Object-Based Evaluation of Marine Heatwave Predictions in SMYLE

Earth Systems Prediction Working Group Meeting

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Jacob T. Cohen, LuAnne Thompson, and Cassia Cai
University of Washington

Anna-Lena Deppenmeier
National Center for Atmospheric Research

Elizabeth Maroon and Evan Meeker
University of Wisconsin

Marine heatwaves drive ecosystem disruptions with local impacts.

- Toxic algal blooms
- Fish and sea bird die-offs
- Negative consequences for fisheries and marine industries

Hindcast data: Seasonal-to-Multiyear Large Ensemble (SMYLE)

- Uses the Community Earth Systems Model (CESM2)

- Initial conditions: forced ocean – sea-ice (FOSI) model (1979-2020)

- **24-month forecasts** initialized quarterly with **20 ensemble members**

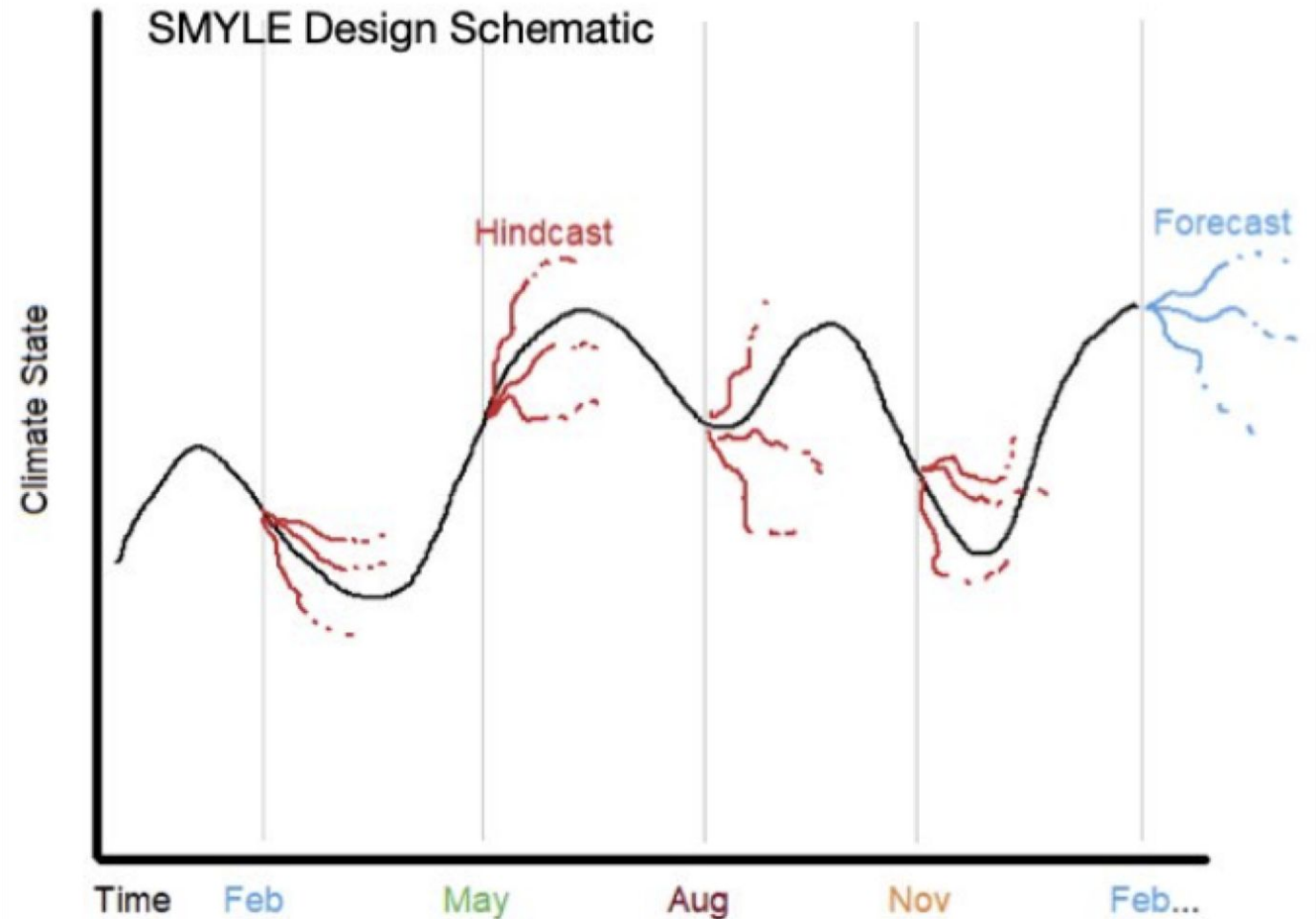- I compare SMYLE initializations from **1989-2018** to FOSI output from 1989-2020

Figure by Evan Meeker

# Object-based verification allows us to look at MHWs as spatially connected events.

- Previous studies examine MHW predictability on a grid cell basis

- Here, we examine MHW predictability on an event basis

SEDI: skill at each grid cell

Perfect Skill

Symmetric Extremal Dependence Index
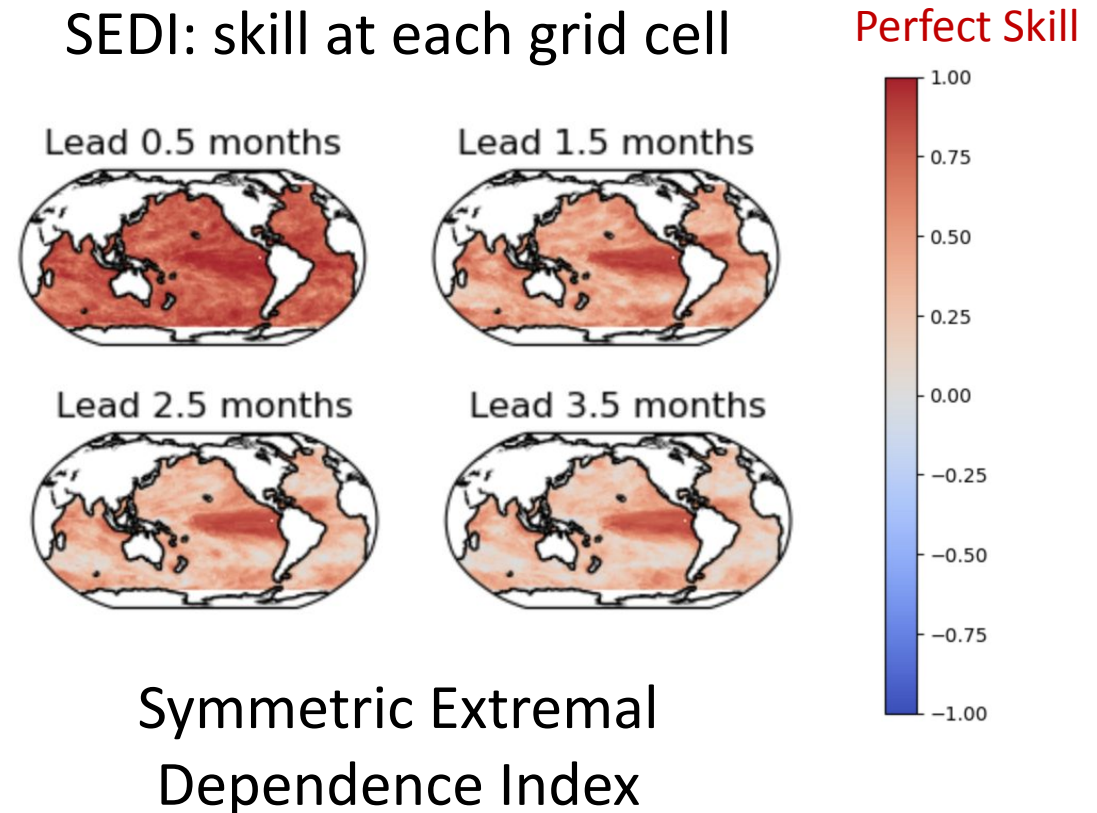
We define monthly MHWs separately in the FOSI and SMYLE datasets.

