Land Surface Hydrology Research Group

Improving confidence in model-based Probable Maximum Precipitation (PMP): **Sources of model uncertainty in storm reconstruction and maximization**

Emilie Tarouilly[1], Forest Cannon[2], Dennis Lettenmaier[3]

[1] Department of Civil & Environmental Engineering, UCLA, Los Angeles, CA

[2] Sr. Atmospheric Scientist, Tomorrow.io, Boston, MA

[3] Department of Geography, UCLA, Los Angeles, CA

UCLA Samueli Civil & Environmental Engineering

Center for Western Weather and Water Extremes

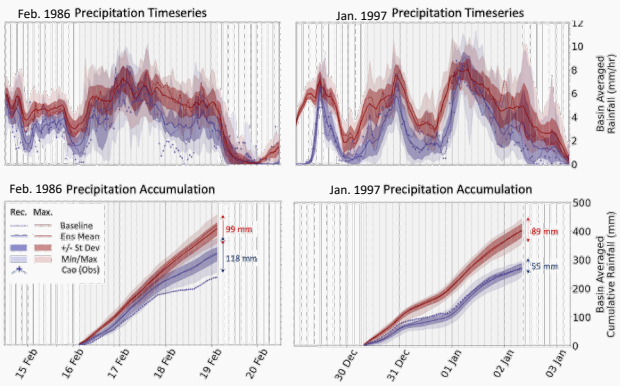
Future Investigators in NASA Earth and Space Science and Technology (FINESST)

Motivation: PMP estimates & dam safety

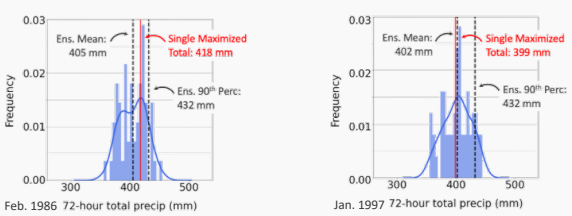
- **Probable Maximum Precipitation (PMP):** "theoretically the greatest depth of precipitation that is physically possible "
- Current PMP estimation guidelines in the U.S. ("**HMR PMP**")
  - Described in Hydrometeorological ("HMR") Reports
  - Scale precipitation of a severe historical storm (observed)
- Recently developed "**Model-based PMP**"
  - Leverage NWP models by reconstructing and amplifying historical storm by scaling moisture in the boundary conditions
- Possible **bias** in the reconstructions and model **uncertainty** main source of concern regarding the credibility of model-based PMP
- Goals: Improve the **robustness** of **model-based PMP** by identifying **sources of model uncertainty** and reflect their impact on the range of possible PMP estimates by providing an **ensemble of PMP values**

Findings

- Model Reconstructions (**blue**)
  - Feb. 1986 has ~90mm bias and twice as much spread than Jan. 1997
  - Ensemble mean captures temporal pattern of precipitation better than baseline configuration for both storms
- Maximized simulations (**red**)
  - Maximization produces a ~**100 mm increase** in 72-hour total precipitation (both storms)
  - Similar amount of spread (~90 mm) and magnitude of maximized precipitation totals (~400 mm) for both storms

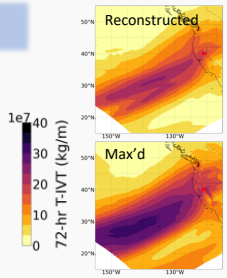


- Ensemble 90th percentile precipitation totals are **at most 110%** of the single-value estimates for both storms
- I.e., maximized totals are not likely to be much greater (due to uncertainty) than the single-value estimate indicates



Methods: Storm Maximization

- **Relative Humidity Maximization** (Ishida et al., 2015): reconstruct and amplify historical storm
- Add **moisture** at the model boundaries (in the forcing dataset): 100% relative humidity at all locations and model levels
- Added moisture leads to a stronger atmospheric river and **more precipitation** than in the reconstructed historical storm



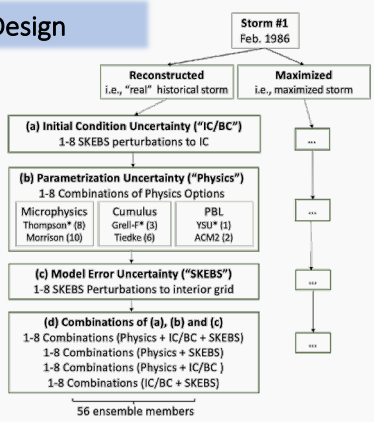
Methods: Study Area and Model Setup

- Feather River watershed (3600 sq mi drainage area), **Oroville dam**, California
- 2 major atmospheric river storms: **Feb. 1986** and **Jan. 1997**
- Baseline setup following Martin et al. (2019) with 9 and 3km nested domains
- Initial/boundary conditions provided by **ERA5 reanalysis** (30 km)

WRF Option	Scheme name
Microphysics	Thompson scheme
Cumulus scheme	Grell-Devenyi
Boundary layer scheme	Yonsei University Scheme
Short & long-wave physics	RRTMG Schemes
Surface layer physics	Revised MM5 scheme
Land surface physics	Unified Noah Land Surface Model

Methods: Ensemble Design

- Each of the 2 storms (only one shown here) has **reconstructed and max'd version**
- Each version has **56-member ensemble** sampling known sources of uncertainty
  a) Initial conditions
  b) Choice of parametrization
  c) Model error
  d) Combinations of the above



Conclusions

- **Numerical weather modeling** represents an important advance over traditional PMP guidance
- Good **quality of WRF precipitation** reconstructions in the Western U.S.
  - Ongoing work on WRF microphysics, bias correction and uncertainty in observations will bring further improvements
- Model **error and uncertainty are modest**: not be a barrier to further development of model-based PMP
  - Characterization of uncertainty should become part of PMP estimation
- Need to (1) work with a larger sample of historical storms and (2) develop process understanding of precipitation response and (3) evaluate **other uncertainty** e.g., how much moisture should be added