

Supplemental:

Subseasonal Forecasts of Opportunity Identified by an Explainable Neural Network

> **Kirsten J. Mayer**, PhD Candidate, Dept. of Atmospheric Science, CSU Elizabeth A. Barnes, Associate Professor, Dept. of Atmospheric Science, CSU

Neural Networks for Subseasonal Prediction

How can we utilize neural networks to identify forecasts of opportunity for subseasonal prediction?

Neural Networks



What are (artificial) neural networks?



Artificial Neural Networks [ANN]





Artificial Neural Networks [ANN]



 $X_1W_1 + X_2W_2 + b$

linear regression!



Example Activation Functions



$= \mathbf{f}_{\text{activation}} (\mathbf{X}_1 \mathbf{W}_1 + \mathbf{X}_2 \mathbf{W}_2 + \mathbf{b})$

- This diagram in words: linear regression with non-linear mapping by an "activation function"
- training of a neural network is merely determining the weights "w" and bias/offset "b"



inputs

Artificial Neural Networks [ANN]

node



Artificial Neural Networks [ANN]



Complexity and nonlinearities of the ANN allow it to learn many different pathways of predictable behaviour

Once trained, you have an array of weights and biases which can be used for prediction on *new* data

Subseasonal prediction network set-up





Forecasts of opportunity with Neural Networks

How can we determine *when* we have periods of enhanced predictability with a neural network?

MODEL CONFIDENCE

Model Confidence: Softmax Activation

Last hidden layer





Do <u>high confidence</u> predictions indicate forecasts of opportunity?



Model Confidence as Forecasts of Opportunity

Do <u>high confidence</u> predictions indicate forecasts of opportunity? YES! As **confidence threshold** ↑s, **accuracy** ↑s We expect this -- MJO!





Forecasts of opportunity with Neural Networks

Why is there predictability?

LAYER-WISE RELEVANCE PROPAGATION

Neural Network Explainability

What did the model learn?

Layer-wise Relevance Propagation (LRP)

What are *relevant physical structures of OLR* in the tropics for prediction over the North Atlantic?



Layer-wise Relevance Propagation



where the network looked to determine it was a "cat"

Colorado State University

Montavon et al. (2017), Pattern Recognition; Montavon et al. (2018), Digital Signal Processing

Layer-wise Relevance Propagation



Toms, B. A., Barnes, E. A., & Ebert-Uphoff, I. (2020). Physically interpretable neural networks for the geosciences: Applications to Earth system variability. Journal of Advances in Modeling Earth Systems, https://doi.org/ 10.1029/2019MS002002

Subseasonal prediction network set-up



Example: network correctly guesses the sign of the circulation is positive



Subseasonal prediction network set-up



"Where did the network look to determine that the sign of the circulation was positive?"





Email: kjmayer@rams.colostate.edu Twitter: @kiri_mayer Graduation (expected): Fall 2022

- We can use **Neural Networks** to further understand **subseasonal prediction**
- Model Confidence can identify *opportunities* for increased accuracy
- Layerwise Relevance Propagation opens the 'black box'
 - We can learn how the network made its prediction
 - We can find new sources of predictability from extracting knowledge from the neural network

Mayer, Kirsten J. & Elizabeth A. Barnes: Subseasonal Forecasts of Opportunity Identified by an Explainable Neural Network, Earth and Space Science Open Archive, <u>https://doi.org/10.1002/essoar.10505448.2</u>.

