Subsurface Characteristics of Recent Marine Heat Waves off Central Oregon

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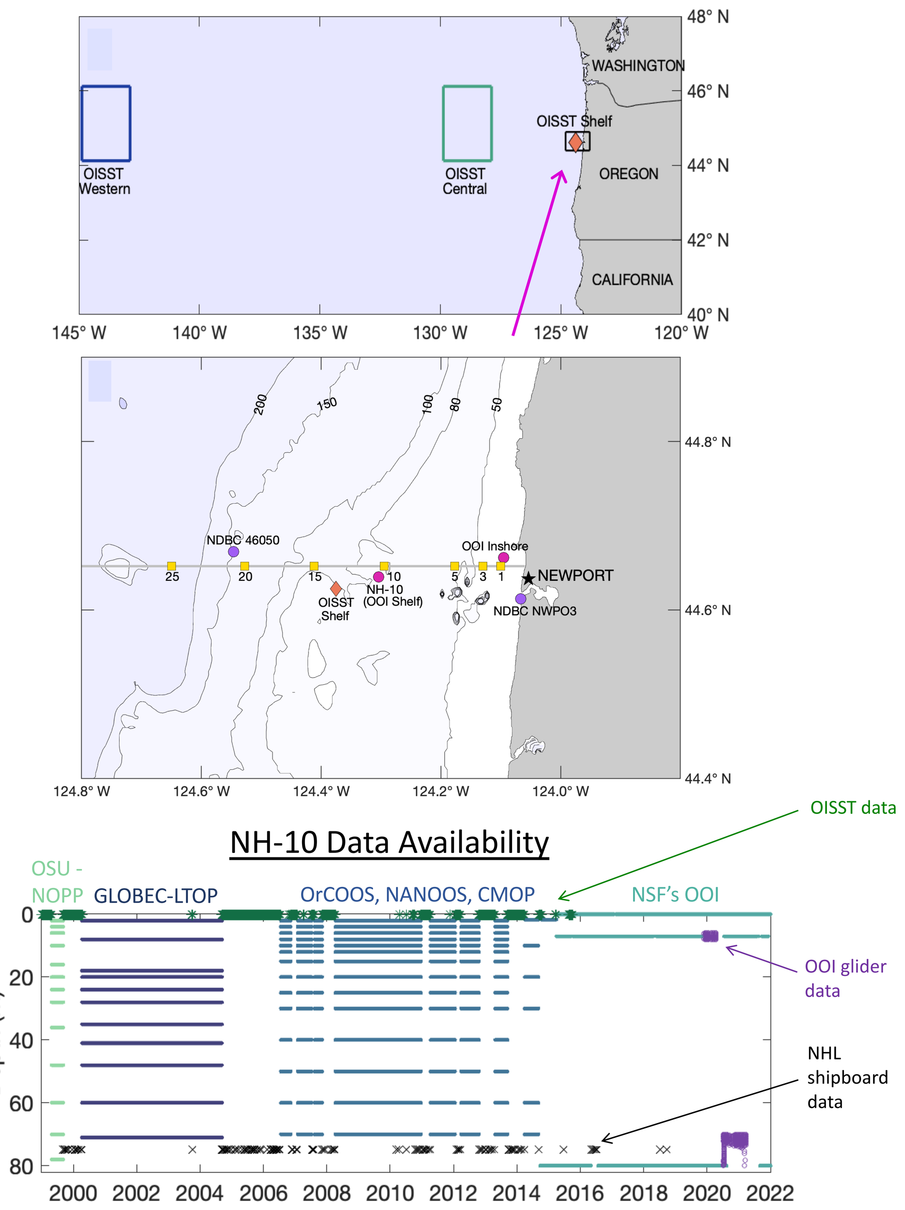
1. Introduction

- Most Northeast Pacific marine heatwave (MHW) studies focus on surface expression due to availability of satellite SST data
- Here we characterize surface and subsurface temperature anomalies 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 during recent temperature anomalies and create a climatology that approaches climate community standard of 30 years

