Impact of parameters on runoff sensitivities in CLM: a study over the Upper Colorado headwaters

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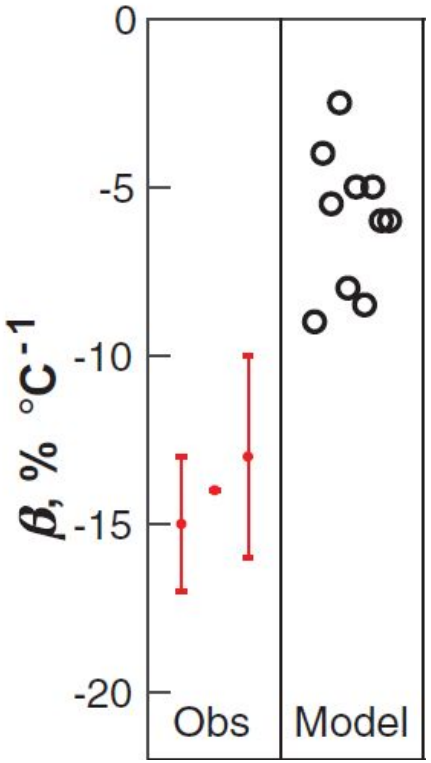
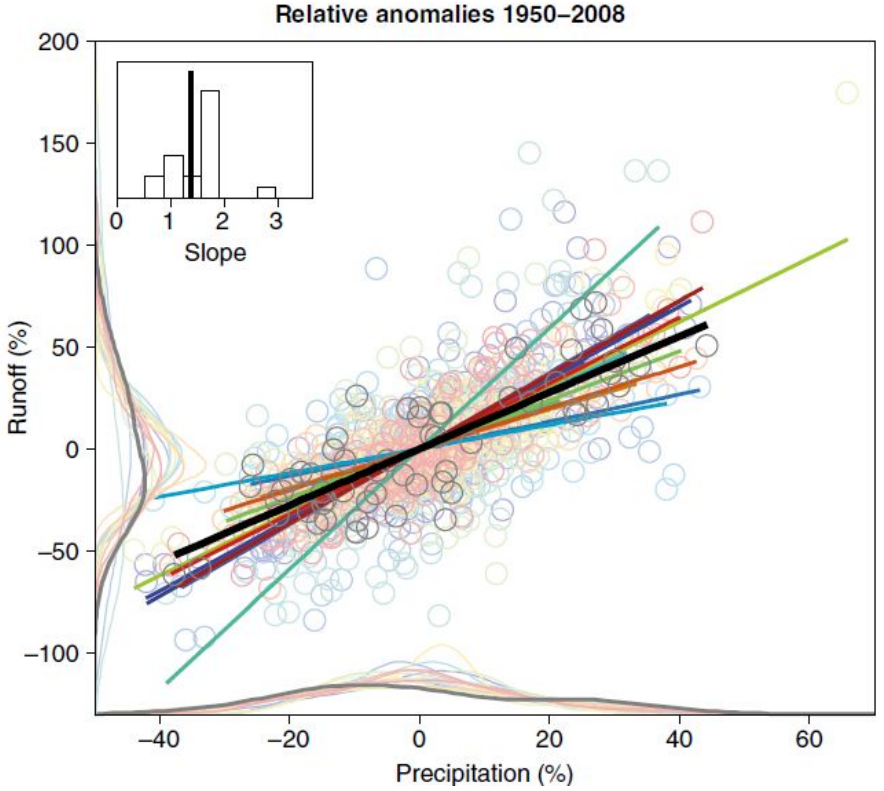
Model biases in runoff sensitivities

