

WPC Excessive Rainfall Outlook

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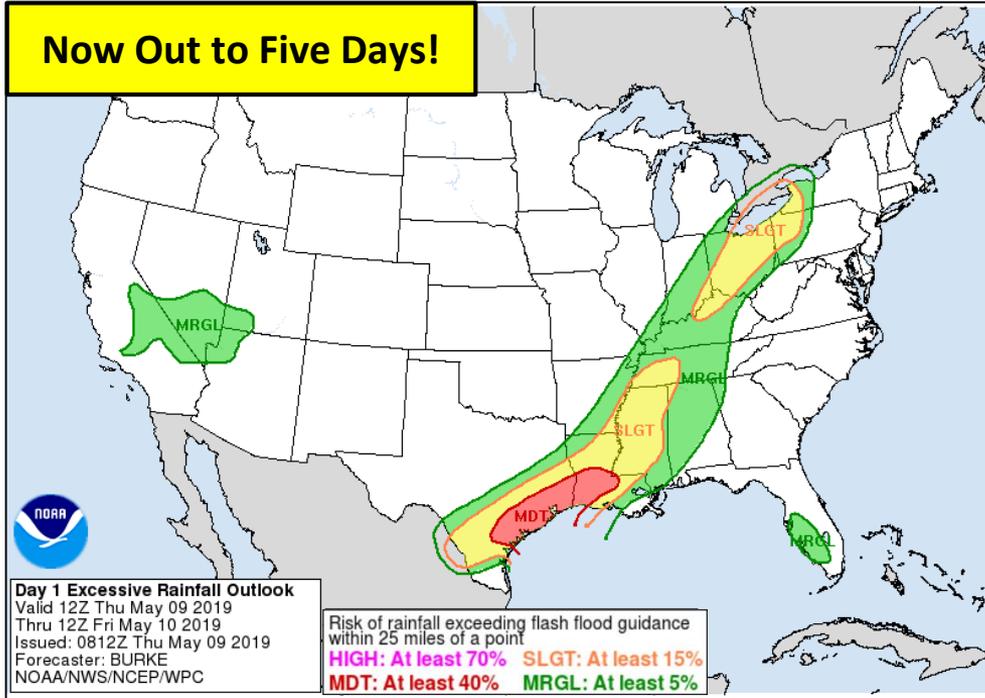
FFaIR 2023



Excessive Rainfall Outlook (ERO)

We Try to “Translate” the Rainfall Forecast with the ERO

Now Out to Five Days!



Graphic legend updated for new probability definitions as of February 10, 2022

Answers the question:

What are the chances of rainfall intense enough that it would be expected to cause flash flooding?

Other things to know:

- ✓ A key situational awareness and planning tool.
- ✗ Not an explicit forecast of flash flooding at a specific location
- ✓ Accounts for uncertainty in placement, timing of intense rainfall and summarizes the larger scale risk factors
- ⚠ Know your vulnerability! Lower risk categories may still be meaningful decision thresholds.

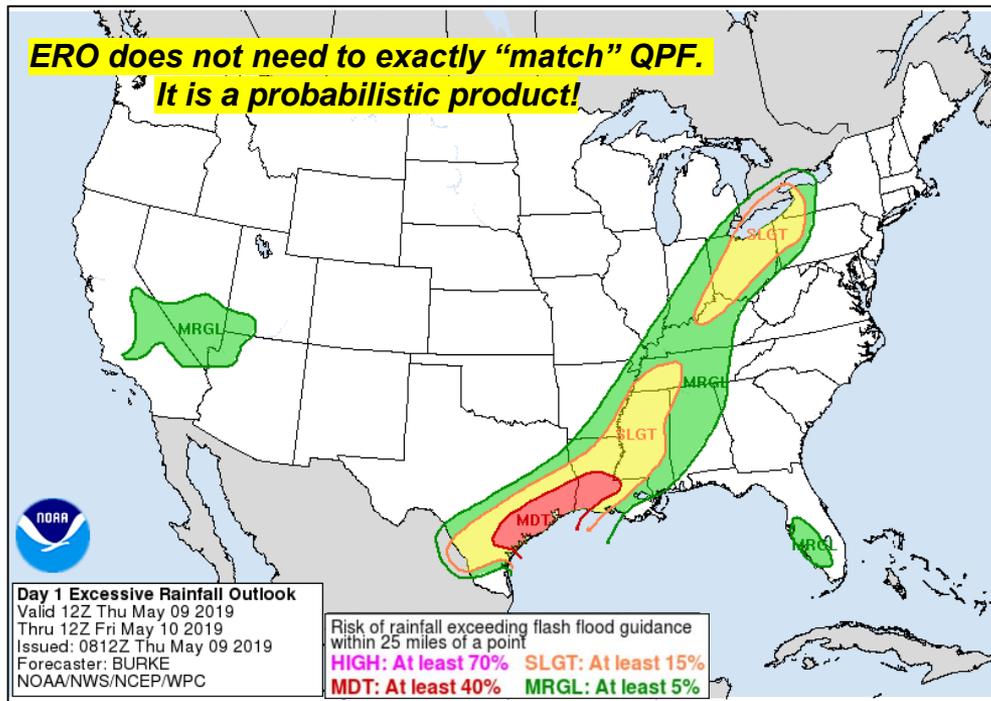


WEATHER PREDICTION CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

A significant step beyond QPF...

