International Institute for Applied Systems Analysis
IIASA

PAS Biennial Plenary 2026
Vatican City, 26 Sep 2026

The Future of Climate Change and Tipping Points

Hans Joachim Schellnhuber PAS

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Founder, Bauhaus Earth gGmbH

清華大學 Tsinghua University

BAUHAUS ● EARTH

Grand Questions for Climate-Change Analysis & Management

Q_1	What is the current dynamics of the climate system?
Q_2	Can we rule out a *"Hothouse Earth"* trajectory?
Q_3	How to restore the Holocene climate?
Q_4	Which major climate-change disruptions can be expected?
Q_5	How to survive the overshoot episode?
Q_6	Will revolutionary innovations help with tackling $Q_1 – Q_5$?

Q_1 What is the current dynamics of the climate system?

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Global Surface Air Temperature

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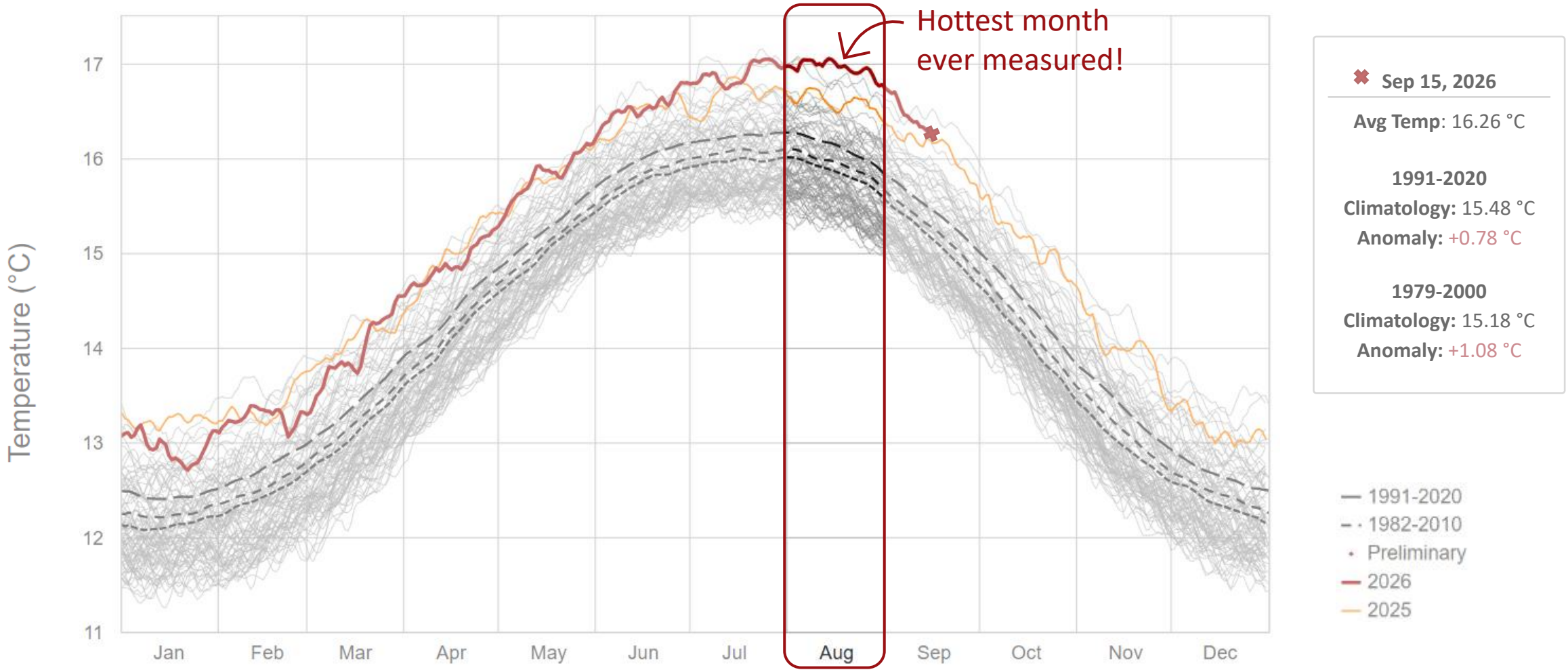
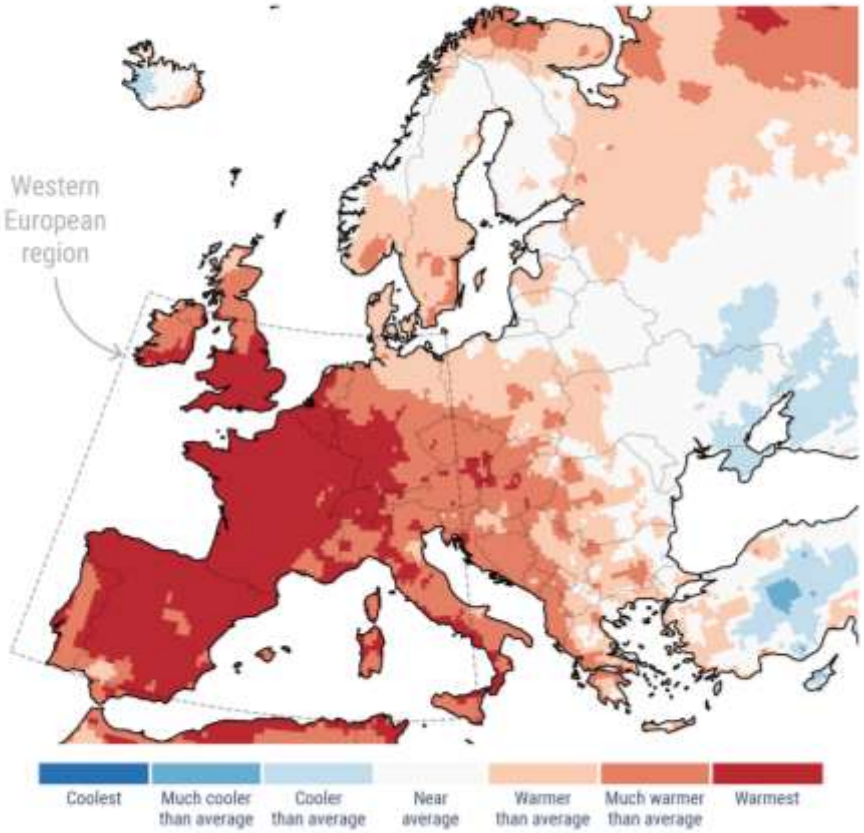


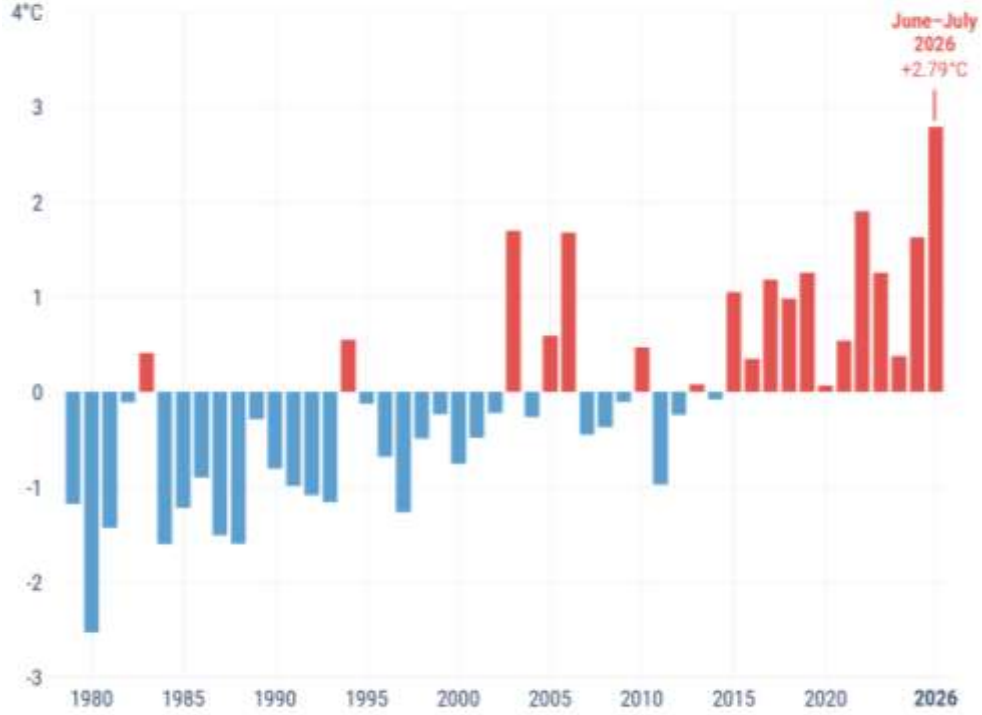
Climate Change Service

Average June–July temperature for western Europe reaches record high

Anomalies and extremes in surface air temperature for June–July 2026



Surface air temperature anomalies in June–July averaged over western Europe



Colour categories refer to the percentiles of the temperature distributions for the 1991–2020 reference period. The "coolest" and "warmest" categories are based on June–July rankings for the period 1979–2026.
The western European region outlined in the map and used for the time series covers all land area within 11°W–15°E, 37°–55°N. Full press release: here

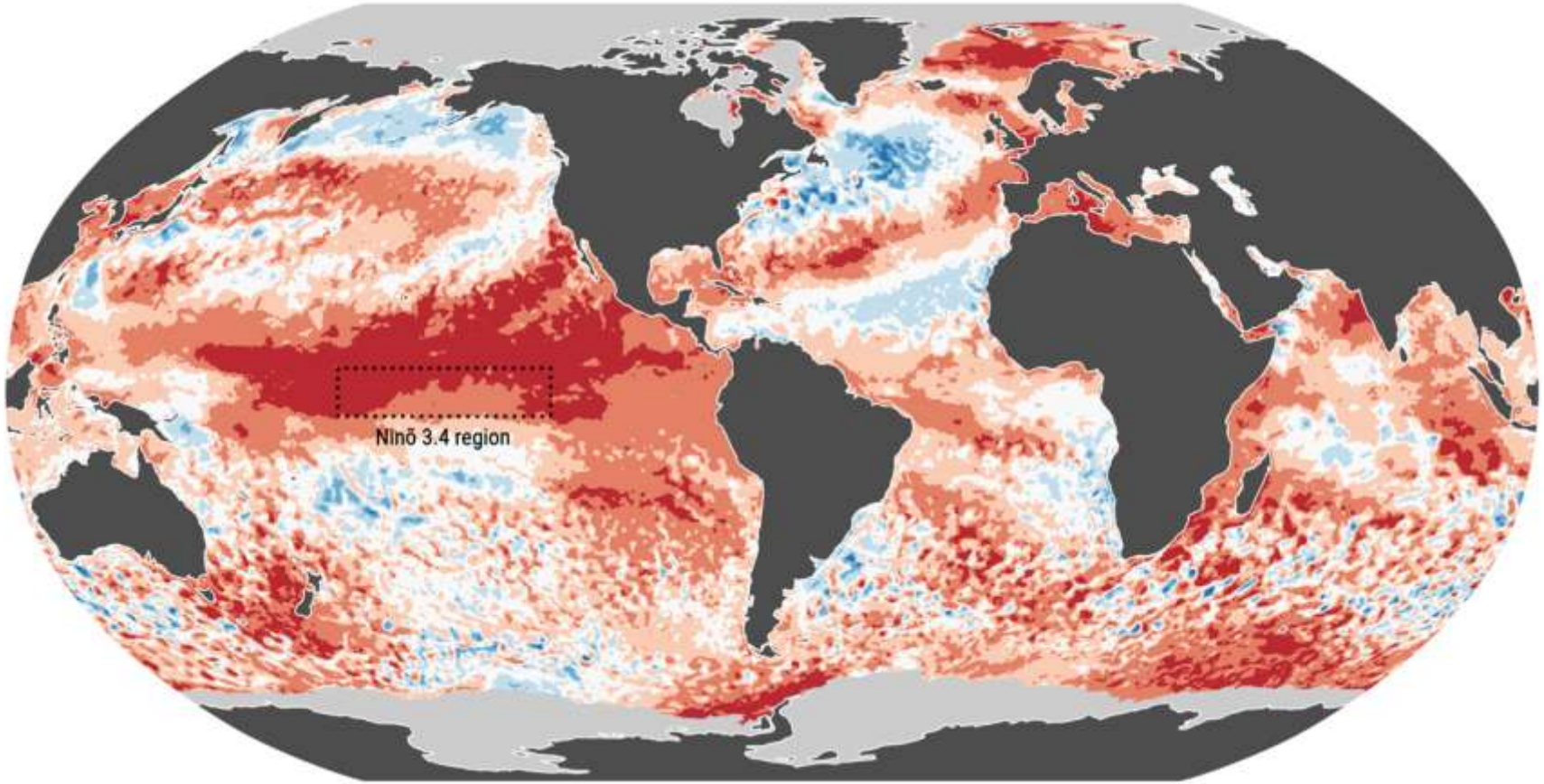
PROGRAMME OF THE EUROPEAN UNION
Copernicus
Climate Change Service
IMPLEMENTED BY ECMWF

