# Subsurface Temperature Anomalies off Central Oregon During 2014-2021


**Acknowledgments:**

**OSU/CIMRS**
Michael Banks
LeAnne Rutland

**NOAA/NWFS**
Bill Peterson
Kym Jacobson
Jennifer Fisher

**OSU/CEOAS**
Ted Strub
Phil Barbour



Brandy Cervantes, Melanie Fewings, Craig Risien

Oregon State University, College of Earth, Ocean and Atmospheric Sciences



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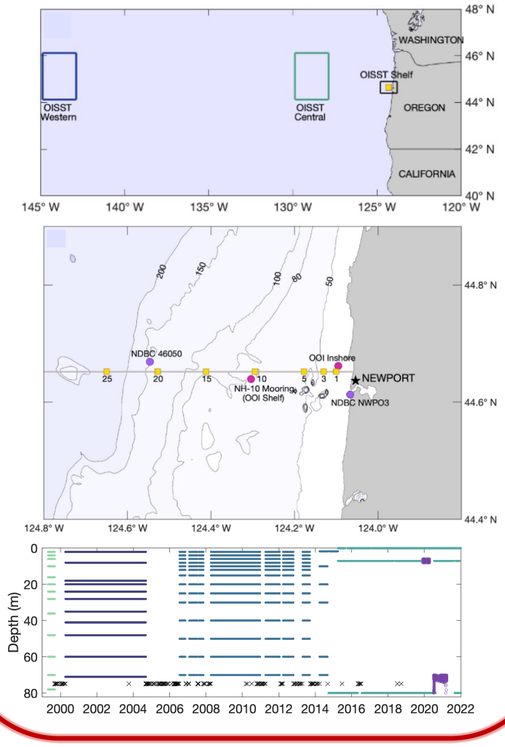
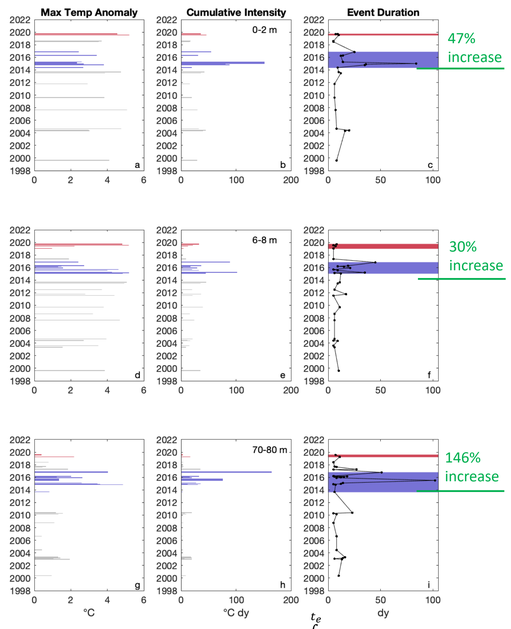
## 1. Introduction

- Most NE Pacific marine heat wave (MHW) studies focus on surface expression, but this dataset allows a subsurface characterization of temperature anomalies from 2014-present with focus on MHW events of 2014-16 and 2019-20
- Long time series allow 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

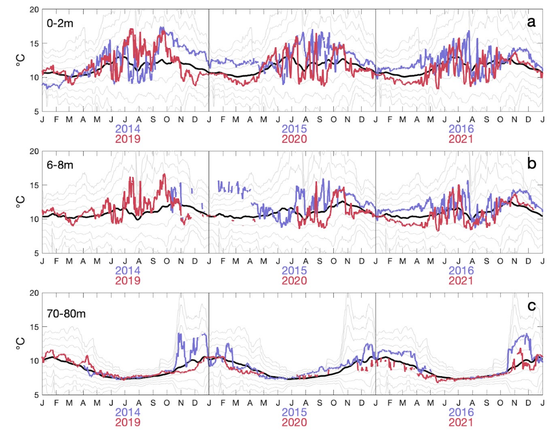



## 3. Results: Marine heat wave events are increasing over time on central Oregon shelf



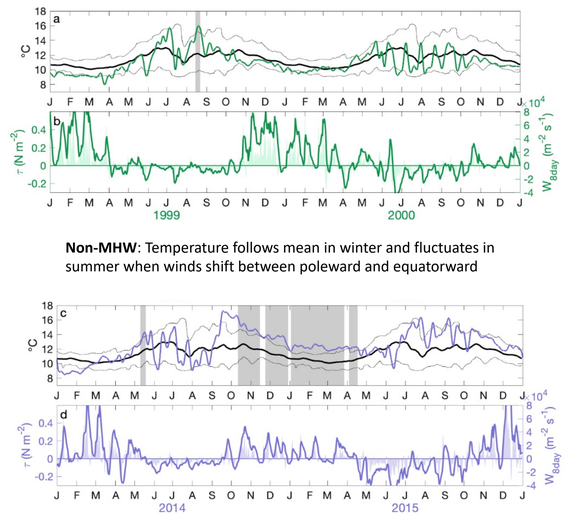

- Cumulative Intensity (°C-days) $I_{cum} = \int_{t_s}^{t_e} (T(t) - T_{mean})dt$
- Hobday et al. 2016 MHW criteria applied to NH-10 time series at surface, near surface, and bottom
- MHW occurs if T anomalies greater than 90th percentile of climatology persist for 5 days
- Shift occurred with the 2014-16 MHW and the mean cumulative intensity before and after 2014 shows an increase at all depths (shown in green)
- From 1999-2021, frequency and duration have increased at all depths with slopes significantly different from zero, while cumulative intensity has increased at all depths but with an insignificant slope at the near surface, and maximum temperature has only increased at the bottom

