Anthropogenic Aerosol Forcing of Hemispheric Rainfall Shifts

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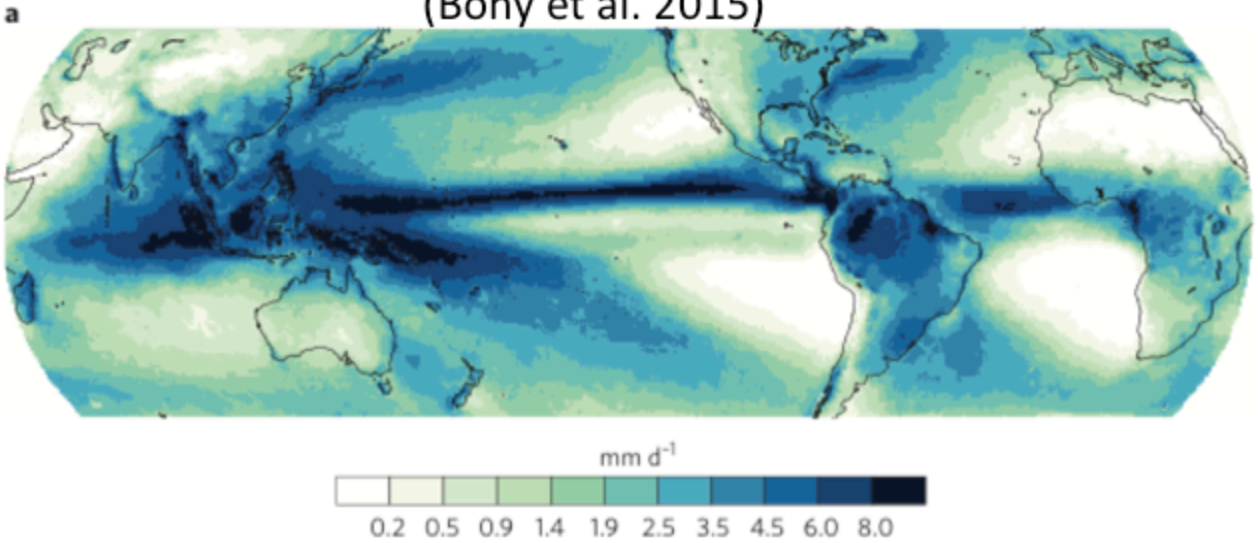
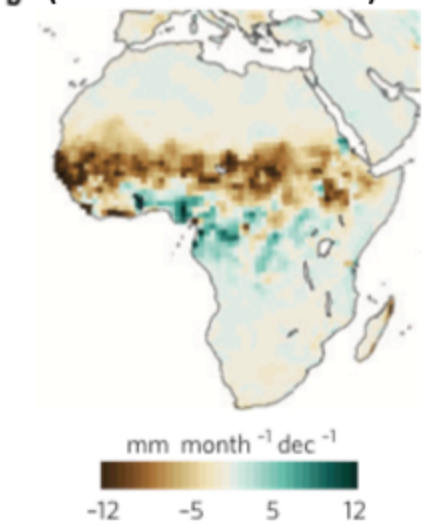
8TH GEWEX OPEN SCIENCE CONFERENCE: EXTREMES AND WATER ON THE EDGE

Hemispheric Shift of Tropical Rain Belts

Precipitation Climatology from TRMM 1998-2005 (Bony et al. 2015)



Precipitation Trend 1950-2000 (Held et al. 2005)



- Southward shift of the tropical rain belt during latter half of 20th Century associated with severe droughts in both Sahel and Amazon.
- Shift in ITCZ linked to changes in the cross-equatorial energy transport driven by the hemispheric contrast in warming → NH aerosol forcing
- See: Ming and Ramaswamy 2011, Hwang et al. 2013, Haywood et al. 2013, Frierson et al. 2013, Allan et al. 2015, Wang 2015, among others.

Questions

- How does the aerosol-induced circulation change affect clouds?

- How do these changes in clouds feedback on the circulation change?

