

**The West Coast's
ocean heat wave of
2014-16:
*is this the new
normal, or a speed-
bump on a rocky
ride to the future?***

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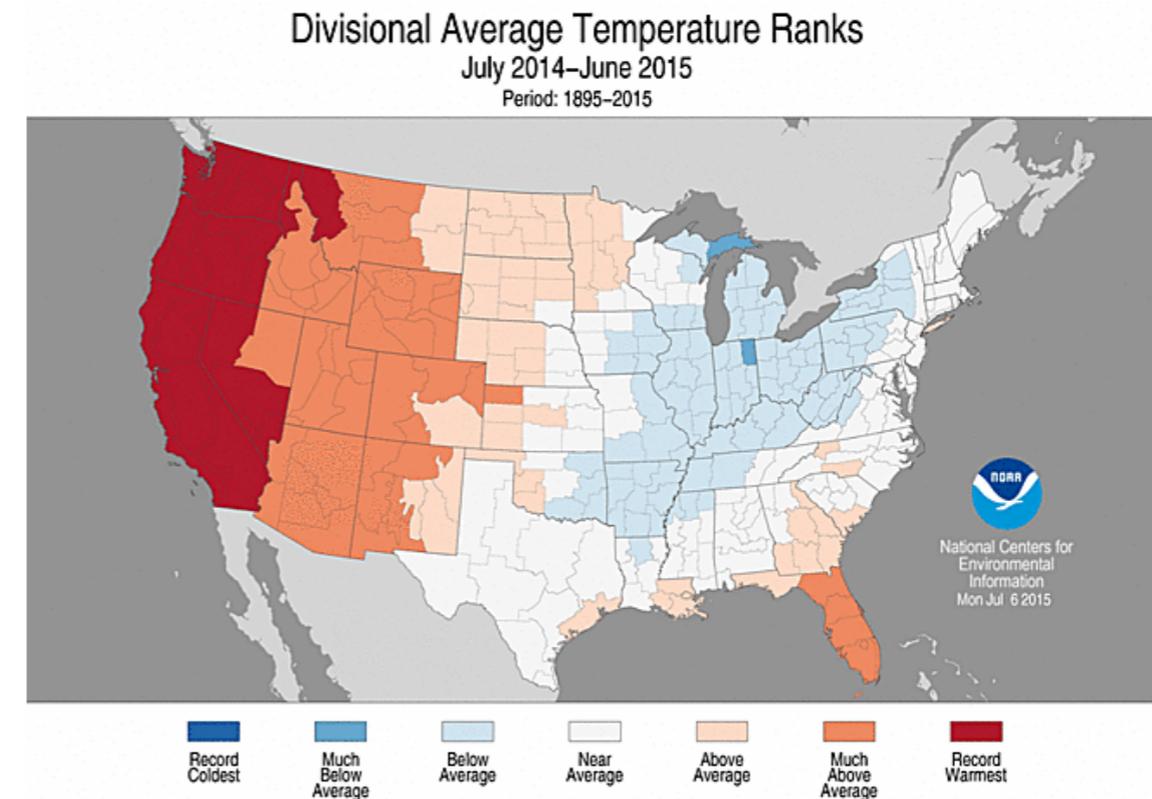
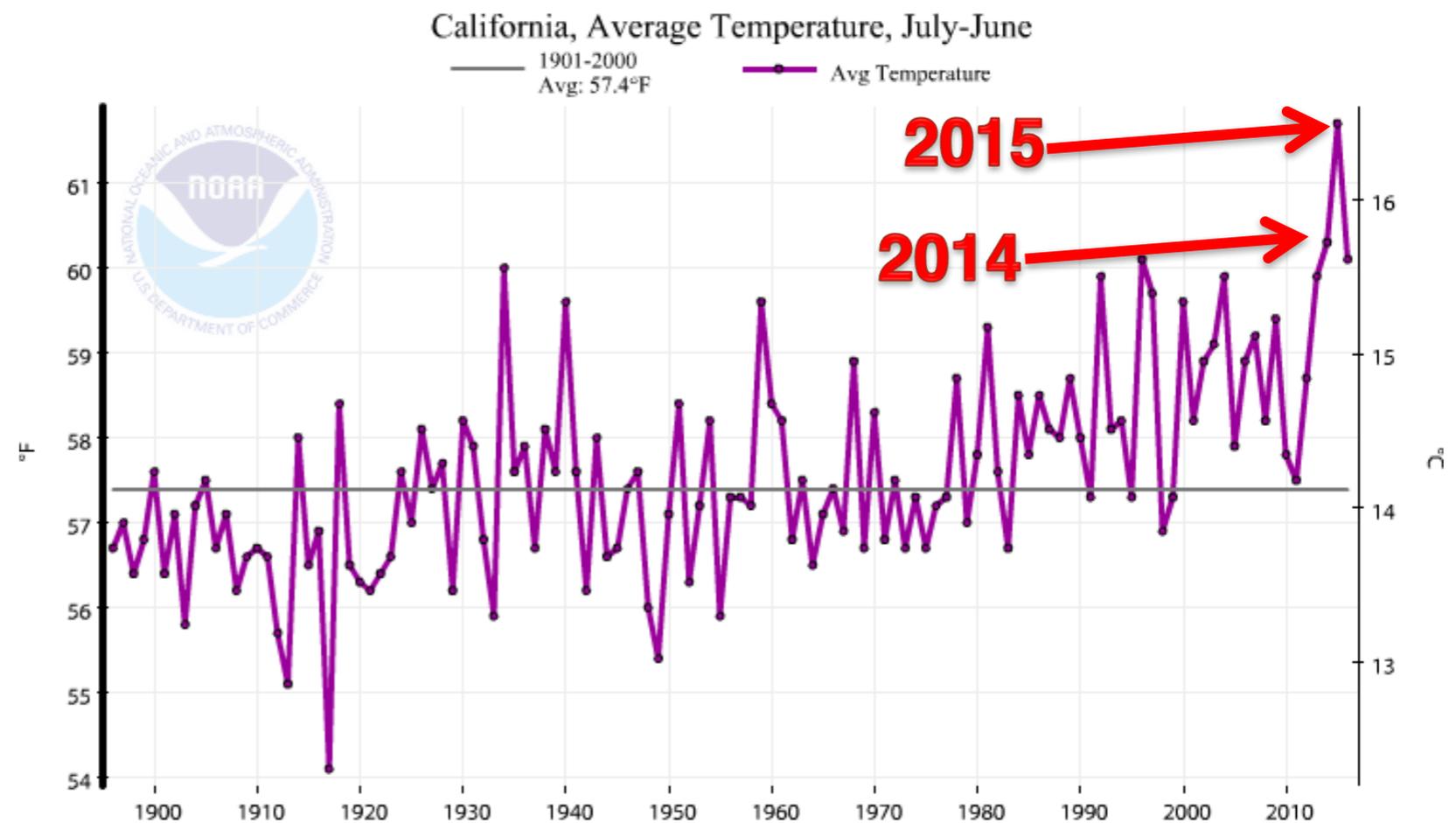
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2014-15: record warm in California

- Surface air temperature record for July 2014-June 2015 was almost off the charts, ~ 1 °C warmer than the previous record
- This “hot drought” was amplified ~30% by high temperatures
- 2016 just a bit cooler than 2014



- Northeast Pacific warmed *before* the Eastern Tropical Pacific
 - Gulf of Alaska has been extremely warm since **Fall 2013**
 - Baja and So. California near-shore was extremely warm from **June 2014 – August 2016**
- Wide-ranging impacts on Pacific marine life

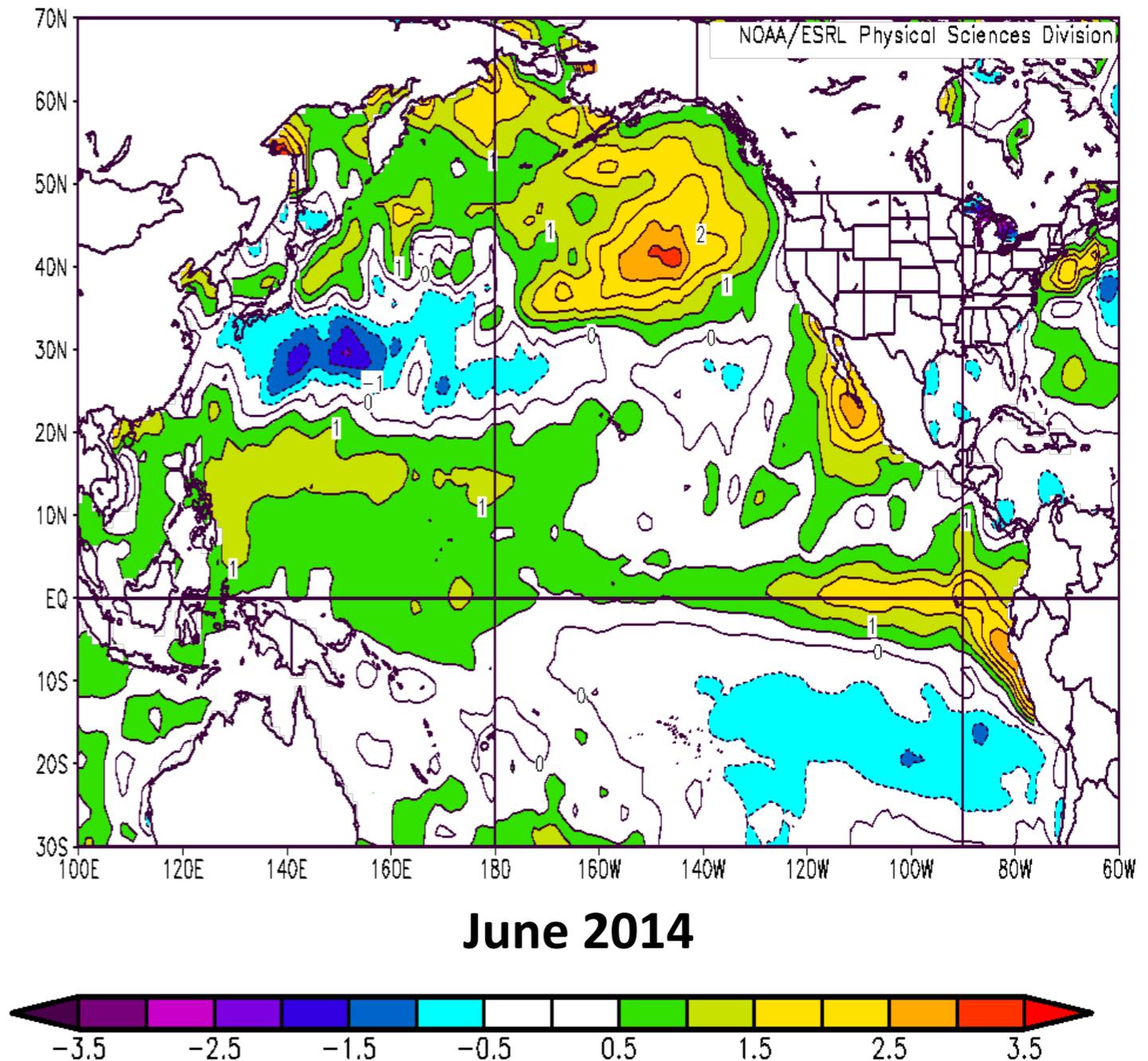


Extraordinary conditions

Sea Surface Temperature Anomaly (relative to 1981-2010)

