The Geothermal Paradox: How the Earth’s Second Largest Heat Source May Be Driving the Most Recent Warming

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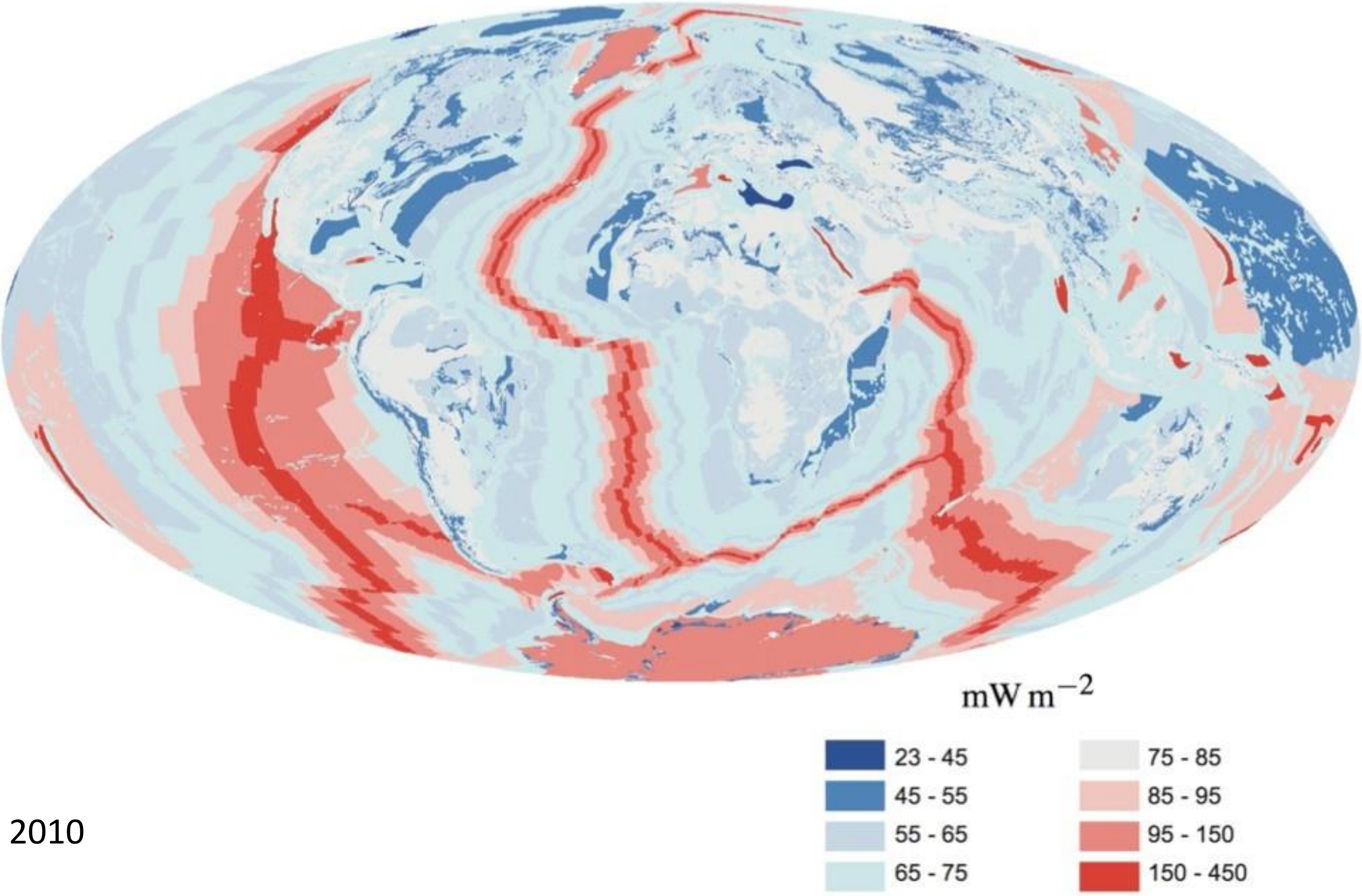
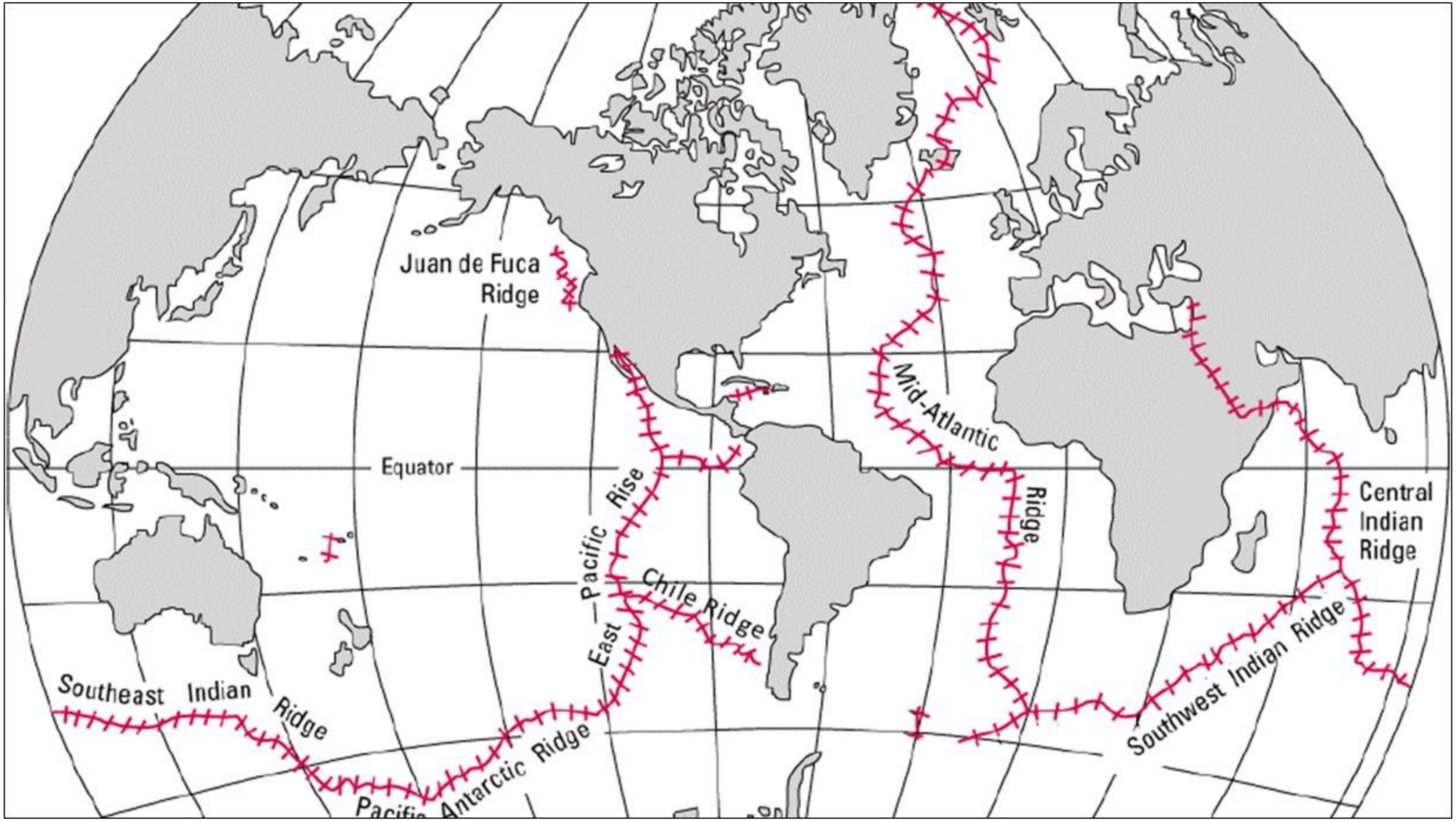
Until recently, there has been very little research on the impact geothermal heat may have on global temperature.

The vast majority of geothermal heat is emitted by volcanoes and hydrothermal vents in the middle of the world's ocean basins.

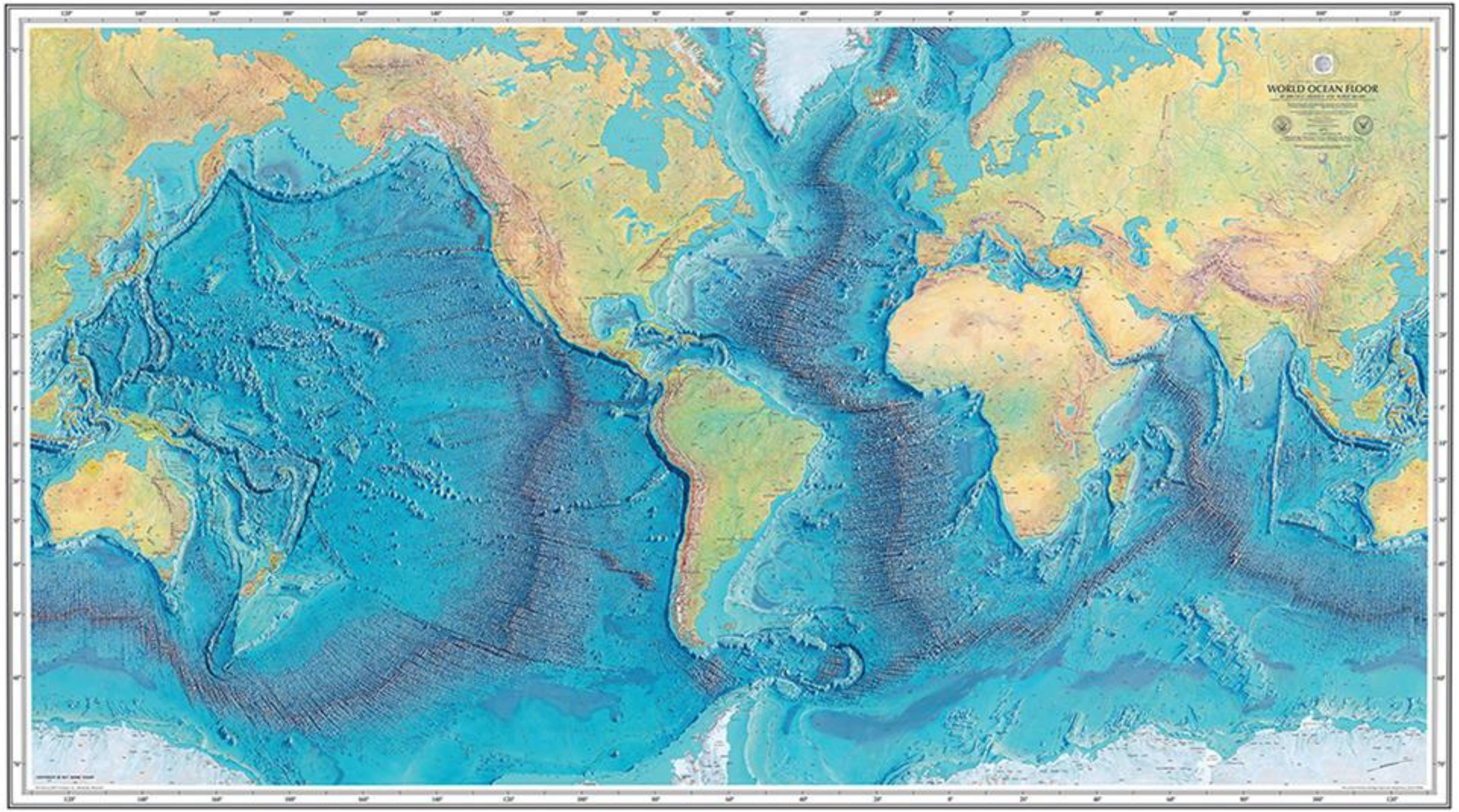


Davies and Davies, 2010

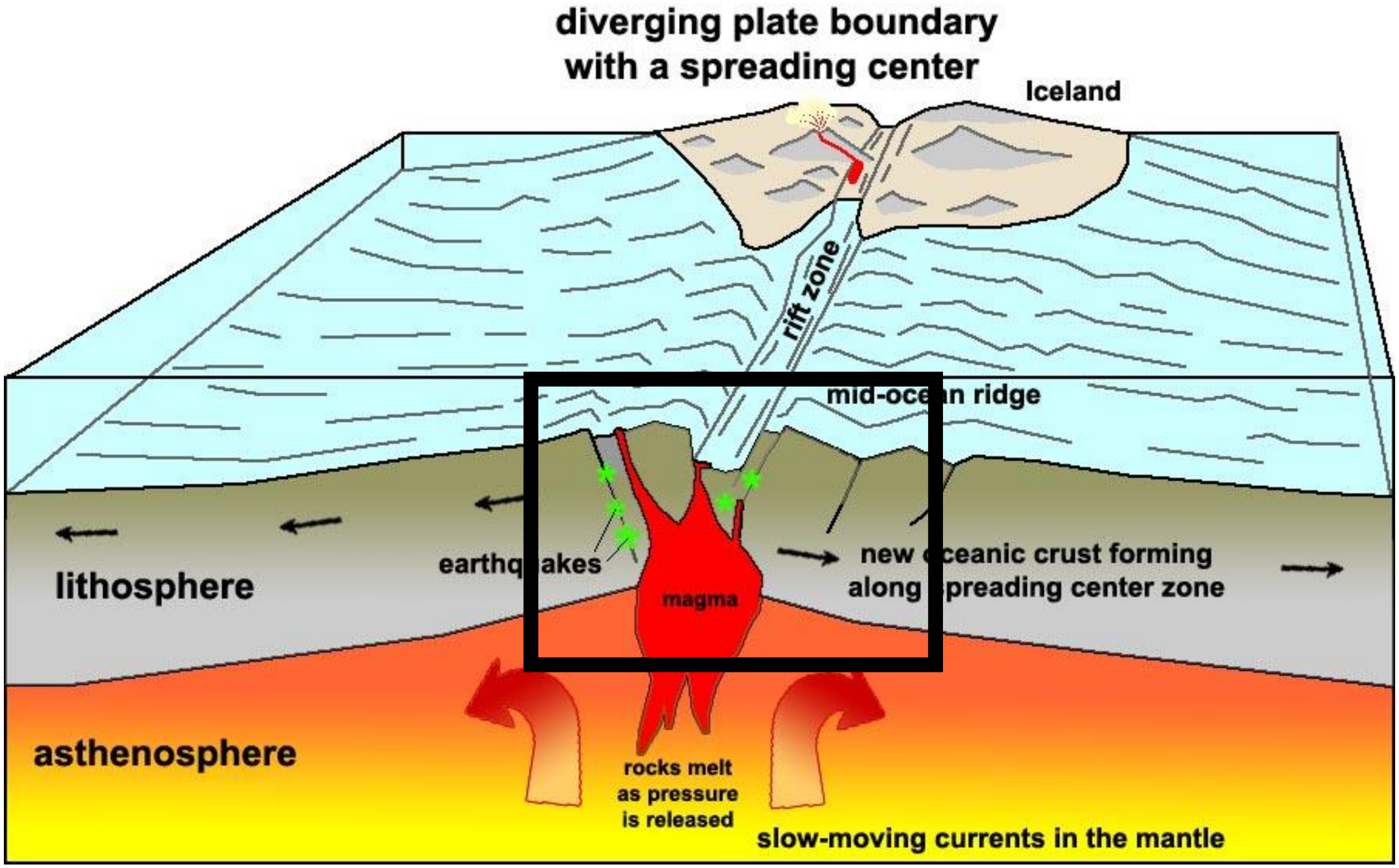
Here is a map of the 60,000 km long system of underwater volcanic mountains and associated hydrothermal vents. This is called the mid-ocean ridge system.



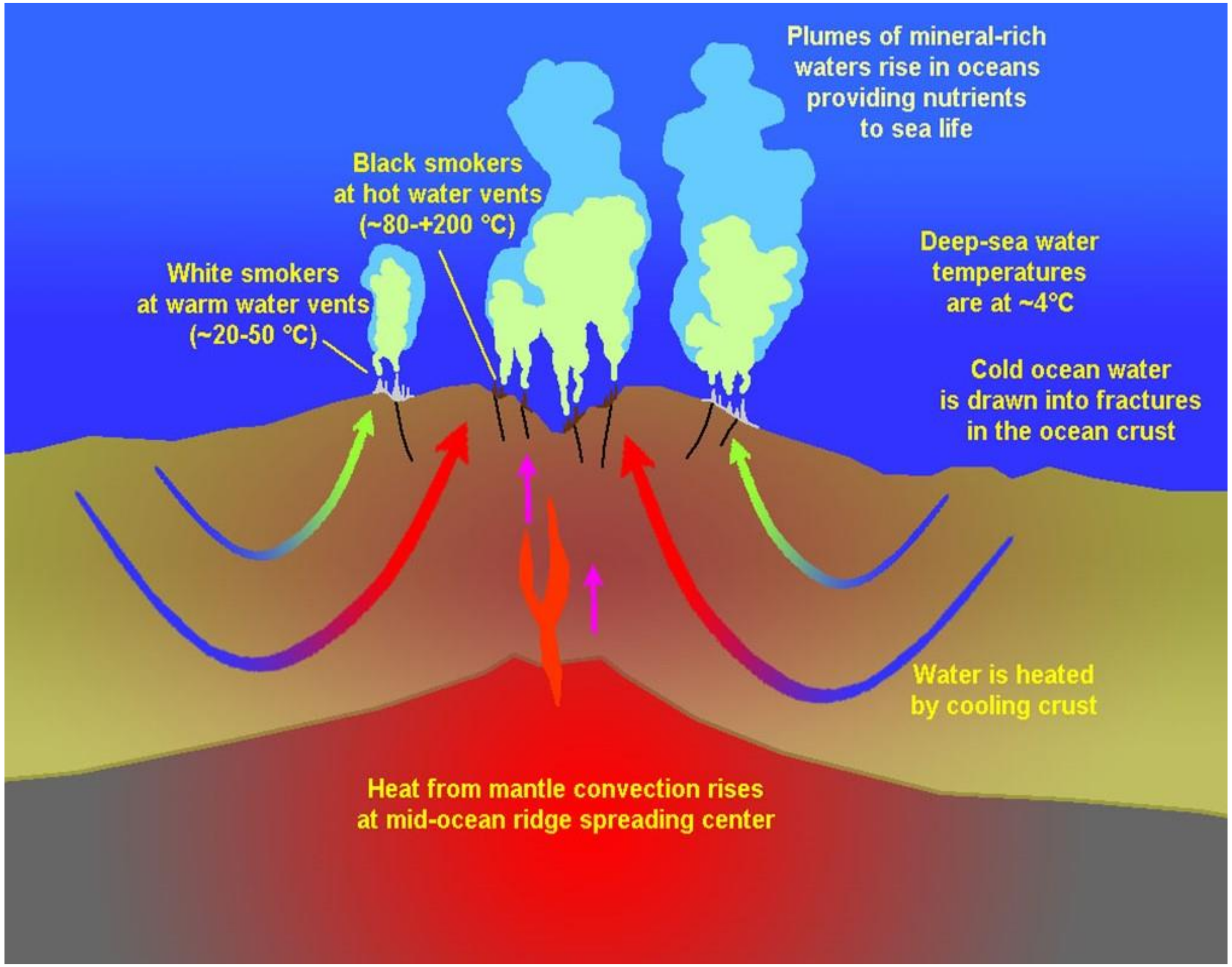
Here is a map of the mid-ocean ridge system that was produced by sonar and LIDAR.



Cross-sectional view of the mid-ocean ridge system



Schematic of hydrothermal vents. It is now thought that the mid-ocean ridge system may have as many as 30,0000 vent fields



https://www.sciencemag.org/news/2016/06/our-oceans-may-have-six-times-many-hydrothermal-vents-thought

The "paradox" of geothermal heat is that:

- Although the global average geothermal flux at the surface is low, averaging just 0.1 watts per m^2, heat from the mantle performs a tremendous amount of work. Most notably, it is able to move the Pacific Plate 4 inches per year, and widen the Atlantic Basin by 1 inch per year.

- It can eject enough ash to cool the globe many degrees Celsius (i.e., Krakatoa, Tambora, etc).

- It can eject ash and water 35 miles into the atmosphere as in the 2022 Tonga eruption

Although we have very little direct measurement of the geothermal flux in these Mid-Ocean Ridges (also called Mid-Ocean Spreading Zones), a good proxy indicator is provided by the number of seismic events in these areas.