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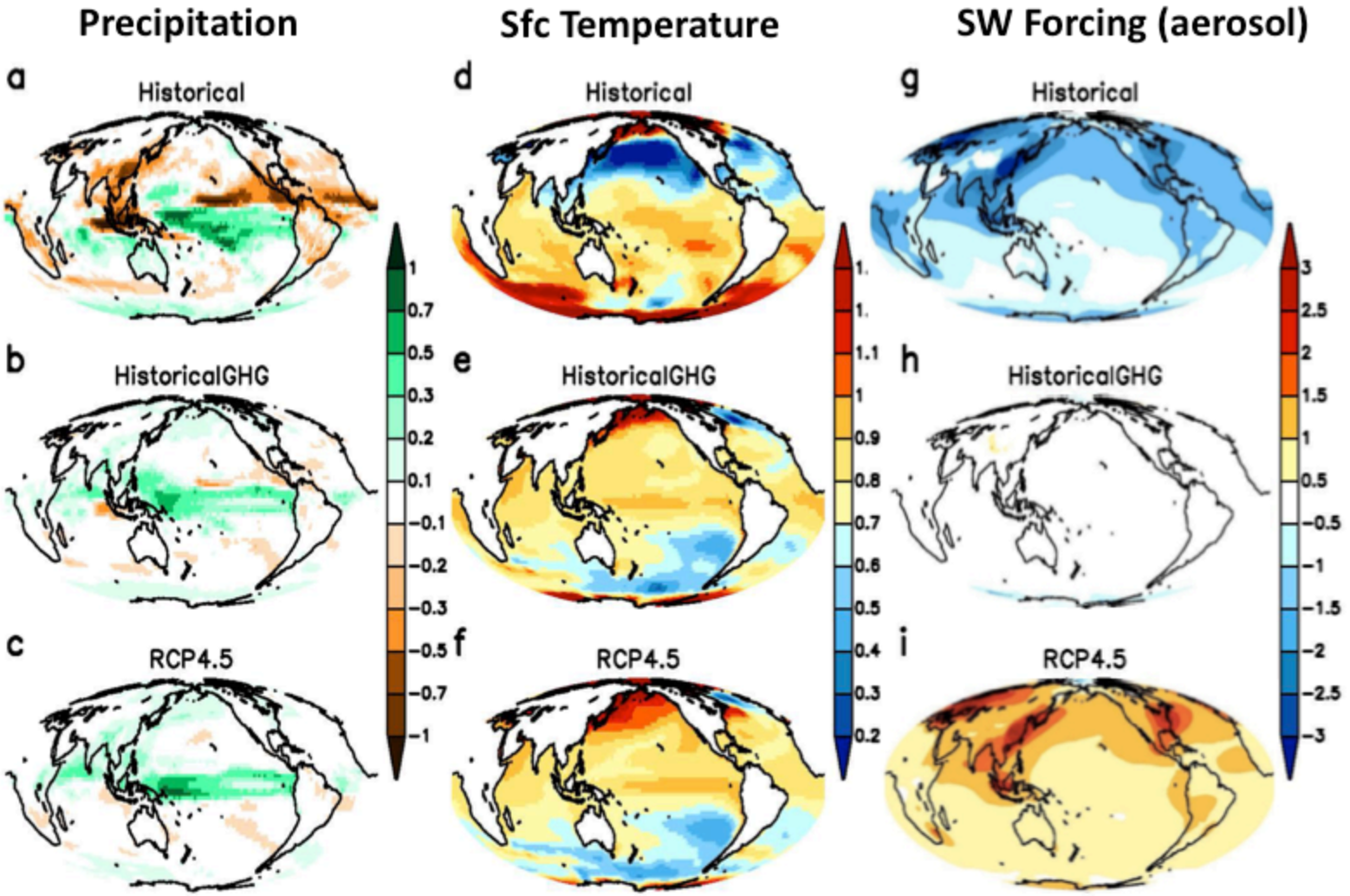
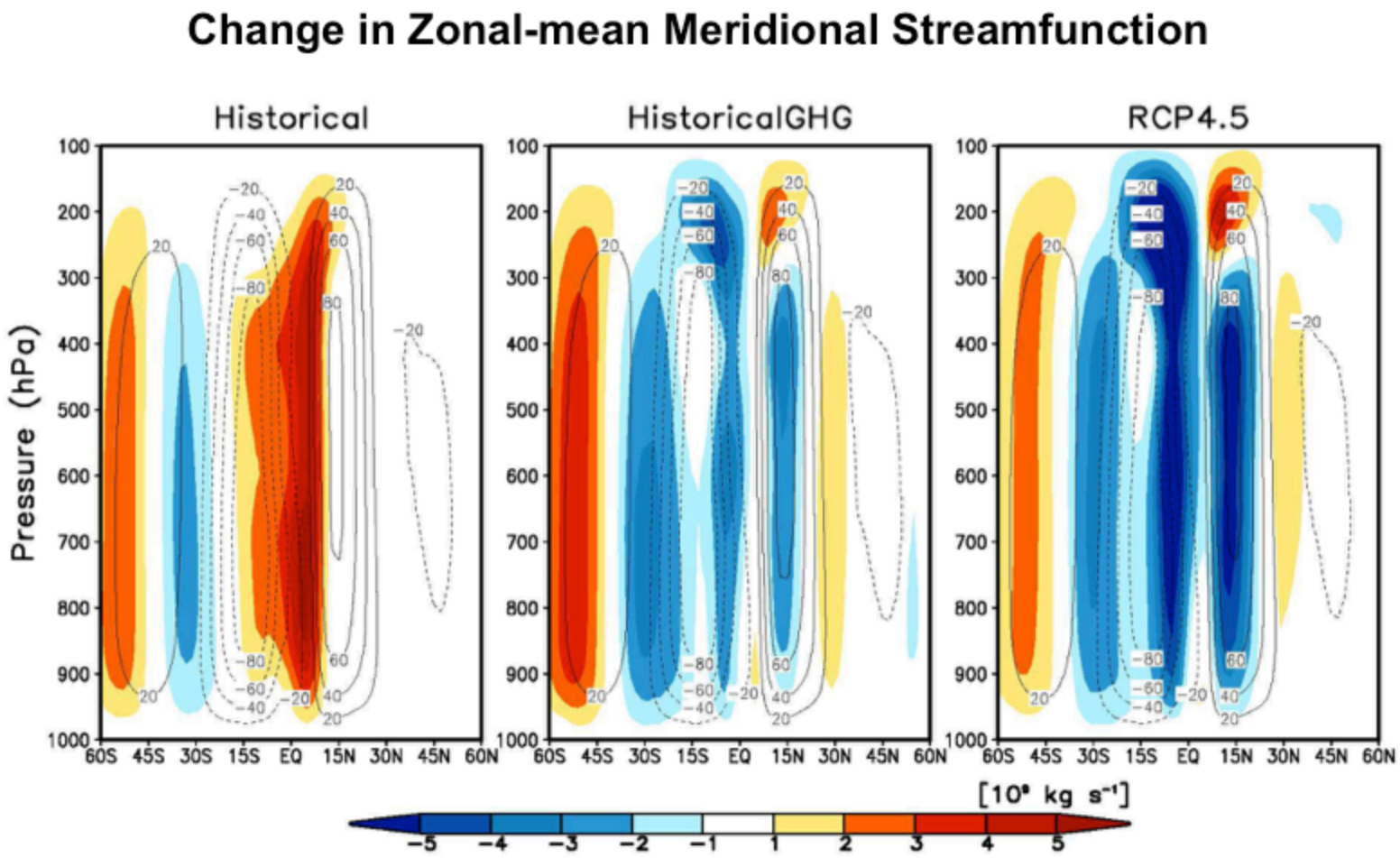
- How does the aerosol-induced circulation change affect clouds?
  - **Aerosols alter clouds locally (microphysical) and non-locally (dynamical)**

- How do these changes in clouds feedback on the circulation change?
  - **Dynamical cloud changes amplify hemispheric contrast of radiative forcing**
    → roughly doubles shift in circulation/precipitation.

