Climate Change and Life in the Coastal Ocean

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Oregon State University

Engineers for a Sustainable Future

virtual March 11, 2025

"I need the sea because it teaches me." Pablo Neruda

Climate Change and Life in the Coastal Ocean

Outline:

- Ocean Trivia
- Changes in the Ocean
- Underwater gliders
- Mapping low-oxygen zones
- Q&A

Ocean Trivia

1. How much of Earth is covered by the ocean?

a. 33%

b. 50%

c. 70%

d. 85%

Ocean Trivia

Planet Ocean

1. How much of Earth is covered by the ocean?

Answer: c. 70%

Ocean Trivia

2. How much of Earth's water is in the ocean?

a. 50%

b. 1,000,000 Crater Lakes

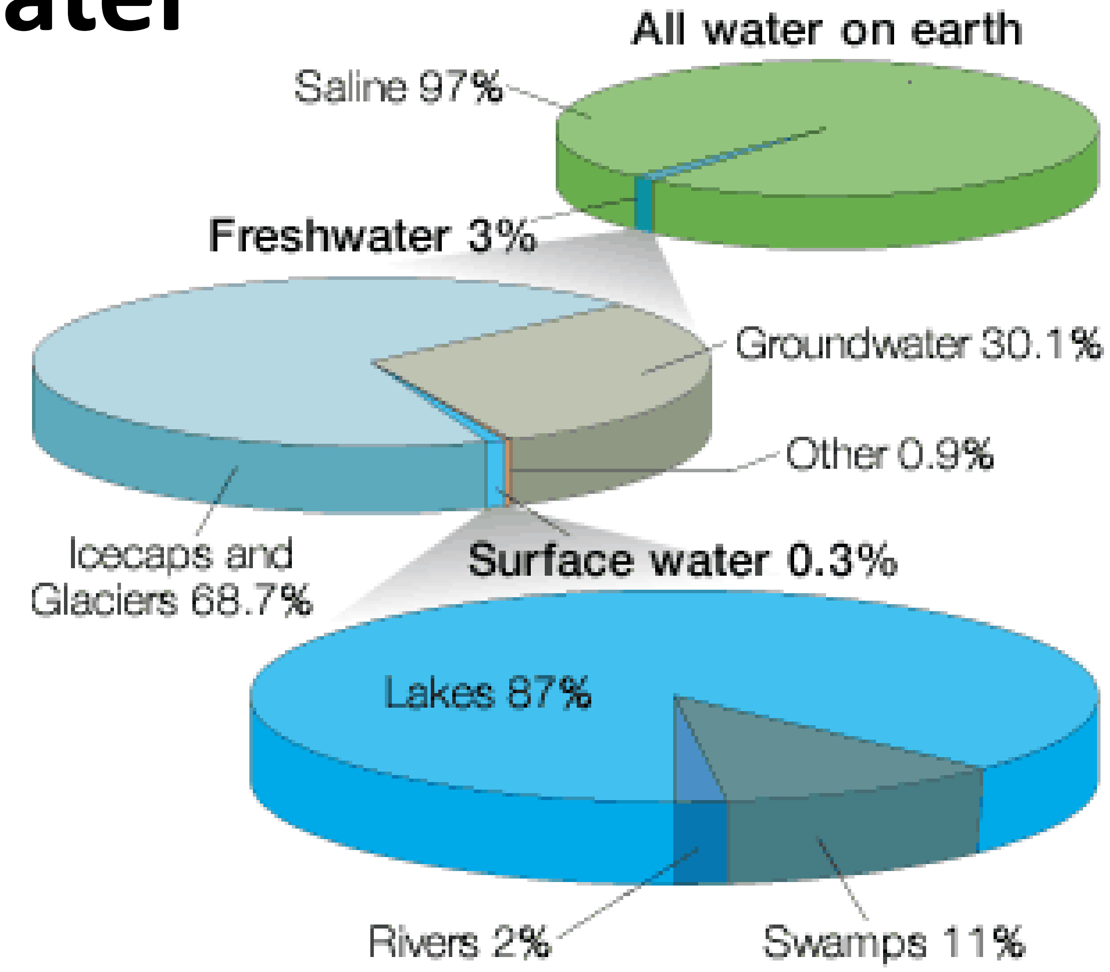
c. 70%

d. 97%

Ocean Trivia

2. How much of Earth's water is in the ocean?

Answer: d. 97%



Ocean Trivia

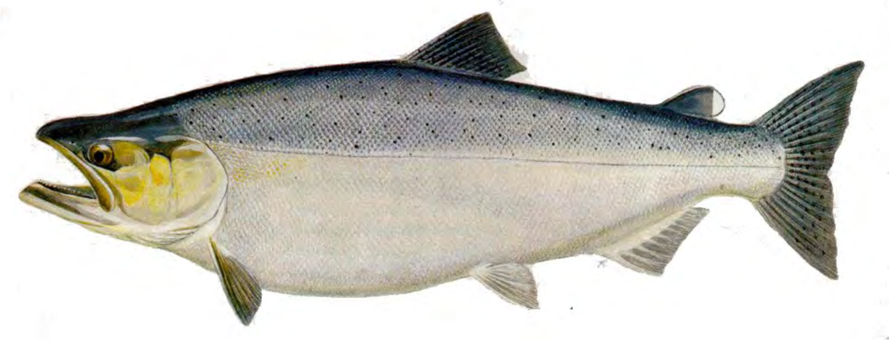
3. How many people on the planet rely solely on fish as their primary protein source?

a. About four billion people
b. About three billion people
c. About two billion people
d. About one billion people

Ocean Trivia

3. How many people on the planet rely solely on fish as their primary protein source?

Answer: b. about 3 billion people



Ocean Trivia

4. What percentage of the world’s population lives within 50 miles of the coast?

a. 10%

b. 25%

c. 50%

d. 95%

Ocean Trivia

4. What percentage of the world's population lives within 50 miles of the coast?

Answer:
c. 50%

Credit: DoD satellites; Time

Ocean Trivia

5. What percentage of world trade goods are shipped by ocean-going vessels?

a. 25%
b. 50%
c. 75%
d. 90%

Ocean Trivia

5. What percentage of world trade goods are shipped by ocean-going vessels?

Answer: d. 90%

Credit: Maersk


Pyxis Ocean sets sail in August on its first voyage since being retrofitted with WindWings.

Ocean Trivia

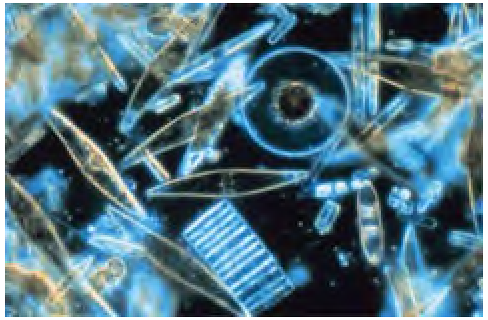
6. How much of the oxygen in the atmosphere is produced by ocean’s plants?

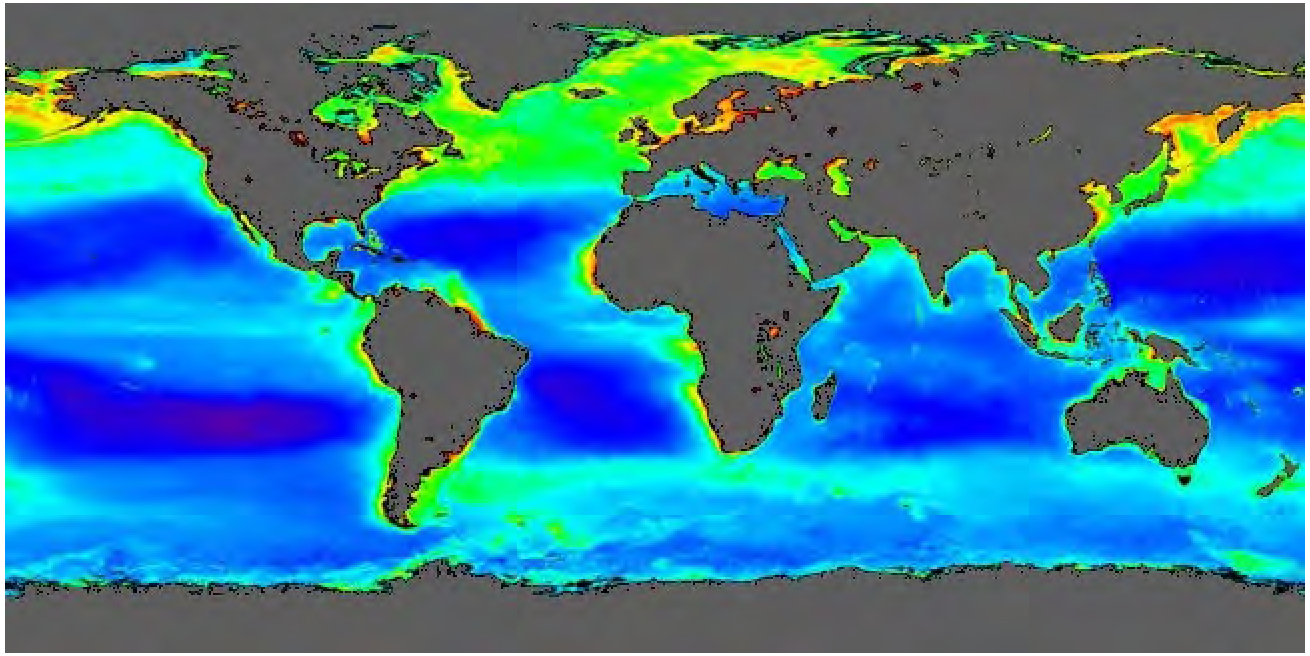
a. 10%
b. 25%
c. 50%
d. 95%

Ocean Trivia

6. How much of the oxygen in the atmosphere is produced by ocean's plants?

Answer: c. 50%





NASA

Every other breath, you can thank the ocean


United Nations
SUSTAINABLE DEVELOPMENT GOALS
1 NO POVERTY
2 ZERO HUNGER
3 GOOD HEALTH AND WELL-BEING
4 QUALITY EDUCATION
5 GENDER EQUALITY
6 CLEAN WATER AND SANITATION
7 AFFORDABLE AND CLEAN ENERGY
8 DECENT WORK AND ECONOMIC GROWTH
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE
10 REDUCED INEQUALITIES
11 SUSTAINABLE CITIES AND COMMUNITIES
12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER
15 LIFE ON LAND
16 PEACE, JUSTICE AND STRONG INSTITUTIONS
17 PARTNERSHIPS FOR THE GOALS
SUSTAINABLE DEVELOPMENT GOALS



UNITED NATIONS:
THE OCEAN DECADE

10 YEARS . 10 CHALLENGES . 1 OCEAN .

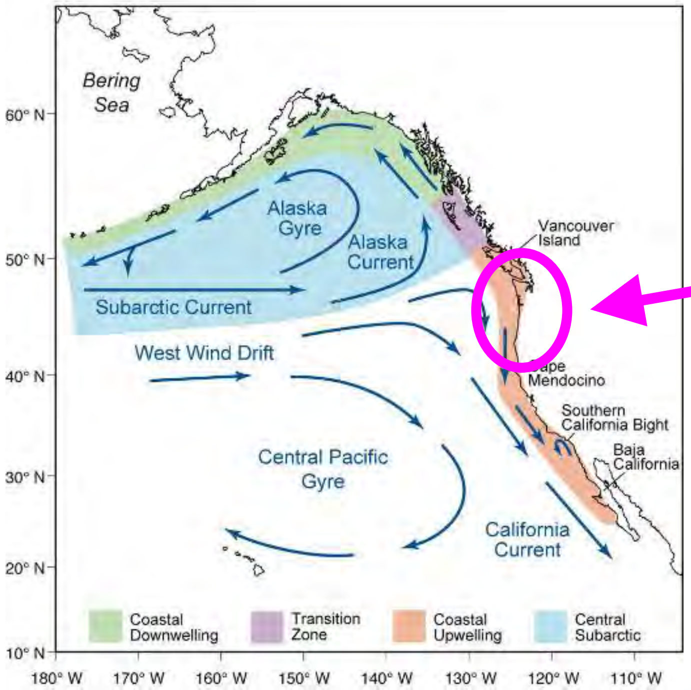
2021 2030 United Nations Decade of Ocean Science for Sustainable Development

Among the 17 other sustainable development goals set forth by the United Nations, **goal #14** is to “conserve and sustainably use the ocean, seas, and marine resources for sustainable development.“

14 LIFE BELOW WATER

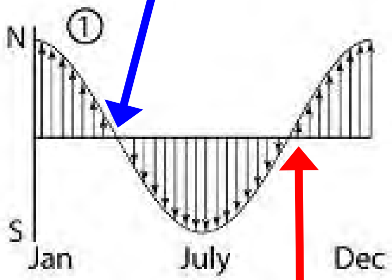


Upwelling and productivity in the Northern California Curr

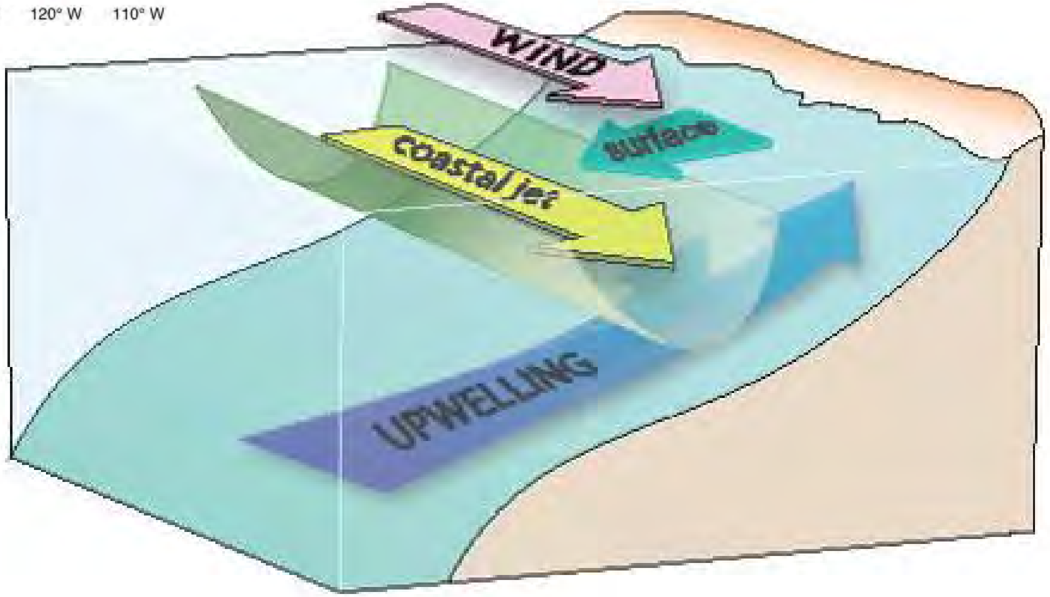


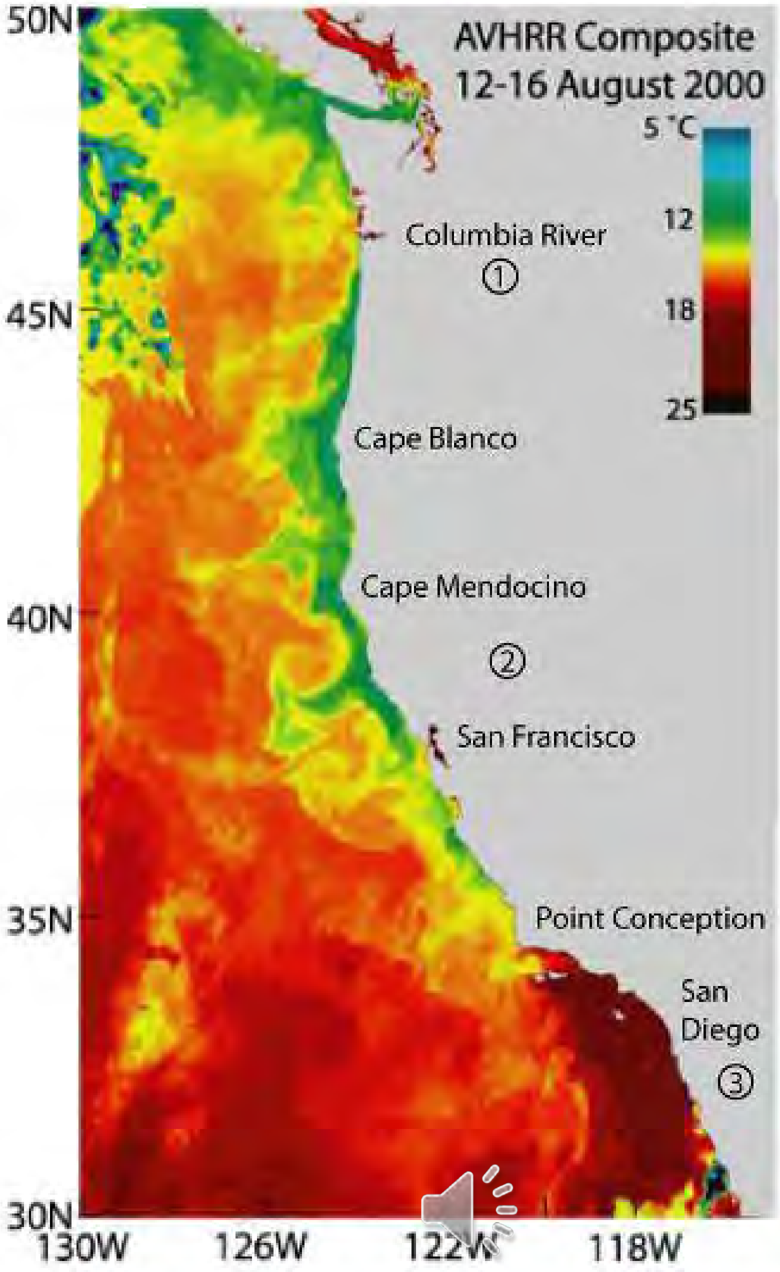
Area of interest

spring transition



fall transition





Oregon Seafood Value

Commercial Fisheries ($124M total/year)