"Seafloor hydrothermal systems are known to respond to seismic and magmatic activity along mid-ocean ridges, often resulting in locally ***positive changes in hydrothermal discharge rate, temperature*** *and microbial activity, and shifts in composition occurring at the time of earthquake swarms and axial crustal dike injections.* ***Corresponding regional effects have also been observed."***

Davis E, Becker K, Dziak R, Cassidy J, Wang K, et al. (2004) Hydrological response to a seafloor spreading episode on the Juan de Fuca Ridge. *Nature* 430(6997): 335-338. DOI: 10.1038/nature02755

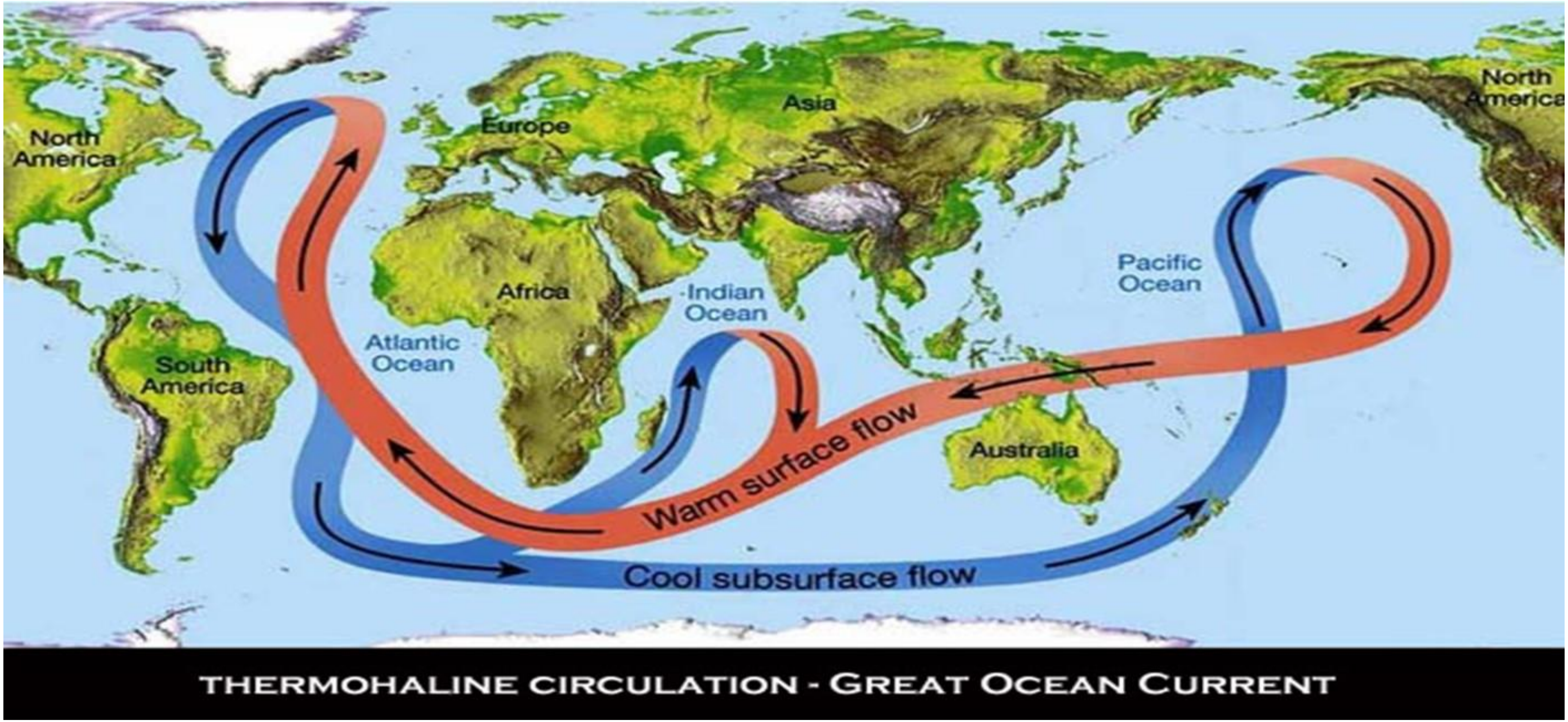
These hydrothermal systems can cover large areas of the ocean ridges and their flanks

“Thermally driven convection of seawater occurs through oceanic crust of all ages, at the seafloor spreading axis, on mid-ocean ridge flanks, and in the ocean basins.”

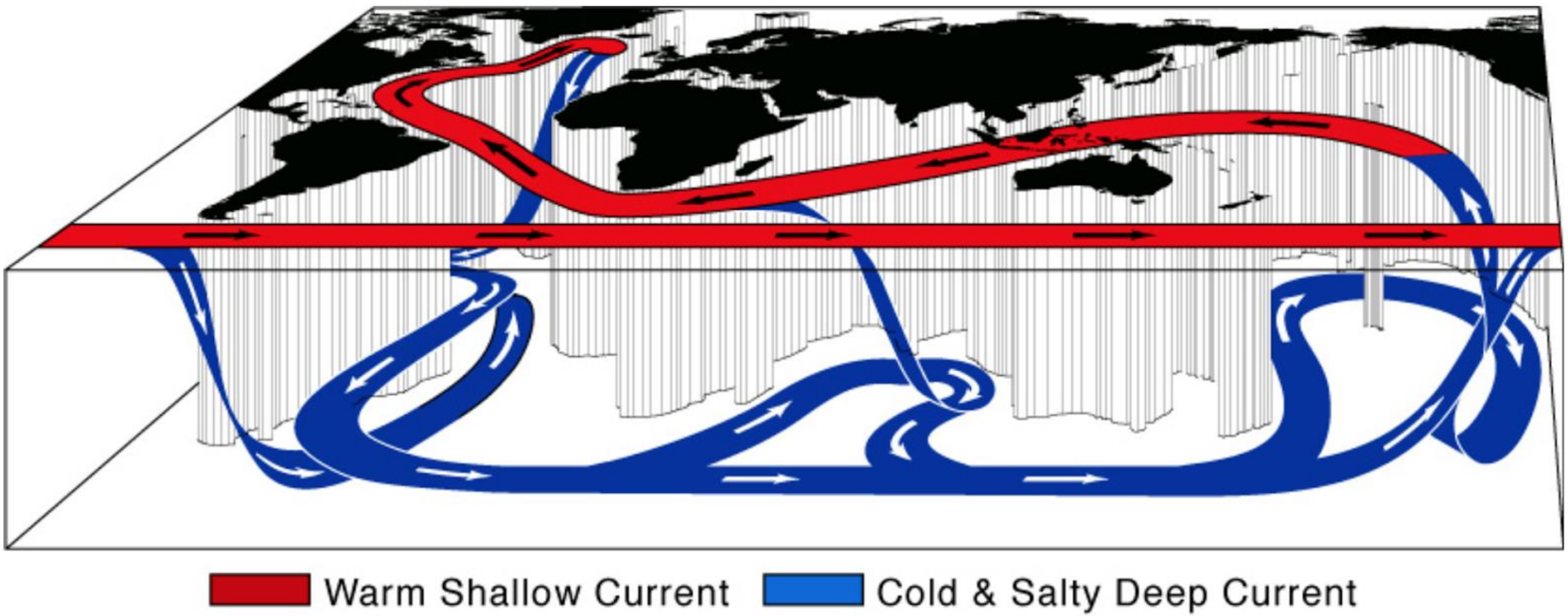
“Most of the hydrothermal heat loss, however, occurs on the mid-ocean ridge flanks, where the temperatures are lower and the seawater flux correspondingly larger. ***The estimated heat loss on the flanks is so large that upwelling must occur over a large fraction (5–30%) of the seafloor less than 65 Ma in age****, if temperatures are < 20°C and seepage velocities are on the order of 10 to 100 cm/y.”*

Hydrothermal circulation through mid-ocean ridge flanks: Fluxes of heat and magnesium - ScienceDirect

Even though a large area of the ocean floor is geothermally heated, the low output will do little to *directly* warm the atmosphere. However, there is ample evidence that it can cause the global thermohaline circulation to intensify. This is the "game changer" as the oceans contain 1,000 times as much heat as the atmosphere! This, in turn, enables geothermal heating to enhance the ocean's ability to transfer heat.



A 3-dimensional view of the thermohaline circulation



“*Although the ocean is largely heated and thermally driven at the surface, several recent studies suggest that the OGH (ocean geothermal heating) can also affect the ocean dynamic and heat budget. …. By applying spatially constant or variable heat flux in Ocean General Circulation Models (OGCMs) forced with the present day climate, it is shown that the* ***OGH is a significant forcing that can weaken the stability of the water column, warm the bottom water and strengthen the thermohaline circulation…”***

Ballarotta, M. et al., (2015), “Impact of the oceanic geothermal heat flux on a glacial ocean state”, *Climate of the Past Discussions*, 11, 3597-3624

*"….the additional destabilizing **(geothermal) heat flux tends to promote a more vigorous full-depth overturning having approximately 10% greater volume flux than with no bottom heating."***

Mullarney, J.C., Griffiths, R.W., and Hughes, G.O., (2006), "The effects of geothermal heating on the ocean overturning circulation", *Geophysical Research Letters*, DOI:10.1029/2005GL024956

"….geothermal heating induces a substantial change in the deep circulation which is larger than previously assumed…. The numerical ocean model responds most strongly in the Indo-Pacific with an increase in meridional overturning of 1.8 Sv, ***enhancing the existing overturning by approximately 25%."***

Adcroft, A., Scott, J.R., and Marotzke, J., (2001) "Impact of geothermal heating on the global ocean circulation", *Geophysical Research Letters*, DOI:10.1029/2000GL012182

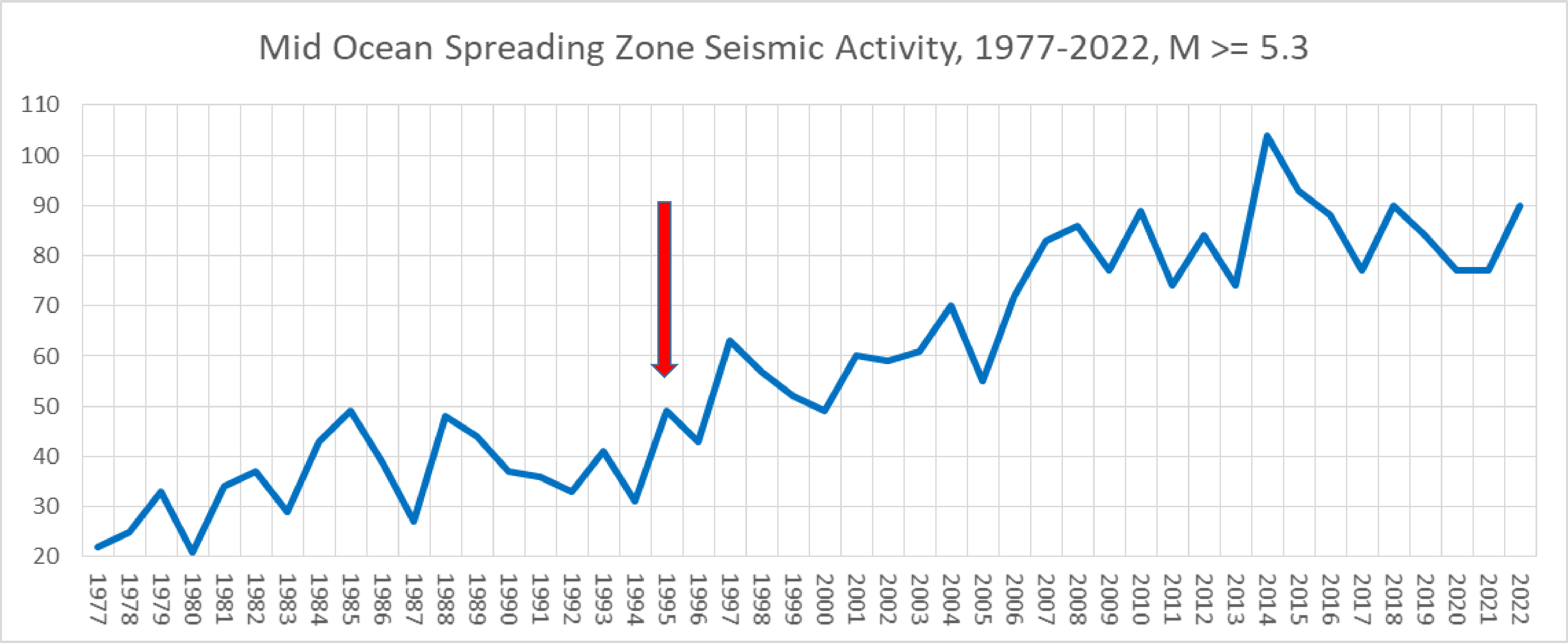
“It is known that the geothermal heat strongly intensifies meridional overturning circulations (MOCs). ……The Atlantic NADW-cell enhancement in the globally heated experiment of Adcroft et al. [2001] is much weaker than ours (i.e.,Urakawa and Hasumi). ***This might be because of the difference of the magnitude of the geothermal heat flux. Our geothermal heat flux is twice as large as that of theirs.”***

Urakawa, L.S., and Hasumi, H. (2009), “A remote effect of geothermal heat on the global thermohaline circulation”, *Journal of Geophysical Research*, DOI: 10.1029/2008JC005192

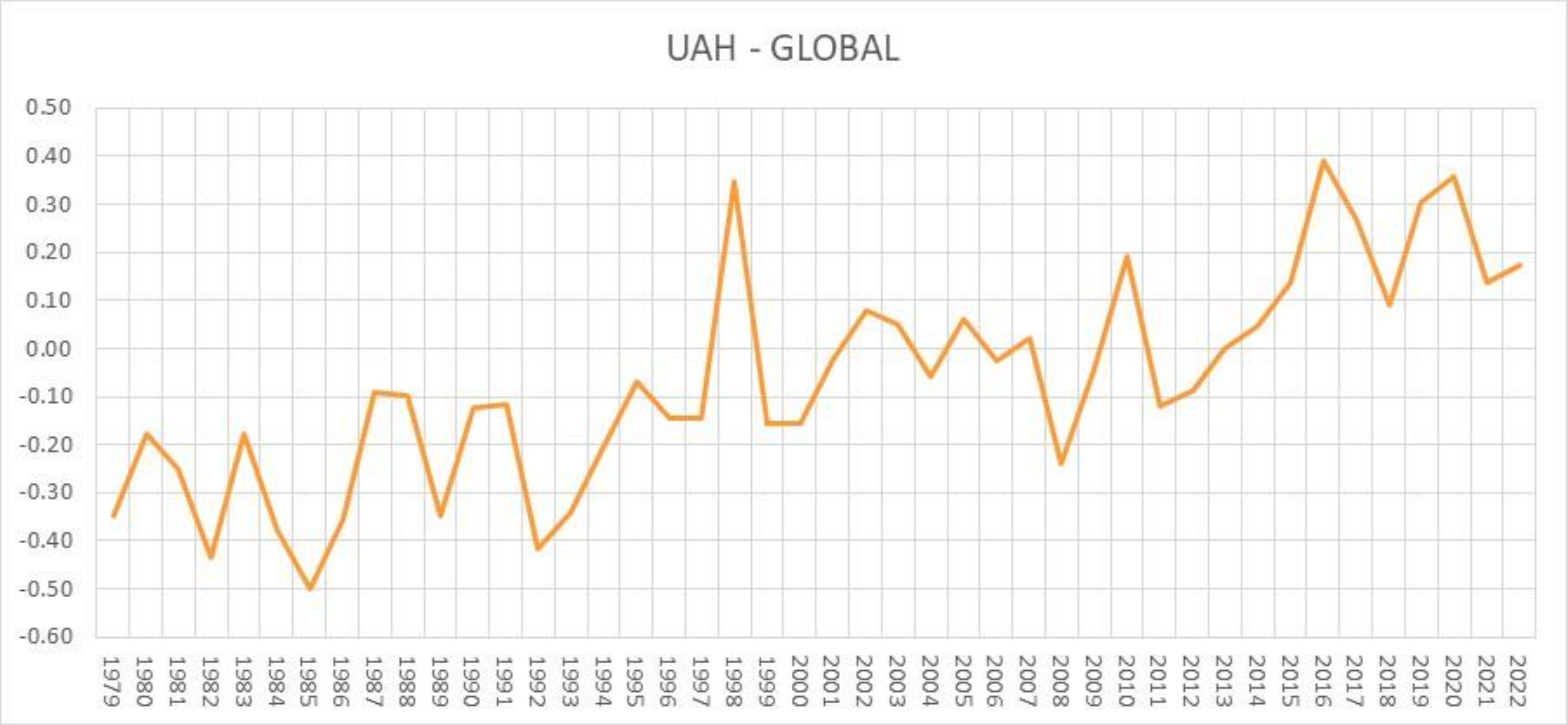
"The abyssal warming around Antarctica is one of the most prominent multidecadal signals of change in the global ocean. Here we investigate its dynamical impacts on the Atlantic Meridional Overturning Circulation (AMOC)…. The simulations suggest that ***the ongoing warming of Antarctic Bottom Water (AABW), already affecting much of the Southern Hemisphere with a rate of up to 0.05°C decade^{-1}, has important implications for the large-scale meridional overturning circulation in the Atlantic Ocean. While the abyssal northward flow of AABW is weakening, we find the upper AMOC cell to progressively strengthen by 5–10% in response to deep density changes in the South Atlantic."***

Abyssal ocean warming around Antarctica strengthens the Atlantic overturning circulation. Lavinia Patara, Claus W. Böning. *Geophysical Research Letters* First published: 20 May 2014 https://doi.org/10.1002/2014GL059923

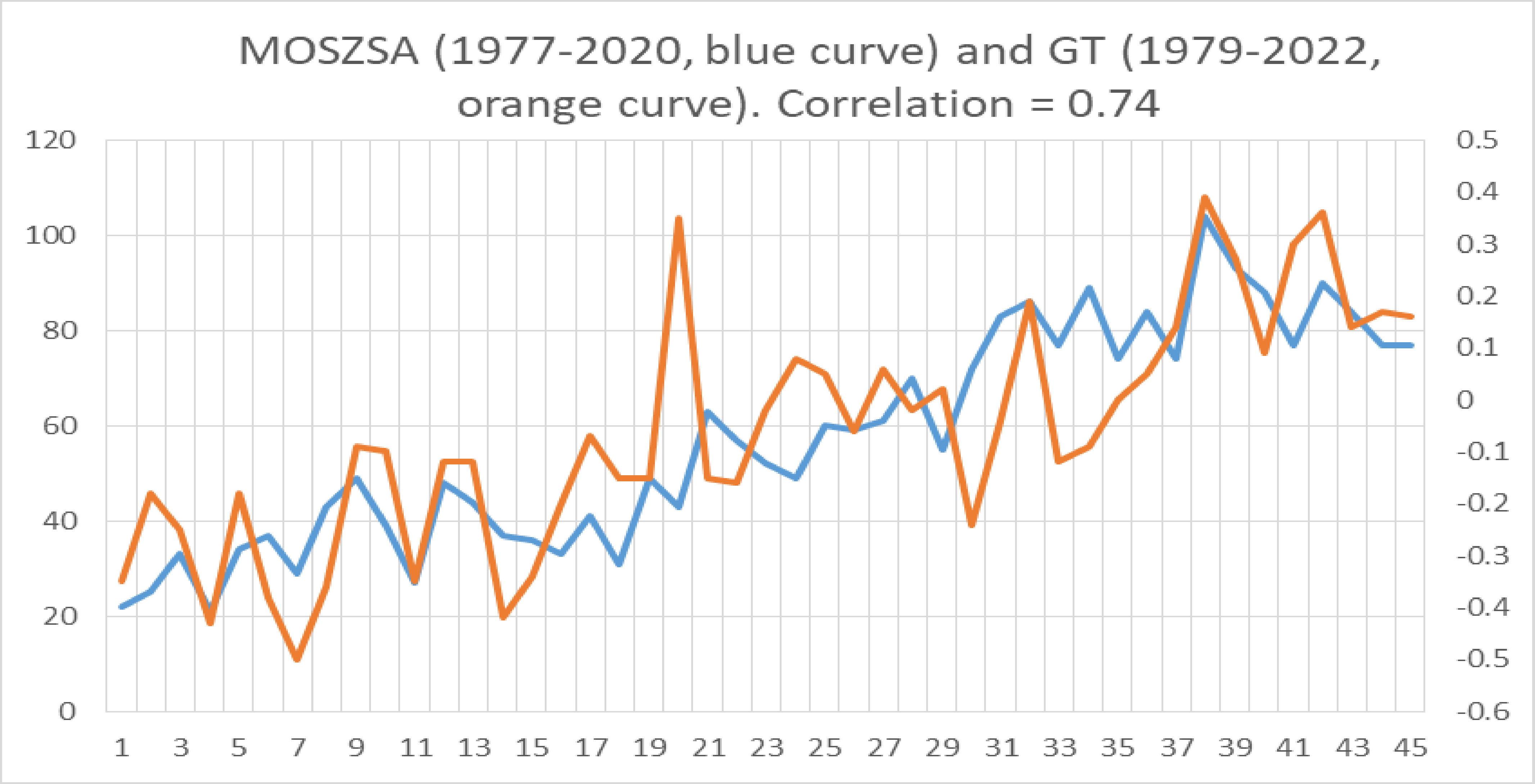
Knowing this, we can then calculate the number of mid-ocean ridge seismic events, and see how well they correlate with global temperatures. Here is a graph of mid-ocean spreading zone seismic activity (MOSZSA) since 1977 as culled from the GCMT catalogue, a complete catalogue of seismic events magnitude 5.3 or greater. Notice the 1995 inflection point.



