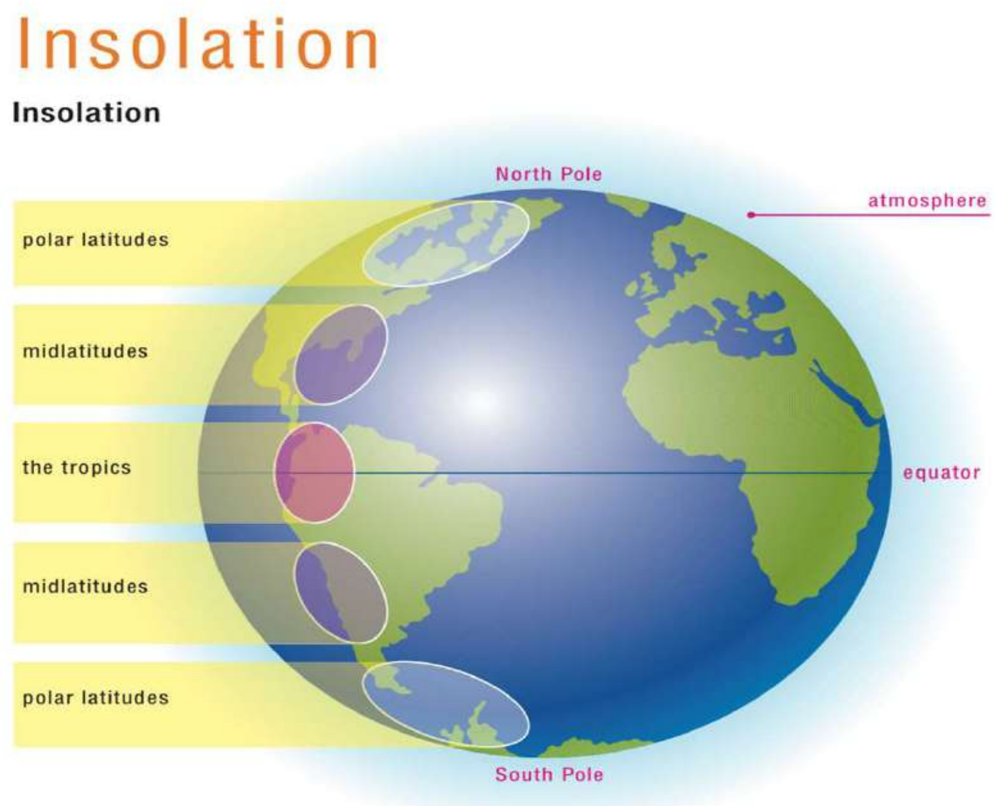
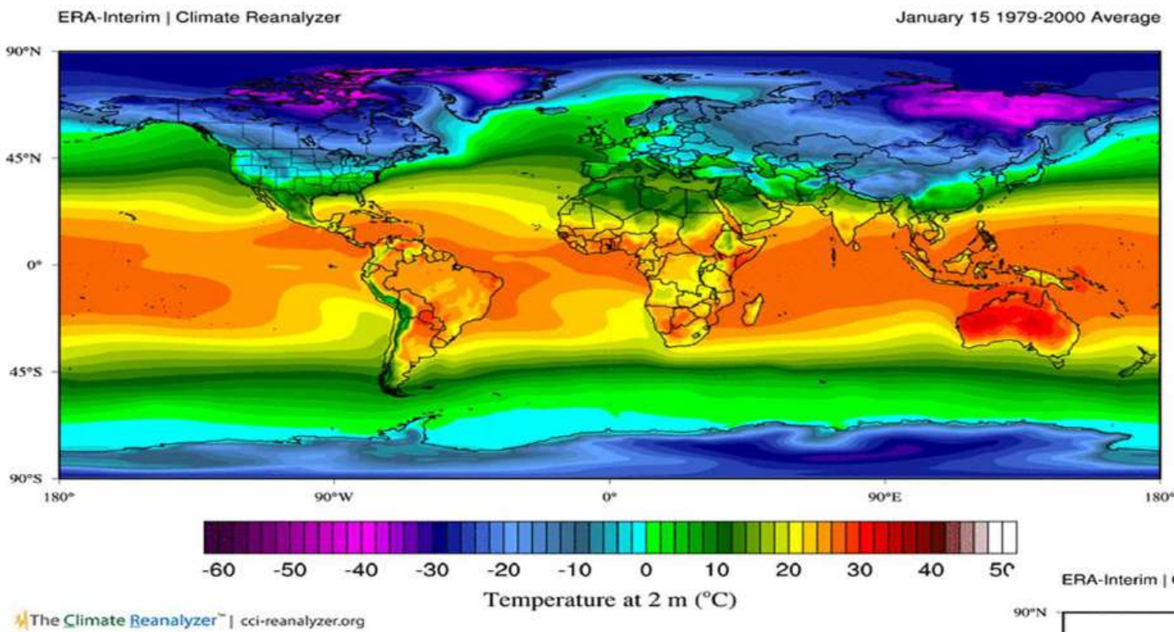
https://www.freepik.com/free-photos-vectors/boiling-water

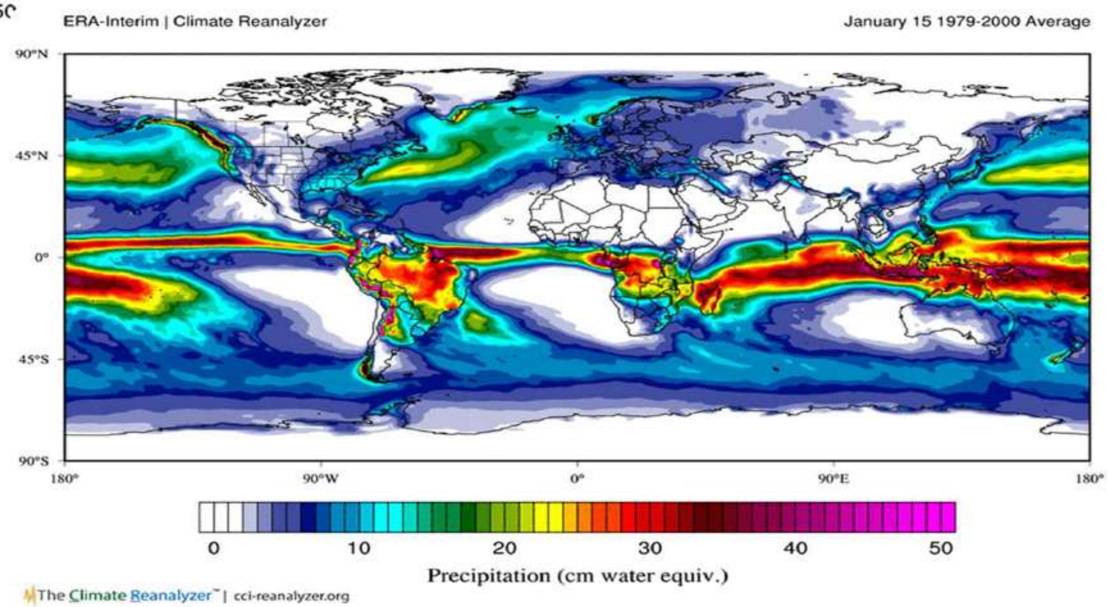
We know many things about the Climate/Earth System



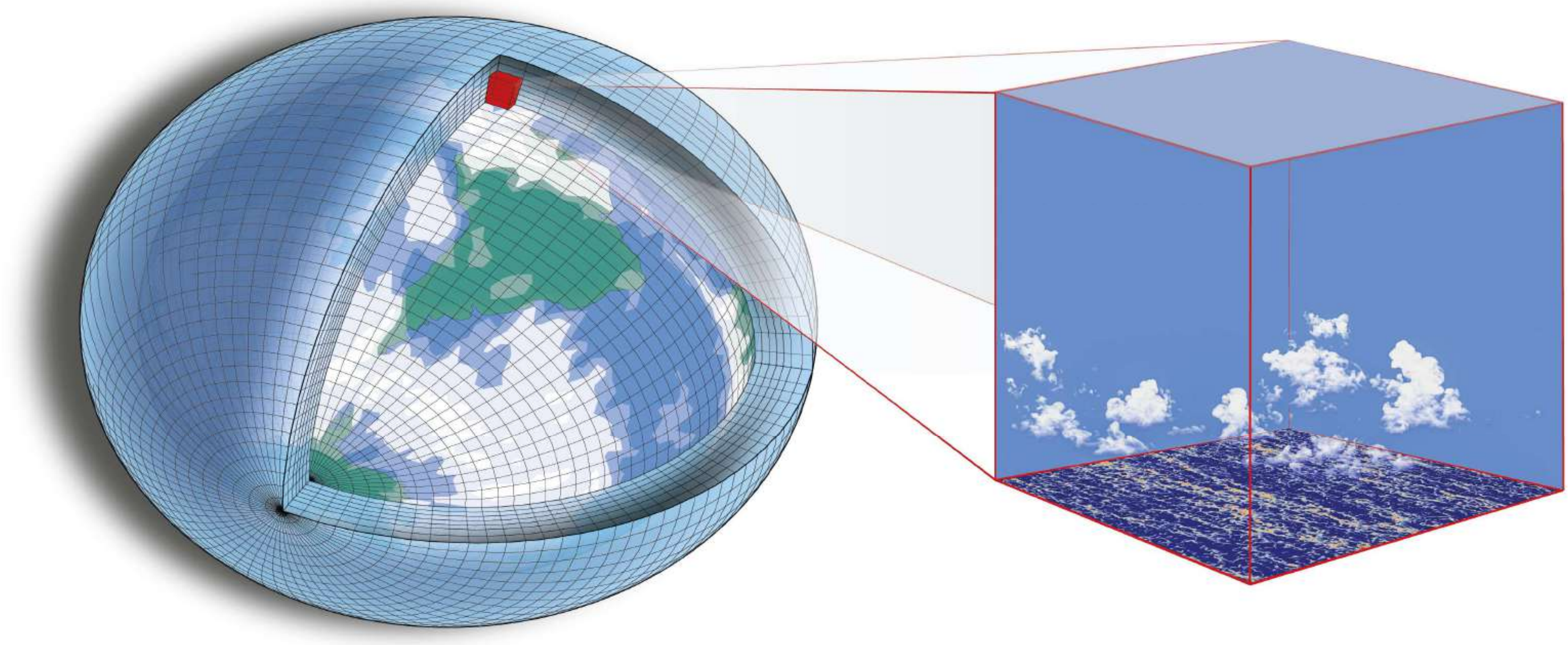


But most Fundamental Questions remain Unanswered.

