

An underwater photograph showing a large school of small, silvery fish swimming in clear blue water above a dark, rocky reef. Sunlight rays are visible filtering down from the surface.

GLOBAL CHANGE ECOLOGY AND SUSTAINABILITY
a.a. 2023-2024

Conservation and Management of Marine Ecosystems
Prof. Stanislao Bevilacqua (sbevilacqua@units.it)

Climate change

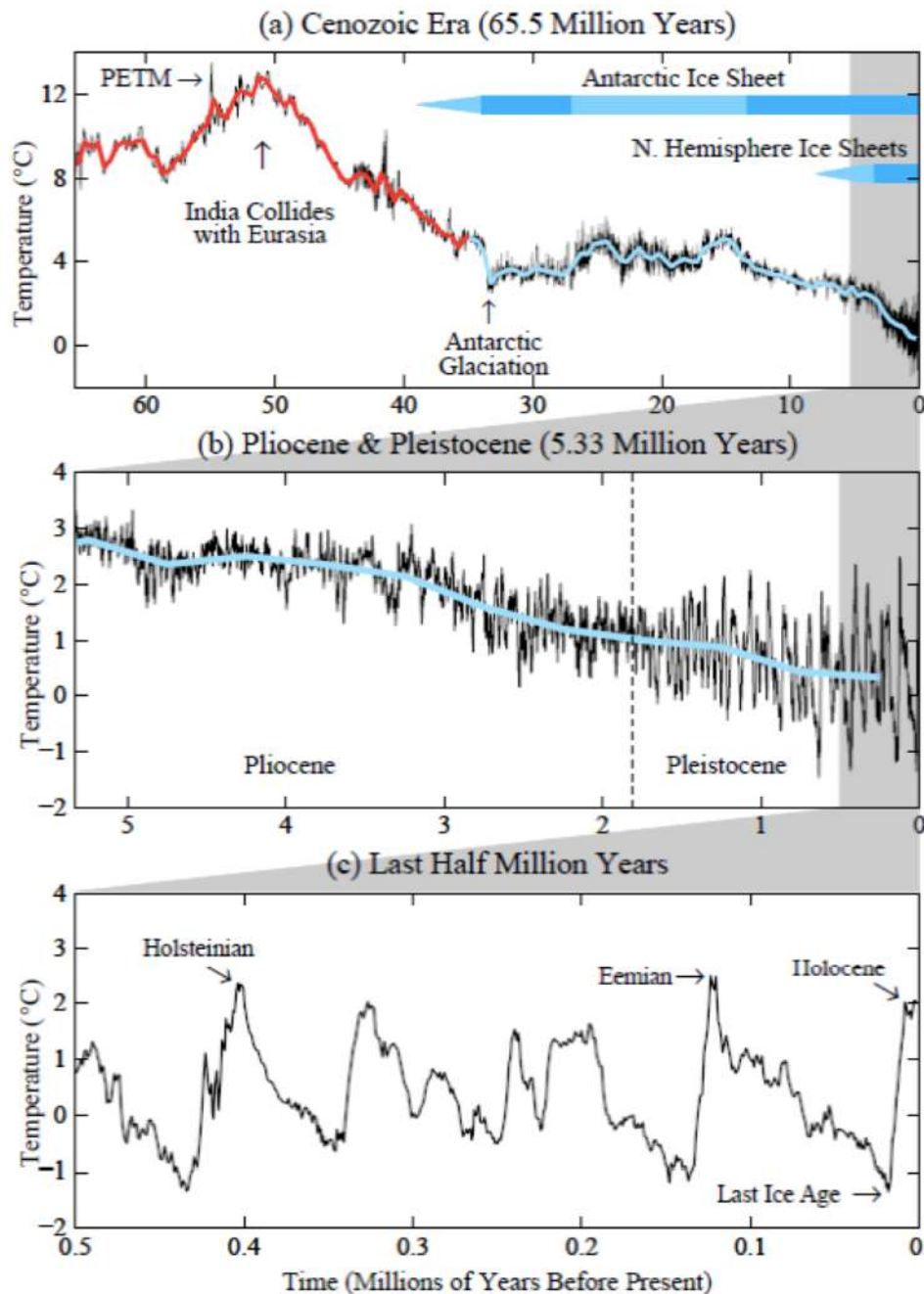
Climate change and global change

Climate change refers to changes of climatic factors at a global scale (e.g., increasing SST, but also sea level rise, ice melting, and atmospheric phenomena)

Global warming is the increasing warming temperature at global scale in the last century, mostly due to fossil fuel use, referring to the baseline of 1961-1990 (WMO), 1850-1900 for comparison with pre-industrial period

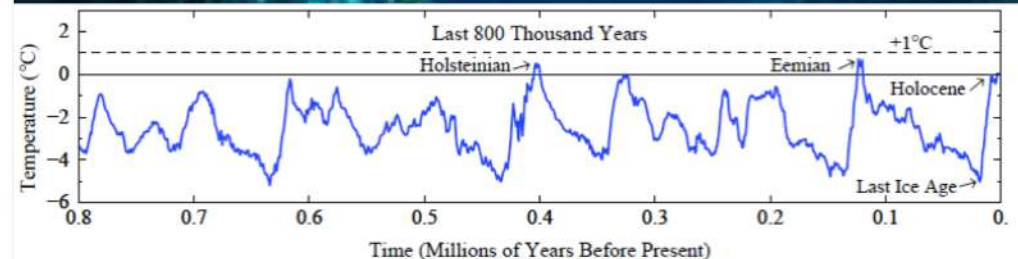
Global change refers to all changes that are occurring as a consequence human activities, including climate modifications, biodiversity loss, alterations of the natural environments and so on...

Paleoclimate

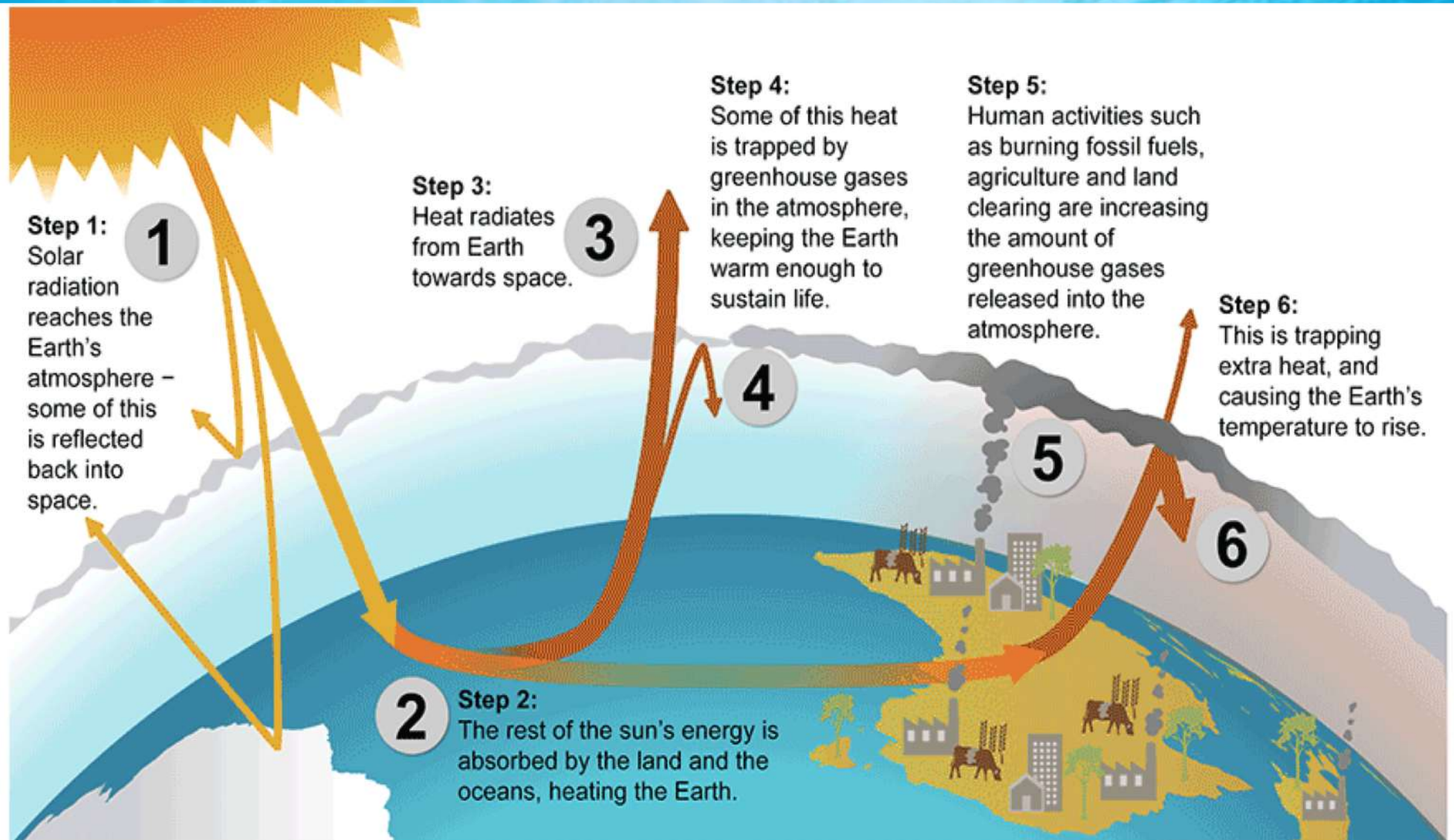


We are in a Glacial Era started 40 millions years ago. Within a glacial era, glacial and interglacial periods alternate. The last glacial period started more than 100k years ago and finished about 10k years ago.

