Current and Future Marine Conditions – Implications for Salmon Management

Tommy Moore

Oceanographer

Northwest Indian Fisheries Commission - Coastal Office

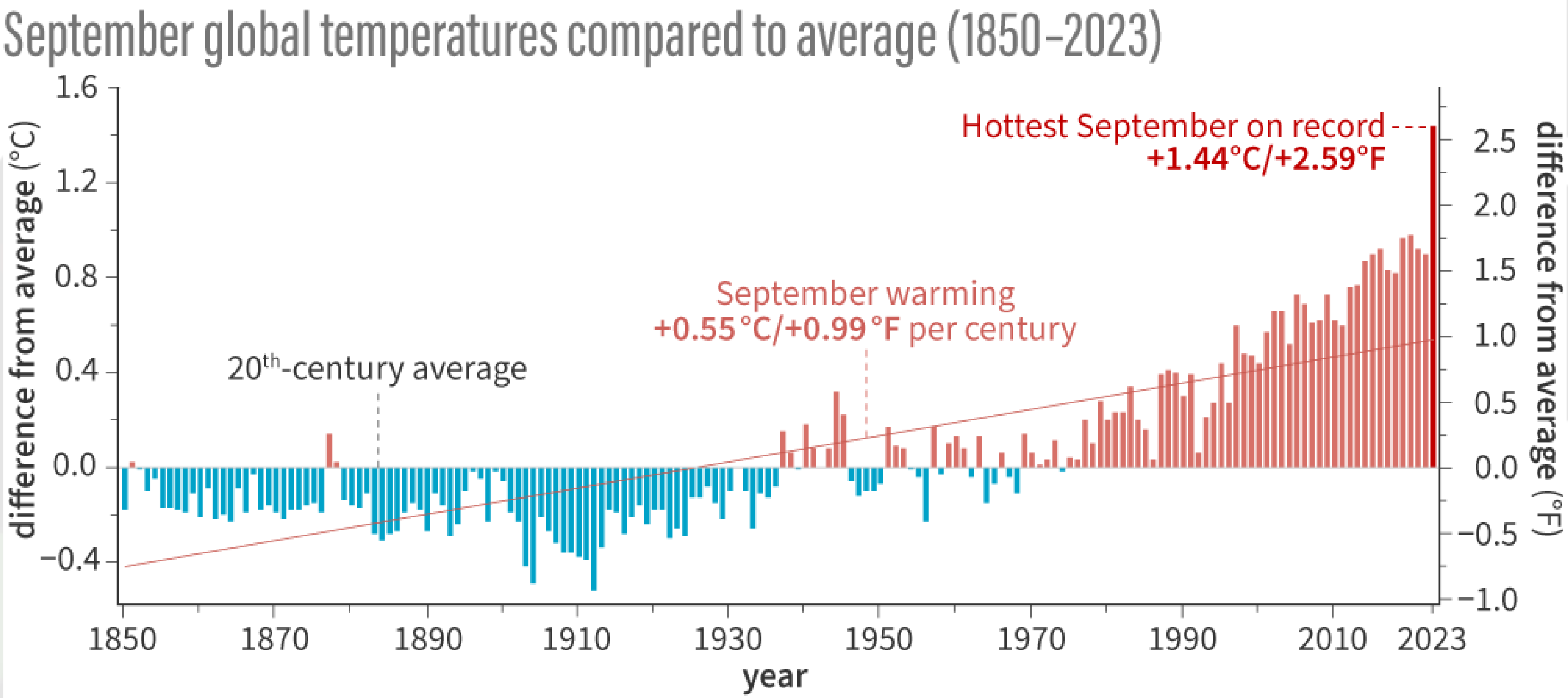
tmoore@nwifc.org

Overview

- Marine climate drivers of concern?
  - Global/Basin scale – ENSO, PDO, NPGO
  - Regional – MHWs, upwelling timing and intensity, foodweb
  - Local – near shore SST, productivity, O_2
- How is this information used in management?

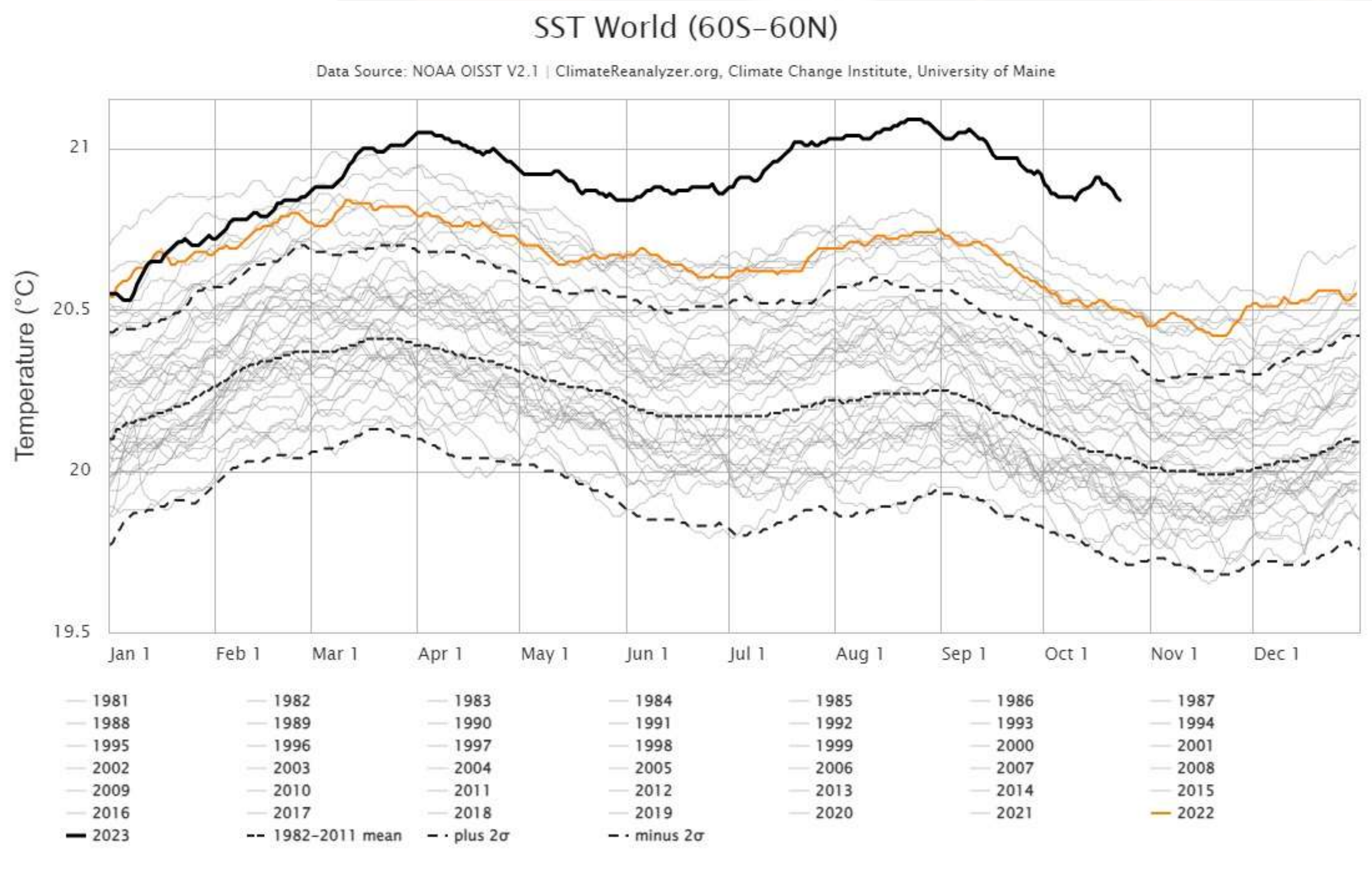
Global Climate Trends

- September was the 4th month in a row of record-warm global temps

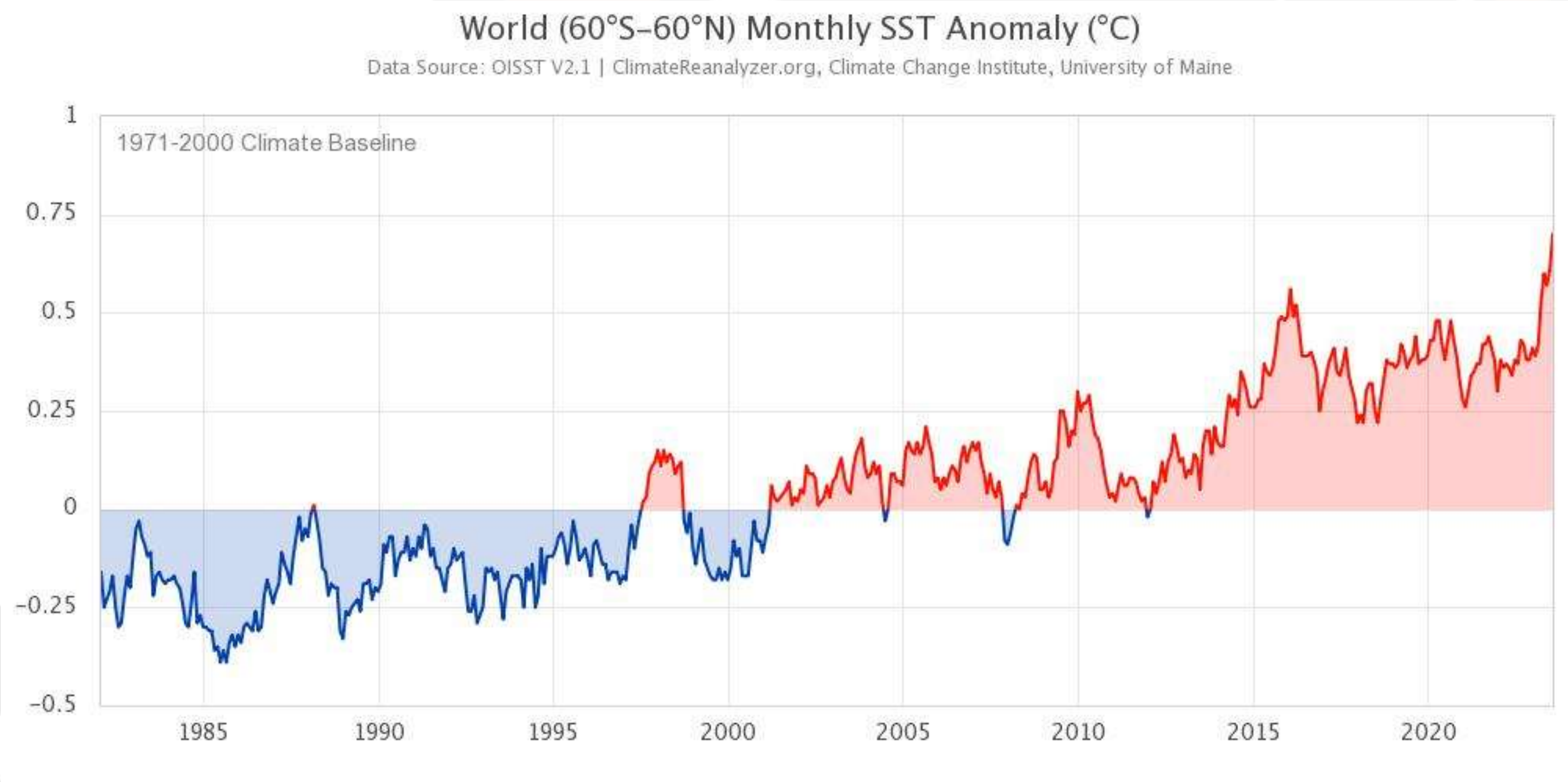


https://www.climate.gov/news-features/understanding-climate/global-climate-summary-september-2023

