Present oceanic conditions in the North Pacific

(Ocean conditions, climate change, what next?)

Cisco Werner
SWFSC

John Stein
NWFSC

68th PSMFC Annual Meeting
24 August 2015
Girdwood, AK

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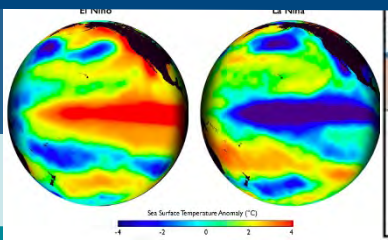
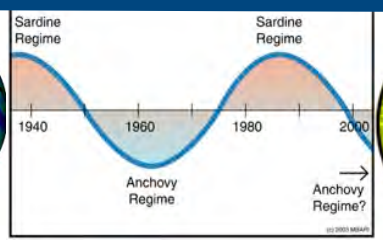
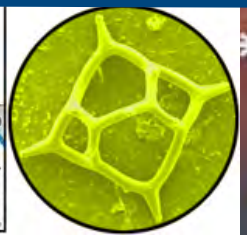
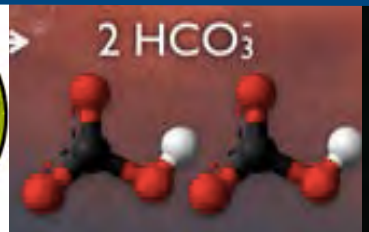
Thanks to: N. Mantua, S. Bograd, J. Field, J. Polovina, L. Weitkamp, S. Busch and many others for their input.









Last year's summary (Skamania, 25 Aug 2014)

- Present conditions in the N. Pacific are anomalous and record warm SSTs, but are not all related to an El Niño (EN)
- Possible signals of a positive (warm) PDO evolving
- Models are predicting a moderate EN in the Fall and Winter of 2014-2015.
- Ocean Acidification impacts the North Pacific in different ways
- We are in a challenging position because of the unprecedented number of variables changing simultaneously and their rates of change

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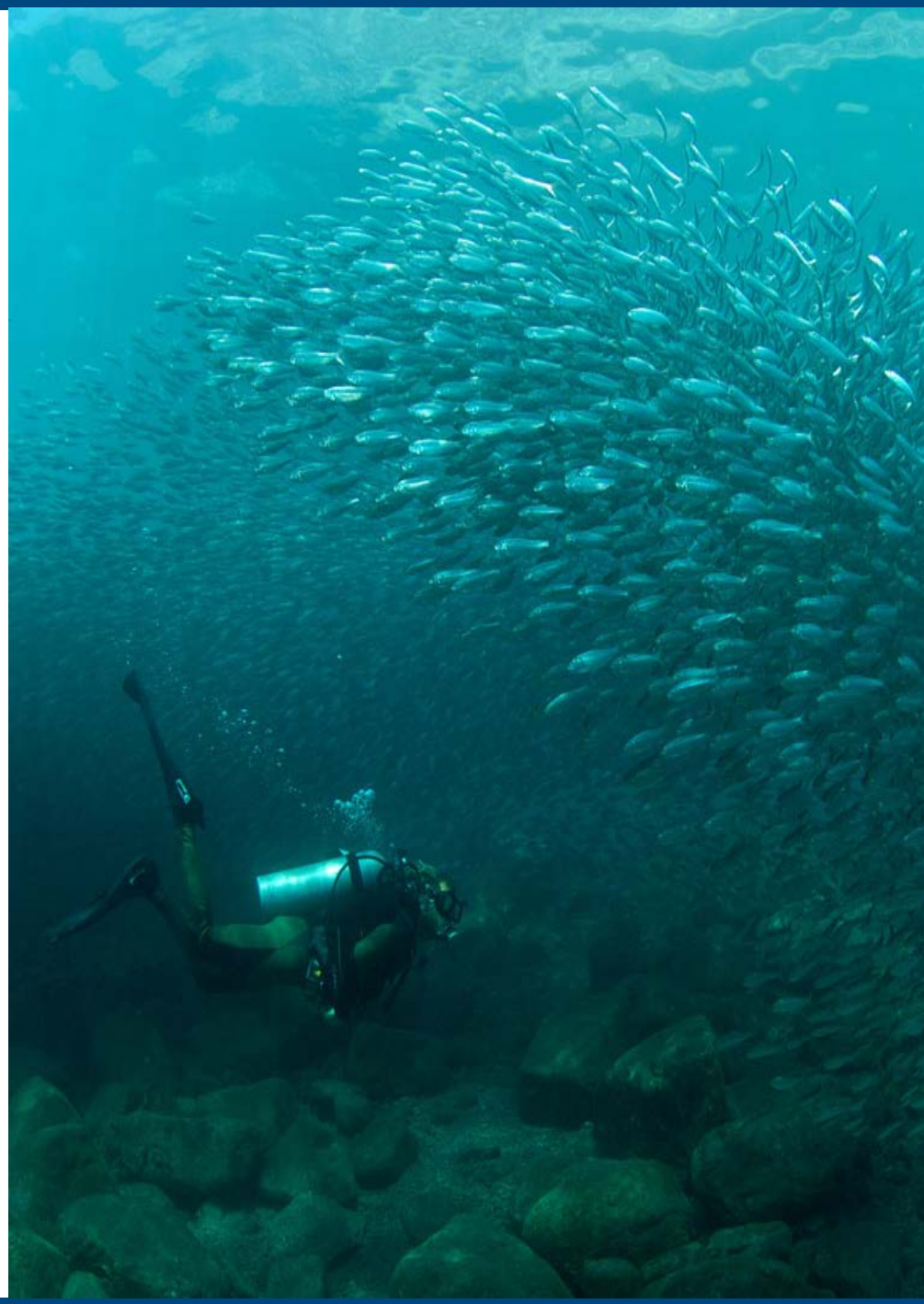
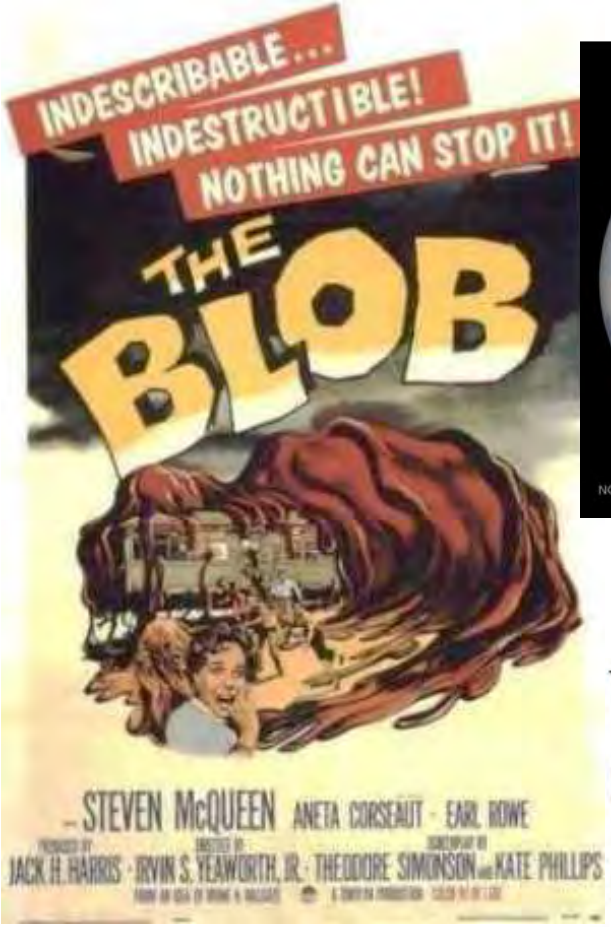
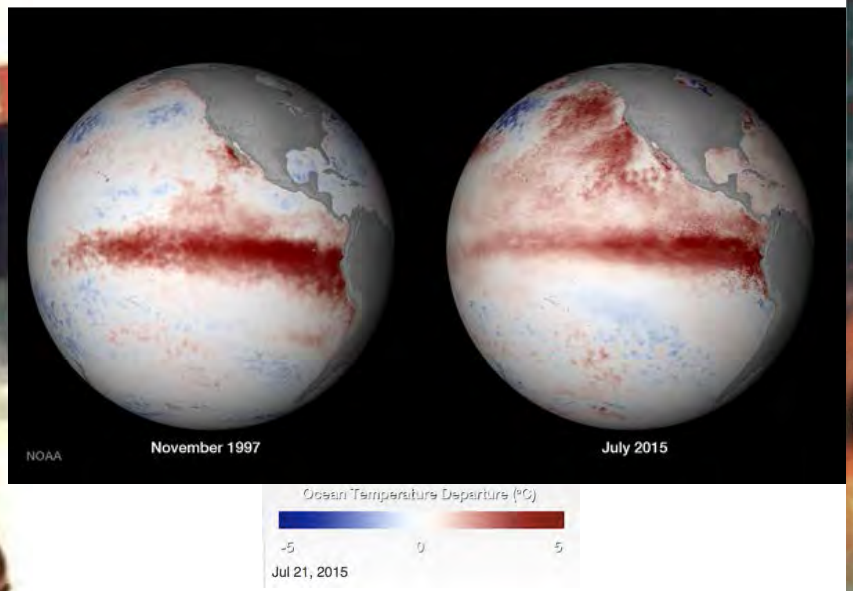


SFGATE NEWS SPORTS BUSINESS A&E FOOD LIVING TRAVEL REAL ESTATE

Expanse of warm water dubbed the blob consumes North Pacific

Updated 10:08 am, Monday, August 3, 2015





What happens when 'the blob' meets Godzilla El Niño? Climate chaos and more hot, dry weather for B.C.

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NP JOHN COLEBOURN AND DAAN FUMANO, POSTMEDIA NEWS | August 19, 2015 1:59 PM ET

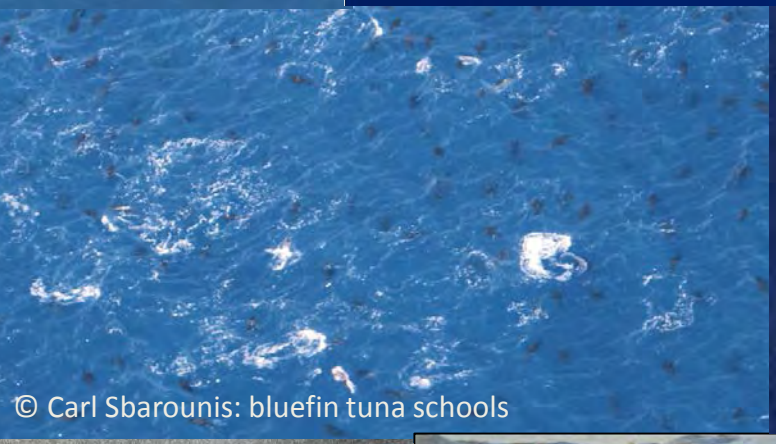
More from Postmedia News

More objectively… but still eye-opening

Shortbelly rockfish young, Pt. Sur

Salps and pyrosomes, Pt. Piedras Blancas

Pelagic red crabs, San Nicolas Isl.



© Carl Sbarounis: bluefin tuna schools

HAB modeling

False Killer Whales, 24 Feb 2015; Photo: M. Robbins

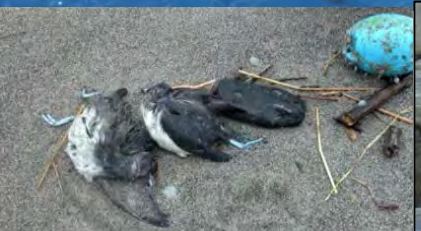
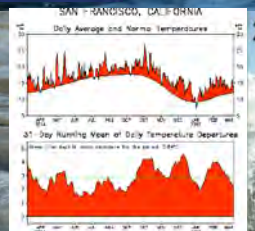
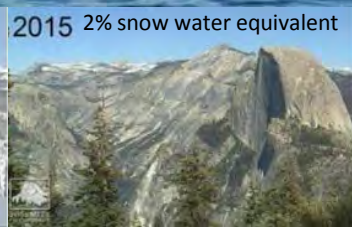
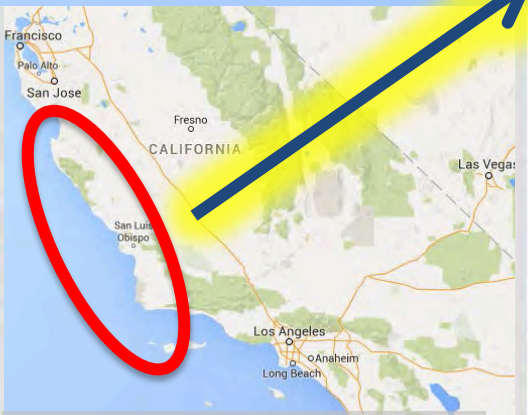


Photo: Sharon Melin, NOAA

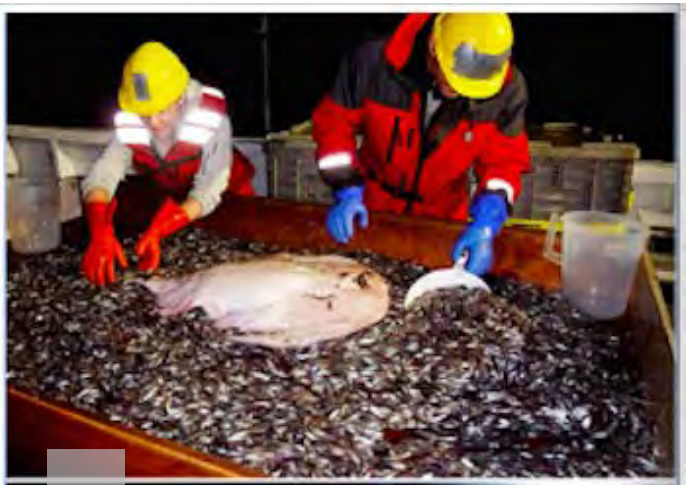




2% snow water equivalent



Central California
Summer 2015
Rockfish Survey



May-June 2015

NEWS RELEASE
August 20, 2015
Julie Speegle, 907-586-7032 w., 907-321-7032 c.

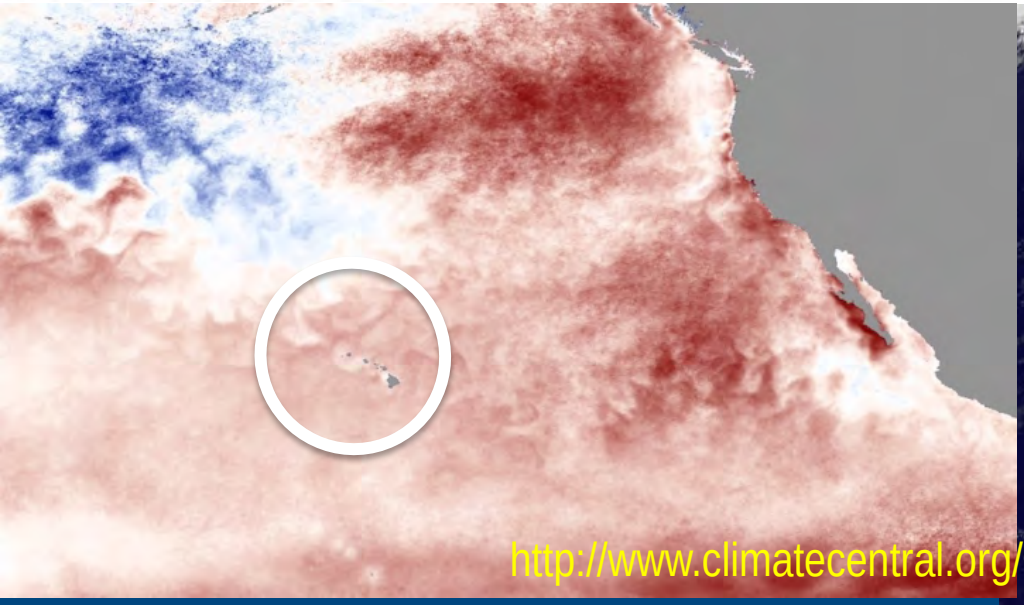
NOAA DECLARES DEATHS OF LARGE WHALES IN GULF OF ALASKA AN UNUSUAL MORTALITY EVENT

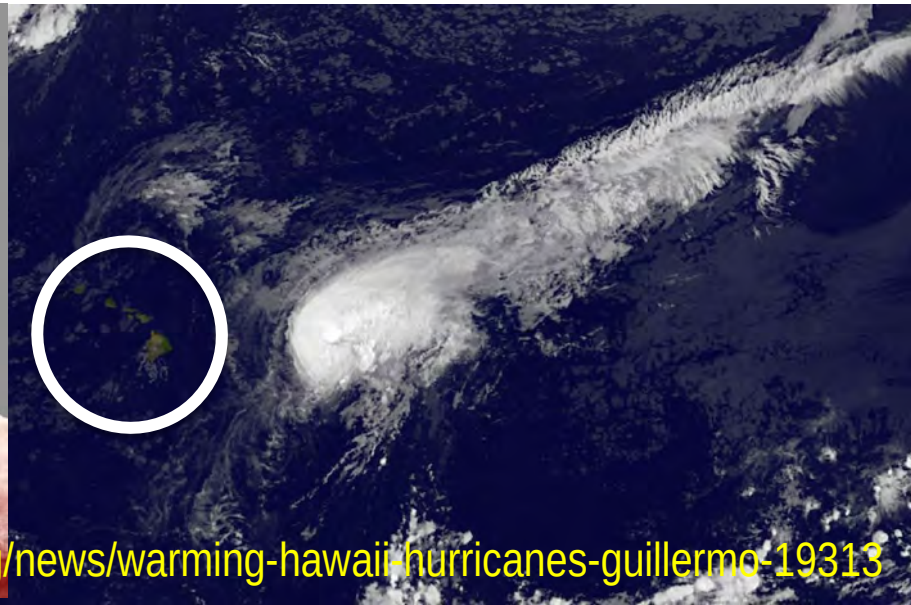
Bears feeding on a fin whale carcass in Larson Bay, Alaska, near Kodiak. Credit: NOAA

http://alaskafisheries.noaa.gov/newsreleases/2015/whales-ume082015.htm

Hawaii May Say 'Aloha' to More Hurricanes

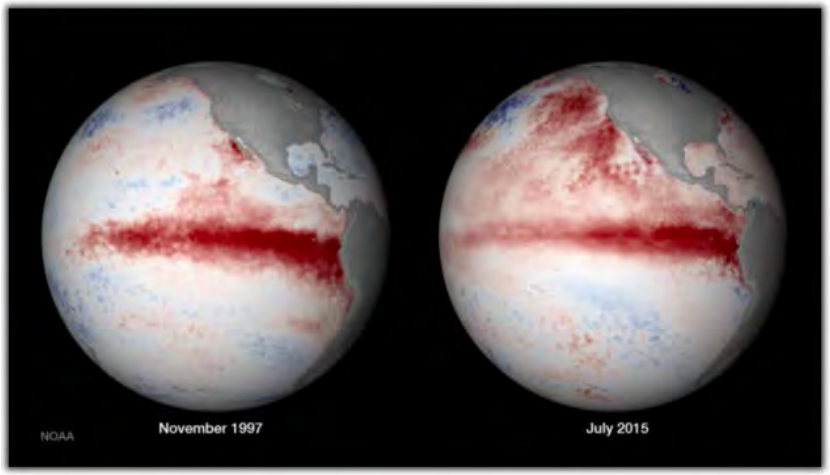
Published: *August 5th, 2015*



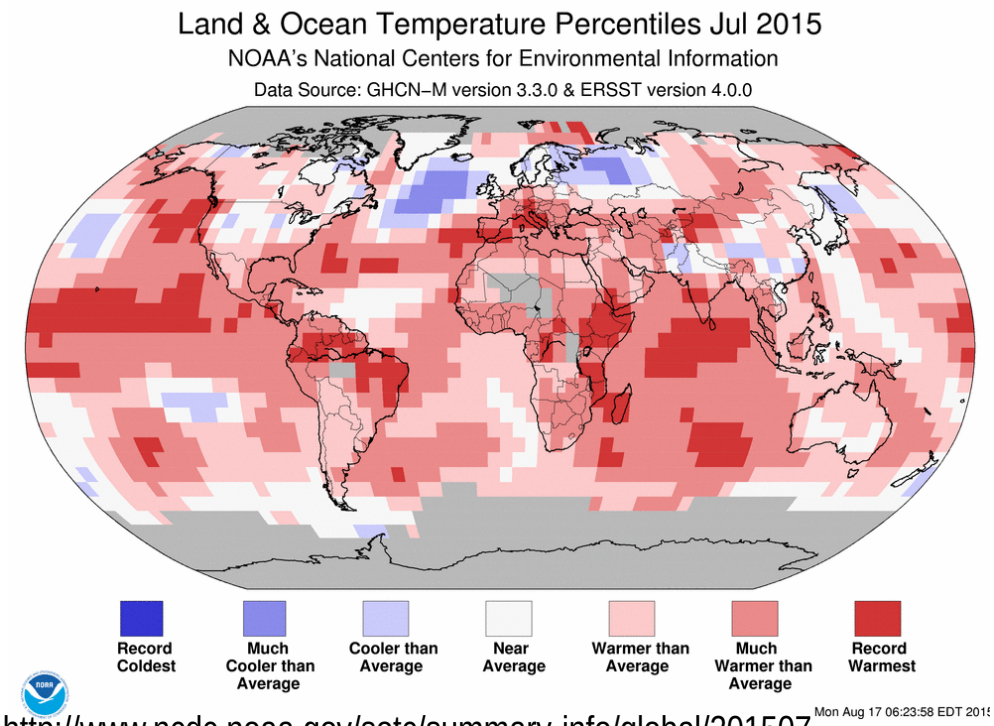


http://www.climatecentral.org/news/warming-hawaii-hurricanes-guillermo-19313

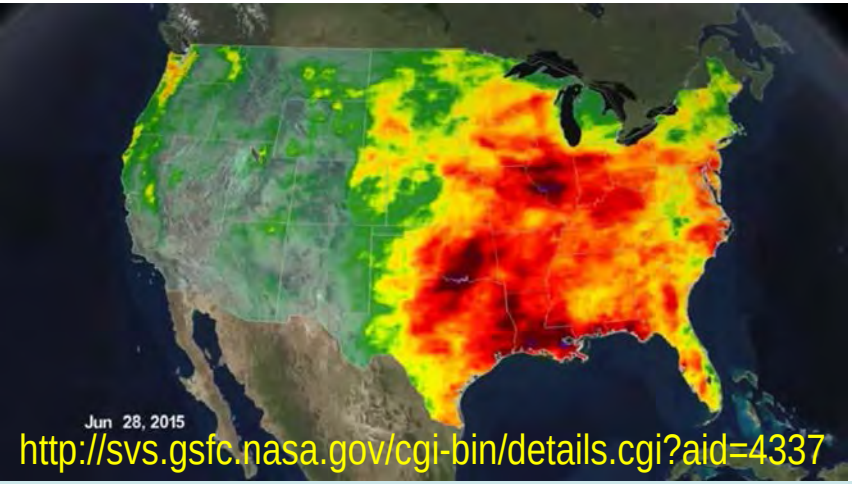
So, what's causing all these conditions? Have we seen them before? What next?



