Record Sea Surface Temperature Jump in 2023–2024

Implications for the transient climate response to emissions and a possibly upcoming warming hiatus

Climate Coffee, 23rd April 2026

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Globally-averaged sea surface temperatures have been at record highs from April 2023 to July 2024 and shattered previous records

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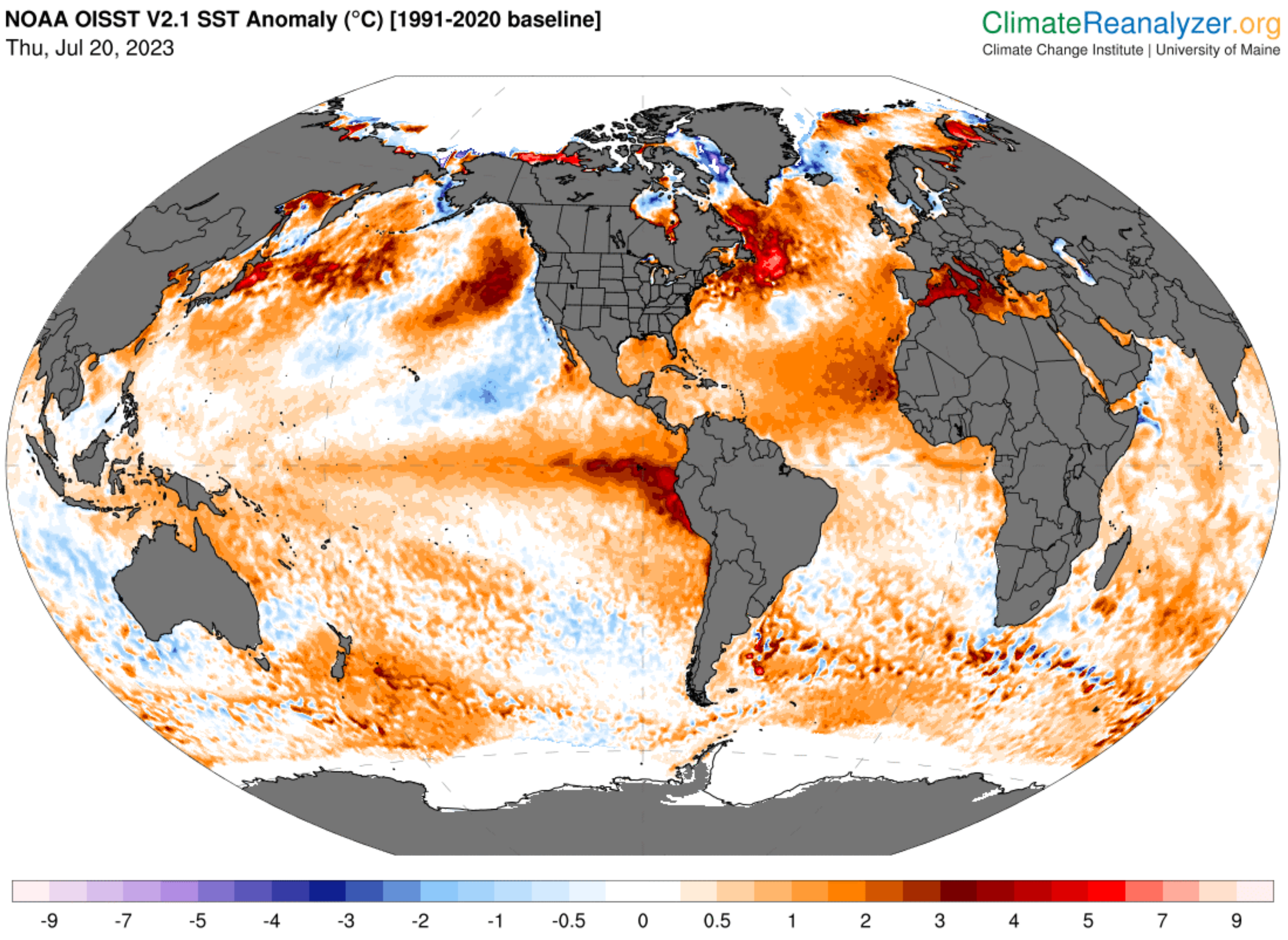

Sea surface temperatures have jumped since April 2023 and shattered previous records by 0.2-0.3℃

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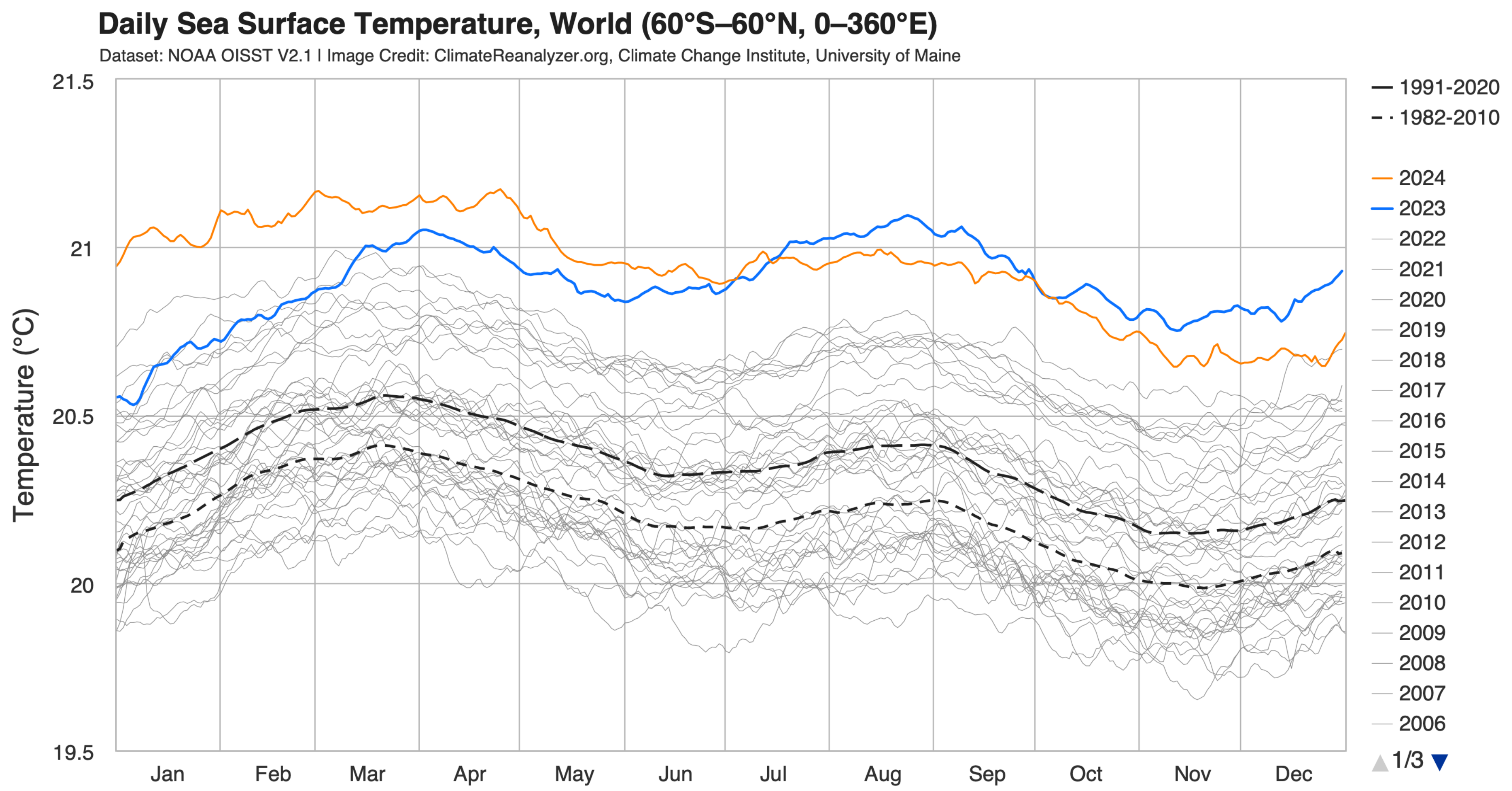

Climate Reanalyzer
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Averaged over one year, SSTs broke the old record by 0.25°C

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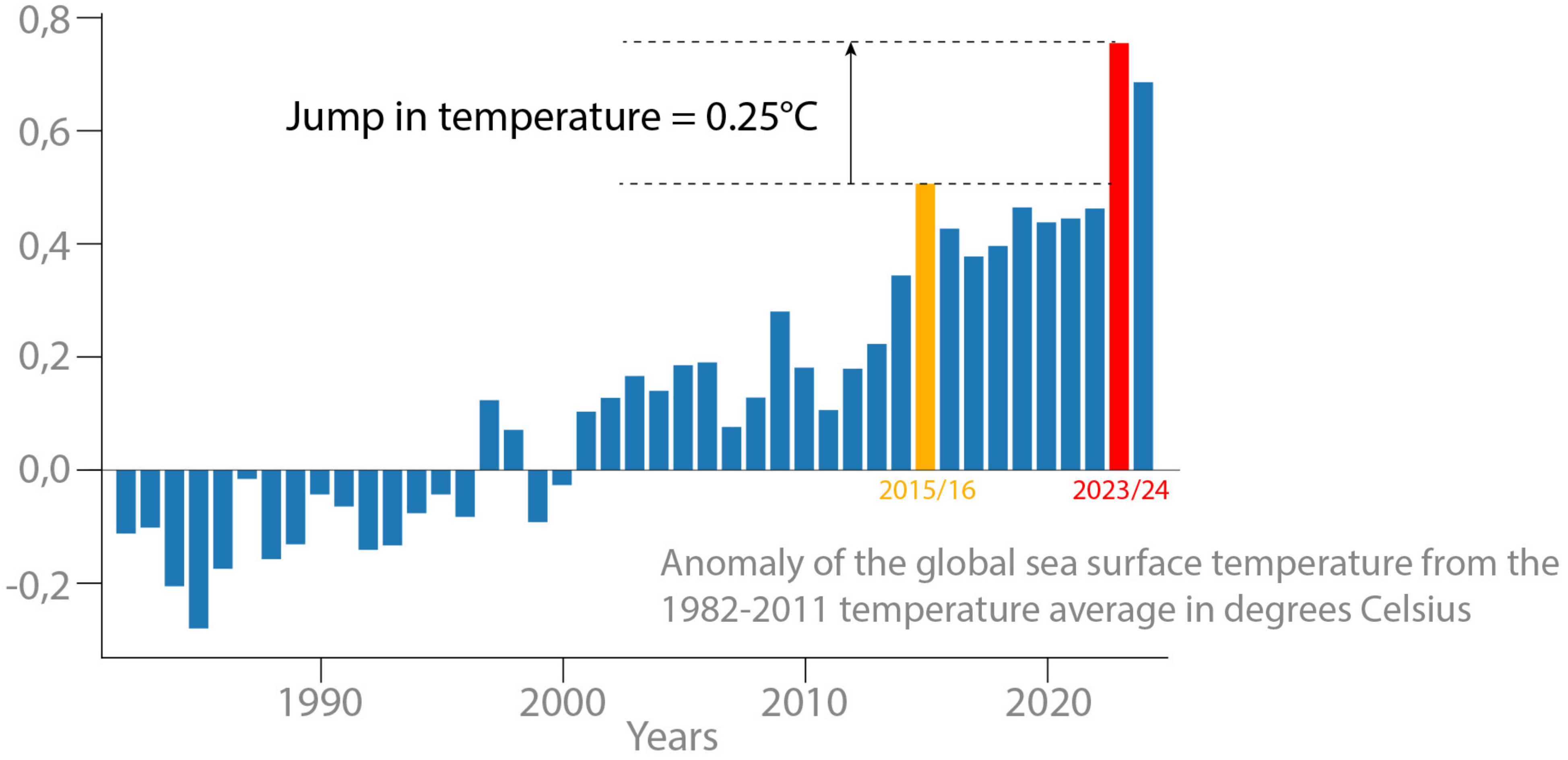

Terhaar et al. (2025)

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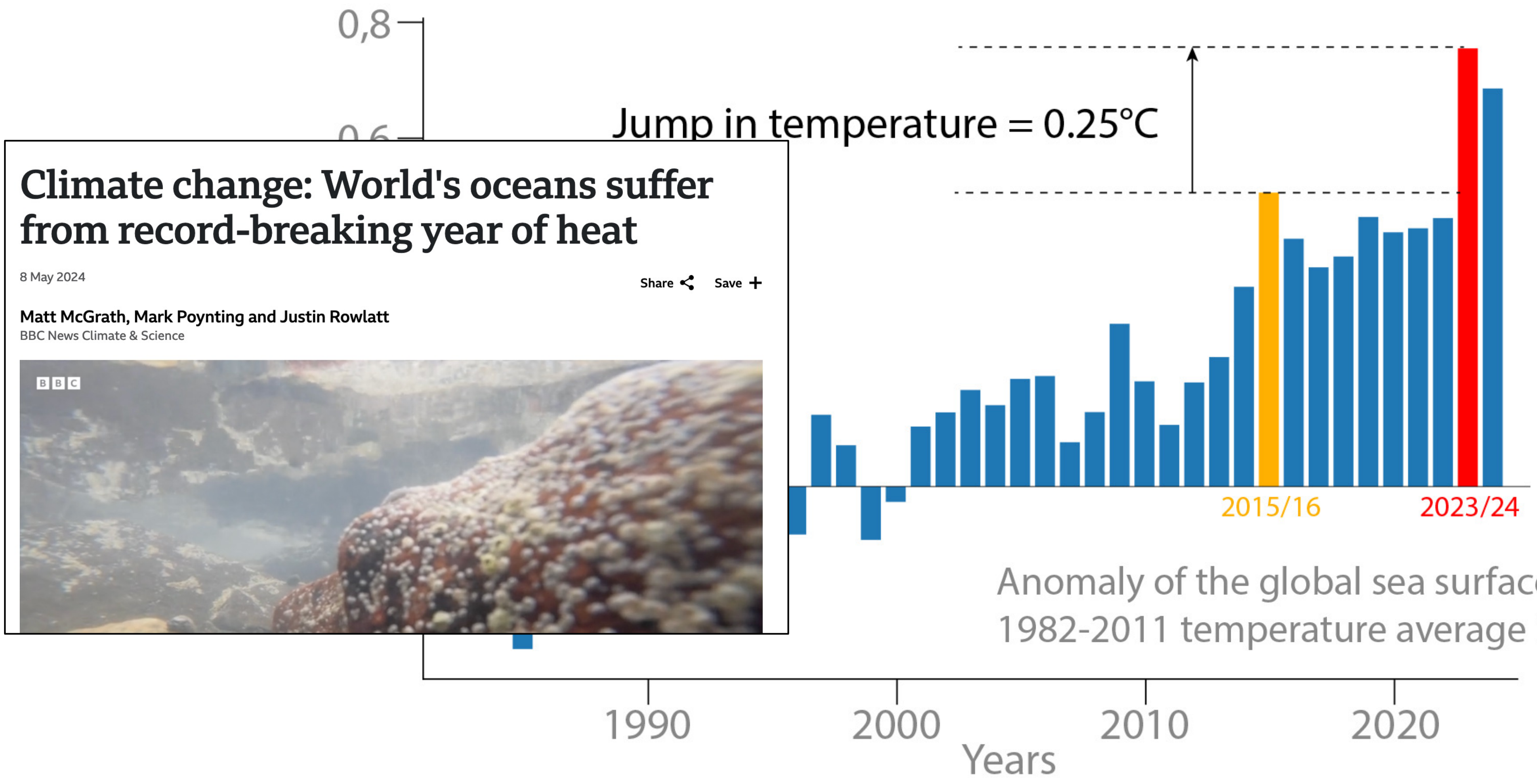

