

DEEP LEARNING IDENTIFICATION OF OCEAN TELECONNECTIONS DRIVING EARLY-WINTER NORTH ATLANTIC CLIMATE

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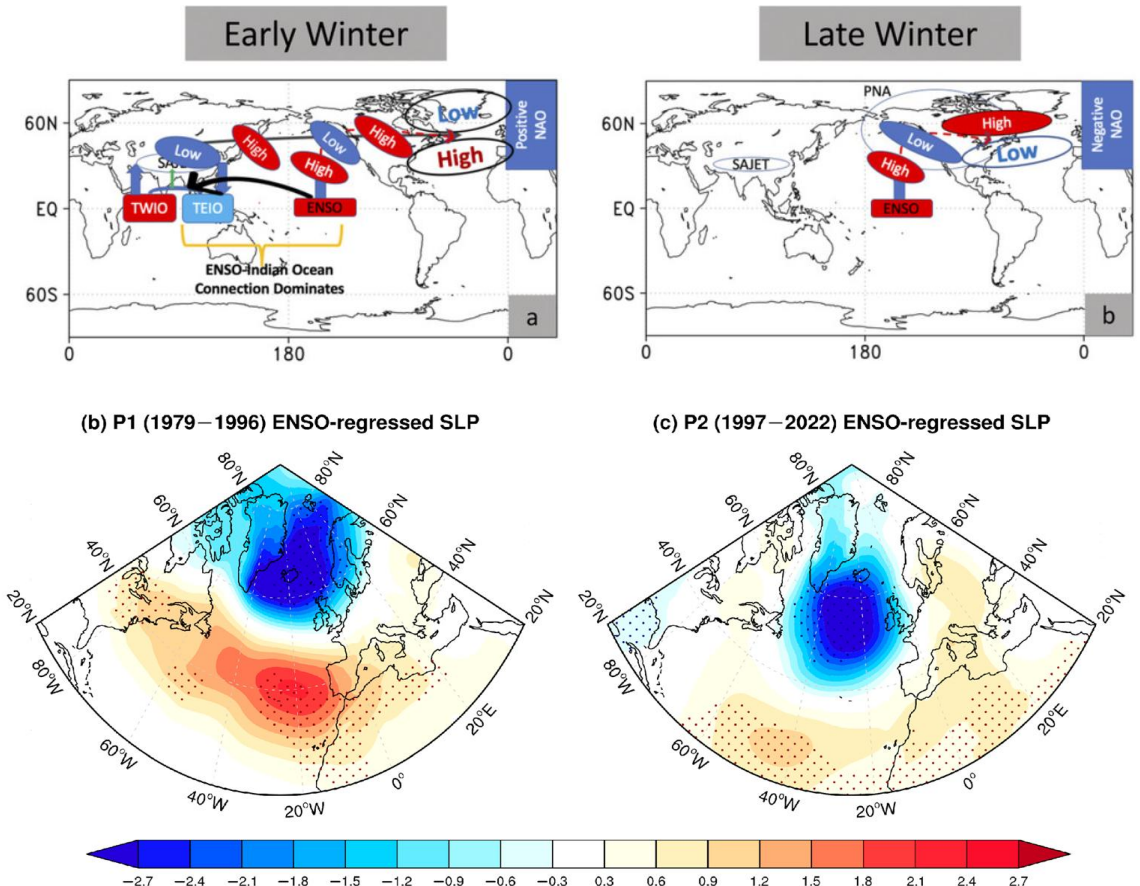
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1. Motivation: ENSO Europe-North Atlantic Early Winter (ND) Teleconnection

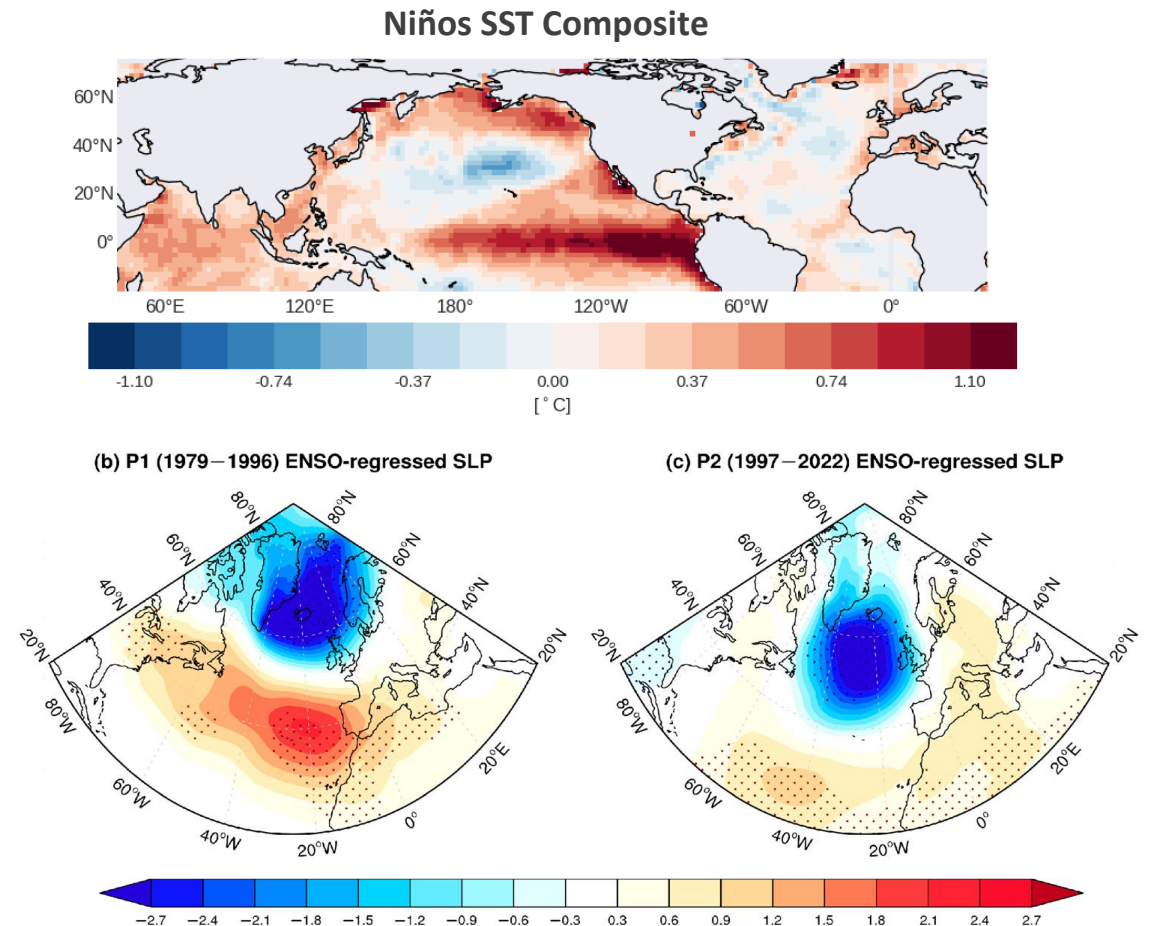
- ❖ Different teleconnection between early and late winter.
- ❖ Non-stationary ENSO teleconnection.
- ❖ Dynamical models have problem in modeling the non-stationarity nature of this teleconnection.



