

Climate Change and the Olympic Coast: Interpreting Potential Futures AN UPDATE

**A presentation to the OCNMS Sanctuary Advisory Council
21 Sept 2012**

Ian Miller, WA Sea Grant

(on behalf of the OCNMS Climate
Change Assessment Working Group)



Goals

- Provide a status update on the project (5 min)
- Provide an overview of some results and conclusions from the “Physical Chapter” (30 min)
- Outline continuing steps (5 min)
- Questions (20 min)

Motivation and Background



- At the request of the Office of National Marine Sanctuaries (ONMS), develop *Climate Change Site Scenario* that describes what the site and its environs may ~~will likely~~ look like in 50 to 100 years
- Guidance from the ONMS Climate-Smart Sanctuaries program states that the draft *Climate Change Site Scenario* should:
 - Be based on best available information, including historic baseline information, recent resources assessment(s), and any climatologies, models, or forecasts available for the site and its surrounding region;
 - Use the best local expertise;
 - Provide for the involvement of stakeholders, including an advisory group if present;
 - Provide for other public review; and
 - Undergo a rigorous peer review process.

Proposed Outline

- Abstract (including a summary of key issues and a list of recommendation)
- Introduction (defining the need)
- Physical Effects of Climate Change
 - Precipitation and Land Run-off
 - Atmosphere
 - Ocean Currents (e.g. upwelling)
 - Waves
 - Sea Level Rise
 - Coastal Erosion and Shoreline Change
 - Changing Ocean Properties (e.g. Acidification, Oxygen)
- Expected Response of Biological Communities
 - Marine Organisms
 - Range Shifts
 - Responses in Marine Habitats
- Human and Biological Vulnerability to Coastal Change
- A Review of Relevant Adaptation Strategies
- Needs Assessment: Priority Research Areas

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Acidification of Ocean Water

Sea Level Rise

Increasing Frequency and Severity of Storms

Changing Ocean Current Patterns

Increasing Occurrence of Coastal Hypoxia and Anoxia

Altered Hydrologic Patterns

Implications for Priority Habitats of the OCNMS

VI. The Response of Biological Communities

Implications For the Marine Ecosystem of the OCNMS

The Response of Selected Species or Communities

VII. Sensitivity of OCNMS Resources to Coastal Climate Change

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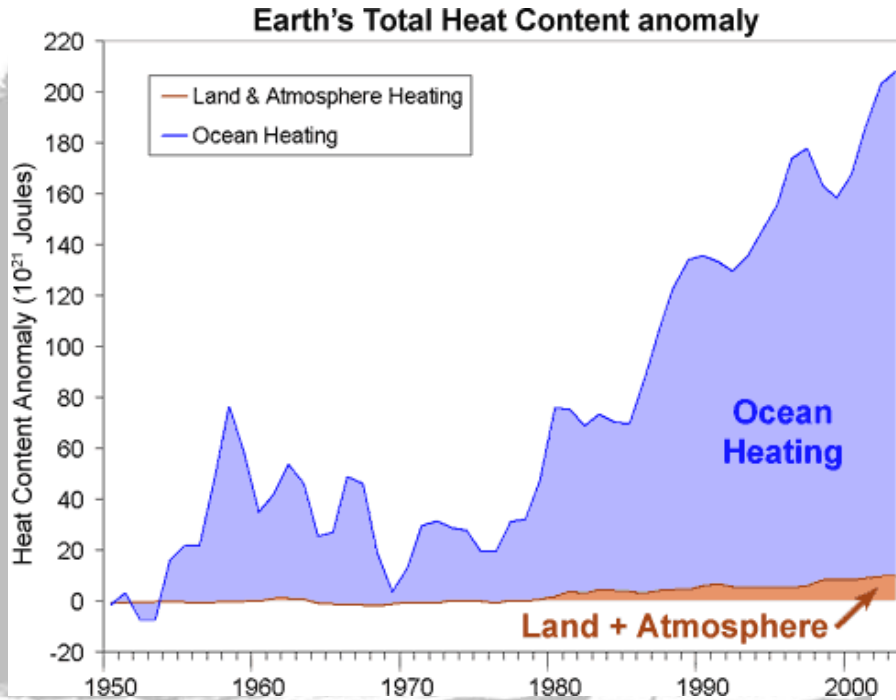
XII. Bibliography

~28 Working Group Contributors representing ~13 separate entities or agencies...

Name	Affiliation	Title	Role	Writing Assignments
Ian Miller	WA Sea Grant	Coastal Hazards Specialist	Editor, Lead Physical, Author	SST, SLR, Storms
Caitlin Shashido	WA Sea Grant	MMA Candidate	Lead Biological, Author	Plankton, Bivalves
Lara Whitely Binder	Climate Impacts Group	Outreach Specialist	Editor, Lead Sensitivity, Author	Sensitivity, Adaptation
Amy Snover	Climate Impacts Group	Co-director, Research Scientist	Editor, Review/Consult	
Liam Antrim	Olympic Coast NMS	Resource Protection Specialist	Editor, Review/Consult, Author	OCNMS Description
Carol Bernthal	Olympic Coast NMS	Superintendent	Review/Consult	
Ed Bowlby	Olympic Coast NMS	Research Coordinator	Review/Consult	
Steve Rubin	US Geological Survey	Fisheries Biologist	Lead Biological, Author	Fish
Brian Bylhouwer	Simon Fraser University	MS Candidate	Author	Ocean Currents
Steven Fradkin	Olympic National Park	Coastal Ecologist	Review/Consult	
Jennifer Hagen	Quileute Nation	Marine Biologist	Review/Consult	
Hillary Burke			Author?	Sensitivity, Adaptation
Tom Mumford	U Washington, OCNMS SAC		Author, Lead Biological?	Algae/Seagrasses
Jan Newton	U Washington, OCNMS SAC	Principal Oceanographer	Review/Consult	
Sandra Brooke	Marine Conservation Biology Institute, OCNMS SAC	Director, Coral Conservation	Author	Deep Water Coral
Tom Connolly	U Washington	PhD Candidate	Author	Anoxia/Hypoxia
Nick Bond	U Washington, JISAO	Research Meteorologist	Review/Consult	
Peter Hodum	U Puget Sound	Professor	Author	Seabirds
Sean McDonald	U Washington	Faculty, Program on the Environment	Author	Crustaceans (Crab)
Deanna Lynch	US Fish and Wildlife	Fish and Wildlife Biologist	Author	Sea Otters
Ingrid Tohver	Climate Impacts Group	Research Scientist	Author	Hydrology
Helen Berry	WA Dept Natural Resources		Review/Consult, Author	Algae/Seagrasses
Julie Keister	U Washington		Review Consult	
Terrie Klinger	U Washington		Review/Consult	
Frank Shipley	US Geological Survey	Senior Scientist	Consult	
Lyman Thorsteinson	US Geological Survey		Review/Consult	
Adrienne Sutton	NOAA PMEL	Postdoctoral Researcher	Author	OA
Nancy Elder	USGS	Fisheries Biologist	Author	Urchins

...who have contributed an estimated 1200 hours to produce ~200 pages of analysis after reviewing well over 170 manuscripts or reports

