CLIMATE CHANGE

Challenges of ocean observations: drivers and associated impacts

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WGII CH. 6, Ocean Systems,
ocean products in TS and SPM, CC-Boxes, SYR

ipcc
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE

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Large-scale climate-related isssues in the global ocean

Oceans play a major role in climate regulation globally:

- absorb >90% of the heat accumulating in the atmosphere → ocean warming, hypoxia
- absorb 25% of man-made CO_2 → ocean acidification
- accumulate excess water from melting ice sheets → sea level rise
- redistribution of nutrients → productivity shifts

Human activities also influence ocean conditions locally:

- overfishing, pollution, eutrophication etc.

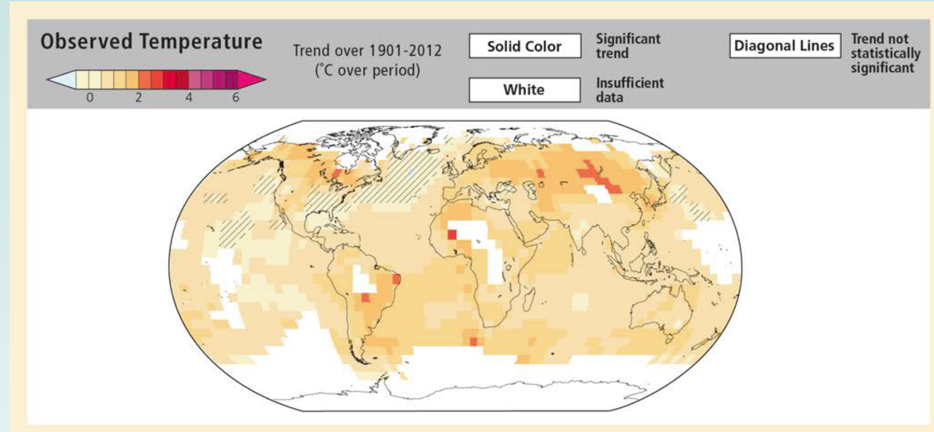
DETECTION AND ATTRIBUTION

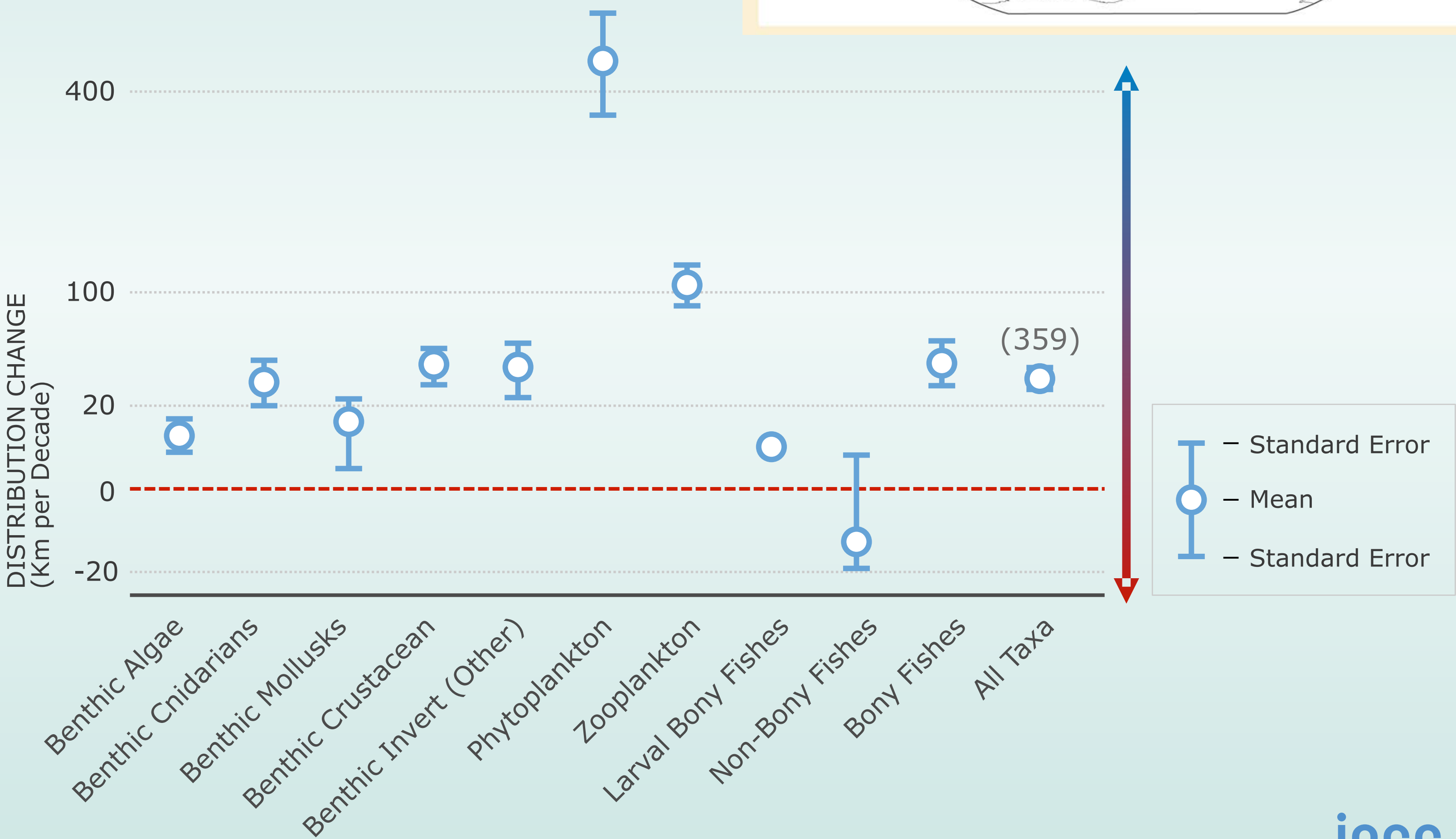
…with temperature presently being the predominant driver of ongoing global changes,

effects of ocean acidification and hypoxia reported in some areas

OBSERVATIONS

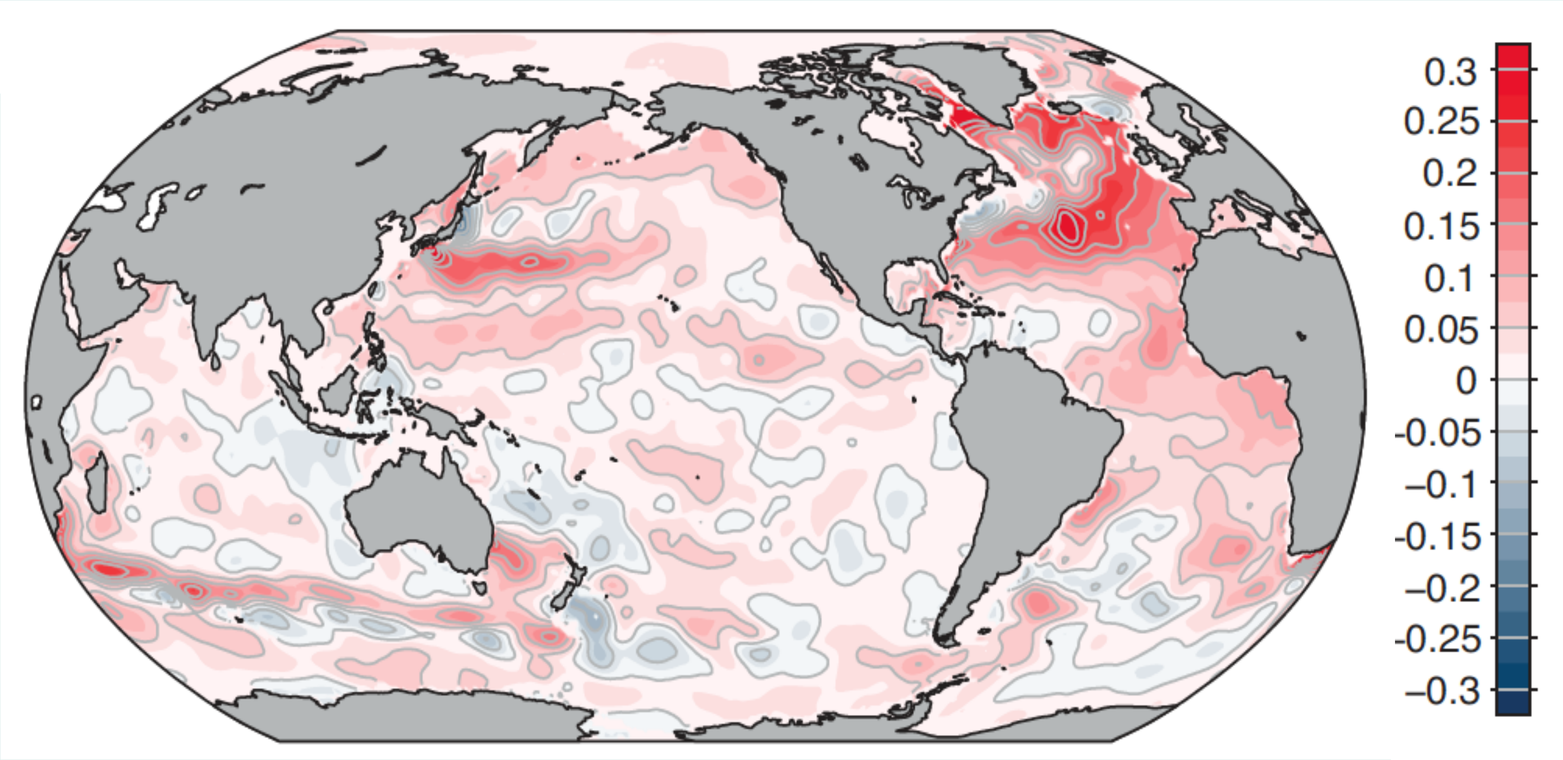
World-wide marine species displacements due to climate change