Now we are in a interglacial period. However, we are less than 1 degree cooler than warmer peak in past interglacial periods.
(Hansen and Sato, 2011)



Greenhouse effect

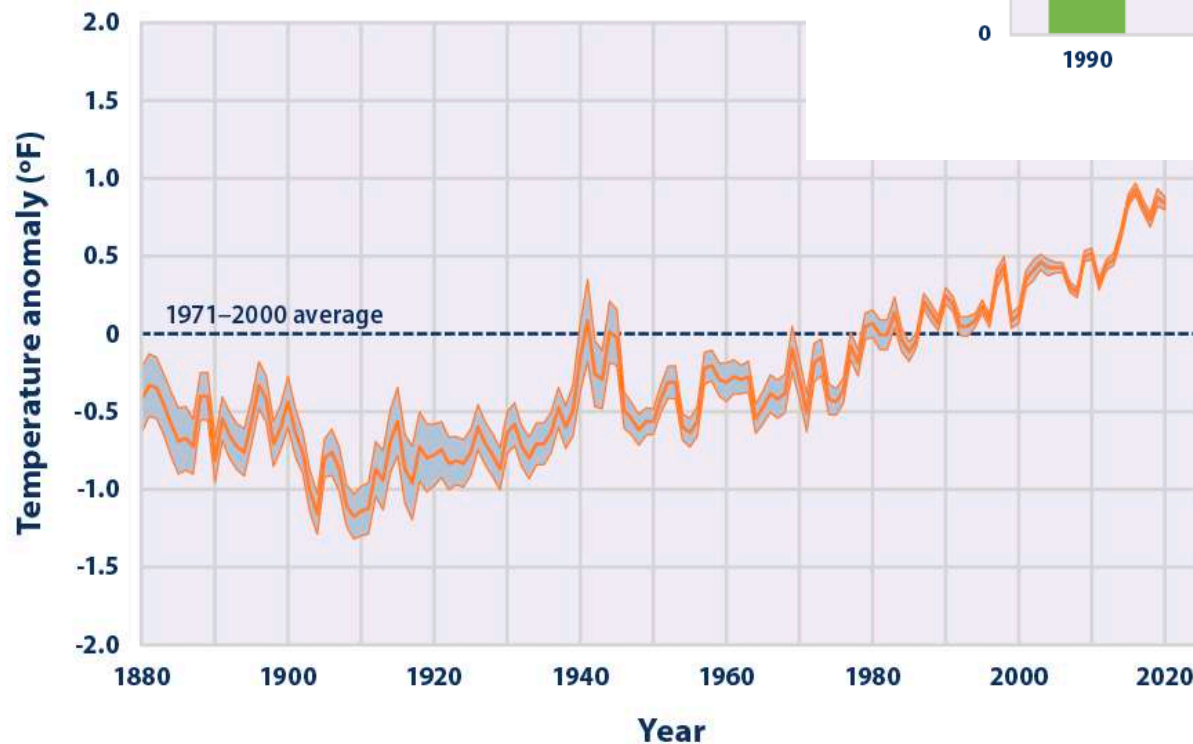
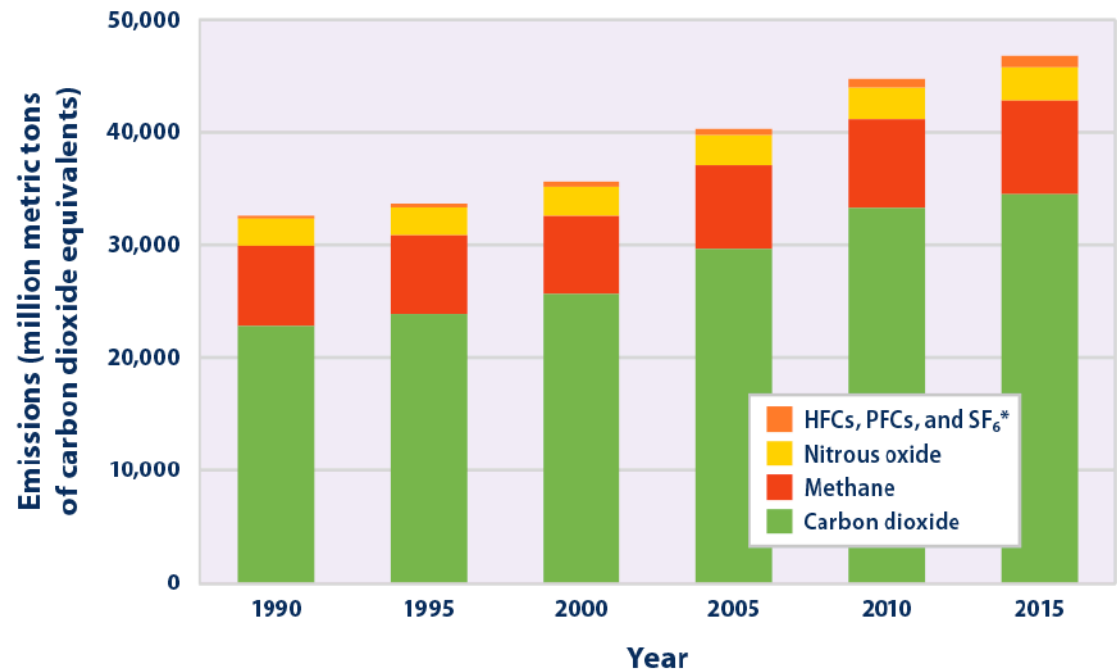


Greenhouse effect

CO₂ N₂O CH₄ H₂O CFC

Carbon dioxide emissions

Global emissions per type of GHG



0.13 ° C per decade over the last 100 years
(0.014 ° C last 5k y)

Methane in the subpolar regions



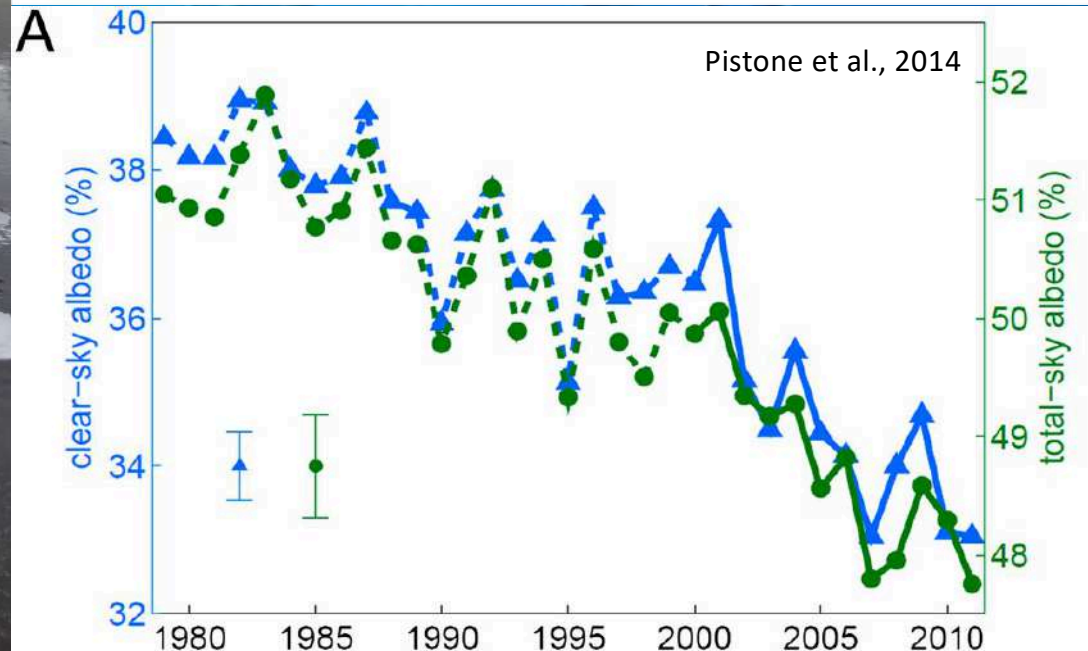
Release of methane
Albedo reduction



Article | [OPEN](#) | Published: 15 August 2018

21st-century modeled permafrost carbon emissions accelerated by abrupt thaw beneath lakes

Katey Walter Anthony , Thomas Schneider von Deimling, Ingmar Nitze, Steve Frolking, Abraham Emond, Ronald Daanen, Peter Anthony, Prajna Lindgren, Benjamin Jones & Guido Grosse



Specific heat

Specific heat: the amount of heat necessary to raise the temperature per unit mass by 1 degree Kelvin

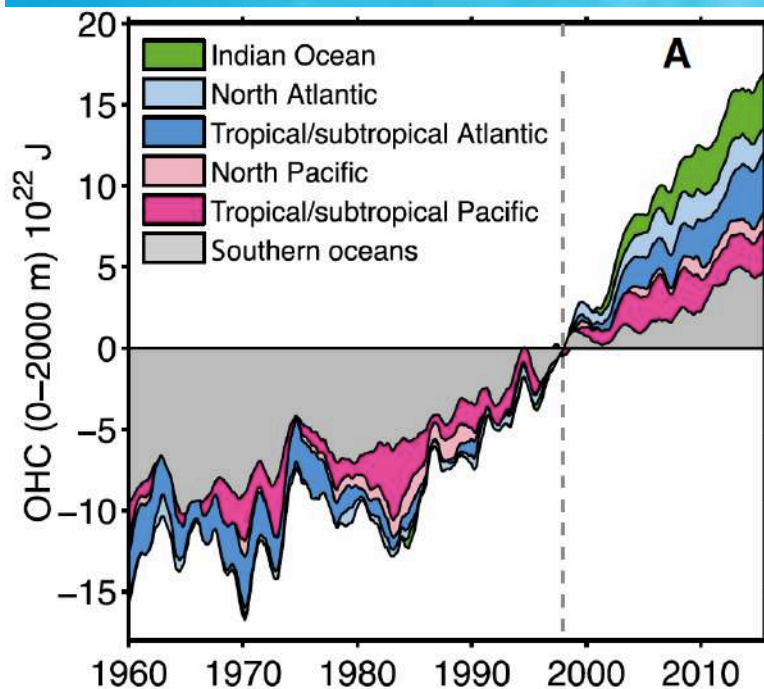
Air 0.25 Kcal/kg ° C

Rock (average) 0.20 Kcal/kg ° C

Seawater 0.95 Kcal/kg ° C



Earth Energy Imbalance



Improved estimates of ocean heat content from 1960 to 2015

Lijing Cheng,^{1*} Kevin E. Trenberth,² John Fasullo,² Tim Boyer,³ John Abraham,⁴ Jiang Zhu¹



More than 90% of energy imbalance of the planet is stored in the ocean, increasing ocean heat content (OHC), while the residual heat is manifest in melting of both land and sea ice, and in warming of the atmosphere and land surface. OHC is increasing due to greenhouse gases.

