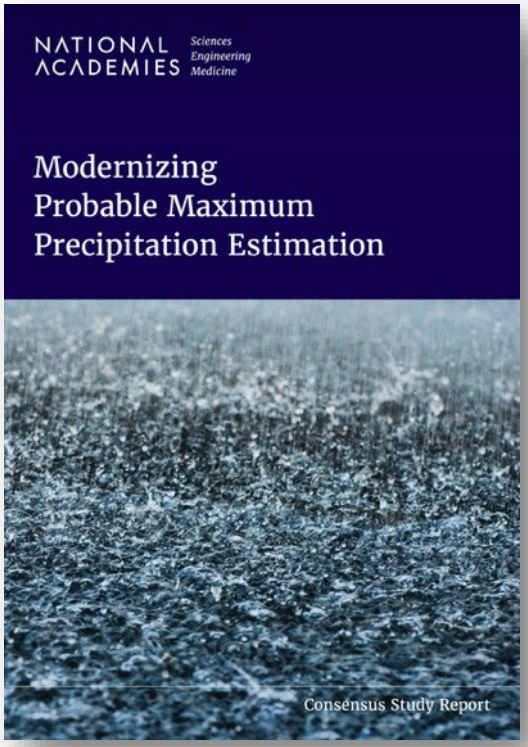
Stochastic Storm Transposition in mountainous terrain: probabilistic spatial methods for extreme rainfall and flood analysis in mountainous terrain

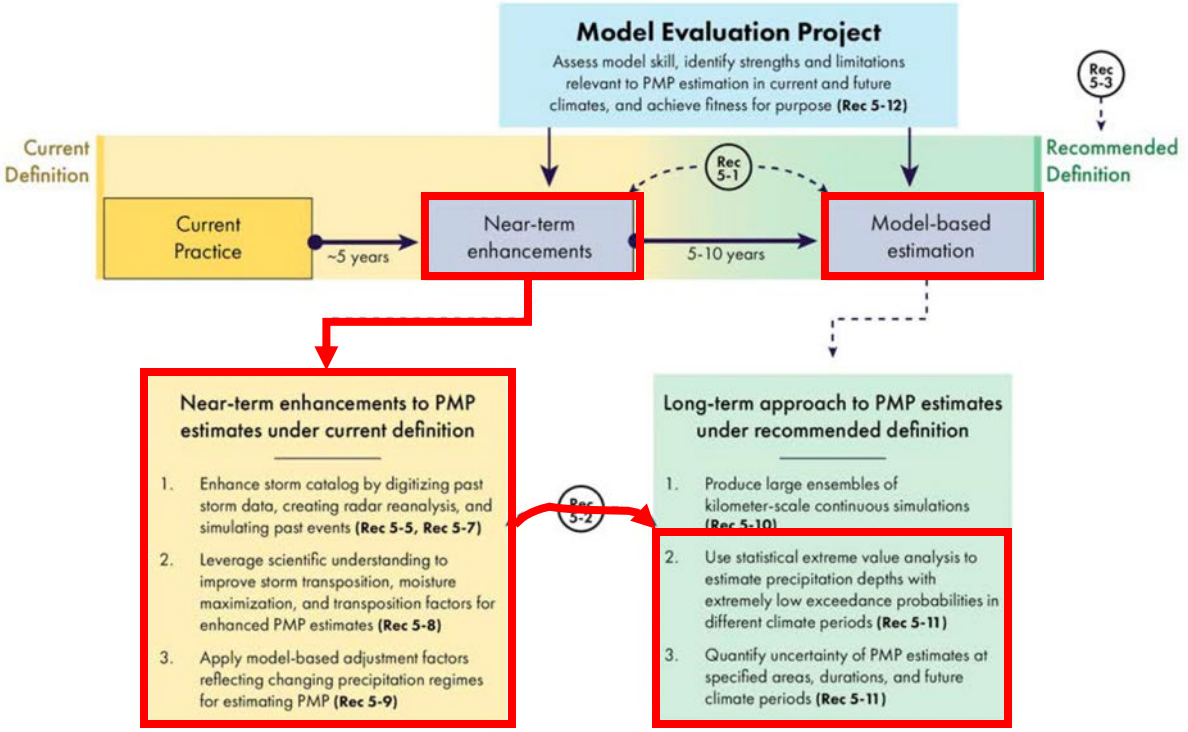
Daniel Wright
Arno Lenz Memorial Associate Professor
Civil and Environmental Engineering
University of Wisconsin-Madison

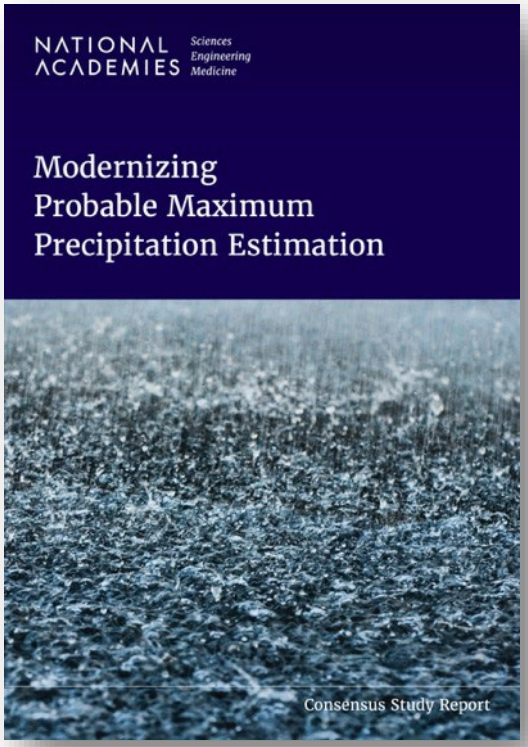
WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON

Olympus Dam
Oil on Canvas
X. Gonzalez (1898-1993)



- **Recommendation 5-8:** Leverage scientific understanding to improve **storm transposition... and transposition factors** for enhanced PMP estimates
- **Recommendation 5-11:** Use statistical extreme value analysis to **estimate precipitation depths with extremely low exceedance probabilities; quantify uncertainty of PMP estimates [for] specific areas, durations, and future climate periods**