Monthly definition

- Above 90th percentile climatological threshold

- Duration of at least one month

- In SMYLE, the climatology and threshold are defined by lead time and season

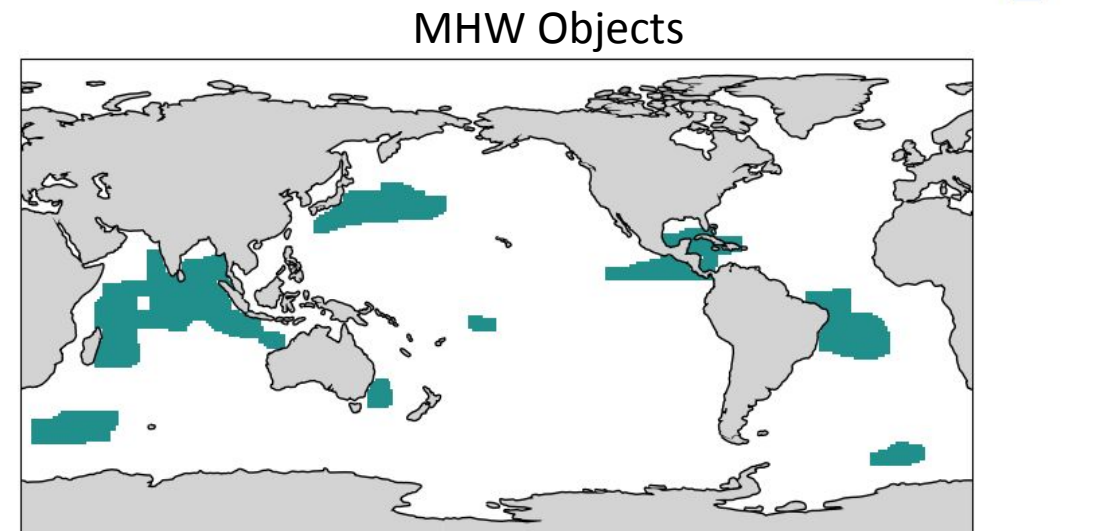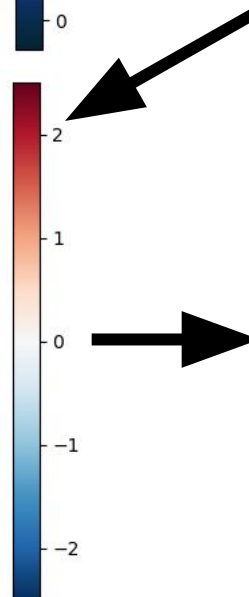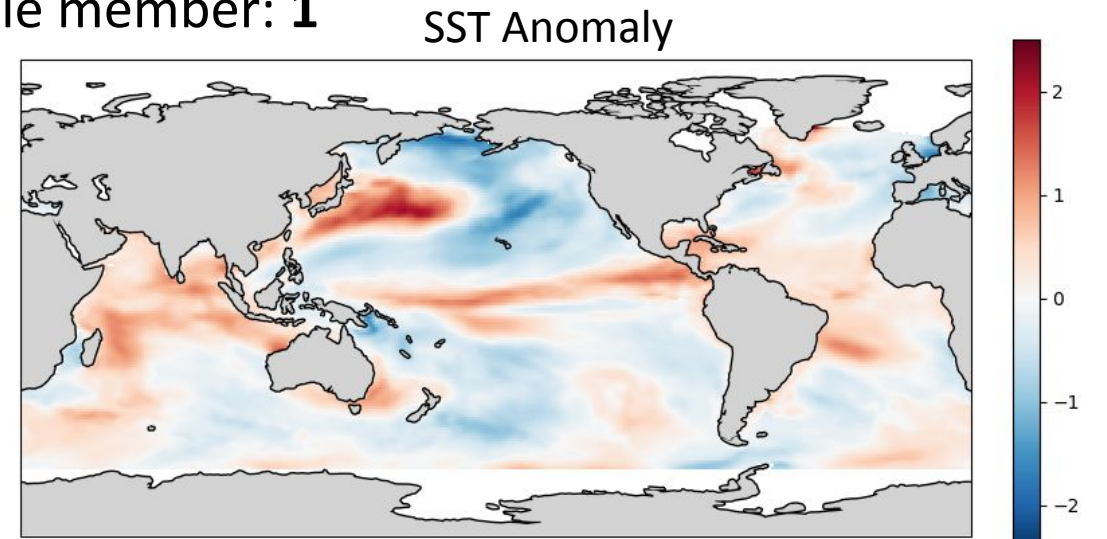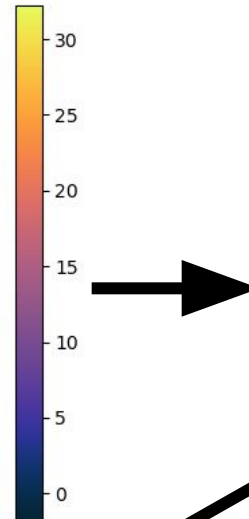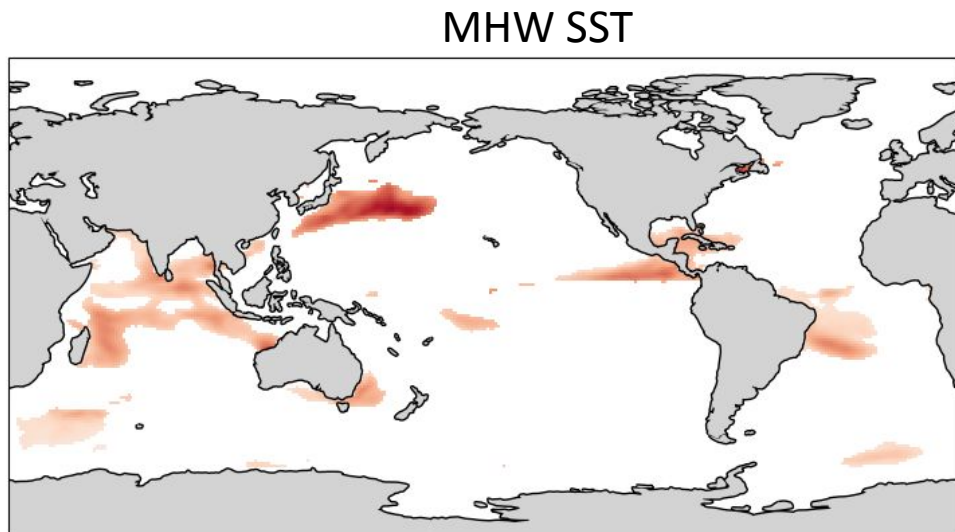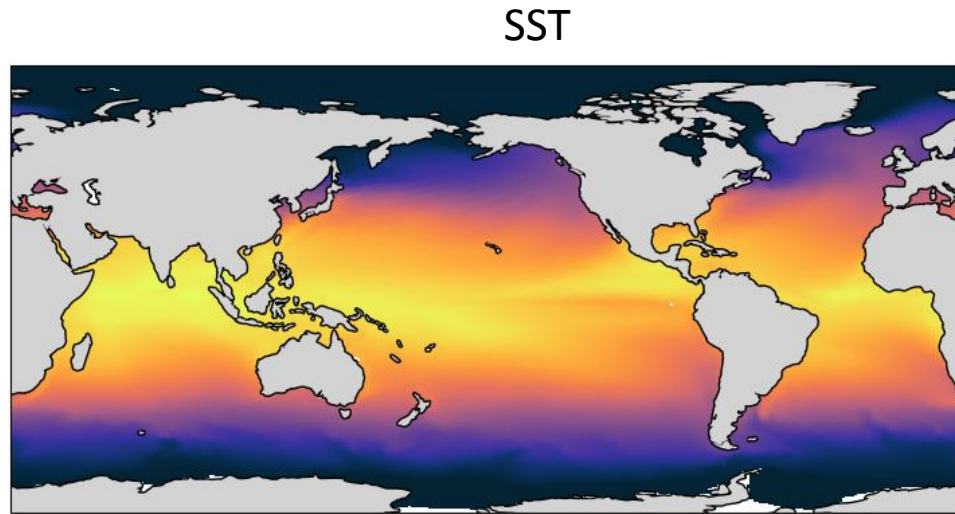- See Jacox et al. 2022
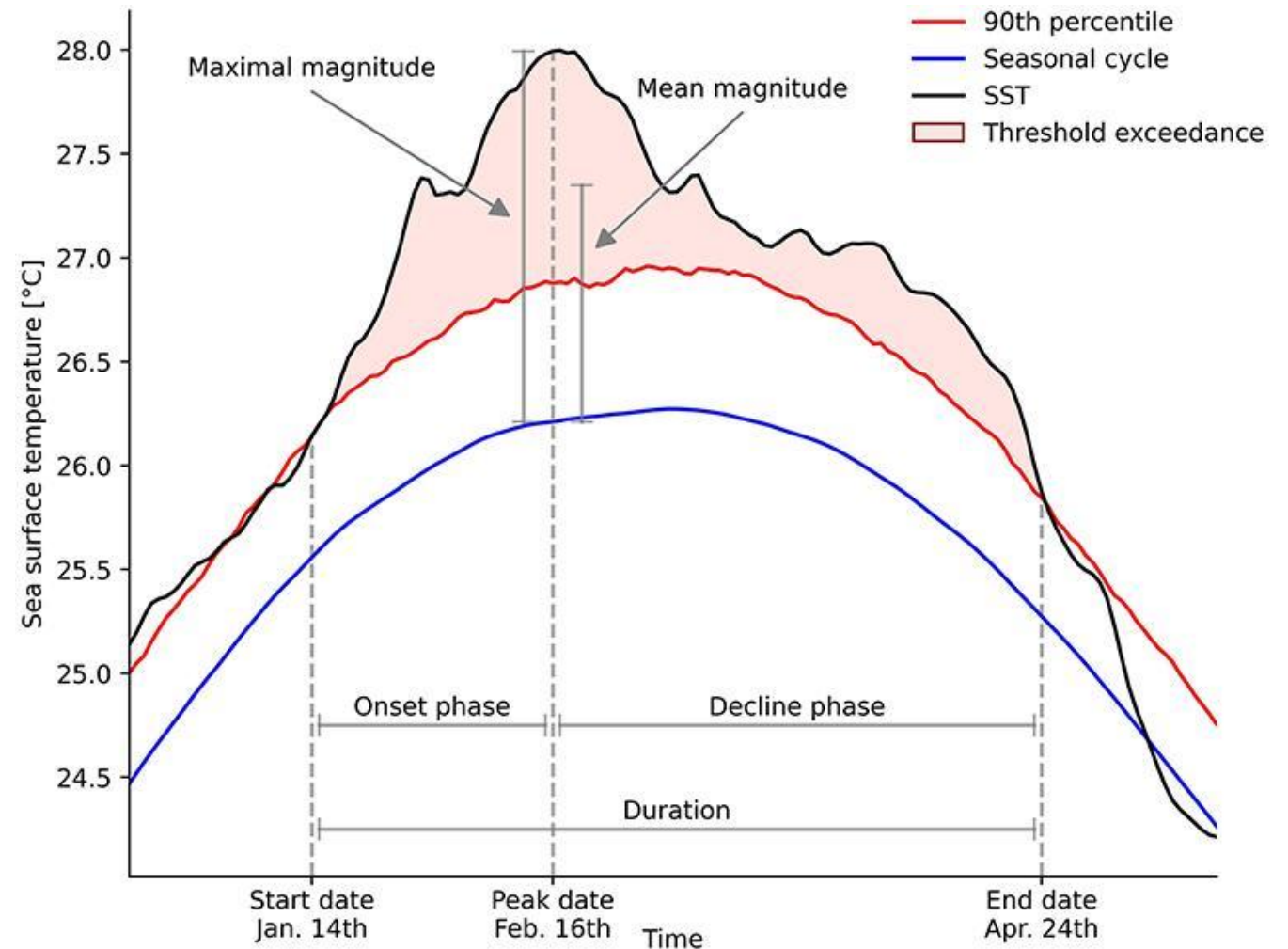
Vogt et al. (2022)

Example snapshot:

Forecast initialization: **2010-02-01**

Forecast valid time: **2010-05-15**
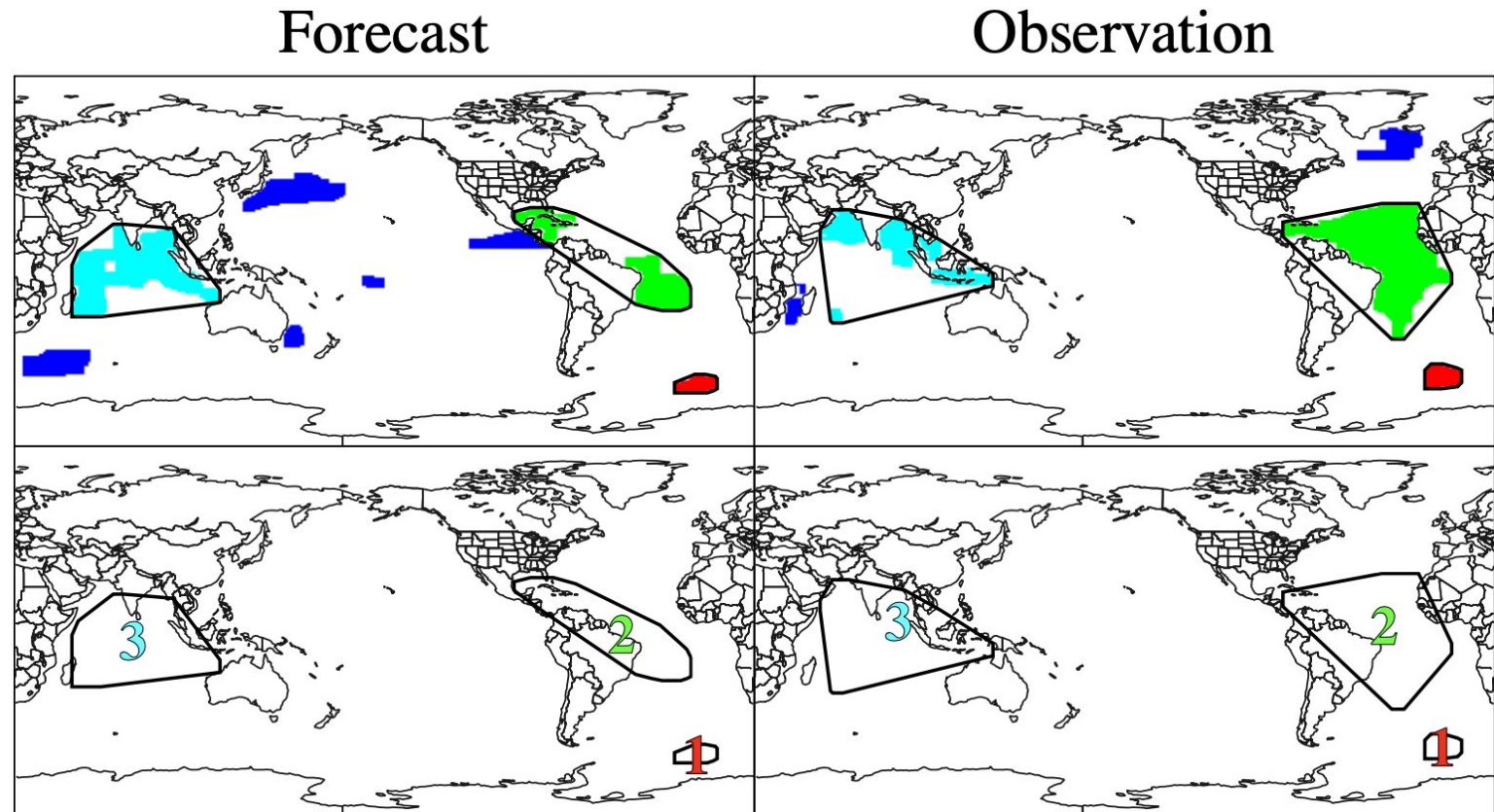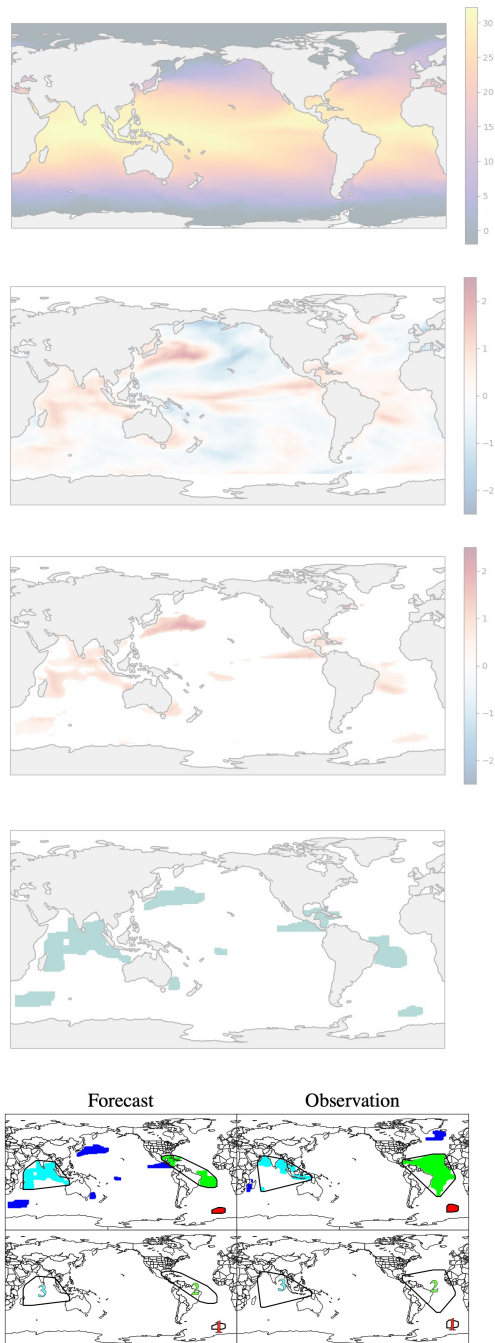
Lead: **3.5 months**

Ensemble member: **1**

Method for Object-based Diagnostic Evaluation (MODE)

