

Future oceans

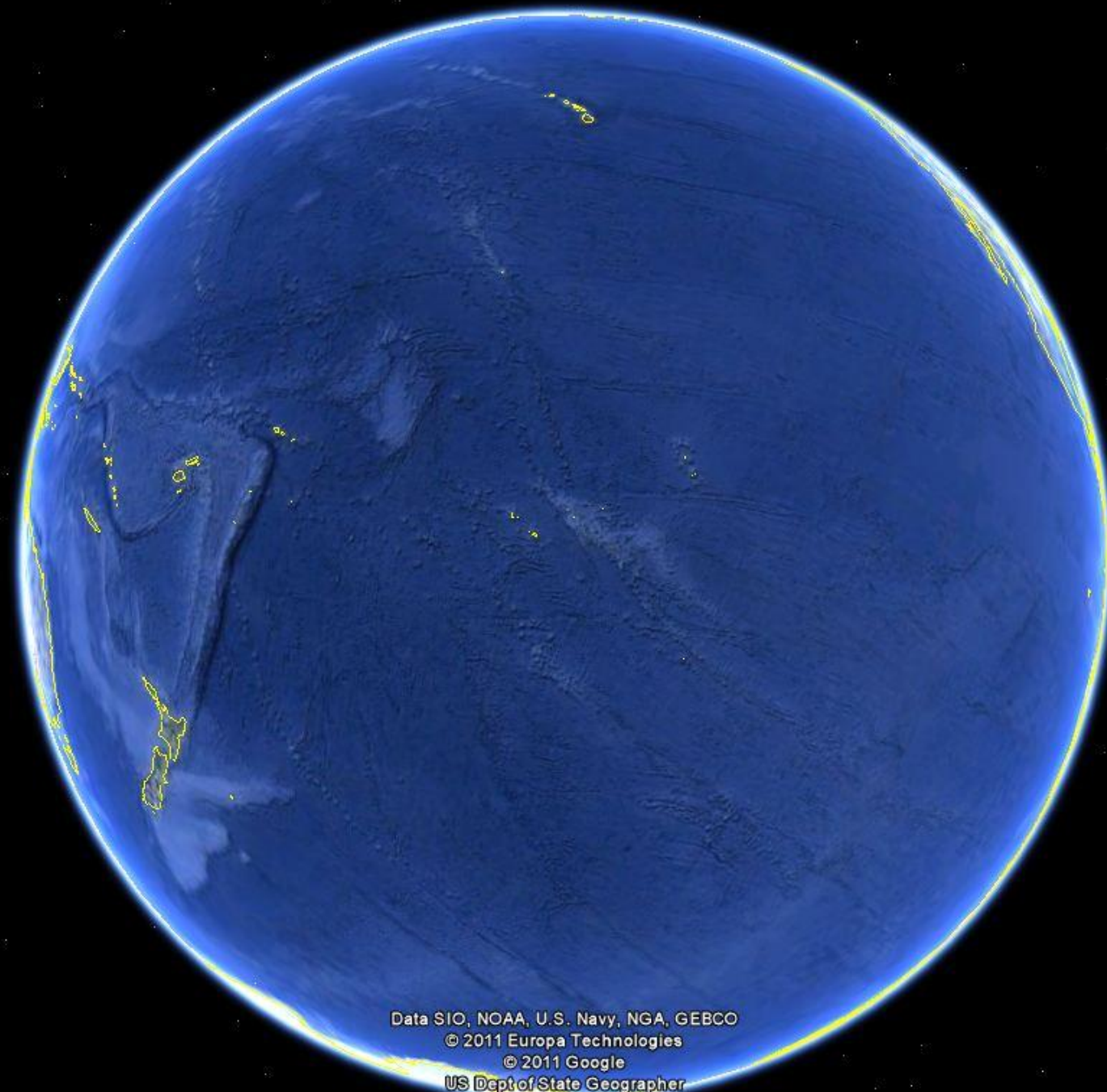
Callum Roberts
Professor of Marine Conservation
University of Exeter





We are used to thinking of the world as 29% land, 71% ocean

But adding
depth, 97% of
the living space
on Earth is
ocean



Data SIO, NOAA, U.S. Navy, NGA, GEBCO
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US Dept of State Geographer

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Eye alt 7567.76 mi

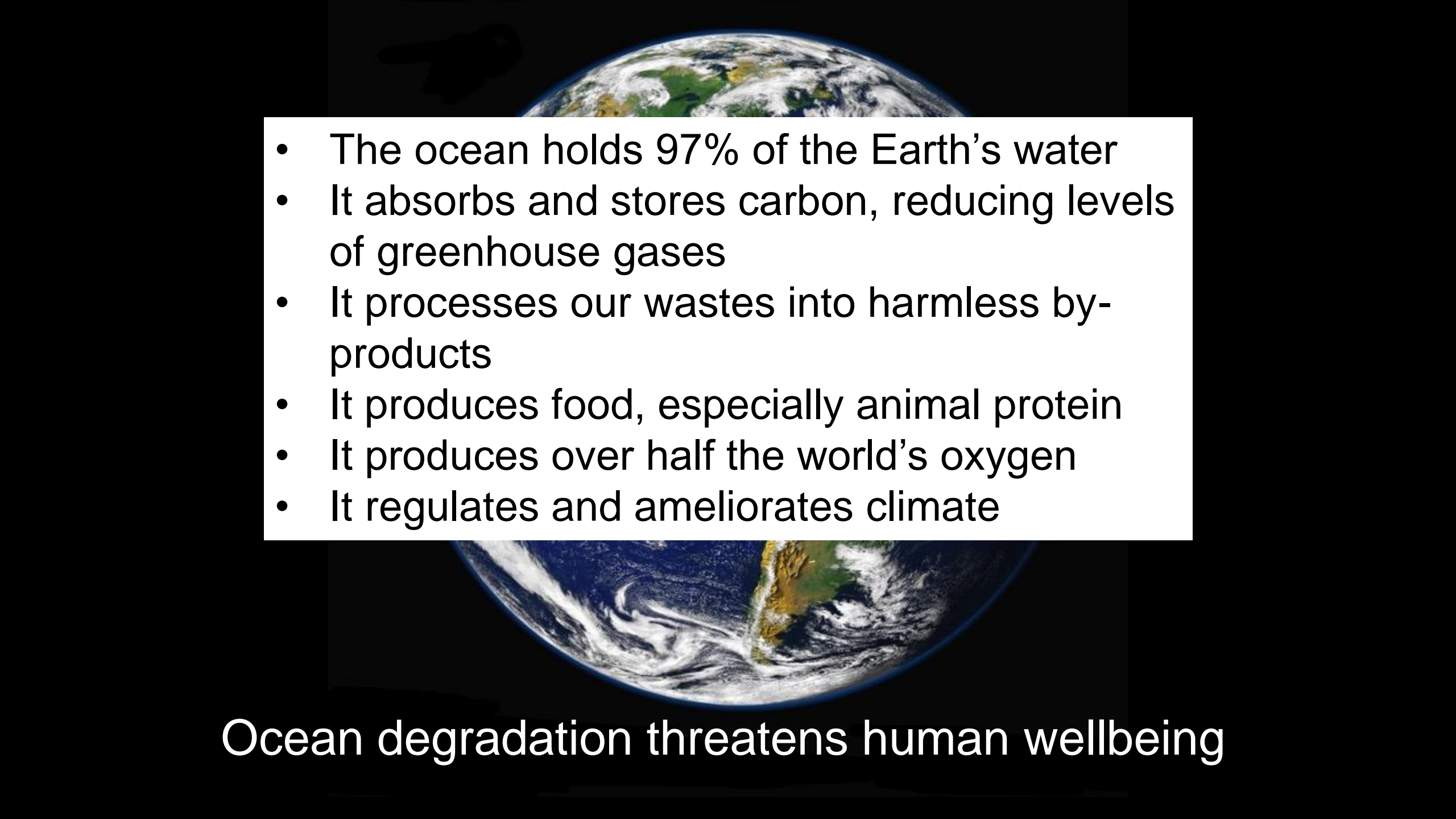


The two fallacies of immense ocean size:



We can dump in
the sea whatever
we don't want

We can take from the
sea whatever we want

- 
- The ocean holds 97% of the Earth's water
 - It absorbs and stores carbon, reducing levels of greenhouse gases
 - It processes our wastes into harmless by-products
 - It produces food, especially animal protein
 - It produces over half the world's oxygen
 - It regulates and ameliorates climate

Ocean degradation threatens human wellbeing





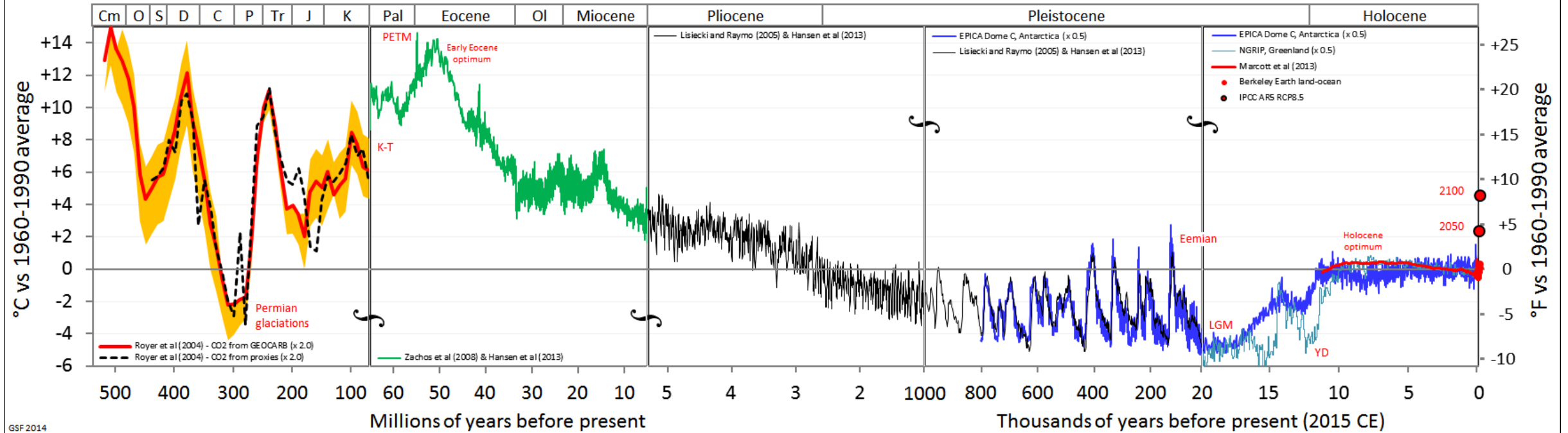
The world is changing faster
than at any time in human
history and probably far longer

- Pre-industrial atmospheric CO₂ 280 ppm
- Without rapid action, forecast to rise to >800 ppm by 2100
- Temperatures could rise by 2-4°C



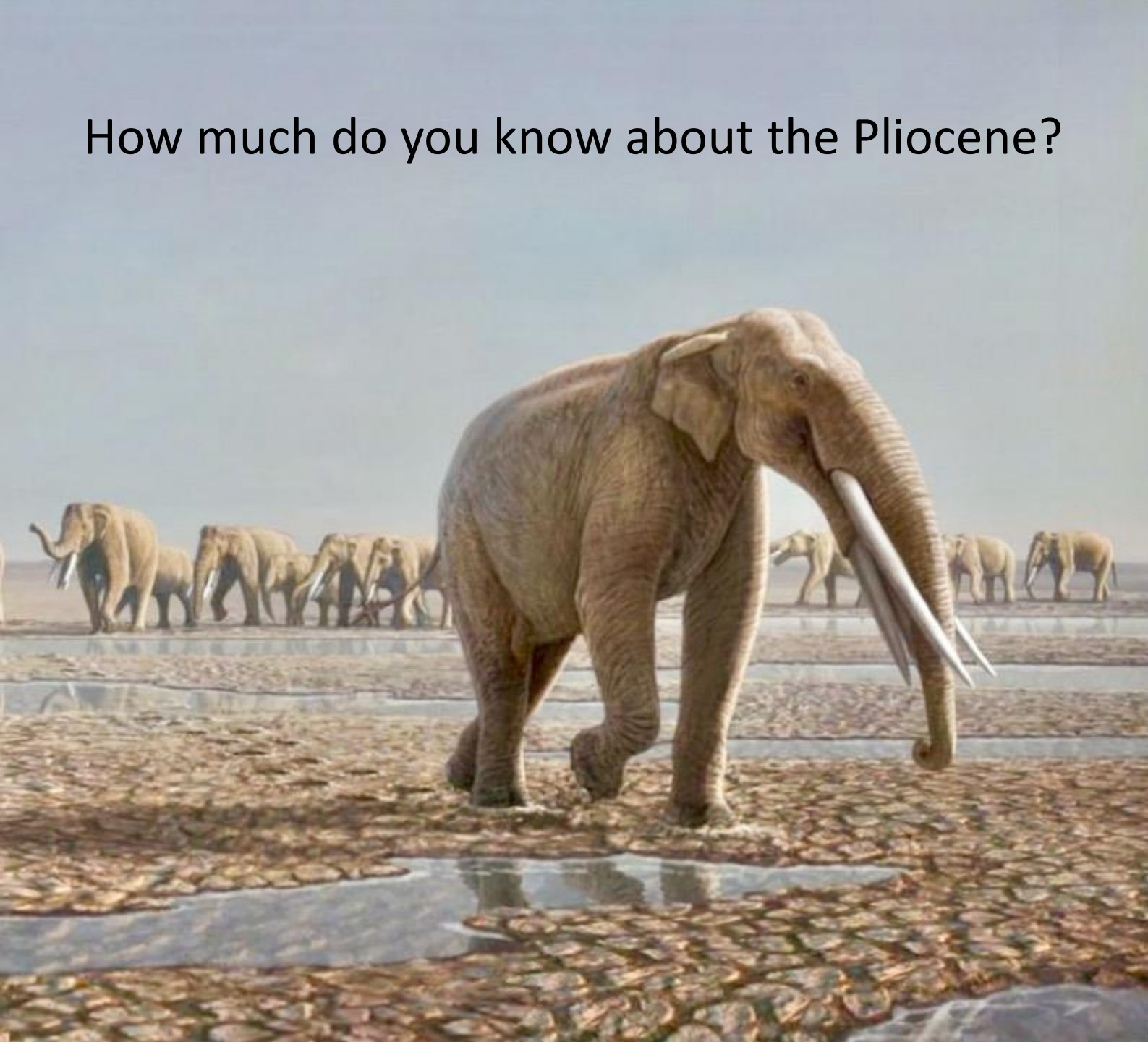
<http://co2.earth>

Temperature of Planet Earth



The Earth is warming, again. It has been hotter.

