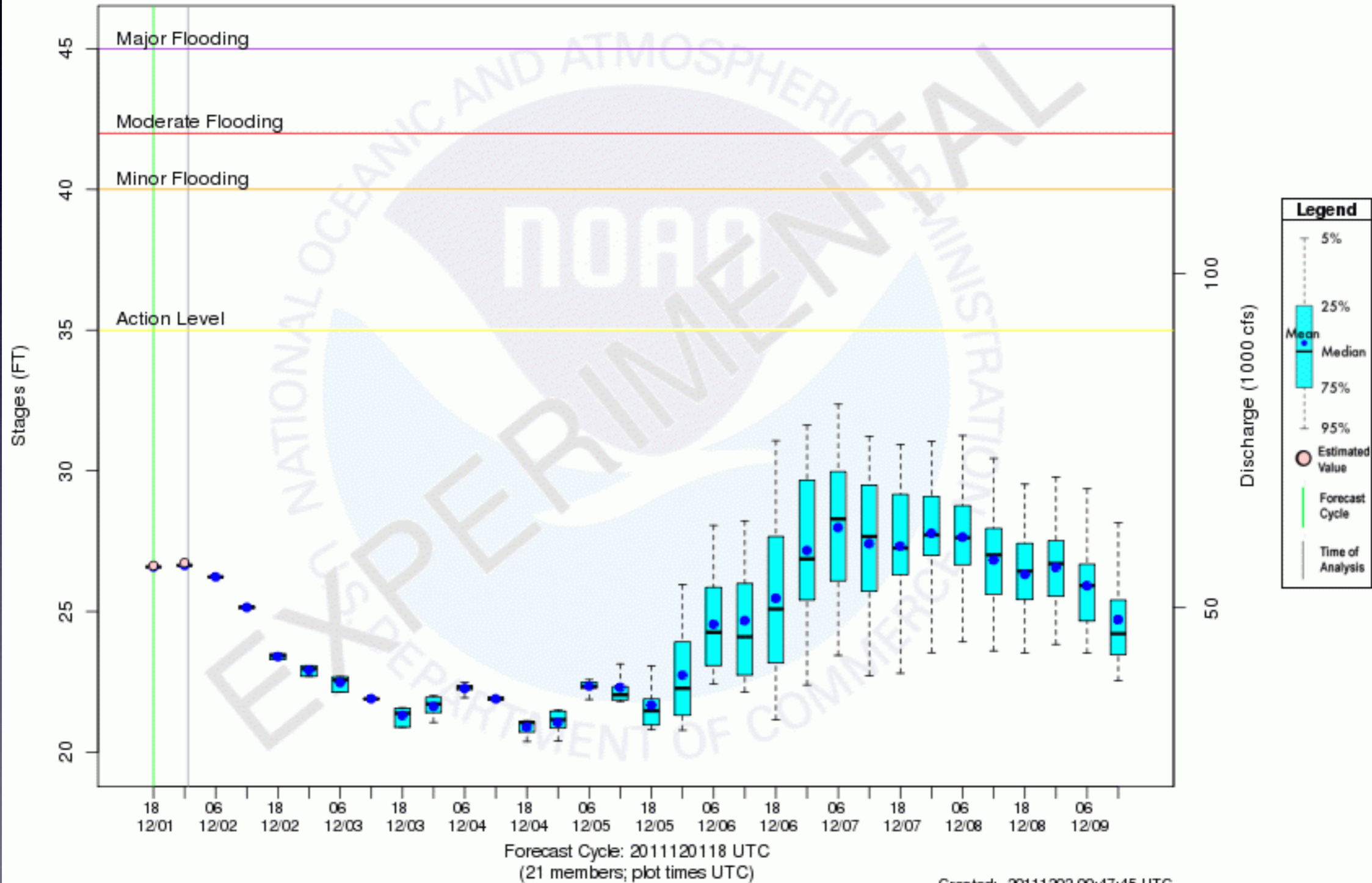


# Conveying Uncertainty



# Nashville, TN GEFS Example

GEFS-based Stage Simulations Expected Value Plot  
Cumberland River at Nashville, TN (NAST1)  
Analysis for the period 12/01/2011 18 UTC - 12/09/2011 12 UTC



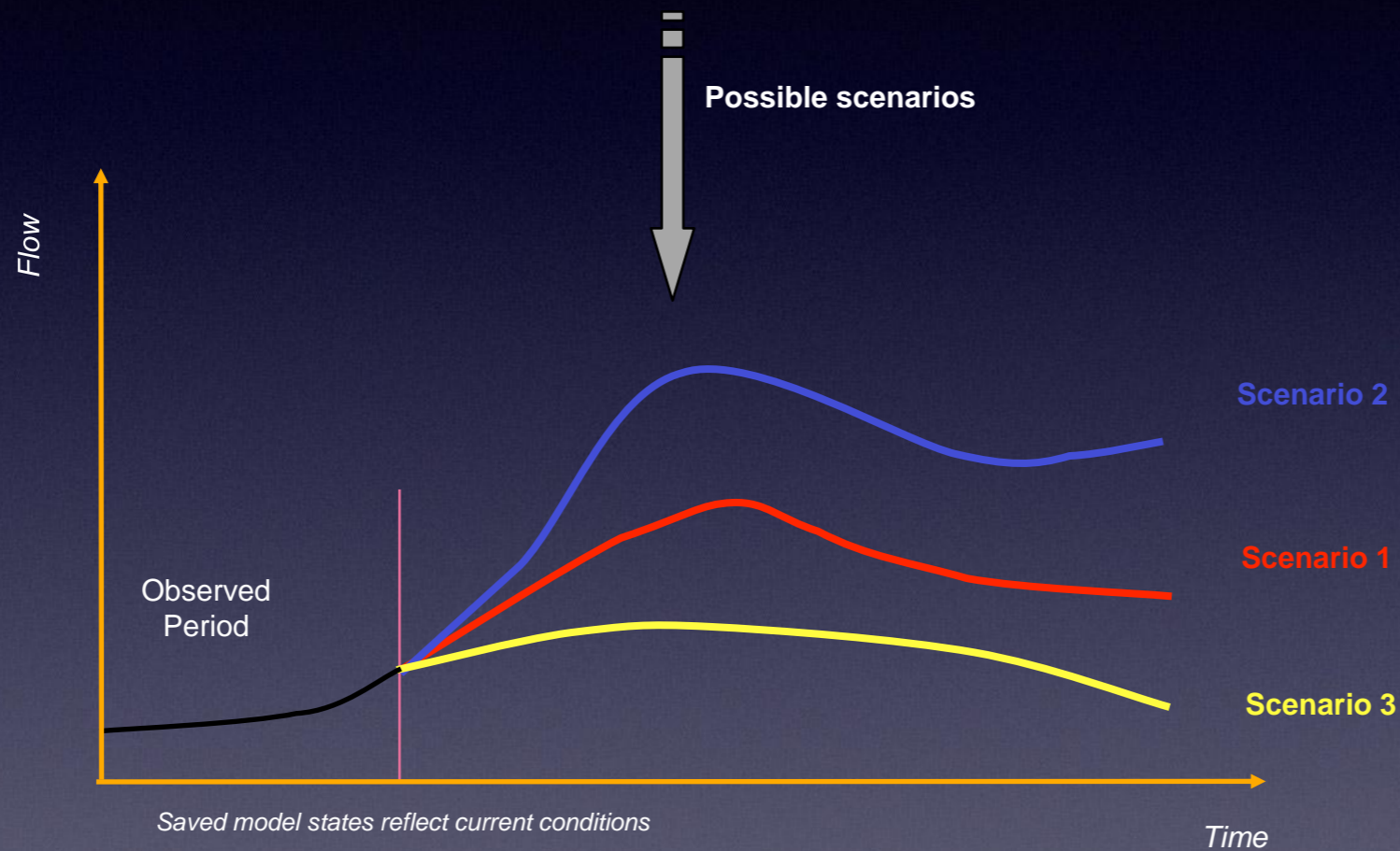
# Short lead-time probabilistic streamflow forecasting (MMEFS)

# OHRFC 694 modeled subbasins



# Ensemble Streamflow Prediction

Multiple streamflow scenarios from the NWP ensemble model runs

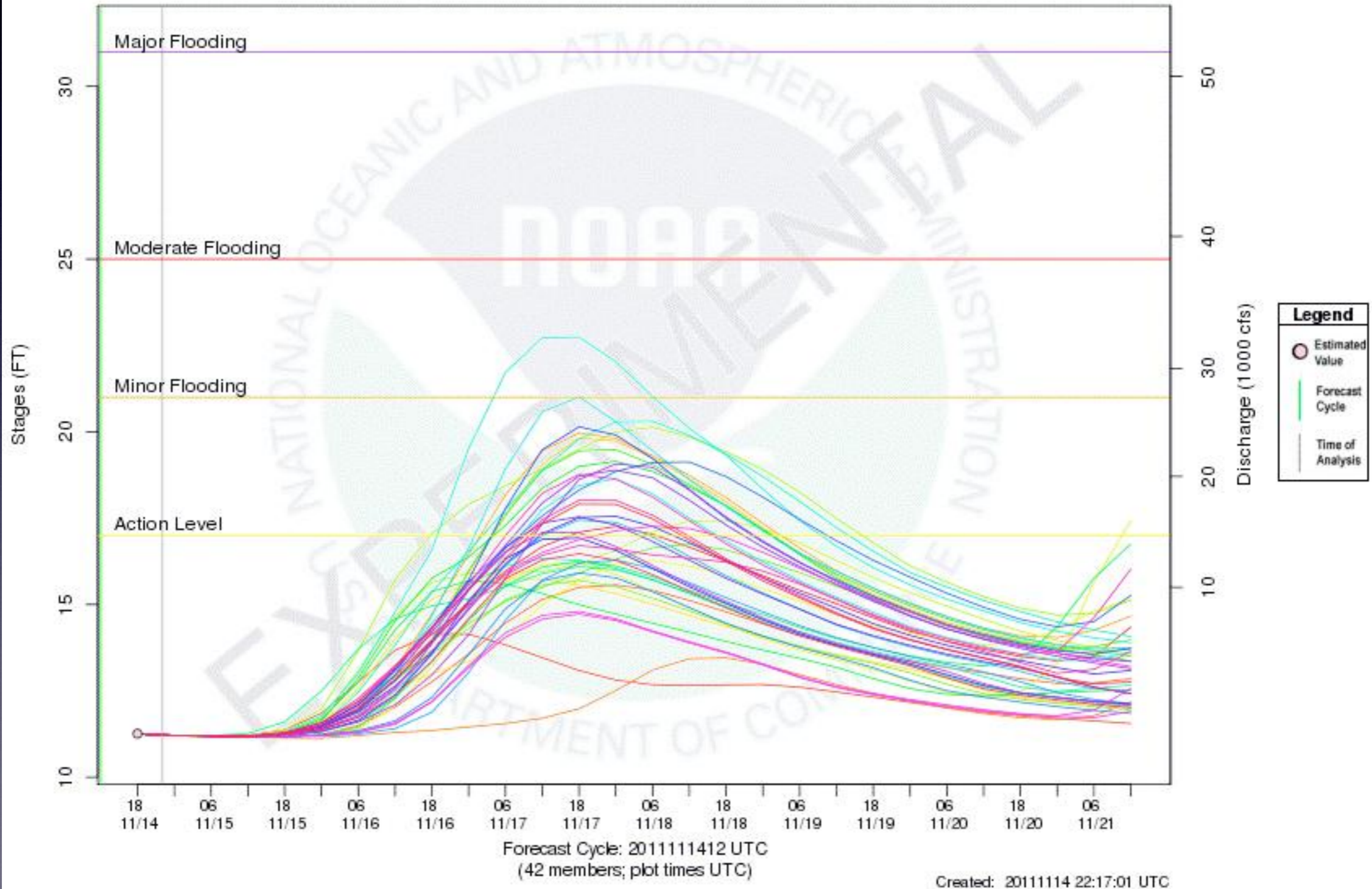


Results used in statistical analysis to produce forecasts with probabilistic values

Courtesy: Rick Koehler (COMET)

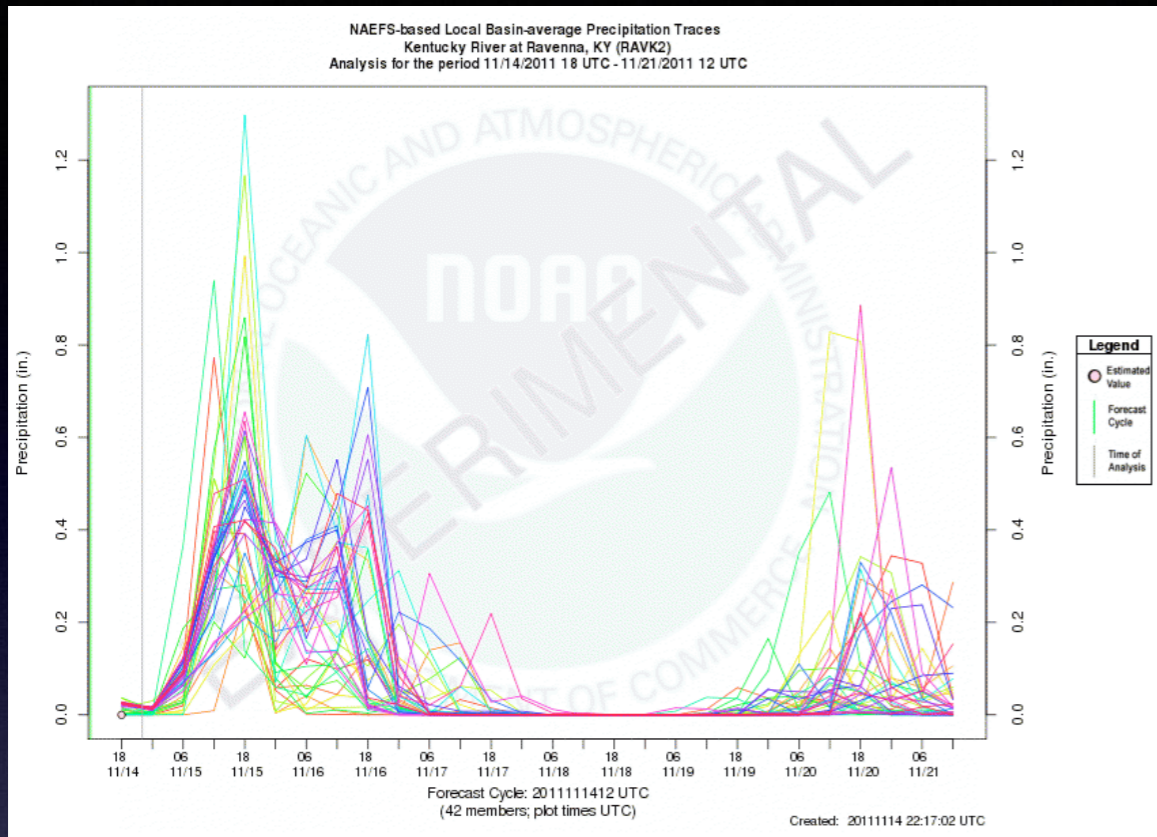
# ESP Ensemble Traces

NAEFS-based Stage Simulations Traces  
Kentucky River at Ravenna, KY (RAVK2)  
Analysis for the period 11/14/2011 18 UTC - 11/21/2011 12 UTC

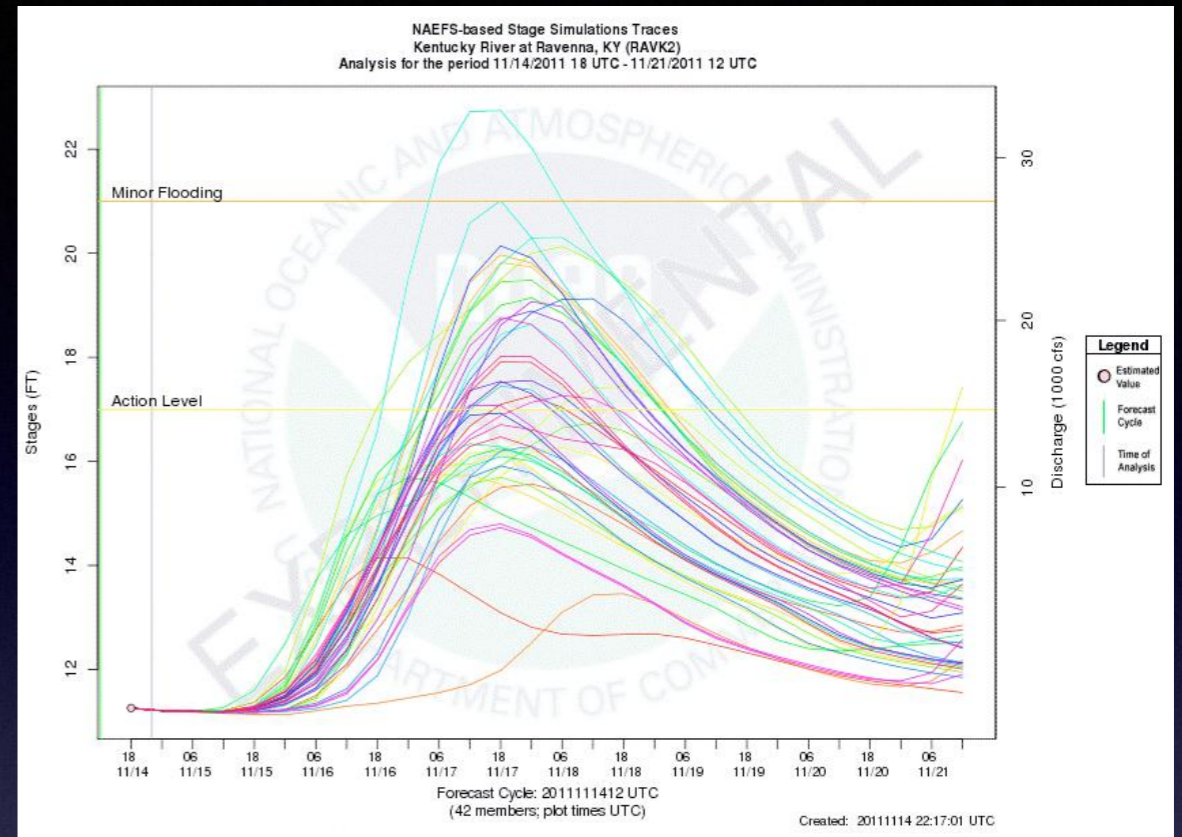




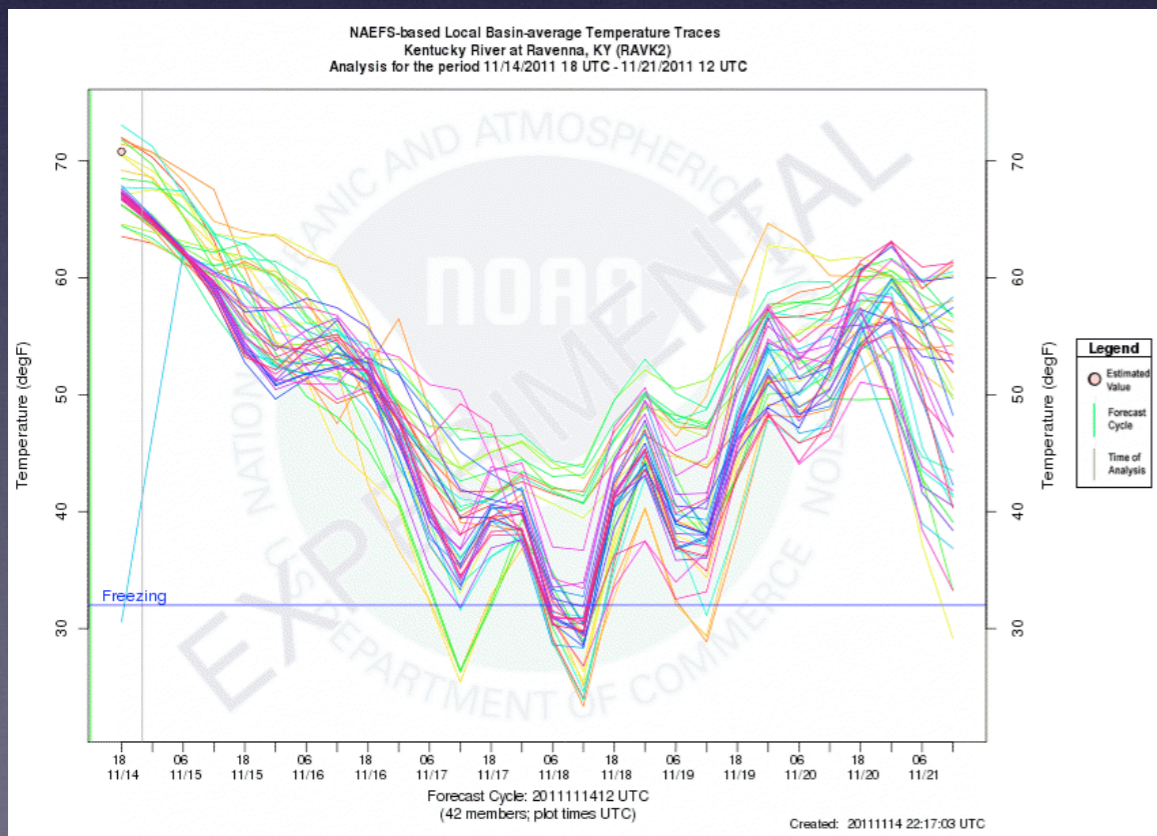
## Precipitation



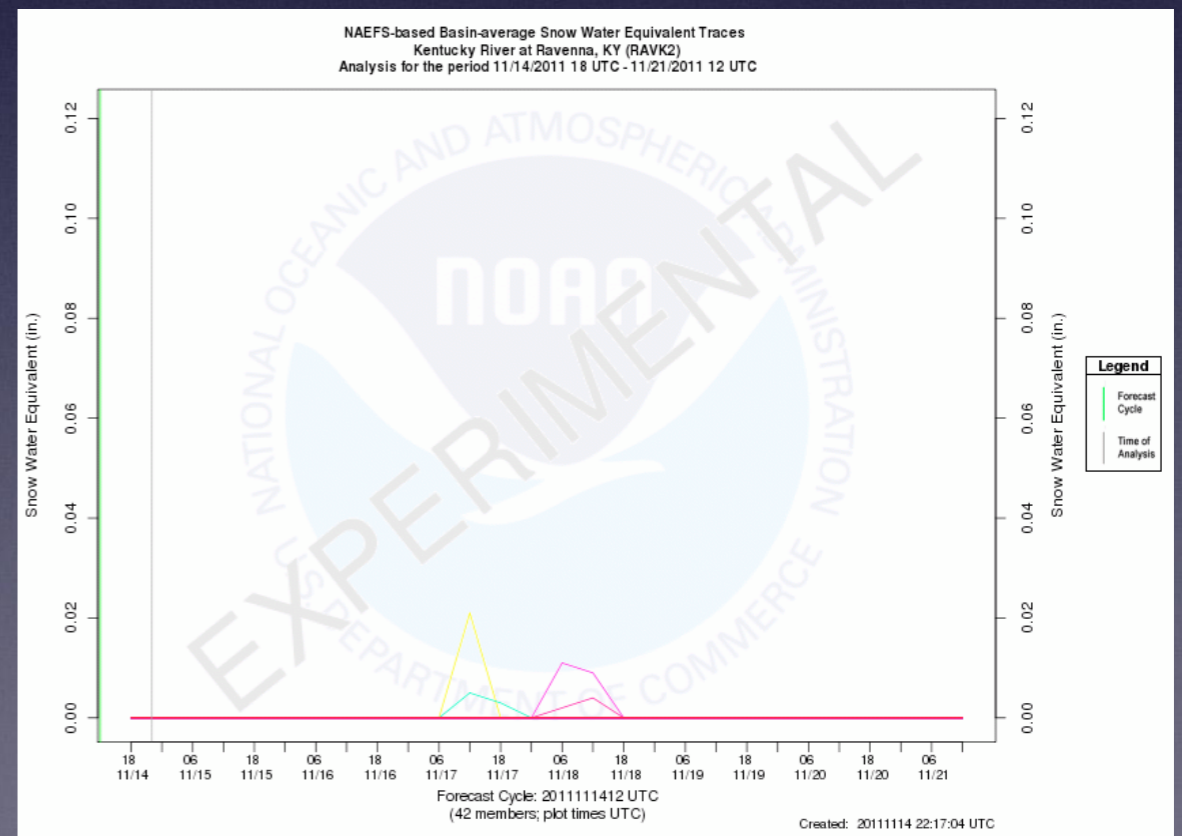
## Streamflow



## Temperature

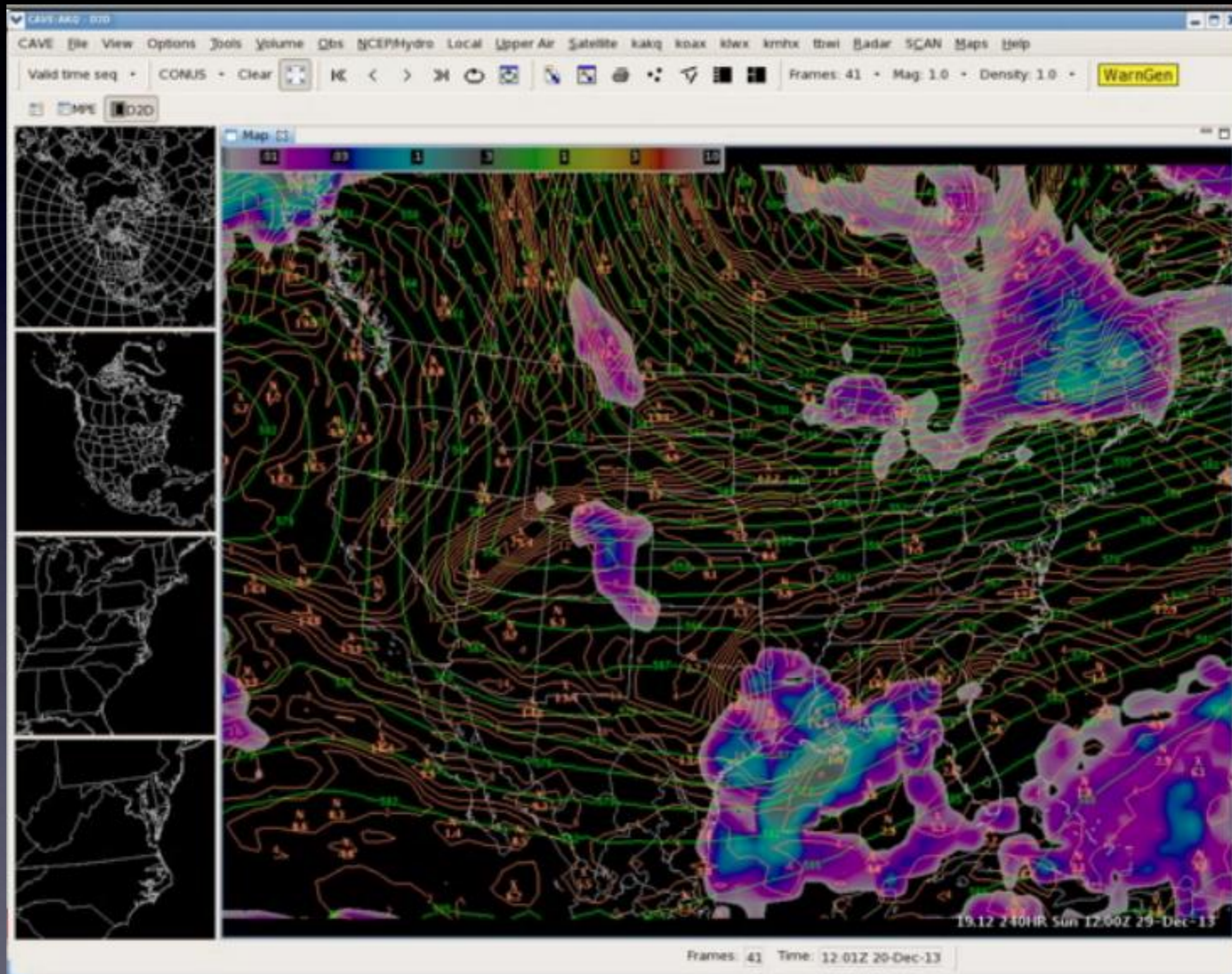


## Snow Water Equivalent



Ohio River Valley 20-23 Dec.  
2013

# 19 Dec. 2013, 240-hour ECMWF model forecast



Please see the [Product Description Document](#) for detailed information about this service.

