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Recent findings on the effects of aerosols on the climate

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Conclusions

- Anthropogenic aerosols currently mask at least 0.5°C of global warming

- Aerosol climate impacts (temperature, precipitation and extremes) are regionally heterogeneous, and follow different patterns than those from greenhouse gases – and from emissions emission patterns

- **Sulfate** aerosols (from SO2 emissions) are the main temperature driver
  - …with aerosol-cloud interactions representing a major source of uncertainty

- **Black carbon (BC)** has a lower climate impact (and radiative forcing) than previously thought
  - …with emission estimates representing a major source of uncertainty

- **Organic carbon (OC)** emissions are moderately cooling
  - …with emission estimates and brown carbon (**BrC**) representing major sources of uncertainty

- Aerosols (very likely) affect precipitation, globally (ITCZ, surface cooling, atmospheric stability) and regionally (monsoon patterns, mediterranean and South African drying)

- Present and future air quality measures will affect the climate, but it’s far from clear just how and how much

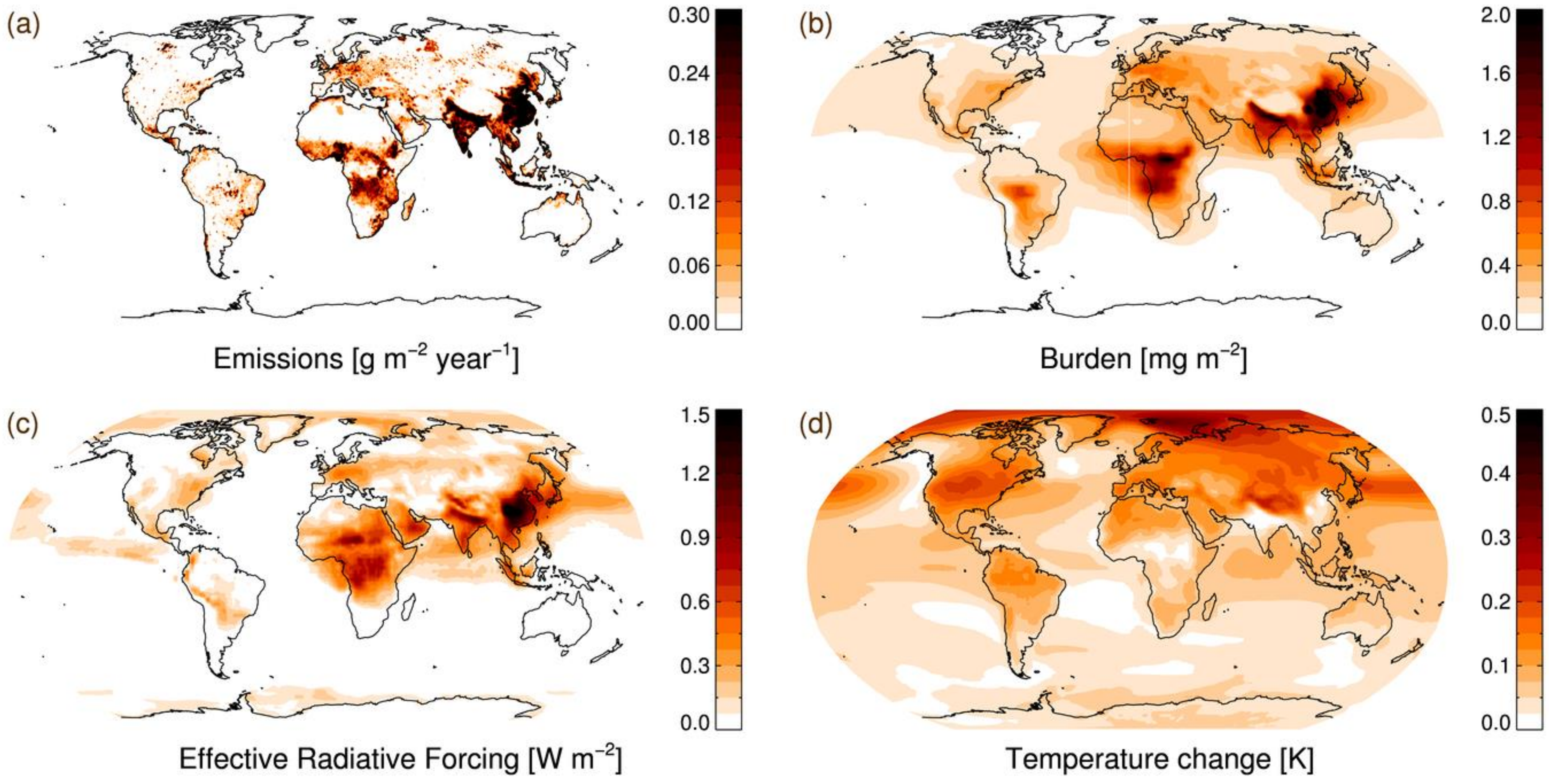
The climate impact of aerosols (here: BC)
Breaking it down:

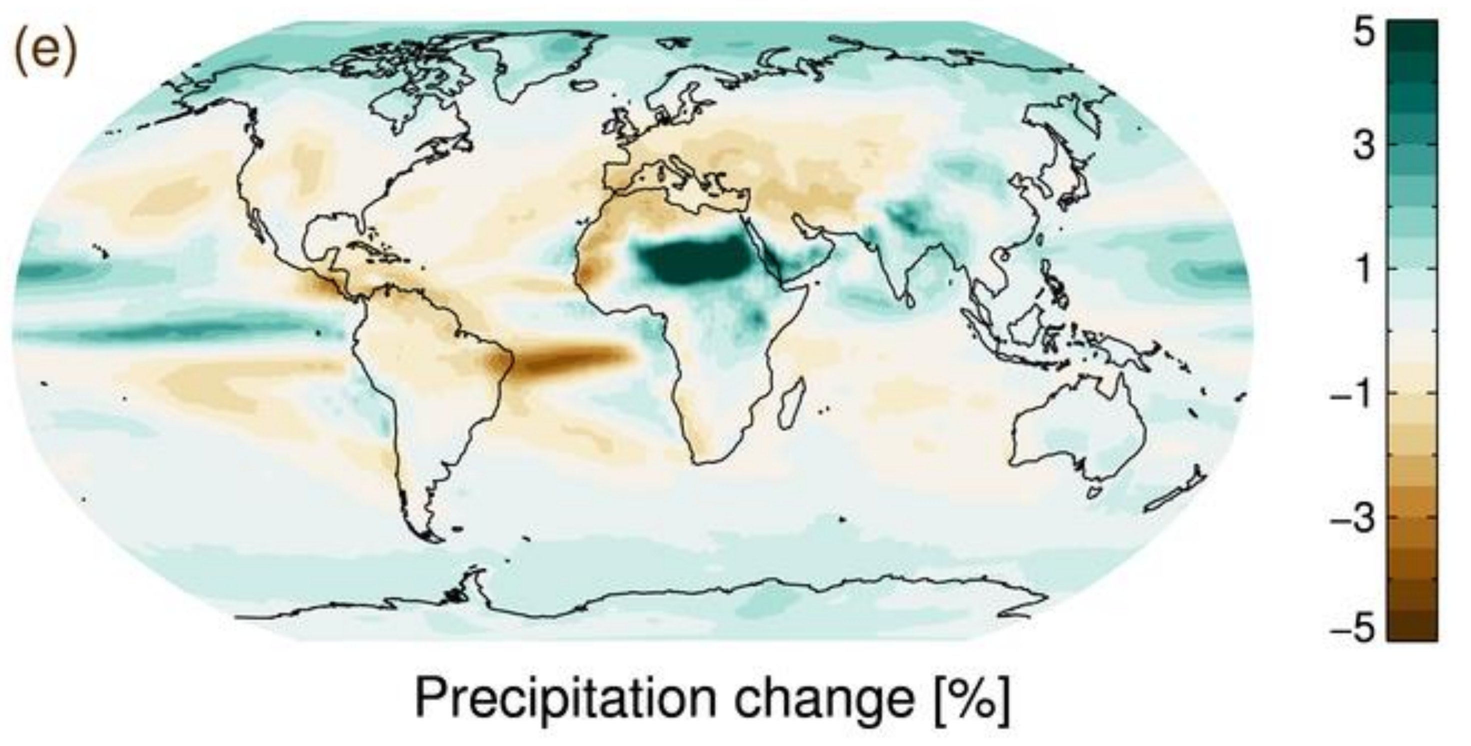
$$Em \times LT \times MAC \times RFE = RF$$

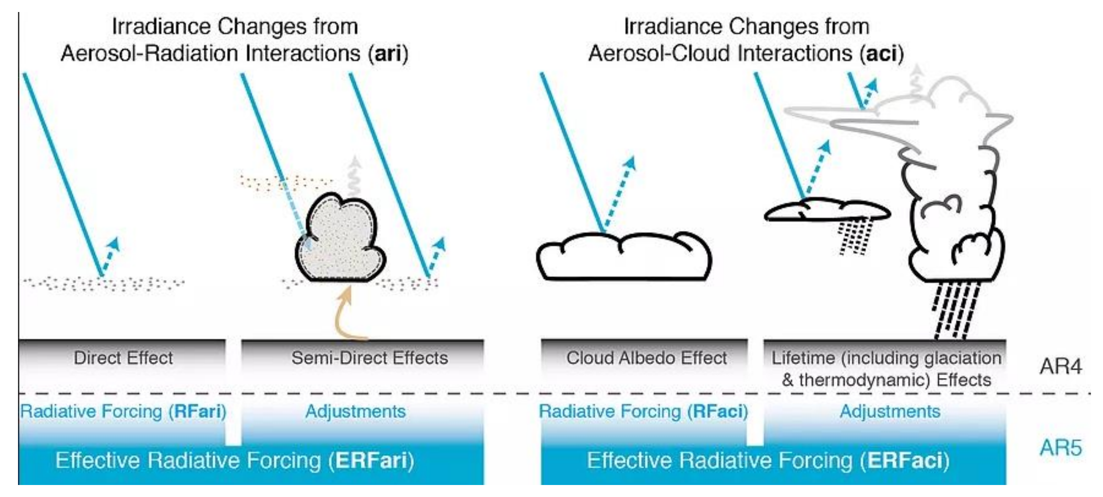
$$AAOD \times RFE = RF$$

$$RF \rightarrow dT, dP$$

Em	=	Emissions
LT	=	Lifetime / residence time
MAC	=	Mass absorption coefficient
RFE	=	Radiative forcing efficiency
AAOD	=	Aerosol abosrption optical depth
RF	=	Radiative forcing
dT	=	Surface temperature change
dP	=	Precipitation change







Hoesly et al. 2018 / Myhre et al. 2013 / Stjern et al. 2017 / IPCC AR5 WG1

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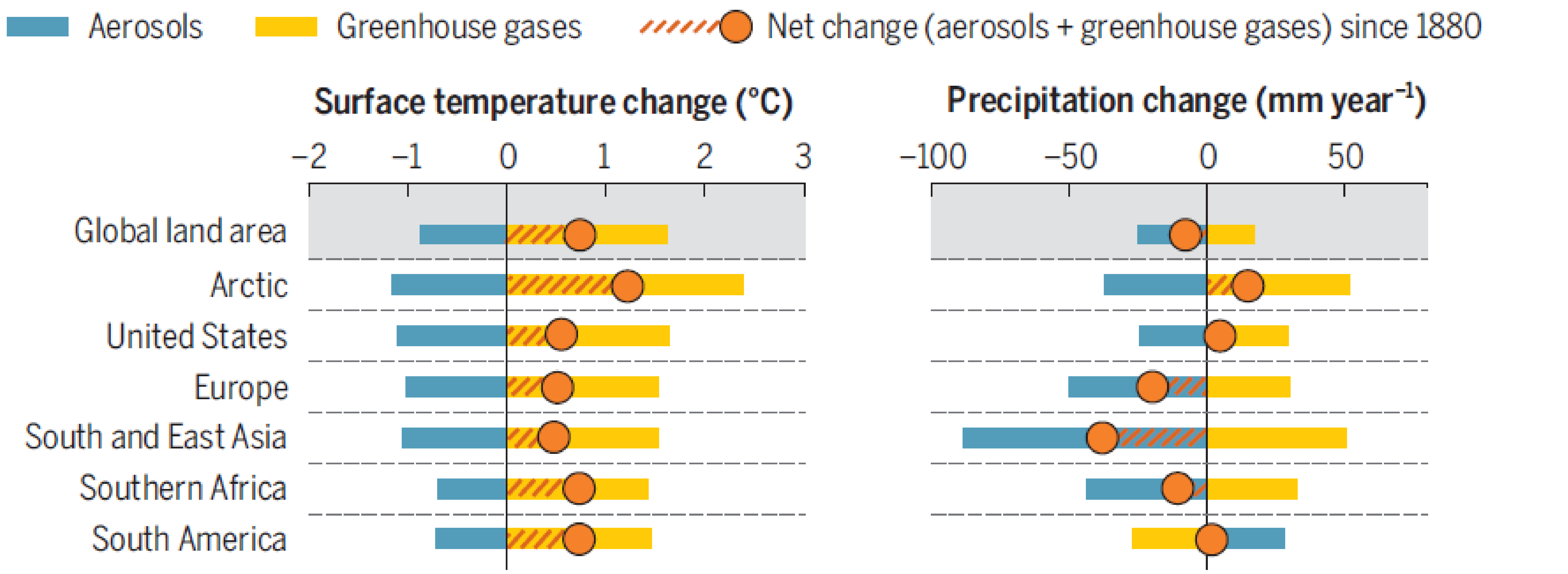
The climate impact of present day emissions of anthropogenic aerosols

