Cornell University

Modeling 2020 regulatory changes in international shipping emissions helps explain 2023 anomalous warming

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CESM Workshop 2024
June 12th, Boulder

The pretext: changes in IMO regulations

IMO2020 fuel oil sulphur limit - cleaner air, healthier planet

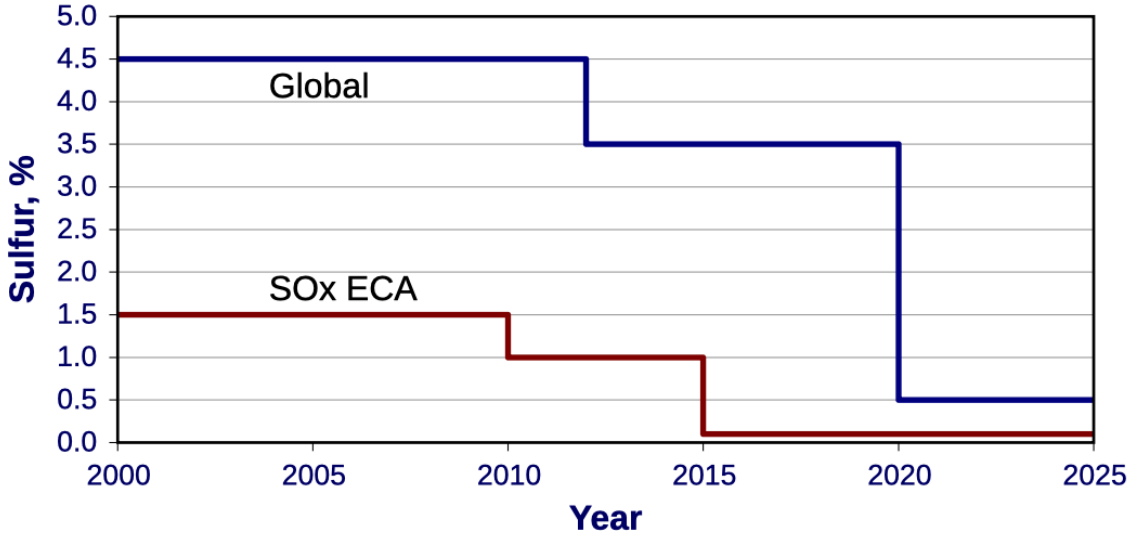


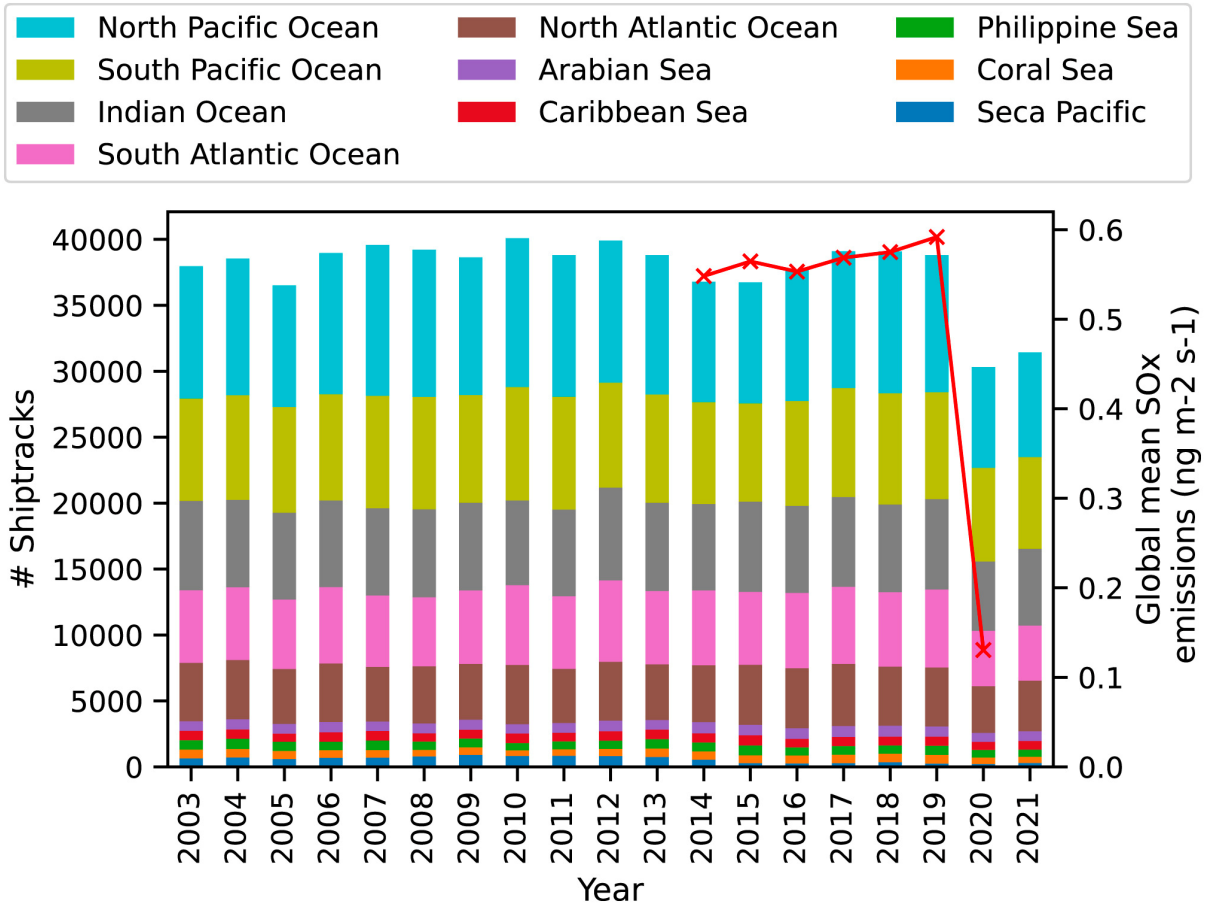
Figure from MARPOL Annex VI *Fuel Sulphur Limits*

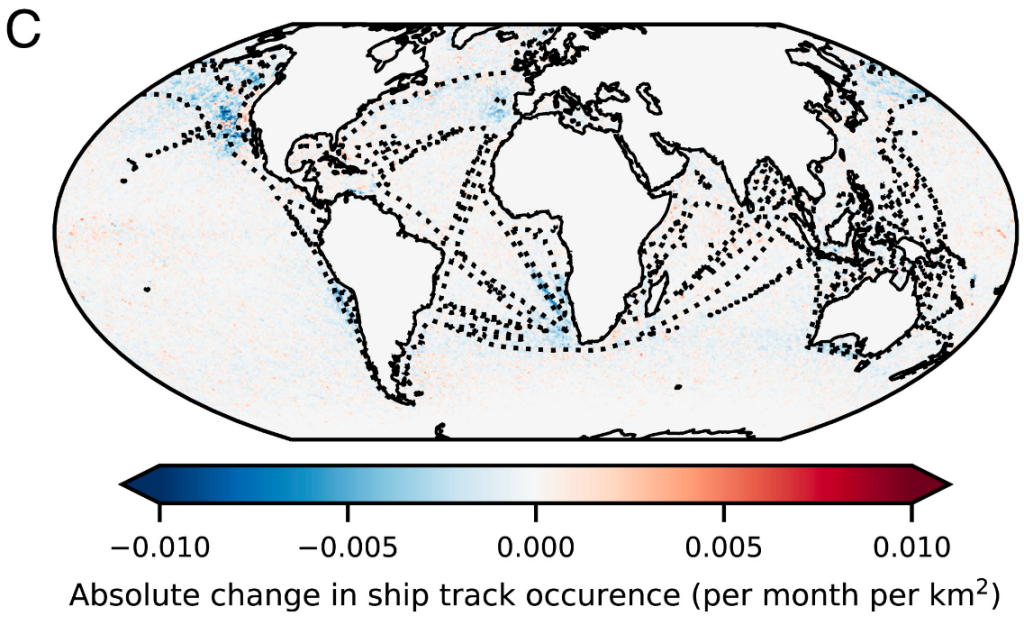
Already estimated in Partanen et al. (2013)

- decreased ERF from -0.43 to −0.06 W/m^2
- 96% deaths avoided per year

What are the open questions?

- Can we detect compliance to the regulations by observing changes in ship tracks?





Watson-Parris et al. (2022, PNAS)

What are the open questions?