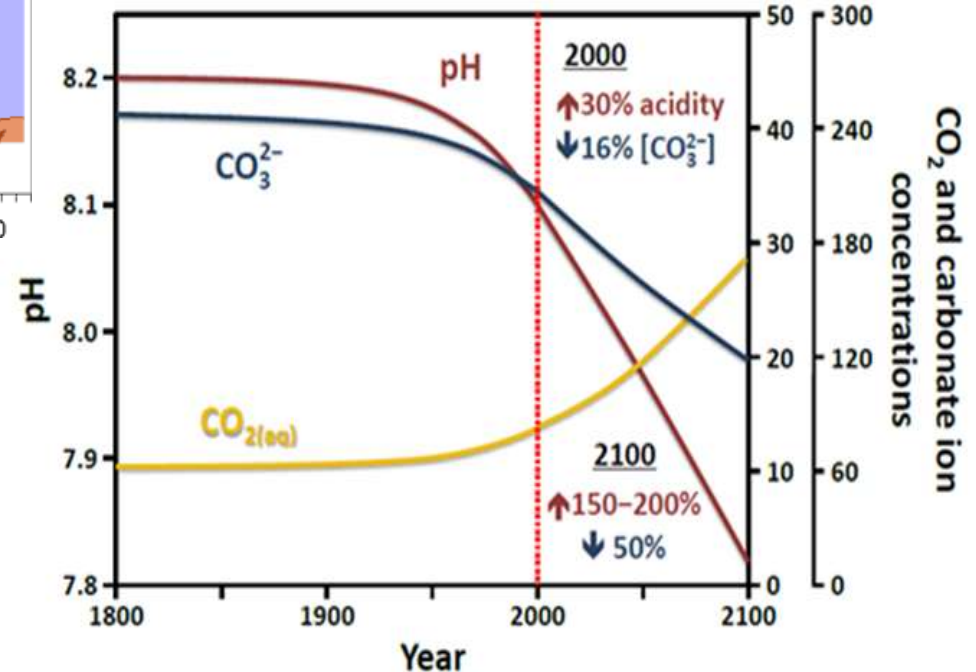
The two drivers of change



Cook (2010) with data from Murphy et al. (2009)

Heat Budget Imbalance

Shifting CO_2 Equilibria

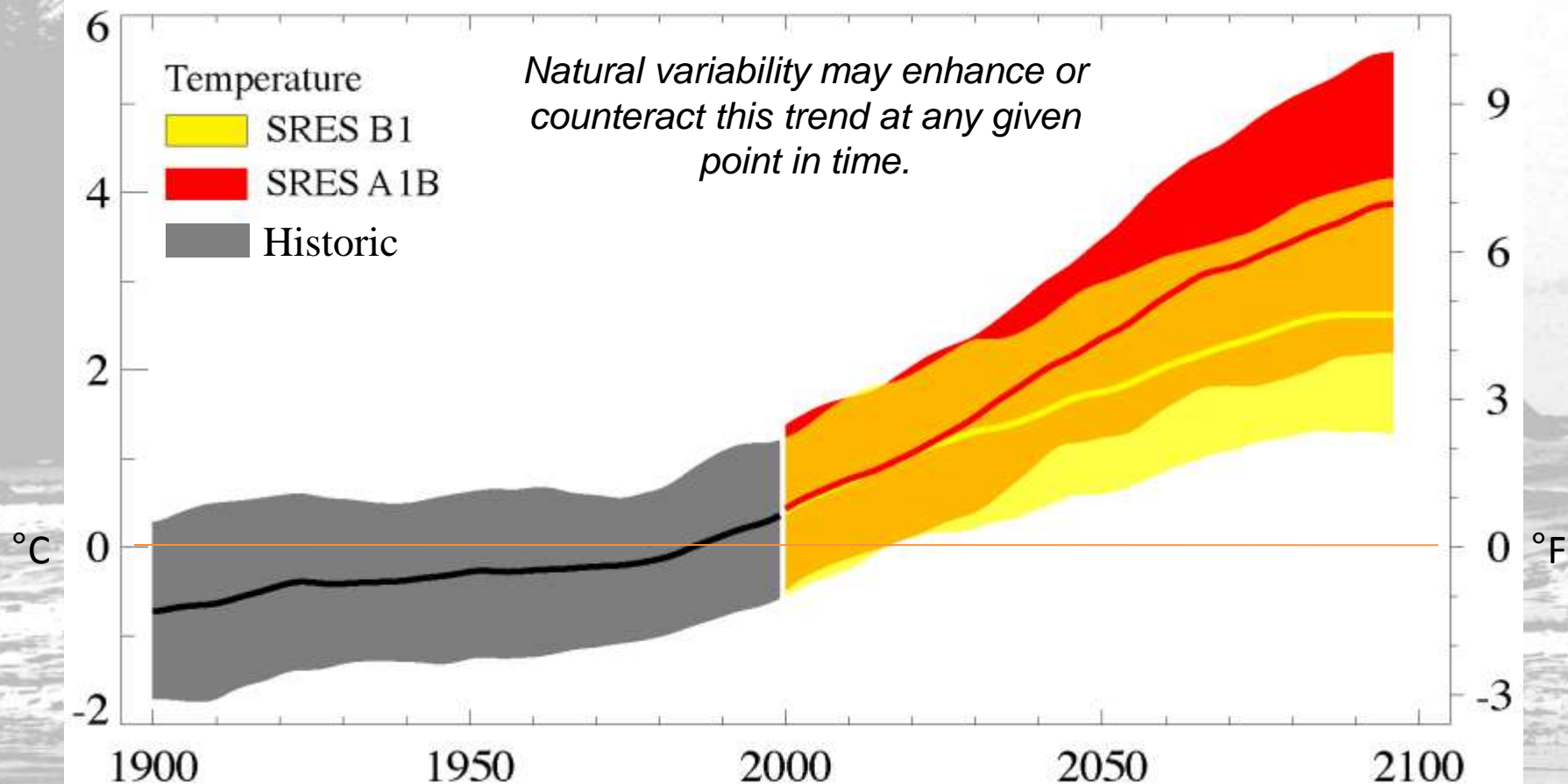


Simone Alin, NOAA PMEL; adapted from Wolf-Gladrow et al. (1999)

Projected Increases in Annual PNW Temperature

* Relative to 1970-1999 average

2020s	+2.0°F (1.1-3.4°F)
2040s	+3.2°F (1.6-5.2°F)
2080s	+5.3°F (2.8-9.7°F)

