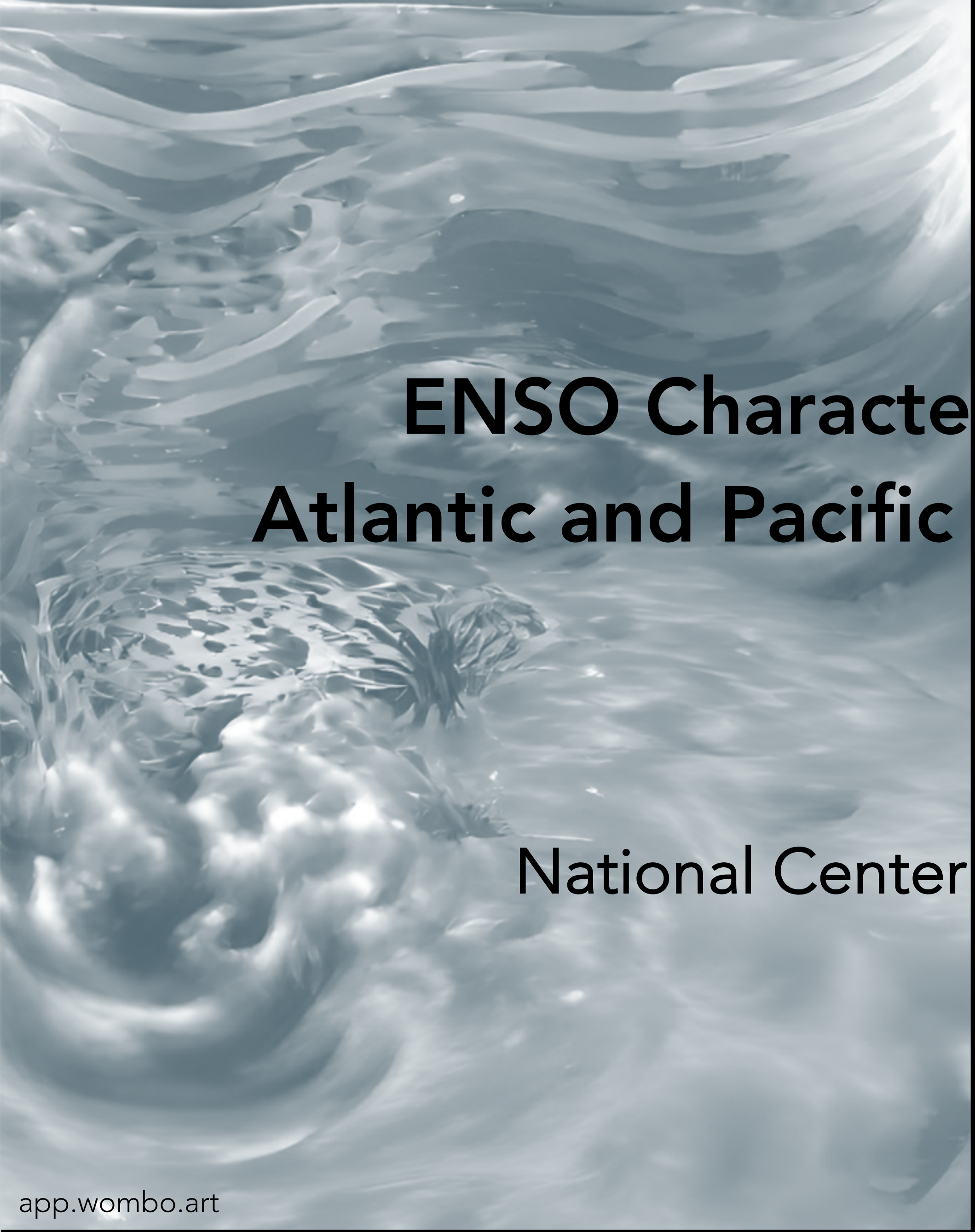

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ENSO Characteristics during Different States of the Atlantic and Pacific Meridional Overturning Circulations

Maria J. Molina, Aixue Hu, and Gerald Meehl
National Center for Atmospheric Research, Boulder, Colorado

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catalyst

The Atlantic meridional overturning circulation (AMOC) is a large-scale ocean circulation that redistributes heat from low to high latitudes (Hu et al. 2012).

Source: NASA/Goddard Space Flight Center

BRIEF COMMUNICATION
https://doi.org/10.1038/s41561-021-00699-z
nature geoscience

Current Atlantic Meridional Overturning Circulation weakest in last millennium

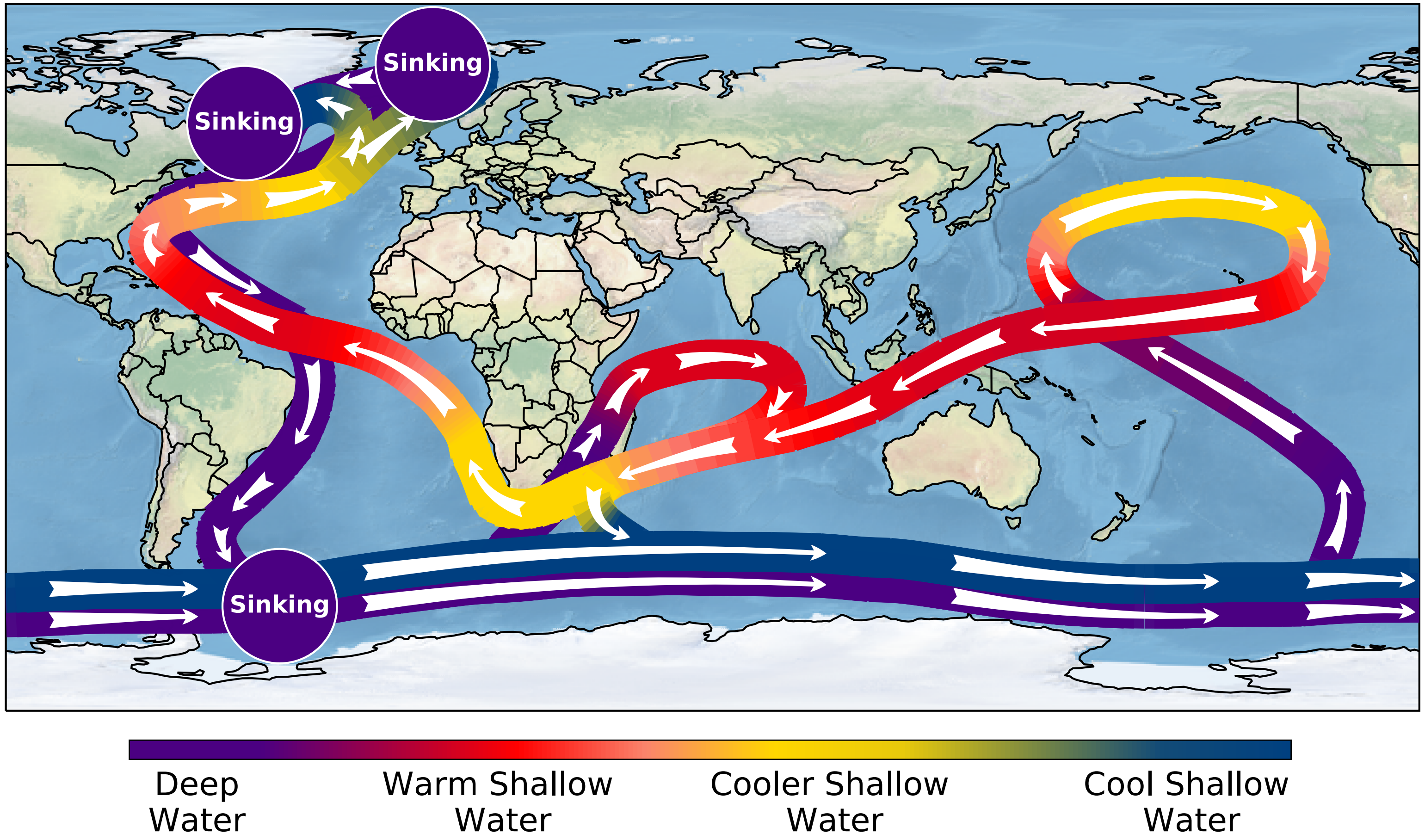
L. Caesar[1,2] ✉, G. D. McCarthy[1], D. J. R. Thornalley[3], N. Cahill[4] and S. Rahmstorf[2,5]

The Atlantic Meridional Overturning Circulation (AMOC)—one of Earth's major ocean circulation systems—redistributes heat on our planet and has a major impact on climate. Here, we compare a variety of published proxy records to reconstruct the evolution of the AMOC since about AD 400. A fairly consistent picture of the AMOC emerges: after a long and relatively stable period, there was an initial weakening starting in the nineteenth century, followed by a second, more rapid, decline in the mid-twentieth century, leading to the weakest state of the AMOC occurring in recent decades.