Ocean’s Role in Climate Variability, Trend and Extremes



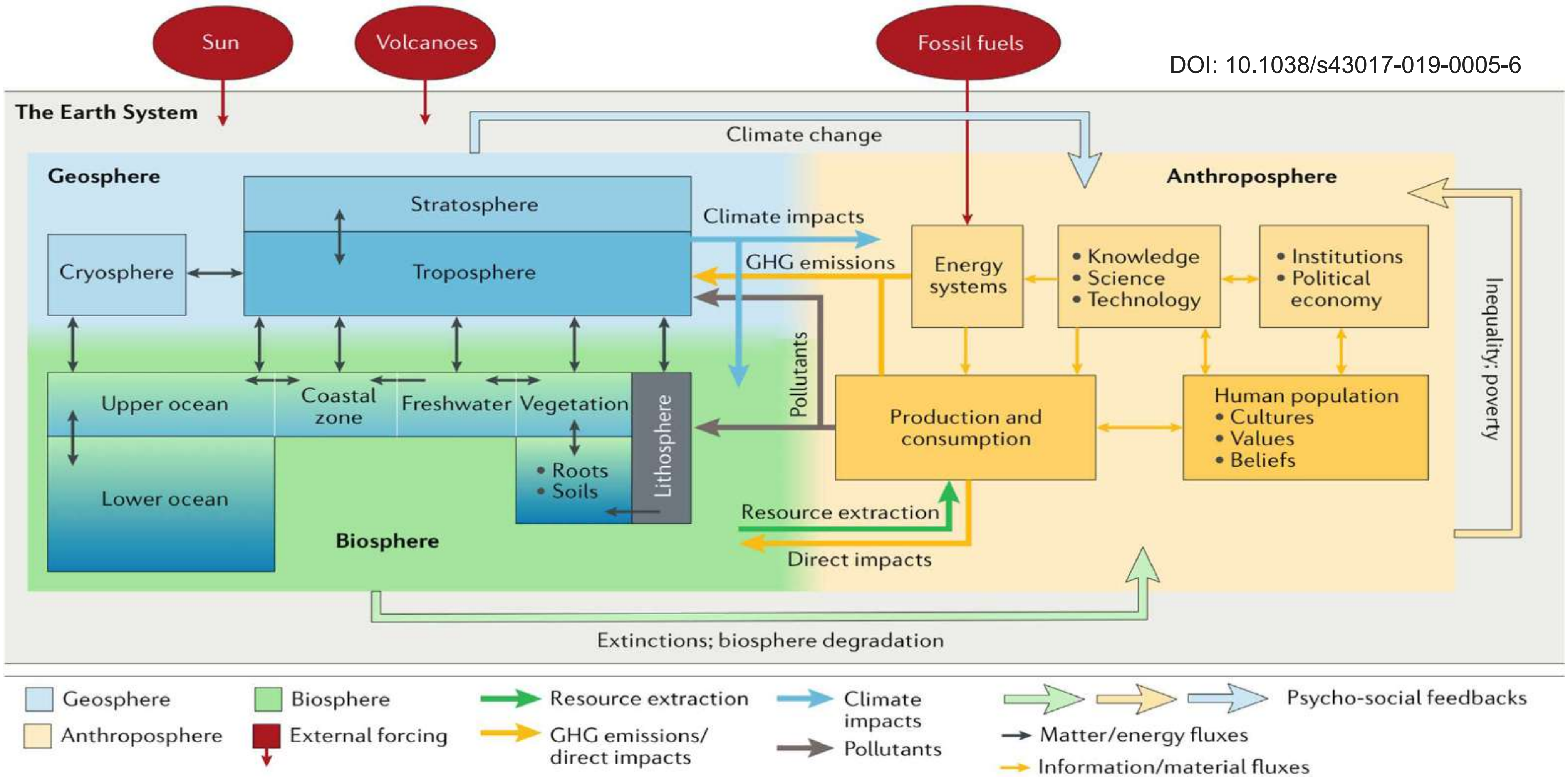
Missing Understandings, Irreducible Uncertainties. Data-Driven Models to Rescue
Ocean Mixing remains the biggest Challenge for Physics, Chemistry and Biology

