Examining MHWs in the observational record in the context of MHWs in climate models

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How can we compare marine heatwaves (MHWs) tracked in climate models with MHWs in the observational record?

MHWs occur throughout the global ocean and display complex spatio-temporal behavior with complex spatiotemporal connectivity. Non-eddy resolving ocean climate models can miss details of this structure may not accurately capture the tails of the temperature distribution, resulting in temperature extremes that are not as frequent or intense as in higher resolutions and in observations.

Assessing marine heatwaves is difficult due to the (1) short observational record and (2) limited sample size of extreme events.

1. Define a MHW and compute sea surface temperature anomalies

**OISST SSTA:** We remove the **linear trend** and seasonal cycle from 1981 through 2021.

CESM2 LE SSTA: We remove the **30-year rolling mean as the trend** and seasonal cycle from 1850 through 2015.
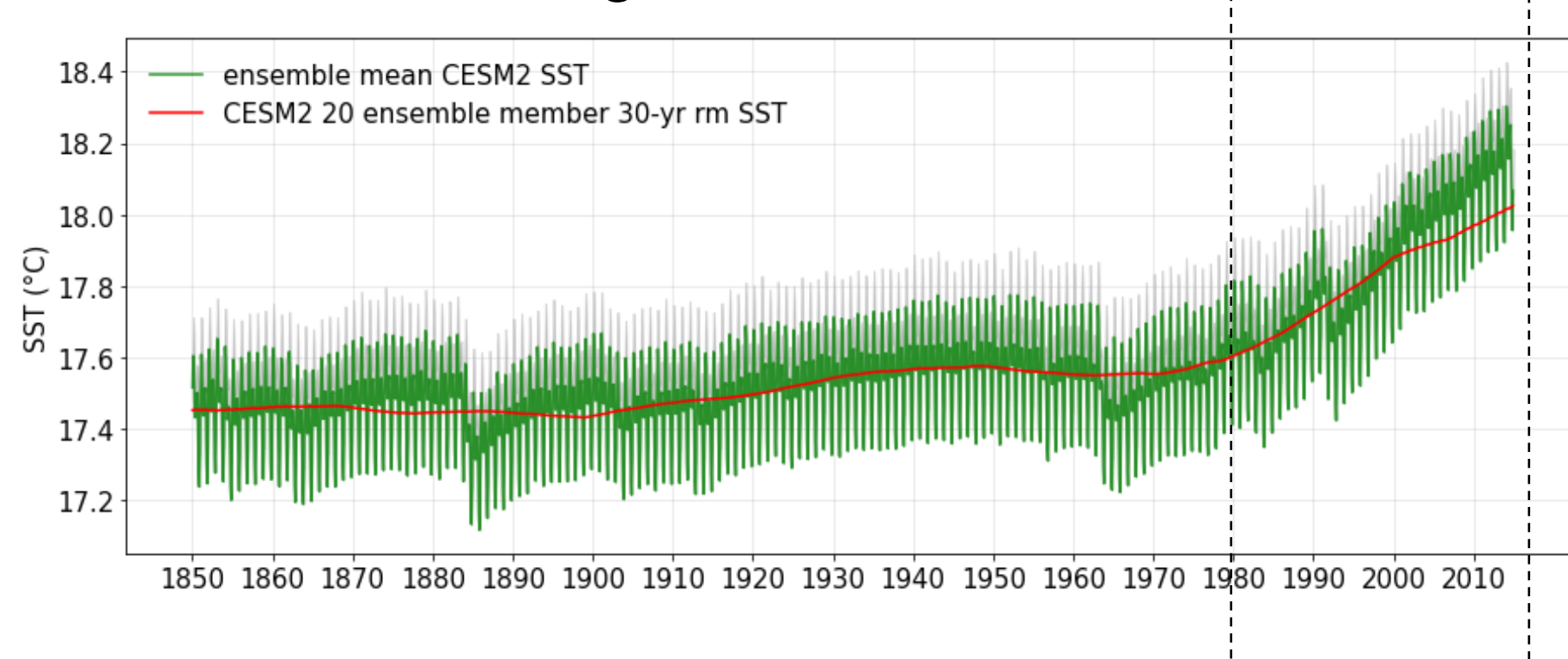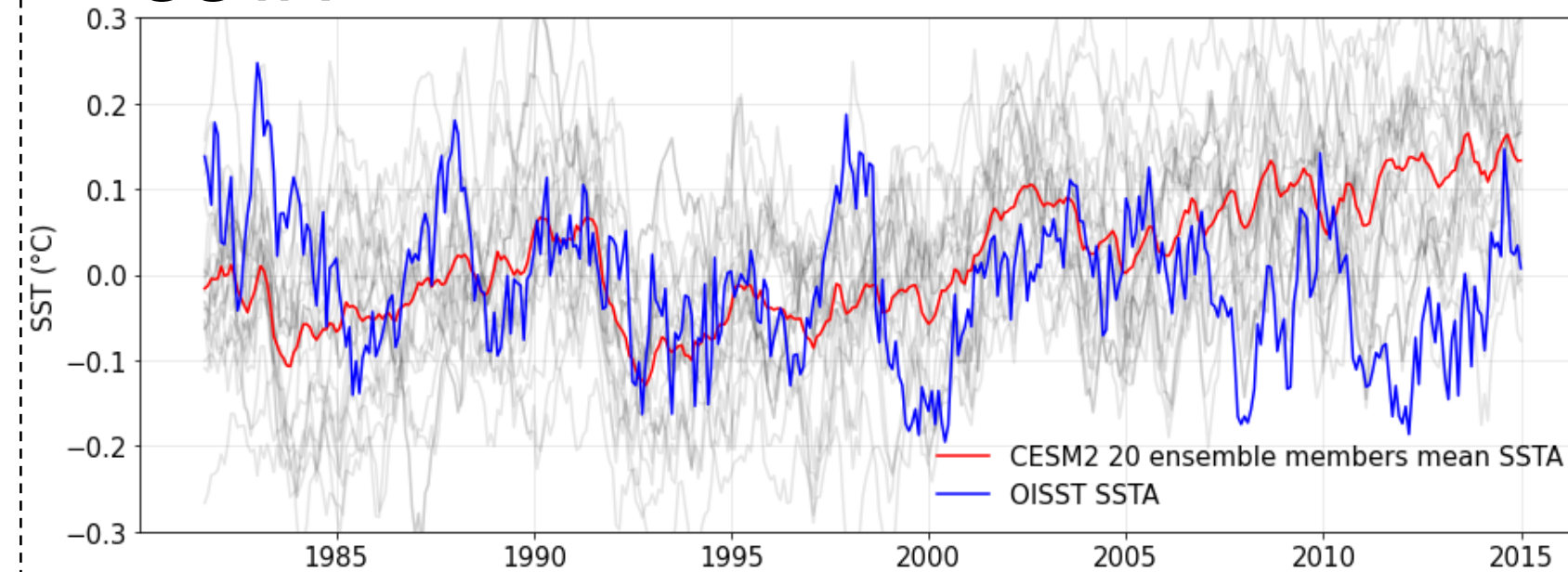
Data sources
- Ensemble members of the CESM2 (Community Earth System Model Version 2) Large Ensemble Community Project (1° spatial resolution, monthly from 1850 to 2015)
- OISST (Optimal Interpolation of Sea Surface Temperature) satellite data (1/4° spatial resolution, monthly from 1981 to 2021)

