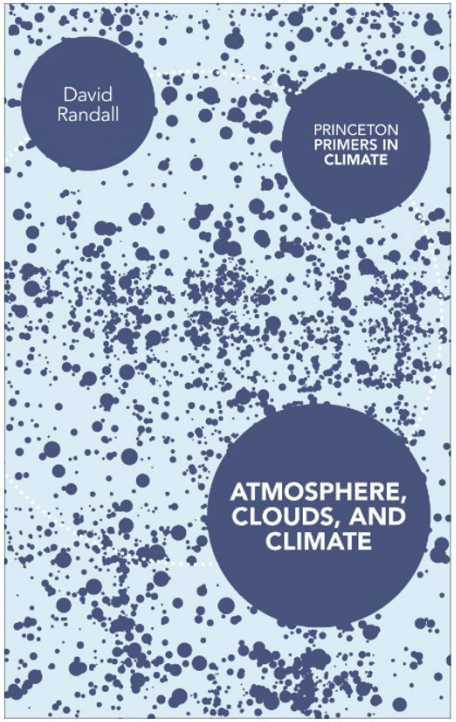
Atmosphere, Clouds, and Climate: Water Planet & Predictability

AOSC 680

Ross Salawitch

Class Web Sites:

http://www2.atmos.umd.edu/~rjs/class/fall2024
https://umd.instructure.com/courses/1367293



Lecture 13

17 October 2024

What To Do About The “Hot Models”

nature

COMMENT | 04 May 2022

Climate simulations: recognize the ‘hot model’ problem

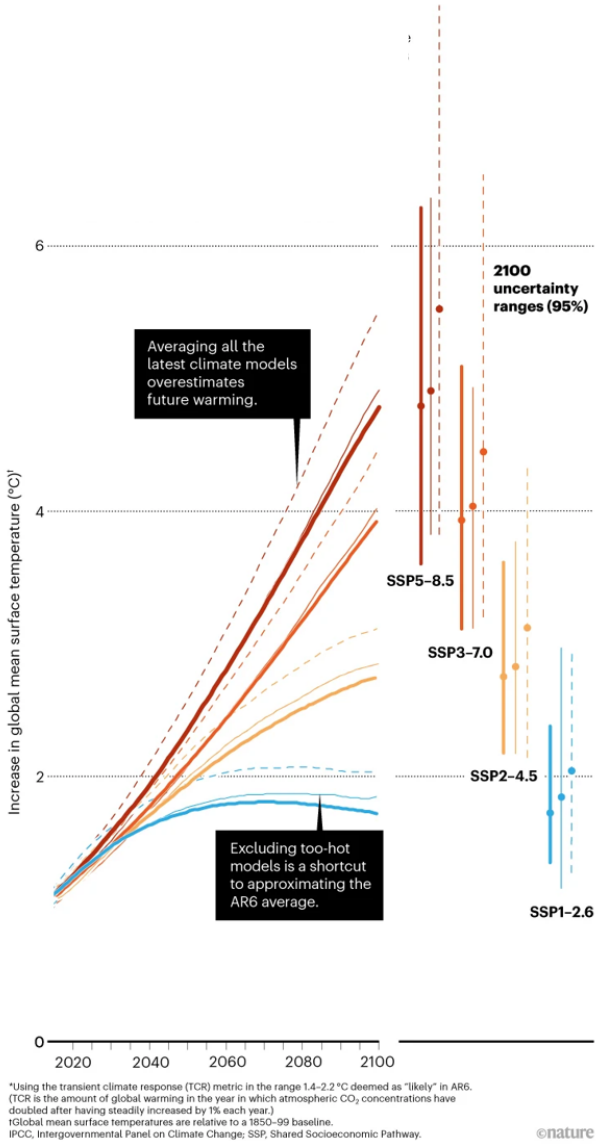
The sixth and latest IPCC assessment weights climate models according to how well they reproduce other evidence. Now the rest of the community should do the same.

