Implications of the Paris Agreement for the ocean and society

Jean-Pierre Gattuso
CNRS-Université Pierre et Marie Curie-Paris 6
IDDRI-Sciences Po

Ocean: considerable value

- Moderates climate change
- Represents more than 90% of the habitable space of the planet
- Hosts 25% of high-level species
- Provides 11% of global animal protein consumed by humans
- Ocean ecosystems protect coastlines
- …

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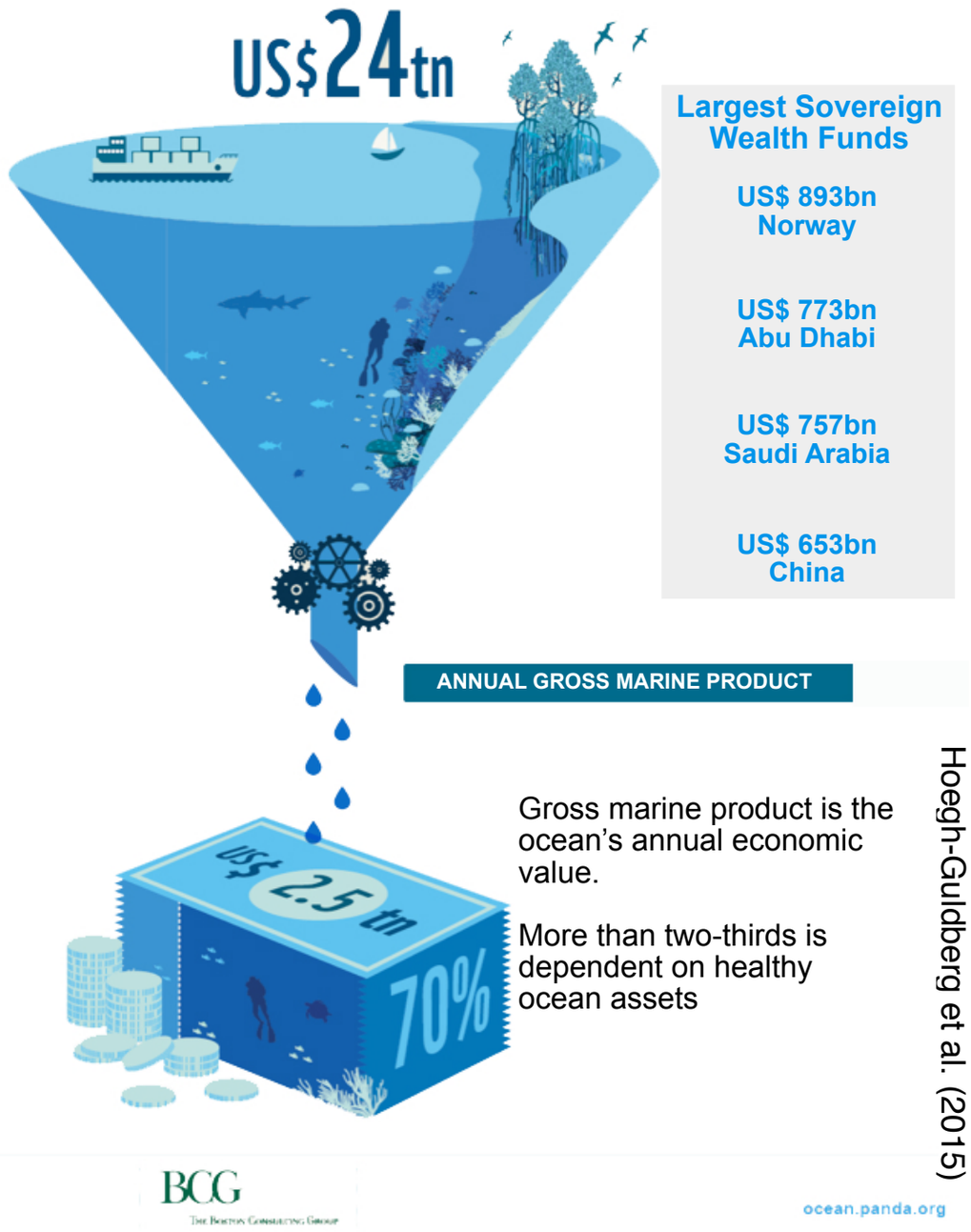

Hoegh-Guldberg et al. (2015)

Ocean: considerable value

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- …

Largest Sovereign Wealth Funds

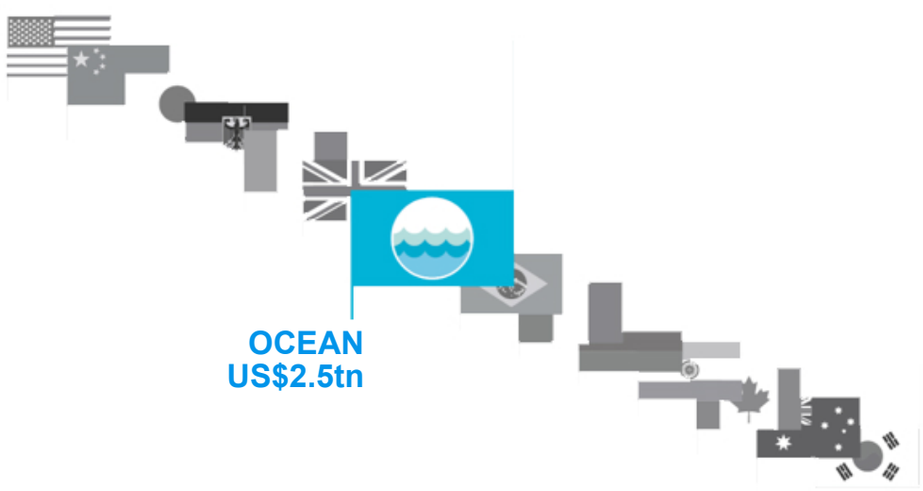
US$ 893bn
Norway

US$ 773bn
Abu Dhabi

US$ 757bn
Saudi Arabia

US$ 653bn
China

ANNUAL GROSS MARINE PRODUCT



ANNUAL GROSS MARINE PRODUCT

Gross marine product is the ocean's annual economic value.

More than two-thirds is dependent on healthy ocean assets

Hoegh-Guldberg et al. (2015)

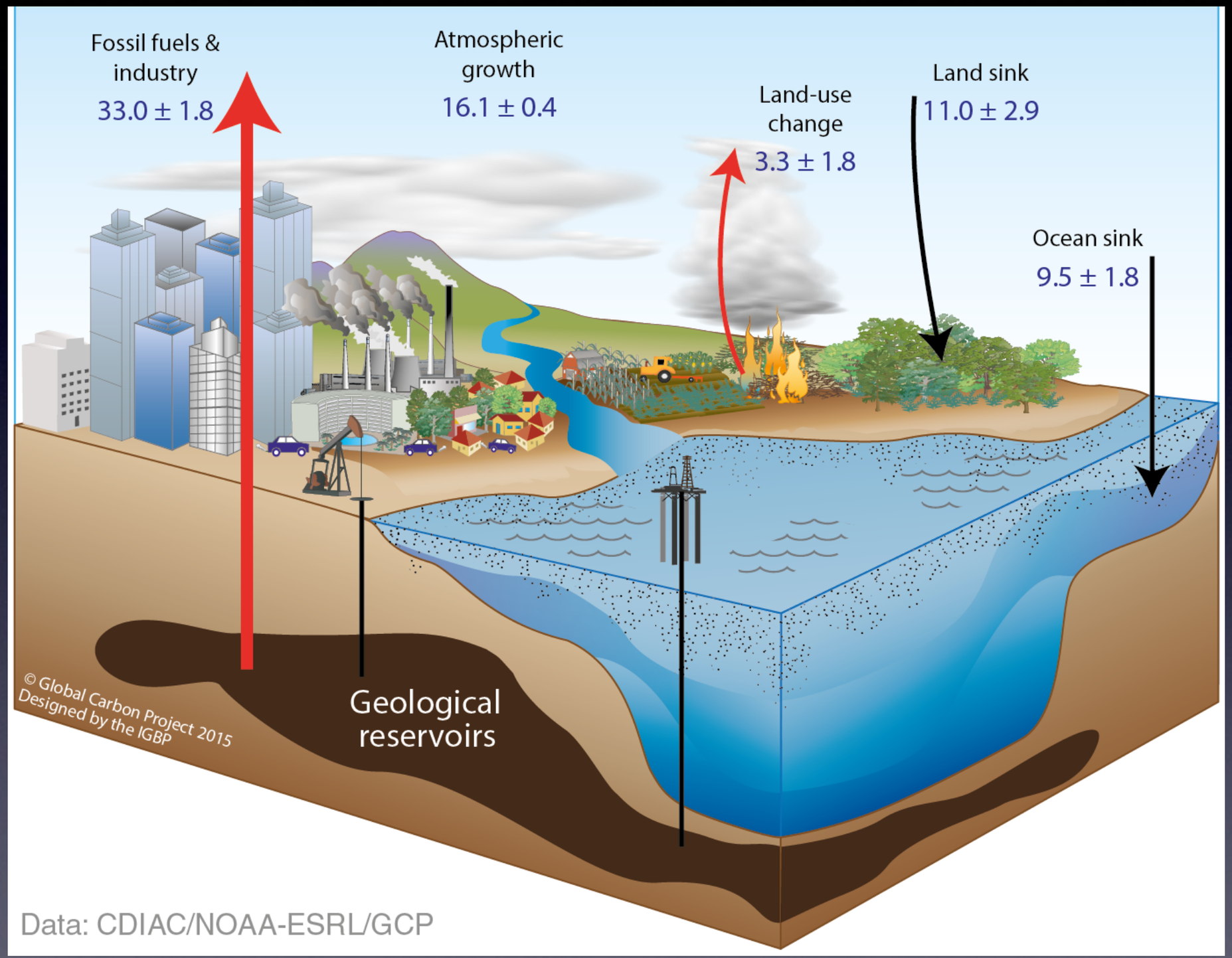
BCG
The Boston Consulting Group

ocean.panda.org

Impacts of human activities

McCauley et al. (2015)

Anthropogenic perturbation of the global carbon cycle (2005-2015; Gt CO_2/yr)

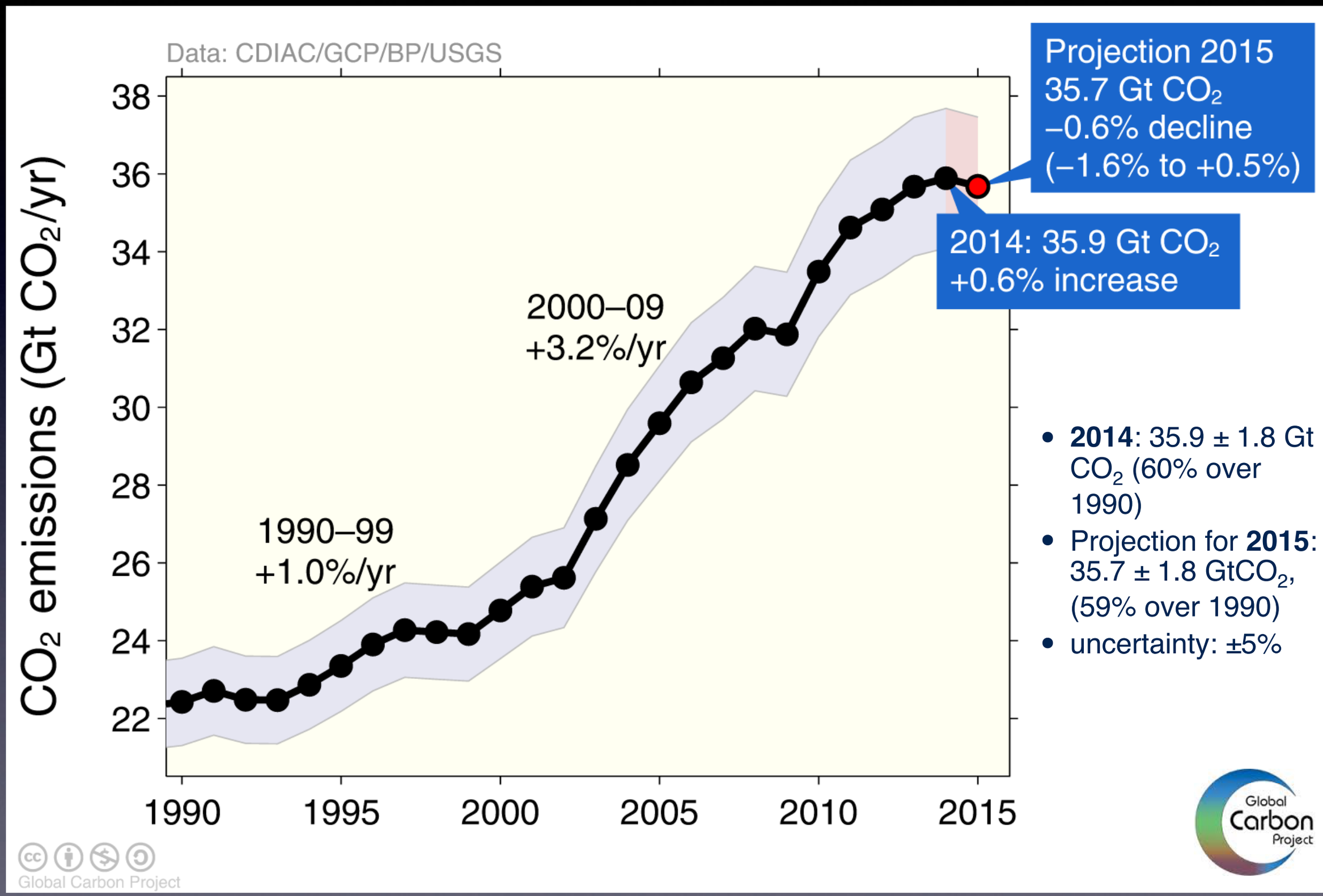


Source: CDIAC; NOAA-ESRL; Le Quéré et al 2015; Global Carbon Budget 2015

CO_2 emissions from fossil fuels and industry

This generation has altered the composition of the atmosphere on a global scale through radioactive materials and a steady increase in carbon dioxide from the burning of fossil fuels.
President Lyndon B. Johnson, 1965

CO_2 emissions from fossil fuels and industry



- **2014**: 35.9 ± 1.8 Gt CO_2 (60% over 1990)
- Projection for **2015**: 35.7 ± 1.8 GtCO_2, (59% over 1990)
- uncertainty: ±5%

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Global carbon budget (2005-2014)

33.0 ± 1.6 Gt CO_2/yr (91%)

+

3.4 ± 1.8 Gt CO_2/yr (9%)

Le Quéré et al. (2013)

Global carbon budget (2005-2014)

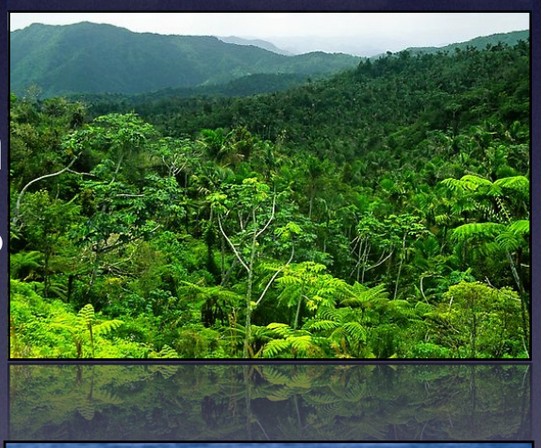
33.0 ± 1.6 Gt CO_2/yr (91%)

+

3.4 ± 1.8 Gt CO_2/yr (9%)

Atmosphere
44%

Vegetation
30%



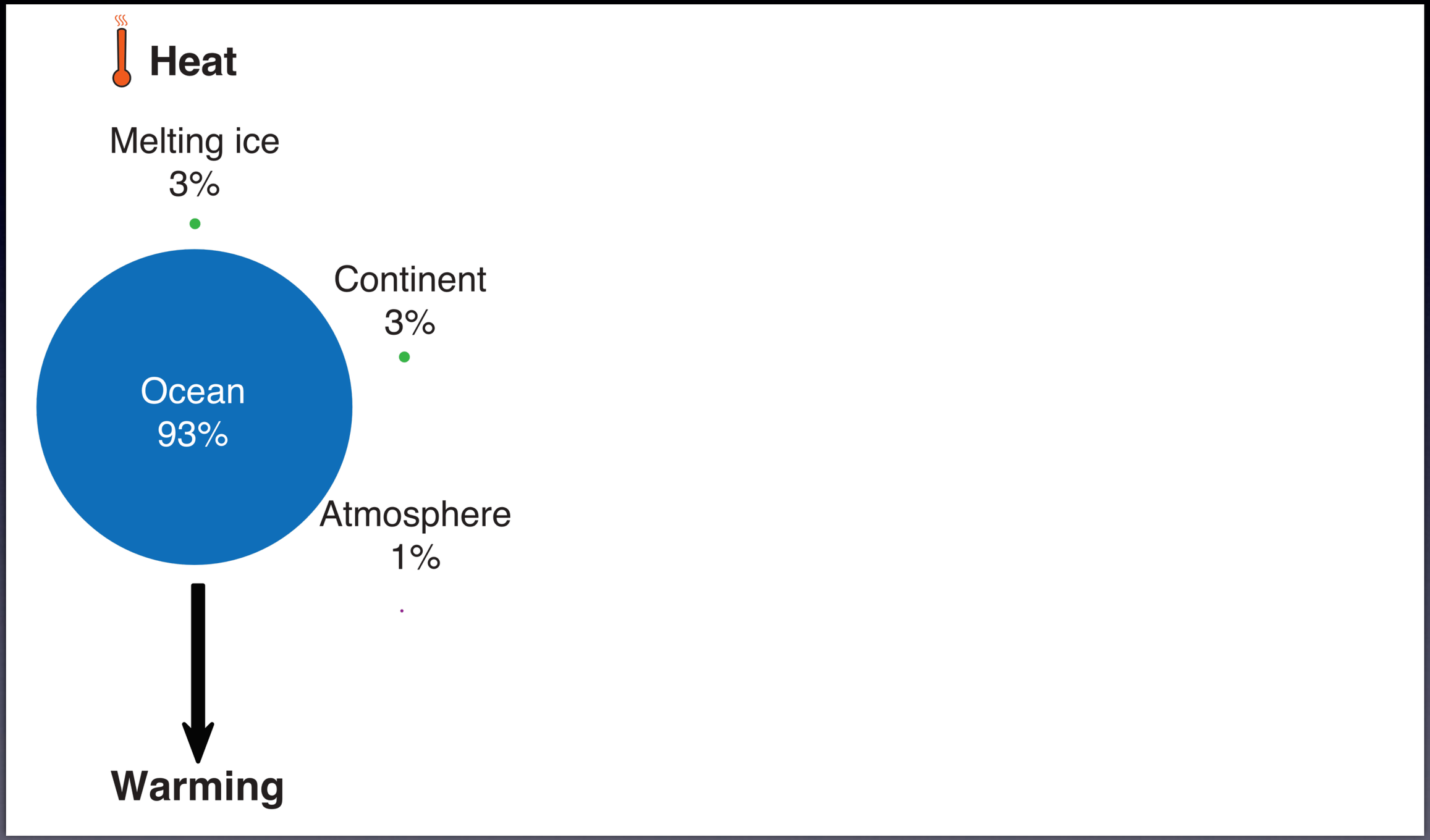
Oceans
26%

30 millions tonnes CO_2 per day

Global Carbon Project

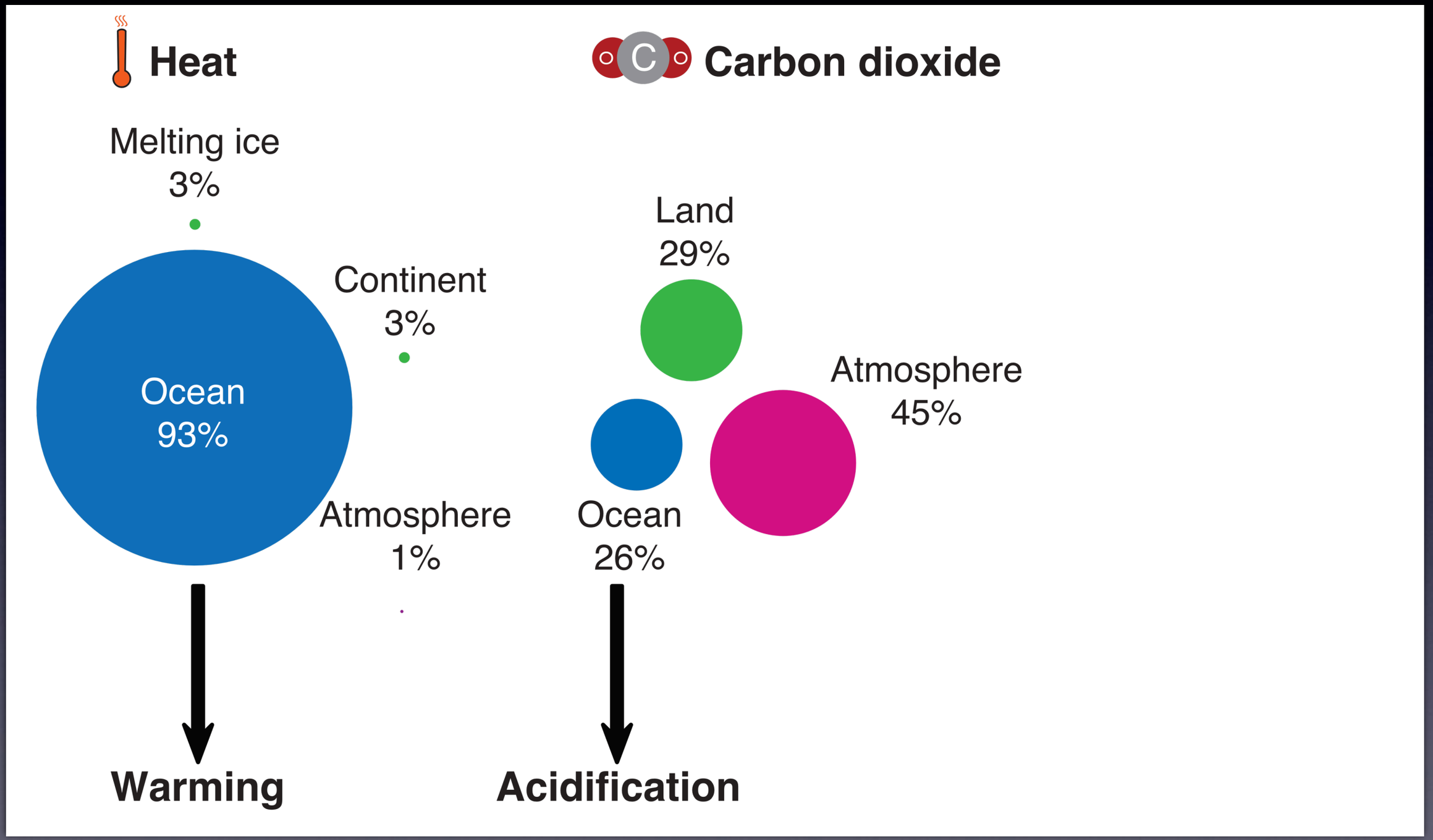
Le Quéré et al. (2013)

Ocean: actor and victim of climate change



Magnan et al. (2015)

Ocean: actor and victim of climate change



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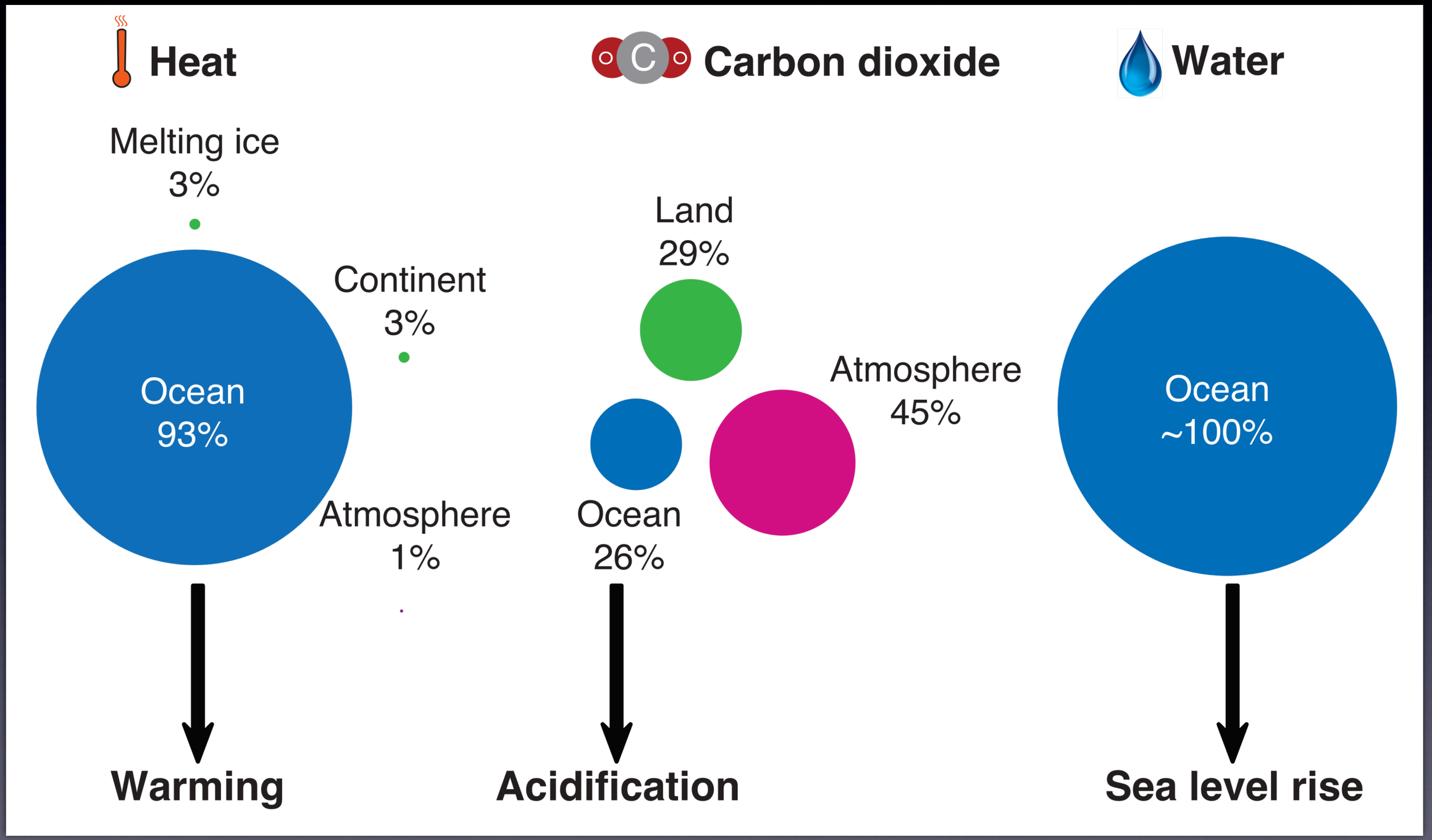
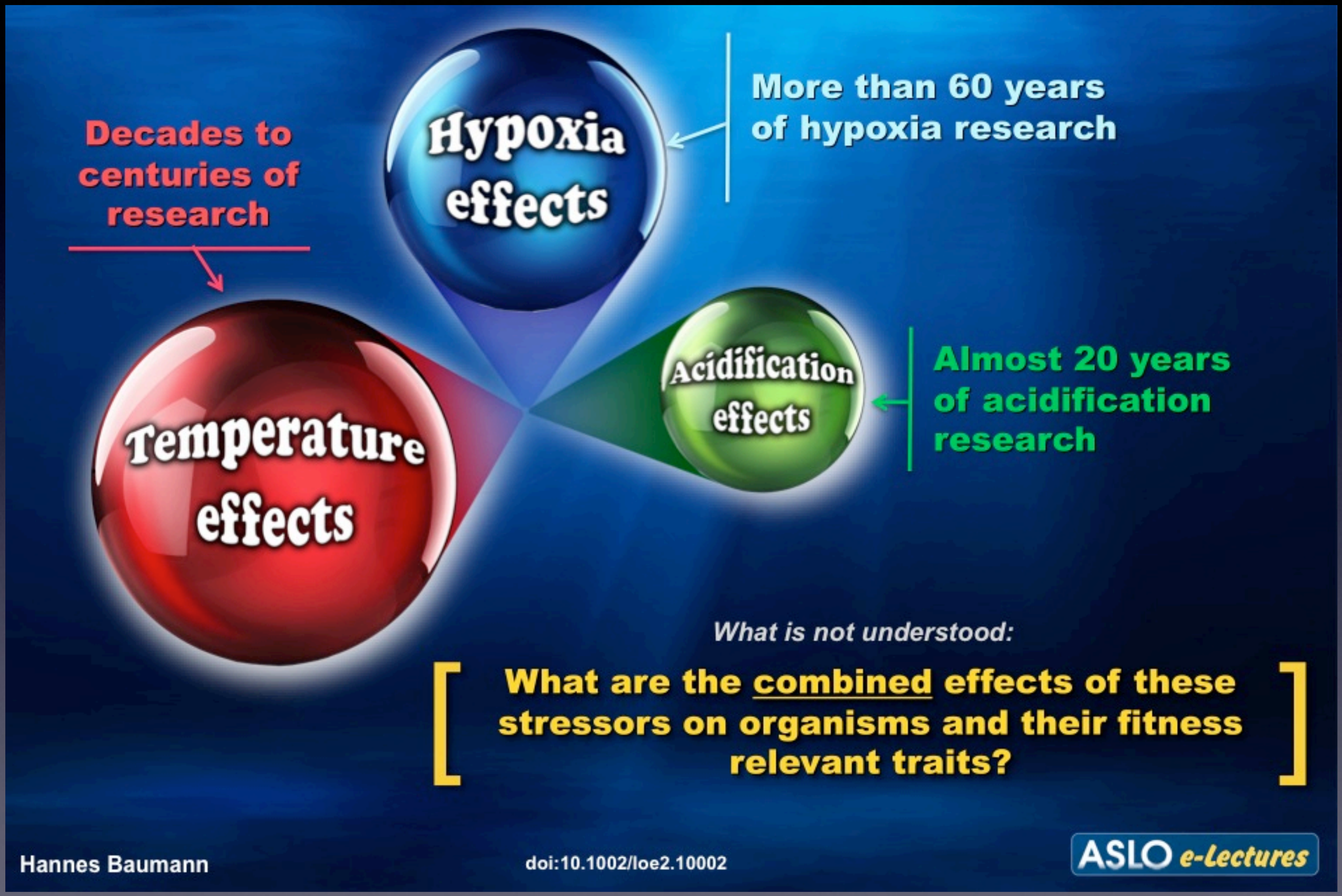


