A larger convection allowing ensemble: How many members does it take to get to Meaning?

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Work done as part of the HydroMeteorological Testbed (HMT) during the 2023 Flash Flood and Intense Rainfall Experiment

Research Challenge/Operational Challenge

Extreme precipitation has characteristics similar to a tornado. Small, short lived, hard to predict.

Flash flooding usually occurs at the intersection of:

- People & possessions,
- Precipitation (rate and/or amount), and
- imPervious surfaces: pipes & pavement, burn scars, or canyons/hollers

These are low predictability events (at a location, at a time, and may only come into focus late)

Probability May be low;

Will it be lower with increasing membership?

Question: What is the tradeoff between membership and Probability?

Predicting extreme precipitation events
(Rhetorical Questions related to Value)

Can forecasters use the Probabilistic guidance at any one initialization?

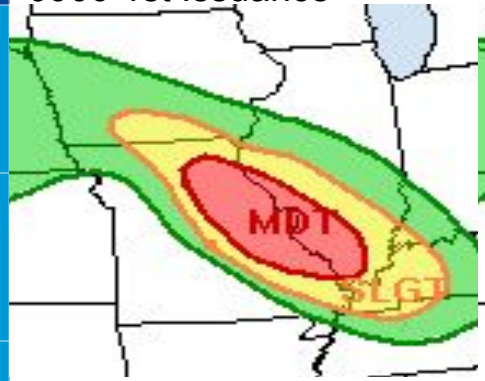
Is there forecast consistency* across a set of initializations?

Is the ensemble Adequate-For-Purpose across the range of extreme events?

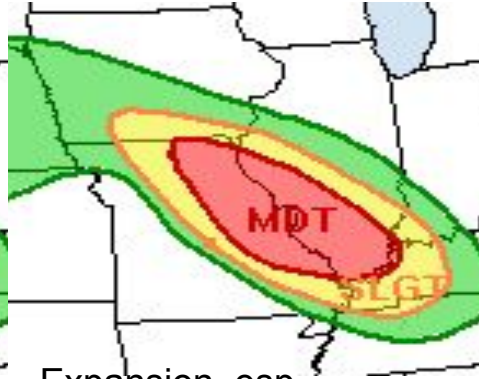
*consistency in time, location, duration, intensity