The Atlantic Meridional Overturning Circulation (AMOC) is a major mechanism for heat redistribution on our planet and an important factor in climate variability and change. The AMOC is a sensitive nonlinear system dependent on subtle thermohaline density differences in the ocean, and major AMOC transitions have been implicated, for example, in millennial climate events during the last glacial period[1]. There is evidence that the AMOC is slowing down in response to anthropogenic global warming[2]—as predicted by climate models—and that the AMOC is presently in its been related to the AMOC[9,10]. The records going the furthest back in time (AD 400) are taken from marine sediments (sortable-silt data[3], proxy records of subsurface ocean temperatures[3], $\delta^{18}O$ in benthic foraminifera[7], $\delta^{15}N$ of deep-sea gorgonian corals[6], relative abundance of certain planktic foraminifera (*Turborotalita quinqueloba*)[10]). The temperature-based AMOC index[5], however, is based on a Northern Hemisphere land-and-ocean temperature reconstruction that uses a range of terrestrial proxies, including, for example, tree rings and ice-core data[11]. Data taken from Greenland ice cores (the methanesulfonic acid concentration) furthermore provide an estimate for AMOC-related changes in productivity in the subpolar gyre region[9]. Most of these records extend into the modern era, for which additional AMOC proxies exist that are based on instrumental temperature records[2,8].

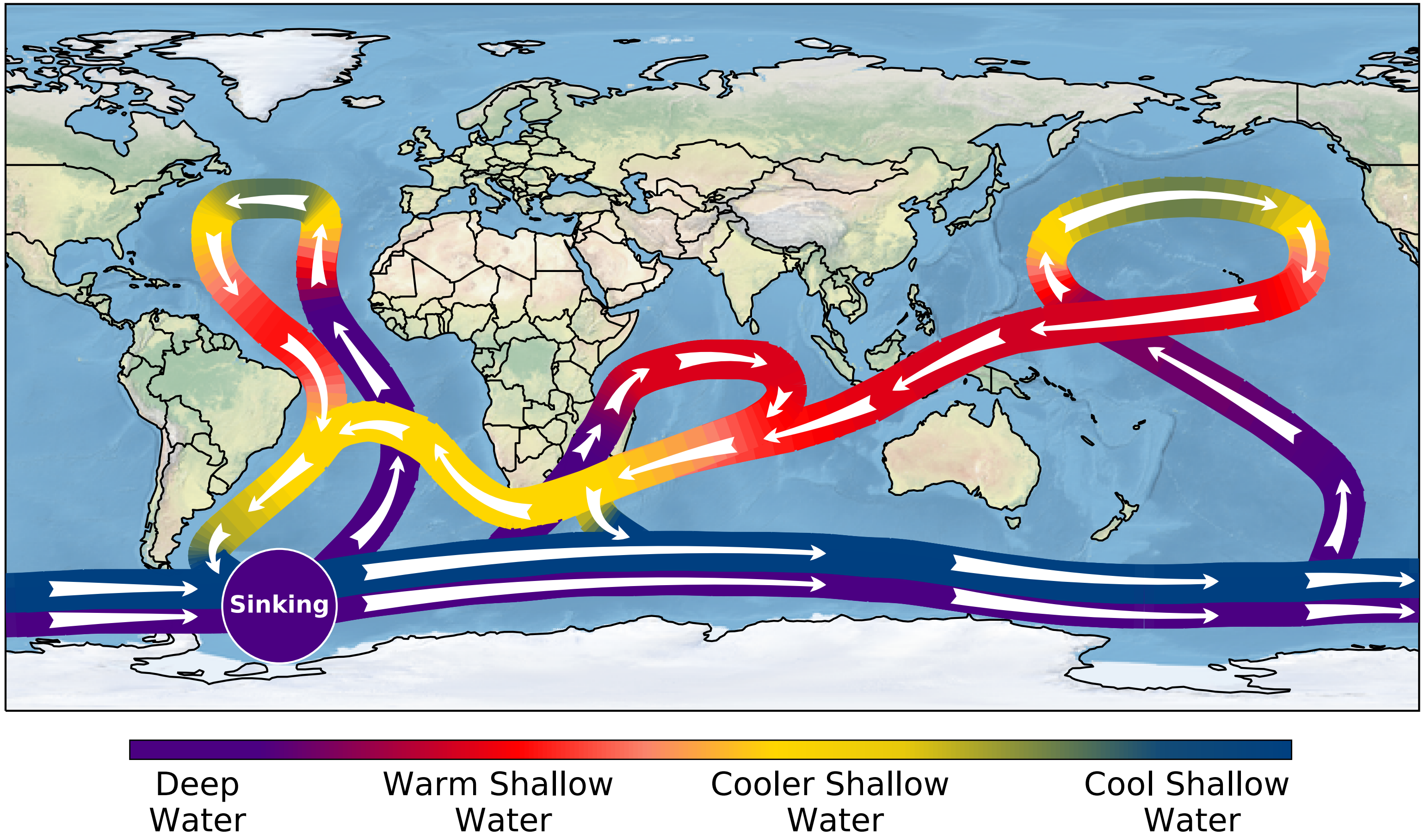
Despite the different locations, timescales and processes represented by these proxies, they provide a consistent picture of the AMOC evolution since about AD 400: before the nineteenth century, the AMOC was relatively stable. A decline in the AMOC, beginning during the nineteenth century, is evident in all the proxy records

A global circulation…



Hu, A., Meehl, G. A., Rosenbloom, N., Molina, M. J. and Strand, W. G., 2021. The influence of variability in meridional overturning on global ocean circulation. Journal of Climate, 34(18), pp.7697-7716.

…with global impacts.