Zeke Hausfather, Kate Marvel, Gavin A. Schmidt, John W. Nielsen-Gammon & Mark Zelinka

CLIMATE MODELS: CHOICE MATTERS

The IPCC’s Sixth Assessment Report (AR6) assessed dozens of computer models to project global temperature change (four scenarios shown). Some of these projections were ‘too hot’ when compared with other lines of evidence for climate warming in response to carbon dioxideemissions[8]. Researchers using all these models without the AR6 statistical adjustments could end up overestimating future temperature change.

– – Mean of all models
—— Limited range of models, no ‘too hot’ ones*
▬▬ Best estimate of warming as assessed in AR6



https://www.nature.com/articles/d41586-022-01192-2

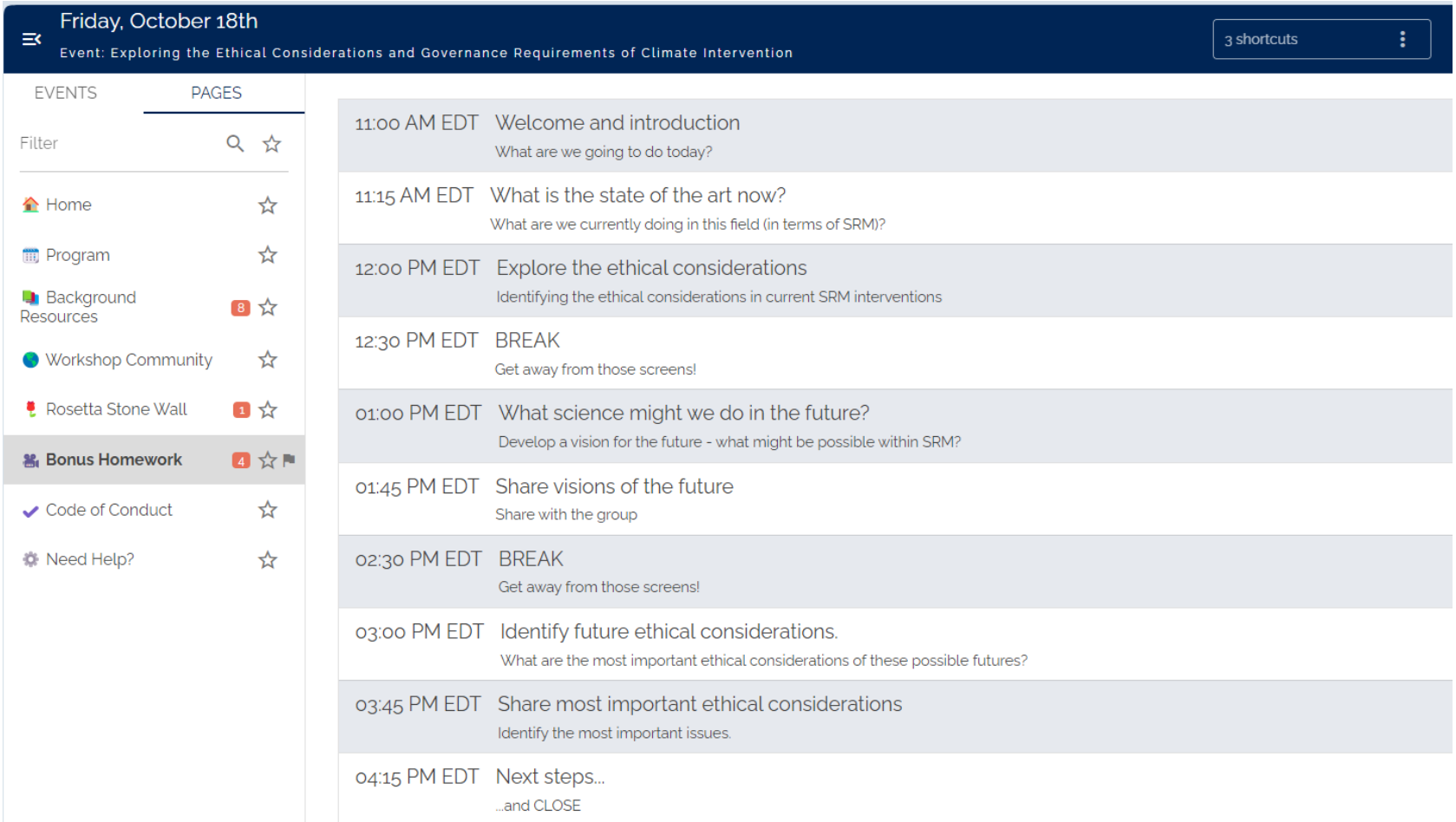
Announcement 3:

