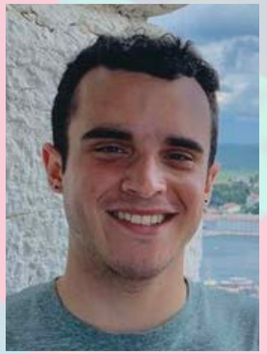
How the good and the bad conspire to the ugly





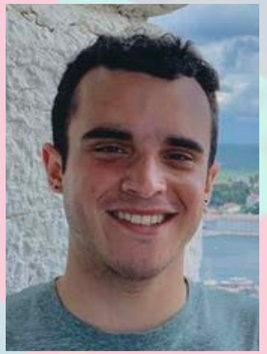
Maria Rugenstein, Dirk Olonscheck, Shreya Dhame, Marc Alessi

How the good and the bad conspire to the ugly

Observable TOA radiation trends

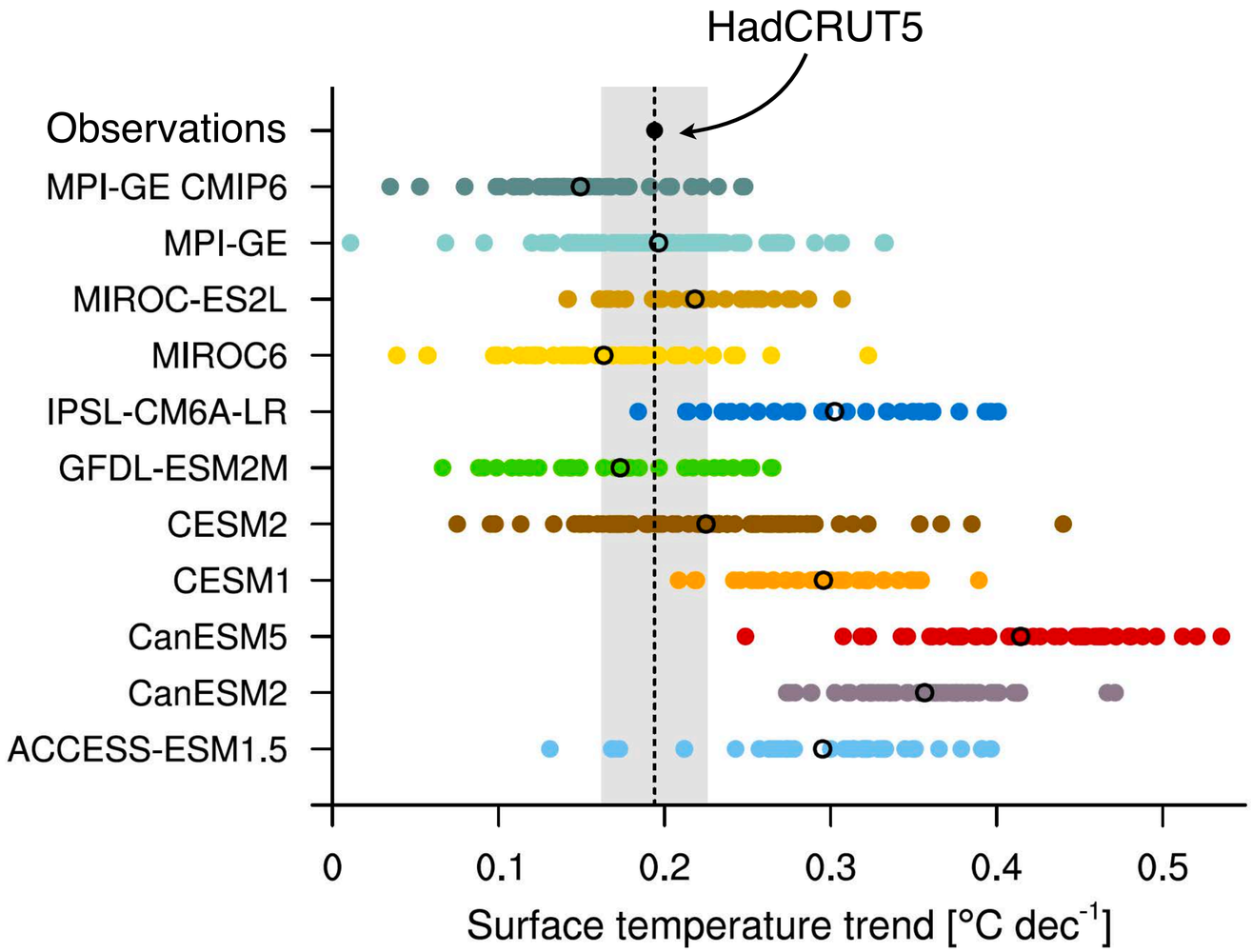
Observable surface temperature trends

Implications for projections of climate change



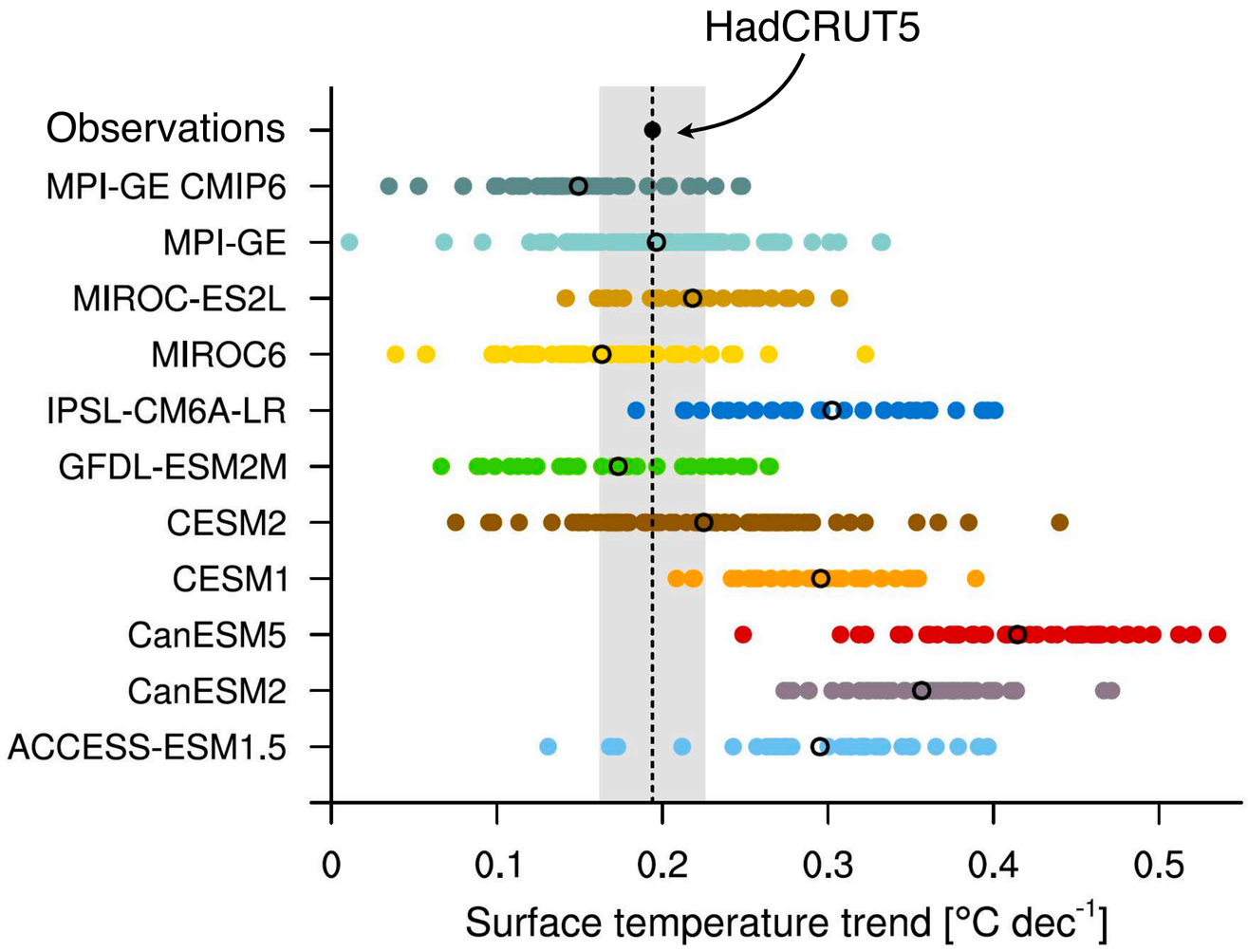
Maria Rugenstein, Dirk Olonscheck, Shreya Dhame, Marc Alessi

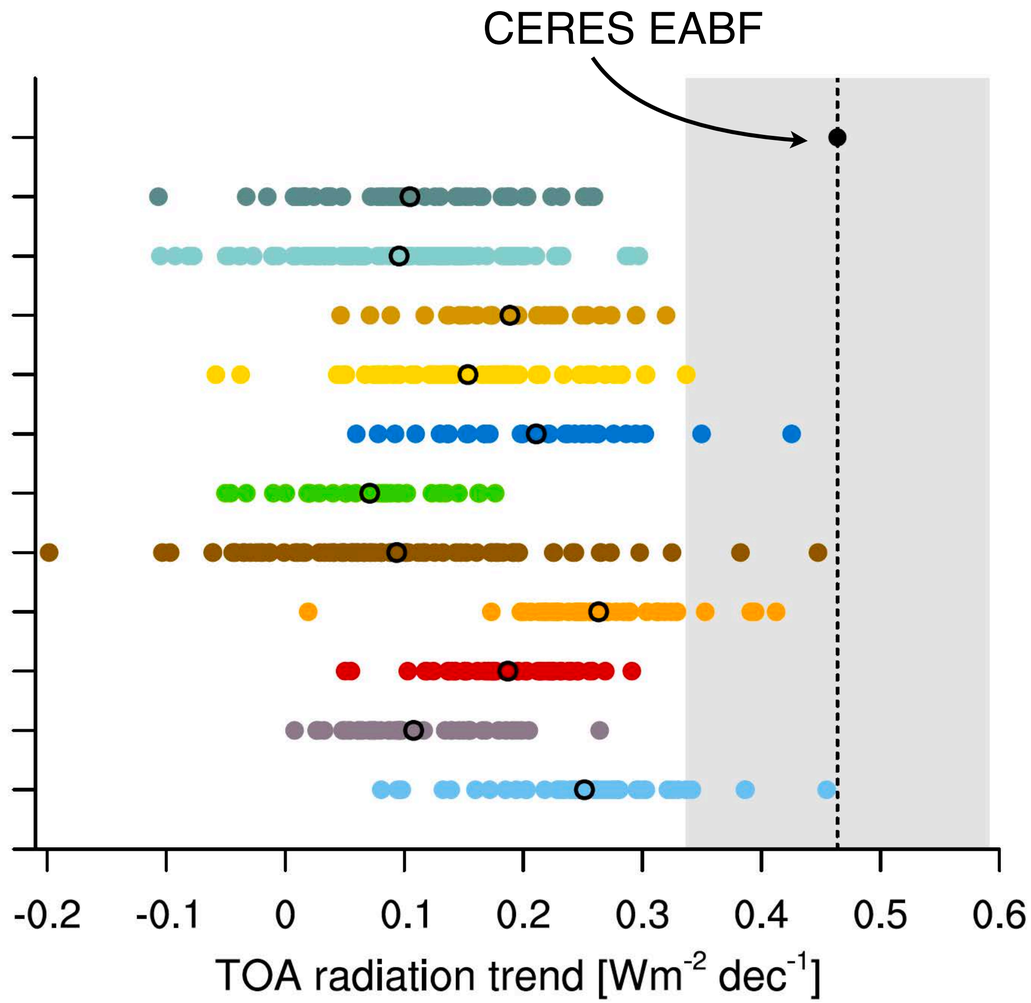
2000 - 2022 global-mean surface temperature is good



Olonscheck & Rugenstein, 2024: Coupled climate models systematically underestimate radiation response to surface warming

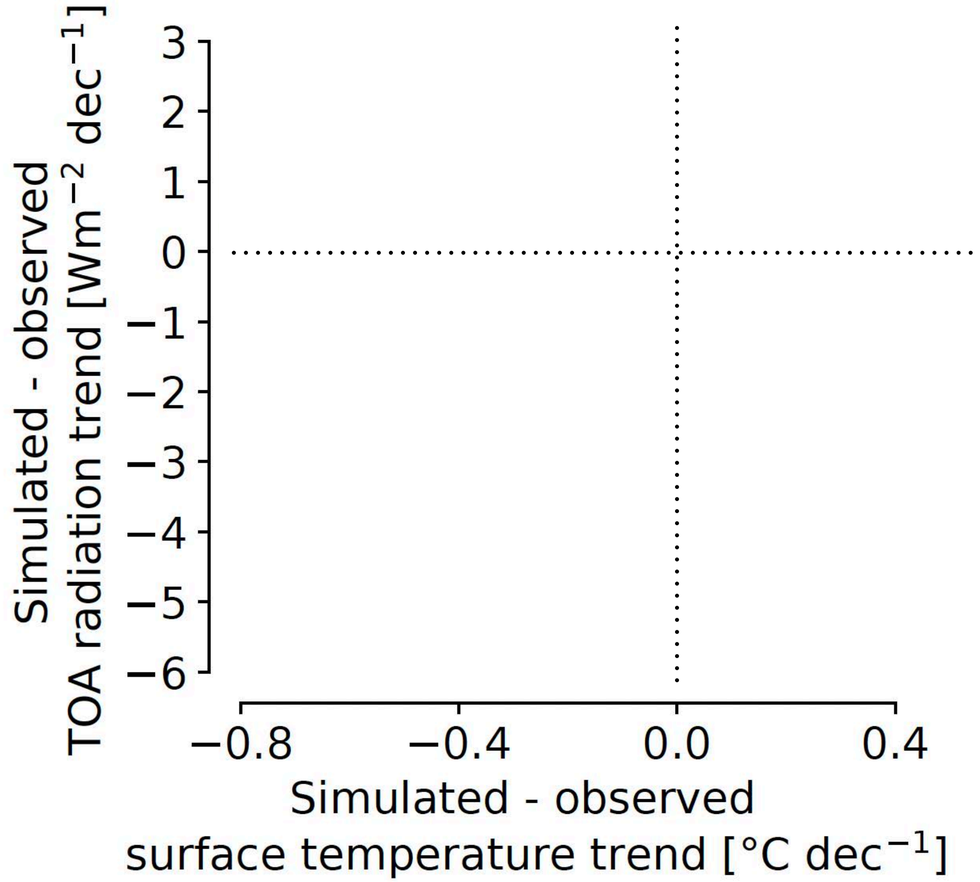
Global-mean top of the atmosphere radiation is bad

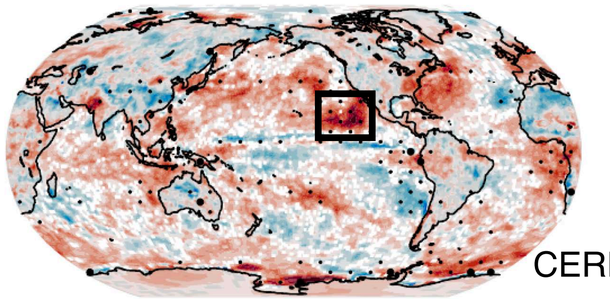




Olonscheck and Rugenstein 2024

Bias measure: if surface trend is correct, how off is radiation trend





CERES EABF 4.2

Olonscheck and Rugenstein 2024

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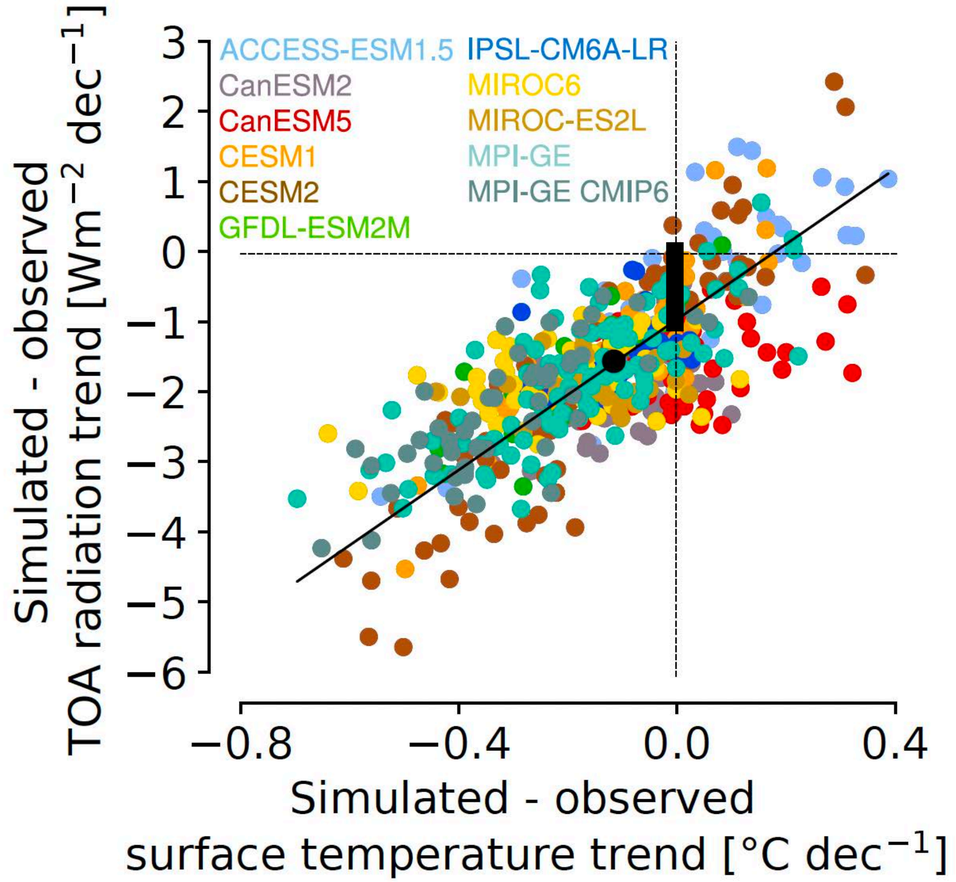
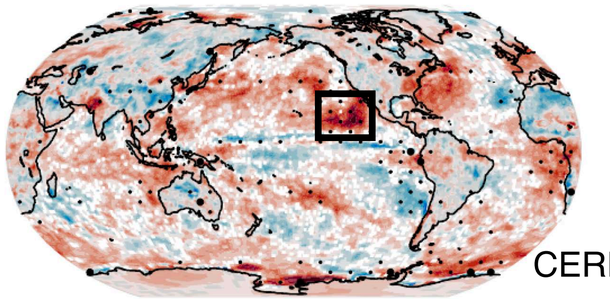
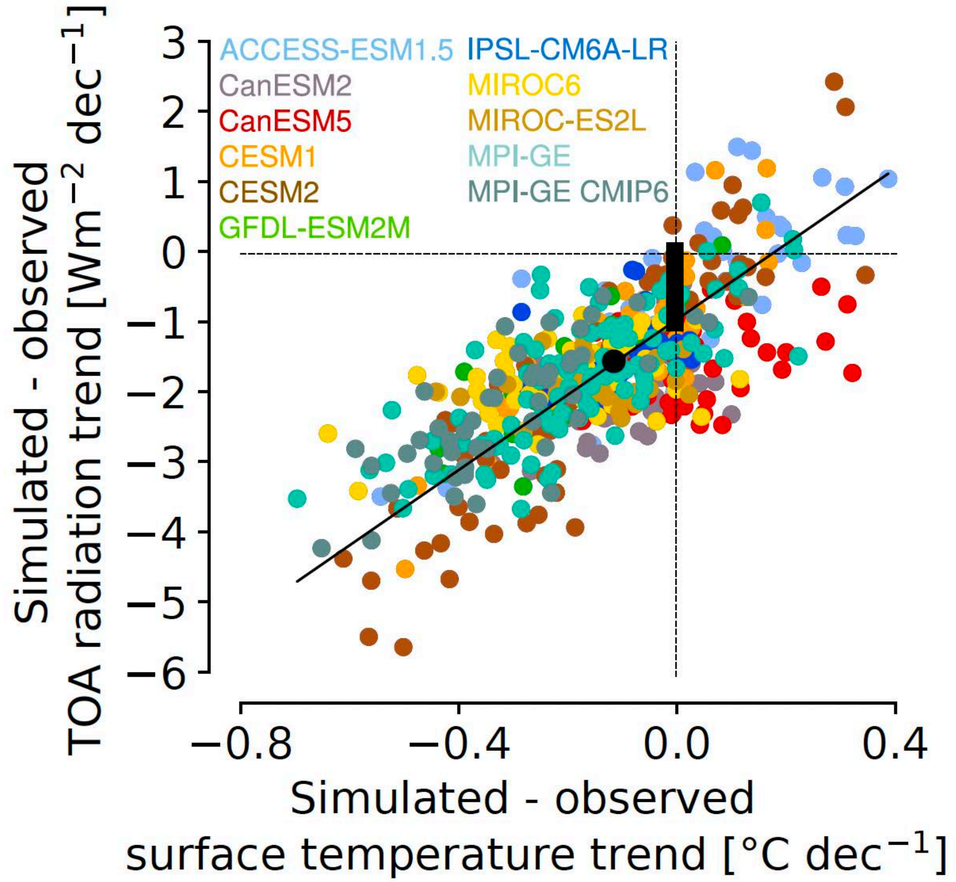