Climate Change Service

Anomalies and extremes in sea surface temperature in June 2026

Data: ERA5 1979–2026 • Reference period: 1991–2020 • Credit: C3S/ECMWF

Full press release: here

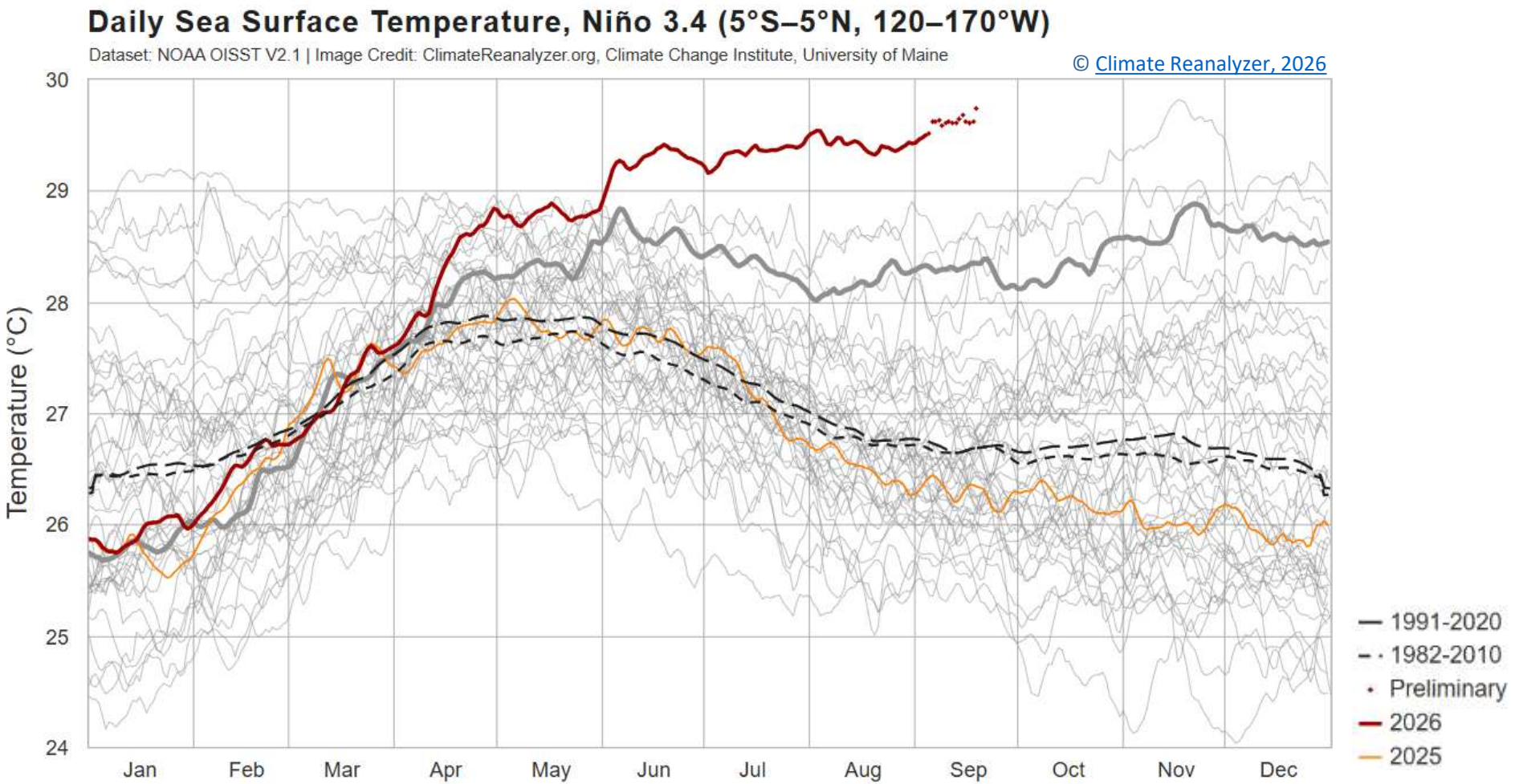


PROGRAMME OF THE EUROPEAN UNION

Copernicus

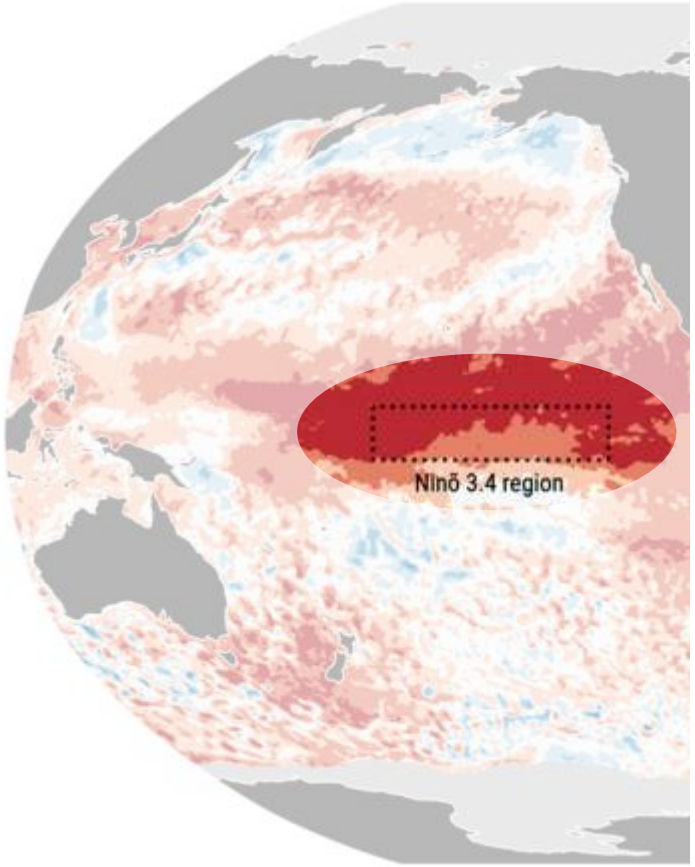
Climate Change Service

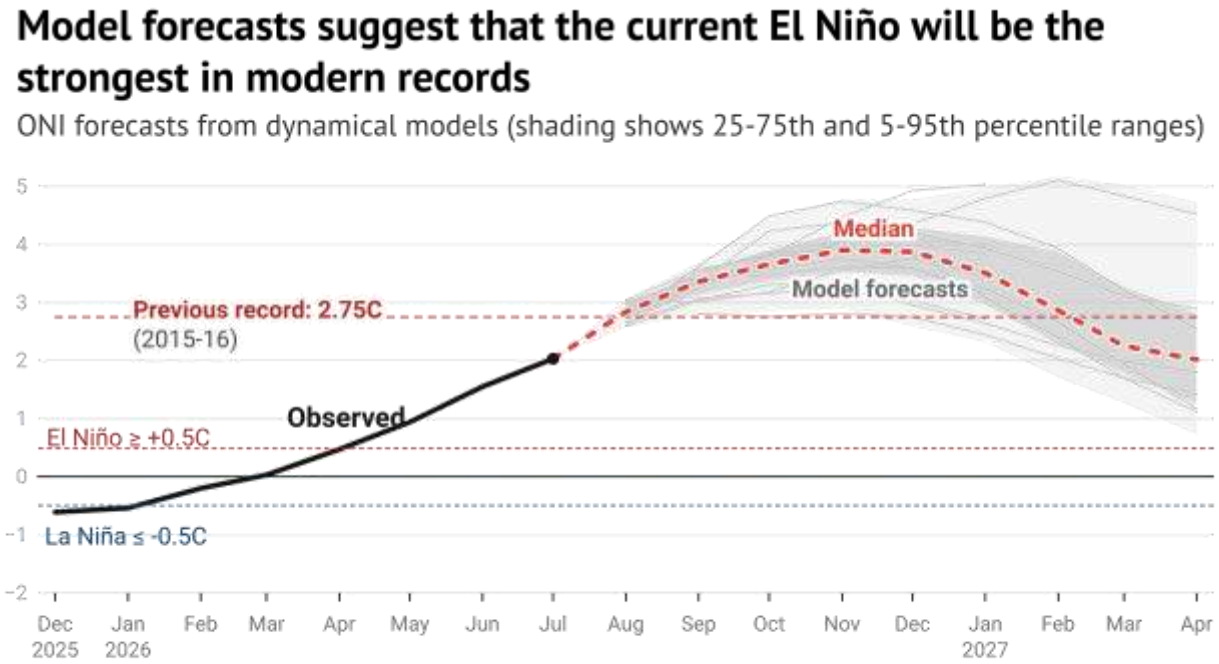
IMPLEMENTED BY ECMWF


Daily Sea Surface Temperature, Niño 3.4 (5°S–5°N, 120–170°W)
Dataset: NOAA OISST V2.1 | Image Credit: ClimateReanalyzer.org, Climate Change Institute, University of Maine
© Climate Reanalyzer, 2026
Temperature (°C)
30
29
28
27
26
25
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
1991-2020
1982-2010
Preliminary
2026
2025

Recent strengthening of eastern Pacific ENSO in the last millennium paleorecord

Cole et al., 2026





Q_2 Can we rule out a *"Hothouse Earth"* trajectory?

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One Earth

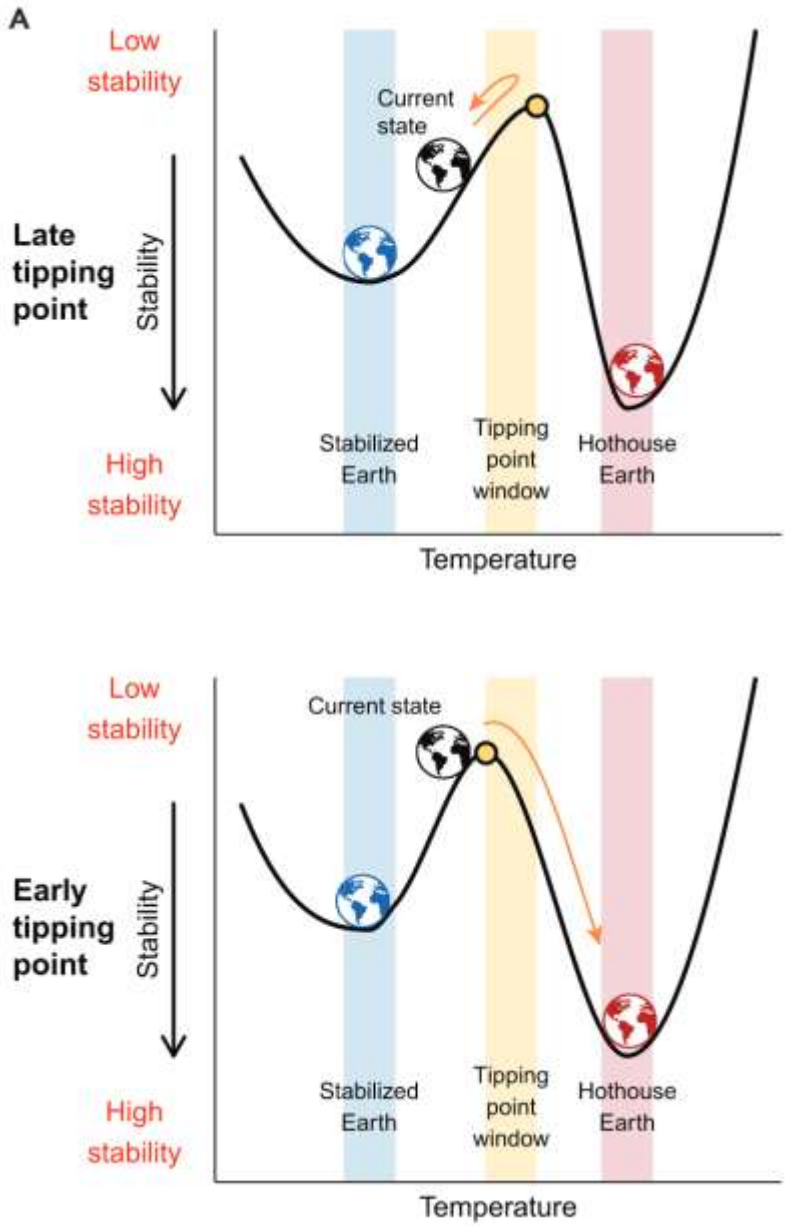
CellPress

February 20, 2026

The risk of a hothouse Earth trajectory

William J. Ripple,[1,2,10] Christopher Wolf,[3,10,*] Johan Rockström,[4] Katherine Richardson,[5] Nico Wunderling,[4,6,9] Jillian W. Gregg,[3] Thomas Westerhold,[7] and Hans Joachim Schellnhuber[8]

Earth's climate is now departing from the stable conditions that supported human civilization for millennia. Crossing critical temperature thresholds may trigger self-reinforcing feedbacks and tipping dynamics that amplify warming and destabilize distant Earth system components. Uncertain tipping thresholds make precaution essential, as crossing them could commit the planet to a hothouse trajectory with long-lasting and potentially irreversible consequences.



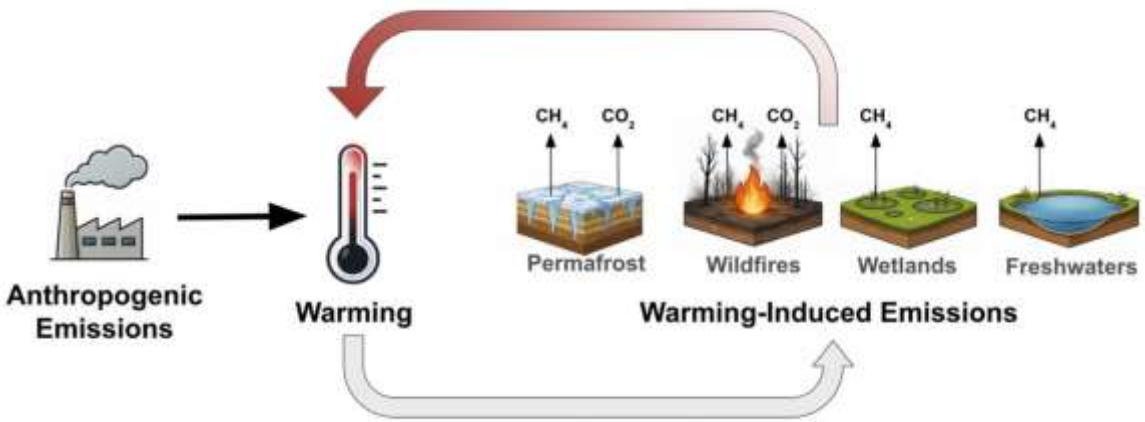
Full paper: here

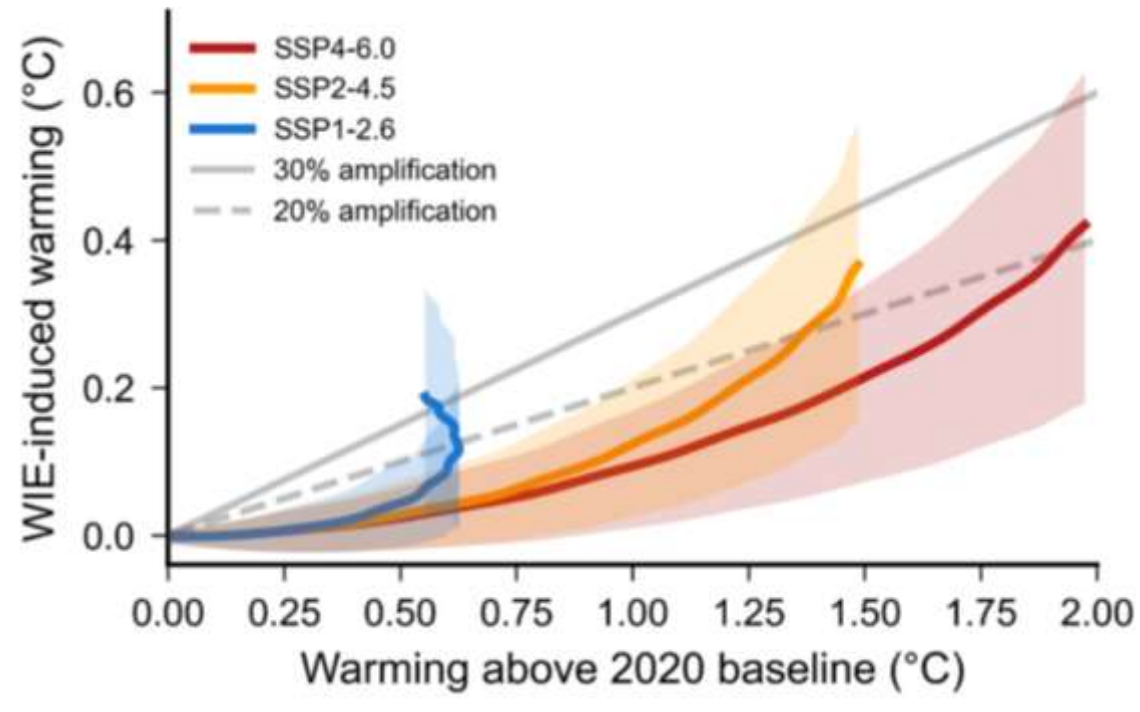
ENVIRONMENTAL RESEARCH
LETTERS

10 September 2026

Projected amplification of global warming by warming-induced greenhouse gas emissions

Sam Abernethy*, Danielle Monteverde, Christina Schädel, Brian Buma, Philip B Duffy, Robert B Jackson, Susan M Natali, Ilissa Ocko, Brendan M Rogers and Benjamin Poulter





Full paper: here

NewScientist

19 August 2026

World may warm by 25 per cent more than current projections suggest

Official projections for how much the world will warm are already catastrophic, and now it appears they significantly underestimate future warming

The Edersee, a lake in Waldeck, Germany, on 11 August

Ina FASSBENDER / AFP via Getty Images

Full article: here

Earth's Future

RESEARCH ARTICLE

10.1029/2026EF008356

Recent Temperature and Energy Imbalance Trends Point to Higher Estimates of Future Warming

G. Gyuleva[1], E. Fischer[1], R. Knutti[1], and S. Sippel[1]

[1]Institute of Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, [2]Institute for Meteorology, Leipzig University, Leipzig, Germany

Abstract Climate models simulate a wide range of 21st century warming for a given forcing scenario. Constraining this uncertainty is a central challenge in climate science because of its implications for climate policy and adaptation. The transient climate response (TCR) is a key idealized metric used to quantify future warming in response to an exponentially increasing CO_2 concentration. Climate models span a range of 1.3–3 K for TCR. In attempts to constrain this range, emergent constraints on TCR based on historical temperature trends consistently pointed toward TCR values at the lower end of the range of models. However, recent evidence from trends in the short-wave and long-wave components of Earth's energy imbalance (EEI) at the top-of-atmosphere suggests that models with higher TCR lie closer to the observed EEI trends. Here, we reconcile this discrepancy and provide a revised range for TCR of 1.9–2.6 K. Using a statistical variability-filtering approach, we show that previous temperature-based constraints were biased low due to internal variability, according to our method. We then provide an EEI-based constraint and demonstrate that short- and long-wave EEI trends have a strong potential to constrain future warming, due to the much larger inter-model spread in EEI compared to surface temperature. When considering the recent 2001–2025 period, our results show that both surface temperature and EEI trends support higher TCR values than previously estimated. This result implies that it is increasingly difficult to exclude high climate sensitivity models from the plausible range of future warming.

Plain Language Summary Predicting how much the Earth will warm as carbon dioxide concentrations rise is a major challenge for climate science, with consequences for climate policy and adaptation. Different global climate models produce widely varying projections of future warming, even when using the same emission scenario. Previous attempts to narrow down this range based on observed 20th century warming suggested that Earth might warm less than some models predicted. However, recent data of the amount of heat energy trapped within the Earth system—the energy imbalance—indicates that Earth may actually be warming faster, aligned with models that forecast higher temperatures. We partially resolve this contradiction by showing that during the recent observational period, both temperature and the energy imbalance point to higher future warming. We also show how previous analyses were skewed by natural, short-term climate fluctuations, known as internal variability. By filtering out this natural variability and using trends of temperature and the energy imbalance, we provide a revised very likely range of future warming. We show that the energy imbalance is a potentially strong new line of evidence to narrow our uncertainty about future warming. Our findings indicate that it becomes increasingly difficult to exclude models with strong future warming.

1. Introduction

Global climate models (GCMs) simulate a wide range of future warming in the 21st century, even when run with the same scenario of anthropogenic and natural forcings (Forster et al., 2021). Reducing the uncertainty in future warming is a key challenge in climate science: it is the basis for assessing carbon budgets and shaping climate policy (Matthews et al., 2021), and it informs the development of climate adaptation measures from global to regional and local levels.

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Full paper: here

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Key Points:

- Recent surface warming and top-of-atmosphere energy imbalance point to higher future warming than previously estimated
- Previous constraints on transient climate response using observed surface temperature trends are biased low due to internal variability in recent decades
- The energy imbalance has a strong potential to constrain future warming due to large model spread in top-of-atmosphere radiative fluxes

Supporting Information:

Supporting Information may be found in the online version of this article.