Pink Shrimp
$27M

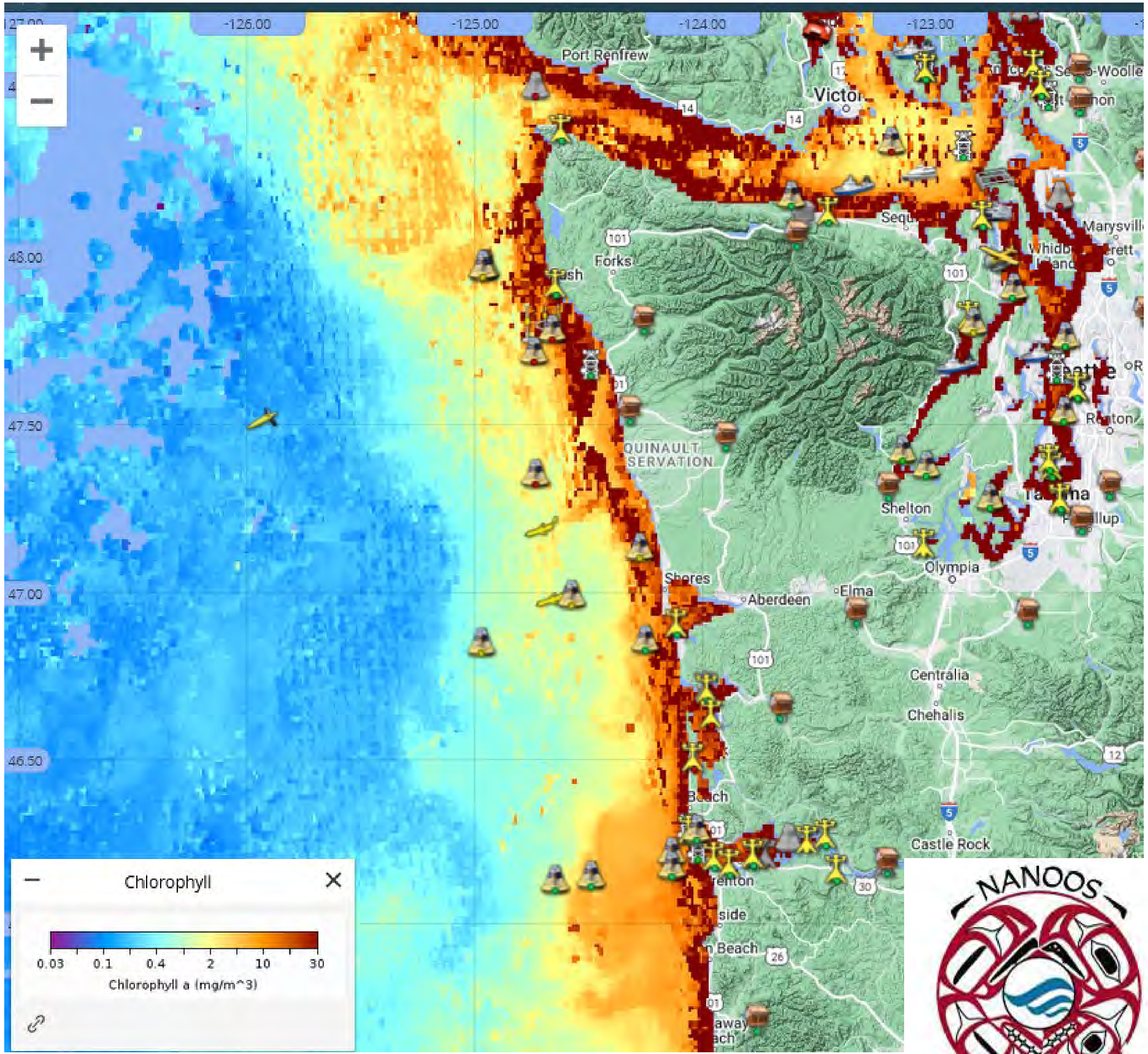
Dungeness Crab
$74M

Salmon $2M

Groundfish $21M

Annual Ex-Vessel Values
(2018)

Satellite chlorophyll from July 17, 2022

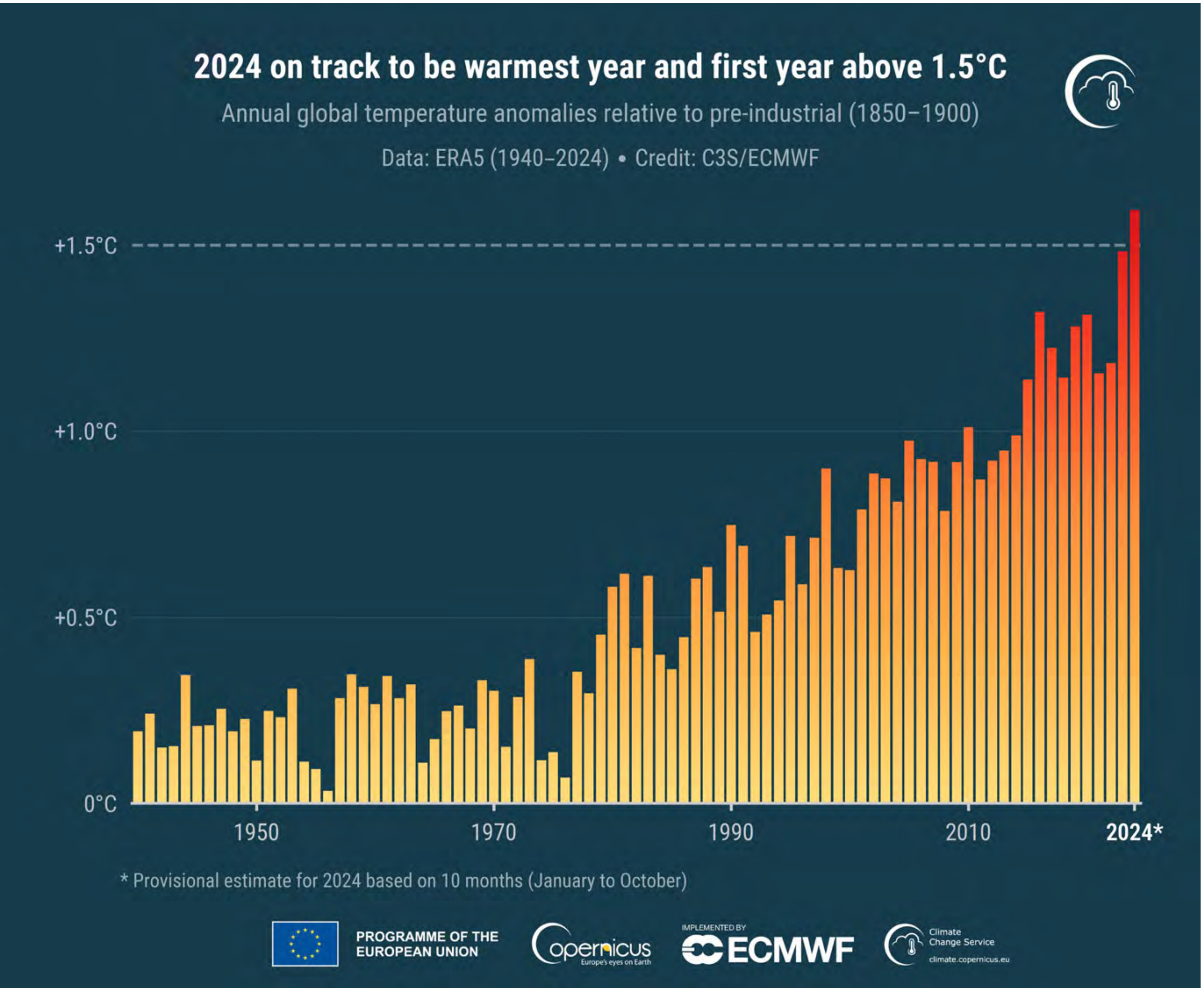


http://nvs.nanoos.org/Explorer

What changes are we seeing in the ocean?

What changes are we seeing in the ocean?

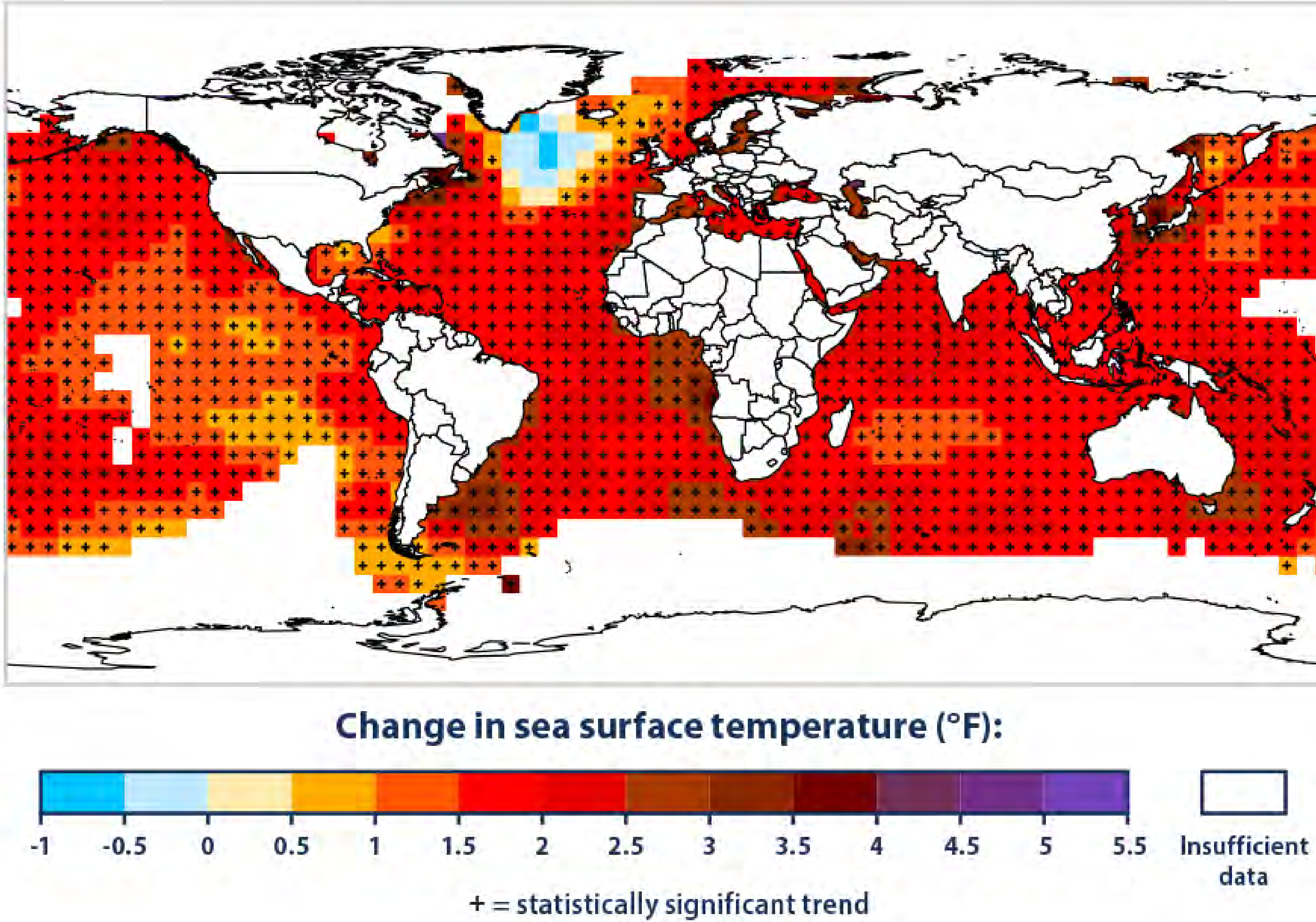
- **The atmosphere and ocean are heating up**



Paris Agreement
(signed Dec 2015)

Hold "the increase in the global average temperature to well below **2°C** above pre-industrial levels" and pursue efforts "to limit the temperature increase to **1.5°C** above pre-industrial levels."

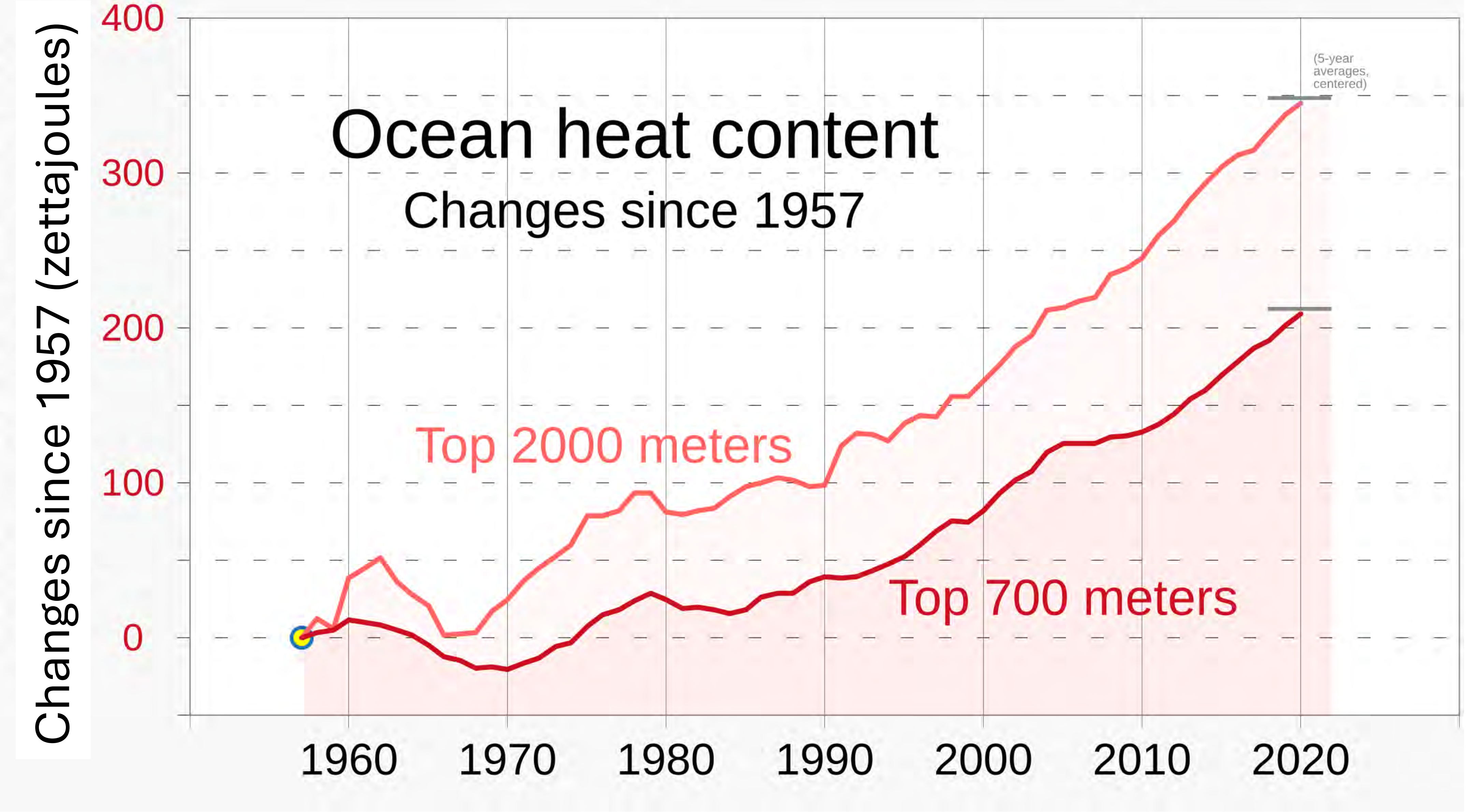
Sea Surface Temperature change from 1901 to 2022



Credit: NOAA 2023

Ocean warming is penetrating deep into the ocean

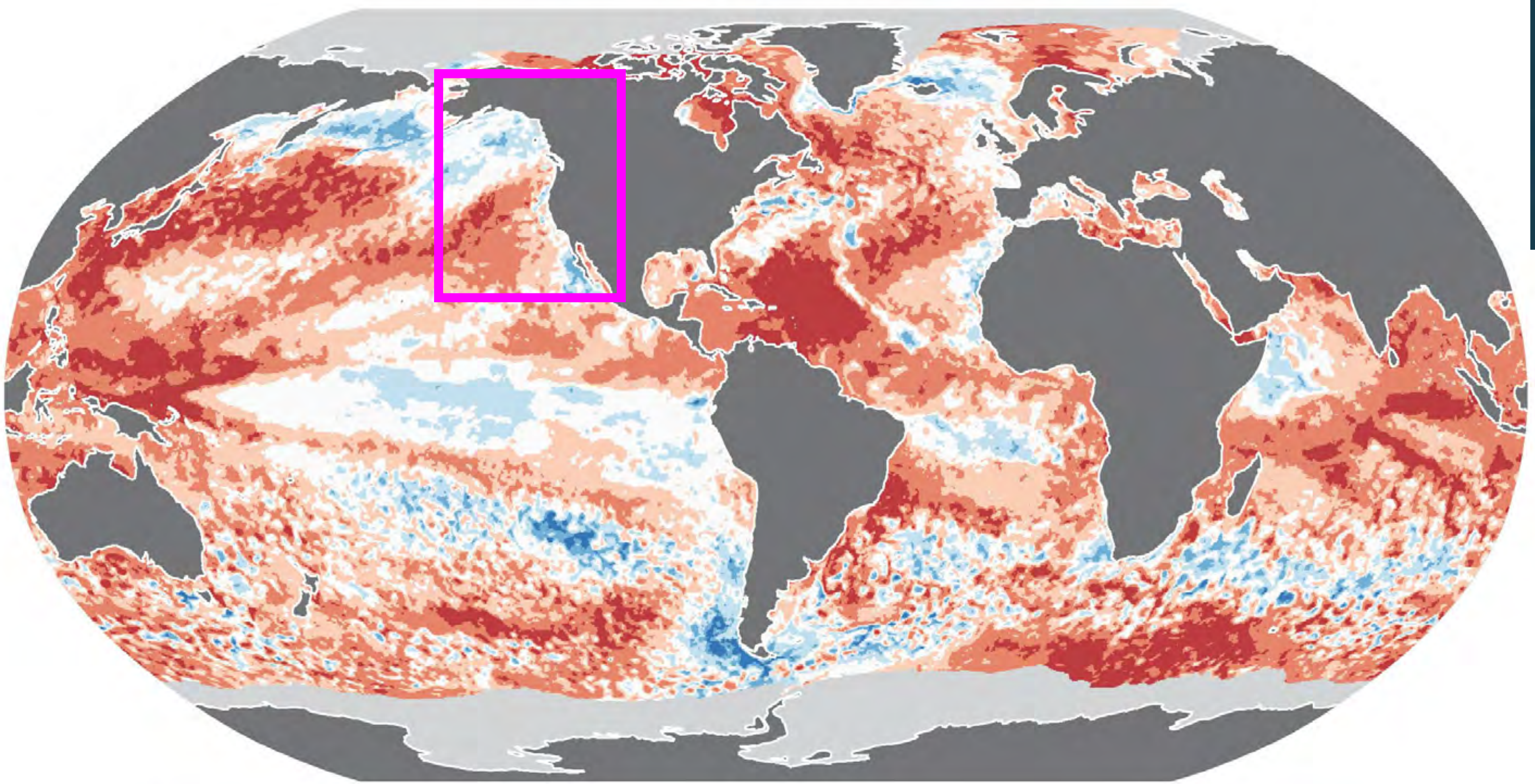
mega = 10^6
giga = 10^9
tera = 10^{12}
peta = 10^{15}
exa = 10^{18}
zetta = 10^{21}

