ICSF Irish Climate Science Forum

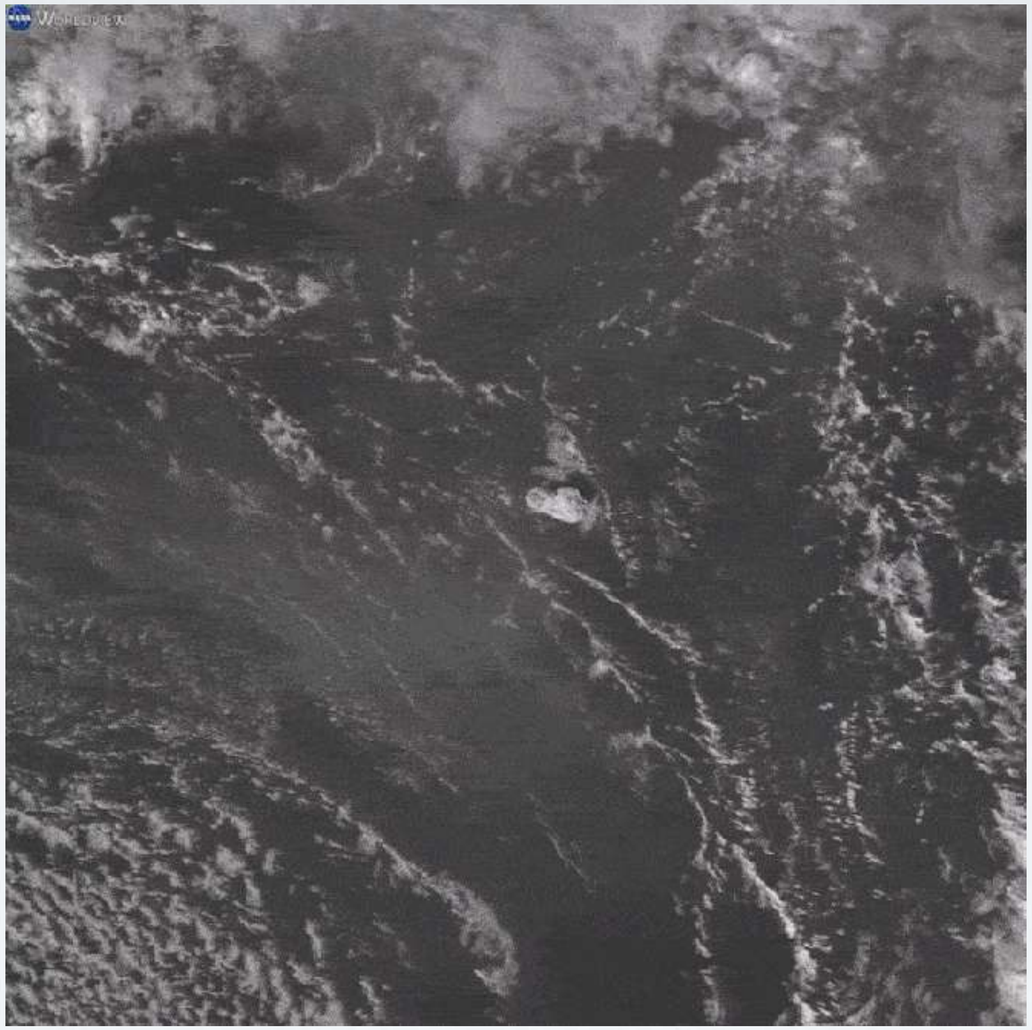
The 2022 Hunga Tonga Subsea Eruption, What Effect Did It Have on Climate?

Javier Vinós

February 25th, 2026

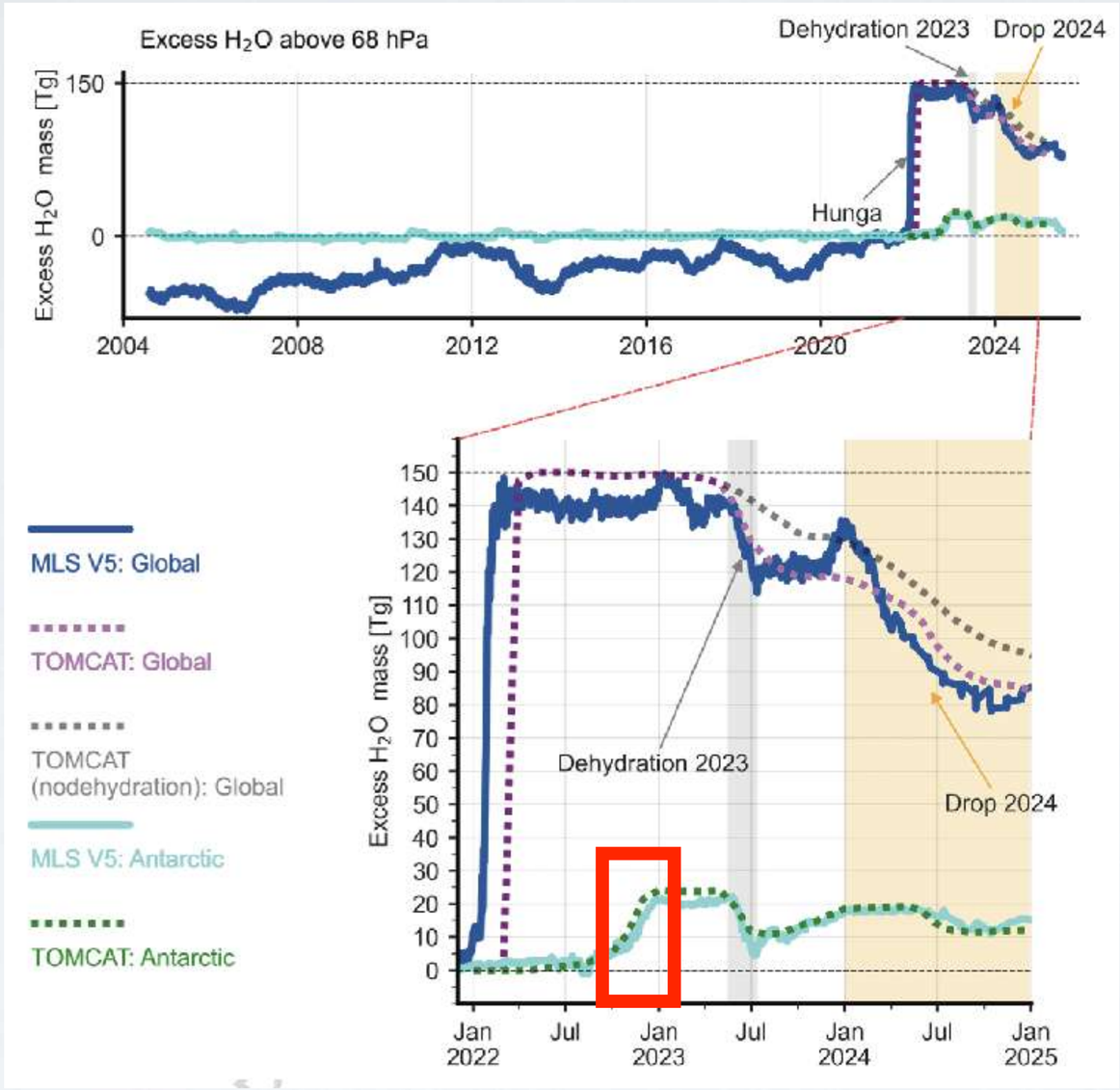
1. An unprecedented volcanic eruption

The Hunga Tonga–Hunga Ha‘apai submarine volcano in the South Pacific Ocean erupted on January 15, 2022



This is the first underwater eruption known to have reached the stratosphere.