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Author Contributions:

Conceptualization: G. Gyuleva, E. Fischer, R. Knutti, S. Sippel
Data curation: G. Gyuleva
Formal analysis: G. Gyuleva
Funding acquisition: R. Knutti, S. Sippel
Methodology: G. Gyuleva, E. Fischer
Resources: R. Knutti
Supervision: R. Knutti, S. Sippel
Visualization: G. Gyuleva
Writing – original draft: G. Gyuleva
Writing – review & editing: G. Gyuleva, E. Fischer, R. Knutti, S. Sippel

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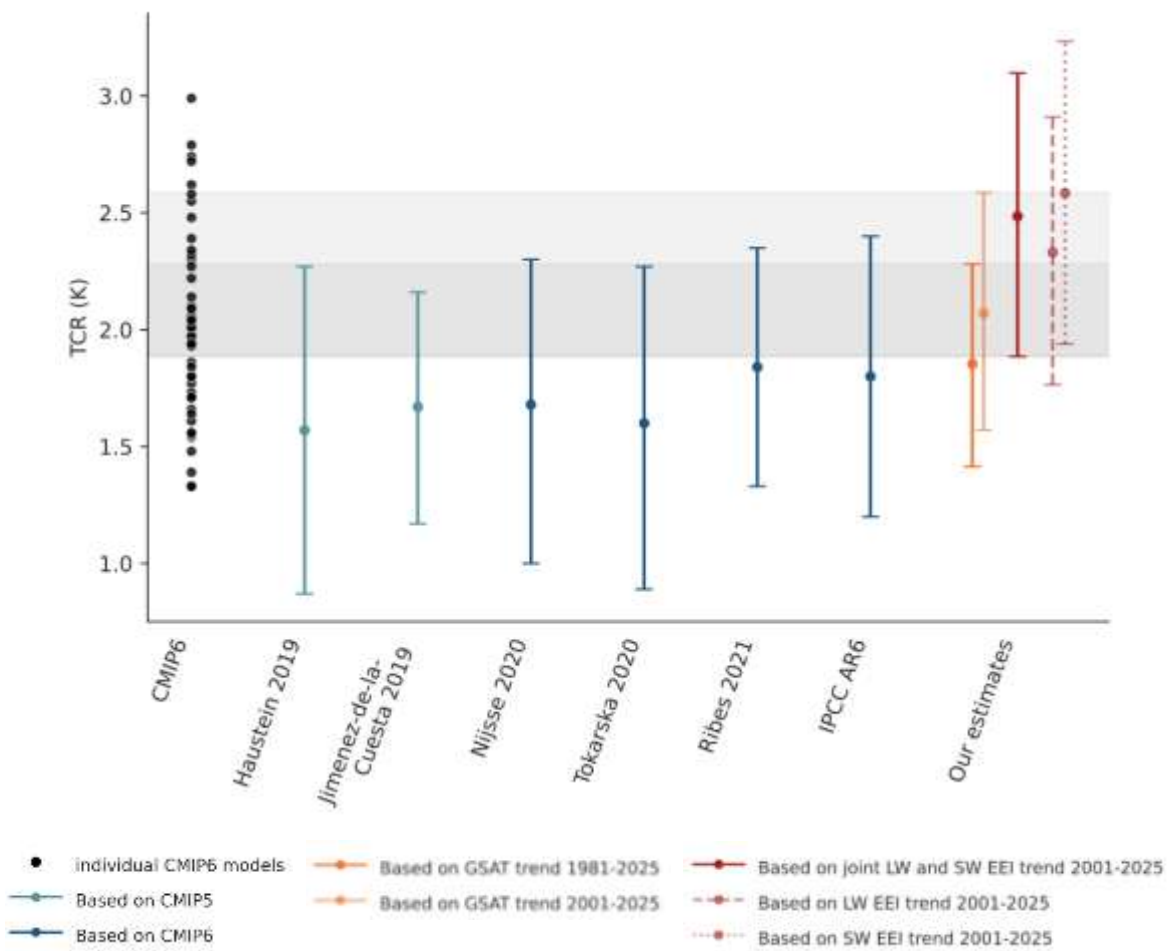

Full paper: here

Earth's Future

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Visualization: G. Gyuleva
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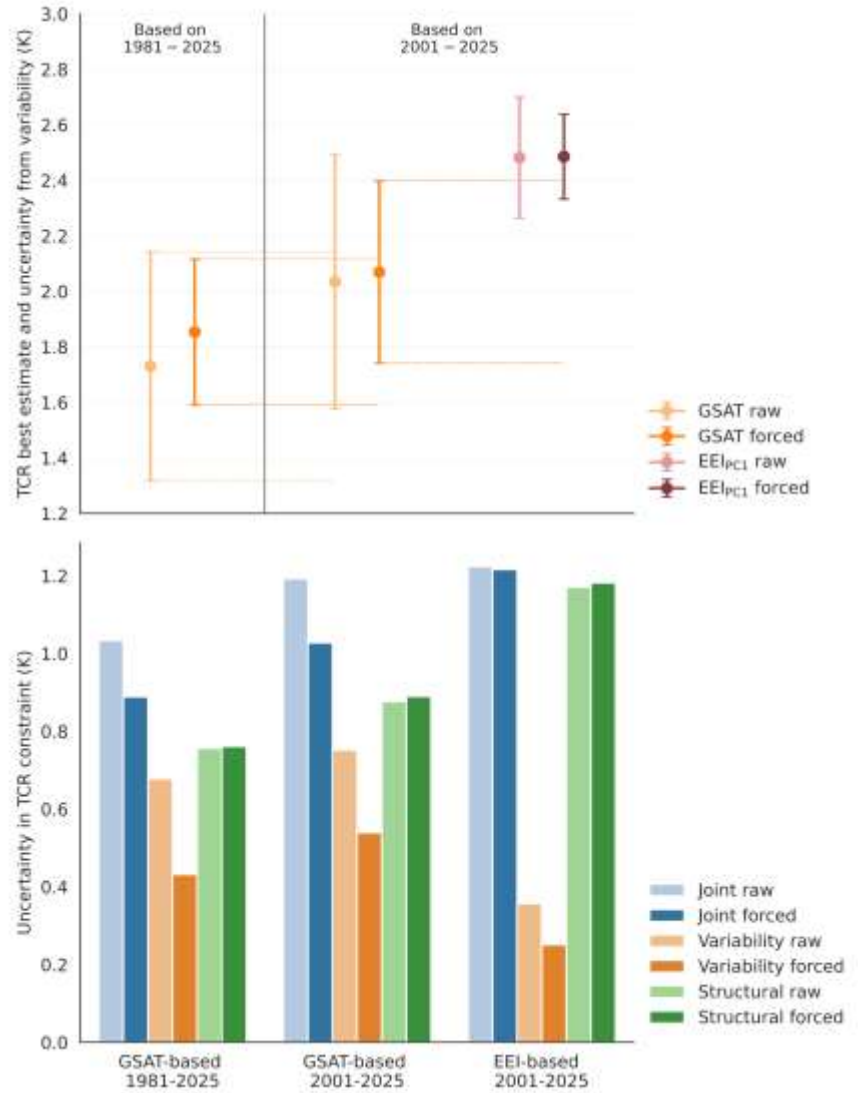

Full paper: here

Science

20 Sep 2024

A 485-million-year history of Earth's surface temperature

EMILY J. JUDD, JESSICA E. TIERNEY, DANIEL J. LUNT, ISABEL P. MONTAÑEZ, BRIAN T. HUBER, SCOTT L. WING, AND PAUL J. VALDES

Full paper: here

Abstract

A long-term record of global mean surface temperature (GMST) provides critical insight into the dynamical limits of Earth's climate and the complex feedbacks between temperature and the broader Earth system. Here, we present PhanDA, a reconstruction of GMST over the past 485 million years, generated by statistically integrating proxy data with climate model simulations. PhanDA exhibits a large range of GMST, spanning 11° to 36°C. Partitioning the reconstruction into climate states indicates that more time was spent in warmer rather than colder climates and reveals consistent latitudinal temperature gradients within each state. There is a strong correlation between atmospheric carbon dioxide (CO_2) concentrations and GMST, identifying CO_2 as the dominant control on variations in Phanerozoic global climate and suggesting an apparent Earth system sensitivity of ~8°C.

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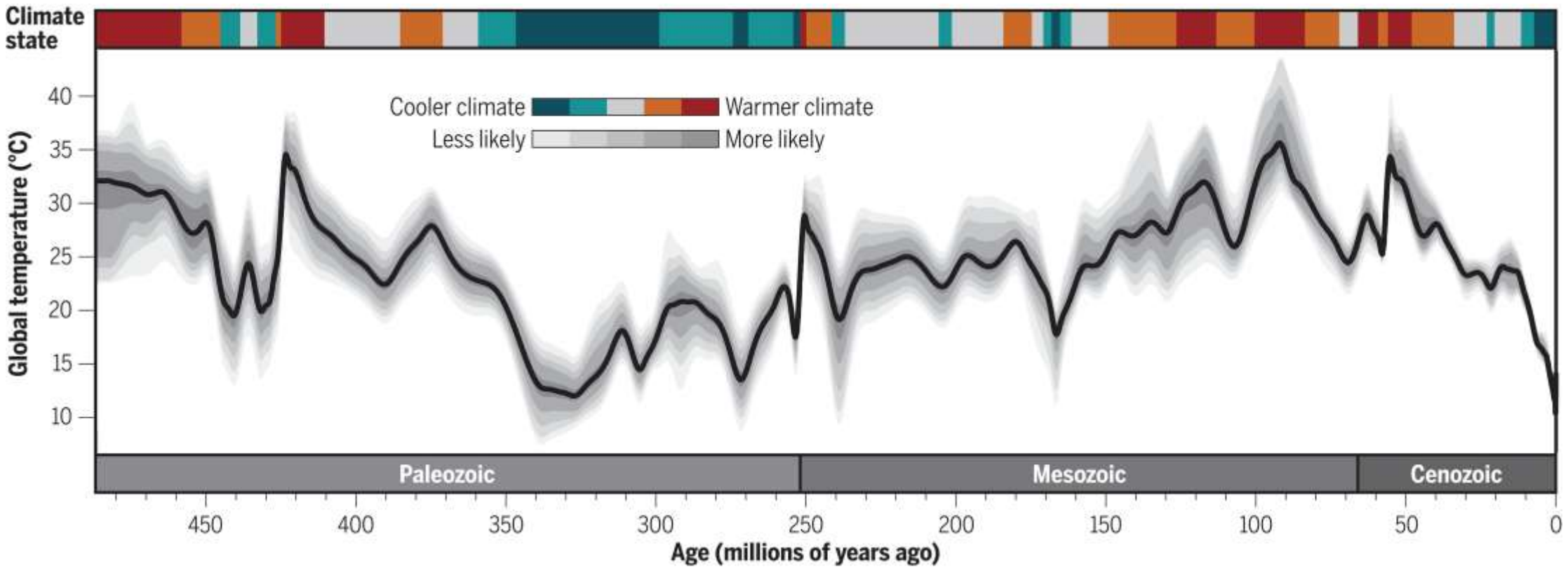

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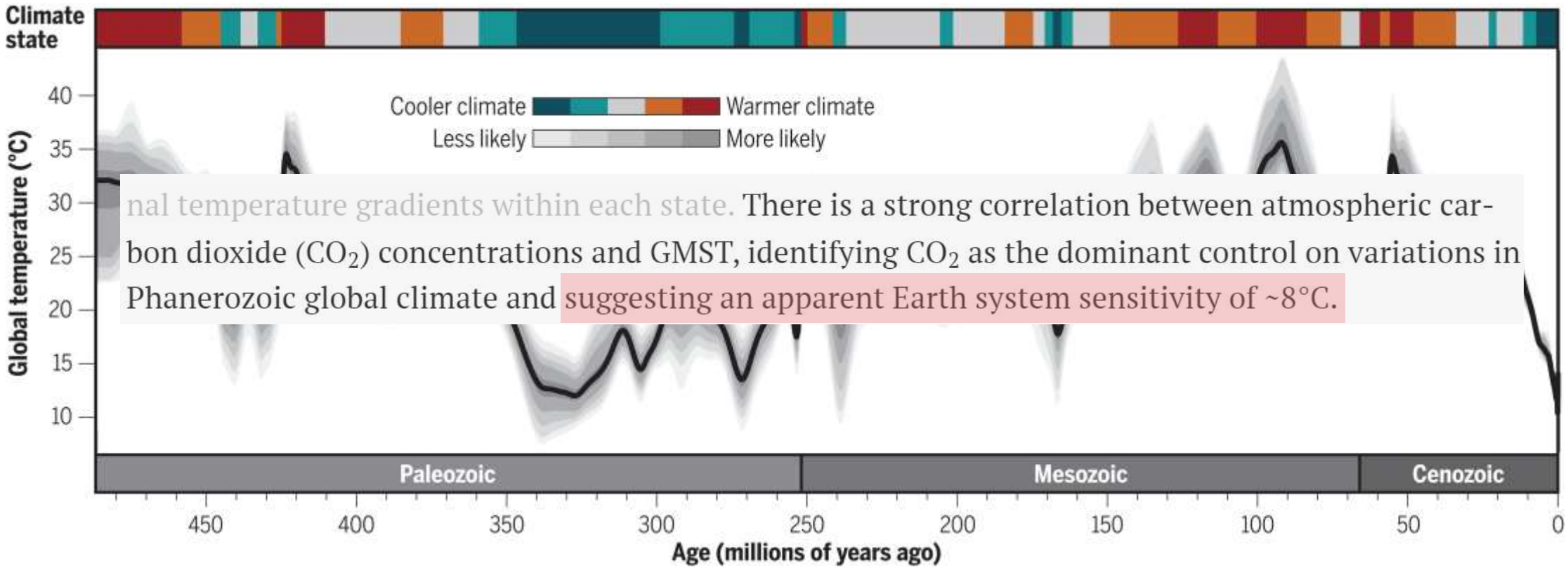

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Super El Nino? Super Warming is the Main Issue.

James Hansen, Pushker Kharecha, Dylan Morgan and Jasen Vest

20 March 2026

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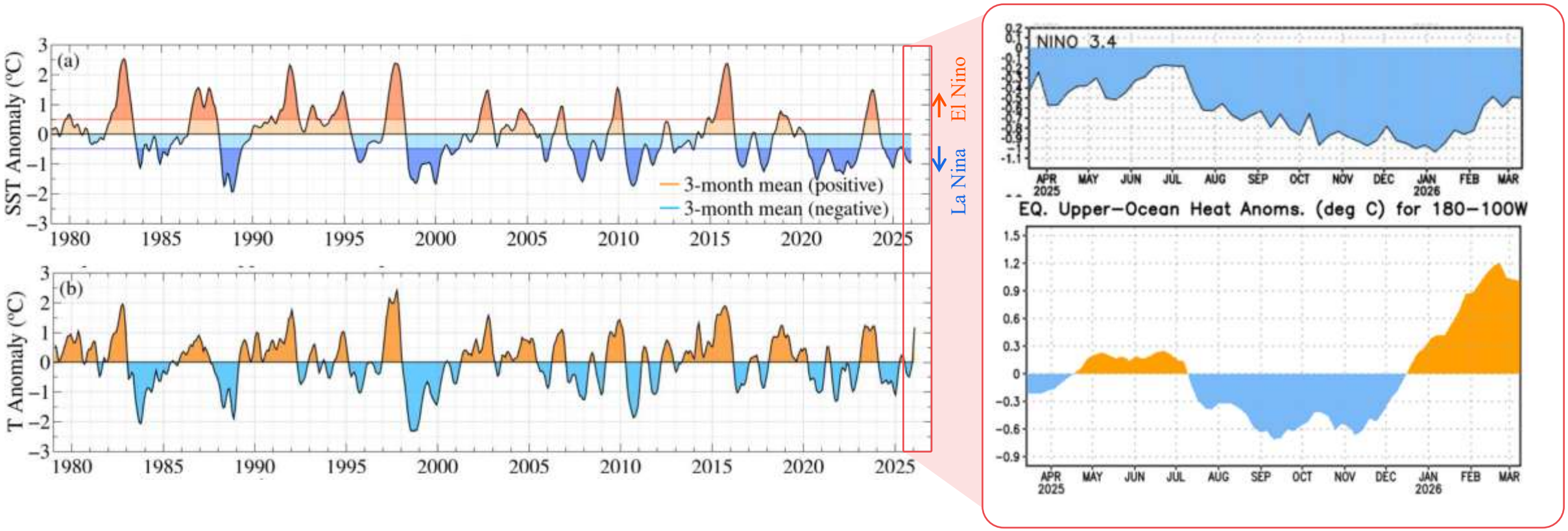


