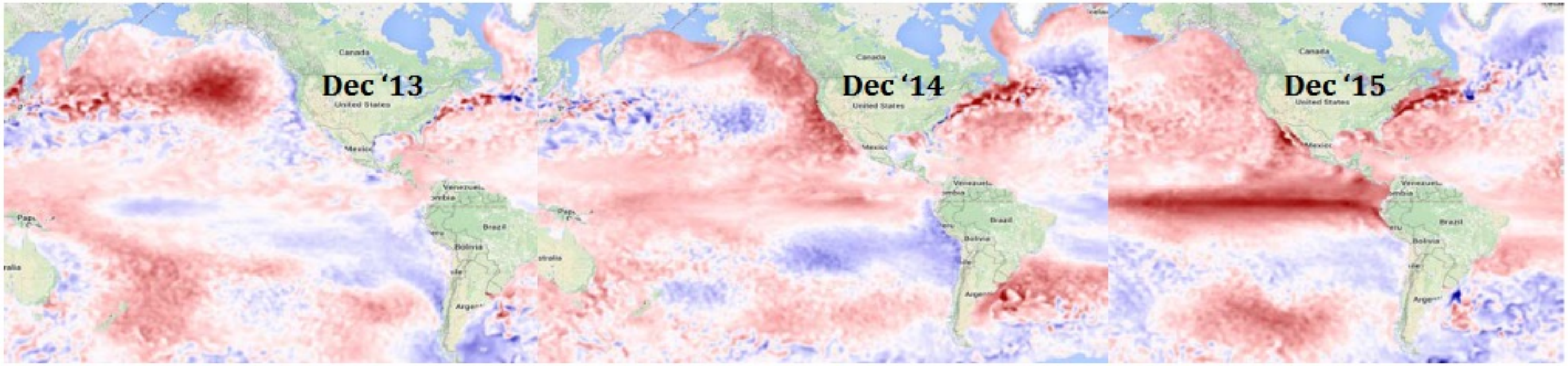


SST anomaly plots: http://nvs.nanoos.org/Climatology

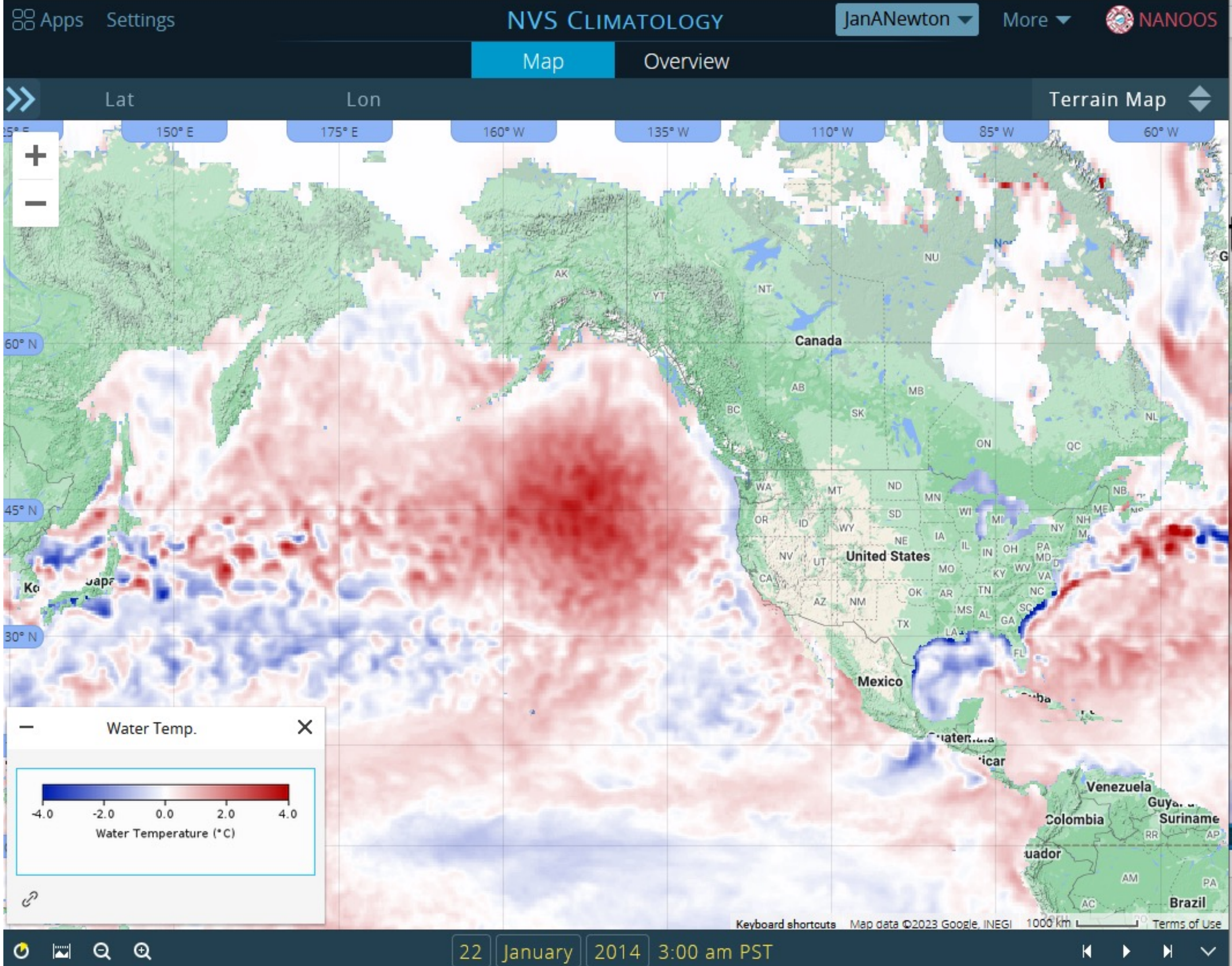
heatwaves in the Pacific Northwest

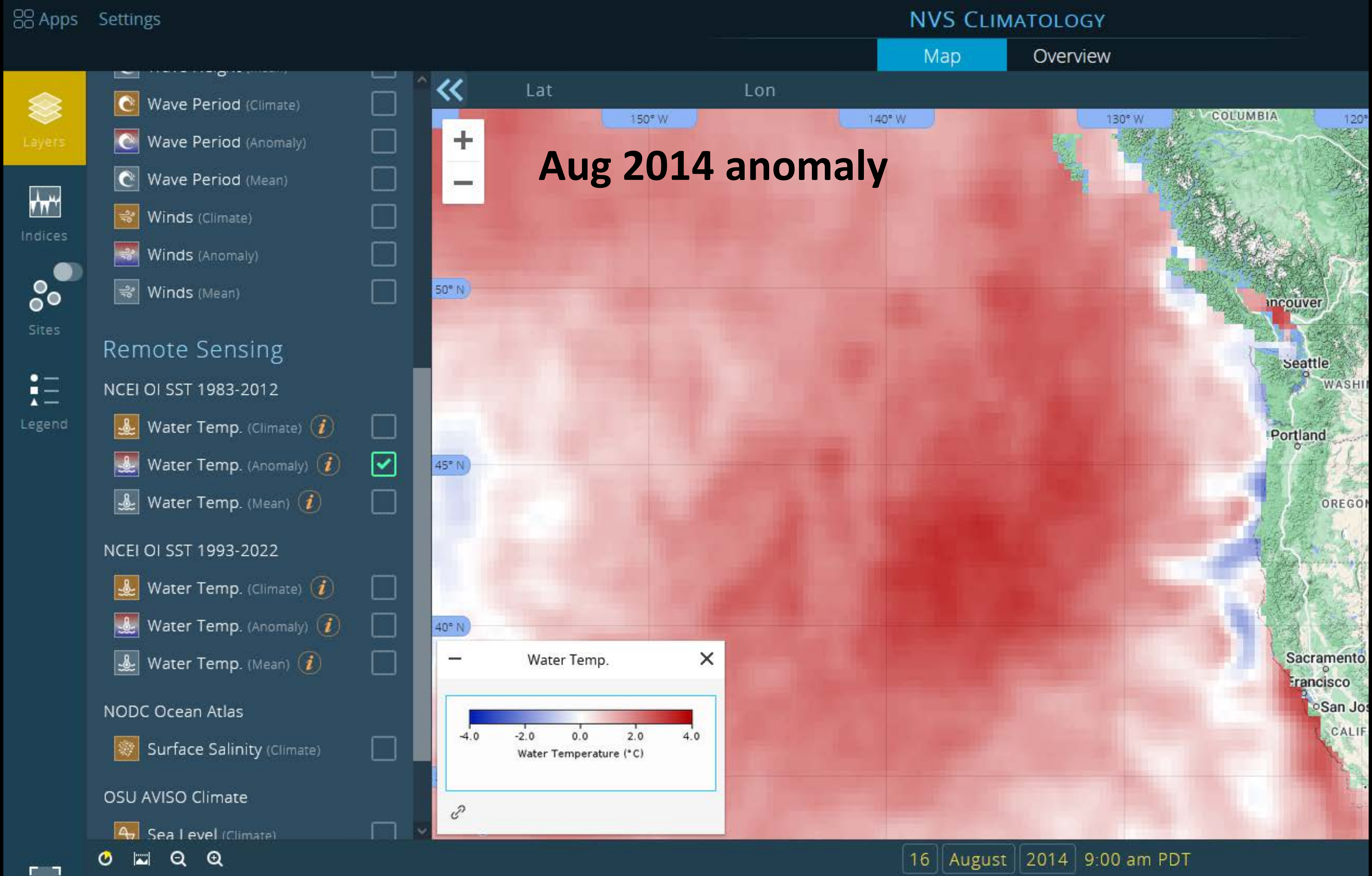
Jan Newton
University of Washington

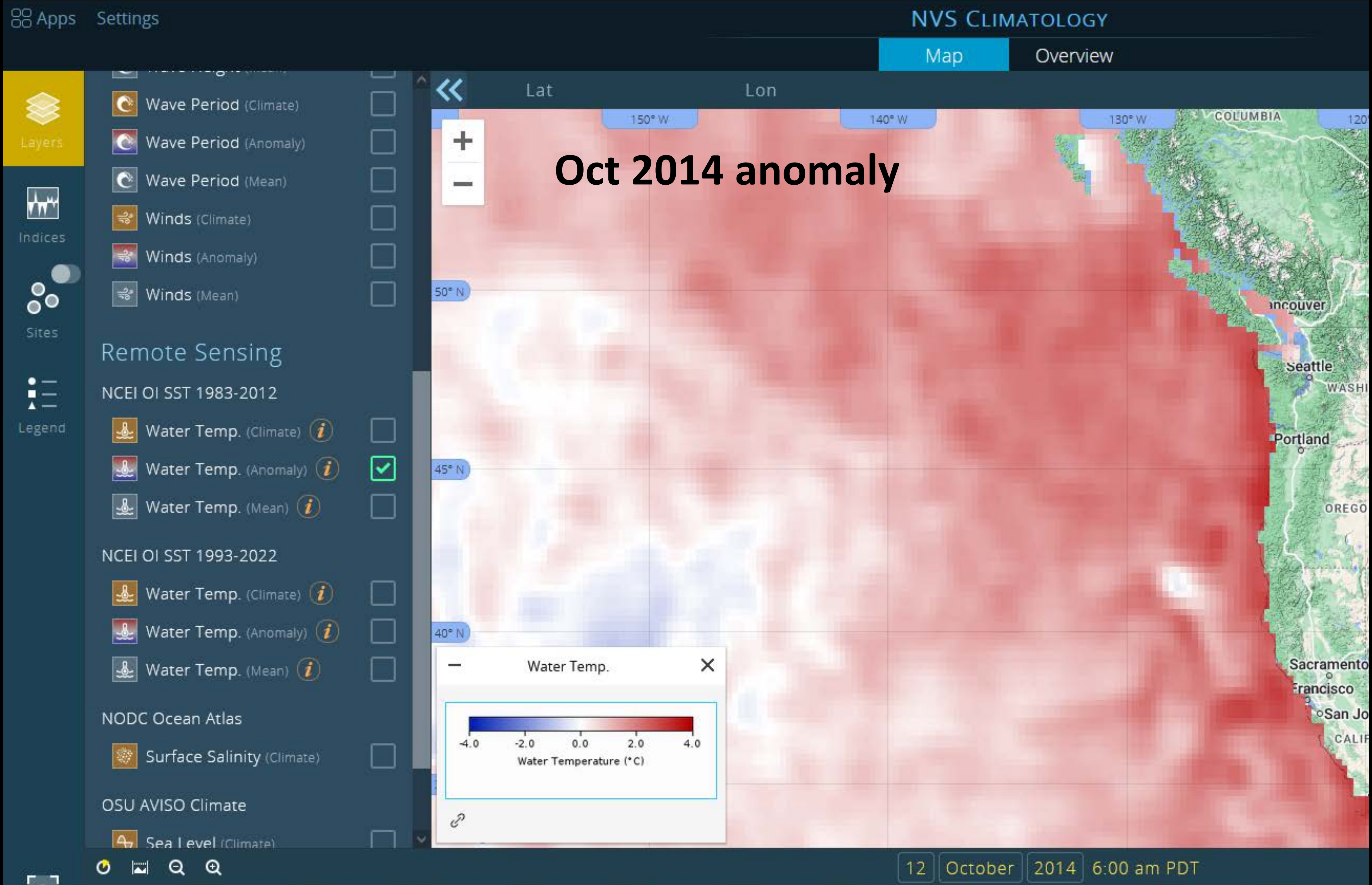
“the blob”

