# S2S Predictability of Weather Regimes

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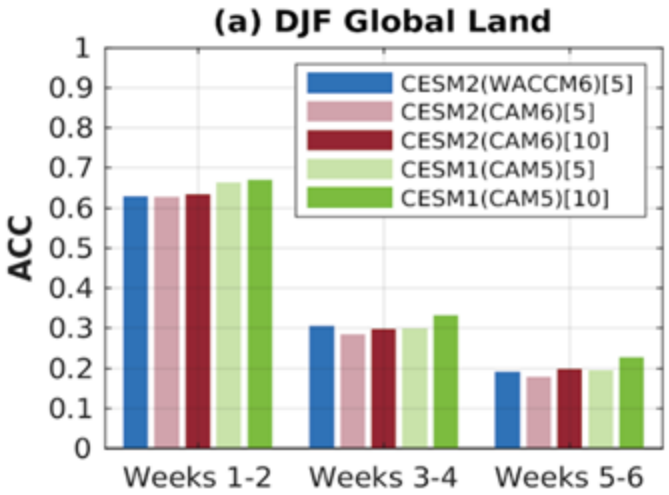
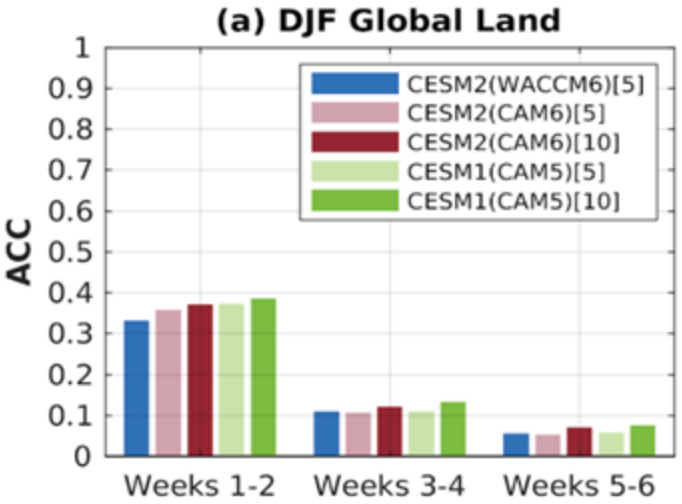
## Temperature skill




## Precipitation skill

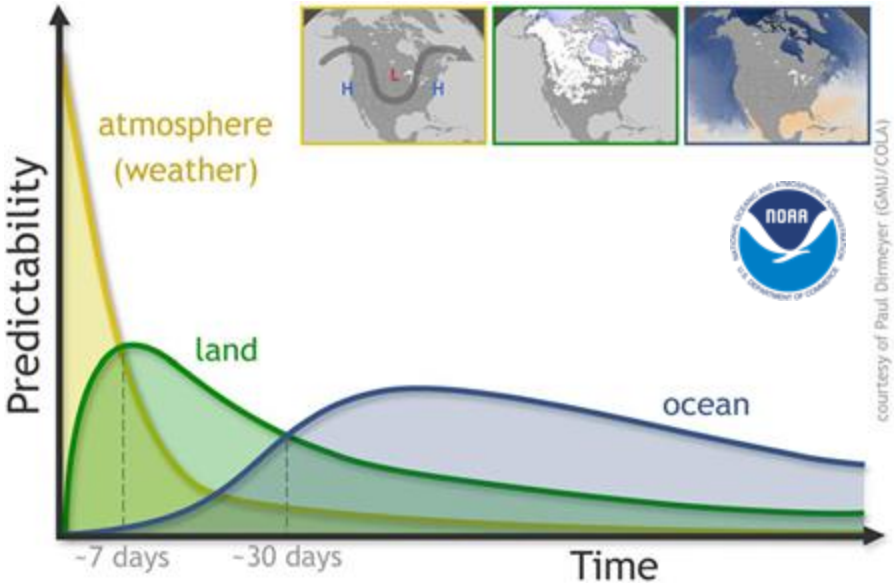



Richter, J. H., Glanville, A. A., Edwards, J., … & Oleson, K. W. (2022). Subseasonal Earth system prediction with CESM2. Weather and Forecasting, 37(6), 797-815.

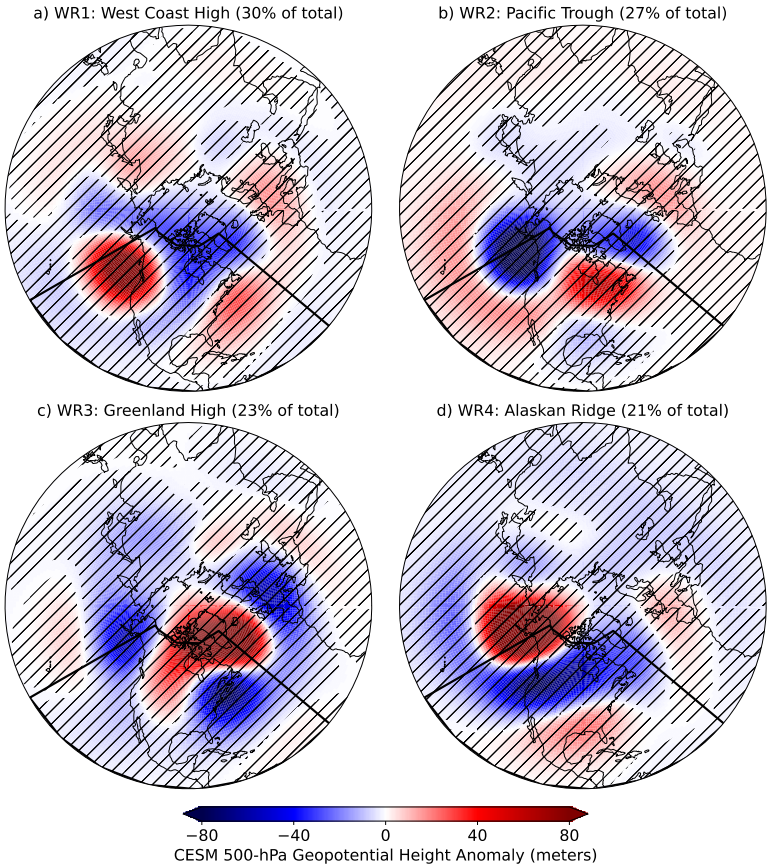
Let's "simplify" the forecasting problem…

S2S simulations created using CESM2 (Richter et al. 2022).

Subseasonal reforecasts follow SubX protocol (Pegion et al. 2019).