**ERO does not need to exactly “match” QPF.
It is a probabilistic product!**



Graphic legend updated for new probability definitions as of February 10, 2022

EROs convey ***impact*** potential beyond QPF and incorporate the following:

- ✓ Rain rates (one-hour, three-hour)
- ✓ Runoff potential/terrain (varies by region)
- ✓ Rain duration (banded/training convection)
- ✓ Flash flood guidance
- ✓ Prior rainfall/flash flood impacts
- ✓ Urban/metro area and population

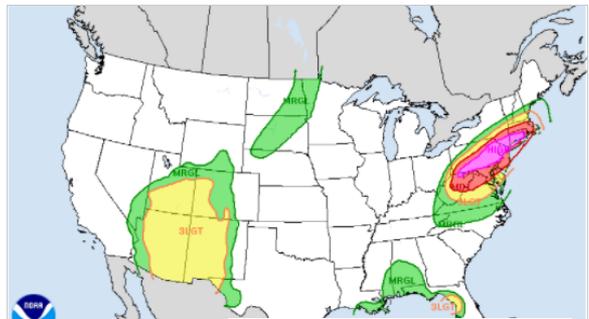
Excessive Rainfall Discussion

HAZARD	SEP 01	SEP 02	SEP 03	WPC'S MEDIUM RANGE HAZARDS FORECAST
EXCESSIVE RAINFALL	HEAVY	SLIGHT	SLIGHT	WPC'S MEDIUM RANGE HAZARDS FORECAST
HEAVY SNOW (≥ 4")	NO AREA	NO AREA	NO AREA	WINTER STORM SEVERITY INDEX
ICE (≥ 0.25")	NO AREA	NO AREA	NO AREA	

Overview Surface Analysis Fronts QPF Excessive Rain Winter Wx Day 3-7 Forecast Tools

Excessive Rainfall Forecasts [Legacy Page](#) Valid Wed Sep 01 2021 - 12Z Thu Sep 02 2021

Valid Until 12Z Day 1 Day 2 Day 3



CLICK TO EXPAND

+ Forecast Discussion

Day 1 Excessive Rainfall Outlook
 Valid 12Z Wed Sep 01 2021
 Thru 12Z Thu Sep 02 2021
 Issued: 1526Z Wed Sep 01 2021
 Forecaster: GPHW
 DOC: NNAANWS/NCEP/WPC

+ Forecast Discussion

Excessive Rainfall Discussion
 NWS Weather Prediction Center College Park MD
 428 AM EDT Wed Sep 01 2021

Day 1
 Valid 12Z Wed Sep 01 2021 - 12Z Thu Sep 02 2021

...THERE IS A HIGH RISK FOR EXCESSIVE RAINFALL THROUGH PORTIONS OF THE NORTHEAST.
 ...WIDESPREAD AND POTENTIALLY LIFE THREATENING FLASH FLOODING LIKELY TODAY AND TONIGHT ACROSS PARTS OF THE MID ATLANTIC REGION INTO SOUTHERN NEW YORK AND SOUTHERN NEW ENGLAND...

...Northeast...
 Signals remain strong for potentially deadly and damaging flash flooding from parts of the Mid-Atlantic region across southern New York into the southern portion of New England today and tonight...especially across highly urbanized metropolitan areas and areas of steep terrain...later today as Tropical Depression Ida moves through the area. The latest WPC GPF guidance maintained areal average rainfall amounts of 3 to 8 inches with isolated higher amounts from western Maryland and Pennsylvania northeastward across southern New York and into the southern portion of New England. High resolution guidance continues to support higher amounts embedded with this area...with amounts in

- Meteorological reasoning, scenarios, potential rain rates
- Location and timing details
- Antecedent conditions
- Forecaster confidence
- Model preferences

Meteorology Behind the ERO

Ingredients-based approaches and conceptual models are important!

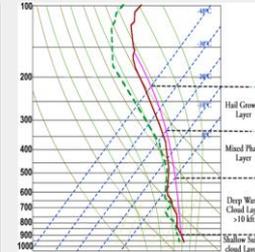
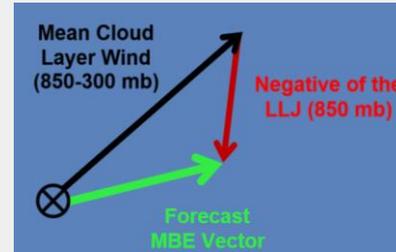
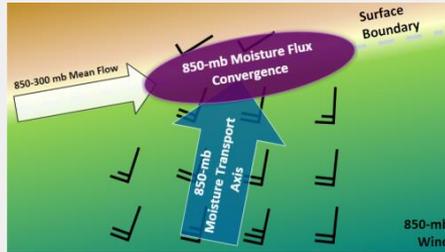
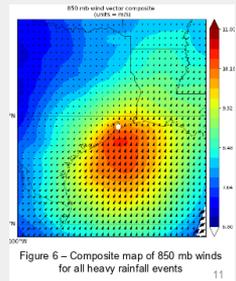
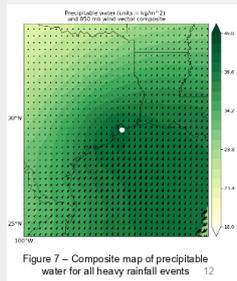
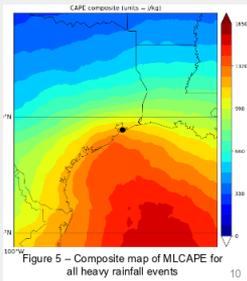


Figure 5 – Composite map of MLCAPE for all heavy rainfall events 10

Figure 7 – Composite map of precipitable water for all heavy rainfall events 12

Figure 6 – Composite map of 850 mb winds for all heavy rainfall events 11

Forcing

All else equal, greater synoptic scale forcing will result in higher rainfall rates

Some things we look at: 500mb heights and vorticity, 250mb jet streaks, warm air advection, isentropic lift, fronts, convergence, frontogenesis from surface to 700mb, etc.