Zoom to a Location

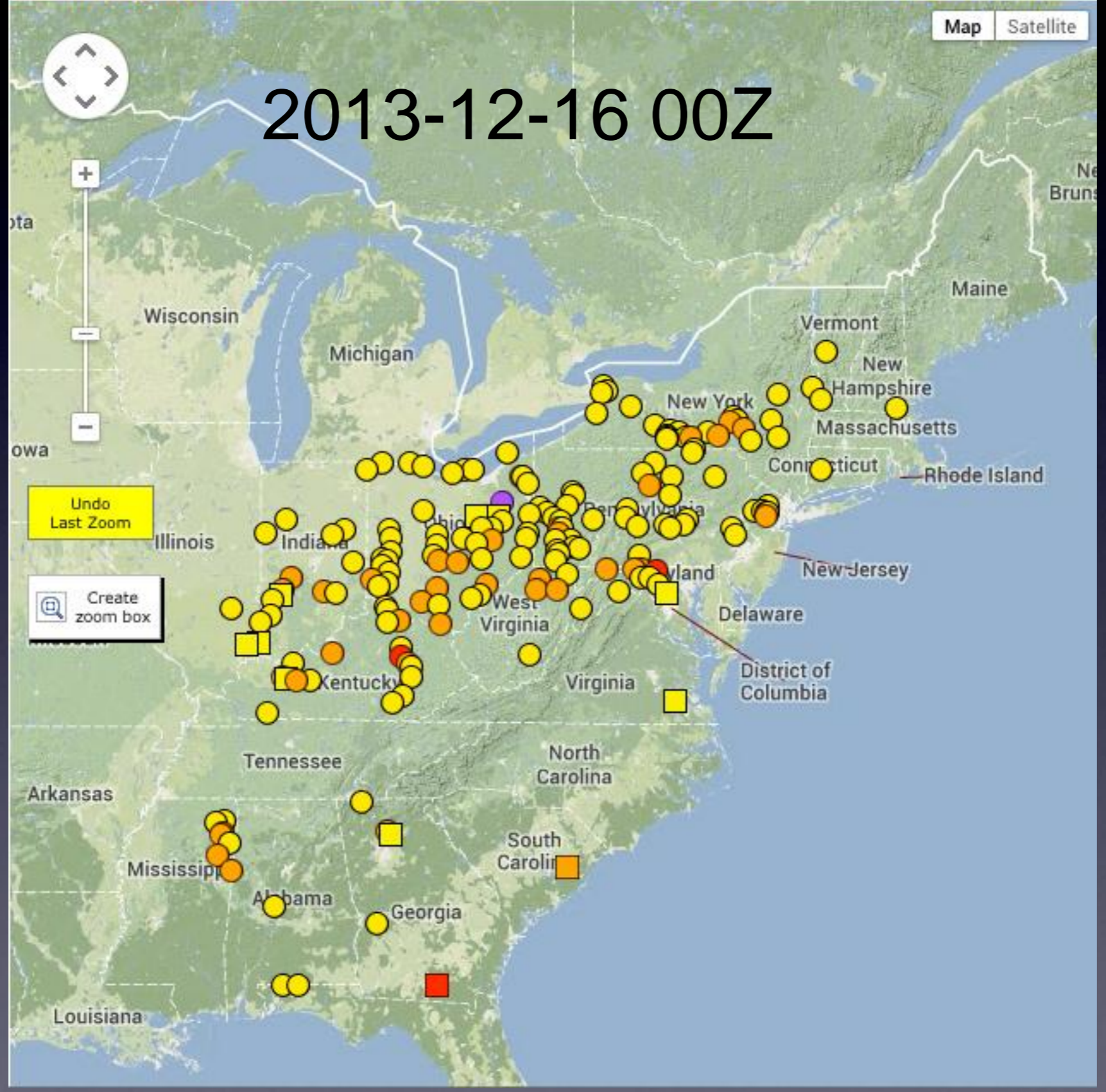
GEFS  
(default)  NAEFS  SREF

MMEFS  
Overview

**Only locations with a greater than 30% chance of reaching action stage are shown.**

Recorded  
Training

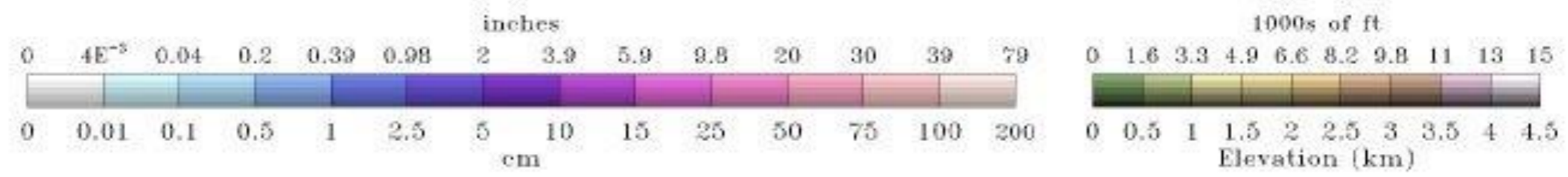
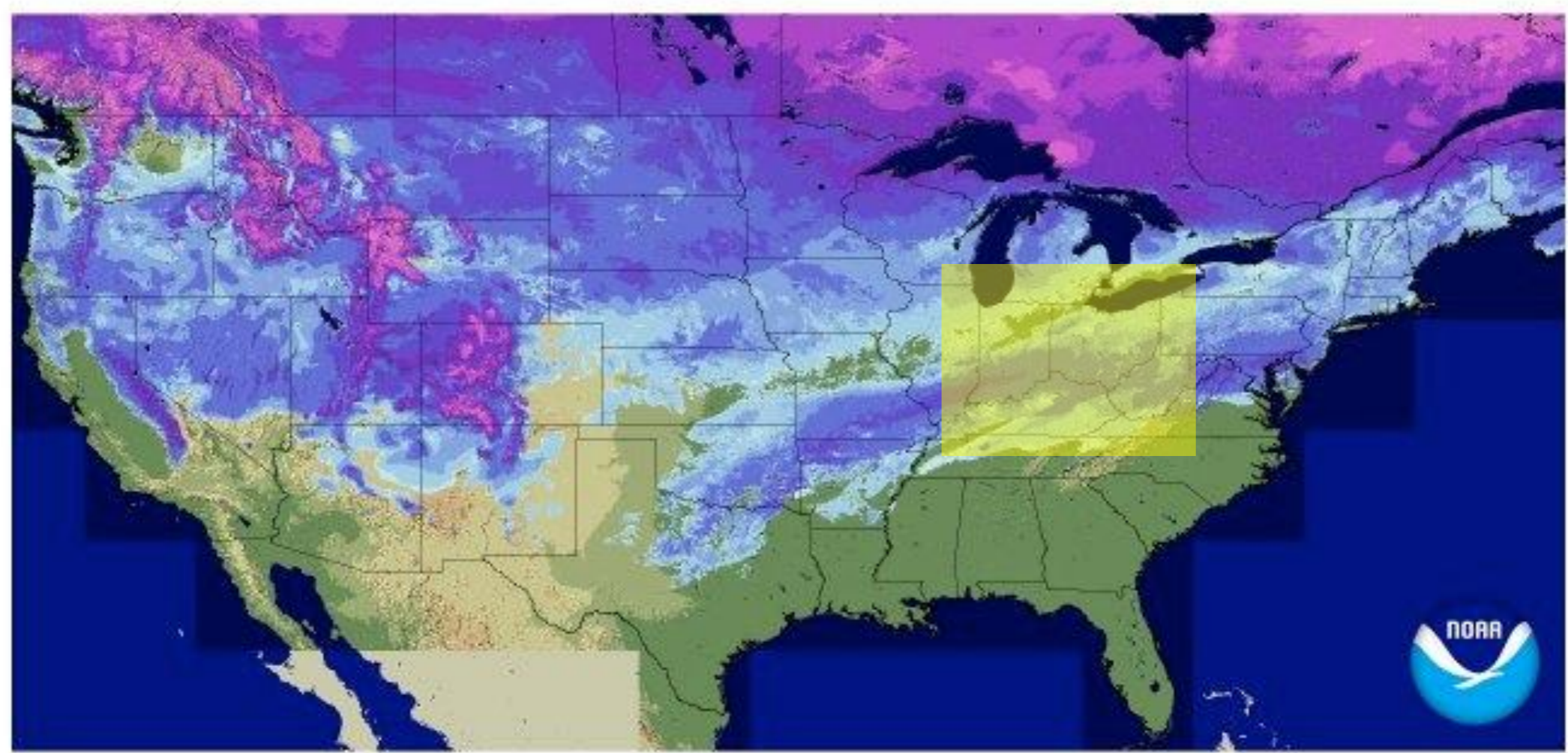
MARFC News Alert | **NERFC Status** | OHRFC Status | SERFC Status



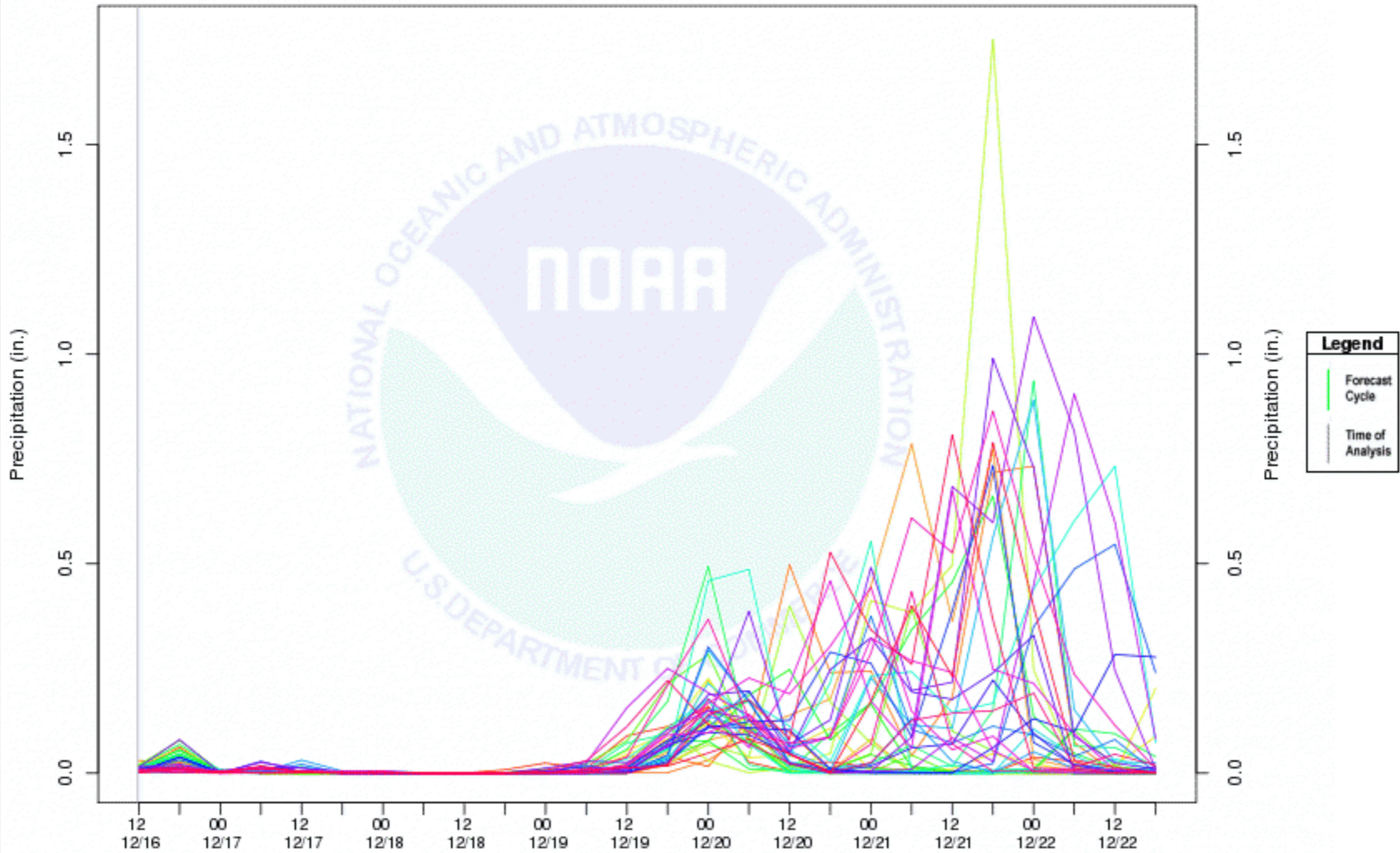
2013-12-16 00Z

# Snow Water Equivalent

2013-12-11 06



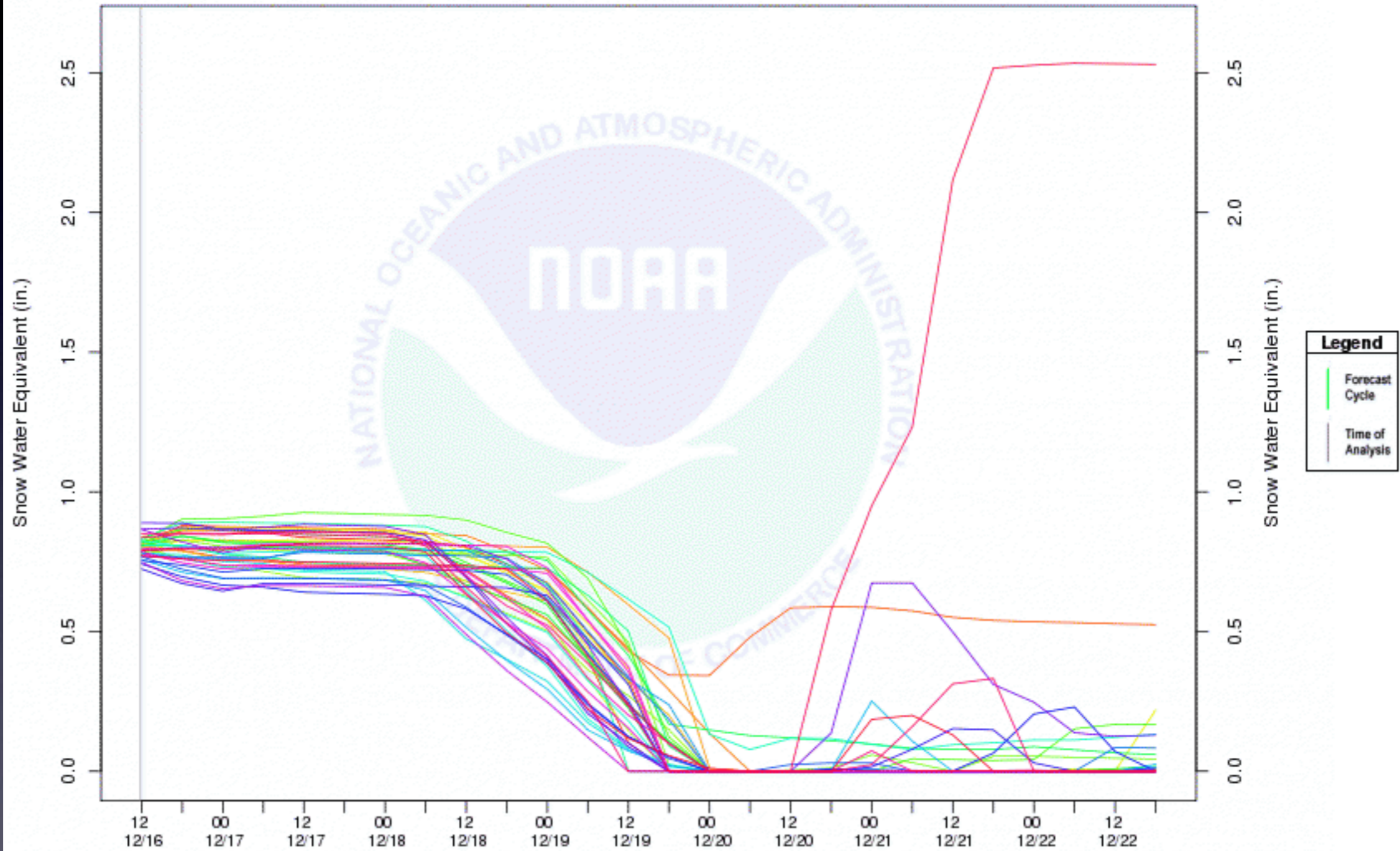
NAEFS-based Local Basin-average Precipitation Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/16/2013 12 UTC - 12/22/2013 18 UTC



Forecast Cycle: 2013121600 UTC  
(42 members; plot times UTC)

Created: 20131216 12:00:16 UTC

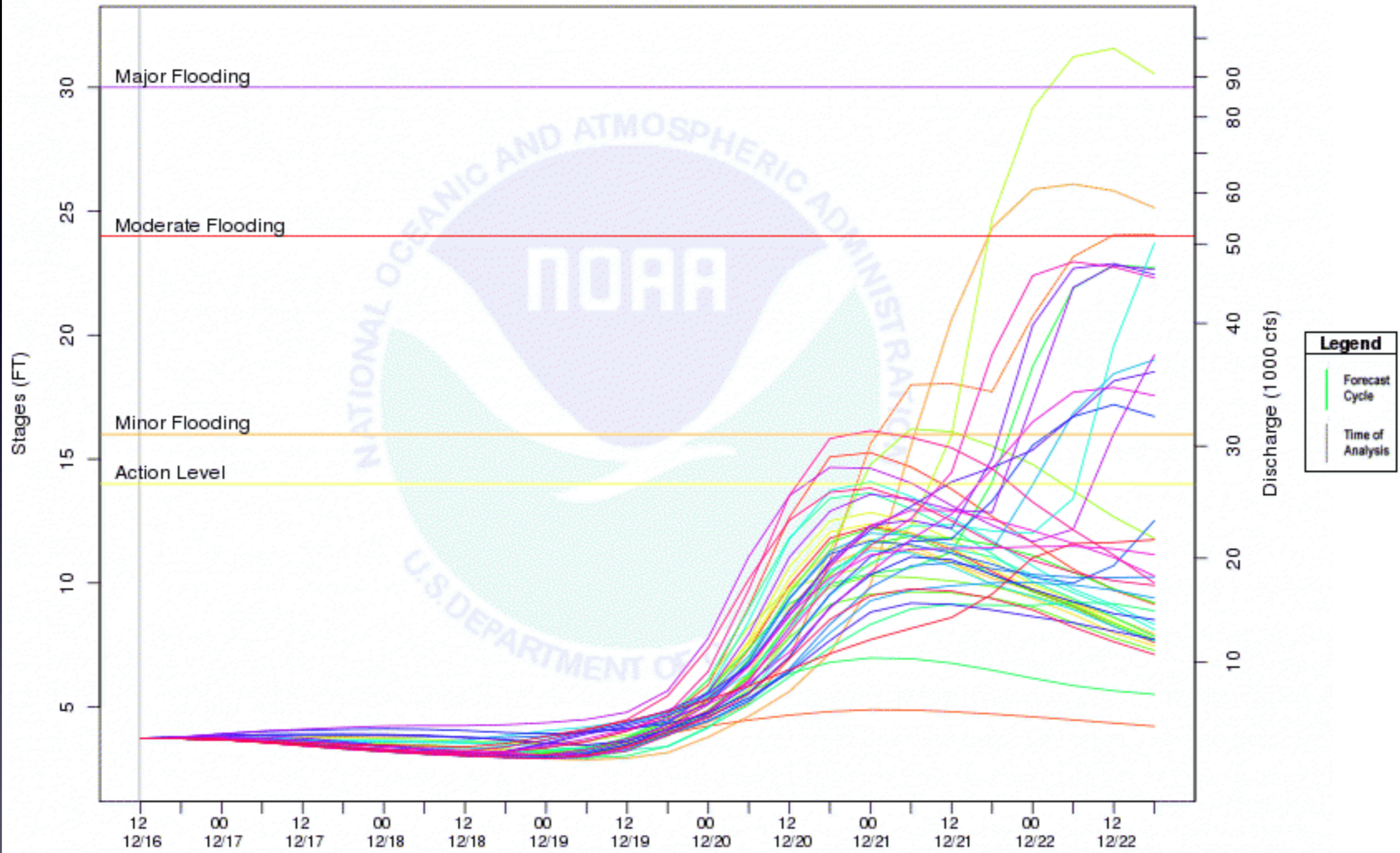
NAEFS-based Basin-average Snow Water Equivalent Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/16/2013 12 UTC - 12/22/2013 18 UTC



Forecast Cycle: 2013121600 UTC  
(42 members; plt times UTC)

Created: 20131216 12:00:18 UTC

NAEFS-based Stage Simulations Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/16/2013 12 UTC - 12/22/2013 18 UTC

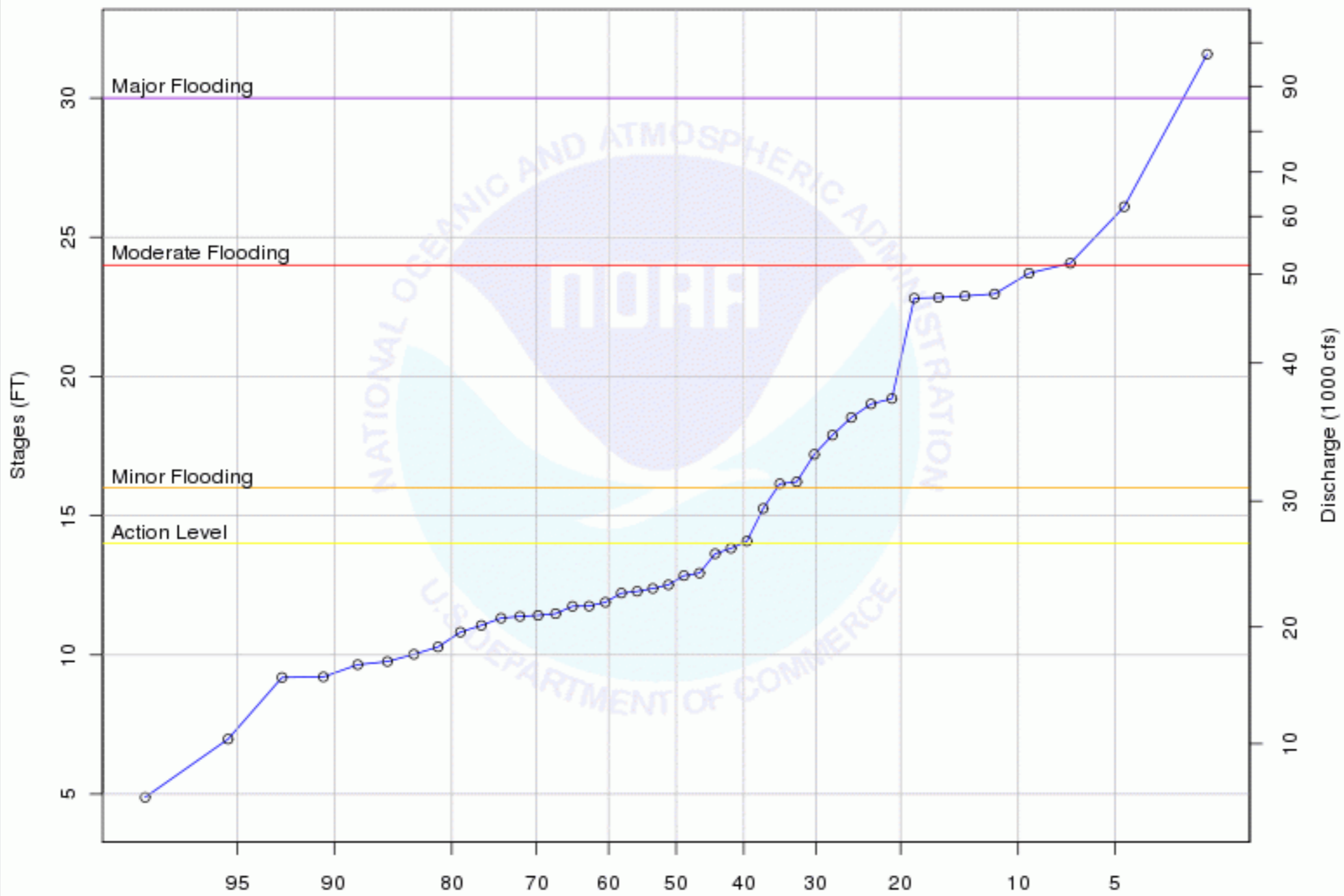


Forecast Cycle: 2013121600 UTC  
(42 members; plot times UTC)

