Land Surface Hydrology Research Group

Improving confidence in model-based PMP: **Sources of uncertainty in storm reconstruction and maximization**

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

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

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

[3] Department of Geography, University of California, Los Angeles, 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

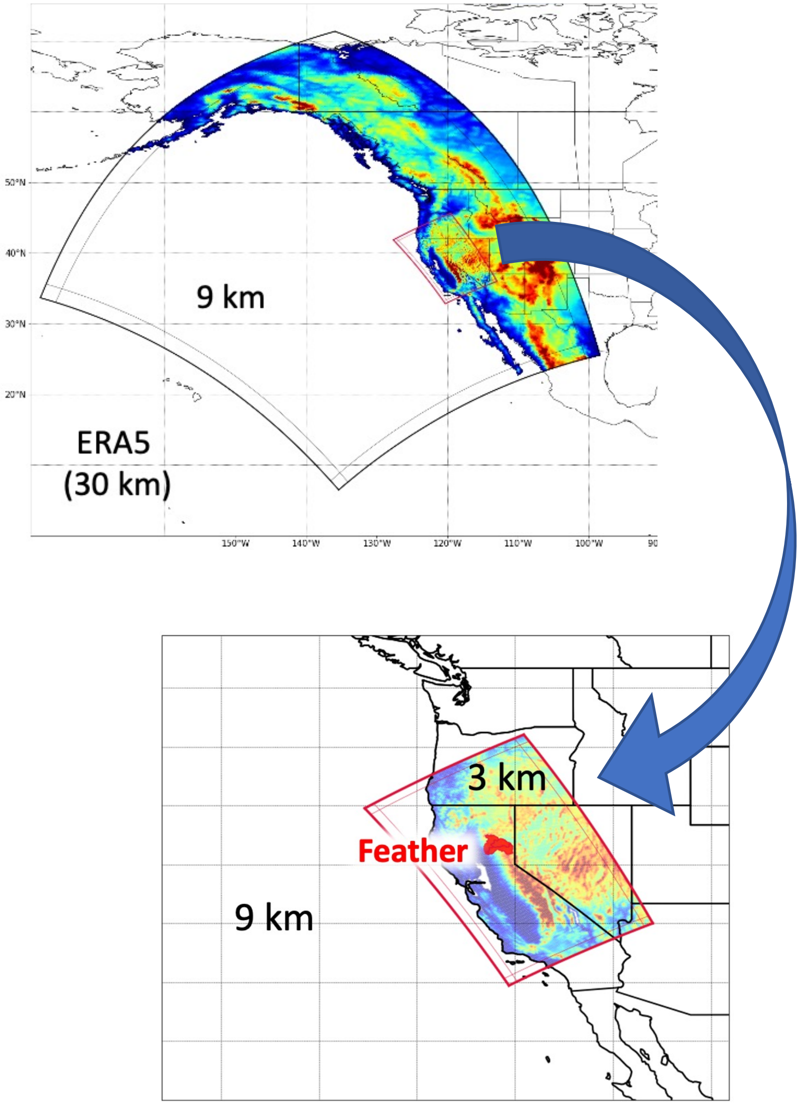
- Probable Maximum Precipitation **(PMP**):
  - “the greatest depth of precipitation physically possible”
- Recently developed “**model-based PMP**”
  - Leverage **NWP models** to reconstruct and amplify historical storms
  - Major improvement over current U.S. guidelines, which scale precipitation linearly
- Overarching challenge: how to obtain a PMP estimate of the appropriate magnitude, given:
  - **Model uncertainty**: choice of parametrization, initial conditions, model errors
  - **Maximization uncertainty**: how much moisture should be added? Where?

