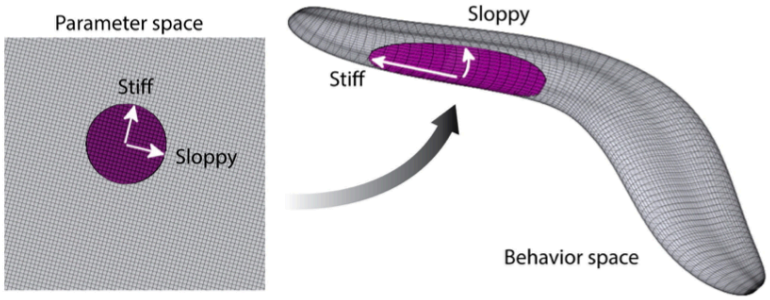
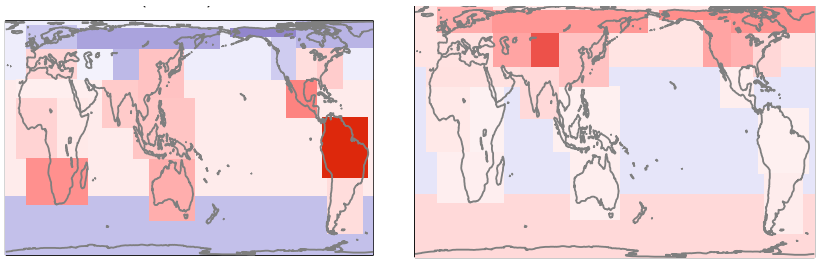
The geometry of parameter space in standard and ultra-low resolution CESM PPEs

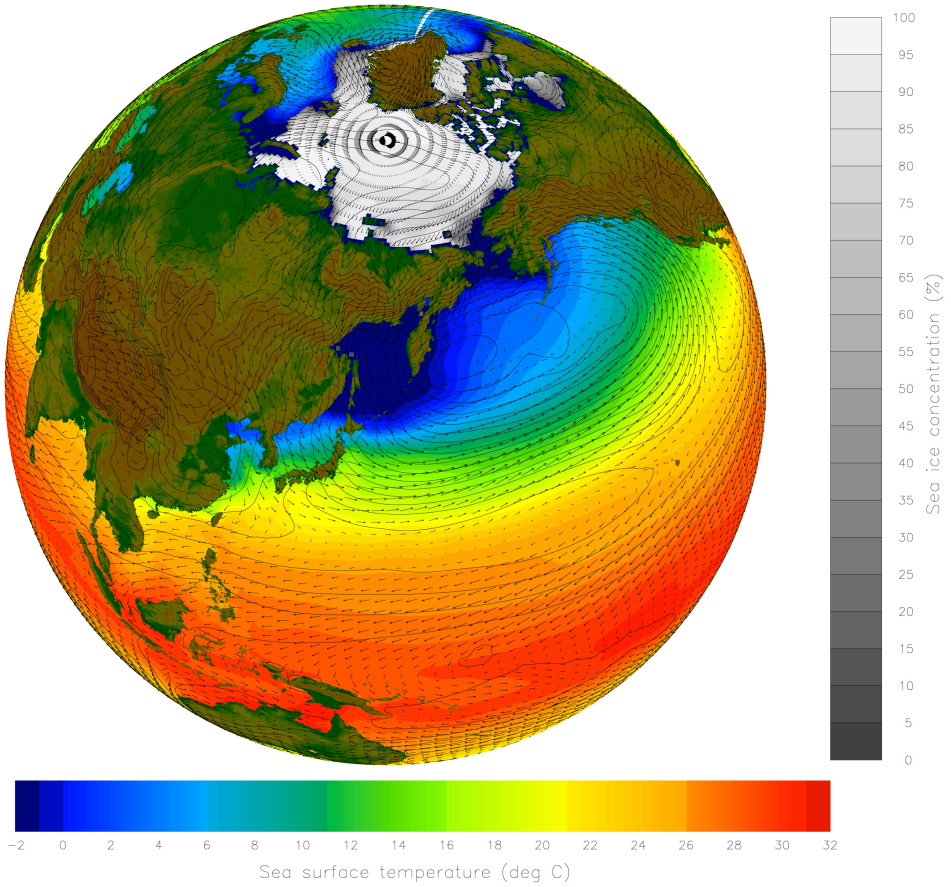




Sanderson et al. 2008

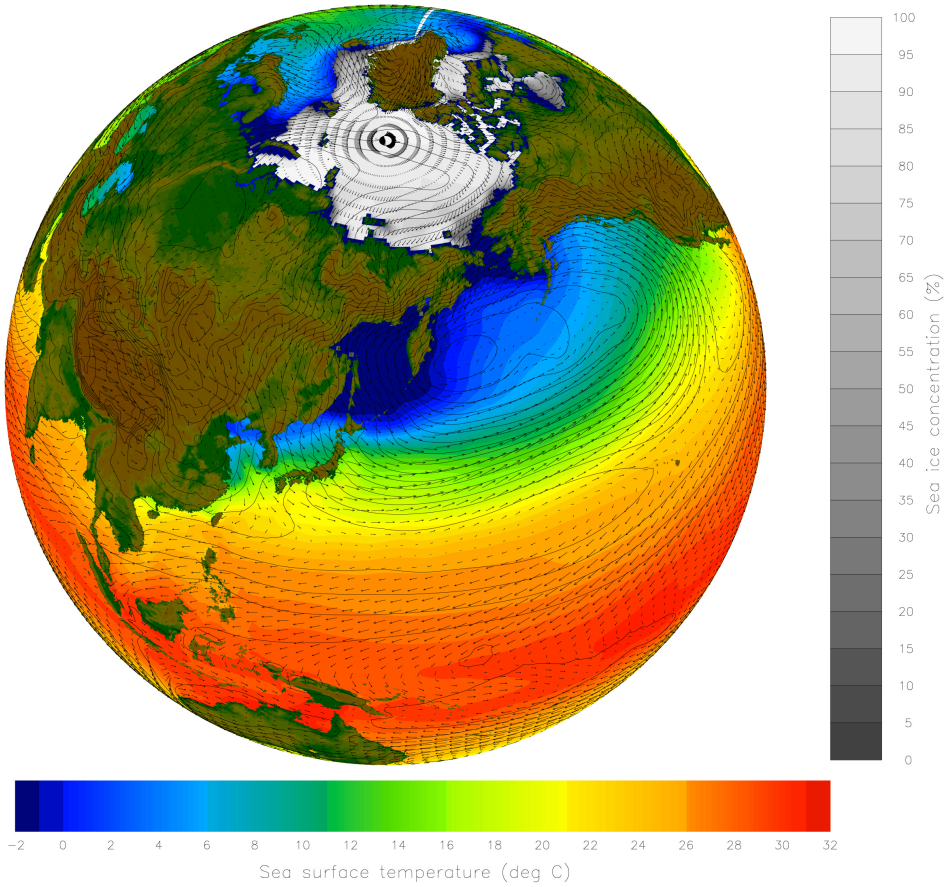
June 2024, CESM Workshop - AMWG
Itay Griniasty, Benjamin Moose, Joshua Fan, James P. Sethna & Angeline Pendergrass
Cornell University

