

Understanding Climate Change Impacts on the Ocean

Global Insights for Regional Planning

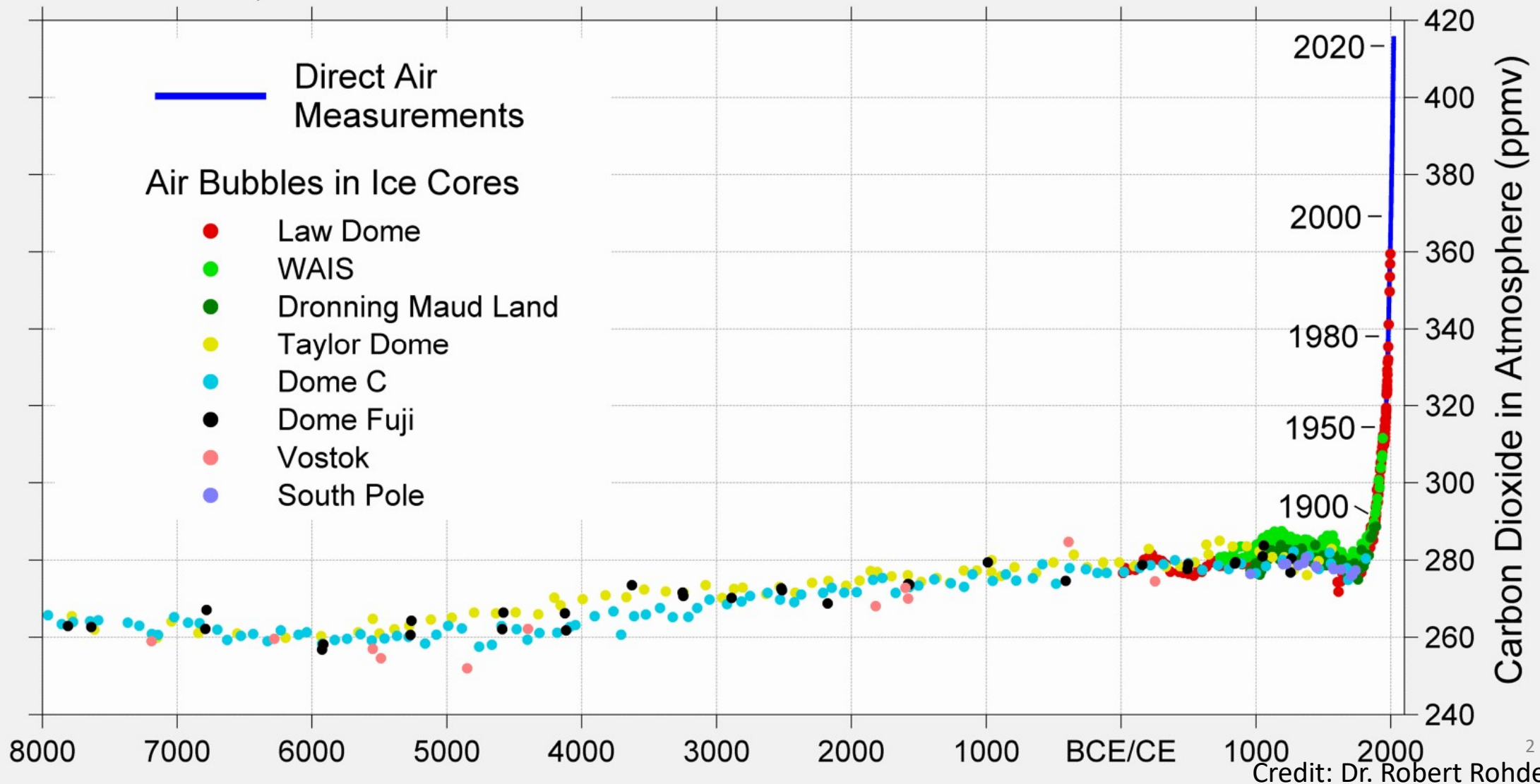
By Levke Caesar, 25 March 2025

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**Planetary Boundaries
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10,000 Years of Carbon Dioxide



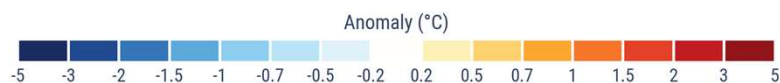
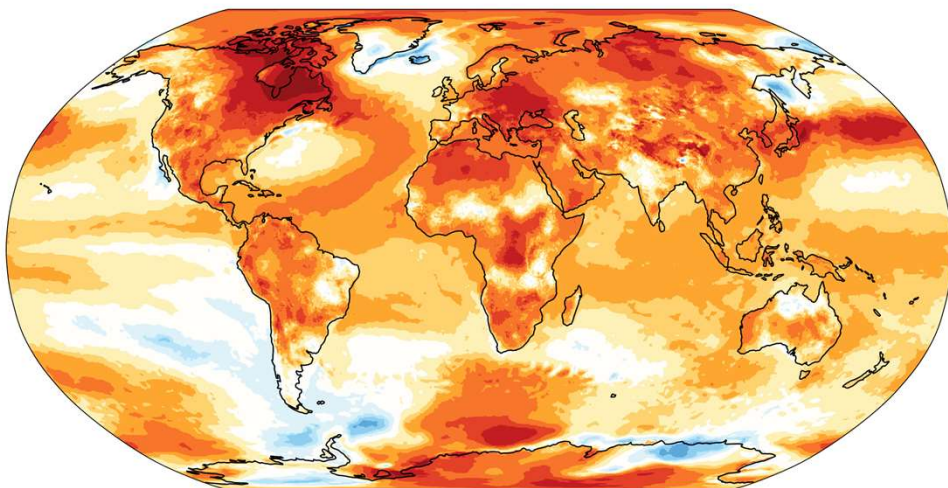


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Surface air temperature anomalies in 2024

