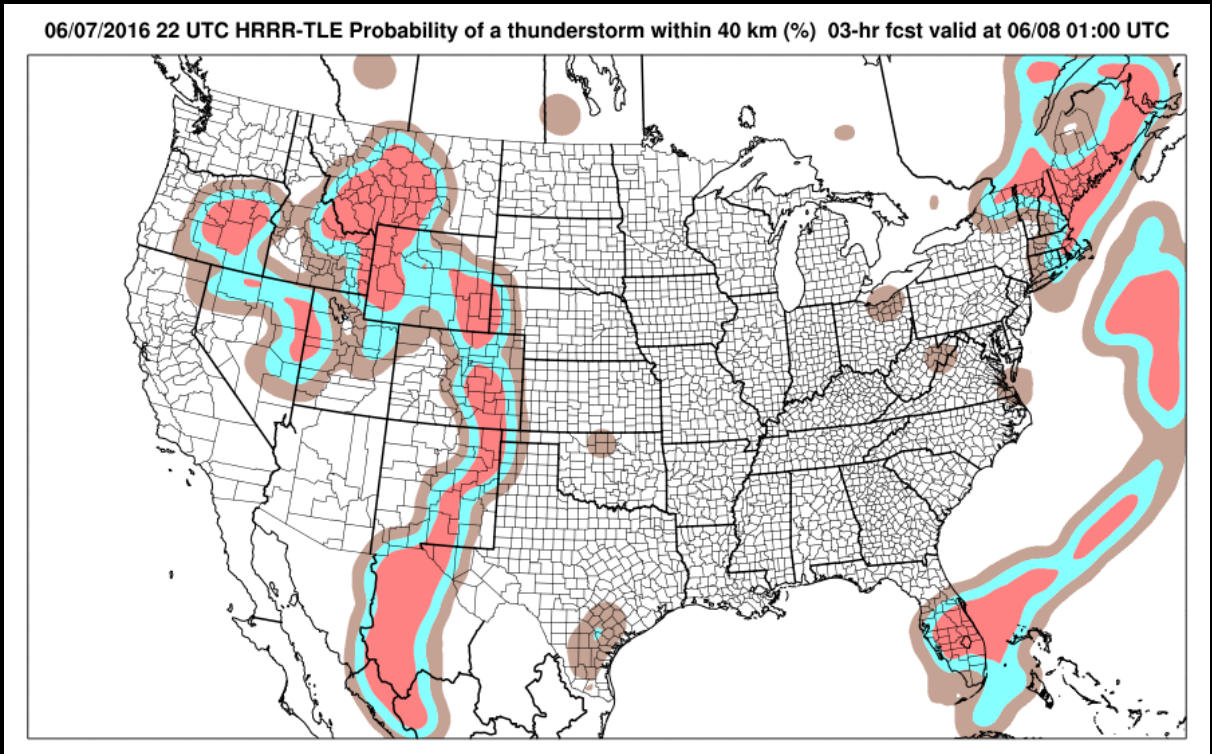
http://rapidrefresh.noaa.gov/hrrrtle/

HRRR Time-Lagged Ensemble (HRRR-TLE) Update



Trevor Alcott, Isidora Jankov, Curtis Alexander
Steve Weygandt, Stan Benjamin
ESRL Global Systems Division, Boulder, CO

RAP/HRRR Suite: Hourly-Updating Forecast Models

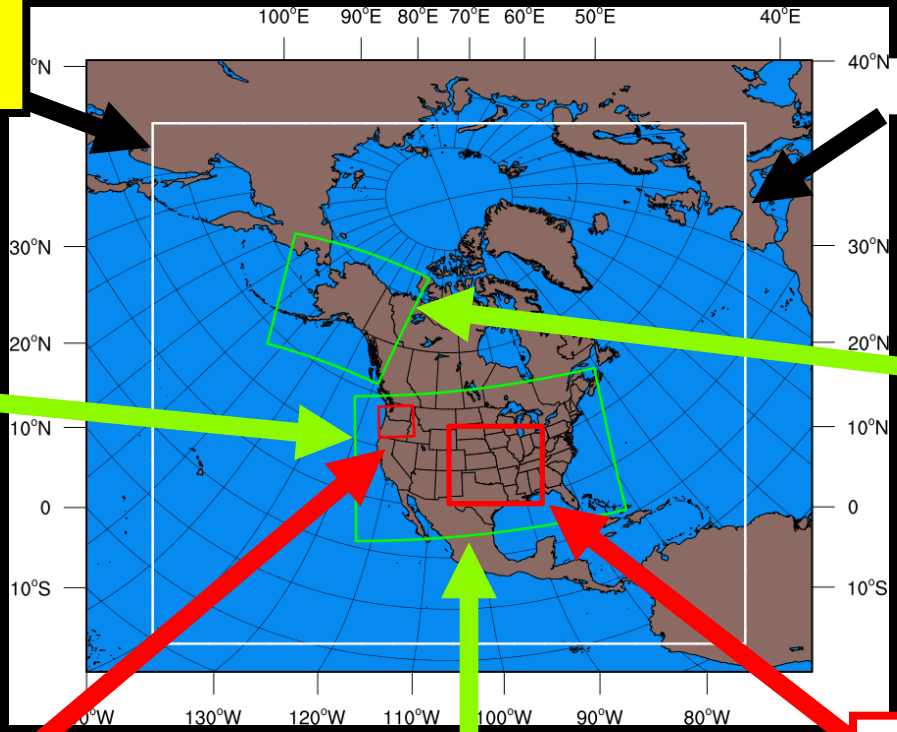
13-km Rapid Refresh (RAP) –
21h (NCEP in July 2016)
39h (testing now at ESRL)

Initial & Lateral Boundary Conditions

3-km High-Resolution Rapid Refresh (HRRR) –
18h (NCEP in July 2016)
36h (testing now at ESRL)

Initial & Lateral Boundary Conditions

750-m HRRR nest Wind Forecast Improvement Project Experiment (ongoing)



Expanded RAP

3-km HRRR-Alaska

Testing now at ESRL

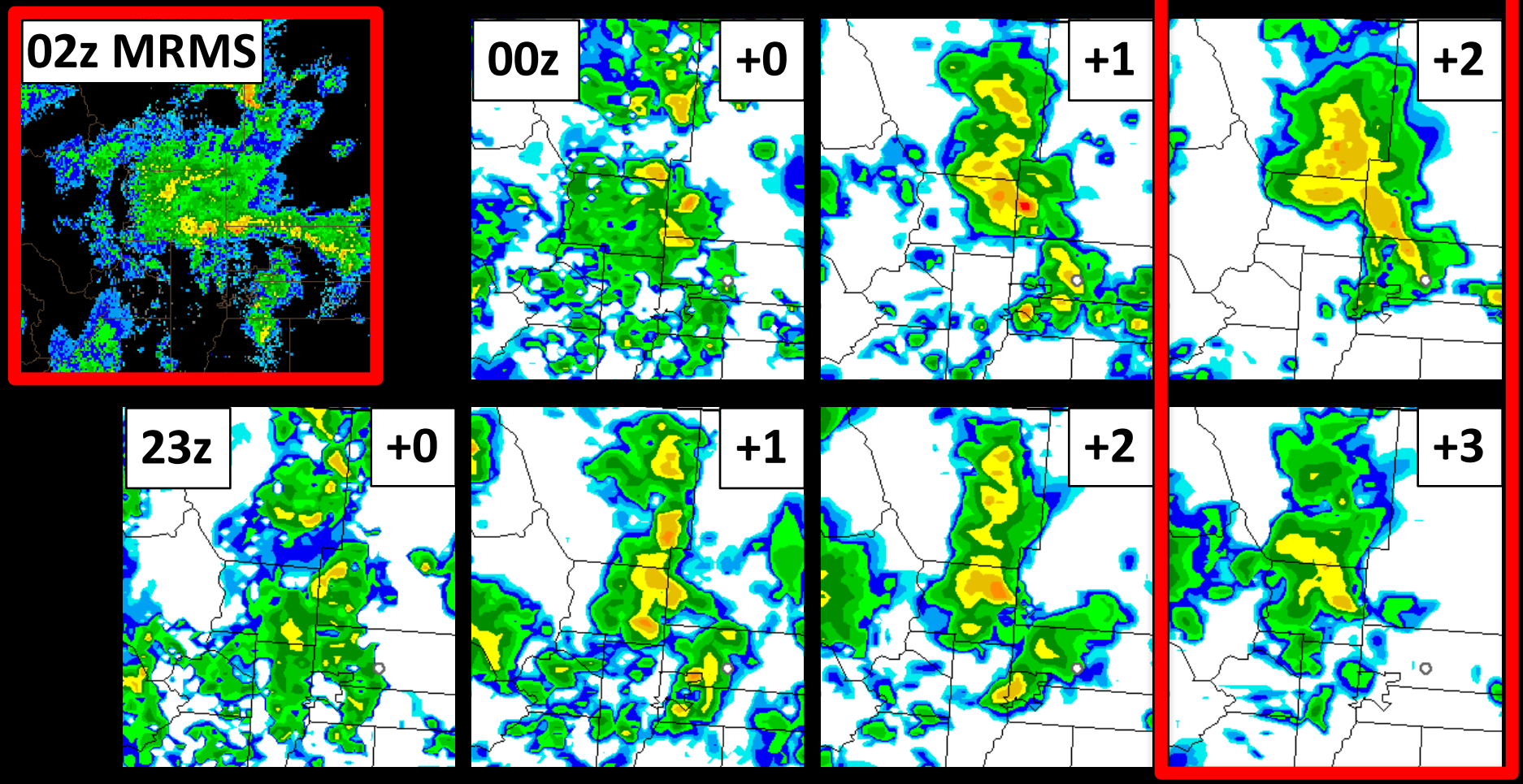
3-km HRRR Time-Lagged Ensemble (HRRR-TLE)

