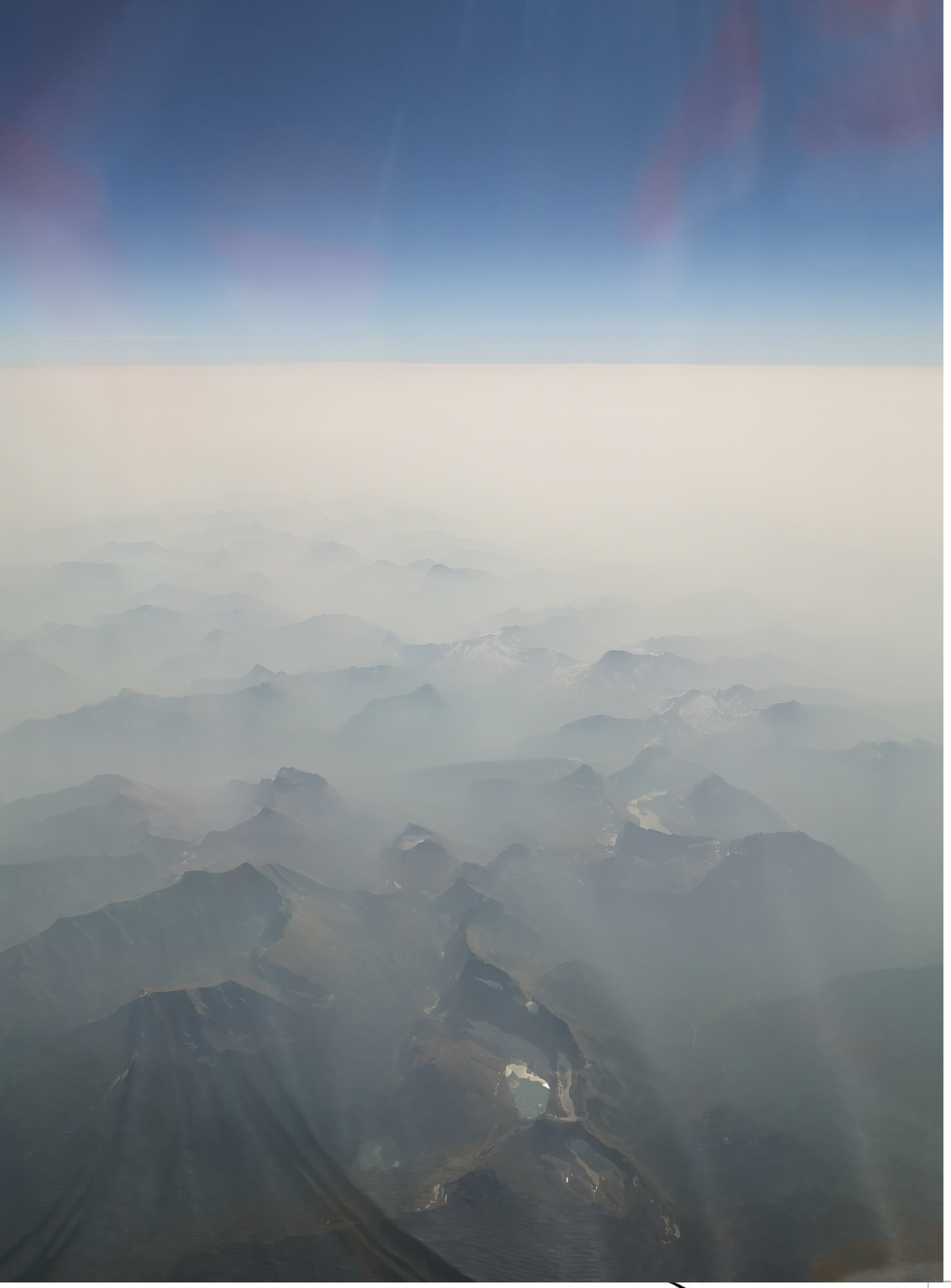

# Climate responses to regional aerosol emissions: Early multi-model results from RAMIP

Laura Wilcox, Bjørn Samset, Robert Allen, Molly MacRae

and the RAMIP modelling team: Luke Fraser-Leach, Paul Griffiths, James Keeble, Tsuyoshi Koshiro, Paul Kushner, Anna Lewinschal, Risto Makkonen, Joonas Merikanto, Pierre Nabat, Declan O'Donnell, Naga Oshima, David Paynter, Steve Rumbold, Toshi Takemura, Kostas Tsigaridis, and Daniel Westervelt

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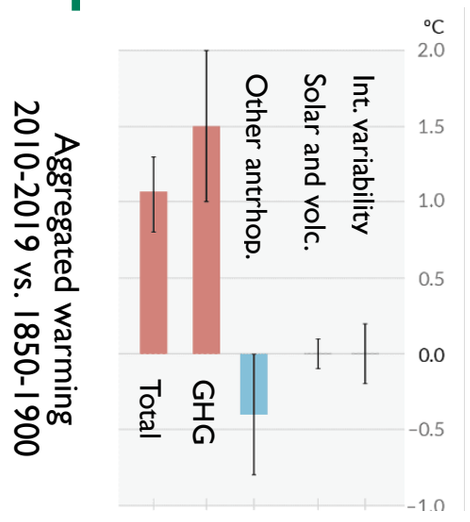
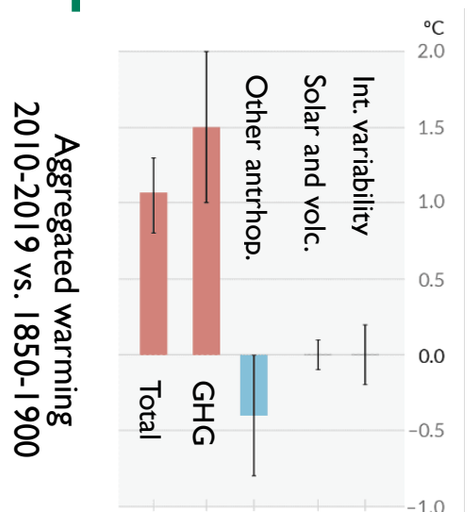
# Aerosol is an important driver of regional climate trends




The effect of aerosol changes is an important but uncertain contributor to anthropogenic climate change

AR6 SPM (2021)

# Aerosol is an important driver of regional climate trends

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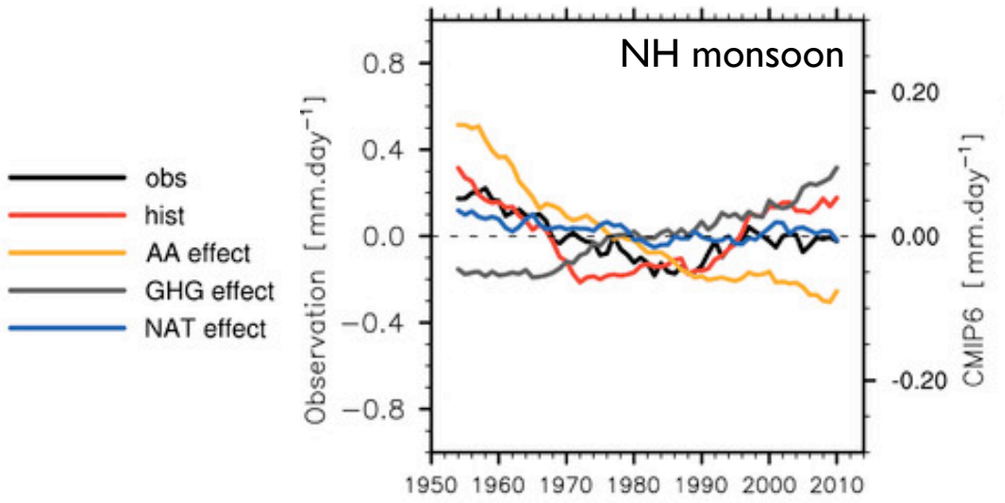


Aerosol changes are the main driver of key regional trends, such as observed monsoon changes

Monerie et al. (2022); AR6 SPM (2021)

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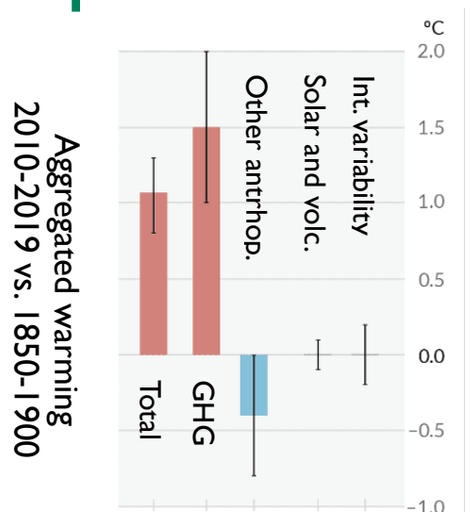


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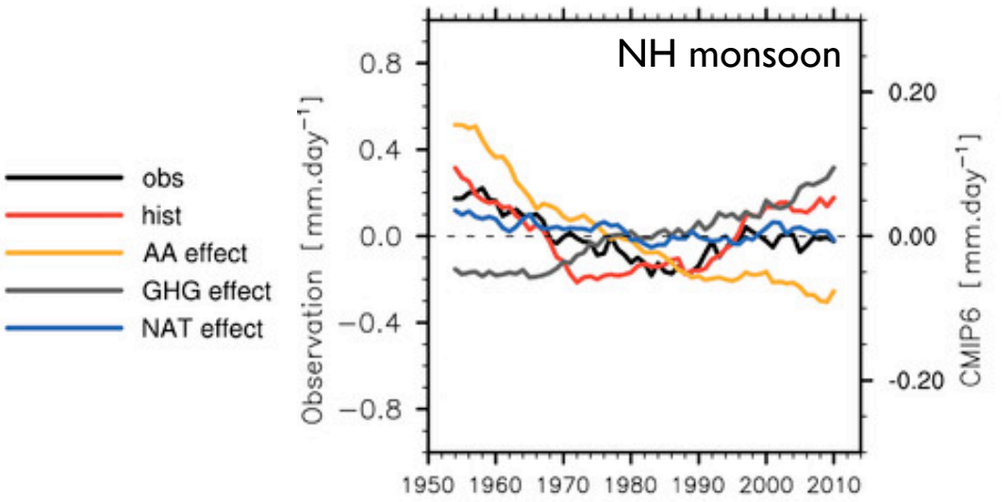