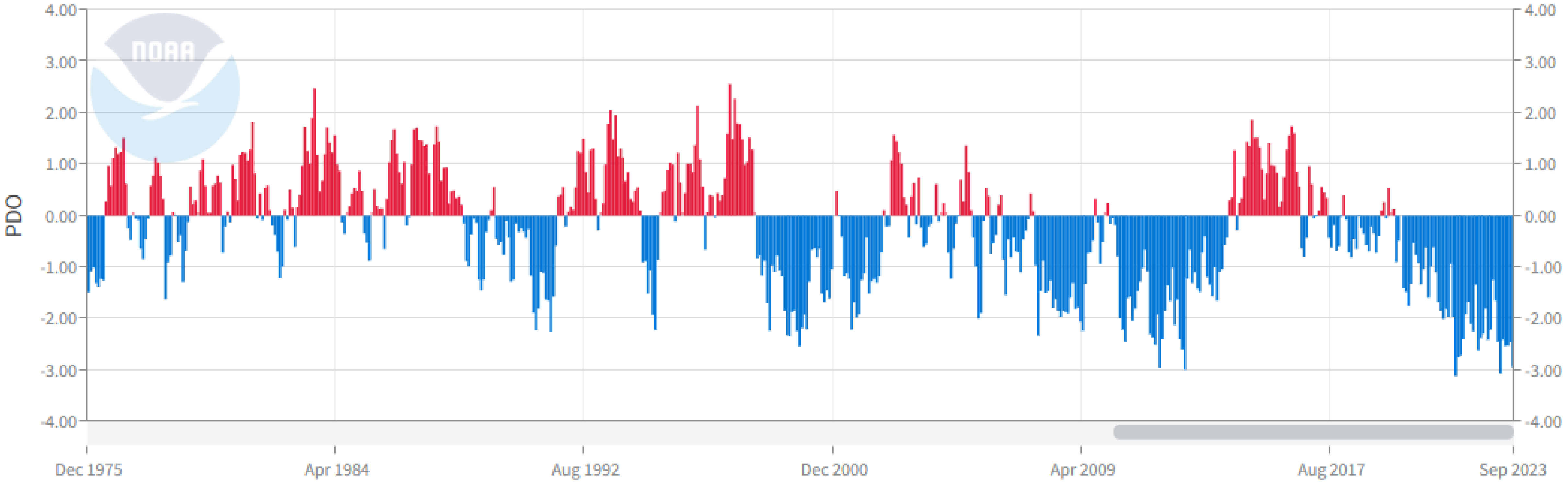
Global Climate Trends



Global Climate Trends

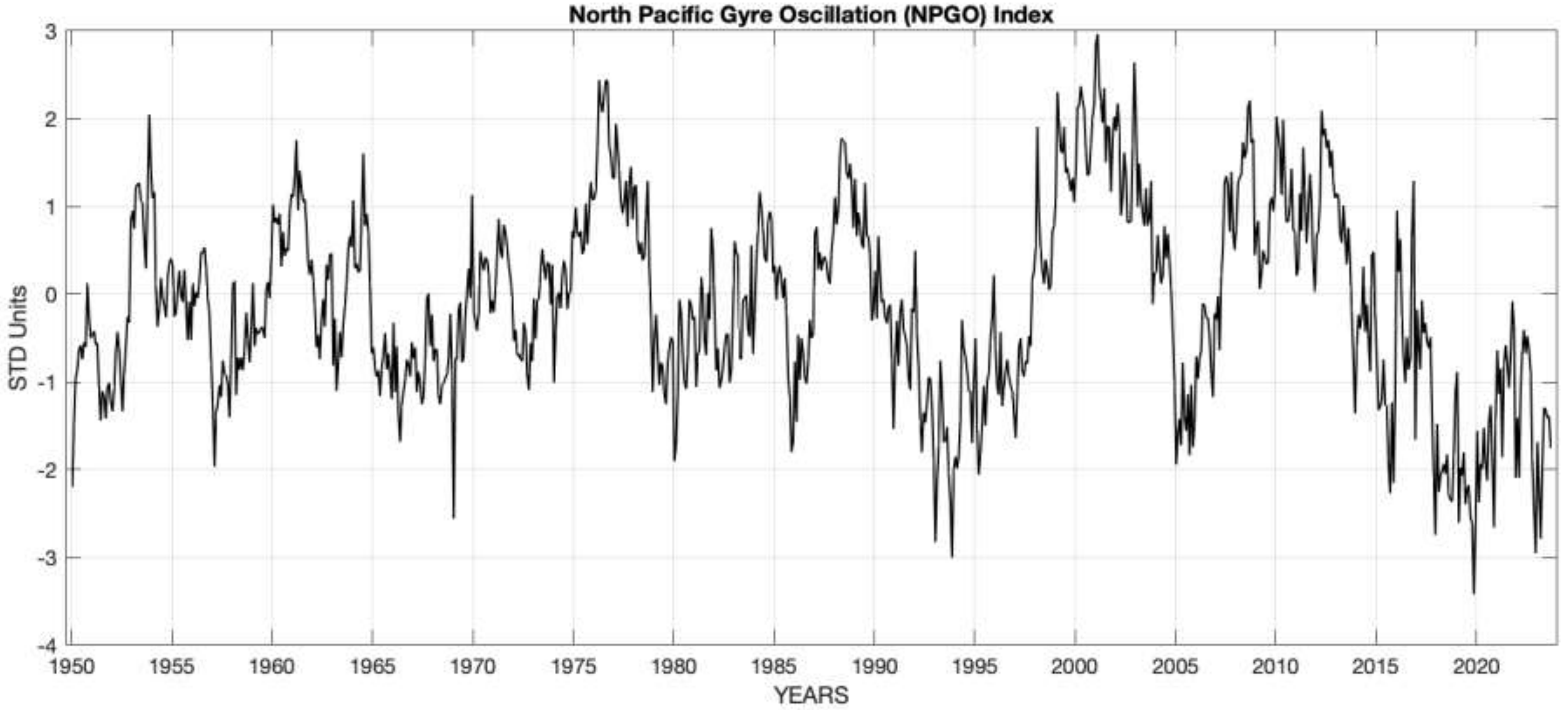


Basin Scale Marine Conditions - PDO



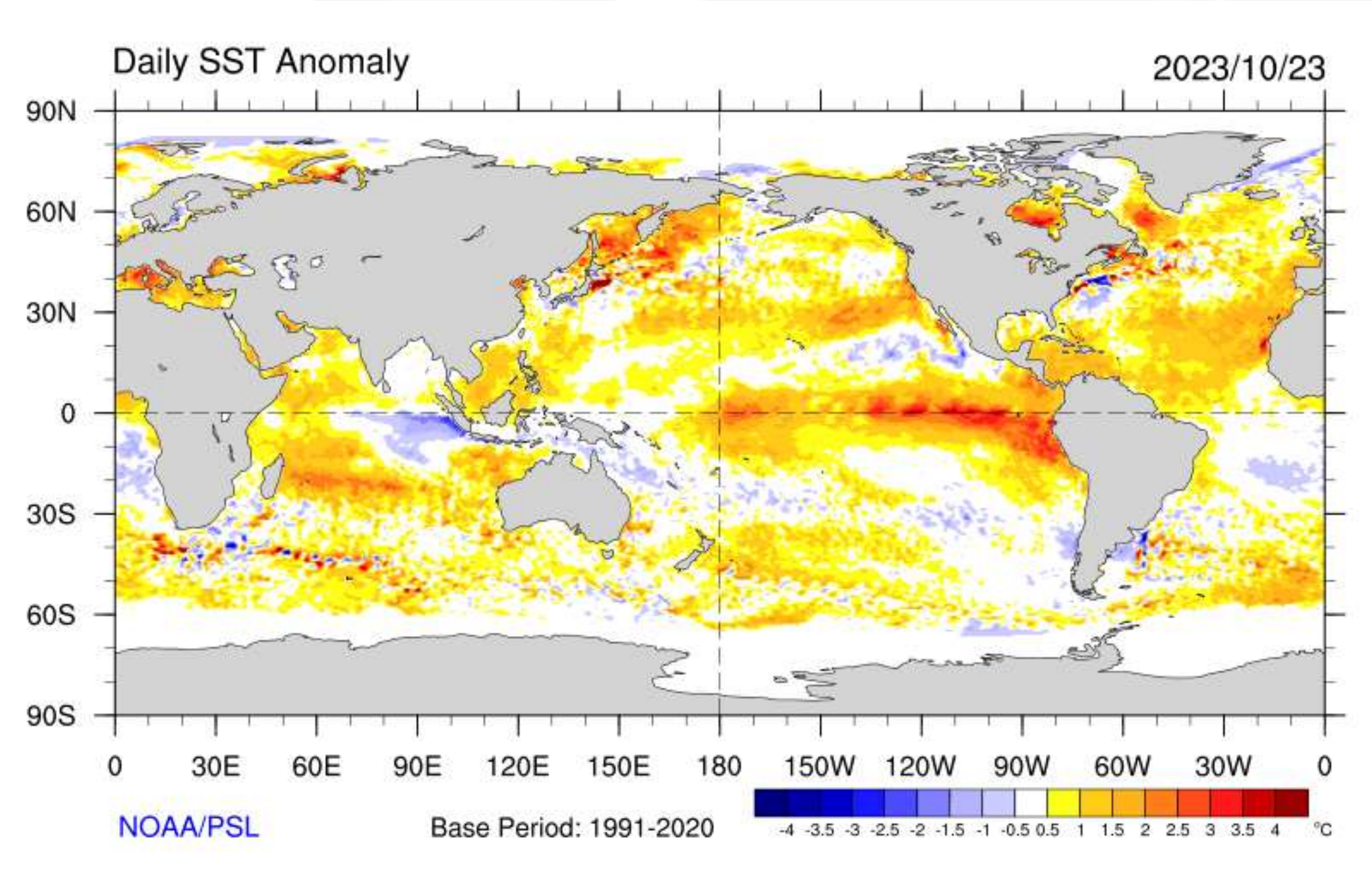
https://www.ncei.noaa.gov/access/monitoring/pdo/

