Ocean Conditions, Salmon, and Climate Change

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Why study the ocean?

- Ocean productivity sets salmon recruitment levels - return rates can vary >10x with similar freshwater conditions/survival

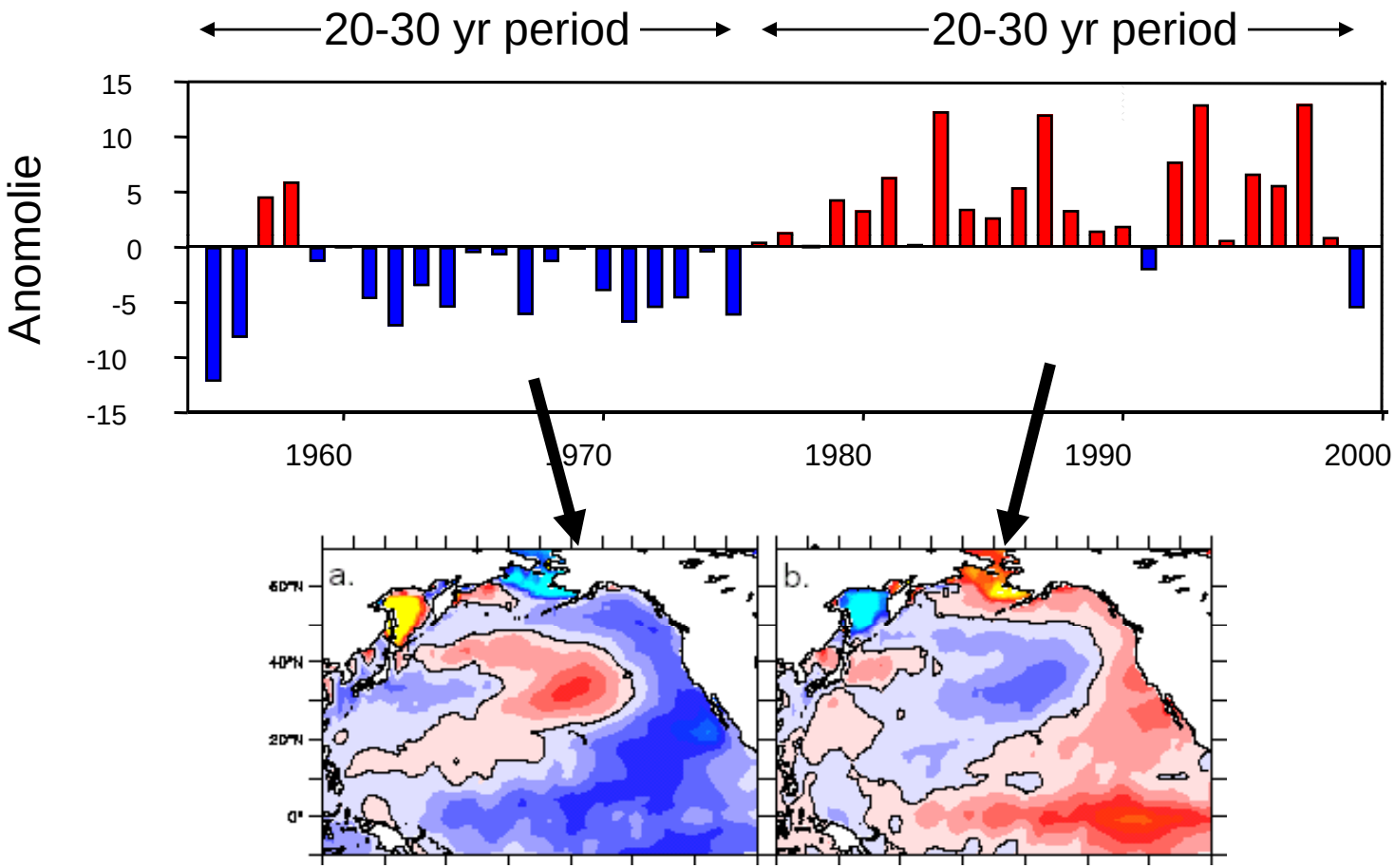
- The coastal pelagic ecosystem is dynamic and the variability seems to be increasing – need to put FW actions in this context

- Objective – Understand processes and develop tools (models and ocean indices) for forecasting salmonid survival and returns

Questions Being Addressed

- Can we define ‘ocean conditions’, how it changes, and how it affects salmon growth and survival
- How do we assemble a forecasting tool
- What does the future hold – climate change?

Atmopheric and Ocean Phase shifts are tracked by the Pacific Decadal Oscillation (PDO): negative values = cool phase; positive values = warm phase.



NE Pacific Ecosystem Response To PDO

Negative PDO

- SST Cooler
- Secondary Productivity – Alaska↓, PNW↑
- Salmon Abundance - Alaska↓, PNW↑