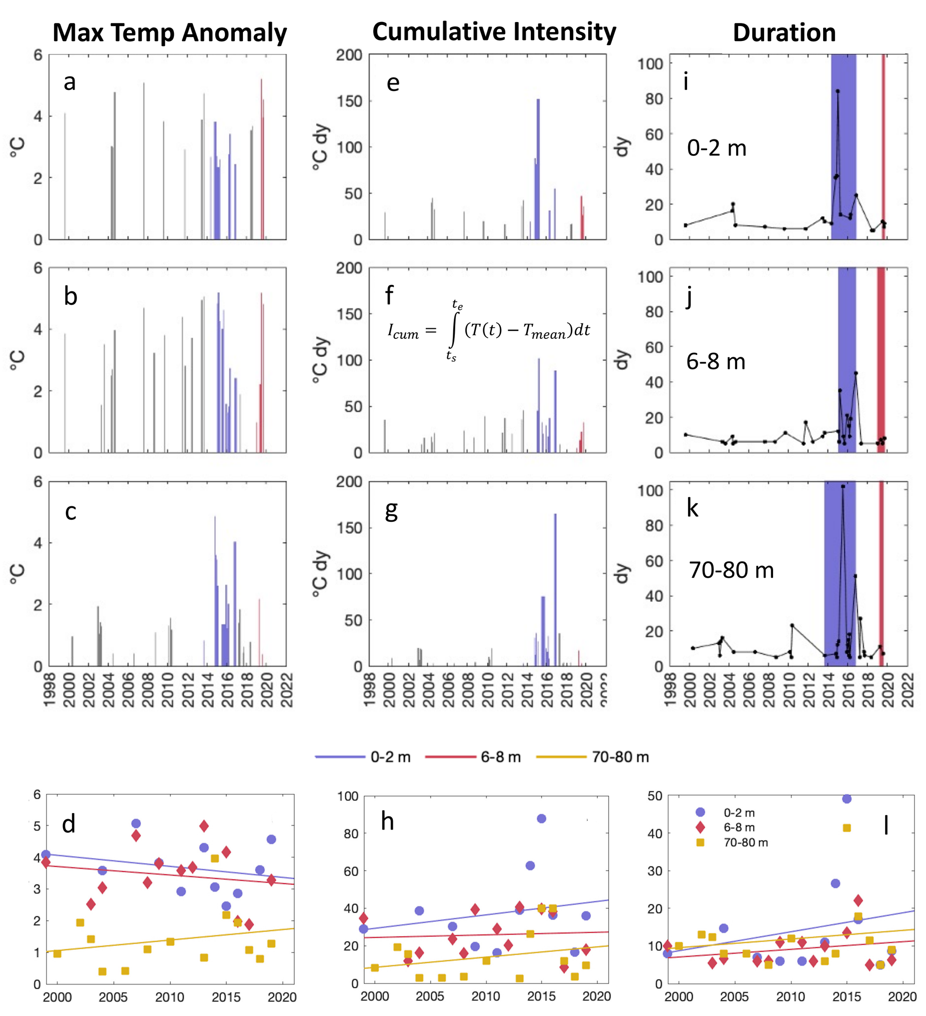
2. Data: The NH-10 Mooring



- Newport Hydrographic Line station NH-10 (10 nautical miles from the coast) has been the site of six programs (labeled above the NH-10 Data Availability panel) from 1997-present
- Hourly temperature, salinity, and velocity combined time series at NH-10, detailed in Risien et. al (2023), available at Zenodo
- Time series from NOAA ¼° Daily Optimal Interpolation Sea Surface Temperature (OISST) offshore regions and grid cell nearest NH-10 also examined to compare with shelf response

