Identifying relevant large-scale predictors for sub-seasonal precipitation forecast using explainable neural networks

N.Rieger[1,2], E. Olmedo[2], A. Corral[1], L.Ferranti[3], L. Magnusson[3], A. Turiel[2]

[1]*Centre de Recerca Matemática, Barcelona Spain;* [2]*Institut de Ciències del Mar, Barcelona, Spain;* [3]ECMWF, Reading, UK

1 | Why do we care?

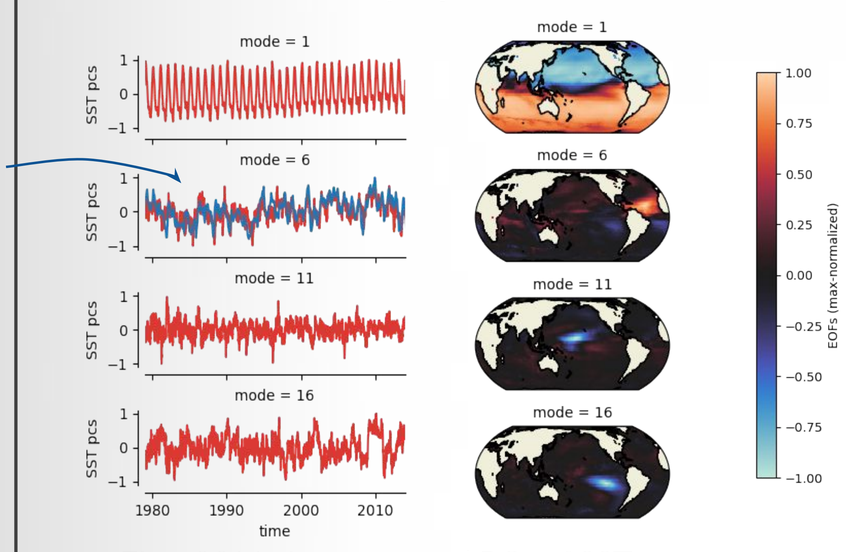
Forecasting precipitation beyond 2 weeks is very limited with modest skills over the tropics and little to no skills over the extra-tropics. This raises the question of which environmental variables and processes are suitable as meaningful predictors.

Here, we develop a forecasting model based on **sea surface temperatures (SSTs) to predict week-4 precipitation** using **feed-forward neural networks** (FF-NN) which performs comparable to current operational model of ECMWF. In combination with a recently developed framework of *forecast opportunities*[1] based on layer-wise relevance propagation (LRP)[2], we examine the **relative contributions of different oceanic modes** to make skillful precipitation forecasts on **sub-seasonal time scales**.