*The rolling mean trend Does not quite correspond to the mean
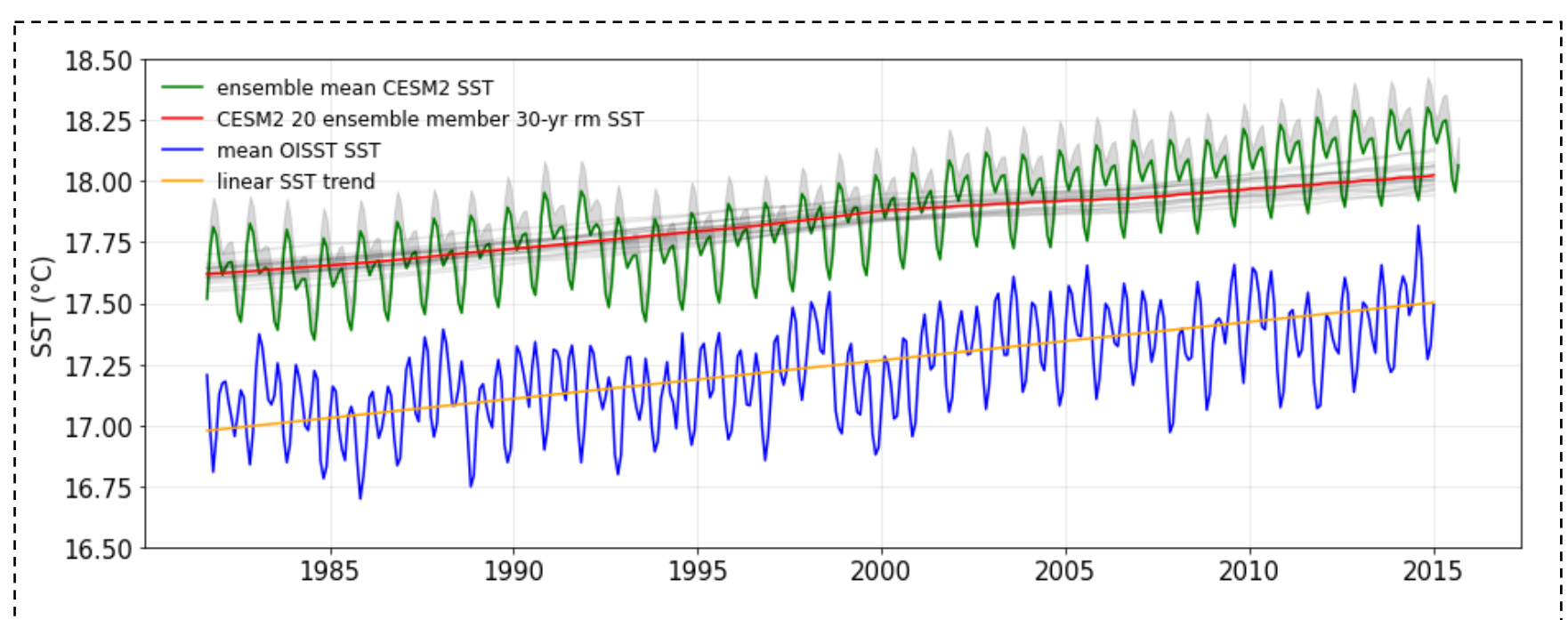

SSTA

3. Identify and track MHWs with a focus on the North Pacific Ocean

Identify MHWs as coherent patches of sea surface temperature anomalies that are at or above the 90th percentile temperature threshold.

