Linking the Hydrologic and Atmospheric Communities Through Probabilistic Flash Flood Forecasting

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NOAA/NWS/Weather Prediction Center

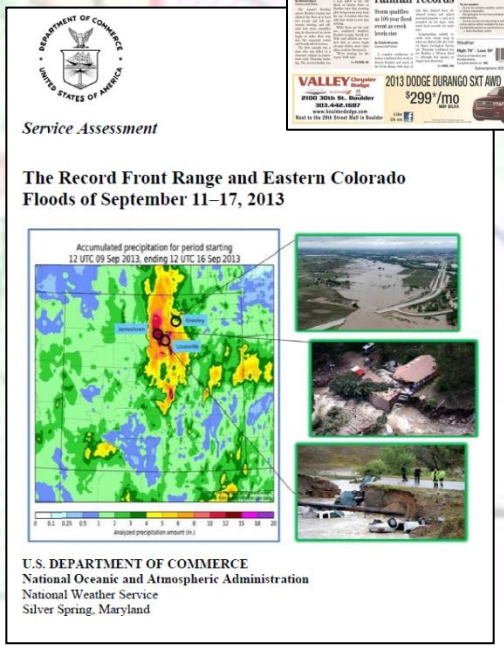
with numerous contributions from WPC staff

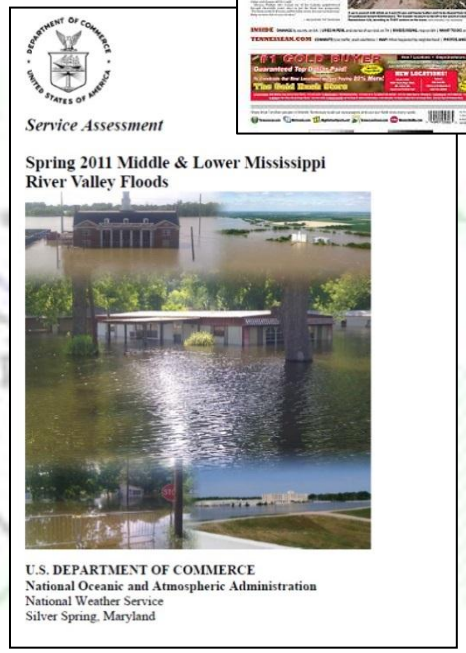
Outline

- Weather Prediction Center (WPC) operations
- Probabilistic precipitation tools and products
- WPC's operational flash flood product suite
  - Flash flood outlooks
  - Mesoscale precipitation discussions
- Flash Flood and Intense Rainfall (FFaIR) Experiment
- Summary

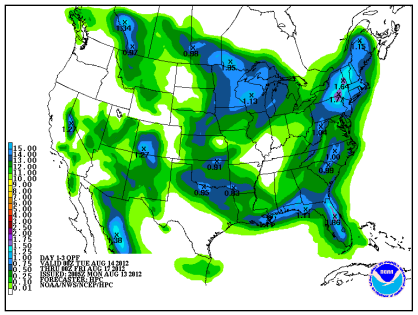
Why are Flash Floods Important?

- Historic flash floods often come as a surprise
- Recent NWS service assessments have repeatedly emphasized the need to improve skill in forecasting damaging floods

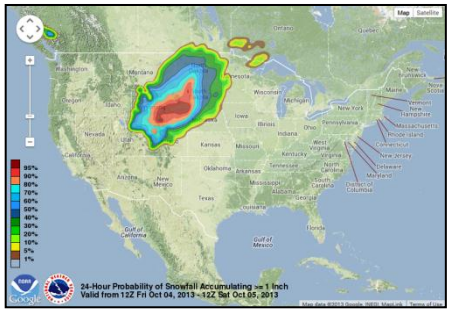




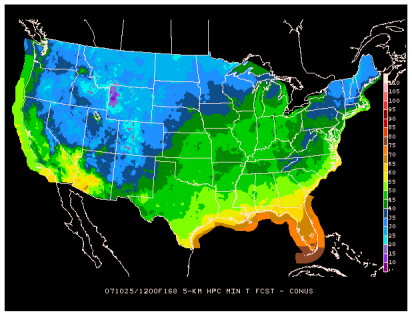
WPC Operational Desks



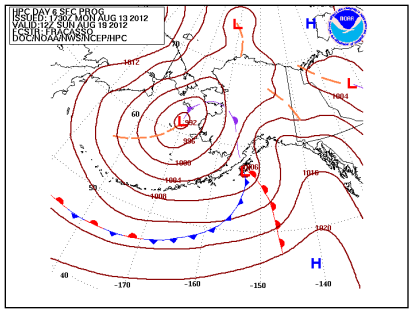
QPF



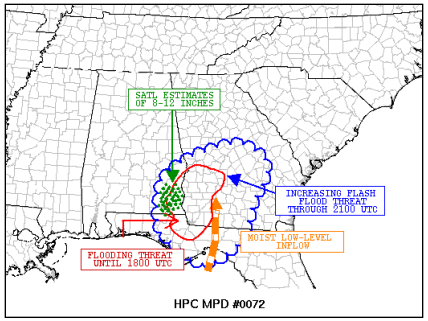
Winter Weather



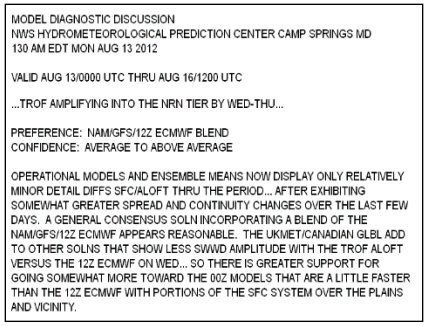
Medium Range



Alaska Med. Range



Met Watch



MODEL DIAGNOSTIC DISCUSSION
NWS HYDROMETEOROLOGICAL PREDICTION CENTER CAMP SPRINGS MD
130 AM EDT MON AUG 13 2012

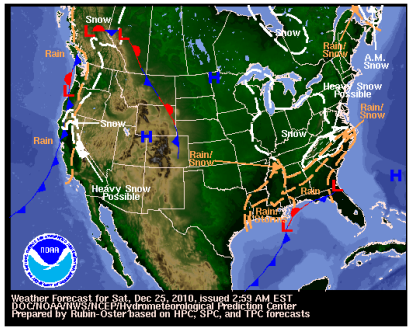
VALID AUG 13/0000 UTC THRU AUG 16/1200 UTC

...TROF AMPLIFYING INTO THE NRN TIER BY WED-THU...