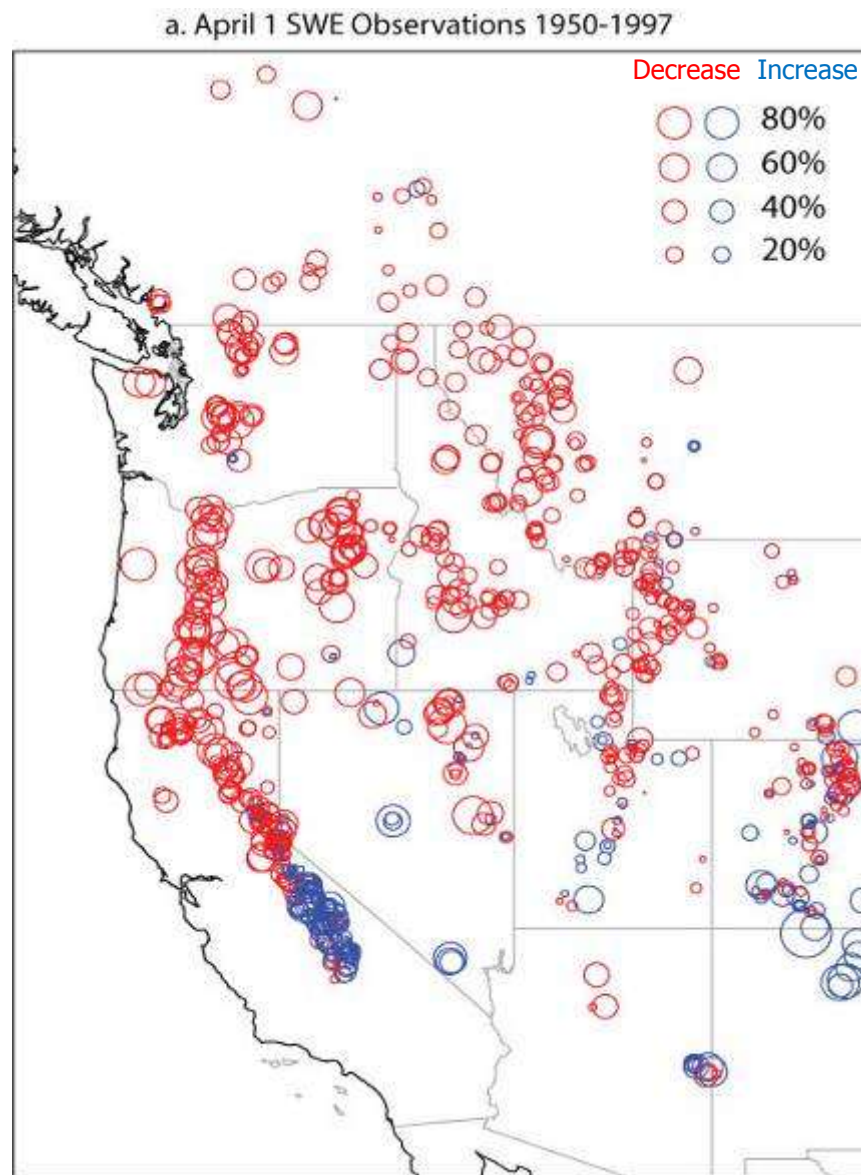


Key Trends in PNW Climate

Average annual temperature increased **+1.5°F** in the PNW during the 20th century

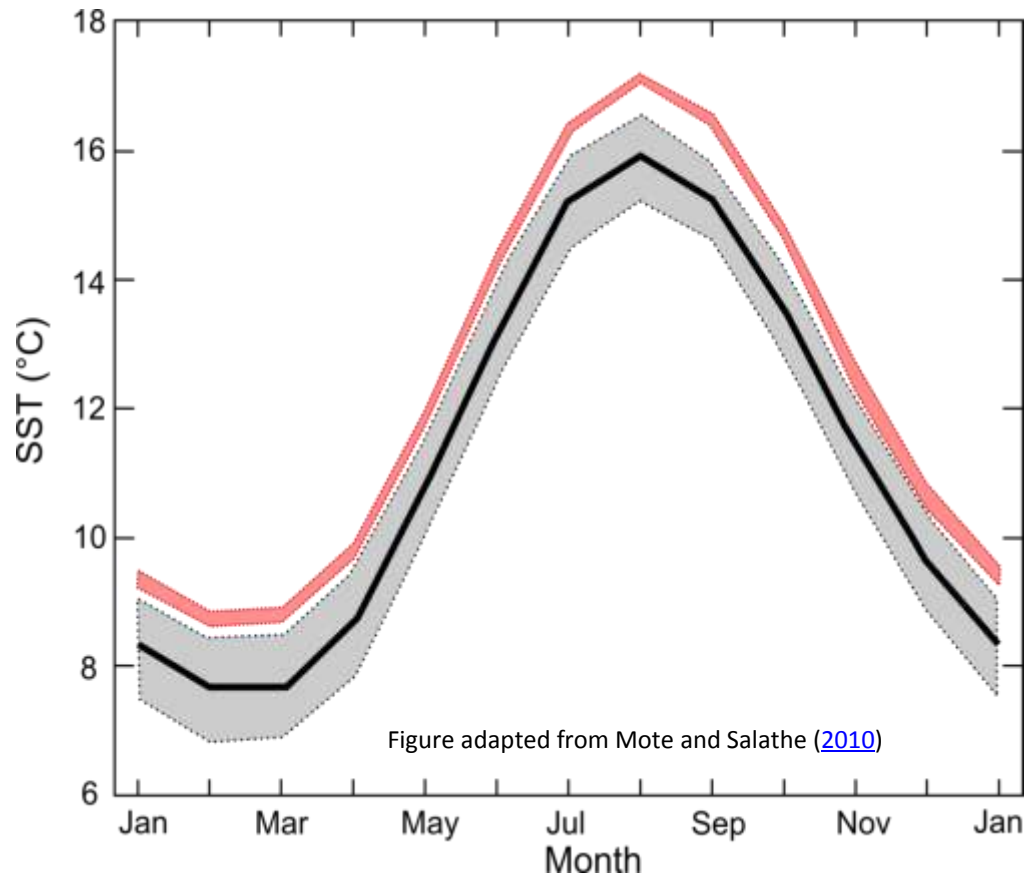
April 1 snowpack has **decreased** throughout the PNW with losses of 30-60% at many individual stations (1950-2000)

Similar snowpack declines are seen throughout the western United States

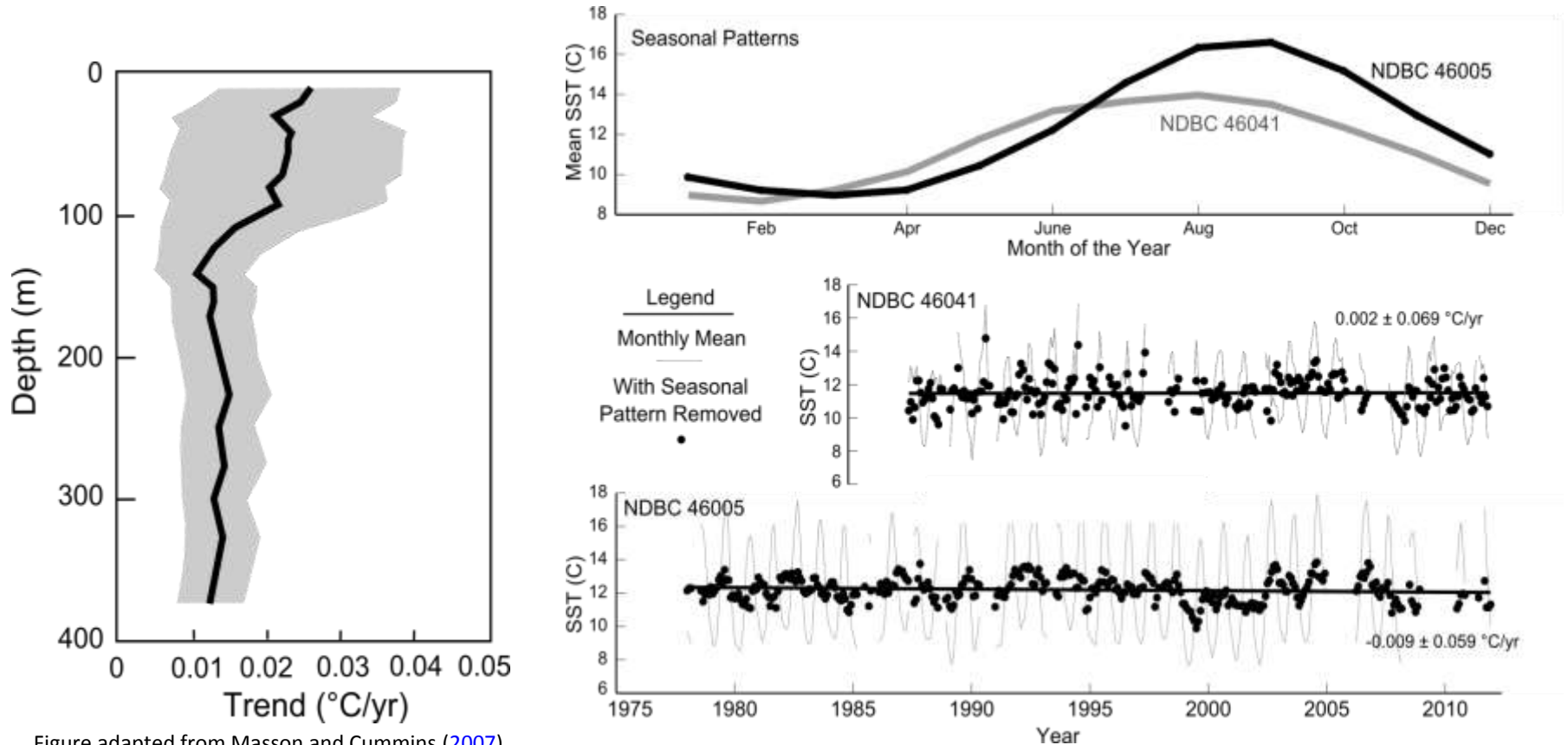


Ocean Temperature

- Ocean heat content and water temperature is expected to increase throughout the global oceans over the next century, with average warming of the oceans by 1.5° to 2.6° C by 2100.
- The coastal waters of Washington State are expected to roughly follow global projections, with one study projecting an increase of at least 1° C by 2050 for the region
- There are some significant increasing trends in ocean temperature for data records from inside or adjacent to the OCNMS, while other investigations find that temperature variability is too high, and data record too short, to identify significant trends.