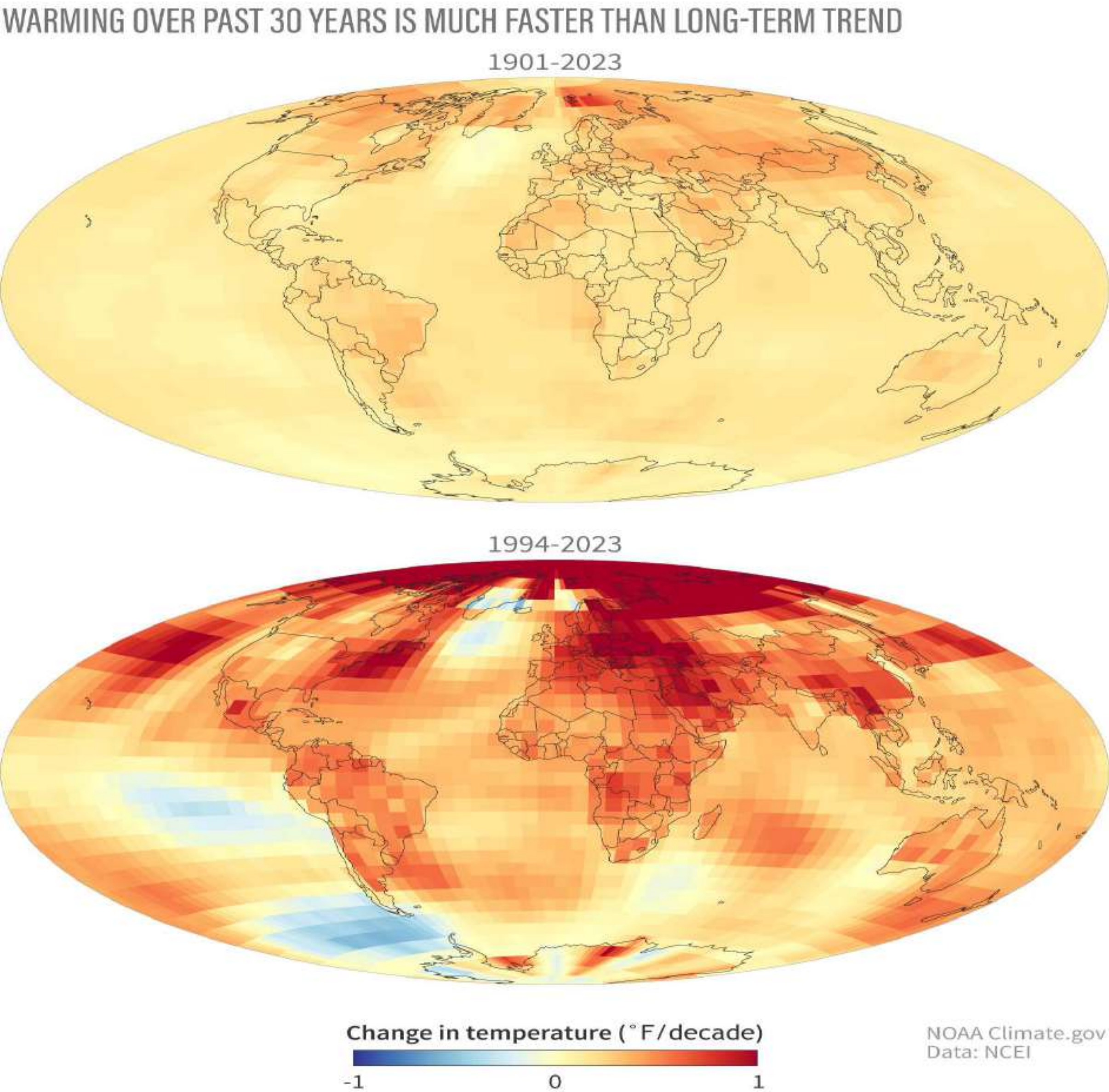


https://www.caltech.edu/about/news/new-climate-model-be-built-ground-84636

Bio-Climate Feedbacks Not getting Enough Attention

DOI: 10.1038/s43017-019-0005-6





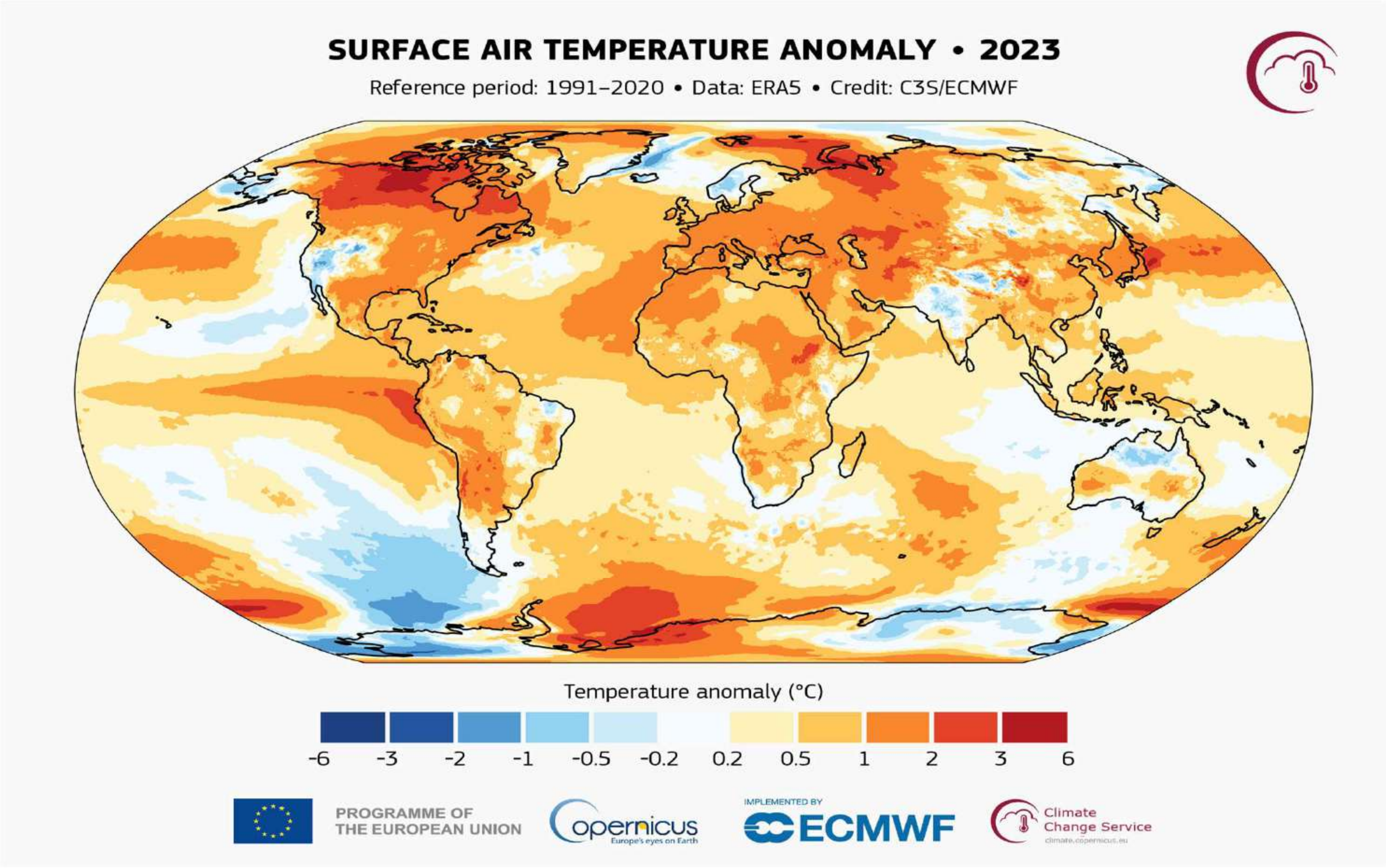
Can we really explain the patterns of Warming?

Can AI/ML help?

YES!!

Ocean Modulates Global Warming!

What is the role of Bio-Climate Feedbacks?



SURFACE AIR TEMPERATURE ANOMALY • 2023
Reference period: 1991–2020 • Data: ERA5 • Credit: C3S/ECMWF
Temperature anomaly (°C)
-6 -3 -2 -1 -0.5 -0.2 0.2 0.5 1 2 3 6
PROGRAMME OF THE EUROPEAN UNION
Copernicus Europe's eyes on Earth
IMPLEMENTED BY ECMWF
Climate Change Service climate.copernicus.eu

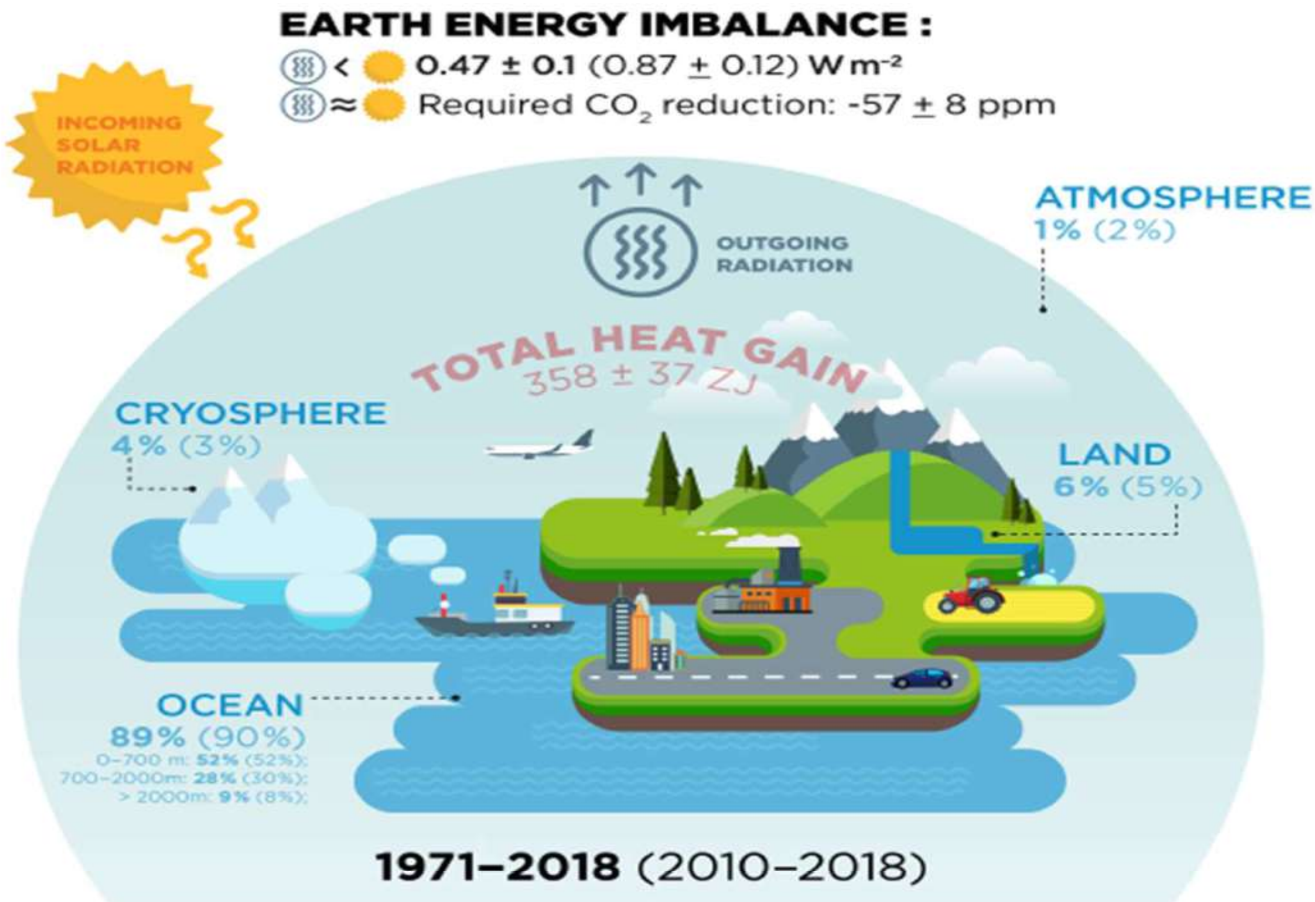
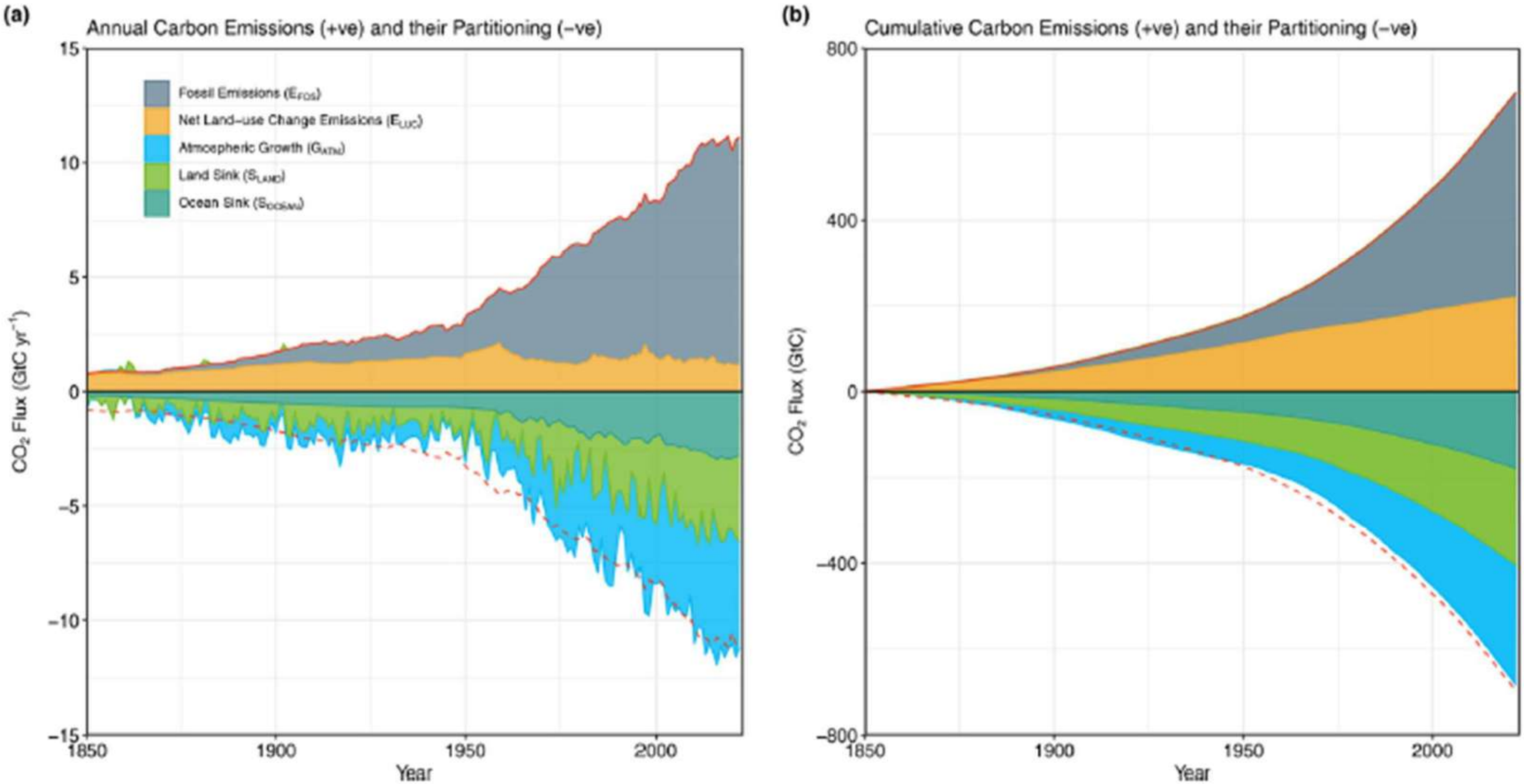


Figure 8. Schematic presentation on the Earth heat inventory for the current anthropogenically driven positive Earth energy imbalance at the top of the atmosphere (TOA). The relative partition (in %) of the Earth heat inventory presented in Fig. 6 for the different components is given for the ocean (upper: 0–700 m, intermediate: 700–2000 m, deep: > 2000 m), land, cryosphere (grounded and floating ice) and atmosphere, for the periods 1971–2018 and 2010–2018 (for the latter period values are provided in parentheses), as well as for the EEI. The total heat gain (in red) over the period 1971–2018 is obtained from the Earth heat inventory as presented in Fig. 6. To reduce the 2010–2018 EEI of $0.87 \pm 0.12\,W\,m^{-2}$ towards zero, current atmospheric CO_2 would need to be reduced by -57 ± 8 ppm (see text for more details).

https://doi.org/10.5194/essd-12-2013-2020



https://essd.copernicus.org/articles/15/5301/2023/

The Washington Post
Democracy Dies in Darkness

mahatma

See the dozens of new species this deep-sea robot just discovered

Alien-looking lobsters, sponges, urchins, sea stars and sea lilies are among the creatures deep-sea explorers found off the coast of Chile

By Dino Grandoni

February 24, 2024 at 6:30 a.m. EST

Marine Ecosystems – Diversity, Resilience, Productivity – Organising Principles?