Terhaar et al. (2025)

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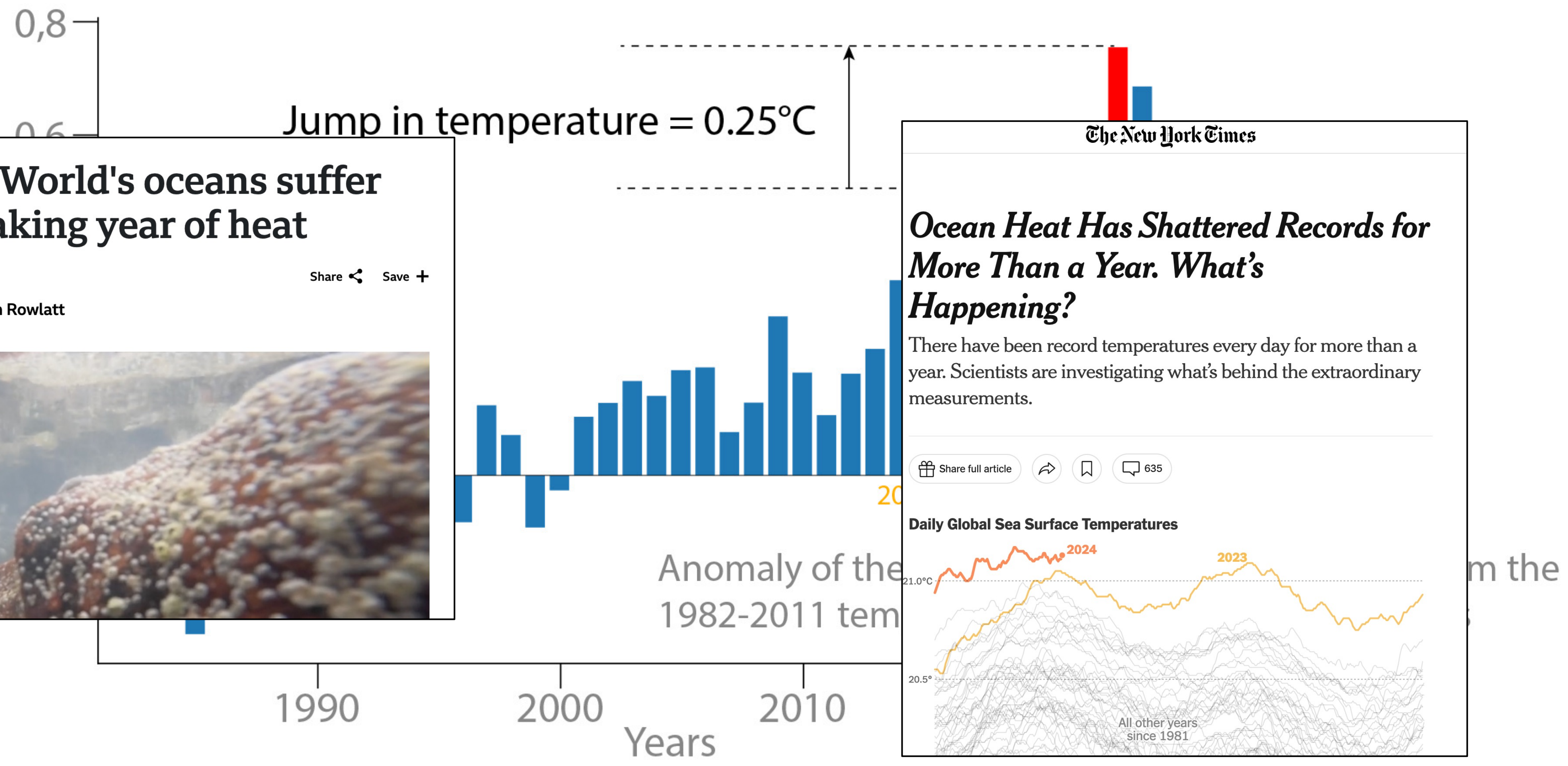

Climate change: World's oceans suffer from record-breaking year of heat

8 May 2024

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Ocean Heat Has Shattered Records for More Than a Year. What's Happening?

There have been record temperatures every day for more than a year. Scientists are investigating what's behind the extraordinary measurements.

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Daily Global Sea Surface Temperatures

Terhaar et al. (2025)

Speculations emerged if this event has come as a surprise and even if it is a sign of unexpected accelerated warming

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WORLD VIEW | 19 March 2024

Climate models can’t explain 2023’s huge heat anomaly — we could be in uncharted territory

Taking into account all known factors, the planet warmed 0.2 °C more last year than climate scientists expected. More and better data are urgently needed.

By Gavin Schmidt

Speculations emerged if this event has come as a surprise and even if it is a sign of unexpected accelerated warming

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Taking into account all known factors, the planet warmed 0.2 °C more last year than climate scientists expected. More and better data are urgently needed.

By Gavin Schmidt

"A general warming trend is expected because of rising greenhouse-gas emissions, but this sudden heat spike greatly exceeds predictions made by statistical climate models that rely on past observations."

We have addressed the question if the event was expectable with statistical and dynamical climate models

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Article

Record sea surface temperature jump in 2023–2024 unlikely but not unexpected

https://doi.org/10.1038/s41586-025-08674-z

Received: 28 June 2024

Accepted: 17 January 2025

Published online: 12 March 2025

Open access

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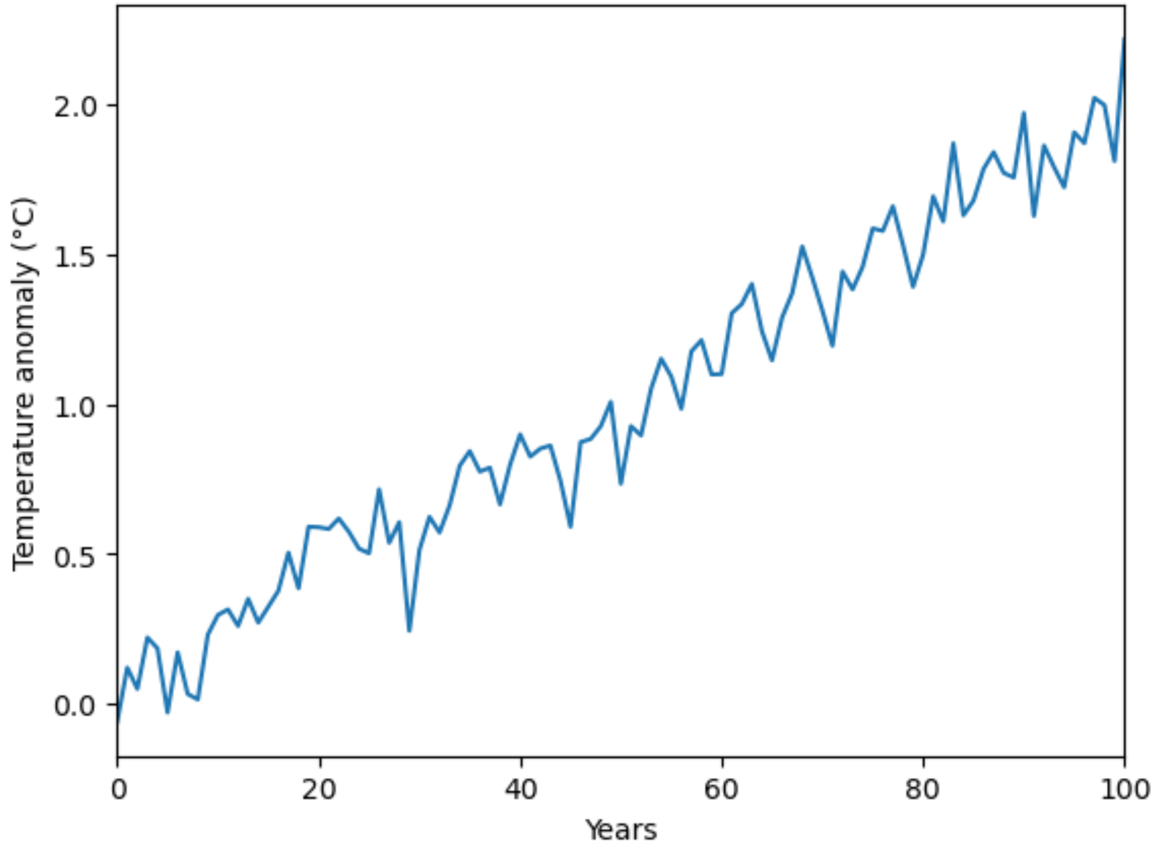
Jens Terhaar[1,2]✉, Friedrich A. Burger[1,2], Linus Vogt[3], Thomas L. Frölicher[1,2] & Thomas F. Stocker[1,2]

Global ocean surface temperatures were at record levels for more than a year from April 2023 onwards, exceeding the previous record in 2015–2016 by 0.25 °C on average between April 2023 and March 2024[1]. The nearly global extent and unprecedented intensity of this event prompted questions about how exceptional it was and whether climate models can represent such record-shattering jumps in surface ocean temperatures[2]. Here we construct observation-based synthetic time series to show that a jump in global sea surface temperatures that breaks the previous record by at least 0.25 °C is a 1-in-512-year event under the current long-term warming trend (1-in-205-year to 1-in-1,185-year event; 95% confidence interval). Without a global warming trend, such an event would have been practically impossible. Using 270 simulations from a wide range of fully coupled climate models, we show that these models successfully simulate such record-shattering jumps in global ocean surface temperatures, underpinning the models' usefulness in understanding the characteristics, drivers and consequences of such events. These model simulations suggest that the record-shattering jump in surface ocean temperatures in 2023–2024 was an extreme event after which surface ocean temperatures are expected to revert to the expected long-term warming trend.

Terhaar et al. (2025)

We built a statistical model to create an observation-based estimate of the return period of such events



We built several 100-million-year long time-series with prescribed **variance, autocorrelation, and trend** to calculate the return period of jumps in SSTs that exceed previous records by at least 0.25℃

Terhaar et al. (2025)

Trend, variance, and autocorrelation are estimated based on observation-based datasets (ERA5, HadISST, ERSST, NOAA OI SST V2.1)

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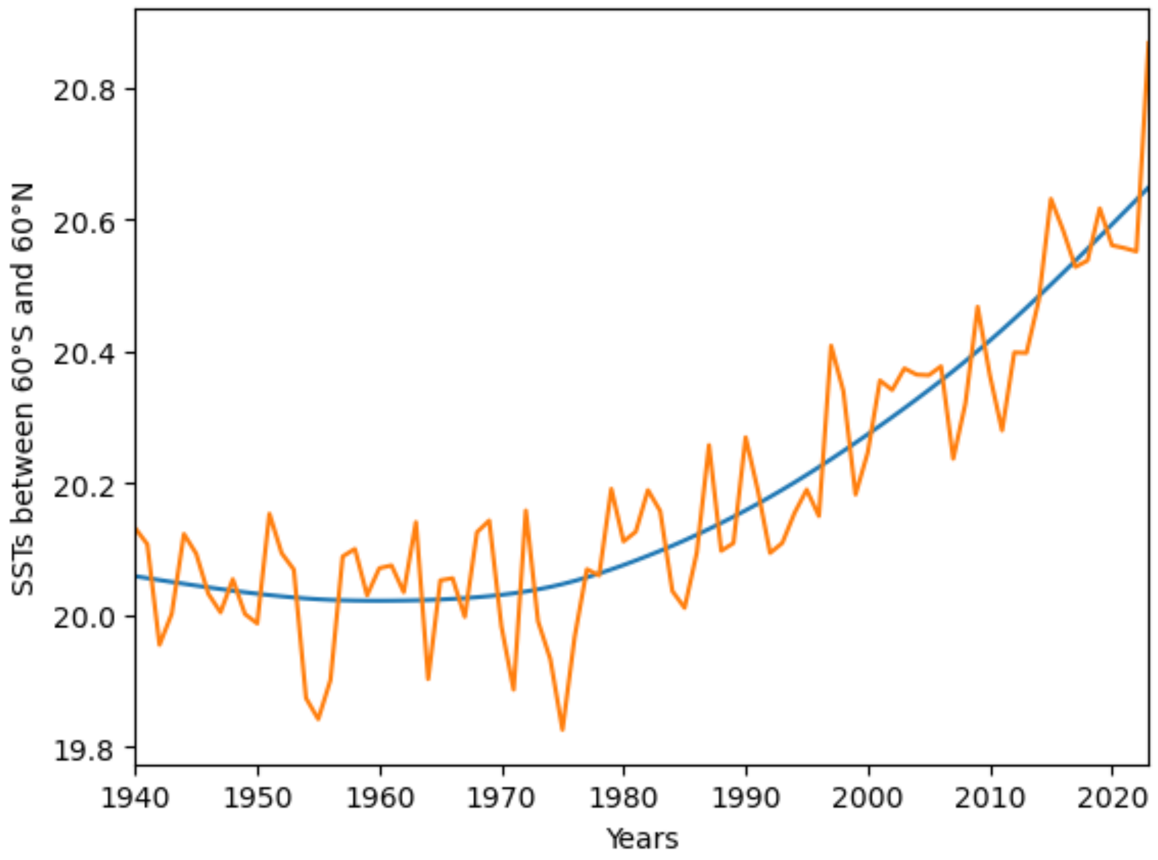