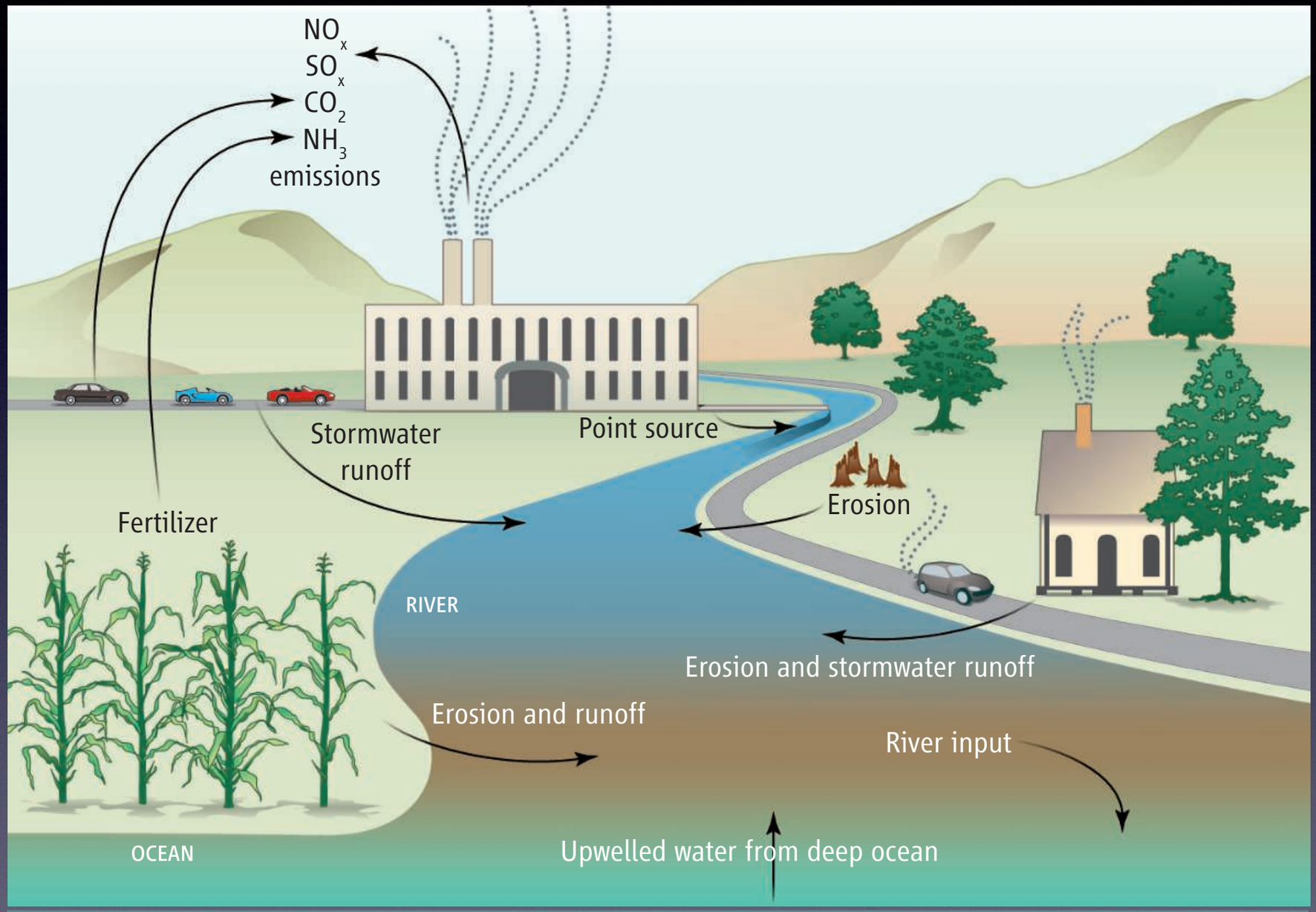
Magnan et al. (2015)

Vastly different knowledge



Ocean acidification

Causes of ocean acidification



Kelly et al. (2011)

What is ocean acidification?

More acidity

Less acidity

Concentrations of Hydrogen ions compared to distilled water (pH)		Examples of solutions and their respective pH
10,000,000	0	Battery Acid
1,000,000	1	Hydrochloric Acid
100,000	2	Lemon Juice, Vinegar
10,000	3	Orange Juice, Soda
1,000	4	Tomato Juice
100	5	Black Coffee, Acid Rain
10	6	Urine, Saliva
1	7	“Pure” Water
1/10	8	Sea Water
1/100	9	Baking Soda, Toothpaste
1/1,000	10	Milk of Magnesium
1/10,000	11	Household Ammonia
1/100,000	12	Soapy Water
1/1,000,000	13	Bleach, Oven Cleaner
1/10,000,000	14	Liquid Drain Cleaner

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More acidity

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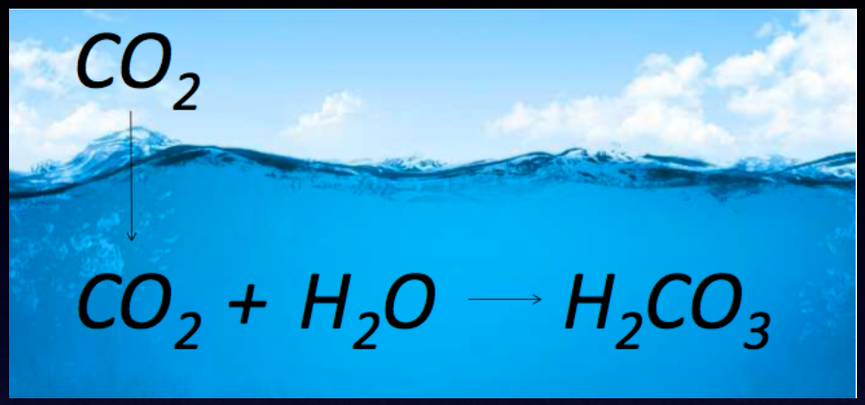
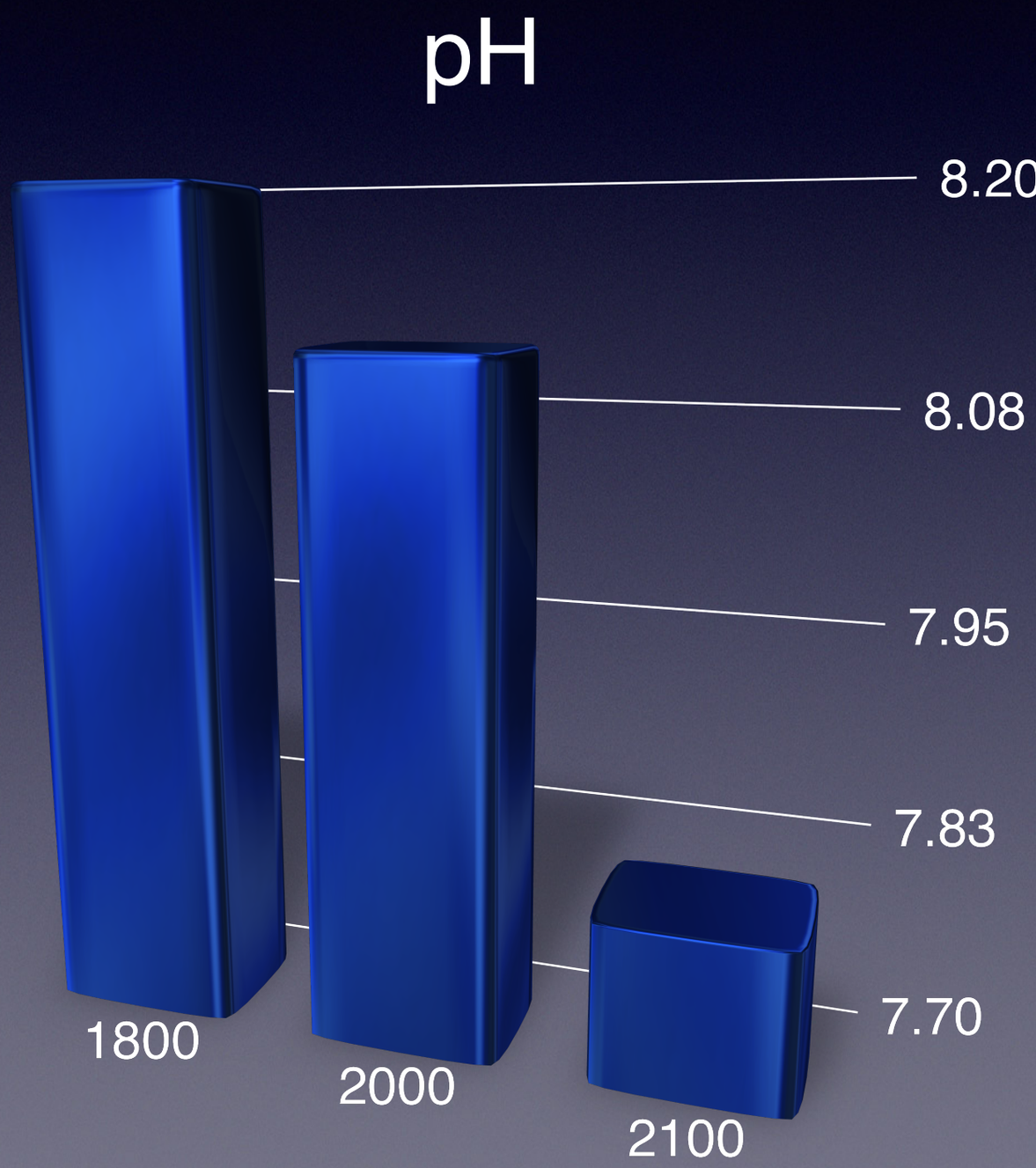


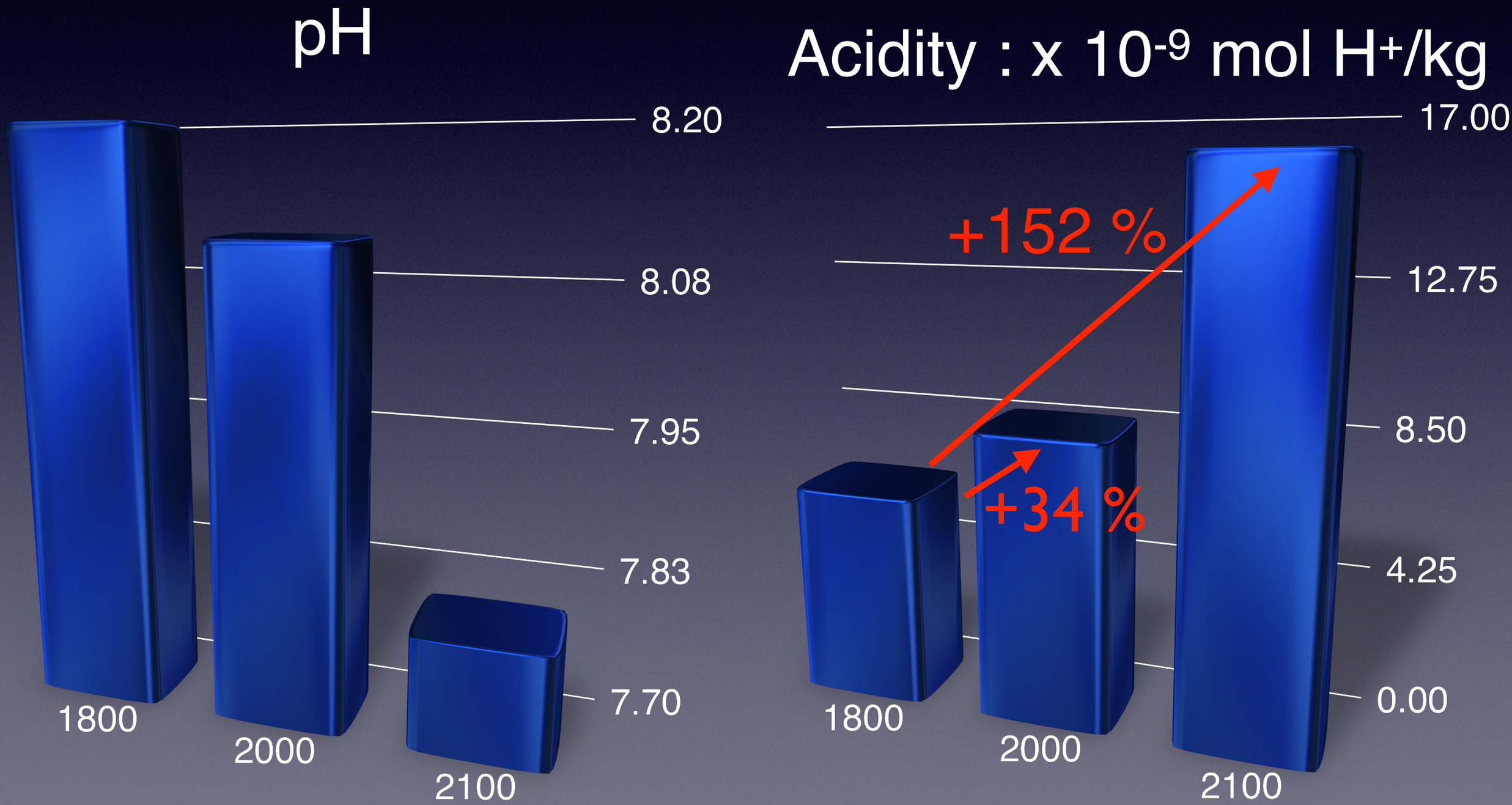
Sam Dupont

- CO_2 is an acid gas (it produces acid when combined with water)
- Each of us adds 4 kg CO_2 per day to the ocean (increasing acidity, reducing pH)

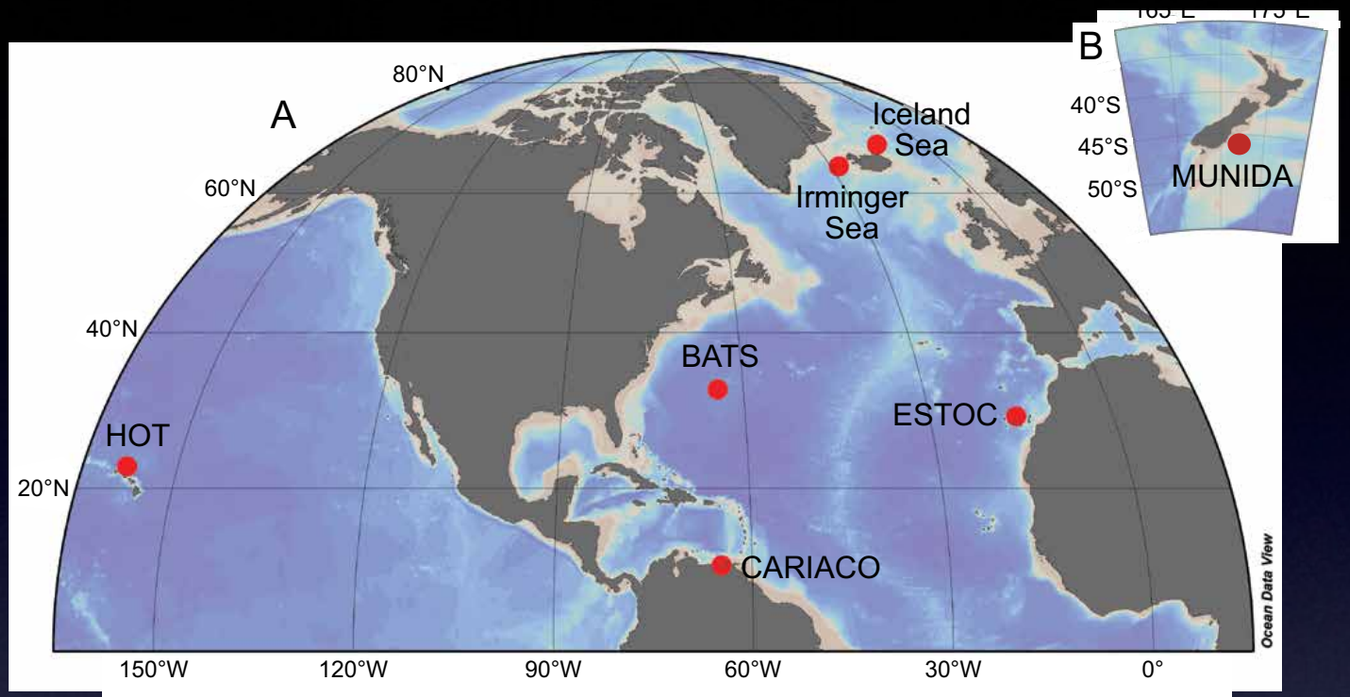
pH and acidity



pH and acidity



Ocean acidification can be measured



Bates et al. (2014)

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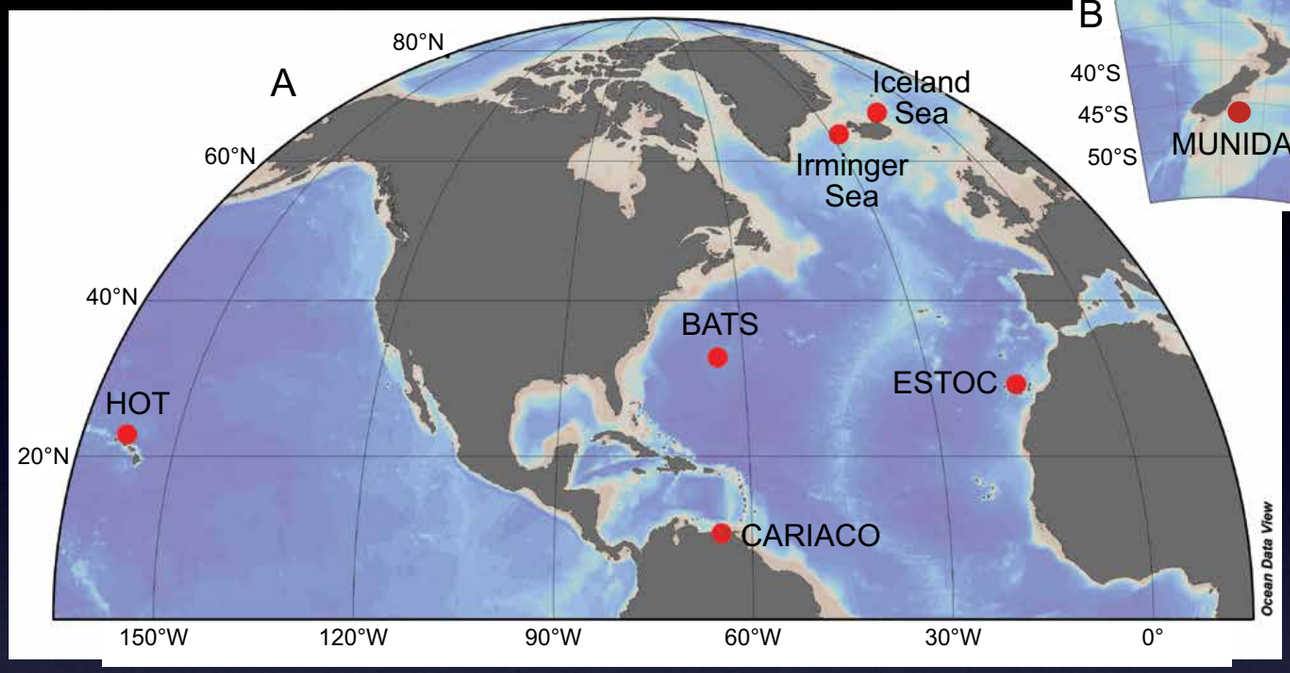
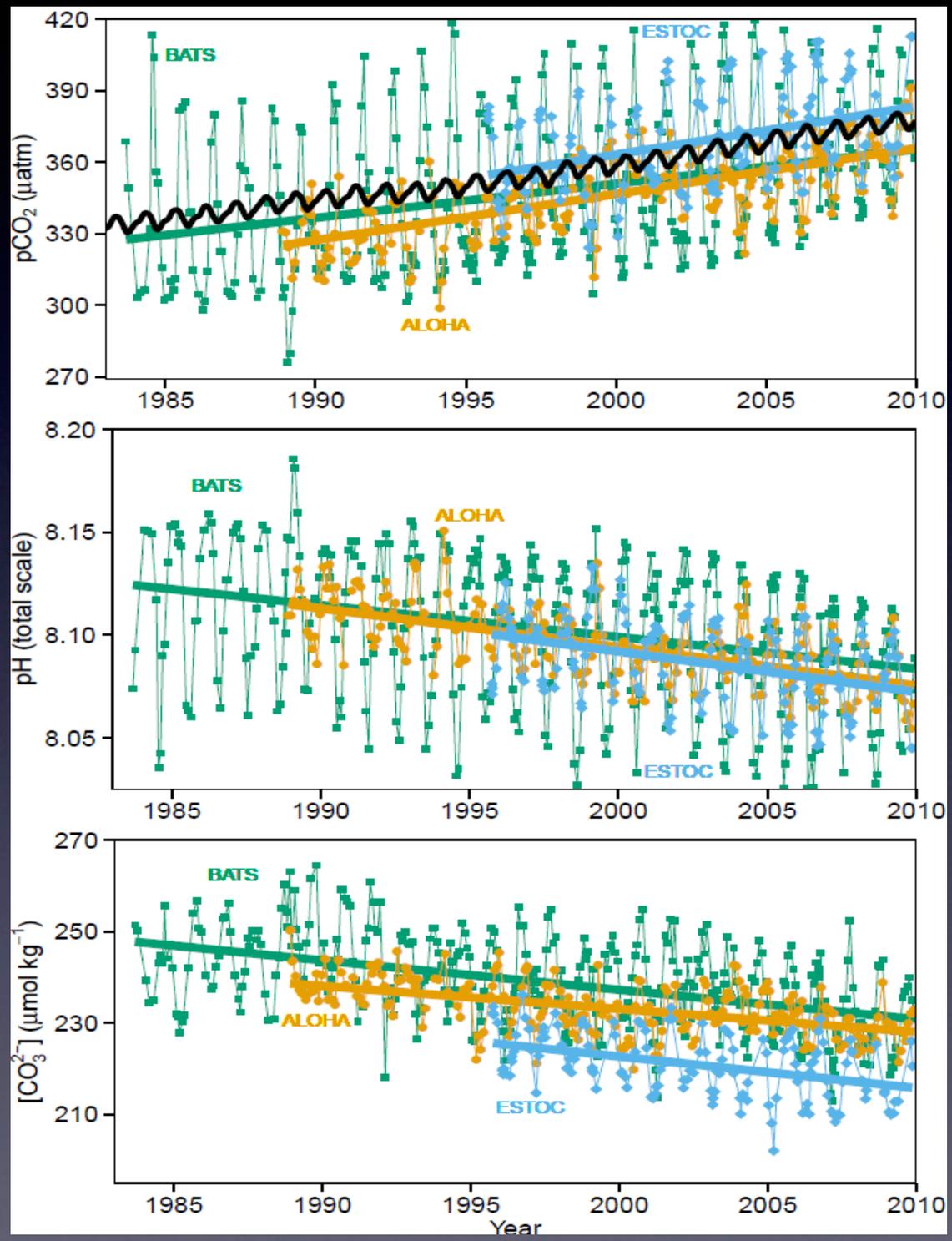


