8-Month Snowpack Prediction Potential

Sarah B. Kapnick, Ph.D.
NOAA/GFDL

WCRP S2S-S2D

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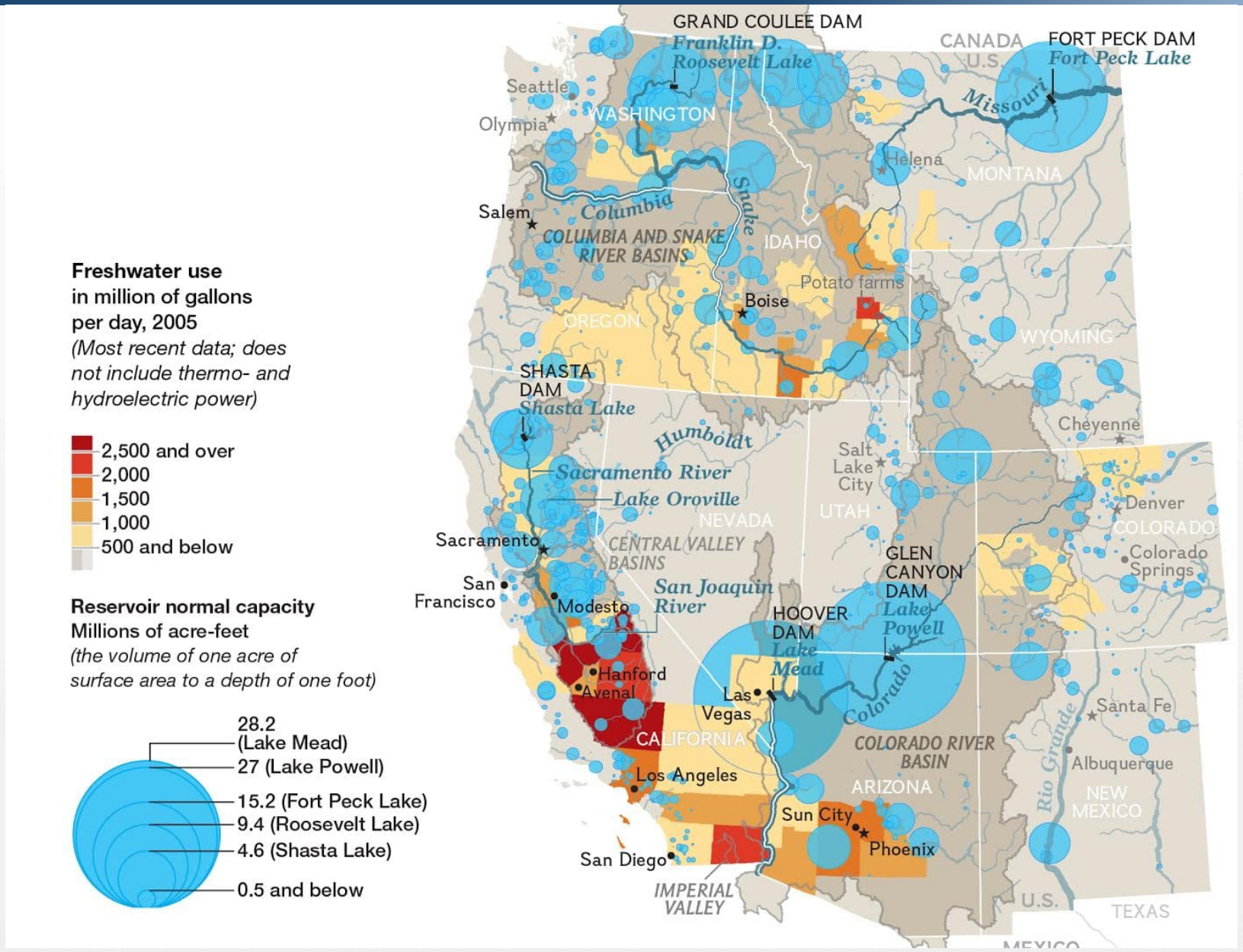
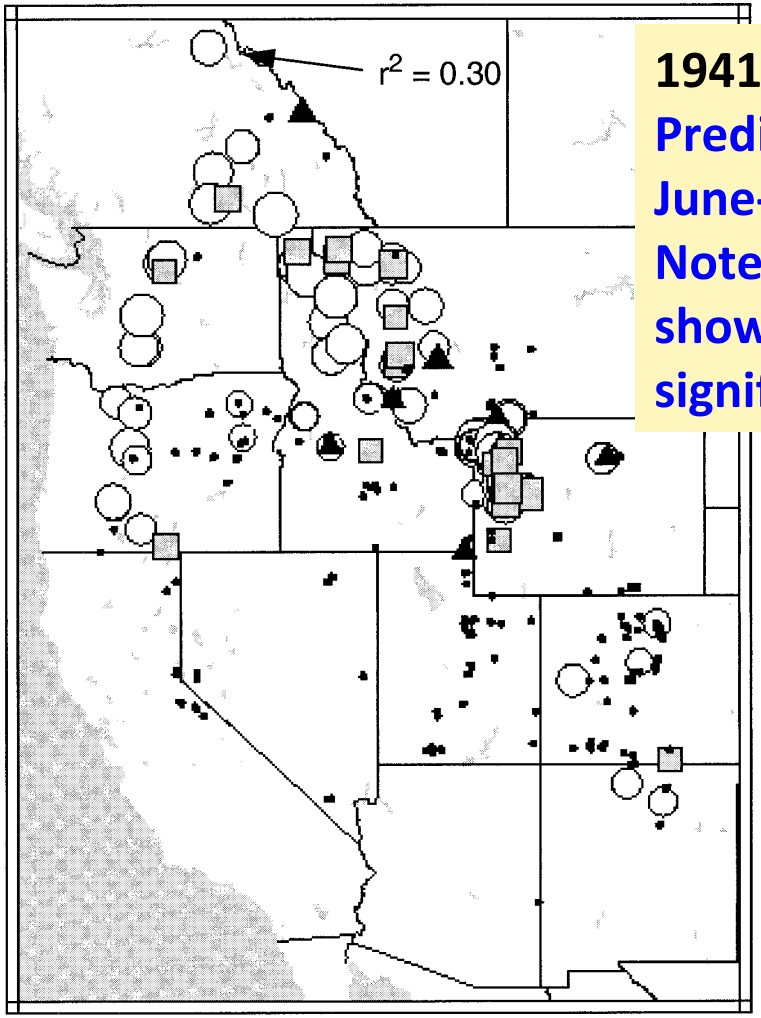
Characteristics of western U.S. mountain climate