Sources: Abid. et al (2021); Hou et al. (2023); Fernández et al (2025).

1. Motivation: ENSO Europe-North Atlantic Early Winter (ND) Teleconnection

- ❖ Analyze the ND predictability of SLP over the NAE based on SSTs.
- ❖ Analyze models skill and error.
- ❖ Look for predictable signals through model attributions.



2. Methodology: NN4CAST

- ❖ Python application based on neural networks that allows assessing climate predictability.

Assessing seasonal climate predictability using a deep learning application: NN4CAST

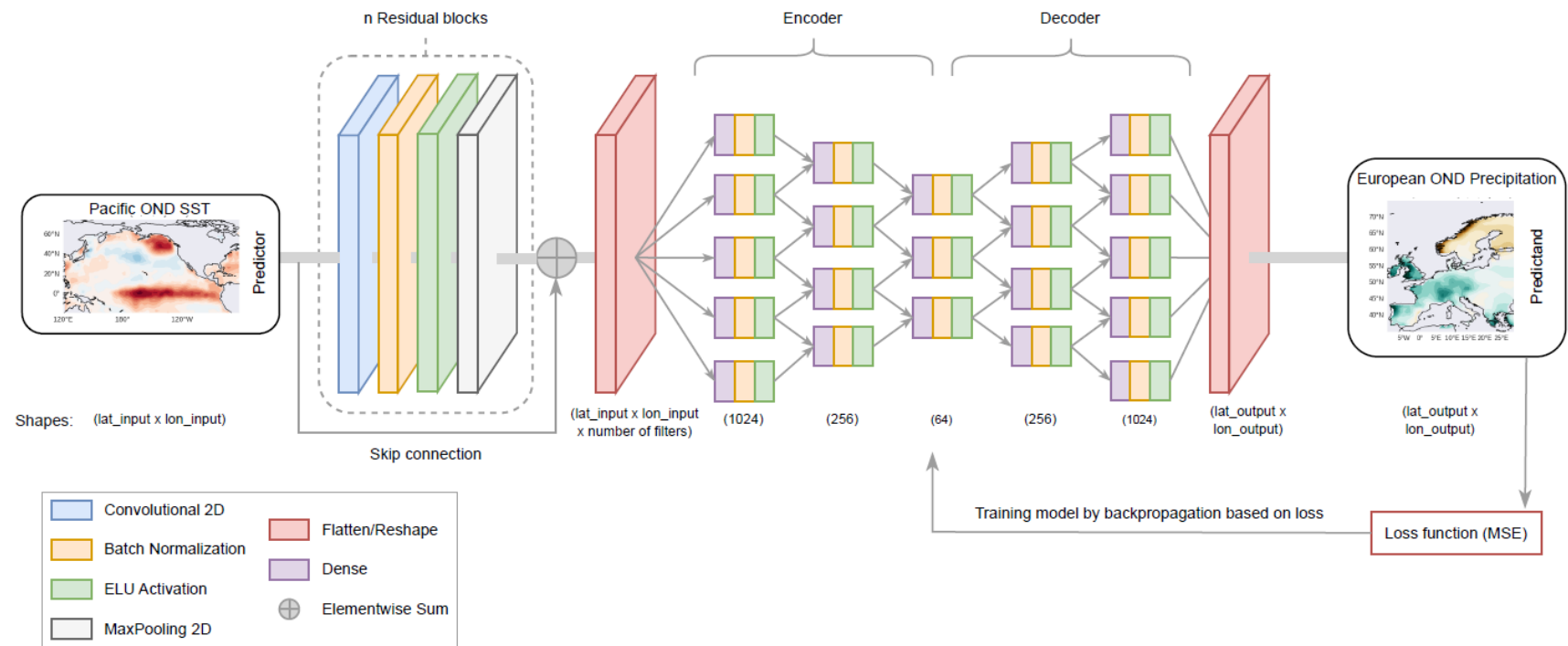
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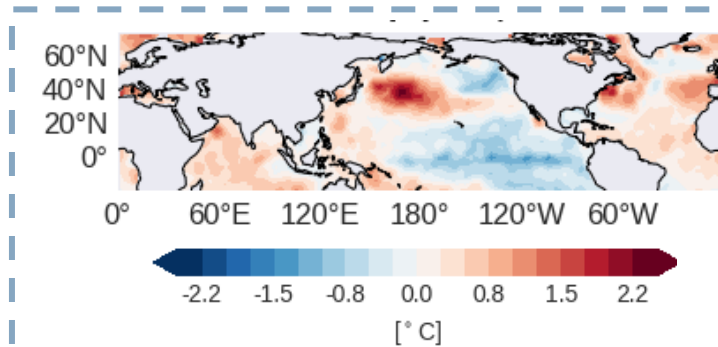


Sources: Galván. et al (2026).

