Modernizing probable maximum precipitation at NOAA

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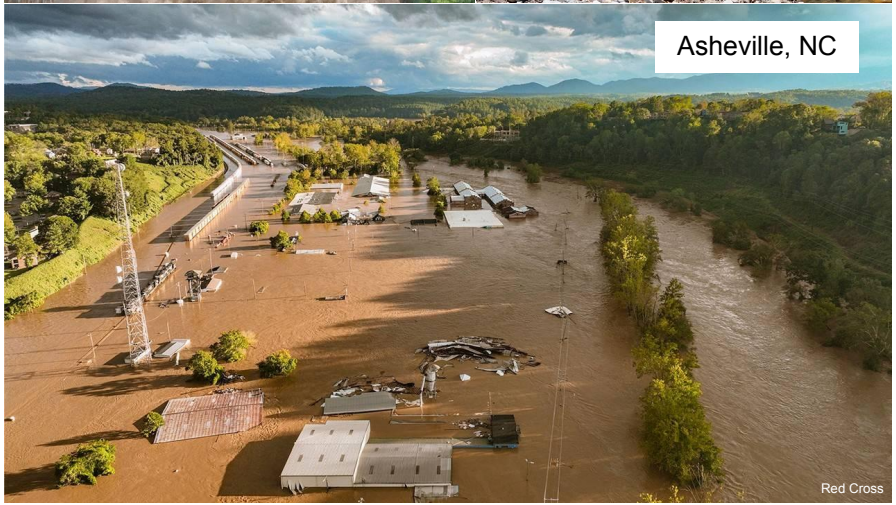
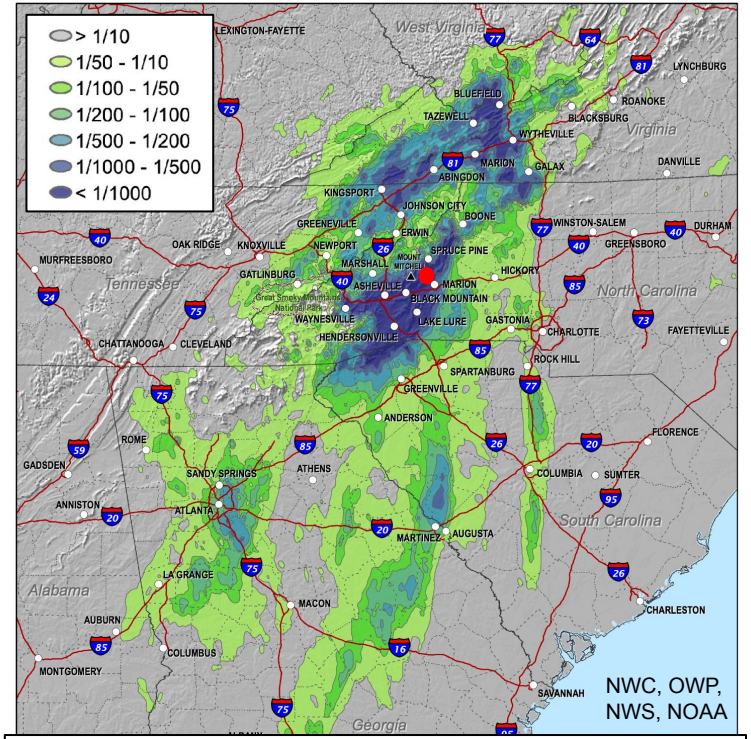
Hurricane Helene, Sept. 23–28, 2024

Nolichucky River Dam, TN

Chimney Rock, NC

Asheville, NC



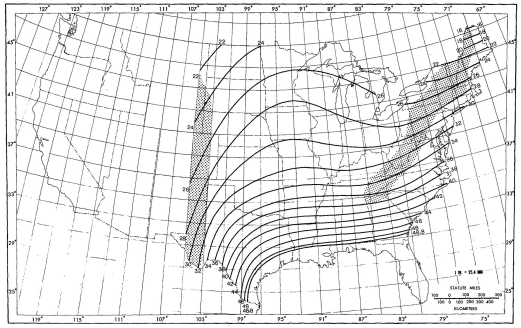


Helene, 23 - 28 September 2024
Annual Exceedance Probabilities (AEPs) for the Highest 3-day Rainfall Period