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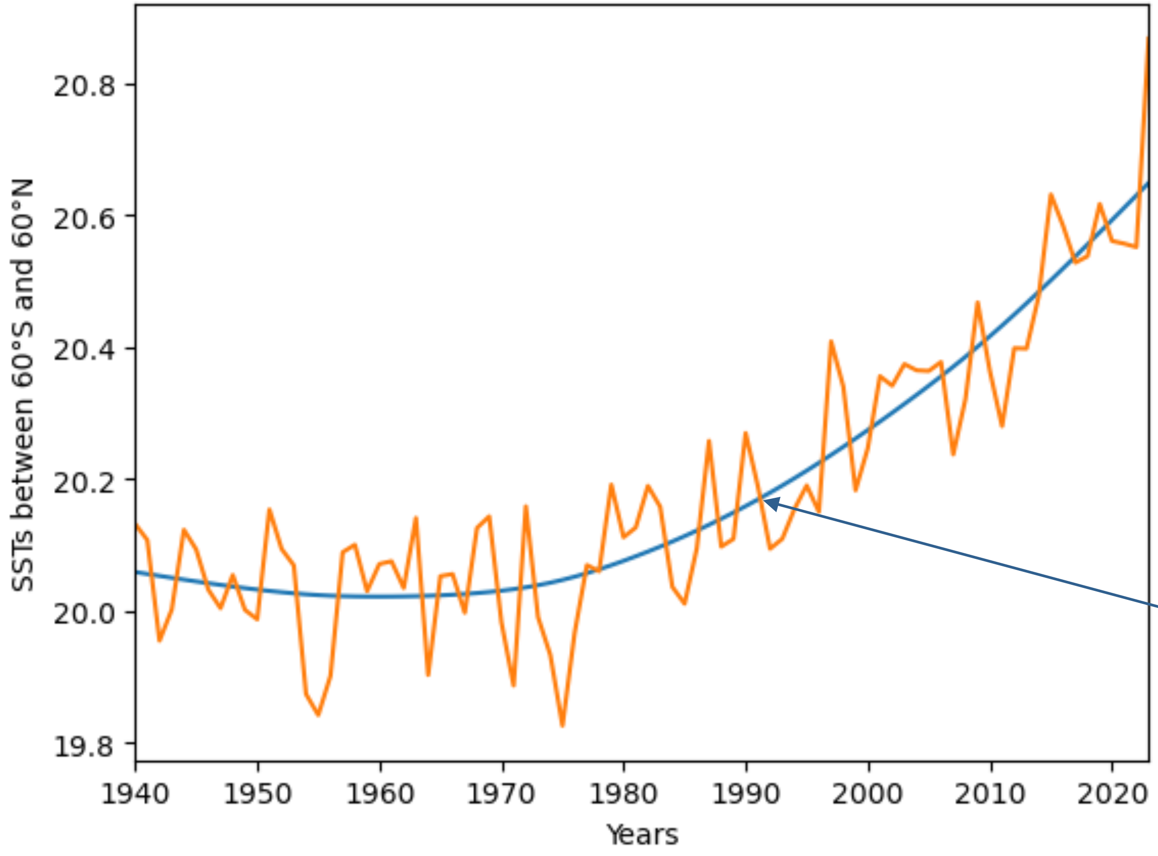

Remove fit to calculate variance and autocorrelation from observational datasets (ERA5, HadISST, ERSST)

Terhaar et al. (2025)

Trend, variance, and autocorrelation are estimated based on observation-based datasets (ERA5, HadISST, ERSST, NOAA OI SST V2.1)

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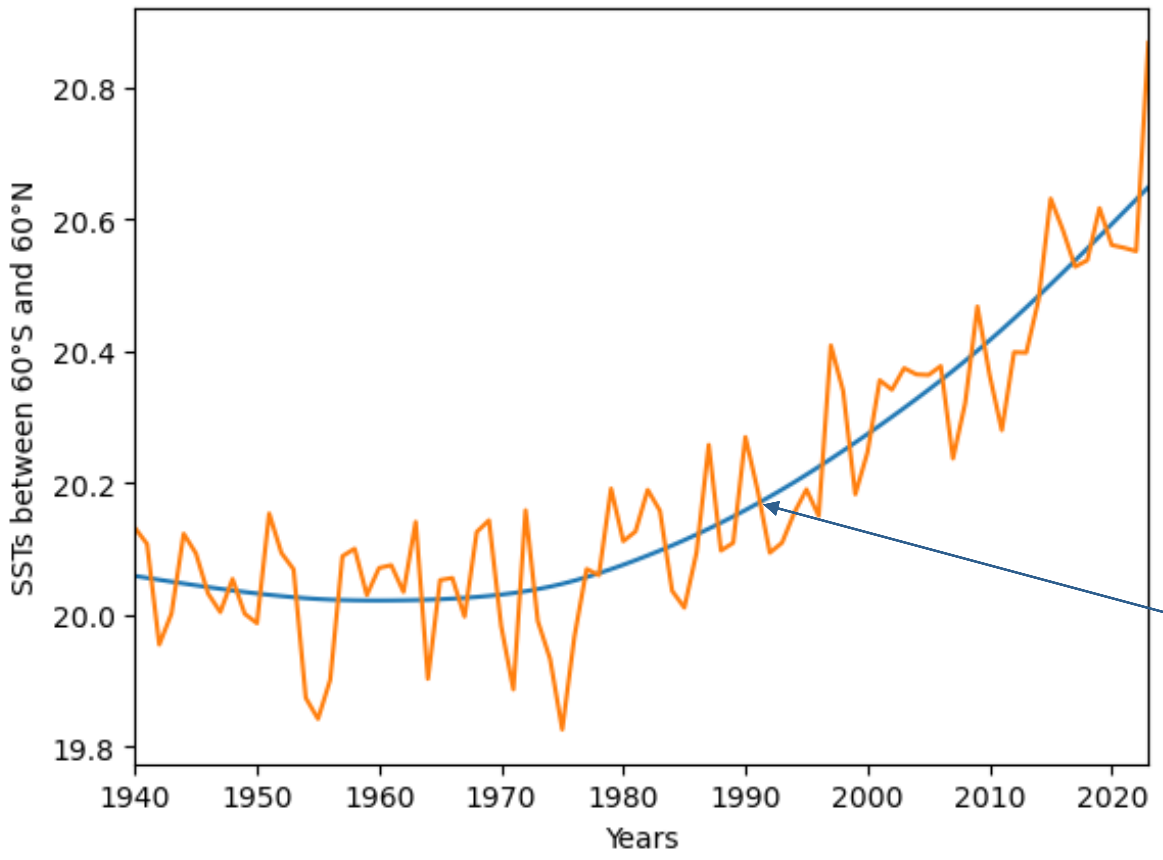

Calculate the trend in 2023 based on best available observational data (NOAA OISST V2.1)

Remove fit to calculate variance and autocorrelation from observational datasets (ERA5, HadISST, ERSST)

Terhaar et al. (2025)

Based on these estimates, we created 10,000 combinations of possible trends, variances, and autocorrelations

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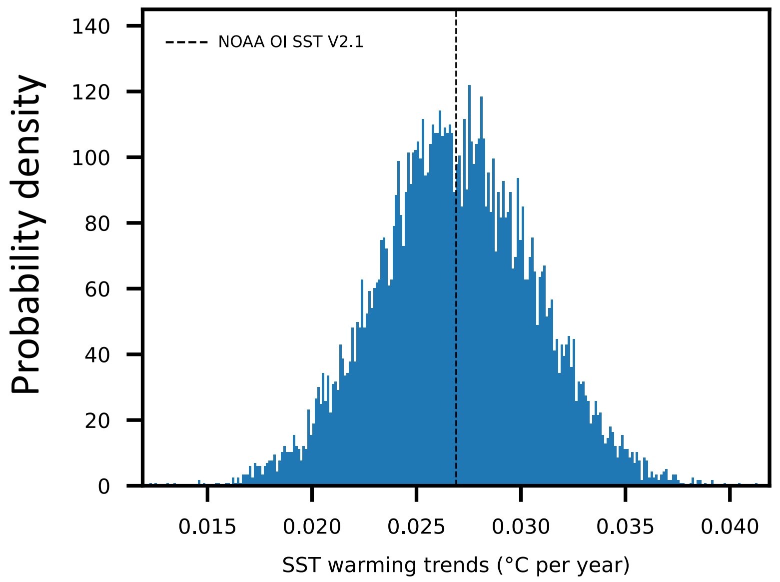
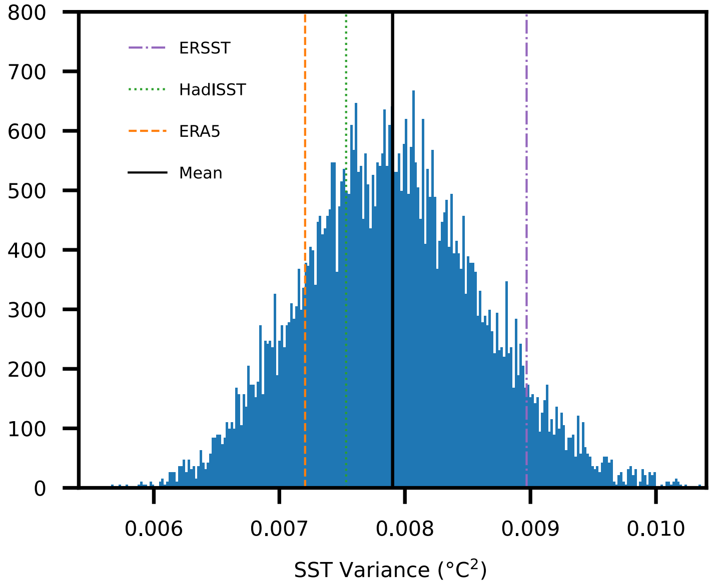
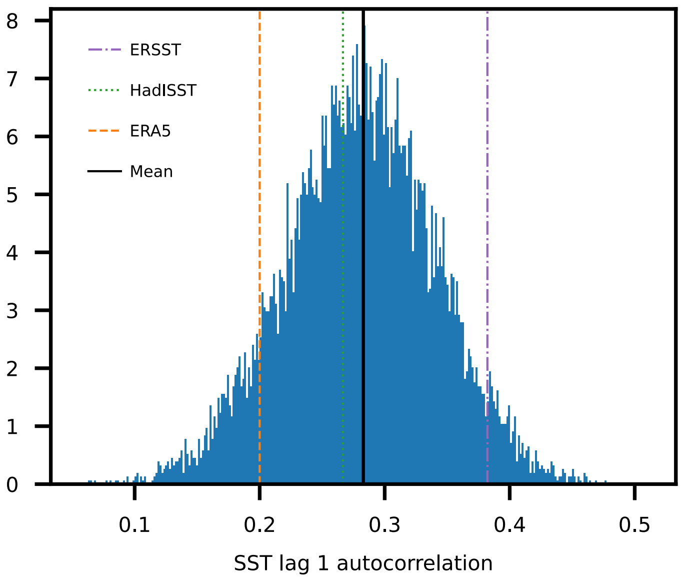
Warming trends



Variance

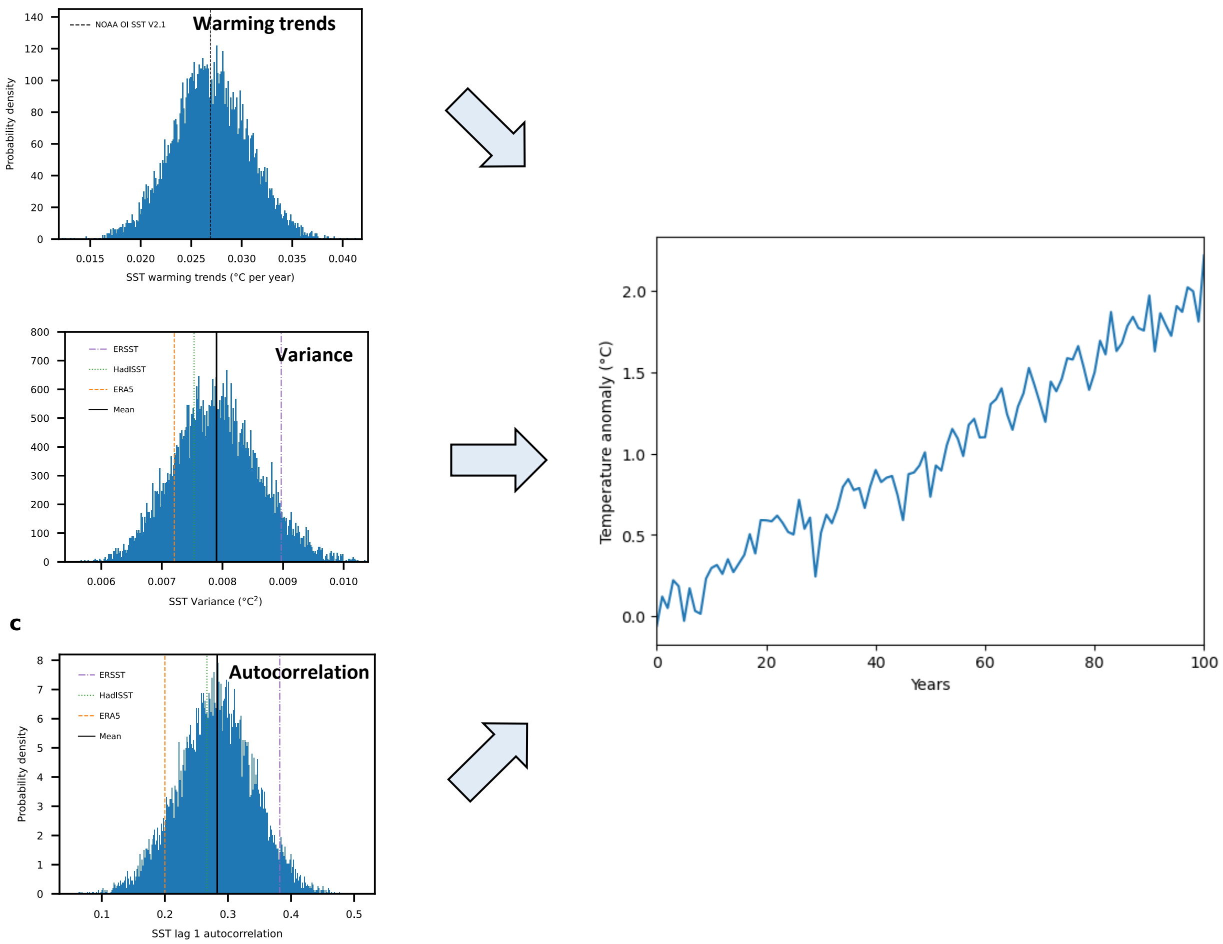


Autocorrelation



Terhaar et al. (2025)

For each of these 10,000 combinations, we created 100 million years long timeseries



Terhaar et al. (2025)

For each of these 10,000 combinations, we created 100 million years long timeseries and estimate the return period of jumps in SSTs that break the old record by more than 0.25℃

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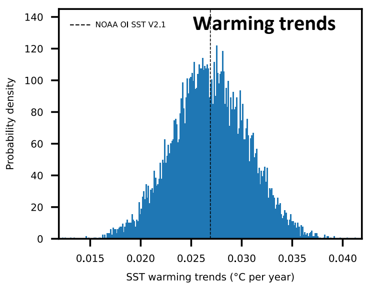

