Hydroclimate variability, predictability, and extremes

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Geophysical Fluid Dynamics Laboratory Review

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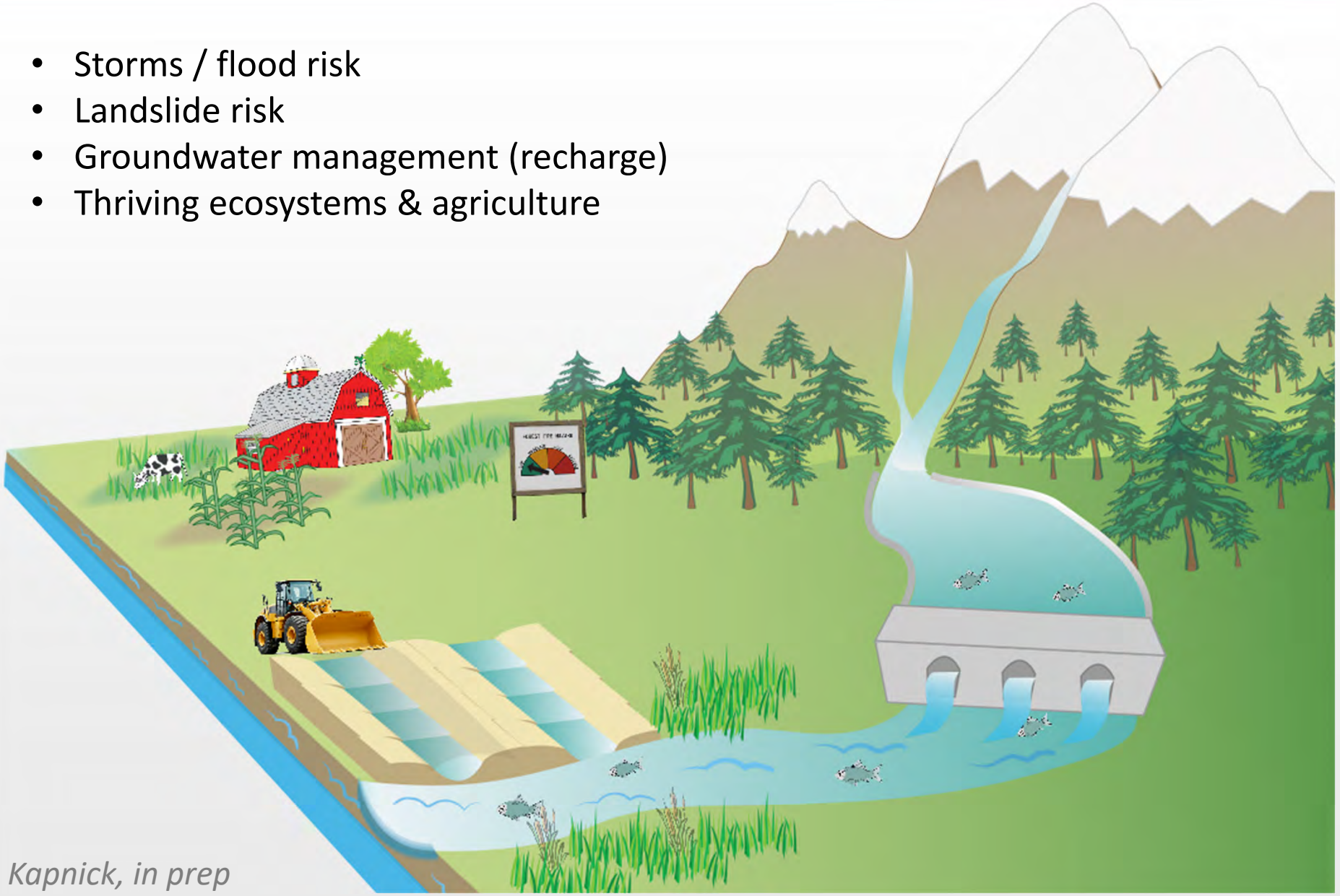
Stakeholder needs: Understanding Wet Years