Hunga Tonga is an unusual and unprecedented eruption whose effects are unknown

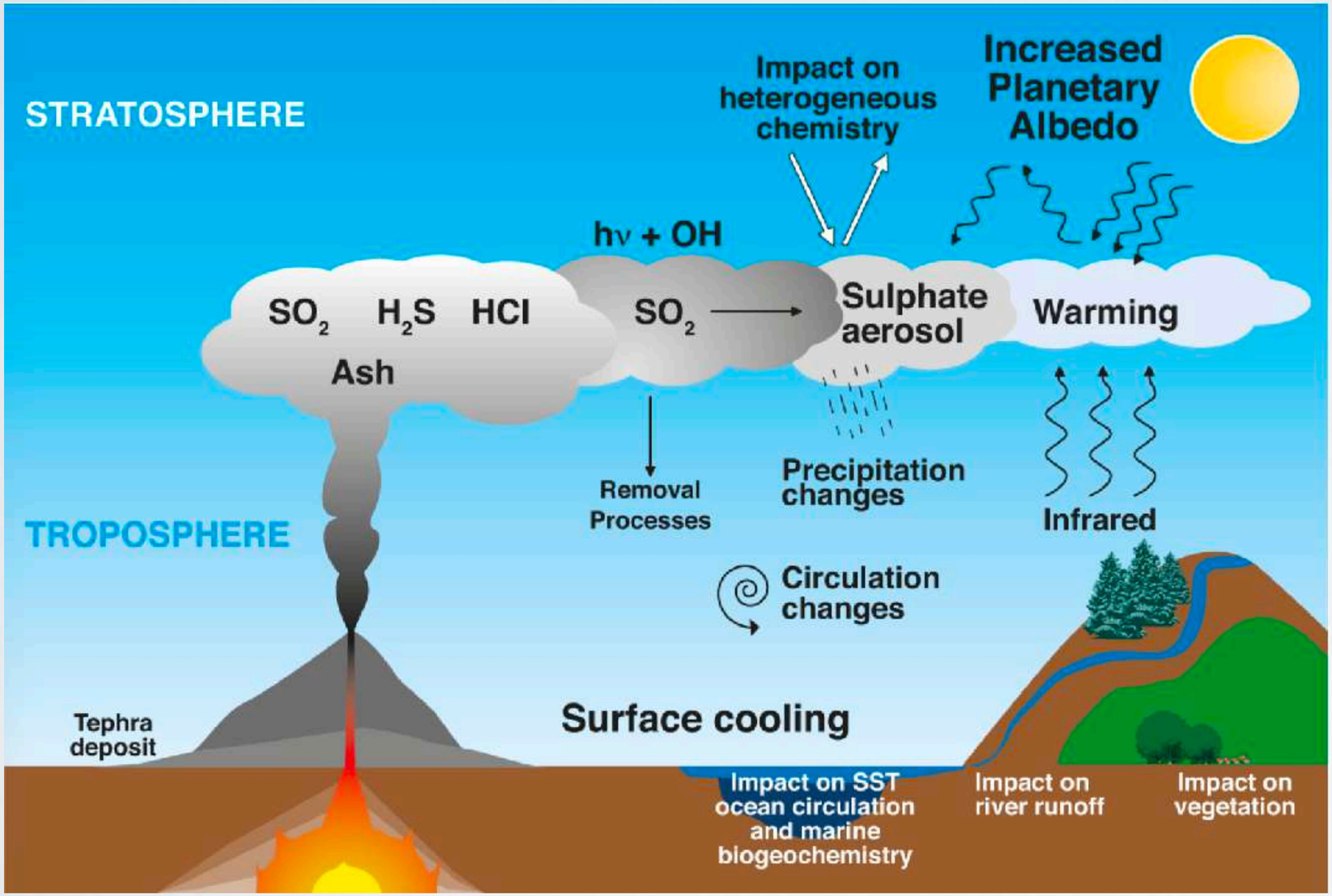


3 years of e-folding time, should reach pre-Hunga levels by 2030

Zhou et al. 2026

2. The three types of volcanic effects that affect the climate

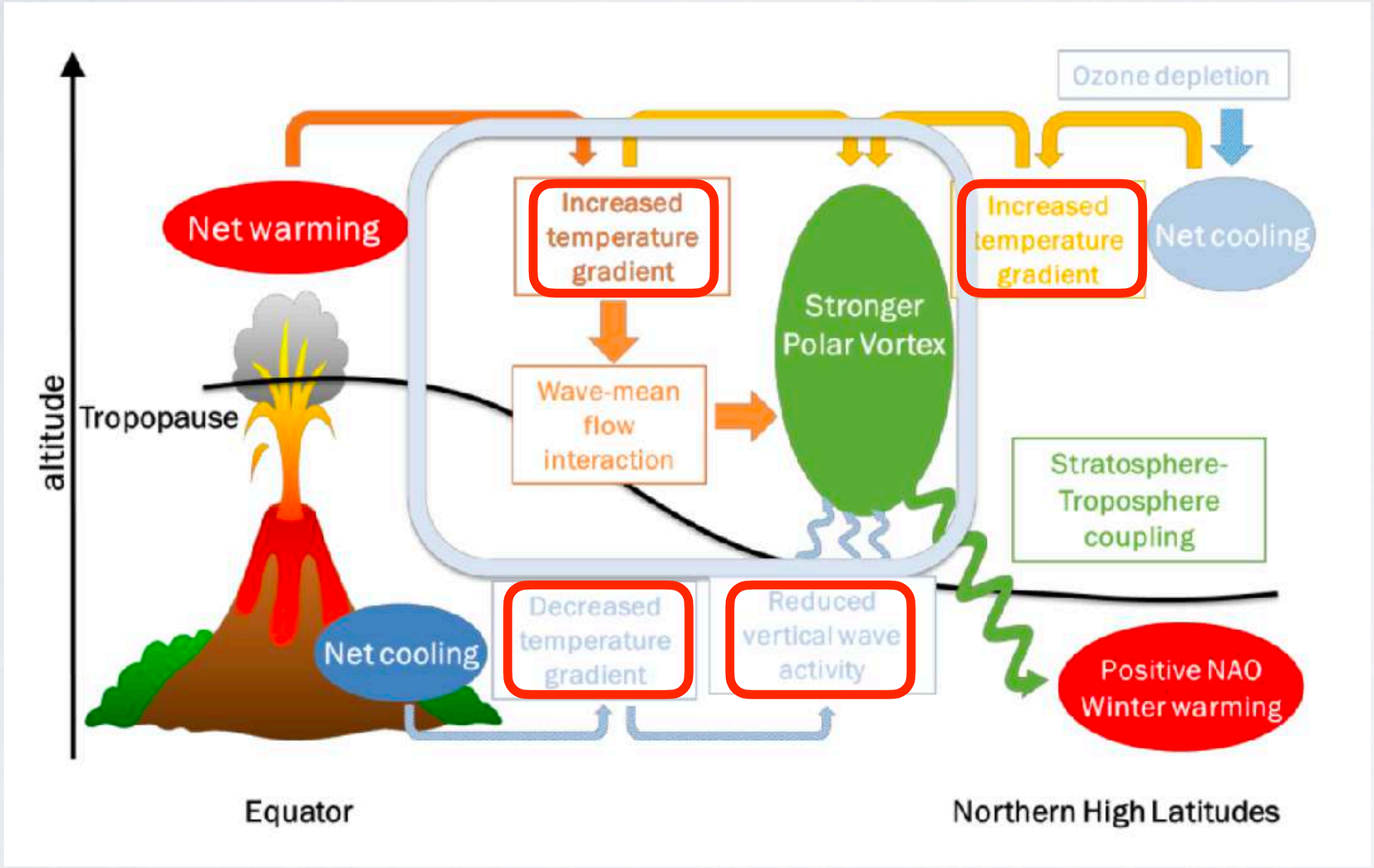
Radiative and chemical effects of large volcanic eruptions



They are very well known and well-modeled

Timmreck 2018

Dynamic effects of large volcanic eruptions



They are poorly understood and modeled. Our understanding of them is based on very limited statistics.

They are postulated to act by changing temperature gradients and planetary wave activity. This links them to the **Winter Gatekeeper hypothesis**.

Timmreck 2018

3. Water vapor in the STRATOSPHERE

Stratospheric water vapor is known to strongly affect global warming rates

Contributions of Stratospheric Water Vapor to Decadal Changes in the Rate of Global Warming

Susan Solomon,[1] Karen H. Rosenlof,[1] Robert W. Portmann,[1] John S. Daniel,[1] Sean M. Davis,[1,2] Todd J. Sanford,[1,2] Gian-Kasper Plattner[3]

Stratospheric water vapor concentrations decreased by about 10% after the year 2000. Here we show that this acted to slow the rate of increase in global surface temperature over 2000–2009 by about 25% compared to that which would have occurred due only to carbon dioxide and other greenhouse gases. More limited data suggest that stratospheric water vapor probably increased between 1980 and 2000, which would have enhanced the decadal rate of surface warming during the 1990s by about 30% as compared to estimates neglecting this change. These findings show that stratospheric water vapor is an important driver of decadal global surface climate change.

Solomon et al. 2010

If a decrease in stratospheric water vapor slows surface warming, an increase should enhance warming.

4. The 2023 climate event

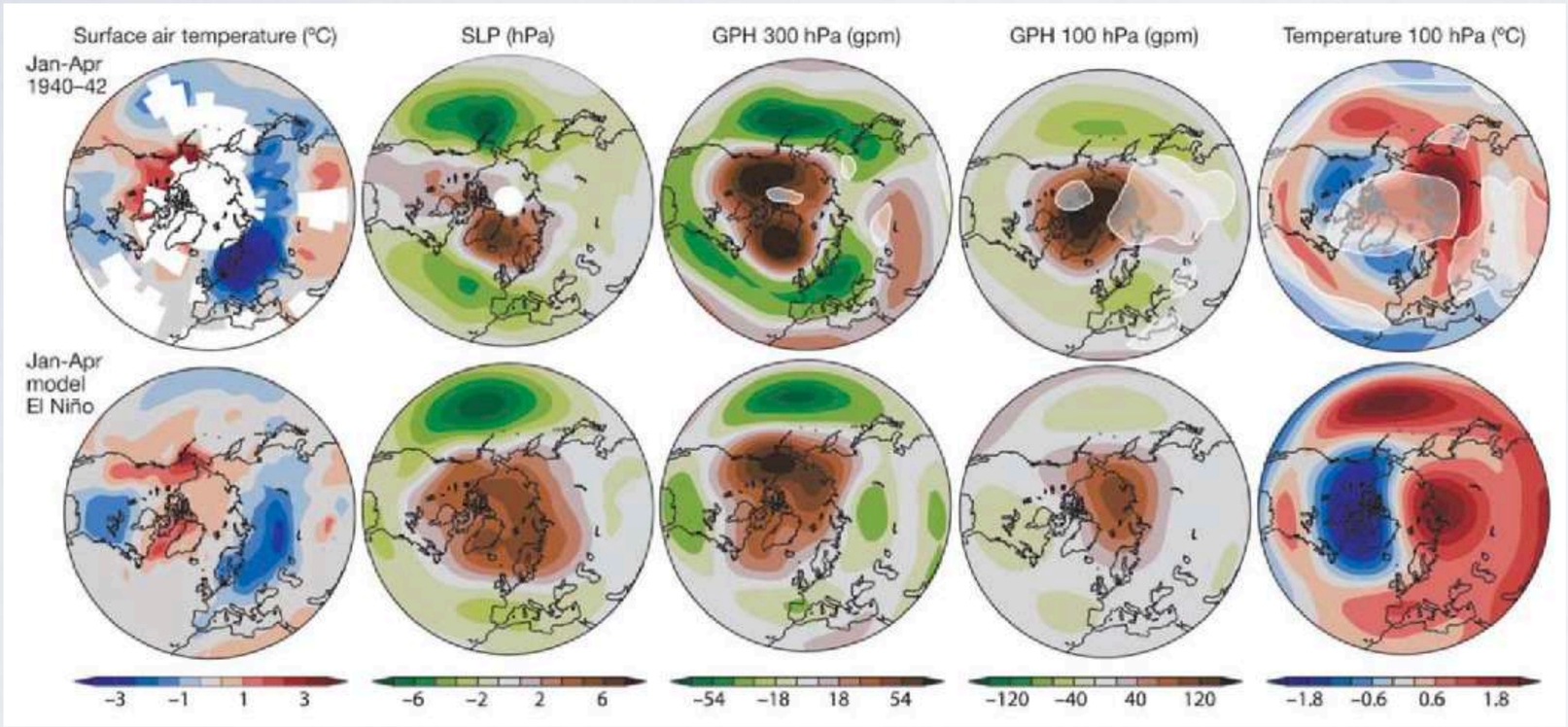
A climate event

- Climate refers to the long-term average and variability of weather conditions in a specific area, typically calculated over a period of 30 years or more. It encompasses various factors, including temperature, humidity, precipitation, wind patterns, and atmospheric pressure.

- A climate event is a marked departure from normal climate patterns and variability due to its intensity, duration, or impact.

- Examples of climate events with a duration ranging from pluriannual to pluridecadal include the Dust Bowl (regional) and the 8.2 kiloyear event (global).

The last global, pluriannual climate event occurred more than 80 years ago

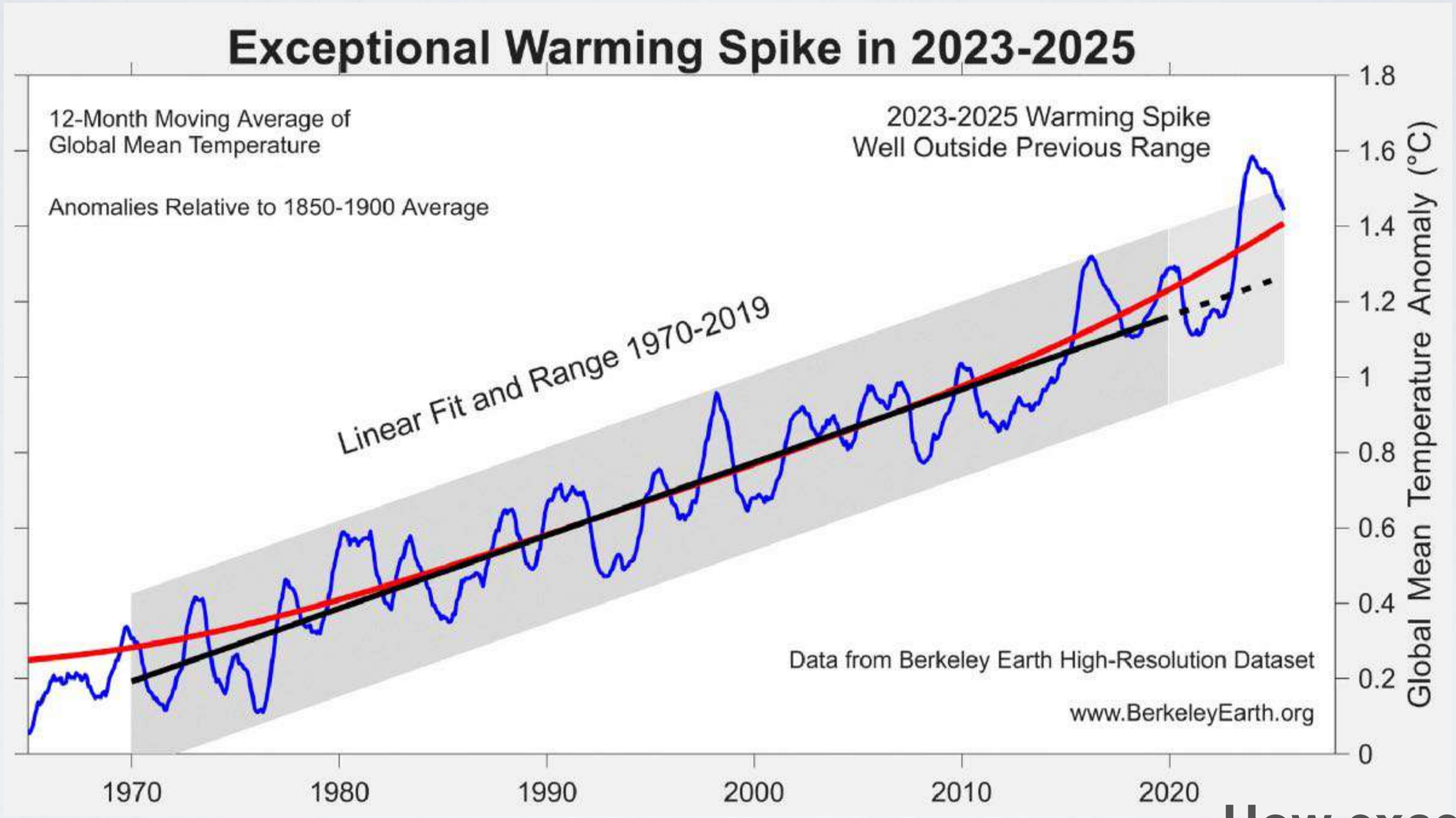


Extreme climate of the global troposphere and stratosphere in 1940–42 related to El Niño

S. Brönnimann[1], J. Luterbacher[1], J. Staehelin[1], T. M. Svendby[2], G. Hansen[2] & T. Svenøe[2]

From 1940 to 1942 occurred a strong and long-lasting El Niño event, inducing an anomalous state of the troposphere and stratosphere in the Northern Hemisphere. Exceptionally low temperatures in Europe and the north Pacific Ocean coincided with high temperatures in Alaska and frequent stratospheric warmings.

Since they are so rare, we have been lucky to observe a new global, pluriannual climate event



How exceptional?