Students Welcome To Listen In On Meeting Entitled

Exploring The Ethical Considerations and Governance Requirements of Climate Intervention

Friday, 18 Oct (tomorrow)

11 am to 4:15 pm, ATL 3425



Hadley Walker Circulation

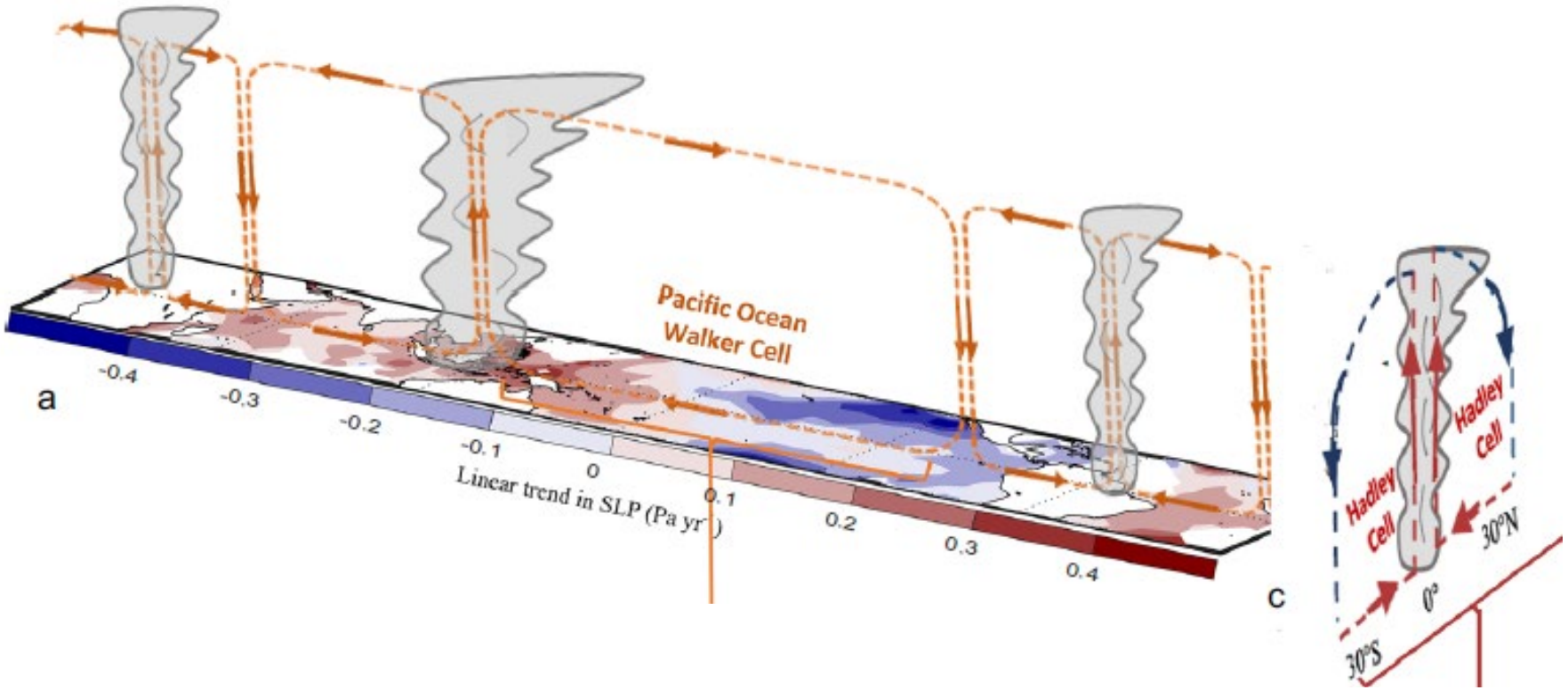


Fig. 1 Schematic representations of the Walker and Hadley circulations

Chand et al., 2023: https://link.springer.com/article/10.1007/s10584-022-03467-z

Hadley Walker Circulation

Over the past decades, results from observations and model simulations indicate that the Hadley circulation has widened (i.e. undergone poleward expansion) considerably in both hemispheres (Hu et al. 2018; Power et al. 2021). The expansion of the Hadley circulation is sometimes referred to as an expansion of the tropics. Climate model experiments, such as those from the World Climate Research Programme's Coupled Model Intercomparison Project (WCRP-CMIP), further indicate that the widening trend is likely to continue as the concentration of greenhouse gases further increases in the atmosphere, but there is no general agreement on the changes in the intensity of the Hadley circulation (Hu et al. 2018; Power et al. 2021). A study by Grise et al. (2019) provides a comprehensive review of past studies on tropical expansion and consolidates discrepancies noted in the literature using updated information and consistent analysis.

Such changes in the mean state of the Hadley circulation can have huge implications for the severe climatic events in the Pacific. For example, tropical cyclone formation regions, as well as the location of tropical cyclone maximum intensity, are likely to shift poleward due to tropical expansion (Sharmila and Walsh 2018). Consequently, this may expose several higher-latitude island nations to catastrophic winds and storm surge events in the future.

Chand et al., 2023: https://link.springer.com/article/10.1007/s10584-022-03467-z

Hadley Walker Circulation

2.2 The Walker circulation