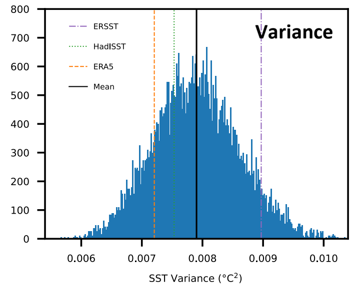

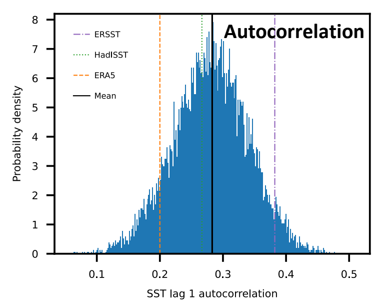

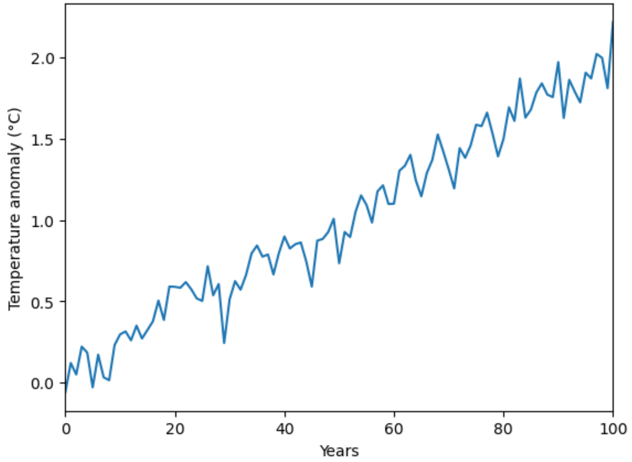

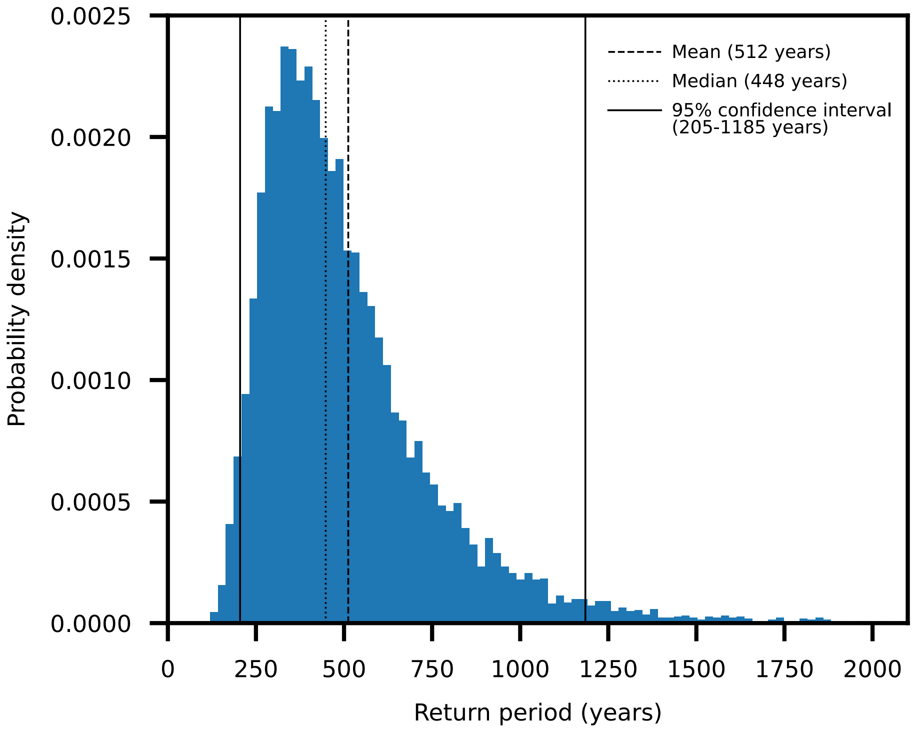

Terhaar et al. (2025)

Climate models can simulate such record-shattering jumps in SSTs that exceed previous temperature records by 0.25℃

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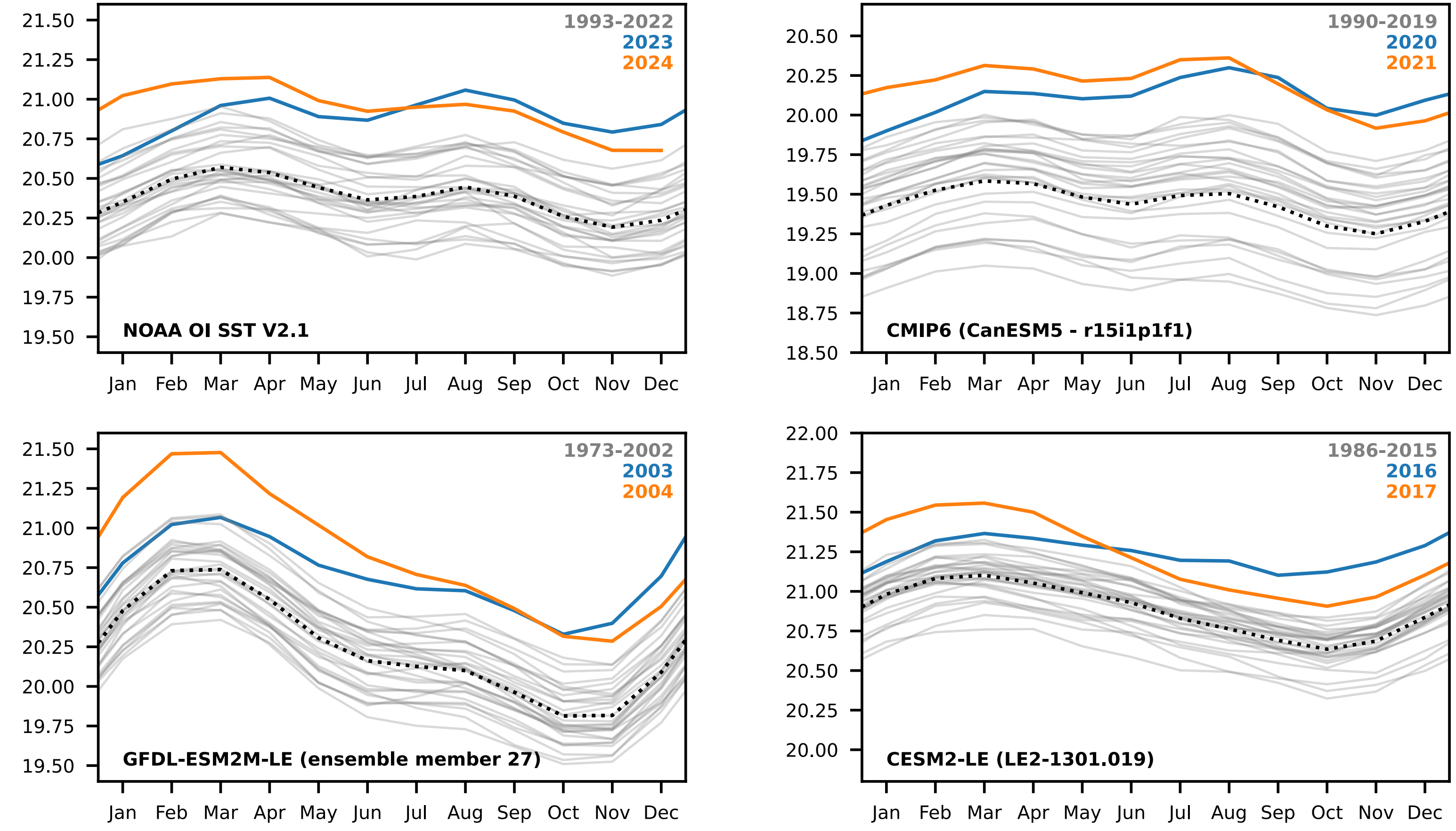
SSTs between 60ºS and 60ºN

190 simulations from the CMIP6 archive



30 simulations from the GFDL-ESM2M large ensemble

Burger, F. A., Terhaar, J. & Frölicher, T. L. Compound marine heatwaves and ocean acidity extremes. Nat. Commun. 13, 4722 (2022).

50 simulations from the CESM2 large ensemble

Rodgers, K. B. et al. Ubiquity of human-induced changes in climate variability. Earth Syst. 488 Dyn. 12, 1393–1411 (2021).

Terhaar et al. (2025)

Events as in 2023/24 are very unlikely but the event still lies within the range of simulated events

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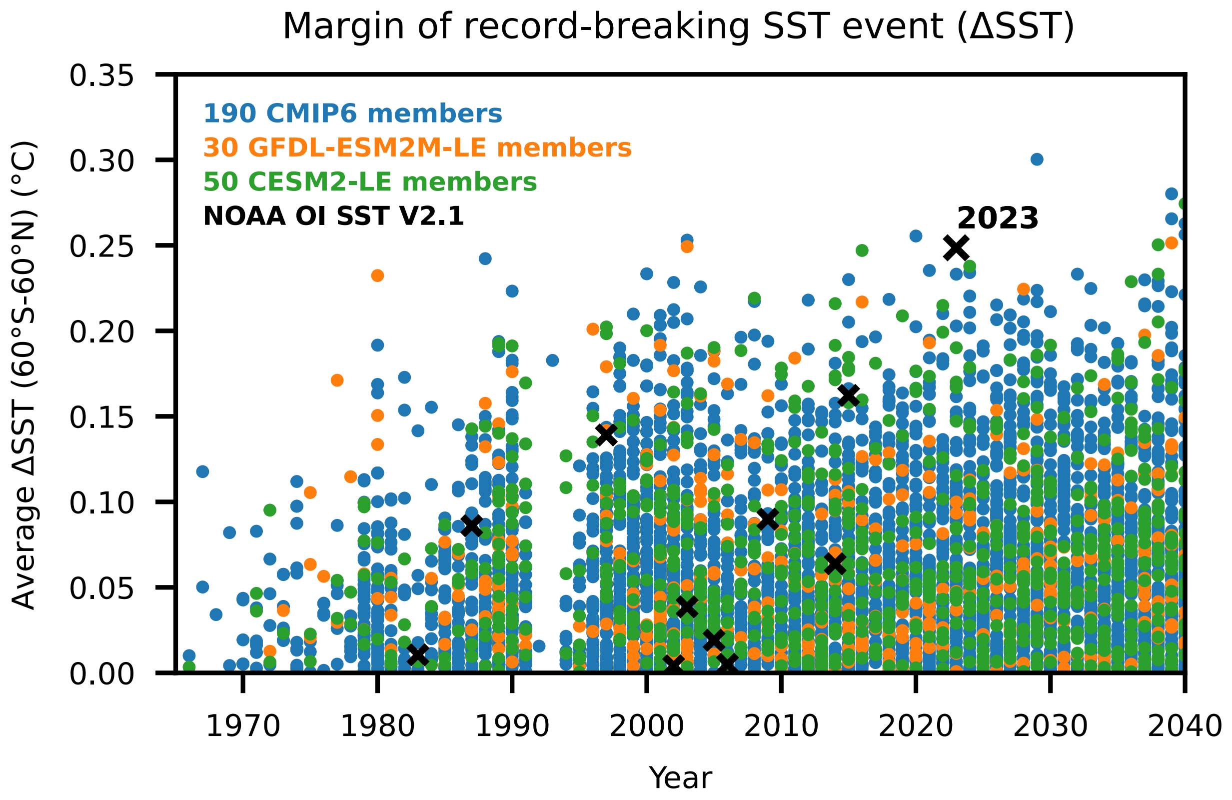

11 jumps in SSTs that break the old record by at least 0.25℃ are simulated by climate models from 2000 to 2040 in 270 climate simulations (11,070 years)

Terhaar et al. (2025)

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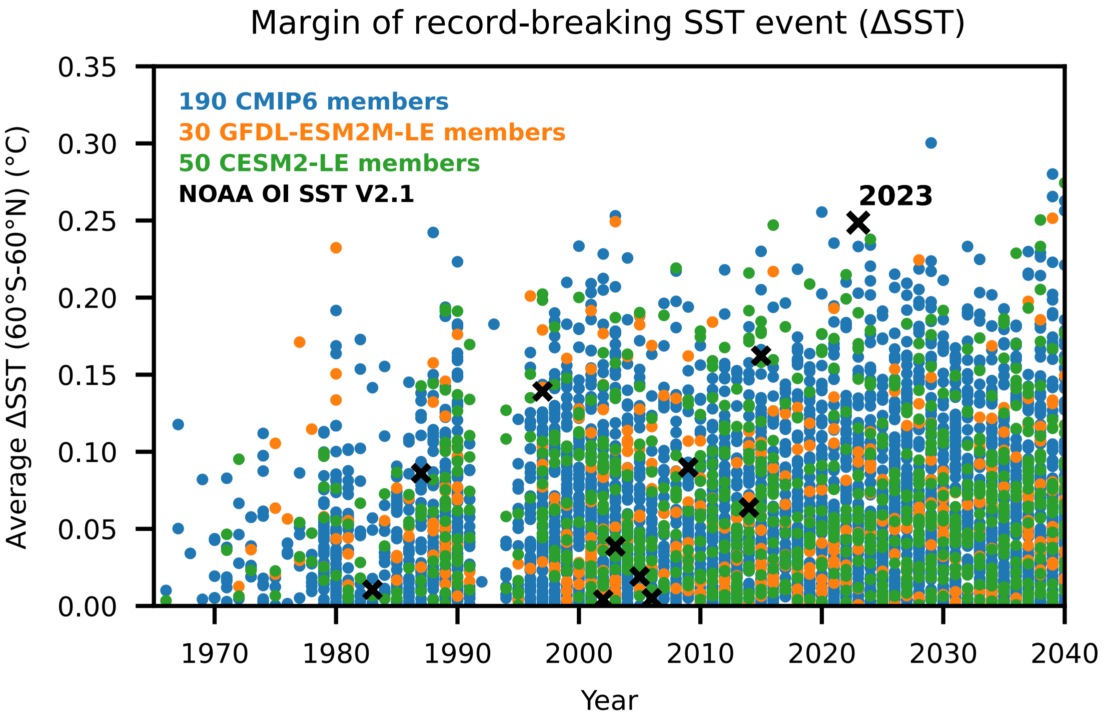