The 2023 Climate Event has only a 0.2% chance according to CMIP6 climate models

BRIEF COMMUNICATION OPEN

Check for updates

The jump in global temperatures in September 2023 is extremely unlikely due to internal climate variability alone

Mika Rantanen[1]✉ and Ari Laaksonen[1,2]

September 2023 was the warmest September on record globally by a record margin of 0.5 °C. Here we show that such a record-breaking margin is an extremely rare event in the latest generation of climate models, making it highly unlikely ($p \sim 1\%$) that internal climate variability combined with the steady increase in greenhouse gas forcing could explain it. Our results call for further analysis of the impact of other external forcings on the global climate in 2023.

npj Climate and Atmospheric Science (2024)7:34 ; https://doi.org/10.1038/s41612-024-00582-9

An external cause is likely

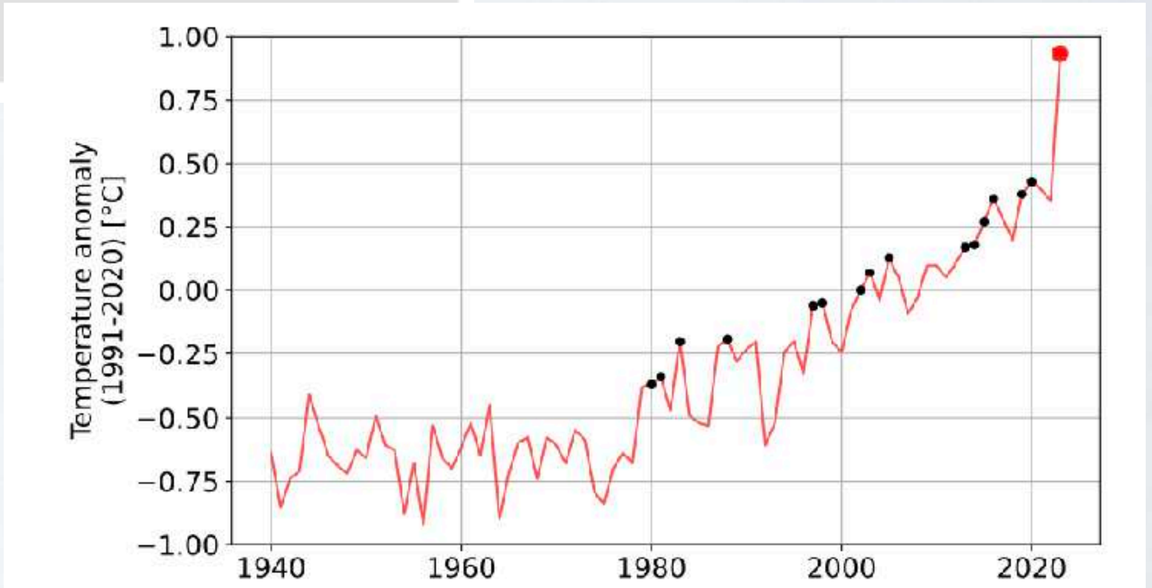


Fig. 1 September 2023 shattered the record globally. Time series

Scientists are confused, models can’t explain

World view

Why 2023’s heat anomaly is worrying scientists

By Gavin Schmidt

Climate models struggle to explain why planetary temperatures spiked suddenly. More and better data are urgently needed.

When I took over as the director of NASA’s Goddard Institute for Space Studies, I inherited a project that tracks temperature changes since 1880. Using this trove of data, I’ve made climate predictions at the start of every year since 2016. It’s humbling, and a bit worrying, to admit that no year has confounded climate scientists’ predictive capabilities more than 2023 has.

For the past nine months, mean land and sea surface temperatures have overshot previous records each month by up to 0.2 °C – a huge margin at the planetary scale. A

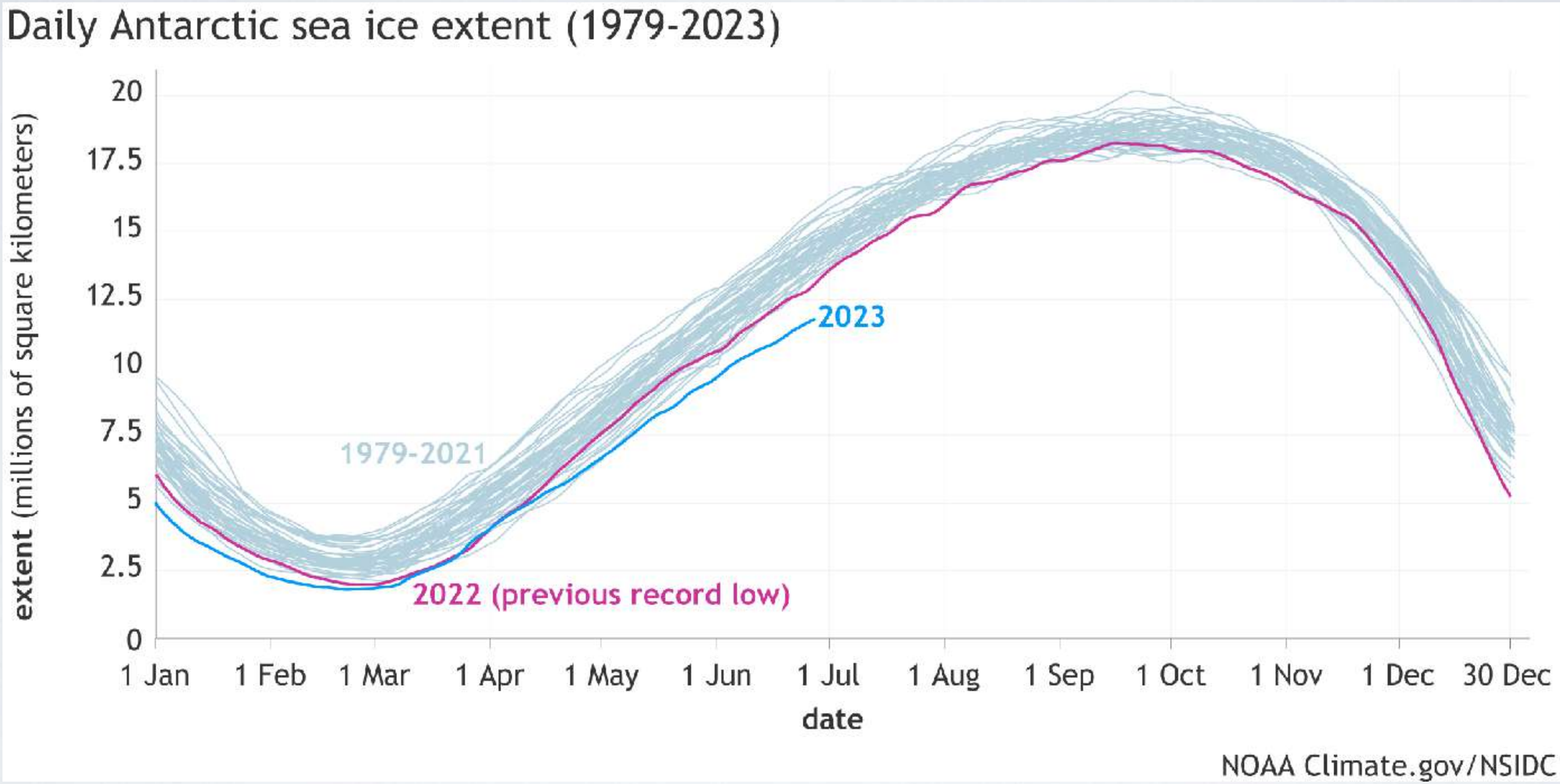
> “If the anomaly does not stabilize by August, then the world will be in uncharted territory.”

from stratospheric water vapour, and the ramping up of solar activity in the run-up to a predicted solar maximum. But these factors explain, at most, a few hundredths of a degree in warming (Schoeberl, M. R. *et al. Geophys. Res. Lett.* **50**, e2023GL104634; 2023). Even after taking all plausible explanations into account, the divergence between expected and observed annual mean temperatures in 2023 remains about 0.2 °C – roughly the gap between the previous and current annual record.

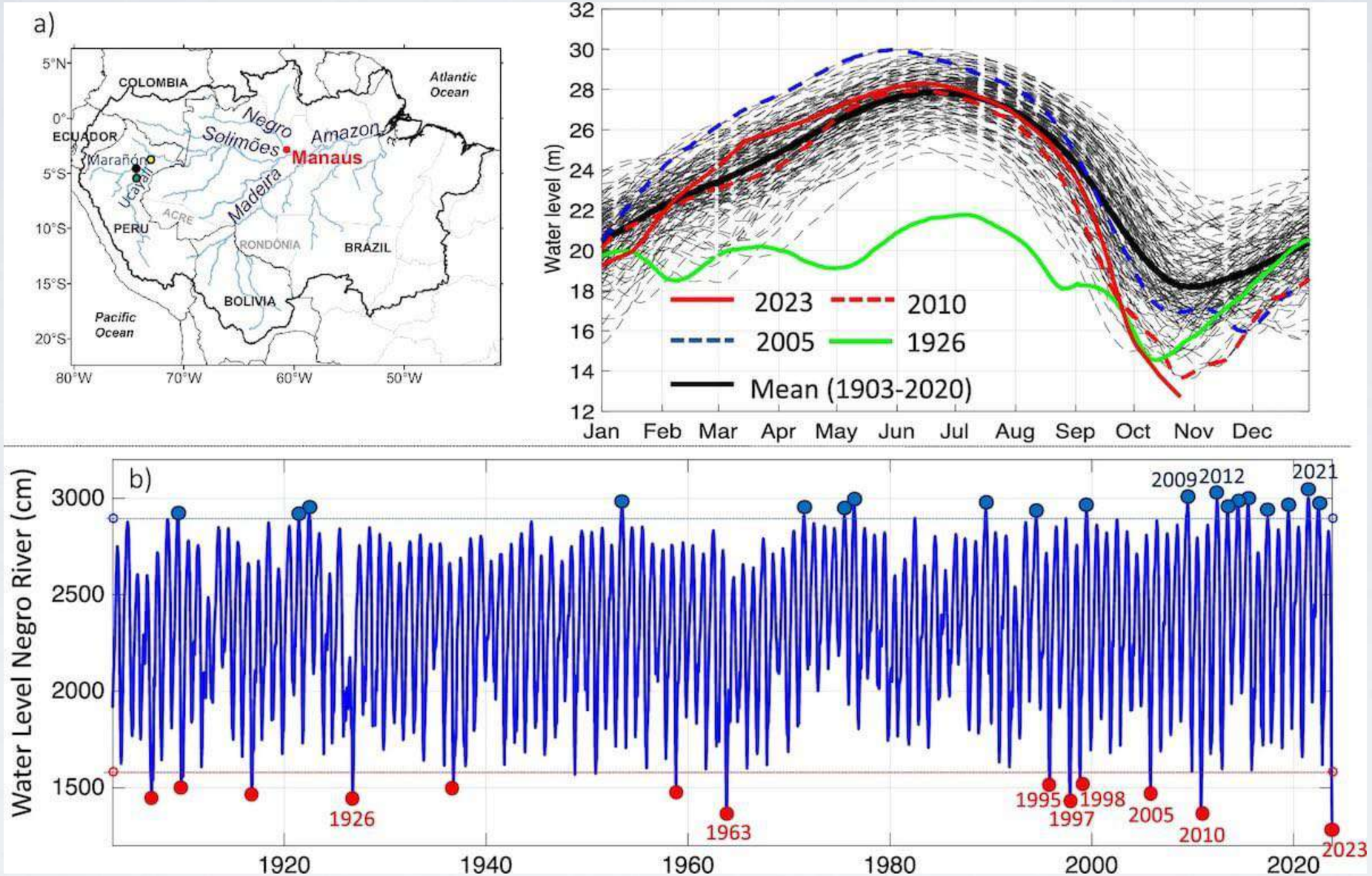
There is one more factor that could be playing a part. In 2020, new regulations required the shipping industry to use cleaner fuels that reduce sulfur emissions. Sulfur compounds in the atmosphere are reflective and influence several properties of clouds, thereby having an overall cooling effect. Preliminary estimates of the impact of these rules show a negligible effect on global