Upper Colorado basin



Milly & Dunne 2020

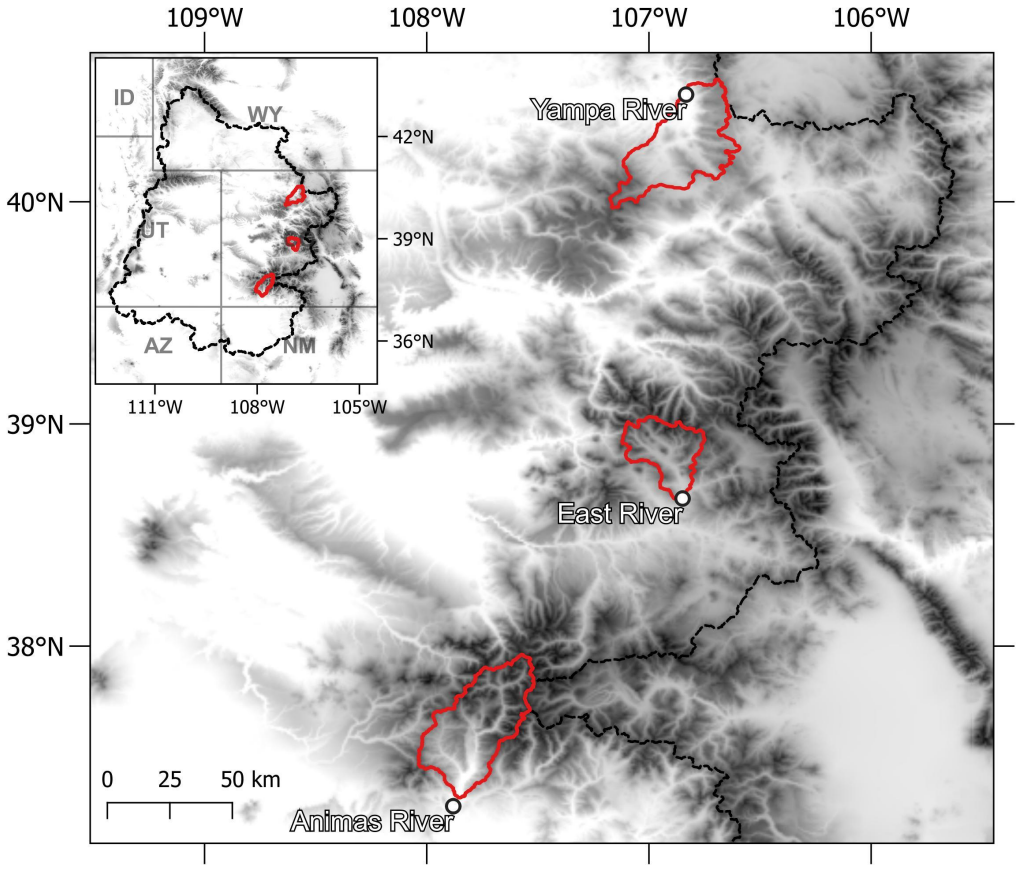


Lehner et al. 2019

- What are the most sensitive parameters for runoff sensitivities in CLM?
- How parameter values affect modelled runoff sensitivities?