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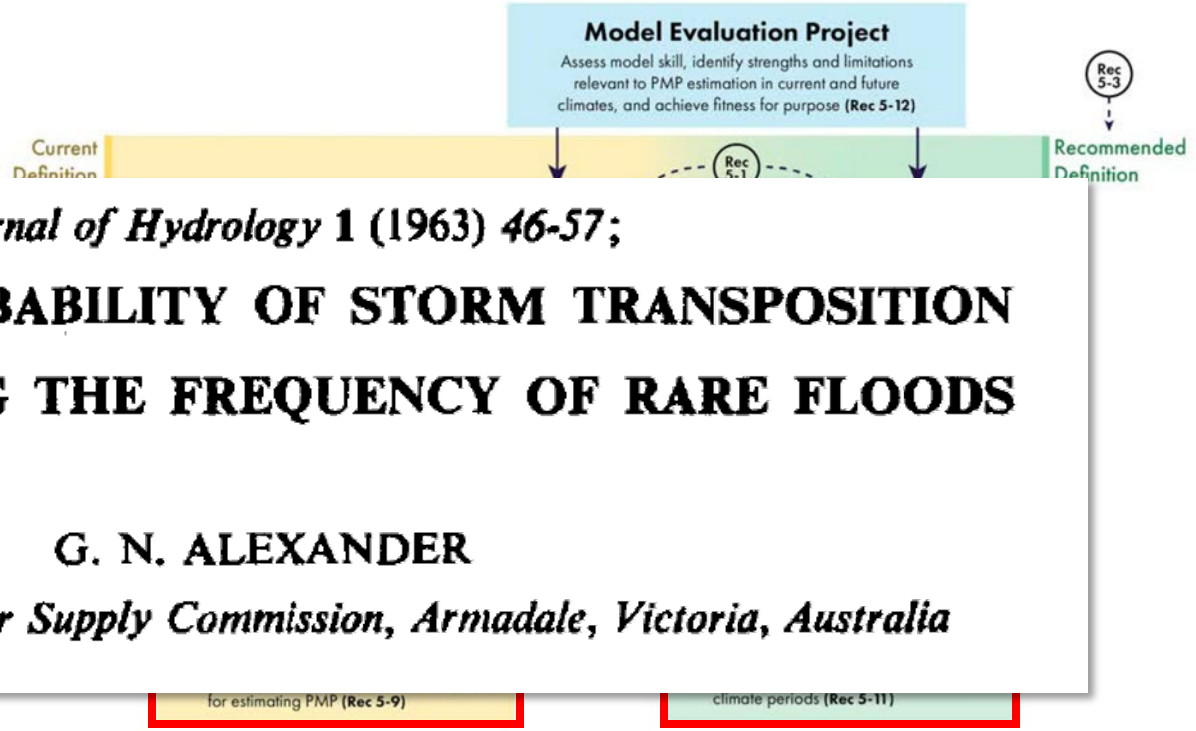


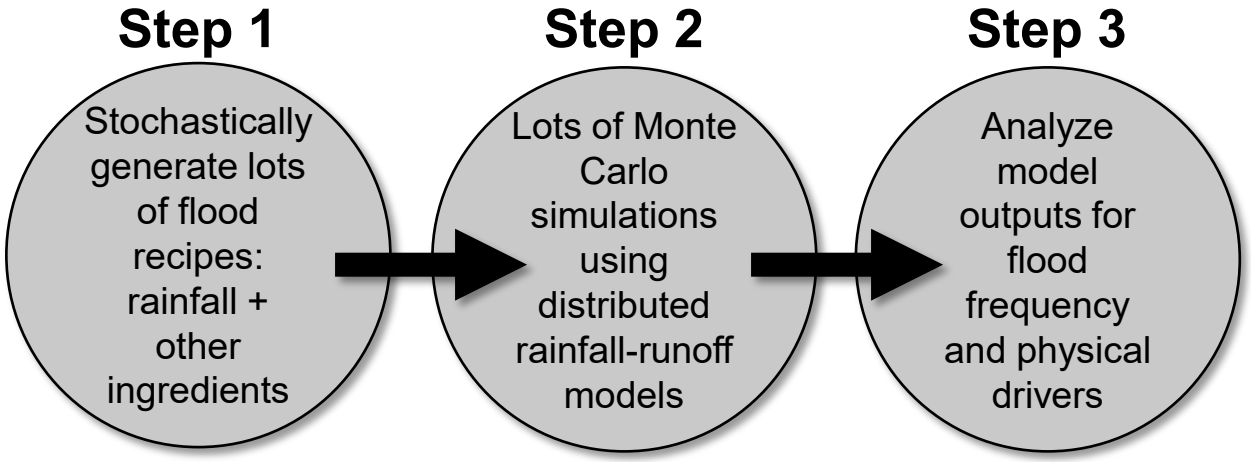
Journal of Hydrology **1** (1963) *46-57*;

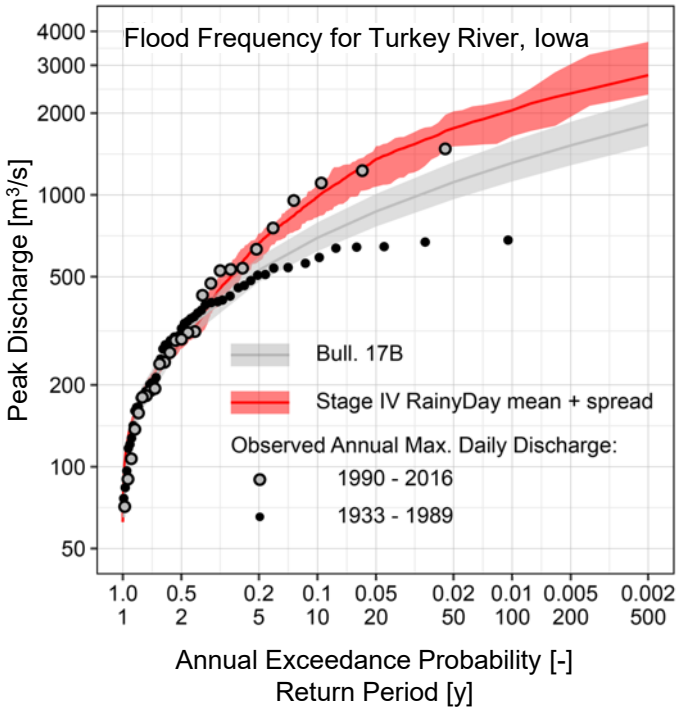
USING THE PROBABILITY OF STORM TRANSPOSITION FOR ESTIMATING THE FREQUENCY OF RARE FLOODS