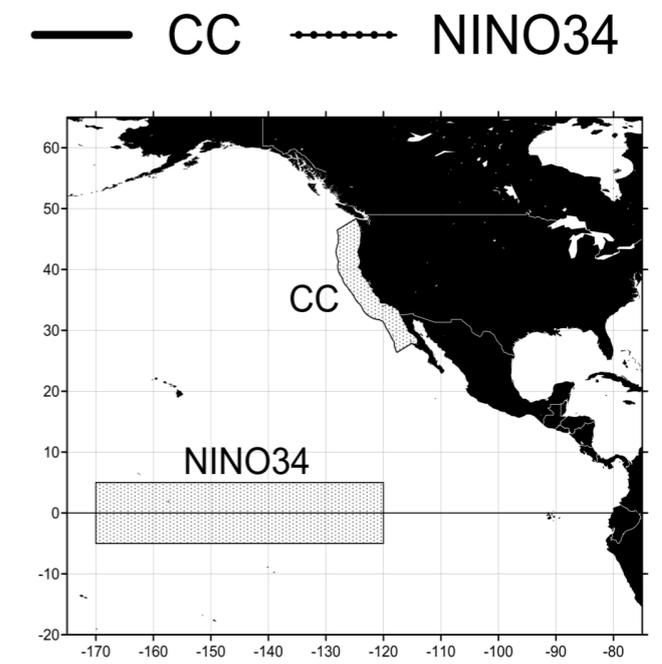
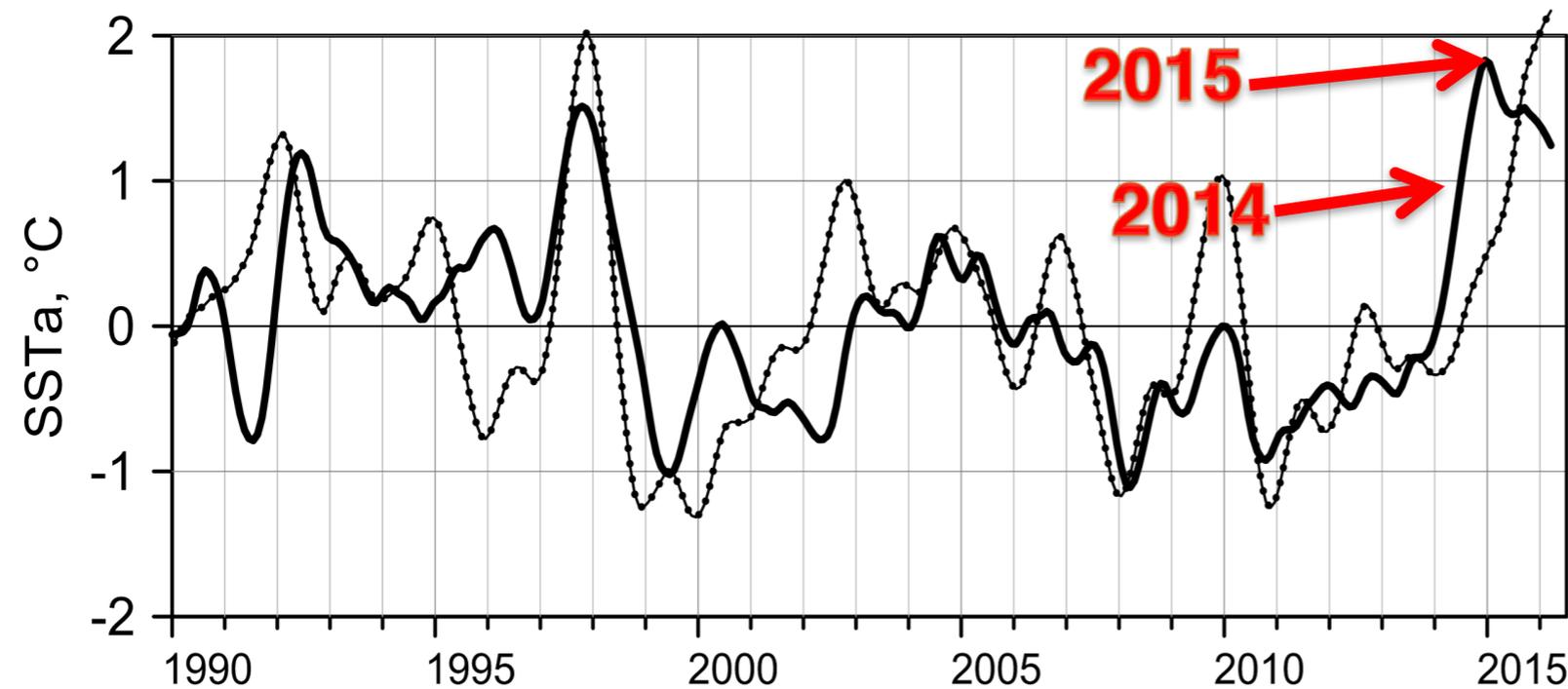
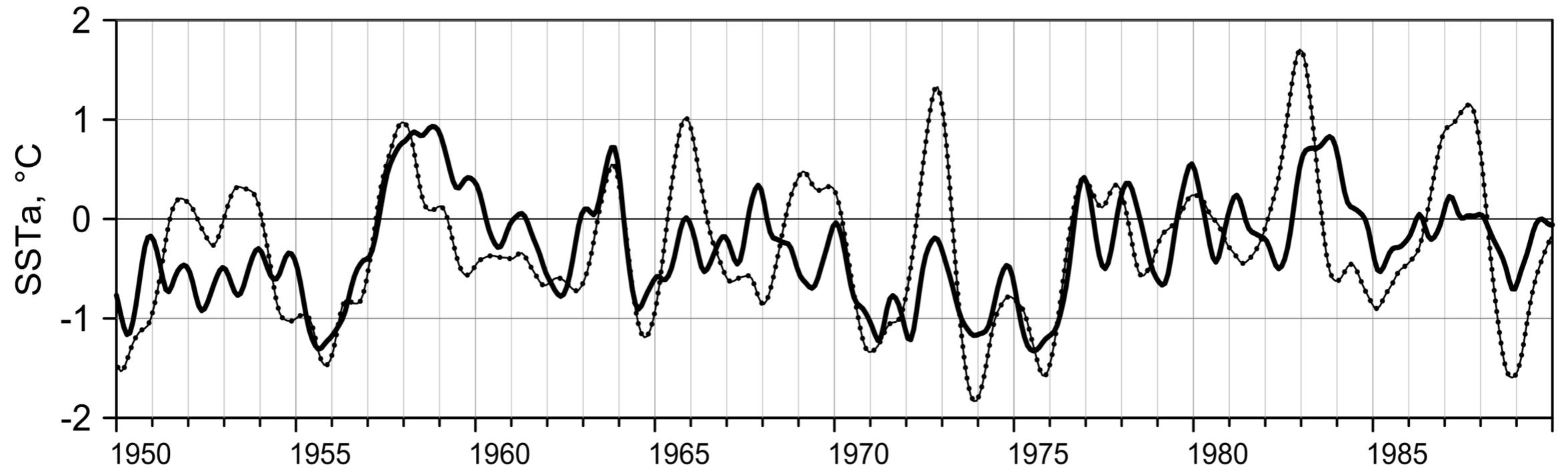
NOAA OI SST

Surface SST (C) Composite Anomaly 1981-2010 clima



Extraordinary conditions

California Current Sea Surface Temperature Anomaly (relative to 1981-2010)



Ridiculously Resilient Ridge(s) are to blame!

- A few “ridge patterns” kept storms away and temperatures high in CA
 - What caused the atmosphere to get stuck like this?

Unusual warm-west cool-east temperatures in the tropical Pacific? The warm Arctic and reduced sea ice cover? The warmth of the northeast Pacific Ocean? A combination of these factors?

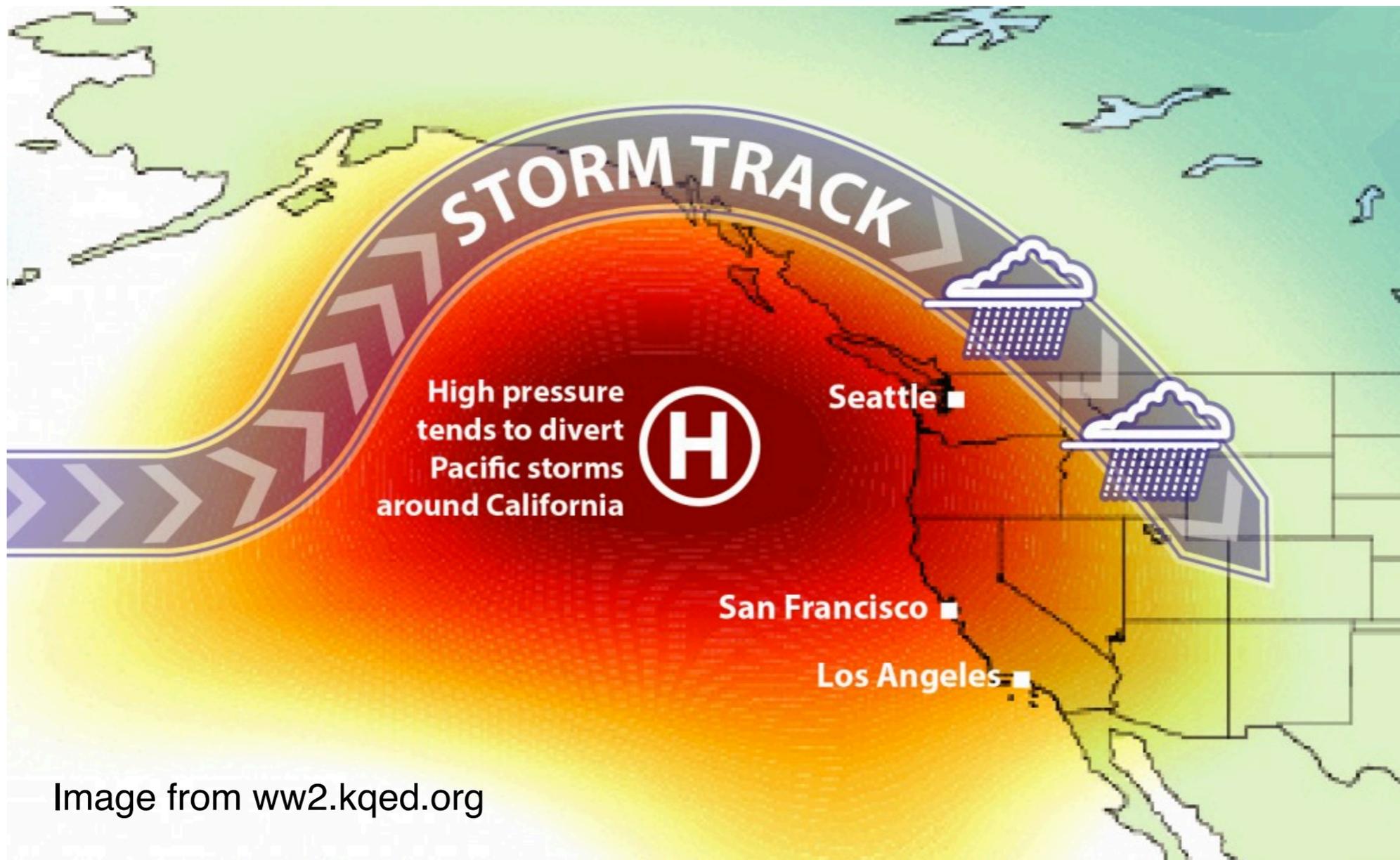
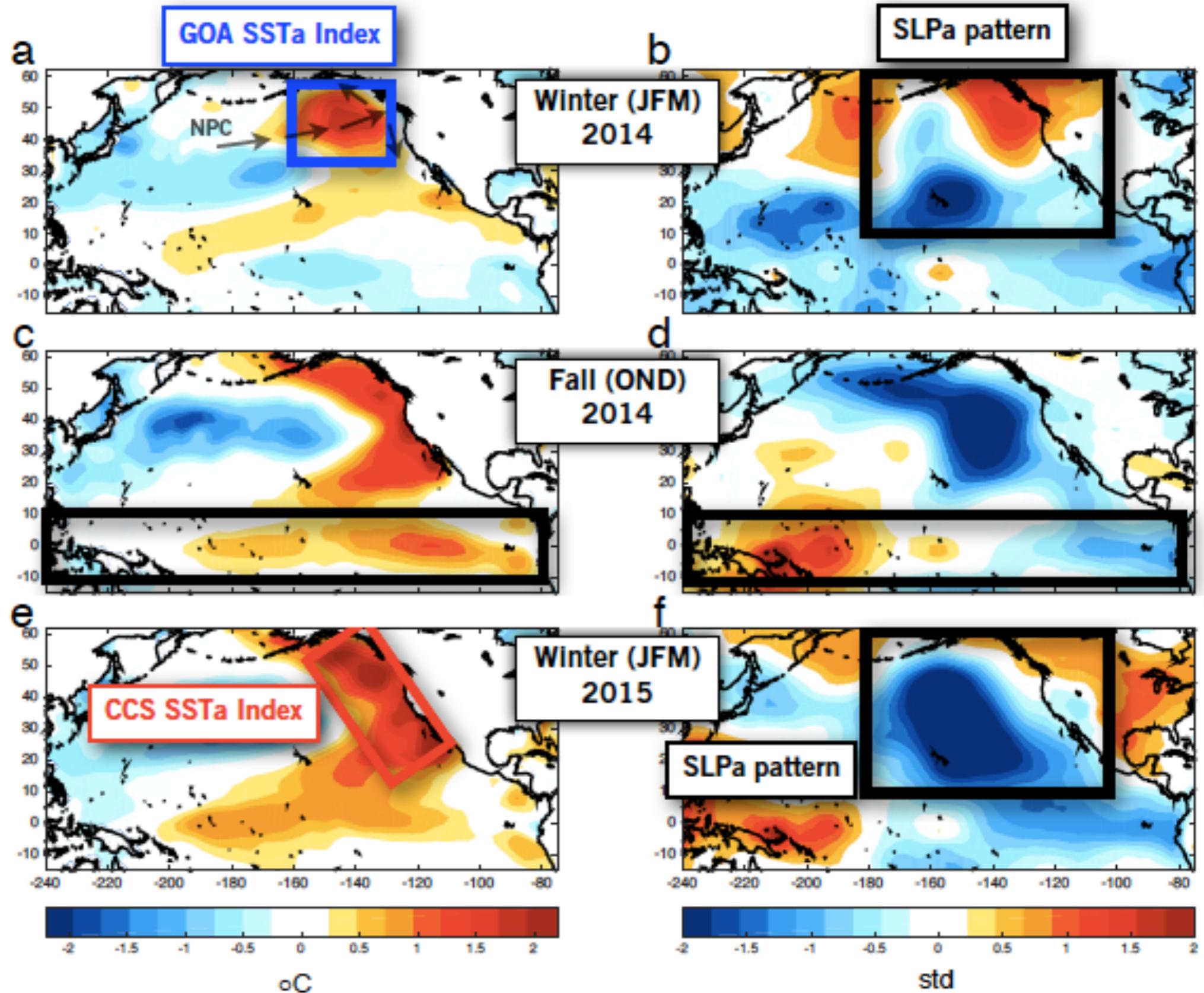