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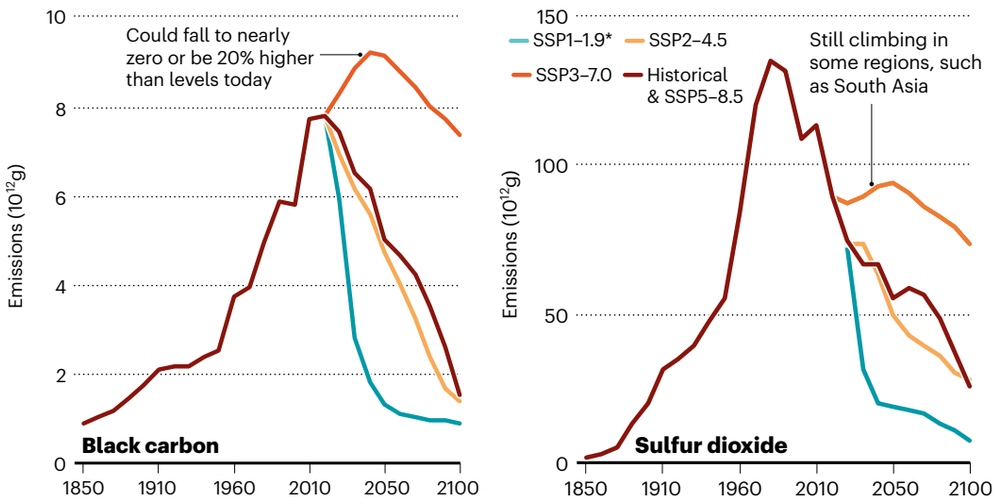


Large, rapid, changes in aerosol are plausible over the coming three decades. Changes on these timescales may be comparable to the change from 1850 to 2000

Persad et al. (2023); Monerie et al. (2022); AR6 SPM (2021)

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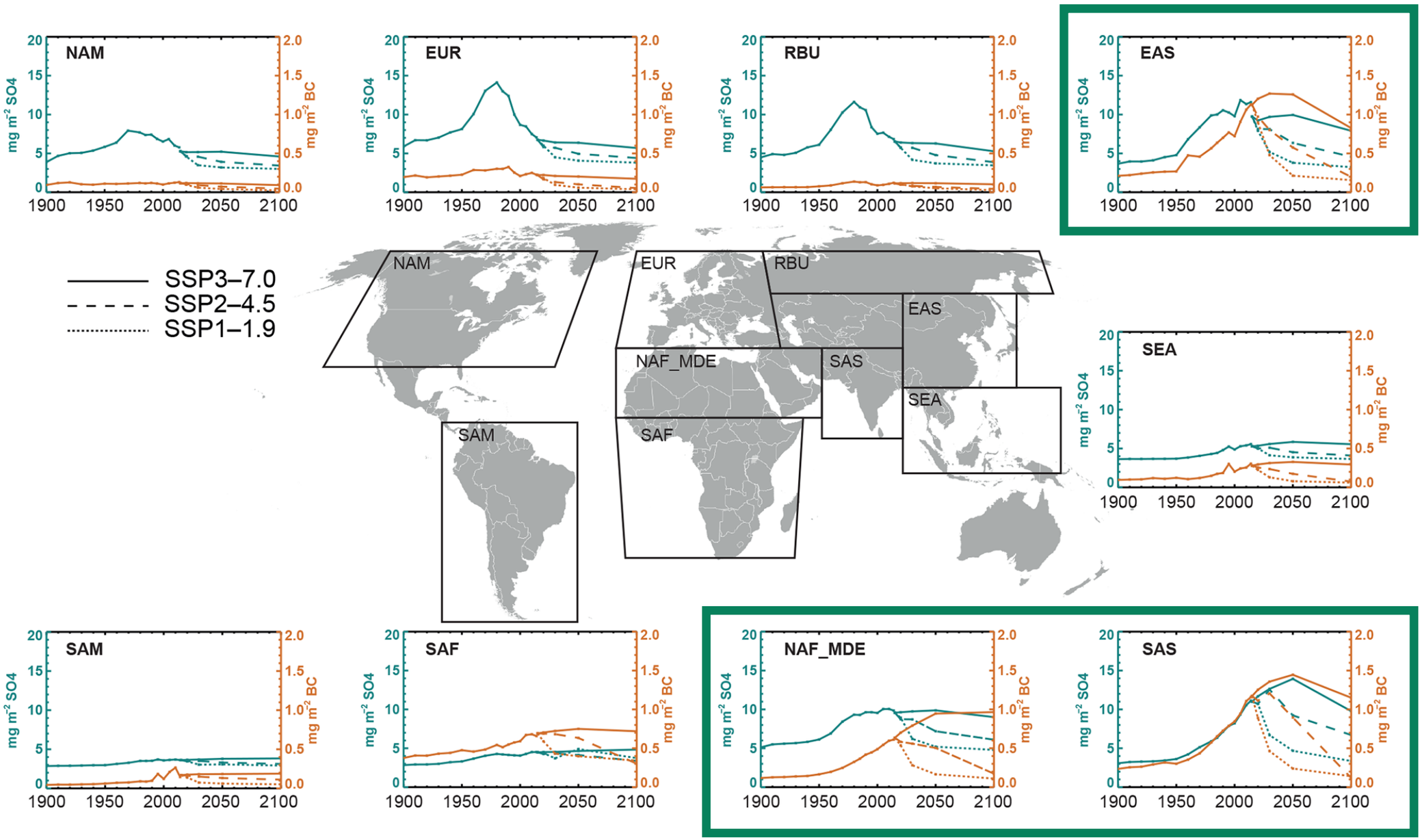
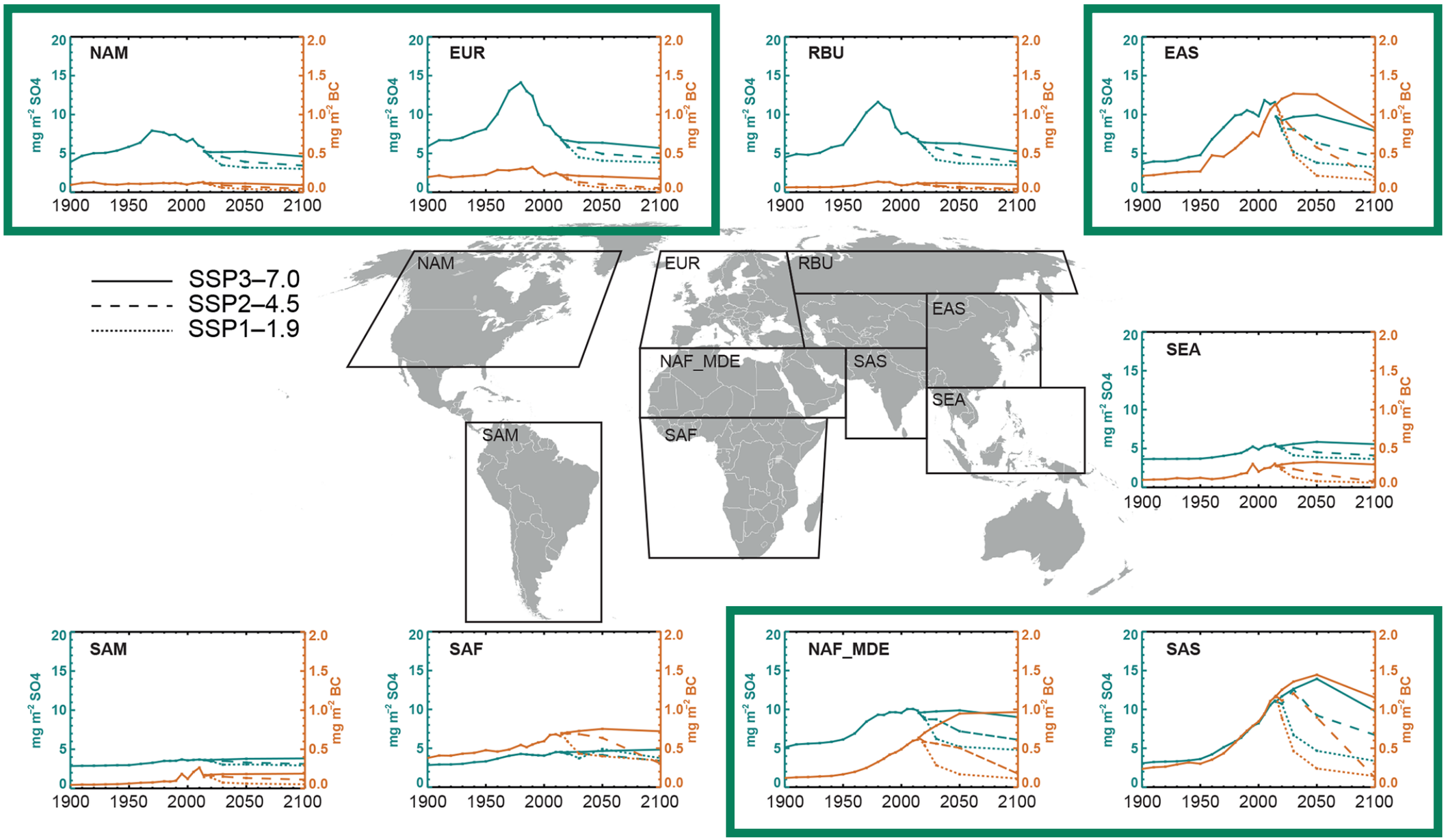
# Regional Aerosol MIP




Focus on regions with **large emission uncertainty:** East Asia, South Asia, and Africa and the Middle East

Lund et al. (2019)

# Regional Aerosol MIP




Focus on regions with **large emission uncertainty:** East Asia, South Asia, and Africa and the Middle East

And regions with **high efficacy:** North America and Europe

Lund et al. (2019)