5. How unusual is the 2023 climate event?

Record-low Antarctic sea ice

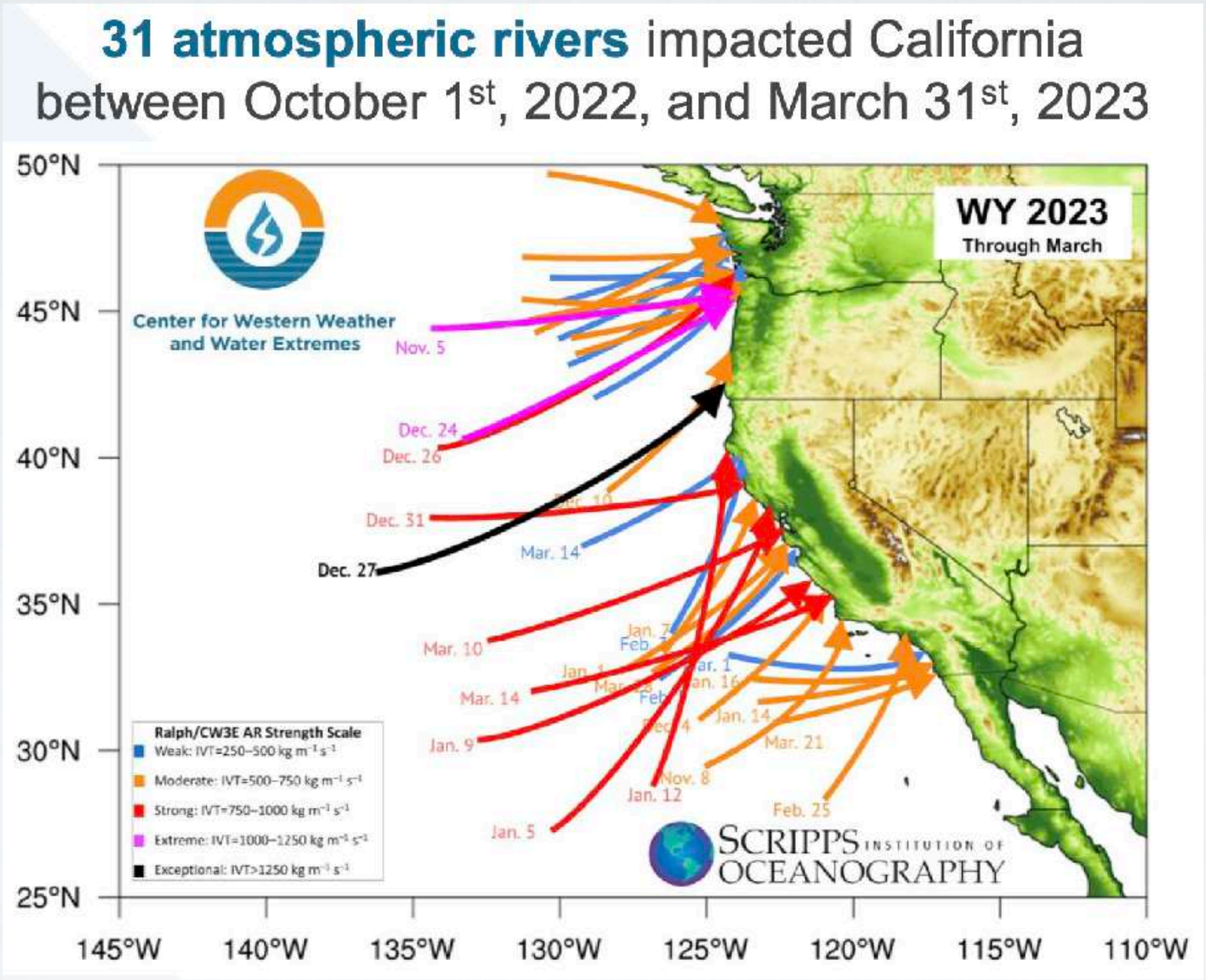


A record-breaking Amazon drought in 2023

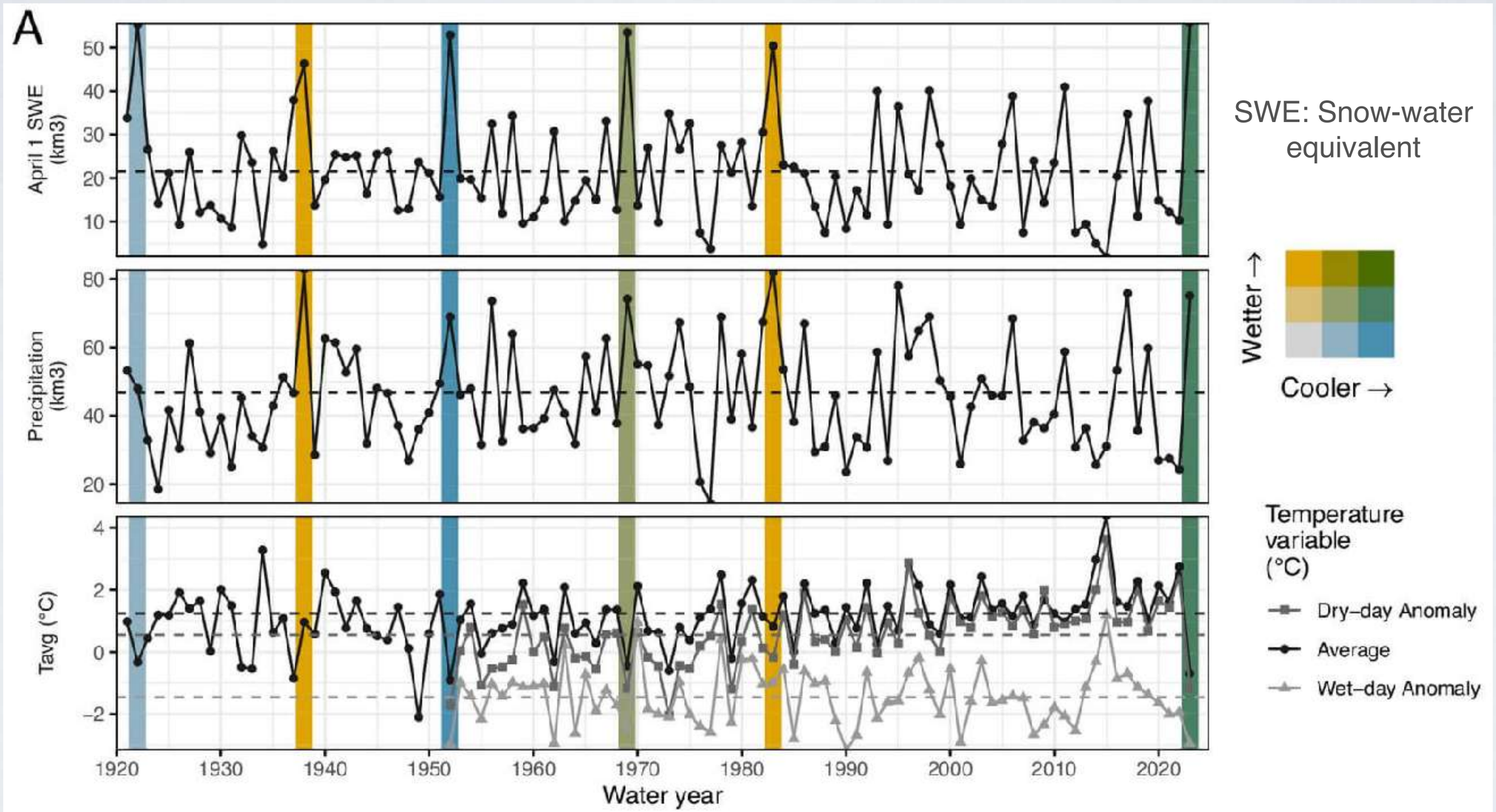


Espinoza et al. 2024

A 70-year record of atmospheric river events in California during the 2022-23 season



The snowiest season in 71 years occurred in California after a 1-in-54-year snow deluge



Marshall et al. 2024

NYC had the least snowy season on record, breaking a 50-year record on latest first snow

NEWS

2023 least snowiest year in NYC on record, says National Weather Service

Published: Jan. 01, 2024, 12:22 p.m.

METRO

Snowless NYC breaks 50-year record of longest winter without flurries

By Isabel Keane

Published Jan. 29, 2023 | Updated Jan. 29, 2023, 5:12 p.m. ET

79 Comments

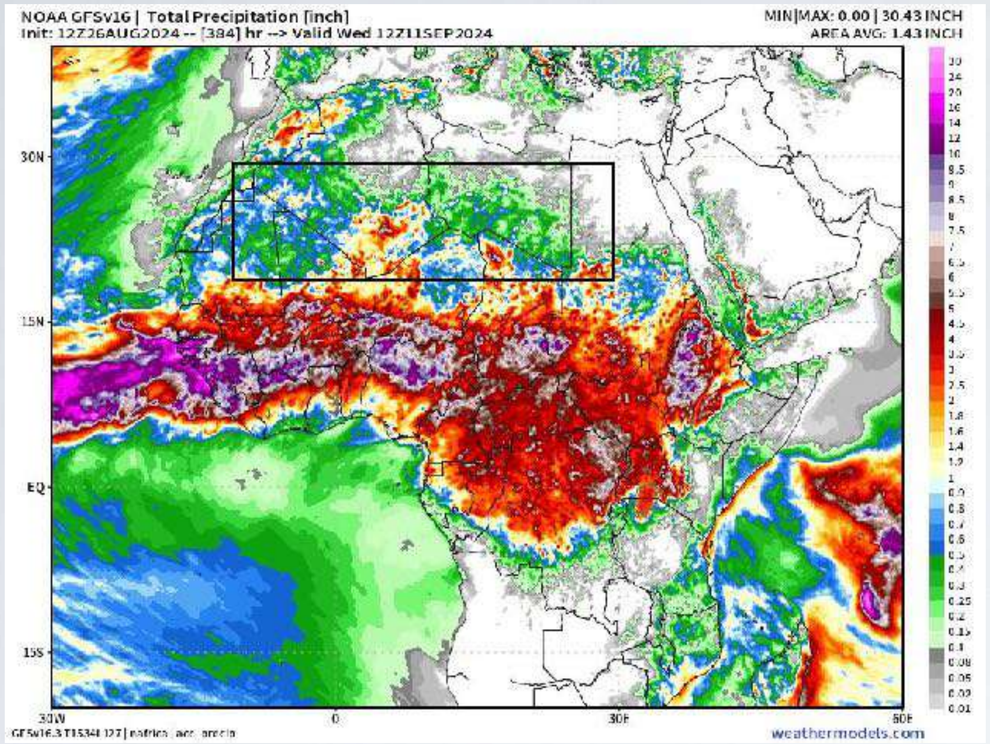
Cyclone Freddy in the Indian Ocean was the longest-lasting tropical cyclone ever

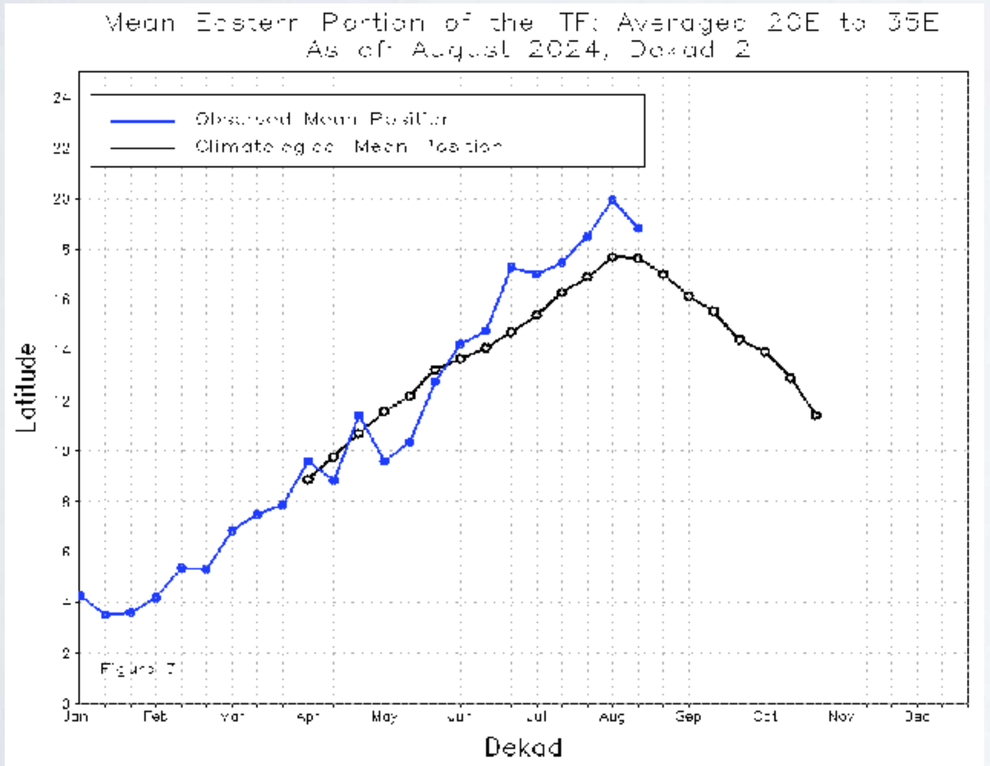
Tropical Cyclone Freddy is the longest tropical cyclone on record at 36 days: WMO

PRESS RELEASE

02 July 2024

The World Meteorological Organization (WMO) has declared Tropical Cyclone Freddy to be the longest-lasting tropical cyclone on record, at 36 days. Freddy crossed the Indian Ocean basin, starting off the coast of Northwest Australia and reached southern Africa, in February and March 2023. It caused major human and economic losses in the worst-affected countries.