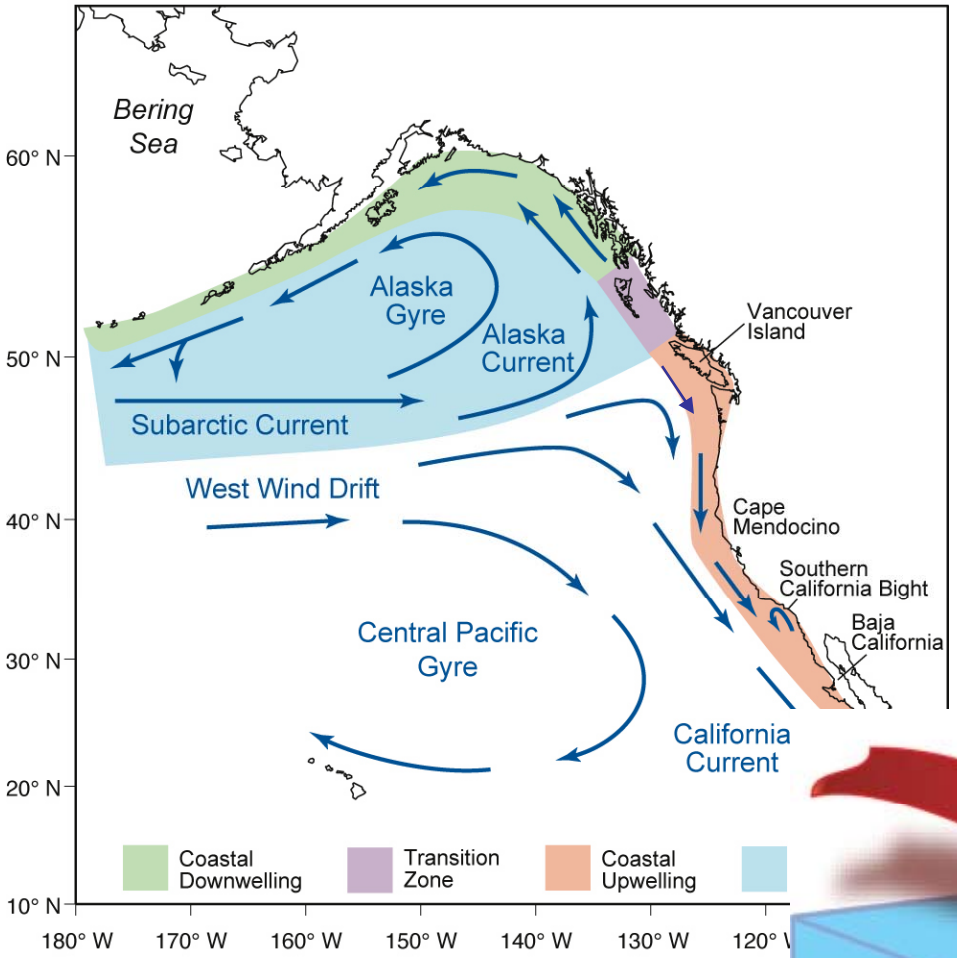
Positive PDO

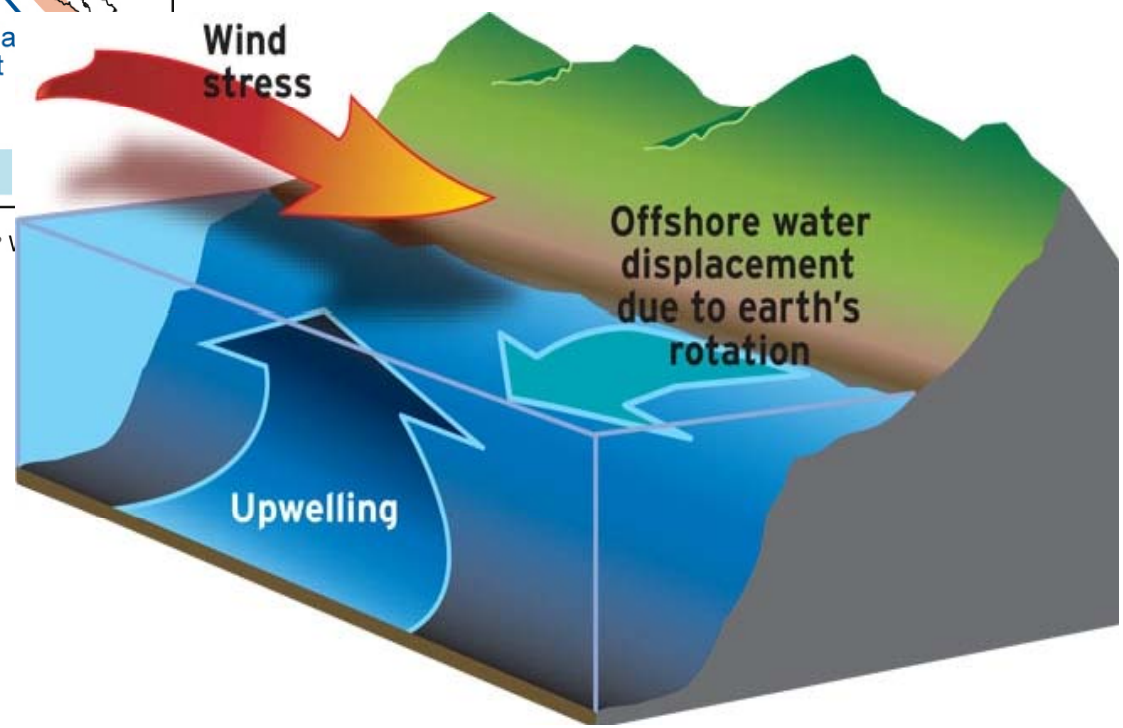
- SST Warmer
- Secondary Productivity – Alaska↑, PNW ↓
- Salmon Abundance - Alaska↑, PNW ↓

Circulation off the Pacific Northwest

Note: CC begins at ~ N end of Vancouver Island

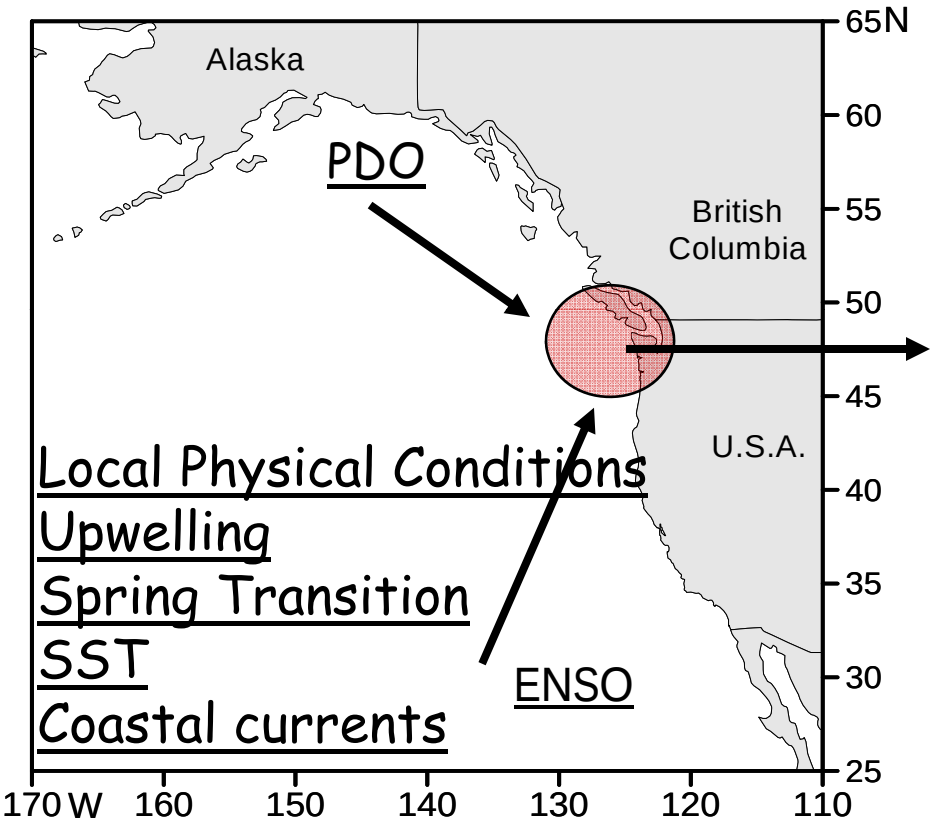
Winds drive currents and cause upwelling

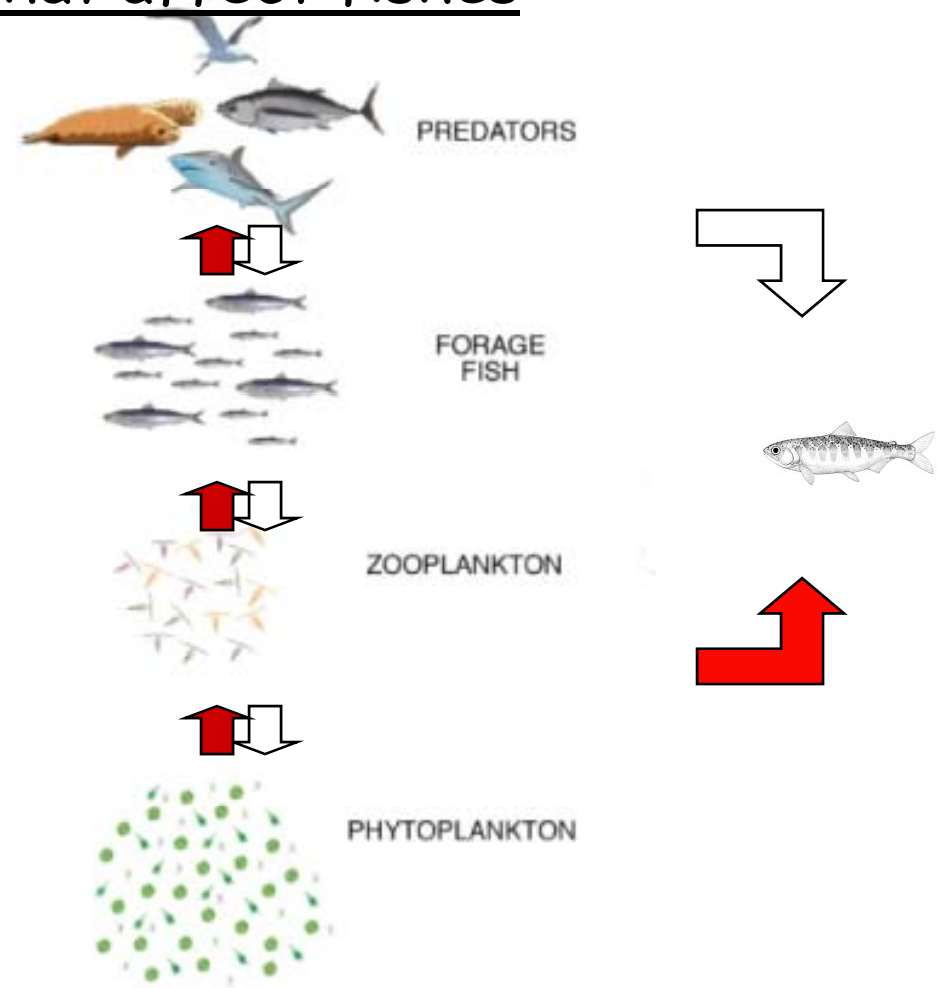




We are taking a holistic approach to development of indices and management advice by considering a suite physical and biological factors that affect fishes

Large scale forces acting at the local scale can influence biological process important for salmon

