

Pathway to regular and sustained delivery of climate forcing datasets workshop: 28-31 October 2024, ECMWF Reading

Session 4: Identifying and addressing gaps and uncertainties

Chairs: Paul J. Durack, Vaishali Naik

Session outline

- Paul D: set the stage - 5 mins
- Olivier: How are historical/DECK forcings implemented in an ESM - 10+3 mins
- Stephanie F: How do we identify and recommend forcings datasets for models - example of simple plume aerosols - 10+3 mins

Discussion on uncertainties in forcing implementations in models

- Alternate datasets? Address missing processes or elucidate forcing uncertainties
- Ken M: Freshwater from ice sheets - 10+3 mins
- Yi Y: Groundwater for irrigation - 10+3 mins
- Douglas H: Alternative fire emissions - 10+3 mins

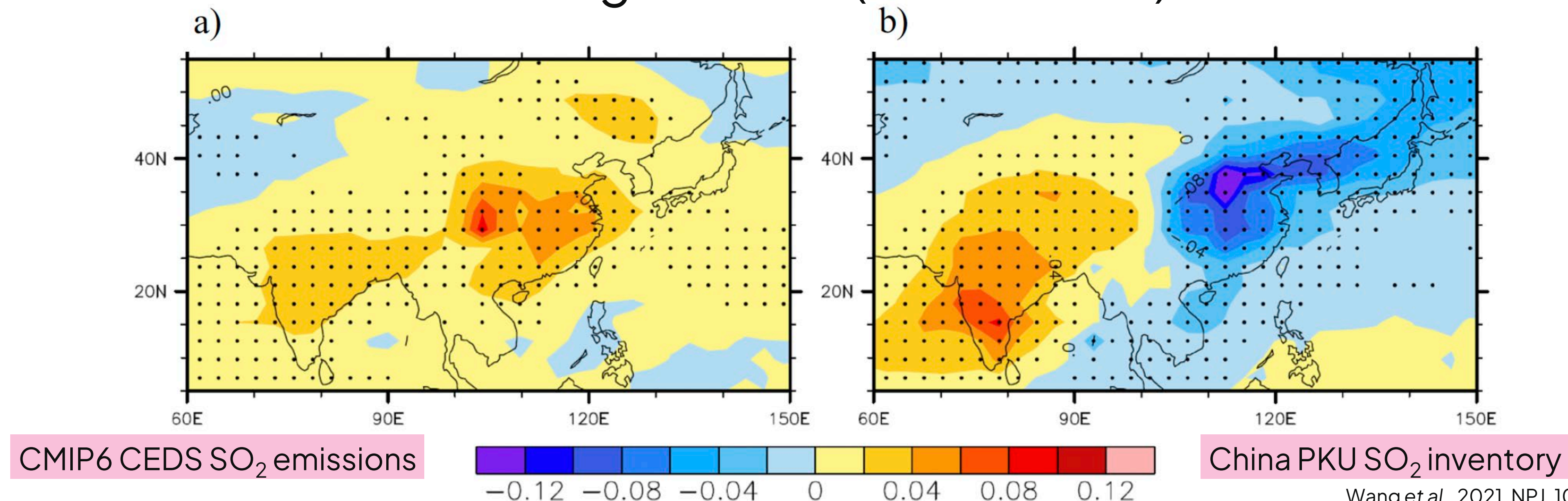
Discussion: decisions on additional forcings for CMIP7

Forcings: implications and uncertainties

Past CMIP analyses highlight simulated climate discrepancies due to forcing, e.g.,

- CMIP3, models that **excluded volcanic/stratospheric aerosol optical depth (SAOD) forcing** had ocean heat content (OHC) warming trends 2-4x higher than observations ([Domingues et al., 2008, NAT](#))
- CMIP5, **SAOD forcing corrections** brought early 21st century OHC warming rates down in line with observations ([Durack et al., 2018, Oceanog.](#)); Model simulations without effects of moderate modern volcanoes (after 2000) overestimate observed tropospheric warming since 1998 ([Santer et al., 2014, NATGeo](#); [Schmidt et al., 2014, NATGeo](#))
- CMIP6, models failed to capture observed dipole pattern of AOD trends over Asia during 2006-2014 due to the **underestimate of SO₂ emissions decline in China** ([Wang et al., 2021, NPJ](#); see also [Paulot et al., 2018, ACP](#); [Quaas et al., 2022, ACP](#))

Change in AOD (2014-2006)

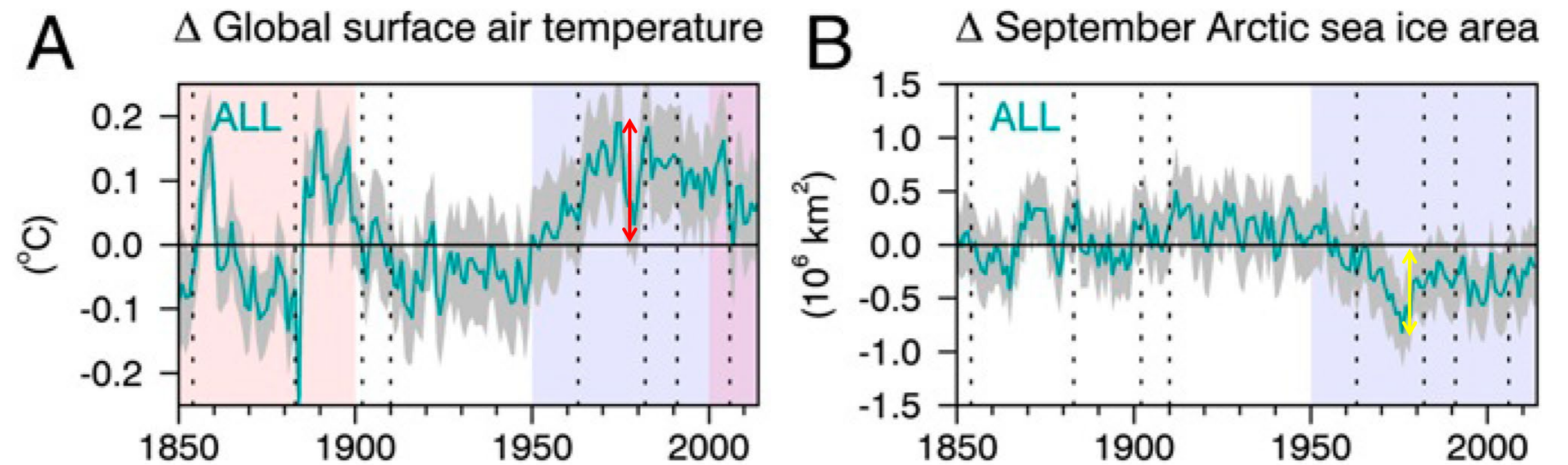


Forcings: how much do they matter?