Nocturnal heavy rain Event on 3 August 2023 00-12z

0900 1st Issuance



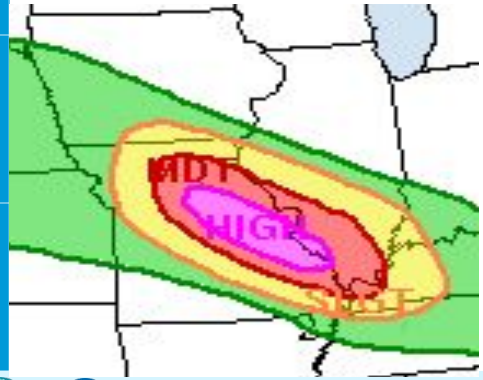
1600 2nd Issuance



Excessive Rainfall Outlooks WPC 2-3 August

Expansion, esp Northeast

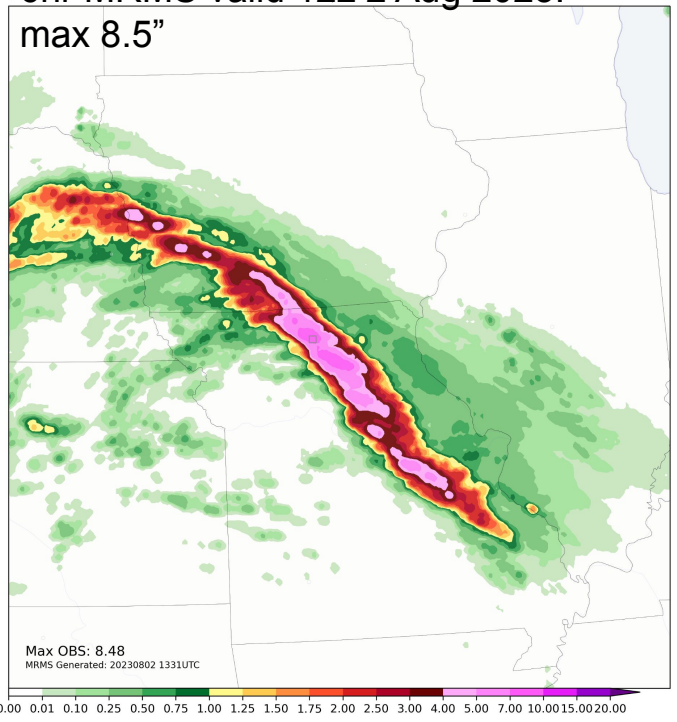
0100 3rd Issuance



Event imminent, upgrade to High; Location southwest of STL

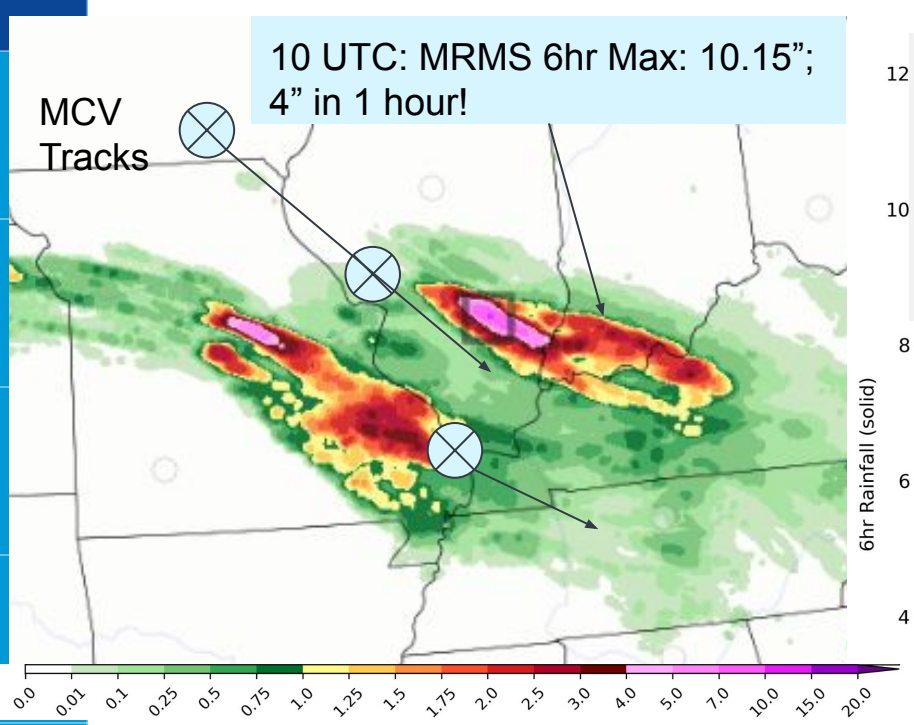
Context: rained the night before with a large area of 4-5”

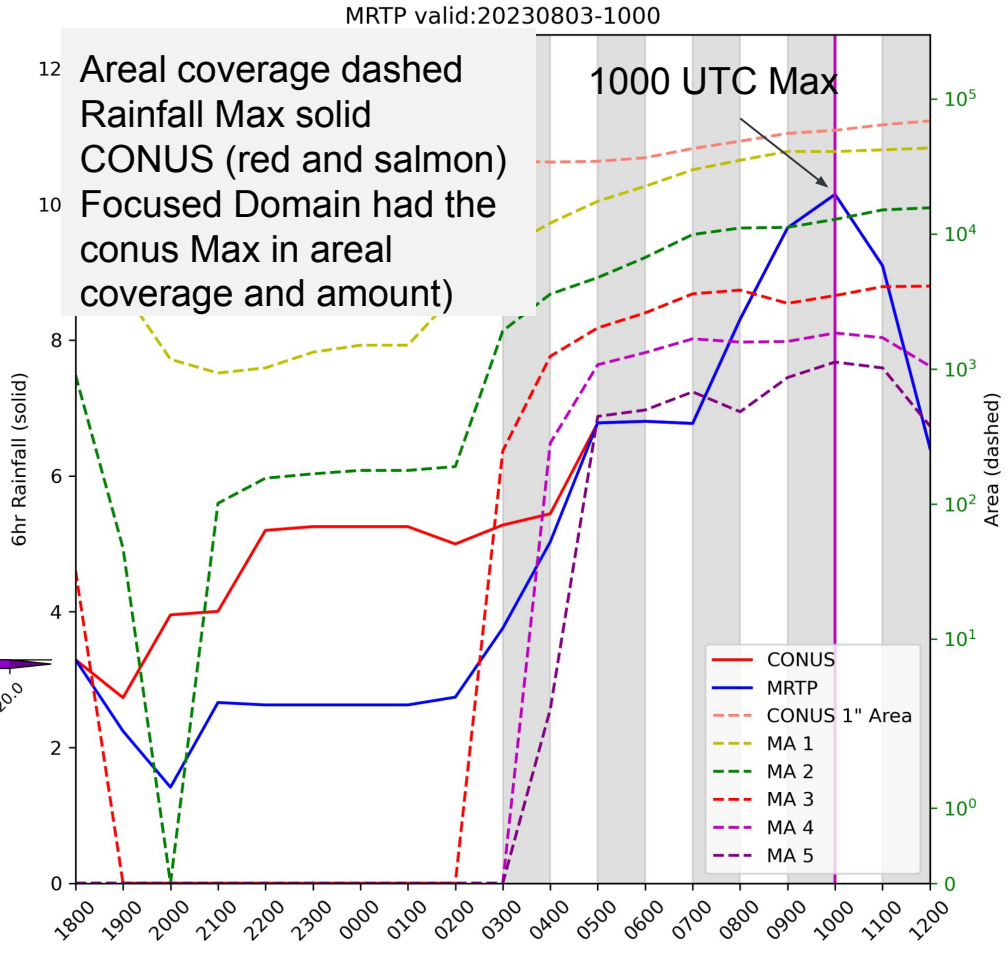
6hr MRMS valid 12z 2 Aug 2023: max 8.5”