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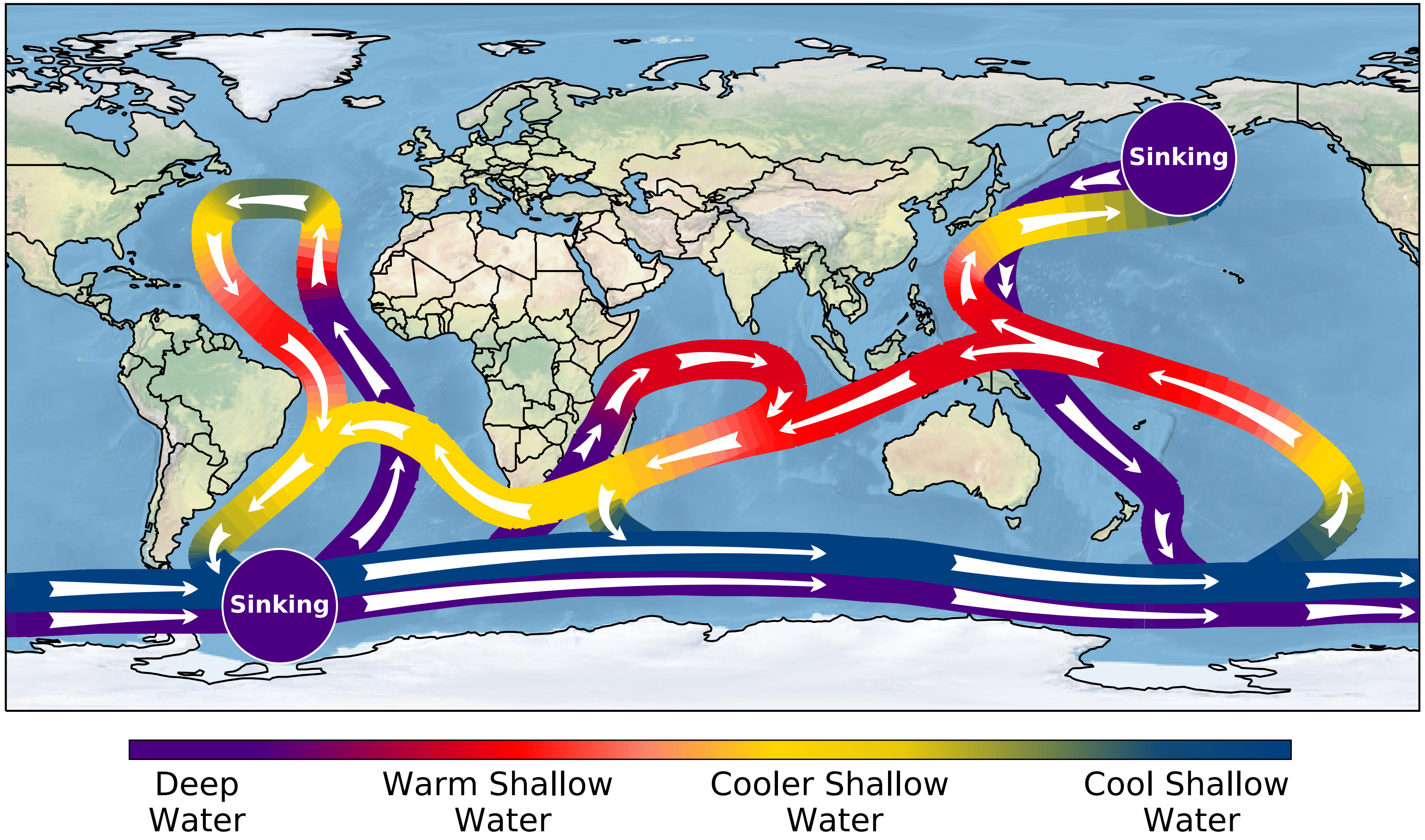

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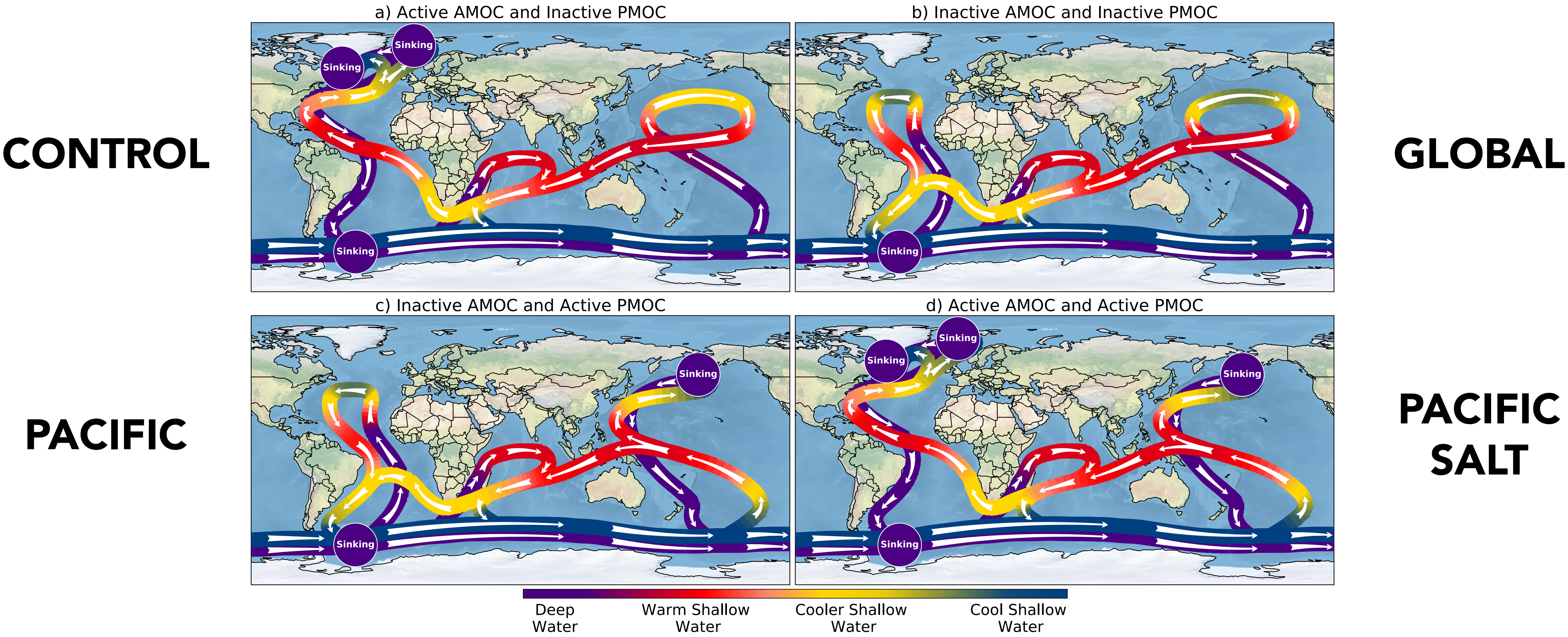
CESM1 experiments spanning 800 years were created.