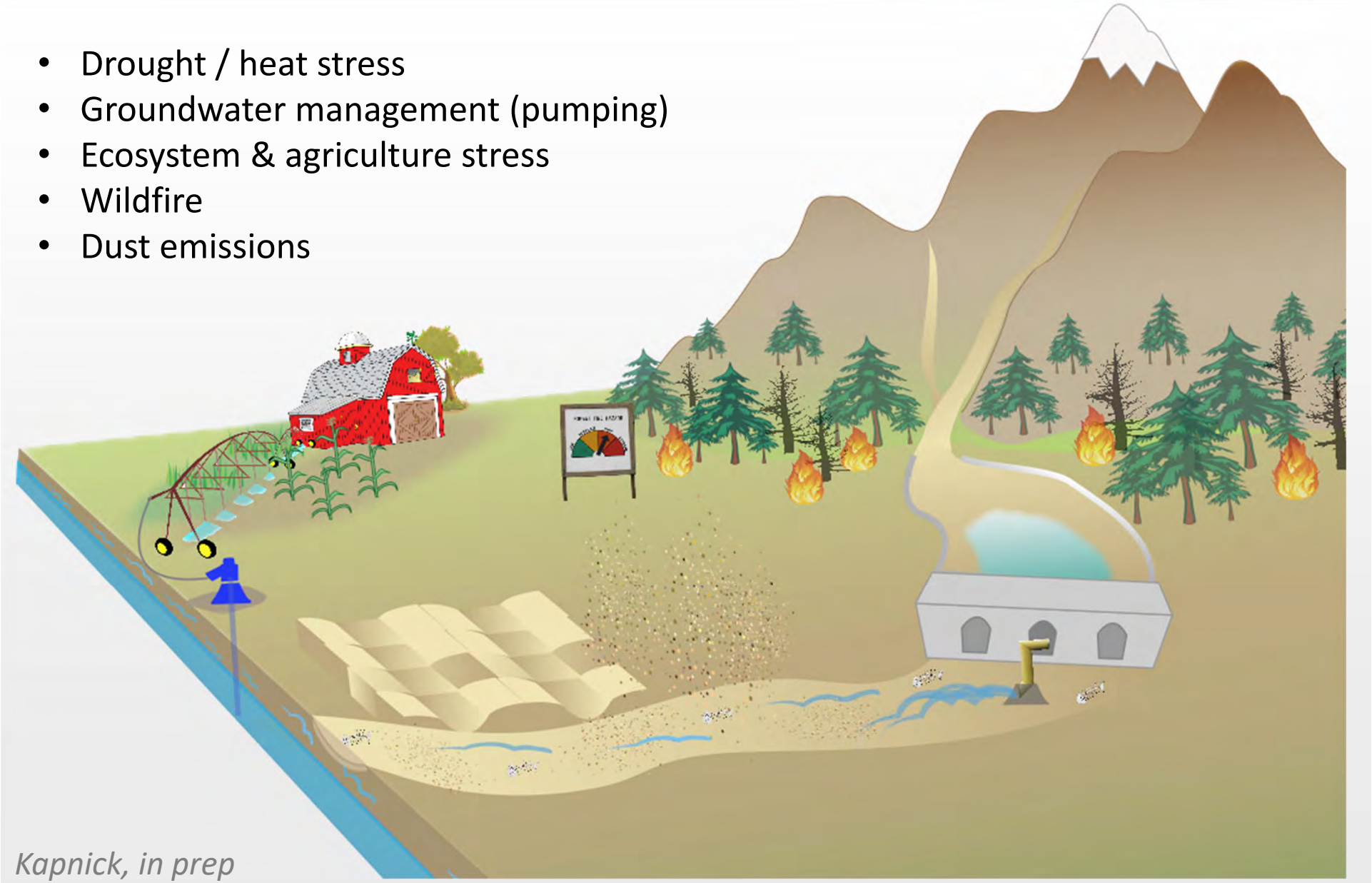
- Storms / flood risk
- Landslide risk
- Groundwater management (recharge)
- Thriving ecosystems & agriculture