Nocturnal heavy rain Event on 3 August 2023 00-12z

10 UTC: MRMS 6hr Max: 10.15”; 4” in 1 hour!

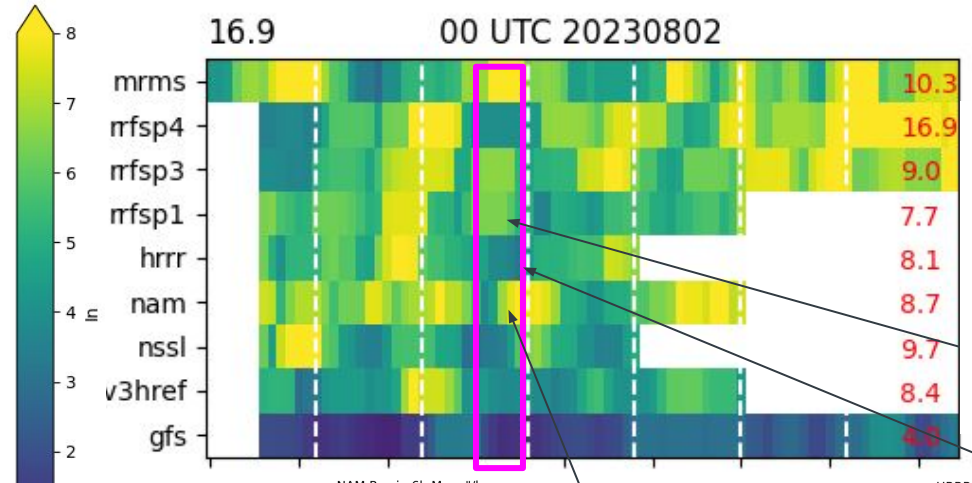


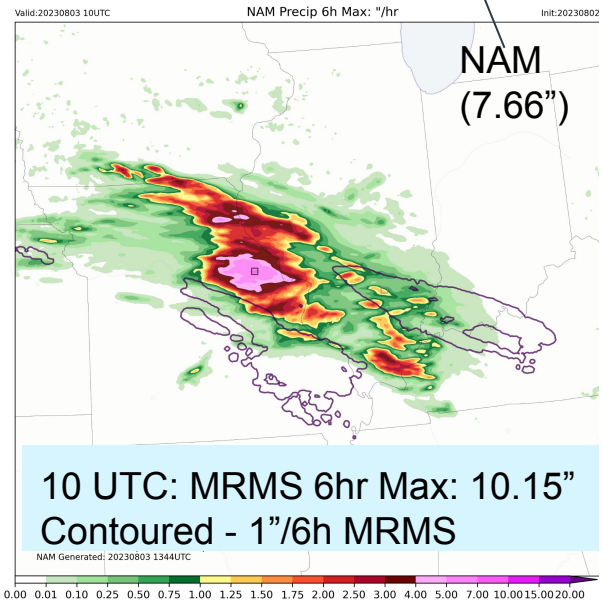


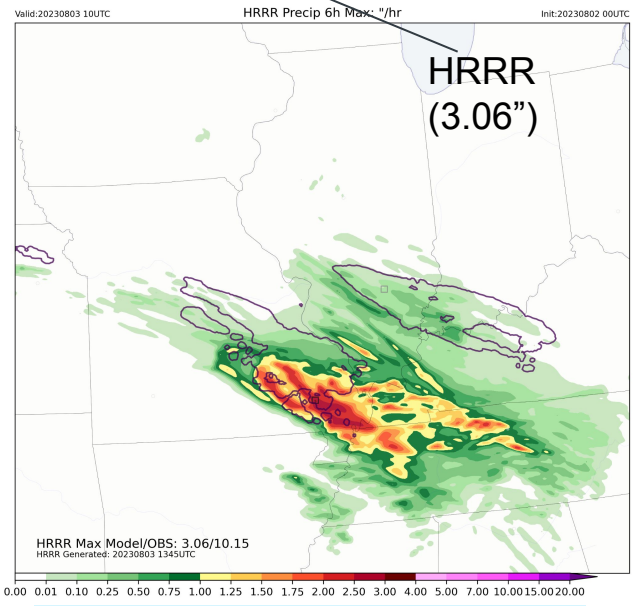
Event starts after 00 UTC,
Medium size footprint of 40k km^2 for 1”, exceeding 900 km^2 for 5”
Extremes in multiple ways, locations!

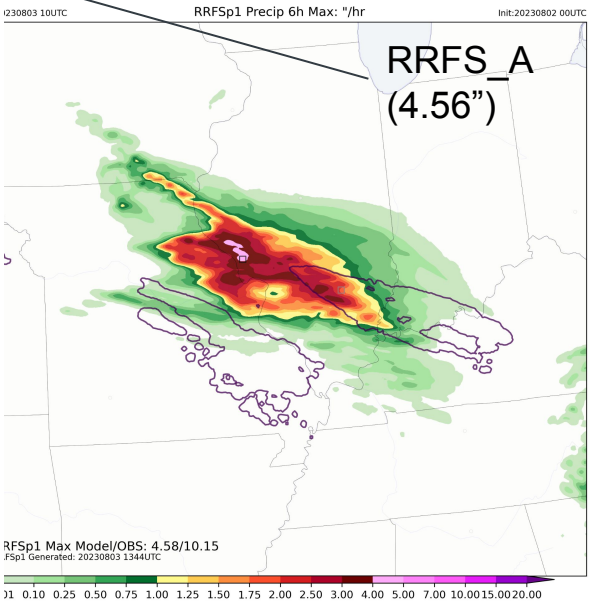
00z Deterministic models

MCV like features evolved from prior night convection in NE. The MCV(s) position, strength, and reinvigoration appear to be related to the precip distribution at the finest scales of the models. HRRR has faster evolution with weakening MCV. RRFS grows upscale faster ending event early. NAM grows upscale slowly which extends the life of its extreme event





