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Weather and Coastal Conditions

DEPARTMENT OF ECOLOGY State of Washington

2016

2016 - Monthly — *Recent marine weather and coastal conditions*

2015 - Summary — *A yearly review of atmospheric and oceanic conditions*

Figure Explanation — *Figure Explanation and data sources*

"Boundary conditions play an important role for water quality in Puget Sound and coastal Bays"

Note: Weather data for this presentation are summarized from external sources.

www-k12.atmos.washington.edu/k12/grayskies/nw_weather.html

(●) Weather ( ) Coastal conditions

Summary: January began cold and dry with light winds from the north, lower river flows, and a strong temperature inversion. Then it became warm and wet, with increasing river flows particularly to the south, and southerly wind. Overall January had near-to-above normal temperatures and above normal precipitation to the south. Strong El Niño and downwelling along the coast.

Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3											
	Everett	1.5											
	SeaTac	1.5											
	OlyWA	0.8											
	Coast	1.1											

Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14											
	Everett	0.16											
	SeaTac	0.19											
	OlyWA	0.08											
	Coast	0.37											

Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5											
	Everett	-0.5											
	SeaTac	-0.6											
	OlyWA	0.0											
	Coast	-0.2											

River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3											
	Skagit	11											
	Puyallup	9											
	Nisqually	16											
	Chehalis	-4											

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111											
	PDO	1.5											
	NPGO	0.7											
	ENSO (MEI)	2.2											

*Upwelling Anomalies (PFEL) higher — expected — lower ■ No data

Summary: February was warm, wet, and cloudy around Puget Sound, with higher river flows and southerly wind. There was a notable break from the rain from the 6th through the 9th that resulted in record maximum daily temperatures on the 9th. Strong El Niño and downwelling along the coast.

Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3	2.0										
	Everett	1.5	2.5										
	SeaTac	1.5	2.2										
	OlyWA	0.8	1.7										
	Coast	1.1	2.1										

Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14	0.19										
	Everett	0.16	-0.07										
	SeaTac	0.19	0.09										
	OlyWA	0.08	-0.02										
	Coast	0.37	-0.09										

Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5	-0.2										
	Everett	-0.5	-0.5										
	SeaTac	-0.6	-0.2										
	OlyWA	0.0	-0.5										
	Coast	-0.2	-0.5										

River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3	19										
	Skagit	11	55										
	Puyallup	9	34										
	Nisqually	16	33										
	Chehalis	-4	8										

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111	-78										
	PDO	1.5	1.8										
	NPGO	0.7	0.0										
	ENSO (MEI)	2.2	2.1										

*Upwelling Anomalies (PFEL) higher — expected — lower ■ No data

(●) Weather ( ) Coastal conditions

Summary: March temperatures, precipitation, and river flow were all above normal. Two sunny periods occurred from March 15-19 (Central and South Sound surveys) and March 28-30 (Coastal survey). Wind during these drier periods was out of the north. Strong El Niño and downwelling along the coast.

Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3	2.0	1.9									
	Everett	1.5	2.5	0.9									
	SeaTac	1.5	2.2	0.9									
	OlyWA	0.8	1.7	0.6									
	Coast	1.1	2.1	0.5									

Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14	0.19	0.05									
	Everett	0.16	-0.07	0.18									
	SeaTac	0.19	0.09	0.21									
	OlyWA	0.08	-0.02	0.31									
	Coast	0.37	-0.09	0.56									

Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5	-0.2	0.2									
	Everett	-0.5	-0.5	-0.2									
	SeaTac	-0.6	-0.2	-0.1									
	OlyWA	0.0	-0.5	-0.2									
	Coast	-0.2	-0.5	-0.2									

River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3	19	29									
	Skagit	11	55	30									
	Puyallup	9	34	23									
	Nisqually	16	33	38									
	Chehalis	-4	8	57									

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111	-78	-70									
	PDO	1.5	1.8	2.4									
	NPGO	0.7	0.0										
	ENSO (MEI)	2.2	2.1	2.0									

*Upwelling Anomalies (PFEL) higher expected lower No data

Summary: April temperatures were above normal and it ranked as one of the warmest Aprils on record in many locations, with extremely warm temperatures noted April 7-9 and April 17-20. Precipitation was below normal, but rivers fed by snowmelt ran high. Strong El Niño continues.

Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3	2.0	1.9	2.4								
	Everett	1.5	2.5	0.9	2.2								
	SeaTac	1.5	2.2	0.9	3.2								
	OlyWA	0.8	1.7	0.6	2.5								
	Coast	1.1	2.1	0.5	2.4								

Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14	0.19	0.05	-0.03								
	Everett	0.16	-0.07	0.18	-0.05								
	SeaTac	0.19	0.09	0.21	-0.12								
	OlyWA	0.08	-0.02	0.31	-0.18								
	Coast	0.37	-0.09	0.56	-0.29								

Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5	-0.2	0.2	-1.5								
	Everett	-0.5	-0.5	-0.2	-1.9								
	SeaTac	-0.6	-0.2	-0.1	-1.6								
	OlyWA	0.0	-0.5	-0.2	-2.1								
	Coast	-0.2	-0.5	-0.2	-0.8								

River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3	19	29	90								
	Skagit	11	55	30	20								
	Puyallup	9	34	23	2								
	Nisqually	16	33	38	4								
	Chehalis	-4	8	57	-23								

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111	-78	-70	-2								
	PDO	1.5	1.8	2.4	2.6								
	NPGO	0.7	0.1	0.7	-0.4								
	ENSO (MEI)	2.2	2.1	2.0	2.1								

*Upwelling Anomalies (PFEL) higher — expected — lower ■ No data

Summary: May temperatures were much above normal, while precipitation was below normal around western Washington. The warmer than normal May temperatures caused relatively rapid melting of our mountain snowpack. By mid-month, all river flows were below normal, even the Fraser. El Niño abating.

Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3	2.0	1.9	2.4	1.6							
	Everett	1.5	2.5	0.9	2.2	0.4							
	SeaTac	1.5	2.2	0.9	3.2	1.7							
	OlyWA	0.8	1.7	0.6	2.5	1.7							
	Coast	1.1	2.1	0.5	2.4	0.8							

Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14	0.19	0.05	-0.03	-0.10							
	Everett	0.16	-0.07	0.18	-0.05	-0.11							
	SeaTac	0.19	0.09	0.21	-0.12	-0.07							
	OlyWA	0.08	-0.02	0.31	-0.18	-0.17							
	Coast	0.37	-0.09	0.56	-0.29	-0.19							

Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5	-0.2	0.2	-1.5	-0.4							
	Everett	-0.5	-0.5	-0.2	-1.9	-0.5							
	SeaTac	-0.6	-0.2	-0.1	-1.6	-0.4							
	OlyWA	0.0	-0.5	-0.2	-2.1	-1.0							
	Coast	-0.2	-0.5	-0.2	-0.8	-0.6							

River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3	19	29	90	22							
	Skagit	11	55	30	20	-22							
	Puyallup	9	34	23	2	-11							
	Nisqually	16	33	38	4	-14							
	Chehalis	-4	8	57	-23	-17							

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111	-78	-70	-2	21							
	PDO	1.5	1.8	2.4	2.6	2.4							
	NPGO	0.7	0.1	0.7	-0.4								
	ENSO (MEI)	2.2	2.1	2.0	2.1	1.7							

*Upwelling Anomalies (PFEL) higher expected lower No data

(●) Weather ( ) Coastal conditions

Summary: June air temperatures remained above normal in the Puget Sound lowlands, though less extreme. Precipitation levels are normal to below normal at our western Washington stations. Sunshine levels have been above normal. River flows are below normal, particularly to the north. Upwelling is normal and ENSO & PDO are above normal.

Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3	2.0	1.9	2.4	1.6	0.8						
	Everett	1.5	2.5	0.9	2.2	0.4	-0.2						
	SeaTac	1.5	2.2	0.9	3.2	1.7	1.1						
	OlyWA	0.8	1.7	0.6	2.5	1.7	0.9						
	Coast	1.1	2.1	0.5	2.4	0.8	0.5						

Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14	0.19	0.05	-0.03	-0.10	-0.09						
	Everett	0.16	-0.07	0.18	-0.05	-0.11	-0.04						
	SeaTac	0.19	0.09	0.21	-0.12	-0.07	-0.01						
	OlyWA	0.08	-0.02	0.31	-0.18	-0.17	-0.05						
	Coast	0.37	-0.09	0.56	-0.29	-0.19	-0.11						

Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5	-0.2	0.2	-1.5	-0.4	-1.3						
	Everett	-0.5	-0.5	-0.2	-1.9	-0.5	-1.8						
	SeaTac	-0.6	-0.2	-0.1	-1.6	-0.4	-1.1						
	OlyWA	0.0	-0.5	-0.2	-2.1	-1.0	-1.9						
	Coast	-0.2	-0.5	-0.2	-0.8	-0.6	-1.8						

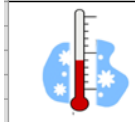
River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3	19	29	90	22	-100						
	Skagit	11	55	30	20	-22	-38						
	Puyallup	9	34	23	2	-11	-20						
	Nisqually	16	33	38	4	-14	-10						
	Chehalis	-4	8	57	-23	-17	-7						

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111	-78	-70	-2	21	-2						
	PDO	1.5	1.8	2.4	2.6	2.4	2.0						
	NPGO	1.1	0.1	0.7	-0.2	-0.4	-0.7						
	ENSO (MEI)	2.2	2.1	2.0	2.1	1.7	1.0						

*Upwelling Anomalies (PFEL) higher — expected — lower ■ No data

(●) Weather ( ) Coastal conditions

Summary: Mean July temperatures in the Puget Sound lowlands were near normal - slightly cooler during the first half of the month. Precipitation was variable and river flows low, and lower to the north. Cloud cover was greater than normal, especially in the first half of the month.