4. Results: Marine heat wave events are increasing over time off central Oregon

Application of Hobday et al. (2016) MHW criteria



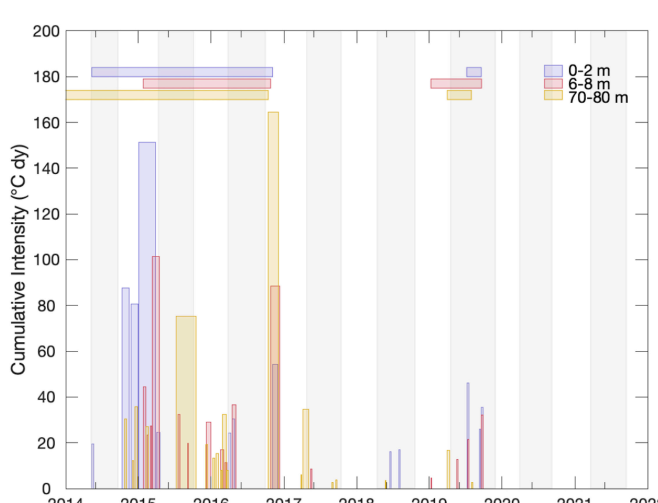
Max temperature increases at the bottom only

Cumulative intensity increases at all depths

Rate of increase highest at surface

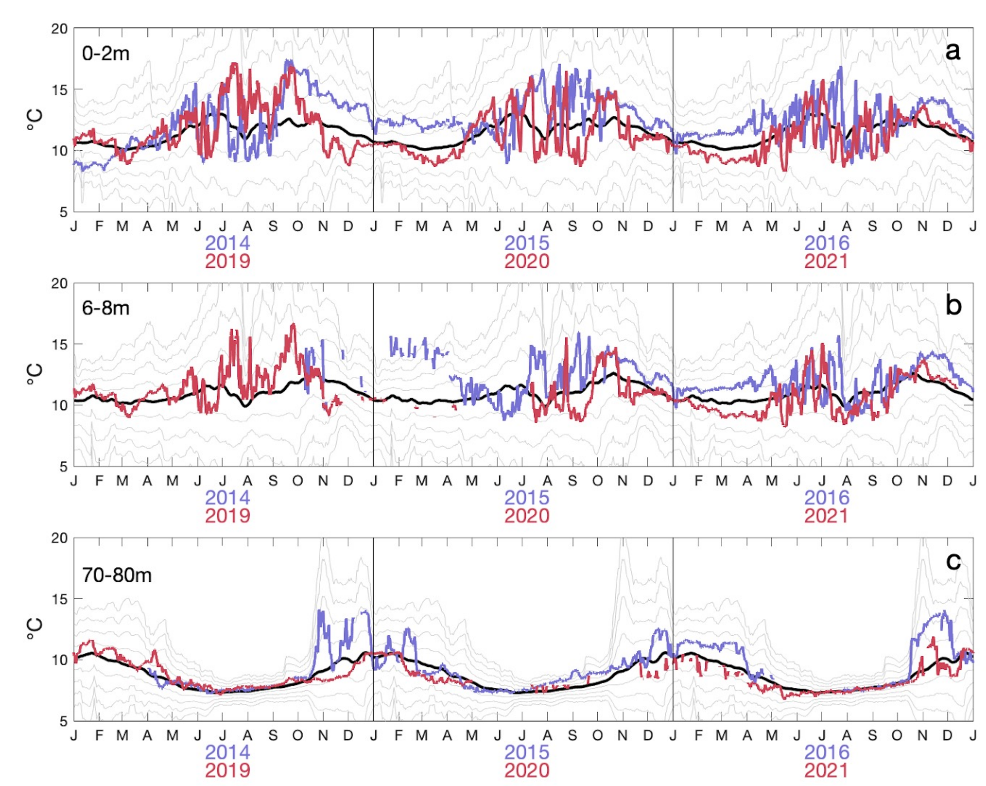
Duration increases at all depths

Rate of increase highest at surface



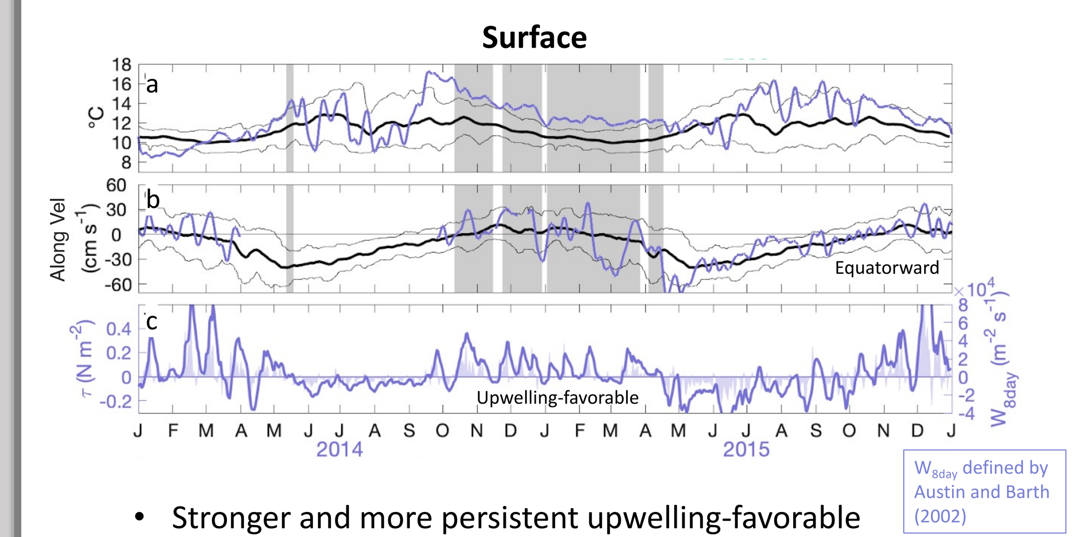
- Signature of warming events at NH-10 is very different during the two MHW periods, with fewer events, shorter durations, and smaller intensities during 2019-20 compared to 2014-16.
- Most events in 2019-20, including all surface events, occurred during the upwelling season, a dramatic contrast to the 2014-16 period (upwelling season indicated by gray shading).