Moisture

All else equal, greater available moisture will result in higher rainfall rates

Some things we look at: Precipitable water, integrated moisture transport, 850mb moisture transport (*heaviest rain most likely on northern gradient*), deep layer high RH, etc.

Instability and P.E.

Typically need some instability to get heavy rainfall rates

Some things we look at: CAPE profile (*thin and skinny; too thick leads to lofting of hydrometeors into hail growth layer*), deep warm cloud layer, deep layer high RH, lack of dry layers aloft, etc.

Duration

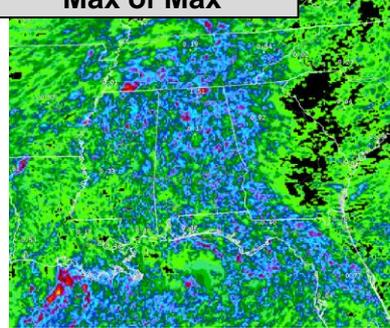
This one is simple: the longer rainfall lasts the higher totals will be

Some things we look at: cloud layer flow (*weak or parallel to boundary*), MBE vector, persistent upstream synoptic forcing, boundary motion, CAPE pool upstream, etc.

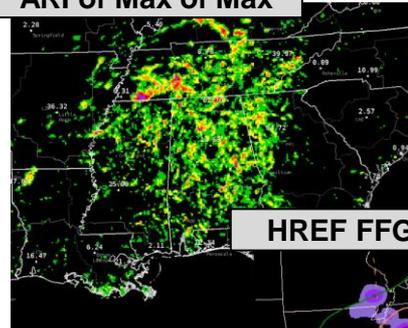
Tools available for ERO

- **Model QPF fields**
 - Trends, run to run consistency and model to model consistency all important
- **Ensemble Probabilities**
 - HREF: FFG and ARI exceedance, neighborhood and EAS probabilities
 - ECMWF ensemble and GEFS: threshold exceedance probabilities and spaghetti plots
- **Max of Max tool**
 - Maximum 1hr or 3hr rainfall over the ERO period for a given model, and then the maximum of all selected models. Can then compare this to FFG or ARIs
- **CSU machine learning**
 - The Colorado State University Machine Learning Probabilities model is intended to synthesize many different facets of forecast information to generate a 'first guess' ERO forecast
- **PQPF first guess field**