Prototype 3-km storm-scale HRRR ensemble (HRRRE)

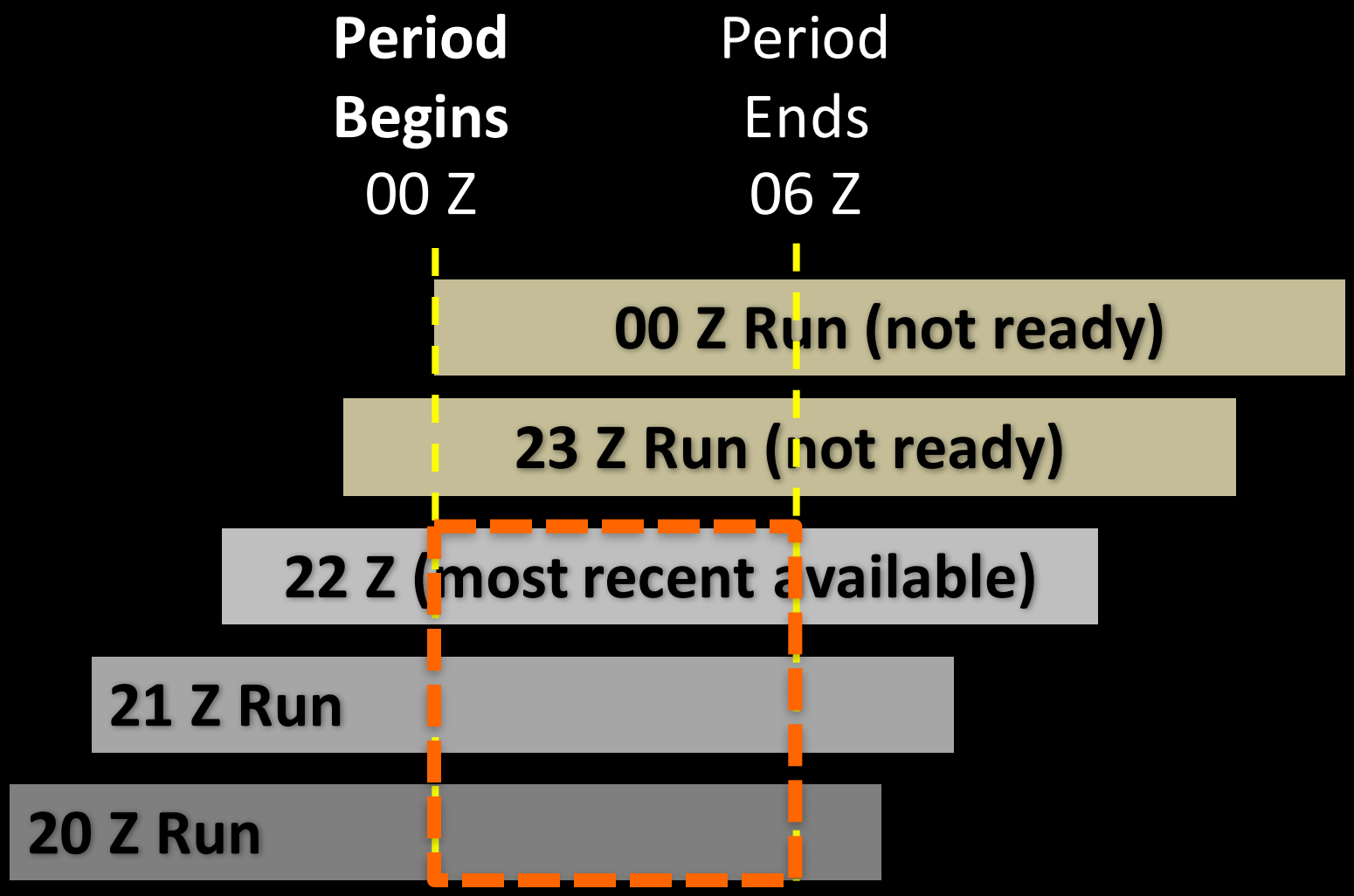
Testing Spring 2016

Time-Lagged HRRRx
2013 Colorado Flood

Composite Reflectivity (dBZ)
valid 02 UTC 12 Sep



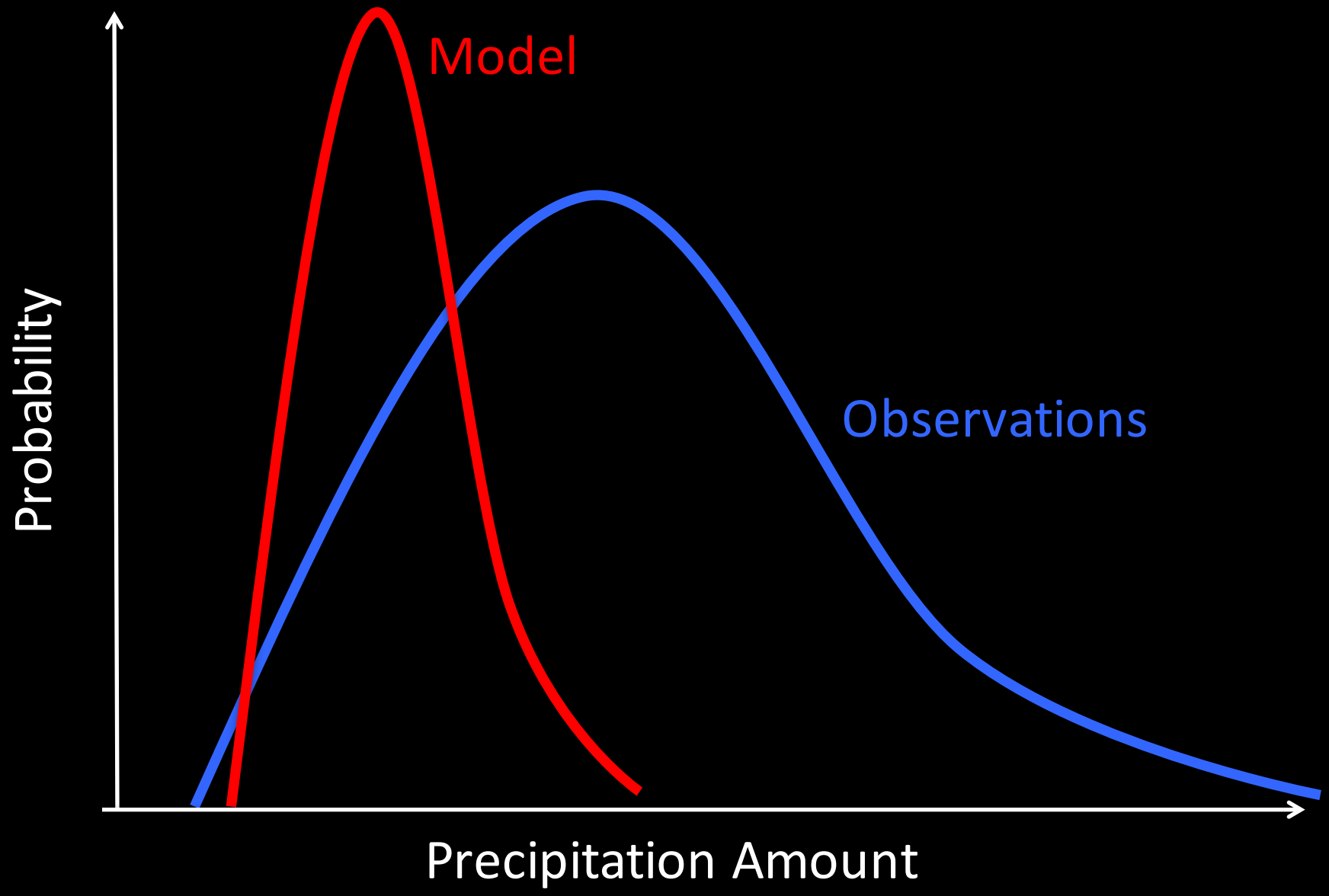
Exp 3-Member Time-Lagged Ensemble
with 2-hour Latency