Remote mountain precipitation (& snowmelt) delivers water supply

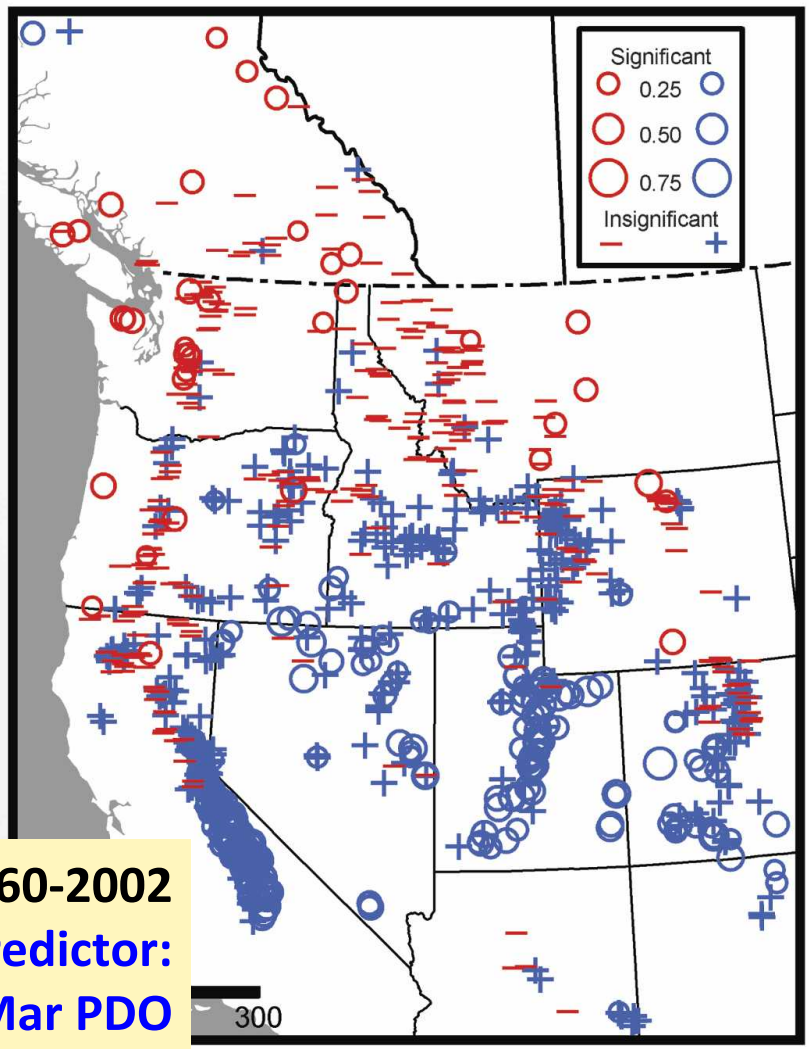


Climate index / April 1 snow link: PDO & Niño3

4-month & 0-month lead



1941-90
Predictor:
June-Nov
Note: 63% show no significance



1960-2002
Predictor:
Oct-Mar PDO

Source: McCabe and Dettinger 2002; Mote 2006

Developing a western U.S. prediction system

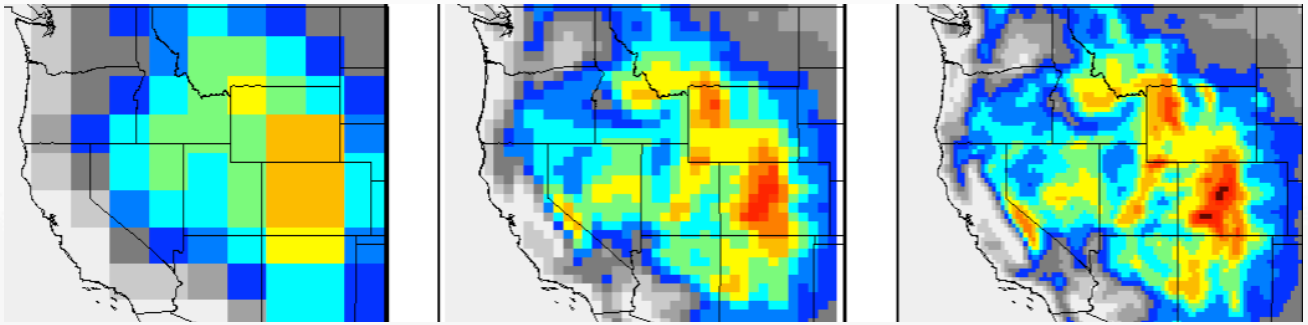
Scientific questions to ask

- *Why do we have mountain precipitation / snow?*
- *How does it vary?*
- *Can we predict it?*
- *What else are we missing?*
- *Are we asking the right prediction questions? (For science? For stakeholders?)*