Hemispheric Asymmetry of Forcing and Response

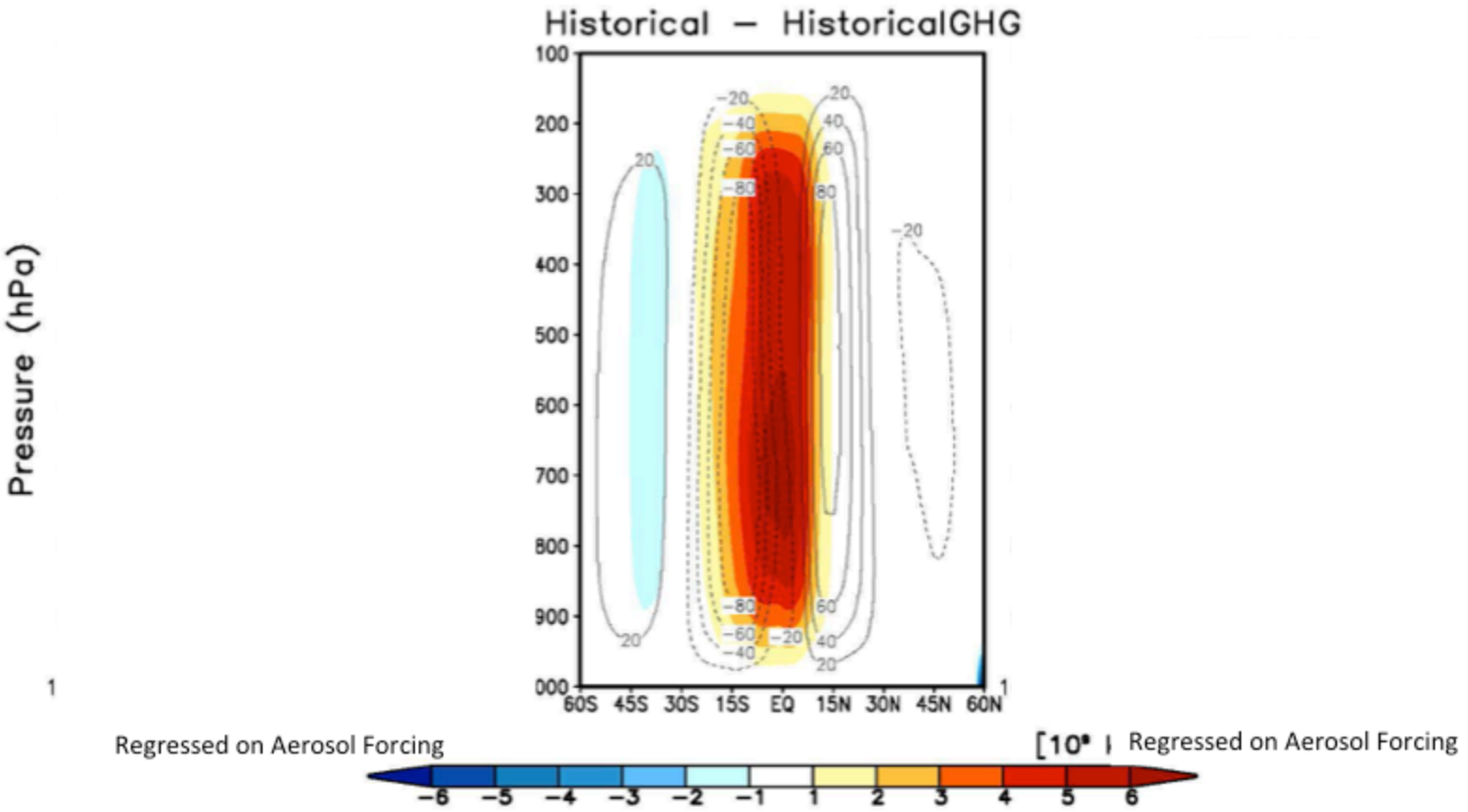


Change in Atmospheric Circulation

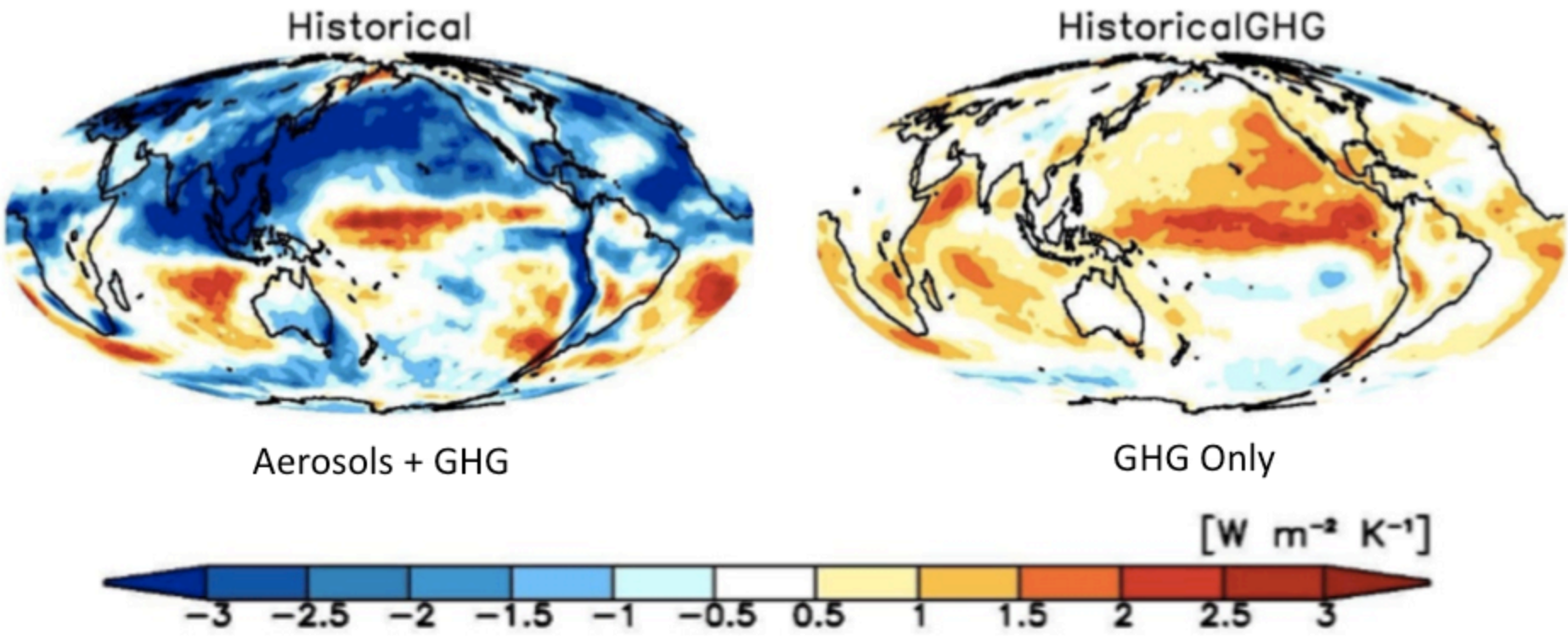


Change in Atmospheric Circulation

Aerosol-Mediated Change in Meridional Streamfunction