ITCZ displacement and unusual rains in the Sahara in 2024

Intertropical Convergence Zone (ITCZ), The Earth’s climatic equator

The first half of the 2024 hurricane season was surprisingly quiet, and models can't explain it

Geophysical Research Letters

RESEARCH LETTER
10.1029/2025GL116714

The Remarkable 2024 North Atlantic Mid-Season Hurricane Lull

P. J. Klotzbach[1], E. Bercos-Hickey[2], K. M. Wood[3], C. J. Schreck III[4], M. M. Bell[1], E. S. Blake[5], S. G. Bowen[6], L.-P. Caron[7], D. R. Chavas[8], J. M. Collins[9], E. J. Gibney[10†], K. A. Hansen[11], A. T. Hazelton[12], J. J. Jones[13], M. R. Lowry[14], A. T. Nieves-Jimenez[1], C. M. Patricola[2,15], L. G. Silvers[1], R. E. Truchelut[16], and J. Uehling[4]

†Deceased

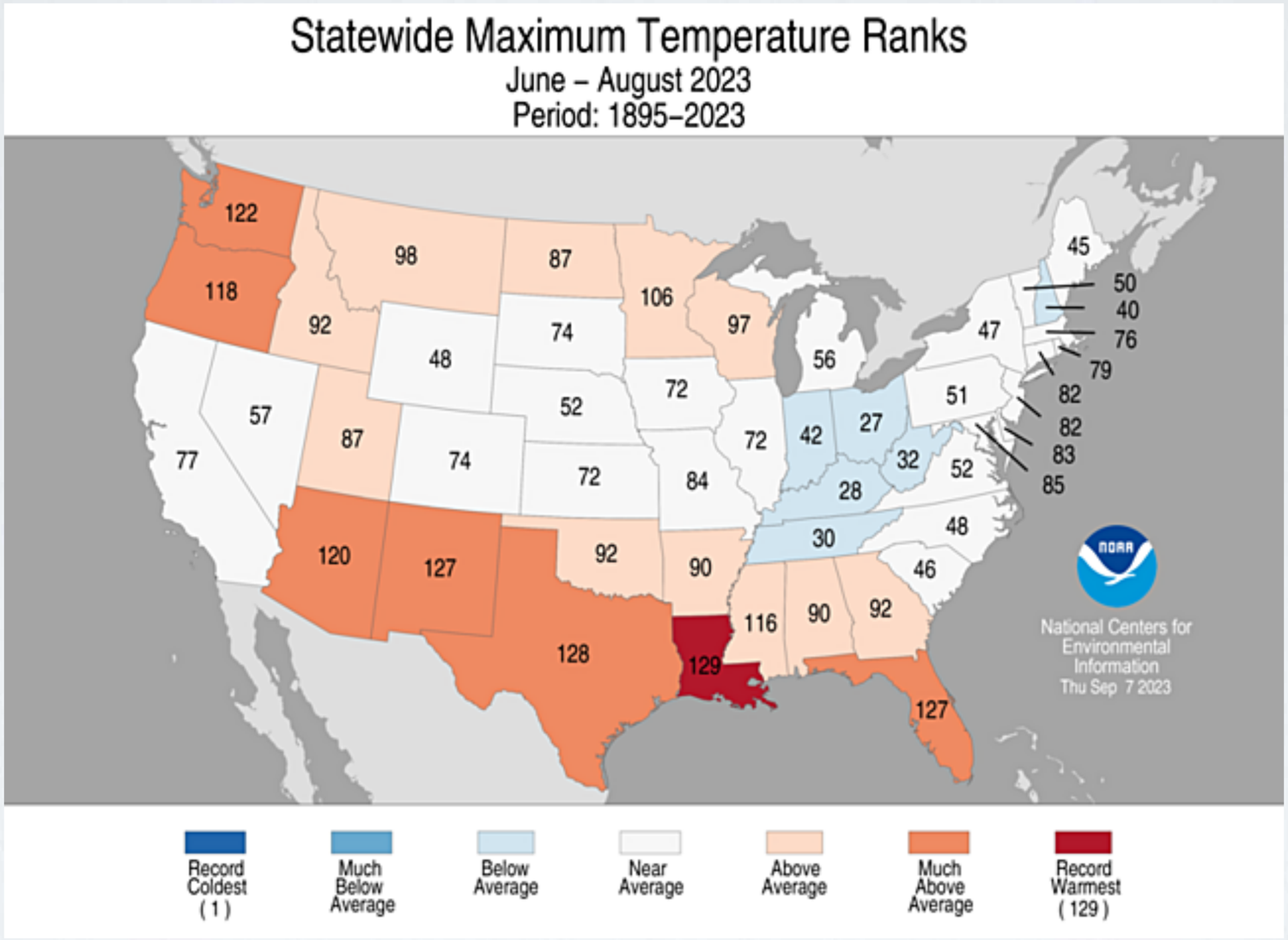
[1]Department of Atmospheric Science, Colorado State University, Fort Collins, CO, USA, [2]Climate and Ecosystem Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA, [3]Department of Hydrology and Atmospheric Sciences, The University of Arizona, Tucson, AZ, USA, [4]North Carolina Institute for Climate Studies, Cooperative Institute for Satellite Earth Systems Studies, North Carolina State University, Asheville, NC, USA, [5]NOAA/National Hurricane Center, Miami, FL, USA, [6]Gallagher Re, Chicago, IL, USA, [7]Ouranos, Montreal, QC, Canada, [8]Department of Earth, Atmospheric and Planetary Sciences, Purdue University, West Lafayette, IN, USA, [9]School of Geosciences, University of South Florida, Tampa, FL, USA, [10]University Corporation for Atmospheric Research/Cooperative Programs for the Advancement of Earth System Science, San Diego, CA, USA, [11]National Research Council, Washington, DC, USA,

Key Points:

- Following an active start, the 2024 Atlantic hurricane was quiet during the climatological peak with only 1 tropical storm and 1 hurricane
- The lull was not anticipated by seasonal forecasting agencies, which called for an extremely active 2024 Atlantic hurricane season
- Factors reducing storm count included a northward shift in African easterly waves, broad-scale subsidence, and reduced mid-level moisture

The models failed completely in their predictions, indicating conditions that had not been seen before.

In 2023, 42% of the globe experienced heat exceeding two standard deviations. Louisiana had its hottest summer in 129 years of records



2023 was the warmest year on record, and 2024 was even warmer

In the UAH temperature record, since 1979 there have been eight warmest years. All but 2023 were followed by a cooler year.

The three sudden stratospheric warming events that occurred in the same season are a one-in-250-year event according to models

One in 250-year event underway high in the atmosphere

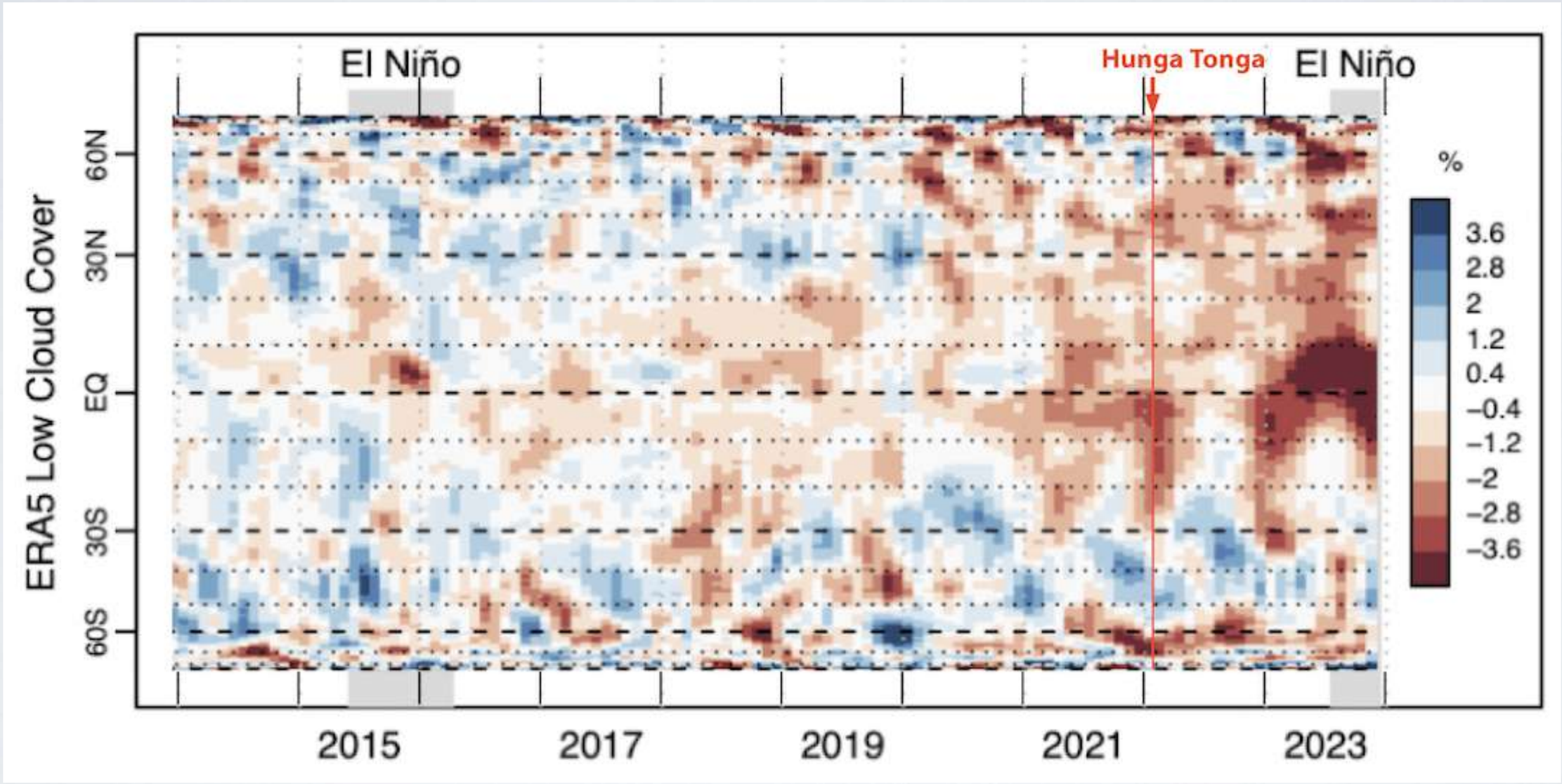
Author: Press Office

6 March 2024

For the first time since records began in the mid 20th century , this extended winter period (November to March) is the first in our observational records to see three Sudden Stratospheric Warming (SSW) events.

Met Office research suggests the likelihood of having three SSW events in one winter period is just a one in 250-year chance, although it is more likely to happen during an El Niño winter, such as this winter.

The biggest global low cloud cover anomaly ever recorded occurred in 2023



Goessling et al. 2024

A multitude of 3-6 σ events all over the globe

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Summer 8-2025

Do Unprecedented Weather Extremes Since Early 2022 Have an Association with the Hunga Tonga-Hunga Ha'apai Eruption?

Ana M. Trueba

This thesis utilizes global climate reanalysis and satellite water vapor observations to explore possible teleconnections between the January, 2022 Tonga eruption and observed climate and weather extremes in the ensuing years. Results from this analysis show a series of unusually large meteorological events with standardized anomalies ranging 3–6 standard deviations (σ) above or below a 30-year, 1991–2020 climate reference period. These pronounced extremes appear to be unique "fingerprints" of the post-eruption climate system response. Of particular note among many identified extremes: an Antarctic heat wave in

The 2023 Climate Event is the most important climate shift of our time

At a time when climate change is occupying so much of our attention, why is there almost absolute silence about the 2023 Climate Event?

- It is not human-caused
- We cannot satisfactorily explain it
- Therefore, it ruins the narrative

6. Possible causes of the 2023 CLIMATE EVENT

Occam's Razor

"***Entia non sunt multiplicanda praeter necessitatem***"

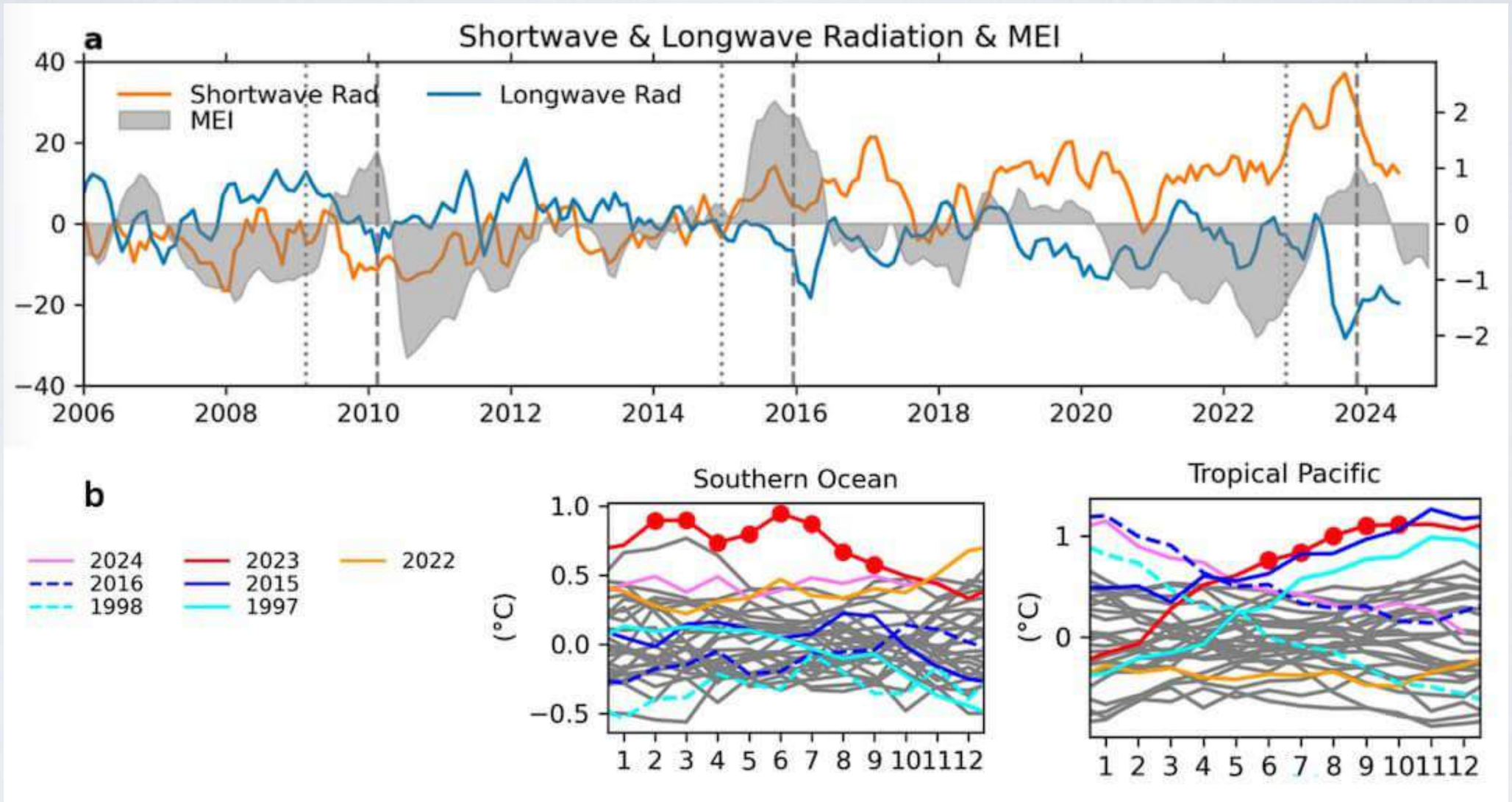
- The 2023 El Niño
- The 2020-22 triple Niña
- The 2020 marine fuel regulation
- The 2022 Hunga Tonga eruption