Storming



Geophysical Research Letters

Research Letter

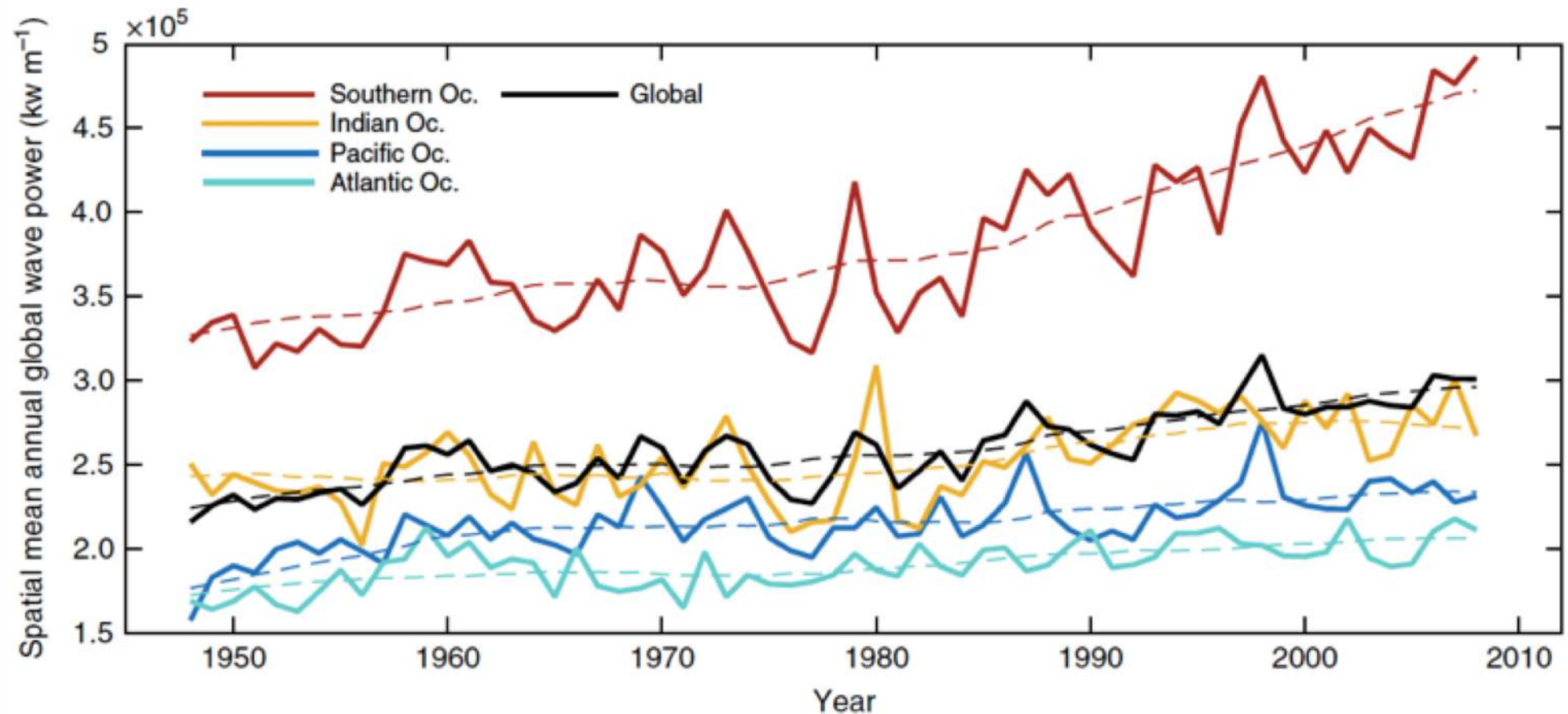
Attributable Human-Induced Changes in the Likelihood and Magnitude of the Observed Extreme Precipitation during Hurricane Harvey

Mark D. Risser , Michael F. Wehner

Increase in strength and frequency of hurricanes, coastal flooding



Increasing energy in weather phenomena



A recent increase in global wave power as a consequence of oceanic warming

Borja G. Reguero^{1,2}, Iñigo J. Losada¹ & Fernando J. Méndez¹

Increasing storm intensity and frequency, and wave energy

El Nino

Atmospheric-oceanic coupled process El Nino - Southern Oscillation (ENSO)

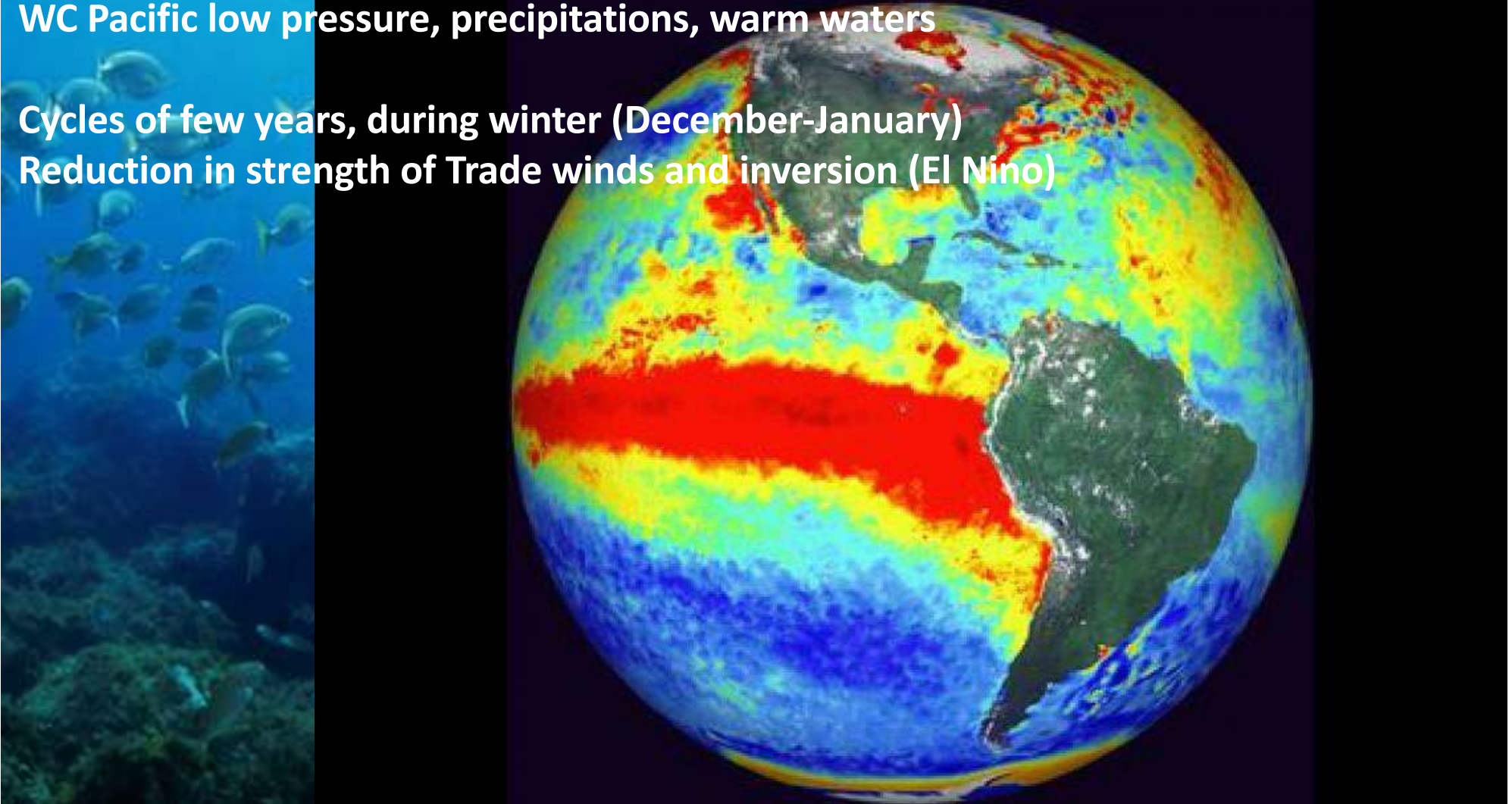
Strong Trade winds

EC Pacific high pressure, cold waters (upwelling)

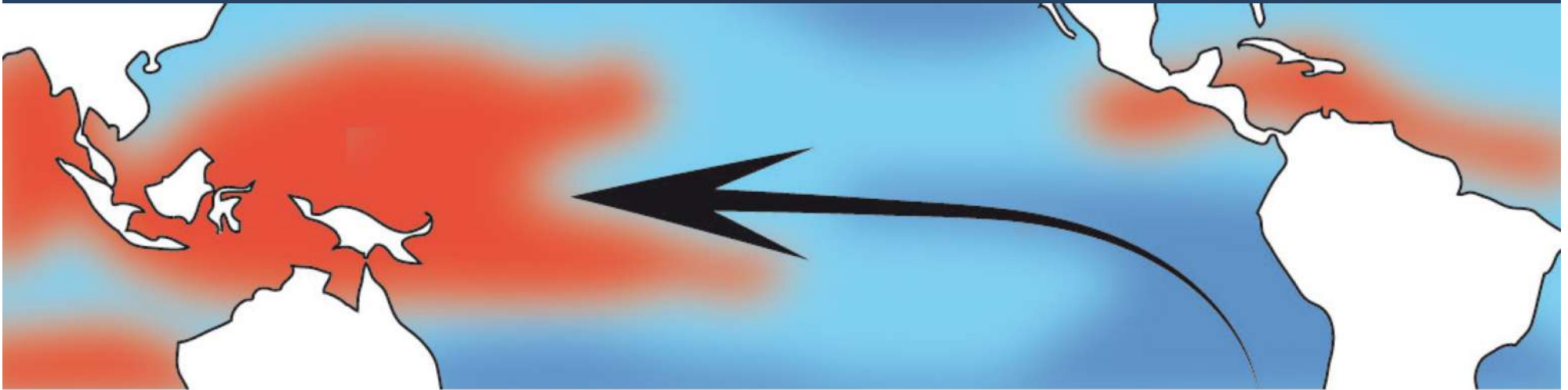
WC Pacific low pressure, precipitations, warm waters