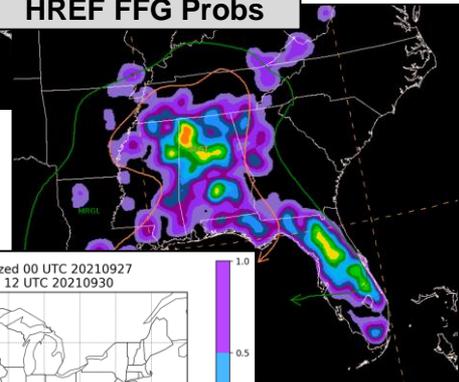
Max of Max



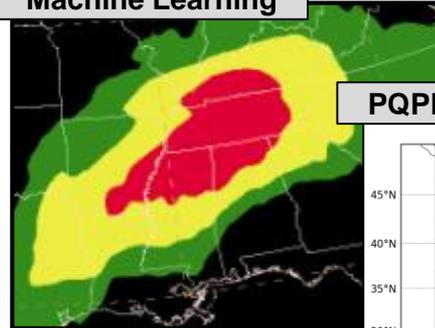
ARI of Max of Max



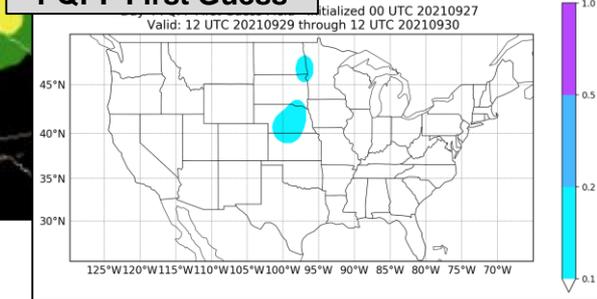
HREF FFG Probs



Machine Learning



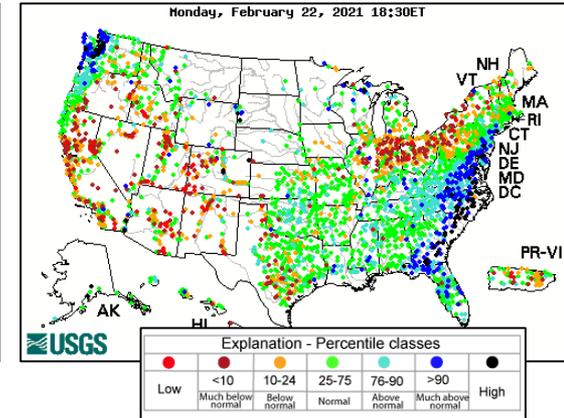
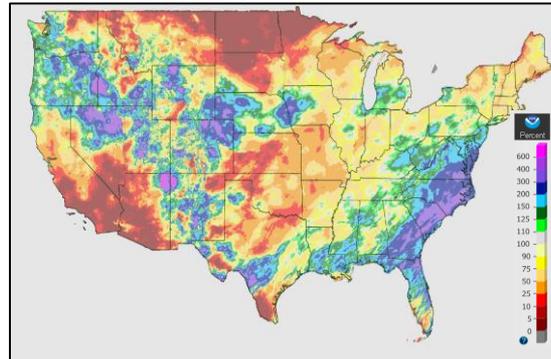
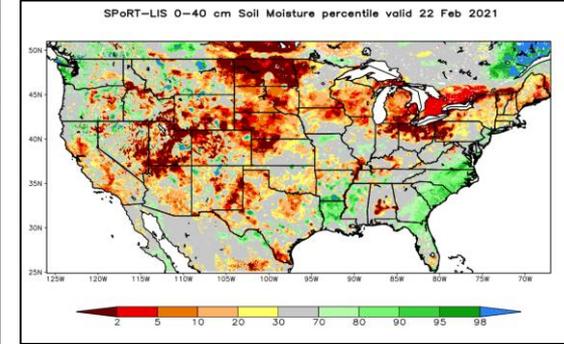
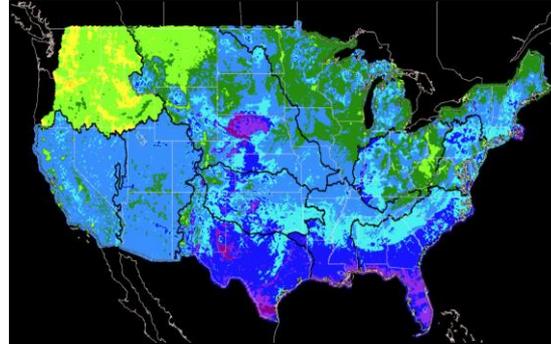
PQPF First Guess



Tools available for ERO

Antecedent Conditions

- Soil Moisture
 - NASA SPORT daily updating soil moisture percentiles. From 0-10cm to 0-200cm
- Streamflows
 - USGS percentiles
 - National Water Model
- Antecedent rainfall
 - AHPS anomalies
- Flash Flood Guidance



ERO Forecast Process at WPC

Start

WFO/RFC/NWC feedback solicited and incorporated through the process

End

If all these are pointing towards a potentially big event, confidence is increased in potentially significant impacts

Start with Continuity (previous ERO)

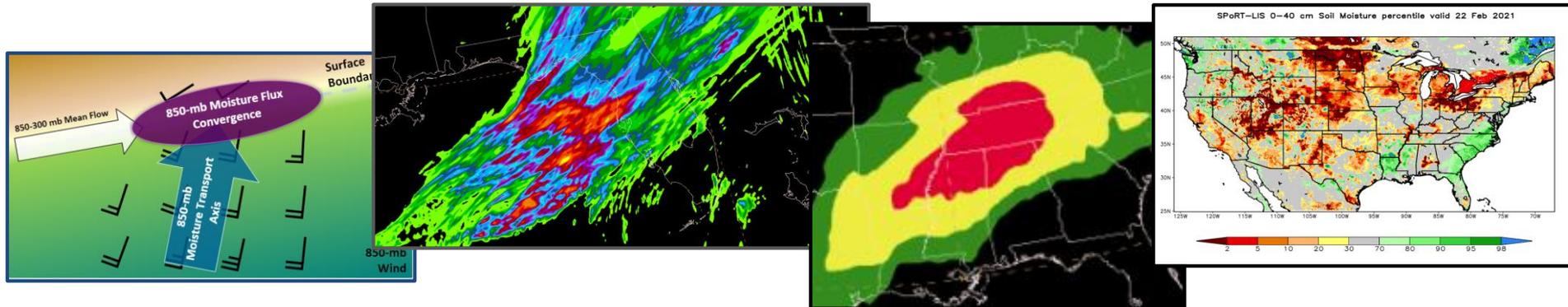
Ingredients based approach and conceptual models

Model QPF forecasts, trends and consistency

Post processed tools...e.g. FFG exceedance probabilities, machine learning

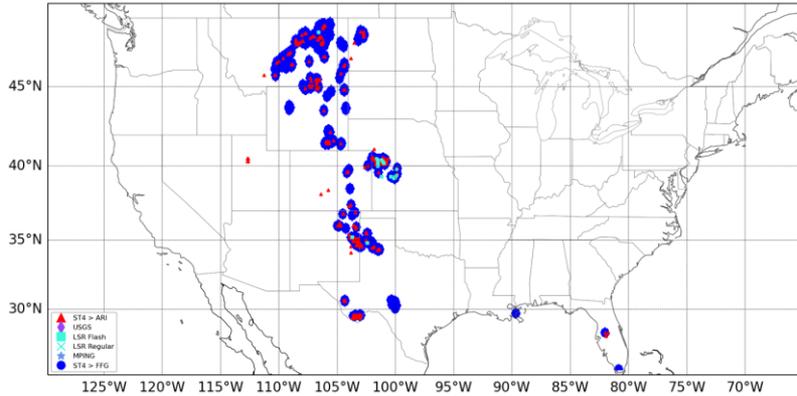
Antecedent conditions (hydrology concerns)