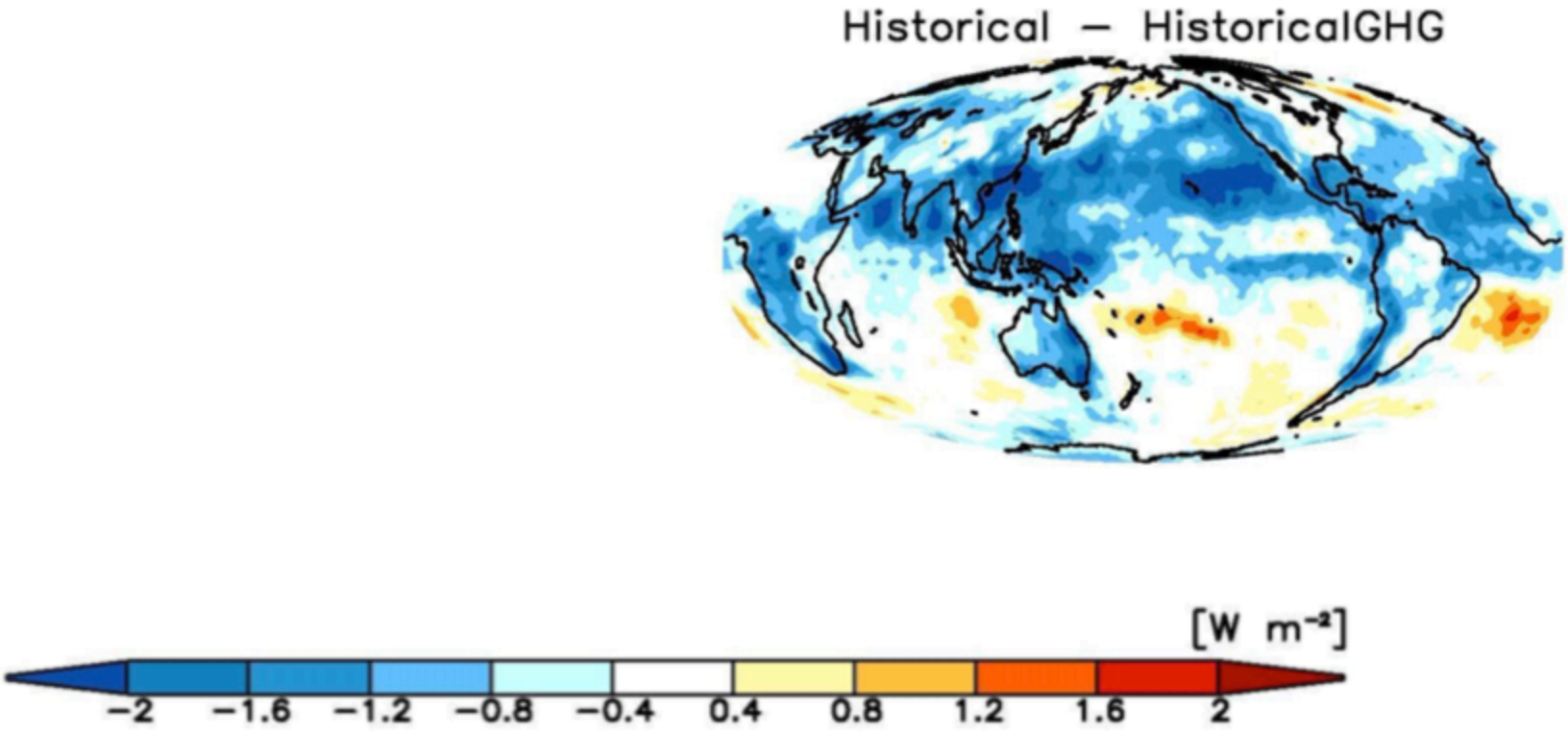


Cloud Response to Aerosol/GHG Forcing



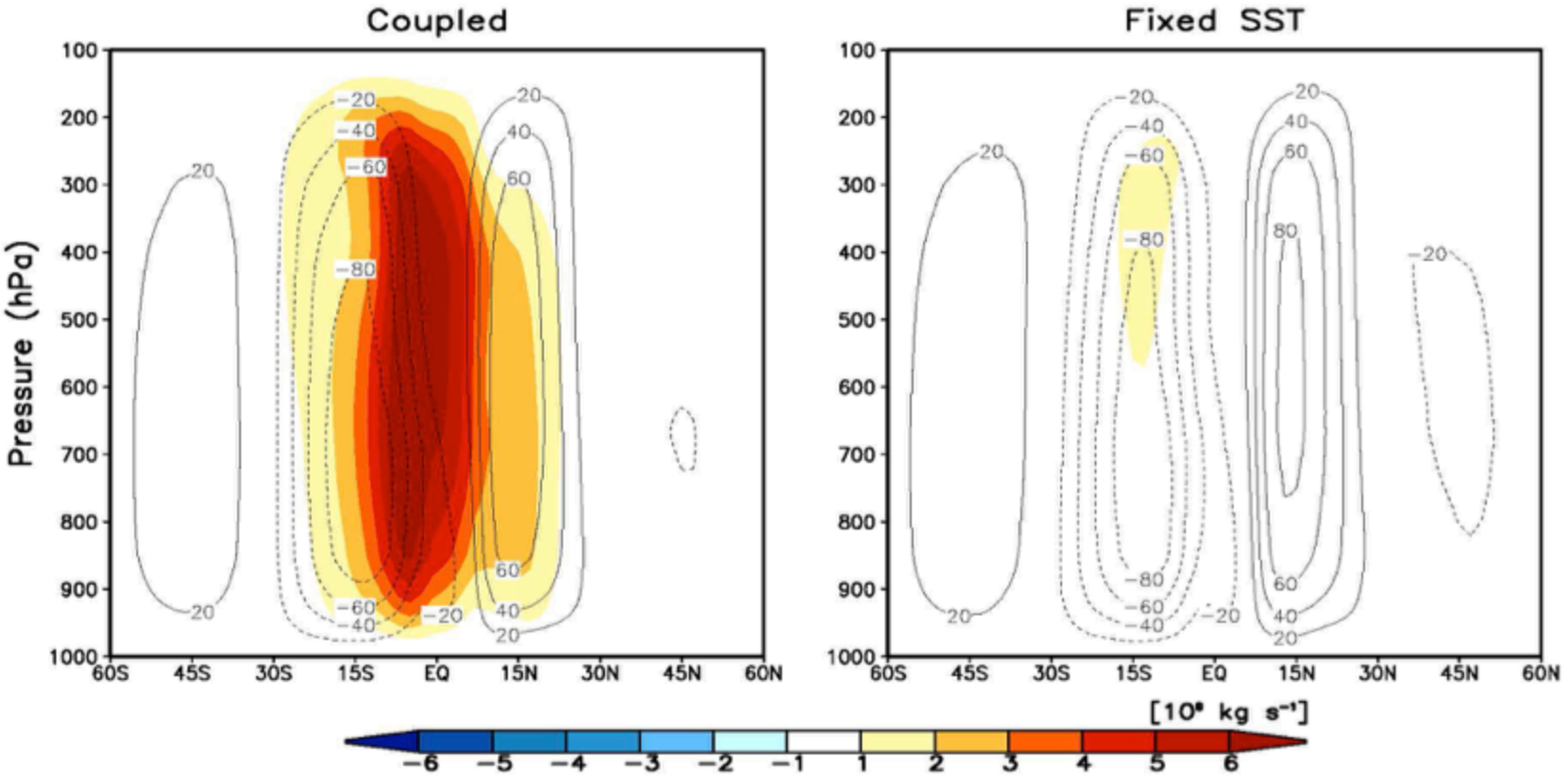
Cloud Response to Aerosol Forcing

Aerosol-Mediated Cloud Radiative Response



