Subsurface Temperature Anomalies off Central Oregon During 2014-2021

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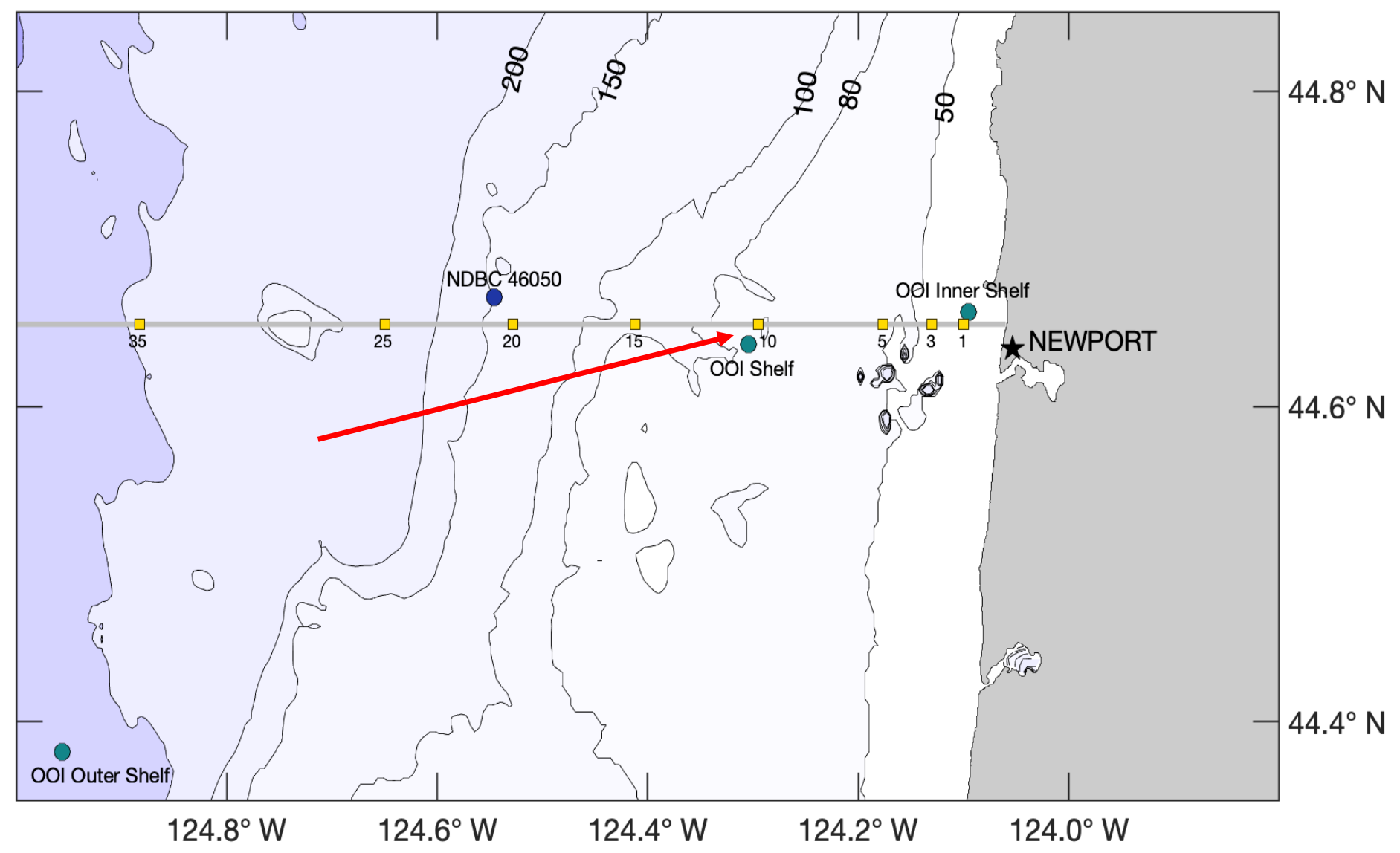
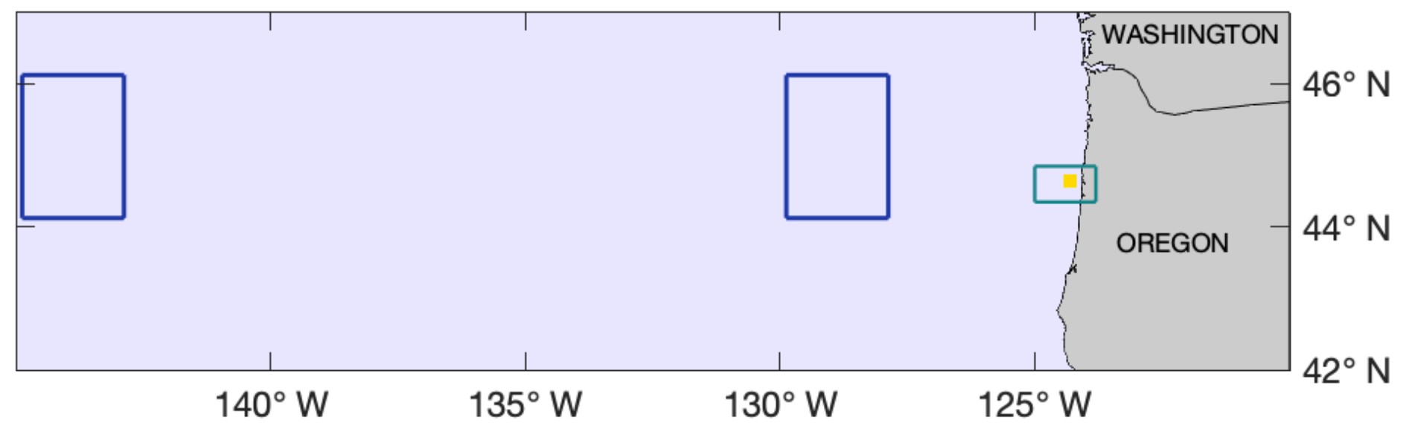
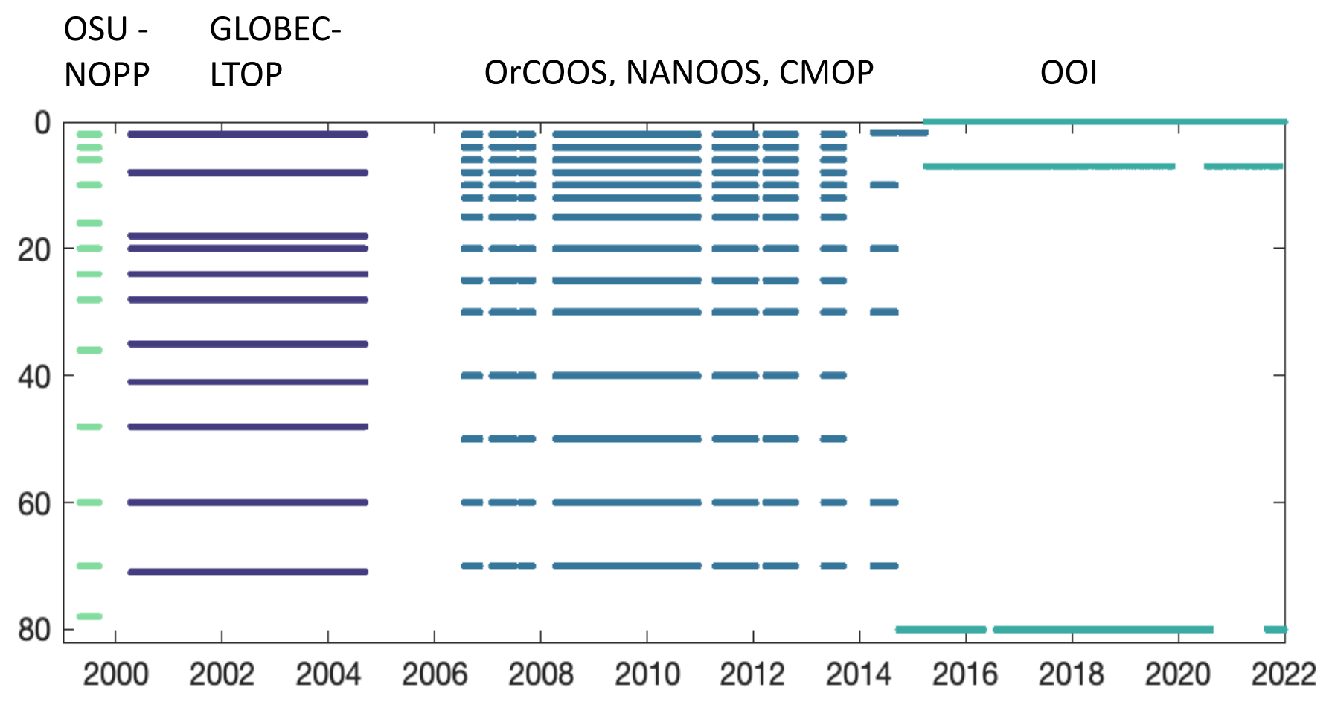
1. Introduction