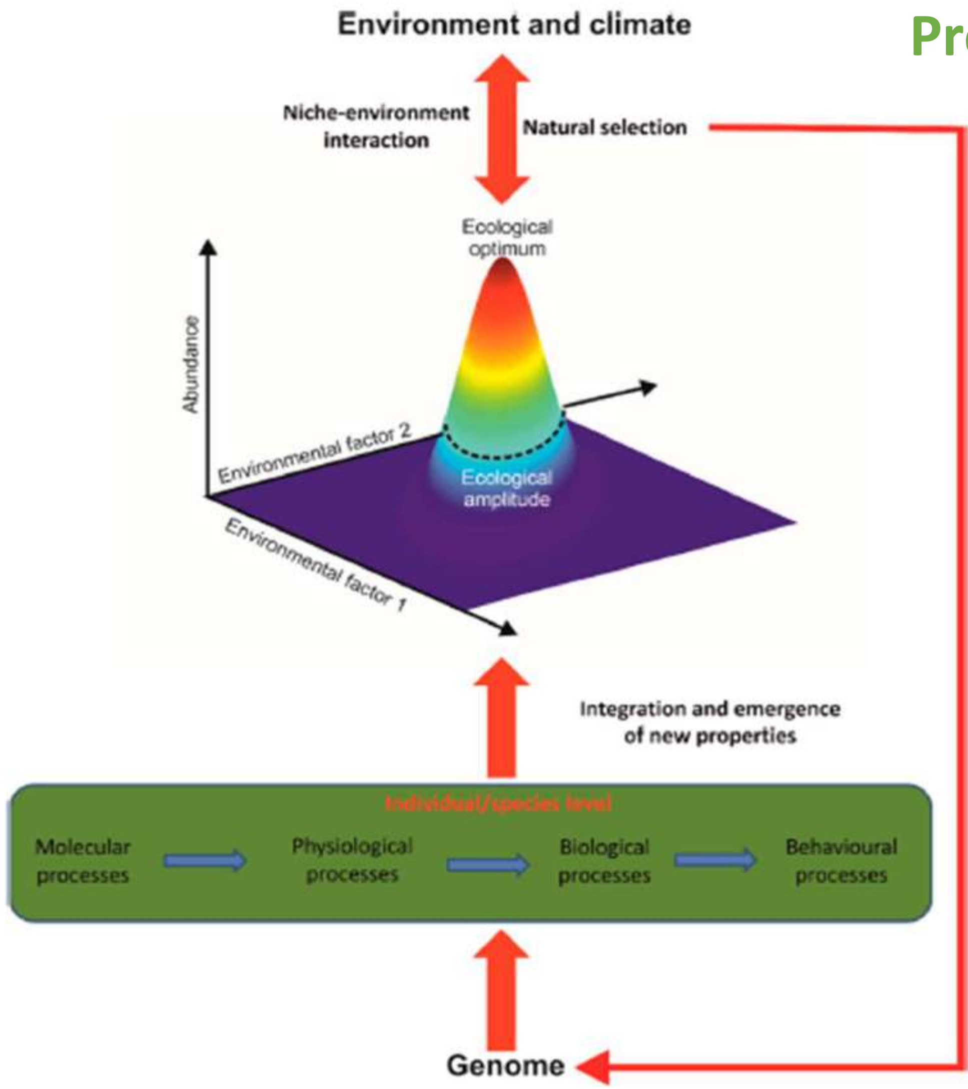


Figure 3. The concept of the ecological niche, the elementary macroscopic brick of METAL. The ecological niche of a species is quantified by simultaneously considering all the ecological factors that influence its abundance. The concept is therefore multidimensional. The ecological optimum represents the values of the ecological parameters for which the maximum abundance is observed. Ecological amplitude is the degree of ecological valence that a species tolerates. Put simply, it is the width of the ecological niche. The use of the ecological niche within METAL makes it possible to integrate molecular, physiological, biological and behavioural processes controlled in part by the genome and the environment. Such processes are impossible to model for all living species on our planet using a reductionist approach. Moreover, the concept of niche makes it possible to consider the emergence of new properties at a specific organisational level. The niche–environment (including climatic) interaction makes it possible to explain, unify and predict a large number of patterns observed in ecology, paleoecology, biogeography and climate change biology. The niche–environment interaction affects the species genome through processes involved in natural selection.

macroecological theory on the arrangement of life' (METAL)

https://doi.org/10.3390/biology12030339

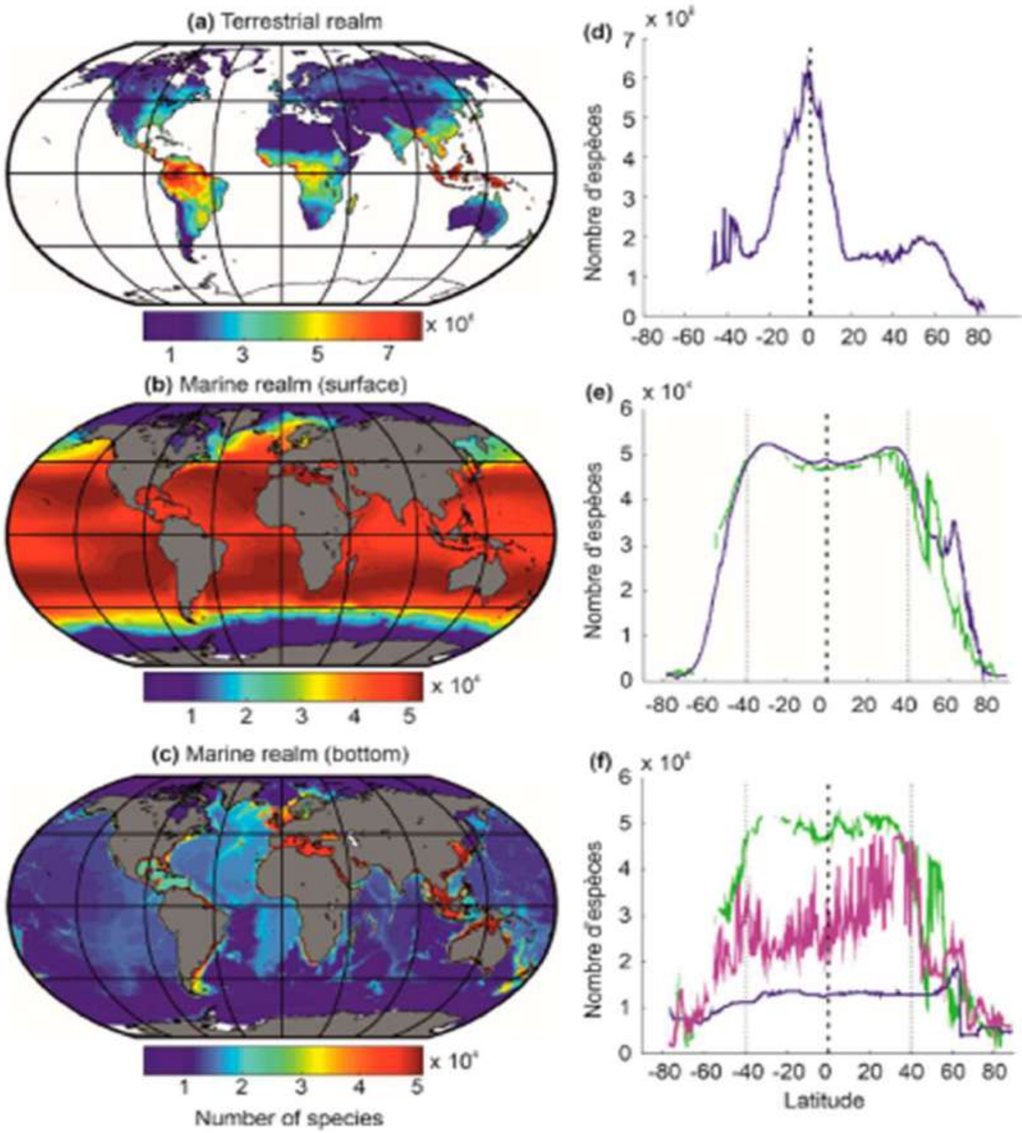
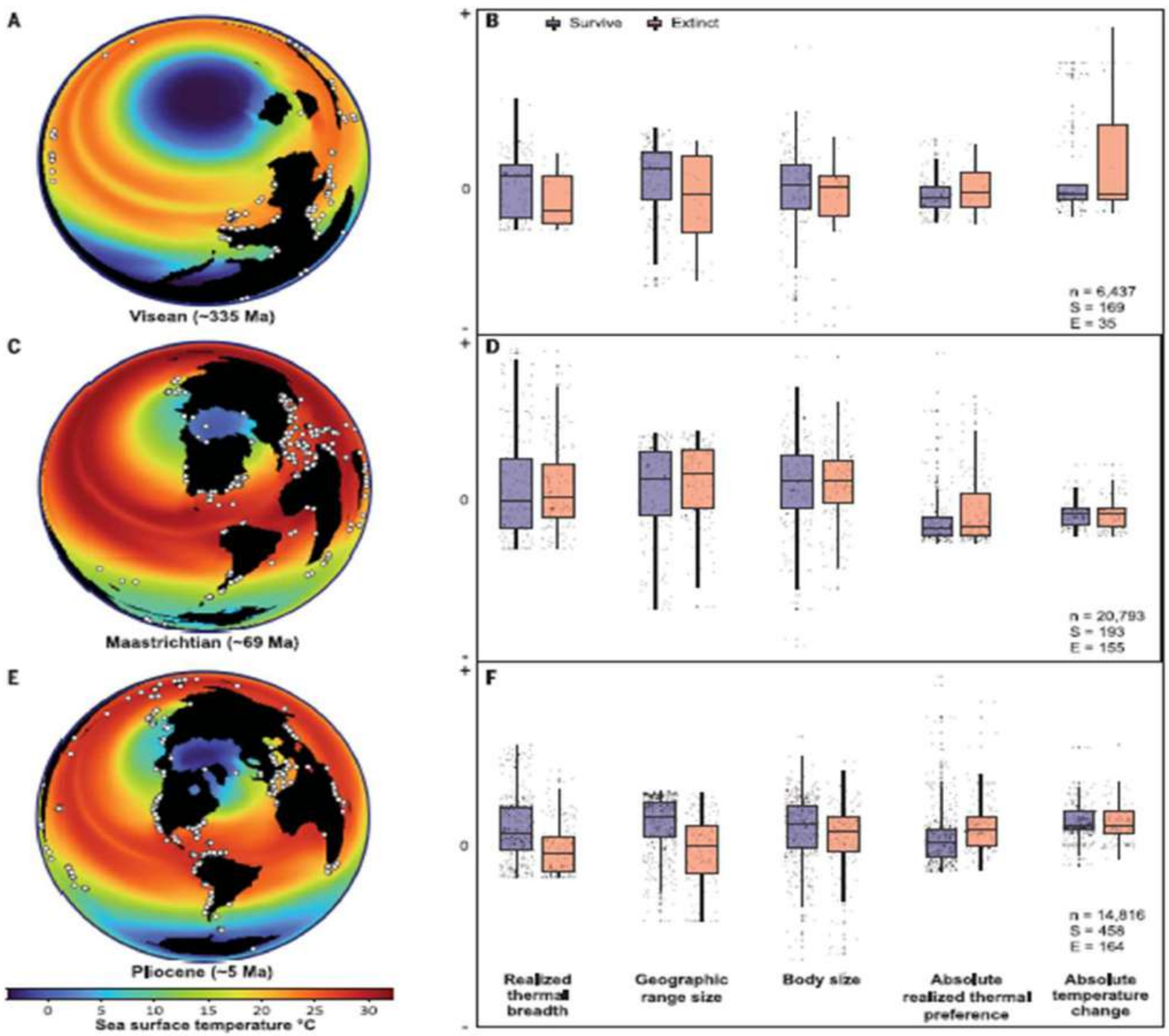