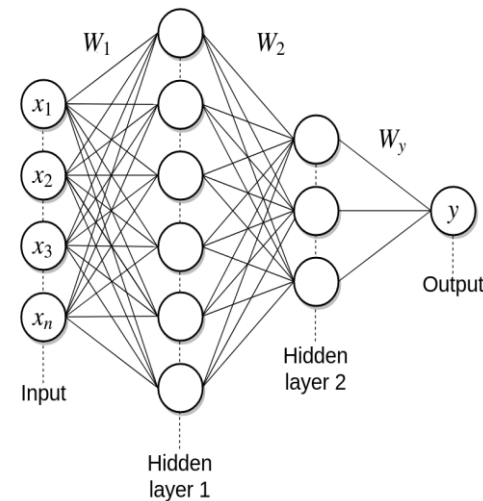
2. Data:

- ❖ **Predictor:** Global **SST** anomalies in **OCT** [HadISST].
- ❖ **Predictand:** Global **SLP** anomalies in **Nov-Dec** [ERA5].
- ❖ **Time period:** 1940-2019.
- ❖ **Leave-one-out Cross Validation** strategy.

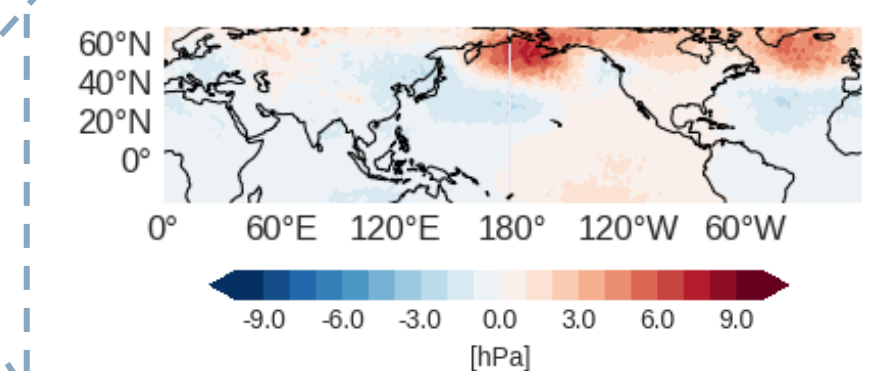
Global SST OCT



Model Structure

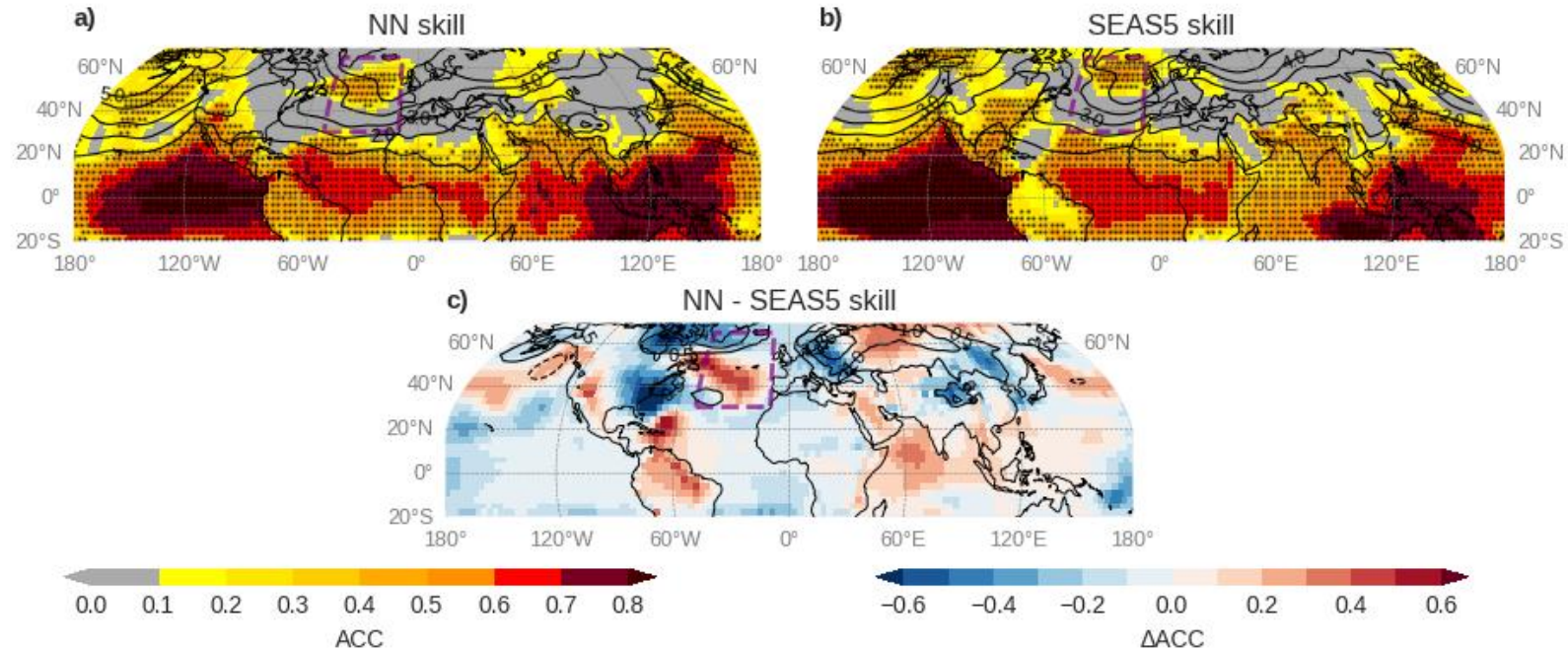


Global SLP ND



3. Application: Prediction of ND SLP

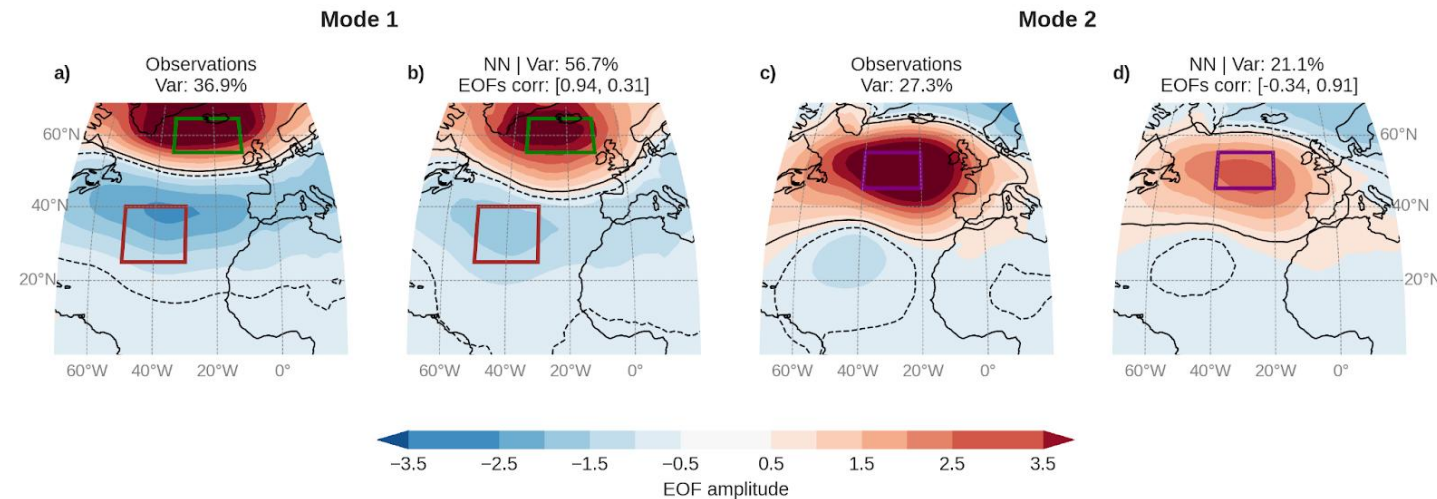
- ❖ Similar pattern of skill in terms of ACC and RMSE.
- ❖ Higher skill in the tropical regions.