Image from ww2.kqed.org

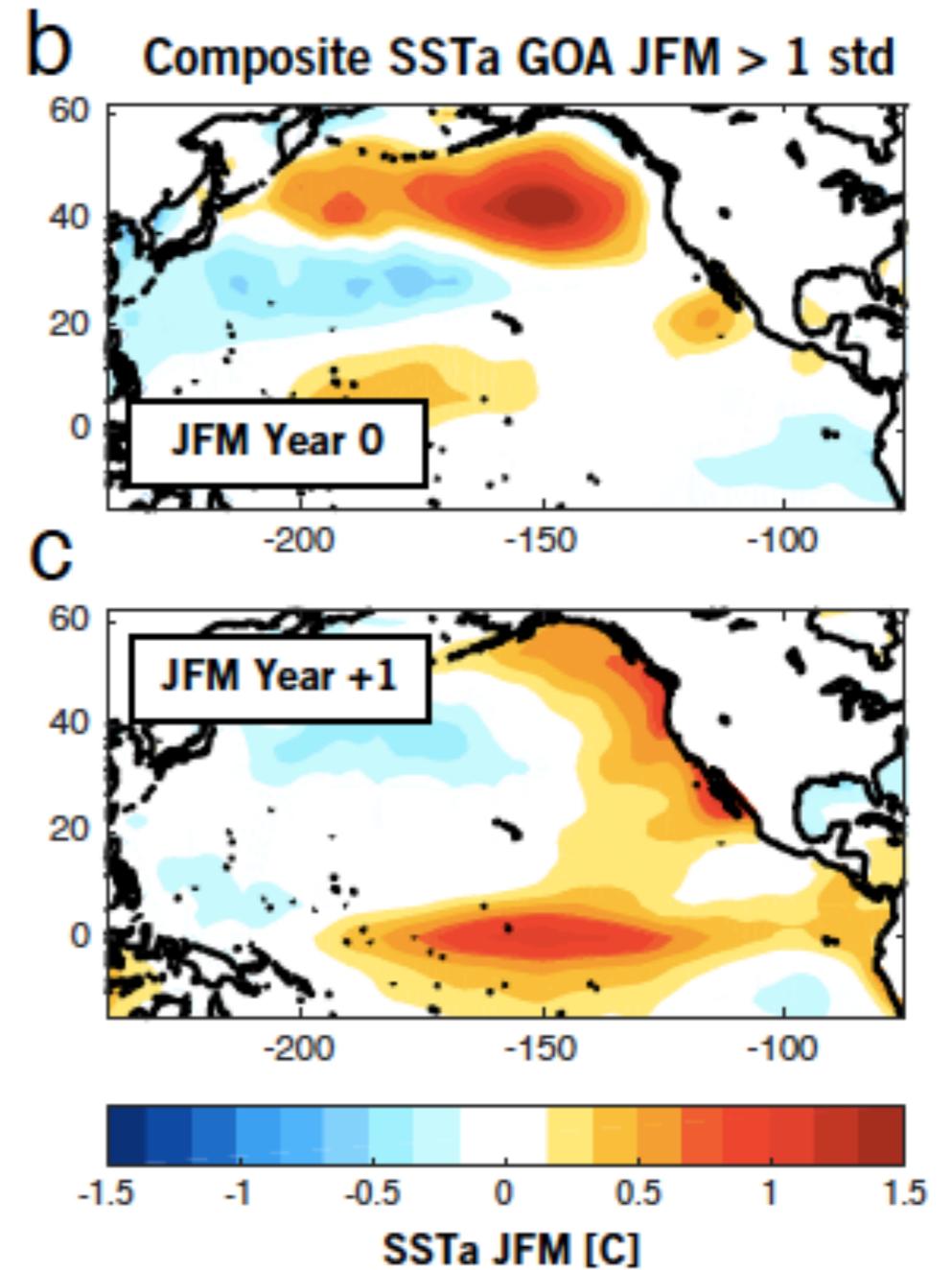
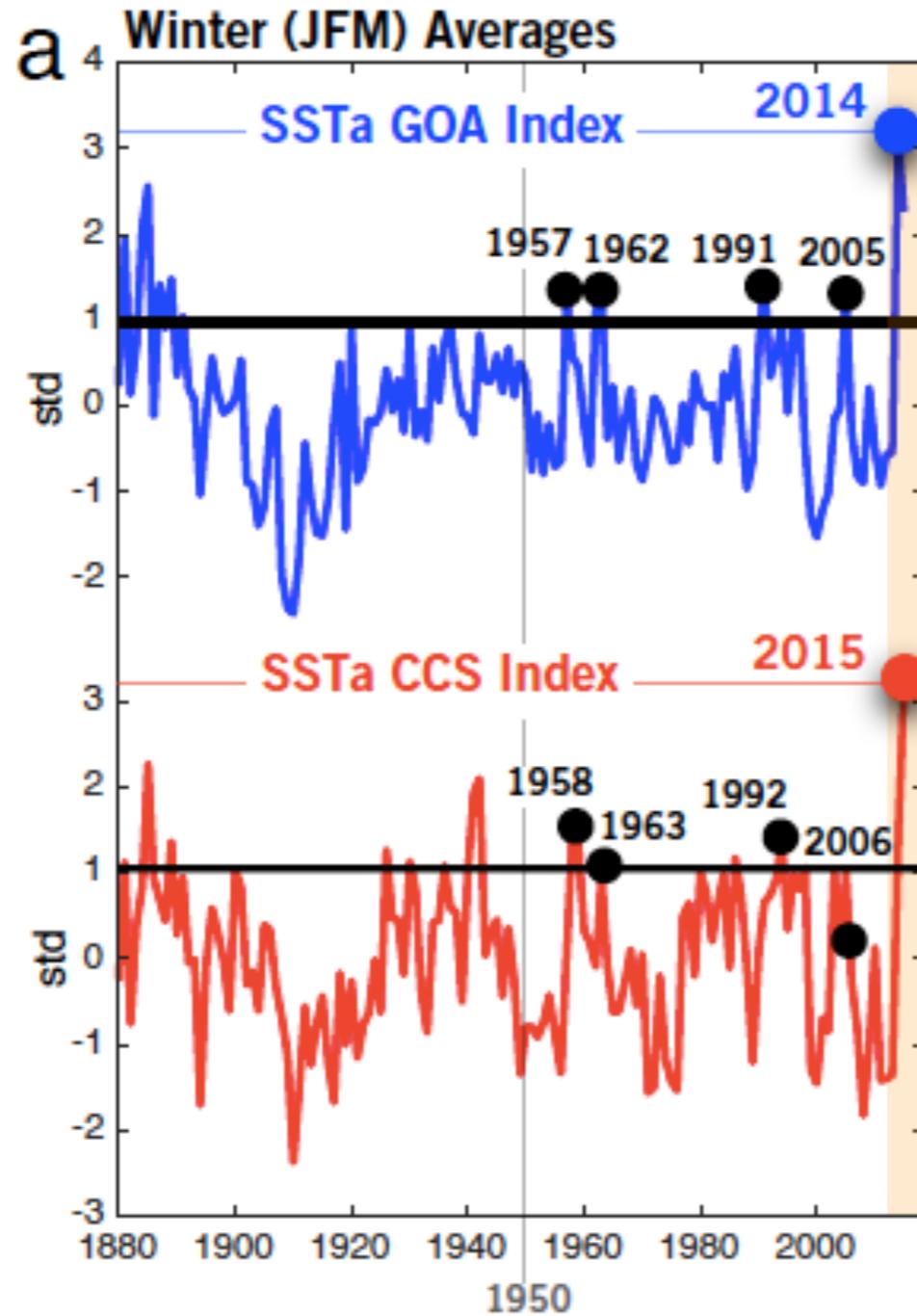
Understanding the record North Pacific heat wave of 2014-15