Jan 2014

https://nvs.nanoos.org/Climatology




Aug 2014 anomaly
Apps
Settings
NVS CLIMATOLOGY
Map
Overview
Layers
Indices
Sites
Legend
Lat
Lon
Wave Period (Climate)
Wave Period (Anomaly)
Wave Period (Mean)
Winds (Climate)
Winds (Anomaly)
Winds (Mean)
Remote Sensing
NCEI OI SST 1983-2012
Water Temp. (Climate)
Water Temp. (Anomaly)
Water Temp. (Mean)
NCEI OI SST 1993-2022
Water Temp. (Climate)
Water Temp. (Anomaly)
Water Temp. (Mean)
NODC Ocean Atlas
Surface Salinity (Climate)
OSU AVISO Climate
Sea Level (Climate)
150° W
140° W
130° W
120°
COLUMBIA
50° N
45° N
40° N
Seattle
Portland
OREGON
Sacramento
Water Temp.
-4.0
-2.0
0.0
2.0
4.0
Water Temperature (°C)
16
August
2014
9:00 am PDT


Apps
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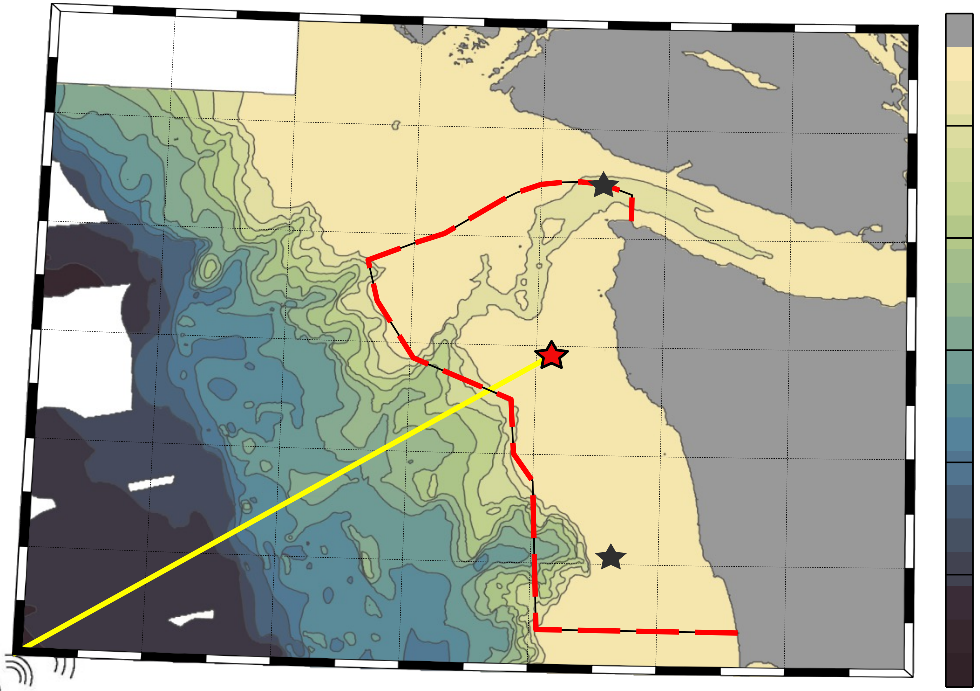
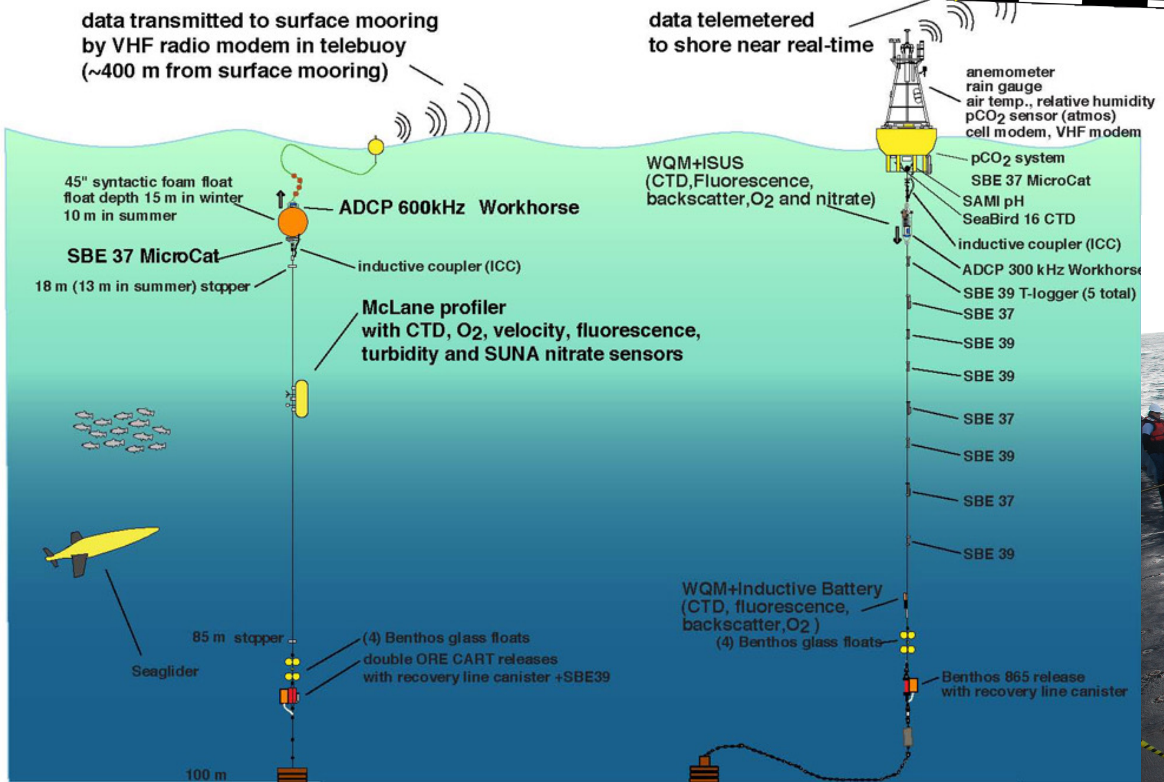
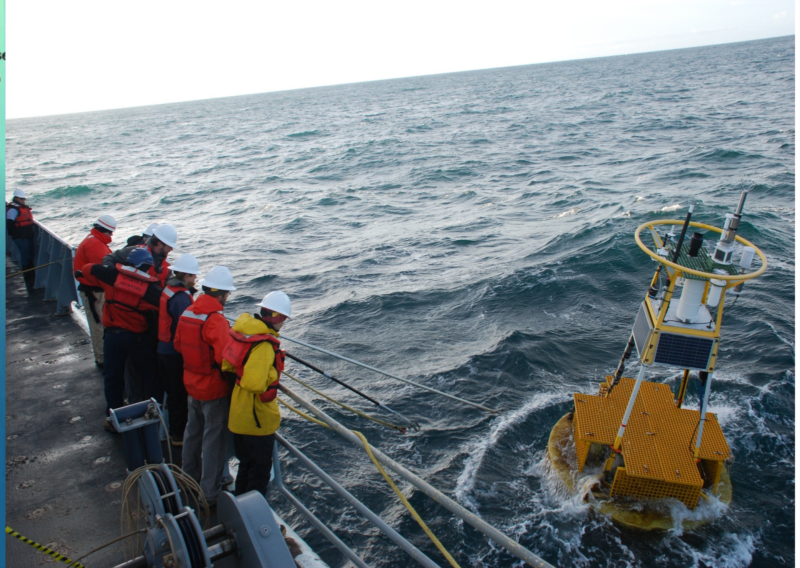
Map
Overview
Layers
Indices
Sites
Legend
Wave Period (Climate)
Wave Period (Anomaly)
Wave Period (Mean)
Winds (Climate)
Winds (Anomaly)
Winds (Mean)
Remote Sensing
NCEI OI SST 1983-2012
Water Temp. (Climate)
Water Temp. (Anomaly)
Water Temp. (Mean)
NCEI OI SST 1993-2022
Water Temp. (Climate)
Water Temp. (Anomaly)
Water Temp. (Mean)
NODC Ocean Atlas
Surface Salinity (Climate)
OSU AVISO Climate
Sea Level (Climate)
Lat
Lon
150° W
140° W
130° W
COLUMBIA
Oct 2014 anomaly
50° N
45° N
40° N
Seattle
Portland
Sacramento
Water Temp.
-4.0
-2.0
0.0
2.0
4.0
Water Temperature (°C)
12
October
2014
6:00 am PDT