Created: 20131216 12:00:15 UTC



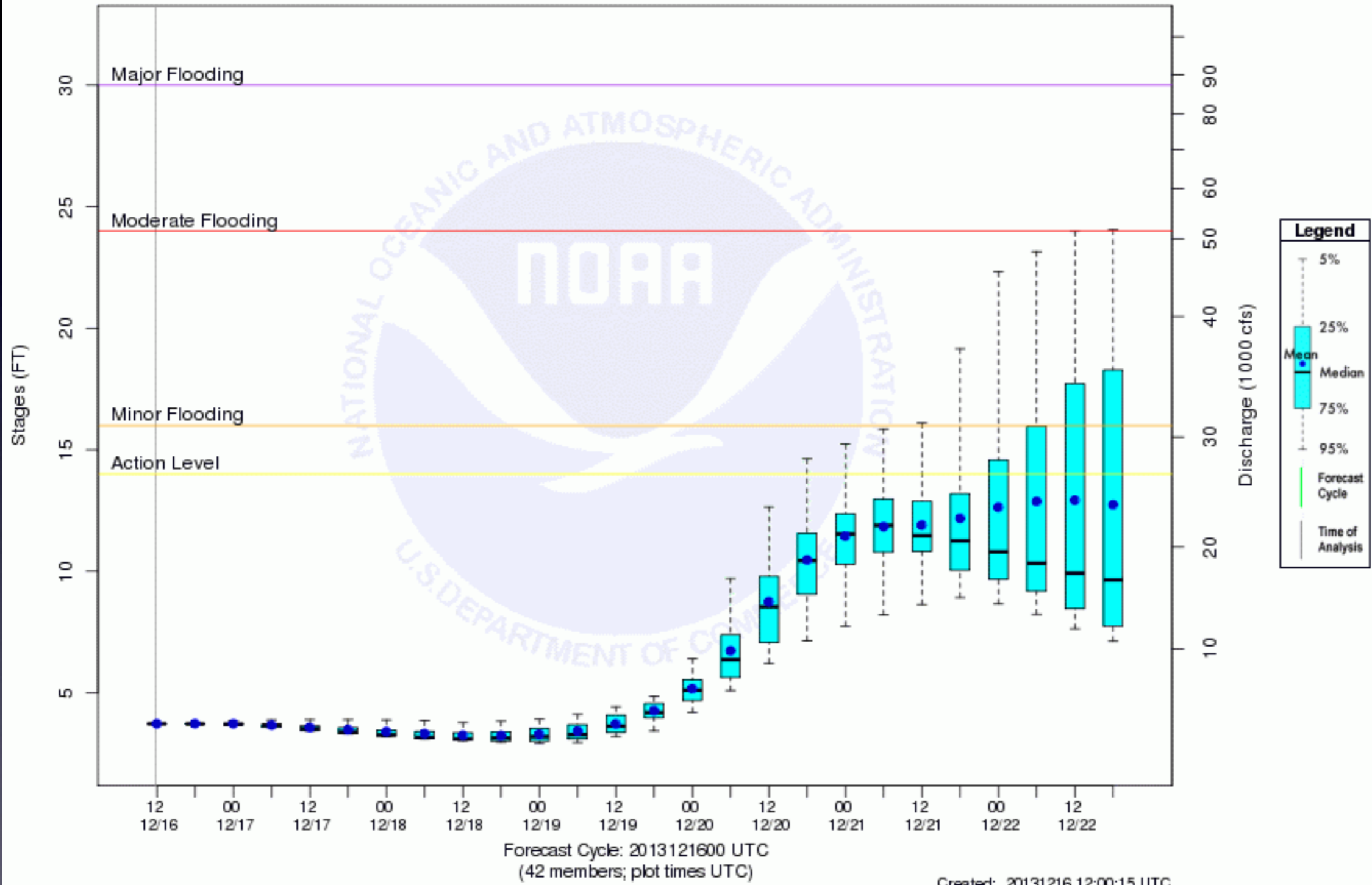
NAEFS-based Stage Simulations Probability of Exceedance Plot  
 Great Miami River at Miamitown, OH (MIAO1)  
 Analysis for the period 12/16/2013 12UTC - 12/22/2013 12UTC



Probability of Exceedance in %  
 Forecast Cycle: 2013121600 UTC (42 members)

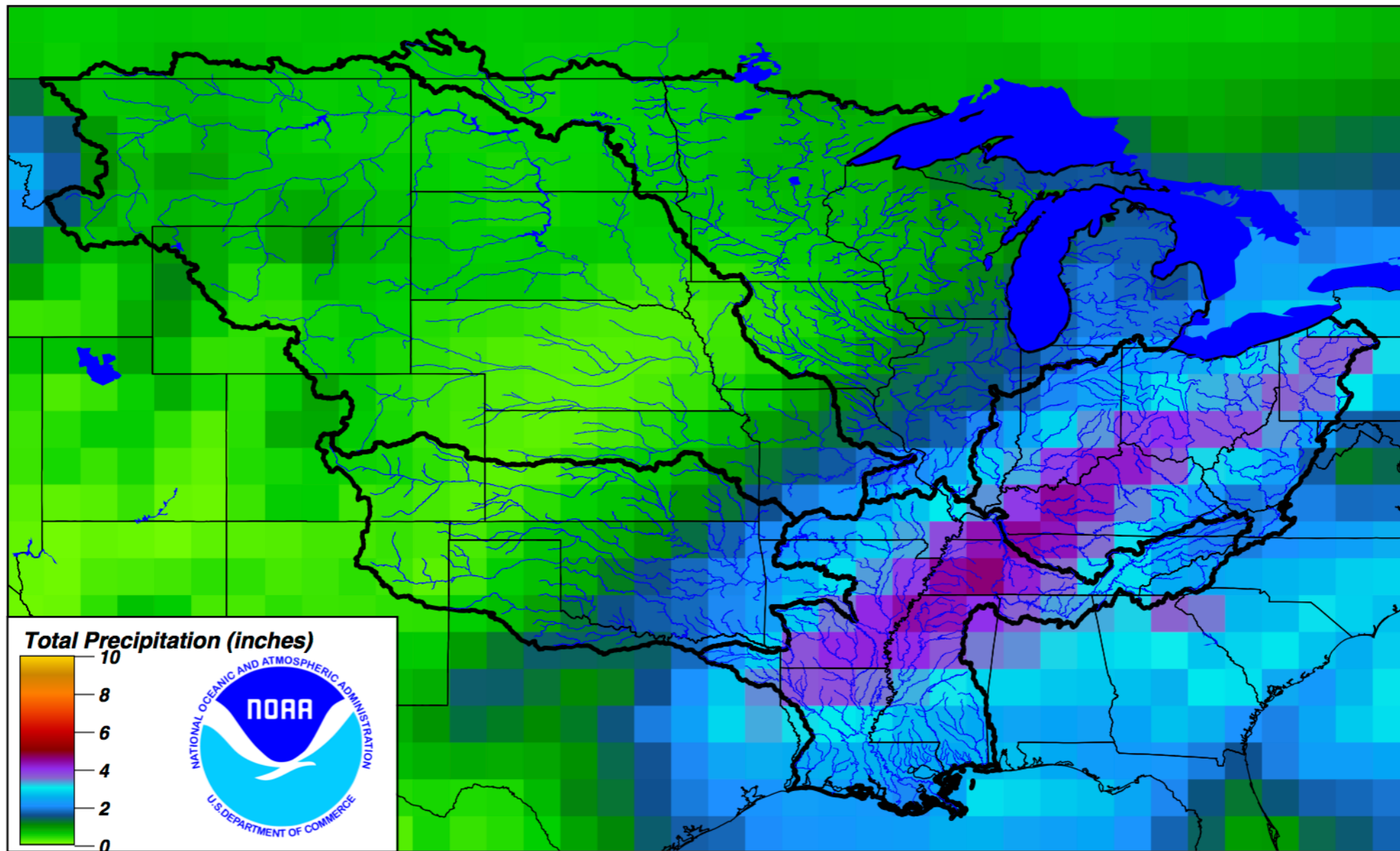
Quantile: qnorm  
 Created: 20131216 12:00:15 UTC

NAEFS-based Stage Simulations Expected Value Plot  
 Great Miami River at Miamitown, OH (MIAO1)  
 Analysis for the period 12/16/2013 12 UTC - 12/22/2013 18 UTC



# NAEFS 16-day Ensemble Mean Total QPF from 12/19/2013 12Z

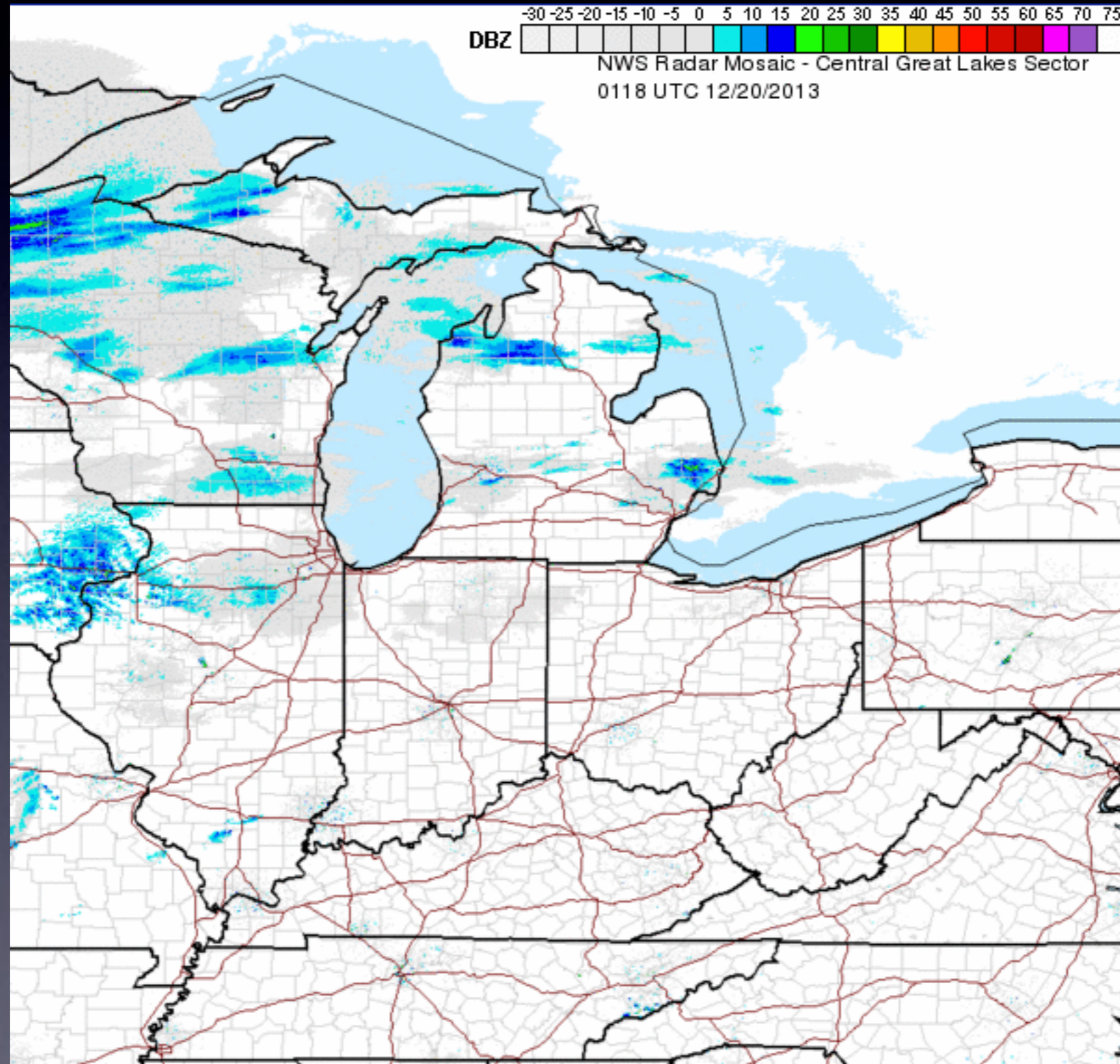
Creation date/time: Thu Dec 19 18:30:16 EST 2013



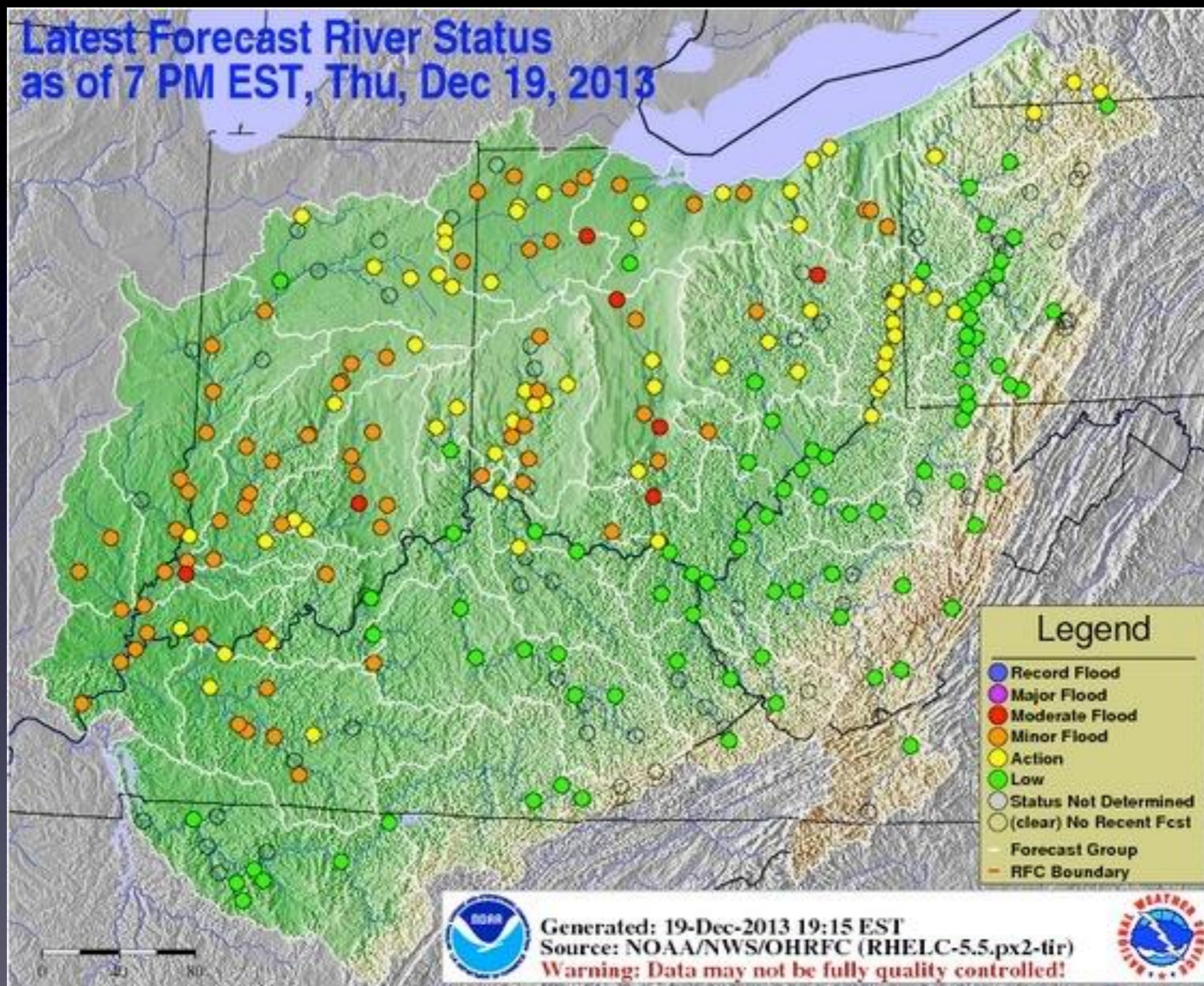
For individual location specifics visit [water.weather.gov](http://water.weather.gov)

# Regional Radar 2013-12-20

## 01Z



# Latest Forecast River Status as of 7 PM EST, Thu, Dec 19, 2013



Generated: 19-Dec-2013 19:15 EST  
Source: NOAA/NWS/OHRFC (RHELC-5.5.px2-tir)  
Warning: Data may not be fully quality controlled!



Zoom to a Location

GEFS (default)  NAEFS  SREF

MMEFS Overview

Recorded Training

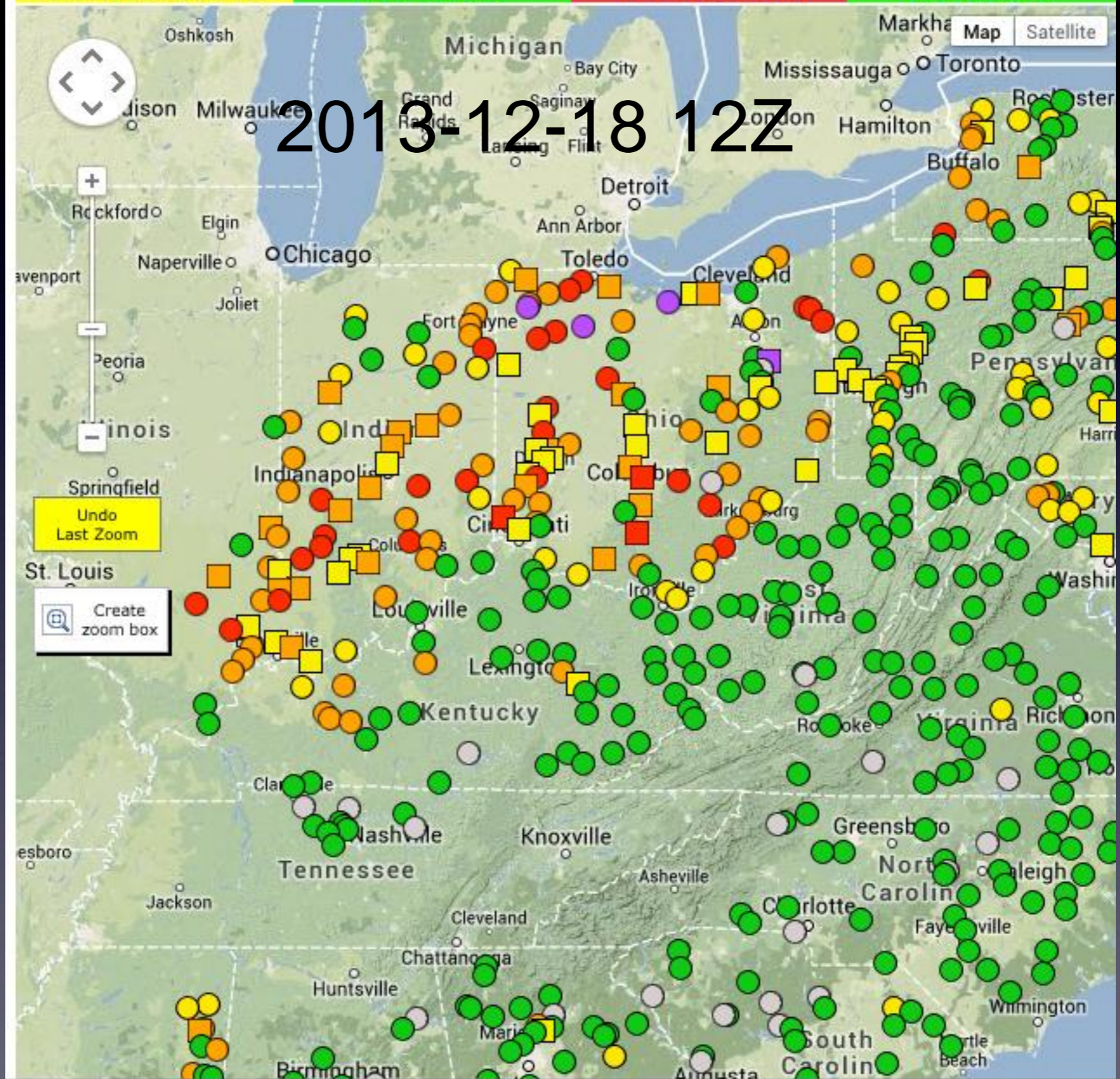
MARFC Status & News

NERFC Status

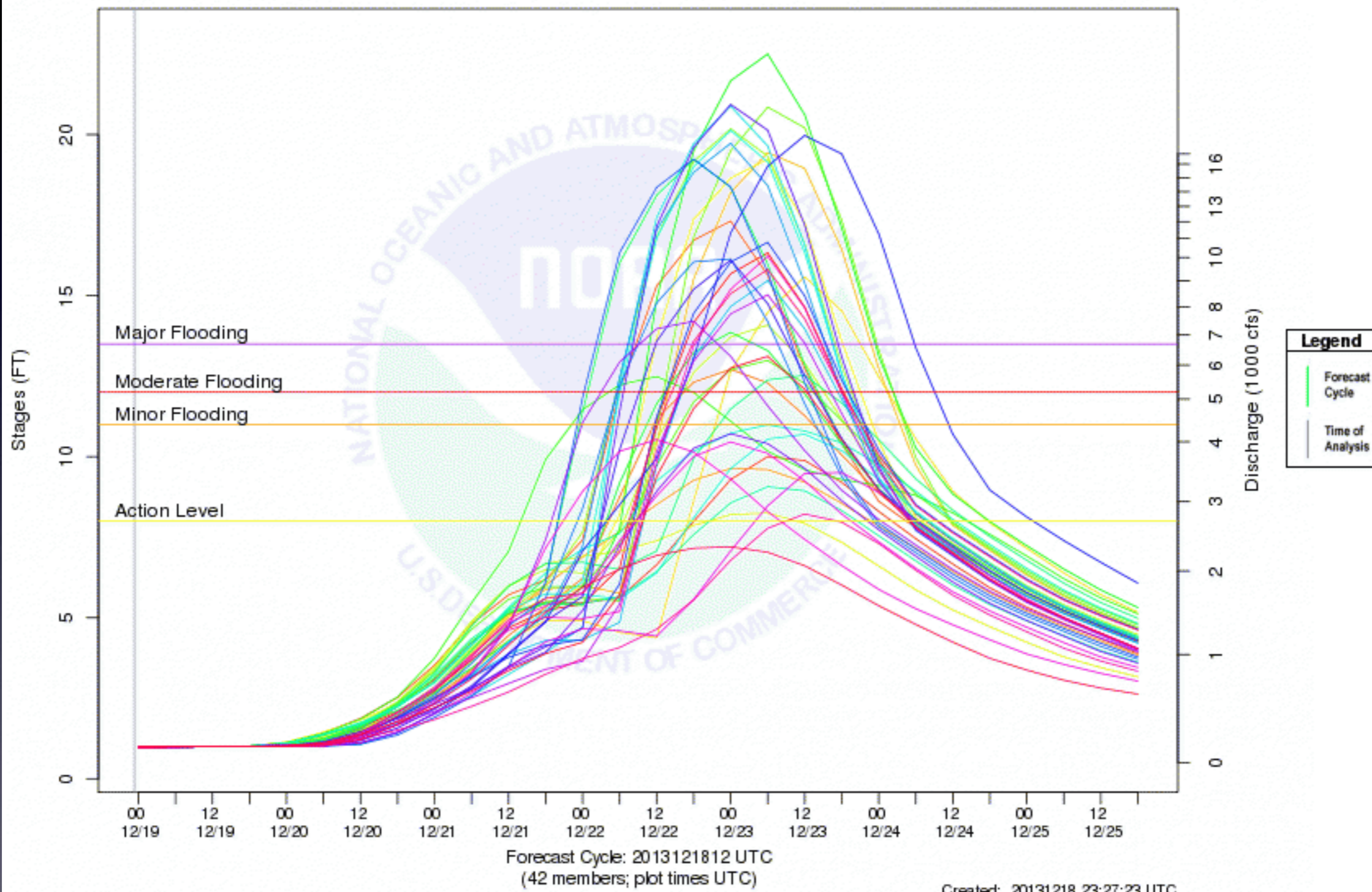
OHRFC News Alert

SERFC Status

2013-12-18 12Z

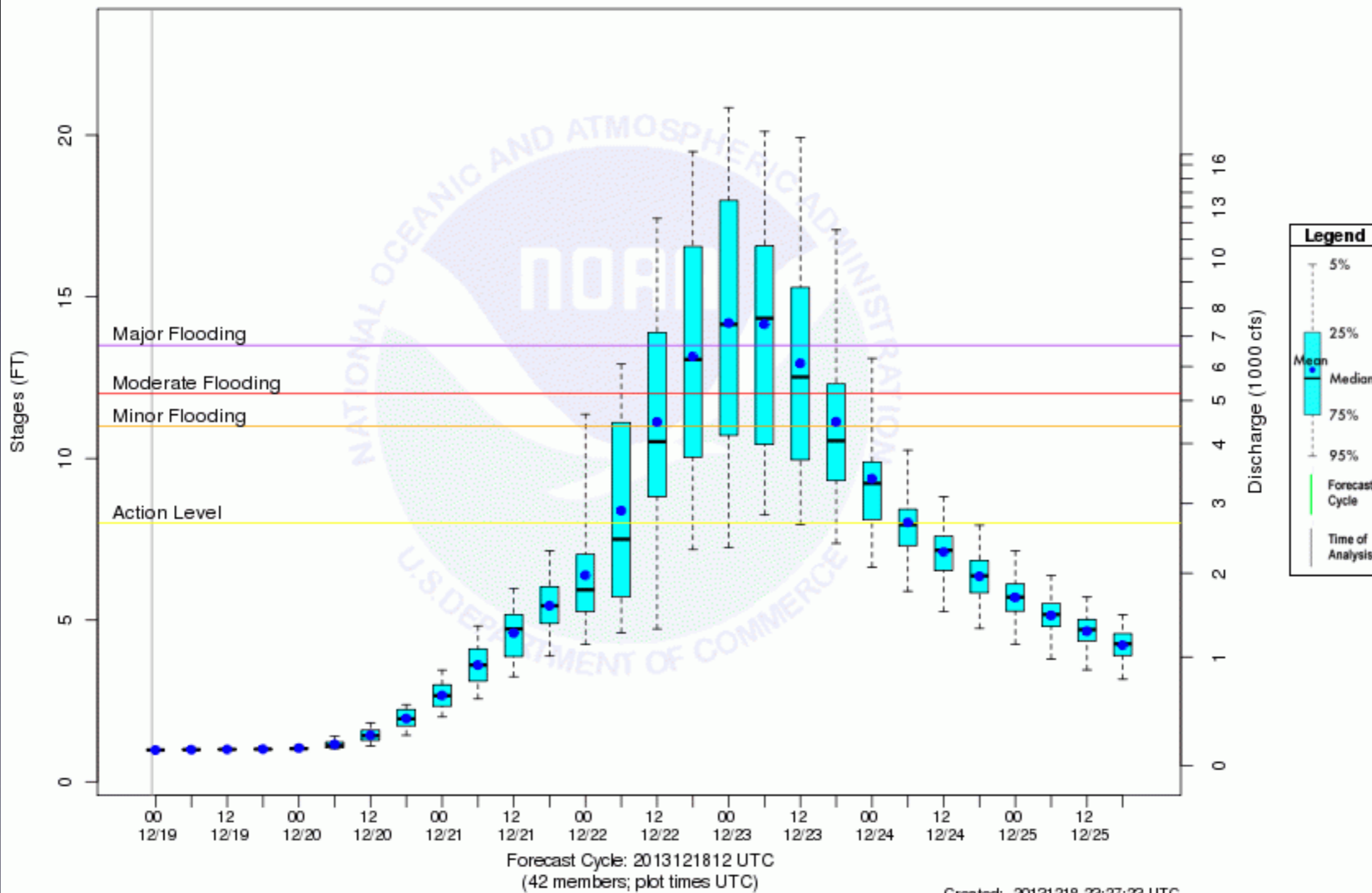


NAEFS-based Stage Simulations Traces  
Blanchard River at Findlay, OH (FDYO1)  
Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC



Created: 20131218 23:27:23 UTC

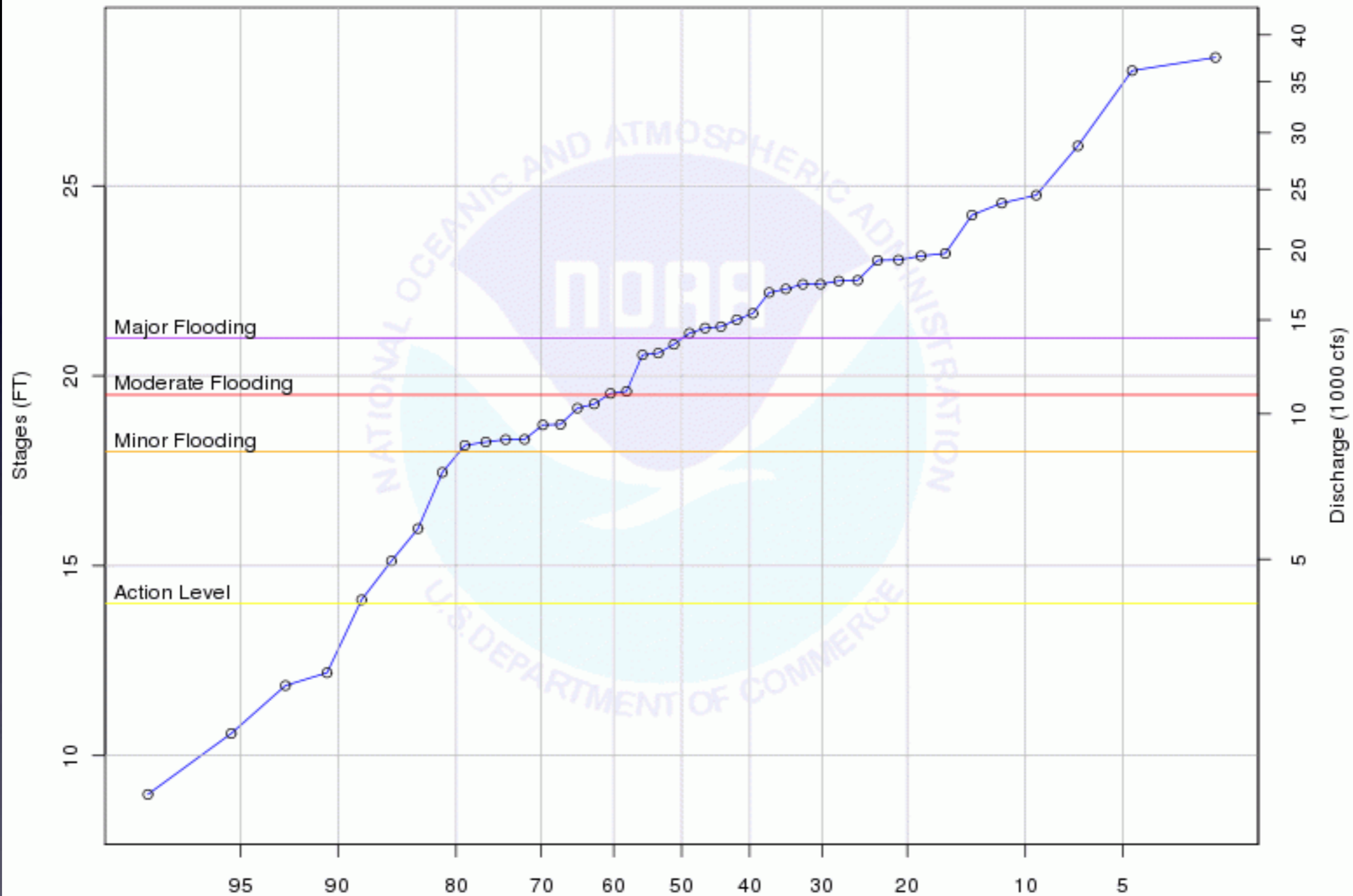
NAEFS-based Stage Simulations Expected Value Plot  
 Blanchard River at Findlay, OH (FDYO1)  
 Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC



Created: 20131218 23:27:23 UTC



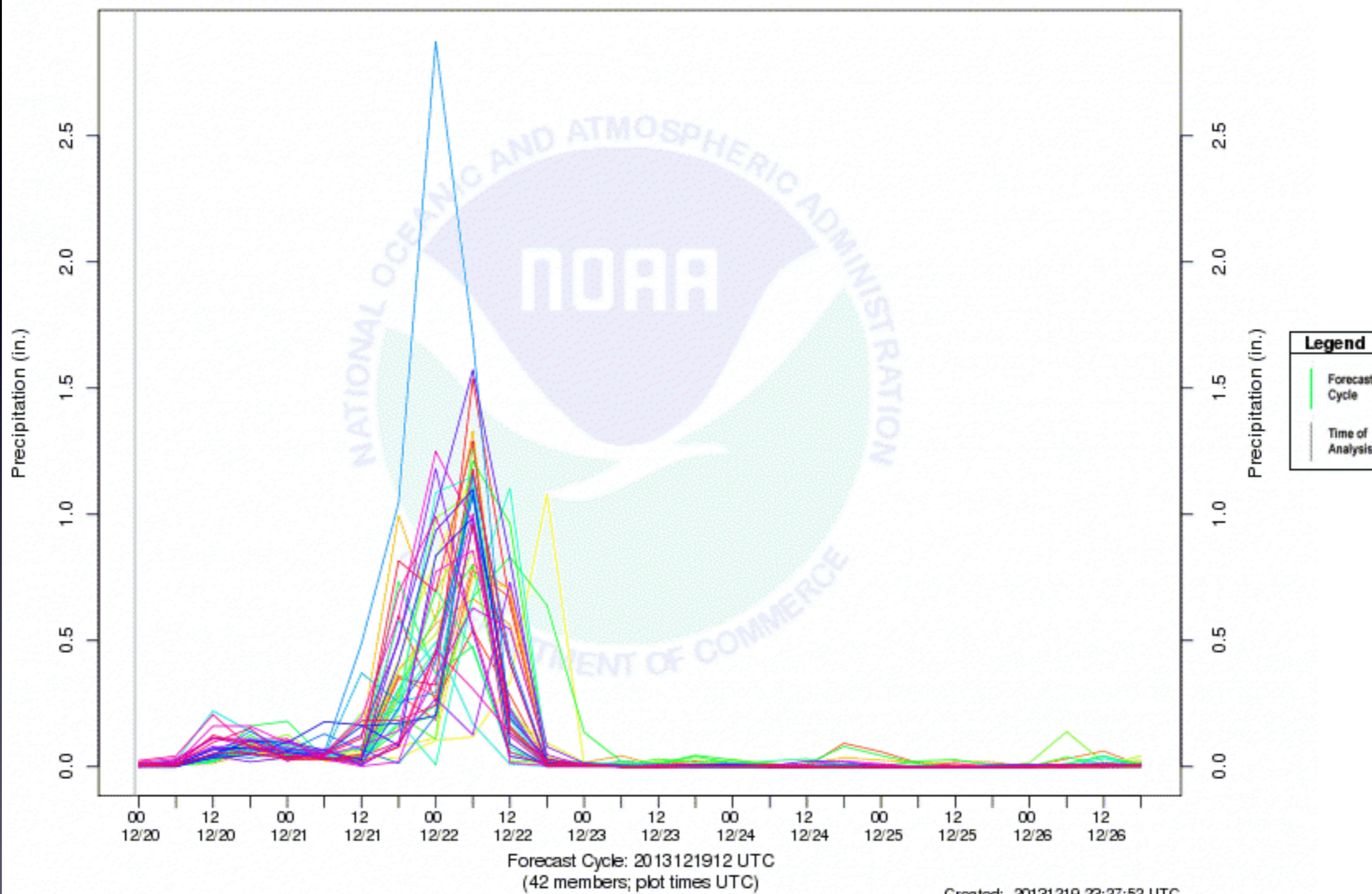
NAEFS-based Stage Simulations Probability of Exceedance Plot  
 Huron River at Milan, OH (MILO1)  
 Analysis for the period 12/19/2013 00UTC - 12/25/2013 12UTC



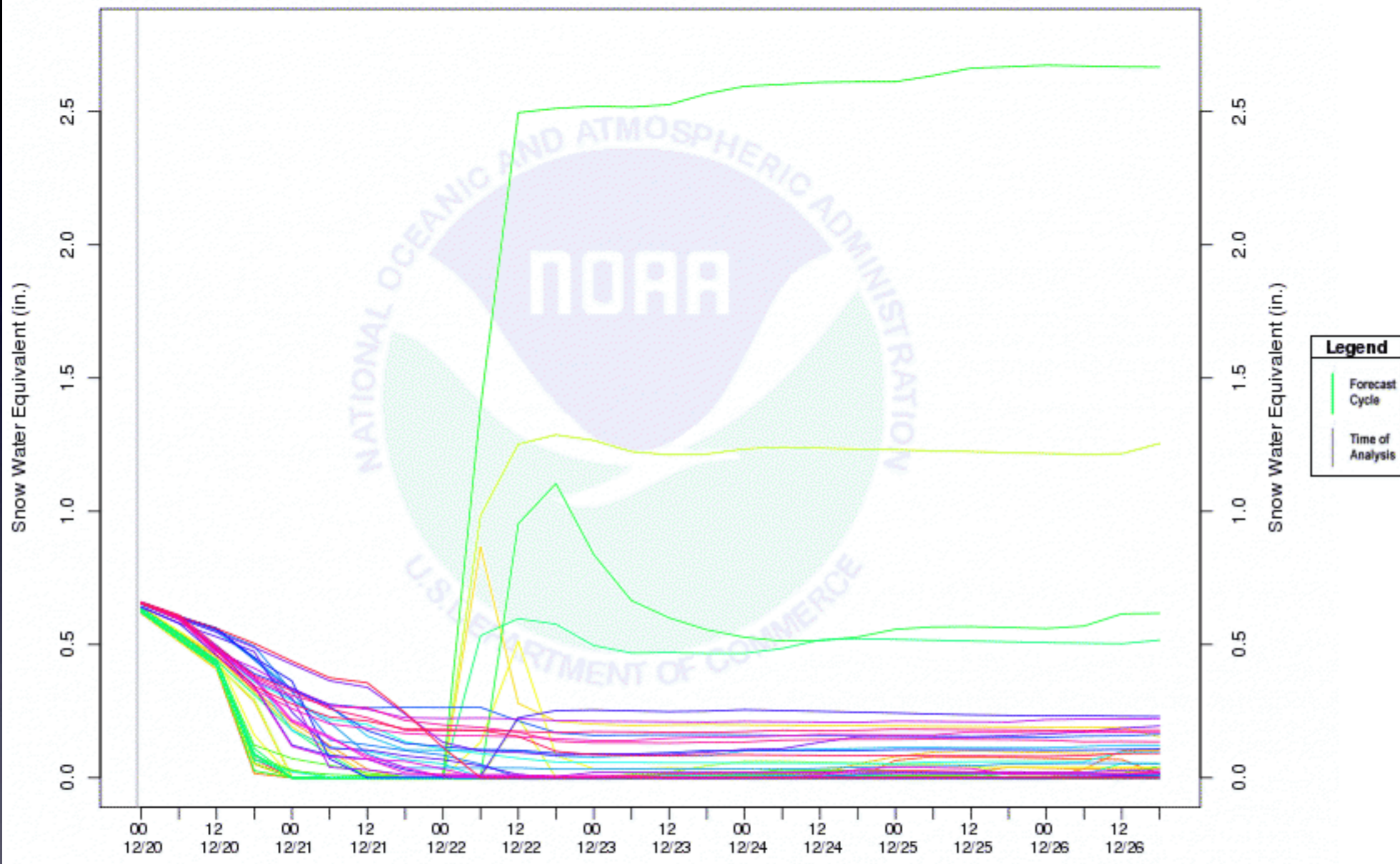
Probability of Exceedance in %  
 Forecast Cycle: 2013121812 UTC (42 members)

Quantile: qnorm  
 Created: 20131218 23:31:34 UTC

NAEFS-based Local Basin-average Precipitation Traces  
Blanchard River at Findlay, OH (FDYO1)  
Analysis for the period 12/20/2013 00 UTC - 12/26/2013 18 UTC



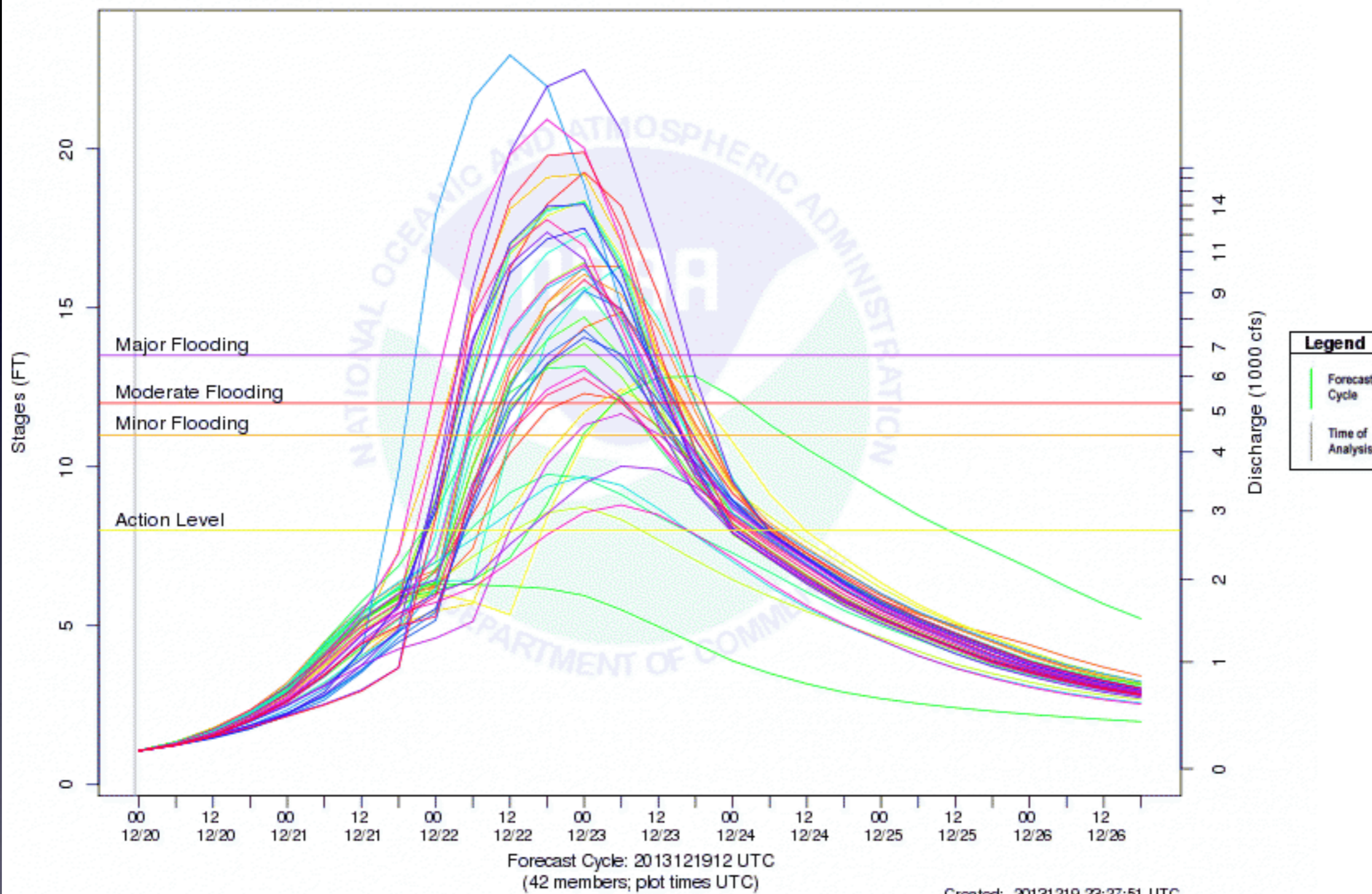
NAEFS-based Basin-average Snow Water Equivalent Traces  
Blanchard River at Findlay, OH (FDYO1)  
Analysis for the period 12/20/2013 00 UTC - 12/26/2013 18 UTC



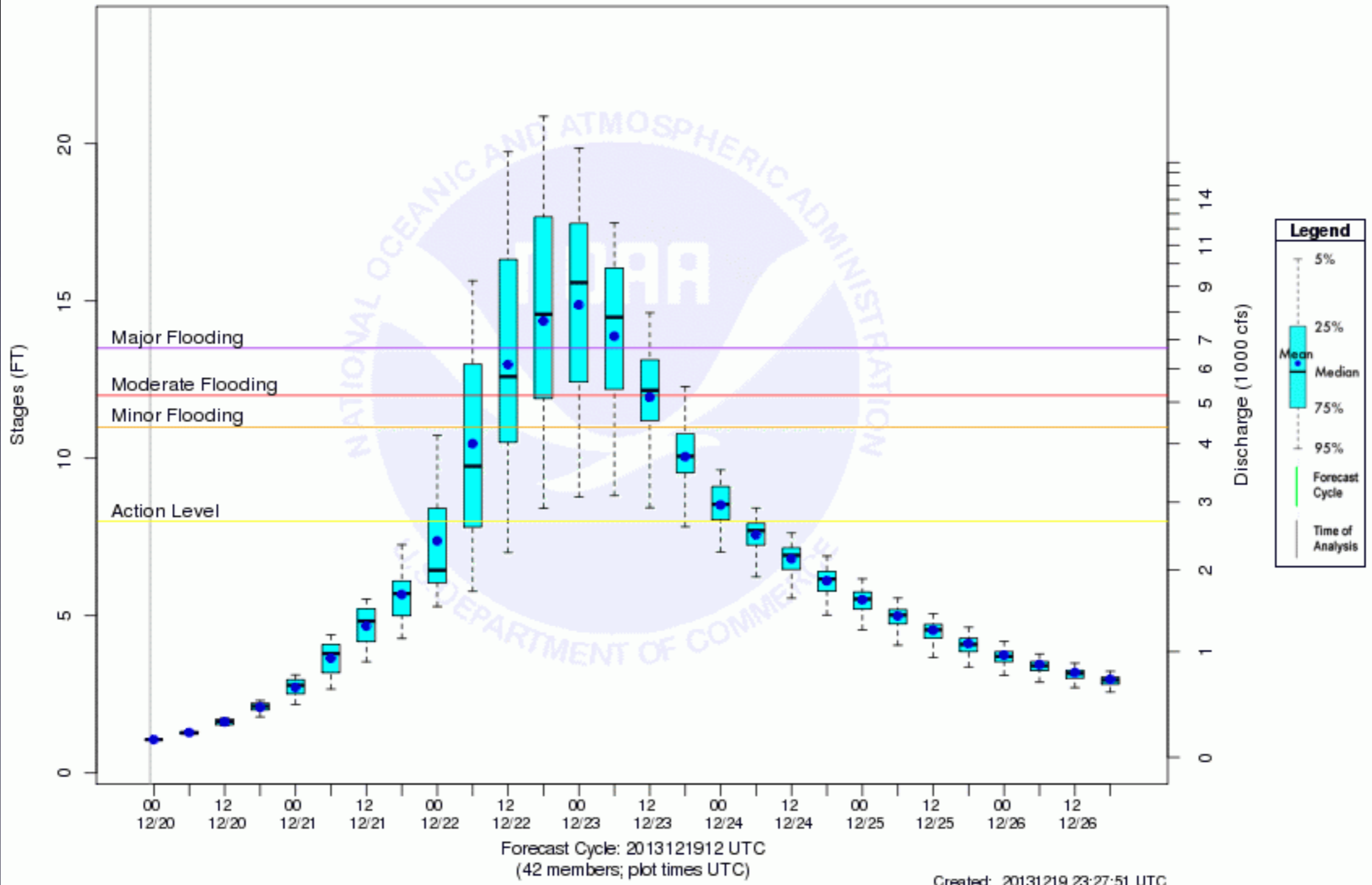
Forecast Cycle: 2013121912 UTC  
(42 members; plot times UTC)

Created: 20131219 23:27:54 UTC

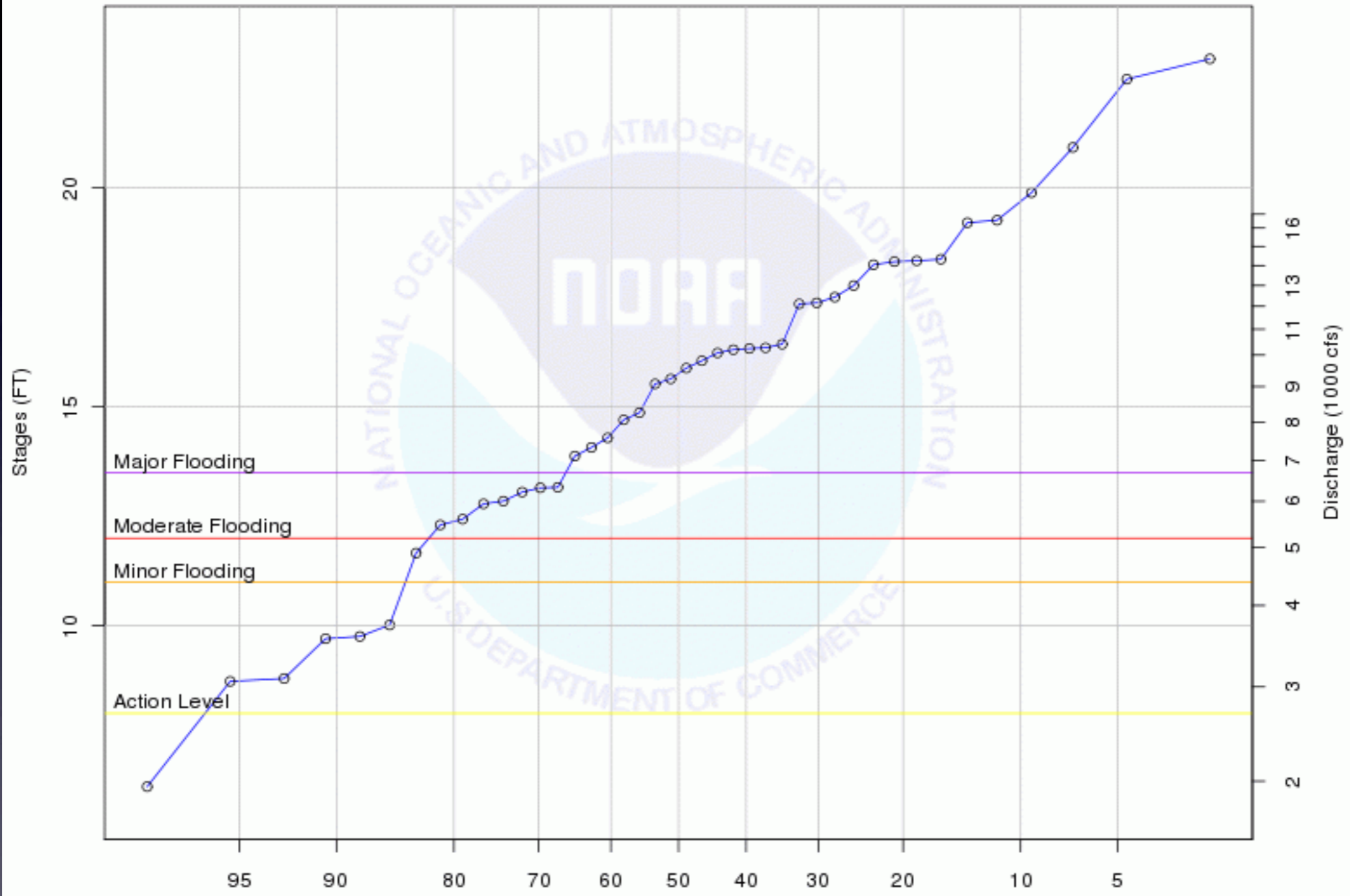
NAEFS-based Stage Simulations Traces  
Blanchard River at Findlay, OH (FDYO1)  
Analysis for the period 12/20/2013 00 UTC - 12/26/2013 18 UTC