The Walker circulation is the east–west component of the tropical circulation, which is driven by the sea-level pressure gradient force (and associated sea surface temperature gradient) between the western and the eastern Pacific. The main Walker cell is in the Pacific Ocean (hereafter referred to as the Pacific Walker cell) with ascending air normally over the maritime continent (i.e. the region between the Indian and Pacific Oceans including the archipelagos of Indonesia, Borneo, New Guinea, the Philippine Islands, the Malay Peninsula, and the surrounding seas) and descending air in the eastern Pacific. Two secondary cells are located over South America and Africa with compensating subsidence over the Atlantic Ocean and the Indian Ocean, respectively.

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Hadley Walker Circulation

2.2 The Walker circulation

Studies have shown that during the twentieth century, the Walker circulation weakened due to increasing greenhouse warming (e.g. Vecchi et al. (2006); Power and Kociuba (2011); Kociuba and Power (2015)). However, since the early 1980s, the Walker circulation—like the Hadley circulation—strengthened (Kociuba and Power 2015; Power et al. 2021). While some studies have attributed this strengthening to anthropogenic warming (e.g. Seager et al. (2019)), others argue that such changes are short-term and are largely due to internal climate variability (England et al. 2014; Chung et al. 2019; Kociuba and Power 2015). Previous and current generations of climate models generally simulate a weaker Walker circulation over the coming century due to increasing greenhouse warming (e.g. Power and Kociuba (2011); Kociuba and Power (2015); Chung et al. (2019); Power et al. (2021)), as well as a shift eastward (Bayr et al. 2014). Under these circumstances, expectations are for enhanced convective activity, such as tropical cyclones, to occur farther east into the central Pacific (such as near Hawaii) and suppressed activity elsewhere in the Pacific (e.g. Murakami et al. (2013); Chand et al. (2017)). However, given the inability of climate models to simulate the magnitude of the recent strengthening, confidence in the projected weakening is low (e.g. Kociuba and Power (2015)).