Di Lorenzo and Mantua (2016): Nature Climate Change



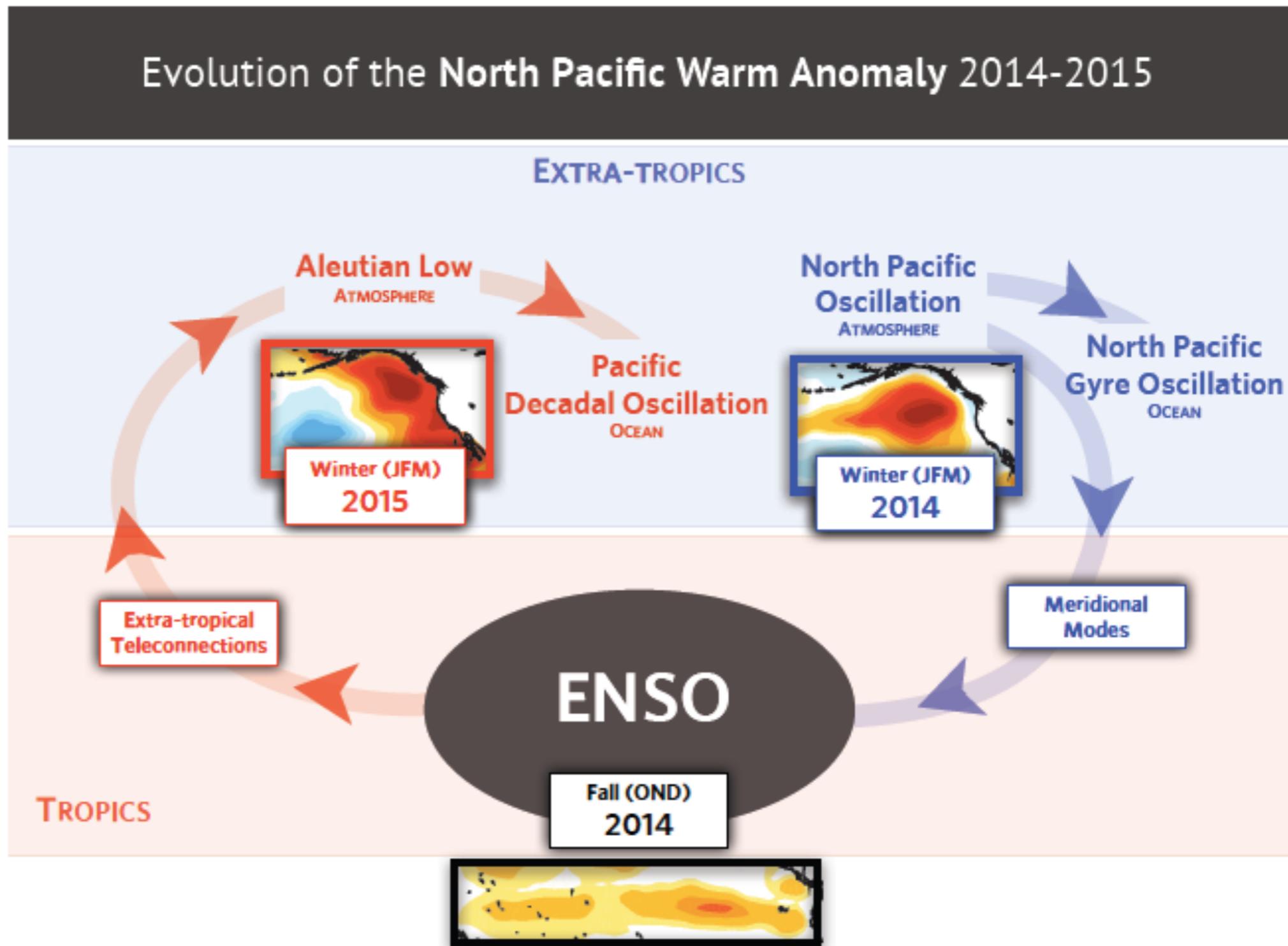
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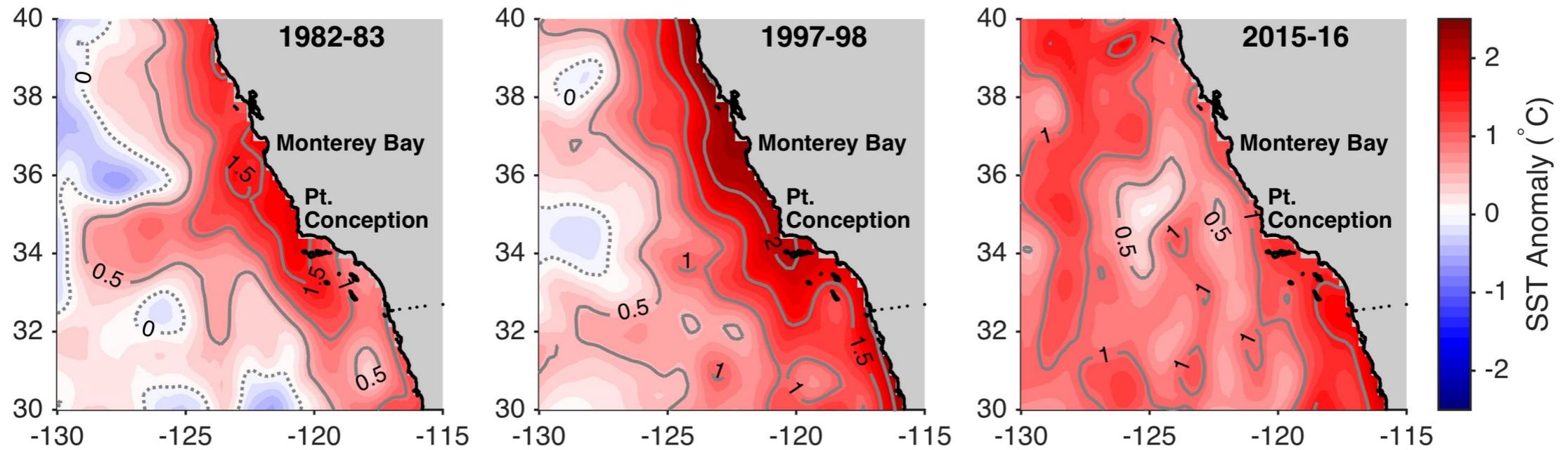
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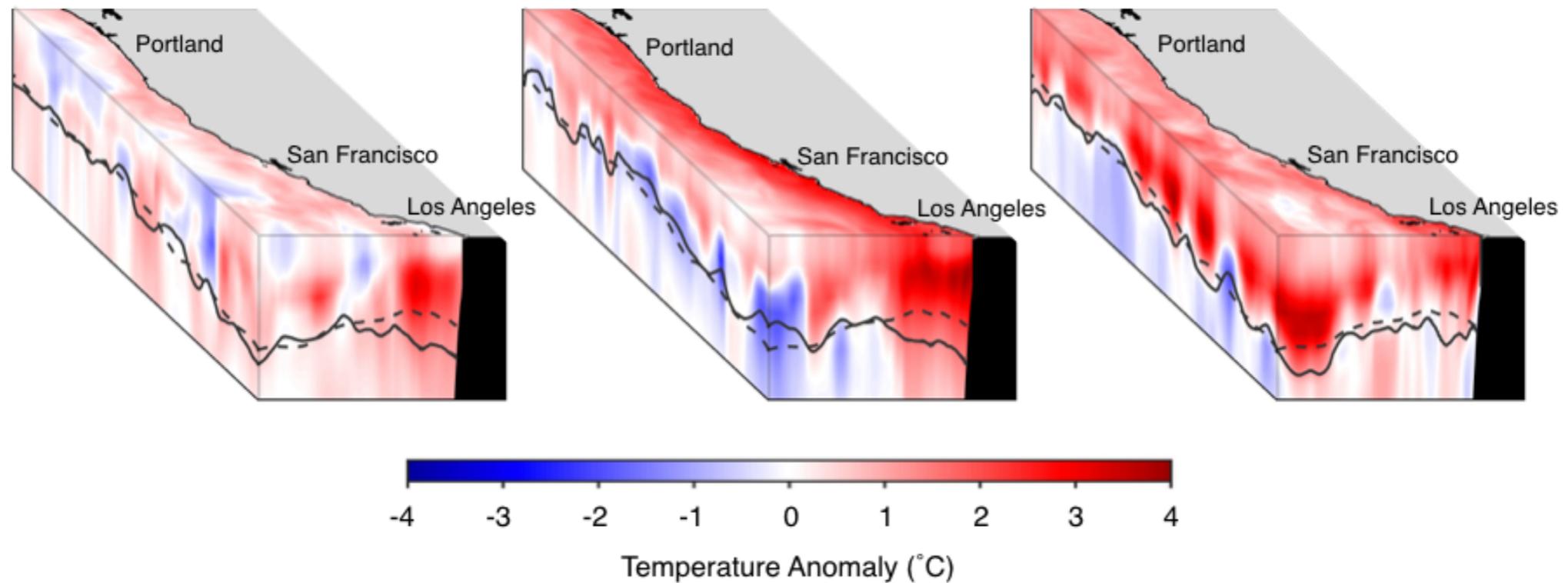




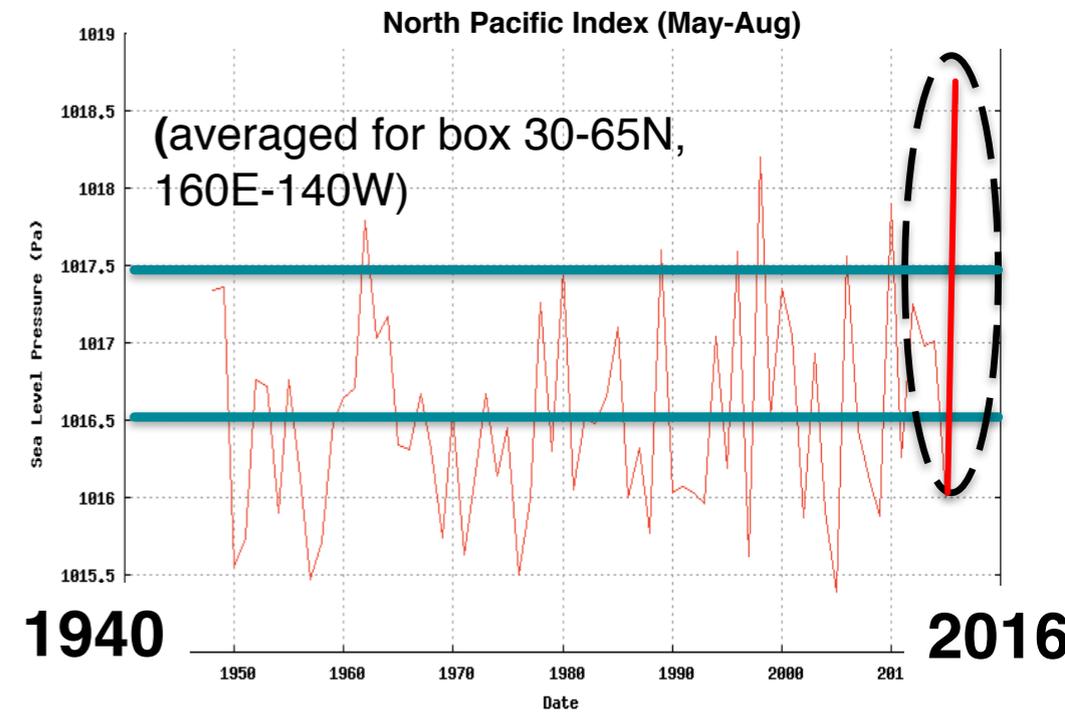
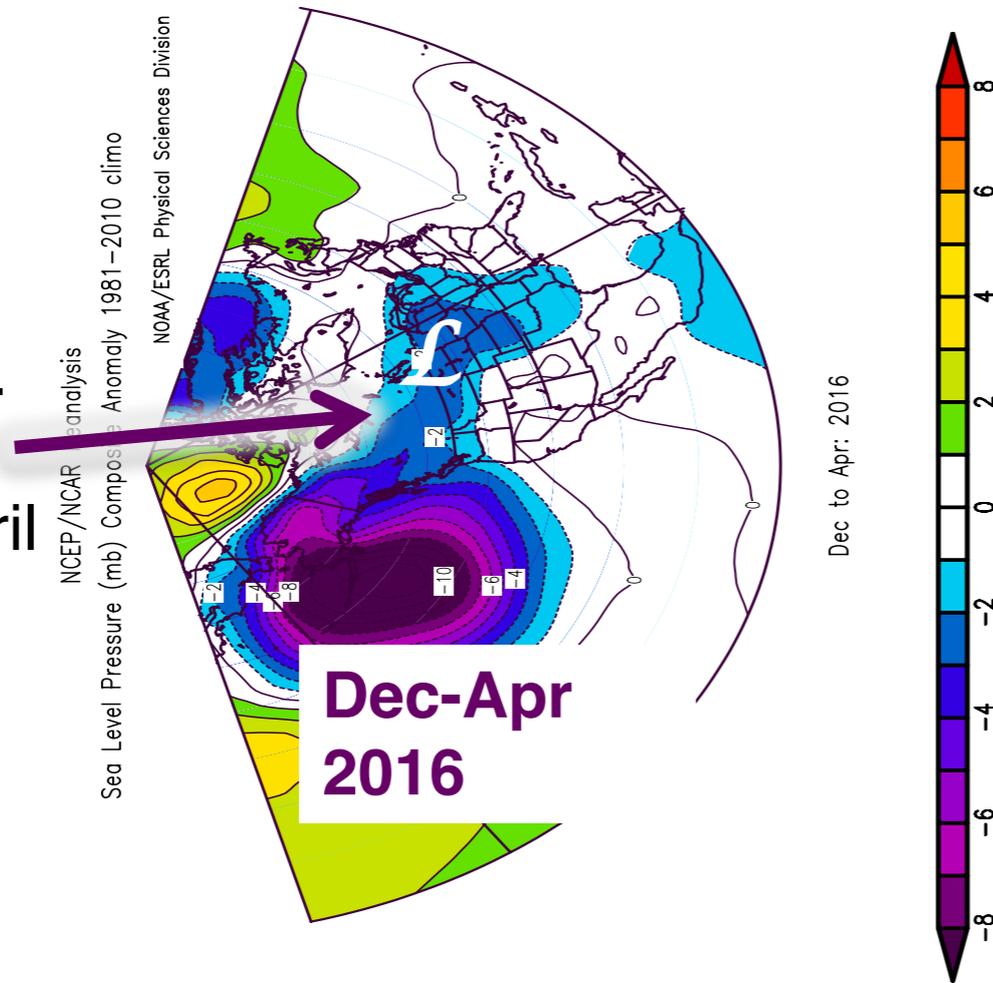
OBSERVED DEC-FEB SST ANOMALIES (OISST)



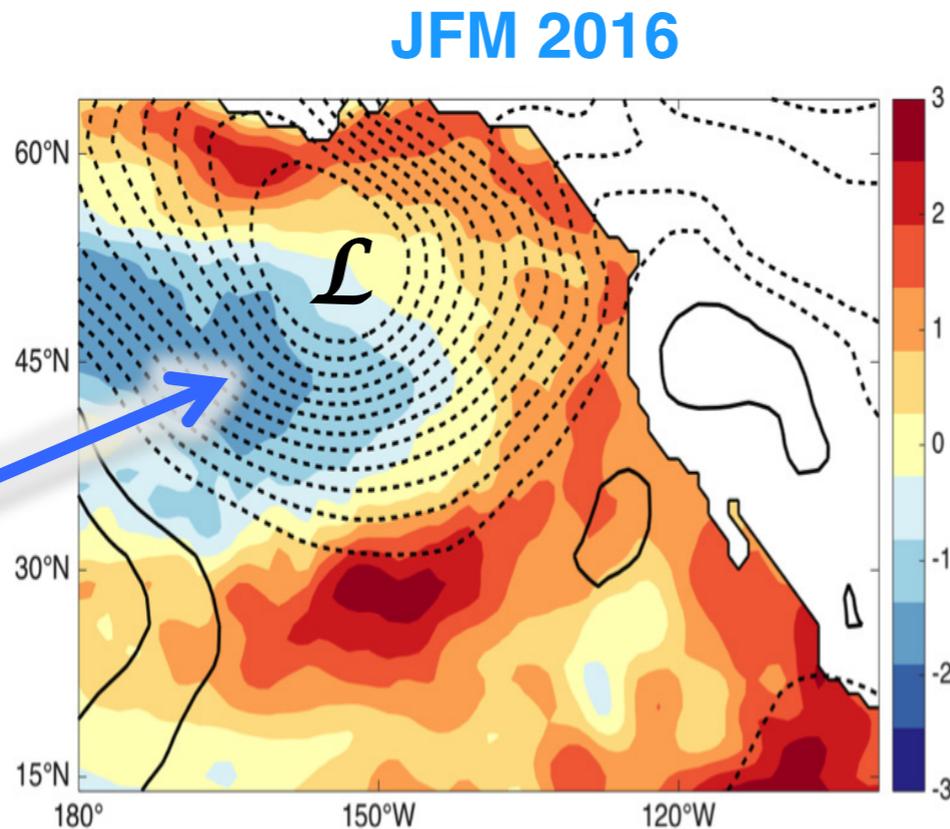
MODELED DEC-FEB UPPER OCEAN TEMPERATURE ANOMALIES