WESTERN U.S. SNOWPACK PREDICTION

Current Research: GFDL seasonal prediction models

Global coupled models for regional applications



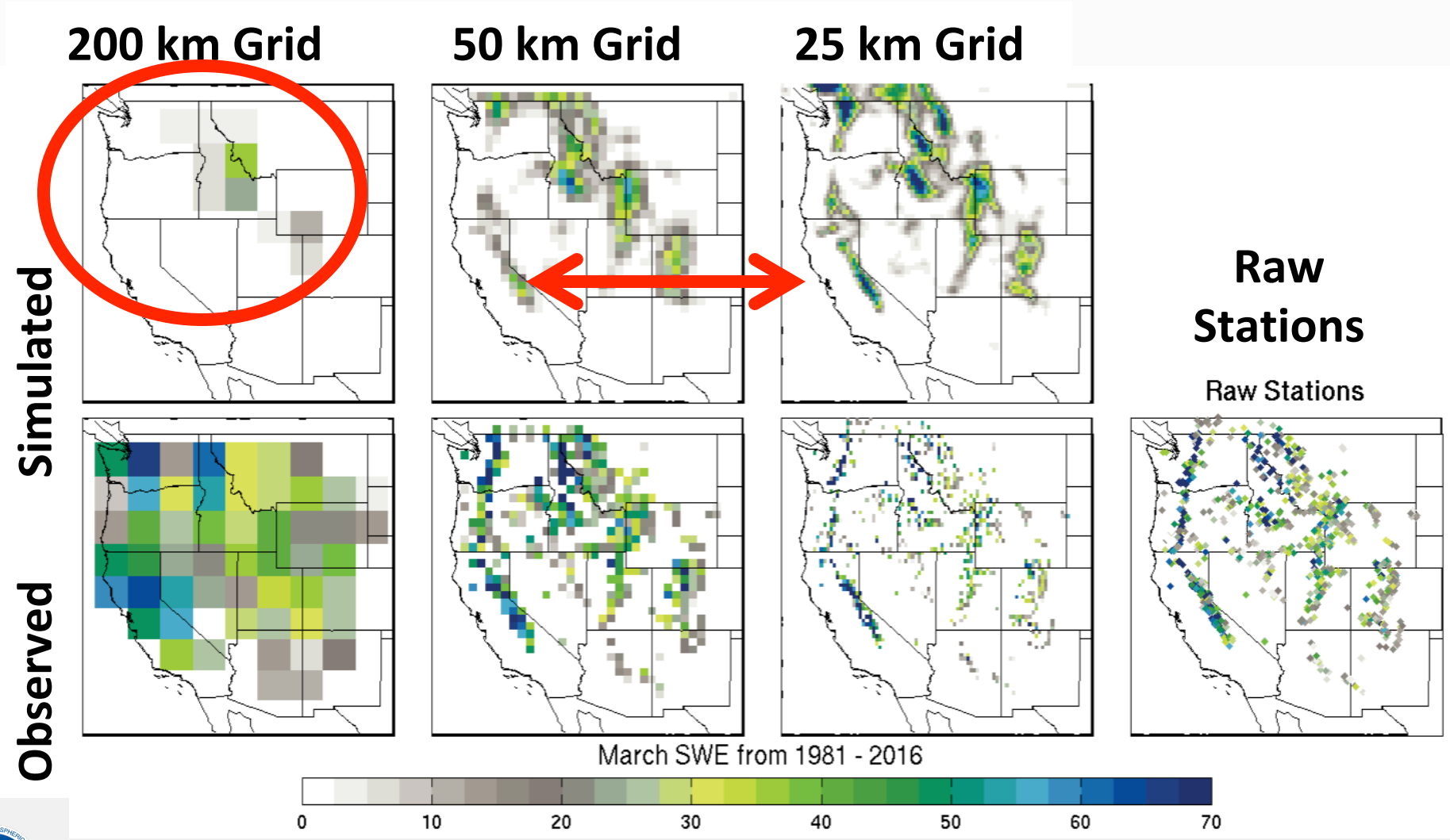
Atmospheric/Land Grid Size	***200 km***	***50 km***	***25 km***
Ensemble members	*10*	*12*	*12*

"Ensemble members" provide individual solutions for the future

- Seasonal prediction: initialize on the 1st of the month and left to run for 12 months total to provide a potential future (for 4 seasons)
- Collectively ensembles provide a probabilistic forecast of the future—a likely solution but also a range of potential values and probabilities
- Note: Our "seasonal" model is used to produce seasonal to multi-seasonal (beyond 3 months) to decadal predictions and has been designed for this