- Forcing changes over CMIP phases
- But so do model changes
- CCCma, NCAR, E3SM evaluated forcing impact
 - Change the forcing, keep model same
 - Change the model, keep forcing the same
- CCCma:
 - “..results provide evidence that global change uncertainty arising between different forcing estimates can be as large as uncertainty arising from different model versions..”

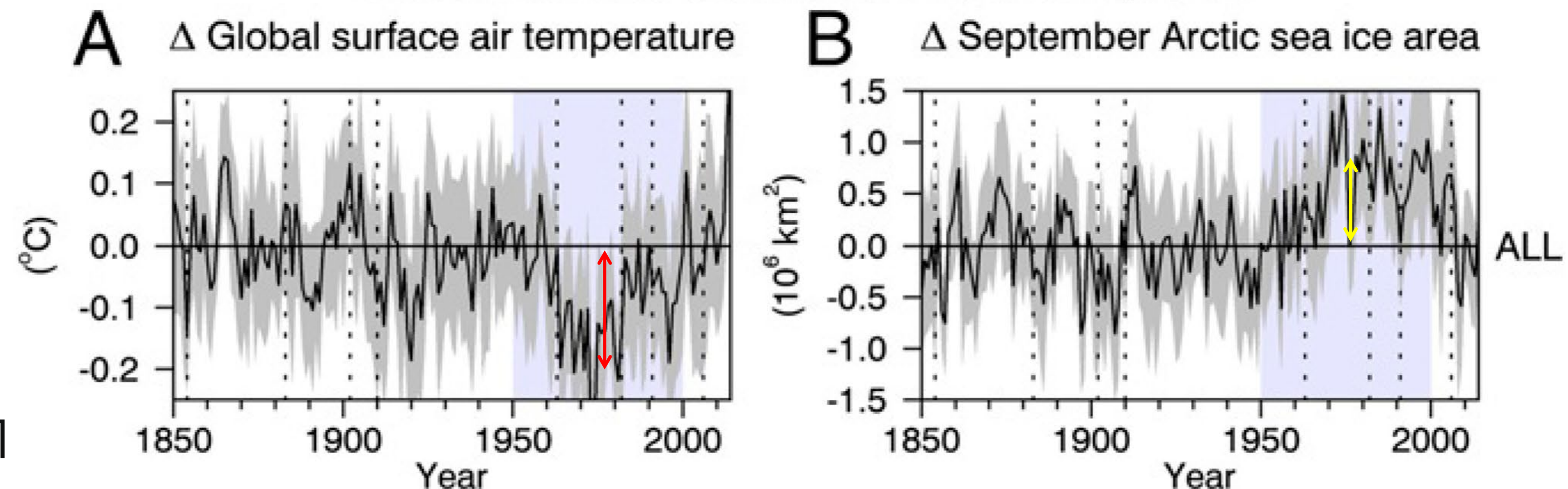
Fyfe *et al.*, 2021, PNAS, 10.1073/pnas.20165491