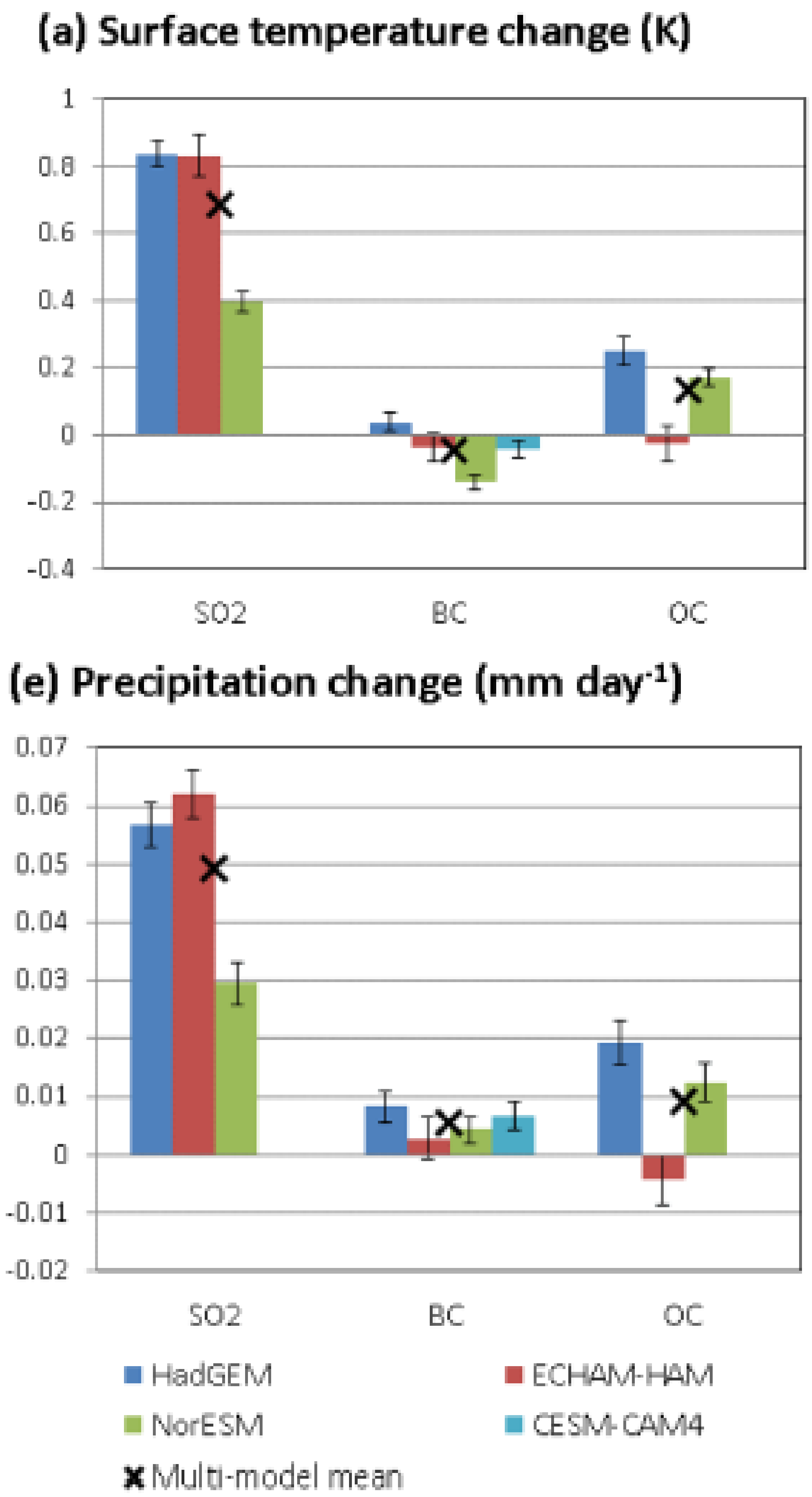
Samset, 2018, Science

Tug-of-war between aerosol cooling and greenhouse gas warming

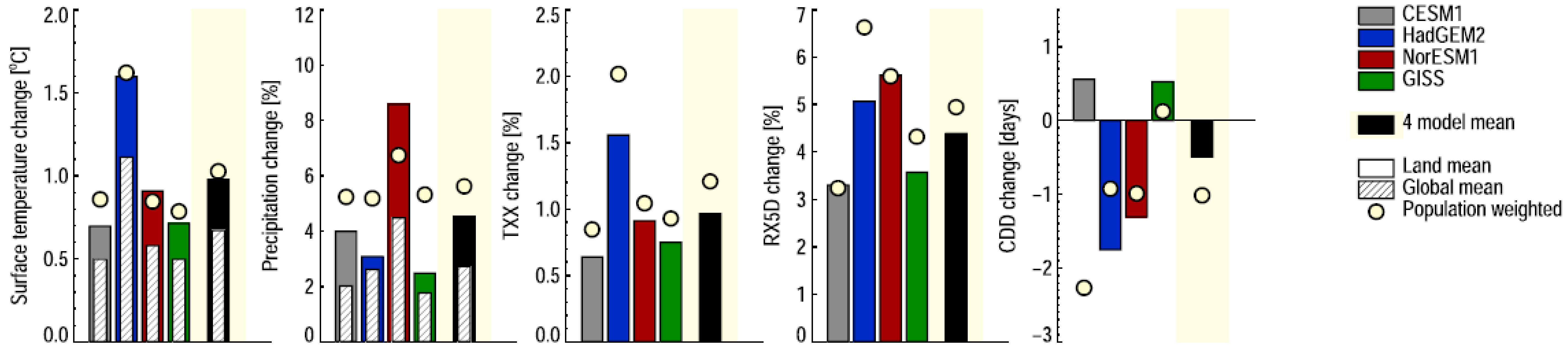
Surface temperature and precipitation have, since preindustrial times, been affected by both greenhouse gases and aerosols. Model simulations comparing the periods 1985 to 2005 and 1880 to 1900 show that across the global land area, aerosols have limited the impacts of greenhouse gas warming. The regional patterns are more complex for precipitation. Data from (*14*).



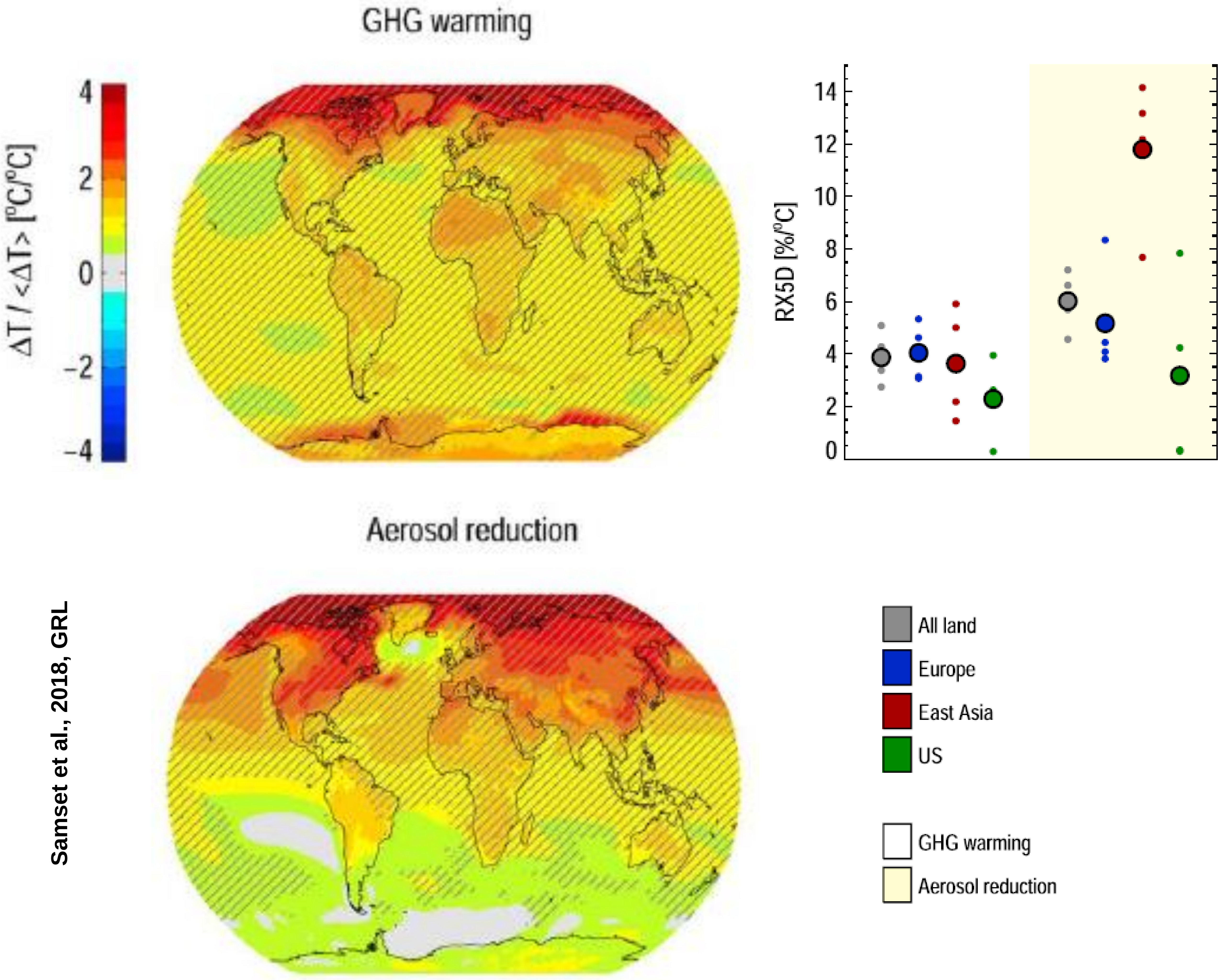
Baker et al., 2015, ACP



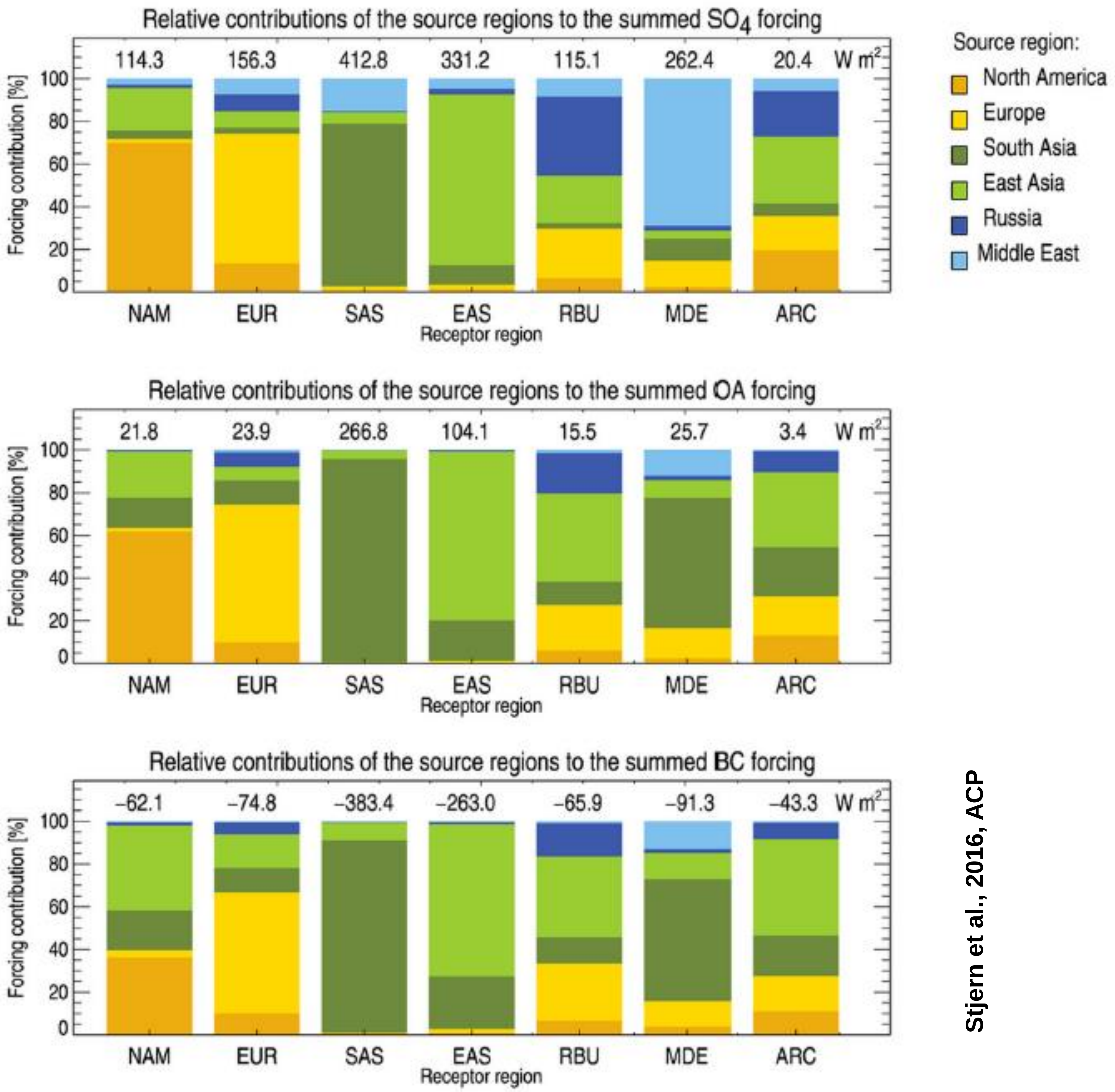
Samset et al., 2018, GRL



Aerosol impacts follow a different pattern to GHG, due – partly – to long range transport