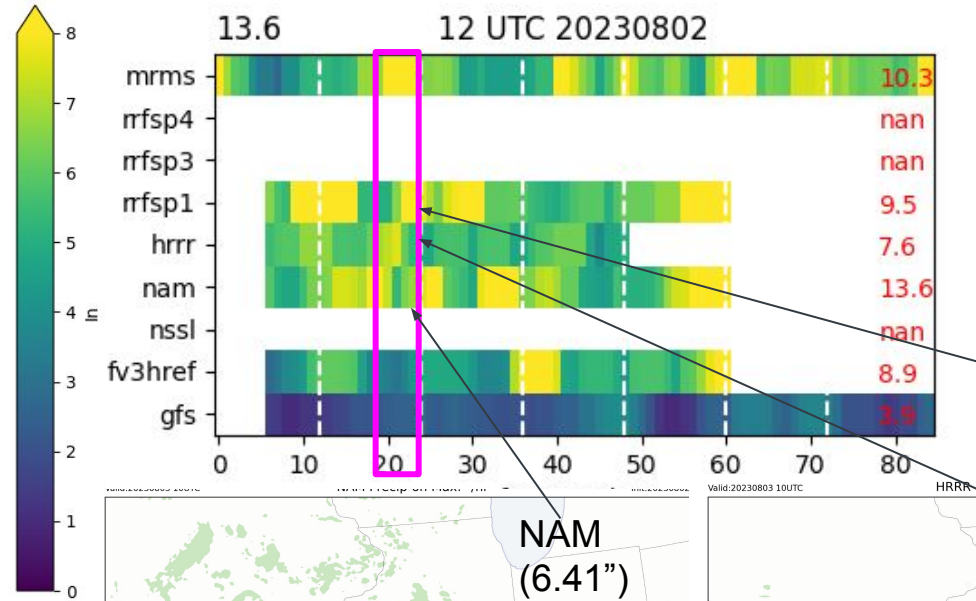


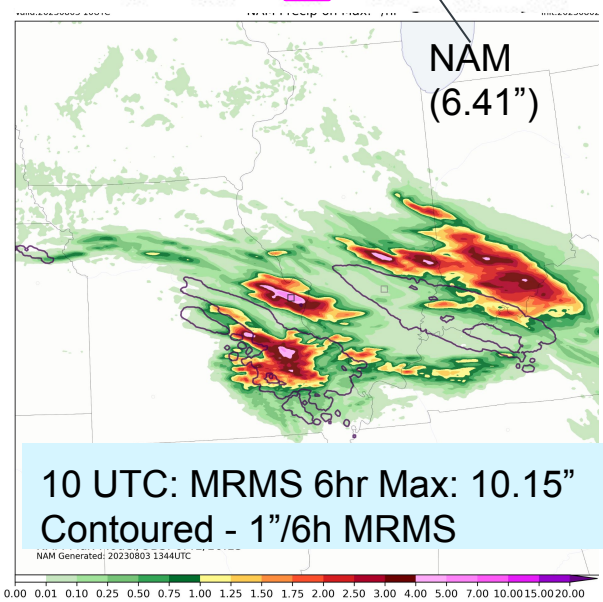


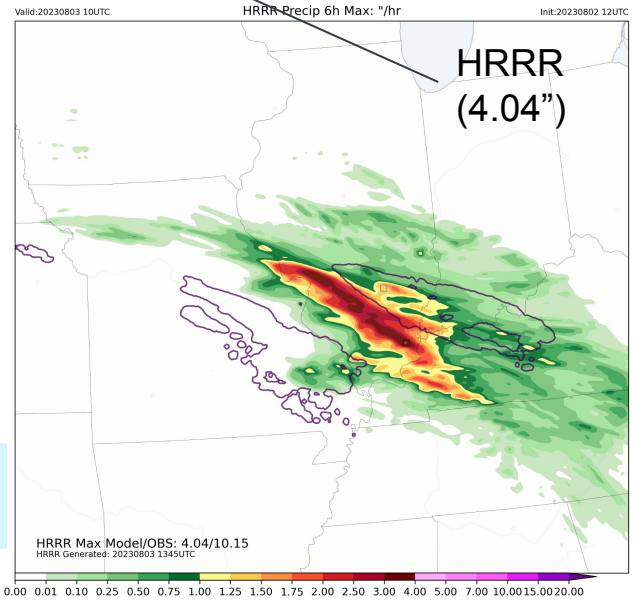
10 UTC: MRMS 6hr Max: 10.15"
Contoured - 1"/6h MRMS