Circulation Response to Aerosol Forcing:

Coupled vs Fixed SST Models

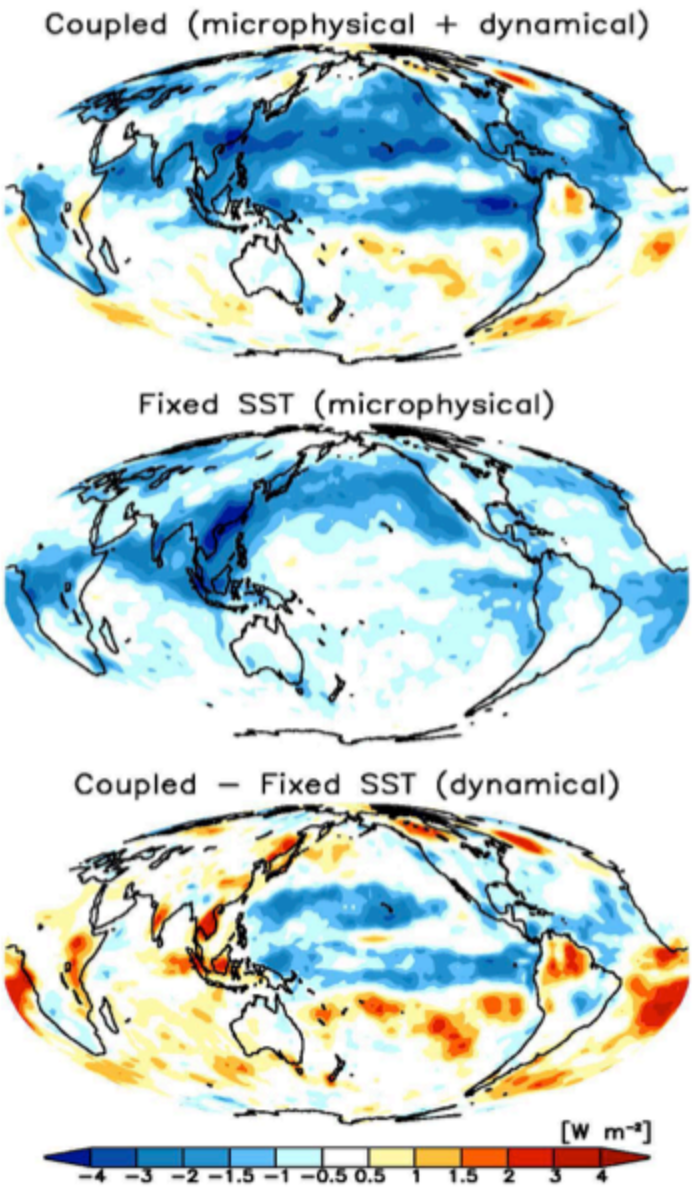


Coupled Models with Aerosol-only Forcing (HistoricalAA - piControl)

Fixed SST Models with Aerosol-only Forcing (sstClimAerosol-sstClim)