Air Temperature	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	1.3	2.0	1.9	2.4	1.6	0.8	0.7					
	Everett	1.5	2.5	0.9	2.2	0.4	-0.2	-0.9					
	SeaTac	1.5	2.2	0.9	3.2	1.7	1.1	0.1					
	OlyWA	0.8	1.7	0.6	2.5	1.7	0.9	0.1					
	Coast	1.1	2.1	0.5	2.4	0.8	0.5	0.0					

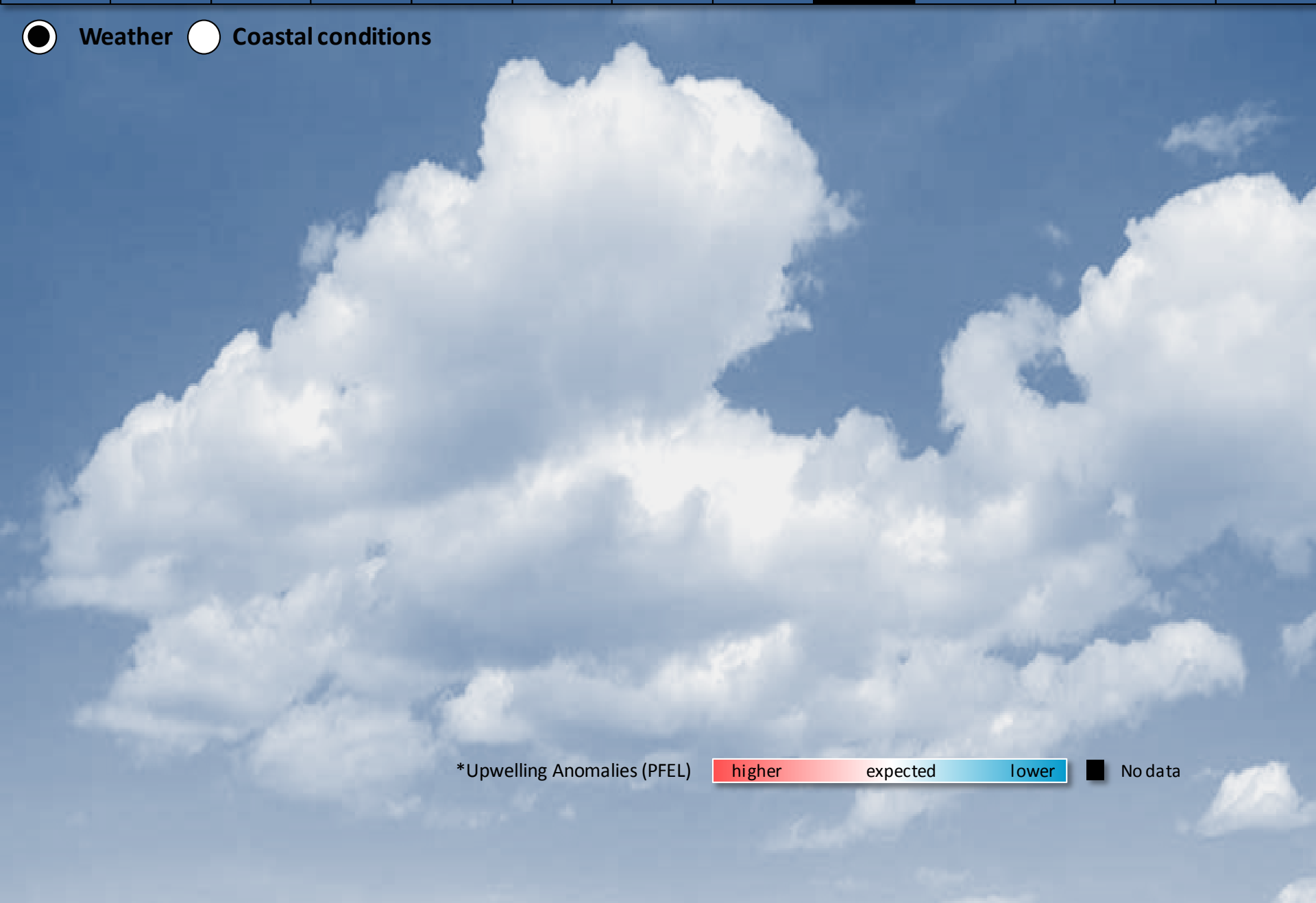
Precipitation	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.14	0.19	0.05	-0.03	-0.10	-0.09	-0.06					
	Everett	0.16	-0.07	0.18	-0.05	-0.11	-0.04	-0.05					
	SeaTac	0.19	0.09	0.21	-0.12	-0.07	-0.01	-0.01					
	OlyWA	0.08	-0.02	0.31	-0.18	-0.17	-0.05	-0.02					
	Coast	0.37	-0.09	0.56	-0.29	-0.19	-0.11	-0.08					

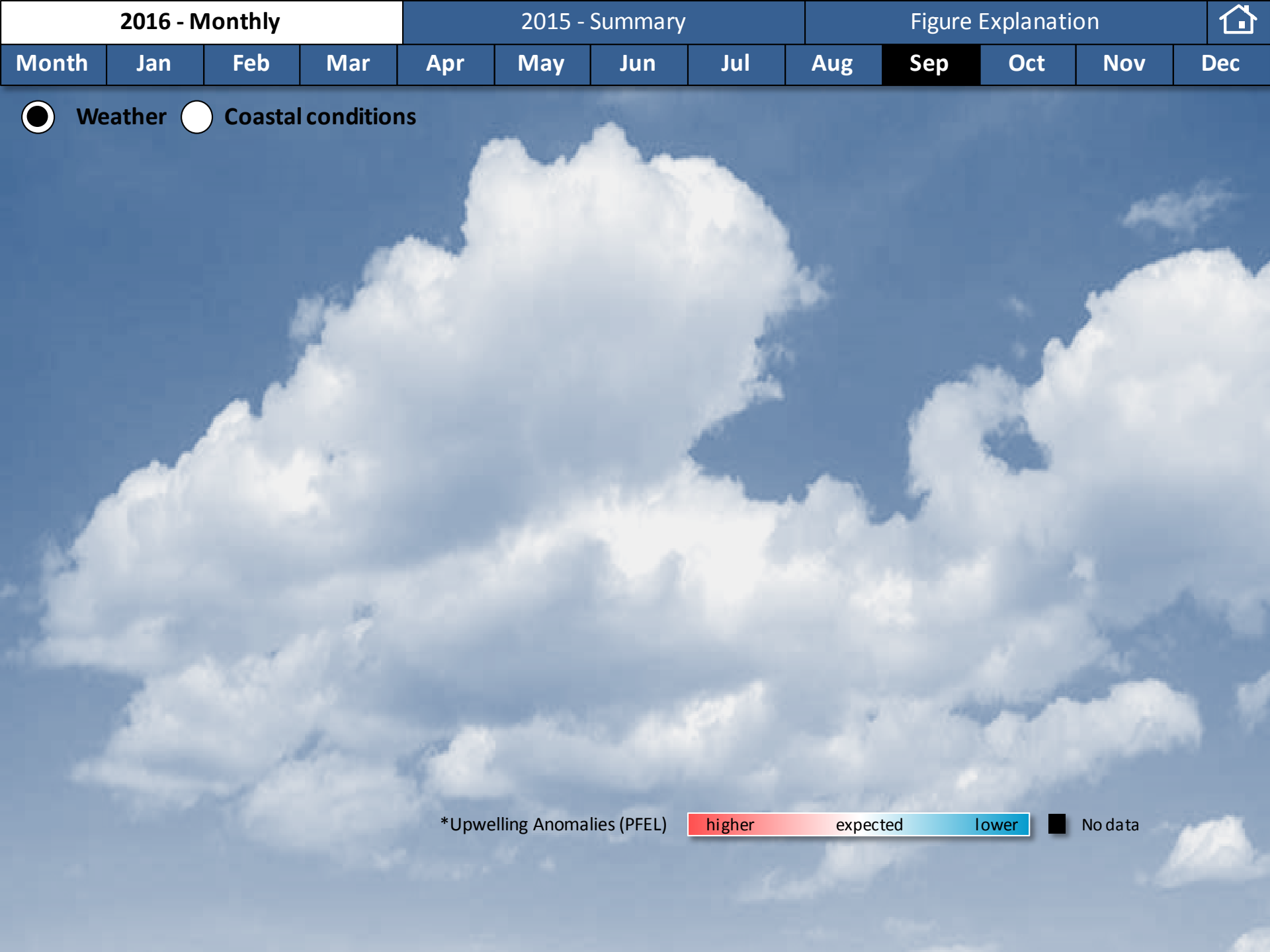
Cloud Cover	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Bell	-0.5	-0.2	0.2	-1.5	-0.4	-1.3	0.5					
	Everett	-0.5	-0.5	-0.2	-1.9	-0.5	-1.8	0.7					
	SeaTac	-0.6	-0.2	-0.1	-1.6	-0.4	-1.1	0.6					
	OlyWA	0.0	-0.5	-0.2	-2.1	-1.0	-1.9	0.7					
	Coast	-0.2	-0.5	-0.2	-0.8	-0.6	-1.8	0.5					

River Inflow	Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Fraser	3	19	30	90	22	-100	-61					
	Skagit	11	54	29	19	-23	-38	-36					
	Puyallup	9	34	23	3	-11	-20	-11					
	Nisqually	16	33	38	4	-14	-10	0					
	Chehalis	-4	8	57	-23	-17	-7	-2					

Ocean Influence	Indices	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Upwelling*	-111	-78	-70	-2	21	-2	-8					
	PDO	1.5	1.8	2.4	2.6	2.4	2.0	1.3					
	NPGO	1.1	0.1	0.7	-0.2	-0.4	-0.7	-0.1					
	ENSO (MEI)	2.2	2.1	2.0	2.1	1.7	1.0	0.3					