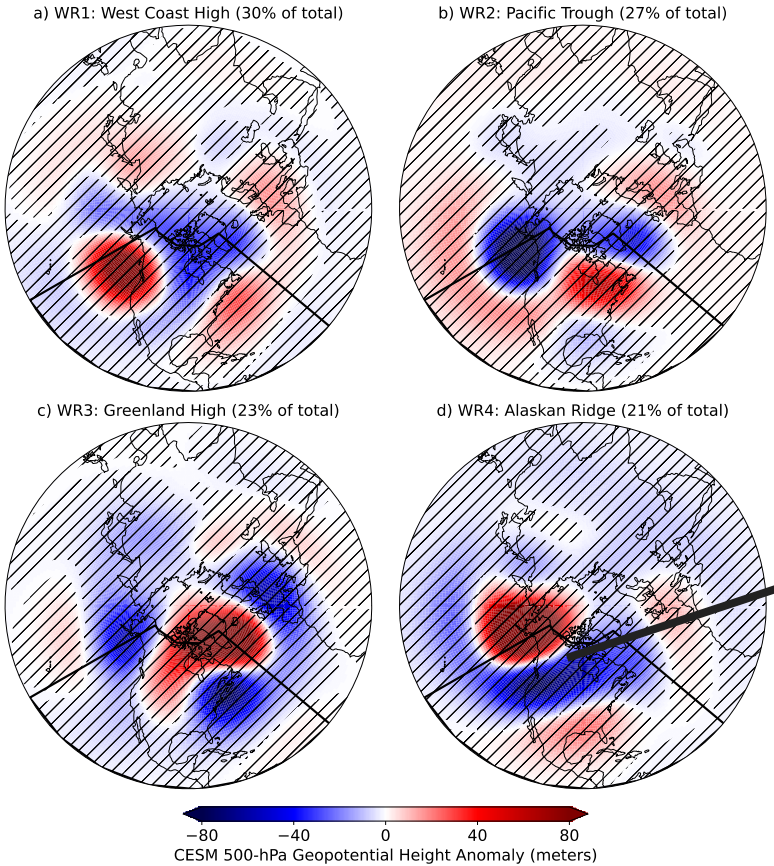

Richter, J. H., Glanville, A. A., Edwards, J., … & Oleson, K. W. (2022). Subseasonal Earth system prediction with CESM2. Weather and Forecasting, 37(6), 797-815.



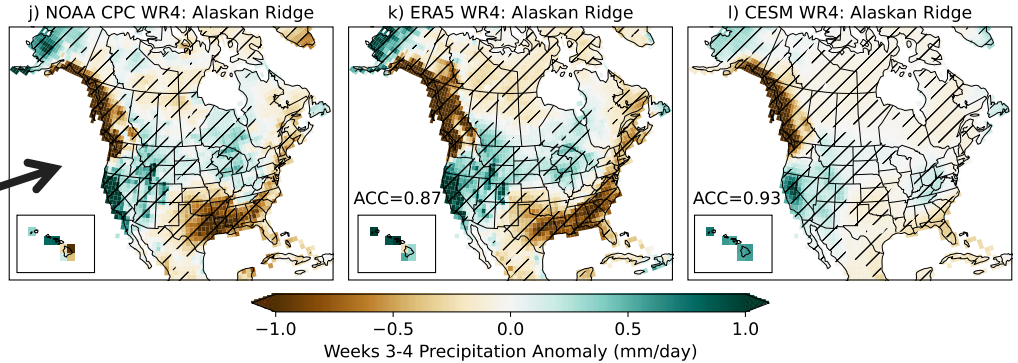

Prediction of precipitation on longer (than weather) timescales is challenging…

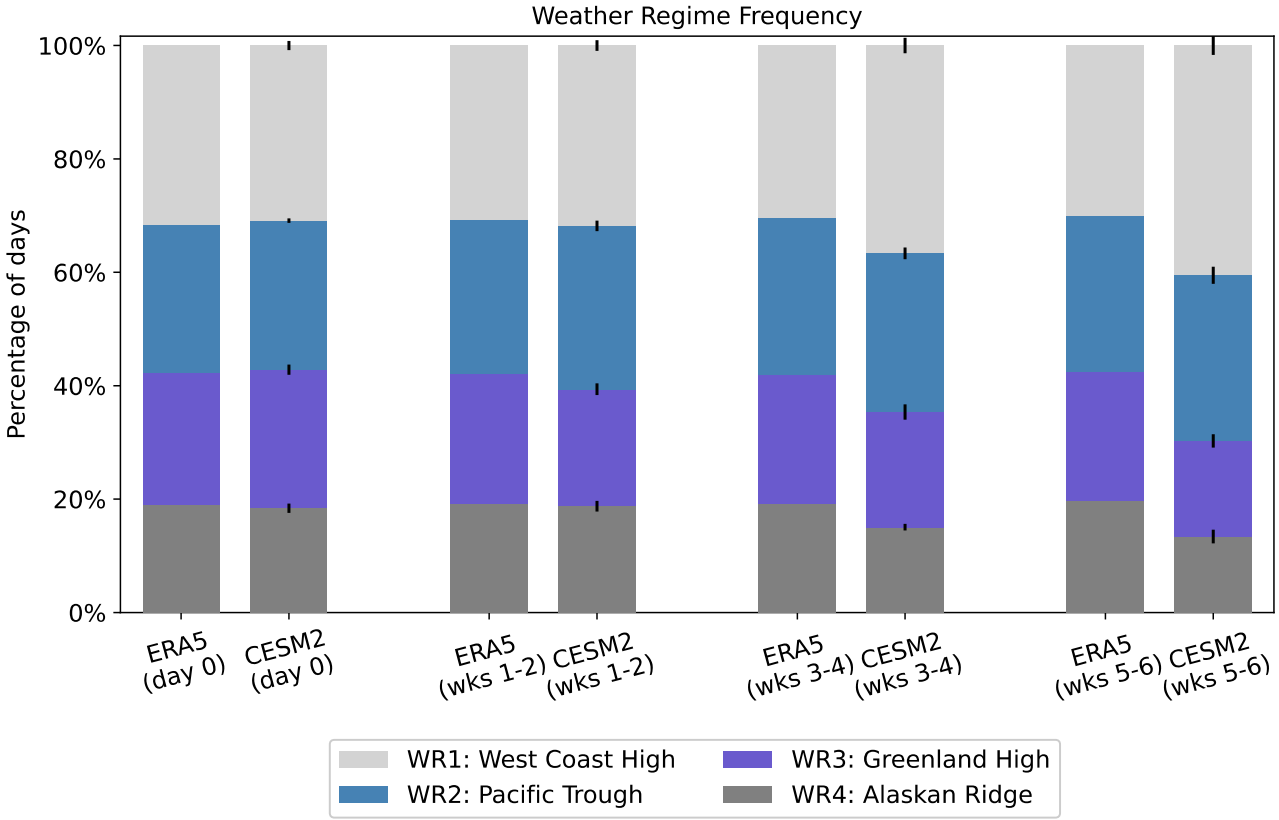
We can use weather regimes by using ERA5-based centroids to classify CESM2 data.