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# Regional Aerosol MIP

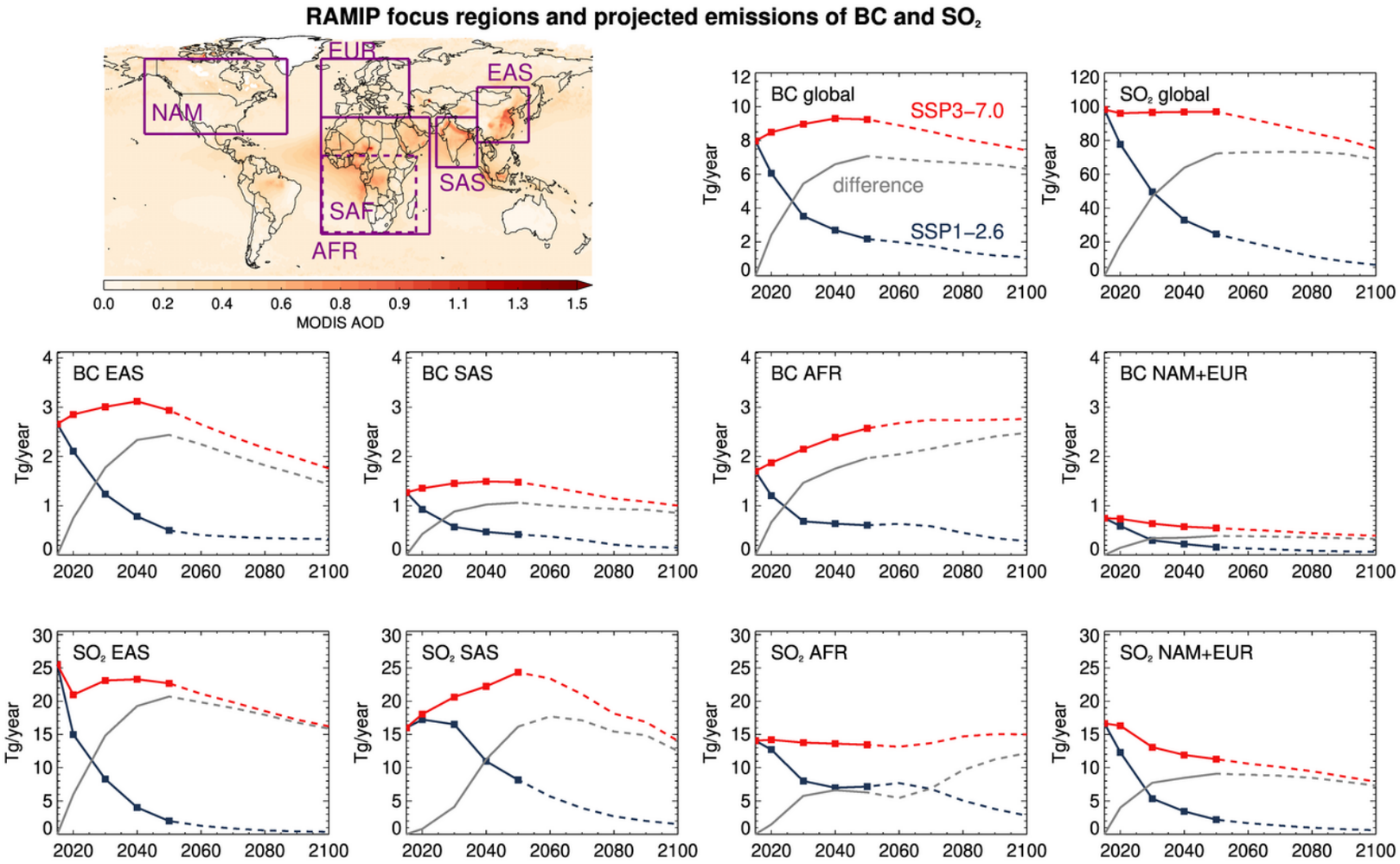
- SSP3-7.0 baseline, with **regional $SO_2$, BC, and OC perturbations following SSP1-2.6**
- Coupled transient simulations (January 2015 to February 2051). Fixed SST partners for all Tier 1 experiments using 2050 emissions
- **At least 10 members** per transient experiment, continuing from historical simulation

## Tier 0

- SSP3-7.0

## Tier 1

- Global
- Africa and the Middle East
- East Asia
- North America and Europe
- South Asia




Wilcox et al. (2023)

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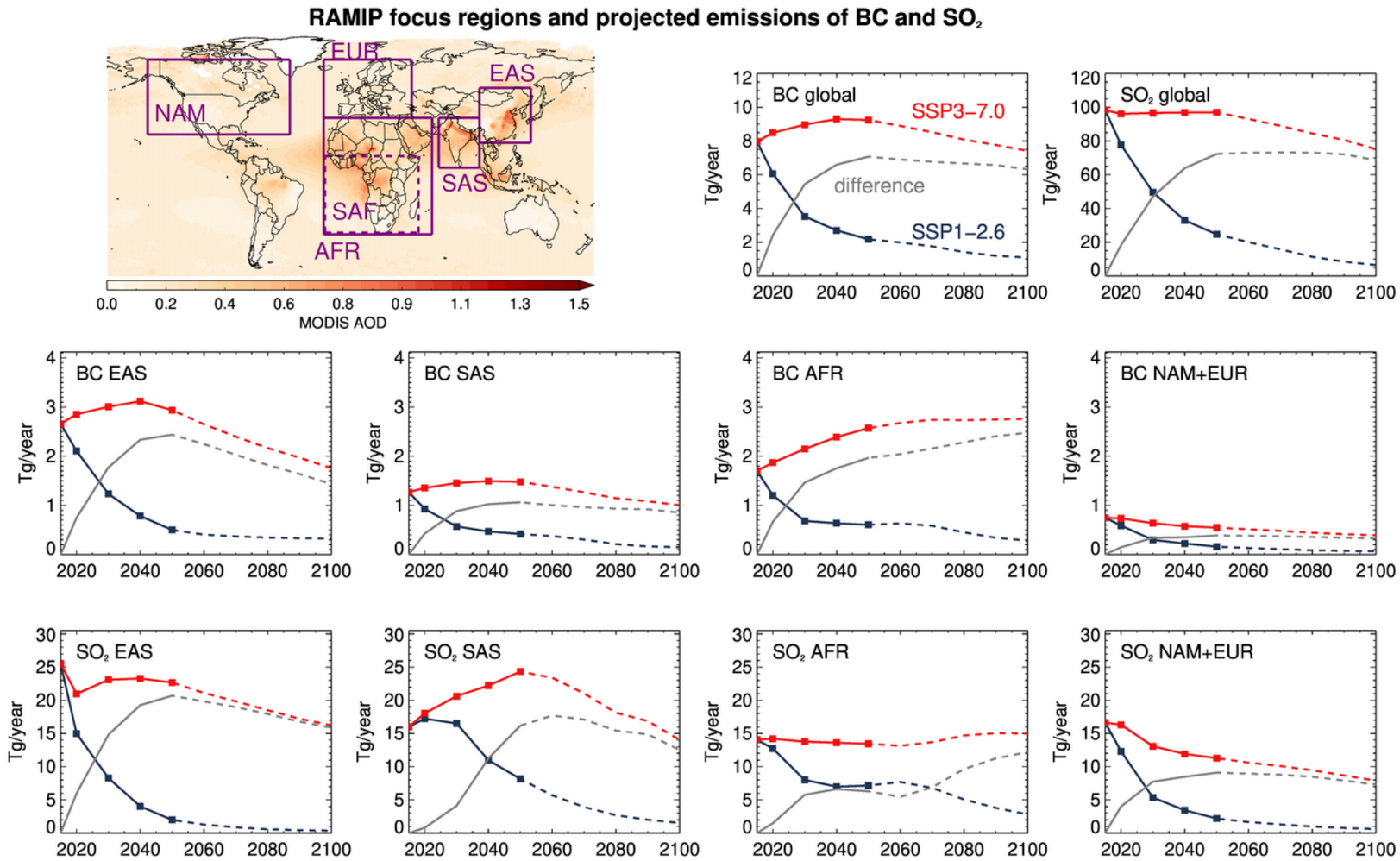
## Tier 2

- South+East Asia
- Sub-Saharan Africa carbonaceous
- South Asia carbonaceous
- Global, with $NH_3$ and $NO_x$

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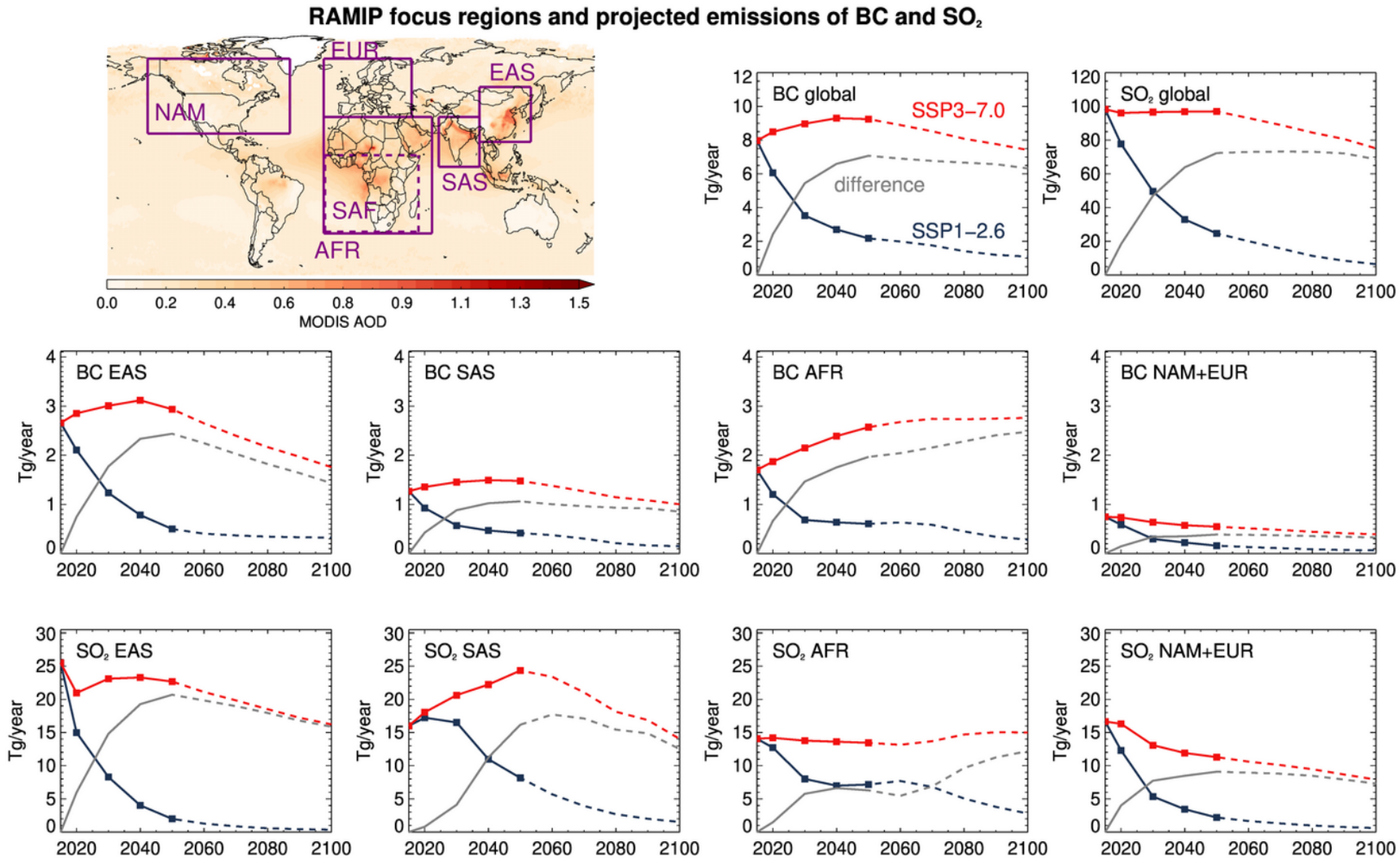