Cycles of few years, during winter (December-January)

Reduction in strength of Trade winds and inversion (El Nino)

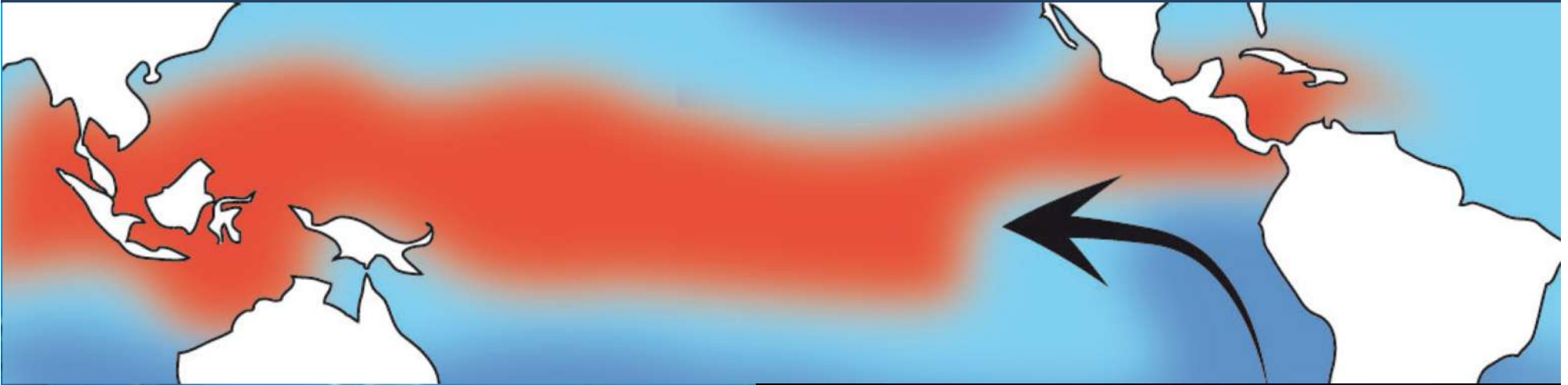


ENSO (El Nino Southern Oscillation)

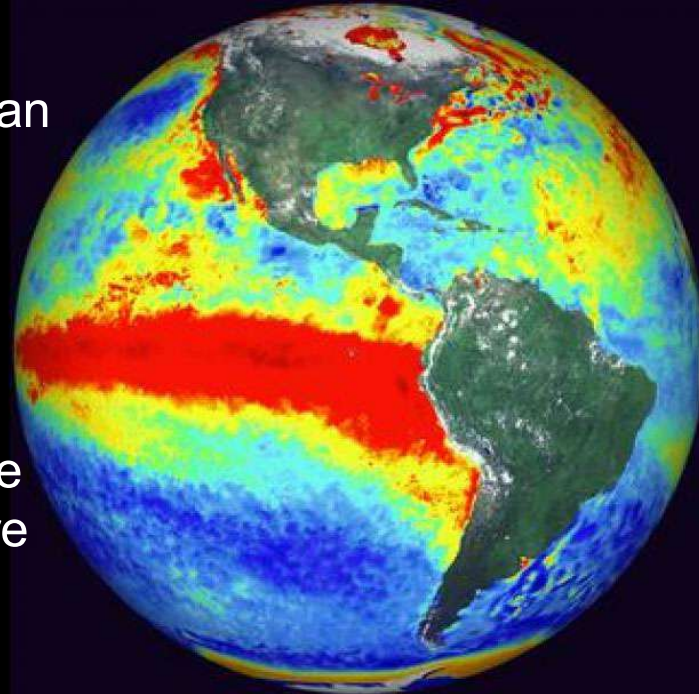


Normal conditions: wind trades blow strong, the Humboldt current is strong, upwelling occurs on the S America coasts (Chile and Ecuador), high pressure is on S-central Pacific and low pressure (wet, warm) on the Australian and Indonesian coasts. Superficial waters in the east Pacific are cold. When T is 0.5°C or more below the seasonal average, we have **La Nina**.

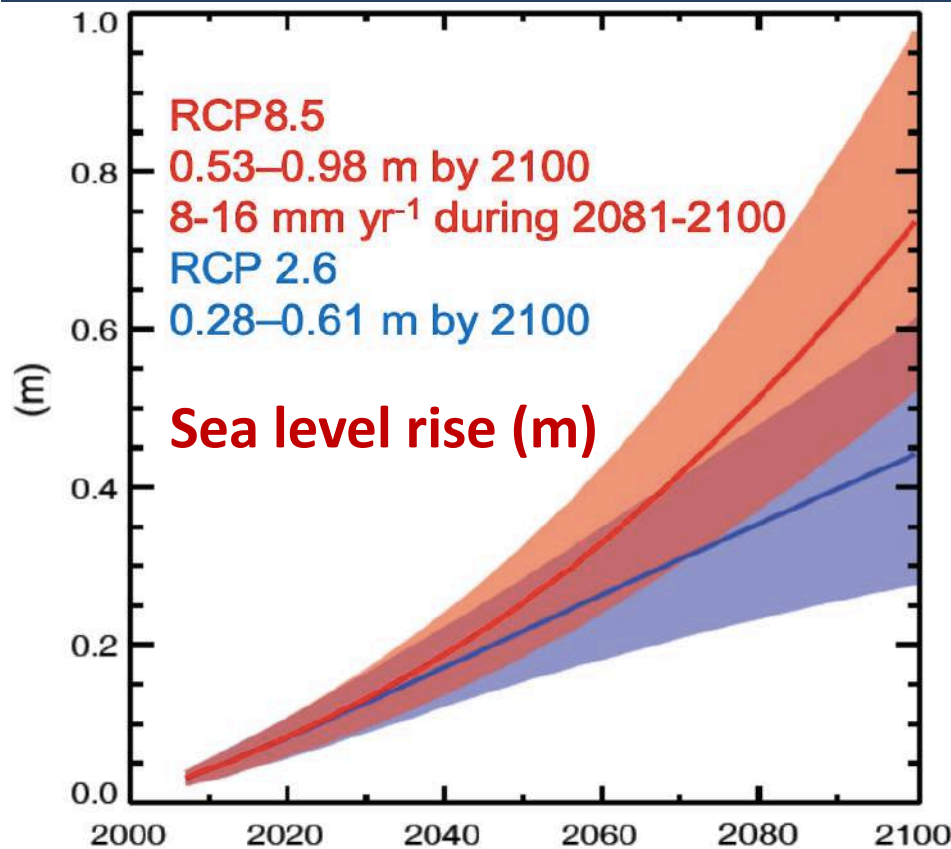
ENSO (El Nino Southern Oscillation)



El Nino: cyclic but irregular, every 2-7 years (5 on average) with max during winter (december). It is an increase in superficial water temperature in the central-SE Pacific of at least 0.5° C above the average T for at least 5 months. Wind trades are weak, the Humboldt current is weak, upwelling on the S America coasts (Chile and Ecuador) is strongly reduced or absent, high pressure is on the Australian and Indonesian coasts and low pressure (wet, warm) on the S-central Pacific coasts. Superficial waters in the east Pacific are warm.



Sea level rise



Representative Concentration Pathway (RCP) has been defined by IPCC, as carbon dioxide atmospheric concentration, to depict climate scenario by IPCC.

Numbers (2.6, 4.5, 6.0, 8.5 are radiative forcing levels, delta between radiation adsorbed and dispersed back to space, in W/m²).