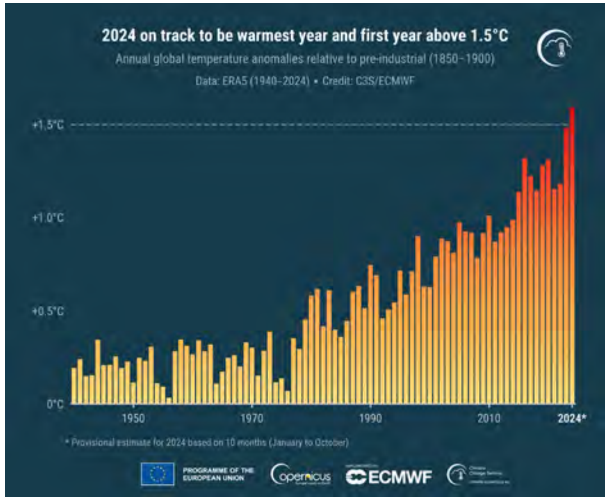


(https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content

Anomalies and extremes in sea surface temperature in October 2024

Data: ERA5 1979–2024 • Reference period: 1991–2020 • Credit: C3S/ECMWF





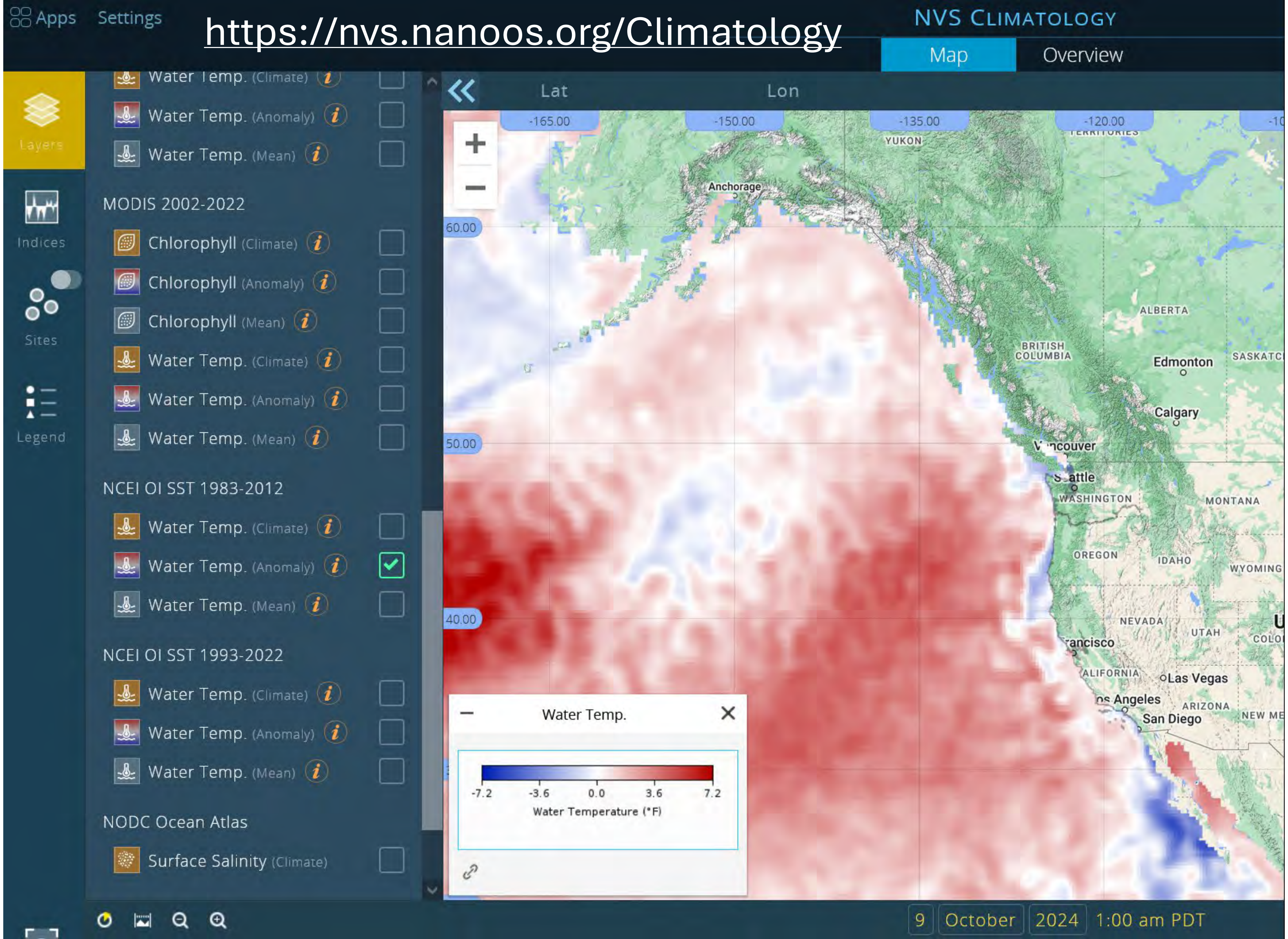
Sea ice & ice shelves | Coolest | Much cooler than average | Cooler than average | Near average | Warmer than average | Much warmer than average | Warmest

PROGRAMME OF THE EUROPEAN UNION

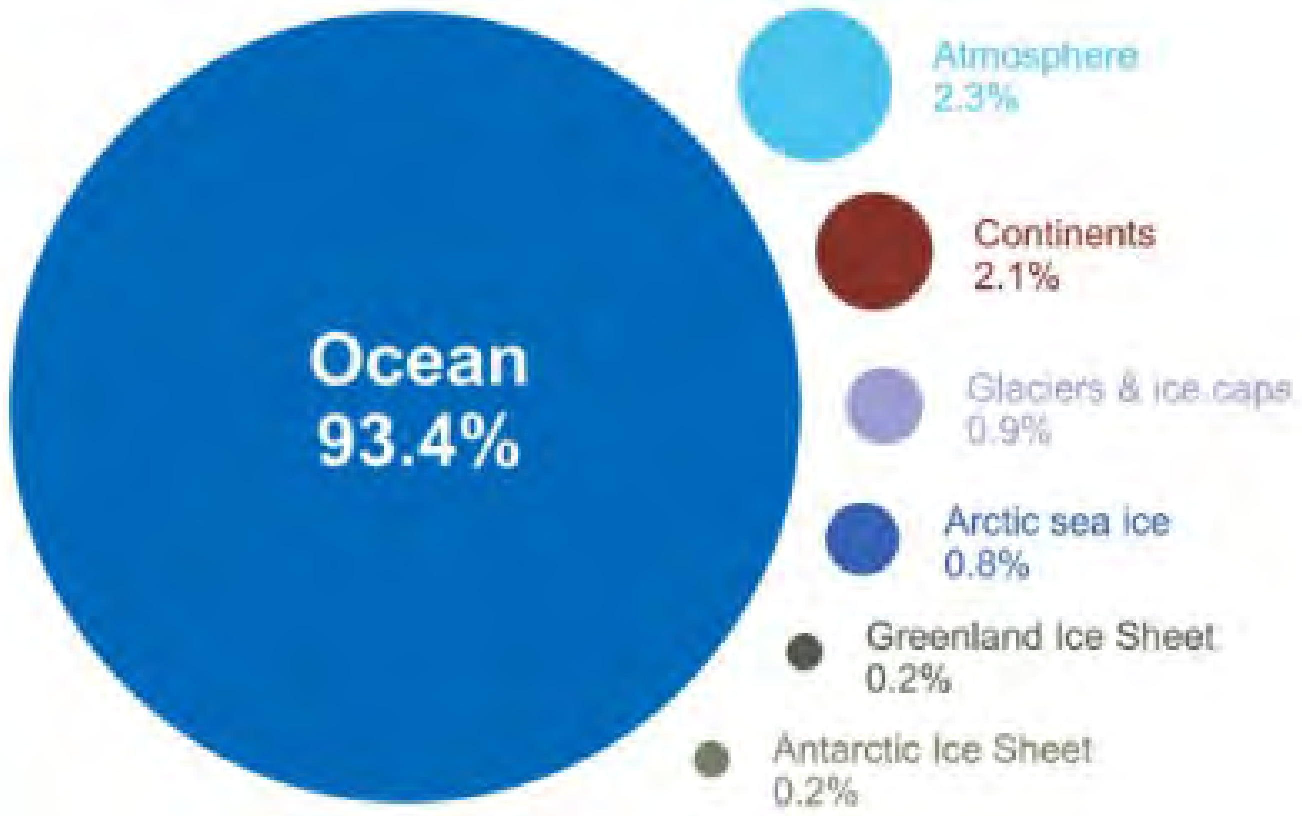
Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Climate Change Service climate.copernicus.eu https://nvs.nanoos.org/Climatology



Over 90% of the extra heat on our planet is going into the ocean!

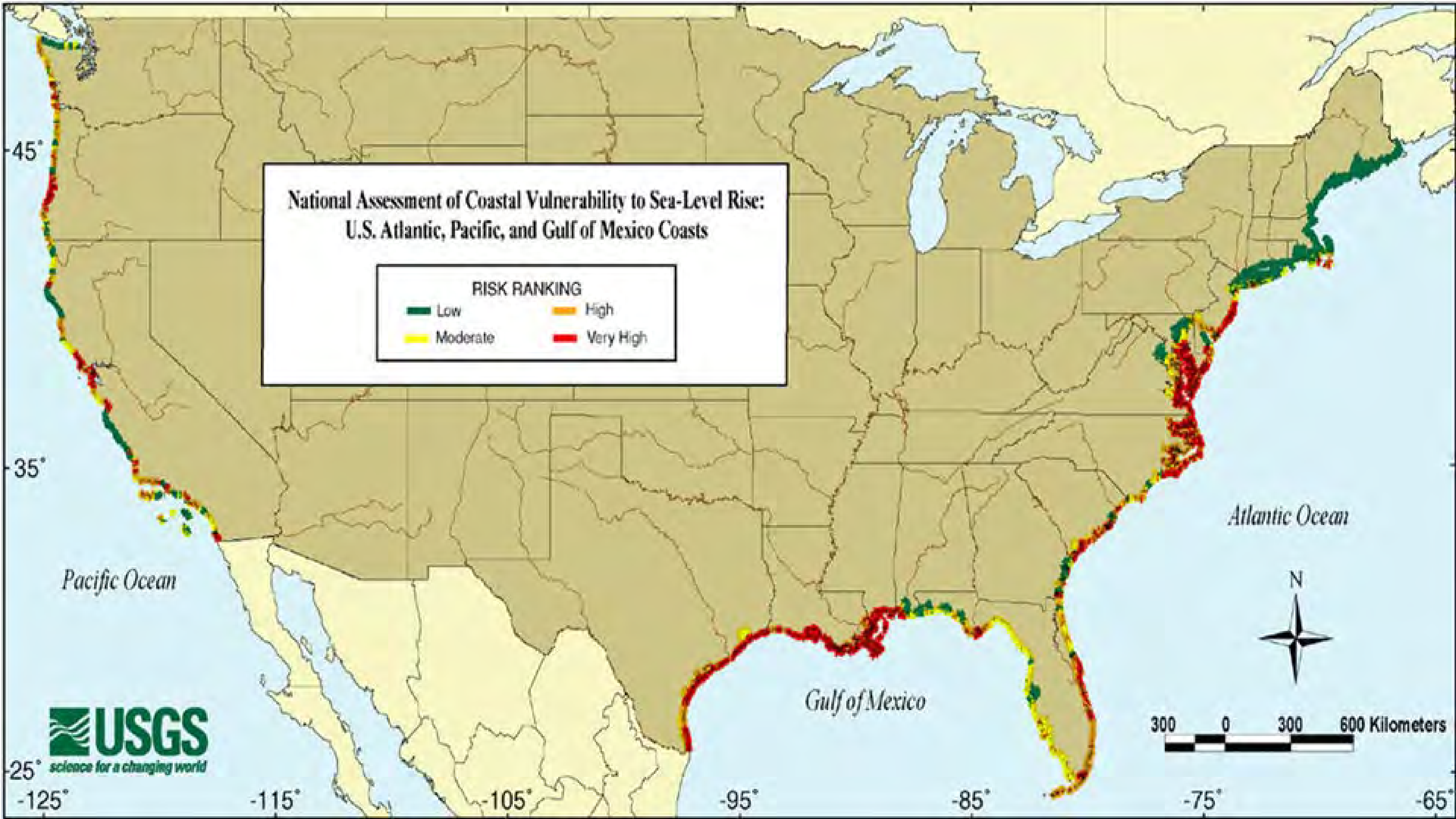


The ocean is doing us a huge favor by absorbing excess greenhouse warming heat … but it comes at a cost

Credit: Adapted from https //skepticalscience.com/Infographic-on-where-global-warming-is-going.html

What changes are we seeing in the ocean?

- The atmosphere and ocean are heating up
- **Sea levels are rising**



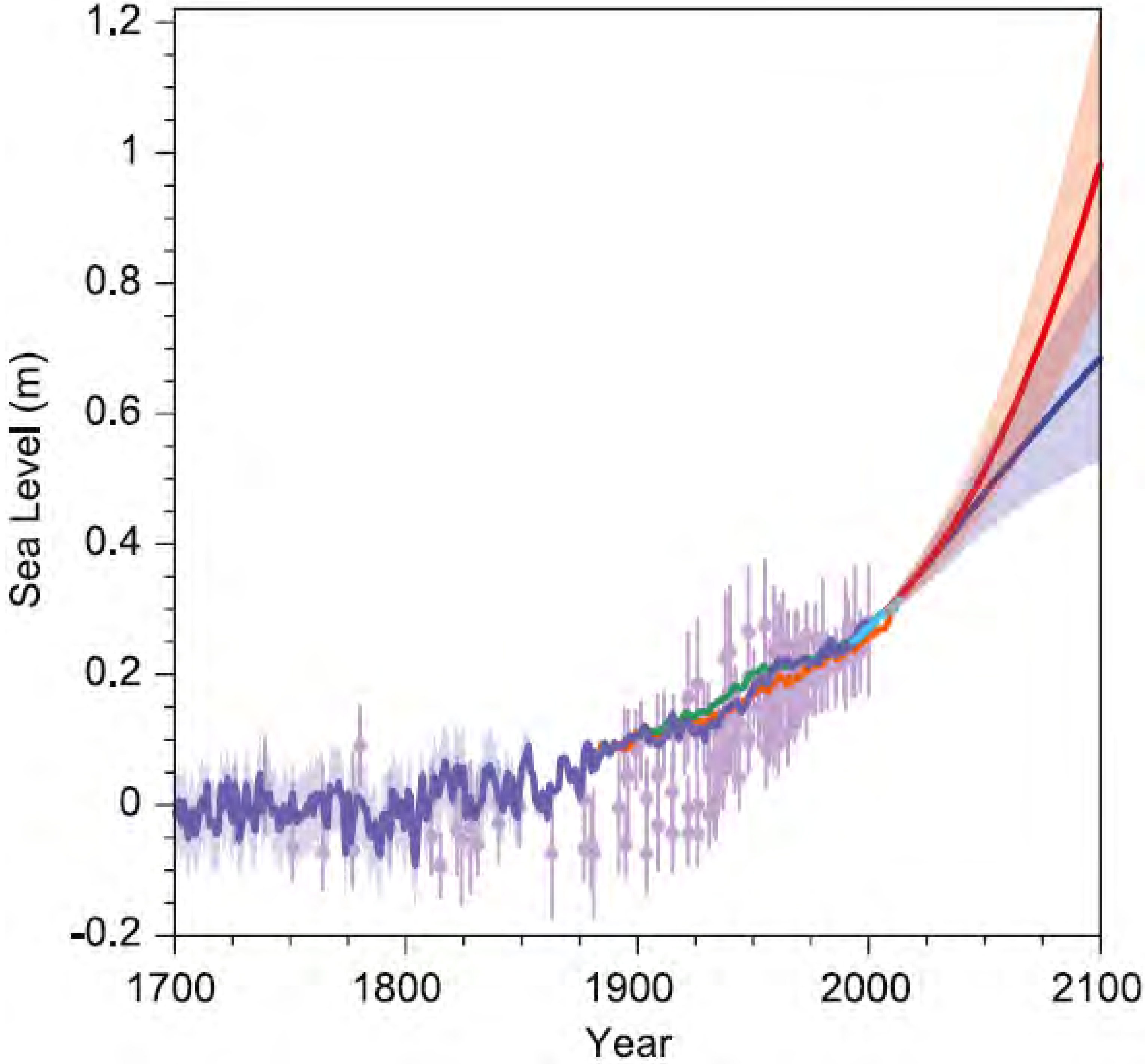
National Assessment of Coastal Vulnerability to Sea-Level Rise:
U.S. Atlantic, Pacific, and Gulf of Mexico Coasts
RISK RANKING
Low
High
Moderate
Very High
Pacific Ocean
Atlantic Ocean
Gulf of Mexico
N
300 0 300 600 Kilometers
USGS
science for a changing world
45°
35°
25°
-125°
-115°
-105°
-95°
-85°
-75°
-65°