We identified over 30,000 MHWs across the 100 CESM2 large ensemble members and identify types of MHWs using the intersection over union measure.
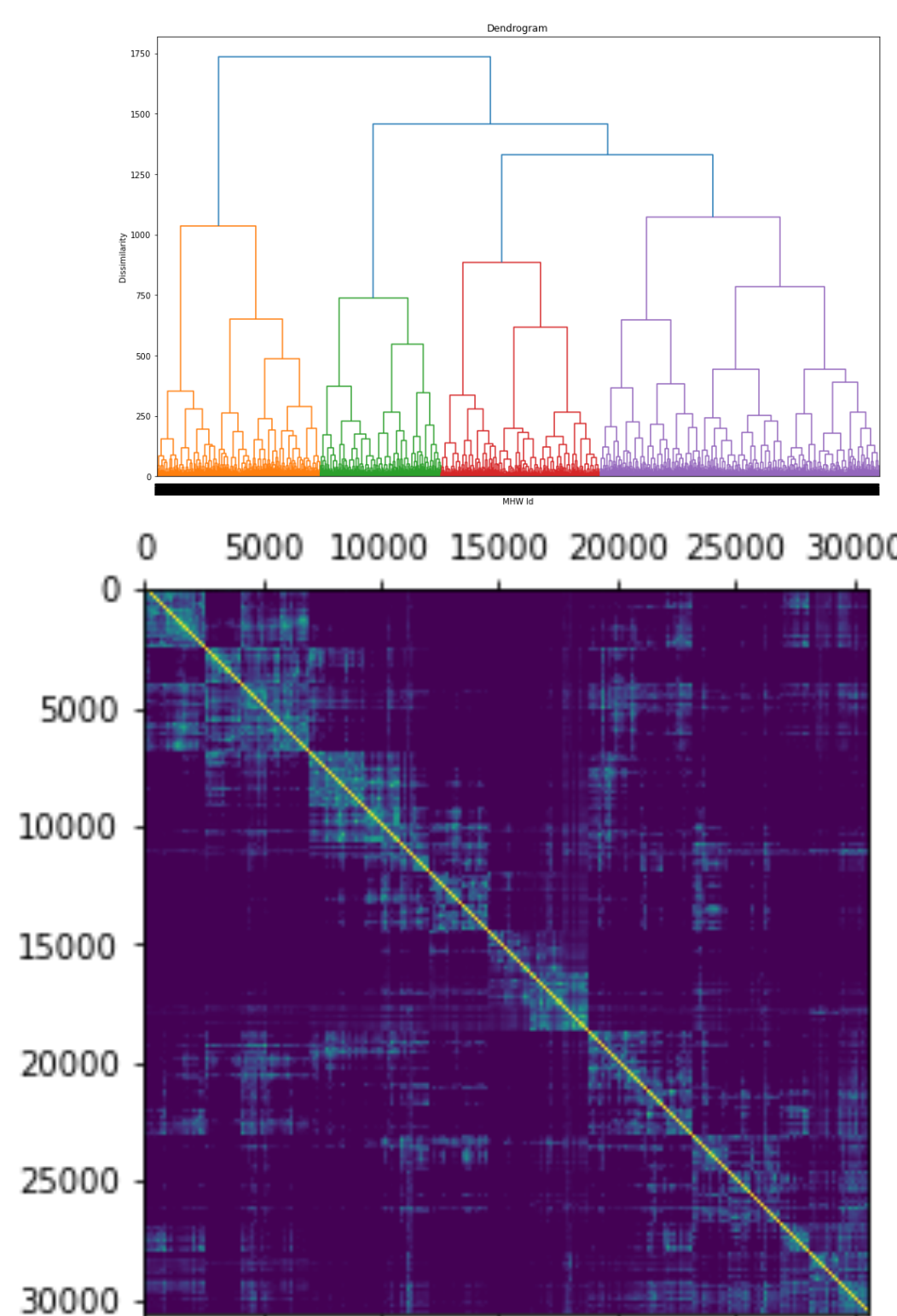