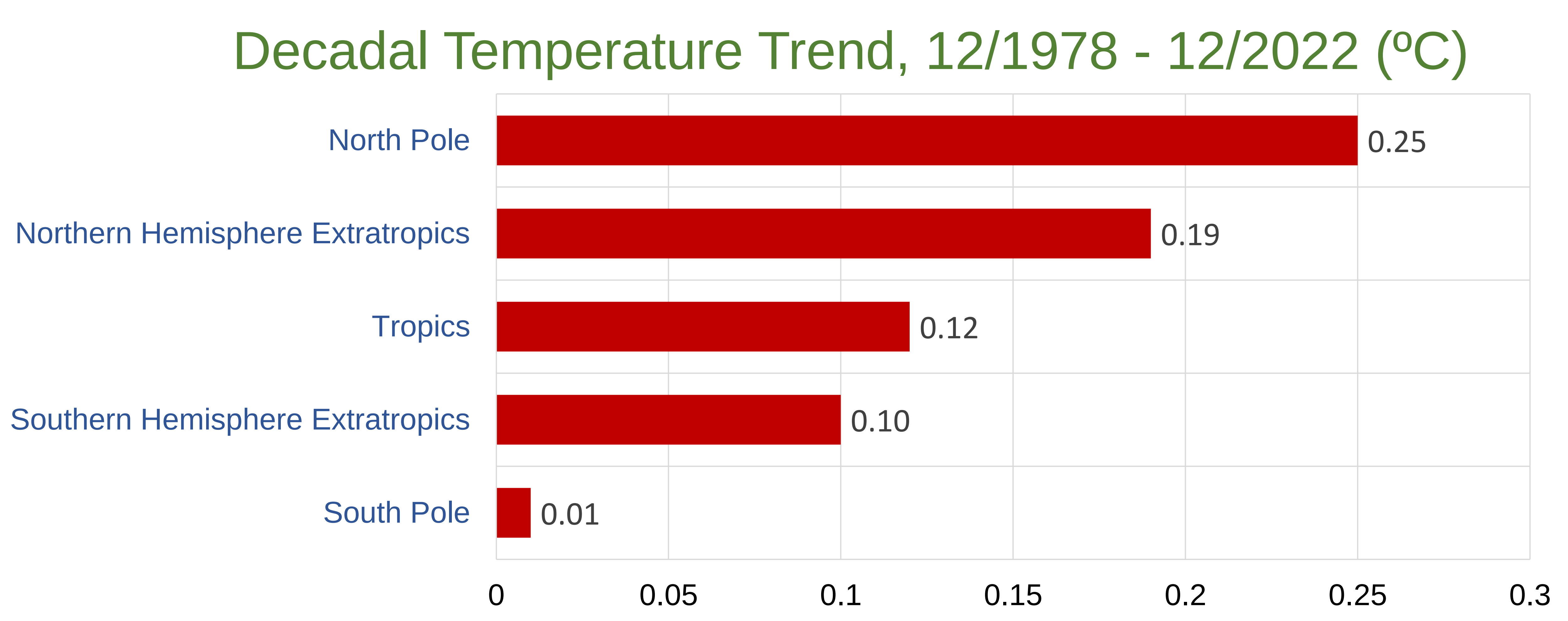
Global temperatures from 1979, the first year for satellite temperature data, through 2022.



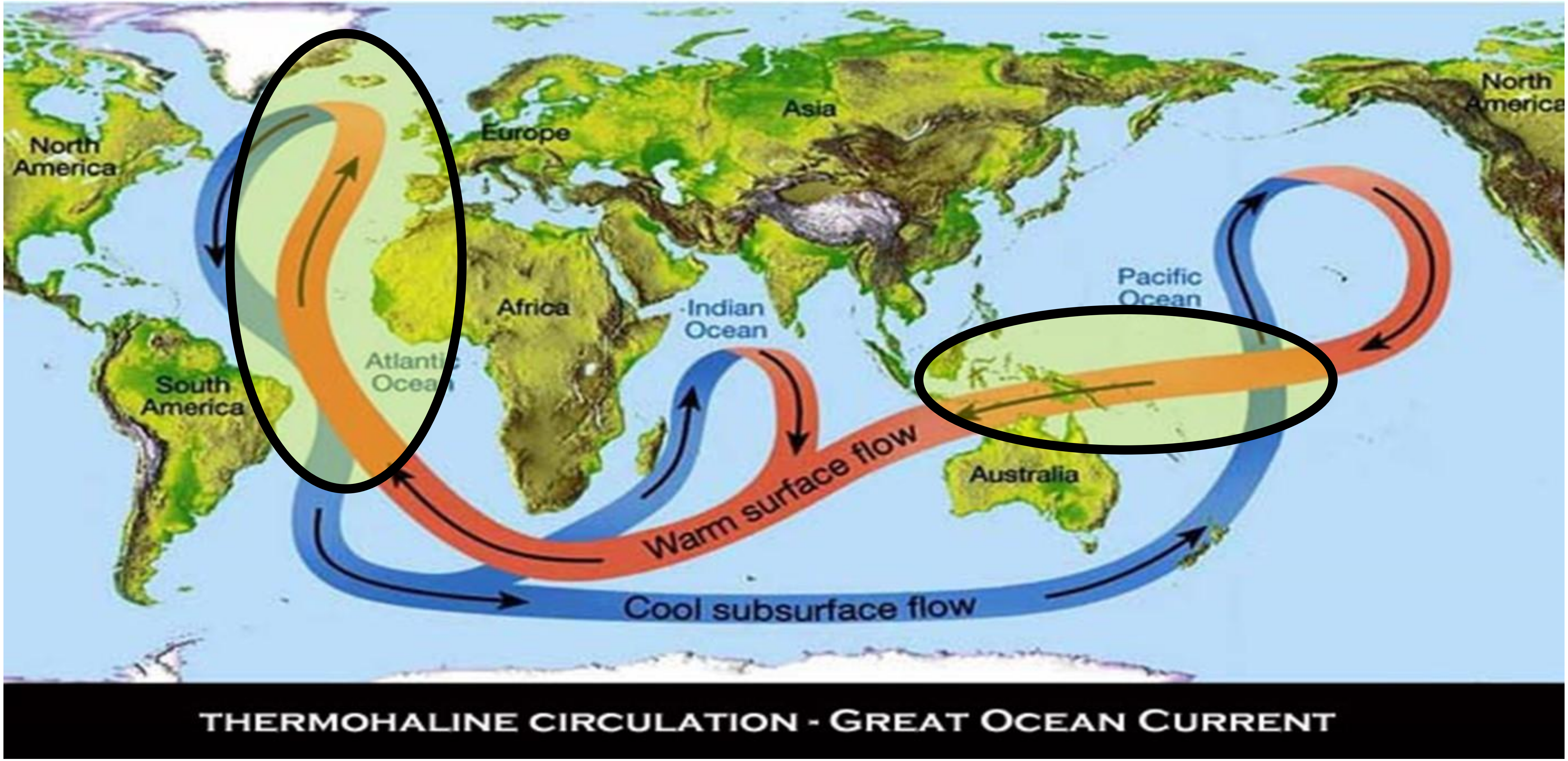
Here is the MOSZSA curve combined with the global temperature curve (GT), with a 2-year lag factored in, 1979 – 2022. The correlation is 0.74. Notice the goodness of fit for most of the El Nino and La Nina episodes.



By region, the Arctic has warmed the most (i.e., the Arctic Amplification) while the tropics and SH Extratropics have warmed to a significant yet lesser degree by amplified El Nino effects. The NH Extratropics are warmed by the combined effects of the warmed North Atlantic along with the Arctic, Kuroshio, and El Nino amplifications.

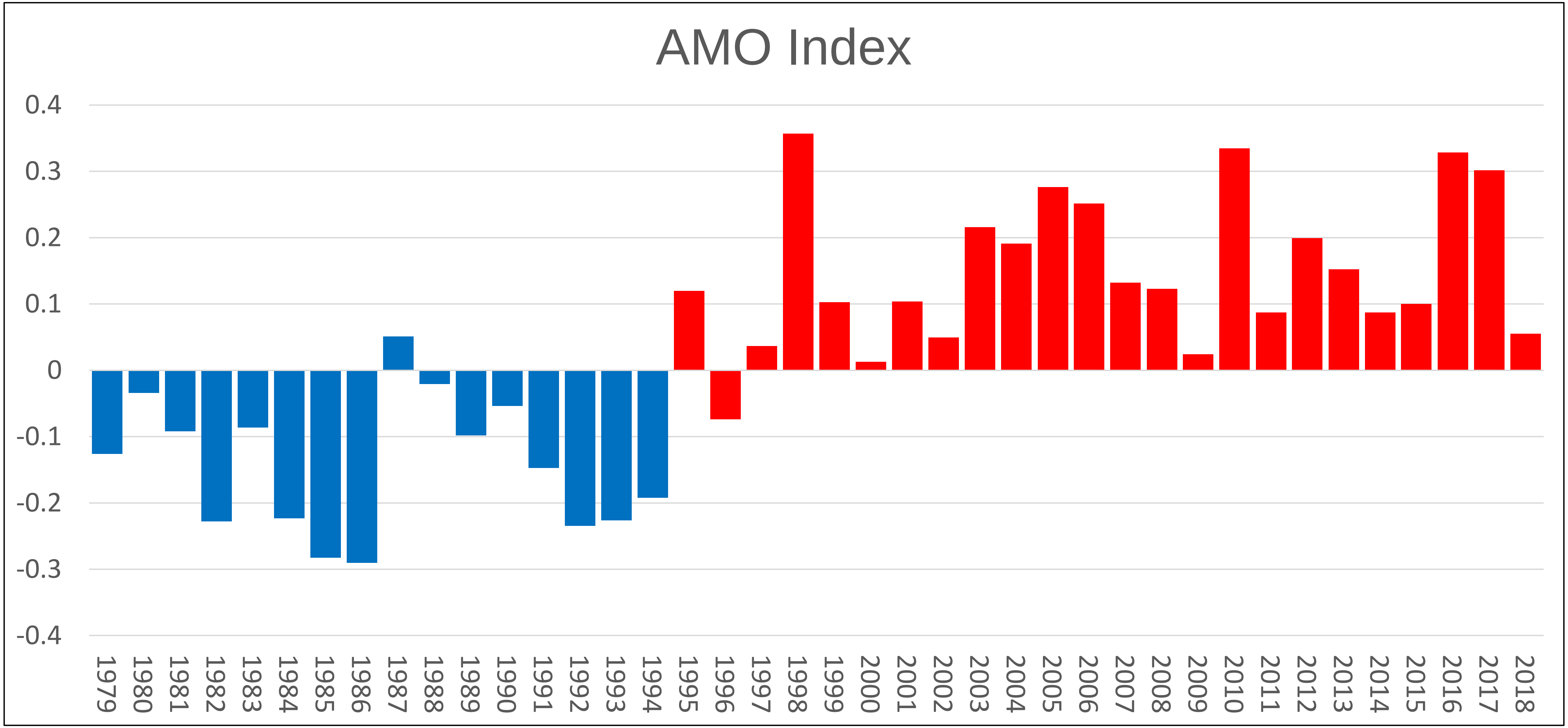


Two areas of intensified thermohaline flow are especially important to the global and regional temperature changes seen since 1995. These are the Western Pacific and the North Atlantic/Arctic regions

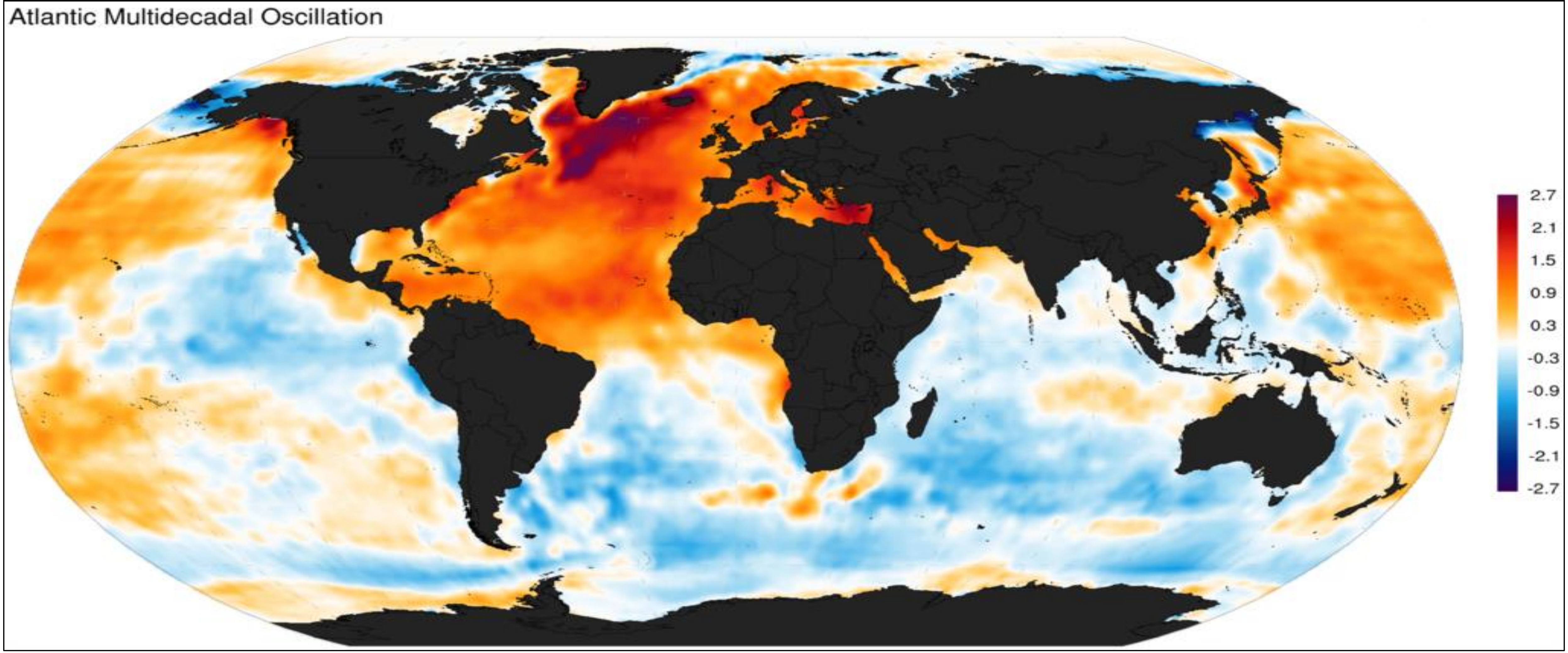


The next 12 slides will provide concrete evidence that, starting in 1995, the intensified thermohaline circulation significantly impacted temperatures along with a host of other geophysical phenomena in the North Atlantic and the Arctic.

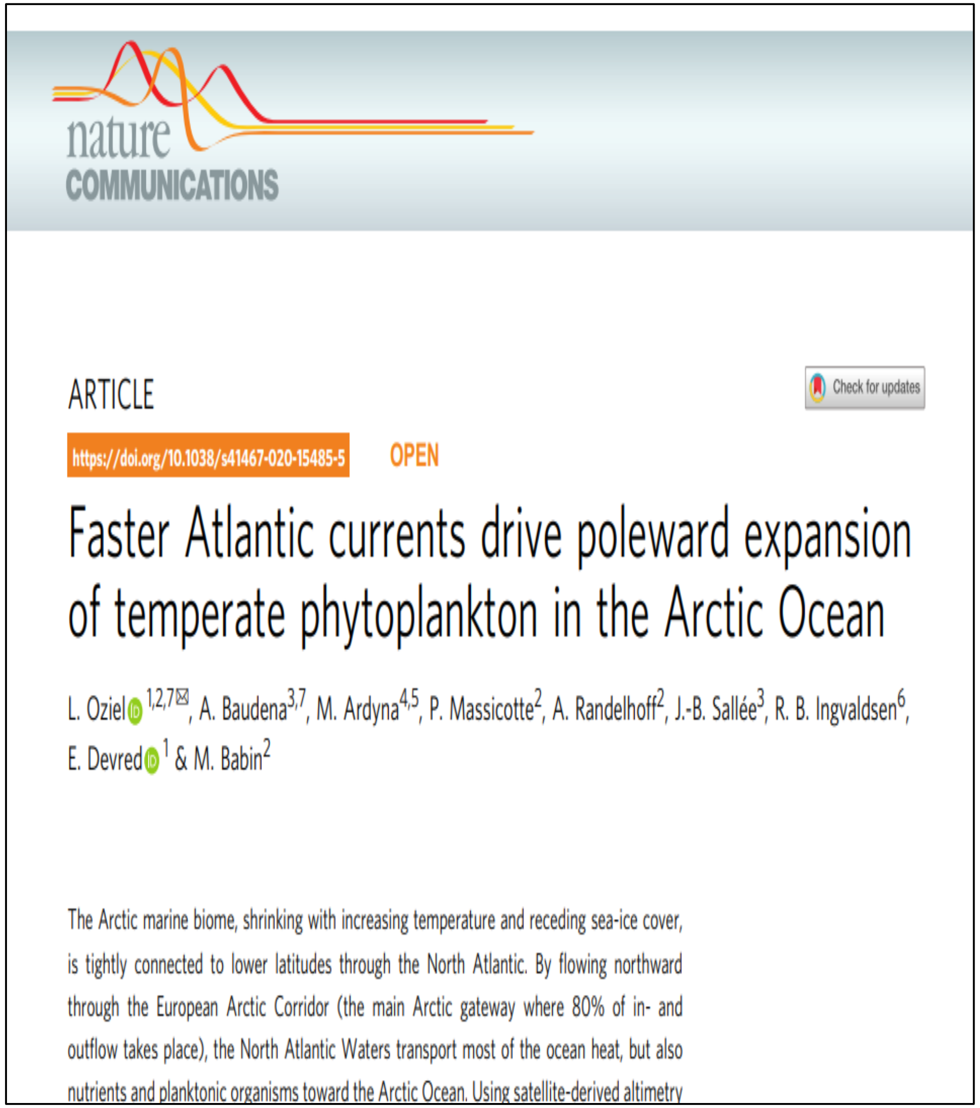
We see an abrupt shift in the Atlantic Multidecadal Oscillator commencing with the upswing in mid-ocean seismic activity in 1995. The red bars indicate the positive (warm) phase while the blue bars indicate the negative (cool) phase.



Here we see the anomalously high temperatures associated with a positive AMO. The area of higher temperatures begins just north of the equator as the ocean circulation is intensified in the Southern Atlantic, increasing the heat flow into the North Atlantic.