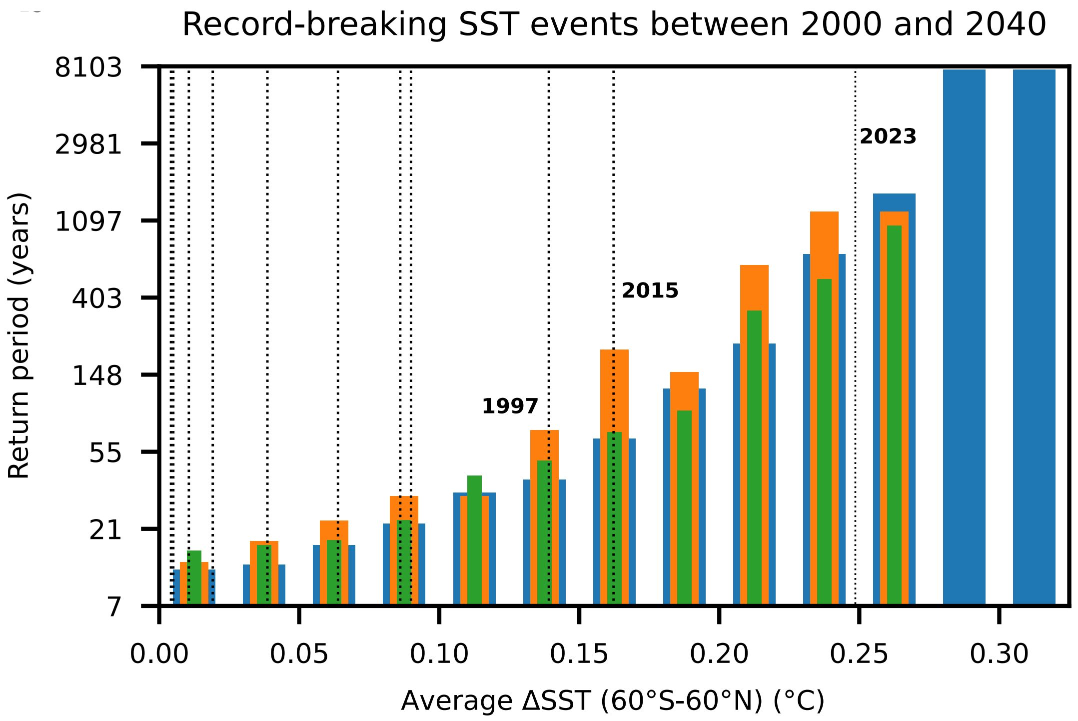

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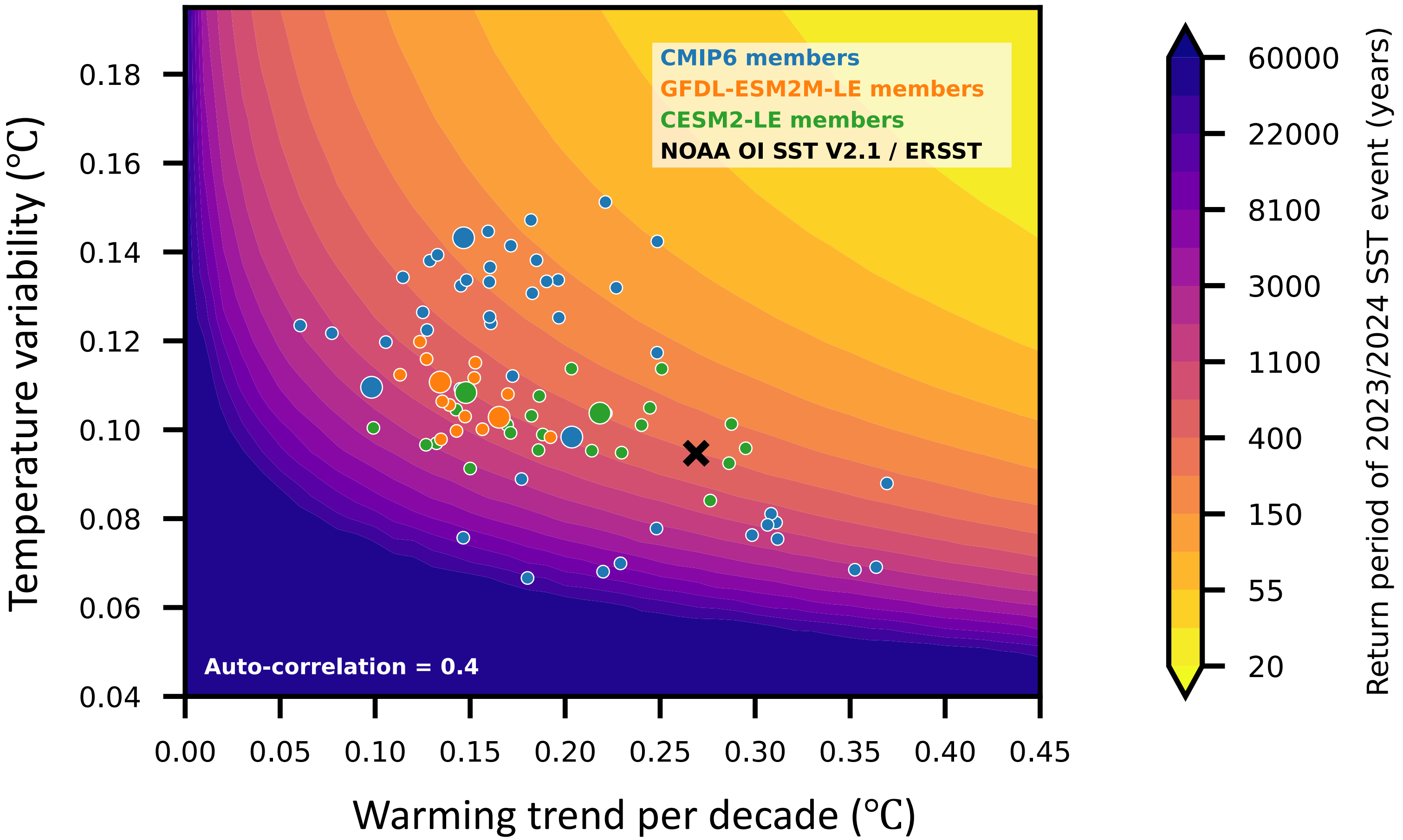
Such jumps in SSTs are found in climate models with a wide range of variances, autocorrelations, and warming trends



Terhaar et al. (2025)

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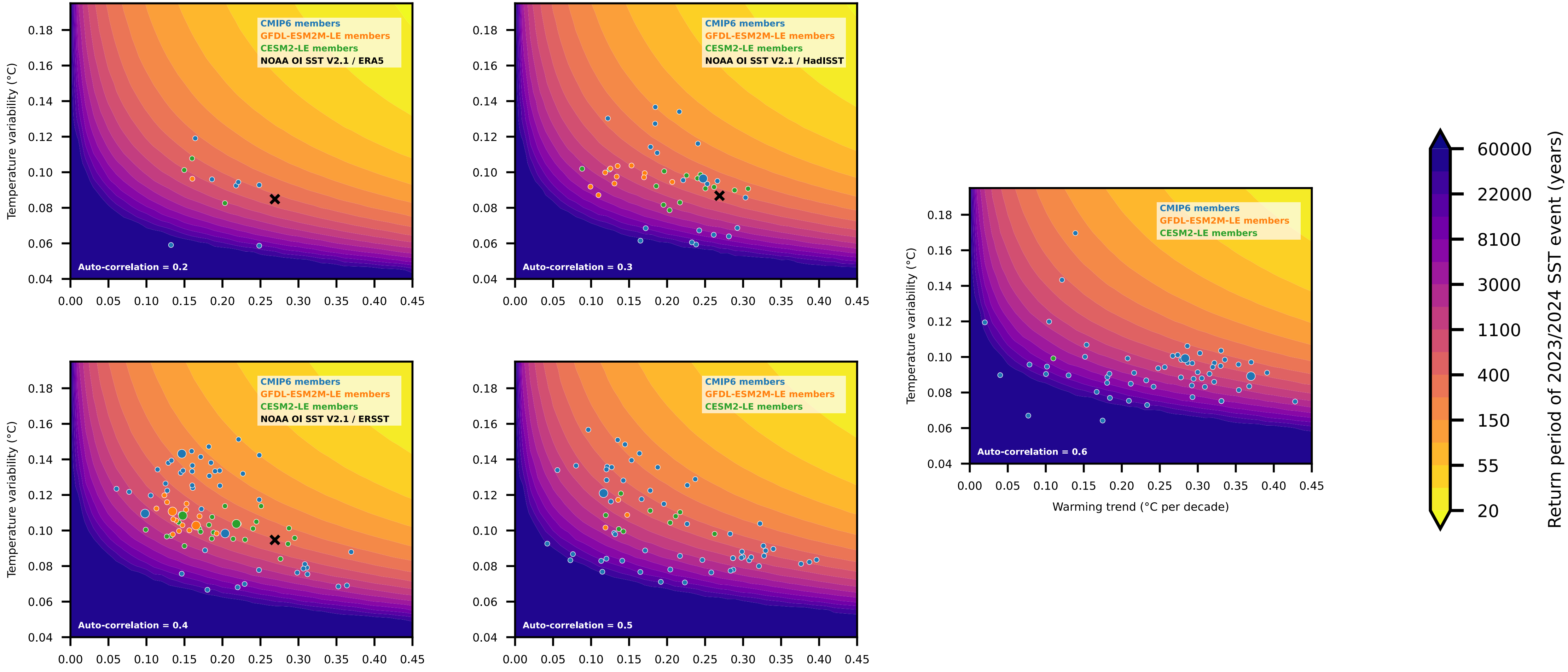

Terhaar et al. (2025)

SST patterns in models look similar to observations with a positive El-Niño phase, a warm North Pacific, and a relatively warm Indian Ocean

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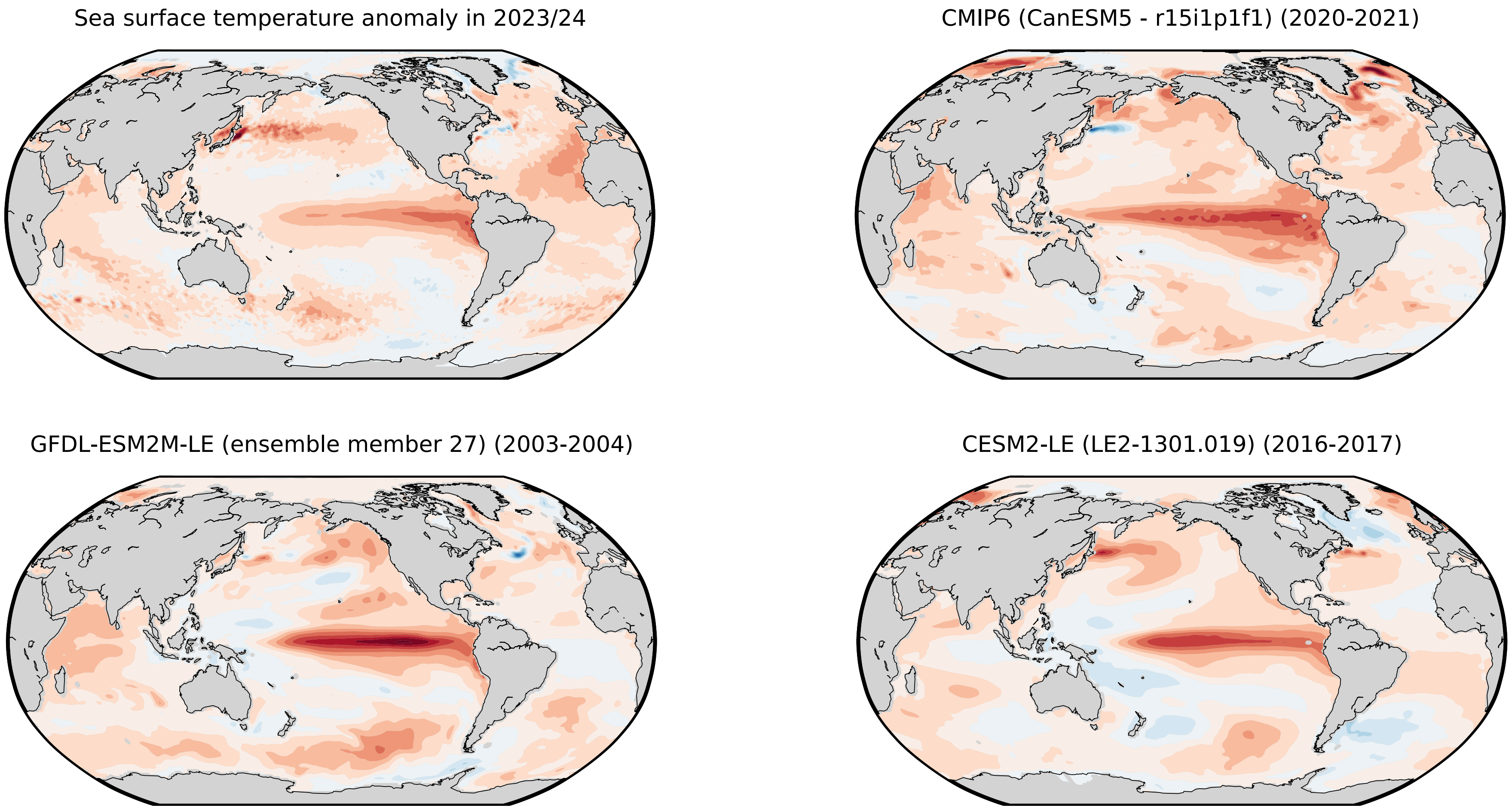

Terhaar et al. (2025)

SSTs stop to be record-breaking between May and September in the year after the jump

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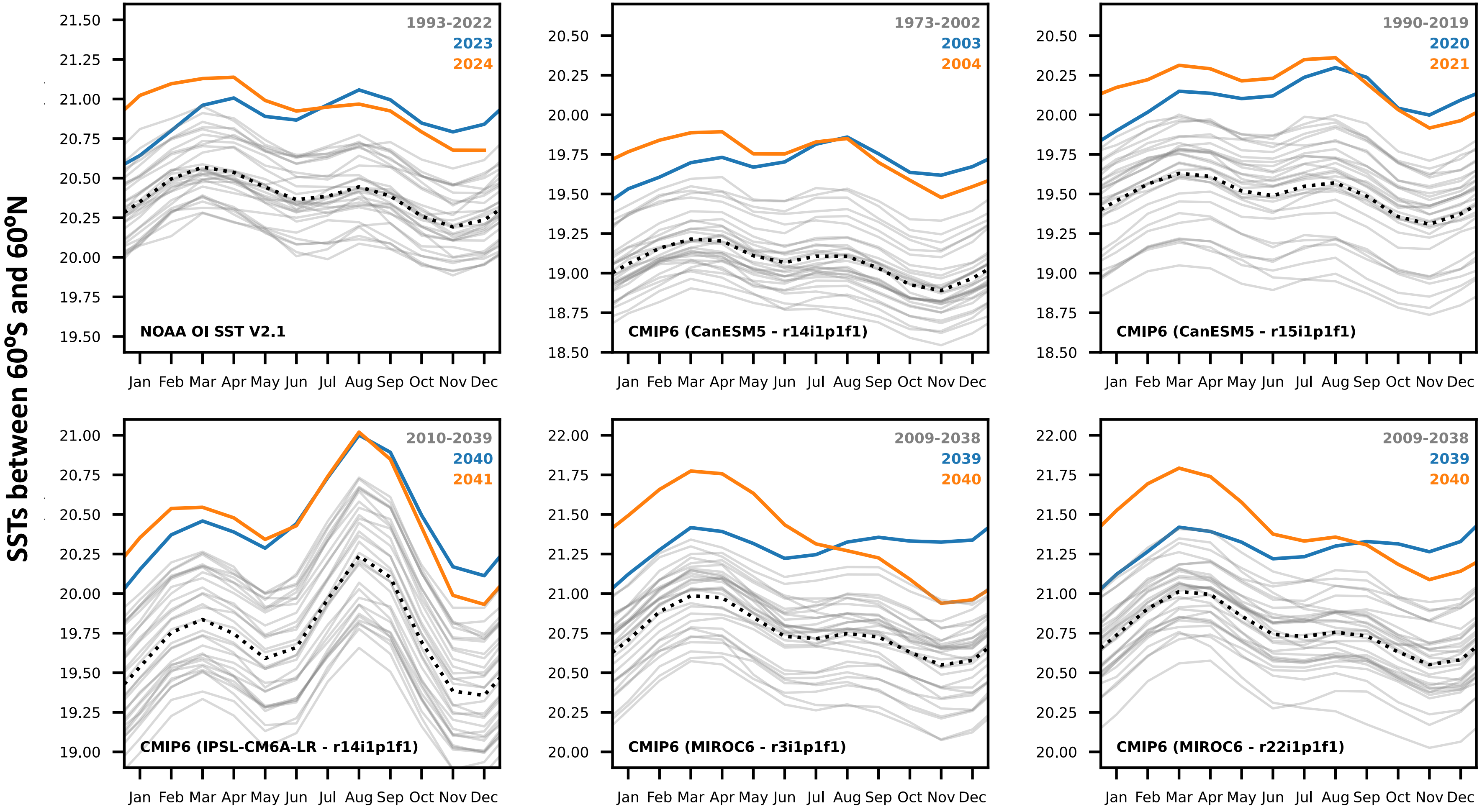