Participating models:
CanESM5, **CESM2**, CNRM-ESM2-1, EC-Earth3, GFDL-SPEAR, **GISS-E2-1**, MIROC6, **MRI-ESM2**, **NorESM2**, **UKESM1**

Wilcox et al. (2023)

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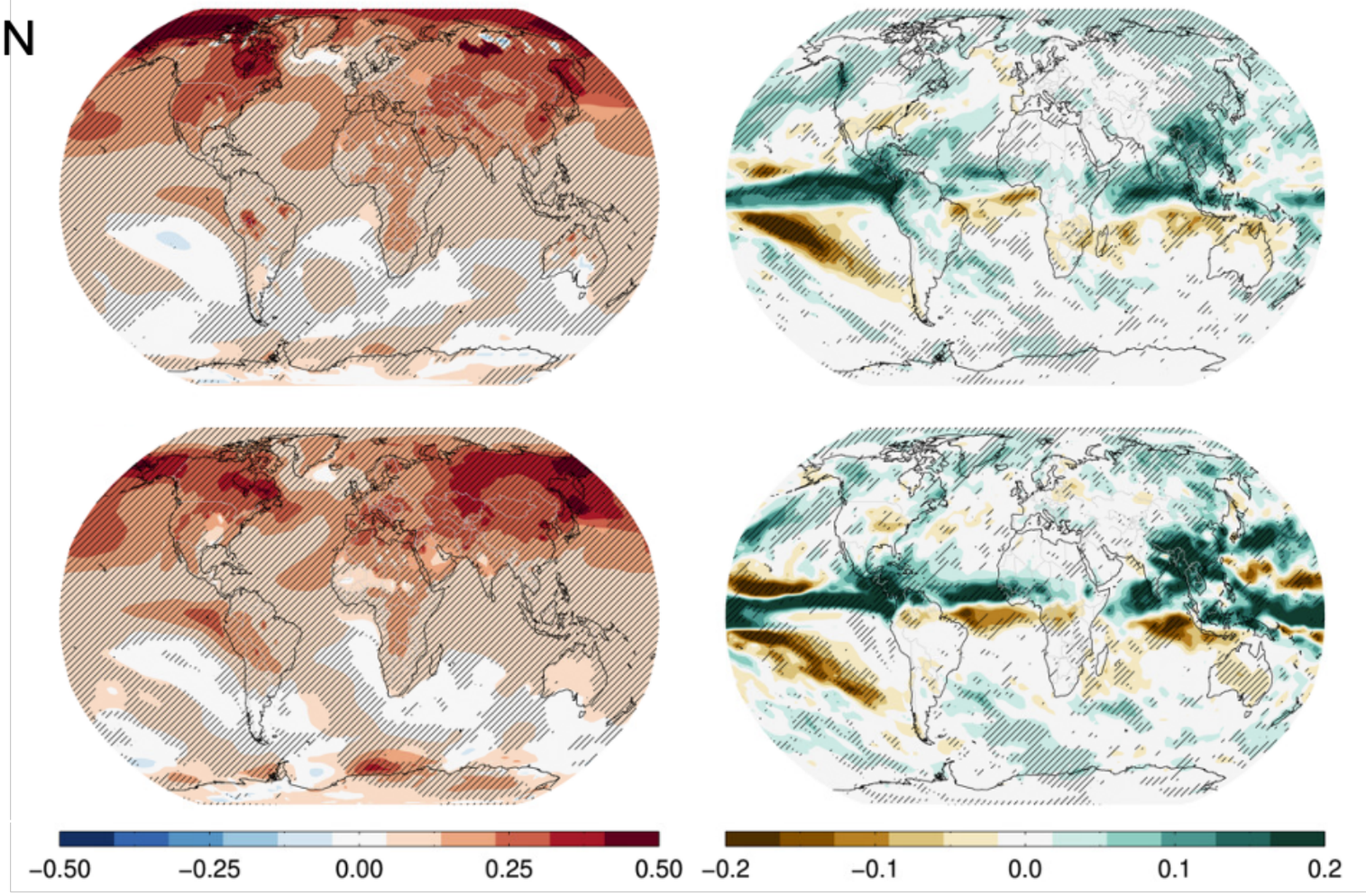
# Robust response to global aerosol reductions

ANN

JJA




Linear trend: 2015-2044
Hatching when **4/5 models agree**

| | 2014 v. 1850 | SSP1 v. SSP3 |
|---|---|---|
| CESM2 | -1.37 $Wm^{-2}$ | 1.20 $Wm^{-2}$ |
| GISS-E2-1-G | -1.32 $Wm^{-2}$ | |
| NorESM2-LM | -1.21 $Wm^{-2}$ | |
| MRI-ESM2-0 | -1.19 $Wm^{-2}$ | |
| UKESM1-0-LL | -1.11 $Wm^{-2}$ | 0.56 $Wm^{-2}$ |

Wilcox et al. (in prep.)

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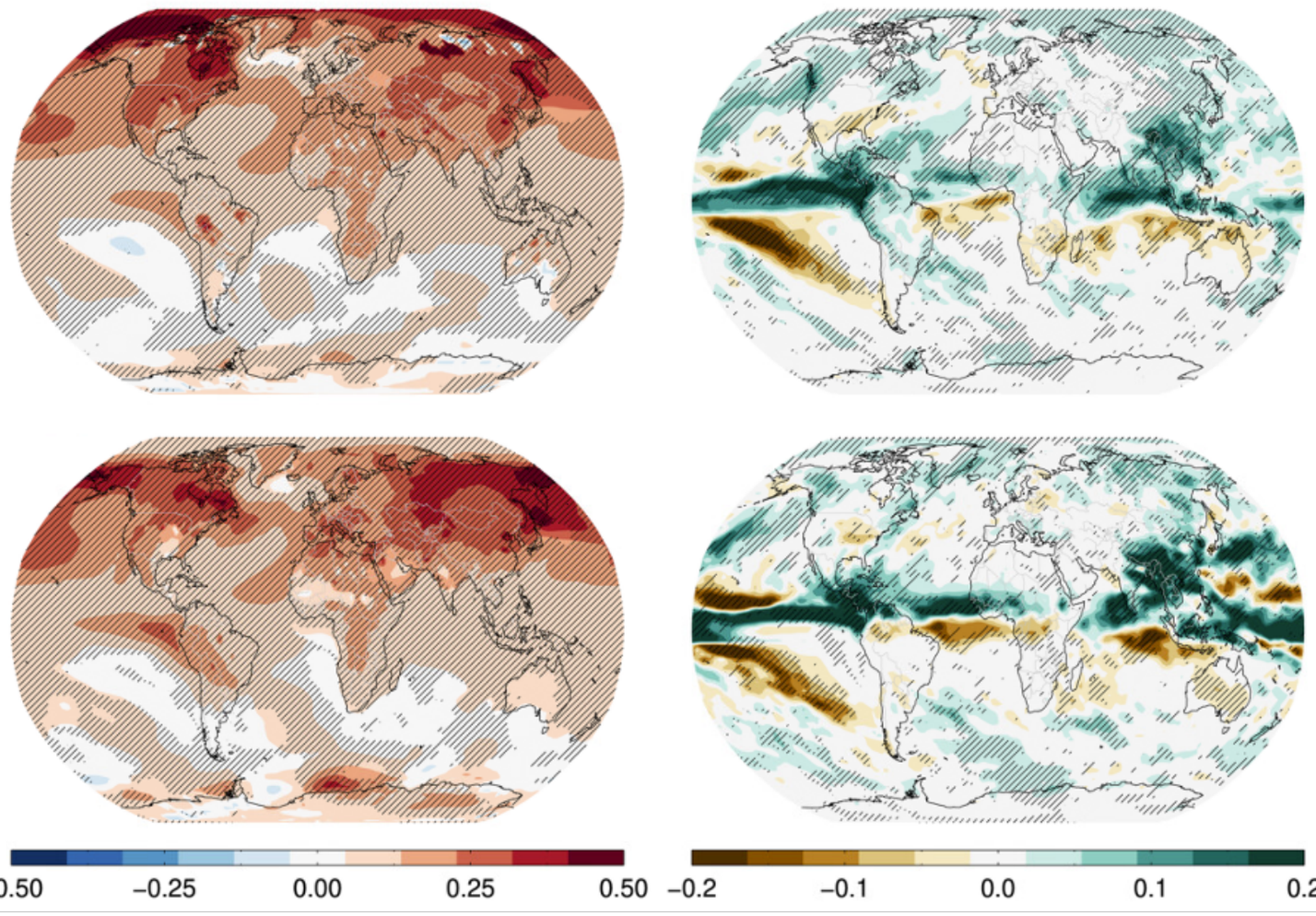