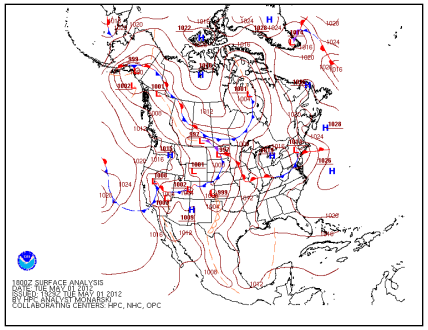
PREFERENCE: NAM/GFS/12Z ECMWF BLEND
CONFIDENCE: AVERAGE TO ABOVE AVERAGE

OPERATIONAL MODELS AND ENSEMBLE MEANS NOW DISPLAY ONLY RELATIVELY MINOR DETAIL DIFFS SFC/ALOFT THRU THE PERIOD... AFTER EXHIBITING SOMEWHAT GREATER SPREAD AND CONTINUITY CHANGES OVER THE LAST FEW DAYS. A GENERAL CONSENSUS SOLN INCORPORATING A BLEND OF THE NAM/GFS/12Z ECMWF APPEARS REASONABLE. THE UKMET/CANADIAN GLBL ADD TO OTHER SOLNS THAT SHOW LESS SWWD AMPLITUDE WITH THE TROF ALOFT VERSUS THE 12Z ECMWF ON WED... SO THERE IS GREATER SUPPORT FOR GOING SOMEWHAT MORE TOWARD THE 00Z MODELS THAT ARE A LITTLE FASTER THAN THE 12Z ECMWF WITH PORTIONS OF THE SFC SYSTEM OVER THE PLAINS AND VICINITY.

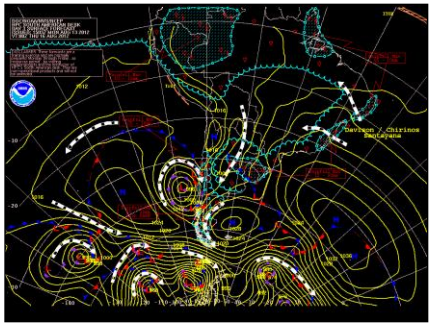
Model Diagnostics



Short Range



Surface Analysis

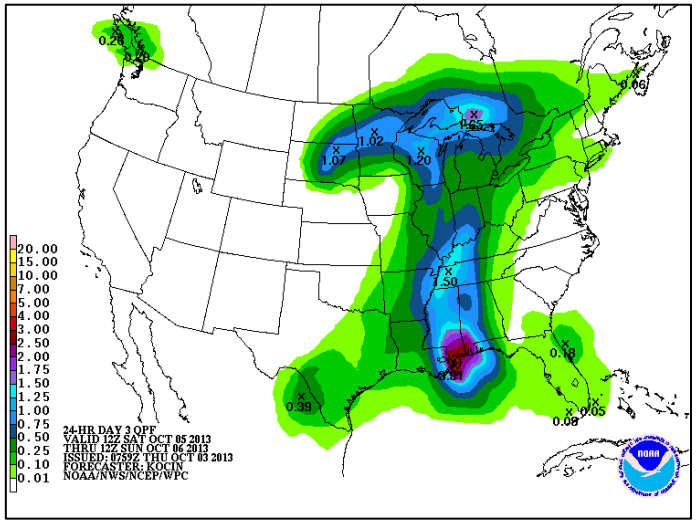


International

Tropical

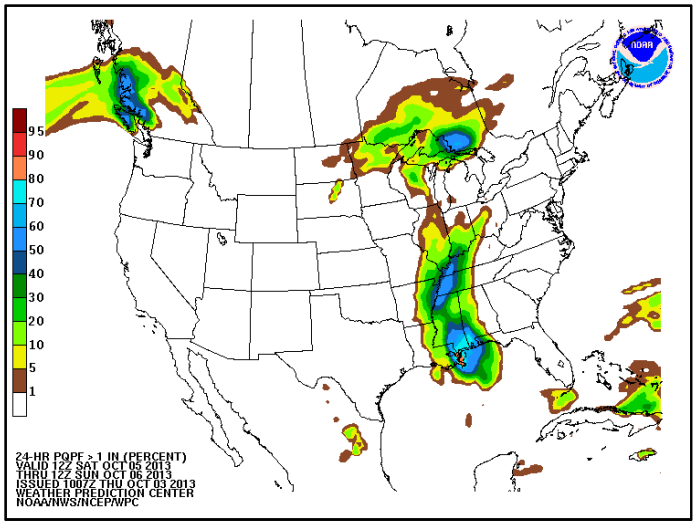
Quantitative Precipitation Forecast (QPF)

Deterministic QPF



Forecaster assimilates all available guidance to determine the most likely deterministic solution

Probabilistic QPF (PQPF)

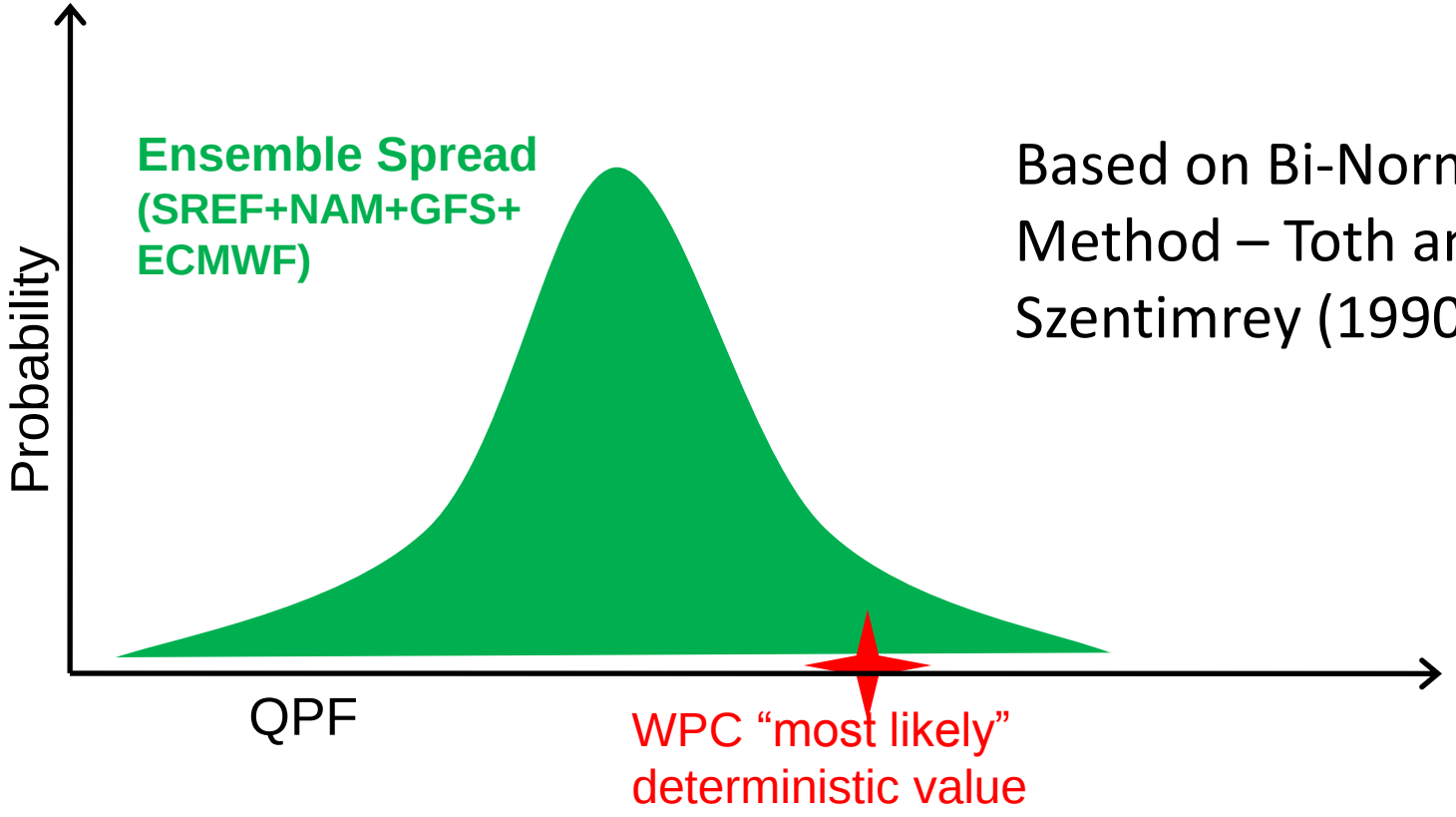


Automated process creates a PDF from a multi-model ensemble. WPC forecast is the mode.

