Sea Surface Salinity Provides Subseasonal Predictability for Forecasts of Opportunity of U.S. Summertime Precipitation

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INTRODUCTION

- As oceanic moisture evaporates, it leaves a signature on sea surface salinity.
- Roughly 10% of the moisture that evaporates over the ocean is transported over land, allowing the *salinity fields to be a predictor of terrestrial precipitation*.
- **How?**
  - Saltier waters (positive salinity anomalies) = oceanic evaporation
  - Fresher waters (negative salinity anomalies) = oceanic precipitation
- This research is among the first in published literature to **quantify the role of sea surface salinity for improved predictions on low-skill *subseasonal summertime precipitation*** in the U.S. Midwest.

METHODS

Data: CESM2-Large Ensemble daily anomalies; May-Aug 1850-1949
Preprocessing: Input- 3-day smoothed salinity anomalies; Output- 3-day cumulative sum of precipitation with 80th percentile and above events deemed as "heavy", randomly undersampled to balance classes

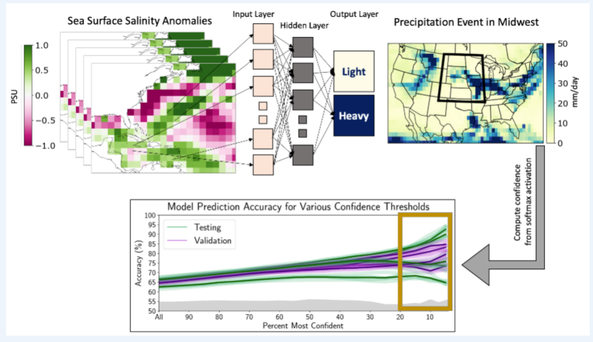

Figure 1. (top) Schematic of the neural network architecture. (bottom) Accuracy vs. confidence of predictions. The gold box highlights the 20% most confident predictions.

Seamless transition across timescales via *Poisson weighting*

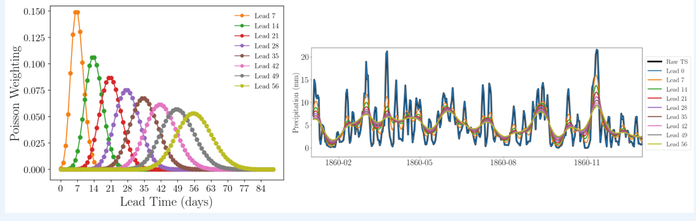

Figure 2. Poisson weights as a function of lead time (left) and smoothed timeseries (right). The Poisson weighting smooths data as lead time increases.

RESULTS

Subseasonal Forecasts of Opportunity:

Network accuracy increases as confidence increases (Fig. 2), indicating predictable states of the climate system. The 20% most confident predictions are deemed *forecasts of opportunity*.

Forecast skill for forecasts of opportunity peaks at 21-day leads, demonstrating **salinity anomalies as a meaningful predictor on subseasonal timescales**.

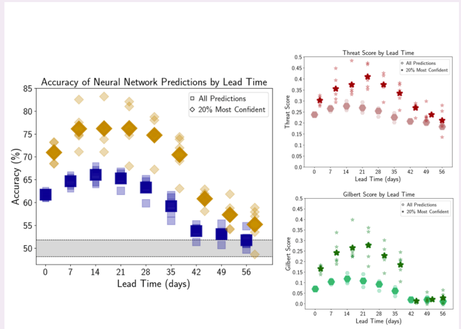

Figure 3. (left) Accuracy as a function of lead time for all predictions (squares) and forecasts of opportunity (diamonds). (right) Skill scores for predictions with unbalanced data; 0-random chance, 1- perfect score.

Pinpointing Sources of Predictability with Explainable AI:

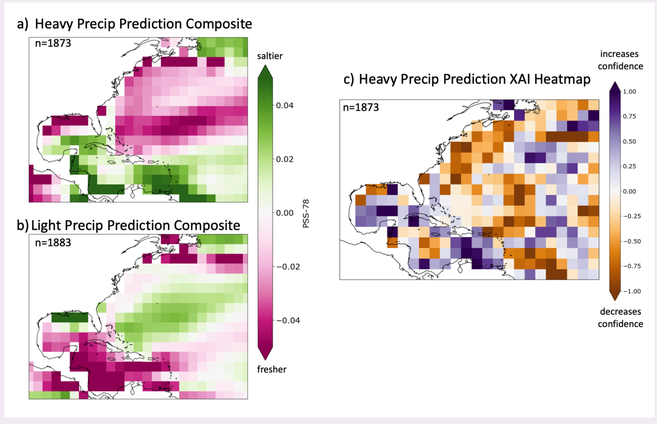

Figure 4. (left) Composite maps of salinity anomalies for forecasts of opportunity for (a) heavy and (b) light precipitation events. (right) Saliency XAI heatmaps for the forecasts of opportunity showing a unitless measure of sensitivity.

We want to know *why the* network made confident, correct subseasonal predictions. Composite maps reveal that **subseasonal forecasts of opportunity for heavy precipitation are informed by positive salinity anomalies** (green) **in the Caribbean Sea and Gulf of Mexico**.

Saltier waters in these regions imply evaporation and atmospheric moisture available for transportation for heavy precipitation events. Conversely, negative salinity anomalies indicative of precipitation are found in these regions for predictions of light precipitation events.

Explainable AI (XAI) heatmaps pinpoint regions that the networks deem as important in making predictions. **Saltier waters in the Caribbean Sea and Gulf of Mexico increase confidence in heavy event predictions.**

RESULTS

What about the real world?

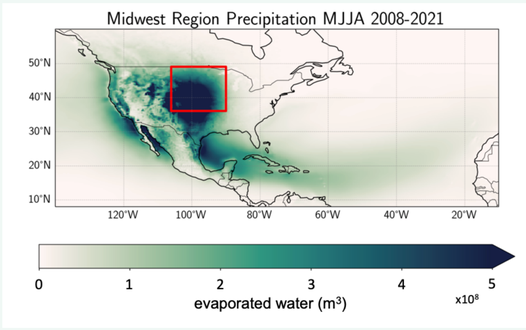

Figure 5. The sum of evaporated water which fell as precipitation in the red boxed region using the WAM2 layers backtracking algorithm.

A moisture-tracking model, WAM2layers, is used to track where evaporation occurred which eventually fell as precipitation in a specific region using modern-day ERA5 reanalysis data. **Regions identified by the neural networks are found to provide a *direct* moisture source for precipitation in the Midwest.**

KEY TAKEAWAYS

- Sea surface salinity anomalies provide predictability for heavy summertime Midwest precipitation events
- Subseasonal forecasts of opportunity for heavy precipitation are informed by positive salinity anomalies in the Caribbean and Gulf of Mexico
- Regions of evaporation identified by neural networks provide a direct moisture source for precipitation in the Midwest region

ACKNOWLEDGEMENTS

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