RCP2.6 carbon dioxide emission peak is now and then decline

RCP4.5 peak in 2040

RCP6.0 peak in 2080

RCP8.5 continue to increase until the end of century

ipcc

INTERGOVERNMENTAL PANEL ON climate change

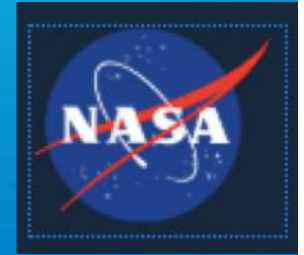


Thermal anomalies and melting ice



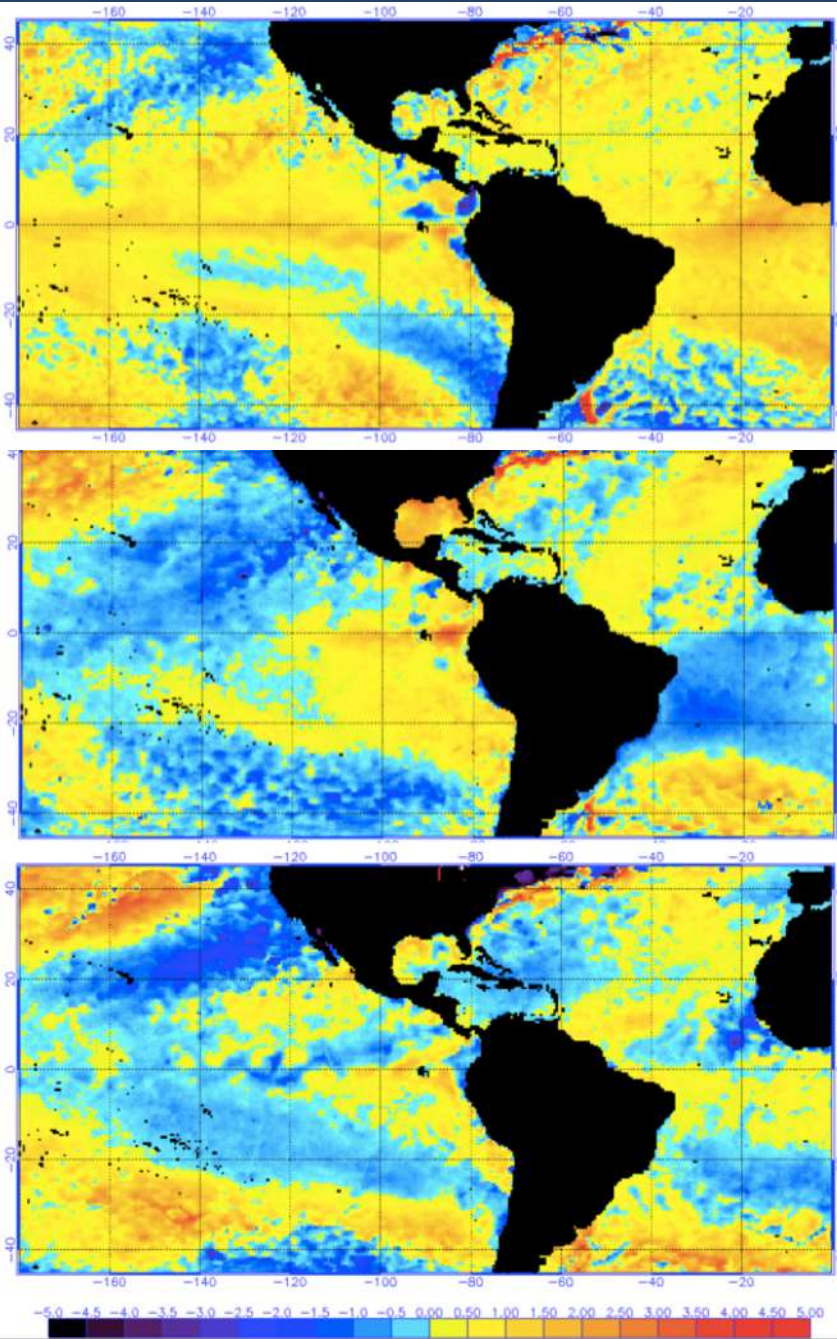
2019

Increasing SST, causing thermal anomalies, melting polar ice, and altering oceanic currents



2012

2009

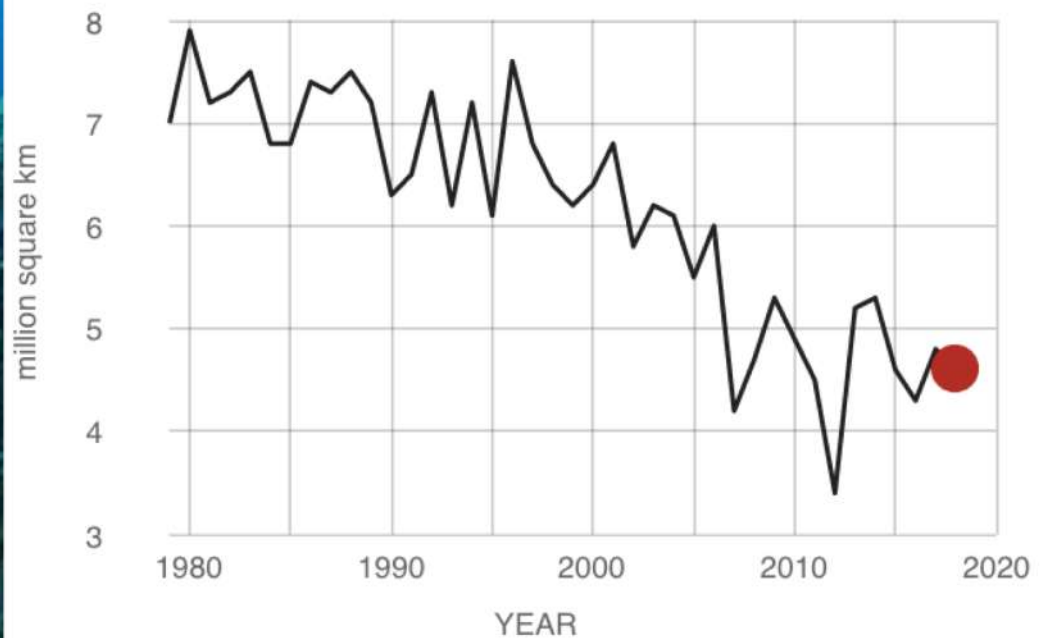


AVERAGE SEPTEMBER EXTENT

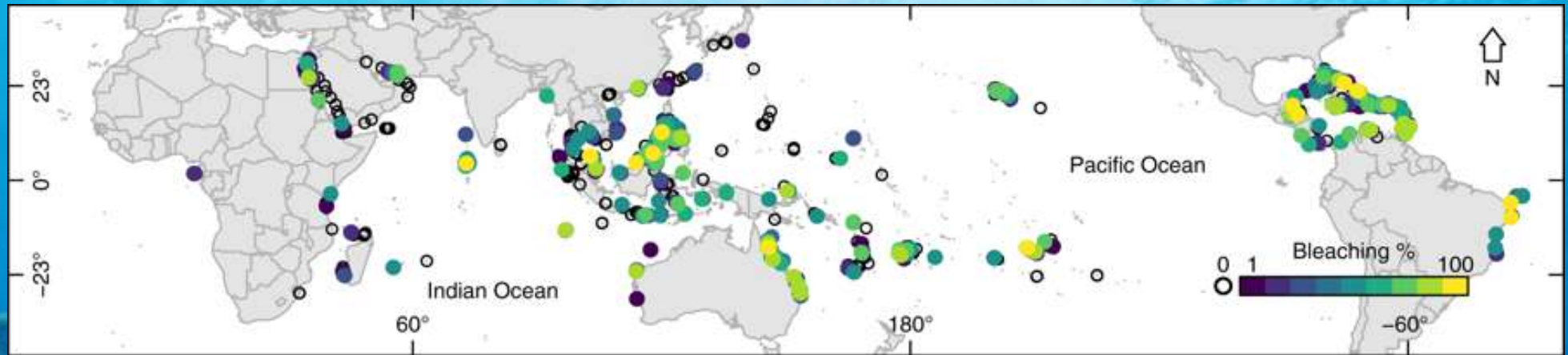
Data source: Satellite observations. Credit: NSIDC/NASA

RATE OF CHANGE

↓ 12.8 percent per decade



Mass mortalities



nature COMMUNICATIONS

A global analysis of coral bleaching over the past two decades

S. Sully, D. E. Burkepille, M. K. Donovan, G. Hodgson & R. van Woesik

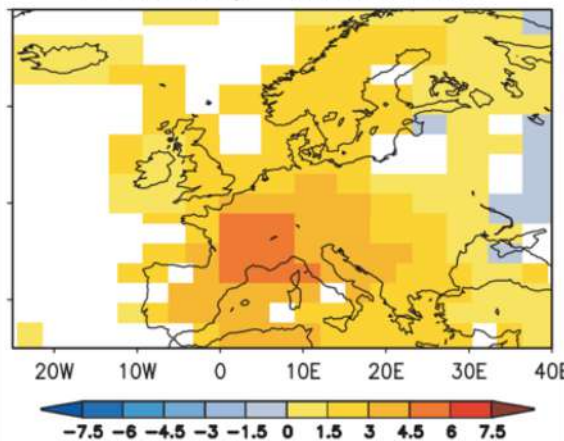
Mass mortality of marine species of key ecological role



European Seasonal and Annual Temperature Variability, Trends, and Extremes Since 1500

Jürg Luterbacher, et al.
Science 303, 1499 (2004);
DOI: 10.1126/science.1093877

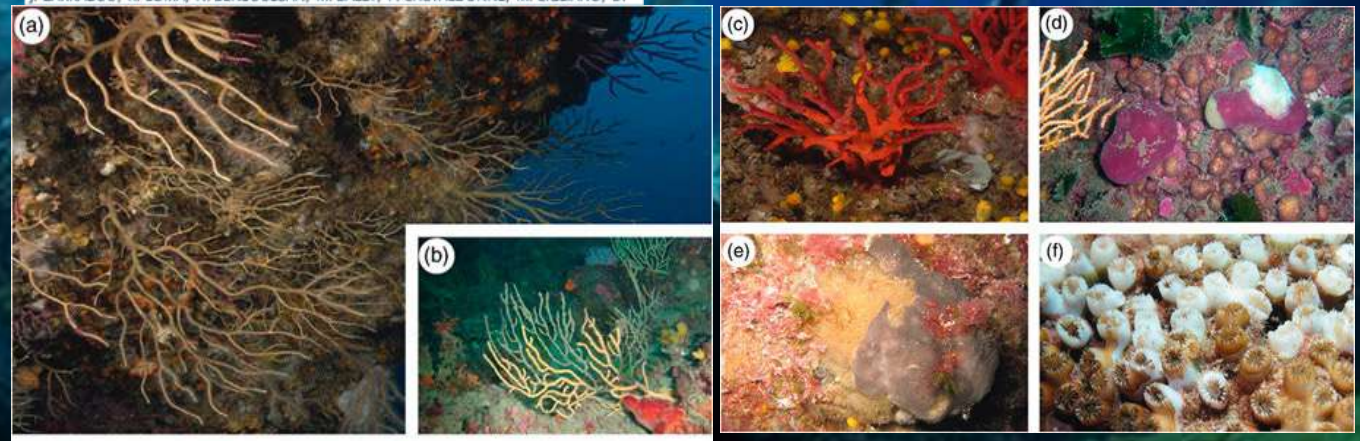
TT Anomaly Summer 2003



Global Change Biology

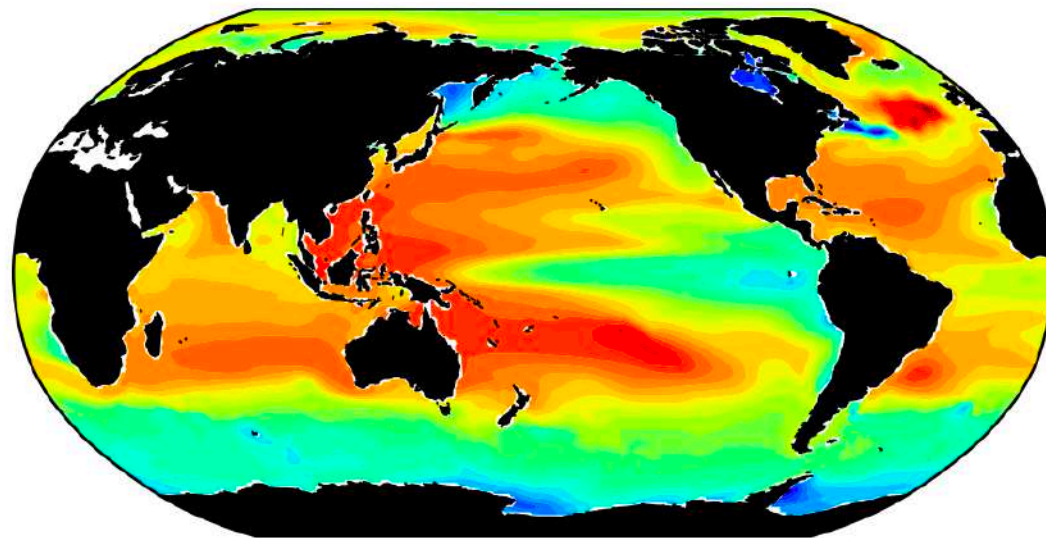
Mass mortality in Northwestern Mediterranean rocky benthic communities: effects of the 2003 heat wave