El Niño 1997 vs. 2015



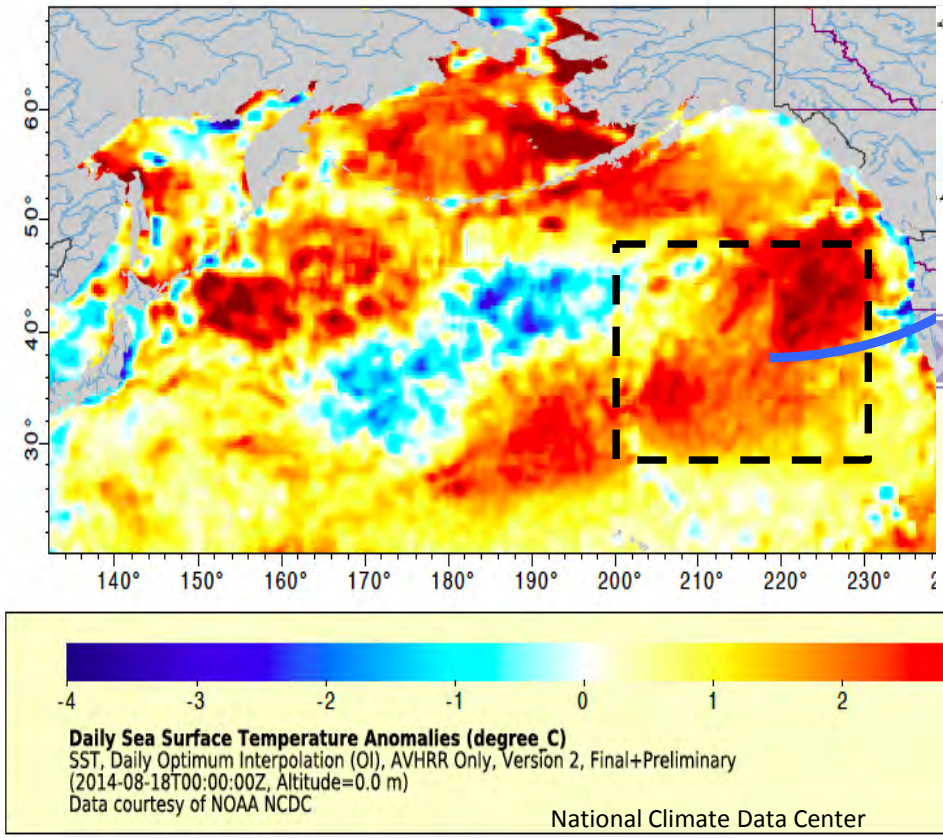
http://www.ncdc.noaa.gov/sotc/summary-info/global/201507

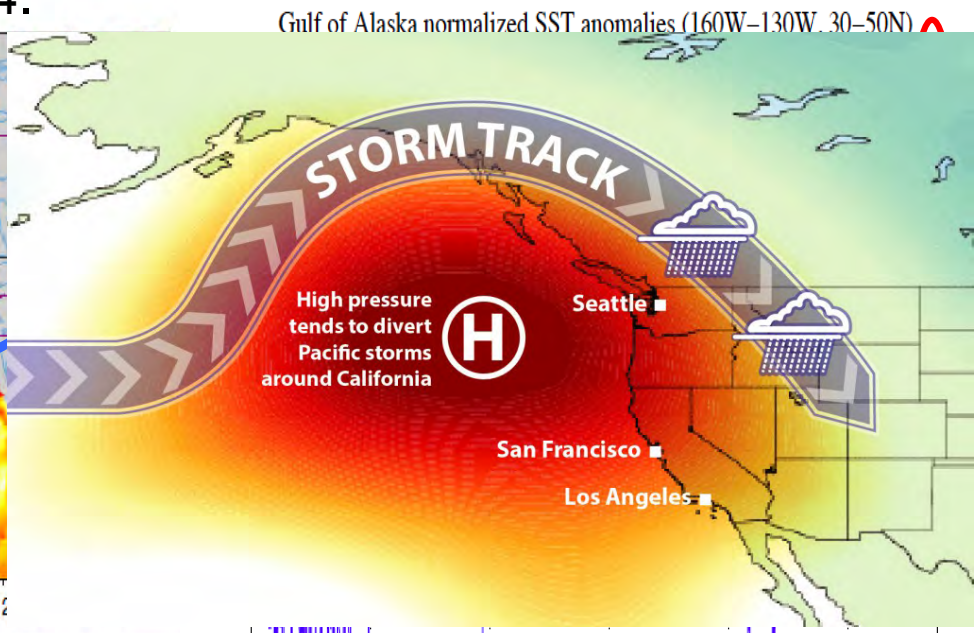


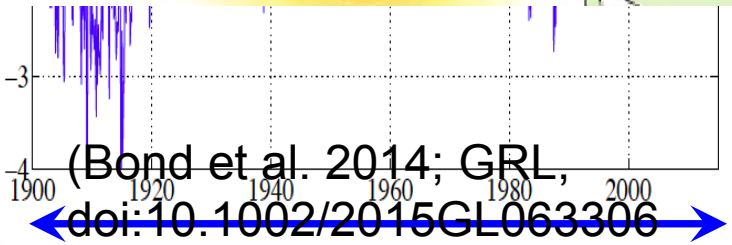
http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=4337

Rainfall Accumulation Across the U.S.
(1/1/2015 - 7/16/2015)

The Blob: A prominent mass of positive temperature anomalies developed in the NE Pacific Ocean during winter of 2013–2014. This development can be attributed to strongly positive anomalies in SLP (the *Ridiculously Resilient Ridge*), which served to suppress the loss of heat from the ocean to the atmosphere. The extra Mixed Layer heat persisted through the summer of 2014.







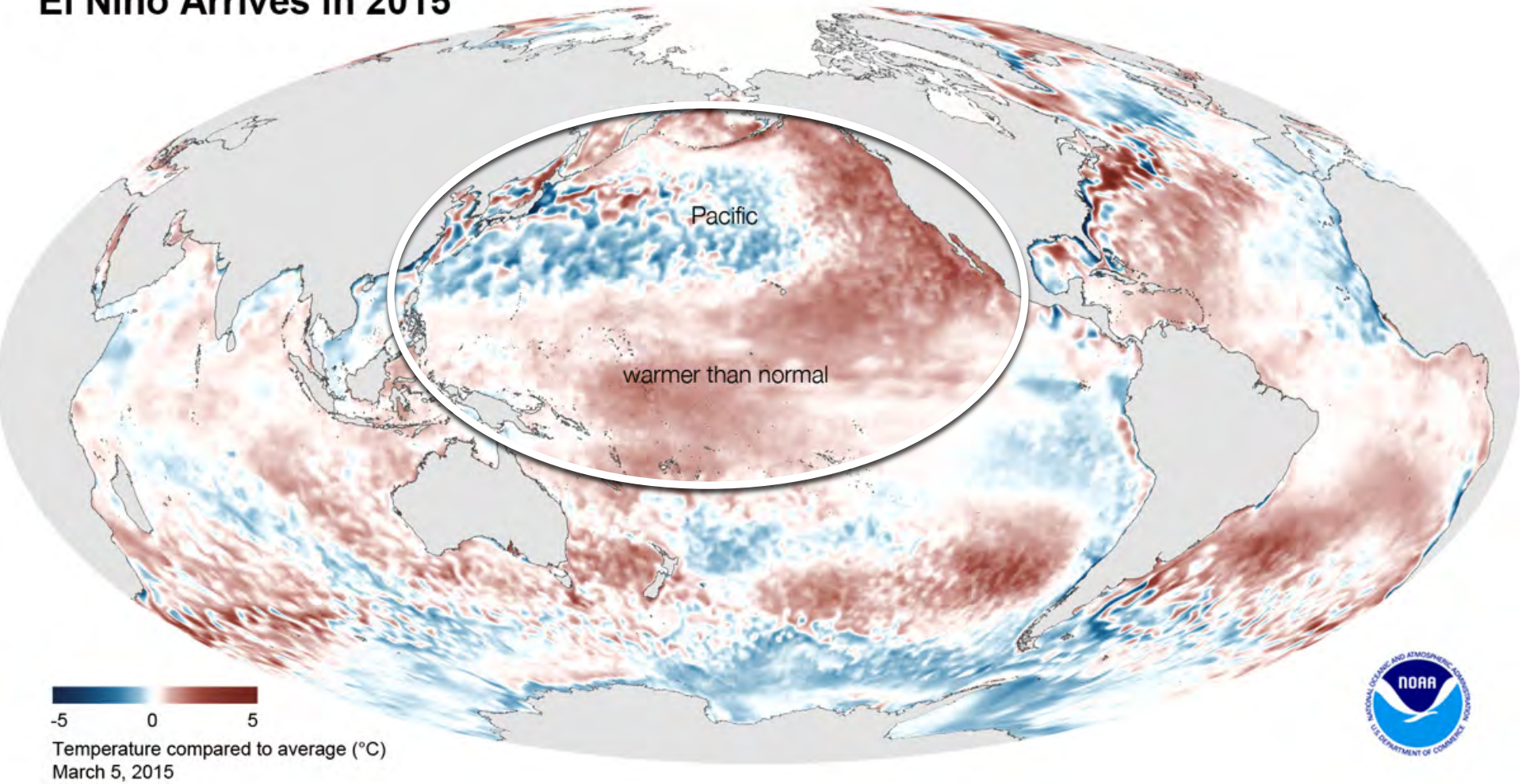
(Bond et al. 2014; GRL, doi:10.1002/2015GL063306)

114 Years

Daily SST anomaly (18 Aug 2014) relative to the 30-year (1982-2010) climatology

The 100+ year time series of Sea Surface Temperature in the eastern Pacific shows this is the warmest

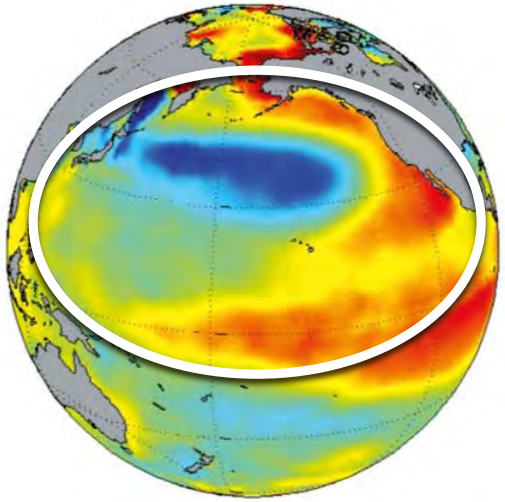
El Niño Arrives in 2015

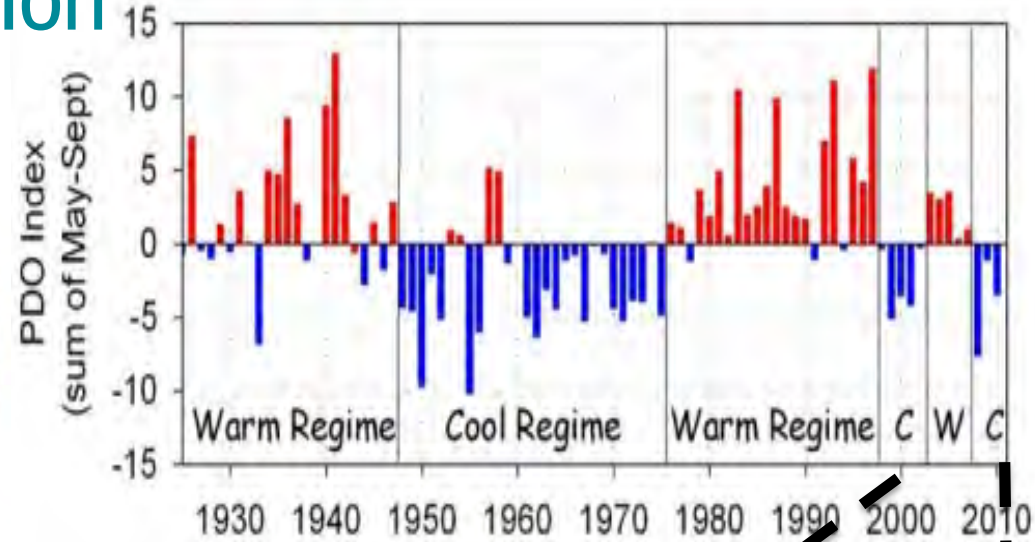


Aug 24, 2015 update: There is a greater than 90% chance that El Niño will continue through the Northern Hemisphere winter 2015-16, and around an 85% chance it will last into early spring 2016. All multi-model averages suggest that Niño 3.4 will be above +1.5ºC (a "strong" El Niño) during late 2015 into early 2016. ***http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/***

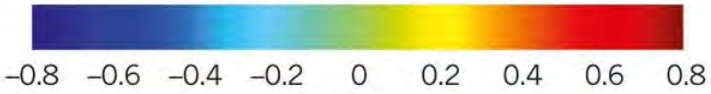
Pacific Decadal Oscillation (PDO)

Warm (Positive) Phase

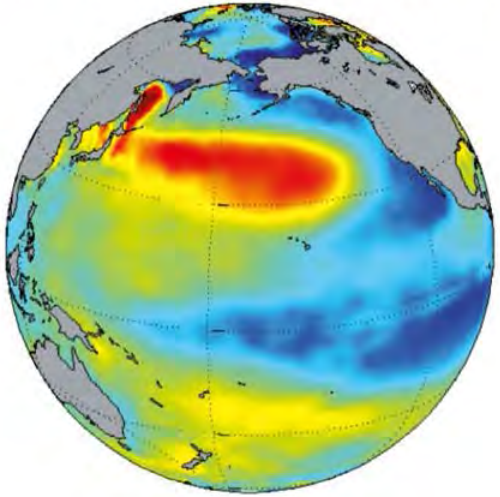


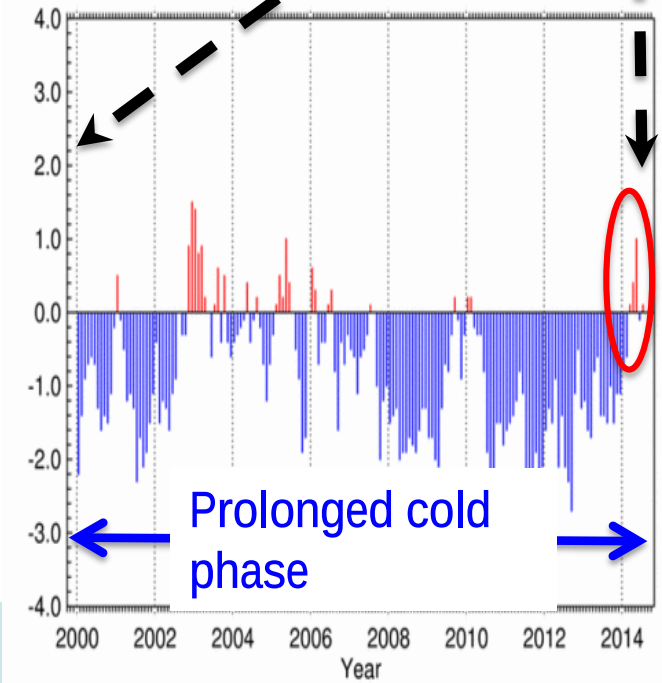


Departures from average ocean temperatures (°C) associated with the warm and cool phases of the PDO

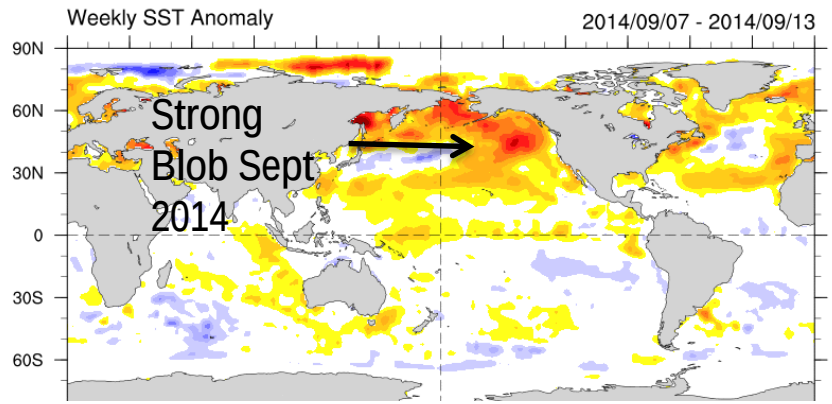


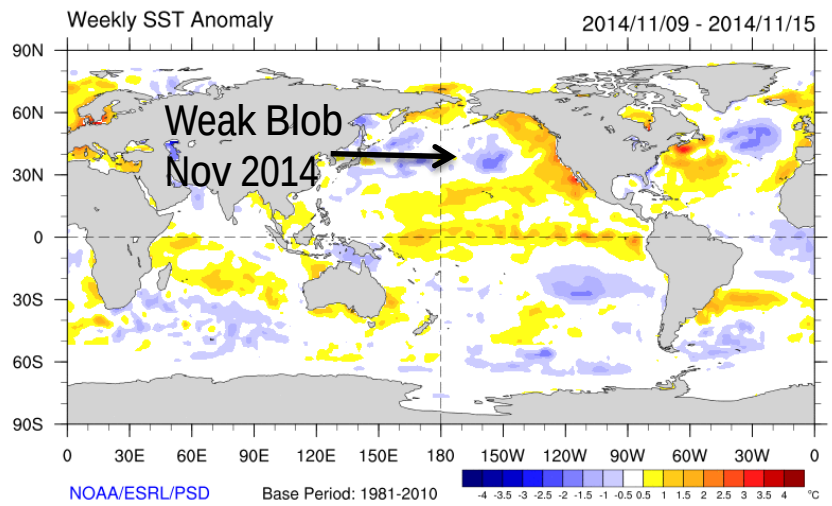
Cold (Negative) Phase





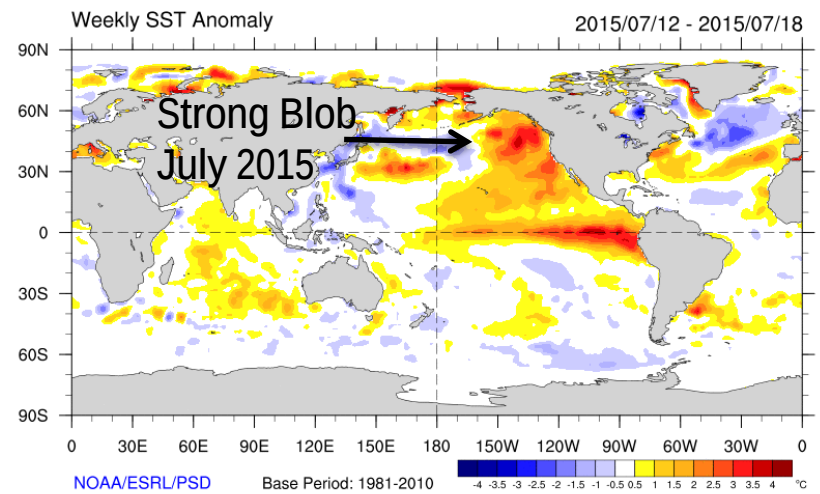
The Blob's recent coming and going; a hint of what may be next?





- The Blob was exceptionally strong in late summer and early fall 2014, but persistently low pressure and frequent storms over the Gulf of Alaska in fall 2014 substantially weakened the very warm SST anomalies in the Gulf of Alaska (the Blob got weaker in less than 3 months!).