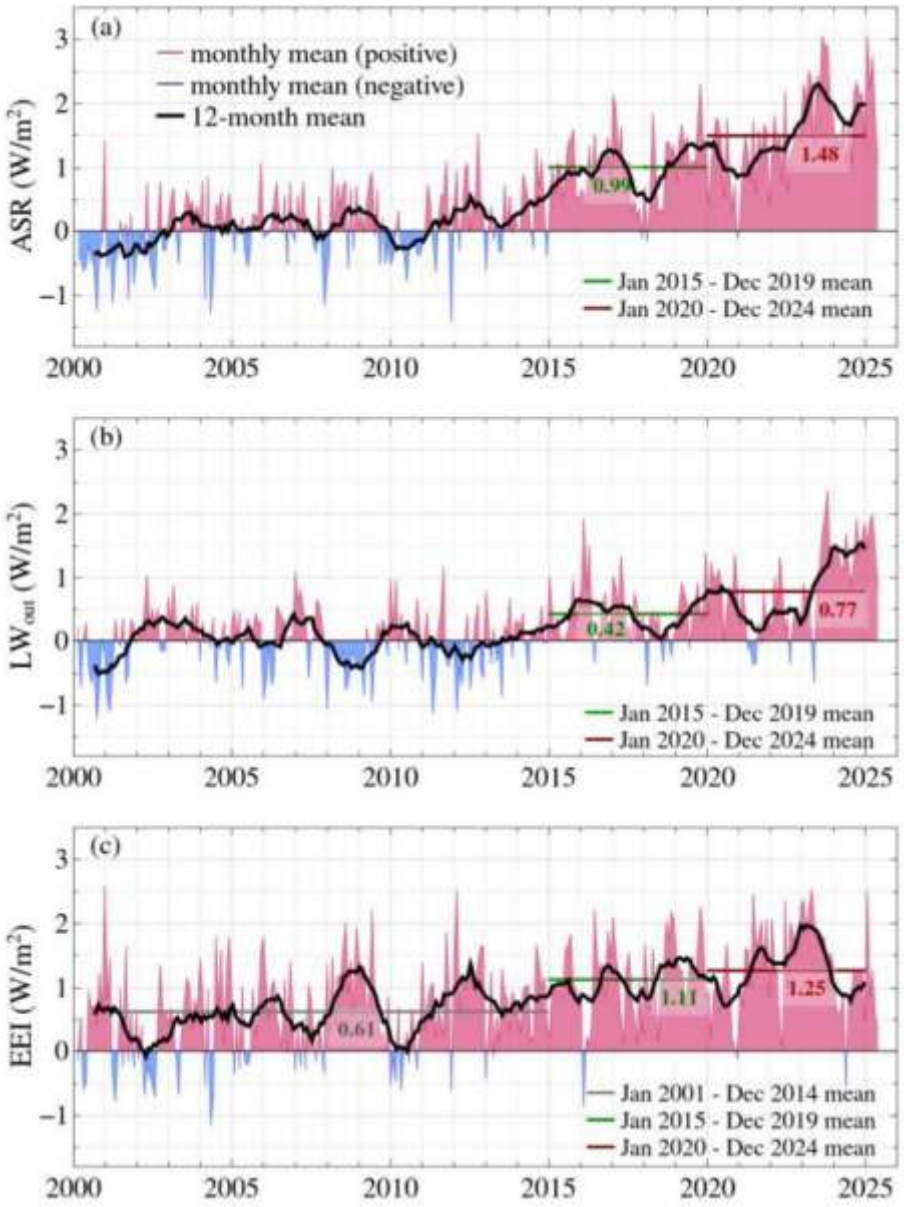
6 August 2025

Full paper: here

Seeing the Forest for the Trees

James Hansen, Pushker Kharecha

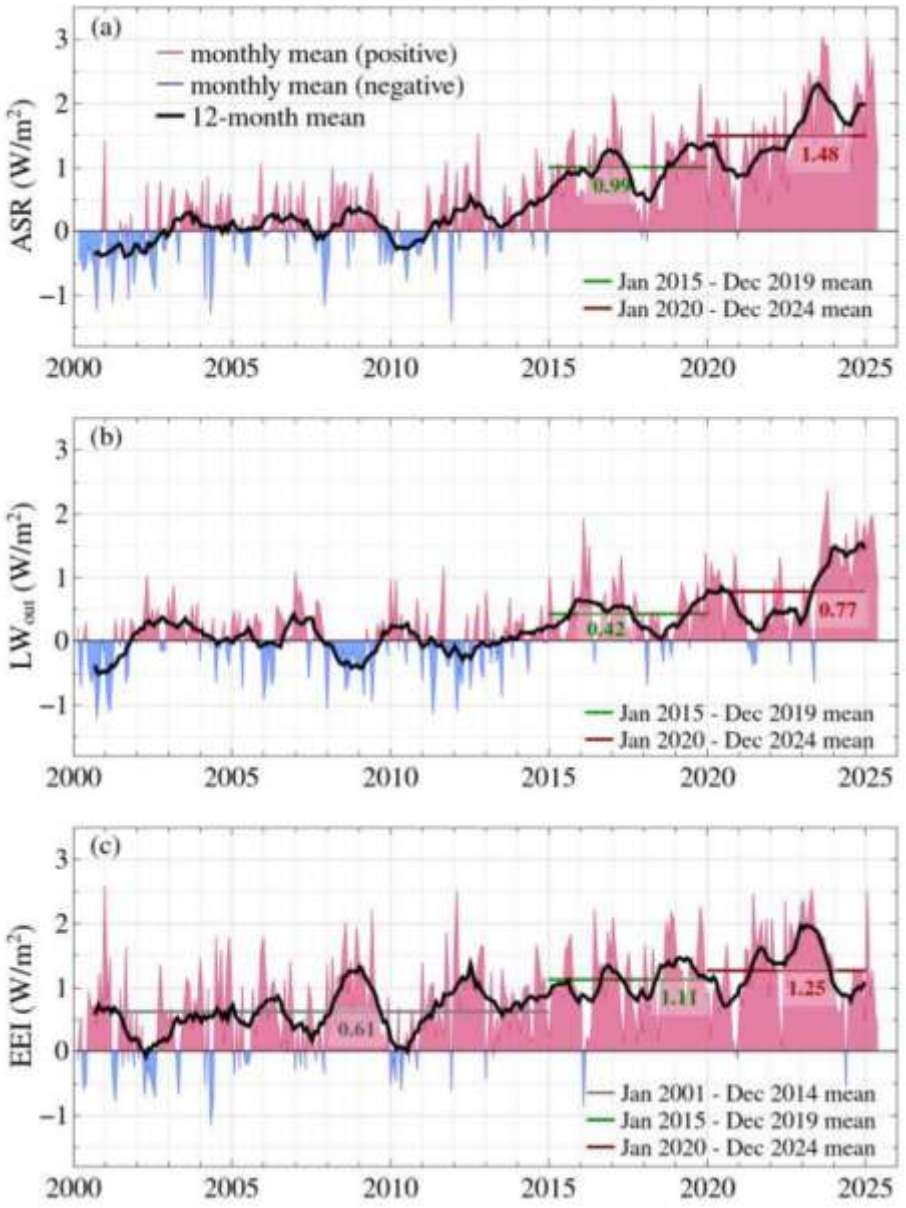
Abstract. Climate sensitivity is substantially higher than IPCC's best estimate (3°C for doubled CO2), a conclusion we reach with greater than 99 percent confidence. We also show that global climate forcing by aerosols became stronger (increasingly negative) during 1970-2005, unlike IPCC's best estimate of aerosol forcing. High confidence in these conclusions is based on a broad analysis approach. IPCC's underestimates of climate sensitivity and aerosol cooling follow from their disproportionate emphasis on global climate modeling, an approach that will not yield timely, reliable, policy advice.



6 August 2025

Full paper: here

Climate sensitivity ~ 4-5 °C



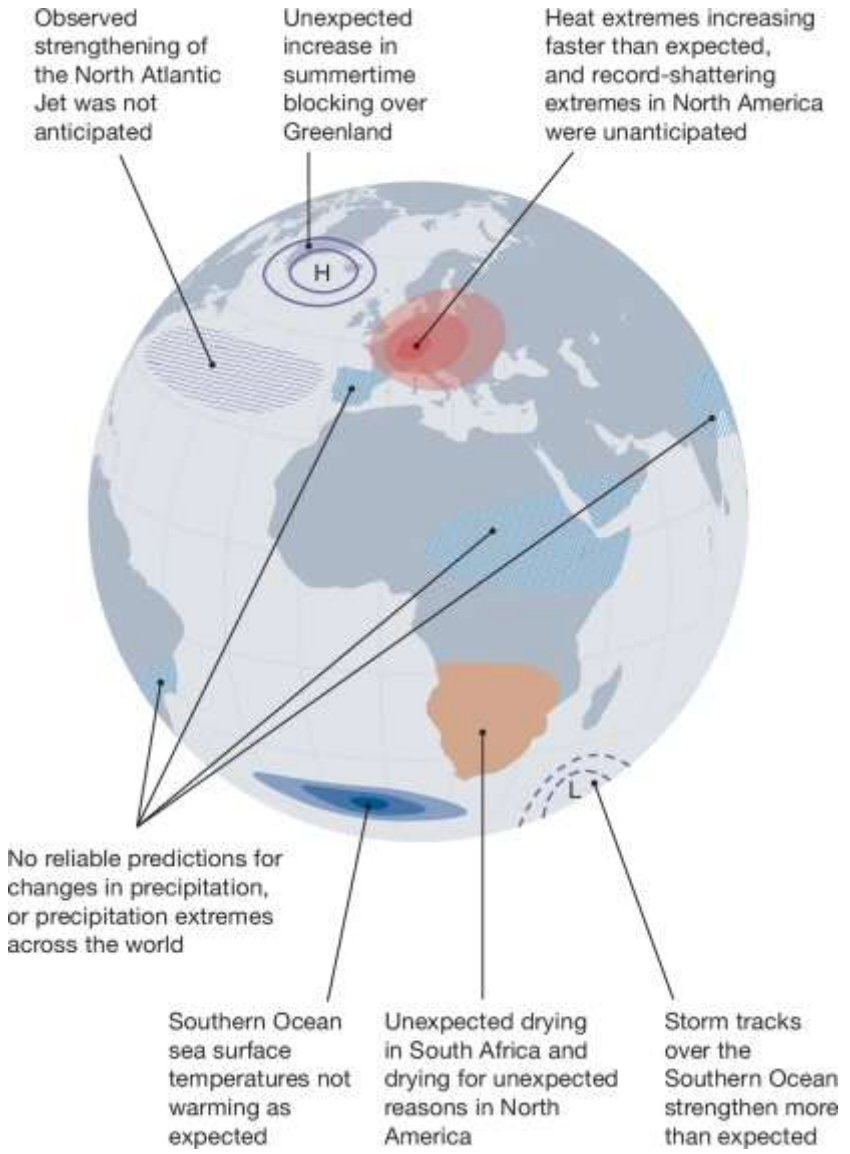
nature
26 March 2025

The other climate crisis

Tiffany A. Shaw ✉ & Bjorn Stevens

Abstract

As Earth warms, regional climate signals are accumulating. Some signals, for example, land warming more than the ocean and the Arctic warming the most, were expected and successfully predicted. Underlying this success was the application of physical laws under the assumption that large and small spatial scales are well separated. This established what we call the standard approach, climate science's dominant paradigm. With additional warming, however, discrepancies between real-world signals and expectations based on this standard approach are piling up, especially at regional scales. At the same time, disruptive computational approaches are advancing new paradigms. Philosophers of science characterize situations where accumulating discrepancies (anomalies) and disruptions lead to a loss of confidence in the dominant paradigm as a 'crisis'. Here we articulate what we consider to be the dominant paradigm, or standard approach, and the discrepancies and disruptions that have emerged in recent years. The policy implications of a purported crisis are discussed, as well as paths forward, crisis or no crisis. These paths include using signals to test assumptions and processes driving a warming Earth for the first time, developing testable hypotheses, and revitalizing conceptual thinking by filling gaps across climate-system components and spatial scales.



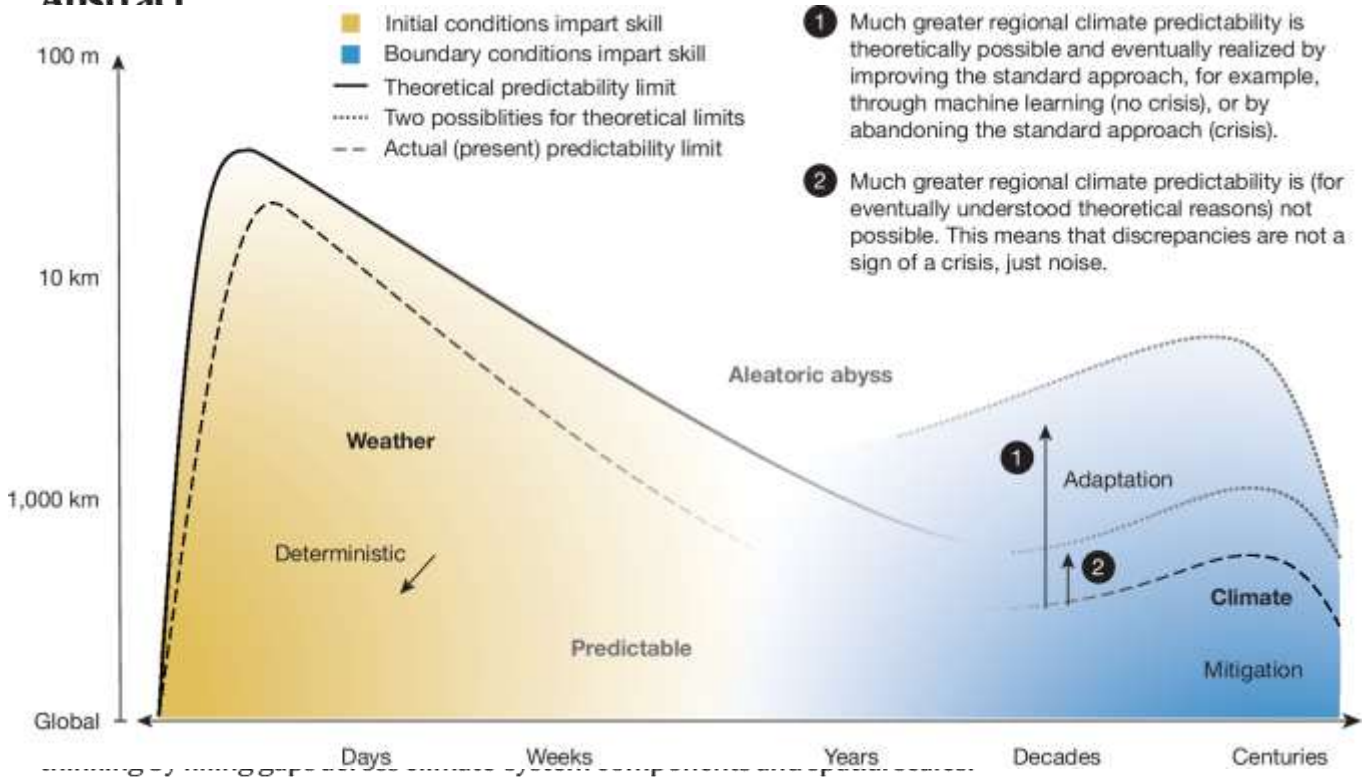
Full paper: here

nature
26 March 2025

The other climate crisis

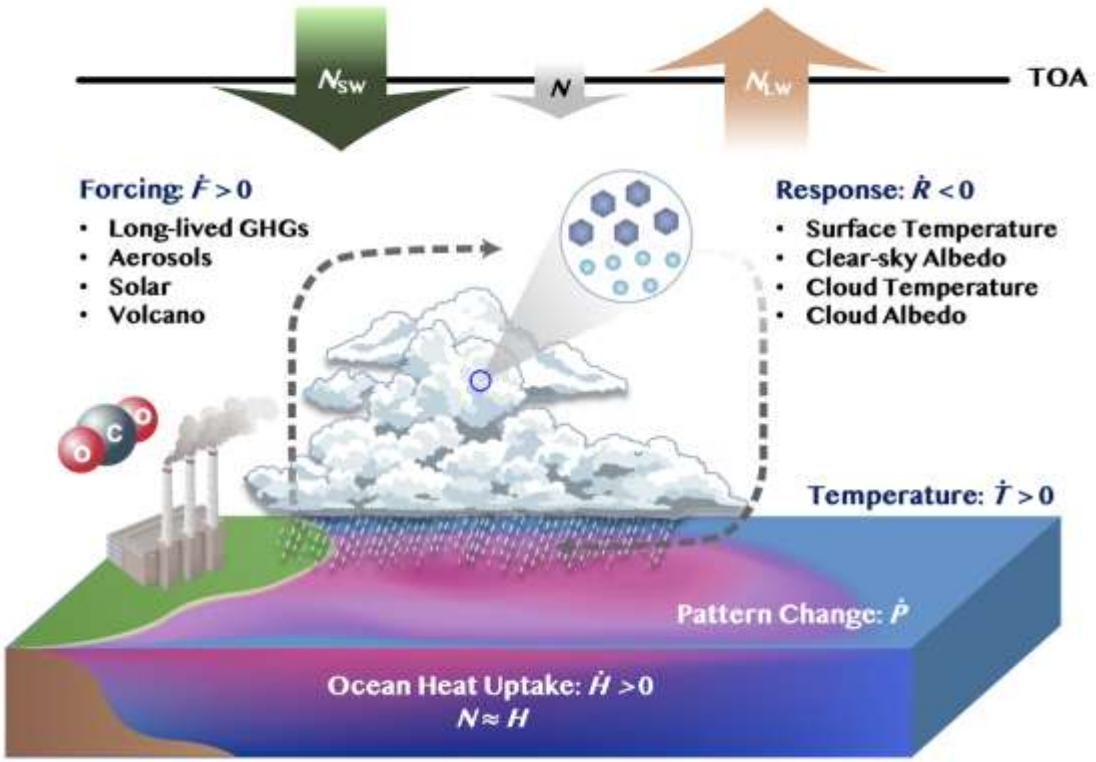
Tiffany A. Shaw ✉ & Bjorn Stevens

Abstract



Is runaway climate dynamics via cloud feedback possible?

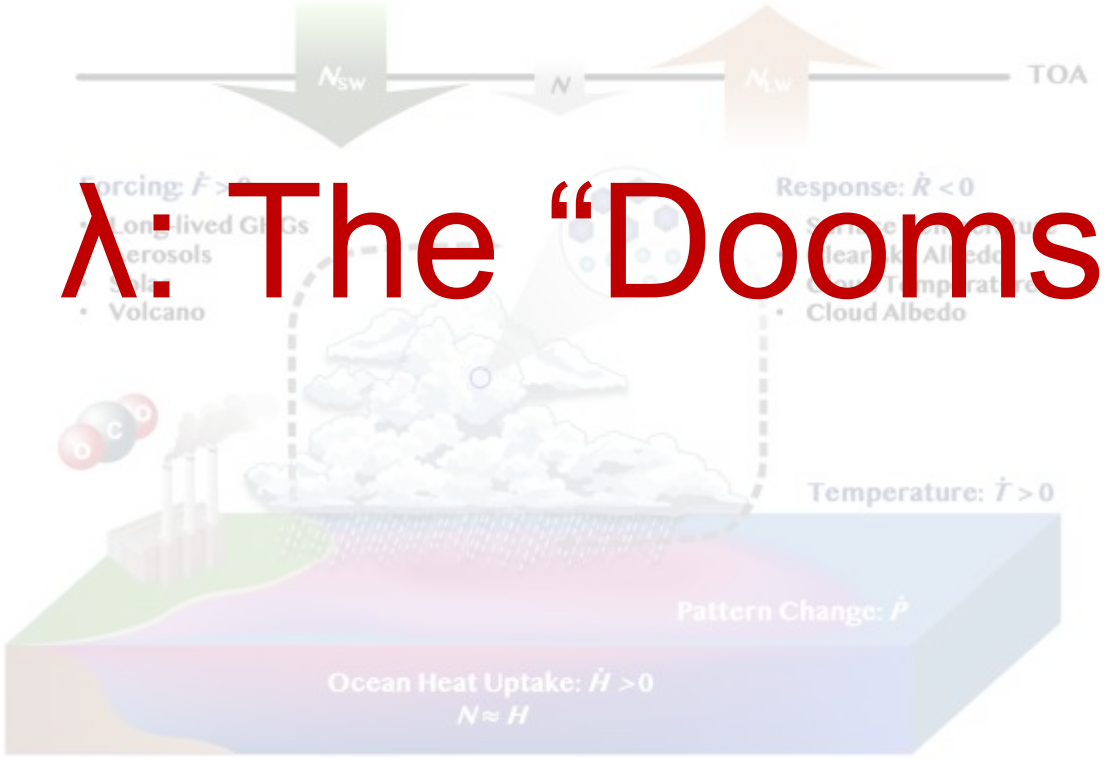
Full paper: here



Earth's net incoming energy-flux imbalance

– and its implications for understanding climate change –

Full report: here



λ: The "Doomsday Parameter"?