How much do you know about the Pliocene?



5-2.5 million years ago

The mid-Pliocene warm period (3.3 to 3 mya) was the last time CO₂ levels were as high as today

Temperatures were 2-3°C higher than today

Trees grew within 300 miles of
the South Pole



Greenland was ice free





Sea level was 22m higher

The background of the slide is an underwater scene. The top half shows the surface of the water with gentle ripples and a bright blue sky with scattered white clouds. Below the surface, the water is a deep, clear blue. In the lower half, a vibrant coral reef is visible, featuring various types of coral, including branching and brain corals, in shades of blue, green, and brown. The lighting is bright, suggesting a sunny day.

The oceans have absorbed 93% of the heat building up from greenhouse gas emissions

Without the ocean, global atmospheric temperature would have increased not by the present 1°C since 1750, but by...

36°C

Sources: McNutt, Science, 2015
Levitus et al., 2012

- Ocean heating since 1871 is equivalent to 1.5 Hiroshima bombs per... second
- Since 1990, heating is equivalent to 3 to 6 bombs per ... second

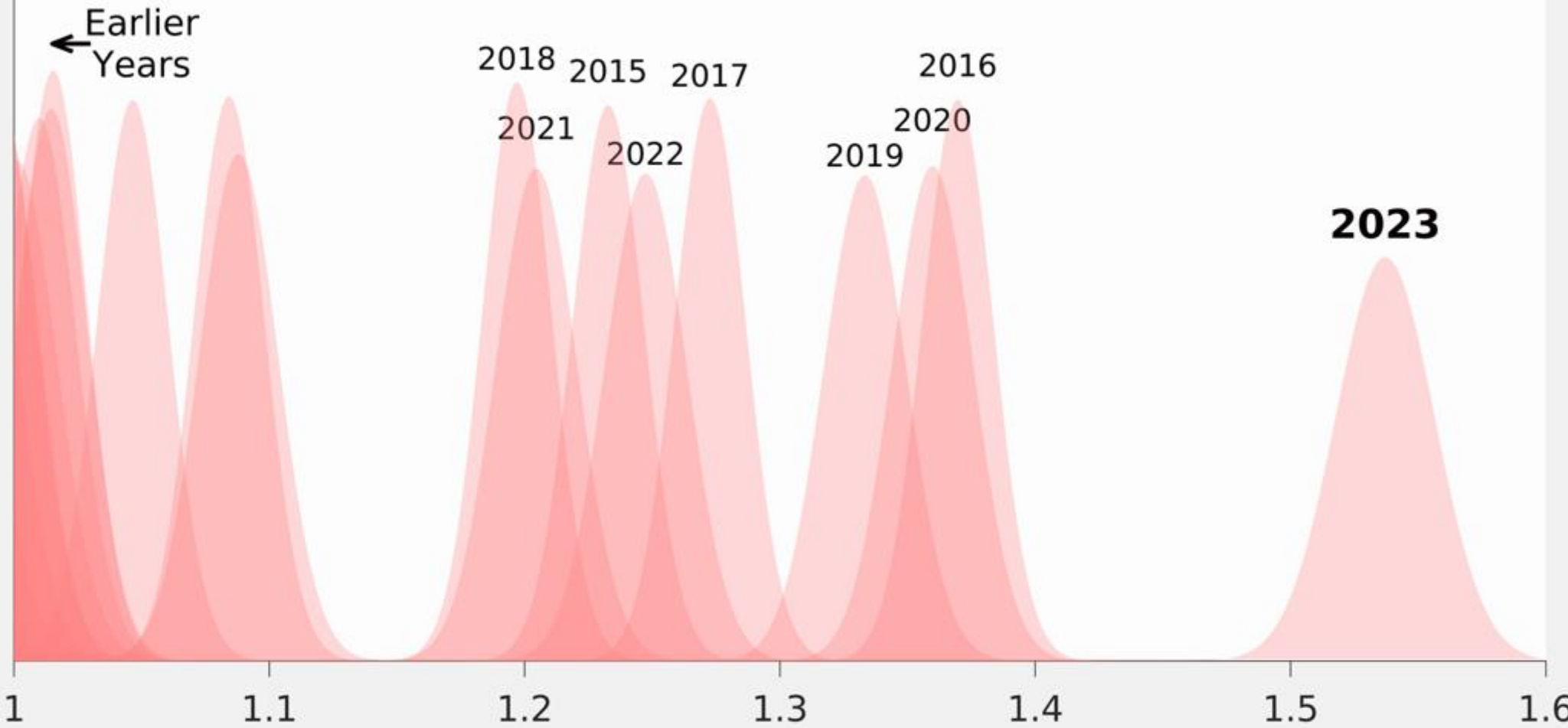
Zanna et al. (2019) PNAS www.pnas.org/cgi/doi/10.1073/pnas.1808838115



What on Earth has been going on in the last 12 months?!