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- Can we quantify what global effect they would have on RF?
  - most studies agree on O(0.1 W/m^2)

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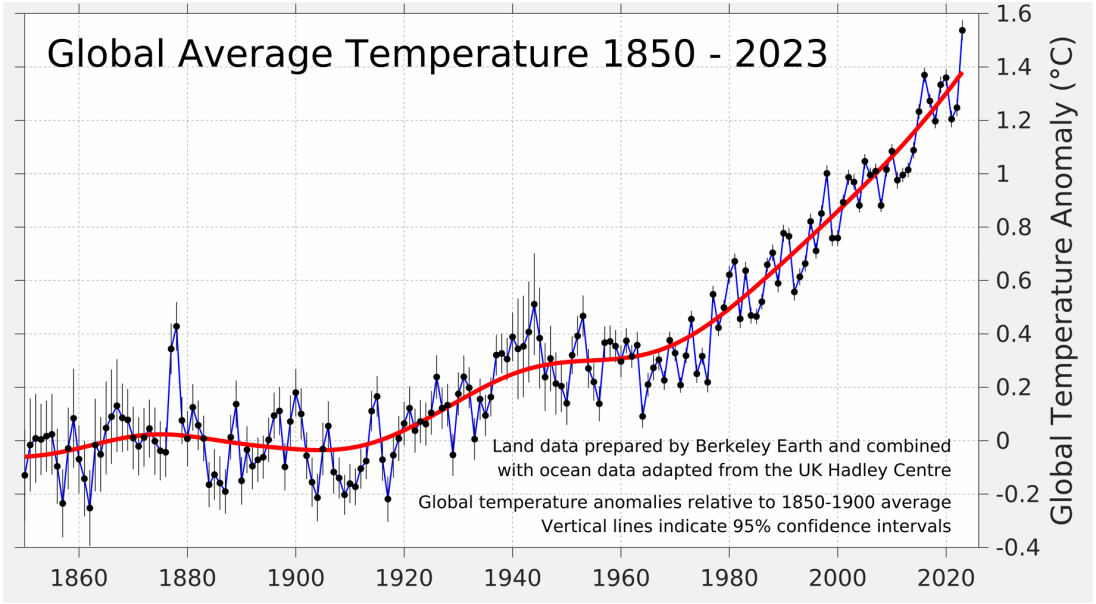
- Can we detect compliance to the regulations by observing changes in ship tracks?
- Can we quantify what global effect they would have on RF?
  - most studies agree on O(0.1 W/m^2)
- Can we attribute any of the observed climatic changes in the last few years to the IMO regulations? How would we do it?



What are the open questions?

05 Jun 2024

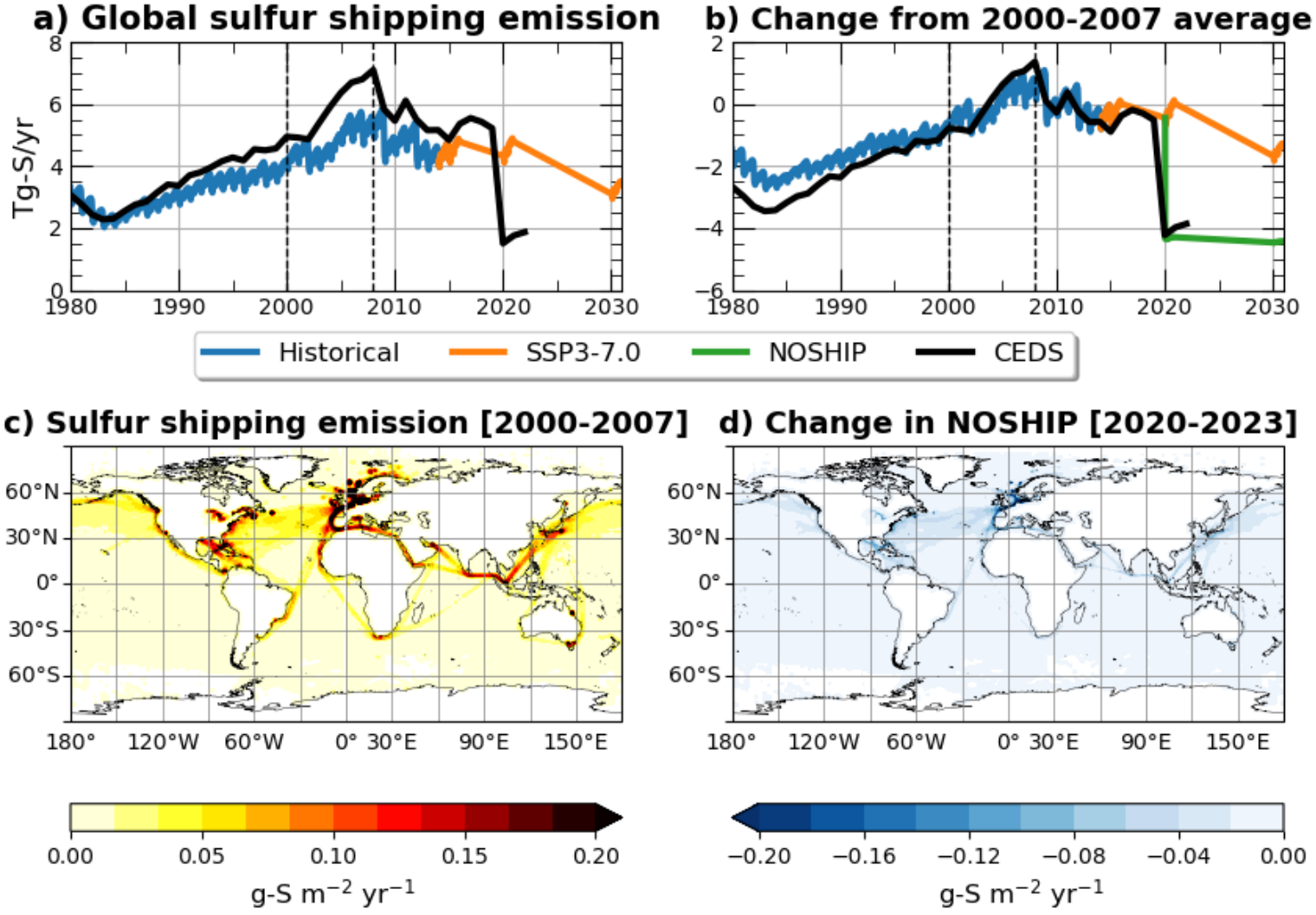
Status: this preprint is open for discussion.

Modeling 2020 regulatory changes in international shipping emissions helps explain 2023 anomalous warming

Ilaria Quaglia and Daniele Visioni

Abstract. The summer of 2023 has seen an anomalous increase in temperatures even when considering the ongoing greenhouse-gases driven warming trend. Here we demonstrate that regulatory changes to sulfate emissions from international shipping routes, which resulted in a significant reduction in sulfate particulate released during international shipping starting on January 1 2020, have been a major contributing factor to the monthly surface temperature anomalies during the last year. We do this by including in Community Earth System Model (CESM2) simulations the appropriate changes to emission databases developed for the Climate Model Intercomparison Project version 6 (CMIP6). The aerosol termination effect simulated by the updated CESM2 simulations is consistent with observations of both radiative forcing and surface temperature, manifesting a similar delay as the one observed in observational datasets between the implementation of the emission changes and the anomalous increase in warming. Our findings highlight the importance of considering realistic near-future changes in short-lived climate forcers for future climate projections, such as for CMIP7, for an improved understanding and communication of short-term climatic changes.