Point Observations



.Figure adapted from Masson and Cummins ([2007](#))

Ocean Acidification

- Due to a combination of anthropogenic and natural drivers, the Pacific Northwest coast is likely to be particularly vulnerable to ocean acidification.
- Observations along the Pacific Northwest coast, including sites within the OCNMS, suggest that the coastal ecosystem is already seasonally exposed to corrosive waters
- Models forecast expansion of corrosive waters in the near future

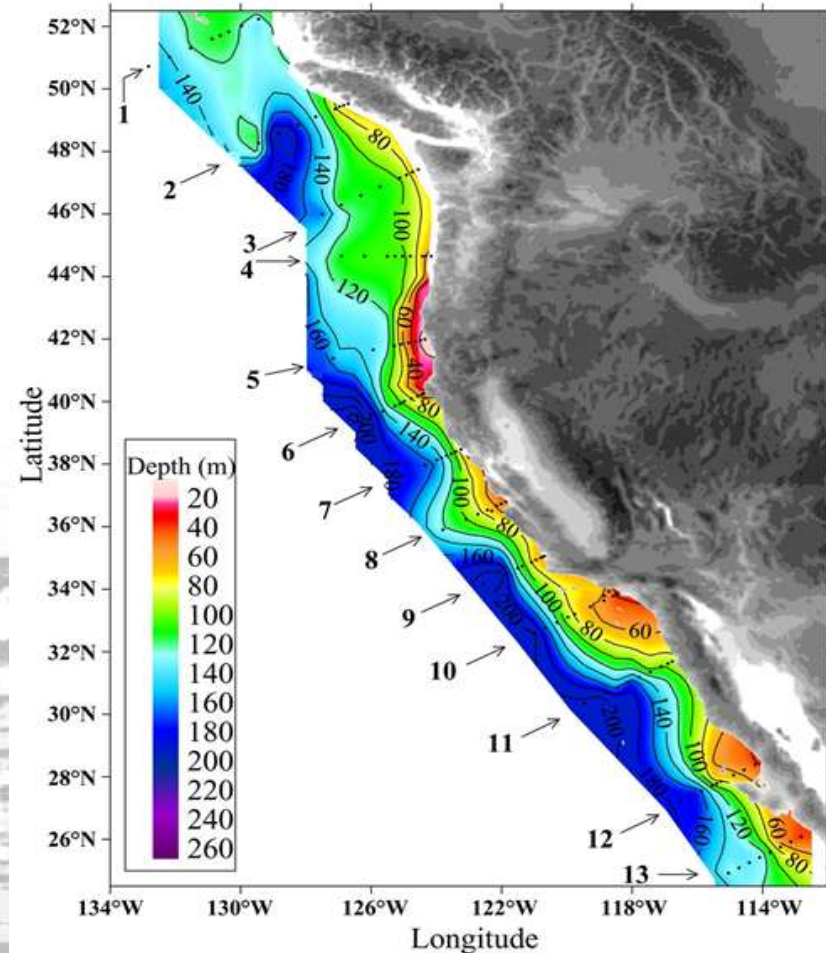


Figure from Feely et al. (2008)

Projections for
summer-long under-
saturation with
respect to aragonite
by 2050 in surface
waters, and year-
round benthic
exposure (>60 m)

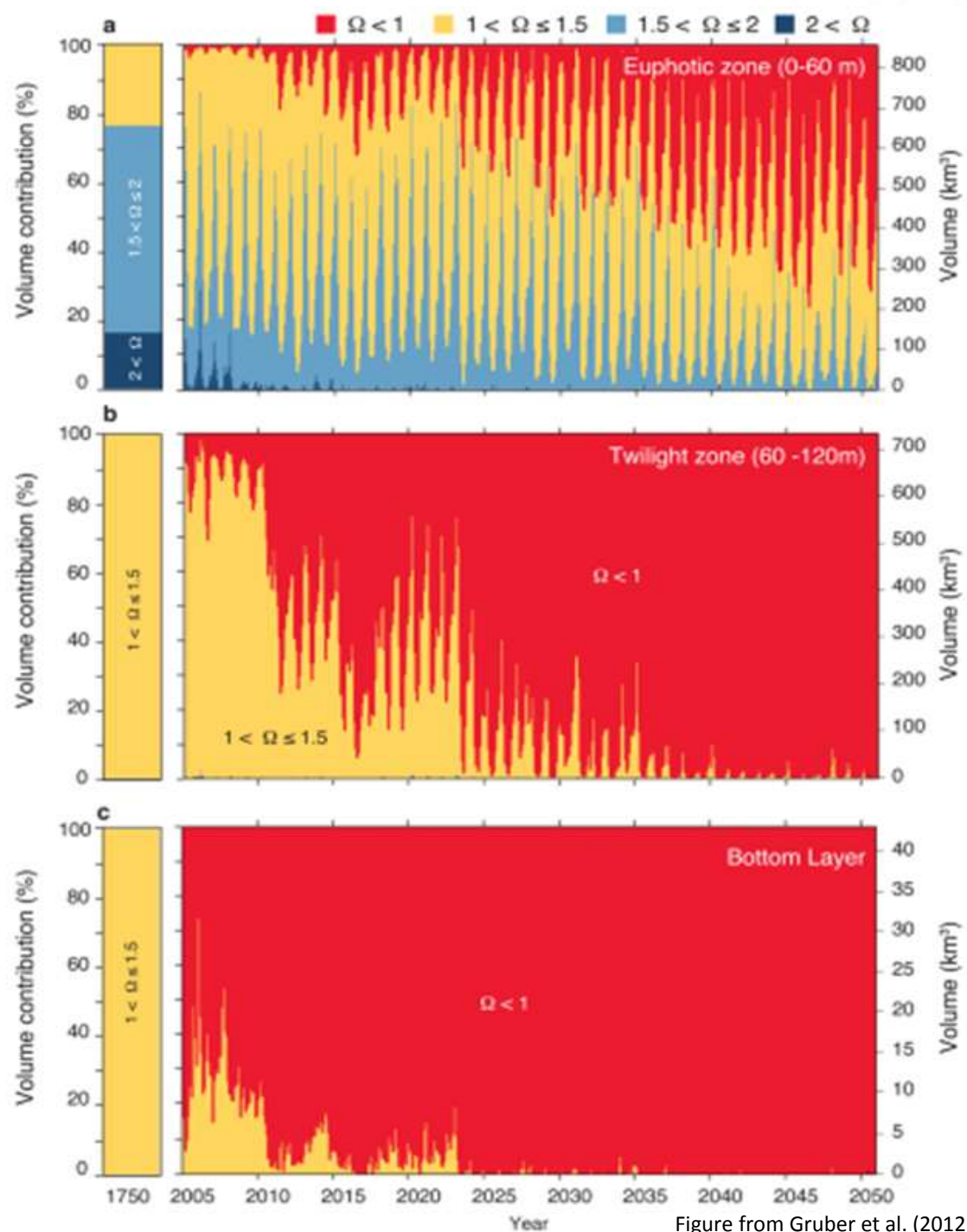


Figure from Gruber et al. (2012)