- ❖ Moderate skill in the North Atlantic-Europe (NAE) region.
- ❖ NN4CAST improves in certain regions: **Amazonas, Indian Ocean and NAE.**



SLP Skill in terms of ACC (shaded) and RMSE (contours) for the common hindcast period [1981-2019]

3. Application: Prediction of ND SLP

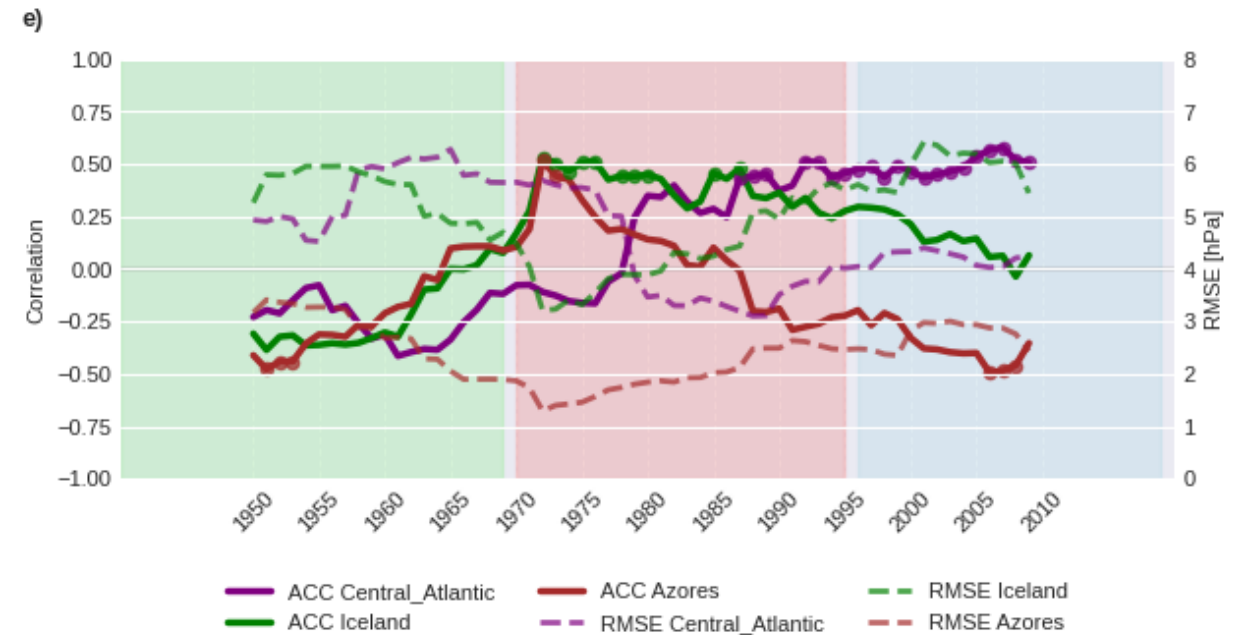
- ❖ First observed/predicted EOF modes represent a NAO pattern
- ❖ Second observed/predicted EOF mode represent an East Atlantic pattern
- ❖ 3 regions selected: Iceland (green), Azores (red) and Central Atlantic (purple).