J. GARRABOU, R. COMA, N. BENSOUSSAN, M. BALLY, P. CHEVALDONNÉ, M. CIGLIANO, D.

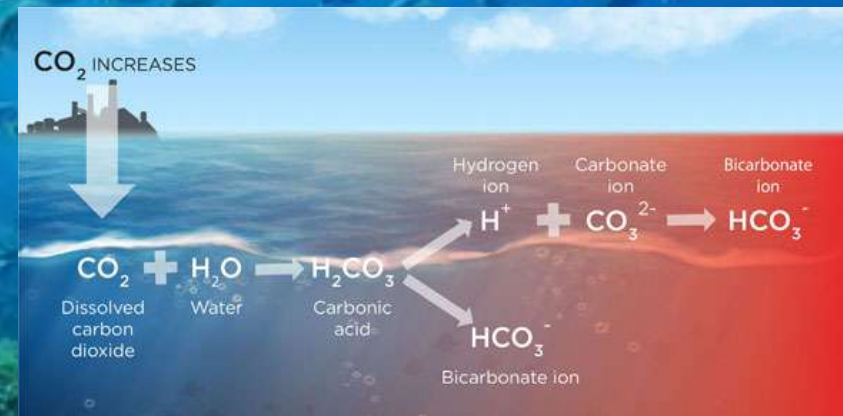
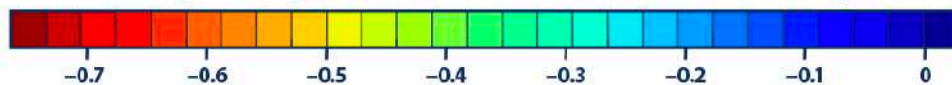


Acidification

ipcc
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE
WMO UNEP



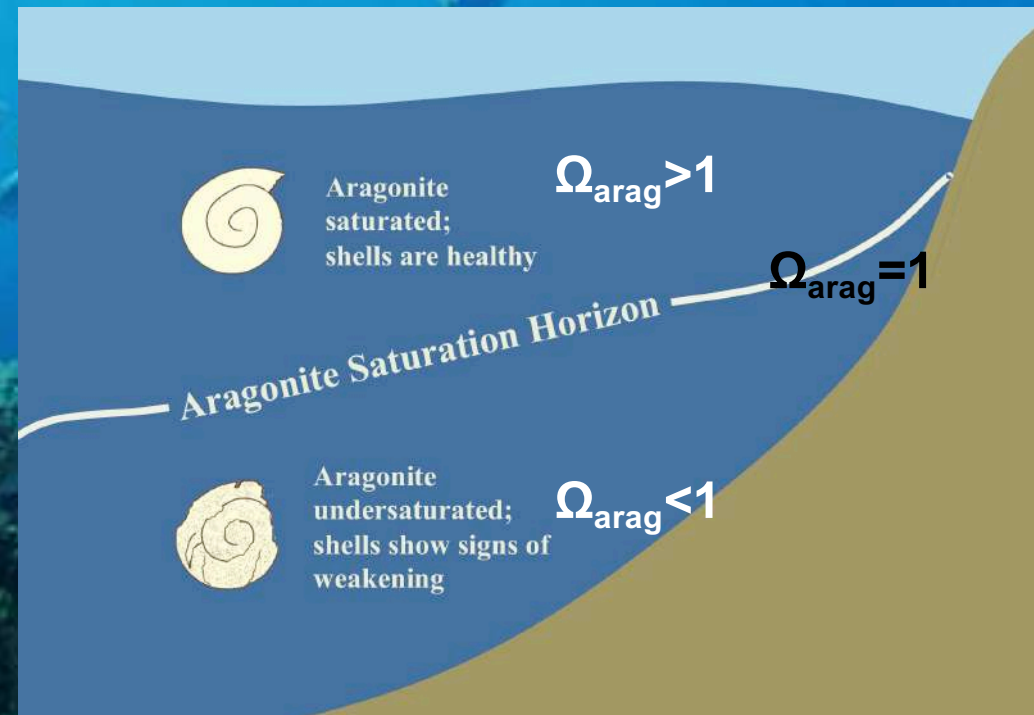
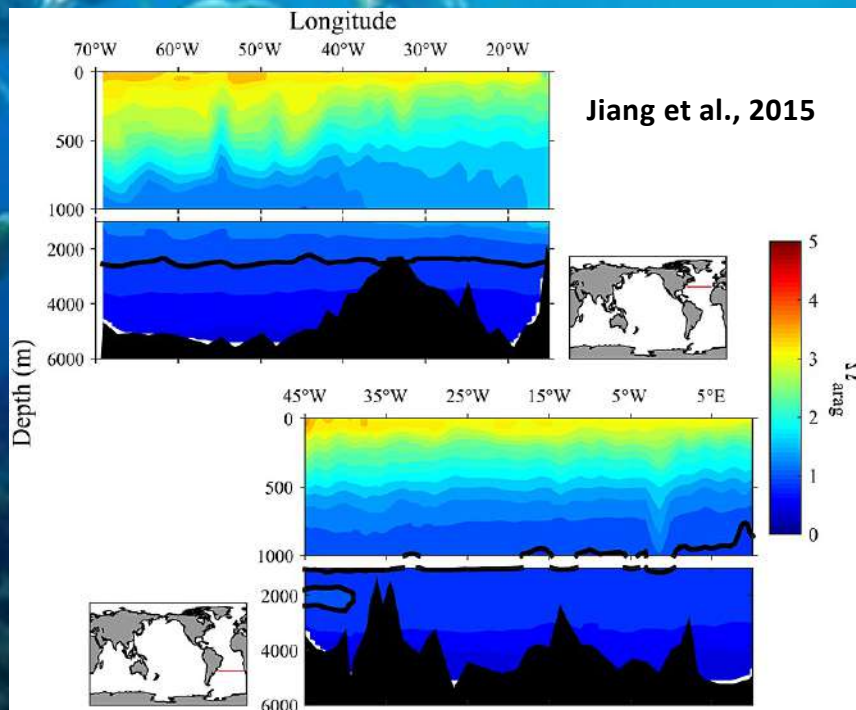
Change in aragonite saturation at the ocean surface (Ω_{ar}):



Oceans absorb about one third of atmospheric CO₂. So, increasing level of carbon dioxide in the air results in increasing levels in sea water. This lead to increase in carbonic acid, and H⁺ ions that decrease ocean pH, which is generally slightly basic.

Effects on carbonate deposition

Aragonite and calcite are the two crystalline forms of calcium carbonate, used by most of marine organisms with calcified structures (corals, molluscs, crustaceans, coralline algae, etc.). Ω_{arag} was higher in the surface mixed layer. Higher hydrostatic pressure, lower water temperature, and more CO_2 buildup from biological activity in the absence of air-sea gas exchange helped maintain lower Ω_{arag} in the deep ocean.



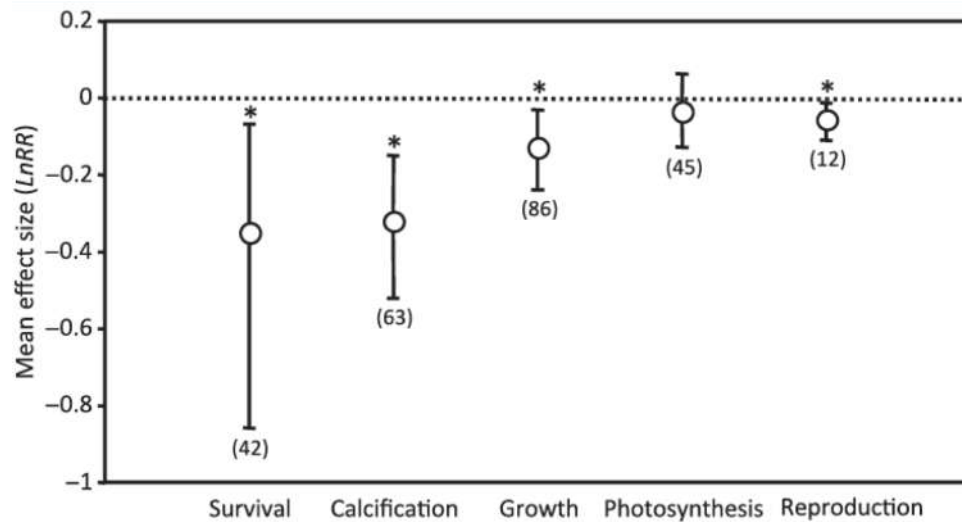
Effects

ECOLOGY LETTERS

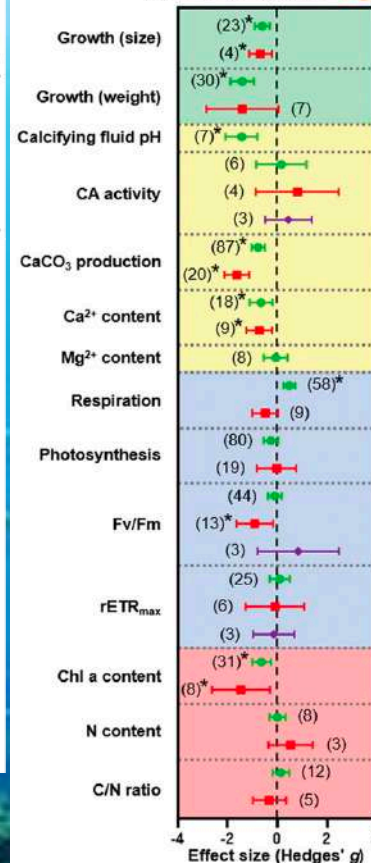
Ecology Letters, (2010) 13: 1419–1434 doi: 10.1111/j.1461-0248.2010.01518.x