Sea Level Rise

Historic and projections

Rise from thermal expansion and ice melting

Does not include collapse of polar ice sheets that would result in tens of meters sea level rise



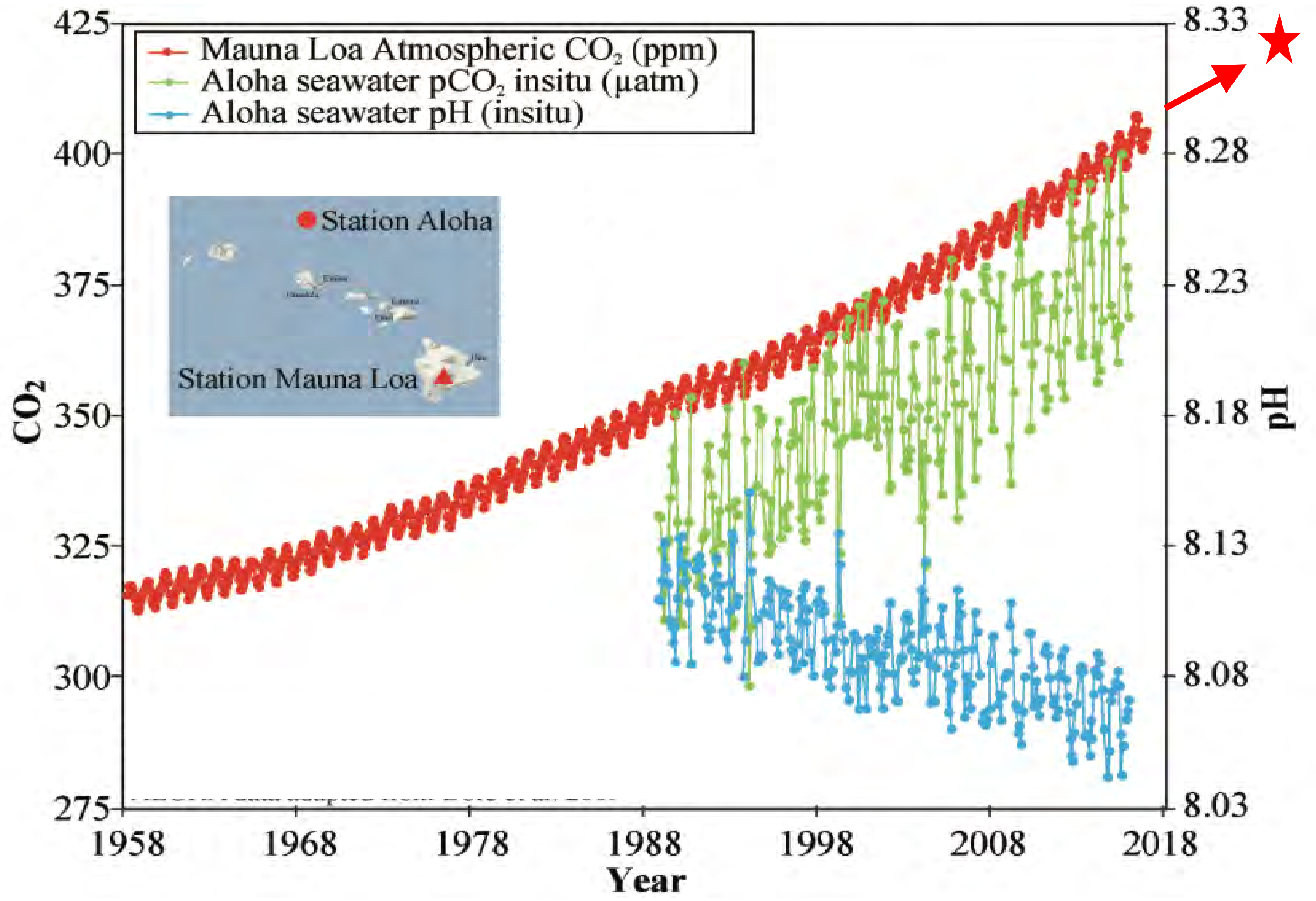
Source: IPCC AR5 Fig. 13.27

What changes are we seeing in the ocean?

- The atmosphere and ocean are heating up
- Sea levels are rising
- **The ocean is becoming more acidic**

Ocean Acidification … need a whole other talk for this …

Sea surface CO_2 and pH time series, Hawaii



2024 value is 422 ppm

Remember "350.org" ?

CO_2 in atmosphere

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

dissolved carbon dioxide

carbonic acid

bicarbonate ions

$$H^+ + CO_3^{2-} \rightarrow HCO_3^-$$

carbonate ion

Ocean Carbon Chemistry

consumption of carbonate ions impedes calcification

CO_2 in atmosphere

$$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

dissolved carbon dioxide

carbonic acid

bicarbonate ions

$$H^+ + CO_3^{2-} \rightarrow HCO_3^-$$

carbonate ion

H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+ H^+

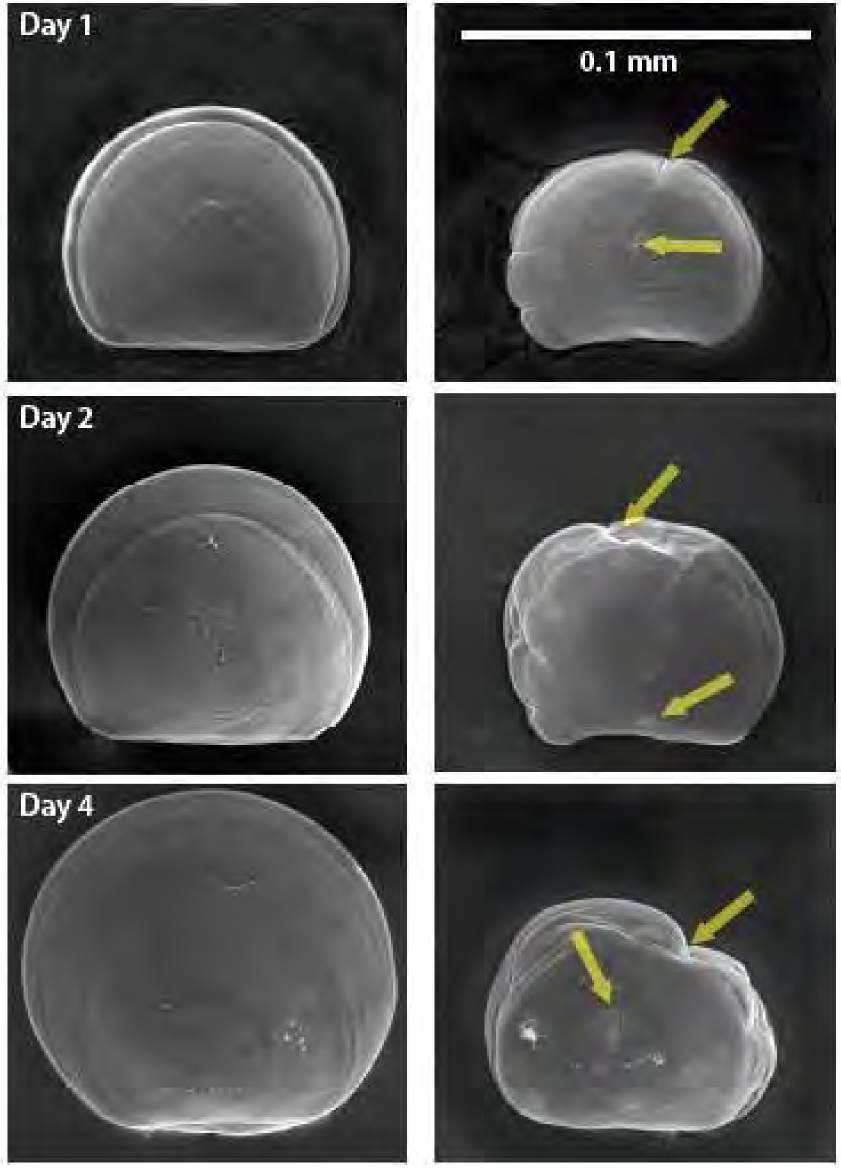
Ocean Carbon Chemistry

consumption of carbonate ions impedes calcification

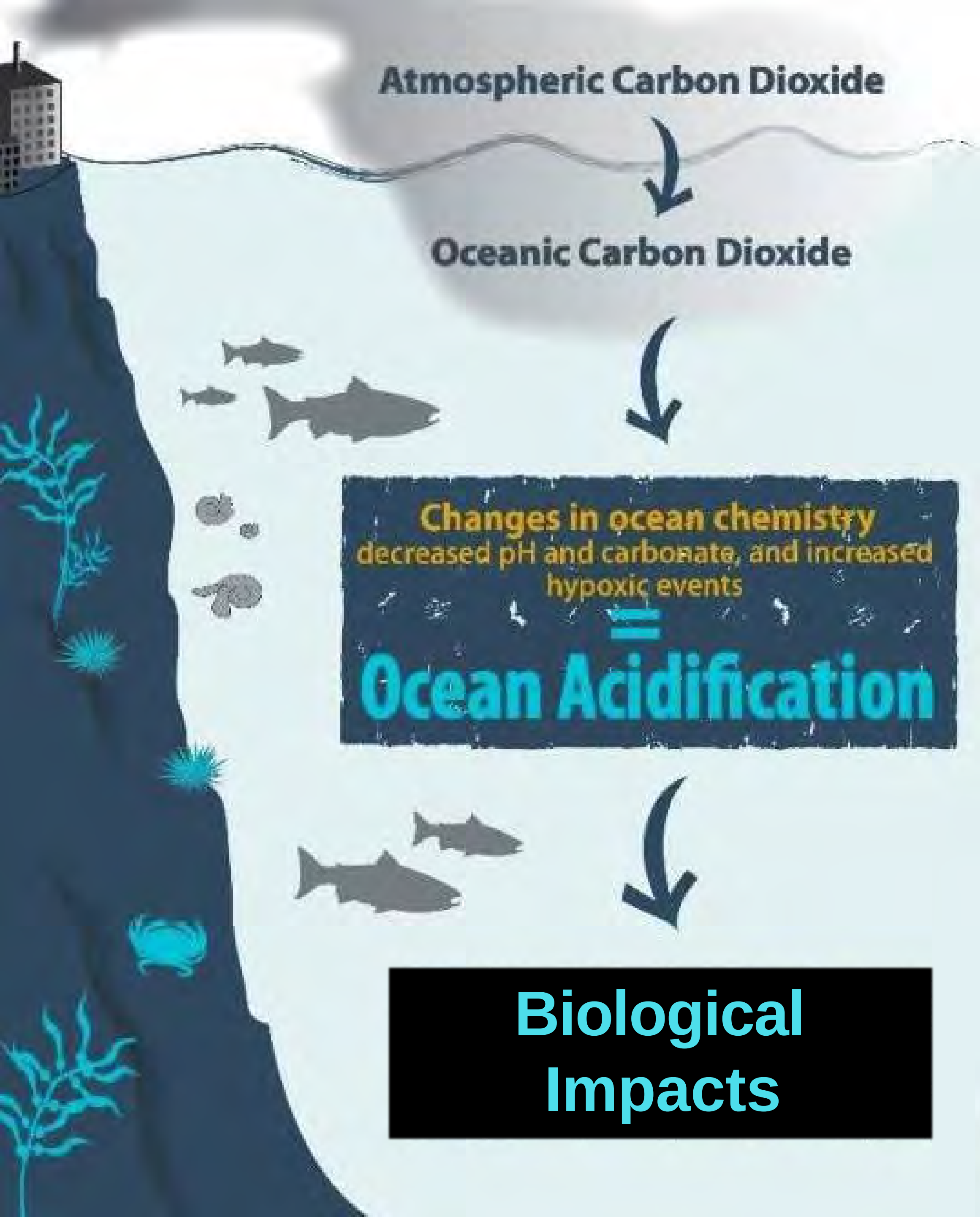
Acidification inhibits shell growth

Whiskey Creek Shellfish Hatchery
Netarts Bay, Oregon

Three examples of damage to oyster larvae from ocean water acidity and low available carbonate, compared with healthy larvae on left. Micrograph by OSU



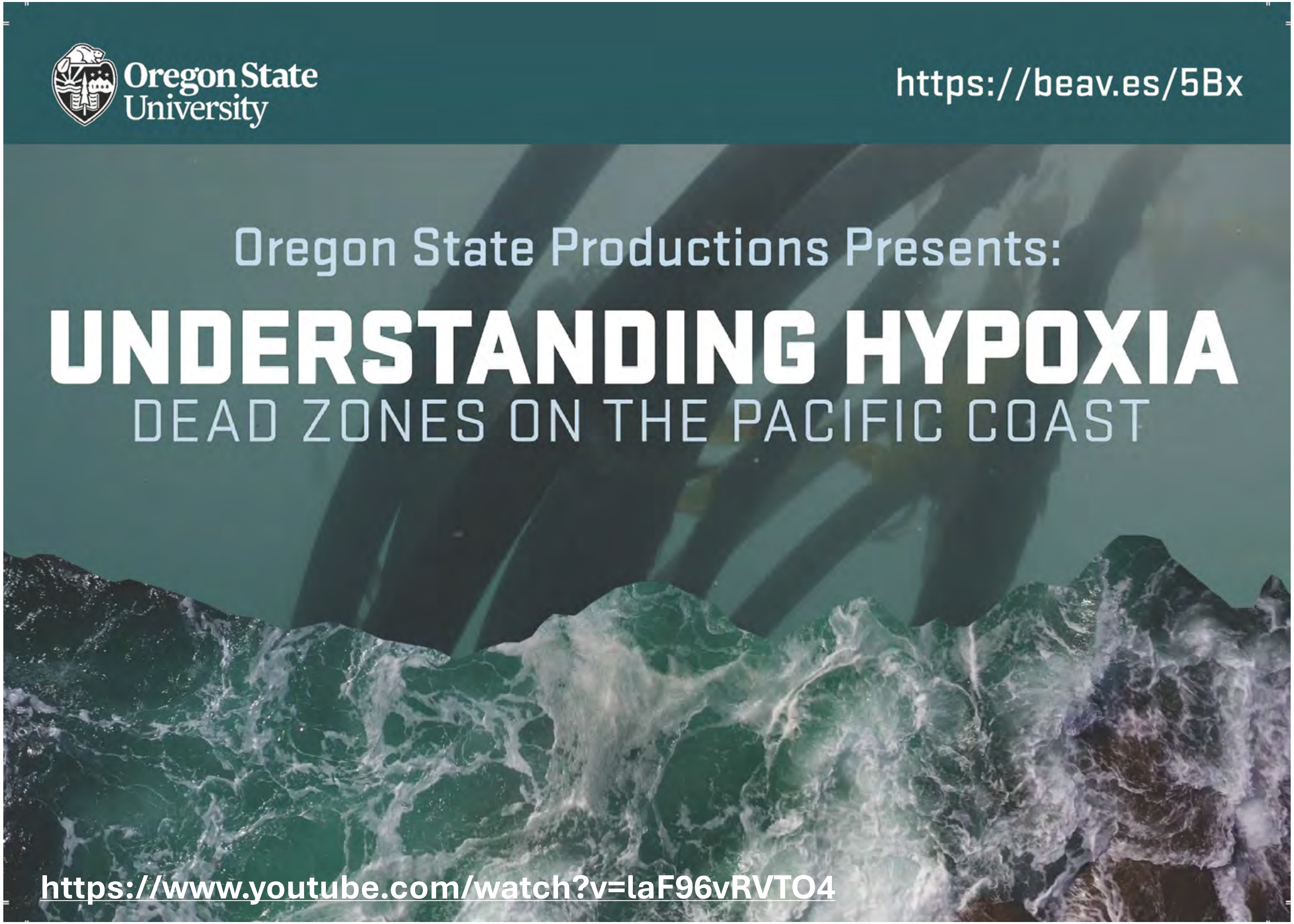
grown in acidified water



Economic Impacts
Commercial & Sport

What changes are we seeing in the ocean?