NAEFS-based Stage Simulations Expected Value Plot  
 Blanchard River at Findlay, OH (FDYO1)  
 Analysis for the period 12/20/2013 00 UTC - 12/26/2013 18 UTC



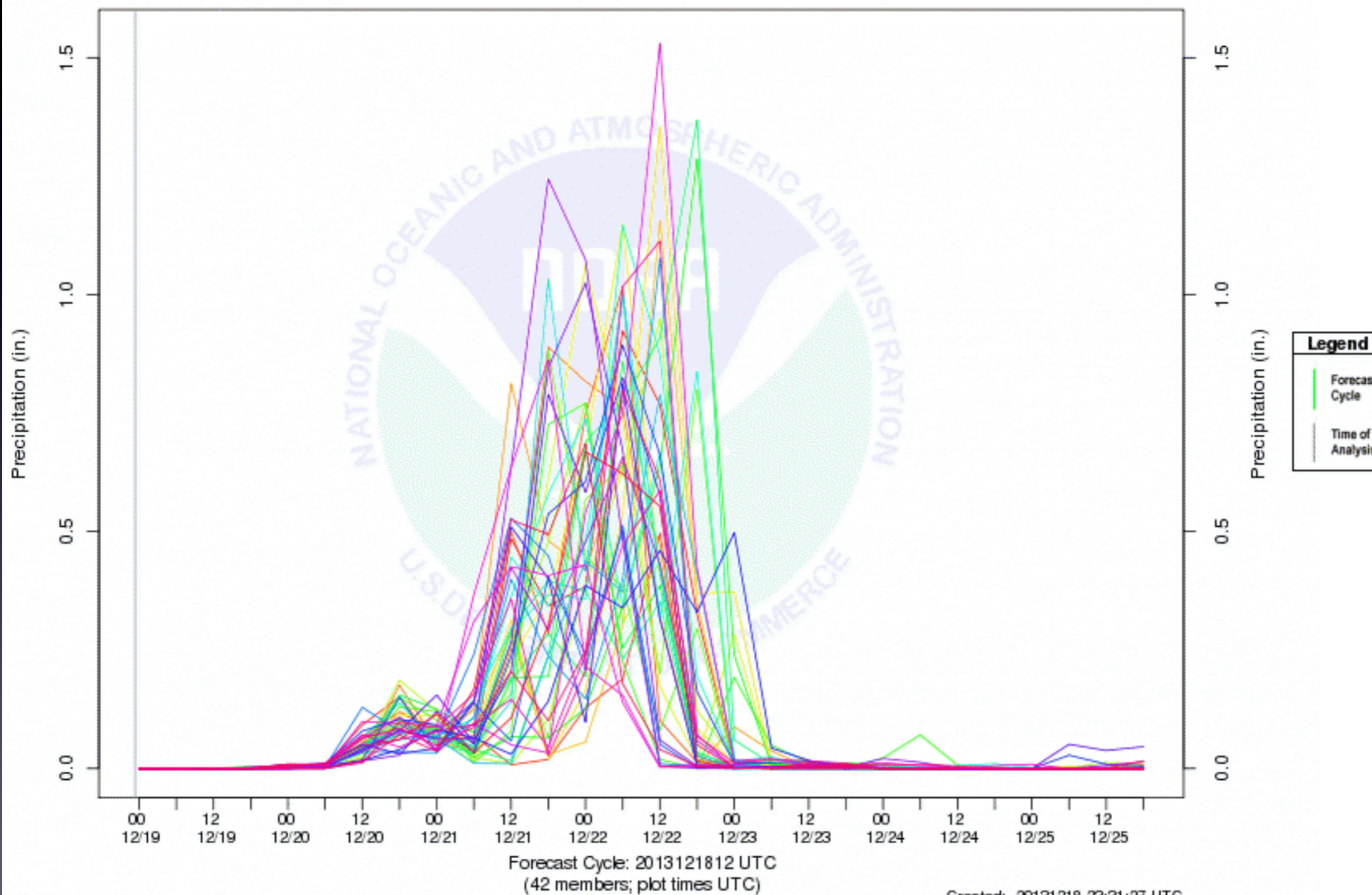
NAEFS-based Stage Simulations Probability of Exceedance Plot  
 Blanchard River at Findlay, OH (FDYO1)  
 Analysis for the period 12/20/2013 00UTC - 12/26/2013 12UTC



Probability of Exceedance in %  
 Forecast Cycle: 2013121912 UTC (42 members)

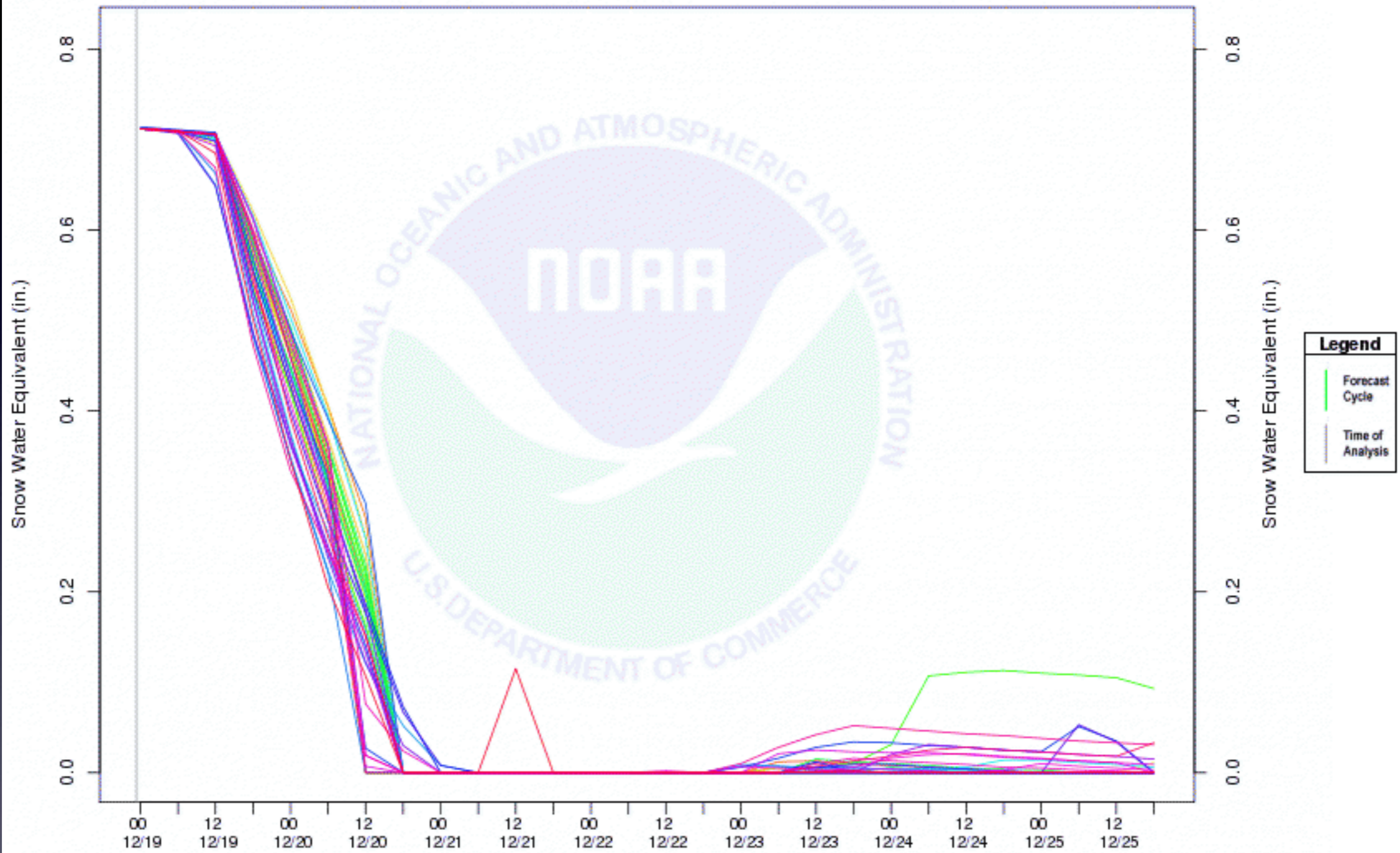
Quantile: qnorm  
 Created: 20131219 23:27:52 UTC

NAEFS-based Local Basin-average Precipitation Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC



Created: 20131218 23:31:27 UTC

NAEFS-based Basin-average Snow Water Equivalent Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC

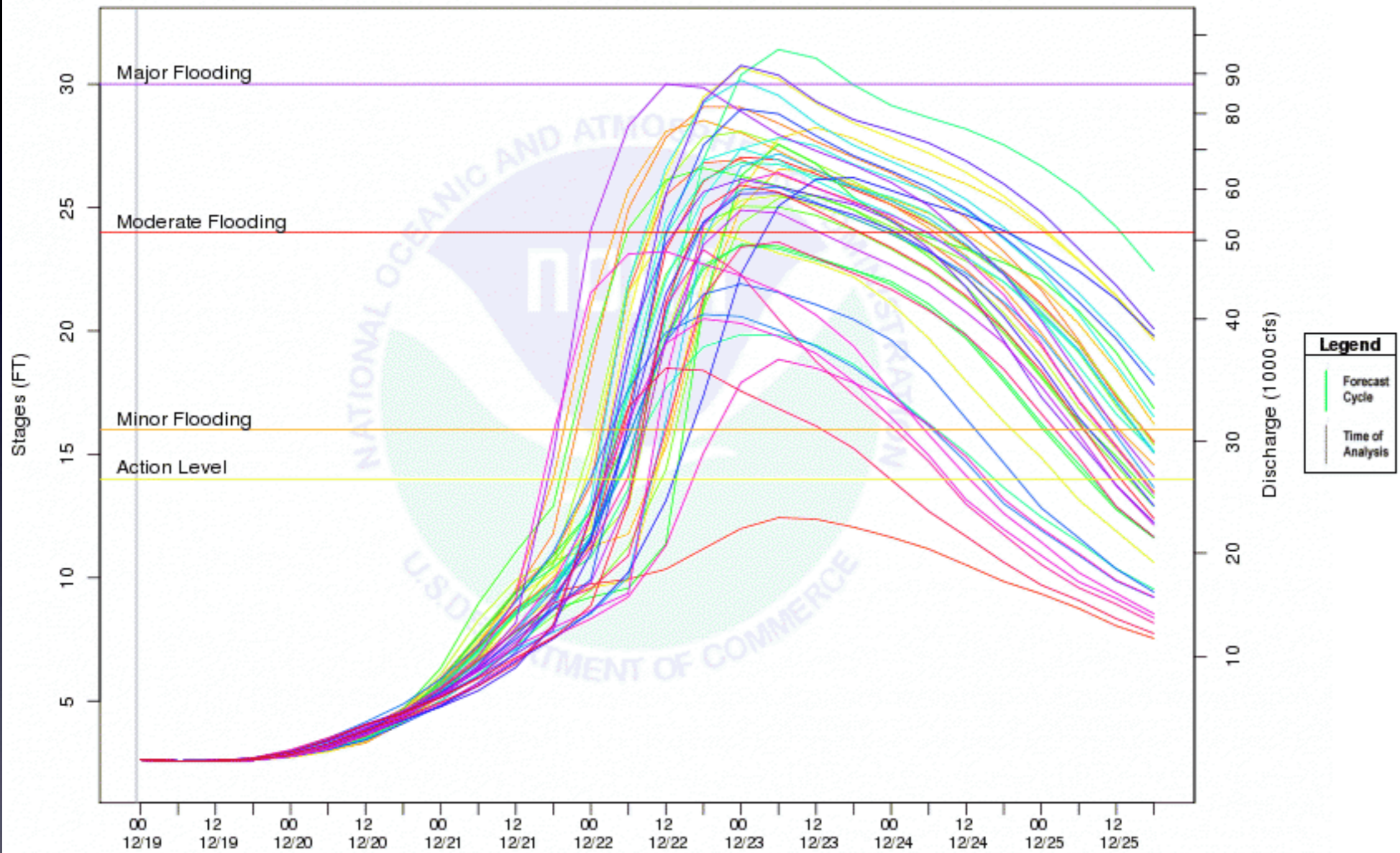


Forecast Cycle: 2013121812 UTC  
(42 members; plot times UTC)

Created: 20131218 23:31:29 UTC



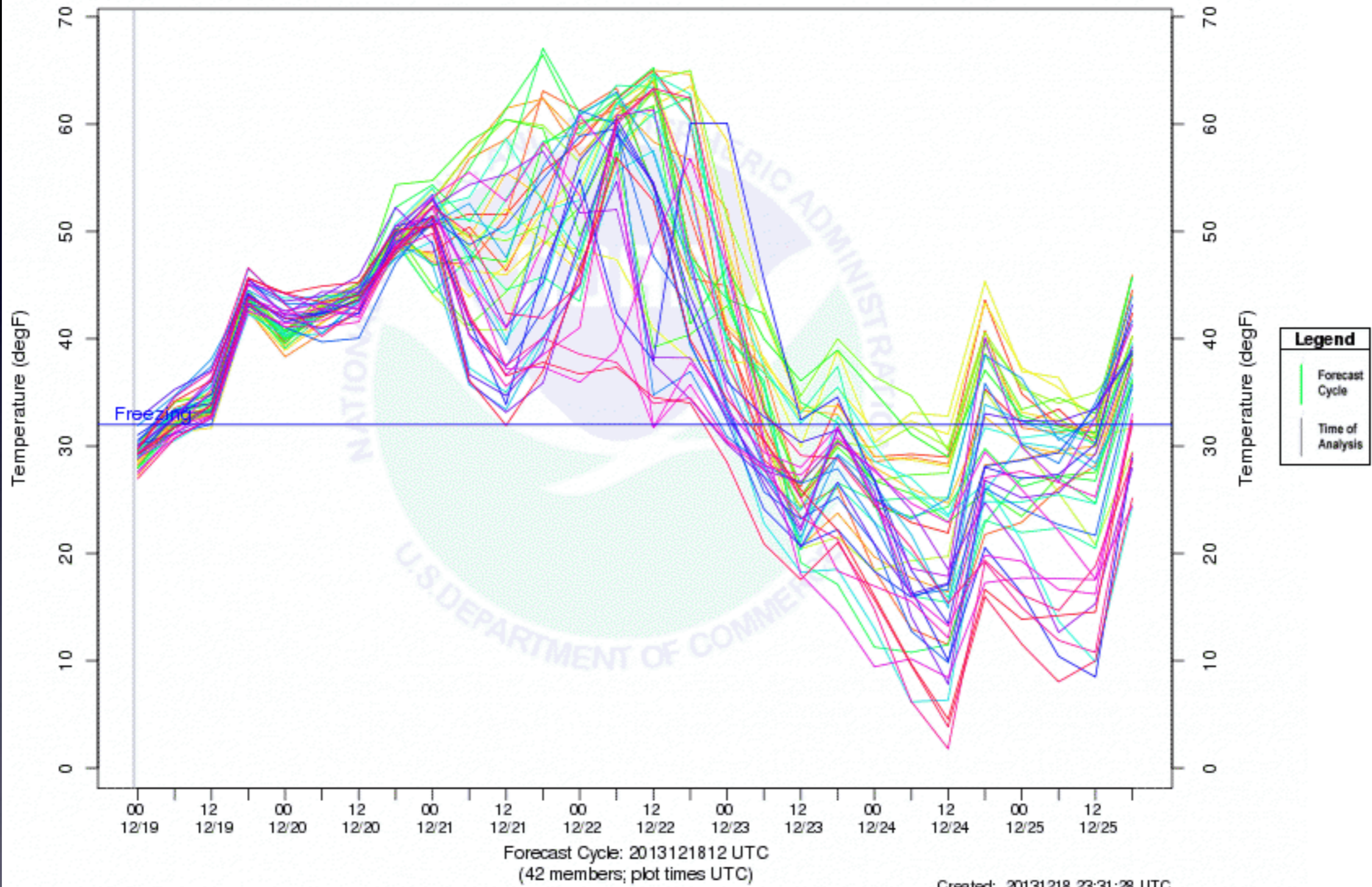
NAEFS-based Stage Simulations Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC



Forecast Cycle: 2013121812 UTC  
(42 members; plot times UTC)

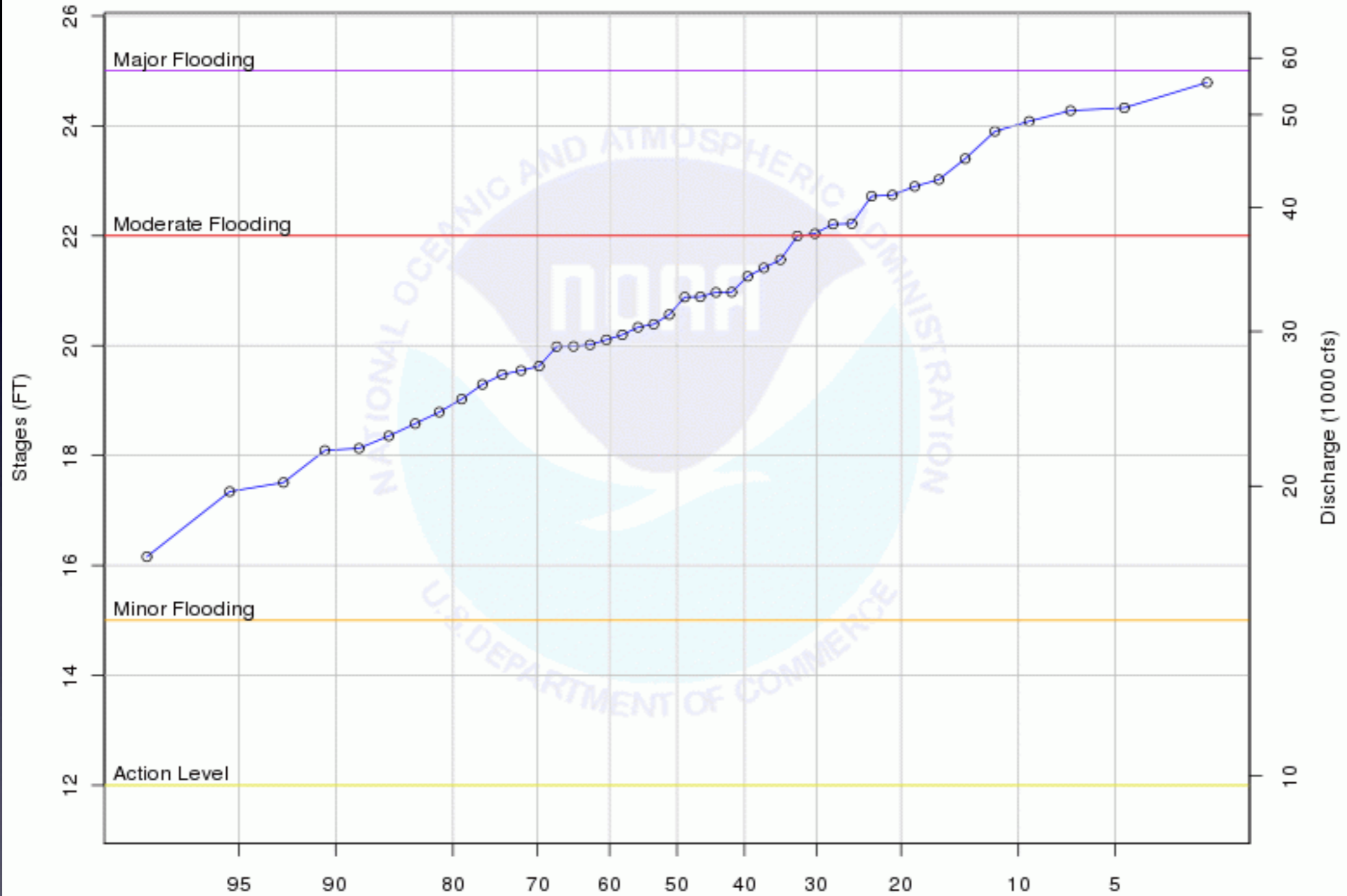
Created: 20131218 23:31:26 UTC

NAEFS-based Local Basin-average Temperature Traces  
Great Miami River at Miamitown, OH (MIAO1)  
Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC



Created: 20131218 23:31:28 UTC

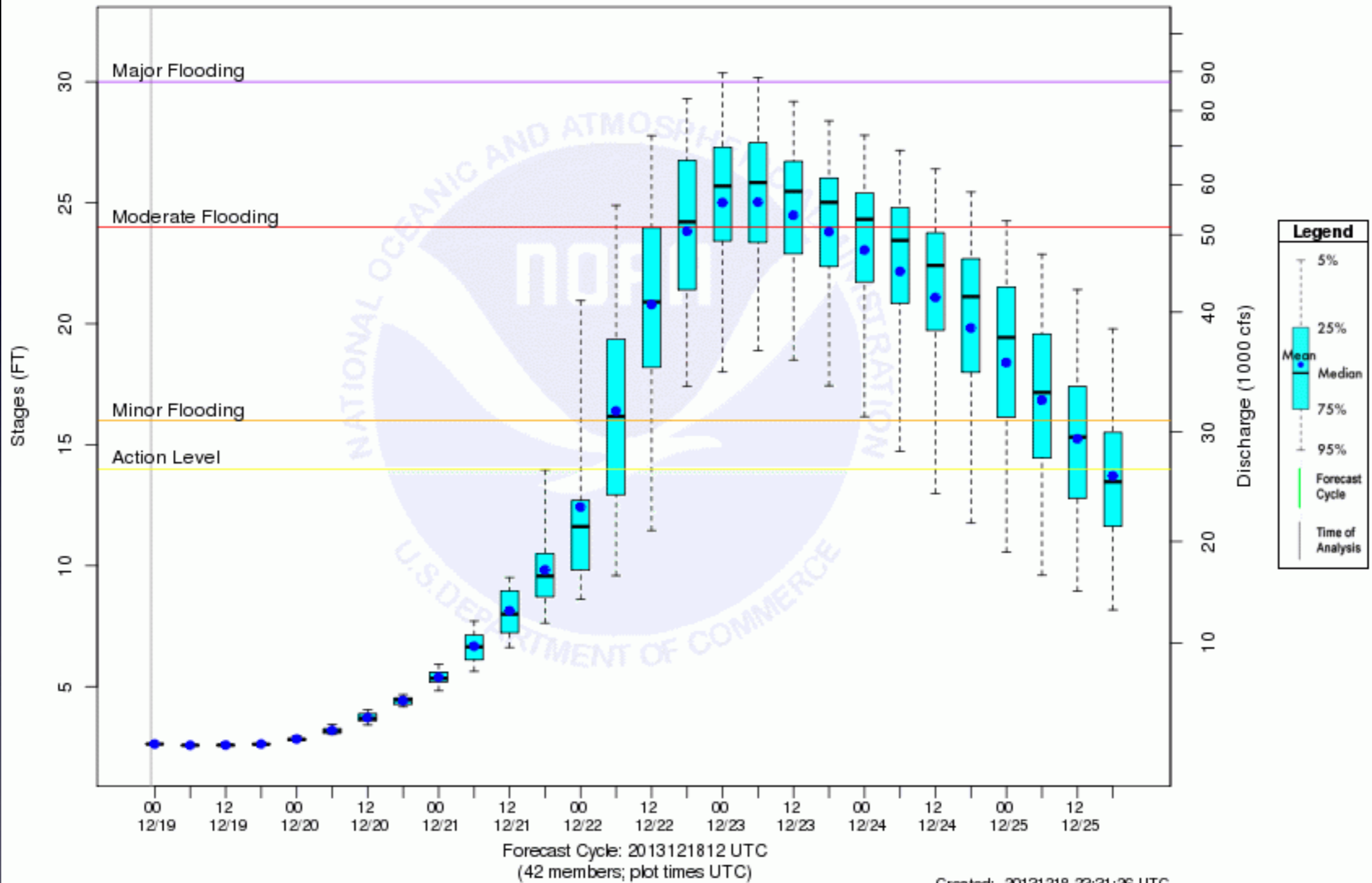
NAEFS-based Stage Simulations Probability of Exceedance Plot  
White River at Edwadsport, IN (FRE13)  
Analysis for the period 12/19/2013 00UTC - 12/25/2013 12UTC



Probability of Exceedance in %  
Forecast Cycle: 2013121812 UTC (42 members)

Quantile: qnorm  
Created: 20131218 23:27:48 UTC

NAEFS-based Stage Simulations Expected Value Plot  
 Great Miami River at Miamitown, OH (MIAO1)  
 Analysis for the period 12/19/2013 00 UTC - 12/25/2013 18 UTC



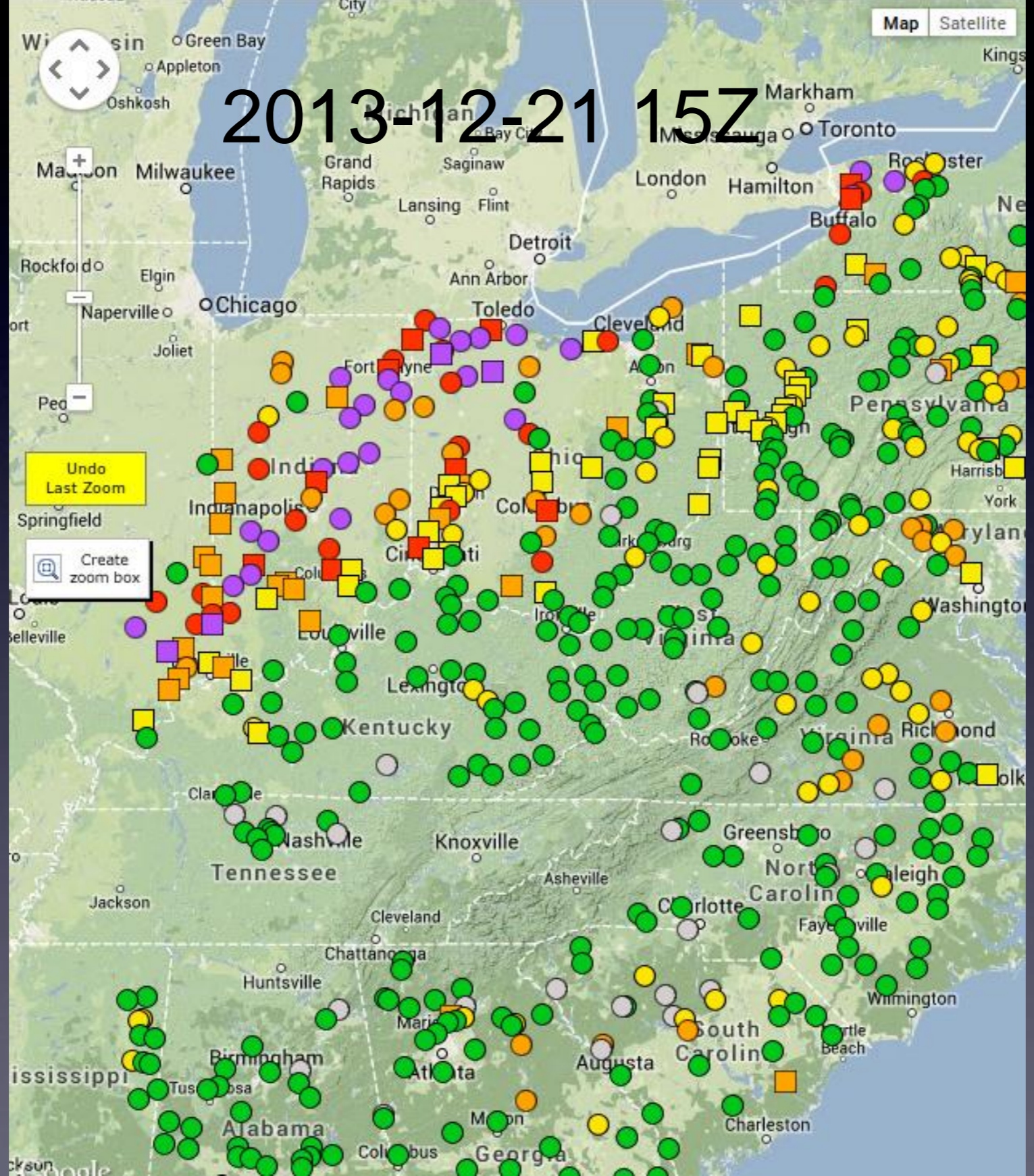
Please see the [Product Description Document](#) for detailed information about this service.