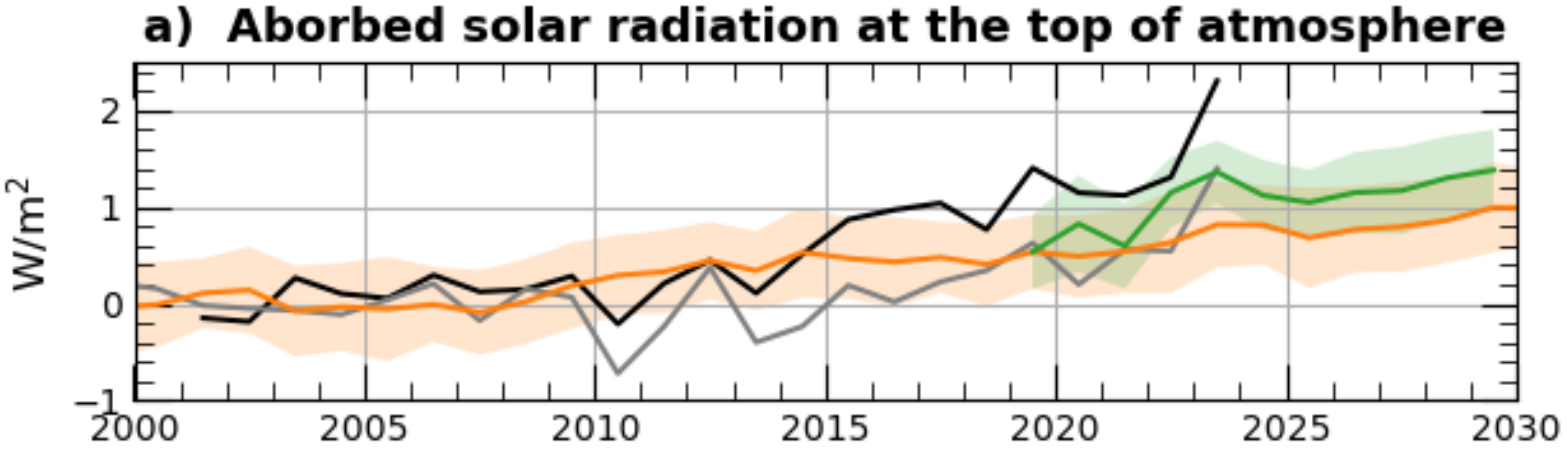
Starting point: the CESM2 LENS

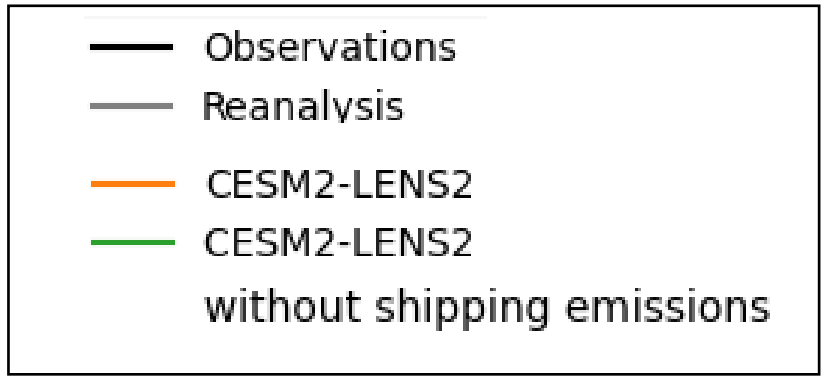


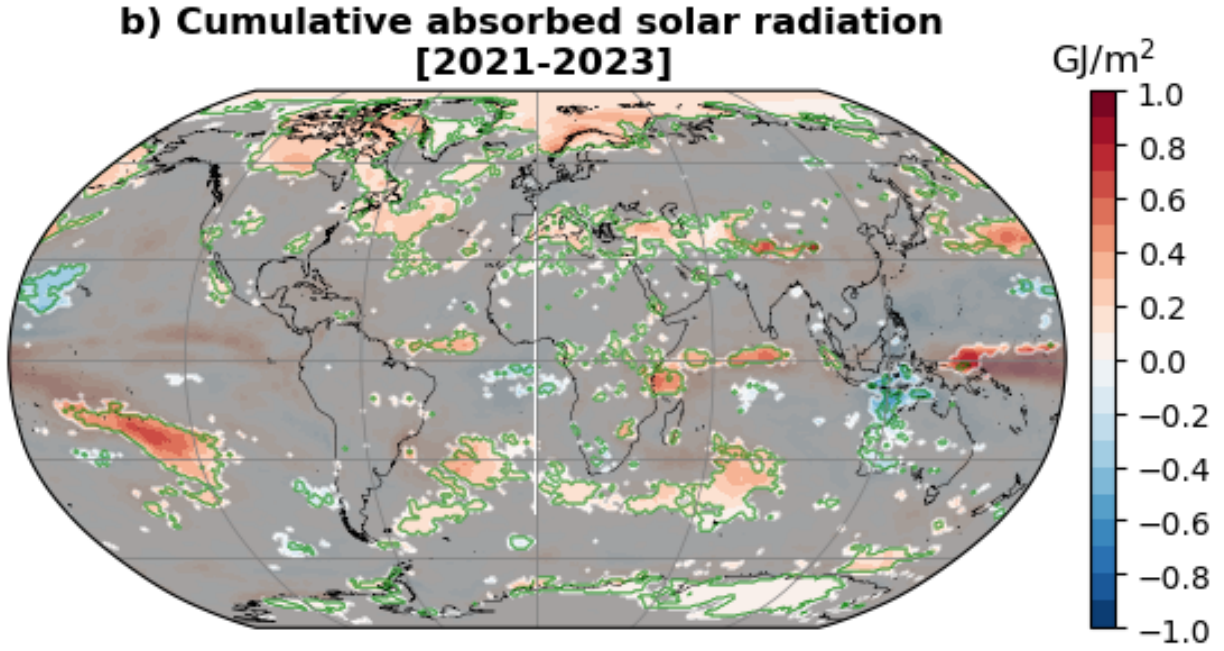
CESM2 Large Ensemble (LENS2)

- **Historical:** pre-2014, 50-member ensemble
- **SSP3-7.0:** post-2014, 50-member ensemble
- **NOSHIP**: 10-member ensemble, SSP3-7.0 with 90% drop in SO_2 emissions suddenly in 2020