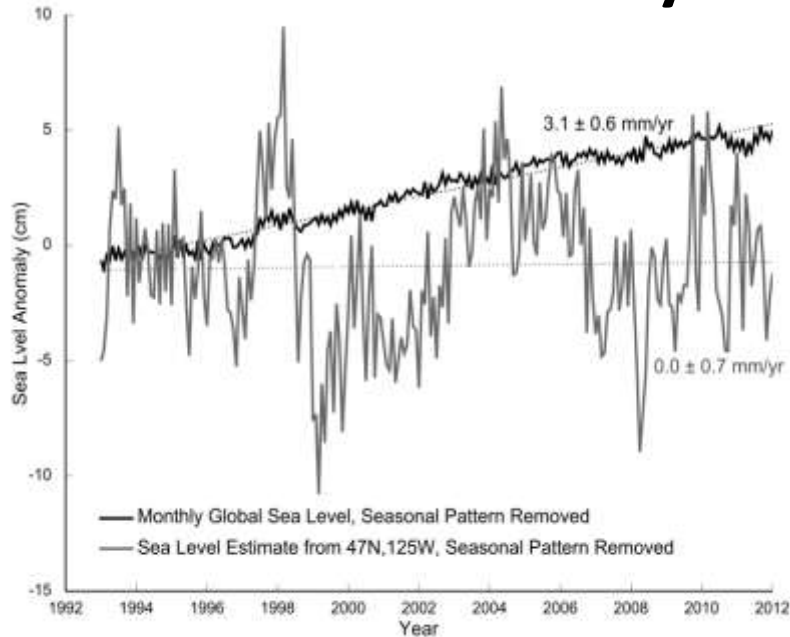
Mean Sea Level

- Mean sea level is projected to increase throughout the Northeast Pacific, though there remains debate regarding the magnitude of that increase. We suggest a minimum planning horizon of 1.0 m by 2100 is reasonable, though both higher and lower rates are justified given the available evidence
- Sea level relative to the shoreline varies from north to south within the OCNMS due to variability in the rate of tectonically-driven uplift. Sea level rise is therefore likely to impact the southern coast of the OCNMS earlier and to a greater extent than along the northern coast.
- Sea level within the OCNMS is highly variable, with pronounced seasonal variation due to seasonal oceanographic and meteorologic effects and annual variation due to, for example, ENSO events, and decadal scale variability. Despite this variability, there is strong evidence that observable sea level rise is already occurring with the OCNMS.

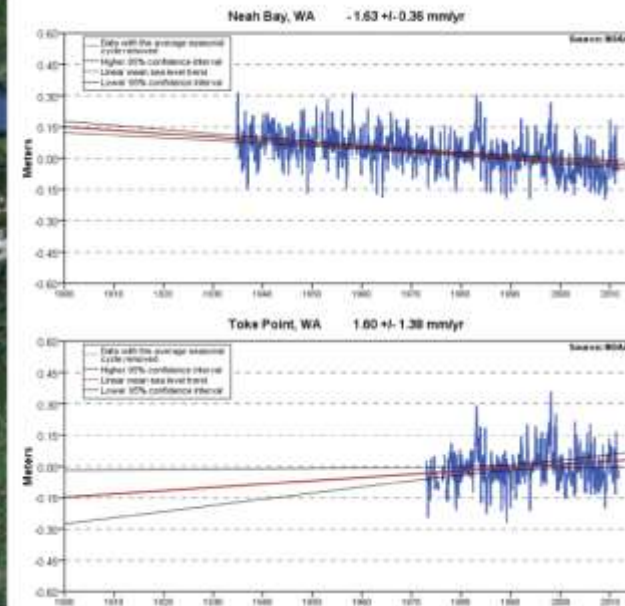
Scenario	NW Olympic Peninsula	Central and Southern WA Coast
Very Low	-24 cm (-9")	6 cm (2")
Medium	4 cm (2")	29 cm (11")
Very High	88 cm (35")	108 cm (43")