How to constrain climate projections with observational data given the huge dimension of parameter space?



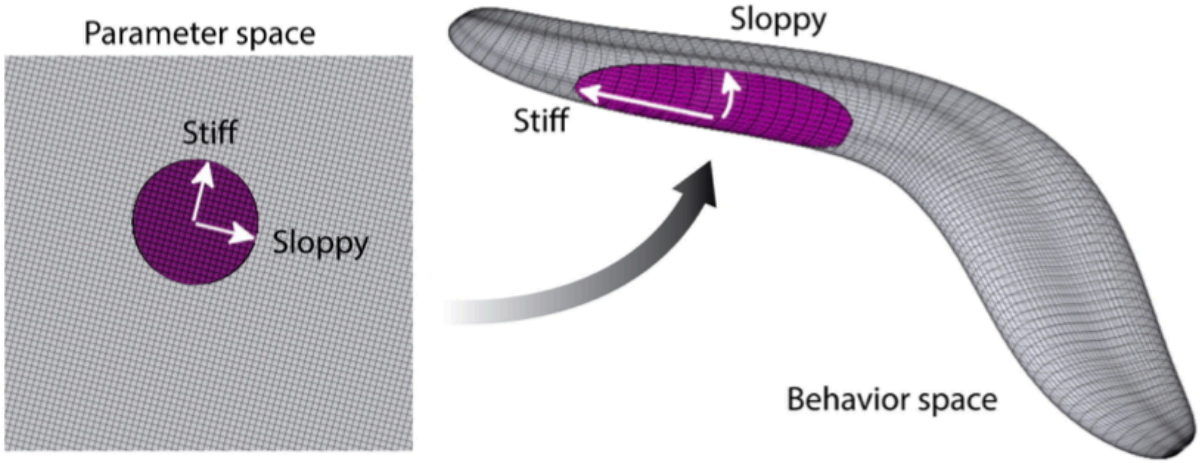
$\sim \mathcal{O}(1000)$ parameters

Do We need to Know the Value of all Climate Model Parameters?

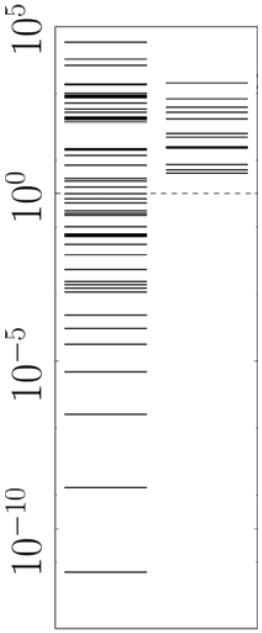


$\sim \mathcal{O}(1000)$ parameters

Simple Questions Lead To Simple Models?



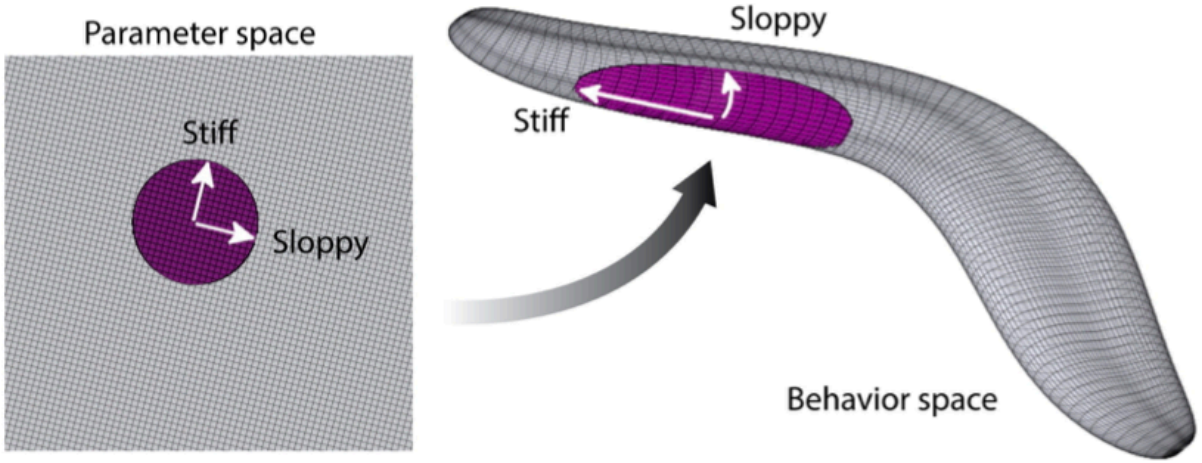
Quinn et al. 2022



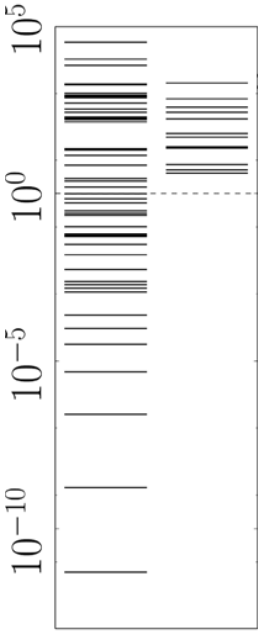
Importance to prediction of parameter combination