http://www.wpc.ncep.noaa.gov/pqpf/conus_hpc_pqpf.php

WPC PQPF Method

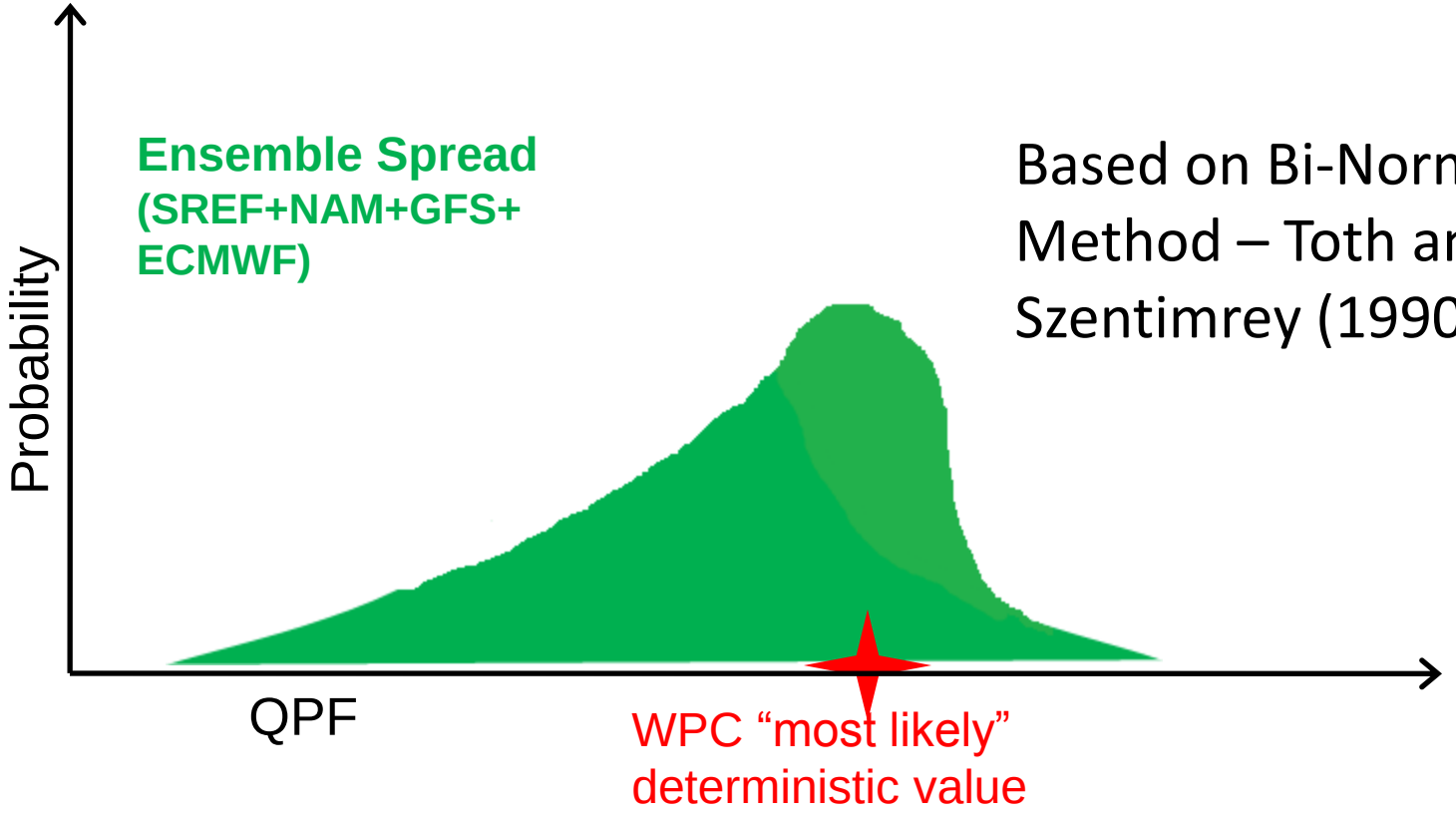
Modifies ensemble distribution such that WPC deterministic QPF is the mode, while allowing skew



Based on Bi-Normal Method – Toth and Szentimrey (1990)

WPC PQPF Method

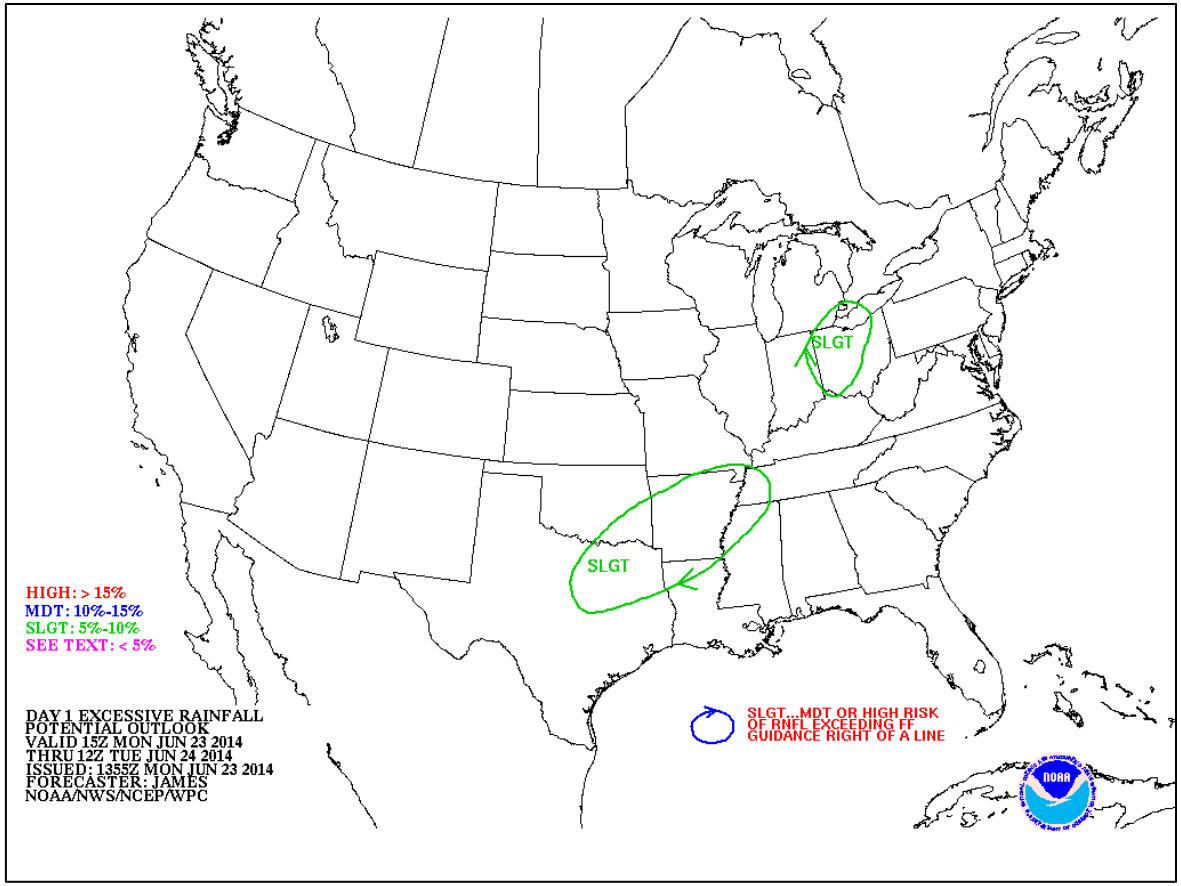
Modifies ensemble distribution such that WPC deterministic QPF is the mode, while allowing skew