Probability Distribution



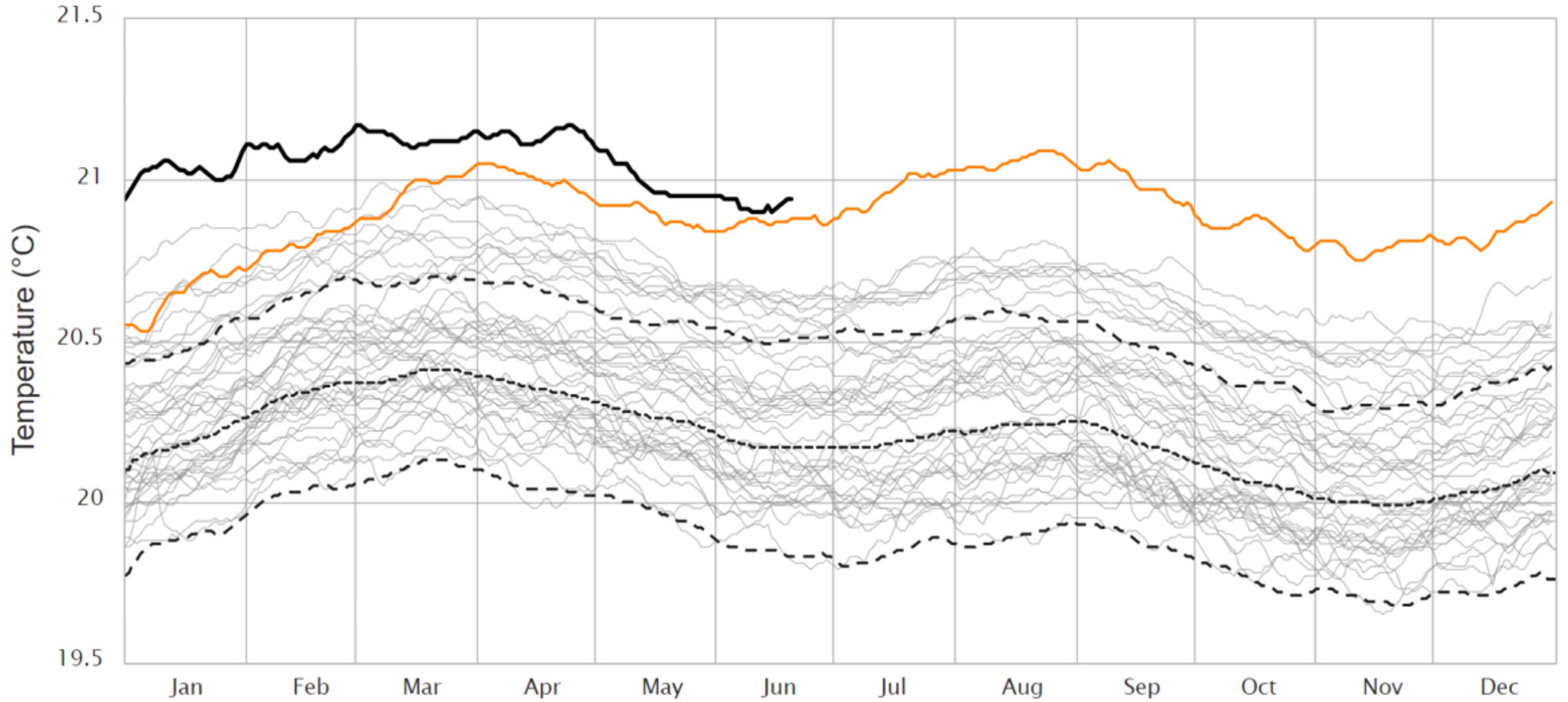
Global Mean Temperature Anomaly and Uncertainty (°C)

Based on Berkeley Earth's estimates of the global annual average temperature increase relative to 1850-1900. Each year's individual uncertainty is shown, but does not include the systematic uncertainty in the baseline.

Daily Sea Surface Temperature, World (60°S–60°N, 0–360°E)

☰ [Export Chart](#)

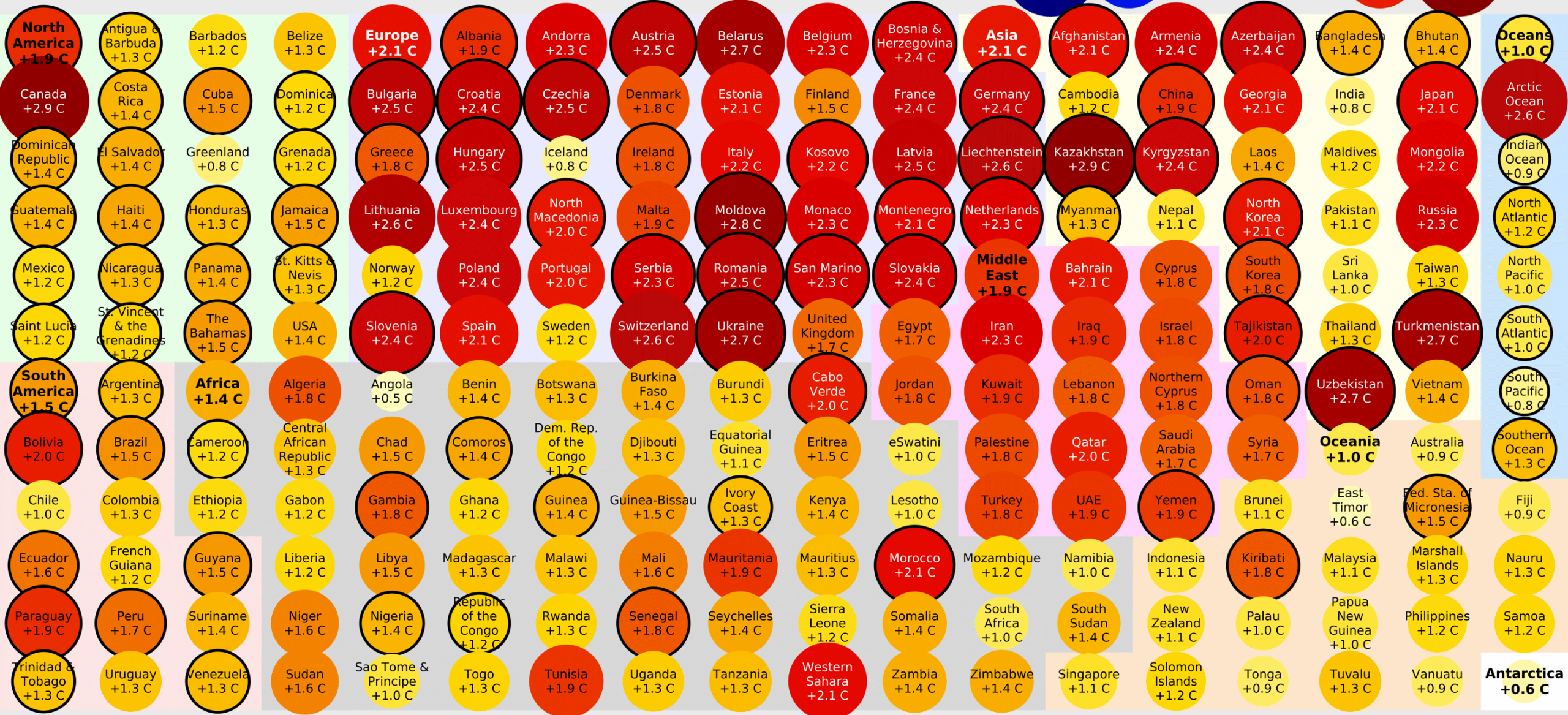
Dataset: NOAA OISST V2.1 | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine