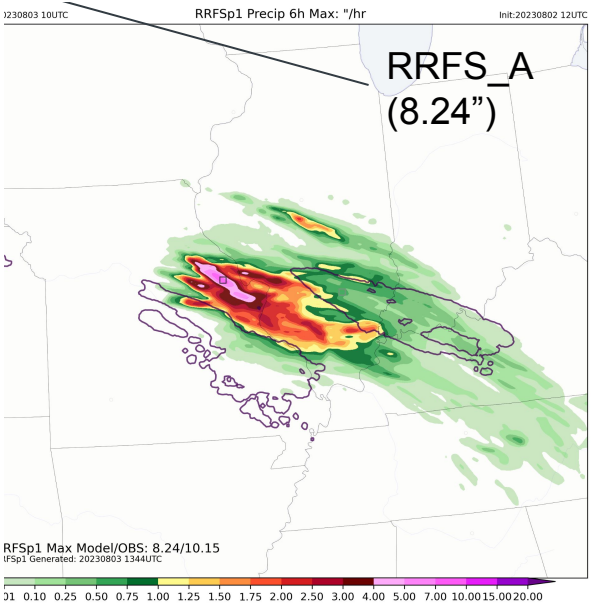
12z Deterministic models

Initialized MCVs in NAM produce multiple bands; HRRR weak s/w trough yet faster convective line evolution (but backbuilding convection weaker). RRFS s/w extensive and convective cells numerous which results in faster backbuilding but northeastward of obs (hint of second area but later than observed).









10 UTC: MRMS 6hr Max: 10.15”
Contoured - 1”/6h MRMS

Ensemble Systems (HREF and RRFS)

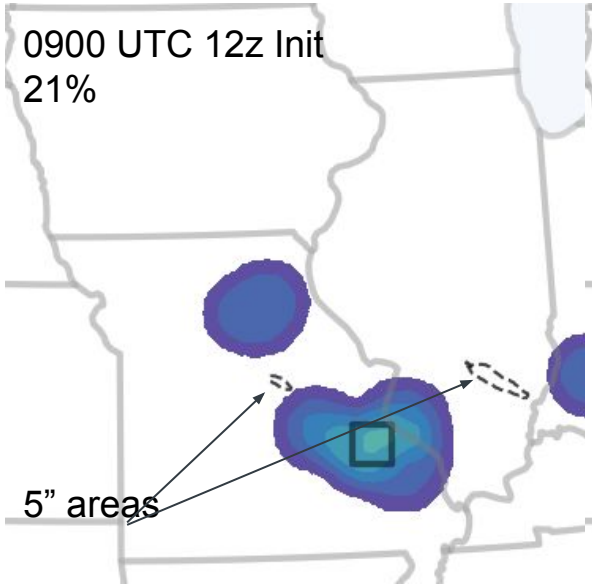
Here we look at the HREF and RRFS (exp) probabilities for exceeding 5”/6h (similar for 3”/3hr)

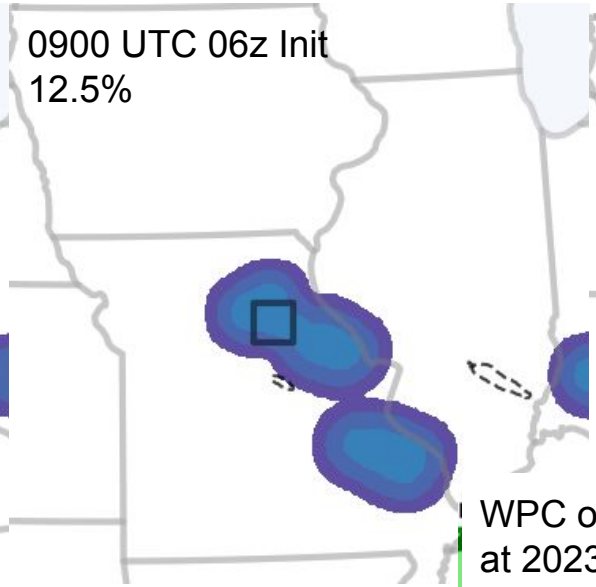
HREF: Time lagged 10 member ensemble

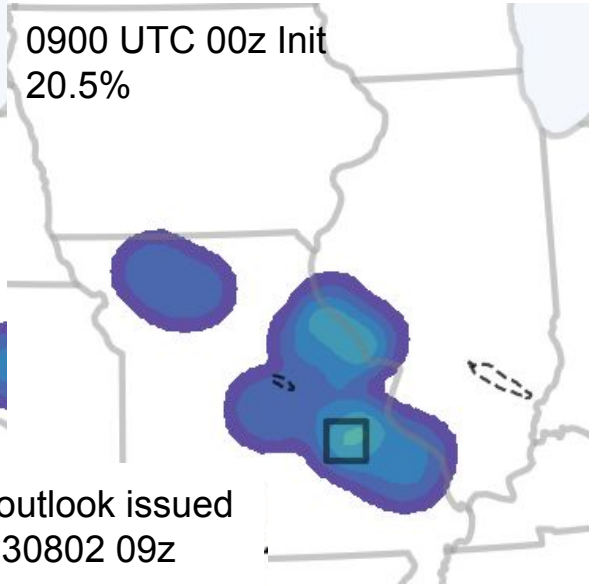
RRFS: Time lagged 12 member ensemble (single phys)