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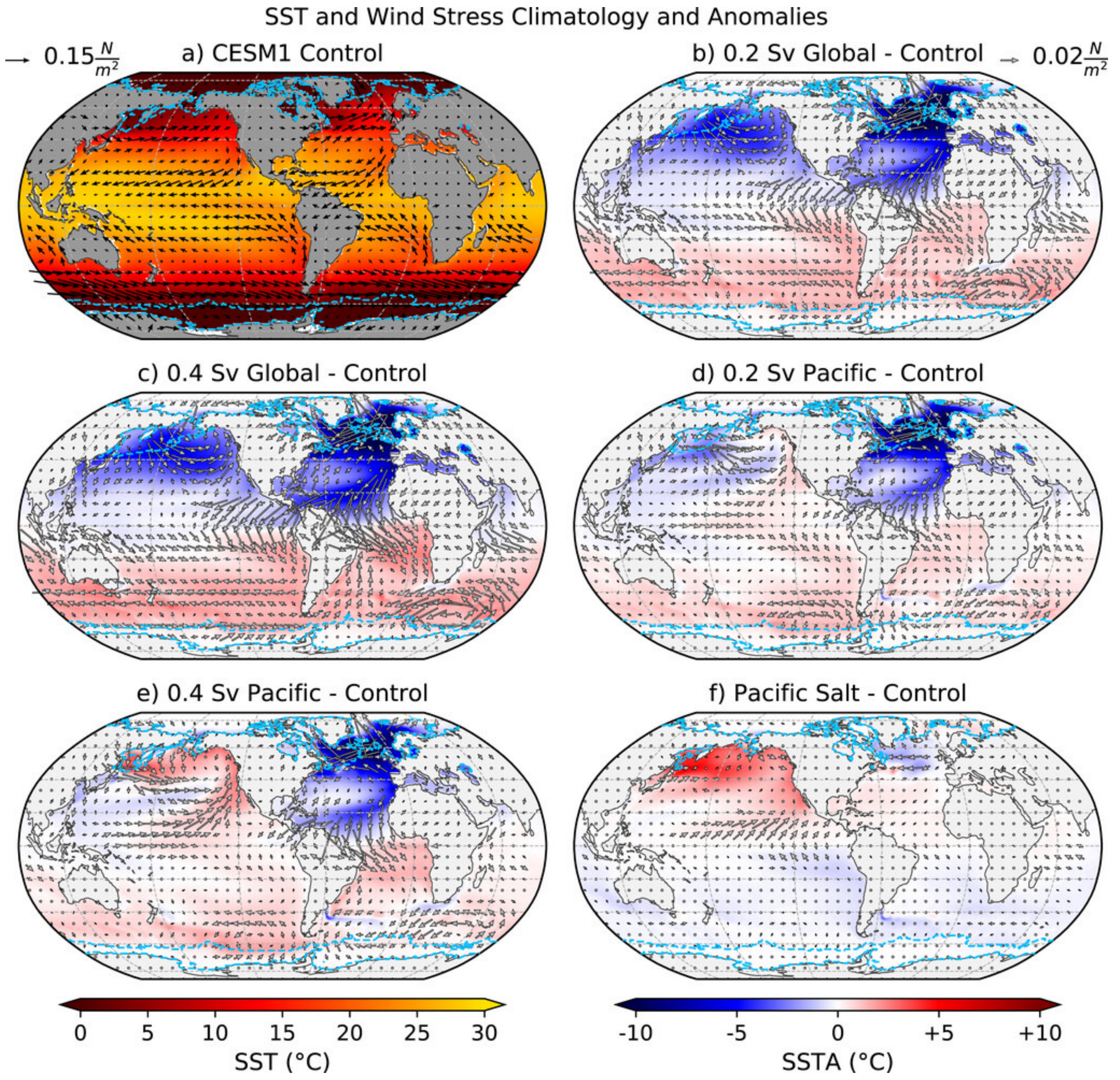
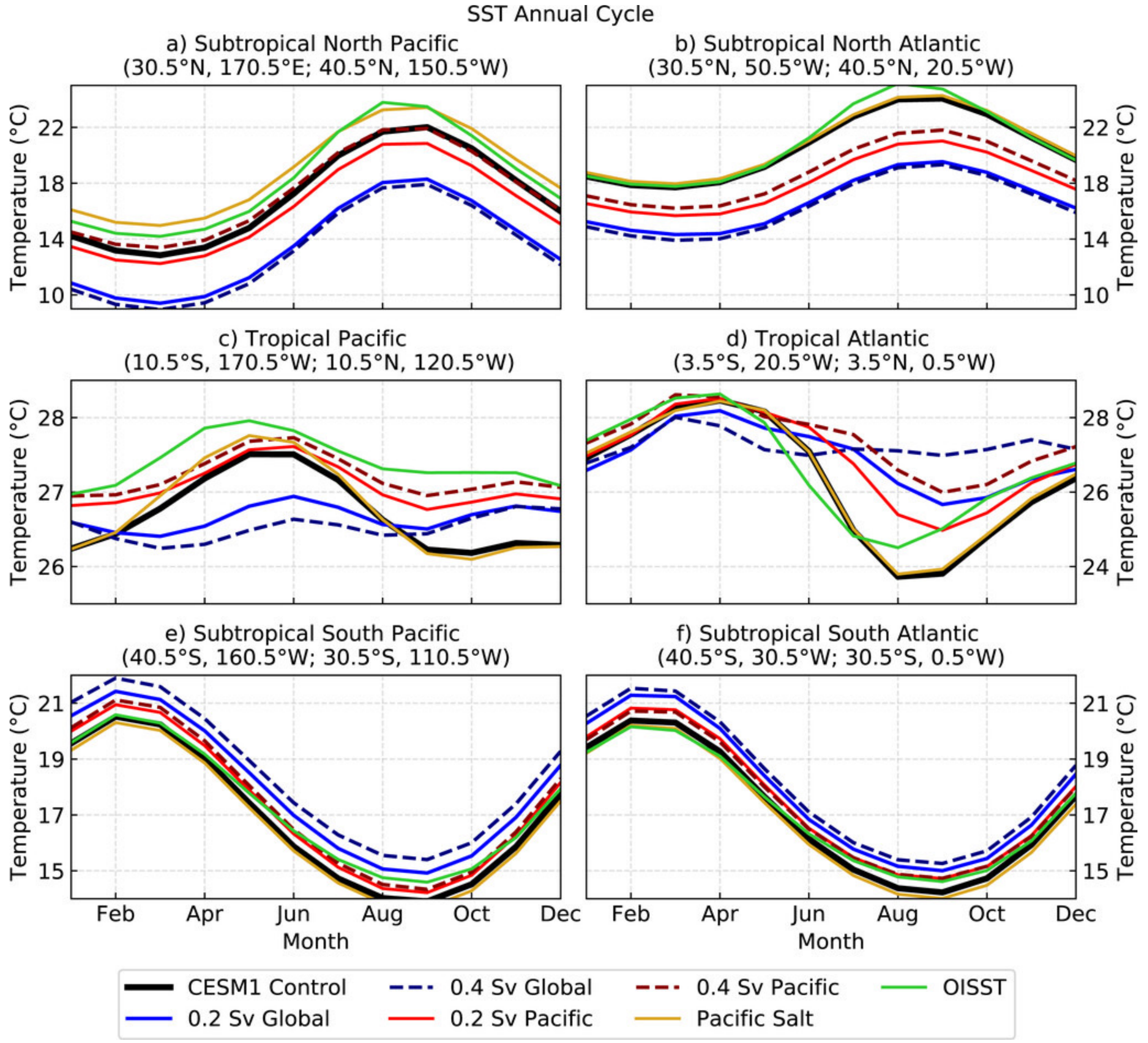


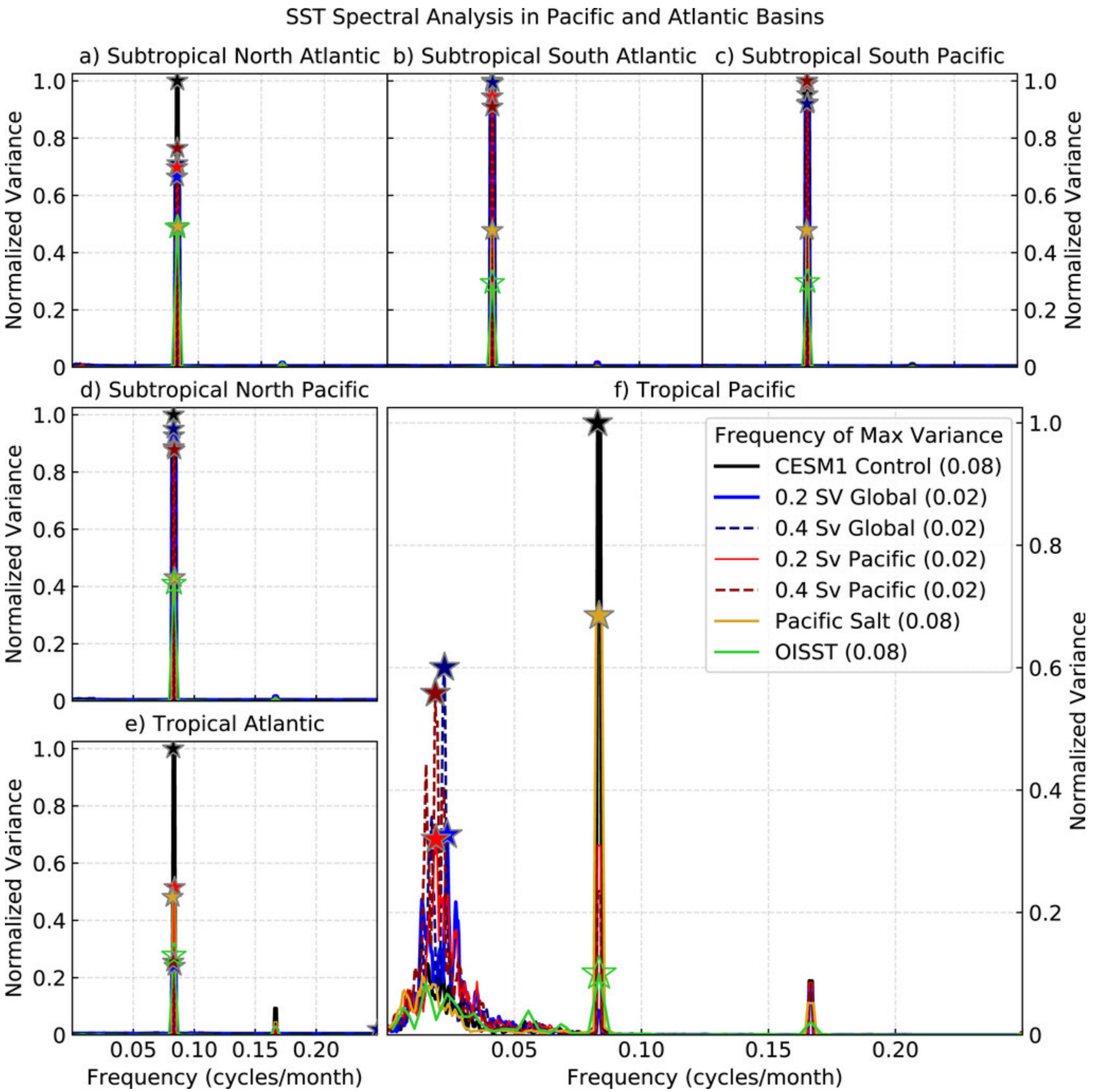
Molina et al. (2022).