Results: global and local RF

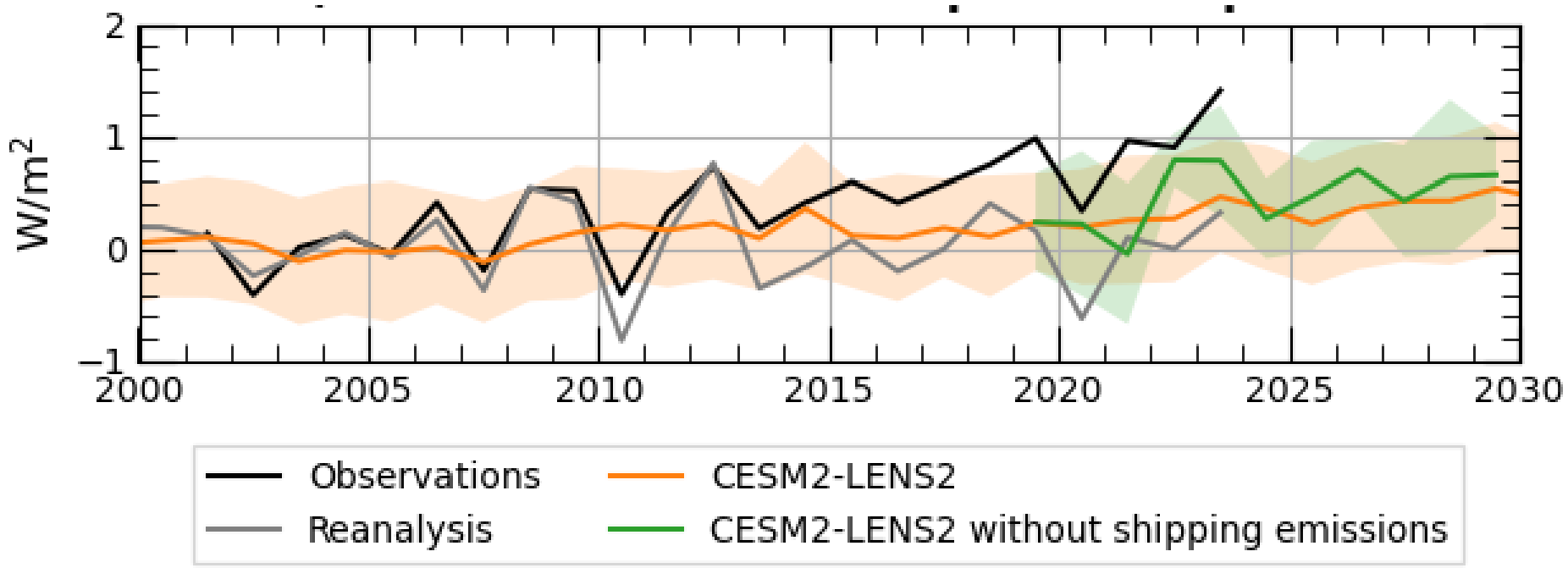






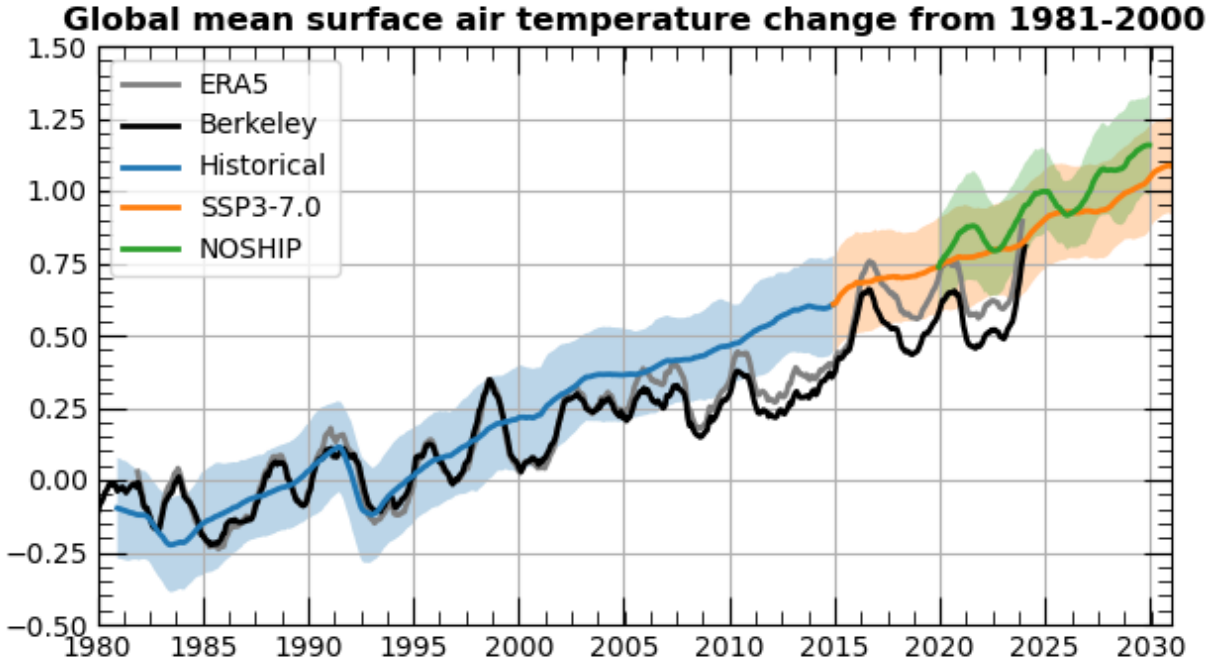
Results: global and local RF

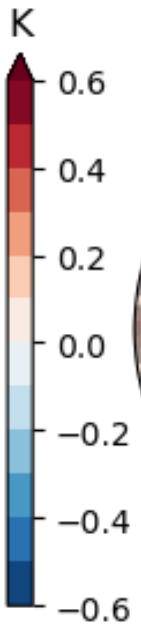
NET Radiation at Top of Atmosphere changes from 2000-2007 period