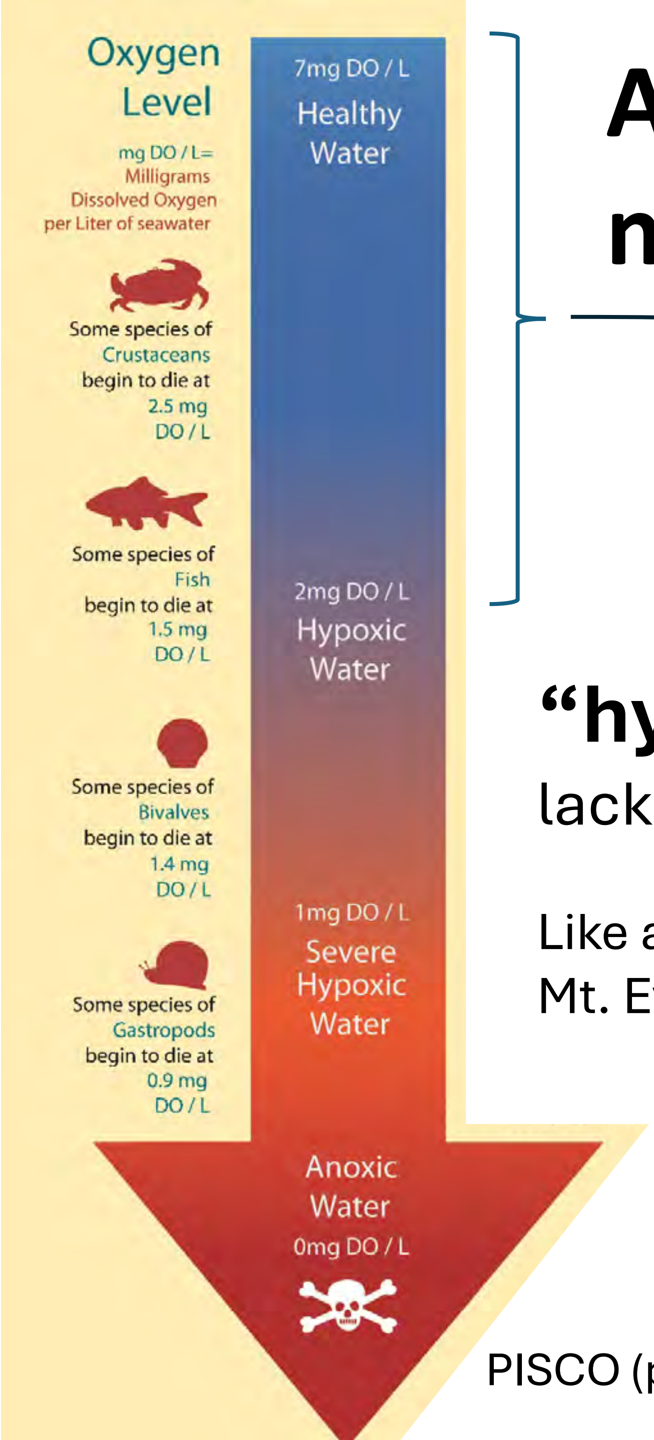
- The atmosphere and ocean are heating up
- Sea levels are rising
- The ocean is becoming more acidic
- **The ocean is losing oxygen**



https://www.youtube.com/watch?v=laF96vRVTO4

Funding provided by:
NOAA's National Centers for Coastal Ocean Science

Additional footage and imagery provided by:
ODFW
Quinault Dept. of Fisheries



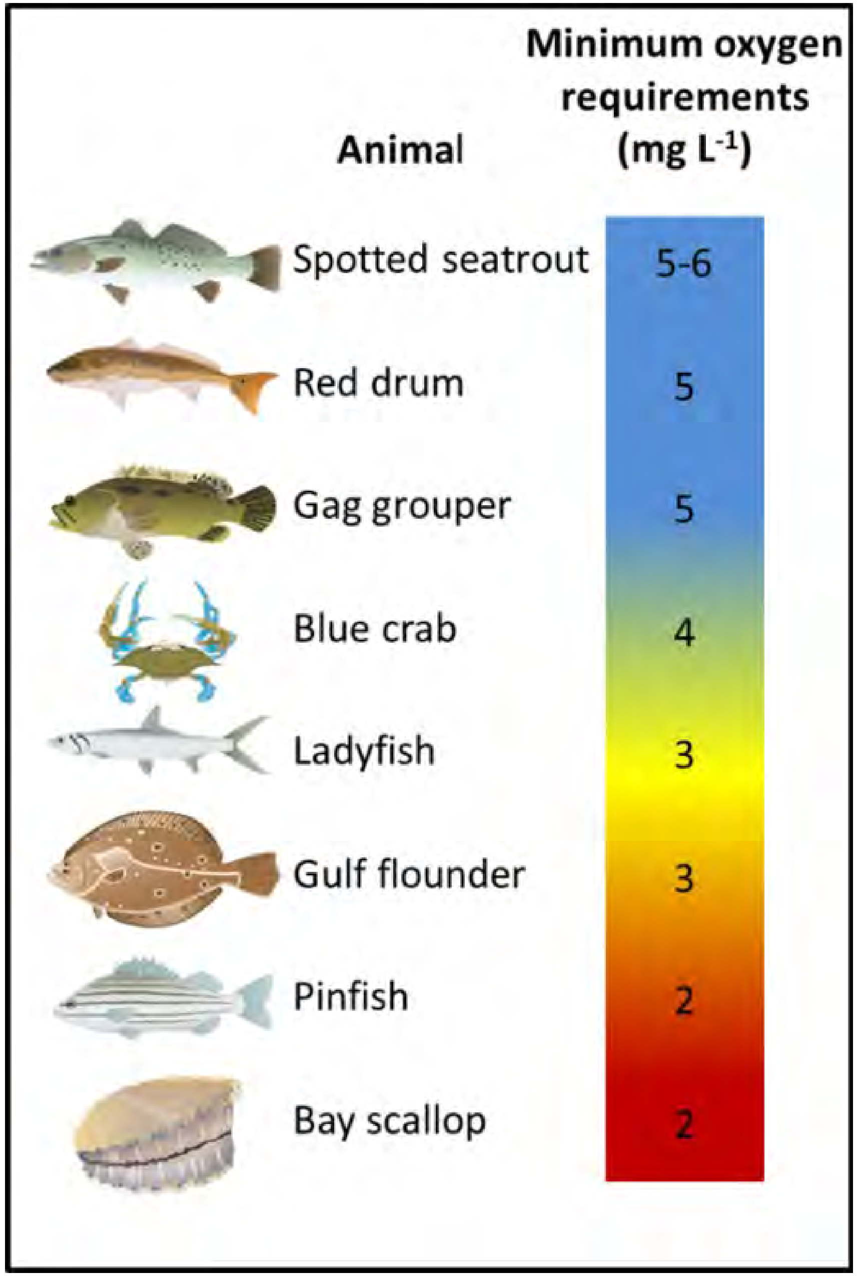
All marine animals need oxygen to live

"hypoxia"

lack of oxygen

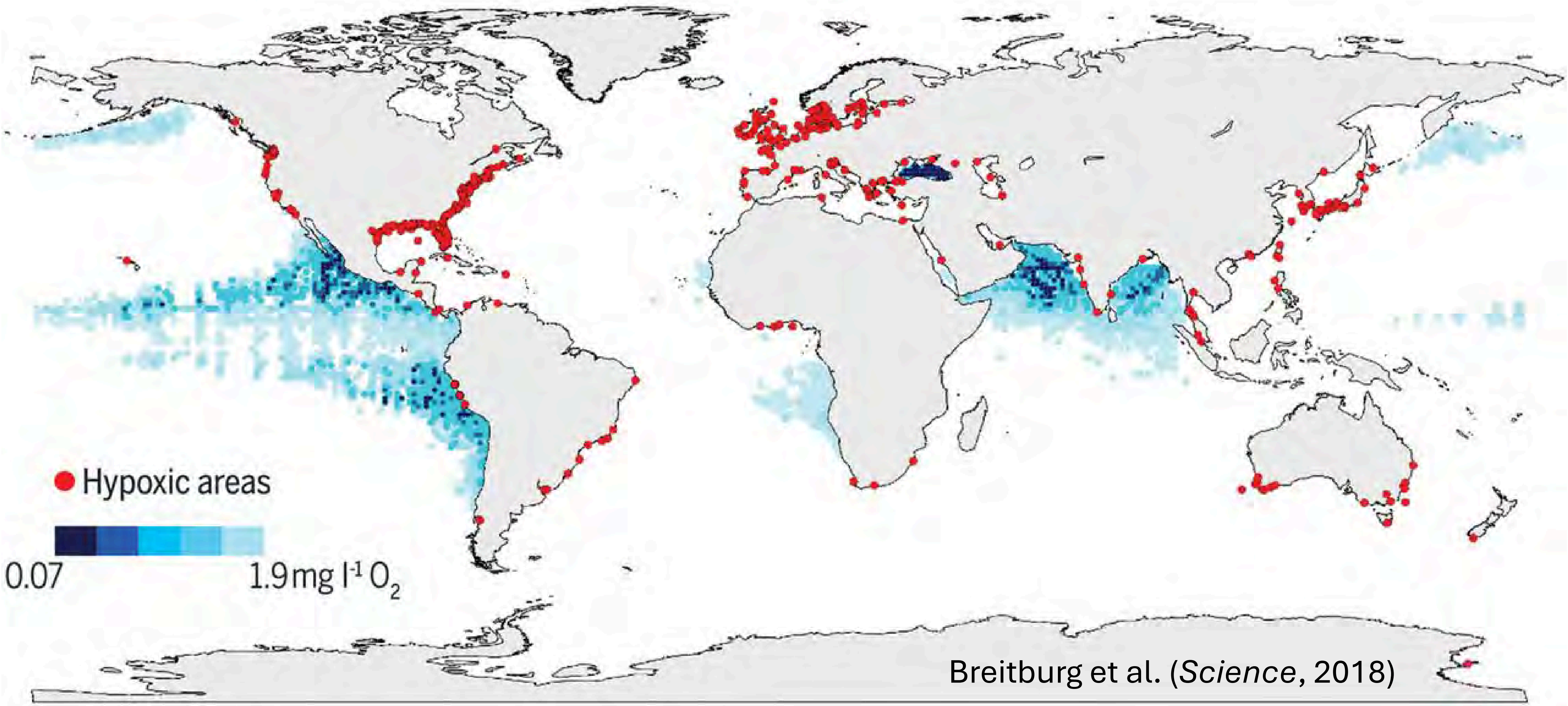
Like amount of oxygen at top of Mt. Everest or higher

PISCO (piscoweb.org)

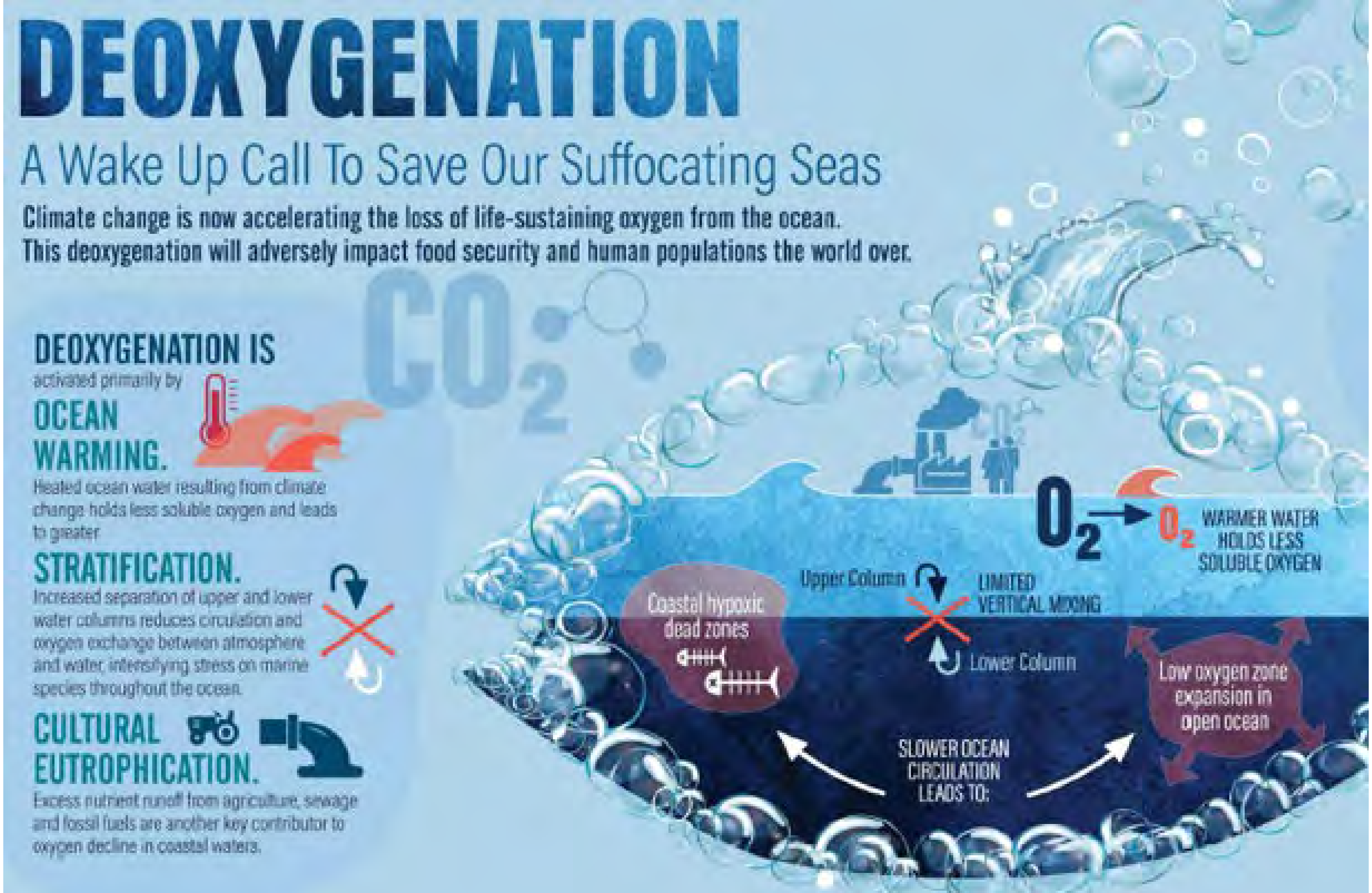


Sanibel -Captiva Conservation Foundation, SW Florida

Oxygen concentrations in both the open ocean and coastal waters have been declining since at least the middle of the 20th century. This oxygen loss, or **deoxygenation**, is one of the most important changes occurring in an ocean increasingly modified by human activities



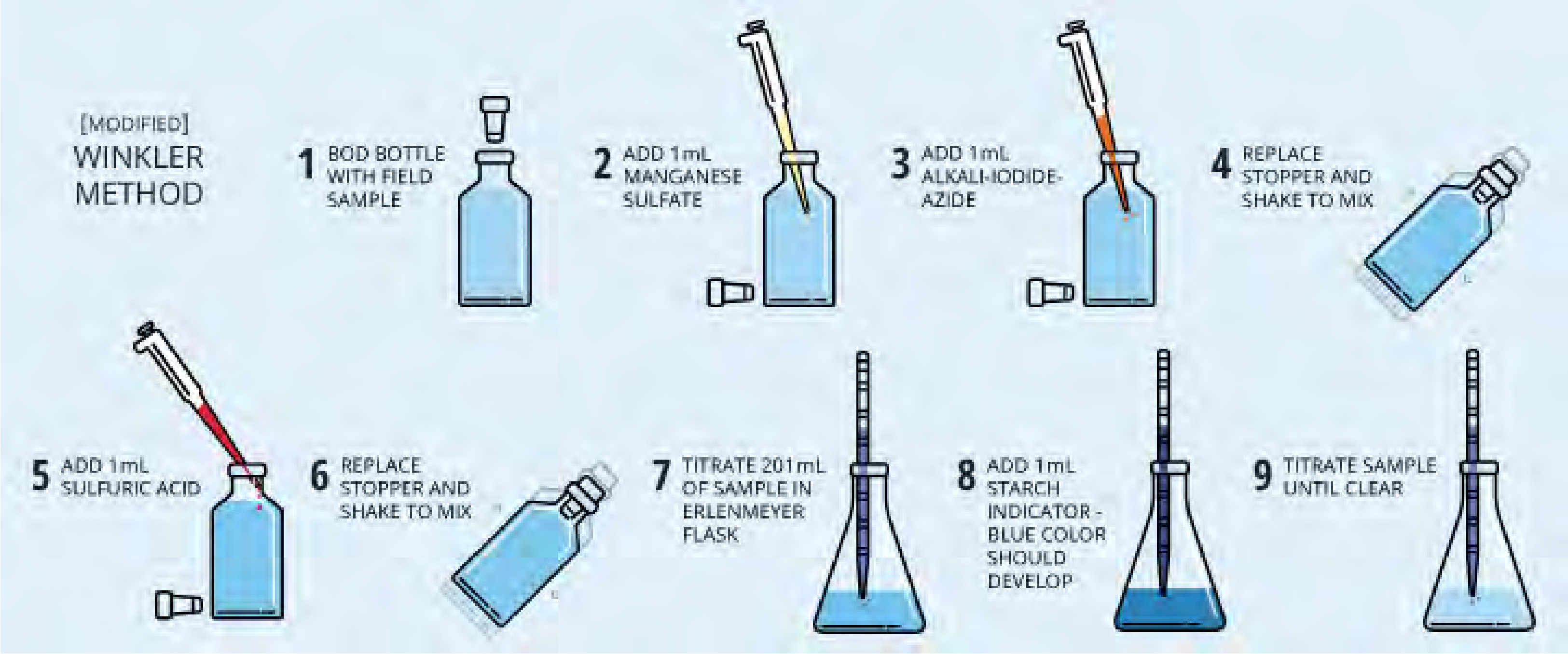
Breitburg et al. (*Science*, 2018)



Source: IUCN, "Ocean deoxygenation: Everyone's problem" report (December 2019)

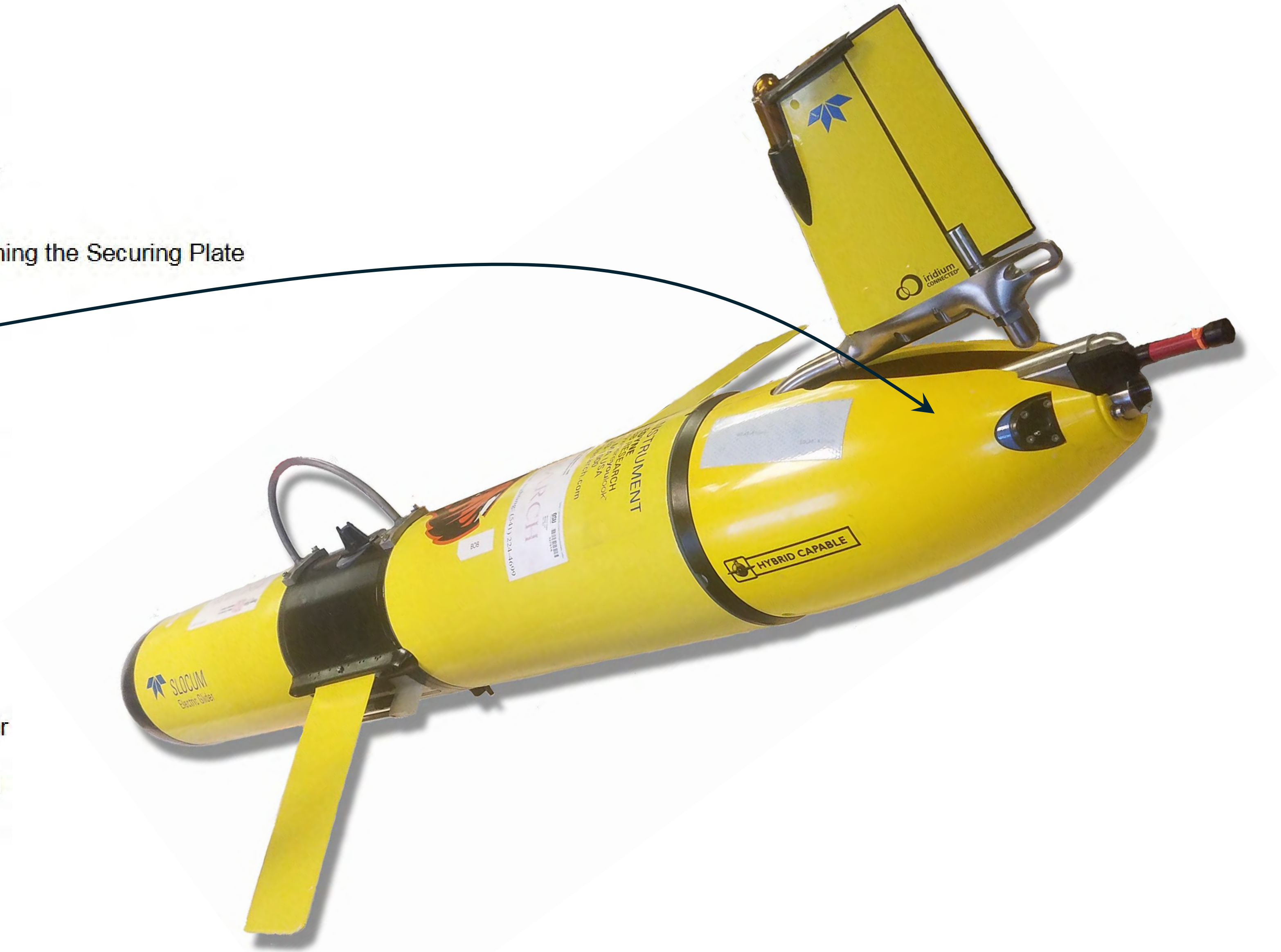
How do we measure the amount of dissolved oxygen in the water?