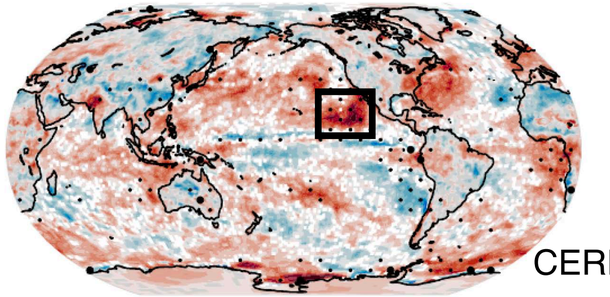


CERES EABF 4.2

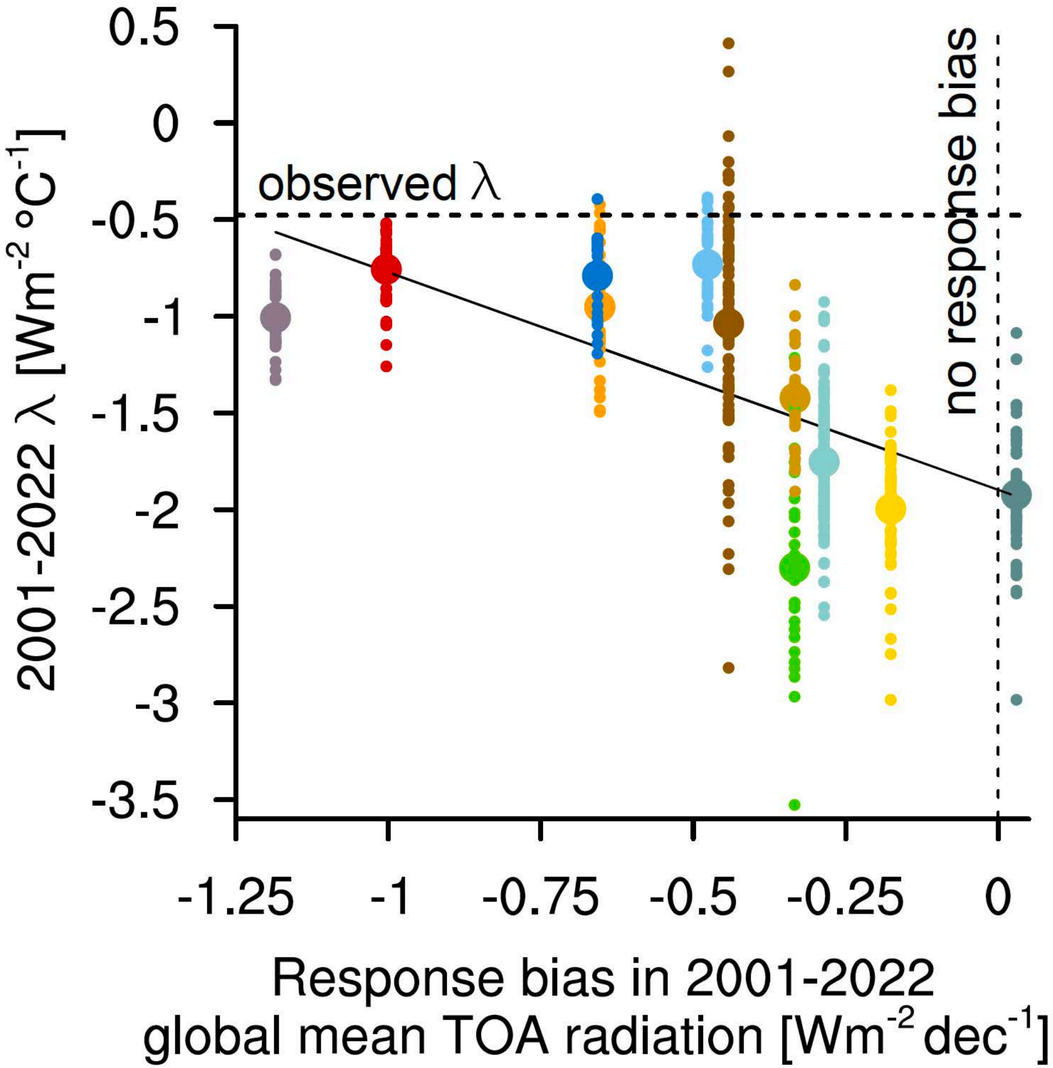
Olonscheck and Rugenstein 2024

Radiative feedbacks d(N-F)/dT are pretty ugly





CERES EABF 4.2



Olonscheck and Rugenstein 2024

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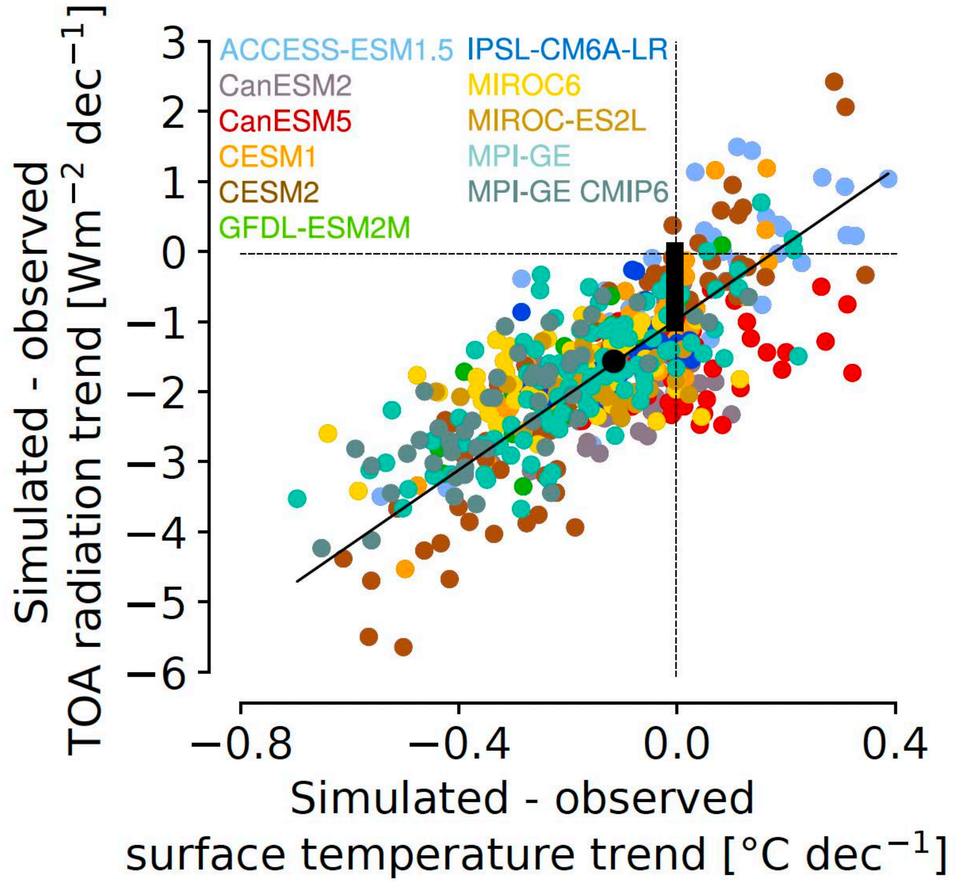
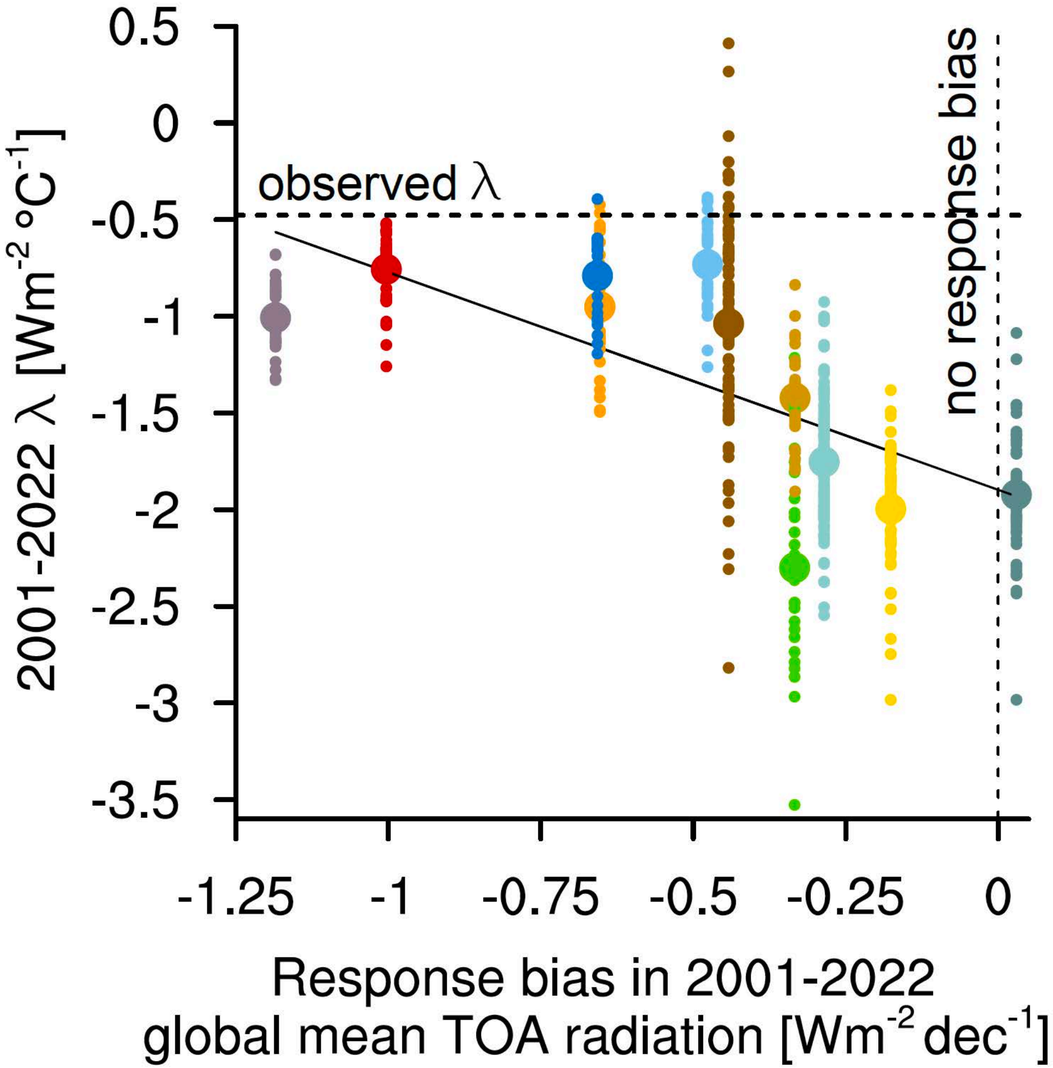
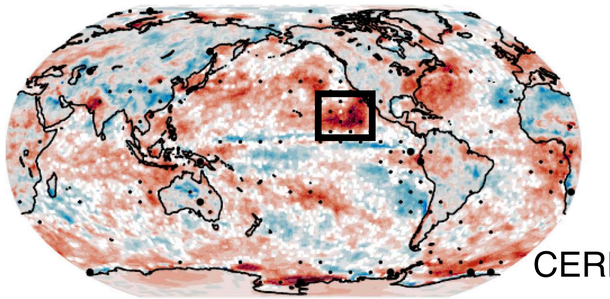


~1/ECS



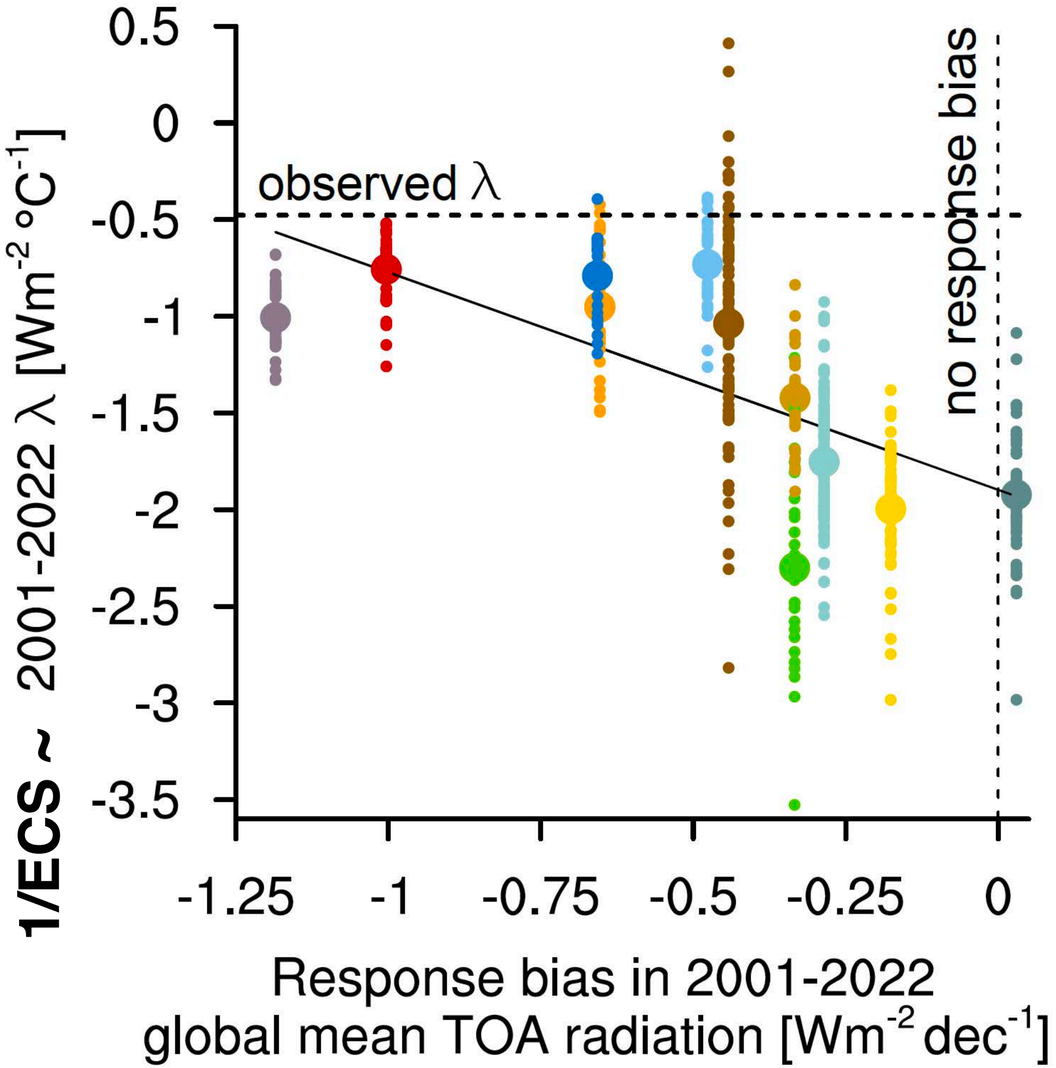


CERES EABF 4.2

Olonscheck and Rugenstein 2024

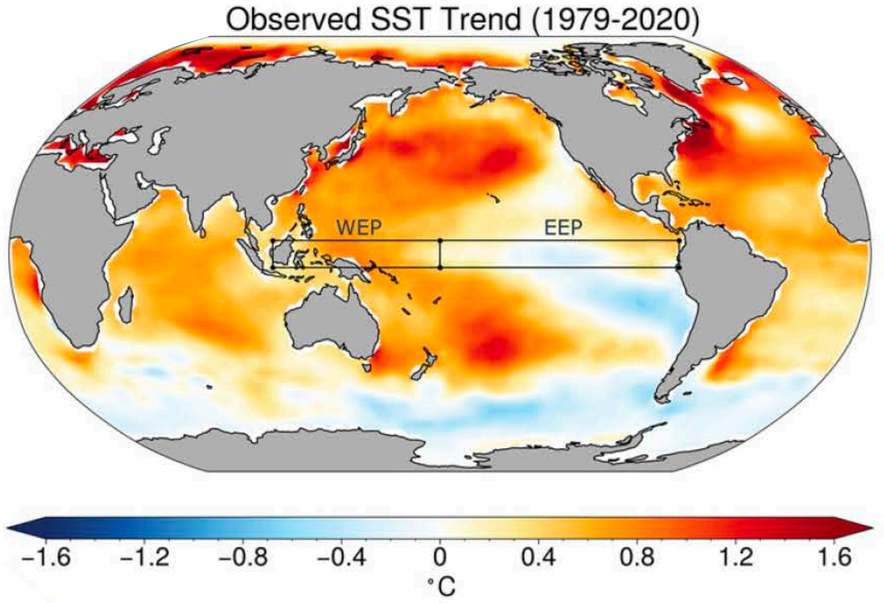
Radiative feedbacks d(N-F)/dT are pretty ugly

- Good = observations fall into modeled range
- Bad = all models share the same (strong) bias
- Ability of an ensemble to get physics might be possible even fore otherwise uninterpretable 20-ish trends
- Our radiation response bias indicates models with a stronger stabilizing radiative feedback, and hence a lower climate sensitivity, are better able to reproduce observations
- Radiative feedbacks by themselves are unable to constrain models yet because the regressions are too noisy
- Good models might have better SST patterns or better cloud physics



Uribe et al. 2022, Raghuraman et al. 2021, 2023, Loeb et al. 2021, Schmidt et al. 2023, CERES MIP, Olonscheck & Rugenstein 2024