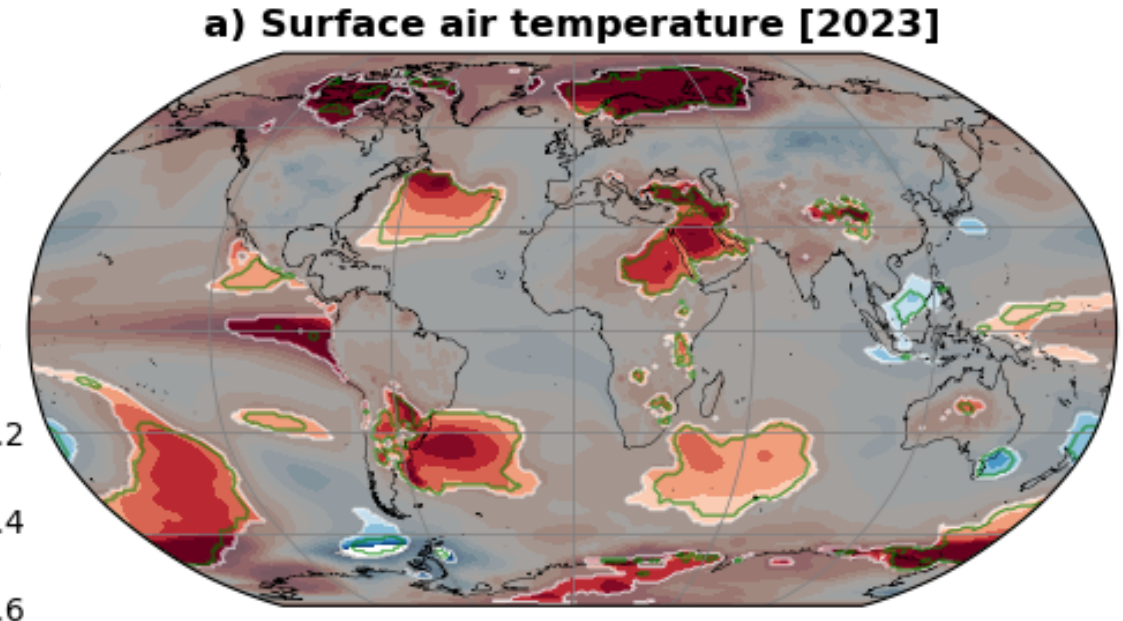


- RF = 0.2 W/m^2

Results: global and local SAT

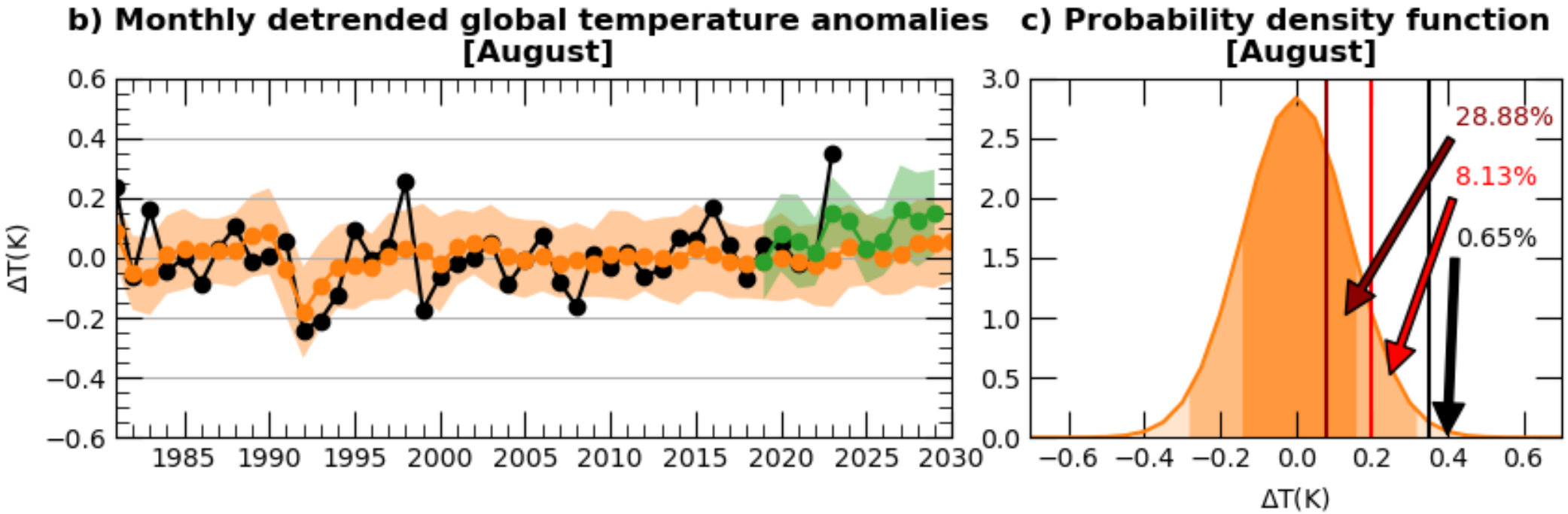






- $\Delta T = 0.2$ K

Results: global and local SAT



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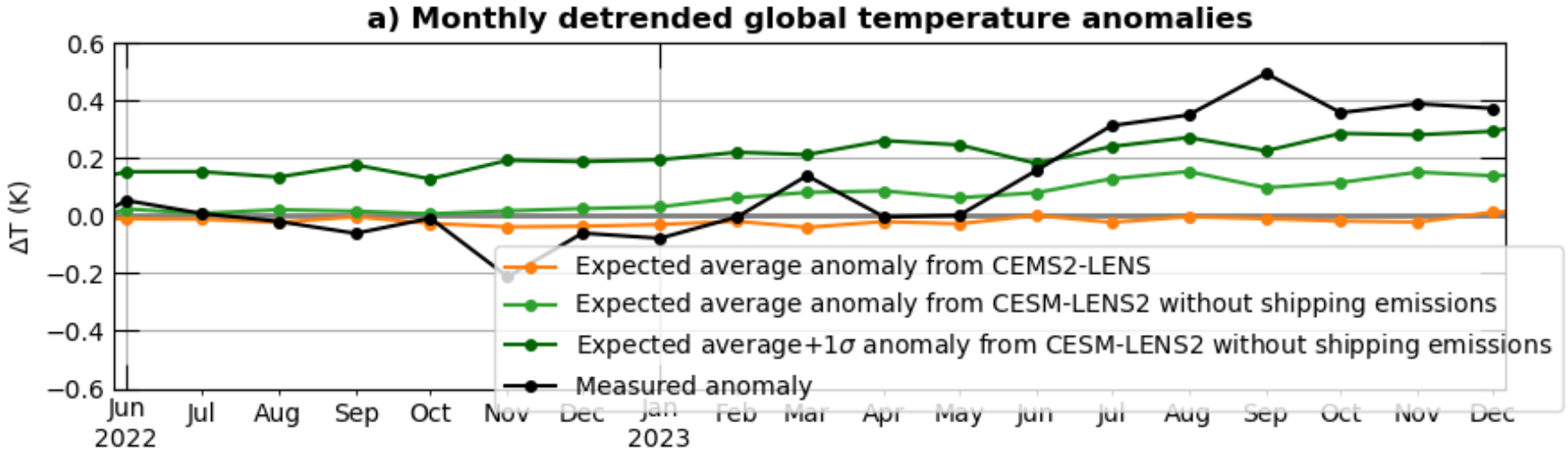
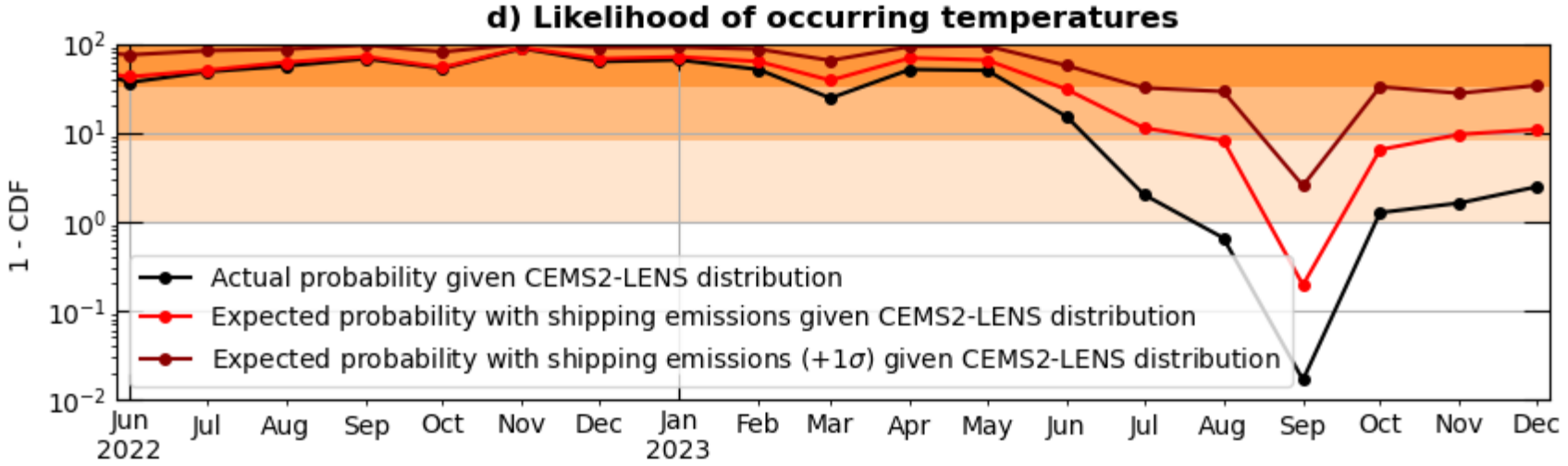


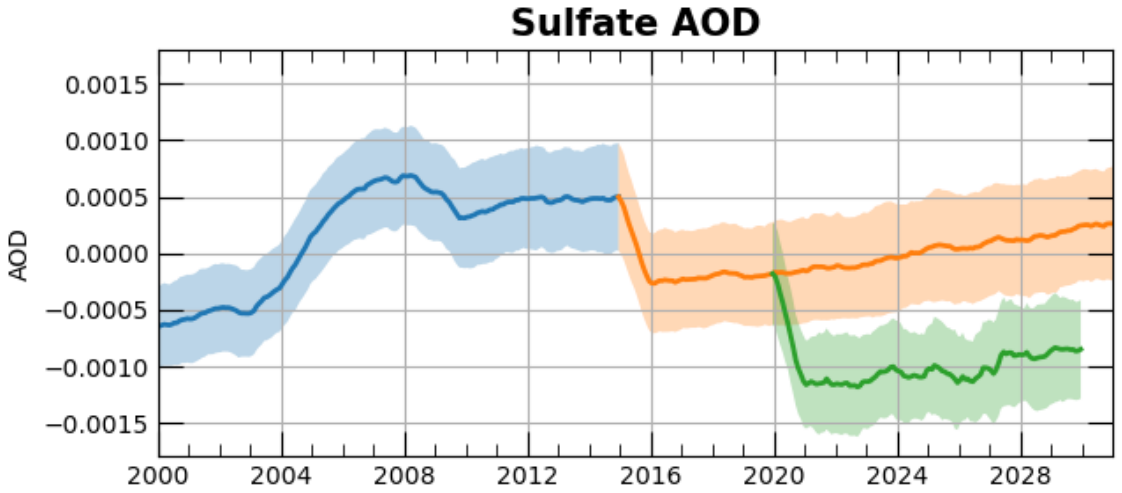


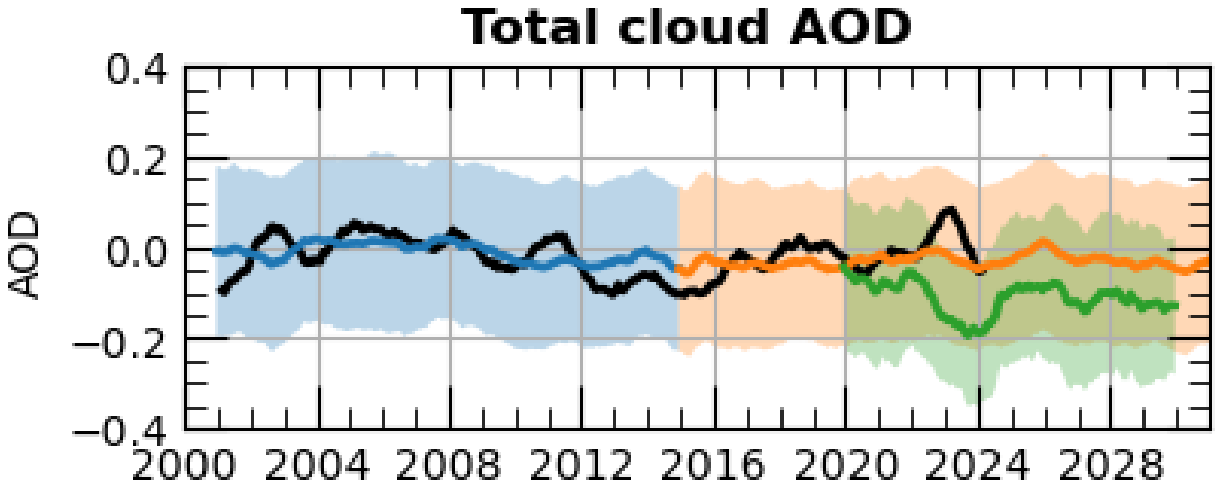
Wrapping up…

- Our study confirm previous findings of a TOA radiative forcing due to the IMO regulations of o(0.1) W/m^2, globally: **RF = 0.2 W/m^2, T = 0.2 K**
- The warming anomalies observed in August-December 2023 in Berkley can be partially attributed to the IMO regulations
- Changes in TOA radiative forcing are mainly due to changes in cloud optical properties

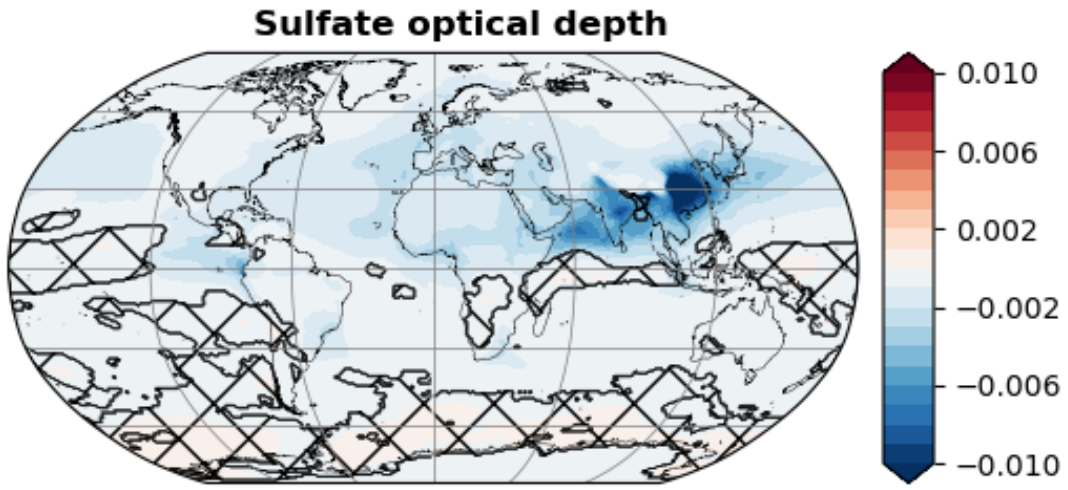
What might be the causes?