CMIP6 minus CMIP5 forcing response



↑ CMIP6 vs CMIP5 forcing difference – same model ↑

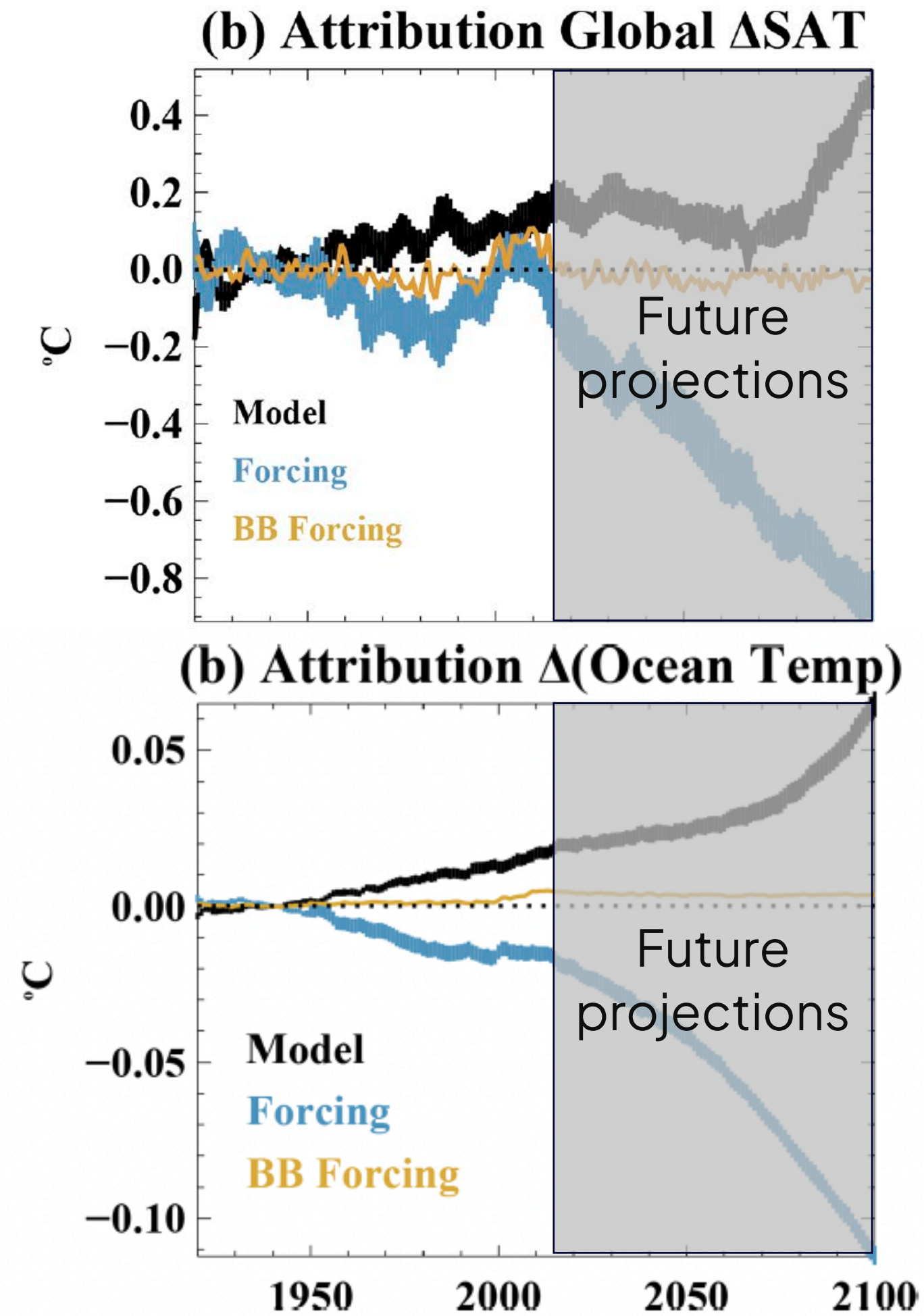
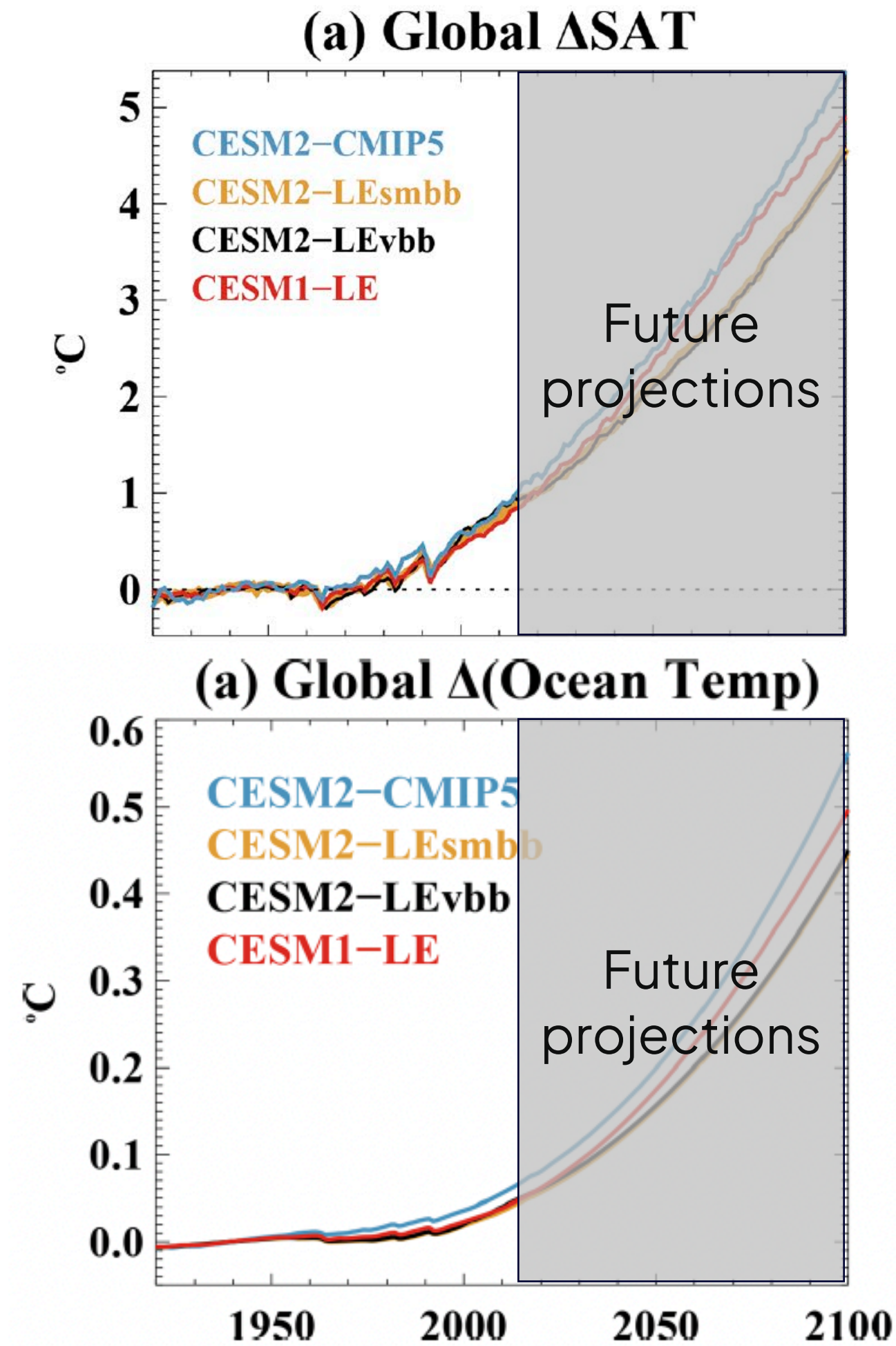
CanESM5 minus CanESM2 model response



↑ CanESM5 vs CanESM2 model difference – same CMIP5 forcing ↑

Forcings: how much do they matter?