Assimilate all this information and modify ERO as needed

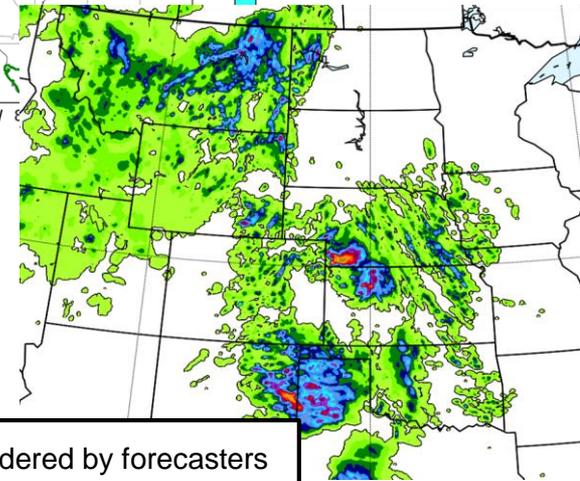
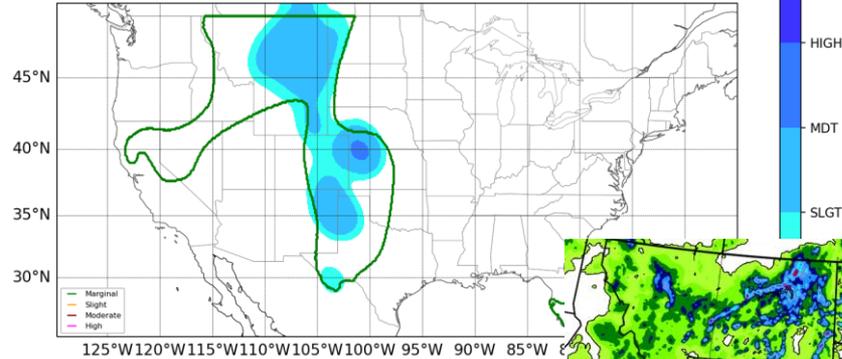


Complexity of the ERO forecast process

WPC Day 1 Verification Only
Valid: 12 UTC on 20230525 to 12 UTC on 20230526



WPC Day 1 ERO With ALL Practically Perfect: Issued 09 UTC
Valid: 12 UTC on 20230525 to 12 UTC on 20230526



What would have been the best forecast for MT...

Marginal? Only 1 flood report, so limited reported impacts

Moderate? ARI/FFG exceedance coverage would have supported one

Slight? Compromise of reported impacts and coverage of exceedance. Maybe best answer?

Practically Perfect supports a Slight

- ERO is objectively defined as a probability of exceeding FFG, however expected impacts are considered by forecasters
- Thus even knowing the verification, there is some subjectivity to what a perfect forecast would have been

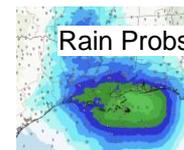
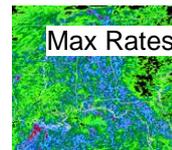
High Risk Decisions

To issue a **High Risk**, we are mostly looking for cases that have both:



High confidence in flash flooding occurring, to meet the 70% neighborhood probability definition

Tends to be an easier call, more relevant guidance available



Potential for exceptional impacts, which are generally **caused by sustaining high rain rates for an unusual duration**

Often a harder call; mesoscale subtleties more important
Antecedent conditions can be over-weighted – vulnerability of land surface important, but sustained high rain rates key



Most areas: fairly high confidence in 100+ yr ARI (and potential to go beyond that) for 24 hour period

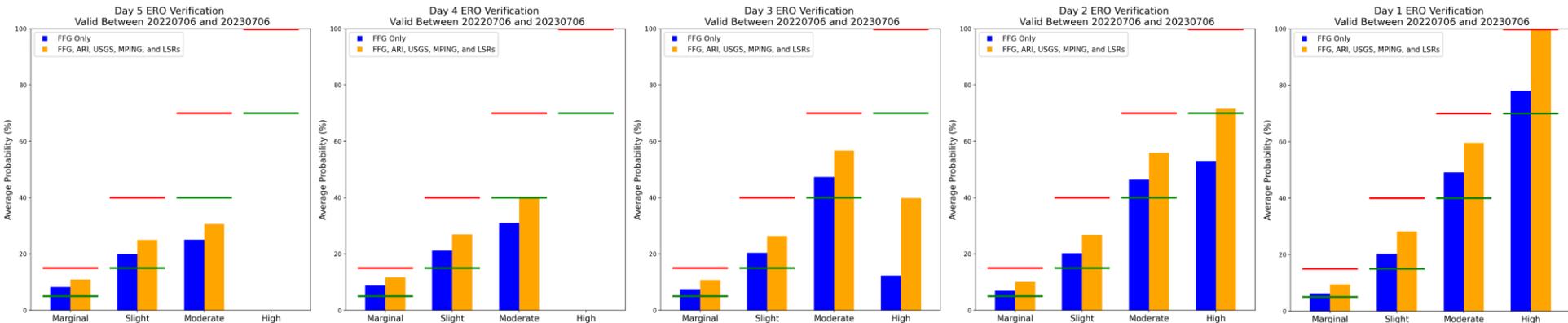


Urban areas: fairly high confidence in 100+ yr ARI (and potential to go beyond that) for 6 hour period



ERO Bulk Probabilities by Risk Category Past Year

HIGH: At Least 70% **SLGT: At Least 15%**
MDT: At Least 40% **MRGL: At Least 5%**