A single improbable cause is much more likely than a combination of improbable causes

The 2023 El Niño cannot be the cause

- Effects started in late 2022. Consequences cannot precede their cause

The extraordinary warming started in the Southern Ocean in late 2022

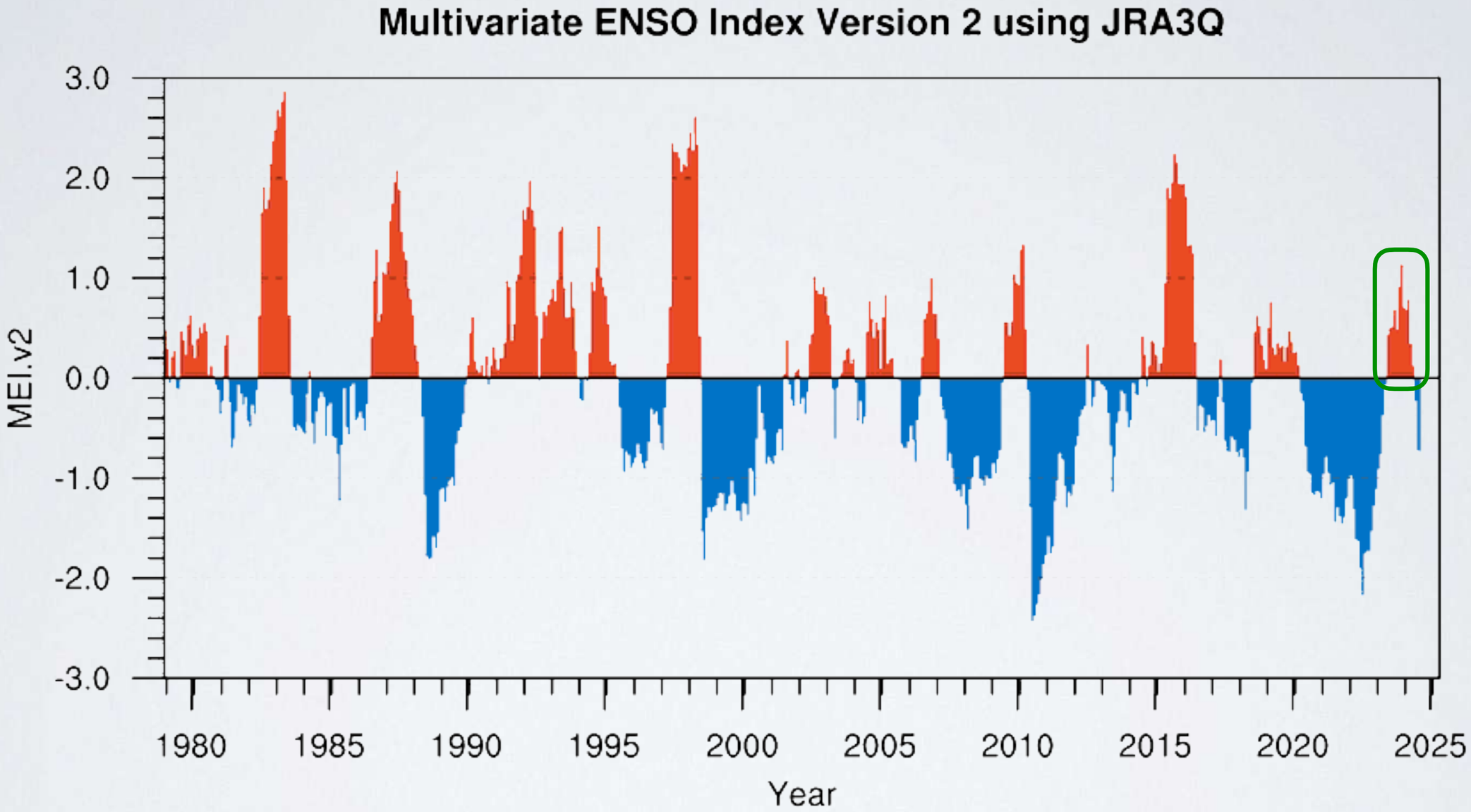


Minobe et al. 2025

The 2023 El Niño cannot be the cause

- Effects started in late 2022. Consequences cannot precede their cause
- The 2023 El Niño was of moderate strength (Multivariate El Niño Index)

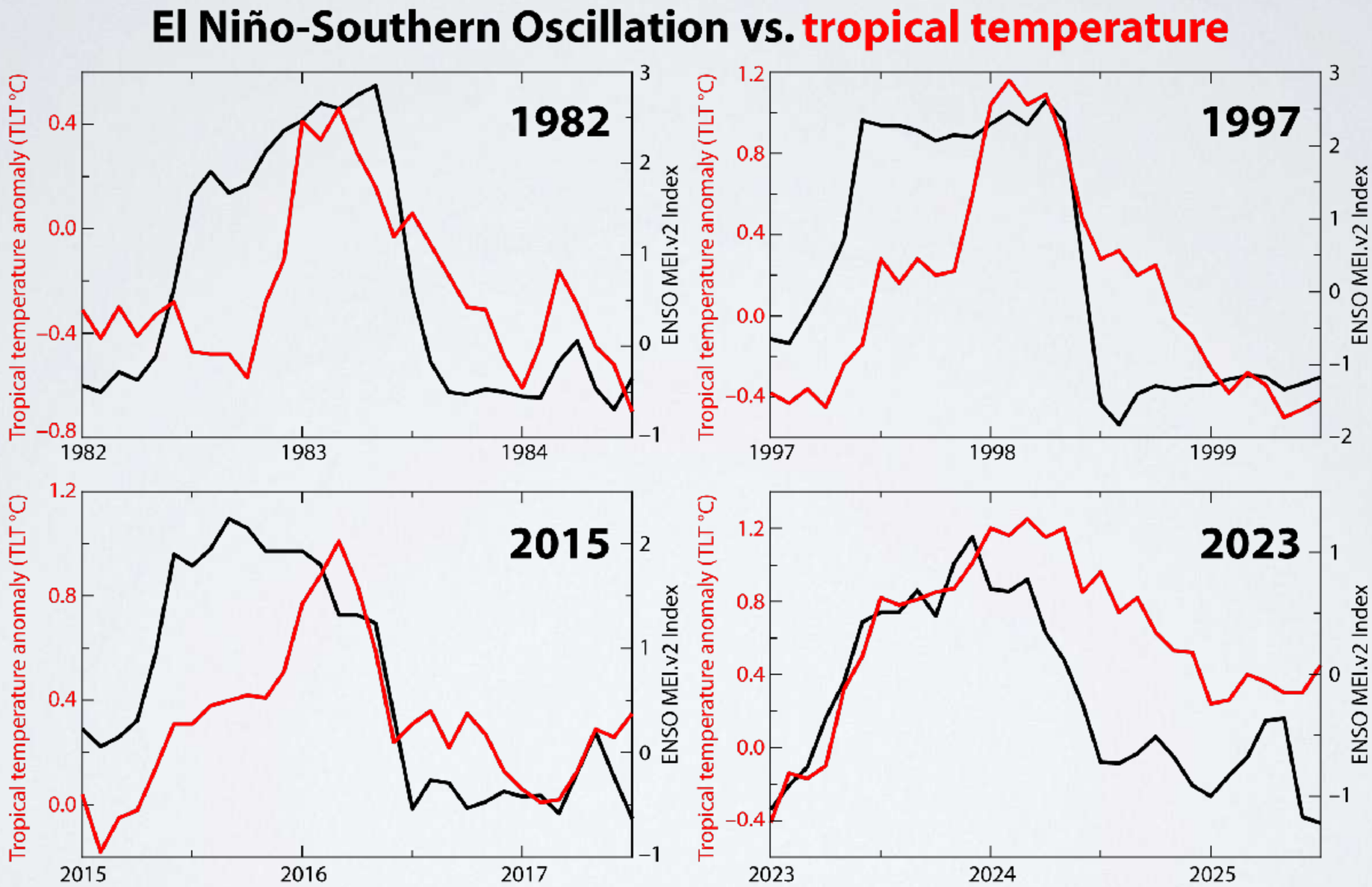
The 2023 El Niño was not a big one



The 2023 El Niño cannot be the cause

- Effects started in late 2022. Consequences cannot precede their cause
- The 2023 El Niño was of moderate strength (Multivariate El Niño Index)
- The temporal profile of the warming shows a simultaneous warming of the Niño region and the tropics, ruling out a cause-and-effect relationship.

Spot the imposter!



@frankbosse1

There have been previous occurrences of triple Niñas

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
1970	0.5	0.3	0.3	0.2	0.0	-0.3	-0.6	-0.8	-0.8	-0.7	-0.9	-1.1
1971	-1.4	-1.4	-1.1	-0.8	-0.7	-0.7	-0.8	-0.8	-0.8	-0.9	-1.0	-0.9
1972	-0.7	-0.4	0.1	0.4	0.7	0.9	1.1	1.4	1.6	1.8	2.1	2.1
1973	1.8	1.2	0.5	-0.1	-0.5	-0.9	-1.1	-1.3	-1.5	-1.7	-1.9	-2.0
1974	-1.8	-1.6	-1.2	-1.0	-0.9	-0.8	-0.5	-0.4	-0.4	-0.6	-0.8	-0.6
1975	-0.5	-0.6	-0.7	-0.7	-0.8	-1.0	-1.1	-1.2	-1.4	-1.4	-1.6	-1.7
1976	-1.6	-1.2	-0.7	-0.5	-0.3	0.0	0.2	0.4	0.6	0.8	0.9	0.8

1973-1976

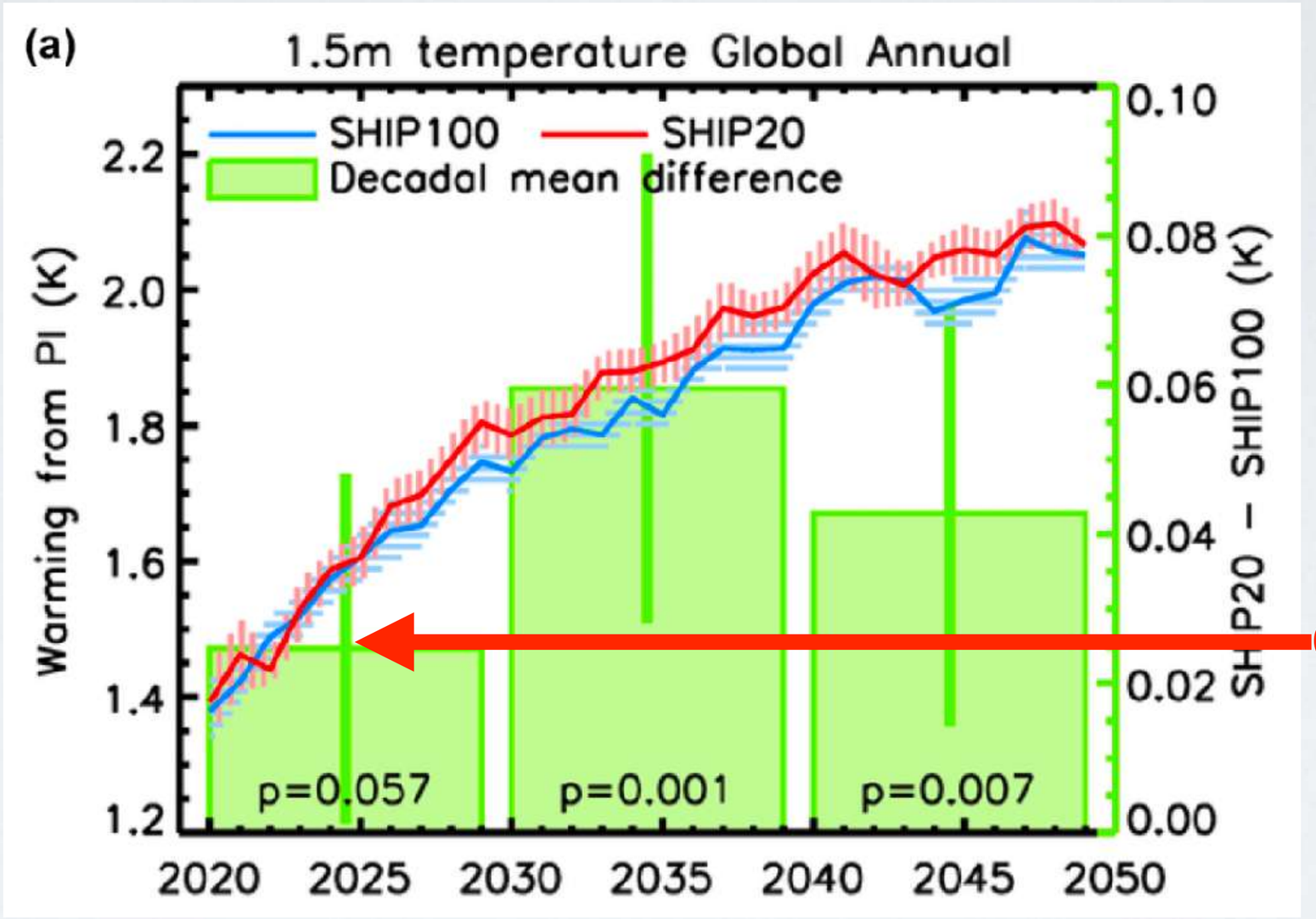
1997	-0.5	-0.4	-0.1	0.3	0.8	1.2	1.6	1.9	2.1	2.3	2.4	2.4
1998	2.2	1.9	1.4	1.0	0.5	-0.1	-0.8	-1.1	-1.3	-1.4	-1.5	-1.6
1999	-1.5	-1.3	-1.1	-1.0	-1.0	-1.0	-1.1	-1.1	-1.2	-1.3	-1.5	-1.7
Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2000	-1.7	-1.4	-1.1	-0.8	-0.7	-0.6	-0.6	-0.5	-0.5	-0.6	-0.7	-0.7
2001	-0.7	-0.5	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
2002	-0.1	0.0	0.1	0.2	0.4	0.7	0.8	0.9	1.0	1.2	1.3	1.1