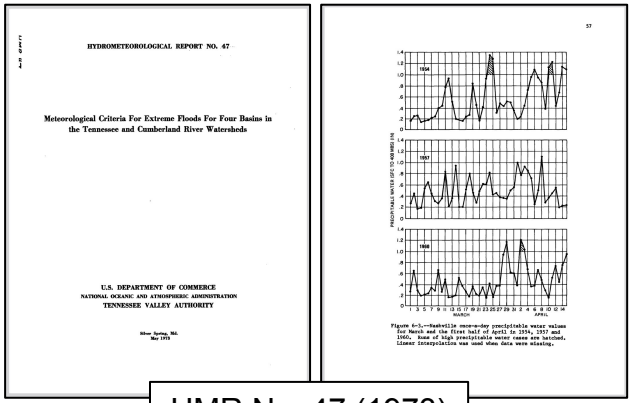
Max rain:
~31 inches
Busick, NC
Sept. 25-27
(72h period)

Probable Maximum Precipitation (PMP)

- Definition: *"maximum depth of precipitation over a given area and duration that is meteorologically possible"*
  - *Storm-based: worst case maximum rainfall*
- Design standard for high-hazard infrastructure, e.g., dams
- Calculated from observations in NOAA Hydrometeorological Reports (HMRs) during 1960s to 1990s



HMR No. 51 (1978)

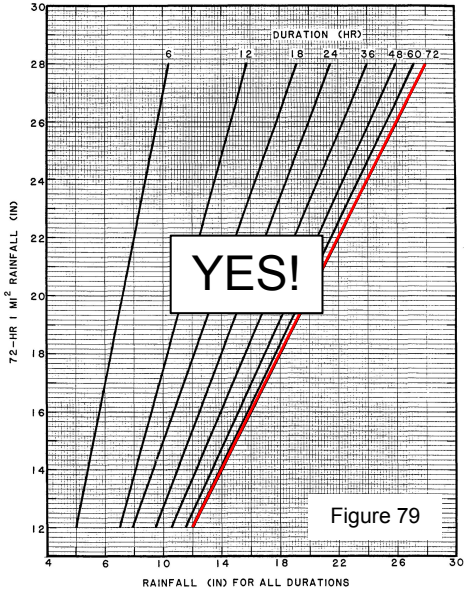


HMR No. 47 (1973)

Was Hurricane Helene a PMP event?

- Maximum rainfall measurement: ~31 inches over 72-hour period (Busick, NC)

HMR 56 (1986)



For TVA region, PMP = 28 inches for 72h rainfall

HMR 51 (1978)