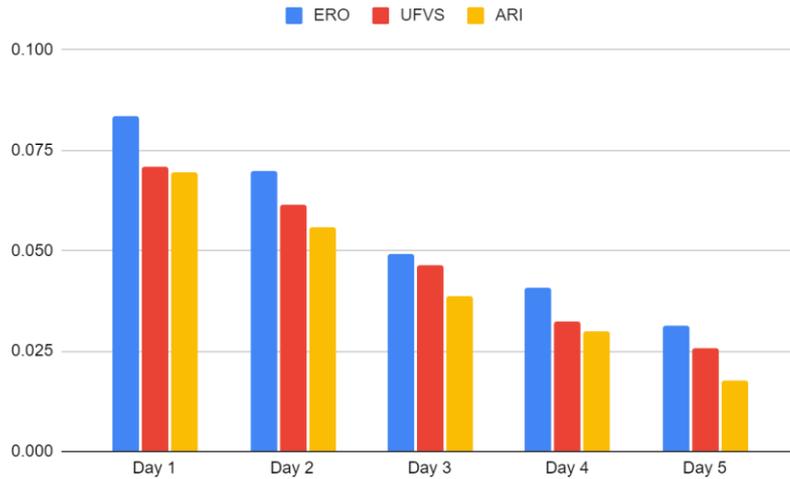
WPC EROs generally well calibrated to the definition

Upper Bound ———

Lower Bound ———

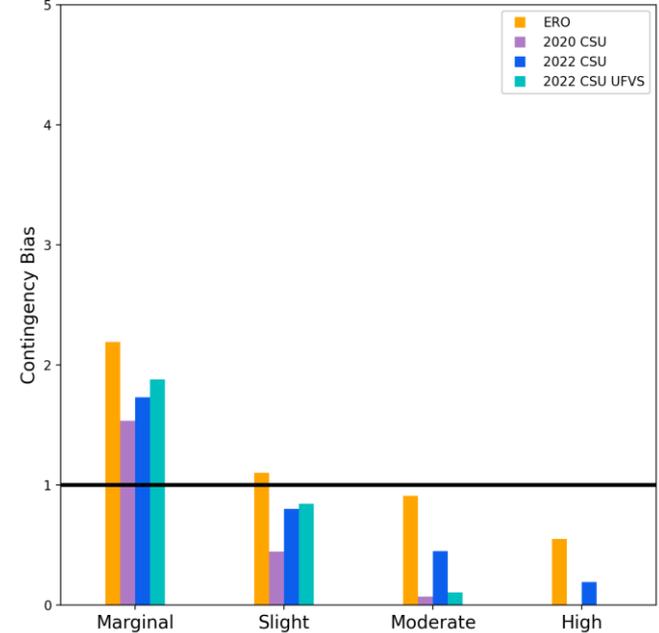
ERO BSS and Contingency Bias

BSS mean scores Apr-present



Generally a linear skill improvement from day 5 to 1

Day 1 Contingency Bias Compared to Practically Perfect Valid Between 20220706 and 20230706

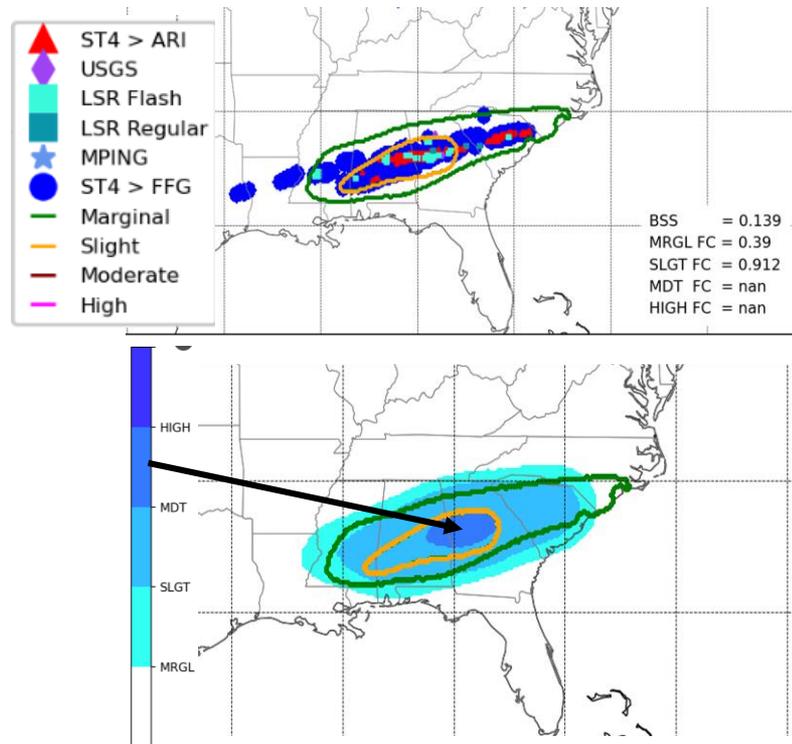


High bias with Marginal risk issuances
Slight and MDT risks show little bias on day 1



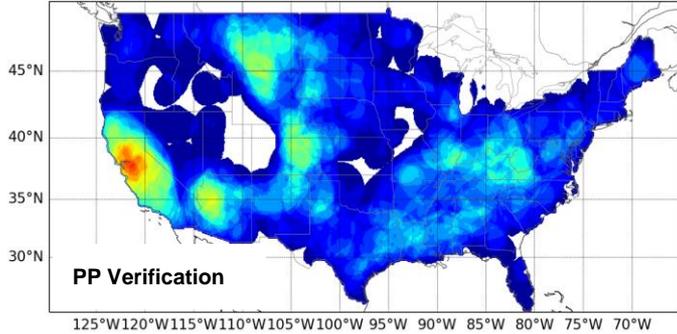
Practically Perfect Verification

- The Practically Perfect (P-P) method is a “Probabilistic Observation” used to evaluate the goodness of a probabilistic forecast
- P-P is derived from a field of “observations” and smoothed to subjectively match the forecast
- P-P can be used to answer the question “Did yesterday’s event justify a ERO High Risk?”
- P-P configuration utilizes:
 - a. USGS and Local Storm Reports (weighting of 1). Both flood and flash
 - b. Stage IV exceeding Flash Flood Guidance (weighting 0.35-0.6)
 - c. Stage IV exceeding Average Recurrence Interval (weighting 0.35-0.6)