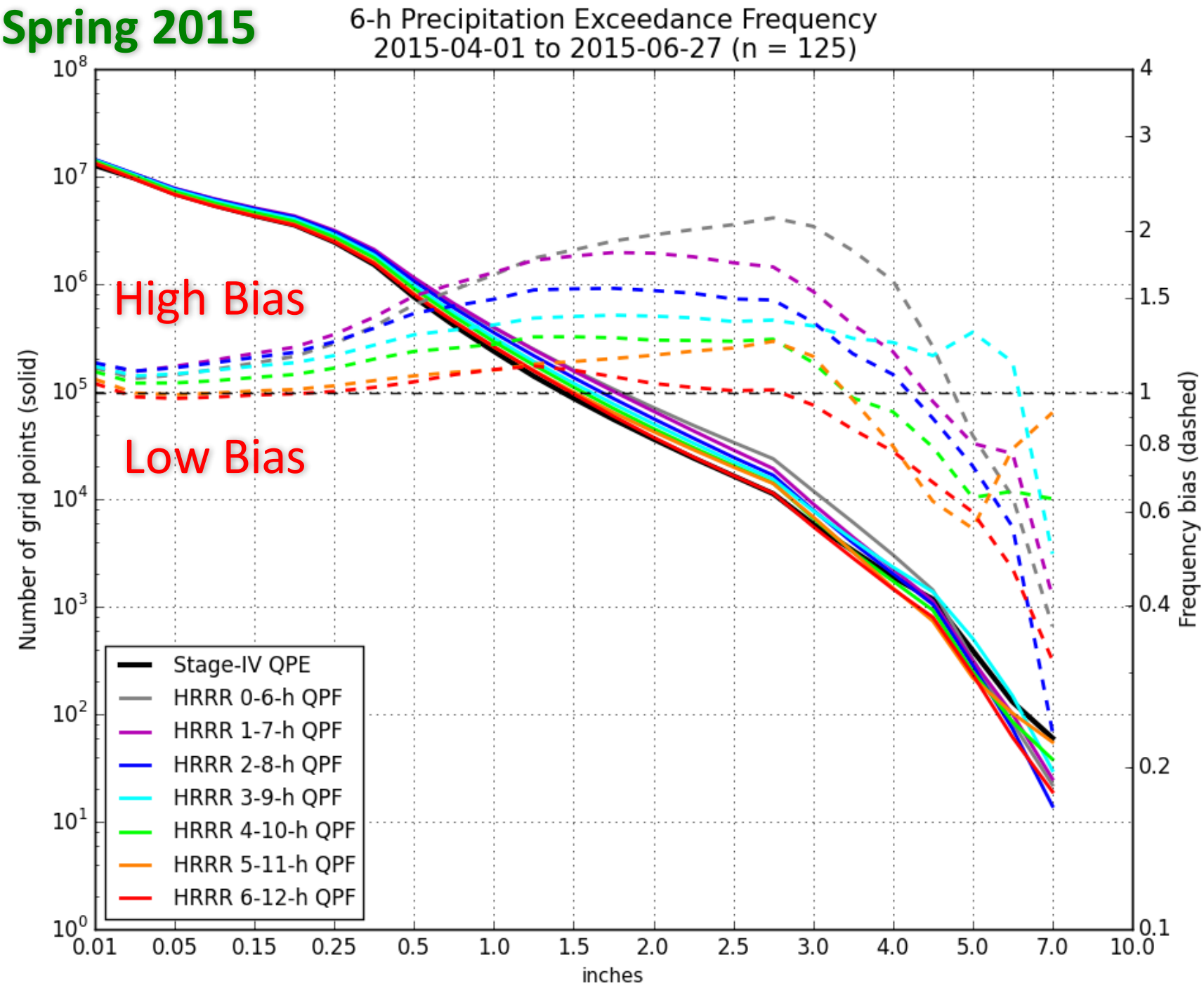
Time-Lagged Ensemble trade-offs

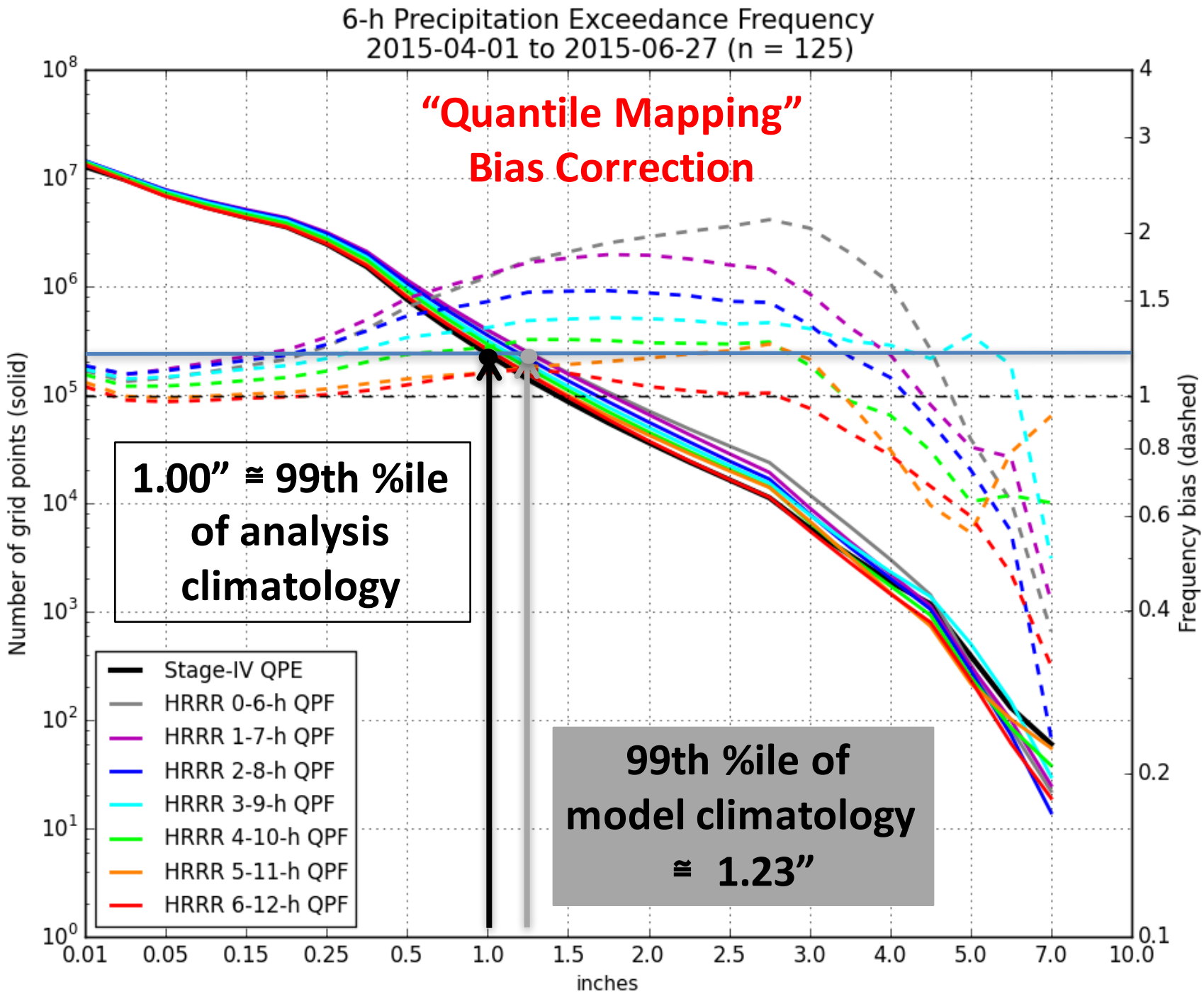
More members	→	More spread Lower skill Shorter lead time
More models	→	More spread *Useful spread?*
Member weighting	→	Gives newest data the highest impact >3 runs has little additional impact even at 100% weight