1998-2001

Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.6	0.6	0.5	0.3	0.0	-0.2	-0.4	-0.5	-0.8	-1.1	-1.2	-1.1
2021	-0.9	-0.8	-0.7	-0.5	-0.4	-0.3	-0.3	-0.4	-0.6	-0.8	-0.9	-0.9
2022	-0.8	-0.8	-0.9	-1.0	-0.9	-0.8	-0.8	-0.9	-1.0	-0.9	-0.8	-0.7
2023	-0.5	-0.3	0.0	0.3	0.6	0.8	1.1	1.4	1.6	1.8	2.0	2.1
2024	1.9	1.6	1.3	0.8	0.5	0.2	0.1	-0.1	-0.2	-0.2	-0.3	-0.4
2025	-0.4	-0.2	-0.1	0.0	0.0	0.0	-0.1	-0.3	-0.4	-0.5	-0.6	-0.5

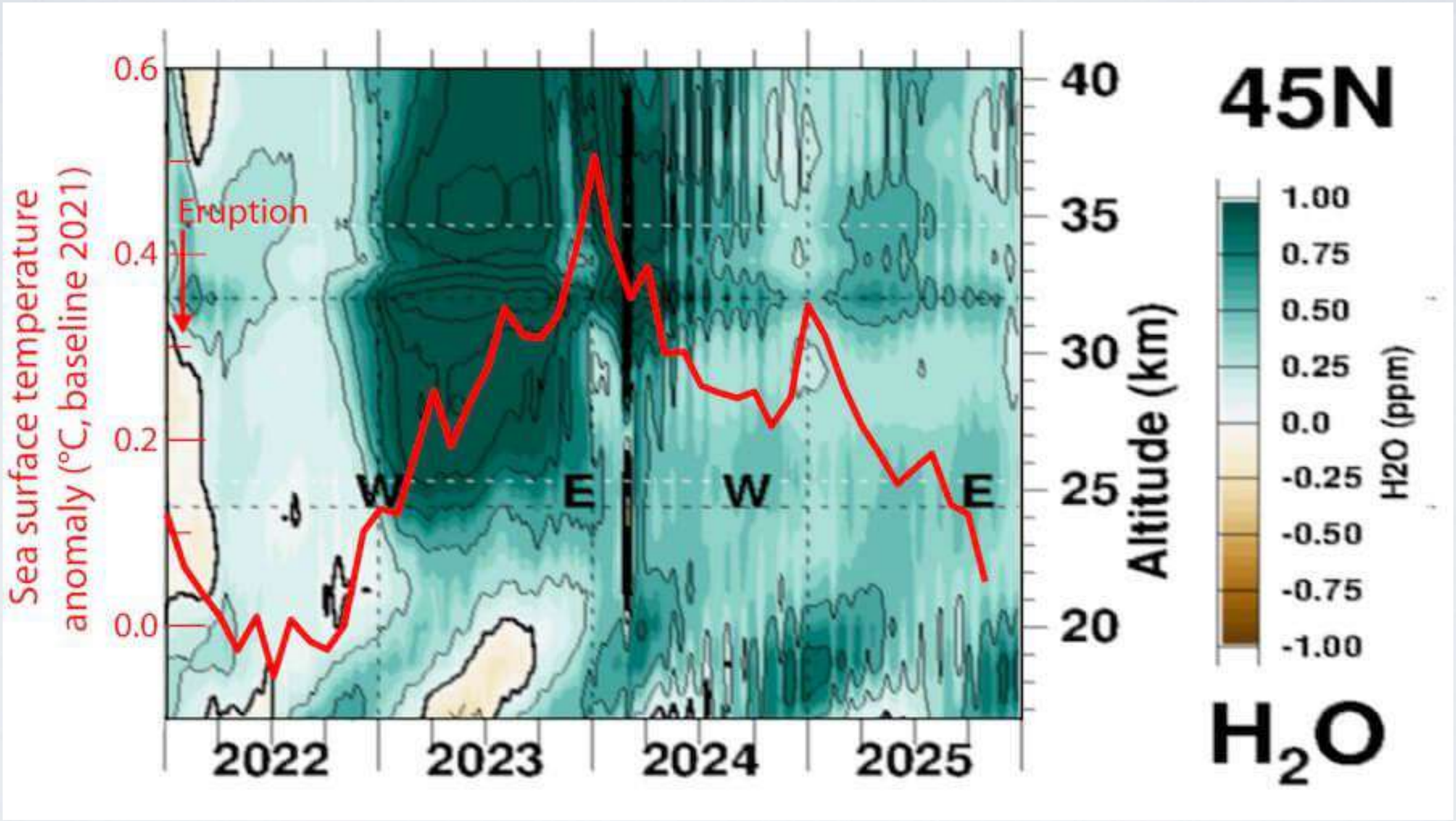
2020-2023

The 2020 marine fuel regulation results in a small permanent change



Yoshioka et al. 2024

Water vapor reached the NH in 2023



7. The precedent of Tambora

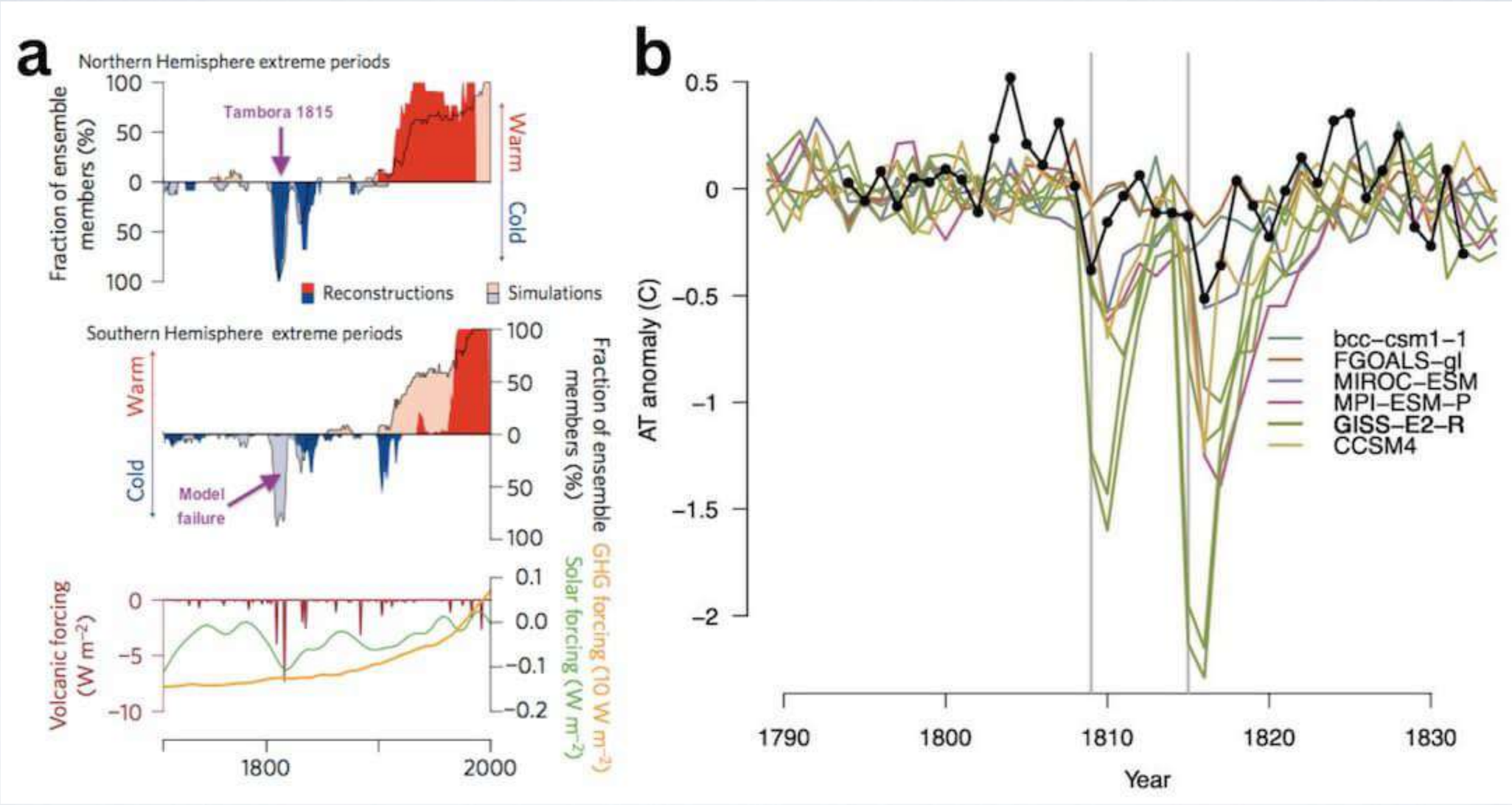
Similitudes with 1815 Tambora eruption

- Strongest climate effects delayed by more than a year.

- Plume aerosols spread to the SH the first year and to the NH the second.

- Much stronger climate effects in the NH (models can’t explain).

Models are unable to reproduce the climatic effects of Tambora



Neukom et al. 2014

Broham 2012

Tambora's "Year Without a Summer" may have resulted from changes in cloud cover

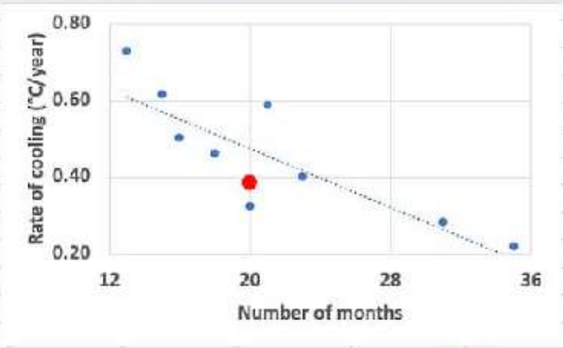
Sub-daily temperature observations also give indications as to the underlying processes causing the cold summer of 1816. For instance, afternoon temperatures in Central Europe dropped more strongly (the maximum decrease in summer temperature relative to neighbouring decades is 3.8°C in Geneva, Switzerland) than those at sunrise (1.8°C; Fig. 10, top). This is most likely due to an increase in cloud cover, which can be confirmed by an increase in cloudiness in observations.[102] Clouds lead to a cooling during the day by reducing solar radiation, but to a warming during night by preventing emission of longwave radiation. Furthermore, the frequency distributions of temperature anomalies changed in such a way that warm sunrises were mostly missing, while very cold sunrises were not more frequent in 1816 than in other years (small diagrams in Fig. 10, top) – again a consequence of an increased cloud cover. For plant growth, this increased cloud cover and change in the temperature frequency distribution has a large negative effect (see Section "Biophysical effects"). South of the Alps (e.g., Torino, Fig. 10, top) cloud cover did not increase.

