G6-1.5K-MCB: Mid-latitude Marine Cloud Brightening Scenario Simulations

Haruki Hirasawa[1], Matthew Henry[2], Alex Mason[2], Phil Rasch[1], Jim Haywood[2], JF Lamarque[3], Sarah Doherty[1], Rob Wood[1]

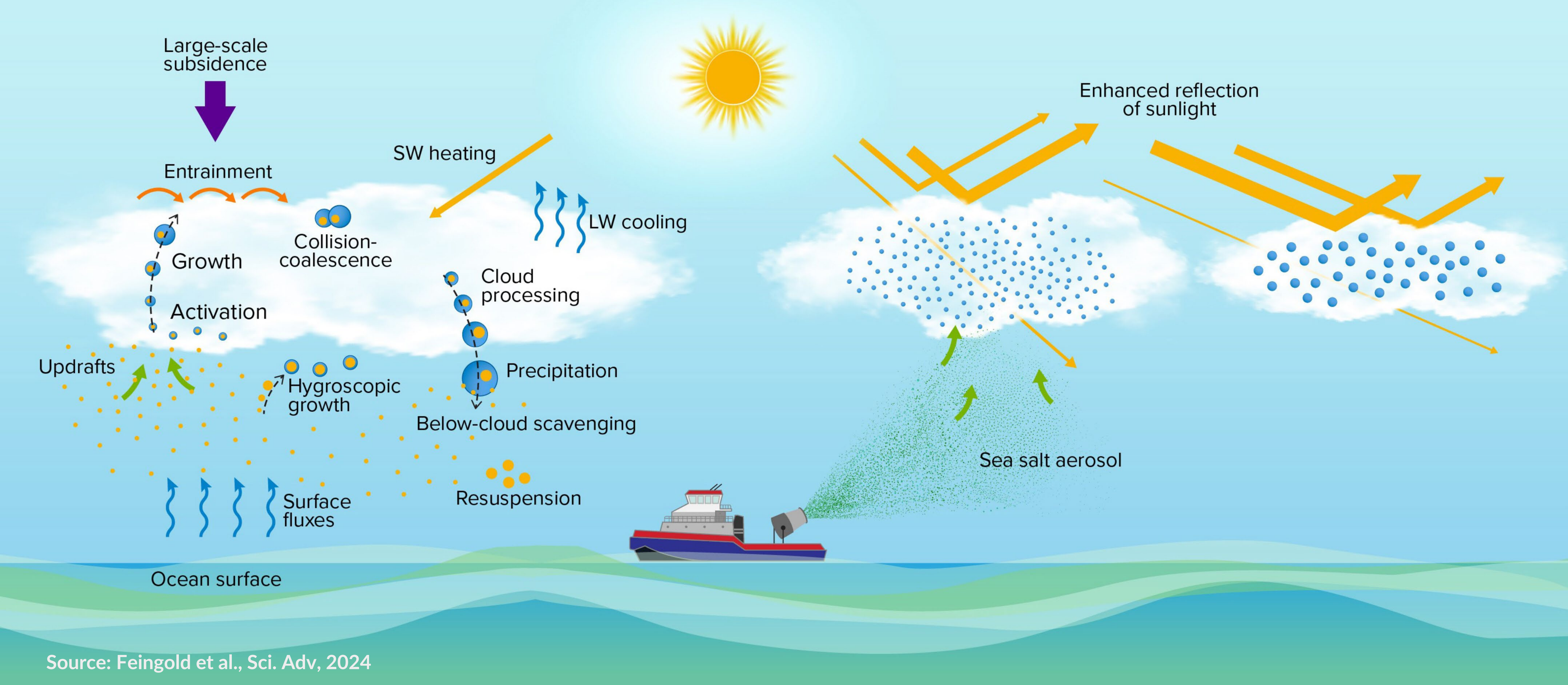
1 UNIVERSITY of WASHINGTON

2 UNIVERSITY OF EXETER

3 SILVER LINING ENSURING A SAFE CLIMATE

Marine Cloud Brightening (MCB)

- Aims to leverage the Twomey effect from injected sea salt aerosol (iSSA) to reduce SW downwelling at the surface