- AMOC collapse without PMOC results in N. Pac./Atl. cooling.
- AMOC collapse with active PMOC reduces N. Pac./Atl. cooling.
- Active AMOC and PMOC results in N. Pac. warming.

AMOC and PMOC can **strongly influence** the SST annual cycle in the tropics.

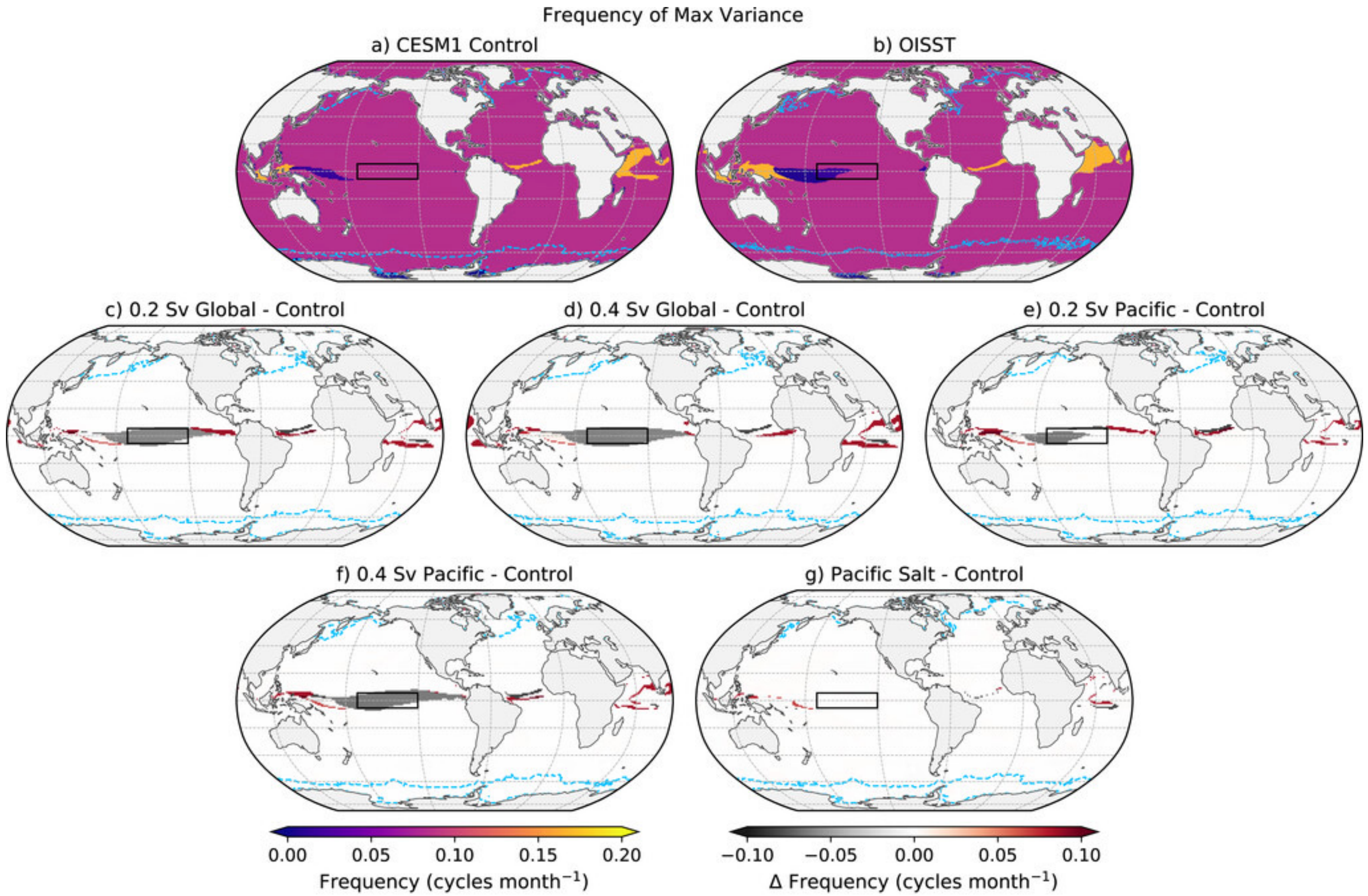


Molina et al. (2022).



Molina et al. (2022).

The dominant frequency in SST patterns sees **stark changes** across the tropical Pacific.



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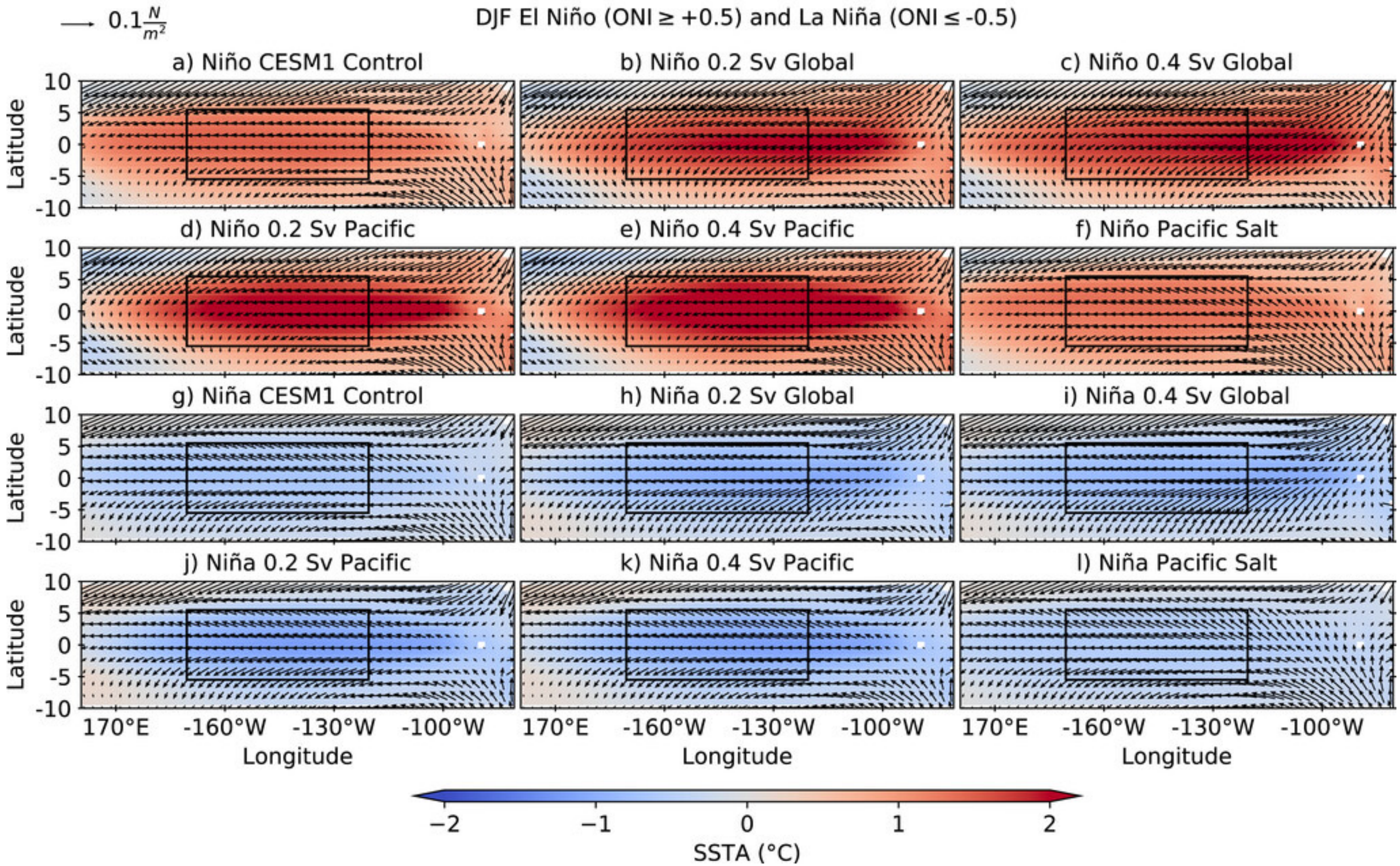