Hierarchical clustering groups similar objects into a dendrogram (top). The matrix below is simply the previous matrix reordered according to the dendrogram.
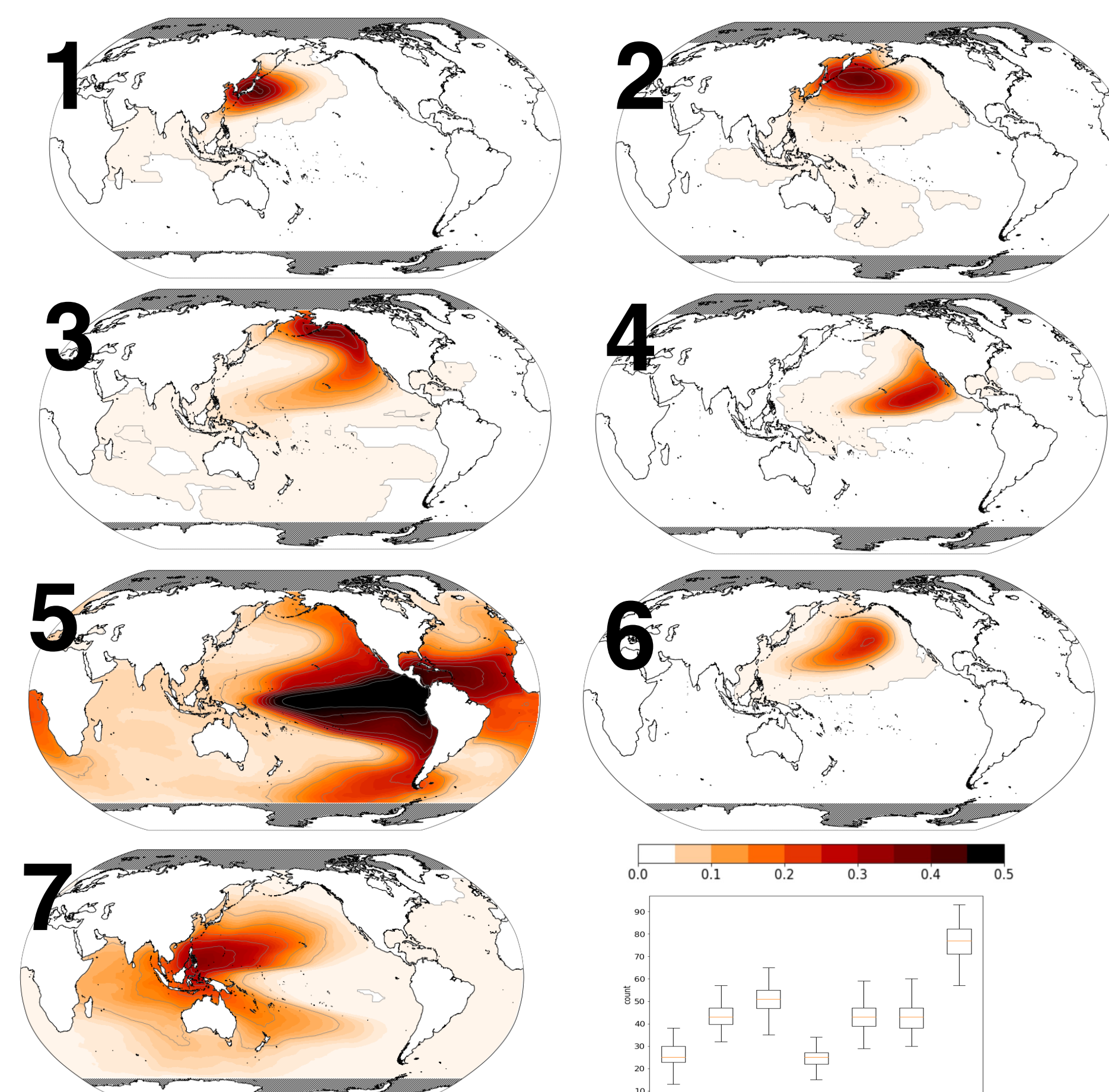