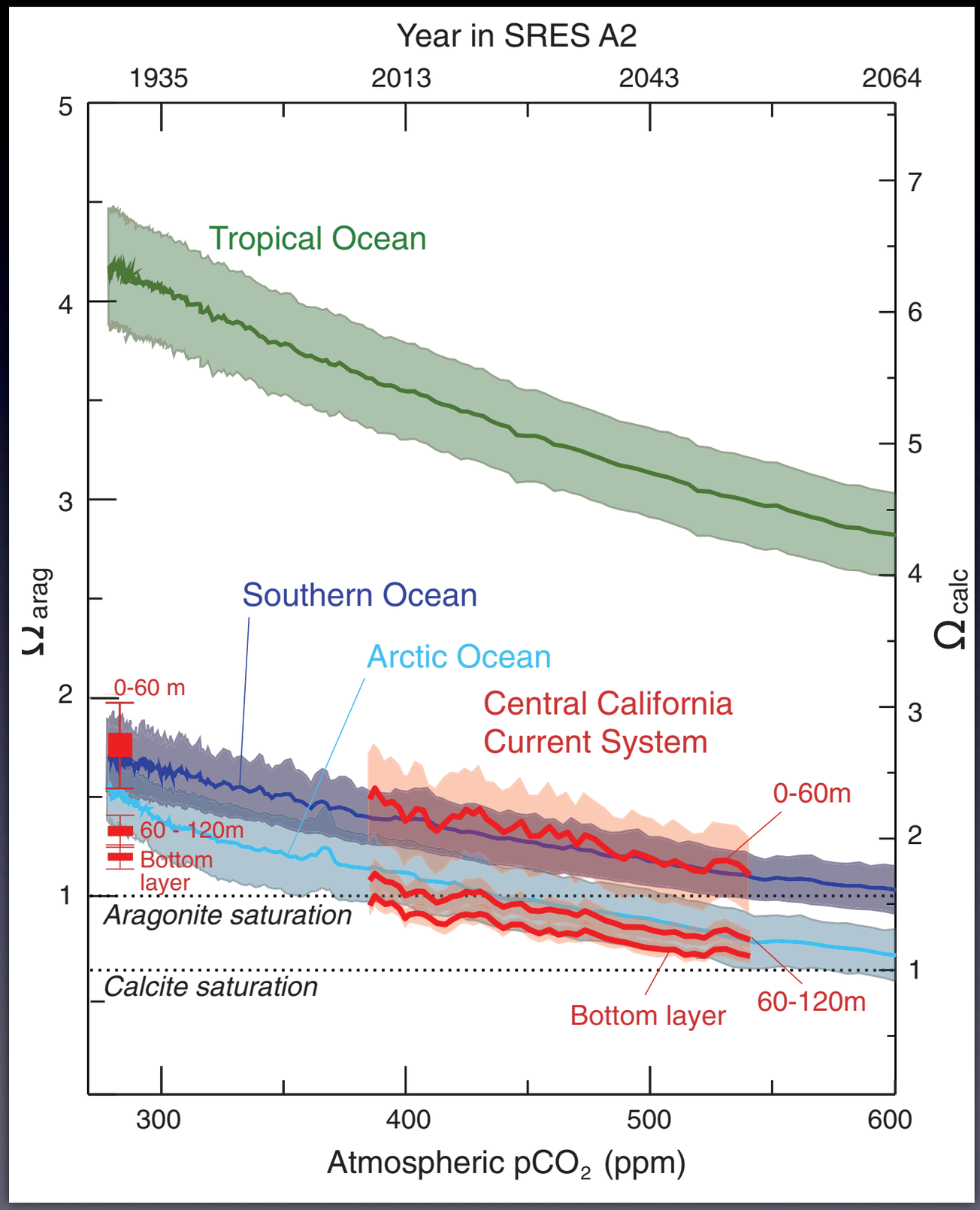
Bates et al. (2014)



IPCC AR5 WG I

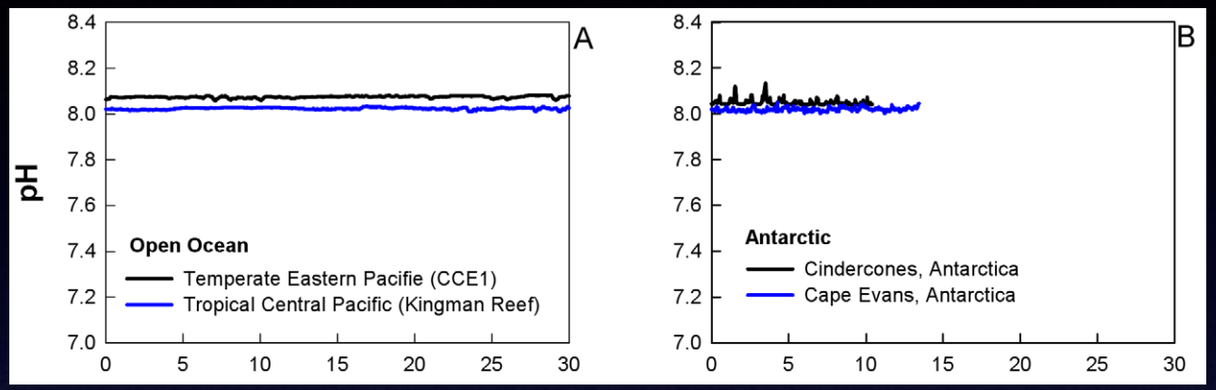
Range 1995-2009:
-0.0015 to -0.0022 units yr^{-1}

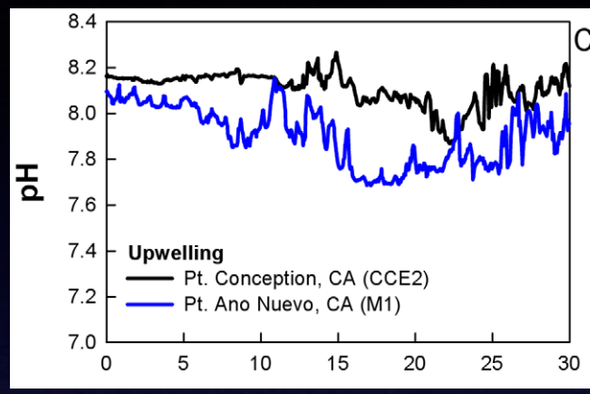
Geographical differences

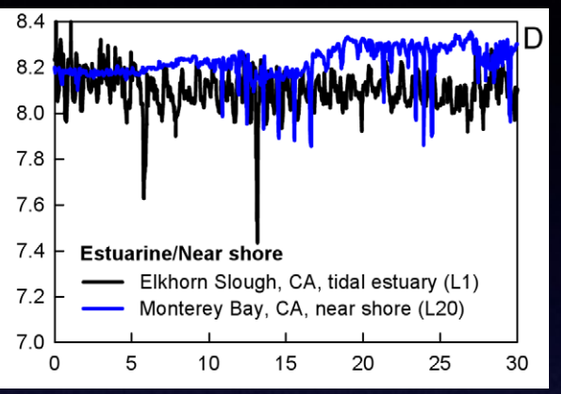


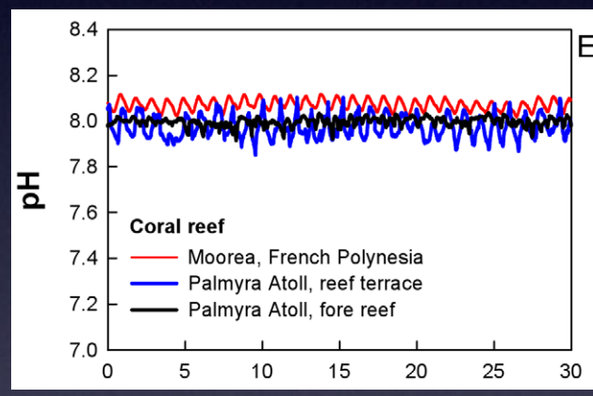
Gruber et al. (2012)

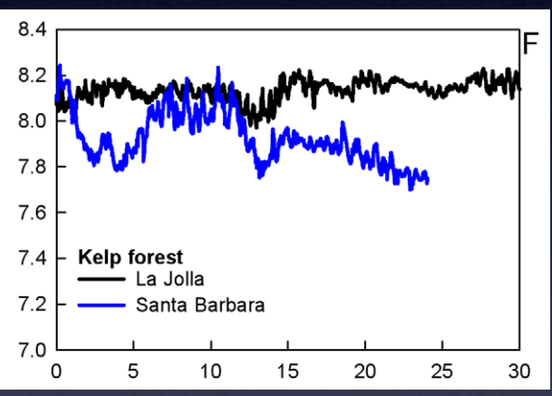
Spatial and temporal variability of surface pH

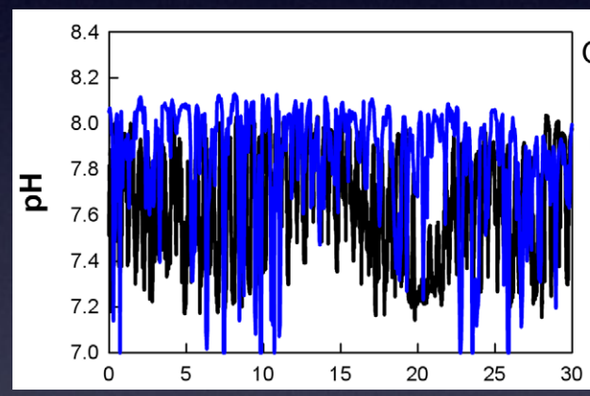


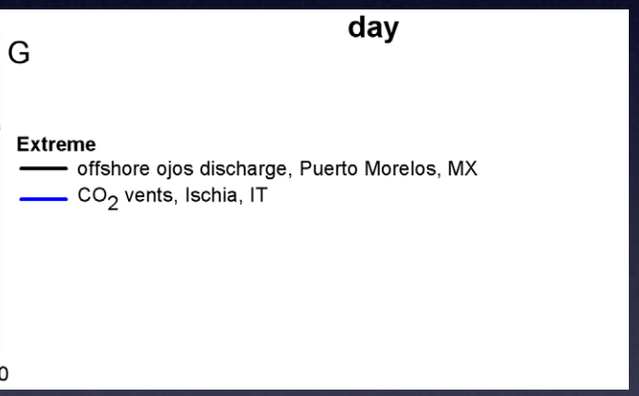






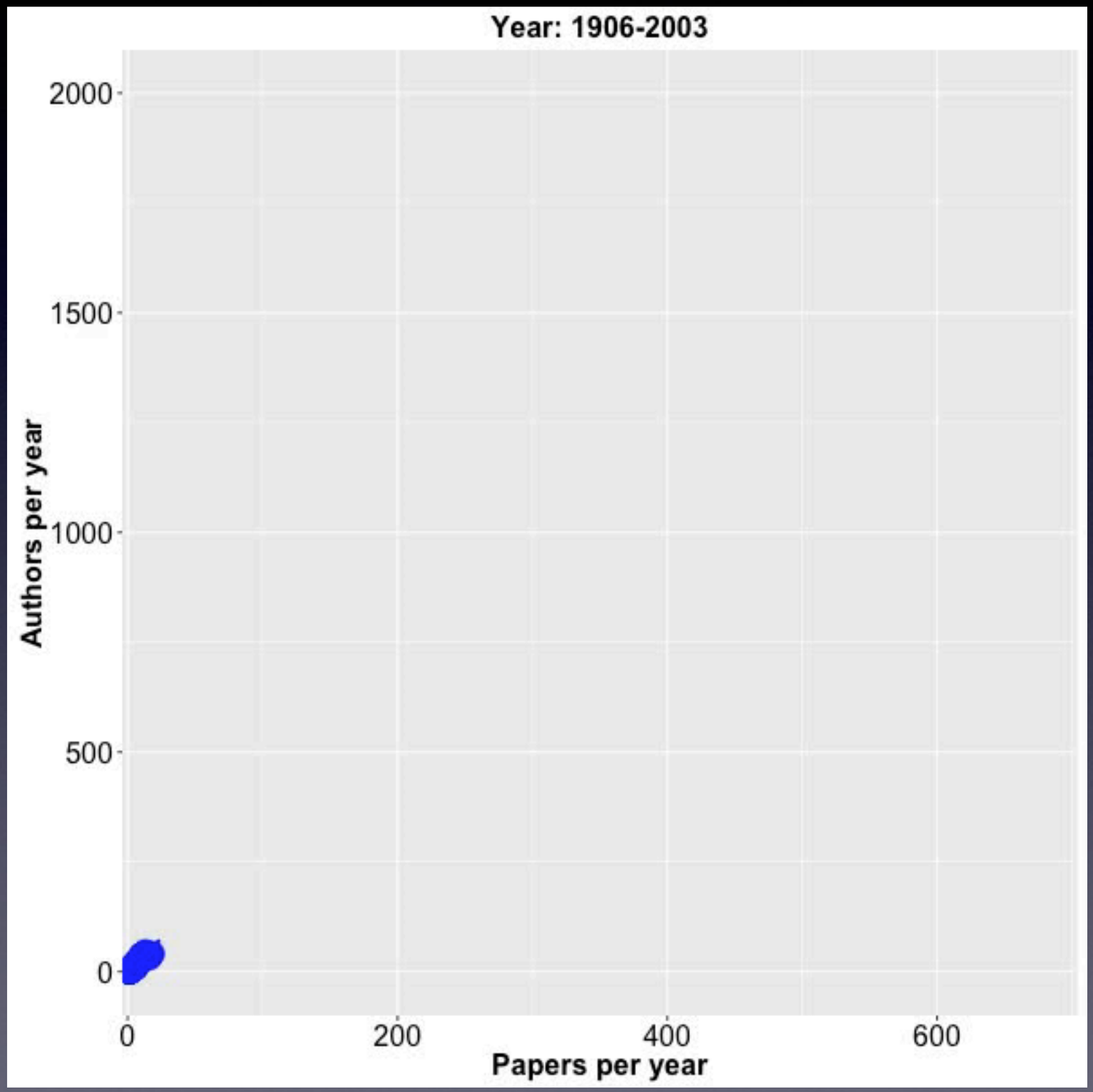






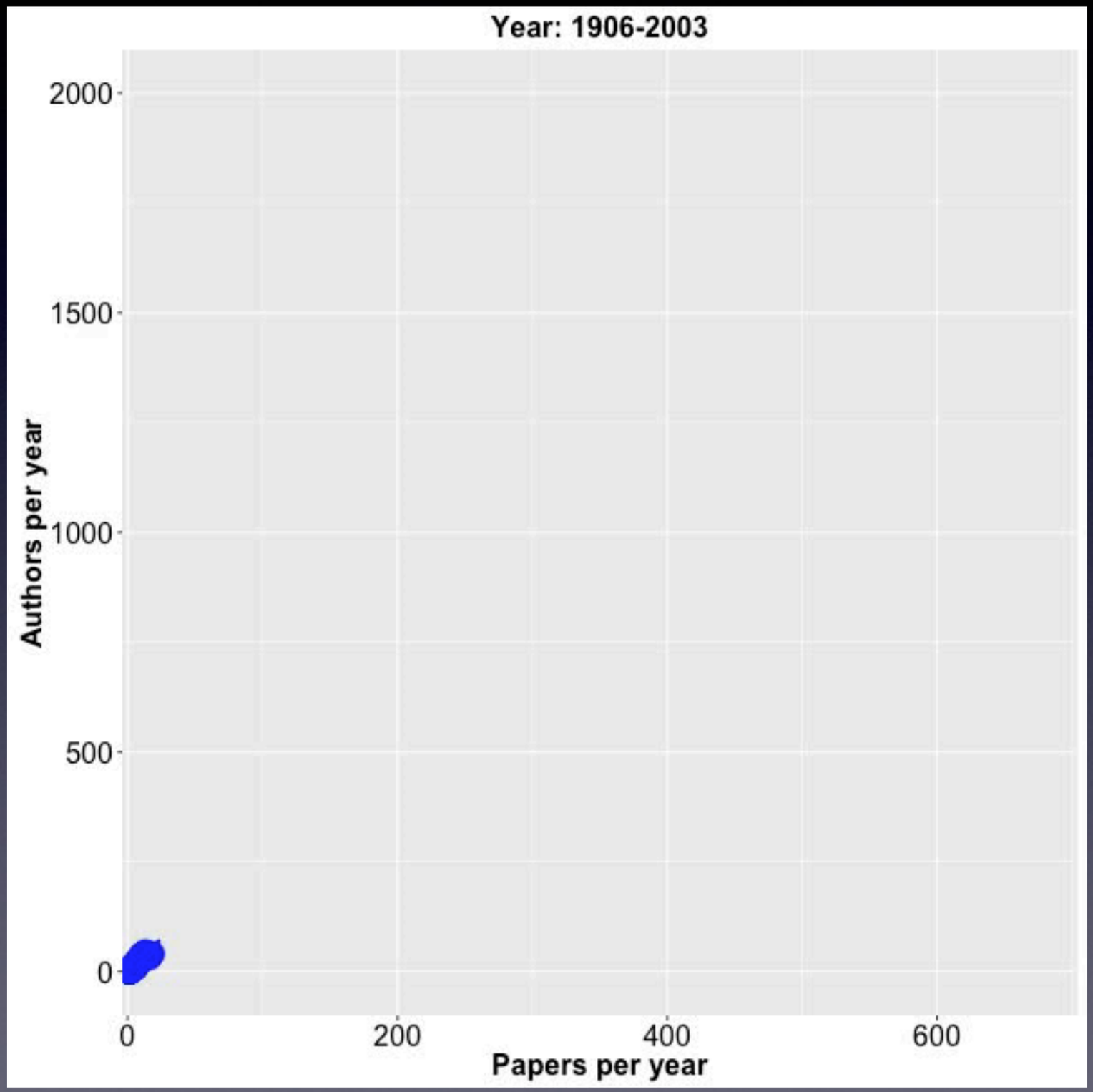
Hofmann et al. (2011)

Papers on ocean acidification



Gattuso & Hansson, OA-ICC

Papers on ocean acidification



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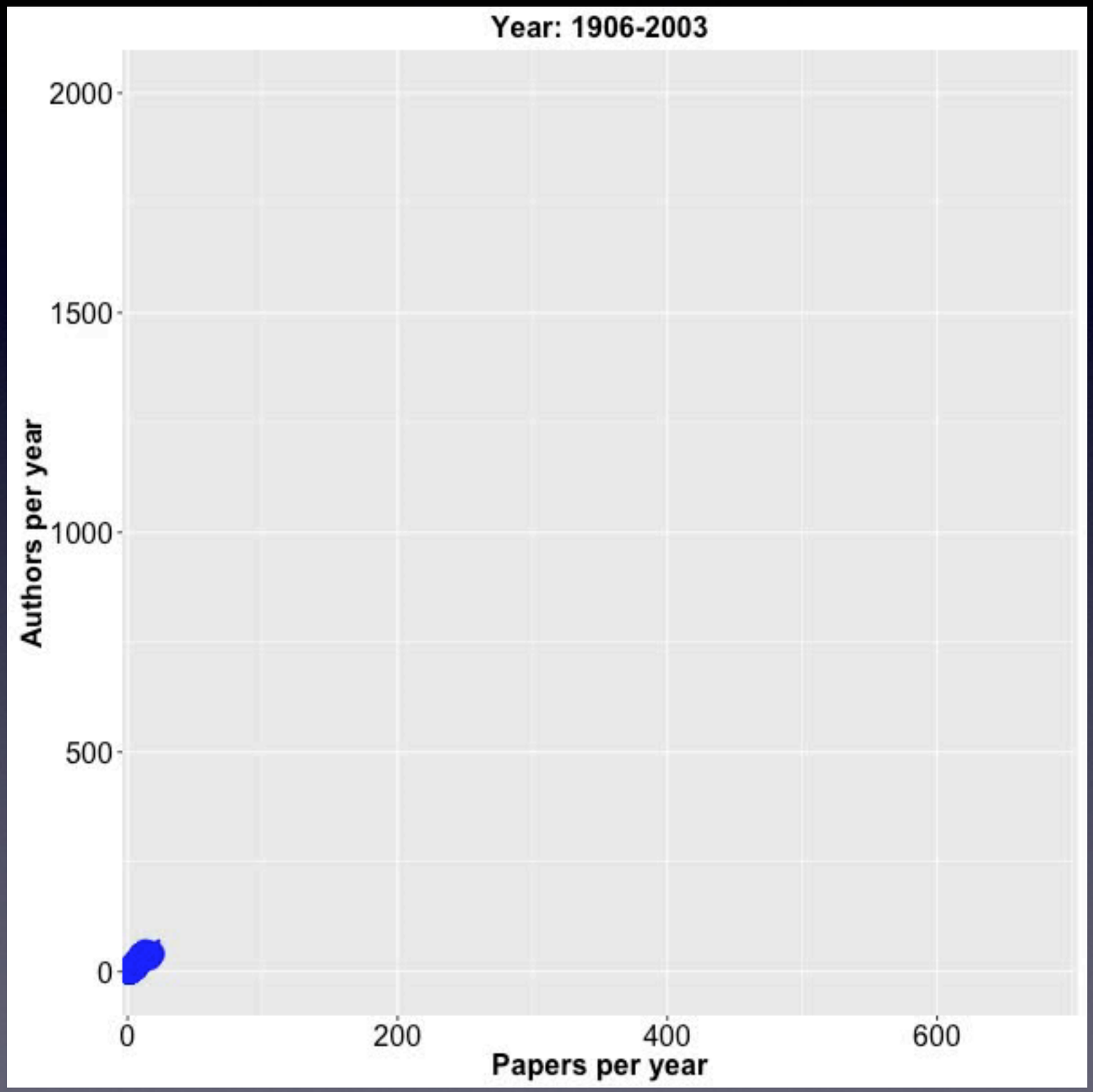


Papers:

- 604 in 2015
- 50% in past 4 years
- +33% y^{-1} since 2000 vs +4% y^{-1} in WoS

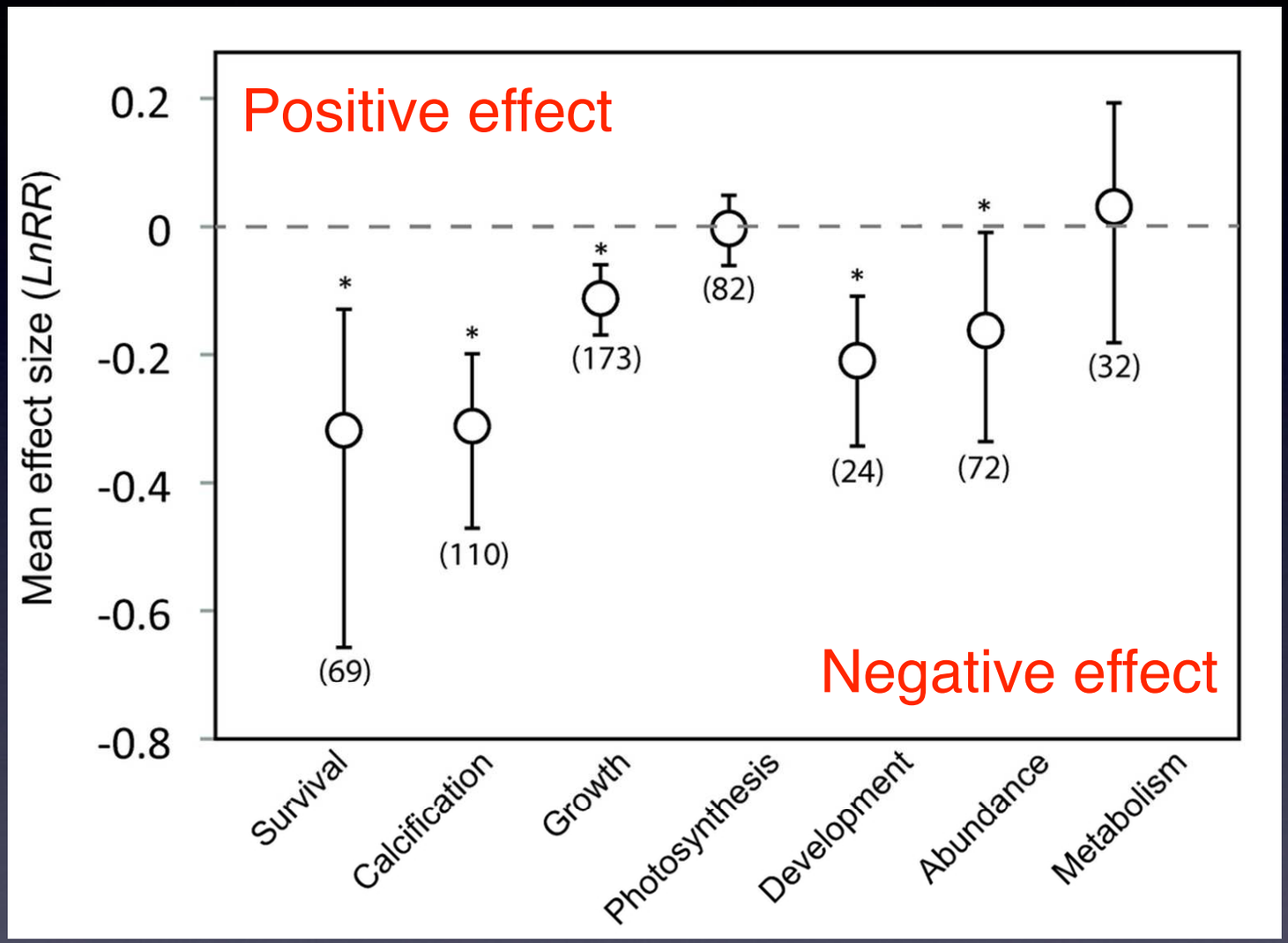
Authors:

- 1947 in 2015

Gattuso & Hansson, OA-ICC

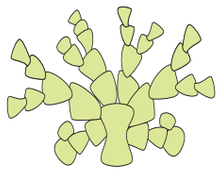
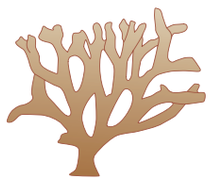
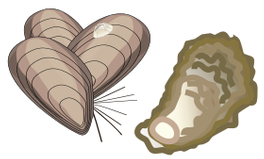
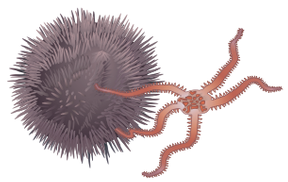
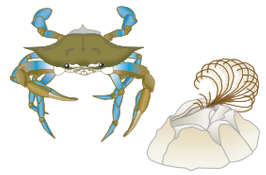
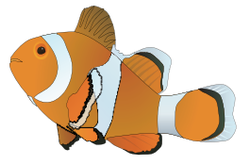
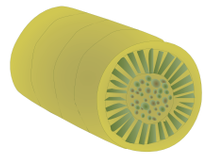
Meta-analysis: Kroeker et al. (2013)

- Significant negative effect on:
  - survival
  - calcification
  - growth
  - development
  - abundance