Individual ensemble member MHWs
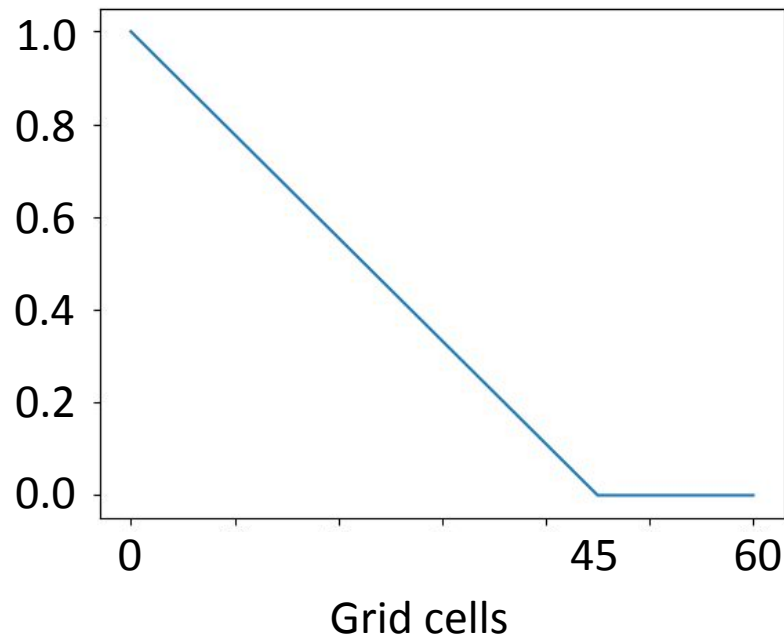

Forecast

Observation

MODE: object-based forecast verification package that matches objects between the forecast and observation fields
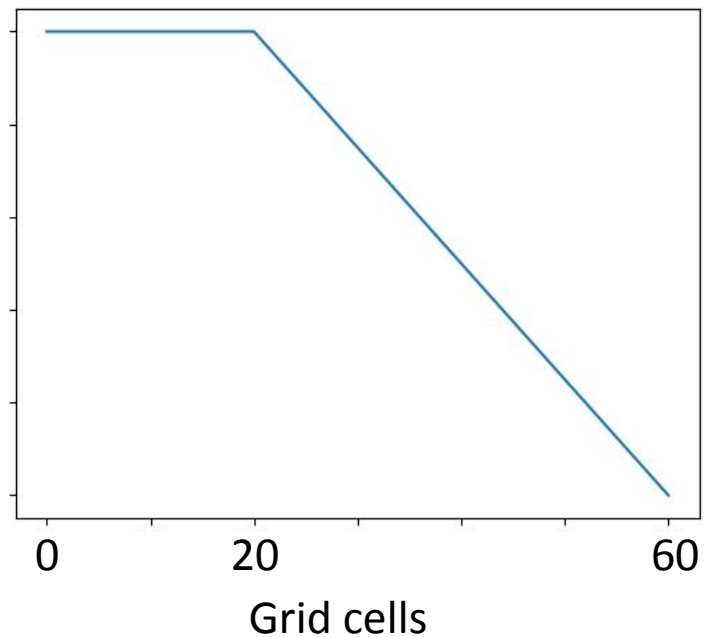
MODE calculates an interest score for each pair of forecast/observed objects.

$$\text{Interest} = \begin{array}{l} 0.2\times(\text{centroid distance}) + \\ 0.2\times(\text{convex hull distance}) + \\ 0.2\times(\text{intersection area ratio}) + \\ 0.4\times(\text{boundary distance}) \end{array}$$
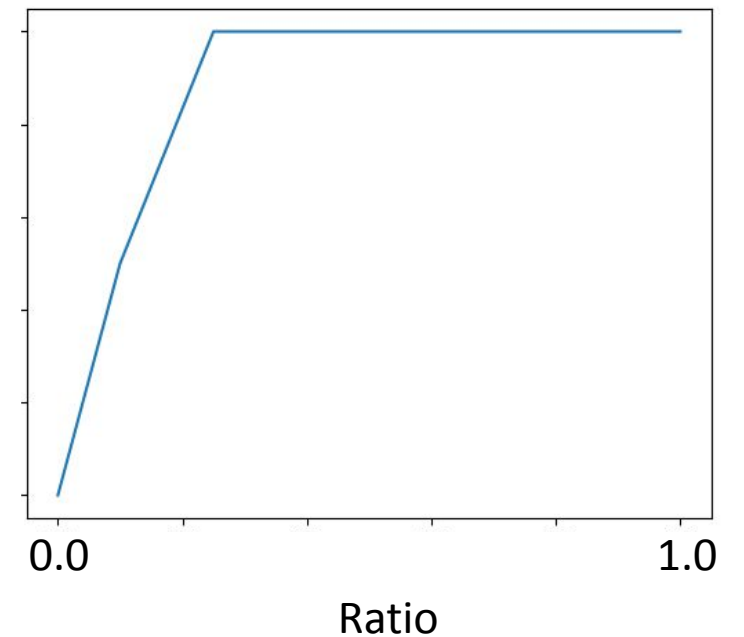
Method for Object-based Diagnostic Evaluation (MODE)

Individual ensemble member MHWs

Forecast   Observation
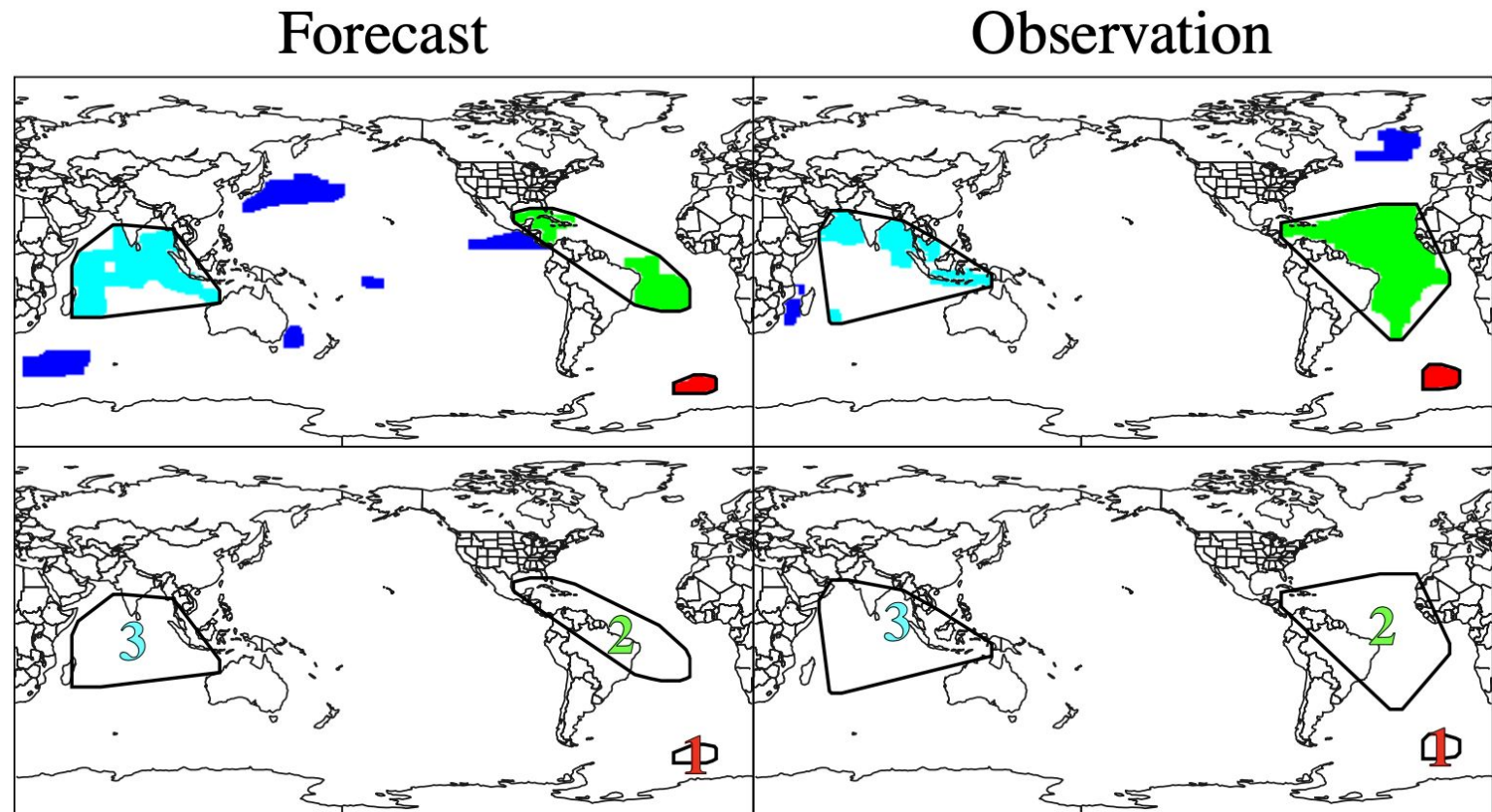
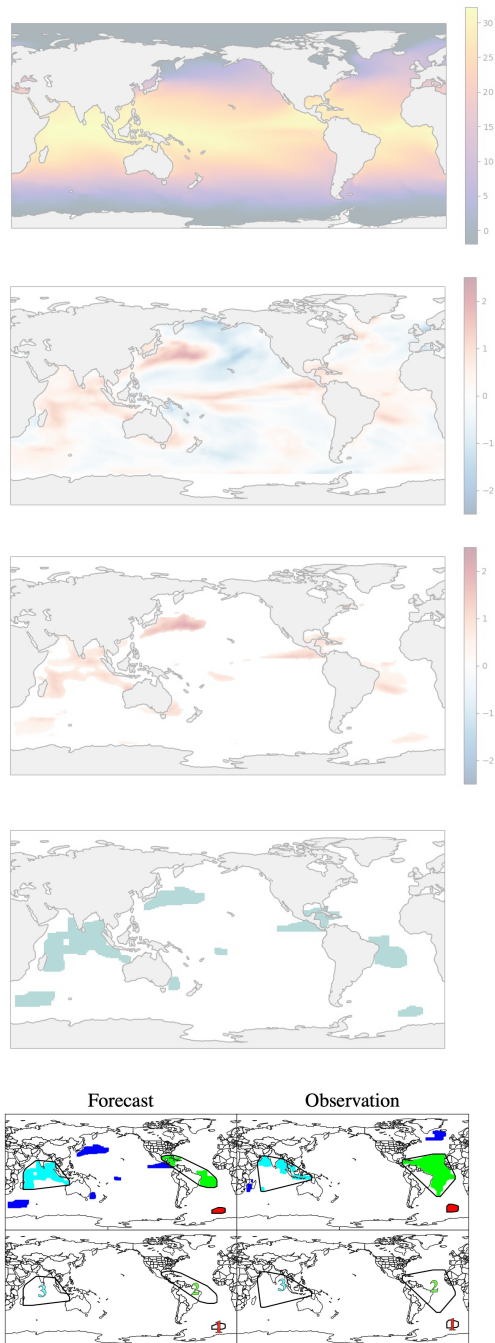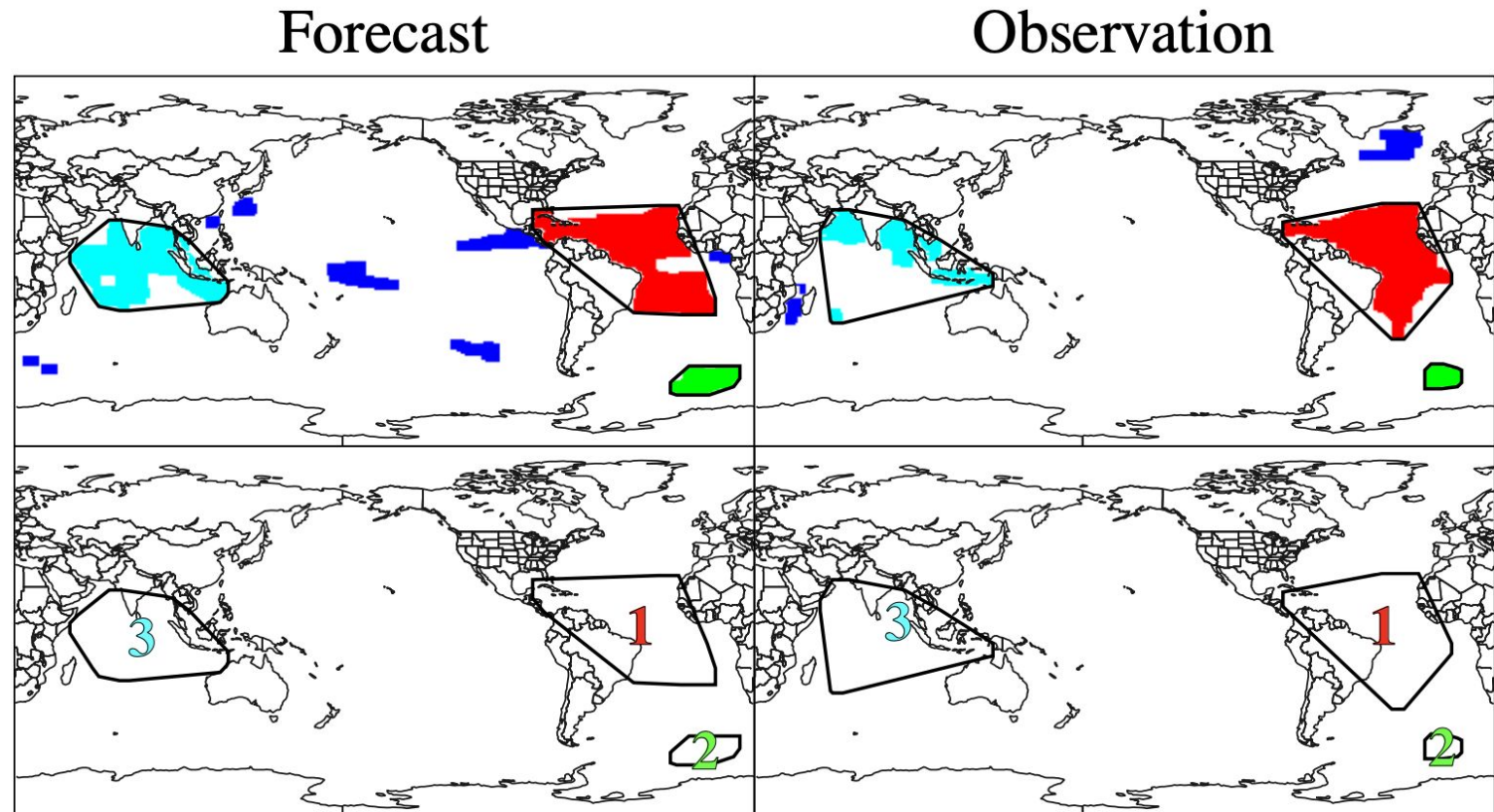*MODE: object-based forecast verification package that matches objects between the forecast and observation fields*