This rapid change in the AMO Index is clearly reflected in an abrupt change in the phytoplankton populations in the Arctic. Furthermore, this sudden change in the marine flora is tied to a rapid intensification of the North Atlantic Currents in 1996.



nature COMMUNICATIONS

ARTICLE

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https://doi.org/10.1038/s41467-020-15485-5 OPEN

Faster Atlantic currents drive poleward expansion of temperate phytoplankton in the Arctic Ocean

L. Oziel[1,2,7✉], A. Baudena[3,7], M. Ardyna[4,5], P. Massicotte[2], A. Randelhoff[2], J.-B. Sallée[3], R. B. Ingvaldsen[6], E. Devred[1] & M. Babin[2]

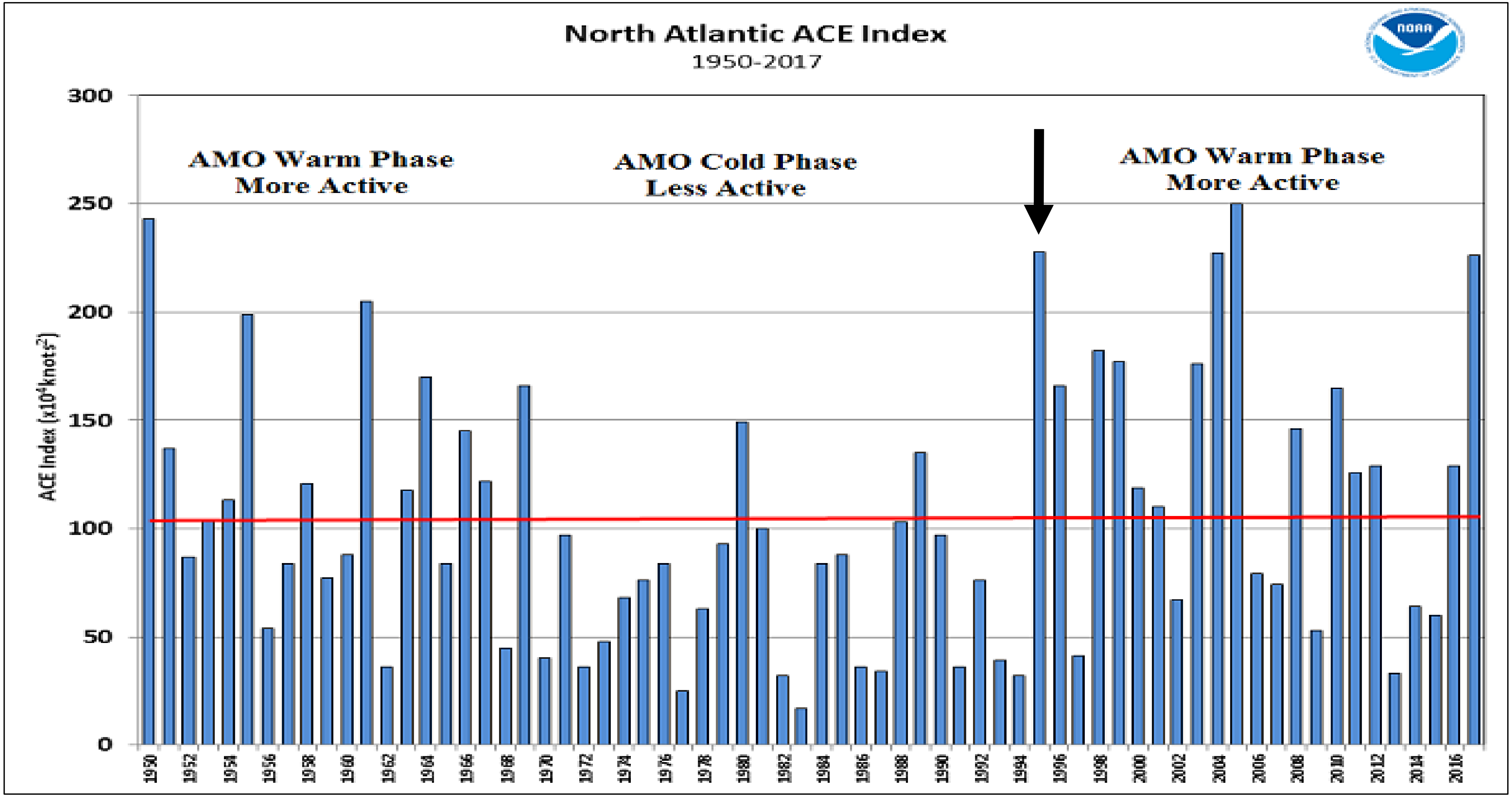
The Arctic marine biome, shrinking with increasing temperature and receding sea-ice cover, is tightly connected to lower latitudes through the North Atlantic. By flowing northward through the European Arctic Corridor (the main Arctic gateway where 80% of in- and outflow takes place), the North Atlantic Waters transport most of the ocean heat, but also nutrients and planktonic organisms toward the Arctic Ocean. Using satellite-derived altimetry

A study by Oziel et al. in Nature Communications states that:

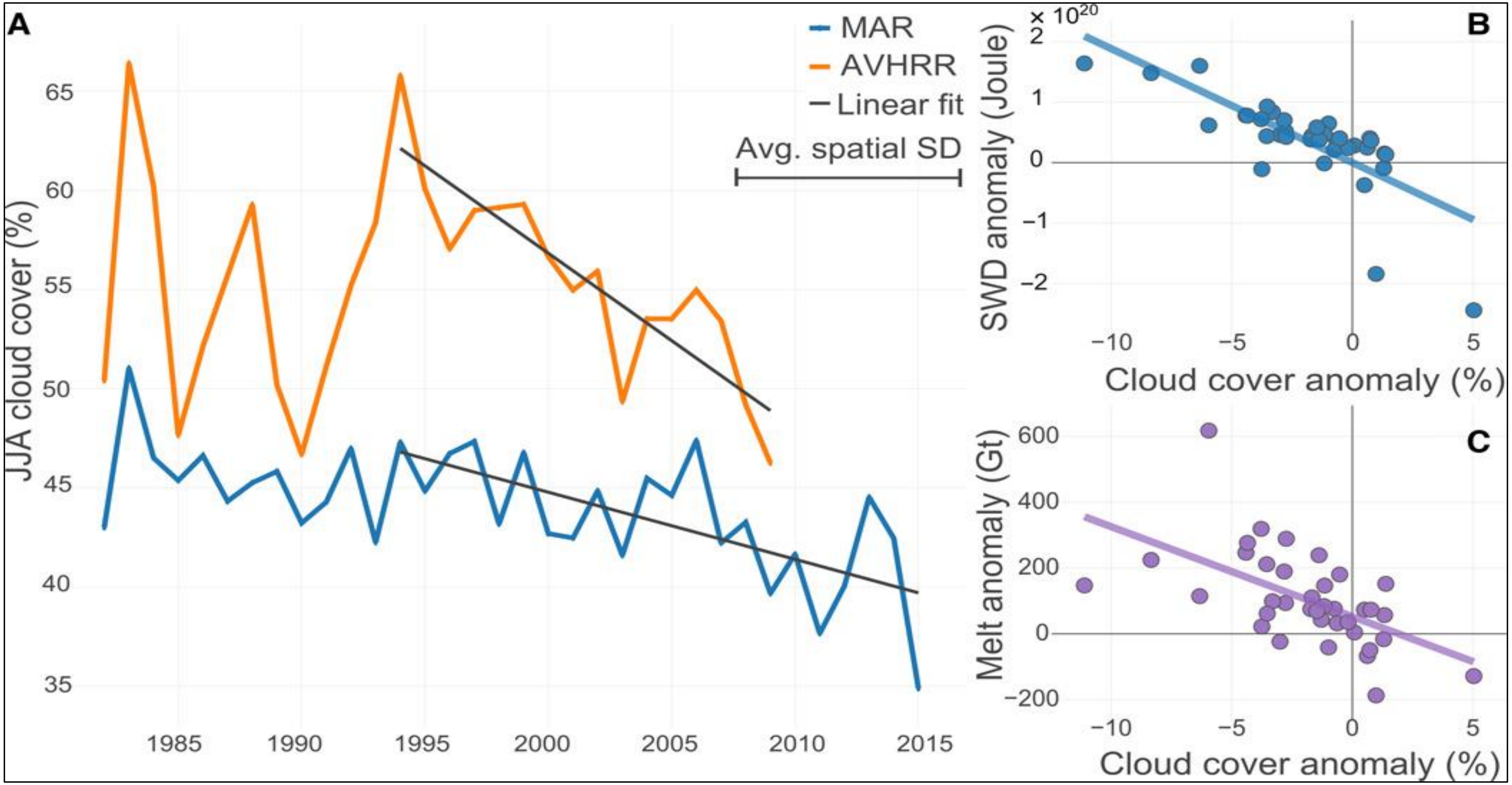
“The Arctic marine biome, shrinking with increasing temperature and receding sea-ice cover, is tightly connected to lower latitudes through the North Atlantic. By flowing northward through the European Arctic Corridor (the main Arctic gateway where 80% of in- and outflow takes place), the North Atlantic Waters transport most of the ocean heat, but also nutrients and planktonic organisms toward the Arctic Ocean. ***Using satellite-derived altimetry observations, we reveal an increase, up to two-fold, in North Atlantic current surface velocities over the last 24 years. …”***

Oziel, L., Baudena, A., Ardyna, M. et al. Faster Atlantic currents drive poleward expansion of temperate phytoplankton in the Arctic Ocean. Nat Commun 11, 1705 (2020). https://doi.org/10.1038/s41467-020-15485-5

We also saw an abrupt increase in North Atlantic hurricanes in 1995 and their accumulated energy (ACE)

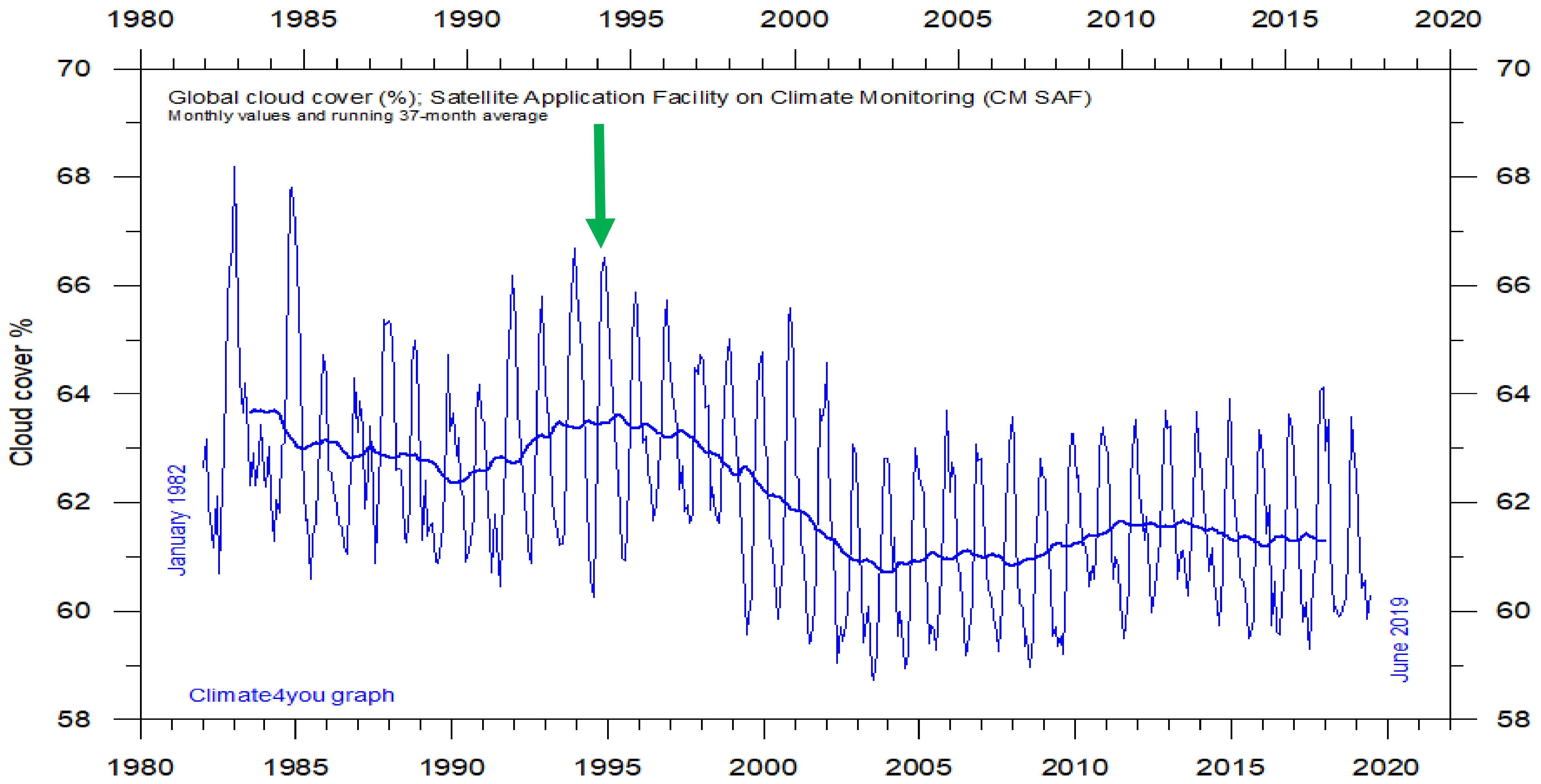


We also saw the beginning of a decline in cloud cover over Greenland in 1995. Higher temperatures lead to a greater ability of the overlying atmosphere to hold more water vapor.



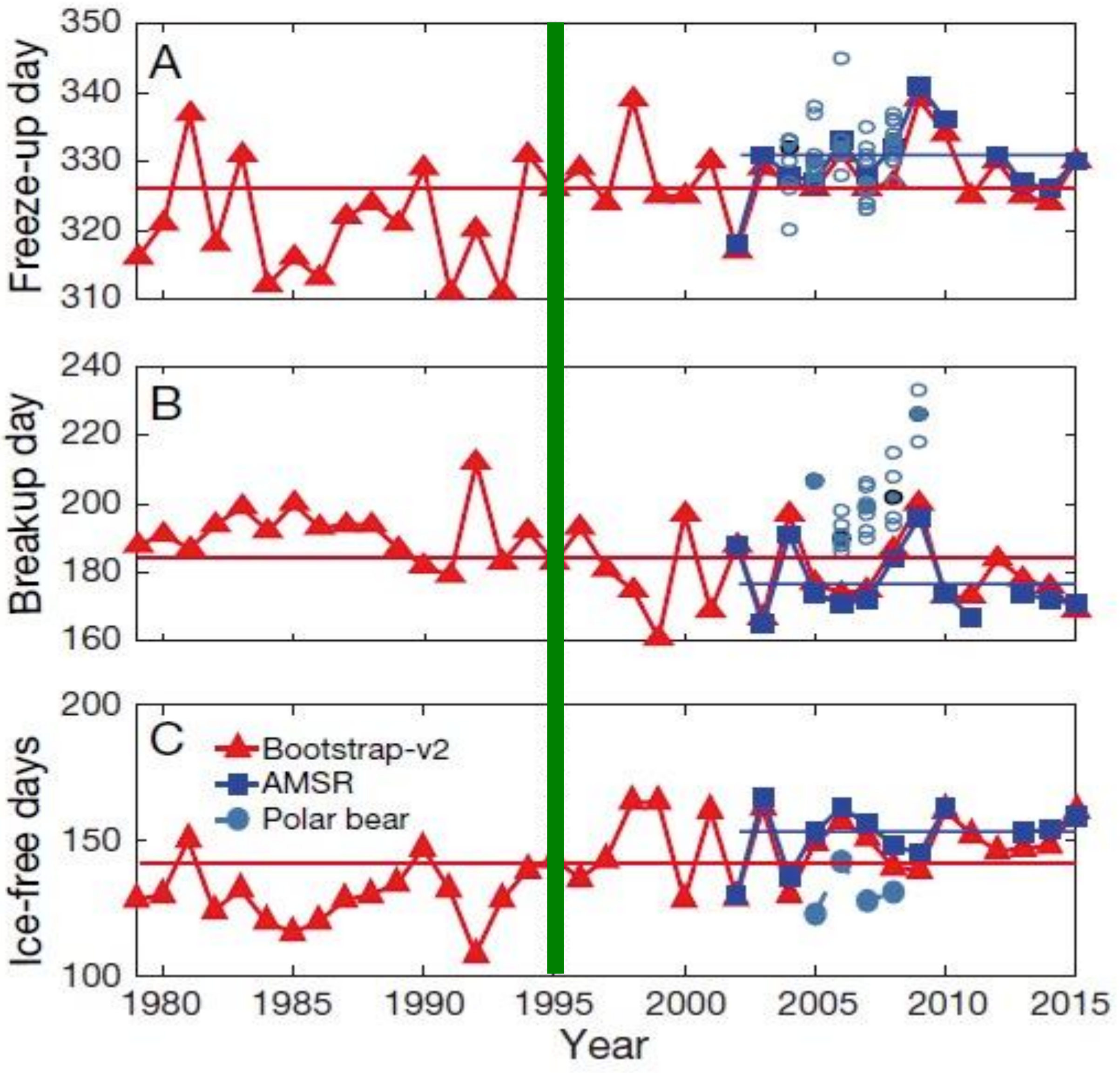
Decreasing cloud cover drives the recent mass loss on the Greenland Ice Sheet Stefan Hofer1,*, Andrew J. Tedstone1, Xavier Fettweis2 and Jonathan L. Bamber *Science Advances* 28 Jun 2017: Vol. 3, no. 6, e1700584 DOI: 10.1126/sciadv.1700584

In lockstep, *global* cloud cover also started to decline in 1995.



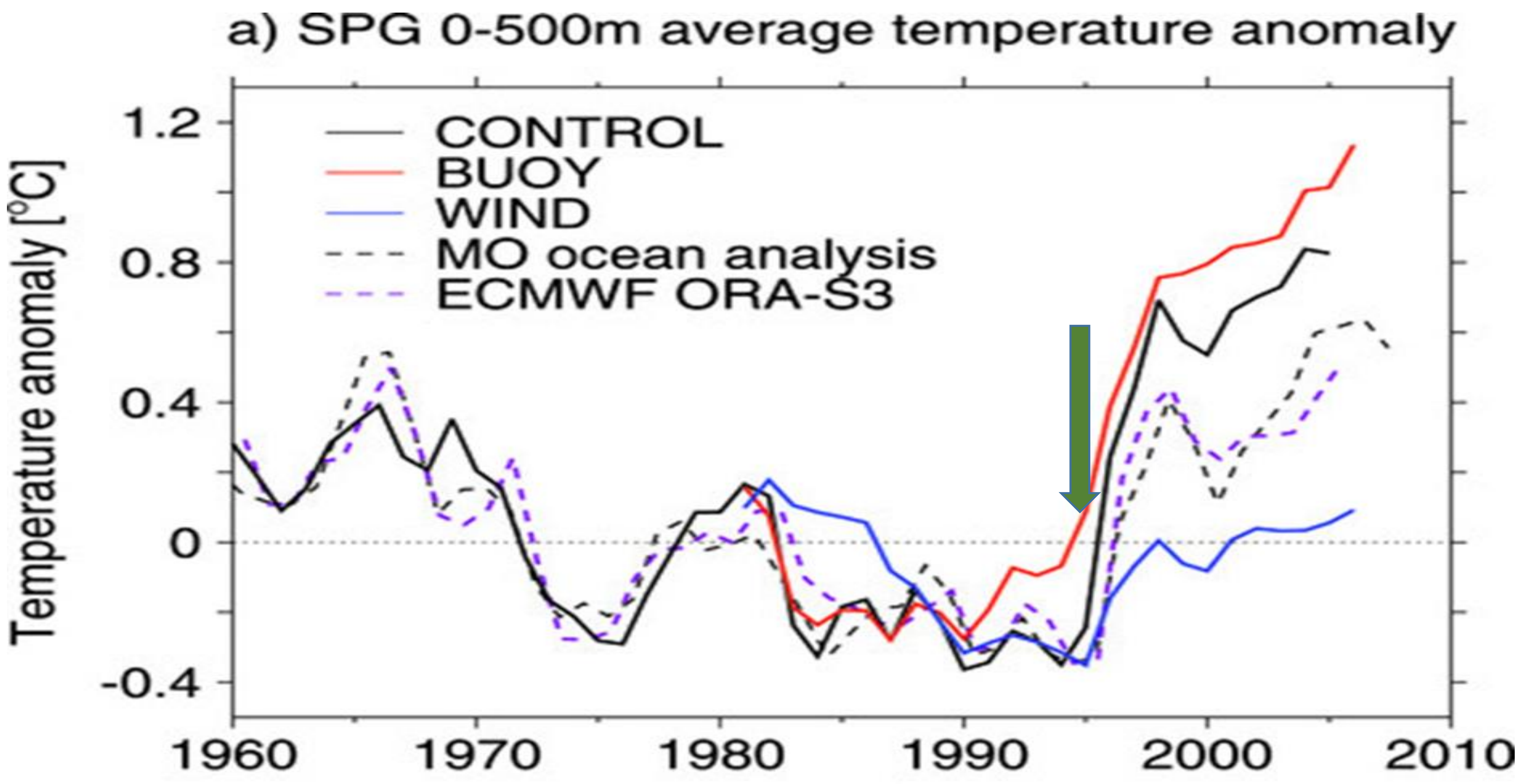
Also commencing in 1995 are changes in freeze and breakup dates of ice in the Hudson Bay region

Figure 3 from Castro de la Guardia (2017) showing freeze-up and breakup dates and ice-free days 1979-2015 for Western Hudson Bay, showing that the earliest freeze-up dates since 1979 (top panel) came on 6 November, Day 310 (in 1991 and 1993).