Study domain and model setup

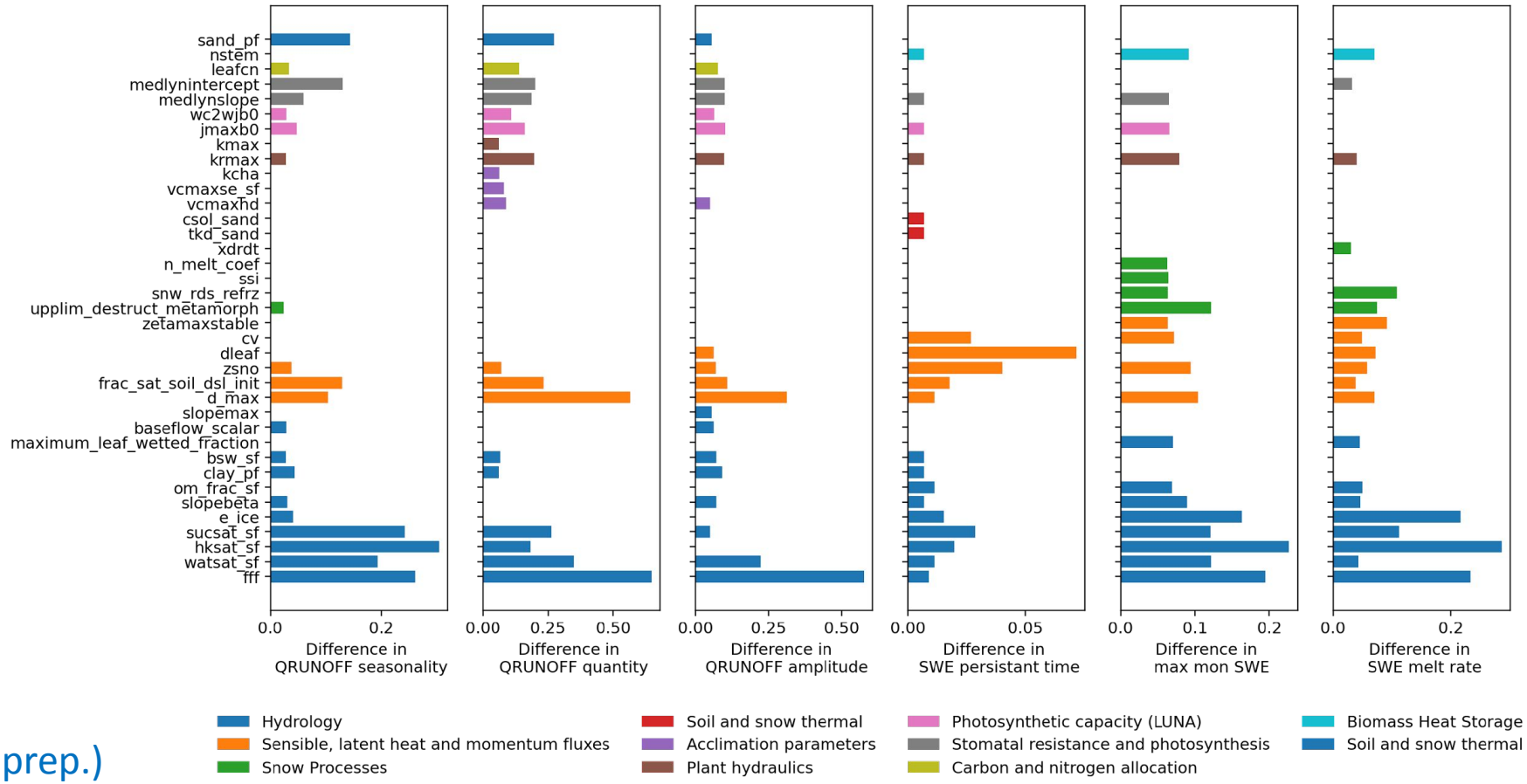
- Representative of the unregulated headwaters regions
- Consideration in many CC and parameter sensitivity analyses (e.g., Mendoza et al. 2015)
- Relatively Small area (thousands of model runs)
- ctsm5.1.dev108, Satellite Phenology (SP), 0.9x1.25 surface dataset
- Model runs over **60-year (1951-2010)**
- Precipitation and Temperature from Livneh et al. (2015), other forcing from GSWP3
- T and P sensitivities of runoff are estimated through regression (with storage correction Milly et al. 2018)