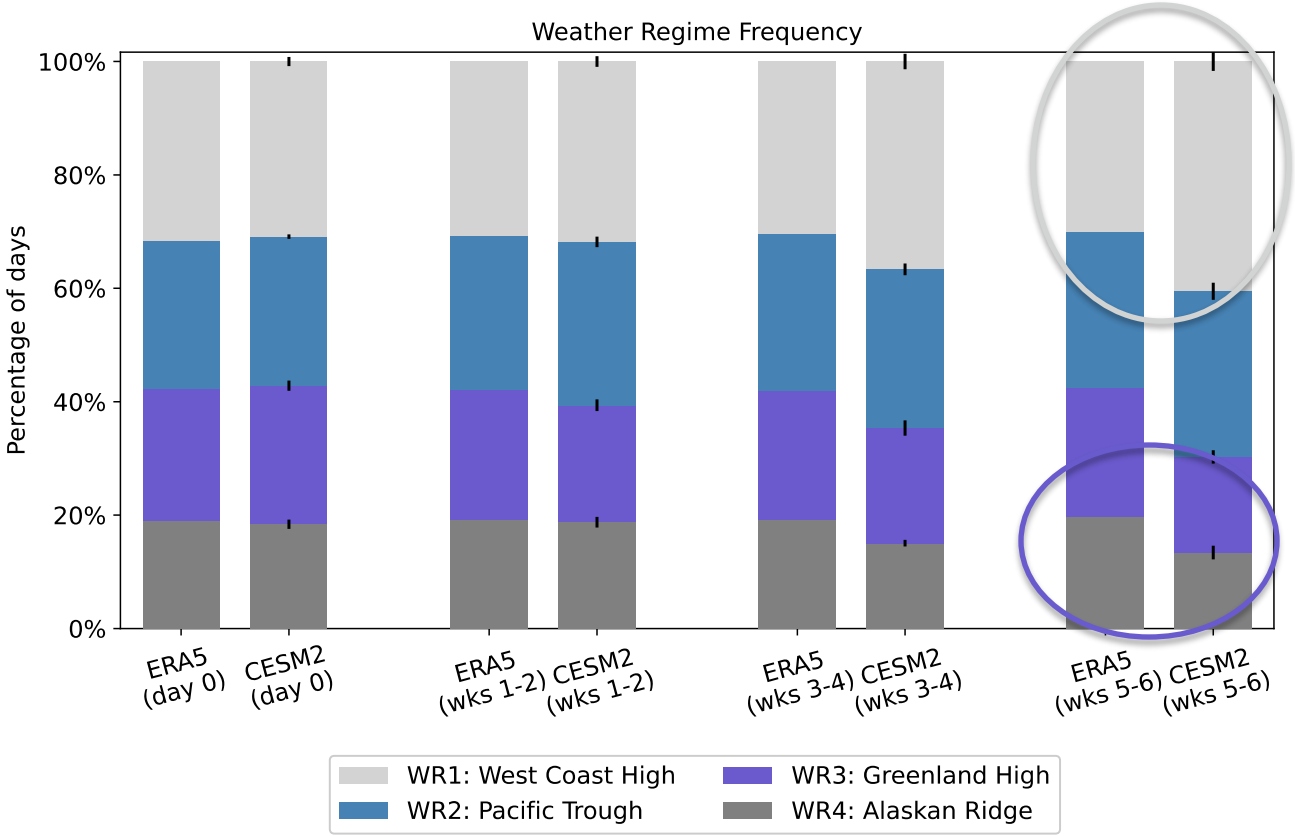
**Molina, M. J.,** et al., (2023). Subseasonal Representation and Predictability of North American Weather Regimes using Cluster Analysis. AI for the Earth Systems.