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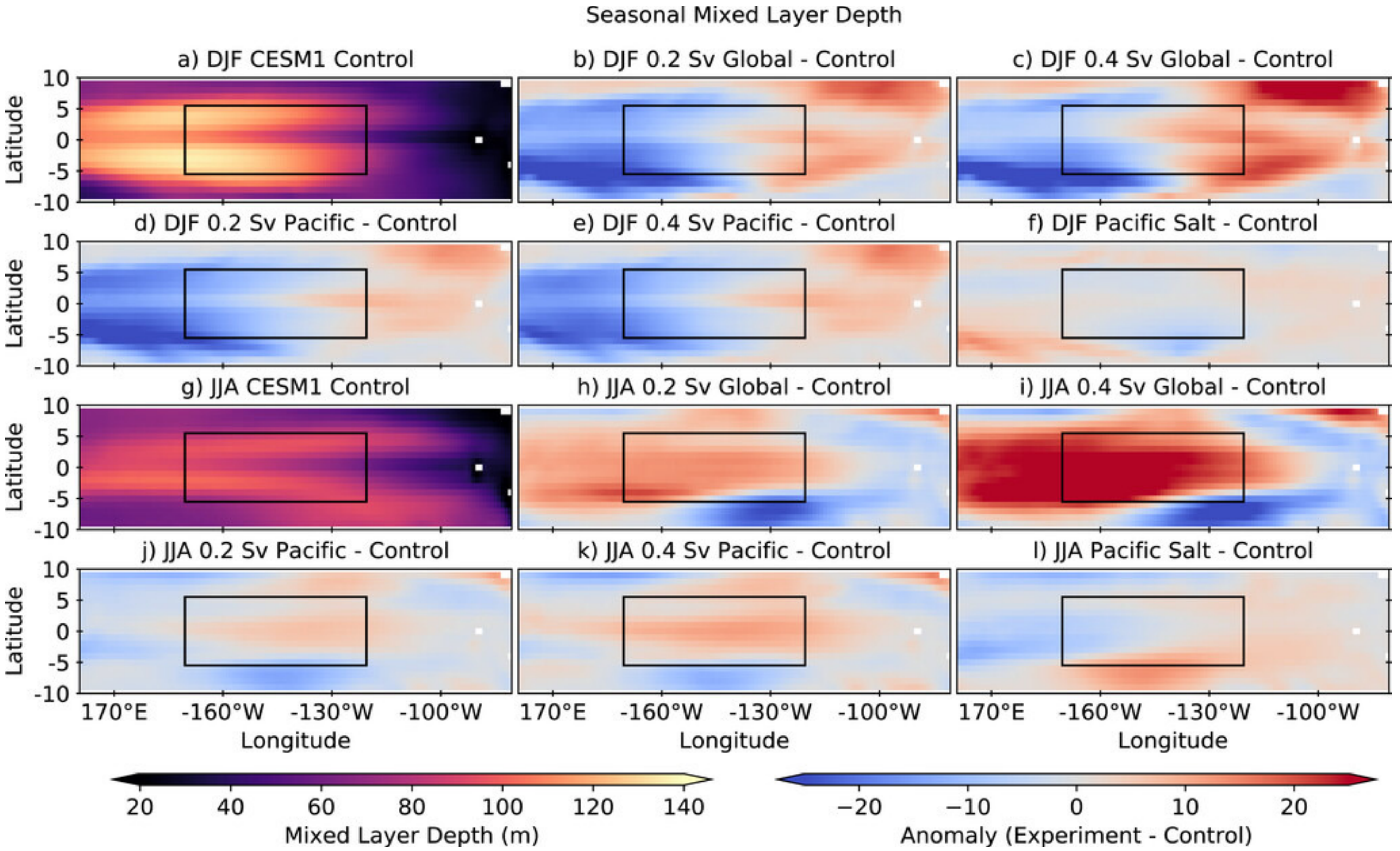
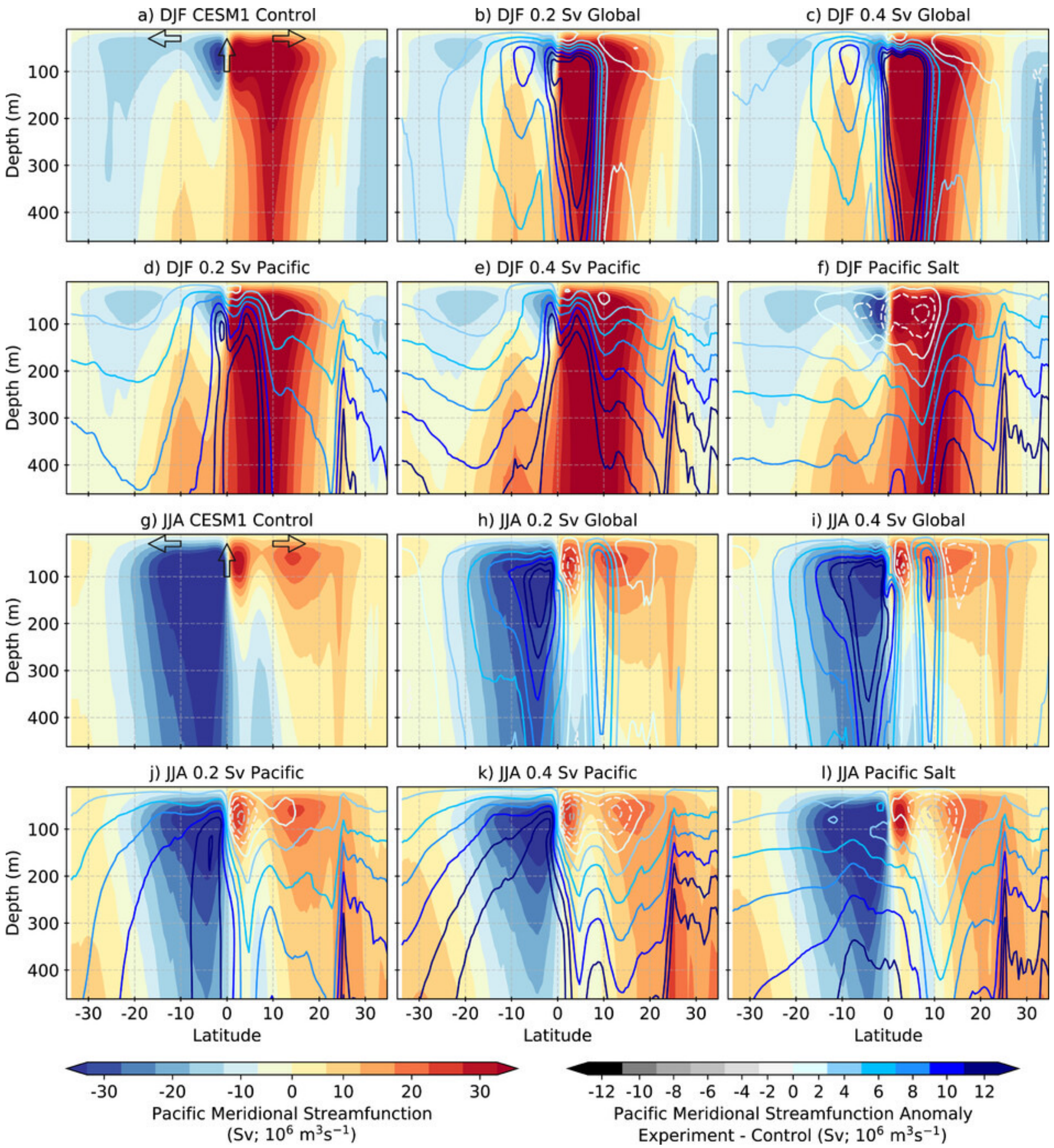


Molina et al. (2022).