Chand et al., 2023: https://link.springer.com/article/10.1007/s10584-022-03467-z

Tropical Pacific Trends

Colder Eastern Equatorial Pacific and Stronger Walker Circulation in the Early 21st Century: Separating the Forced Response to Global Warming From Natural Variability

Ulla K. Heede, Alexey V. Fedorov

First published: 20 January 2023 | https://doi.org/10.1029/2022GL101020 | Citations: 4

Abstract

Since the early 1990s the Pacific Walker circulation shows a multi-decadal strengthening, which contradicts future model projections. Whether this trend, evident in many climate indices especially before the 2015 El Niño, reflects the coupled ocean-atmosphere response to global warming or the negative phase of the Pacific Decadal Oscillation (PDO) remains debated. Here we show that sea surface temperature trends during 1980–2020 are dominated by three signals: a spatially uniform warming trend, a negative PDO pattern, and a Northern Hemisphere-Indo-West Pacific warming pattern. The latter pattern, which closely resembles the transient ocean thermostat-like response to global warming emerging in a subset of CMIP6 models, shows cooling in the central-eastern equatorial Pacific but warming in the western Pacific and tropical Indian Ocean. Together with the PDO, this pattern drives the Walker circulation strengthening in the equatorial band. Historical simulations appear to underestimate this pattern, contributing to the models' inability to replicate the Walker cell strengthening.

Key Points

- A multi-decadal strengthening of the Pacific Walker cell is observed in a wide range of indices, especially after 1990
- A Northern Hemisphere - Indo West Pacific warming sea surface temperature pattern, which differs from the Pacific Decadal Oscillation, is evident since 1980
- This pattern resembles a forced response to abrupt CO_2 forcing, emerging in a subset of climate models, and contributes to the Walker circulation strenthening

Heede and Fedorov, 2023: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2022GL101020

Tropical Pacific Trends

Together, these findings suggest that the current trends may reflect a transient ocean-thermostat-like (OT) forced response to global warming, in which the western EP and the Indian Ocean warm faster than the central-eastern Pacific, strengthening the Walker circulation.