EOF modes for observed and predicted ND SLP anomalies

3. Application: Prediction of ND SLP

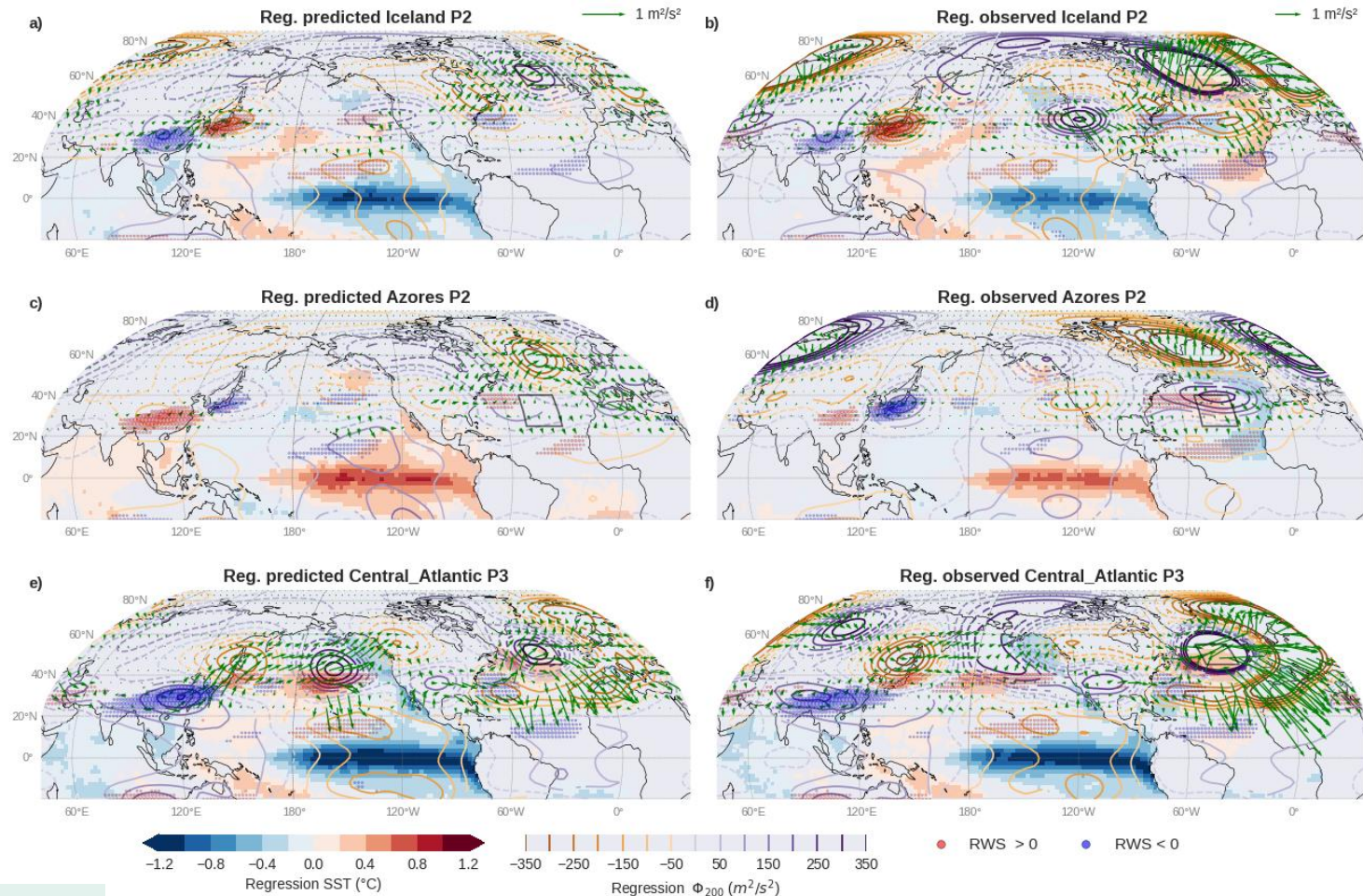
- ❖ 3 regions selected: Iceland (green), Azores (red) and Central Atlantic (purple).
- ❖ Non-stationarity captured by the model.
- ❖ 3 periods: P1 [1940-1969], P2 [1970-1995] and P3 [1996-2019].



Moving 20-year correlation and rmse of indices.

3. Application: Prediction of ND SLP

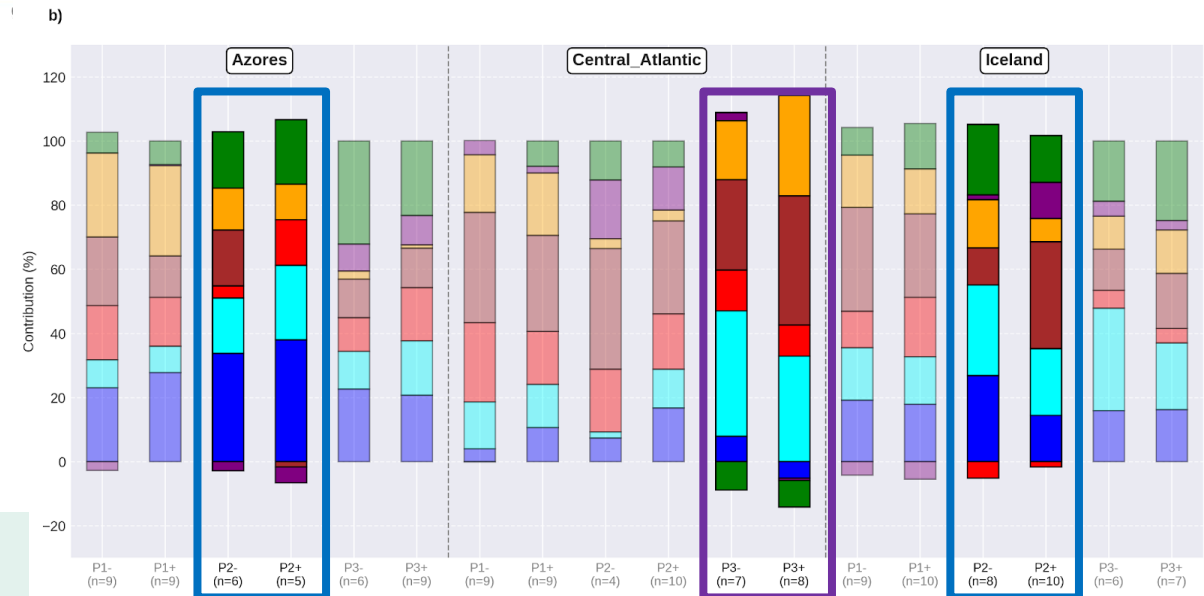
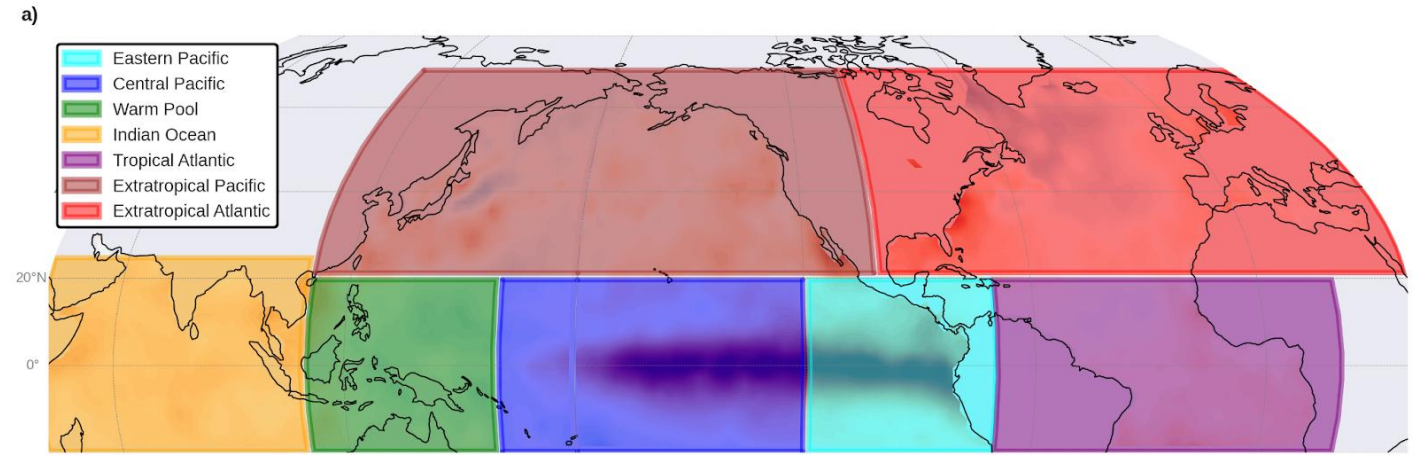
- ❖ Regressions for **Iceland and Azores** in **P2 [1970-1995]** and **Central Atlantic** in **P3 [1997-2019]**.
- ❖ Predicted/Observed regressions show similar patterns.
- ❖ Central Pacific more important in P2 while also the eastern in P3.
- ❖ Effective wave propagation from Pacific warm pool in P3.