Transtrum and Qiu 2014

Sloppiness: Importance to Precdictions Decay Exponentially



Quinn et al. 2022



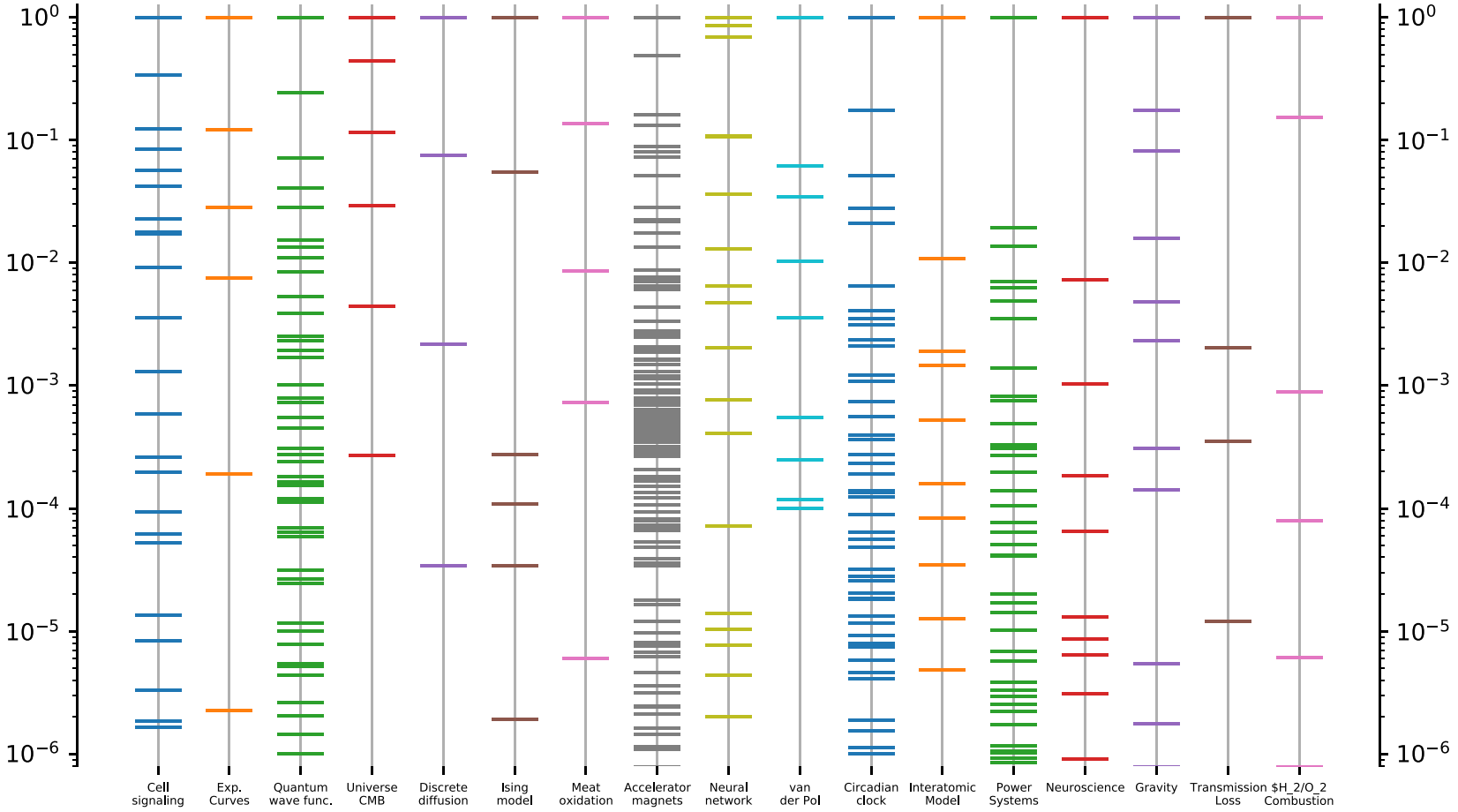
Fisher Metric: How much can we tell models apart?

$$\mathcal{I}_{i,j}(\theta) = \mathbb{E}[\partial P(\theta)/\partial_{\theta_i} \cdot \partial P(\theta)/\partial_{\theta_j}]$$