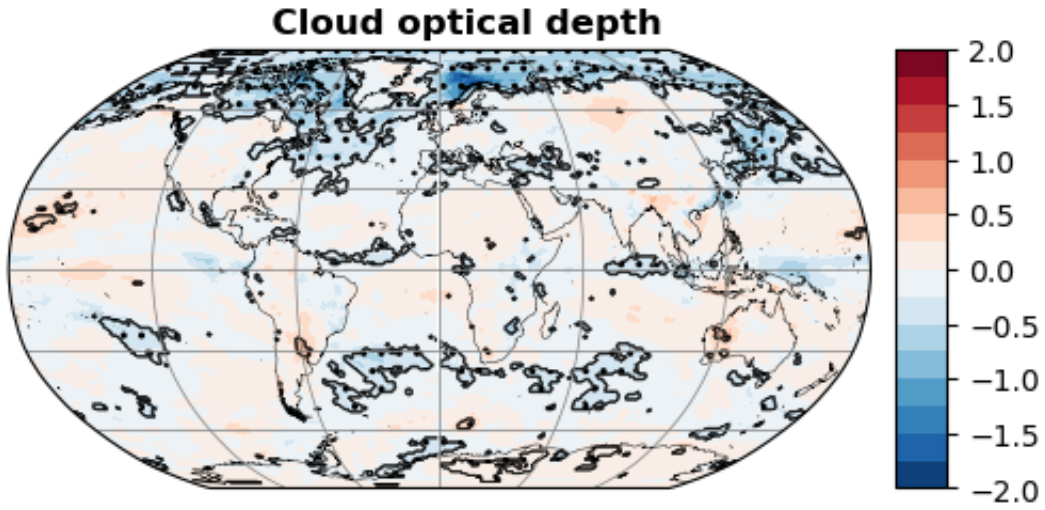
Changes from 2000-2007





Changes due to Shipping emissions change in from 2020-2023





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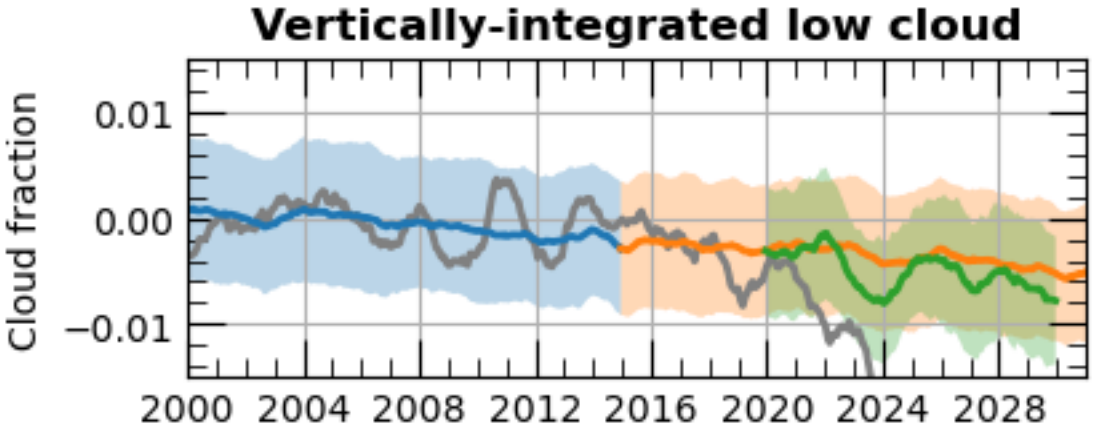