Basin Scale Marine Conditions - NPGO

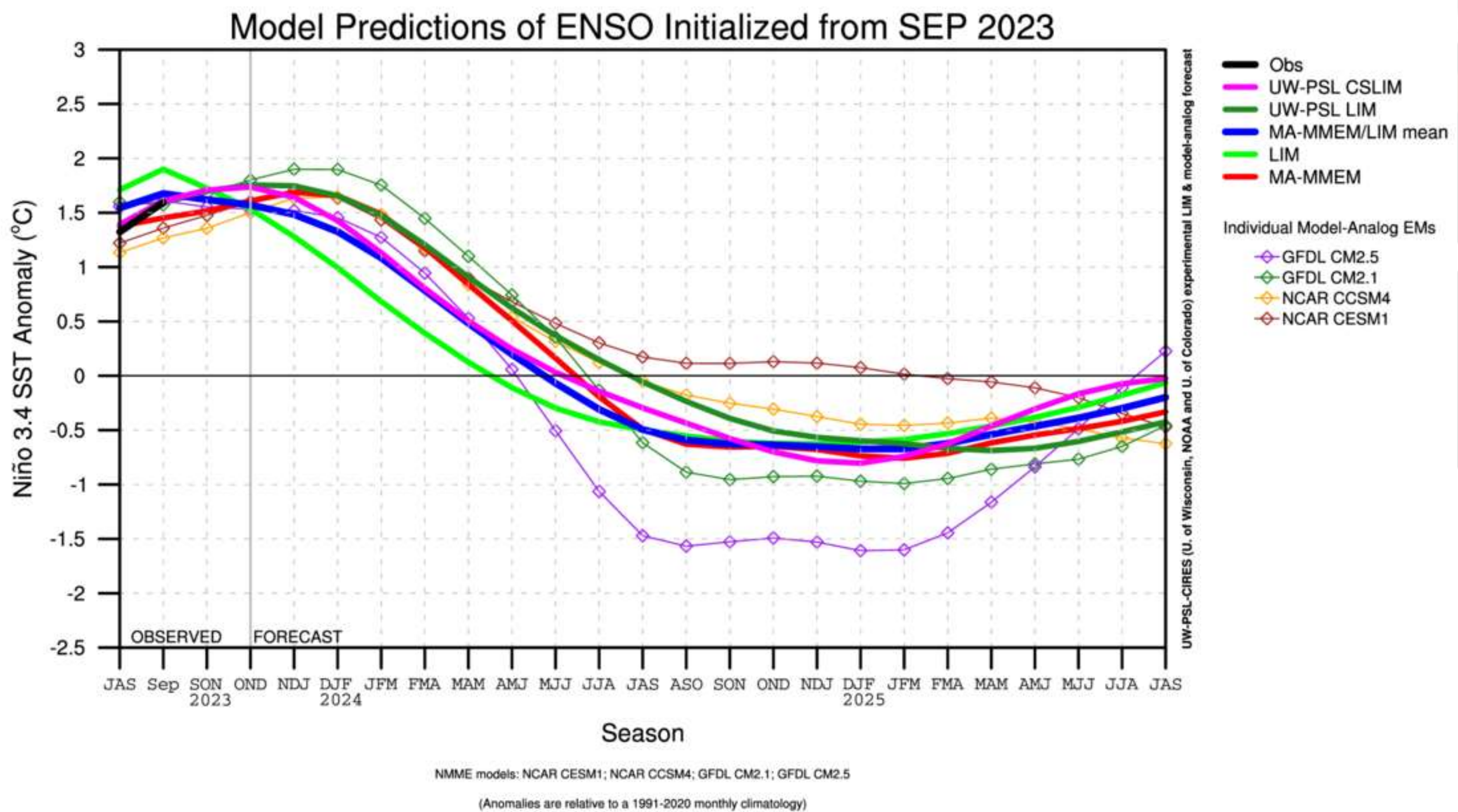


http://www.o3d.org/npgo/

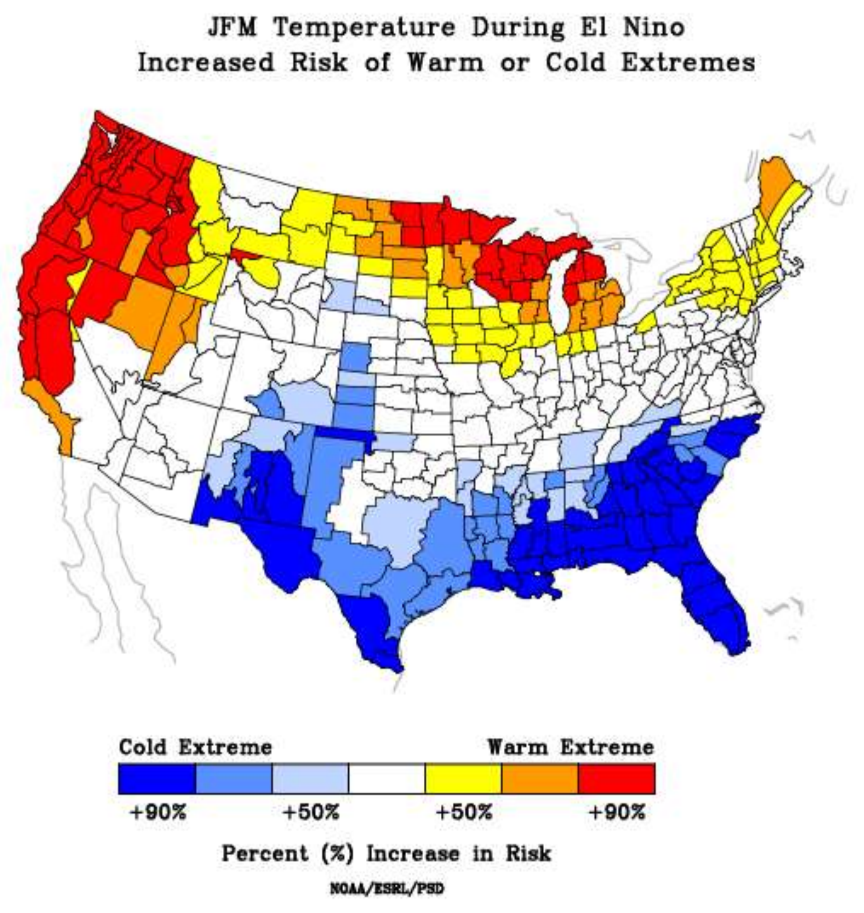
Basin Scale Marine Conditions - ENSO

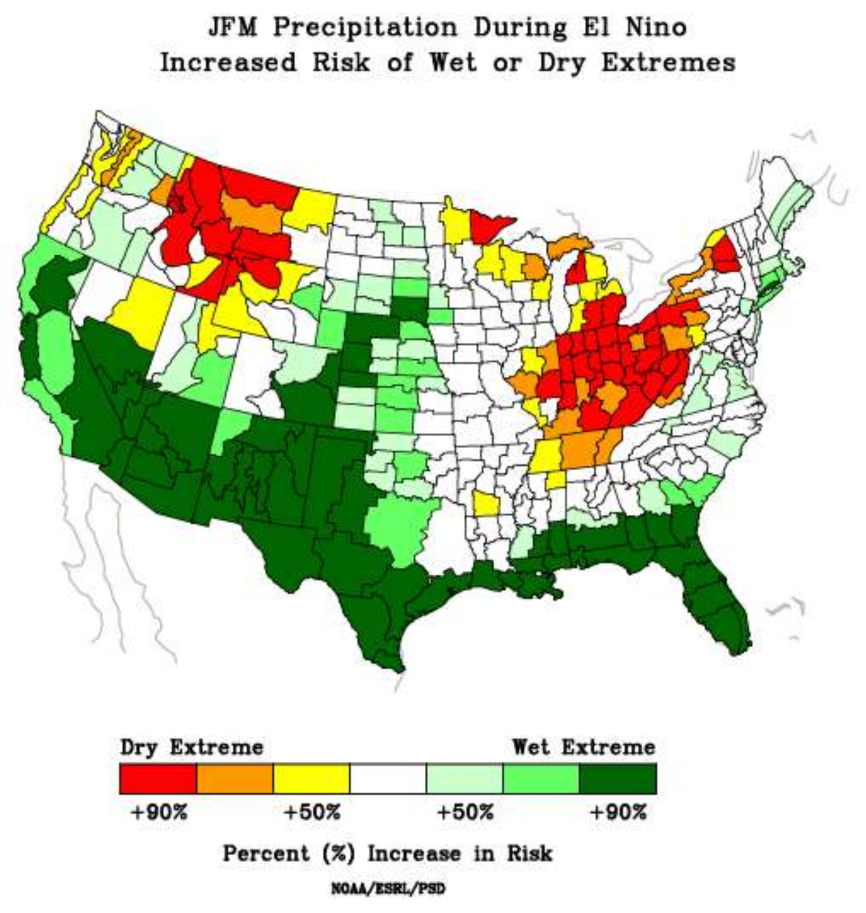


Basin Scale Marine Conditions - ENSO