Comparing MHWs in the observational record with MHWs in the CESM2 LE
- Identified 142 MHWs in the observational record with a footprint in the North Pacific Ocean
- 89 out of the 142 MHWs were longer than 1 month long
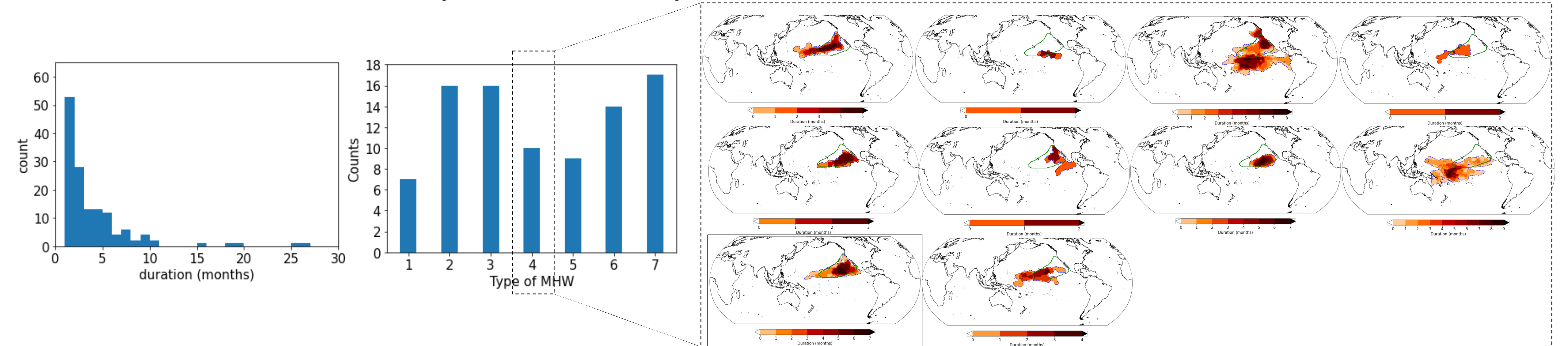
Framework to contextualize MHWs in the observational record using a set of similar MHWs in a climate model ensemble spread.

Example: Want to examine this MHW from 11/2017 to 05/2018

1. Which type of MHW is it most like? It is most similar in terms of spatial footprint to the footprint of Type 4 MHWs (outline in green).