Zoom to a Location

- GEFS (default)
- NAEFS
- SREF

MMEFS Overview | Recorded Training

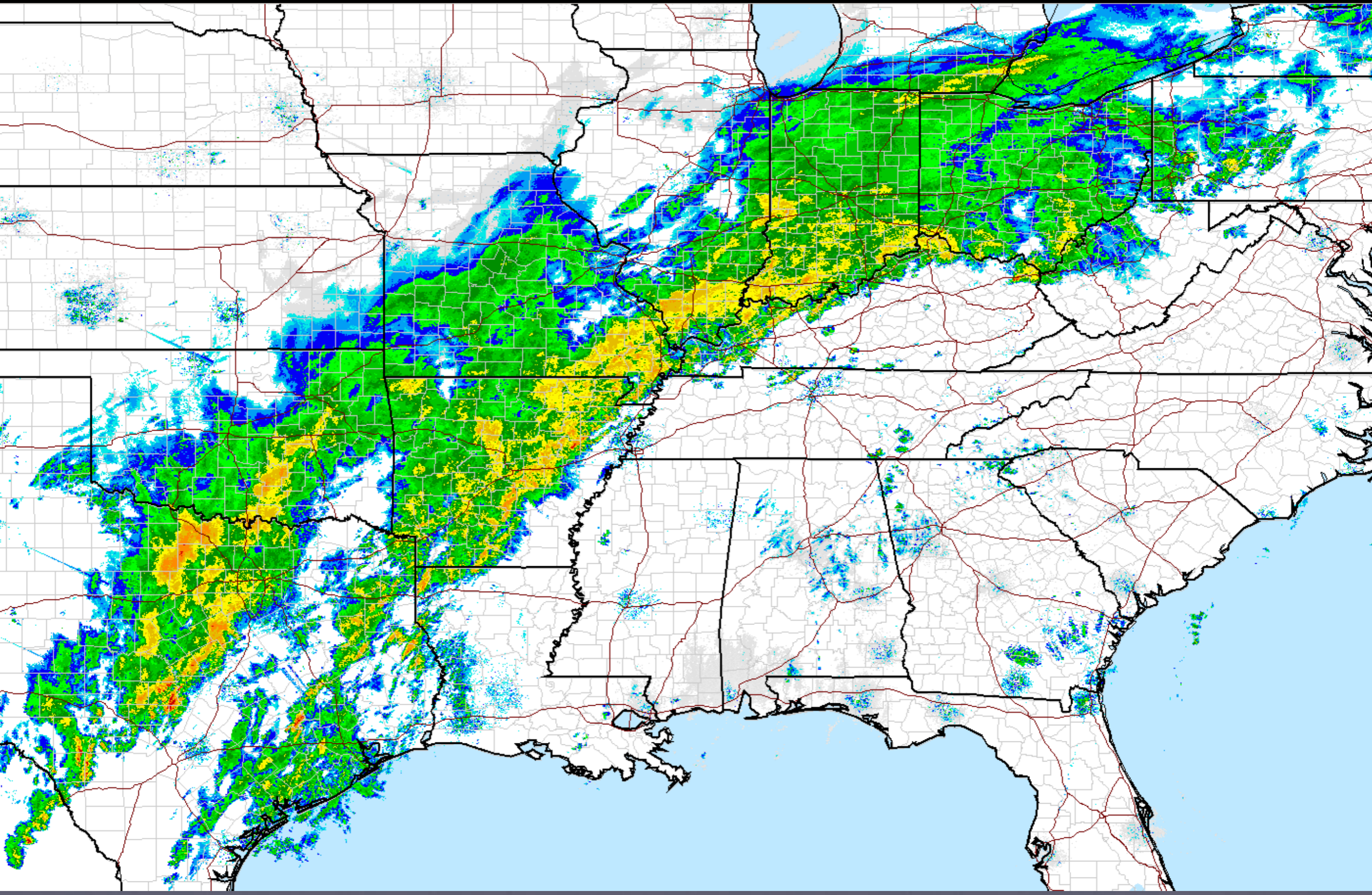
MARFC Status & News | **NERFC Status** | OHRFC Status | SERFC Status



2013-12-21 15Z

Undo Last Zoom

Create zoom box



Please see the [Product Description Document](#) for detailed information about this service.

Zoom to a Location

GEFS  
(default)

NAEFS

SREF

MMEFS  
Overview

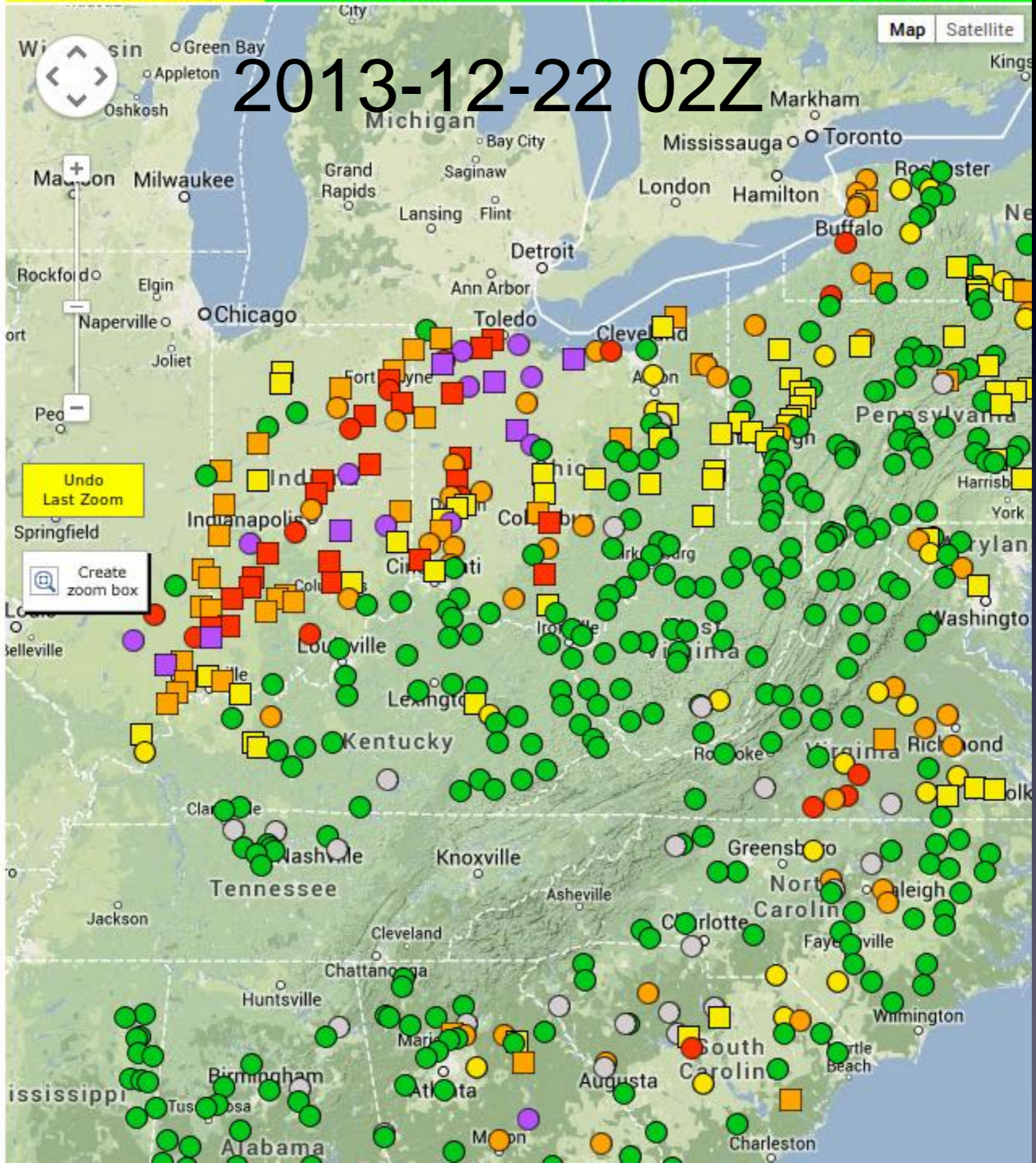
Recorded  
Training

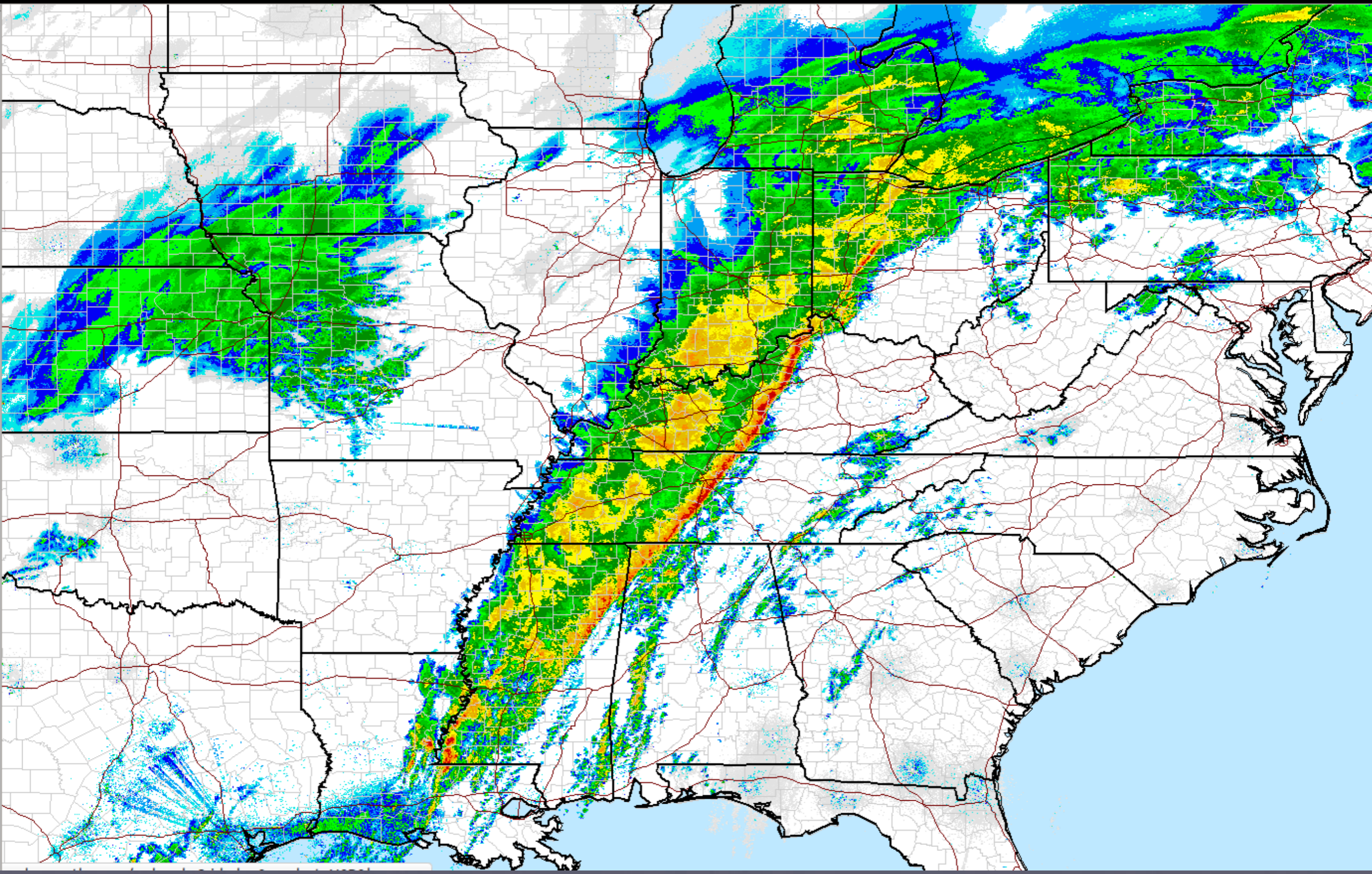
MARFC Status & News

NERFC Status

OHRFC Status

SERFC Status

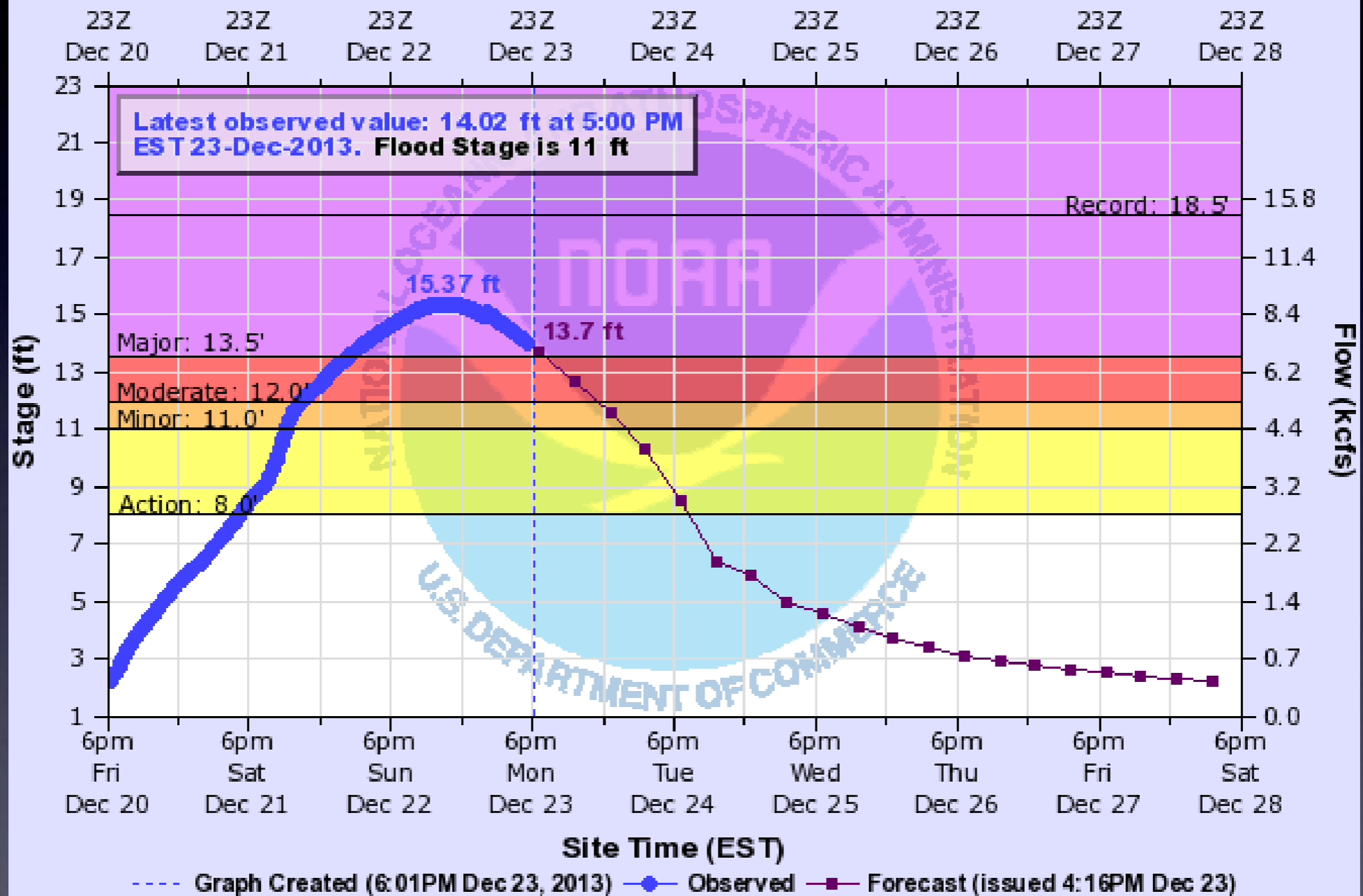






# BLANCHARD RIVER AT FINDLAY

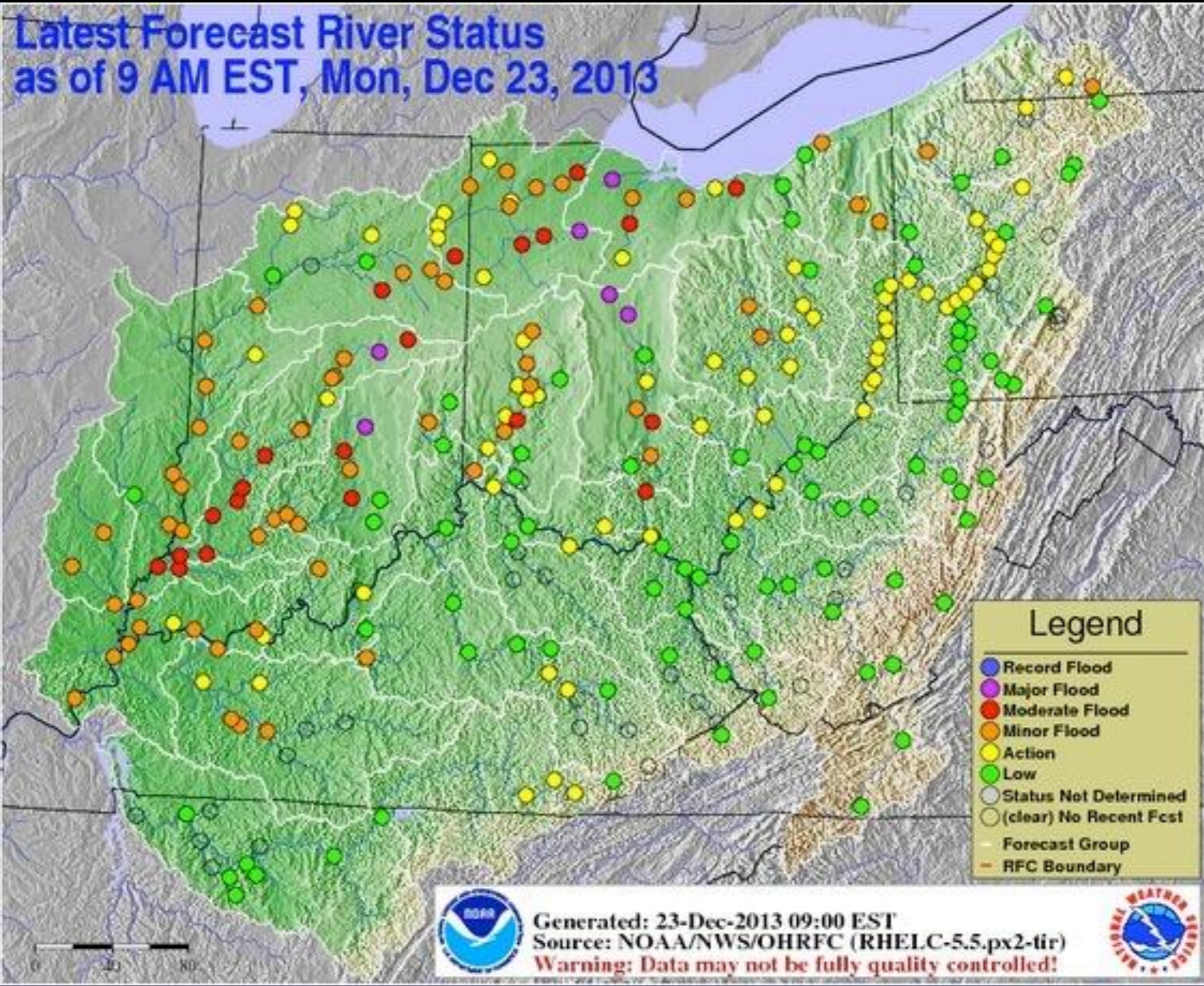
Universal Time (UTC)



FDYO1(plotting HGIRG) "Gage 0" Datum: 753.76'

Observations courtesy of US Geological Survey

# Latest Forecast River Status as of 9 AM EST, Mon, Dec 23, 2013

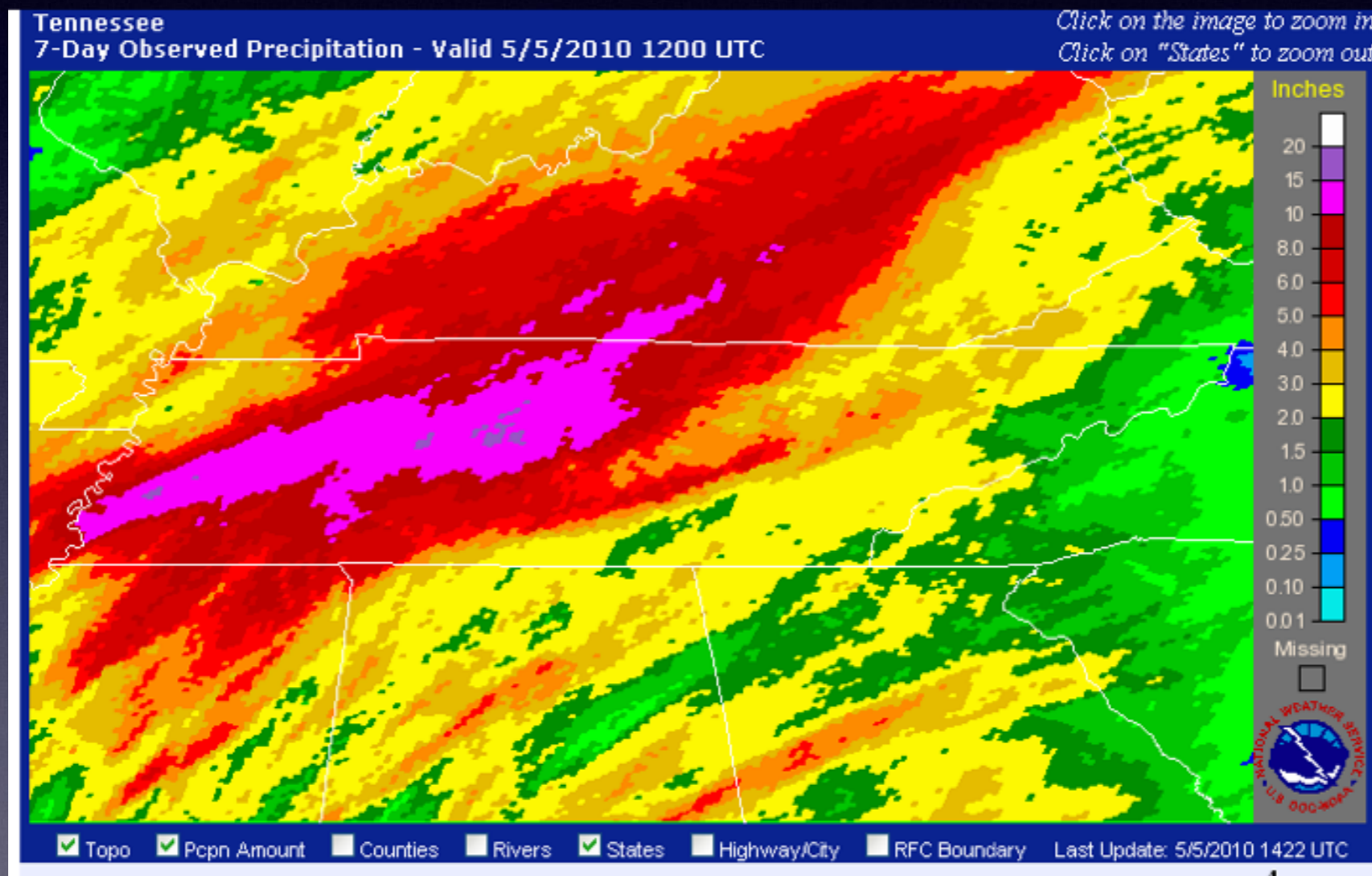


Generated: 23-Dec-2013 09:00 EST  
Source: NOAA/NWS/OHRFC (RHELC-5.5.px2-tir)  
**Warning: Data may not be fully quality controlled!**