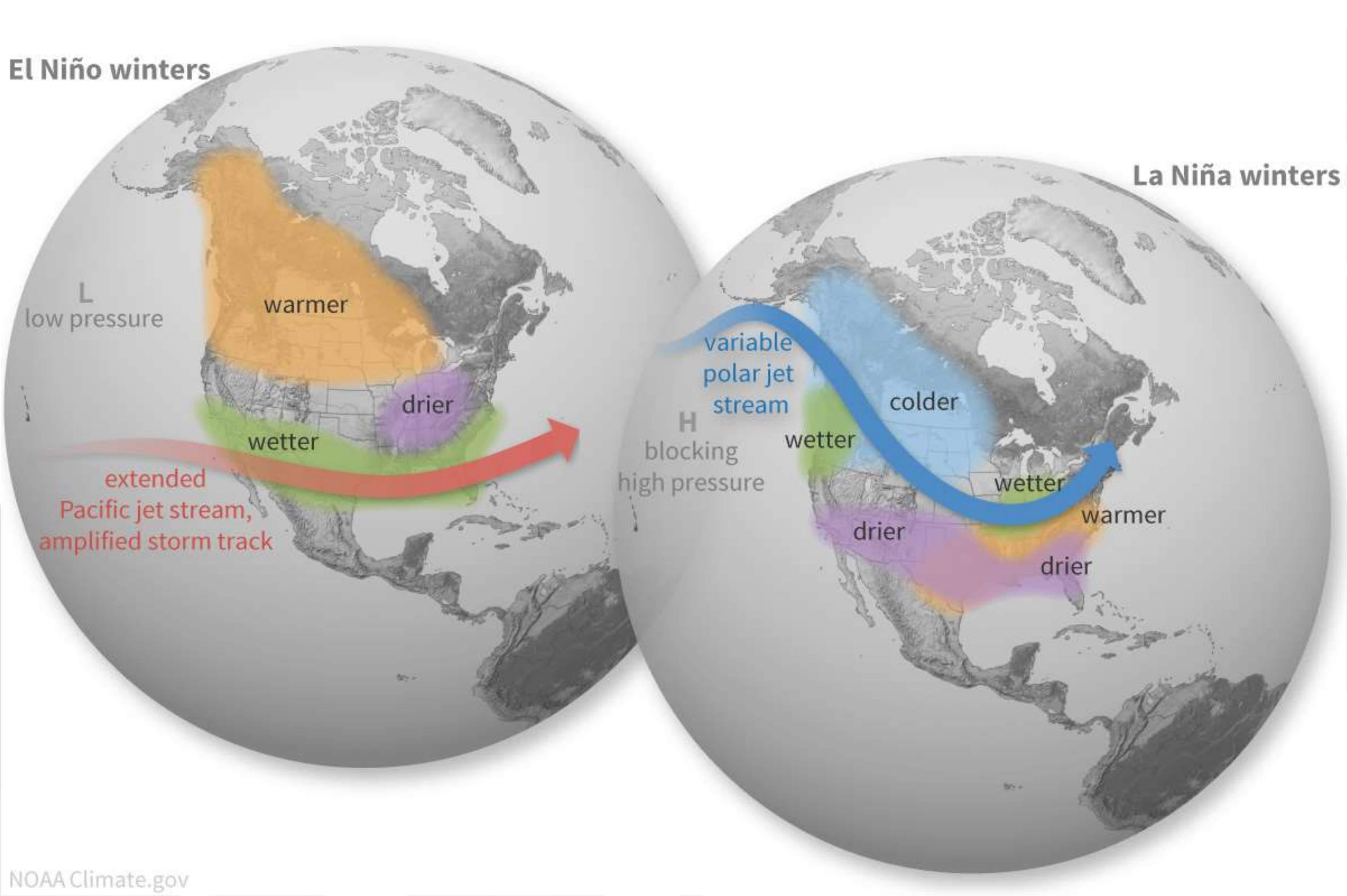


El Nino Impacts on the PNW



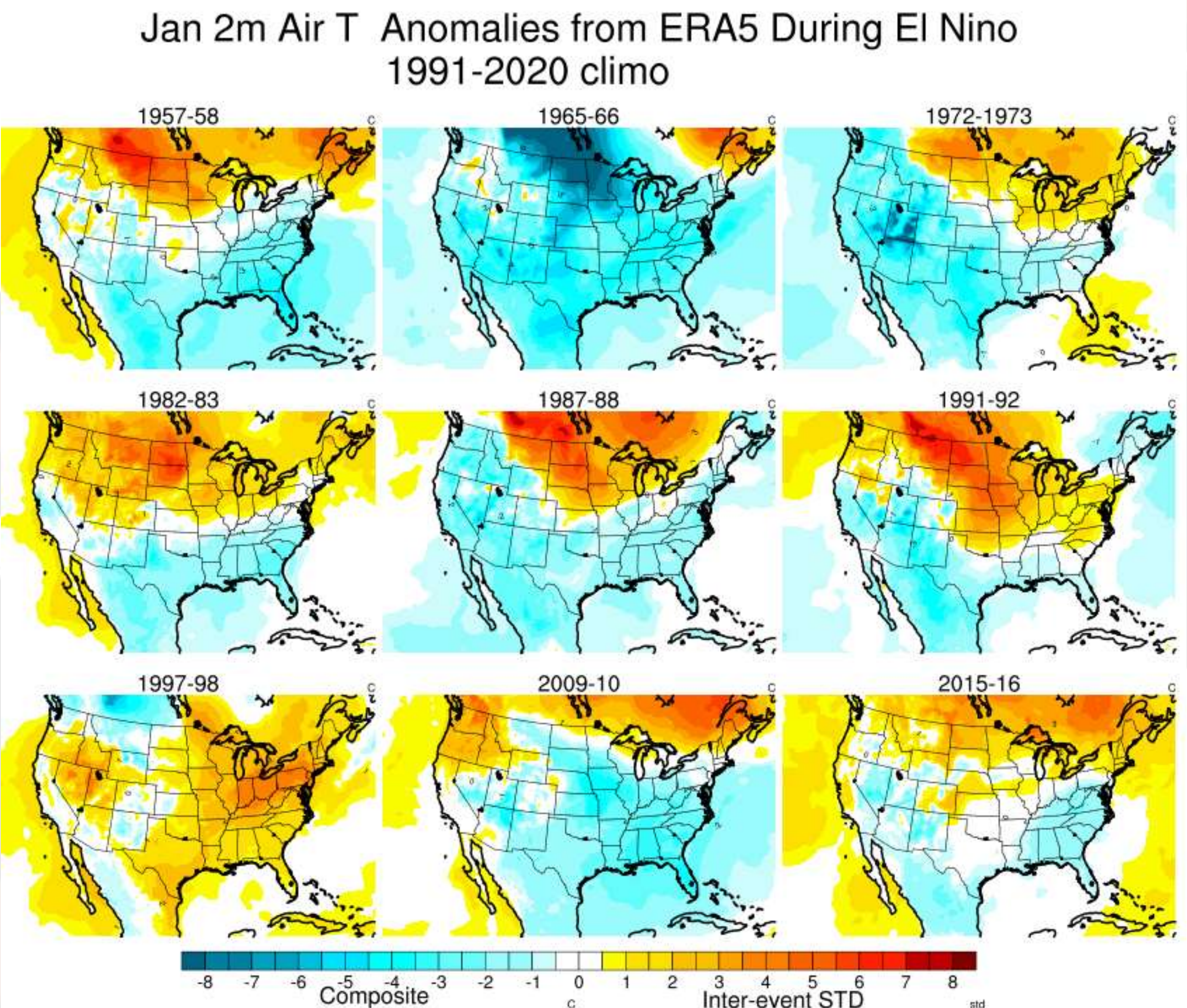


https://psl.noaa.gov/enso/climaterisks/

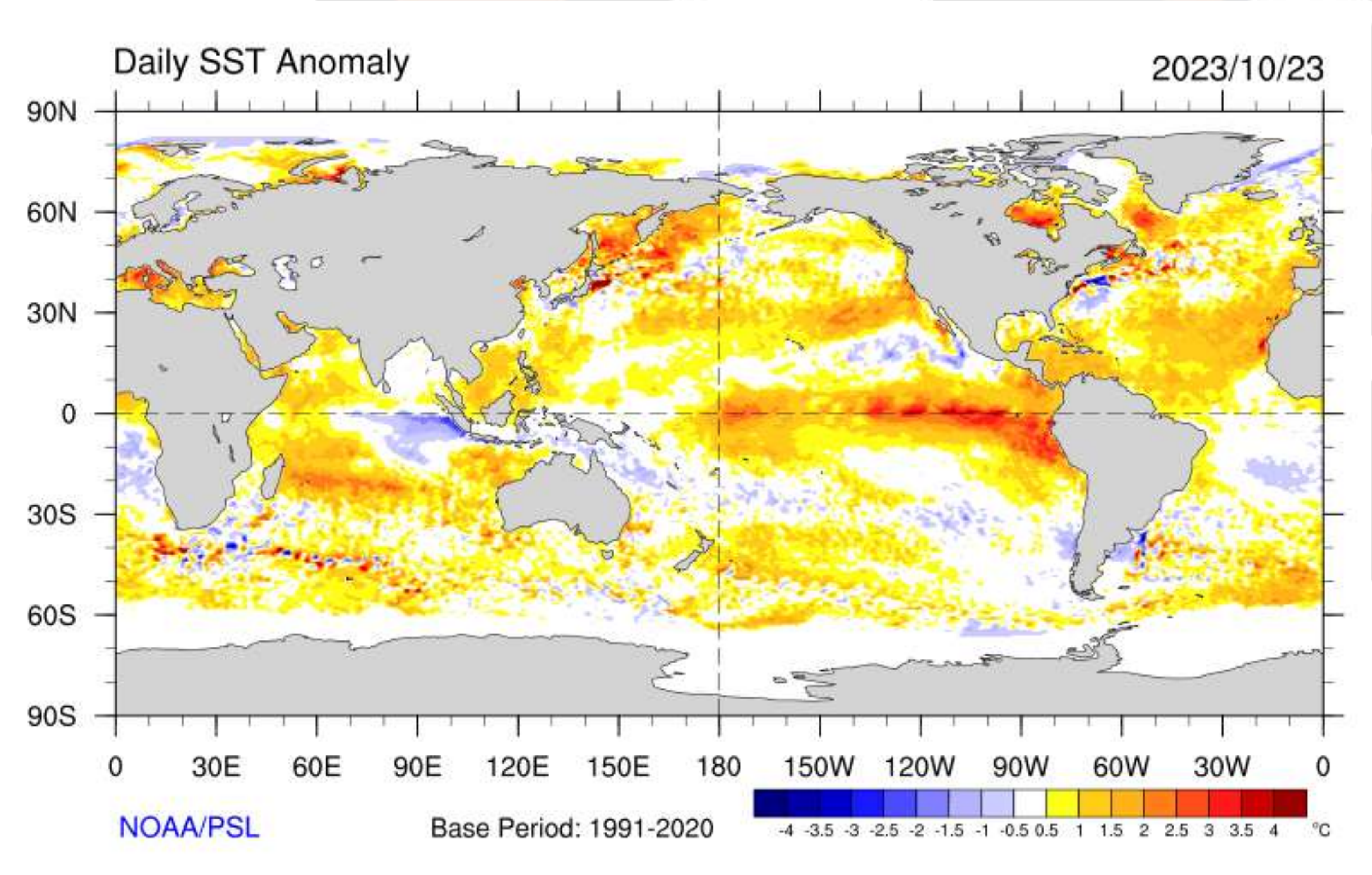


https://www.climate.gov/news-features/blogs/what-we-talk-about-when-we-talk-about-jet-stream-and-el-nino