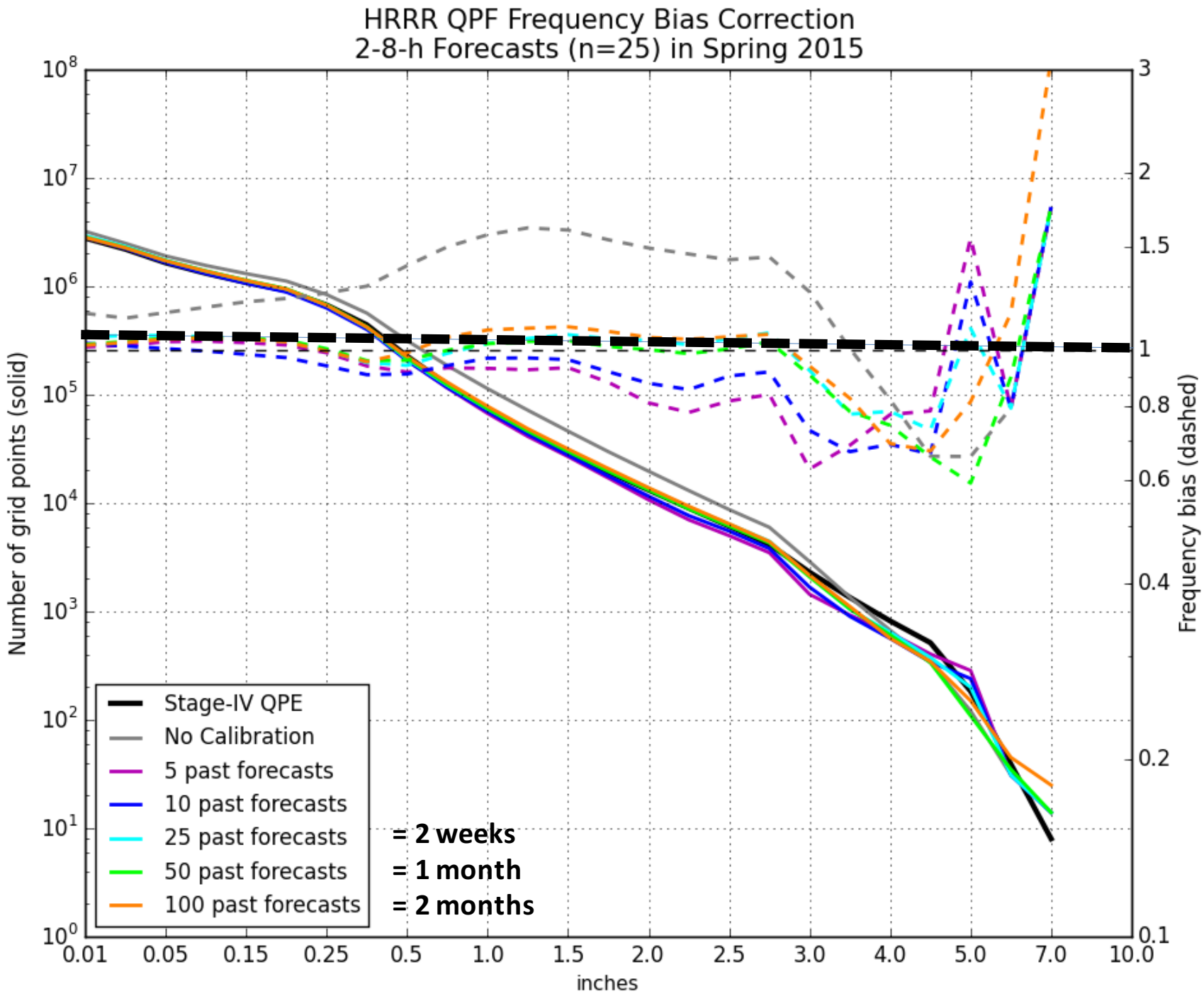
Addressing Bias and Underdispersion



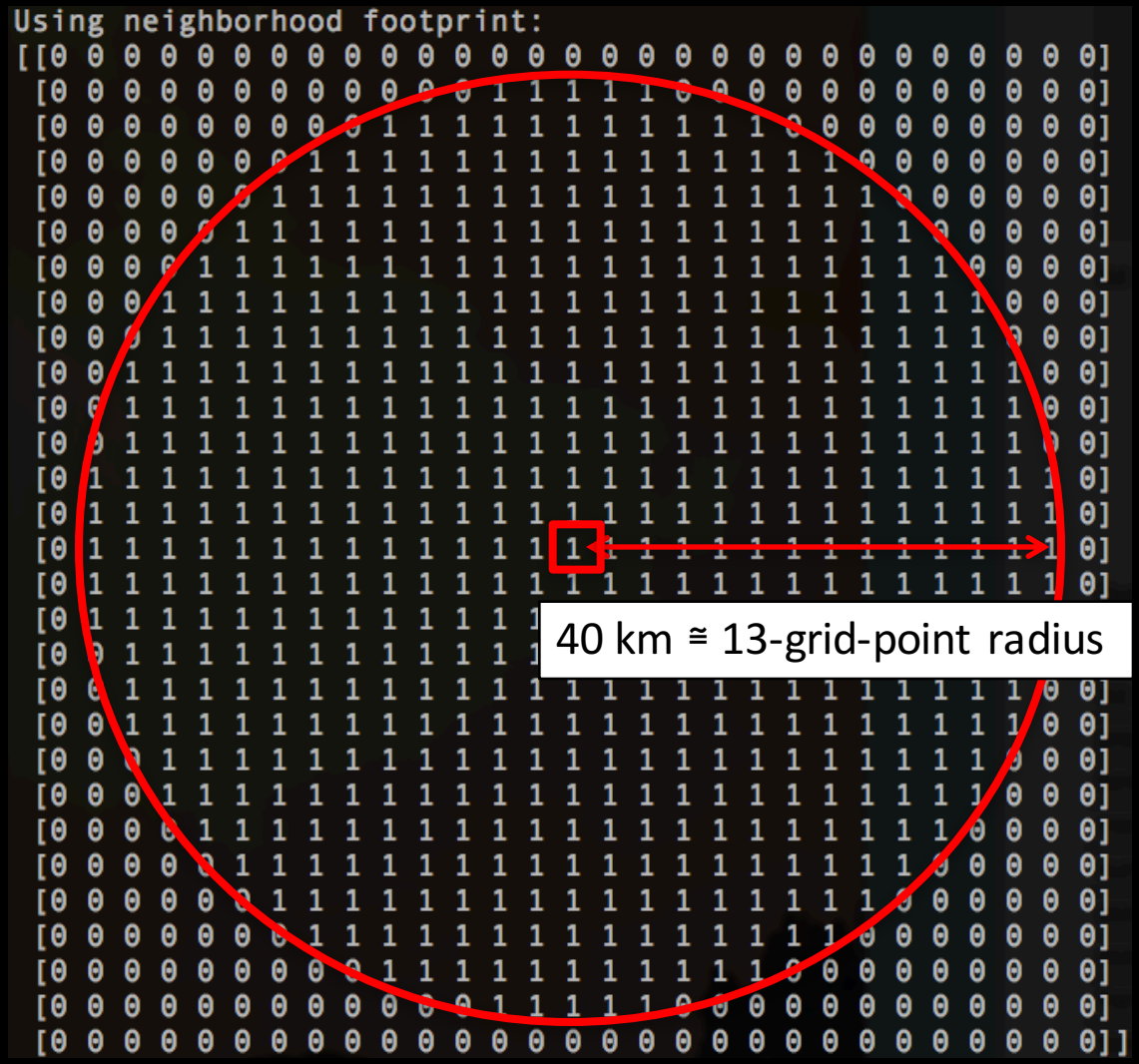
Spring 2015


6-h Precipitation Exceedance Frequency
2015-04-01 to 2015-06-27 (n = 125)
High Bias
Low Bias
Number of grid points (solid)
Frequency bias (dashed)
inches
Stage-IV QPE
HRRR 0-6-h QPF
HRRR 1-7-h QPF
HRRR 2-8-h QPF
HRRR 3-9-h QPF
HRRR 4-10-h QPF
HRRR 5-11-h QPF
HRRR 6-12-h QPF


6-h Precipitation Exceedance Frequency
2015-04-01 to 2015-06-27 (n = 125)
"Quantile Mapping"
Bias Correction
1.00" ≅ 99th %ile of analysis climatology
99th %ile of model climatology ≅ 1.23"
Stage-IV QPE
HRRR 0-6-h QPF
HRRR 1-7-h QPF
HRRR 2-8-h QPF
HRRR 3-9-h QPF
HRRR 4-10-h QPF
HRRR 5-11-h QPF
HRRR 6-12-h QPF
Number of grid points (solid)
Frequency bias (dashed)
inches
0.01
0.05
0.15
0.25
0.5
1.0
1.5
2.0
2.5
3.0
4.0
5.0
7.0
10.0

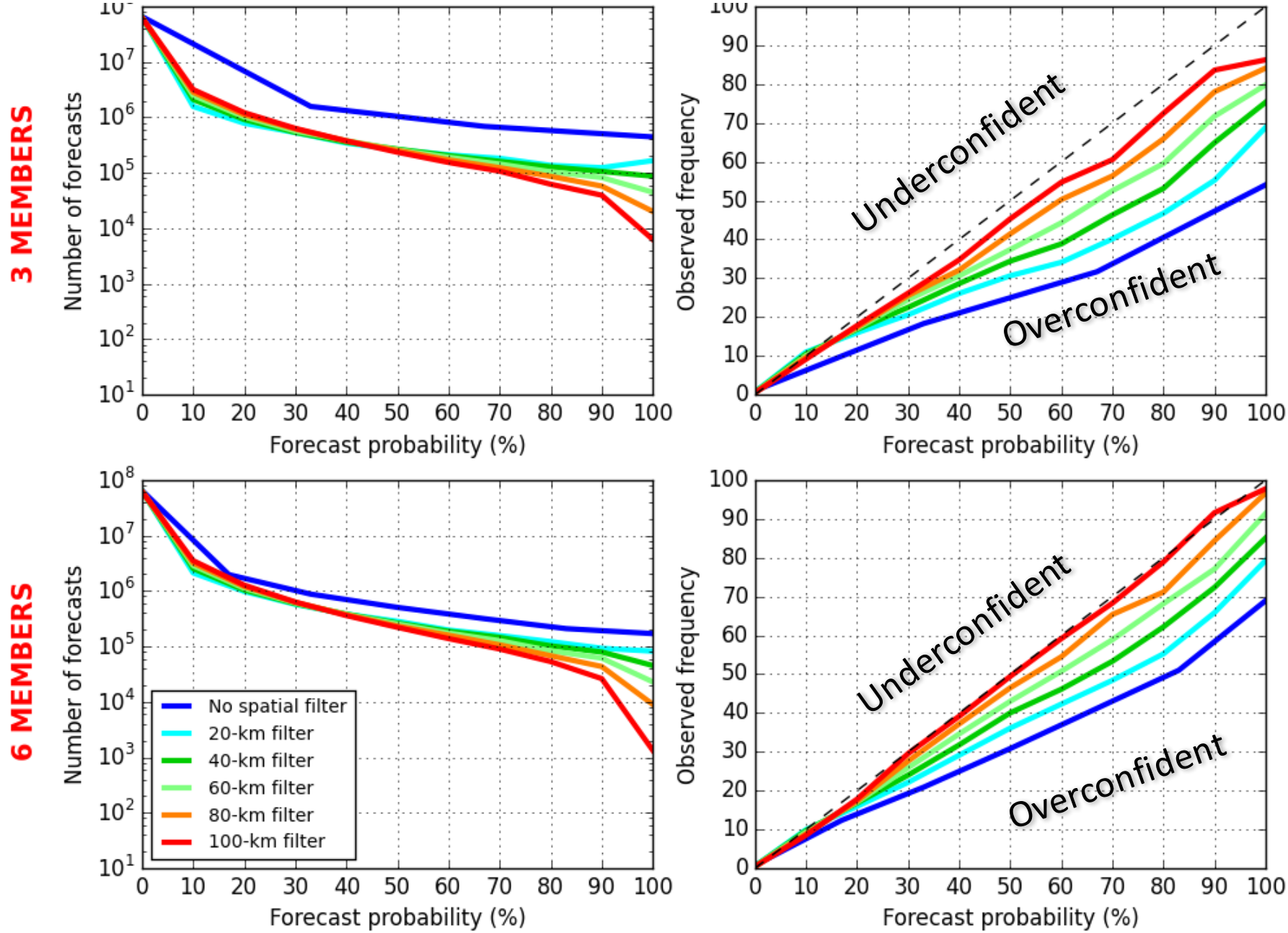

HRRR QPF Frequency Bias Correction
2-8-h Forecasts (n=25) in Spring 2015
Number of grid points (solid)
Frequency bias (dashed)
inches
Stage-IV QPE
No Calibration
5 past forecasts
10 past forecasts
25 past forecasts
50 past forecasts
100 past forecasts
= 2 weeks
= 1 month
= 2 months