# Prediction of precipitation on longer (than weather) timescales is challenging…




Weather Regime Frequency
Percentage of days
100%
80%
60%
40%
20%
0%
ERA5 (day 0)
CESM2 (day 0)
ERA5 (wks 1-2)
CESM2 (wks 1-2)
ERA5 (wks 3-4)
CESM2 (wks 3-4)
ERA5 (wks 5-6)
CESM2 (wks 5-6)
WR1: West Coast High
WR2: Pacific Trough
WR3: Greenland High
WR4: Alaskan Ridge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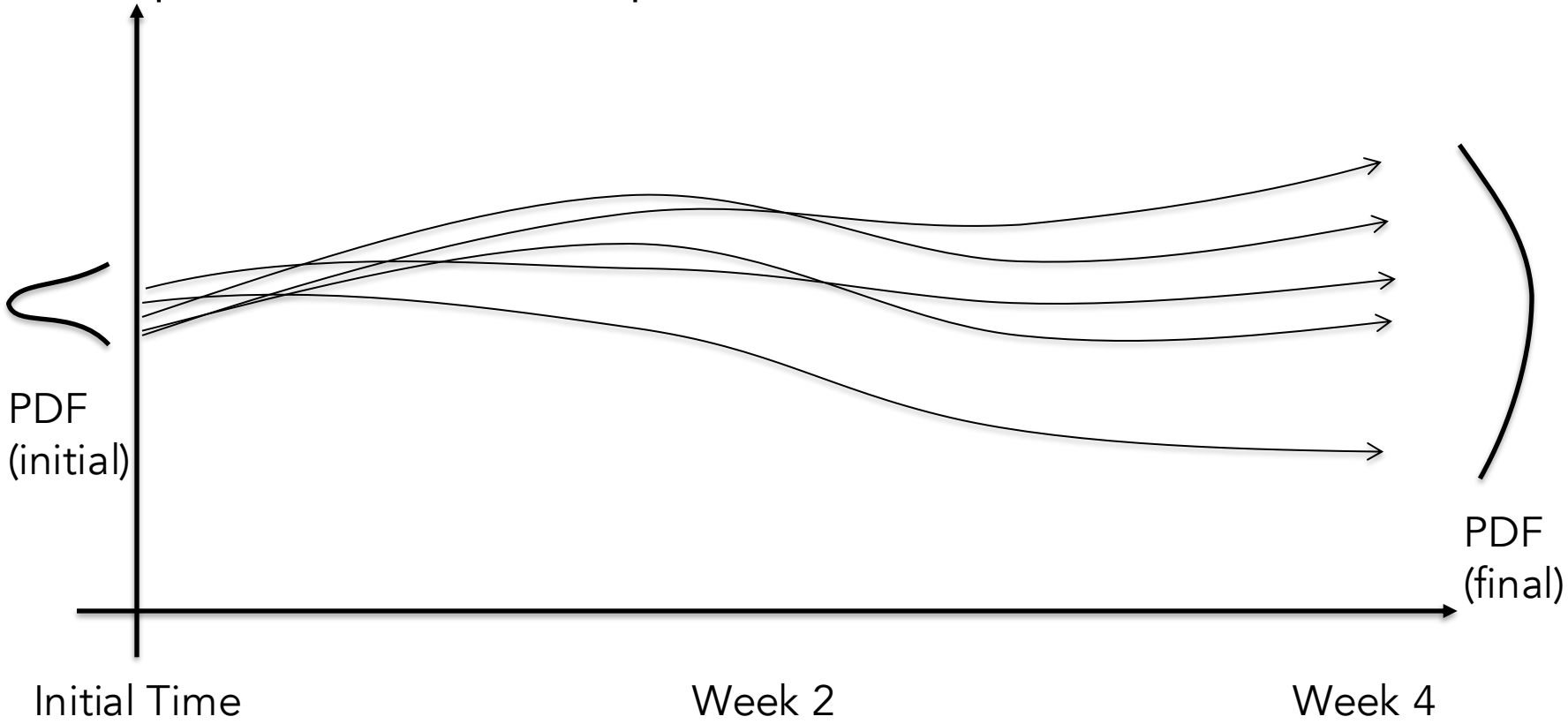
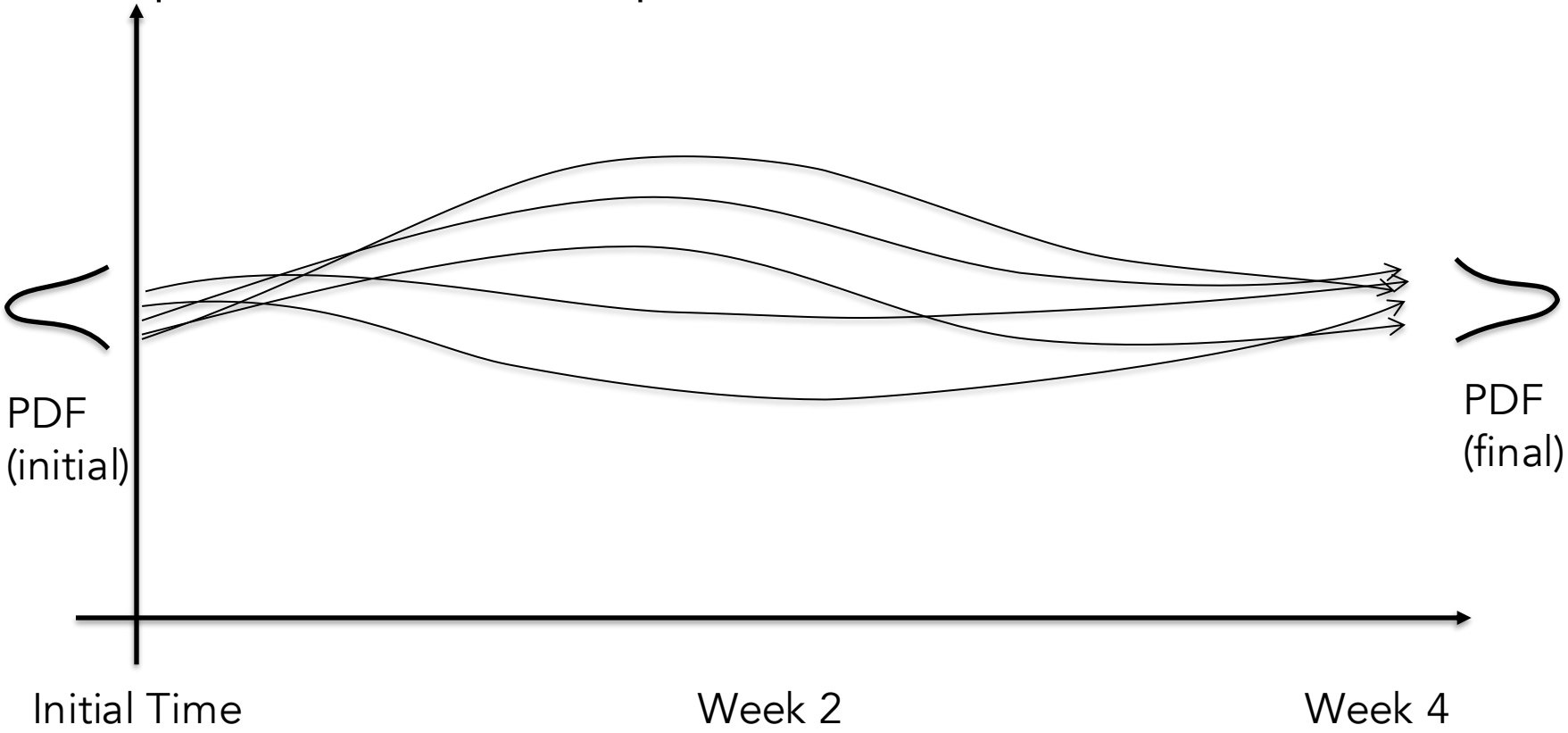
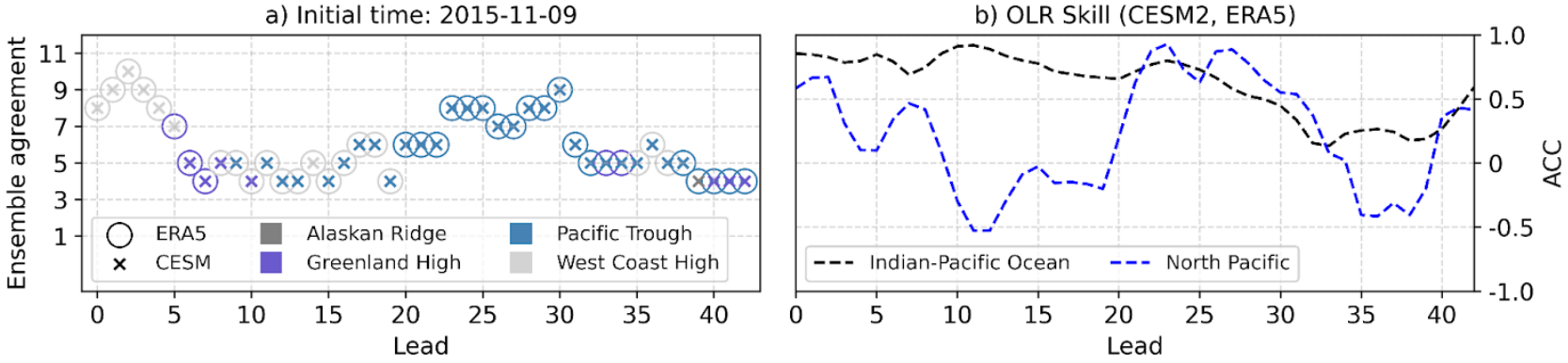
# Typically, ensemble spread increases with lead time…



# Typically, ensemble spread increases with lead time…

Huh?