WPC Flash Flood Outlooks

http://www.wpc.ncep.noaa.gov/qpf/excess_rain.shtml

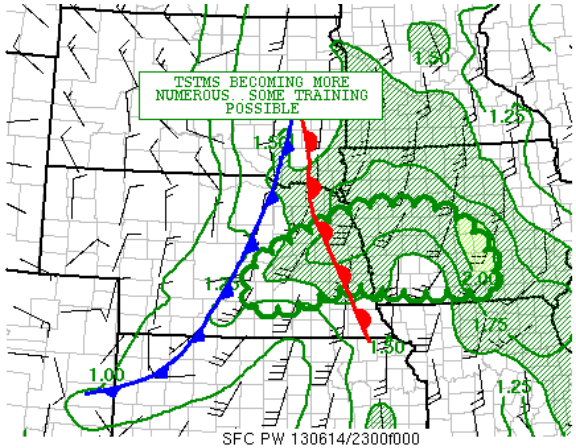
- Categorical outlooks
  - forecast days 1-3
  - slight/moderate/high
- Outlines areas where risk for rainfall in excess of flash flood guidance, provided by the NWS River Forecast Centers (RFCs)



WPC Met Watch Desk

http://www.wpc.ncep.noaa.gov/metwatch/metwatch_mpd.php

- Mesoscale Precipitation Discussions
  - Event-driven
  - Highlight regions where heavy rainfall may lead to flash flooding in the next 1-6 hours
  - Consideration of atmospheric and hydrologic conditions



MESOSCALE PRECIPITATION DISCUSSION 0104
NWS WEATHER PREDICTION CENTER COLLEGE PARK MD
818 PM EDT FRI JUN 14 2013

AREAS AFFECTED...EASTERN NEB...WESTERN IA

CONCERNING...HEAVY RAINFALL...FLASH FLOODING POSSIBLE

VALID 150017Z - 150430Z

SUMMARY...THERE WILL BE AN INCREASING THREAT OF FLASH FLOODING OVER PARTS OF EASTERN NEB AND WESTERN IA.

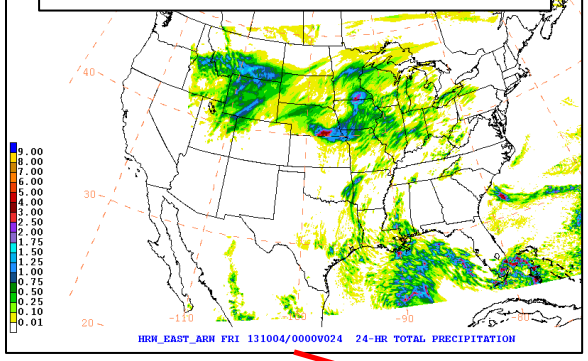
DISCUSSION...THE THREAT OF FLASH FLOODING WILL BE INCREASING THROUGH THE EVENING OVER PORTIONS OF NEB AS CELLS MOVE TO THE NORTHEAST ALONG A SOUTHWEST TO NORTHEAST LINE. THIS WAS ALONG AND AHEAD OF A COLD FRONT MAKING ITS WAY ACROSS THE AREA. THE STORMS WILL BE ENCOUNTERING **DEEPER MOISTURE** WHICH SHOULD INCREASE THE **RAINFALL EFFICENCY** AND THE RISK OF HEAVY RAIN OVER EXTREME EASTERN NEB AND WESTERN IA. THE APPROACH OF A LOW LEVEL JET WITH SPEEDS AROUND 35 KTS WILL ENHANCE THE LOW LEVEL LIFT NORTH OF THE WARM FRONT IN ADDITION TO DRAWING IN MORE MOISTURE. PARTS OF WESTERN IA **ALREADY RECEIVED MODERATE TO LOCALLY HEAVY RAINFALL** THIS AFTERNOON AND EVENING WHICH HAS RESULTED IN AREAS OF LOWERED FLASH FLOOD GUIDANCE.

RAINFALL RATES APPROACHING 2 INCHES PER HOUR ARE POSSIBLE. LOCALIZED STORM TOTAL AMOUNTS OF 3 INCHES ARE POSSIBLE.

BANN

Linking Atmospheric and Hydrologic Information: Flash Flood Forecasts

High-Res Ensemble QPF



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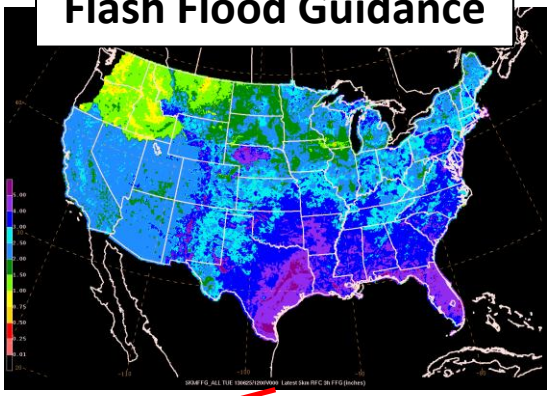
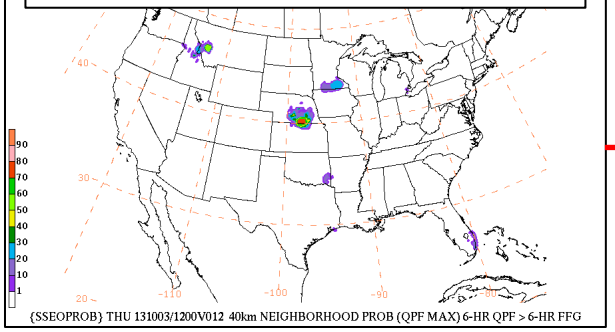
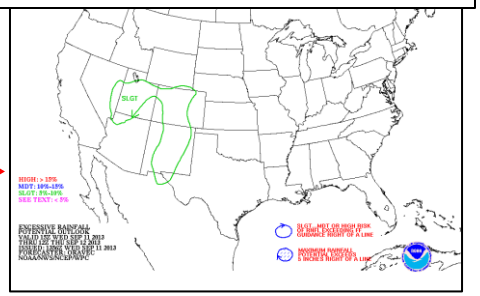
Flash Flood Guidance