Models do not reproduce swings in the Pacific SST patterns

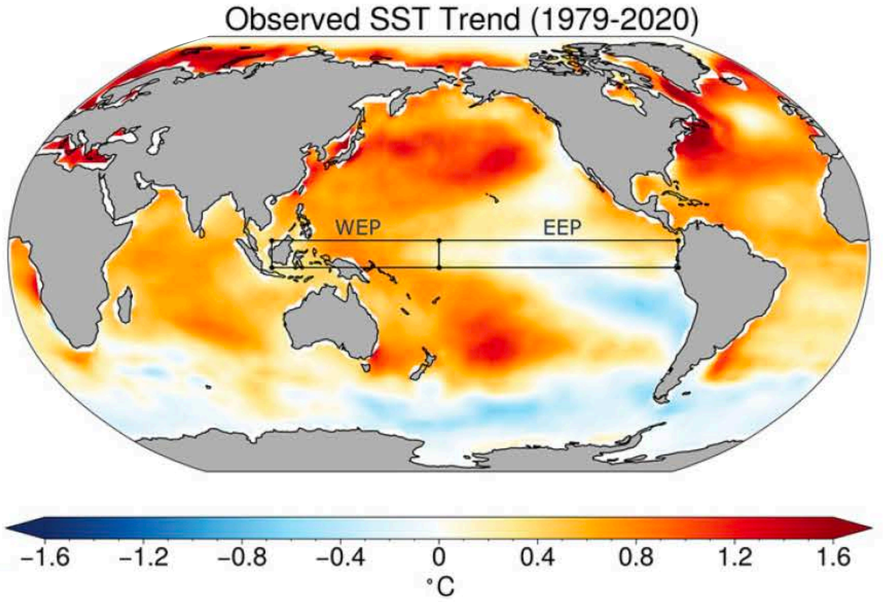


Rugenstein, Dhame, Olonscheck, Wills, Watanabe, Seager, 2023
Connecting the SST pattern problem and the hot model problem





Models do not reproduce swings in the Pacific SST patterns



Rugenstein et al. 2023

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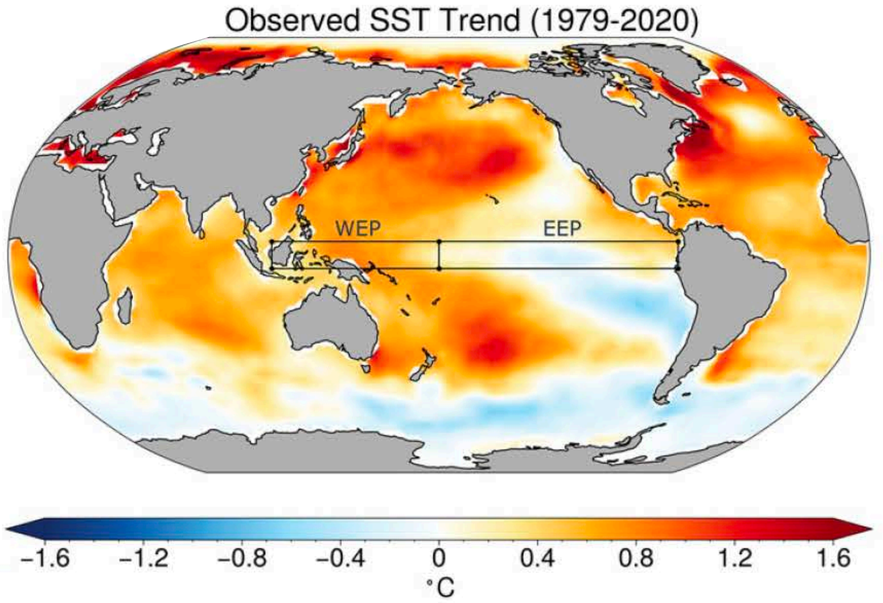

Rugenstein et al. 2023

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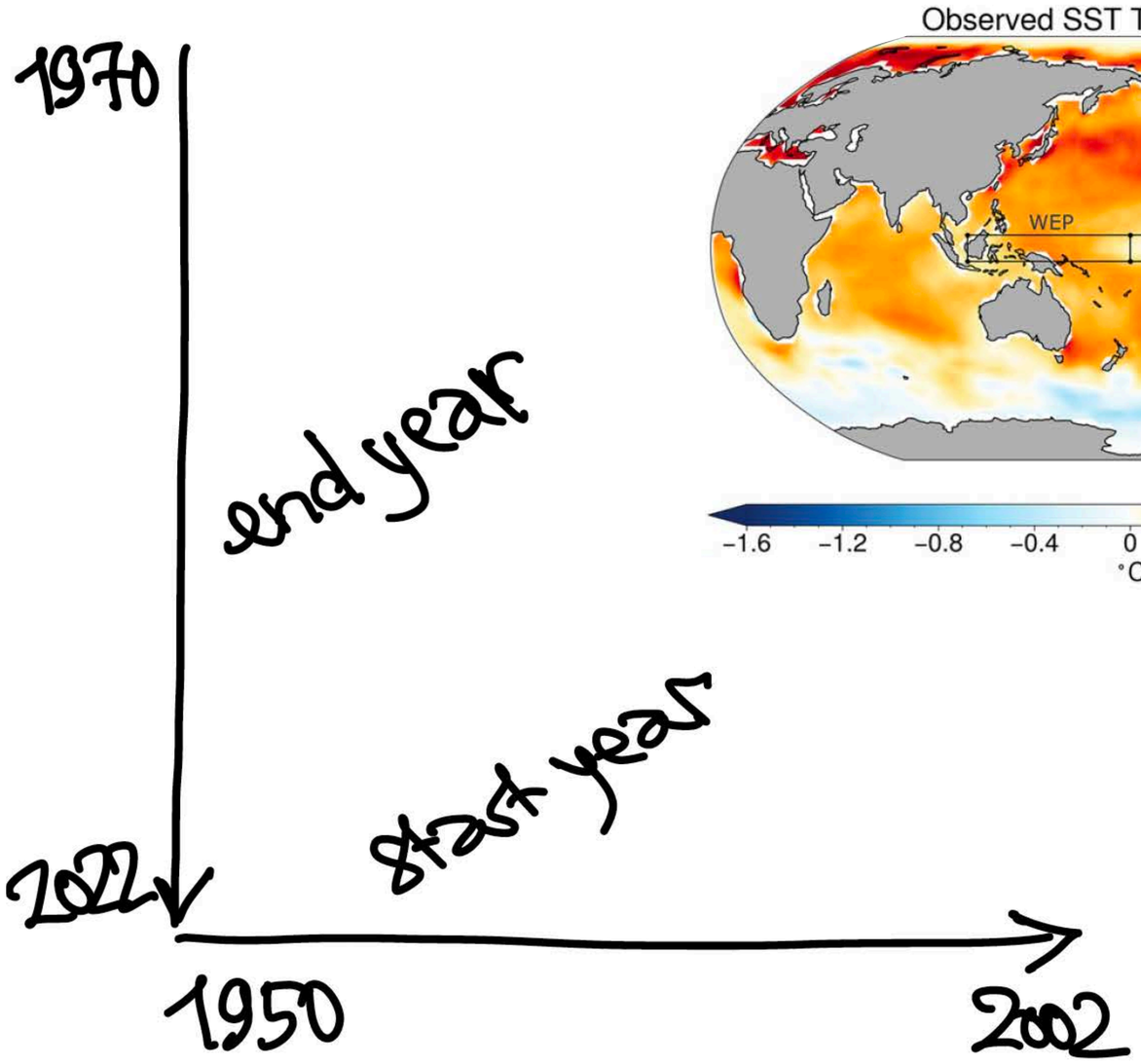

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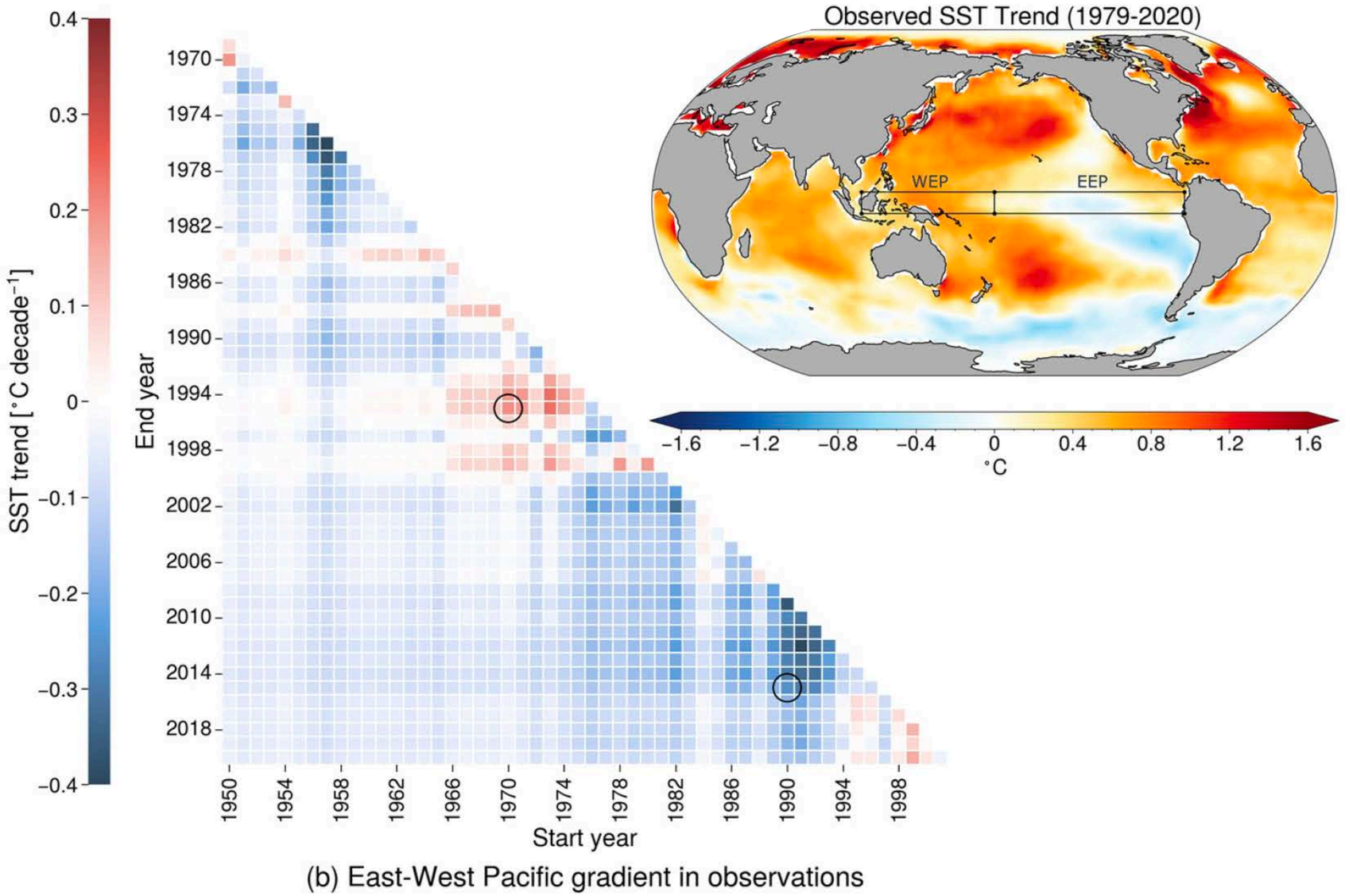

(b) East-West Pacific gradient in observations

Rugenstein et al. 2023

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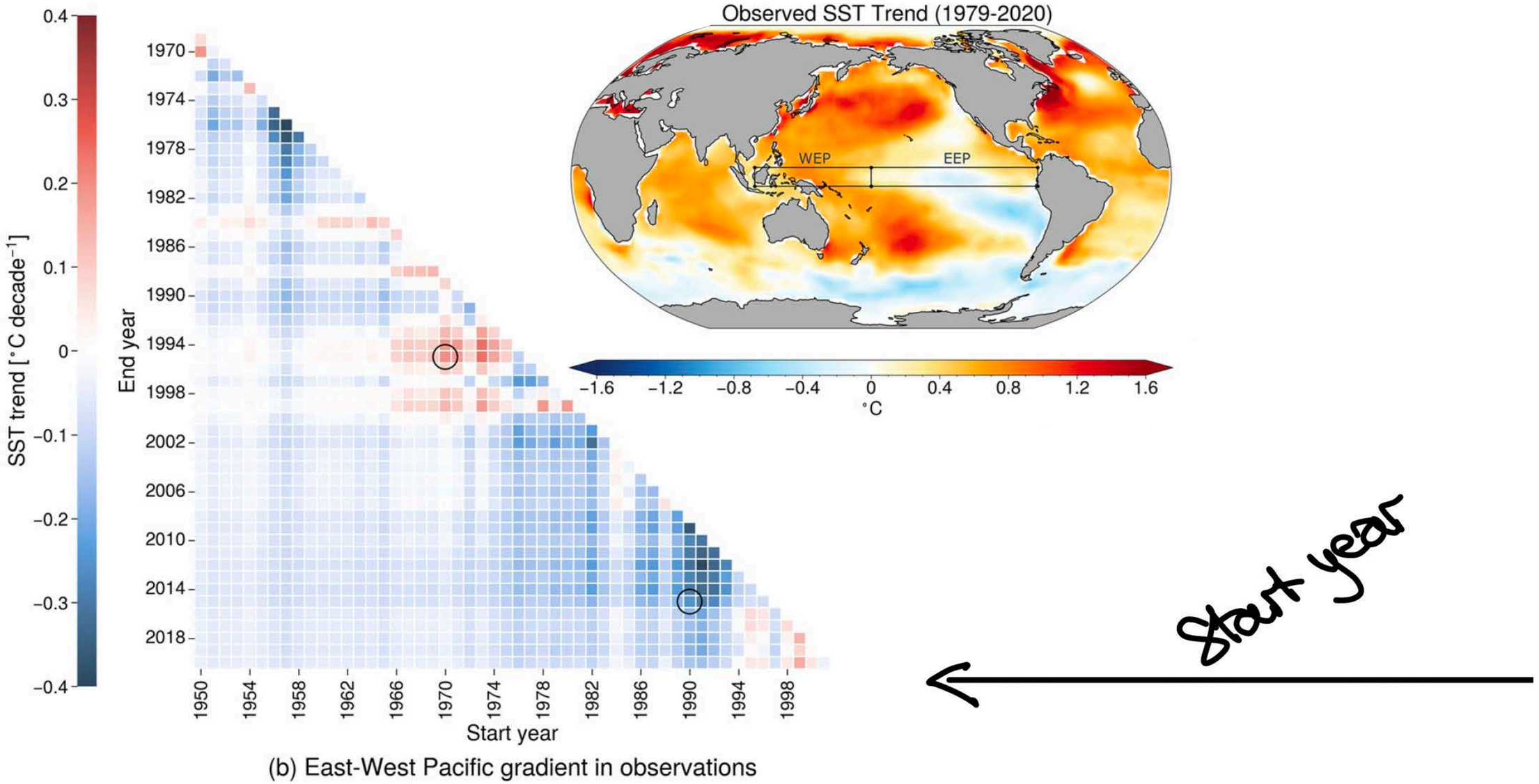

Rugenstein et al. 2023

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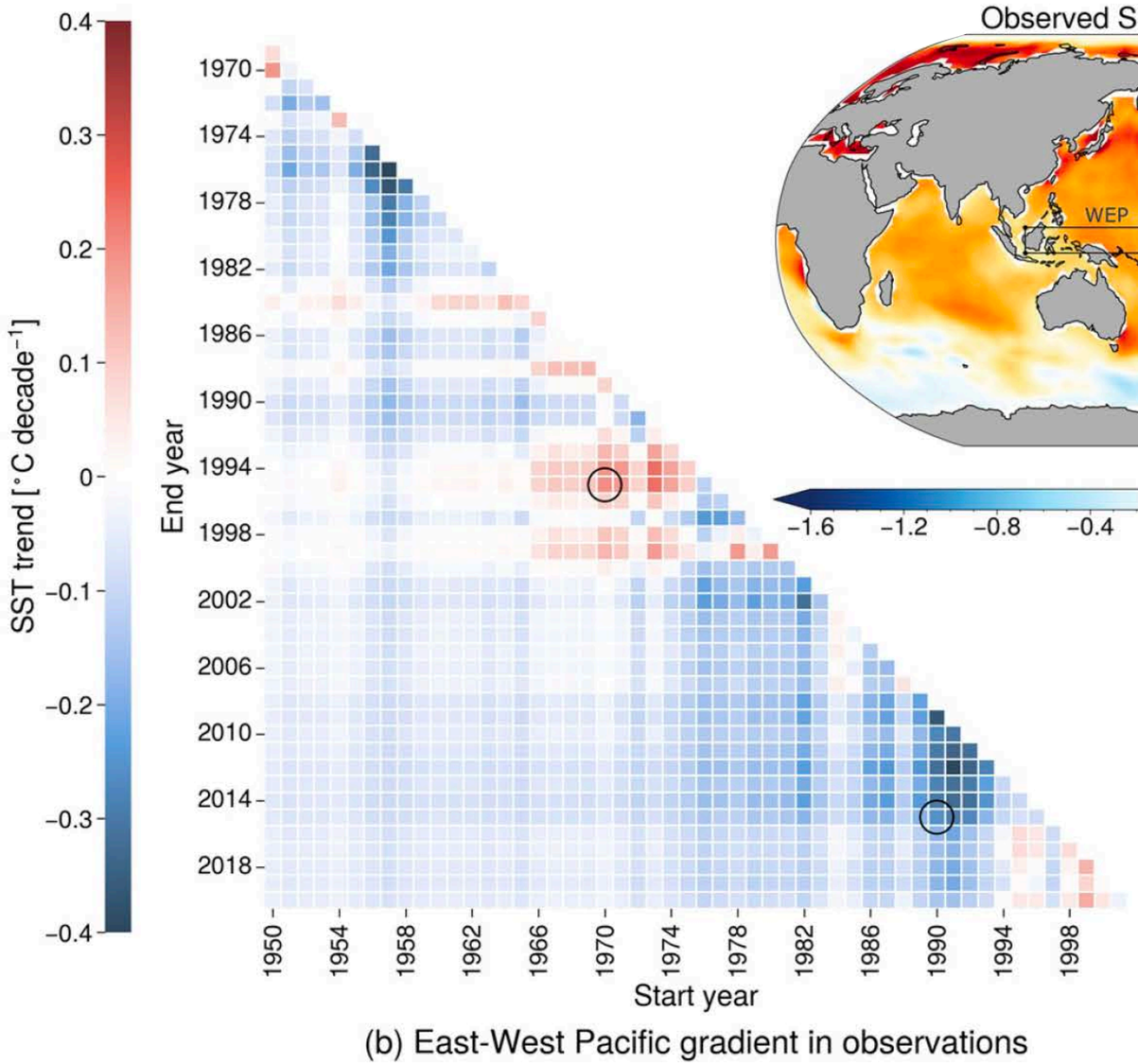