Three basins in the Colorado Headwaters Region

Pre-screening of parameters using PPE

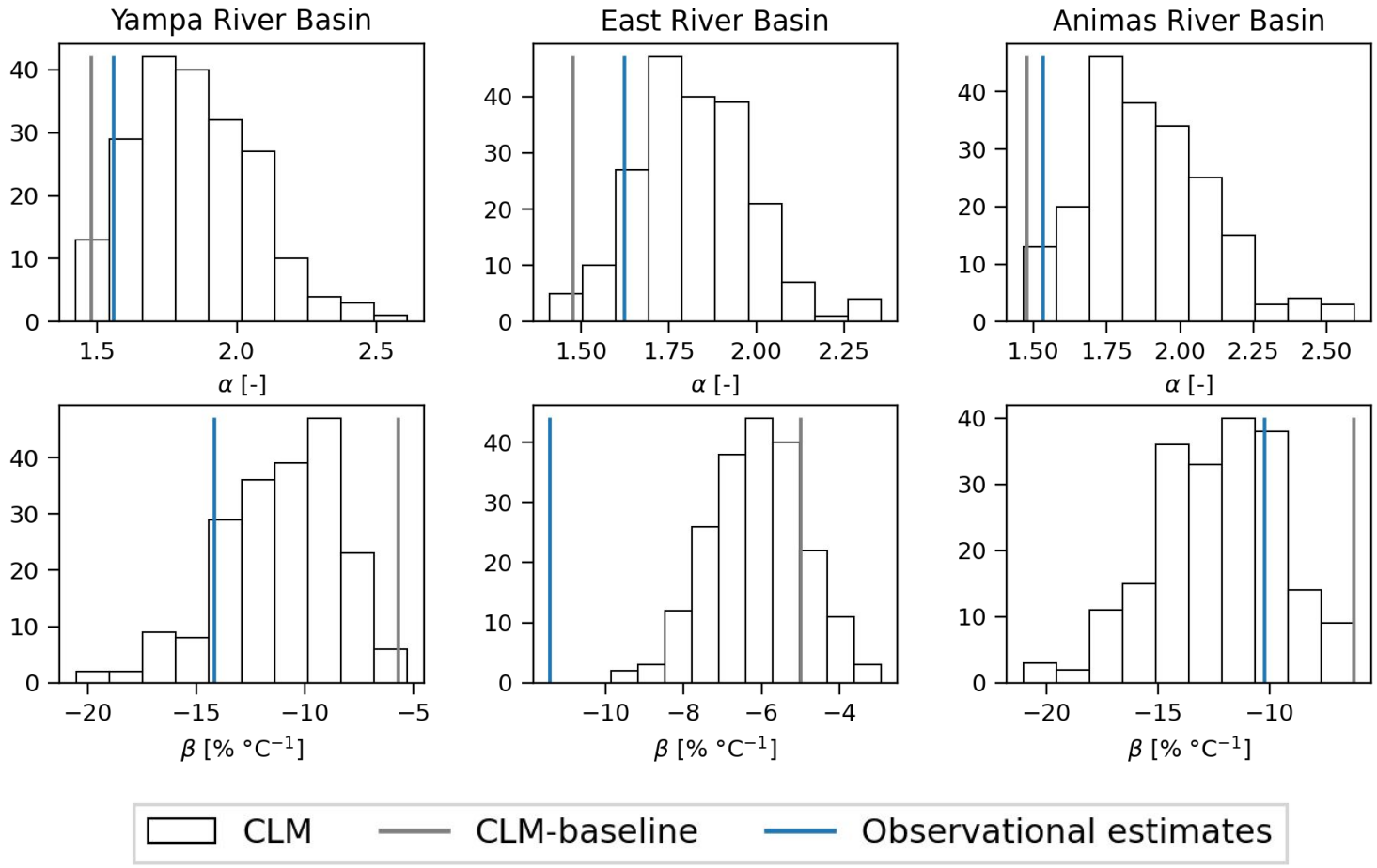
- Perturbed Parameter Ensemble (PPE) used to calculate six metrics following Cheng et al. (2022); Dagon et al. (2020)
- **37 informative parameters** for hydrology in Southwestern US



Elkouk et al. (in prep.)