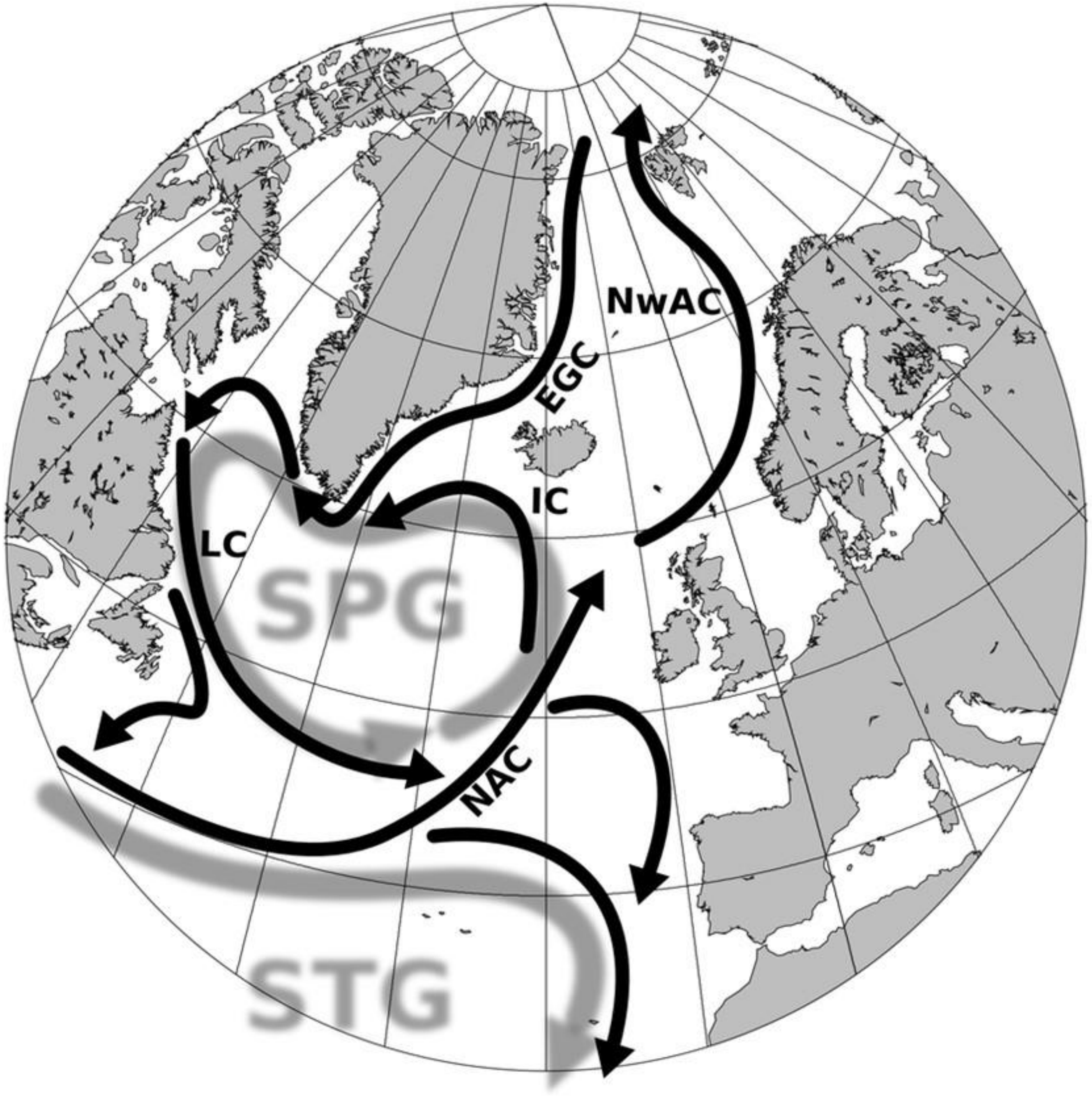
https://climatechangedispatch.com/wh-freeze-up-earlier-1980-average/

We saw rapid warming of the North Atlantic Sub-polar Gyre commencing in 1995

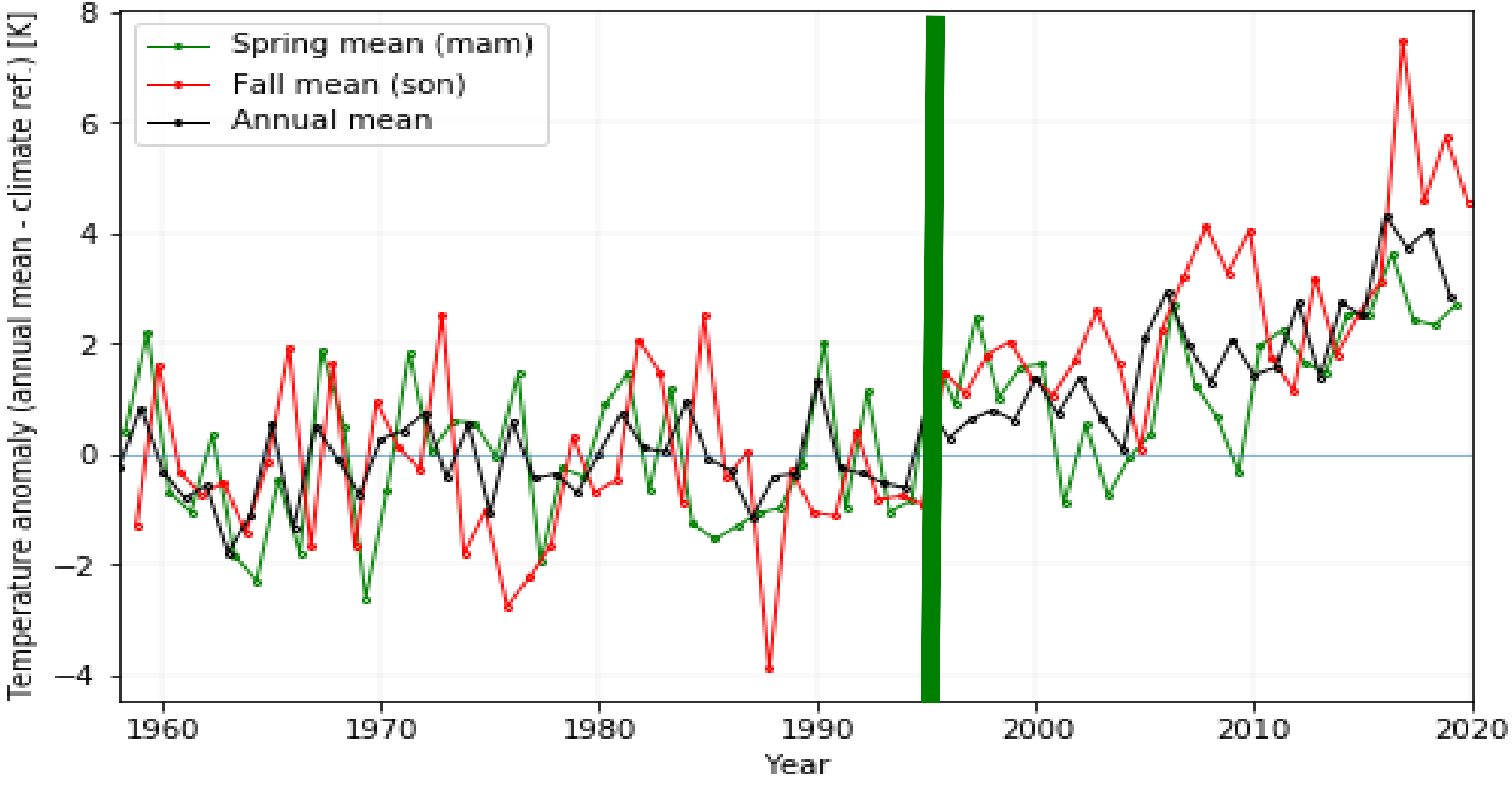


42. Robson J, Sutton R, Lohmann K, Smith D, Palmer MD (2012) Causes of the rapid warming of the North Atlantic Ocean in the mid-1990s. J Climate 25(12): 4116-4134.

Here is a map of the North Atlantic Sub-Polar Gyre (SPG)

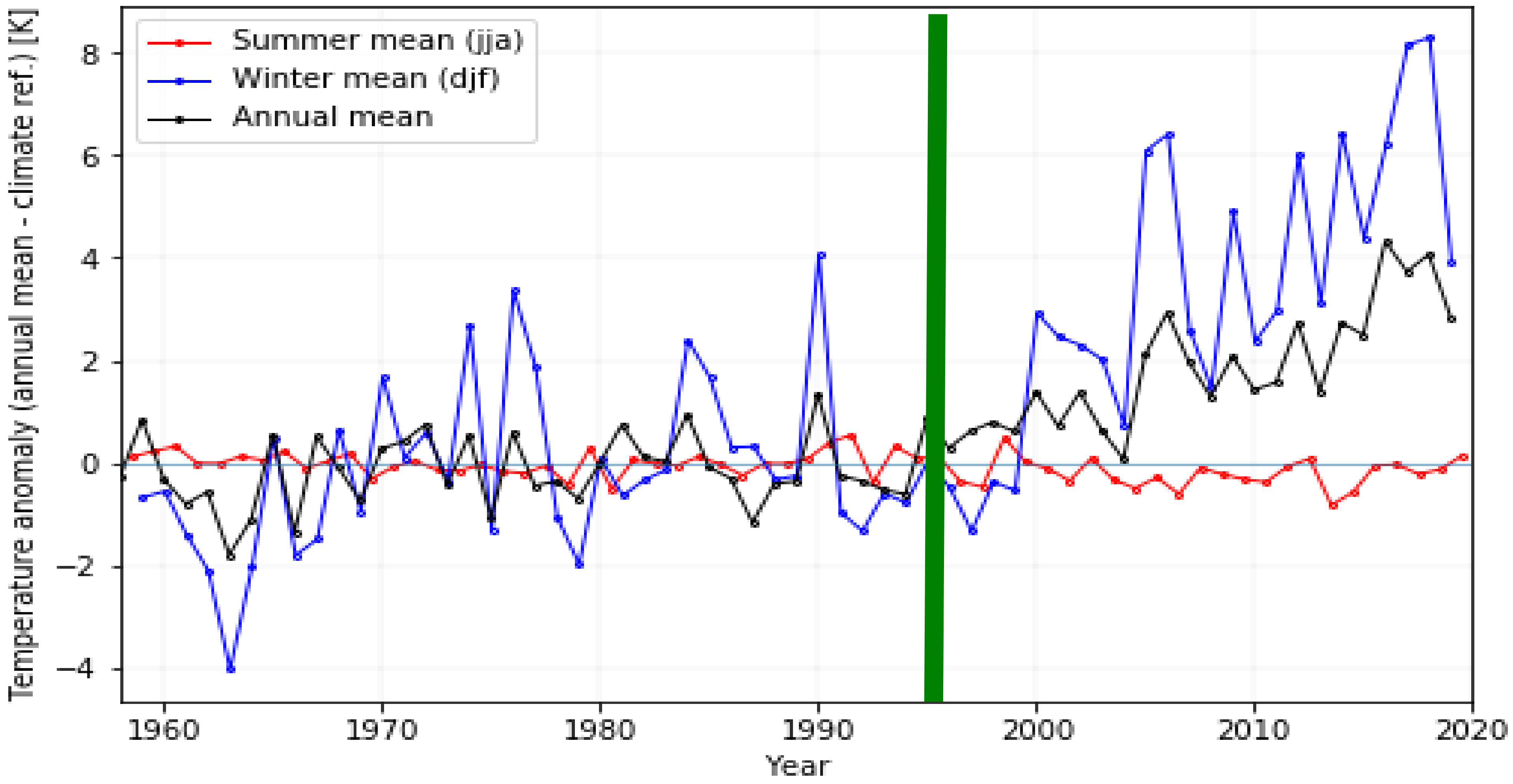


Commencing in 1995 there was an abrupt change in fall and spring Arctic (>80° N lat.) temperatures



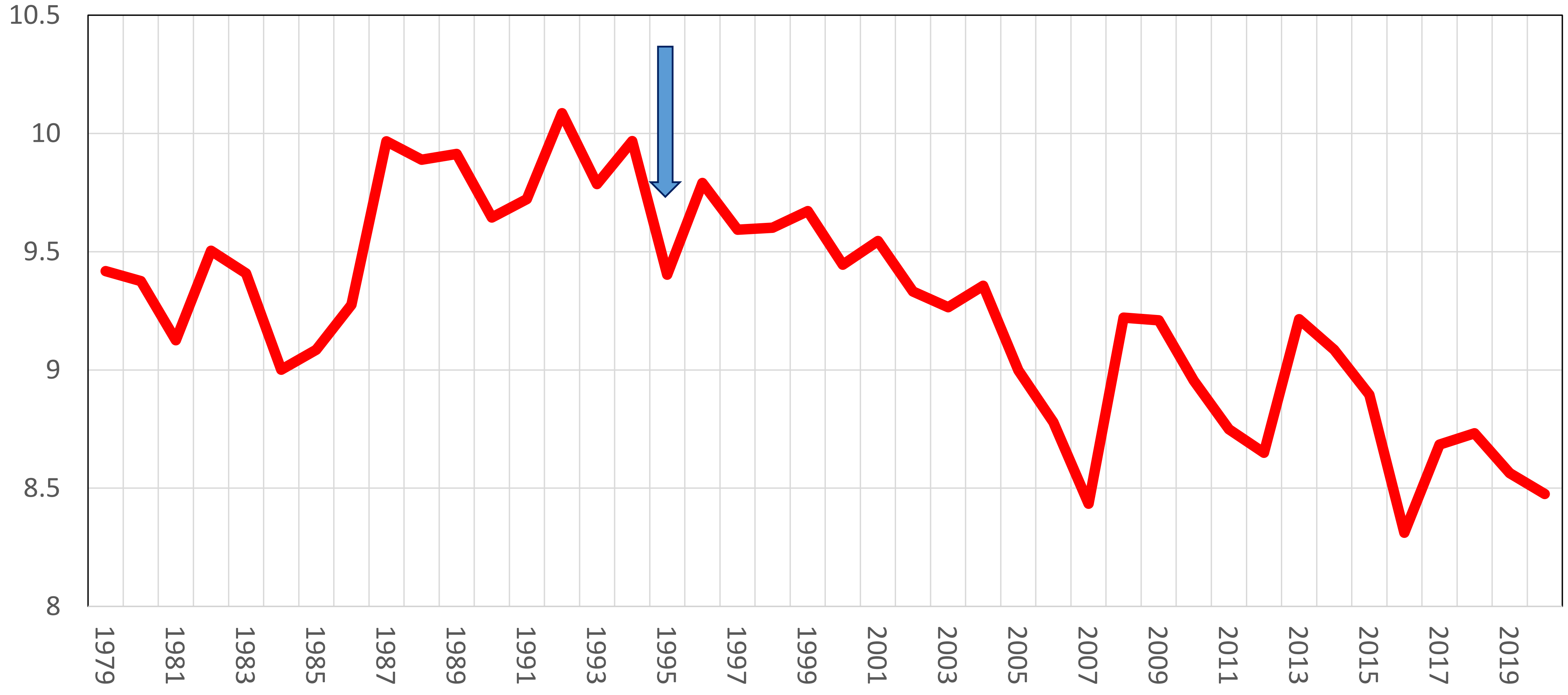
Danish Meteorological Institute

Winter temperatures followed suit shortly thereafter



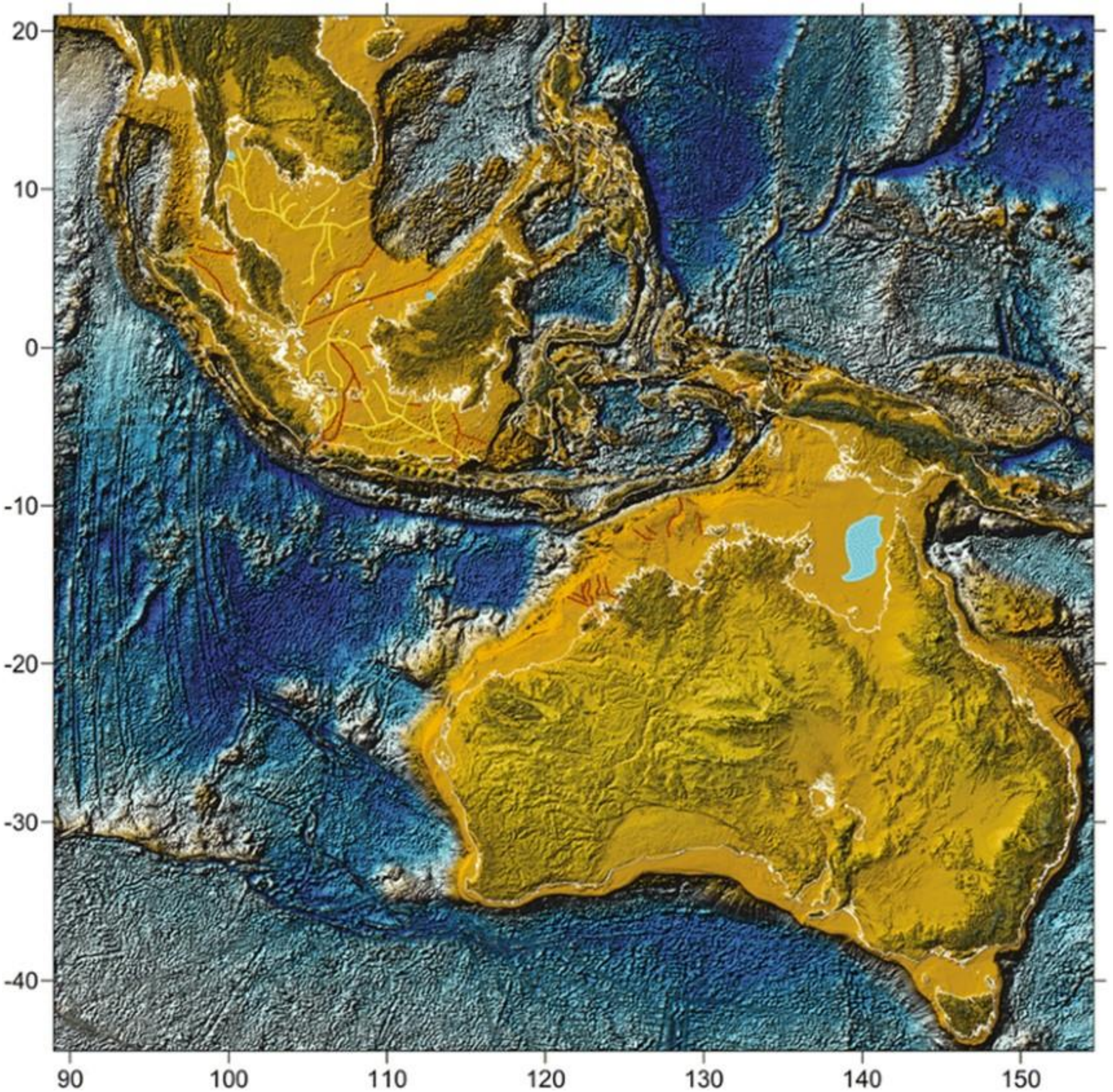
Danish Meteorological Institute

Northern Hemisphere sea ice area also started to decline in 1995.