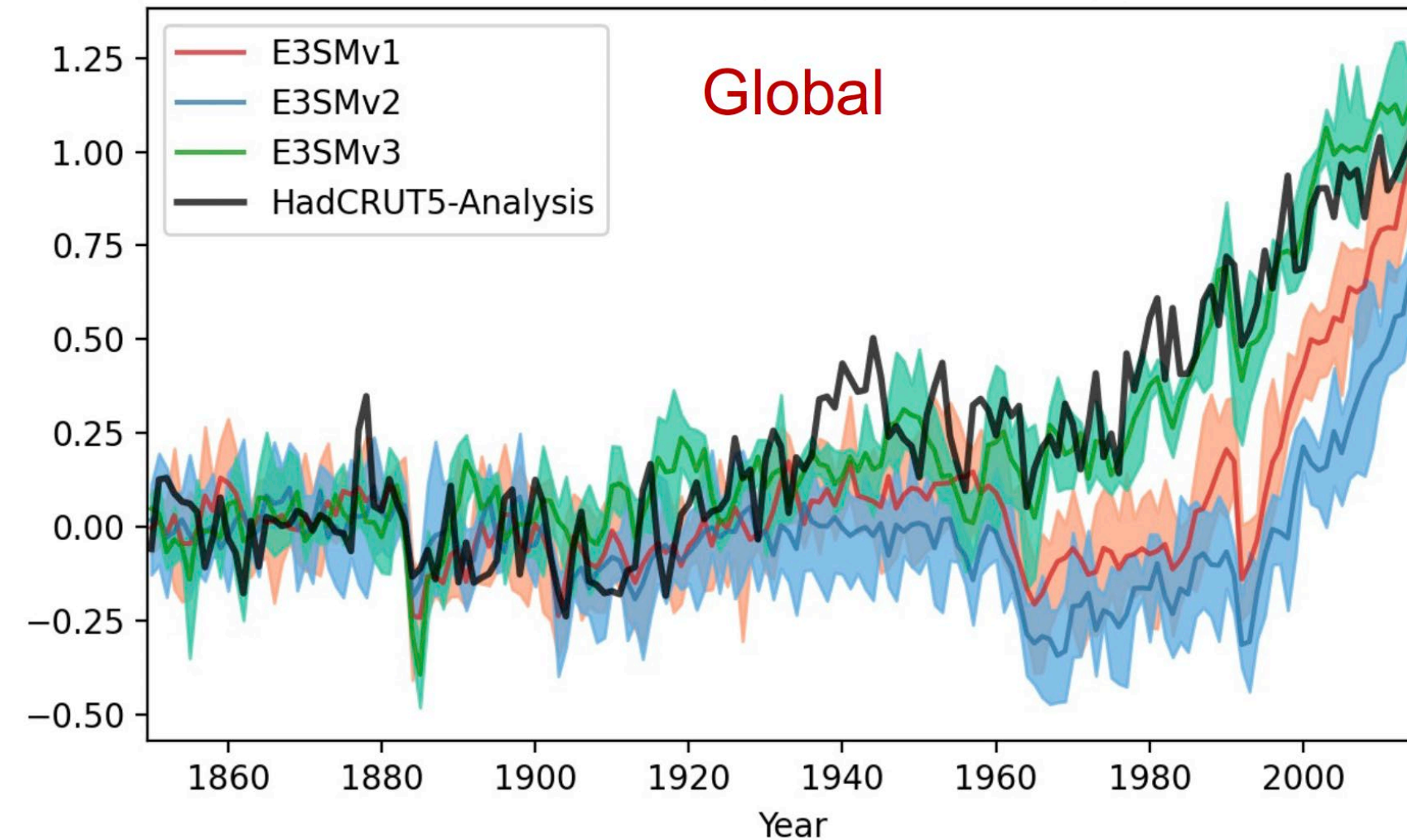
- Forcing changes over CMIP phases
- But so do model changes
- CCCma, NCAR, E3SM evaluated forcing impact
 - Change the forcing, keep model same
 - Change the model, keep forcing the same
- NCAR:
 - “..For global mean, CMIP6 forcing drives reduced ocean heat uptake, and global surface air temperature change relative to the CMIP5 forcing. Model structural changes between CESM2 and CESM1 counteract this, driving larger global average warming in CESM2..”



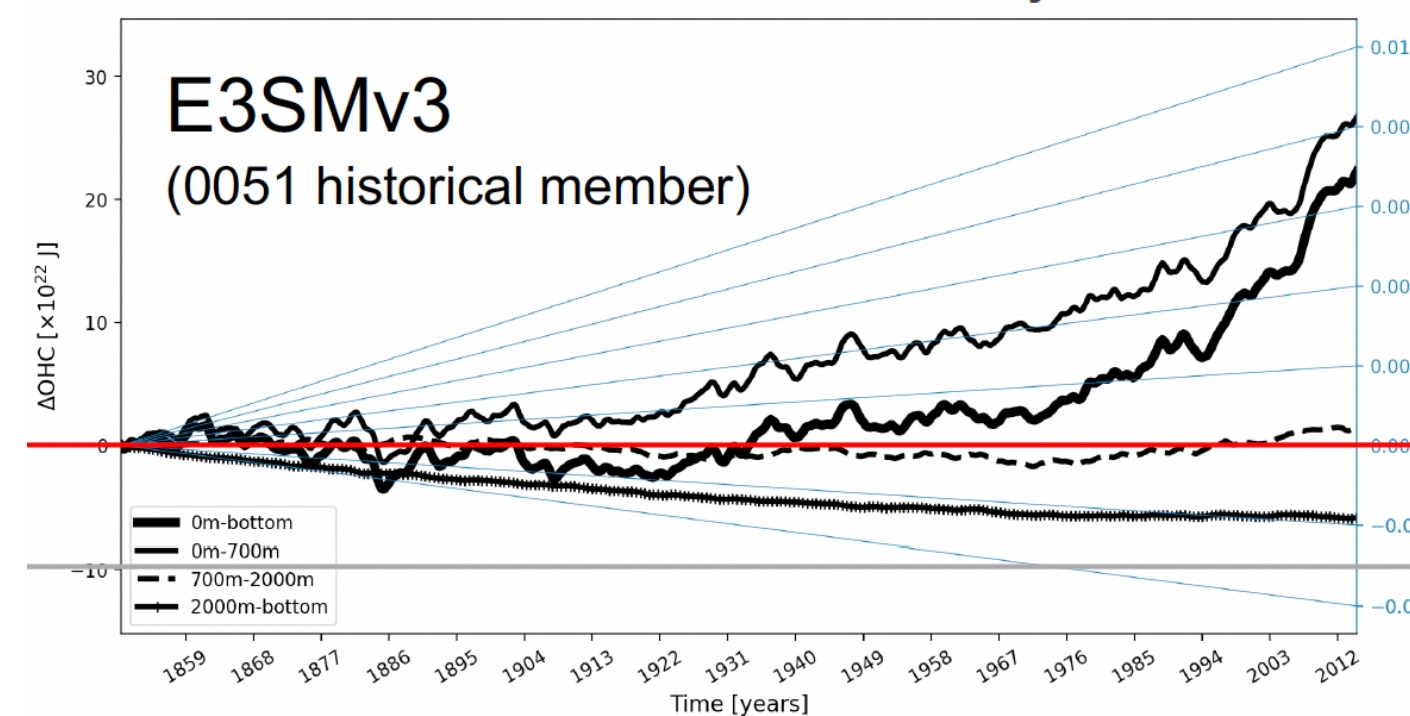
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 - Change the forcing, keep model same
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- E3SM:
 - CMIP6-only forcing
 - Time evolving global mean surface air temperature has 0.3-0.6degC impact
 - Time evolving global mean ocean heat content changes sign, from negative to positive

