VU VRIJE UNIVERSITEIT AMSTERDAM | IVM Institute for Environmental Studies | KNMI Ministerie van Infrastructuur en Waterstaat

EXPECT

USING AN EXPLAINABLE NEURAL NETWORK TO IDENTIFY TROPICAL DRIVERS OF THE NORTHERN HEMISPHERE WAVE-5 TREND PATTERN

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This is a work-in-progress poster outlining our plans. We welcome any feedback on our proposed methodology, so feel free **to reach out!**

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THE WAVE-5 TREND PATTERN

There is a trend in the **summertime** Northern Hemisphere (NH) upper-atmospheric circulation that resembles a **wave-5 pattern** (Fig. 1) and is linked to **surface temperature extremes** (Teng et al., 2022). This trend lies outside historic CMIP6 simulations, suggesting that the climate models might be missing dynamic responses (Happé et al., 2025). Currently, there is no consensus on potential physical drivers, nor whether it reflects a single circumglobal wave or **multiple regional wave trains** (Happé et al., 2025).

The objective of this study is to identify potential drivers for two parts of the wave-5 pattern (**US-Atlantic and Eurasian part**, identified by Happé et al., 2025). In doing so, we may also gain confidence in whether the two parts are linked, or driven by entirely different processes.

TROPICAL DRIVERS

Diabatic heating from tropical convection — during **monsoons**, **MJO**, or **ENSO** — can initiate **Rossby wave trains** that propagate along the jet stream. Hence, tropical processes are linked to midlatitude circulation through **teleconnections**. Here, we will test whether these teleconnections drive the wave-5 pattern and explore if they emerge at certain time scales.

EXPLAINABLE NEURAL NETWORK

We task a **neural network** (**NN**) to predict the midlatitude circulation, given **tropical outgoing longwave radiation** (**OLR**) fields. We then apply **Layer-wise Relevance Propagation** (**LRP**), an XAI method that generates heatmaps.

Why NN? NNs are good at capturing complex, non-linear relationships.
Why LRP? LRP identifies which input features influence the NNs prediction, helping us verify if information from known teleconnection regions is used.

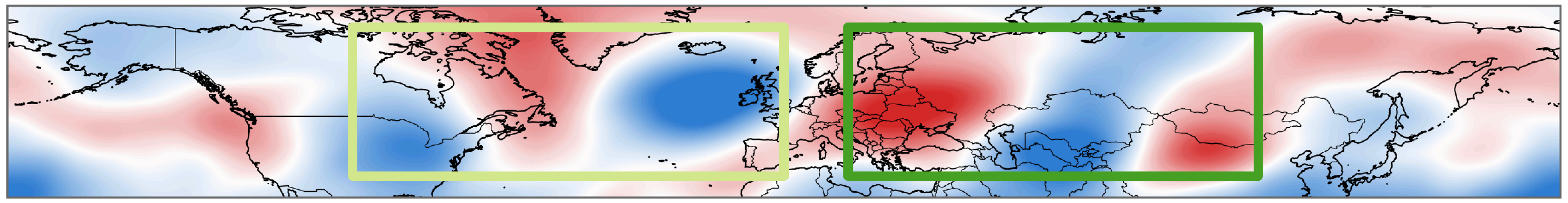

Figure 1: Trend in the summertime (1940-2023) streamfunction at 250 hPa. The US-Atlantic (light green) and Eurasian (dark green) regions are outlined.

METHODOLOGY

1 Obtain and preprocess the data.
We use daily mean ERA5 data (1980-2023; 44 years):
1. **Input**: OLR anomalies in the tropics (20 °S - 30 °N), at different lead times, May-August.
2. **Target**: streamfunction at 250 hPa in the NH midlatitudes (35 °N - 70 °N), June-August. To smoothen the data, we apply a **5-day rolling mean**.