- Most NE Pacific marine heat wave (MHW) studies focus on surface expression, but this moored dataset allows a subsurface characterization of major temperature anomalies from 2014-present with focus on marine heat wave events of 2014-16 and 2019-20
- Long time series allows us to address gaps in knowledge regarding the subsurface response on the shelf to recent temperature anomalies and create a climatology that approaches the standard of 30 years
- Six programs contributed to T, S and velocity data at NH-10 from 1999-present (velocity starts in 1997) to form a long-term record we call the concatenated time series
- Time series from two offshore OISST regions and OISST grid cell nearest NH-10 also shown to compare with shelf response



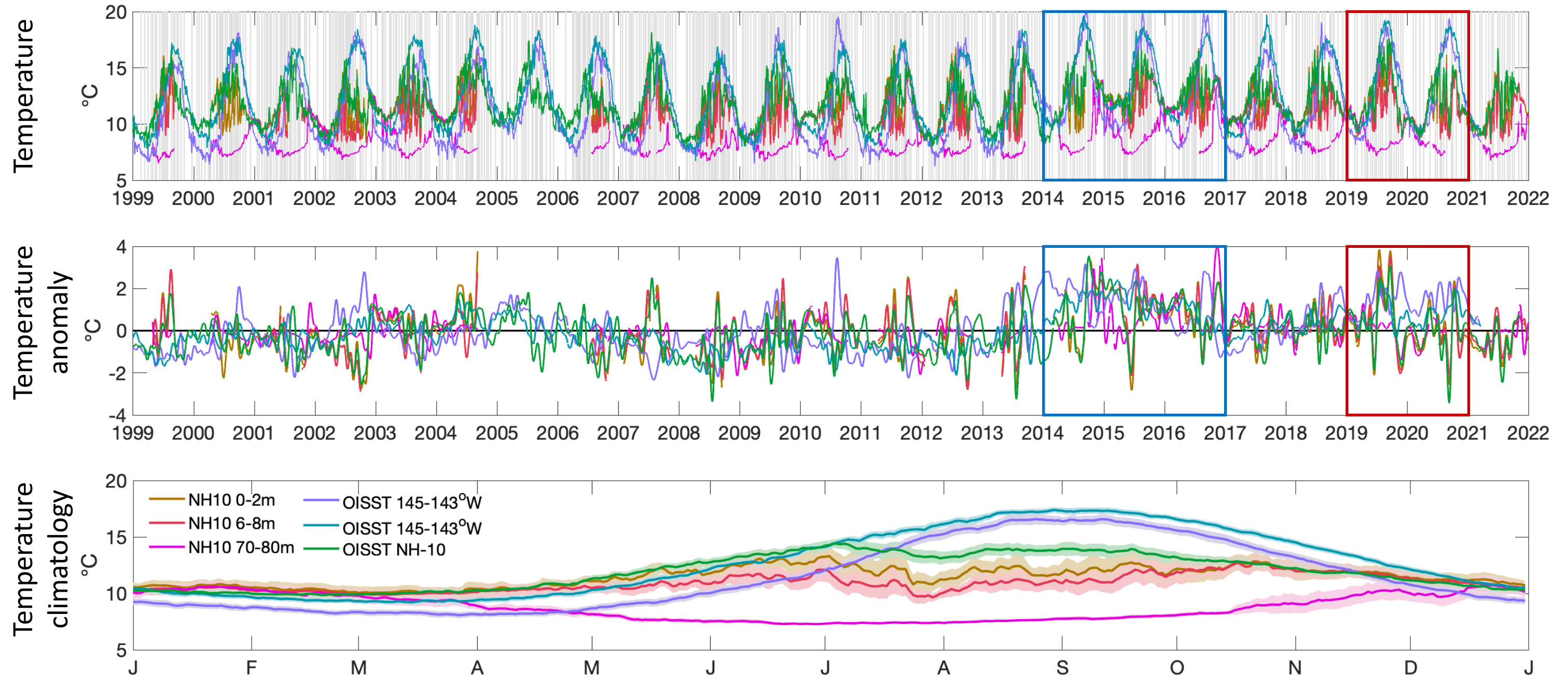




2. Data: Temperature Climatologies and Anomalies

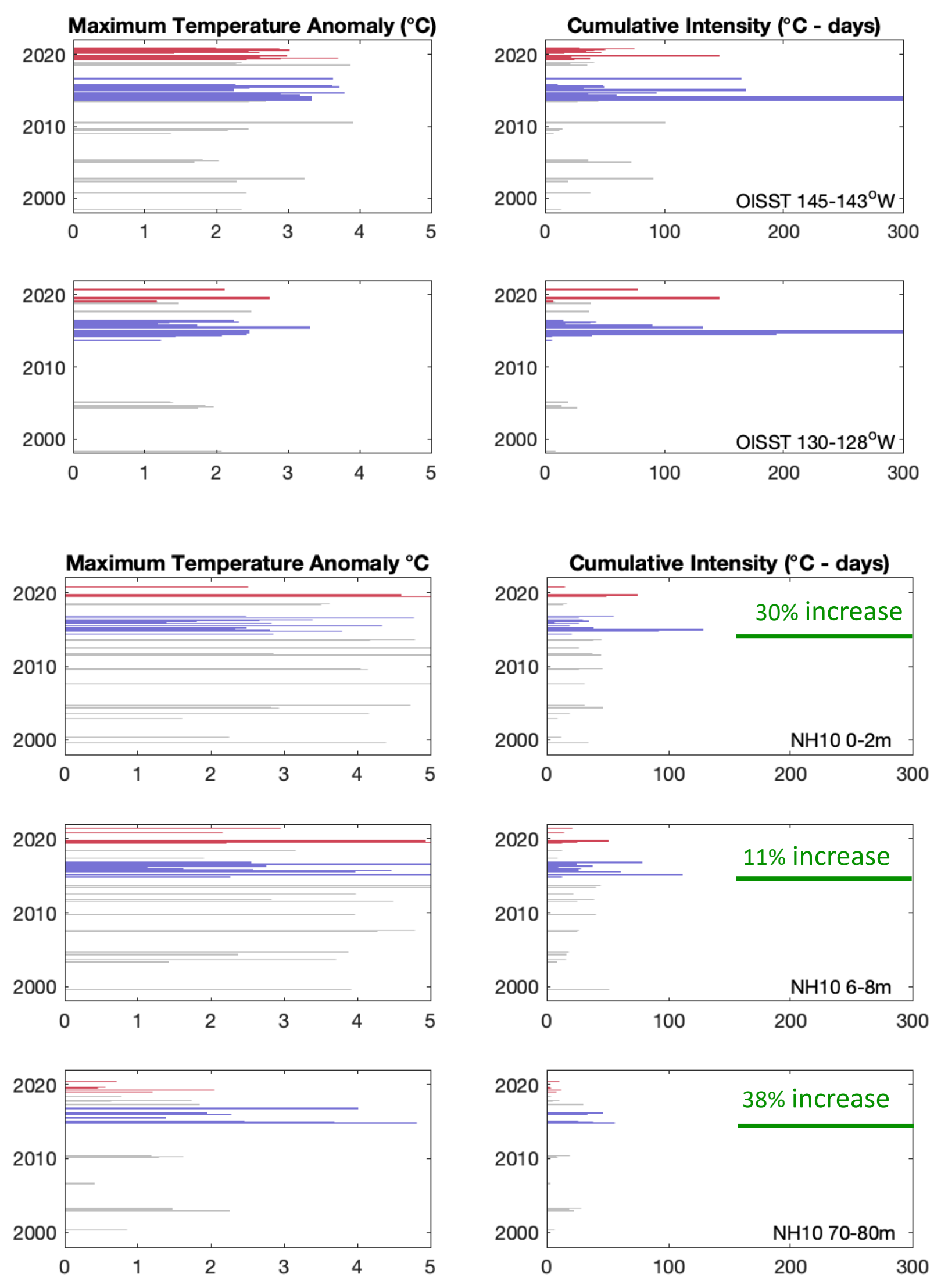
Marine Heat Wave #1

Marine Heat Wave #2



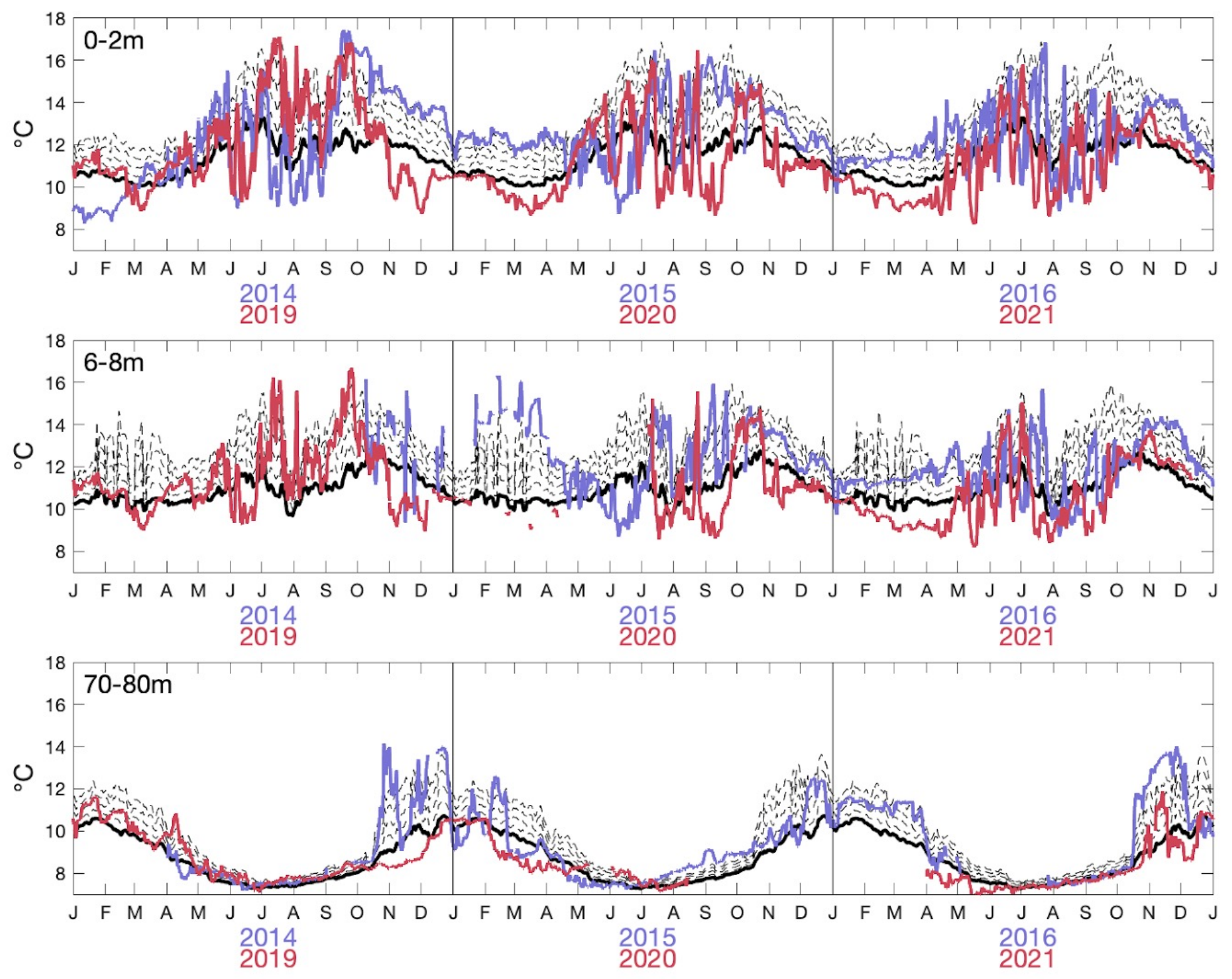
- OISST near NH-10 agrees well with the NH-10 surface data and has a correlation significant at 95%, so we use it to fill in a time period of missing NH-10 surface data
- Sustained anomalous warming at all locations during 1st MHW, which first appears in the westernmost OISST region at the end of 2013
- Weaker and shorter warming during the 2nd MHW but anomalous warm temperatures at all near surface locations in the summer of 2019 and farther offshore in 2020