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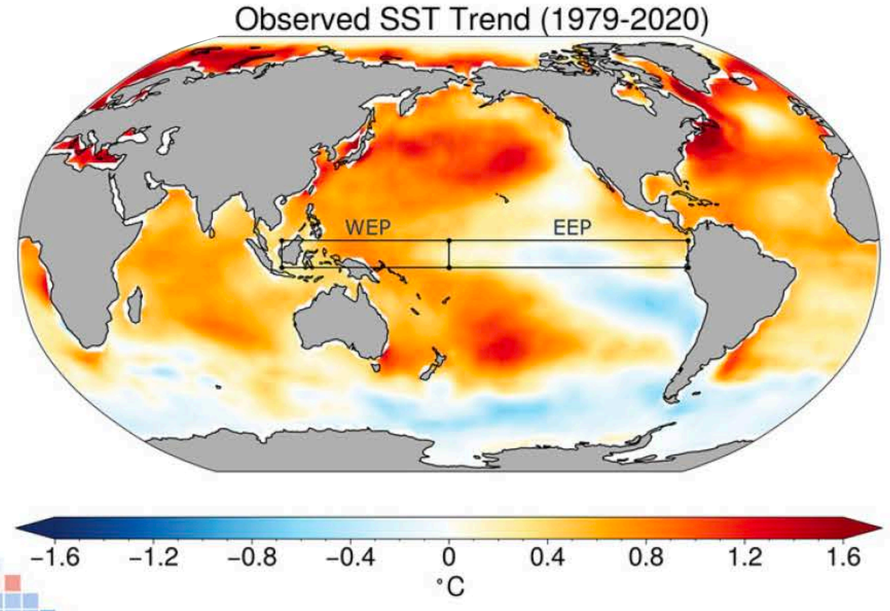

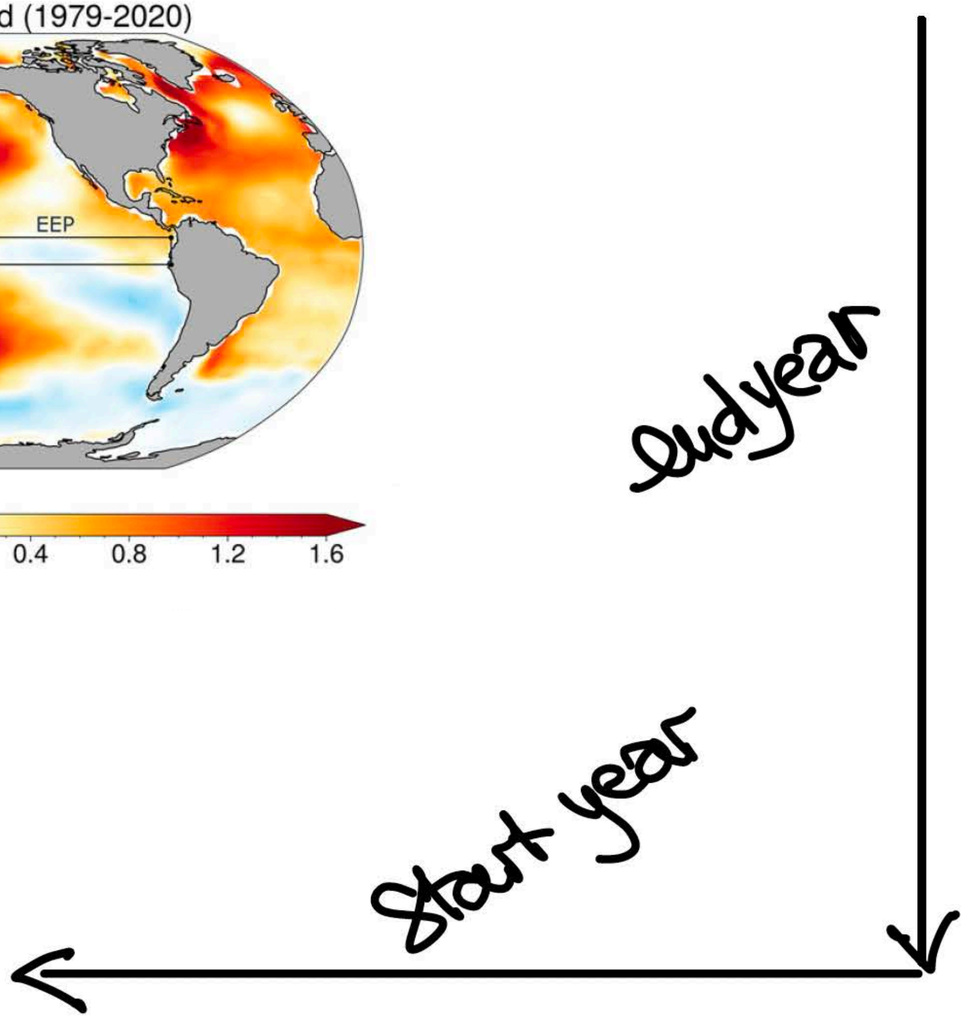

Rugenstein et al. 2023

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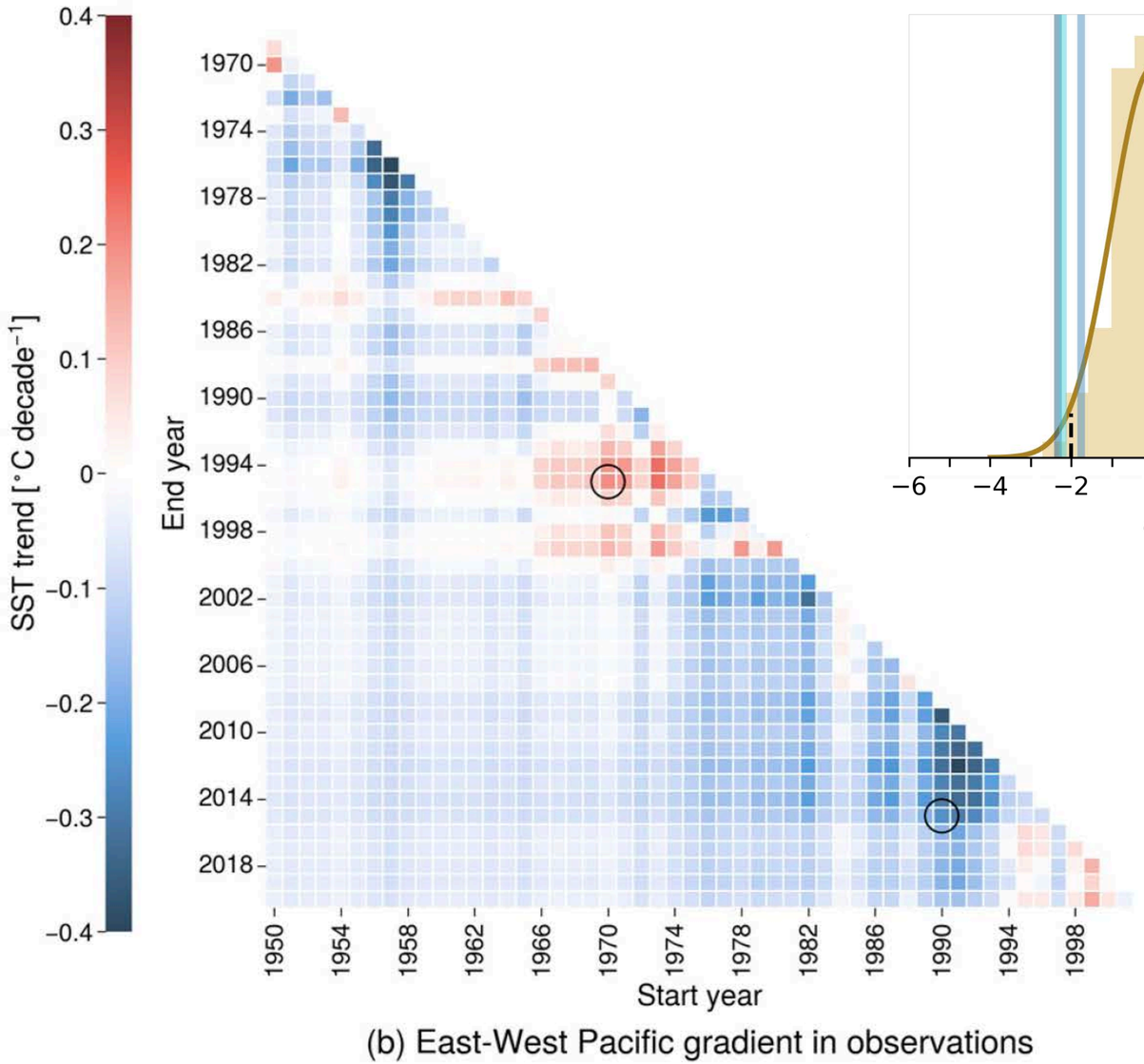

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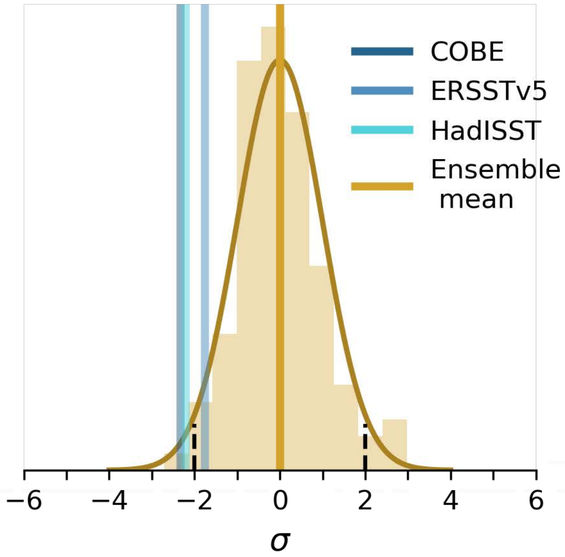

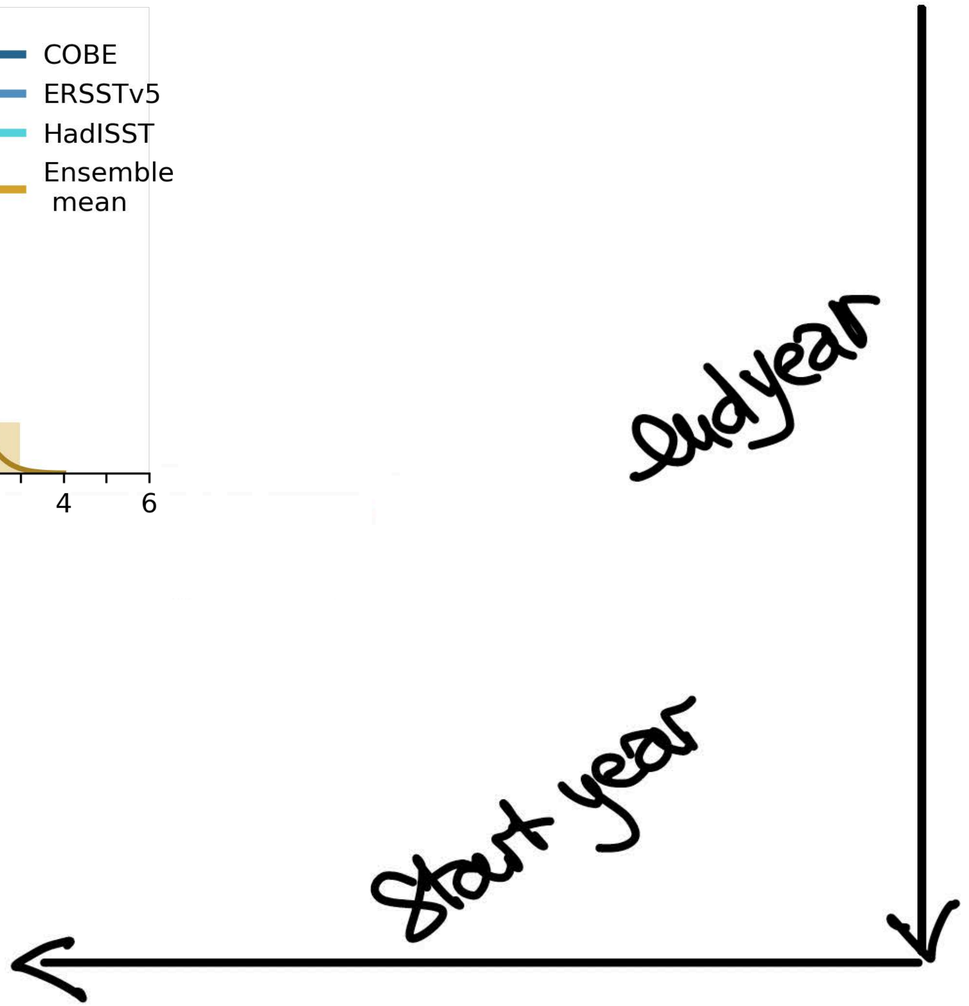

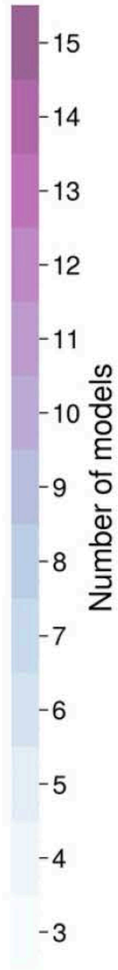

Rugenstein et al. 2023

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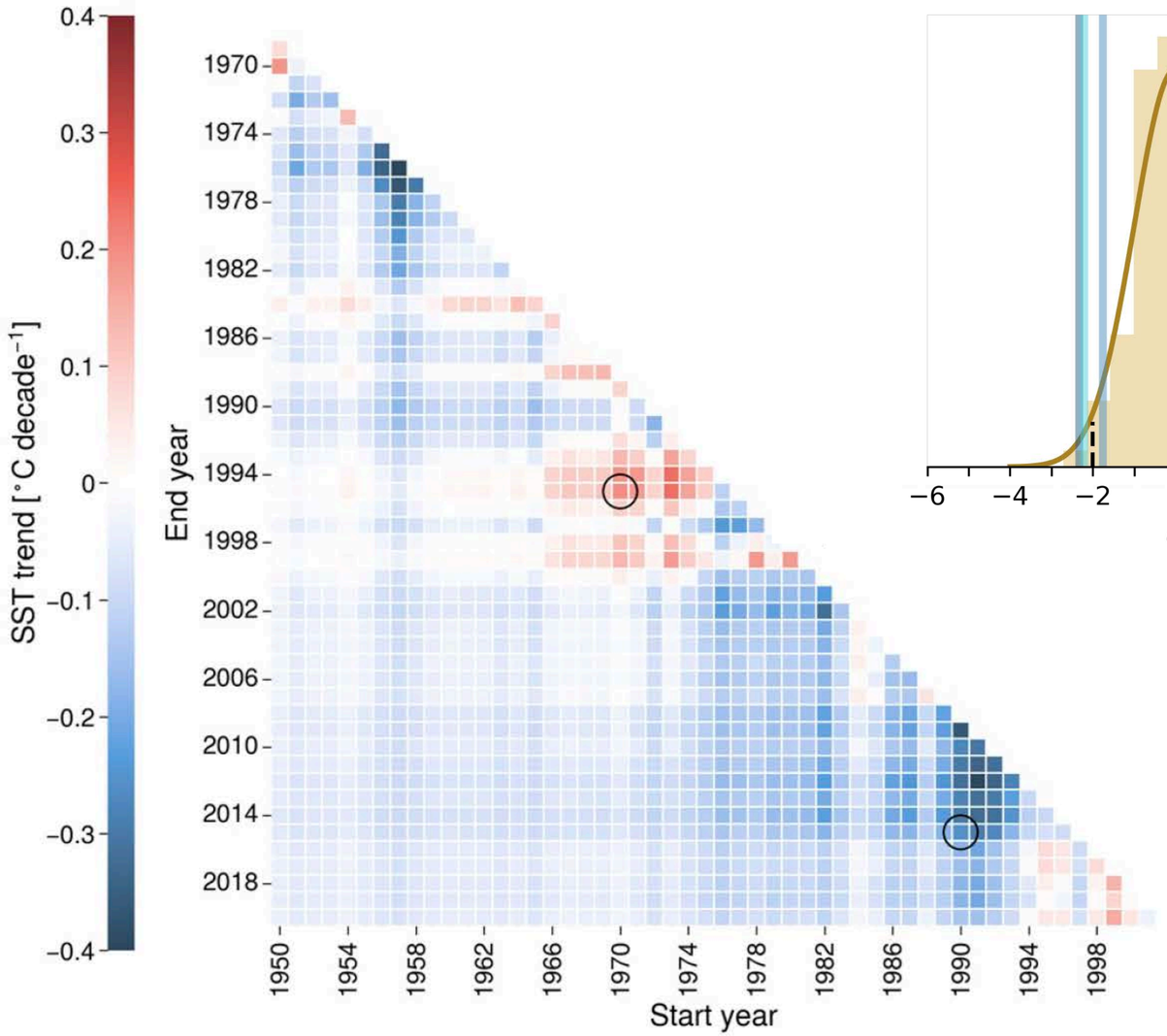