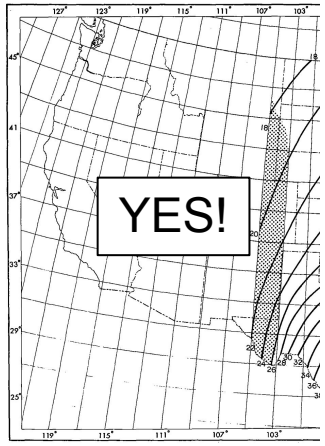


Figure 32

72h 1,000 mi^2
28–30 inches

Figure 27

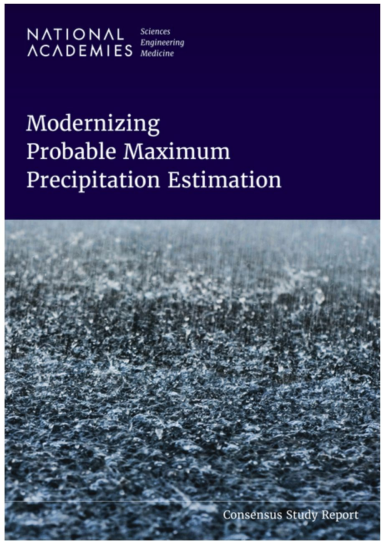
72h 200 mi^2
34–36 inches

Figure 22

72h 10 mi^2
44–46 inches

Modernizing PMP estimation

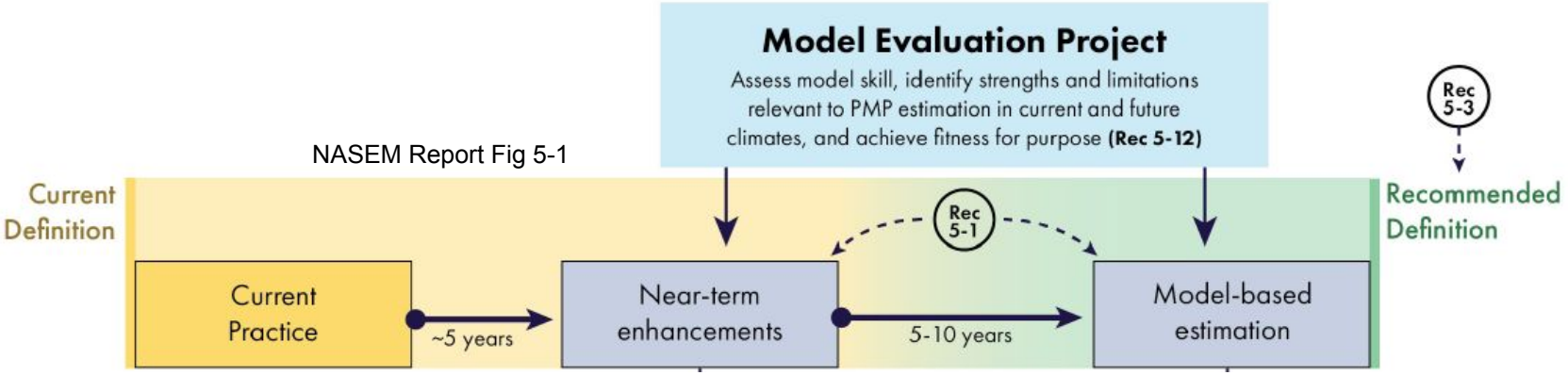
- Outside of specific private sector activities, PMP has not been updated in decades
- Congress tasked NOAA with modernizing PMP estimation with language in the Bipartisan Infrastructure Law and PRECIP Act (2022)
- National Academies of Sciences, Engineering, and Medicine (NASEM) report released in 2024
  - Issued short- and long-term recommendations to NOAA



National Academies of Sciences, Engineering, and Medicine. 2024. *Modernizing Maximum Precipitation Estimation*. Washington, DC: The National Academies Press. https://doi.org/10.17226/27460