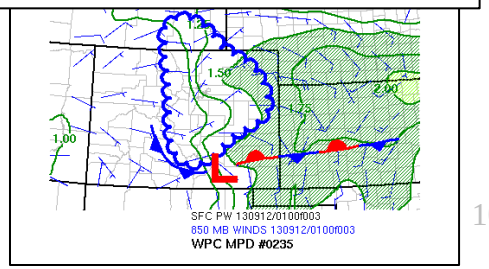
Probability of Flash Flood



Flash Flood Outlooks



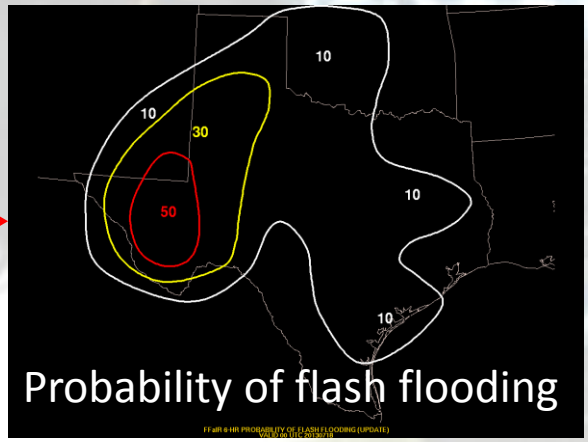
Mesoscale Discussions

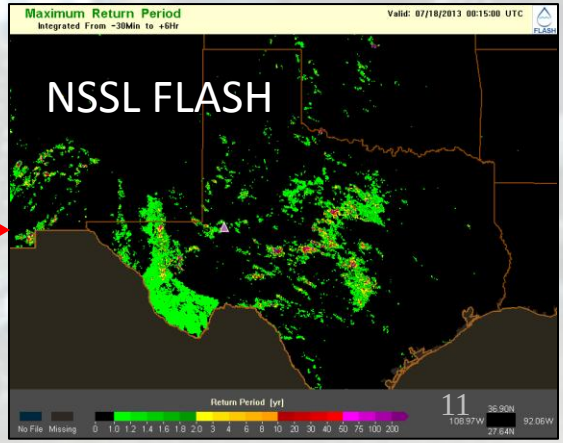


- Combine atmospheric and hydrologic information into higher-level tools

Flash Flood and Intense Rainfall (FFaIR) Experiment

- In 2013, WPC hosted a real-time forecasting experiment focusing on short-term flash flood forecasts
  - Produced probabilistic flash flood forecasts
  - Developed tools using operational and experimental ensemble QPF and hydrologic information
- Upcoming: July 2014 experiment



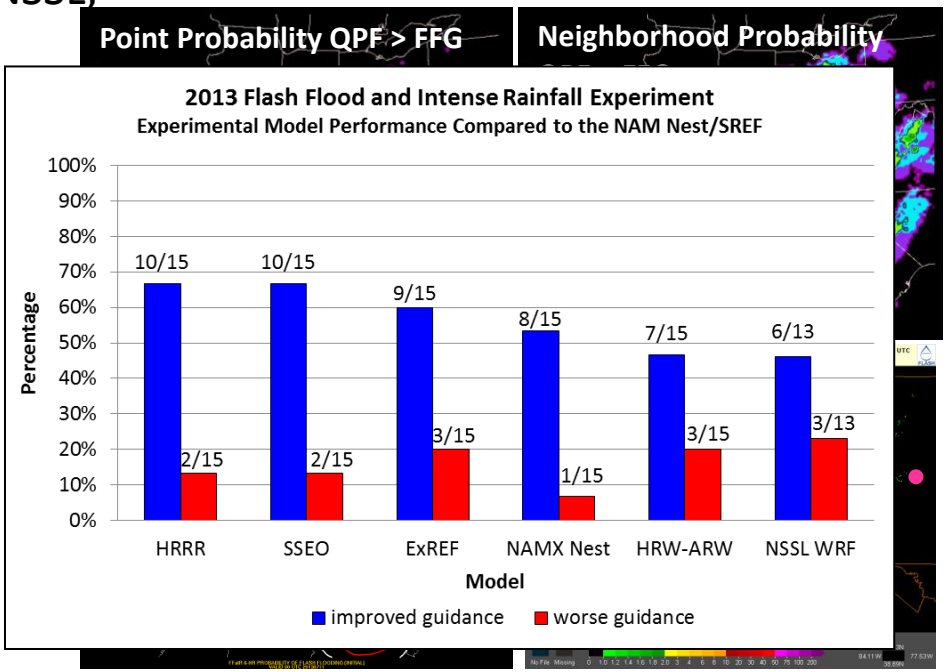


2013 Flash Flood and Intense Rainfall Experiment

July 8-26, 2013

Explore techniques to improve short-term QPF and flash flood forecasts in support of WPC's Met Watch Desk

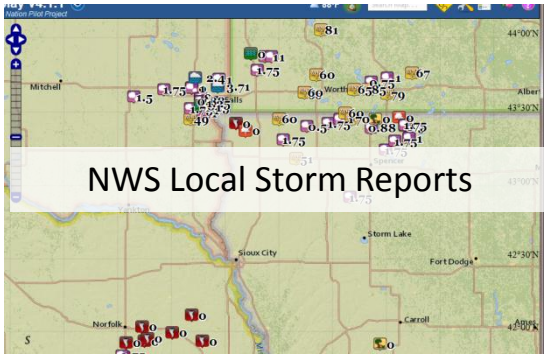
- Collaborative effort between HMT-WPC, NSSL, and ESRL
- 26 participants (8 remote) representing operations, research, and academia
- Experiment Activities
  - Probabilistic QPF and flash flood forecasts
  - Subjective evaluation
- Lessons Learned
  - High resolution convection-allowing guidance is a vital component to a full evaluation of the flash flood threat
  - Gap in understanding exists between the meteorological and hydrologic aspects of flash flood forecasting
  - Neighborhood probabilities of QPF > FFG provide valuable forecast guidance
    - Account for spatial uncertainty in both QPF and hydrologic response