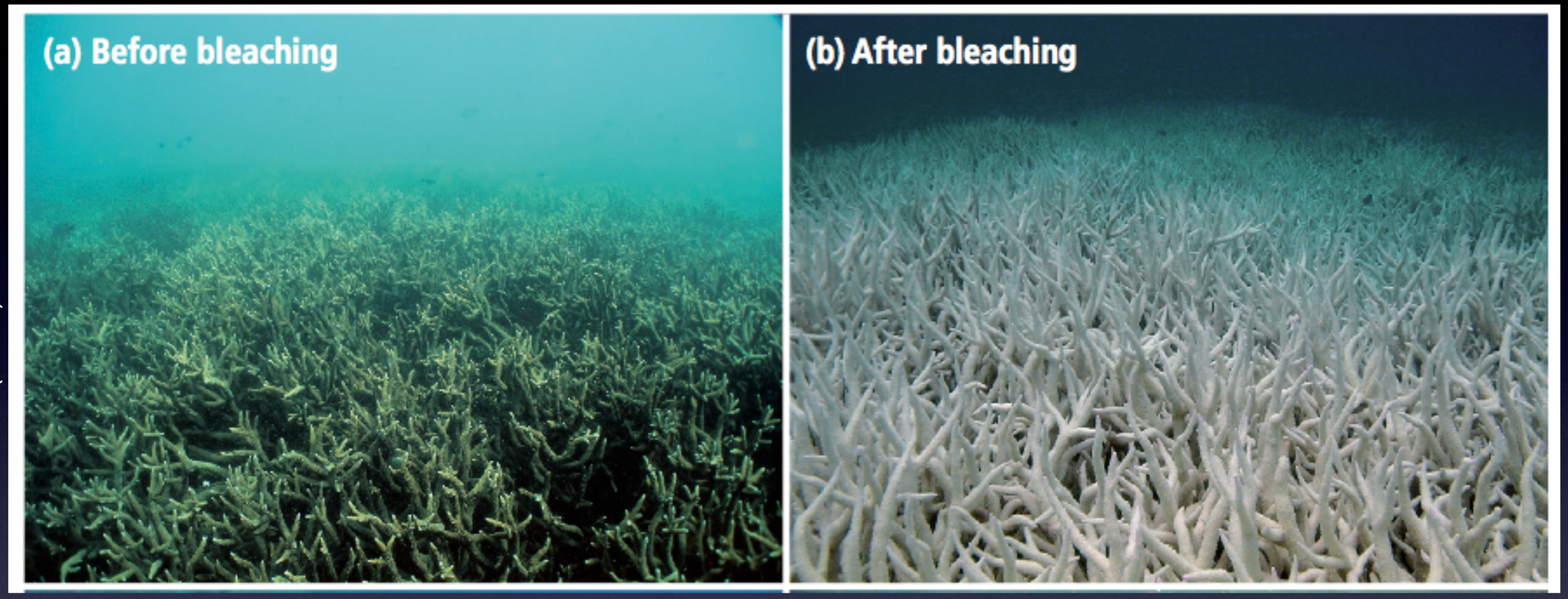
Meta-analysis: Kroeker et al. (2013)

- Enhanced <25%
- No effect
- Reduced <25%
- Reduced >25%
- Not tested

Taxa	Response	Mean Effect
 Calcifying algae	Survival	
	Calcification	
	Growth	
	Photosynthesis	-28%
	Abundance	-80%
 Corals	Survival	
	Calcification	-32%
	Growth	-23%
	Photosynthesis	
	Abundance	-47%
 Coccolithophores	Survival	
	Calcification	-9%
	Growth	
	Photosynthesis	
	Abundance	
 Molluscs	Survival	-34%
	Calcification	-40%
	Growth	-17%
	Development	-25%
	Abundance	
 Echinoderms	Survival	
	Calcification	
	Growth	-10%
	Development	-11%
	Abundance	
 Crustaceans	Survival	
	Calcification	
	Growth	
	Development	
	Abundance	
 Fish	Survival	
	Calcification	
	Growth	
	Development	
	Abundance	
 Fleshy algae	Survival	
	Calcification	
	Growth	+22%
	Photosynthesis	
	Abundance	
 Seagrasses	Survival	
	Calcification	
	Growth	
	Photosynthesis	
	Abundance	
 Diatoms	Survival	
	Calcification	
	Growth	+12%
	Photosynthesis	
	Abundance	

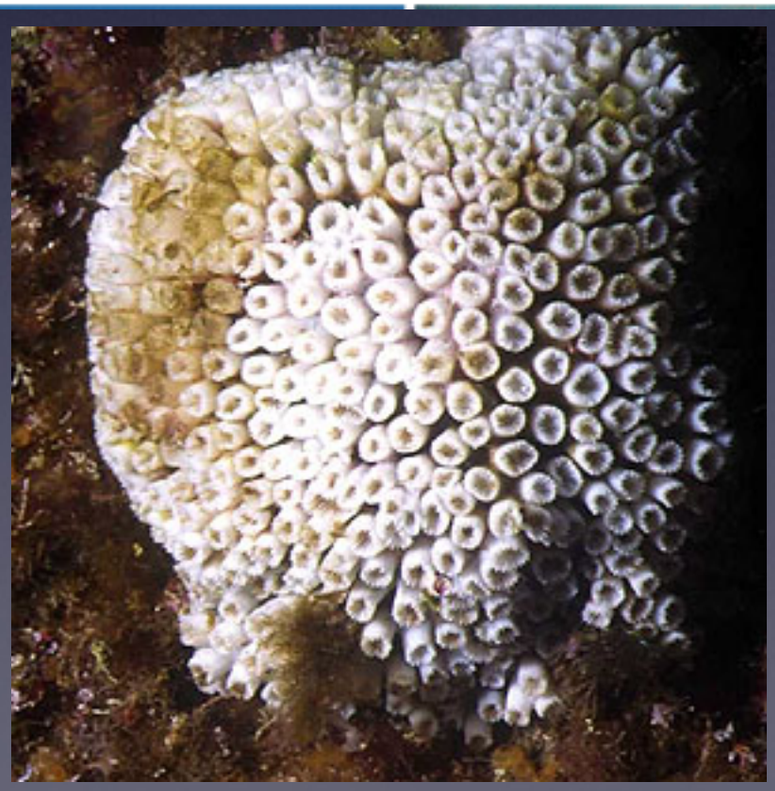
Ocean warming

Warming: mass mortalities

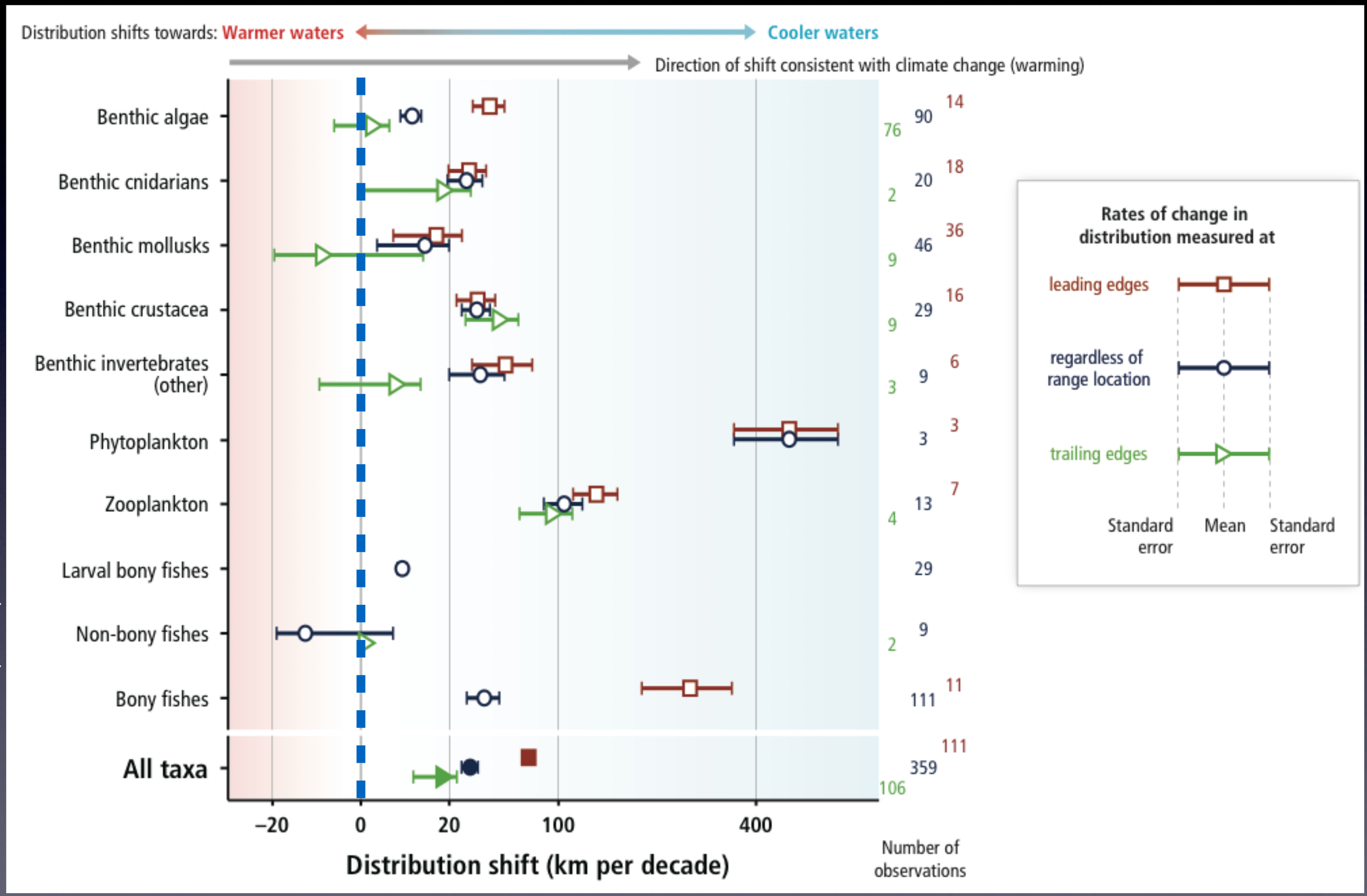


Gattuso et al. (2014). © R. Berkelmans

Also elsewhere:
Mediterranean Sea

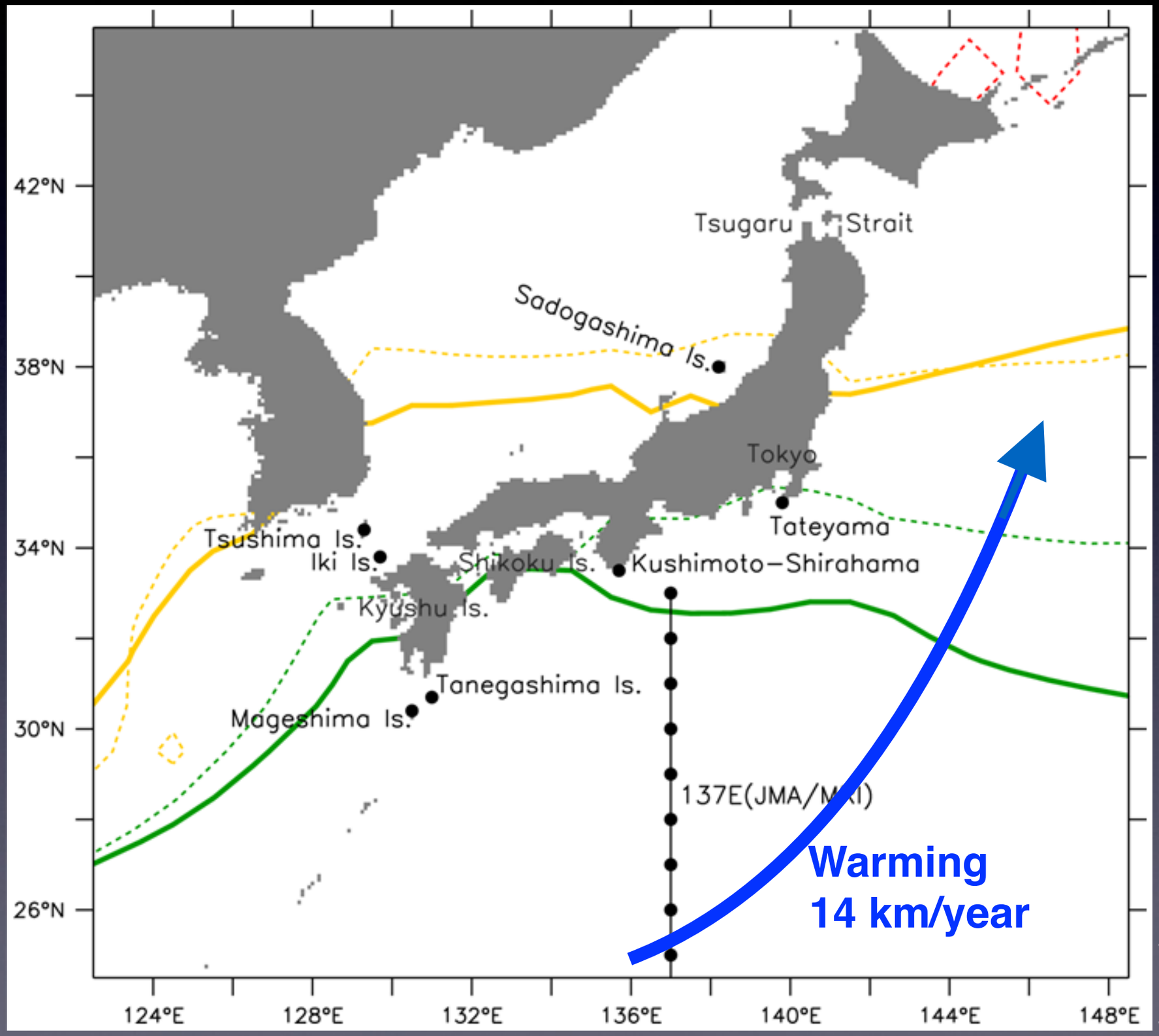


Warming: redistribution of species



Poloczanska et al. (2014)

Polar displacement?
A few corals do not make a reef



Yara et al. (2012)

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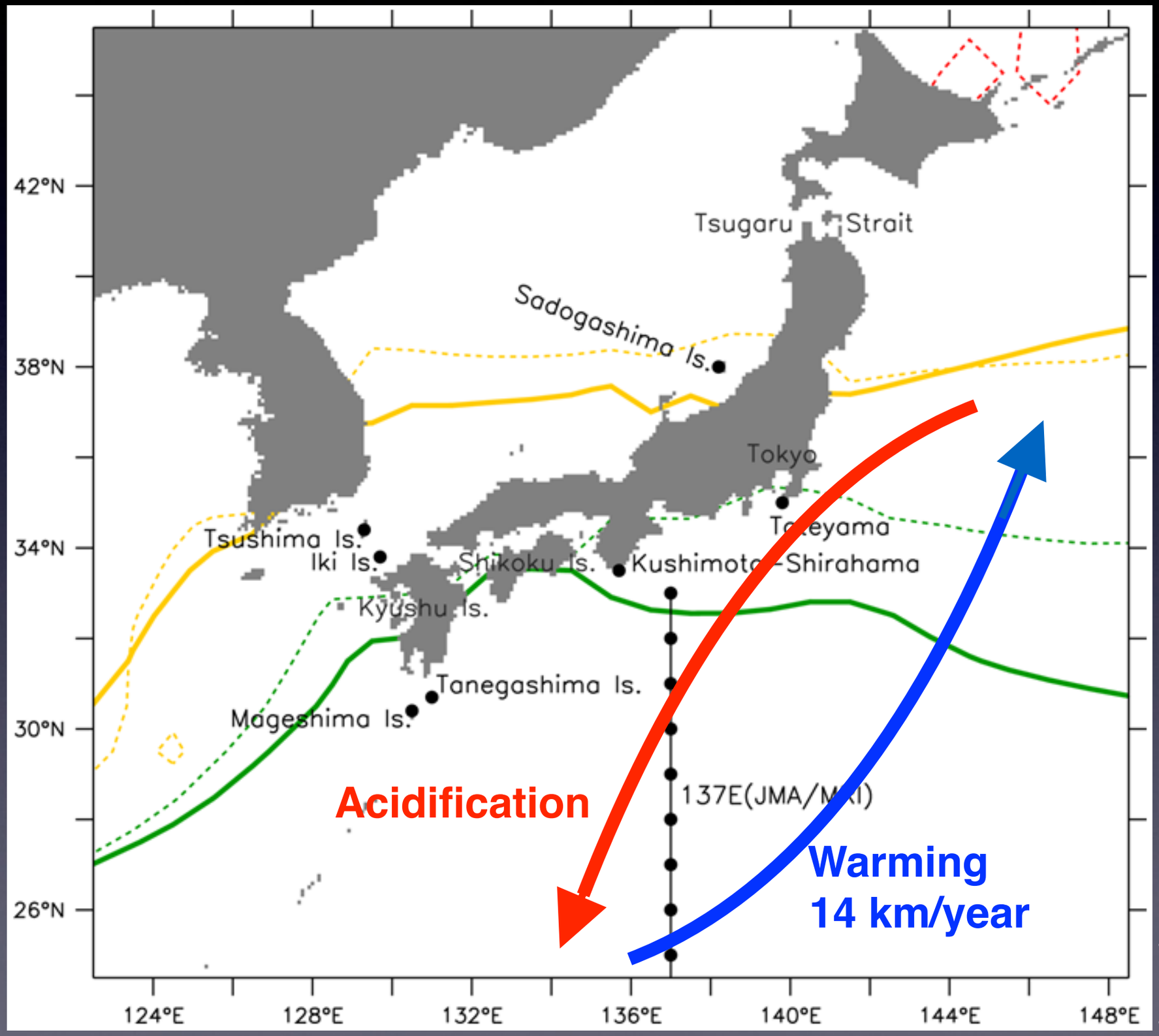


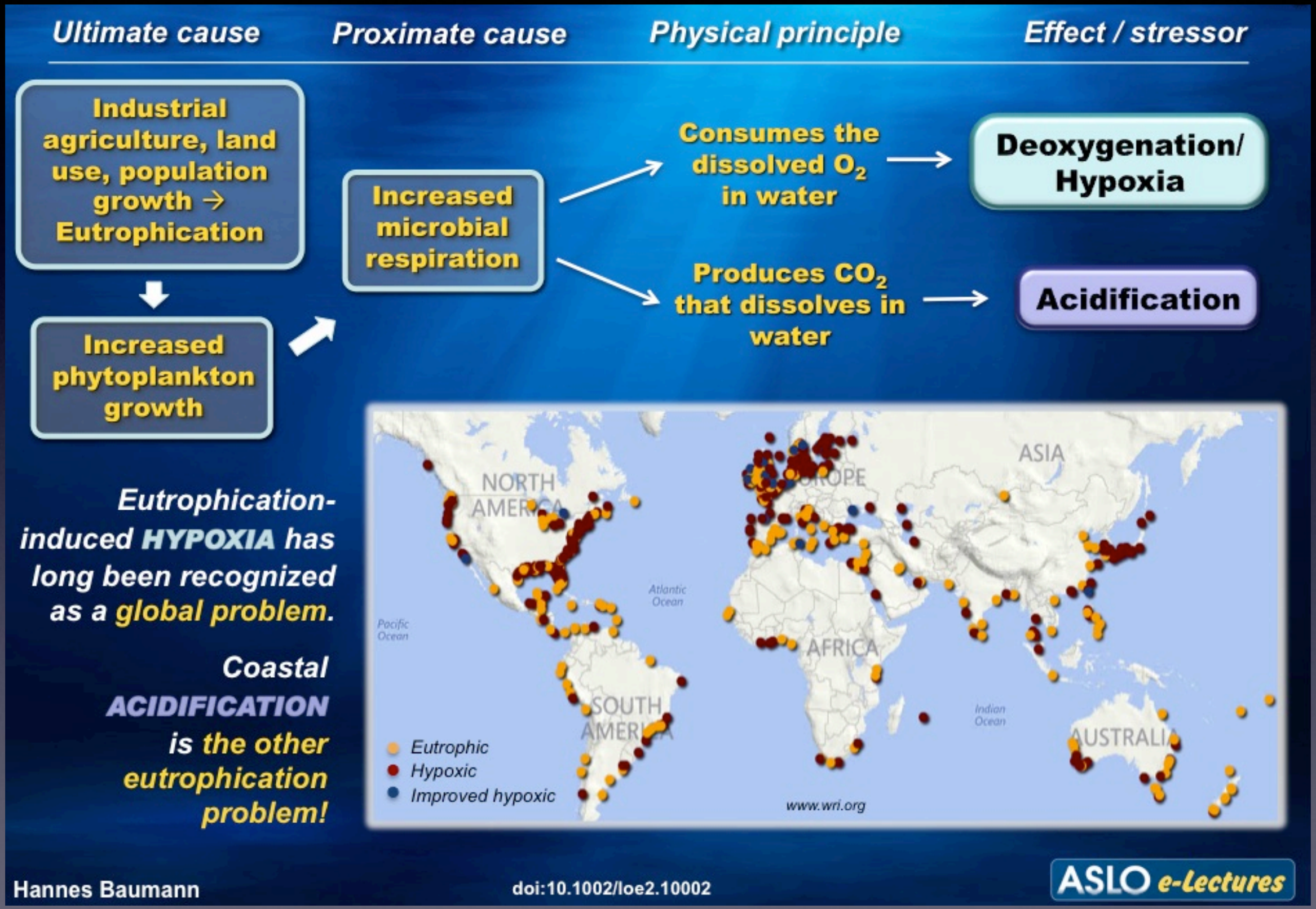
Yara et al. (2012)

Ocean deoxygenation

Causes of deoxygenation

- O_2 decreases due to increase in ocean warming and stratification
- Like ocean acidification, regional and local drivers too

Causes of deoxygenation



Hannes Baumann

doi:10.1002/loe2.10002

ASLO e-Lectures

Global impacts on the ocean

REVIEW

OCEANOGRAPHY

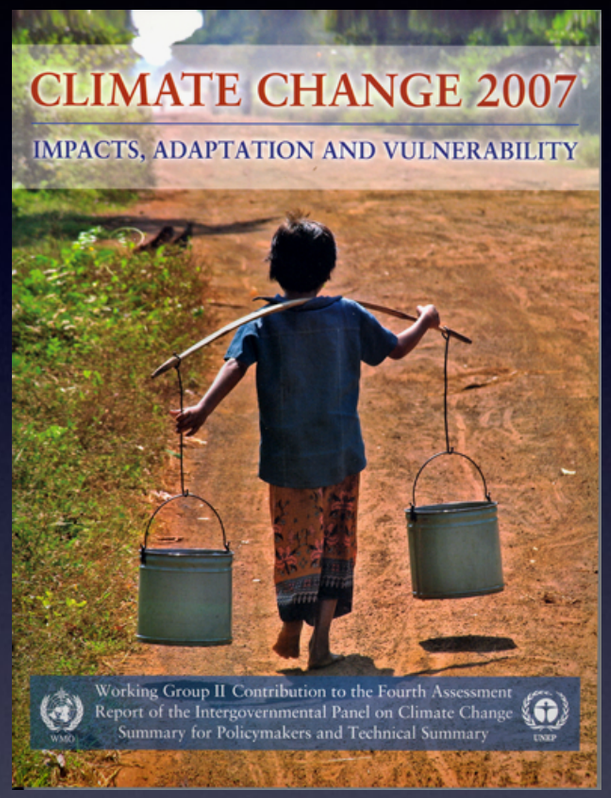
Contrasting futures for ocean and society from different anthropogenic CO_2 emissions scenarios

J.-P. Gattuso,[1,2,3*] A. Magnan,[3] R. Billé,[4] W. W. L. Cheung,[5] E. L. Howes,[6] F. Joos,[7] D. Allemand,[8,9] L. Bopp,[10] S. R. Cooley,[11] C. M. Eakin,[12] O. Hoegh-Guldberg,[13] R. P. Kelly,[14] H.-O. Pörtner,[6] A. D. Rogers,[15] J. M. Baxter,[16] D. Laffoley,[17] D. Osborn,[18] A. Rankovic,[3,19] J. Rochette,[3] U. R. Sumaila,[20] S. Treyer,[3] C. Turley[21]

Science, July 2015

IPCC coverage of the ocean

2007: AR4



- C6: Coastal systems

2014: AR5

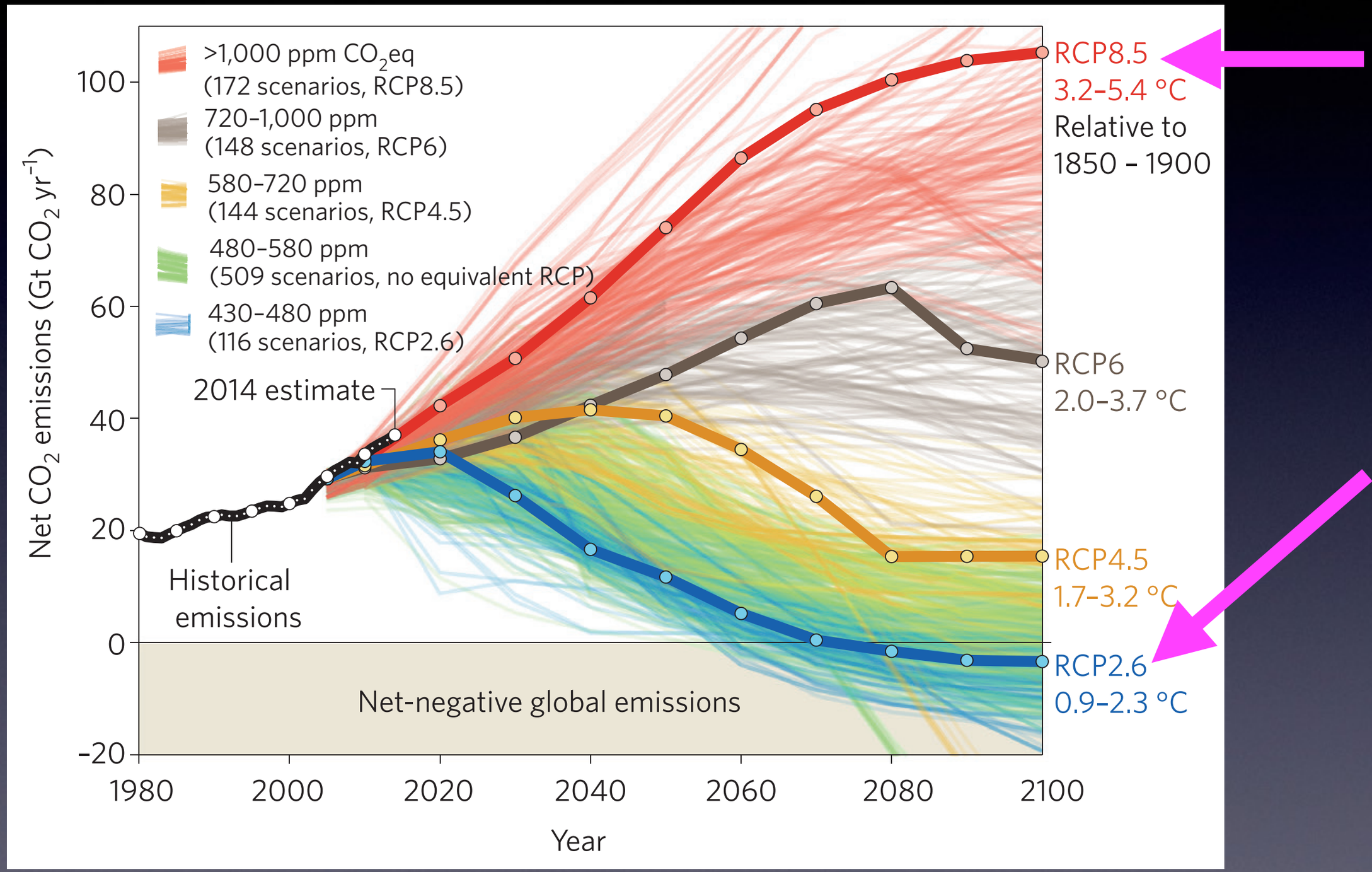
- C5: Coastal systems
- C6: Ocean systems
- C30: The ocean
- Ocean reprint package
- Ocean web site