The “old fashioned” way, circa 1950 ...



How do we measure the amount of dissolved oxygen in the water?

The modern, electronic way, circa 2000 ...



More about underwater gliders …

Made possible by a convergence of technologies …

- 4” computer and fast chips
- GPS
- Iridium satellite cell phone
- flash memory

battery and power advances
still needed …

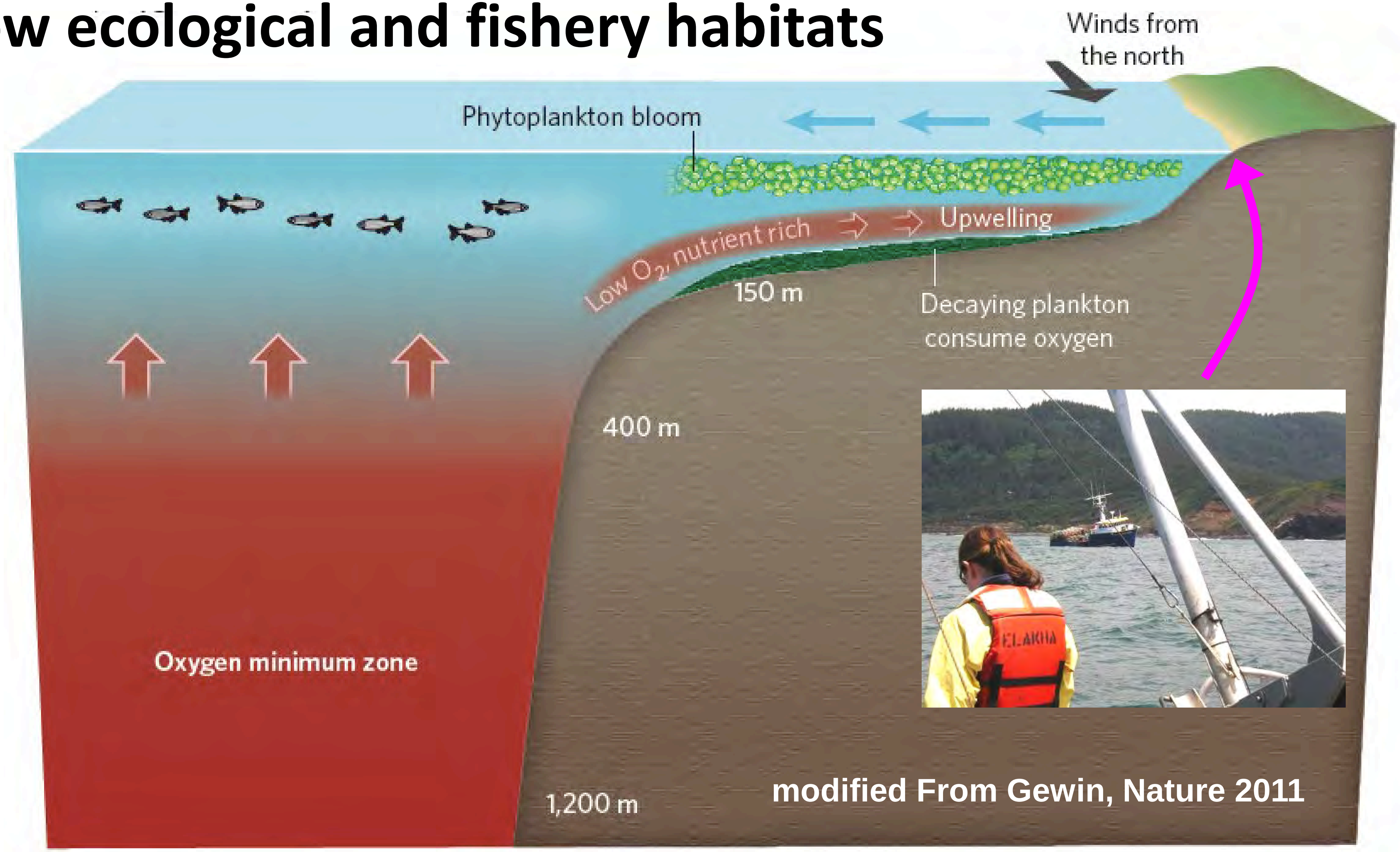
temperature
salinity
pressure (depth)
dissolved oxygen
chlorophyll fluorescence (phytoplankton)
Colored Dissolved Organic Matter (river input)
light backscatter (sediments)
depth-averaged water velocity

Launching an underwater glider just south of the Columbia River, Oregon

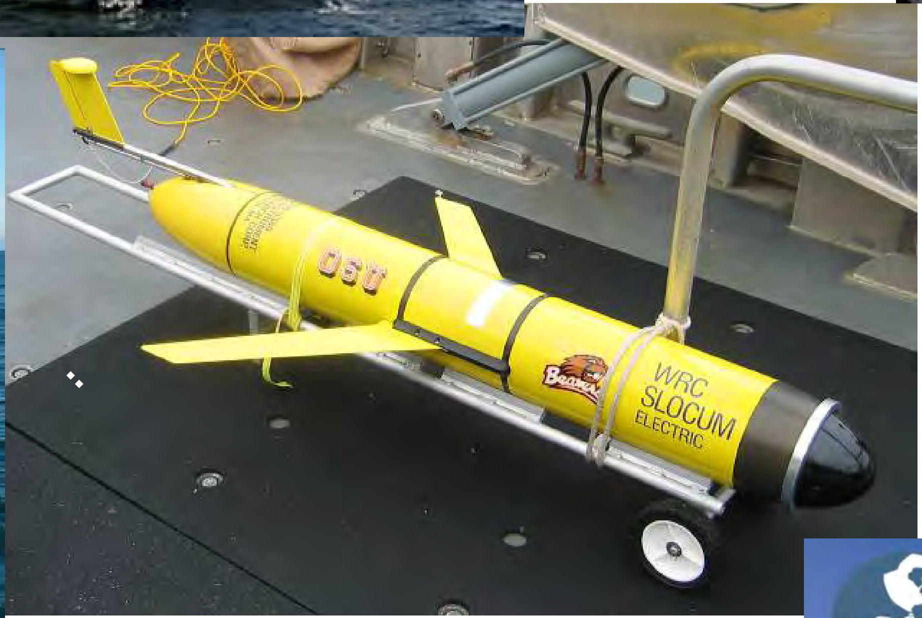
August 2018

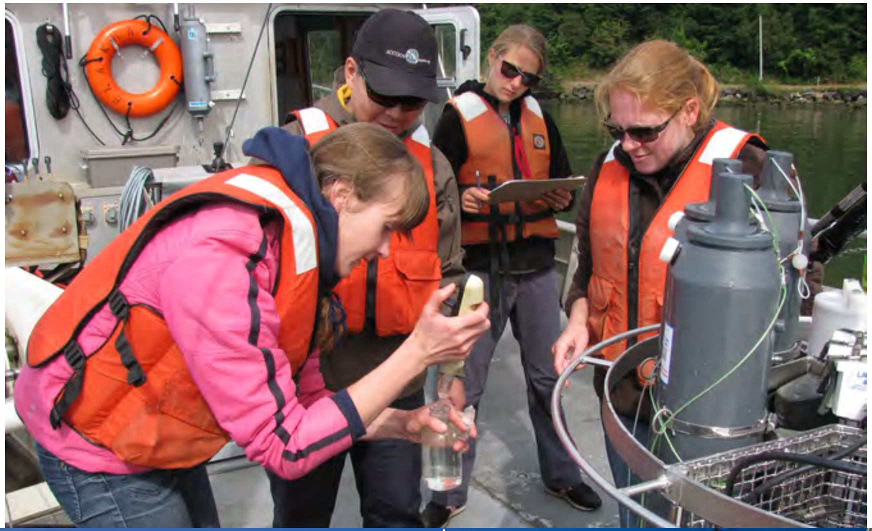
Credit:
Kristian Foden-Vencil, Oregon Public Broad-casting

Low-oxygen (hypoxia) threatens important shallow ecological and fishery habitats



Measuring dissolved oxygen at sea





2021 was a remarkable year for at-sea sampling !!

→ Total of about 800 vertical profiles

NOAA cruises

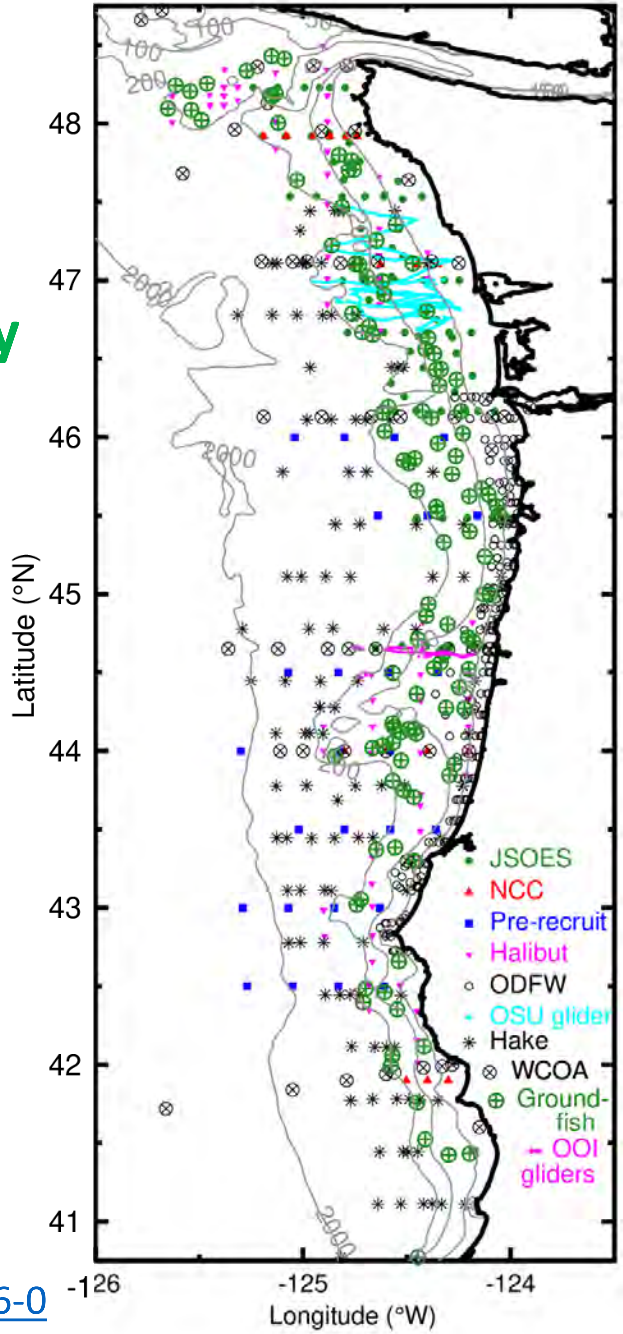
- **JSOES – Juvenile Salmon and Ocean Ecosystem Survey**
- **Pre-recruit survey**
- **NCC – Northern California Current**
- **Hake**
- **Groundfish**
- **WCOA – West Coast Ocean Acidification survey**

IPHC – International Pacific Halibut Commission

ODFW – Oregon Department of Fish and Wildlife

gliders

- **OSU WA shelf**
- **OOI – Ocean Observatories Initiative**



From Barth et al. (2024), *Nature Sci. Rep.*, **14-3798**, https://doi.org/10.1038/s41598-024-54476-0

2021 Near-bottom DO upwelling season+ average (+defined by CUI)

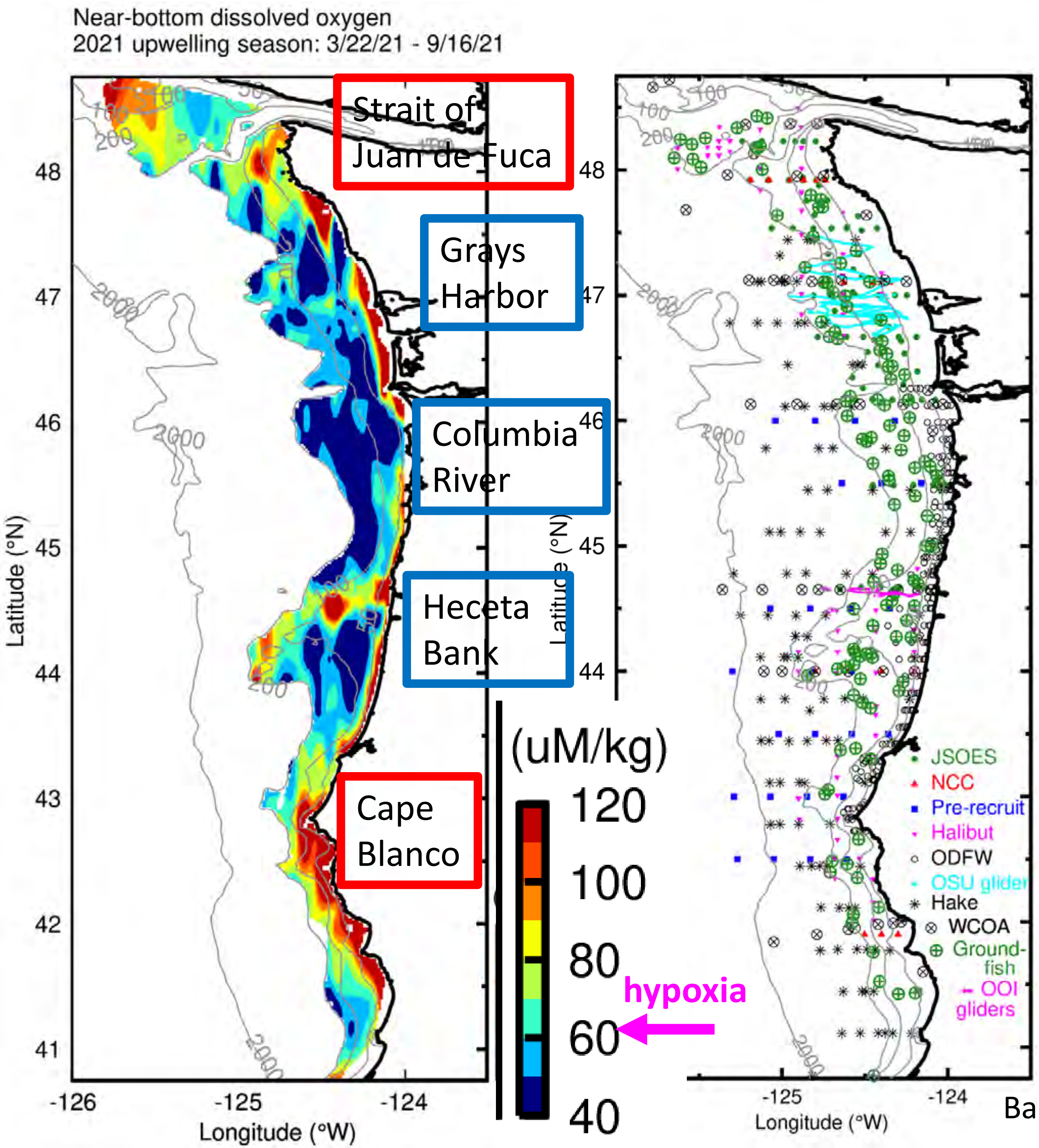
48% of shelf hypoxic (DO < 61 µM/kg)
15,500 km² (~6000 square miles)
Using 10-25 m thick bottom layer
→ **645-1612 km³**
(150-400 cubic miles)