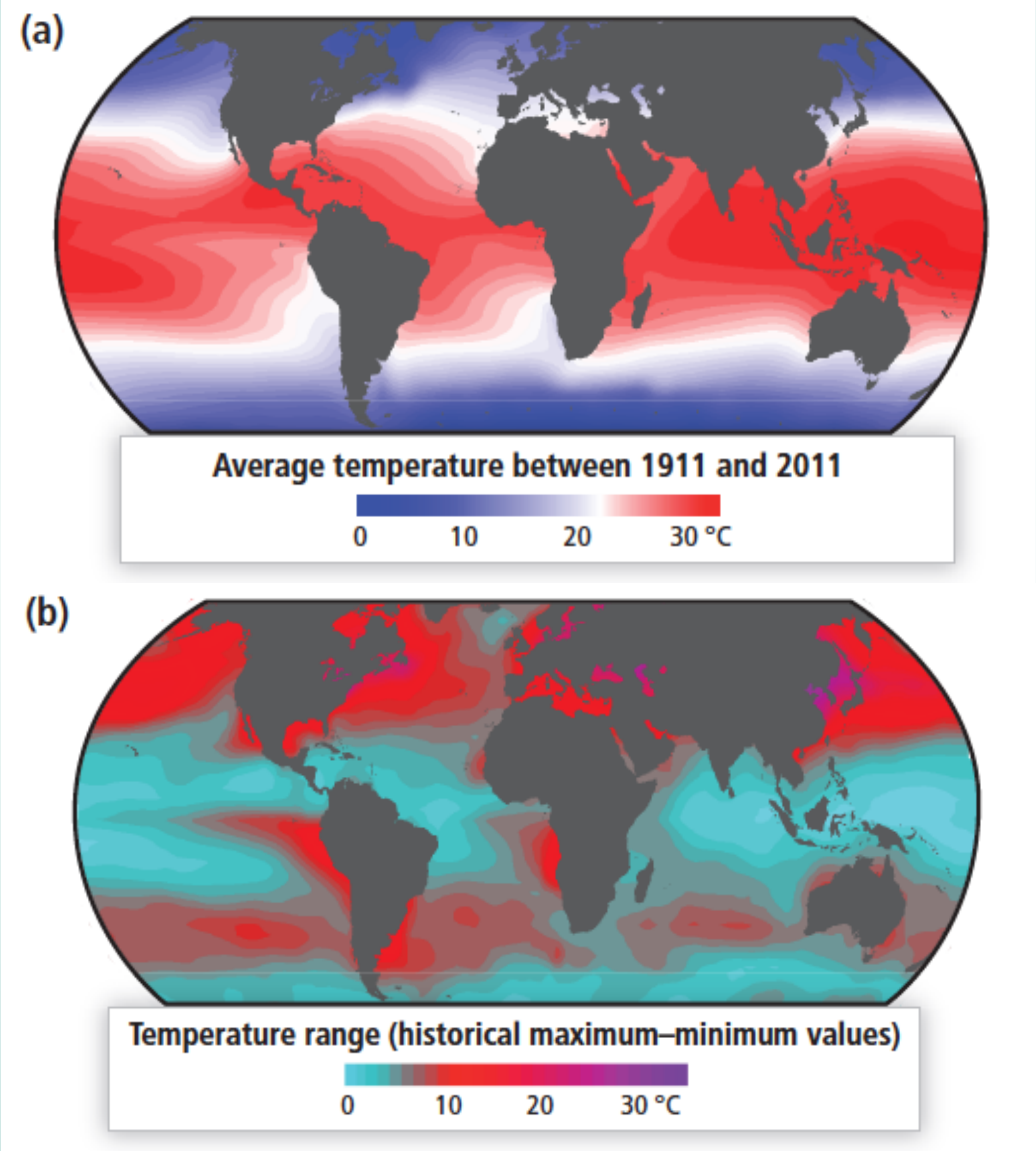
OBSERVATIONS: ocean warming

IPCC AR5 WGI Ch.3



Depth-averaged 0 to 700 m temperature trend for 1971–2010
°C per decade
1971 – 2010

Temperature means and variability: the two hemispheres



Temperature stability: key feature of the Southern hemisphere ... and Antarctica:

shaping climate dependent evolution

IPCC AR5 WGII Figure 6.1

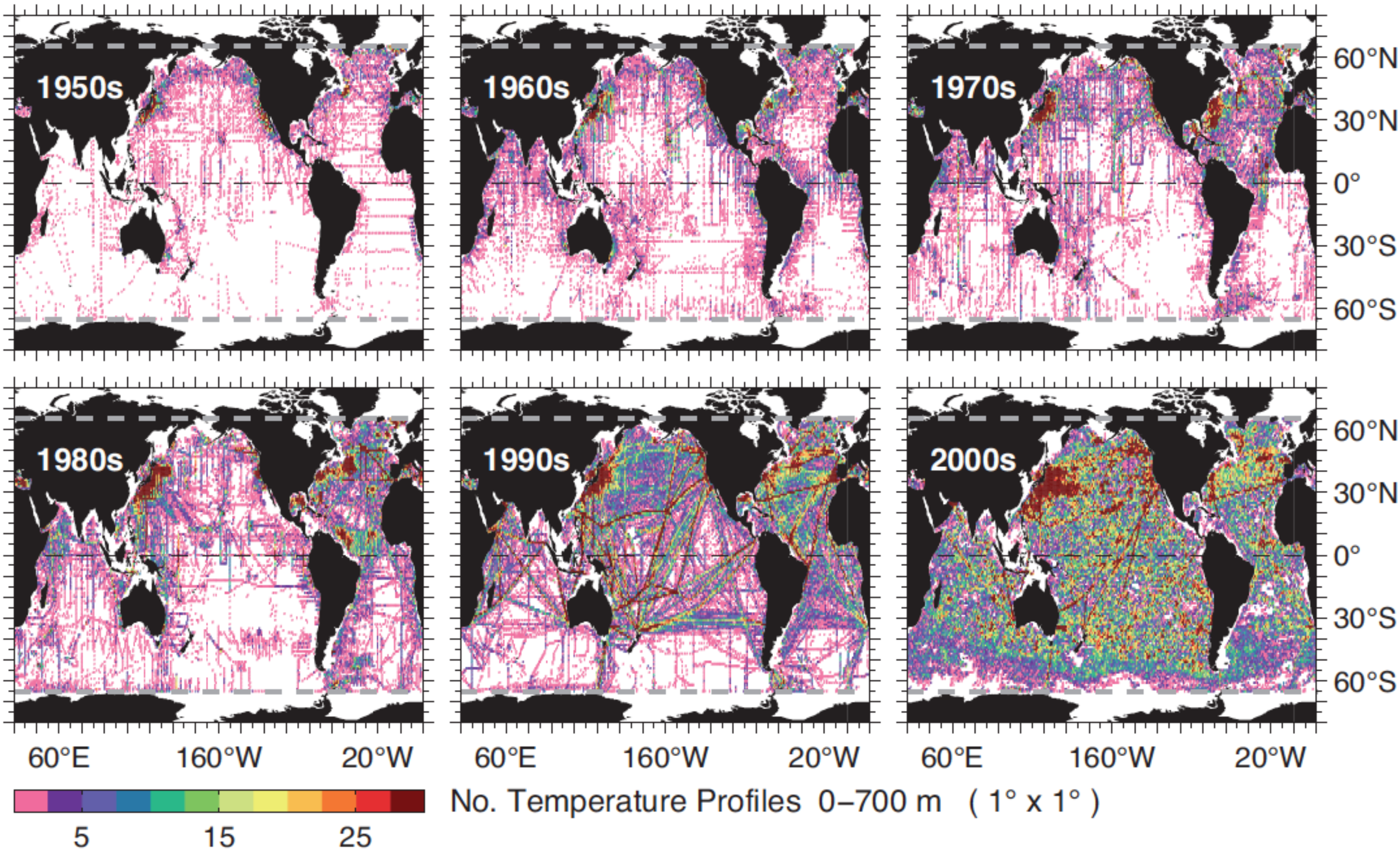
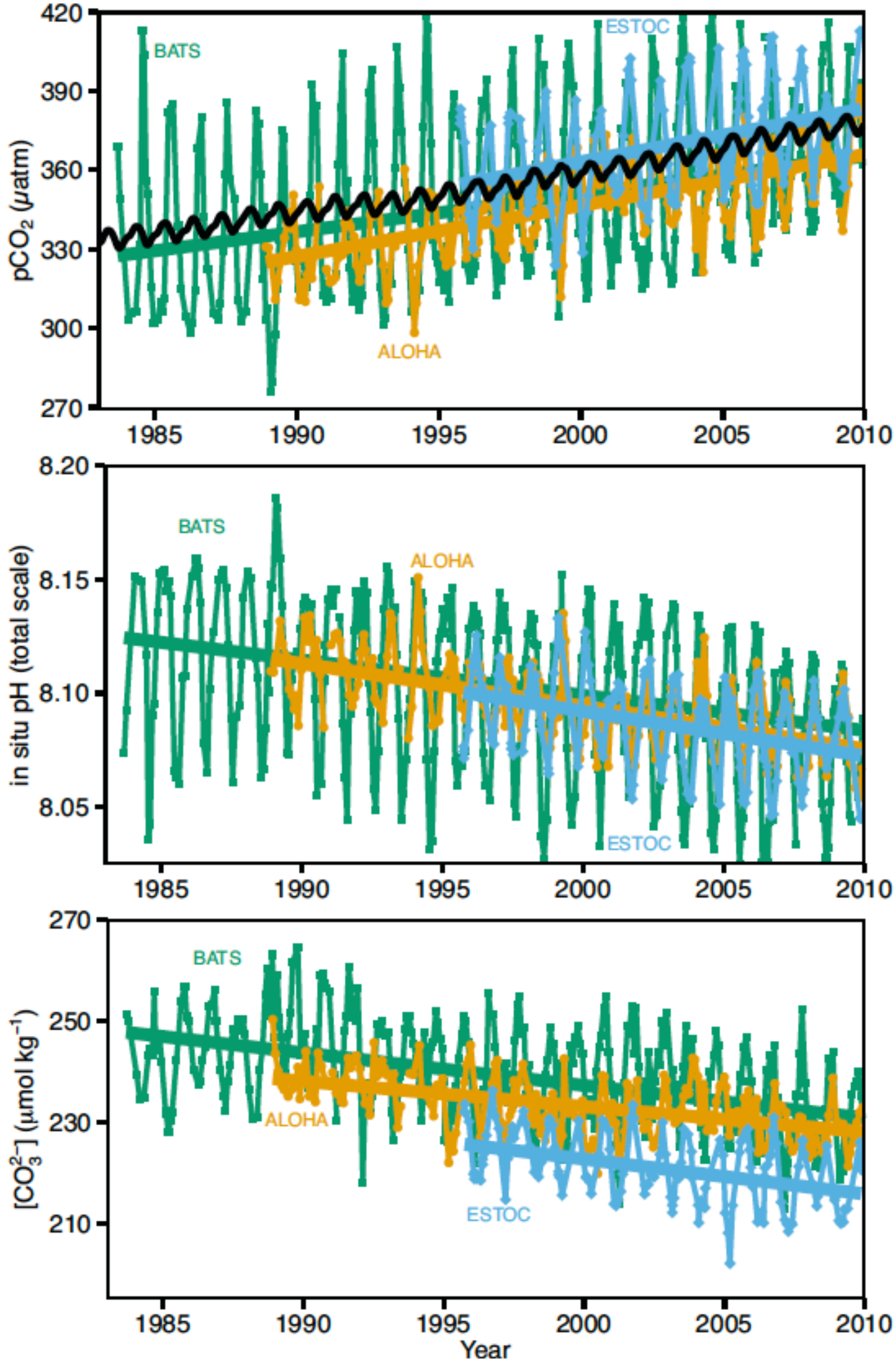
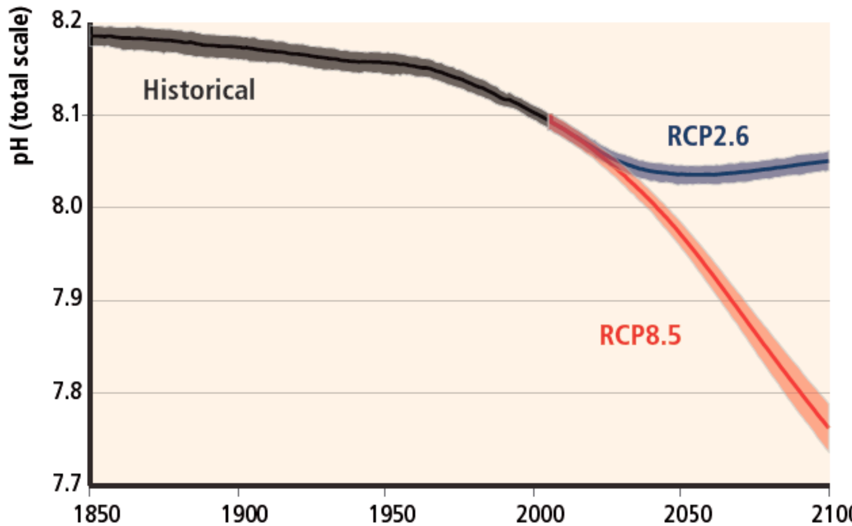