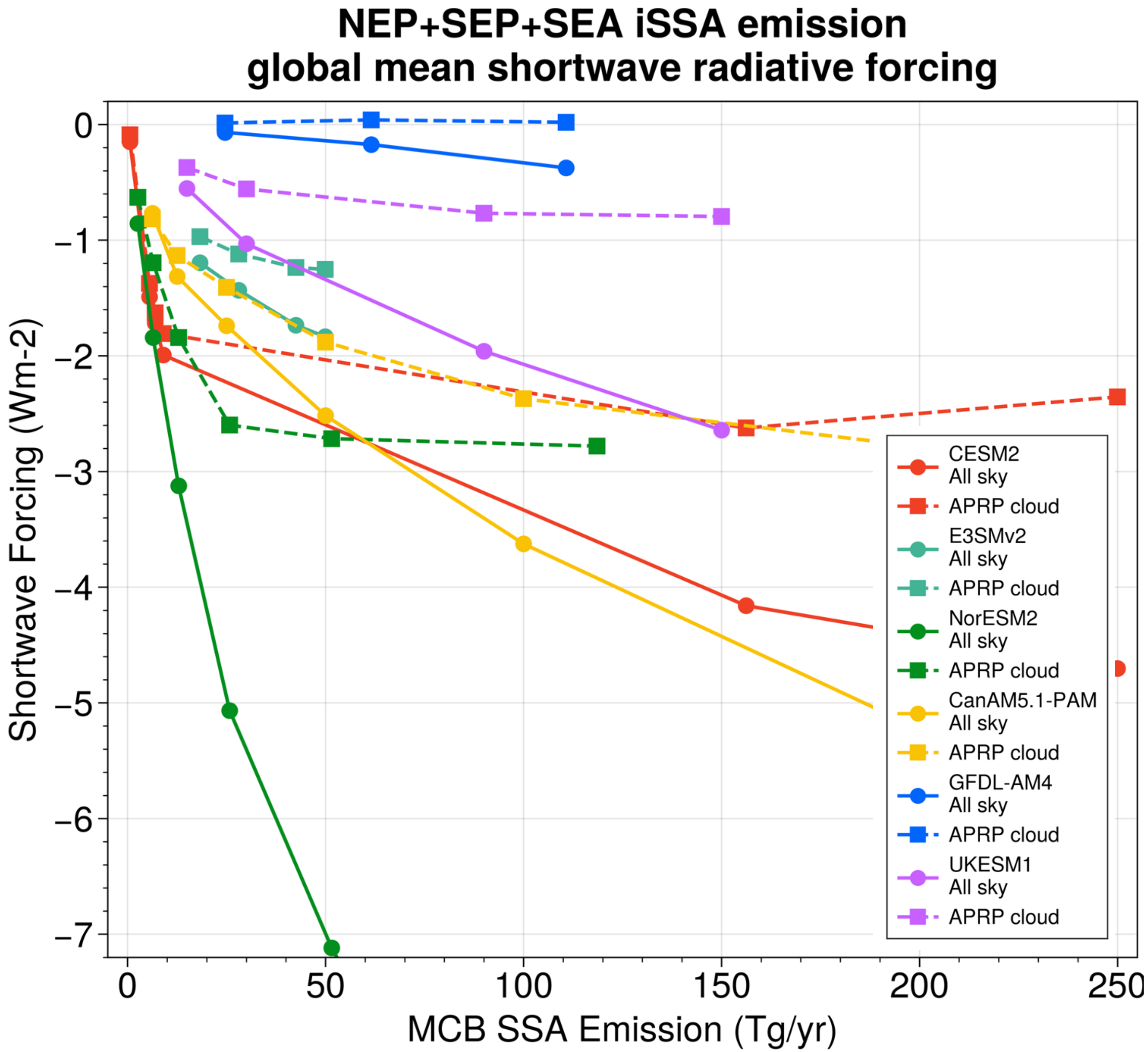
Source: Feingold et al., Sci. Adv, 2024

Protocol design decisions

1. How do we represent MCB in GCMs?
2. Where should MCB be deployed?
3. When and how much MCB is required to cool?

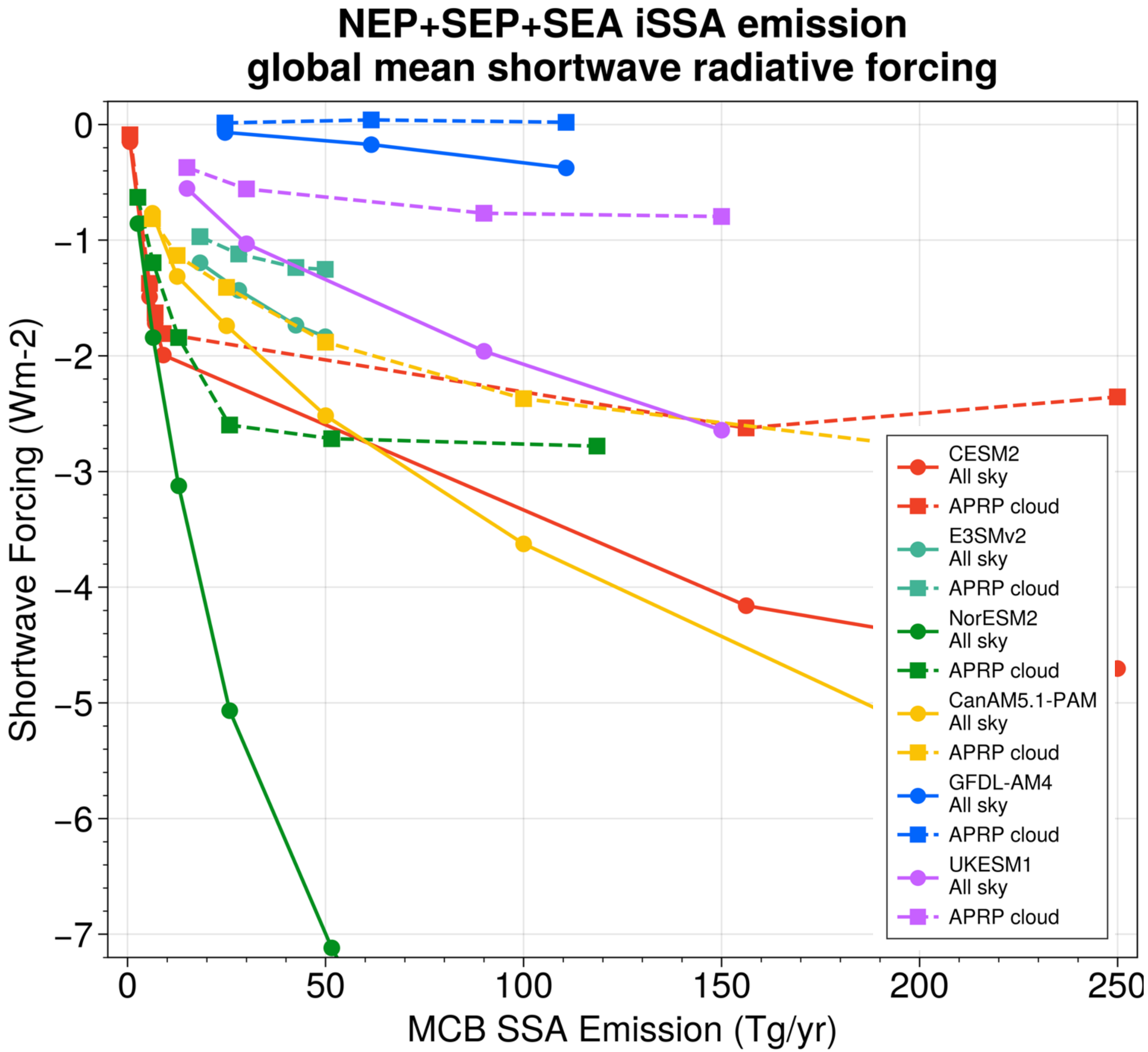
Protocol design decisions

1. **How do we represent MCB in GCMs?**
2. Where should MCB be deployed?
3. When and how much MCB is required to cool?