2 Evaluate the presence of the wave-5 pattern.
We **calculate the trend** in stream function per grid point. Next, we calculate the **pattern correlation** between the 5-day mean stream function field with the ERA5 trend pattern for the region of interest.
Fields are a **'positive match'**, i.e. matching the wave-5 trend pattern, if the **correlation > 0.5**.

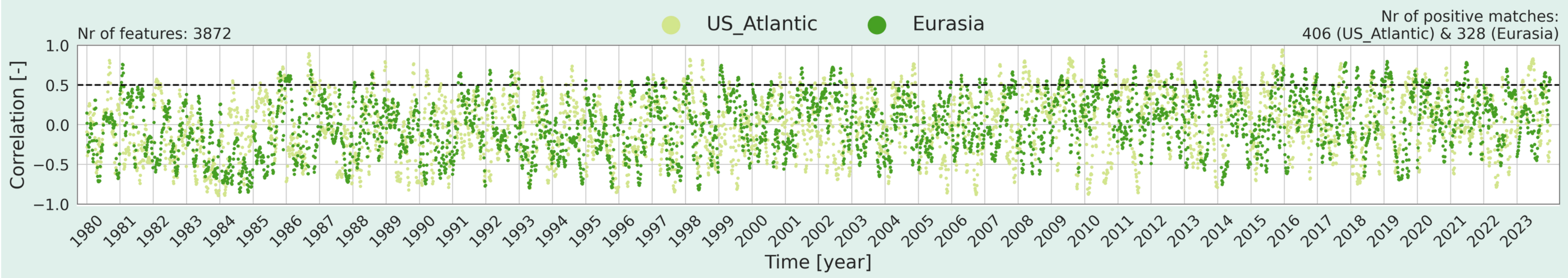

Figure 2: Pattern correlation time series. Black horizontal line indicates the threshold of 0.5 for selecting the positive matches.

3 Prepare the data for the NN.
1. **Input**: we standardize all input variables to a mean $\mu = 0$ and std $\sigma = 1$
2. **Target**: we assign labels to the fields, with 1 = wave, 0 = non-wave.

4 Set up the NN.
1. **Input layer**: standardized OLR anomaly fields, number of nodes is equal to number of OLR grid points.
2. **Hidden layers**: two hidden layers that use **rectified linear activation function**.
3. **Output layer**: two nodes that describe the **categorical prediction**.

5 Training the NN.

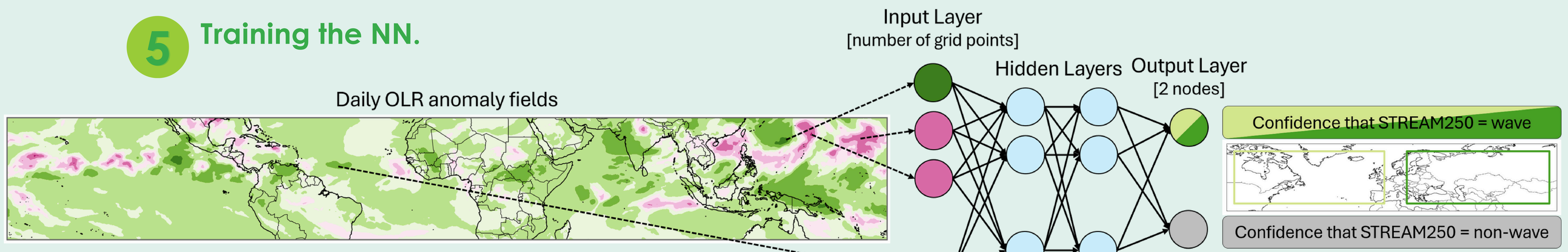

Figure 3: NN architecture (based on Mayer & Barnes, 2021)

6 Evaluate the predictions and apply LRP.
For the correct **10% most confident predictions** we propagate the prediction back through the network using LRP.

SUMMARY Assuming the observed wave-5 trend consist of two regional wave trains, we set up an explainable NN for each region. We task the NN to predict whether the regional streamfunction field matches the trend based given OLR fields. If so, we apply LRP to locate relevant tropical regions that drive the trend.

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