Figure 3.A.1 | Number of temperature profiles extending to 700 m depth in each 1° × 1° square, by decade, between 65°N and 65°S.

Ocean acidification

Historical ➔ **Projections**





CMIP5 models

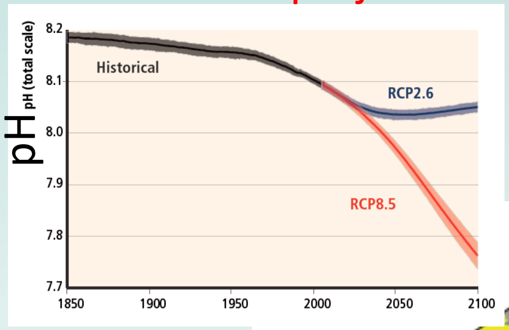
Observations in surface waters

WGI 3-18

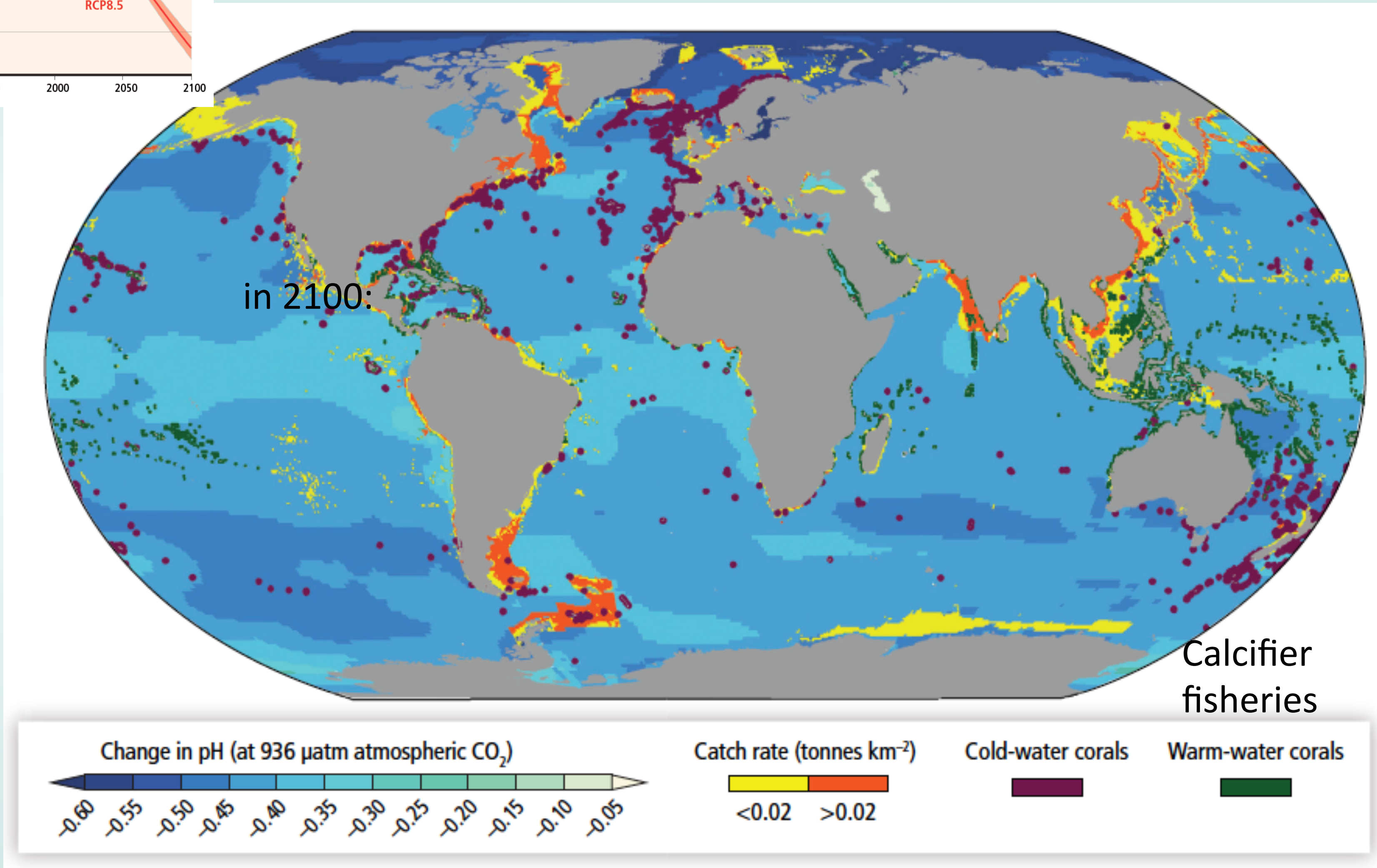
The emerging risk: Ocean acidification

Special vulnerabilities of polar species?