2019: Special reports

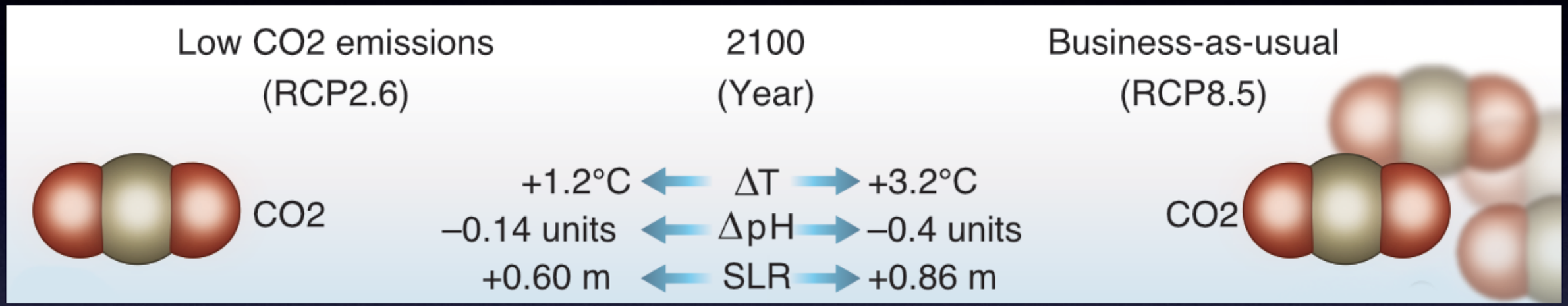
- 1.5 vs 2°C
- Ocean and Cryosphere (Proposal from the Government of Monaco)

2021 (?): AR6

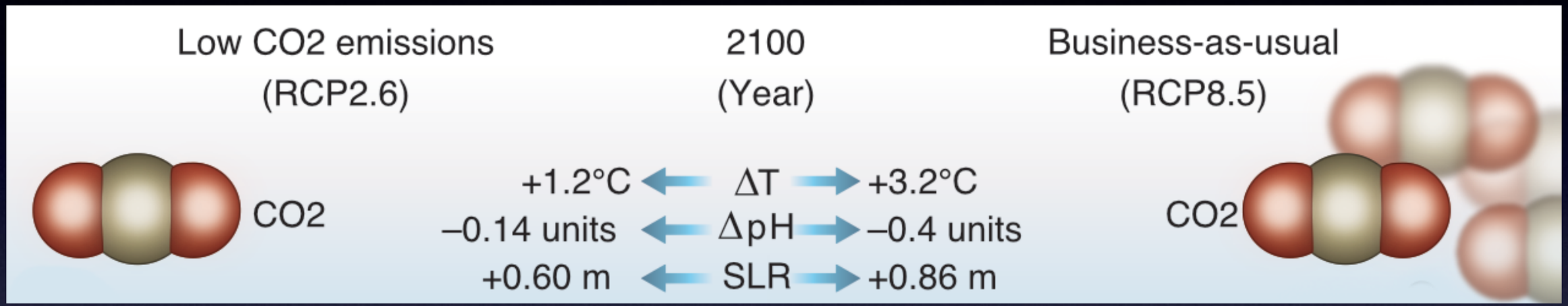
Future scenarios



Physics and chemistry

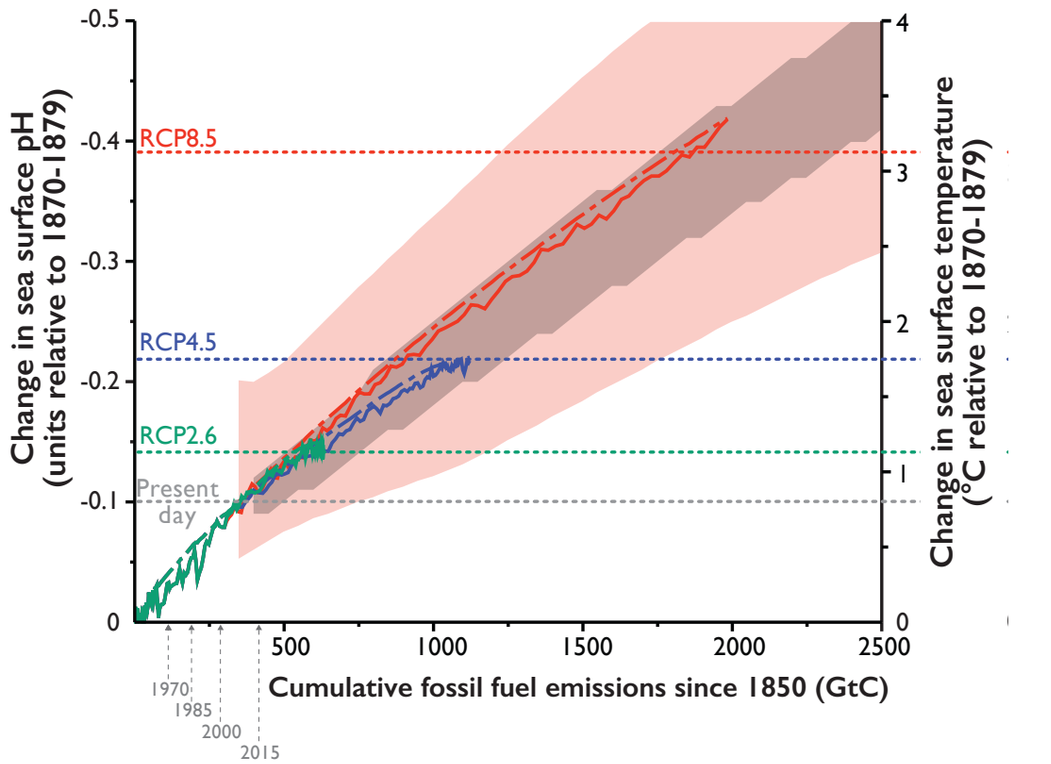


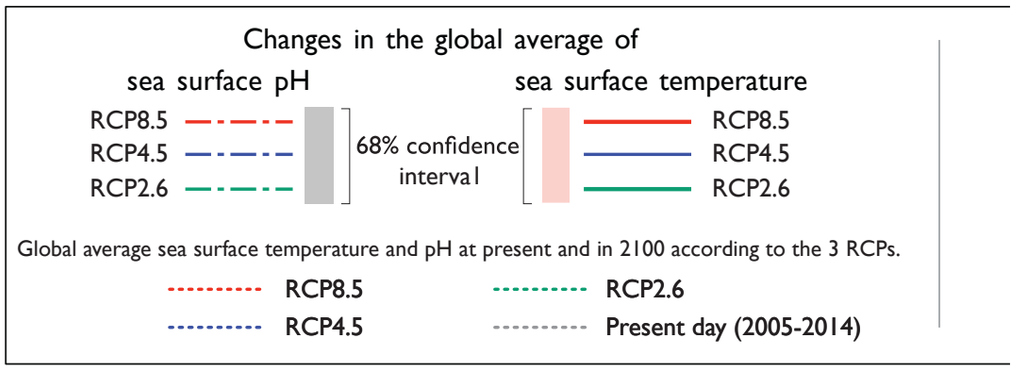
Physics and chemistry



- Thresholds: +1.5 °C and -0.2 pH units relative to preindustrial
- RCP8.5: **69%** of the ocean surface will exceed both thresholds
- RCP2.6: < **1%**

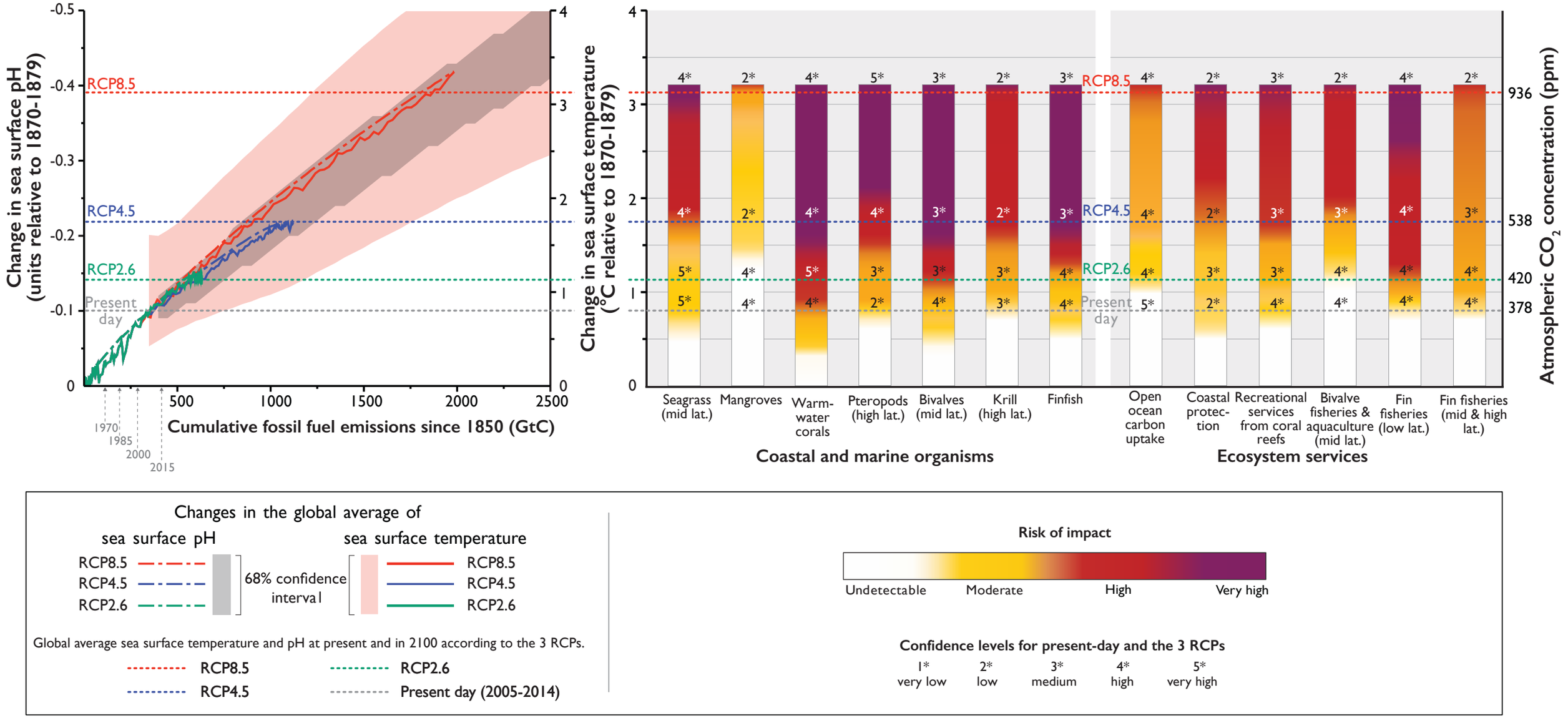
Risks of impact on marine and coastal organisms and ecosystem services





Gattuso et al. (2015)

Risks of impact on marine and coastal organisms and ecosystem services



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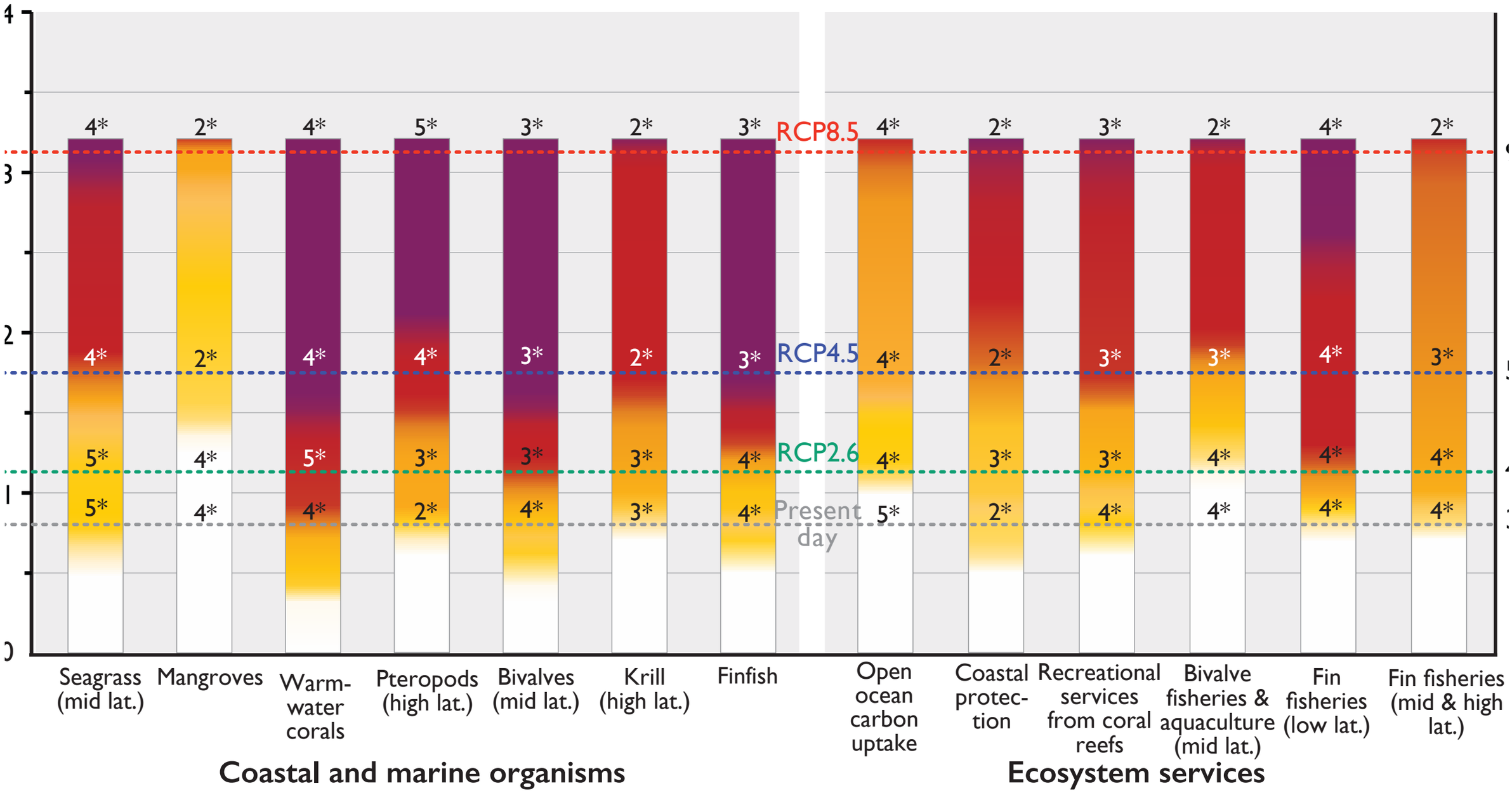

Risk of impact

Undetectable — Moderate — High — Very high

Confidence levels for present-day and the 3 RCPs

1*	2*	3*	4*	5*
very low	low	medium	high	very high

4 key messages

1. Ocean strongly influences the climate system and important provider of key services
2. Impacts already detectable, high risk of impacts well before 2100, even with a low emission scenario
3. Immediate and substantial reduction of CO_2 emissions to prevent massive and mostly irreversible impacts
4. As CO_2 increases, the protection, adaptation, and repair options become fewer and less effective

IDDRI

PRINCE ALBERT II OF MONACO FOUNDATION

IAEA Ocean Acidification International Coordination Centre OA-ICC

FONDATION BNP PARIBAS

AMAO

OCEANS 2015 INITIATIVE

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This is a product of "The Oceans 2015 Initiative", an expert group supported by the Prince Albert II of Monaco Foundation, the Ocean Acidification International Coordination Centre of the International Atomic Energy Agency, the BNP Paribas Foundation and the Monégasque Association for Ocean Acidification.

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SciencesPo

POLICY BRIEF

N°04/15 SEPTEMBER 2015 I CLIMATE - OCEANS AND COASTAL ZONES

Intertwined ocean and climate: implications for international climate negotiations

Alexandre K. Magnan (IDDRI), Raphaël Billé (Secretariat of the Pacific Community), Sarah R. Cooley (Ocean Conservancy), Ryan Kelly (University of Washington), Hans-Otto Pörtner (Alfred Wegener Institute), Carol Turley (Plymouth Marine Laboratory), Jean-Pierre Gattuso (CNRS-INSU, Sorbonne Universités, IDDRI)

INTRODUCTION

The atmosphere and ocean are two components of the Earth system that are essential for life, yet humankind is altering both. Contemporary climate change is now a well-identified problem: anthropogenic causes, disturbance in extreme events patterns, gradual environmental changes, widespread impacts on life and natural resources, and multiple threats to human societies all around the world. But part of the problem remains largely unknown outside the scientific community: significant changes are also occurring in the ocean, threatening life and its sustainability on Earth.

This Policy Brief explains the significance of these changes in the ocean. It is based on a scientific paper recently published in *Science* (Gattuso *et al.*, 2015), which synthesizes recent and future changes to the ocean and its ecosystems, as well as to the goods and services they provide to humans. Two contrasting CO_2 emission scenarios are considered: the high emissions scenario (also known as "business-as-usual" and as the Representative Concentration Pathway 8.5, RCP8.5) and a stringent emissions scenario (RCP2.6) consistent with the Copenhagen Accord[1] of keeping mean global temperature increase below 2°C in 2100.

1. Copenhagen Accord, *Decision 2/CP.15: Copenhagen accord* (United Nations Framework Convention on Climate Change, Geneva, 2009).

KEY MESSAGES

- Climate and ocean are inseparable: the ocean moderates anthropogenic climate change by absorbing significant proportions of the heat and CO_2 that accumulate in the atmosphere, as well as by receiving all water from melting ice.
- This climate-regulating function happens at the cost of profound alterations of the ocean's physics and chemistry, leading to ocean warming and acidification, as well as to sea level rise. These changes significantly affect the ocean's ecology (organisms and ecosystems) and eventually marine and coastal human activities (fisheries, aquaculture, tourism, health…).
- As atmospheric CO_2 increases, possible human responses become fewer and less effective.
- This scientific statement provides further compelling arguments for immediate and ambitious CO_2 emissions reduction at the international level. This conclusion applies to COP21 as well as to the post-2015 climate regime at large.

COP21

Paris Agreement

COP21 · CMP11
PARIS 2015
UN CLIMATE CHANGE CONFERENCE

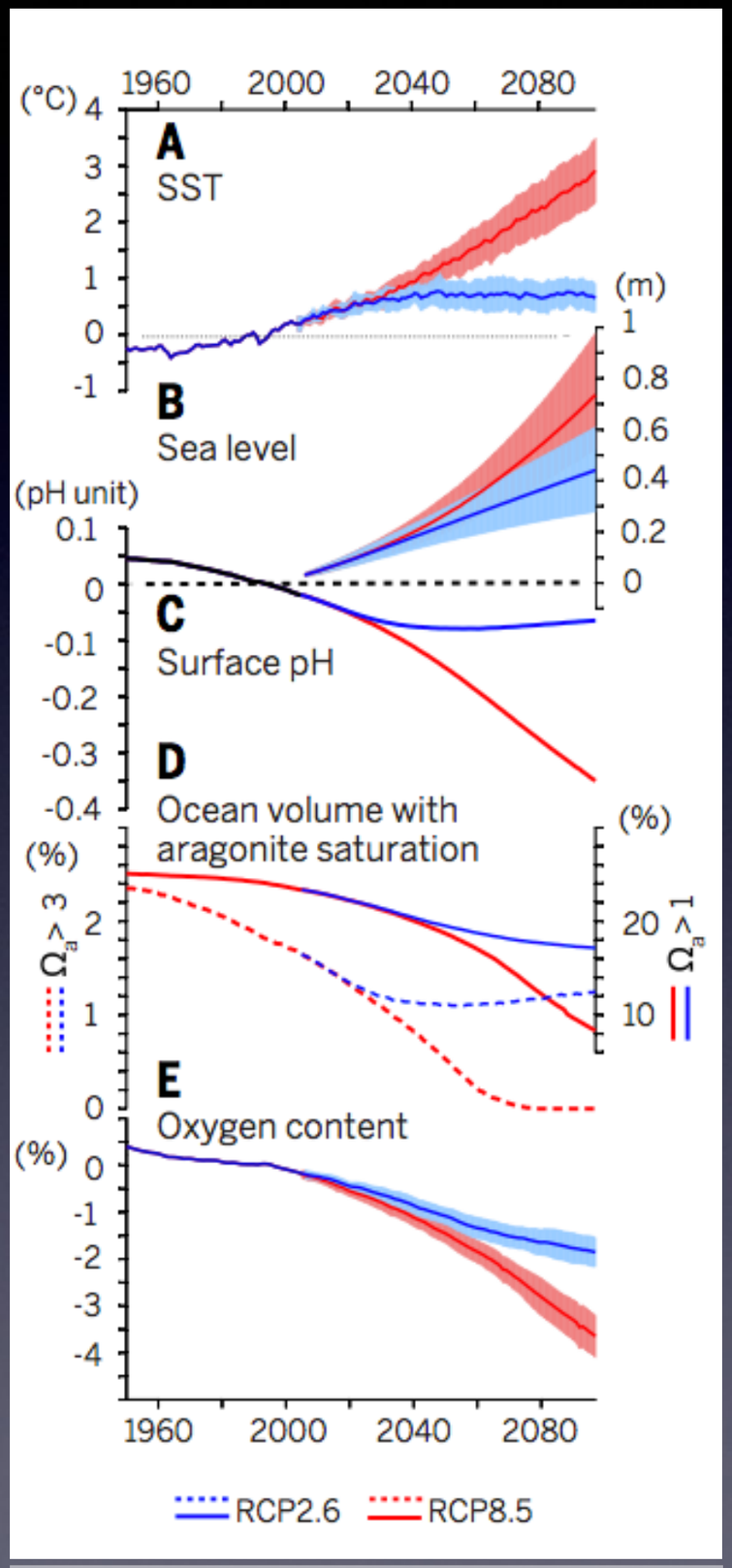
"Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels…"

Implications of the Paris agreement for the ocean

Alexandre K. Magnan, Michel Colombier, Raphaël Billé, Fortunat Joos, Ove Hoegh-Guldberg, Hans-Otto Pörtner, Henri Waisman, Thomas Spencer and Jean-Pierre Gattuso

Nature Climate Change, May 2016

What does it means for the ocean?



Gattuso et al. (2015)

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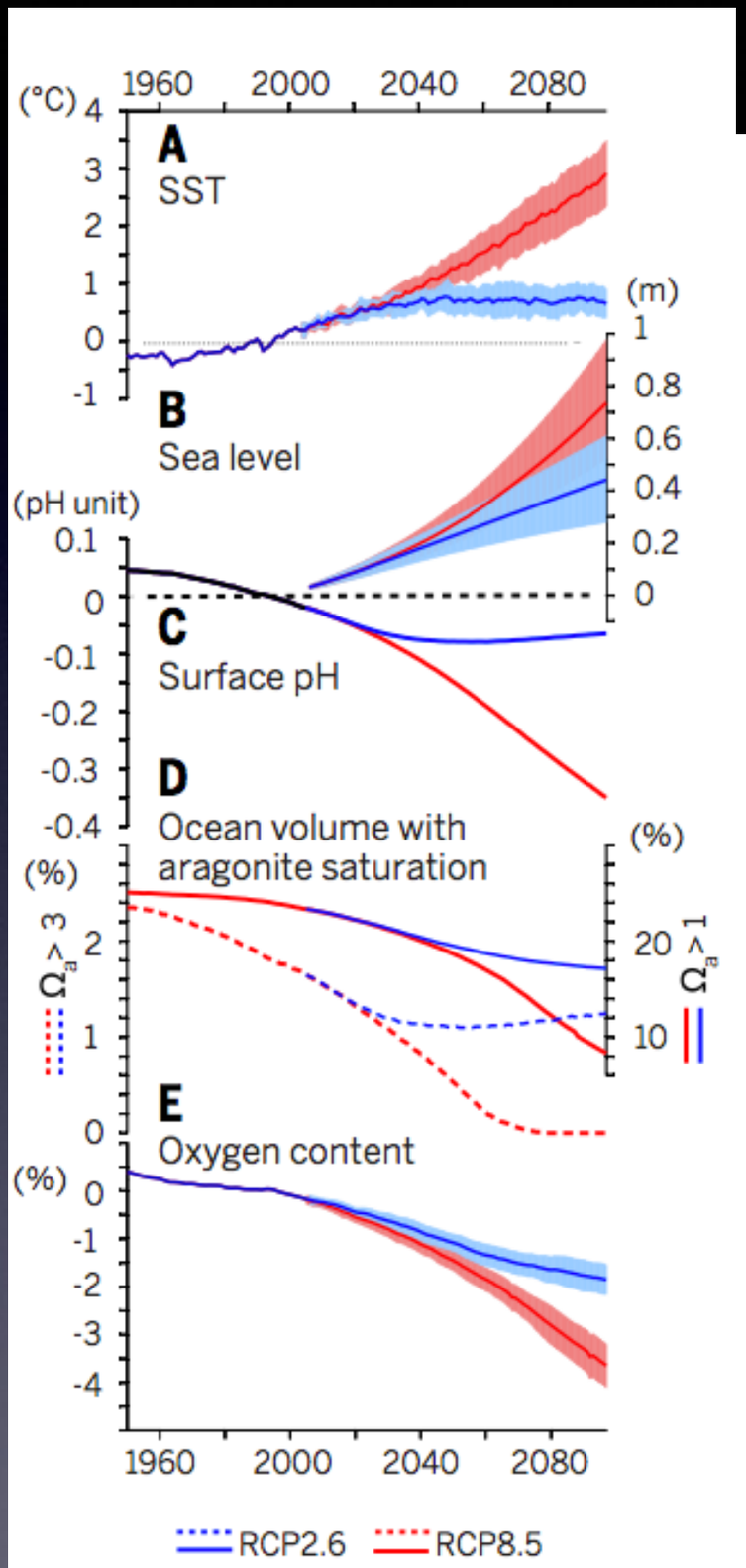