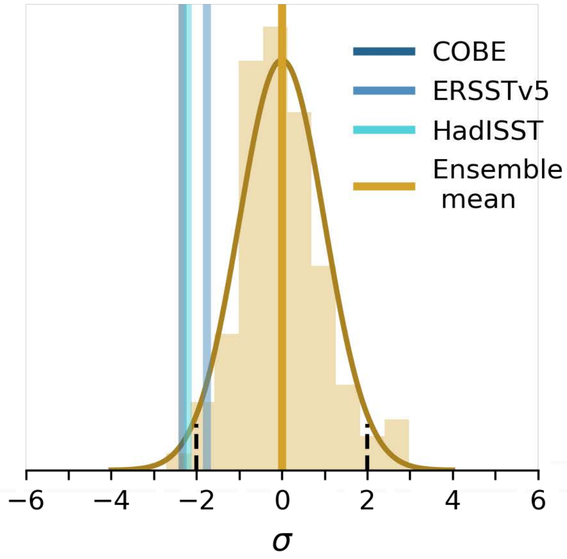

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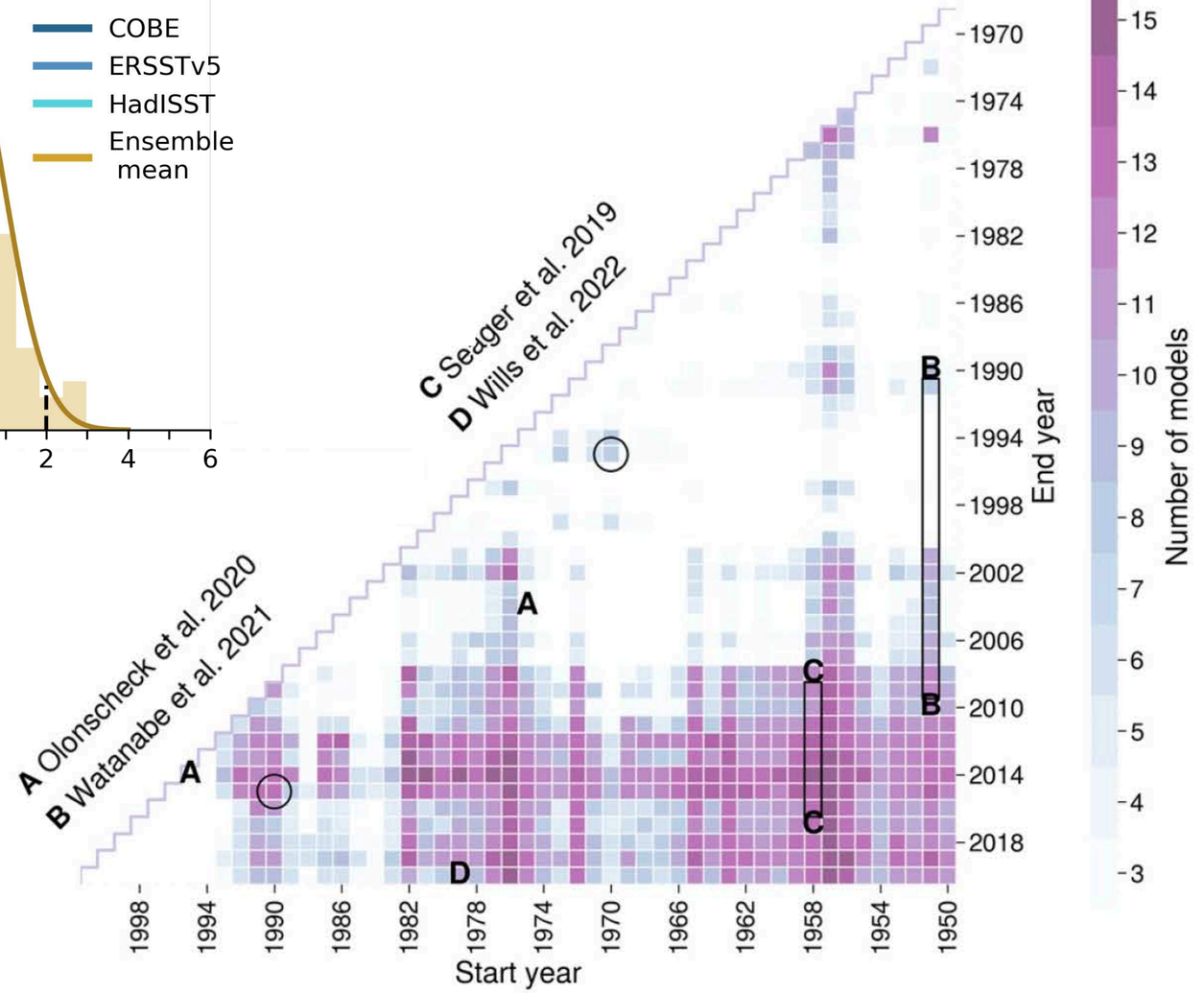
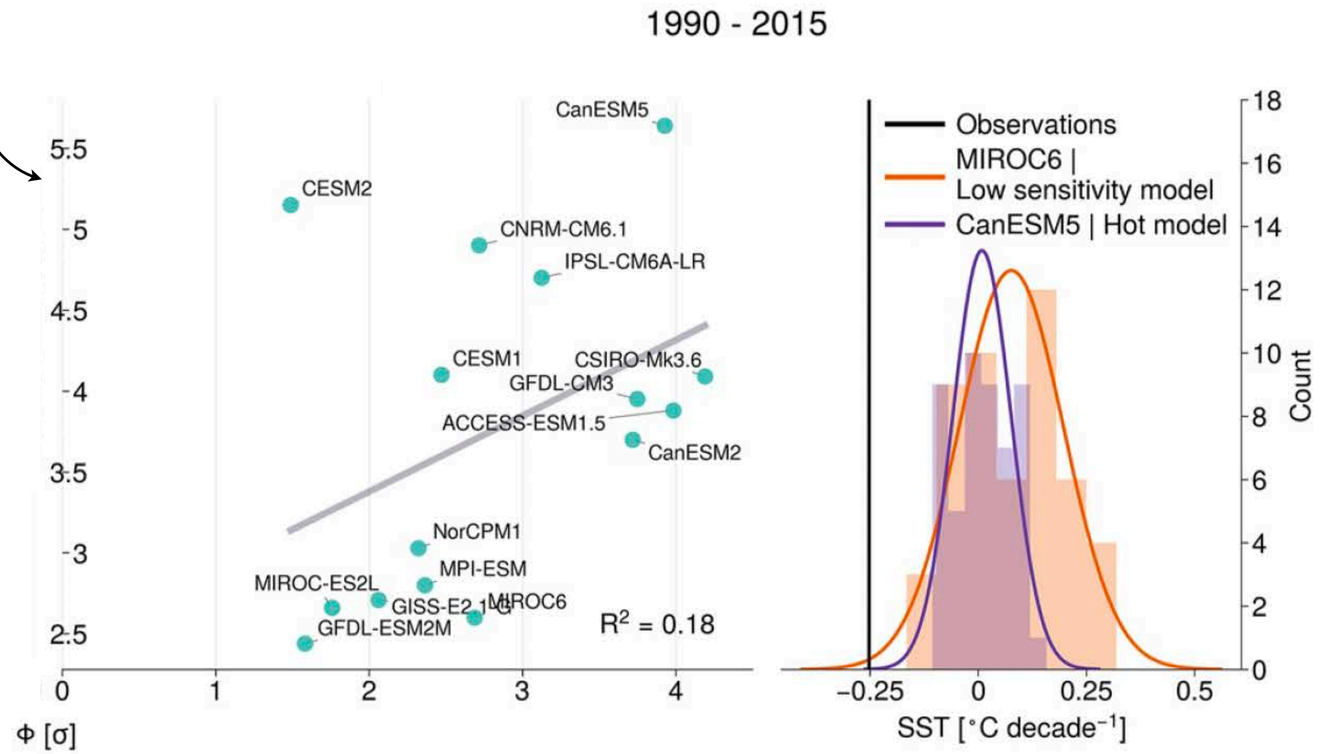


(c) CMIP model discrepancy with observations

Rugenstein et al. 2023

Models which cannot reproduce swings tend to have very high ECS

Effective Climate Sensitivity



Rugenstein et al. 2023

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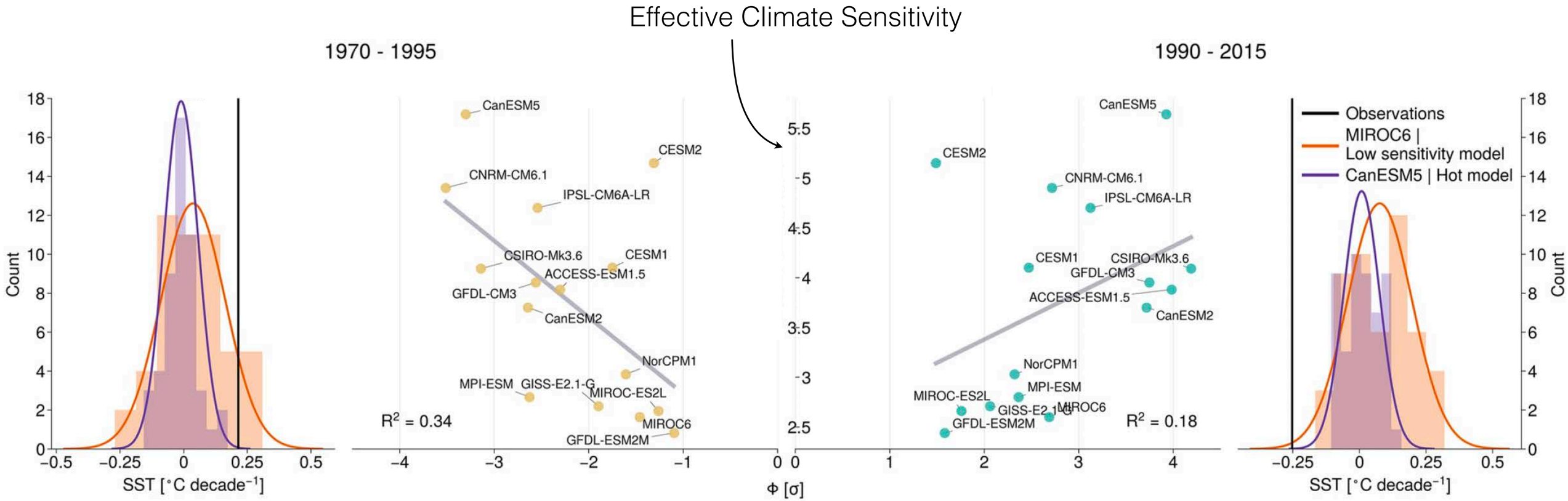
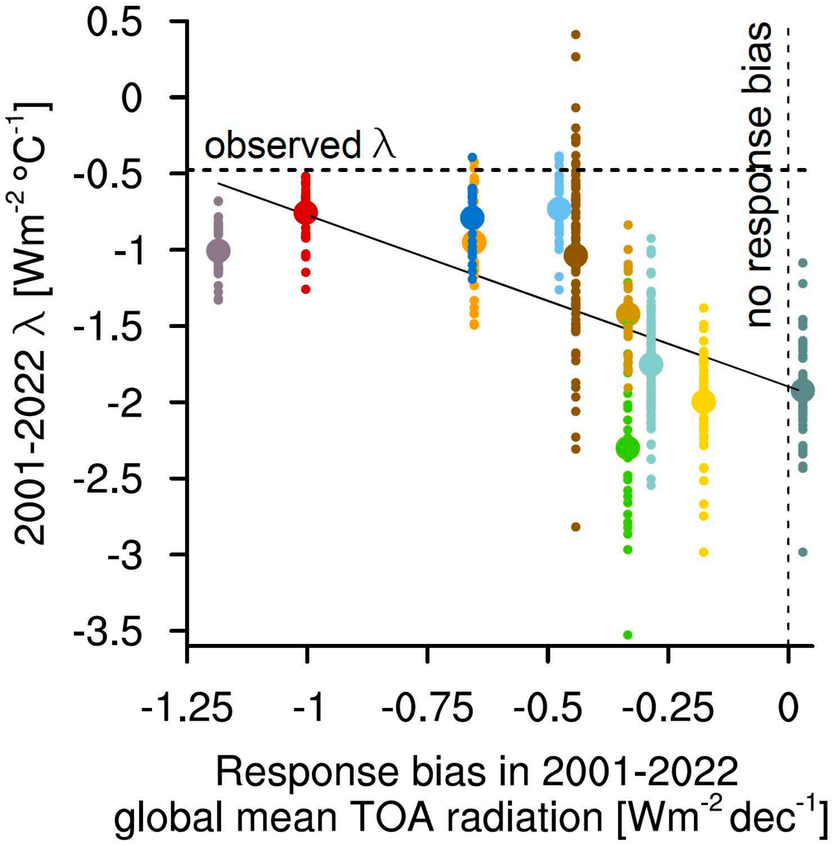


- Models all underestimate the slightly negative equatorial SST gradient on long timescales
- Half of the models underestimate the decadal-scale positive and negative swings
- Models with low variability tend to have a high climate sensitivity — possibly due to a mismatch between SST and EIS short-wave cloud feedback

Rugenstein et al. 2023

Radiative feedbacks change in time (unverifiably though)



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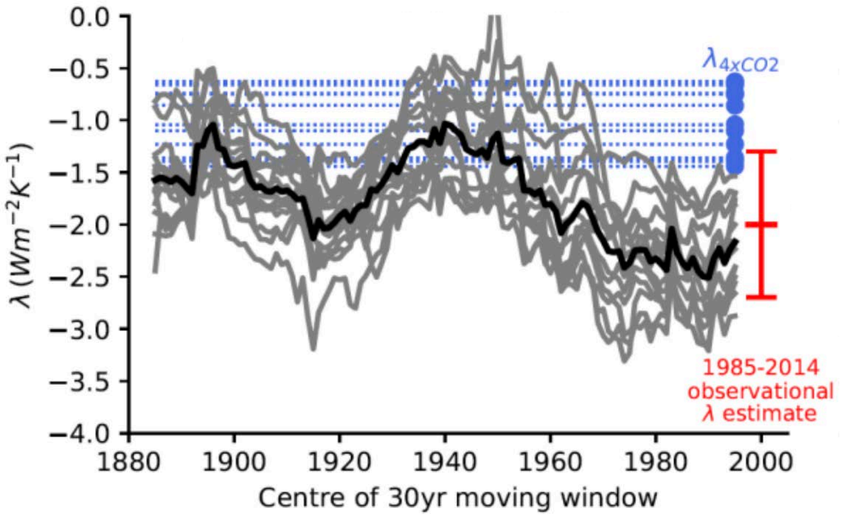
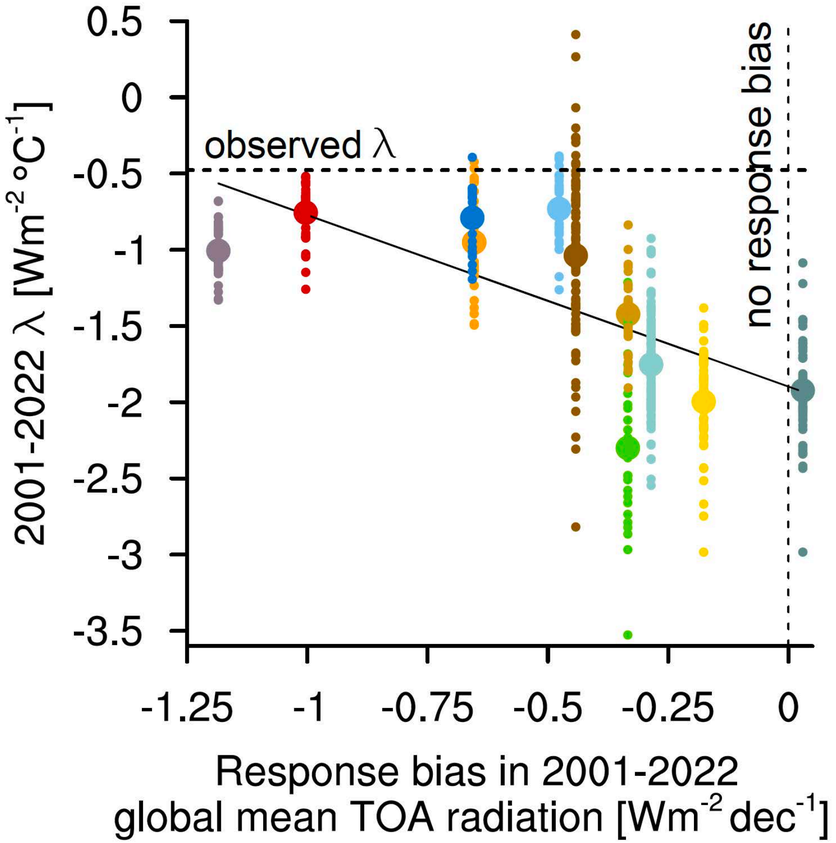
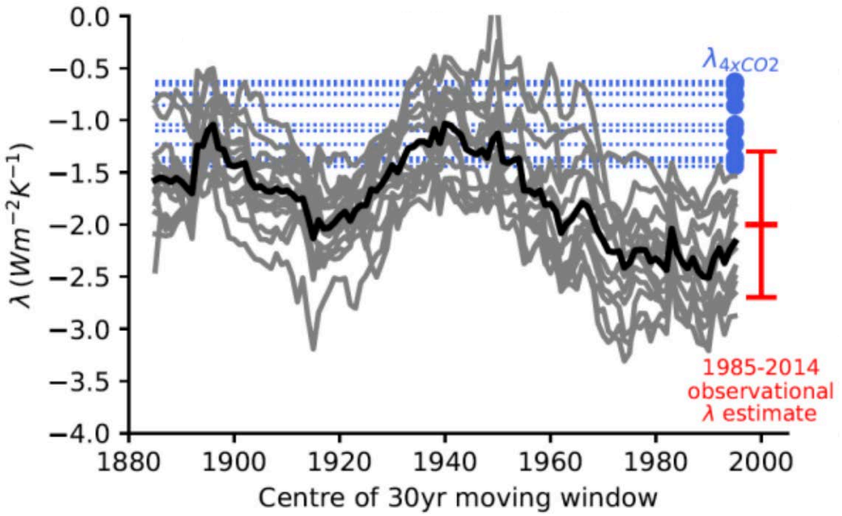


Andrews et al. 2022

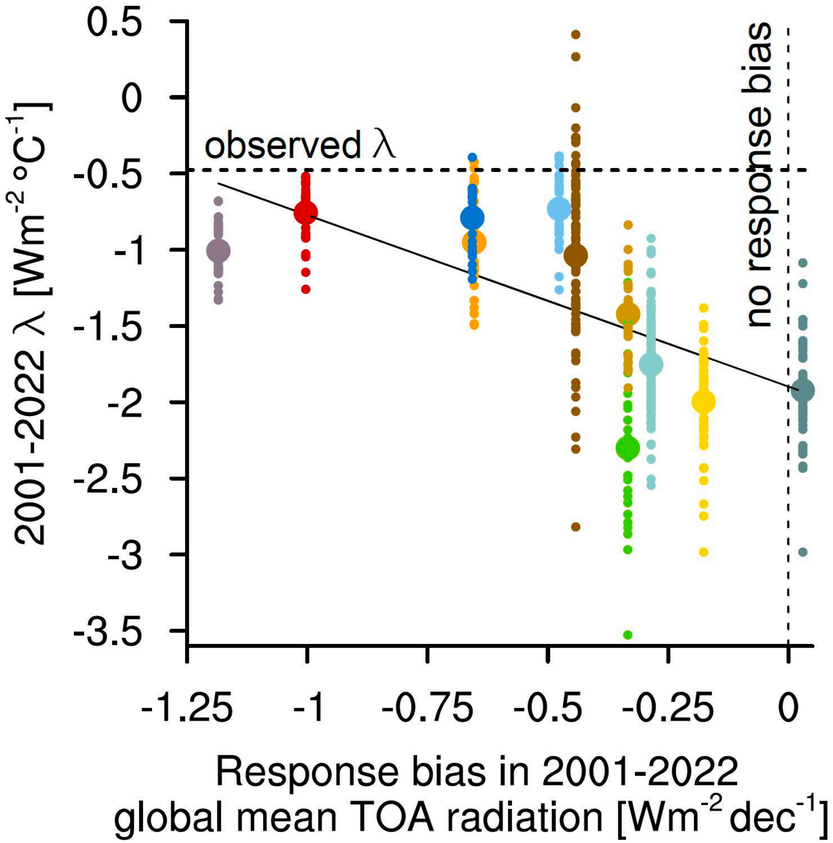


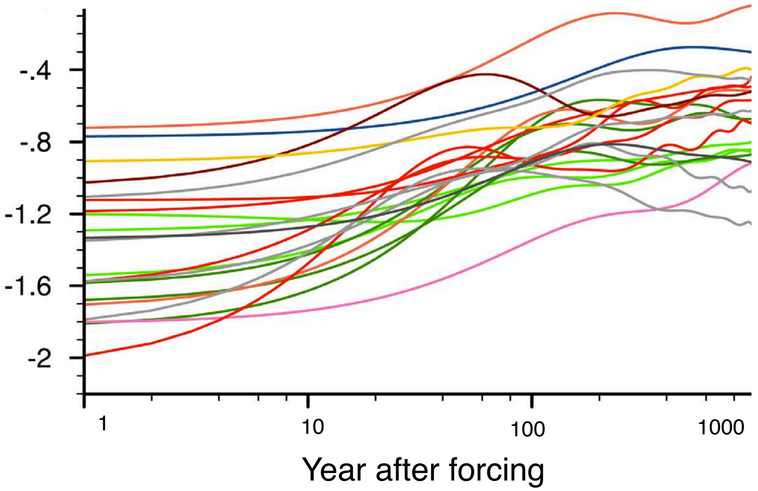
Andrews et al. 2015, 2017, 2018, 2022; Williams et al. 2008, Winton et al. 2010, Armour et al. 2013, 2017; Zhou et al. 2016, 2017; Dong et al. 2019, 2020, Williams et al. 2023, Gregory et al. 2018, Ceppi and Gregory 2019, Rugenstein et al. 2016, 2020; Salvi et al. 2022, …

How will SST patterns and radiative feedbacks change in the future?