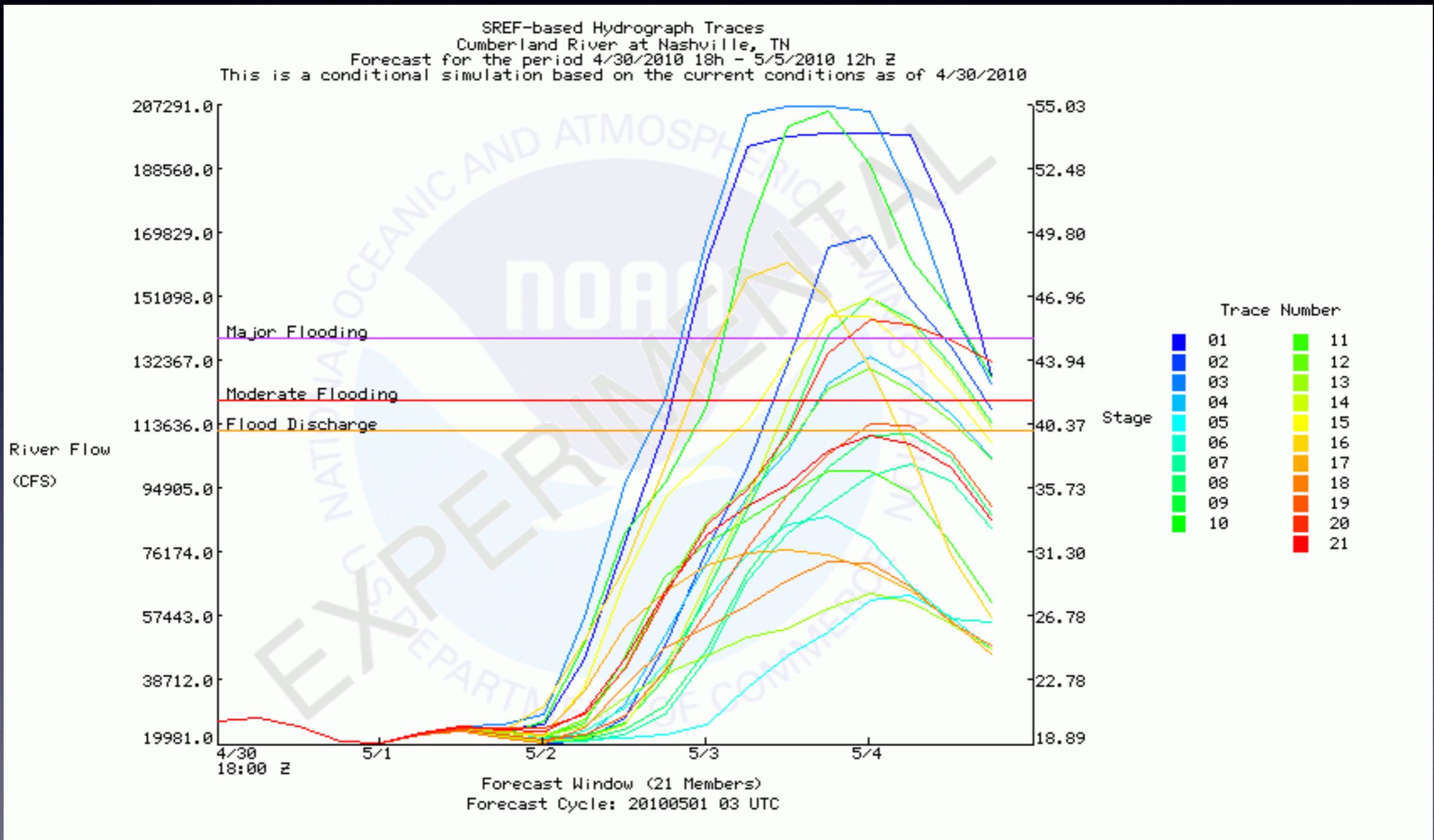


Nashville, TN  
April 30 - May 4, 2010

# 7-day precipitation ending 05 May 2010 12Z

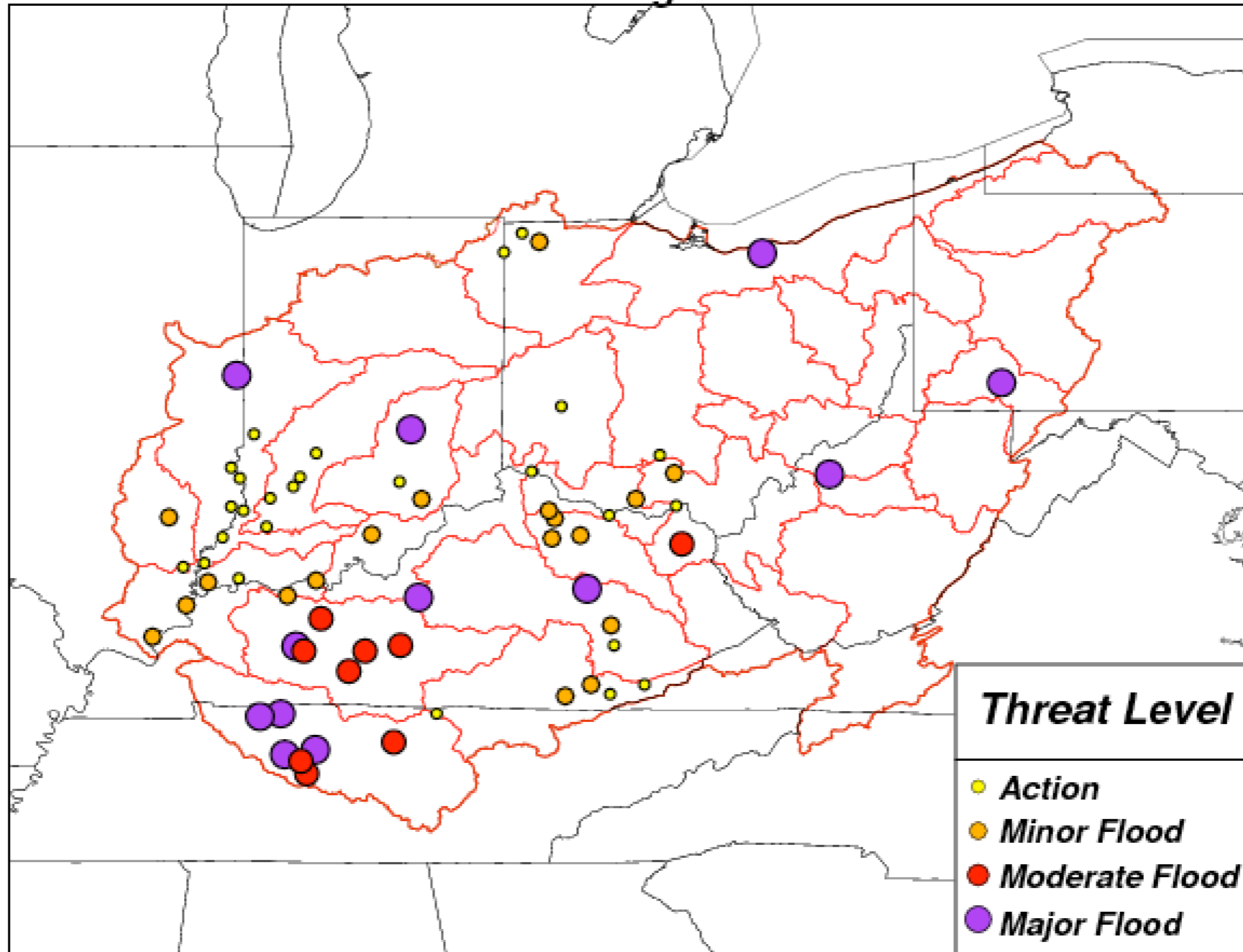


# Nashville, TN (NAST1) MMEFS SREF 04/30/2010

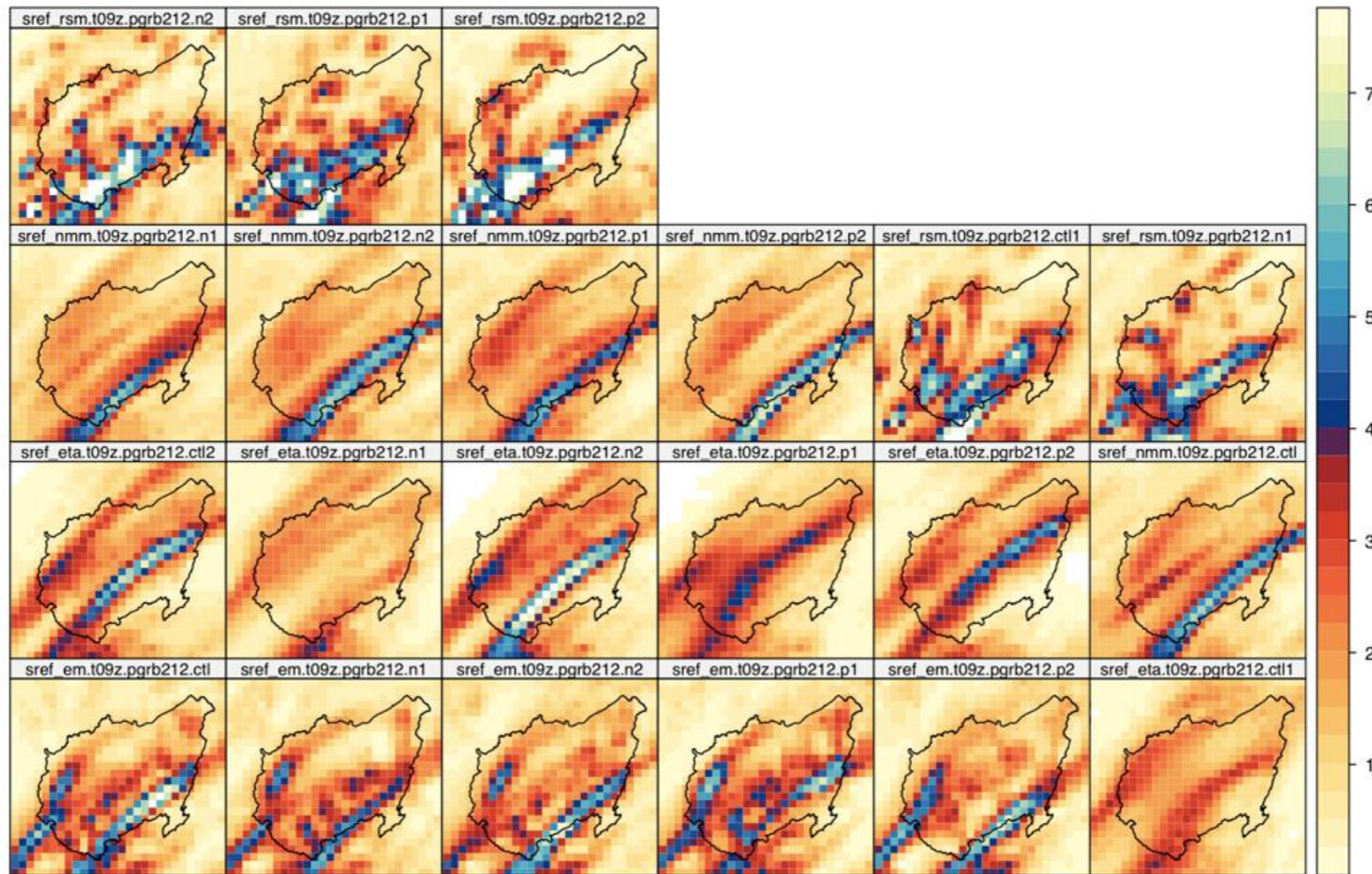


Friday, April 30, 2010

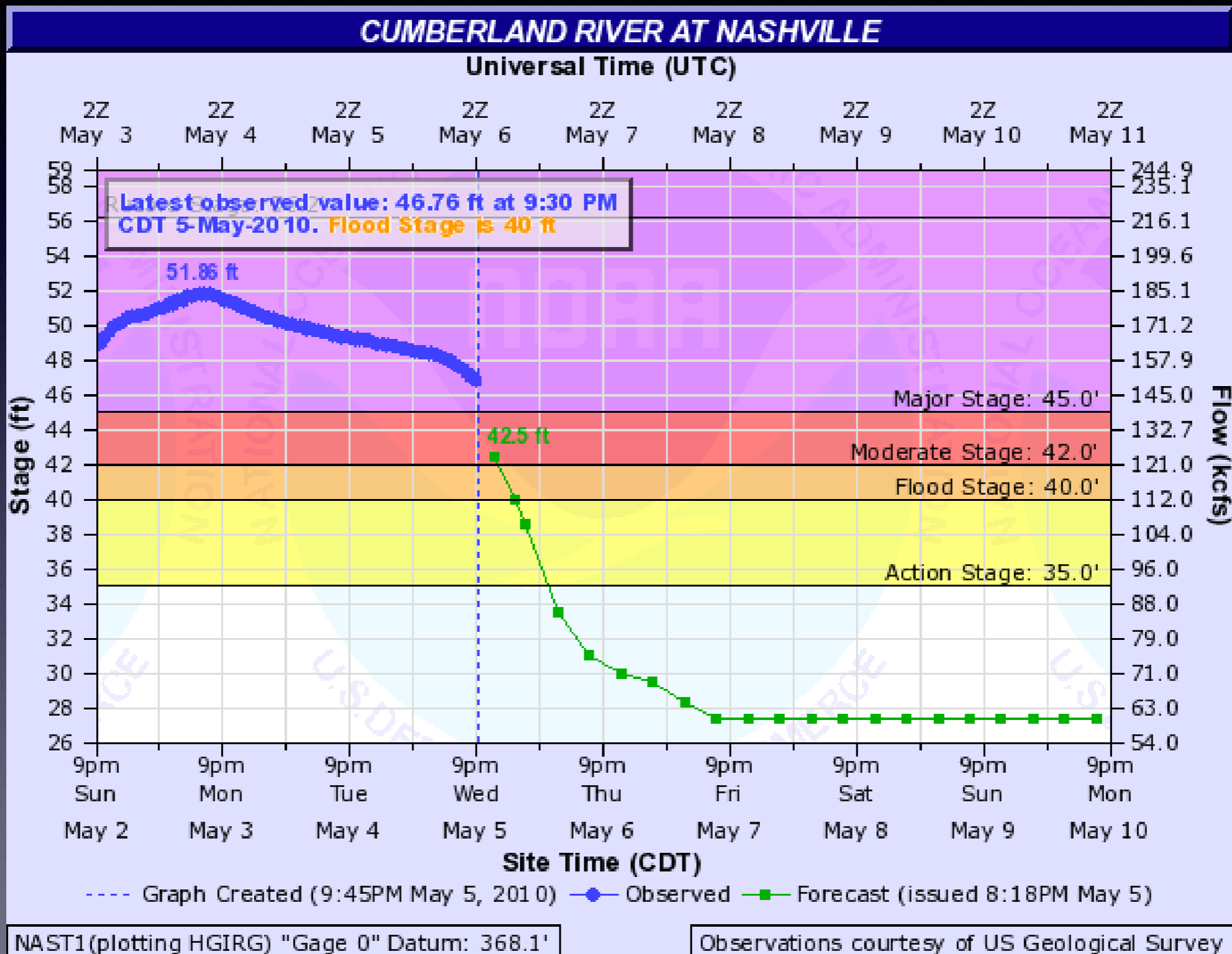
*High water observations for OHRFC  
2010-04-30 through 2010-05-10*



### OHRFC – SREF 87-hr Ensemble Model Precipitation: 20100501–09Z



# Nashville, TN



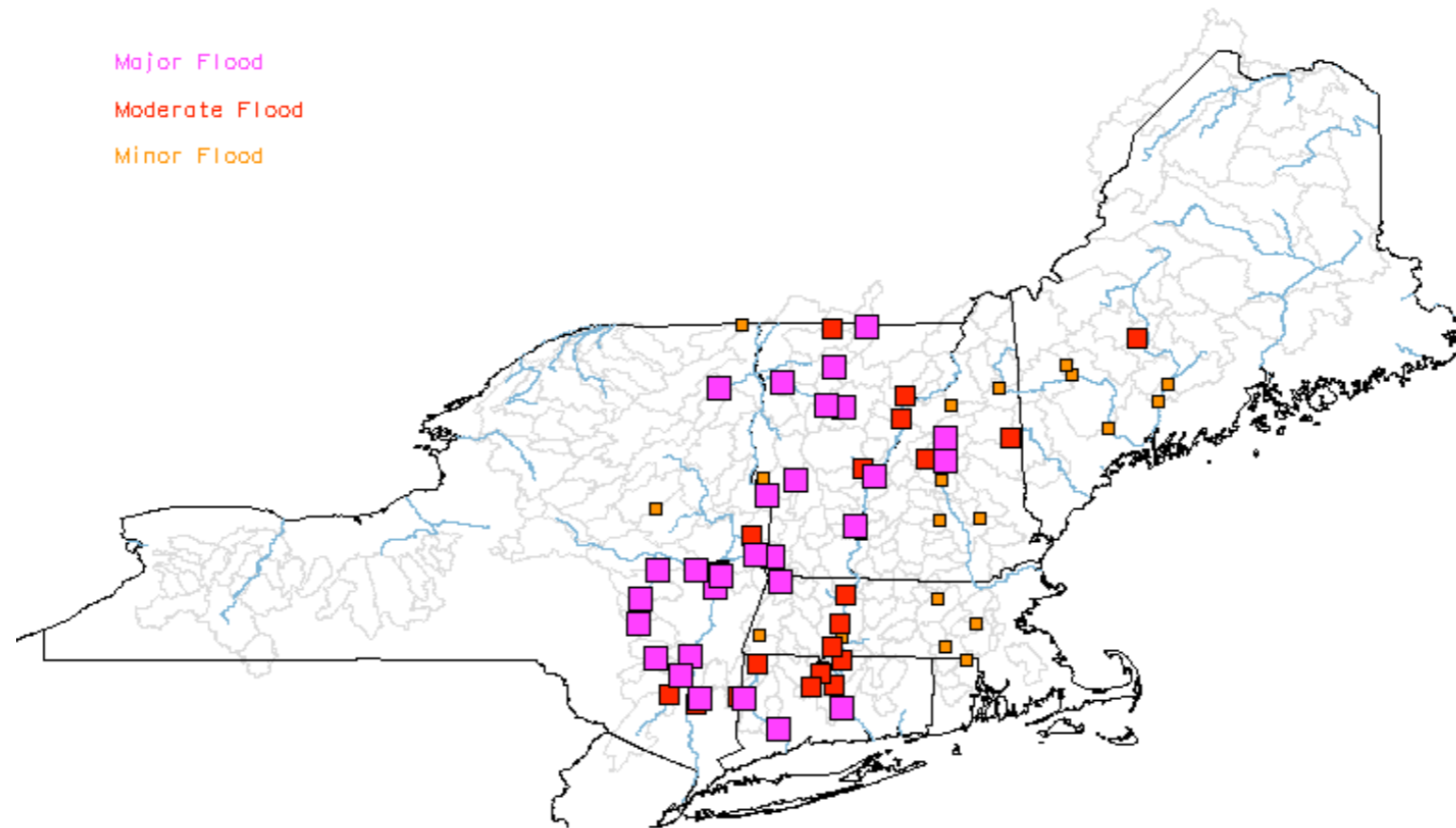


# Hurricane Irene 2011

# NERFC

## Northeast Flooding

2011-08-27 to 2011-09-01



Height of storm, Sunday, Aug.  
28

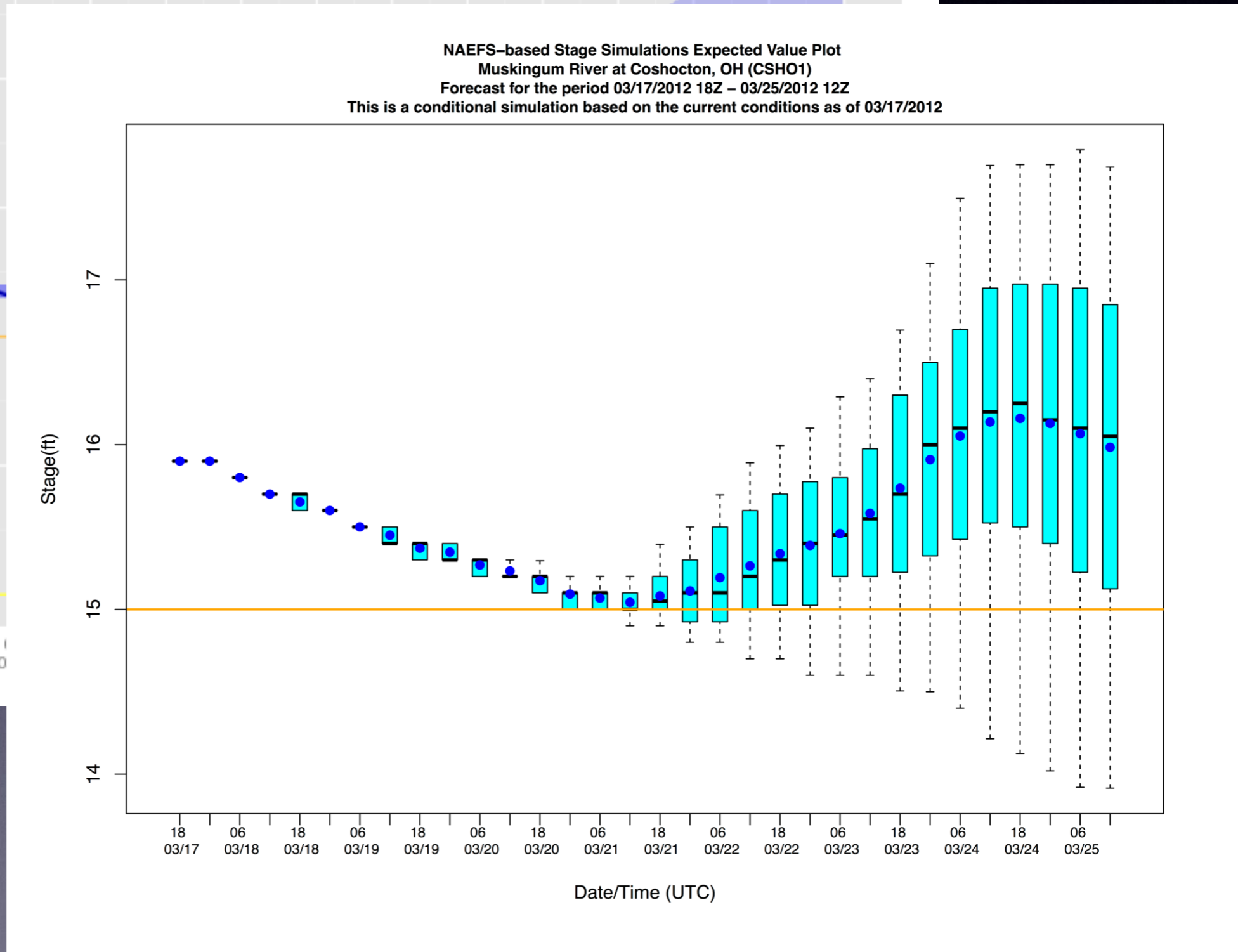
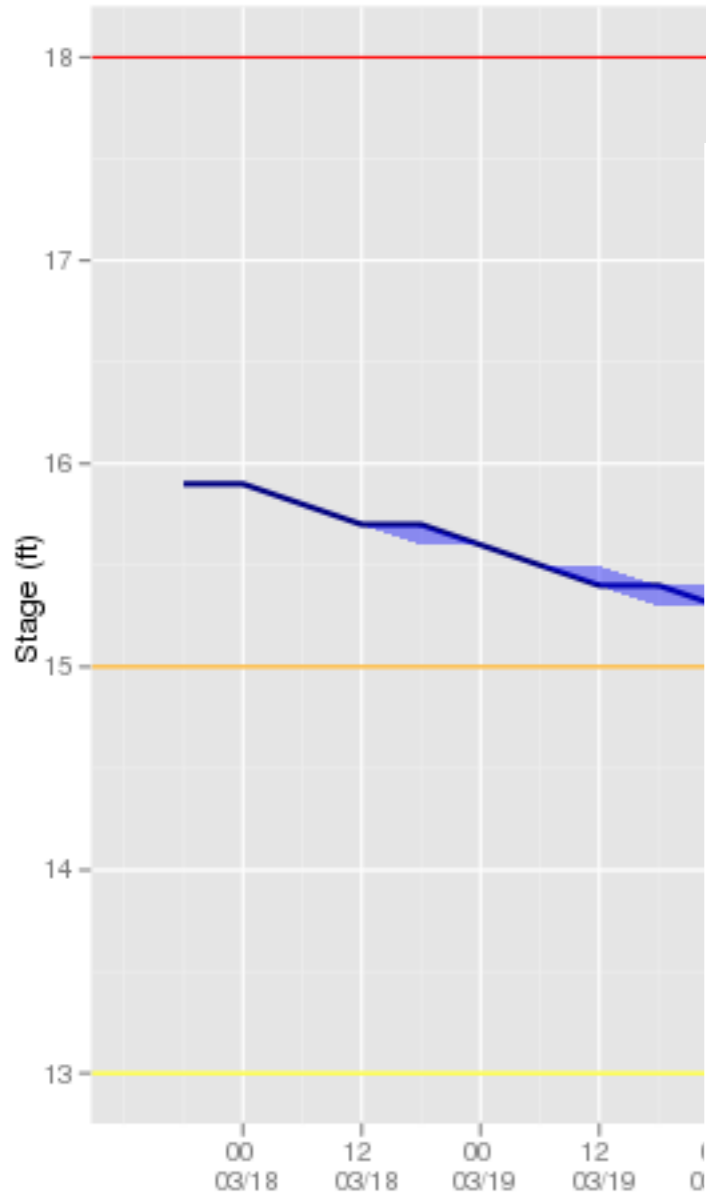
Issues