Method for Object-based Diagnostic Evaluation (MODE)

Probable MHWs (>=30% agreement)

Forecast

Observation
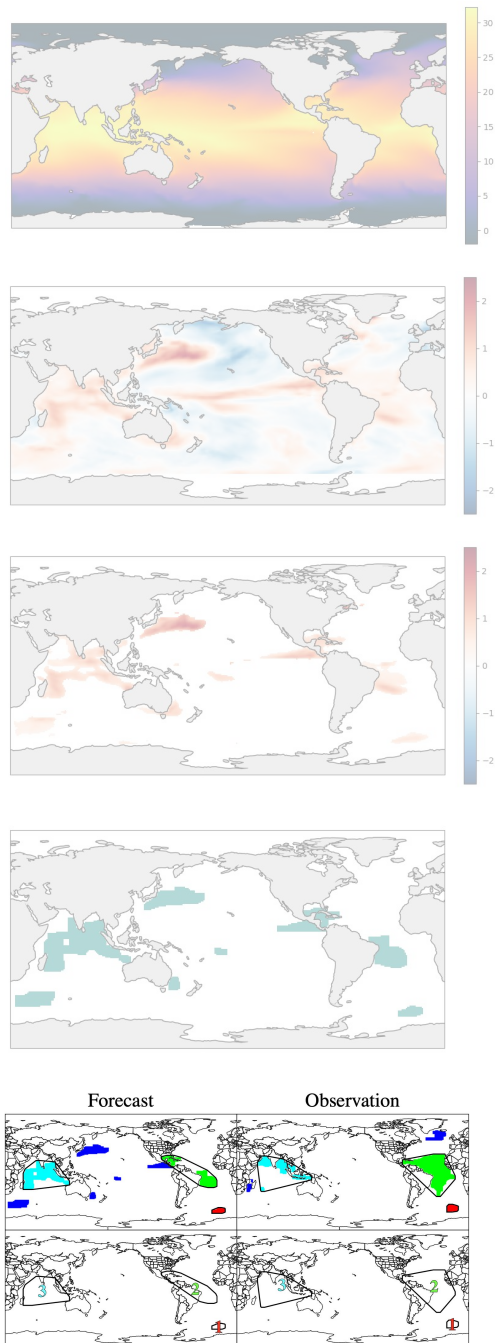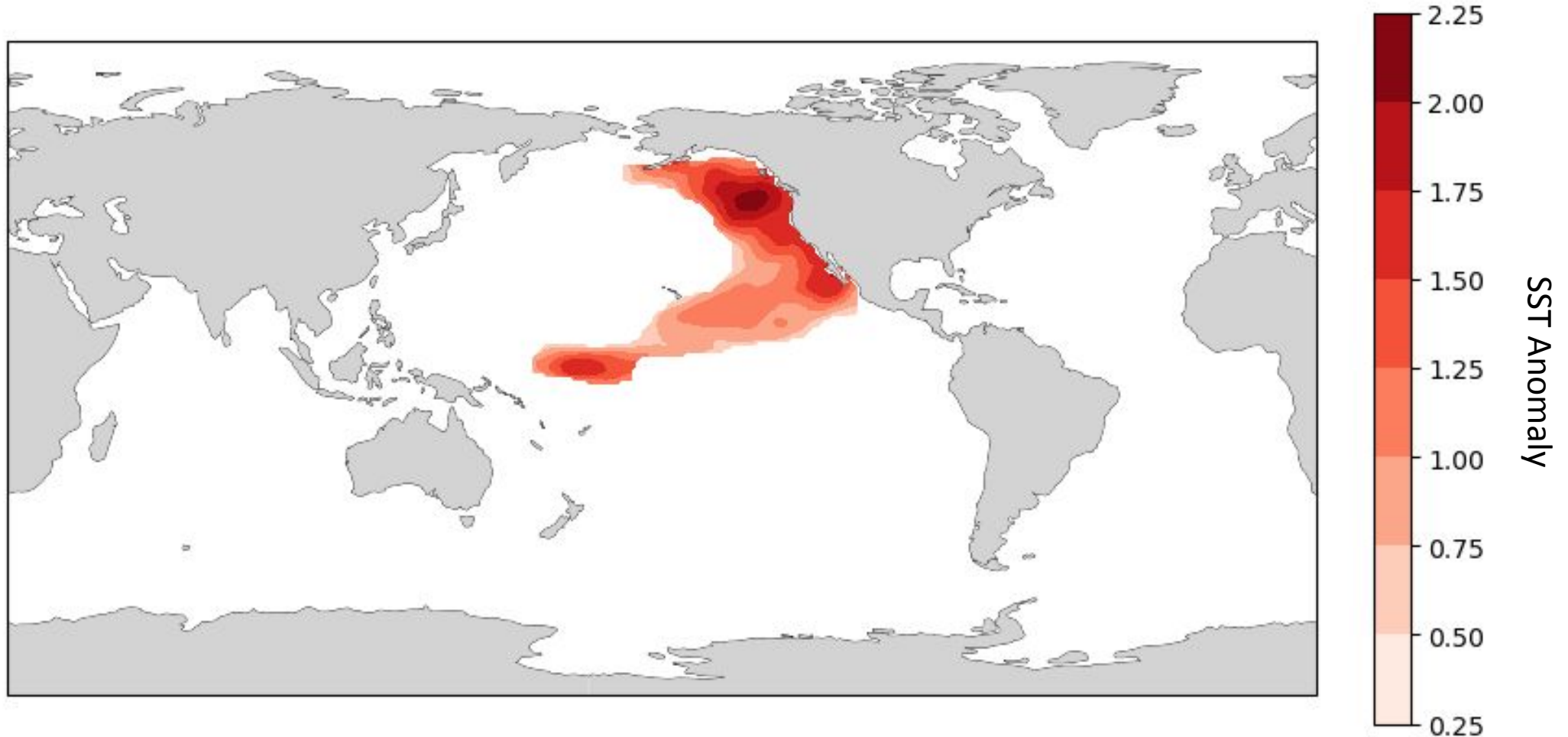
MODE: object-based forecast verification package that matches objects between the forecast and observation fields

Questions we can answer:

- How well did we predict a specific heatwave?

- How accurate are MHW hindcasts?

- What are the uncertainties in MHW forecasts?

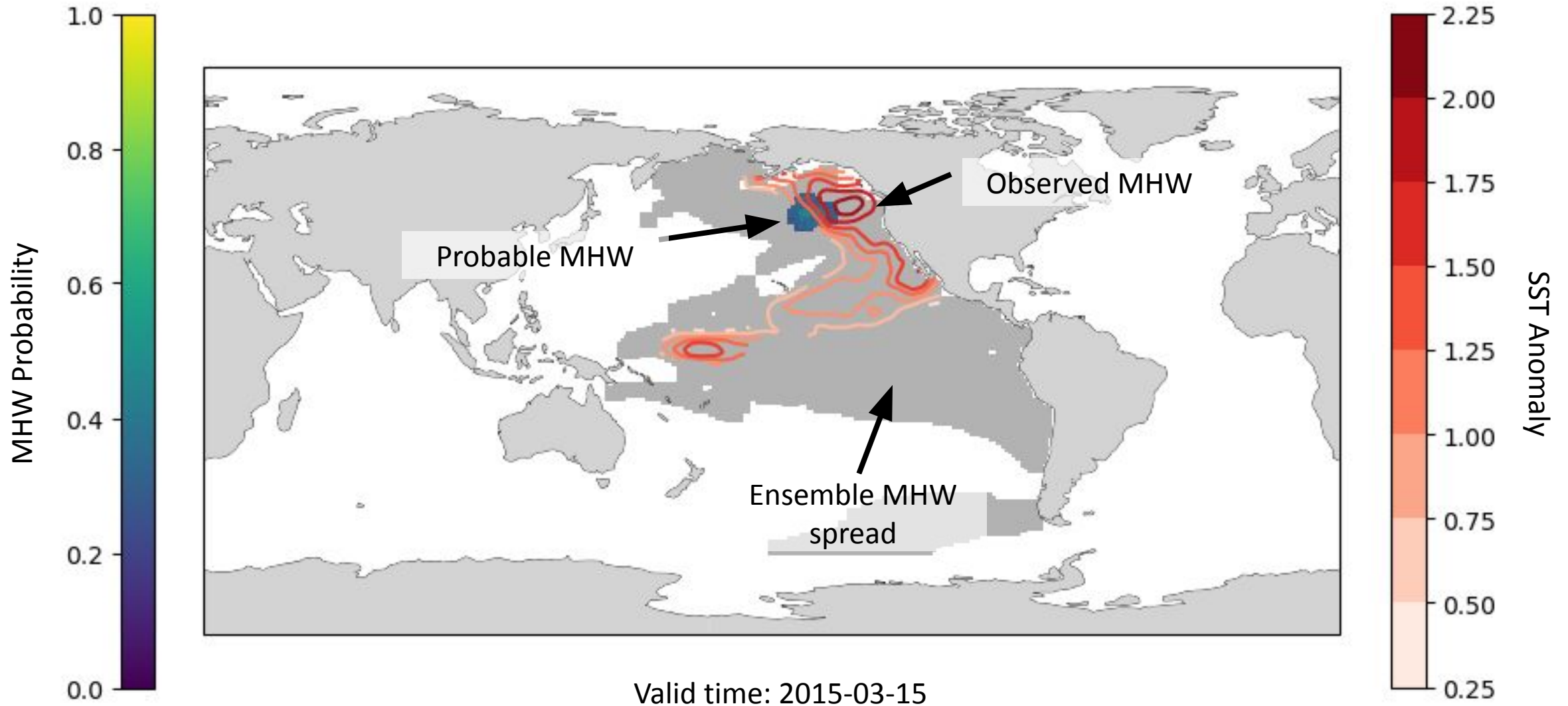# 1. How well did we predict a specific heatwave?

Example: Predicting the peak of the Blob
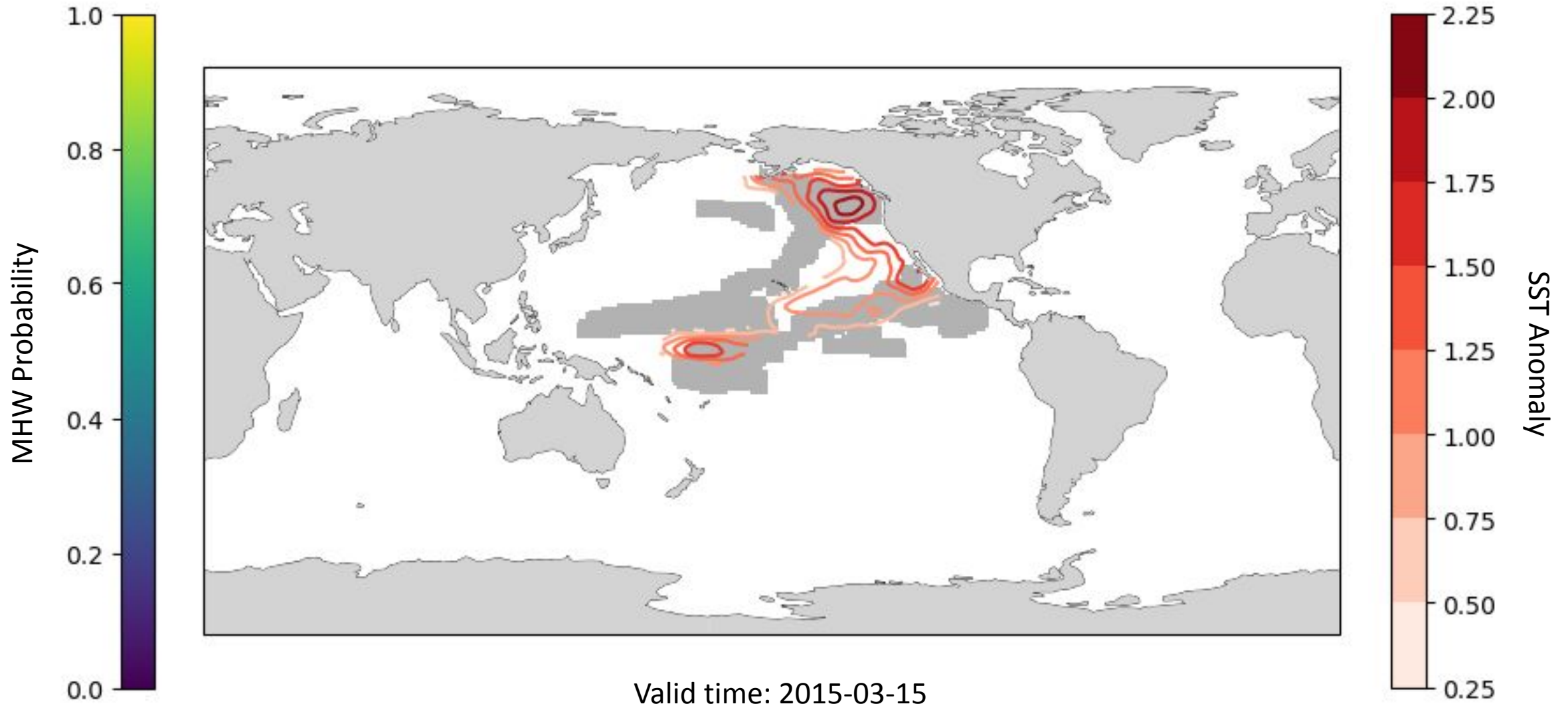