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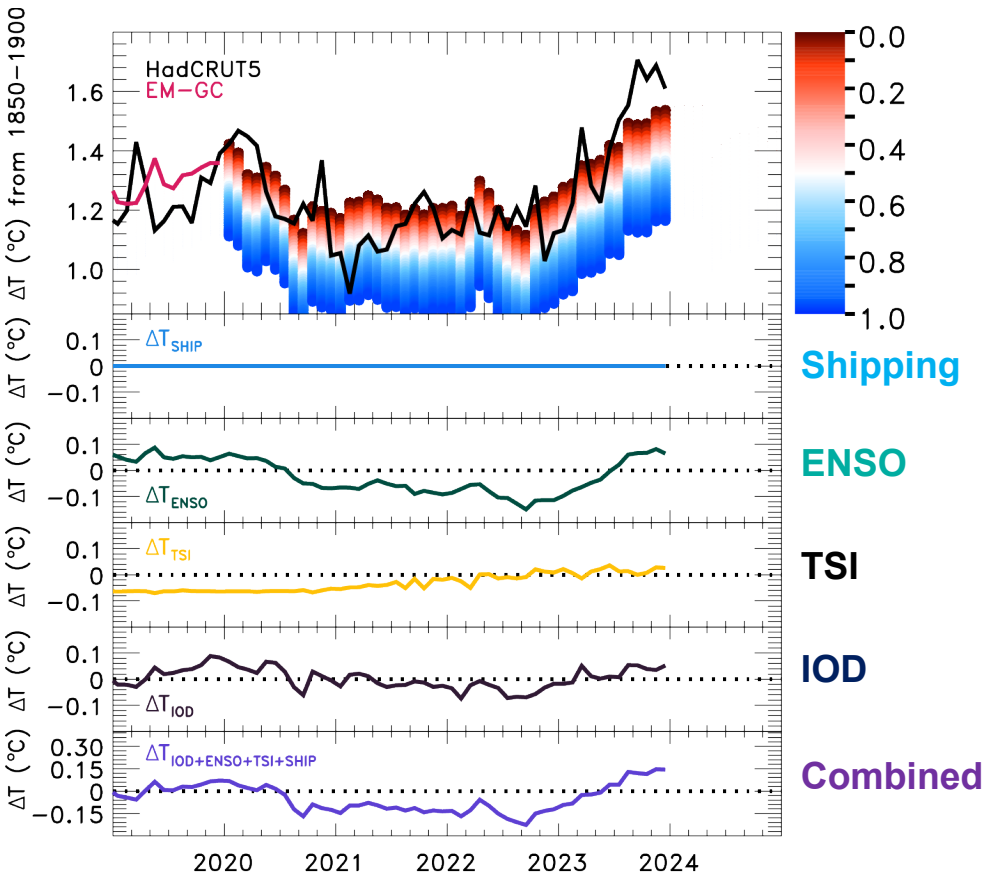
Modeling Recent GMST