Data: ERA5 • Reference period: 1991–2020 • Credit: C3S/ECMWF



PROGRAMME OF
THE EUROPEAN UNION

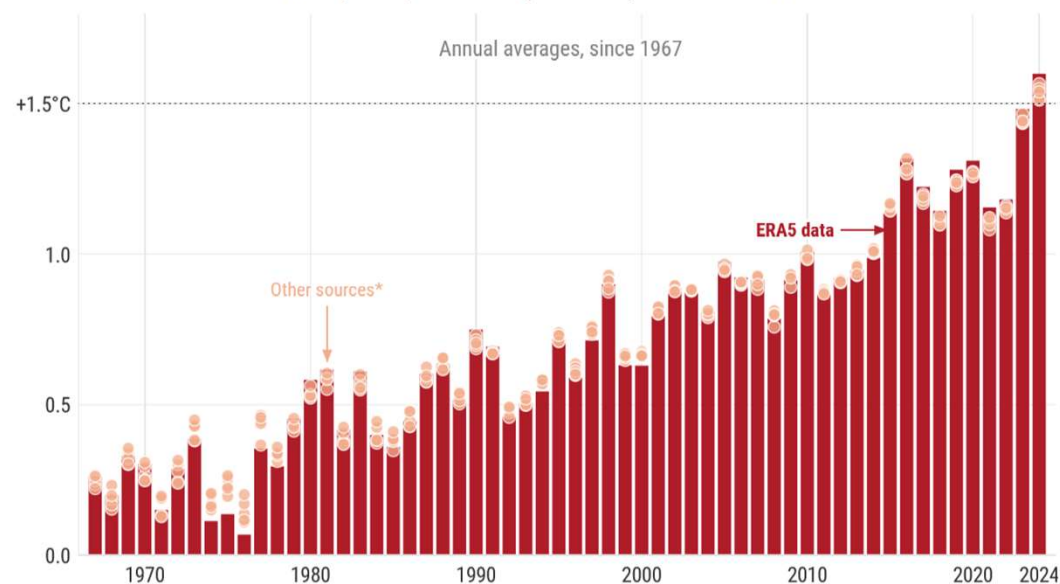


Region	Anomaly (vs 1991–2020)	Actual temperature	Rank (out of 85 years)
Globe	+0.72°C (+1.60°C vs pre-industrial)	15.10°C	1st highest 2nd - 2023
Europe	+1.47°C	10.69°C	1st highest 2nd - 2020
Arctic	+1.34°C	-11.37°C	4th highest 1st - 2016
Extra-polar ocean	+0.51°C	20.87°C	1st highest 2nd - 2023



Global surface temperature: increase above pre-industrial

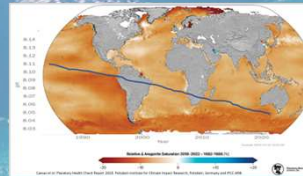
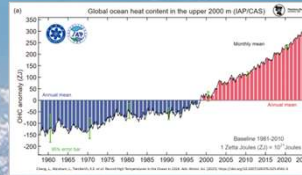
Reference period: pre-industrial (1850–1900) • Credit: C3S/ECMWF



Credit: <https://climate.copernicus.eu/global-climate-highlights-2024>

The Ocean as our Climate Buffer

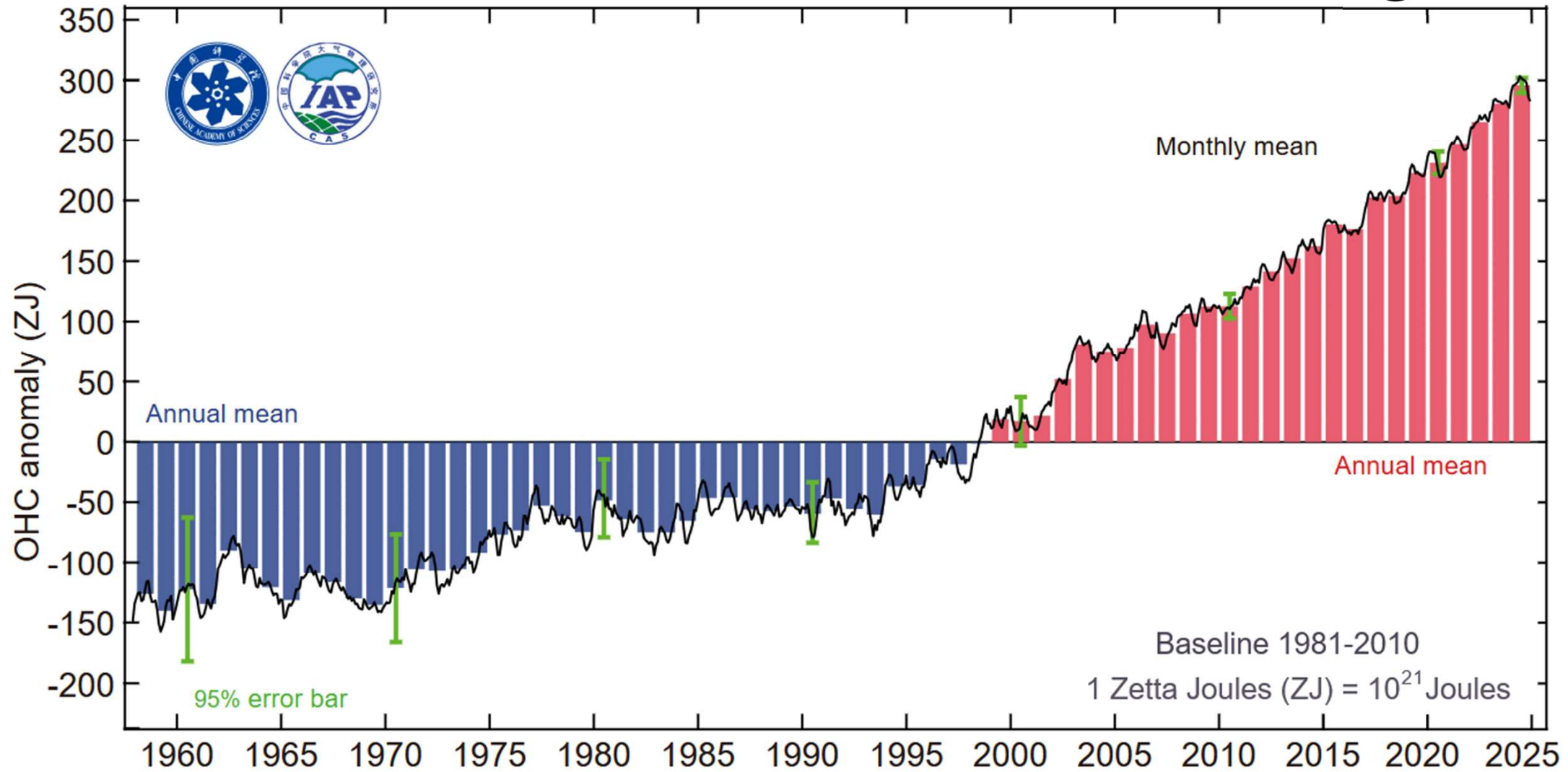
- The ocean absorbs **over 90% of the excess heat** from climate change.
- It acts as a carbon sink, absorbing **25-30% of human-produced CO₂**.
- The **buffering capacity** of the ocean **slows climate impacts** but has limits and consequences..



