Skillful Wintertime Temperature Forecasts out to 6 Weeks with Machine Learning Methods

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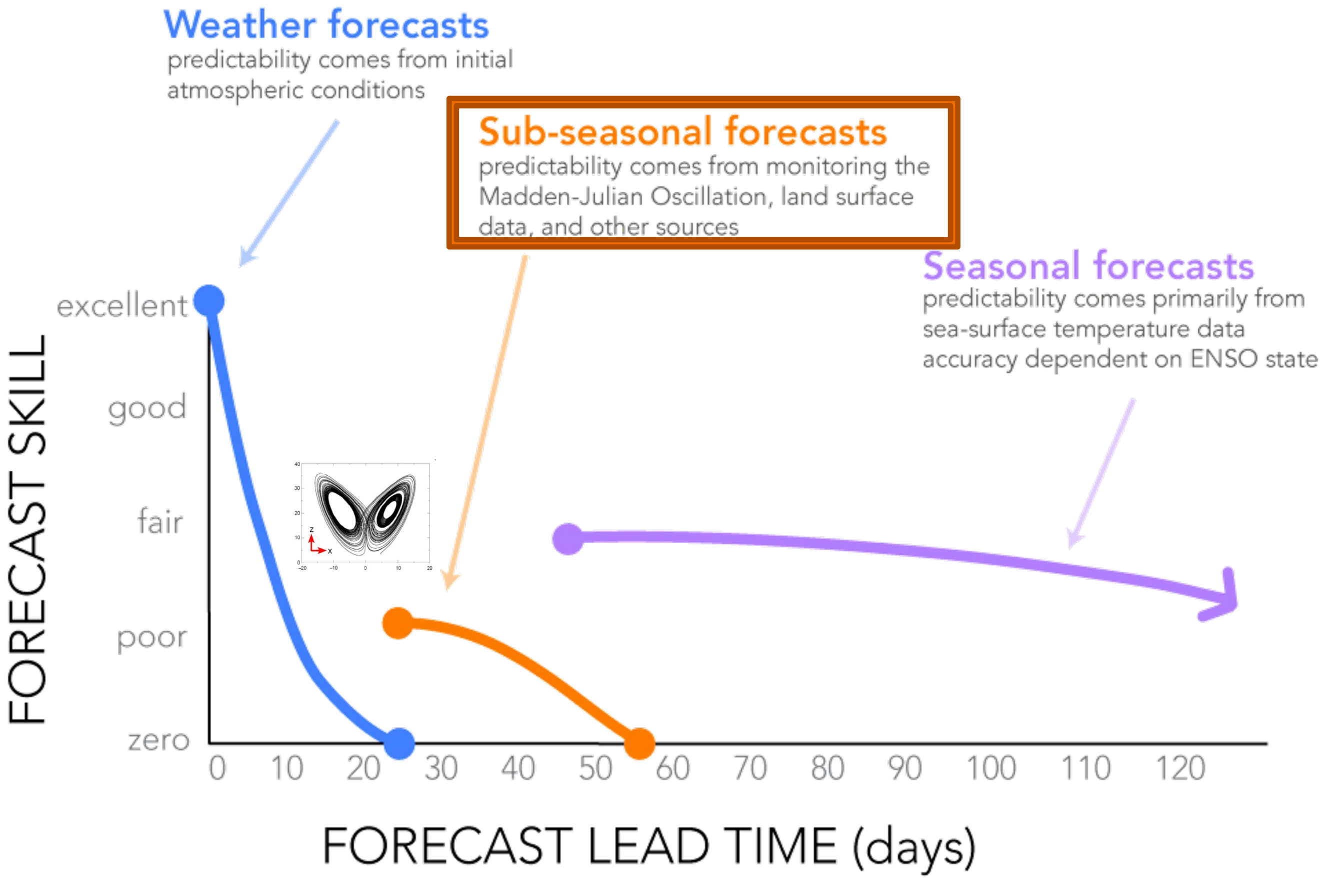
NCAR UCAR ASP Advanced Study Program

NSF

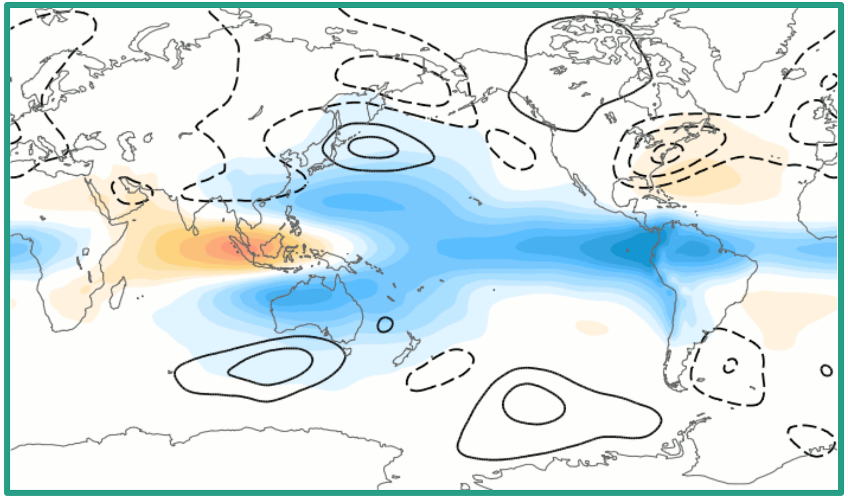
Subseasonal Skill



IRI. Infographic adapted by Elisabeth Gawthrop from figure by Tony Barnston.