Index regressions over
SST, SLP, WAF and RWS.

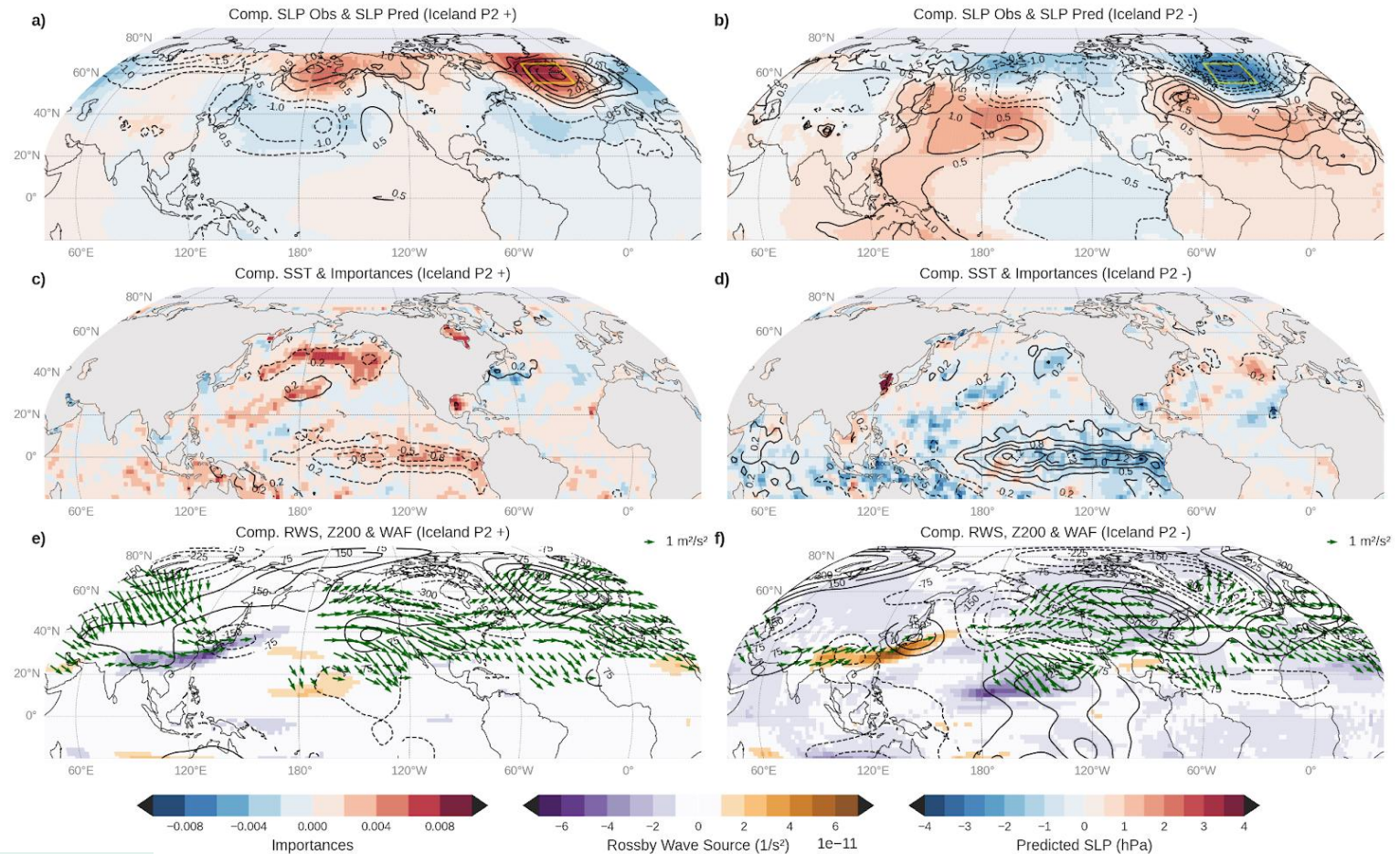
3. Application: Prediction of ND SLP

- ❖ Model attributions with Integrated Gradients.
- ❖ Predictor field divided into ocean regions to assess their contributions in the NAE signal.
- ❖ Greater importance of the Pacific basin in P2 for Iceland and Azores.
- ❖ Shifted importance towards eastern pacific in P3 for Central Atlantic and contribution from Indian Ocean.