5. Results: Seasonal Timing and vertical structure of warming differs in two MHW periods

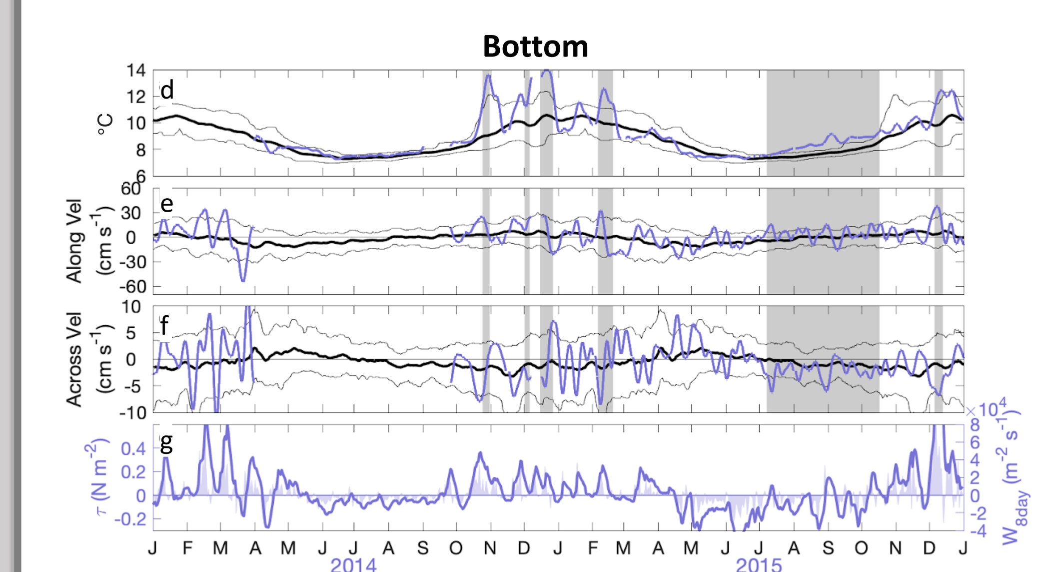


- **We use the Hobday et al. (2018) MHW categories:**
  - Stronger MHWs when maximum temperature exceeds multiples of 90th percentile difference from mean
  - Moderate > 1X, Strong > 2X, Severe > 3X, Extreme > 4X
  - MHWs at NH-10 typically fall within moderate or strong categories at all depths
- **0-2 m depth**
  - 1st MHW period – sustained warm anomalies except in summer due to interruption by upwelling-favorable winds
  - 2nd MHW period – warm anomalies in first summer and early fall due to its start in summer 2019
- **6-8 m depth**
  - 1st MHW period – reaches extreme category during early 2015 when it is warmer than surface water, possibly due to winter cooling of fresh coastal river waters at surface
  - 2nd MHW period – very similar to surface
- **70-80 m depth**
  - 1st MHW period – MHW observed at bottom when warm anomalies in surface and near surface are largest
  - 2nd MHW period – no bottom MHW associated with warm anomalies at surface and near surface in summer/fall 2019