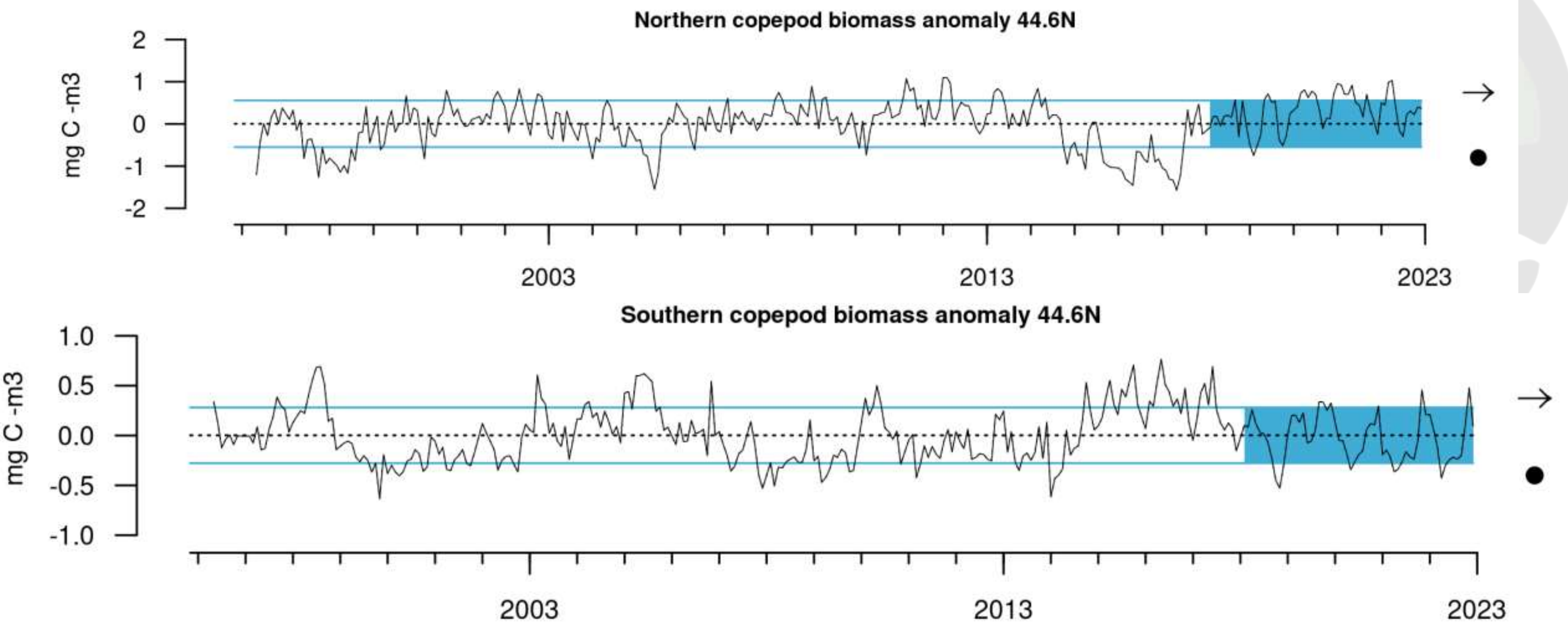
El Nino Impacts on the PNW



El Nino Impacts on the CCE

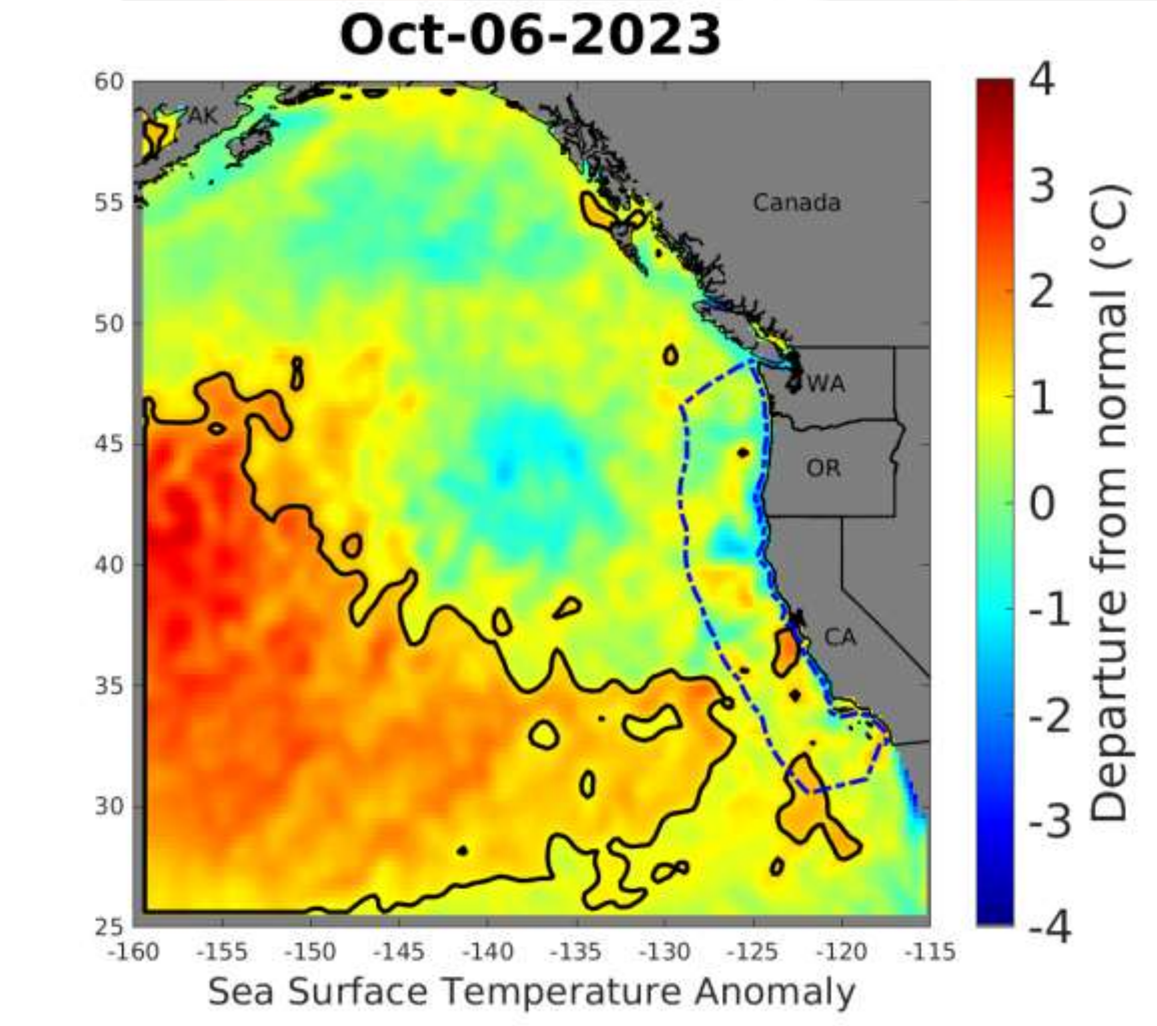


El Nino Impacts on the CCE



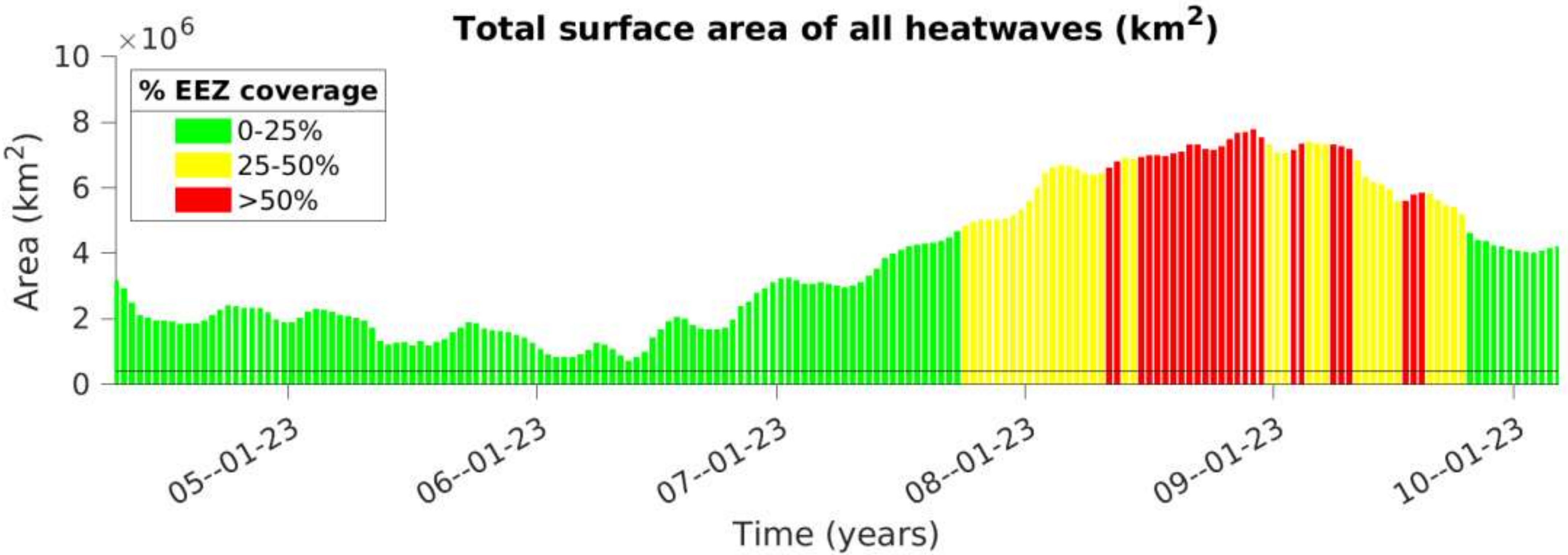
https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-iea-indicators