Valid time: 2015-03-15

Forecast initialization: 2013-05-01
Lead: 22.5 months
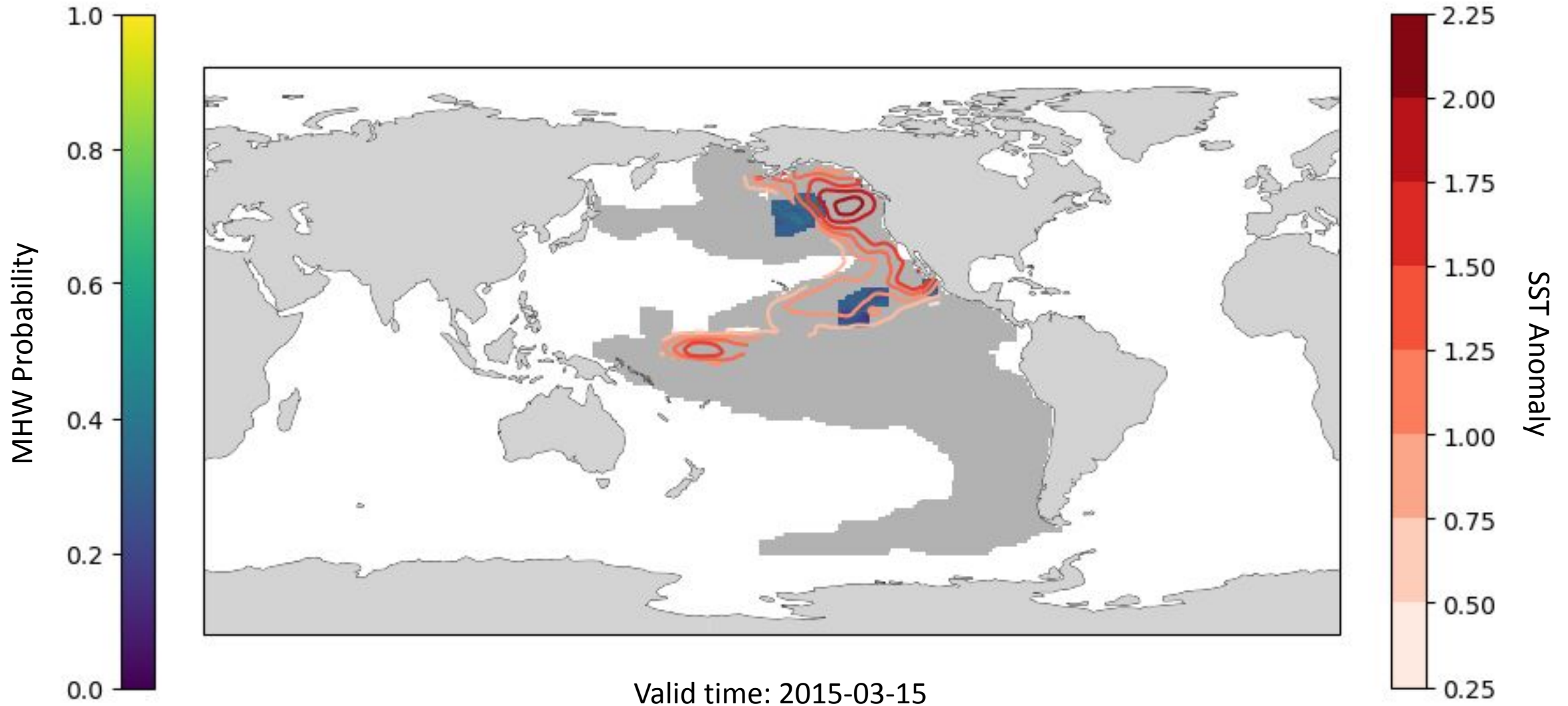
MHW Probability

SST Anomaly

Observed MHW

Probable MHW

Ensemble MHW spread

Valid time: 2015-03-15

Forecast initialization: 2013-08-01
Lead: 19.5 months

Valid time: 2015-03-15

Forecast initialization: 2013-11-01
Lead: 16.5 months

Valid time: 2015-03-15

Forecast initialization: 2014-02-01
Lead: 13.5 months

Valid time: 2015-03-15
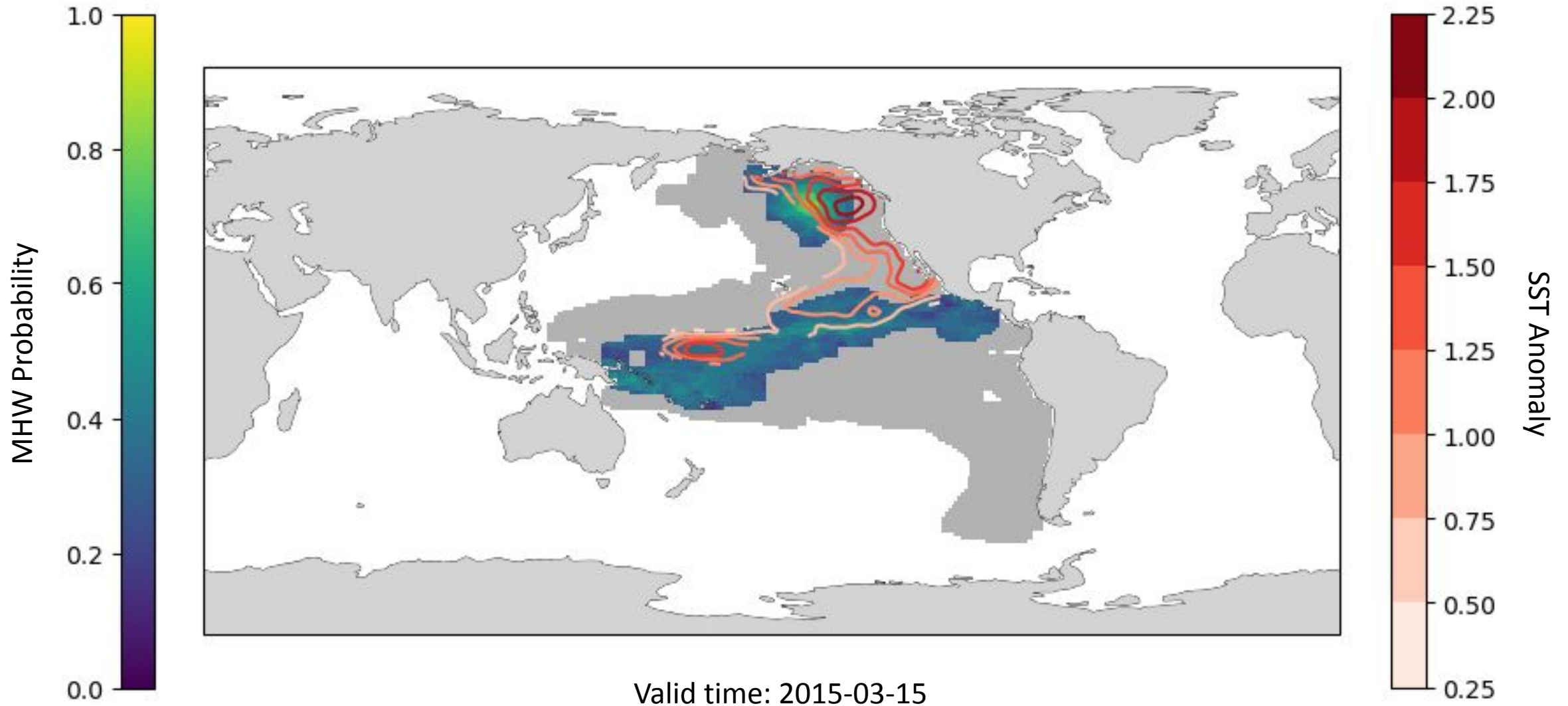
Forecast initialization: 2014-05-01
Lead: 10.5 months

Valid time: 2015-03-15
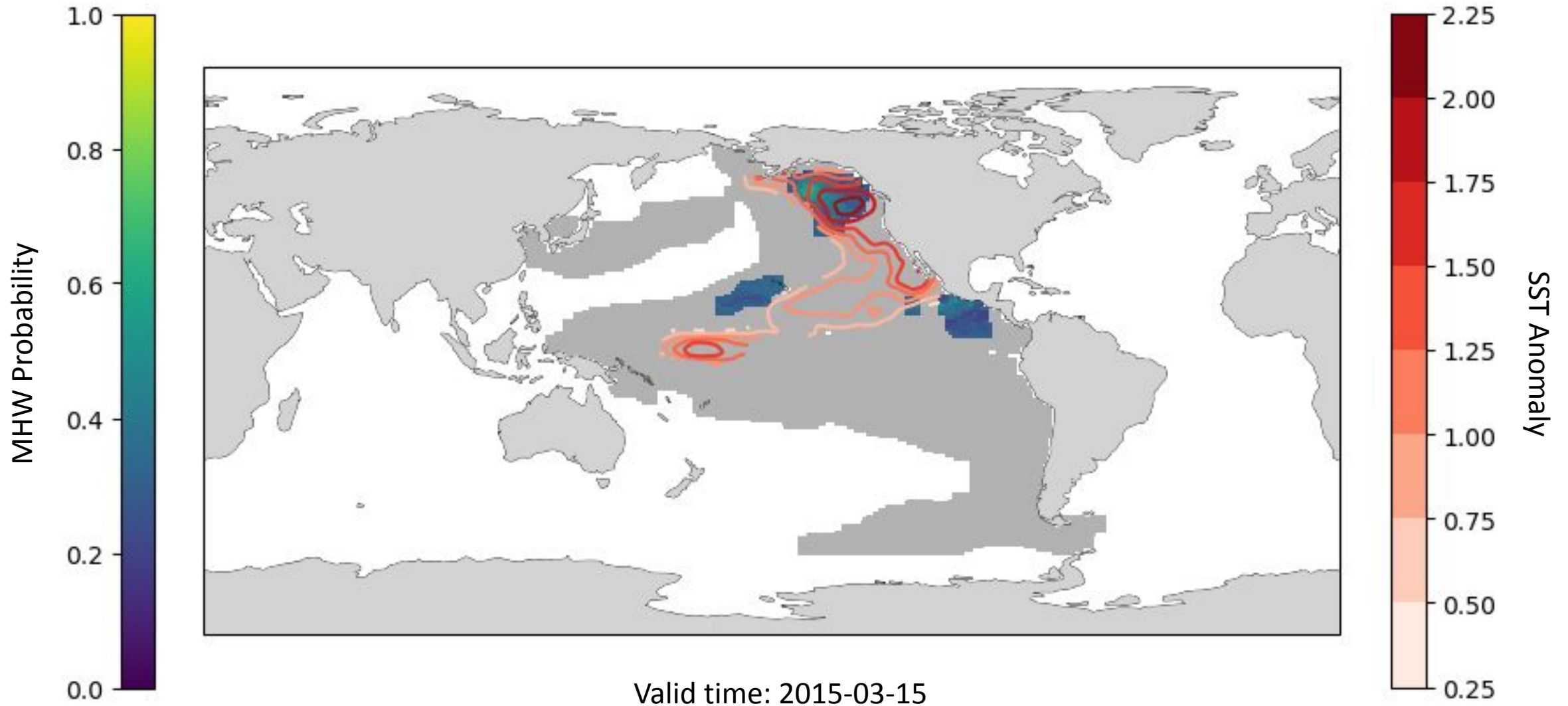
Forecast initialization: 2014-08-01
Lead: 7.5 months