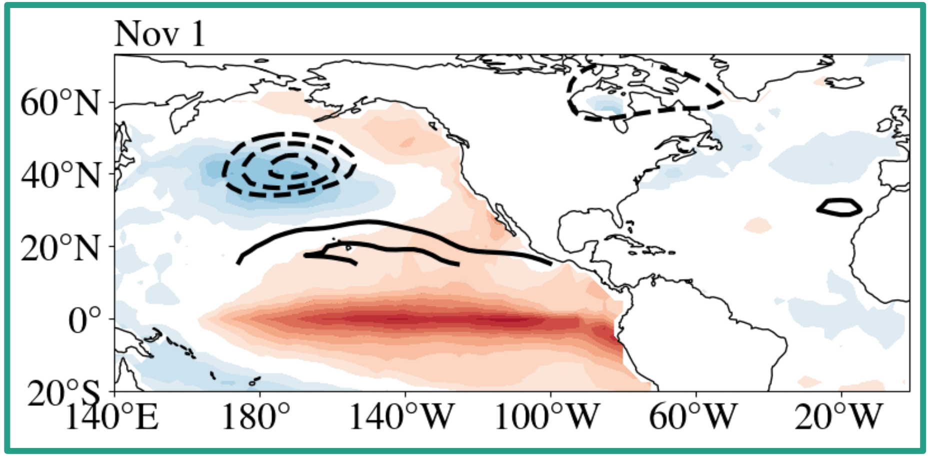
Teleconnections

-MJO-



Credit: Adames MJO Dynamics Group

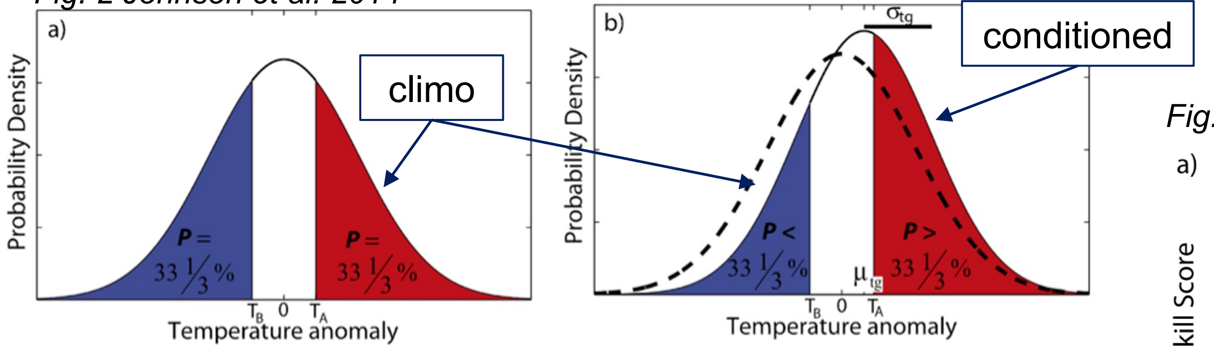
-ENSO-



Motivation

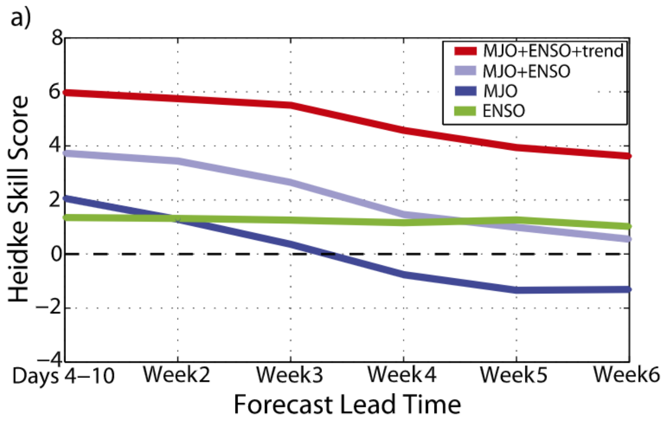
Johnson et al. 2014: Skillful Wintertime North American Temperature Forecasts out to 4 Weeks ***Based on the State of ENSO and the MJO***

Fig. 2 Johnson et al. 2014



Heidke skill score:

Fig. 3 Johnson et al. 2014



"we assume that the ENSO and MJO impacts are independent"

$$\mu_{tg} = \mu_{tig} + \mu_{tjg} \qquad \sigma_{tg}^2 = \sigma_{tig}^2 + \sigma_{tjg}^2$$