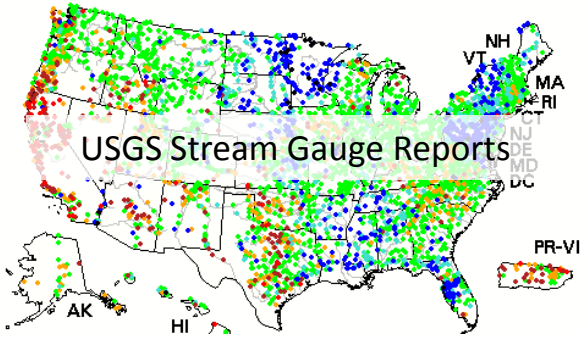


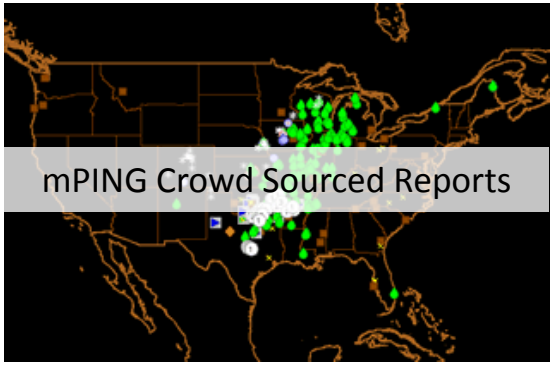
Courtesy Faye Barthold

New for 2014 FFaIR Experiment: Flash Flood Verification Database

Postgres Component Database	Strengths	Weaknesses
NWS Local Storm Reports	-Official, accepted NWS product -Relatively dense coverage -Descriptive language	-Subjective description -Coverage depends on population density and time of day -Location, time, categorization errors
USGS Stream Gauge Observations	-Objective measure of stream condition (flow) -Official, accepted USGS stream flow data -Large number of gauges	-Subset of gauges with actual flood stage limited -Differentiating flood/flash flood is subjective -Regulation complications -Coverage can be sparse, limited to rivers
mPING Crowd-Sourced Reports	-Potential for dense reports	-Subjective -Dependent on participation -Quality control issues given non-professional source -Differentiating flood/flash flood is not possible -Currently sparse coverage



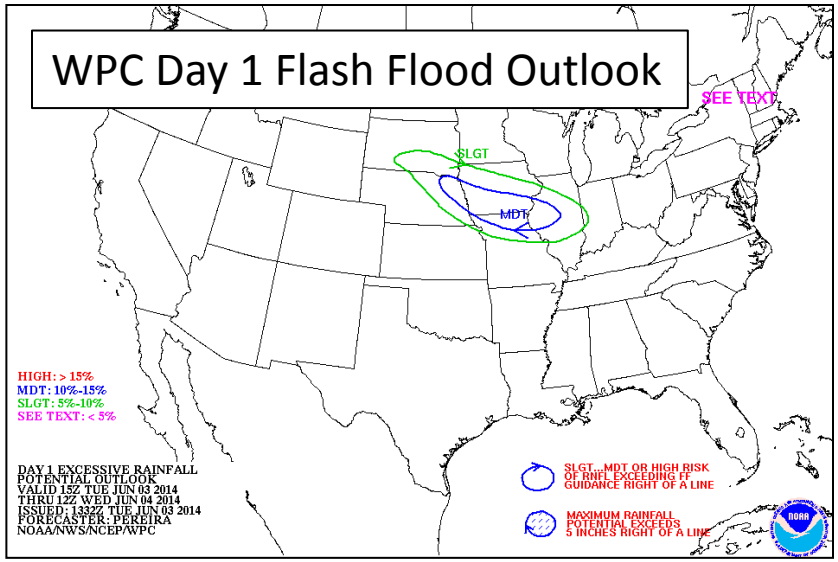


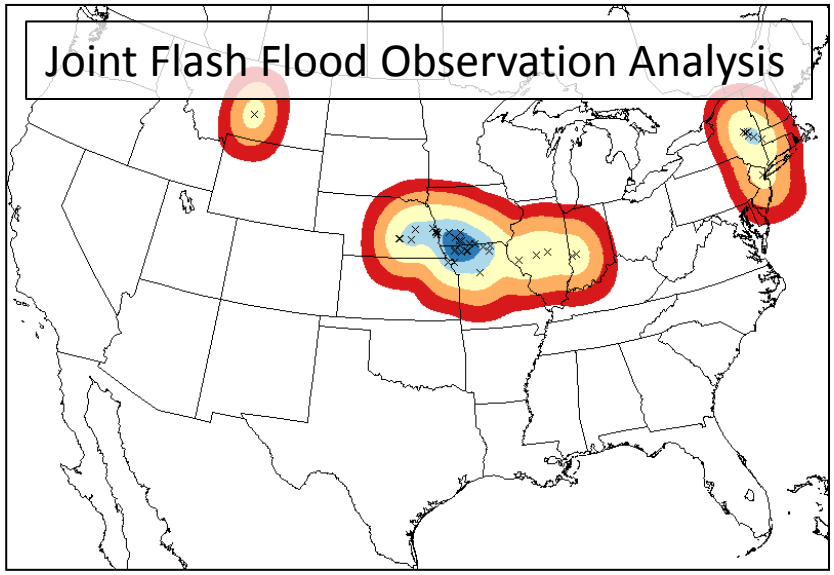


Courtesy Brian Cosgrove

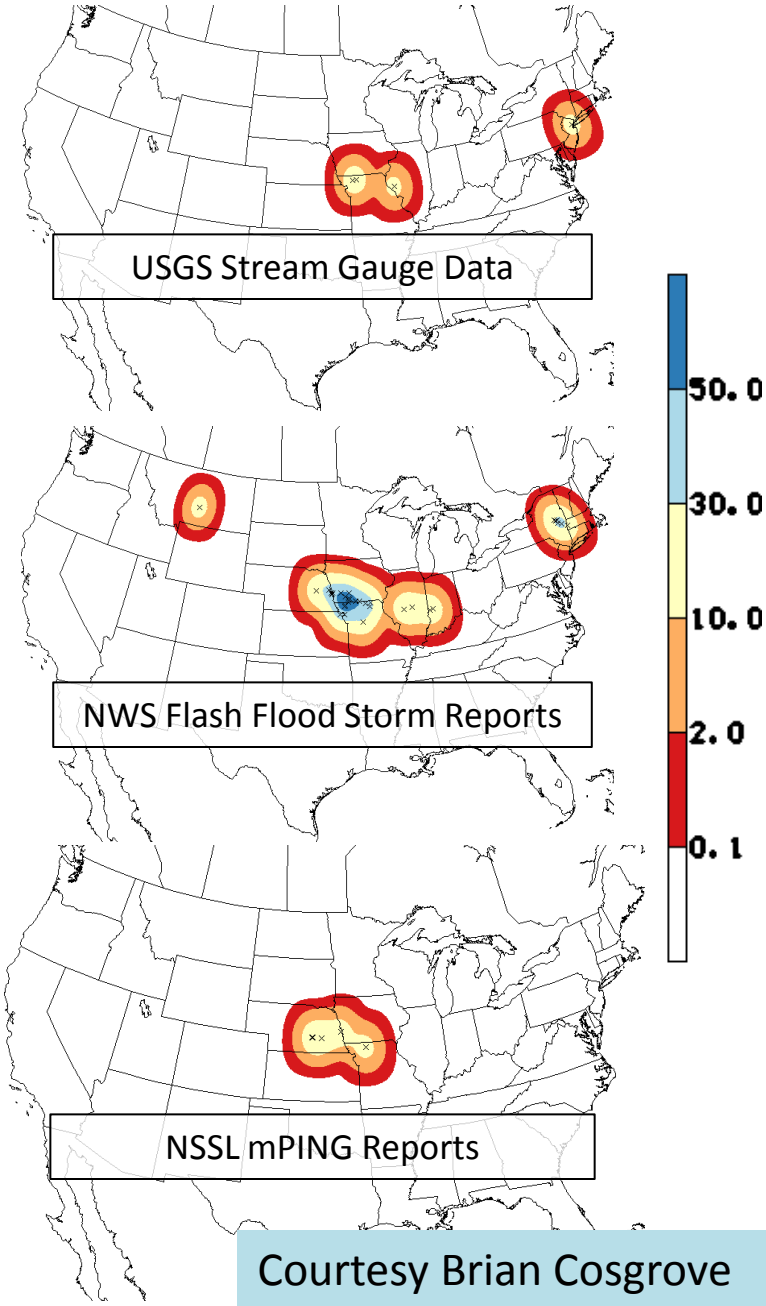
Using the database to verify WPC flash flood outlooks