Valid time: 2015-03-15
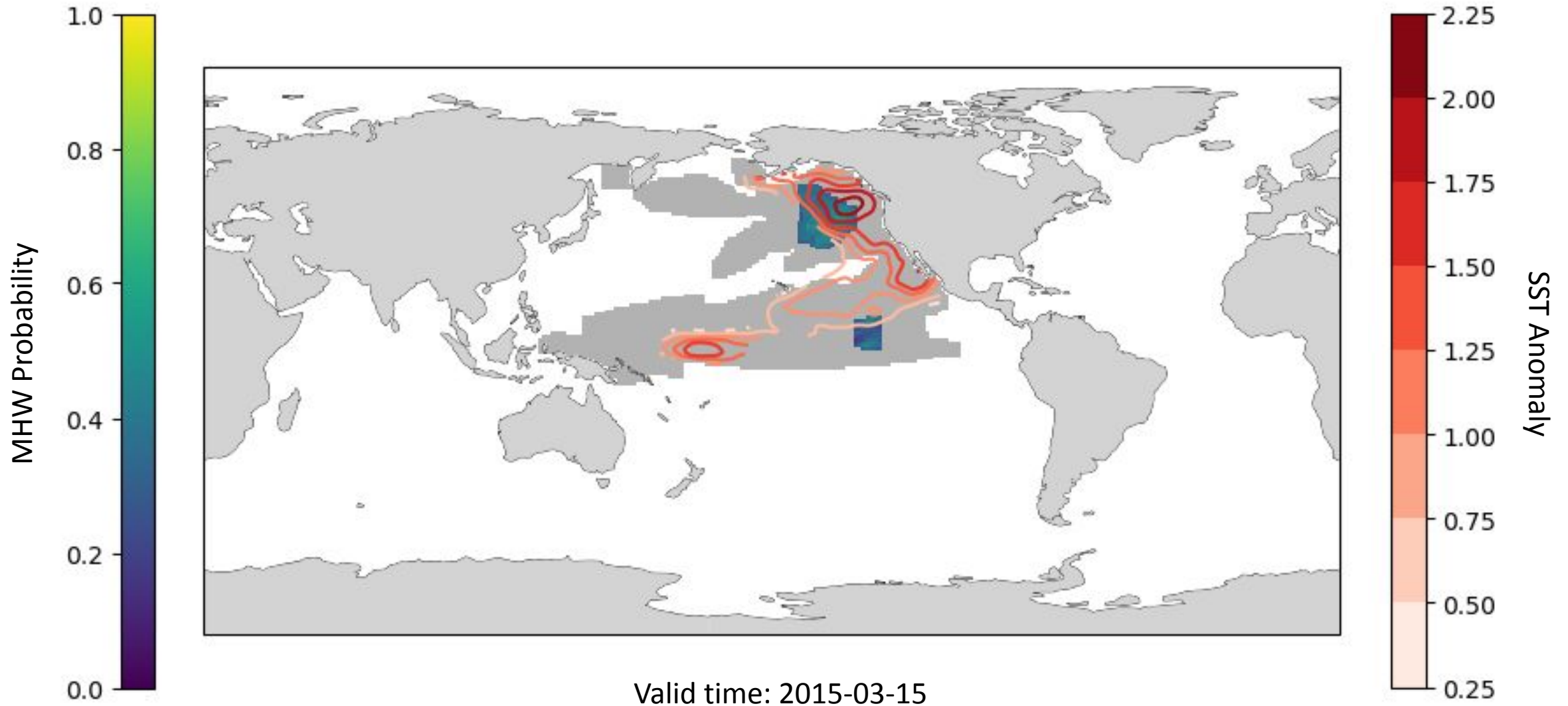
Forecast initialization: 2014-11-01
Lead: 4.5 months

Valid time: 2015-03-15
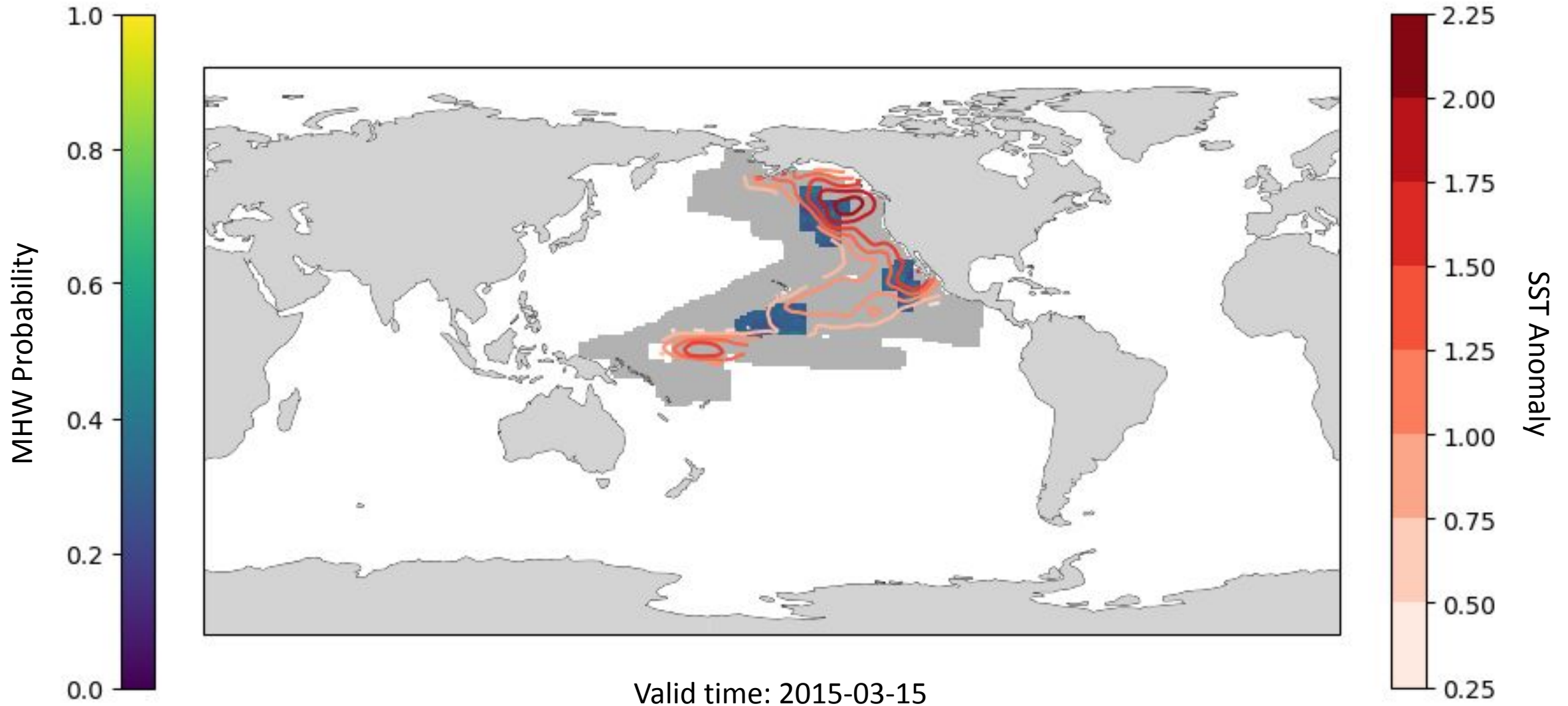
Forecast initialization: 2015-02-01
Lead: 1.5 months

Valid time: 2015-03-15
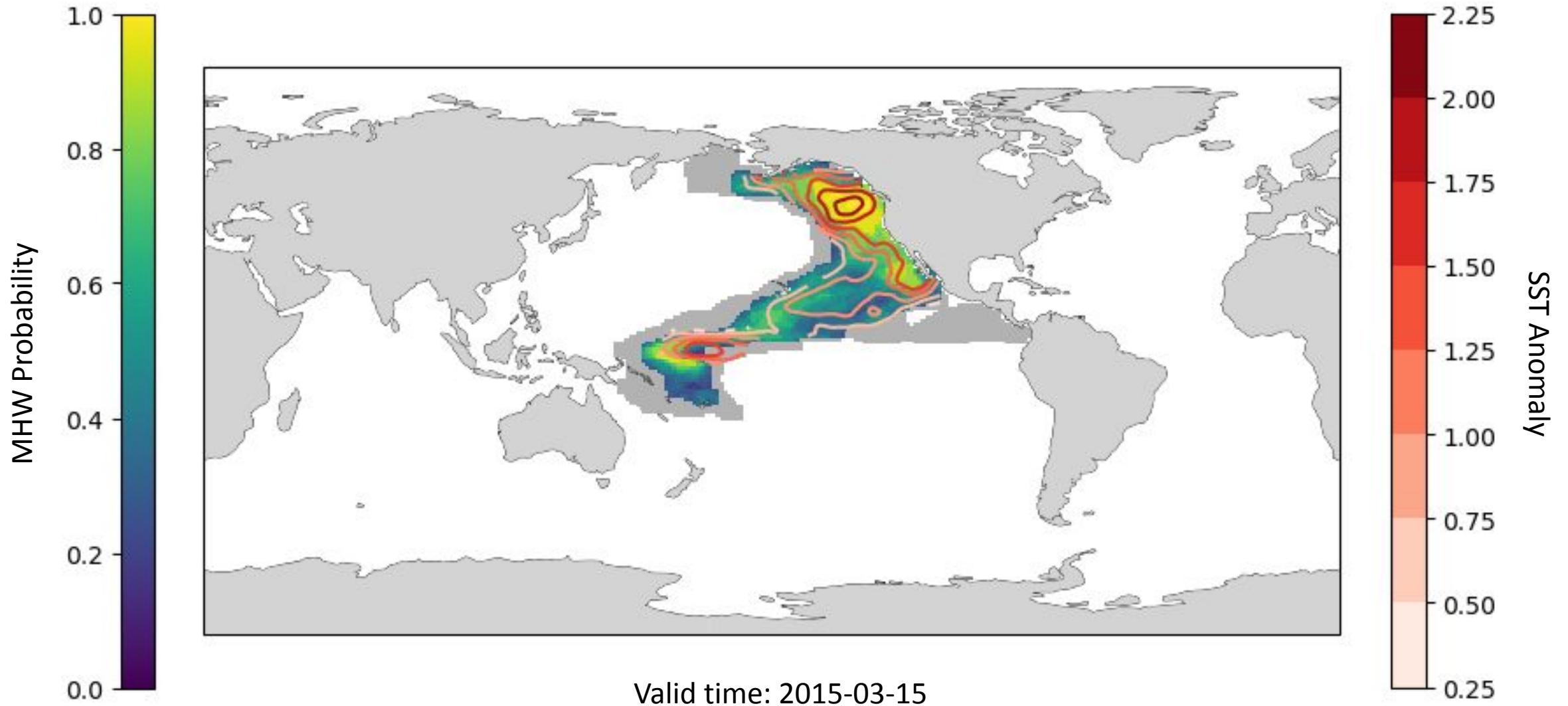
Forecasts of the Blob improved as they were initialized closer to the event.