Probabilities not provided hourly, get as close to 10z by looking at 09z probs

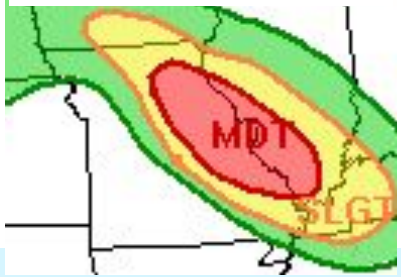
Ensemble Depictions of 5”/6hr HREF







WPC outlook issued at 20230802 09z

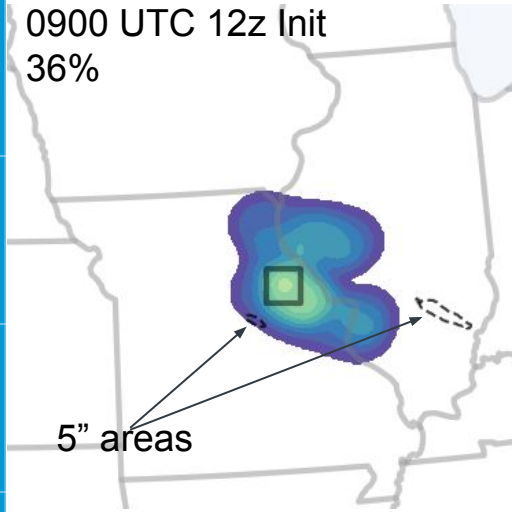


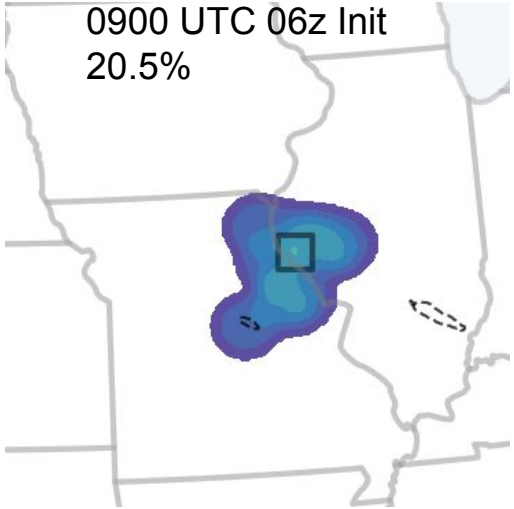
Some consistency for low probability, multiple areas in MO

HREF has maybe 4-5 members contributing heavy rain but still only 1-3 generating extreme rainfall depending on the cycle.

What does 10% mean? At least 1 member with sizable coverage (hunt for outliers!)

Ensemble Depictions of 5”/6hr RRFS



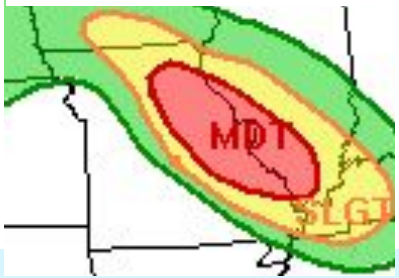


0900 UTC 00z Init

Missing;
no 18z members

More consistency for low probability, multiple areas in MO
From a probability view: it was less members and more areal coverage that increased the probability!

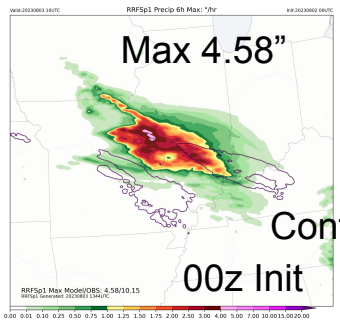
WPC outlook issued at 20230802 09z

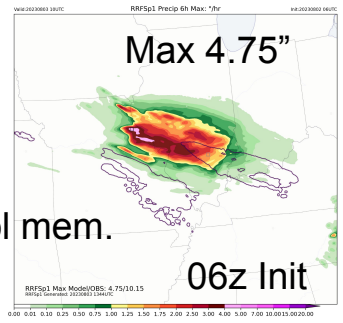


IL had the 10” maximum and no ensemble probability areas were in any cycle prior to 18z.

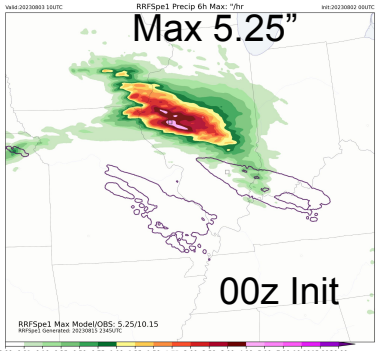
RRFS membership summary

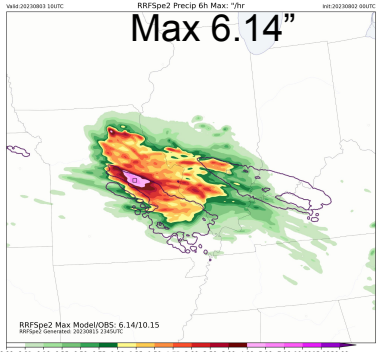
Singular bands mostly
Max accums below 6”
1-2 members w/ more 4” areal coverage
3 mem < 4”