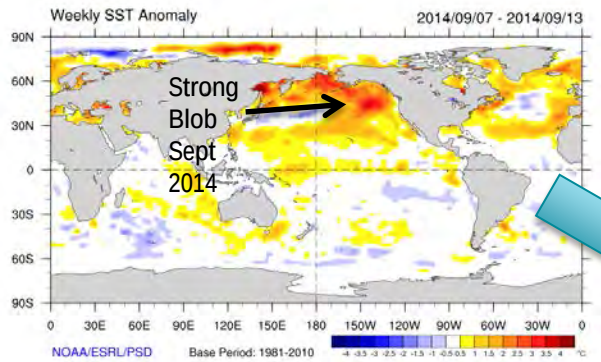
- But then after Christmas 2014, high sea level pressure returned to West Coast and Gulf of Alaska which shut off the winds and storms that normally cool the Gulf of Alaska… and the Blob returned as

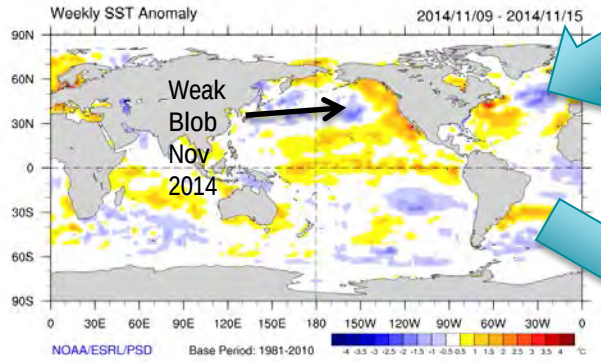


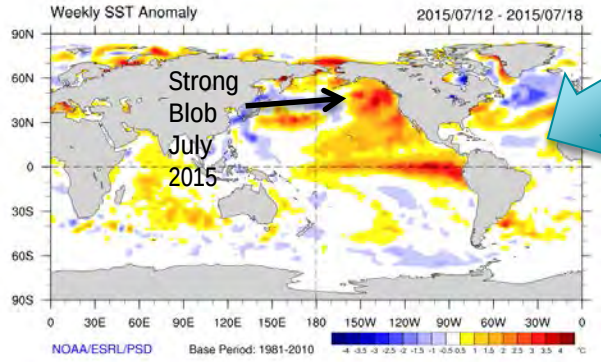
Mantua and DiLorenzo, in prep.

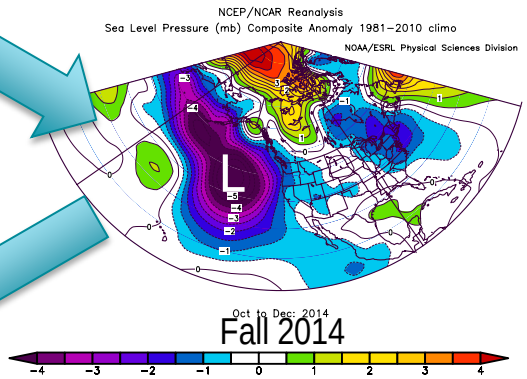
Fall/Winter 2014/15 sea level pressure (SLP) anomalies

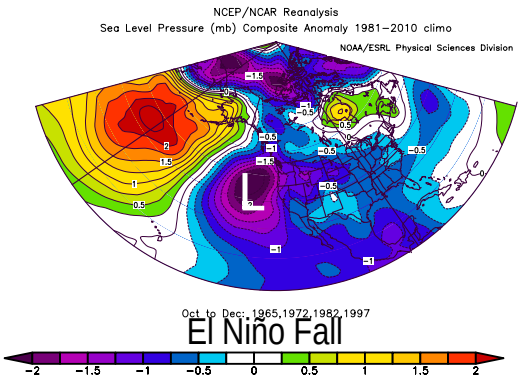
Strong El Niño Fall/Winter SLP anomalies based on 1965, 1972, 1982, and 1997 events

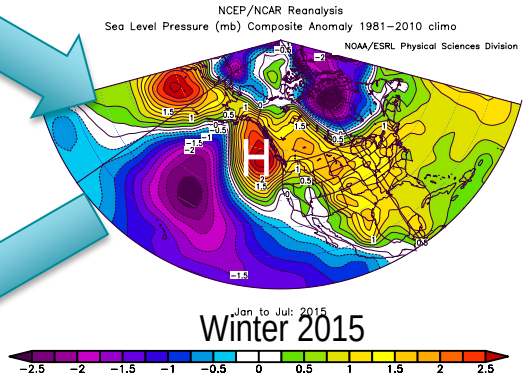


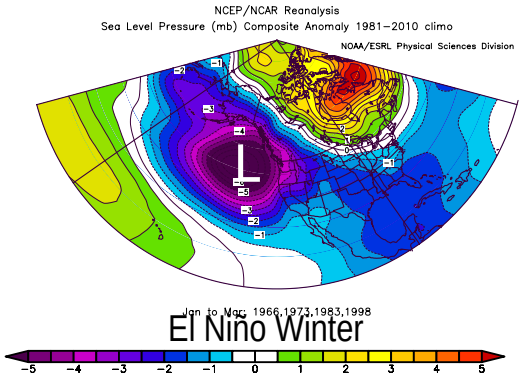












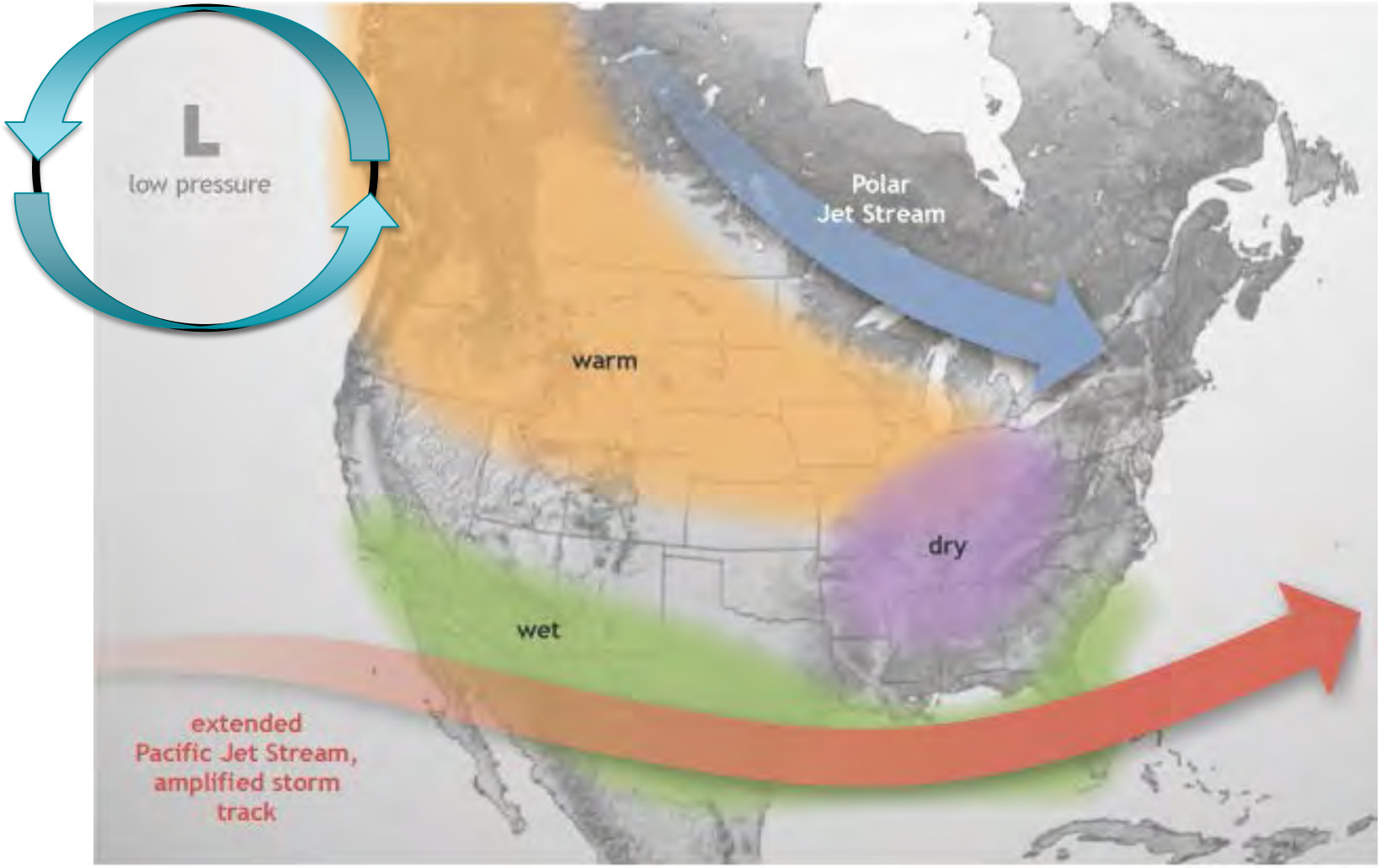
Note the broad area of low SLP off the West Coast in fall 2014. This caused winds that substantially weakened the Blob, and moved the warmest waters close to the coast. High SLP in the Gulf of Alaska in Jan – July 2015 brought the Blob back to life.

Past El Niño fall/winter periods have had intense low pressure anomalies in the Gulf of Alaska, just like Oct-Dec 2014. The winds caused by this pattern tend to focus warm ocean waters on the coastal zone, like Nov-Dec 2014.

Mantua and DiLorenzo, in prep.

NOAA FISHERIES

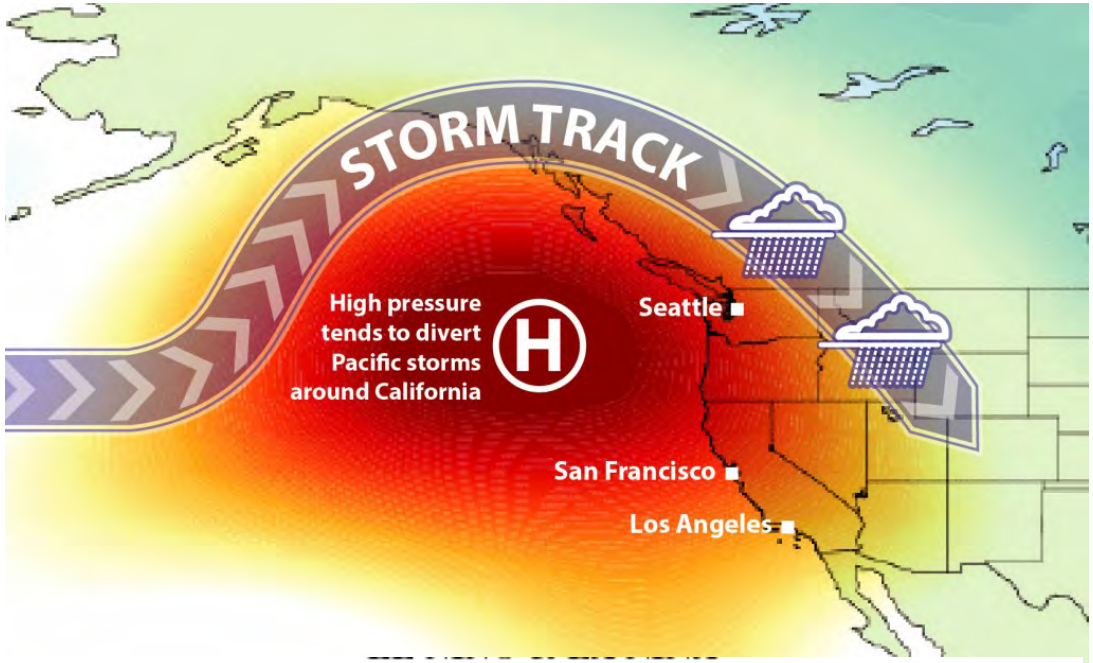
Wintertime El Niño pattern



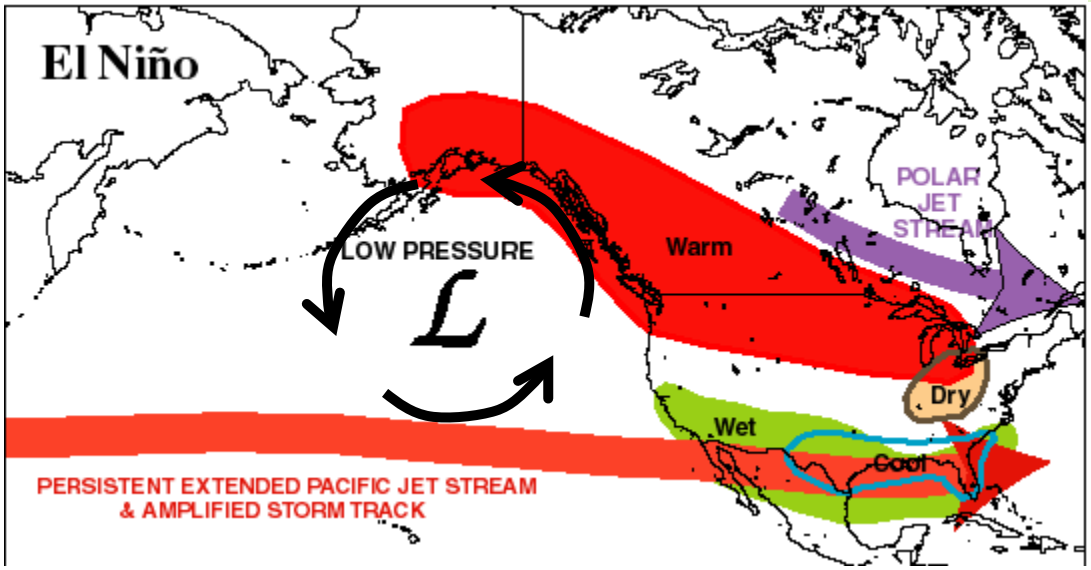
NOAA Climate.gov

https://www.climate.gov/news-features/blogs/enso/june-el-ni%C3%B1o-update-damn-torpedoes-full-speed-ahead

The *Ridiculously Resilient Ridge*: the proximate cause for California's extended drought and the "Blob" of exceptionally warm ocean temperatures in the NE Pacific (2013-15)



The typical El Niño winter pattern, featuring persistent and intense low pressure over the Gulf of Alaska and a very active jet stream and storm track just north of Hawaii extending over the southern US and northern Mexico.

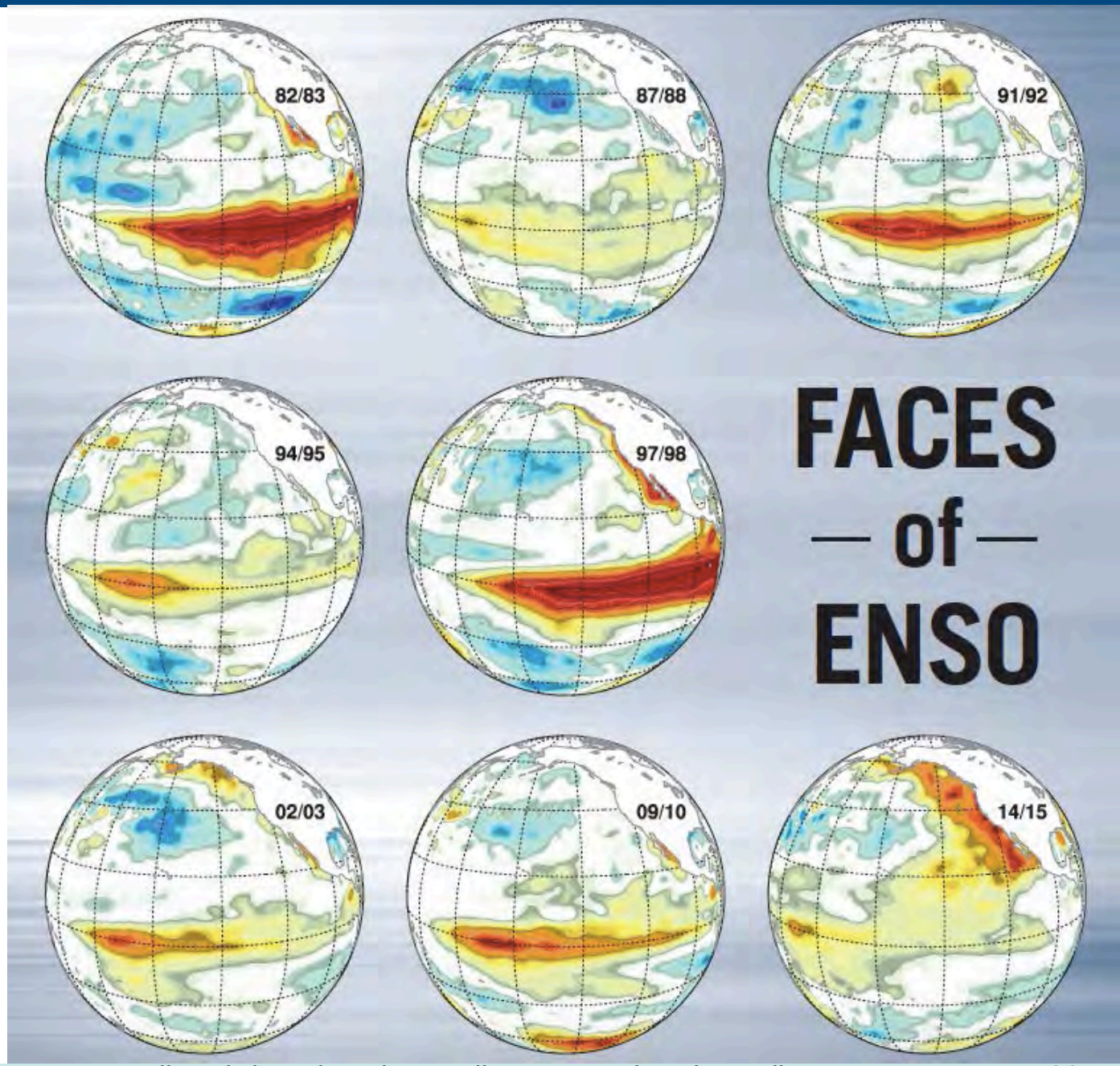


Possible Fall 2015 El Niño-Blob interactions

- Under this scenario, this fall (2015) we could see:
  - the warm SST anomalies of the "blob" cool down on the offshore side where westerly winds intensify, but
  - within a few hundred km of the U.S. West Coast ocean temperatures would rise dramatically under the influence of the strong southerly winds.
- As noted previously, this shift in North Pacific winds happened last fall (2014), but then reverted to the high-pressure ridge and fair weather in the winter.
- With El Niño, the persistence of a broad trough of low pressure in the GOA is likely to persist through the entire fall and winter. If this plays out as it has in the past it would result in more intensified warming off the coast that could persist through the end of winter.

But what will the 2015-2016 El Niño look like?

(*i.e.*, not all El Niños are the same.)