Goals: Improve the **robustness** of **model-based PMP** by identifying **sources of uncertainty** and reflect their impact on the range of possible PMP estimates by providing an **ensemble of values**

Damage to the Oroville dam spillway (February 2017) that prompted the evacuation of 180,000 people

Methods: Study Area & Setup

- **Feather River** watershed, California (**Oroville Dam**)
- 2 major **atmospheric rivers** storms: **Feb. 1986** and **Jan. 1997**
- **Baseline run** against which ensemble is compared: **West-WRF** (Martin et al., 2019)
  - West-WRF is the Center for Western Weather and Water Extremes (CW3E) operational model
- 2 nested domains (9 km and 3 km)
- Initial/boundary conditions provided by **ERA5 reanalysis** (30 km)
- Validation using **Cao et al. (2019)** gridded hourly precipitation (1/32 degree)

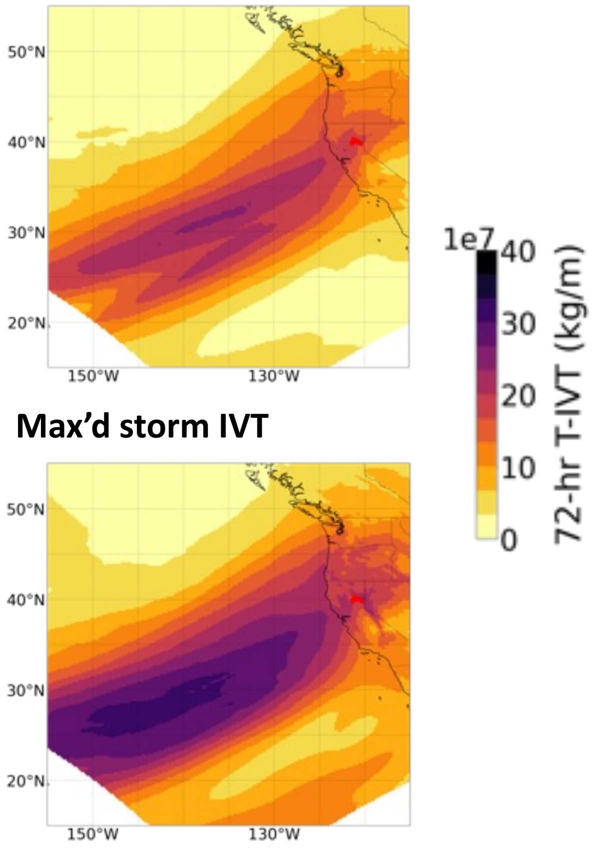


Methods: Baseline Storm Maximization

- Most widespread method: **Relative Humidity Maximization (RHM)** (Ishida et al., 2015)
- Maximize by **adding moisture** at the model boundaries (in the forcing dataset)
    - Increase moisture such that relative humidity is 100%
    - I.e., saturate the entire atmospheric column at all locations and model levels
- Added moisture leads to **more precipitation** than in the reconstructed historical storm
- PMP estimate is the total basin average precipitation total (current guidelines focus on 72-hour duration)