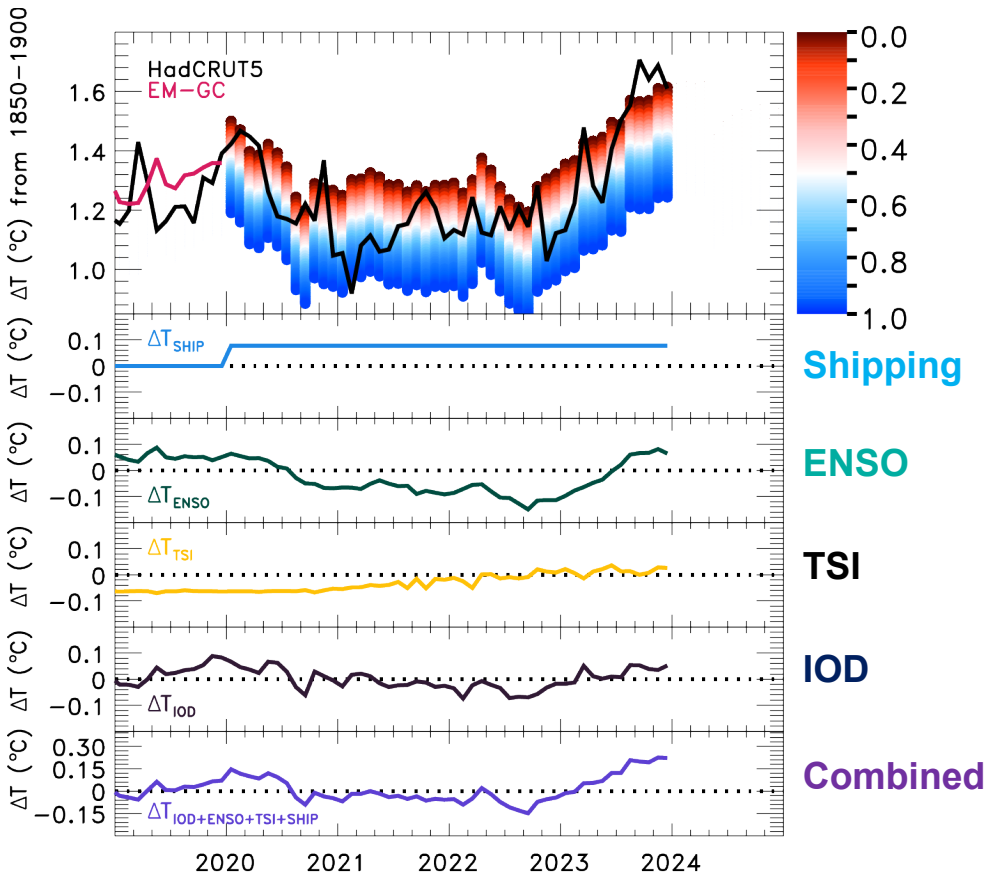


No change in RF from IMO regulations

IMO: International Maritime Organization
IMO regulations reduced global SO_2 emissions from shipping by ~70% from 2019 to 2020
0.1 Wm^{-2} case is consistent with most literature best estimates for the change in RF_{AER} from shipping
0.2 Wm^{-2} is consistent with literature upper limit estimates for the change in RF_{AER} from shipping

Farago *et al*. 2024, manuscript in preparation

Modeling Recent GMST



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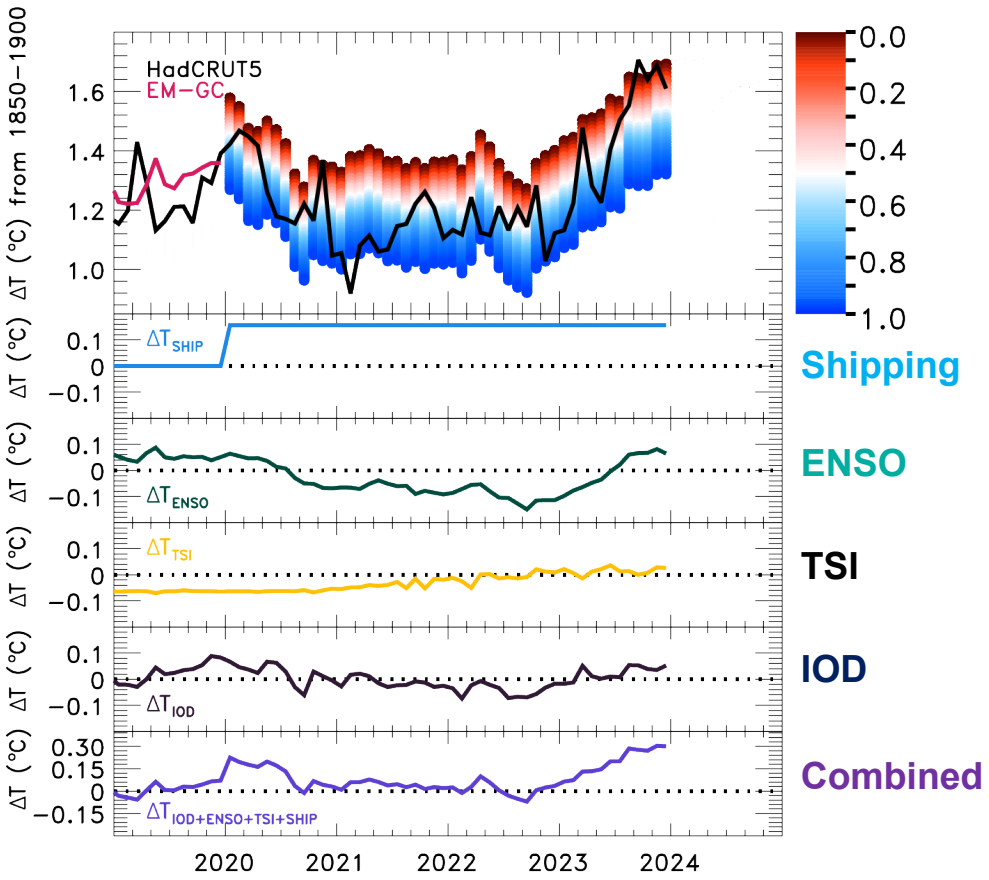

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