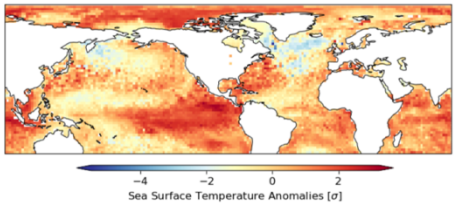


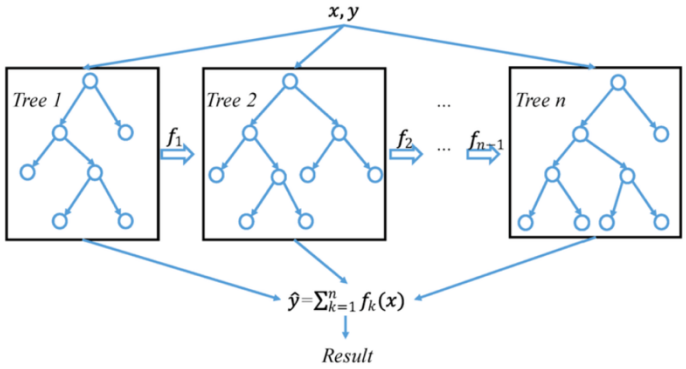



"Ensemble realignment"?


## **XGBoost:** Decision tree-based model

**Example:** SST

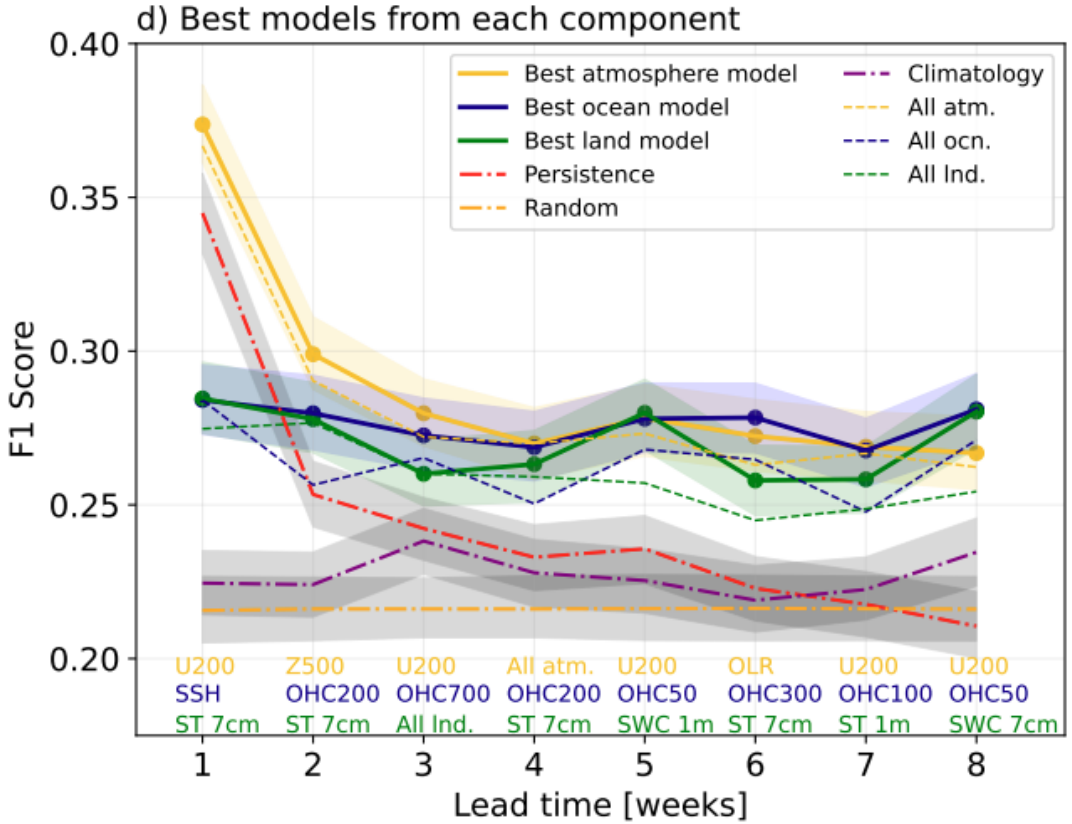



**Weather regimes**

Trained a model separately for each variable (23 variables) and for each lead time (8 weeks) with Bayesian optimization and cross-validation for hyperparameters, and cross-testing.

Perez-Carrasquilla, J.S., and **M.J. Molina** (under review). An Earth-system-oriented view of the S2S predictability of Weather Regimes. Artificial Intelligence for the Earth Systems. https://arxiv.org/abs/2409.08174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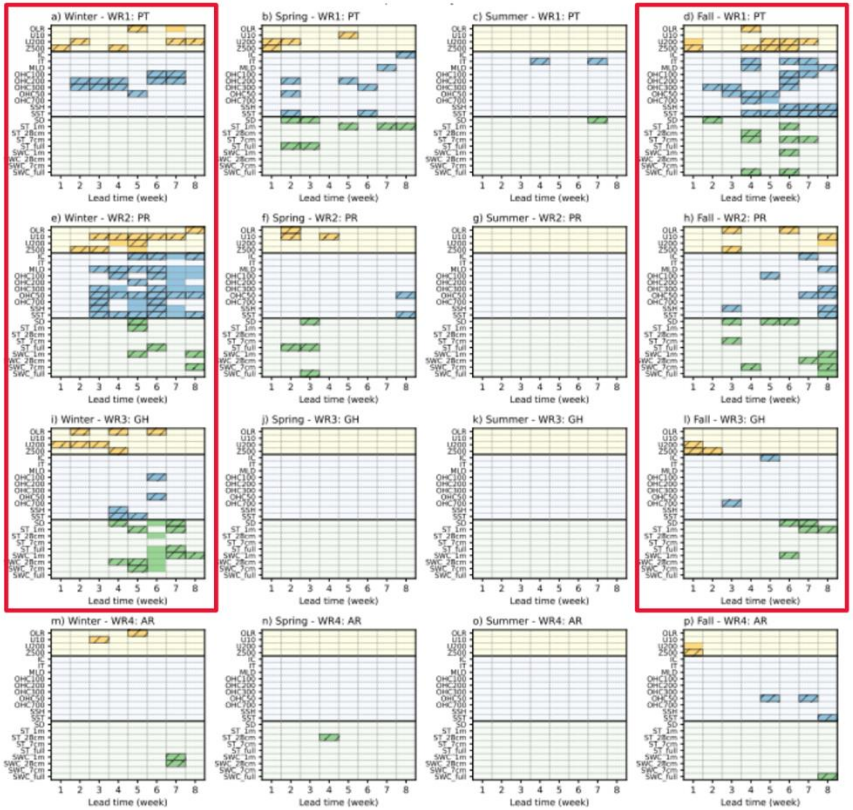
Winter Spring Summer Fall