G. N. ALEXANDER

State Rivers and Water Supply Commission, Armadale, Victoria, Australia

Stochastic Storm Transposition (SST) for Rainfall AND Flood Frequency Analysis

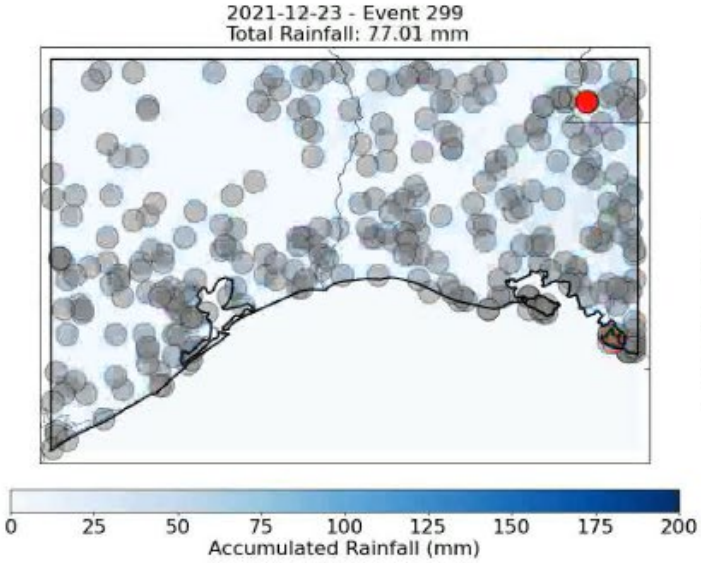


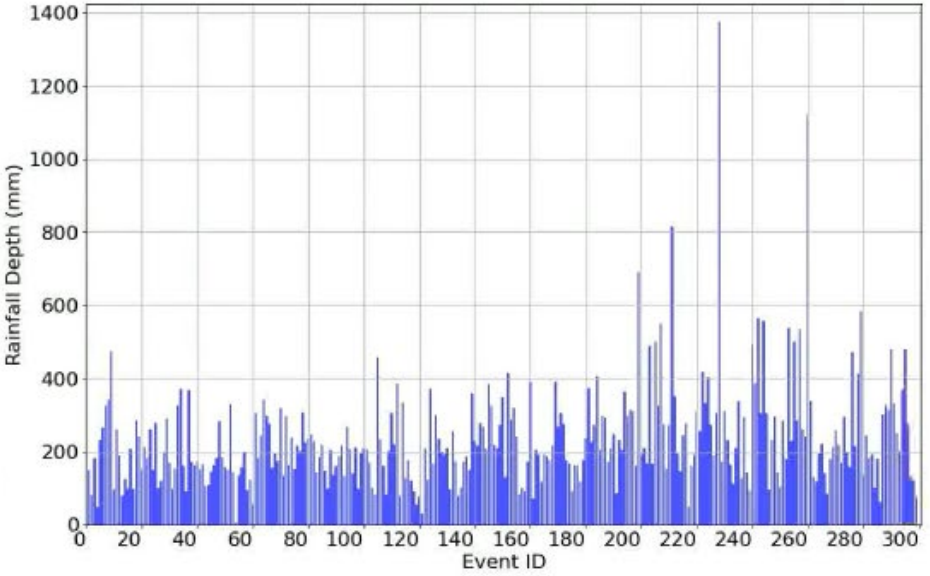


Yu et al., Process-based flood frequency analysis in an agricultural watershed exhibiting nonstationary flood seasonality, *HESS* (2019)

What is Stochastic Storm Transposition?