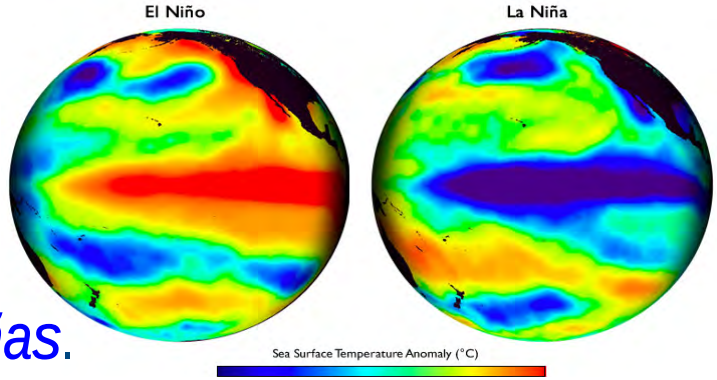


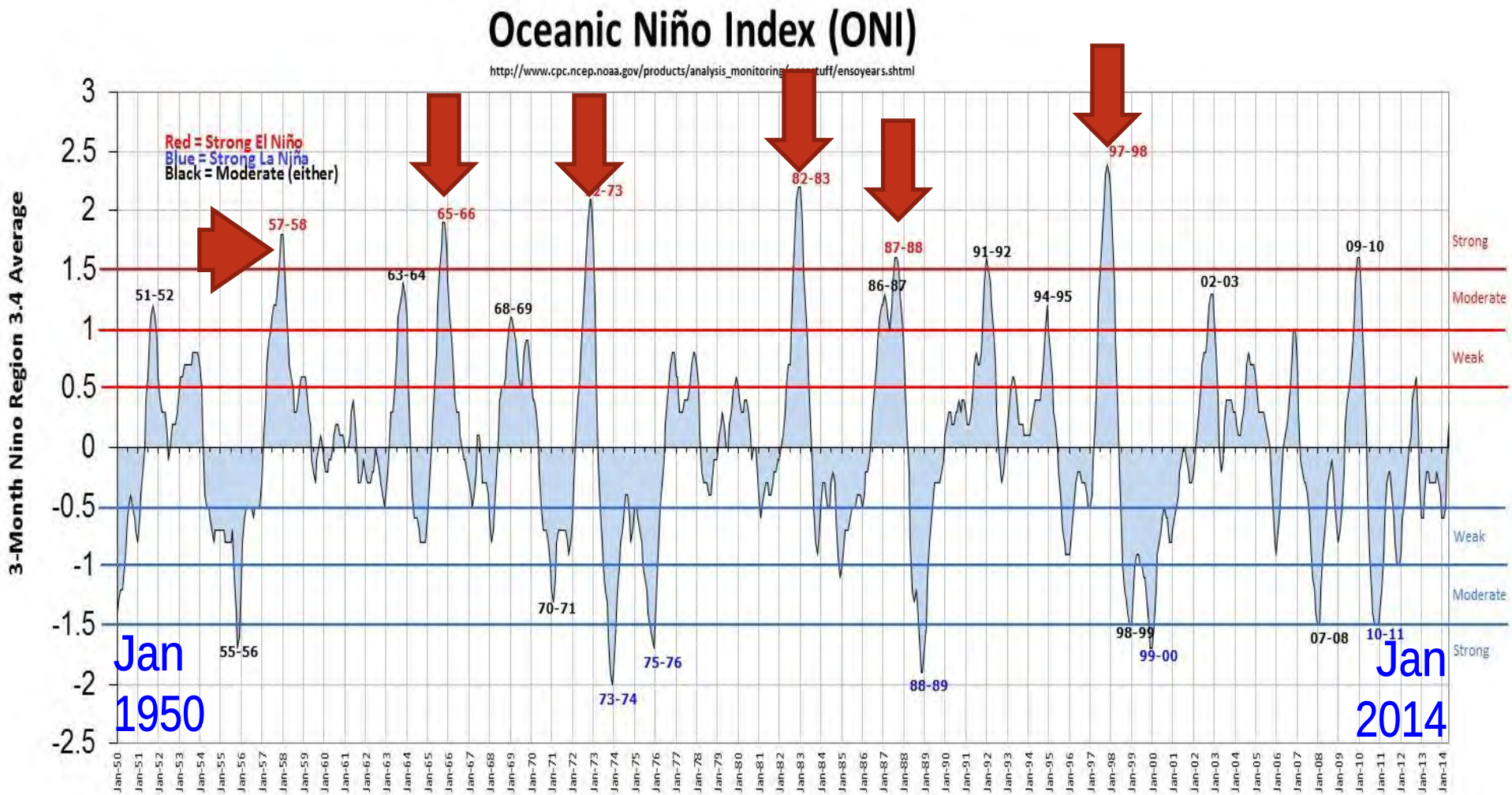
Capotondi et al. (2015) Understanding ENSO Diversity. *Bull. Amer. Meteor. Soc.*, 96, 921–938. doi: http://dx.doi.org/10.1175/BAMS-D-13-00117.1

History since 1950 of El Niño - La Niña occurrences

Six “strong” and eight “moderate” *El Niños*

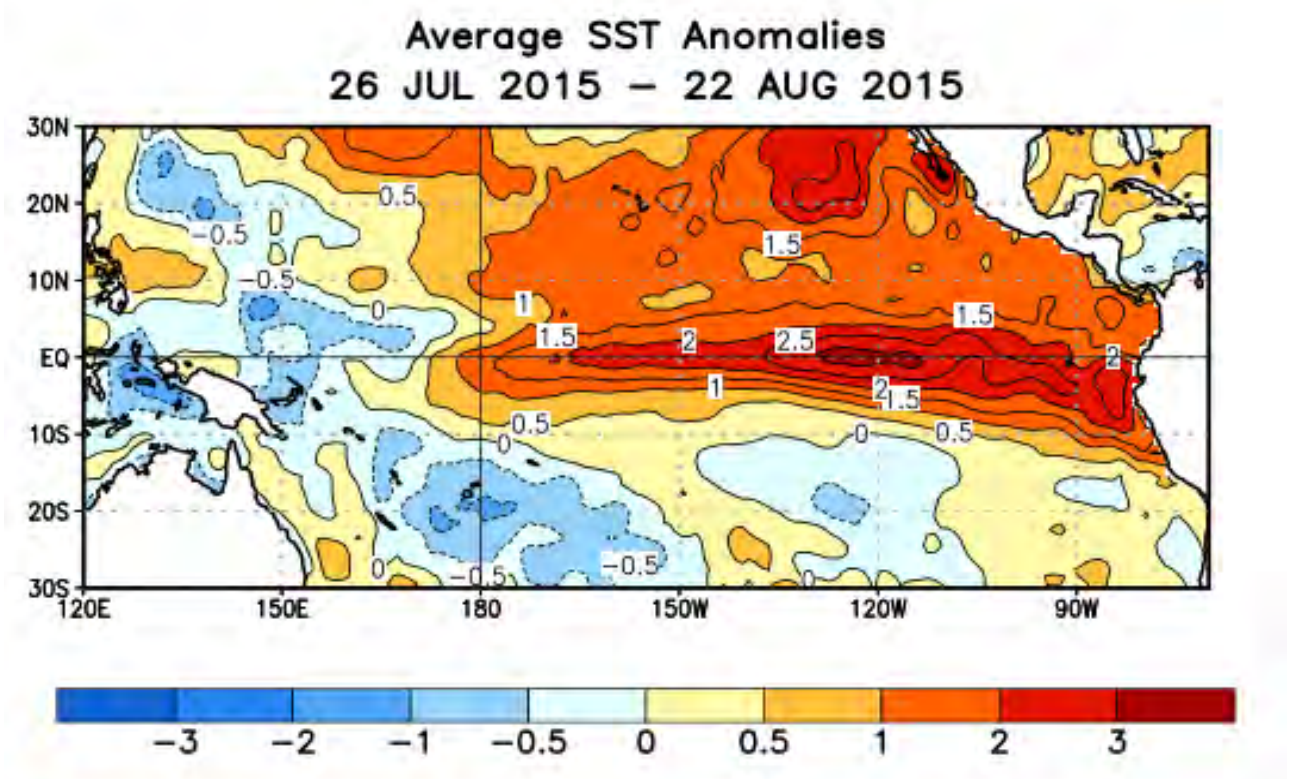
And five “strong” and four “moderate” *La Niñas*.





SST Departures (ºC) in the Tropical Pacific During the Last Four Weeks

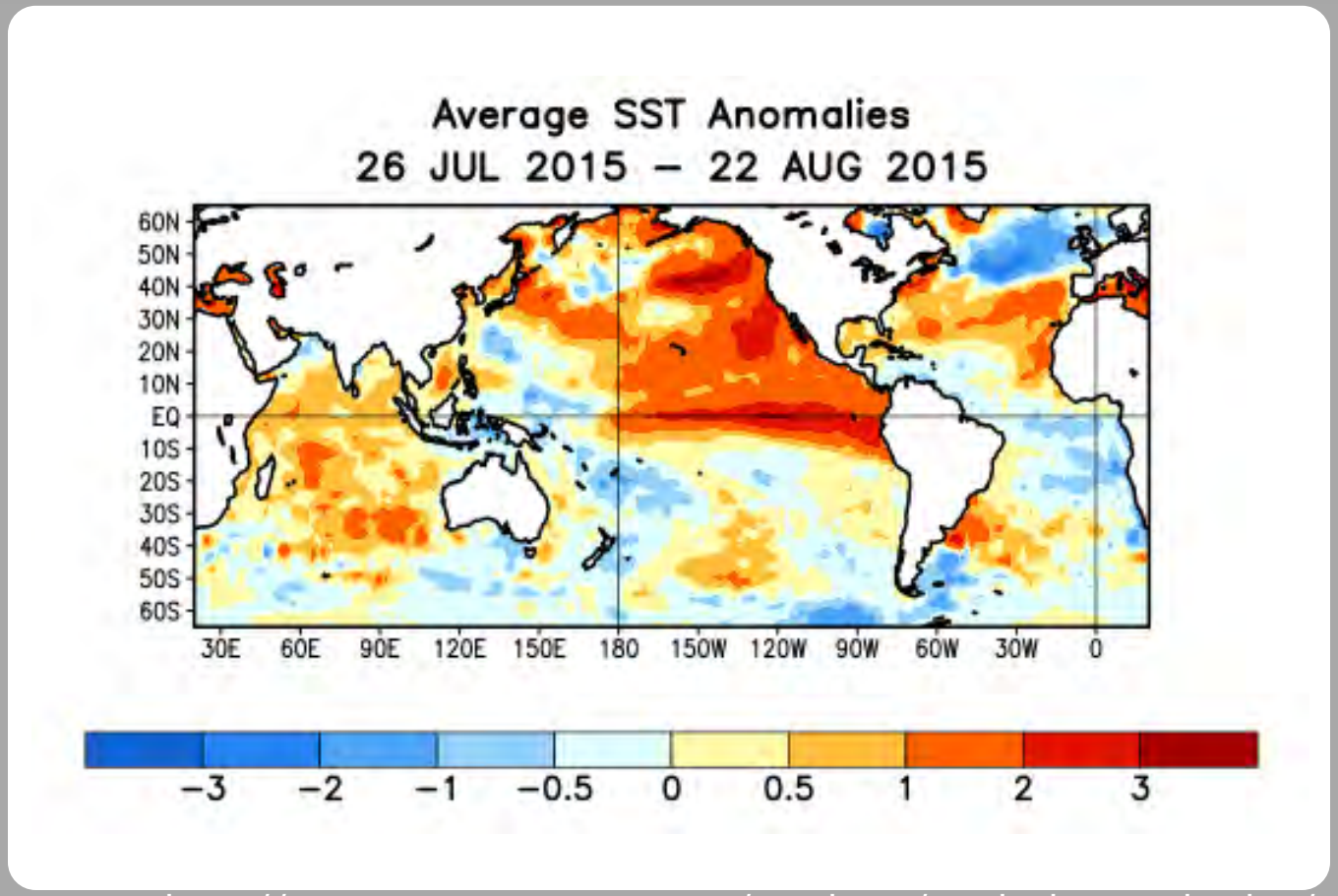
During the last four weeks, equatorial SSTs were above average across the central and eastern Pacific, with the largest anomalies in the east-central and eastern Pacific.



http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/

Global SST Departures (ºC) During the Last Four Weeks

During the last four weeks, equatorial SSTs were above average across the central and eastern Pacific and the Indian Ocean, and below average in the Atlantic Ocean.



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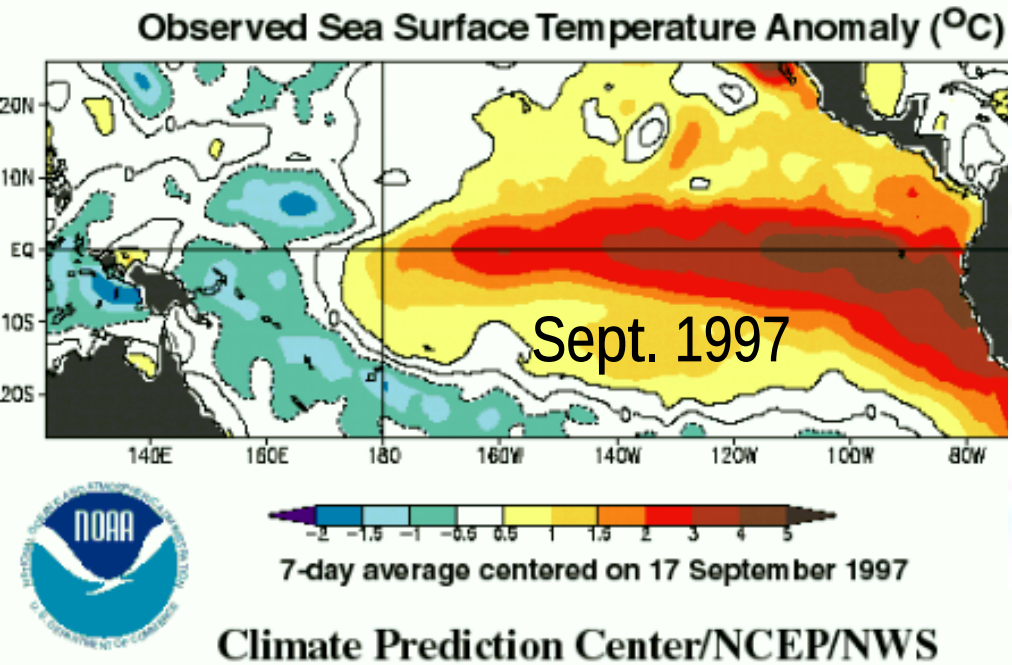
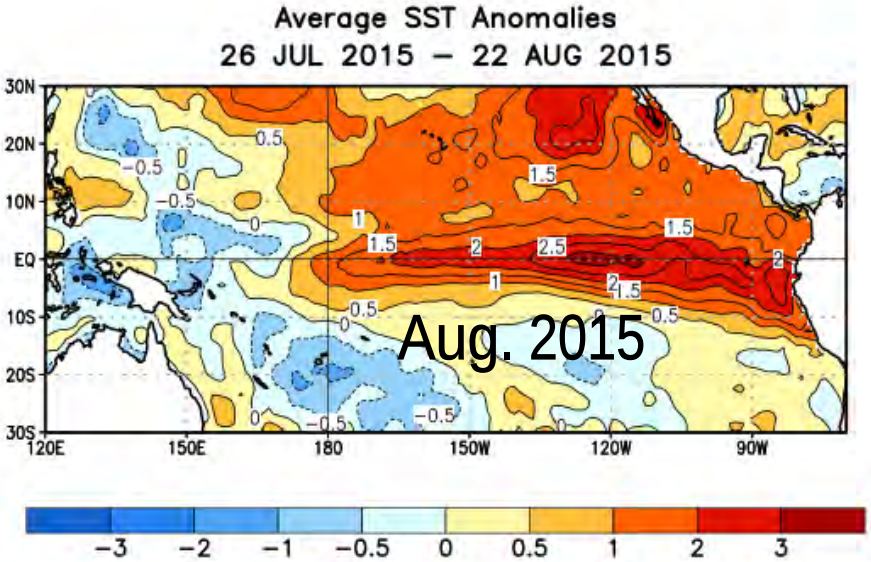
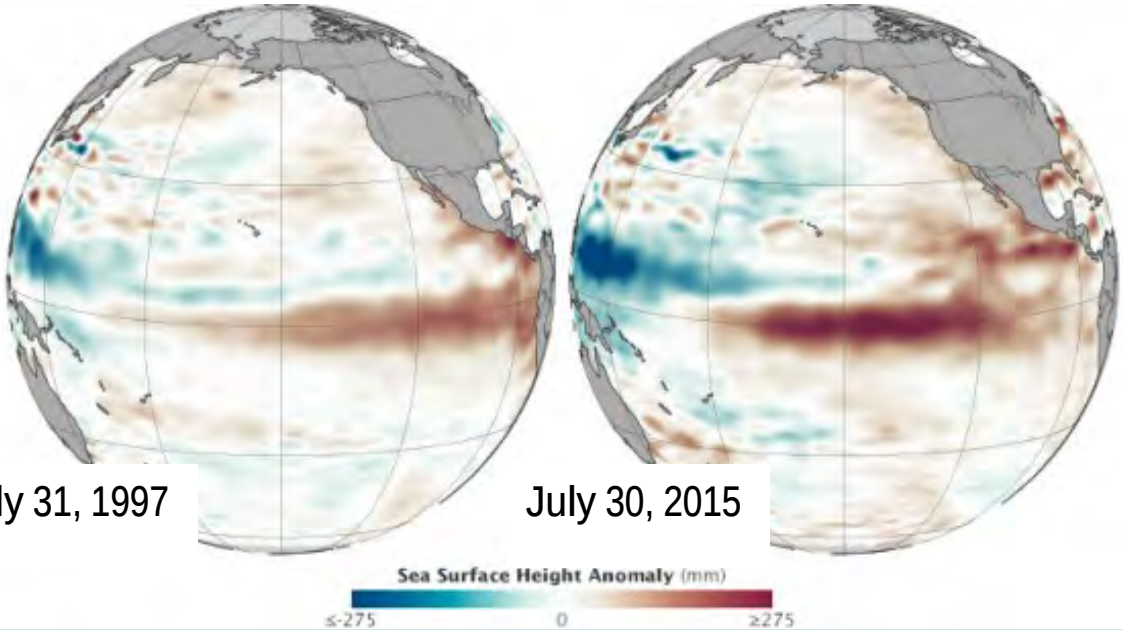


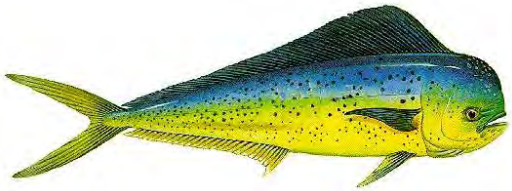


Presently it's not unreasonable to expect that 2015-16 could look like 1997-98



El Niño's Effects in the California Current

- Increased winter storms and rainfall in *Southern CA.*
- Warmer, more subtropical, ocean conditions; reduced primary and secondary production
- Anchovy, market squid and CA sea lion populations in So. California decline; whiting and sardines migrate further north, into Canadian waters
- Improved growth and recruitment for some species, such as sardines; reduced recruitment for rockfish, squid, anchovies, etc.
- Tropical fish like mahimahi, swordfish, and marlin, and subtropical fish like Albacore and Pacific bonito, move north/onshore



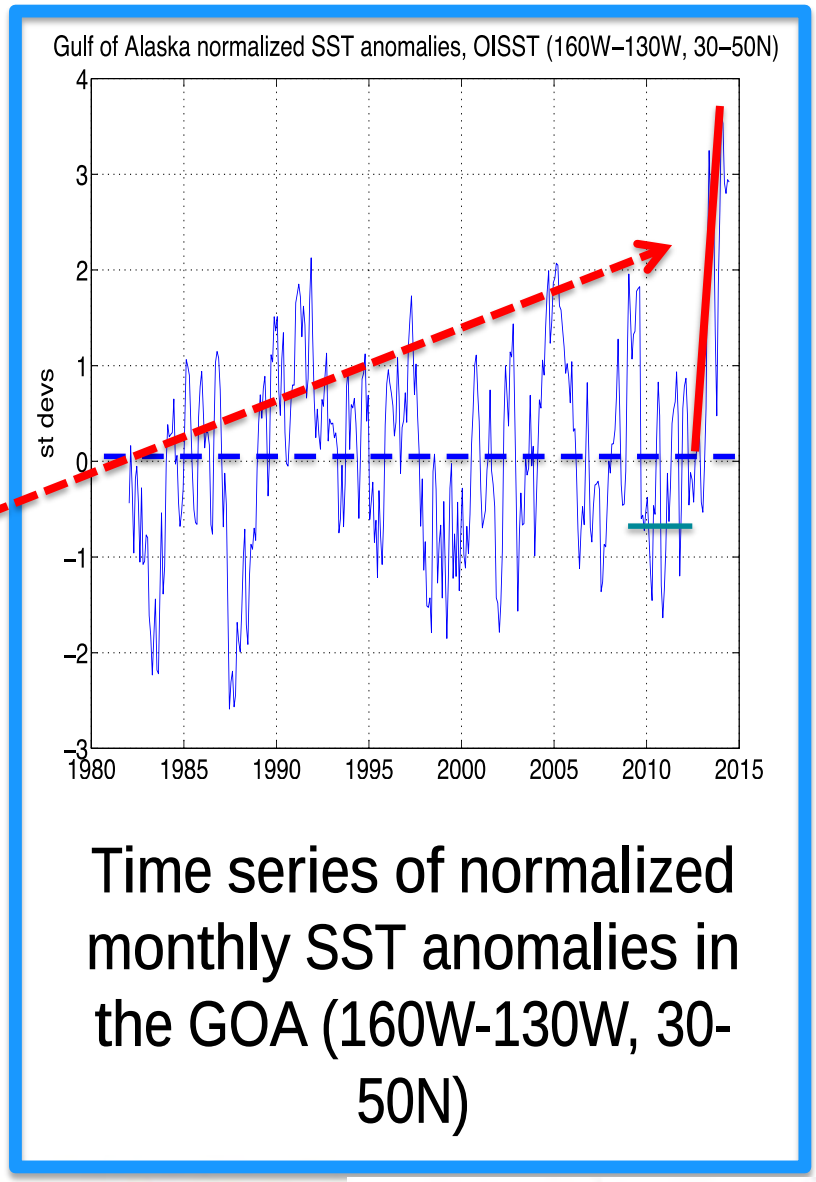
El Niño's Effects: Salmon in the California Current

- **Positive PDO or an El Niño =** base of food web limited.
  - Bodes ill for west coast salmon marine growth and survival

- **El Niño or not**, juvenile salmon in the CA Current in 2015 are likely to experience low survival and returns could be below average
  - This has implications for fisheries and Threatened and Endangered species management in 2016 for coho, and 2017-18 for Chinook
  - And expands beyond PNW to Alaska, as some PNW salmon migrate to the Gulf of Alaska

El Niño's Effects: Gulf of Alaska

- Increases in early marine survival (faster growth) and adult returns for Alaska's Pacific salmon
- Increases in flatfish recruitment
- But the extremely warm water in the central Gulf of Alaska may ultimately lead to poor survival
  - Why? Likely declines in prey production

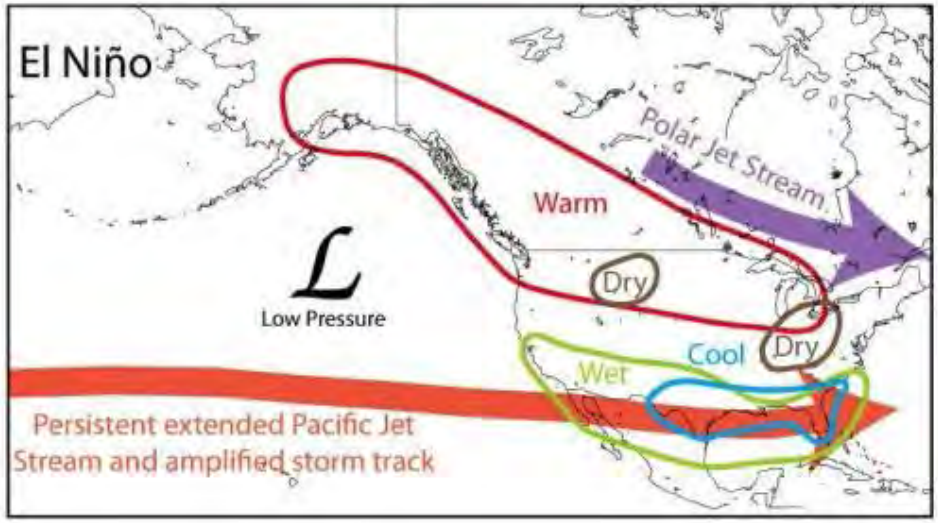


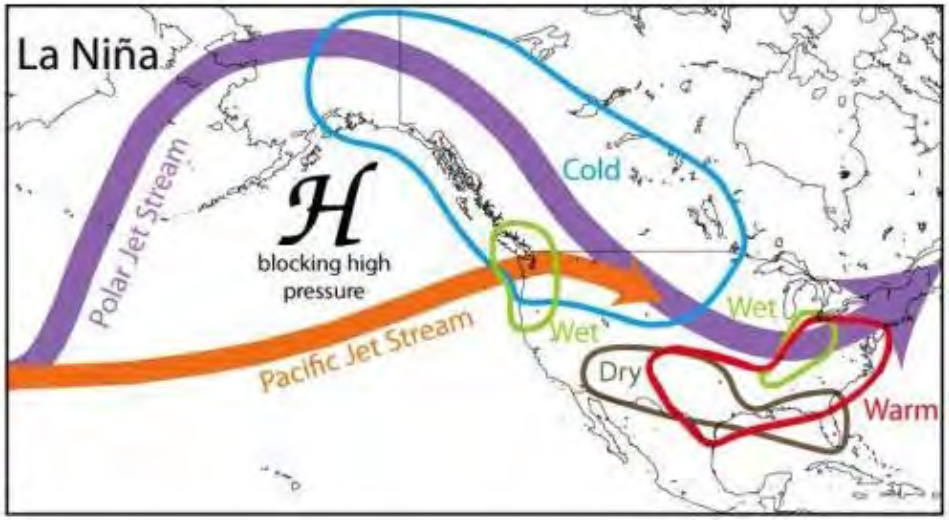
Time series of normalized monthly SST anomalies in the GOA (160W-130W, 30-50N)




What about *after* the El Niño?... seesaw to La Niña?