3. Results: Marine heat wave events are increasing over time on central Oregon shelf



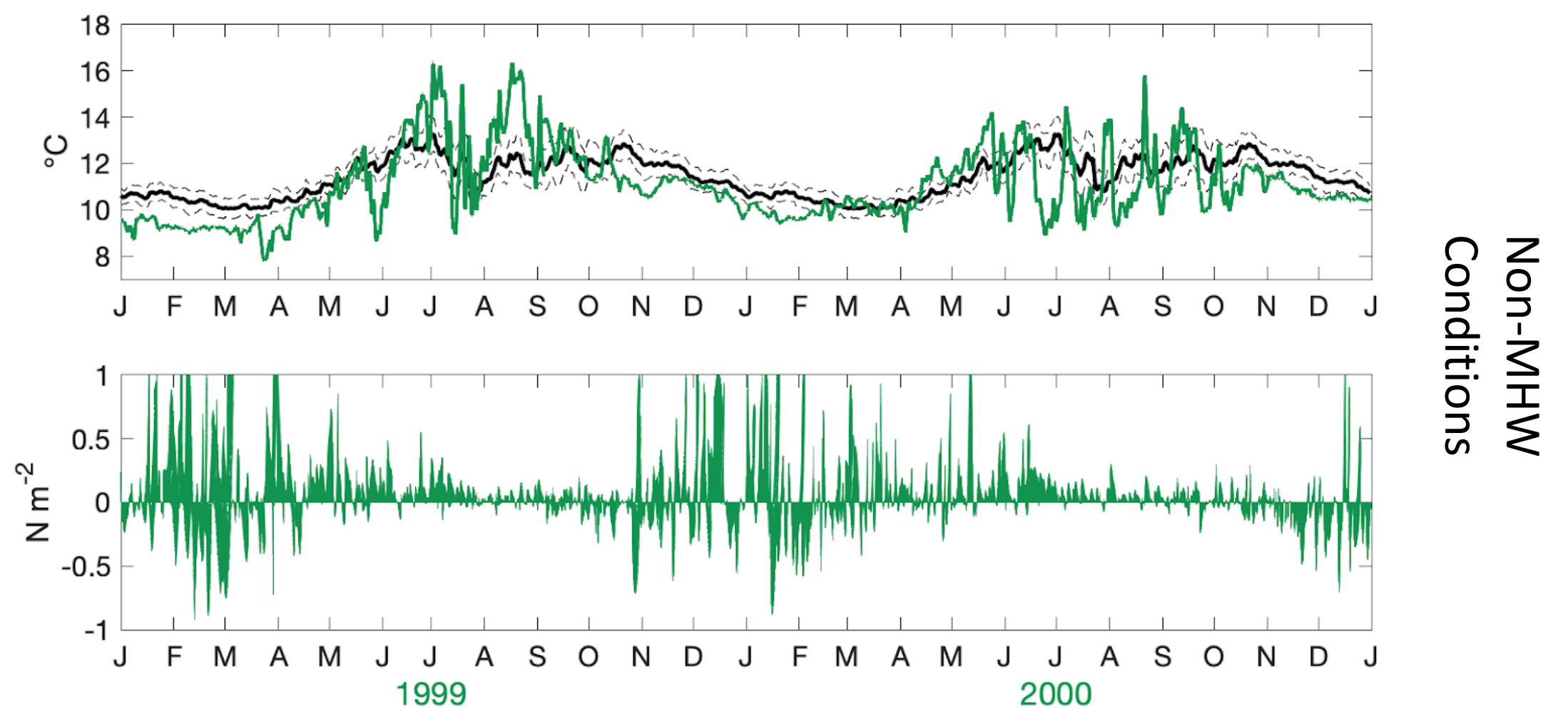
- Cumulative Intensity (°C-days) $I_{cum} = \int_{t_s}^{t_e} (T(t) - T_{mean})dt$
- Hobday et al. 2016 MHW criteria applied to OISST regions and NH-10 time series
- MHW occurs if T anomalies greater than 90th percentile of 30-year climatology persist for 5 days (we use the available 23-year climatology)
- Shift occurred with the 2014-16 MHW, and the mean cumulative intensity before and after 2014 shows an increase at all depths (shown in green)
- First event is longer with higher intensity and observed at all depths compared to the second event where signal near the bottom is much weaker