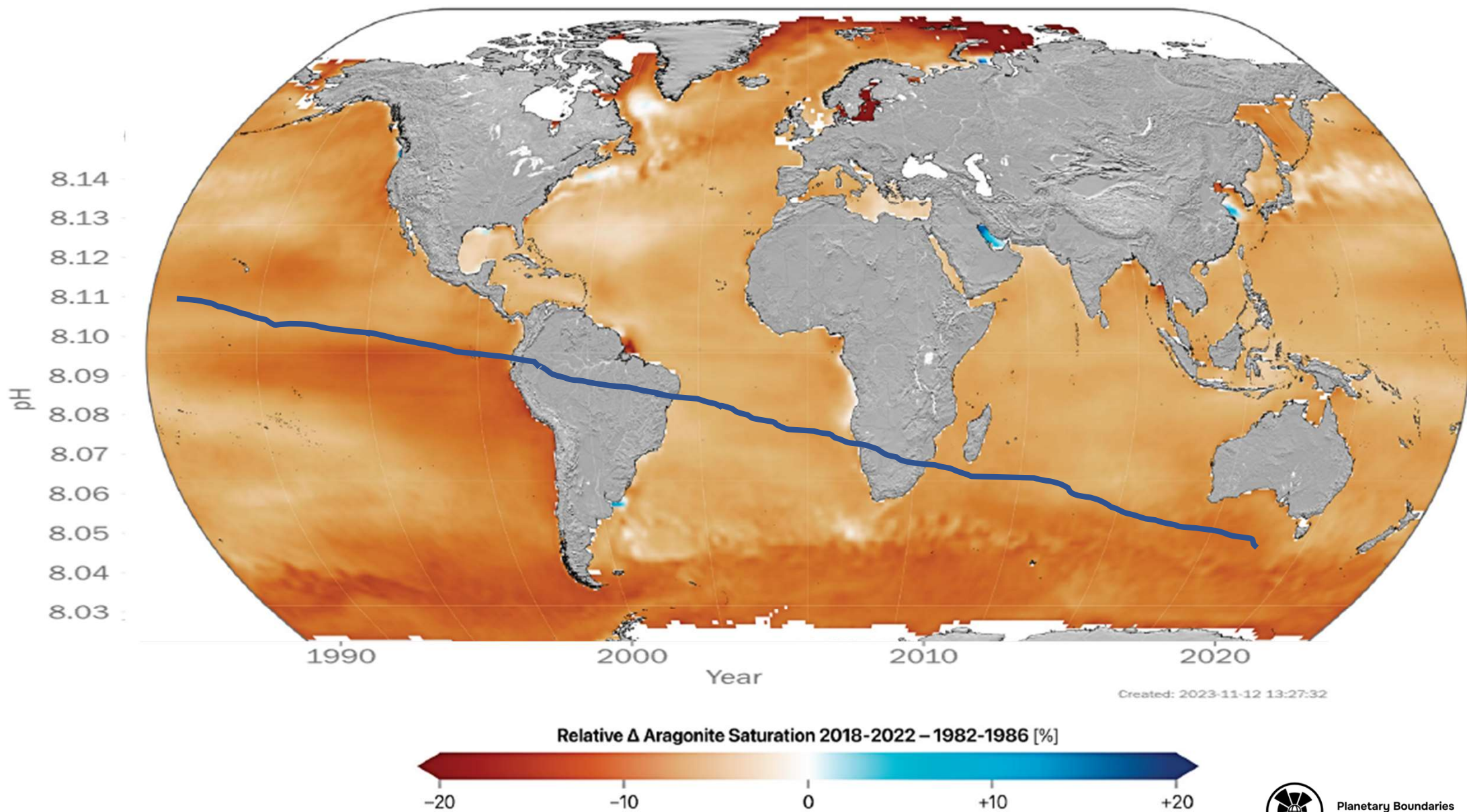
Credit: NASA

(a)

Global ocean heat content in the upper 2000 m (IAP/CAS)