g: $grid\ point$

t: $lead\ time$

i: $MJO\ phase\ (9)$

j: $ENSO\ phase\ (3)$

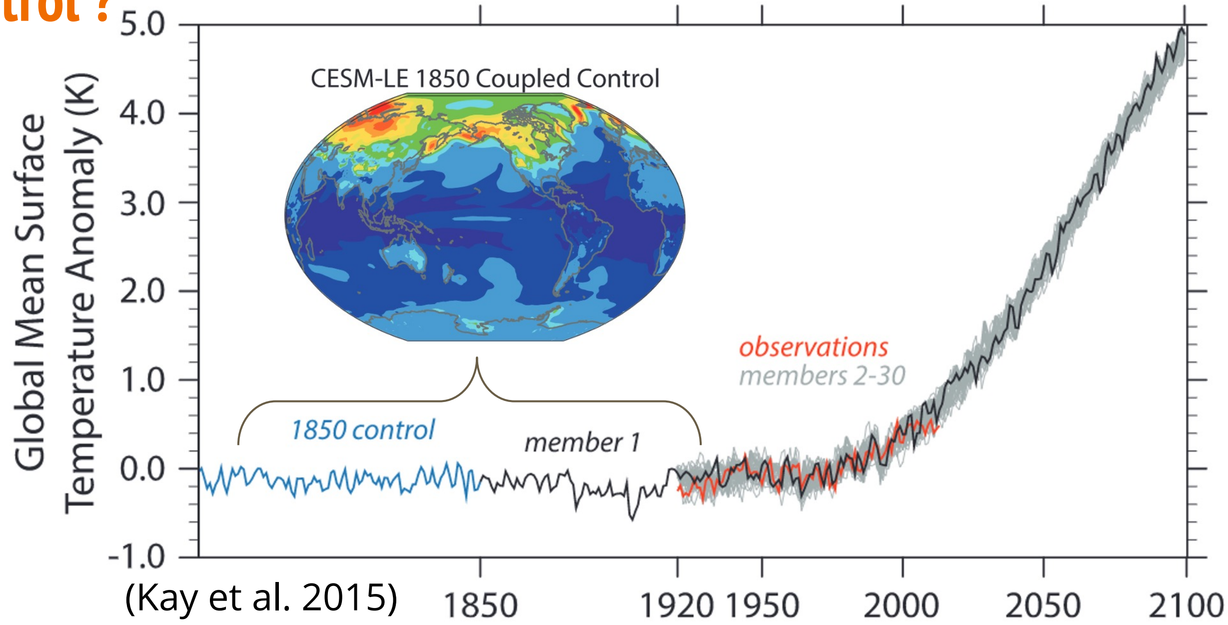
Dataset

What / Motivation for using CESM

What:

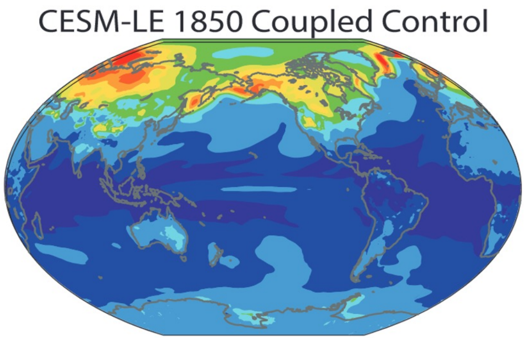
1) Test various statistical models for T2m prediction skill at S2S lead times
2) See if the statistical models can identify forecast windows of opportunity

Why CESM LENS pi - control ?



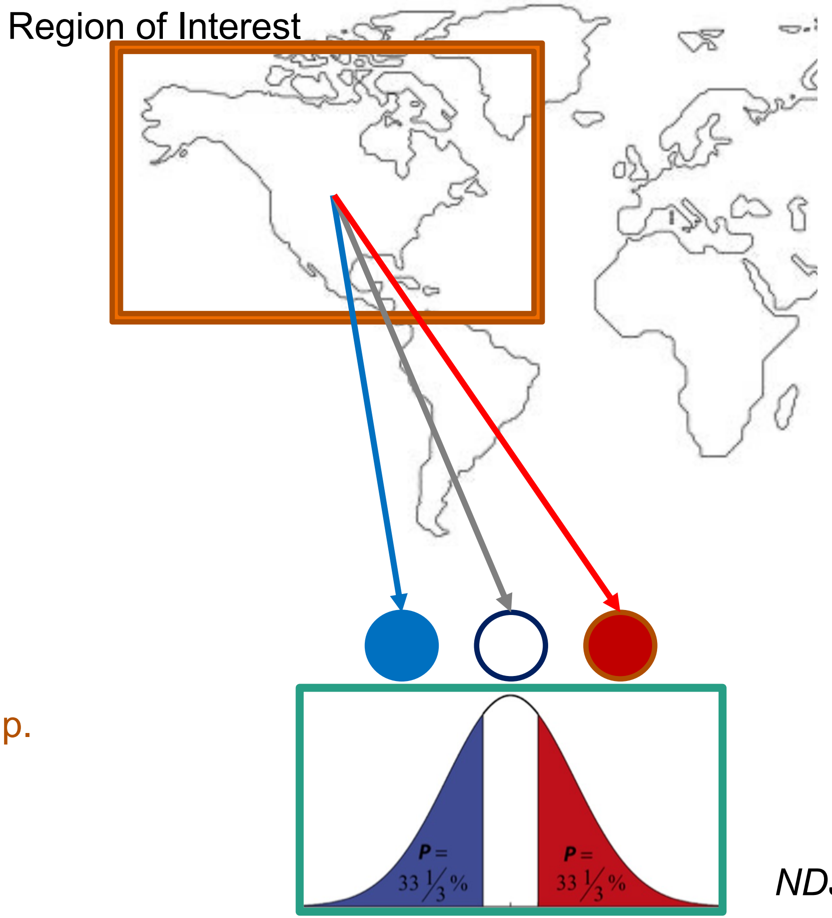
(Kay et al. 2015)