Fisher Spectrum
Importance to prediction of parameter combination

Transtrum and Qiu 2014

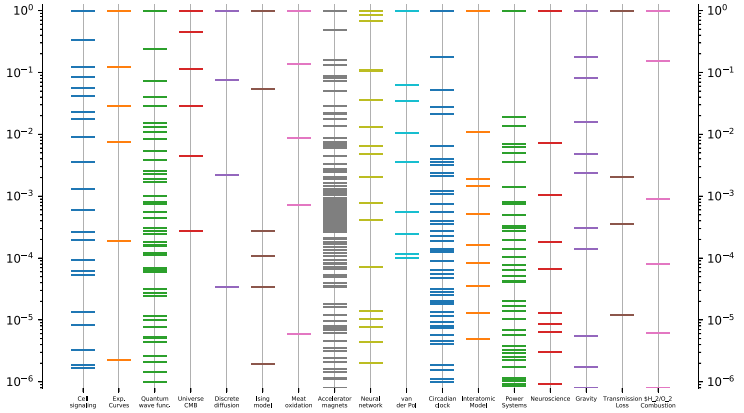
Sloppyness is Universal



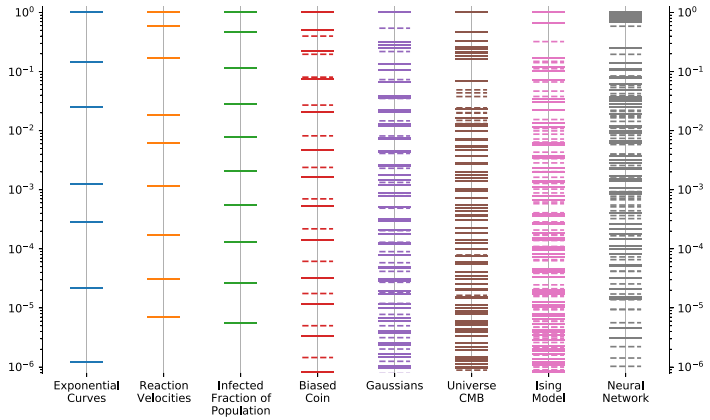
Quinn et al. 2022

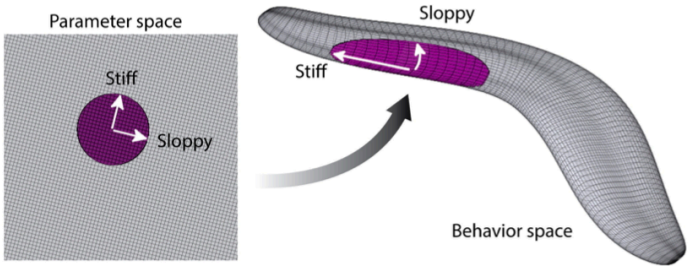
Global and Local Sloppiness

Parameter Hierarchy

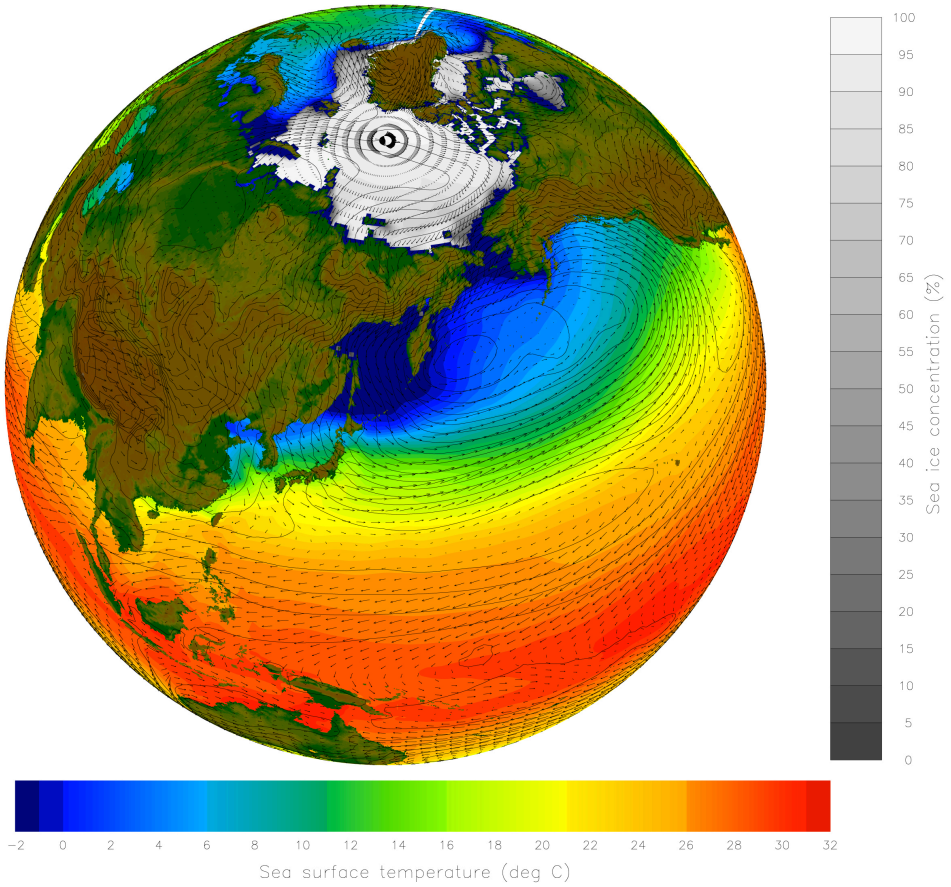


Model Widths





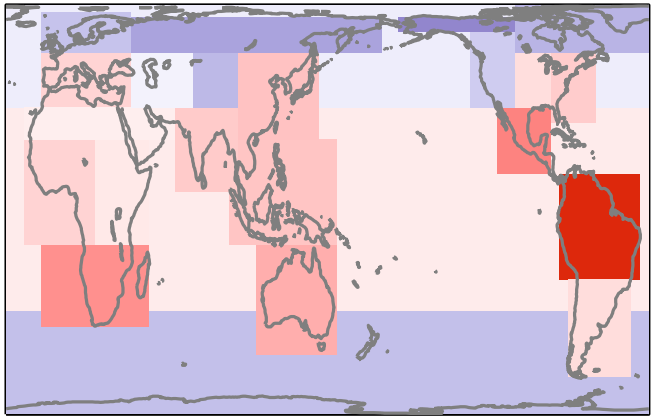
Understand Model Variability by Dimensional Reduction