*Upwelling Anomalies (PFEL) higher expected lower No data


Weather
Coastal conditions
*Upwelling Anomalies (PFEL)
higher
expected
lower
No data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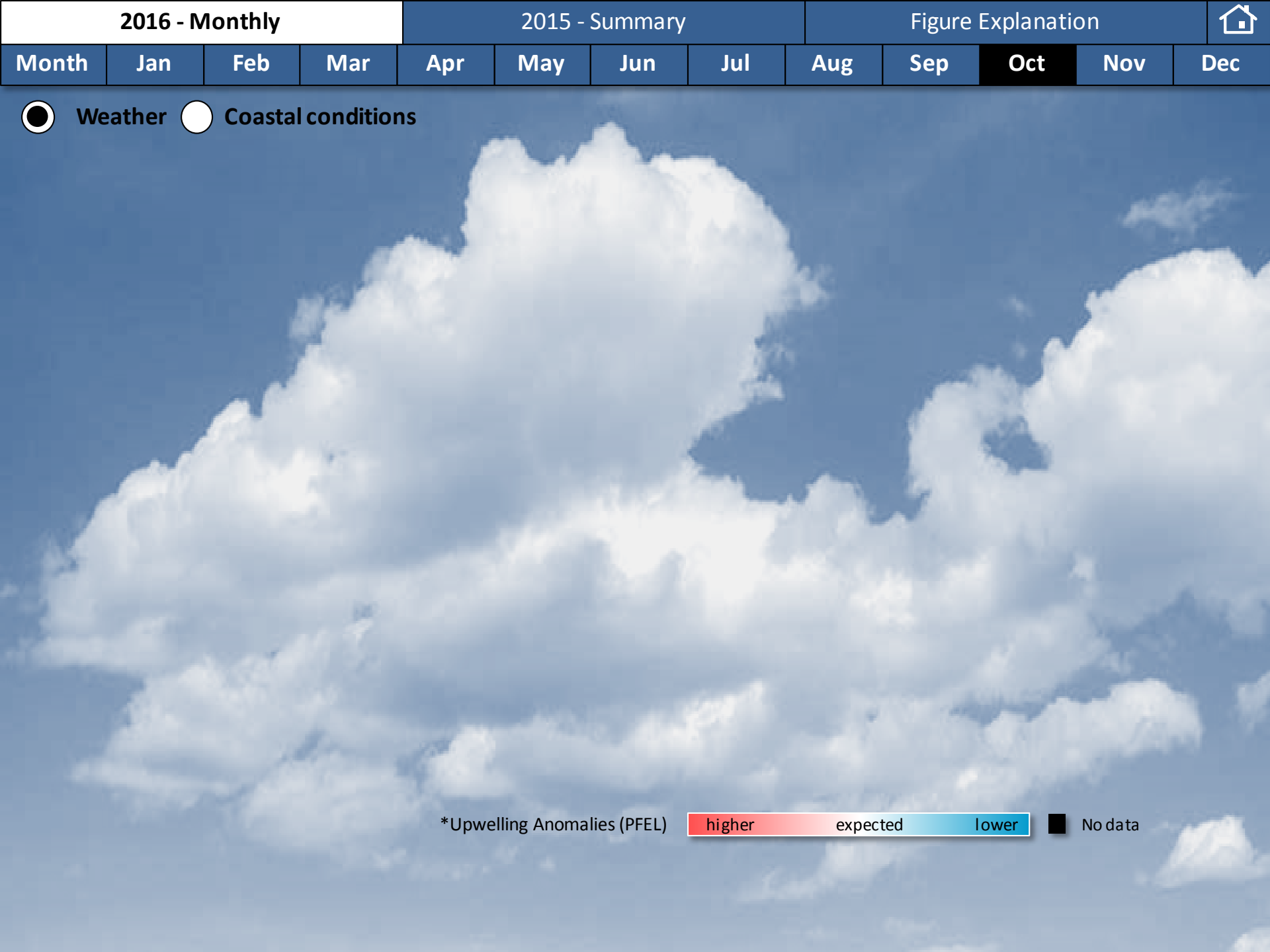
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Weather
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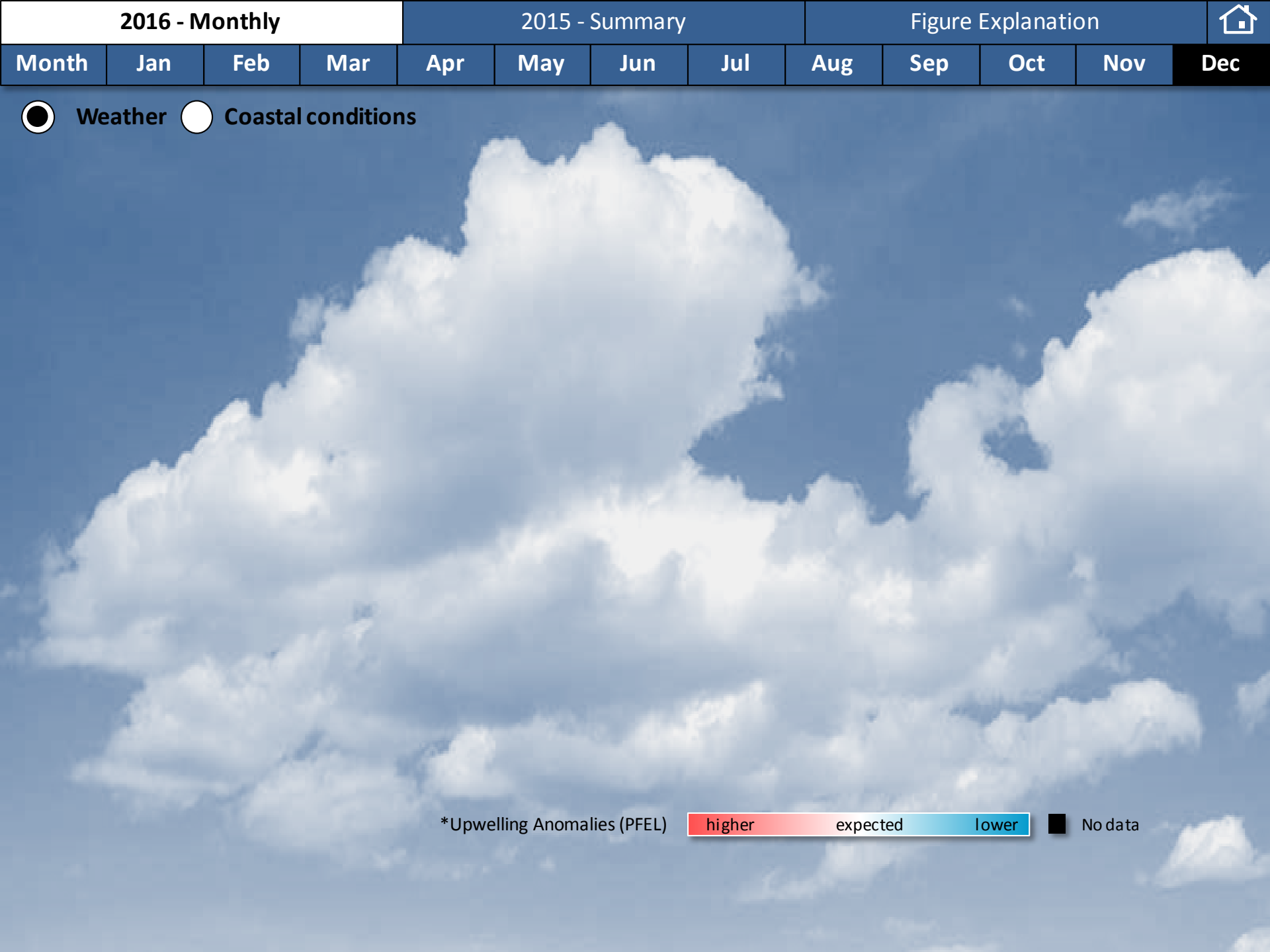
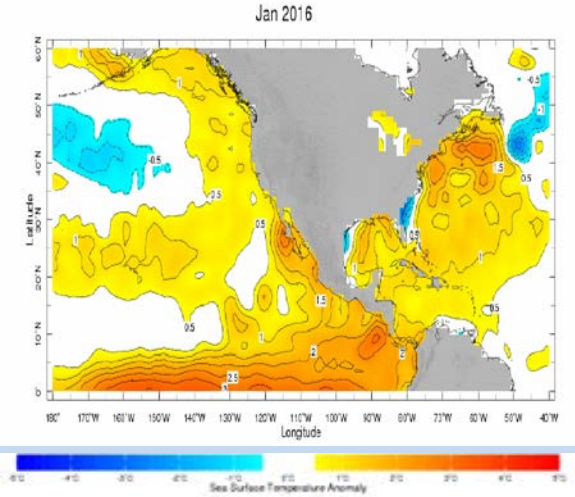

Weather
Coastal conditions
*Upwelling Anomalies (PFEL)
higher
expected
lower
No data

Indices describing oceanic boundary conditions which can affect marine water quality in our state



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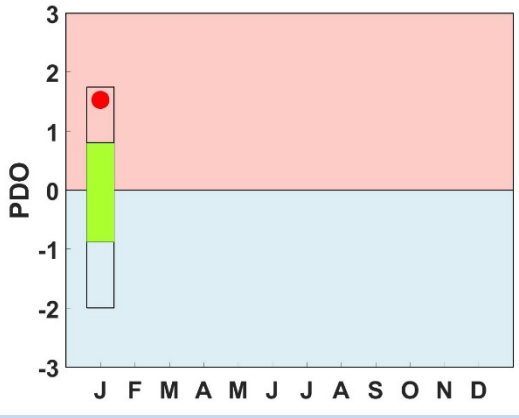
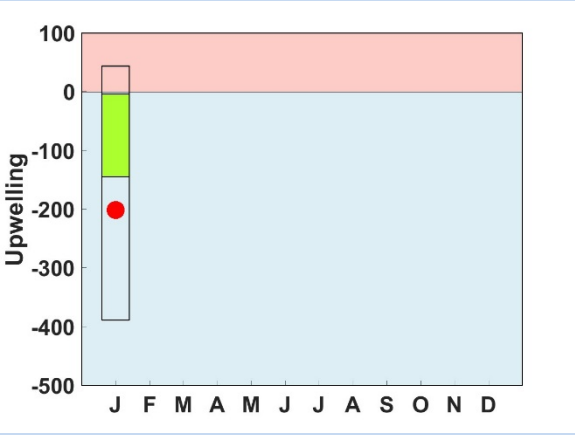
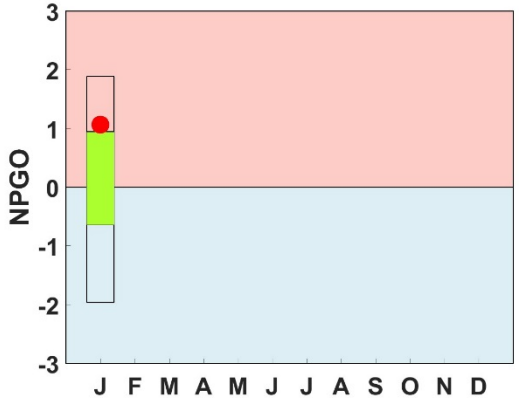


Warm phase
Cool phase





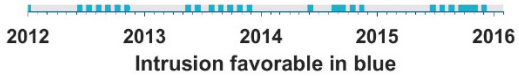
Summary:

Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

Upwelling Anomalies:
Downwelling significantly stronger than typical.

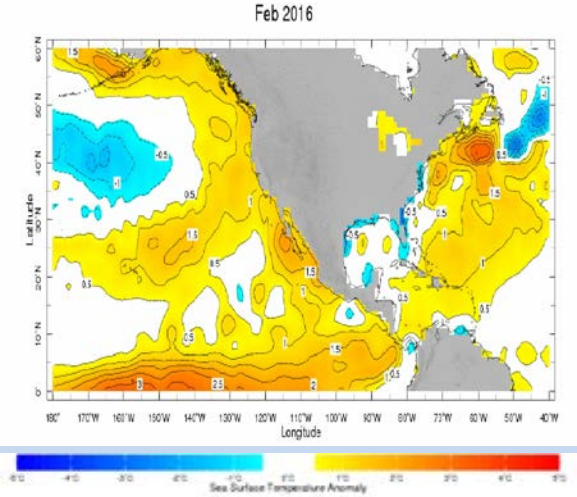
North Pacific Gyre Oscillation:
The NPGO is above normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.



Ocean-cold/warm and upwelling dominate year-to-year variability in Puget Sound.