Kapnick, in prep

Stakeholder needs: Understanding Dry Years

- Drought / heat stress
- Groundwater management (pumping)
- Ecosystem & agriculture stress
- Wildfire
- Dust emissions



Kapnick, in prep

The Seamless Prediction Approach

① Validate the model in control simulations and targeted experiments against observations, identify bias

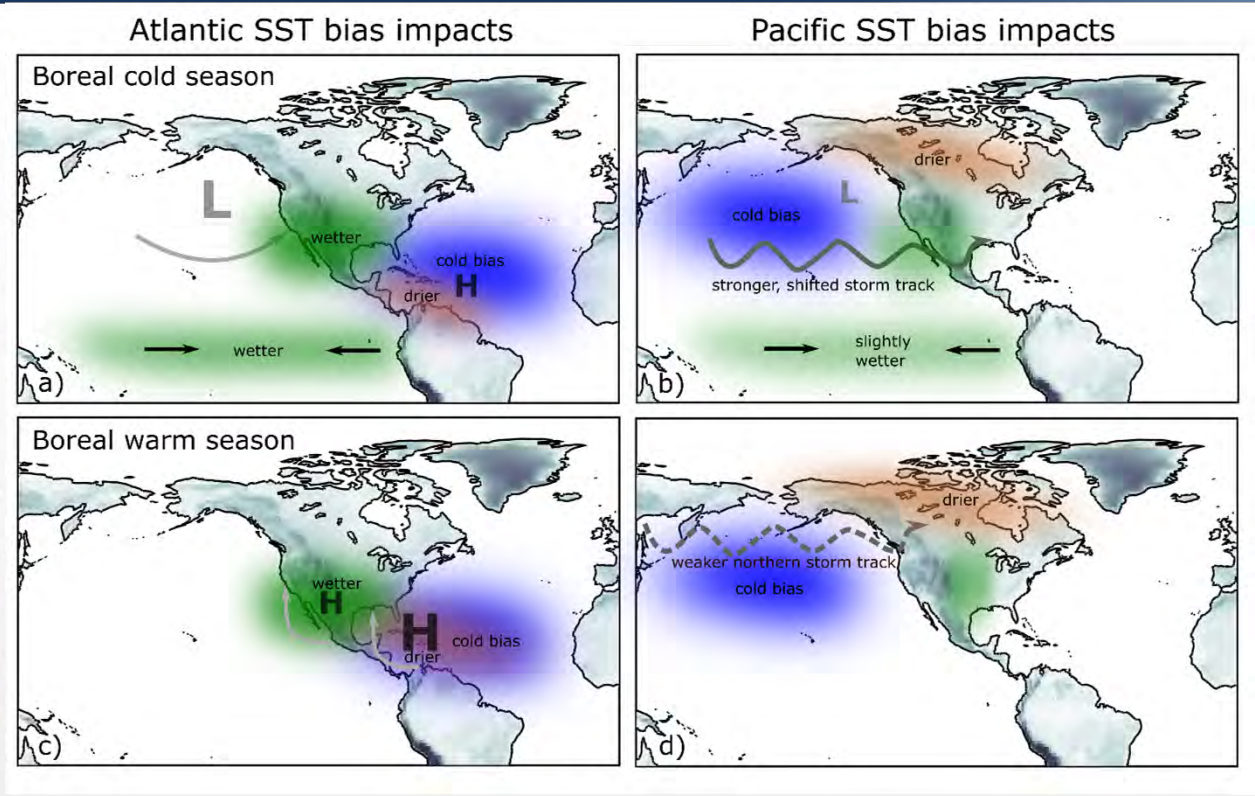
② Explore variability and trends in historical simulations

③ Use the same system to provide seasonal predictions, explore the skill of phenomena with increasing complexity. Expand to multi-annual to decadal

④ Extend the transient climate simulations for decadal projections to understand future climate