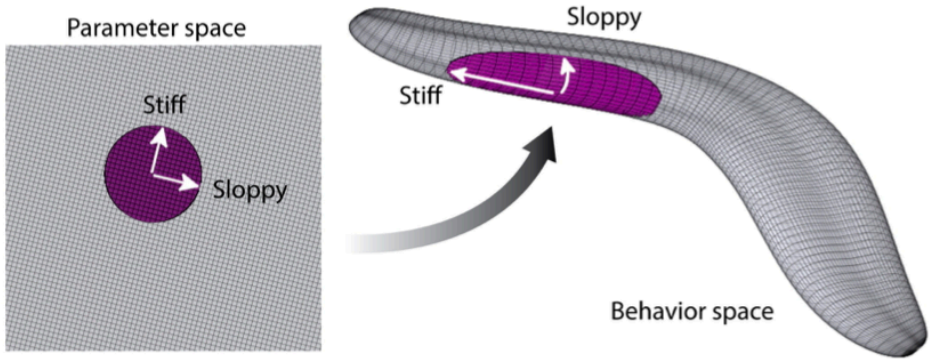
$\sim \mathcal{O}(1000)$ parameters

Dimensionality Reduction for Climate Predictions

Low Resolution $10^\circ \times 15^\circ$ Model

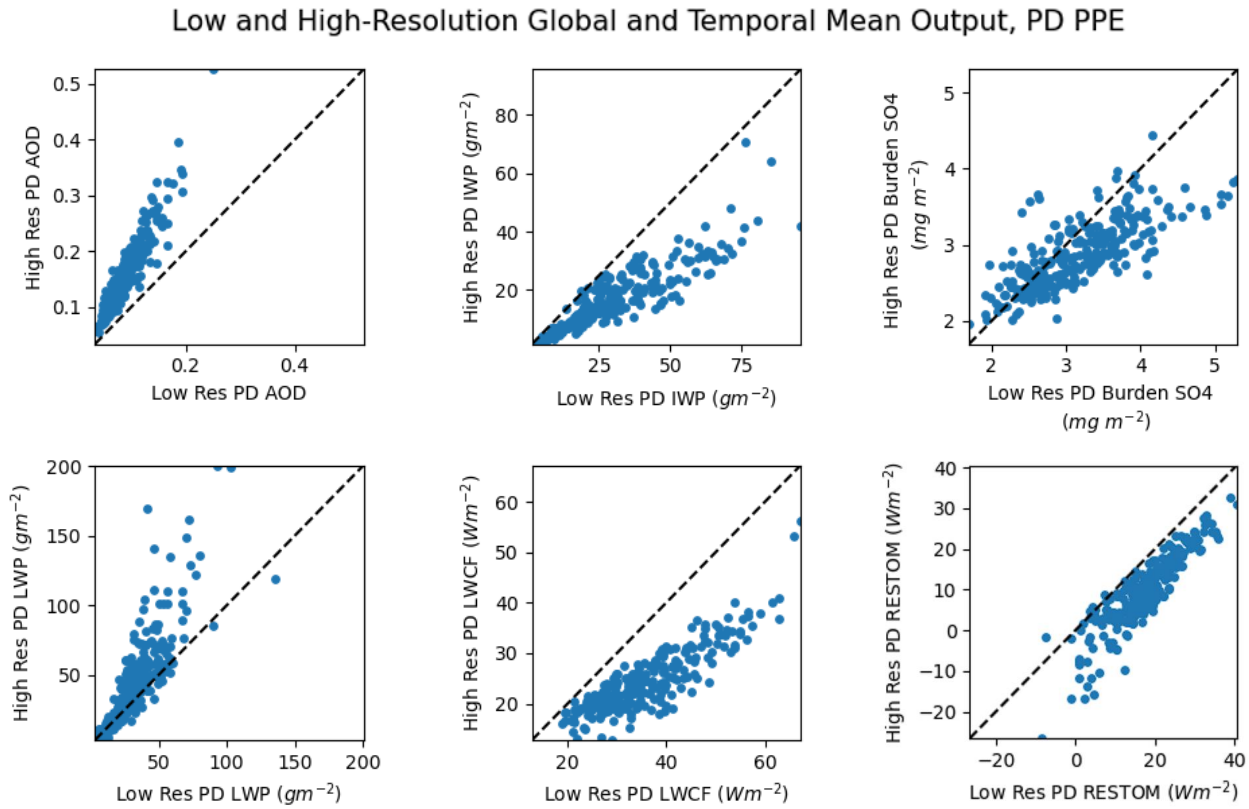


Find Low Dimensional Representation



- Explore Behavior manifold & Fisher Metric
- Analyze Robustness of predictions

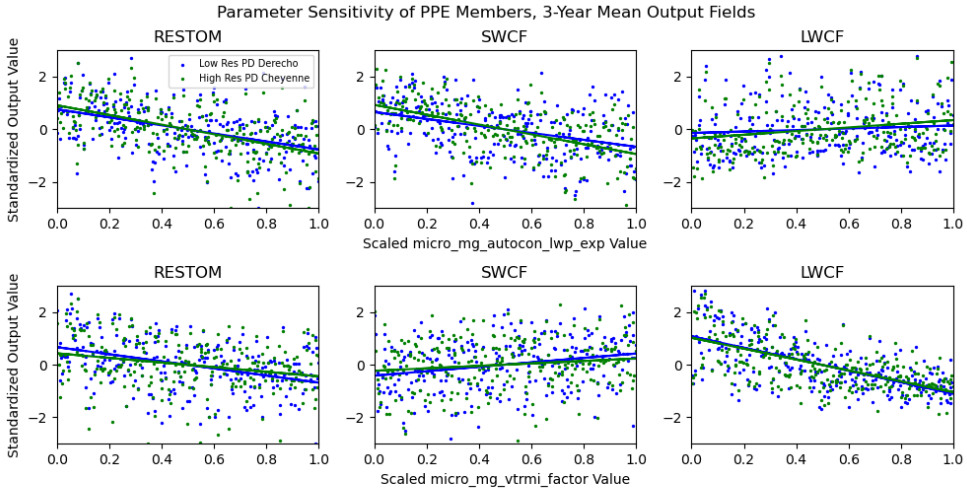