Increasing spread with a spatial filter

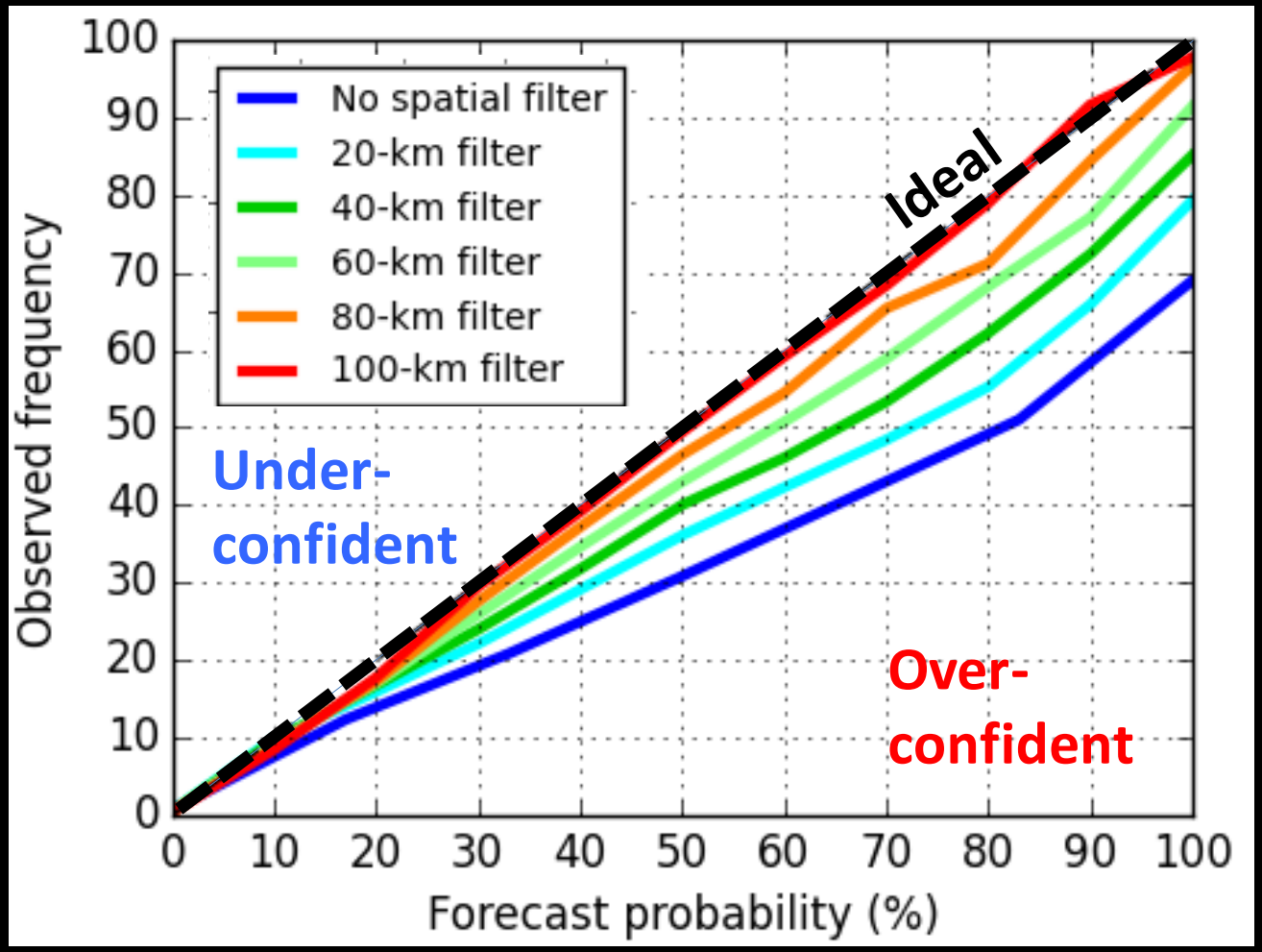


553 points **X** 3 runs = **1659** ensemble “members”

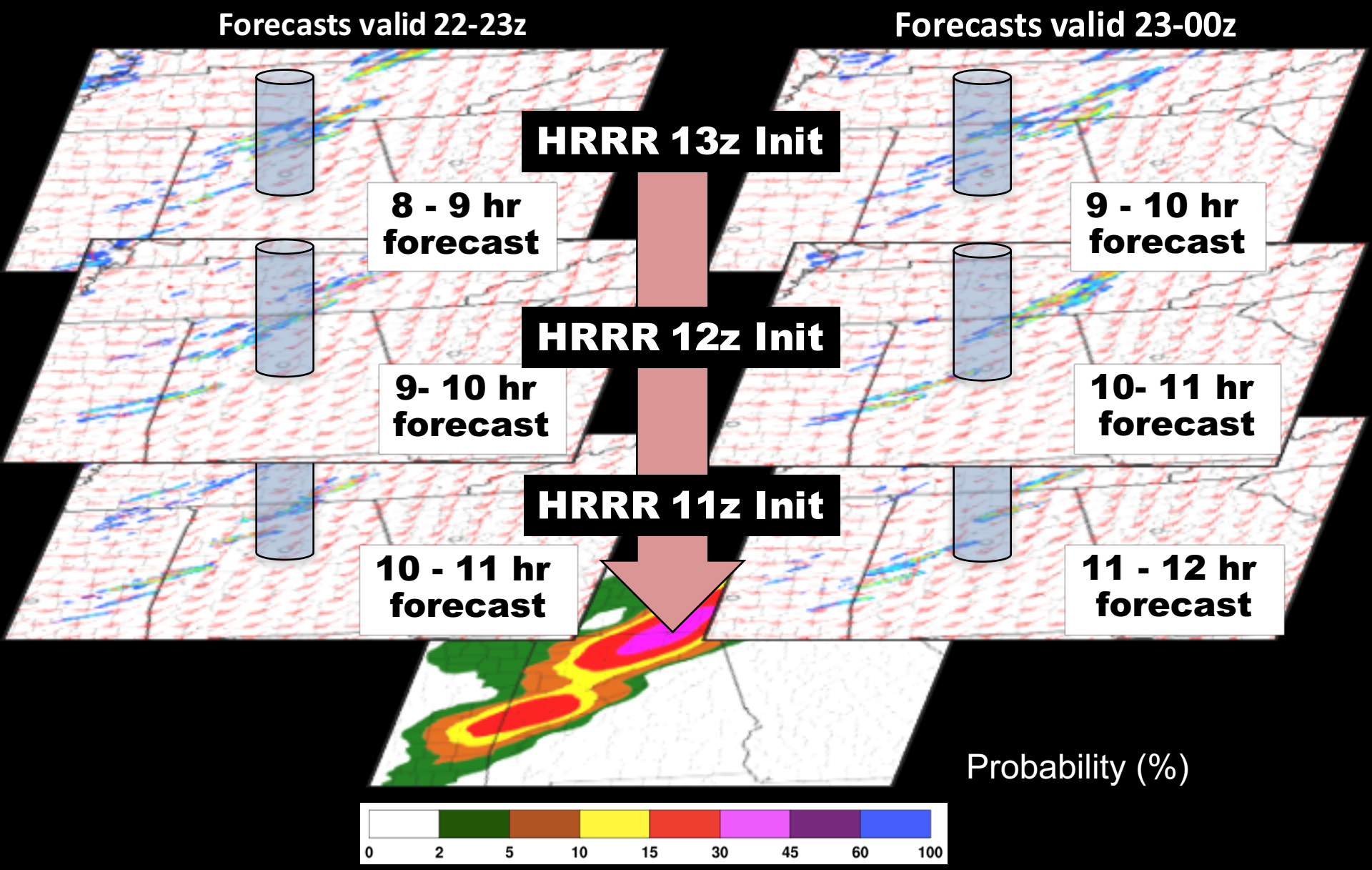
3 vs. 6 Time-Lagged Members



Results: Probability of 0.5” Precipitation in 6 hours May-Aug 2015



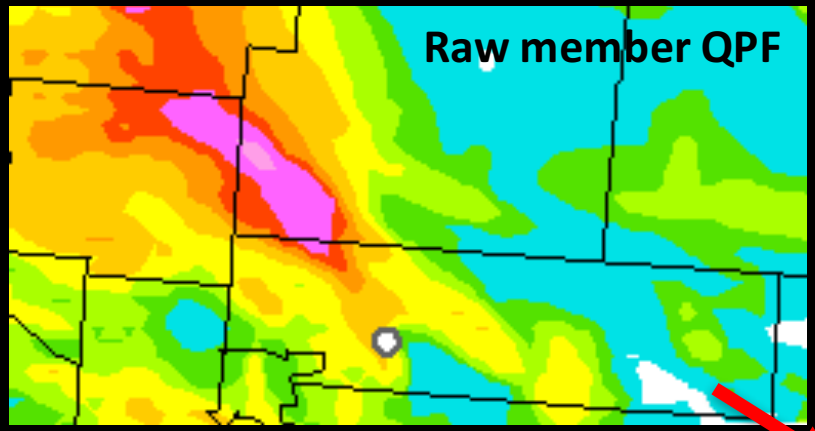
Combining spatial and temporal filters



Recent Changes to HRRR-TLE

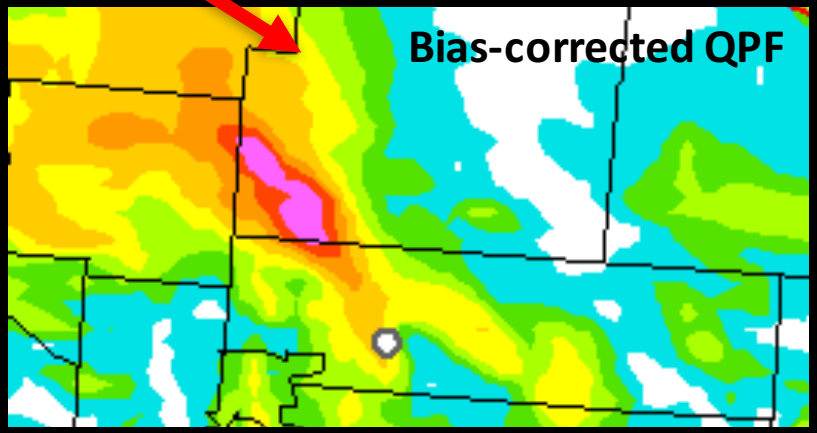
- 24-h forecast length
- New severe, flash flood, aviation products, all experimental (of course)
- Conversion of all fields to 40-km neighborhood probabilities
- Tested in WPC winter weather and SPC/HWT spring experiments, and WPC FFaIR