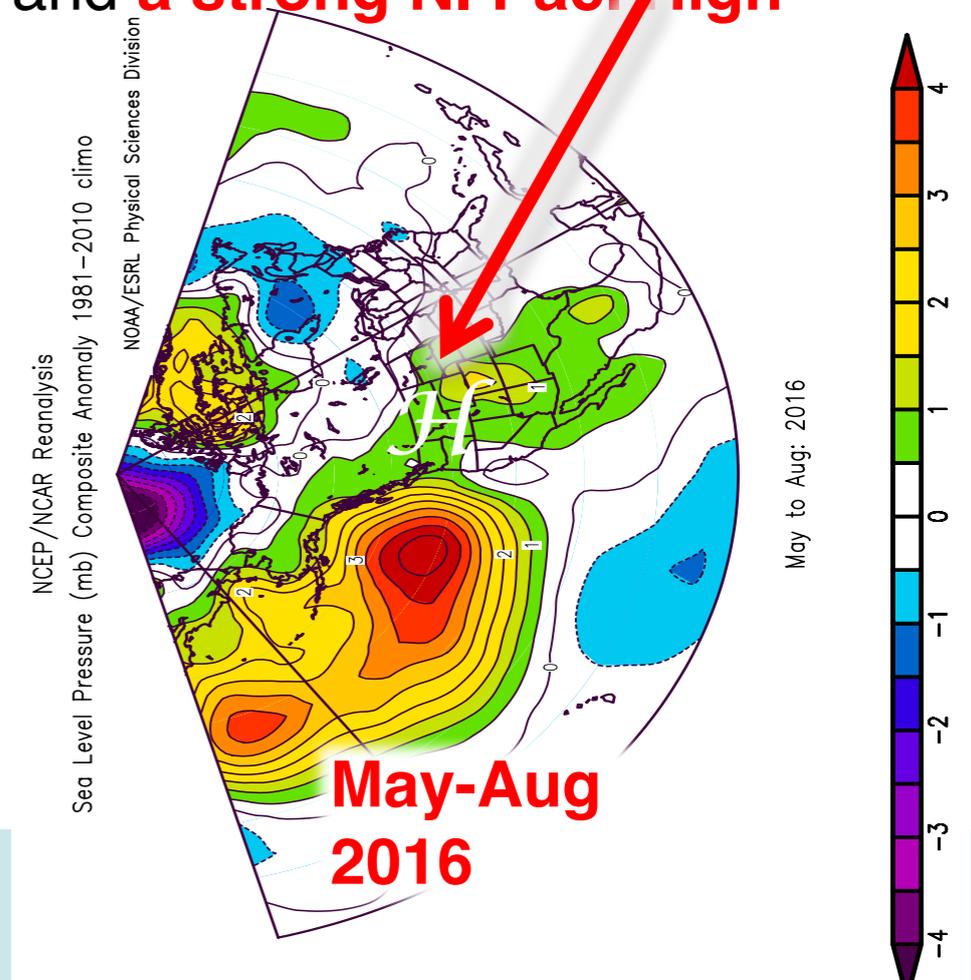
Past year: the N. Pacific shifted between Dec-April and May-Aug



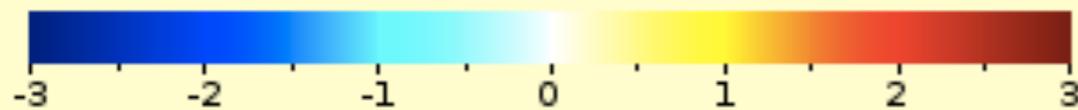
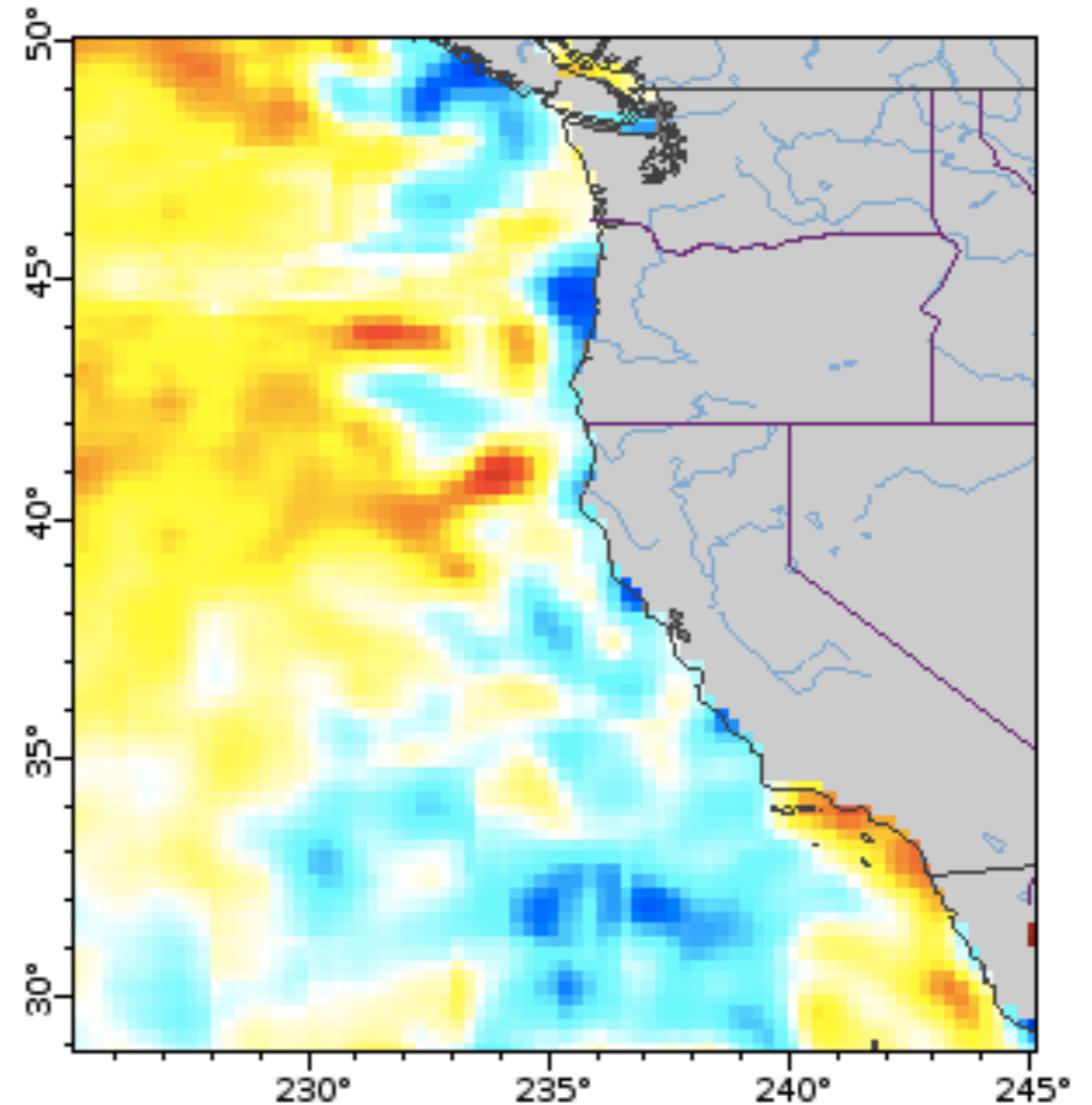
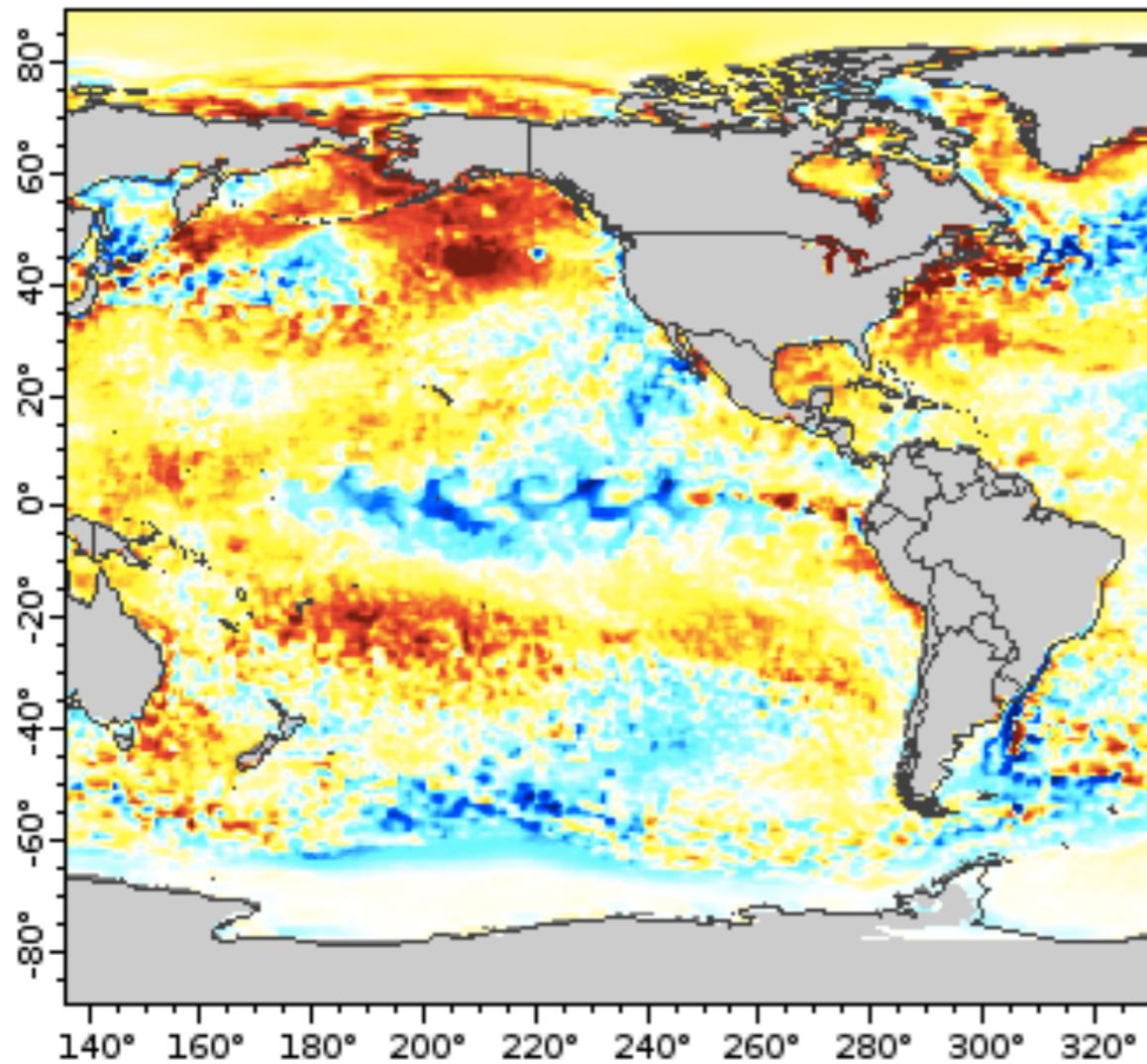
JFM 2016 N. Pacific SST and SLP anomalies show a **PDO-like pattern of SST anomalies, with cold anomalies in the central North Pacific** and a warm “arc”.