Center of Mass Distance

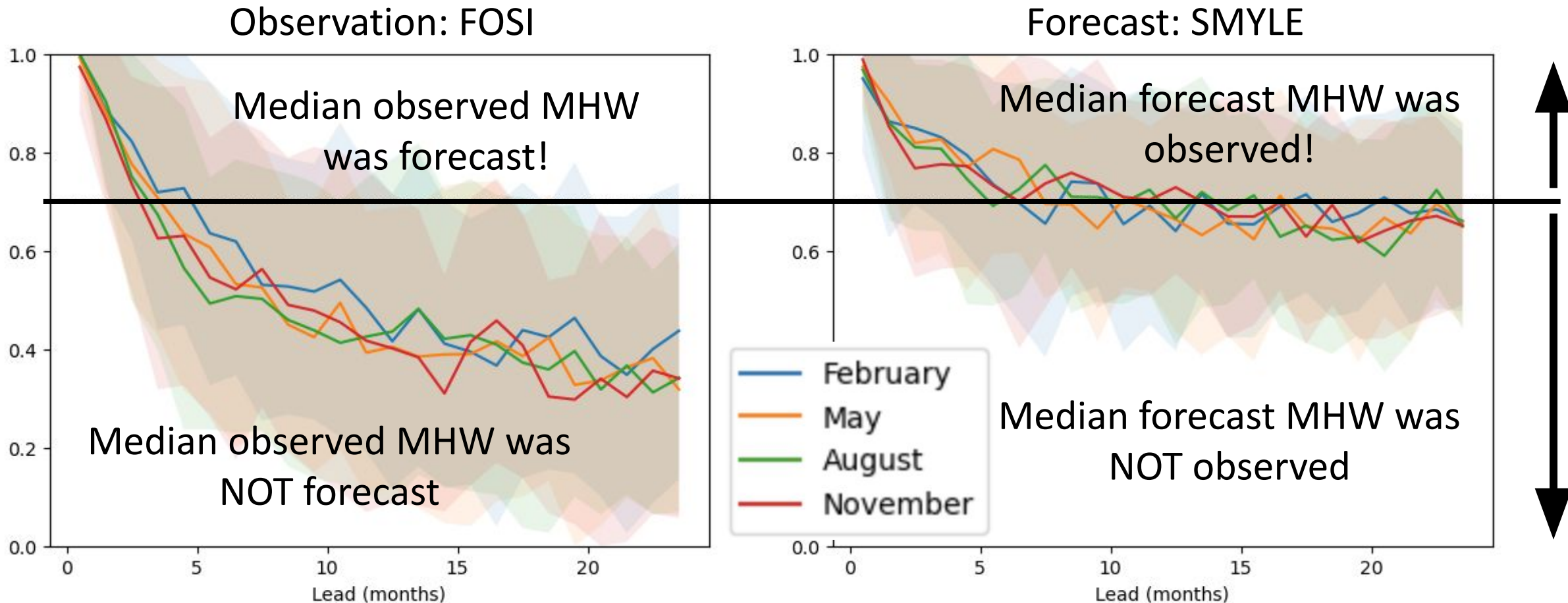Probable forecast MHW centers of mass
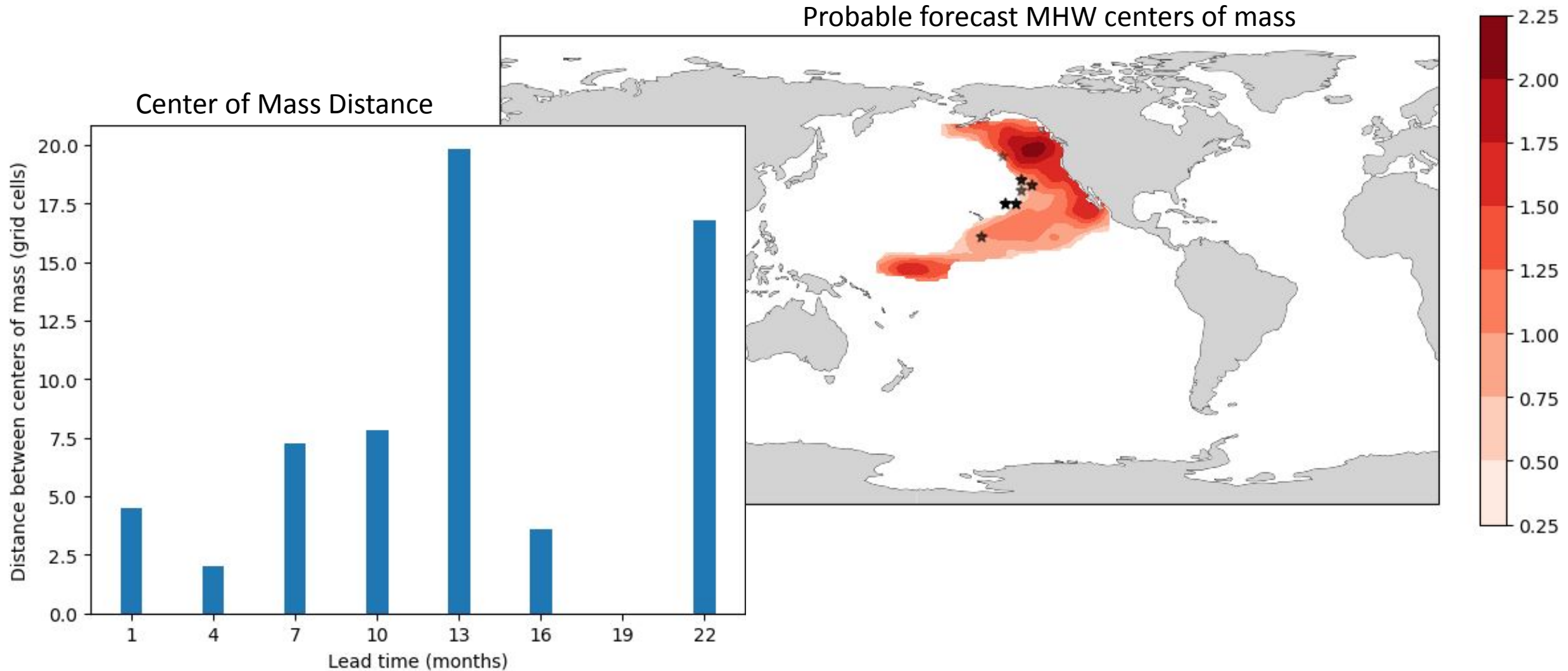
Most observed MHWs are not forecast in SMYLE…

Maximum of Median Interest (MMI)

Observation: FOSI
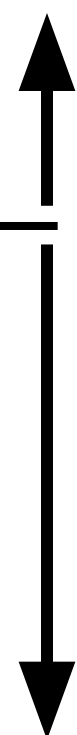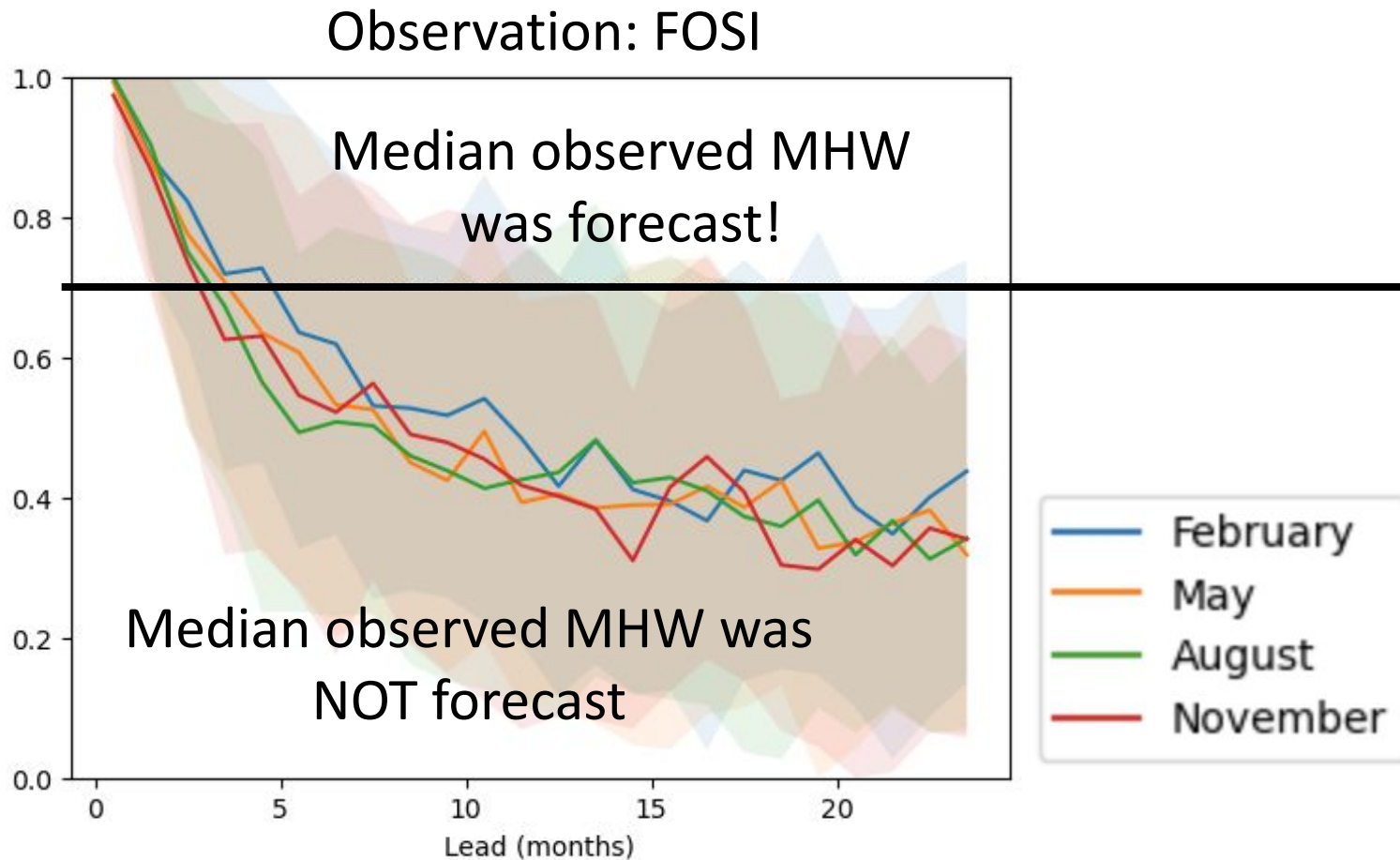
BUT forecast MHWs are usually observed!

Maximum of Median Interest (MMI)

Observation: FOSI

Forecast: SMYLE

Median observed MHW was forecast!

Median forecast MHW was observed!

Median observed MHW was NOT forecast

Median forecast MHW was NOT observed

Legend:
- February
- May
- August
- November

Lead (months)

Most of the forecast MHW area is observed over long lead times.
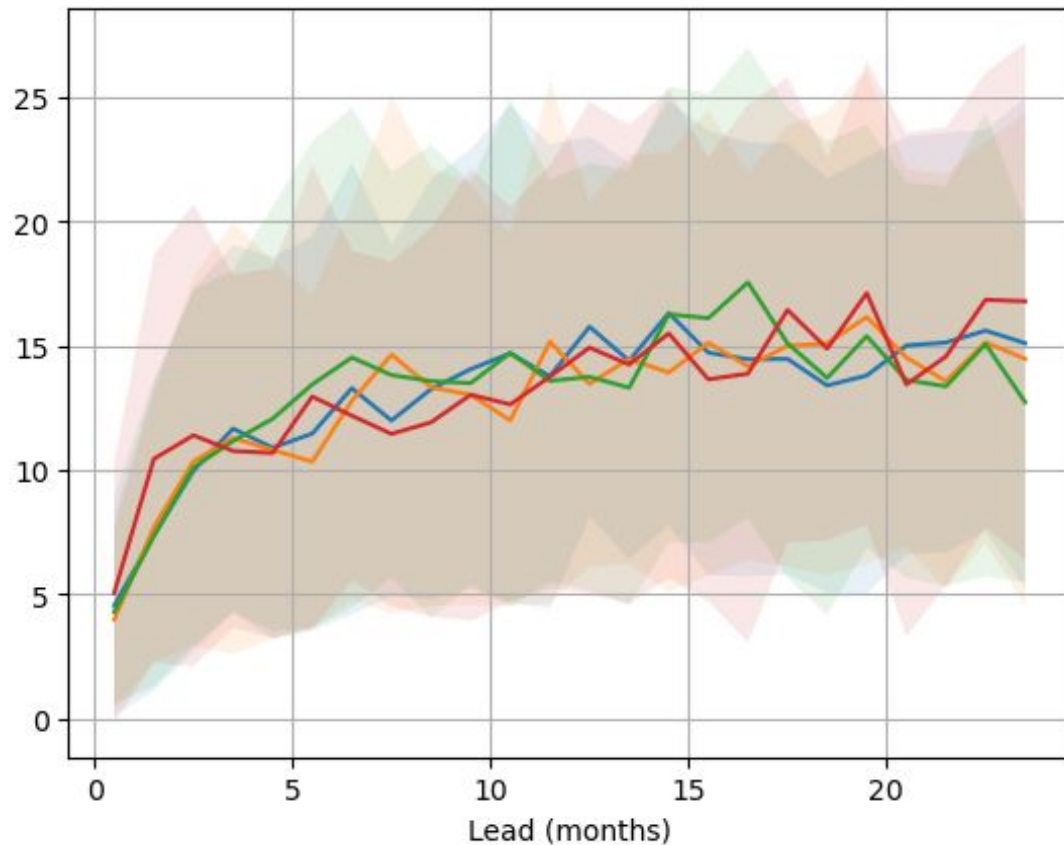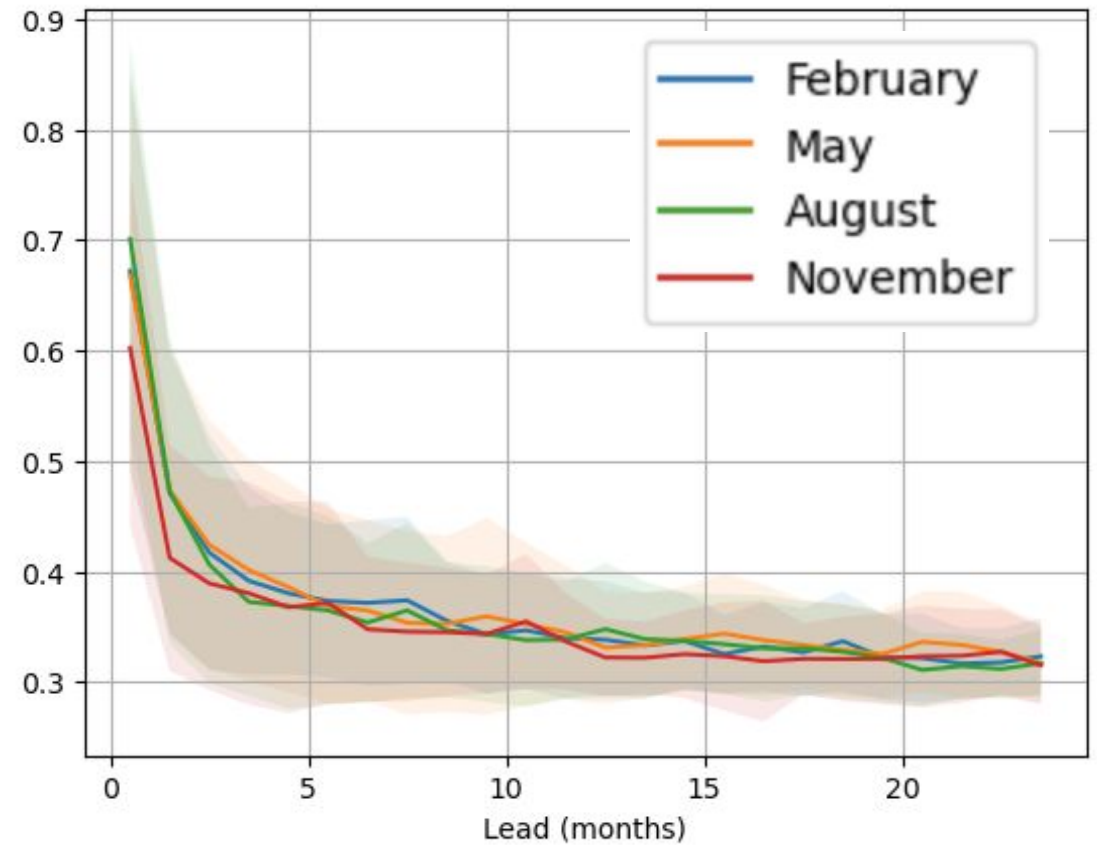
Percentage of matched MHW area
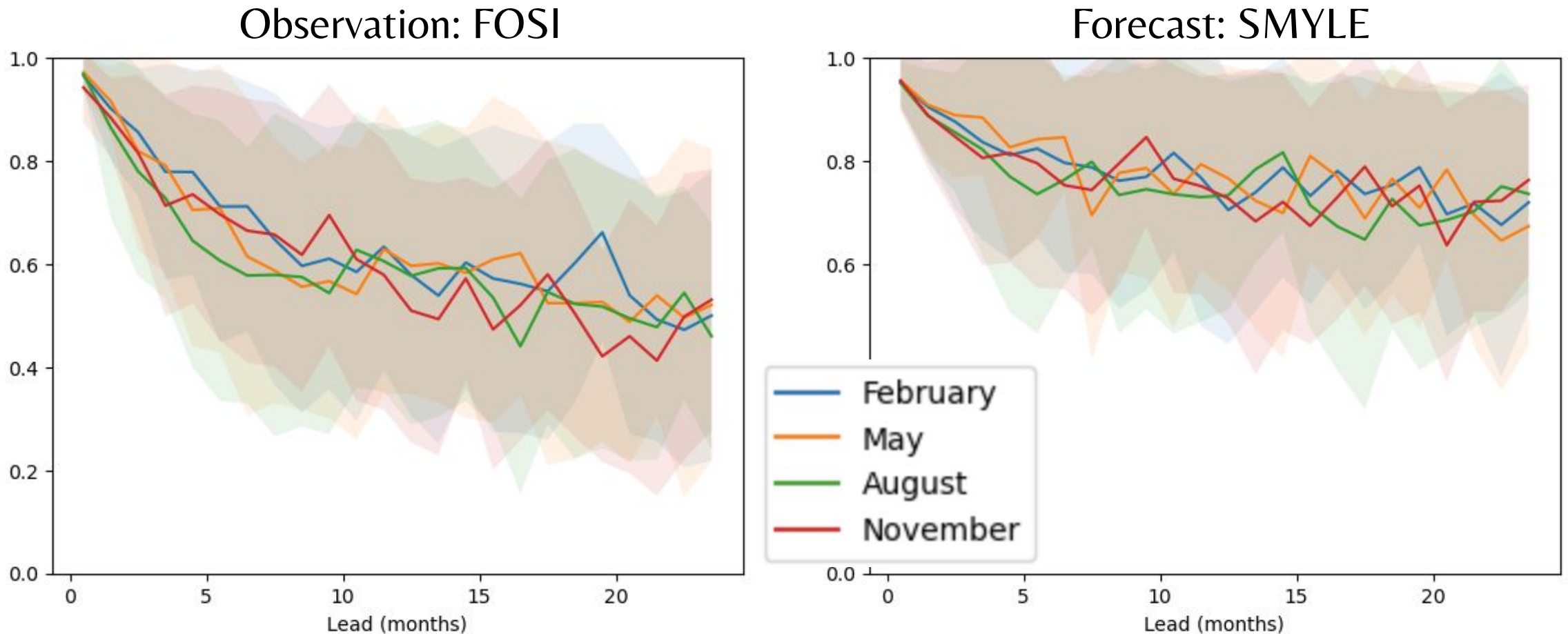
Matched object statistics demonstrate decreasing predictive skill at longer lead times.