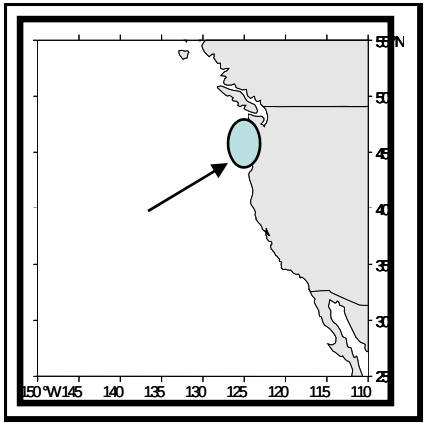




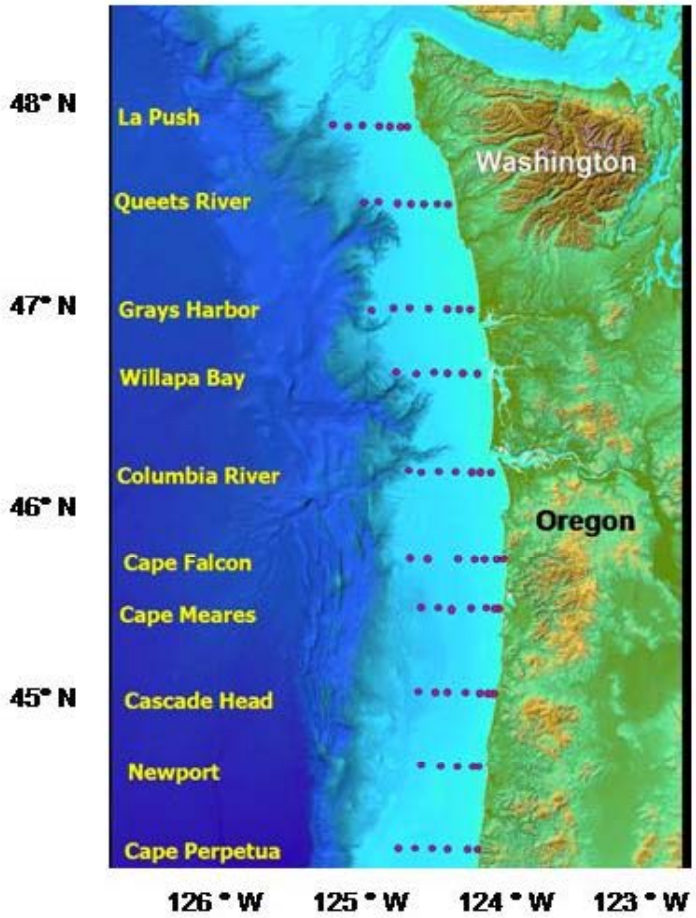
Approach

1. Develop time series
2. Relate to salmon through simple bivariate analyses

Local Biological Conditions

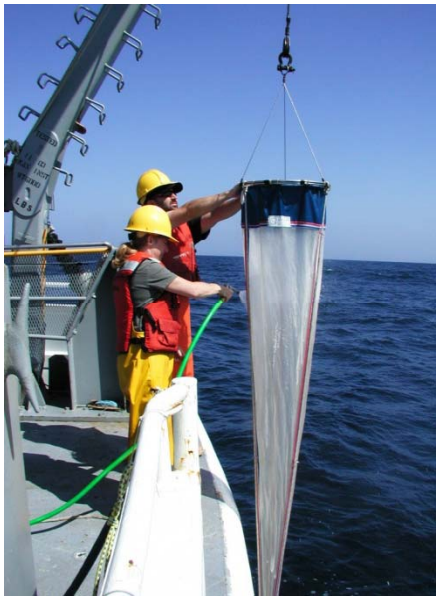


Plankton, Salmon and Pelagic Fish Sampling

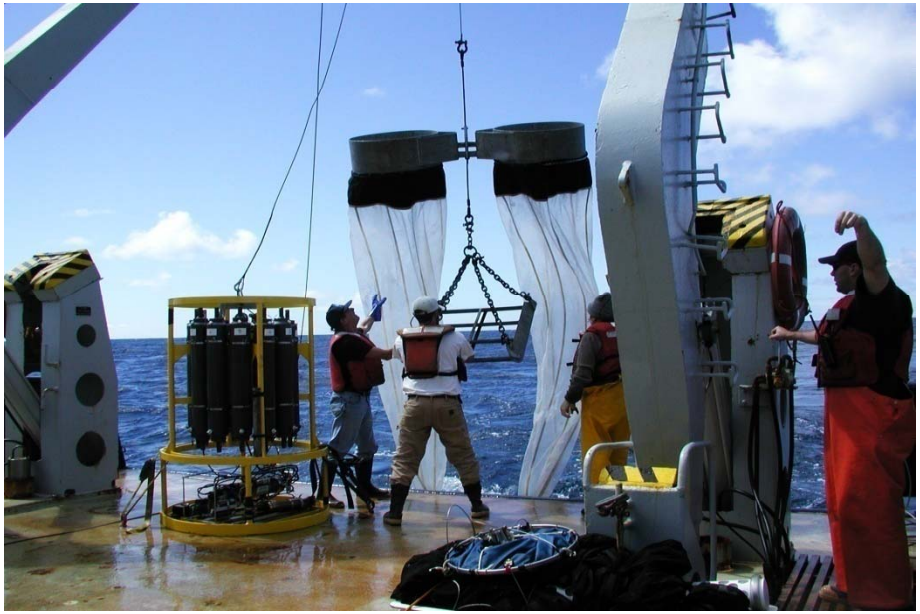


- Sample in May, June and September (50 stations) since 1998
- Sample Columbia River and Willapa Bay every 10 days from April through July (AT NIGHT) at ~ 10 stations; since 1998
- Sample off Newport every two weeks, since 1996
- Have historical data on hydrography and zooplankton from 1970s and 1983; salmon abundance data from 1981-1985 but only some of these data are part of this talk

Sampling Methods

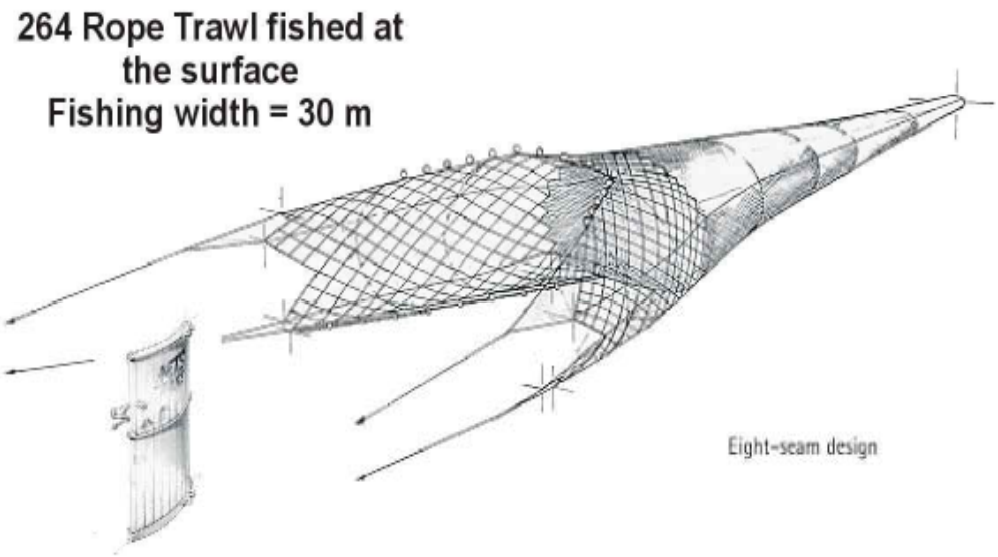


- Water sampling with CTD, Niskin Bottles, and buckets for hydrography, chl-a and nutrients
- Mesozooplankton with $\frac{1}{2}$ m 200 μm mesh net towed vertically
- Euphausiids with 70 cm 505 μm mesh net towed obliquely