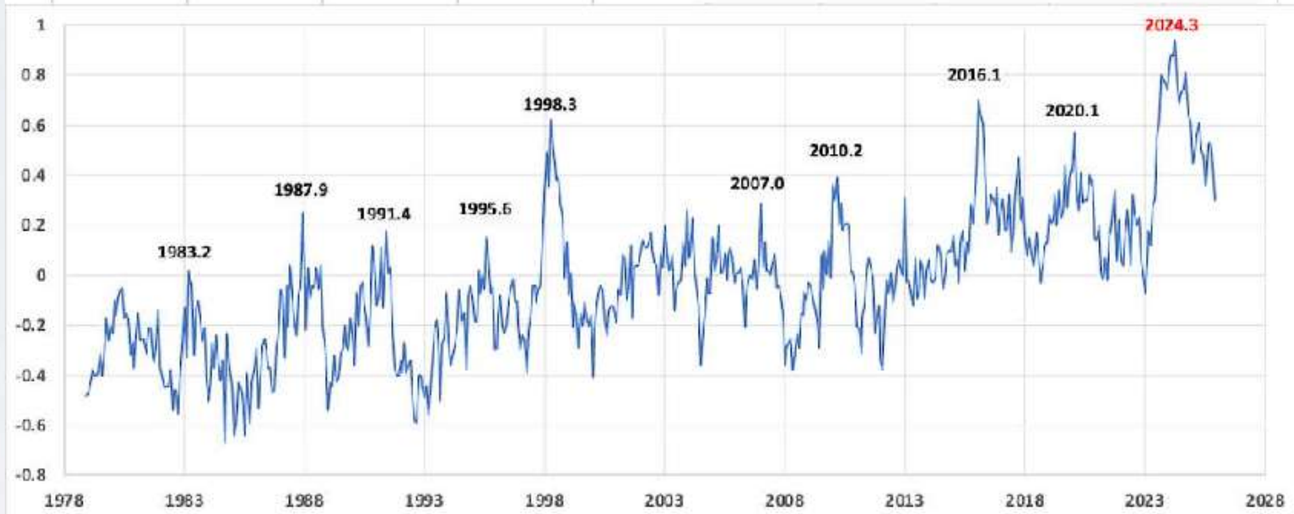
Brönnimann 2016

8. An unusual cooling

The cooling from the 2023 Climate Event is not being driven by La Niña

Start year	Difference (°C)	N. months	Rate (°C/year)	Cause
1983.2	0.69	18	0.45	Niña
1987.9	0.79	13	0.73	Niña
1991.4	0.77	15	0.62	Pinatubo
1995.6	0.54	20	0.32	Niña
1998.3	1.03	21	0.59	Niña
2007.0	0.57	16	0.50	Niña
2010.2	0.77	23	0.40	Niña
2016.1	0.73	31	0.28	Niña
2020.1	0.64	35	0.22	Niña
2024.3	0.64	20	0.38	????

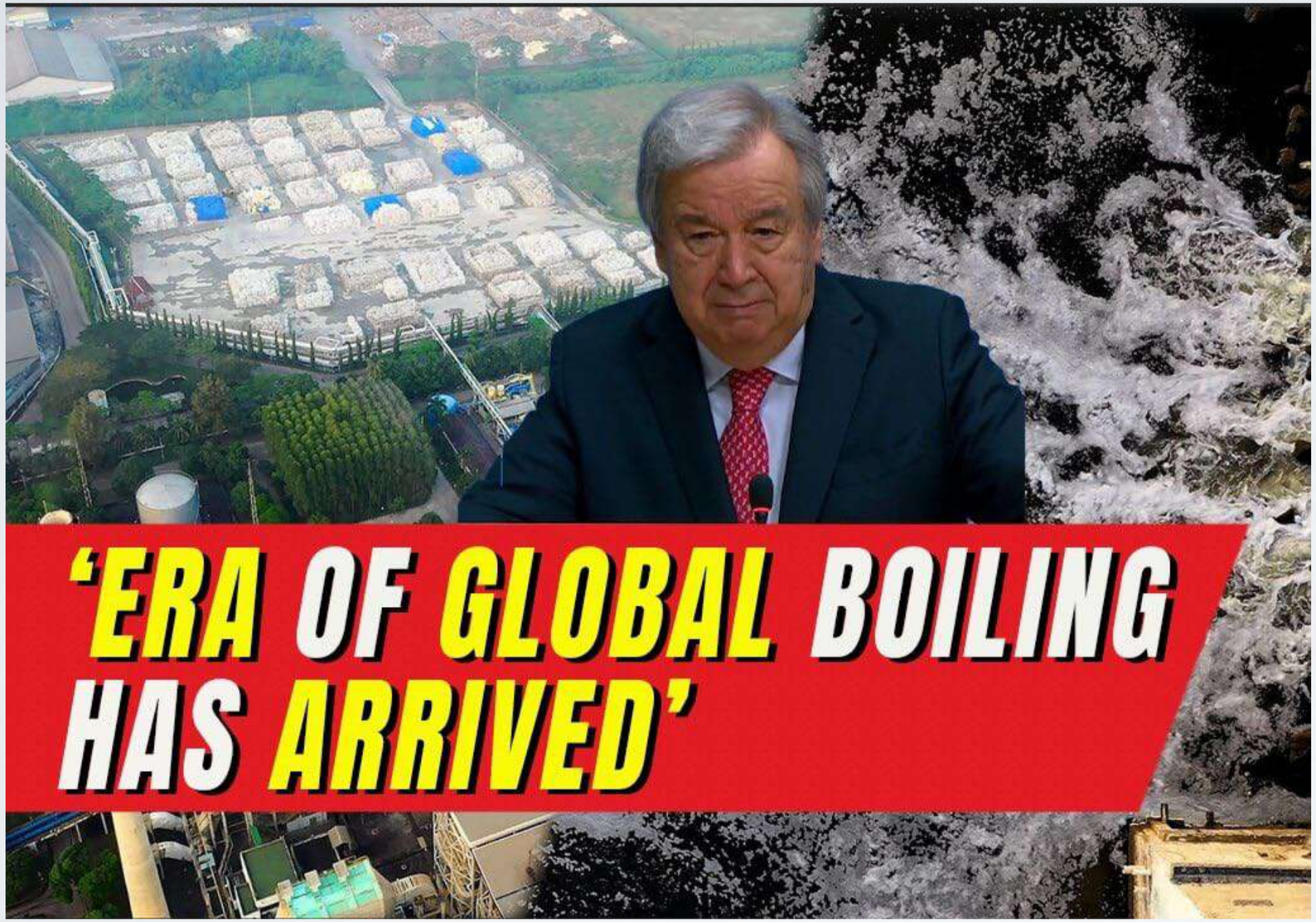




Year	DJF	JFM	FMA	MAM	AMJ	MJJ	JJA	JAS	ASO	SON	OND	NDJ
2020	0.6	0.6	0.5	0.3	0.0	-0.2	-0.4	-0.5	-0.8	-1.1	-1.2	-1.1
2021	-0.9	-0.8	-0.7	-0.5	-0.4	-0.3	-0.3	-0.4	-0.6	-0.8	-0.9	-0.9
2022	-0.8	-0.8	-0.9	-1.0	-0.9	-0.8	-0.8	-0.9	-1.0	-0.9	-0.8	-0.7
2023	-0.5	-0.3	0.0	0.3	0.6	0.8	1.1	1.4	1.6	1.8	2.0	2.1
2024	1.9	1.6	1.3	0.8	0.5	0.2	0.1	-0.1	-0.2	-0.2	-0.3	-0.4
2025	-0.4	-0.2	-0.1	0.0	0.0	0.0	-0.1	-0.3	-0.4	-0.5	-0.6	-0.5

9. The official position

The UN blames our emissions and demands Net-Zero



United Nations Secretary-General António Guterres. July 27, 2023. https://www.youtube.com/watch?v=og7QrAZJQP8

A scientific consensus has been built to deny that Hunga Tonga could be responsible

THE HUNGA VOLCANIC ERUPTION ATMOSPHERIC IMPACTS REPORT

Zhu et al. 2025

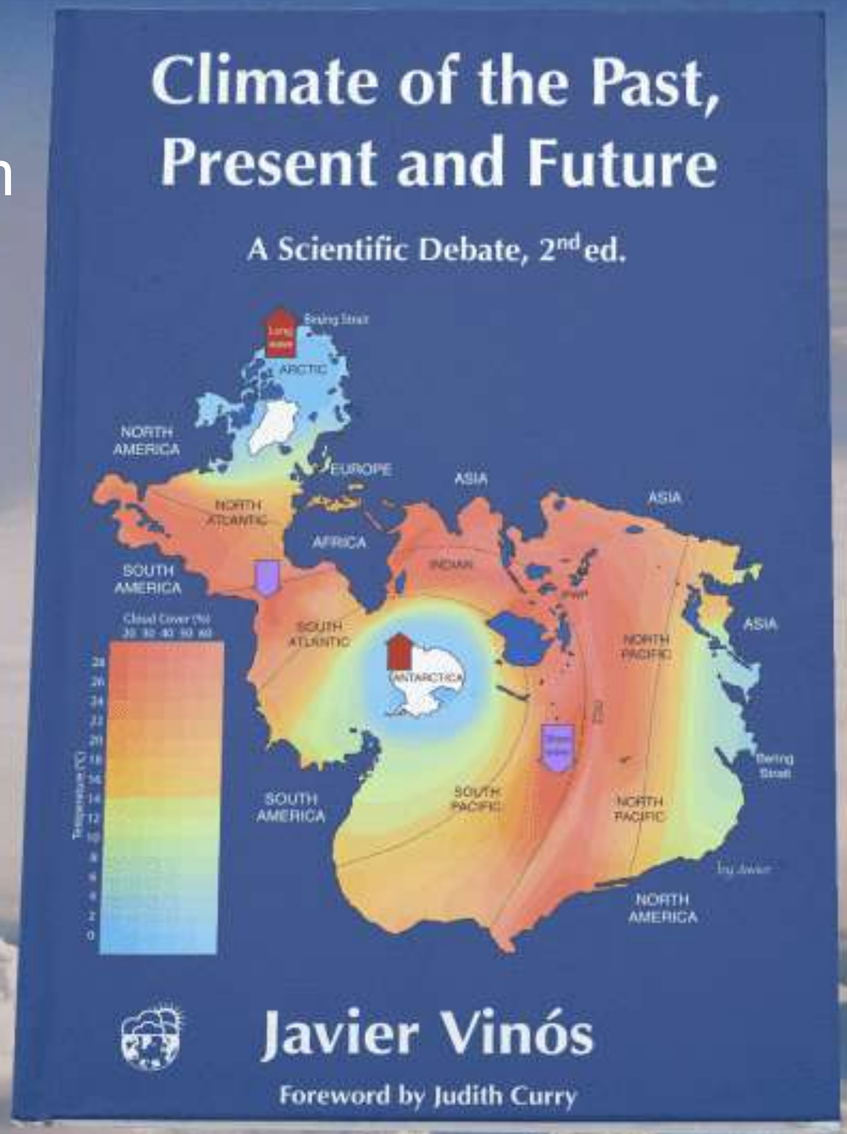
- **The record-high global surface temperatures in 2023/2024 were not due to the Hunga eruption.** The Hunga global-mean tropopause radiative forcing was about $-0.4\ \mathrm{W\,m^{-2}}$ averaged over the first two years; this cooling was mainly caused by aerosol attenuation of solar radiation. The maximum Hunga-induced cooling in global surface air temperature was estimated to be 0.05 K (with about 50% uncertainty), but this cooling is indistinguishable from background variability in the current climate. Surface climate impacts of the eruption—driven either directly by radiation or indirectly by Hunga-induced changes in atmospheric circulation and stratosphere–troposphere coupling—are relatively small and not distinguishable from the background internal variability of the Earth system.

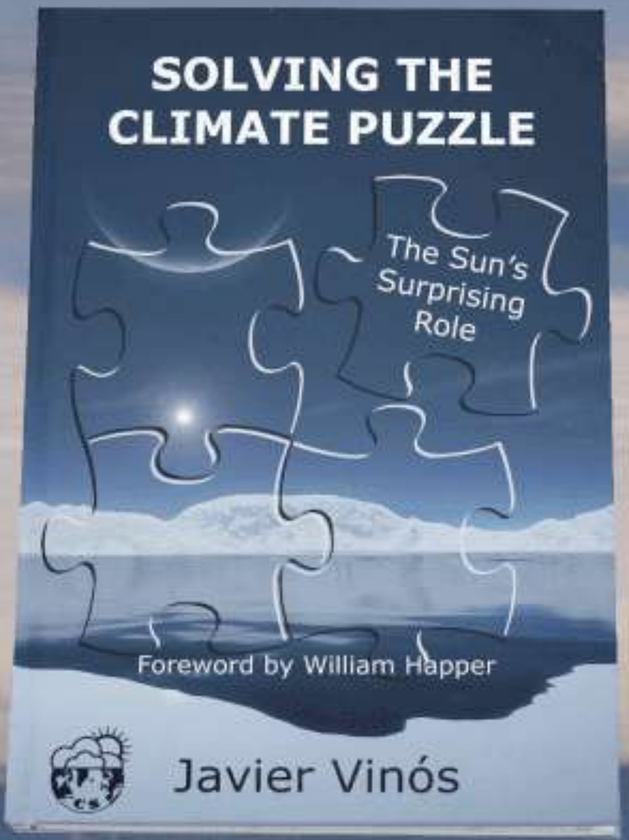
- **After 2024, the Hunga aerosol loading largely disappeared. The remaining Hunga stratospheric water vapour positive radiative forcing is expected to be negligible.**

This makes it difficult for other researchers to conduct studies that contradict this consensus and publish their findings.

Youtube:
@ScienceClimate-uf4xm

𝕏: @JVinos_Climate





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