How we represent MCB in GCMs?

- Increase accumulation mode sea salt aerosol (iSSA) emissions in fixed regions
- Large inter-model uncertainty ERF due to iSSA emissions
  - Strong sensitivity to radii of emitted aerosol
  - Activation rates differ
- Protocol:
  - Explicitly define fixed-SST simulations for ERF benchmarking (G4SST-seasalt). (SSA emissions for ~-2Wm^{-2}



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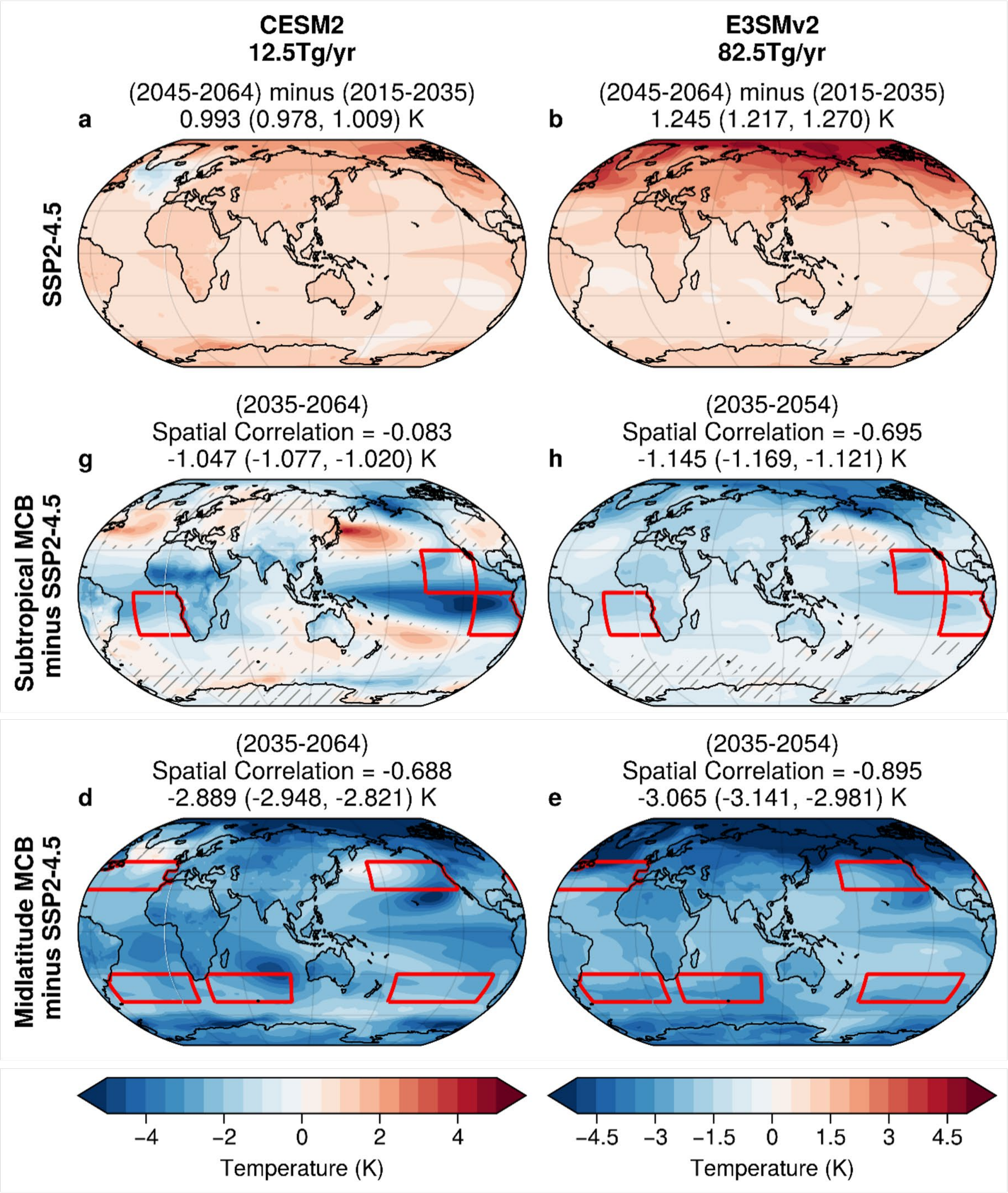
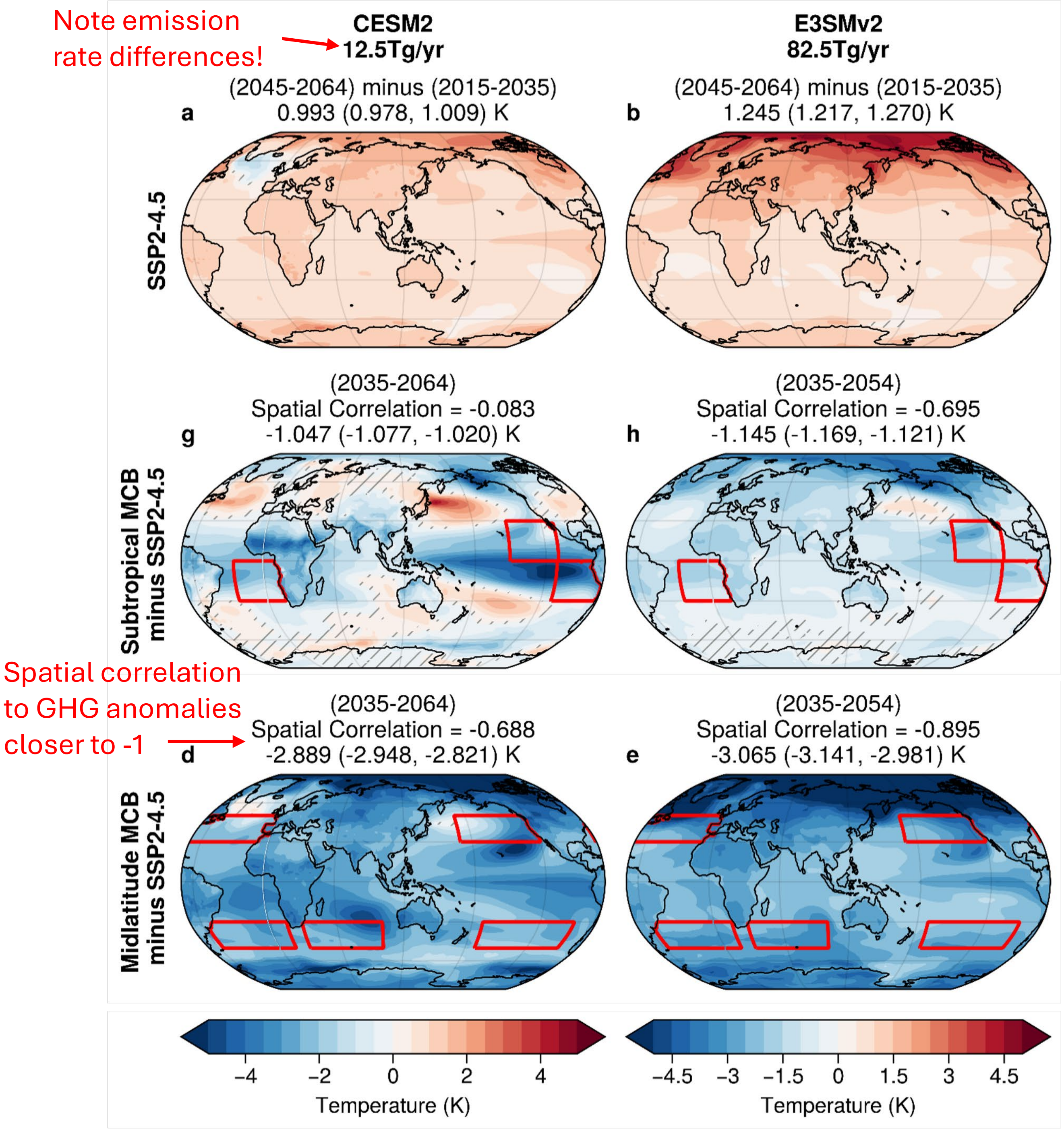