Neighborhood/Spatial Filter Algorithm Demonstration

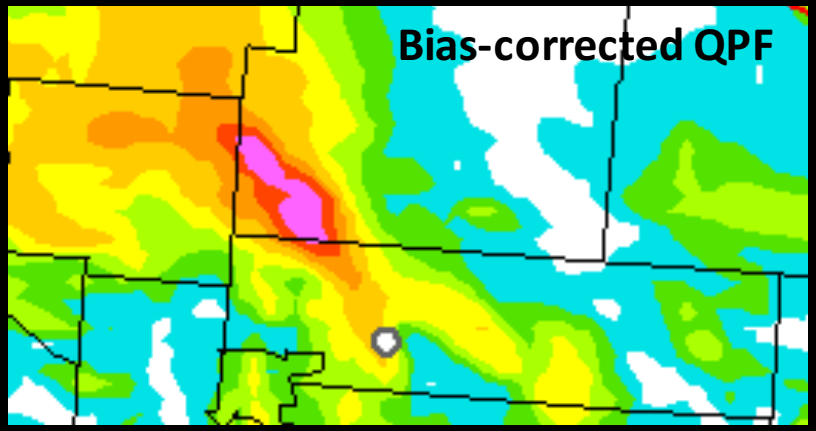


50 forecast/analysis pairs

bias correction



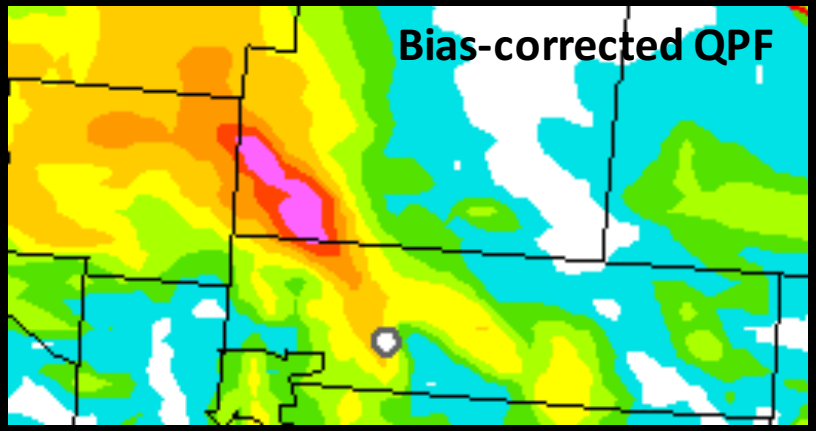
Neighborhood/Spatial Filter Algorithm Demonstration



Identify grid points where bias-corrected QPF exceeds the threshold of interest and mark these as a "hit" (1)

0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	0	0	1	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0

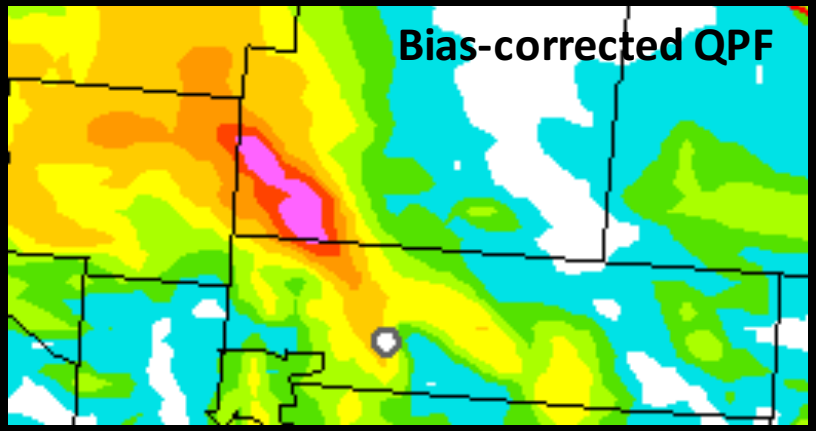
Neighborhood/Spatial Filter Algorithm Demonstration



0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0

Also set neighboring grid points to 1. Simplified example uses a 1-grid-point radius, but real products use 40-km (about 13 grid points)

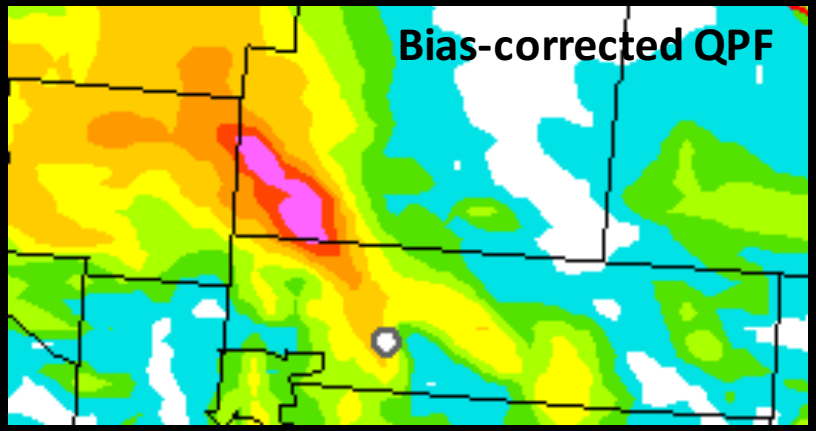
Neighborhood/Spatial Filter Algorithm Demonstration



Now apply the spatial filter (typically a much larger radius than the neighborhood)

0	0	0	0	0	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	1	1	1	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	1	1	1	0	0
0	0	0	0	0	0	0	0	0	0

Neighborhood/Spatial Filter Algorithm Demonstration



Python "fft_convolve" function

0	0	0	0	0	0	0	0	0	0
0	0	1			0	0	0	0	0
0	0				0	0	0	0	0
0	0				0	0	0	0	0
0	0				0	0	0	0	0
0	0	0	0	0			1	0	0
0	0	0	0	0			1	0	0
0	0	0	0	0		1	1	0	0
0	0	0	0	0	0	0	0	0	0

In this example, 48% of points in the spatial filter radius are "hits". Repeat this for each member, and the final probability is the average of 48%, A%, B%...

http://rapidrefresh.noaa.gov/hrrrtle/

HRRR Time-Lagged Ensemble - Experimental

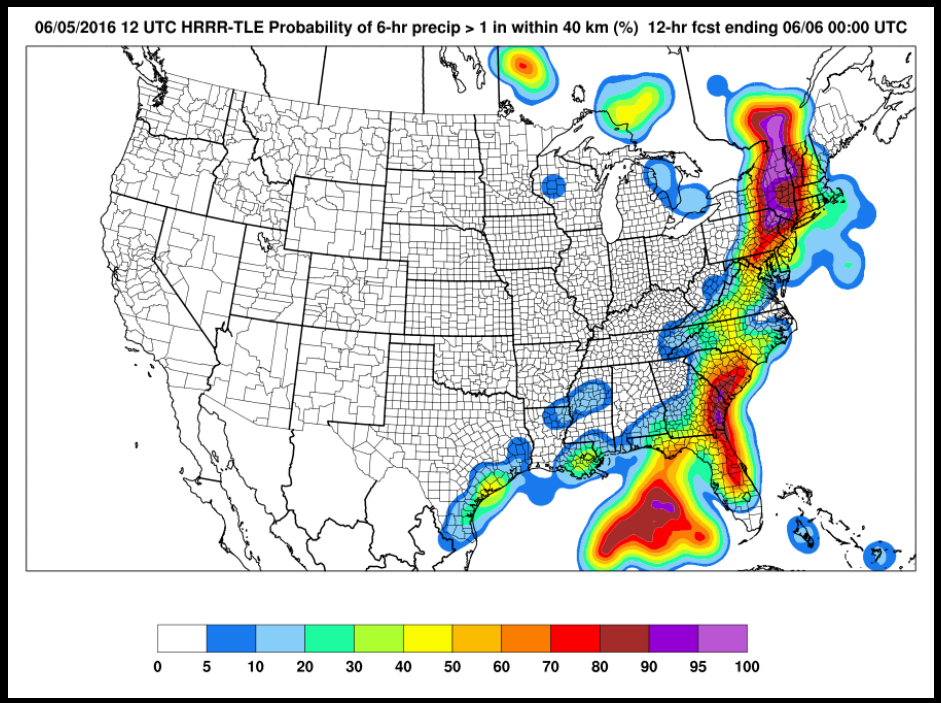
Model: HRRRX Neighborhood Probability (Experimental) Area: Full Date: 07 Jun 2016 - 22Z

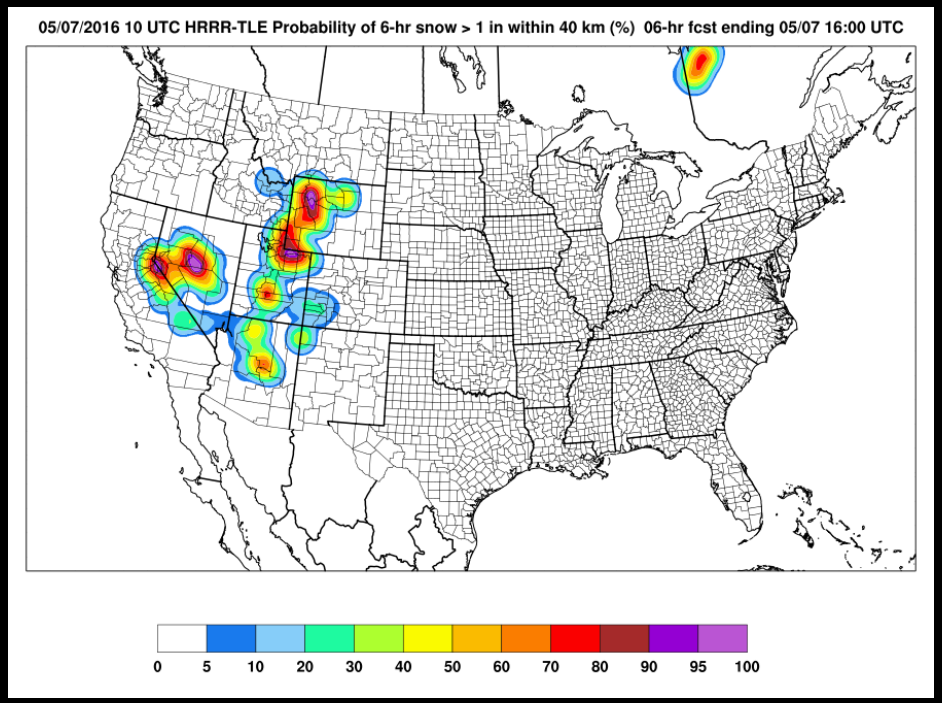
Model: HRRRX Neighborhood Probability (Experimental) **Domain:** Full **Date:** 07 Jun 2016 - 22Z