Indices describing oceanic boundary conditions which can affect marine water quality in our state



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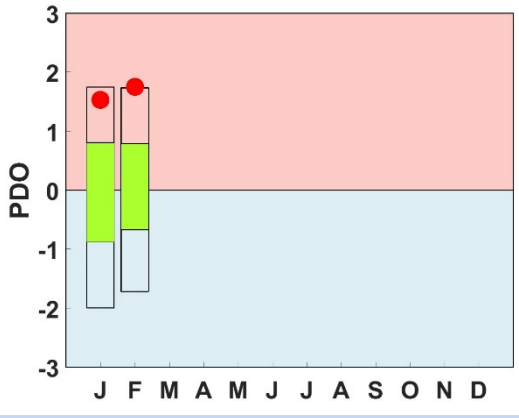
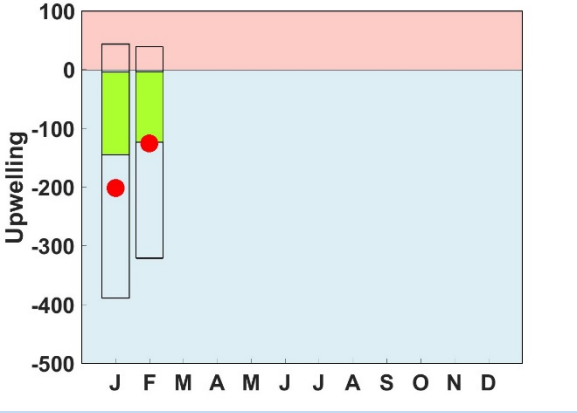
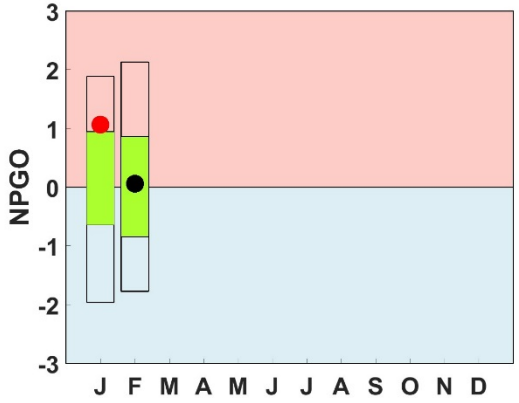


Warm phase
Cool phase





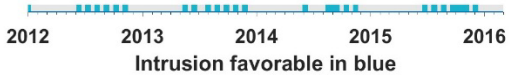
Summary:

Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

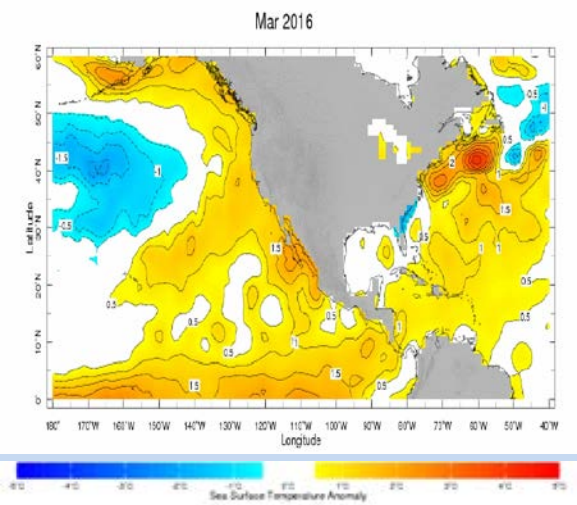
Upwelling Anomalies:
Downwelling significantly stronger than typical.

North Pacific Gyre Oscillation:
The NPGO was normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.



Indices describing oceanic boundary conditions which can affect marine water quality in our state



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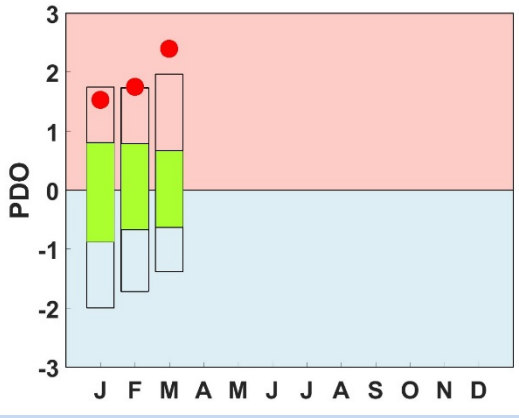
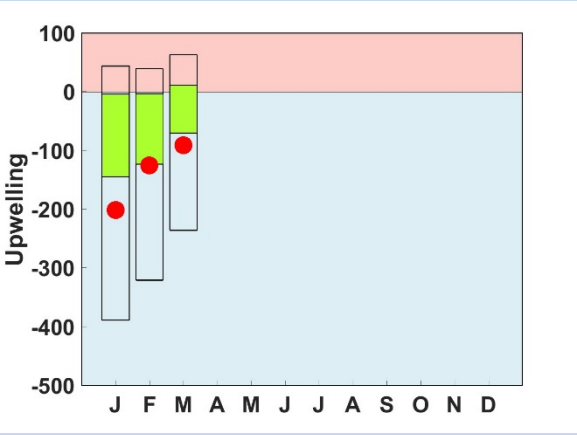
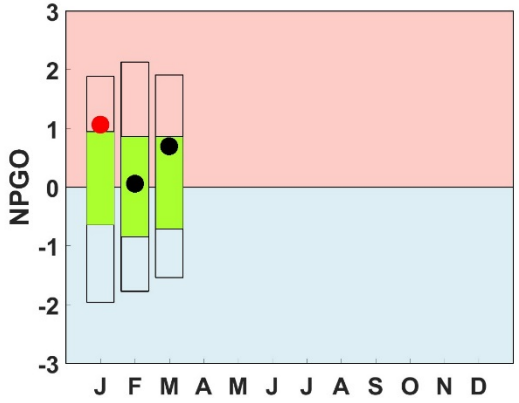


Warm phase
Cool phase





Summary:

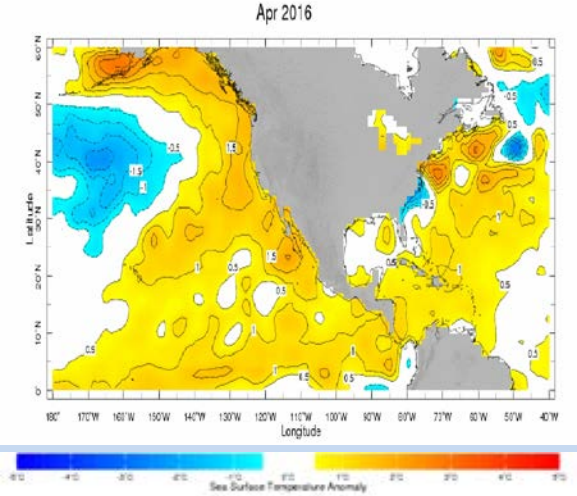
Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

Upwelling Anomalies:
Downwelling significantly stronger than typical.

North Pacific Gyre Oscillation:
The NPGO is on the high side of normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.

Indices describing oceanic boundary conditions which can affect marine water quality in our state



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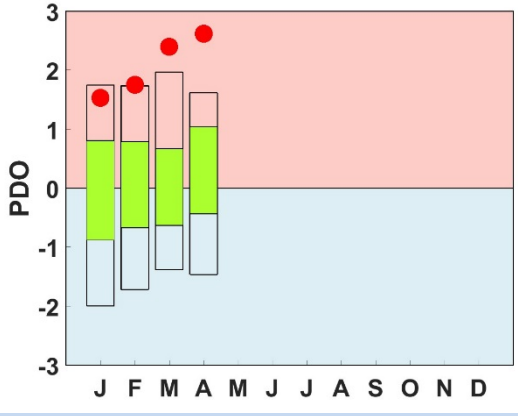
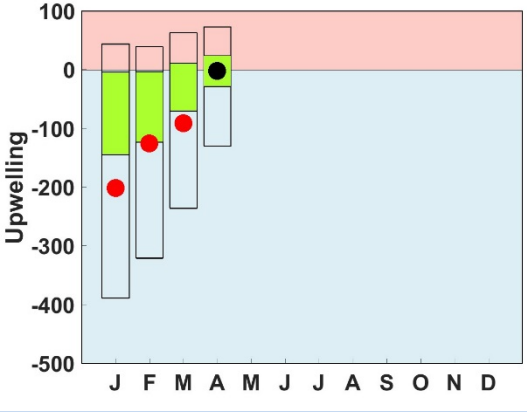
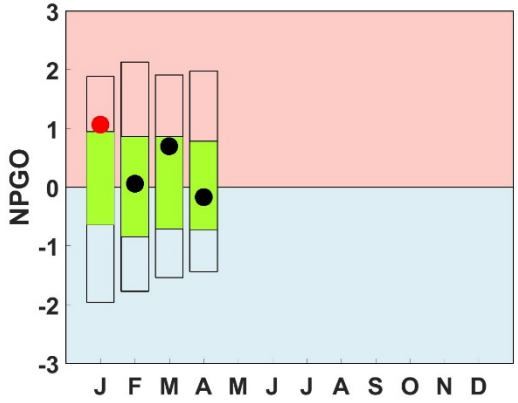


Warm phase
Cool phase





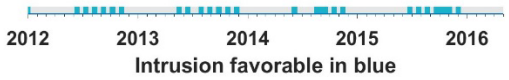
Summary:

Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

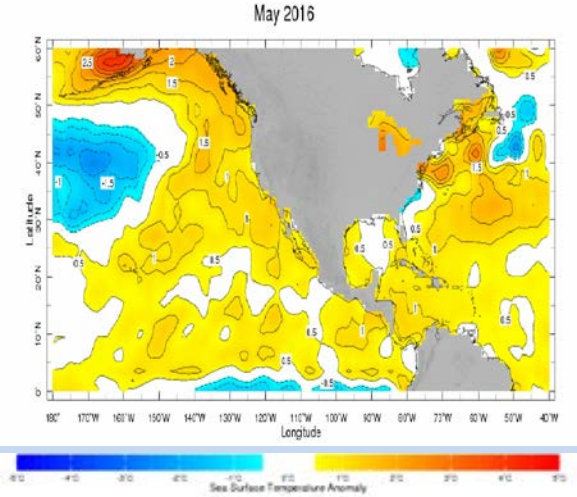
Upwelling Anomalies:
Upwelling tendency returns to normal.

North Pacific Gyre Oscillation:
The NPGO is on the low side of normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.