Low-Dissolved Oxygen

- North of Grays Harbor, WA* (47N)
- South of Columbia River (46N)
- Heceta Bank* (44-45N)

High-Dissolved Oxygen

- Near the coast* (< 25-50 m water depth)
- mouth of Strait of Juan de Fuca (48N)
- south of Coos Bay/Cape Blanco* (43N)



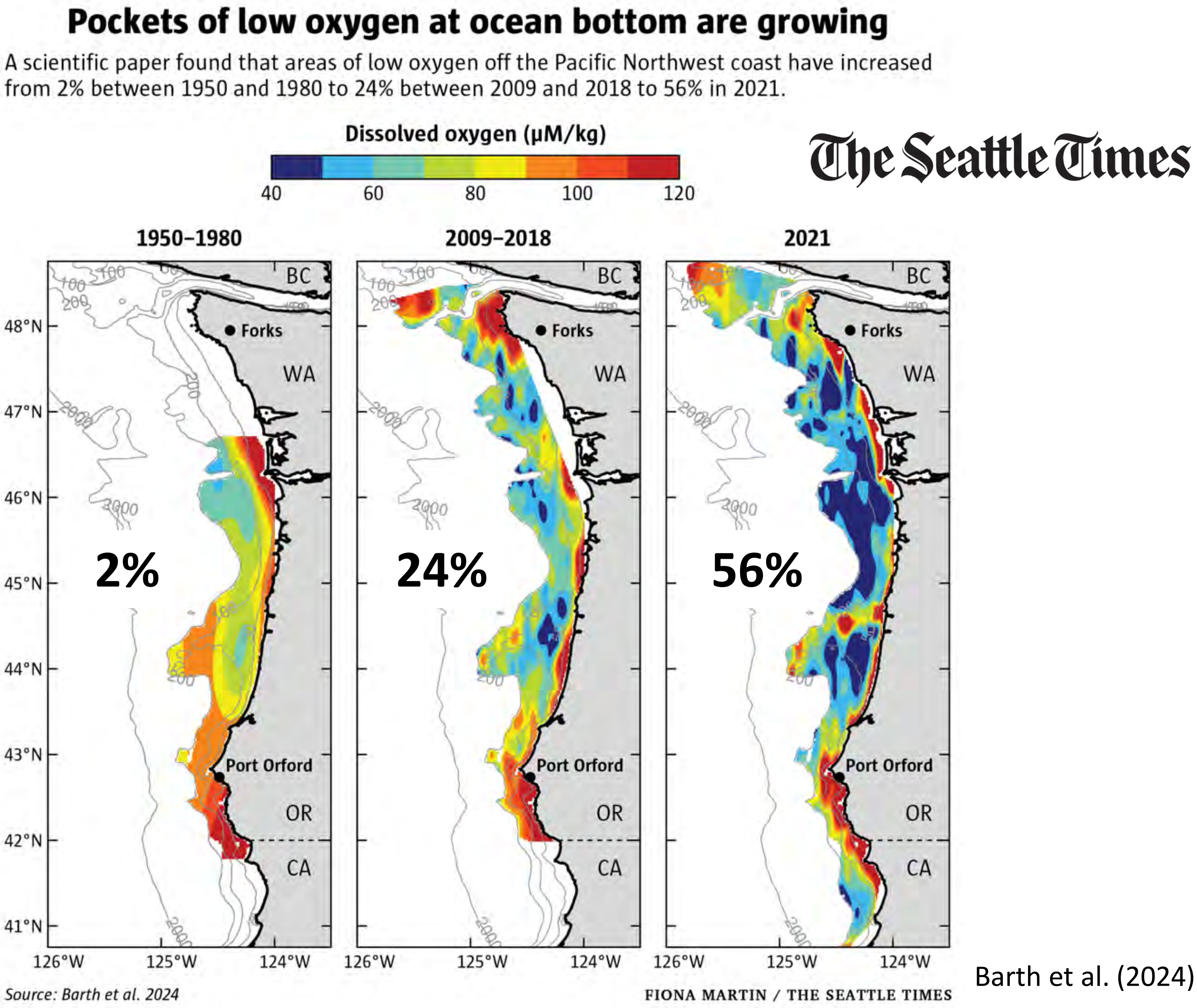
Barth et al. (2024)

Changes over time …

similar patterns suggest oceanographic mechanisms robust

but oxygen decreasing with time

Percent of shelf that is hypoxic (using common overlap area →



Barth et al. (2024)

For groundfish survey results, see Keller et al. (2017, *Marine Ecology Progress Series*) and references therein

Climate change is…

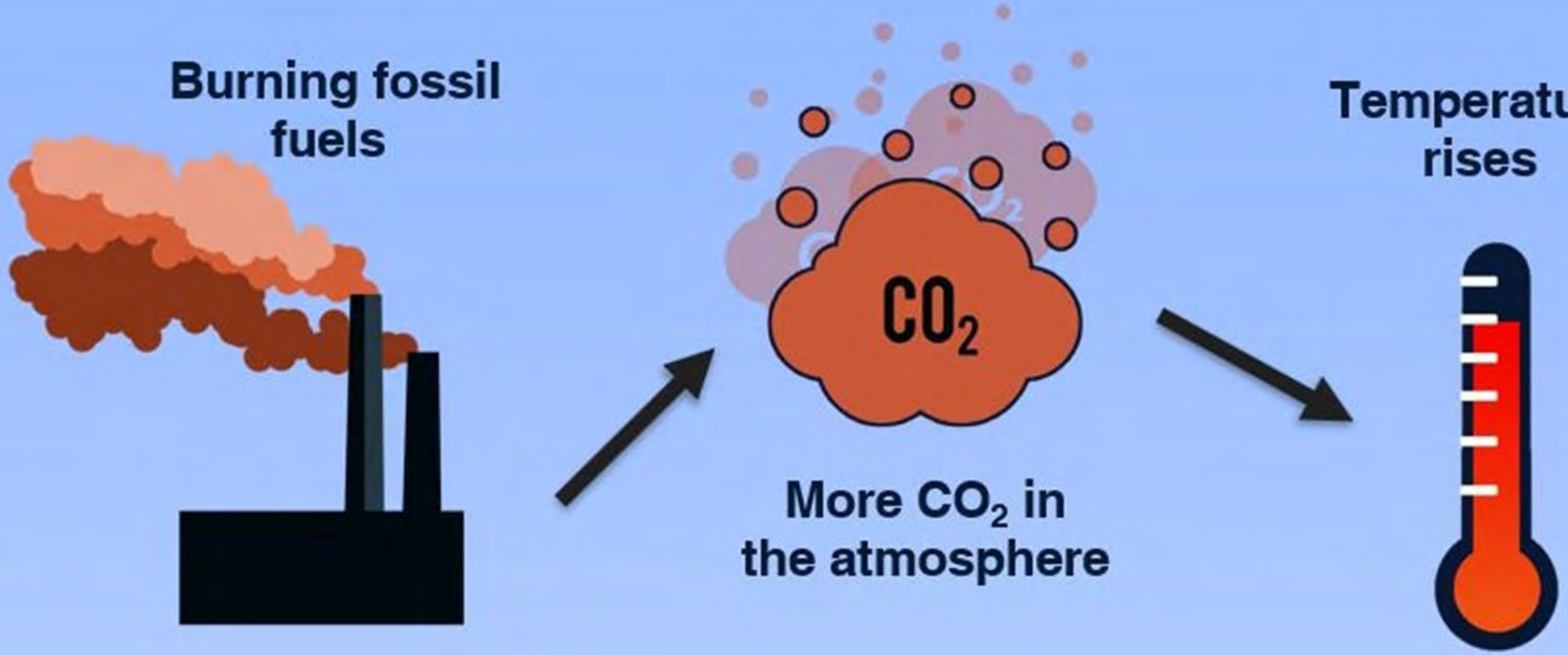
Simple

Serious

Solvable

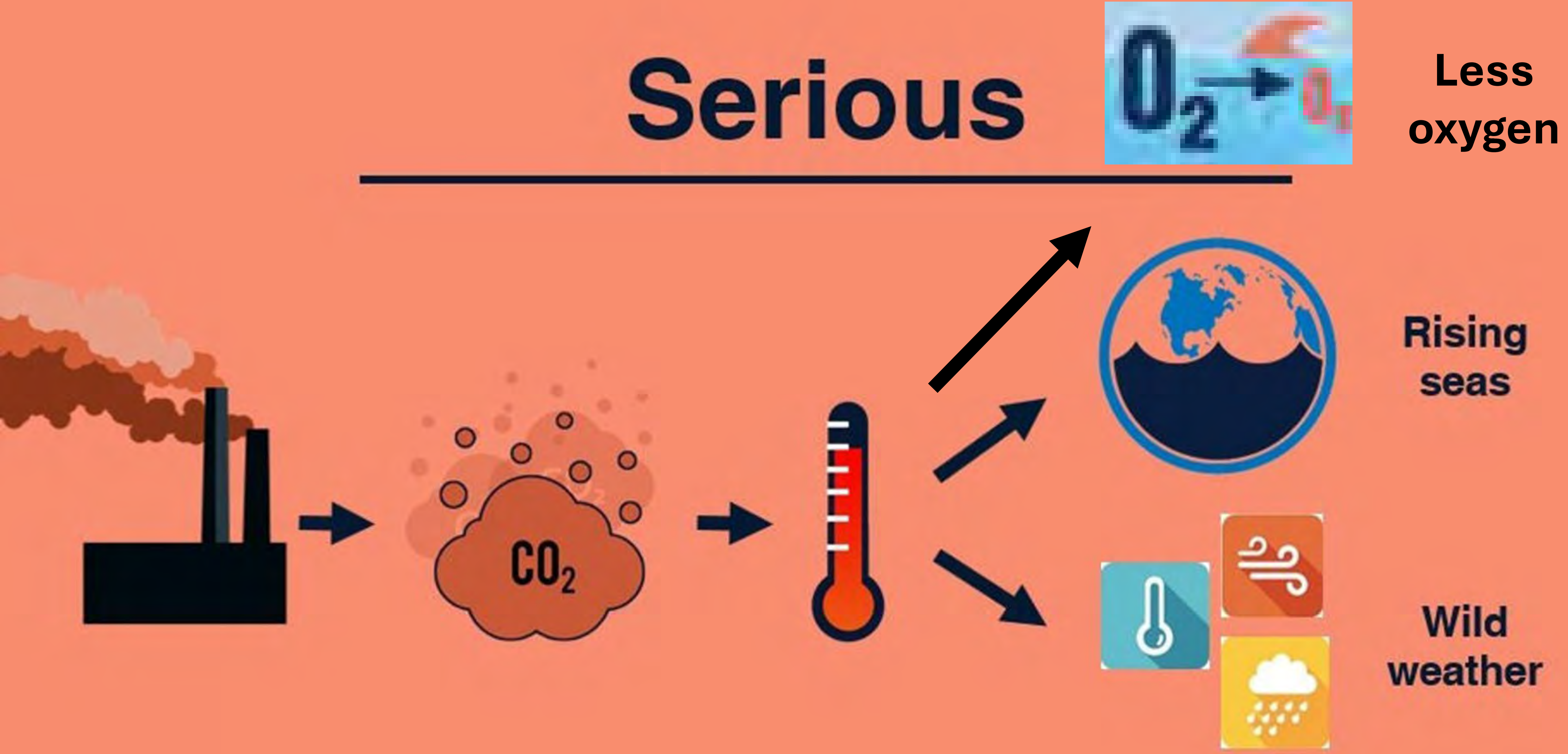
Credit: CLIMATE CENTRAL

Simple



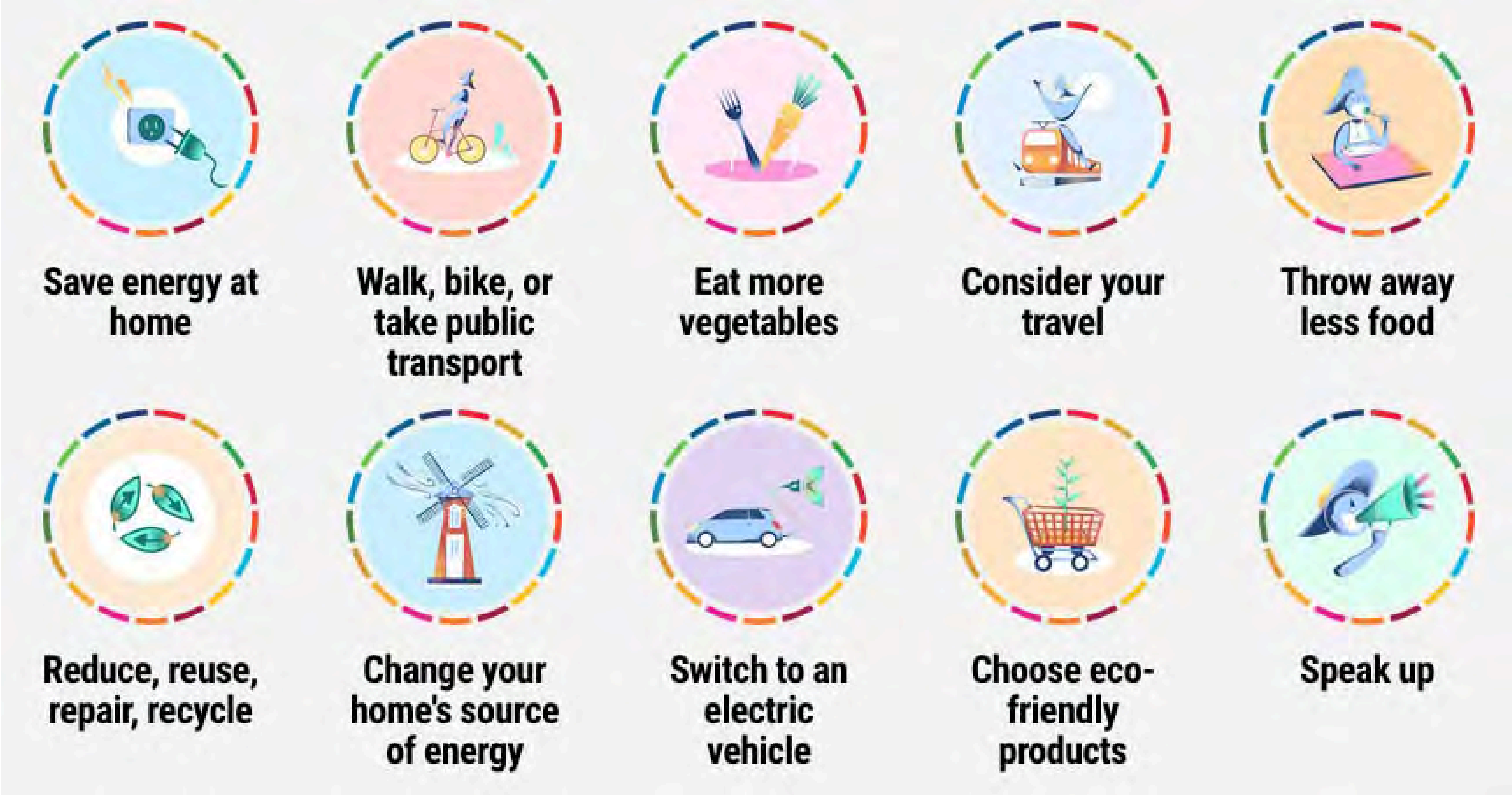
Credit: CLIMATE CENTRAL

Serious



Credit: CLIMATE CENTRAL

Solvable

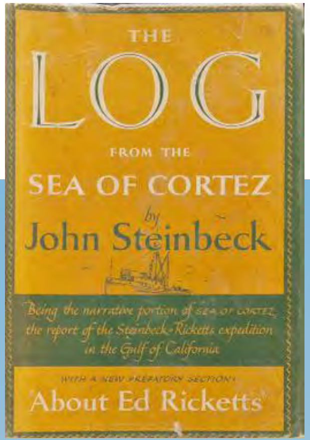


Credit: Rachel Carson Council

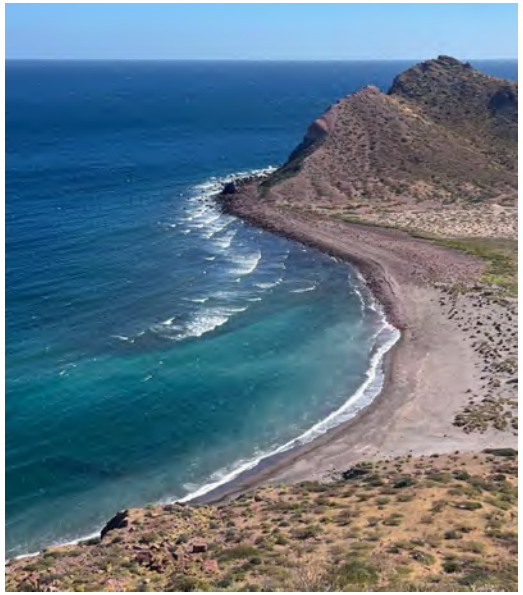
"Come join us :" https://www.westernflyer.org/join-the-western-flyers-historic-return-to-the-gulf-of-california/