Terhaar et al. (2025)

The observed SSTs also stopped to be record-breaking in the year that followed the jump (2024)

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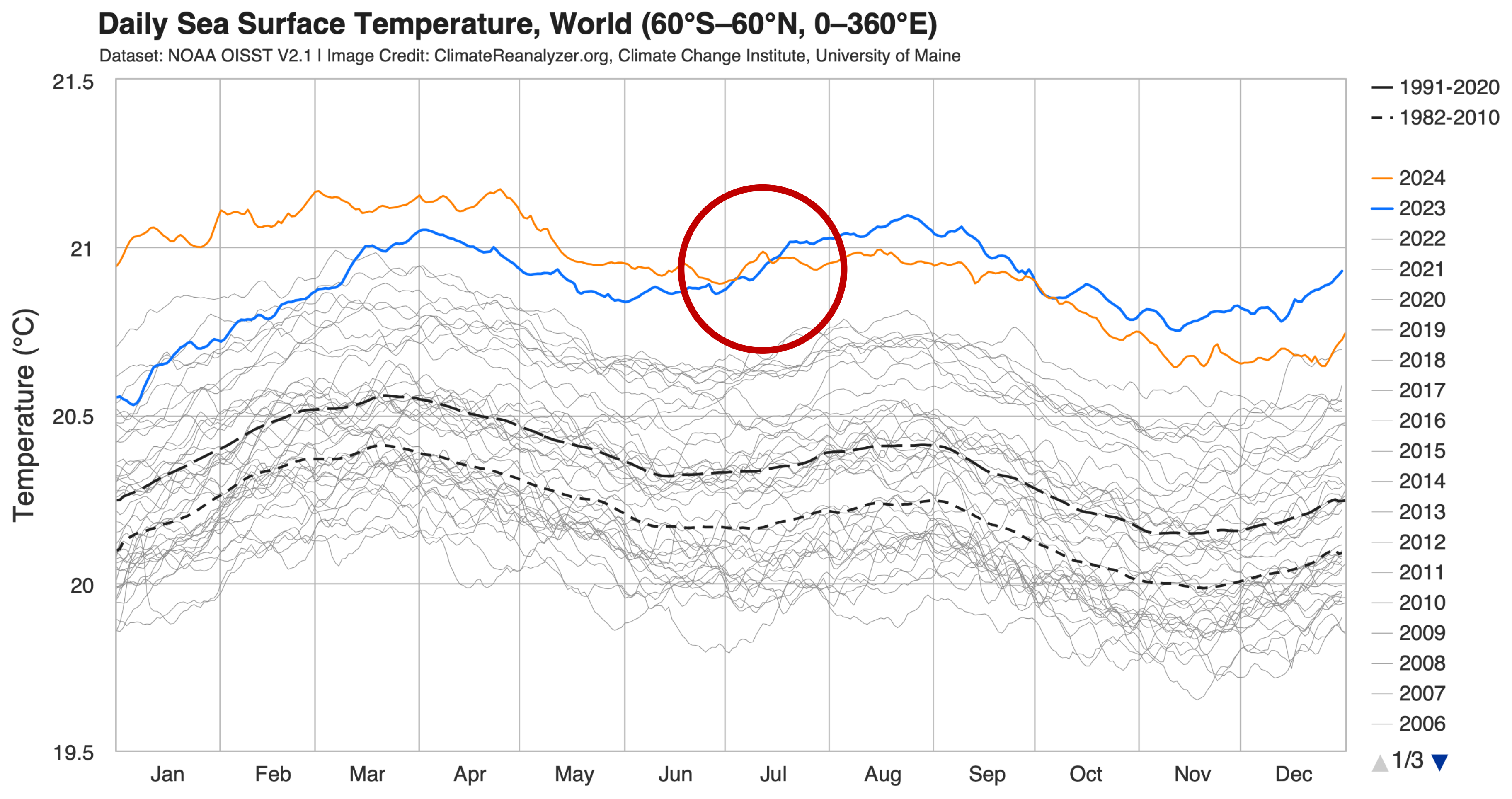

SSTs return to pre-jump temperatures in 8 of 11 simulations

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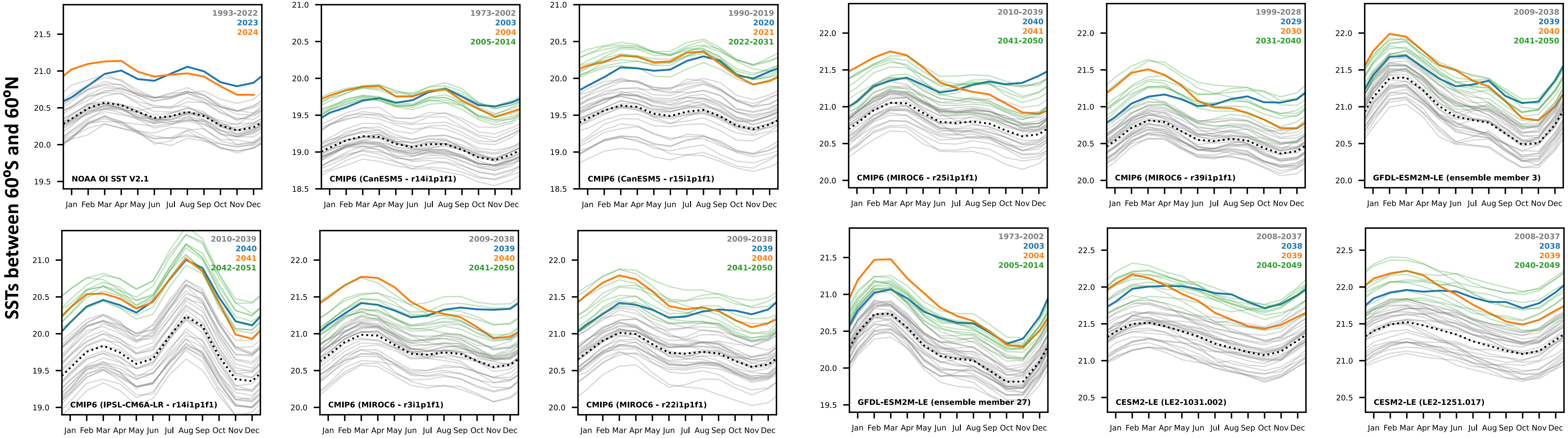

Terhaar et al. (2025)

Only in models with very high climate sensitivities do SSTs not return to pre-jump levels

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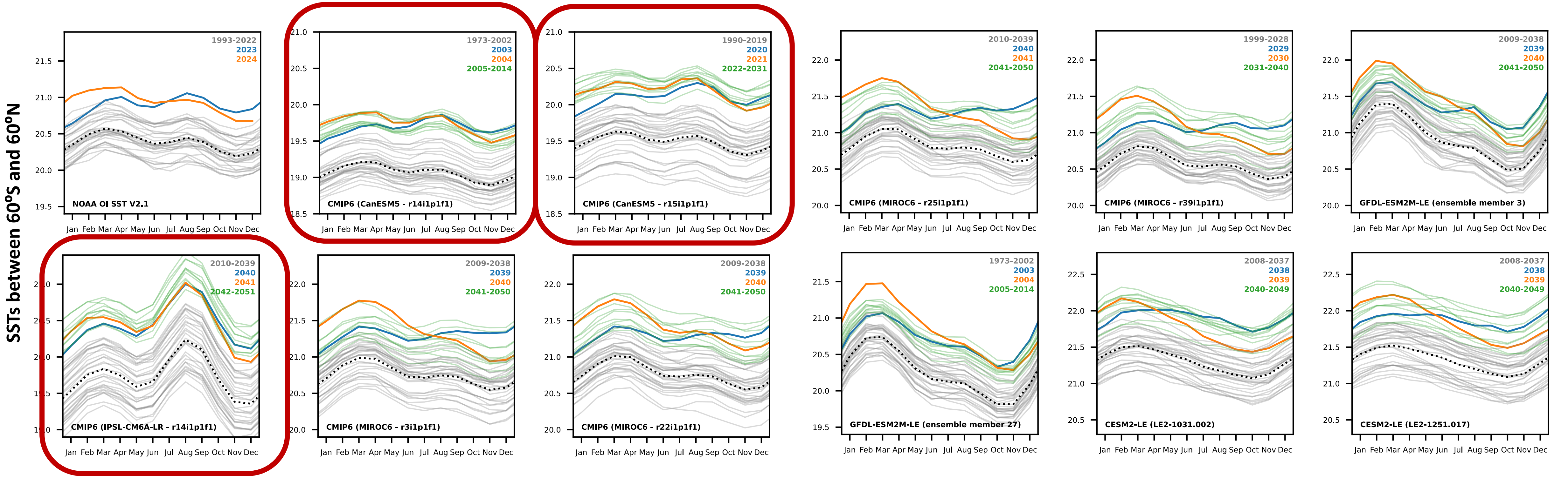

Terhaar et al. (2025)

Even when the ‘gap’ is not closed, warming does not unexpectedly accelerate and remains or returns to on the ensemble mean path

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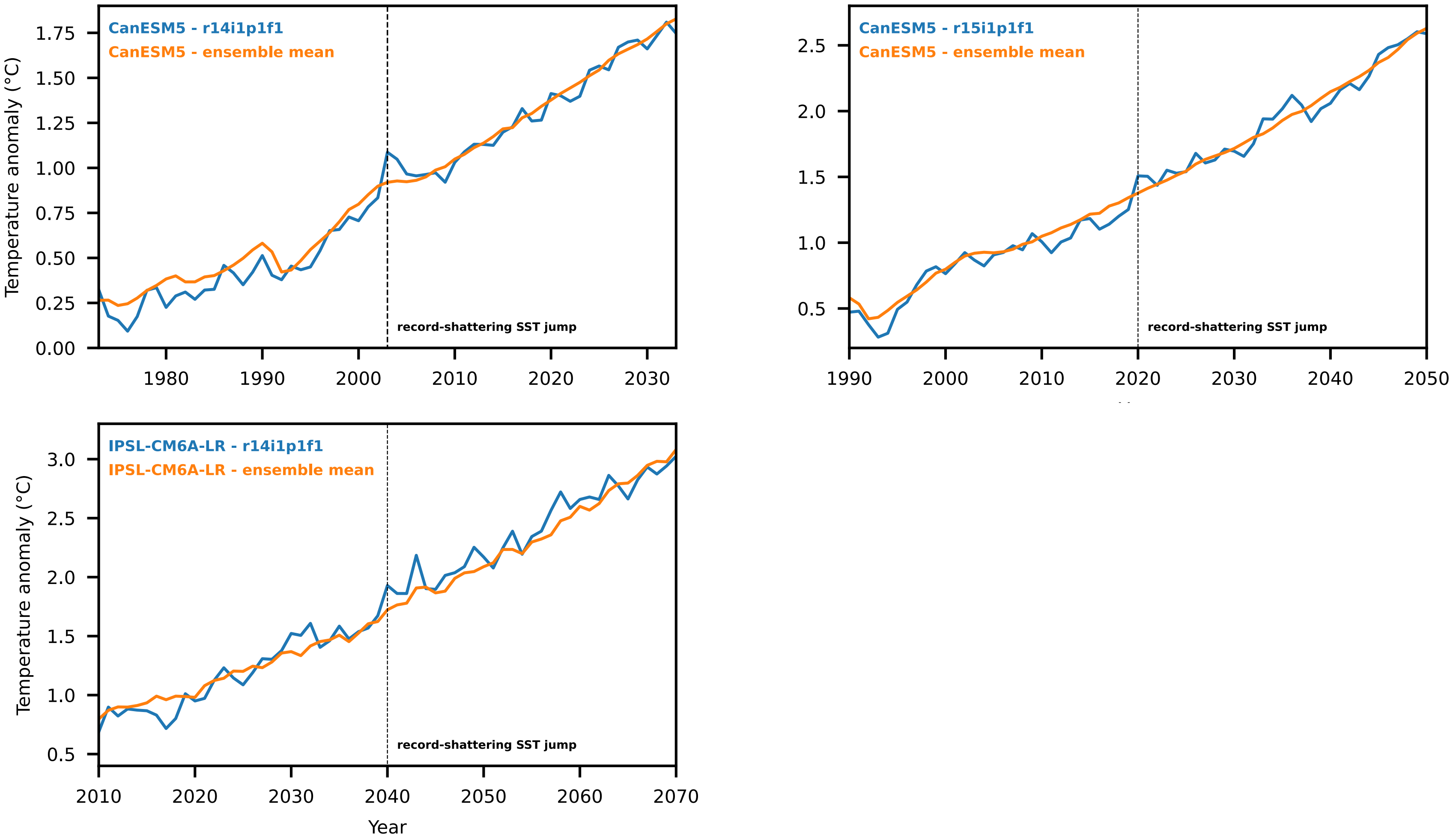

Observed SSTs returned to pre-jump levels in November 2025, two years after the jump in SSTs