6. Results: Upwelling winds interrupt MHWs

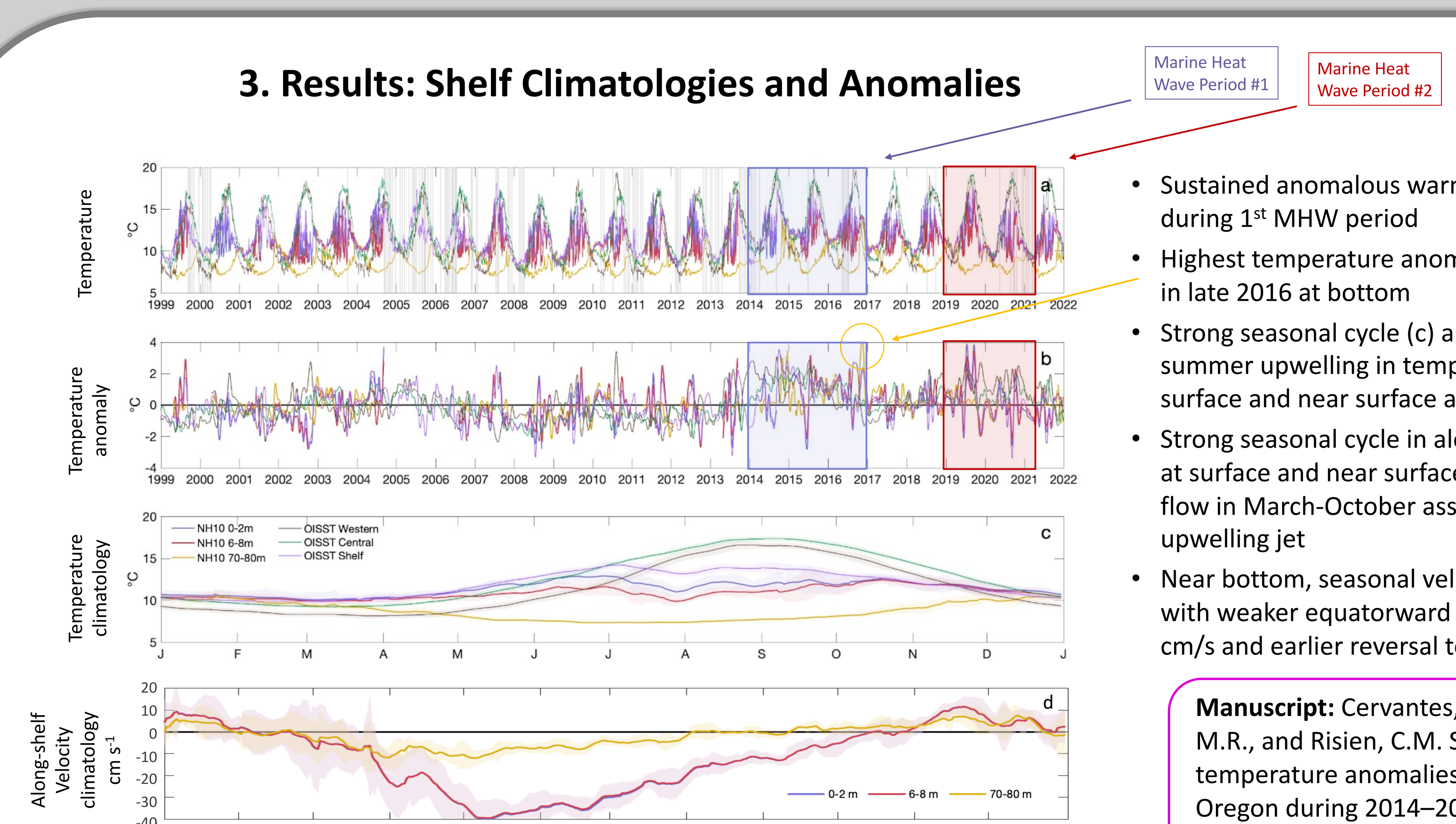


- Stronger and more persistent upwelling-favorable winds (c) in 2015 than 2014, but MHW reappears at surface in early July 2015 after short wind reversal
- Equatorward surface currents (b) reach over 70 cm/s at start of upwelling season in April 2015 then weaken in mid-May
- Warm anomalies (a) persist for remainder of 2015 and surface currents fluctuate with wind stress