https://climatereanalyzer.org/clim/sst_daily/

Global Warming by Country & Region

2023

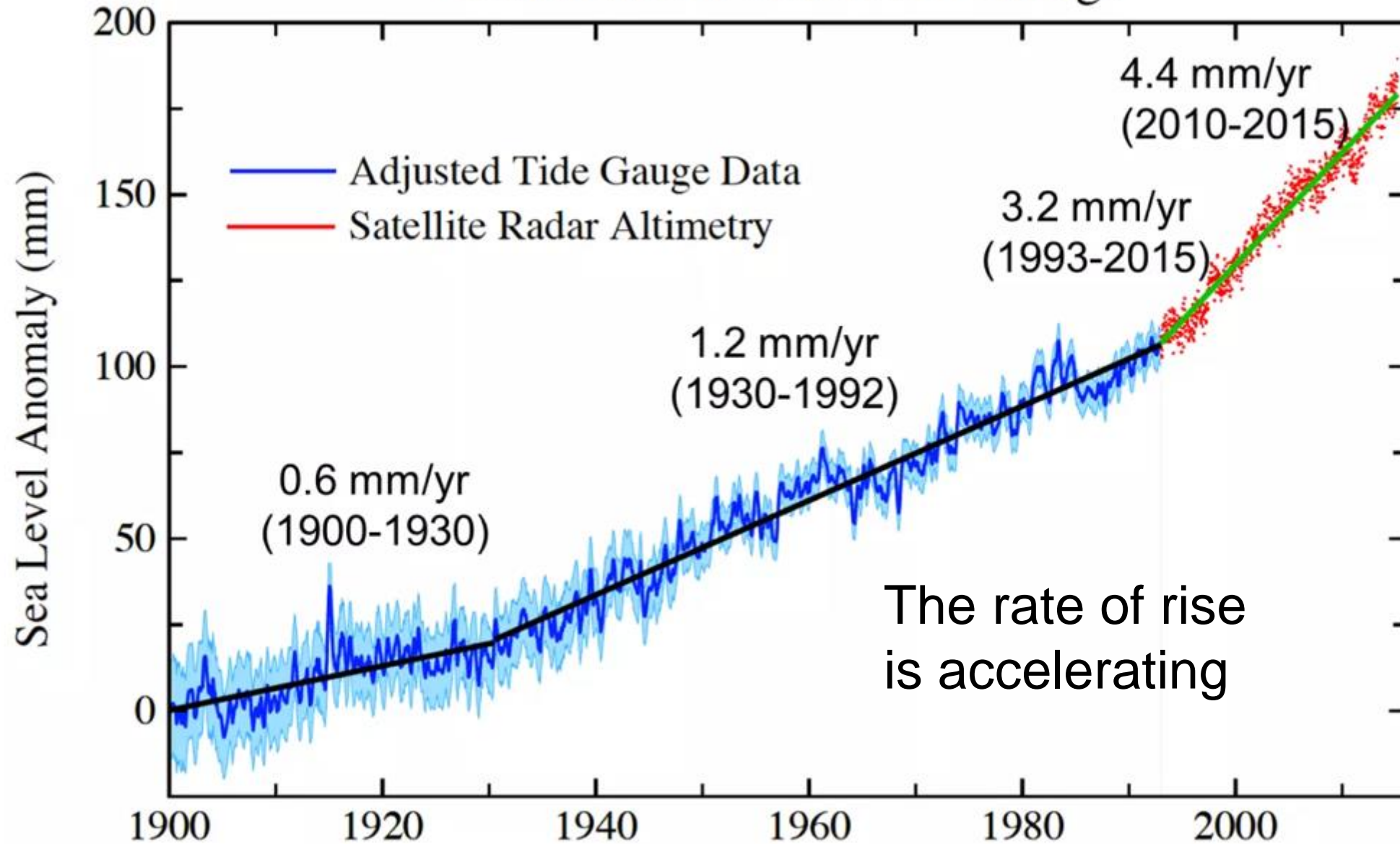


Based on Berkeley Earth's Land+Ocean Dataset
<http://www.berkeleyearth.org/data/>

Land Average: +1.62 C, +2.92 F
Global Average: +1.21 C, +2.17 F
 Ocean Average: +1.04 C, +1.87 F

Anomalies relative to the 1951-1980 climatology
 Black outlines indicate a new record year