Create regional <u>Storm Catalog</u>

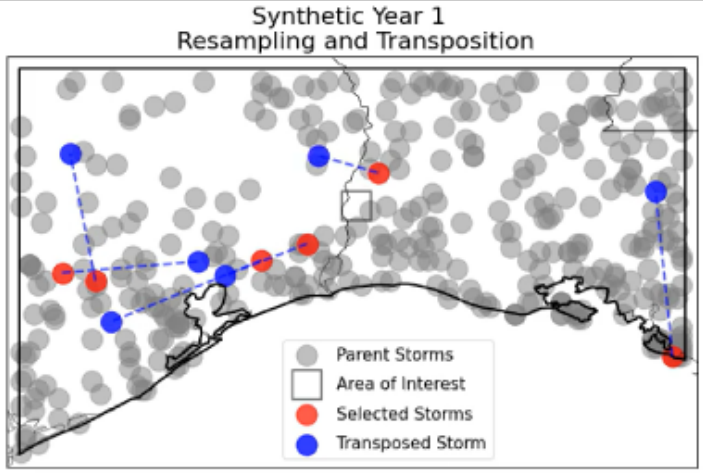


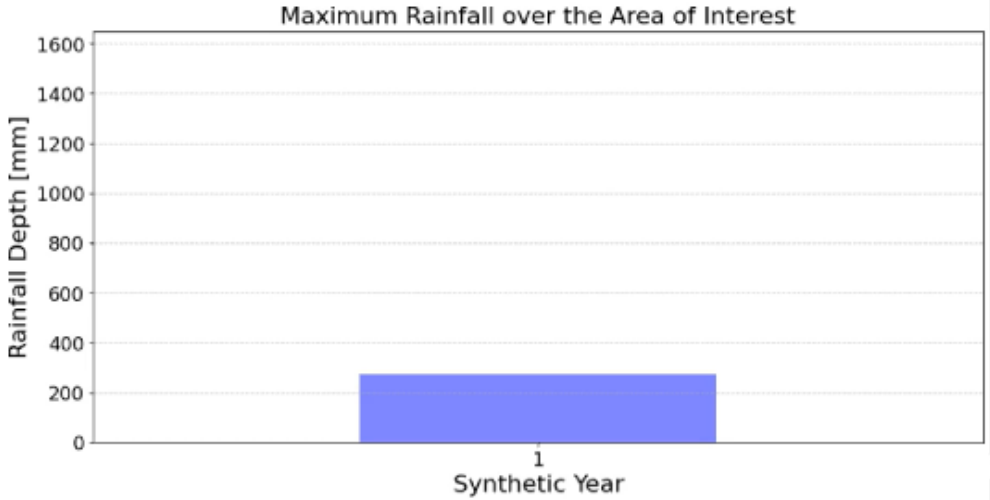


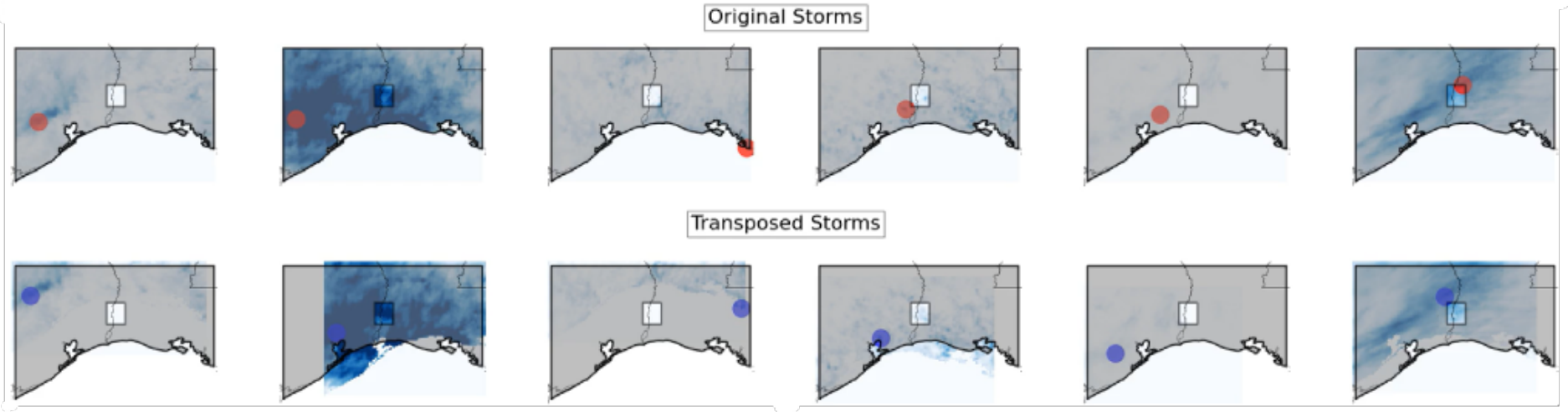
Videos courtesy of G. Perez-Mesa, Oklahoma State University

What is Stochastic Storm Transposition?

Randomly sample and transpose to create hypothetical year



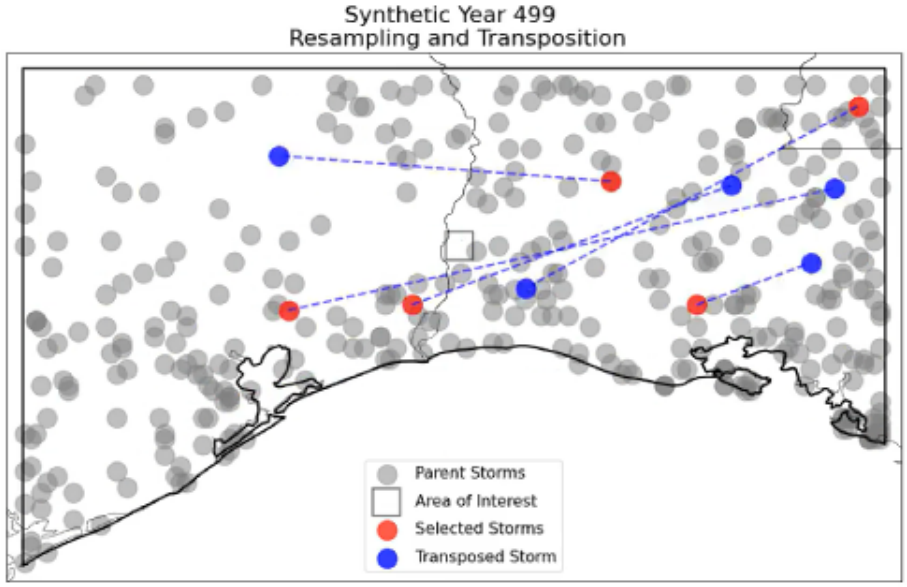


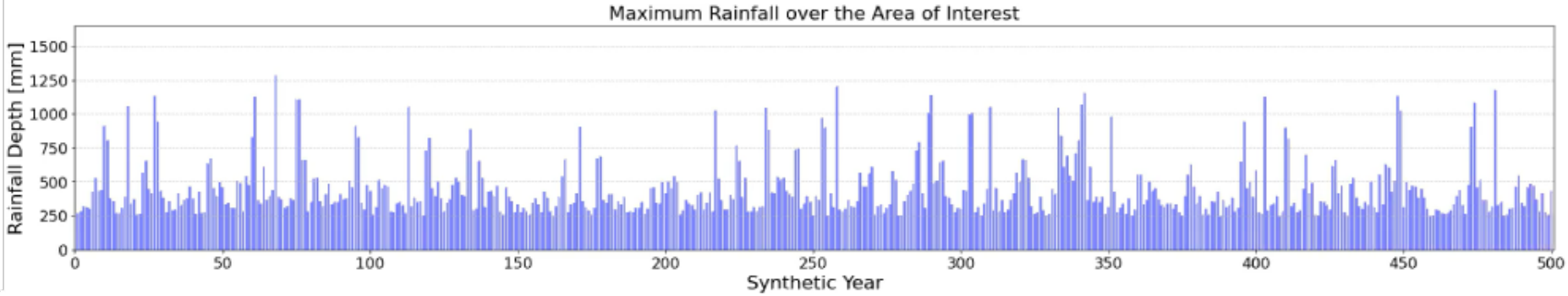


Videos courtesy of G. Perez-Mesa, Oklahoma State University

What is Stochastic Storm Transposition?