⑤ Use of seamless system to perform risk assessments

Hydroclimate Validation & Improved Understanding



- Targeted modeling experiments allow us to pinpoint sources of hydroclimate bias
- SST biases:
  - Annual precipitation (Johnson et al., *J Clim*, 2019)
  - North American monsoon (Pascale et al. *J Clim*, 2016; Pascale et al. *Nature Climate Chg*, 2017)

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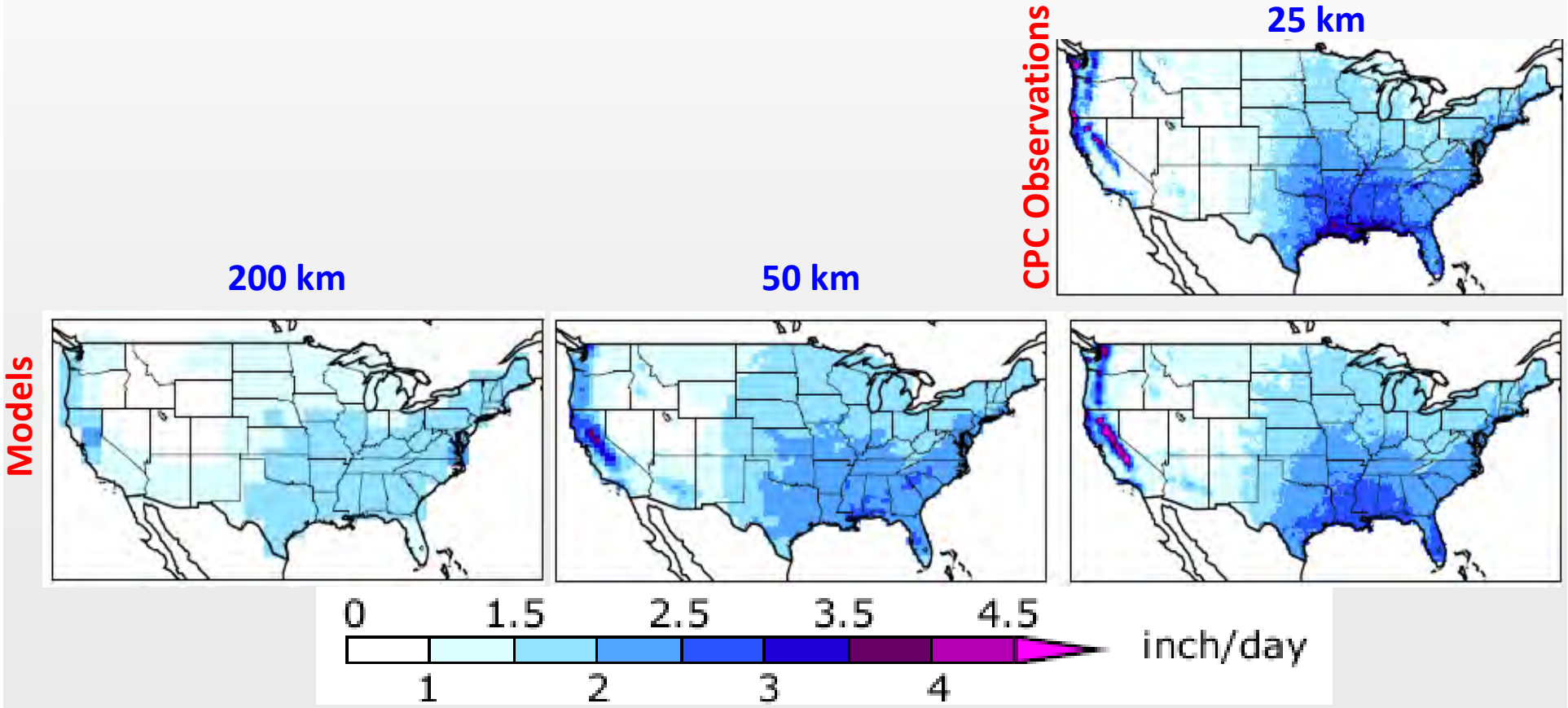
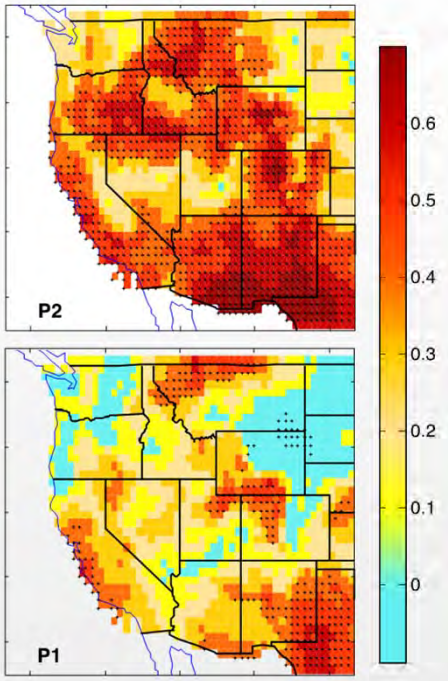
- Role of resolution:
  - Precipitation extremes (van der Wiel et al. *J Clim,* 2016; Pascale et al., *J Clim*, 2016)