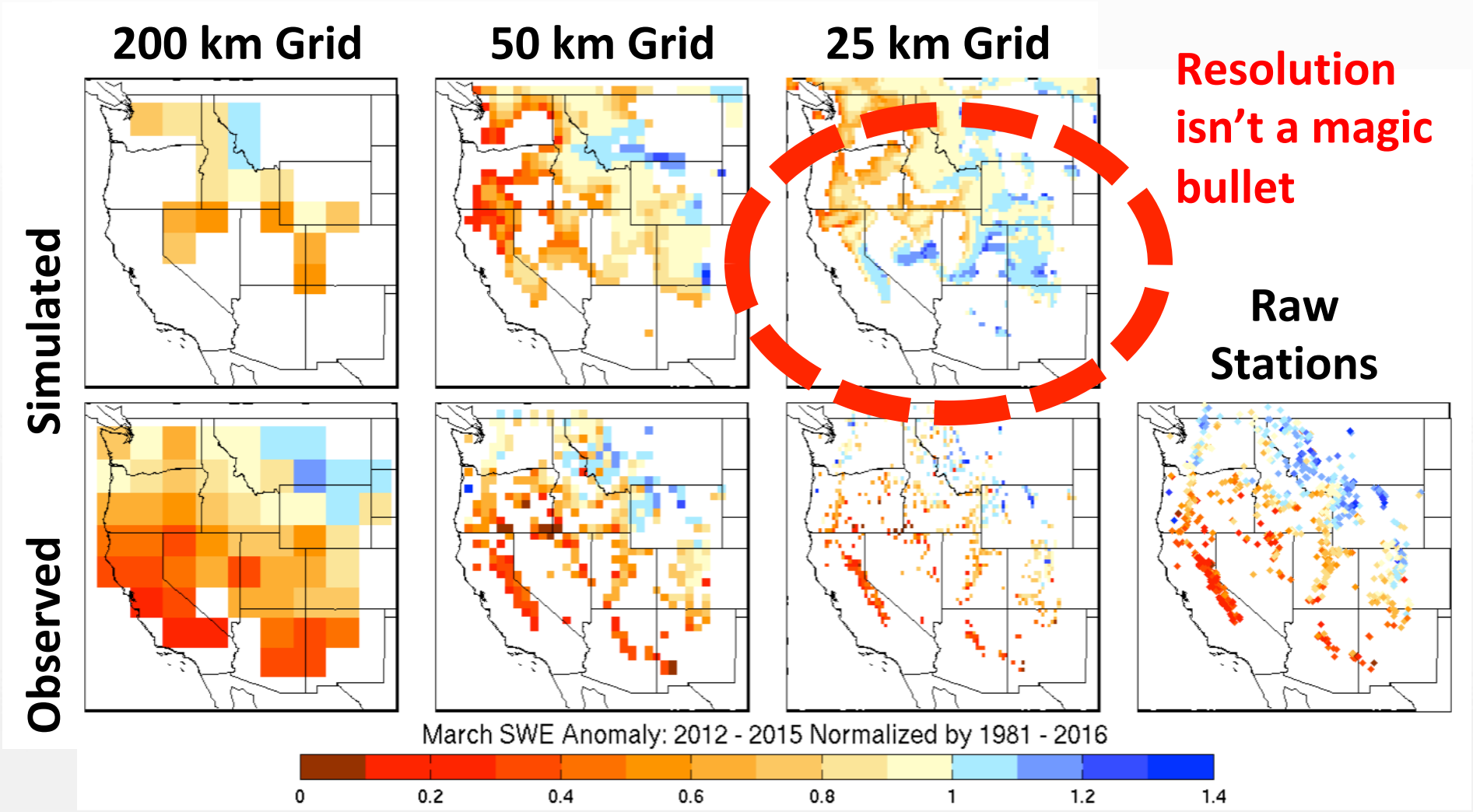
Climatology of western U.S. Snowpack

Model Initialized July 1: 8-mon prediction vs. Observed March



Source: Kapnick et al., PNAS, 2018