Earth's net incoming energy flux imbalance
– and its implications for understanding climate change –

Full report: here

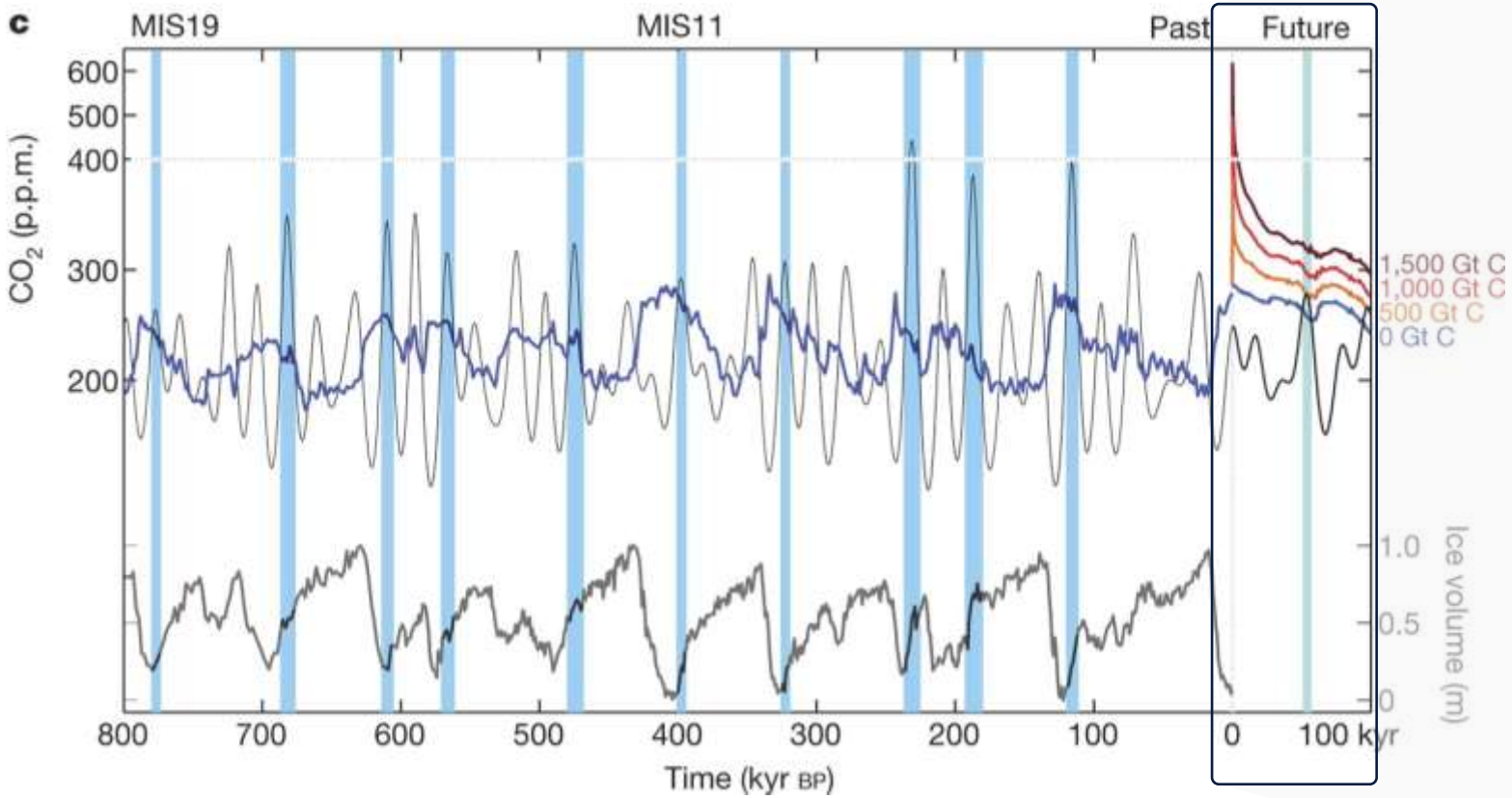
Q_3 How to restore the Holocene climate?

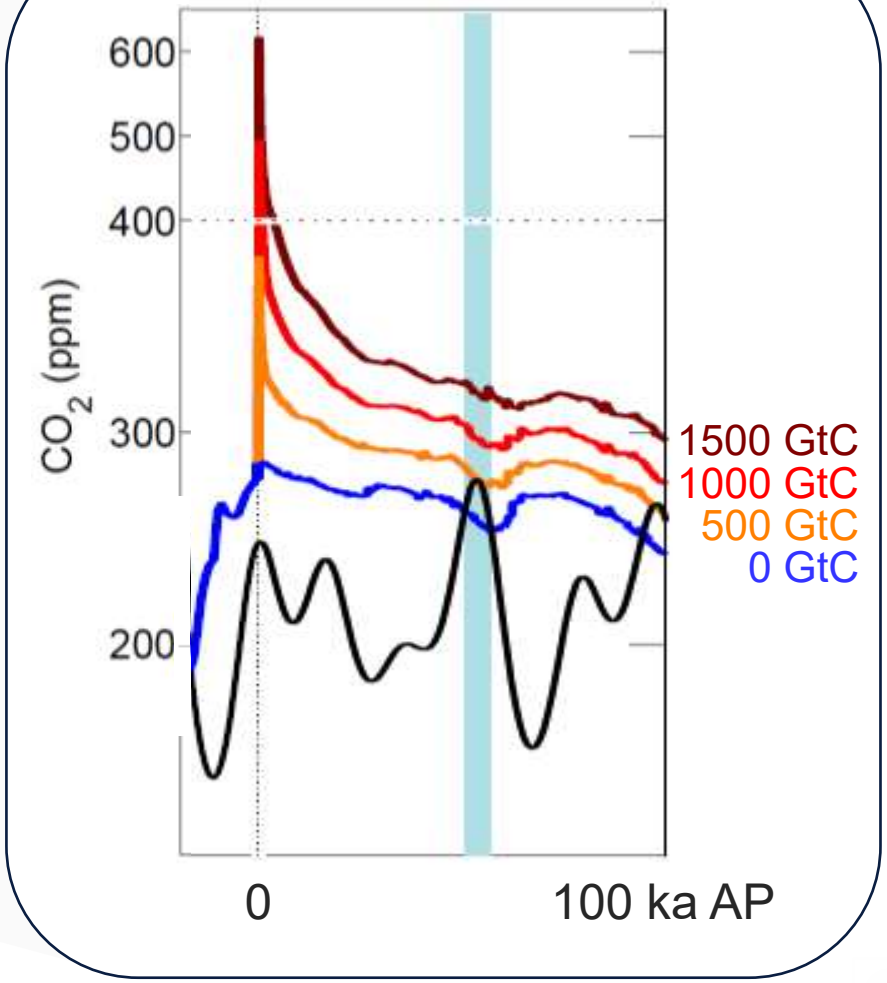
© Nils Leonhardt | Unsplash

nature
13 January 2016

Critical insolation–CO_2 relation for diagnosing past and future glacial inception

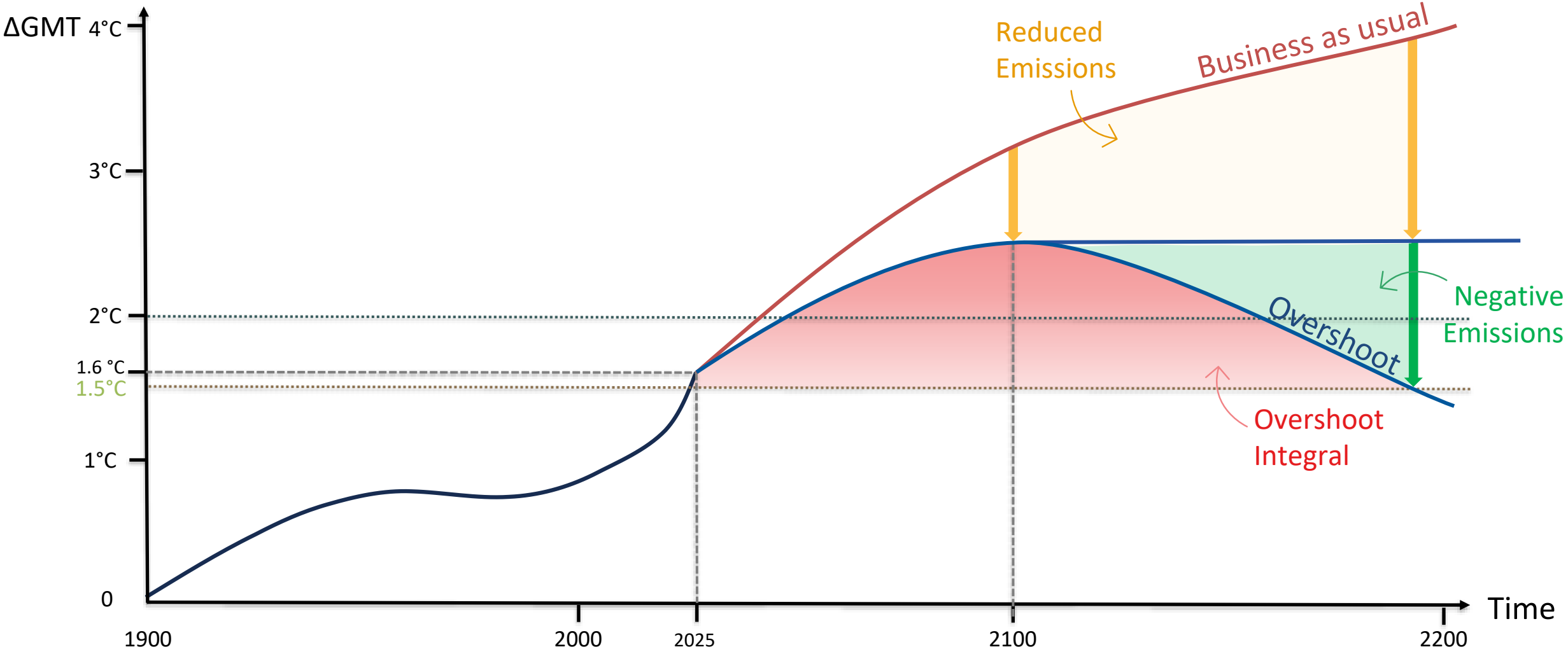
A. Ganopolski ✉, R. Winkelmann & H. J. Schellnhuber





Full paper: here

Climate Restoration: Repair or Despair!

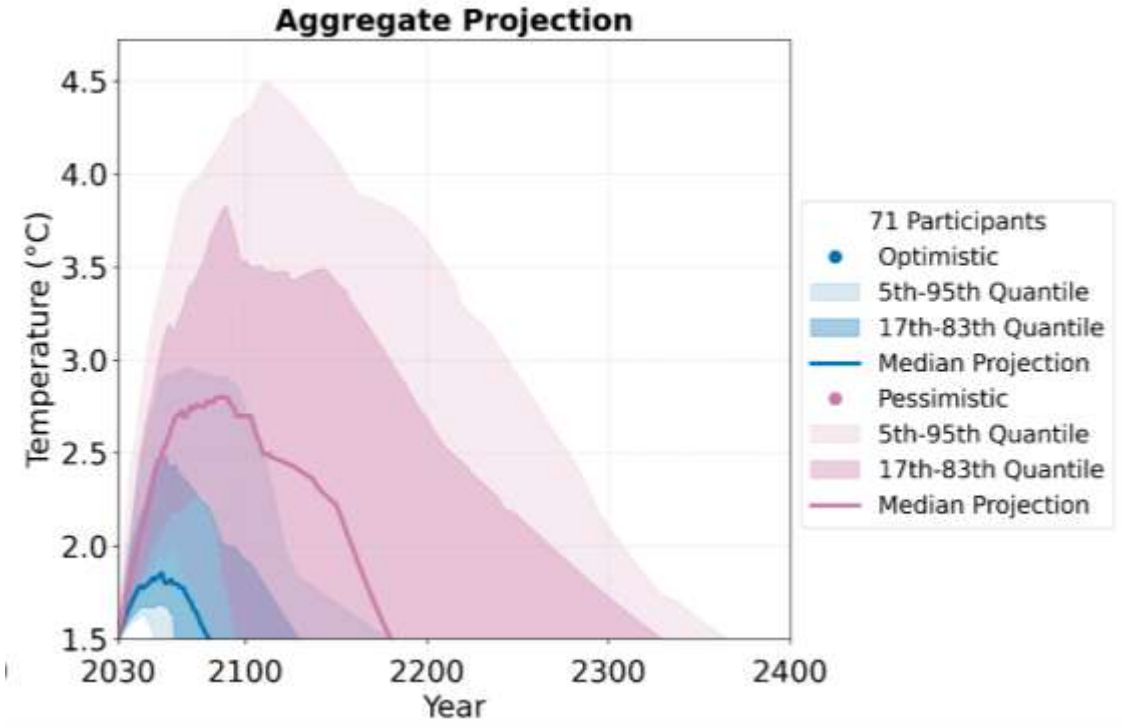


Schematic Illustration

Schellnhuber & Köllner 2022 (unpublished)

OVERSHOOT CONFERENCE
2025 | Laxenburg
30.Sep – 02.Oct

Overshoot as a paradigm shift



Expert eliciation conference participants on optimistic and pessimistic climate overshoot scenarios

- **The world is on track to exceed** global warming of **1.5°C** and has **entered the period where 1.5°C impacts** need to be expected
- Ever more solidified science on the need, and obligations unter international law, to **bring warming back down below 1.5°C in the long run**
- **Overshoot means the task got a lot harder**, and will take a lot longer
- **Overshoot is the 2nd best world**, **characterised by trade-offs** that require an integrated, interdisciplinary perspective

With courtesy of
Carl-Friedrich Schleussner

The Atlantic
JULY 10, 2025

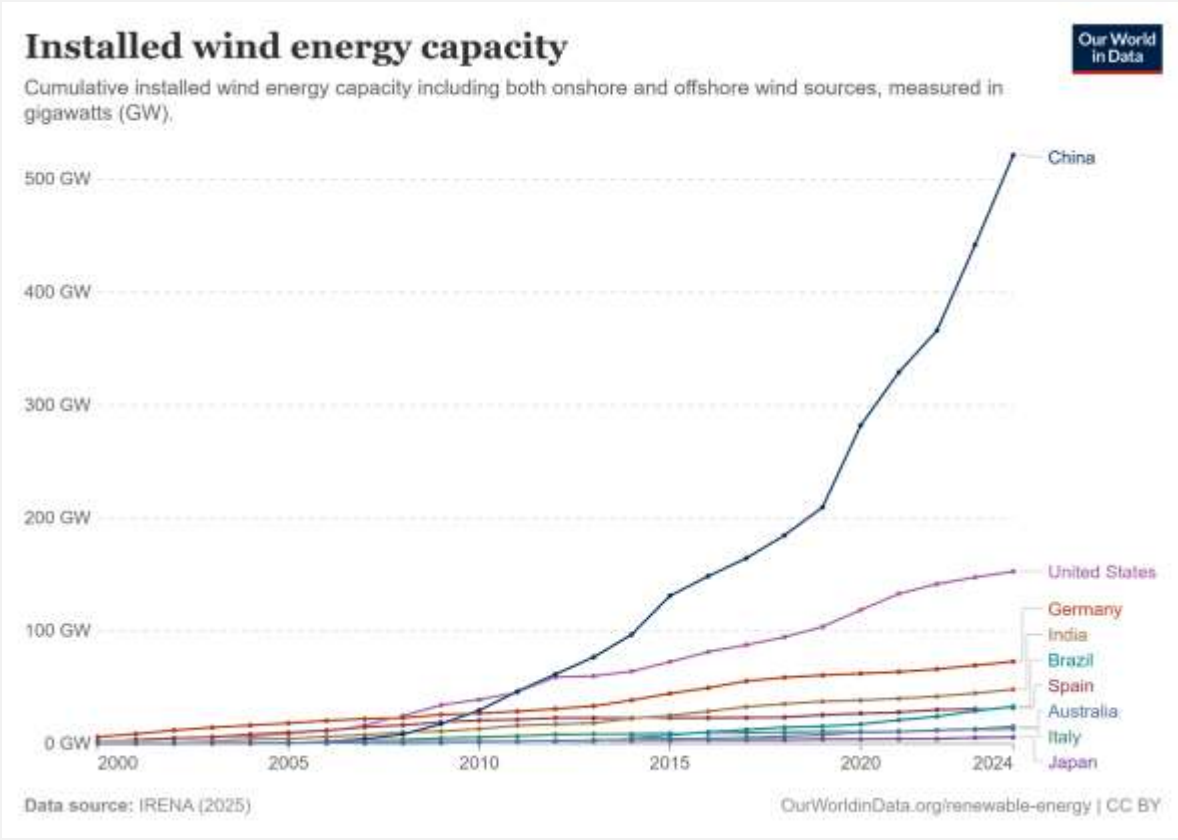
The Scale of China's Solar-Power Project

As the Trump administration's "Big, Beautiful Bill" eliminates many clean-energy incentives in the U.S., China continues huge investments in wind and solar power, reportedly accounting for 74 percent of all projects now under construction worldwide.