Benchmark low resolution model

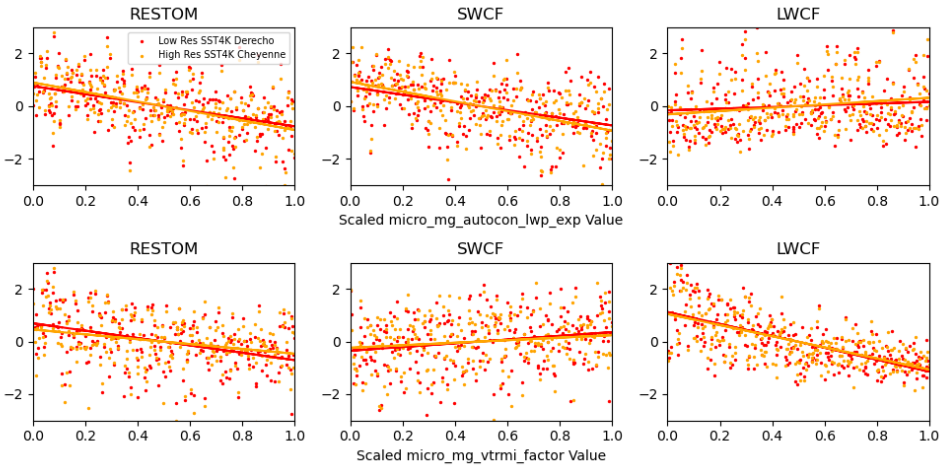


Linear Relationship
Low Res to High Res

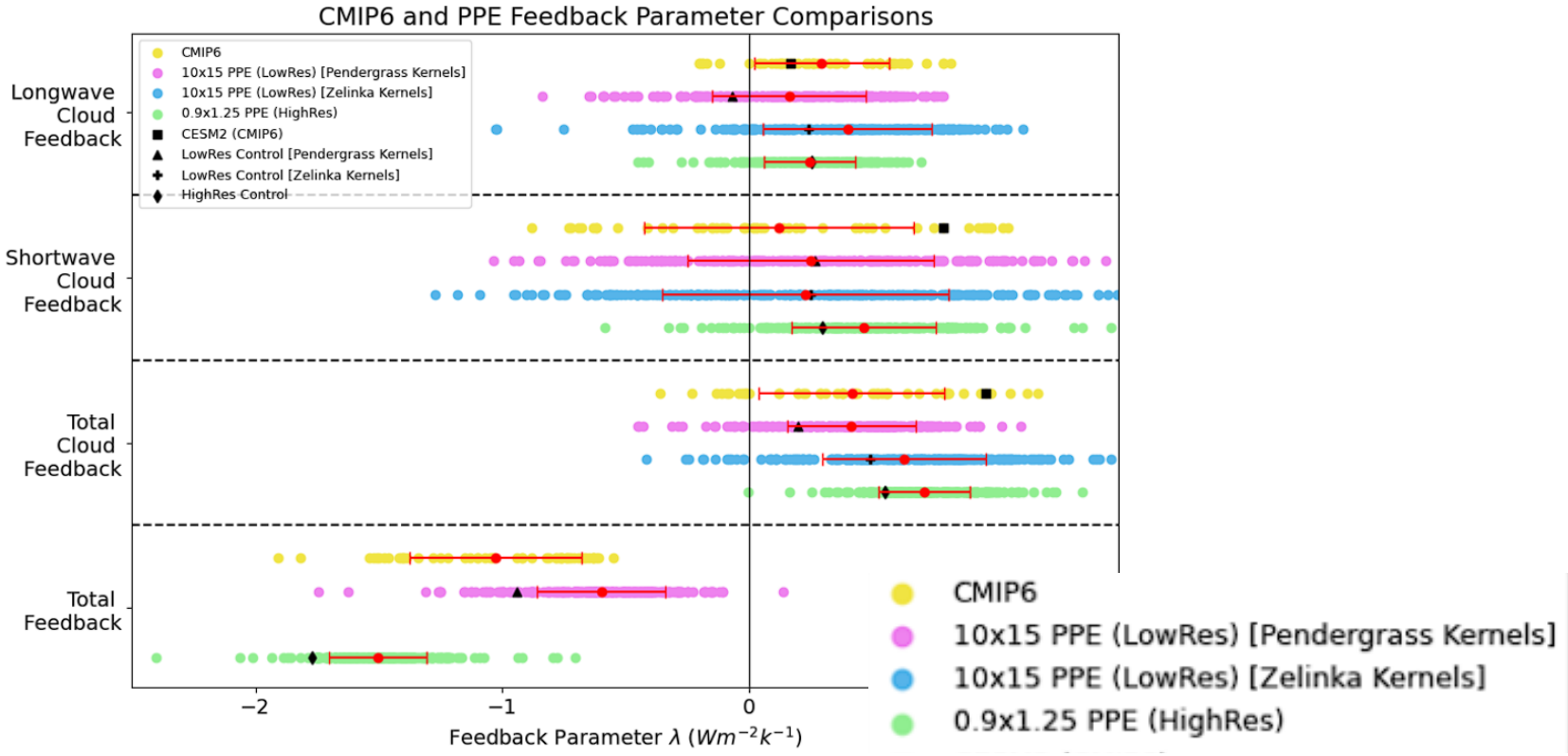
Compare to High Resolution PPE: Eidhamer et al. 2024, Low Res PPE & analysis by B.H. Moose
Cost: 8000 core hours

PD and SST4K show alignment of Low Res to High Res Reponse to Parameter Variation