Indices describing oceanic boundary conditions which can affect marine water quality in our state



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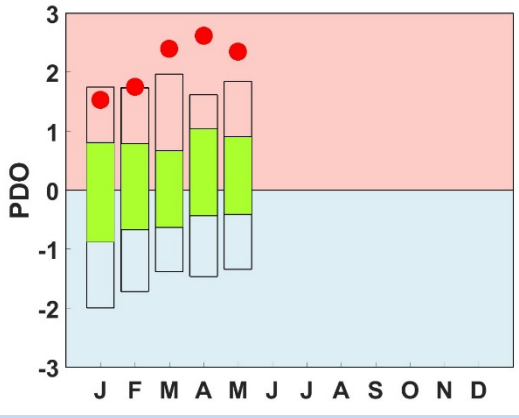
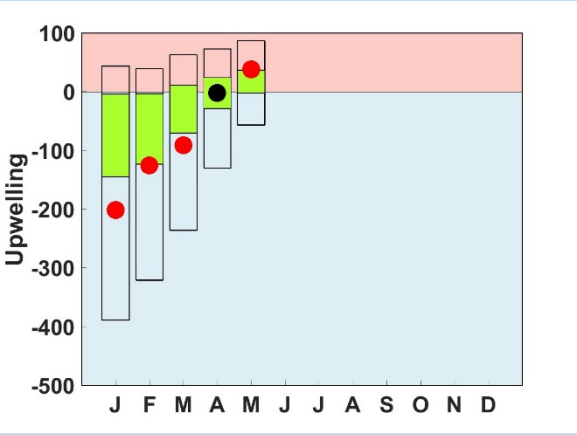
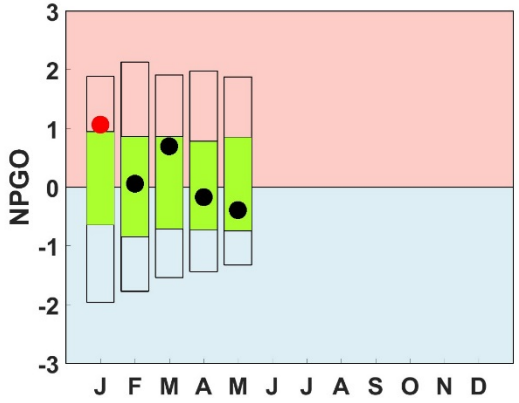


Warm phase
Cool phase





Summary:

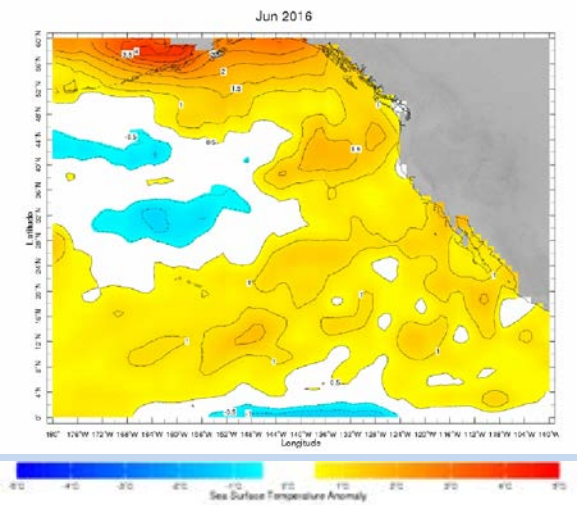
Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

Upwelling Anomalies:
Upwelling is significantly stronger than typical.

North Pacific Gyre Oscillation:
The NPGO is on the low side of normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.

Indices describing oceanic boundary conditions which can affect marine water quality in our state



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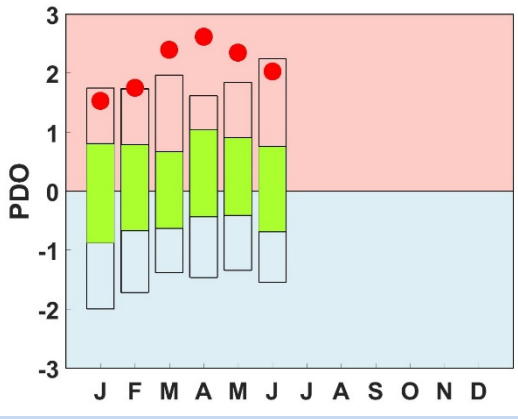
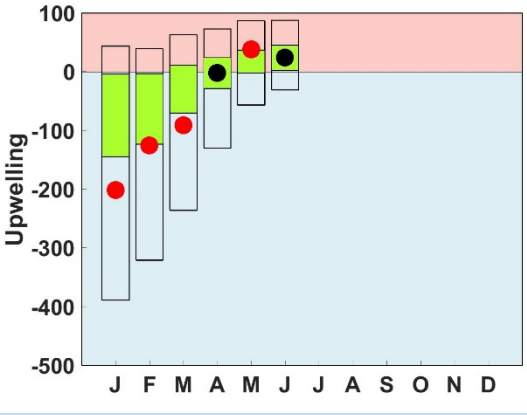
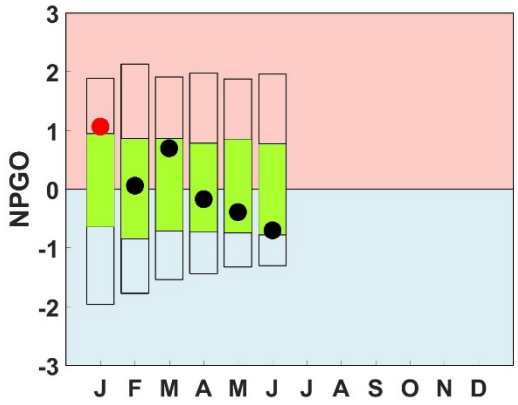


Warm phase
Cool phase





Summary:

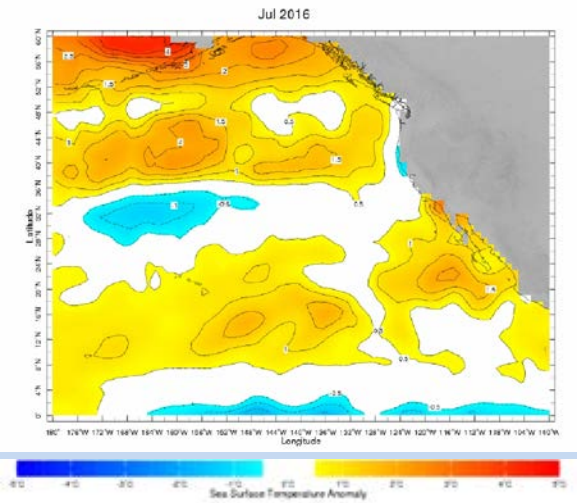
Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

Upwelling Anomalies:
Upwelling is typical.

North Pacific Gyre Oscillation:
The NPGO is on the low side of normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.

Indices describing oceanic boundary conditions which can affect marine water quality in our state



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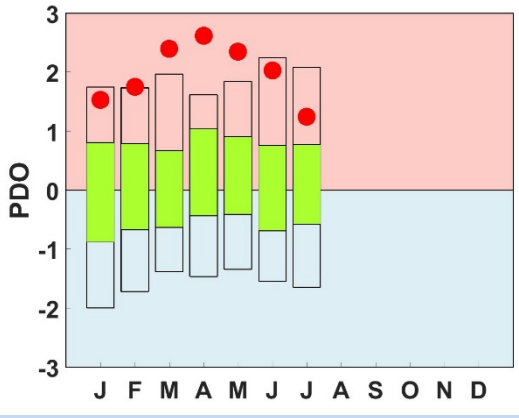
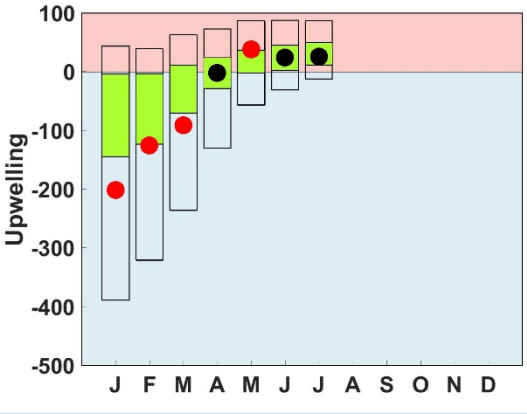
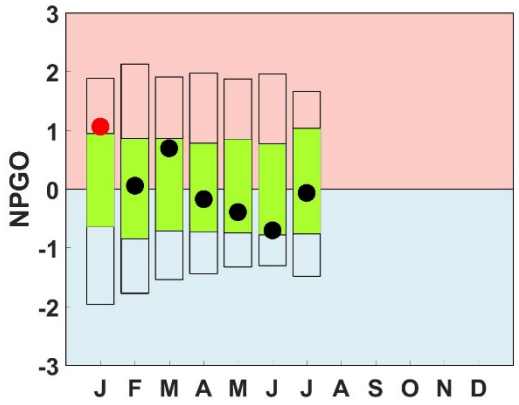


Warm phase
Cool phase





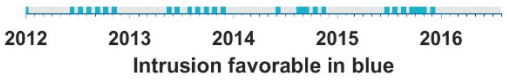
Summary:

Pacific Decadal Oscillation:
PDO is significantly above normal for most months since March 2015.

Upwelling Anomalies:
Upwelling is significantly stronger than typical.

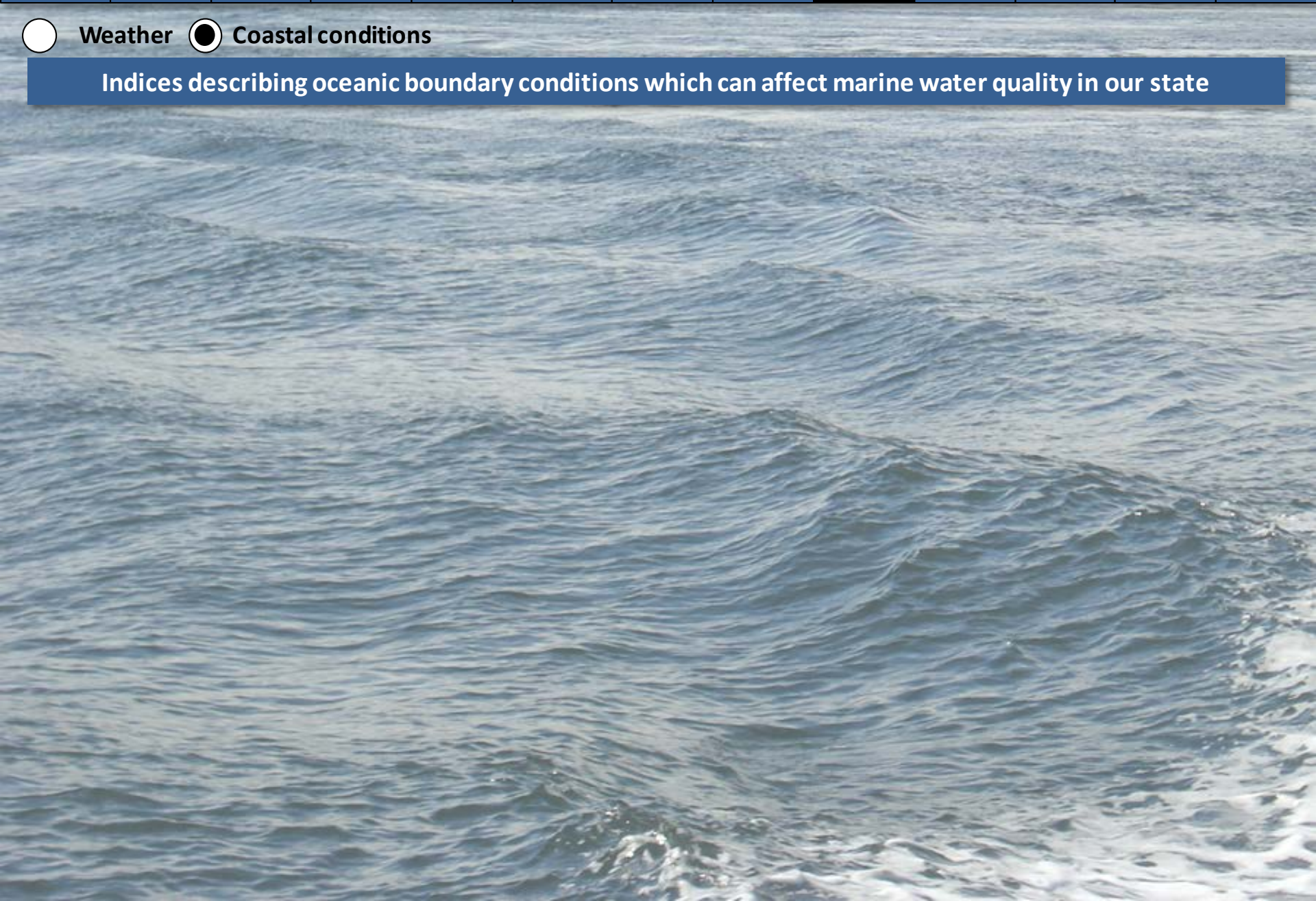
North Pacific Gyre Oscillation:
The NPGO is on the low side of normal.