Figure 7. Average distribution of biodiversity (i.e., number of species) in terrestrial (**a**,**d**) and marine (**b**,**e**) surface biodiversity and (**c**,**f**) benthic biodiversity reconstituted from a bioclimatic model derived from METAL [29,100]. (**d**–**f**) The curves show the latitudinal gradient of biodiversity observed for each environment. (**e**) The blue curve reflects the latitudinal biodiversity of the oceanic regions (bathymetry above 200 m) and the green curve reflects the latitudinal biodiversity of the continental-shelf regions (bathymetry below 200 m). (**f**) The curve in green reflects the latitudinal biodiversity of the continental shelf (bathymetry lower than 200 m), the curve in blue reflects that of the deep regions (bathymetry higher than 2000 m), and that in magenta reflects the latitudinal biodiversity of the continental slope (bathymetry between 200 and 2000 m). From Beaugrand and colleagues [29].

Nature makes the Rules

Biology finds the Loopholes



Lack of Baselines can lead to erroneous assumptions and conclusions.

Find new ways to Quantify the Impacts of Warming, SLR, Acidification, Deoxygenation

10.1126/science.adj5763

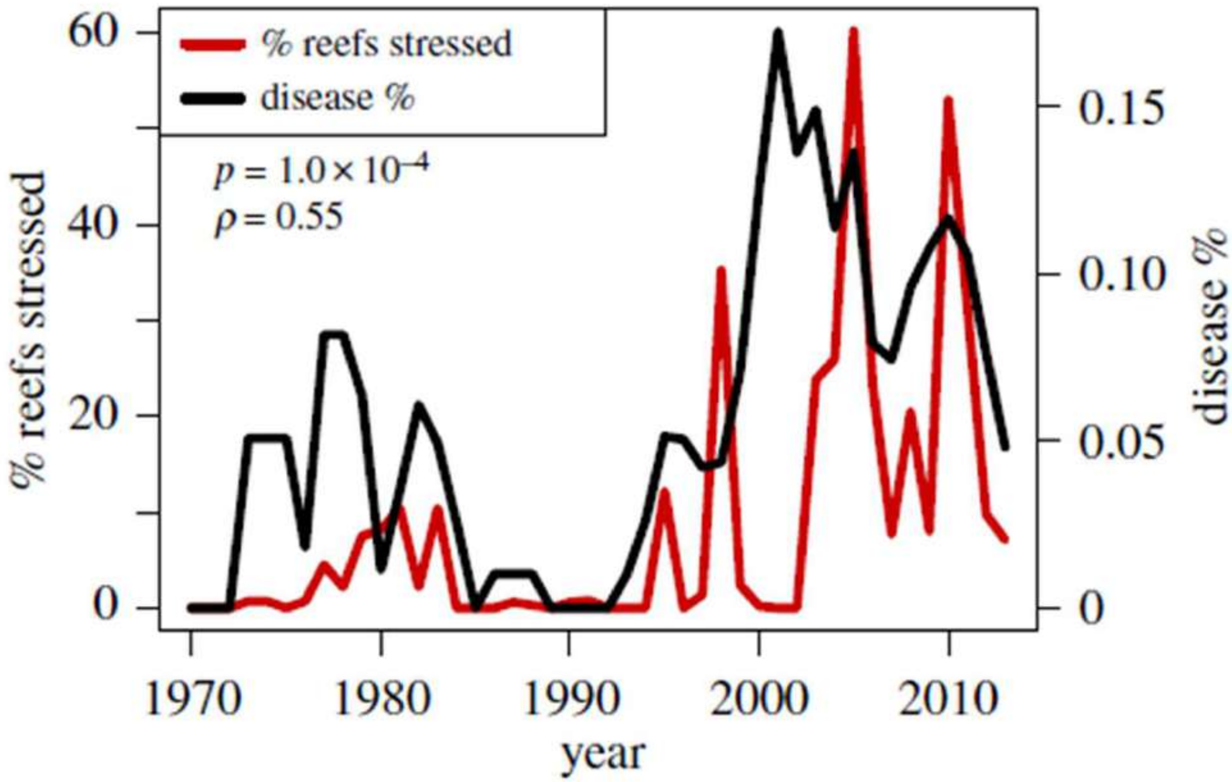


Figure 3. The proportion of Caribbean reef pixels exposed to bleaching-level heat stress (DHM ≥ 1°C-months, 1970–84; DHW ≥ 4°C-weeks, 1985–2013) and normalized disease reports for corals in the Caribbean both increase over time. (Online version in colour.)

Is it all bad news?

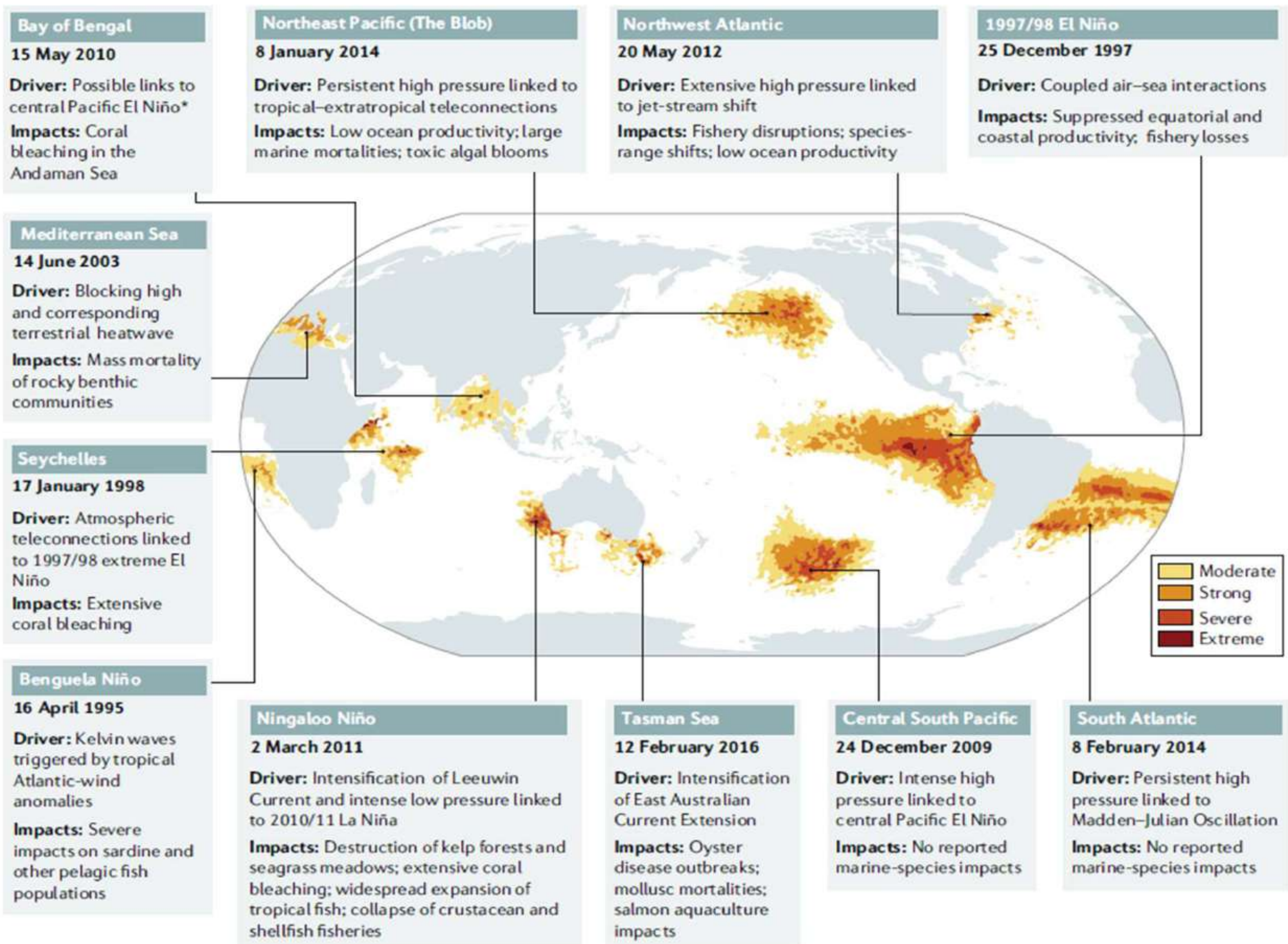
Who is finding the Loopholes?