Timeline for modernization

NASEM Report Fig 5-1



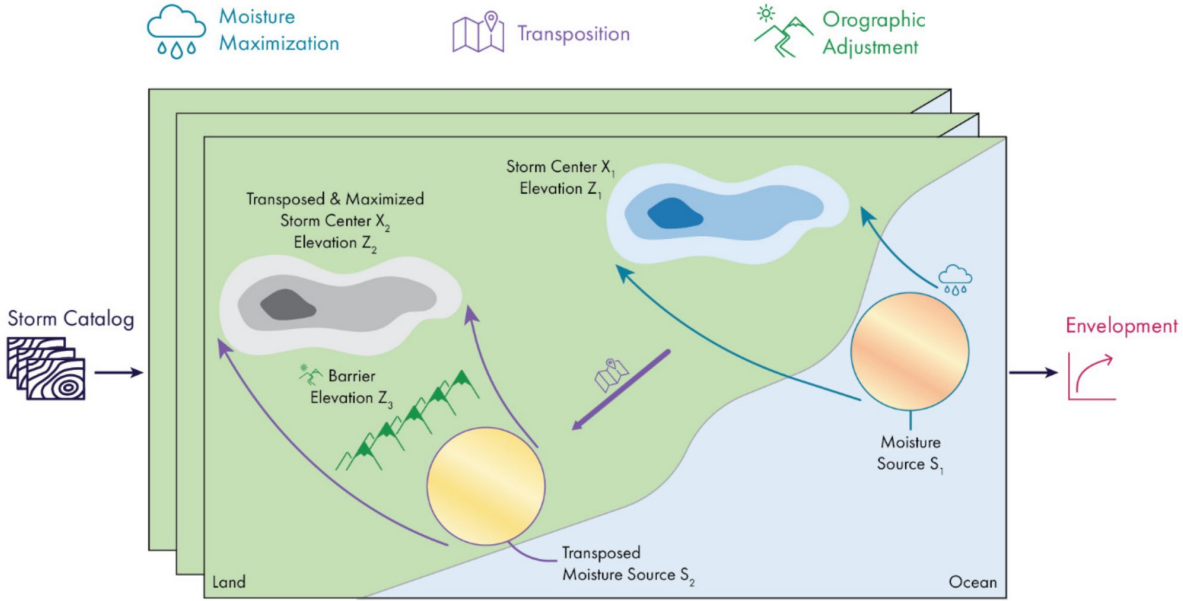
Current Practice

- PMP is defined as a theoretical maximum (i.e., "*upper bound*")
- Estimates based on "*limited observational datasets*"
- "*Subjective estimation procedures*" applied to historical storms to achieve maximization

Italics are quotes from NASEM Report

"*Subjective estimation procedures*"

- Transposition and moisture maximization of historical storms



NASEM Report Fig 2-1

Current PMP estimation

NOAA HMR

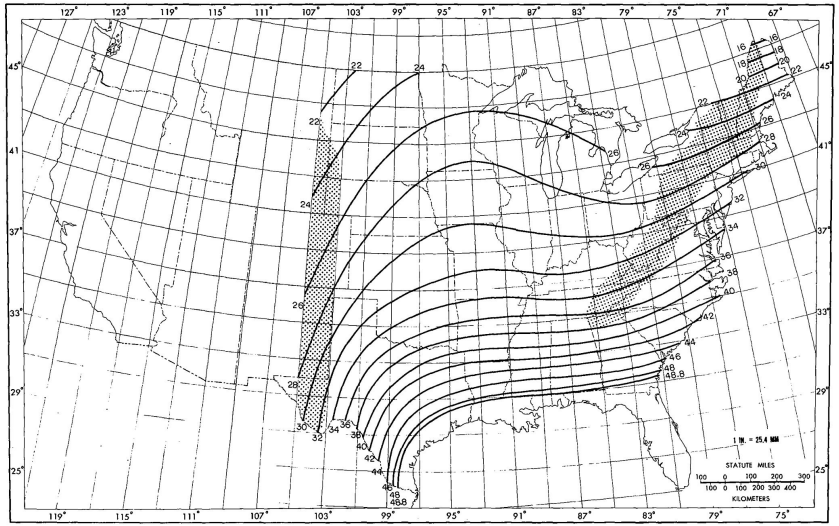
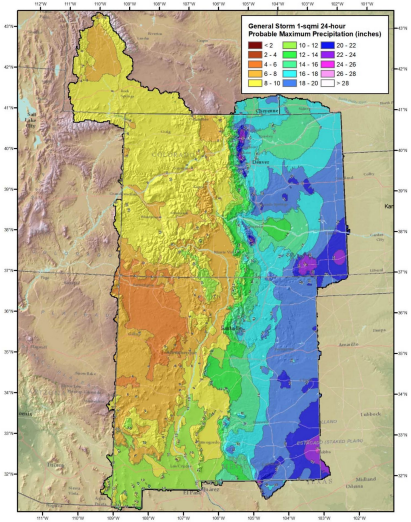


Figure 27. --All-season PMP (in.) for 72 hr 200 mi^2 (518 km^2)

HMR No. 51 (1978)