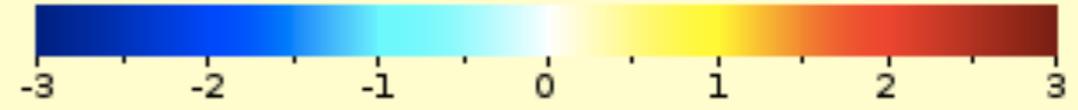
Recently (May-Aug) we have had months with weak Aleutian Low and a strong N. Pac. High



Ocean temperature anomalies: October 9, 2016



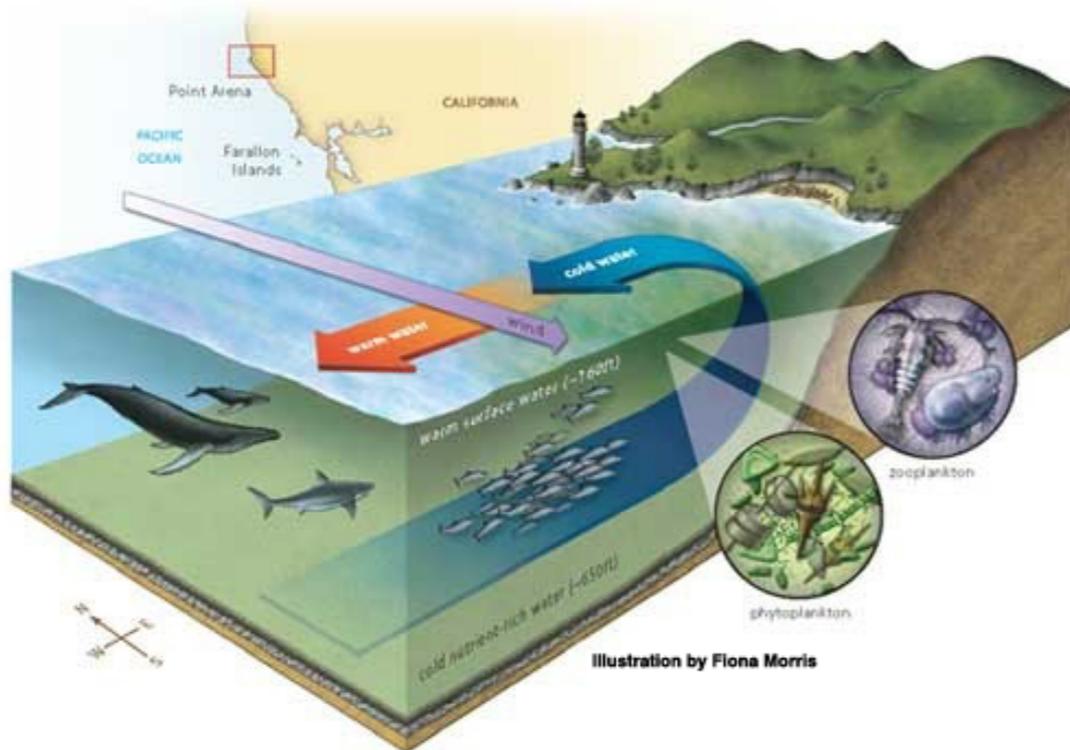
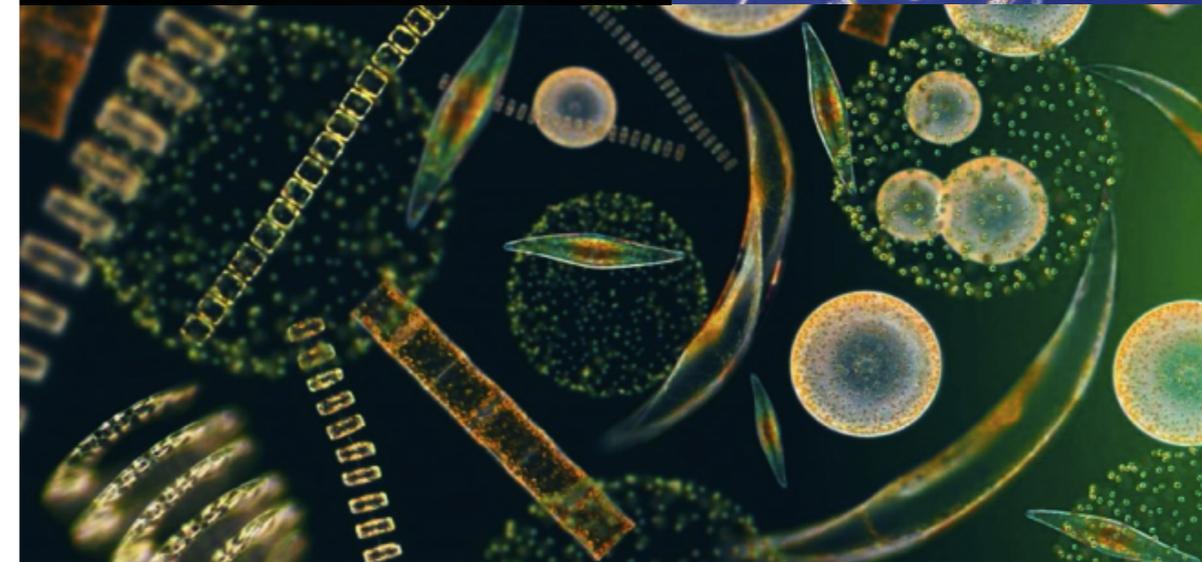
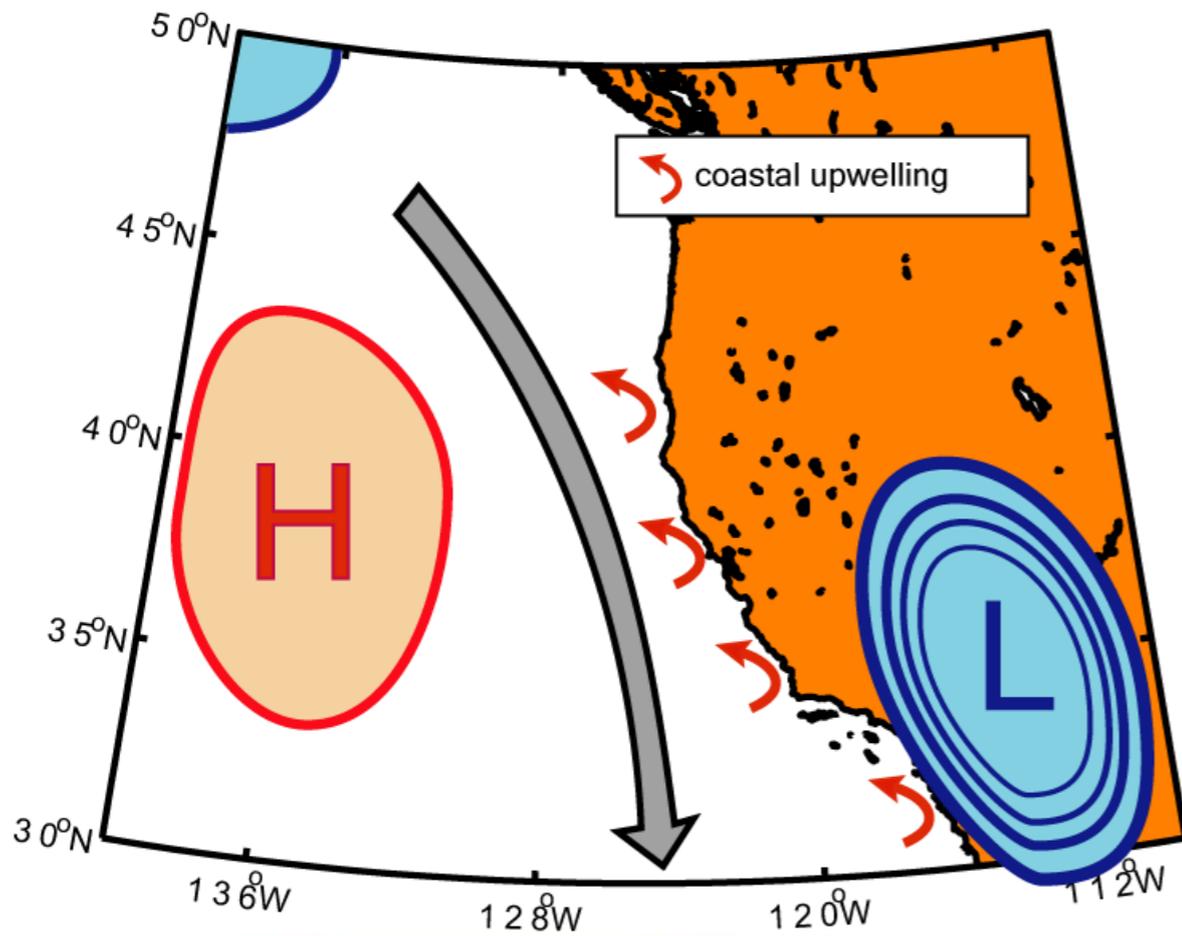
Daily Sea Surface Temperature Anomalies (degree_C)
SST, Daily Optimum Interpolation (OI), AVHRR Only, Version 2, Final+Preliminary
(2016-10-09T00:00:00Z, Altitude=0.0 m)
Data courtesy of NOAA NCDC



Daily Sea Surface Temperature Anomalies (degree_C)
SST, Daily Optimum Interpolation (OI), AVHRR Only, Version 2, Final+Preliminary
(2016-10-09T00:00:00Z, Altitude=0.0 m)
Data courtesy of NOAA NCDC

CALIFORNIA CURRENT FOOD WEB DEPENDS ON UPWELLING

The source waters and upwelling strength determine the primary productivity



Biological Impacts

Warming Pacific Makes for Increasingly Weird Ocean Life

A "blob" of warm water that's partly to blame for dead birds and stranded sea lions in the Pacific may share a cause with Boston's snows and California's drought.



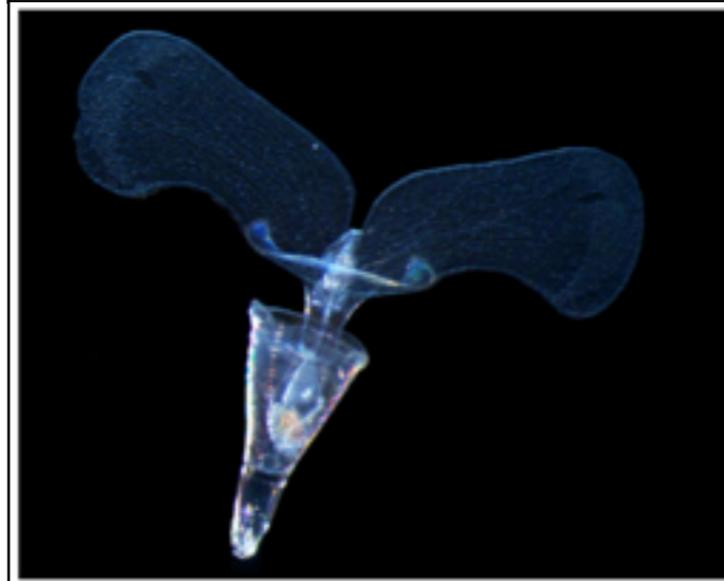
Mysterious Sea Lion Die-Off Strikes Again on California Coast

Tiny sea lion pups are washing up on beaches in unusually high numbers—for the third winter in a row.

Experts puzzled as 30 whales stranded in 'unusual mortality event' in Alaska

Scientists 'very concerned' and suspect toxic algae, though NOAA concedes 'bottom line is we don't know what's causing deaths'

Unusual warm ocean conditions off California, West Coast bringing odd species



Why are so many whales dying on California's shores?

Huge Toxic Algal Bloom Shuts Down West Coast Fisheries

Pacific Ocean 'blob' draws scrutiny of researchers

A huge swath of unusually warm water that has spread to the normally cool Pacific has grown to the size of the entire ocean temperature anomaly on record, researchers now say, profoundly affecting climate and marine life from Baja California to Alaska.