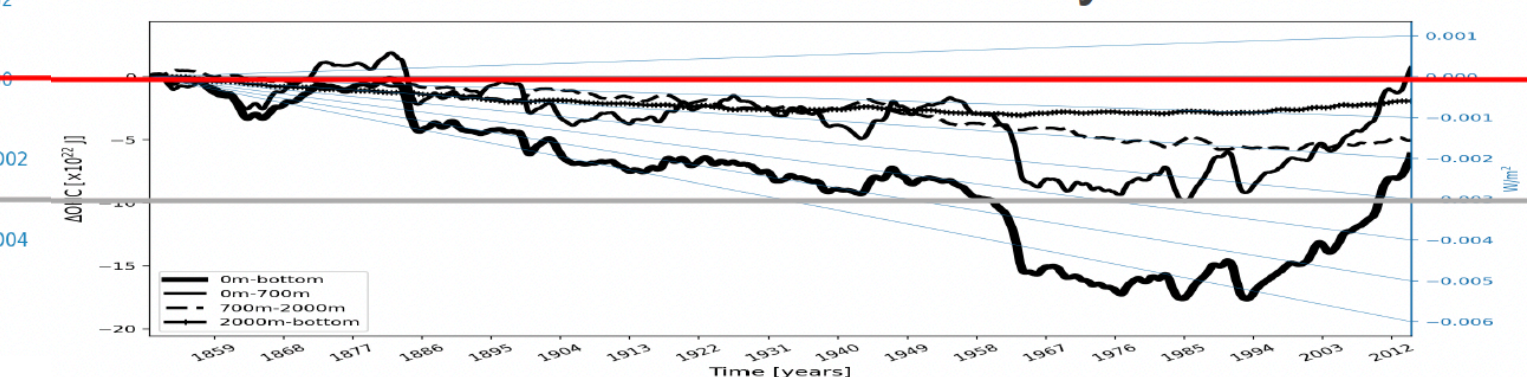
Global surface temperature anomaly (ref 1850-1899)



Global OHC anomaly



E3SMv2-1
Global OHC anomaly



Forcings: what is missing?