Parametric uncertainty in model runoff sensitivities

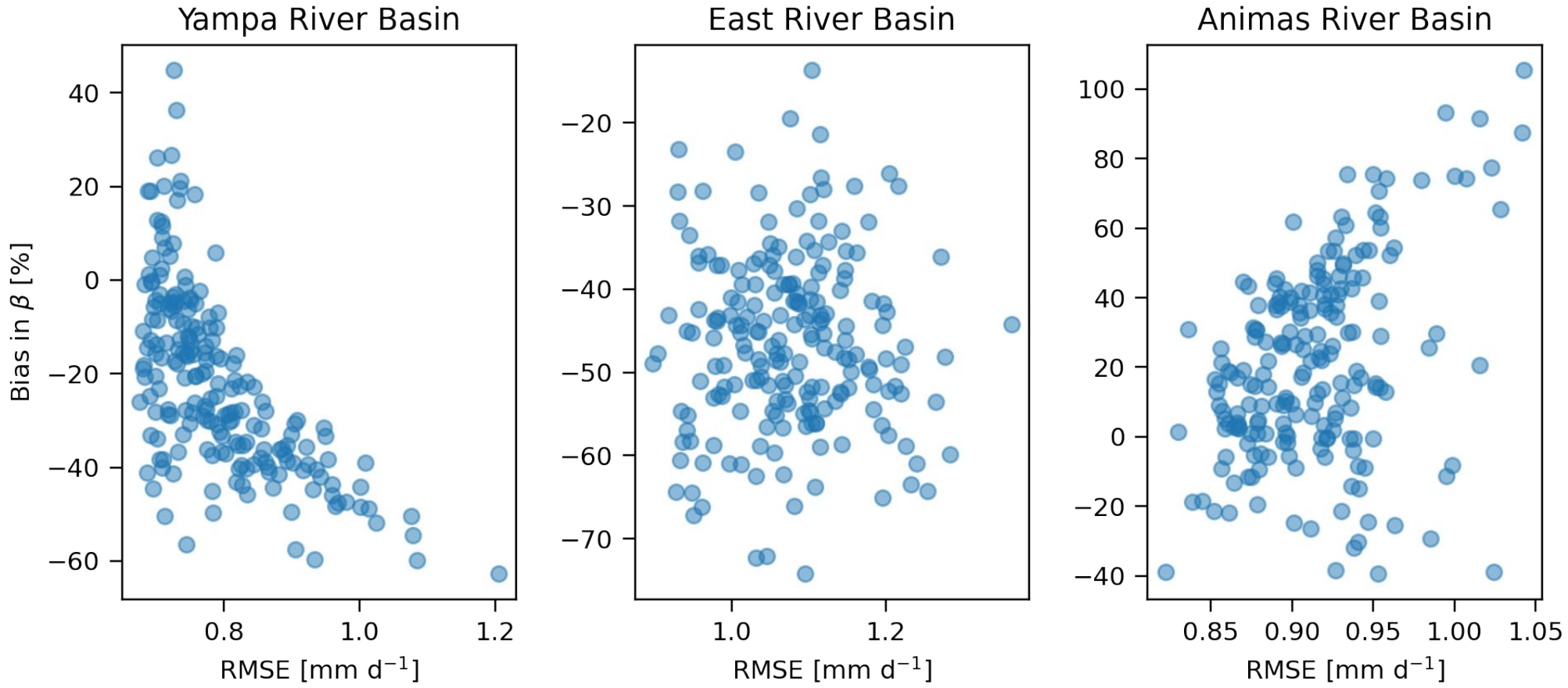
- 37-parameters Latin Hypercube sample (N=200) ensemble of 60-year simulations
- T sensitivity β [-21, -6] % $°C^{-1}$
- T sensitivity varies by a factor of **2** among LSMs e.g., Vano et al. (2012)
- P sensitivity α [1.46, 2.59]



Elkouk et al. (in prep.)

Reducing errors in runoff does not necessarily improve runoff sensitivities

Bias in T sensitivity of runoff (β) 1951-2010



- Reaffirms conclusions of previous studies e.g., Mendoza et al. (2015): reducing errors in runoff might not correctly reproduce catchment processes.