Global Mean Sea Level Change

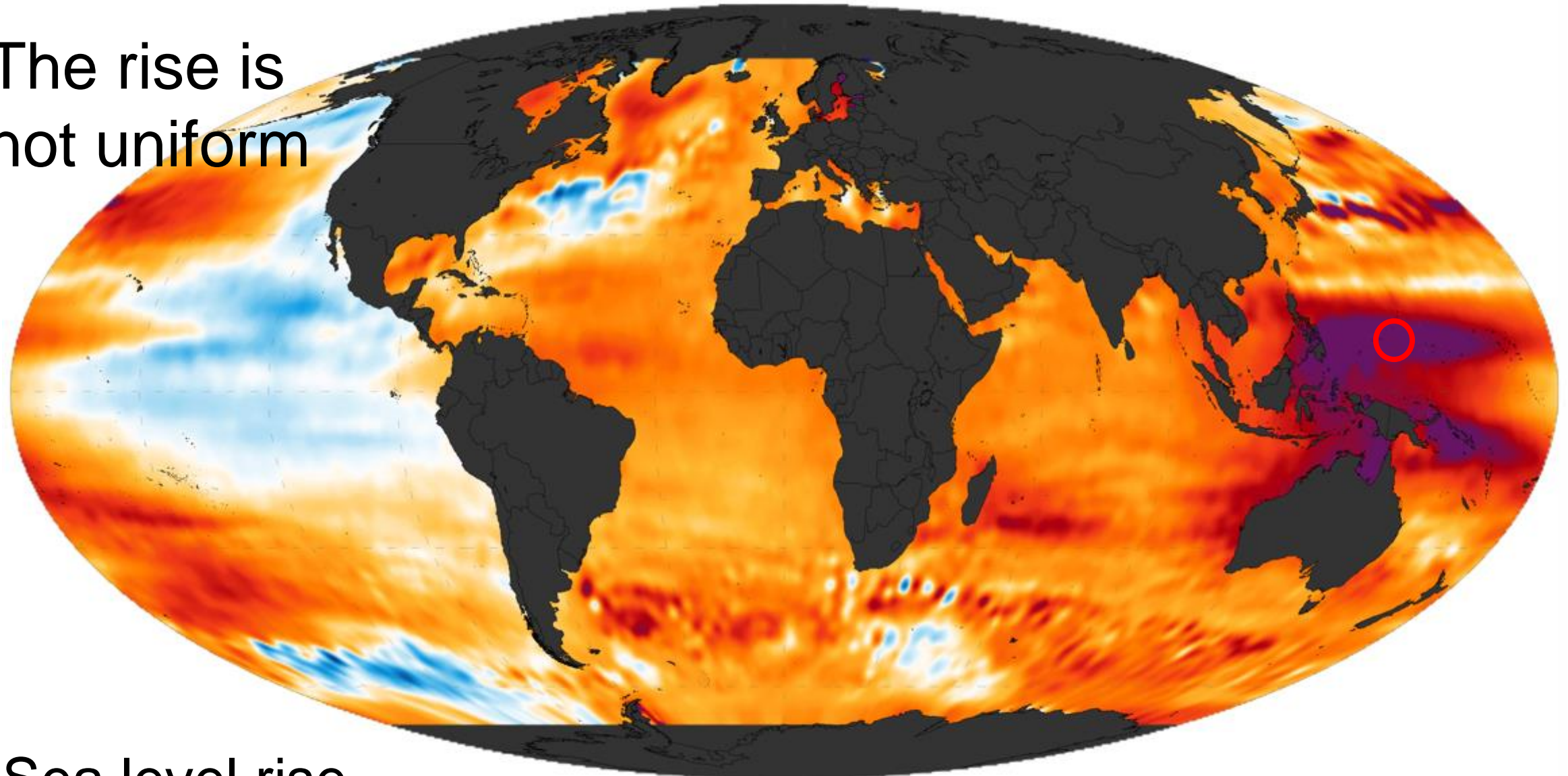


Extremes can increase faster than the average



King tide, Miami Beach, September 2014

The rise is
not uniform



Sea level rise
since 1993

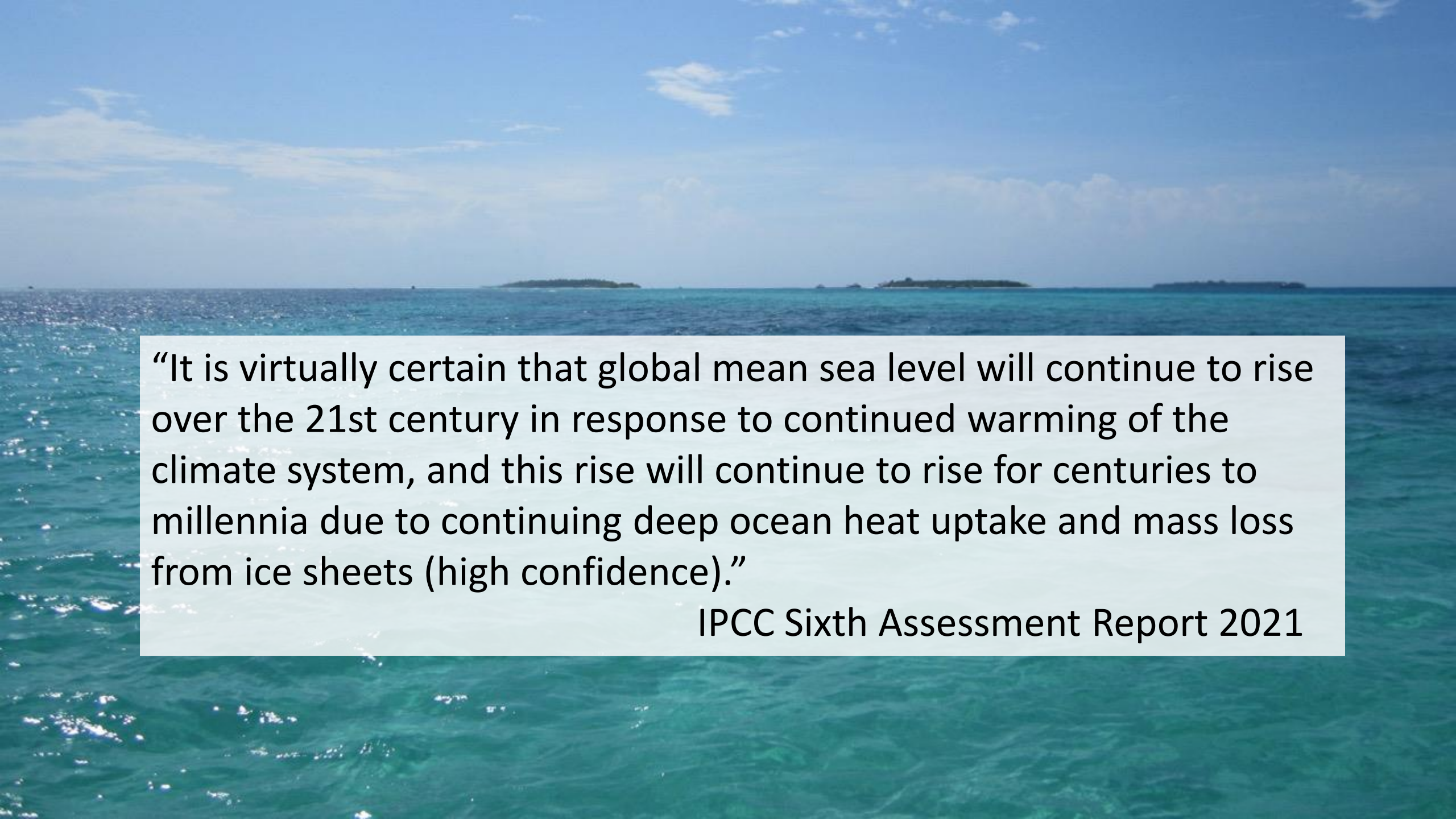


Source: NOAA satellite altimetry data

King tide in Kiribati



Photo: Garry Braasch



“It is virtually certain that global mean sea level will continue to rise over the 21st century in response to continued warming of the climate system, and this rise will continue to rise for centuries to millennia due to continuing deep ocean heat uptake and mass loss from ice sheets (high confidence).”