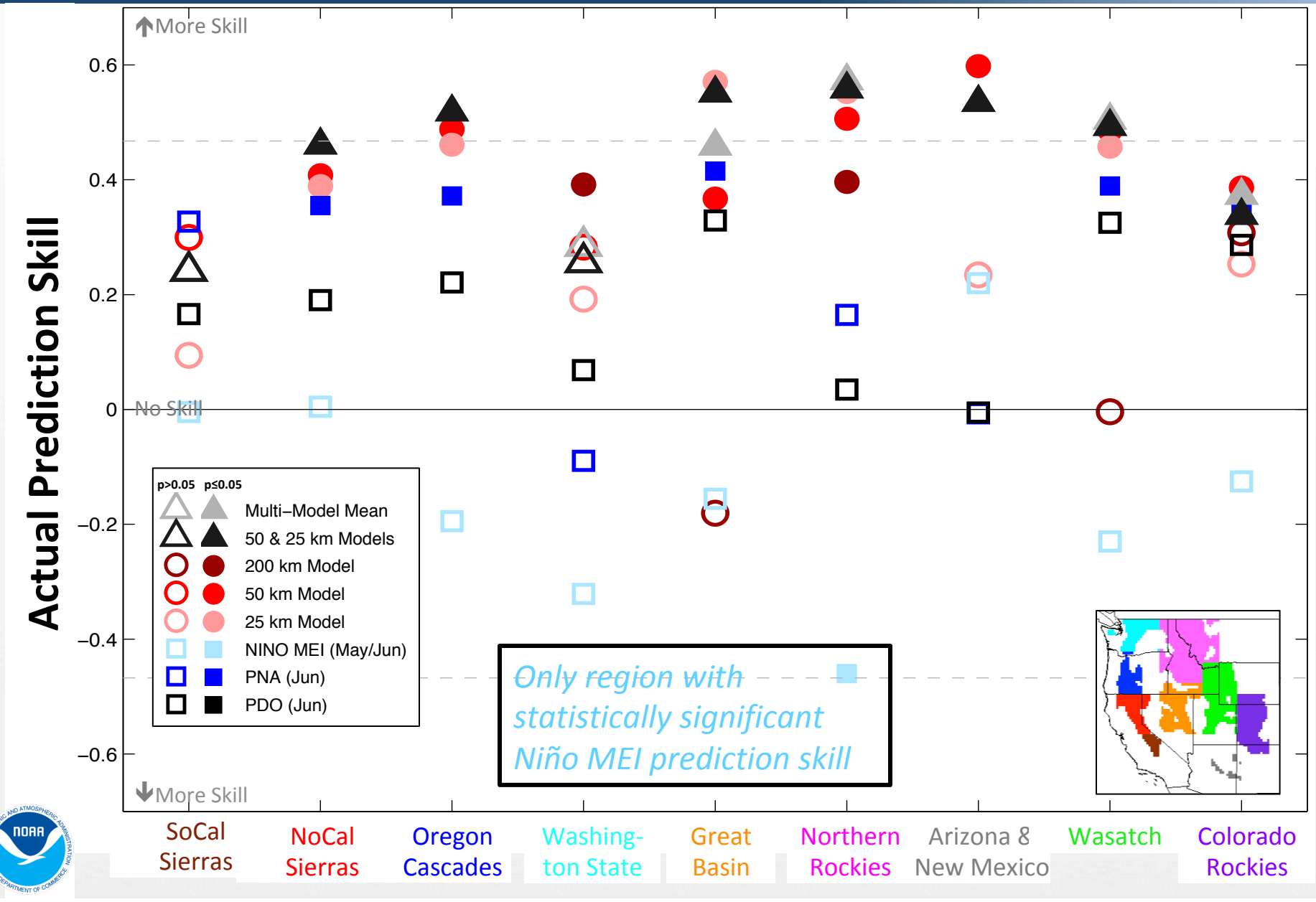
2012-2015 drought 8-m predictions annually



Source: Kapnick et al., PNAS, 2018

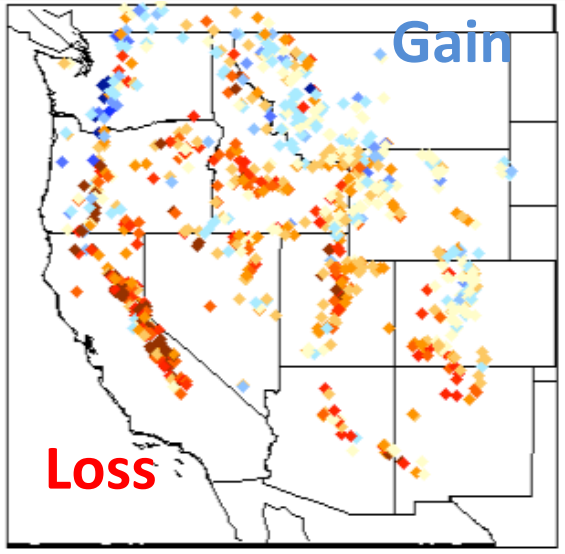
1981-2016 March prediction skill 8 months prior