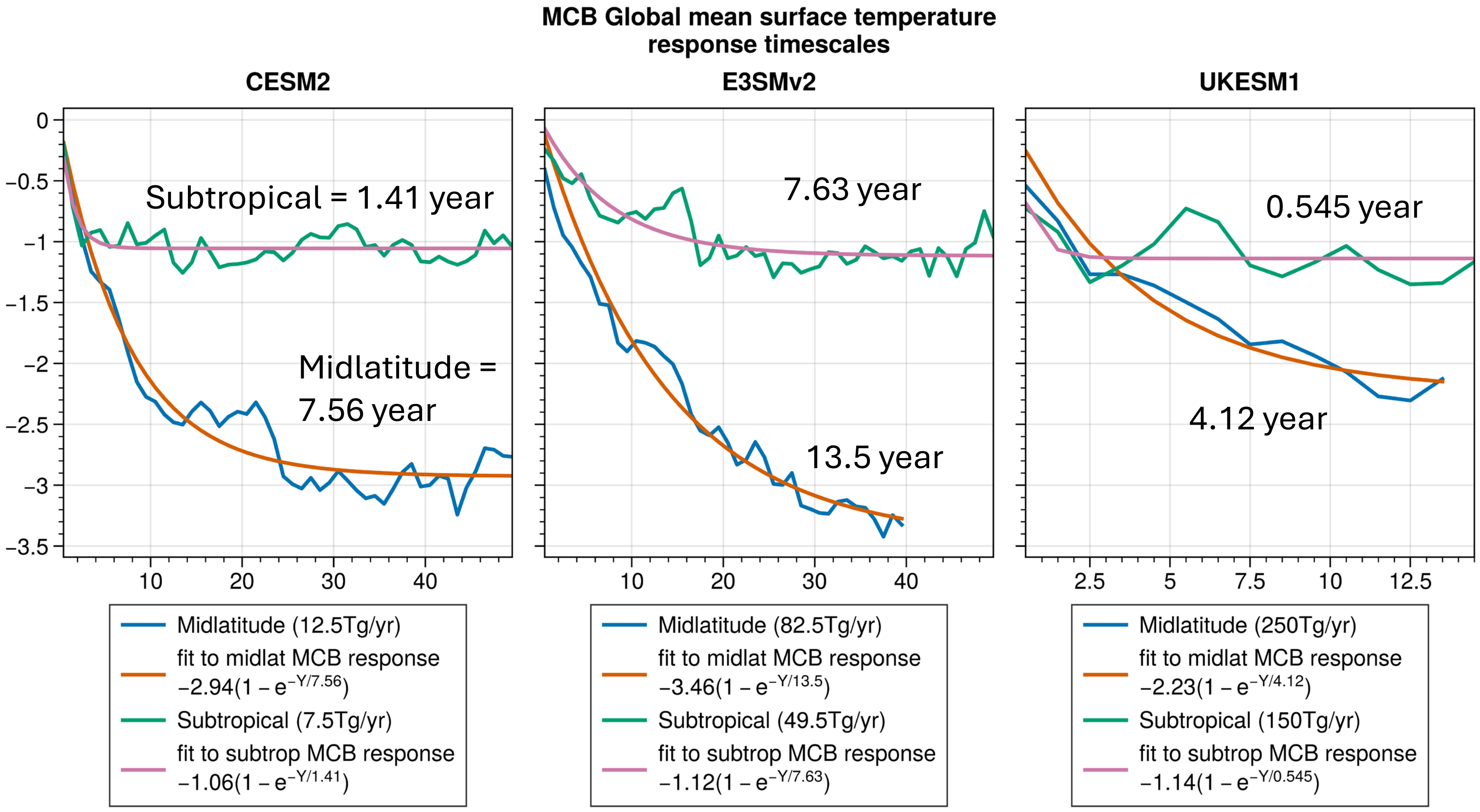
Where should MCB be deployed?