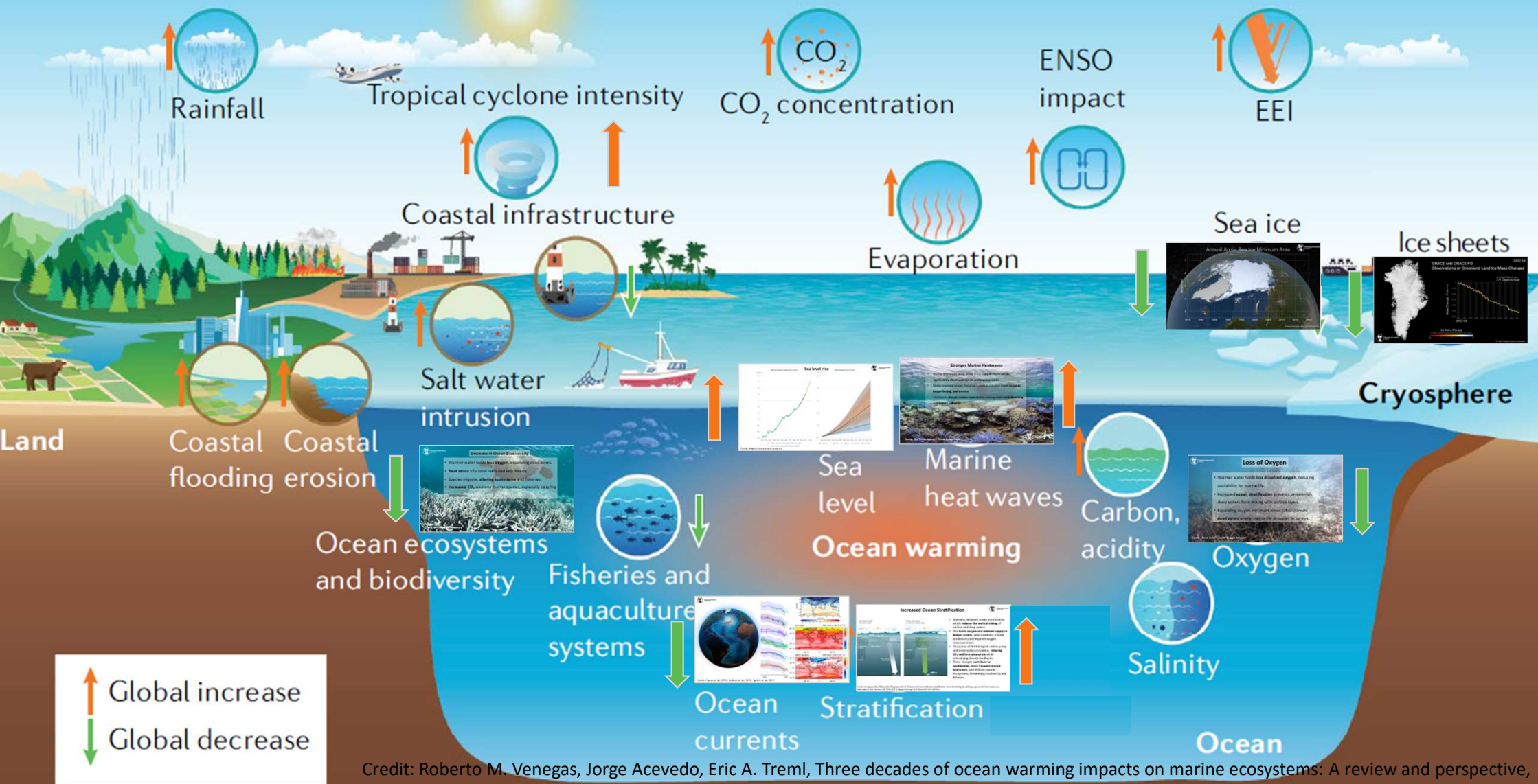


Cheng, L., Abraham, J., Trenberth, K.E. *et al.* Record High Temperatures in the Ocean in 2024. *Adv. Atmos. Sci.* (2025). <https://doi.org/10.1007/s00376-025-4541-3>



Caesar *et al.* Planetary Health Check Report 2024. Potsdam Institute for Climate Impact Research, Potsdam, Germany and IPCC AR&

Atmosphere



Credit: Roberto M. Venegas, Jorge Acevedo, Eric A. Trembl, Three decades of ocean warming impacts on marine ecosystems: A review and perspective,

Stronger Marine Heatwaves

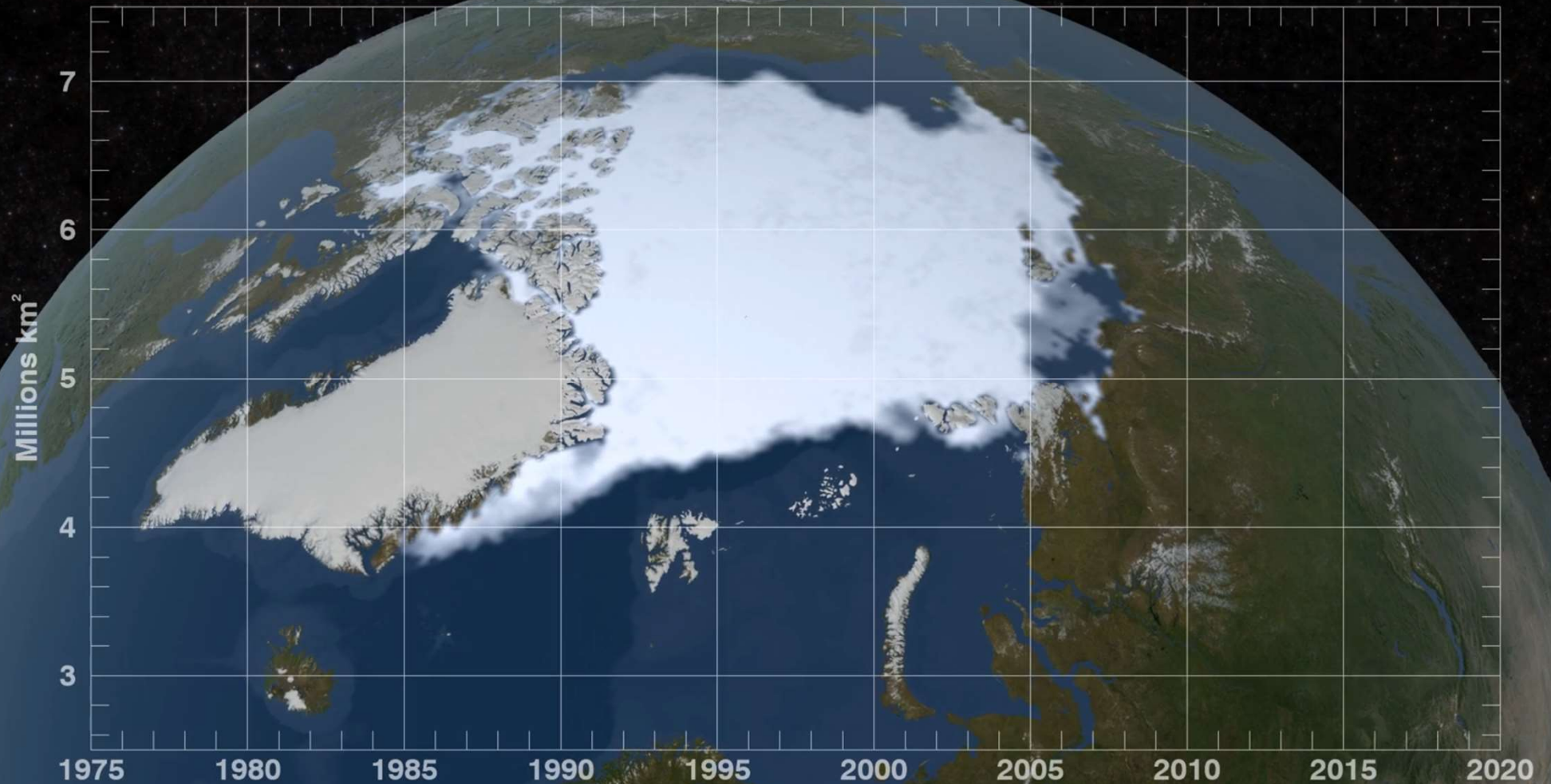
- Marine heatwaves occur when ocean temperatures remain **significantly above average for prolonged periods.**
- Ocean warming causes these heatwaves to become **more frequent, longer-lasting, and intense.**
- Heatwaves **disrupt marine ecosystems**, causing **mass coral bleaching** and **fishery collapses.**