By Alan Taylor

Full article: here

Solar panels cover hillsides in Zhangjiakou, in China's northern Hebei province, on November 15, 2021.



Explore data: here

Cities in the Evolution of the Carbon Cycle

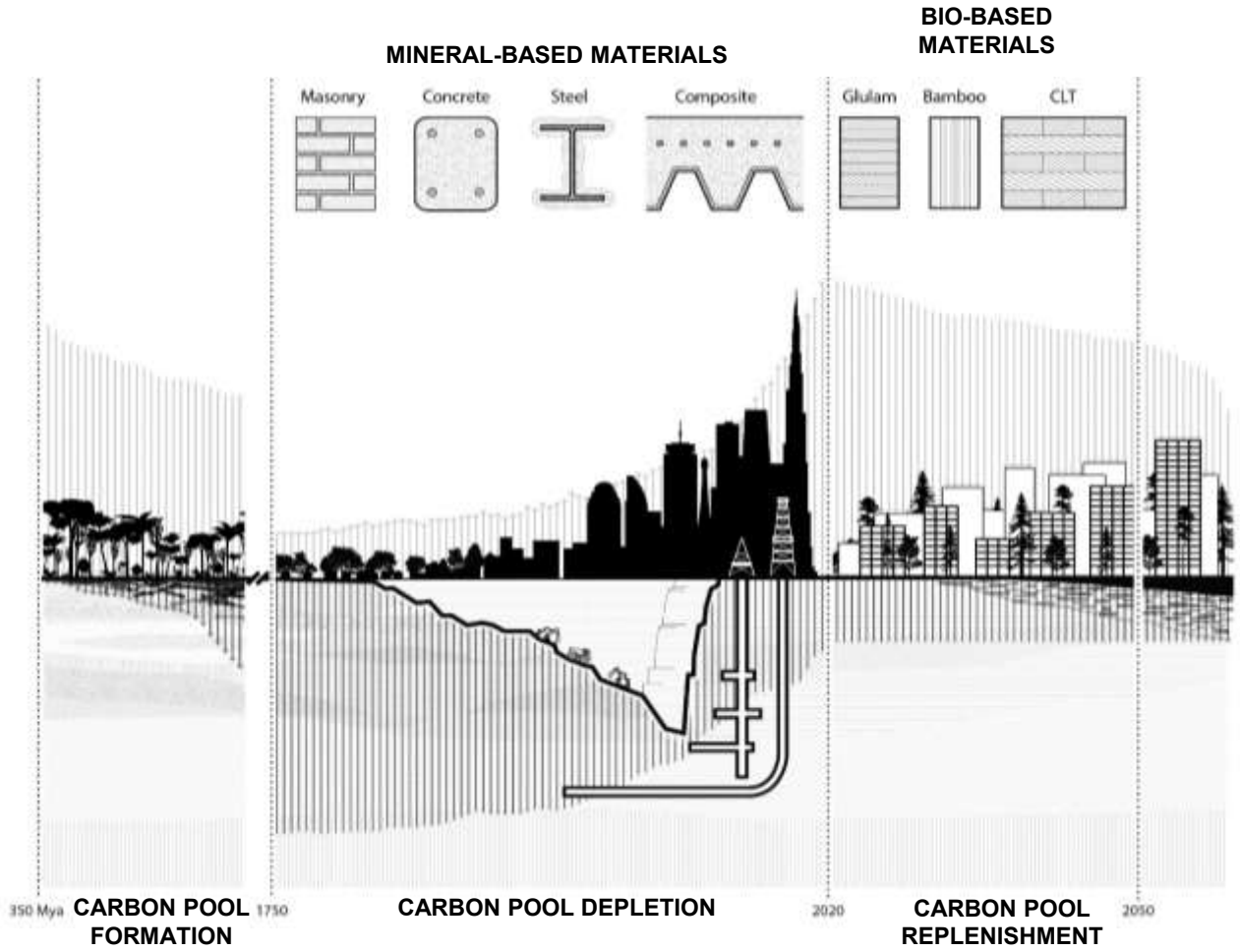
nature sustainability

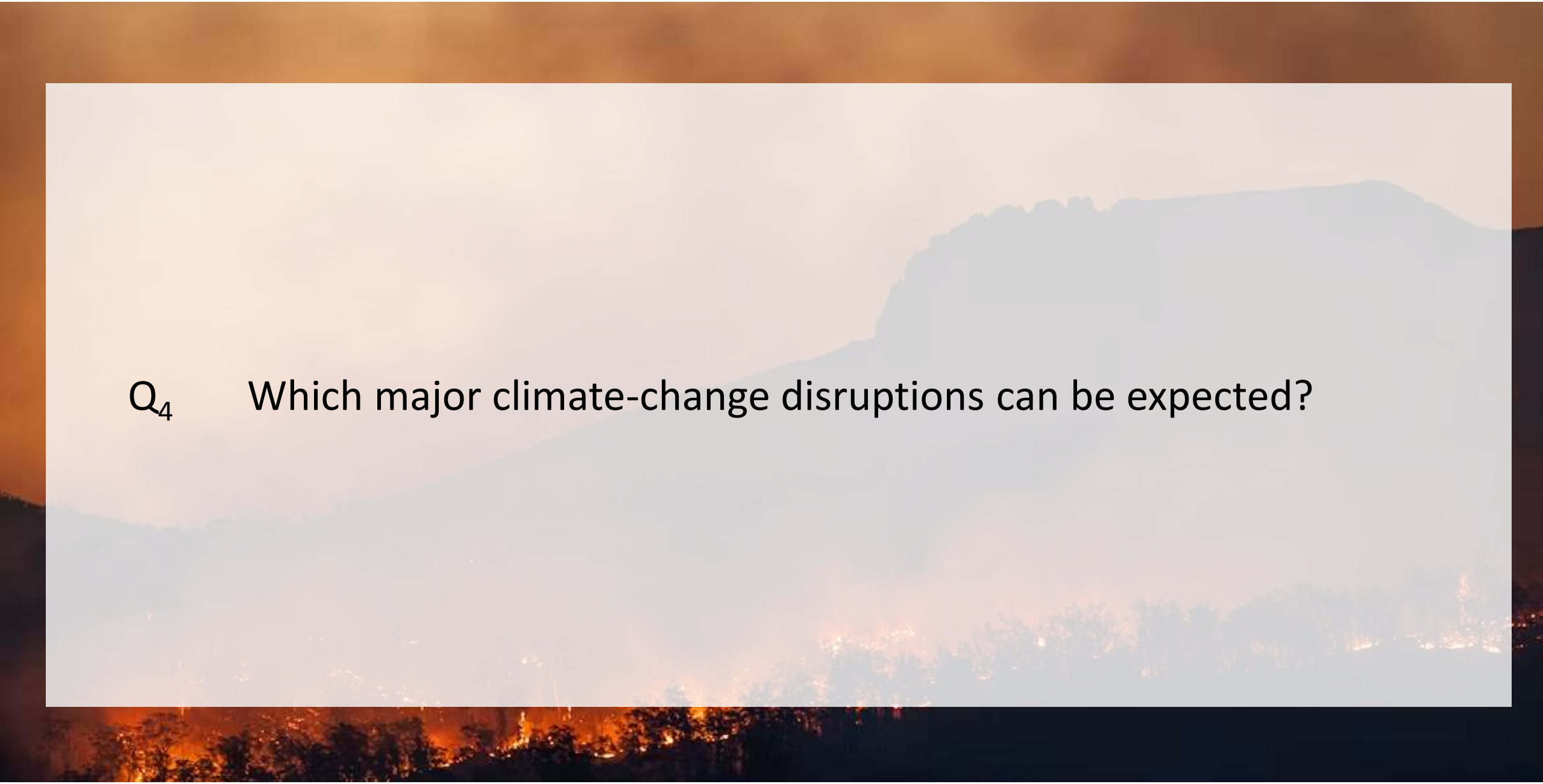
Perspective | Published: 27 January 2020

Buildings as a global carbon sink

Galina Churkina ✉, Alan Organschi, Christopher P. O. Reyer, Andrew Ruff, Kira Vinke, Zhu Liu, Barbara K. Reck, T. E. Graedel & Hans Joachim Schellnhuber

https://doi.org/10.1038/s41893-019-0462-4





Q_4 Which major climate-change disruptions can be expected?

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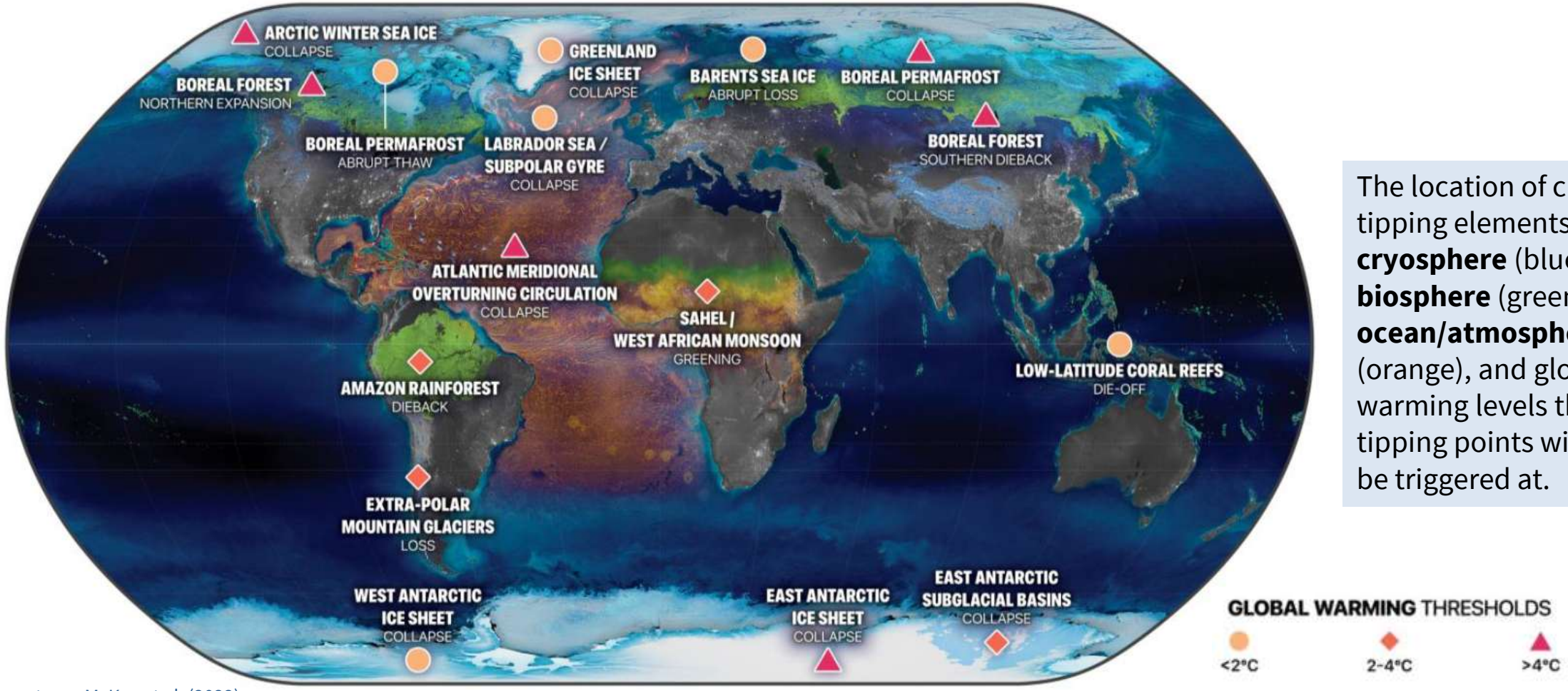
Exceeding 1.5°C Global Warming Could Trigger Multiple Climate Tipping Events

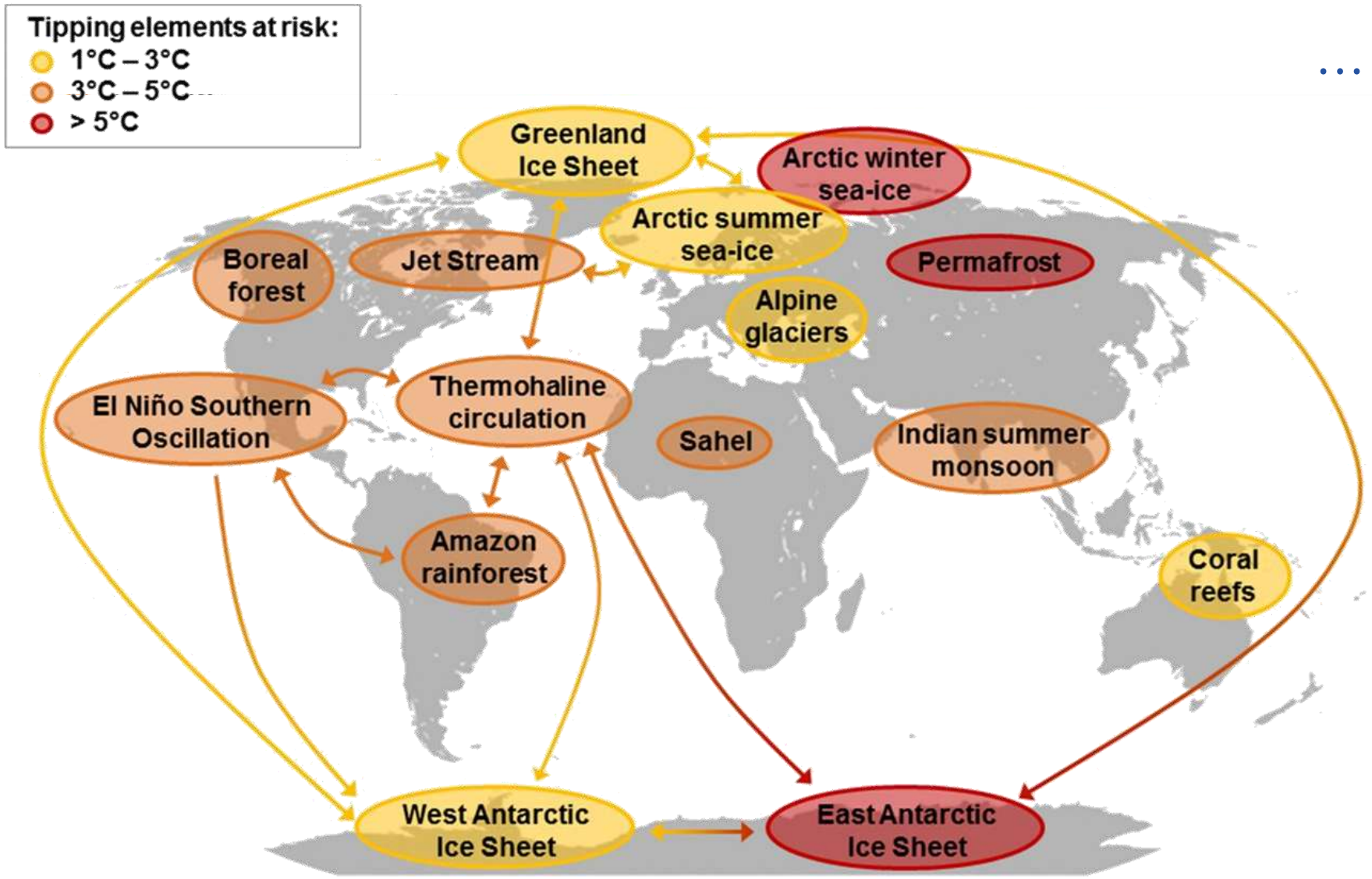


The location of climate tipping elements in the **cryosphere** (blue), **biosphere** (green) and **ocean/atmosphere** (orange), and global warming levels their tipping points will likely be triggered at.