Deppe intrusion index:
Oceanic intrusions are unfavorable this month.

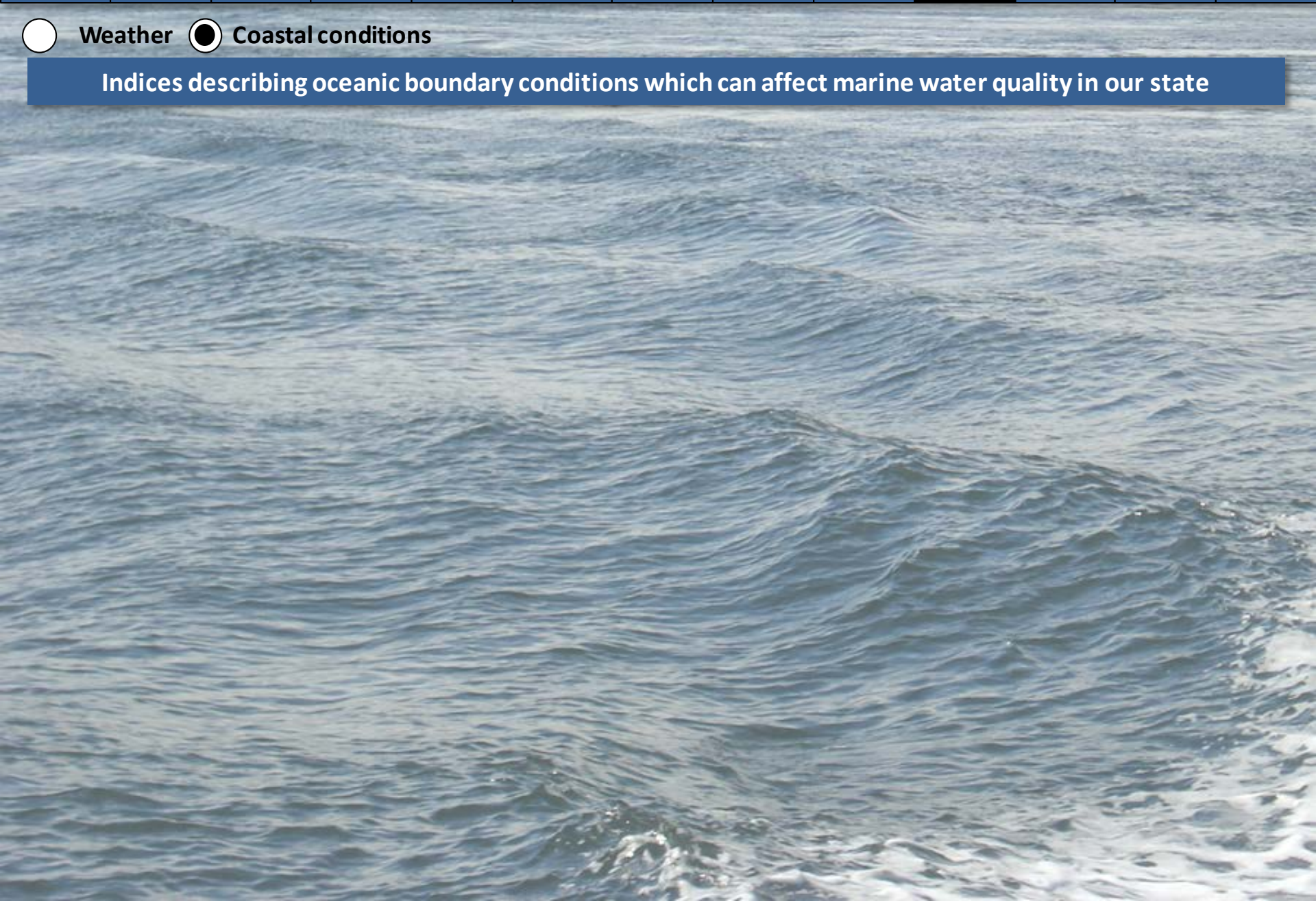


○ Weather ◉ Coastal conditions

Indices describing oceanic boundary conditions which can affect marine water quality in our state

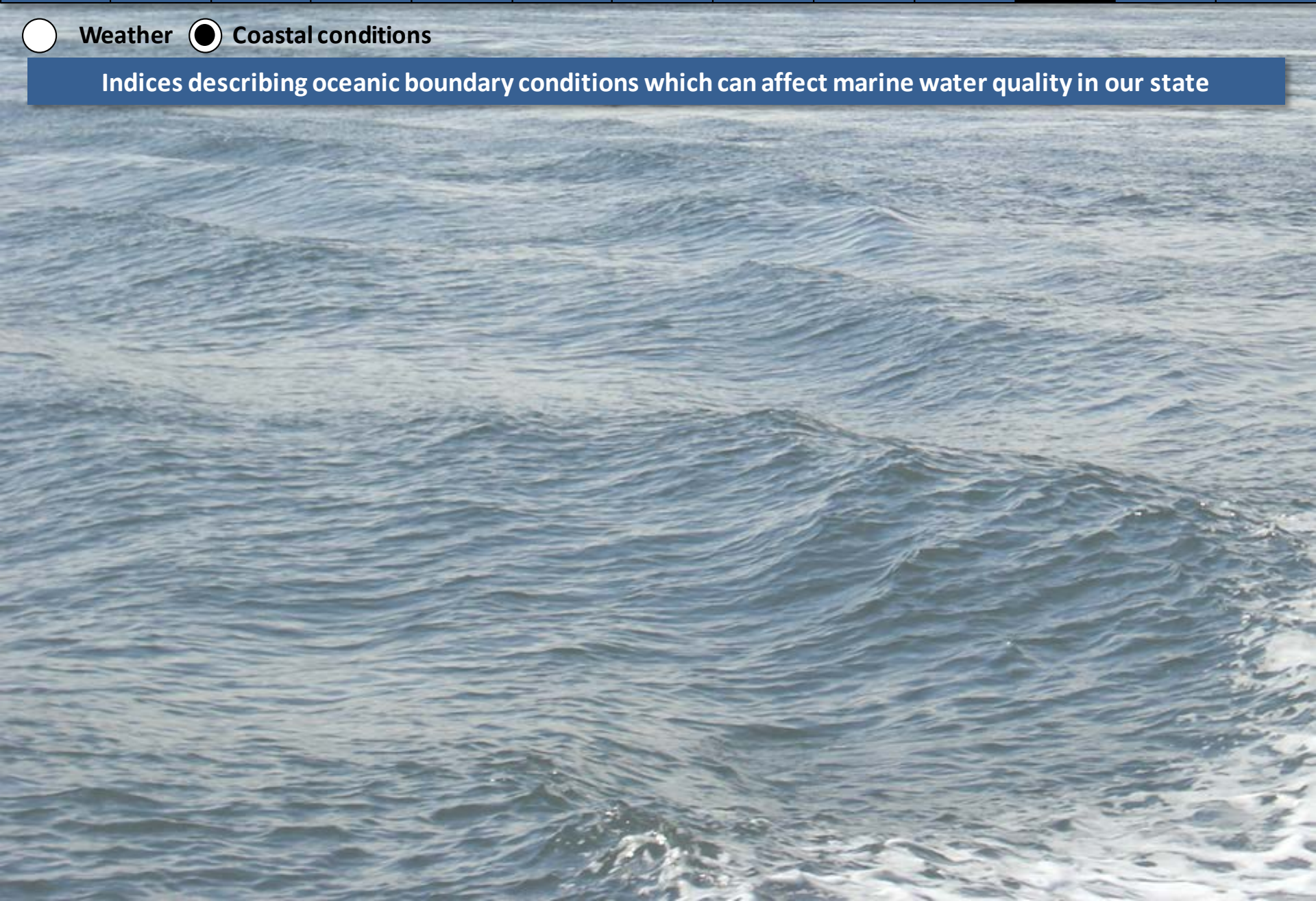


Indices describing oceanic boundary conditions which can affect marine water quality in our state