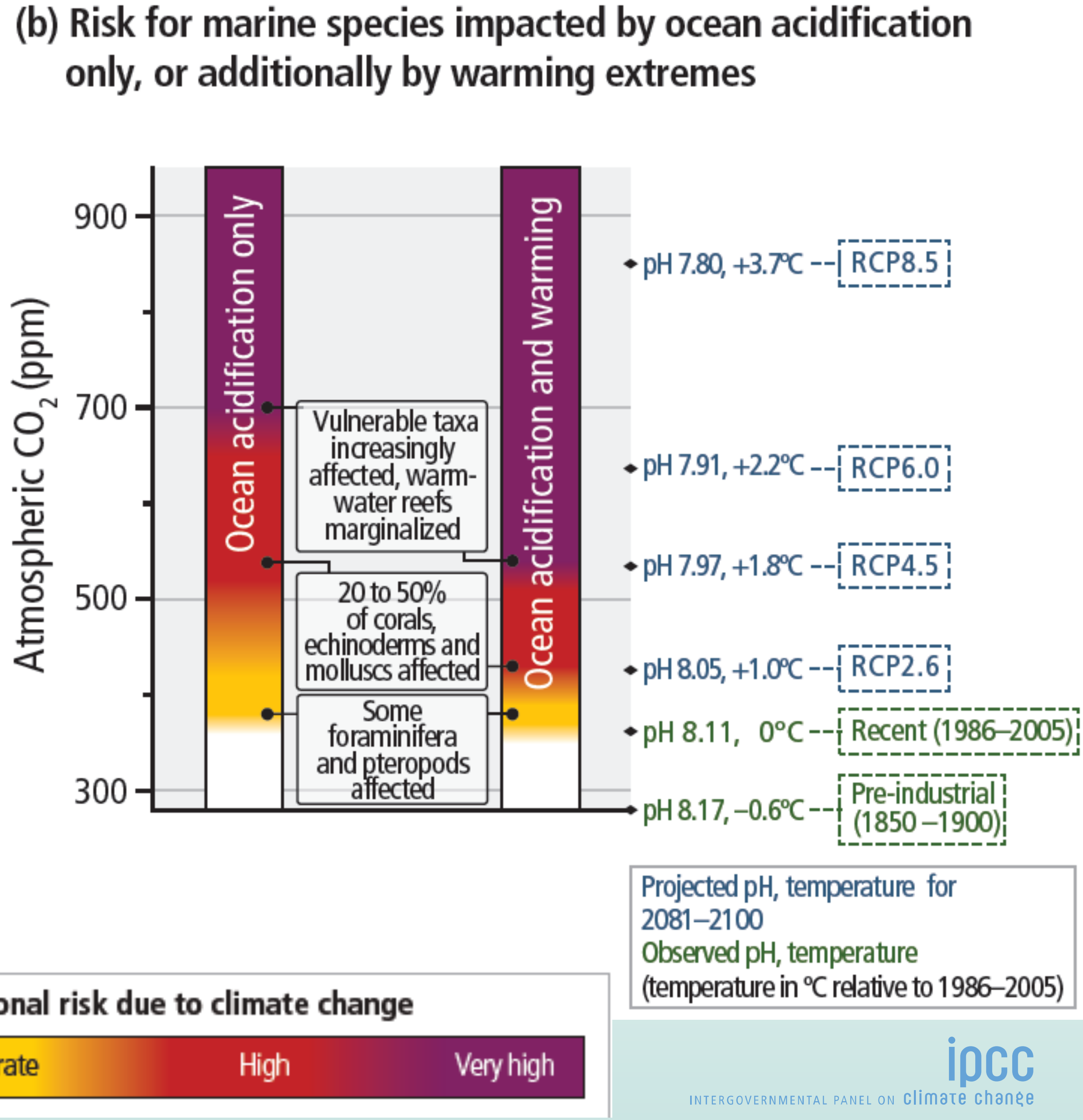
historical projected



in 2100:



IPCC AR5 WGII Figure 6.10, SPM.6



IPCC SYR 2.5

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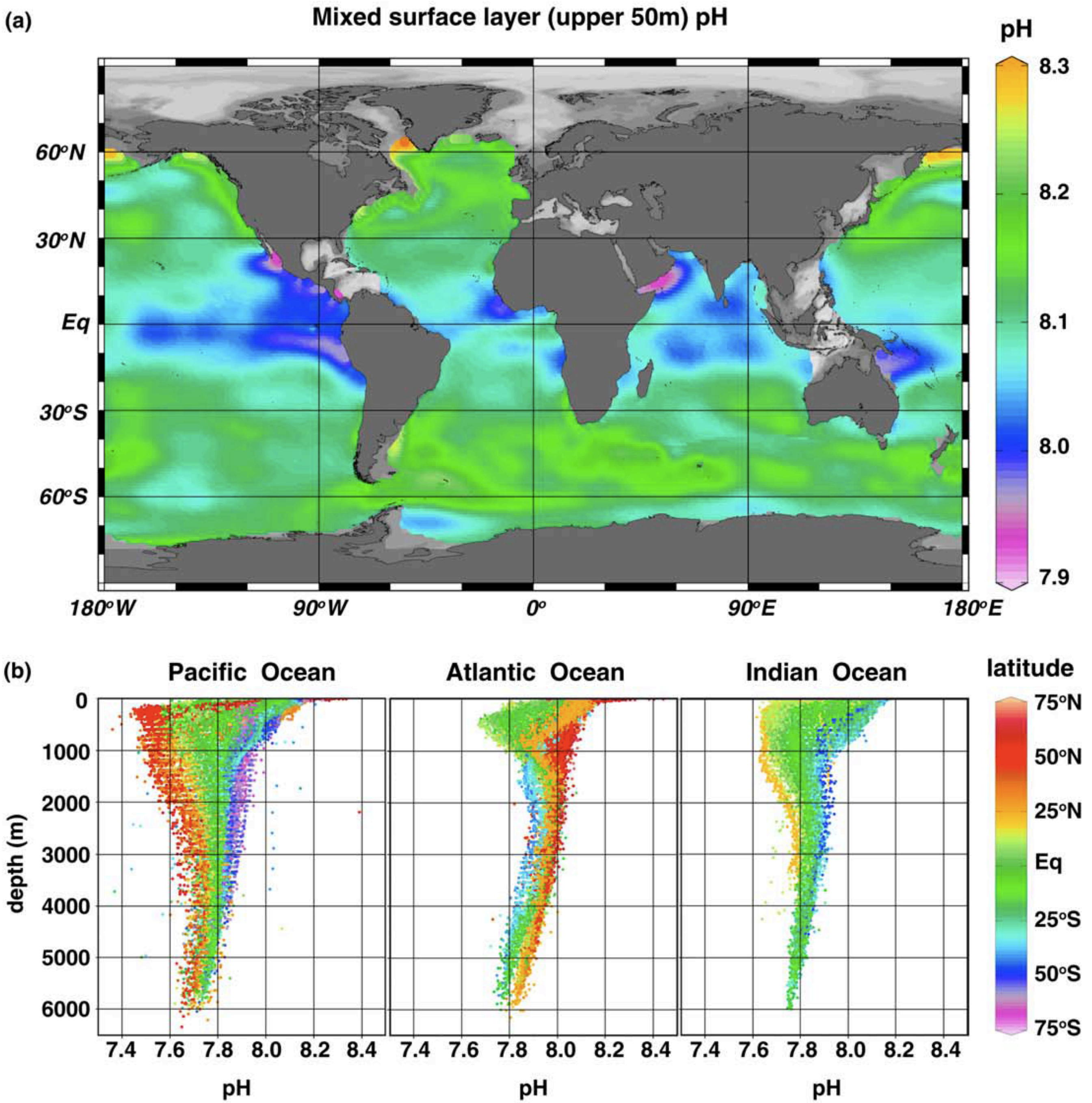


Pelejero et al. 2010

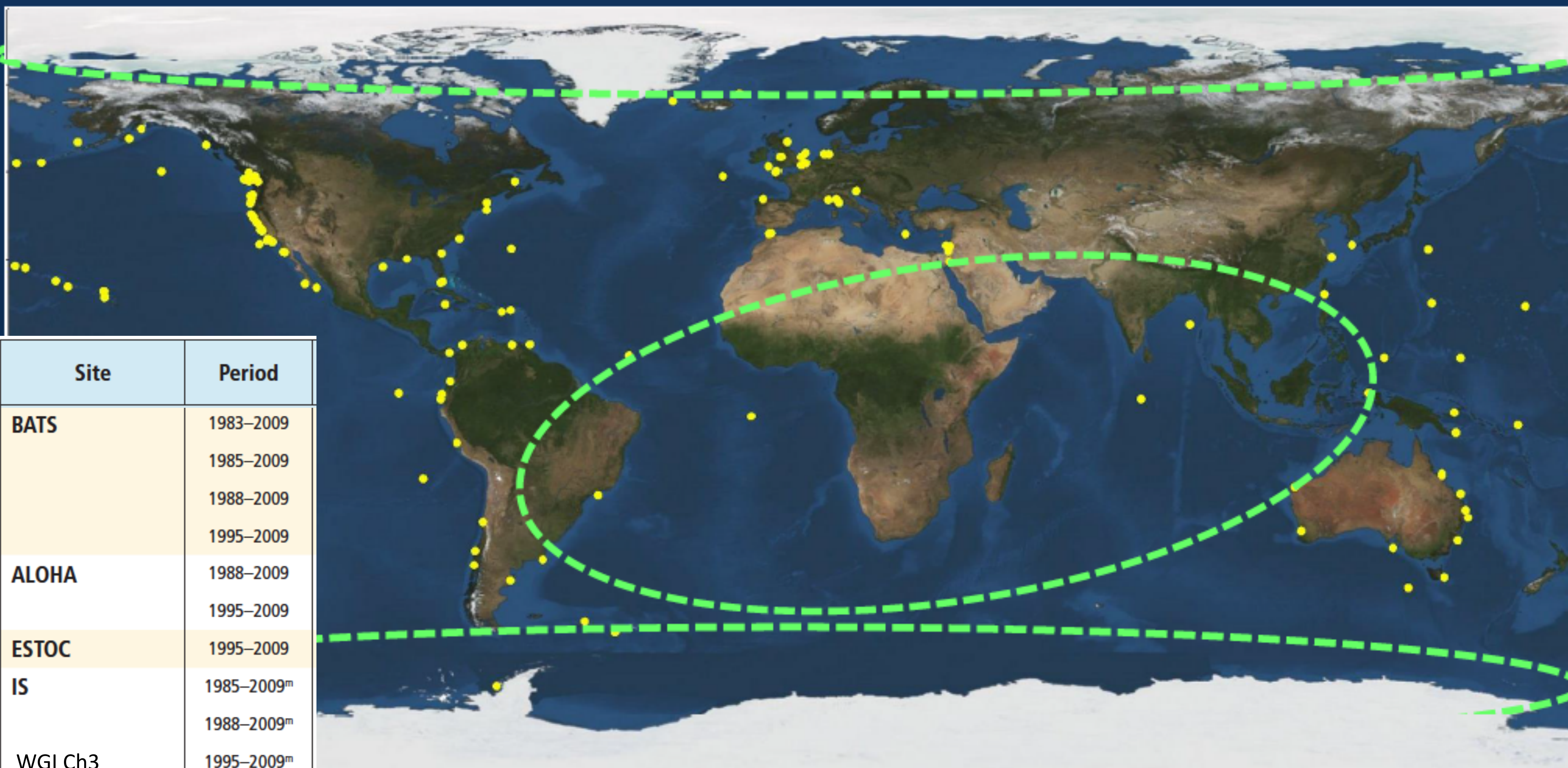
TRENDS in Ecology & Evolution

Natural variability in pH

Ocean surface layer

Deep ocean

OA monitoring sites: current coverage by Global Ocean Acidification Observing Network (GOA-ON)