Several past El Niño events have been followed by multi-year La Niña (cold) conditions (including the 1982/83 and 1997/98 extreme El Niño events).

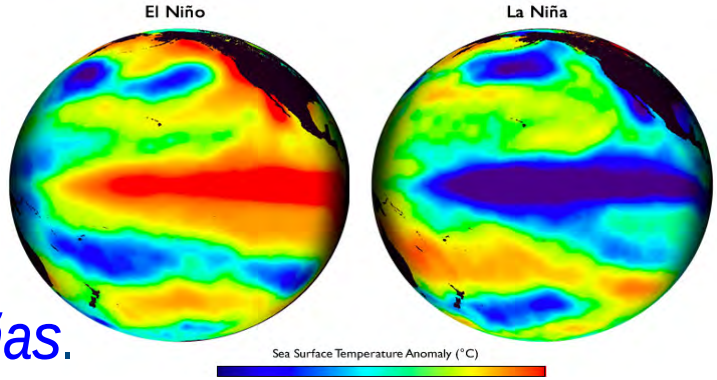


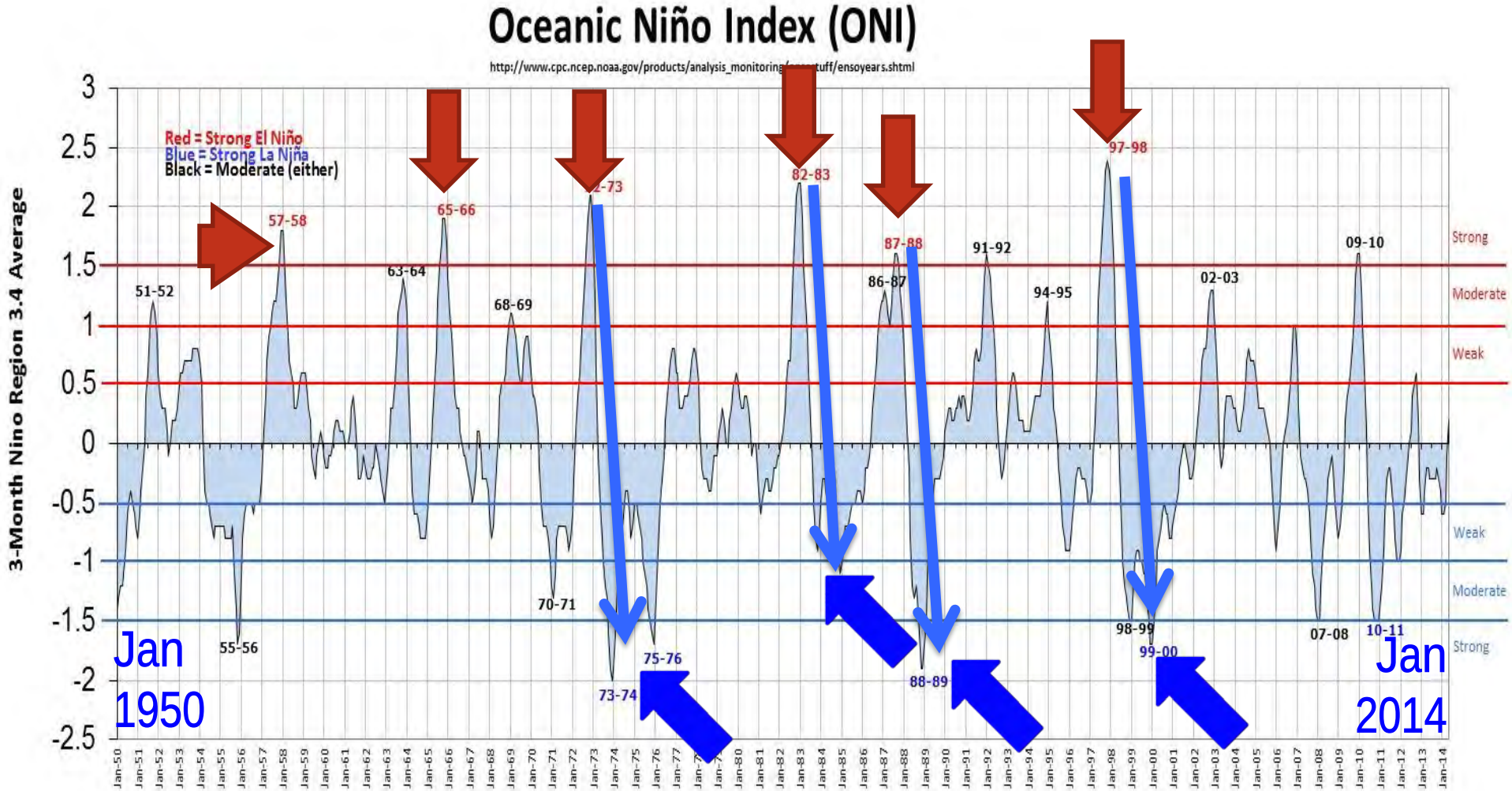


History since 1950 of El Niño - La Niña occurrences

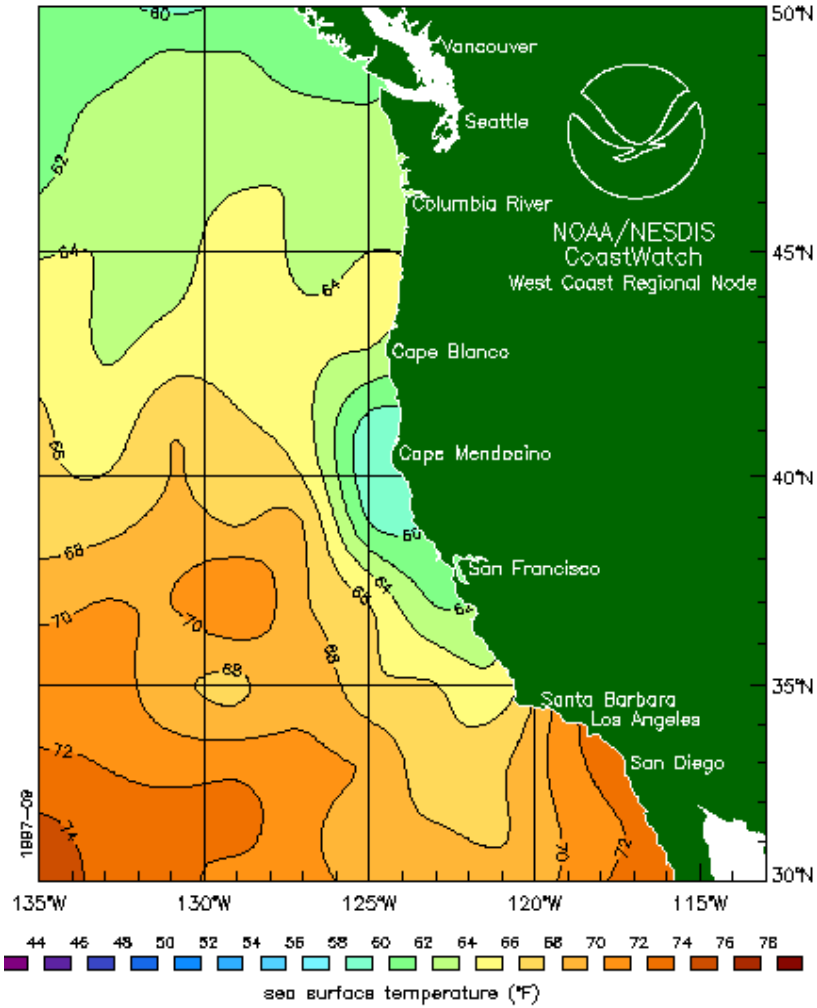
Six “strong” and eight “moderate” *El Niños*

And five “strong” and four “moderate” *La Niñas*.

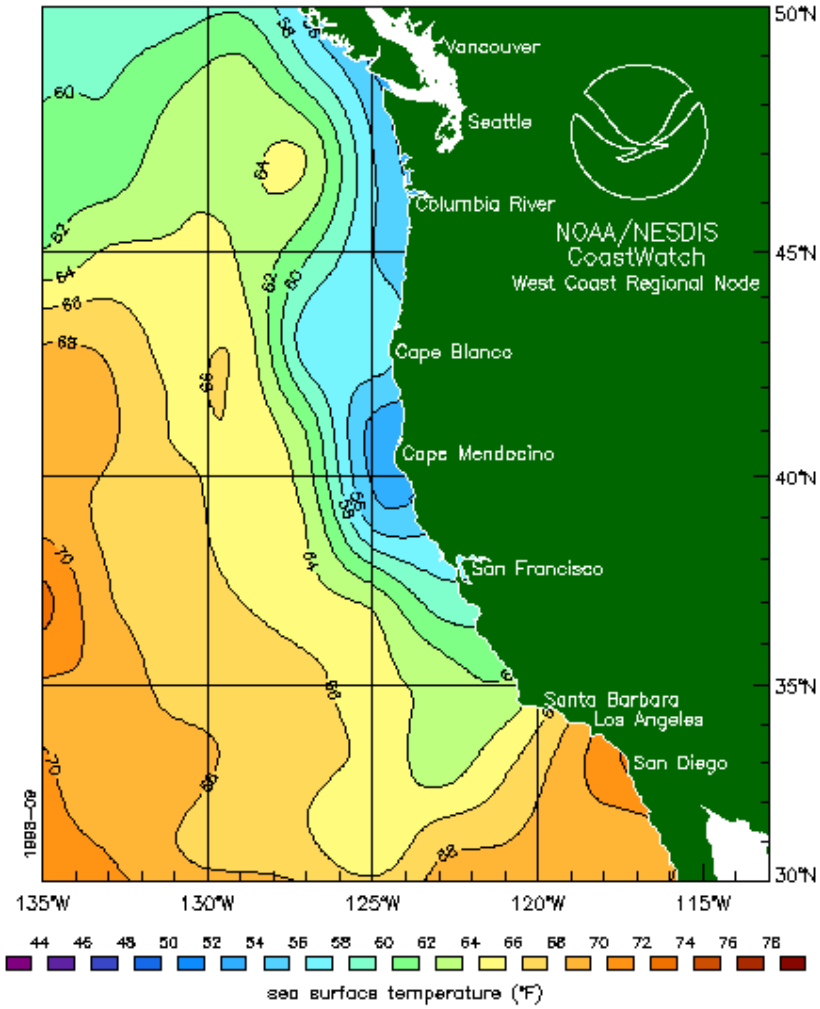




Sept 1997 El Niño



Sept 1998 La Niña



Rolling Stone

The Point of No Return: Climate Change Nightmares Are Already Here

The worst predicted impacts of climate change are starting to happen — and much faster than climate scientists expected

BY ERIC HOLTHAUS | August 5, 2015

"Historians may look to 2015 as the year when [*bleep*] really started hitting the fan.

Snapshots of the past few months:

- record-setting heat waves – Washington state's Olympic National Park, the rainforest caught fire for the first time in living memory;
- London reached 98 degrees Fahrenheit during the hottest July day ever recorded in the U.K.;
- California is suffering from its worst drought in a millennium, and
- A monster El Niño forms in the tropical Pacific Ocean, shifting weather patterns worldwide."

http://www.rollingstone.com/politics/news/the-point-of-no-return-climate-change-nightmares-are-already-here-20150805

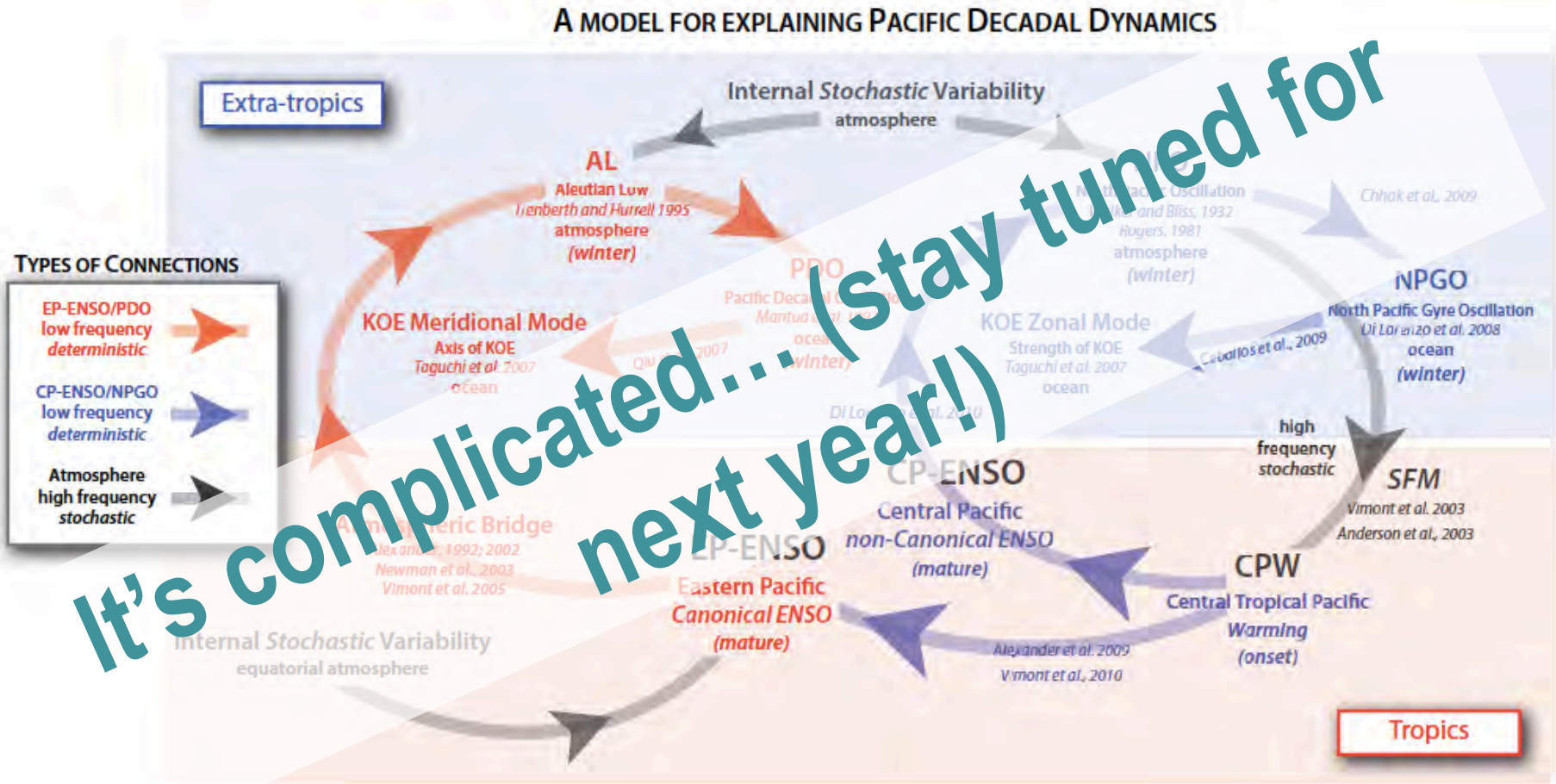
Two bigger picture questions…

- Are “the blob”, the El Niño/La Niña and the PDO connected?

- Are “the blob”, the El Niño/La Niña and the PDO related to even larger/longer scales associated with climate change?

Are “the blob”, the El Niño/La Niña and the PDO connected?

Yes, maybe… although the mechanisms are unclear



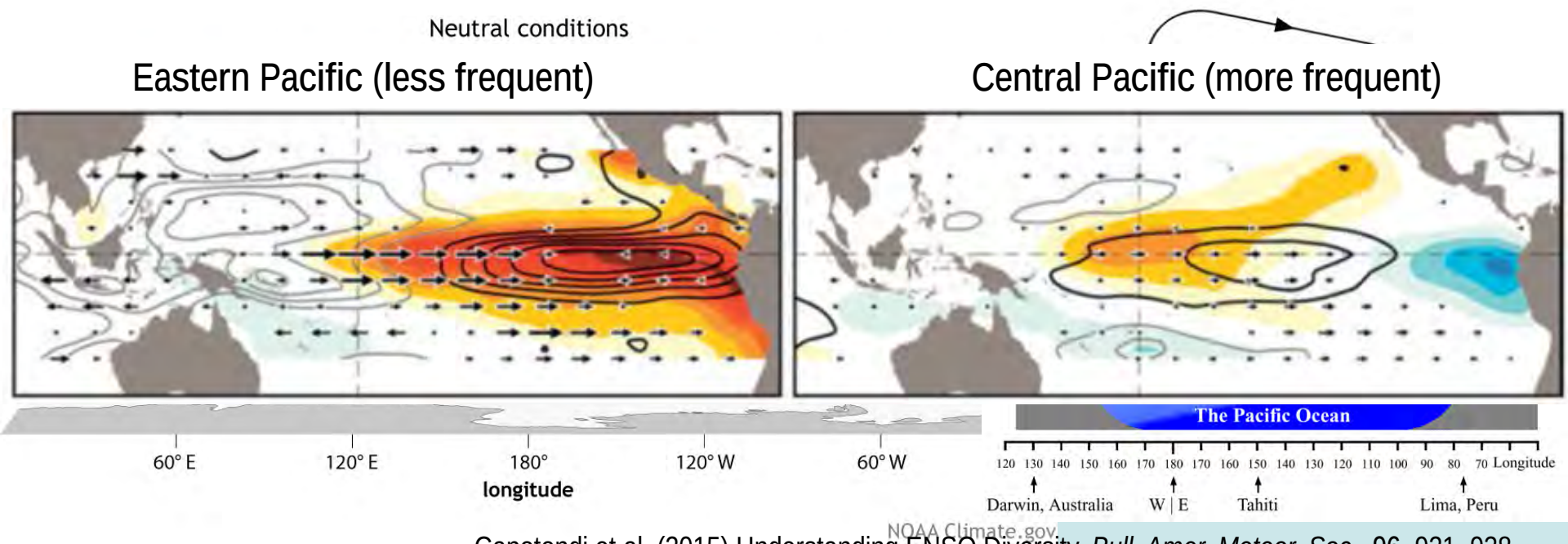
It’s complicated…(stay tuned for next year!)

Di Lorenzo et al. 2013. Synthesis of Pacific Ocean climate and ecosystem dynamics. *Oceanography,* 26(4):68–81, *http://dx.doi.org/10.5670/oceanog.2013.76*.

Are “the blob”, the El Niño/La Niña and the PDO related to even larger/longer scales associated with climate change?

Models project a weakening of the climatological Walker circulation as a result of global warming, with a consequent weakening of the zonal slope of the equatorial thermocline, and a weaker eastern equatorial Pacific cold tongue.

The ratio of Central Pacific- to Eastern Pacific-type El Niño events (in terms of SST patterns) is projected to increase in climate model simulations under global warming scenarios.



Capotondi et al. (2015) Understanding ENSO Diversity. *Bull. Amer. Meteor. Soc.*, 96, 921–938. doi: http://dx.doi.org/10.1175/BAMS-D-13-00117.1

So far, we can say that…

- In the North Pacific we are likely to experience a significant El Niño in the Fall/Winter of 2015/2016 that will have implications to our fisheries and protected species.

- Past El Niños have been followed by multi-year La Niña conditions (including the 1982/83 and 1997/98 extreme El Niño events).

- Over the next 3-4 years (2015-2019) we may see a rich and complex series of events – covering a wide spectrum – in the North Pacific.