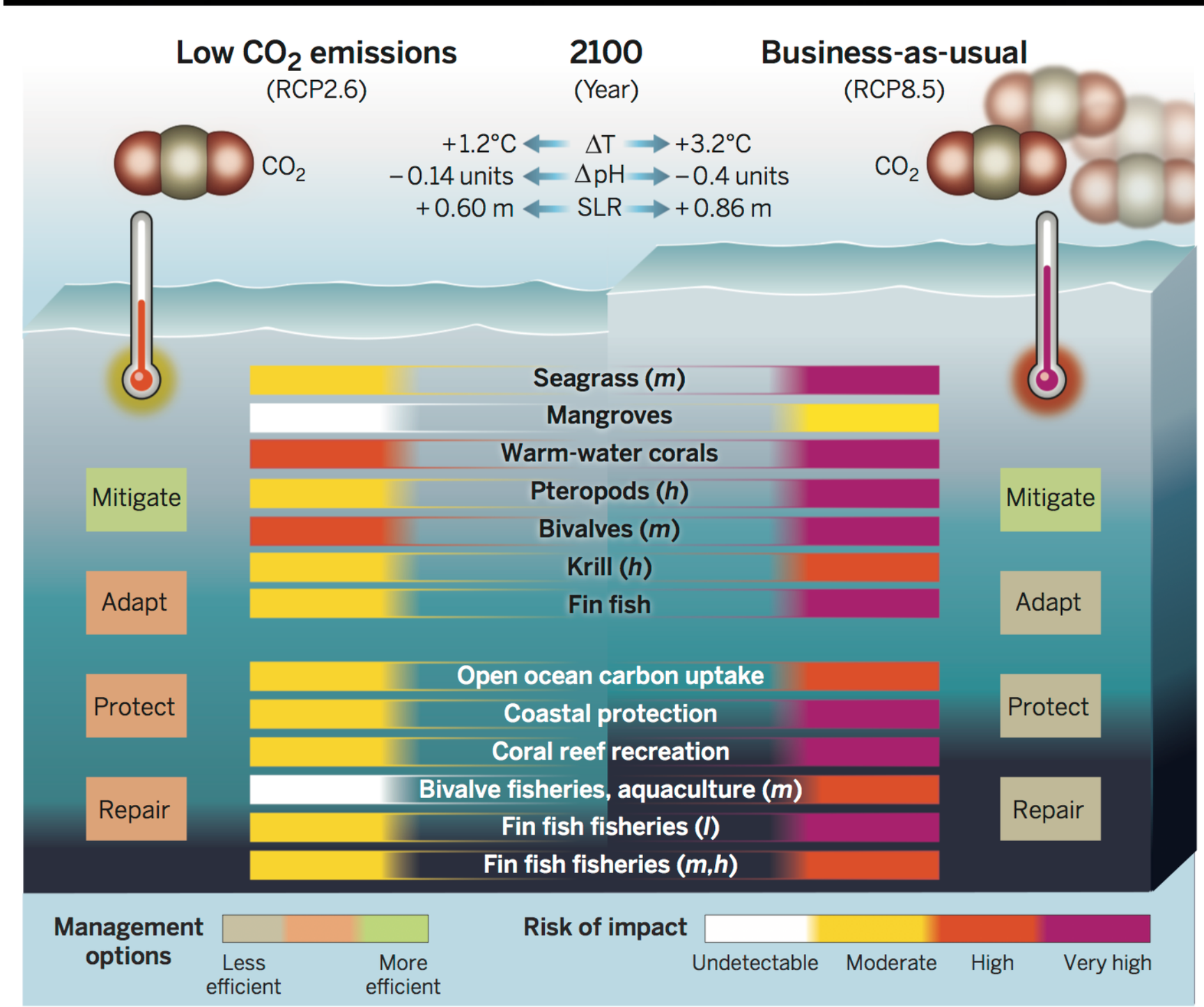

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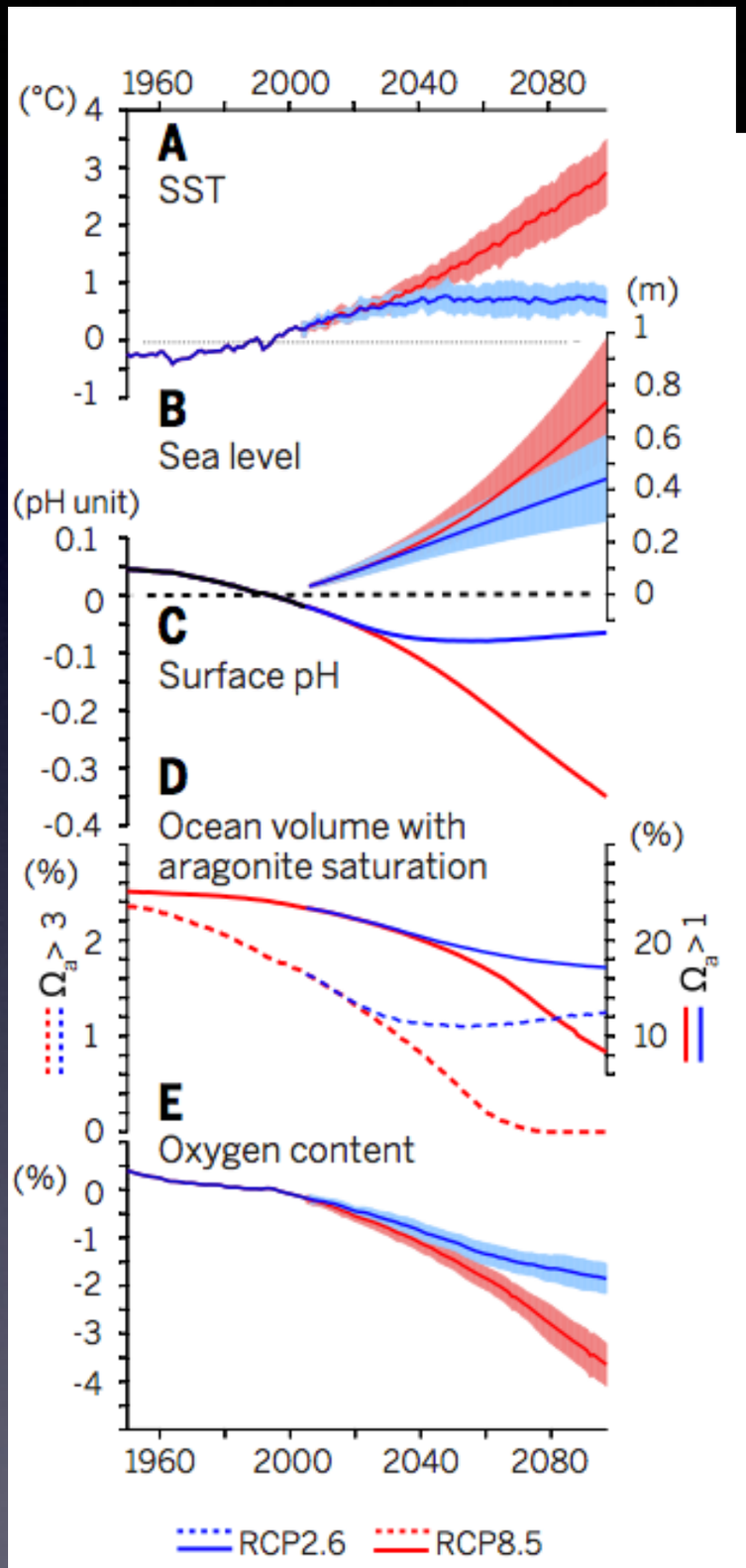

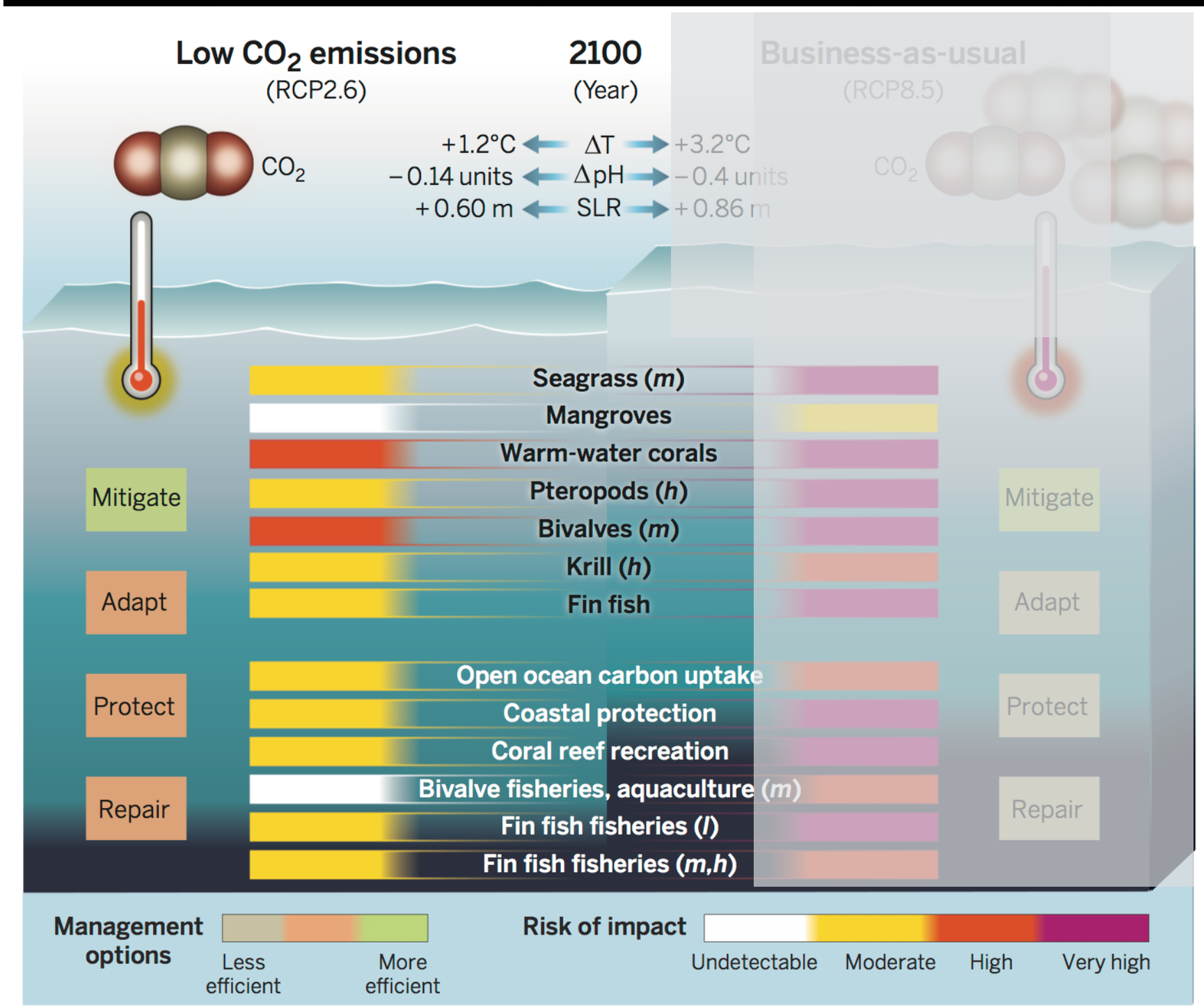

Gattuso et al. (2015)

The remaining carbon quota for 66% chance <2°C

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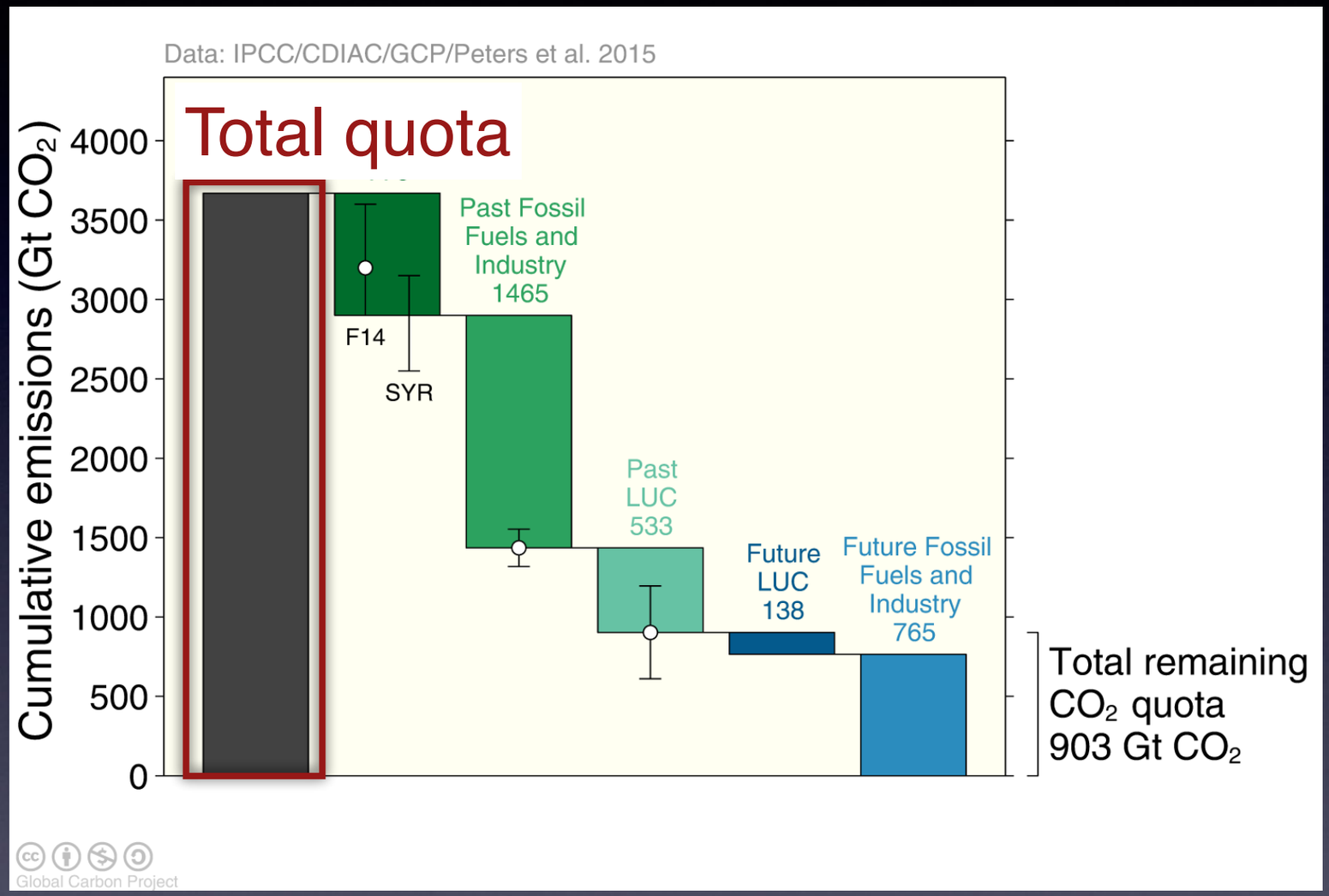
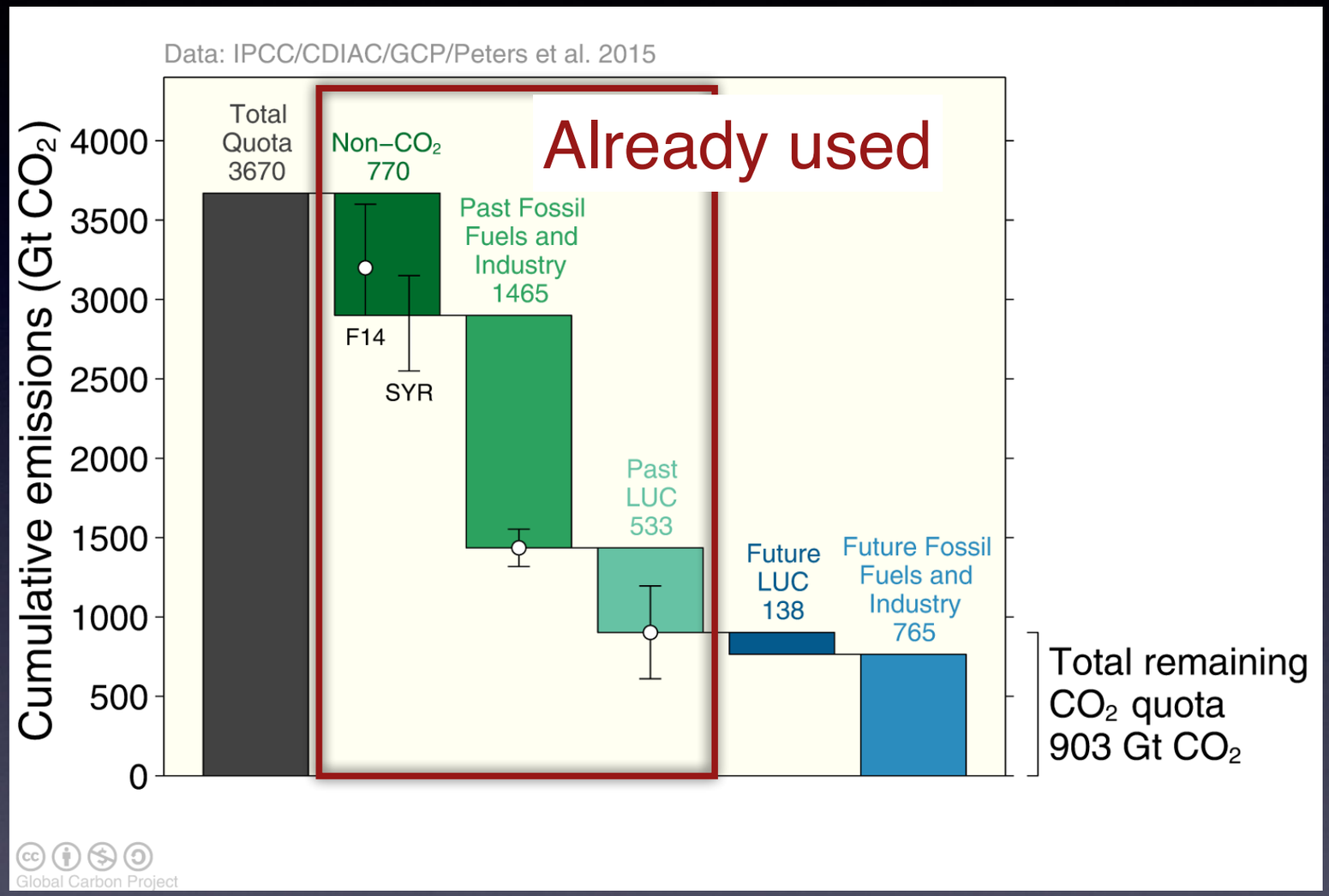


Grey: Total quota for 2°C. Green: Removed from quota. Blue: remaining quota.
With projected 2015 emissions, this remaining quota drops to 865 Gt CO_2

Source: Peters et al 2015; Global Carbon Budget 2015

The remaining carbon quota for 66% chance <2°C



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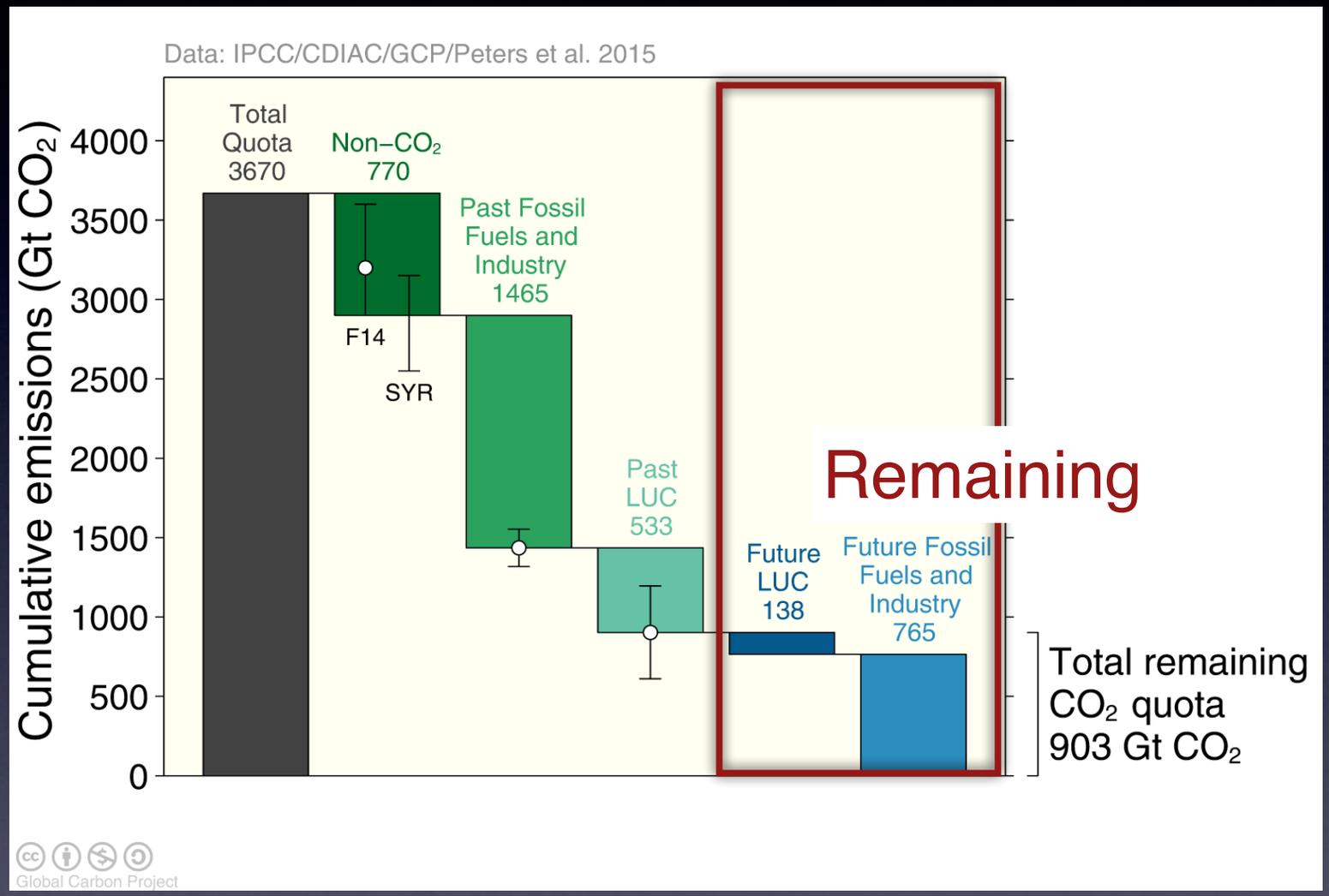

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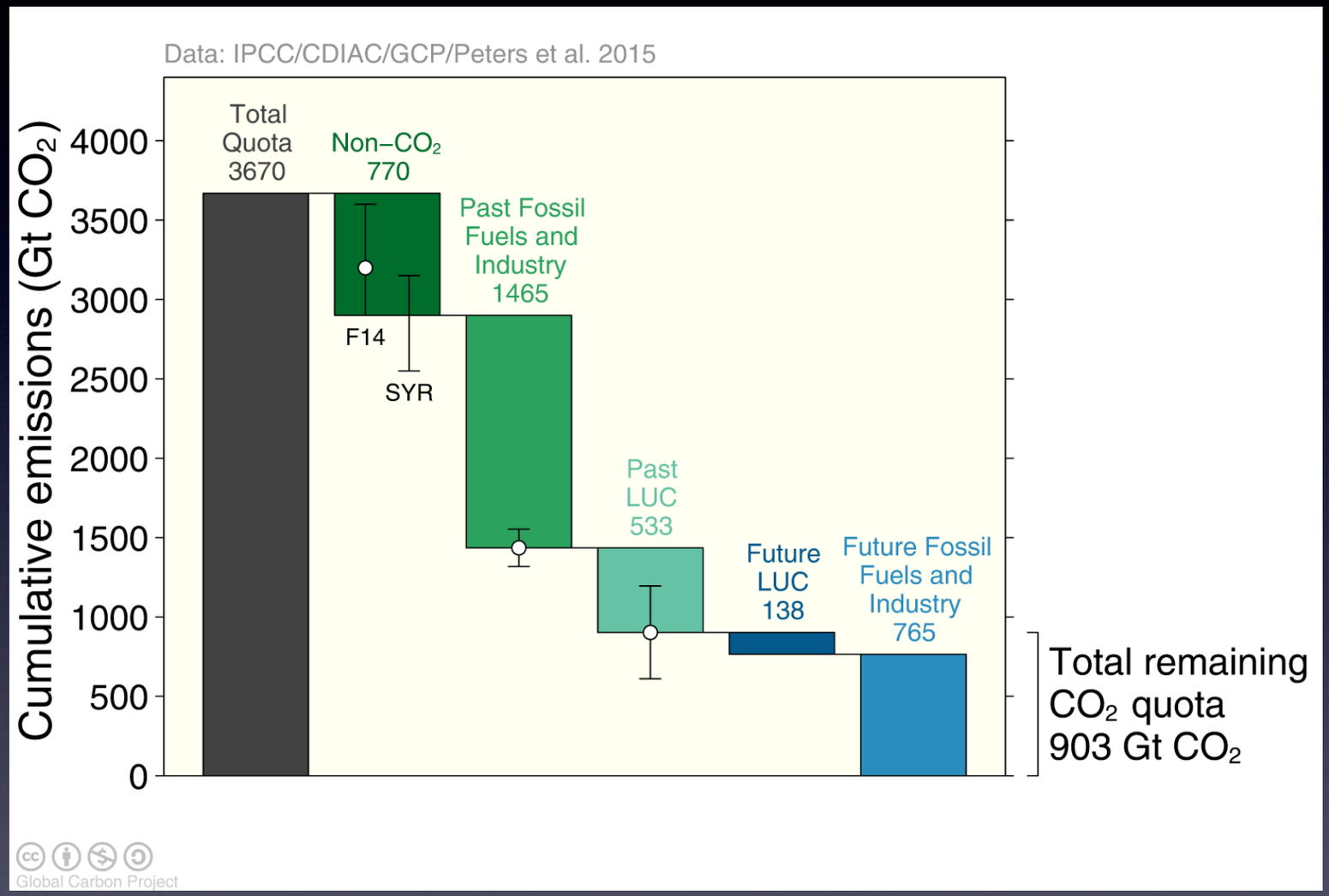
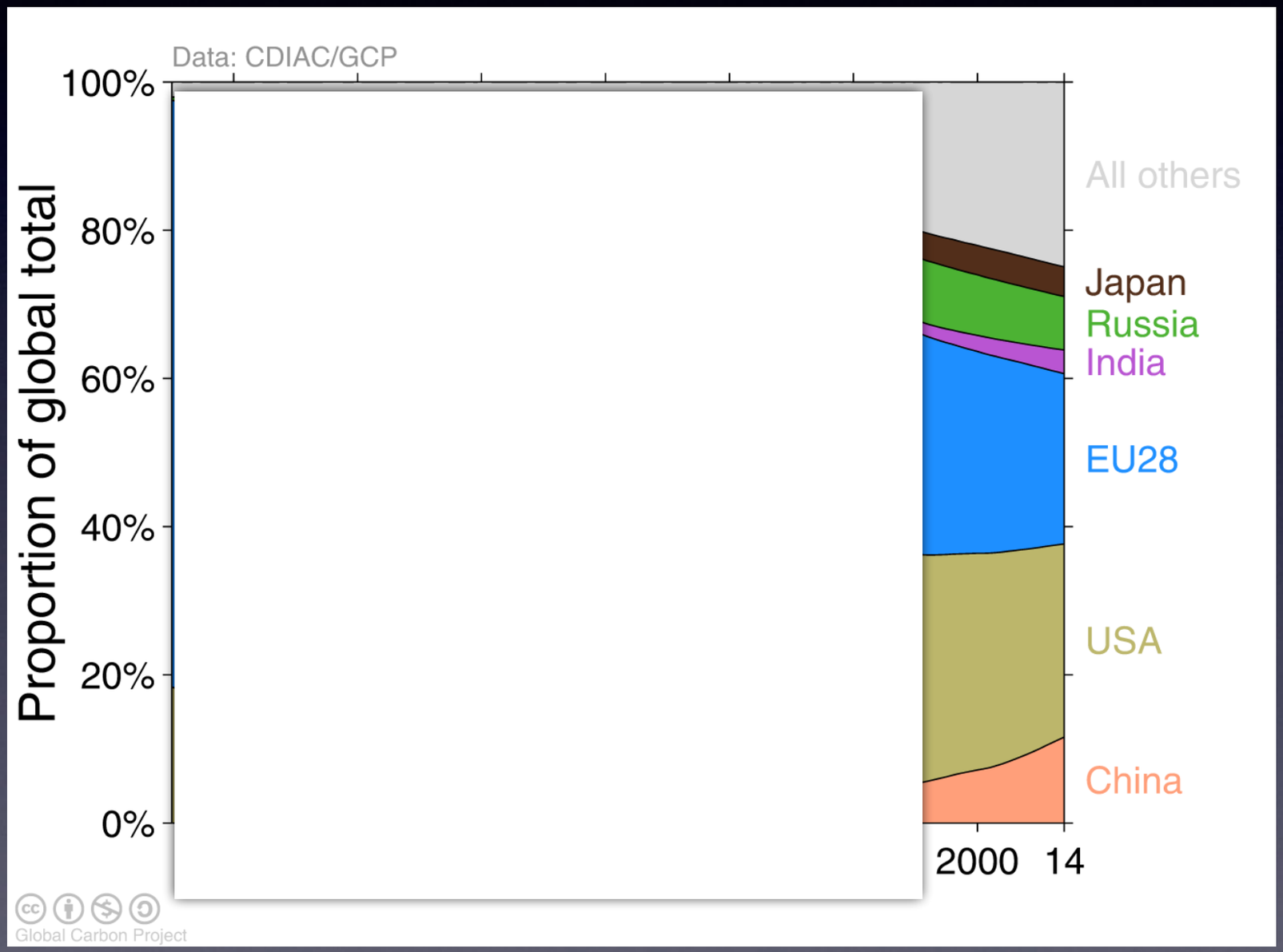