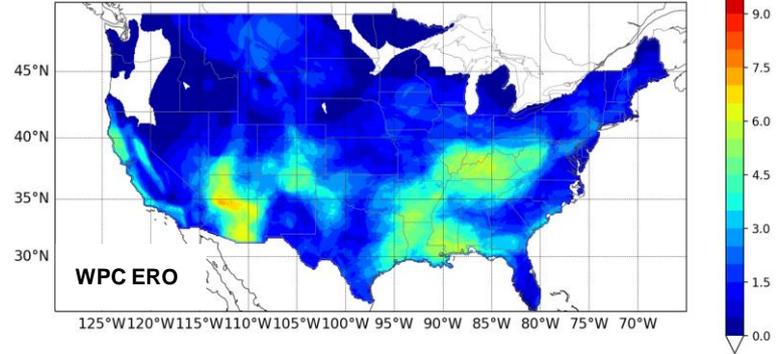


Slight Risk Heat Maps Past Year for Day 1

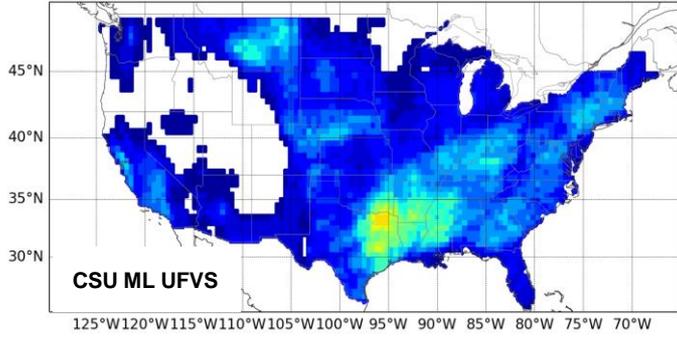
Day 1 Probability of being in a Slight PP Contour
Between 20220706 and 20230706



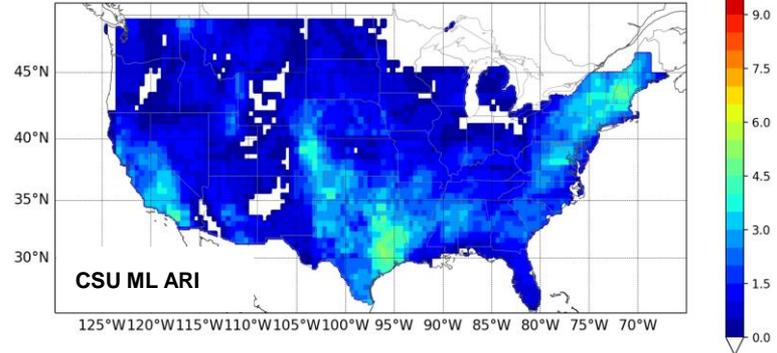
Day 1 Probability of being in a Slight ERO Contour
Between 20220706 and 20230706



Day 1 Probability of being in a Slight CSU UFVS v2022 Operational Contour
Between 20220706 and 20230706



Day 1 Probability of being in a Slight CSU v2022 Operational Contour
Between 20220706 and 20230706



Future of the ERO (topics being tested or in discussion)

Testing of 25% and 55% contours

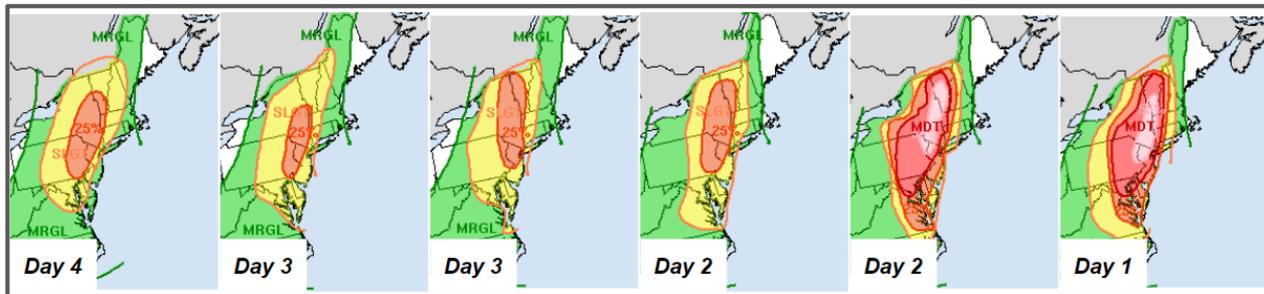
- **What:** Starting in late June WPC forecasters began drawing 25% and 55% contours as needed. Only viewable internal to WPC
- **Why:** Add more detailed probabilities. Big difference in expected impacts between a Marginal and Moderate risk. Forecasters often know whether a Slight is closer to a Marginal or Moderate, so why not share that info graphically?
- **Next Steps:** Collect and verify forecasts. Do we have skill with these new risk levels? If yes, pursue ways to share information outside of WPC. Maybe first just internal to NWS WFOs/RFCs, then maybe eventually a public product.

Extension out in time

- Recently expanded from day 3 to day 5.
- Considering eventual expansion to day 7 or 8

Hatched Contour?