Pacific Trough

Pacific Ridge

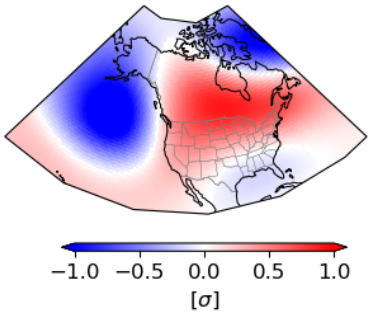
Greenland High

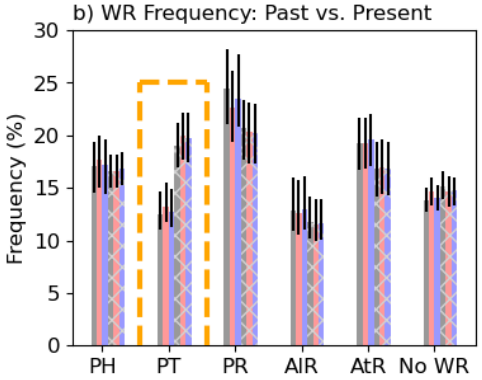
Alaskan Ridge

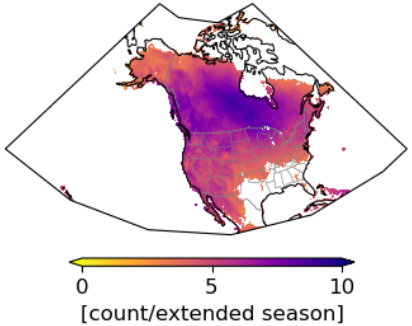


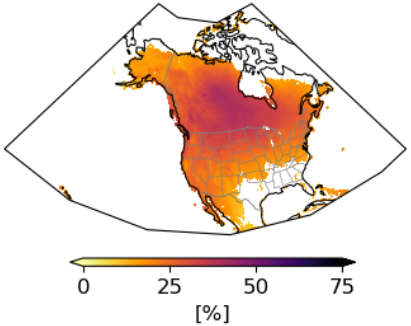

Skill was significant during winter and fall.

Perez-Carrasquilla, J.S., and **M.J. Molina** (under review). An Earth-system-oriented view of the S2S predictability of Weather Regimes. Artificial Intelligence for the Earth Systems. https://arxiv.org/abs/2409.08174

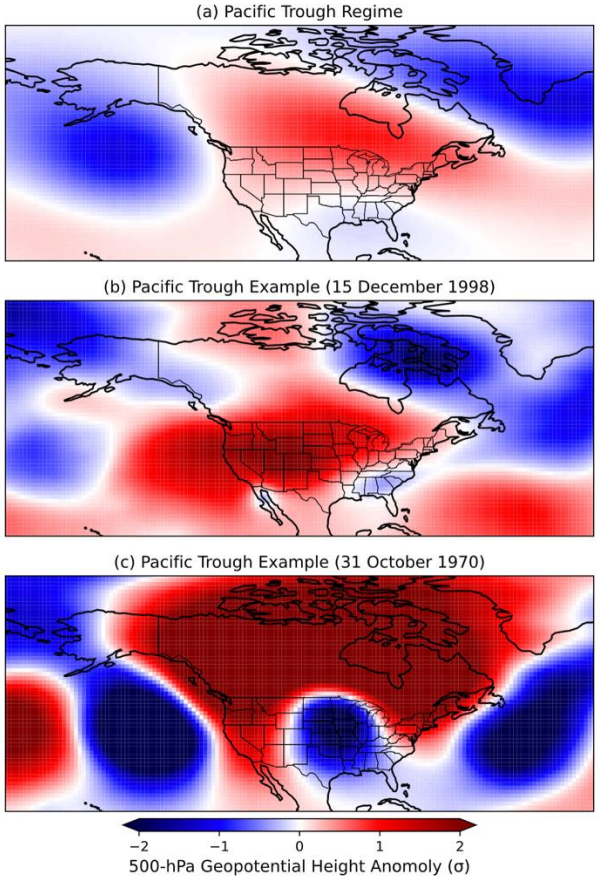



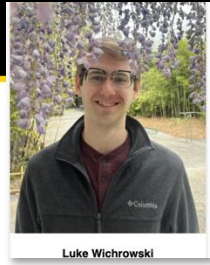




Detect weather regimes (WRs) using observations, then apply it to physics-based models to uncover trends and biases.

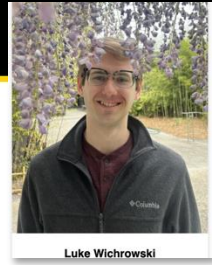
Perez-Carrasquilla, J. S., **M. J. Molina,** K. J. Mayer, K. Dagon, I. R. Simpson, and J. Fasullo (to be submitted). Human-driven increase in Pacific Trough frequency intensifies winter and spring North American heat extremes. Earth's Future.



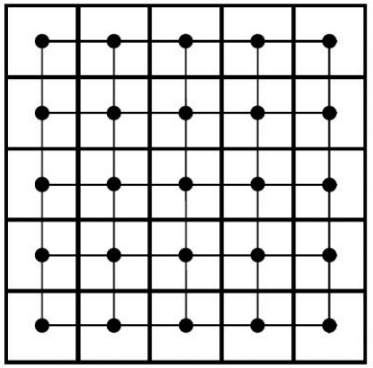




Pacific Trough regime events can take on many different "flavors," stemming from different origin pathways.

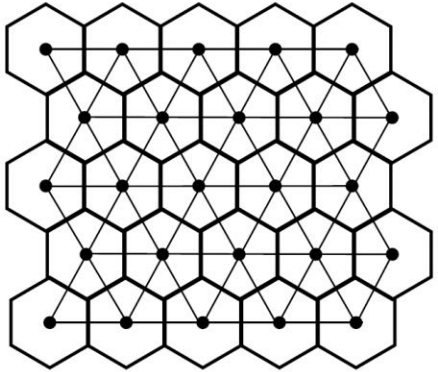
Wichrowski, L., J. S. Perez-Carrasquilla, and **M. J. Molina** (to be submitted). Weather Regime Diversity, Transitions, and Trends using Hexagonal Self-Organizing Maps. JGR: Atmospheres.



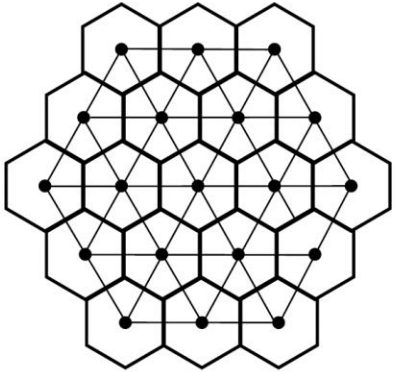

# SOM Topologies and Lattices



Rectangular Topology and Rectangle Lattice



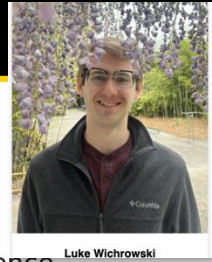
Hexagonal Topology and Rectangle Lattice