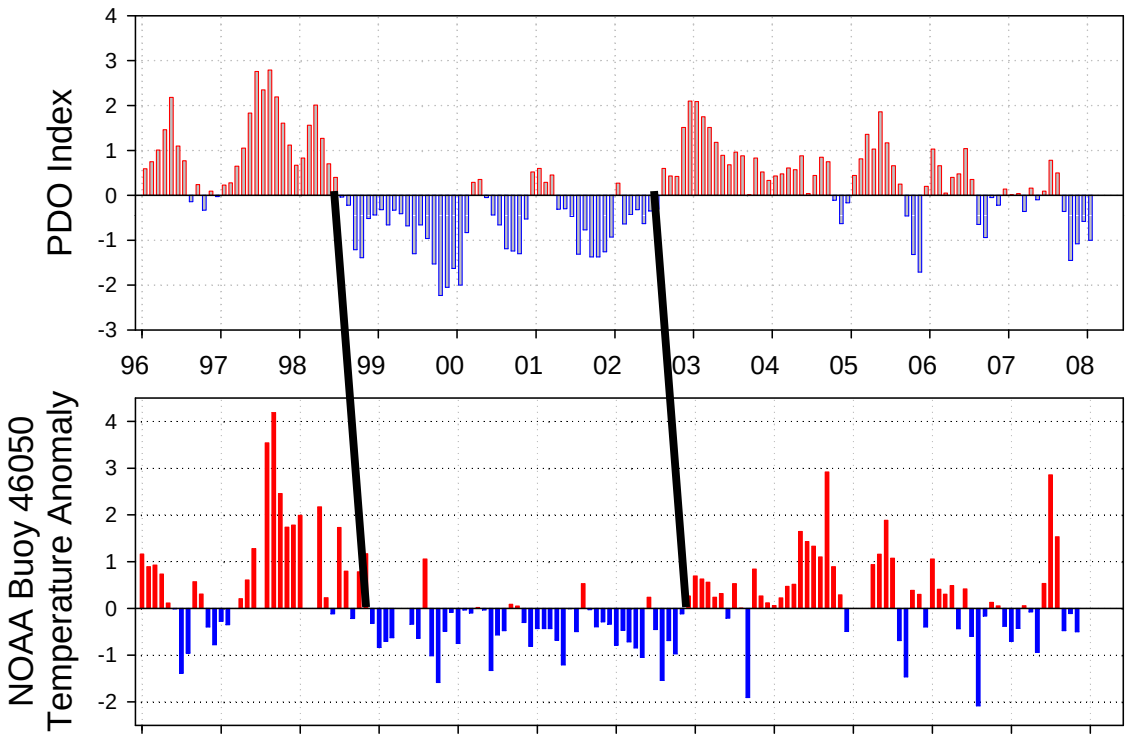
Sampling Methods

- Sample fish with a NET 264 rope trawl: 20 m high x 30 m wide x 200 m long



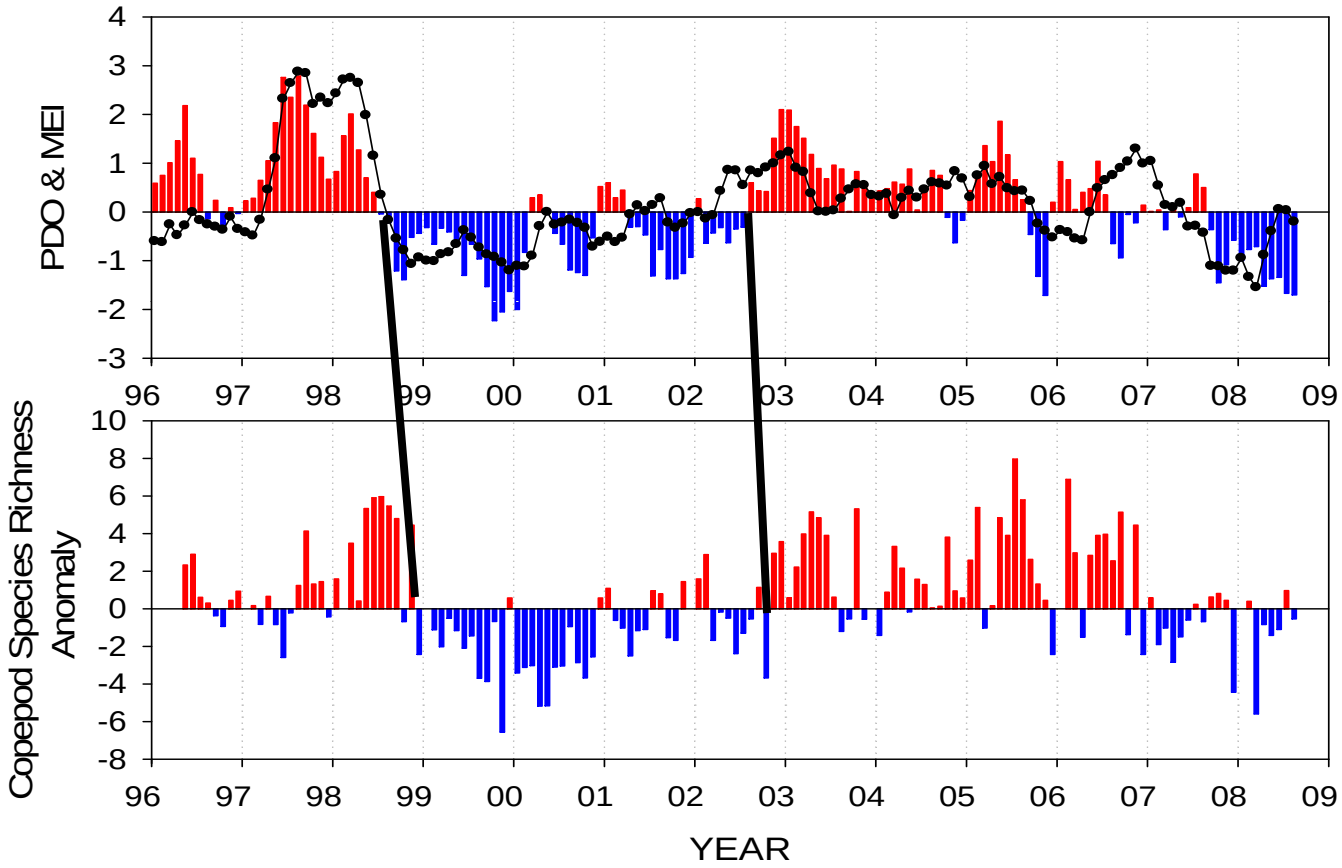
- Standard oceanographic measurements
  - CTD
  - Secchi disc
  - Nutrients & chlorophyll
  - Zooplankton

12 year time series of SST off Newport shows that PDO downscales to local SST



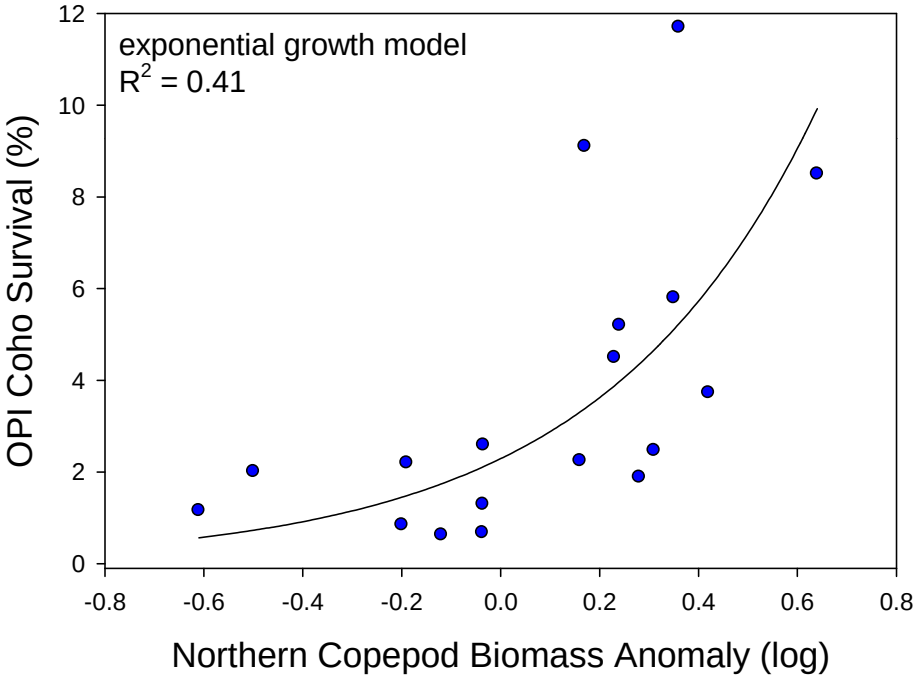
- PDO and SST correlated, as they should be.
- However there are time lags between PDO sign change and SST response of 3-5 months.
- Suggests PDO is an advective signal along the Oregon coast