- The possible El Niño/La Niña seesaw offers an important window to learn how our ecosystems and trust species will respond. We need to gather data not just for immediate information, but also for improvement of future modeling capabilities. (The role of IEAs…)

Emaciated California sea lion pup, San Nicolas Island, early 2015. (photo: Sharon Melin, NOAA)

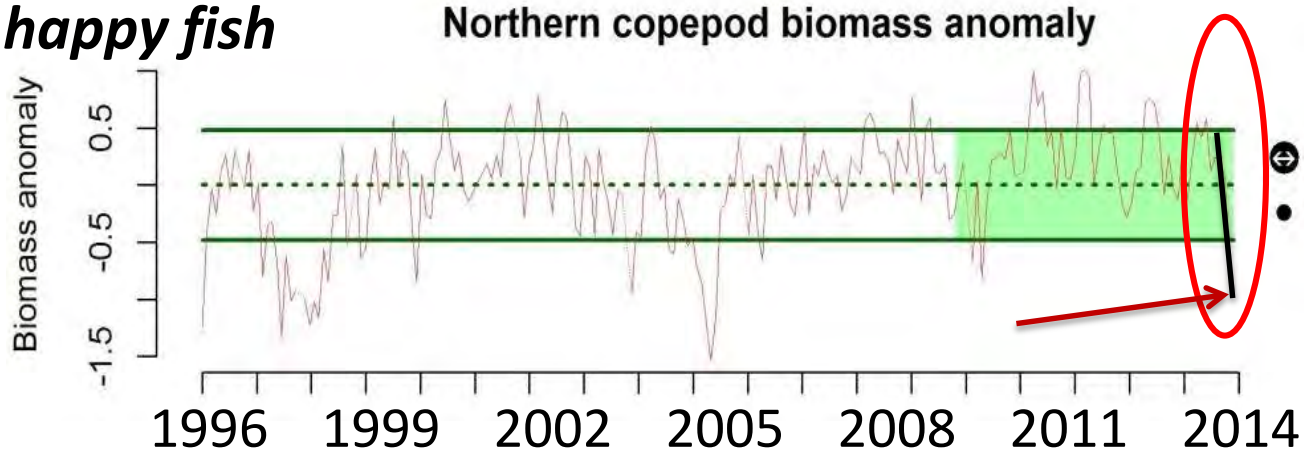
What is Occurring Biologically?

There are northern and southern copepod assemblages:

≈

northern copepod = happy fish

- "Northern" copepods rich in lipids support fish production
- Northern copepods associated with cooler waters in the California Current
- **But, a major shift occurred in late 2014**



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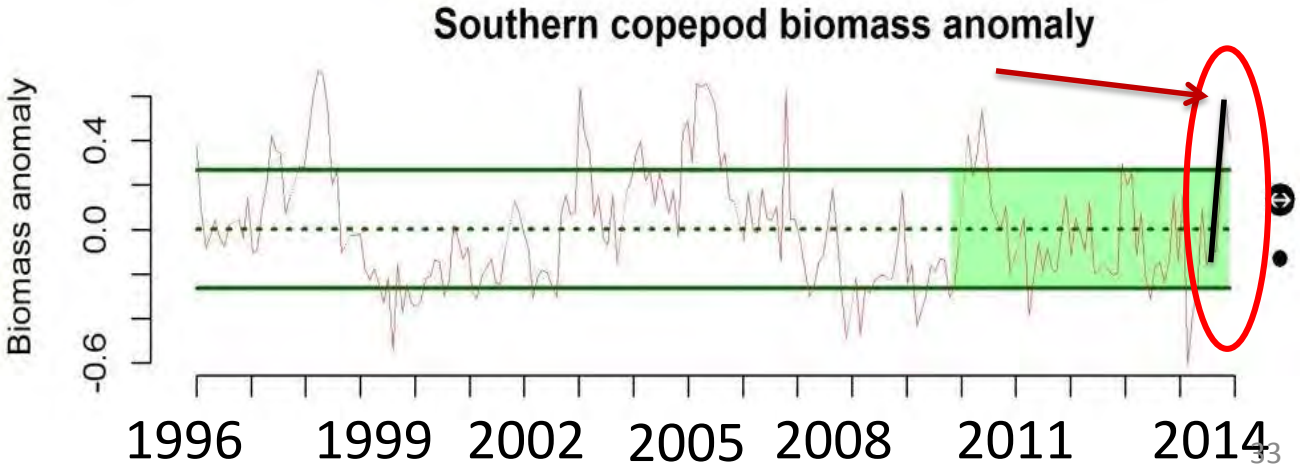


West Coast Harmful Algal Bloom

TUESDAY, JUNE 16, 2015

The Seattle Times

WINNER OF 10 PULITZER PRIZES

PARTLY SUNNY
High, 72. Low, 52. > B8
seattletimes.com/weather

$1.00

1.6 million readers we

Toxic algae bloom might be largest ever

SHELLFISH HARVESTS SHUT DOWN

High temperatures suspected

By SANDI DOUGHTON
Seattle Times science reporter

A team of federal biologists set out from Oregon Monday to survey what could be the largest toxic algae bloom ever recorded off the West Coast.

The effects stretch from Central California to British Columbia, and possibly as far north as Alaska. Dangerous levels of the natural toxin domoic acid have shut down recreational and commercial shellfish harvests in Washington, Oregon and California this spring, including the lucrative Dungeness crab fishery off Washington's southern coast and the state's popular razor-clam season.

At the same time, two other types of toxins rarely seen in combination are turning up in shellfish in Puget Sound and along the Washington coast, said Vera Trainer, manager of the Marine Microbes and Toxins Programs at the Northwest Fisheries Science Center in Seattle.

"The fact that we're seeing multiple toxins at the same time, we're seeing high levels of domoic acid, and we're seeing a coastwide bloom — those are indications that this is unprecedented," Trainer said.

Scientists suspect this year's unseasonably high temperatures are playing a role, along with "the blob" — a vast pool of unusually warm water that blossomed in the northeastern Pacific late last year. The blob has morphed since then, but offshore waters are still about two degrees warmer than normal, said University of Washington climate scientist Nick Bond, who coined the blob nickname.

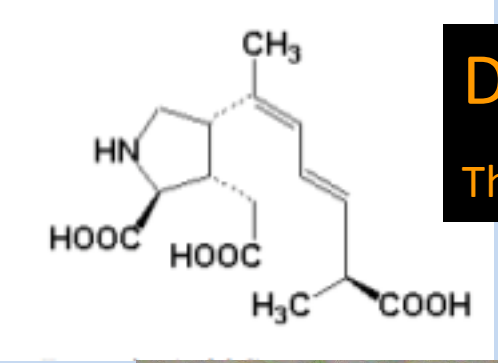
Marine biotoxins

Marine biotoxins are produced by microscopic algae. Unlike the bacteria or viruses that can also contaminate shellfish, biotoxins are not destroyed by cooking or freezing. Also, harmful algal blooms usually don't color the water.

The three biotoxins of concern in Washington are:

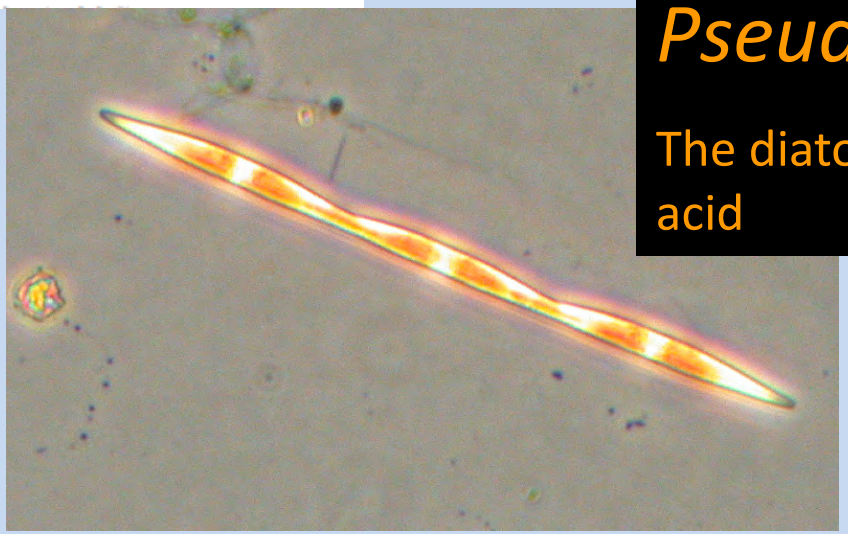
- **Paralytic shellfish poisoning.** Symptoms include tingling in lips, arms and legs, followed by trouble breathing and paralysis. Can be fatal.
- **Domoic acid poisoning,** also called amnesic shellfish poisoning. Caused by Pseudo-nitzschia diatoms, symptoms include vomiting, nausea,

Domoic Acid Poisoning



Domoic acid

The toxin



Pseudo-nitzschia

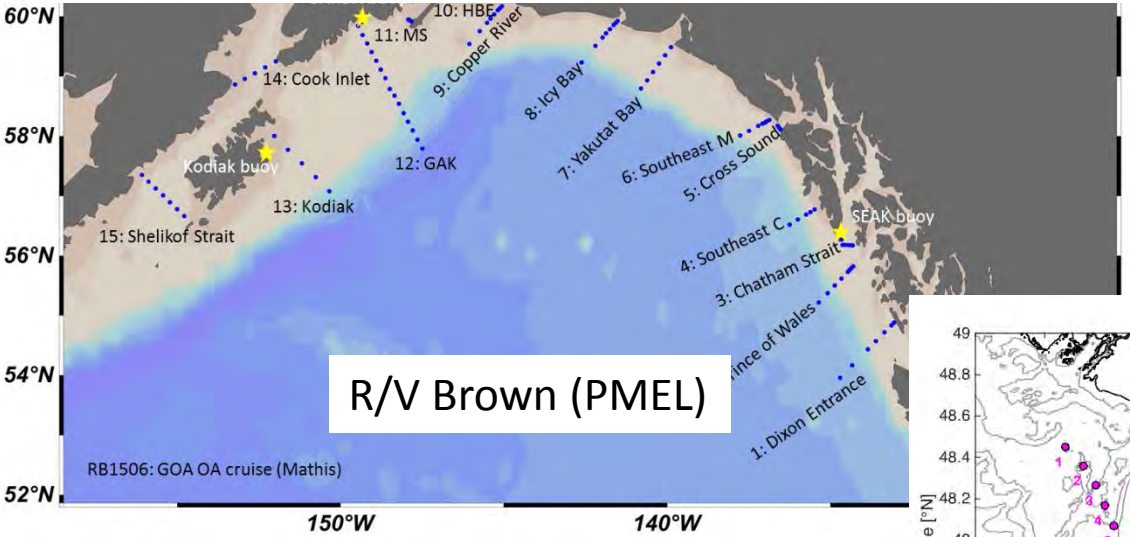
The diatom that can produce domoic acid

Poisoning

Food web transfer

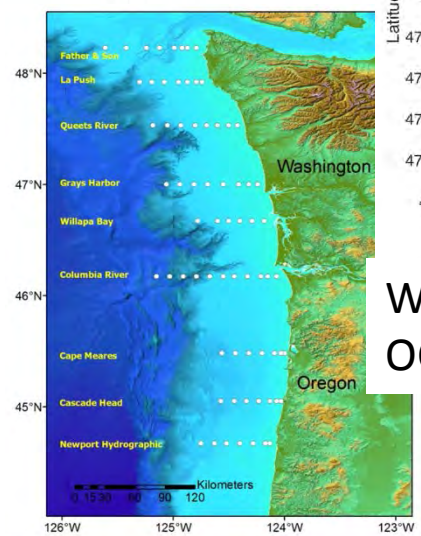
Vectors: plankton feeding shellfish & fish

Monitoring the HAB



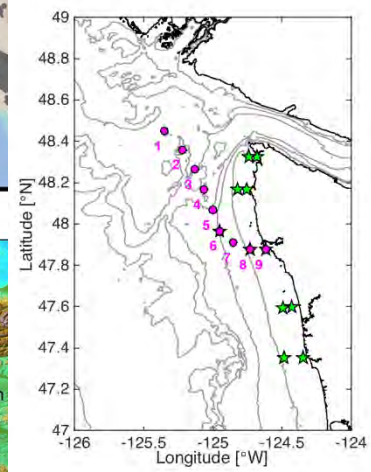
R/V Brown (PMEL)

R/V Ocean Starr:
Juvenile Salmon Ocean Ecology

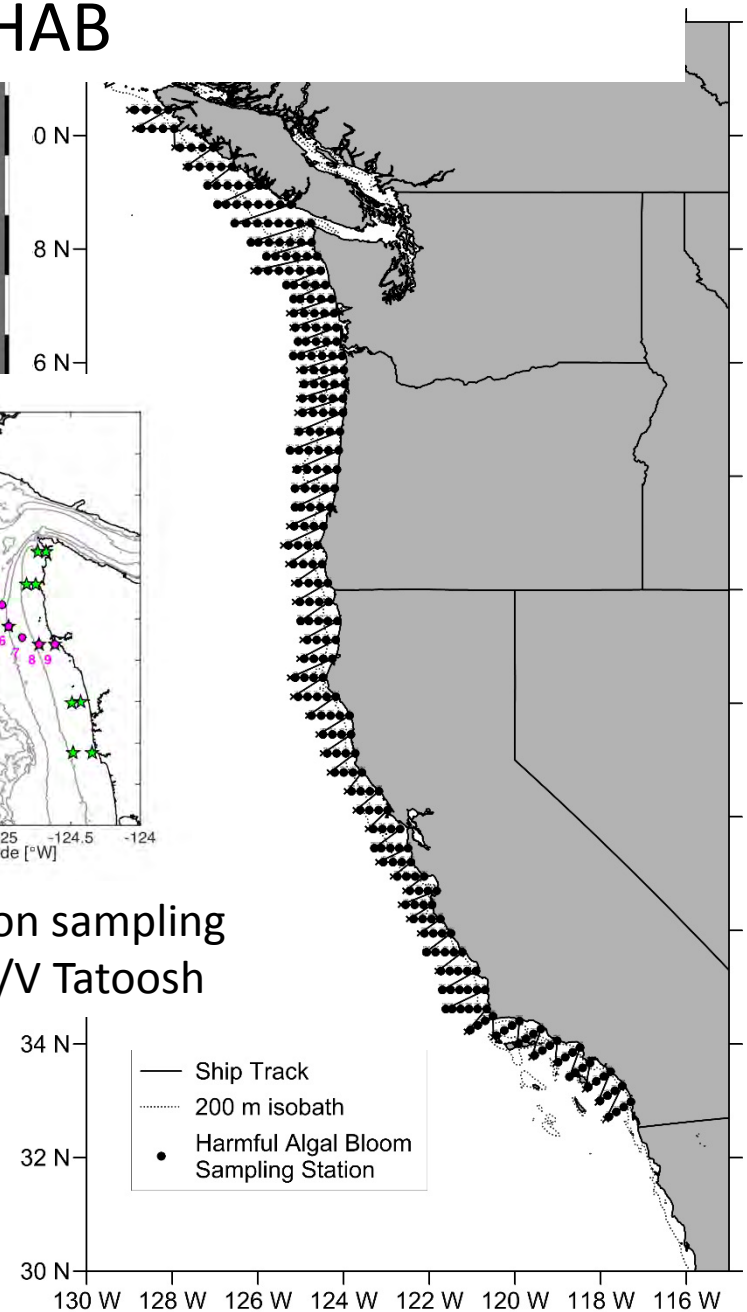


Map of the study location. 55 – 60 stations will be sampled in just over a week's time.

F/V Frosti
NW salmon survey

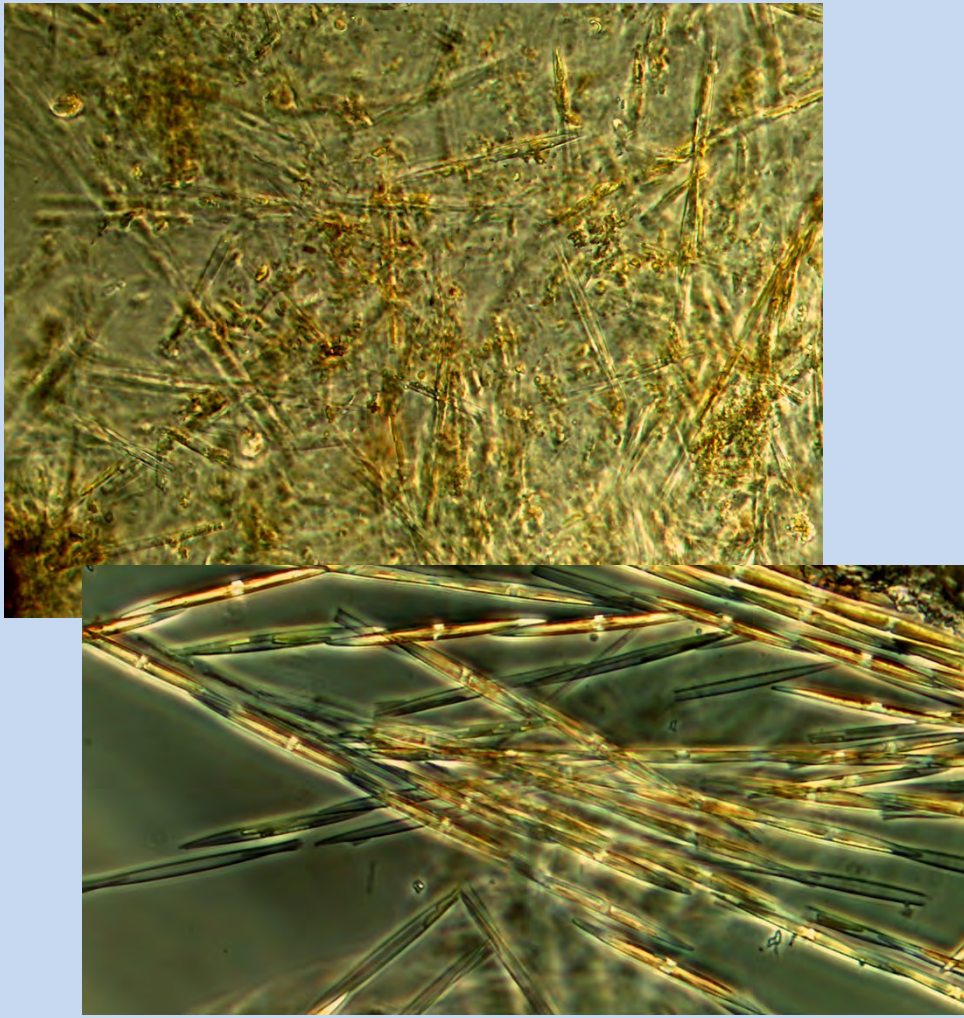


Washington sampling
OCNMS R/V Tatoosh



R/V Bell M. Shimada

Is the HAB big?



Dense blooms of *Pseudo-nitzschia*
Clogged Bongo nets – June 25, 2015
R/V Shimada, Santa Barbara Channel

Is this HAB Huge?

- Breadth – Channel Islands to Aleutian Islands
- Length – Longest lasting (months)
- Levels – Highest toxin concentrations ever measured in anchovies
- “Super” *Pseudo-nitzschia* – large chains, chloroplasts bulging
- Impacts – shellfish, planktivorous fish, Dungeness crab closures
- Impacts – Marine mammal mortalities

Are There impacts?

Closure of razor clam fishery
~$7 million lost in WA State alone

Domoic acid has been detected in some anchovy and sardine

Seizuring sea lion (first ever observed on WA coast)
Many sea lion, seal mortalities in Monterey Bay

Dungeness Crabbers Hit Hard By Algae Bloom On Washington Coast

By ASHLEY AHEARN • 18 HOURS AGO

SHARE
Twitter
Facebook
Google+
Email

Dungeness crab fisheries closed in multiple states. WA crab fishery valued at $84 million

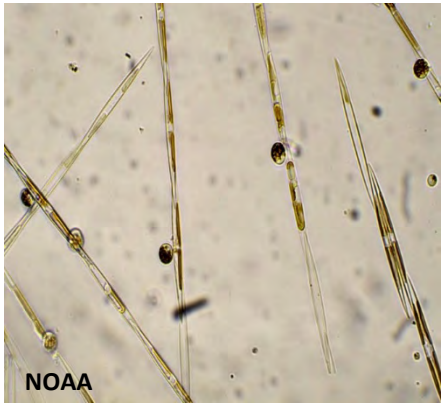
Whale Unusual Mortality Event in Alaska
HAB the Cause?

HAB species benefit from OA?