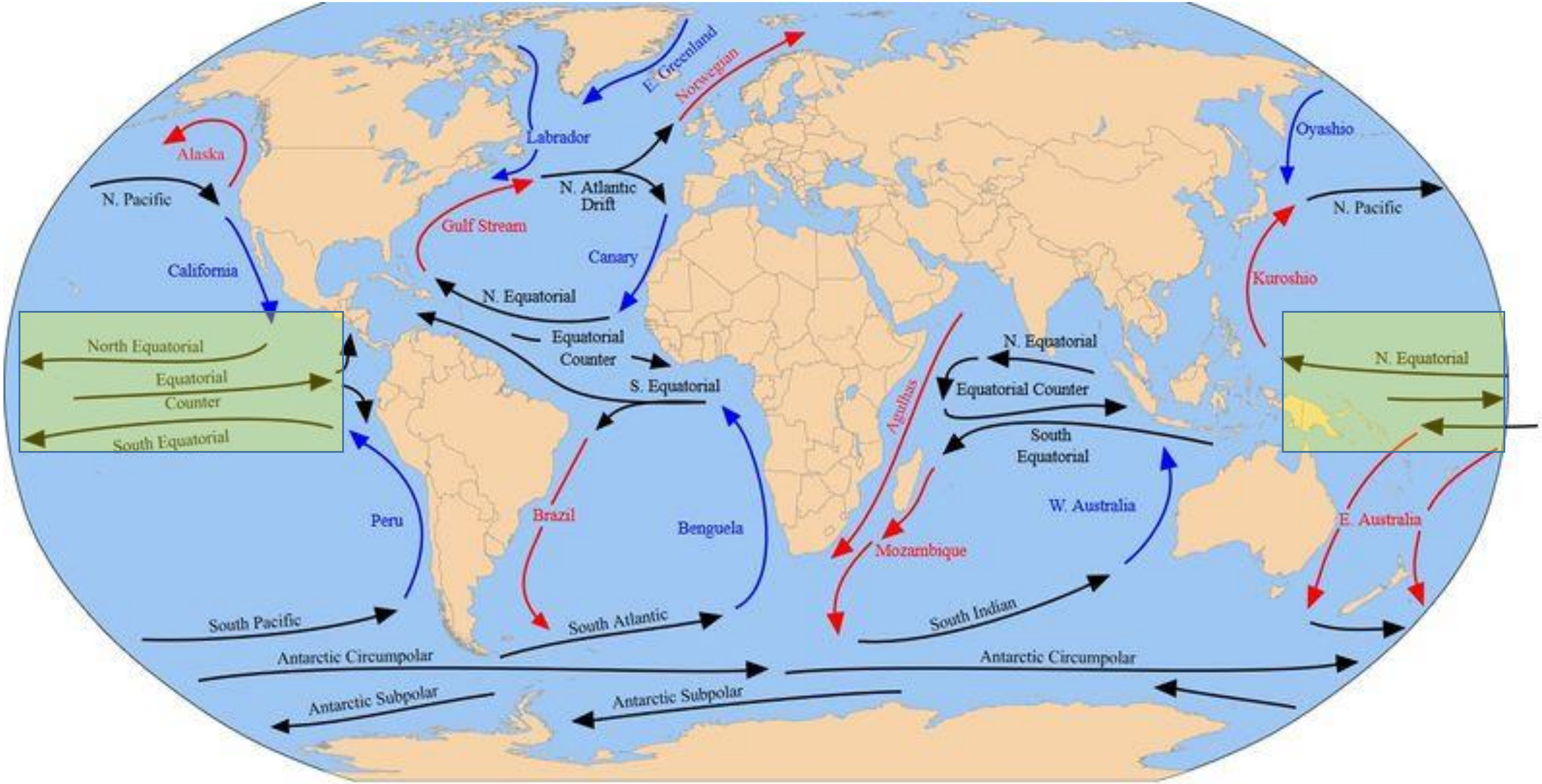


National Snow & Ice Data Center

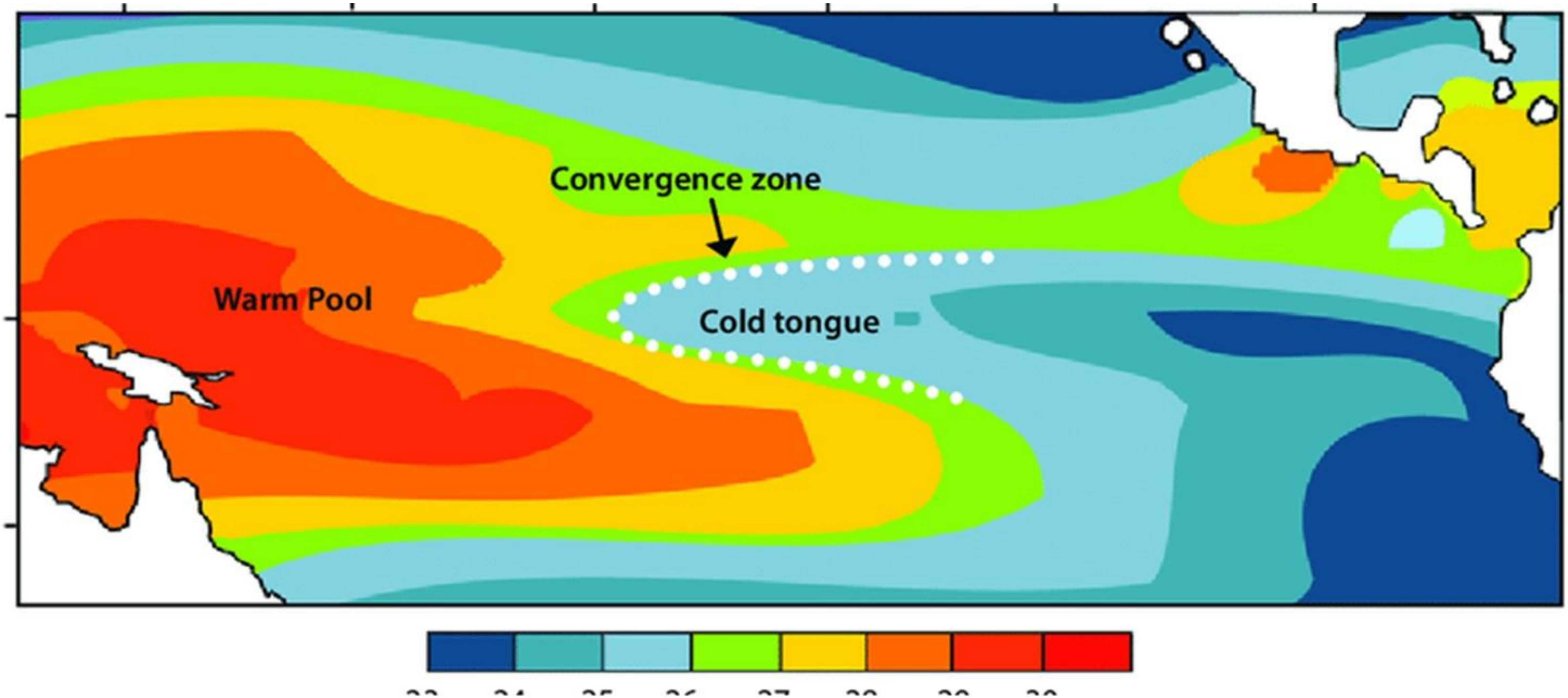
Enhanced thermohaline flow will also cause more warm water to accumulate in the Western Pacific. The physiographic/bathymetric features of that region restrict the flow of the Equatorial Current, creating a vast reservoir of warm water, the driving force behind El Nino events.



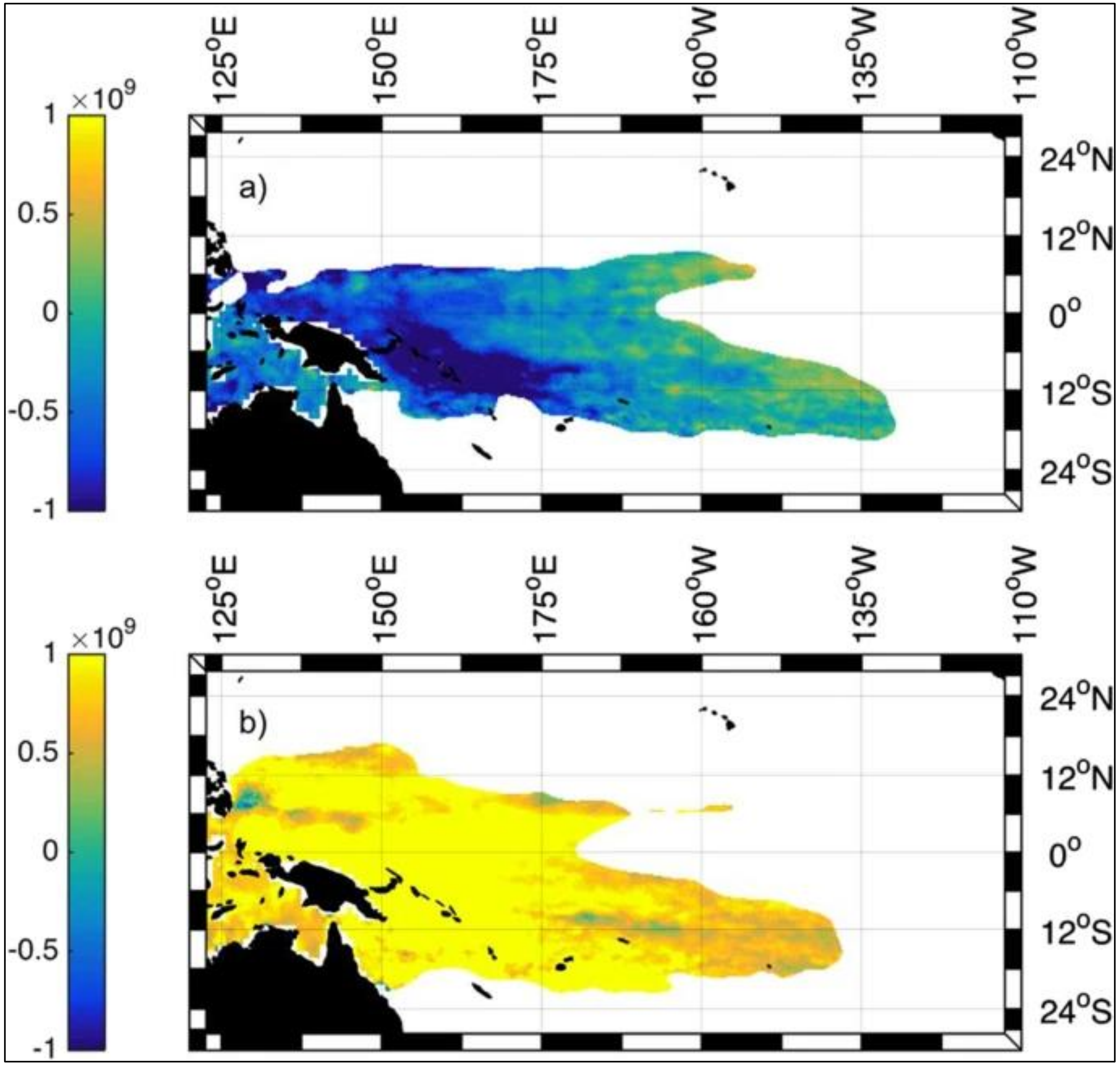
North and South Equatorial Currents



The Western Pacific Warm Pool represents a massive store of heat that can redistribute that heat across the entire Pacific Basin when pressure and wind conditions switch from a "neutral" phase to an El Nino phase.

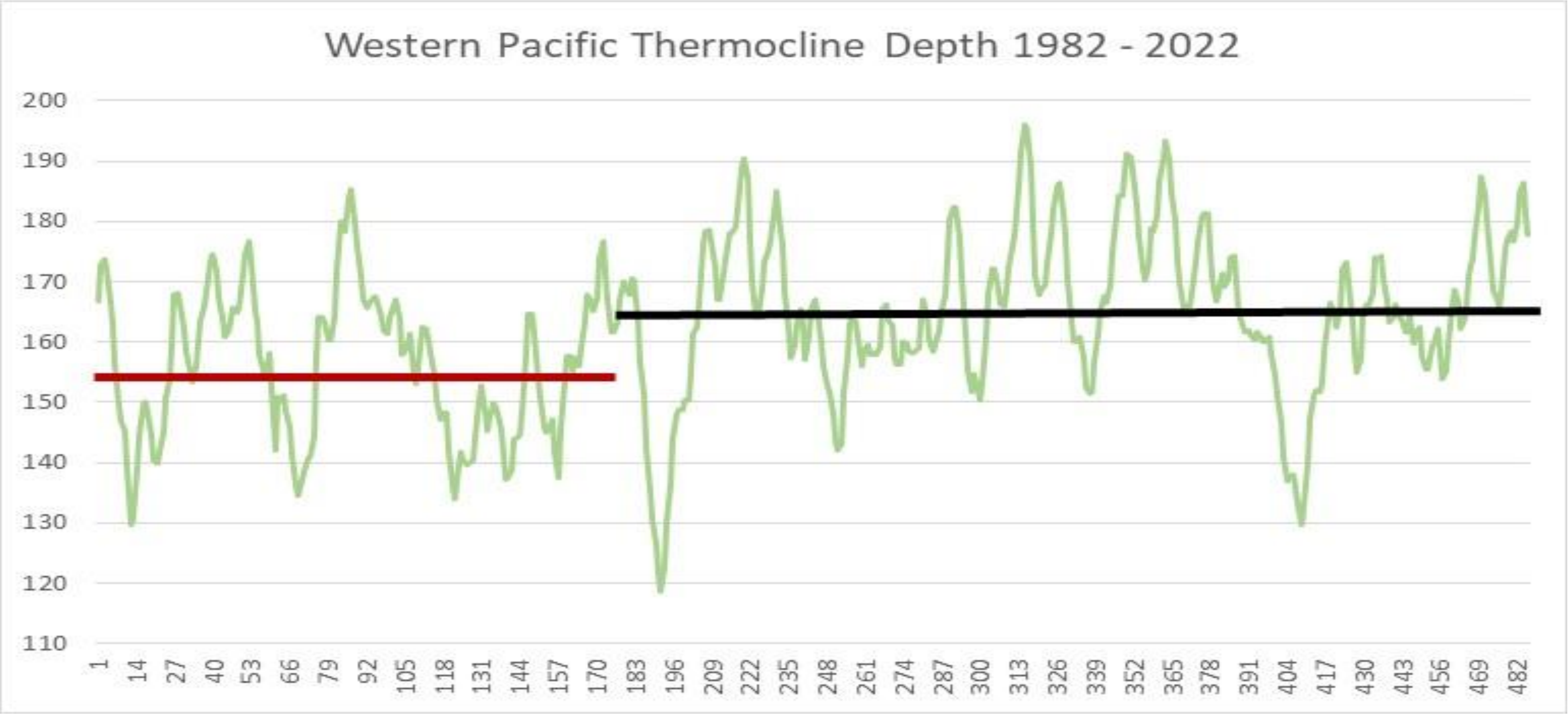


A comparison of the 1993 heat content of the Western Pacific Warm Pool (top image) with the 2014 Pool (bottom image) under "neutral" conditions shows a large increase of heat content over that time. The area of the Pool also increased.



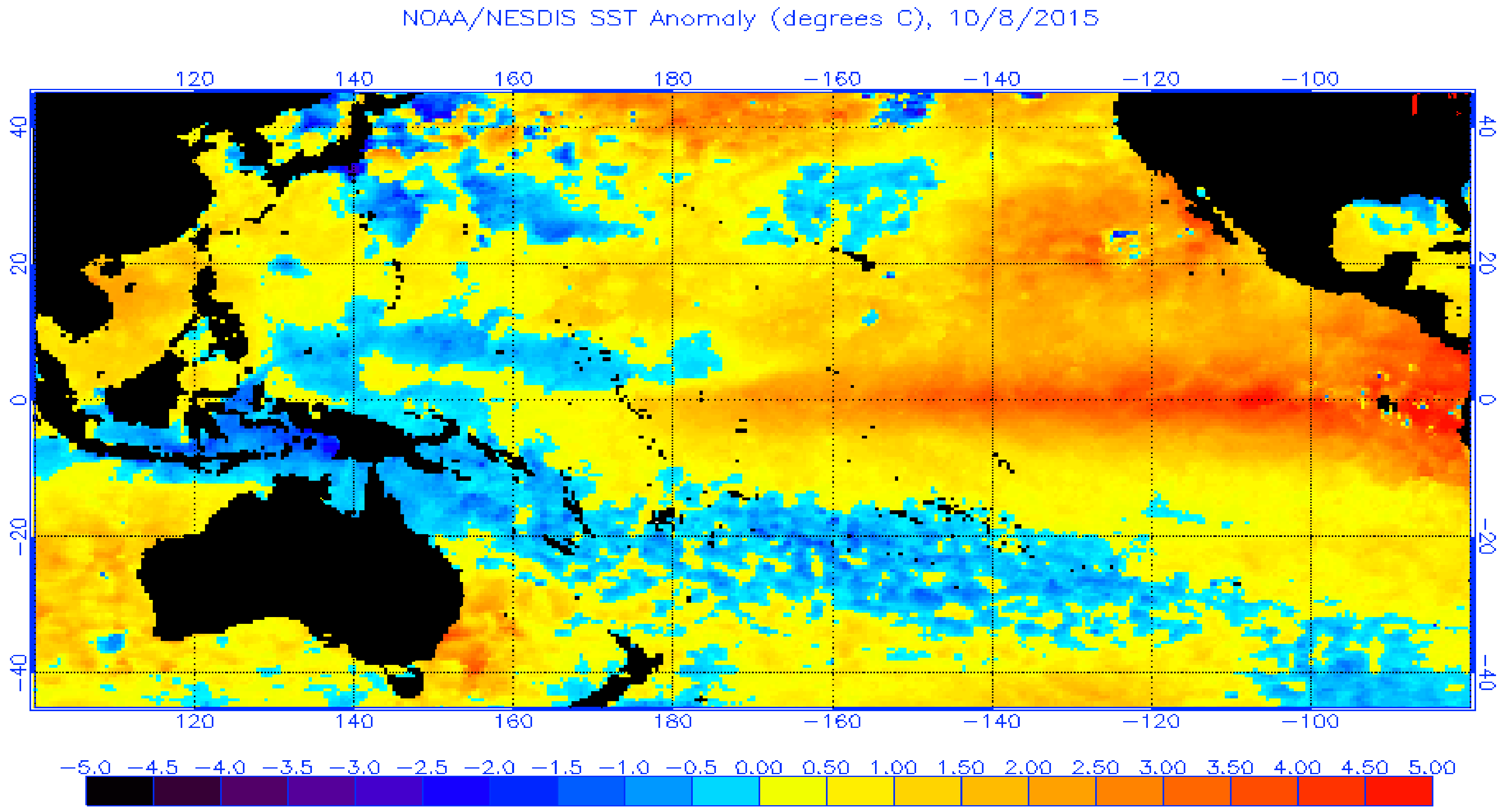
Kidwell, A., Han, L., Jo, YH. et al. Decadal Western Pacific Warm Pool Variability: A Centroid and Heat Content Study. Sci Rep 7, 13141 (2017). https://doi.org/10.1038/s41598-017-13351-x

Further evidence of Western Pacific Warm Pool intensification after 1995 (x axis demarcated in months) is presented by thermocline deepening of 10 meters in the Western Pacific.

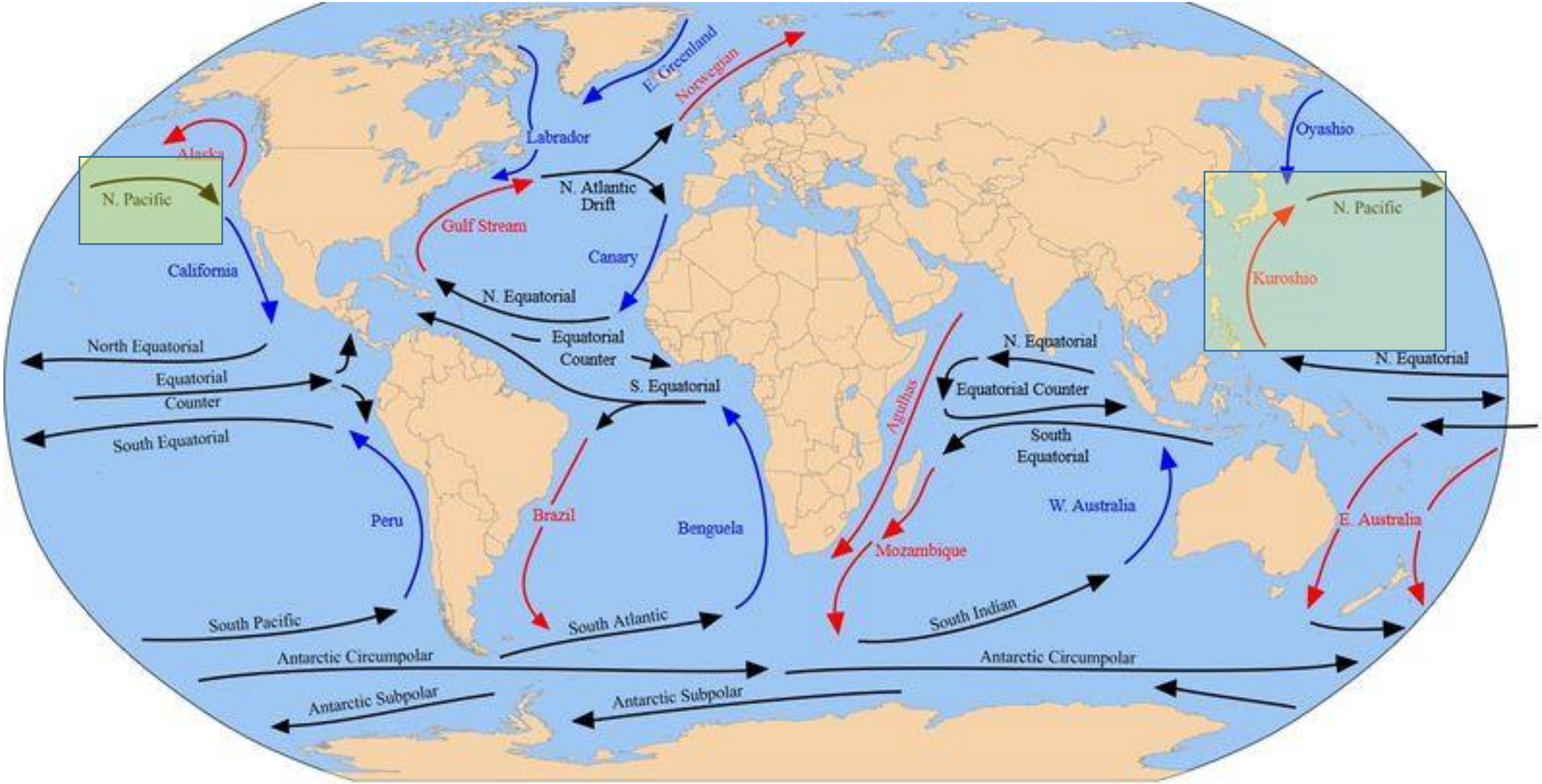


Columbia Climate School /International Research Institute For Climate And Society