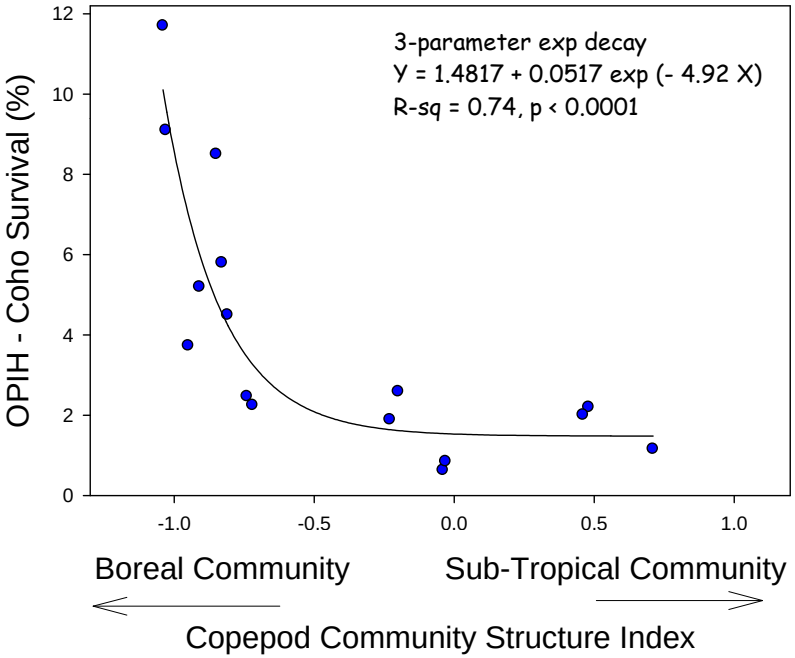
Zooplankton population dynamics off Newport shows that monthly anomalies of copepod species richness are correlated with the PDO



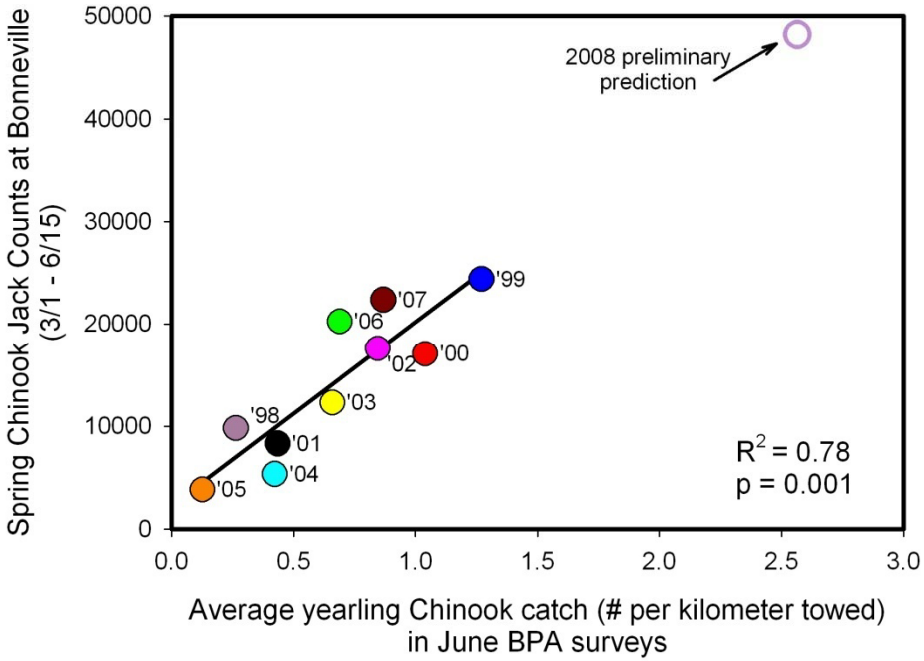
As with SST, there are time lags of a few months between the recent 4-year "cold periods" and "warm periods". Cold periods are characterized by "cold water" copepods and vice versa.

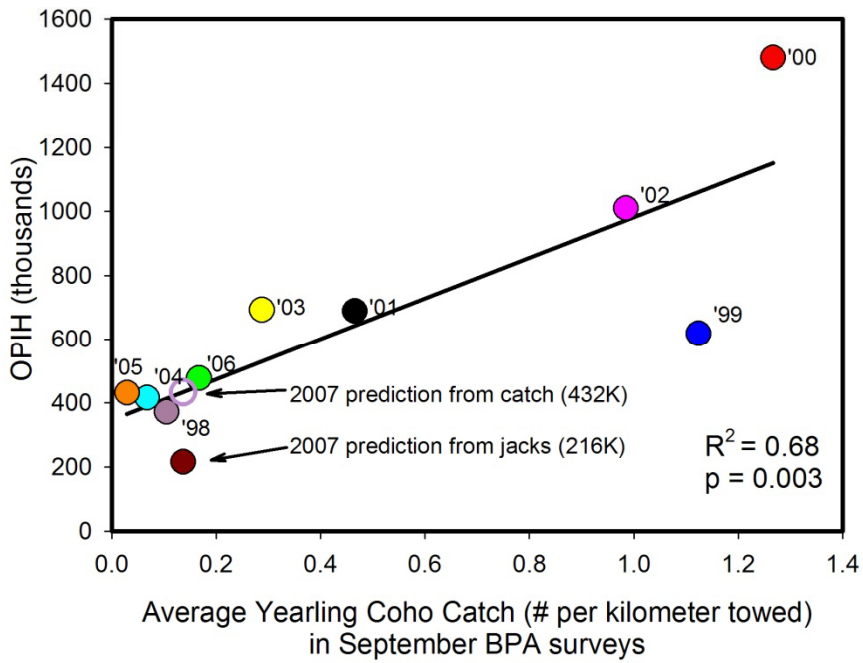
Copepod indices: integrative





Catches of juv. salmon vs. number of returning spring Chinook jacks and OPIH coho one year later