4. Results: Seasonal Timing and vertical structure of warming differs in two MHWs

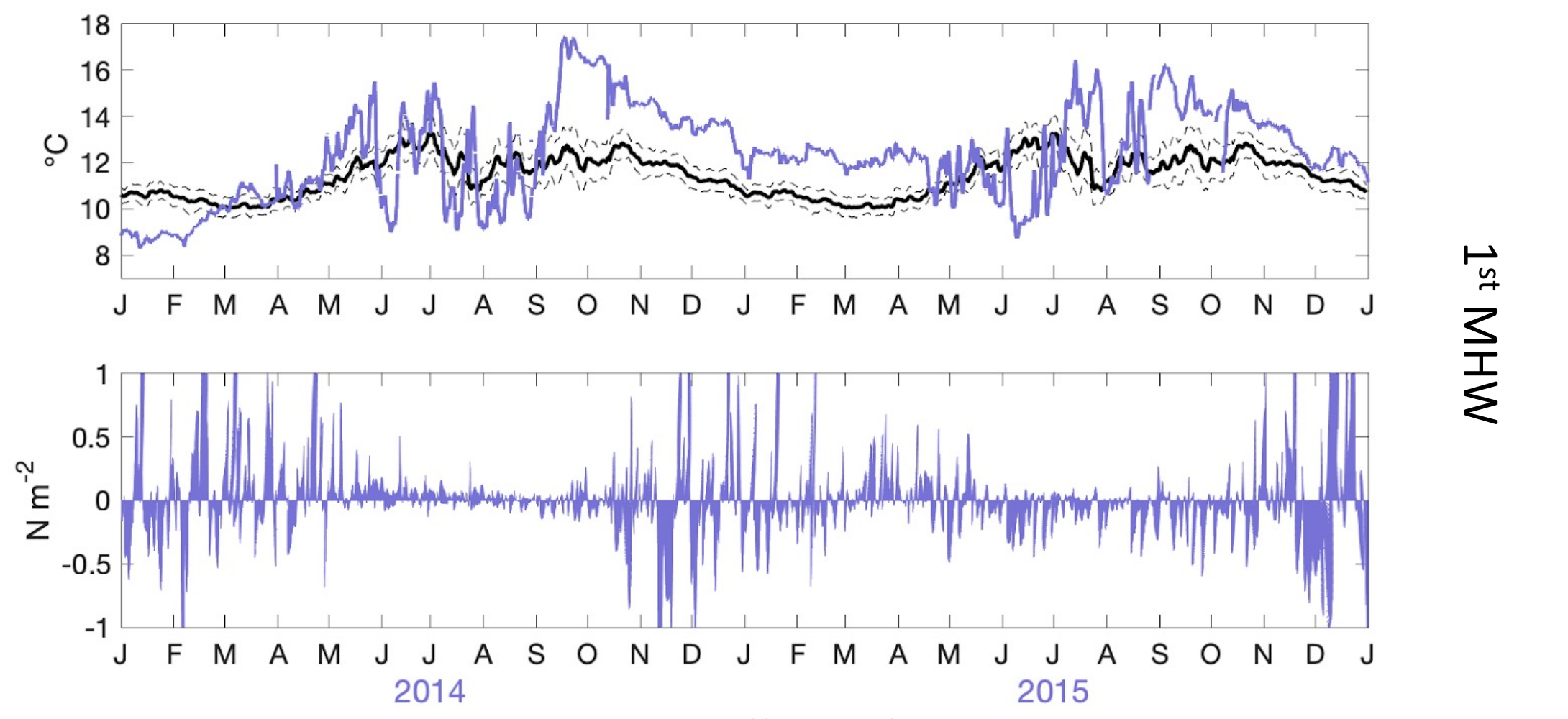


- Stronger MHWs occur when the maximum temperature exceeds multiples of the 90th percentile difference from the mean (Category I or Moderate > 1X, Category II or Strong > 2X, Category III or Severe > 3X, and Category IV or Extreme > 4X, depicted by dashed lines)
- During September – May 2014, the 1st MHW reached the extreme category intermittently at all depths measured. Anomalies during the remainder of the 1st MHW and the duration of the 2nd MHW fluctuate, but are typically in the lesser categories except a few short periods of high temperatures at the surface and near surface in July – October 2019
- 0-2m – 1st event shows sustained warm water anomalies except in summer as compared to the 2nd event, which shows warm anomalies in the first summer and early fall because this event began in summer of 2019, while the 2014-16 event stretched over a longer period and was interrupted by upwelling winds in summer of 2014 and 2015
- 6-8m – Temperature exhibits a similar pattern to 0-2m except the subsurface water is warmer than the surface water in early 2015, possibly due to downwelling of warm water from offshore and winter cooling of fresh coastal river waters at the surface, allowing the water column to remain stable
- 70-80m – Times when warm anomalies in upper part of the water column are largest in 2014-16, warming extends to the bottom, while this does not occur in 2019-20

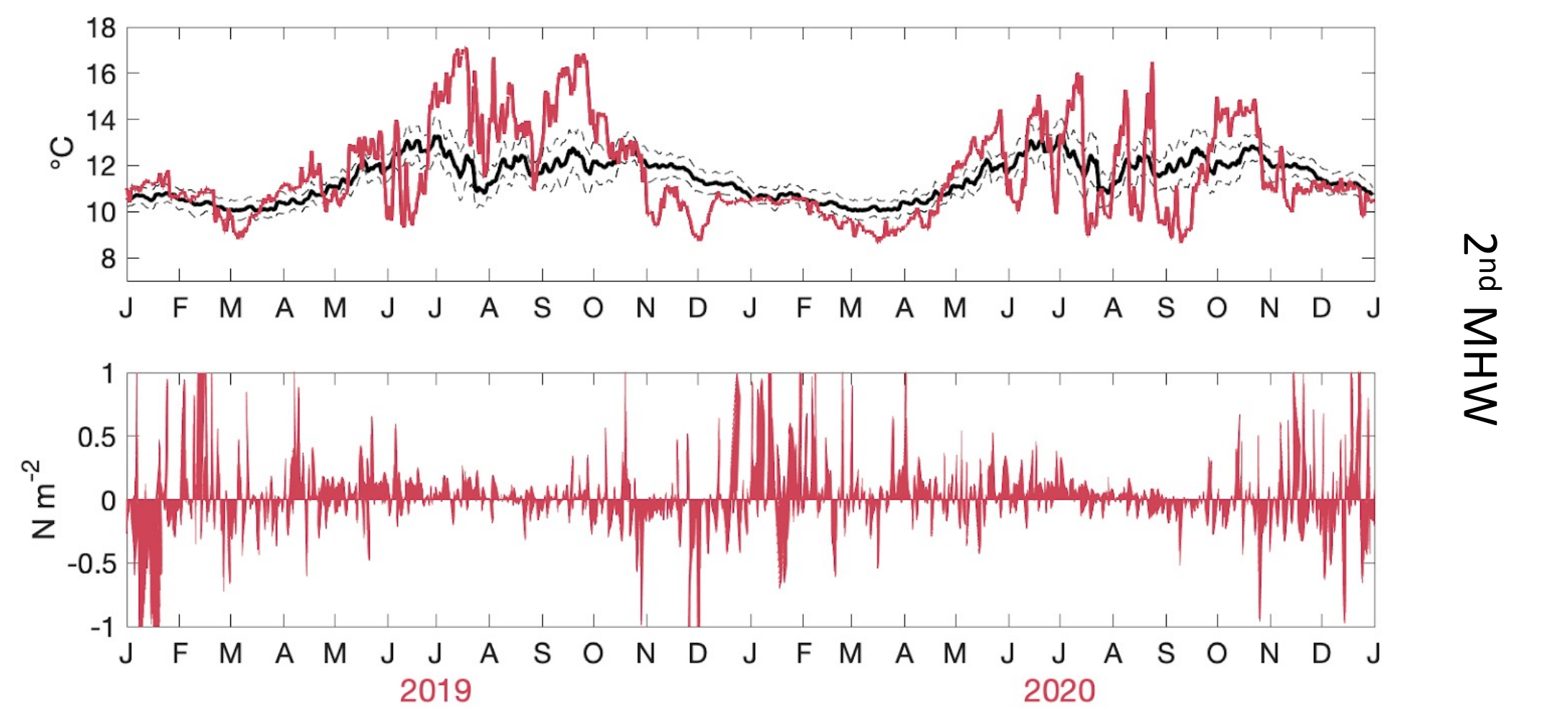
5. Results: Upwelling winds interrupt MHWs and warming shortens upwelling season