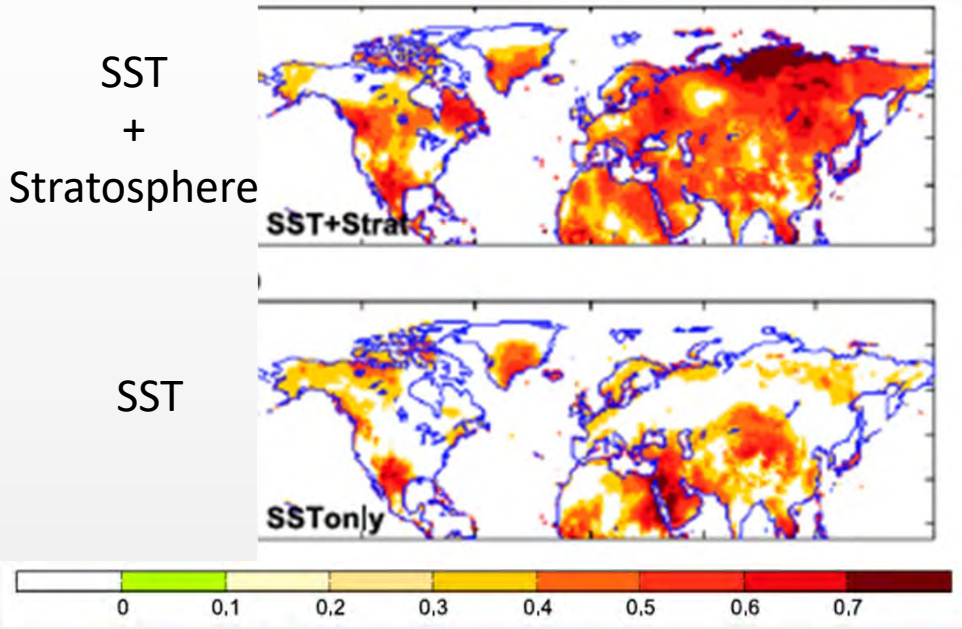
Prediction Skill: Role of Initial Conditions