- Subtropical MCB produces La Nina-like anomalies
- Midlatitude MCB produces more uniform cooling
- Protocol:
  - Emit iSSA in midlatitude oceans



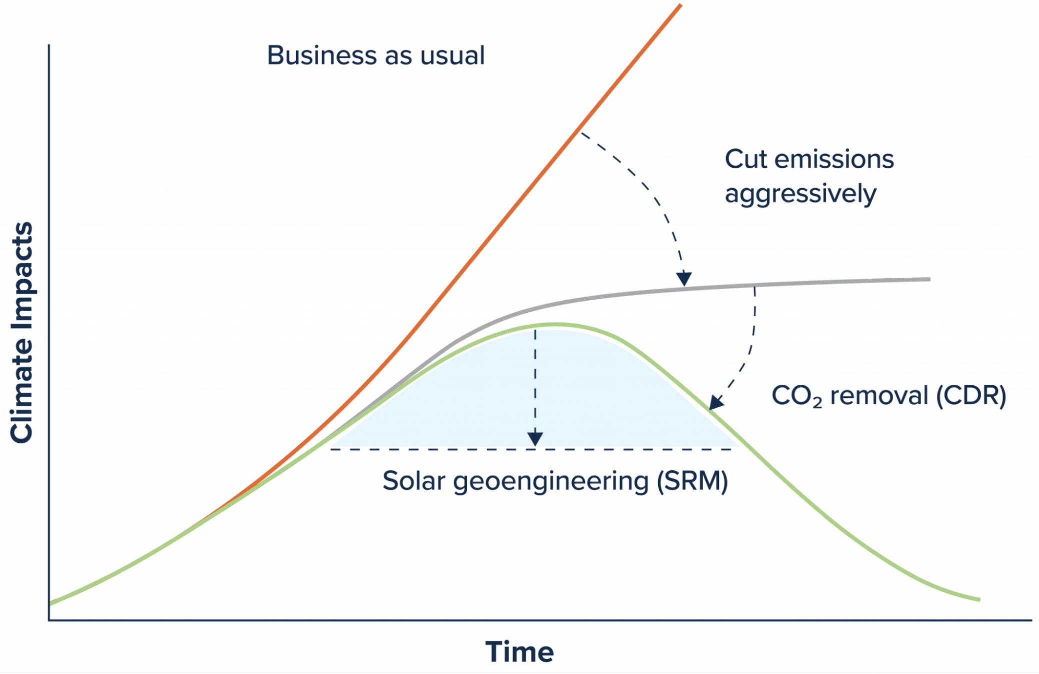
Climate response timescales

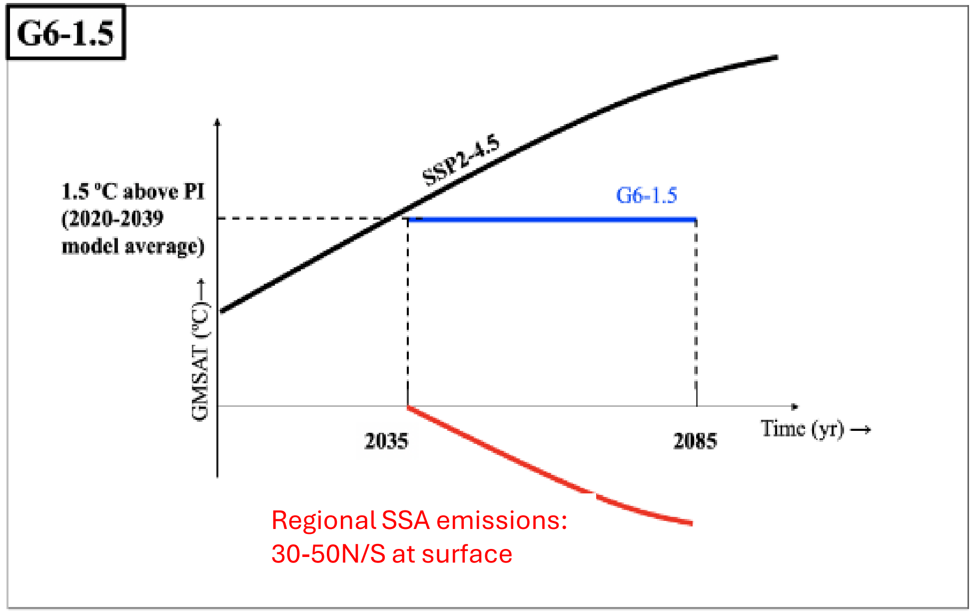
- Different global temperature response timescales depending on model and forcing location



Protocol design decisions

1. How do we represent MCB in GCMs?
2. Where should MCB be deployed?
3. **When and how much MCB is required to cool?**
    1. MCB begins in 2035
    2. iSSA emissions adjusted to maintain target 2020-2039 GMST





When and how much MCB is required to cool?