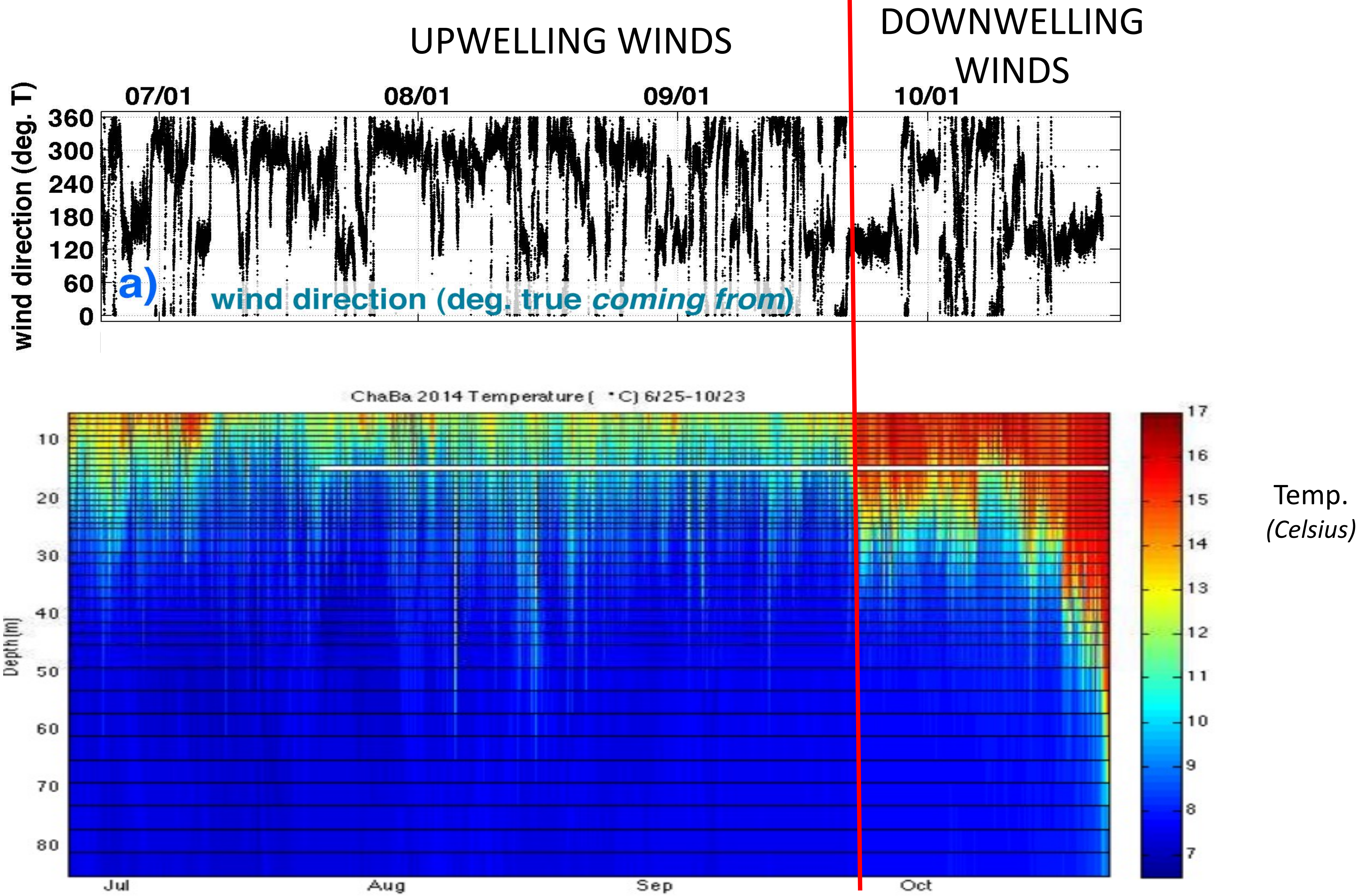
Cha'ba Buoy and NEMO profiler, La Push, WA

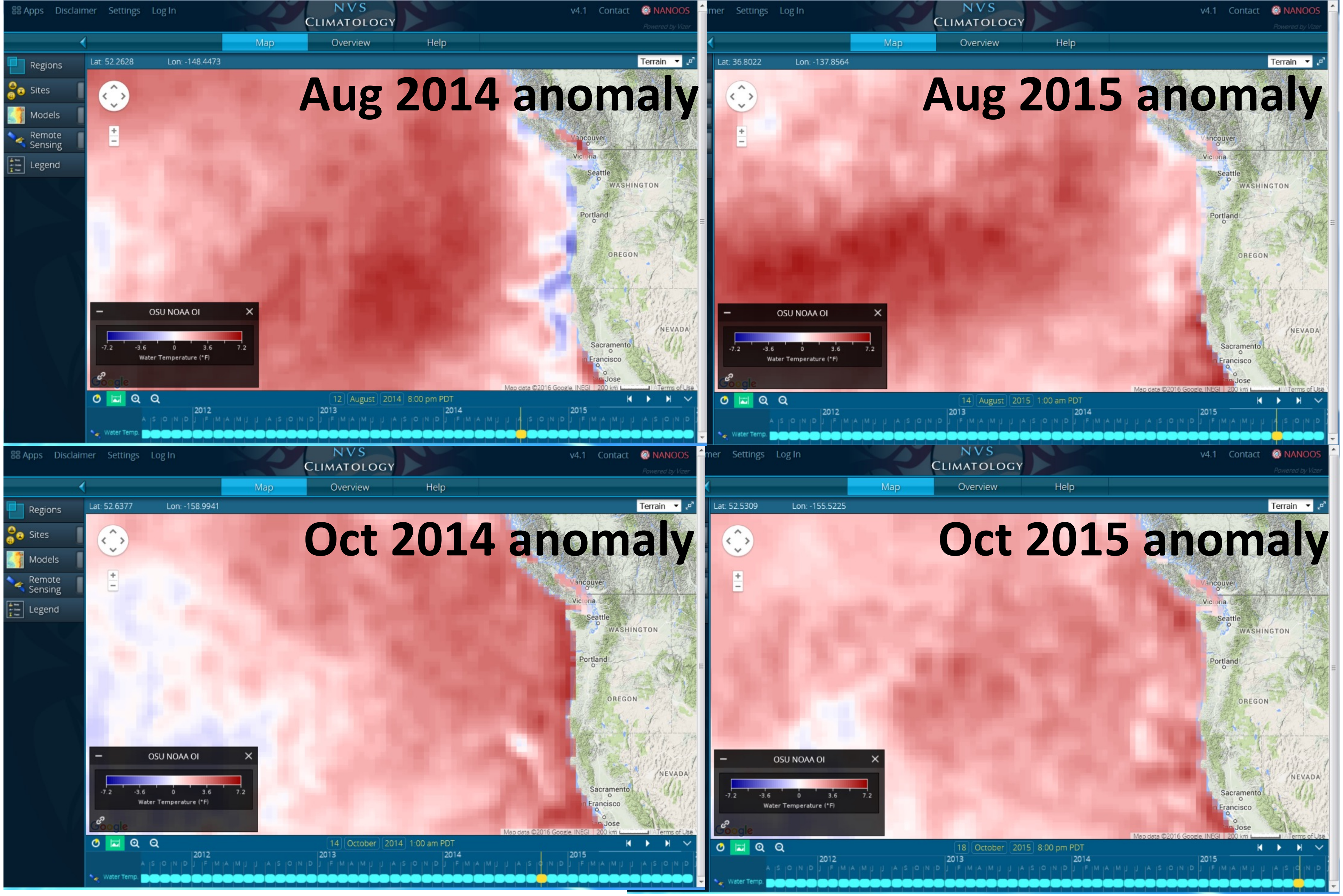






2014


UPWELLING WINDS
DOWNWELLING WINDS
07/01
08/01
09/01
10/01
wind direction (deg. T)
360
300
240
180
120
60
0
a)
wind direction (deg. true coming from)
ChaBa 2014 Temperature (°C) 6/25-10/23
Depth [m]
10
20
30
40
50
60
70
80
Jul
Aug
Sep
Oct
17
16
15
14
13
12
11
10
9
8
7
Temp.
(Celsius)