Credit: The Ocean Agency / Ocean Image Bank



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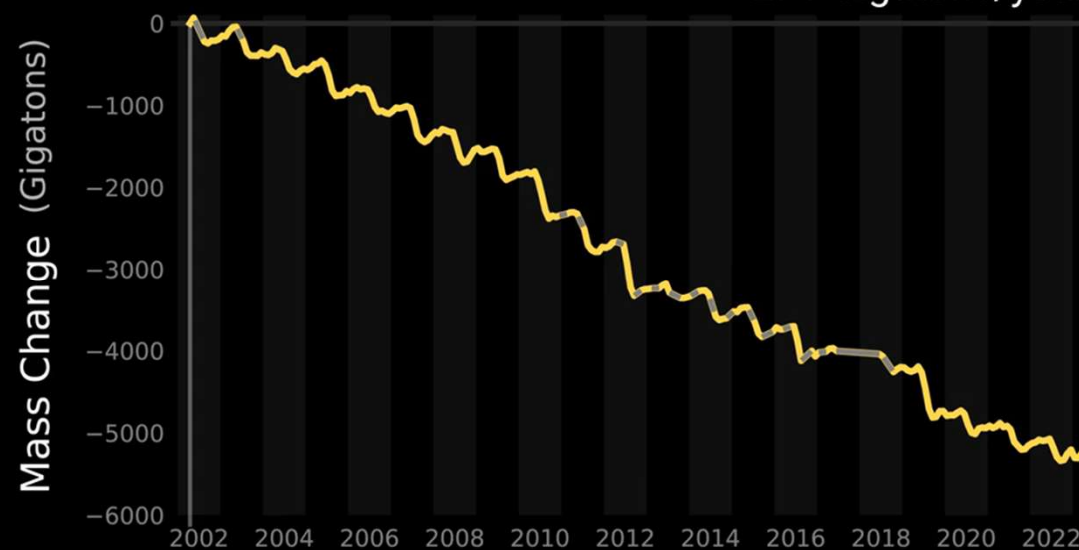
Annual Arctic Sea Ice Minimum Area