2 | Forecasting week-4 probability of "above normal" precipitation

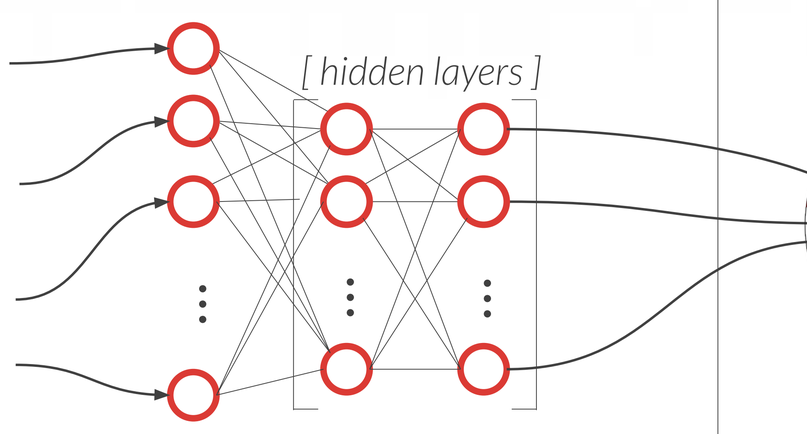
A | Input: SST

Index known as Atlantic Meridional Mode



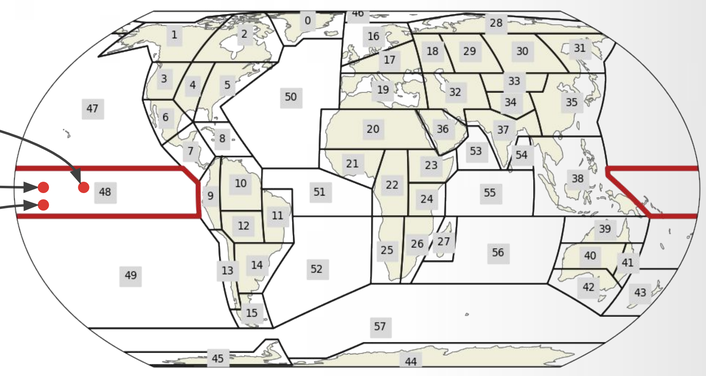
- First 20 Varimax-rotated PCs of SST
- 2° x 2° grid resolution
- daily from 1979-2014

B | Model Architecture



- Feed-forward neural network (FF-NN)
- 58 FF-NNs trained for 58 regions
- Hidden layers: 2x à 12 neurons; dropout 40%
- ReLU activation functions
- Output layer: sigmoid activation ⇒ probabilities

C | Output: Precipitation

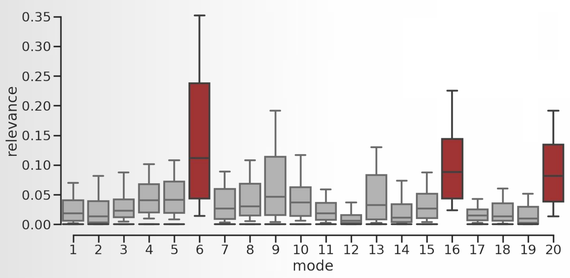


For each grid point:

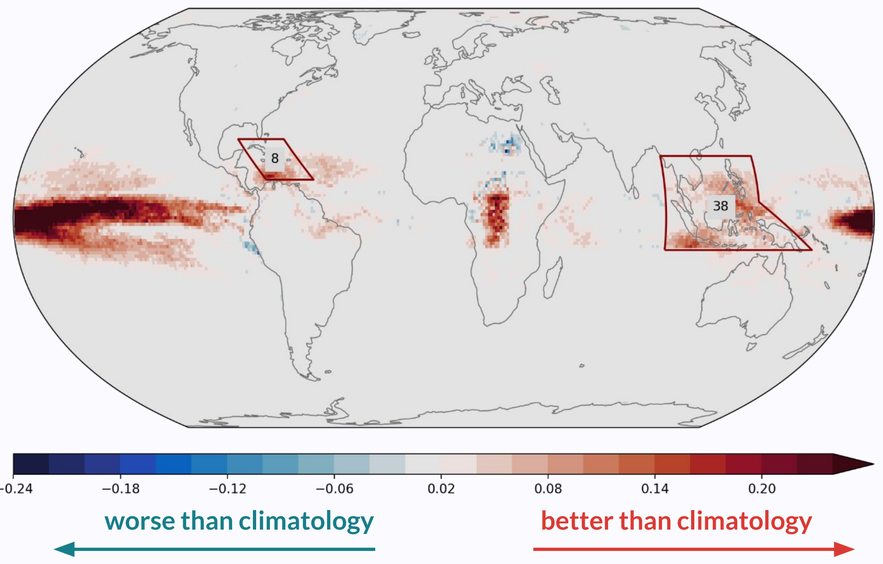
- **Week 4 probability** to be in **upper tercile** of **precipitation** distribution
- Terciles based on each grid point / day of year
- 1° x 1° grid resolution

3 | Which large-scale SST patterns provide forecasting opportunities?