Rise and repeat, a lot of times

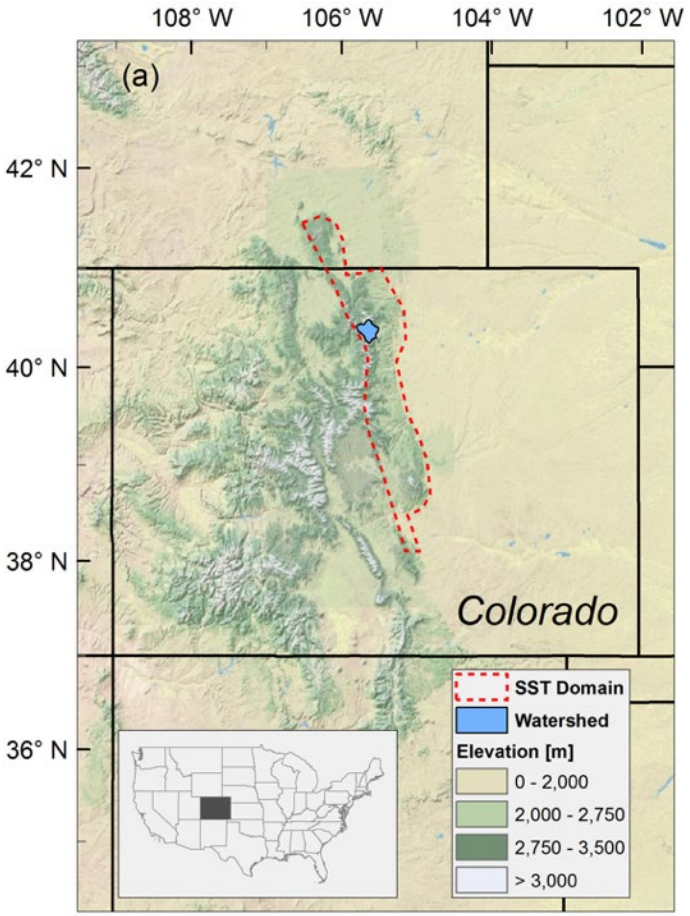


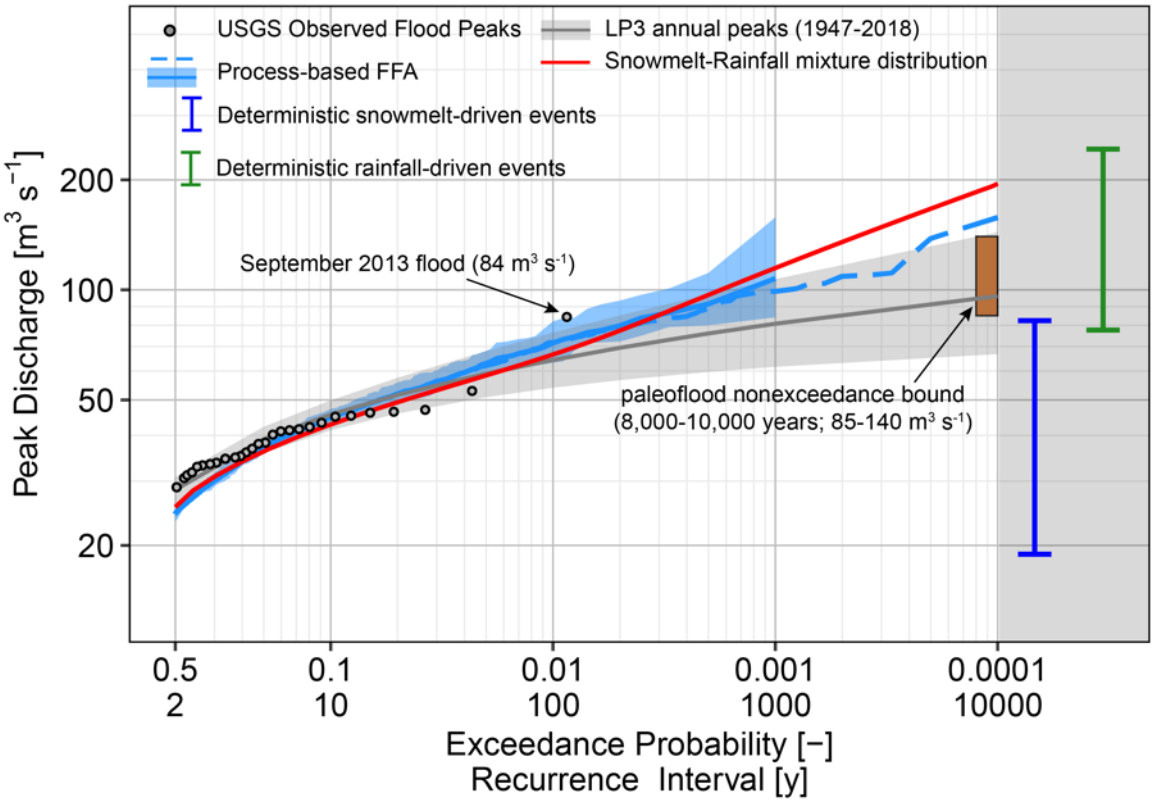


Videos courtesy of G. Perez-Mesa, Oklahoma State University

“Stochastic Storm Transposition using a regional storm catalog”— but what region?