March snowpack predicted on previous July 1 (Kapnick et al. 2018)

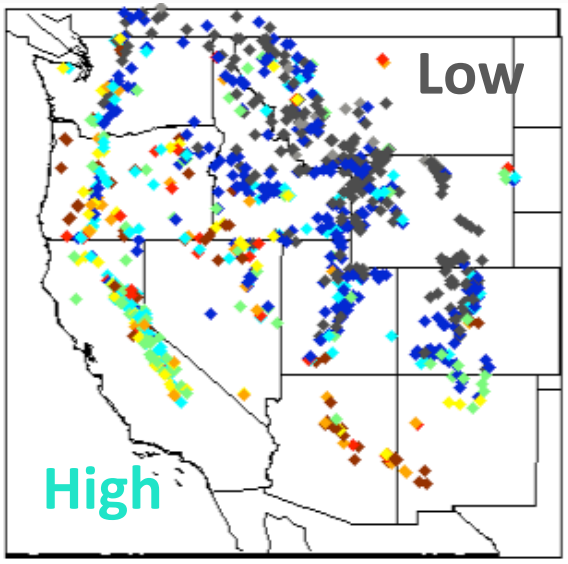


Why are coastal mnts difficult to predict?

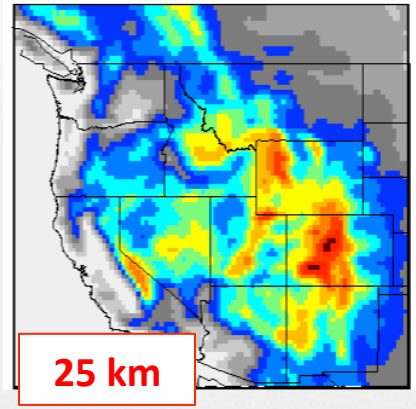
Severe Trends?

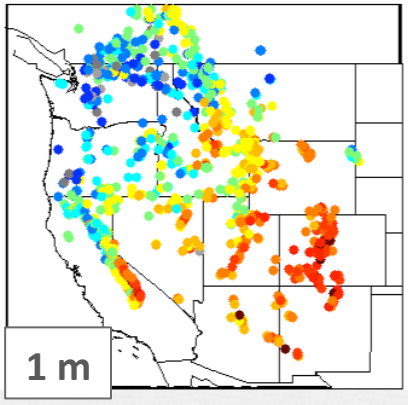


Higher variability?



Resolution/Physics/Mountain Range Scaling?



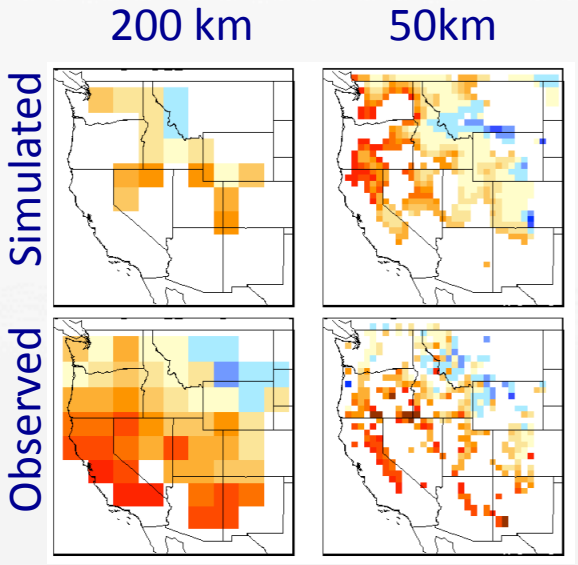


- A fundamental system setup issue (initialization, model configuration, ensemble size)?
- Or *inherently unpredictable* at 8-month leads?