- **Missing freshwater** forcing from ice sheets and glaciers

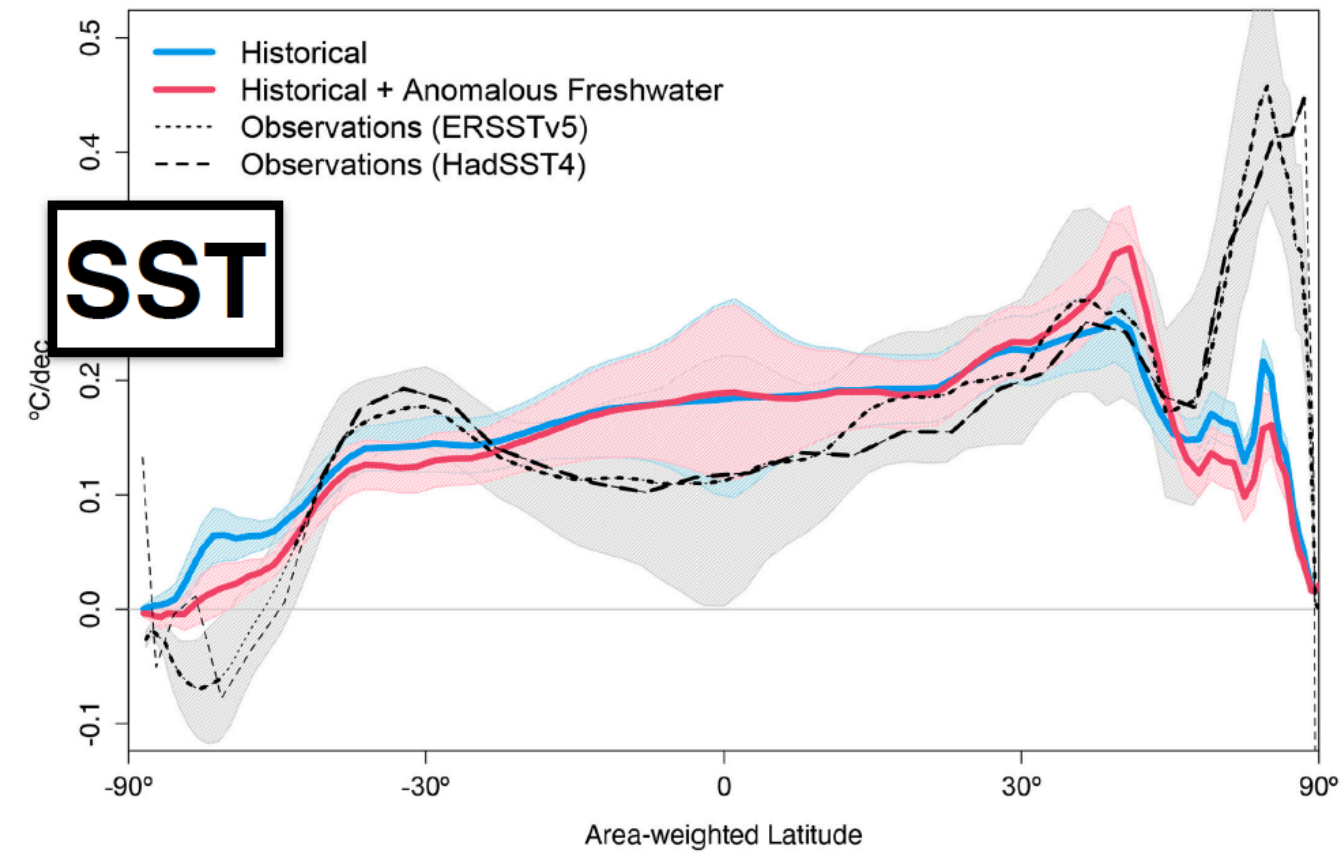


Goddard Institute for Space Studies

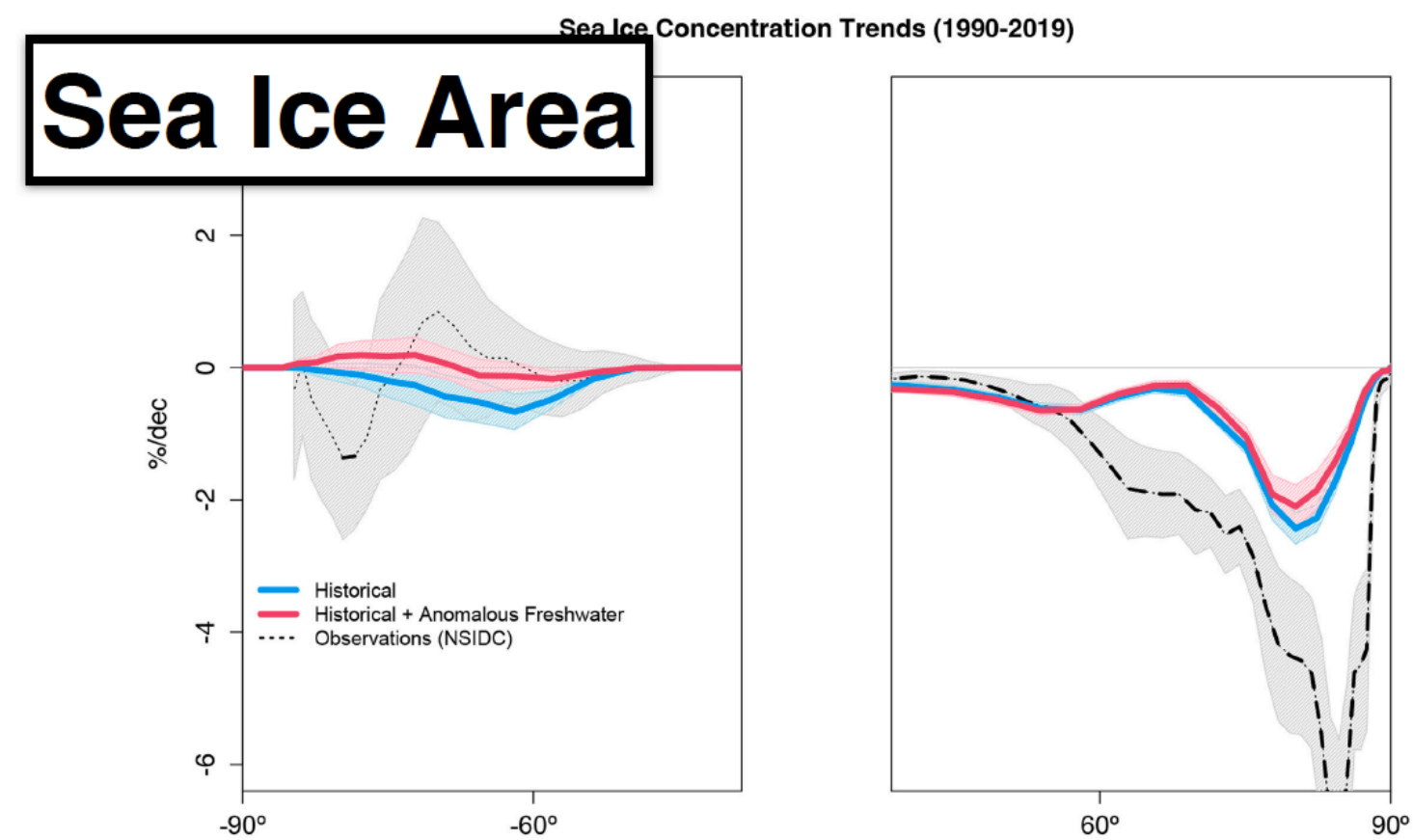
SST and Sea Ice Trend Differences 1990-2019

Significant impact in SH SST

Anomalous freshwater forcing – Antarctica, Greenland, glaciers
Schmidt *et al.*, in prep