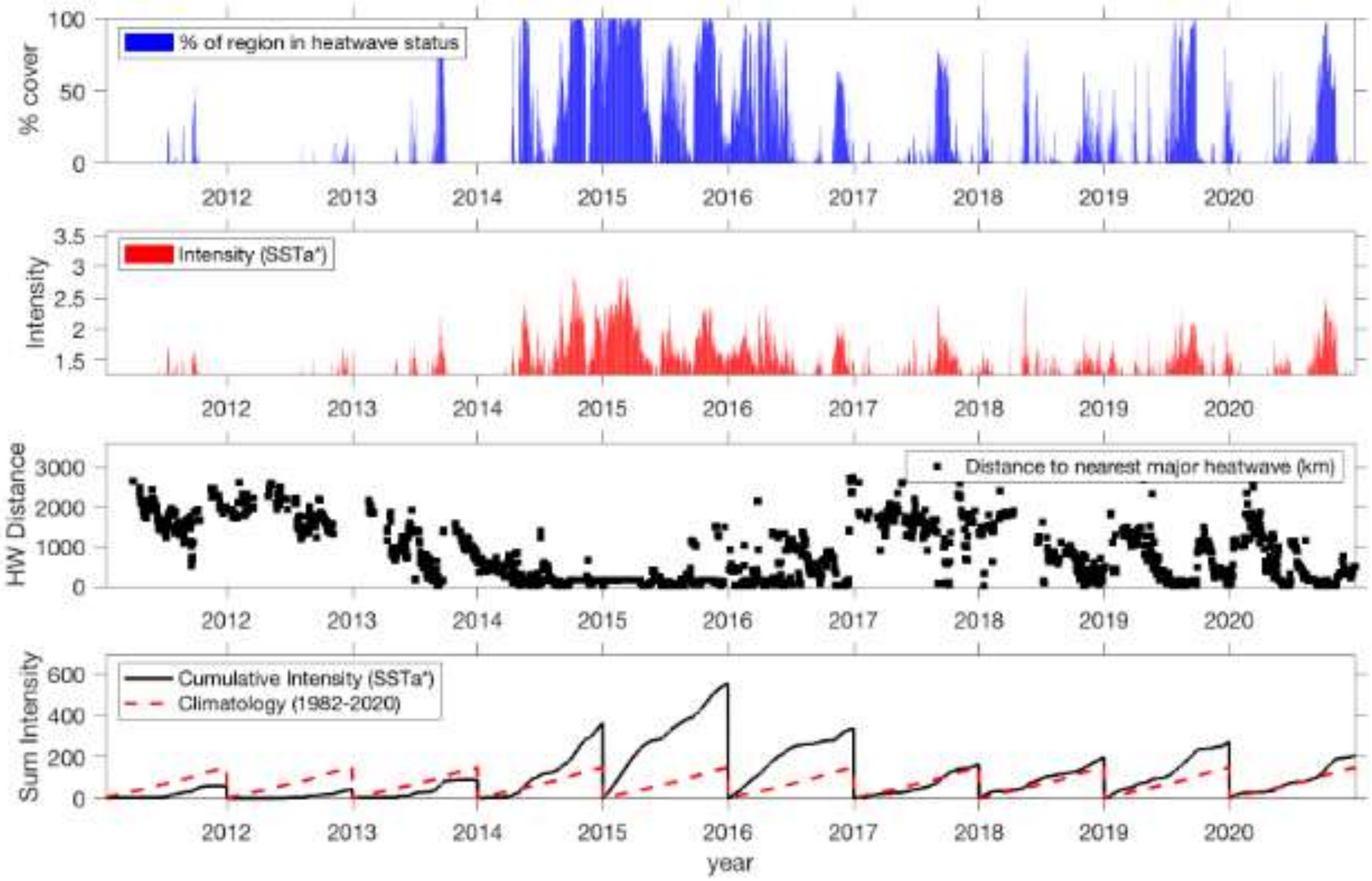
Marine Heat Waves



https://www.integratedecosystemassessment.noaa.gov/regions/california-current/california-current-marine-heatwave-tracker-blobtracker