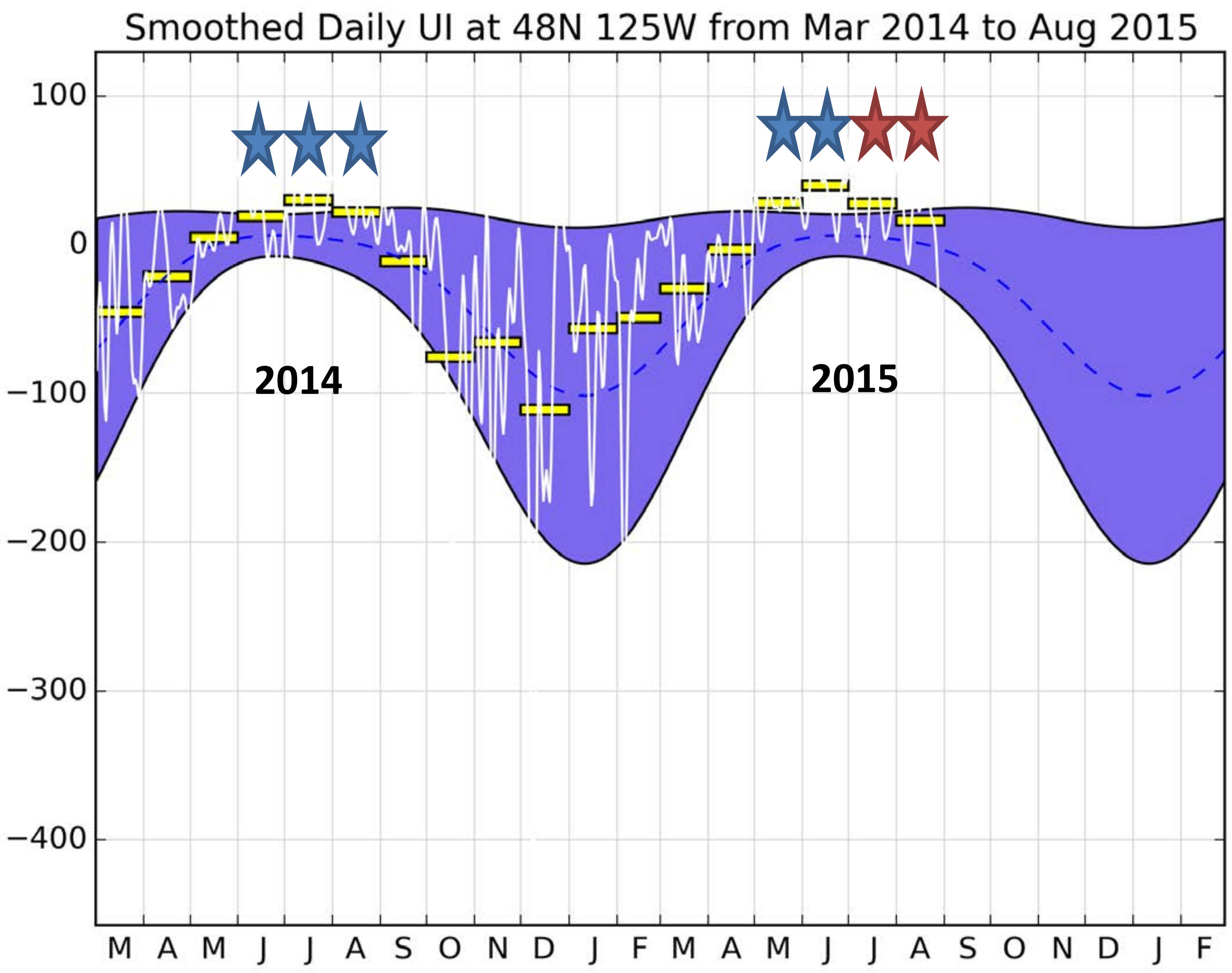


Aug 2015 had warmer than average waters at coast

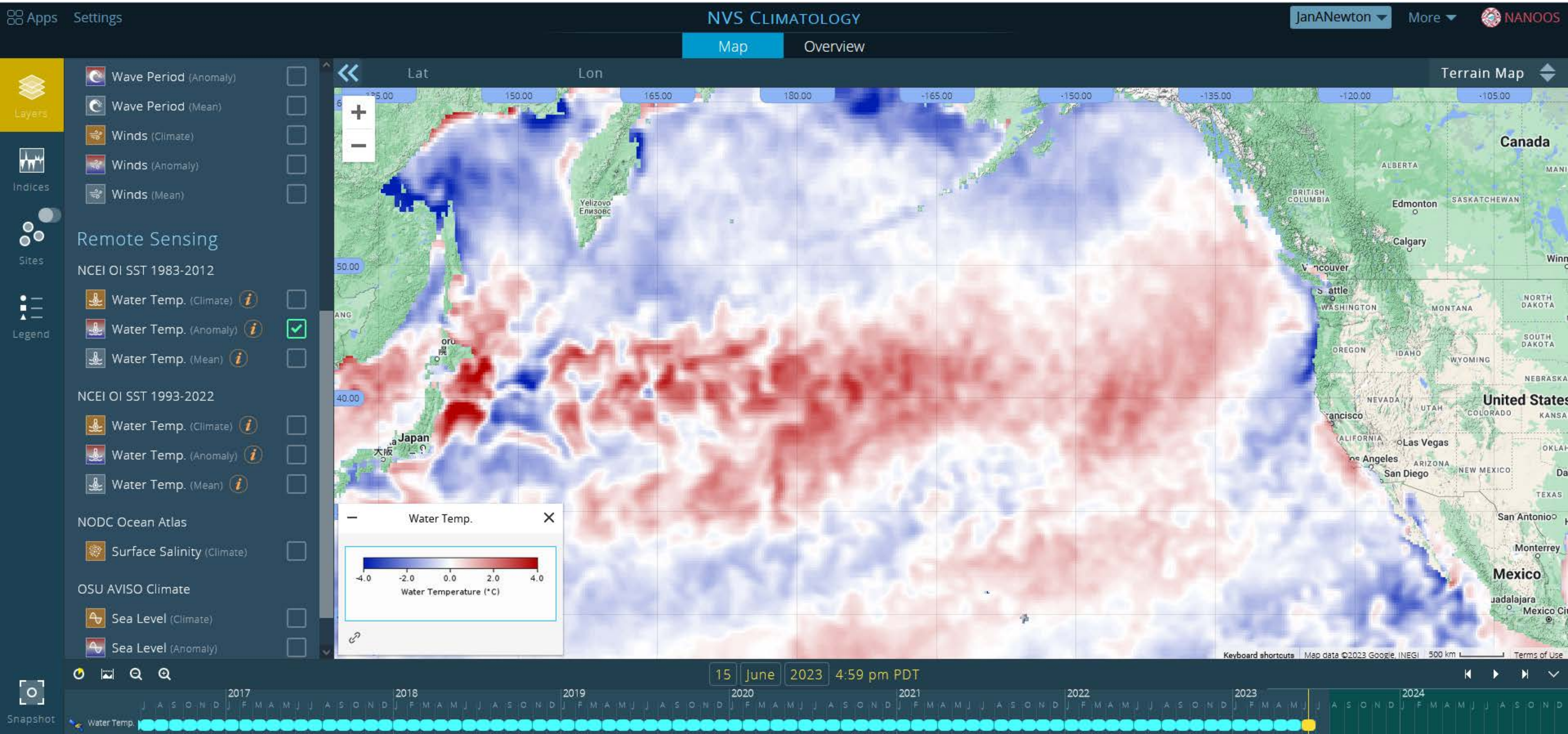
48 N: Upwelling indicated by star

★ = upwelling; cooler than average water T at coast

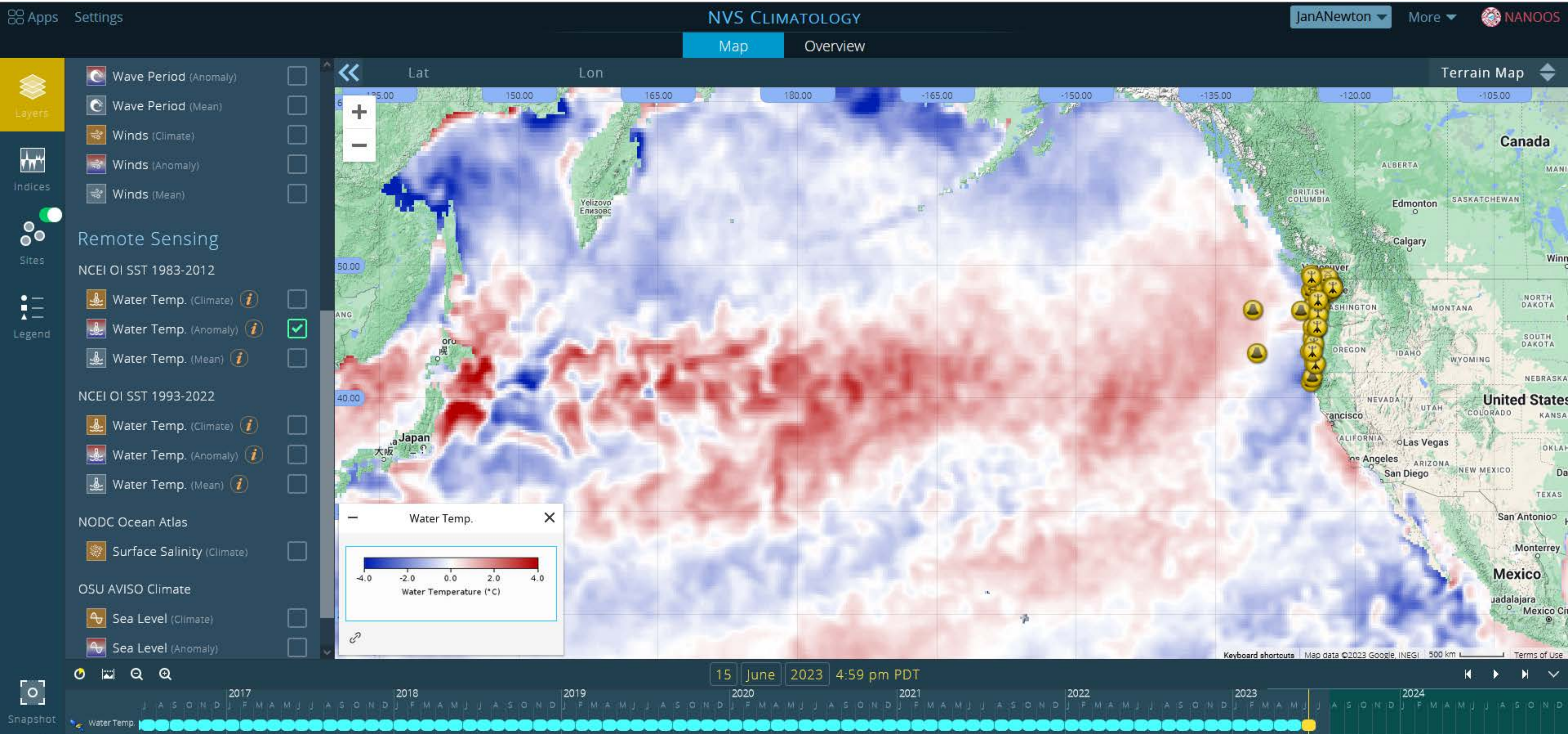
★ = upwelling; warmer than average water T at coast