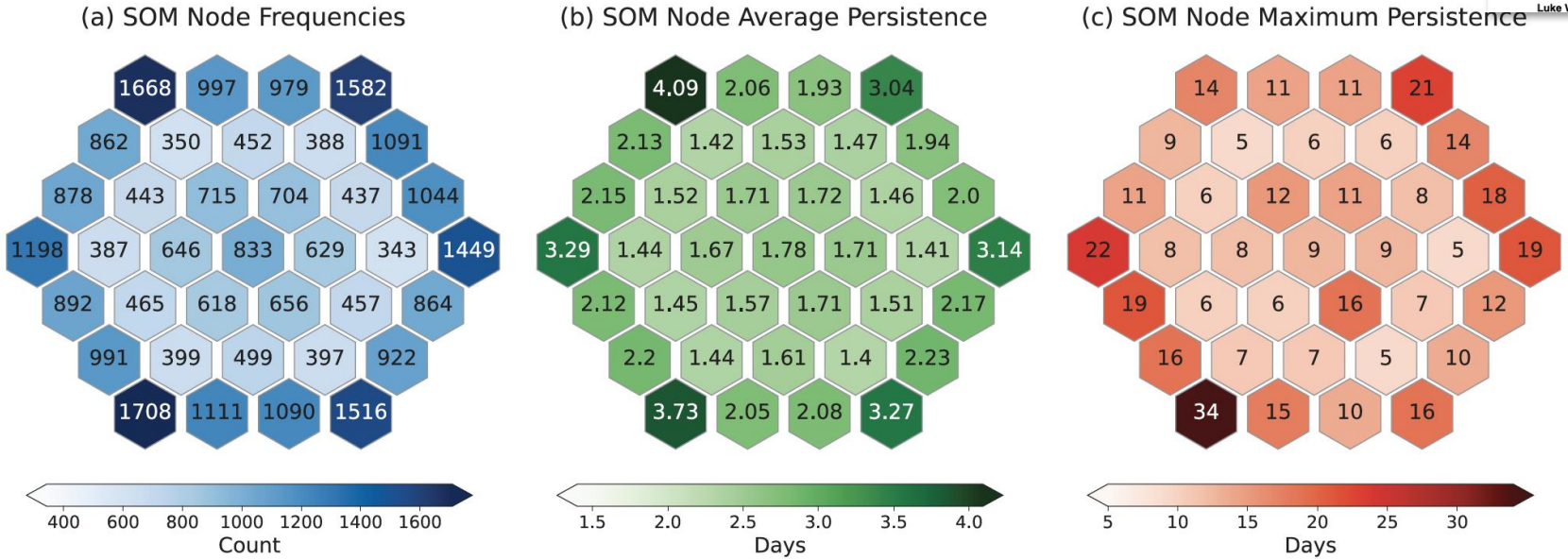


Hexagonal Topology and Hexagon Lattice

Hexagon topology allows for more node transitions.

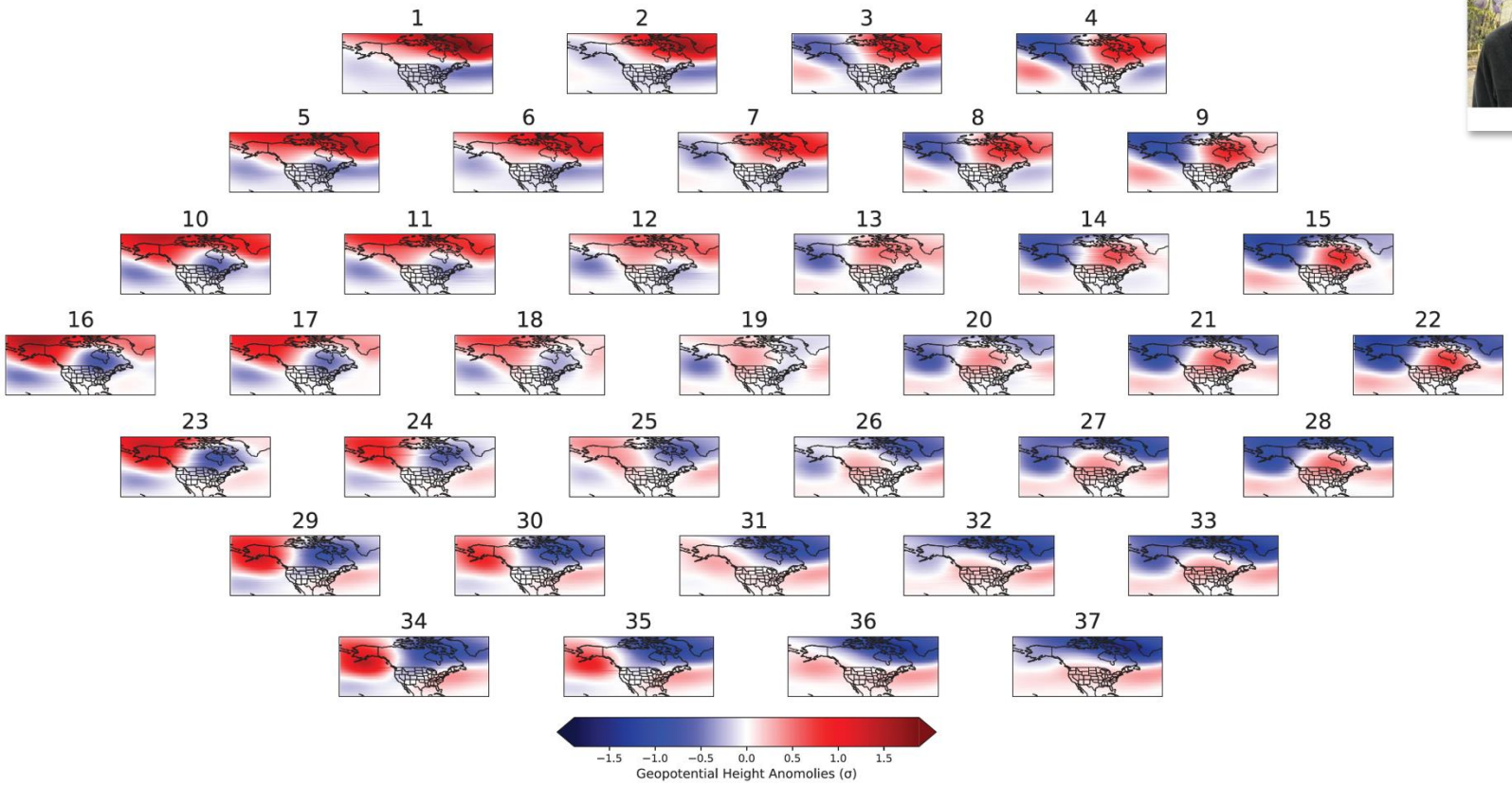
Wichrowski, L., J. S. Perez-Carrasquilla, and **M. J. Molina** (to be submitted). Weather Regime Diversity, Transitions, and Trends using Hexagonal Self-Organizing Maps. JGR: Atmospheres.