Andrews et al. 2022





LongRunMIP.org

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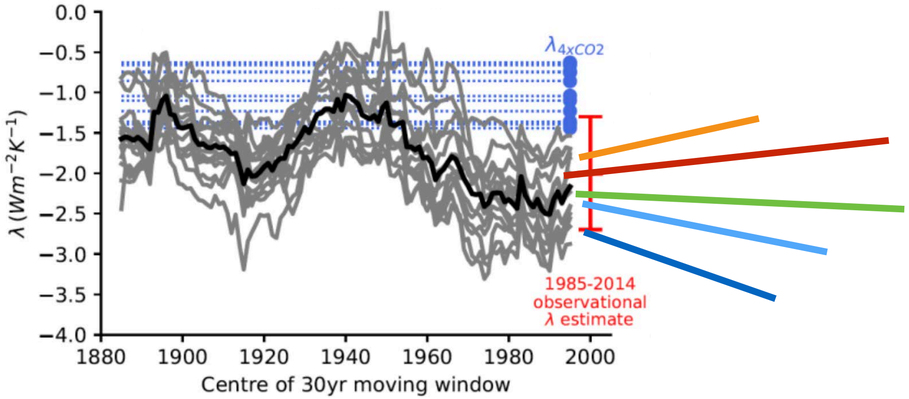
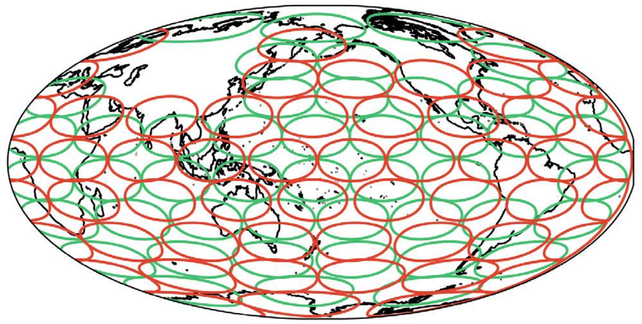
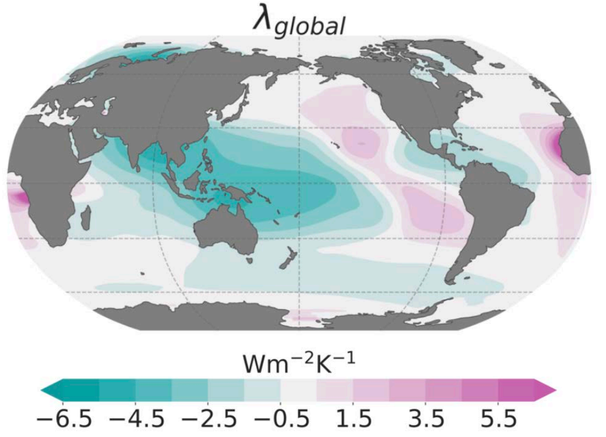


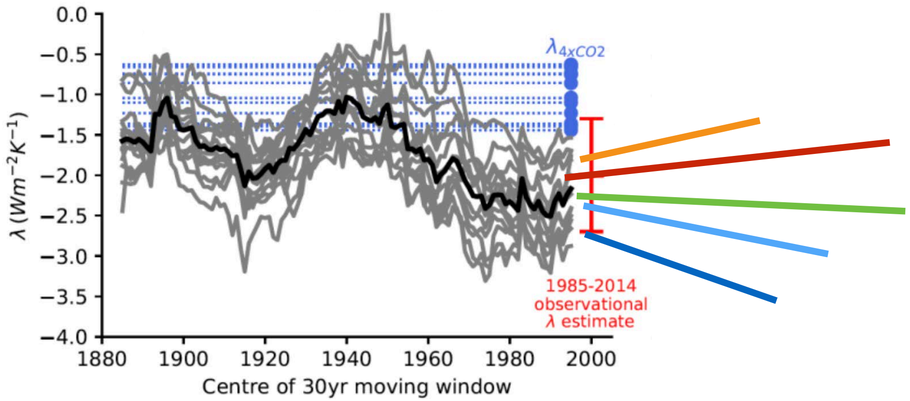


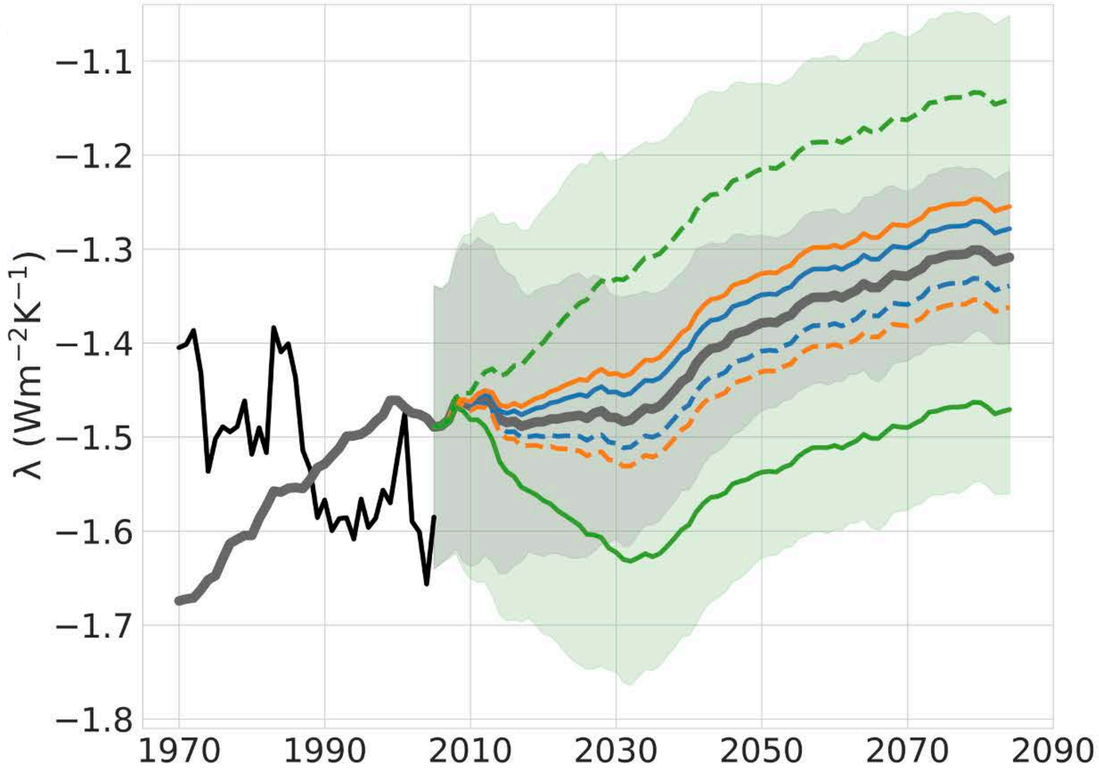
See Green's function MIP
Block-Johnson et al. 2024



Alessi and Rugenstein, 2023: Surface temperature pattern scenarios suggest higher warming rates than current projections

Redistributing warming has strong effect on feedbacks





Alessi and Rugenstein 2023

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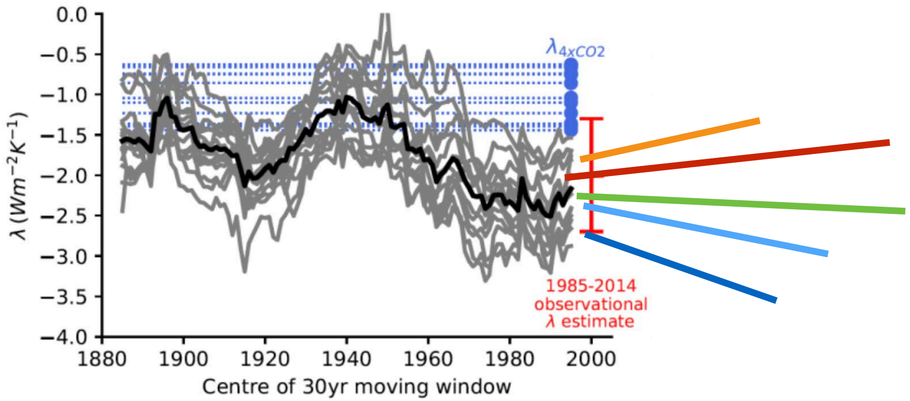

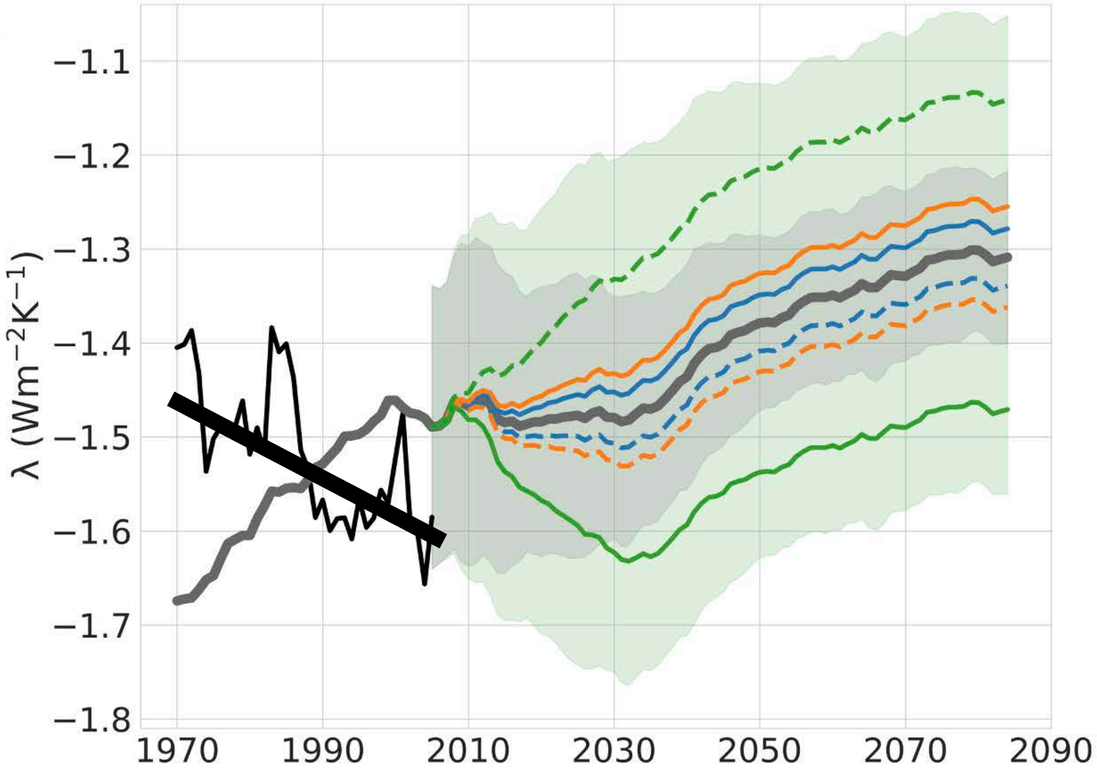

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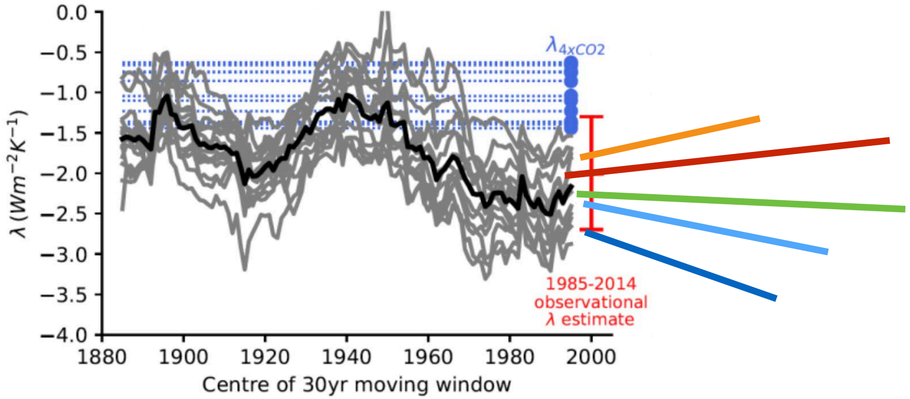

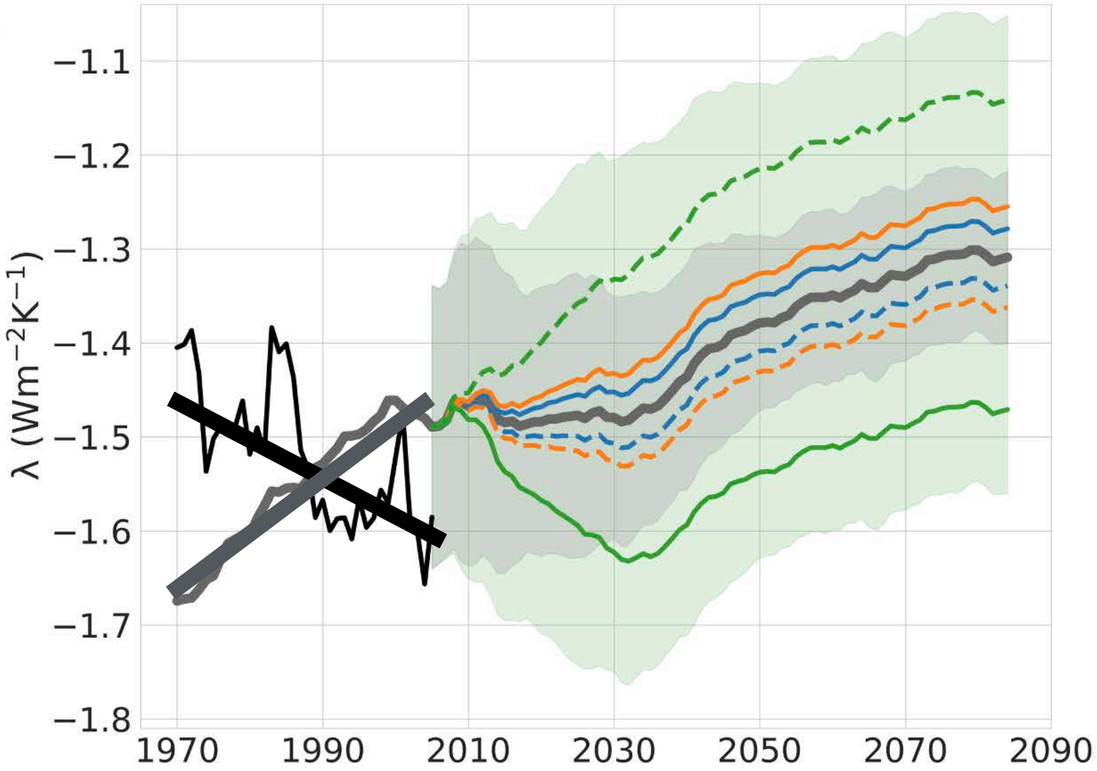

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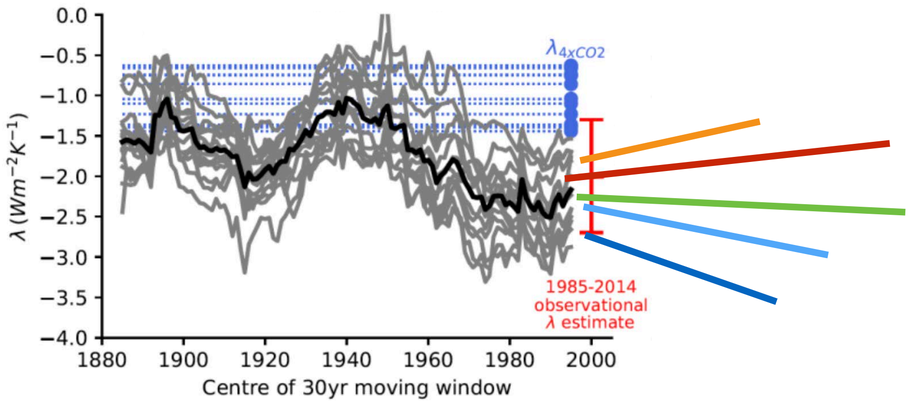