Jan. 1997 example

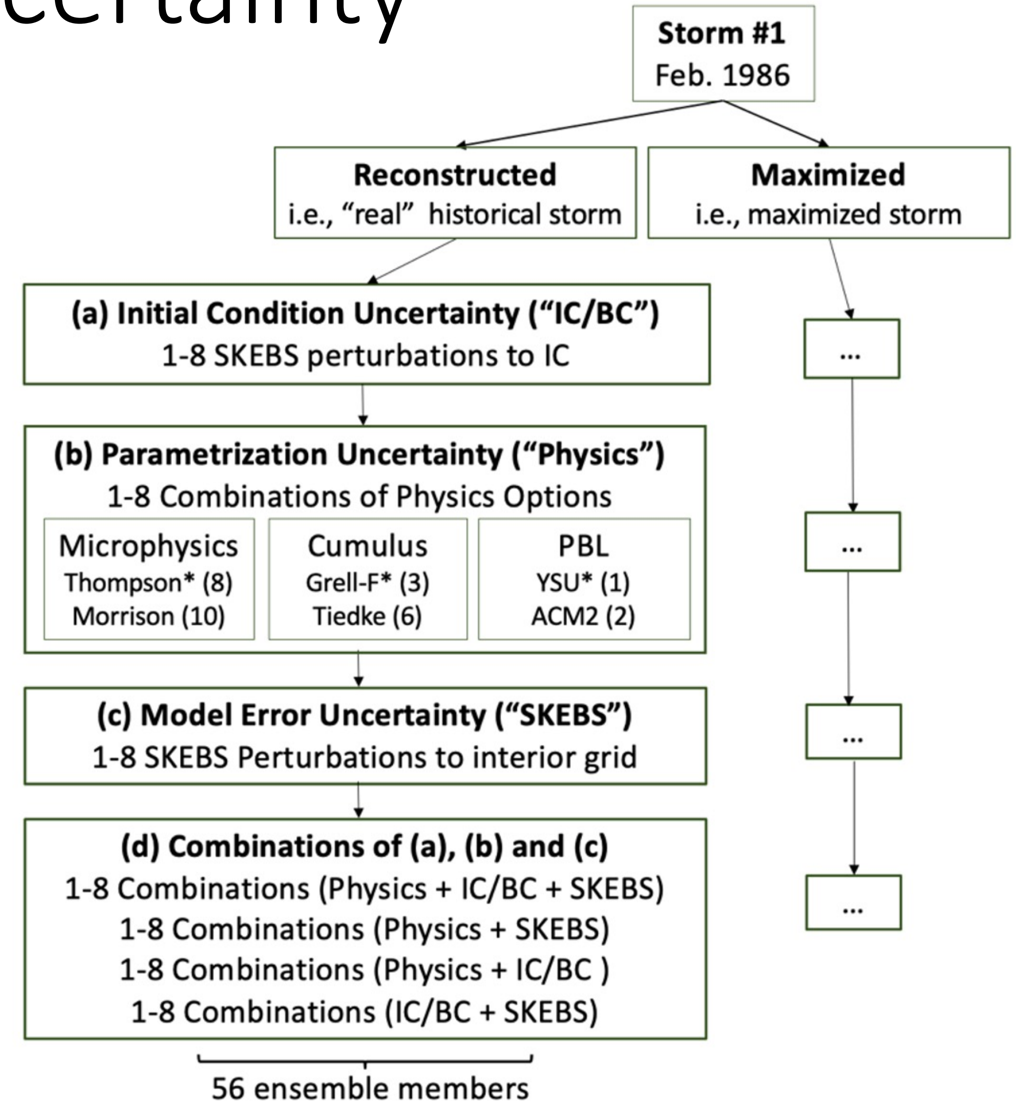
Reconstructed storm IVT



Part I: Model Uncertainty

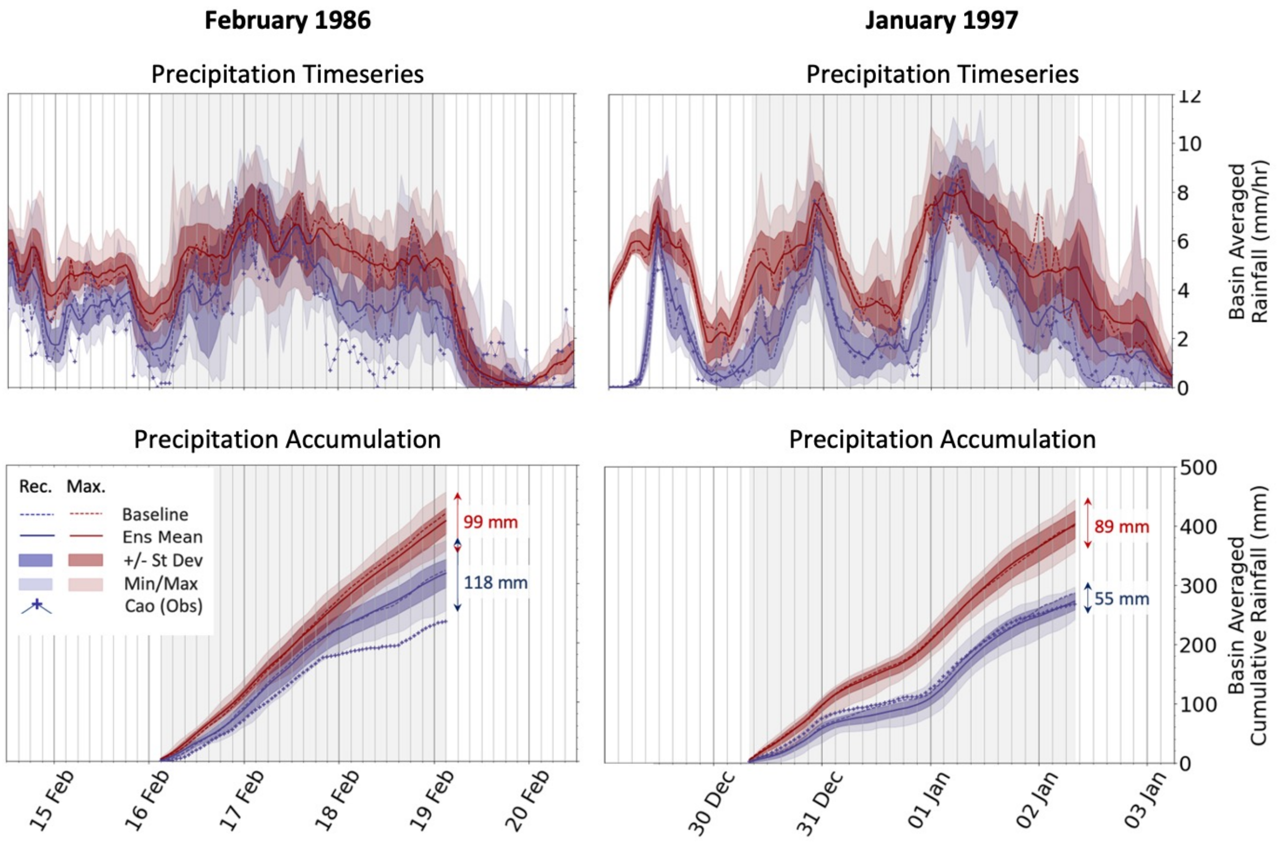
Methods (Part I): Model Uncertainty

- Ensemble of simulations captures widely recognized **sources of model uncertainty** affecting precipitation
  - Error in initial conditions (forcing data)
  - Choice of parametrization
  - Model error (unresolved subgrid processes)
- **56 members** for both "reconstructed" and "maximized" versions of each storm
  - 112 ensemble members for each



Results (Part I): Reconstructed and Max’d Ensembles

- Reconstructed ensembles (**blue**) behave differently
  - Twice as much spread in 1986 (120 mm)
  - Feb. 1986 ensemble does not capture obs
- **Ensemble mean** captures temporal pattern and 72-hour total slightly better than baseline West-WRF (both storms)