2002-04

GRACE AND GRACE-FO Observations of Greenland Land Ice Mass Changes

Average Mass Loss:
271 Gigatons/year

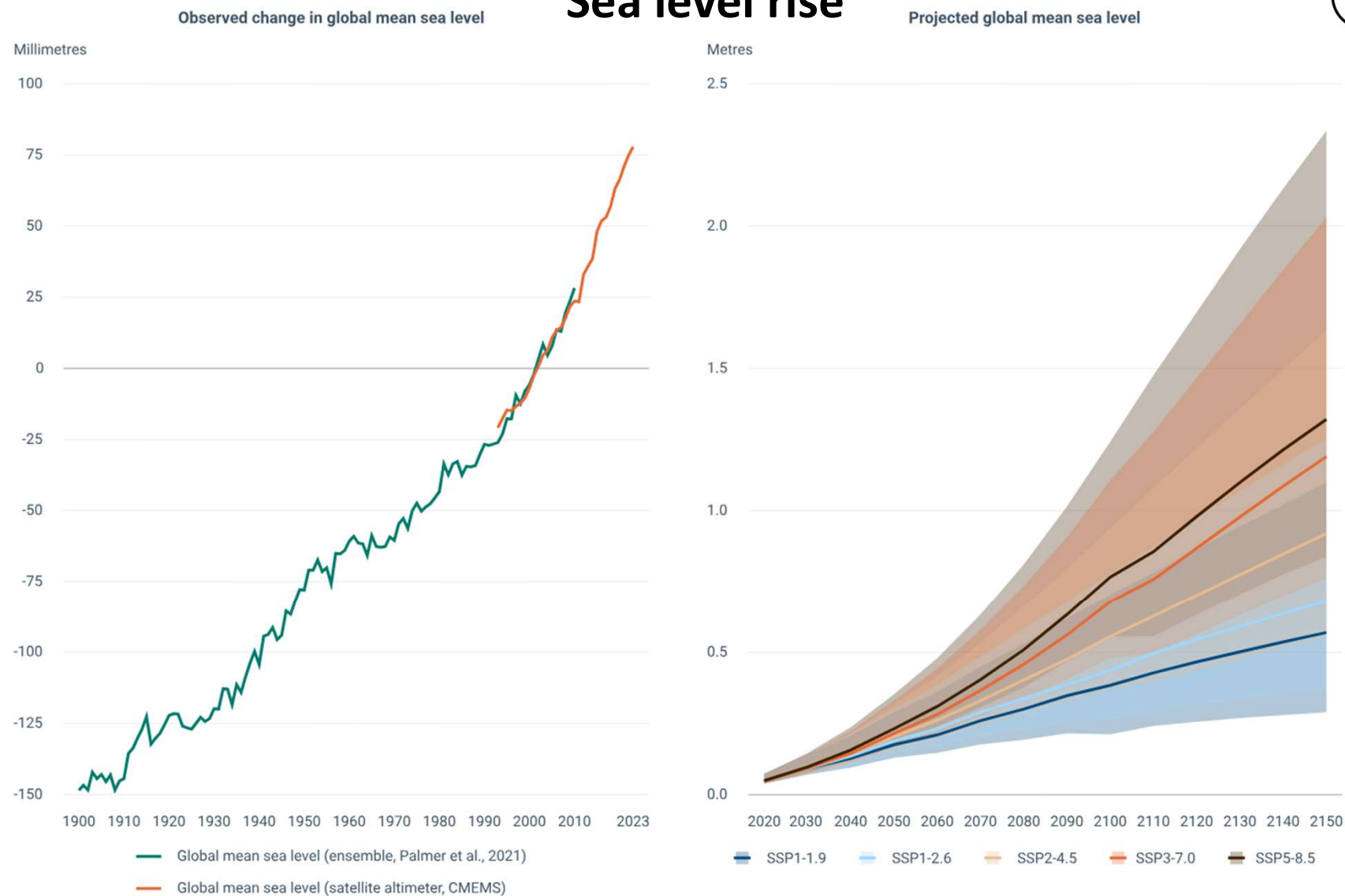


2002-04

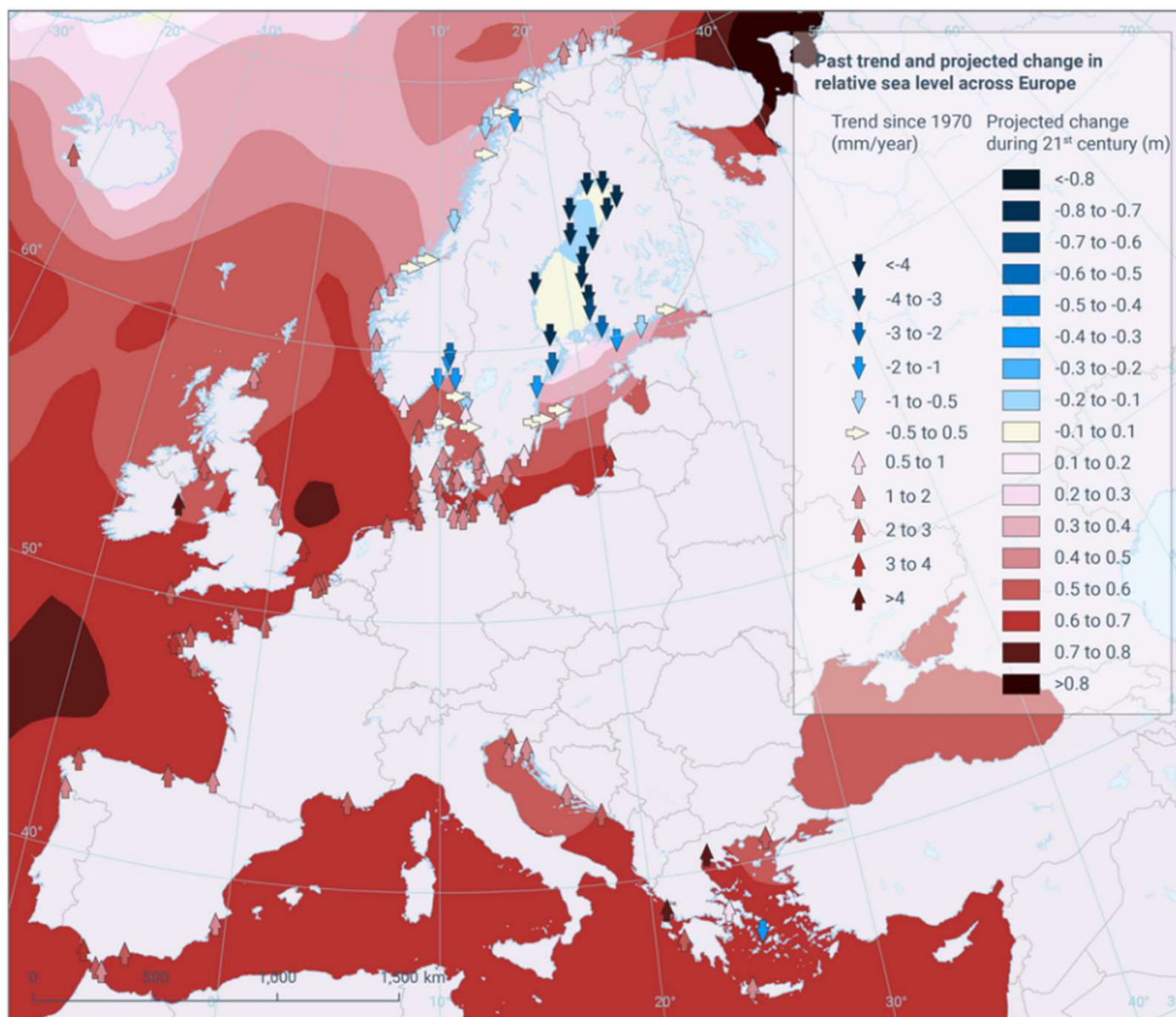
Ice Mass Change
(meters water equivalent relative to 2002)