What processes produce Refugia?

What are the Solutions?

Genetic grafting? Stem cells?

http://dx.doi.org/10.1098/rspb.2019.1718



Impacts? Value of EWSs?

Be careful about jumping onto Bandwagons

DOI: 10.1038/s43017-020-0068-4

Mobile Generalists, Sedentary Specialists.

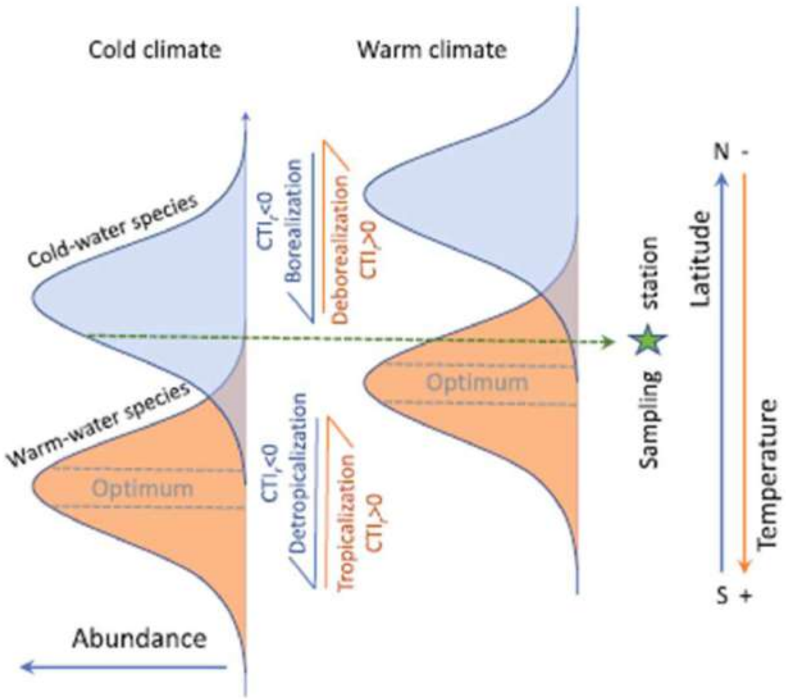
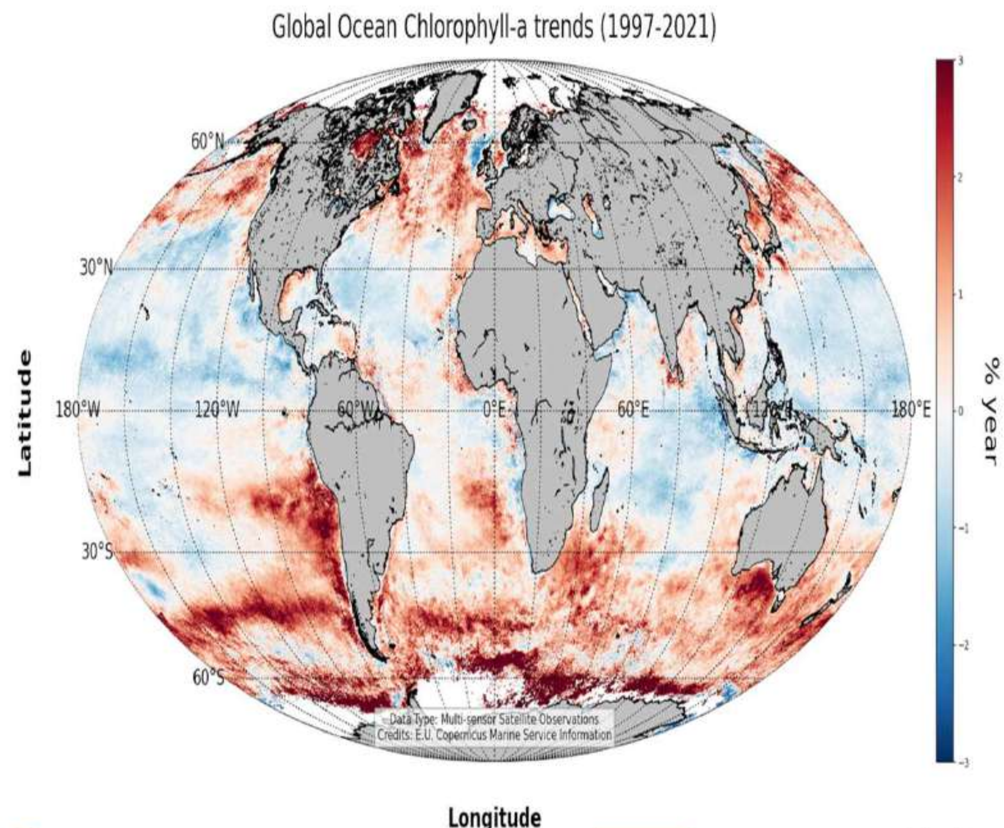
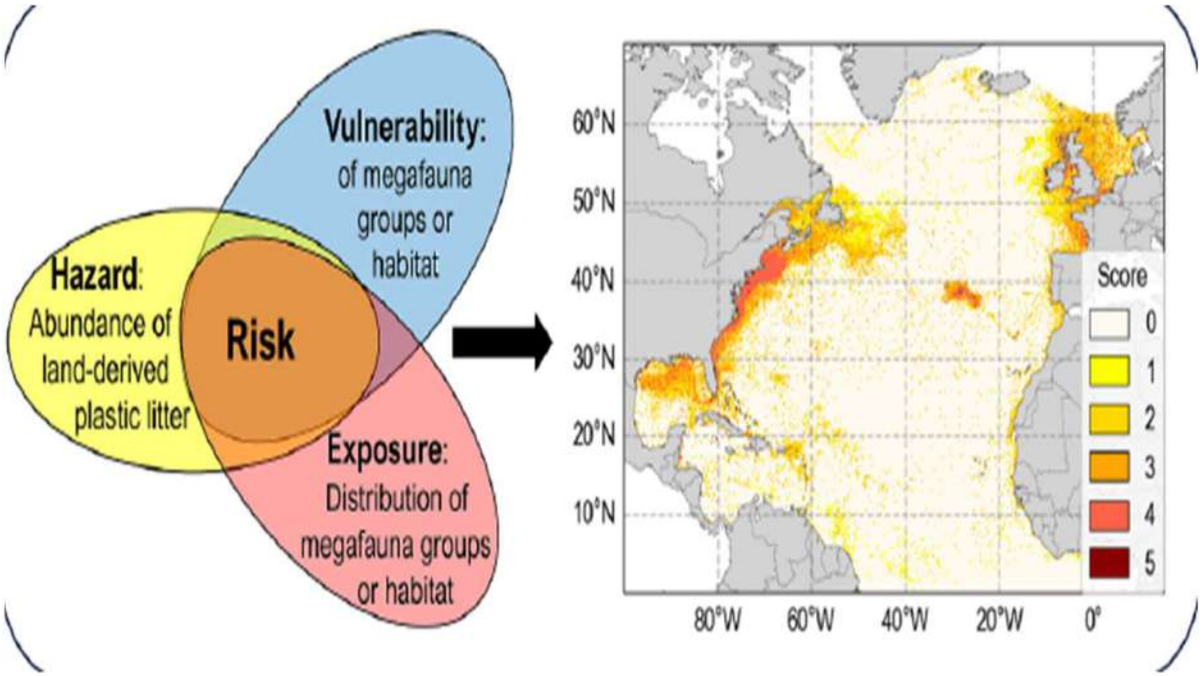


Fig. 1 | Conceptualisation of species poleward distribution shift under warmer conditions. Conceptualisation of poleward distribution shift and the expected abundance response curve of a cold- and warm-water species from cold to warm climate conditions, under the assumption of niche tracking. The sampling station illustrates how a long-term monitoring programme based on a permanent station is expected to detect changes in the abundance of species in a community affected by warming as a result of species' distribution shifts. At the community level, the processes of latitudinal shift triggered by warming at the sampling station can cause a positive rate of change in the Community Temperature Index (CTI_r) through the increase of warm-affinity species (tropicalization) and/or decrease of cold-affinity species (deborealization). Modified from Villarino et al.[79].

https://doi.org/10.1038/s41467-024-46526-y



Copernicus Marine Service



Process Understanding, Predictive Understanding, Predictions, EWSs

HIGHLIGHTS

- Risk of land-derived plastic to North Atlantic megafauna and habitats was assessed.
- Five high-risk zones (HRZs) were assigned through a Spatial Risk Assessment.
- Risk was driven by domestic sources in some HRZs and external sources in others.
- Litter from Caribbean islands is likely to be a significant source of plastic to HRZs.
- Identifying HRZs and sources of plastic could enable more efficient interventions.