Observations

Satellite Altimetry

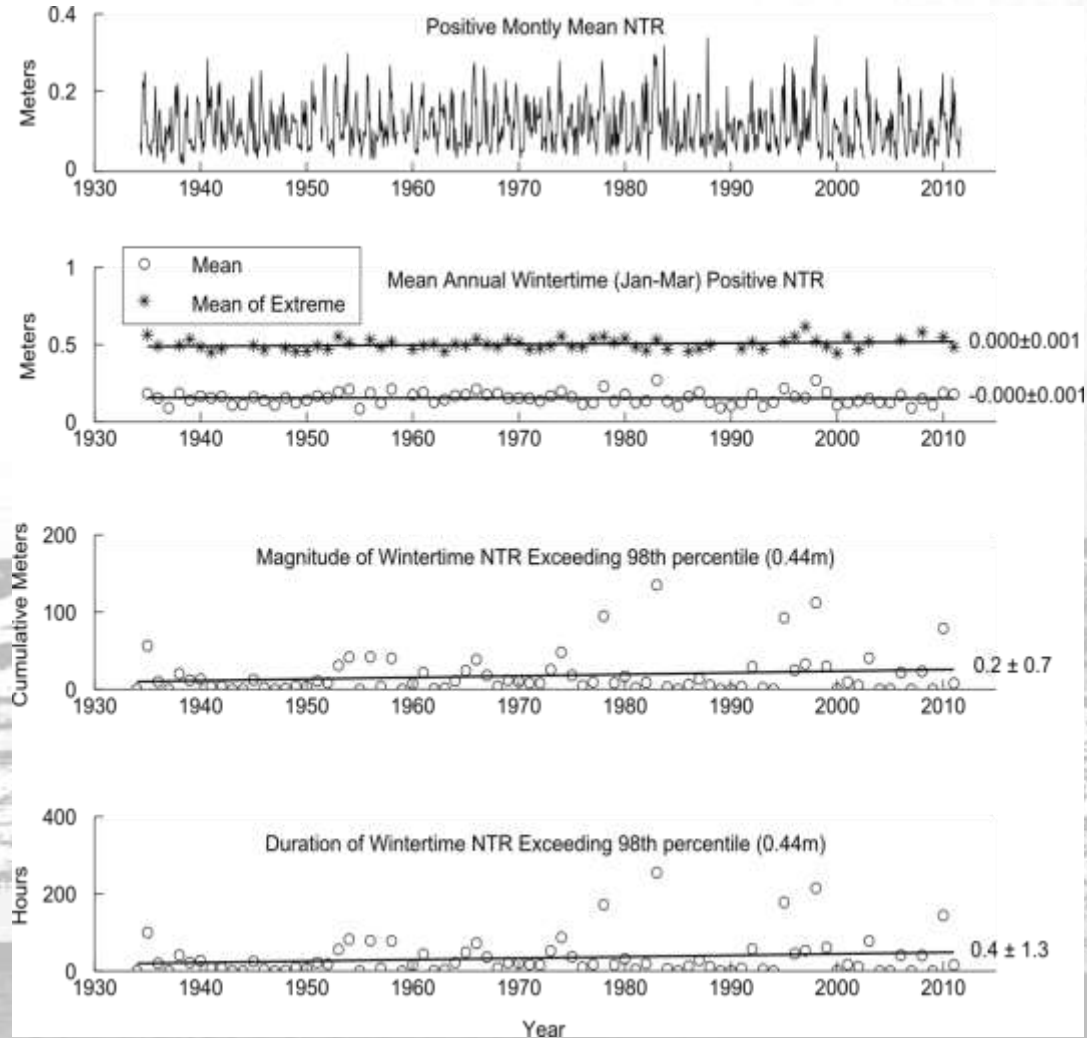


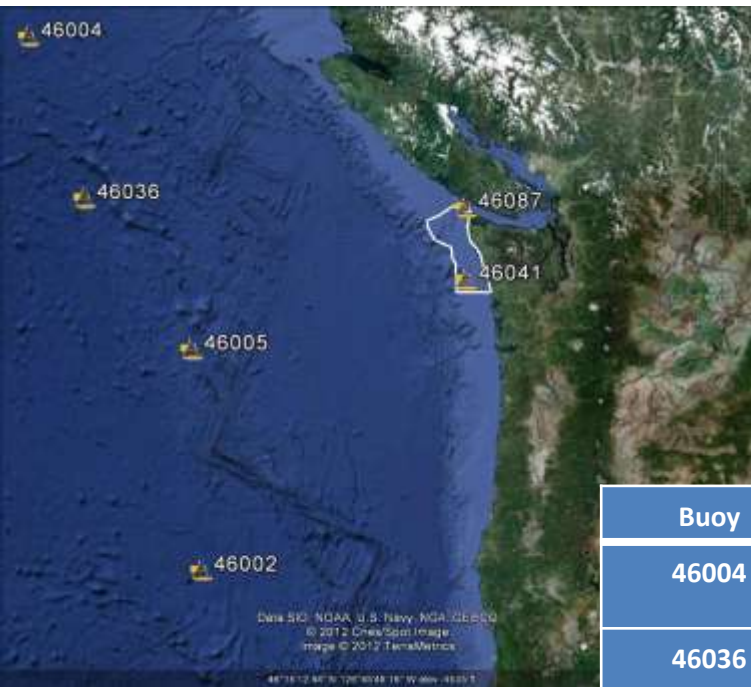
Water Level Measurements



Storminess

- There is strong support for a shift in the tracks of storms in the northeast Pacific by 2100 based on climate model results. Model results also tentatively suggest that the magnitude and frequency of storms in the northeast Pacific will increase by 2100.
- Observational evidence generally suggests increasing winds and wave and wave heights in and adjacent to the OCNMS, though there remains some debate regarding the veracity of those results.
- Other indicators of storminess, including storm surge patterns, are inconclusive due to extreme variability and the relatively short length of available data records.





Waves



Buoy	Trend (cm/yr)	Parameter	Time Range	Reference	Method
46004	NS	Average Winter	1976-2010	Gemmrich	Buoy
	1.8	Annual Mean	1976-1999	Gower	Buoy
46036	NS	Average Winter	1976-2010	Gemmrich	Buoy
	NS	Annual Mean	1976-1999	Gower	Buoy
46005	3.2	Average Winter	1976-2002	Allan and Komar	Buoy
	2.3	Average Winter	1976-2007	Ruggiero	Buoy
	~1.0	Average Winter	1976-2010	Gemmrich	Buoy
	NS	Mean Annual	1976-2010	Gemmrich	Buoy
	NS	Mean Annual	1985-2007	Young	Buoy
	NS	Mean Annual	1985-2007	Young	Altimeter
	2.1	Mean Annual	1976-1999	Gower	Buoy
46002	2.8	Average Winter	1976-2002	Allan and Komar	Buoy
	NS	Average Winter	1976-2007	Ruggiero	Buoy
	NS	Average Winter & Mean Annual	1976-2010	Gemmrich	Buoy
	NS	Mean Annual	1985-2007	Young	Buoy
	NS	Mean Annual	1985-2007	Young	Altimeter
	1.9	Mean Annual	1976-1999	Gower	Buoy
46041	NS	Average Winter	1987-2010	Gemmrich	Buoy
	NS	Annual Mean	1987-1999	Gower	Buoy
46087	NS	Average Winter	2004-	Gemmrich	Buoy

Upwelling

- Upwelling-favorable winds occur during April-October in OCNMS, and serve as a “biological pump” to bring nutrient-rich water from deeper water to the surface.
- There is high interannual variability in the timing, duration and intensity of upwelling, and therefore, availability of nutrient-rich water.
- Projections of upwelling suggest the possibility of enhanced upwelling-favourable winds along the entire Pacific Northwest coast.
- Historical analyses suggest enhanced upwelling favourable winds for southern portions of Pacific coast (coastal Oregon and south), but no similar pattern is evident in data from the Washington coast.

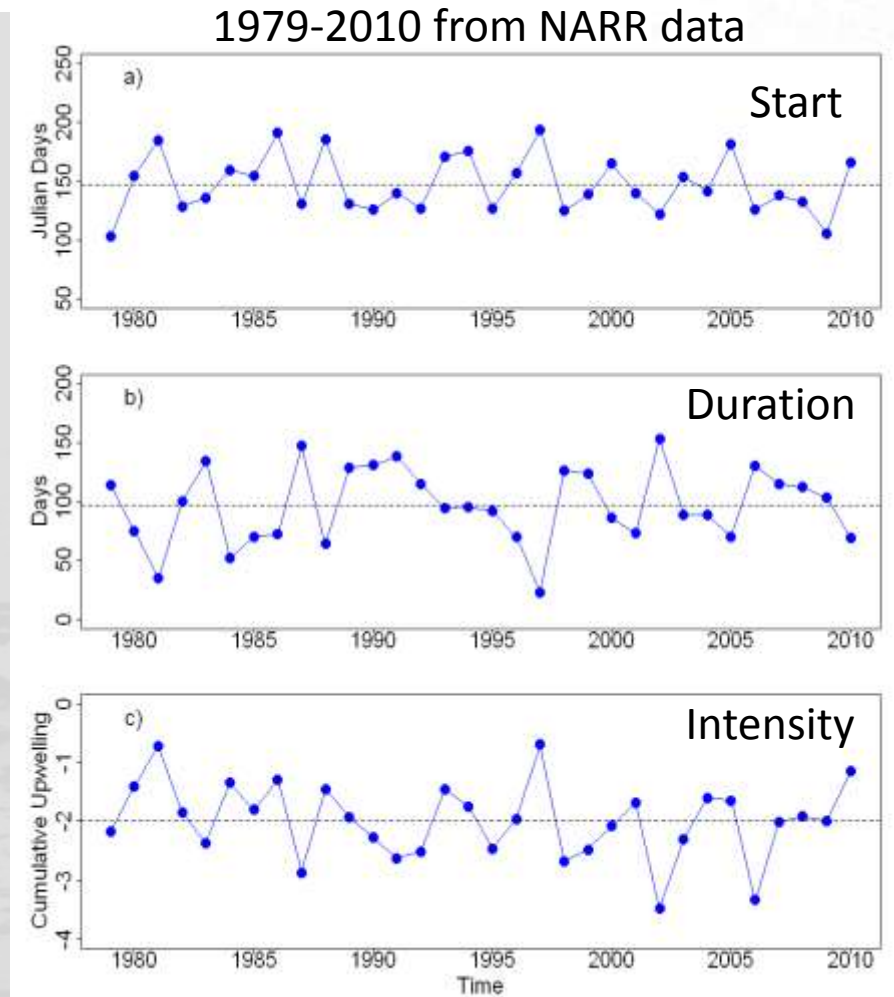


Figure courtesy of Brian Bylhouwer

Coastal Hypoxia

- Concentrations of dissolved oxygen in the northeast Pacific Ocean are expected to decrease as the upper ocean warms and becomes more stratified.
- Although hypoxia is a seasonal occurrence in the OCNMS, severely hypoxic concentrations during a summer of unusually strong upwelling in 2006 were unprecedented in previous historical data.
- Long-term declines in dissolved oxygen have been observed at numerous locations in the northeast Pacific, including coastal locations near the OCNMS.