REVIEW AND SYNTHESIS

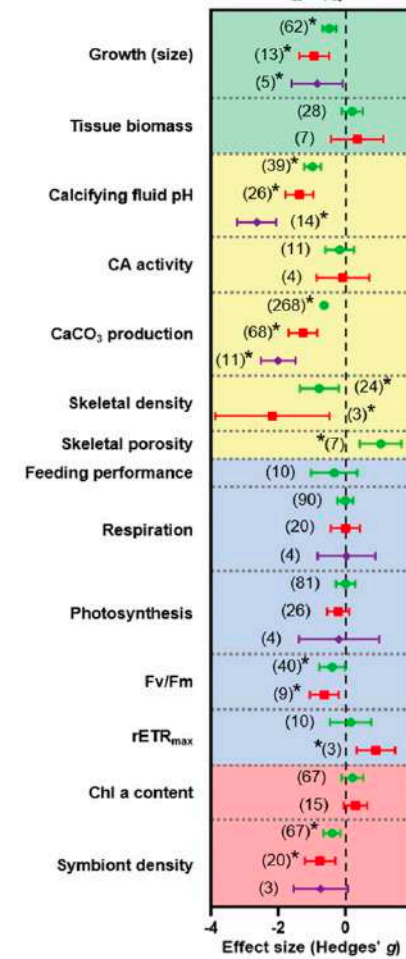
Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms



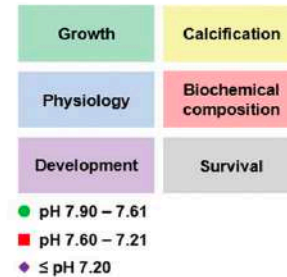
(b) Calcifying algae



(d) Corals



Response category



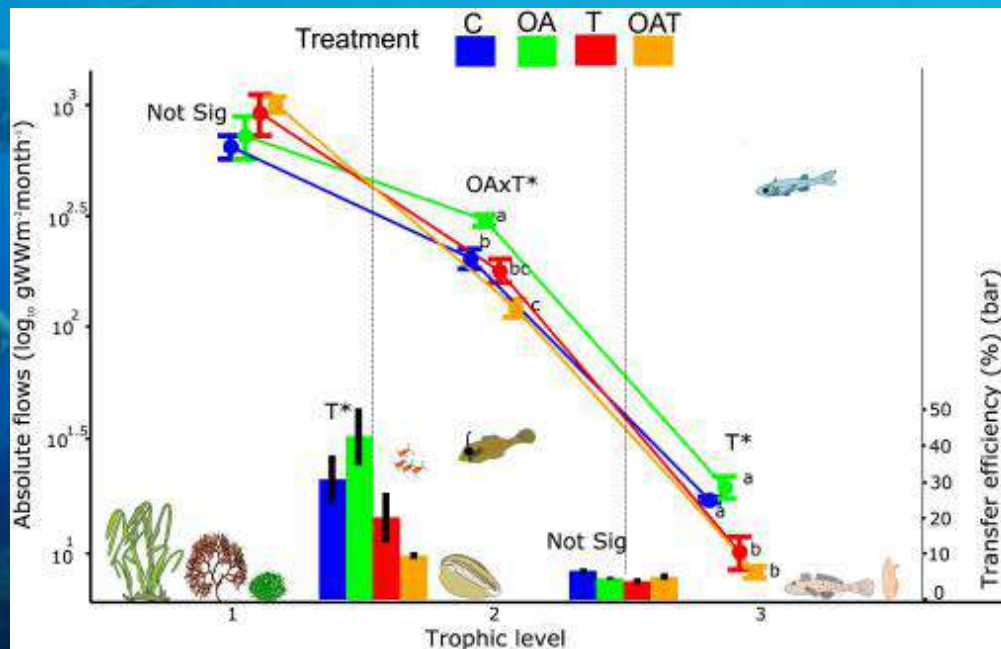
Leung et al. 2022

Many marine organisms, from phytoplankton to fish, are sensitive to changes in carbonate chemistry, and their responses to the predicted changes could lead to profound ecological shifts in marine ecosystems.



Food webs

Climate change could drive marine food web collapse through altered trophic flows and cyanobacterial proliferation



Habitat destruction for seals and bears with consequent loss of feeding grounds and refuge. Plankton can be affected with bottom-up cascading effects. Shift in composition of plankton producers could reduce energy transfer through trophic webs, leading to the decline of apical species populations.

Shifting Patterns of Life in the Pacific Arctic and Sub-Arctic Seas

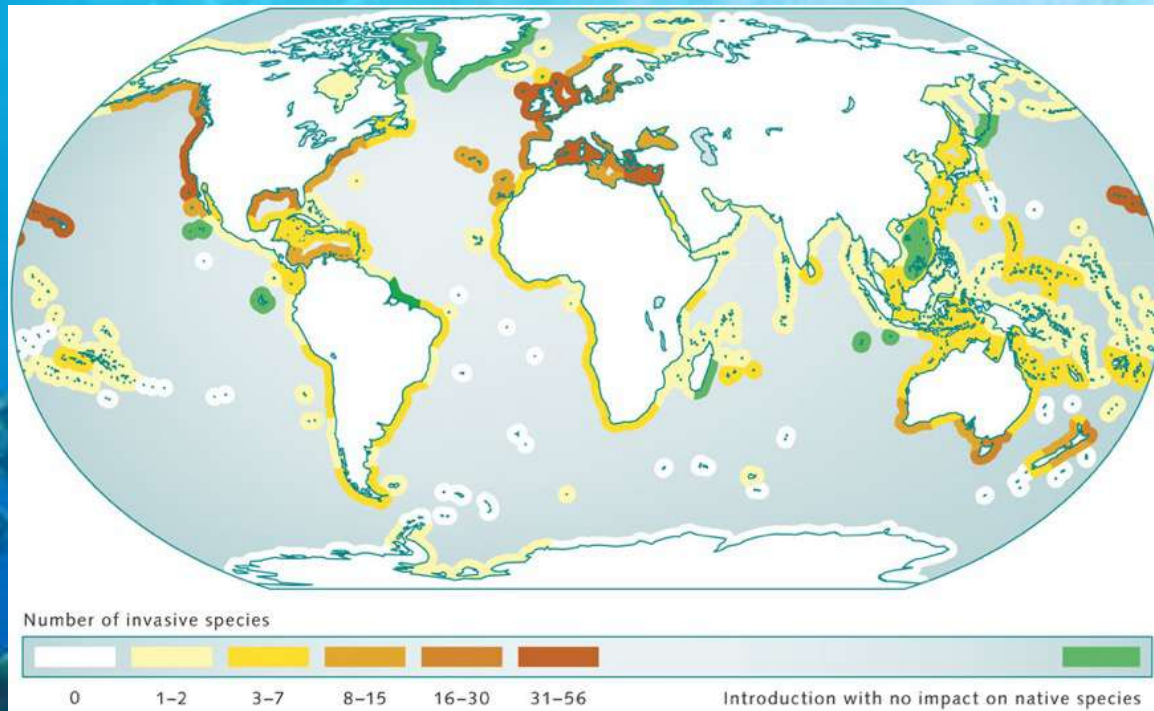
Annual Review of Marine Science

Vol. 4:63-78 (Volume publication date January 2012)
First published online as a Review in Advance on September 19, 2011
<https://doi.org/10.1146/annurev-marine-120710-100926>

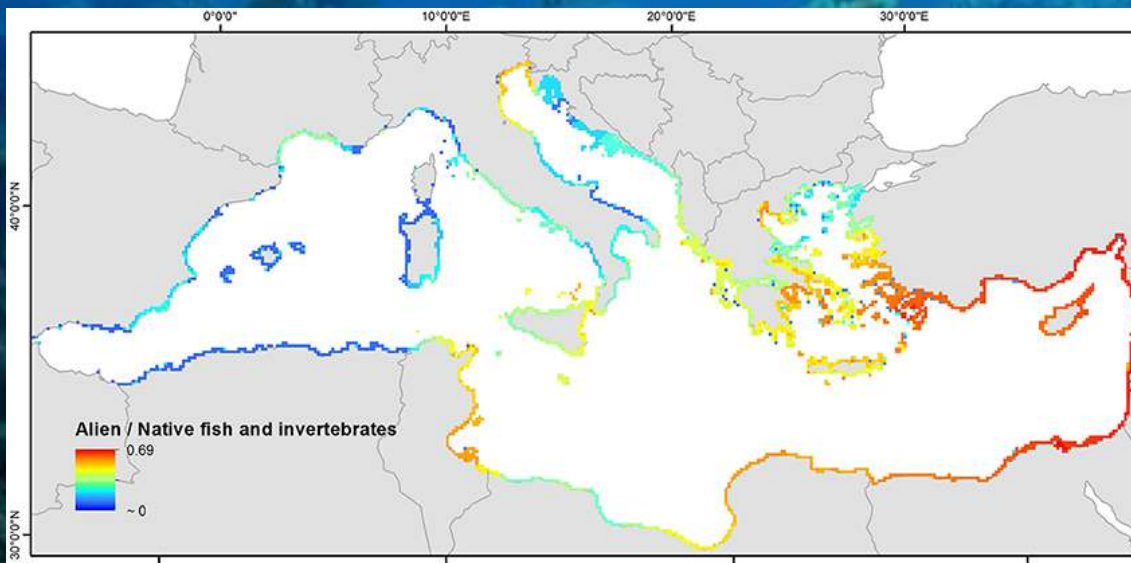
Jacqueline M. Grebmeier



Invasions



Species invasions and poleward shift in distribution



REVIEWS REVIEWS REVIEWS

Assessing the global threat of invasive species to marine biodiversity

Jennifer L Molnar^{1*}, Rebecca L Gamboa¹, Carmen Revenga², and Mark D Spalding³

ECOLOGICAL SOCIETY OF AMERICA
esa

Frontiers in Ecology
and the Environment

PNAS

Proceedings of the
National Academy of Sciences
of the United States of America

Invasive range expansion by the Humboldt squid, *Dosidicus gigas*, in the eastern North Pacific



frontiers
in Marine Science | Marine Ecosystem Ecology
Invading the Mediterranean Sea: biodiversity
patterns shaped by human activities