MCB Emissions

Global mean surface temperatures

2

1

3

G6-MCB-1.5K : Temperature pattern

- MCB returns climate closer to reference in the three models
- Few significant land temperature changes in CESM2 and UKESM1
- Too-weak cooling in Arctic

2 - 1

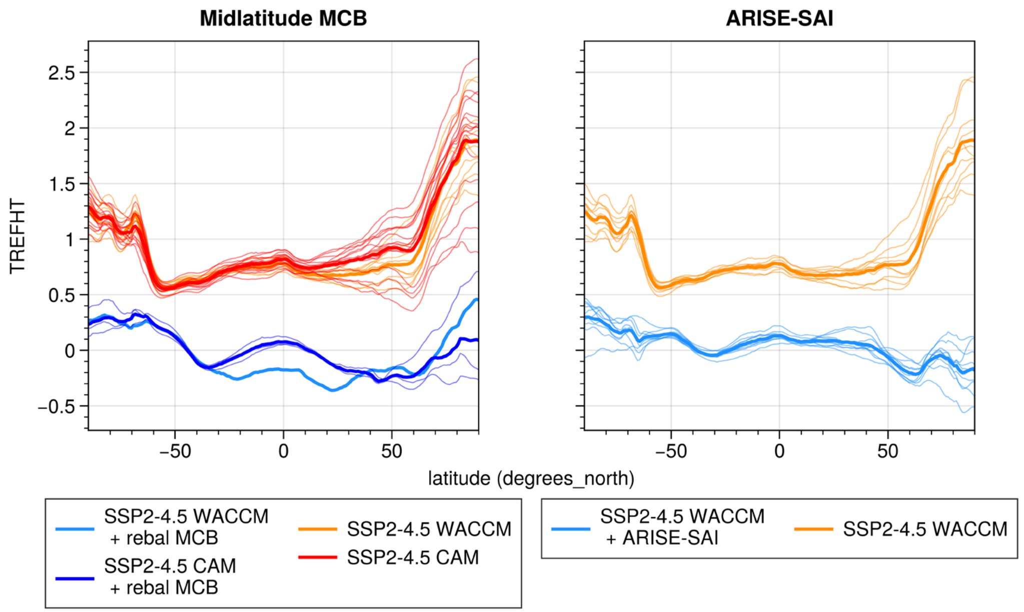
3 - 1

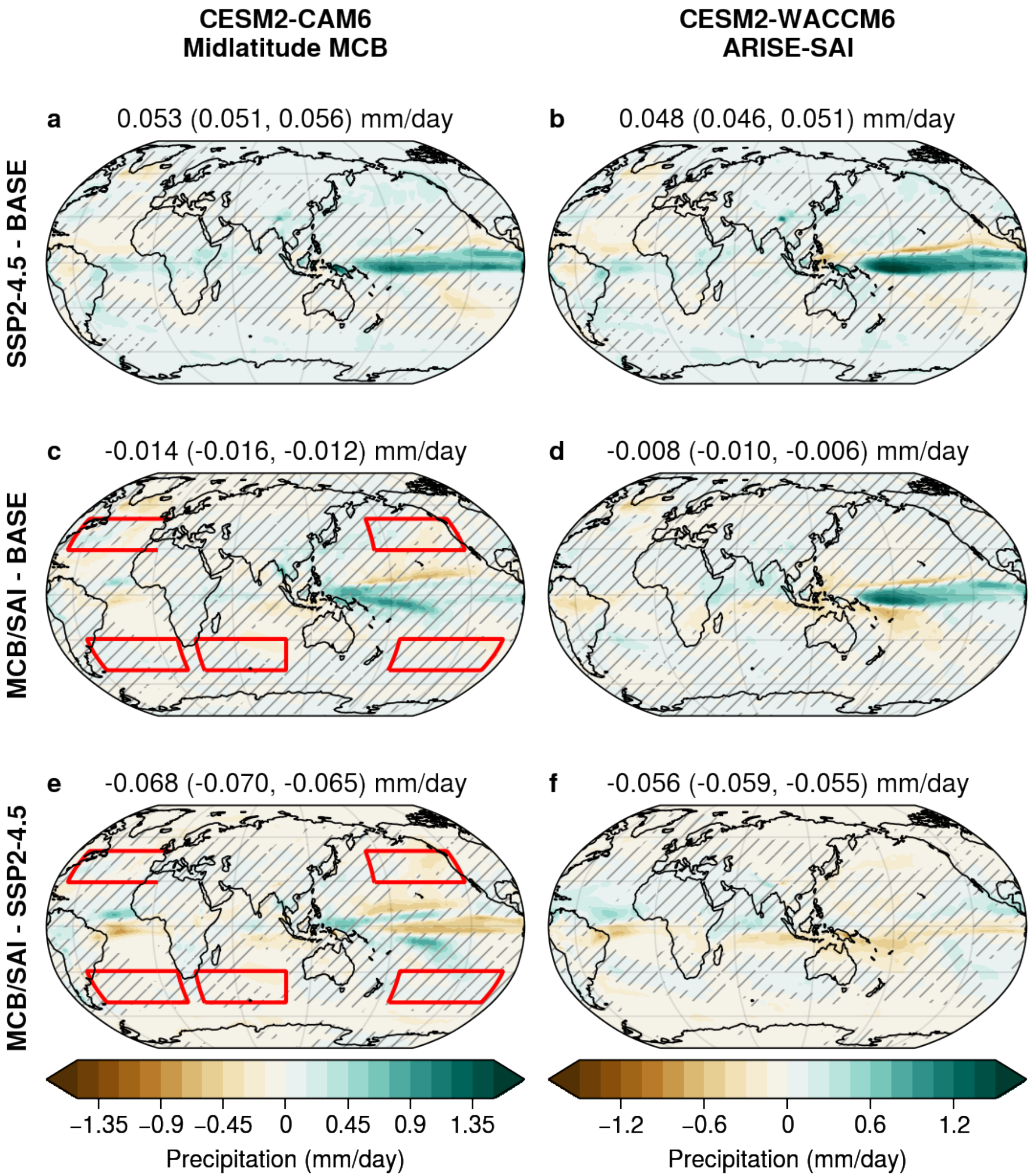
3 - 2

G6-MCB-1.5K vs ARISE-SAI

- MCB and SAI both bring zonal mean temperatures near target levels
- Substantial reductions in precipitation anomalies under MCB/SAI