Samset et al., 2018, GRL



Stjern et al., 2016, ACP

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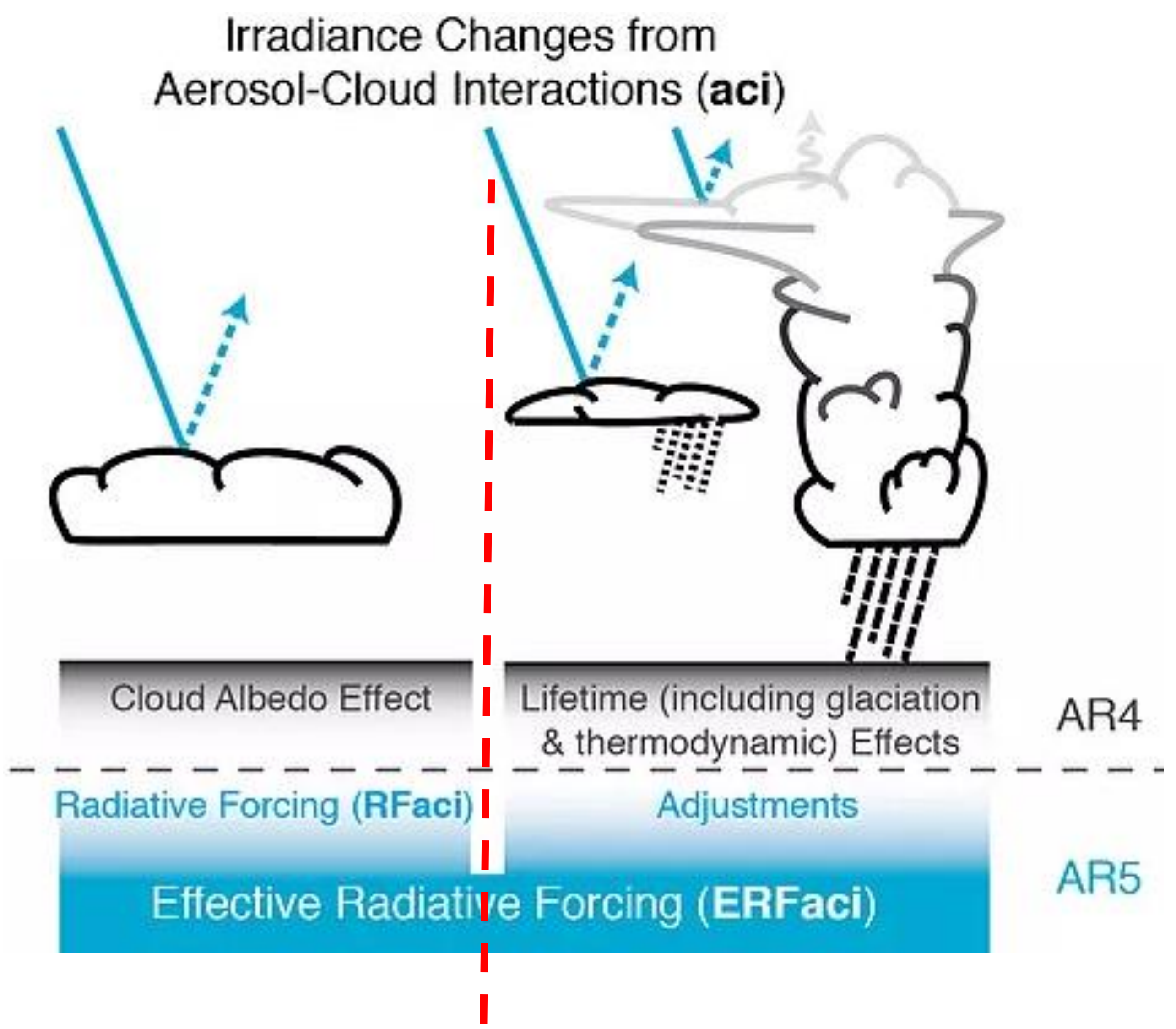
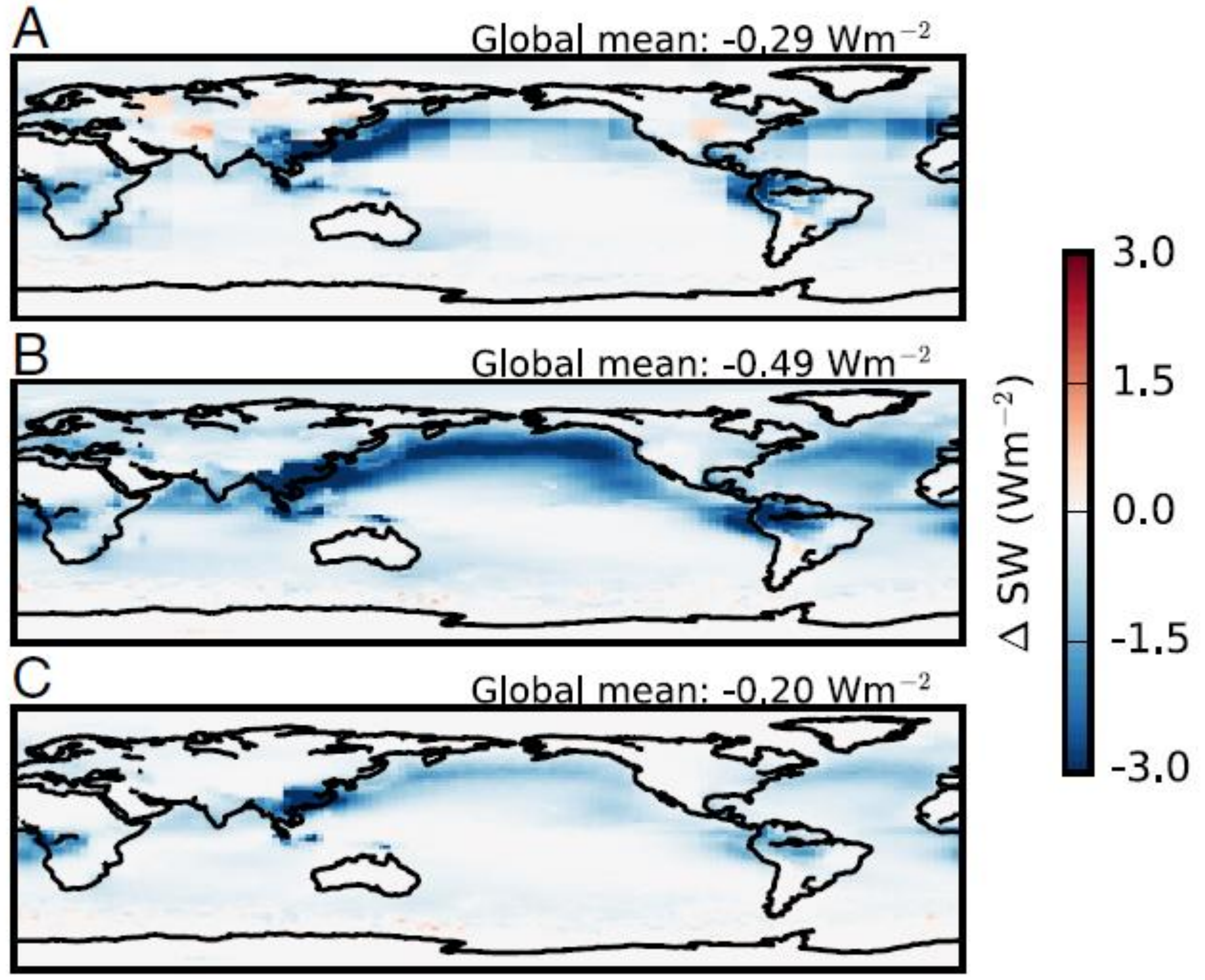
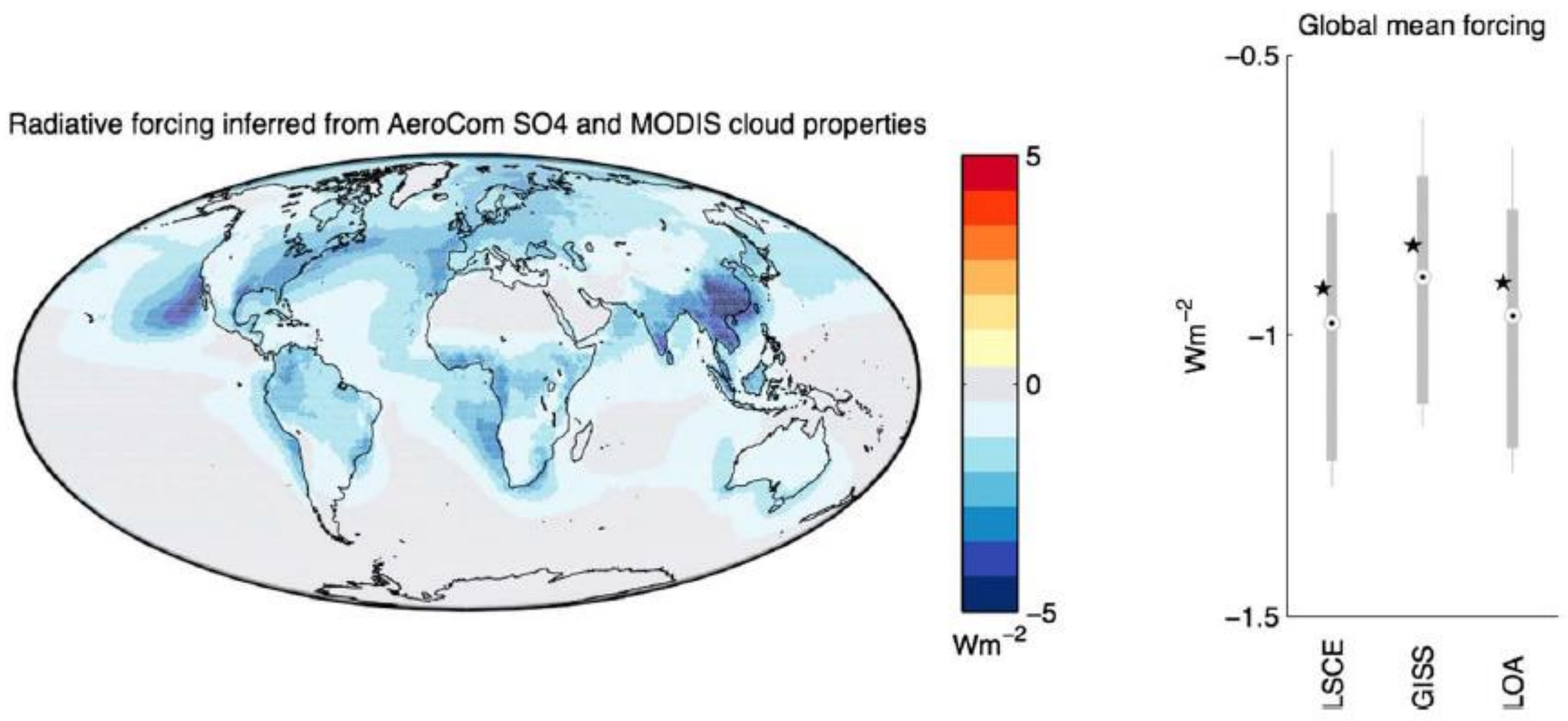
Sulfate

- Emissions: Relatively well characterized
- Climate impact: Uncertain, due to aerosol-cloud-interactions
- Several groups working to unify model estimates with observational estimates

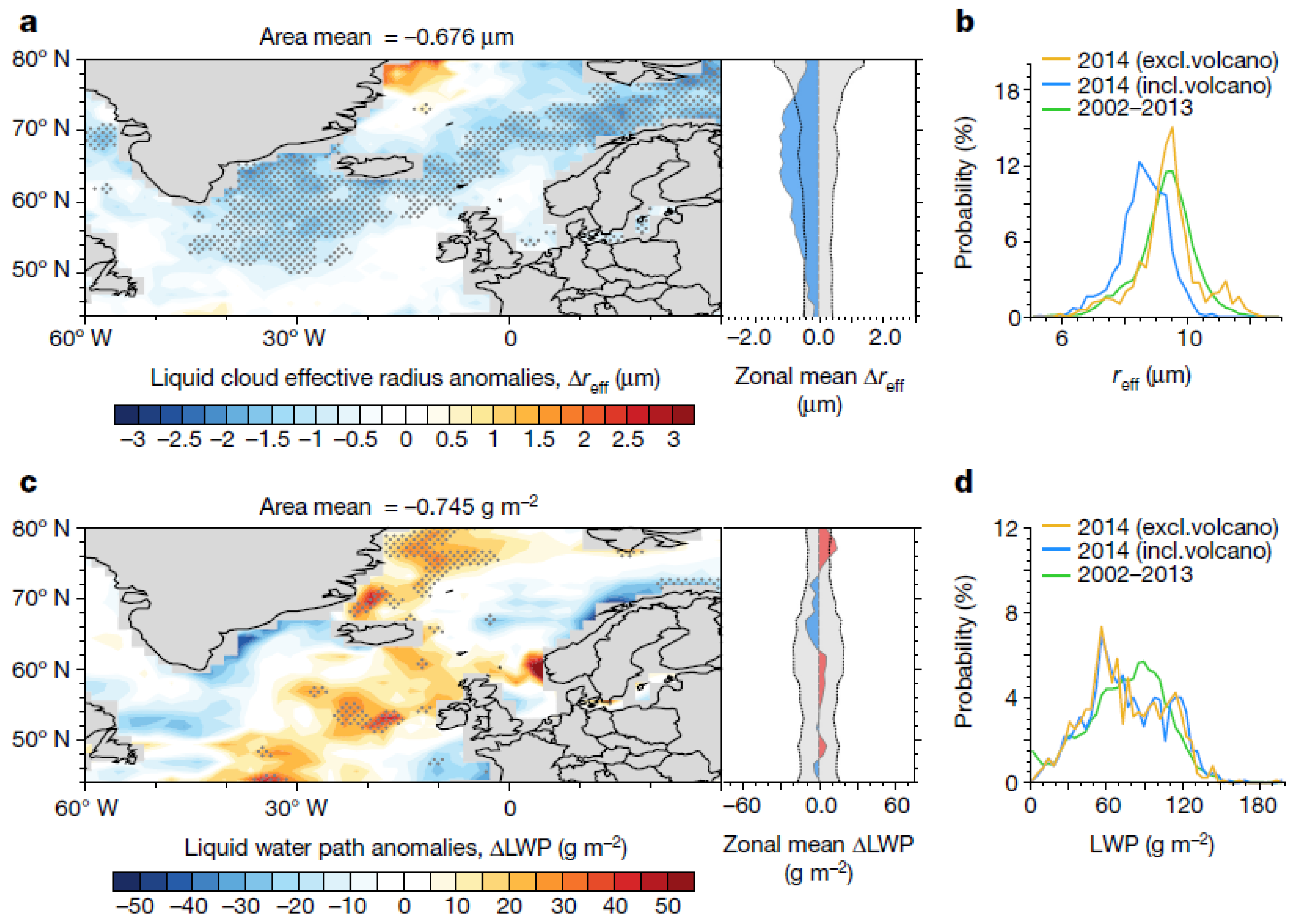




Gryspeerdt et al. 2018 PNAS



McCoy et al. 2017 JGRA



Malavelle et al. 2017 Nature

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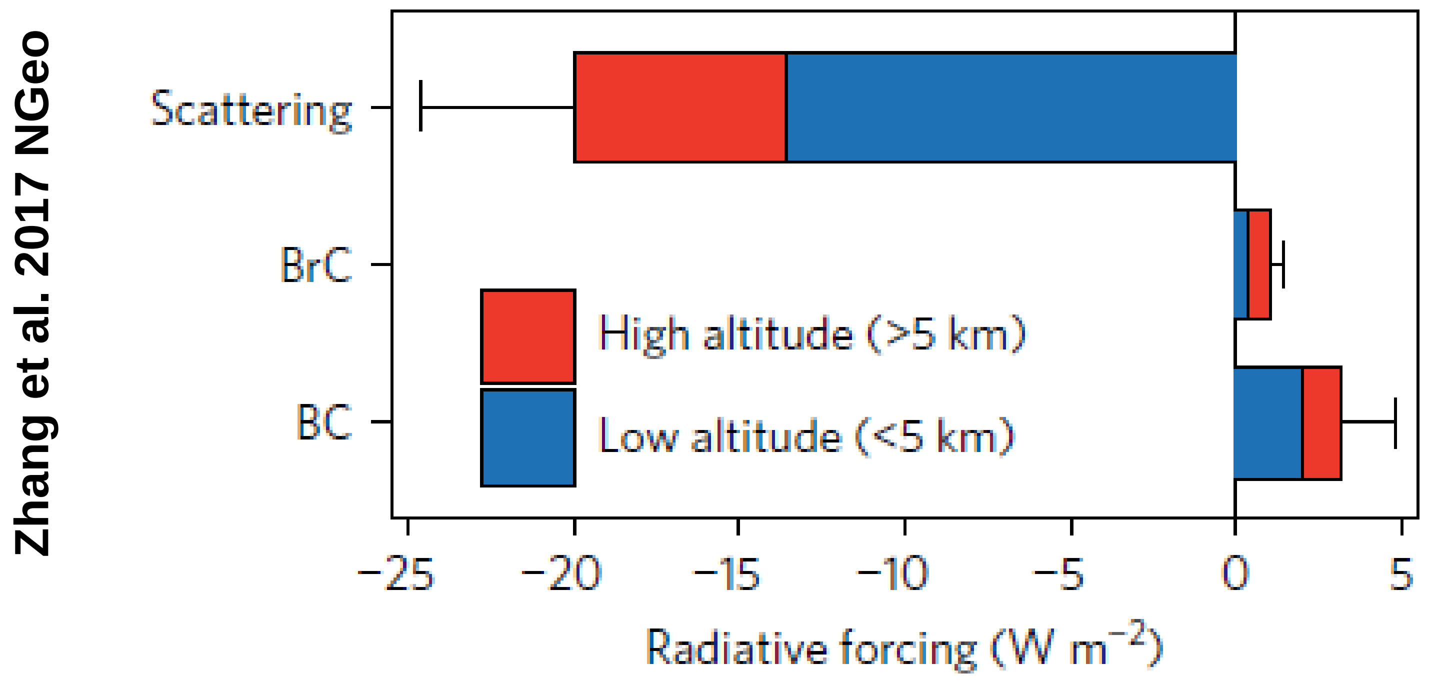
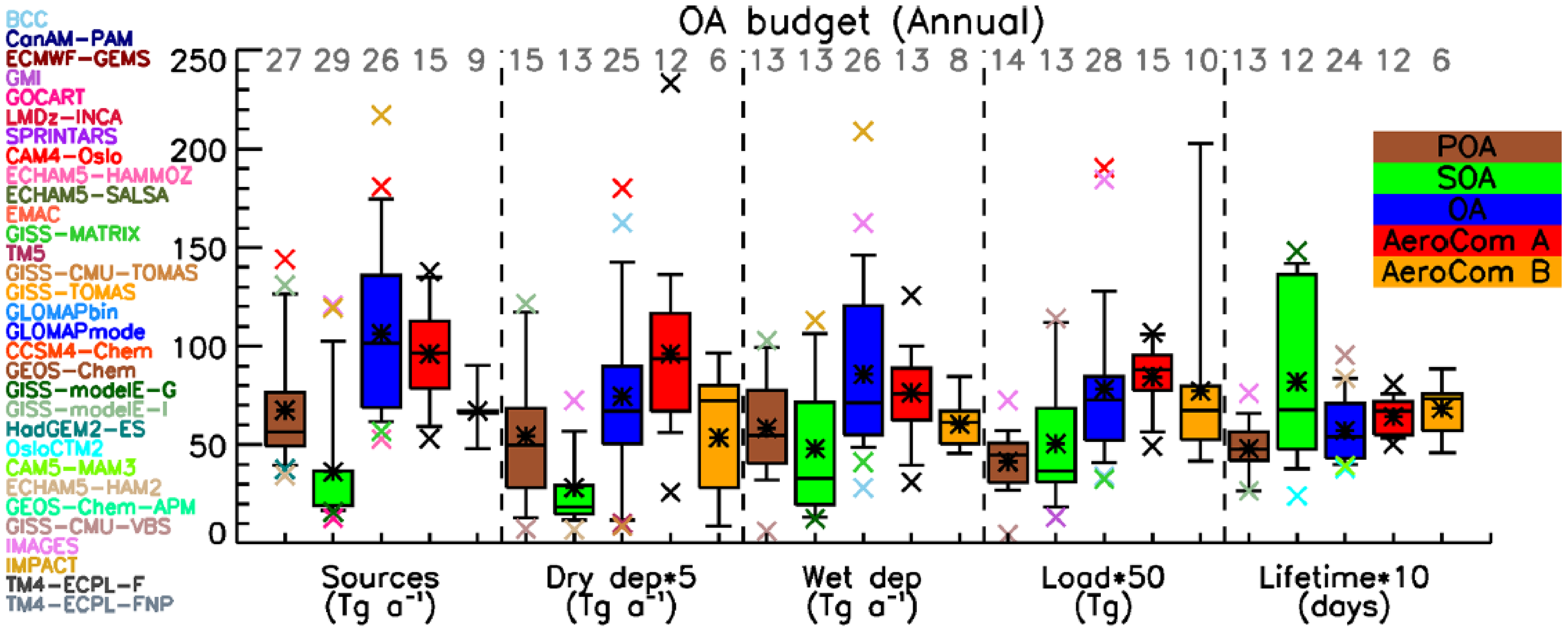
Organic aerosol