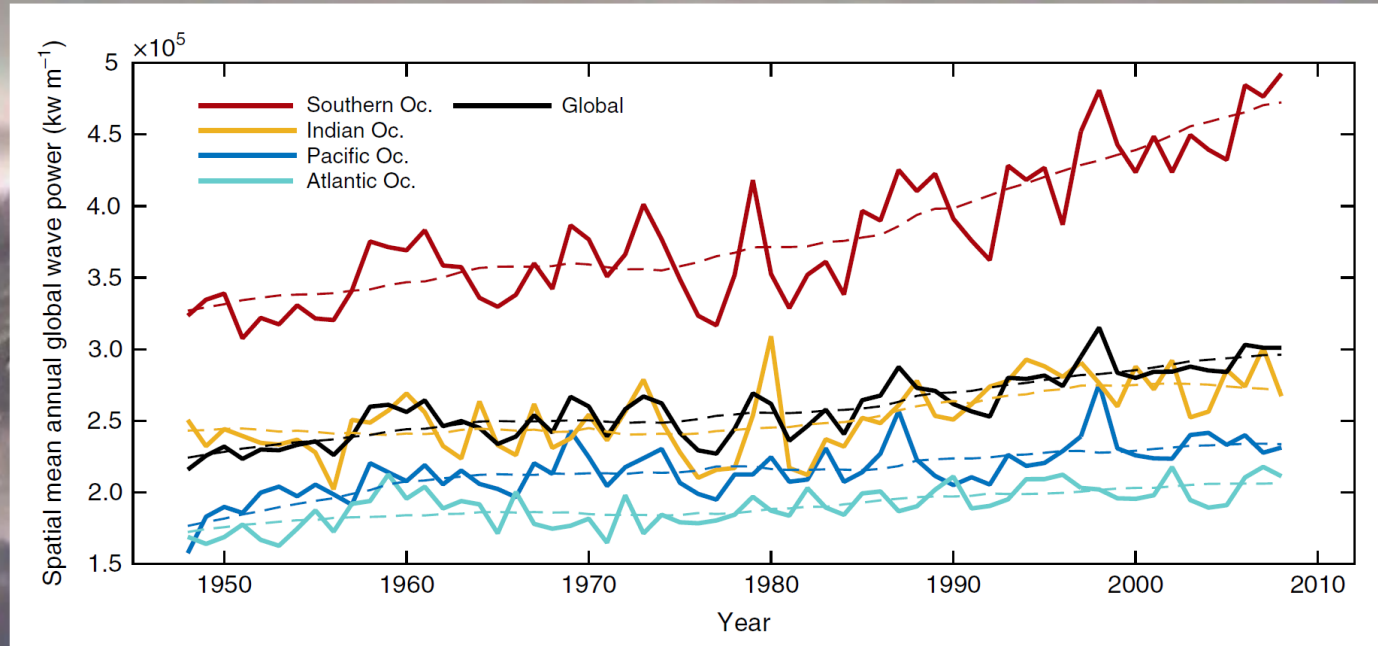
IPCC Sixth Assessment Report 2021

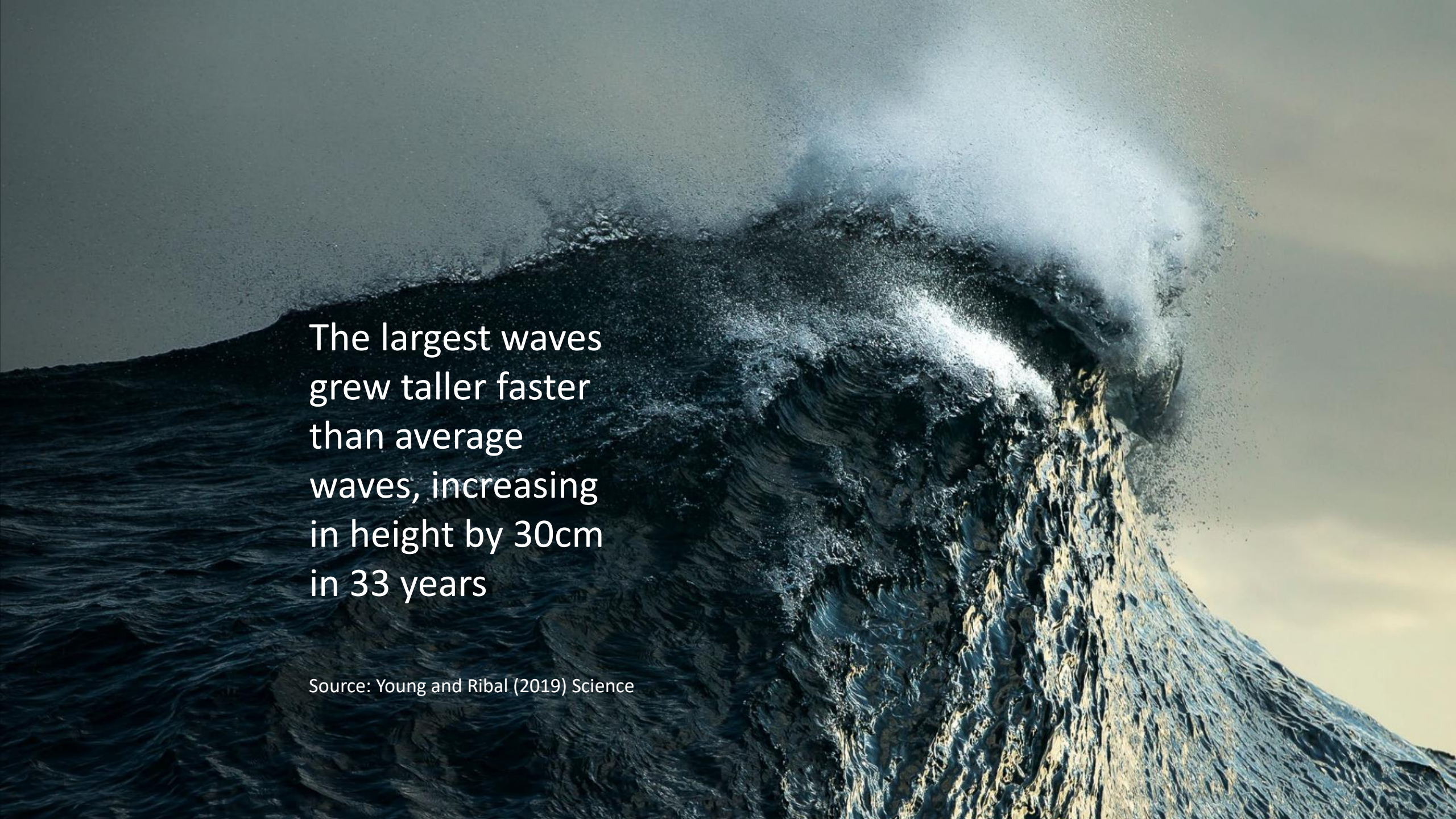


Miami

200 years from now the sea will probably be at least 2-3m higher

Global wave power has increased by 31% in 60 years





The largest waves
grew taller faster
than average
waves, increasing
in height by 30cm
in 33 years

Source: Young and Ribal (2019) Science



Healthy mangrove

Bohai Sea, China

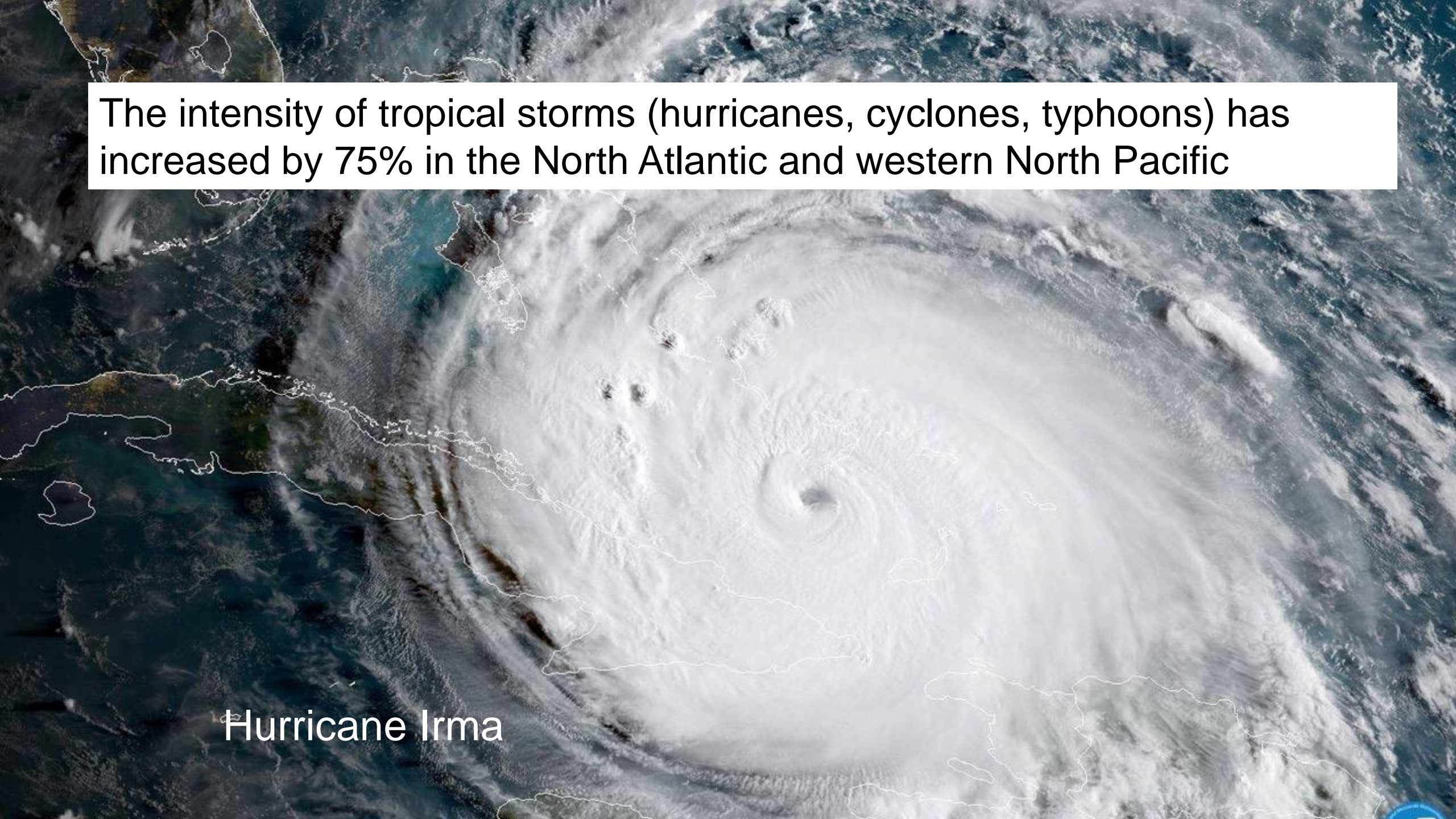
Coastal wetlands provide vital protection for people but are being lost to sea level rise and aquaculture