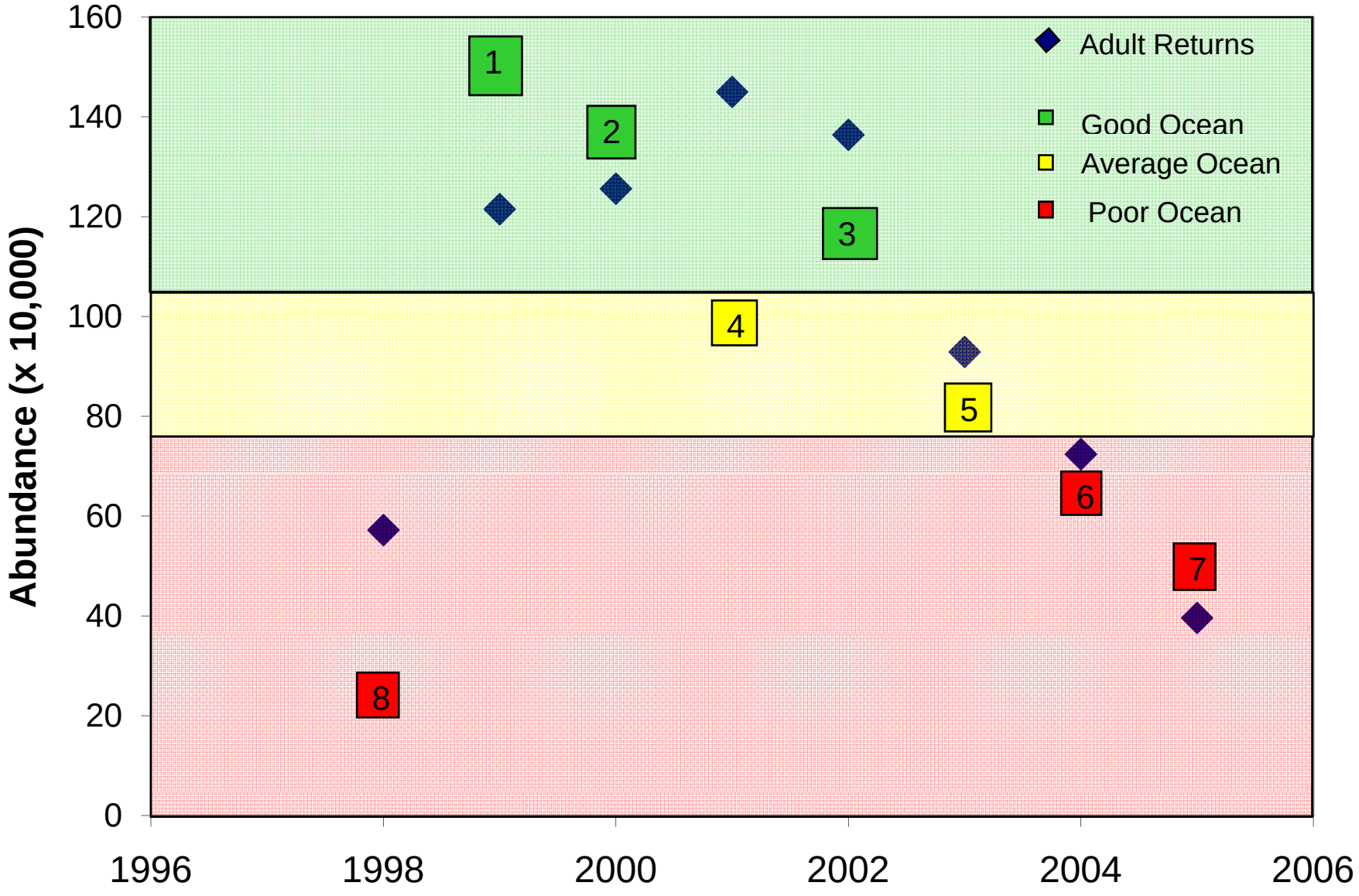


California Current Ocean Condition Index – Salmon Forecast

	Juvenile migration year				Forecast of adult returns	
					Coho	Chinook
	2005	2006	2007	2008	2009	2010
Large-scale ocean and atmospheric indicators						
PDO	🟥	🟥	🟨	🟩	●	●
MEI	🟥	🟨	🟩	🟩	●	●
Local and regional physical indicators						
Sea surface temperature	🟥	🟨	🟥	🟩	●	●
Coastal upwelling	🟥	🟨	🟩	🟩	●	●
Physical spring transition	🟥	🟩	🟨	🟩	●	●
Deep water temp. & salinity	🟥	🟨	🟩	🟩	●	●
Local biological indicators						
Copepod biodiversity	🟥	🟥	🟩	🟩	●	●
Northern copepod anomalies	🟥	🟨	🟩	🟩	●	●
Biological spring transition	🟥	🟨	🟩	🟩	●	●
Spring Chinook--June	🟥	🟨	🟩	🟩	--	●
Coho--September	🟥	🟨	--	--	--	--

Web Page: www.nwfsc.noaa.gov (look for ‘ocean index tool’)

Validation: Coastal Ocean (Oregon and Washington) Fall Chinook Abundance



The Future??

IPCC Model Projections of North Pacific Climate Variability

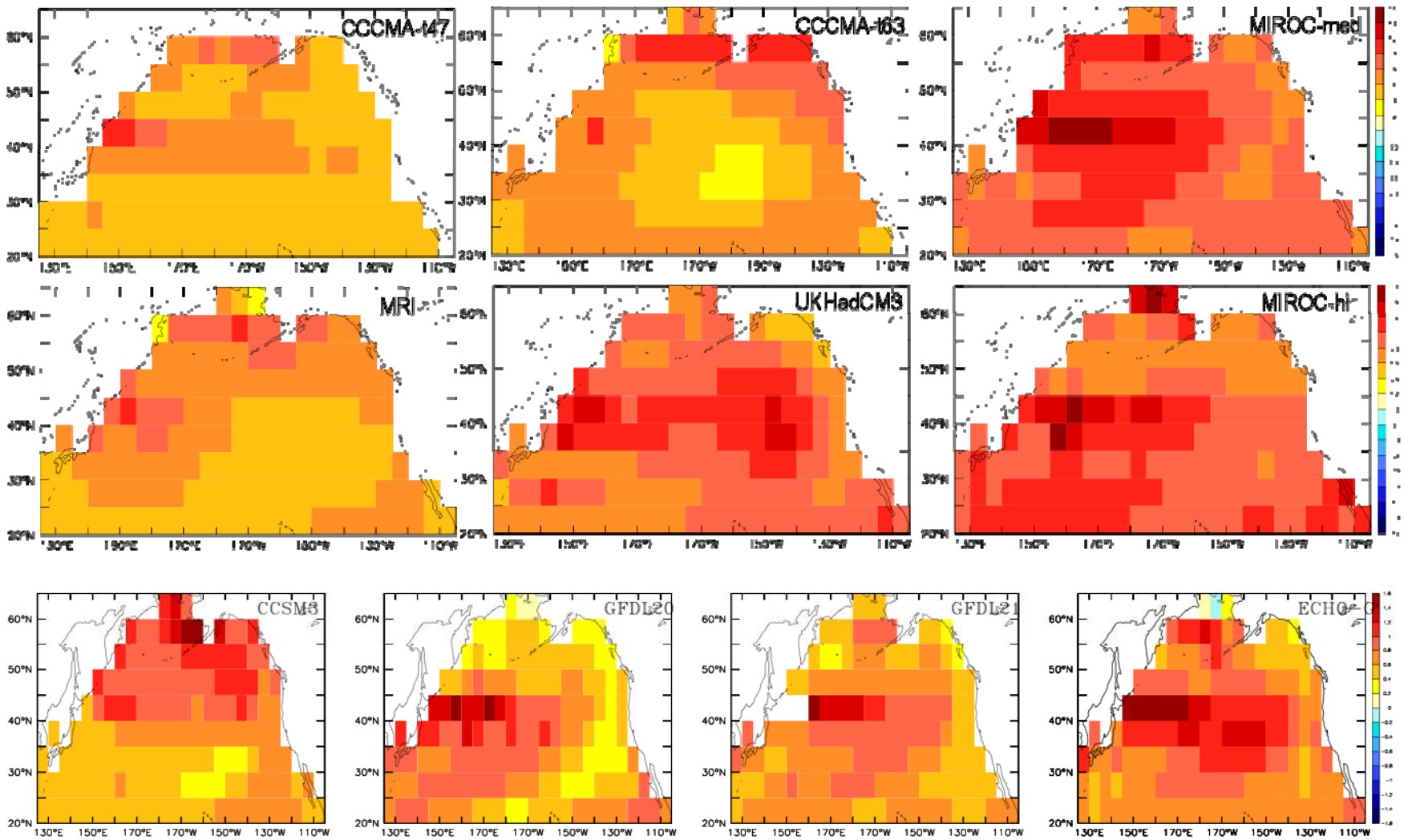
Courtesy of - James E. Overland[2]

Nicholas A. Bond[1] and Muyin Wang[1]