Non-MHW: Temperature follows mean with greater variability in summer when winds shift between poleward and equatorward

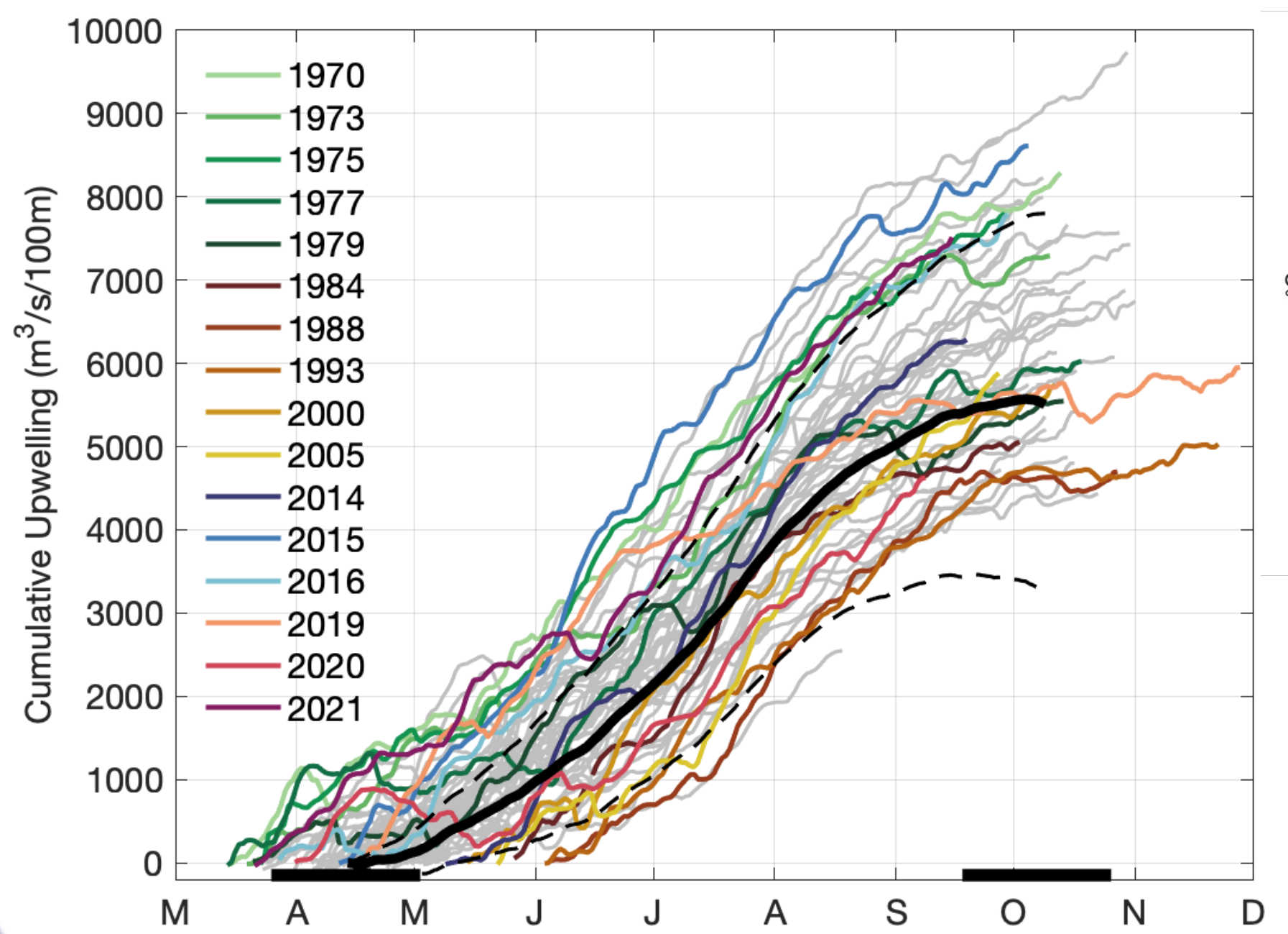


1st MHW: 2015 response very different from 2000 when upwelling winds were much weaker, yet more cold water at surface after July