- Broad term (primary organic aerosols, secondary organics, broad range of sources, chemistry and transport, lack of observations…)
- Thorough multi-model inter- and observational comparison: Tsigaridis et al. 2014 ACP
- Recent topic: Brown Carbon Prevalent, also in upper troposphere:





- However, BrC only weakly modifies global negative RF from OA in most studies. SOA scattering dominates POA, due to altitude. (Lund et al. 2018, ACPD)

The climate impact of aerosols (here: BC)
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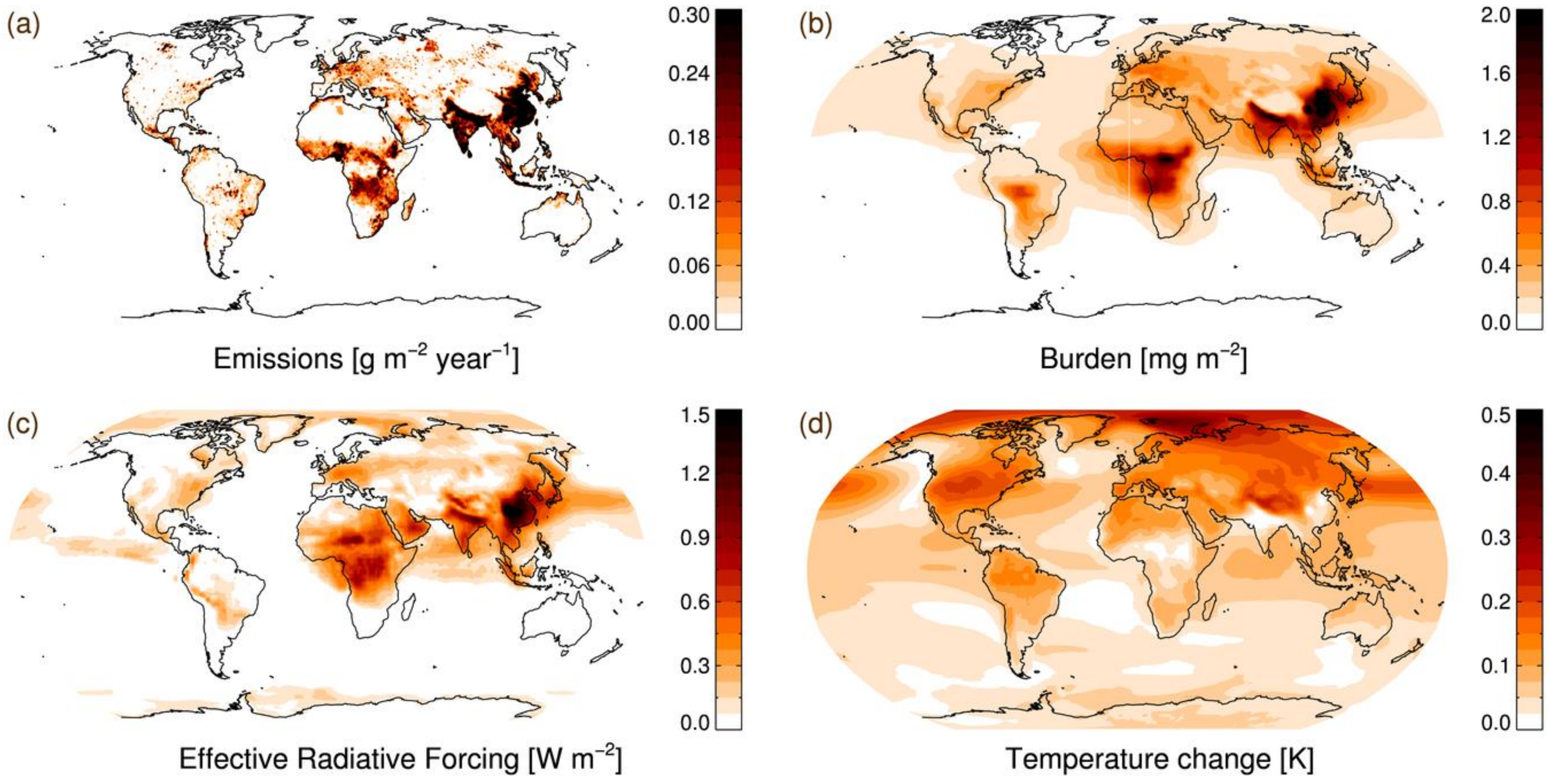