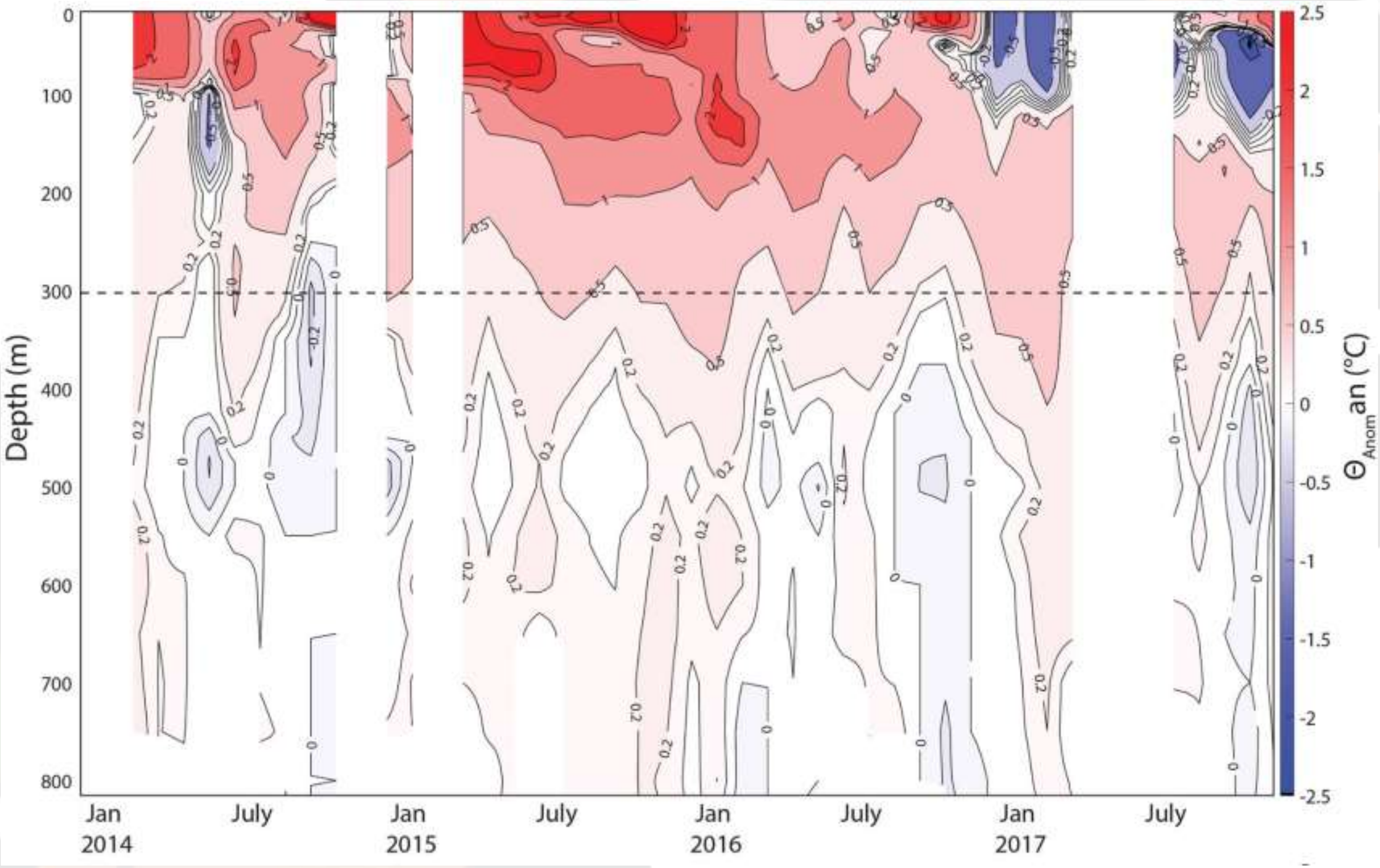
Marine Heat Waves



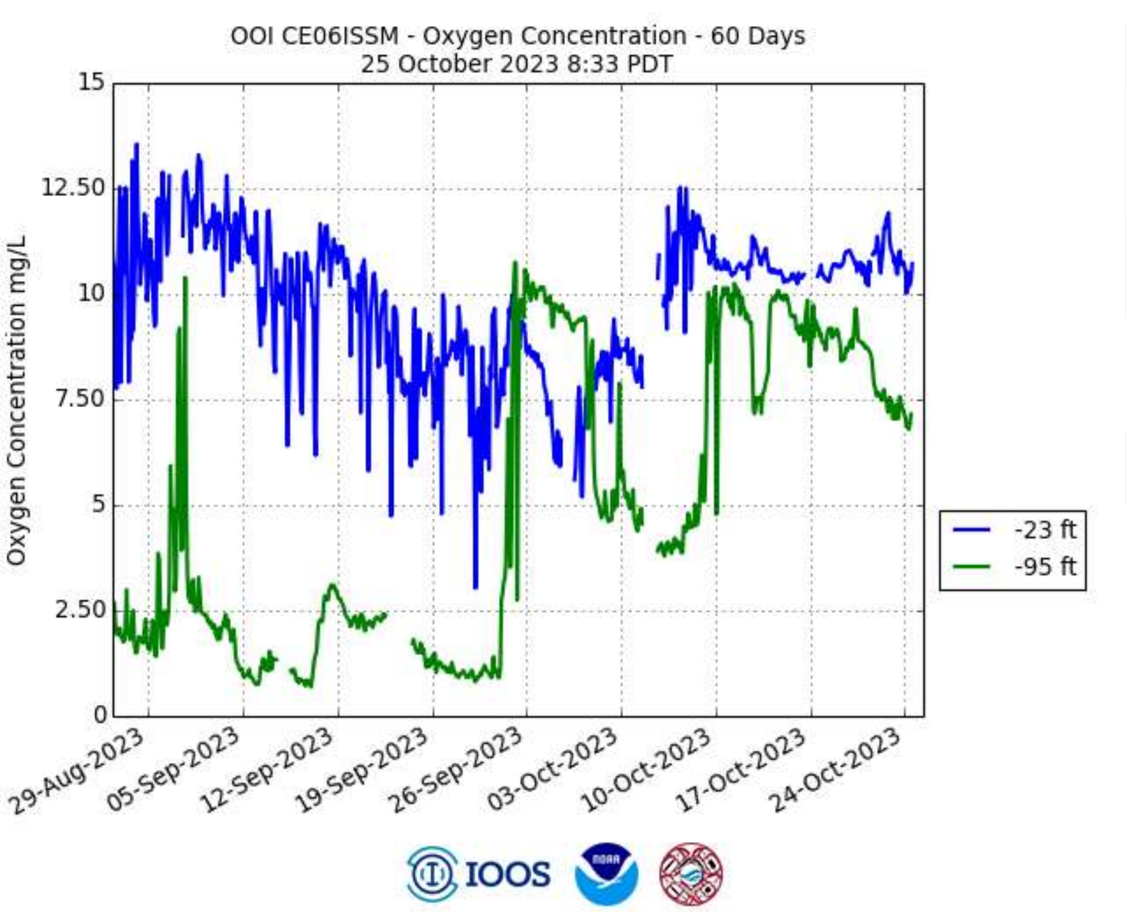


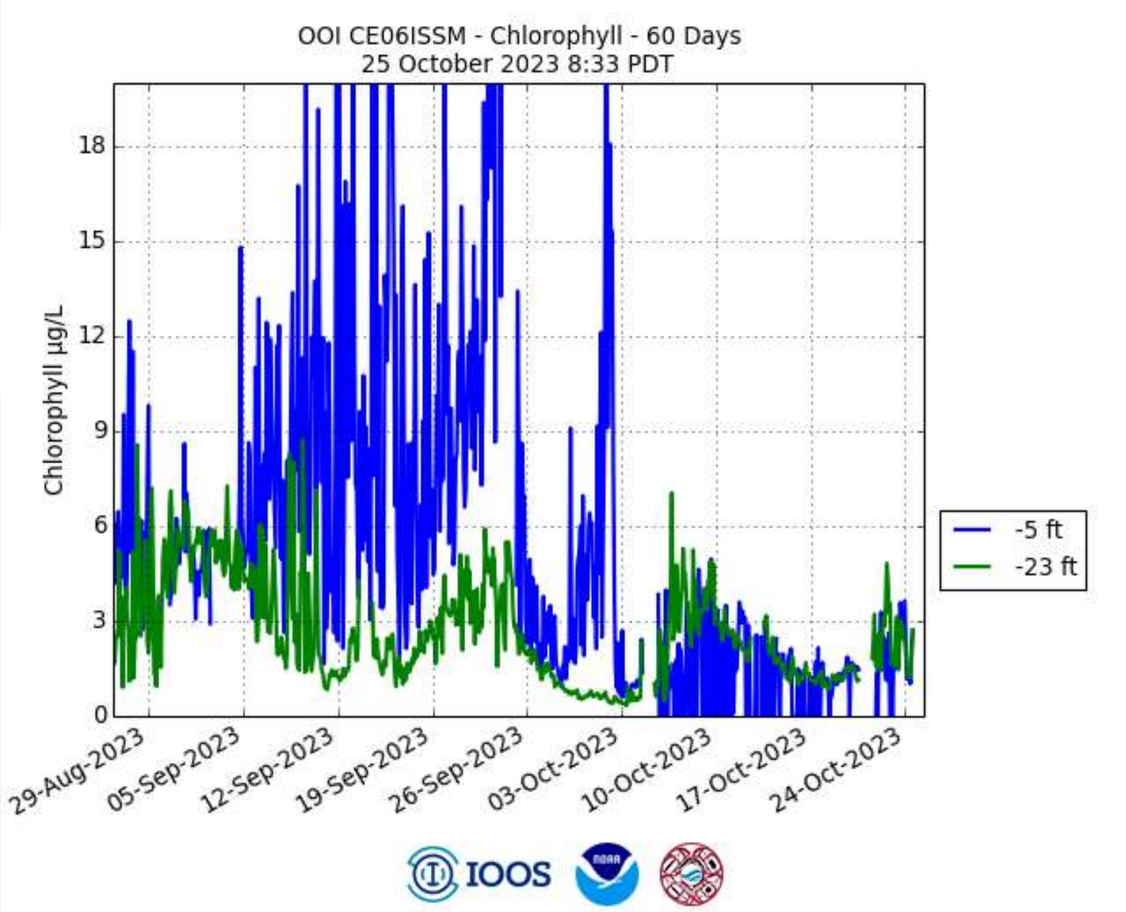
% of region in heatwave status
% cover
Intensity (SSTa*)
Intensity
Distance to nearest major heatwave (km)
HW Distance
Cumulative Intensity (SSTa*)
Climatology (1982-2020)
Sum Intensity
year

Return of the Blob?



Local Conditions – Cape Elizabeth





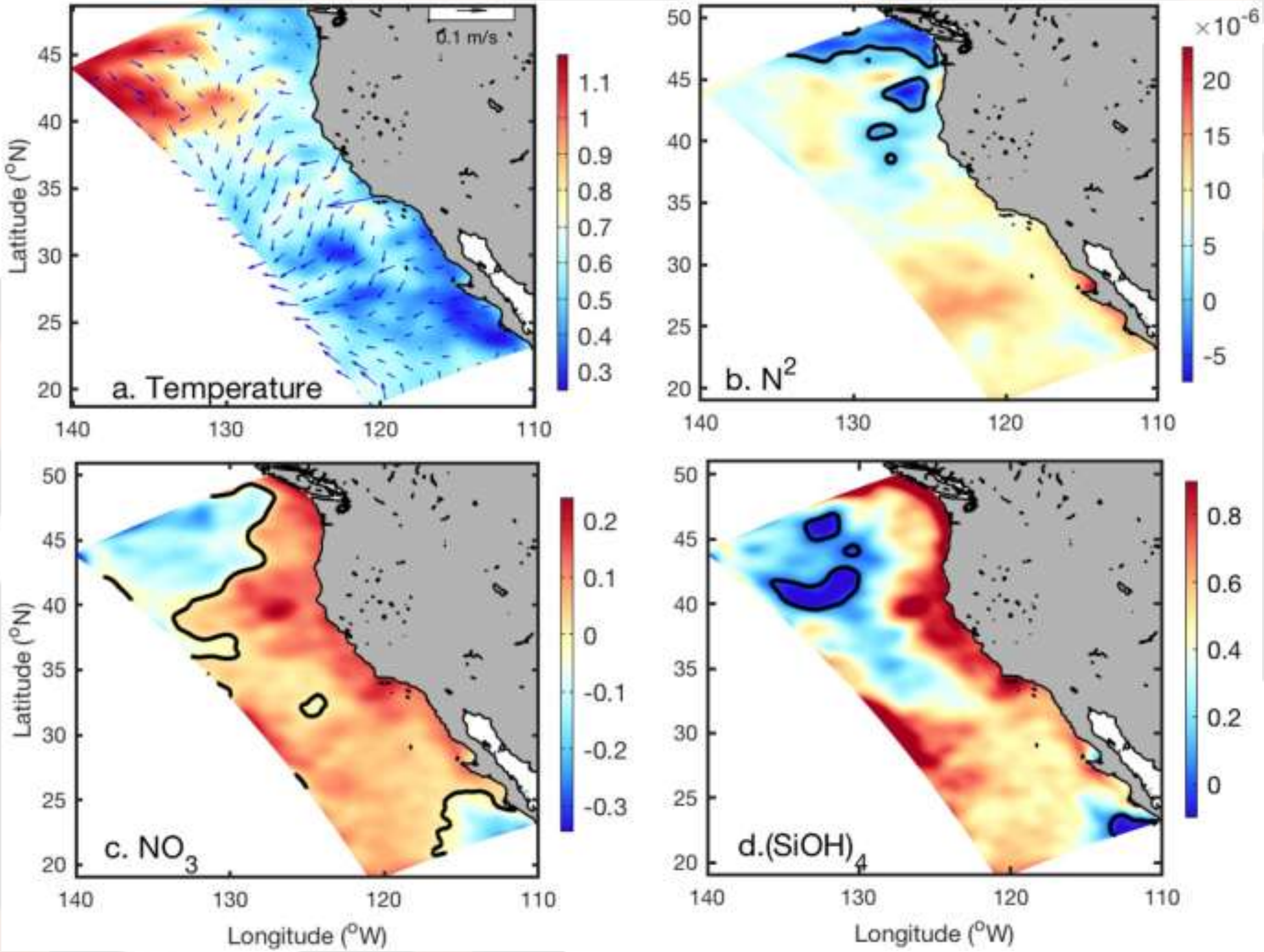
https://nvs.nanoos.org/Explorer

Climate Change Impacts on the CCE

- Pena 2022 – Modeled impacts along the BC continental margin
  - Increased annual average warming of >1.6°C in sea surface temperature, increase in stratification in the upper layer, and decrease in surface pH of as much as 0.21.
  - Stratification and increased winds will likely have limited impact on nitrate availability and productivity, increasing temperatures will lead to increases in primary production by up to 30% in most areas.
  - Impacts on food availability for higher trophic levels and on benthic habitat.