- Area depicting higher end flash flood potential, similar to SPCs hatched area
- How would this be defined? WPC forecasters already take into account expected impacts when issuing ERO, so would this add value?
- For Slight risks that have high end potential? But would the 25% contour handle this adequate already?
- For High Risks with exceptional impacts? High risks are already rarely issued
- Lots of questions, and not currently being tested in WPC ops and no current plan to test



Future of the ERO (topics for thought)

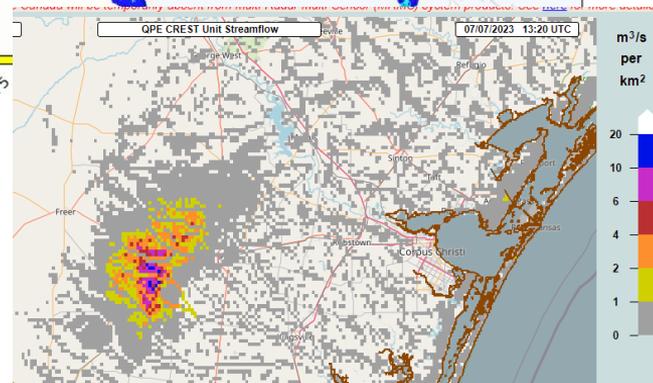
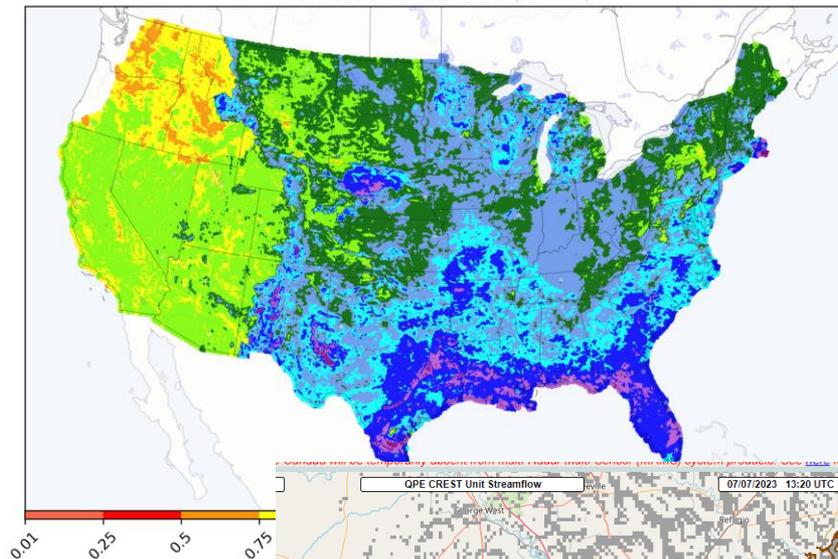
Future of FFG

- ERO objectively defined as exceedance of FFG
- FFG can be unreliable at times. Inconsistencies on RFC borders. Works well in some parts of the country, and not as well in others
- Just use LSRs in ERO definition? Inconsistent reporting of impacts, lagged reporting, different definitions by WFO.
- Just use ARIs in ERO definition? Begin to lose the connection to impacts. Different parts of the country have different impacts when exceeding certain ARIs. Antecedent conditions not accounted for. ERO intended to help partners understand flash flood risk and help inform WFO flood watches.

Next Steps

- Update FFG? Improved and consistent technique across the country, calibrated to flood impacts
- Back out FFG from FLASH or NWM?
- Pivot to using FLASH crest unit streamflow as a proxy instead of FFG exceedance? Correlated to impacts. Could this be run through an ensemble such as the HREF/RRFS to provide guidance
- Could also use NWM observed AEP as proxy. Correlation to impacts less know at this time. Would need the ability to run this though both short and medium range ensembles

12Z 5km RFC 1 HR FFG (inches)



Future of the ERO (topics for thought)

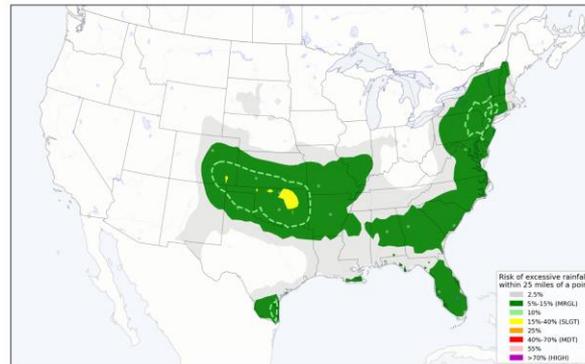
Continue to leverage new science advances...Machine learning (ML) a big part of this

- A majority of past/ongoing research focused more towards severe weather. Need continued investment/research in exploring these techniques for flash flood forecasting.
- Does ML have any skill in predicting higher end flash flood impacts...considerable or emergency tagged FFWs?
 - Might be too rare of an event for ML techniques?
- Can we run ML technique on a high res ensemble?
 - Unfortunately might not have a long enough data to train with
- Run ML technique on the ECMWF ensemble?
 - ECMWF runs a ~20 year reforecast every time the model system is updated. So should have more than enough training data.

FV3GFSR CSU First Guess Field 24hr Day 3 ERO (v2022) Trained on UFVS
Issued at 00z 20230707 Valid from 12z 20230709 to 12z 20230710



HRRR CSU First Guess Field 24hr Day 1 ERO Issued at 00z 20230707
Valid from 12z 20230707 to 12z 20230708



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