FixedSSTs also "fixes" circulation

Cloud Response to Aerosol Forcing:
Microphysical vs Dynamical Changes

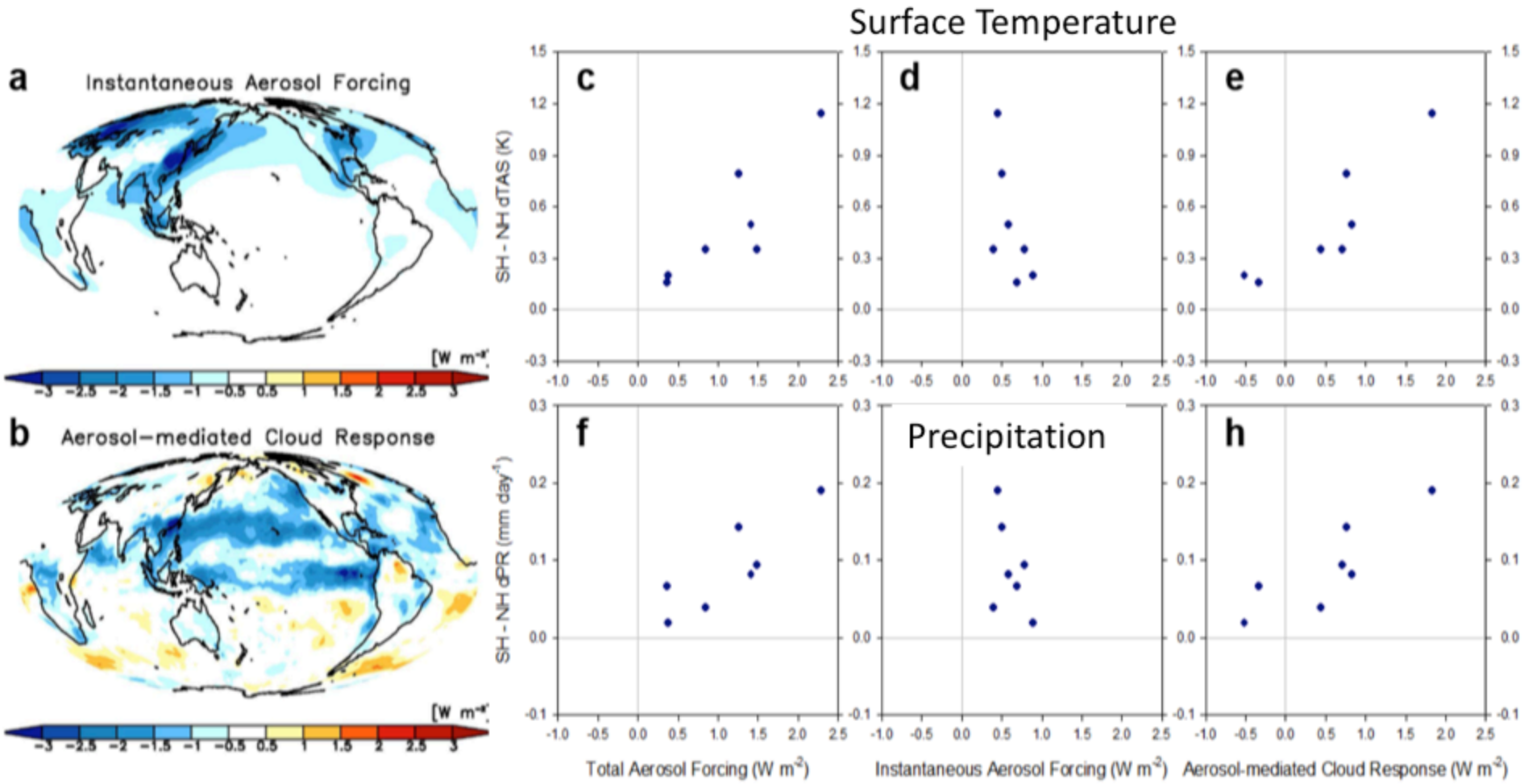


Microphysical + Dynamical Response
Coupled Models with Aerosol-only Forcing

Microphysical only
Fixed SST Models with Aerosol-only Forcing

~Dynamical only
Coupled – Fixed SST

Aerosol Forcing and Hemispheric Shifts