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



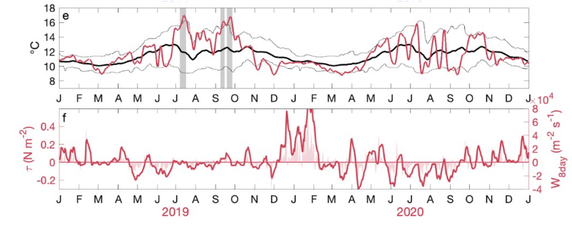

- Stronger MHWs occur when the maximum temperature exceeds multiples of the 90th percentile difference from the mean (Category I or Moderate > 1X, Category II or Strong > 2X, Category III or Severe > 3X, and Category IV or Extreme > 4X, depicted by gray lines)
- Anomalous warming events at NH-10 that qualify as MHWs typically fall within the moderate or strong categories at all depths. During September 2014 – May 2015, the 1st MHW intermittently reaches the moderate category at the surface and bottom and the extreme category at the near surface
- 0-2m (panel a) – 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 (panel b) – 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 (panel c) – 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



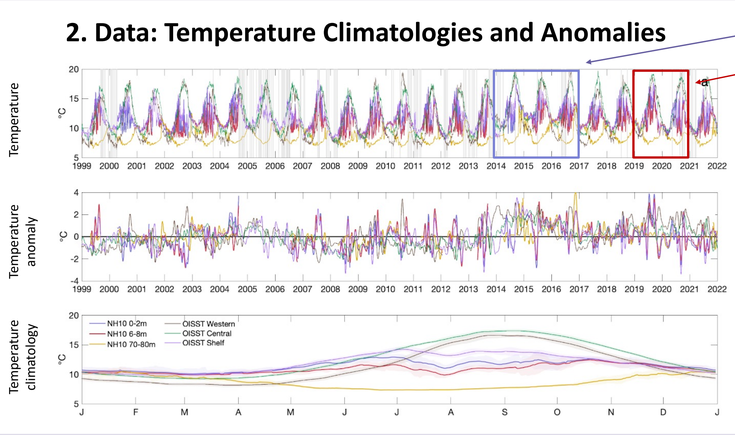

**Non-MHW**: Temperature follows mean in winter and fluctuates in summer when winds shift between poleward and equatorward

**1st MHW**: Weaker upwelling-favorable winds in 2000, yet more cold water at surface after July than in 2015 due to MHW



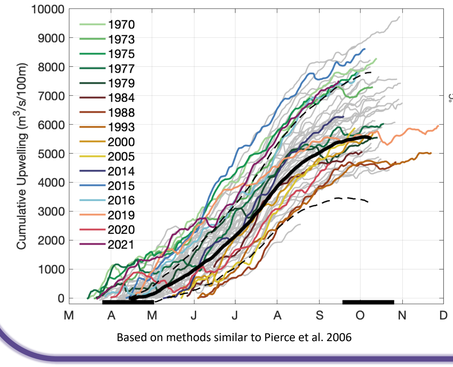

**2nd MHW**: May-October 2019 response mirrors July-October 2015. In 2020, no MHWs at the NH-10 surface and temperature resembles a warmer version of the non-MHW year 2000 with alternating warm and cold anomalies lasting 7-10 days

## 2. Data: Temperature Climatologies and Anomalies

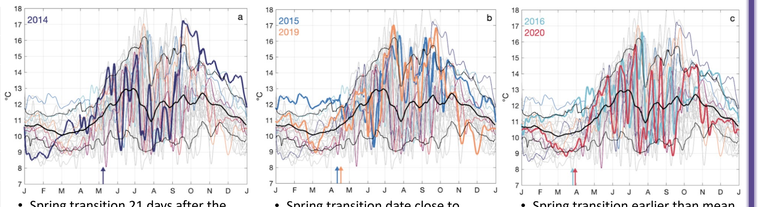



- OISST near NH-10 agrees well with the NH-10 surface data and has a correlation of 0.74 for 2014-16 and 0.94 for 2019-21, both significant at 95%, so we use it to fill gaps in the NH-10 surface temperature time series
- Sustained anomalous warming at all locations during 1st MHW, which first appears 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

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




Based on methods similar to Pierce et al. 2006




- Spring transition 21 days after the mean, just outside σ (20.1 days)
- Steady warming continues in the spring of 2014 after the spring transition, but in late May cooling is observed
- Only 8 years (1984, 1985, 1988, 1993, 2000, 2005, 2009, 2010) since upwelling index record began in 1967 have spring transitions later than 2014

- Spring transition date close to climatological mean of April 15th
- Winter and early spring warming is interrupted by spring transition
- Cumulative upwelling increases in time except during mid-May 2019
- Rapid increase in cumulative upwelling in 2015 when upwelling winds are strong

- Spring transition earlier than mean but within σ
- Cumulative upwelling decreases soon after spring transition with larger decrease in 2020 than 2016
- Brief drop in temperature about 1 week after spring transition in 2020, then strong warming from mid April – late May