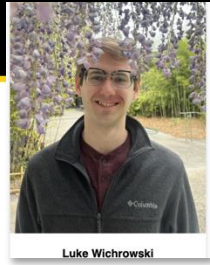



# Hexagon lattice alleviates four corner biases in SOMs.

Wichrowski, L., J. S. Perez-Carrasquilla, and **M. J. Molina** (to be submitted). Weather Regime Diversity, Transitions, and Trends using Hexagonal Self-Organizing Maps. JGR: Atmospheres.

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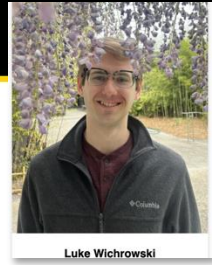
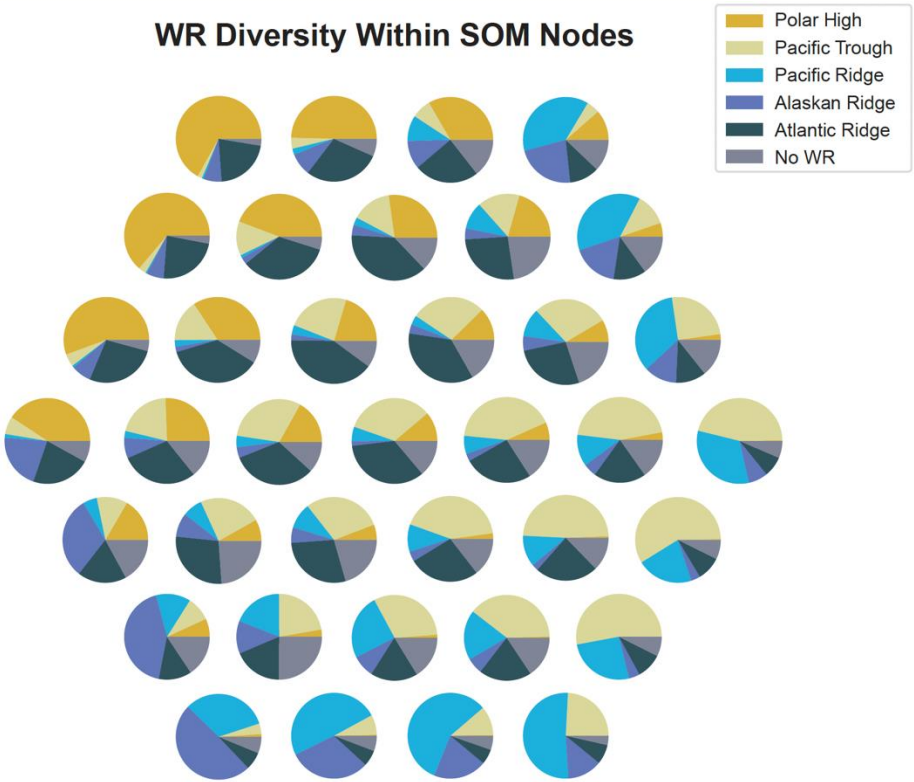


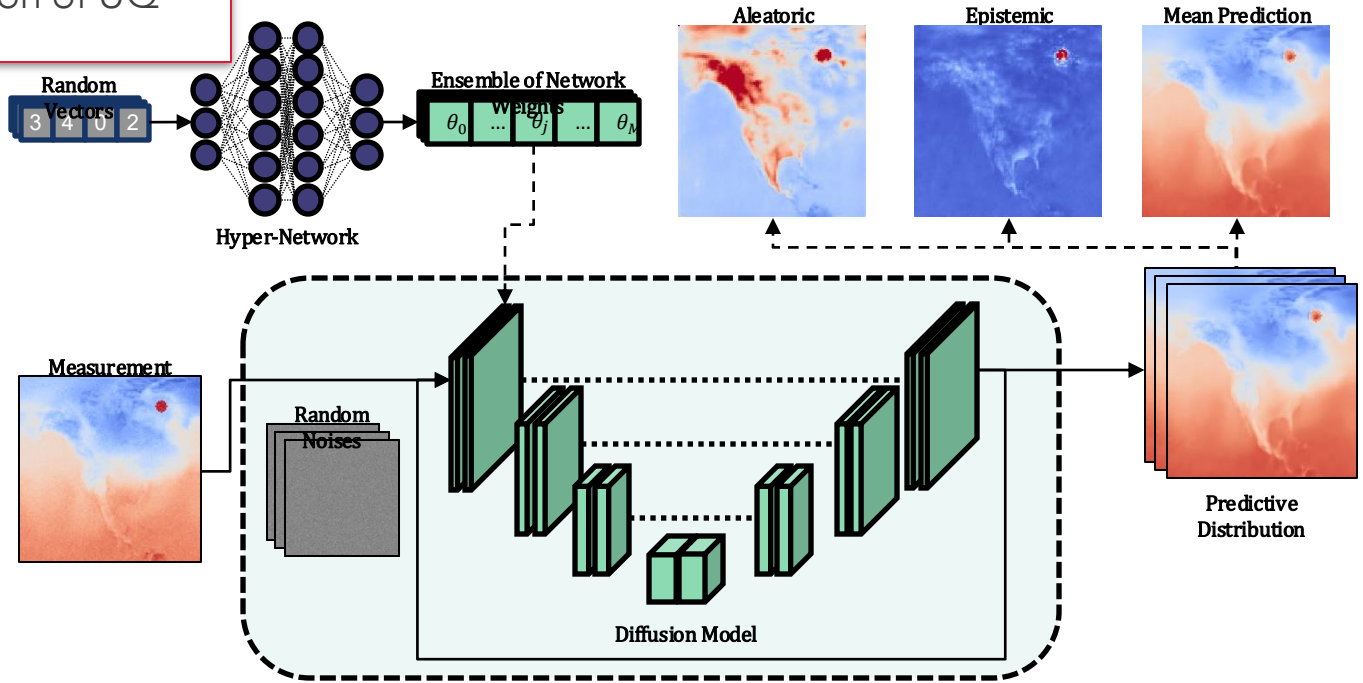

## WR Diversity Within SOM Nodes

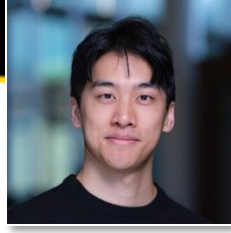



No SOM node contains only one regime class.

Wichrowski, L., J. S. Perez-Carrasquilla, and **M. J. Molina** (to be submitted). Weather Regime Diversity, Transitions, and Trends using Hexagonal Self-Organizing Maps. JGR: Atmospheres.

# Next steps: Incorporation of UQ



Matthew Chan
CS PhD Student

Leverage hypernetworks and diffusion models to decompose uncertainty into aleatoric and epistemic components.

Chan, M. A., **M. J. Molina,** and C. A. Metzler (2024). Estimating Epistemic and Aleatoric Uncertainty with a Single Model. Thirty-Eighth Annual Conference on Neural Information Processing Systems (NeurIPS).