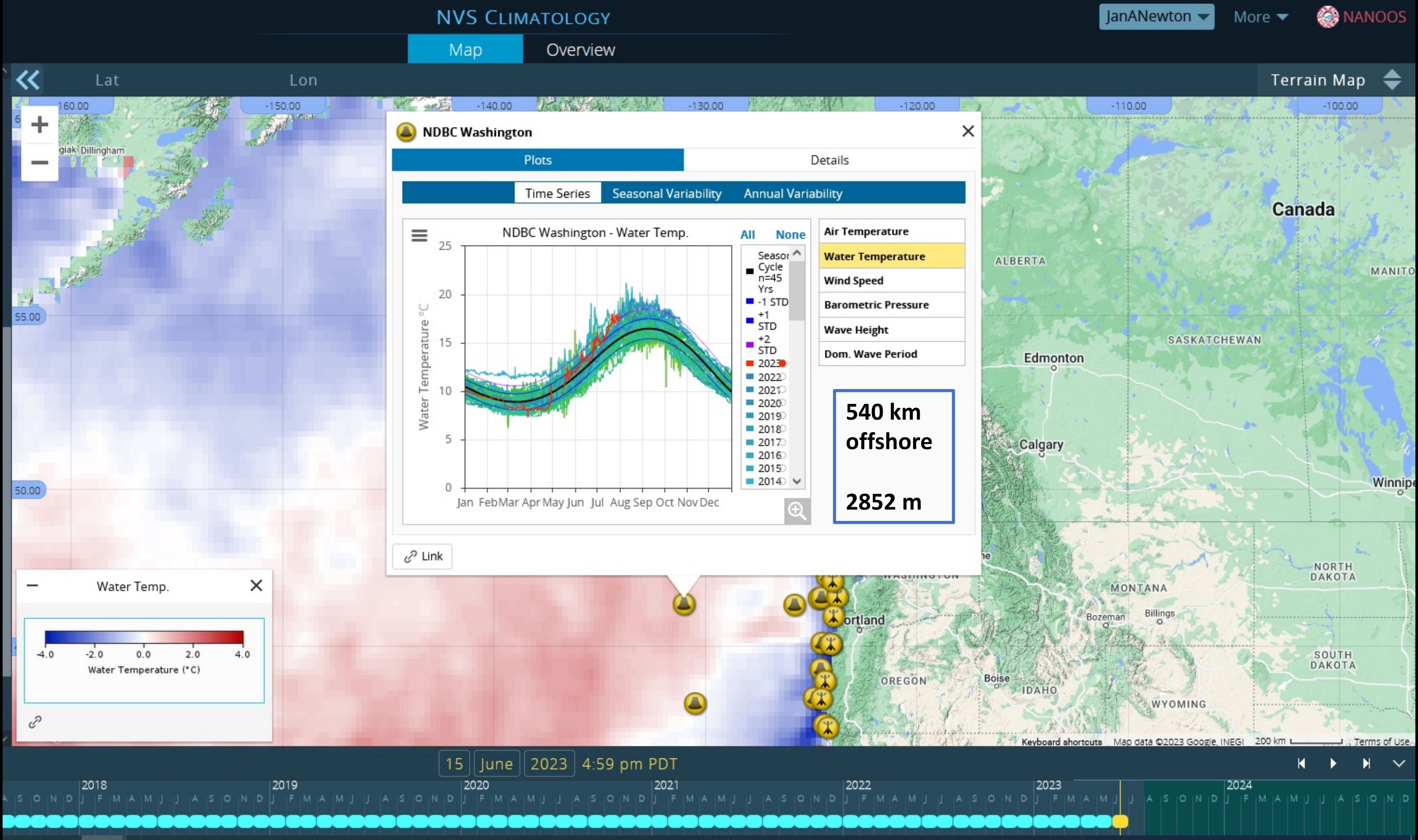


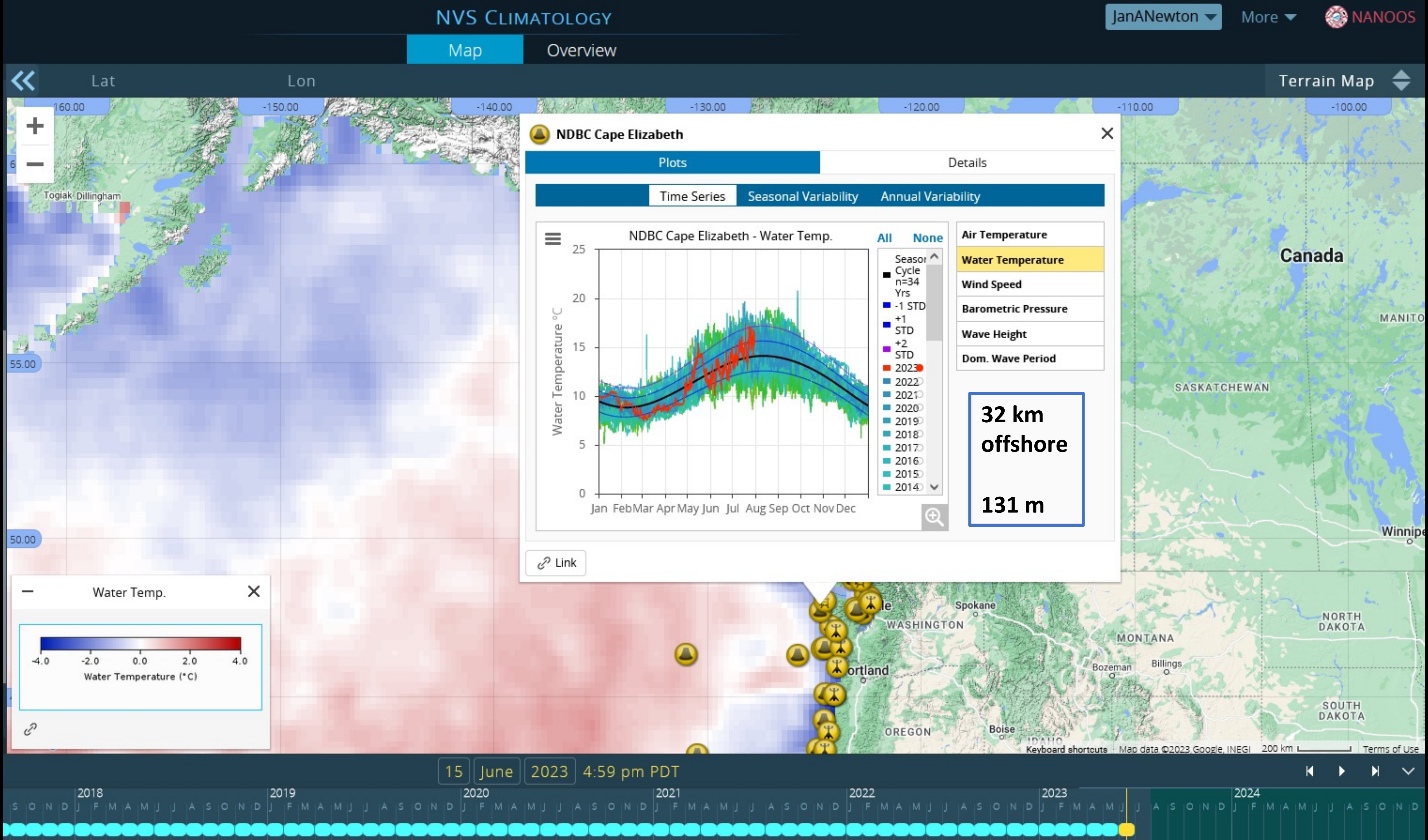
NANOOS NVS Climatology app

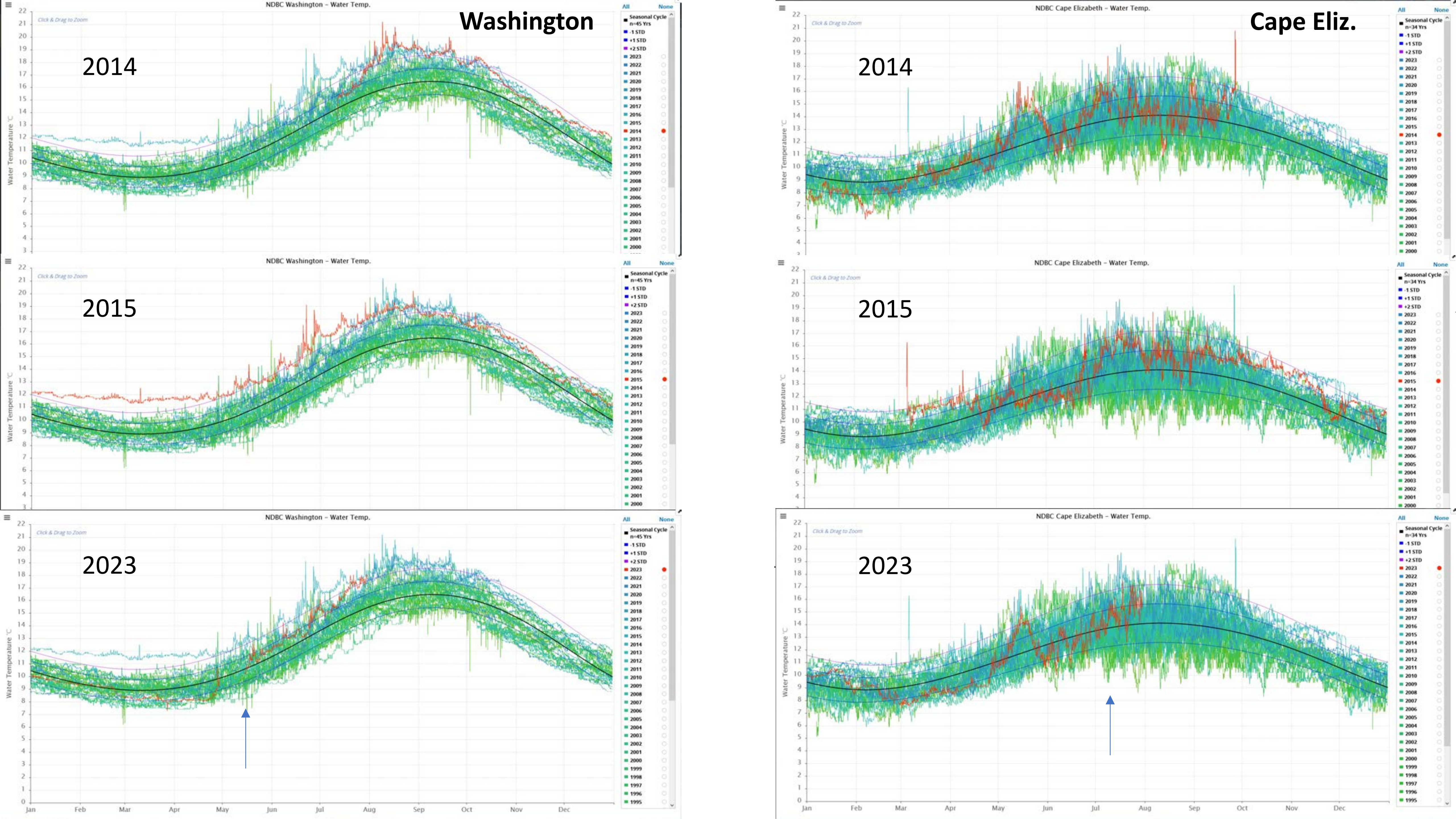


NANOOS NVS Climatology app




NVS Climatology
JanANewton
More
NANOOS
Map
Overview
Lat
Lon
Terrain Map
NDBC Washington
Plots
Details
Time Series
Seasonal Variability
Annual Variability
NDBC Washington - Water Temp.
Water Temperature °C
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
All
None
Season Cycle n=45 Yrs
-1 STD
+1 STD
+2 STD
2023
2022
2021
2020
2019
2018
2017
2016
2015
2014
Air Temperature
Water Temperature
Wind Speed
Barometric Pressure
Wave Height
Dom. Wave Period
540 km offshore
2852 m
Link
Water Temp.
Water Temperature (°C)
Canada
ALBERTA
SASKATCHEWAN
Edmonton
Calgary
MONTANA
OREGON
IDAHO
WYOMING
NORTH DAKOTA
SOUTH DAKOTA
Portland
Boise
Bozeman
Billings
15
June
2023
4:59 pm PDT


NVS Climatology
Map
Overview
NDBC Cape Elizabeth
Plots
Details
Time Series
Seasonal Variability
Annual Variability
NDBC Cape Elizabeth - Water Temp.
Water Temperature °C
Seasonal Cycle n=34 Yrs
-1 STD
+1 STD
+2 STD
2023
2022
2021
2020
2019
2018
2017
2016
2015
2014
Air Temperature
Water Temperature
Wind Speed
Barometric Pressure
Wave Height
Dom. Wave Period
32 km offshore
131 m
Water Temp.
Water Temperature (°C)
Canada
WASHINGTON
OREGON
MONTANA
Terrain Map
15 June 2023 4:59 pm PDT


Washington
Cape Eliz.
NDBC Washington – Water Temp.
NDBC Cape Elizabeth – Water Temp.
2014
2015
2023
Water Temperature °C
Seasonal Cycle n=45 Yrs
Seasonal Cycle n=34 Yrs
-1 STD
+1 STD
+2 STD
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

PLOS ONE

RESEARCH ARTICLE

Large and transient positive temperature anomalies in Washington's coastal nearshore waters during the 2013–2015 northeast Pacific marine heatwave

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☯ These authors contributed equally to this work.
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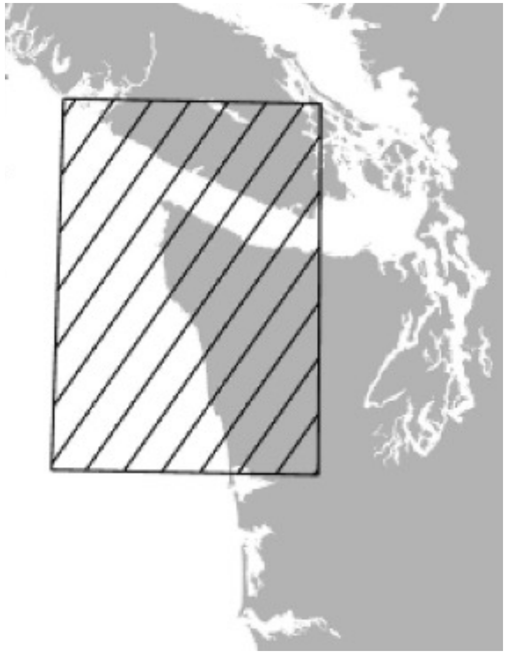
* julie.koehlinger@hohtribe-nsn.org



UW School of Marine and Environmental Affairs

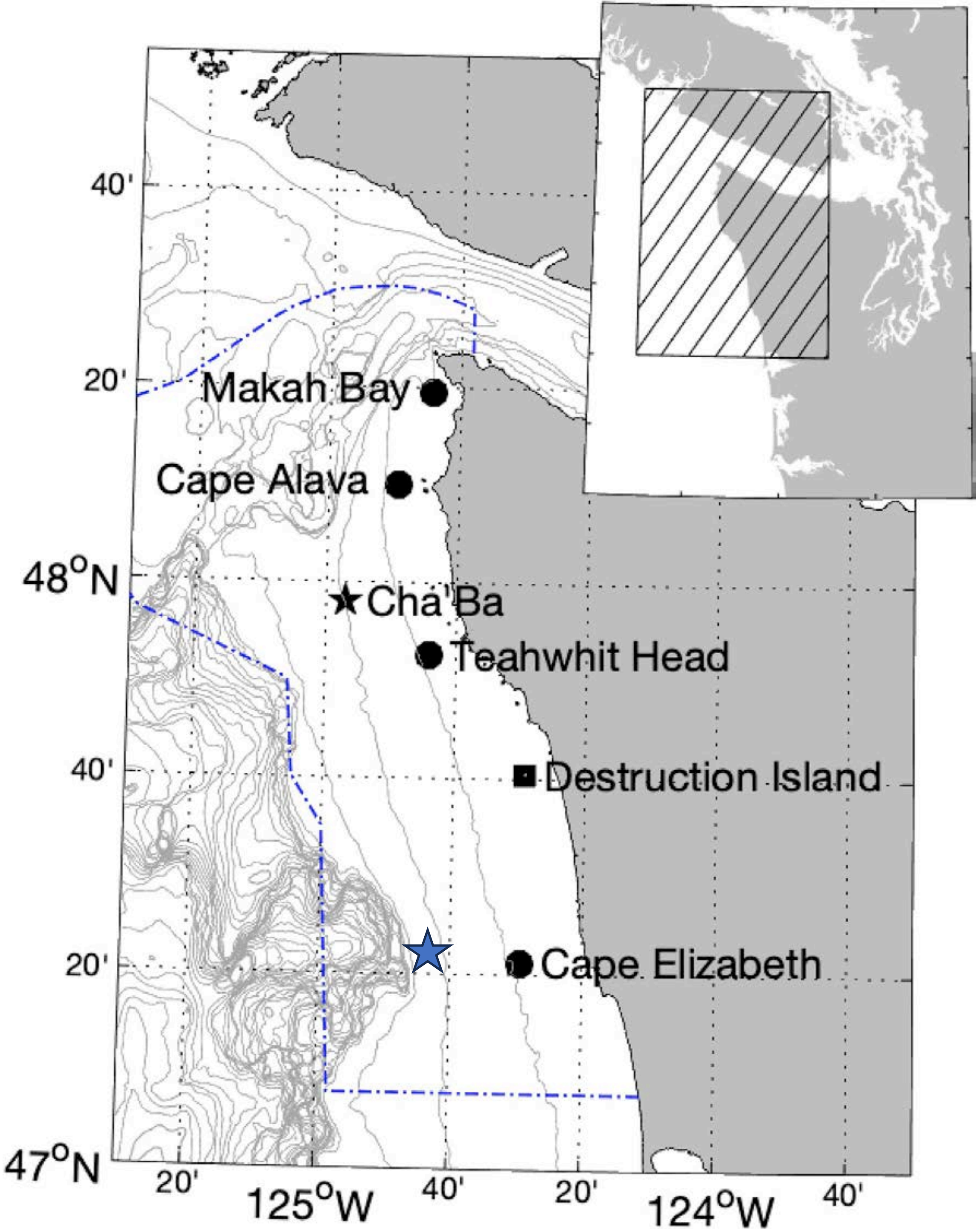
JAK's Masters project

Observations:

Olympic Coast National Marine Sanctuary (OCNMS) stations (circles) are within 15 km offshore with bottom depths of approximately 42 m.