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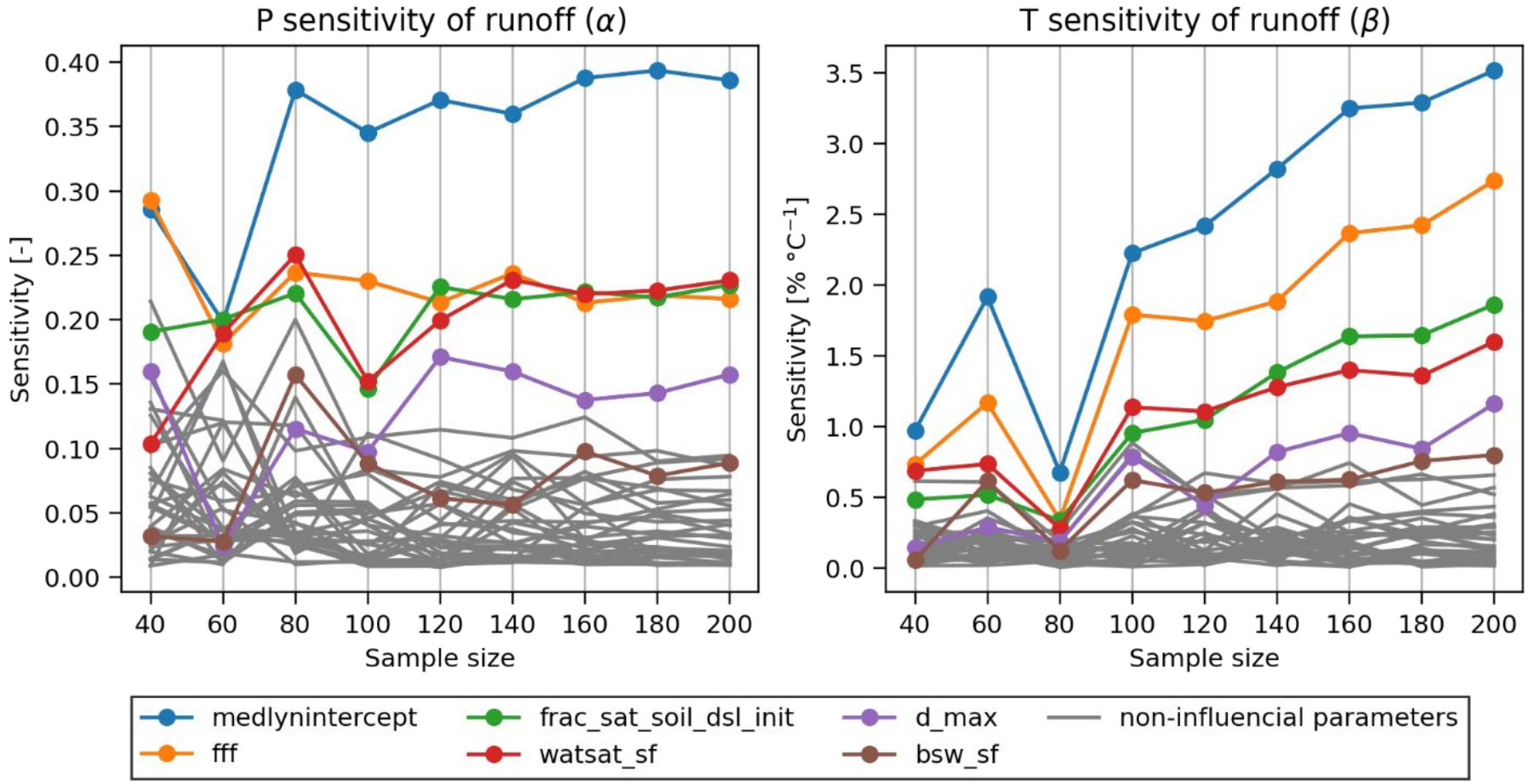
Identification of the most sensitive parameters

- 37-parameters Latin Hypercube sample (N=200) 60-year simulations ensemble
- Surrogate models (Cheng et al. 2022) used to identify the most important parameters



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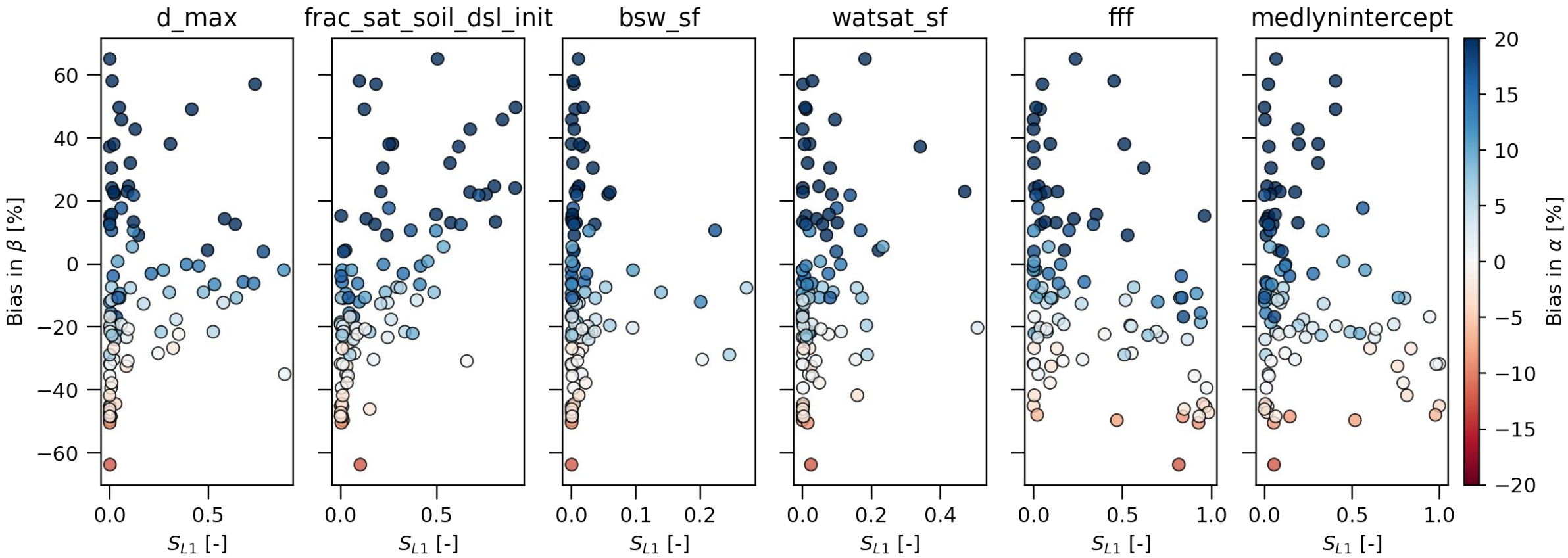
Conditioning of parameter sensitivity using model performance