About 20 years at current emission rates

Grey: Total quota for 2°C. Green: Removed from quota. Blue: remaining quota.
With projected 2015 emissions, this remaining quota drops to 865 Gt CO_2

Source: Peters et al 2015; Global Carbon Budget 2015

Historical cumulative emissions by country



Cumulative emissions (1990–2014) were distributed USA (20%), China (19%), EU28 (15%), India (5%)

'All others' includes all other countries along with bunker fuels and statistical differences

Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

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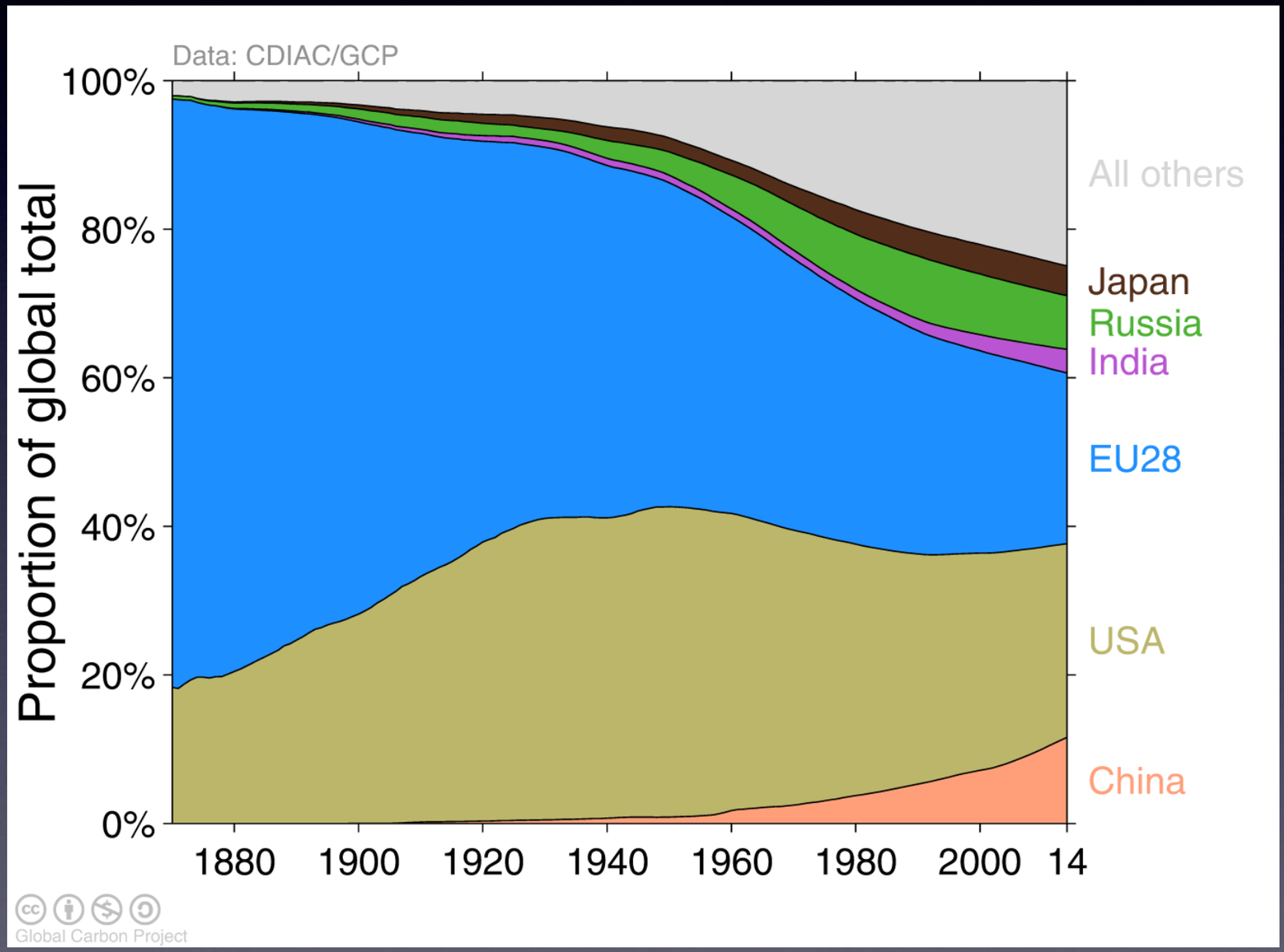

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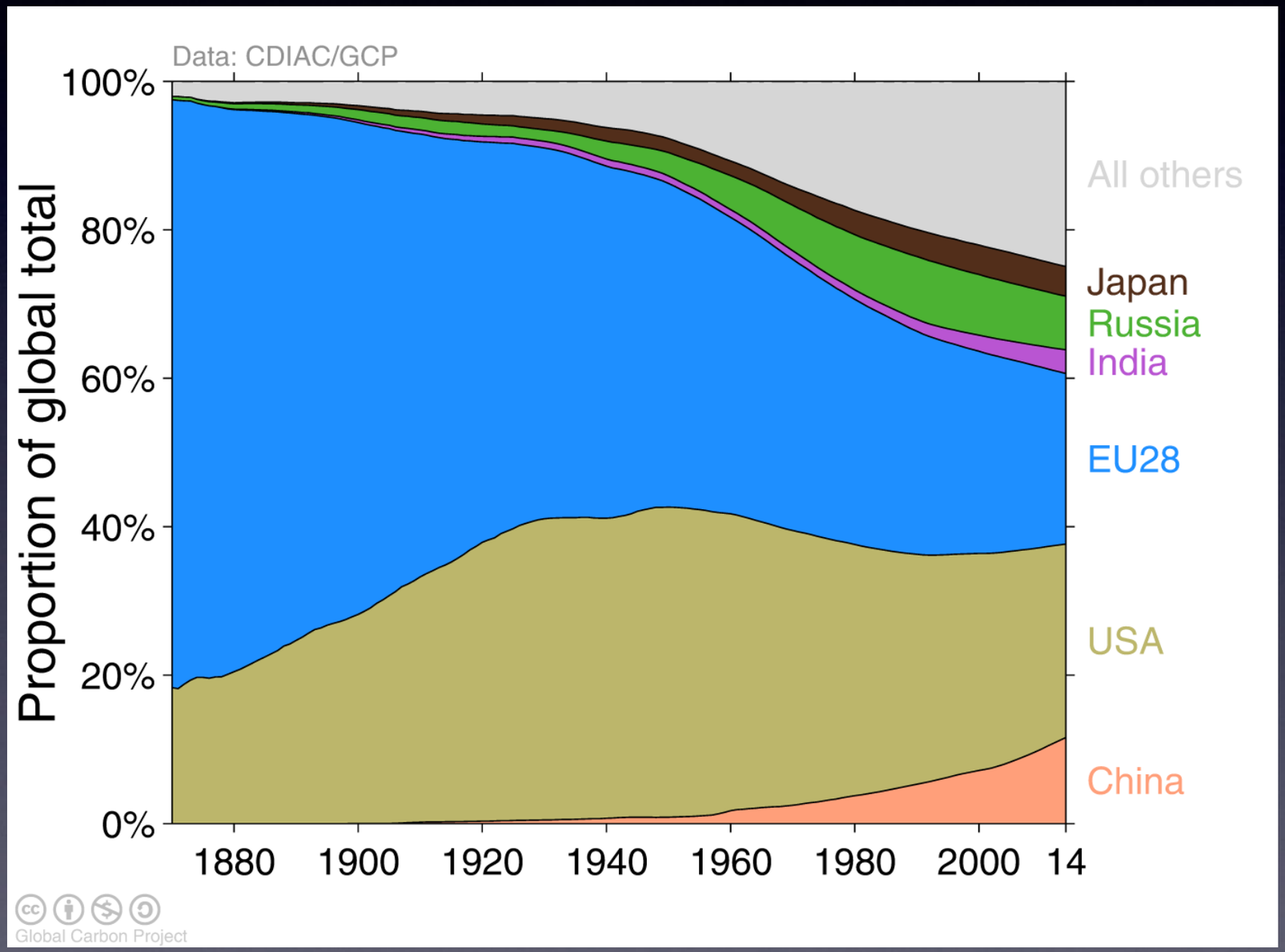
Source: CDIAC; Le Quéré et al 2015; Global Carbon Budget 2015

Historical cumulative emissions by country

Cumulative emissions from fossil-fuel and cement were distributed (1870–2014): USA (26%), EU28 (23%), China (12%), and India (3%) covering 64% of the total share



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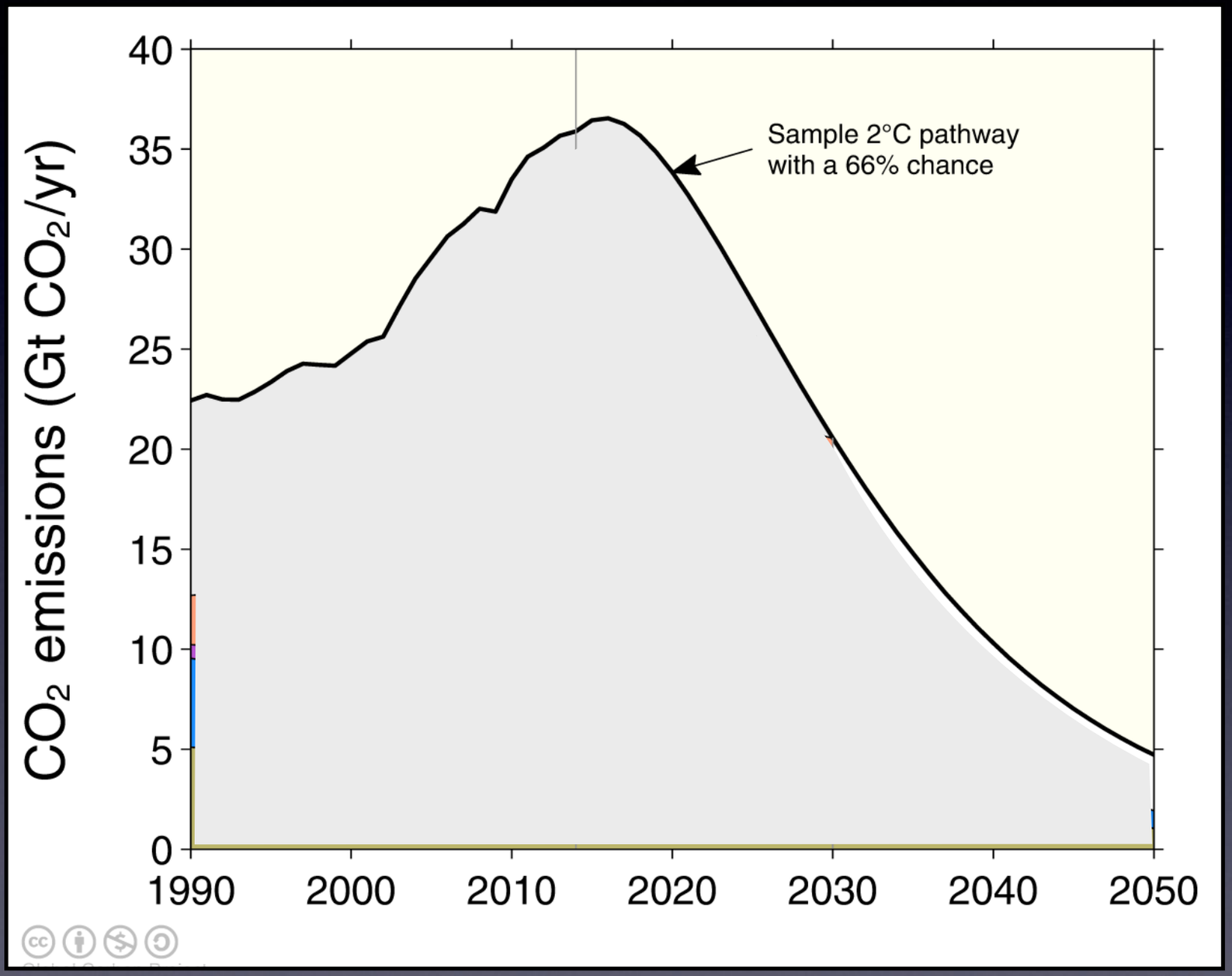
The emission pledges (INDCs) of the top-4 emitters



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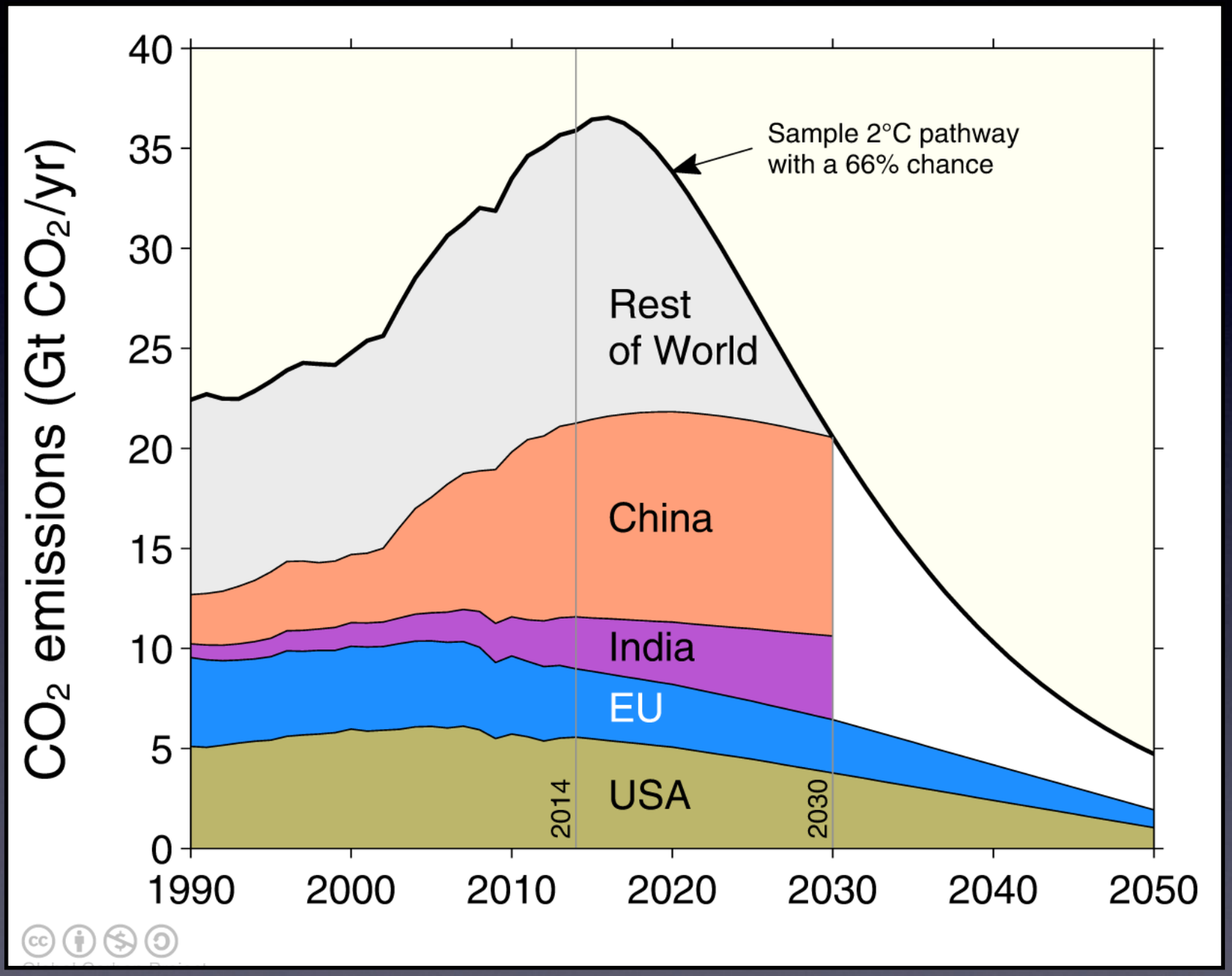

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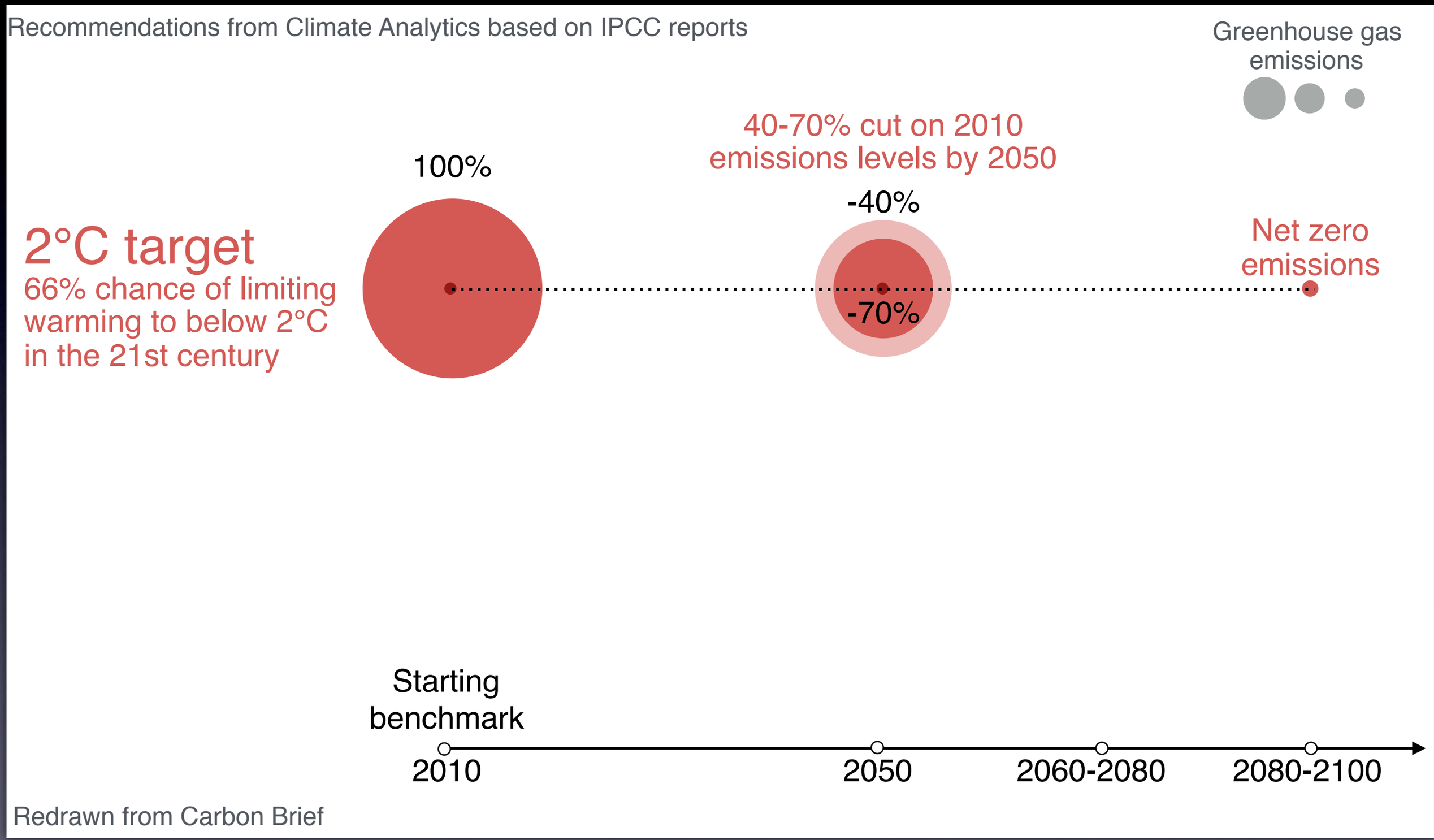
What it means?

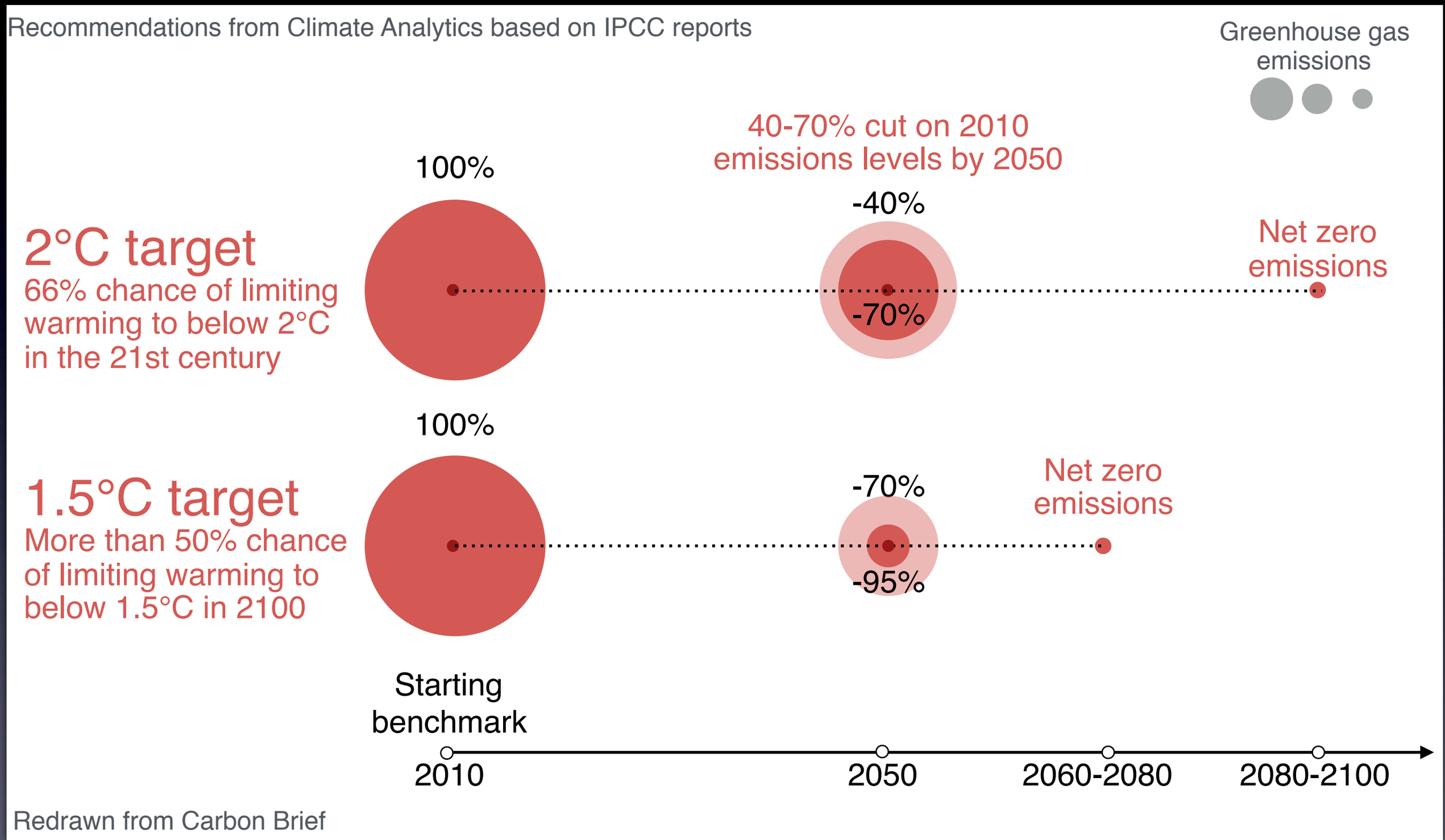
Recommendations from Climate Analytics based on IPCC reports



Redrawn from Carbon Brief

What it means?

Recommendations from Climate Analytics based on IPCC reports



Redrawn from Carbon Brief

How much fossil fuel must stay underground?

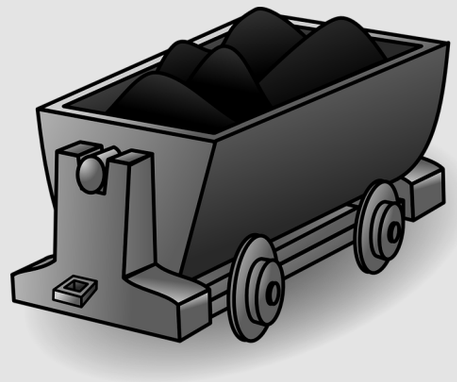
To have a 66% chance to remain below 2°C

How much fossil fuel must stay underground?