June 3rd-4th 2014 Case Study





Prob. of Occurrence (%) w/in a 40km Radius Using the "Practically Perfect" Technique



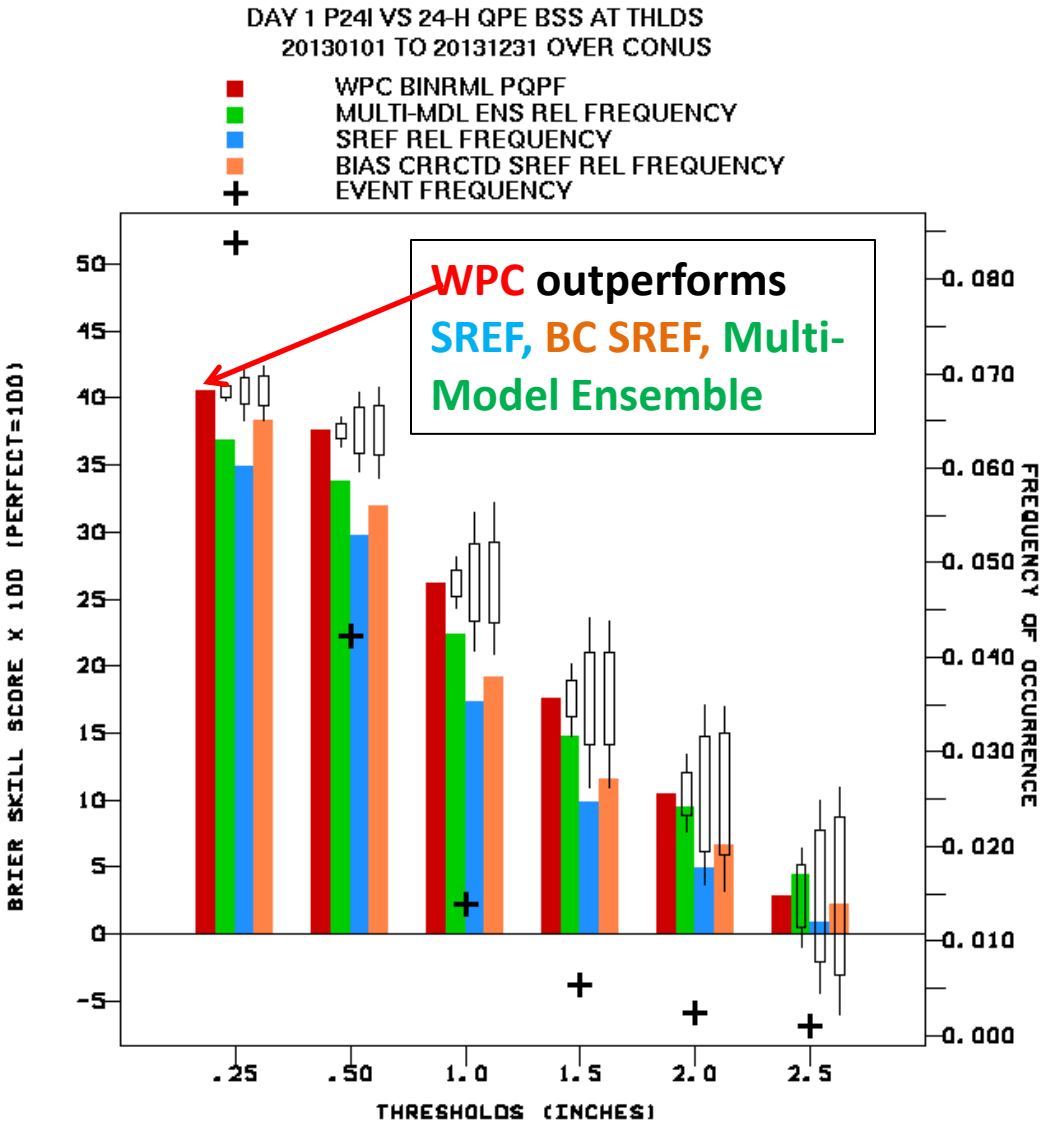
Courtesy Brian Cosgrove

Linking Hydrologic and Atmospheric Forecasts: Summary

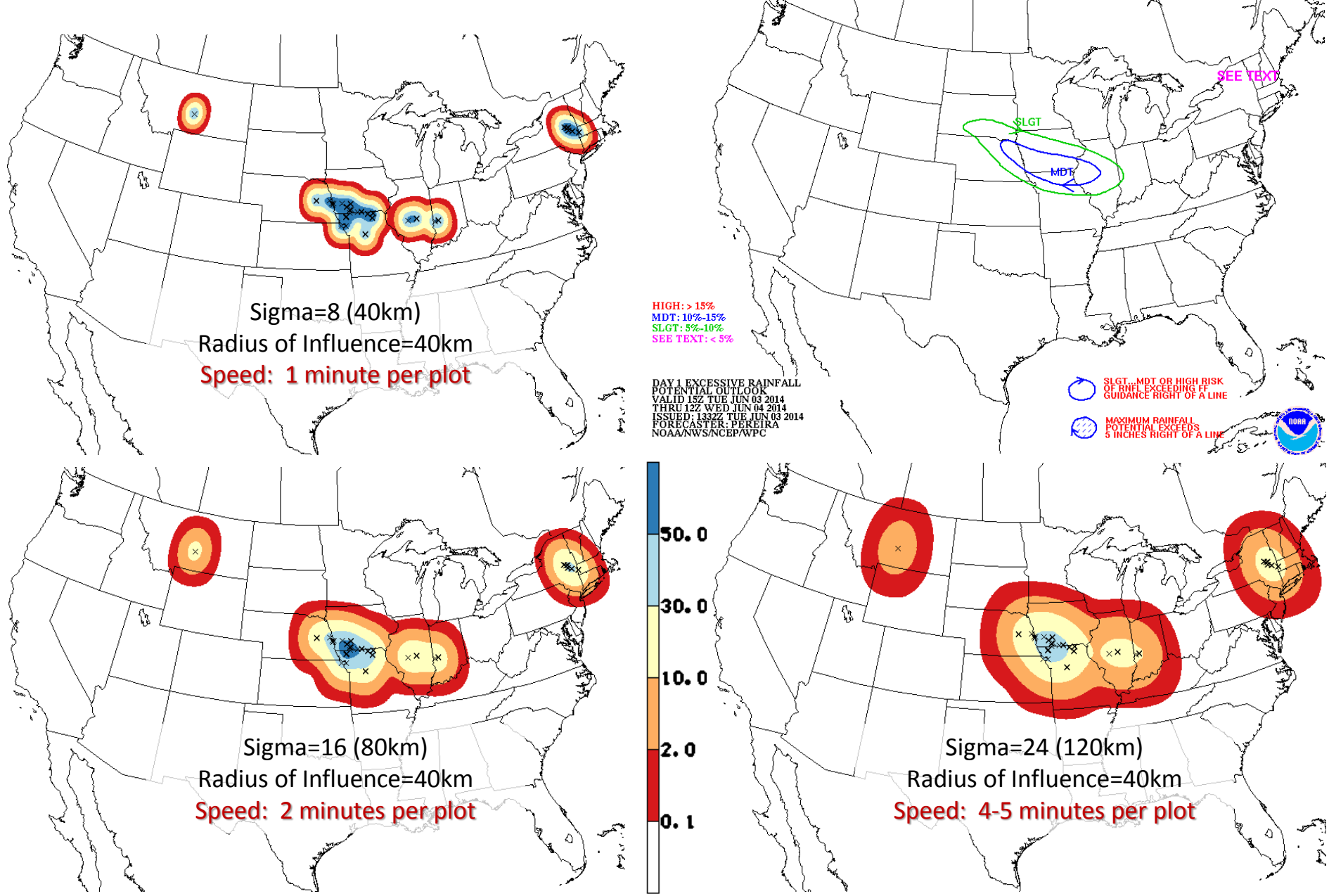
- WPC is developing tools to combine precipitation forecasts and hydrologic response
  - However, we have more ensemble precipitation information than hydrologic information
  - Ongoing work to couple high-res atmospheric and hydrologic models may help to bridge the gap
- Flash Flood and Intense Rainfall (FFaIR) Expt
  - 2013 FFaIR solidified the utility of high-res atmospheric ensembles
  - 2014 FFaIR will continue to test forecast tools and new verification techniques