Historical control
w/anomalous FW

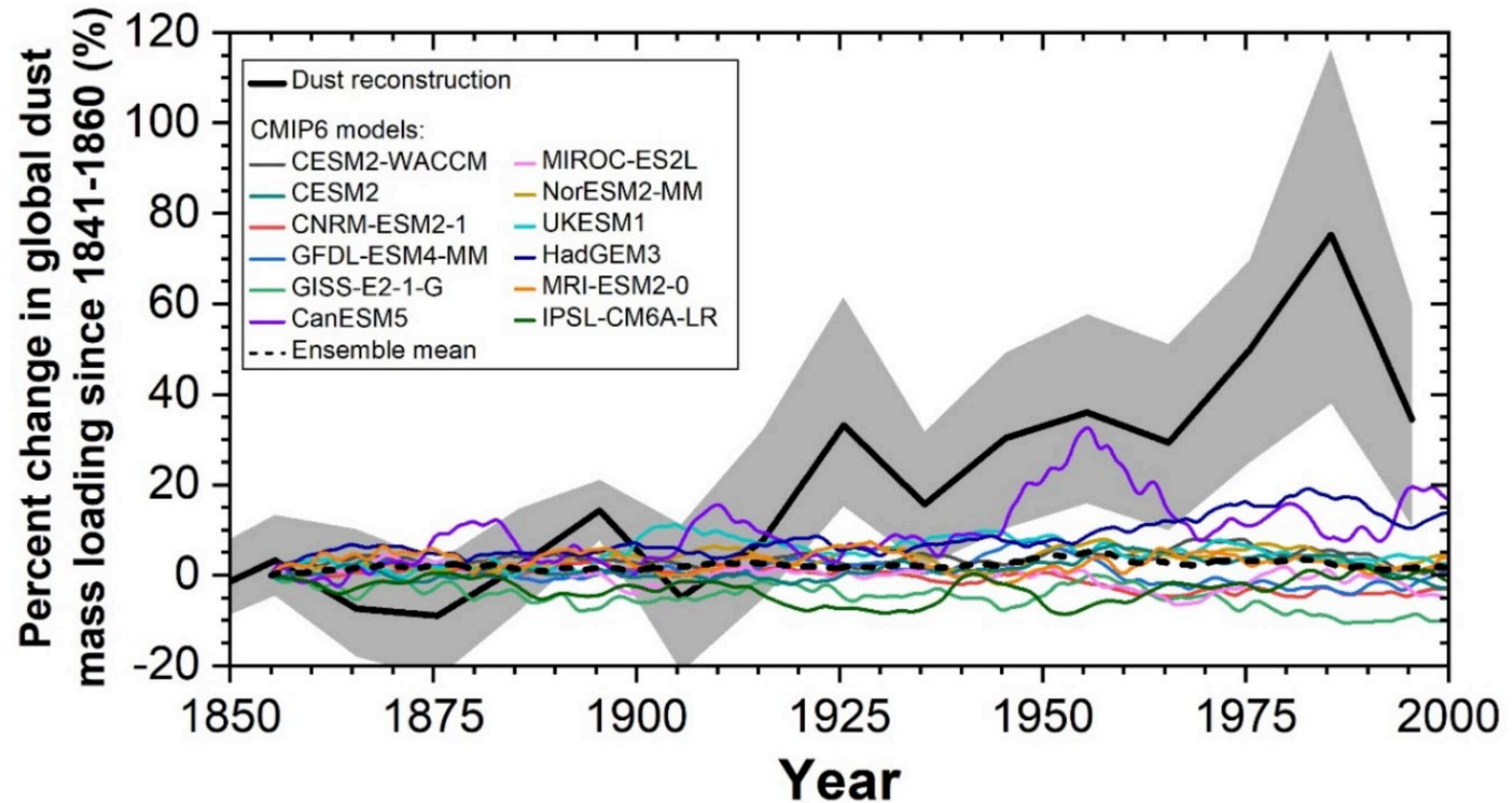


Large enough to flip sign of ensemble Antarctic sea ice trend

Forcings: what is missing?

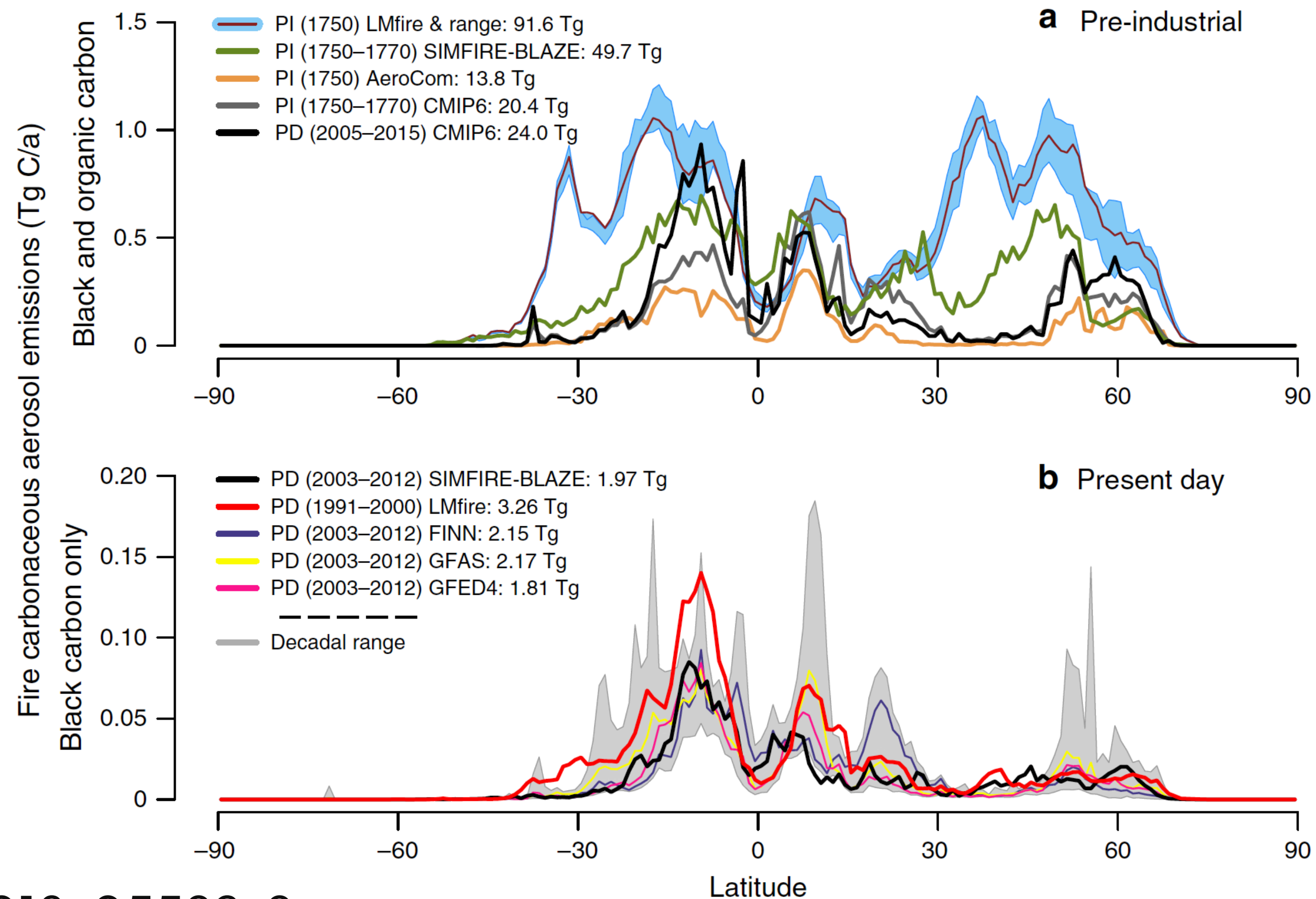
- **Missing freshwater** forcing from ice sheets and glaciers
- **Aeolian dust** underestimated in CMIP6 models