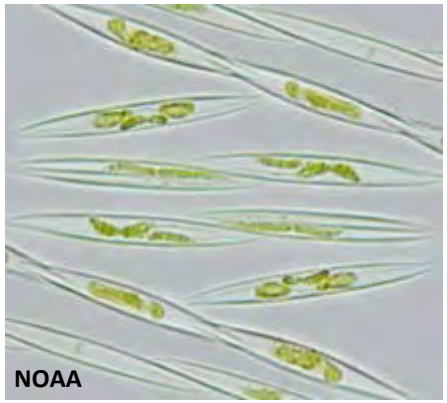
Seattle Times

Grow faster and produce more toxin under OA conditions, including:

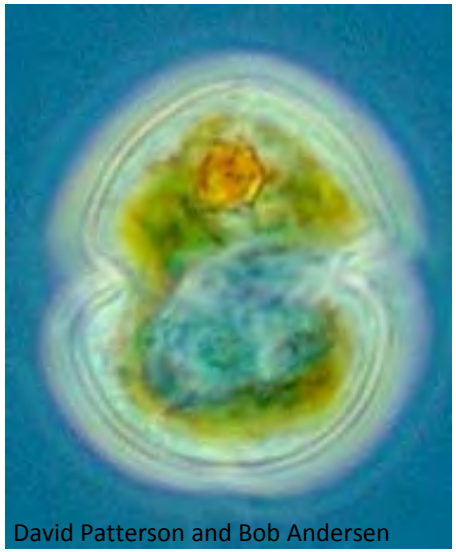
- ✓ *Alexandrium catenella*, which produces paralytic shellfish poisoning toxins
- ✓ *Pseudo-nitzschia fraudulenta,* which produces domoic acid



NOAA



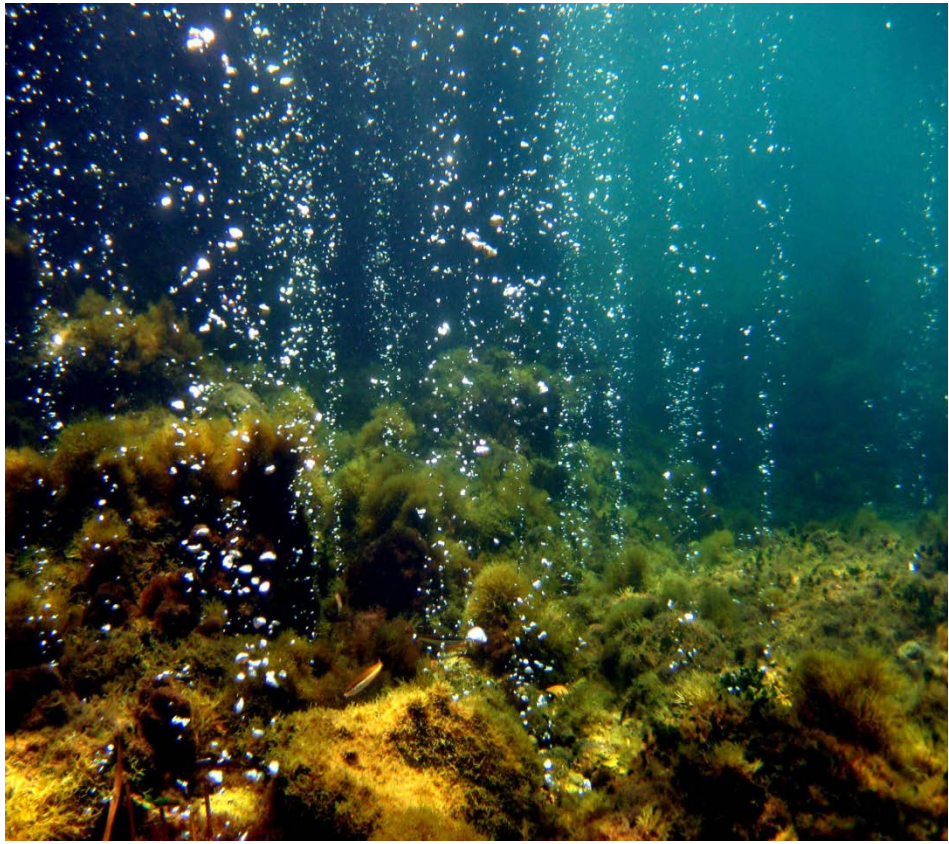
NOAA



David Patterson and Bob Andersen

Tatters et al. 2013, Tatters et al. 2012, Sun et al. 2011, Fu et al. 2010

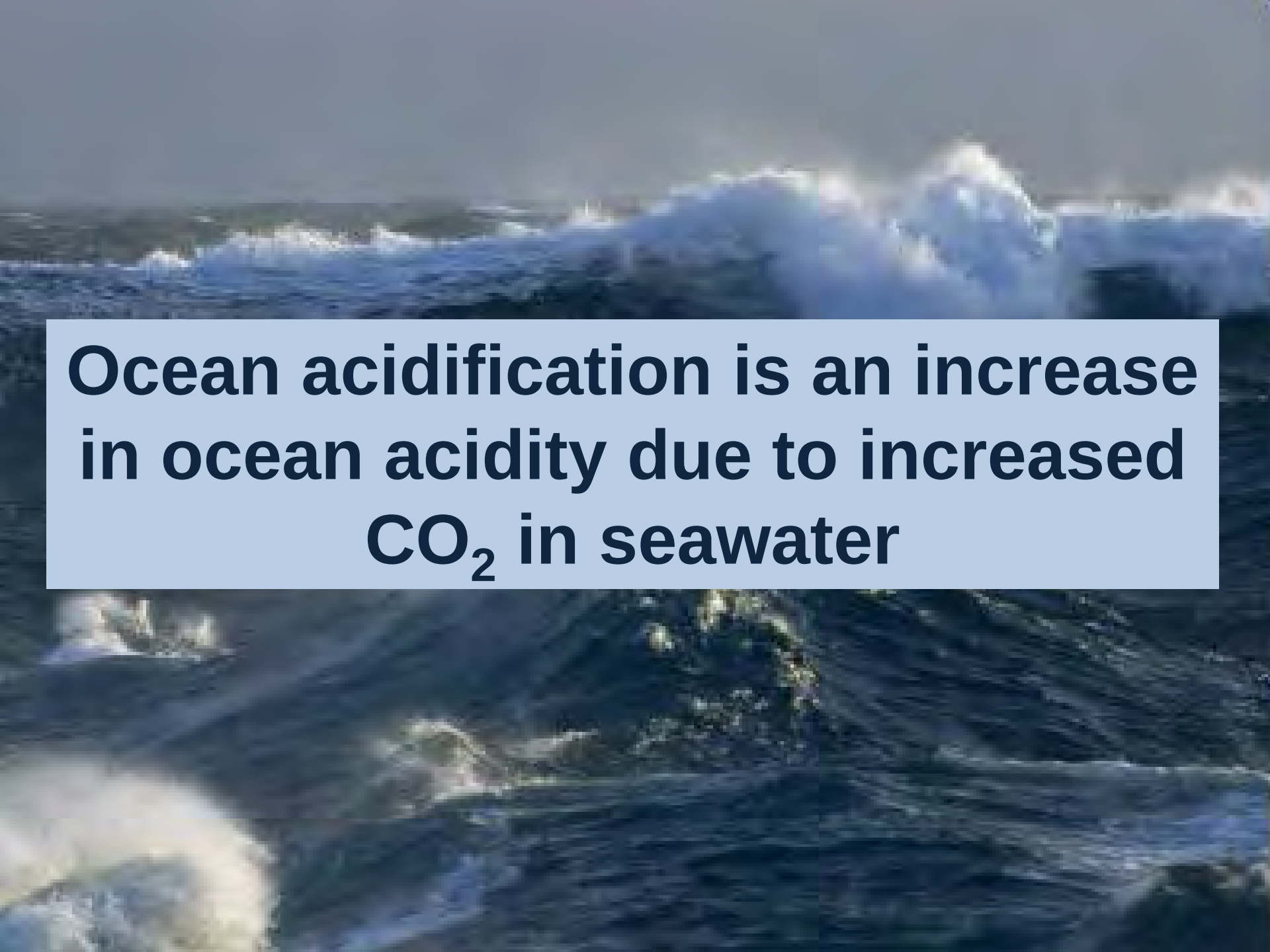
Role of OA in the HAB bloom now and in the future?



Low CO_2 High CO_2

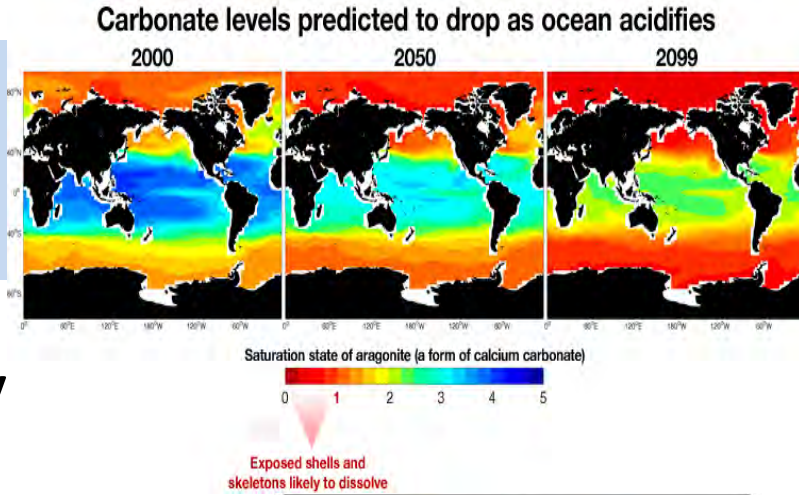
A natural experiment in Italy

J. Hall-Spencer



Ocean acidification is an increase in ocean acidity due to increased CO_2 in seawater

The Bottom Line



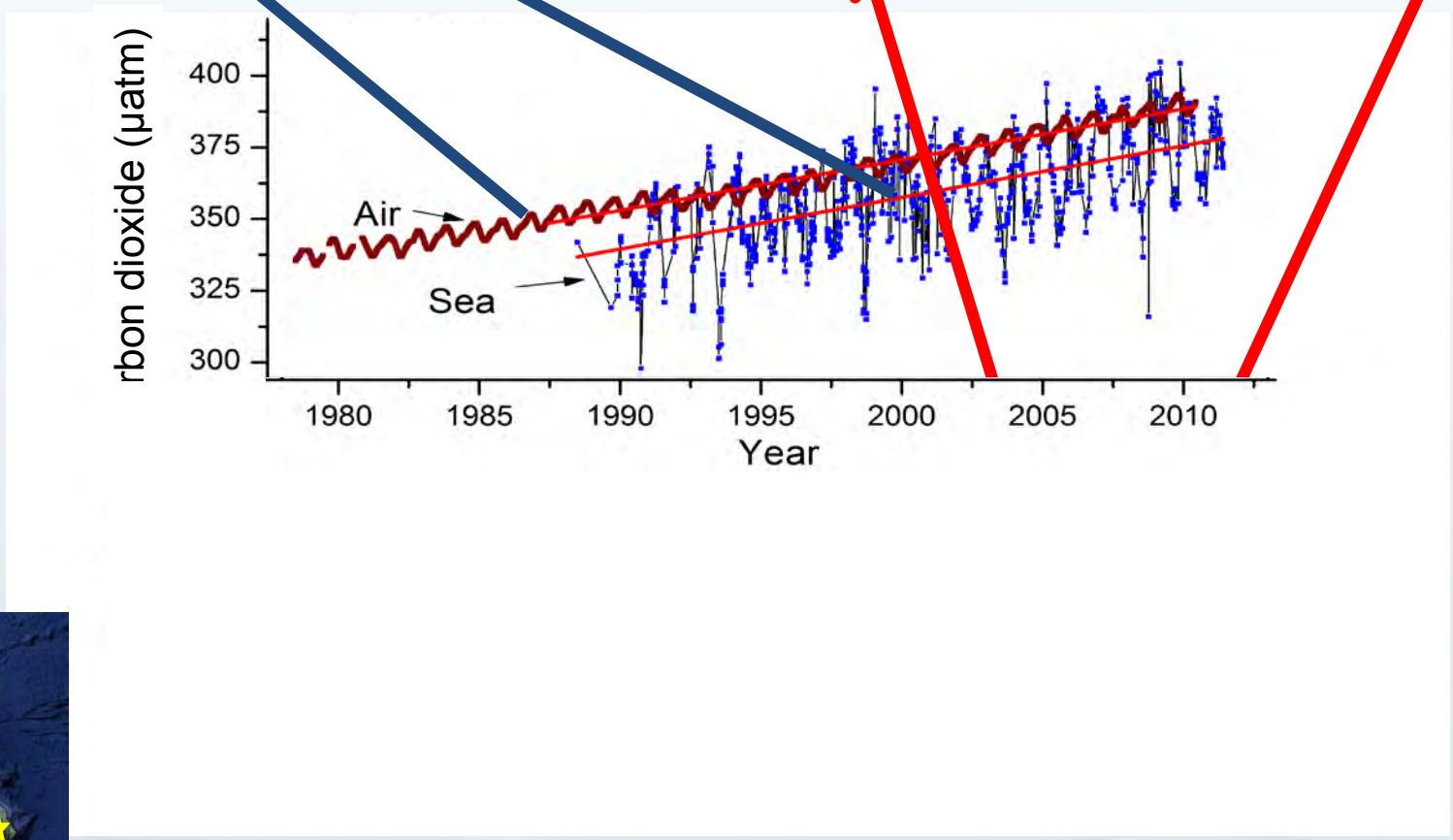
- The ocean is acidifying rapidly
- Some species will be sensitive to OA

Dissolution of pteropod shell in acidified water

- Biological responses to OA are variable
- Impacts of OA will ripple through food webs
- Other stressors can exacerbate species response

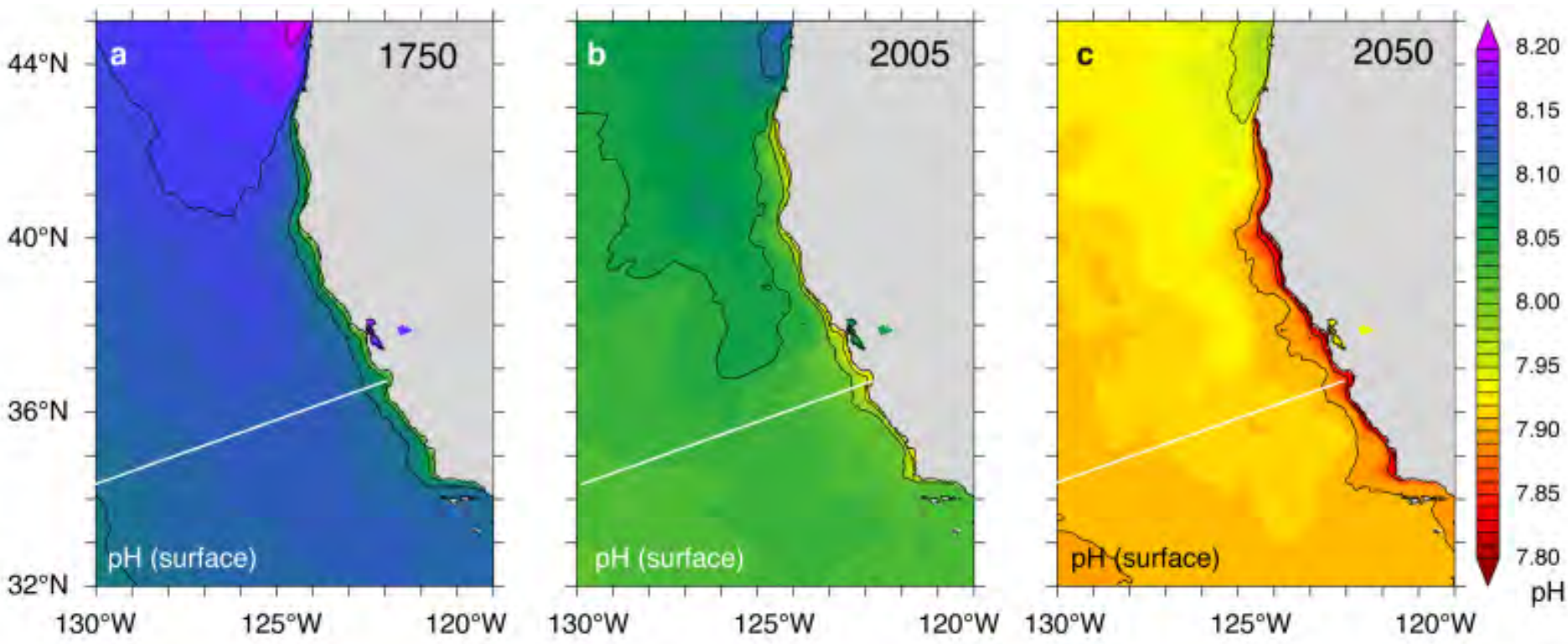
Progression of ocean acidification

$$CO_{2(atmos)} \leftrightarrow CO_{2(aq)} + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-}$$



Dore et al.,

Ocean acidification has already occurred and is progressing rapidly along the West Coast



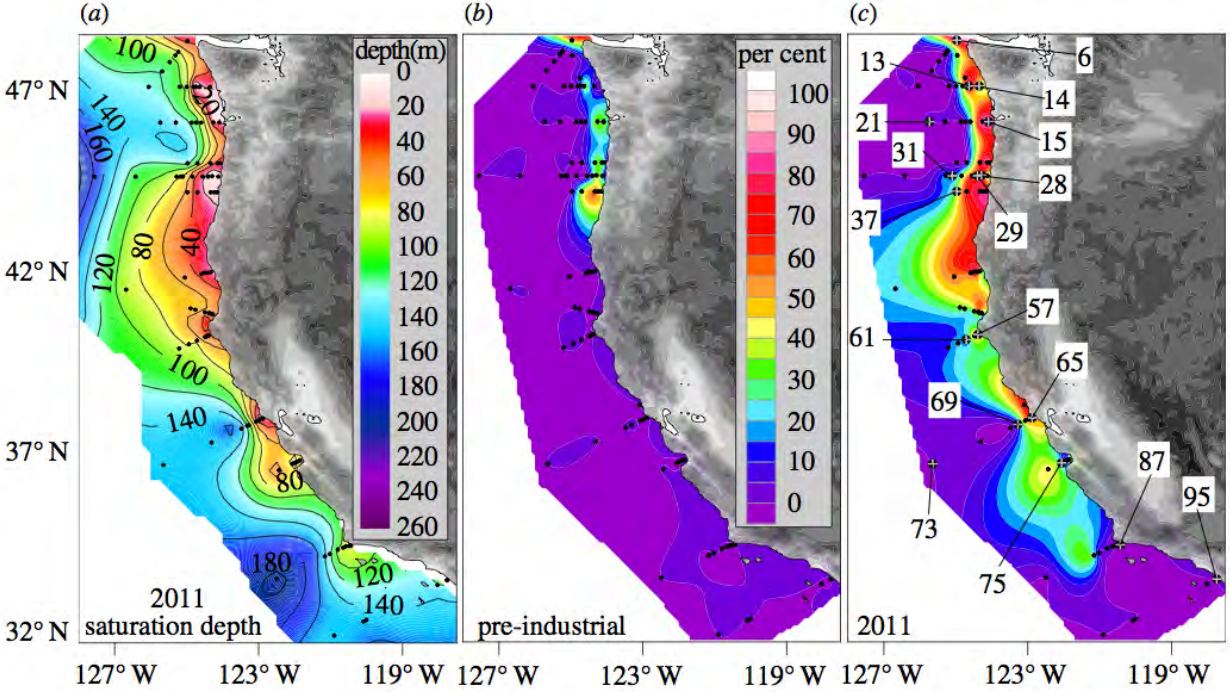
Gruber et al. 2012

Field Results: Pteropods

(also reproduced in the laboratory)

Aragonite Saturation Horizon on West Coast

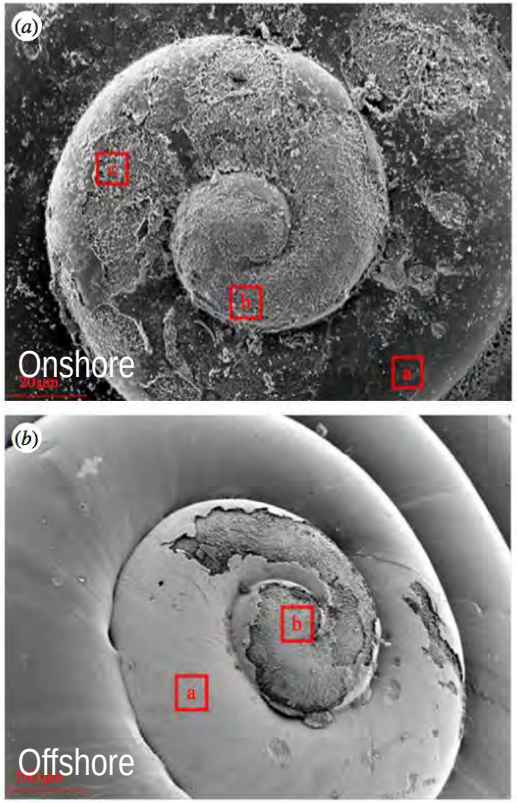
Saturation Depth | Pre-Industrial | Aug-Sept 2011



Busch et al. 2014NWFSC

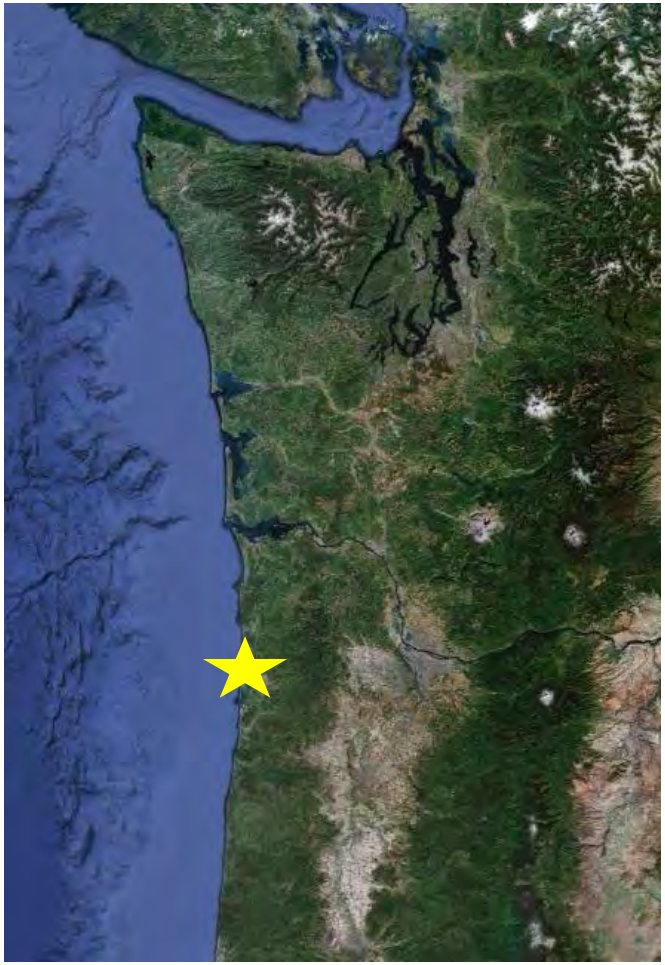
Bednarsek et al. 2014 PMEL

Observed Shell Dissolution (SEM Images)