“[a transposition domain could] include a very large geographic area in the eastern half of the United States where (topographic) relief is generally moderate and it may include relatively small areas in the western United States where extreme topography is encountered.”—V. Gupta, *Transposition of Storms for Estimating Flood Probability Distributions*, 1972



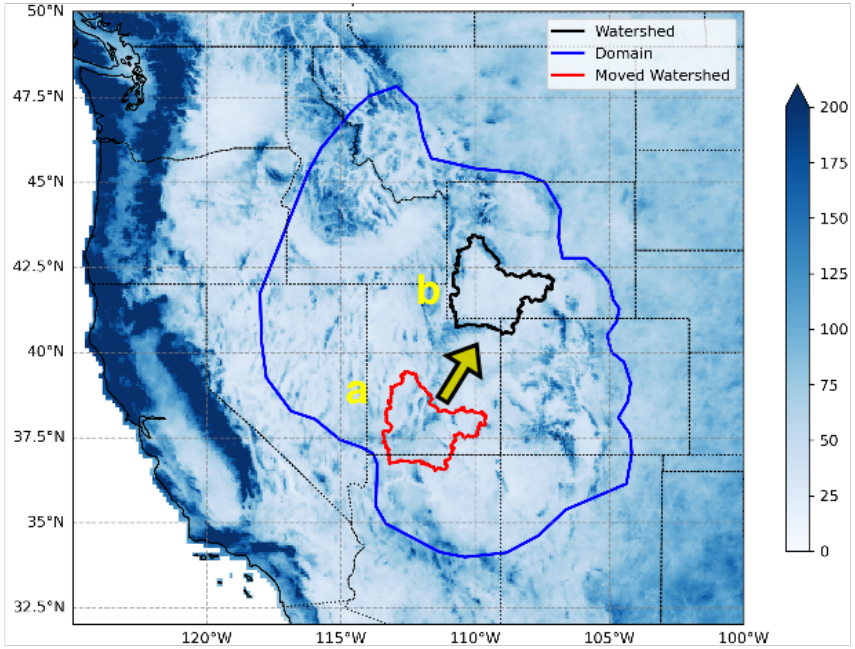


Yu et al., Connecting Hydrometeorological Processes to Low-Probability Floods in the Mountainous Colorado Front Range, *WRR*, 2021

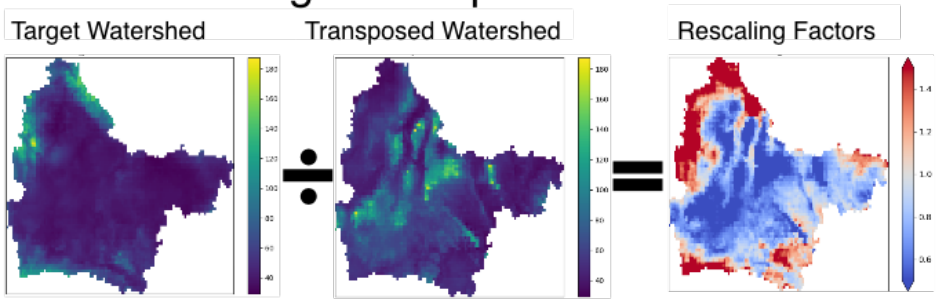
Transposition Regions vs. Transposition Factors

- FitzGerald et al., An L-Moments-Based Hypothesis Test to Identify Homogeneous Storm Transposition Regions, in revision, *J. Hydrology*
- Yan et al., in prep.

Resampling and Transposing



Rescaling: "Transposition Factors"



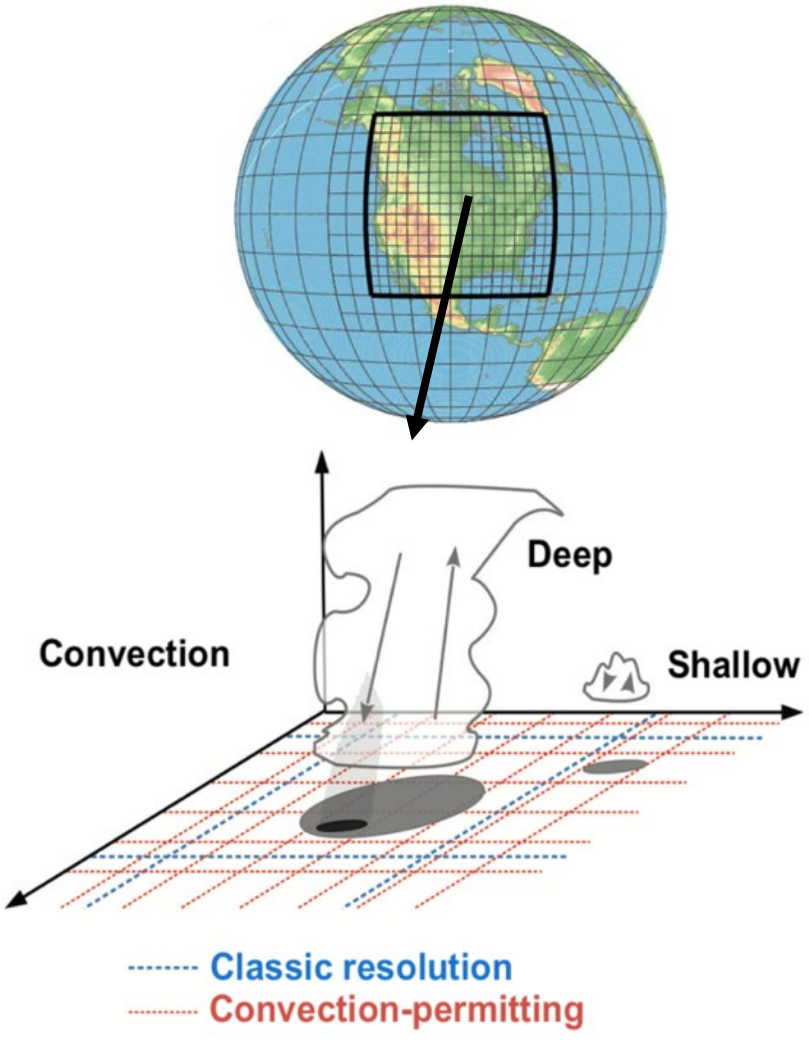
$$p_{trans} = \frac{R_{(x_b,y_b)}}{R_{(x_a,y_a)}} * p_{(x_a,y_a)}$$