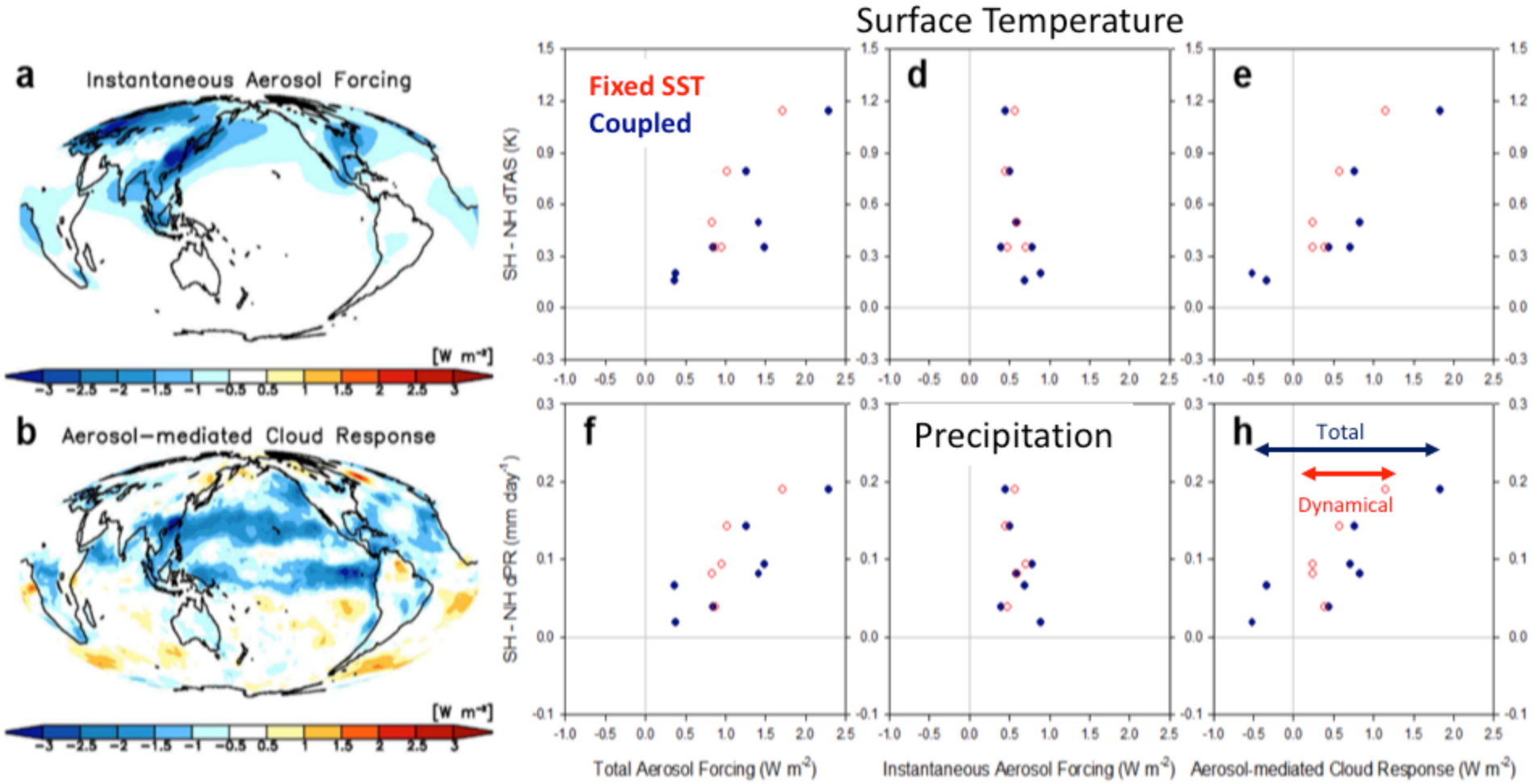


Total

Aerosol Direct

Aerosol-mediated Cloud Response

Aerosol Forcing and Hemispheric Shifts



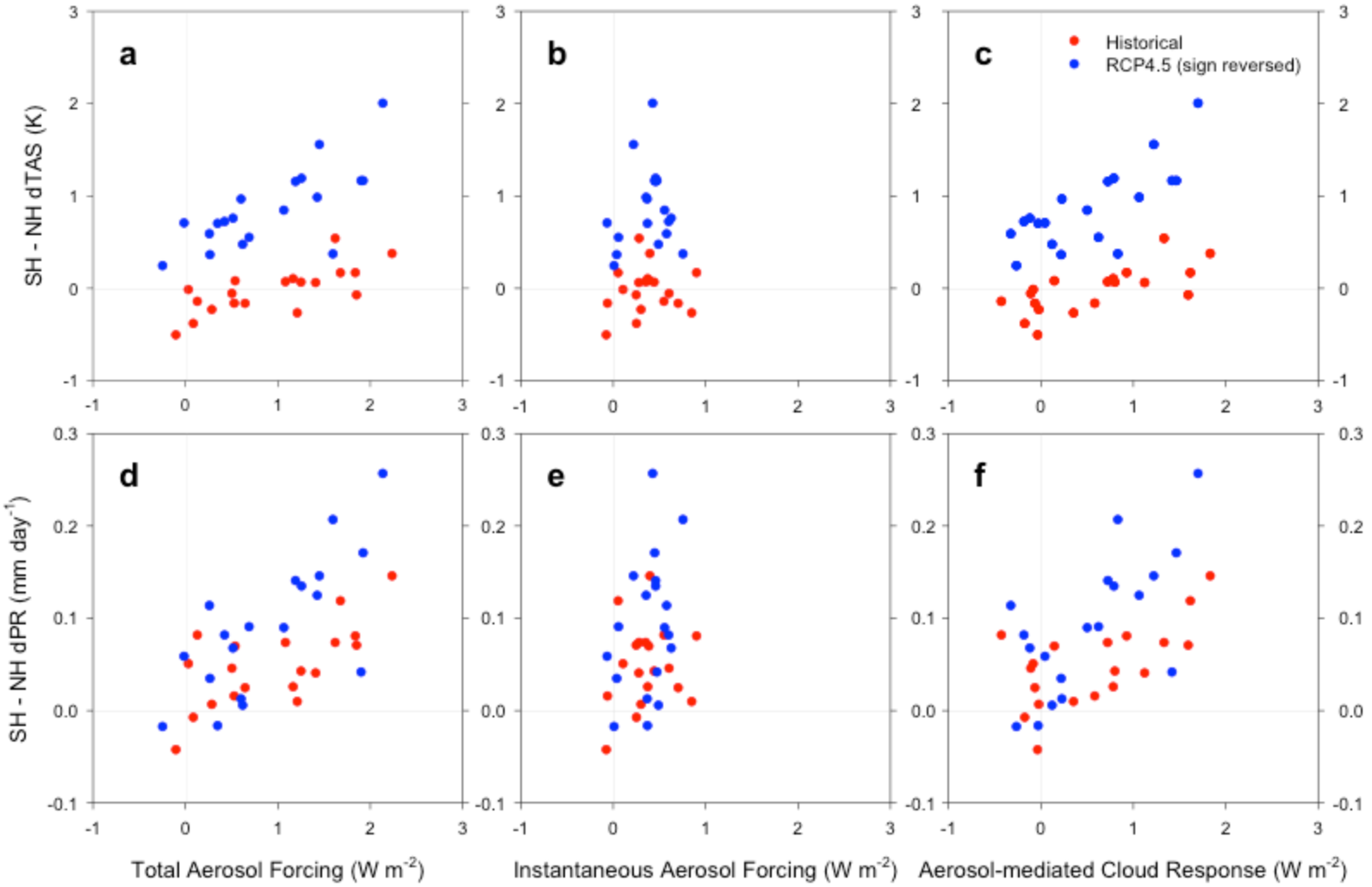
Total

Aerosol
Direct

Aerosol-mediated
Cloud Response

Aerosol Forcing and Hemispheric Shifts

(Historical and RCP4.5 Scenarios using aerosol regression)