Cha’ba (black star) is 25 km offshore at 100 m depth

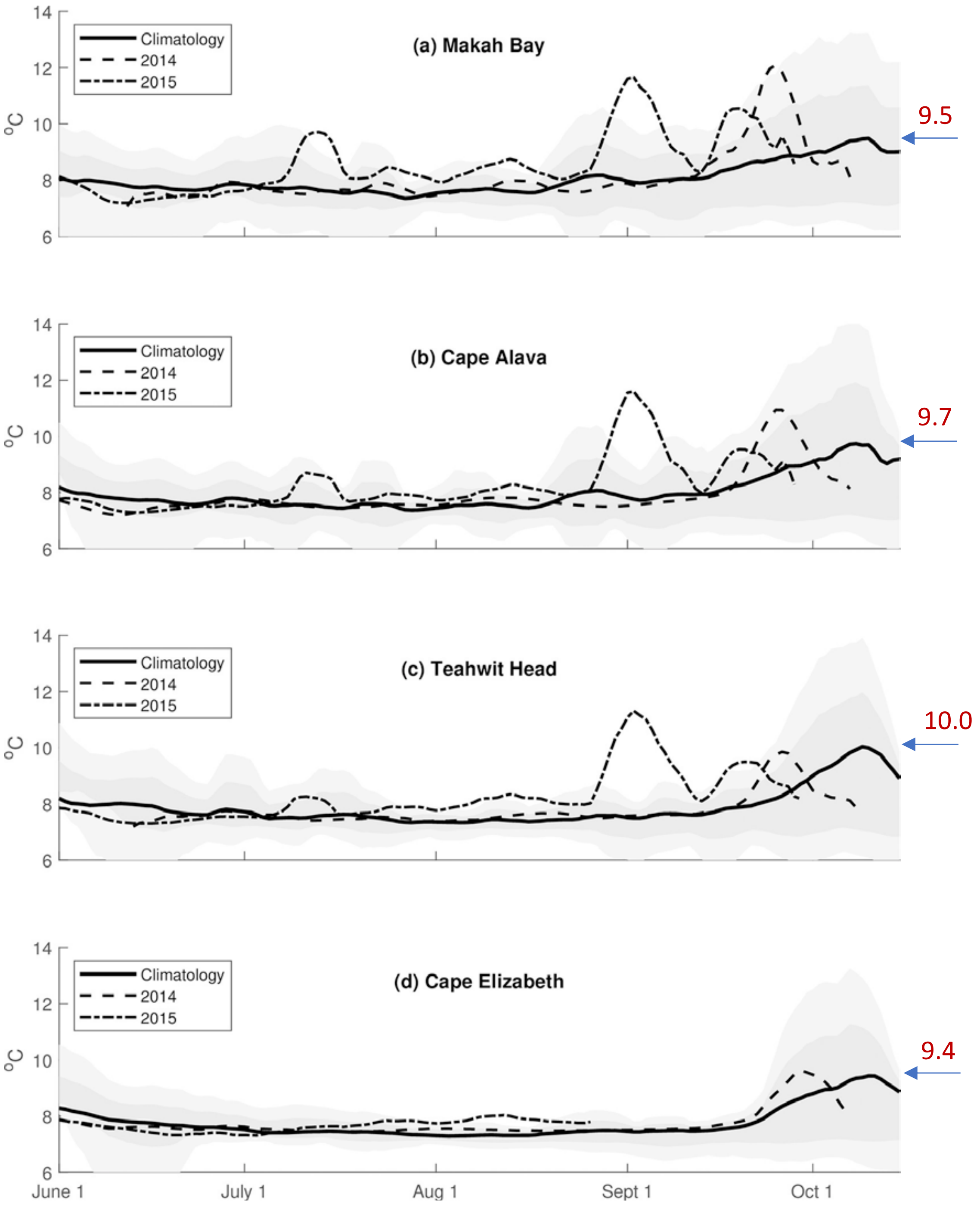
Cape Elizabeth NDBC (blue star) is 32 km offshore at 131 m depth



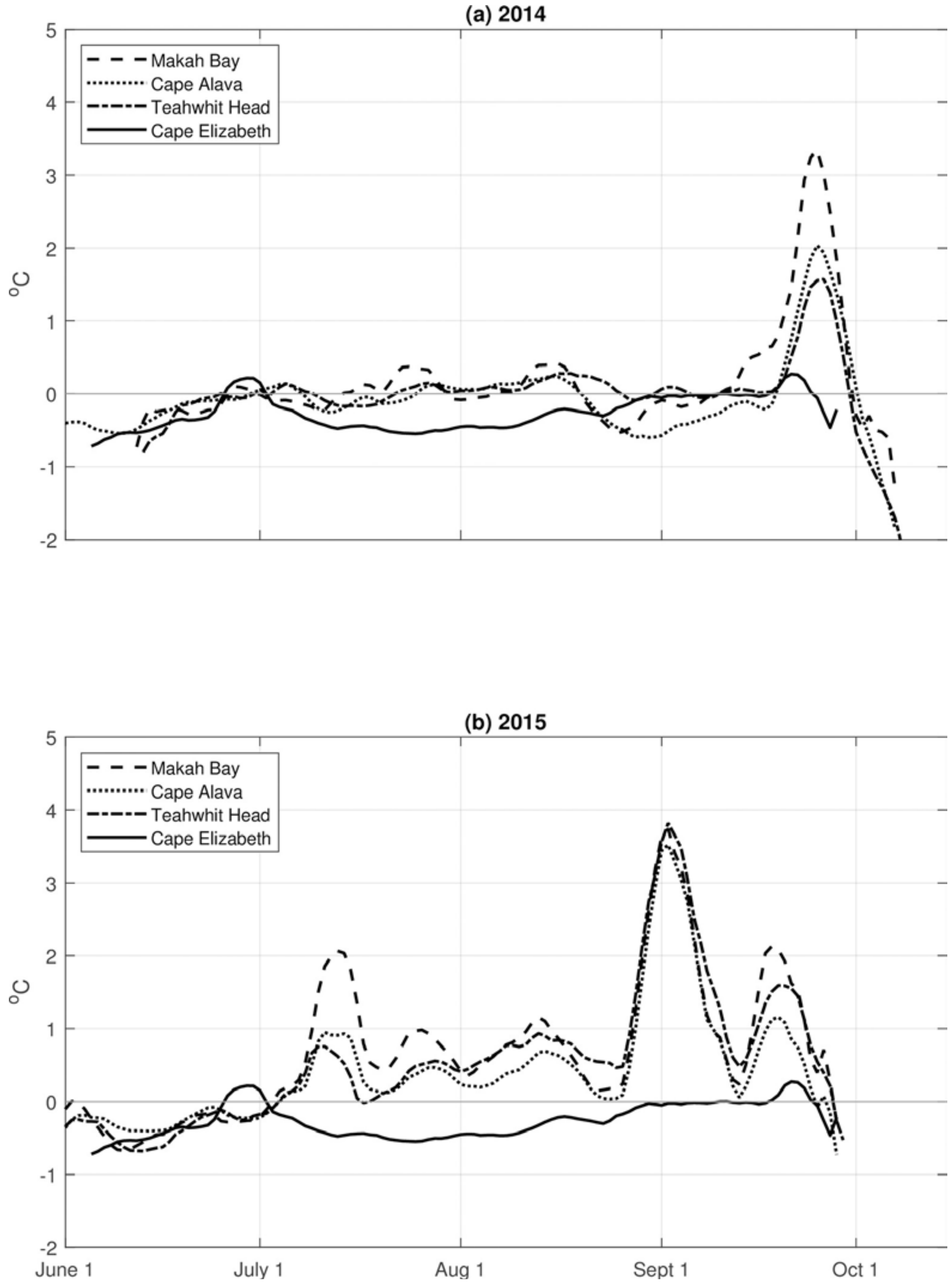
Koehlinger JA, et al. 2023. PLoS ONE 18(2): e0280646.
https://doi.org/10.1371/journal.pone.0280646

Episodic positive temperature anomalies observed

- Compared to a long-term climatology of 2001–2013, seven-day smoothed **temperature anomalies of up to 4.5˚C** are found at 40m depth during 2014 and 2015, seen as short-term events lasting 10–20 days.
- These periods of warming occurring within the Northeast Pacific marine heatwave (MHW) were about **twice the seasonal temperature range** in the climatology at that depth.
- These warm events were strongly correlated with periods of northward long-shore winds and upper ocean currents, consistent with what is expected for the **response to downwelling-favorable winds.**



Koehlinger JA, et al. 2023.



Temperature gradients shifted

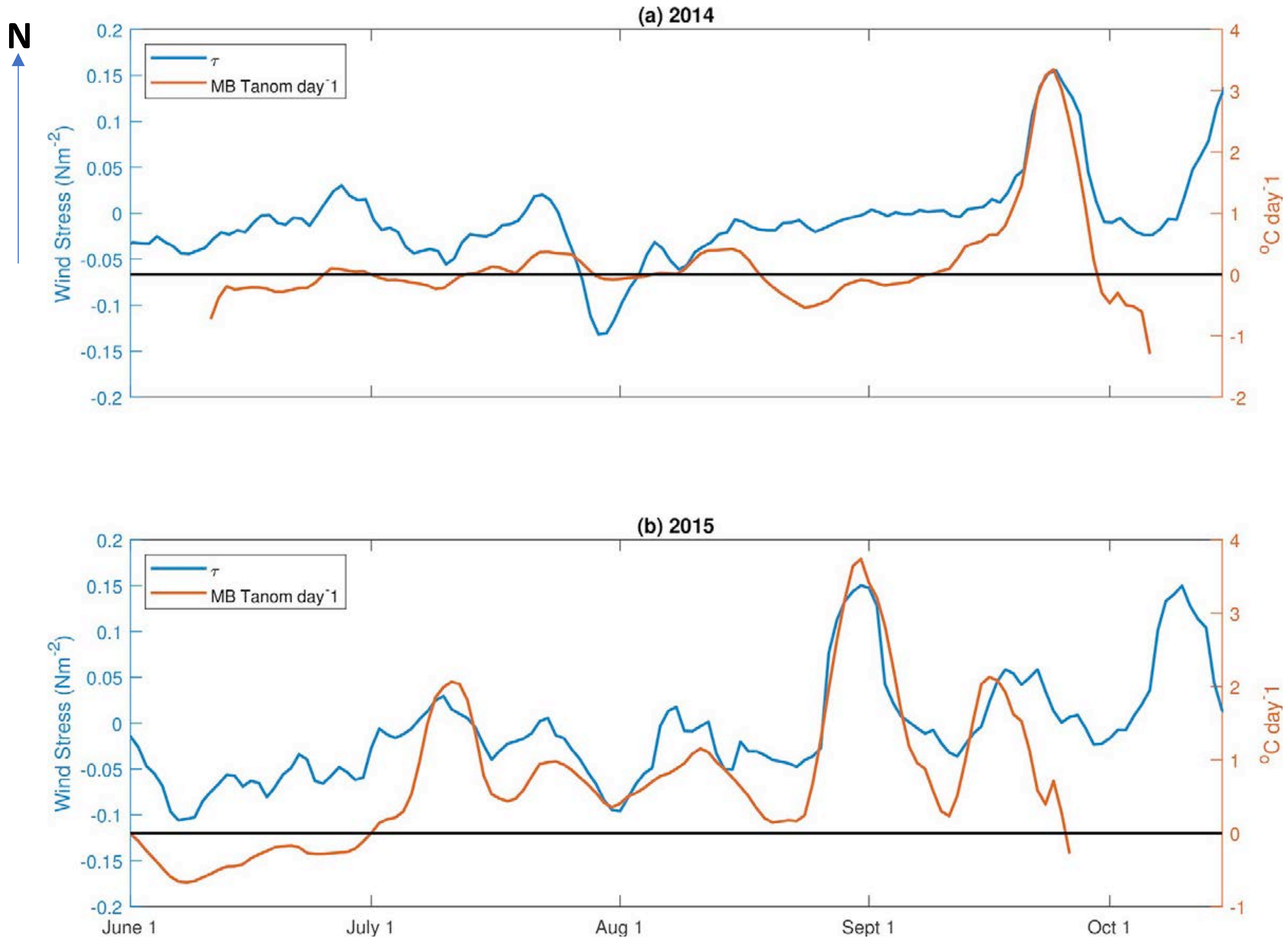
The advection of an offshore water mass of uniform alongshore temperature into the nearshore would result in larger anomalies in the north, given that **our reference climatology shows decreasing temperatures to the north except for Cape Elizabeth**.