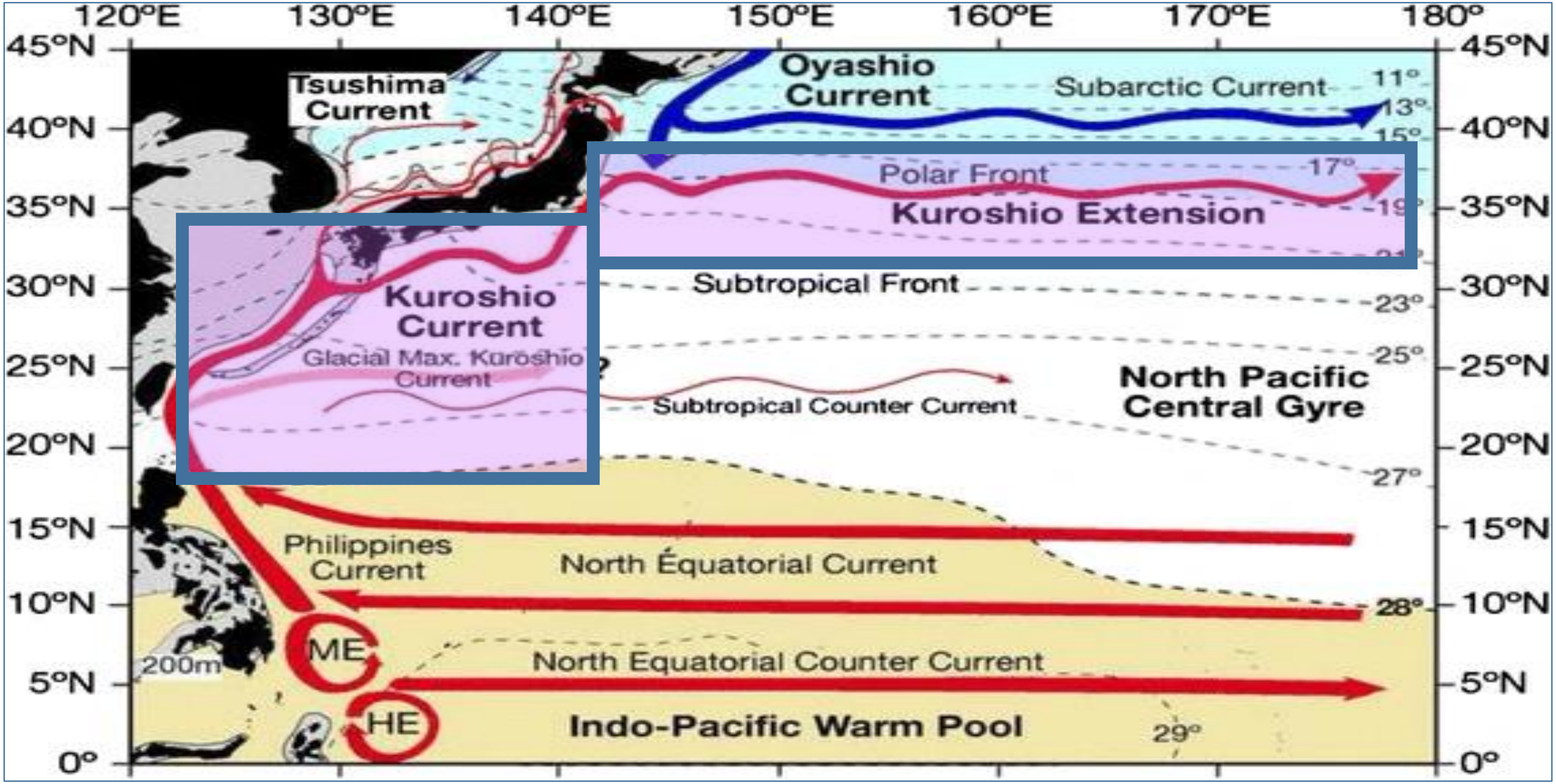
As this map from the 2015 "Super El Nino" shows, the deepened, anomalously warm Western Pacific Warm Pool spread out over an immense area, raising sea surface temperatures down the west coast of South America, while stretching as far north as Central and North America, and as far west as the International Date Line.



The strengthening of the Western Pacific Warm Pool has also warmed and strengthened the Kuroshio Current and the Kuroshio Extension.



A more detailed map of the Kuroshio Current and the Kuroshio Extension



Gallagher, S.J., Kitamura, A., Iryu, Y. et al. The Pliocene to recent history of the Kuroshio and Tsushima Currents: a multi-proxy approach. Prog. in Earth and Planet. Sci. 2, 17 (2015). https://doi.org/10.1186/s40645-015-0045-6

Science News from research organizatio

Major ocean current could warm greatly

Date: September 28, 2021

Source: Binghamton University

Summary: A new study found that the Kuroshio Current Extension is sensitive to global climate change and has the potential to warm greatly with increased carbon dioxide levels.

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FULL STORY

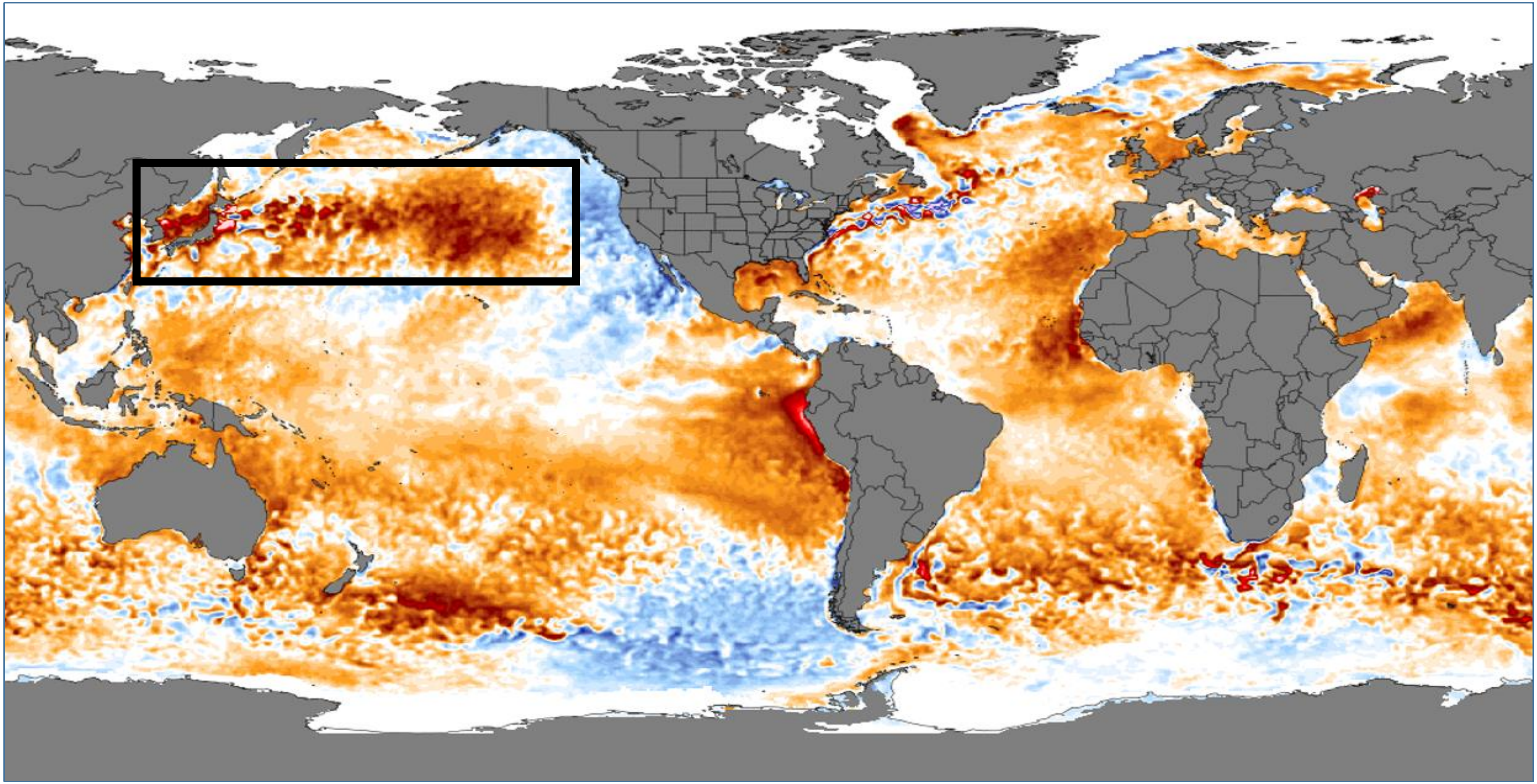
A new study led by researchers at Binghamton University, State University of New York found that the Kuroshio Current Extension is sensitive to global climate change and has the potential to

As reported in Science Daily, a study by Lam et al., shows:

*"…warmth stems from the surface waters that collect in the western Pacific Ocean along the equator, called the Western Pacific Warm Pool. The Kuroshio Current takes these waters north, past the Japanese coast, and then eastward at the 36°N latitude, where it joins the open Pacific Ocean. At this point, it becomes the Kuroshio Current Extension….Today, these currents **are warming two to three times faster than other areas of the ocean**…Ocean model studies and observational data also show that the **Kuroshio Current Extension is shifting northward and increasing its transport capacity**…"*

Adriane R. Lam, Kenneth G. MacLeod, Solveig H. Schilling, R. Mark Leckie, Andrew J. Fraass, Molly O. Patterson, Nicholas L. Venti. **Pliocene to Earliest Pleistocene (5–2.5 Ma) Reconstruction of the Kuroshio Current Extension Reveals a Dynamic Current**. *Paleoceanography and Paleoclimatology*, 2021; 36 (9) DOI: 10.1029/2021PA004318

April, 2023 Sea Surface Temperature map showing the strengthened, and warmed, Kuroshio Current Extension



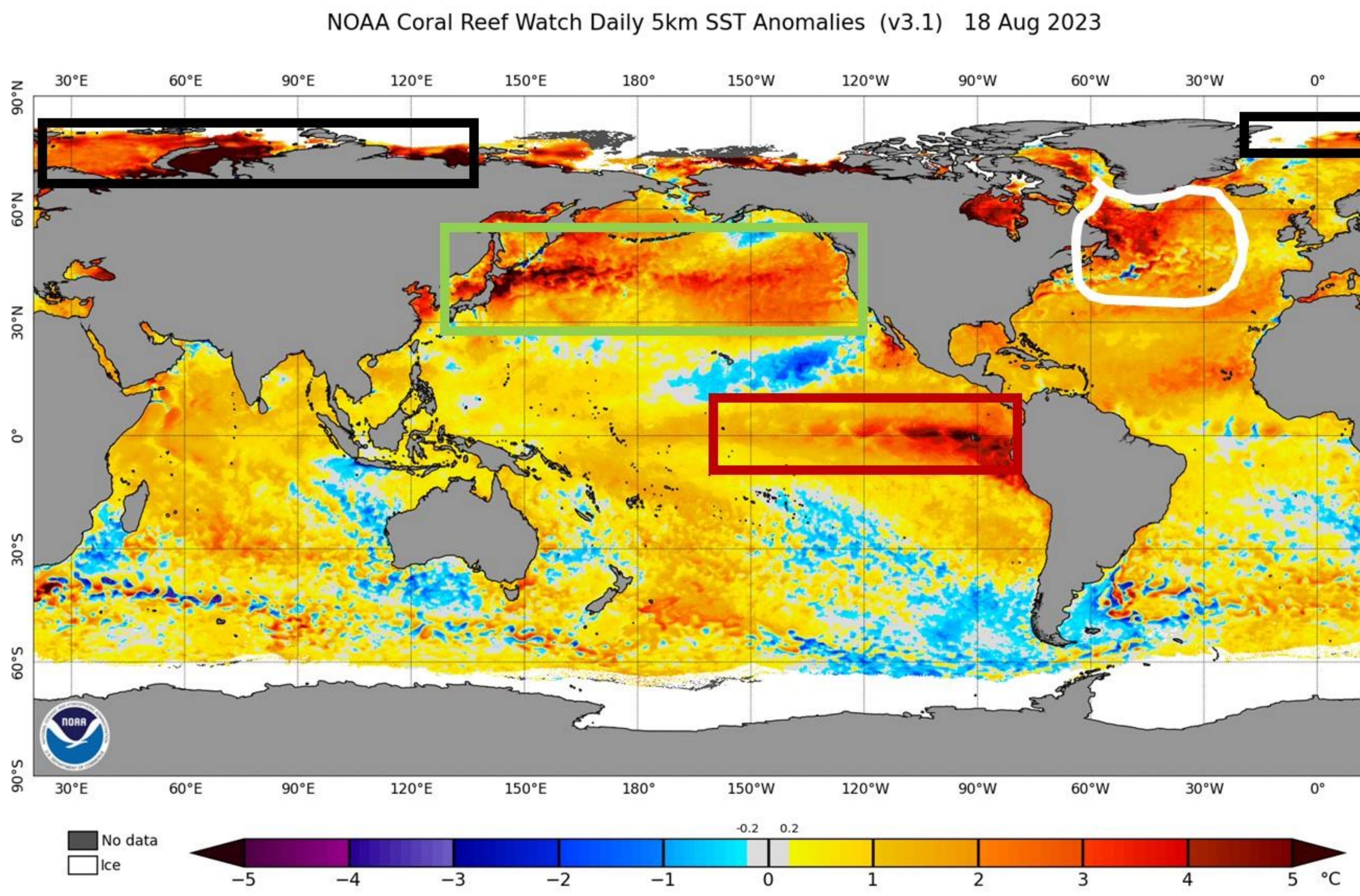
The following slide highlights all of the main “hot spots” that would be expected from enhanced thermohaline flow (SST snapshot, 8/18/2023) .

Black boxes: The “Atlantified/Amplified” Arctic (see slides 21-30)

White circular area: Warmed Sub-Polar Gyre (see slides 31-32)

Green box: Warmed and intensified Kuroshio Current and Extension (see slides 42-45)

Maroon box: Current El Nino with anomalously warm temperatures (see slides 36-41)


NOAA Coral Reef Watch Daily 5km SST Anomalies (v3.1) 18 Aug 2023
30°E
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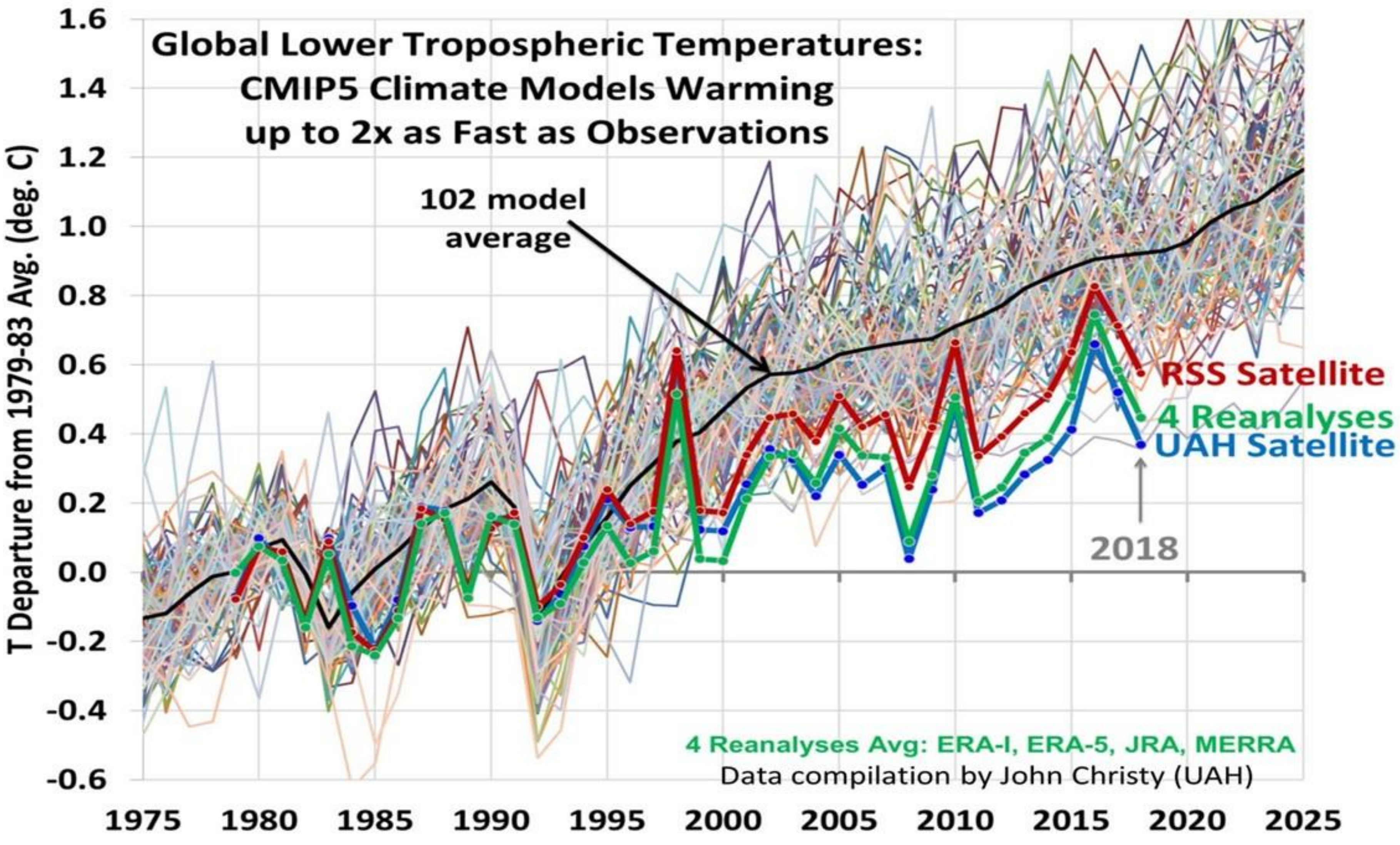
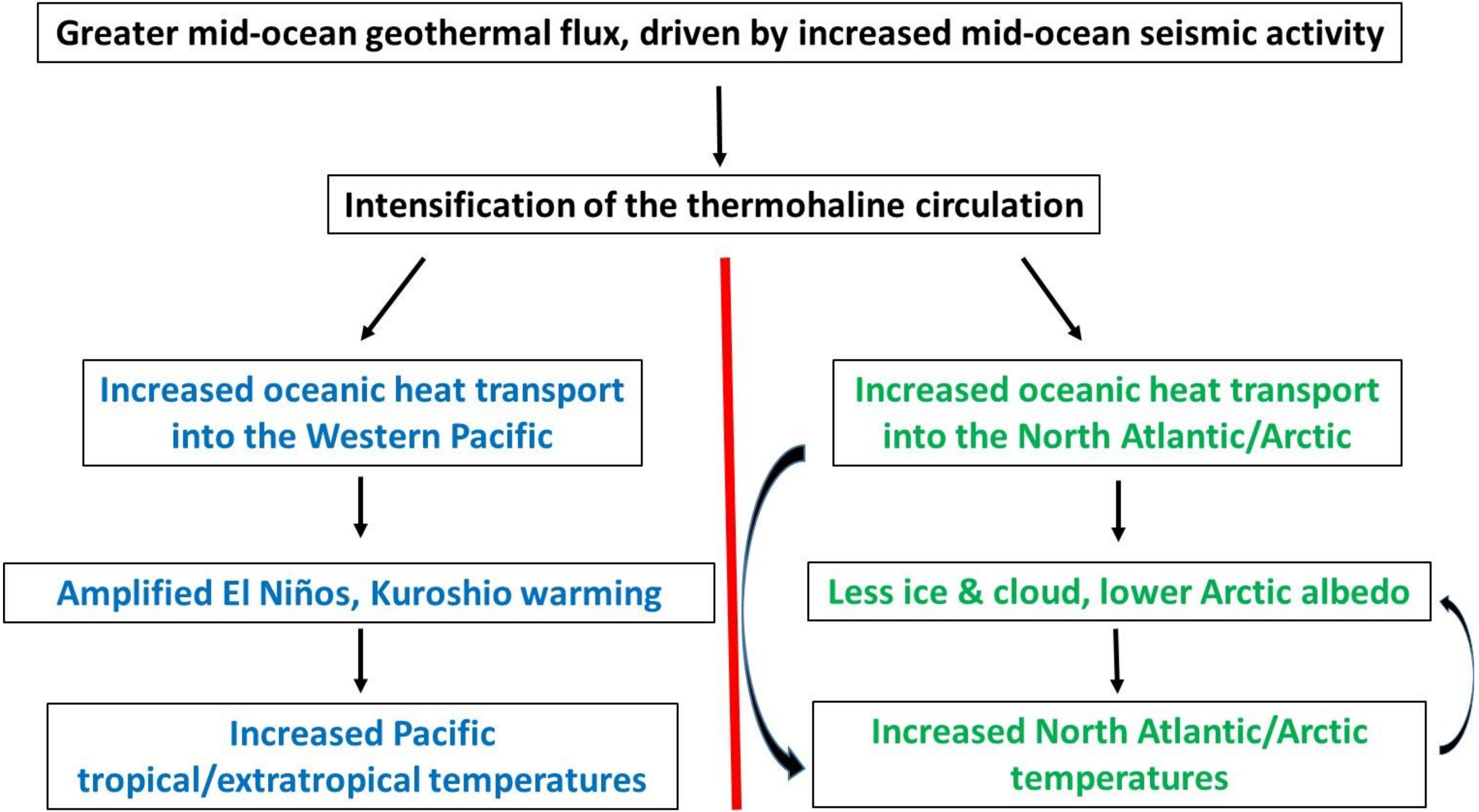
In Summary



We should redirect our research efforts away from this

While directing them towards this hypothesis


Greater mid-ocean geothermal flux, driven by increased mid-ocean seismic activity
Intensification of the thermohaline circulation
Increased oceanic heat transport into the Western Pacific
Amplified El Niños, Kuroshio warming
Increased Pacific tropical/extratropical temperatures
Increased oceanic heat transport into the North Atlantic/Arctic
Less ice & cloud, lower Arctic albedo
Increased North Atlantic/Arctic temperatures

Critics have tried to dismiss the role of geothermal heat on two points:

1. There is not enough heat escaping to the surface to directly warm the overlying ocean and atmosphere to an appreciable degree, and

2. The high correlation between mid-ocean seismic activity and global temperatures does not signify causality as spurious results can arise if confounding variables are omitted from the experimental design.