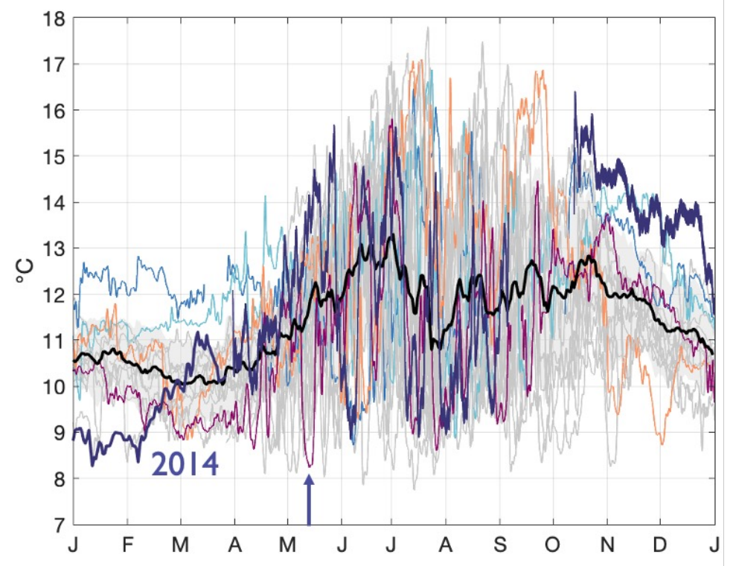


2nd MHW: In 2020 few short MHWs at NH-10 surface and temperature resembles 2000, with stronger upwelling winds in 2020 that likely offset a potentially stronger MHW

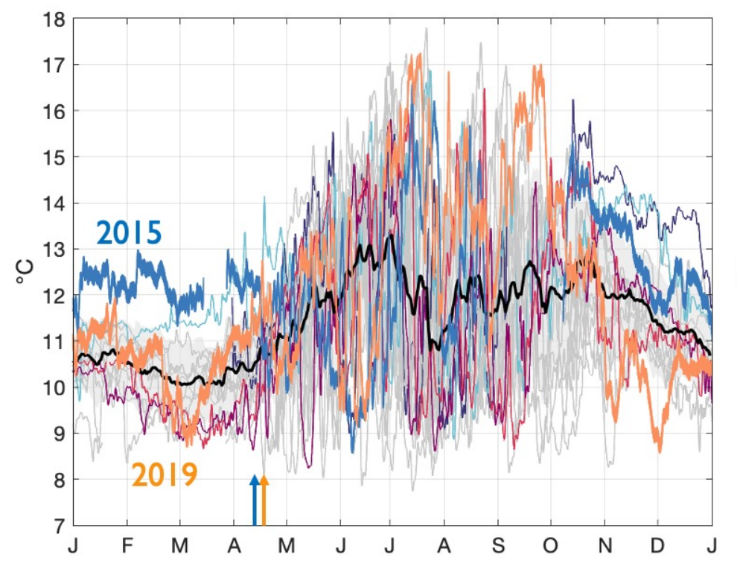
6. Results: Variation in spring transition date relates to timing and severity of MHW



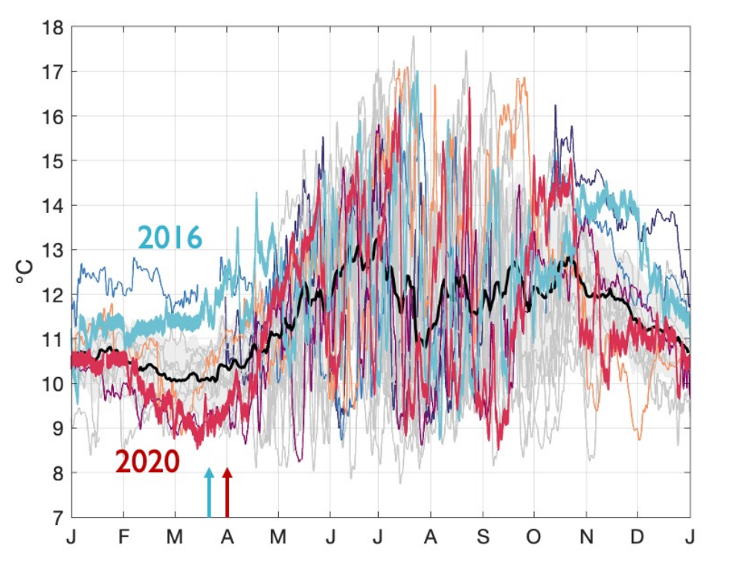
Based on methods similar to Pierce et al. 2006



- Strong increase in temperature at NH-10 surface in winter and spring
- Spring transition 24 days later than the mean and beyond one standard deviation range
- Only 5 years (1984, 1988, 1993, 2000, 2005) since upwelling index record began in 1967 have spring transitions later than 2014



- Spring transition date close to climatological mean of April 15th
- Cumulative upwelling follows typical pattern of increasing in time
- Rapid CU increase in 2015 when upwelling winds are strong
- Winter and early spring warming is interrupted by spring transition



- Spring transition earlier than mean but within one standard deviation
- Cumulative upwelling decreases soon after spring transition with larger decrease in 2020 than 2016