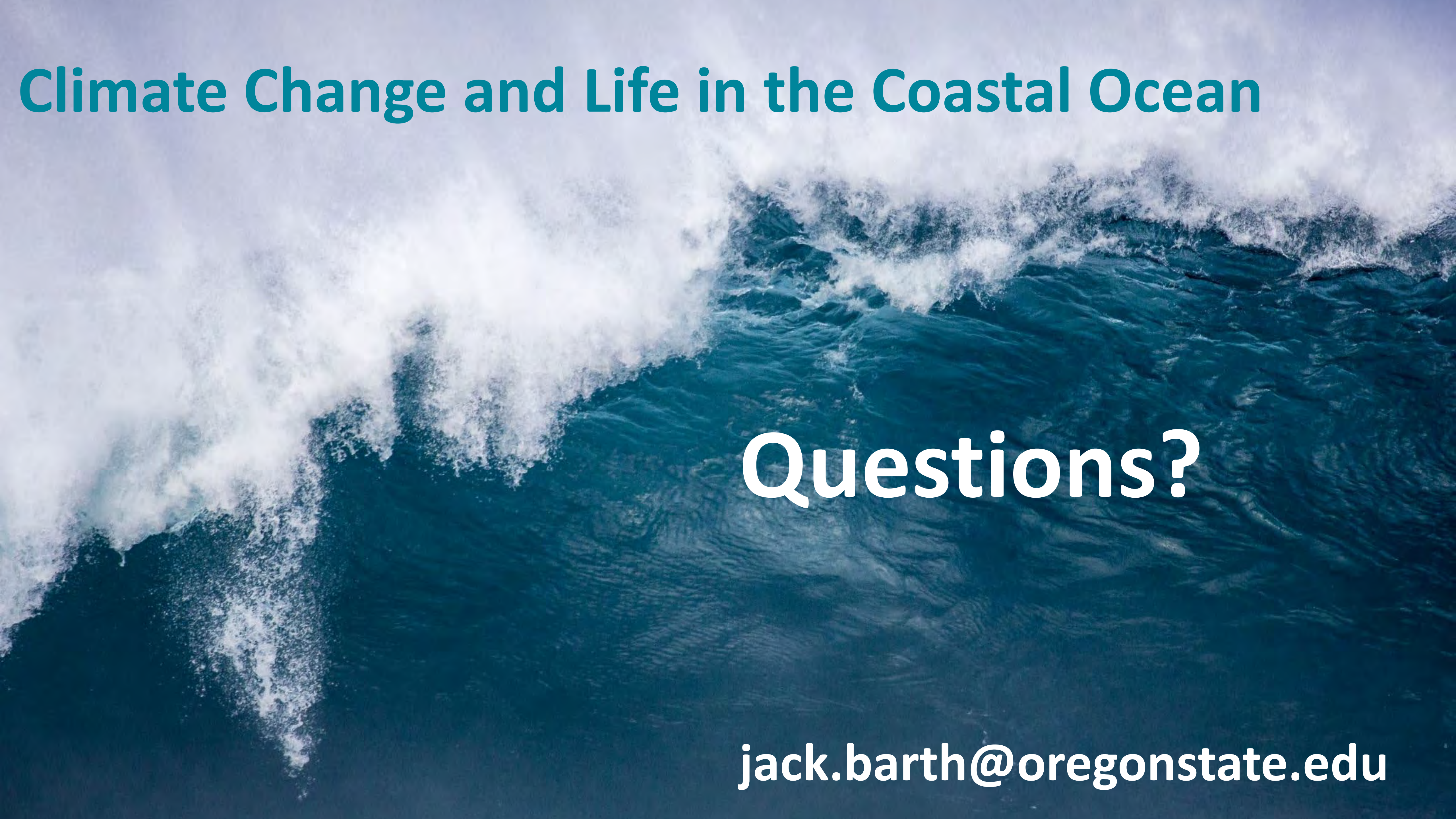
In Steinbeck's Wake: An Epic Journey Through the Sea of Cortez

10 nights on *Safari Voyager*: April 15-25, 2025

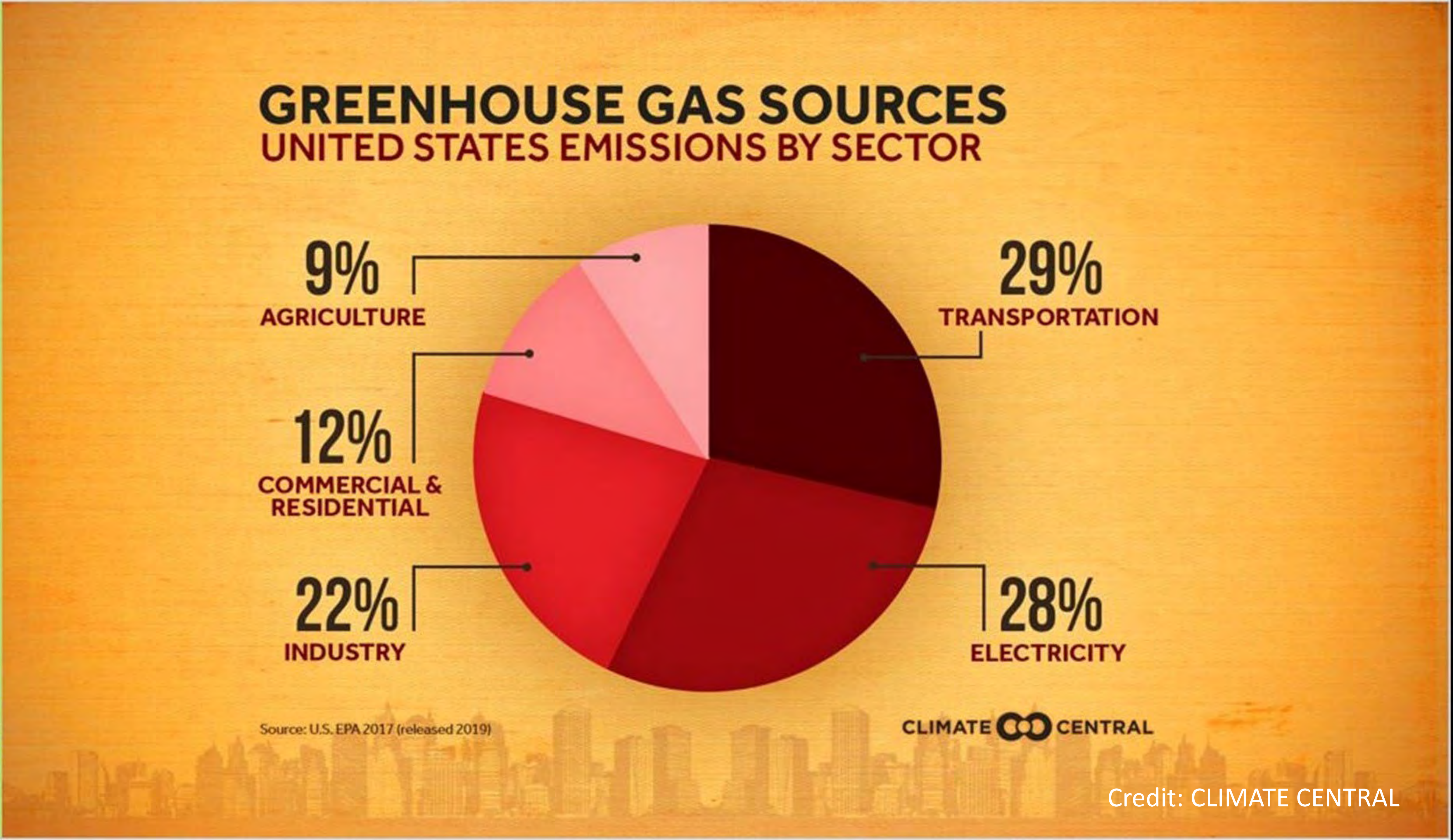


Gulf of California
Sea of Cortez




Climate Change and Life in the Coastal Ocean
Questions?
jack.barth@oregonstate.edu

EXTRAS

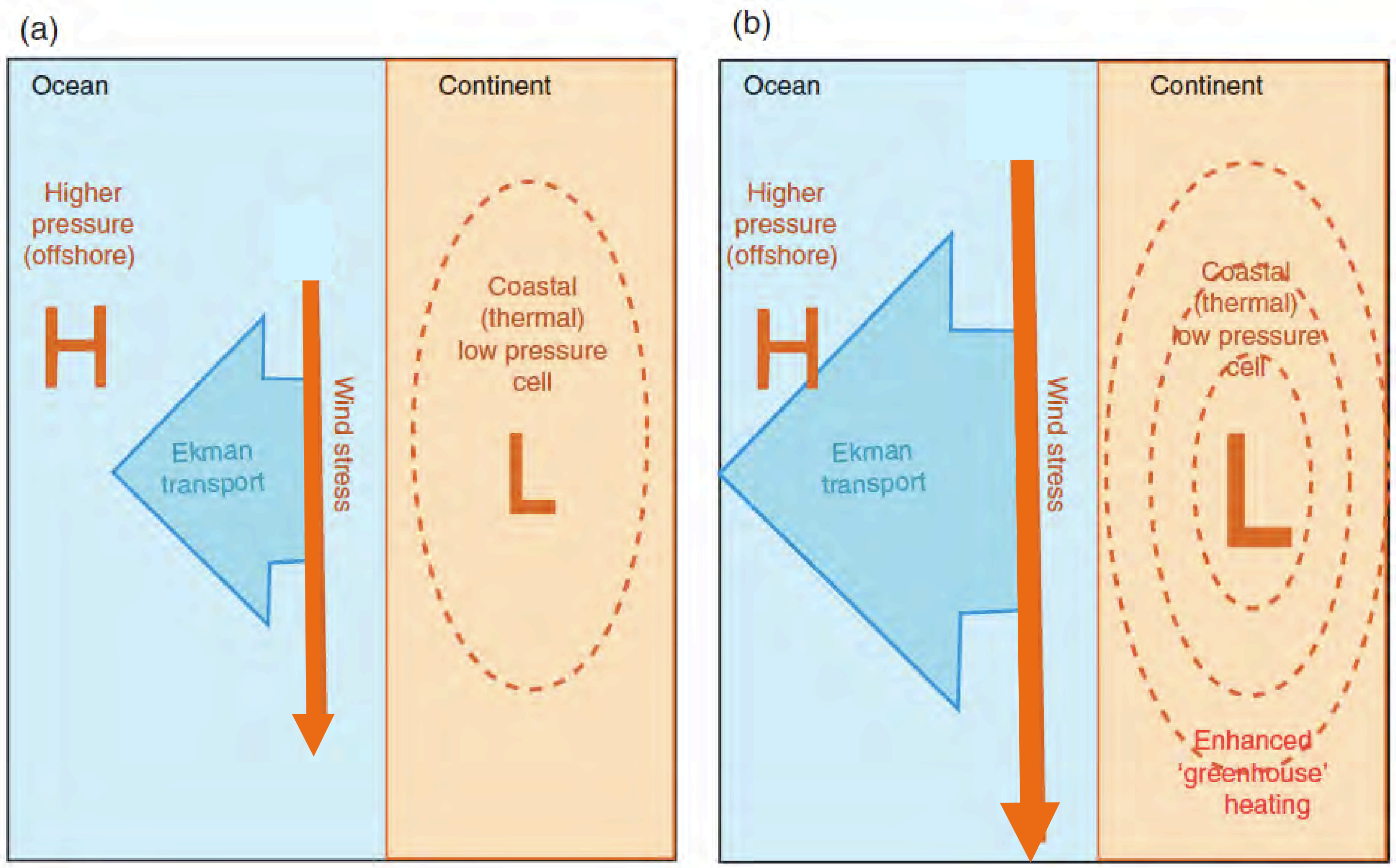


SOLVABLE

Credit: CLIMATE CENTRAL

Possible climate change impacts on near-bottom hypoxia

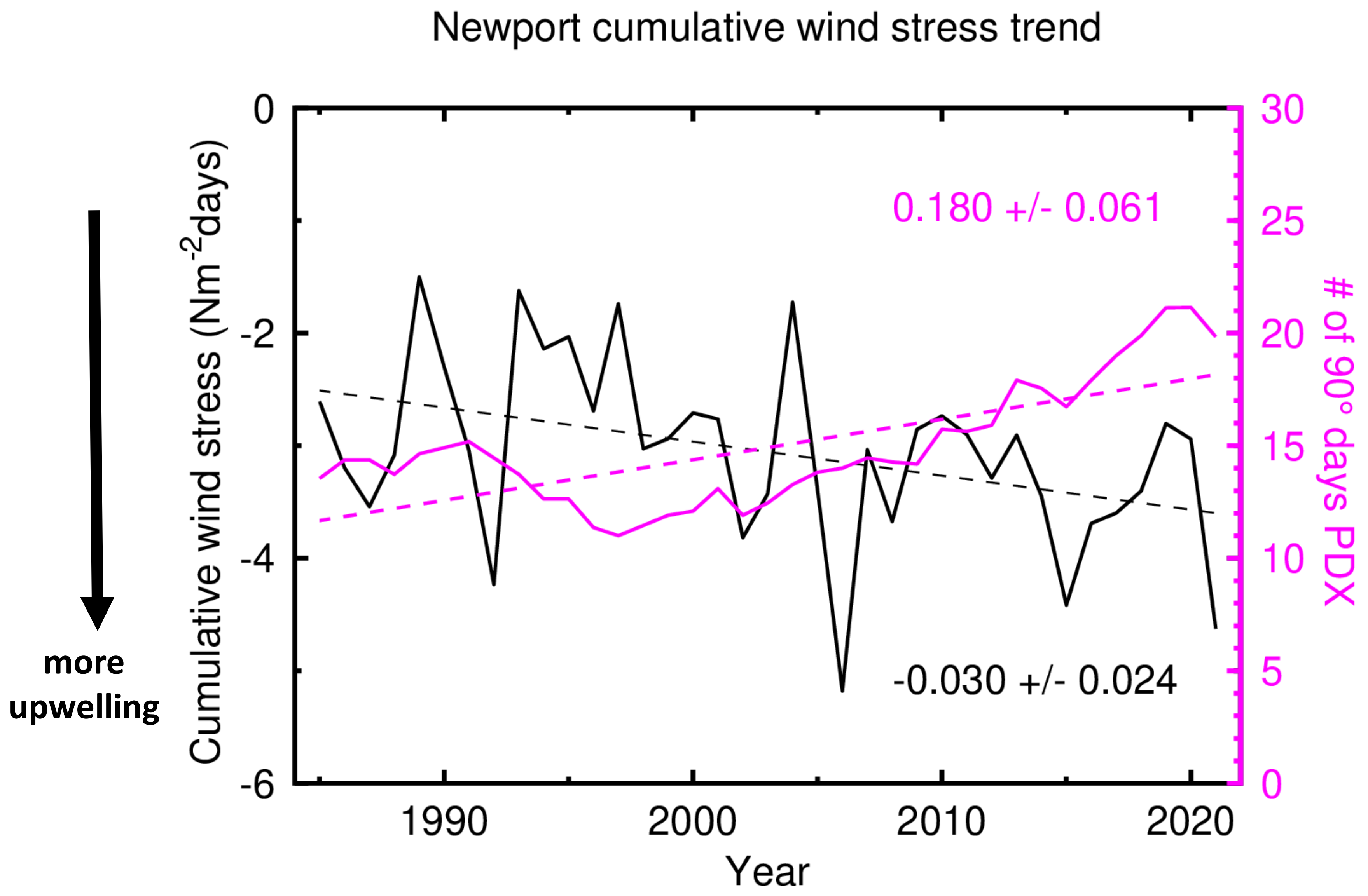
- Surface warming capping off air-sea exchange (“warm blanket”)
- Changes in upwelling source water DO content (from formation regions or along multi-decade path to PNW)
- More respiration
- **Stronger and more persistent upwelling –favorable winds**



Bakun (1990) hypothesis

Possible climate change impacts on near-bottom hypoxia

- Stronger and more persistent upwelling –favorable winds



- 2021 CUI 2nd highest in last 35 years
- One of three large upwelling years in the last 15 years
- Could be routine by 2050

Barth et al. (2024)

Crab-pot based dissolved oxygen sampling

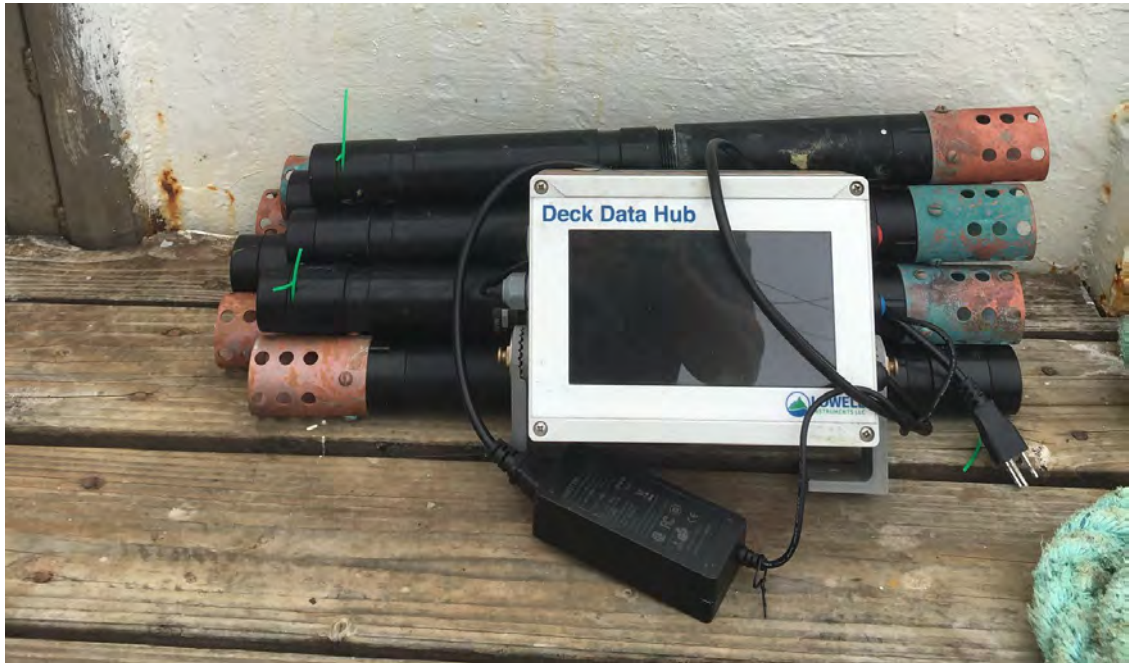
Dissolved oxygen via optode

Low-cost, easy to deploy

Calibrated in the lab

Lasts up to 12 weeks at 15-minute sampling

Bluetooth to deck hub; cell phone to shore → web



Pat Kemmish, *F/V Richard H.*

Sexton
CUSTOM UNDERWATER PRODUCTS

In-Situ

LOWELL
INSTRUMENTS LLC