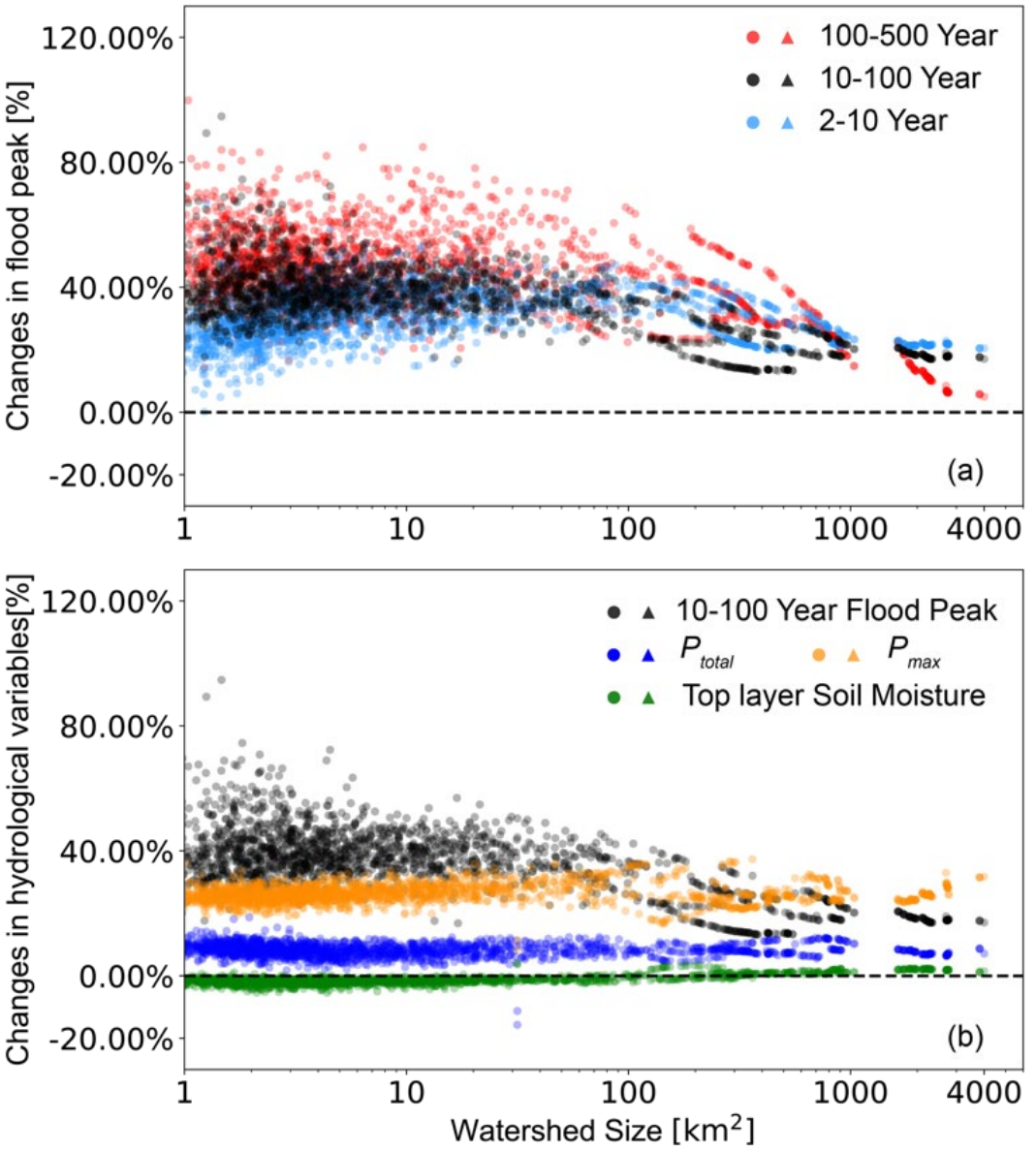
(x_a, y_a) is the **transposed** location and (x_b, y_b) is the **target** location

$p_{(x_a,y_a)}$ and p_{trans} are the rainfall before and after transposition

$R_{(x_a,y_a)}$ and $R_{(x_b,y_b)}$ are the **10-year** design rainfall for location a and b

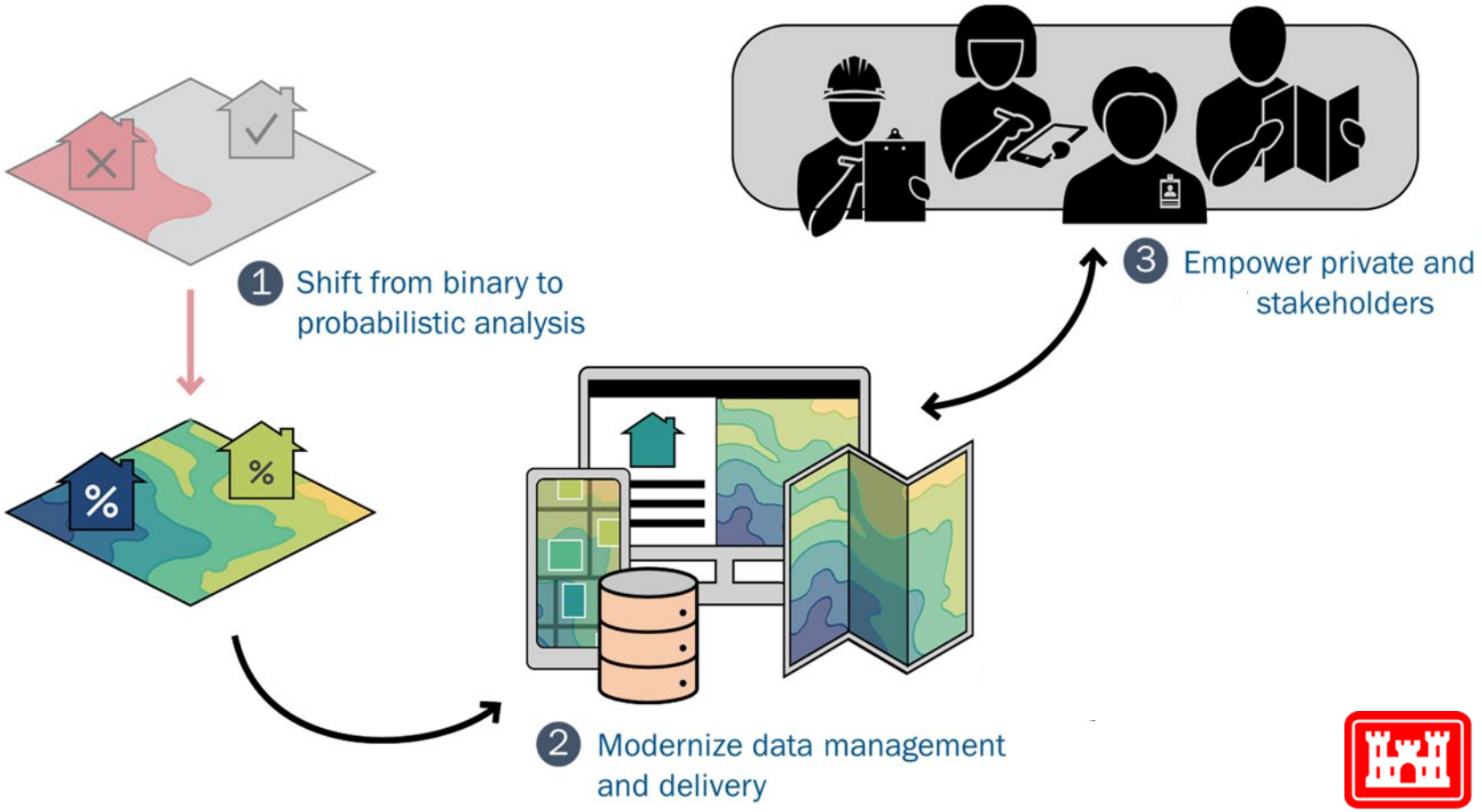
“Model-based estimation”: SST easily handles high-res atmospheric model predictions