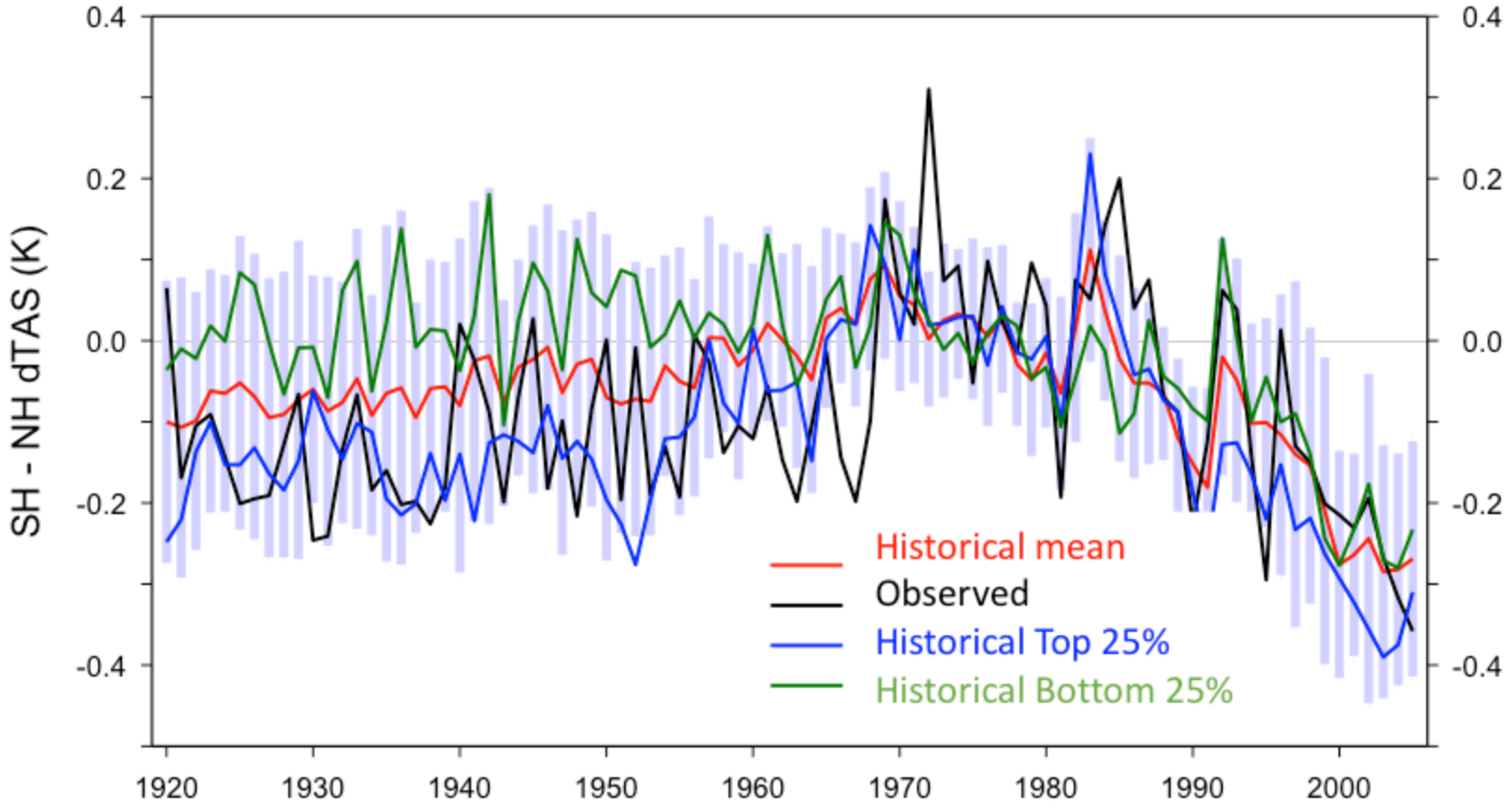


Total

Aerosol Direct

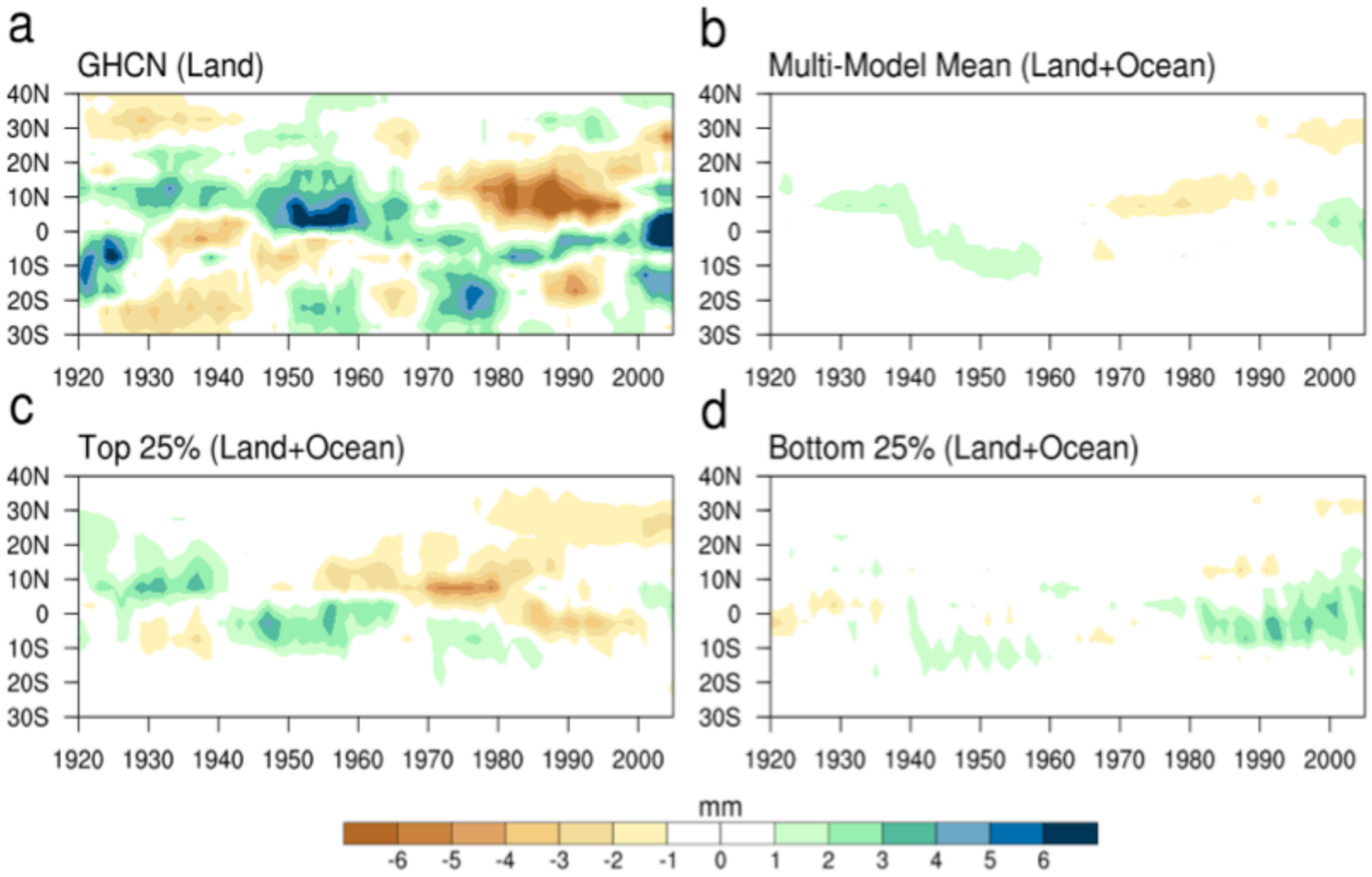
Aerosol-mediated Cloud Response

Observational Constraints: Hemispheric Warming Contrast



→ Models with stronger cloud-aerosol response agree better with observed warming asymmetry

Observational Constraints: Tropical Precipitation Shift



Summary

- **Aerosol forcing induces both local *microphysical* changes and non-local *dynamical* changes in clouds that are of comparable importance.**

- **Hemispheric shifts in precipitation are largely determined by the response of clouds to aerosol forcing, rather than the aerosol forcing itself.**

- **Models with larger aerosol-cloud response are in better agreement with the observed asymmetry of surface warming and precipitation over 20th Century.**

References:

Chung, E-S and BJ Soden, 2017: Hemispheric climate shifts driven by anthropogenic aerosol-cloud interactions, *Nature Geoscience*, 10, 566–571.

Soden, BJ and E-S Chung, 2017: The large-scale dynamical response of clouds to aerosol forcing, *J. Climate*, doi.org/10.1175/JCLI-D-17-0050.1

Thank You

Kernel vs APRP Forcing