Statistics for matched MHW clusters

Centroid Distance

Median Forecast MHW Probability

Predicting MHWs as objects not points

Takeaways:

1. Object-based verification allows us to examine the predictability of individual MHW events and to understand the accuracy of MHW predictions.

2. Predictability of the Blob's peak improved with lower lead times.

3. SMYLE correctly forecasts probable MHWs at long lead times.
   - Misses many observed MHWs
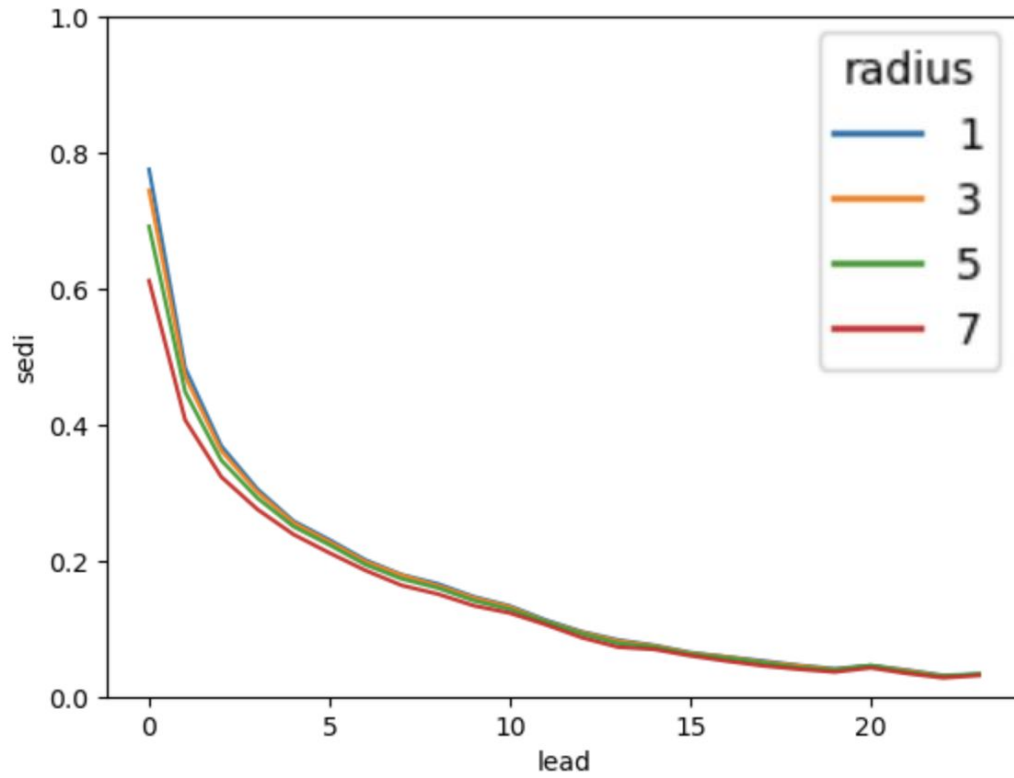   - Regional analysis will resolve where longer-term skill remains
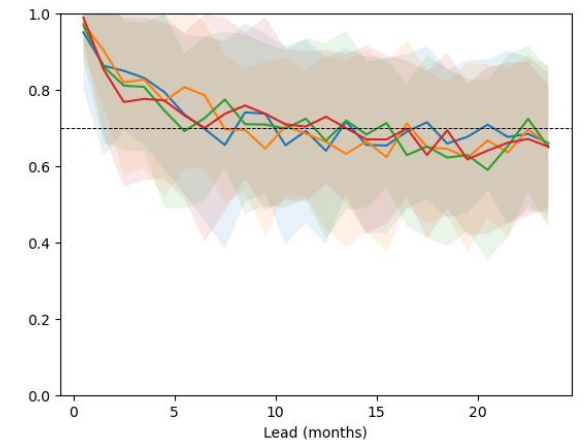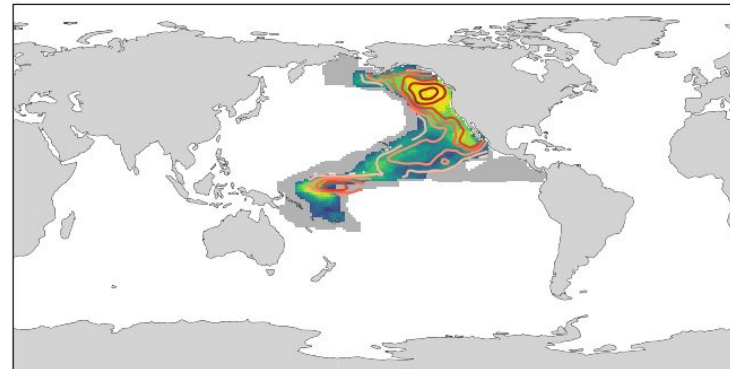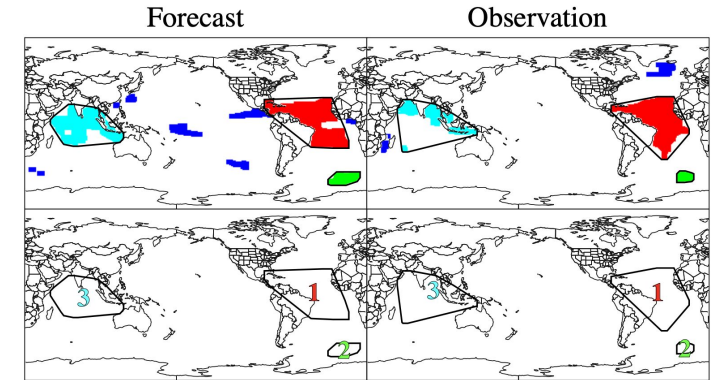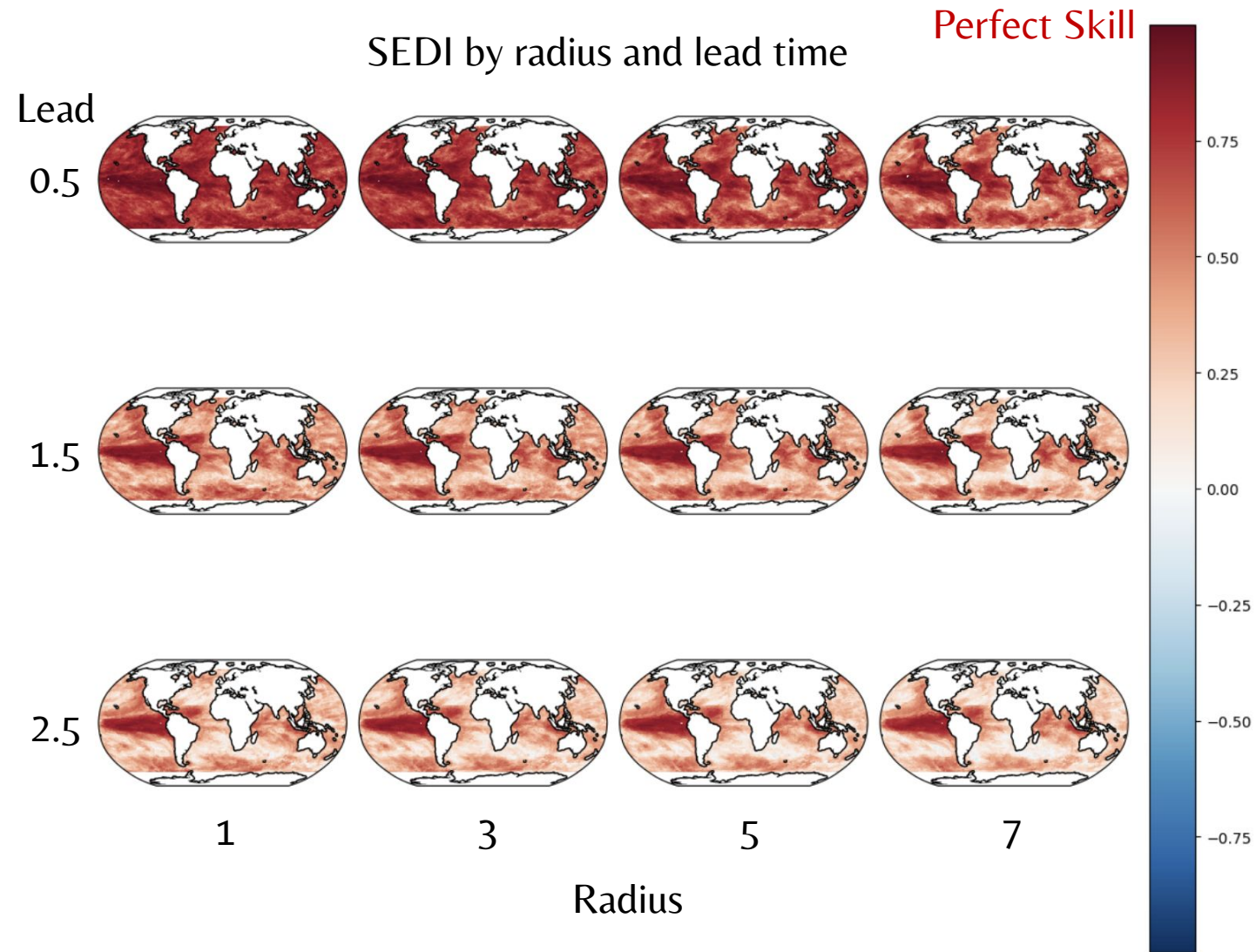
Twitter: @cohenjt
Email: jtcohen@uw.edu

Object-based definitions do not degrade pointwise skill.

Globally averaged SEDI score

SEDI by radius and lead time

Perfect Skill

Lead

0.5

1.5

2.5

Radius

Symmetric Extremal Dependence Index (SEDI) demonstrates predictive skill.