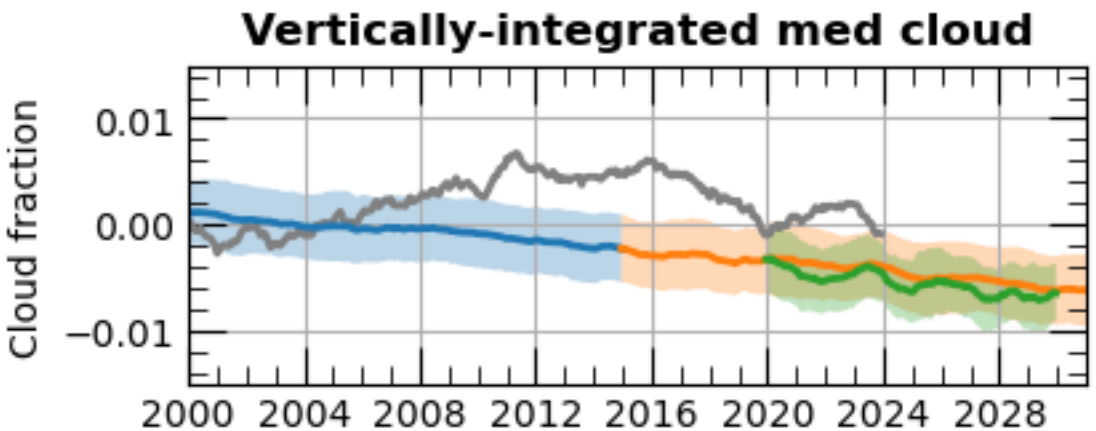

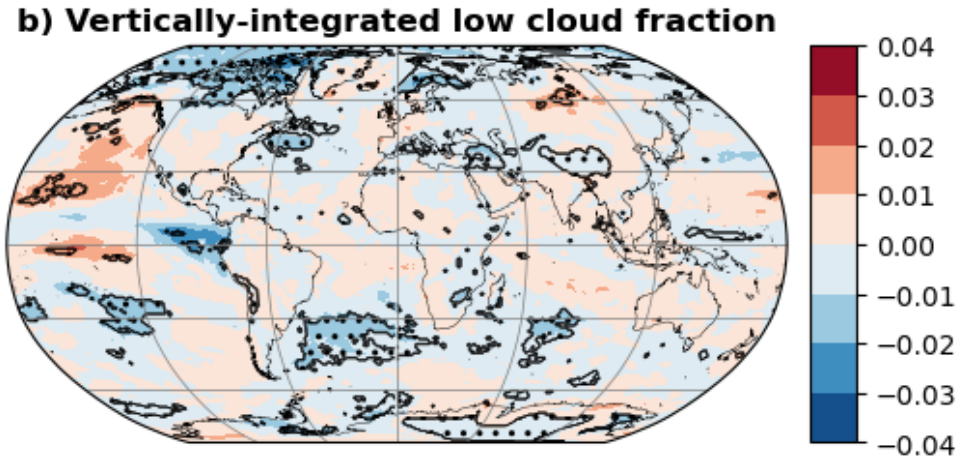

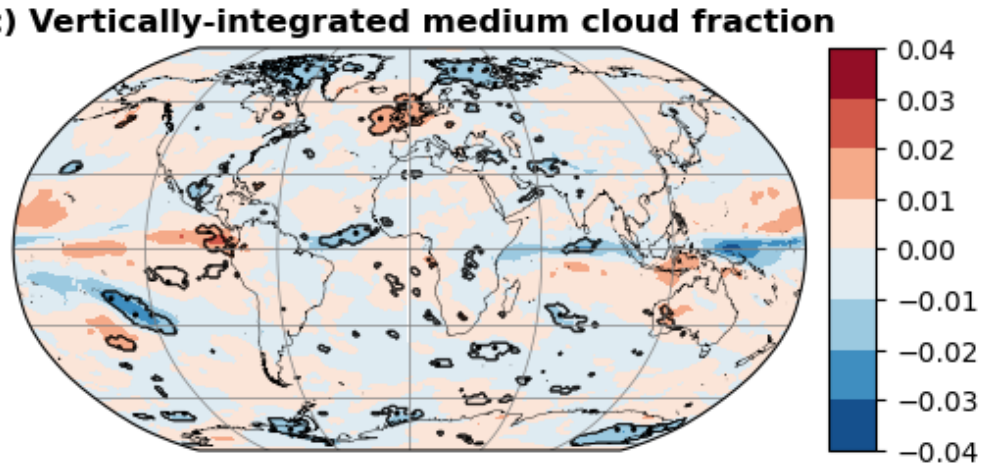

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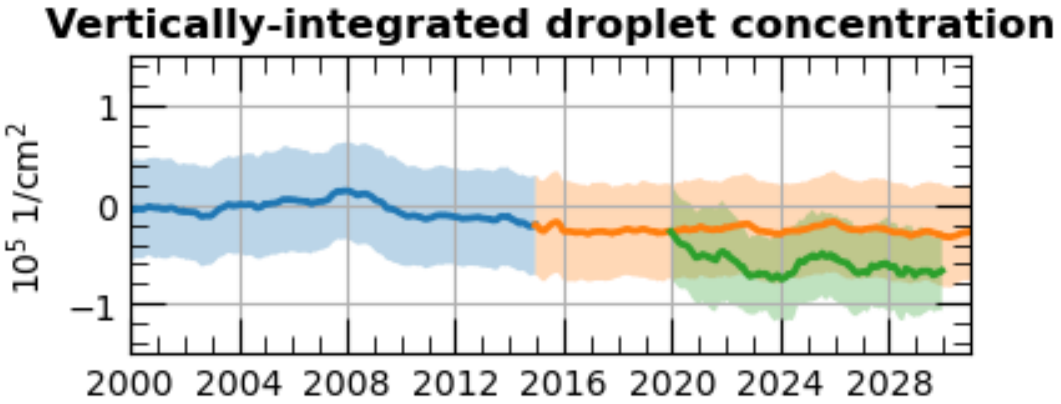