To have a 66% chance to remain below 2°C

52%
of natural gas reserves

35%
of oil reserves

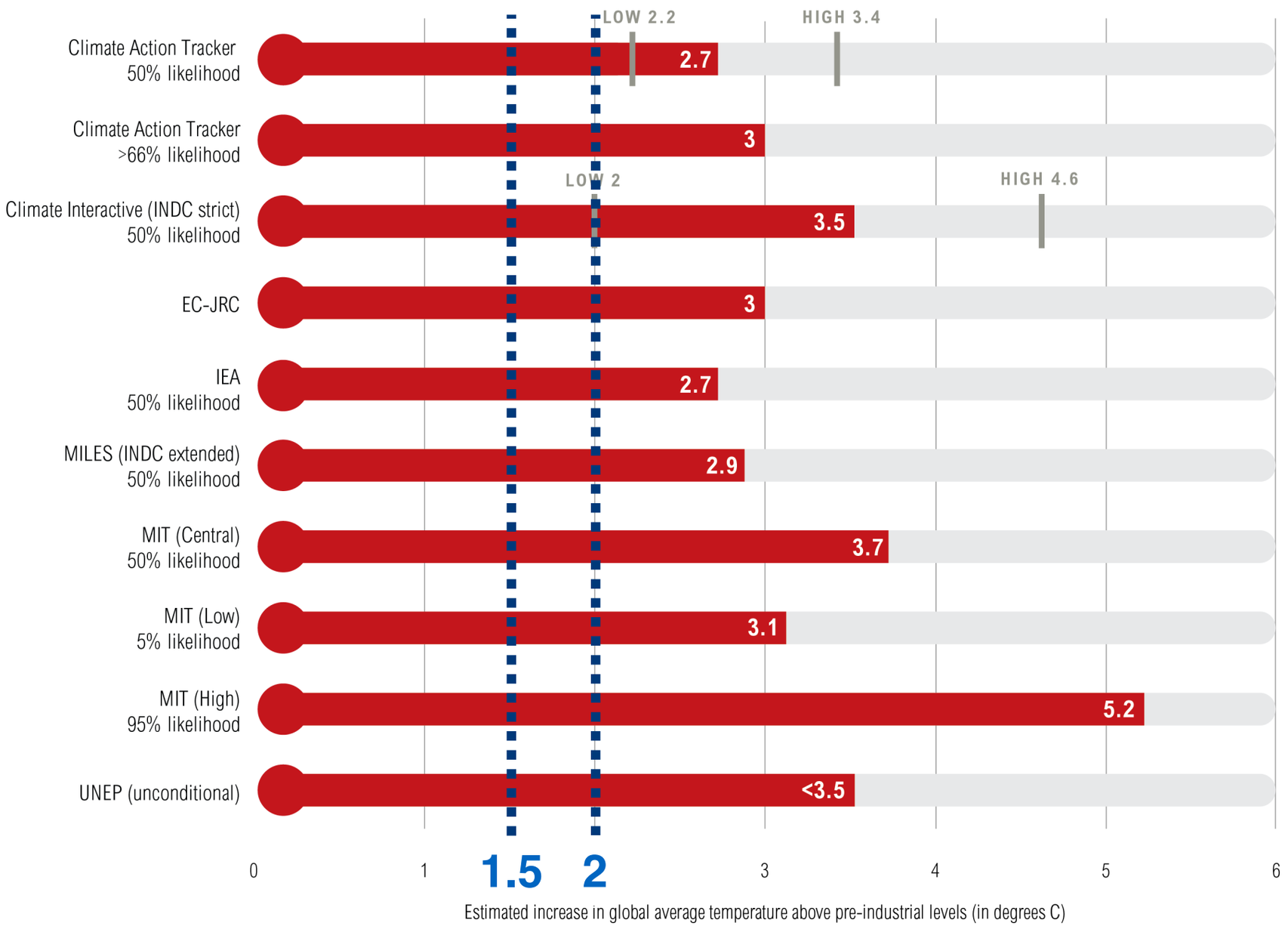


88%
of coal reserves

Redrawn from Carbon Brief

Summary of estimated temperature rise

Estimates for Global Temperature Rise with INDCs

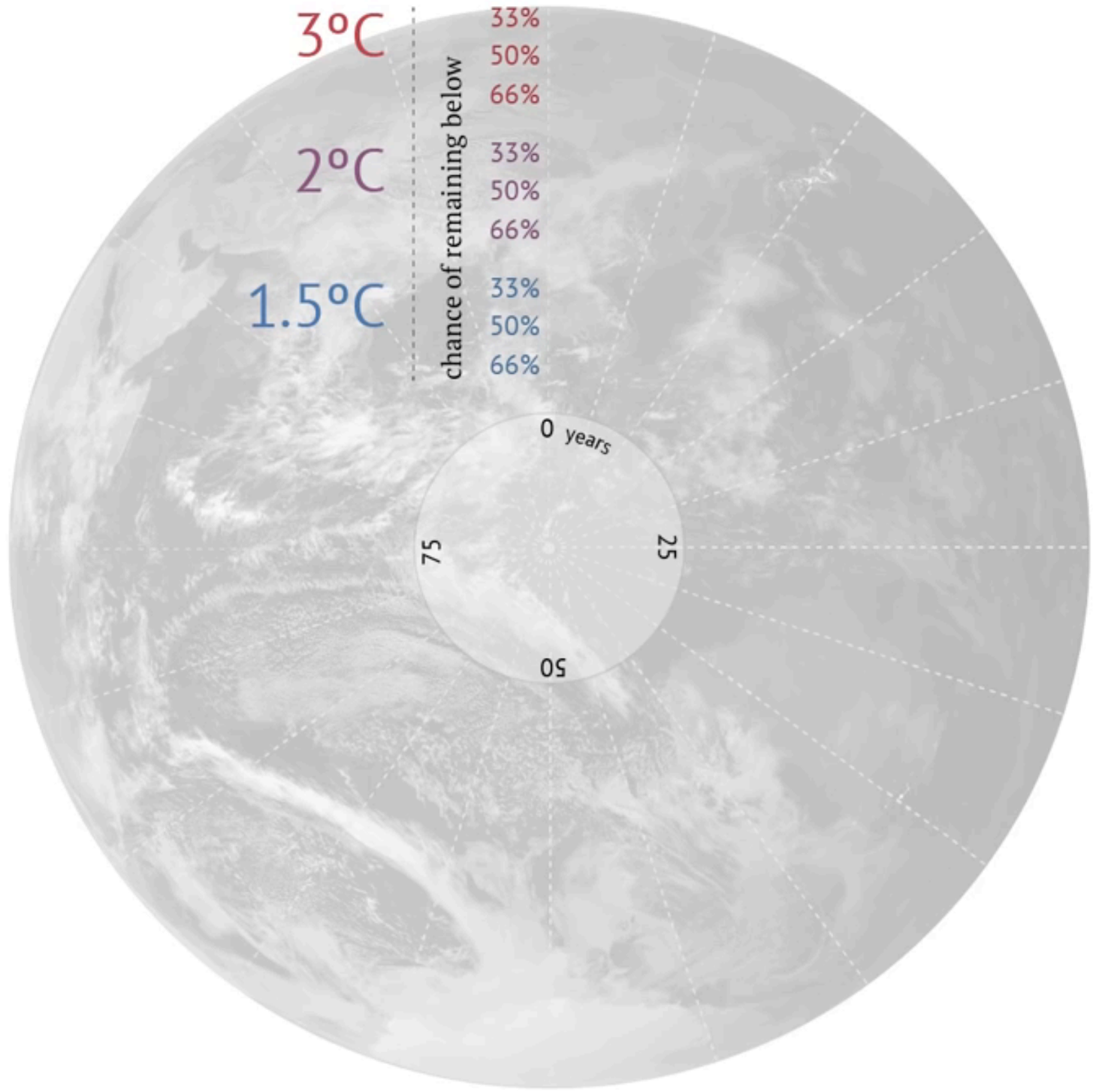


Note: “Likelihood" refers to the probability of limiting global warming to a specified temperature by 2100. For instance, >66% likelihood provides a "likely" chance that warming will not exceed the given temperature.

http://bit.ly/indc-temp

WORLD RESOURCES INSTITUTE

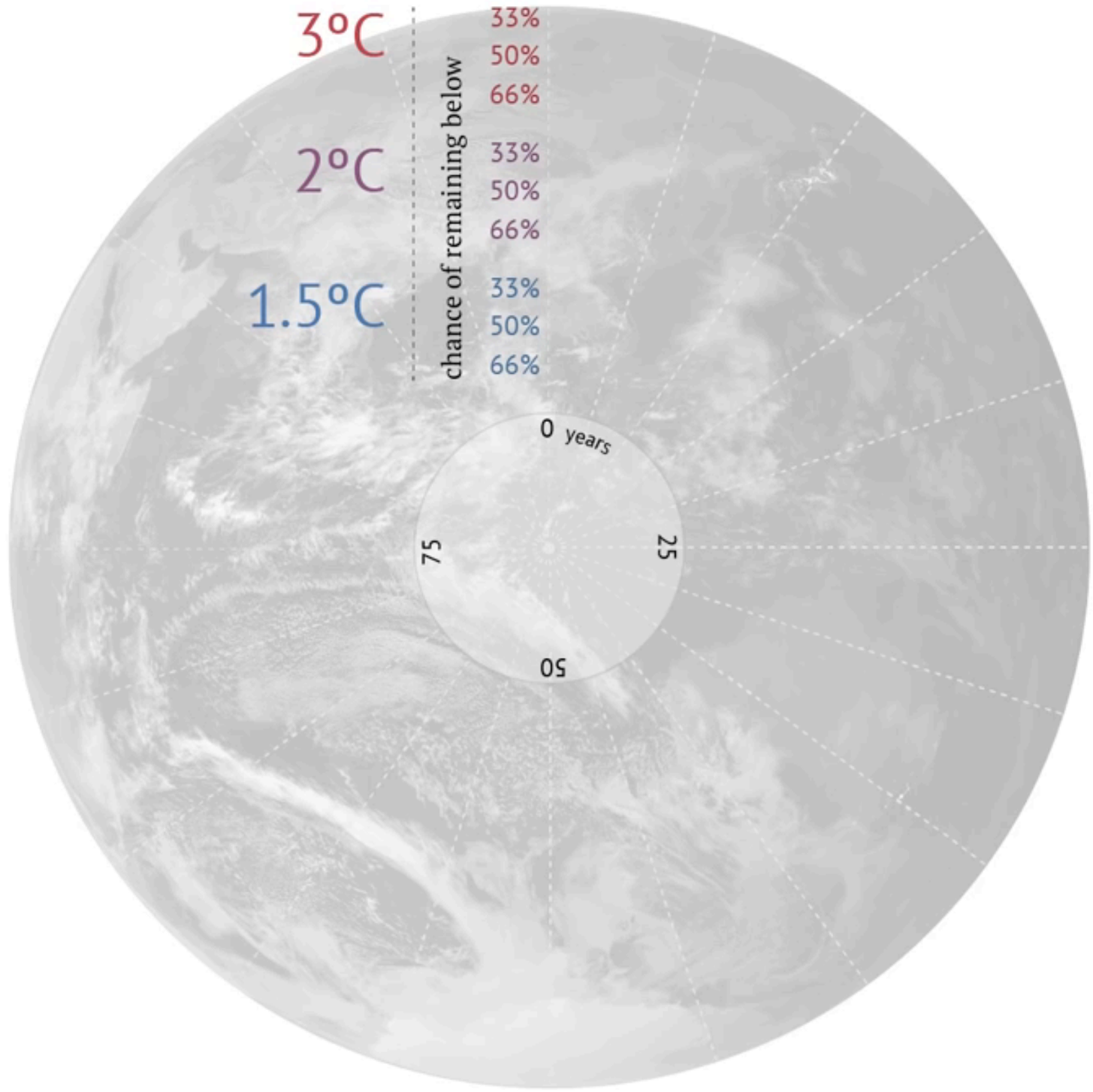
Carbon countdown



CarbonBrief
CLEAR ON CLIMATE

Photo credit: NASA Goddard Space Flight Center
Stopwatch icon: T-Kot/Shutterstock.com

Carbon countdown



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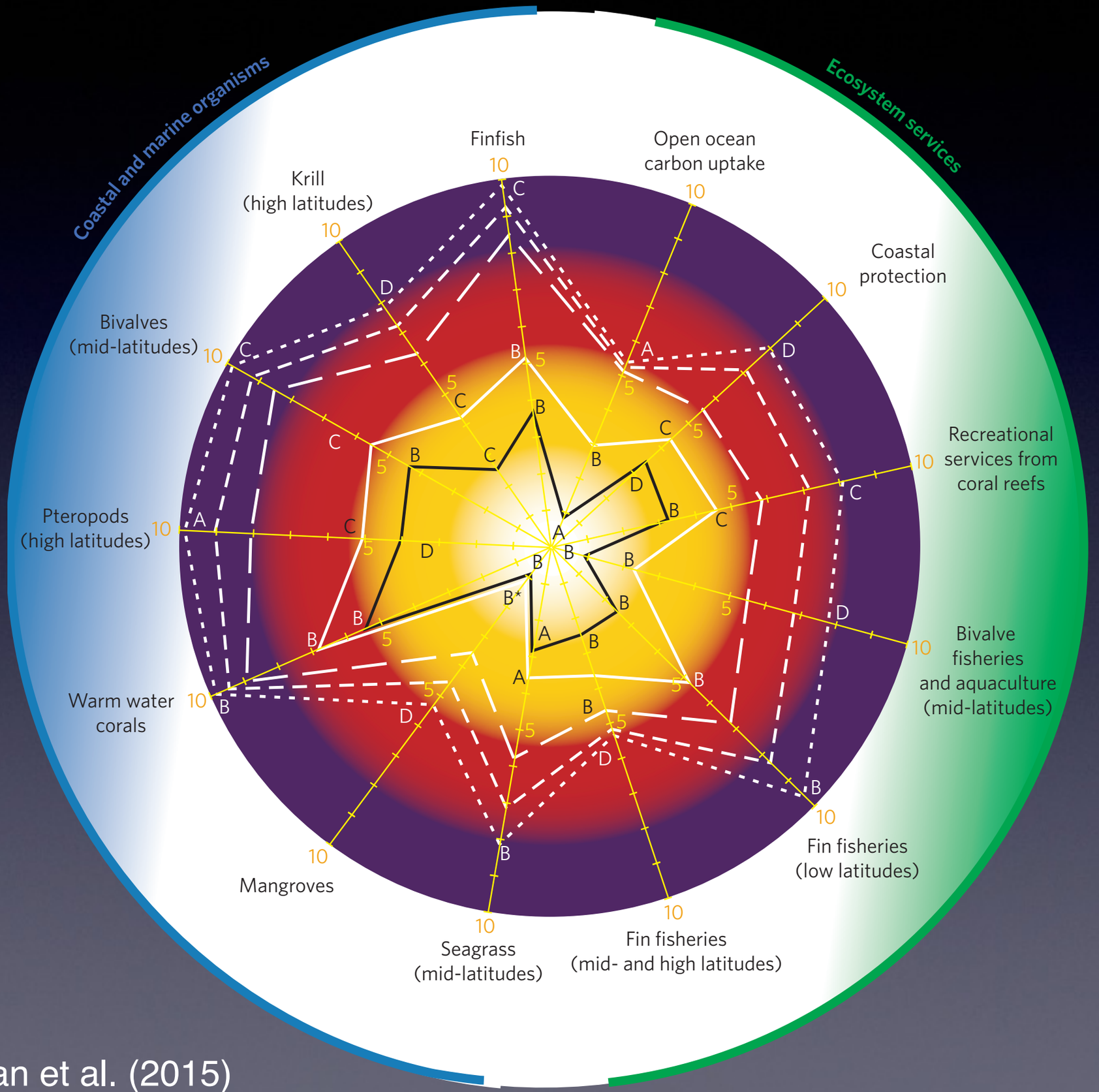
Future risks of impact



Risk of impact

Undetectable
Moderate
High
Very high
0
5
10

Confidence levels for the present day and the RCPs

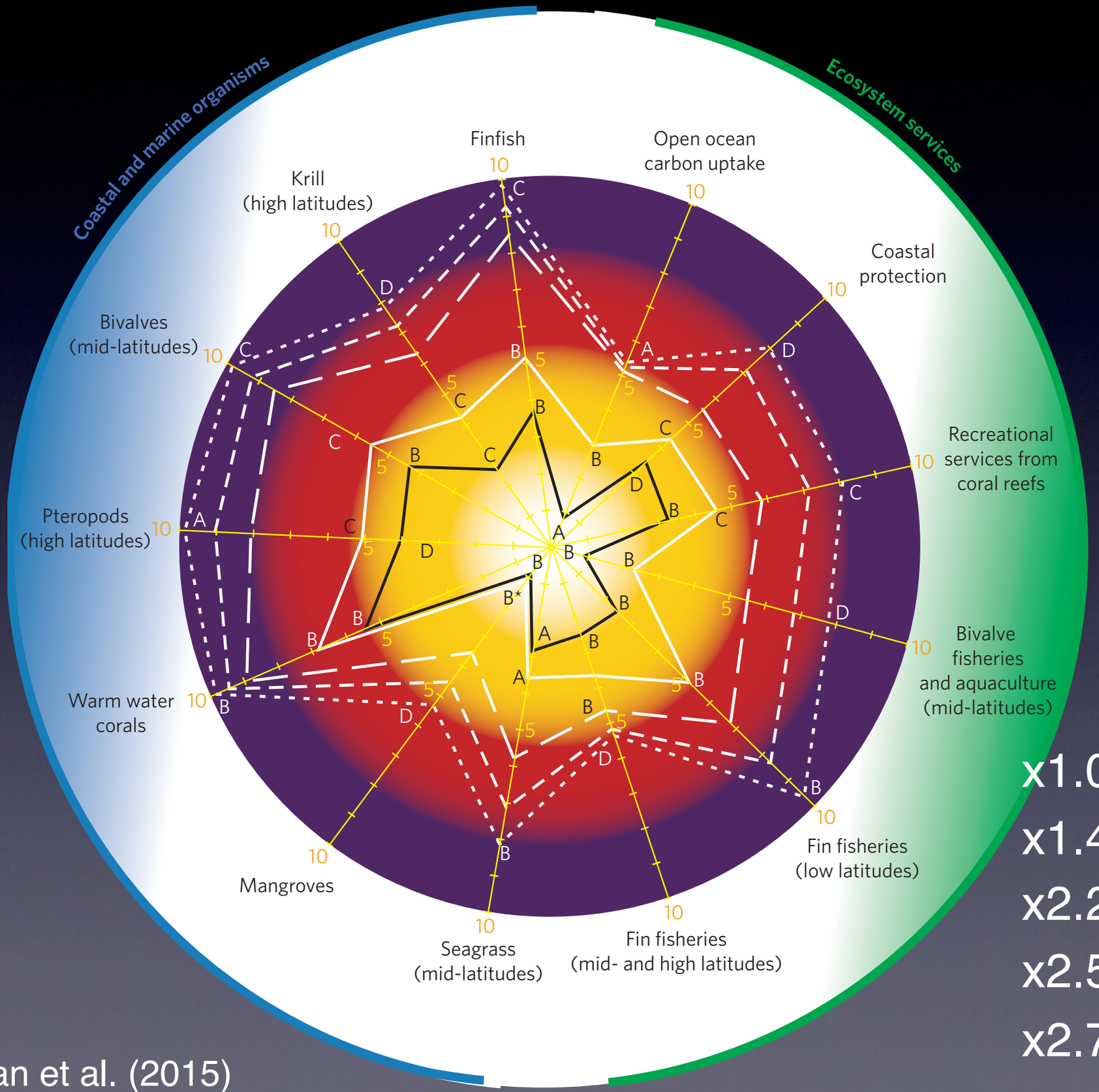
E	Very low
D	Low
C	Medium
B	High
A	Very high

Emission scenarios

- Present day
- IPCC RCP 2.6
- Climate Action Tracker 2015 estimate (+2.7 °C)
- Climate Interactive 2015 estimate (+3.5 °C)
- IPCC RCP 8.5

Magnan et al. (2015)

Future risks of impact



Risk of impact

Undetectable
Moderate
High
Very high
0
5
10

Confidence levels for the present day and the RCPs

E	Very low
D	Low
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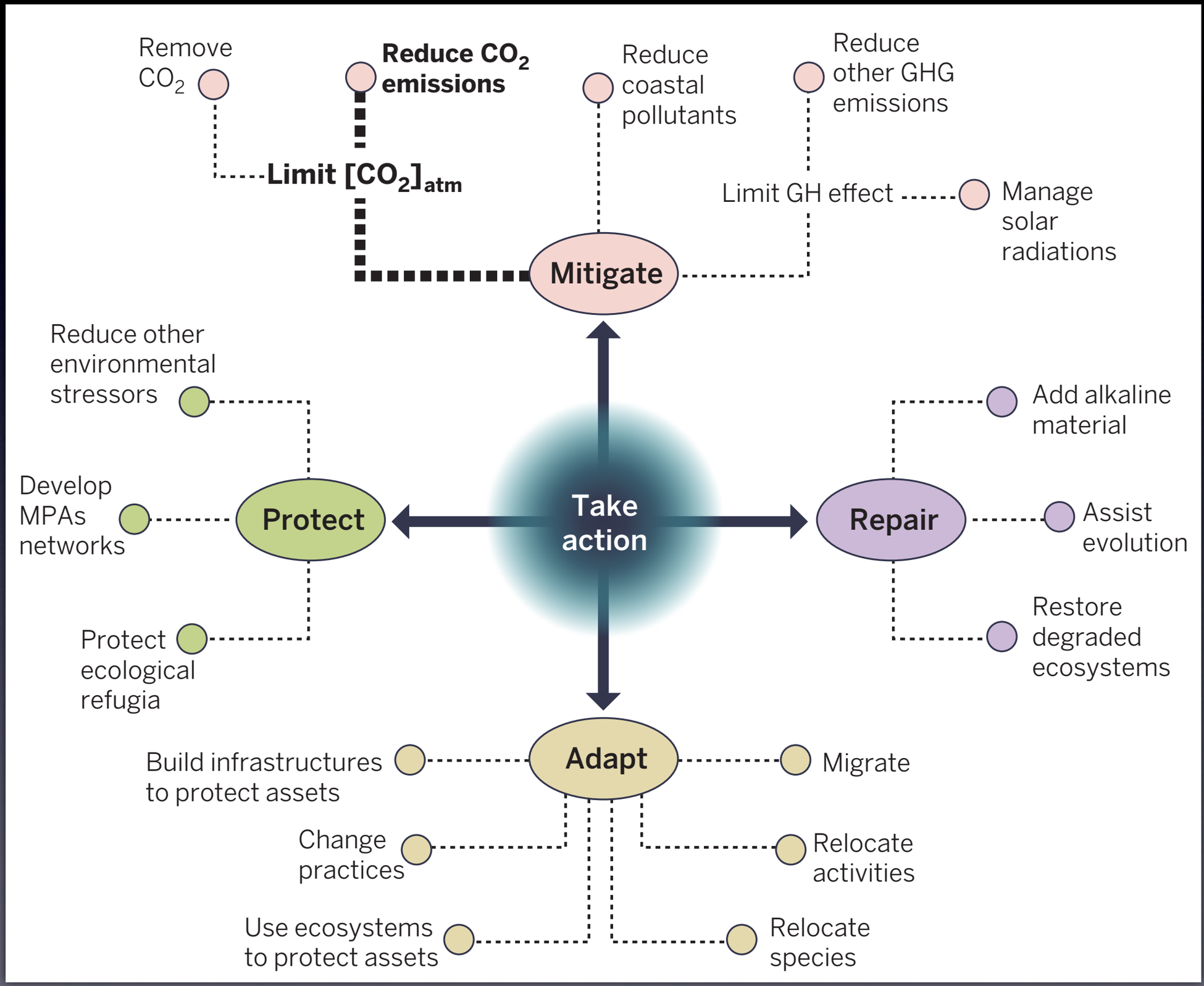
Emission scenarios

x1.0	Present day
x1.4	IPCC RCP 2.6
x2.2	Climate Action Tracker 2015 estimate (+2.7 °C)
x2.5	Climate Interactive 2015 estimate (+3.5 °C)
x2.7	IPCC RCP 8.5

Magnan et al. (2015)

[Ocean-based] Solutions



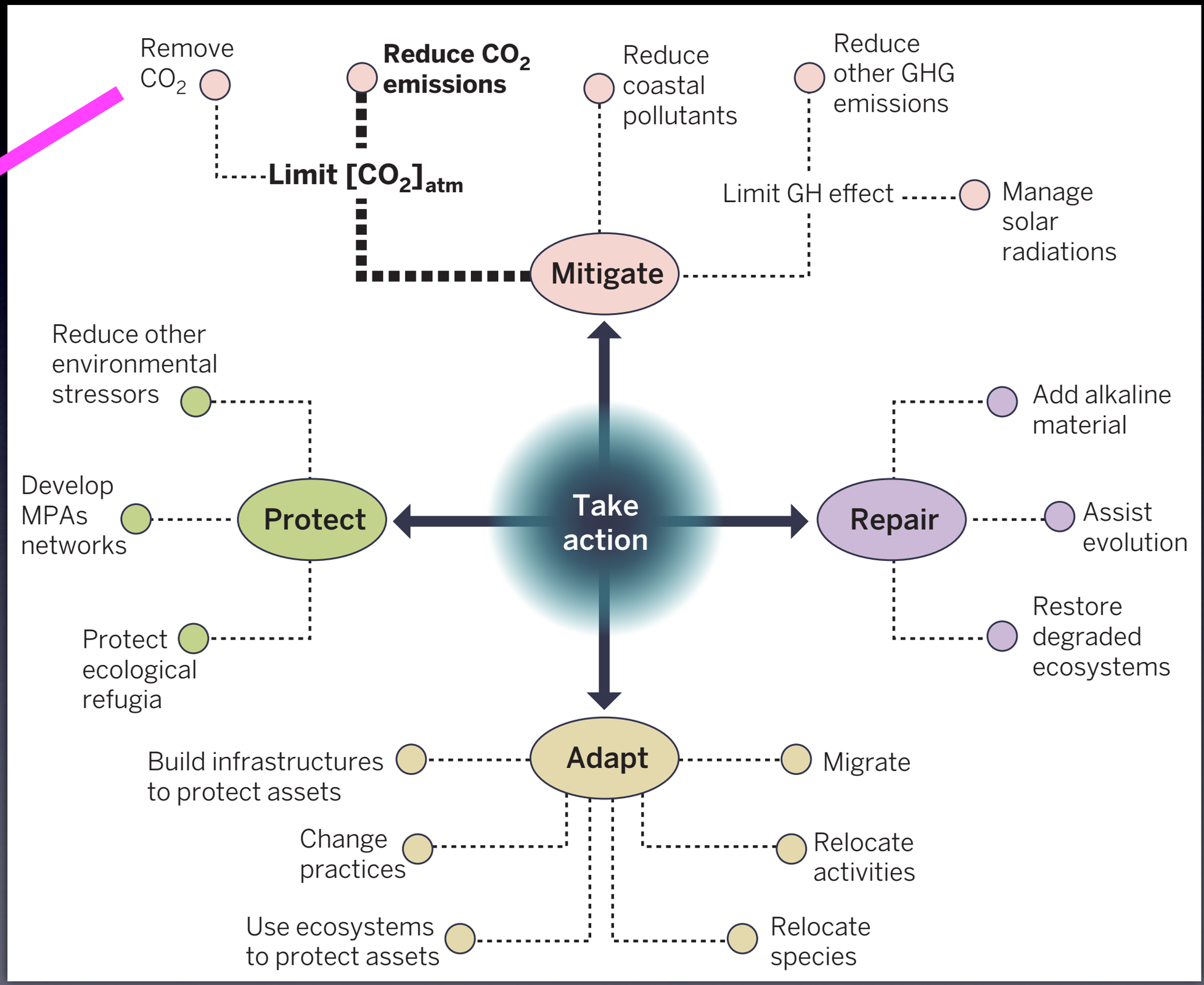
Gattuso et al. (2015)

[Ocean-based] Solutions

CO_2 removal

TECHNIQUE
Bioenergy with carbon capture and storage (BECCS)
Afforestation and reforestation
'Blue carbon' habitat restoration
Biochar
Enhanced ocean productivity
Enhanced weathering (using silicate rock)
Direct air capture (DAC)
Cloud treatment to increase alkalinity
Building with biomass

Williamson (2015)



Gattuso et al. (2015)

More: http://bit.ly/1M6YiS6

Many thanks to coauthors

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