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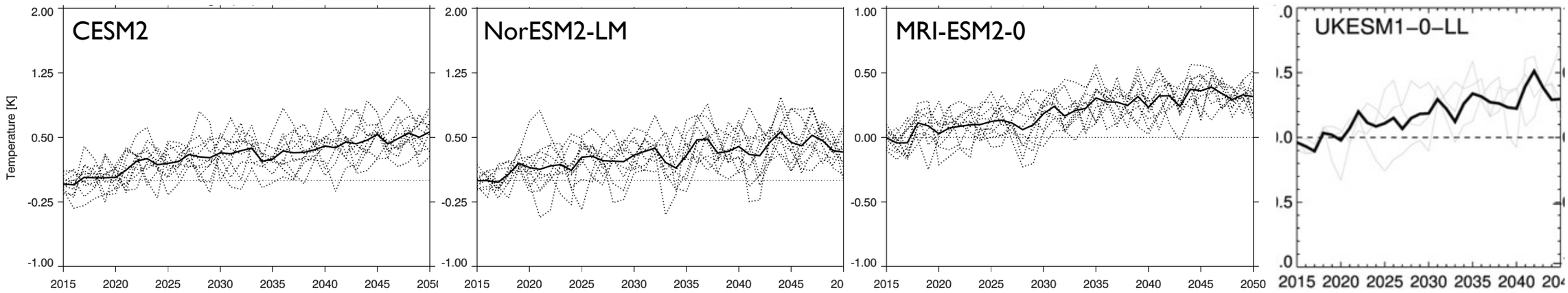
Strong aerosol emissions mitigation leads to **~0.5K global warming**

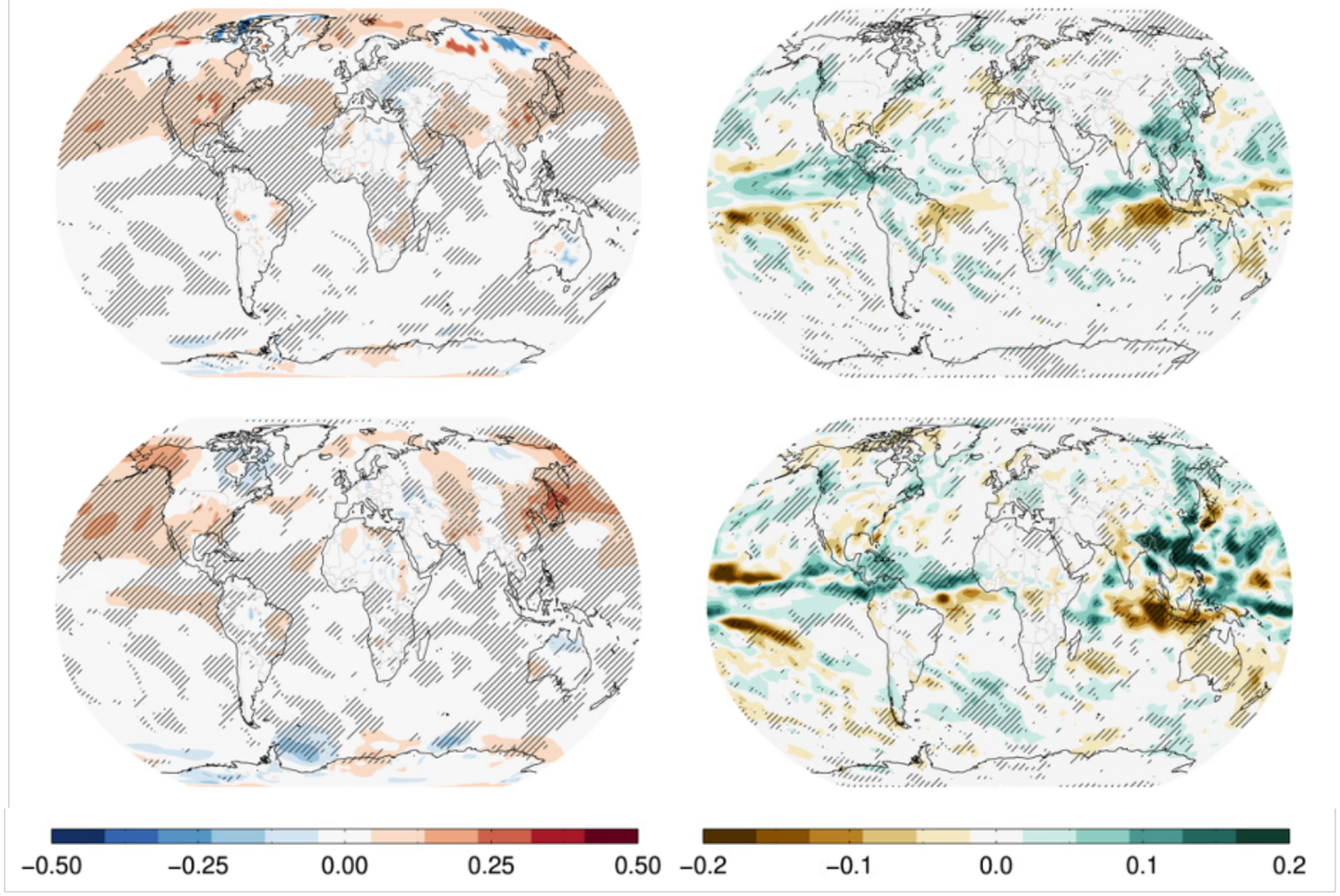



Wilcox et al. (in prep.)

# Robust response to East Asian aerosol reductions

ANN

JJA



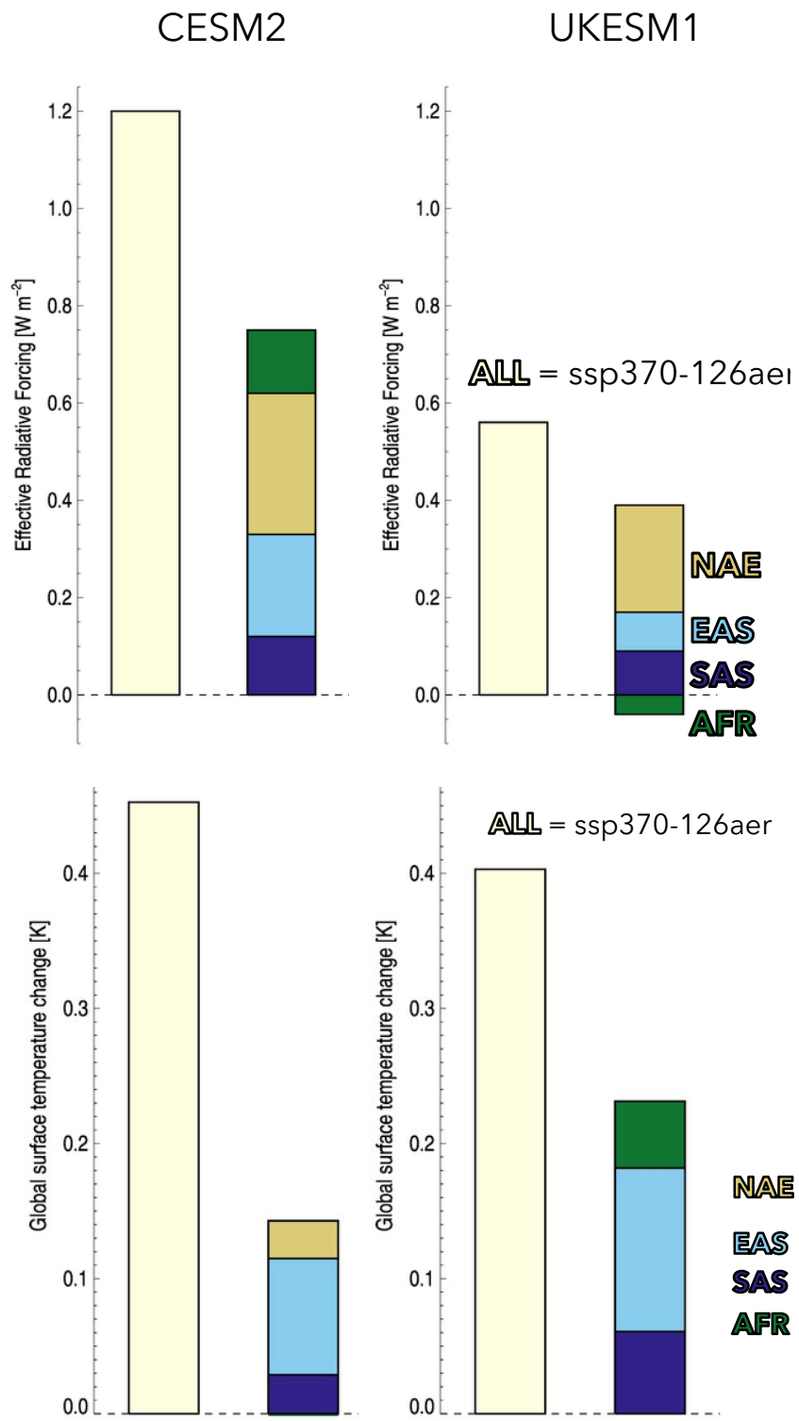

Linear trend: 2015-2044
Hatching when **4/5 models agree**

Smaller responses reflect smaller forcing and reduced model agreement, but still see robust responses

**Strong contribution from local emission changes** to East Asian Summer Monsoon trends

Wilcox et al. (in prep.)