However, in 2014–2015 we detected not only a **positive north-south anomaly gradient, but also a positive north-south absolute temperature gradient**.

That is, 40m temperatures in the north were warmer than temperatures in the south and consistently decreased from Makah Bay to Cape Elizabeth during the summers of 2014 and 2015.

Koehlinger JA, et al. 2023.

Wind stress correlation



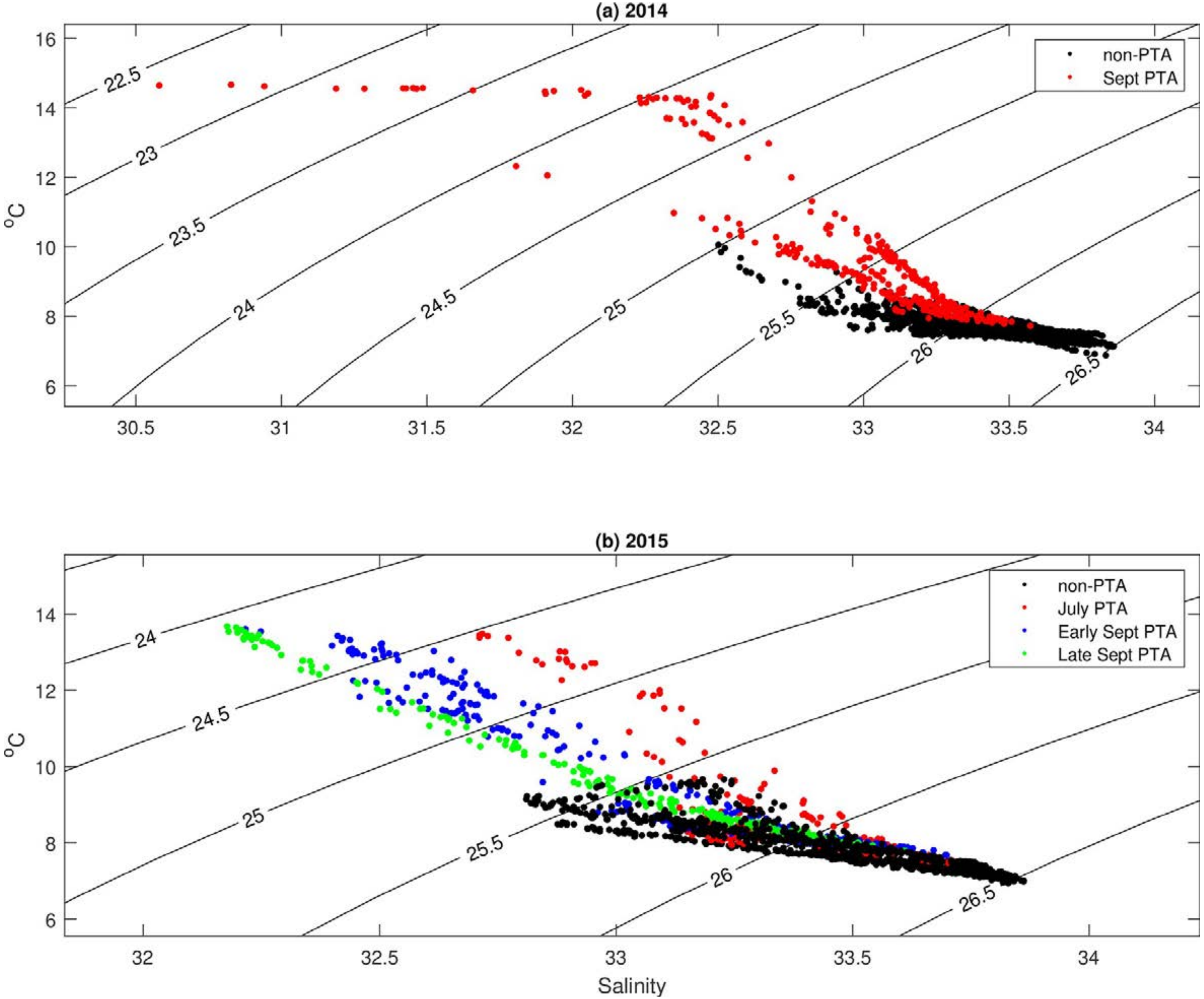
We found that the 40m temperature anomaly was significantly correlated with the along-shore wind stress during both 2014 and 2015.

In 2014, the correlation was strongest when temperature anomalies lagged wind stress by 1 day (r = 0.76).

In 2015, this strong correlation was seen with an increased lag period of 2 days (r = 0.77).

Temperature was higher with downwelling-favorable winds (from the south).

Koehlinger JA, et al. 2023.



Temp anomalies also fresher

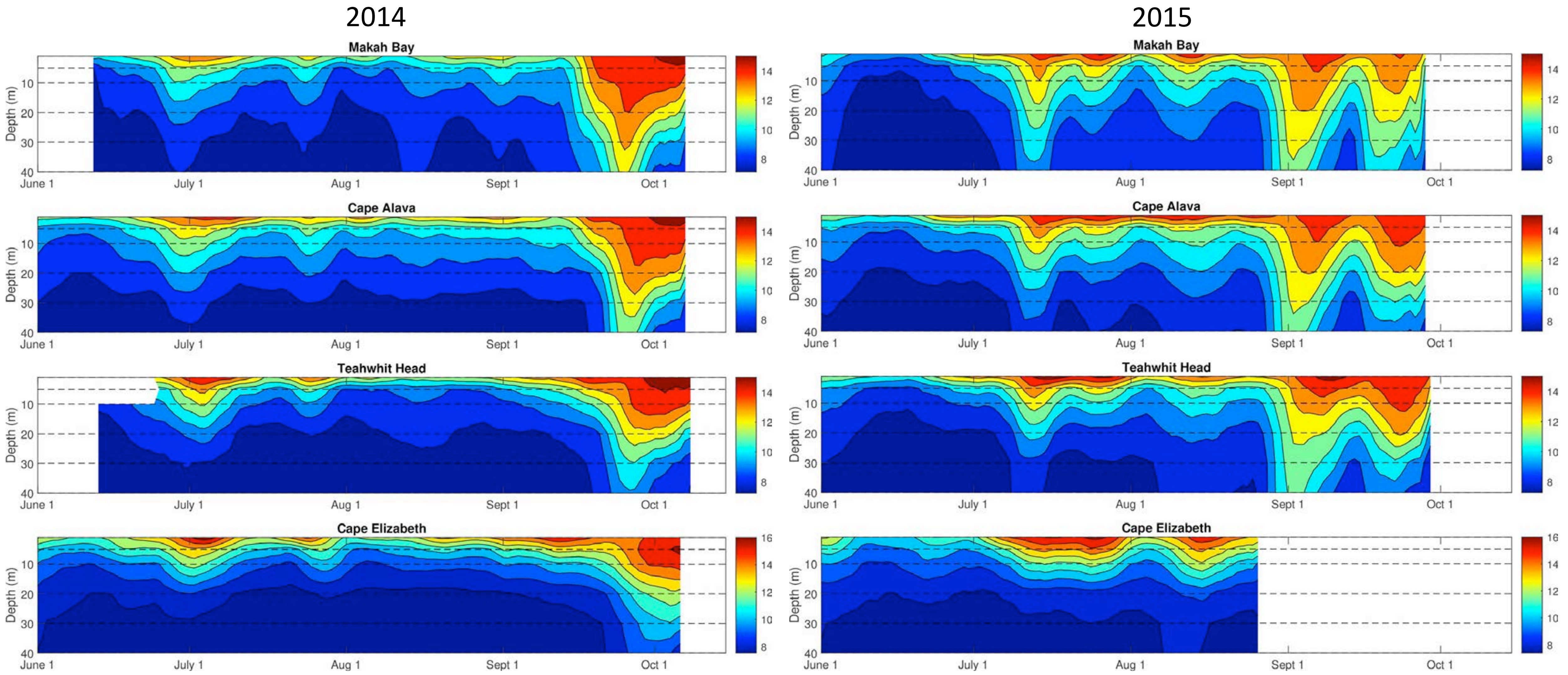
Salinity variations are consistent with our interpretation of the causes of variations in temperature.

At Makah Bay, **when the temperature at 40m began warming it also became fresher for the duration of the positive temperature anomaly.**

Both the cessation of upwelling that transports saltier water to the inner shelf and increased freshwater input via rain and rivers that is associated with strong southerly wind (storm) events may be involved.

Koehlinger JA, et al. 2023.