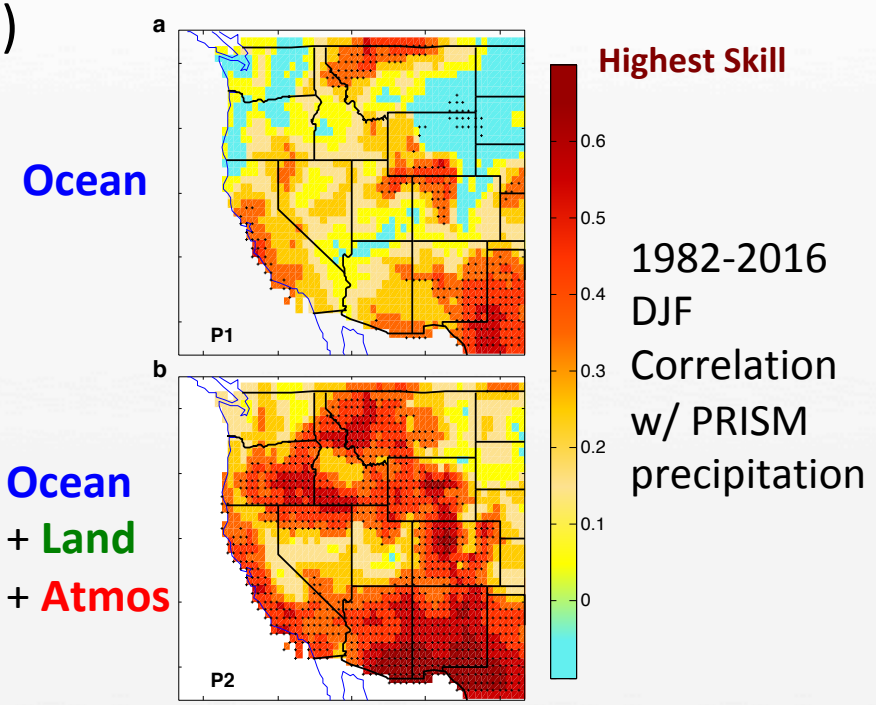
How do we improve weather-to-climate predictions?

Kapnick et al. 2018; Yang et al. 2018

① Improve the **models** (i.e. physics, resolution, processes) for total records & case studies. Increase ensemble size (?)



② Improve **initialization system** (i.e. info to start prediction)



③ Improve **observations** for model development, initialization, verification

Is California snowpack simply unpredictable at 8-mon leads?
What problems can we solve (e.g. for leads, variable, region)?

Key takeaways

- **Snowpack prediction skill exists 8 months in advance** in a dynamic coupled modeling system
  - Prediction in this system comes from the ocean state on July 1 (initialization) & dynamic coupled evolution of weather / climate (prediction from the global coupled model simulating the ocean, atmosphere, and land as it evolves in time)
- **Climate indices lack (or have lesser) prediction skill at 8 months**
  - Dynamic coupled models outperform their climate index counterparts & may be necessary at longer time scales
- **California remains elusive** with lowest skill in coastal mountains, but we have pathways to improve prediction. We can reframe our questions for solvable scientific problems / stakeholder needs
- **The new frontier:** At the GFDL we are developing a next-generation prediction system (SPEAR) to tackle these problems. We are also trying to better engage with stakeholders and regional experts on prediction problems

THANK YOU

Kapnick, Sarah B., Xiaosong Yang, Gabriel A. Vecchi, Thomas L. Delworth, Rich Gudgel, Sergey Malyshev, P. C. D. Milly, Elena Shevliakova, Seth Underwood, and Steven A. Margulis. "Potential for western US seasonal snowpack prediction." *Proceedings of the National Academy of Sciences* (2018): 201716760.

Yang, Xiaosong, Liwei Jia, Sarah B. Kapnick, Thomas L. Delworth, Gabriel A. Vecchi, Rich Gudgel, Seth Underwood, and Fanrong Zeng. "On the seasonal prediction of the western United States El Niño precipitation pattern during the 2015/16 winter." *Climate Dynamics* (2018): 1-19.

sarah.kapnick
@noaa.gov