- Reducing the number of parameters simplifies the sensitivity analysis exercise
- Distributed Evaluation of Local Sensitivity Analysis (DELSA) (Rakovec et al. 2014).



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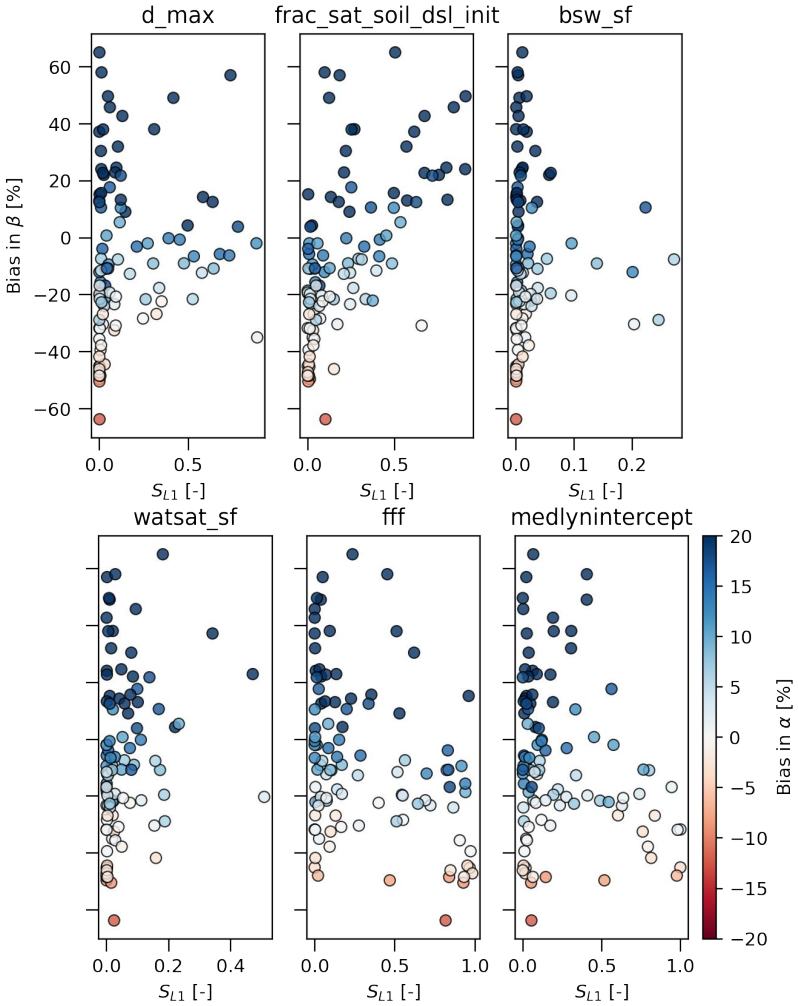
Conditioning of parameter sensitivity using model performance

- Where β is underestimated: **(fff, medlynintercept)**
  - Flashier total runoff ➔ surface runoff ➔ Infiltration ➔ sub-surface runoff & evapotranspiration
  - Higher in stomatal resistance ➔ Transpiration
- Where β is overestimated: **(d_max, frac_sat_soil_dsl_init)**
  - Less surface resistance to evaporation ➔ soil evaporation ➔ sub-runoff (spring and summer)
- Bias in β: **(watsat_sf)**
  - Porosity ➔ Latent heat (*soil evaporation*) and total runoff
  - Increase (decrease) evaporation & subsurface runoff