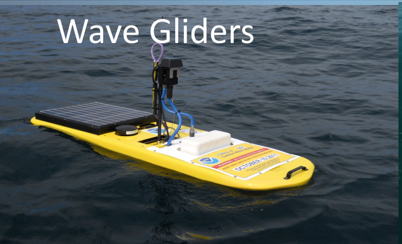
Site	Period
BATS	1983–2009
	1985–2009
	1988–2009
	1995–2009
ALOHA	1988–2009
	1995–2009
ESTOC	1995–2009
IS	1985–2009[m]
	1988–2009[m]
WGI Ch3	1995–2009[m]

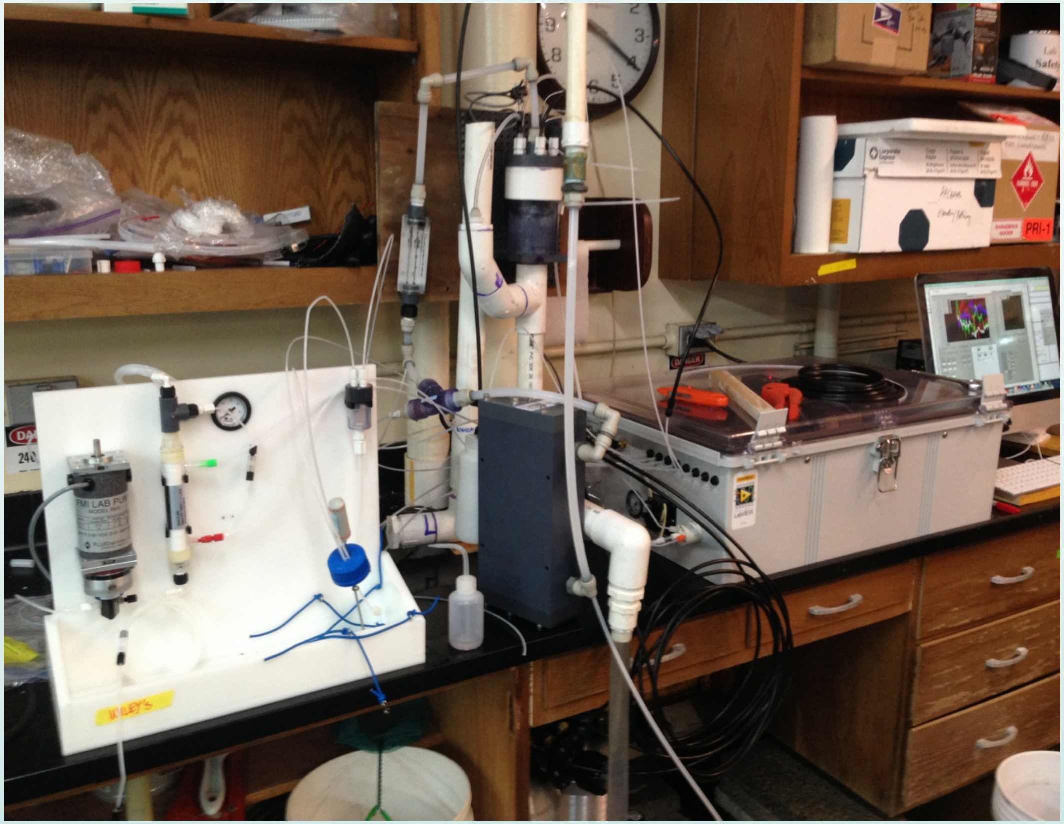
Most sites are chemistry-only. Need to fill gaps, add biology and sustain support

IUCN WCPA World Commission on Protected Areas · Institut océanographique, Fondation Albert Ier, prince de Monaco, Paris • Monaco · OAiRUG Ocean Acidification international Reference User Group · Prince Albert II of Monaco Foundation · GOA-ON Global Ocean Acidification Observing Network

UK Ocean Acidification Research Programme · AMAO · IAEA Ocean Acidification International Coordination Centre OA-ICC · Centre Scientifique de Monaco · XPRIZE

Ocean Acidification Measurement Tools
Global Ocean Acidification Observing Network





Automated pCO_2, DIC System for Hatcheries “the Burkeolator”

Ocean Acidification Measurement Tools
Global Ocean Acidification Observing Network

Estimated pH Uncertainties for Different Measurement Platforms

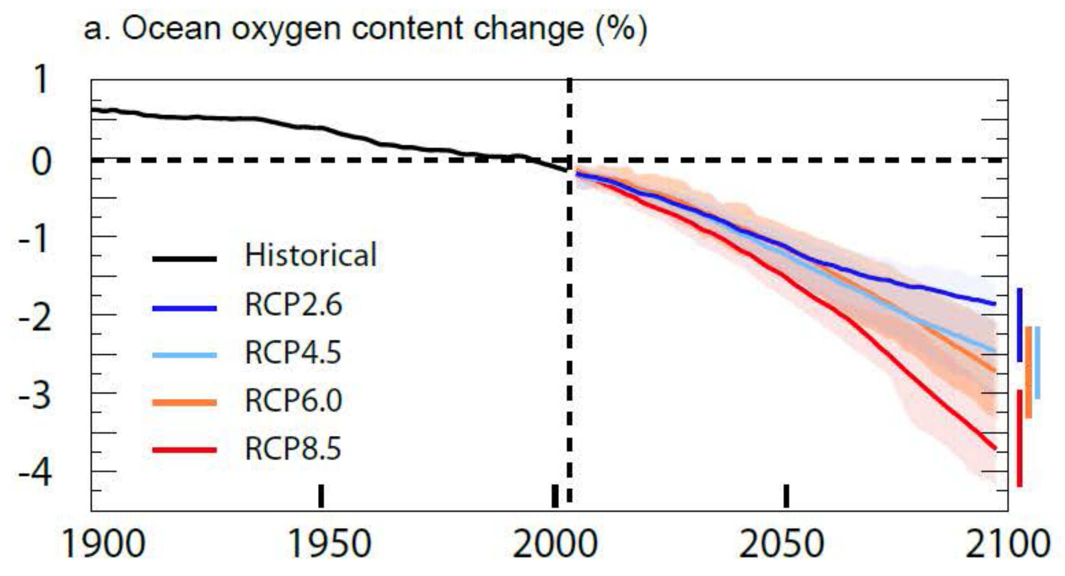
Platform	Analytical Method	Estimated pH Uncertainty	Reference
Shipboard Discrete pH	Spectrophotometric	0.003-0.005	Dickson (2010)
Shipboard Underway pH	Durafet (Potentiometric)	0.005	Martz et al (2010)
Mooring pH	SeaFET (Potentiometric)	0.004	Satlantic Specifications
Glider pH	SeaFET (Potentiometric)	~0.01	Estimate
Profiling Glider pH	Proxi	~0.03	Juranek et al (2011)