# RAMIP can help us to understand nonlinearities in the response to regional emission changes

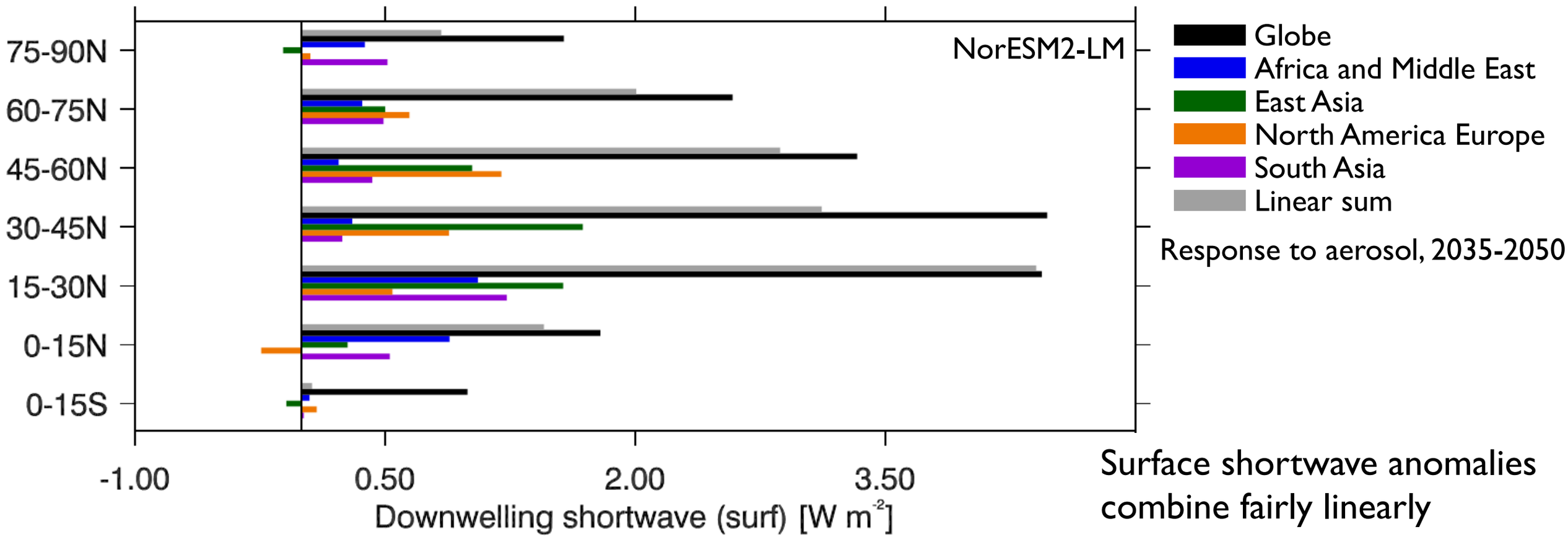



**Regional experiments** capture most of the global emission difference, but **only 50-70% of the total ERF**

**Large model differences in the contribution to the global mean temperature** response from regional emission changes

Wilcox et al. (in prep.)

# RAMIP can help us to understand nonlinearities in the response to regional emission changes




Surface shortwave anomalies combine fairly linearly

Wilcox et al. (in prep.)

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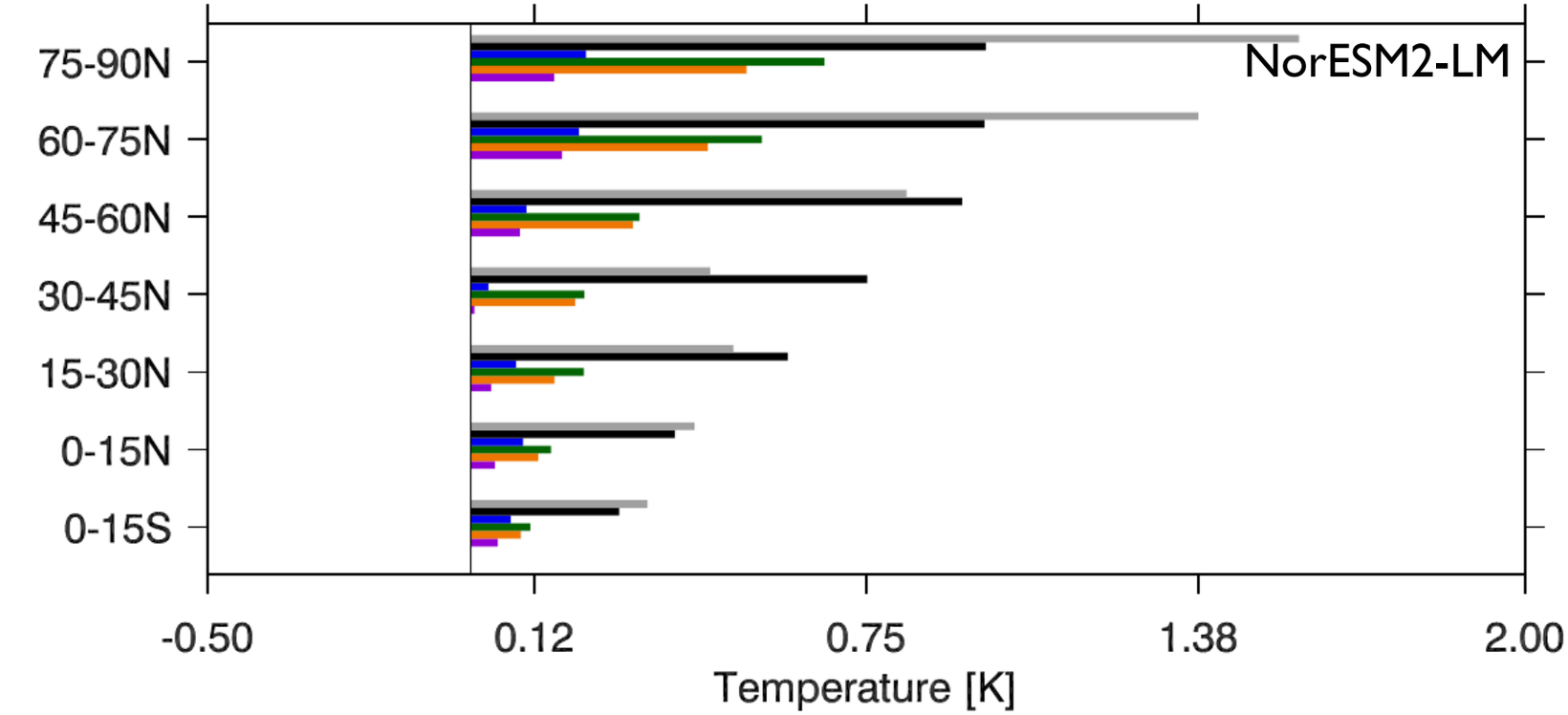


Globe
Africa and Middle East
East Asia
North America Europe
South Asia
Linear sum

Response to aerosol, 2035-2050

Surface shortwave anomalies combine fairly linearly

Temperature response is **not a linear combination**

Wilcox et al. (in prep.)

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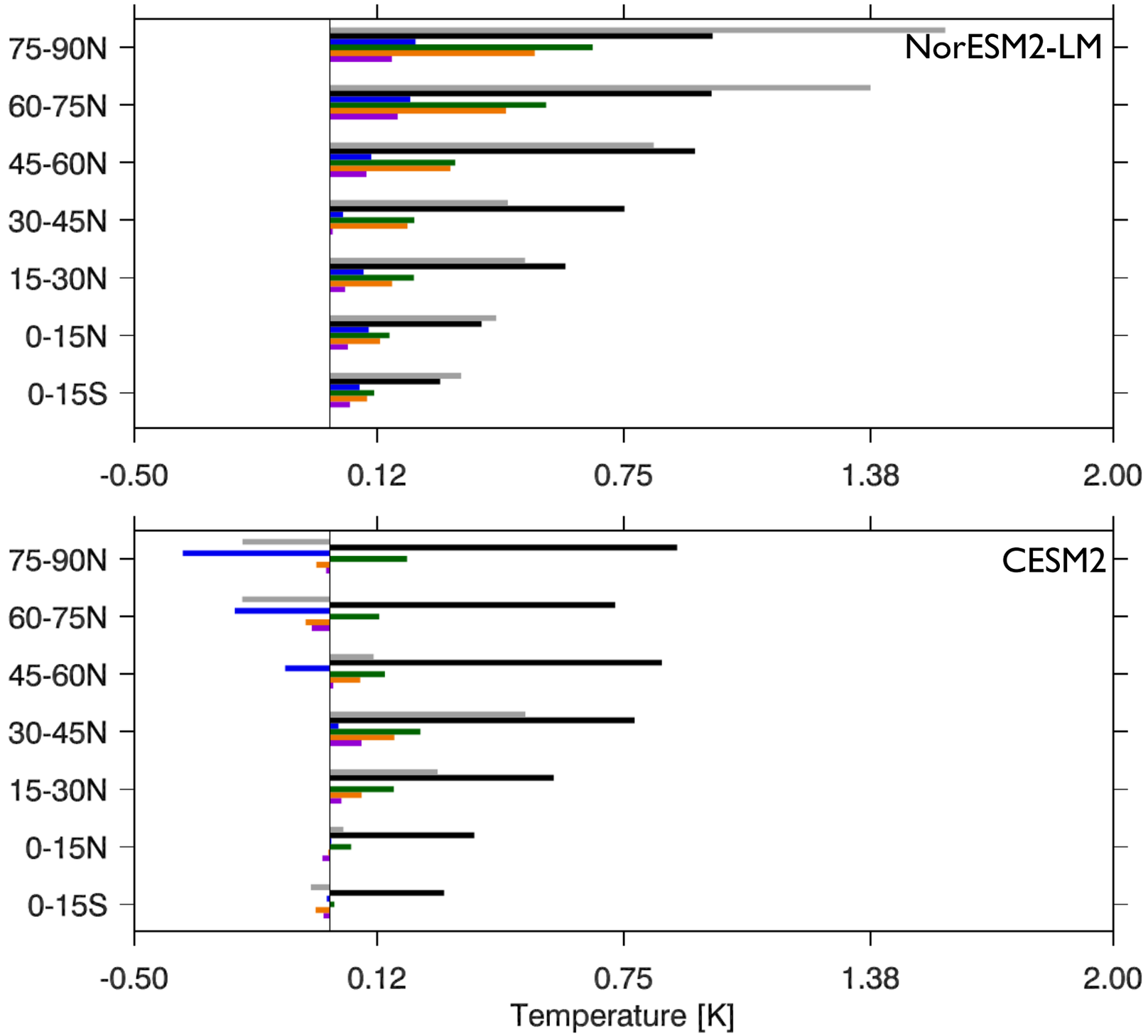


Globe
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Temperature response is **not a linear combination**

Drivers and degree of linearity are strongly model dependent

Wilcox et al. (in prep.)