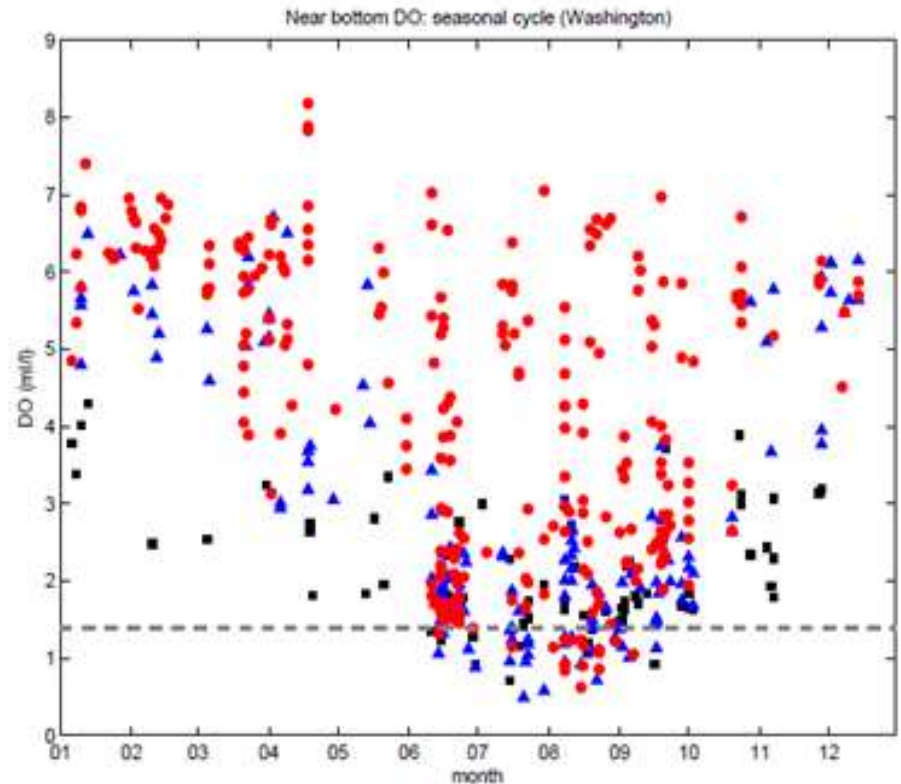


Figure adapted from Connolly et al. (2010)

First Severe Hypoxia

Trends

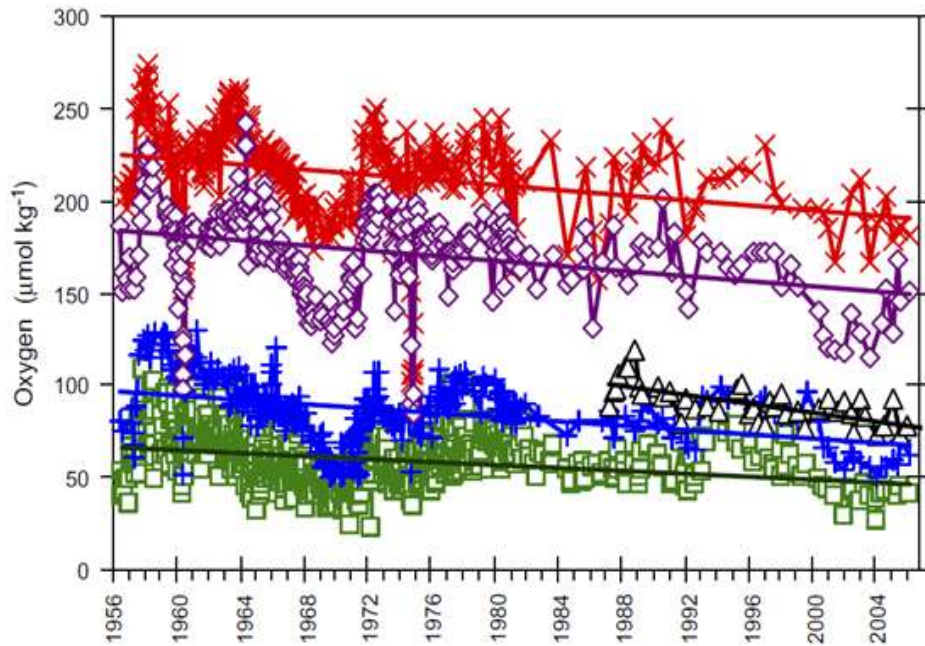


Figure from Whitney et al (2007)

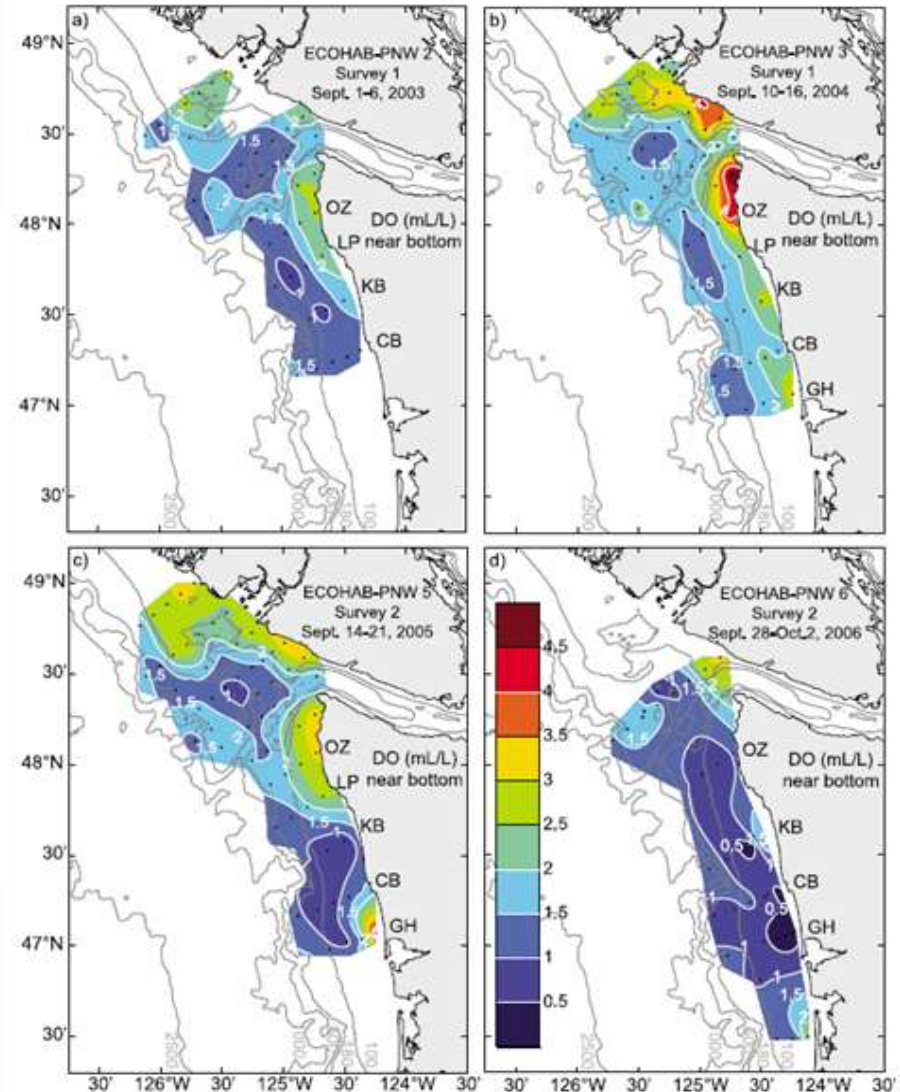
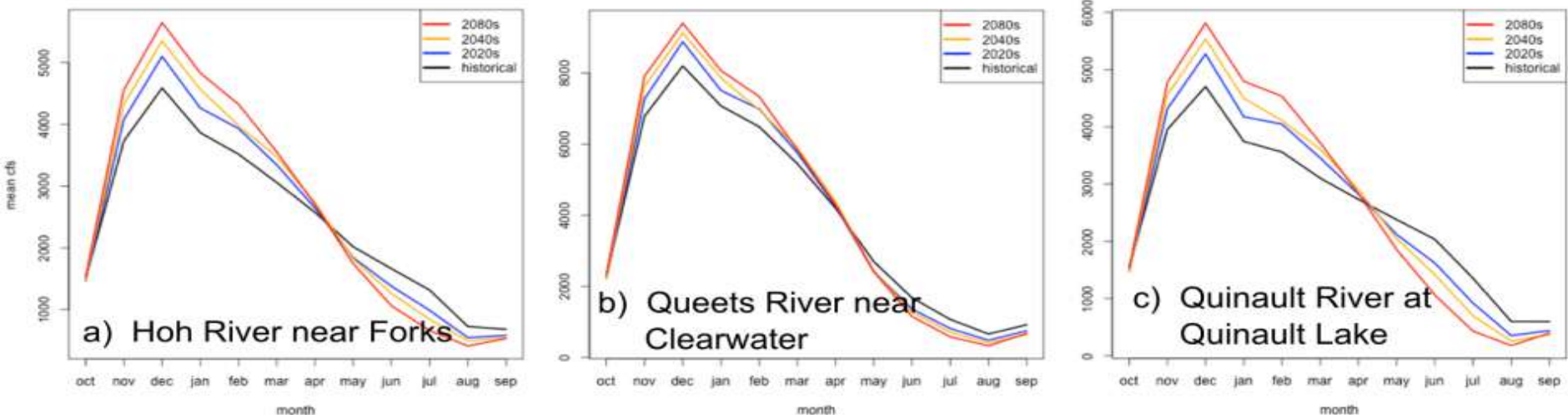