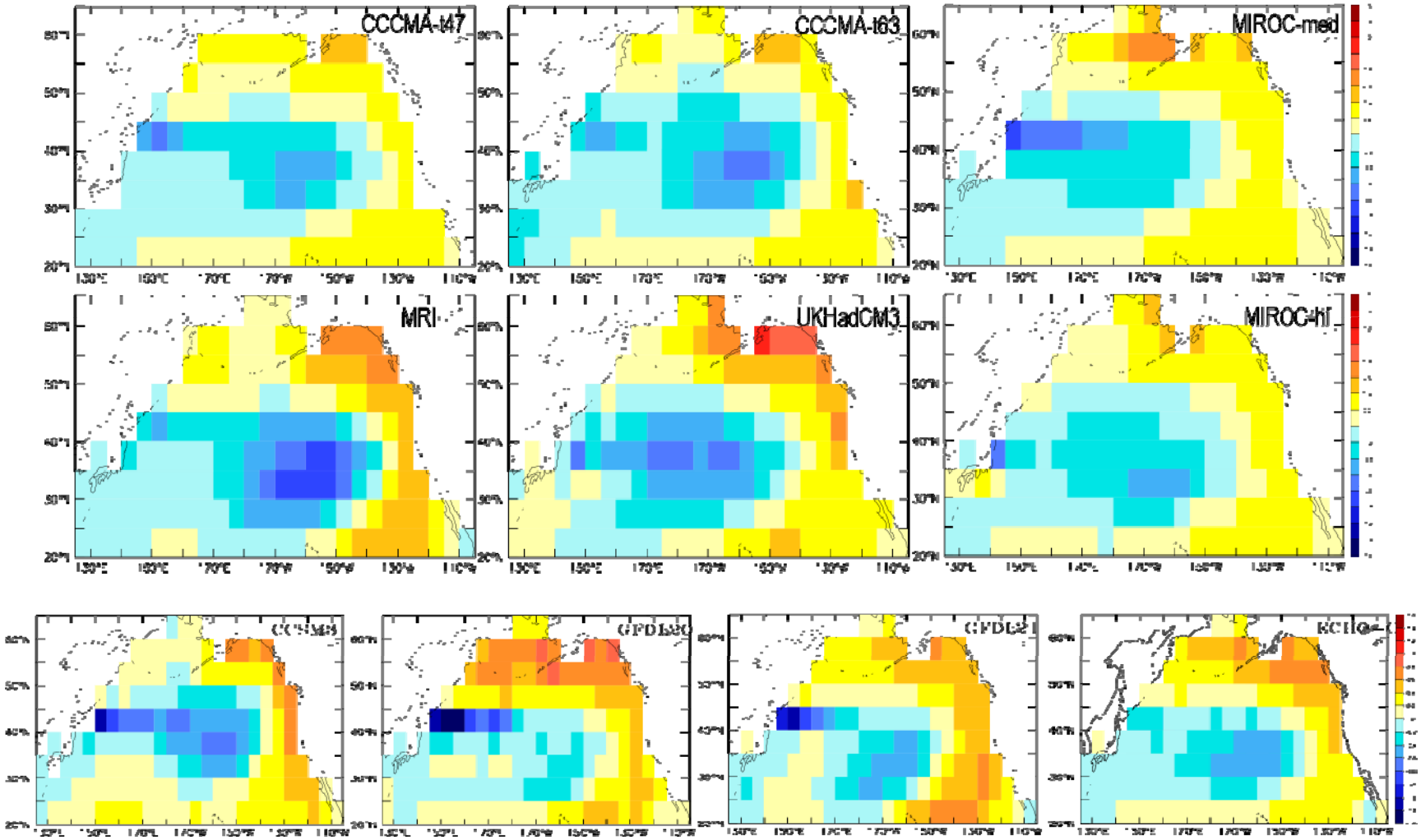
[1] University of Washington/JISAO

[2] NOAA/PMEL

EOF1 of SST for 2001-2099 in A1B



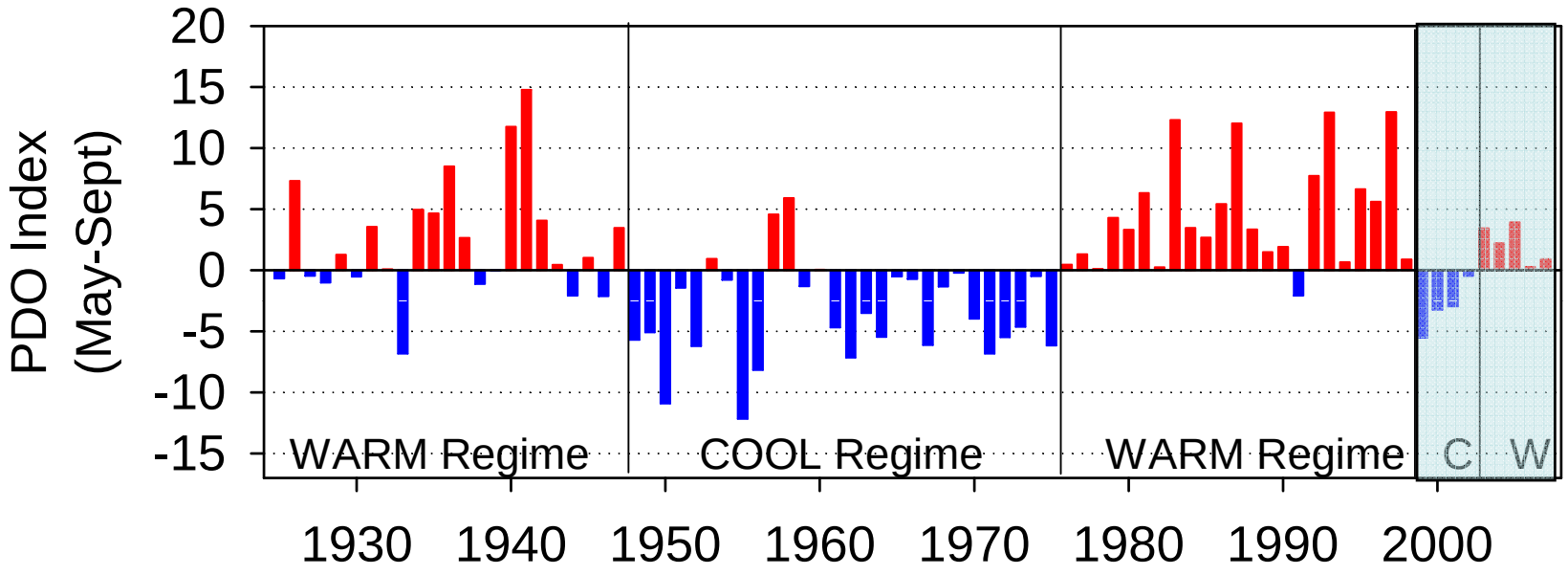
EOF2 of SST for 2001-2099 in A1B –Forecast 2099



Findings

- 10 out of 18 models replicate the major mode of the North Pacific SST variability- the PDO.
- 21st Century simulations feature a rather spatially uniform warming trend.
- This warming will exceed the natural variability over most of the North Pacific before about 2050.

PDO: May-Sep Average, 1925-2007

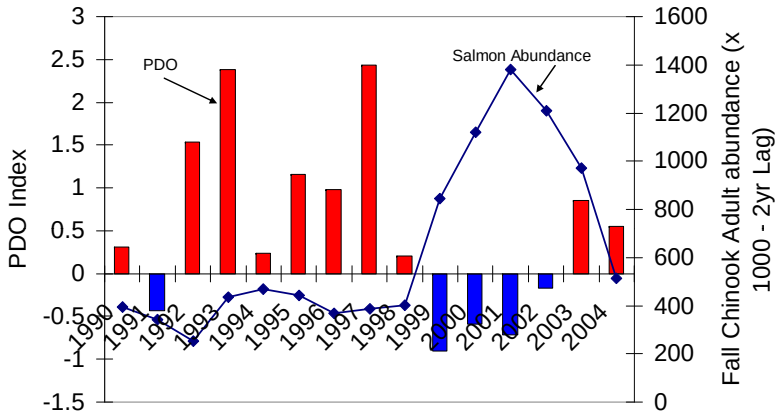


- At no time since 1900, nor during the Warm-Cool-Warm regimes was there a sign change longer in duration than 16 months (1957-58 El Niño), and there was never a period of PDO with an opposite change in sign for more than 8 months within a given year.
- However, we have had two shifts of four years duration recently: 1999-2002 and 2003-2006. Is this what the future holds?

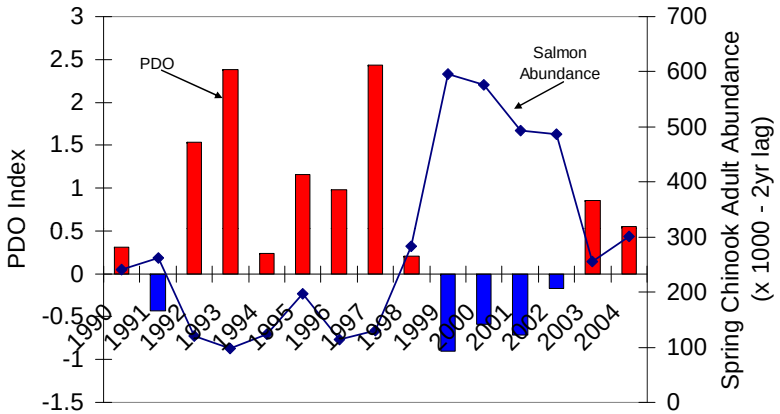
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
PDO (December-March)	10	4	1	7	3	11	6	9	8	5	2
PDO (May-September)	8	2	3	4	5	10	9	11	7	6	1
MEI Jan-June	11	2	3	5	7	9	6	10	4	8	1
SST at 46050 (May-Sept)	9	2	4	5	1	7	11	8	6	10	2
SST at NH 05 (May-Sept)	8	2	1	4	7	6	11	10	5	9	3
SST winter before going to sea	11	6	4	5	3	7	10	9	8	2	1
Physical Spring Trans (Logerwell)	9	5	2	1	4	7	6	10	7	3	***
Upwelling (Apr-May)	6	1	10	3	5	9	8	11	6	2	4
Deep Temperature	11	4	6	2	2	7	8	10	9	5	1
Deep Salinity	11	3	3	5	8	9	10	7	6	1	1
Length of upwelling season	10	2	4	2	1	7	8	9	6	5	***
Copepod richness	11	2	1	5	3	8	7	10	9	6	4
N.Copepod Anomaly	10	7	2	4	1	8	5	9	6	3	***
Biological Transition	11	6	3	2	5	9	7	10	8	4	1
June-Chinook Catches	10	2	3	8	5	7	9	11	6	4	1
Sept-Coho Catches	8	2	1	4	3	5	10	9	6	7	***
Mean of Ranks	9.7	3.3	3.3	4.1	4.0	8.1	8.1	9.6	6.7	4.9	1.8
RANK of the mean rank	11	2	3	5	4	8	9	10	7	6	1