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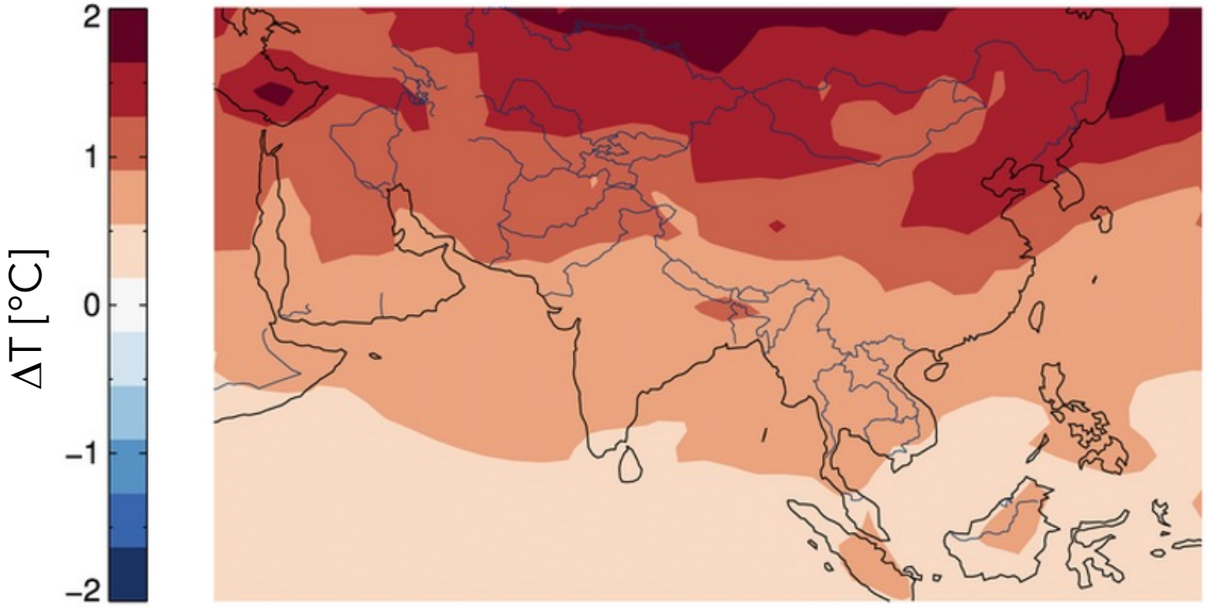
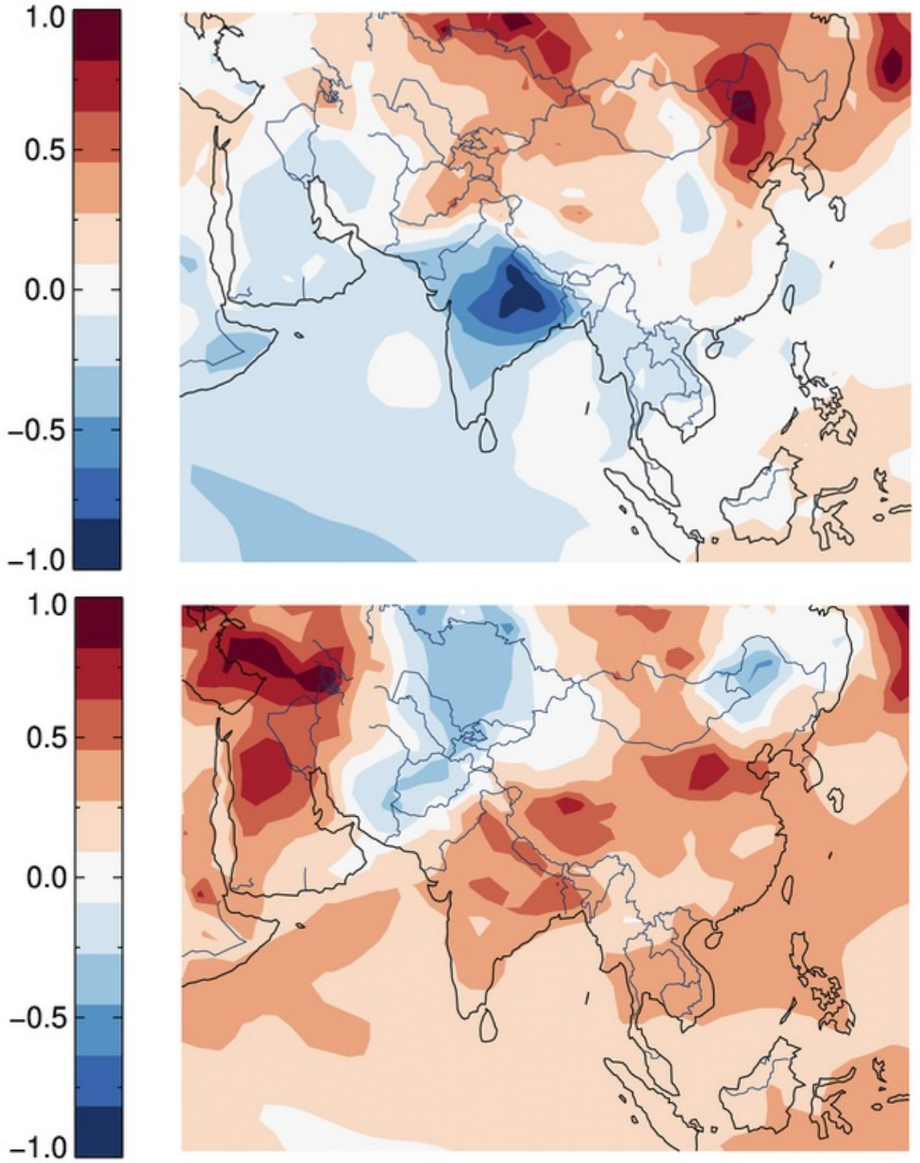
# Ensemble size is crucial

RAMIP requires **at least 10 members per transient experiment**, as a balance between information gained and computational cost




**ALL** = ssp370-126aer - ssp370, JJA mean, 2025-2044
NorESM, **10 ensemble members**

Examples from 3 ensemble members, shown as the deviation from the 10-member mean




**3 members are not sufficient** to identify the forced response to aerosol changes at regional scales

Wilcox et al. (in prep.)

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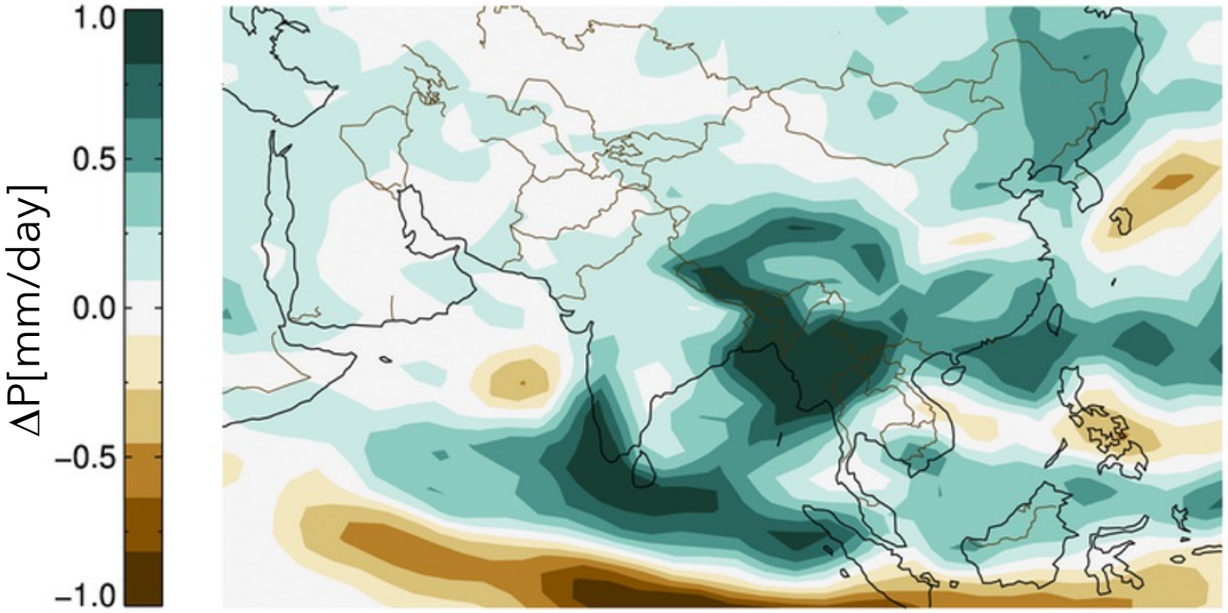