Figure Connolly et al. (2010)

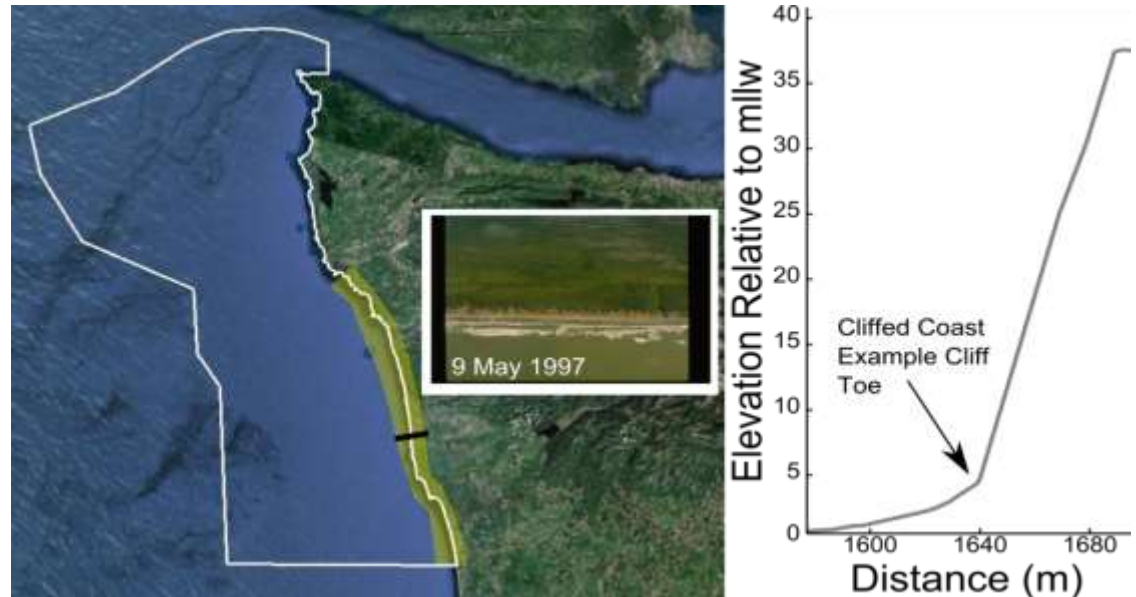
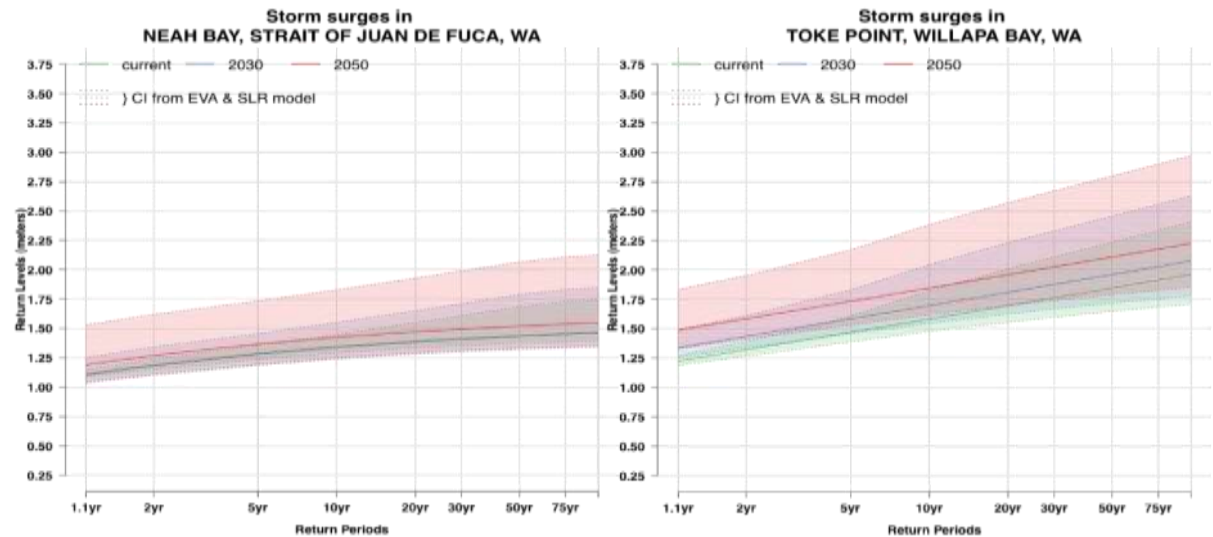
Hydrology

- Projected changes in temperature and precipitation are expected to provoke shifts in streamflow behavior and extreme hydrologic events, particularly attributable to warmer temperatures and less snow accumulation in the future.
- Future warming is projected to trigger greater flood magnitudes for the 100-year flood among basins with substantial snow contributions to streamflows on the west side of the Olympic Peninsula. These include the basins with headwaters at higher elevations, like the Sol Duc, the Hoh, the Queets and the Quinault Rivers.
- Late summer low flows are expected to increase in severity for basins feeding into the Olympic Marine Sanctuary due to warmer temperatures and less snow accumulation at higher elevations.
- Water temperatures are expected to remain within favorable thresholds for salmon migration and rearing habitat for basins on the western coast of the Olympic Peninsula.



Implications

- Shallow Sub-tidal and Intertidal
 - Increased physical impact (shallow)
 - Shoreline erosion and re-distribution of sediment
 - Intertidal community restructuring
- Deepwater Benthic
 - Temperature, hypoxia, surface productivity (upwelling) acidification.
 - Reduced habitat suitability for deepwater coral
- Pelagic Habitats
 - Pelagic fish declines, pelagic invertebrate increases
- Freshwater Habitats
 - Increase sediment supply due to winter high-flow?
 - No temperature affects on salmon, but scouring?



Continuing Steps

Working Draft Available at:

https://dl.dropbox.com/u/19569402/OCNMS_CA_v6_DRAFT_WORKINGGROUPOONLY.docx

Consolidate and incorporate all contributions from biology authors except sea birds and marine mammals (mid-October)

Expand section on ecological implications (mid-October)

Incorporate Sensitivity Analysis and Adaptation Strategies (late October)

Final review and editing (November-December)

Incorporate sea birds and marine mammals? (mid-November?)

Finalize Introduction/Reccomendations (December)

Publication-Ready (mid or late December?)



Thanks!

Ian Miller

360 417 6460

immiller@u.washington.edu

Image: Marine Stewardship Council