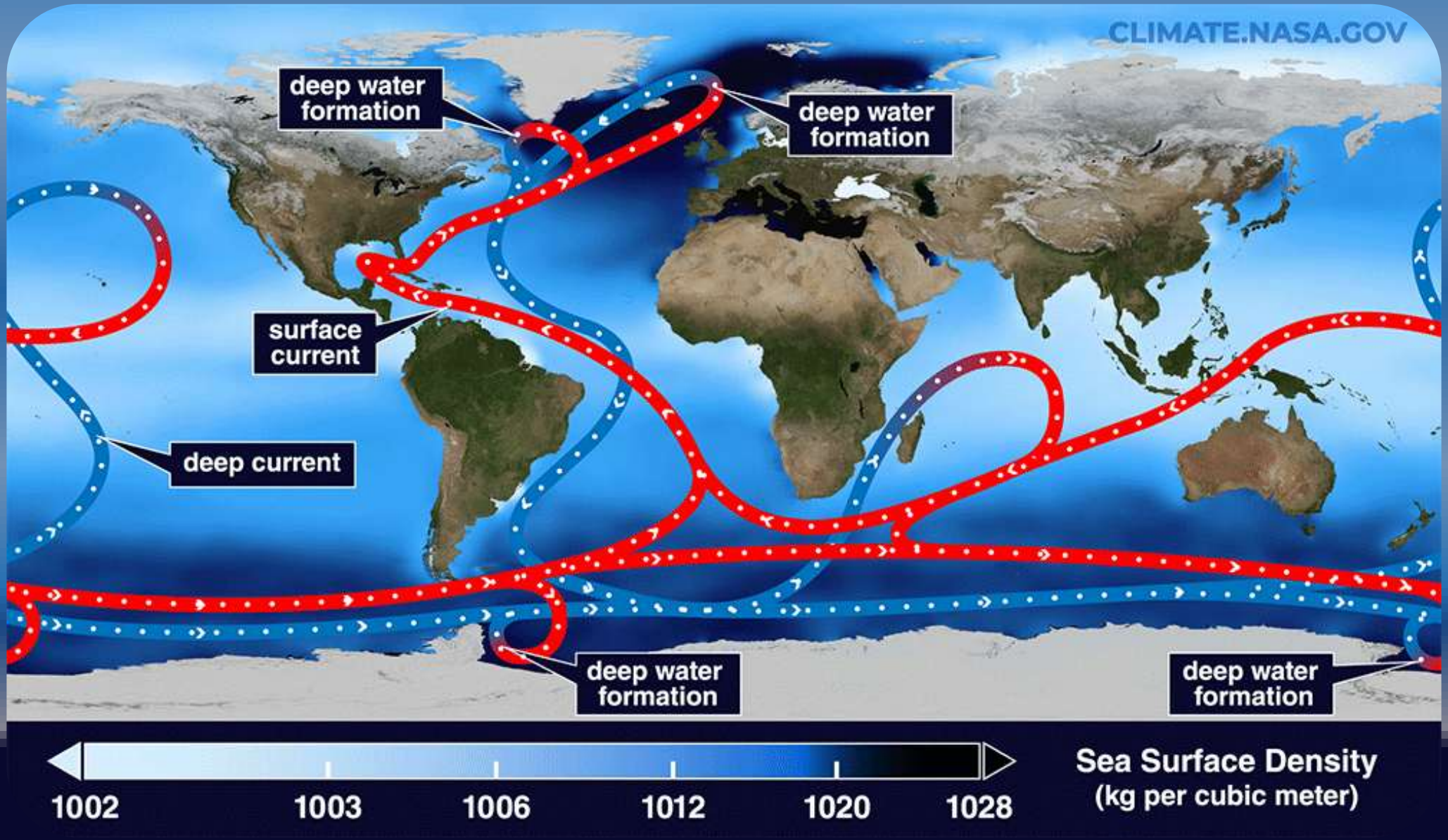
Armstrong McKay et al. (2022)

Exceeding 1.5°C Global Warming Could Trigger Multiple Climate Tipping Events

… and Tipping Cascades



Steffen et al. 2018



© NASA/Goddard Space Flight Center Scientific Visualization Studio

Shutdown of northern Atlantic overturning after 2100 following deep mixing collapse in CMIP6 projections

Sybren Drijfhout*, Joran R Angevaare, Jennifer Mecking, René M van Westen and Stefan Rahmstorf

ENVIRONMENTAL RESEARCH LETTERS
28 August 2025

Full paper: here

Abstract

Several, more recent global warming projections in the coupled model intercomparison project 6 contain extensions beyond year 2100–2300/2500. The Atlantic meridional overturning circulation (AMOC) in these projections shows transitions to extremely weak overturning below the surface mixed layer (<6 Sv; 1 Sv = 10^6 m^3 s^{-1}) in all models forced by a high-emission (SSP585) scenario and sometimes also forced by an intermediate- (SSP245) and low-emission (SSP126) scenario. These extremely weak overturning states are characterised by a shallow maximum overturning at depths less than 200 m and a shutdown of the circulation associated with North Atlantic deep water formation. Northward Atlantic heat transport at 26°N decreases to 20%–40% of the current observed value. Heat release to the atmosphere north of 45°N weakens to less than 20% of its present-day value and in some models completely vanishes, leading to strong cooling in the subpolar North Atlantic and Northwest Europe. In all cases, these transitions to a weak and shallow AMOC are preceded by a mid-21st century collapse of maximum mixed-layer depth in Labrador, Irminger and Nordic Seas. The convection collapse is mainly caused by surface freshening from a decrease in northward salt advection due to the weakening AMOC but is likely initiated by surface warming. Maximum mixed-layer depths in the observations are still dominated by internal variability but notably feature downward trends over the last 5–10 years in all deep mixing regions for all data products analysed. This could be merely variability but is also consistent with the model-predicted decline of deep mixing.

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Shutdown of northern Atlantic overturning after 2100 following deep mixing collapse in CMIP6 projections

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ENVIRONMENTAL RESEARCH LETTERS
28 August 2025

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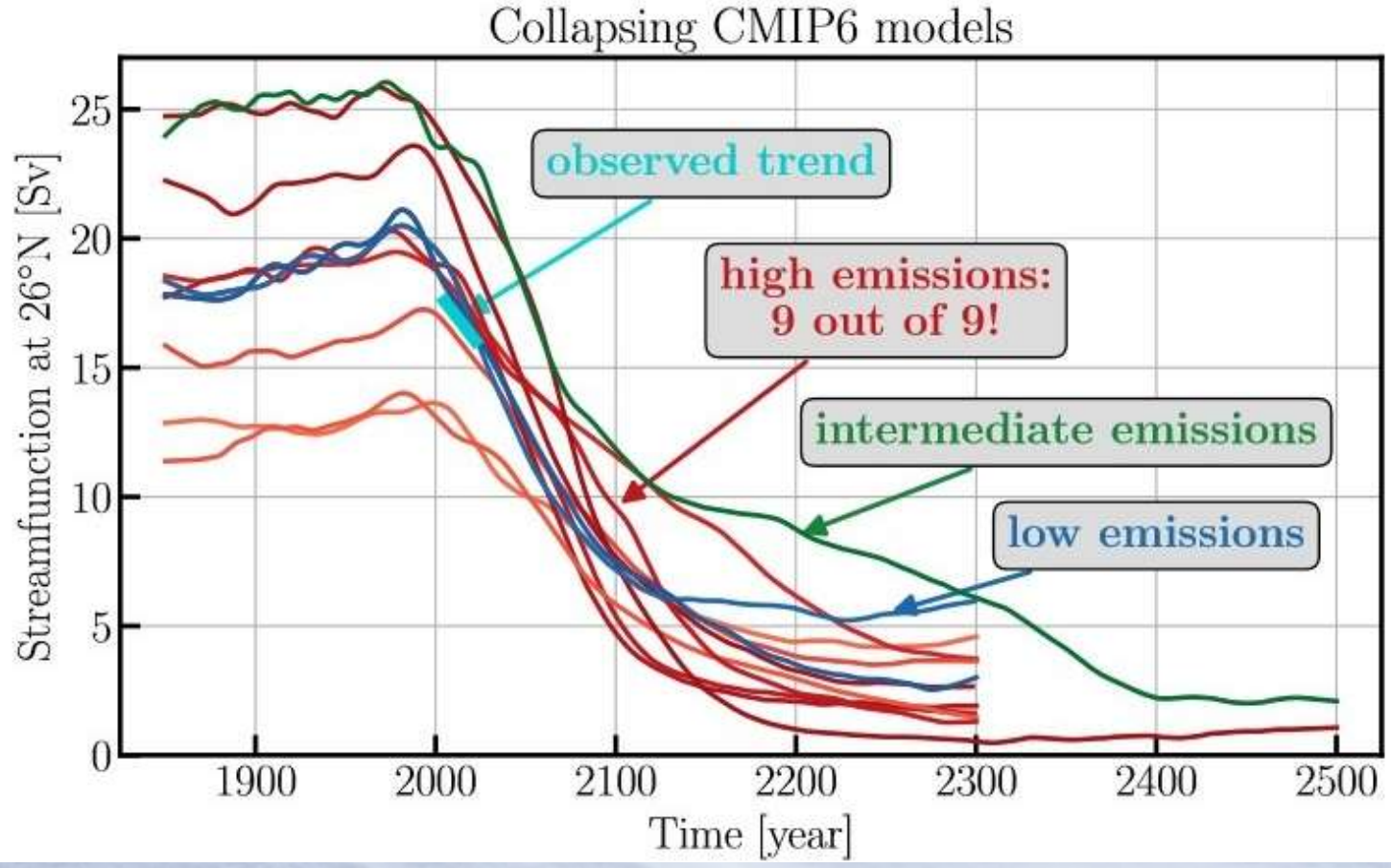

< 10 Sv in 2100:
shutdown

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ScienceAdvances
15 Apr 2026

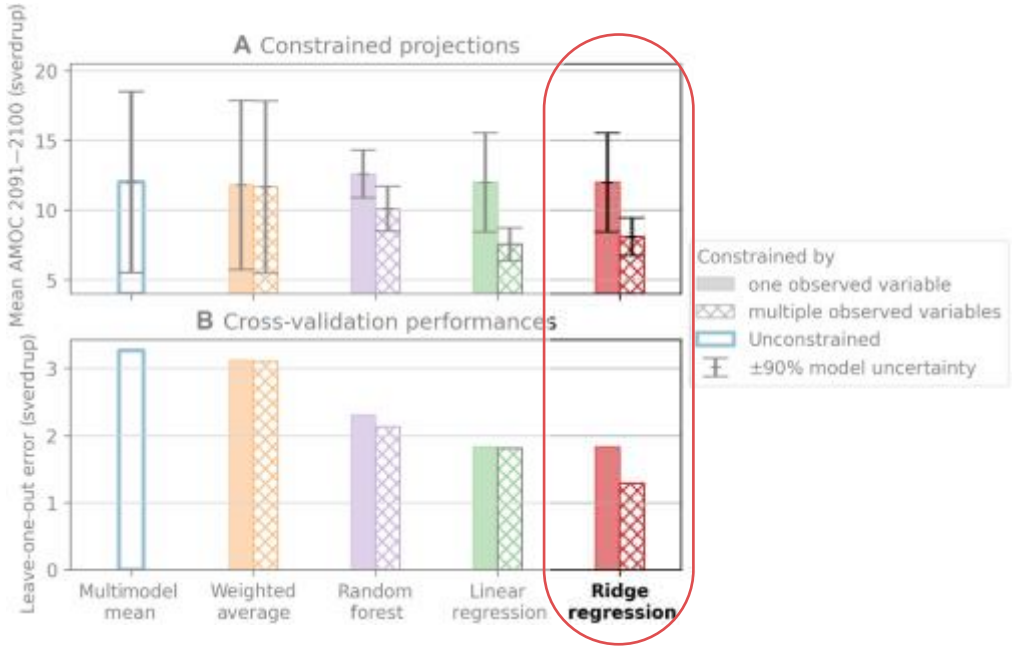
Observational constraints project a ~50% AMOC weakening by the end of this century

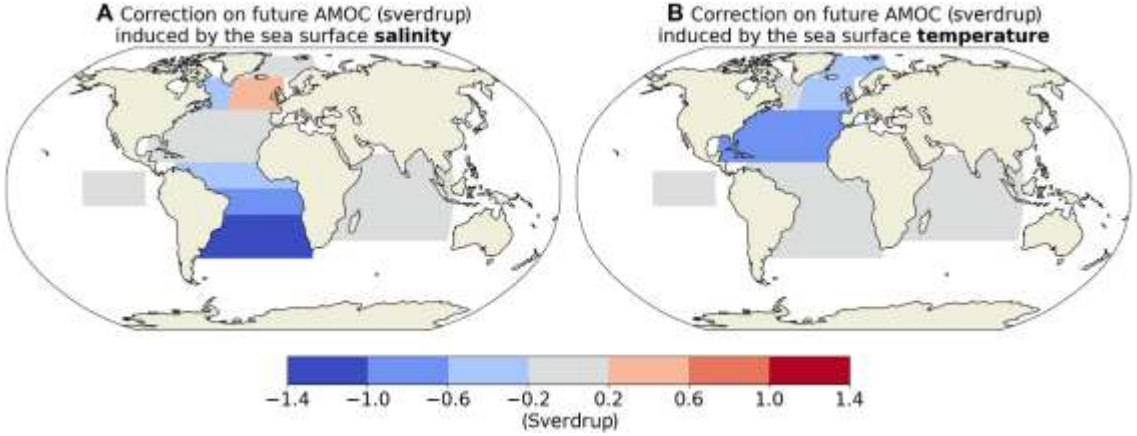
VALENTIN PORTMANN, DIDIER SWINGEDOUW, OMAR KHATTAB, AND MARIE CHAVENT

Abstract

Climate models show considerable discrepancies in their future projections around the Atlantic, mainly due to uncertainties in the fate of the Atlantic Meridional Overturning Circulation (AMOC). Climate models suggest a reduction in AMOC strength of 32 ± 37% by 2100 (90% probability, Shared Socioeconomic Pathways 2-4.5 scenario, Coupled Model Intercomparison Project Phase 6). To refine this estimate and reduce its uncertainty, we use four different observational constraint methods. The best one, which provides the lowest leave-one-out error, integrates a large set of observable variables using ridge-regularized linear regression—a method unusual in climate science. It gives an estimate of the AMOC slowdown of 51 ± 8% (90% probability), i.e., a weakening ~ 60% stronger than suggested by the multimodel mean. This refinement mainly results from correcting a bias in South Atlantic surface salinity, consistent with recent studies emphasizing its role in the proximity to an AMOC tipping point. This more substantial AMOC weakening has key implications for future adaptation strategies.

Full paper: here





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Full paper: here

Q_5 How to survive the overshoot episode?

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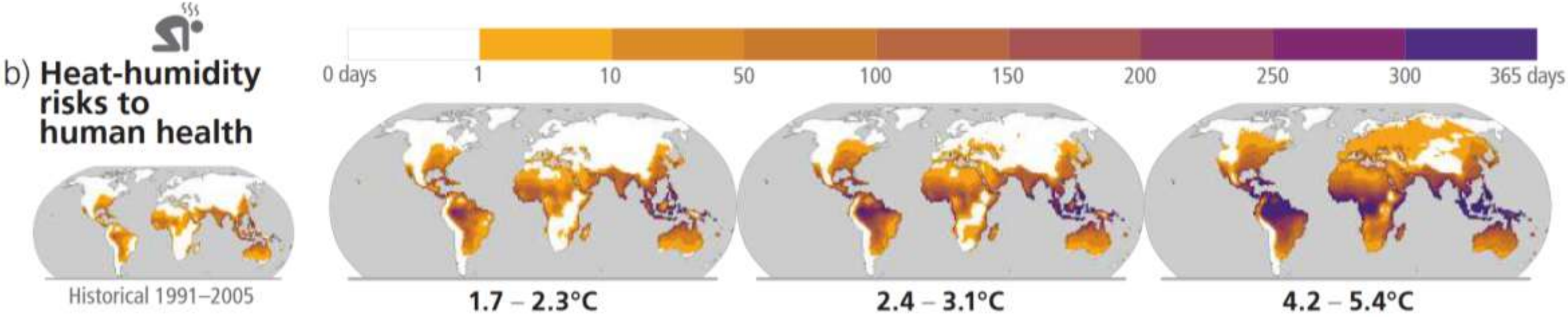
Existential Challenge: Human Health

Climate Change 2023: Synthesis Report

IPCC, 2023



[3]Projected regional impacts utilize a global threshold beyond which daily mean surface air temperature and relative humidity may induce hyperthermia that poses a risk of mortality. The duration and intensity of heatwaves are not presented here. Heat-related health outcomes vary by location and are highly moderated by socio-economic, occupational and other non-climatic determinants of individual health and socio-economic vulnerability. The threshold used in these maps is based on a single study that synthesized data from 783 cases to determine the relationship between heat-humidity conditions and mortality drawn largely from observations in temperate climates.

Full report: here

Full paper: here

22 May 2023 nature sustainability

Quantifying the human cost of global warming

Timothy M. Lenton, Chi Xu, Jesse F. Abrams, Ashish Ghadiali, Sina Loriani, Boris Sakschewski, Caroline Zimm, Kristie L. Ebi, Robert R. Dunn, Jens-Christian Svenning & Marten Scheffer

The Guardian

Global heating will push billions outside 'human climate niche'

World is on track for 2.7C and 'phenomenal' human suffering, scientists warn

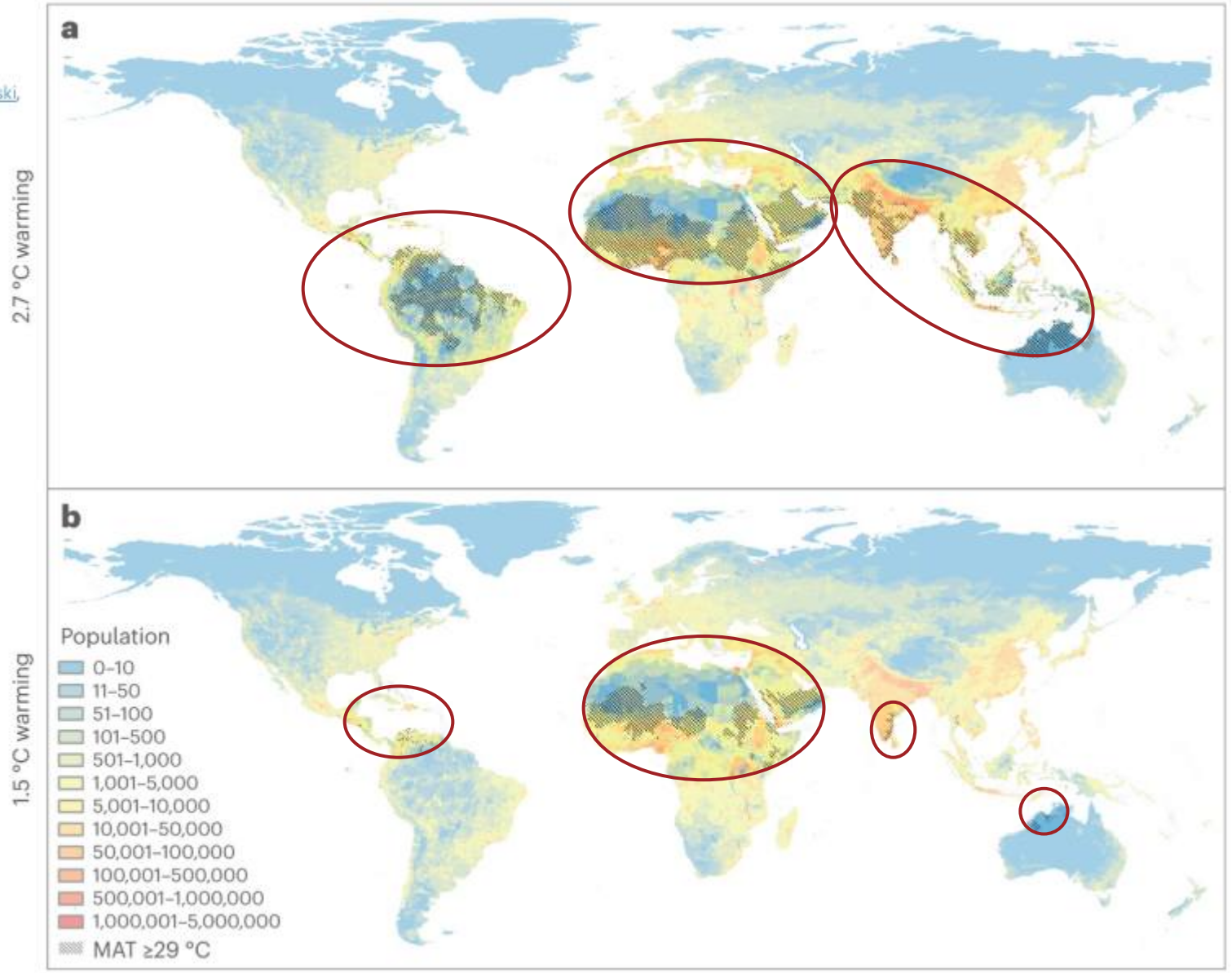
Damian Carrington
Environment editor

The world is on track for 2.7C of heating with current action plans and this would mean 2 billion people experiencing average annual temperatures above 29C by 2030, a level at which very few communities have lived in the past.