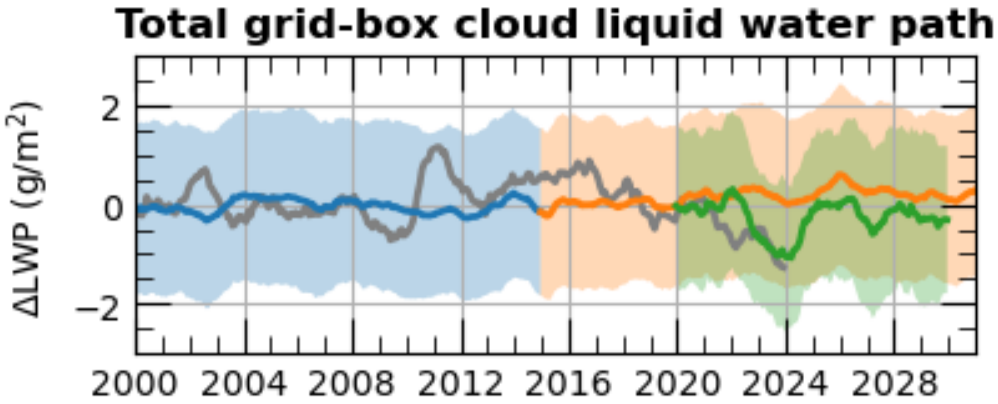

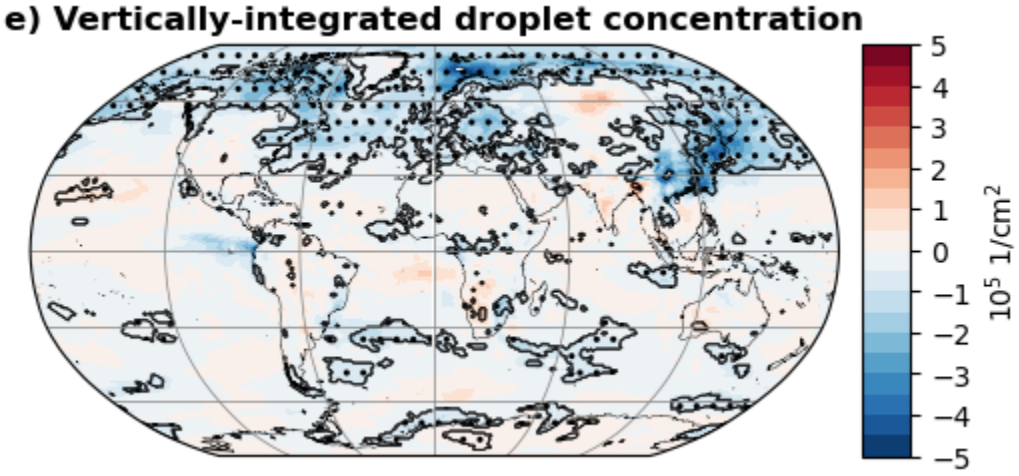

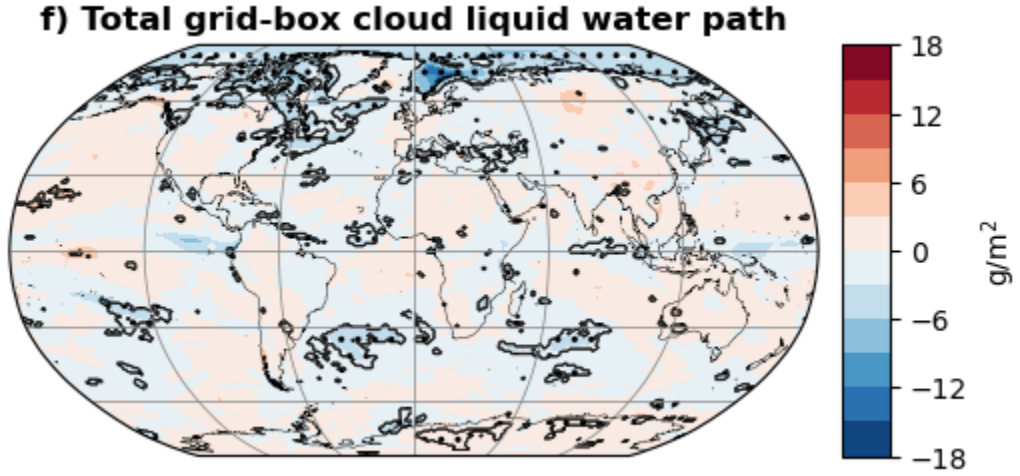

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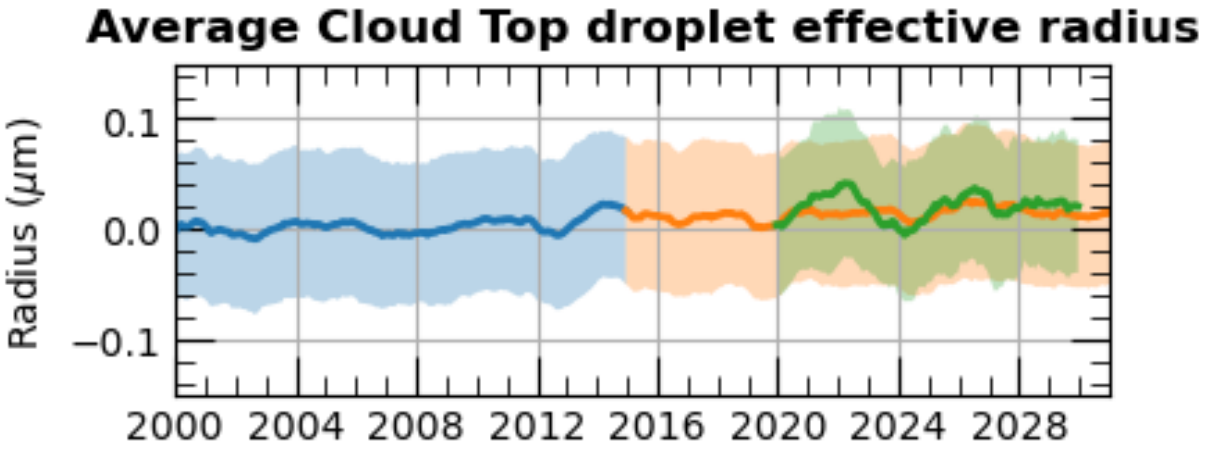
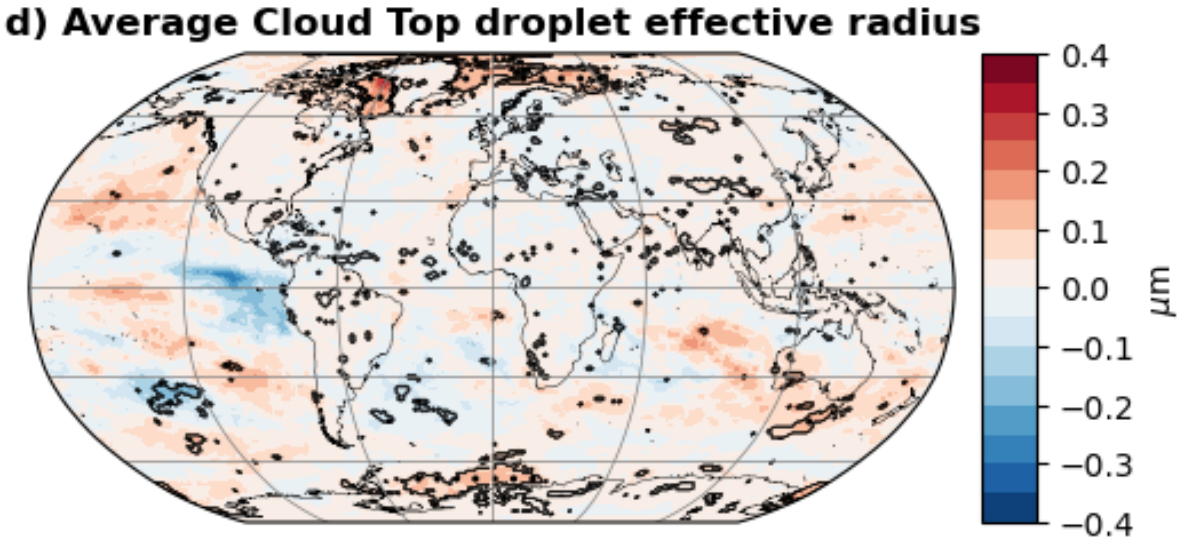
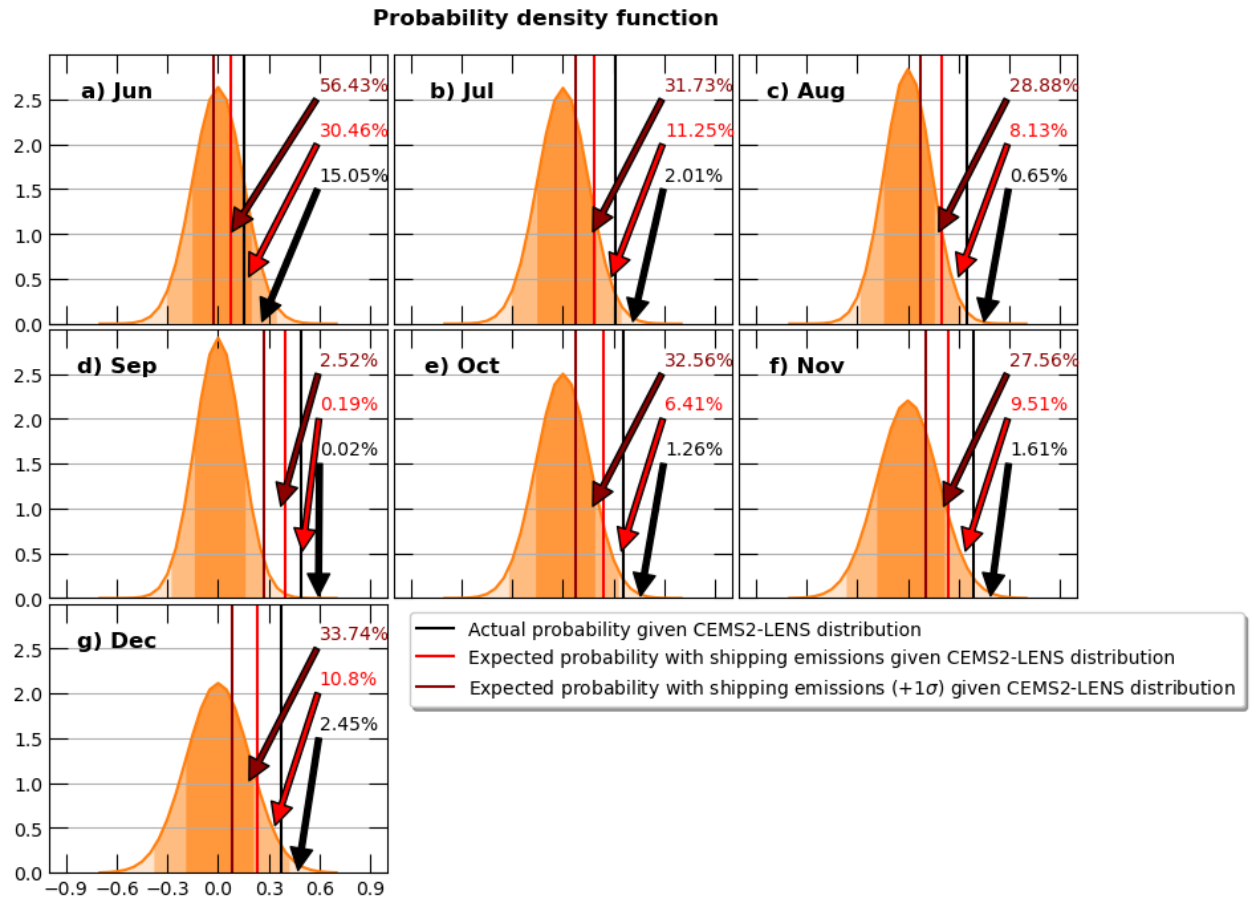
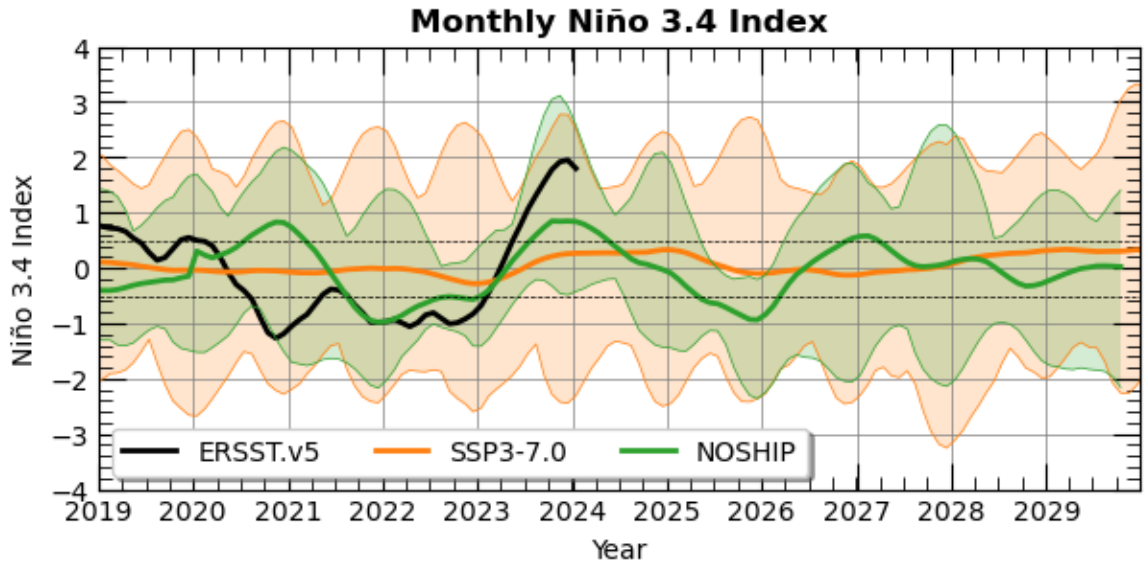





Probability density function
a) Jun
56.43%
30.46%
15.05%
b) Jul
31.73%
11.25%
2.01%
c) Aug
28.88%
8.13%
0.65%
d) Sep
2.52%
0.19%
0.02%
e) Oct
32.56%
6.41%
1.26%
f) Nov
27.56%
9.51%
1.61%
g) Dec
33.74%
10.8%
2.45%
0.0
0.5
1.0
1.5
2.0
2.5
−0.9 −0.6 −0.3 0.0 0.3 0.6 0.9
Actual probability given CEMS2-LENS distribution
Expected probability with shipping emissions given CEMS2-LENS distribution
Expected probability with shipping emissions (+1σ) given CEMS2-LENS distribution


Monthly Niño 3.4 Index
Niño 3.4 Index
Year
ERSST.v5
SSP3-7.0
NOSHIP
4
3
2
1
0
−1
−2
−3
−4
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029