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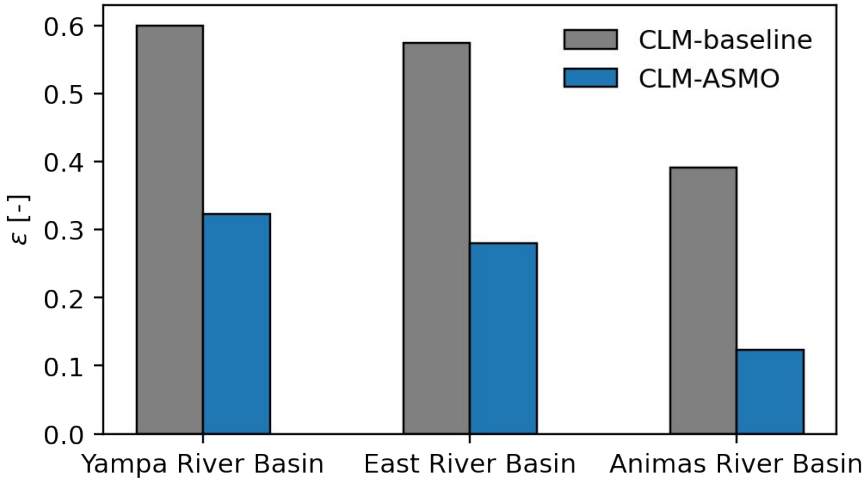
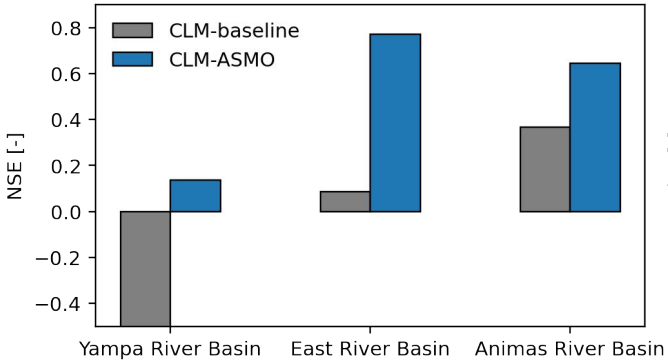
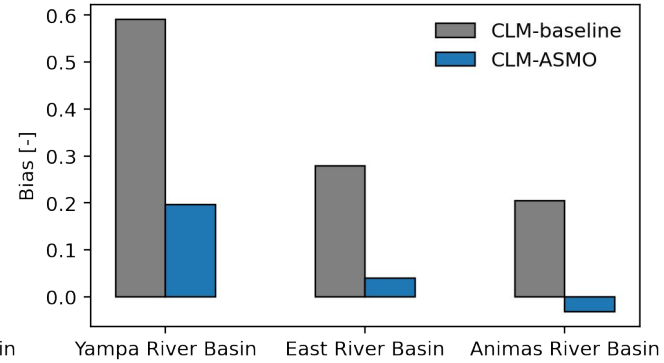
Optimization of most sensitive parameters

- Adaptive Surrogate Based Modeling Optimization (ASMO) in Cheng et al. 2022
- $\epsilon = \sqrt{\left(\frac{\alpha_{sim}-\alpha_{obs}}{\alpha_{obs}}\right)^2 + \left(\frac{\beta_{sim}-\beta_{obs}}{\beta_{obs}}\right)^2}$
- Reduce bias from **52% to 28%** (**mainly in $\boldsymbol{\beta}$**)
- Improvement in other metrics (NSE, long-term bias in runoff)
- High resolution surface dataset could further reduce biases







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Conclusions

- Reducing errors in runoff does not necessarily improve long-term runoff sensitivities
- Surface runoff parametrization, resistance to soil evaporation and transpiration, and soil hydraulic constants (porosity) are important sources for bias in runoff sensitivities in CLM
- Illustrate that consideration of long-term hydrologic sensitivities can help to guide model development (Lehner et al. 2019)
- Expand the analysis to other environments requires development of workflows e.g., make spatially averaged surface dataset over a catchment of interest (similar to single point simulations).

Many Thanks!

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