Sea level rise



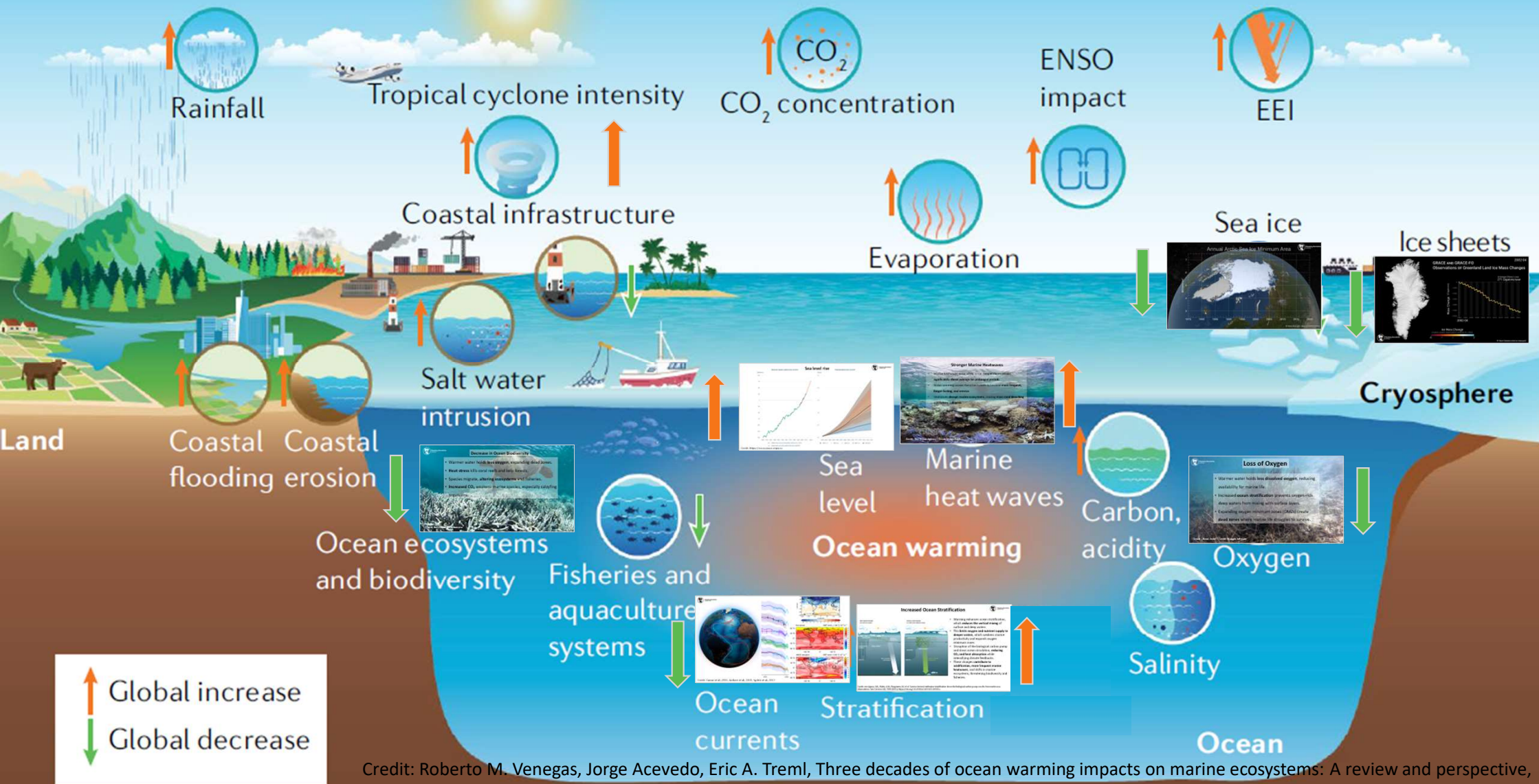
Credit: <https://www.eea.europa.eu>



Reference data: © EuroGeographics, © FAO (UN), © TurkStat Source: European Commission – Eurostat/GISCO

Credit:
<https://www.eea.europa.eu>

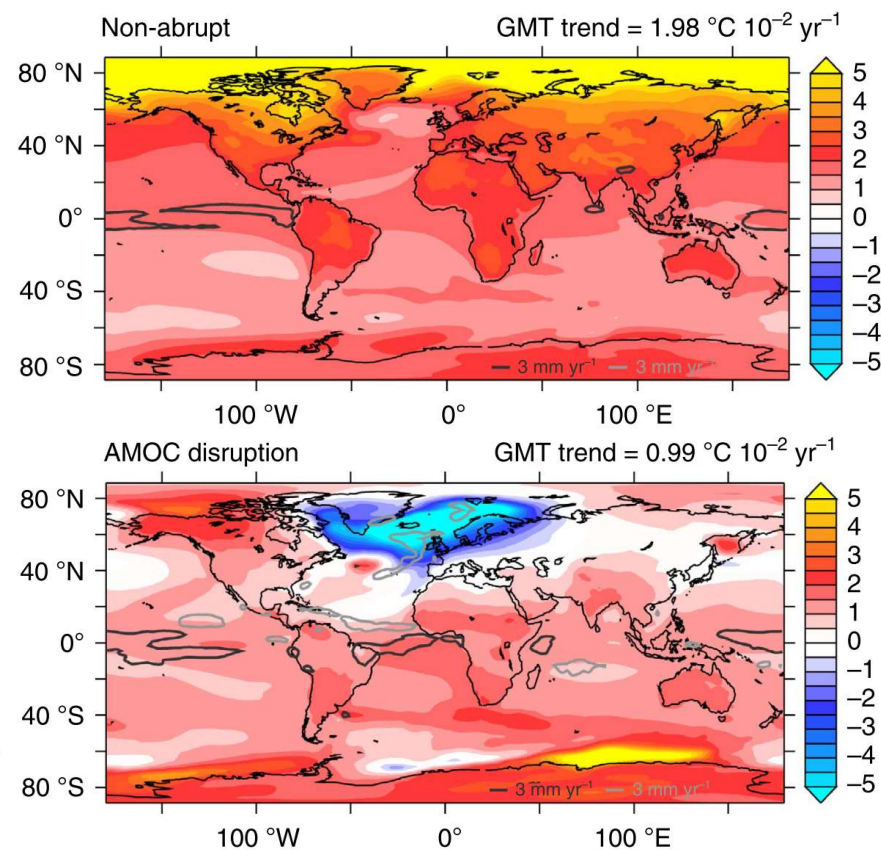
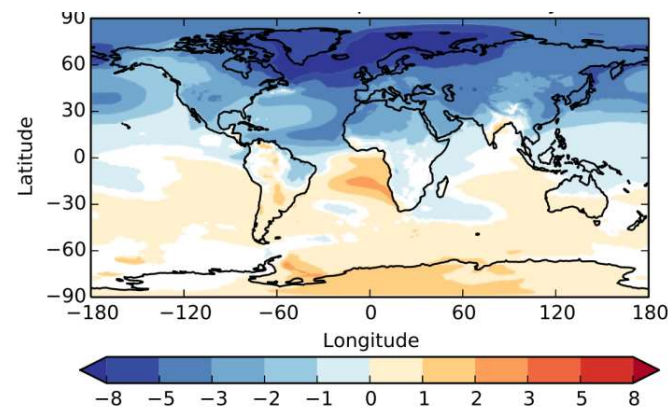
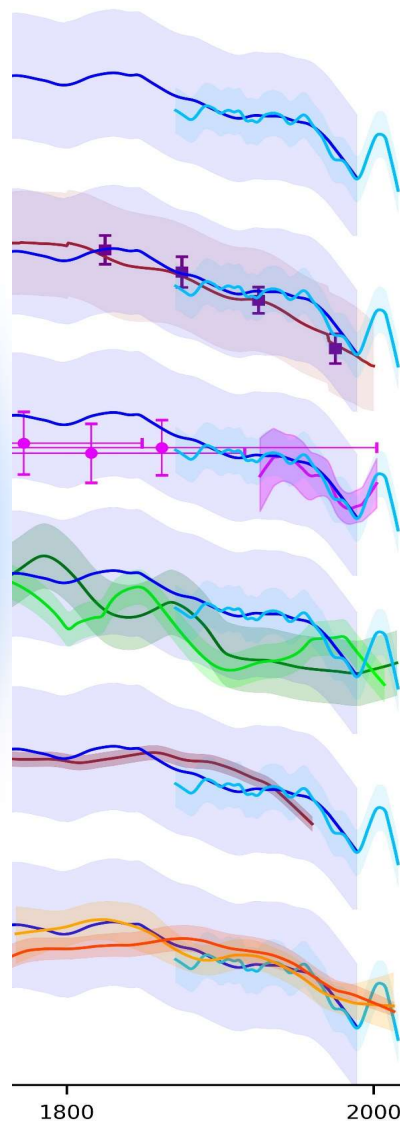
Atmosphere