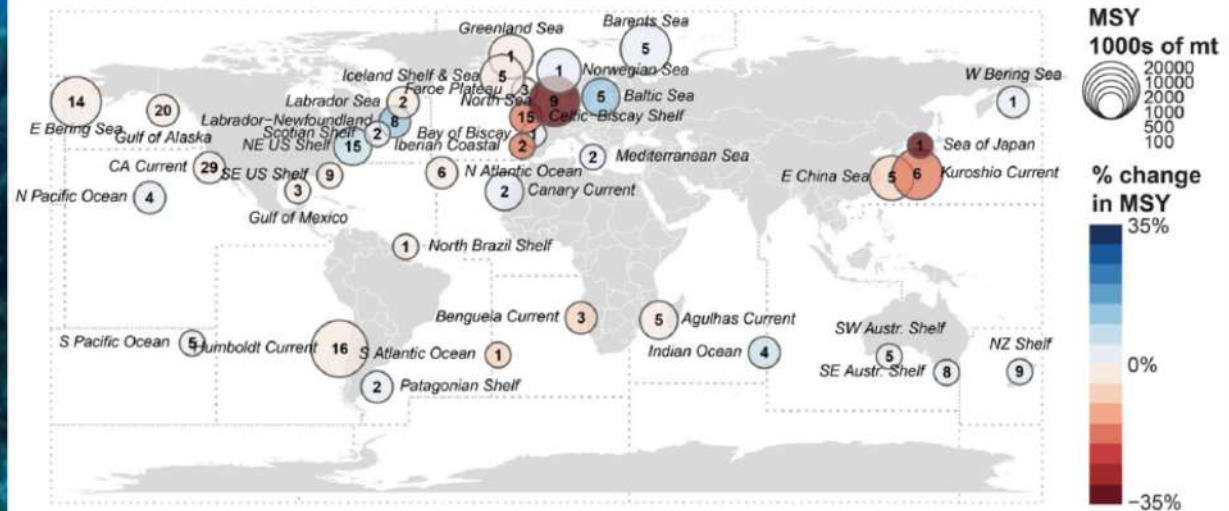
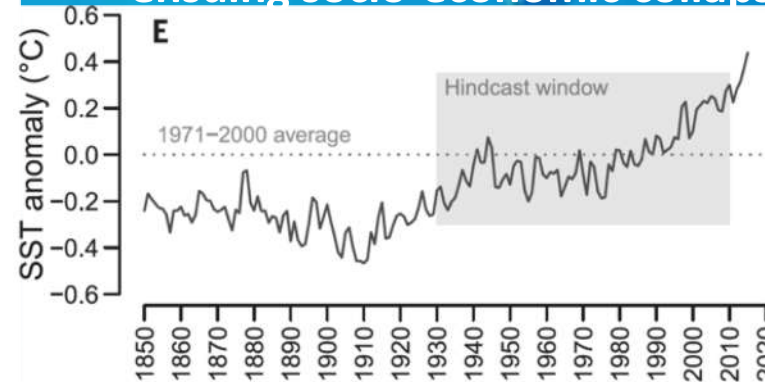
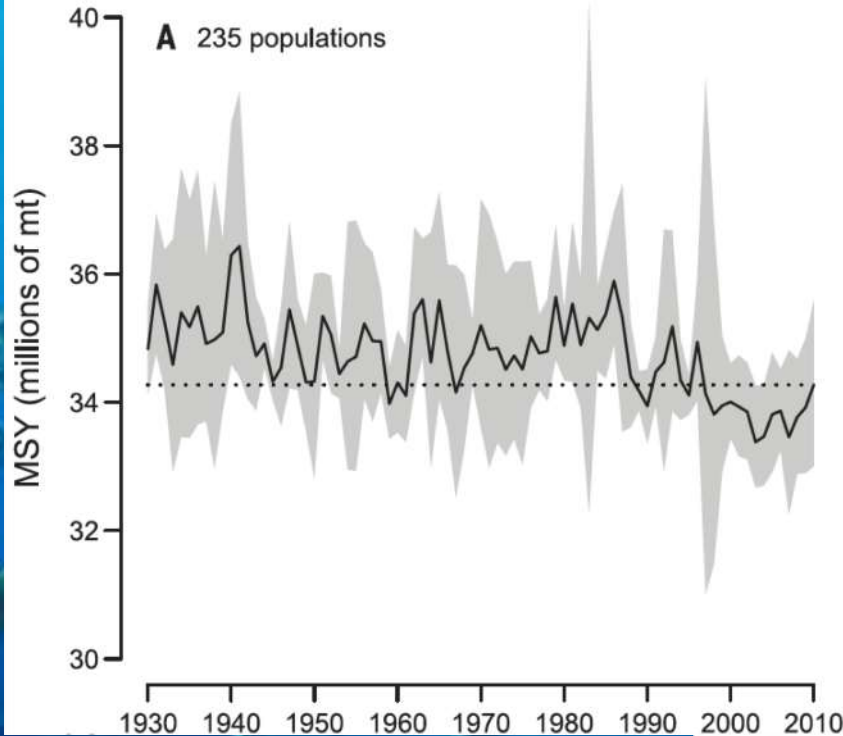
Impact on fisheries

Science

Impacts of historical warming on marine fisheries production

Christopher M. Free^{1,2*}, James T. Thorson^{3,4}, Malin L. Pinsky⁵, Kiva L. Oken^{1,6}, John Wiedenmann⁵, Olaf P. Jensen¹

Decline of fish and invertebrate living resources, reduction of seafood provision and ensuing socio-economic collapses



Harmful species



Plotosus lineatus



Rhopilema nomadica



Pterois miles



Ostreopsis ovata



Lagocephalus sceleratus



Siganus luridus

The Mediterranean Sea

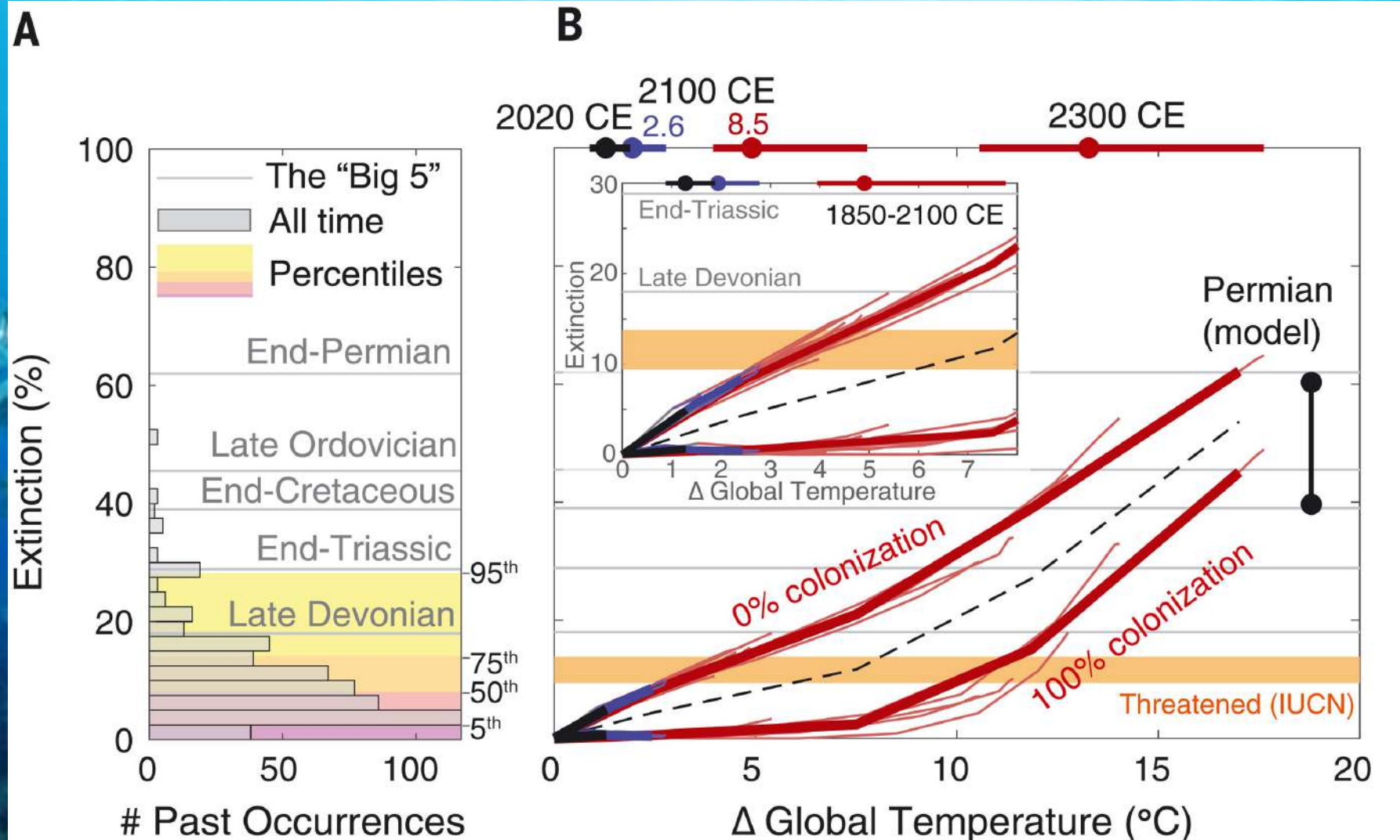
Its history and present challenges

Metamorphoses: Bioinvasions 2014
in the Mediterranean Sea

B.S. Galil and Menachem Goren

Increasing risk for human health due to the
introduction of toxic or harmful species

Extinction scenarios



Extinction rise with increases in annual mean global surface air temperature plotted under historical greenhouse gas emissions (petagrams of carbon per year) and divergent future scenarios, yielding radiative forcings of 2.6 W/m^2 [i.e., RCP/SSP1-2.6 versus 8.5 W/m^2 in 2100] Penn and Deutsch 2022