3. Application: Prediction of ND SLP

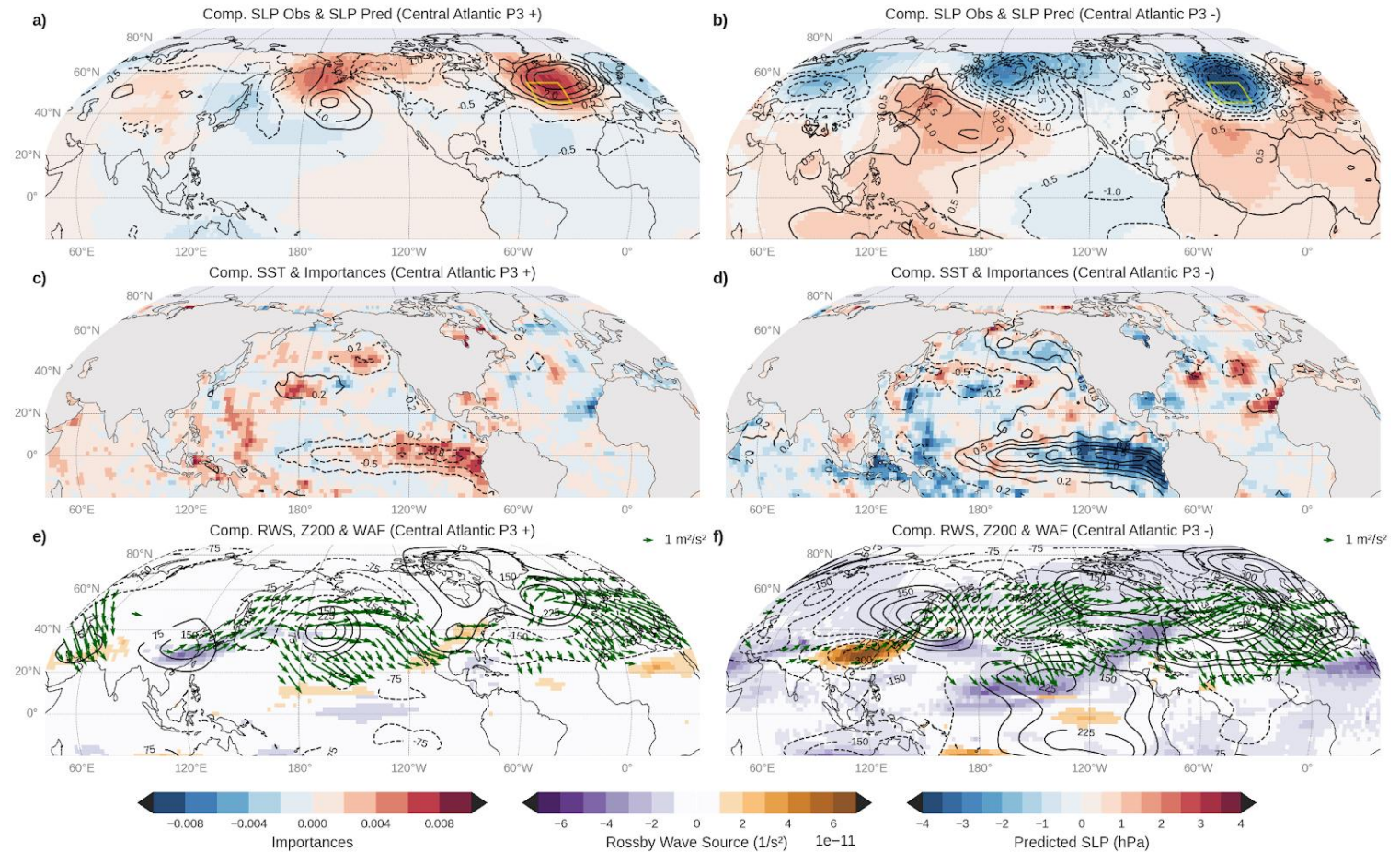
- ❖ Composites for Iceland predictions in P2 (P2+ and P2-).
- ❖ Observed and predicted fields show similar spatial patterns.
- ❖ Importances for positive events coming mainly from extratropical Pacific.
- ❖ Importance for negative events coming from tropical Pacific.



Composites for Iceland predictions in P2 (P2+ and P2-)

3. Application: Prediction of ND SLP

- ❖ Composites for Iceland predictions in P3 (P3+ and P3-).
- ❖ Observed and predicted fields show similar spatial patterns.
- ❖ Importance from the eastern pacific dominates, with local contributions from the North Atlantic.
- ❖ Waves from the Pacific warm pool propagates downstream towards the Atlantic.



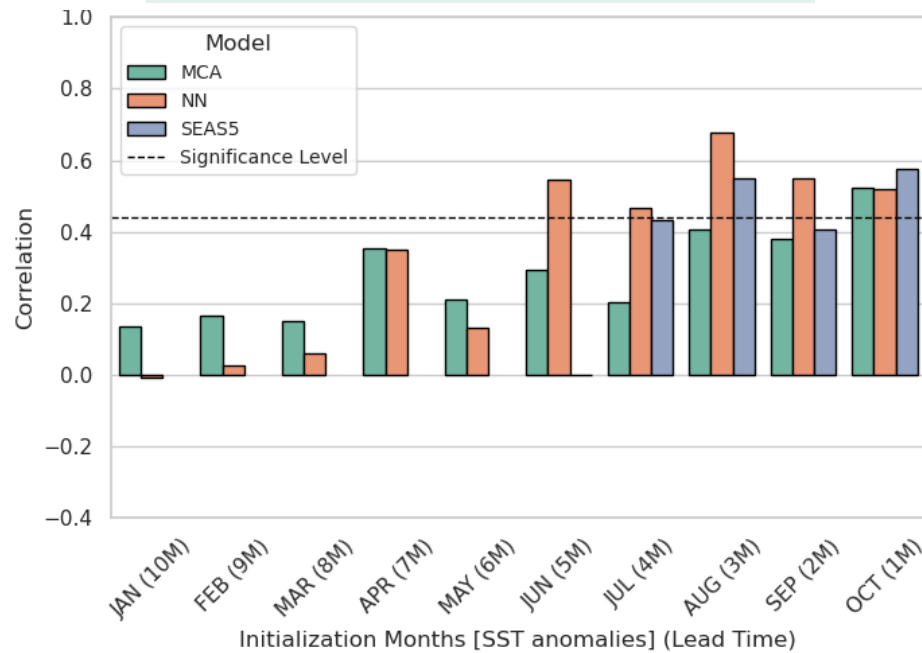
Composites for Central Atlantic predictions in P3 (P3+ and P3-)