Target Variable



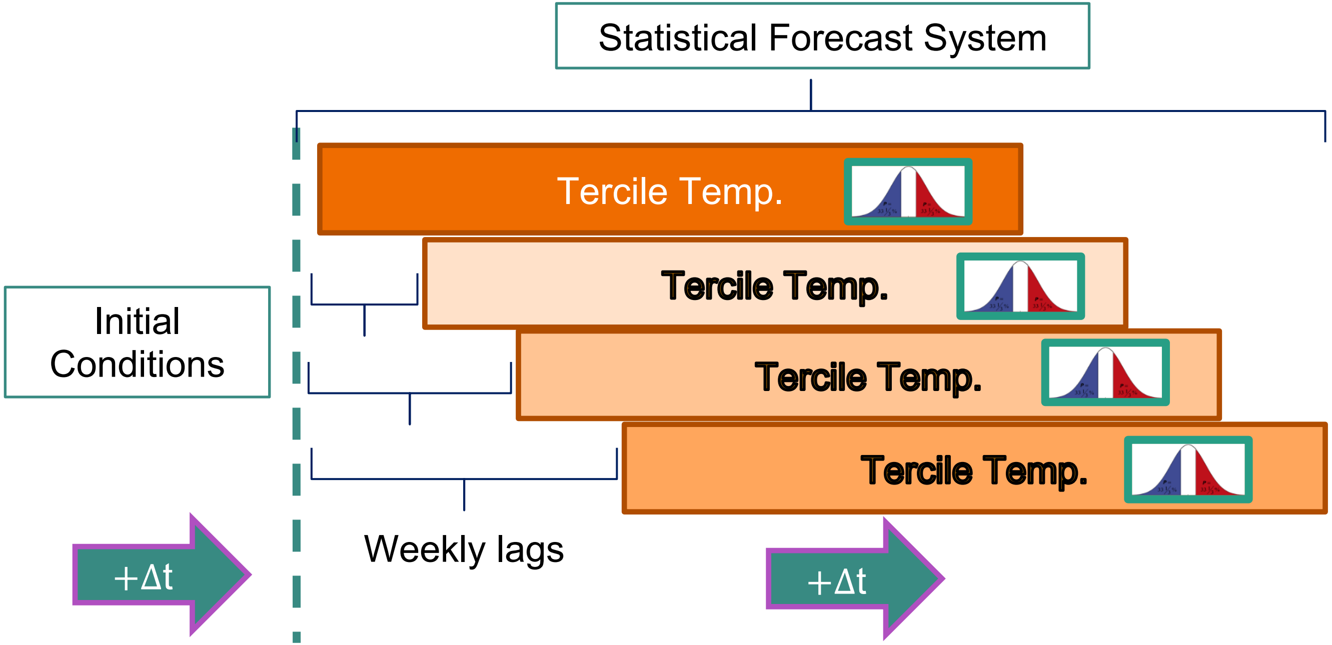
CESM LENS Pi – Control

- Rolling **Weekly Averaged** Surface Temp.
- Train on Model Years 400-600
- Test on Model Years 700-800



NDJFM Climatology

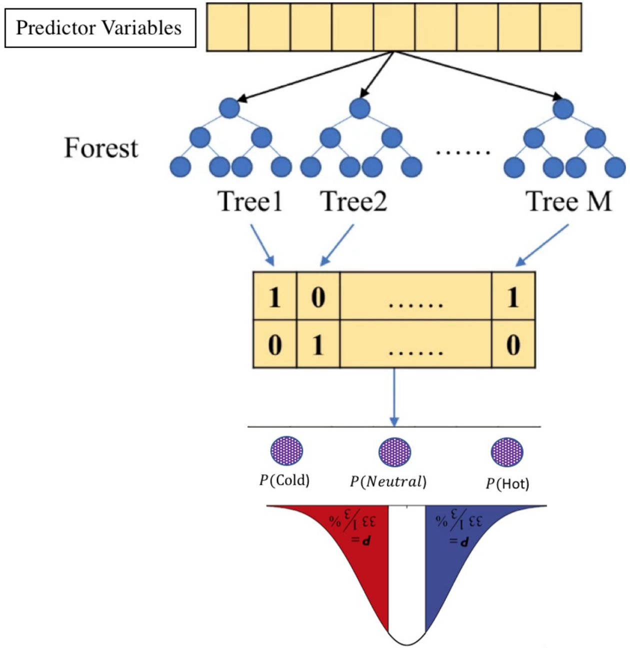
Forecast Framework



Statistical Models (Random Forest):

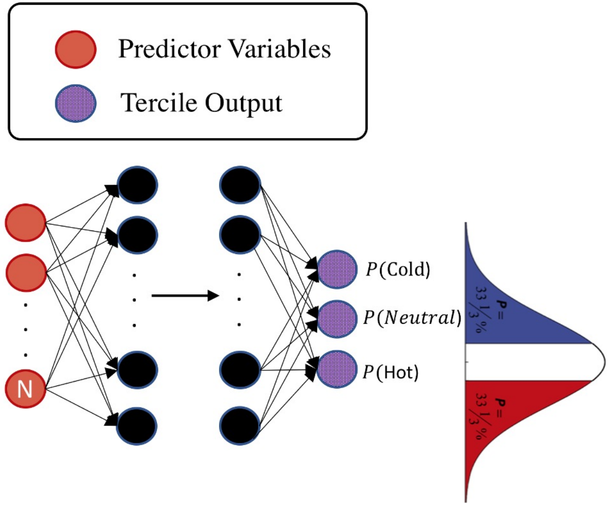
Models: **(a) Independent Gradient Boosted Classifier**