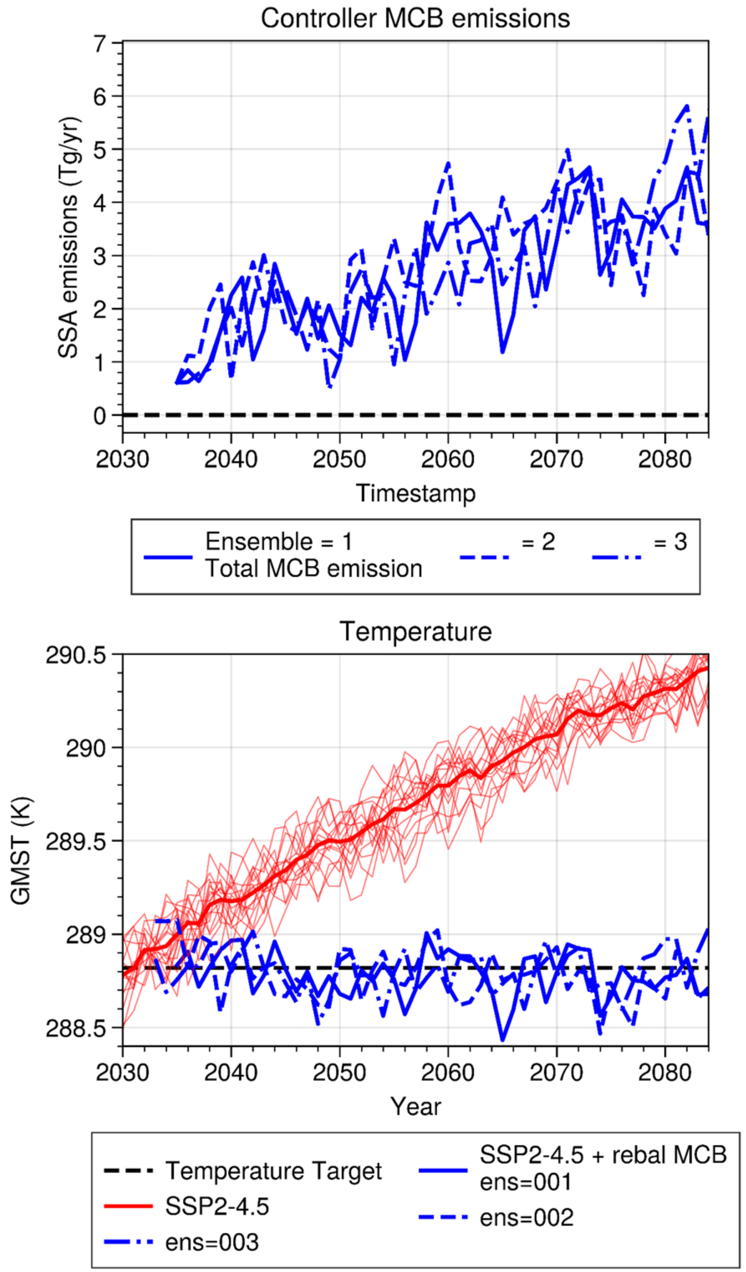
CESM2 Zonal mean temperature anomalies





Conclusions

- Midlatitude SSA emissions are both **efficient at cooling** and have **temperature responses similar to ARISE-SAI**
- Large SSA emission forcing uncertainties motivate inclusion of **explicitly defined fixed SST simulations**