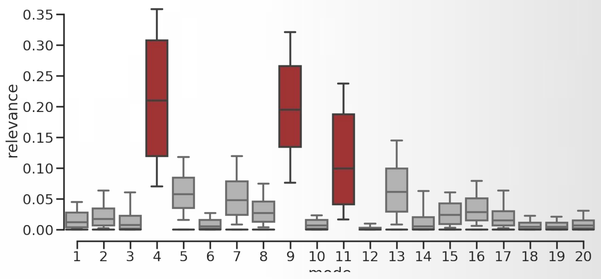
8 : Caribbean



Brier skill score (BSS) vs. climatology

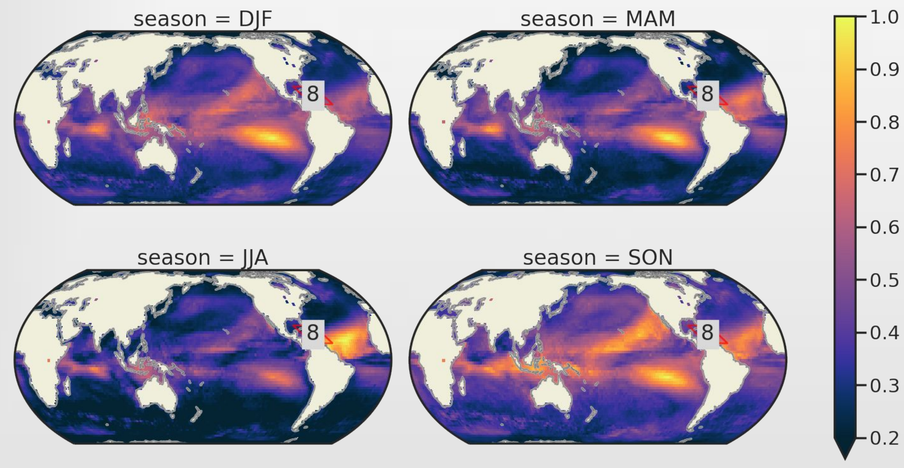


Maritime Continent : 38



Most of the skill resides in the tropical region, in particular over the tropical Pacific where the impact of ENSO is most direct, and to a lesser degree over the Caribbean (8) and the Maritime Continent (38). Beyond the tropics, the models performs as well as climatology.

And ECMWF?

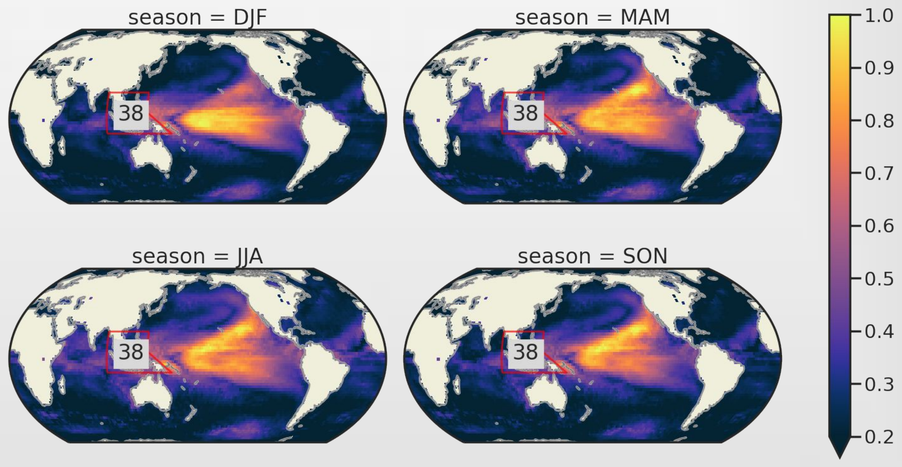


Layer-wise Relevance Propagation (LRP)

LRP[2] is a technique that allows to compute **relevance scores**. These scores indicate which neurons are the most relevant for a given input SST map.

In our case, LRP highlights **relevant PC modes** which can then be transformed via the eigenvectors into heatmaps.

Bright areas are highly relevant for the FF-NN's output decision while dark areas contain no or little predictive power.



References:

1. Mayer, K. J. & Barnes, E. A. Subseasonal Forecasts of Opportunity Identified by an Explainable Neural Network. *Geophysical Research Letters* 48, e2020GL092092 (2021).
2. Bach S, Binder A, Montavon G, Klauschen F, Müller K-R, Samek W (2015) On Pixel-Wise Explanations for Non-Linear Classifier Decisions by Layer-Wise Relevance Propagation. PLoS ONE 10(7): e0130140

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement N°813844