- ***Predictors*** : CESM LENS CNTRL: ENSO and RMM indices, 1hot encode MJO phase (DJF)
- ***Predictand*** : CESM LENS CNTRL: 7-day avg. T2m at every land lat/lon



Statistical Models (Neural Network):

- ***Predictors*** : CESM LENS CNTRL: ENSO and RMM indices, 1hot encode MJO phase (DJF)
- ***Predictand*** : CESM LENS CNTRL: 7-day avg. T2m at every land lat/lon

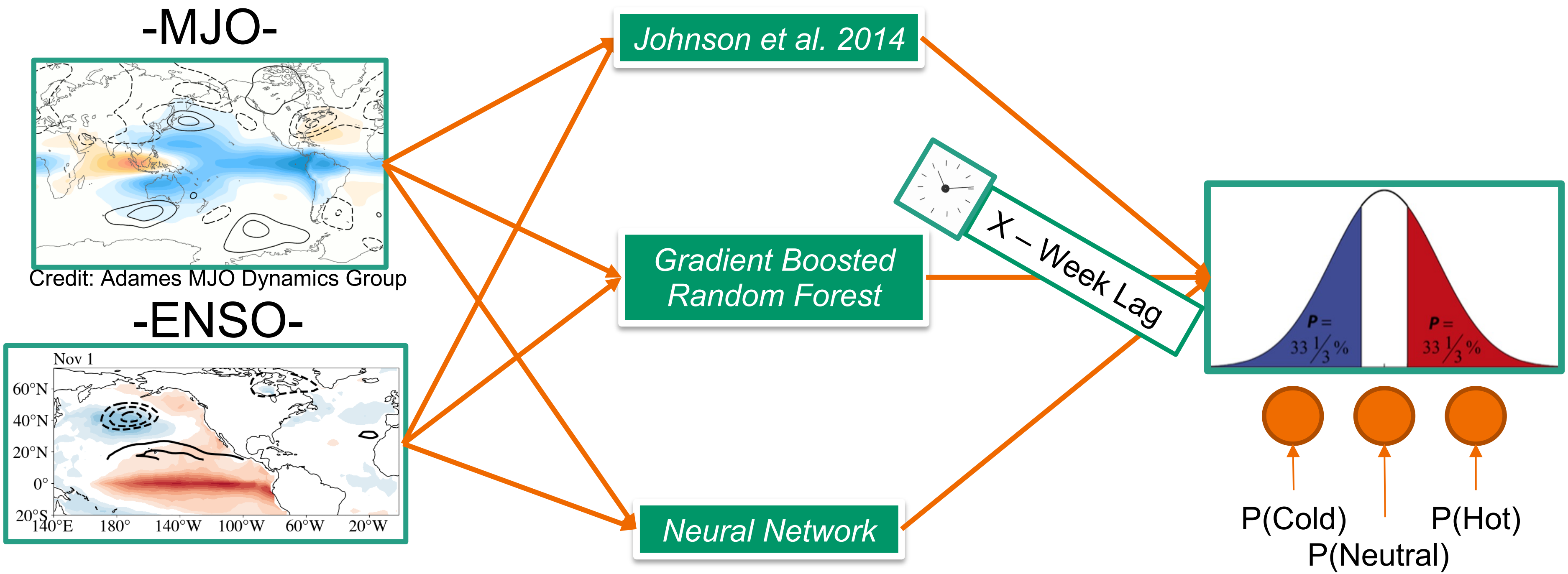


Configuration:

2 layers = [128, 8]
Batch_size = 256
L2 Regularization: a(1e-2)