			Valid Time																								
			Tue 22	Tue 23	Wed 00	Wed 01	Wed 02	Wed 03	Wed 04	Wed 05	Wed 06	Wed 07	Wed 08	Wed 09	Wed 10	Wed 11	Wed 12	Wed 13	Wed 14	Wed 15	Wed 16	Wed 17	Wed 18	Wed 19	Wed 20	Wed 21	Wed 22
	All times	Loop	Forecast																								
			00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
all fields			00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.50" / 1 hr precip	✓	✓		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.00" / 1 hr precip	✓	✓		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2.00" / 1 hr precip	✓	✓		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.50" / 3 hr precip	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.00" / 3 hr precip	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2.00" / 3 hr precip	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
3.00" / 3 hr precip	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.50" / 6 hr precip	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.00" / 6 hr precip	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2.00" / 6 hr precip	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
3.00" / 6 hr precip	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
6.00" / 6 hr precip	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
6 hr precip > 100-yr recurrence	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.00" / 3 hr runoff	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2.00" / 3 hr runoff	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
3.00" / 3 hr runoff	✓	✓				03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0.50" / 1 hr snowfall	✓	✓		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.00" / 1 hr snowfall	✓	✓		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
2.00" / 1 hr snowfall	✓	✓		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1.00" / 6 hr snowfall	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
3.00" / 6 hr snowfall	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
6.00" / 6 hr snowfall	✓	✓							06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Thunderstorm	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Wind > 50 kt in last 4 hr	✓	✓					04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Hail > 1" in last 4 hr	✓	✓					04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Tornado in last 4 hr	✓	✓					04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Visibility < 5 mi	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Visibility < 3 mi	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Visibility < 1 mi	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Ceiling < 3000 ft	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Ceiling < 1000 ft	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Ceiling < 500 ft	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
IFR conditions	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Echo Tops > 25 kft	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Echo Tops > 30 kft	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Echo Tops > 35 kft	✓	✓	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Precipitation Products (exp)

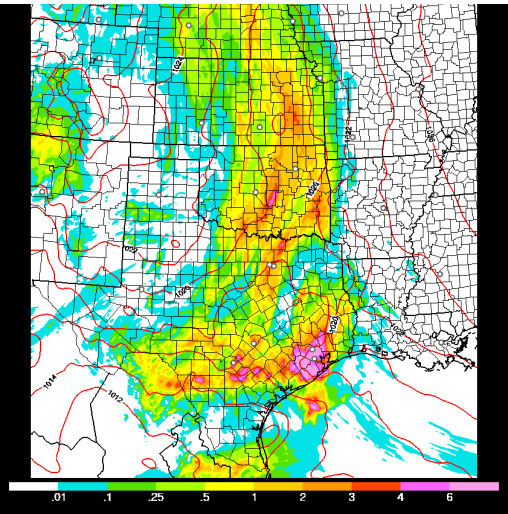
- 1-h, 3-h, 6-h PQPF
- 6-h probability of precip exceeding 100-year ARI
- 3-h probabilistic runoff
- 1-h, 6-h probabilistic snowfall



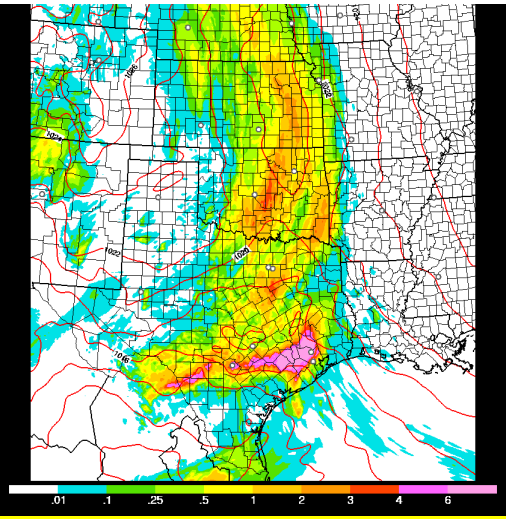


Houston, TX Flash Flooding 12 UTC 18 April 2016

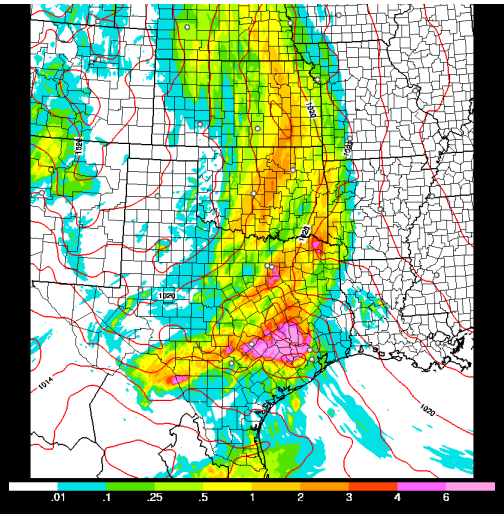
HRRR 23z 13hr pcp fcst



HRRR 00z 12 hr pcp fcst

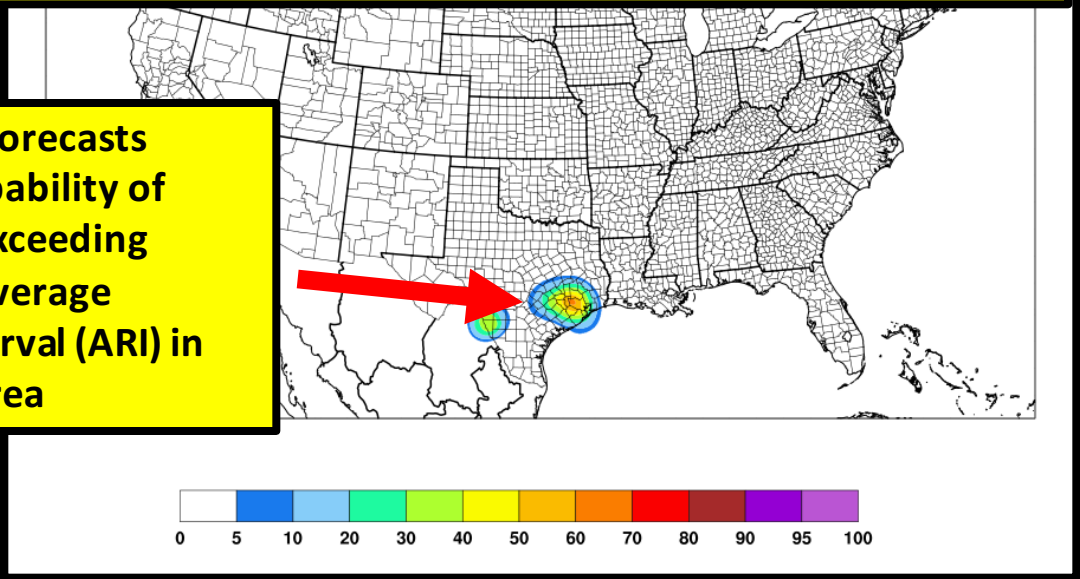


HRRR 01z 11 hr pcp fcst

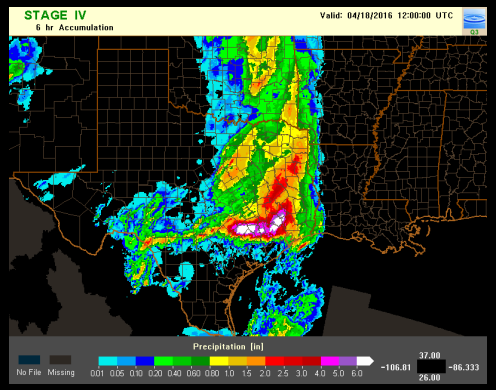


Consecutive HRRR runs produced > 6” precip in ~12 hrs

HRRR-TLE forecasts > 60% probability of 6-hr QPF exceeding 100-year average return interval (ARI) in Houston area