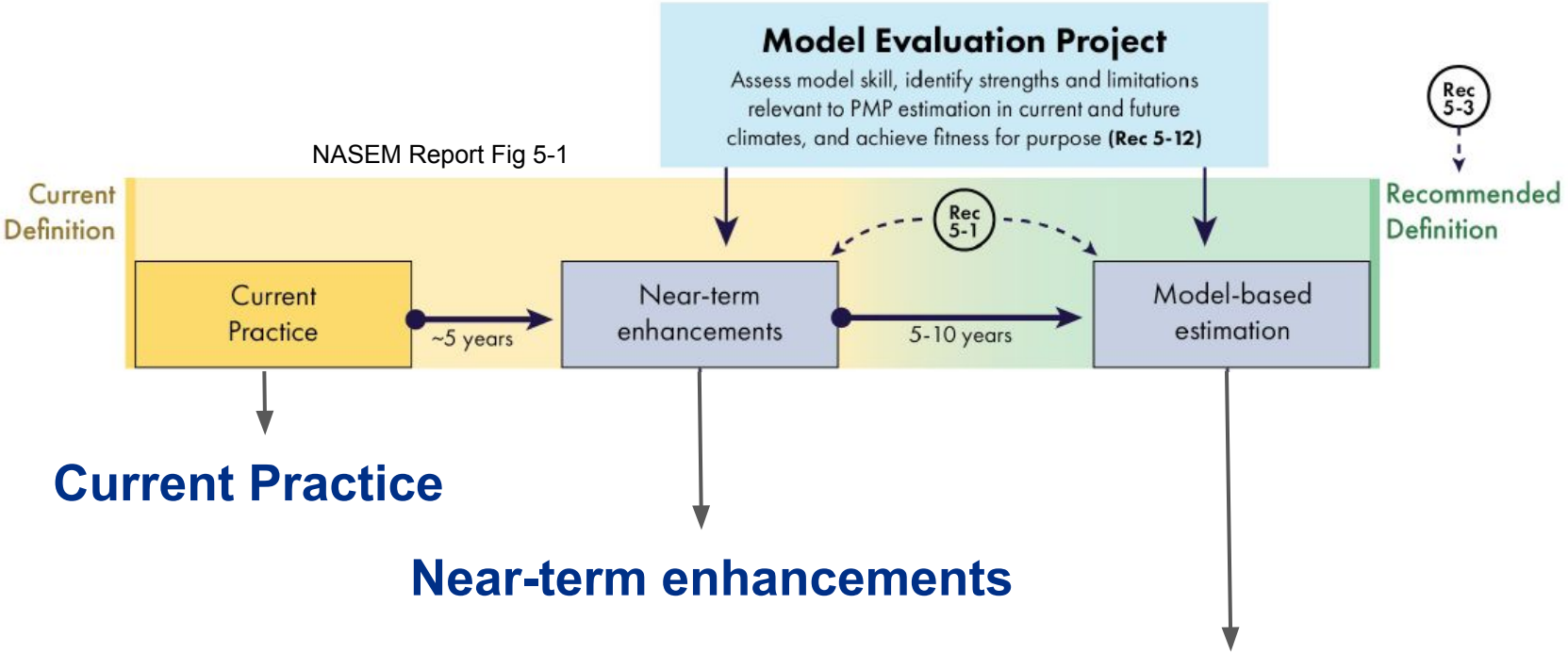
Site-specific studies



General Storm 1mi^2 24h PMP (inches)
(from Volume II Appendix A)

CO-NM Regional Extreme Precipitation Study (2018)

Timeline for modernization



Modernizing PMP estimation

- **New, revised definition** (Recommendation 5-3)

- **Model-based estimation** (Recommendation 5-10)

Recommendation 5-3: Revised definition

- **Current definition:** *"maximum depth of precipitation over a given area and duration that is meteorologically possible"*
  - Assumes rainfall has an upper bound
  - Deterministic → single value with no uncertainty
- **New definition**: *"the depth of precipitation for a particular duration, location and areal extent, such as a drainage basin, with an extremely low annual probability of being exceeded, for a specified climate period"*
  - Assumes no upper bound of rainfall
  - Probabilistic → included annual exceedance probability (AEP)-based uncertainty