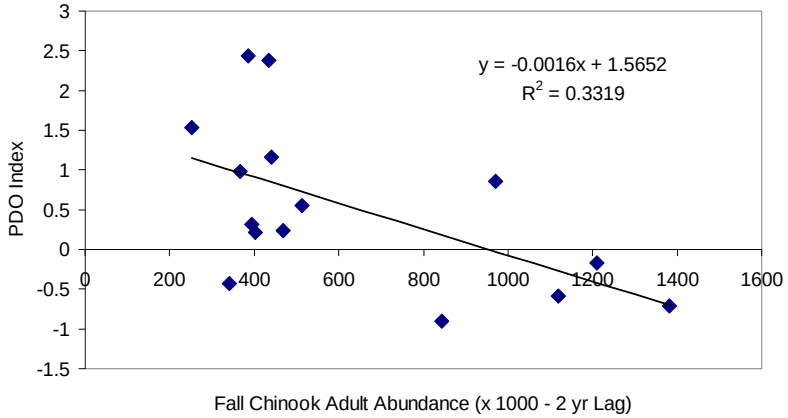
Salmon Abundance in the Ca Current Reacts Quickly to change in PDO sign

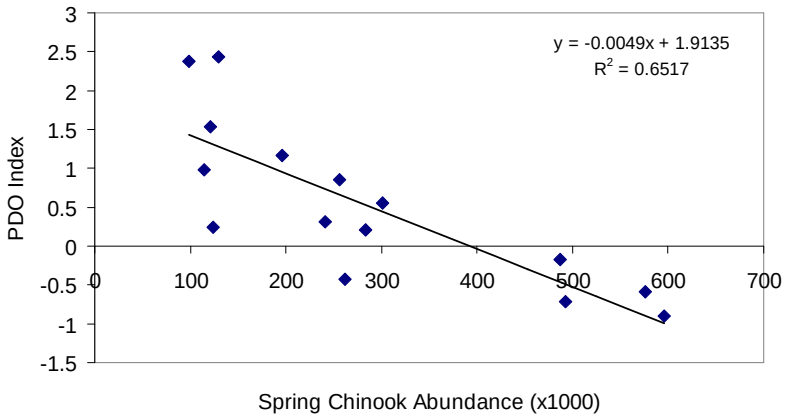
Fall Chinook



Spring Chinook







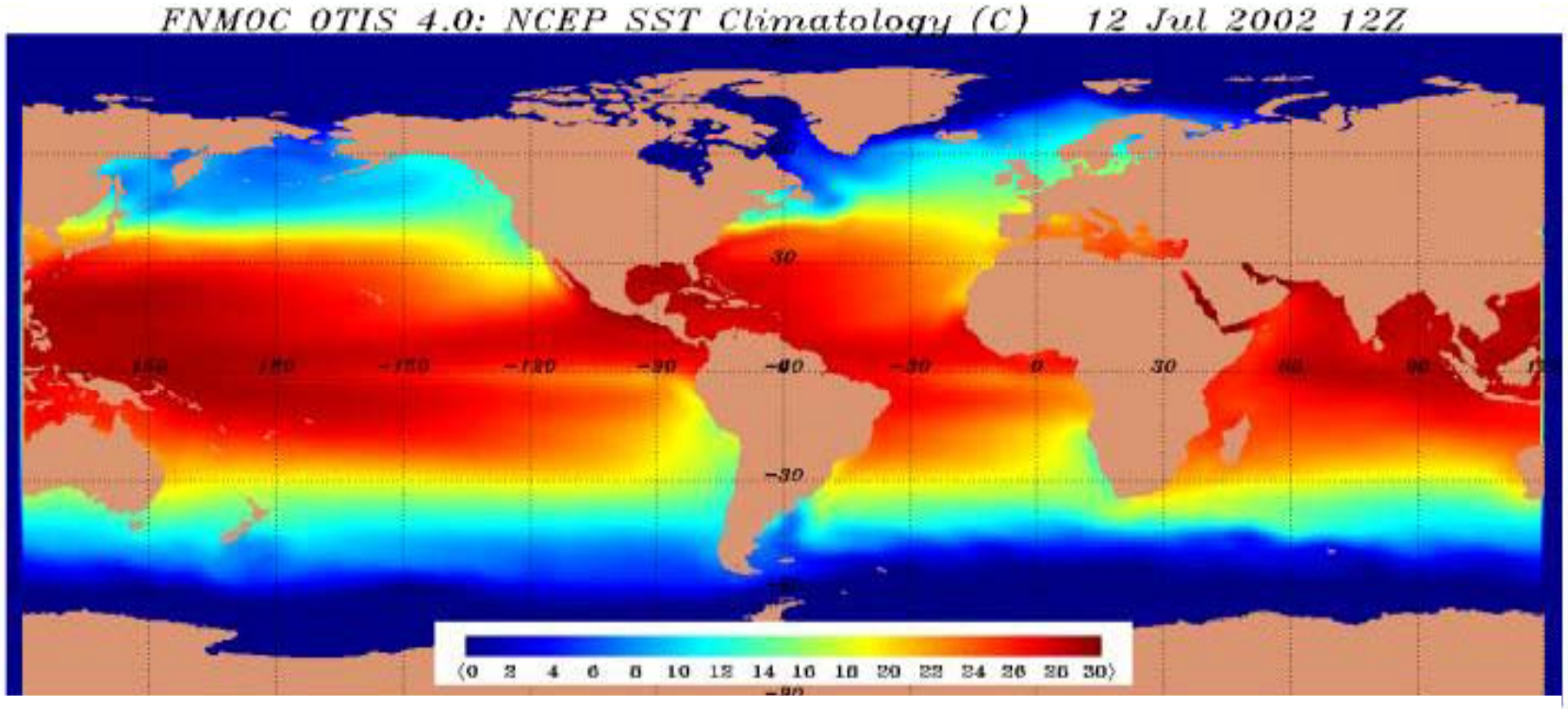


CHART OF SEA SURFACE TEMPERATURE

- Note: warm water between the equator and ~ 30 N
- Because of upwelling off North America, S. America N. Africa and S. Africa, cool water is found at the coast. Without upwelling, the coasts would be ~ 5-10°C warmer during summer because offshore waters would move shoreward.
- Without upwelling we would have no salmon off PNW

Wrap up

- Physical and biological features of the California Current ecosystem appear to change rapidly due to phase shifts in the large scale forces reflected in the PDO
- Marine survival of salmon similarly appears to reflect long term or rapid changes in ocean conditions of the northern California Current ecosystem
- Because global warming could affect duration and variability in large scale forcing, managers of fishery resources will need a broad variety of quick responding forecasting tools
- An example of one set of forecasting tool documents current ocean conditions and potential impact of salmon survival 1 to 2 years ahead of their actual return (www.nwfsc.noaa.gov)
- Even though the PDO will persist, the ocean will be warmer. **Will warmer temperatures trump the PDO?**

Acknowledgements

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- Fisheries and the Environment (FATE-NOAA)
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- Office of Naval Research
- NASA

- See www.nwfsc.noaa.gov, "Ocean Index Tools"