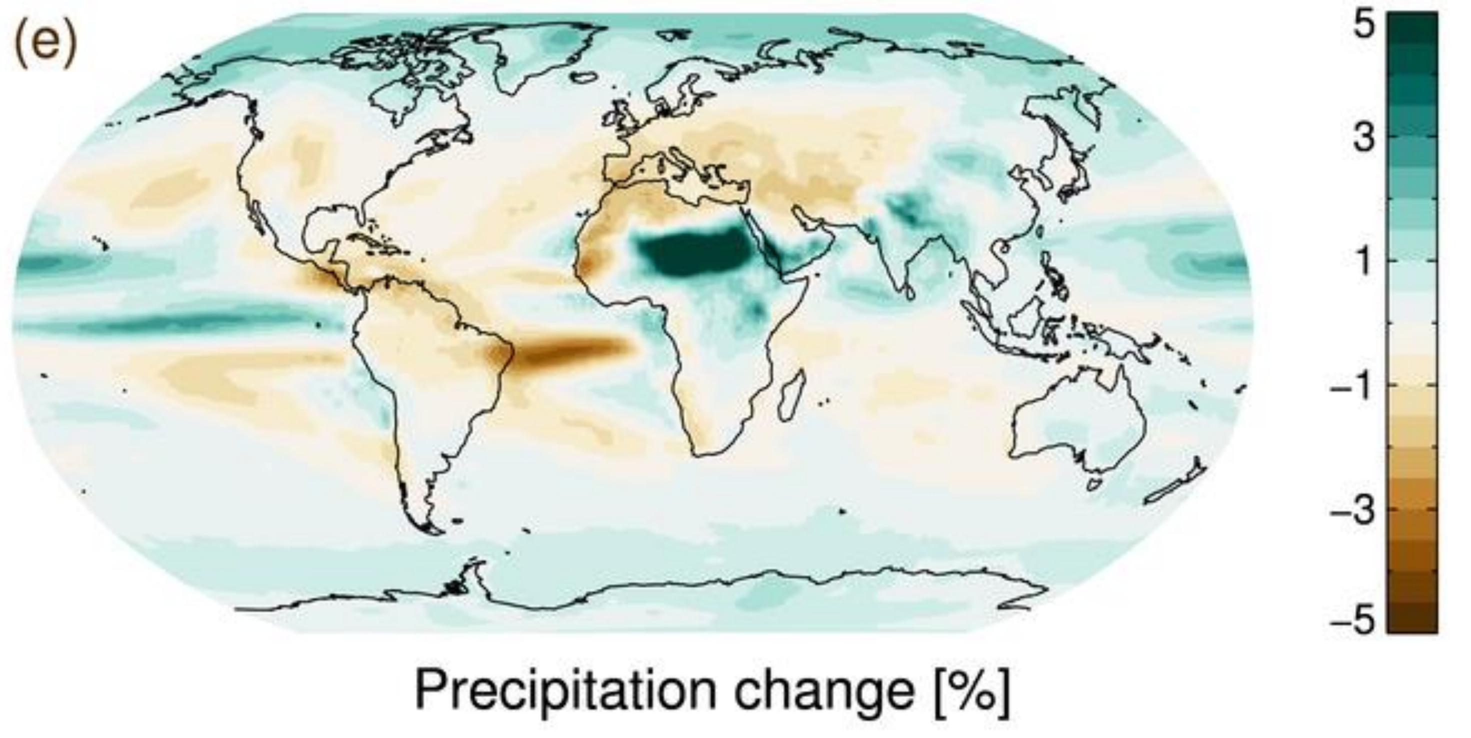

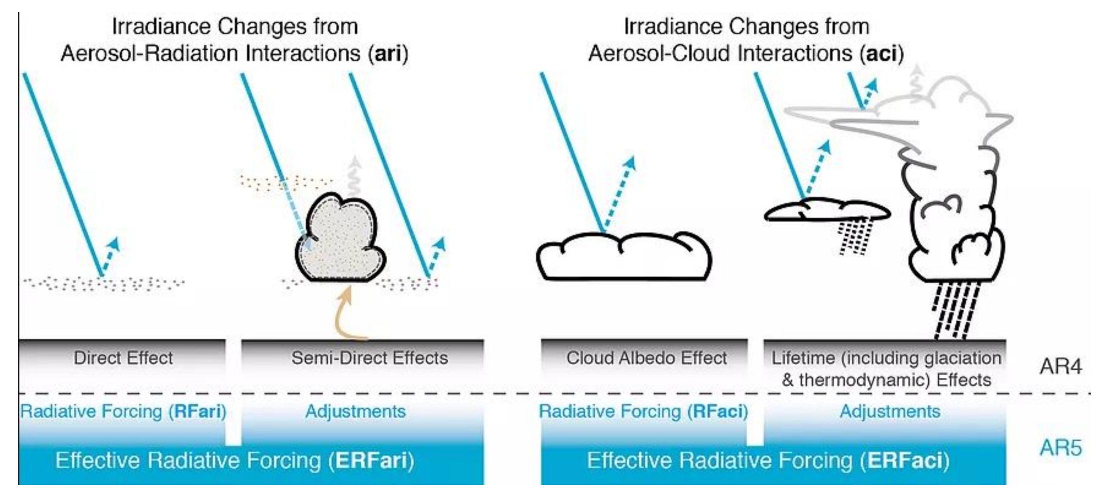

Hoesly et al. 2018 / Myhre et al. 2013 / Stjern et al. 2017 / IPCC AR5 WG1

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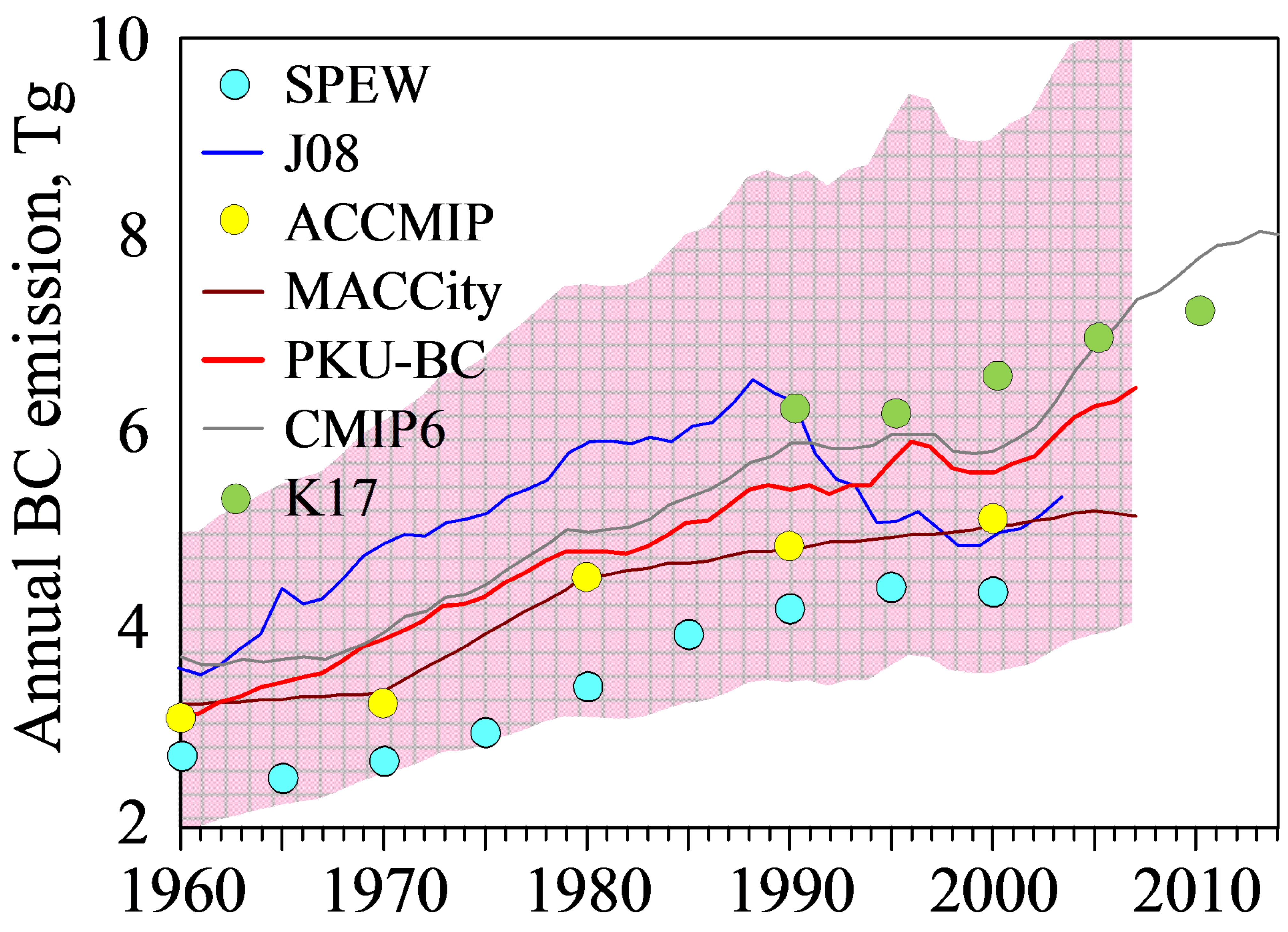
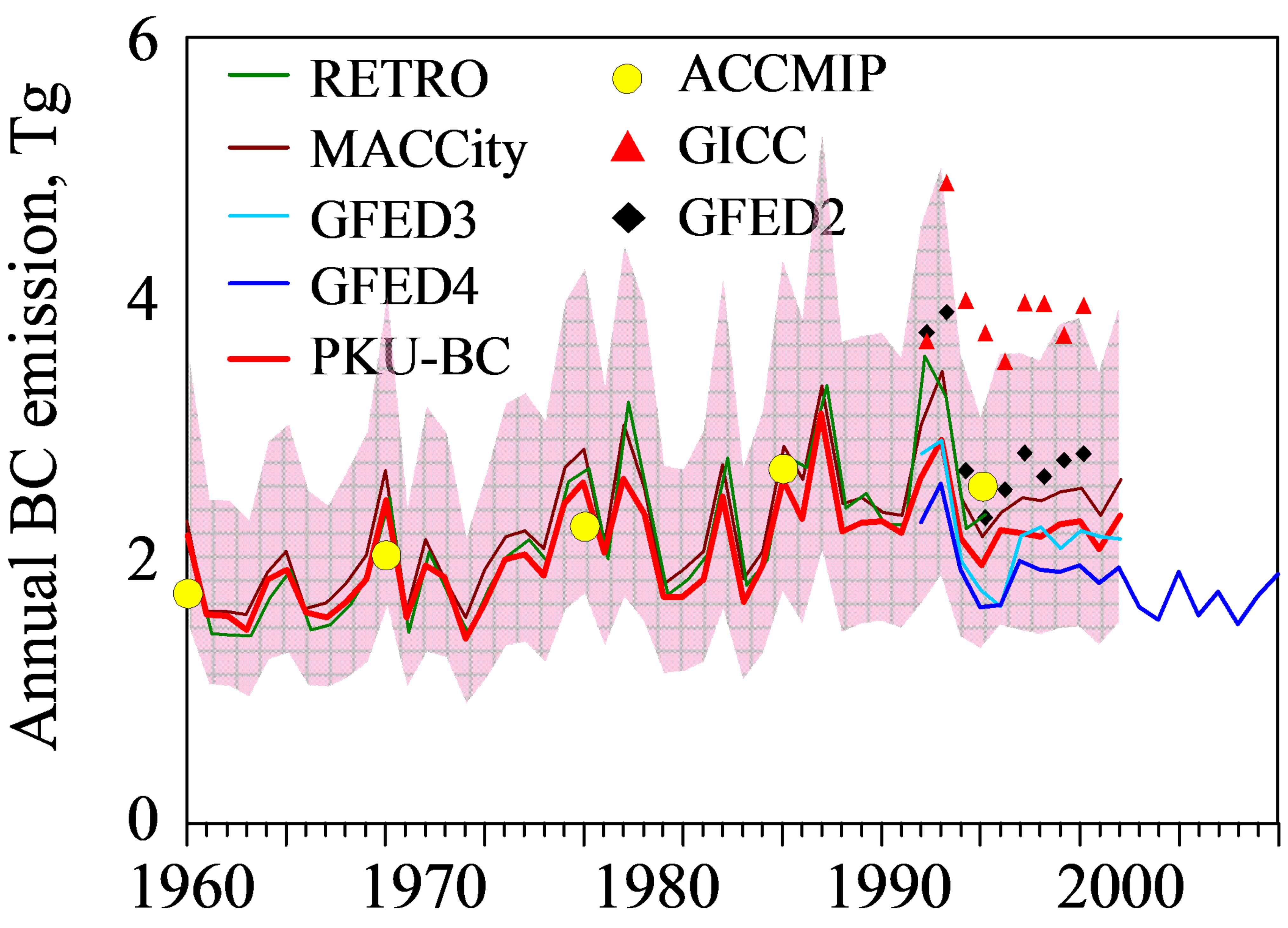
Emissions keep increasing

Em × LT × MAC × RFE = RF → dT, dP





SPEW (Bond et al., 2007), J08 (Junker and Liousse, 2008), ACCMIP and MACCity for the Atmospheric Chemistry and Climate Model Intercomparison Project (Lamarque et al., 2010; Granier et al., 2011), CMIP6 (Coupled Model Intercomparison Project Phase 6) (Hoesly et al., 2017), PKU-BC (Wang et al., 2014), K17 for (Klimont et al, 2017), GFED2 (Global Fire Emissions Database version 2) (van der Werf et al., 2006), GFED3 (van der Werf et al., 2006), GFED4 (Randerson et al., 2015), GICC (Le progamme Gestion et Impacts du Changement climatique) (Mieville et al., 2010) and RETRO (REanalysis of the TROpospheric chemical composition over the past 40 years) (Schultz et al., 2008). For the PKU-BC inventory, annual BC emissions and uncertainties are shown as median values (red line) and inter-quartile ranges (shaded area) from a Monte Carlo simulation.

Many thanks to prof. Rong Wang for this compilation.

NB: Cohen and Wang 2014, Kalman filter estimate, 17.8 ± 5.6 Tg/yr,

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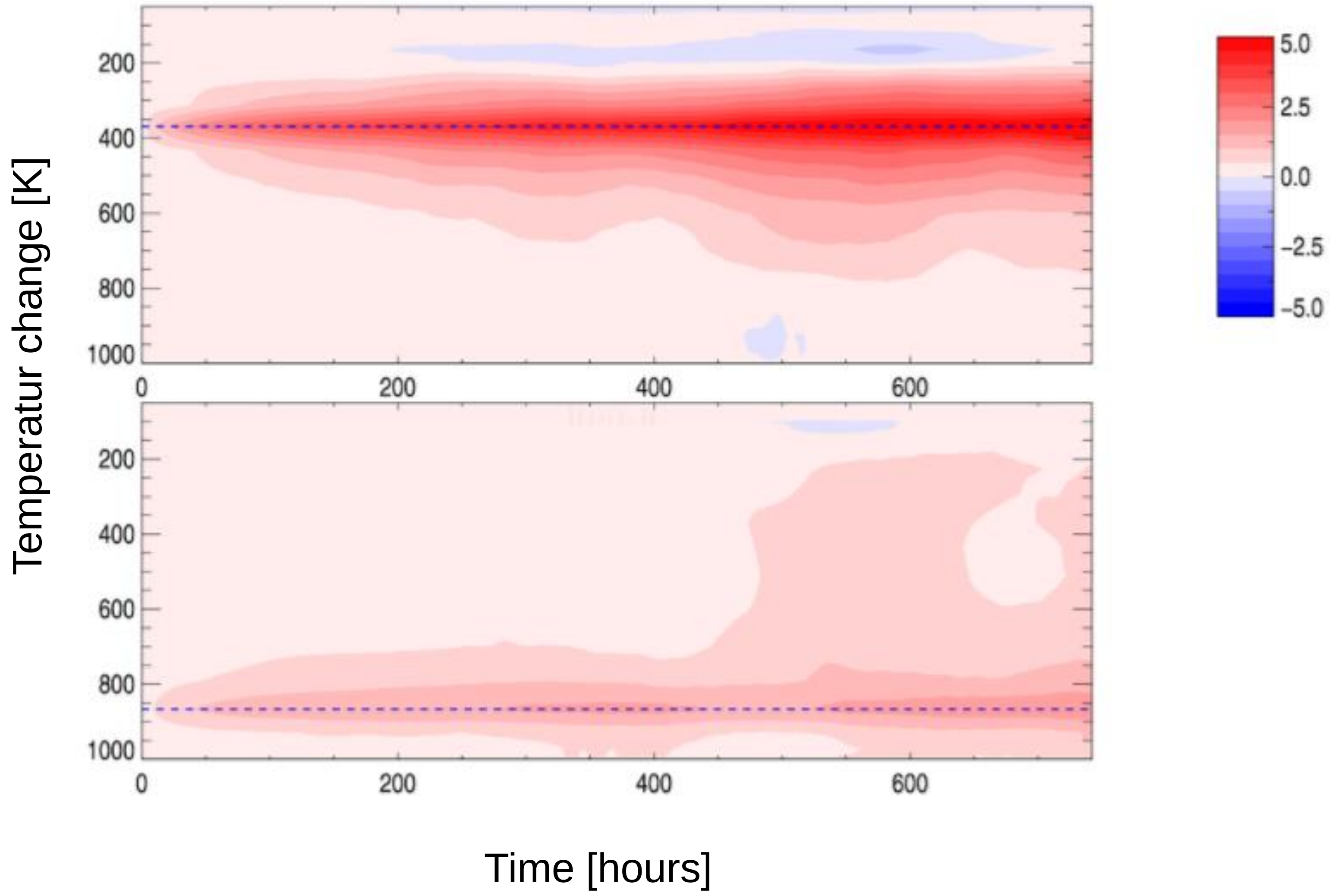
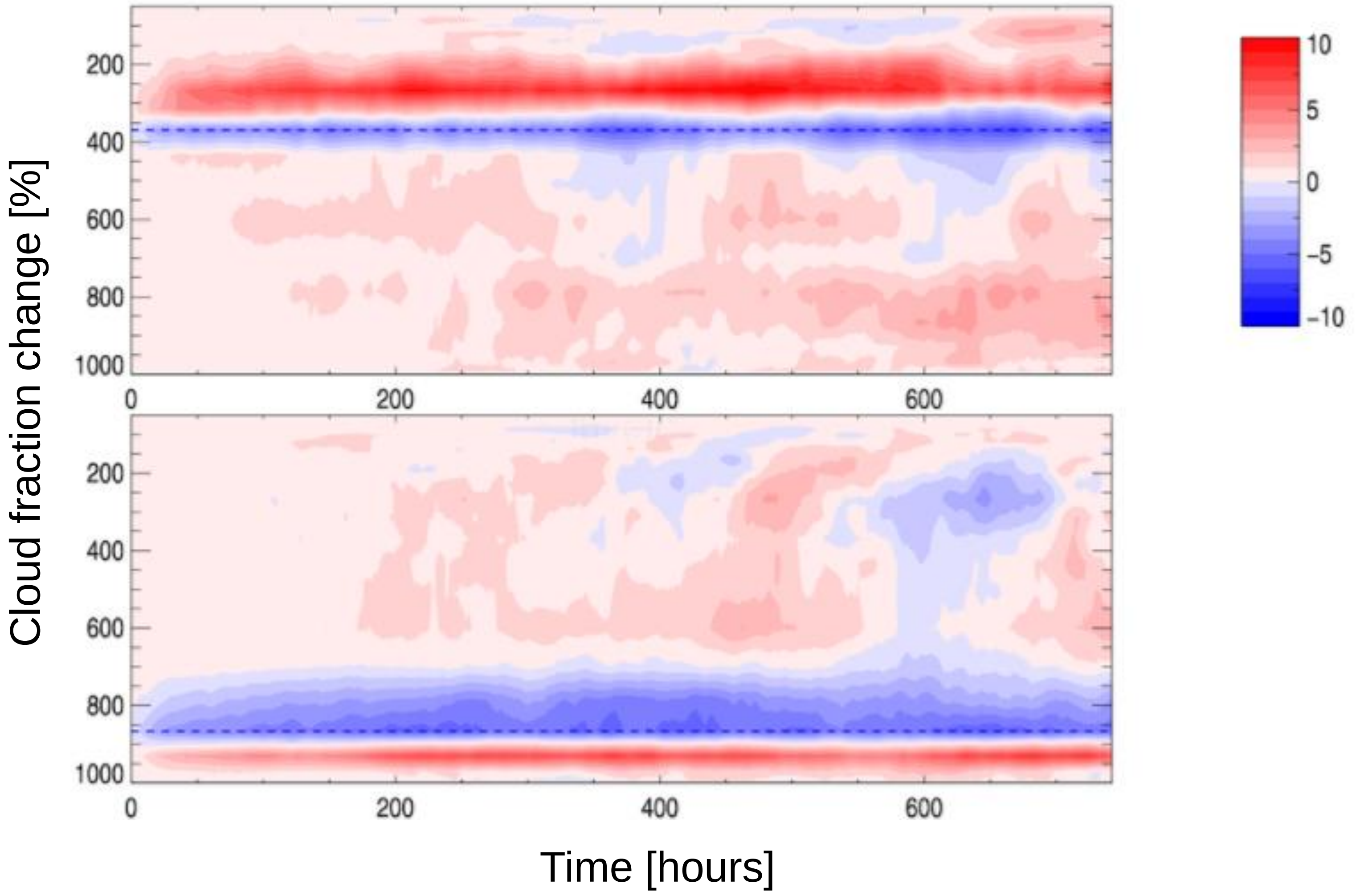
Forcing efficiency:

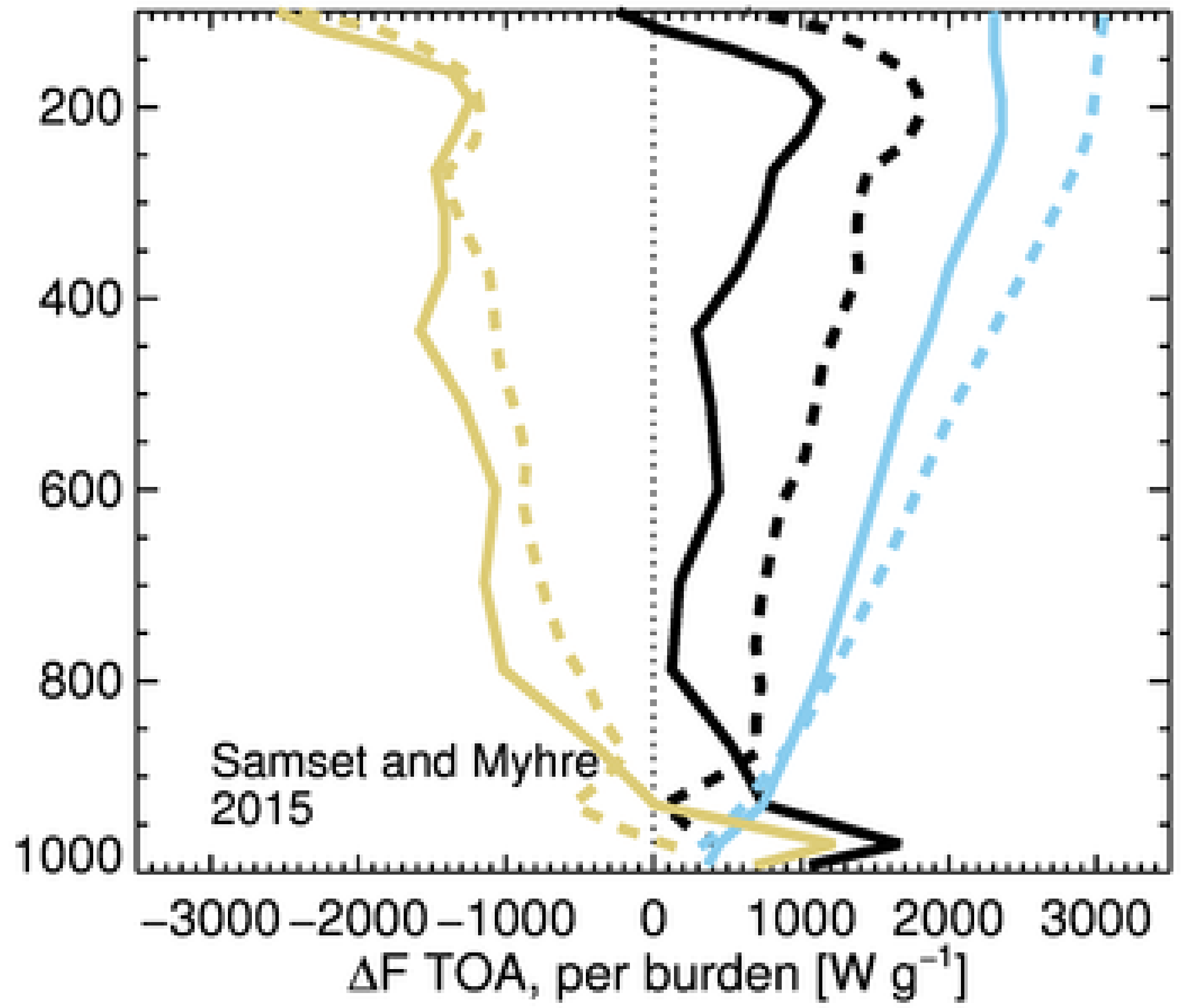
(D)RF is *not* temperature

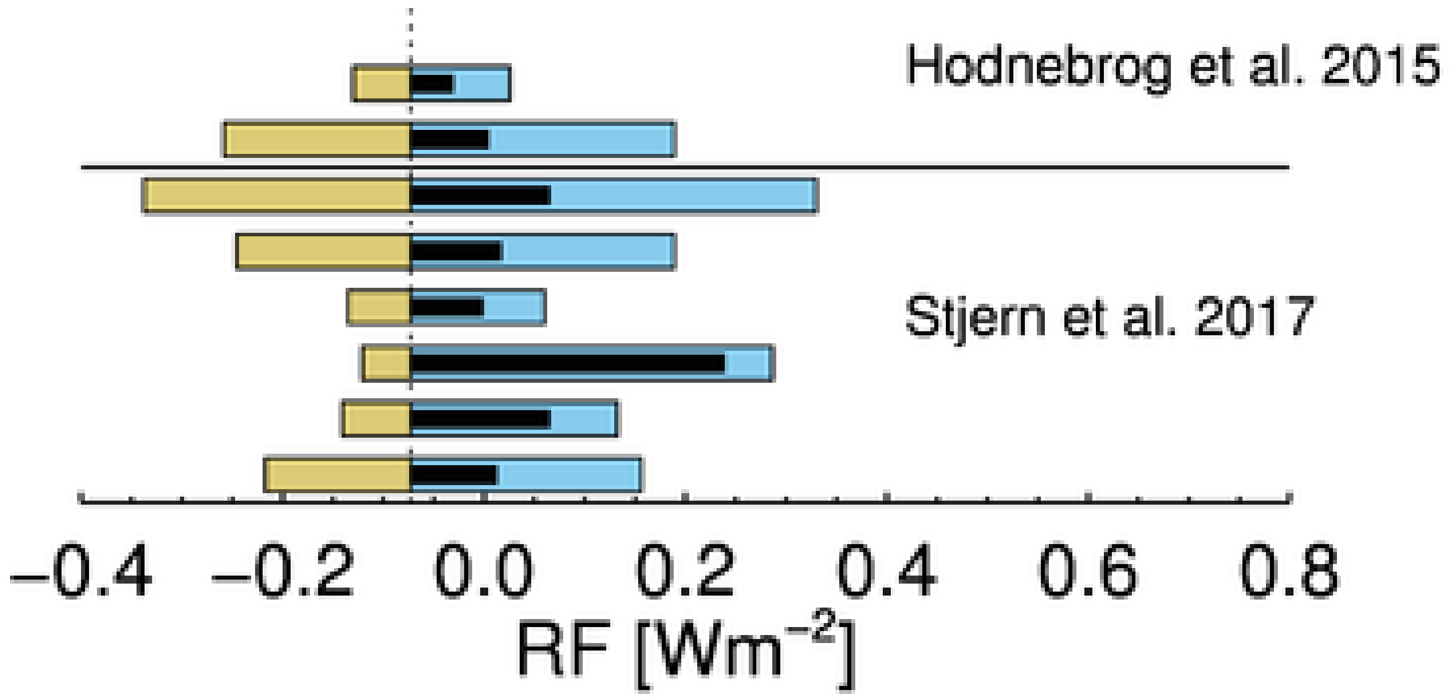
ERF = direct RF + rapid adjustments

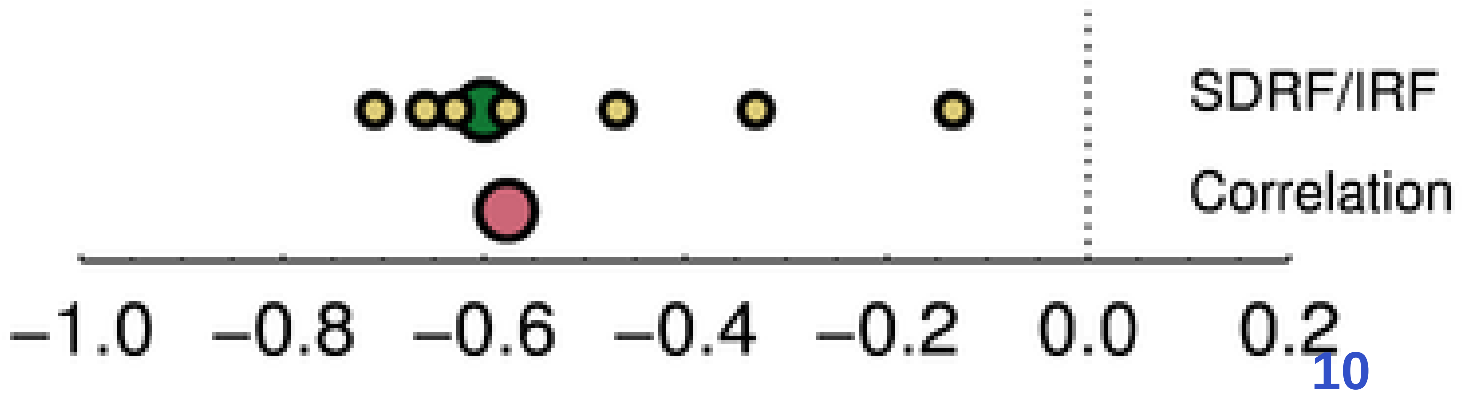
Em × LT × MAC × **RFE** = RF → dT, dP











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Temperature response…
…seems moderate

Em × LT × MAC × RFE = RF → **dT**, dP

AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Atmospheres

+ Baker 2015, ACP

RESEARCH ARTICLE

10.1002/2017JD027326

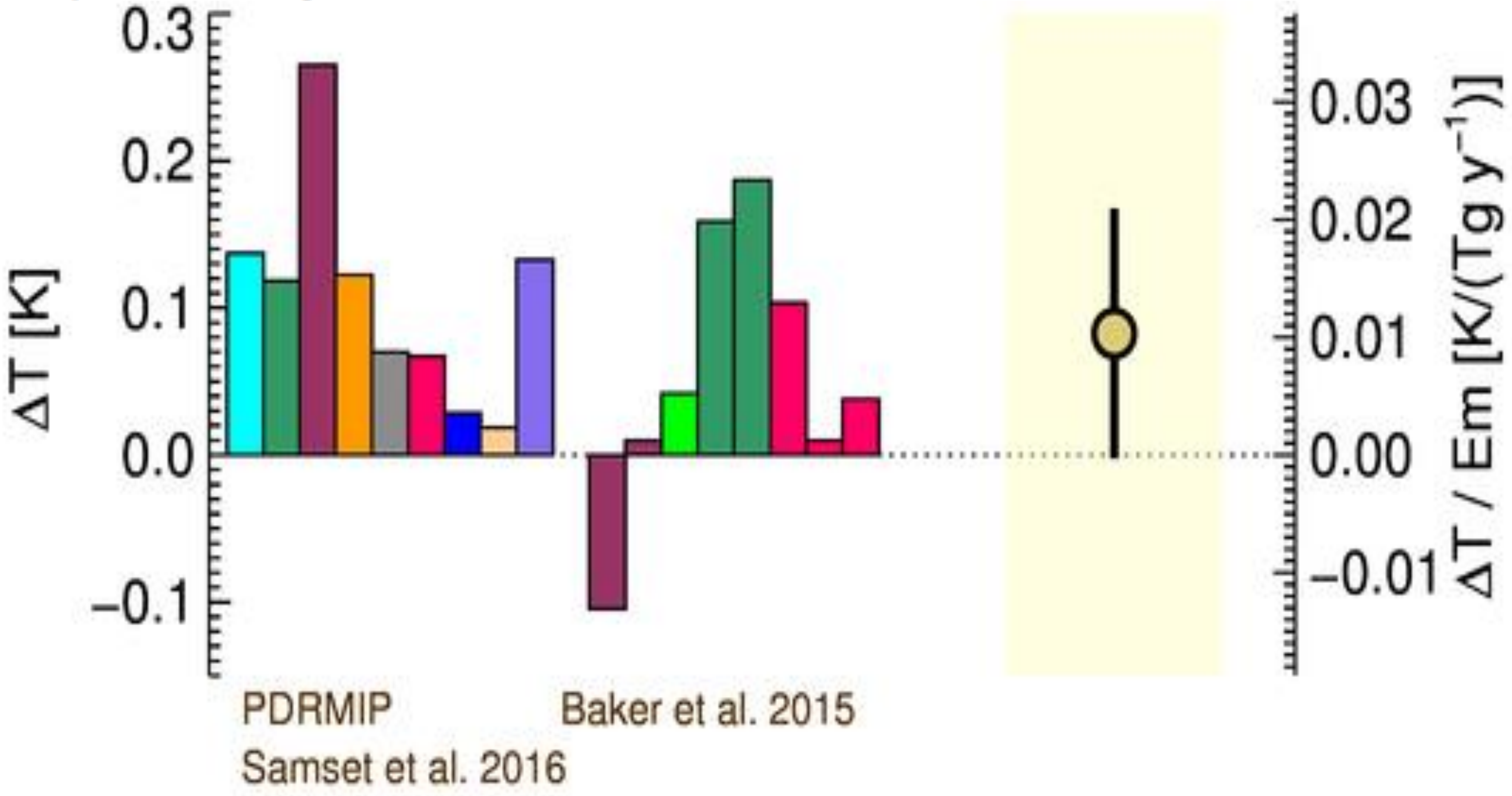
Key Points:
- Countering climate responses result in low-temperature change relative to the large instantaneous radiative forcing that the BC perturbation causes
- Regionally, BC can have considerable impact on precipitation
- The intermodel spread is in general large, and 2.5 times higher if emissions instead of fixed BC concentrations are used in the simulations

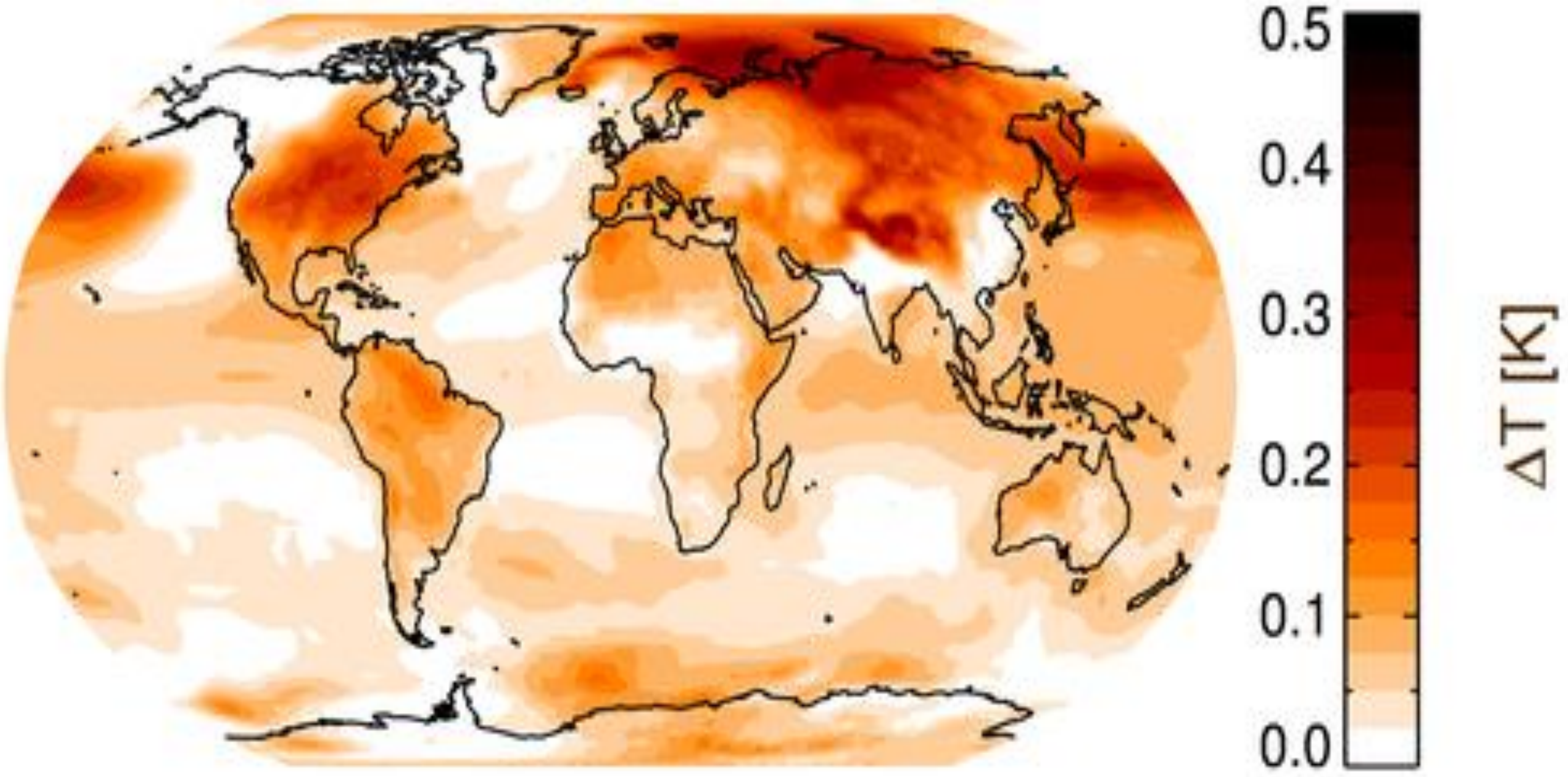
Supporting Information:
- Supporting Information S1