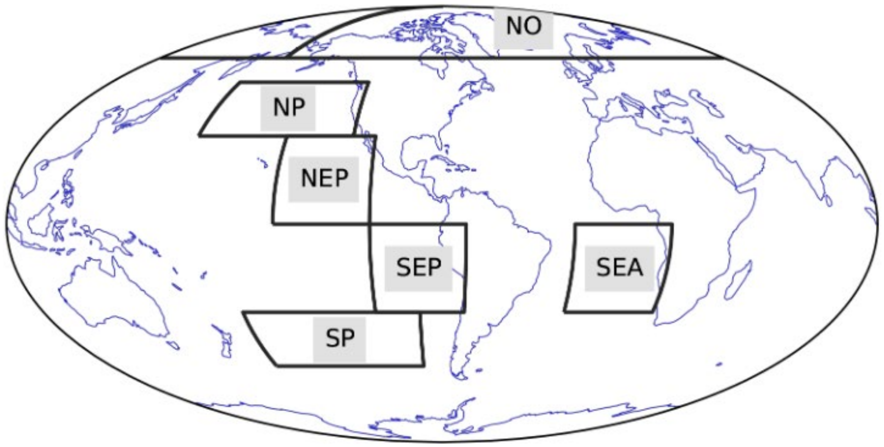


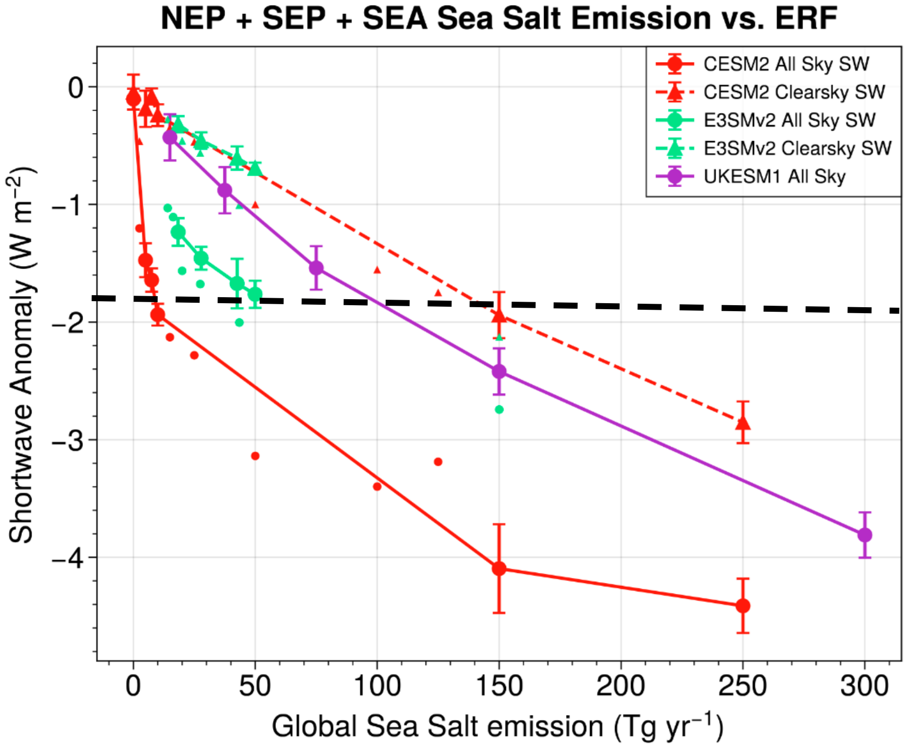
Rasch 2024 Protocol

STAGE 1: Fixed SST simulations to evaluate ERF from SSA emissions

STAGE 2: Coupled simulations with constant SSA emissions to evaluate climate response. SSA emission rates are set as rate that gives ~1.8Wm^{-2} forcing.

Model	SSA diameter	Benchmark mass emission	Benchmark number flux rate
CESM2	80-100nm	2.5Tg/yr per region	4.1 x 10^{19} #/s per region
E3SMv2	80-100nm	16.5Tg/yr per region	2.7 x 10^{20} #/s per region
UKESM1	172nm	50Tg/yr per region	2.7 x 10^{20} #/s per region





Regional MCB Effective Radiative Forcing

- SSA emissions in midlatitude regions generally have high ERF susceptibility
- Stronger Twomey effect in midlatitudes vs. subtropics across all three models
- Large direct aerosol effect in UKESM1 due to large emission mass rate

Regional MCB Global mean surface temperature

- Stronger GMST response to midlatitude MCB versus subtropical MCB
- Less negative feedback parameters in midlatitudes, with strong negative feedbacks in SEA and NEP

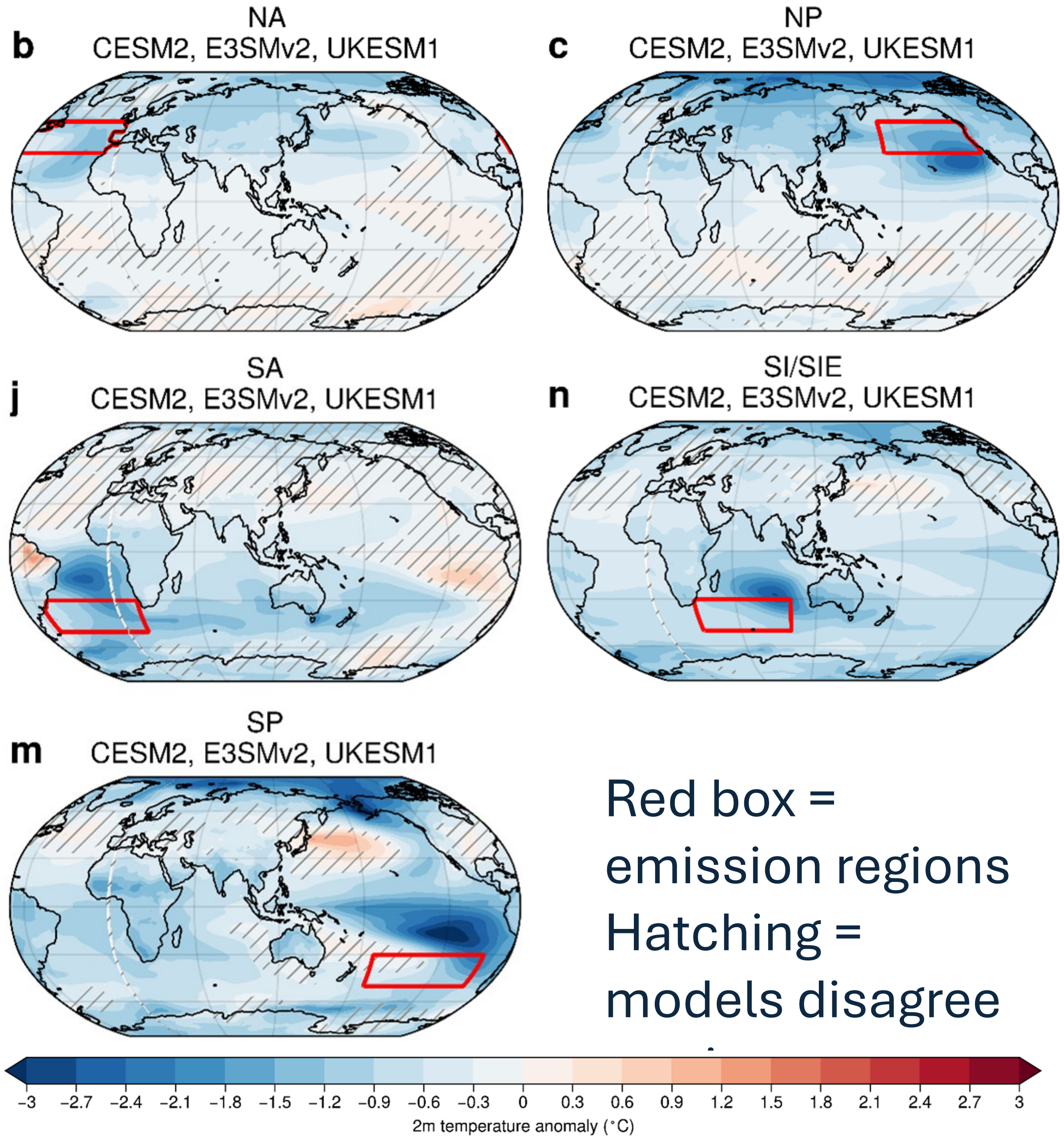
Global Feedback parameter for Regional MCB

- Blue = stronger damping of temperature
- Less negative feedback parameters in midlatitudes, with strong negative feedbacks in SEA and NEP

Climate response patterns

- Broad hemispheric cooling in response to midlatitude MCB

- Consistent cooling responses patterns across the three models



Red box = emission regions
Hatching = models disagree