Extras

WPC PQPF – 2013 Verification



- WPC technique outperformed both SREF and multi-model ensemble in 2013
- Statistically significant improvement up to 2” threshold
- **Verification supports involvement of the forecaster**

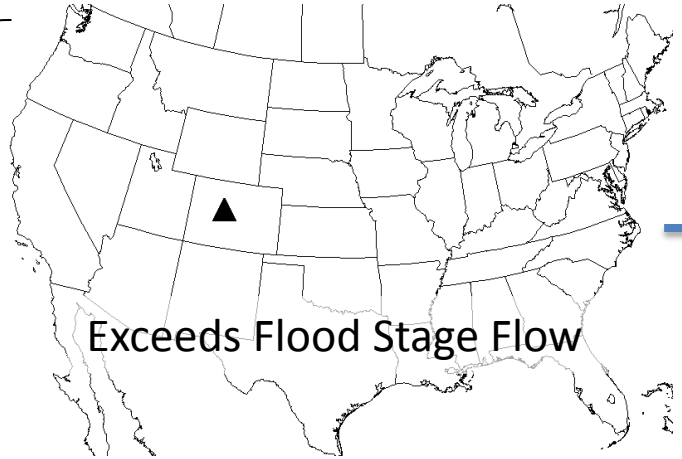


Impact of Altering Sigma Smoothing Parameter

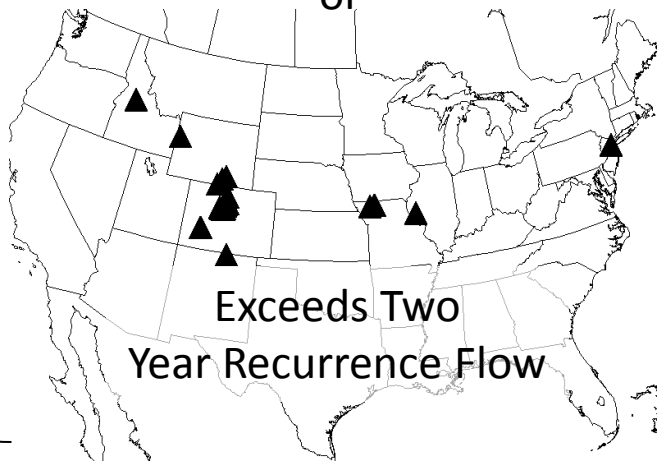
(Goal: match look of forecaster-produced map. Observations are flash flood LSRs)

Challenge: Use USGS stream gauge measurements of stage and discharge to isolate flash flood signatures

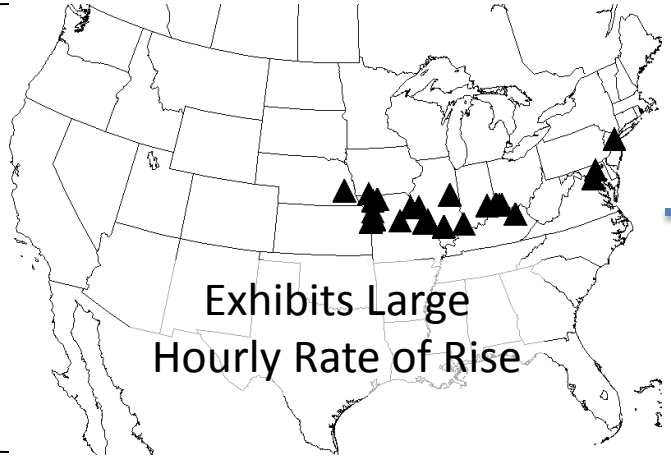
Out of Bank Tests



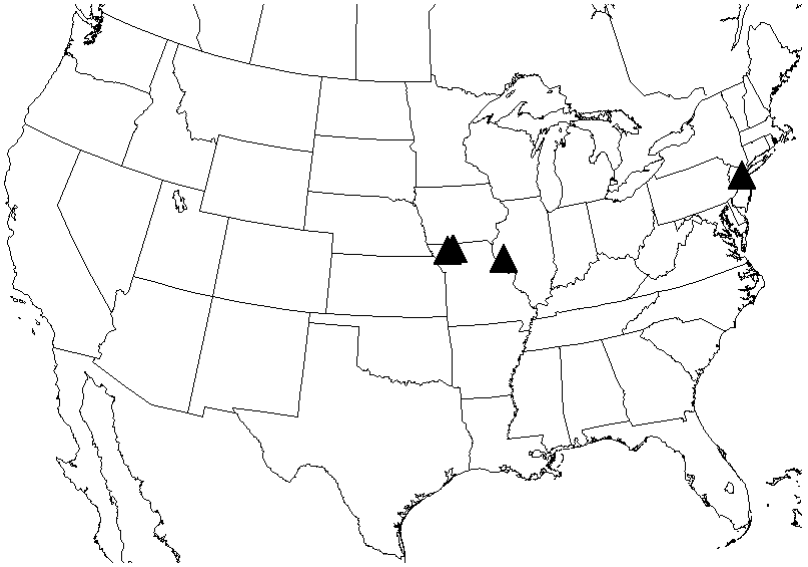
-or-



Rate of Rise Test



Combined Product
USGS Gauge-Based Flash Floods



Solution: Apply set of filters to observations

1) Establish that stream is out of bank…Does flow exceed value associated with flood stage or 2 year recurrence?
2) Establish that flood is "flashy"…Does stage exhibit sharp rate of rise (≥ 1 ft/hr and ≥ 3 ft/hr at two consecutive obs)
3) Establish that flood is likely not from regulation and is small enough to flash flood…Is basin smaller than 260 km^2 ?