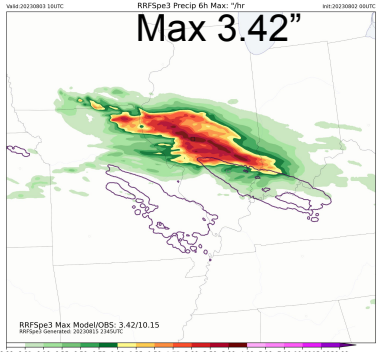


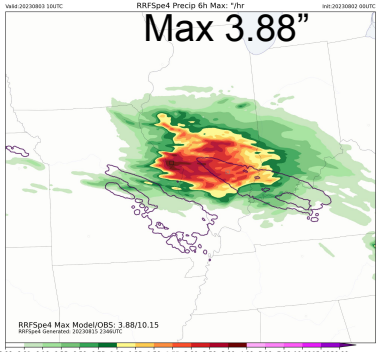


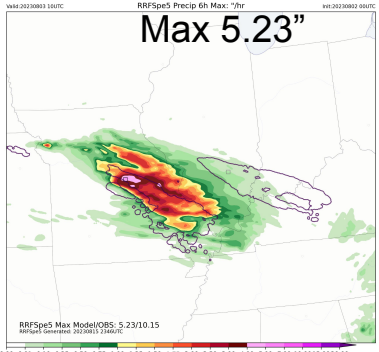
Control mem.

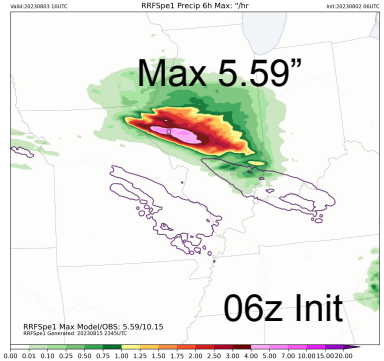


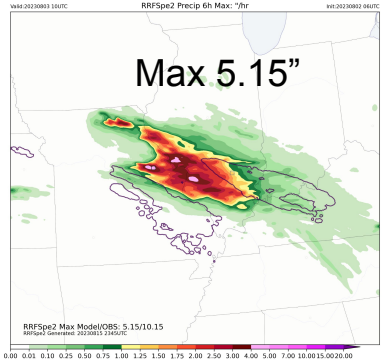


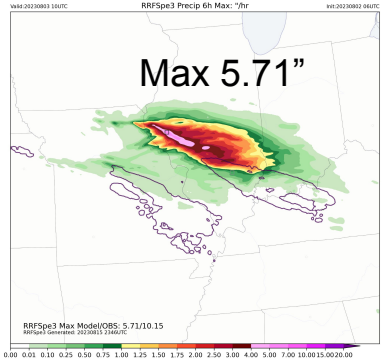


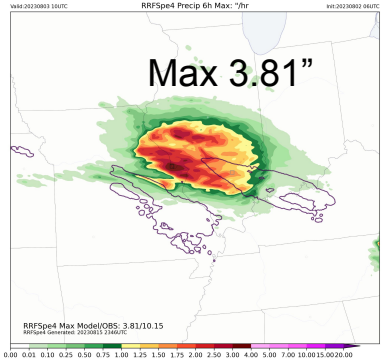


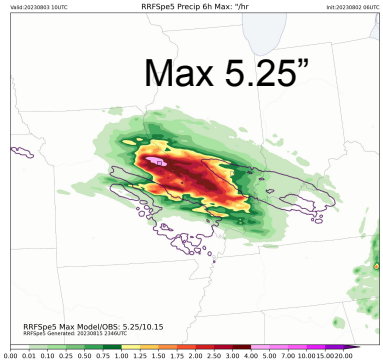








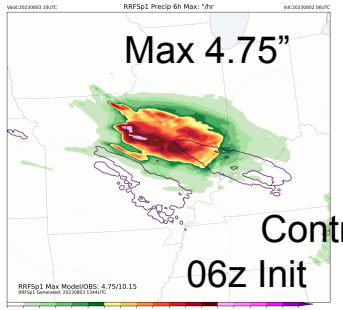


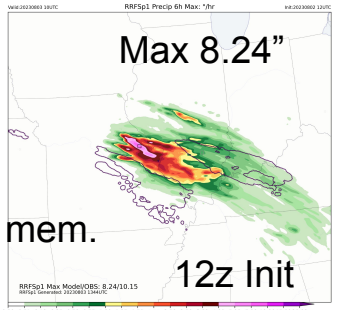


RRFS membership summary

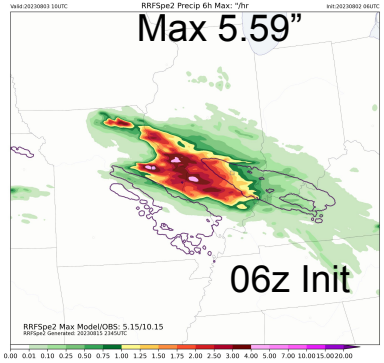
Singular bands mostly
2 members above 6”
6 members w/ 4”+ coverage
3 mem < 4”

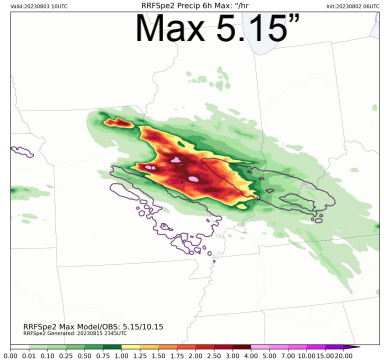
12z: More bands, but reduced precipitation. In effect went from consistent to inconsistent (increased spread!)