courtesy: R.A. Feeley

Parameters to be analyzed:
pH
DIC (C_{CO_2})
Alkalinity

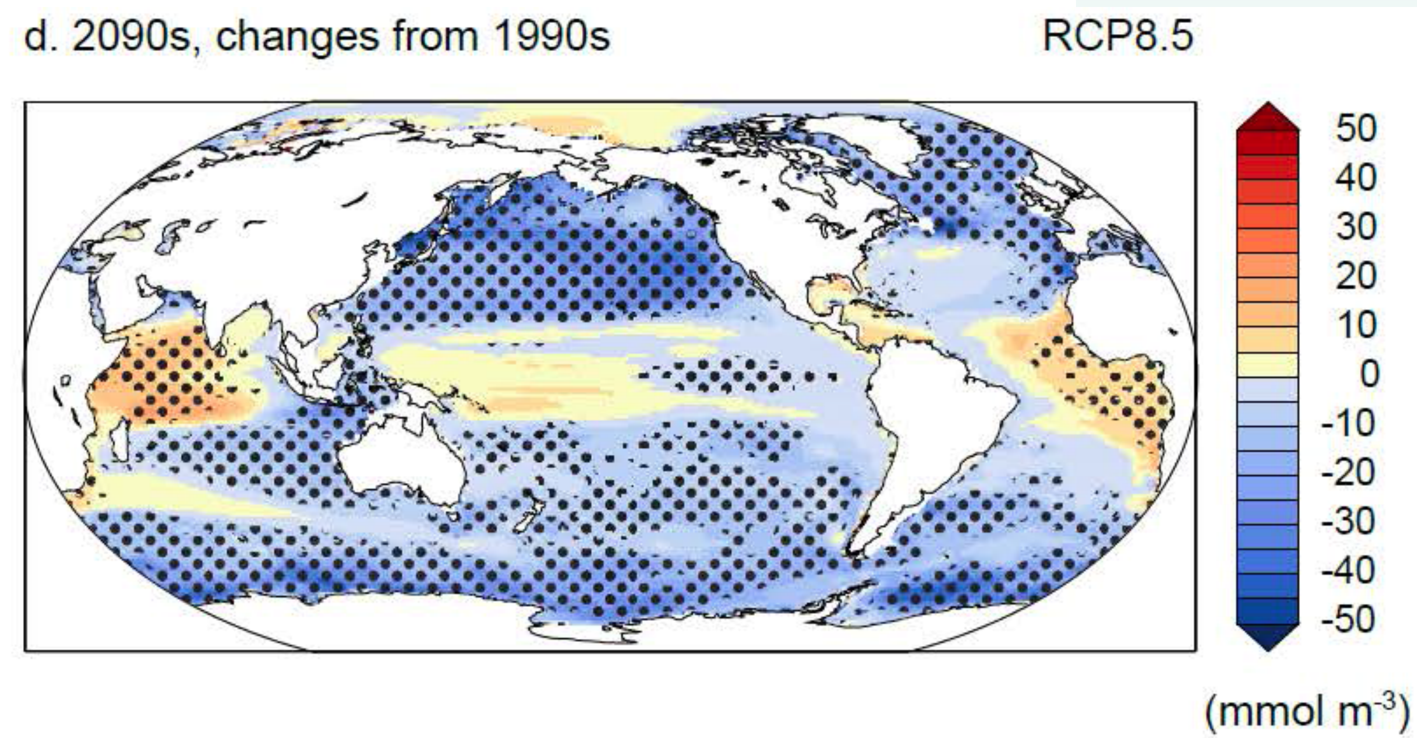
Carbon Dioxide Information Analysis Center (CDIAC)
and Surface Ocean CO_2 Atlas (SOCAT, Bakker et al., 2013).

Historical and projected deoxygenation



RCP8.5: Overall loss in oxygen also affecting Antarctic oceans

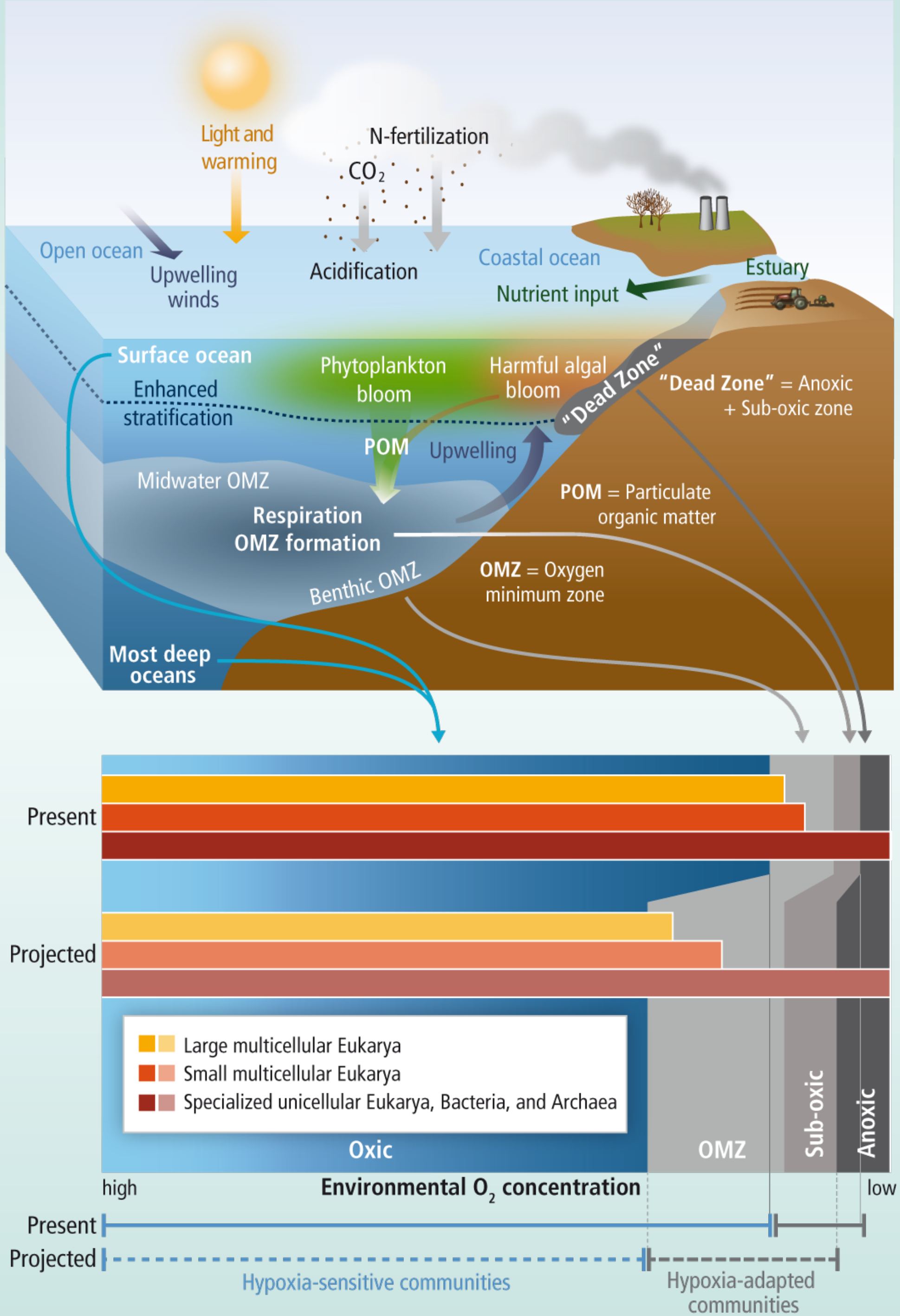
respiratory deoxygenation (e.g. deep water) exacerbates acidification



WGI Figure 6.30

IPCC 2014

Figure 6-11: (a) Principal mechanisms underlying the formation of hypoxic conditions and their biological background
(b) Distribution of free-living marine organisms (...) across the ranges of O2 concentrations in various water layers



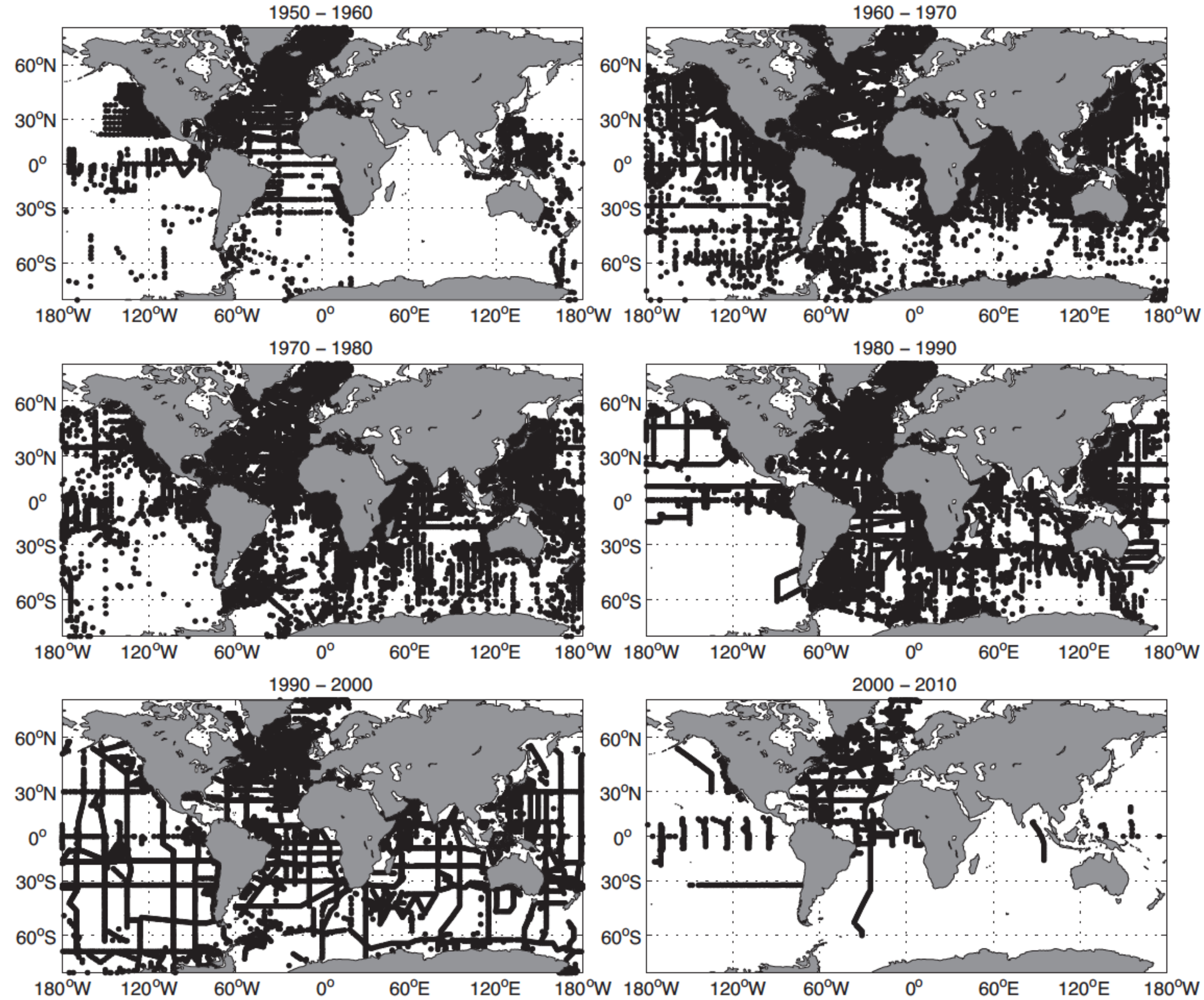


Figure 3.A.6 | Distribution of oxygen measurements at 300 dbar for the decades 1950 to 1960 (upper left) to 2000 to 2010 (lower right frame). (From Stramma et al., 2012.) [Note that additional oxygen data have become available for the 2000–2010 period since that study was completed.]