- Maximized ensembles (**red**)
  - Roughly same amount of spread (~90 mm)
  - Magnitude of maximized precipitation is similar (~400 mm in 72 hours)



Ensemble 90th percentile is at most 107% of the ensemble mean, i.e., uncertainty does not seem to cause maximized totals to be potentially much greater

Part II: Maximization Uncertainty

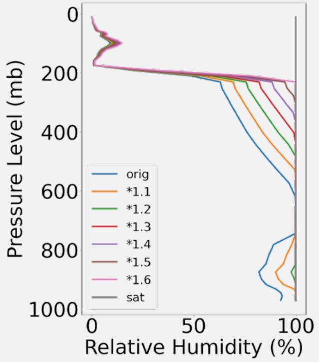
Methods (Part II): Different ways to perform moisture maximization

How much moisture?

RHM
- Set moisture to saturation at all pixels and for the entire column

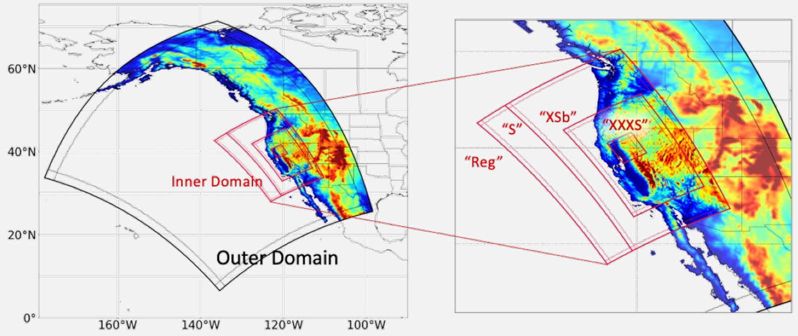
RHM-IVT
- Moisture increase in the path of the AR (IVT > 250 km/m/s)

RHP (Relative Humidity Perturbation)
- Moisture increase proportional to original profile



At what distance from the study basin?