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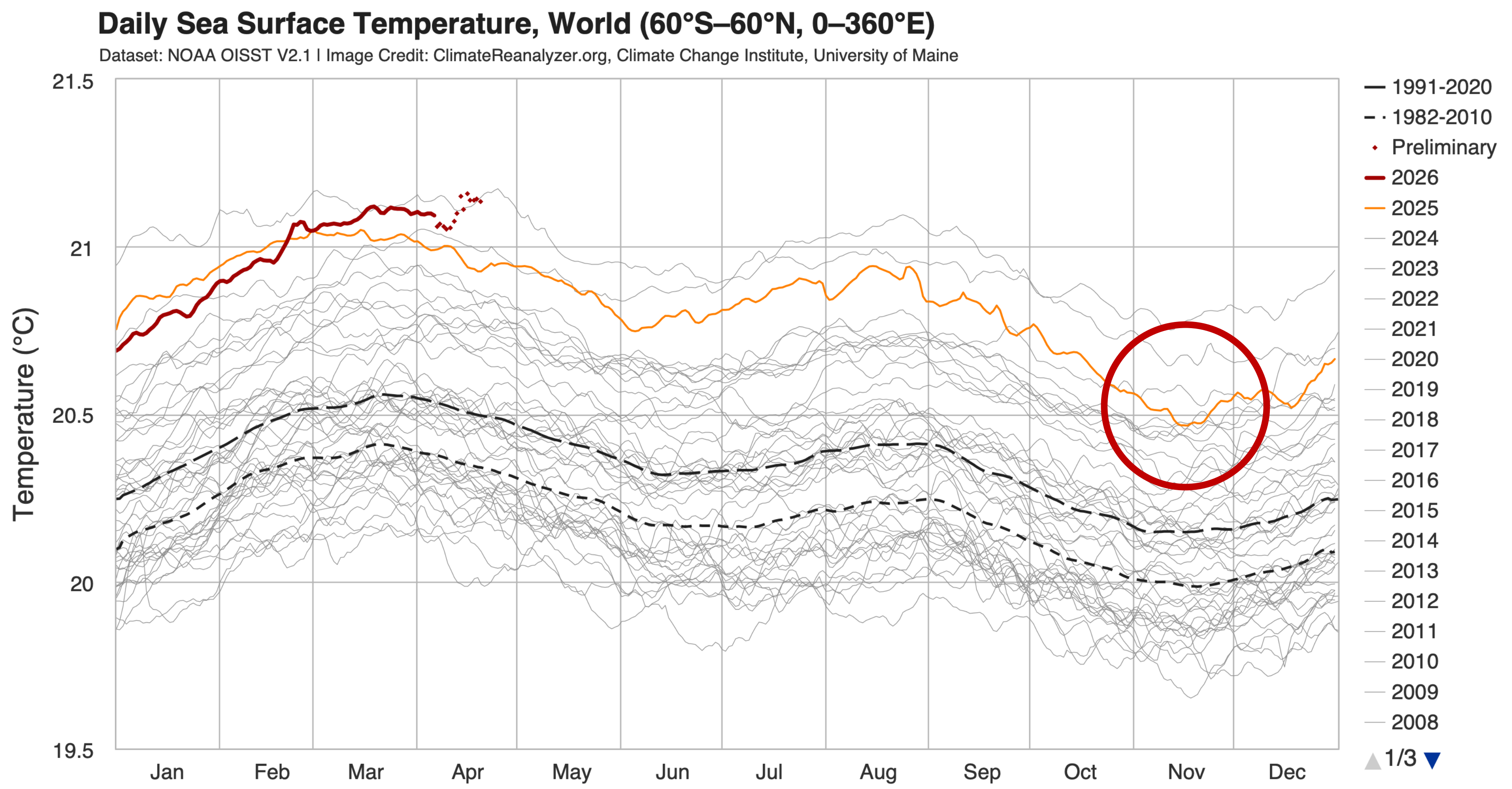

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SSTs returned later to pre-jump levels, the ECS/TCRE might be higher – possibly due to a so far not identified sea ice feedback in the Southern Ocean

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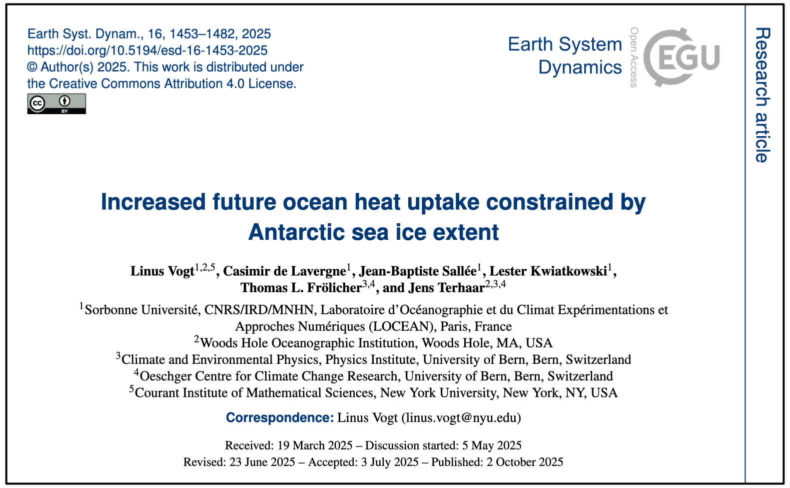
Earth Syst. Dynam., 16, 1453–1482, 2025
https://doi.org/10.5194/esd-16-1453-2025
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Earth System Dynamics
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Research article

Increased future ocean heat uptake constrained by Antarctic sea ice extent

Linus Vogt[1,2,5], **Casimir de Lavergne**[1], **Jean-Baptiste Sallée**[1], **Lester Kwiatkowski**[1], **Thomas L. Frölicher**[3,4], **and Jens Terhaar**[2,3,4]
[1]Sorbonne Université, CNRS/IRD/MNHN, Laboratoire d'Océanographie et du Climat Expérimentations et Approches Numériques (LOCEAN), Paris, France
[2]Woods Hole Oceanographic Institution, Woods Hole, MA, USA
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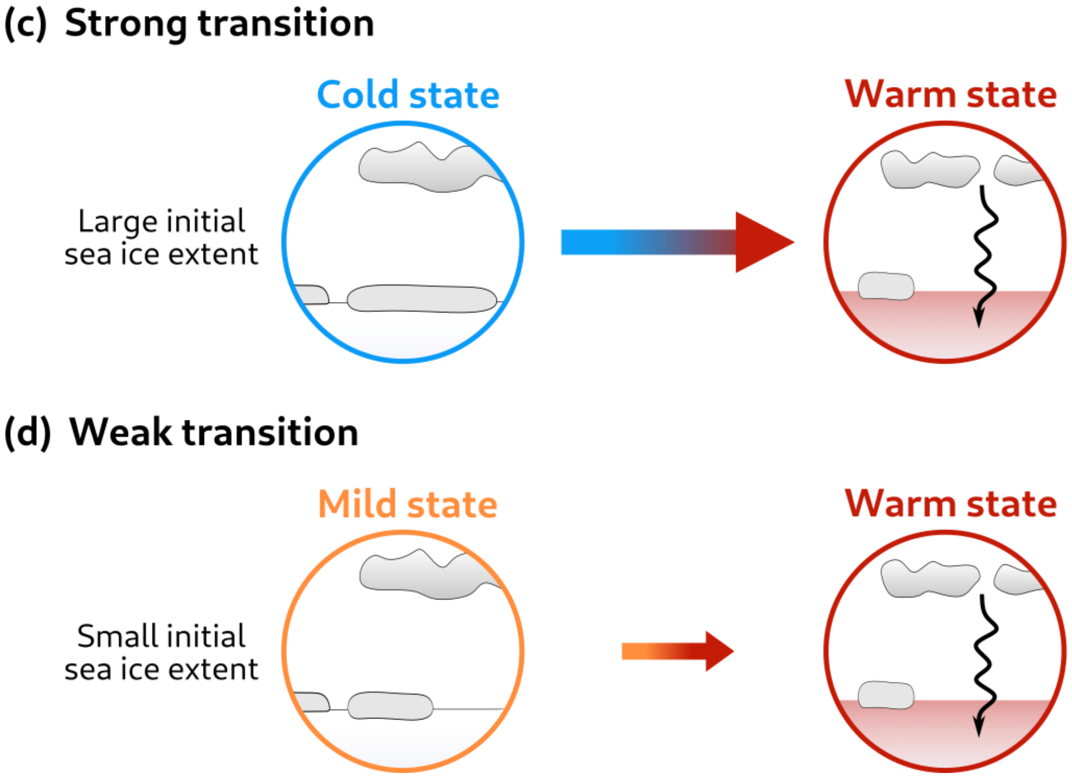
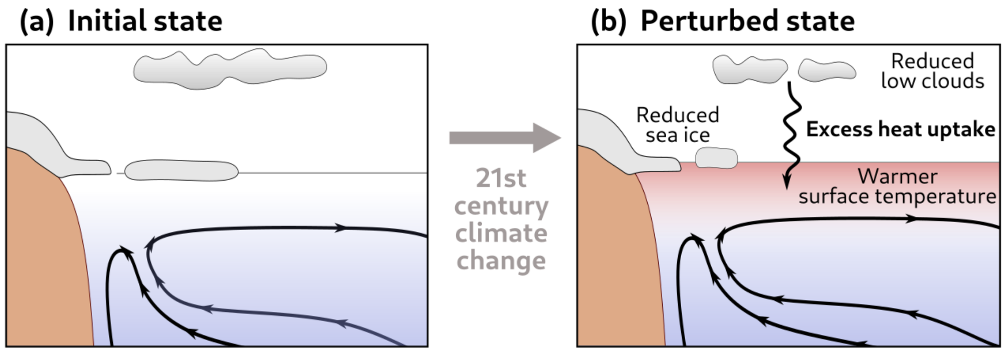
Correspondence: Linus Vogt (linus.vogt@nyu.edu)

Received: 19 March 2025 – Discussion started: 5 May 2025
Revised: 23 June 2025 – Accepted: 3 July 2025 – Published: 2 October 2025





It remains unclear what we expect to happen over the next years

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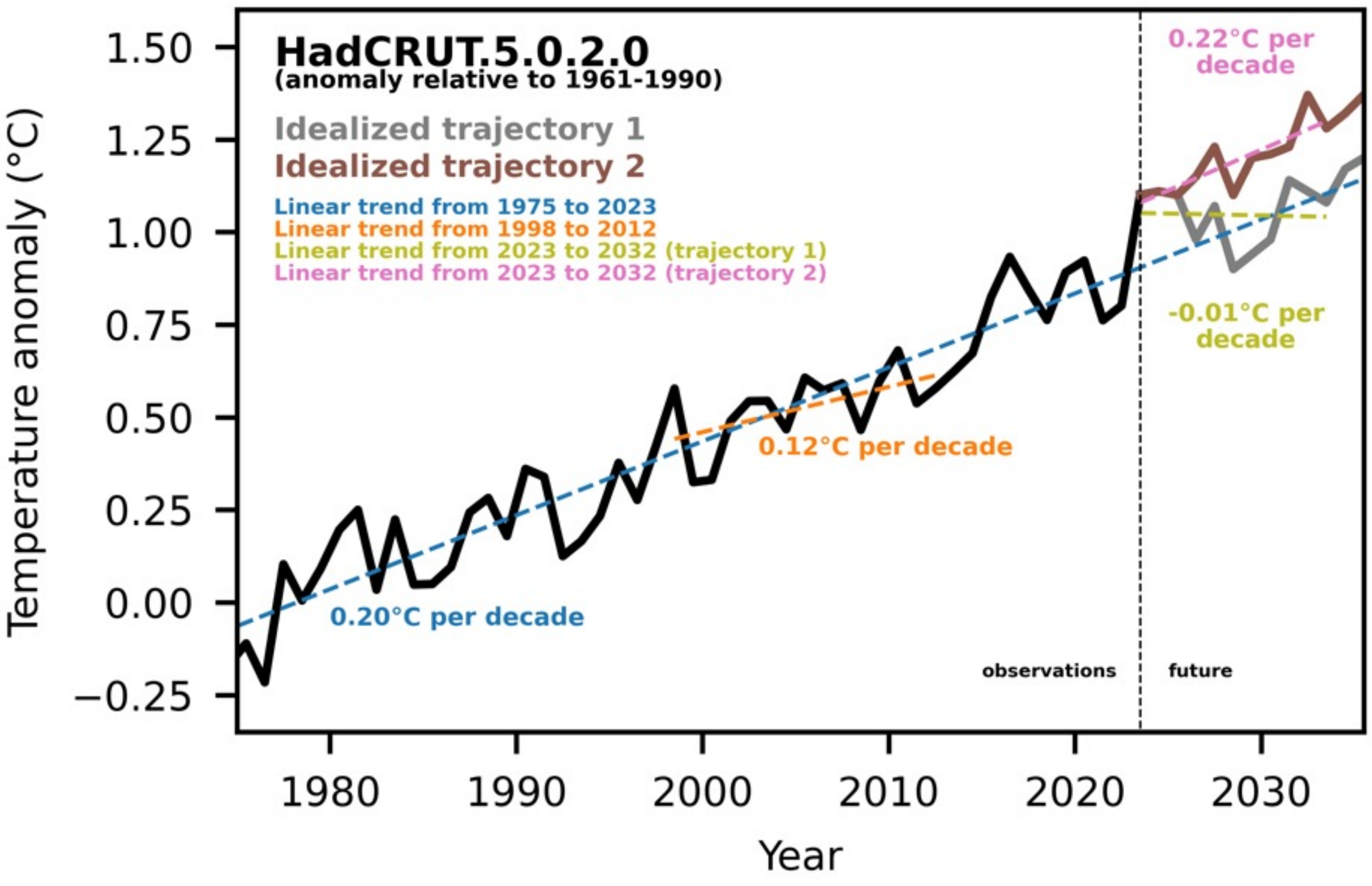

Unpublished / in prep.