3. Application: Prediction of ND SLP

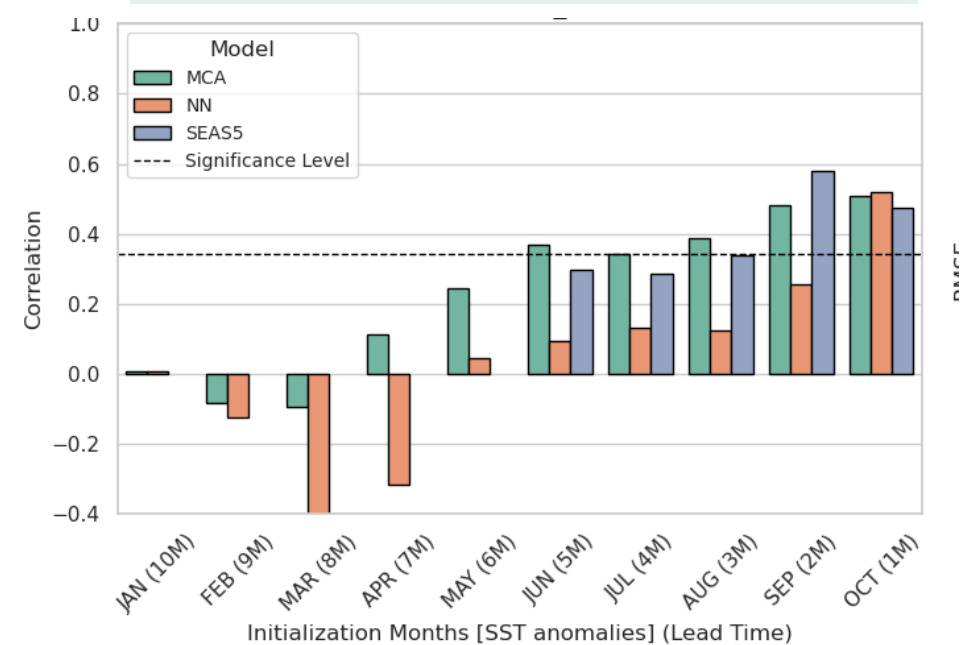
- ❖ Persistent significant skill for Iceland in P2 since June (5 months lead time).

- ❖ Big drop in Central Atlantic skill in P3 with lead time.

Correlation of Iceland index in P2 for different lead times

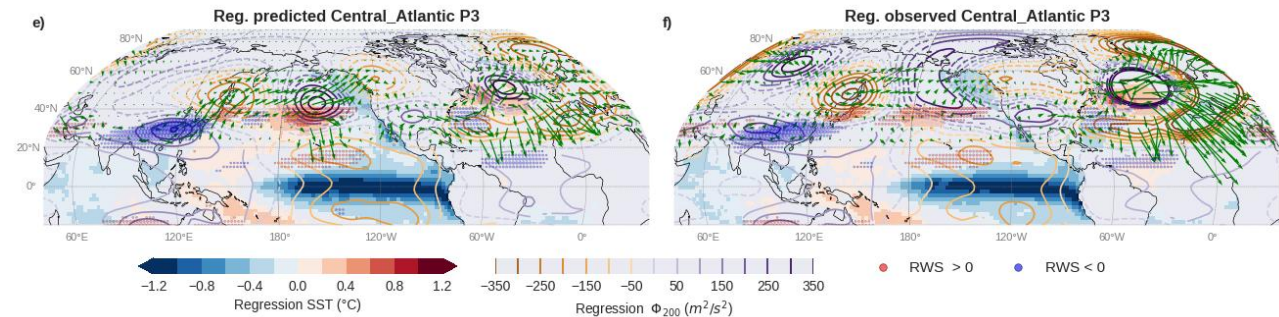
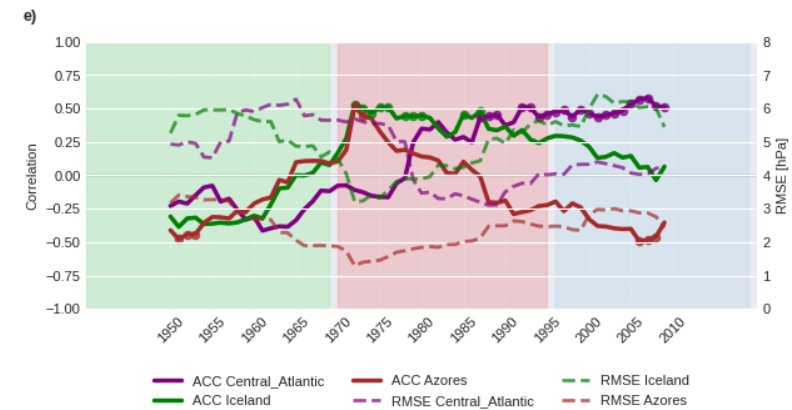
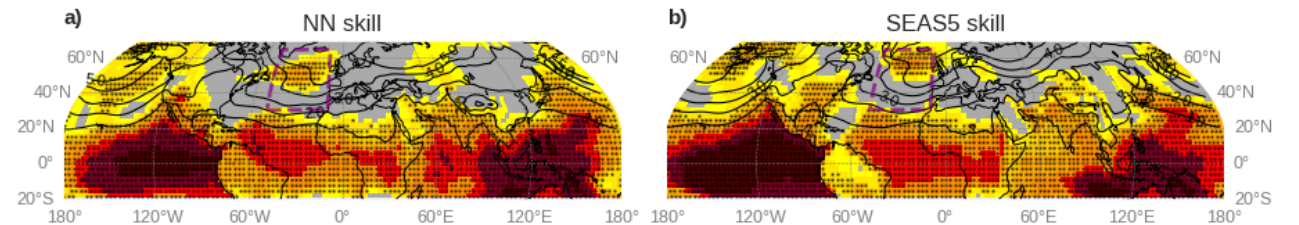


Correlation of Central Atlantic index in P3 for different lead times



4. Conclusions:

- I. Statistical models' ability to capture non-linear teleconnections.
- II. Representation of non-stationarities in the teleconnection.
- III. Model attributions point out regions of predictable signals in accordance with recent studies.



THANK YOU FOR YOUR ATTENTION!

QUESTIONS ?

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