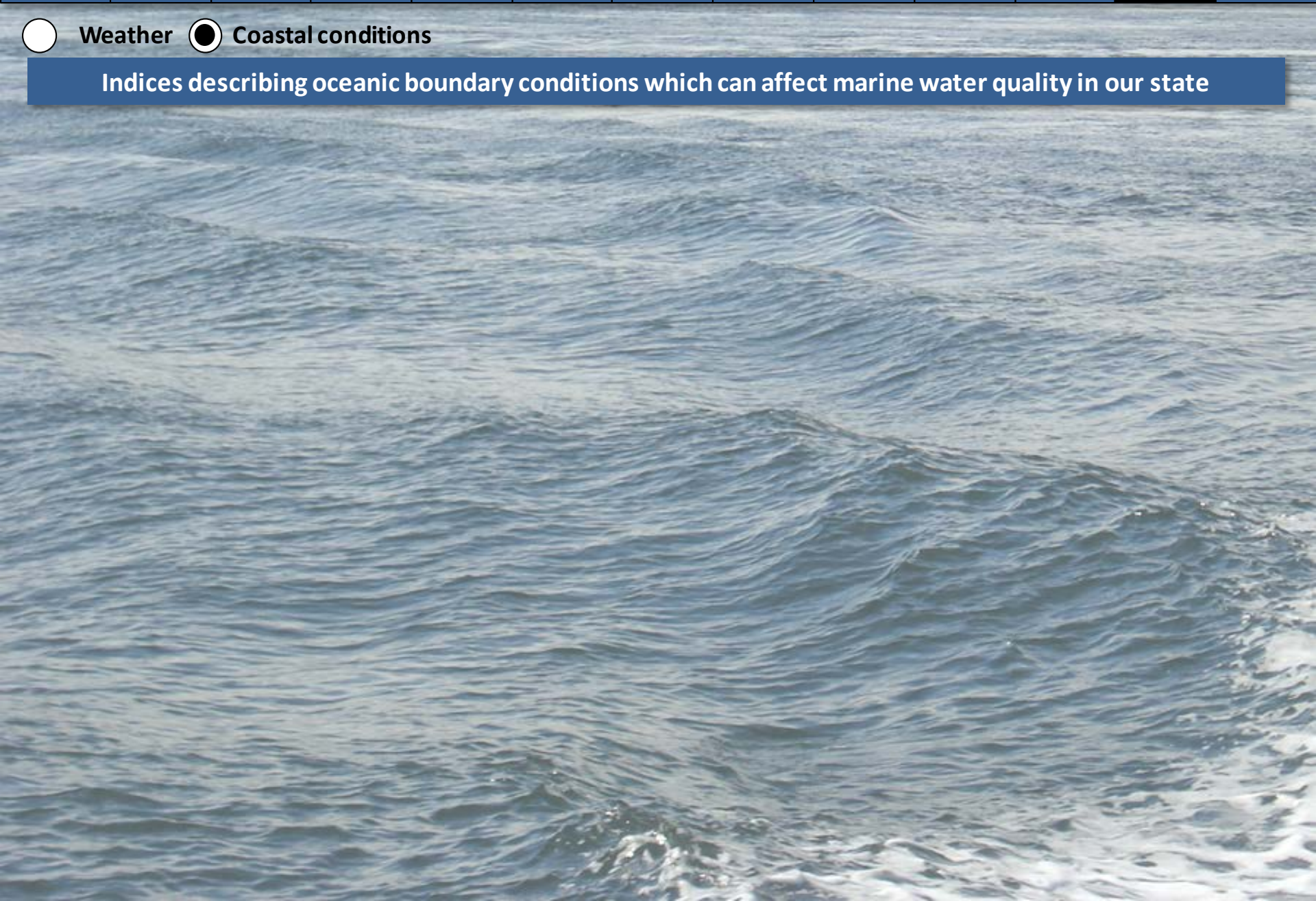
○ Weather ◉ Coastal conditions

Indices describing oceanic boundary conditions which can affect marine water quality in our state

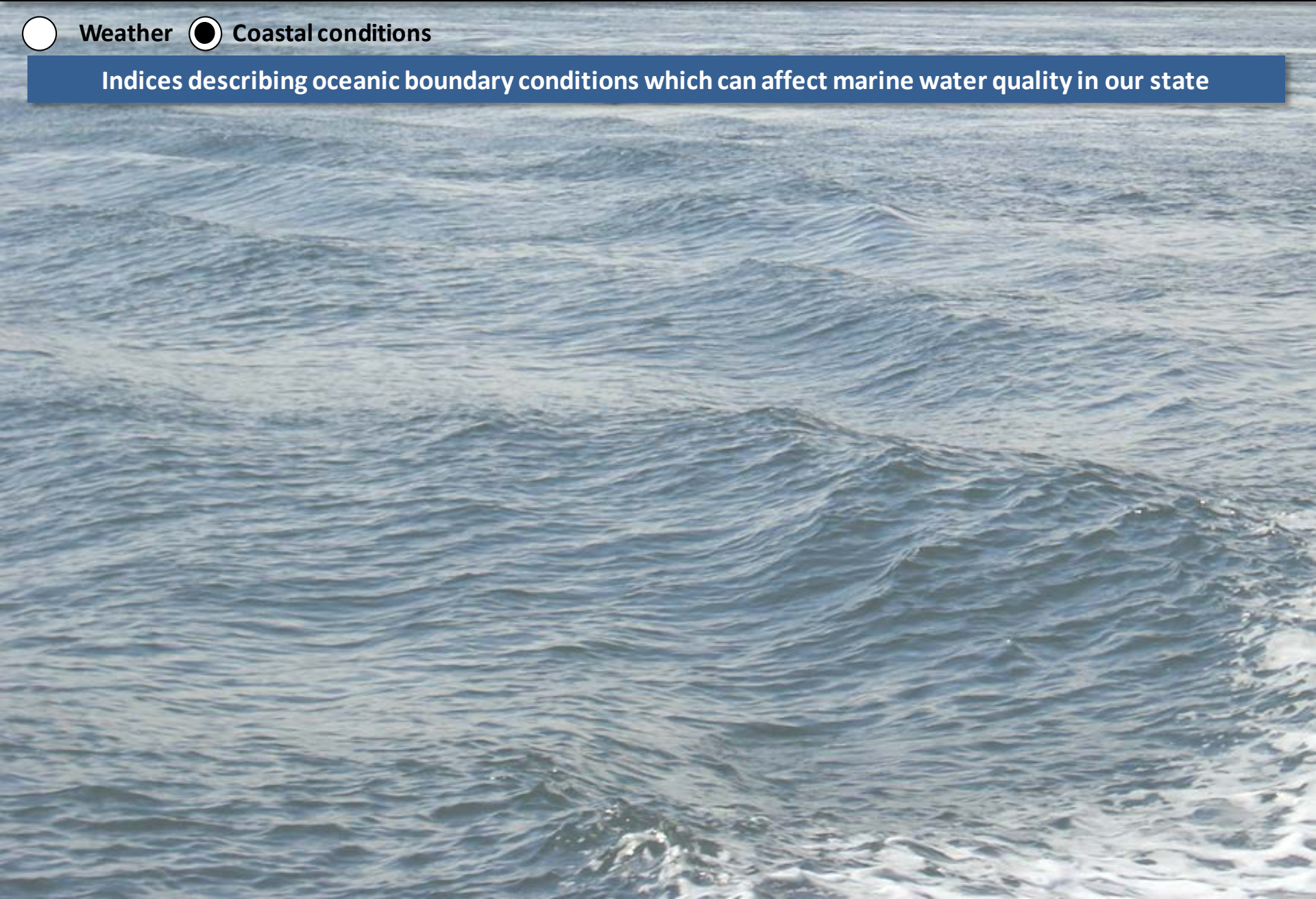


○ Weather ◉ Coastal conditions

Indices describing oceanic boundary conditions which can affect marine water quality in our state

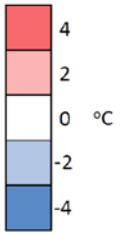


Indices describing oceanic boundary conditions which can affect marine water quality in our state



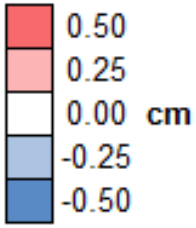
Weather **Coastal conditions**

Anomalies in Air Temperature



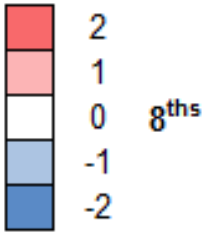
Anomalies of daily mean temperature (°C) from National Climate Data Center, 1971-2000 Climate Normals; red for warmer than normal, blue for cooler than normal.

Anomalies in Cumulative Precipitation



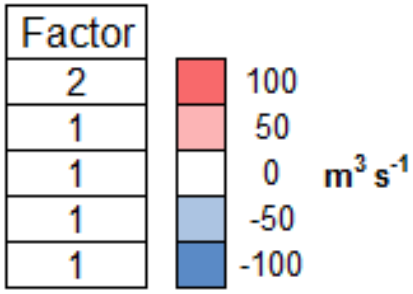
Anomalies of daily mean precipitation (cm) from National Climate Data Center, 1971-2000 Climate Normals; red for wetter than normal, blue for drier than normal.

Anomalies in Cloud Cover



Anomalies of daytime mean cloud cover (8ths) from National Climate Data Center. '0' is fully sunny, '8 is fully cloudy. Red is above monthly averages and blue is below it. Monthly means taken from daylight hours (7-16:00) during 2009-2013.

Anomalies in River Flow

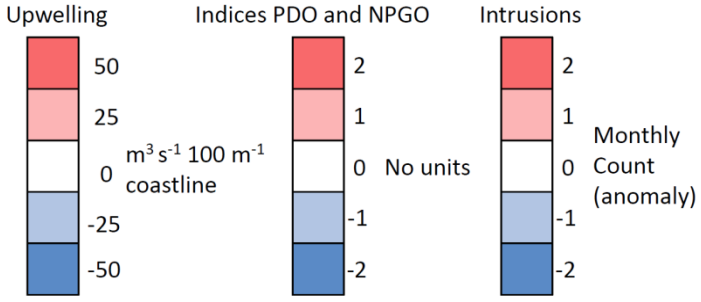


Anomalies of daily river transport (km^3s^{-1}) from USGS, and Environmental Canada for the Fraser River; red for higher flow than normal, blue for lower flow than normal.

Meteorological conditions typically explain up to half of the variance in observed marine variables (Moore et al. 2008), particularly in shallower waters like those of South Puget Sound.

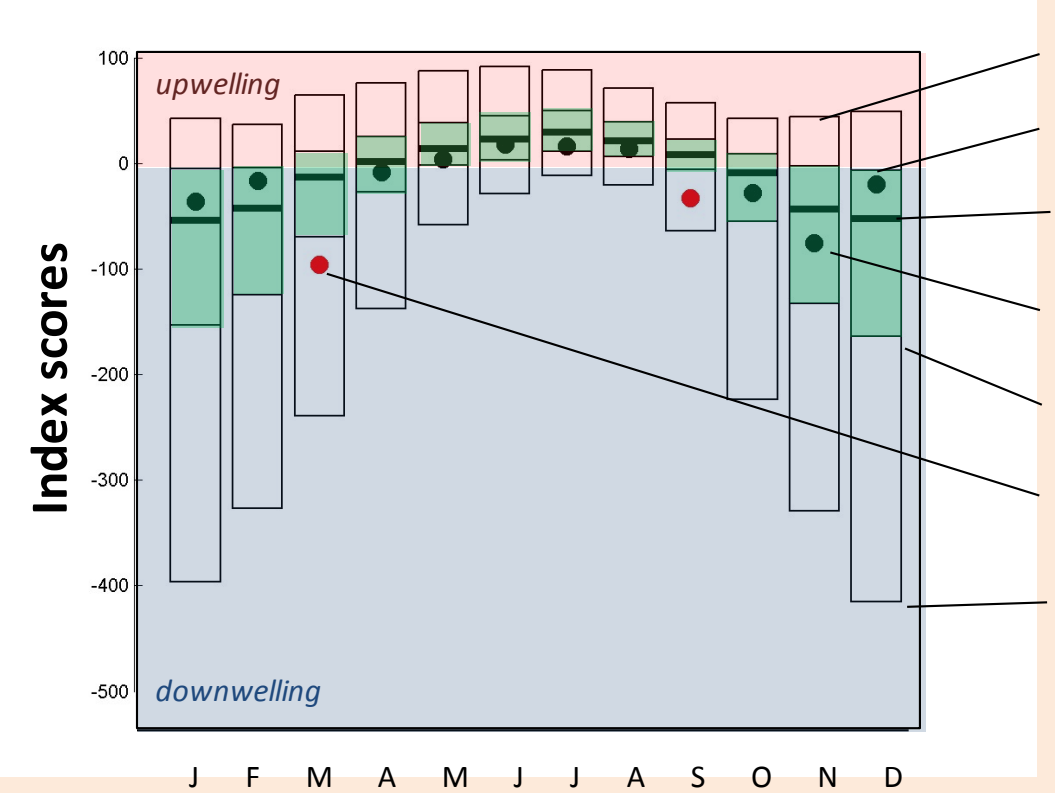
Moore et al. 2008. Local and large-scale climate forcing of Puget Sound oceanographic properties on seasonal to interdecadal timescales. Limnol. Oceanogr., 53(5), 1746–1758