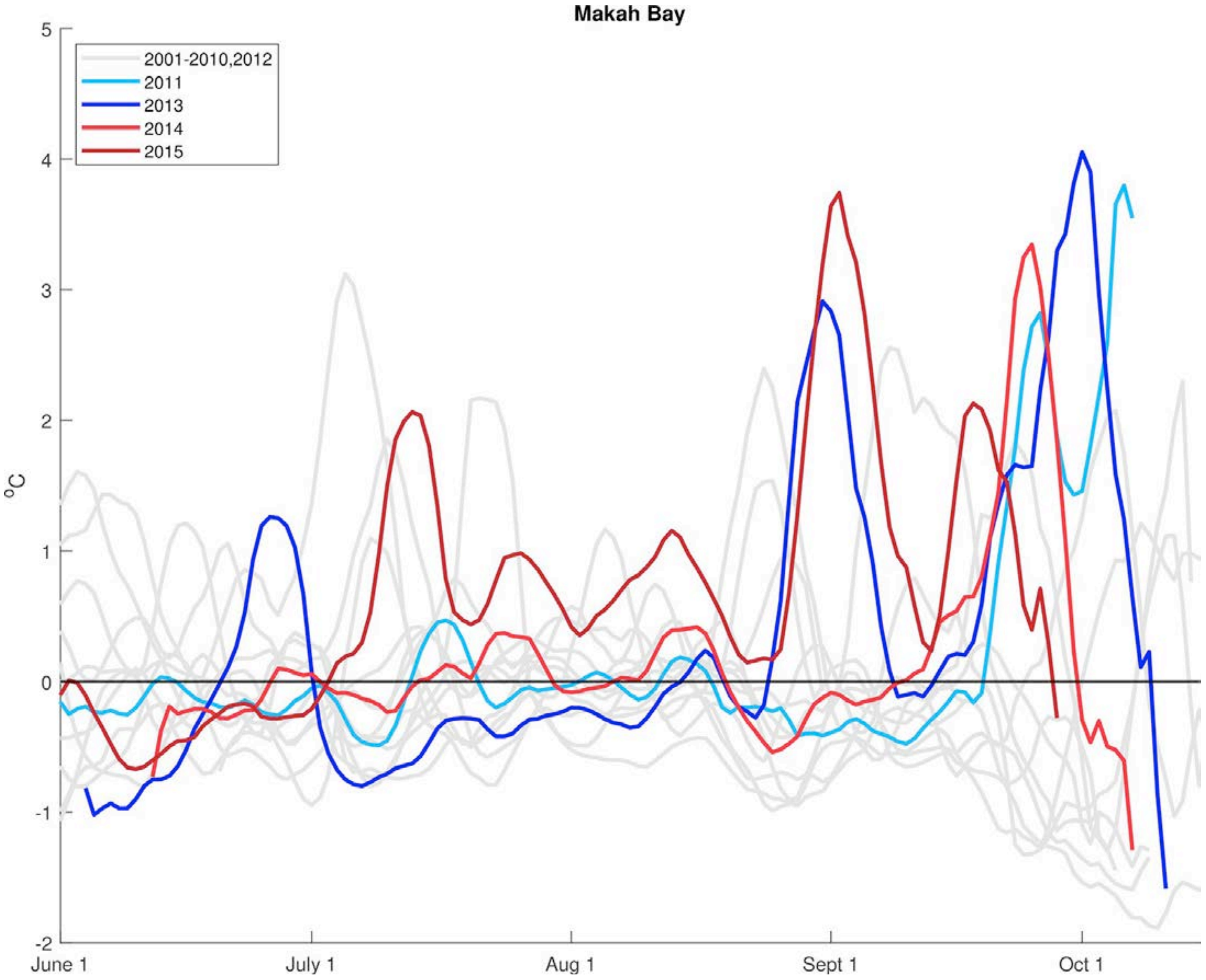
Downwelling exposes more of the water column to MHW conditions, and it happens quickly



Association with MHW ?

While our focus *a priori* was on 2014 and 2015, we also found large positive temperature events in 2013, which were potentially related to the early stage of the MHW, and in 2011, which did not have a documented MHW.

Nearshore short-term warm events occur during periods of large-scale offshore MHWs, but also can occur in their absence; however, the large-scale MHW may have accentuated the magnitude and timing of the nearshore temperature extremes.

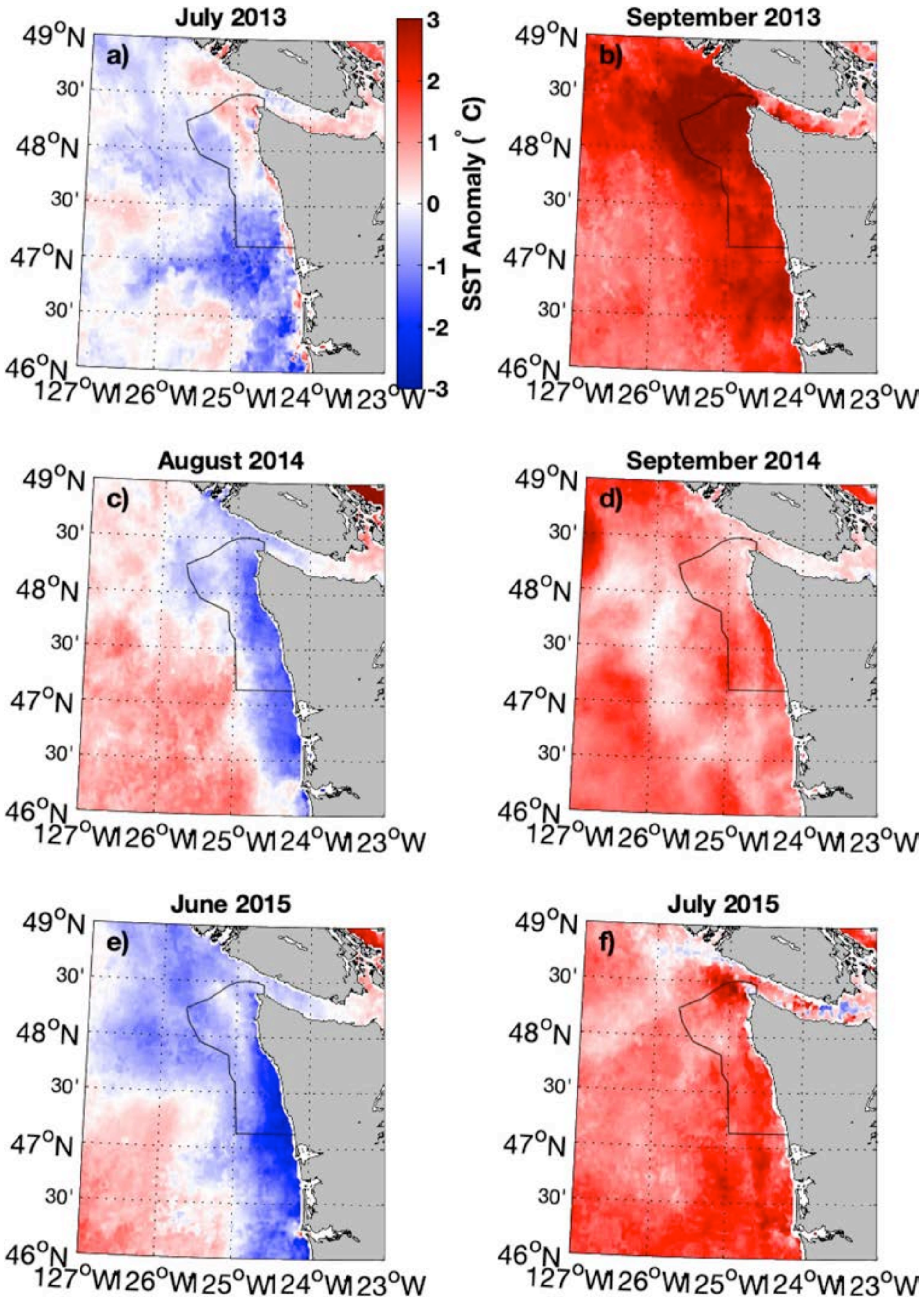


Koehlinger JA, et al. 2023.

Conclusions

- In the coastal waters of the Pacific Northwest during MHWs we observe substantial variation: in temperature along both onshore-offshore and north-south gradients over time, and in the effectiveness of upwelling to buffer the coast from MHW conditions.
- Positive temperature anomalies at depth (40 m) in the nearshore (15 km offshore) were
  - about twice the size of the seasonal cycle.
  - episodic, fluctuating on timescales of days to weeks instead of weeks to months.
  - not restricted to the period of the MHW, but the large scale MHW may have accentuated the magnitude and timing of the nearshore temperature extremes.
- Positive temperature anomalies were correlated with local wind forcing, currents, and Ekman transport implying that shifts between upwelling and downwelling caused much of the observed variability.
- Downwelling exposes more of the water column to MHW conditions, and it happens quickly.
- Such large temperature excursions and their fluctuating nature could impact nearshore biota.
- Understanding the potential effects of such events on nearshore ecosystems can help guide climate change adaptation and underscores the need for continued monitoring of nearshore environments.

Extra slides if needed



July 2013
September 2013
August 2014
September 2014
June 2015
July 2015
a)
b)
c)
d)
e)
f)
SST Anomaly (˚C)
3
2
1
0
-1
-2
-3
49°N
30'
48°N
30'
47°N
30'
46°N
127°W
126°W
125°W
124°W
123°W

Table 3. Minimum and maximum 40 m temperatures (1 June– 15 October) at each station with +/- 1 standard deviation.

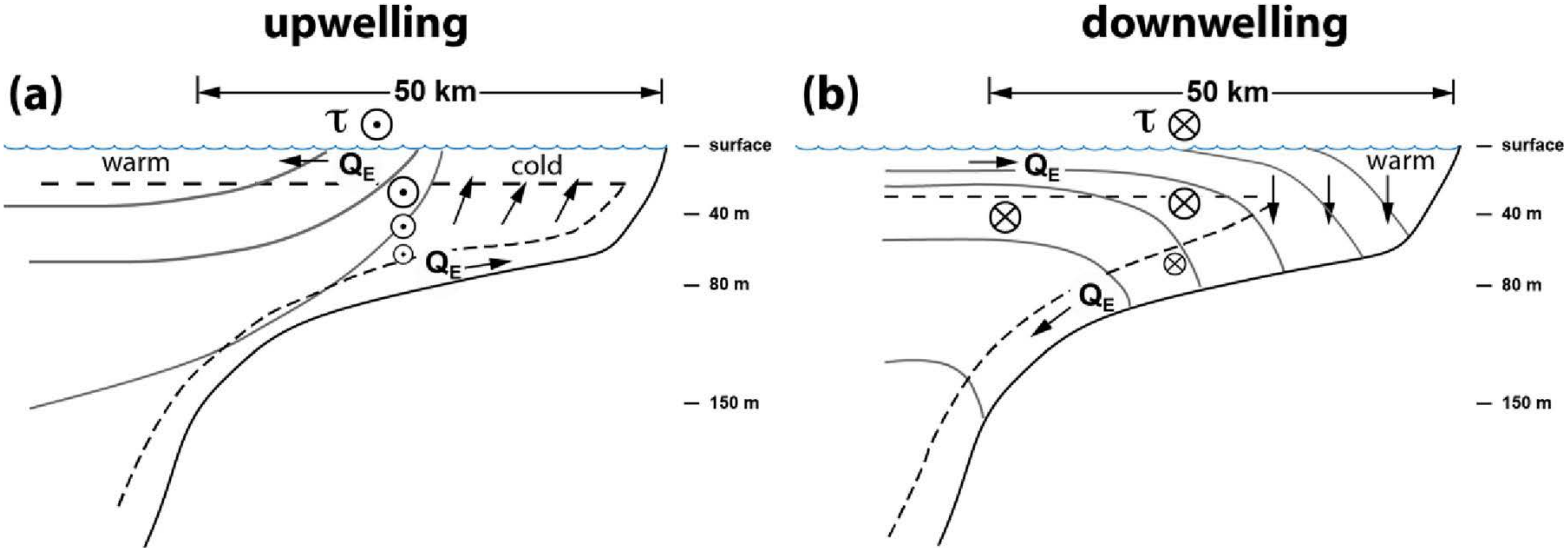
Station (years of climatology)	Minimum (˚C)	Maximum (˚C)
Makah Bay (2001–13)	7.3 +/- 0.3	9.5 +/- 1.9
Cape Alava (2001–13)	7.4 +/- 0.3	9.7 +/- 2.2
Teahwhit Head (2002–13)	7.4 +/- 0.2	10.0 +/- 2.1
Cape Elizabeth (2004–13)	7.3 +/- 0.1	9.4 +/- 1.6

Stations are listed in order from north to south. Initial year of data collection varies as noted.

https://doi.org/10.1371/journal.pone.0280646.t003

Table 4. Maximum temperature at 40-m, maximum temperature anomaly at 40-m, and number of standard deviations above climatology at each station during peak temperature anomaly periods.

Station	Sept 2014	Early Sept 2015
	Temperature (˚C)	Temperature (˚C)
Makah Bay		
Maximum	12.1	11.7
Max. Anomaly	3.4	3.7
Std. dev. (σ) above climatology	2.2	4



upwelling
downwelling
(a)
50 km
τ
warm
Q_E
cold
Q_E
surface
40 m
80 m
150 m
(b)
50 km
τ
Q_E
warm
Q_E
surface
40 m
80 m
150 m