A record-breaking year of atmospheric temperatures increases the likelihood of a hiatus over the next years

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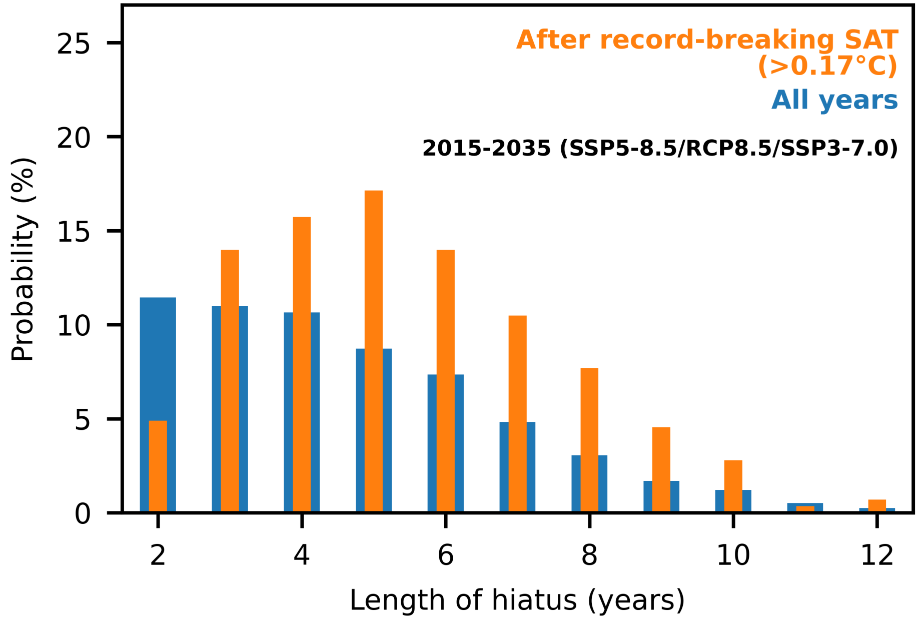

A record-breaking year of atmospheric temperatures increases the likelihood of a hiatus over the next years

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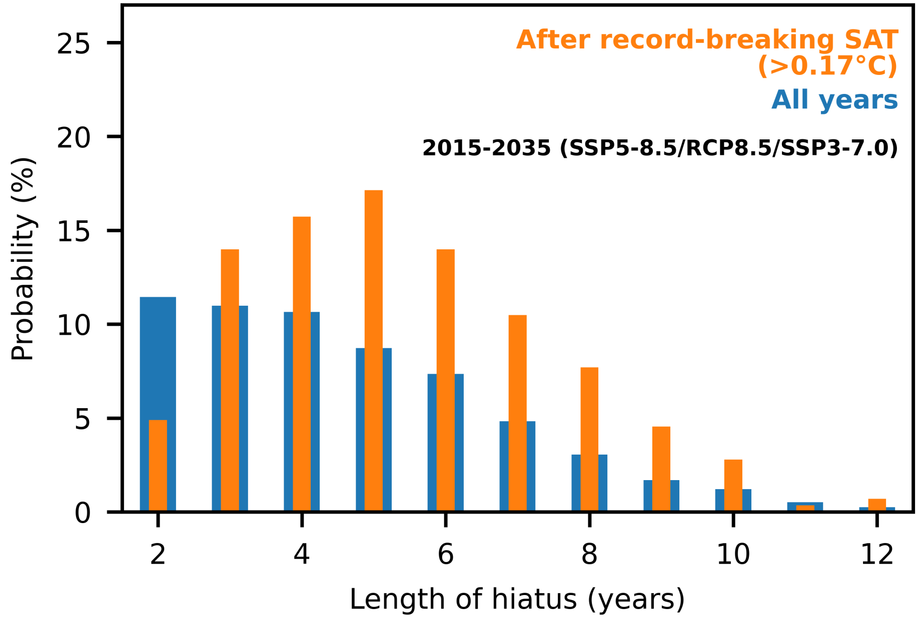

Hiatus length

- **any given year: 3.2±2.5 years**

A record-breaking year of atmospheric temperatures increases the likelihood of a hiatus over the next years

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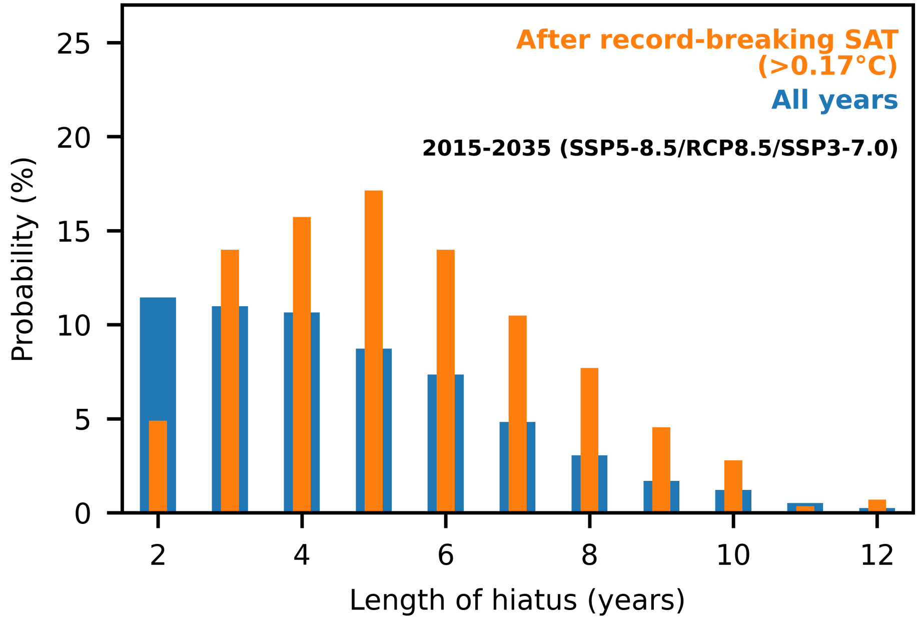

Hiatus length

- **any given year: 3.2±2.5 years**
- **After strong record-breaking atmospheric temperature jump: 5.1±2.4 years**

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A record-breaking year of atmospheric temperatures increases the likelihood of a hiatus over the next years

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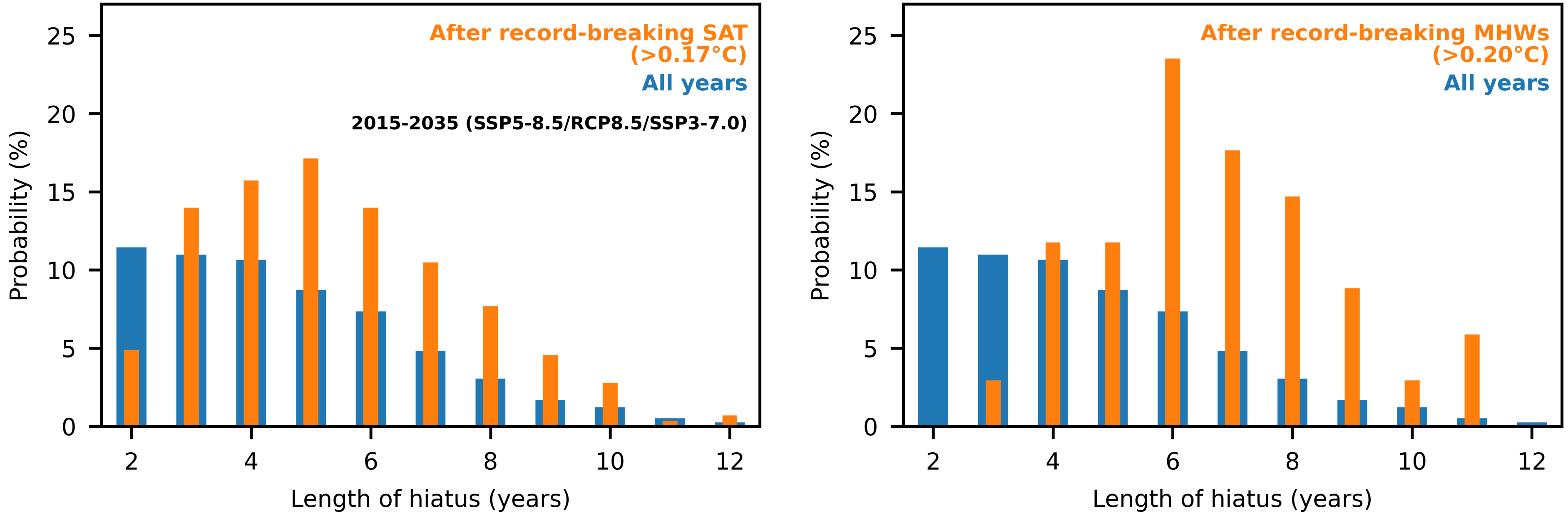

Hiatus length

- **any given year: 3.2±2.5 years**
- **After strong record-breaking atmospheric temperature jump: 5.1±2.4 years**
- **After strong record-breaking temperature jumps in atmosphere and ocean: 6.7±2.0 years**

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Temperature trends show a distinct pattern during the hiatus after record-breaking jumps in atmosphere and ocean

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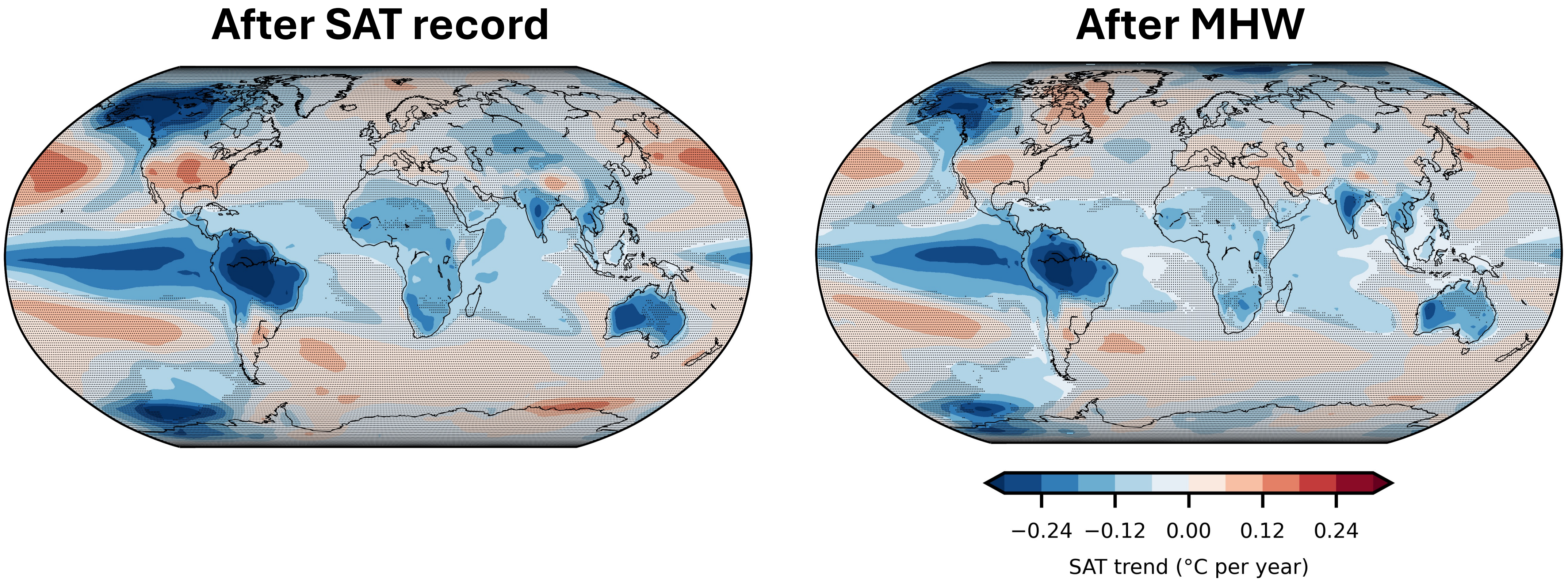

*no stippling indicates where 80% of the simulated hiatus agree on the sign

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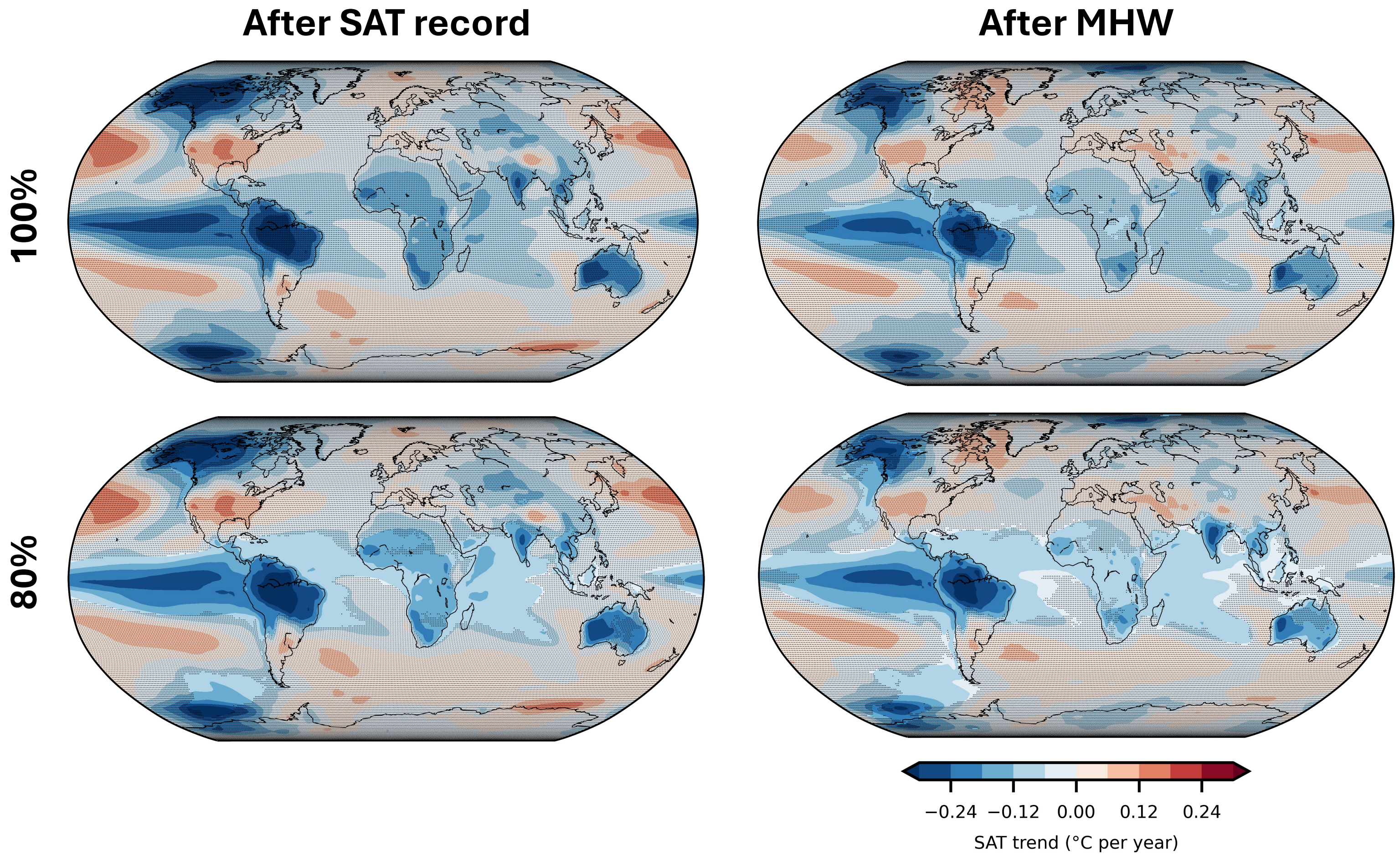

*no stippling indicates where 80% (100%) of the simulated hiatus agree on the sign

Unpublished / in prep.

Take home messages

1) Based on observational estimates of trends, variances, and autocorrelations, the jump in SSTs that broke old SSTs record by 0.25℃ was a 1-in-a-512-years event (205-1185 years)

2) Climate models can simulate such events and can hence be used to assess changes in extreme events in the future

3) An El-Niño event is a necessary for such jumps in SST to occur

4) It is not only the ‘hot models’ that simulate such events but also models with a weak warming trend

5) SSTs stop to be record-breaking in the year after the start of the jump in SSTs and return to expected long-term warming trends

6) After such record-shattering jumps in SST, a relatively long hiatus is very likely