PDO, NGPO, upwelling indices



Weather Coastal conditions

Monthly Index Scores and Anomalies



95th percentile

75th percentile

median

this years monthly index score

25th percentile

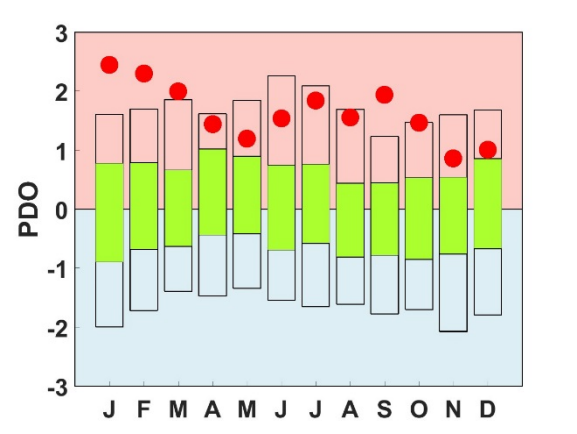
Histogram of Upwelling Index scores

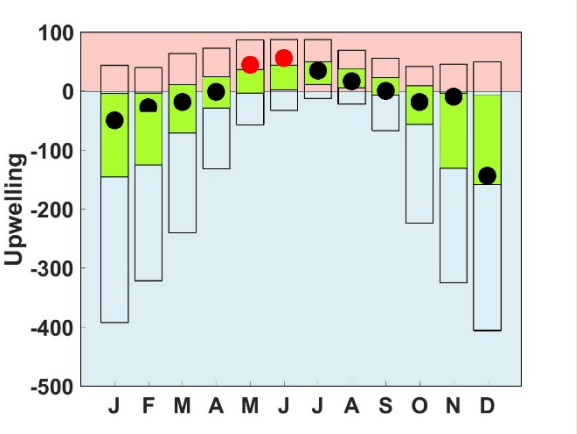
Differs from historical record

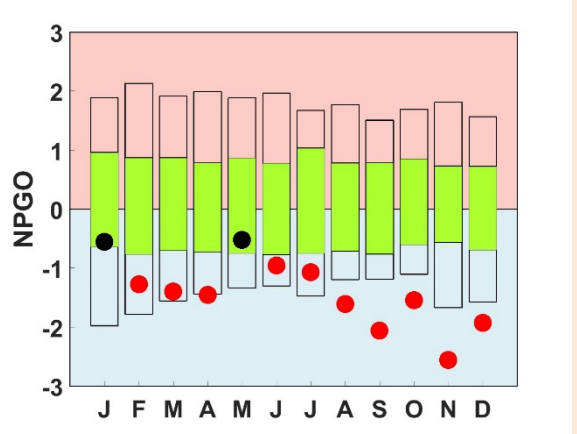
5th percentile

Key indices are the Pacific Decadal Oscillation (PDO, dimensionless) derived from observed Pacific Sea Surface Temperature and Sea Level Pressure, Upwelling ($m^3/s/100$ m coastline) at 48°N and 125°W that is positive for upwelling, and negative for downwelling conditions, and NPGO that is the oceanic expression of the North Pacific Oscillation (Walker and Bliss) the north-south seesaw in sea level pressure.

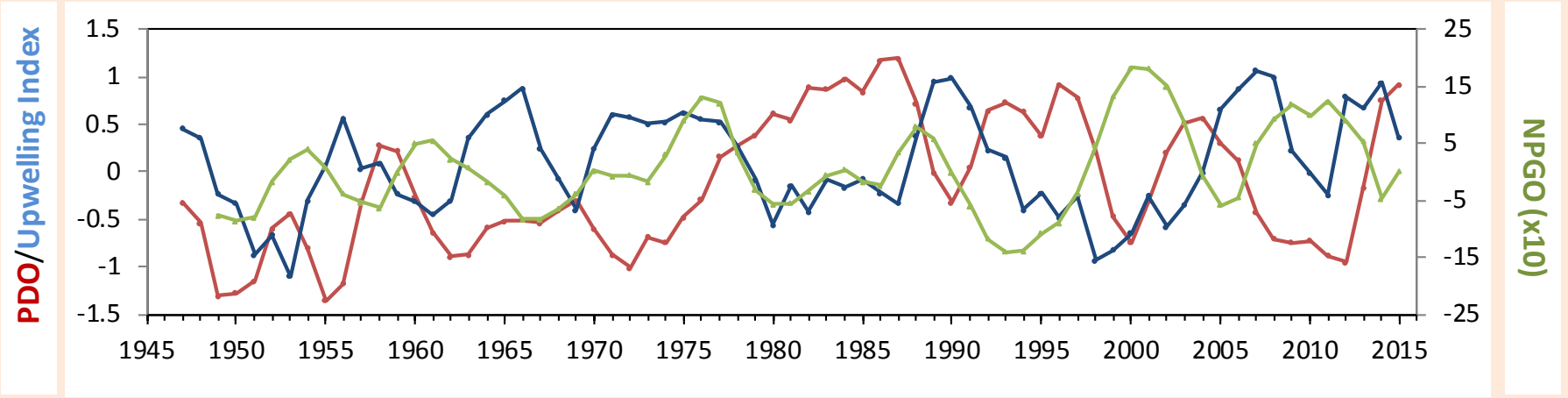
Weather ● Coastal conditions







PDO persisted in warm phase in 2016. Upwelling was above normal in May and June. NPGO is mostly below normal.



◉ **Weather** ○ **Coastal conditions**

Meteorological conditions typically explain up to half of the variance in observed marine variables (Moore et al. 2008), particularly in shallower waters like those of South Puget Sound. The specific conditions prevalent during the past two weeks, from north to south, are shown below.

Summary:

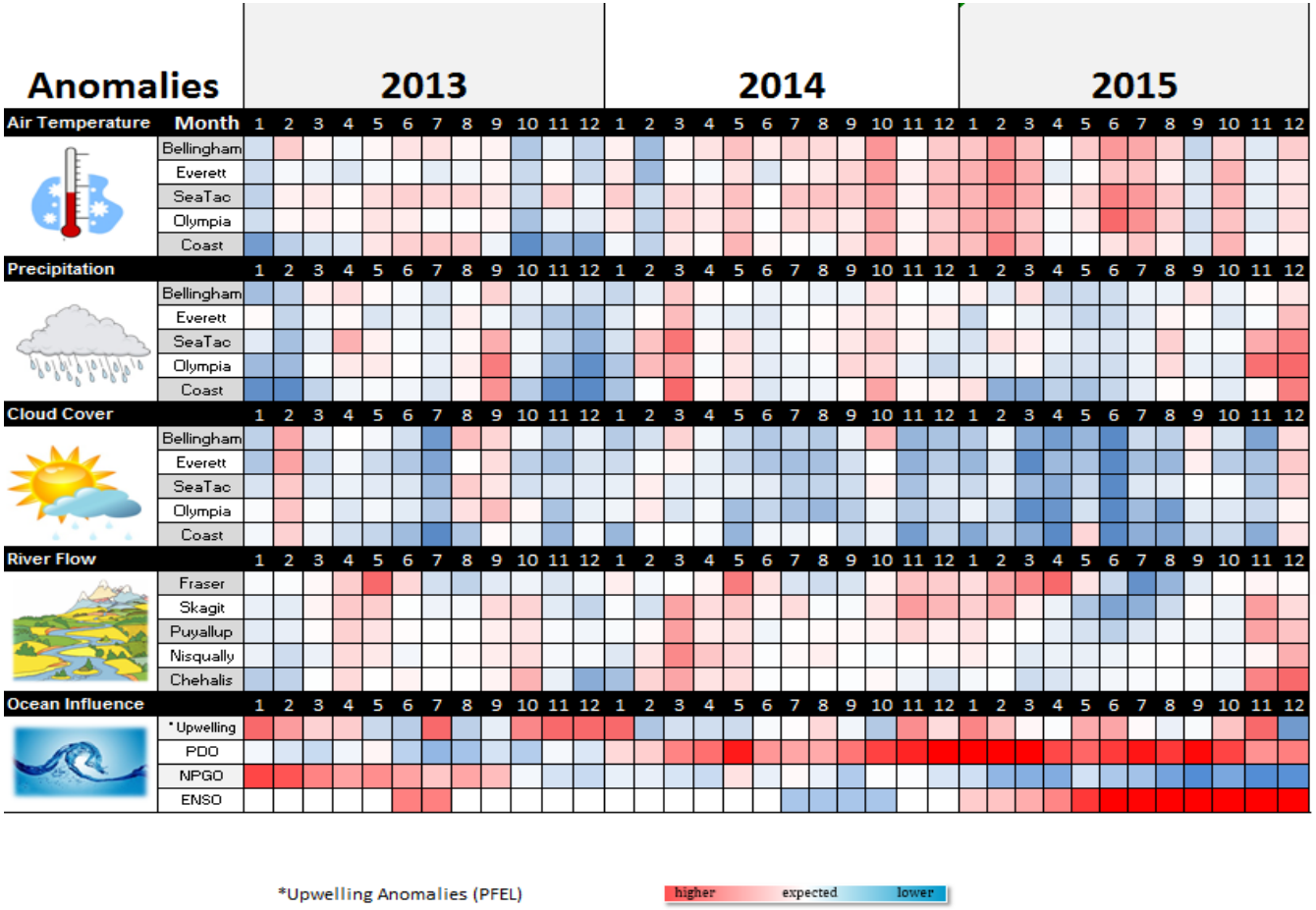
Air temperatures were generally above normal, which was responsible for low snow pack. September and November were cool.

Precipitation was below normal April – July.

Cloud Cover has been mostly below normal, except during December.

Rivers Fraser was high in April, low in summer.

Downwelling has been less vigorous for many winter months & PDO warmer than normal. El Niño developed.



Moore et al. 2008. Local and large-scale climate forcing of Puget Sound oceanographic properties on seasonal to interdecadal timescales. Limnol. Oceanogr., 53(5), 1746–1758