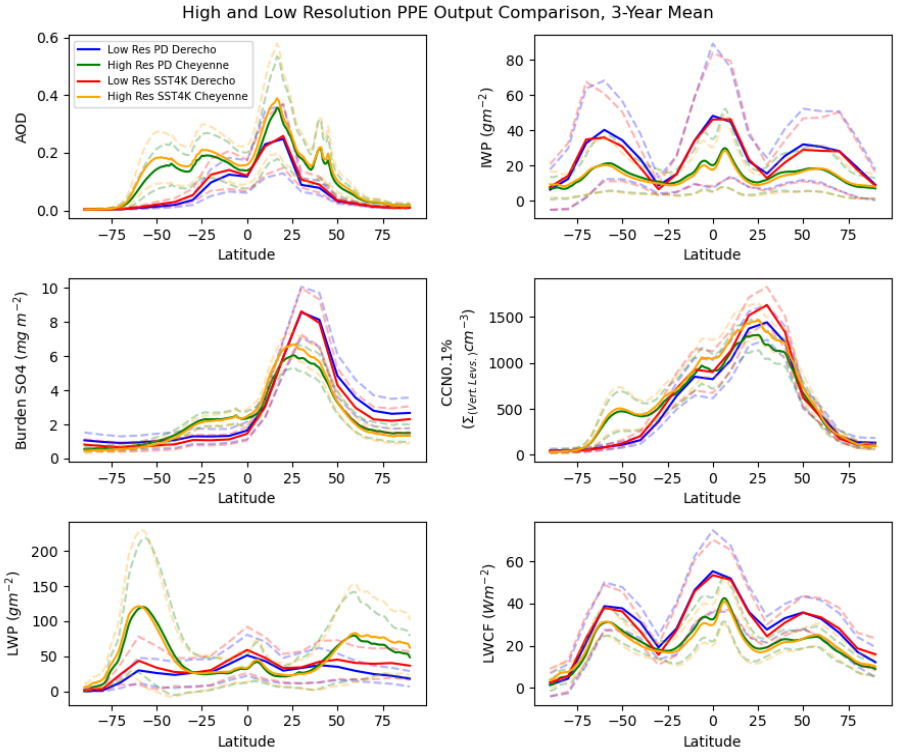


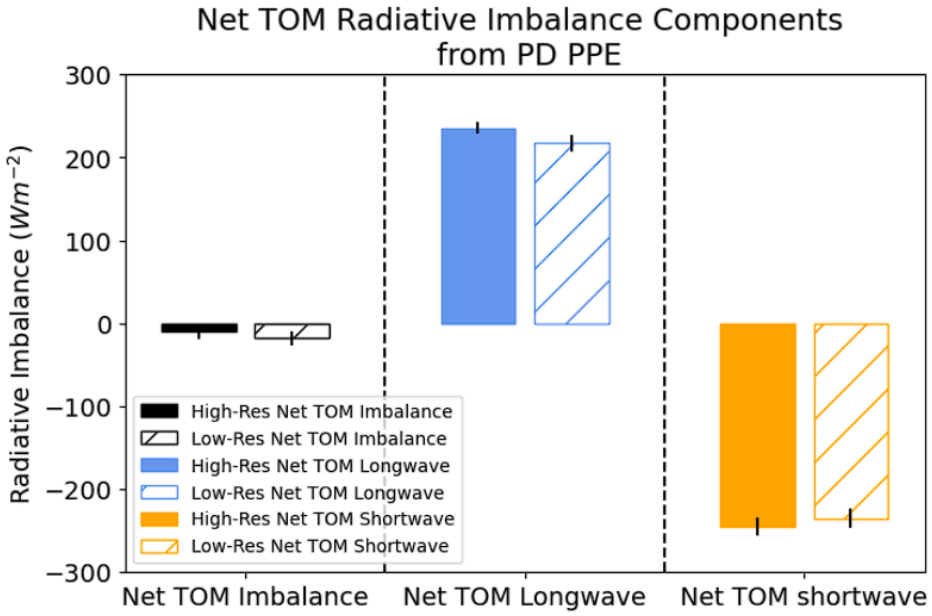


Low Res Captures CMIP6 Variation

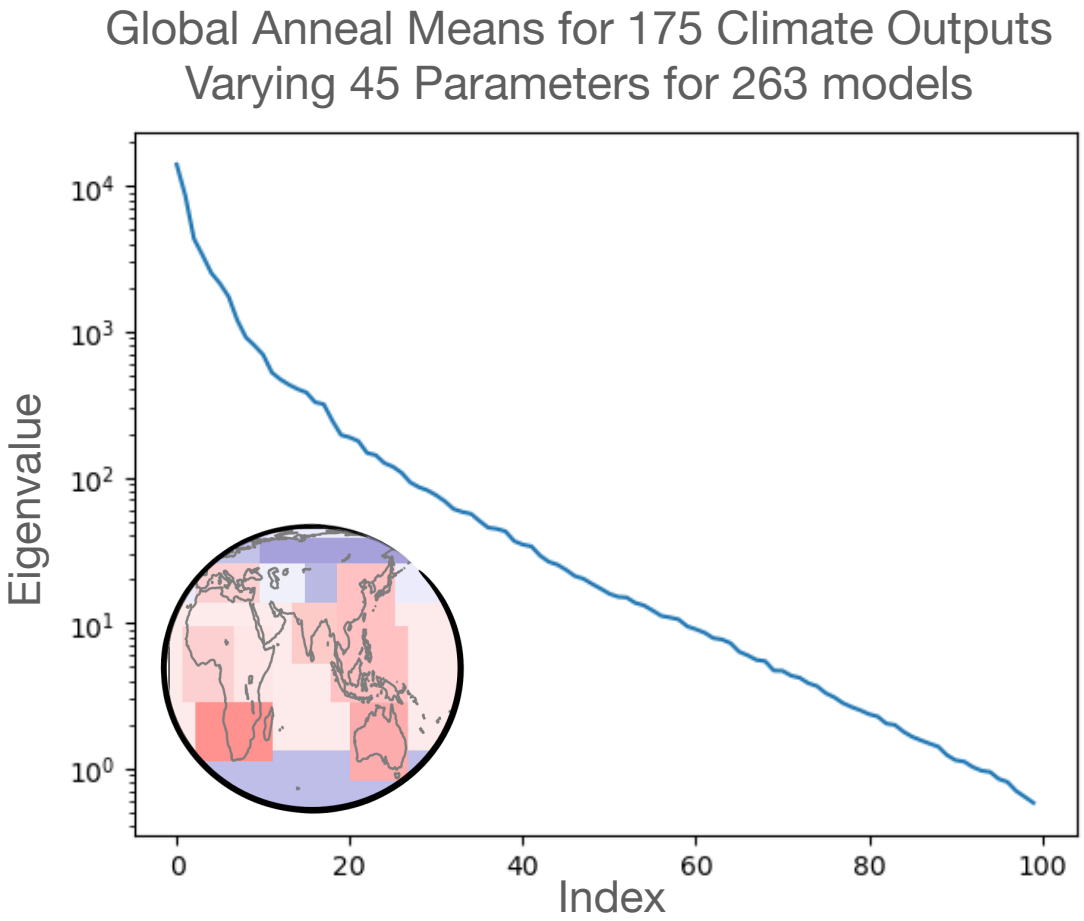


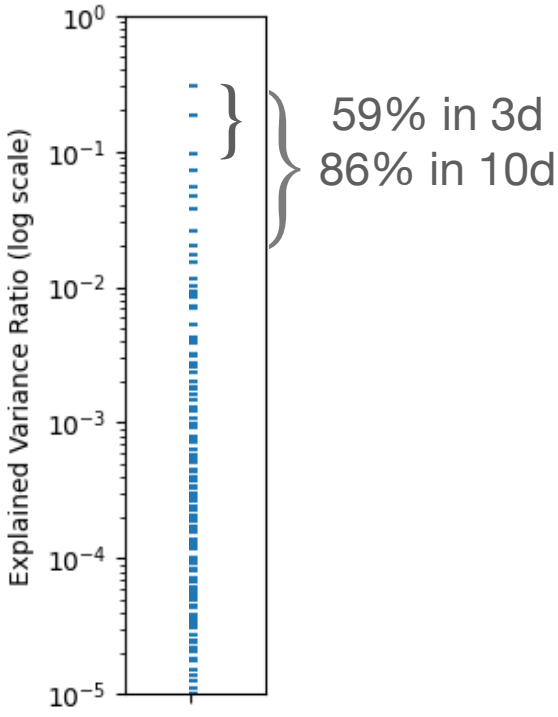
Caveat - Spatial Distribution May be Off For Low Res