Correspondence to:
C. W. Stjern,

Rapid Adjustments Cause Weak Surface Temperature Response to Increased Black Carbon Concentrations

Camilla Weum Stjern[1], Bjørn Hallvard Samset[1], Gunnar Myhre[1], Piers M. Forster[2], Øivind Hodnebrog[1], Timothy Andrews[3], Olivier Boucher[4], Gregory Faluvegi[5,6], Trond Iversen[7], Matthew Kasoar[8], Viatcheslav Kharin[9], Alf Kirkevåg[7], Jean-François Lamarque[10], Dirk Olivié[7], Thomas Richardson[2], Dilshad Shawki[8], Drew Shindell[11], Christopher J. Smith[2], Toshihiko Takemura[12], and Apostolos Voulgarakis[8]



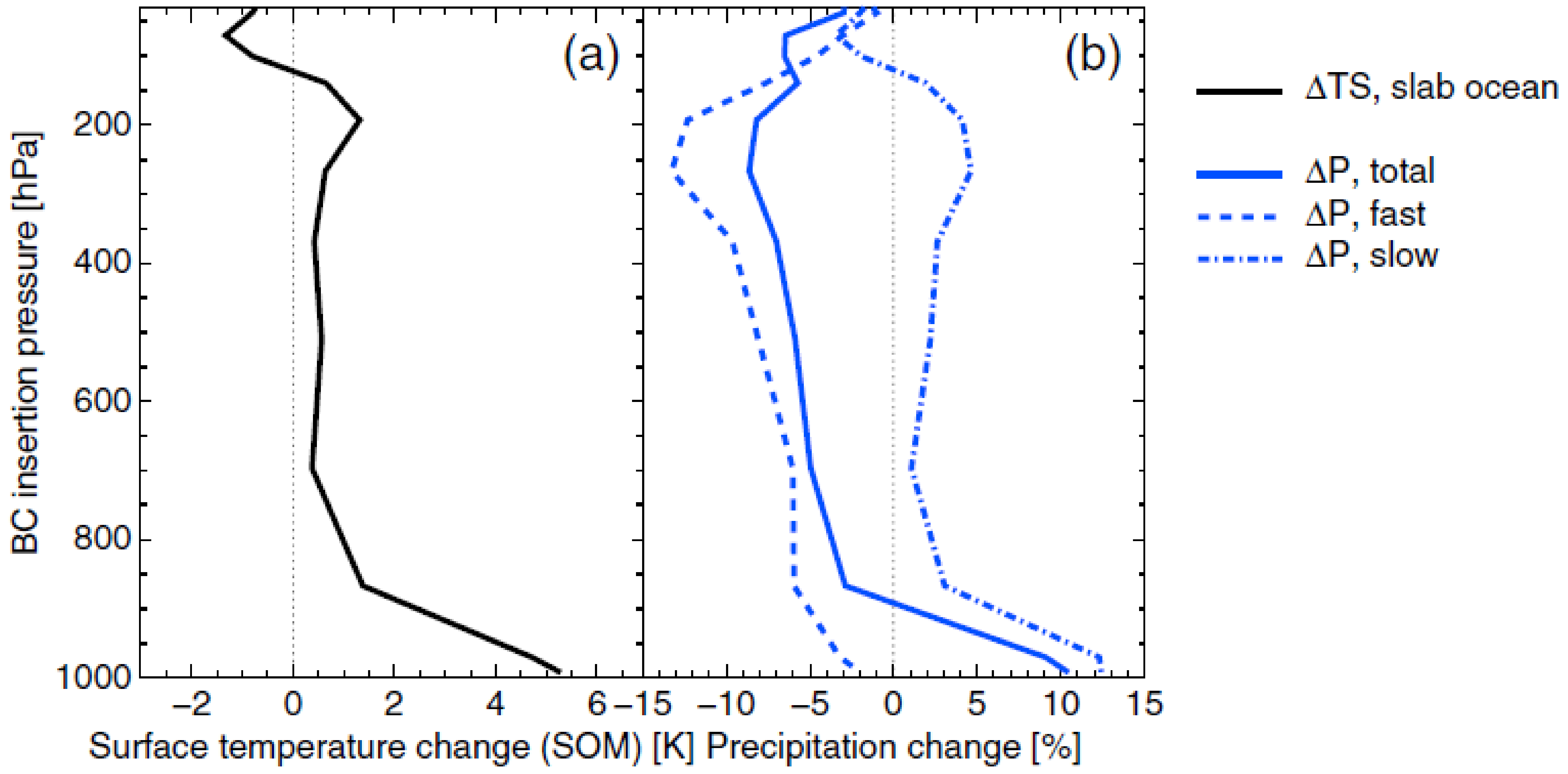


Precipitation impact?

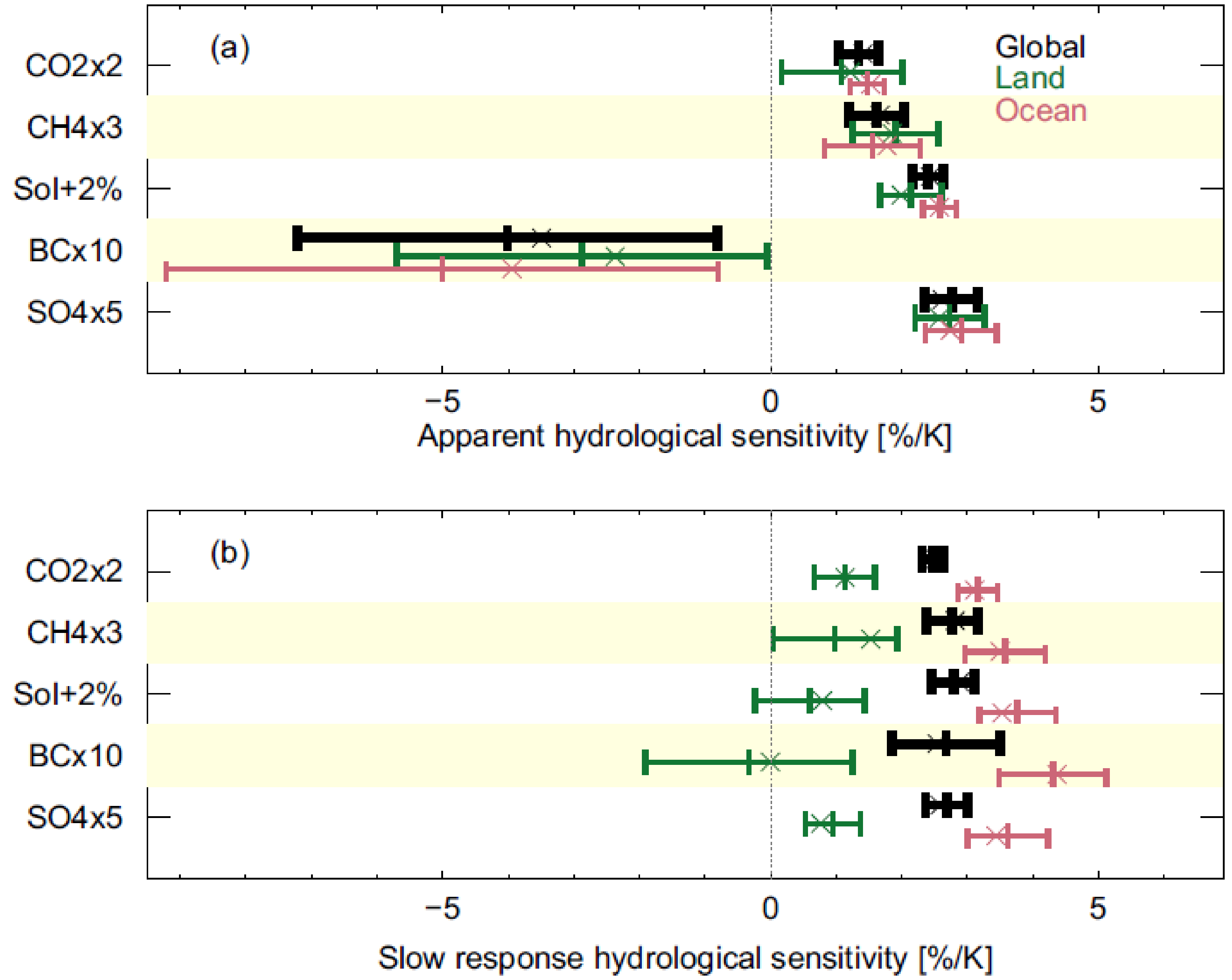
Rapid adjustments and weak temperature response make BC mess up global modelling!

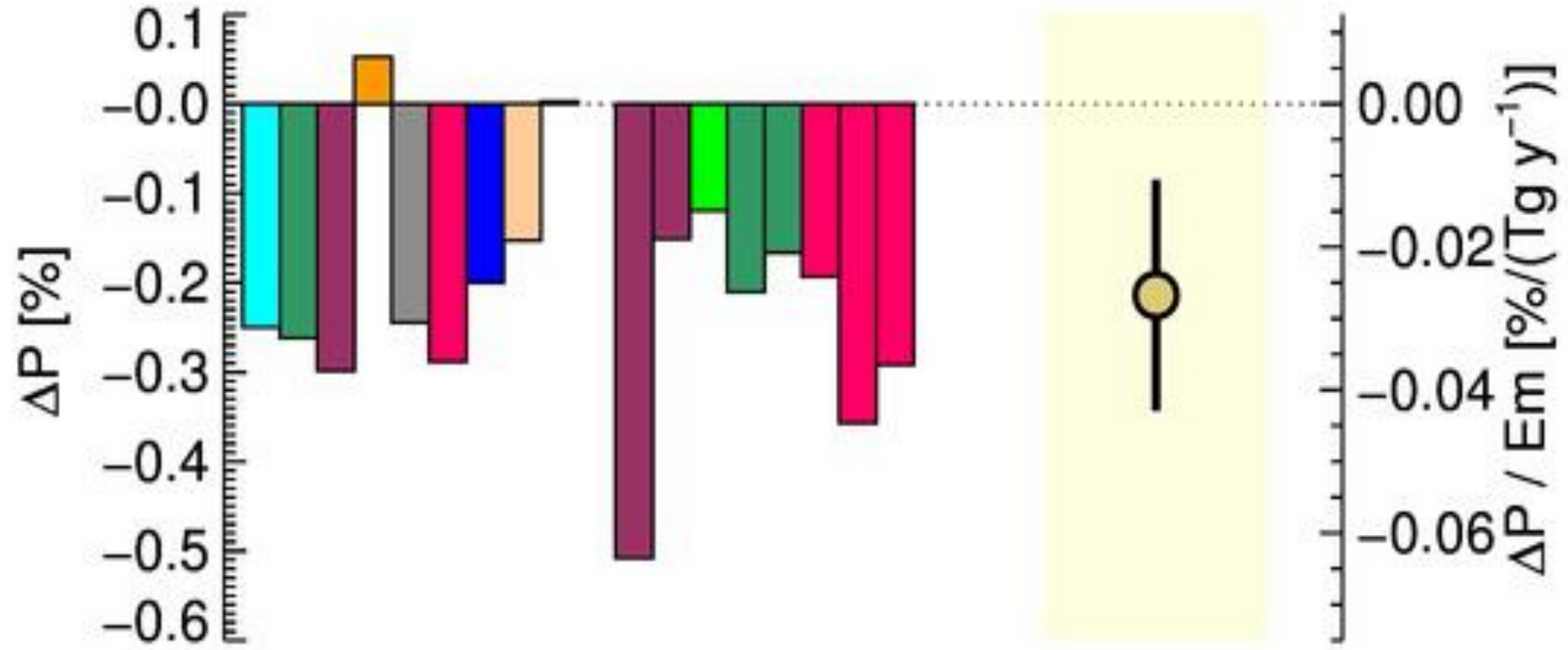
Em × LT × MAC × RFE = RF → dT, **dP**

Samset and Myhre 2015, JGRA



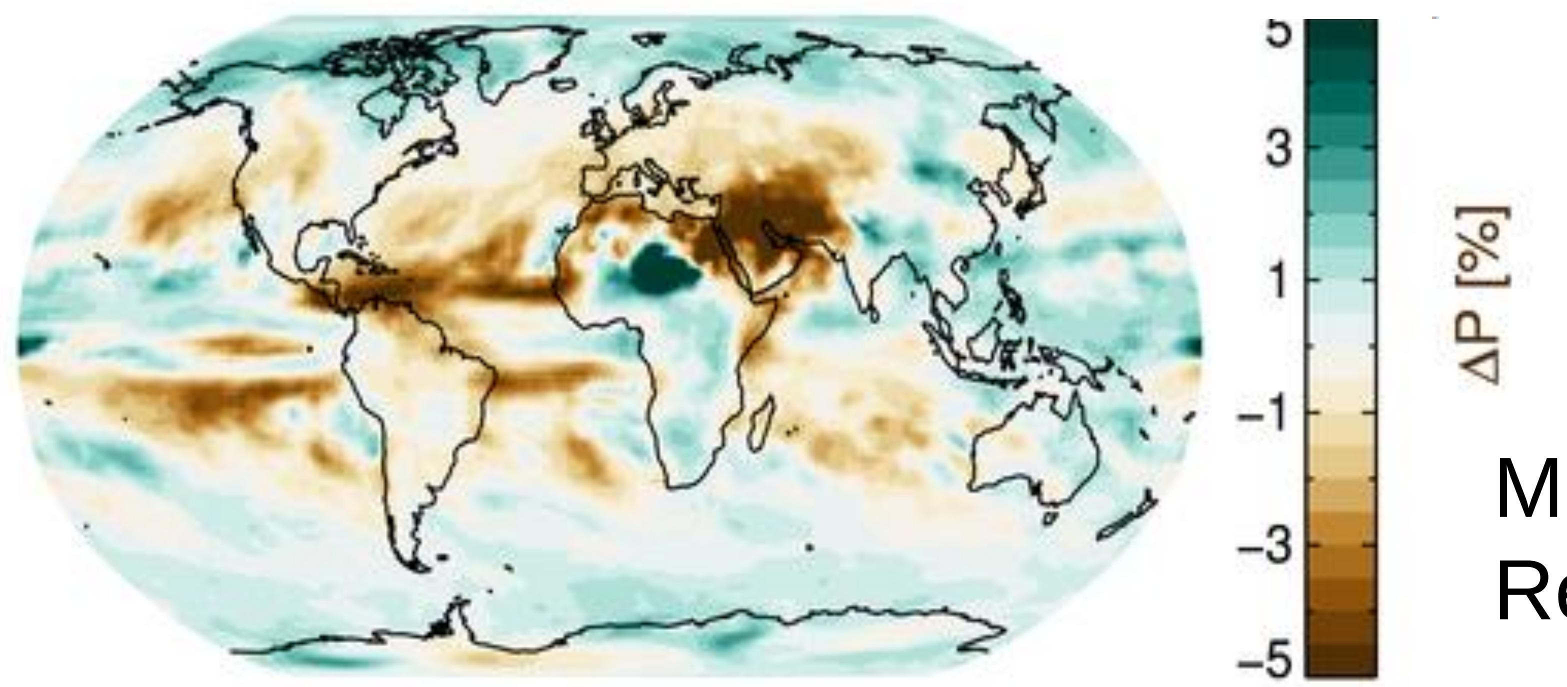
Samset 2018, npj Clim. Atm. Sci.