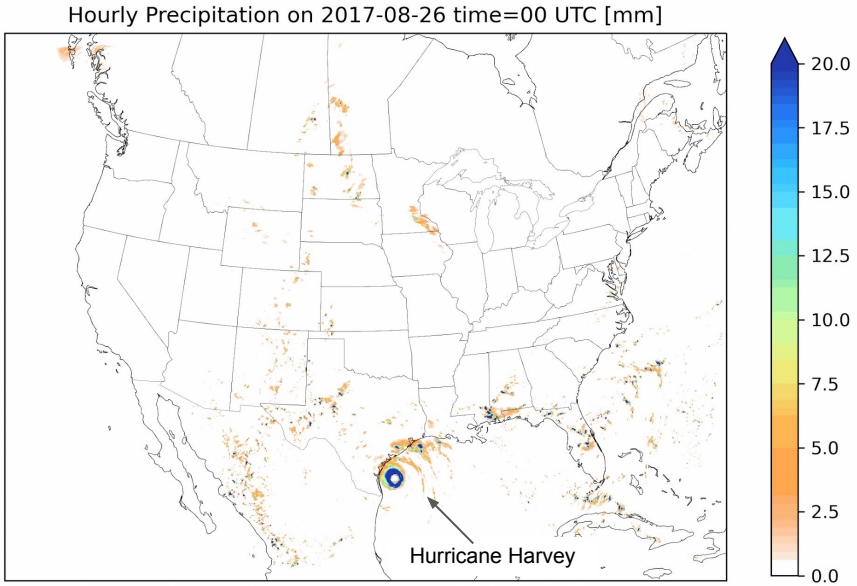
➢ AEPs corresponding to return periods of 10^4 to 10^7 years

Rec 5-10: Model-based PMP estimation

"In the long term, NOAA should adopt a model-based approach to PMP estimation that aligns with the revised PMP definition, consisting of ***multi-model large ensemble kilometer-scale or finer-resolution modeling*** *to construct the probability distribution of precipitation for PMP estimation under different climates."*

Rec 5-10: Model-based PMP estimation

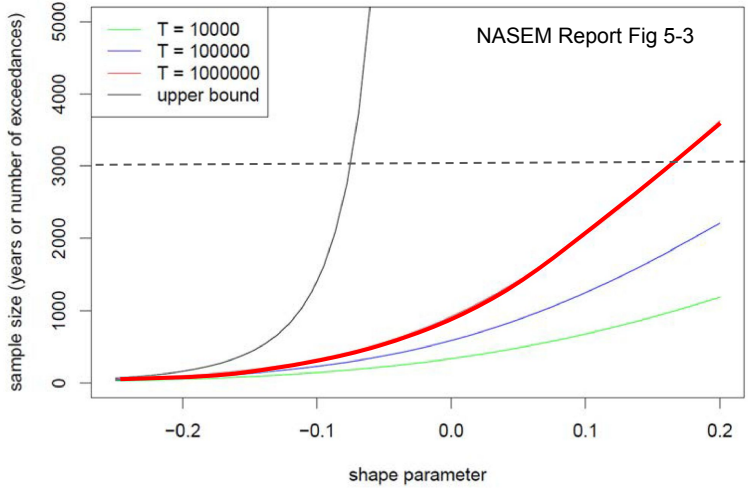
- Kilometer-scale simulations



USGS-NCAR's CONUS404 simulation (Rasmussen et al., 2023)