Patchiness of oxygen measurements depending on field programs, Northern hemisphere bias

WGI, Figure 3.A6

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… in animals strongest impacts are expected where warming, acidification and hypoxia come together,

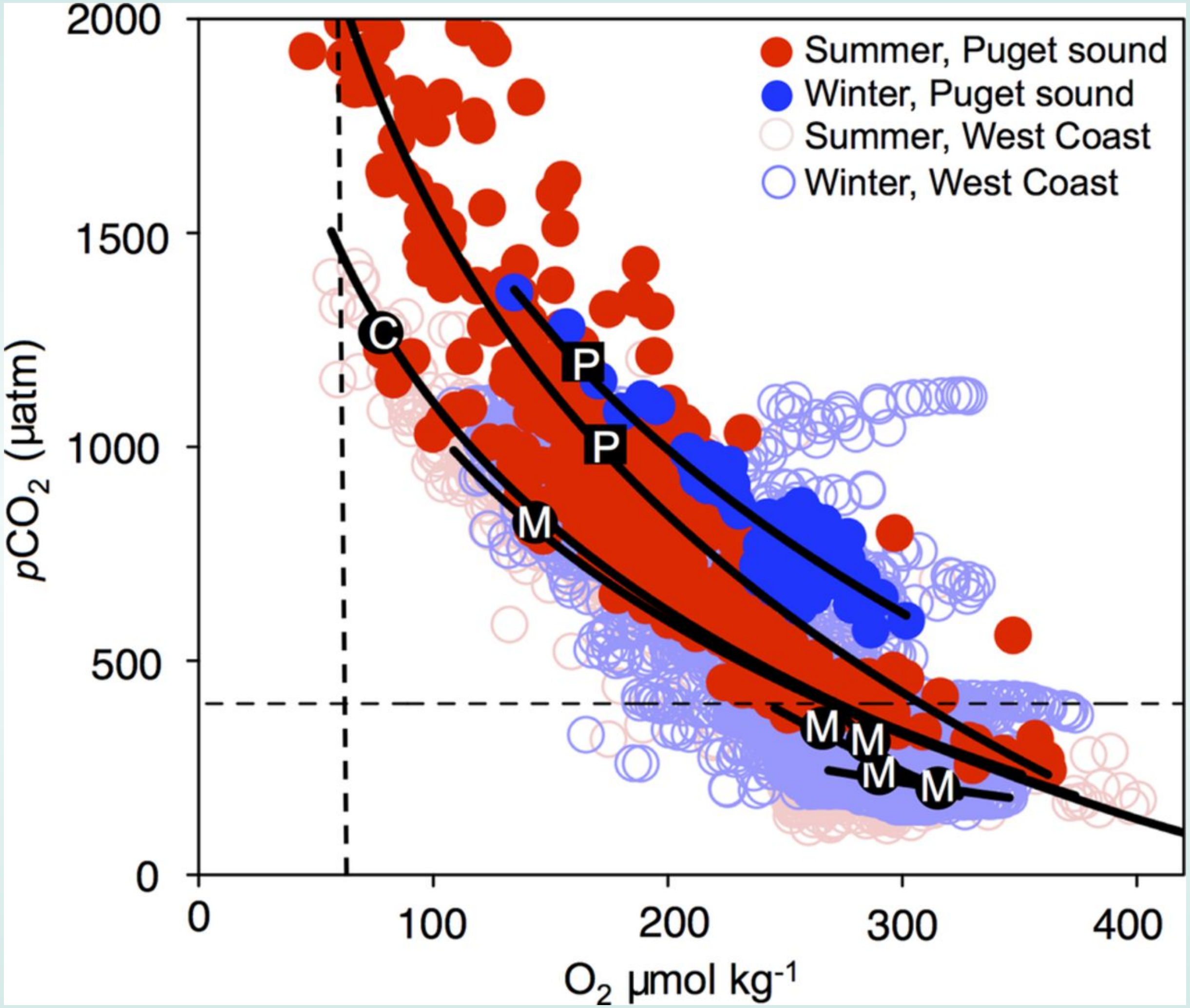
...indicating that assessments based on individual drivers are conservative.

NEEDED:

...observations of <u>biological impact</u>
paralleled by the
comprehensive monitoring of <u>key climate drivers</u>
and <u>local drivers</u>

Correlated changes in oxygen and $P\text{CO}_2$

Relationships between pCO2 and O2 in the top 50 m of the water column during summer upwelling (May through October) and winter downwelling seasons (November through April).



Reum J C P et al. ICES J. Mar. Sci. 2015;icesjms.fsu231

This relationship will shift to higher CO_2 levels under ocean acidification

Local data by Biological stations

Region	Time series	Duration	Type	Interpretation
Global	**SeaWiFS** (Sea-viewing Wide Field-of-view Sensor)	1997-2011	Near surface chlorophyll	lower chlorophyll concentrations and decreased rates of NPP Satellite time-series insufficient to make robust projections on chlorophyll concentrations or rates of NPP
English Channel and later into the open sea	**CPR** (Continuous Plankton Recorder)	1920s - ongoing	Zoo- and phytoplankton abundance/ presence absence	- changes in the seasonal abundance of phytoplankton - rapid northerly movements of temperate and subtropical species of zooplankton and phytoplankton) - climate induced trophic mismatch between phytoplankton and zooplankton and its impact on fisheries
North Sea	**Helgoland Roads** (Alfred Wegener Institute)	1962 - ongoing	salinity, secchi disk depth, macronutrients, phytoplankton, zooplankton, intertidal macroalgae, zoobenthos and bacterioplankton	Increase in green algae, decrease in brown algae, increased number of invaders on macrofauna, changing foodweb and bloom dynamics
California	**CalCOFI** (California Cooperative Oceanic Fisheries Investiga-tions)	1949 - ongoing (quarterly, 1969-1984 triennial) on variable grid	Ecological assessment	- El Niño impacts marine invertebrates and fishes - decline in zooplankton biomass during periods of warming - multidecadal shifts in the pelagic ecosystems (sardines and anchovies)
North Pacific Subtropical gyre	**Climax** **HOT** (Hawaii Ocean Time-series)	1968 - 1985 and 18 expeditions, mostly in summer months 1988 - ongoing monthly	ecosystem structure and variability	- Doubling of ship-measured chlorophyll a concentrations during period 1968-1985. - Change from large eukaryotic to small photosynthetic prokaryotes. - Decrease in dissolved phosphate concentrations due to proliferation of nitrogen fixing microorganisms.
Fisheries data series	**Various**	Various	Fish stock assessments	- from 1950: FAO: http://www.fao.org/fishery/statistics/en - from 1950: www.seaaroundus.org, - from 1950: Global fishing effort data - from 1970: ICES Trawl Surveys – - from 1950: RAM Legacy Stock Assessment Database - from 1903: British landings and effort

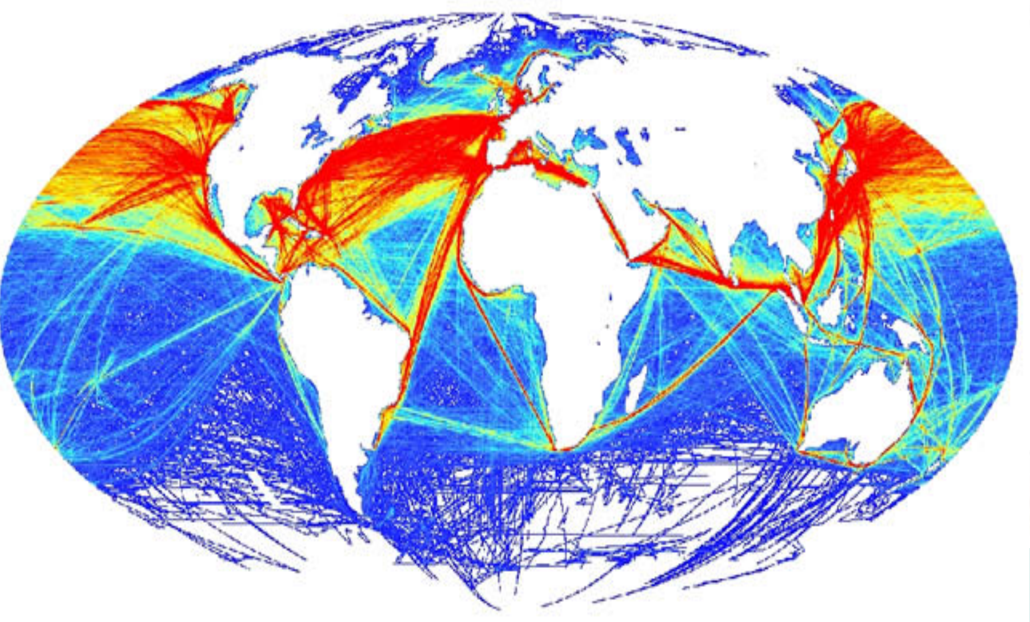
Joining forces with the private sector? Opportunities of Ships