Samset 2016 GRL

Baker 2015 ACP



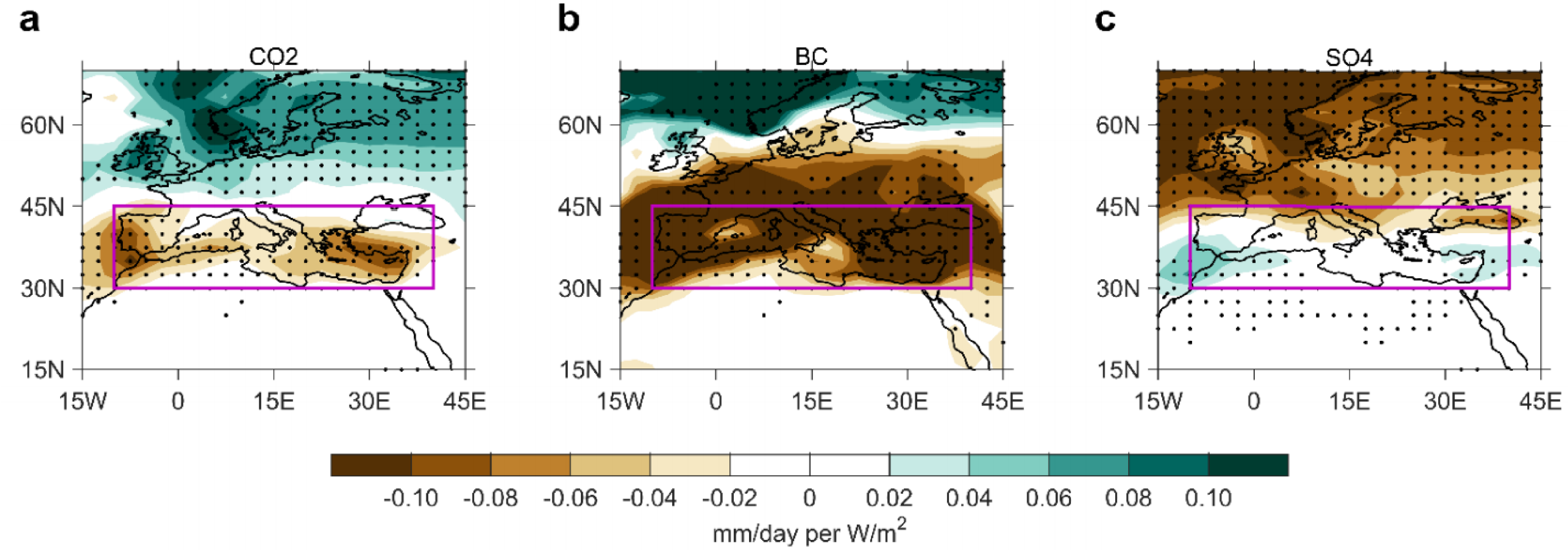
\+ Stjern 2017, JGRA

Mediterranean: See Tao et al. 2018, ACPD

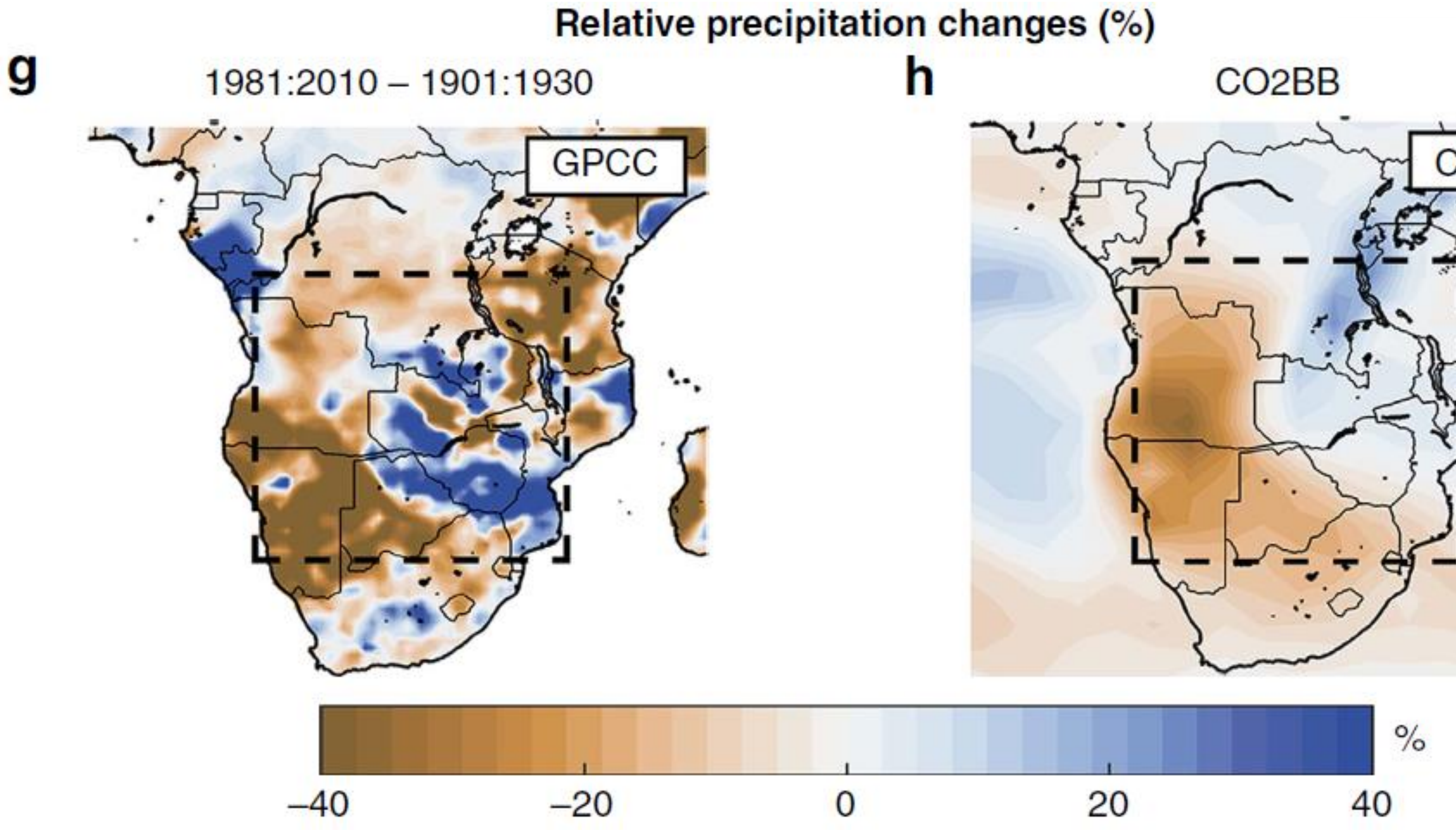
Regional response: See Liu 2018, JCLIM

Regional effects of anthropogenic aerosols

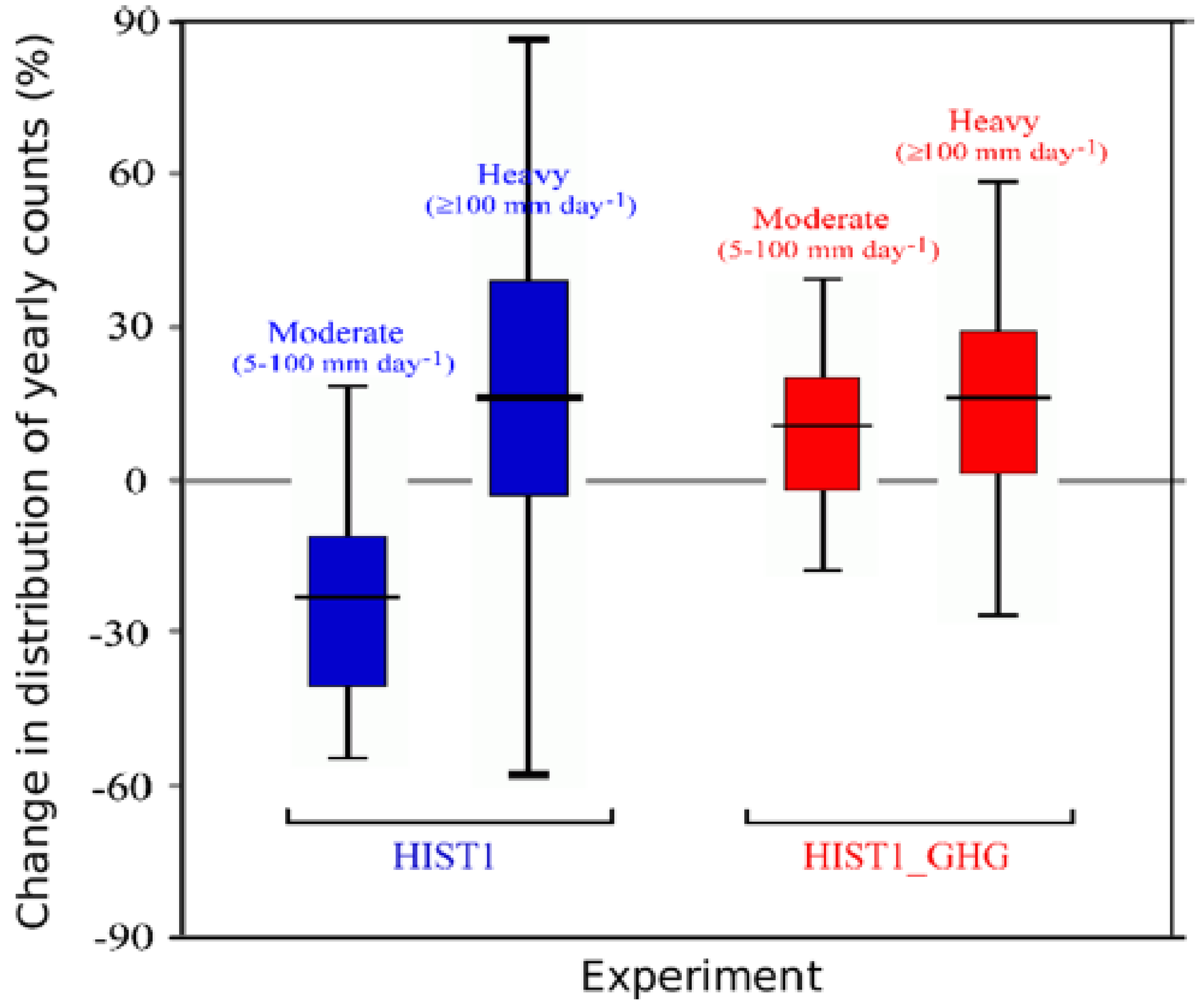
- ITCZ shift
- Asian Monsoon slowdown
- Southern African and Mediterranean drying
- …



Tang et al. 2018 ACPD



Hodnebrog et al. 2016 NComm



Krishnan et al. 2016 Clim. Dyn.

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Conclusions

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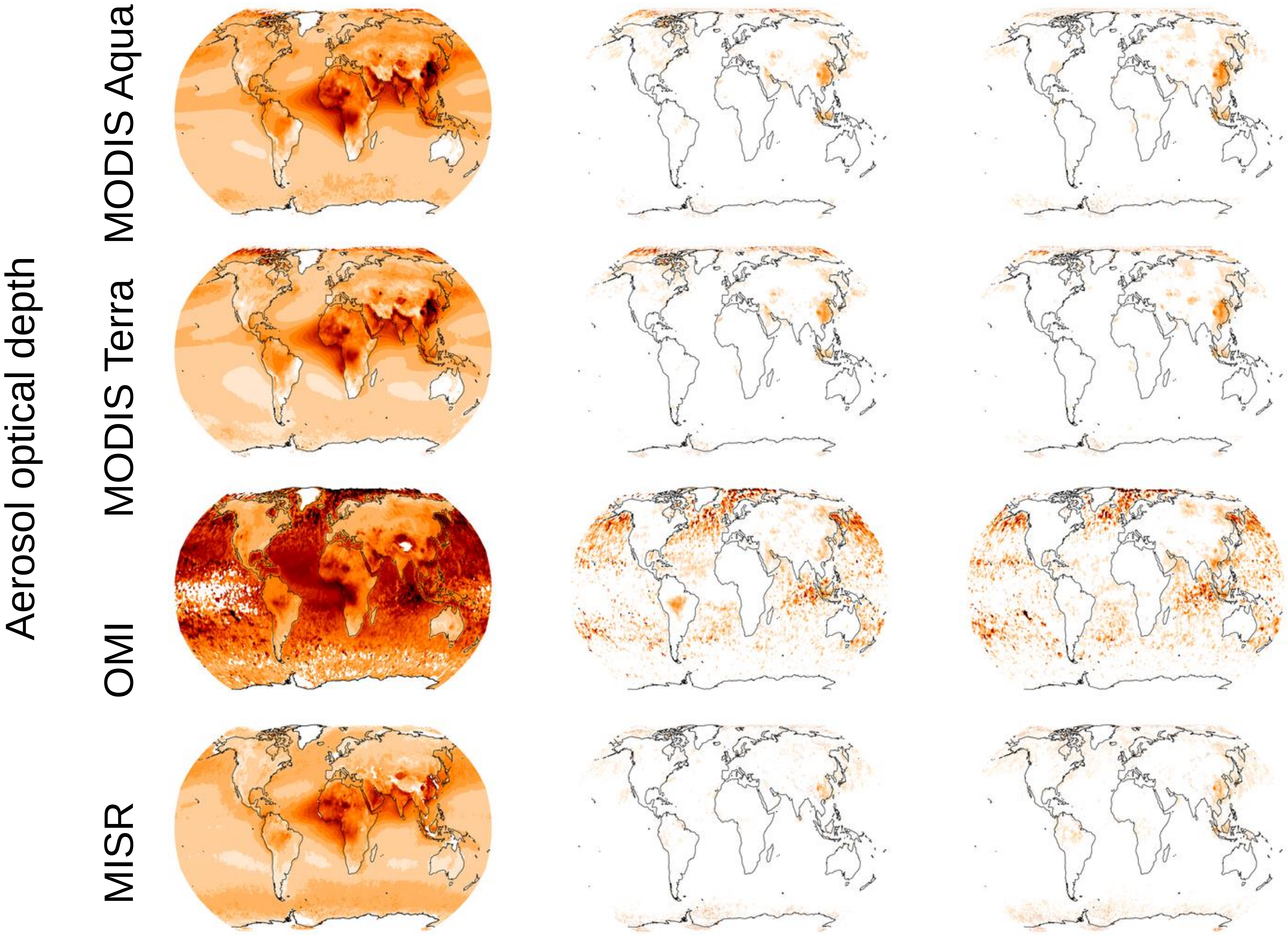
Something funny…



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