Credit: Roberto M. Venegas, Jorge Acevedo, Eric A. Trembl, Three decades of ocean warming impacts on marine ecosystems: A review and perspective,



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Credit: Caesar et al., 2021, Jackson et al., 2015, Sgubin et al., 2017

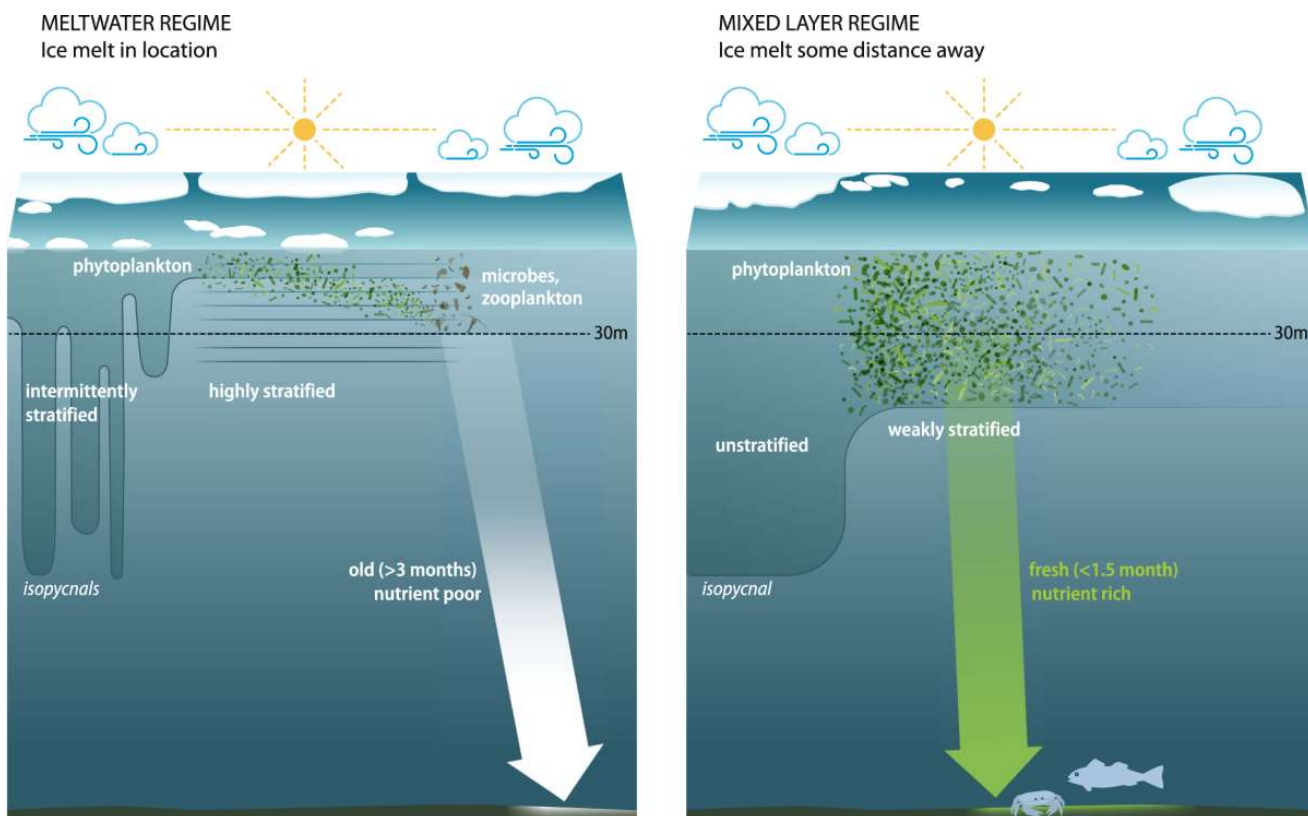
Loss of Oxygen

- Warmer water holds **less dissolved oxygen**, reducing availability for marine life.
- Increased **ocean stratification** prevents oxygen-rich deep waters from mixing with surface layers.
- Expanding oxygen minimum zones (OMZs) create **dead zones** where marine life struggles to survive.

Decrease in Ocean Biodiversity

- Warmer water holds **less oxygen**, expanding dead zones.
- **Heat stress** kills coral reefs and kelp forests.
- Species migrate, **altering ecosystems** and fisheries.
- **Increased CO₂** weakens marine species, especially calzyfing organisms.

Increased Ocean Stratification



- Warming enhances ocean stratification, which **reduces the vertical mixing** of surface and deep waters
- This **limits oxygen and nutrient supply to deeper waters**, which weakens marine productivity and expands oxygen minimum zones
- Disruption of the biological carbon pump and slows ocean circulation, **reducing CO₂ and heat absorption** while intensifying climate feedbacks.
- These changes **contribute to acidification, more frequent marine heatwaves**, and shifts in marine ecosystems, threatening biodiversity and fisheries.

Credit: von Appen, WJ., Waite, A.M., Bergmann, M. *et al.* Sea-ice derived meltwater stratification slows the biological carbon pump: results from continuous observations. *Nat Commun* **12**, 7309 (2021). <https://doi.org/10.1038/s41467-021-26943-z>