- Warm anomalies (d) dominate bottom temperature, but evidence of cooling with downwelling relaxation in winter 2014-15 and strong upwelling events in spring
- Similar to surface, along-shelf velocity at bottom (e) typically aligns with 8-day wind stress with anomalous poleward and equatorward flow during strong winds (g)
- Across-shelf velocity at bottom (f) opposes direction of 8-day wind stress as expected from Ekman forcing

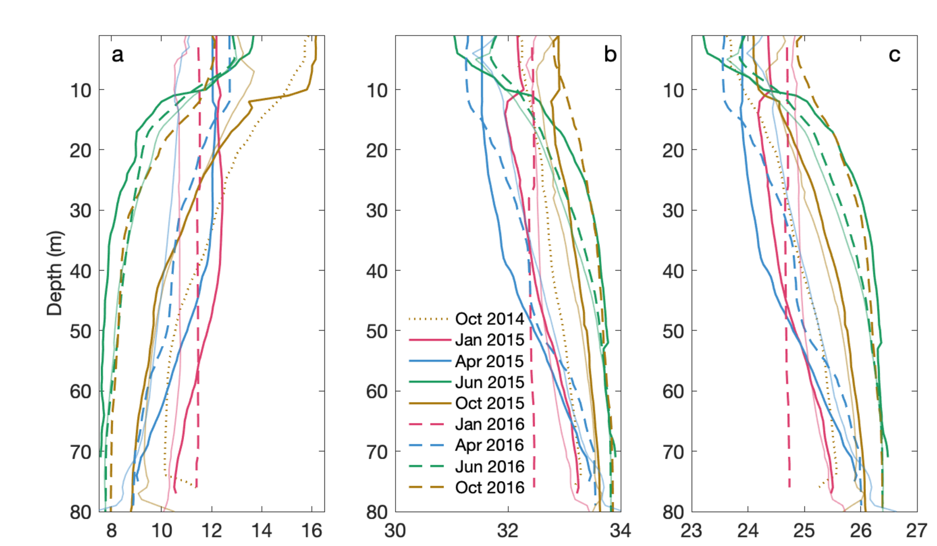
3. Results: Shelf Climatologies and Anomalies