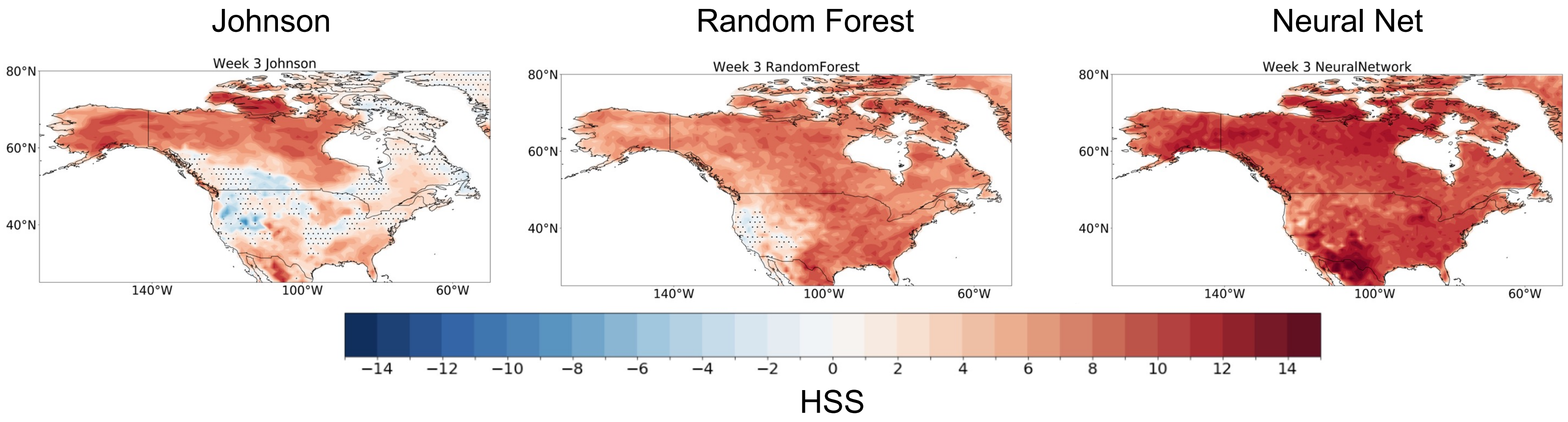
Framework

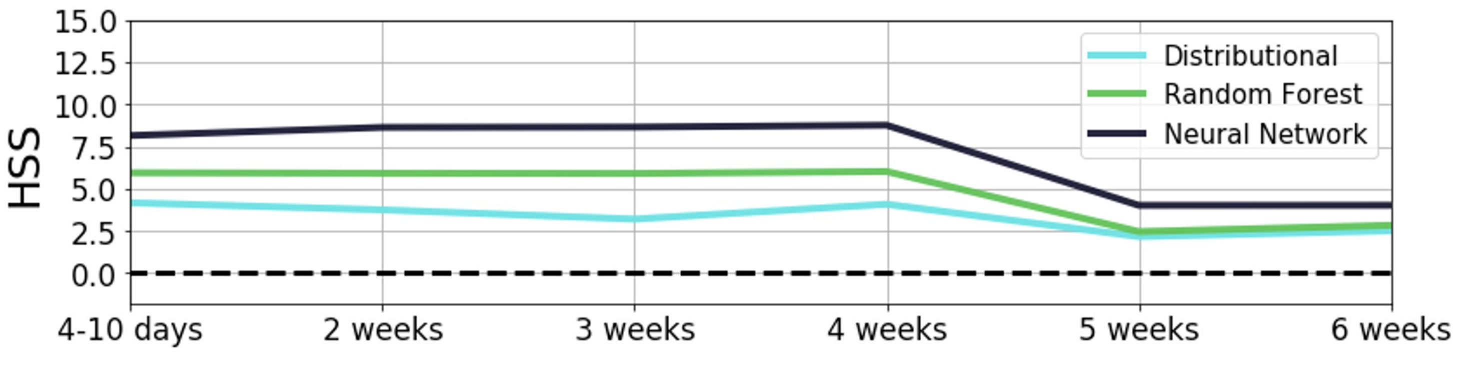
Input: Model: Target:



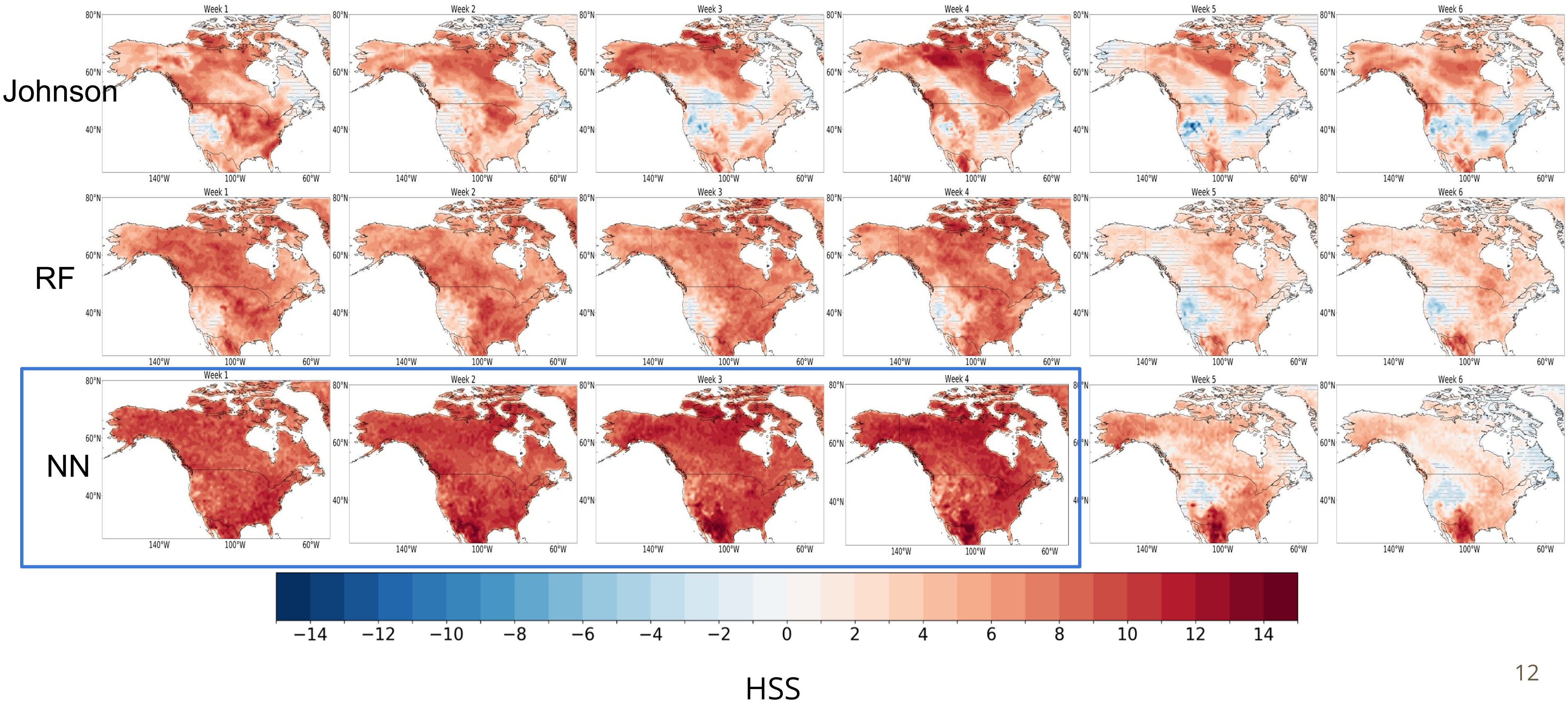
Results

HSS score - Lead time 3 week



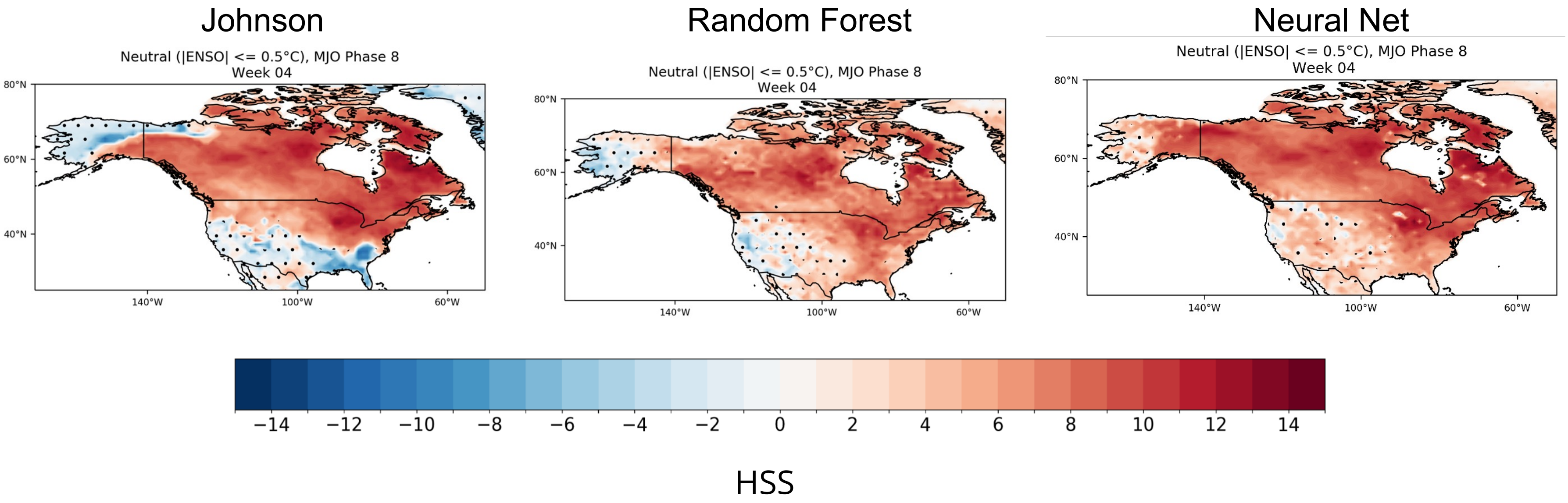


US: NN's performance overshadow Johnson and RF (lead time week 1-4)



Results

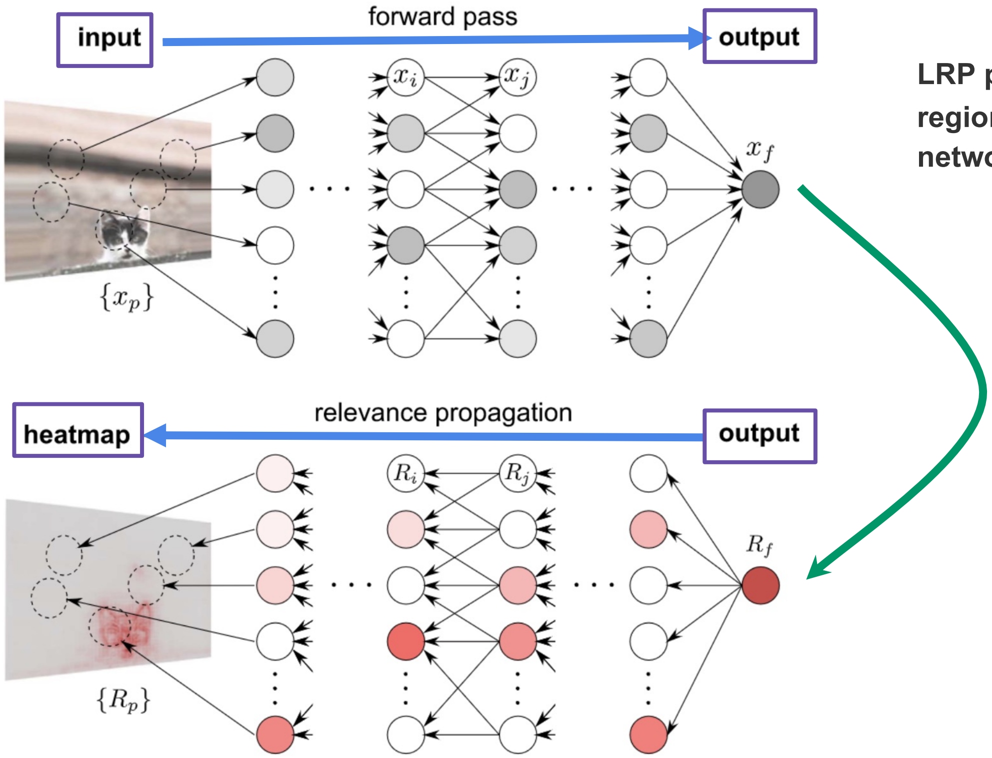
HSS score observed for Neutral ENSO, MJO phase 8 - Lead time 4 week