Explicitly resolves convection

- Multi-model large ensemble

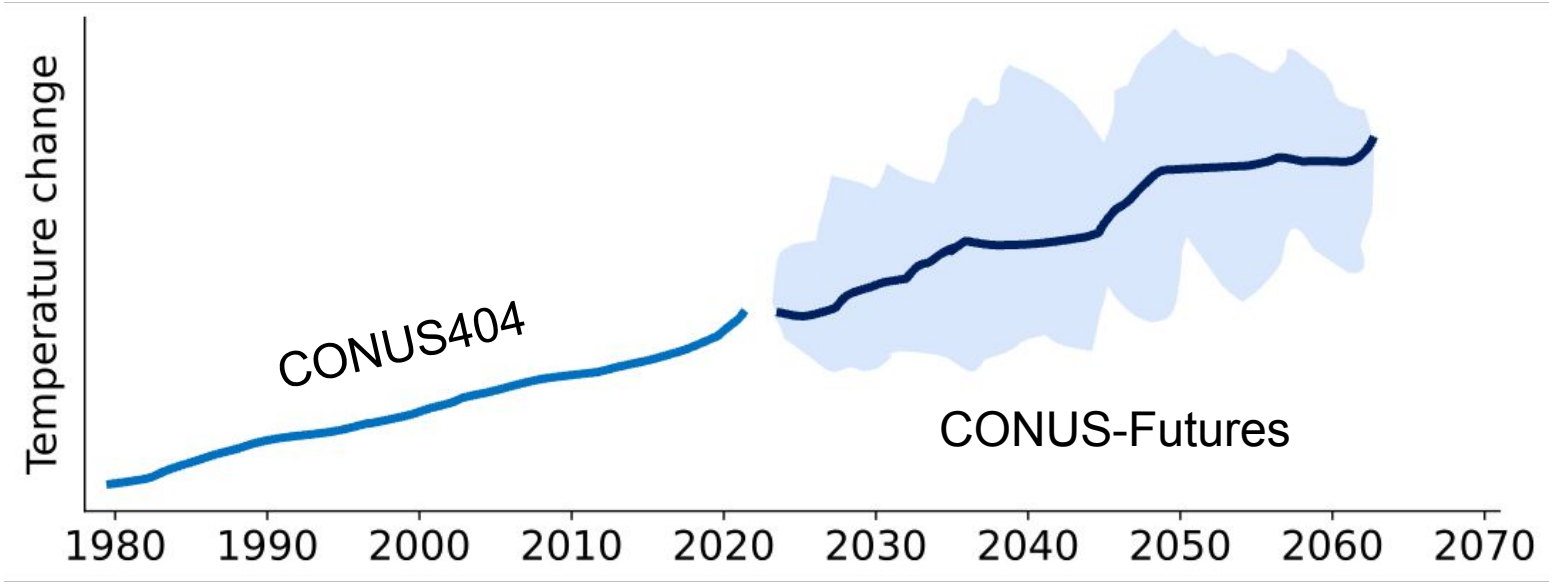


Sample size for AEP of 10^6 years

Requires 1000s of simulated years

Rec 5-10: Model-based PMP estimation

- NOAA effort to produce km-scale simulations of CONUS
  - Using WRF to dynamically downscale individual members of NCAR's CESM2 Large Ensemble at 4km over entire CONUS



Thank you!

Contact info

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NOAA PMP Webpage

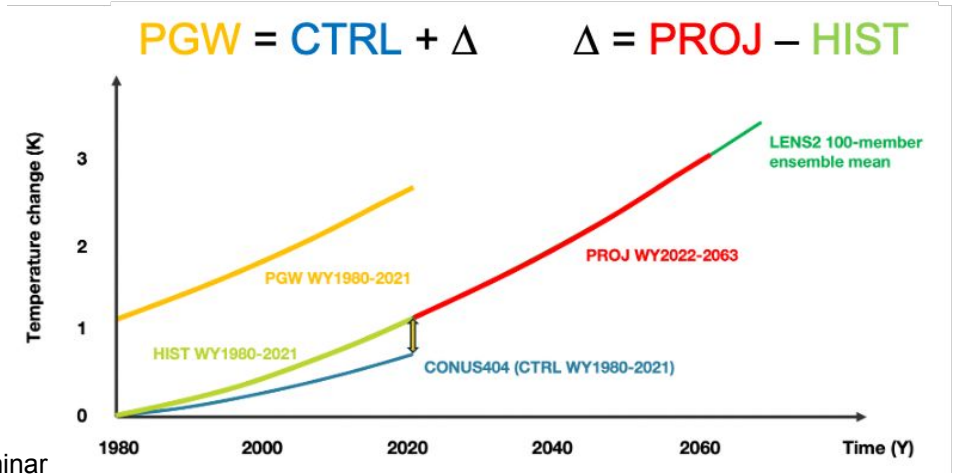
https://www.psl.noaa.gov/precip/pmp

NOAA Boulder, David Skaggs Research Center

Supplemental Slides

CONUS404 (Rasmussen et al., 2023)

- Downscales historical reanalysis (ERA5) with weather model (WRF) over period 1980-2022
- 4km grid across CONUS - explicitly resolves convective processes
- Skillfully simulates extreme precipitation
- Includes PGW simulation using CESM2 Large Ensemble



Xue (2024), USGS HyTest Seminar

Rec 5-11: Extreme Value Theory

"For the long-term approach and in agreement with the recommended PMP definition, NOAA should use statistical approaches to estimate PMP (with associated uncertainty) as the precipitation depth corresponding to an extremely low AEP from the model-simulated precipitation distribution, with particular consideration of ***extreme value analysis based on threshold exceedance methods****."*

Requires thousands of exceedances