Record Algae Bloom Laced With Toxins is Flourishing in "The Blob" — and Spreading in the North Pacific

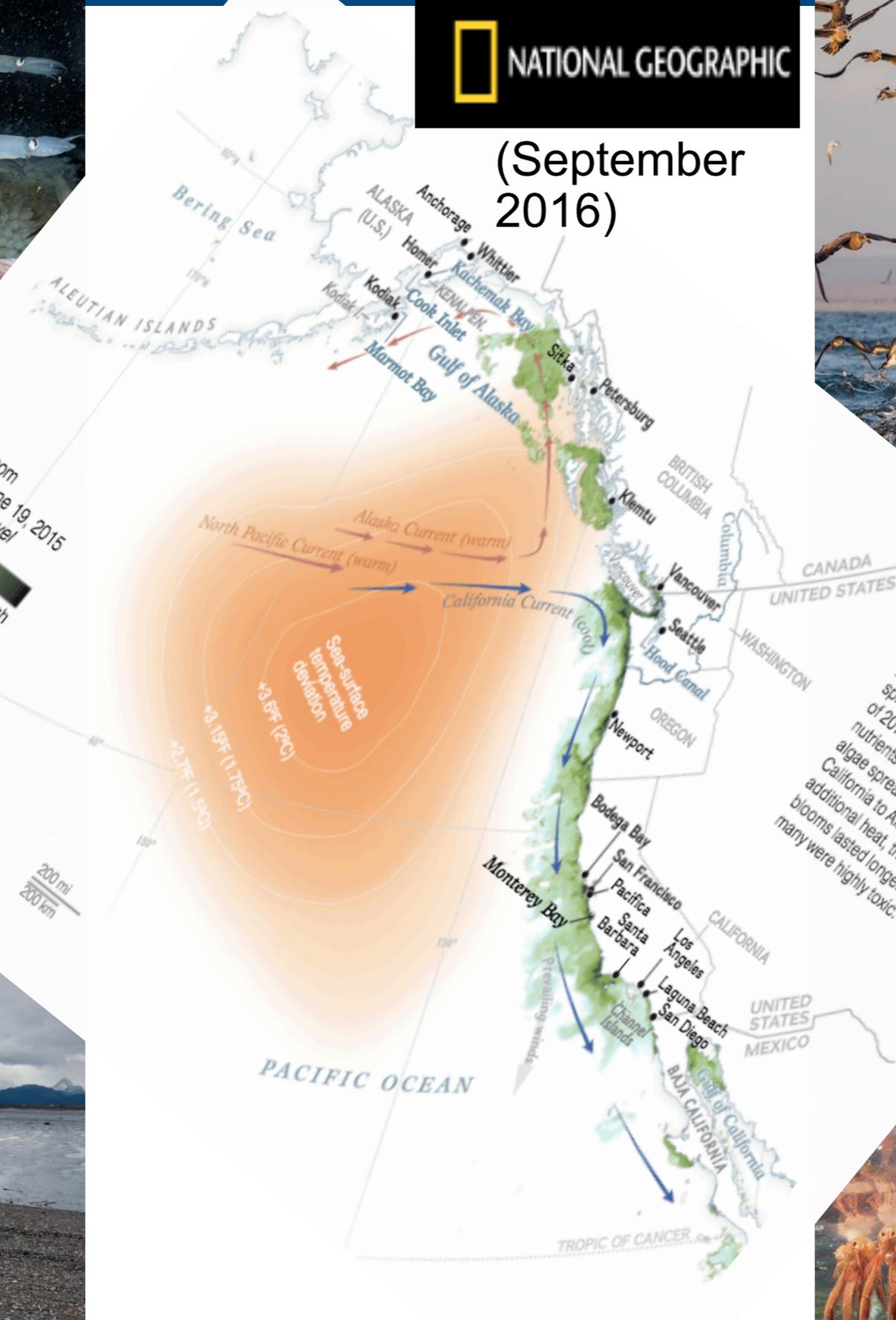
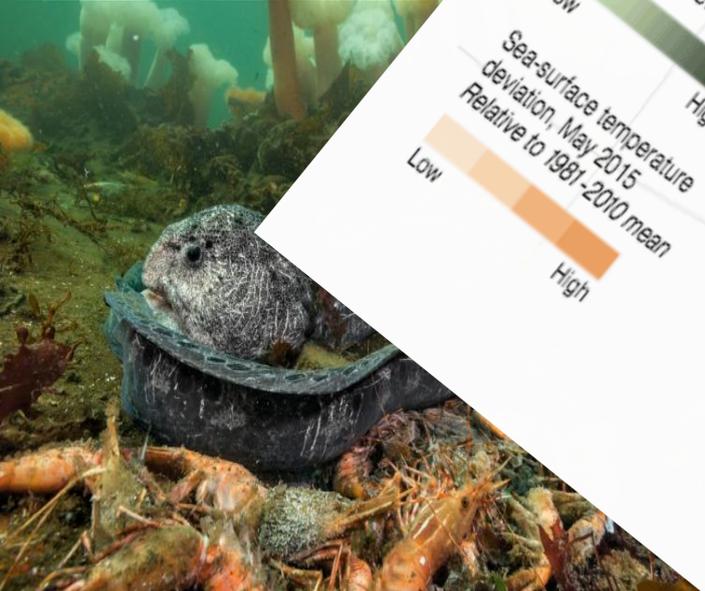
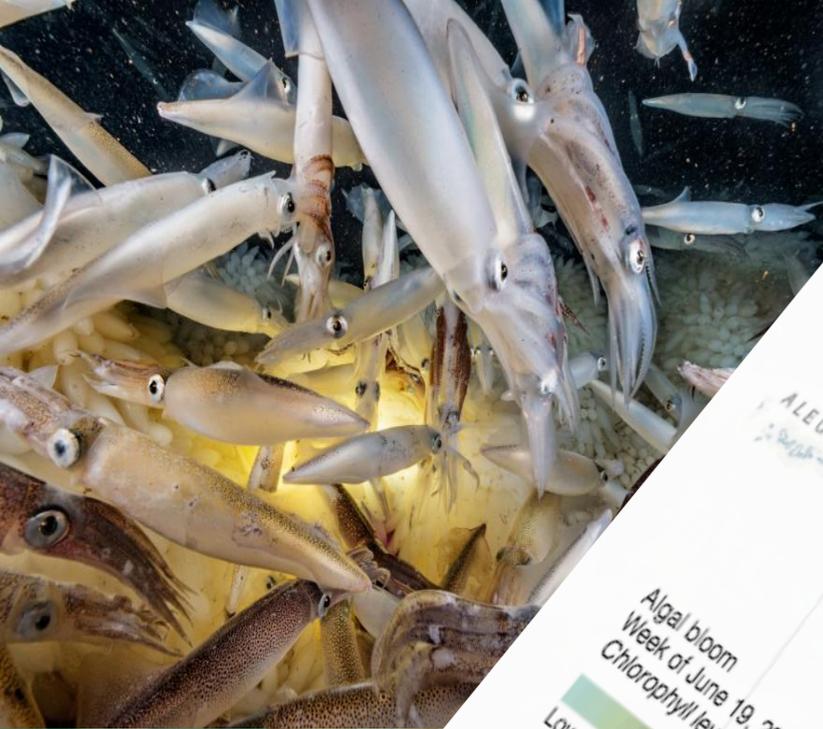
Unusual species in Alaska waters indicate parts of Pacific warming dramatically

The Gulf of Alaska is unusually warm, and weird fish are showing up

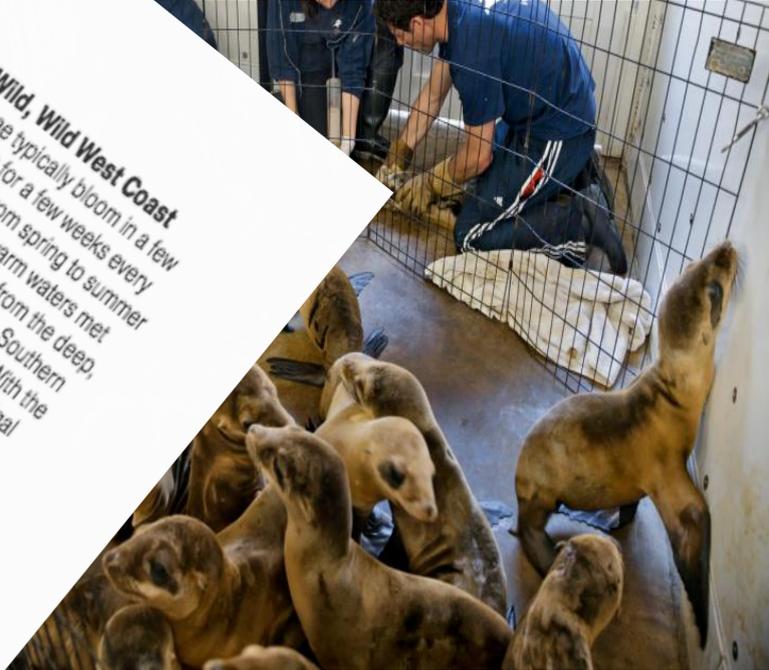


In this Aug. 29 photo, a 7-foot ocean sunfish rarely seen in Washington waters washed ashore on a beach near Ilwaco, Wash., with June Mohler, a biological technician working as an interpretative assistant. (AP Photo/Cape Disappointment State Park, Eric Wall)

(September 2016)



Wild, Wild West Coast
 Algae typically bloom in a few places for a few weeks every spring. From spring to summer of 2015, as warm waters met nutrients rising from the deep, algae spread from Southern California to Alaska. With the additional heat, these algal blooms lasted longer, and many were highly toxic.



http://www.nationalgeographic.com/magazine/2016/09/warm-water-pacific-coast-algae-nino/#/AP_390543457600.ngsversion.1470954342760.jpg