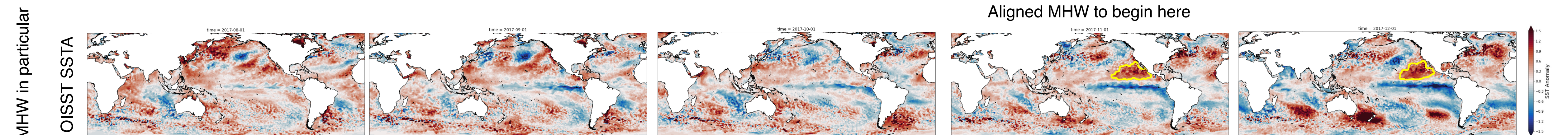MHW from 11/2017 to 05/2018 tracked in OISST
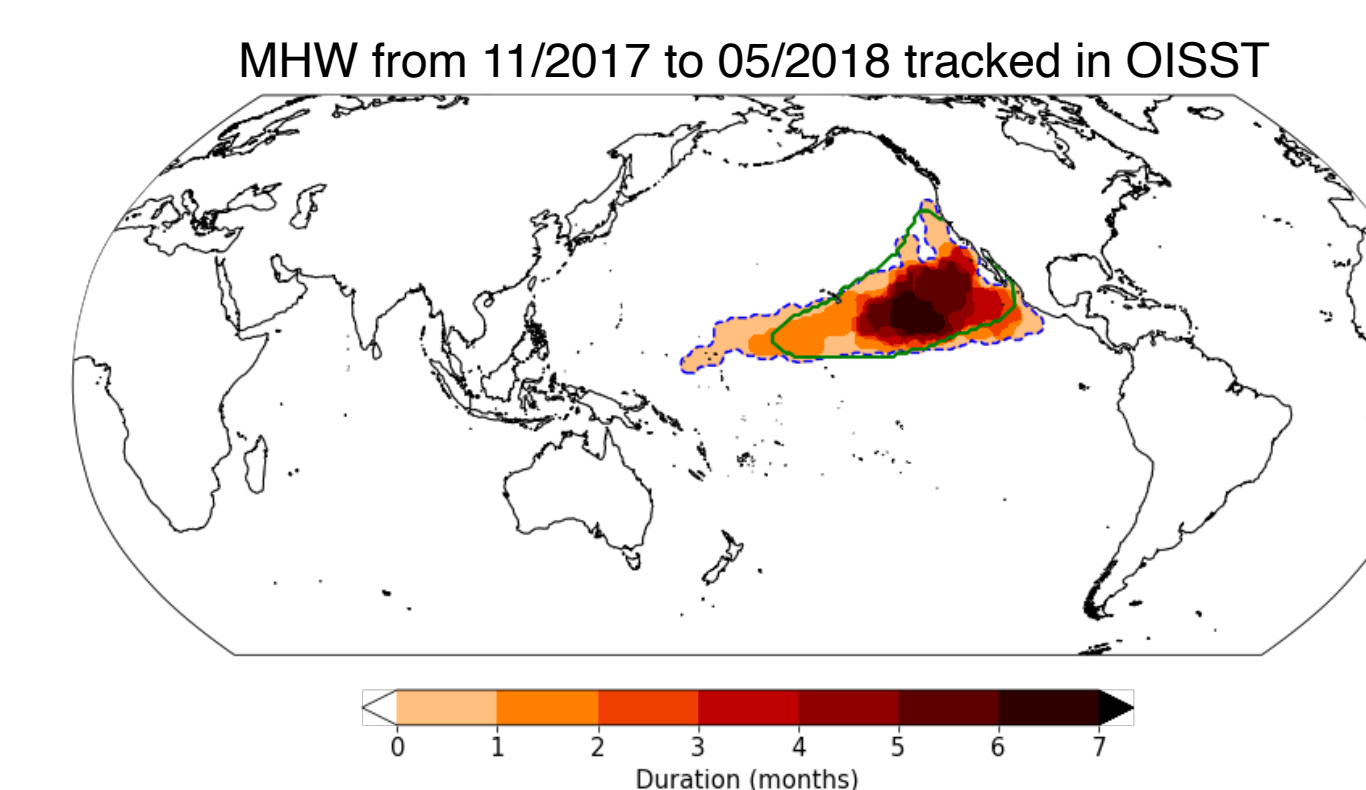
2. From the set of Type 4 MHWs in CESM2 LE, we identify the state of the climate, in terms of modes of climate variability, when these MHWs occur.
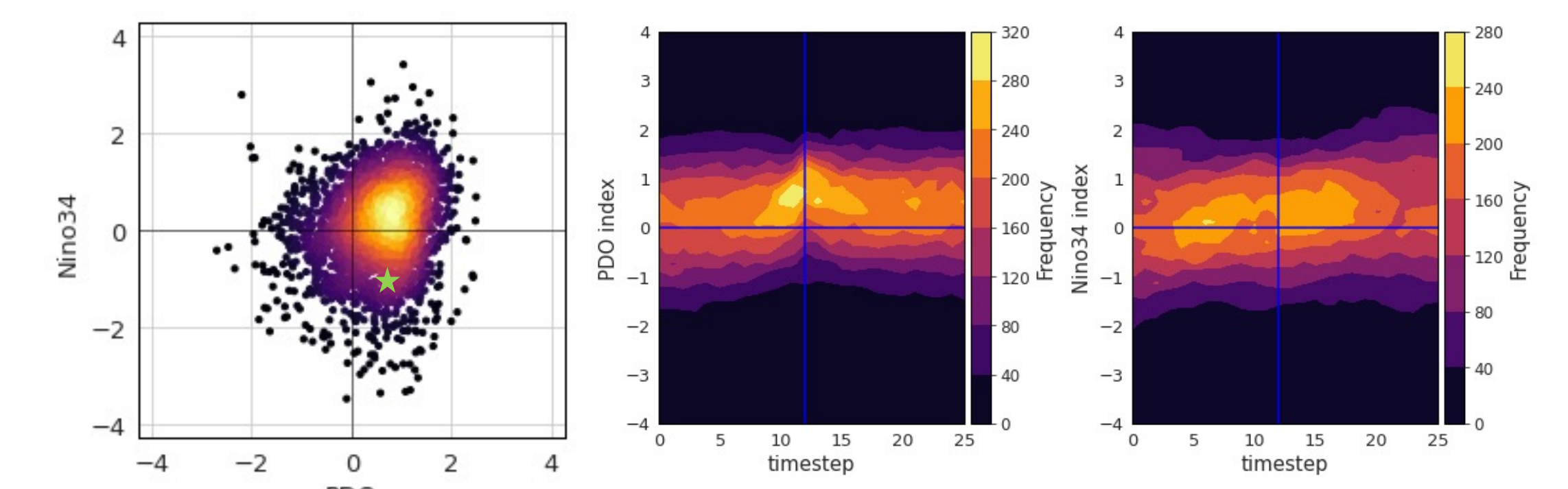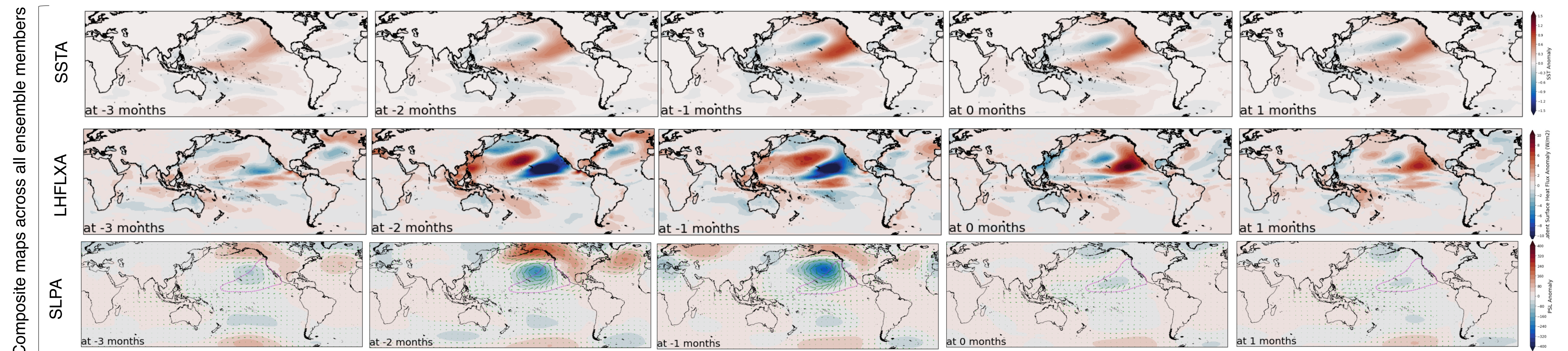

Star = (mean PDO over MHW lifetime, mean Nino34 over MHW lifetime) = (0.29, -0.61)

Aligned MHW to begin here

This MHW in particular — OISST SSTA

4. What do the Type 4 MHW atmospheric fields in CESM2 LE typically look like?

Composite maps across all ensemble members — SSTA / LHFLXA / SLPA

Additional analysis: Lead-lag correlation between the different fields and PDO and NINO34 indices for the region where the MHW is identified

5. TO DO: What do these fields look like in reanalysis data (i.e., ERA5)?

Next questions
- What is the mean state? What does upwelling look like (ocean dynamics)? (Could look at the wind stress curl)
- Identify drivers (remote and local) of each type of MHW