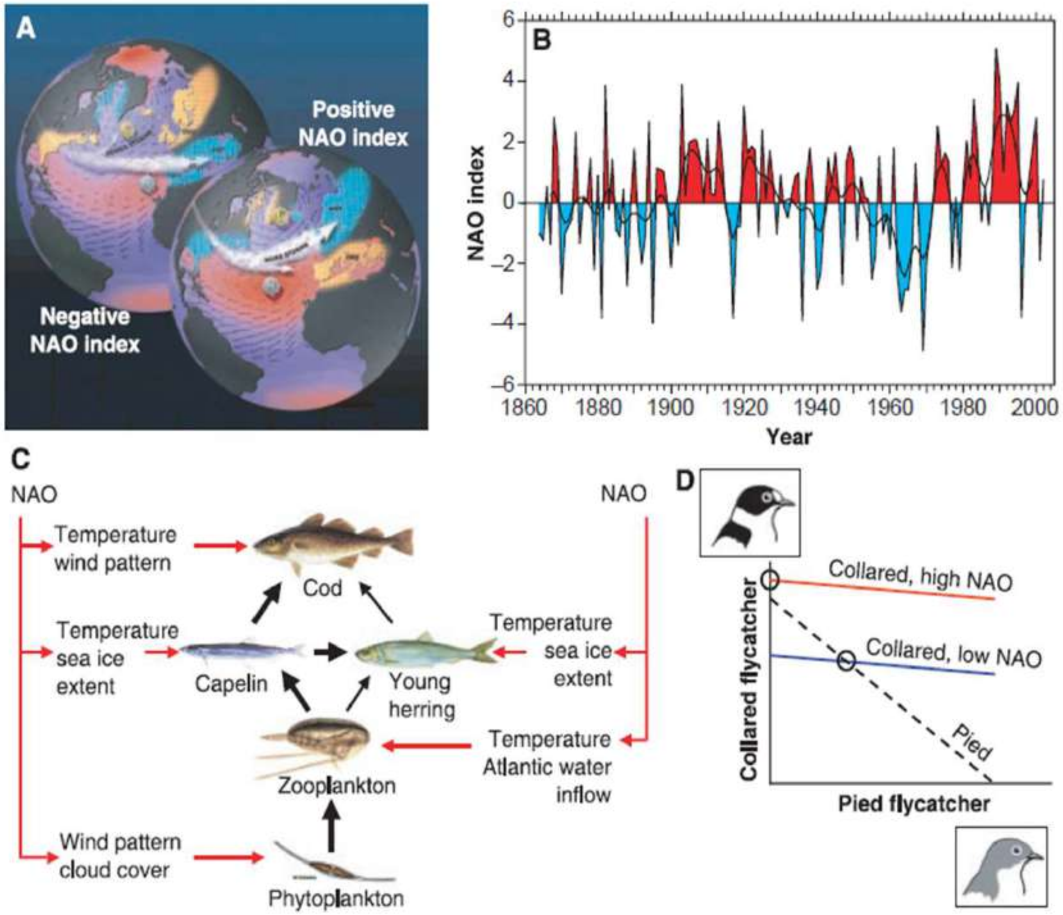


Fig. 1. The North Atlantic Oscillation (NAO), and examples of its ecological effects. The NAO (*3, 61*) is a north-south alternation in atmospheric mass between the subtropical atmospheric high-pressure center over the Azores and the atmospheric subpolar low-pressure center over Iceland. It measures the strength of the westerly winds blowing across the North Atlantic Ocean between 40°N and 60°N. Variability in the direction and magnitude of the westerlies is responsible for fluctuations in wintertime temperatures and the balance of precipitation and evaporation across the Atlantic and the adjoining landmasses (*3, 62*). (**A**) During positive phases of the NAO, the westerly winds are strengthened and moved northward, causing increased precipitation and temperatures over northern Europe and the southeastern United States and dry anomalies in the Mediterranean region. Roughly opposite conditions occur during the negative-index phase. [Graph courtesy of M. Visbeck; www.ldeo.columbia.edu/NAO] (**B**) Temporal evolution of the NAO over the past 140 winters (index at www.cgd.ucar.edu/~jhurrell/nao.html). High- (low-) index winters are shown in red (blue) (*63*). (**C**) Simplified food web for the Barents Sea including phytoplankton, zooplankton, capelin (*Mallotus villosus*), herring (*Clupea harengus*), and cod (*Gadus morhua*). Positive phases of the NAO affect the Barents Sea through increasing volume flux of warm water from the southwest, cloud cover, and air temperature, all leading to increased water temperature, which influences fish growth and survival both directly and indirectly (*31*). (**D**)The breeding ranges of the pied flycatcher (*F. hypoleuca*) and collared flycatcher (*F. albicollis*) overlap in central Europe. The two species compete for resources such as nest sites (*64*). Isoclines (i.e., density-combinations for which each of the species does not change in density) as deducedfrom Sætre *et al.* (*56*). During periods with high positive values of the NAO index, the collared may outcompete the pied flycatcher, whereas during periods with lower values of the NAO index there may be a balanced competitive interaction between the two species leading to stable coexistence.

The Ocean as a Solution to Climate Change

Five Opportunities for Action

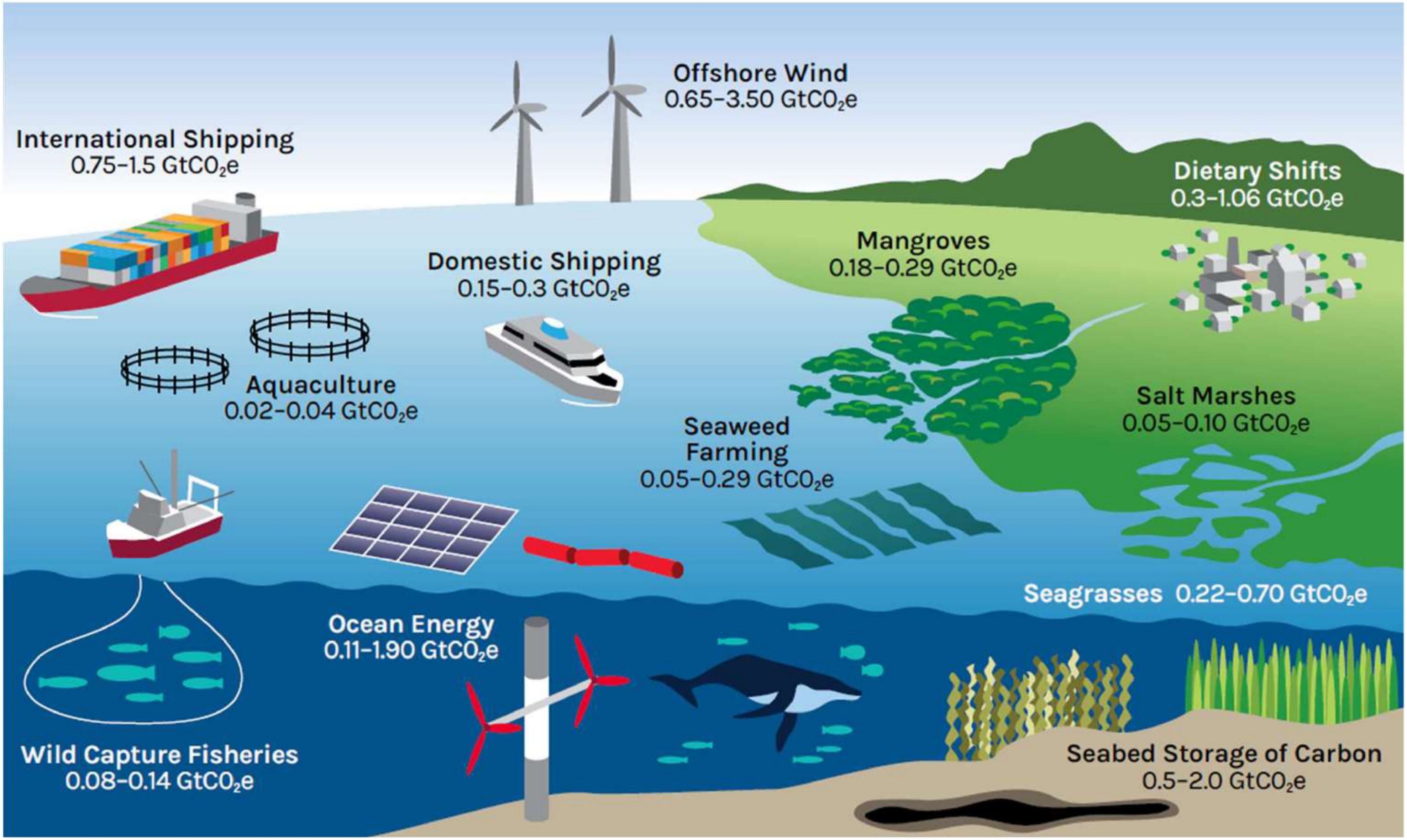
https://oceanpanel.org/publication/ocean-solutions-to-climate-change/

CONVENING LEAD AUTHOR

Ove Hoegh-Guldberg

EXPERT AUTHORS:

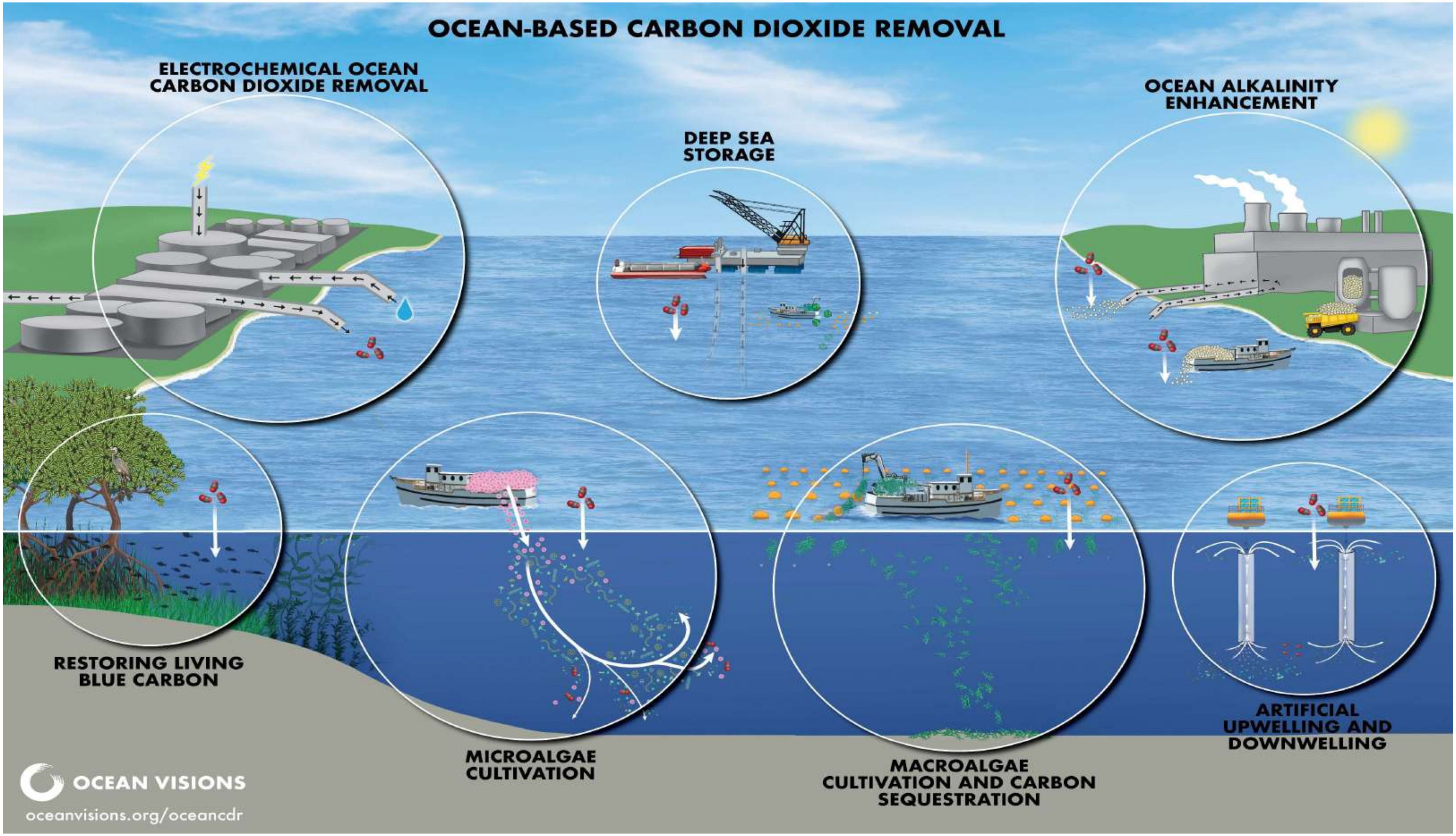
Ken Caldeira, Thierry Chopin, Steve Gaines, Peter Haugan, Mark Hemer, Jennifer Howard, Manaswita Konar, Dorte Krause-Jensen, Elizabeth Lindstad, Catherine E. Lovelock, Mark Michelin, Finn Gunnar Nielsen, Eliza Northrop, Robert Parker, Joyashree Roy, Tristan Smith, Shreya Some, and Peter Tyedmers



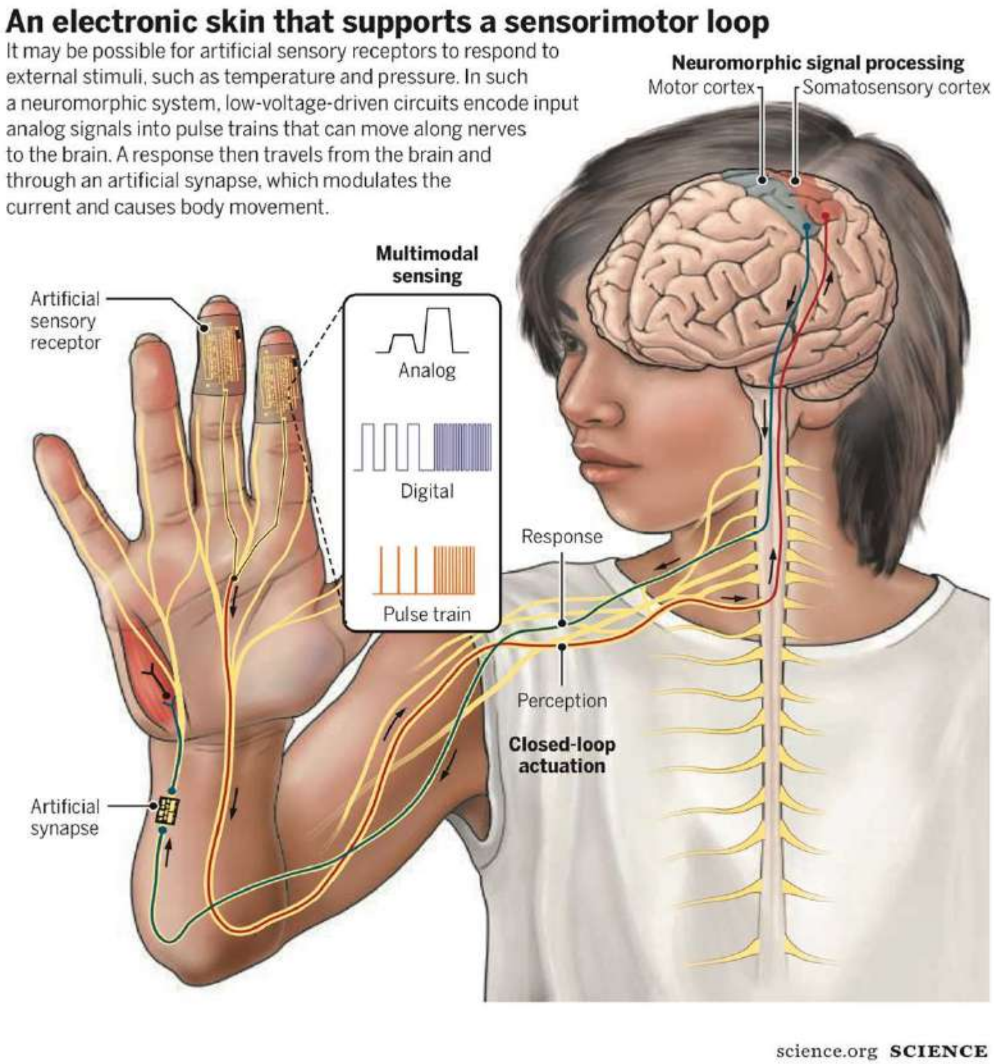
International Shipping
0.75–1.5 GtCO$_2$e
Offshore Wind
0.65–3.50 GtCO$_2$e
Dietary Shifts
0.3–1.06 GtCO$_2$e
Mangroves
0.18–0.29 GtCO$_2$e
Domestic Shipping
0.15–0.3 GtCO$_2$e
Aquaculture
0.02–0.04 GtCO$_2$e
Salt Marshes
0.05–0.10 GtCO$_2$e
Seaweed Farming
0.05–0.29 GtCO$_2$e
Seagrasses 0.22–0.70 GtCO$_2$e
Ocean Energy
0.11–1.90 GtCO$_2$e
Wild Capture Fisheries
0.08–0.14 GtCO$_2$e
Seabed Storage of Carbon
0.5–2.0 GtCO$_2$e

Table ES-1. Summary of Global Mitigation Potential Offered by Each Area of Ocean-based Climate Action

AREAS OF OCEAN-BASED CLIMATE ACTION	2030 MITIGATION POTENTIAL ($GTCO_2E$/YEAR)	2050 MITIGATION POTENTIAL ($GTCO_2E$/YEAR)
1. Ocean-based renewable energy	0.18–0.25	0.76–5.40
2. Ocean-based transport	0.24 – 0.47	0.9 – 1.80
3. Coastal and marine ecosystems	0.32–0.89	0.50–1.38
4. Fisheries, aquaculture, and dietary shifts	0.34–0.94	0.48–1.24
5. Carbon storage in the seabed (Action in this Area Requires Further Research Prior to Implementation at Scale)	0.25–1.0	0.50–2.0
Total	1.32–3.54	3.14–11.82
Total percentage contribution to closing emissions gap (1.5°C pathway)	4–12 %	6–21%
Total percentage contribution to closing emissions gap (2°C pathway)	7–19%	7–25%


OCEAN-BASED CARBON DIOXIDE REMOVAL
ELECTROCHEMICAL OCEAN CARBON DIOXIDE REMOVAL
DEEP SEA STORAGE
OCEAN ALKALINITY ENHANCEMENT
RESTORING LIVING BLUE CARBON
MICROALGAE CULTIVATION
MACROALGAE CULTIVATION AND CARBON SEQUESTRATION
ARTIFICIAL UPWELLING AND DOWNWELLING
OCEAN VISIONS
oceanvisions.org/oceancdr

Small things, Big Ideas/Solutions



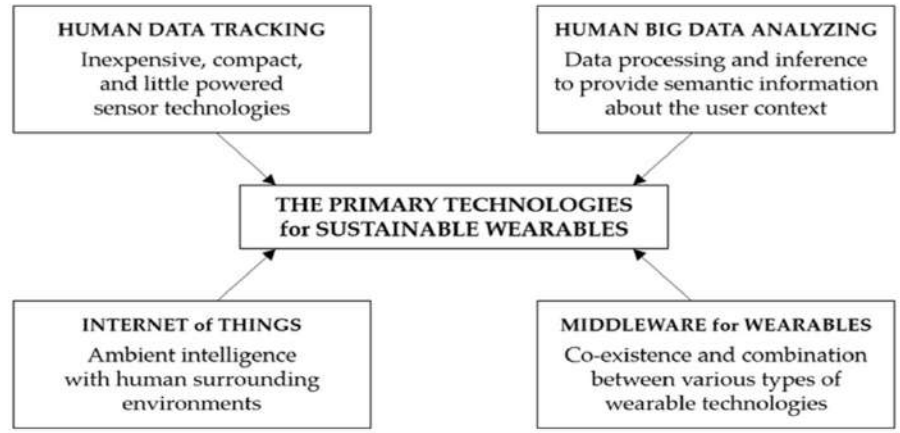


Figure 2. Primary technological keywords for the development of sustainable wearables.

doi:10.3390/su8050466

https://doi.org/10.1038/s41928-023-01078-9; ***Reversible Organic Flexible***

Saving the World and saving the Oceans is going to be real fun. Have an Optimistic Vision for the Future