YOY ROCKFISH



Slender Snipefish



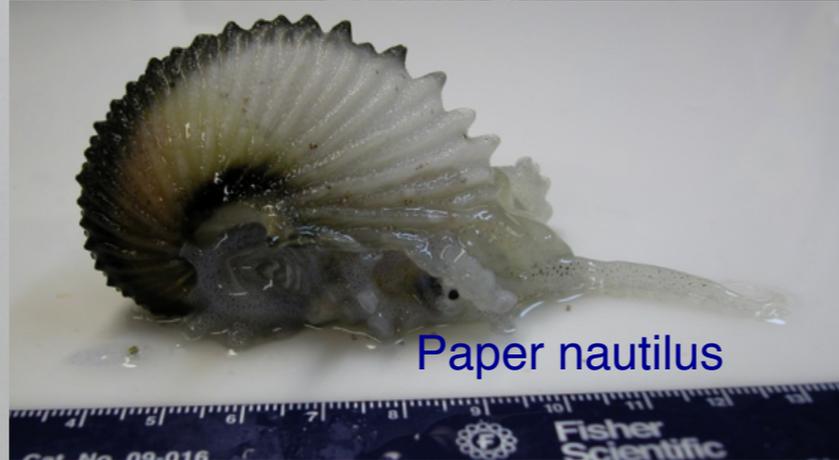
Pelagic red crabs



Pyrosomes and salps

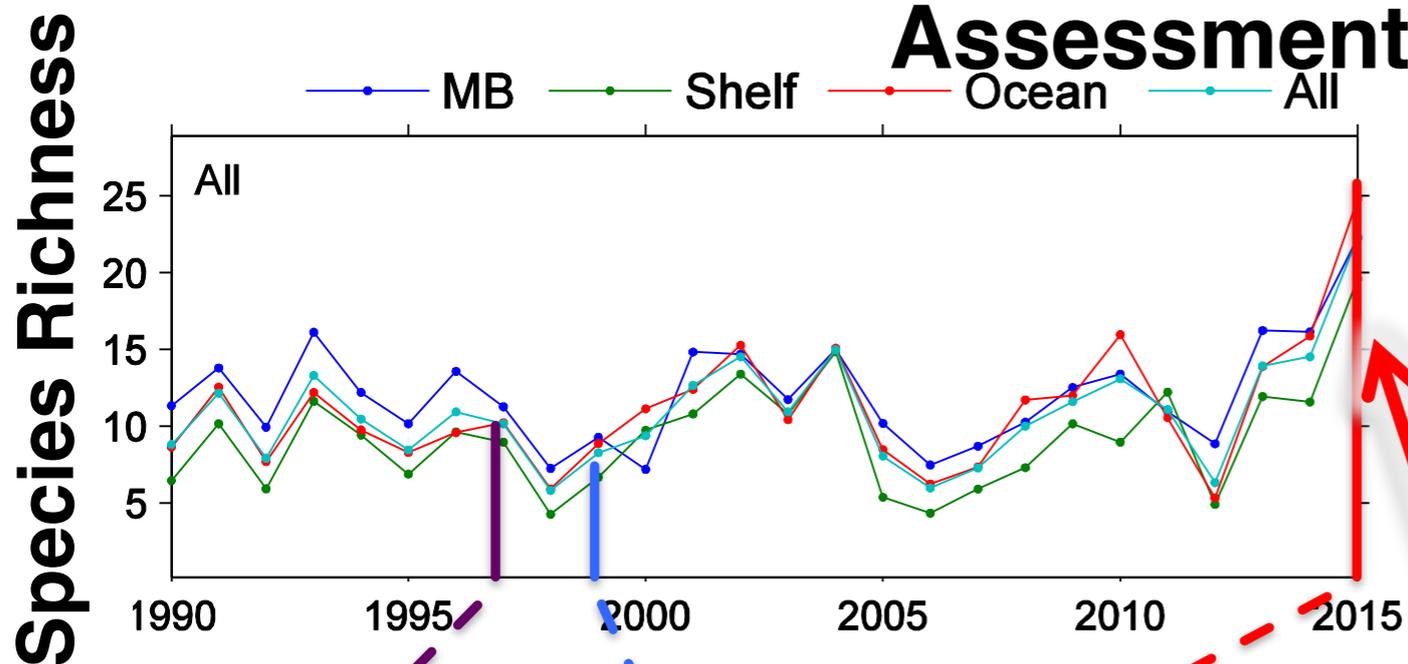


Paper nautilus

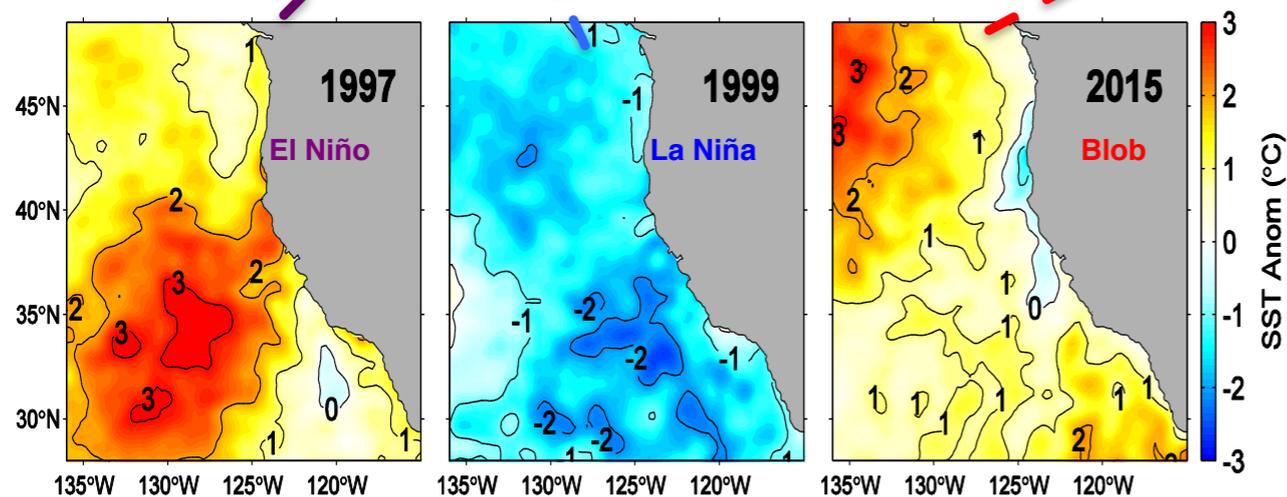


2015 Rockfish recruitment survey catches were unusual in that there were record catches of YOY rockfish and some other YOY groundfish, very high gelatinous organisms (salps, pyrosomes, etc.), and record catches of what have previously considered to be "El Niño" or subtropical water mass species (pelagic red crabs, California lizardfish, lobster phyllosoma), and finally a suite of never observed before were collected such as the slender snipefish and the greater argonaut.

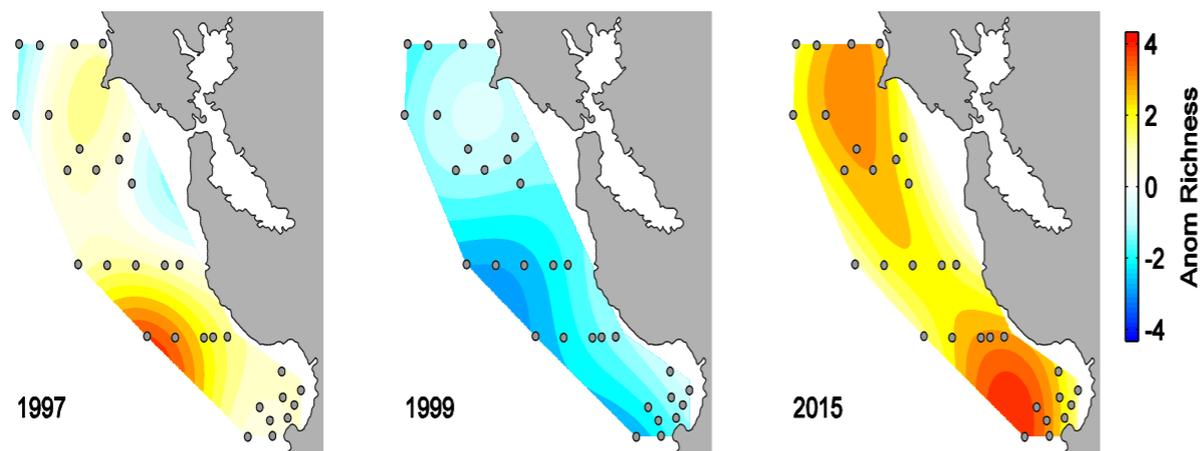
NOAA-NMFS Rockfish Recruitment and Ecosystem Assessment Surveys



- Baseline record of Rockfish/Groundfish and Forage species (e.g., CPS, mesopelagics, squid) diversity indices



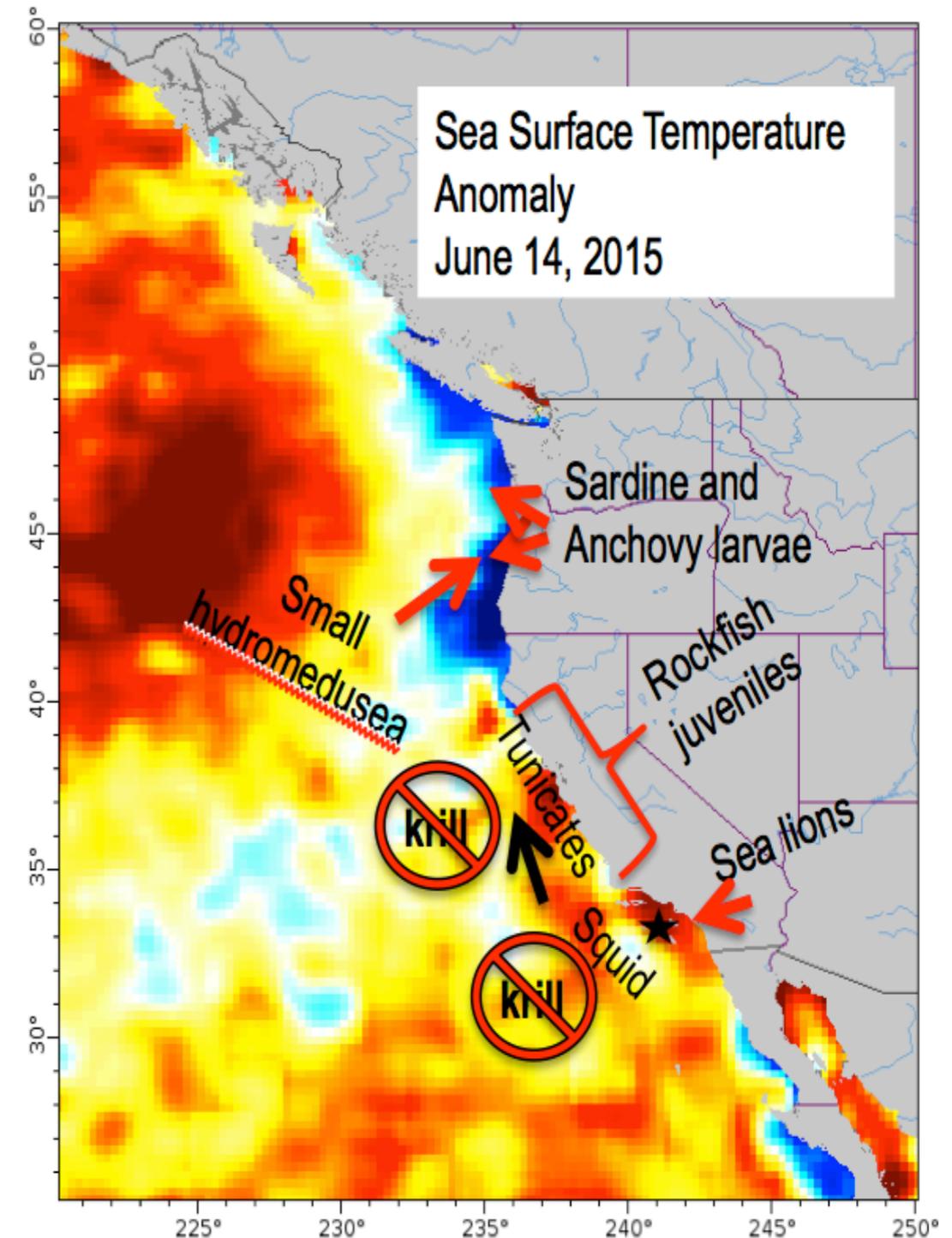
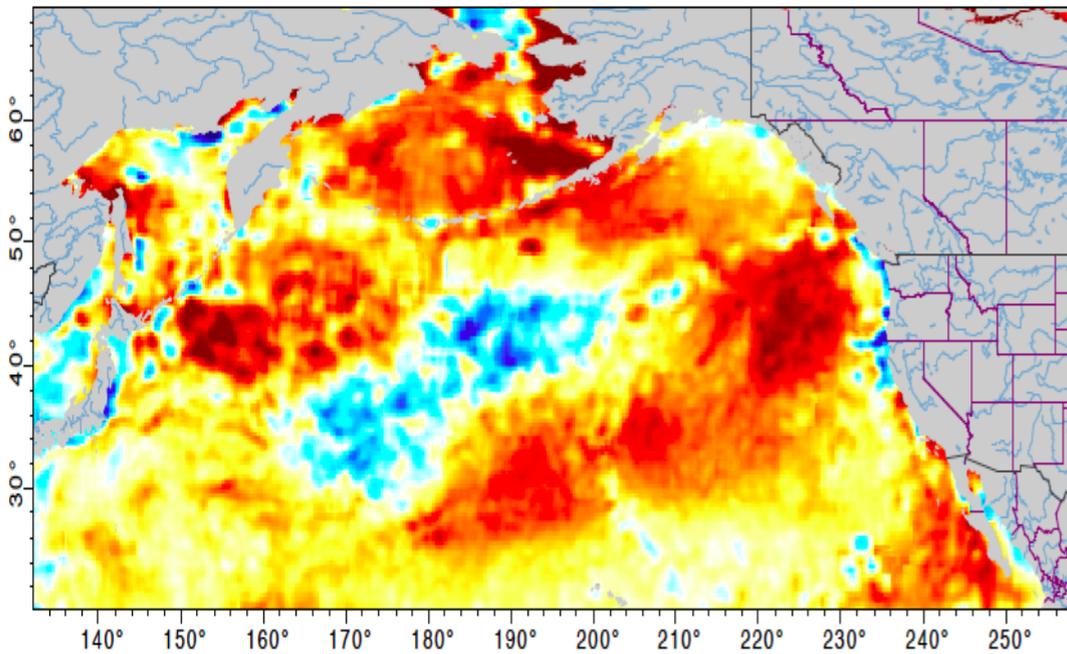
- **Record biodiversity levels observed during the 2015 Blob Event.** Attributed to convergence of northern, southern and offshore water masses and species assemblages.



A climate timeline for West Coast salmon

2012	2013	2014	2015	2016
Year 1 CA drought, carryover storage in reservoirs	Year 2 CA drought, some carryover storage	Year 3 CA drought, record heat	West Coast “snow drought” and record high temperatures	near average precip and snowpack but an early melt
Cold productive NE Pacific	Cold productive NE Pacific	NE Pacific in transition from good to bad conditions	Record warm temperatures in NE Pacific; many signs of stress on “subarctic” species off the West Coast	A still warm unproductive NE Pacific? Pockets of nearshore productivity
BY 2012 chinook	Smolt migration	Ocean year 2	Ocean year 3, majority maturing	
	BY 2013 chinook	Smolt migration	Ocean year 2	Ocean year 3, majority maturing
	BY 2013 steelhead	Smolt migration	Ocean year 2	Typical adult returns

Synthesis: 2015 impacts along the west coast of N. America



Most warming was due to Blob and not El Niño

- Phytoplankton was patchy and lower than previous years
- Sardine and anchovy went north
- Krill decreased
- Rockfish juveniles did OK on central CA coast
- Seabirds... depending on location (e.g., the mass mortality of Cassin's Auklets)
- Sea lions did poorly
- Market squid shifted north and numbers decreased
- record Harmful Algal Bloom, dungeness crab fishery closure
- record number of gear entanglements with whales
- **“New” (oceanic) species along the coast**