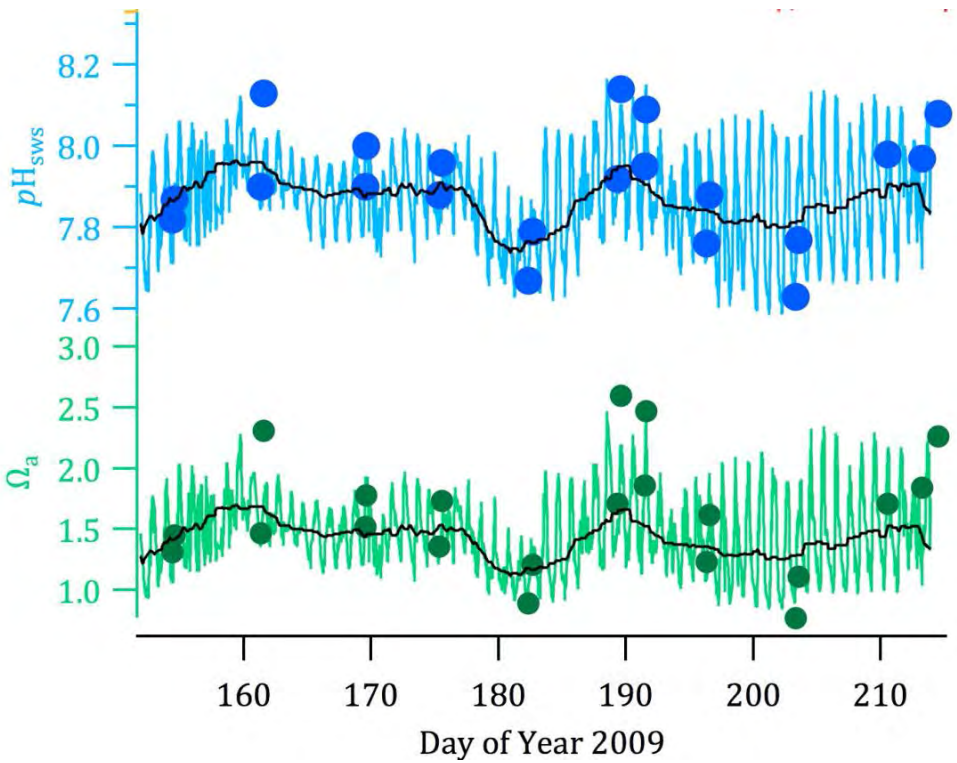


Benjamin Drummond / bdsjs.com

Oysters in Netart's Bay



Google maps

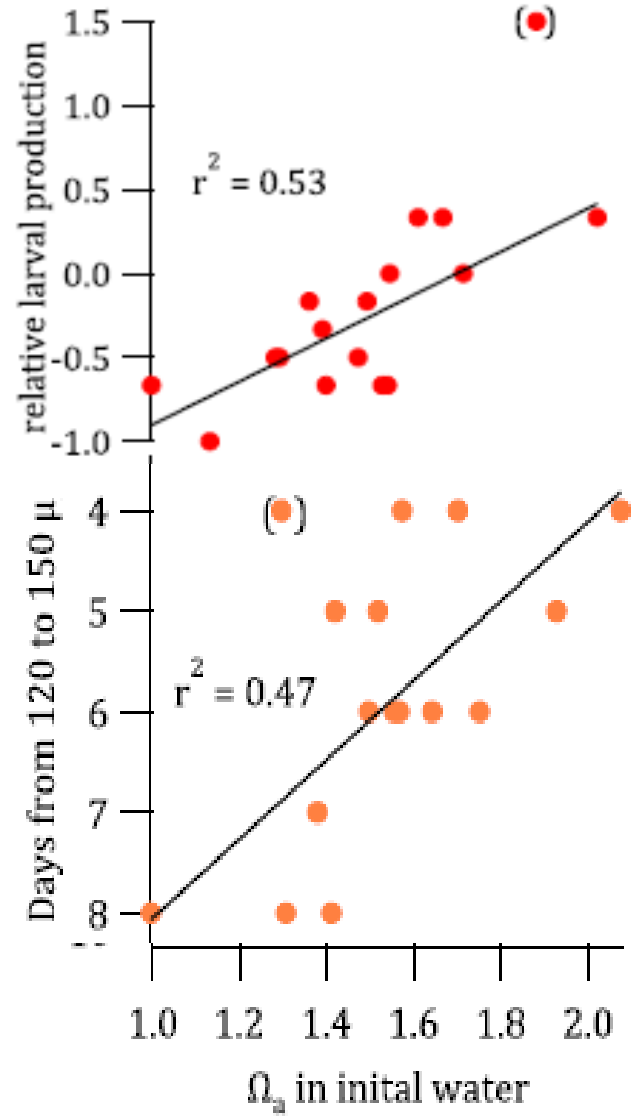


Barton et al. 2012

Oysters in Netart's Bay

Production is lower with lower pH

Growth in feeding stage slower with lower pH

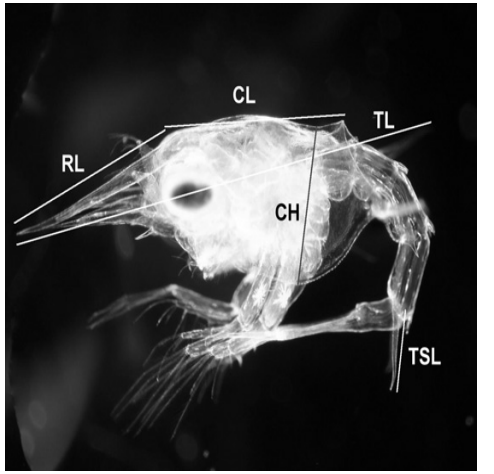


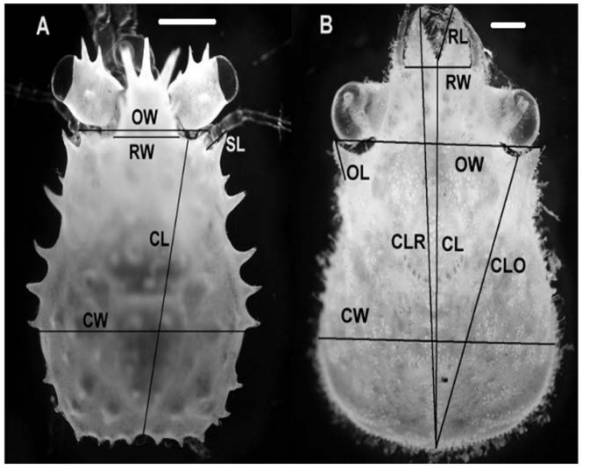
Barton et al. 2012

Ocean Acidification Effects on Alaska Crabs

EXPERIMENTS DIRECTED TOWARD UNDERSTANDING THIS DIFFERENCE AND FORECASTING ABUNDANCE

- Decreases survival and growth of red king and tanner crab juveniles
- Decreases survival of red king crab larvae
- Consequently, recruitment projected to change yield and profitability of the Bristol Bay fishery





Long et al. 2013a, b; Punt et al. 2014

Risk Assessment for Alaska's Fishery Sector

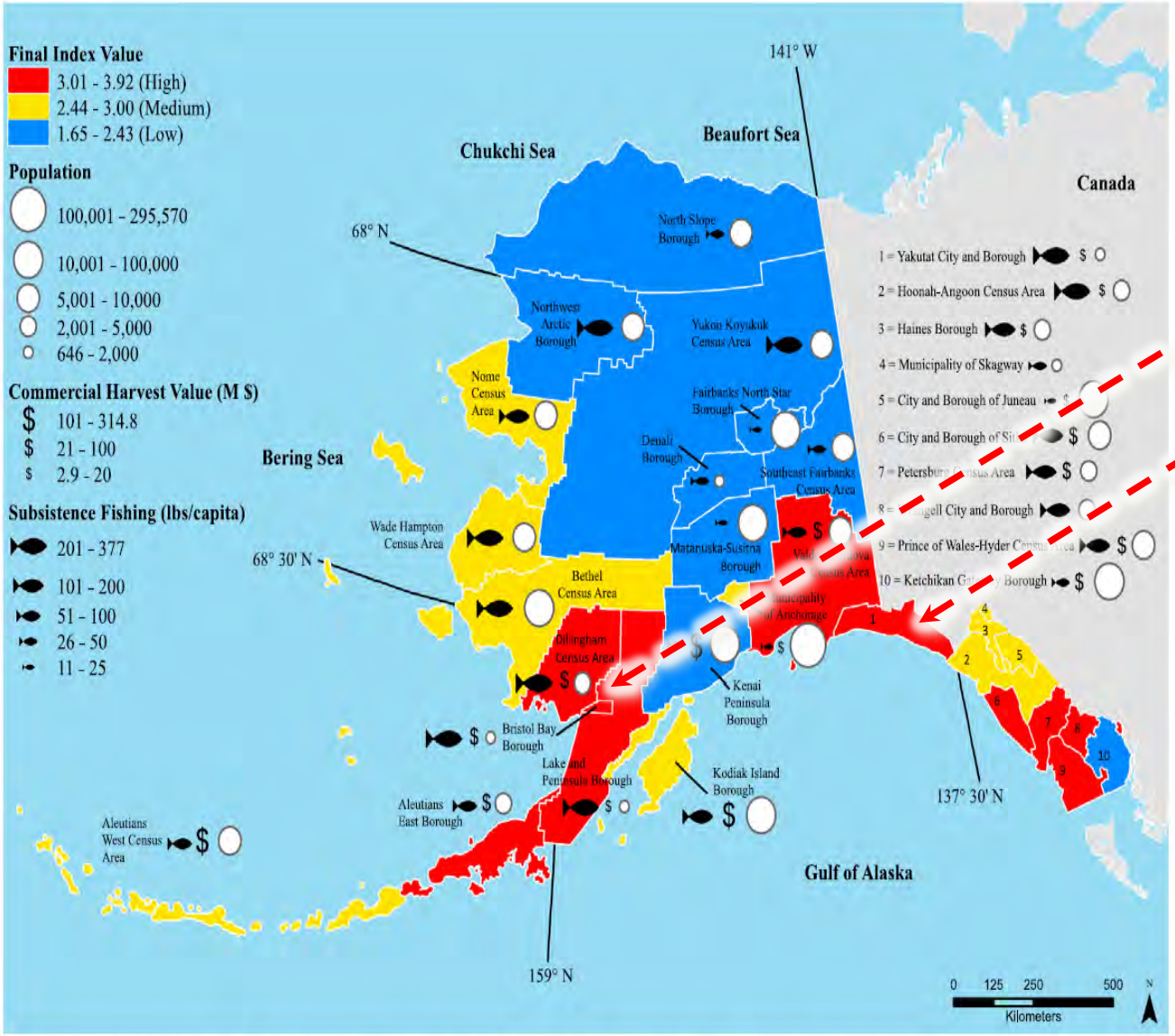


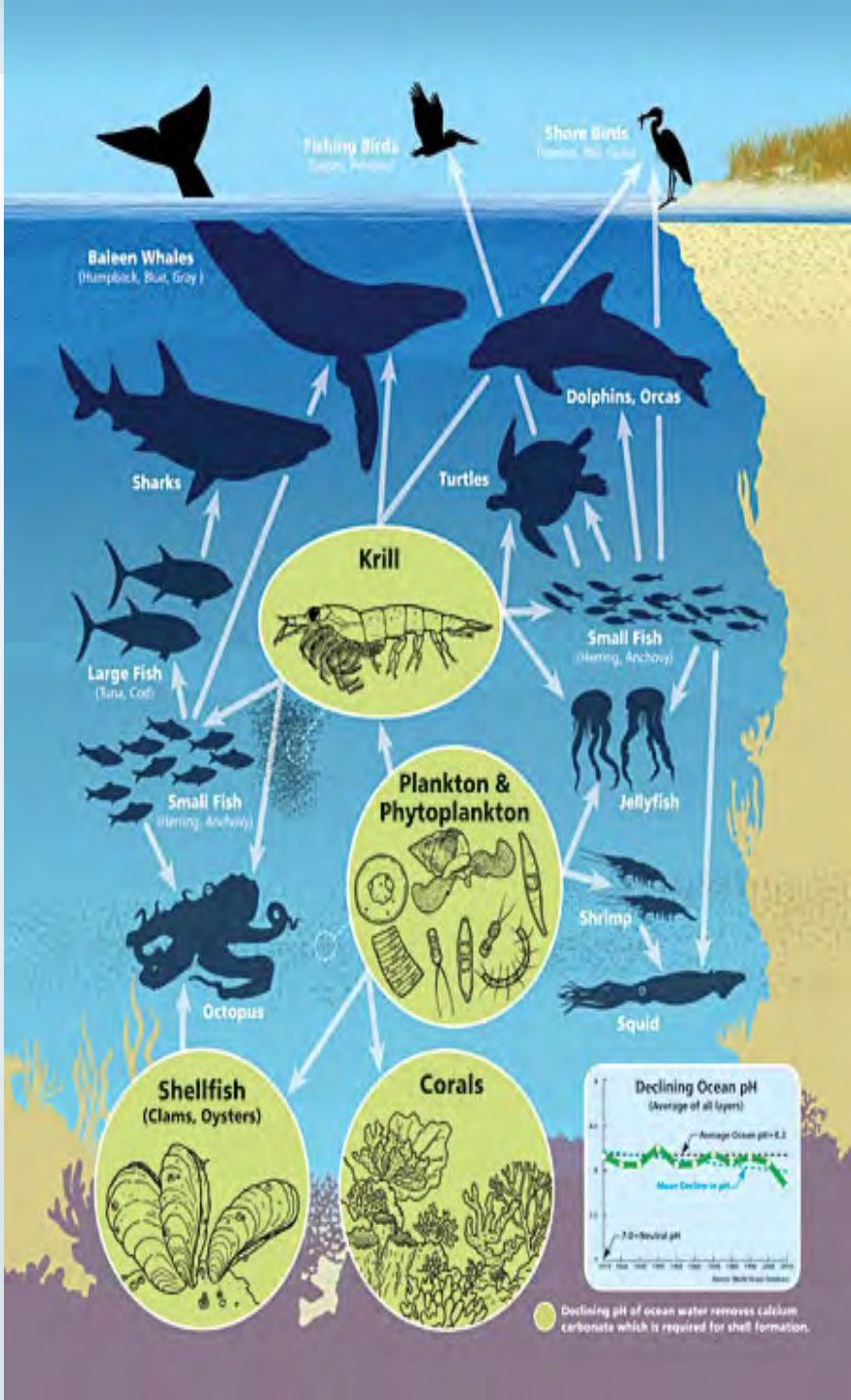
Fig. 11. Individual components of the final ocean acidification risk index for each census area.

Regions in SW and SE Alaska that are highly reliant on fishery harvests and have relatively lower incomes and employment alternatives likely face the highest risk from OA.

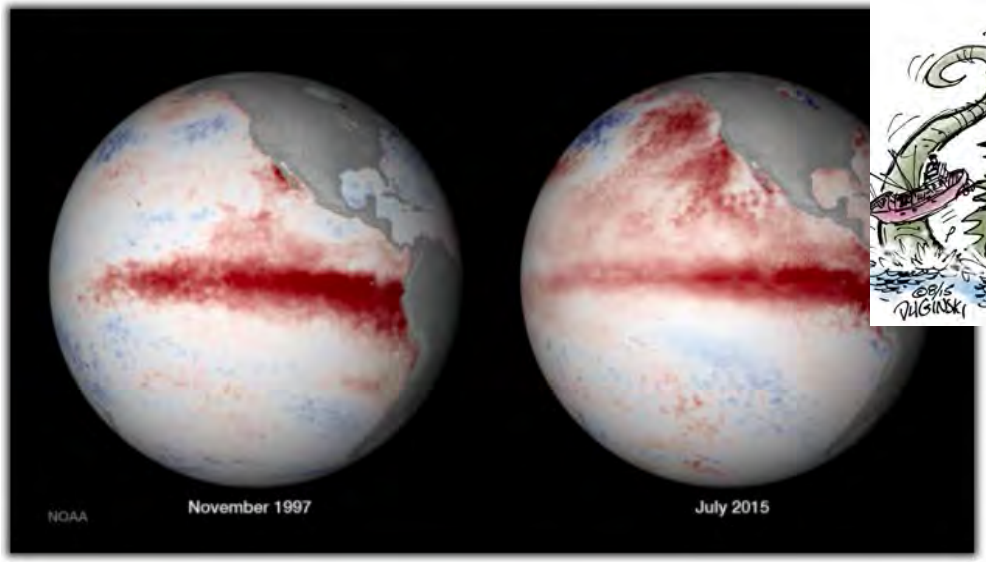
Mathis, J.T., et al. Ocean acidification risk assessment for Alaska's fishery sector. Prog. Oceanogr. (2014), http://dx.doi.org/10.1016/j.pocean.2014.07.001

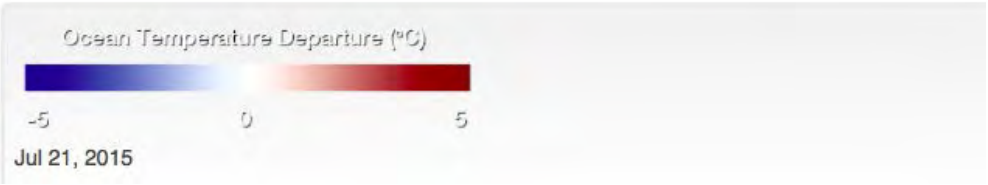
Complex systems – complex responses

- Potential impacts of OA on pteropods could affect whales, fish (salmon, herring, sablefish) and seabirds that eat them.
- The Puget Sound food web responds to declines in krill and copepods in opposite ways.
- Impacts on just one or a few species can have big effects on the food web and ecosystem services (e.g., HABs, krill).

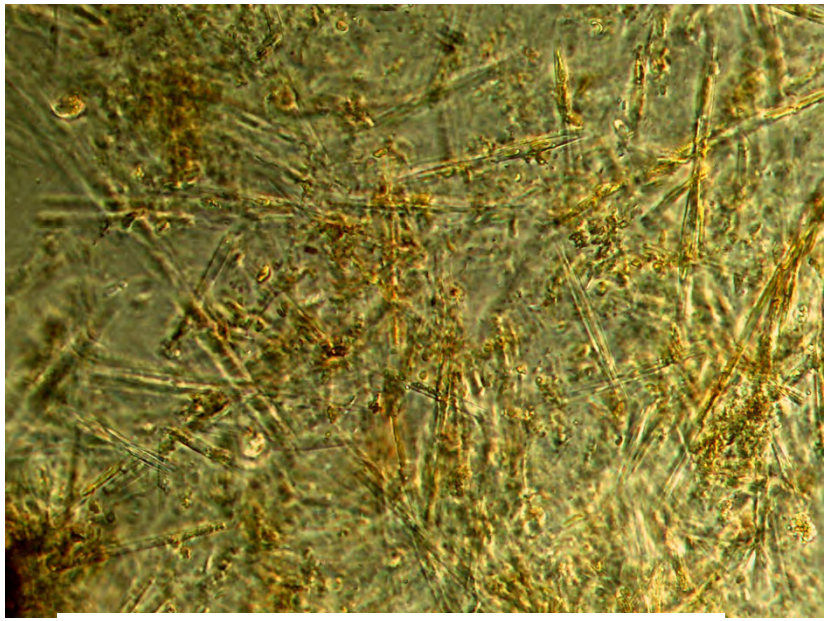


Summary





Massive HAB Event



OA Effects – Now

Dissolution of pteropod shell in acidified water

Major shift in base of food web

≈

And more……

Status Quo

Climate Volatility is a Reality

It ain’t so

Questions?

Last year's summary (Skamania, 25 Aug 2014)

- Present conditions in the N. Pacific are anomalous and record warm SSTs, but are not all related to an El Niño (EN)
- Possible signals of a positive (warm) PDO evolving
- Models are predicting a moderate EN in the Fall and Winter of 2014-2015.
- Ocean Acidification impacts the North Pacific in different ways
- We are in a challenging position because of the unprecedented number of variables changing simultaneously and their rates of change

This year's summary (Girdwood, 24 Aug 2015)

- Present conditions in the N. Pacific are anomalous and record warm SSTs, but are not all related to an El Niño (EN)
- Clear signals of a positive (warm) PDO evolving
- Models are predicting a "strong" EN in the Fall and Winter of 2015-2016.
- Ocean Acidification impacts the North Pacific in different ways
- HABs…
- The possible El Niño/La Niña seesaw offers an important window to learn how our ecosystems and trust species will respond.

Food for Thought…

It “may often be more important to

plan for uncertain climate shifts of likely consequence

than to

anticipate likely shifts of little consequence”

Boughton et al. (2013)