Ph.D. Defense Announcement
Emily Gordon
Thursday, August 10, at 9:00 am MT

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Ph.D. Defense

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Defense
ATS Large Classroom (101 ATS) or [Teams]

Post Defense Meeting
Riehl Conference Room (211 ACRC)

Committee:
Elizabeth Barnes (Advisor)
Maria Rugenstein
James Hurrell
Charles Anderson (Computer Science)

When is the Unpredictable (slightly more) Predictable? An Assessment of Opportunities for Skillful Decadal Climate Prediction Using Explainable Neural Networks

Predicting climate variability on decadal (2-10 year) timescales can have huge implications for society because it can provide better estimates of both global trends as well as regional climate variability for crucial, actionable lead times. The key to skillful decadal prediction is understanding and predicting oceanic variability. However, predictable sig- nals in the ocean can be masked by the inherent noise in the system, and therefore, skillful prediction on decadal timescales is challenging. Machine learning, with its ability to extract nonlinear signals from large sets of noisy data, has been shown a powerful tool for predicting and understanding processes across weather and climate applications. In this dissertation, I explore applications of machine learning to decadal prediction.

First, I present a machine learning approach to predicting the Pacific decadal oscillation (PDO) with artificial neural networks (ANNs) within the Community Earth System Model version 2 (CESM2) pre-industrial control simulation. Predicting PDO transitions and understanding the associated mechanisms has proven a critical but challenging task in climate science. As a form of decadal variability, the PDO is associated with both large- scale climate shifts and regional climate predictability. I show that ANNs predict PDO persistence and transitions at lead times of 12 months onward. Using layer-wise relevance propagation to investigate the ANN predictions, I demonstrate that the ANNs utilize oceanic patterns that have been previously linked to predictable PDO behavior. ANNs recognize a build-up of ocean heat content in the off-equatorial western Pacific 12–27 months before a transition occurs. The ANNs also distinguish

transition mechanisms between positive-to-negative sign transitions, and negative-to-positive transitions.

Secondly, I demonstrate a technique for incorporating an uncertainty estimate into the prediction of a regression neural network, allowing the identification of predictable sea surface temperature (SST) anomalies on decadal timescales in the CESM2 pre-industrial control simulation. Predictability in SSTs can be masked by unpredictable variability, and one approach to extracting predictable signals is to investigate state-dependent predictability – how differences in prediction skill depend on the initial state of the system. I leverage the network's prediction of uncertainty to examine state-dependent predictability in SSTs by focusing on predictions with the lowest uncertainty. In particular, I study two regions of the global ocean– the North Atlantic and North Pacific–and find that skillful initial states identified by the neural network correspond to particular phases of low frequency variability in the North Pacific and North Atlantic oceans.

Finally, I examine the potential role of predictable internal variability in a future, warmer climate by designing an interpretable neural network that can be decomposed to examine the relative contributions of external forcing and internal variability to future regional decadal SST trend predictions. I show that there is additional prediction skill to be garnered from internal variability in the CESM2 Large Ensemble in the near-term climate (2020- 2050), even in a relatively high forcing future scenario. This predictability is especially apparent in the North Atlantic, North Pacific and Tropical Pacific Oceans as well as in the Southern Ocean. I further investigate how prediction skill covaries across the ocean and find three regions with distinct coherent prediction skill driven by internal variability. SST trend predictability is found to be associated with consistent patterns of interannual and decadal variability for the grid points within each region.