Molina et al. (2022).

- Pacific Subtropical Cells (STCs) exhibit asymmetrical changes based on hemisphere.

Key Takeaways

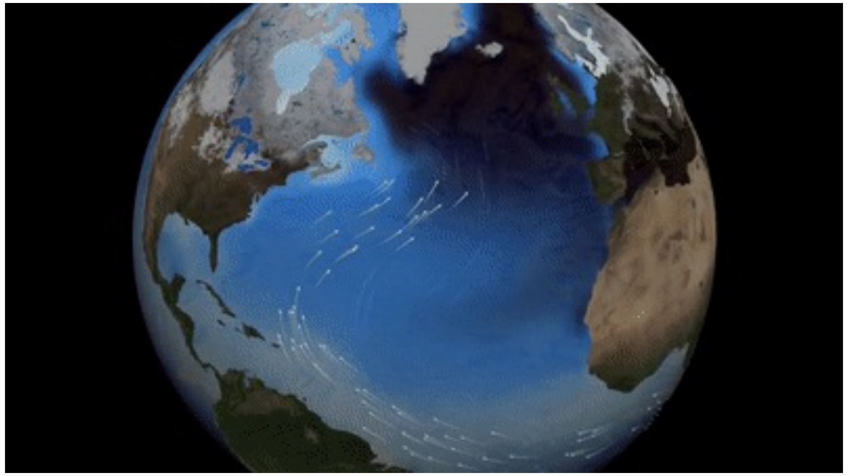
- ENSO amplitude increases as a result of an AMOC shutdown irrespective of PMOC development (within CESM1 experiments).
- Active overturning circulations in both the Atlantic and Pacific basins reduce ENSO amplitude.
- ENSO extends into the eastern equatorial Pacific during AMOC collapse.

Molina et al. (2022).

Future Work Could Address…

- Does this relationship persist in a changing climate?
- What role do other modes of variability play?
- Causal inference analysis to quantify

  influence of physical mechanisms.

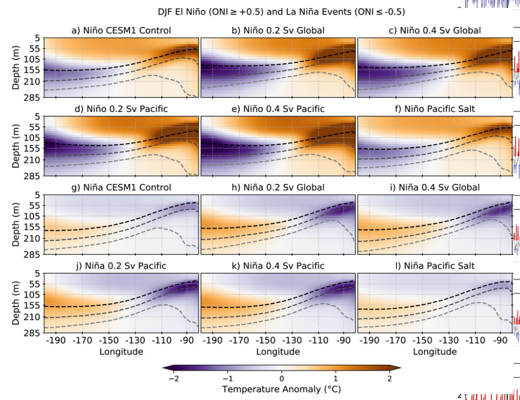


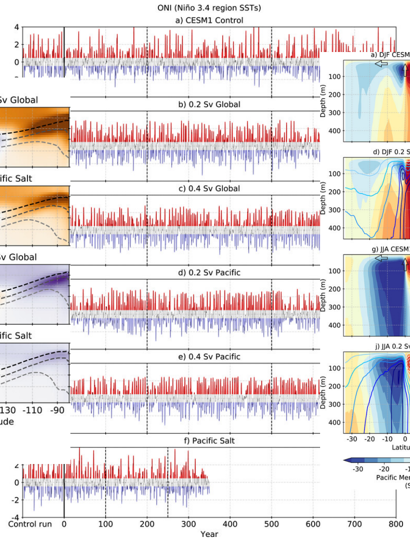
Source: NASA/Goddard Space Flight Center

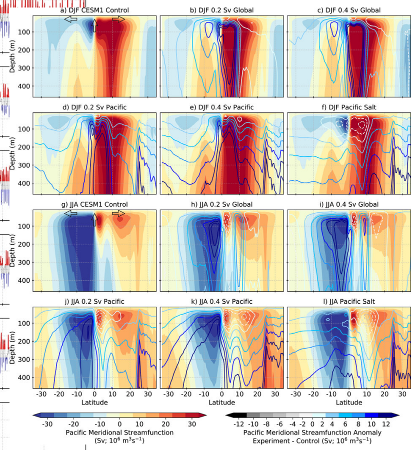
Molina et al. (2022).

For more information, please check out our paper in **Journal of Climate.**

Molina, M. J., Hu, A., & Meehl, G. A. (2022). Response of global SSTs and ENSO to the Atlantic and Pacific meridional overturning circulations. J. Cli., 35(1), 49-72.







Response of Global SSTs and ENSO to the Atlantic and Pacific Meridional Overturning Circulations

MARIA J. MOLINA,[a] AIXUE HU,[a] AND GERALD A. MEEHL[a]

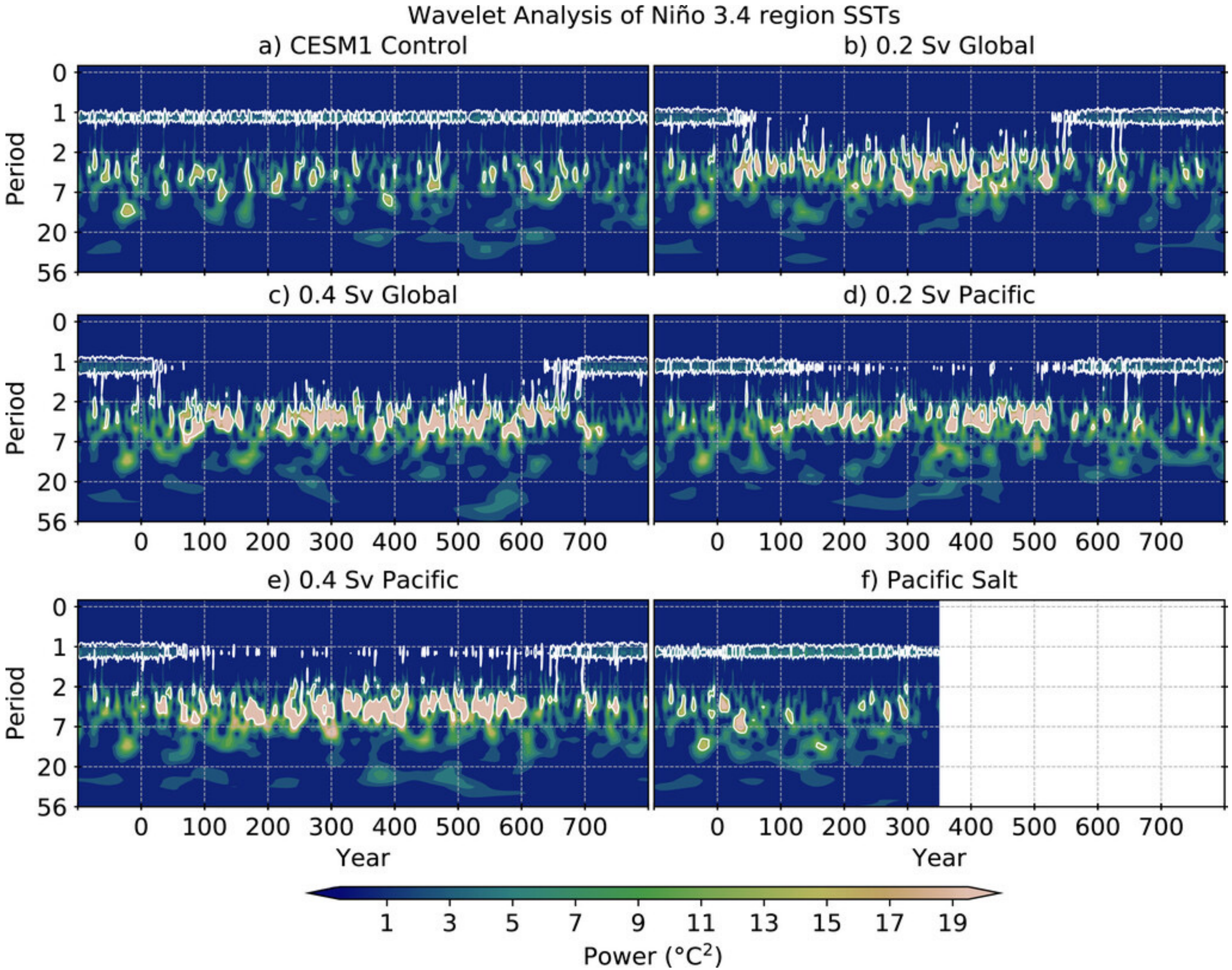
[a] *Climate and Global Dynamics Laboratory, National Center for Atmospheric Research, Boulder, Colorado*