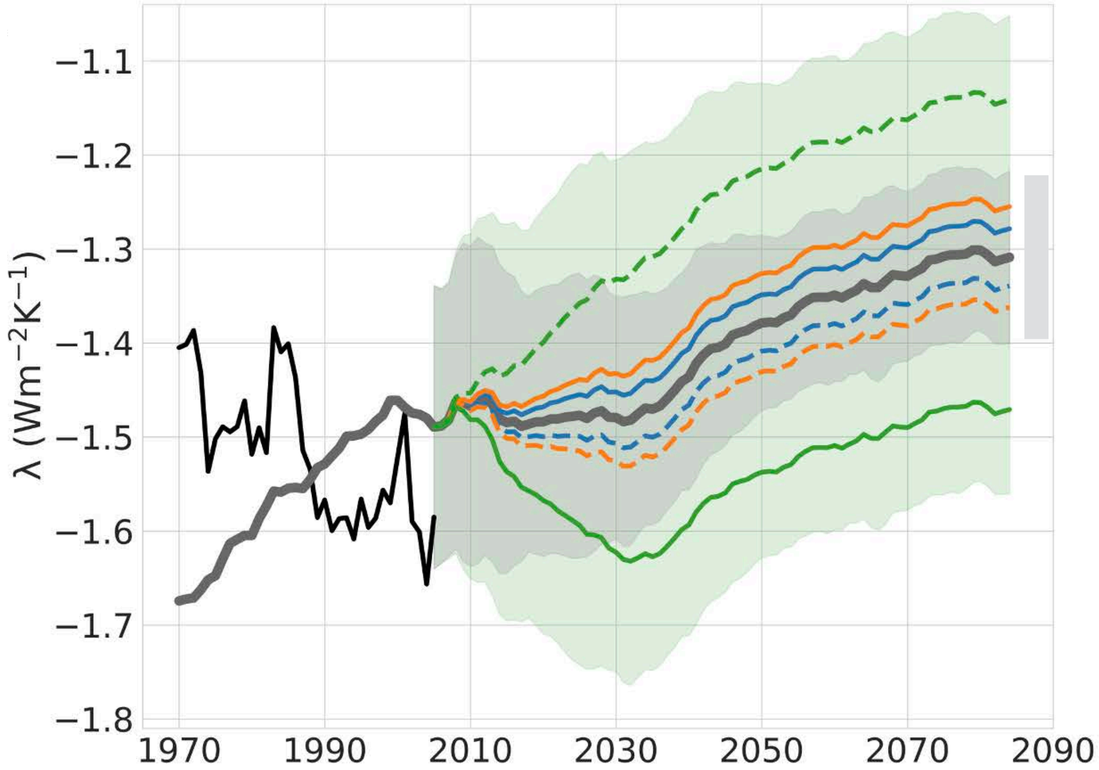

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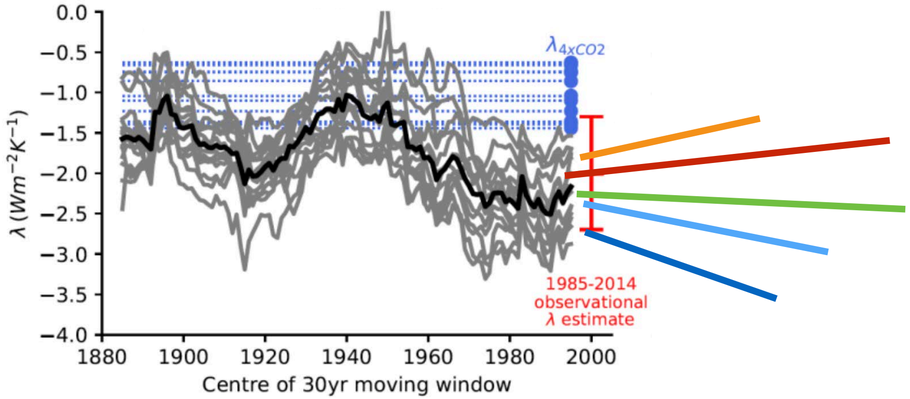
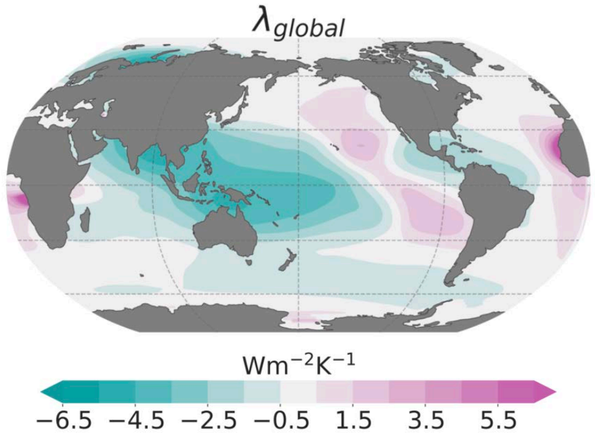
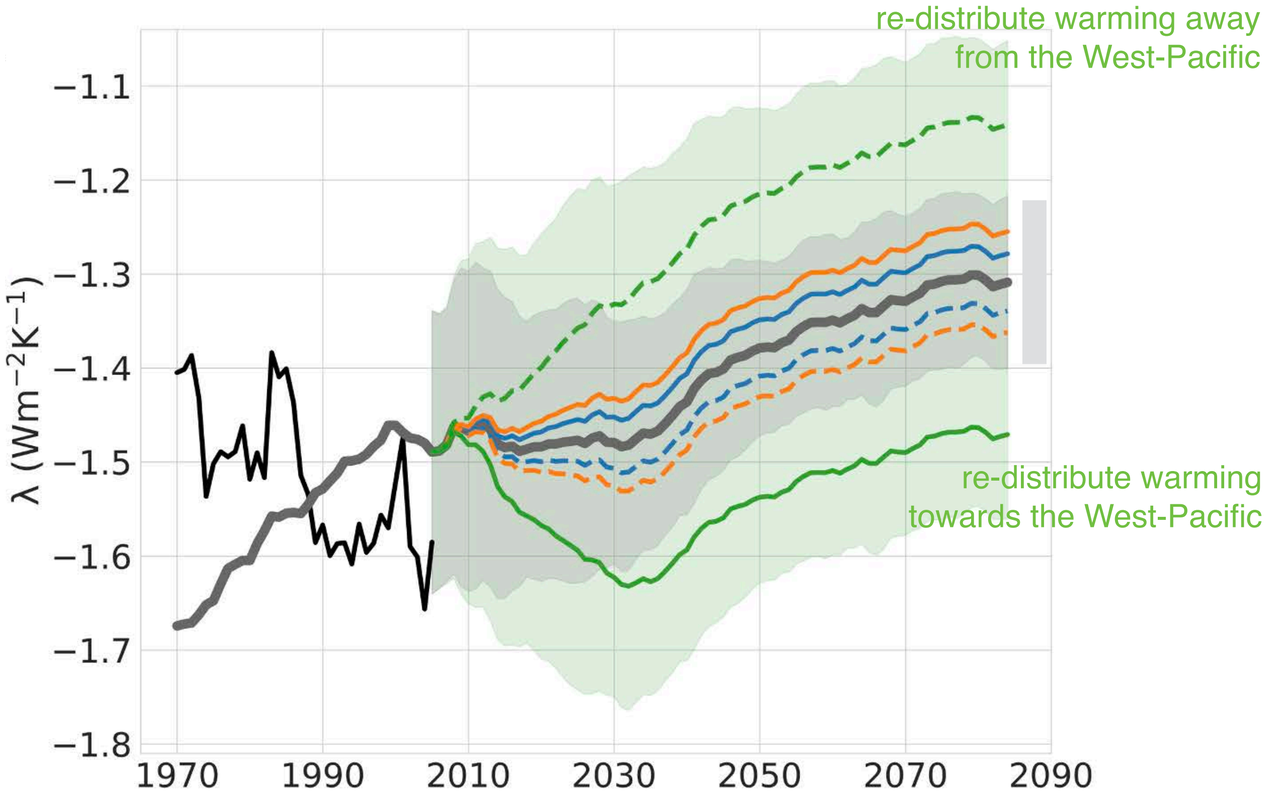
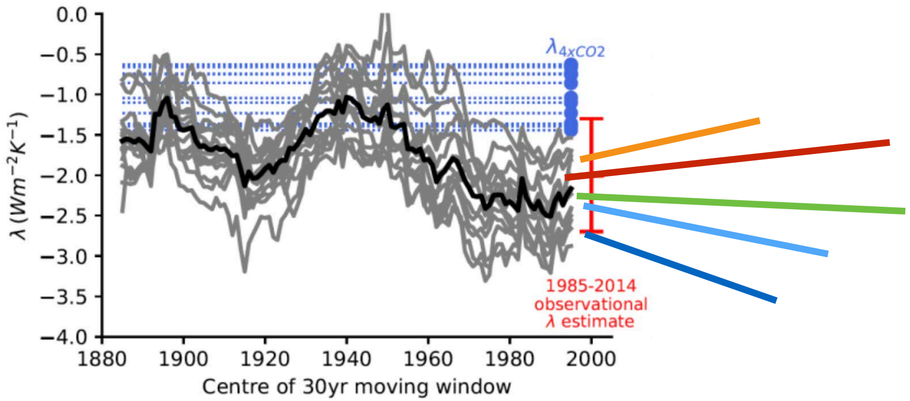


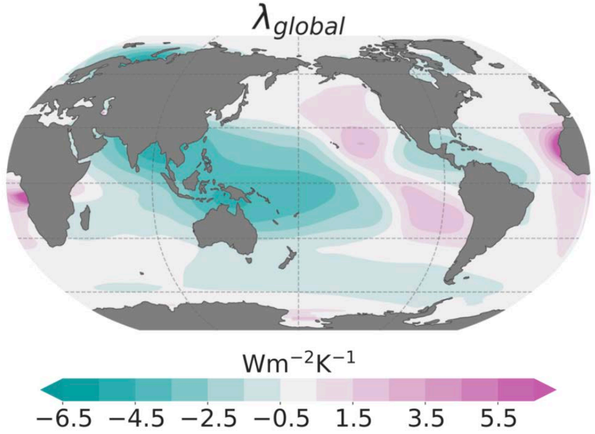


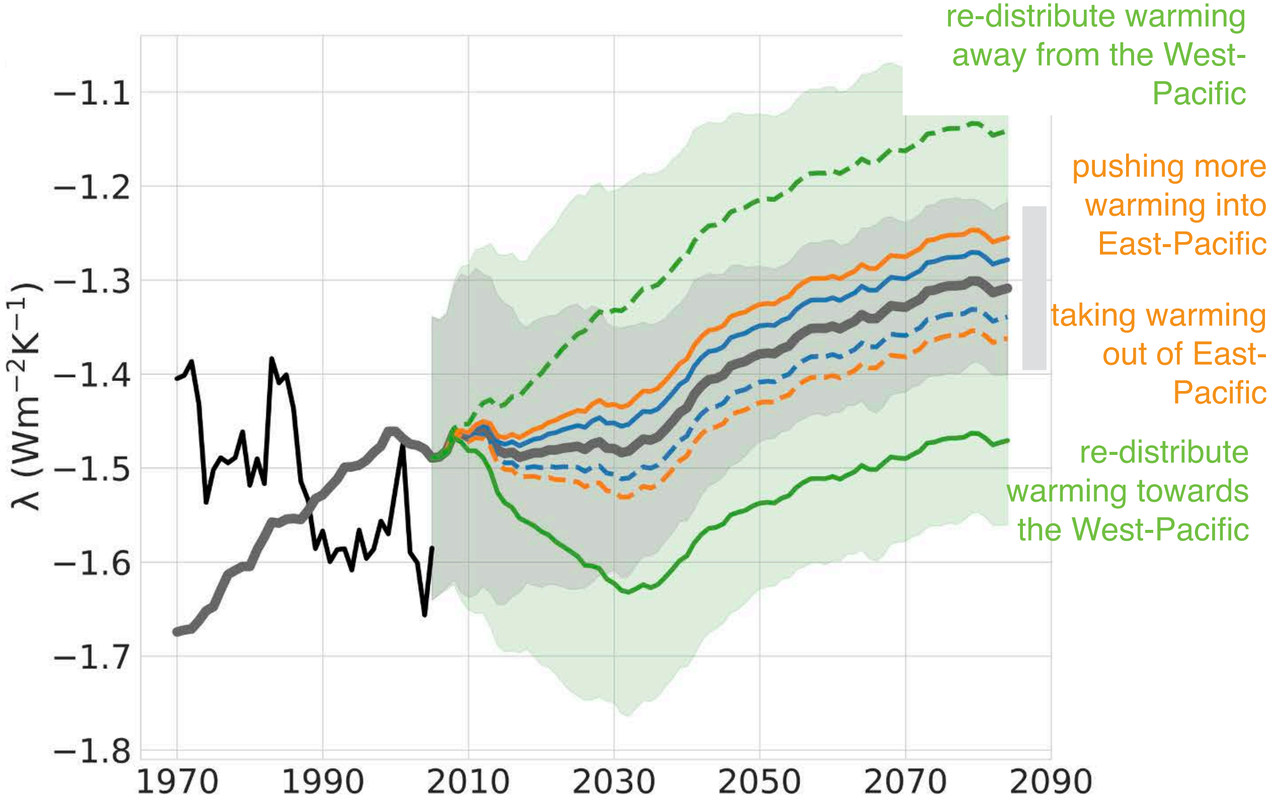


Alessi and Rugenstein 2023

Redistributing warming has strong effect on feedbacks

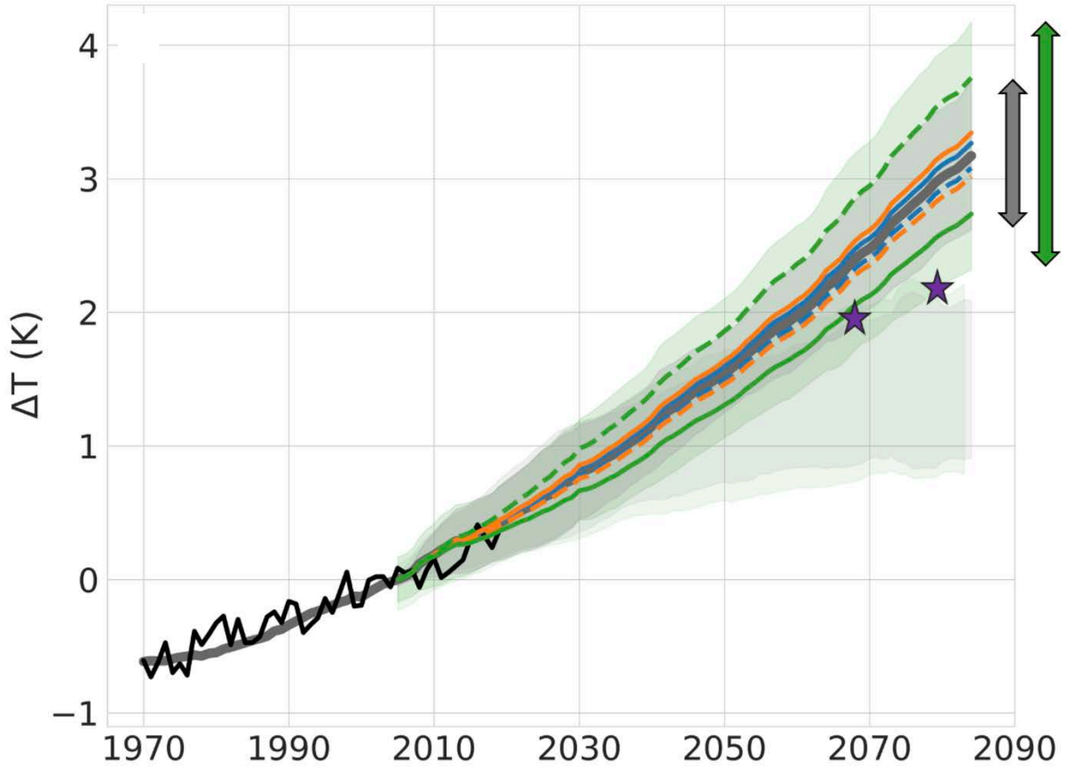


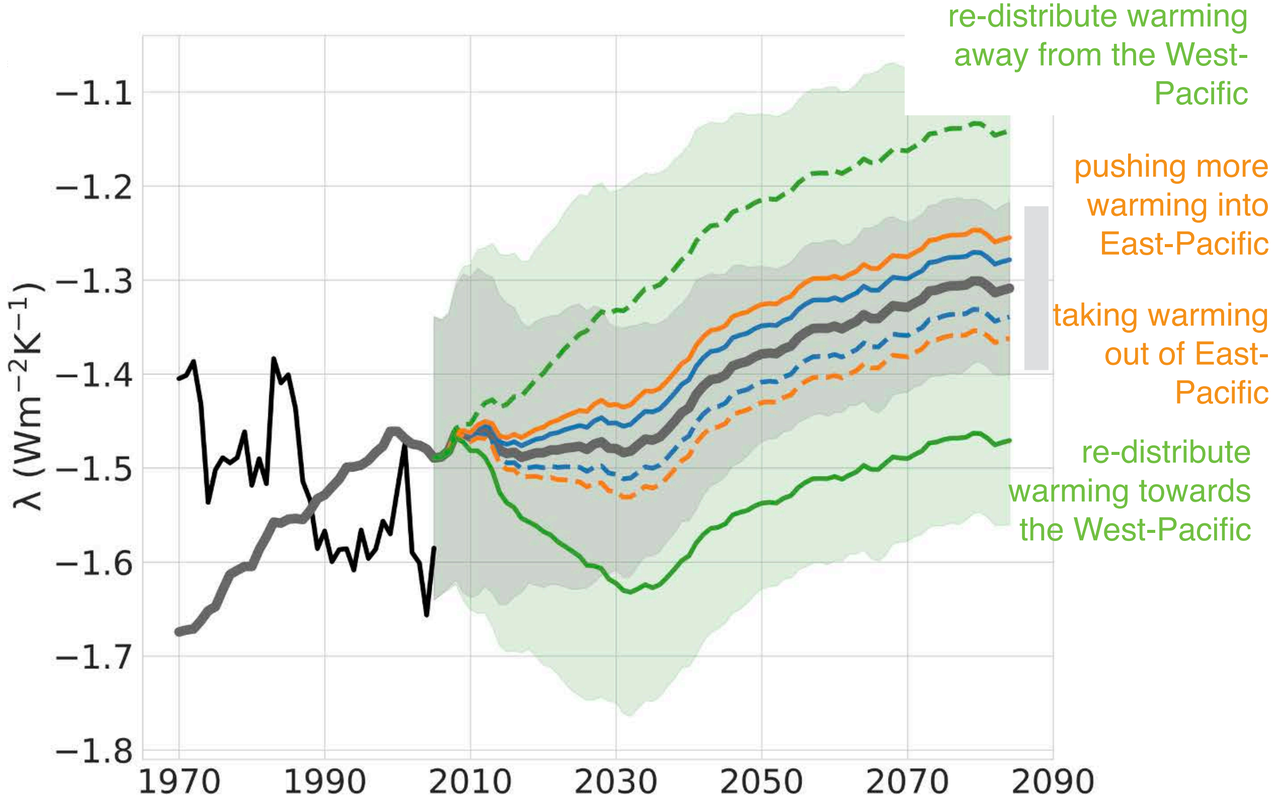




Alessi and Rugenstein 2023

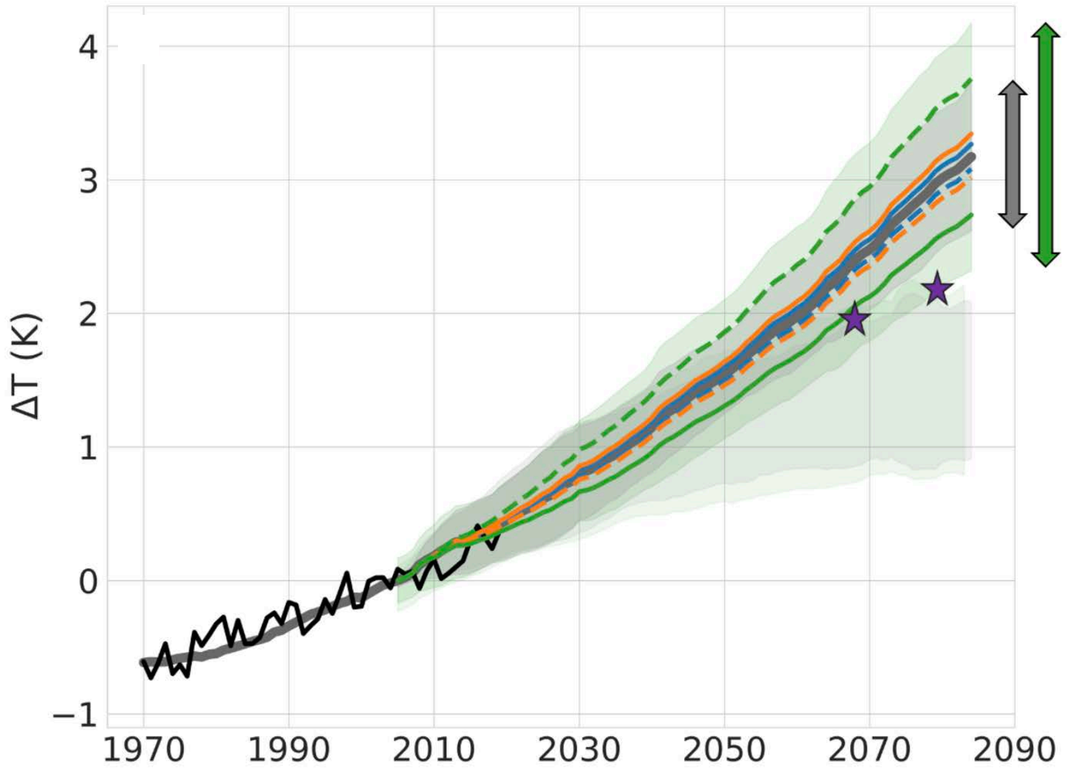
Redistributing warming has strong effect on global temperature