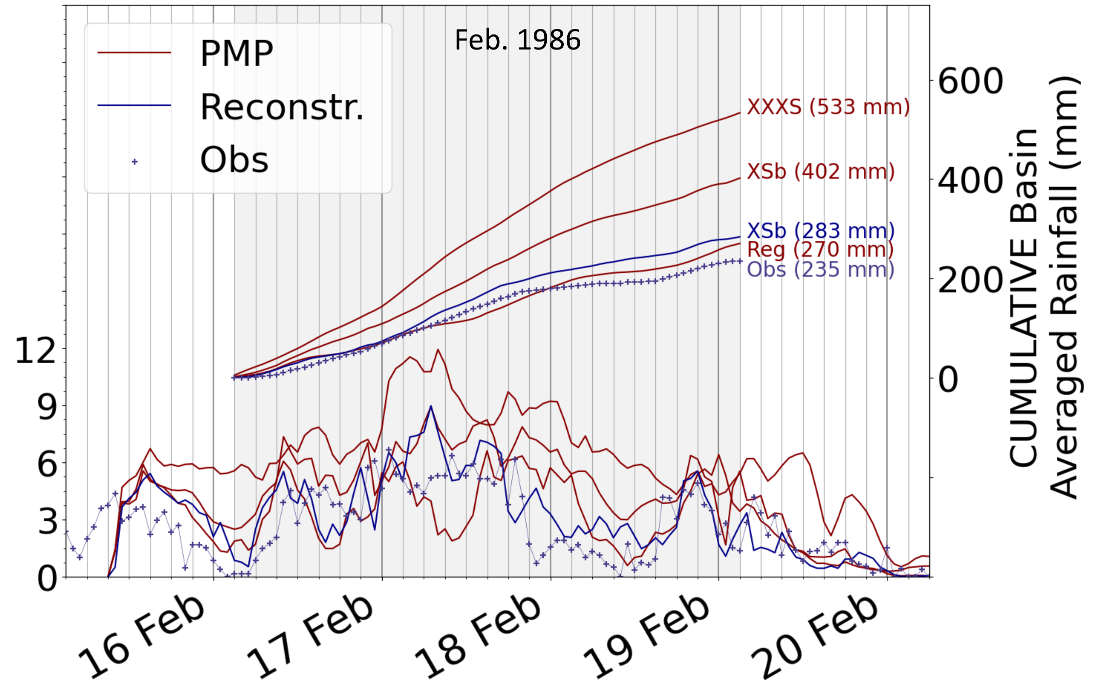
- Vary size of inner domain such that moisture is added closer



Distance between domain edge and study basin:

‘Reg”: ~ 800 km
“S”: ~ 540 km
“XSb”: ~ 400 km
“XXXS”: ~ 60 km

Results (Part II): Comparing different variations of moisture maximization



Precipitation totals are much higher when **moisture added closer** to the basin, especially when beyond the topographic barrier

Conclusions

- **Model uncertainty** is small enough not to be a barrier to further development of model-based PMP
  - But PMP should be presented as an ensemble of values (rather than a single estimate) to appropriately reflect the uncertainty
- The way **moisture maximization** is implemented can be a large source of uncertainty
  - Where moisture is added can make a 2-fold difference in precipitation totals
  - Now that sensitivities have been identified, how do we decide how to implement moisture maximization?
- Challenges to address toward goals to (1) better **justify** the moisture changes we make and (2) **generalize** the guidelines to the U.S. West coast:
  - Develop better process understanding of how precipitation responds to moisture maximization
  - Will help justify how to produce a PMP storm that is large enough to be safe but not unrealistically large
  - Will support the selection of one or few approaches that can be applied to other basins without the need for trial-and-error

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Thank you

Questions/comments?

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