Correlation with Observations

Winter Precipitation



MAM Temperature

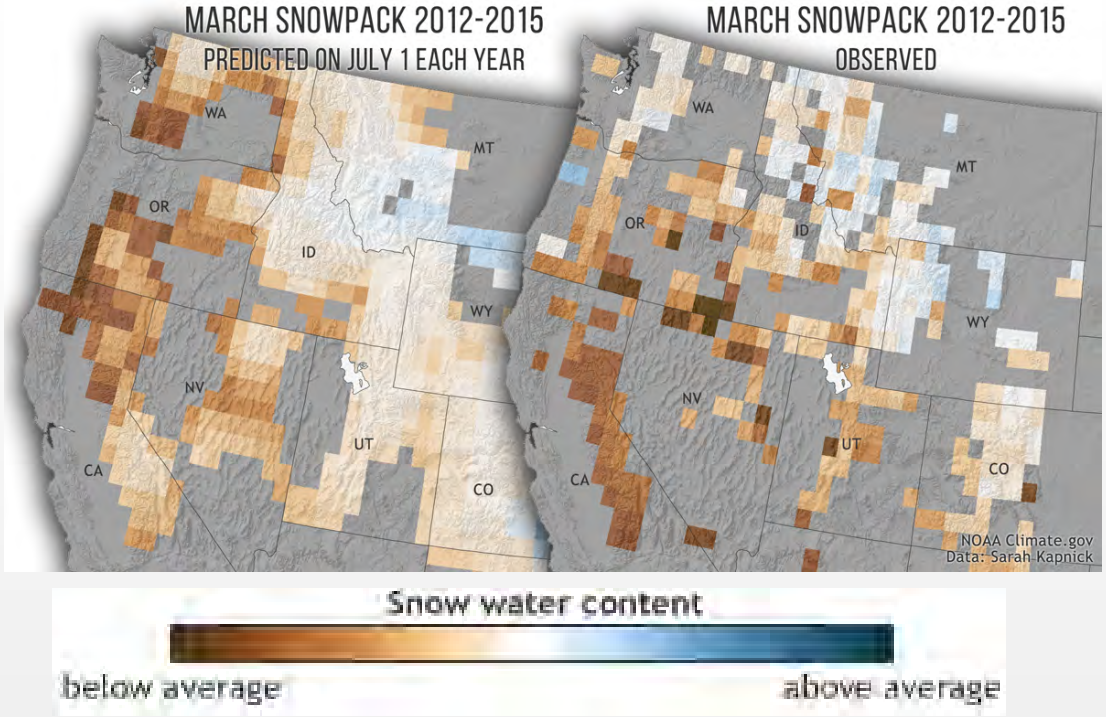


Initial conditions upgrades beyond current system improve:

- Winter western US precipitation
- Global temperature, precipitation
- Tropical cyclone frequency
- Dust

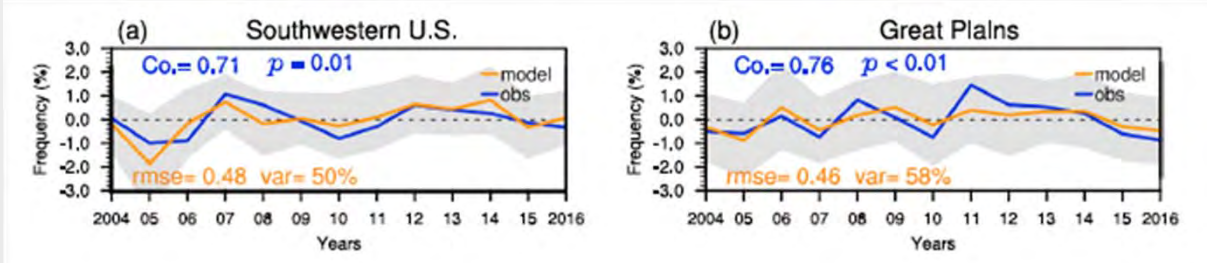
Sources: Yang et al. Climate Dyn, 2018; Jia et al. J Climate, 2016, 2017; Zhang et al. 201X; Pu et al. GRL, *2019*

Prediction Skill: New Skill Identified



Source: Climate.gov image adapted from Kapnick et al., Proc. Natl. Acad. Sci. 2018