Climate Change Impacts on the CCE

Comparison of 1990-2009 to predicted conditions in 2030-2049



Xiu 2018 - https://www.nature.com/articles/s41598-018-21247-7

Salmon Vulnerability to Marine Climate Drivers

- Crozier 2019
  - Considered SST, ocean acidification, sea level rise, timing and intensity of upwelling, changes in ocean currents
  - Most stocks in WA and OR were considered moderately to highly sensitive and highly exposed with moderate to high adaptive capacity
  - For marine variables, exposure to OA and SST were highest, with sea level following
  - Most vulnerable life stage was variable

https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0217711

Salmon Vulnerability to Marine Climate Drivers

- Crozier 2021 – CC and Chinook lifecycle
  - Full lifecycle model for select Columbia River stocks that considered a range of future climate scenarios.
  - Negative effects from increasing SST drove most populations to extinction within the century
  - Future climate impacts in the marine stage reduced survival by 83-90%
  - Caveats – North Pacific might not warm at the modeled rate. There is also potential for an “ecological surprise” – SST impacts both bottom up and top-down trophic processes.

https://www.nature.com/articles/s42003-021-01734-w

Salmon Vulnerability to Marine Climate Drivers

- Crozier 2023 – Review of CC impacts on salmon (lit review)
  - Marine survival generally correlated with overall ocean productivity
  - Understanding species interactions in the marine environment is challenging.
  - Drivers of note: carryover from freshwater lifestage, inconsistent correlations between prey – growth – survival, declining age at maturation and size of older salmon, warming, predation pressure
  - Provides several recommendations
  - Largest research gaps related to species interactions, behavioral responses, and effects that carry over across life stages

https://www.mdpi.com/2410-3888/8/6/319

Salmon Vulnerability to Marine Climate Drivers

- McClure 2023 – Vulnerability assessments of managed stocks in the CCE
  - Looked at sensitivity + exposure to determine vulnerability
  - Salmon stocks all ranked high or very high (Chinook) vulnerability to climate change
  - Only looked at a handful of drivers

https://www.frontiersin.org/articles/10.3389/fmars.2023.1103767/full

	Oncorhynchus kisutch	Attribute Mean	Data Quality	Expert Scores Plots (tallies by bin)
Sensitivity Attributes	Habitat Specificity	2.1	2.8	
	Prey Specificity	1.8	2.8	
	Adult Mobility	1.2	2.8	
	Dispersal of Early Life Stages	3.9	3	
	Early Life History Survival and Settlement Requirements	2.8	3	
	Complexity in Reproductive Strategy	3.5	2.8	
	Spawning Cycle	3.5	3	
	Sensitivity to Temperature	2	2.8	
	Sensitivity to Ocean Acidification	1.8	1.5	
	Population Growth Rate	1.7	2	
	Stock Size/Status	2	2	
	Other Stressors	3.5	2.5	
	Sensitivity Score	High		
Exposure Factors	Mean Sea Surface Temperature	3.2	2.3	
	Mean Sea Surface Salinity	1.4	2.3	
	Ocean Acidification	4	3	
	Air Temperature (Proxy for Nearshore Ocean Temp)	3.4	2.8	
	Mean Precipitation	1.6	1	
	Sea Level Rise	2.6	2.8	
	Currents	1.9	1	
	Phenology of Upwelling	2	1.3	
	Subsurface Oxygen	1.7	1.8	
	Exposure Score	High		
Overall Vulnerability Rank		High		

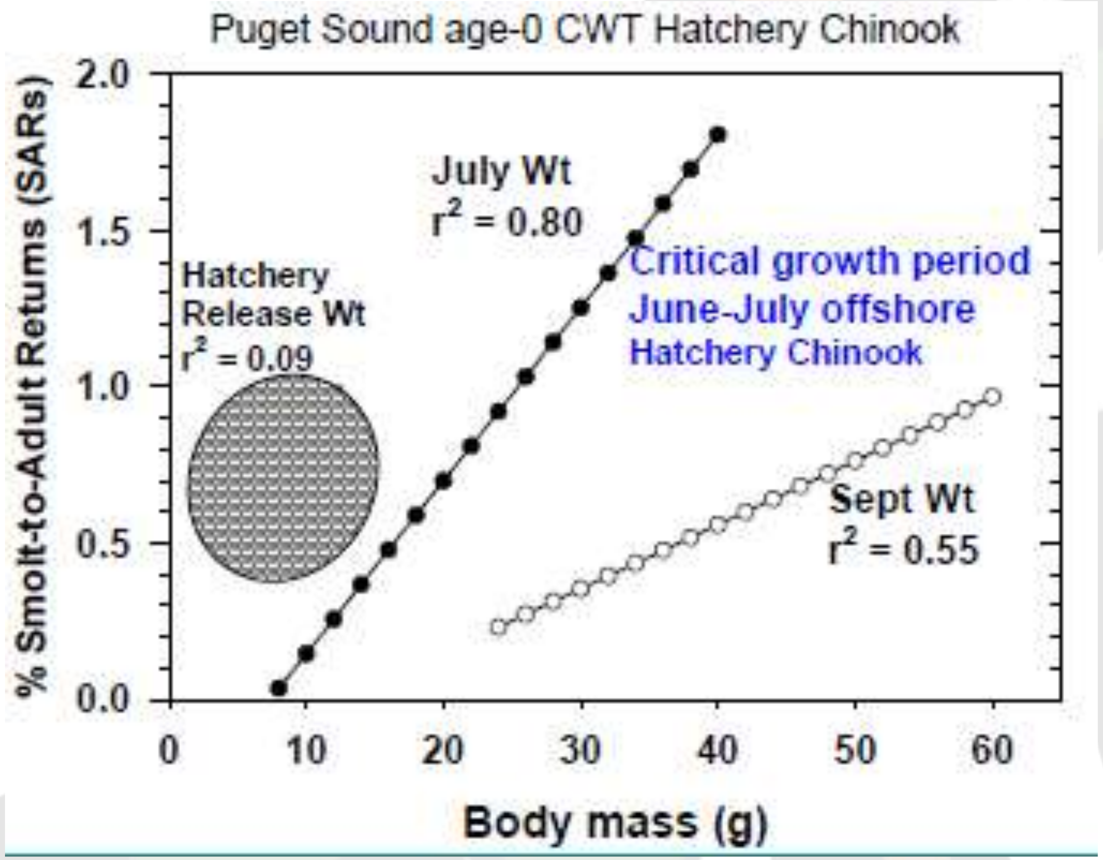
Low
Moderate
High
Very High

Salmon Vulnerability to Marine Climate Drivers

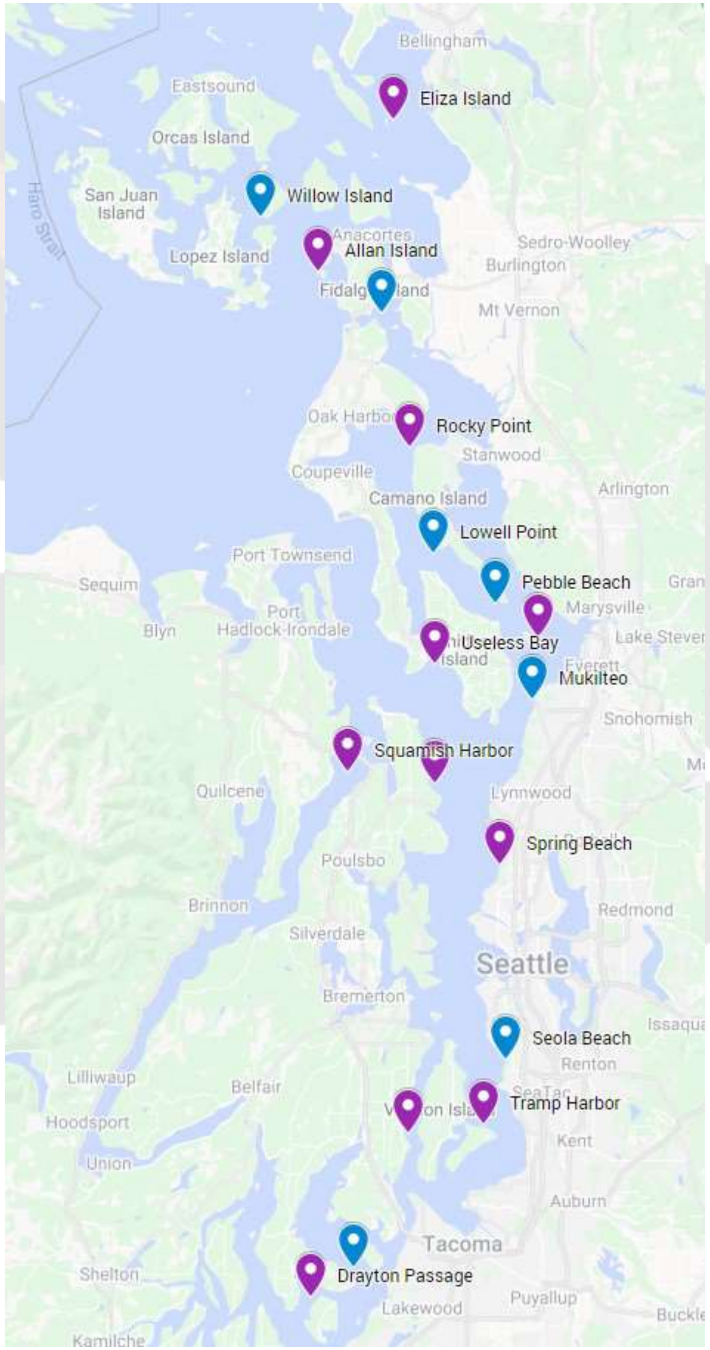
- Salish Sea Marine Survival Project
  - Two overarching phenomena behind declining Salish Sea Marine Surivival
    - Changes in food supply – changing environmental conditions, nutrient availability, temperature – likely driven by climate change, but this is not fully understood. Declining forage fish populations are also a concern.
    - Increase in predators – Increase in seal and sea lion populations, creation of predation “hot spots”, lack of complexity in the near shore environment, consolidated timing of hatchery releases.

https://marinesurvivalproject.com/research-findings/

Early Marine Survival work by the Tulalip Tribe



Modified from Duffy and Beauchamp 2011
https://cdnsciencepub.com/doi/10.1139/F10-144



OPI-H Forecast

- Current forecast model uses jack returns and smolt releases
- New model proposes to use jack returns, smolt releases and will consider 9 different environmental variables in an ARIMA model
- “Kitchen sink” approach – model will evaluate different combinations of 0 to 6 environmental variables, using an ensemble of the top 10 best fits over the last 15 years
- Since 2014 Jacks and NPGO and PDO (lagged 1 year), winter SST, and fall ENSO index have been the best predictors
- Applications elsewhere?

What can be done at the management level?

- Stop light charts – first step at looking at trends and incorporating ecosystem data into management
- Incorporation of environmental variables into forecasting – challenges of increasing uncertainty and variability
  - Increased monitoring and incorporation of local level data – the marine environment is not monotonic and there is significant variability, especially in the near shore environment
- Increased understanding of vulnerability at all life stages, including carryover effects
- Better understanding of marine survival

Questions?

tmoore@nwifc.org