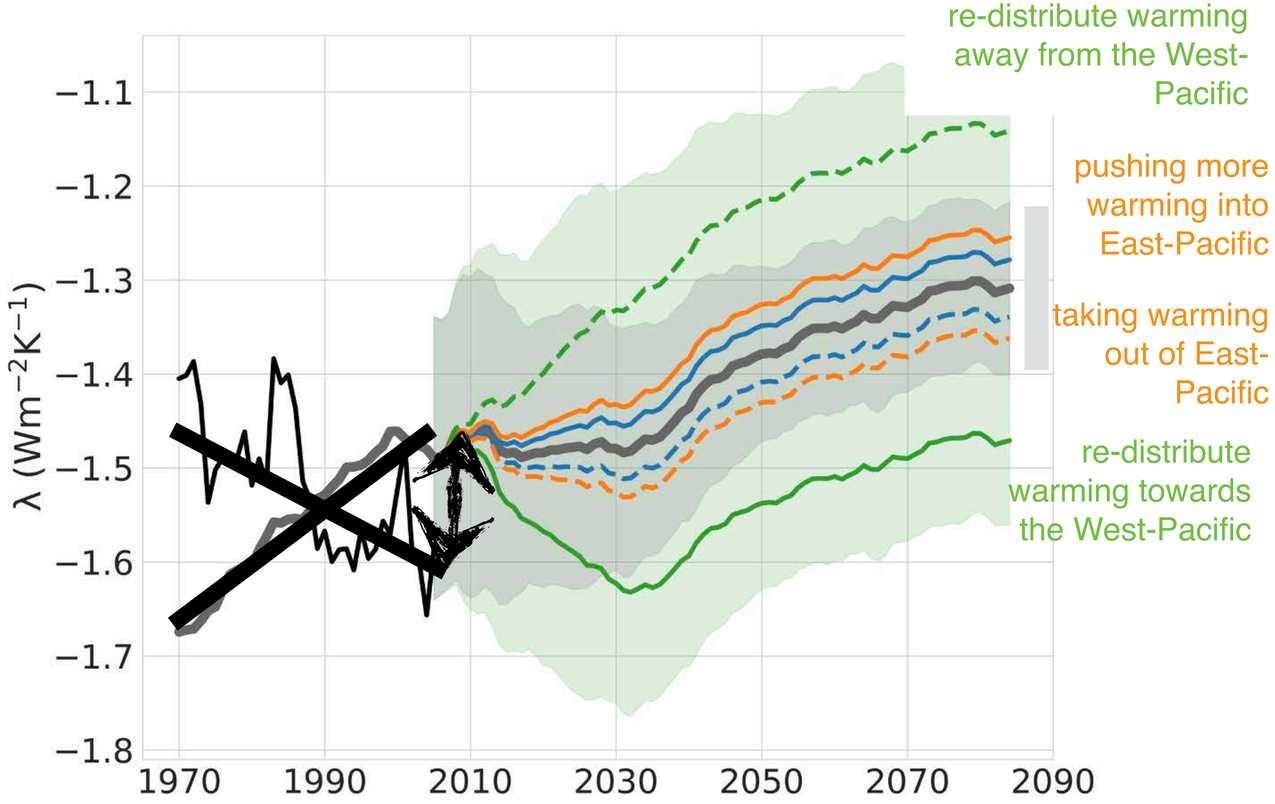




Alessi and Rugenstein 2023

Redistributing warming has strong effect on global temperature

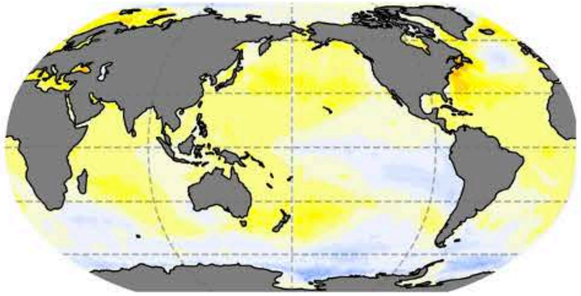


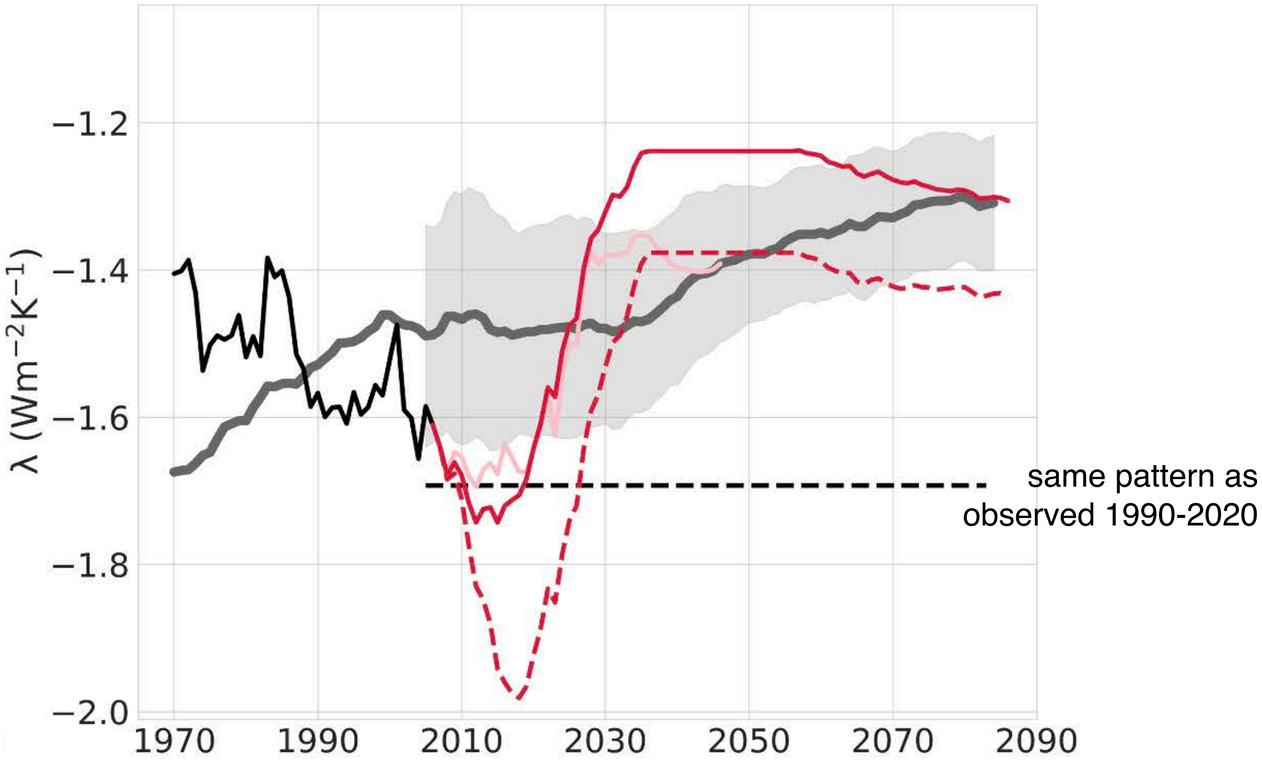


Alessi and Rugenstein 2023

Storylines of realistic trends into the future

Observed SST trend 1990-2020





Alessi and Rugenstein 2023

Storylines of realistic trends into the future

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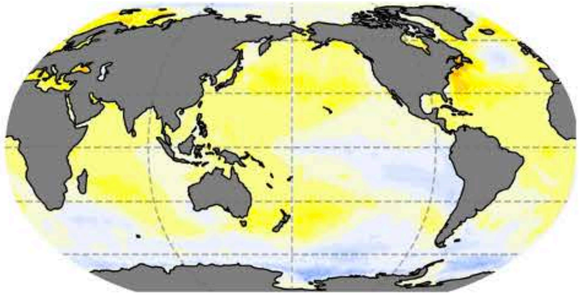
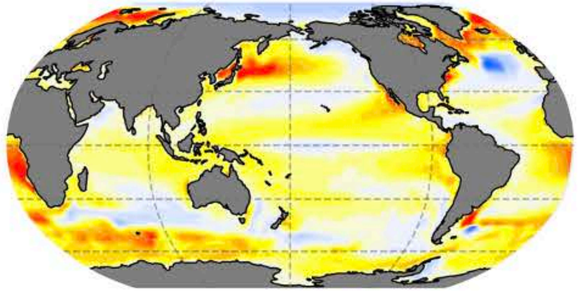
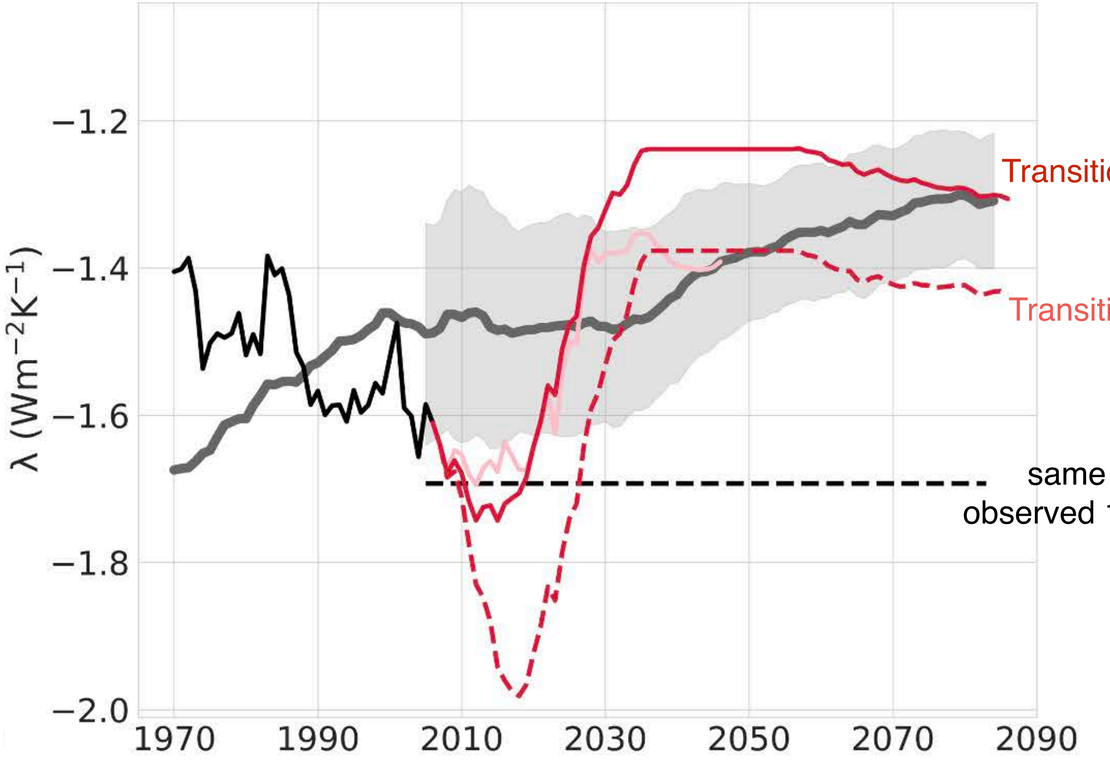


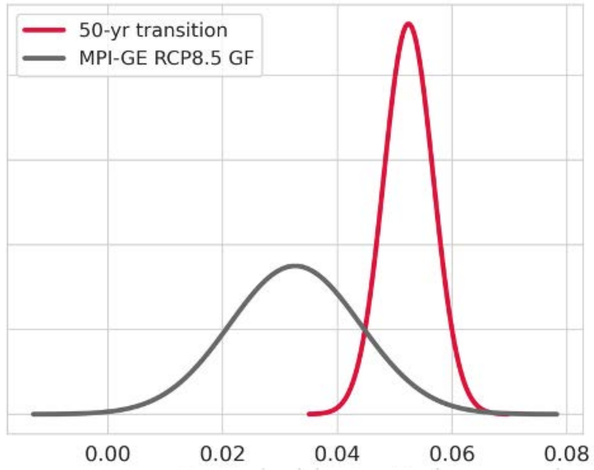
Interpolation observed to future



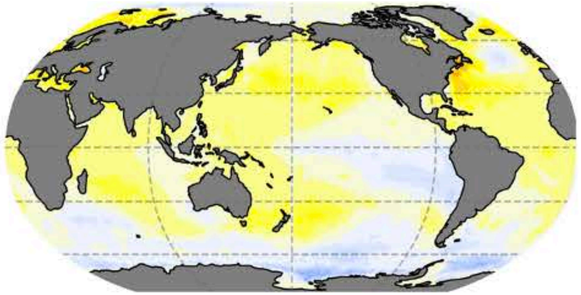


Alessi and Rugenstein 2023

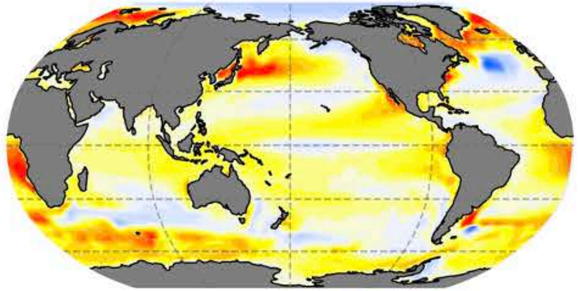
Storylines of realistic trends into the future

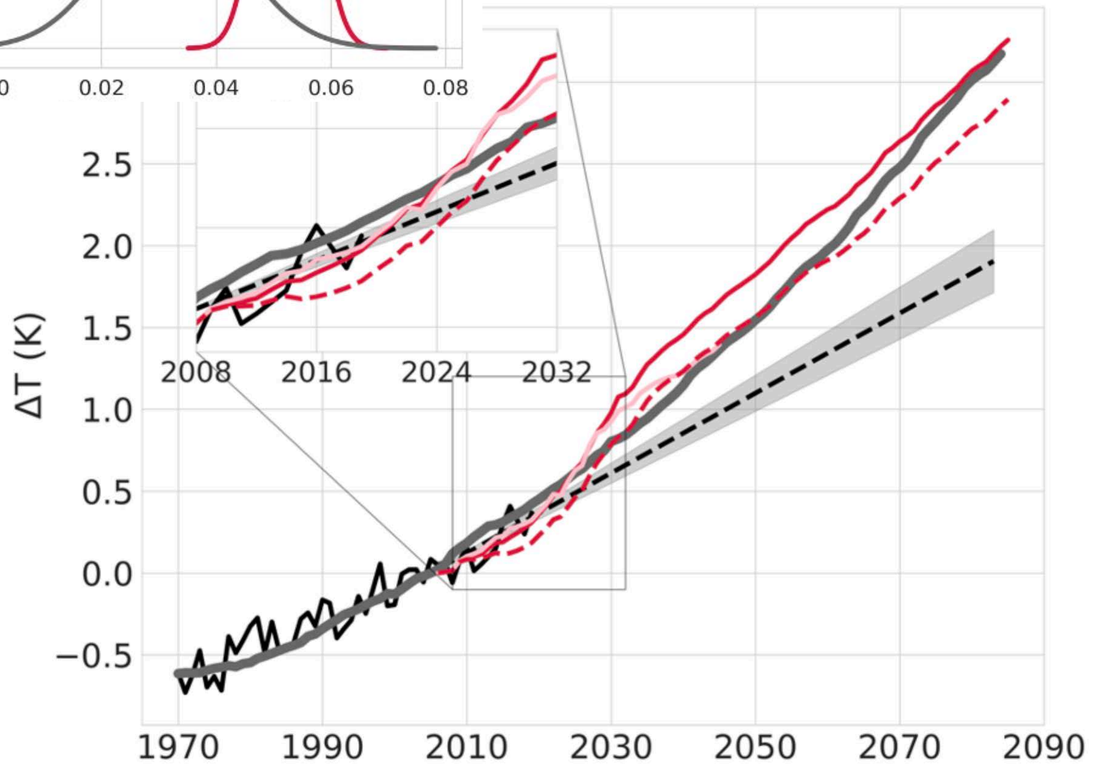


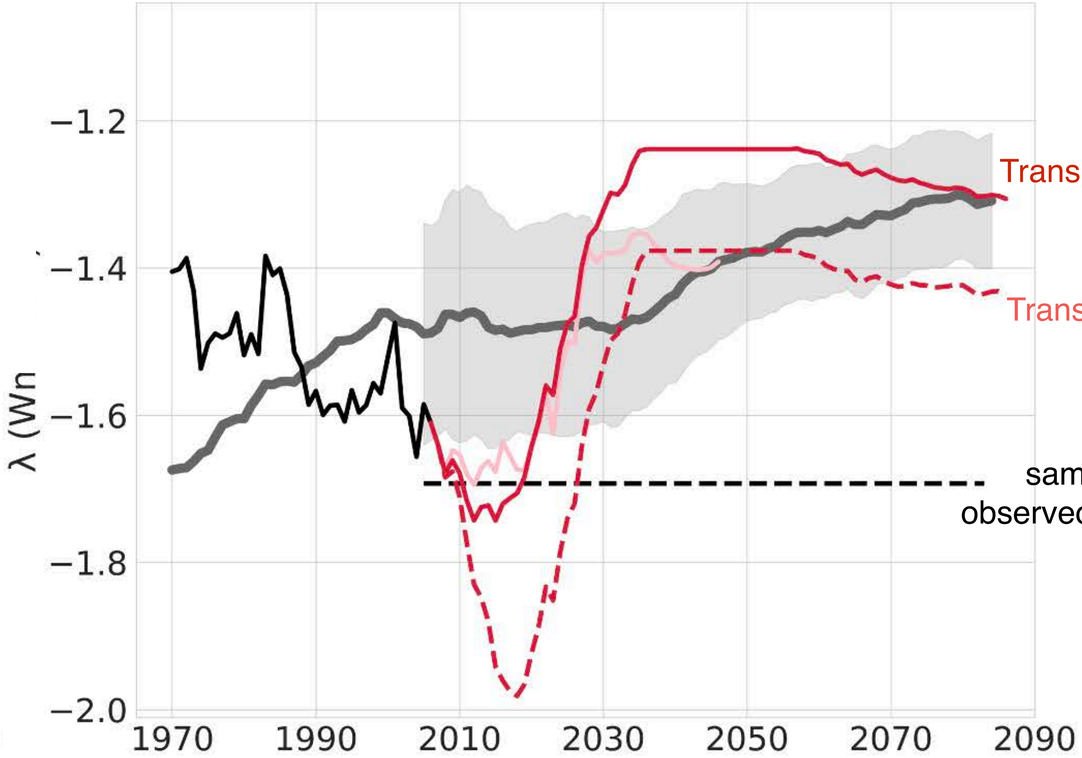
Observed SST trend 1990-2020



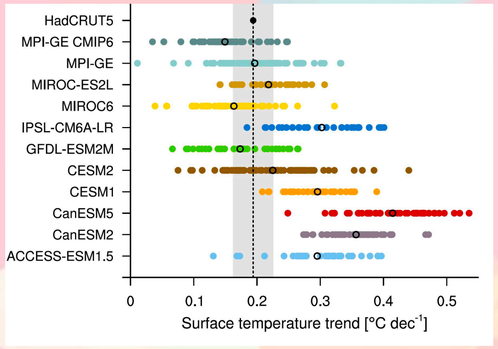
Interpolation observed to future

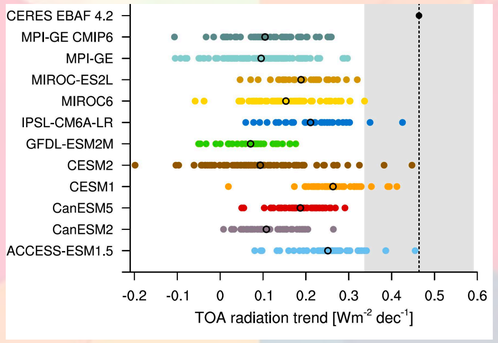


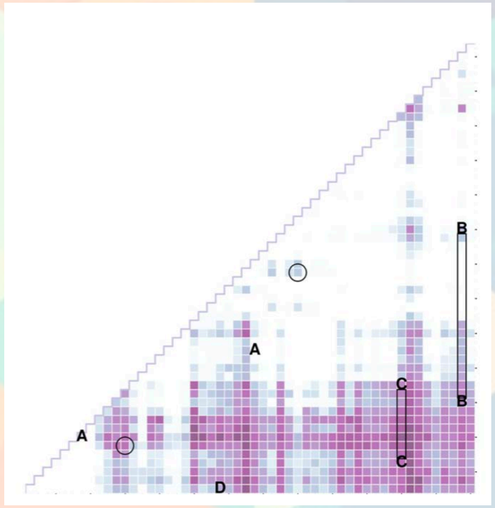




Alessi and Rugenstein 2023







How the good and the bad conspire to the ugly

Observable TOA radiation trends

are seriously underestimated even though surface temperature is OK, feedbacks are unmeaningful

Observable surface temperature trends

are locally and for certain timescales systematically off, radiation is unknown and feedbacks unverifiable

Implications for projections of climate change

If the SST pattern problem and the heat uptake problem persist into the future projections of global-mean temperature might be seriously off

Observations: strong heat uptake balanced by strongly restorative feedback;
Climate models: weak heat uptake balanced by too positive feedbacks