March-May Dust Event Anomalies

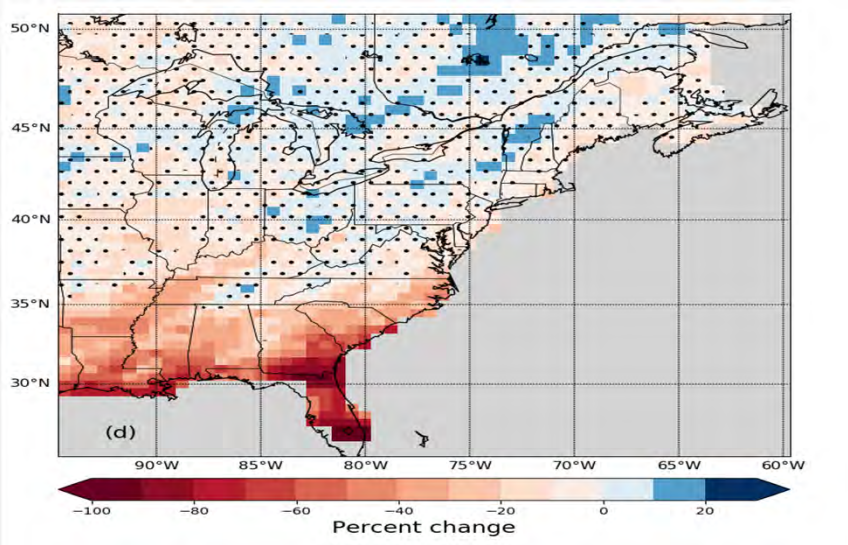


- We are successively looking at more complex prediction problems
  - Start with precipitation & temperature (Jia et al. *J Clim,* 2015, 2016, 2017; Zhang & Delworth, *Nature Comm*, 2018)
  - Extratropical storm tracks (Yang et al., *J Clim,* 2015)
  - Snowpack (Kapnick et al., *PNAS,* 2018)
  - Dustiness (Pu et al, *GRL* 2019)
- Improvements in prediction systems allow us to push the limit of prediction for phenomena, regional scope, & lead time

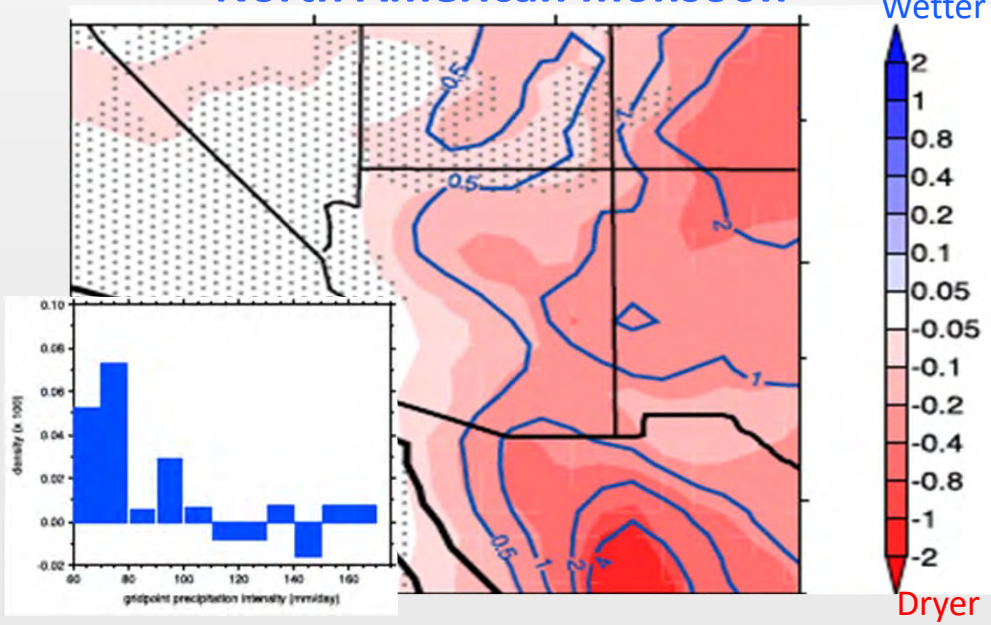
Projections: Traditional & New Phenomena

- Heatwaves (Jia et al., *J Clim,* 2016)
- Droughts / extreme water (Zhang & Delworth, Nature Comm, 2018; Zhang & Delworth, *J Clim,* 2018; Van der Wiel et al., *J Clim,* 2016, Van der Wiel et al., *HESS,* 2017; Delworth & Zhang, *Nature Geo,* 2014)
- Mild Weather (Van der Wiel et al., *Climatic Change,* 2017)
- Snowfall & high winds (Janoski et al., *J Clim,* 2019, Hollings Scholar)
- North American Monsoon (Pascale et al., *J Clim,* 2018)