# MMEFS run times & availability

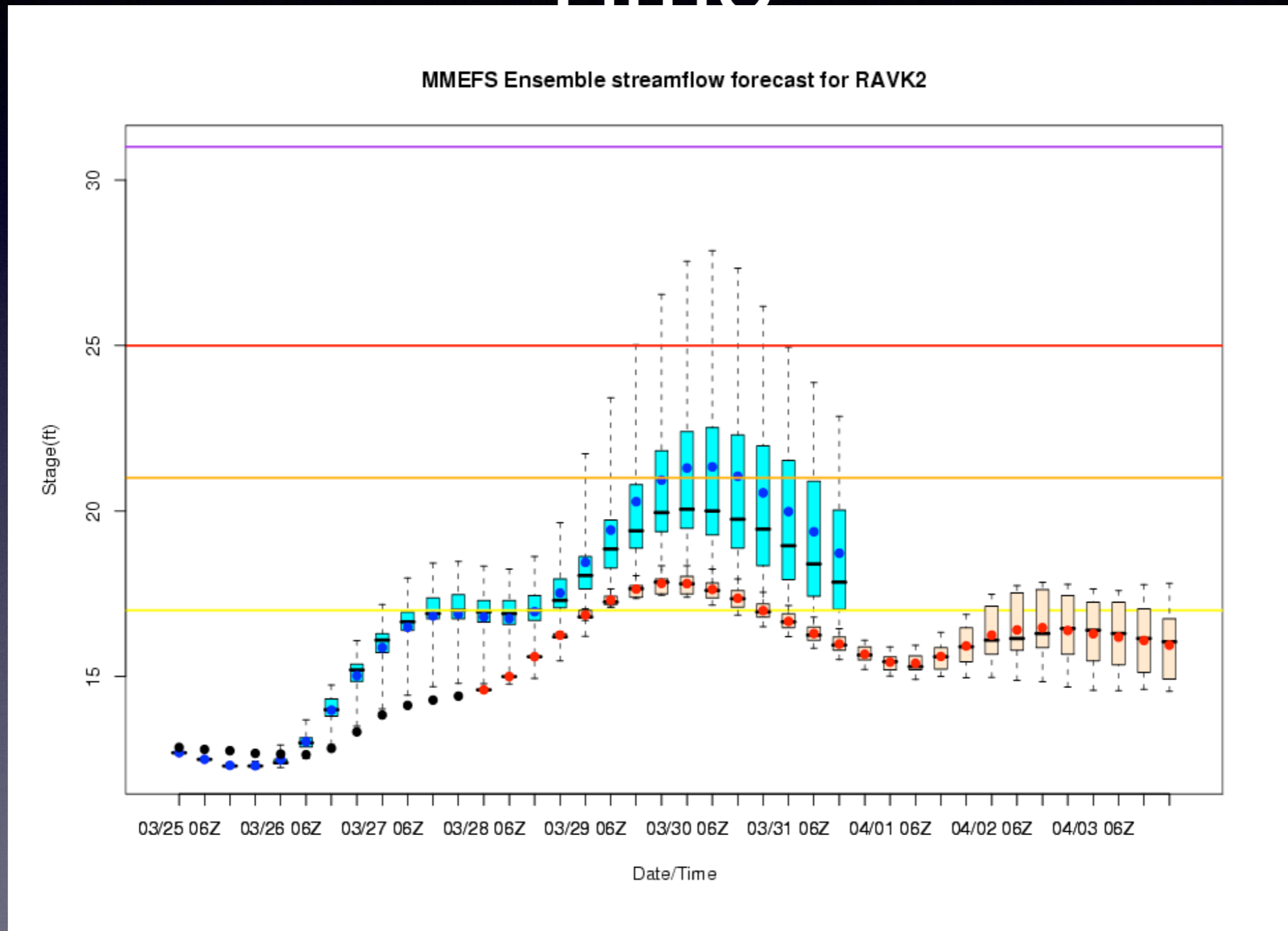
NWP model	Number of Members	Lead Time	Initialization	Availability	MMEFS start	MMEFS availability
06Z GEFS	21	7-days	06Z	12Z	12Z	14Z
18Z GEFS	21	7-days	18Z	00Z	00Z	02Z
00Z NAEFS <sup>†</sup>	42	7-days	00Z	08Z	08Z	11Z
12Z NAEFS	42	7-days	12Z	20Z	20Z	23Z
03Z SREF	21	87-hours	03Z	07Z	07Z	10Z
09Z SREF	21	87-hours	09Z	13Z	13Z	16Z
15Z SREF	21	87-hours	15Z	19Z	19Z	22Z
21Z SREF	21	87-hours	21Z	01Z	01Z	04Z

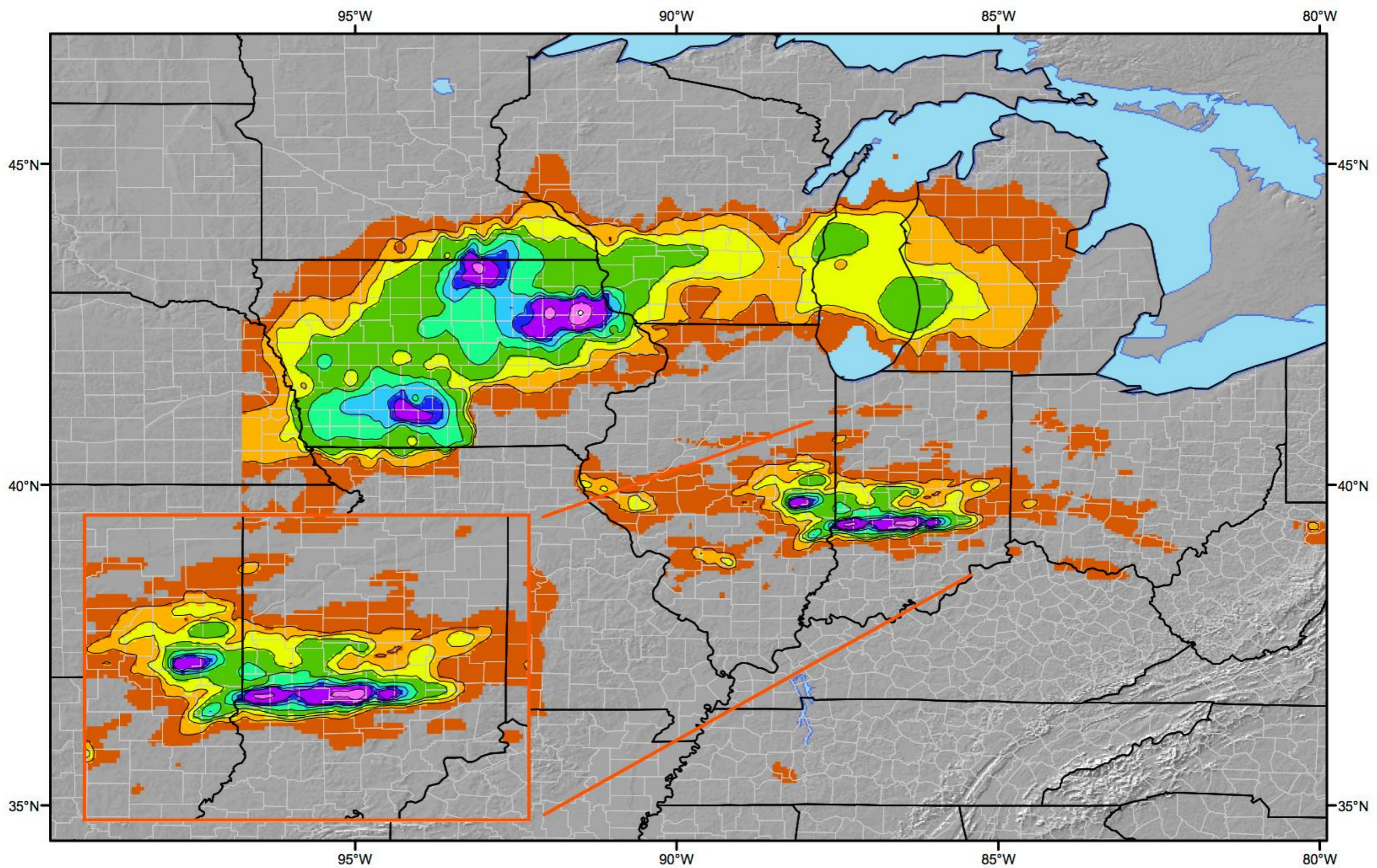
<sup>†</sup> The NAEFS consists of the 21-member GEFS and 21-member Canadian Ensemble

# Which to use?

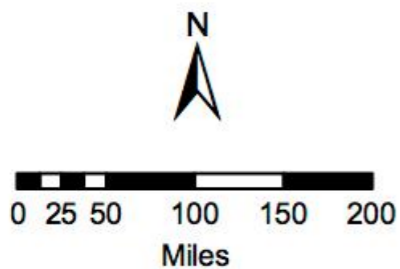


# Ensemble Forecasts over Time





**Annual Exceedence Probability for 20 Day Rainfall**  
**5/23/2008 (8am EDT) to 6/12/2008 (8am EDT)**



Grey	Yellow	Light Blue	Pink
> 1/2	1/10 - 1/20	1/100 - 1/150	1/500 - 1/1000
Orange	Green	Dark Blue	White
1/2 - 1/5	1/20 - 1/50	1/150 - 1/200	< 1/1000
Light Orange	Cyan	Purple	
1/5 - 1/10	1/50 - 1/100	1/200 - 1/500	



# User Community

- WFOs
- Emergency Managers
- City Engineers
- USGS
- USACE
  - Huntington District is ready to use ensemble inflows for 7 reservoirs
- Utilities and utility analysts
- Maumee River Basin Commission, Miami Conservancy District...
- Identified as a *Best Practice* in the Nashville Flood Service Assessment



# Acknowledgements

Rob Shedd, DOH NERFC

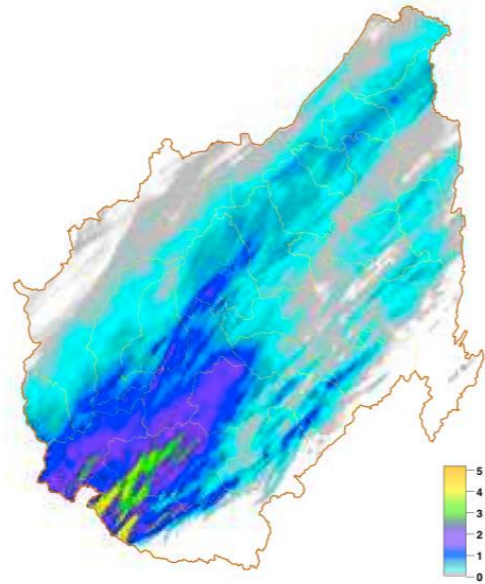
Joe Ostrowski, DOH MARFC (retired)

End

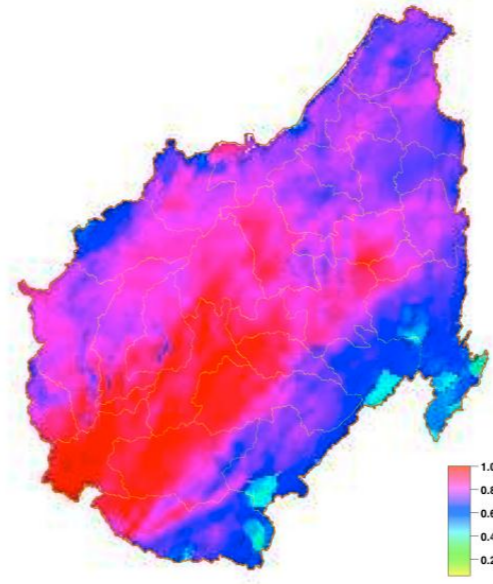
# Lower Ohio River Flooding April/May 2011

**OHRFC 4-panel RDHM Soil Moisture – 04/25/2011**  
(Soil moisture percent of capacity, upper layer 0–10 cm)

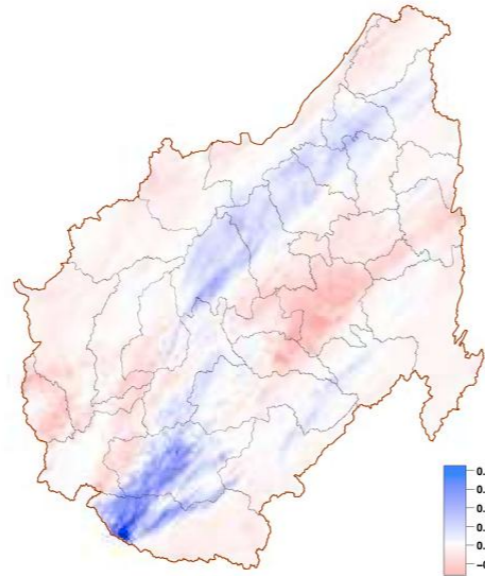
XMRG/MPE 24-hr precipitation (in) ending 04/25/2011



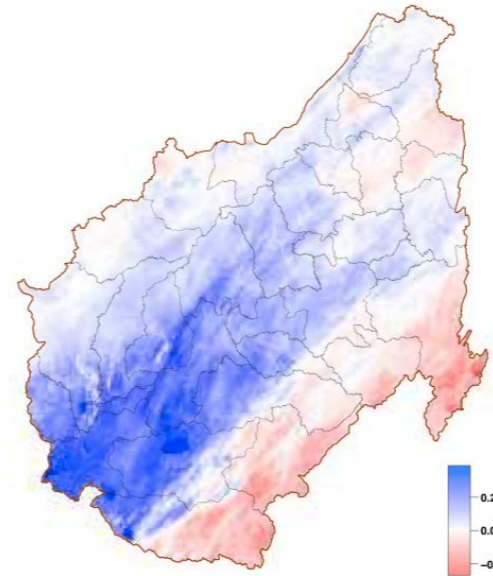
Fraction of soil moisture capacity 04/25/2011–12Z



1-Day Soil Moisture Difference  
04/24/2011–12Z to 04/25/2011–12Z

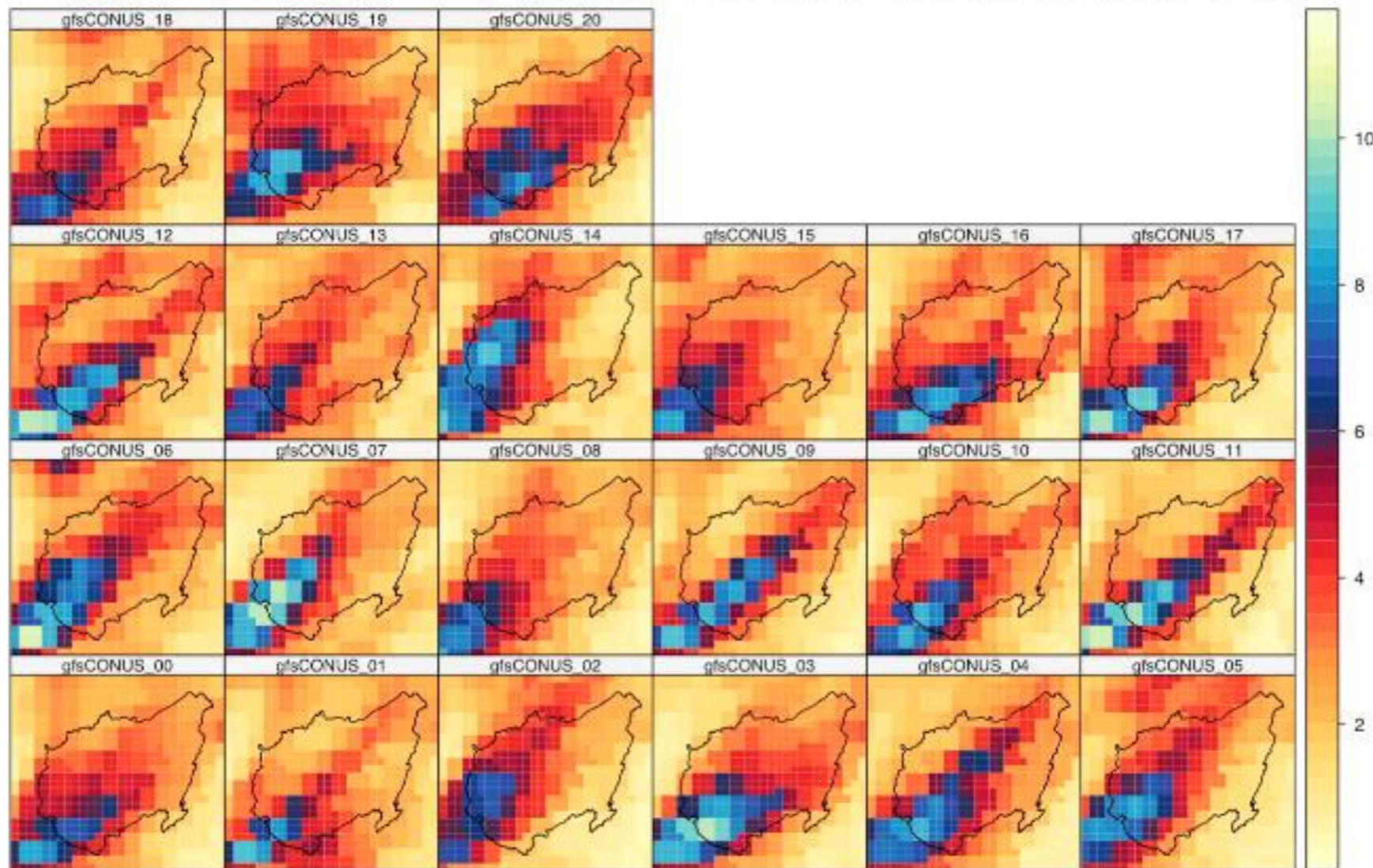


7-Day Soil Moisture Difference  
04/18/2011–12Z to 04/25/2011–12Z

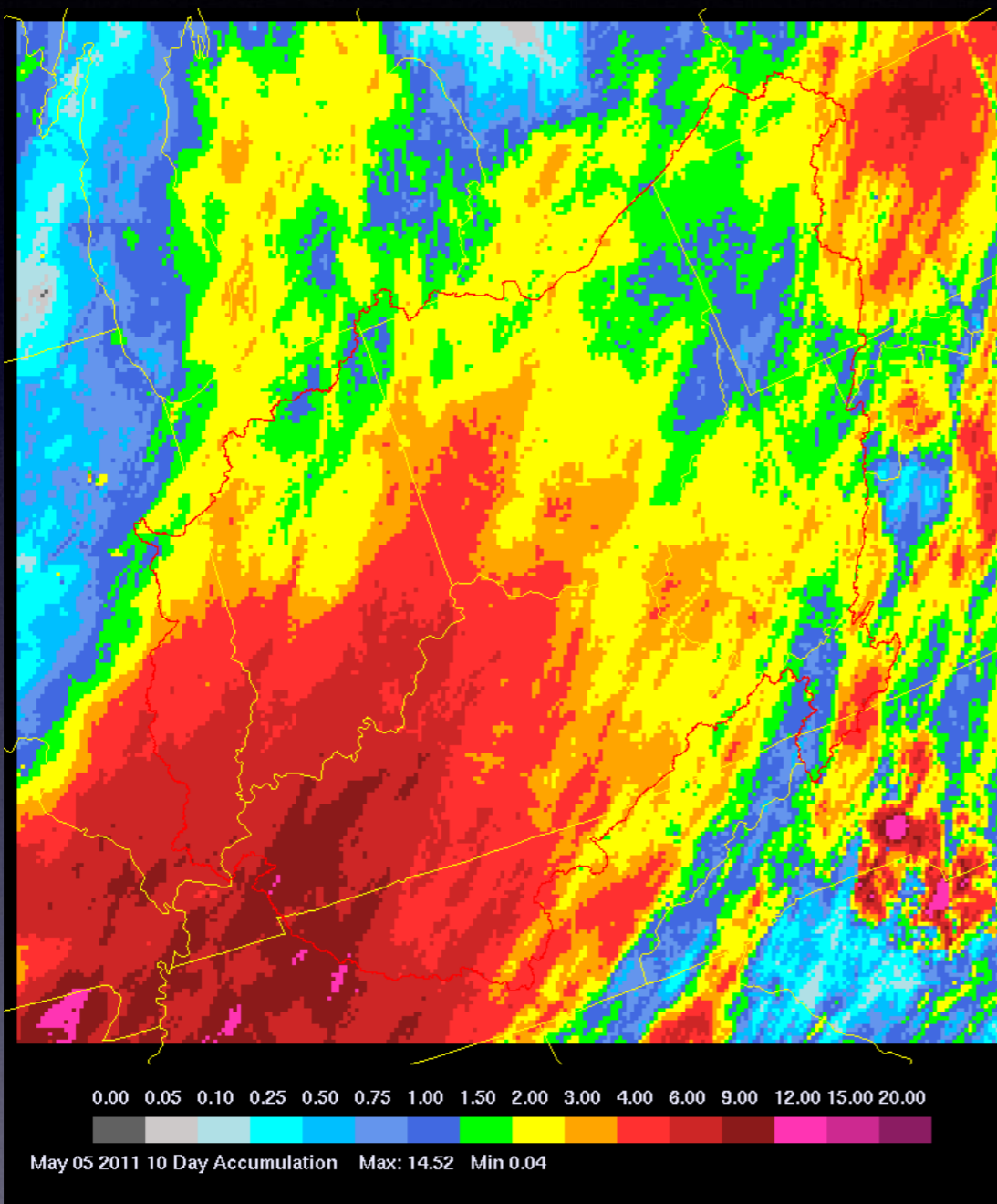


# MMEFS NAEFS/GEFS 7-day Precipitation 04/25/2011 - 05/05/2011

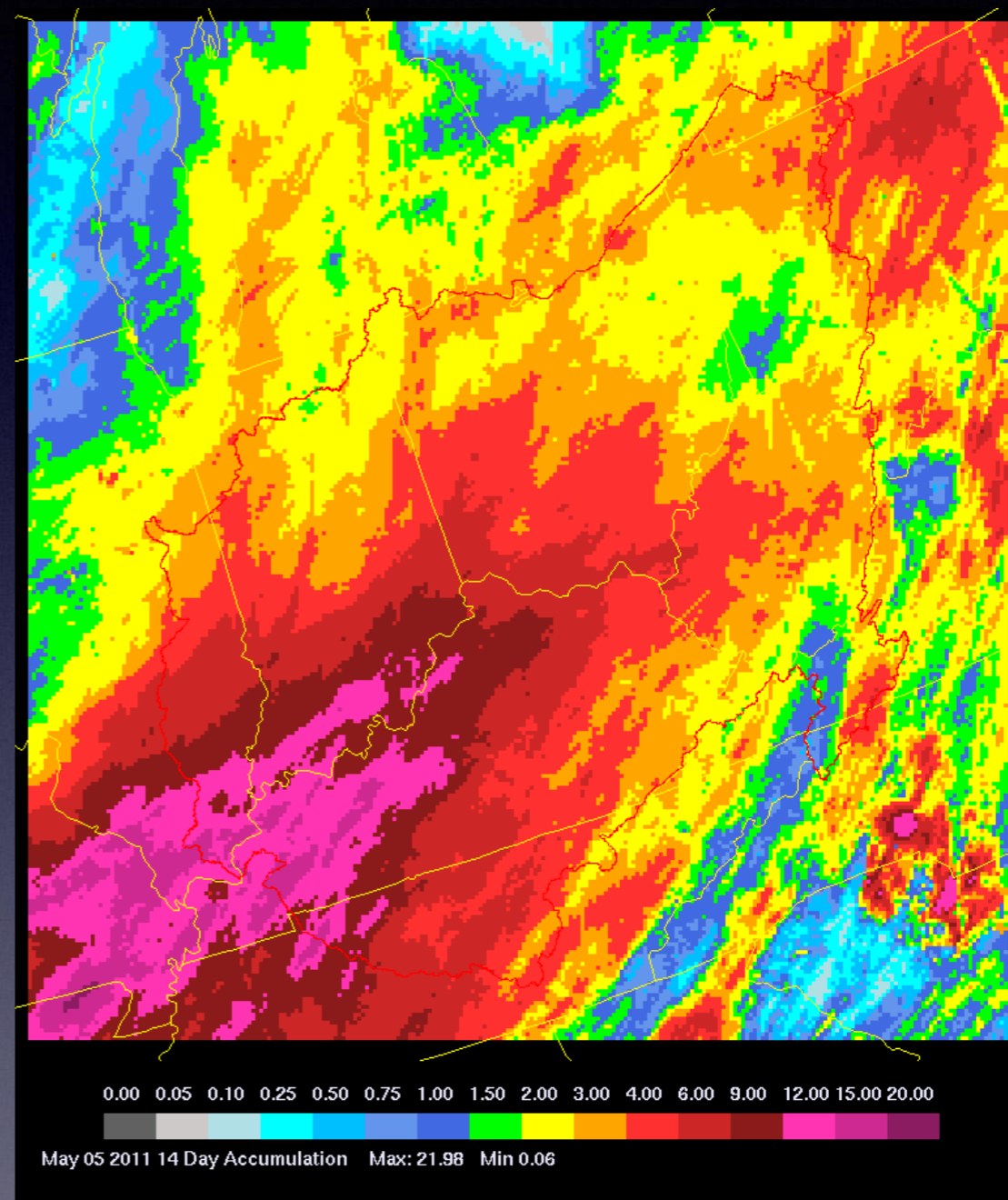
OHRFC 21-member NAEFS GEFS 7-day Total Ensemble Model Precipitation (inches): 20110425-12Z



# Observed MPE



10-day ending 05/05/2011



14-day ending 05/05/2011

# MMEFS NAEFS Summary 04/14/2011 - 05/07/2011

**NAEFS Ensemble Summary for 4/14/2011 - 4/20/2011**  
**Forecast Cycle: 2011/04/14/12**