Up to 1 billion people could choose to migrate to cooler places, the scientists said, although those areas remaining within the climate niche would still experience more frequent heatwaves and droughts.

However, urgent action to lower carbon emissions and keep global temperature rise to 1.5C would cut the number of people pushed outside the climate niche by 80%, to 400 million.

Full article: here



Full paper: here

22 May 2023 nature sustainability

Quantifying the human cost of global warming

Timothy M. Lenton, Chi Xu, Jesse F. Abrams, Ashish Ghadiali, Sina Loriani, Bens Sakschew, Caroline Zimm, Kristie L. Ebi, Robert R. Dunn, Jens-Christian Svenning & Marten Scheffer

2.7 °C global warming could leave one-third (22–39%) of people outside the "niche"!

This is the projected result of current climate policies across the globe!

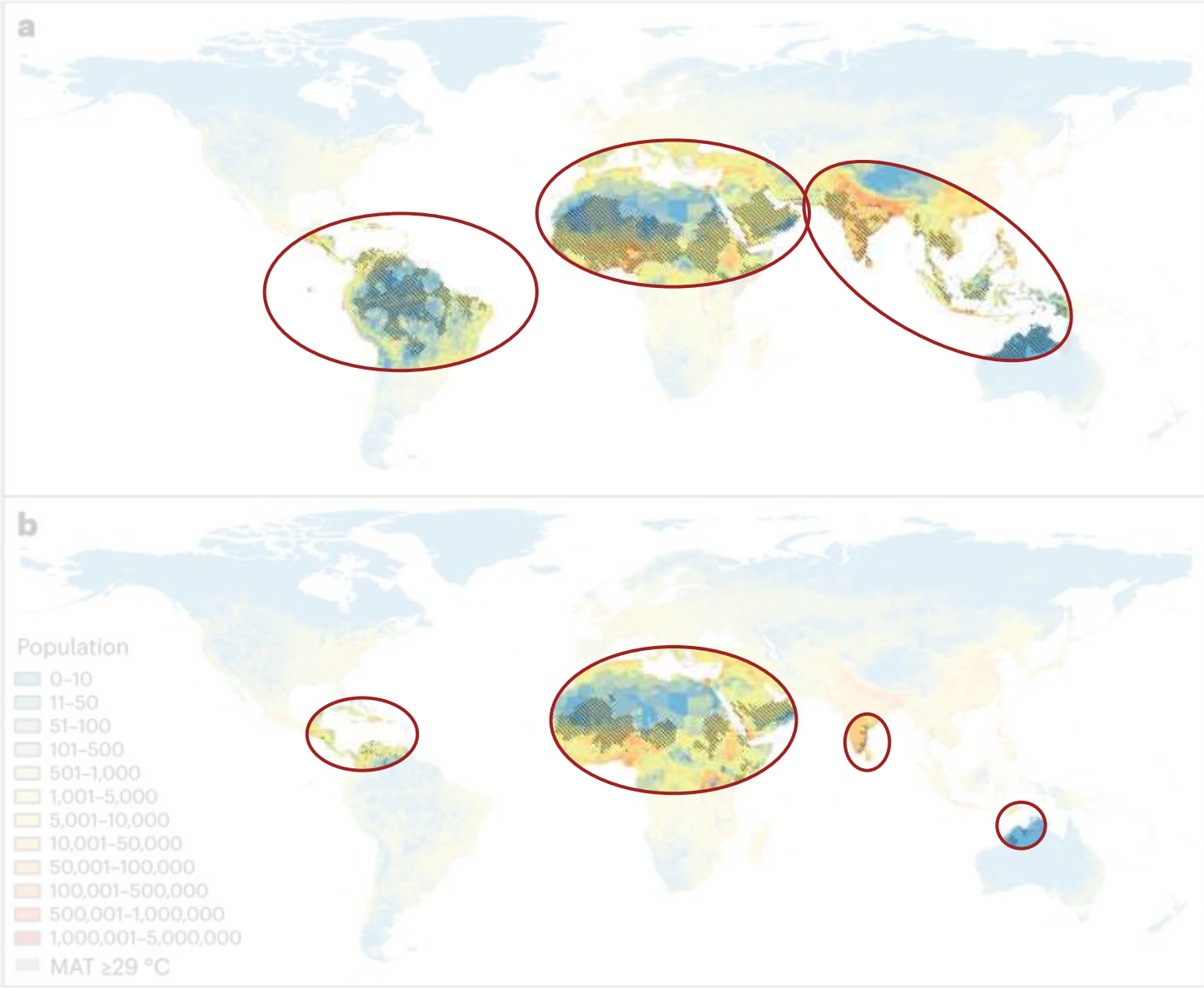
The world is on track for 2.7C of heating with current action plans and this would mean 2 billion people experiencing average annual temperatures above 29C by 2030, a level at which very few communities have lived in the past.

Up to 1 billion people could choose to migrate to cooler places, the scientists said, although those areas remaining within the climate niche would experience more frequent heatwaves and droughts.

However, urgent action to lower carbon emissions and keep global temperature rise to 1.5C would cut the number of people pushed outside the climate niche by 80%, to 400 million.

Full article: here

Can we organize the evacuation and repopulation of the Inner Tropics?



Q_6 Will revolutionary innovations help with tackling $Q_1 - Q_5$?

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Artificial Intelligence and Quantum Computing will revolutionize Climate Systems Analysis.

But How and When?

WEATHER FORECASTING here

Learning skillful medium-range global weather forecasting

Remi Lam[1*†], Alvaro Sanchez-Gonzalez[1*†], Matthew Willson[1*†], Peter Wirnsberger[1†], Meire Fortunato[1†], Ferran Alet[1†], Suman Ravuri[1†], Timo Ewalds[1], Zach Eaton-Rosen[1], Weihua Hu[1], Alexander Merose[2], Stephan Hoyer[2], George Holland[1], Oriol Vinyals[1], Jacklynn Stott[1], Alexander Pritzel[1], Shakir Mohamed[1*], Peter Battaglia[1*]

Article here

A foundation model for the Earth system

Cristian Bodnar[1,2,11], Wessel P. Bruinsma[1,11], Ana Lucic[1,3,11], Megan Stanley[1,11], Anna Allen[4,11], Johannes Brandstetter[1,5], Patrick Garvan[1], Maik Riechert[1], Jonathan A. Weyn[6], Haiyu Dong[6], Jayesh K. Gupta[2,7], Kit Thambiratnam[6], Alexander T. Archibald[4], Chun-Chieh Wu[8], Elizabeth Heider[1], Max Welling[1,3], Richard E. Turner[1,4,9] & Paris Perdikaris[1,10]

Score-Based Generative Emulation of Impact-Relevant Earth System Model Outputs

Shahine Bouabid[1], Andre Nogueira Souza[1], and Raffaele Ferrari[1] here

An LLM Framework for Regional Climate Services: Integrating Climate Knowledge and Ensemble Projections

D. Matsuoka[1], S. Kawahara[1], K. Murakami[1], R. Matsumoto[1], R. Ito[1], S. Sugimoto[1], D. Sugiyama[1], M. Hara[2], M. Hayashida[3], K. Nguyen[3], A. Peng[3], T. Abe[3], and I. Sugiyama[3] here

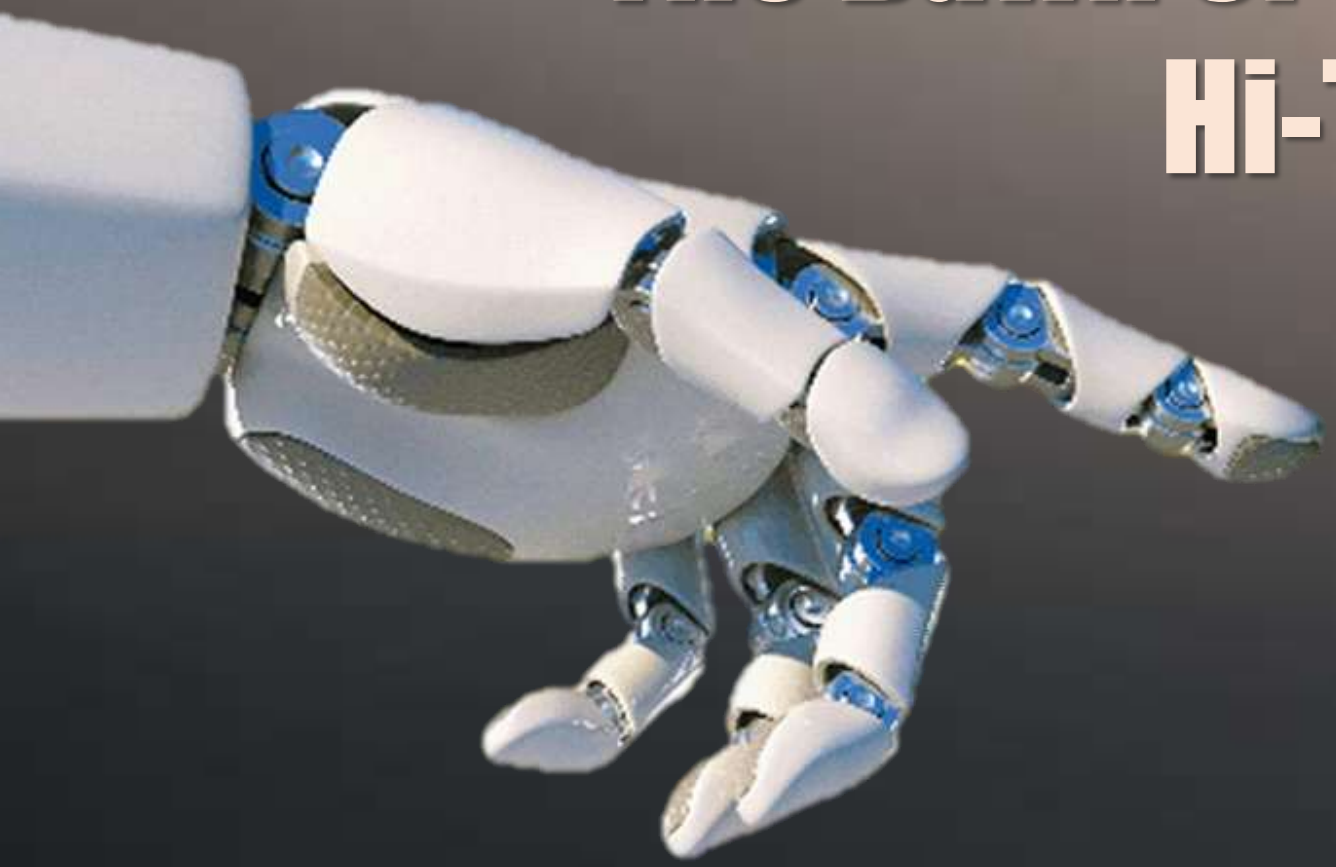
AIFS -- ECMWF's data-driven forecasting system

Simon Lang, Mihai Alexe, Matthew Chantry, Jesper Dramsch, Florian Pinault, Baudouin Raoult, Mariana C. A. Clare, Christian Lessig, Michael Maier-Gerber, Linus Magnusson, Zied Ben Bouallègue, Ana Prieto Nemesio, Peter D. Dueben, Andrew Brown, Florian Pappenberger, Florence Rabier here

Climate in a Bottle: Towards a Generative Foundation Model for the Kilometer-Scale Global Atmosphere here

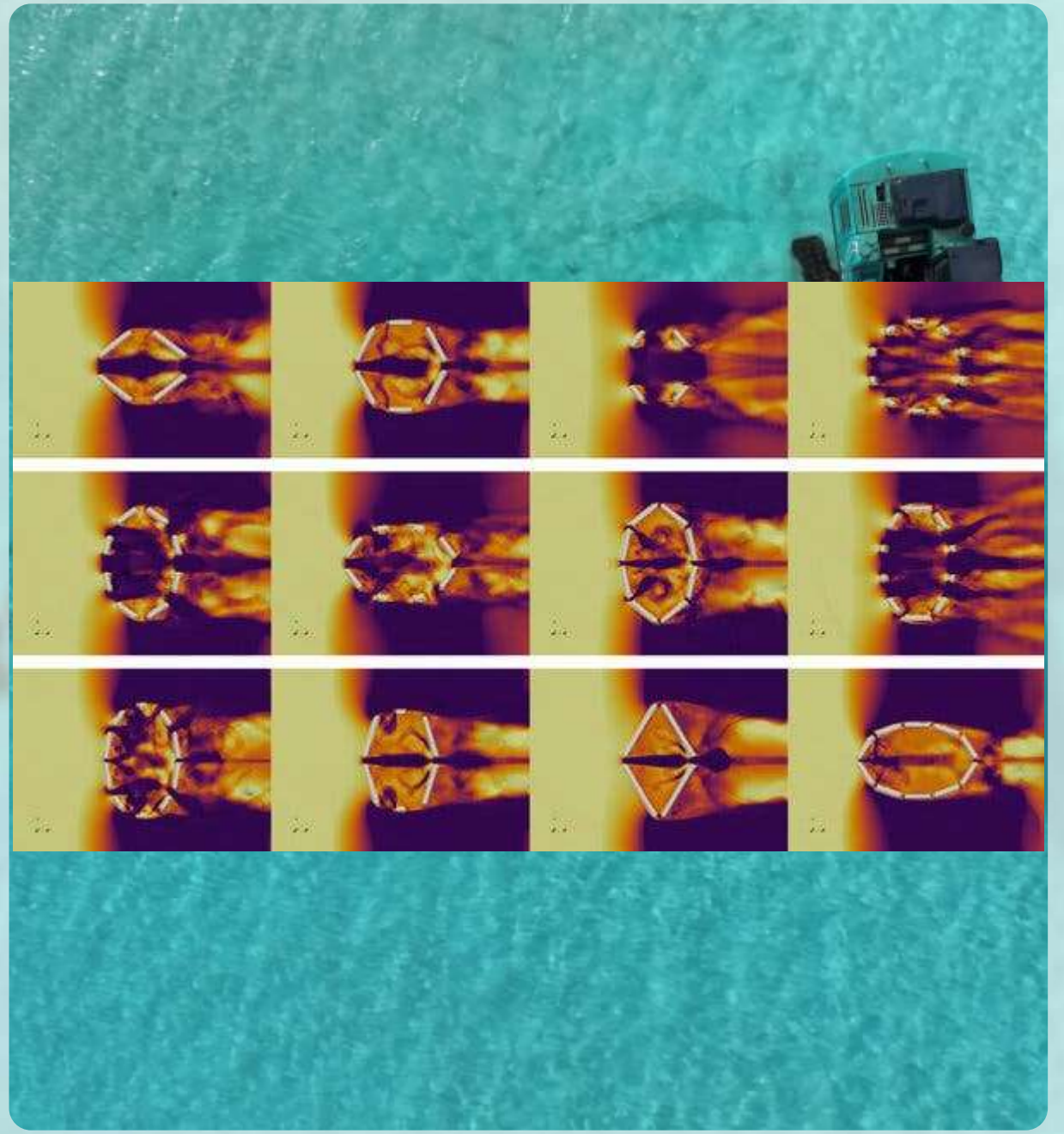
Noah D. Brenowitz* Tao Ge Akshay Subramaniam Peter Manshausen
Aayush Gupta David M. Hall Morteza Mardani Arash Vahdat
Karthik Kashinath Michael S. Pritchard

The Dawn of the Cyborganic Age: Hi-Tech meets No-Tech



Nepal-Tibet Floods, 26 August 2026

Initiative: Advanced Stability Monitoring of Himalaya-Karakoram Range



The New York Times
Sept. 16, 2026

Rising Seas Are Gobbling Up Beaches Around the World. A.I. Might Restore Them.

An experiment with roots at M.I.T. used A.I. and satellite images to grow a coastline in the Maldives. More projects are planned for Boston and Miami.

Full article: here

Conclusion

The future of climate-change science is *exciting*, but *scary*!

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