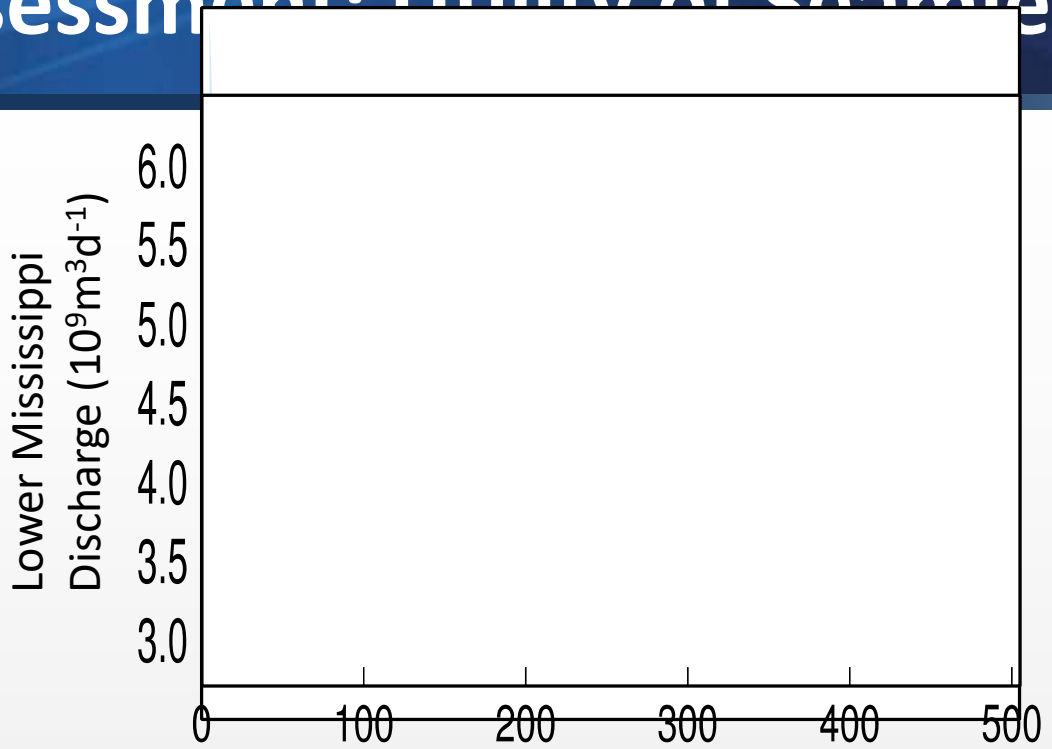
99.99th % snowfall



North American monsoon



Risk Assessment: Utility of Seamless System



- **Long model simulations (100s or 1,000s of years) provide reductions in uncertainty for risk assessment:**
  - Before an event happens: Calculate present or future risks of events for infrastructure / resilience planning
  - After a major event happens: Can isolate causes or risk of a specific event (*Van der Wiel et al., HESS, 2017; Murakami et al., GRL, 2019)*
- **A seamless system allows for extreme risk assessment and validation across timescales to improve verification and understanding**

Sources: Van der Wiel et al. J. Hydrometeo, 2018;

Key takeaways

- **Stakeholder needs:** need to know the past, present and future risks, improve prediction skill & transfer to operations(e.g. via data, understanding, code)
- **Research feeds back on model development from prediction to projection:** the research fundamentally explains what can be modeled to understand where to best focus efforts
- **Novel science:** Improve current understanding and develop new research areas
- **Models provide a risk assessment testbed:** 50+ km resolution for regional problems and develop probabilistic estimates of risk and prediction in a way not possible with observations alone
- **The new frontier:**
  - Development of SPEAR to address questions raised by the past prediction (e.g. reduced SST bias, L65 prediction model)
  - Targeted experiments to seamlessly explore hydroclimate
  - Creative research to explore different kinds of “extremes”
  - Expand quantification capabilities of weather & climate risks; expand to applications (e.g. climate finance, infrastructure)