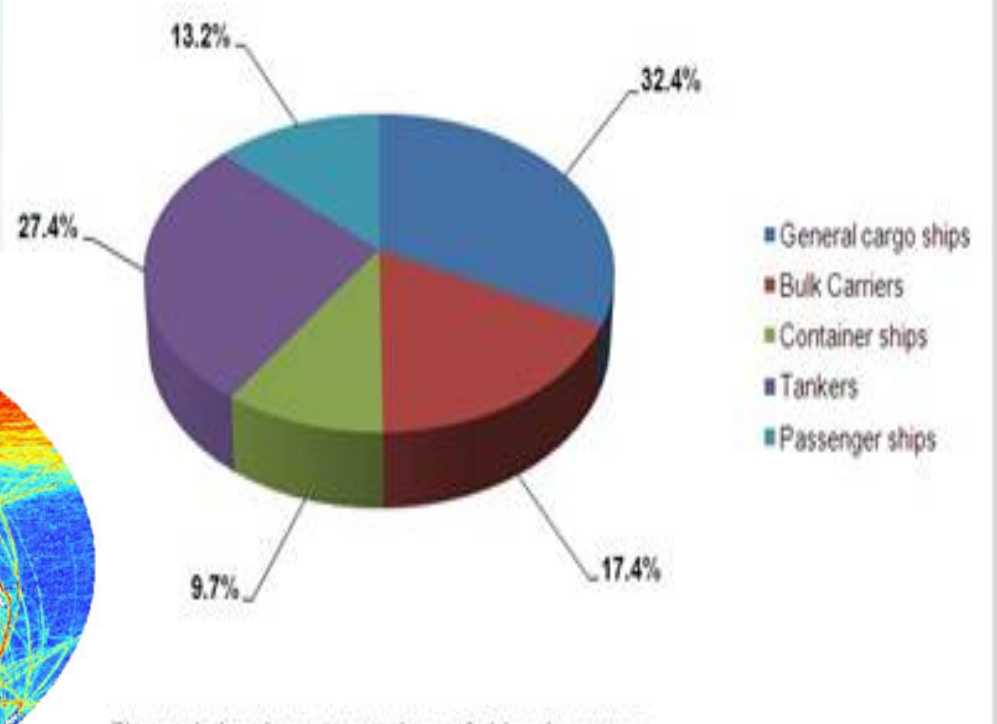
WORLD OCEAN COUNCIL

The International Business Alliance for Corporate Ocean Responsibility

50,054 ships (Oct 2010)

- Tankers: 13,175
- Bulk Carriers: 8,687
- Container ships: 4,831
- Passenger ships: 6,597





Figures in brackets are numbers of ships, by sector.
Source: IHS Fairplay October 2010

courtesy: Paul Holthus

Question

How can GCOS / IPCC help inform and coordinate national and international agencies to establish observation programs for the joint, continuous and reliable **study of physical, physicochemical, and biological indicators of climate change and impacts** in ocean regions? ….*involving the private sector?*

Challenge

...To take into account **biological parameters** and their **regional specificities** and inform the evolution of monitoring for **combined ocean warming, acidification and hypoxia** as well as their specific regional impacts, combined with **local conditions** such as freshening, eutrophication and pollution.

Thank you!

Rhein, M., S.R. Rintoul, S. Aoki, E. Campos, D. Chambers, R.A. Feely, S. Gulev, G.C. Johnson, S.A. Josey, A. Kostianoy, C. Mauritzen, D. Roemmich, L.D. Talley and F. Wang, 2013: **Observations: Ocean**. In: Climate Change 2013: The Physical Science Basis.

Pörtner, H.-O., D.M. Karl, P.W. Boyd, W.W.L. Cheung, S.E. Lluch-Cota, Y. Nojiri, D.N. Schmidt, and P.O. Zavialov, 2014: **Ocean systems**. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects., pp. 411-484.

Hoegh-Guldberg, O., R. Cai, E.S. Poloczanska, P.G. Brewer, S. Sundby, K. Hilmi, V.J. Fabry, and S. Jung, 2014: **The Ocean**. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects., pp. 1655-1731.

GOA-ON will provide:

Goal 1 An understanding of **global OA conditions**

Identify spatial/temporal patterns and assess generality of response; document and assess variation to infer driving mechanisms; quantify rate of change

Goal 2 An understanding of **ecosystem response to OA**

Measure biological responses to physical/ chemical changes; quantify rate of change and identify areas of vulnerability

Goal 3 Data needed to **optimize modeling for OA**

Provide spatially and temporally-resolved chemical and biological data to be used in developing models for societally-relevant analyses and projections

Strong dependence on individual engagement

courtesy: J. Newton

GOA-ON has a nested system design

GOA-ON
Global Ocean Acidification Observing Network

Coral reefs

Coasts & shelf seas

Open ocean

Goal 1 OA conditions	Goal 2 Ecosystem response	Goal 3 OA modeling
L1: carbonate-system constraint, T, S, O, *fluorescence, irradiance*	***L1:*** biomass of functional groups (phytoplankton, zoo-plankton & microbes)	Inputs to models
L2: nutrients, bio-optics, transport, meteorology, trace metals...	***L2:*** species; processes incl. growth, grazing & respiration	
L3: capability-specific	***L3:*** capability-specific	

courtesy: J. Newton

GOA-ON observing shortcoming:

Open ocean: On global scale, significant building blocks are there, but network needs filling-in, enhancing and sustaining.

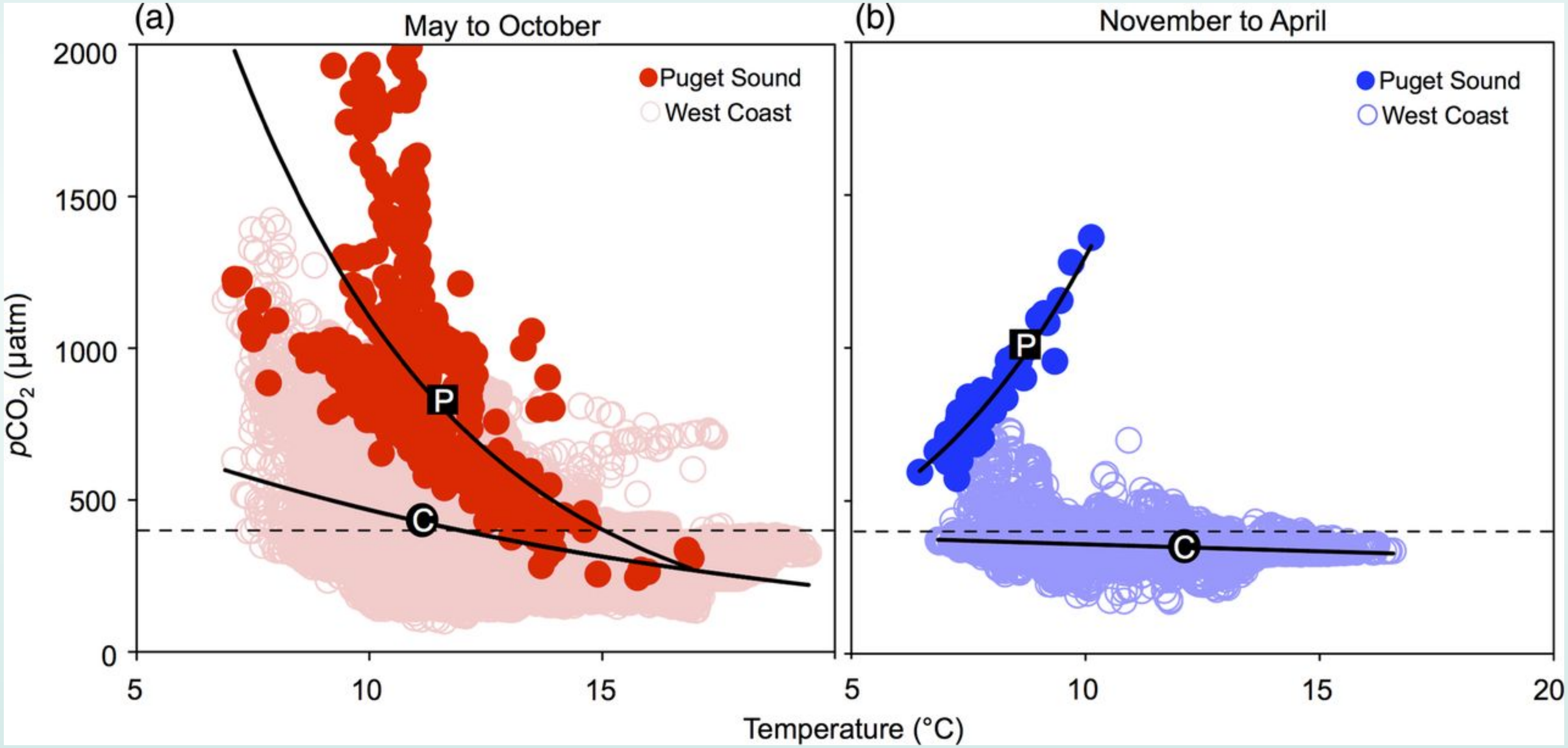
Coasts & shelf seas: On global scale, needs construction.   On regional scale, there are some systems (with ability to leverage), but many gaps. Global design needs to be regionally coordinated and implemented.

Coral reefs: On a global scale, needs construction; on regional scale, some systems can serve as building blocks. Observing assets may not cover full variability range, hence need for detailed site-specific studies.

courtesy: J. Newton

Correlated changes in temperature and $P\text{CO}_2$

(a) Relationship between pCO2 and temperature in the top 50 m of the water column in the northern and central California Current Ecosystem during summer upwelling season which approximately spans May through October and (b) winter (November through April) when downwelling-favourable winds predominate.



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