- Sustained anomalous warming (b) at all locations during 1st MHW period
- Highest temperature anomaly of 4°C is observed in late 2016 at bottom
- Strong seasonal cycle (c) and dominance of summer upwelling in temperature at the NH-10 surface and near surface and OISST shelf
- Strong seasonal cycle in along-shelf velocity (d) at surface and near surface with equatorward flow in March-October associated with coastal upwelling jet
- Near bottom, seasonal velocity pattern is similar with weaker equatorward flow reaching only 10 cm/s and earlier reversal to poleward flow

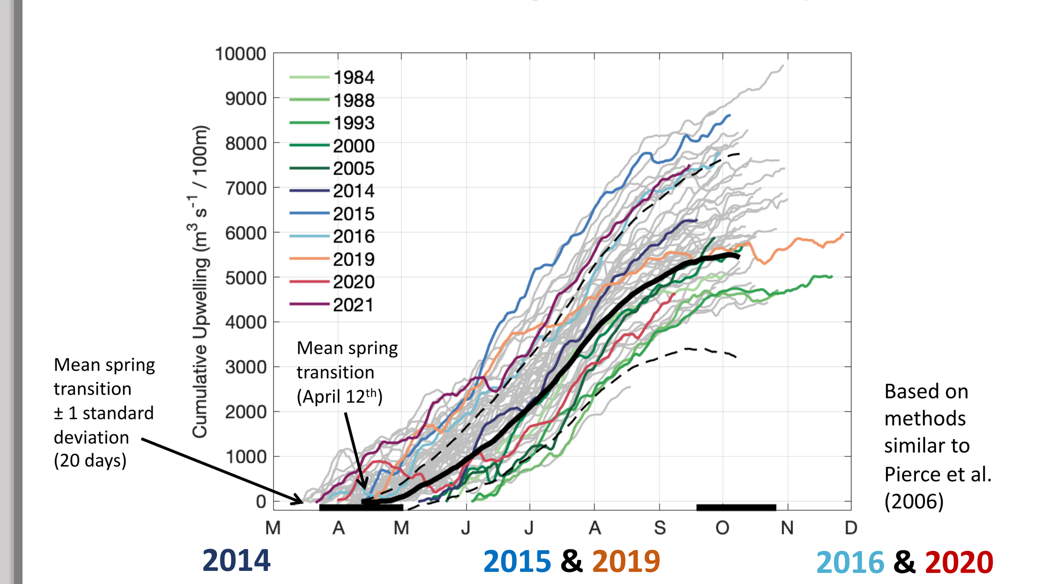
Manuscript: Cervantes, B.T., Fewings, M.R., and Risien, C.M. Subsurface temperature anomalies off central Oregon during 2014–2021, *under review at JGR Oceans*.

7. Results: Stratification contains warm anomalies to the surface



- **January:** shelf water is well-mixed from surface to 40 m depth in 2015 and throughout water column in 2016; warming extends to bottom (panel 5)
- **April:** shelf in transition between well-mixed winter and stratified summer; surface layer deep enough for consistent warming in surface and near surface
- **June:** shallow surface layer and strong stratification in seasonal pycnocline between 10-30 m depth; surface experiences more warming than near surface

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



2014

- MHW first observed at NH10 in spring 2014
- Spring transition 27 days after mean and outside standard deviation
- Only 5 years (in green) since record began in 1967 have spring transitions later than 2014

2015 & 2019

- Strong upwelling winds in spring 2015 interrupt warm winter (panel 6)
- MHW not observed at NH10 until summer 2019
- Spring transition close to mean
- Cumulative upwelling increases rapidly in 2015

2016 & 2020

- Strong upwelling winds in spring 2016 and 2020 preceded by less winter warming (panels 5,6)
- Spring transition earlier than mean but within standard deviation