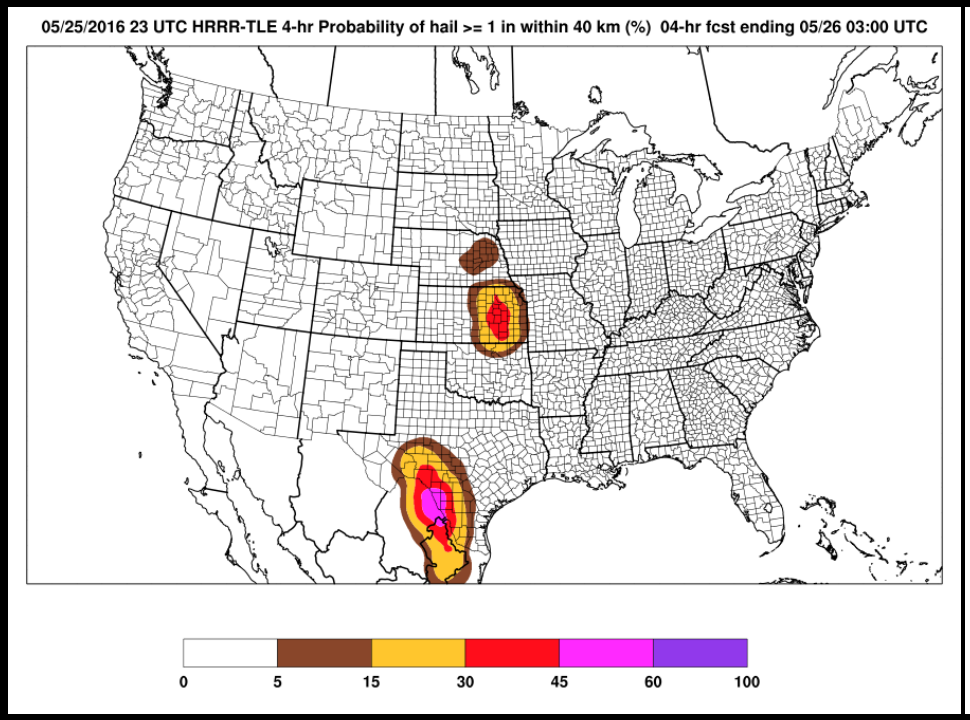


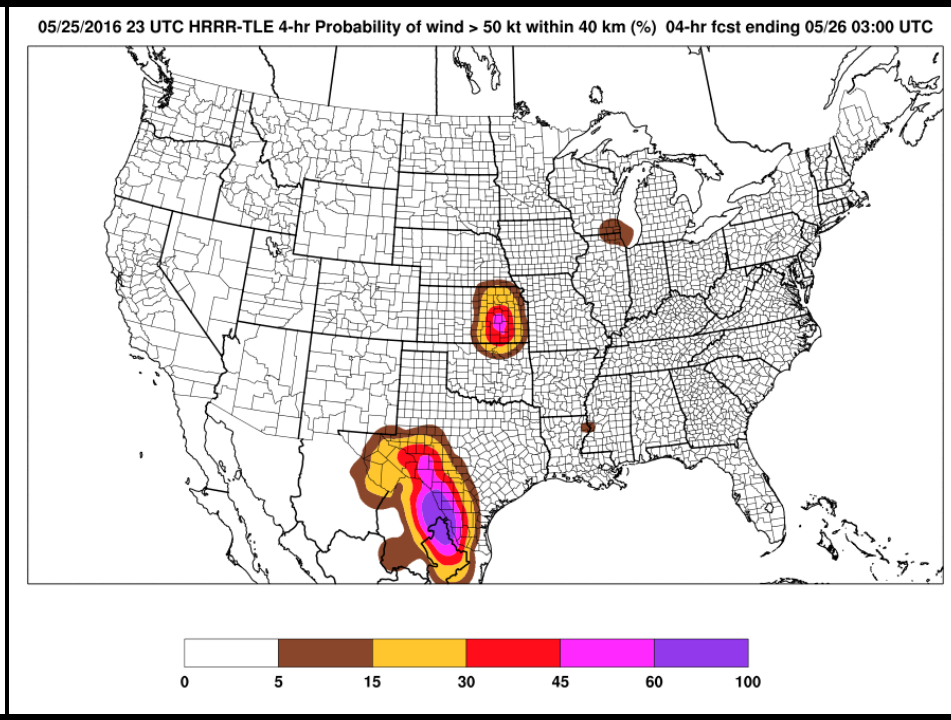
06hr QPE > 6”



Convective Products (exp)

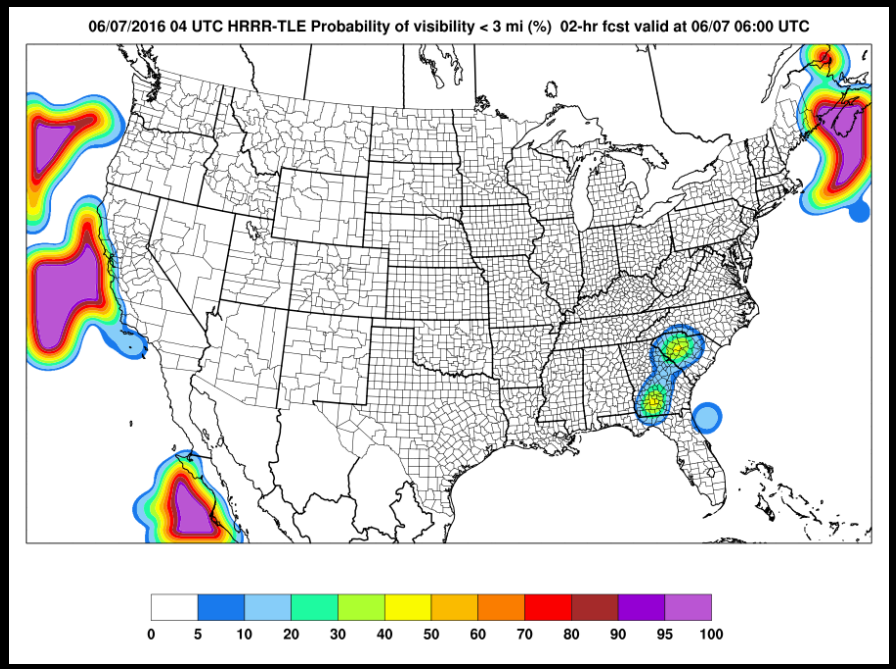
- 4-h probabilities within 40-km of a point:
  - Wind > 50 kt / Hail > 1 in / Tornado
- Hourly thunderstorm probability

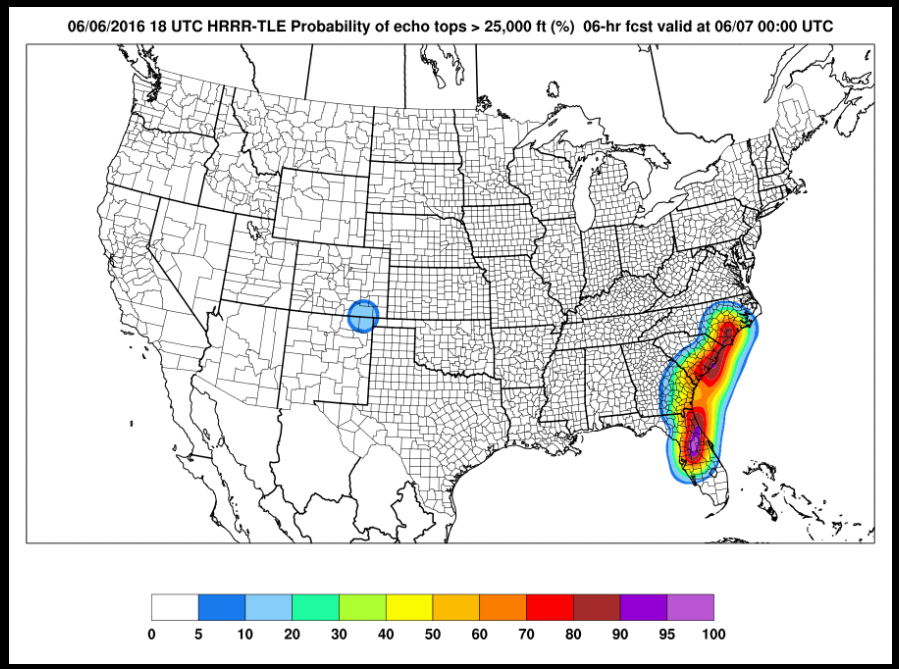




Aviation Products (exp)

- Hourly probability of:
  - Visibility < 5, 3, 1 mi
  - Ceiling < 3000, 1000, 500 ft
  - IFR conditions
  - Echo tops > 25000, 30000, 35000 ft





Fire Weather Products (exp)

- Hourly probability of:
  - Dry thunderstorm
  - 2-m RH < 5, 10, and/or 15%
  - 10- or 80-m wind speed or gust > 20, 25 and/or 30 mph
  - Combination of above conditions

?

Hazard	Model Field	Truth
Heavy rain	QPF	Stage-IV / MRMS
Heavy snow	Explicit snow from model microphysics	National snowfall analysis
Thunderstorm	Lightning threat 3 (graupel flux and column ice)	NLDN
Severe wind	10-m hourly max wind	mesonet
Large hail	Vertically integrated graupel	MESH
Tornado	Updraft helicity, 0-1-km shear, SBCAPE/MUCAPE	storm reports and MRMS rotation tracks
Visibility/Ceiling/EchoTop	Visibility, cloud base, echo top height (18 dBZ)	ASOS, MRMS
Red Flag - Fire	2-m RH, 10-m wind	URMA and/or mesonet

HRRR-TLE: Project Timeline

Product Development Timeline

Engage National Center Testbeds

Organization/Experiment	Hazards	Platform	Timeline
WPC WWE	PQPF, Snowfall, Snow Rate	NAWIPS and web site	January 2016
NSSL/SPC EFP/EWP	Tornadoes, Hail, Wind	NAWIPS and AWIPSII	May 2016
WPC FFaIR	Refined PQPF and FF guidance	NAWIPS	June 2016
AWC Summer Experiment	Initial aviation hazards: ceiling, visibility, convection	NAWIPS	August 2016
WPC WWE	Refined winter hazards and PQPF	NAWIPS	January 2017
AWC Winter Experiment	Ceiling and visibility	NAWIPS	February 2017
NSSL/SPC EFP/EWP	Refined severe weather guidance	NAWIPS and AWPSII	May 2017
WPC FFaIR	Refined FF guidance	NAWIPS	July 2017
AWC Summer Experiment/OPG	Refined aviation hazards	NAWIPS and AWPSII	August 2017
Initiate NCO 'on-boarding"	All	IDP	Late 2017 or 2018

HRRR-TLE is a key component of this USWRP-funded project:
Refinement and Evaluation of Automated High-Resolution Ensemble-Based Hazard Detection Tools for Transition to NWS Operations