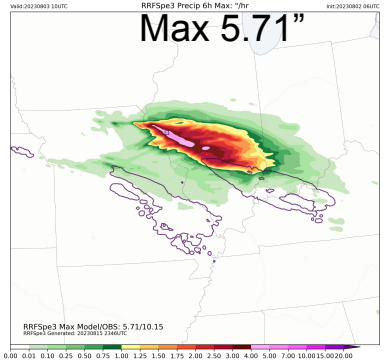


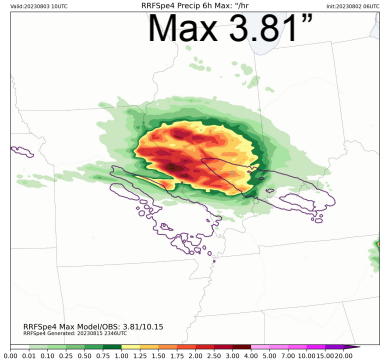


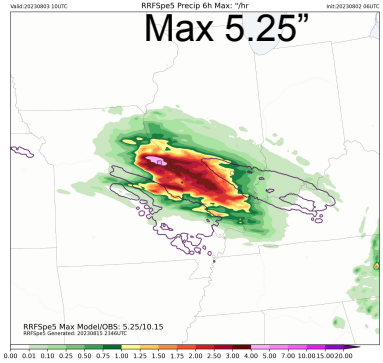
Control mem.

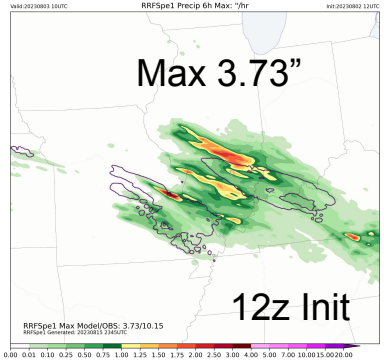


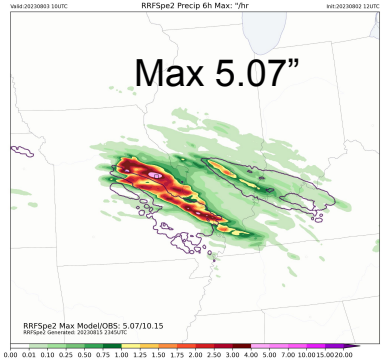


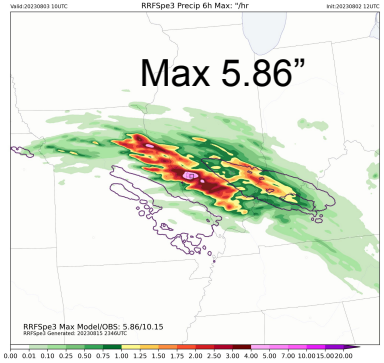


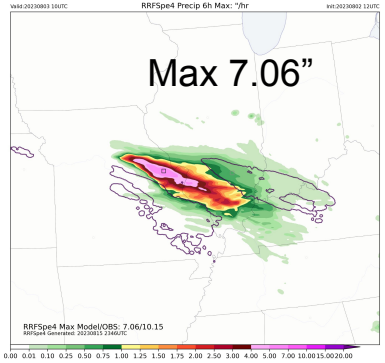


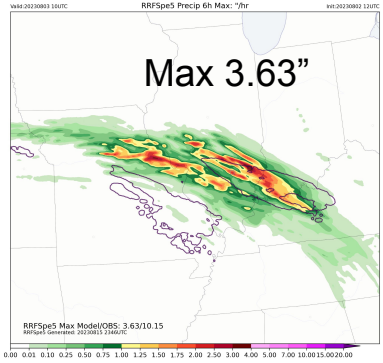












Case Takeaways

Few of the solutions look like the observed, but they capture bits and pieces of both bands. Probabilities fluctuate between 15-40% (across cycle, across time; not shown).

The number of cycles included in the ensemble could be increased.

Tradeoff: smaller events could have lower probability

Consistency, probabilistically, may be more achievable with more cycles.

Confidence came from anchor CNTL models, enhanced by ensemble.

The HREF and RRFS are competitive. But the DA driven RRFS should have an advantage!

Final Thoughts

Consistency, skill: need at least 1 to have the ensemble have meaning.

But you need Confidence to believe the ensemble Probabilities

Simply adding more members may help for large scale events, but at some point skill needs to increase.

- More members, more reasonable chances for extremes (+ or -)
- Of course if extreme events are at the effective resolution of the modeling system, then we need finer scale models
- Probabilities help but we are still looking for outliers and reasons to believe them!