Google earth

The intensity of tropical storms (hurricanes, cyclones, typhoons) has increased by 75% in the North Atlantic and western North Pacific

Hurricane Irma





Marsh Harbour, Great Abaco Island, Bahamas, 2019

By 2100, annual flood damages are expected to increase by 100 to 1,000 times.

IPCC summary for policymakers, 2019

Rare hundred-year extreme flooding events are expected to become annual occurrences in many places by mid-century. That prediction holds true for all the scenarios considered.

IPCC 2019



10% of the world population lives <10m above sea level




Today's migrants represent
the trickle before the flood



Photo: Alex Mustard





A large coral reef is shown, with many of the coral structures appearing white and bleached. The reef is composed of numerous branching coral colonies. The water is clear and blue. The text "Coral reefs are especially sensitive to global change" is overlaid on the image in white font.

Coral reefs are especially sensitive to global change

Photo: Alex Mustard

Coral reefs occur in >100 tropical countries
Support \$2.7 trillion/yr in goods and services





Corals are in trouble

1.5°C warming: 70-90% loss by 2100?

2°C warming: >99% loss by 2100?

Source: IPCC 2018

Photo: Alex Mustard

Many countries depend
on coral reefs for their
existence



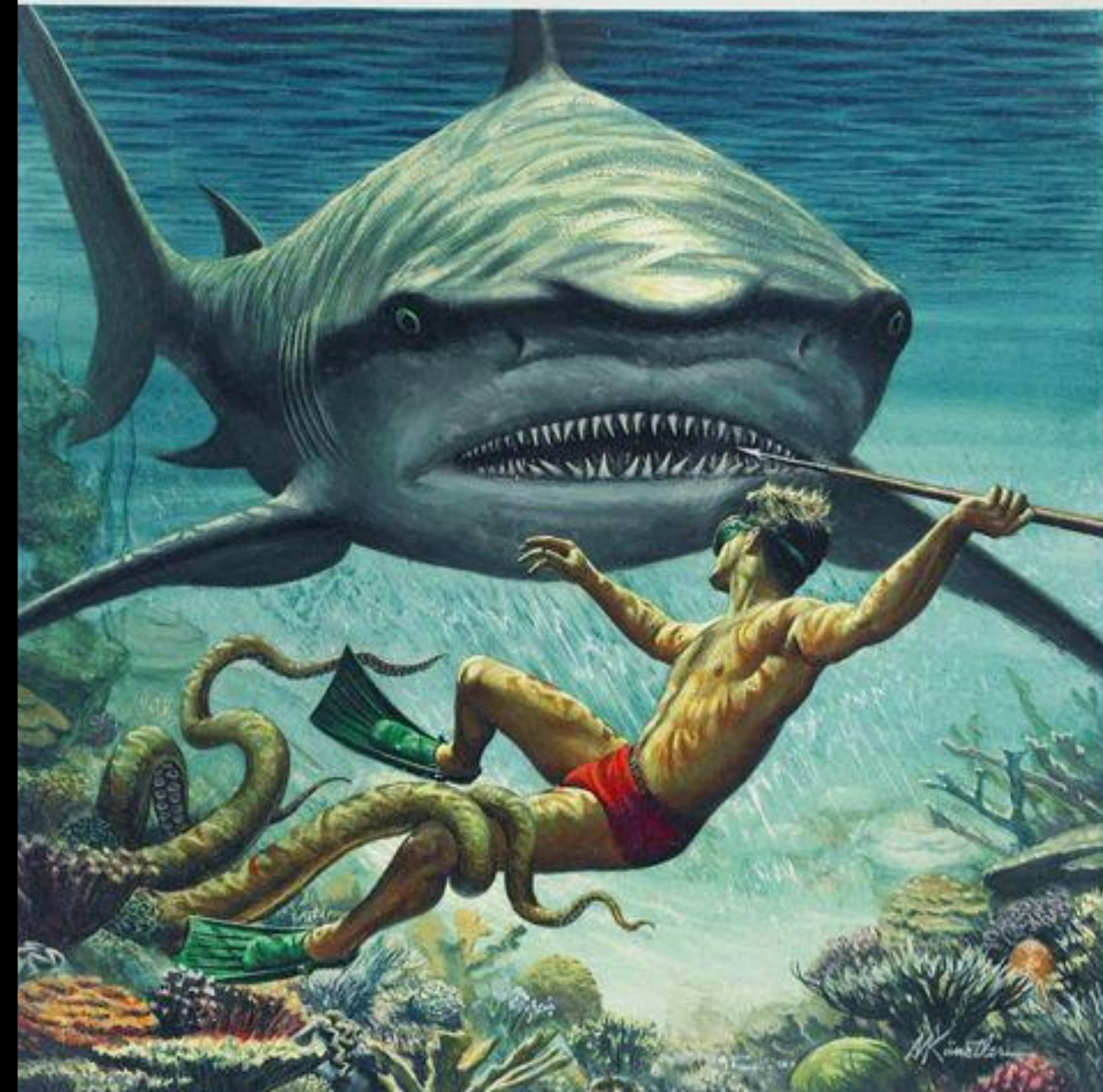


Photo: Alex Mustard

Selective breeding/
assisted evolution

Control of predators/
competitors

Cooling and shading

Innovation and
experimentation

Gene editing of
corals or their
symbiotic algae

Probiotics

Enhanced
reproduction/
survival of
young corals

Bulk production
methods for coral
restoration

Coral relocation

New habitat
structures/
stabilisation



Photo: Alex Mustard