Lack of significance= hatched regions

NN does better mostly everywhere contrary to RF and the baseline method

Layer-wise Relevance Propagation (LRP)

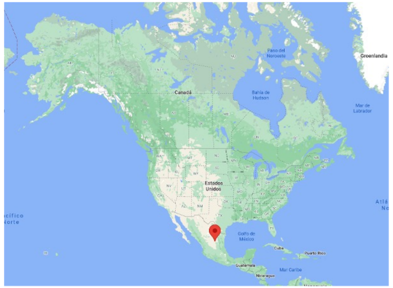


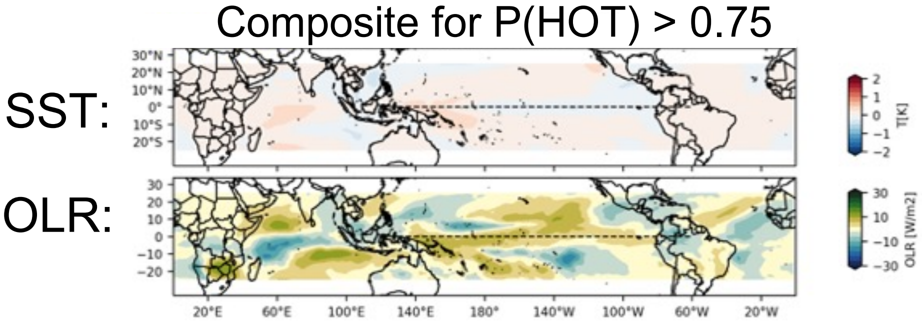
LRP produces a heatmap of the most relevant regions of the input for each prediction by the network

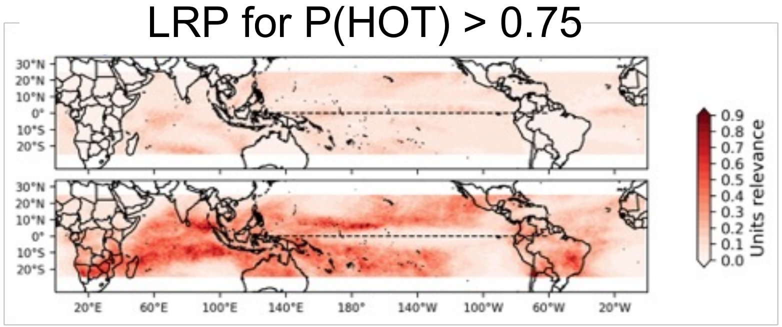
Montavon et al. (2017)

Results

Layer-wise Relevance Propagation (LRP) in Northern Mexico – 3 week forecast







Predictors: tropical 2m temperature and OLR

Predictand: 2 meter air temperature

How Do We Calibrate this Probabilistic Forecast?

1. Non-parametric quantile-based probabilities transformed to a full predictive distribution (Scheuerer et al., 2020)

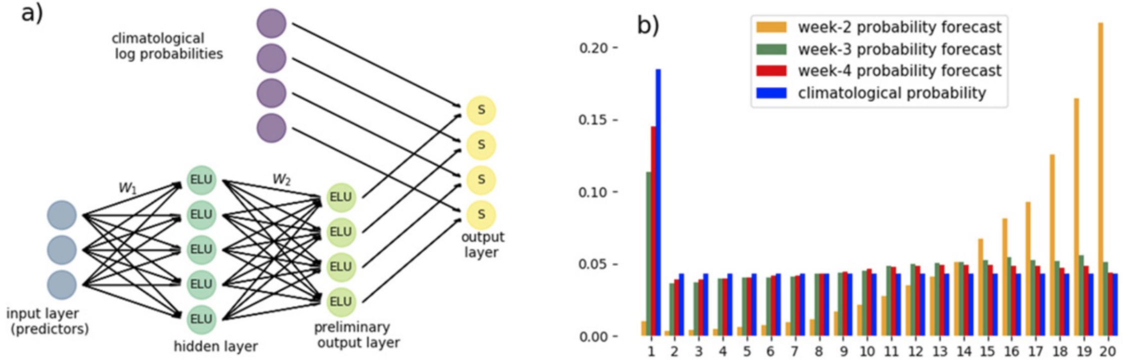


FIG. 2. (a) A schematic of the ANN architecture used in this study. For improved readability the ANN is depicted with 5 (instead of 10) nodes in the hidden layer, and 4 (instead of 20) categories for which forecast probabilities are calculated. (b) The categorical forecast probabilities for 8–14 Jan 2017 precipitation accumulations at a grid point in the Tahoe National Forest.

Transfer Learning → Observations.

Conclusions

- We use the Heidke skill score (HSS) to assess the forecast skill. Both Random Forest (RF) and Neural Network (NN) models produce skillful forecasts.
- Forecast lead times from 1-4 weeks using NN models show higher HSS over the whole domain of interest. After week 4, the NN skill degrades over Midwest and Northeast United States; however, stays skillful in central America to the southern United States.
- The interpretable NN identify coherent spatial patterns of the most known modes of S2S variability (ENSO, MJO) and highlights convective regions with well-known downstream effect over US.
- These results highlight the **NN model's ability to improve the S2S** 2m temperature forecast over the US.