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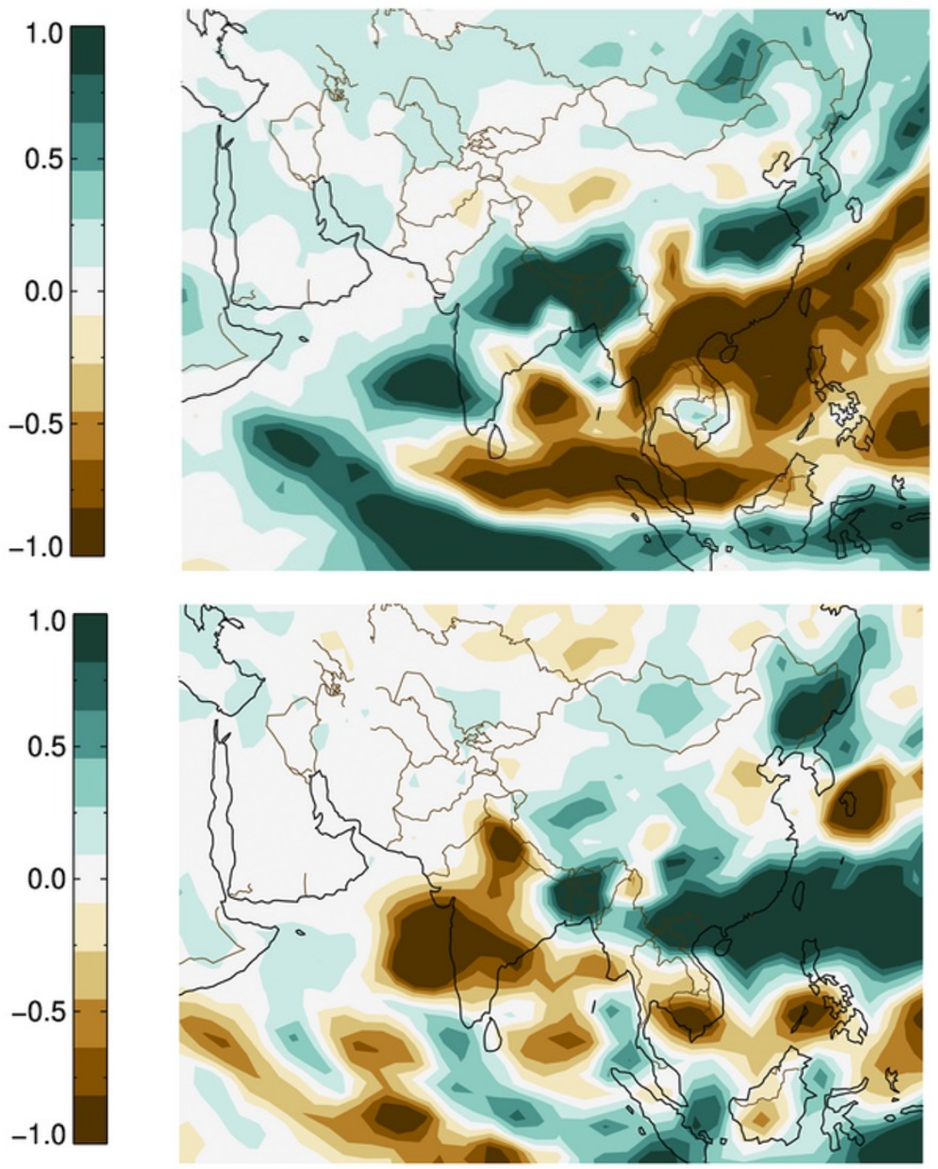


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Wilcox et al. (in prep.)

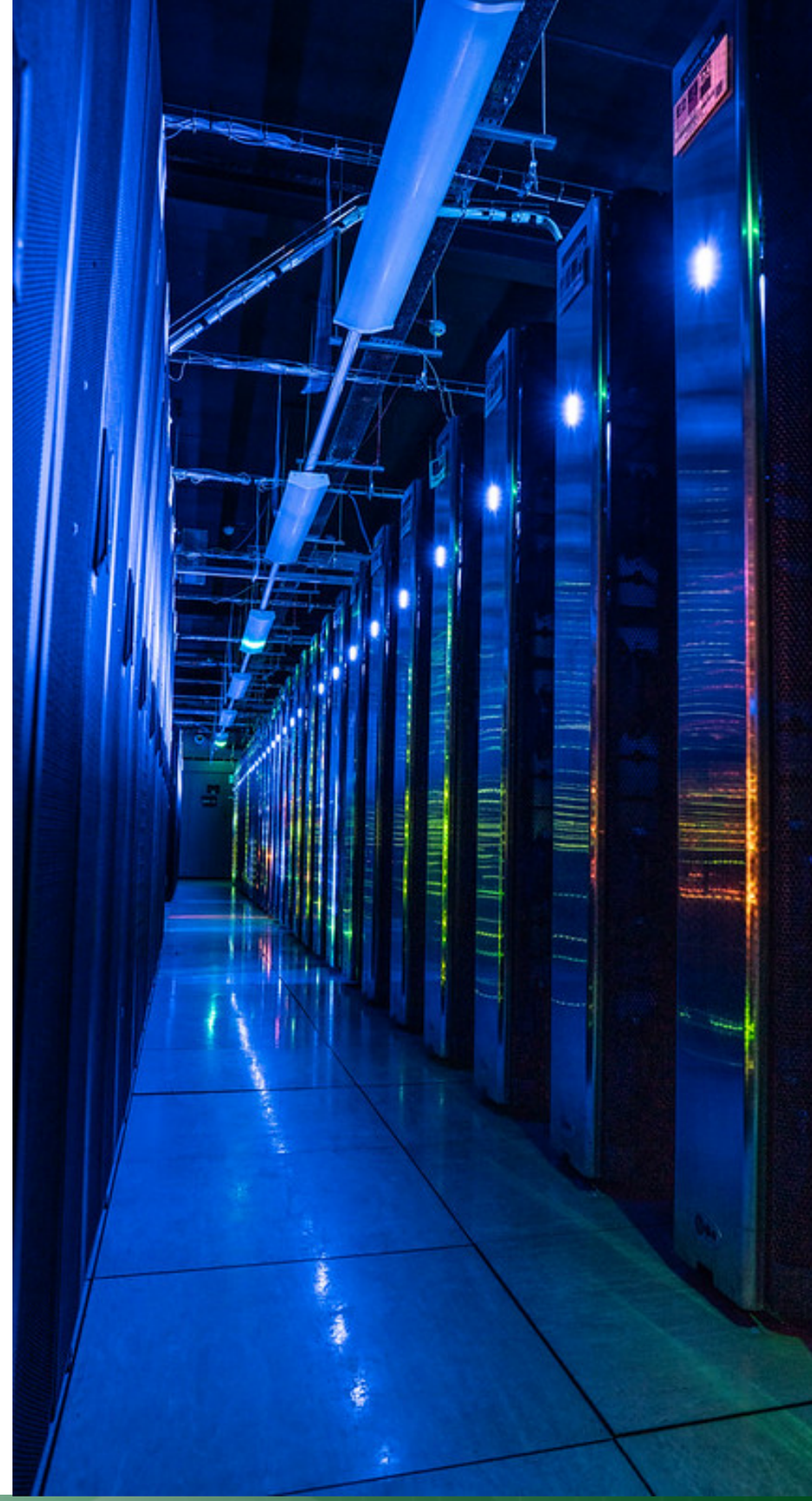
# RAMIP

- **We perform a set of experiments across a number of models that better enable us to assess the potential contribution of aerosols to near-future climate change, to describe the robust features of the response to regional aerosol changes, and to identify where the key uncertainties lie.**
  - Consistent treatment of aerosol emissions
  - Realistic aerosol perturbations, with straightforward parallels to SSPs and air quality
  - Emission regions with a future focus

# Timeline

- **Expect Tier 1 to be completed by all participating models by mid 2024**

- **CMORized data publicly available via CEDA by January 2025**
  - Contact ramip@ncas.ac.uk for early access to data



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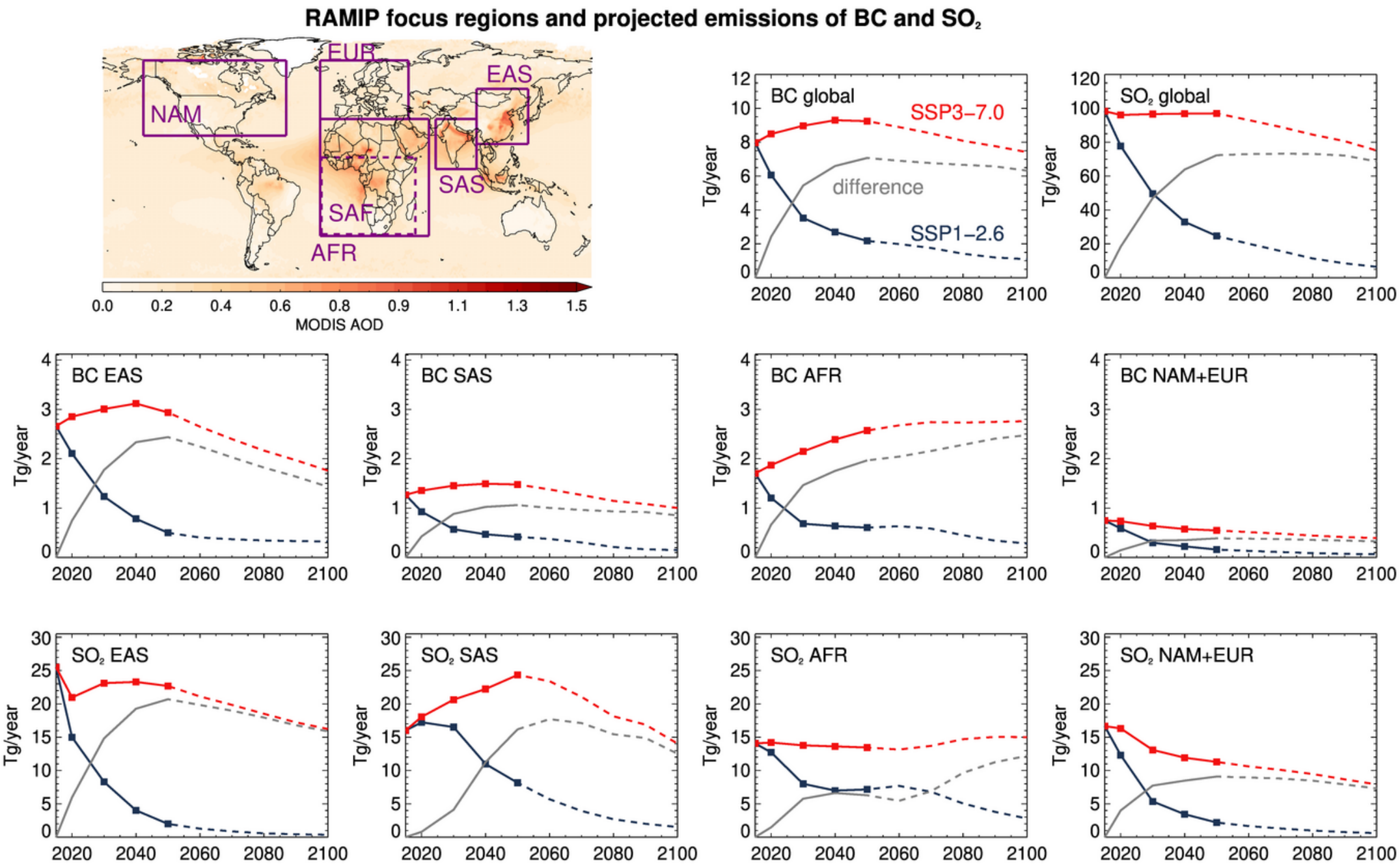
# RAMIP description paper and variable request

https://gmd.copernicus.org/articles/16/4451/2023/




Wilcox et al. (2023)