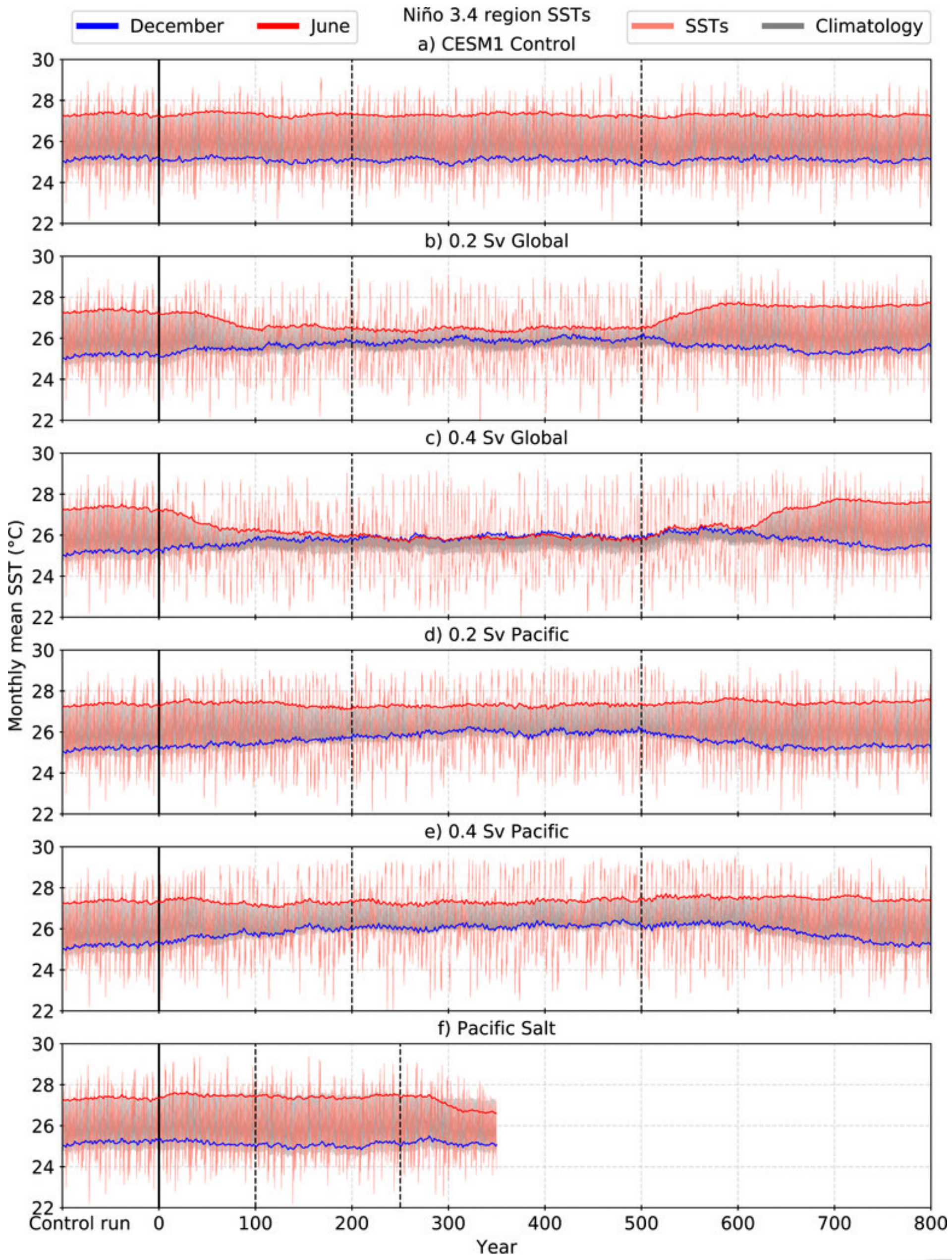
(Manuscript received 1 March 2021, in final form 22 September 2021)

ABSTRACT: Consequences from a slowdown or collapse of the Atlantic meridional overturning circulation (AMOC) could include modulations to El Niño–Southern Oscillation (ENSO) and development of the Pacific meridional overturning circulation (PMOC). Despite potential ramifications to the global climate, our understanding of the influence of various AMOC and PMOC states on ENSO and global sea surface temperatures (SSTs) remains limited. Five multicentennial, fully coupled model simulations created with the Community Earth System Model were used to explore the influence of AMOC and PMOC on global SSTs and ENSO. We found that the amplitude of annual cycle SSTs across the tropical Pacific decreases and ENSO amplitude increases as a result of an AMOC shutdown, irrespective of PMOC development. However, active deep overturning circulations in both the Atlantic and Pacific basins reduce ENSO amplitude and variance of monthly SSTs globally. The underlying physical reasons for changes to global SSTs and ENSO are also discussed, with the atmospheric and oceanic mechanisms that drive changes to ENSO amplitude differing based on PMOC state. These results suggest that if climate simulations projecting AMOC weakening are realized, compounding climate impacts could occur given the far-reaching ENSO teleconnections to extreme weather and climate events. More broadly, these results provide us with insight into past geologic era climate states, when PMOC was active.

SIGNIFICANCE STATEMENT: The global-scale ocean circulation named the Atlantic meridional overturning circulation (AMOC) could be slowing due to climate change. Studies suggest that a slowdown of AMOC could trigger the formation of a Pacific counterpart, which would transport upper-ocean water into the North Pacific that is warmer and saltier than present day. Using several century-scale, fully coupled climate model experiments, our study shows that different states of these circulations can dramatically alter Earth's climate and ocean temperatures, contributing to our understanding of potential future and past geological era climates. Importantly, we show that an AMOC slowdown could increase the strength of El Niño–Southern Oscillation, whether a Pacific meridional overturning circulation develops or not, which could amplify climate extremes via tropical–extratropical teleconnections.

KEYWORDS: Meridional overturning circulation; ENSO; Tropical variability


Wavelet Analysis of Niño 3.4 region SSTs
a) CESM1 Control
b) 0.2 Sv Global
c) 0.4 Sv Global
d) 0.2 Sv Pacific
e) 0.4 Sv Pacific
f) Pacific Salt
Period
0
1
2
7
20
56
0 100 200 300 400 500 600 700
Year
1 3 5 7 9 11 13 15 17 19
Power (°C2)


Niño 3.4 region SSTs
a) CESM1 Control
December
June
SSTs
Climatology
b) 0.2 Sv Global
c) 0.4 Sv Global
d) 0.2 Sv Pacific
e) 0.4 Sv Pacific
f) Pacific Salt
Monthly mean SST (°C)
Control run
0
100
200
300
400
500
600
700
800
Year
22
24
26
28
30