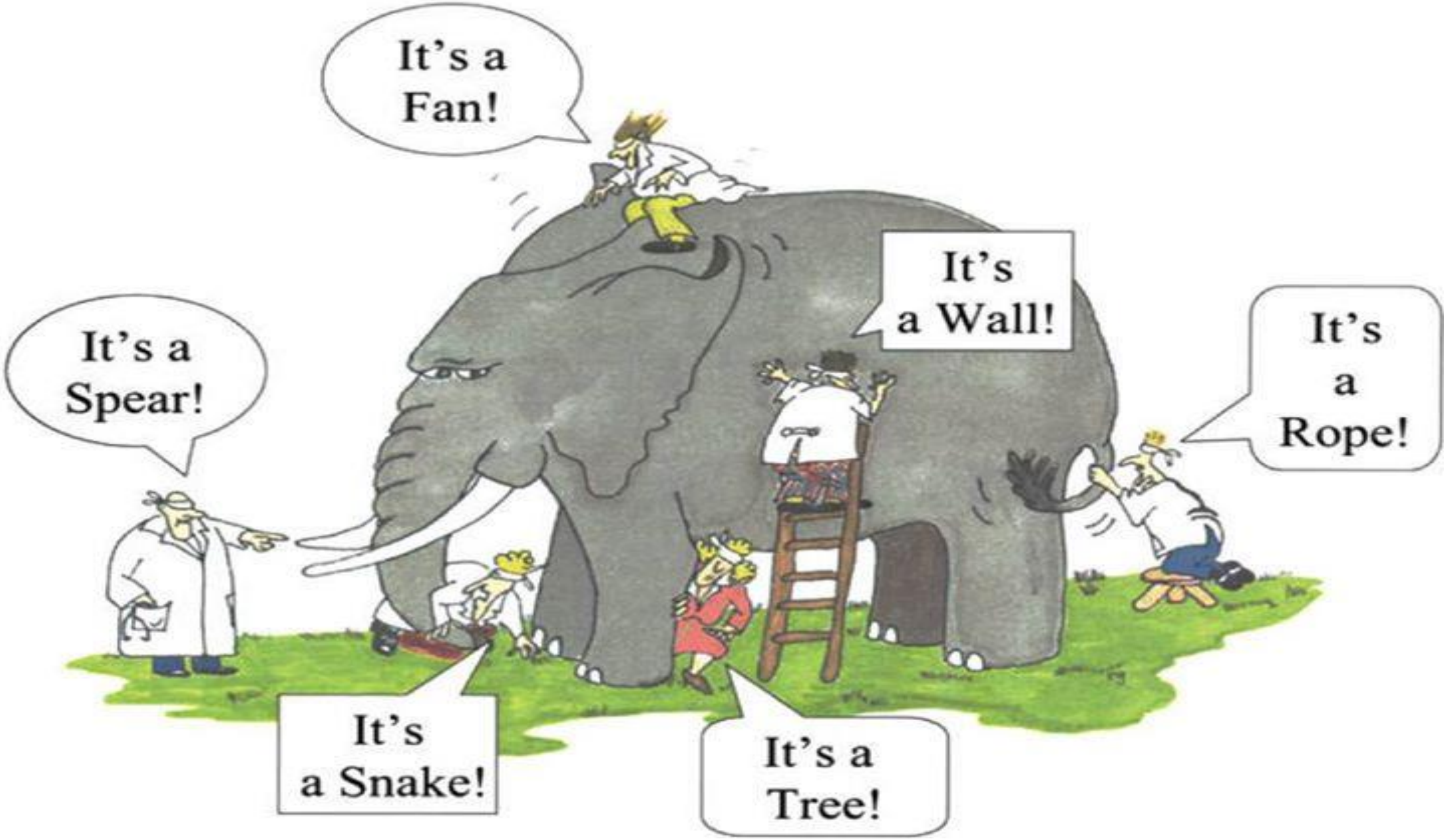
These criticisms are refuted by the following arguments:

1. Although there is not enough heat to directly warm the atmosphere, we have modelling evidence showing that oceanic geothermal heat intensifies the thermohaline circulation. That intensified flow acts as a heat pump to distribute an increased amount of oceanic heat to two major heat sinks, the North Atlantic/Arctic ("Arctic Amplification") and the Western Pacific (Western Pacific Warm Pool).

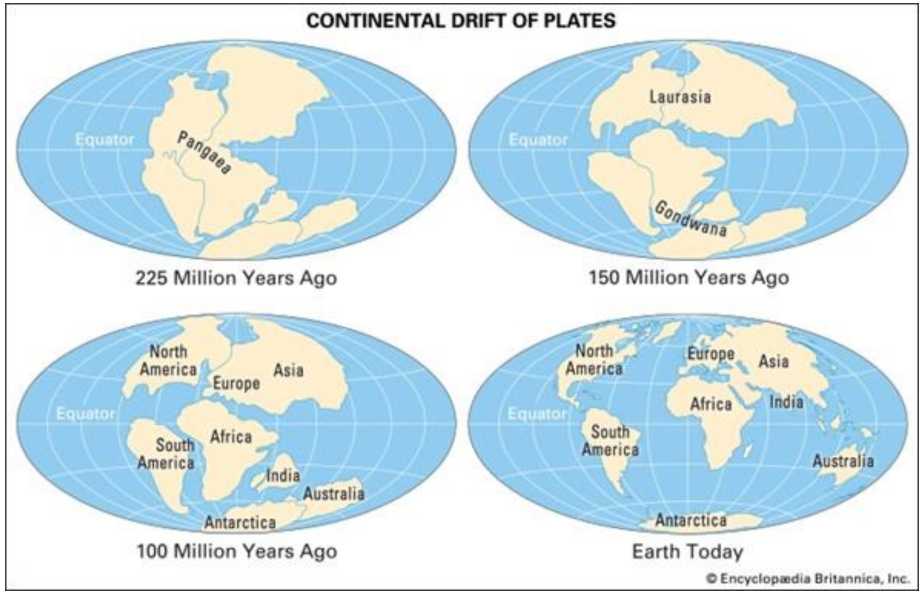
2. We have irrefutable empirical evidence to corroborate the modelling results.

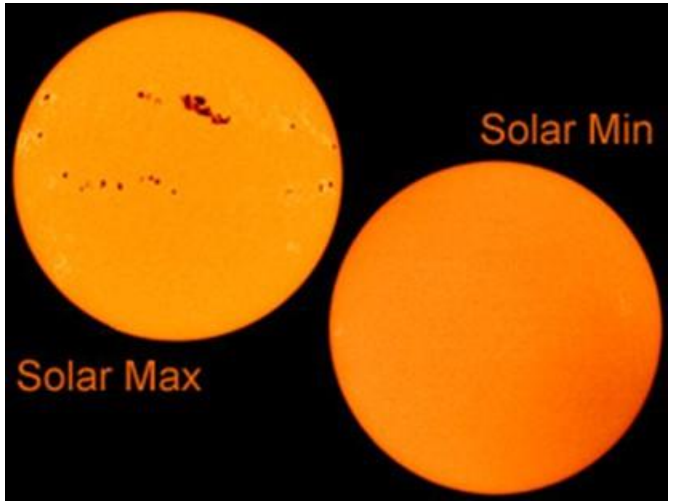
3. The entire chain of environmental changes (i.e., higher global temperatures, reduced ice cover, amplified El Nino events etc.) is anteceded by the change in mid-ocean seismic activity. This is referred to as "Granger Causality" and strongly infers that a "cause" (i.e., one change occurs first) drives time-dependent "effects" (i.e., other perturbations occur afterwards).

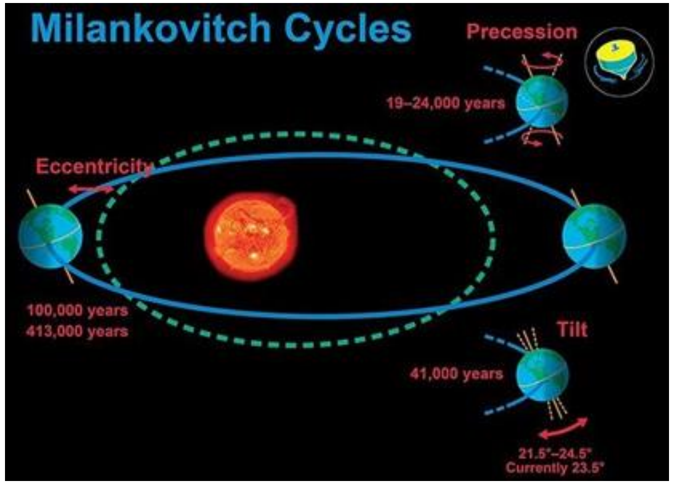
Ultimately, understanding the earth's climate is a classic "epistemological" problem.

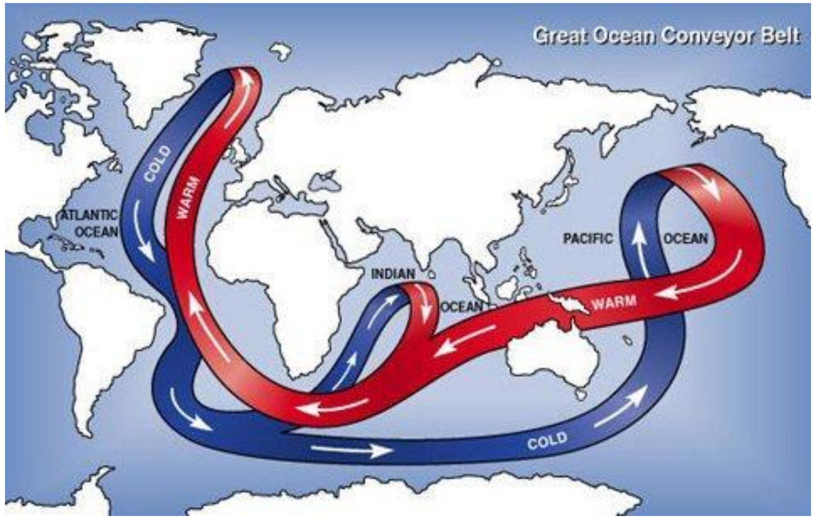


We are just now beginning to grasp the complexities of the climate system.





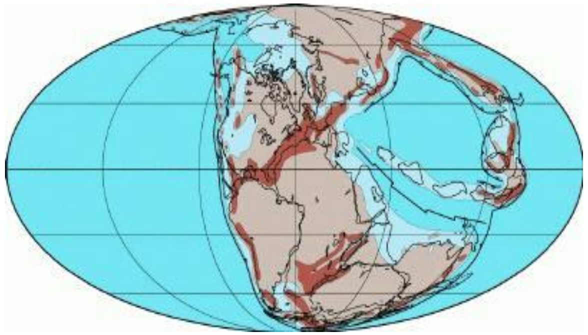




To quote Alfred Wegener:

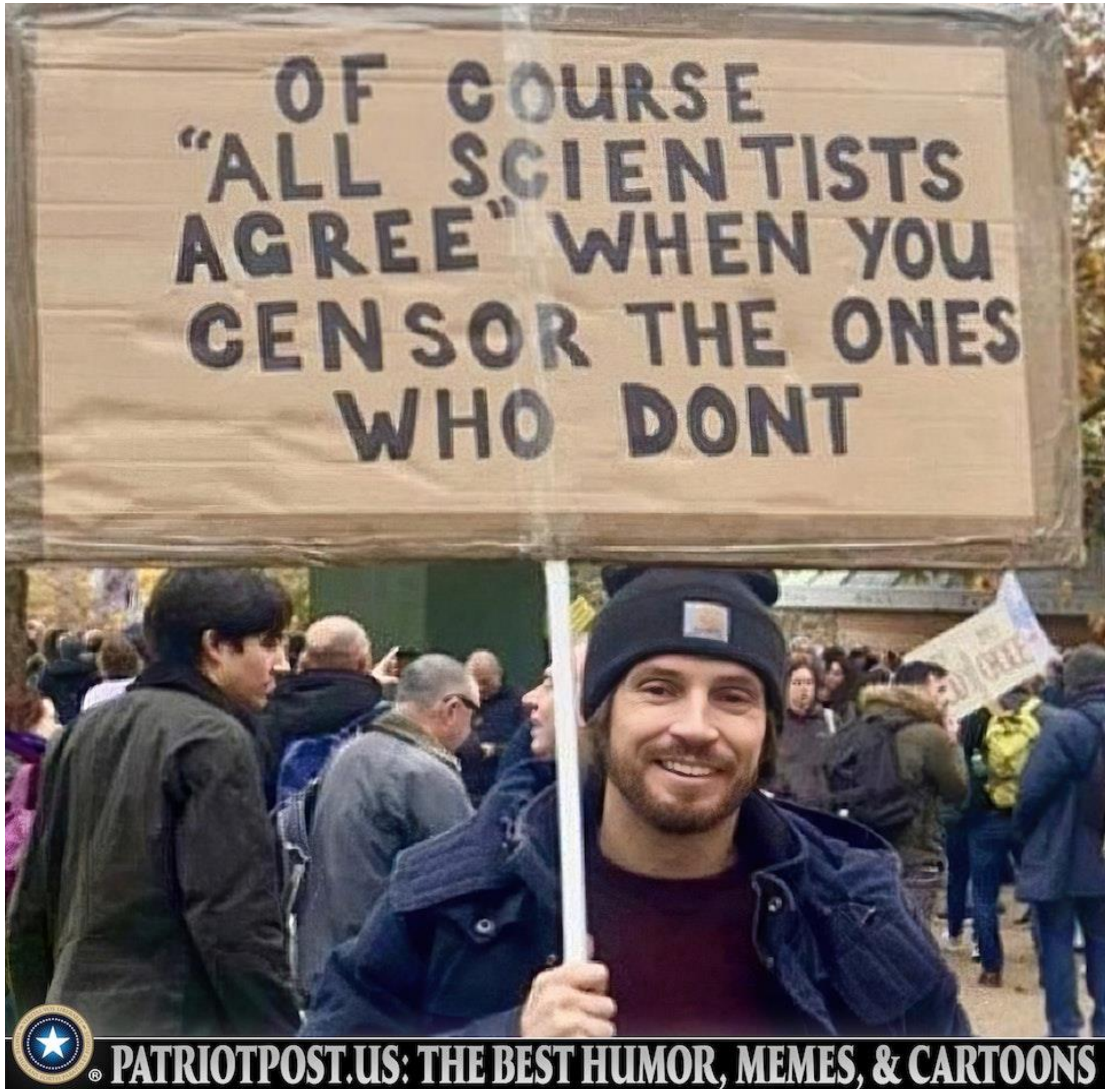
"Scientists still do not appear to understand sufficiently that all earth sciences must contribute evidence toward unveiling the state of our planet …. It is only by combing the information furnished by ***all the earth sciences*** that we can hope to determine 'truth' here….”

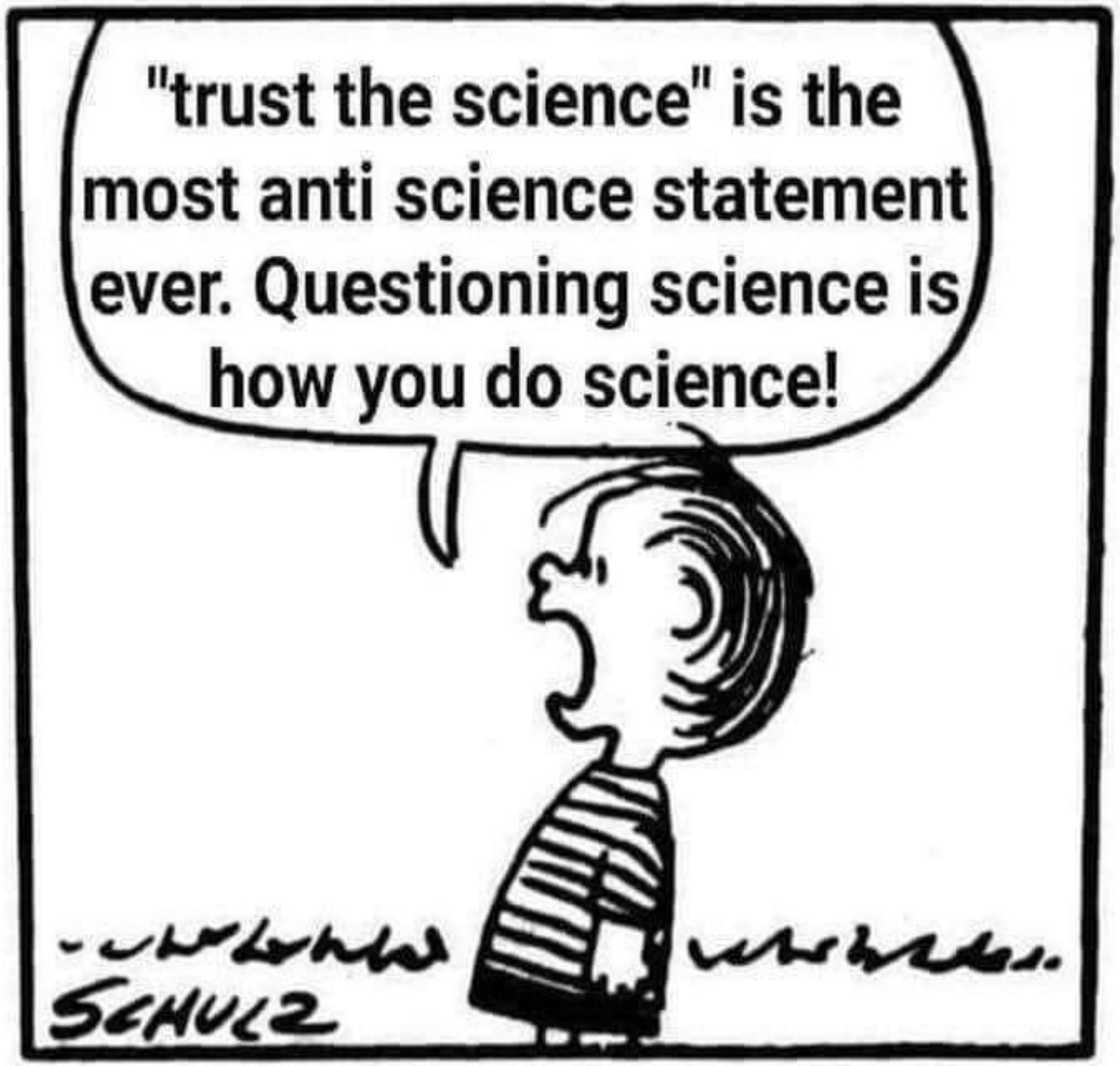
Alfred Wegener. *The Origins of Continents and Oceans* (4th edition, 1929)



http://www.ucmp.berkeley.edu/history/wegener.html

Postscript


OF COURSE "ALL SCIENTISTS AGREE" WHEN YOU CENSOR THE ONES WHO DONT
PATRIOTPOST.US: THE BEST HUMOR, MEMES, & CARTOONS


"trust the science" is the most anti science statement ever. Questioning science is how you do science!
SCHULZ

Thank You!