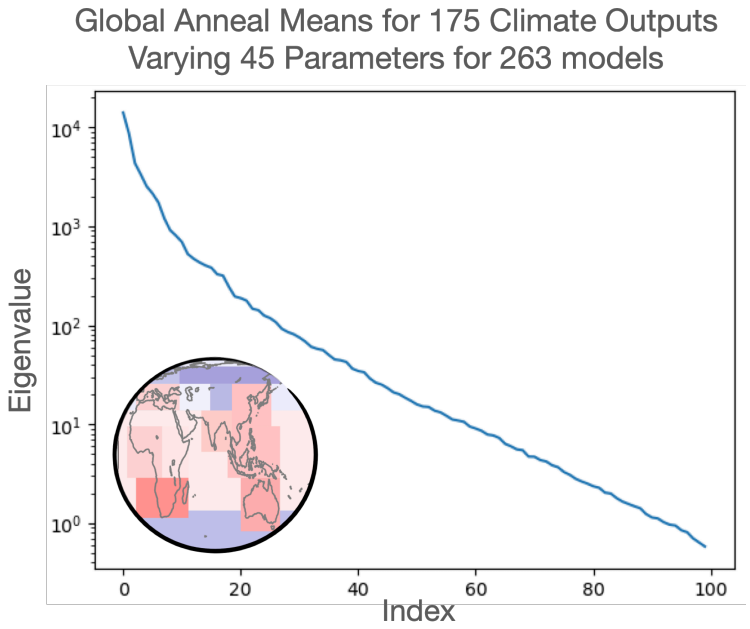
Initial sloppiness analysis



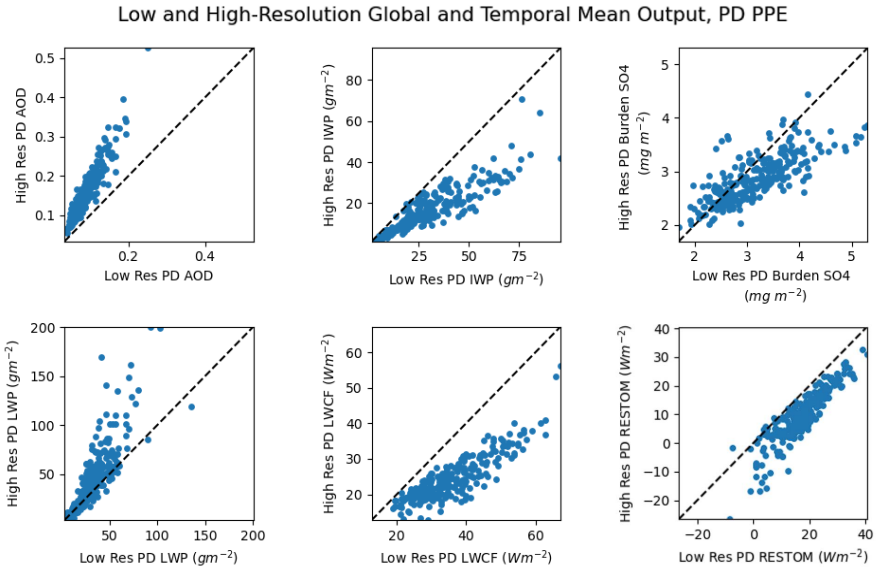


Summary

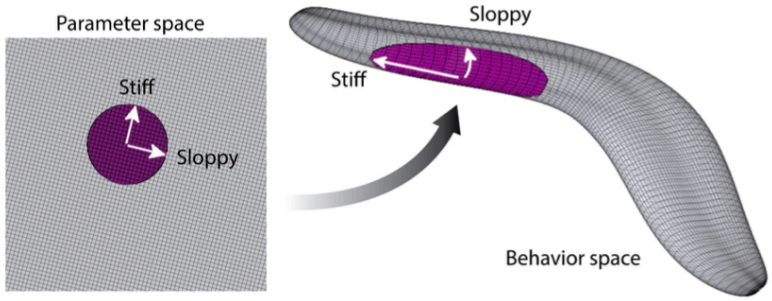
- Climate is Sloppy



- Ultra Low Resolution CESM is **adequate** for exploring global behaviors

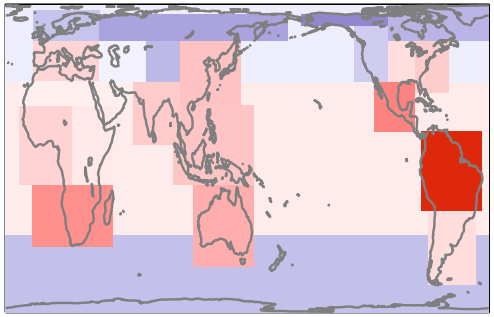


Looking ahead:



- Find low dimensional representation
  by identifying stiff directions in parameter space
  (those that best explain variation)

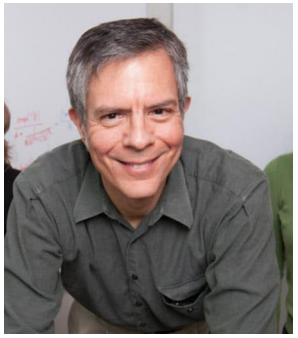
- Explore climate response using low dimensional representation



- Slab ocean
- Interpret physics of stiff directions
- Analyze robustness of predictions

Thank you

Angeline Pendergrass



James Sethna

Benjamin Moose

Joshua Fan

NSF

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