Kok et al., 2023, NATEarthEnv, 10.1038/s43017-022-00379-5



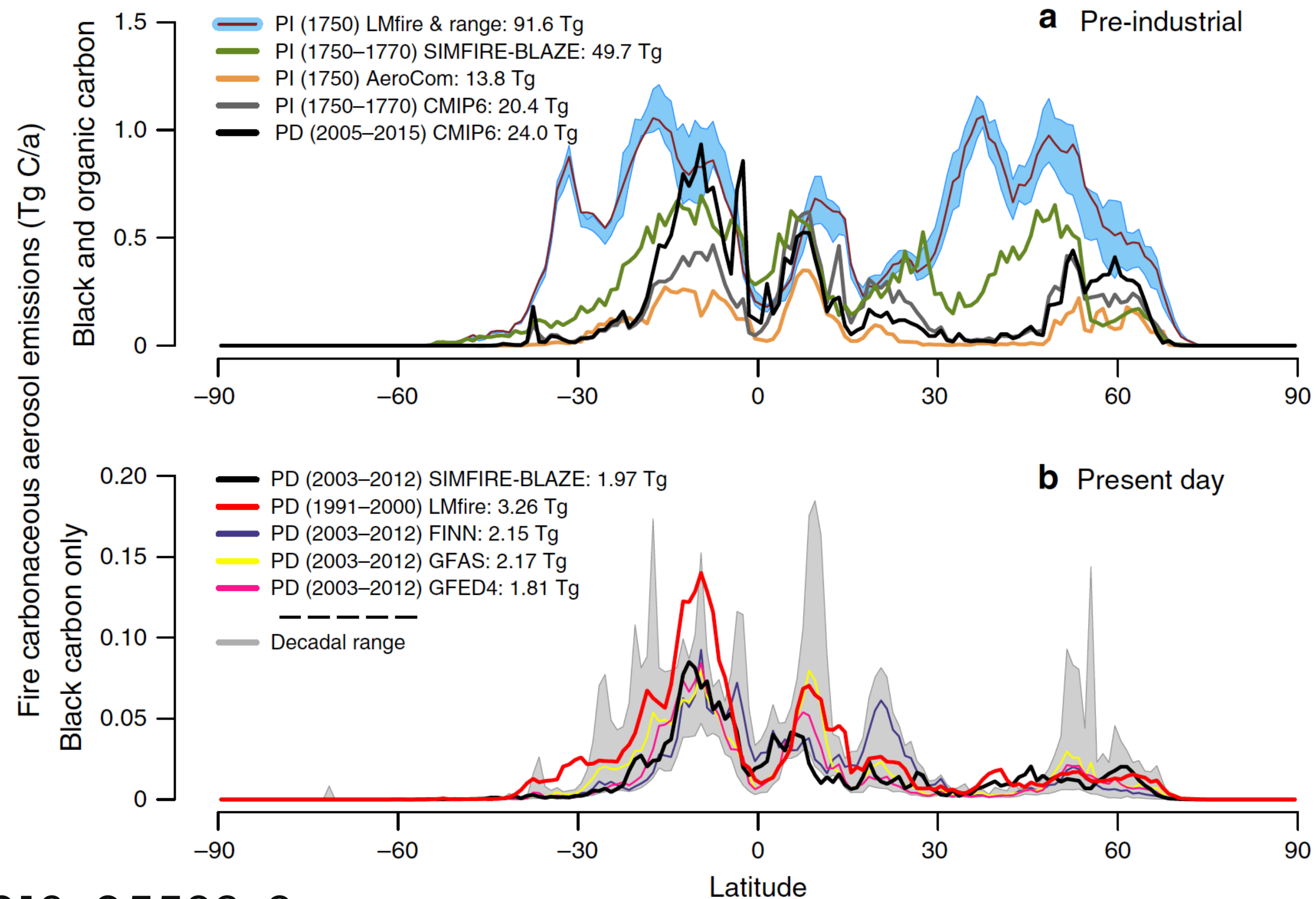
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- **Missing freshwater** forcing from ice sheets and glaciers
- **Aeolian dust** underestimated in CMIP6 models
- **Pre-industrial fire carbon emissions** underestimated in current forcing
- **Water vapour from underwater volcanic events**, e.g., Hunga Tonga–Hunga Ha‘apai
- ? ...



**Over to the modelling
group reps and new
data providers...**

Some questions

- What obvious formatting updates could be made to reduce post-processing steps by modelling groups
 - Padding years at start and end?
 - Additional species to be requested as output alongside ozone (Michaela)?

Thank You

Forcings: why do we care?

- **Modelled climate result of transient forcing**
 - Radiative response
 - Modelled feedbacks
- CMIPx piControl and historical experimental design changed over time
- Address step-change deficiency – piControl (fixed forcing, no volcanoes) transition to historical (transient forcing with large 1860-1880 volcanic forcing) beginning with very large Kie Besi (1861) and Krakatoa (1883) volcanic eruptions with heavy SAOD loads
- Incorporate climatological average volcanic aerosol in piControl experimental protocol
- Solves issues with long-term thermosteric sea-level discrepancies ([Gregory et al., 2006](#); [Gregory, 2010](#); [Gregory et al., 2013](#); [Gregory et al., 2016](#))
- But there are consequences ([Ke et al., 2024](#))