Yu et al., The Upper Tail of Precipitation in Convection-Permitting Regional Climate Models and Their Utility in Nonstationary Rainfall and Flood Frequency Analysis, *Earth's Future*, 2020

SST methods/tools development in a major Federal effort: Future of Flood Risk Data (FFRD)



- **Ultimate goal:** modernize National Flood Insurance Program
- Probabilistic hazard and risk up to 2,000-year return period
- Stochastic Storm Transposition rainfall and hydrology (in HEC-HMS) with objective transposition domains and rainfall transposition factors (from Atlas 15)

US Army Corps of Engineers®

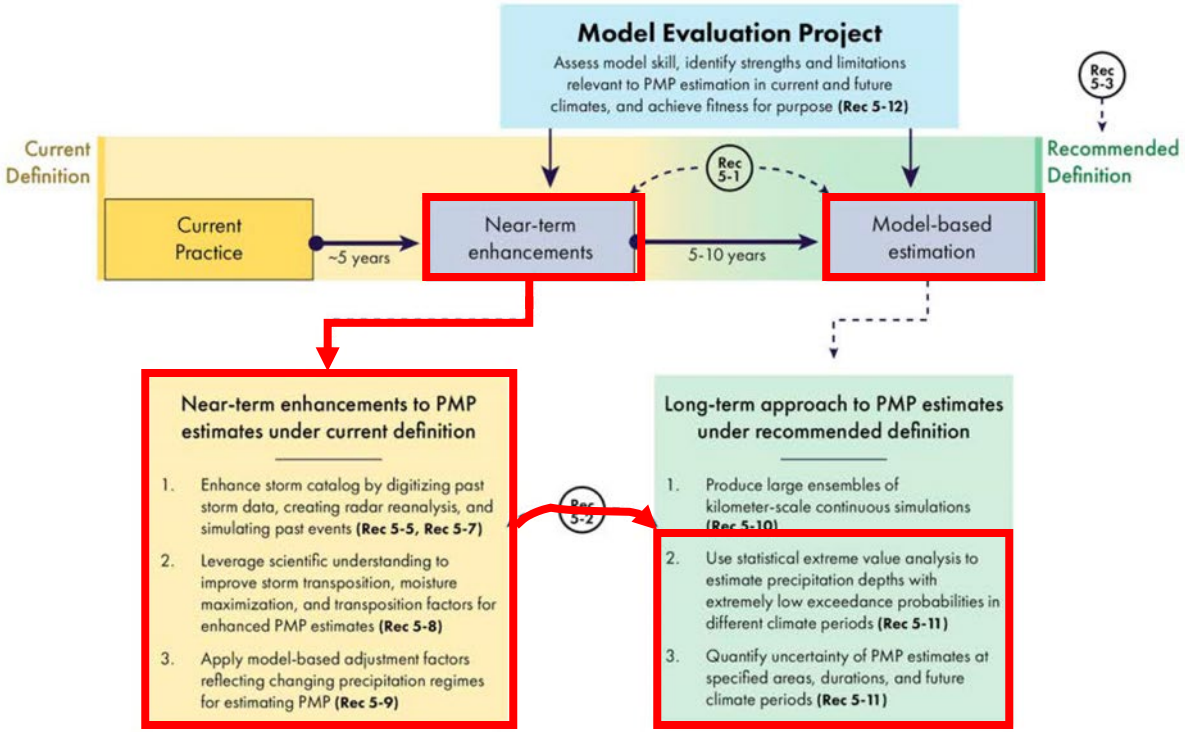
FEMA

Perspectives/Recommendations

1. **We need methods for Probable Maximum Flood, not just PMP:** Particularly if you want annual exceedance probabilities and uncertainty estimates; rainfall and particularly warm-season rainfall in mountainous terrain is still the lynchpin

2. **Stochastic Storm Transposition meets most of both short-term and long-term recommendations of the NASEM report:**
   - Provides AEPs (including low/rare values) and uncertainty
   - Can incorporate climate model simulations and historical storms fairly easily
   - Can consider transposition factors for mountainous terrain

3. **SST approach to PMP/PMF can provide opportunities to coordinate with other Federal rain/flood efforts:**
   - FFRD, Atlas 15, HEC-HMS
   - Maybe more important now than ever!



Questions?

danielb.wright@wisc.edu