Changes in the ITCZ under combined greenhouse gas and solar forcings: Insights from the Geoengineering Model Intercomparison Project

RICK RUSSOTTO, TOM ACKERMAN, JANE SMYTH, TRUDE STORELVMO

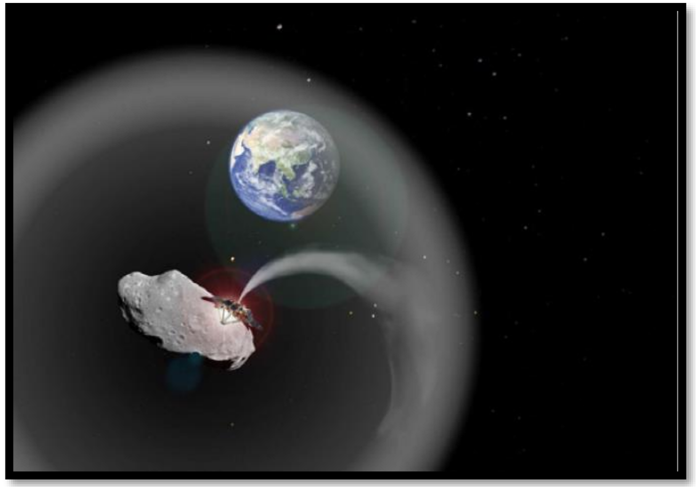
2ND WCRP GRAND CHALLENGE MEETING ON MONSOONS AND TROPICAL RAIN BELTS

TRIESTE, ITALY

5 JULY 2018

Solar geoengineering:
How to cool the Earth from the SW side?

Mirrors/Dust in Space



Bewick et al., 2012

Stratospheric Aerosol Injection

Climate Central

Marine Cloud Brightening

John McNeill

Why study geoengineering with climate models?

Science to inform policy debate

- Could it work?
- How much is necessary?
- Drawbacks/side effects/risks?

Better understand climate response to solar vs. greenhouse forcings

- Detection/attribution of climate change
- Paleoclimates
- Aerosol & volcanic forcings

The Geoengineering Model Intercomparison Project (GeoMIP)

Experiment G1: equal, opposing forcings

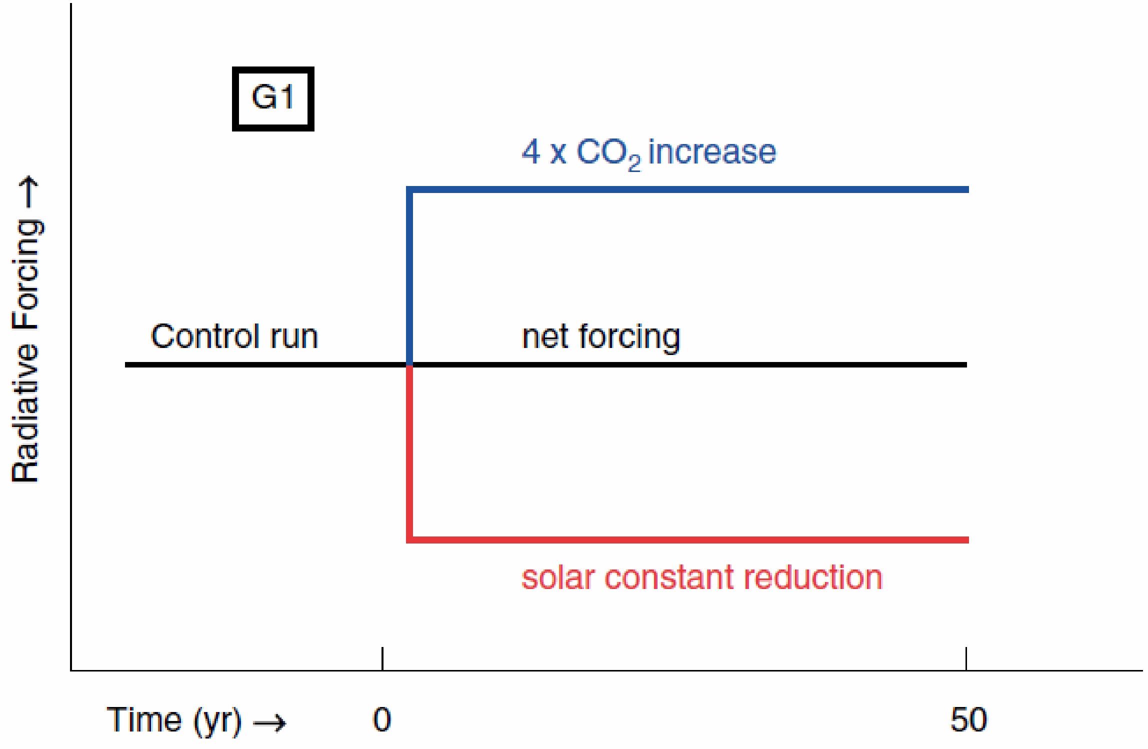
Abruptly quadruple CO_2

Reduce solar constant for zero net forcing/ zero global mean temperature change

Analysis procedure:

Average years 11-50

Subtract out CMIP5 piControl average



Kravitz et al., *Atmos. Sci. Lett.*, 2011

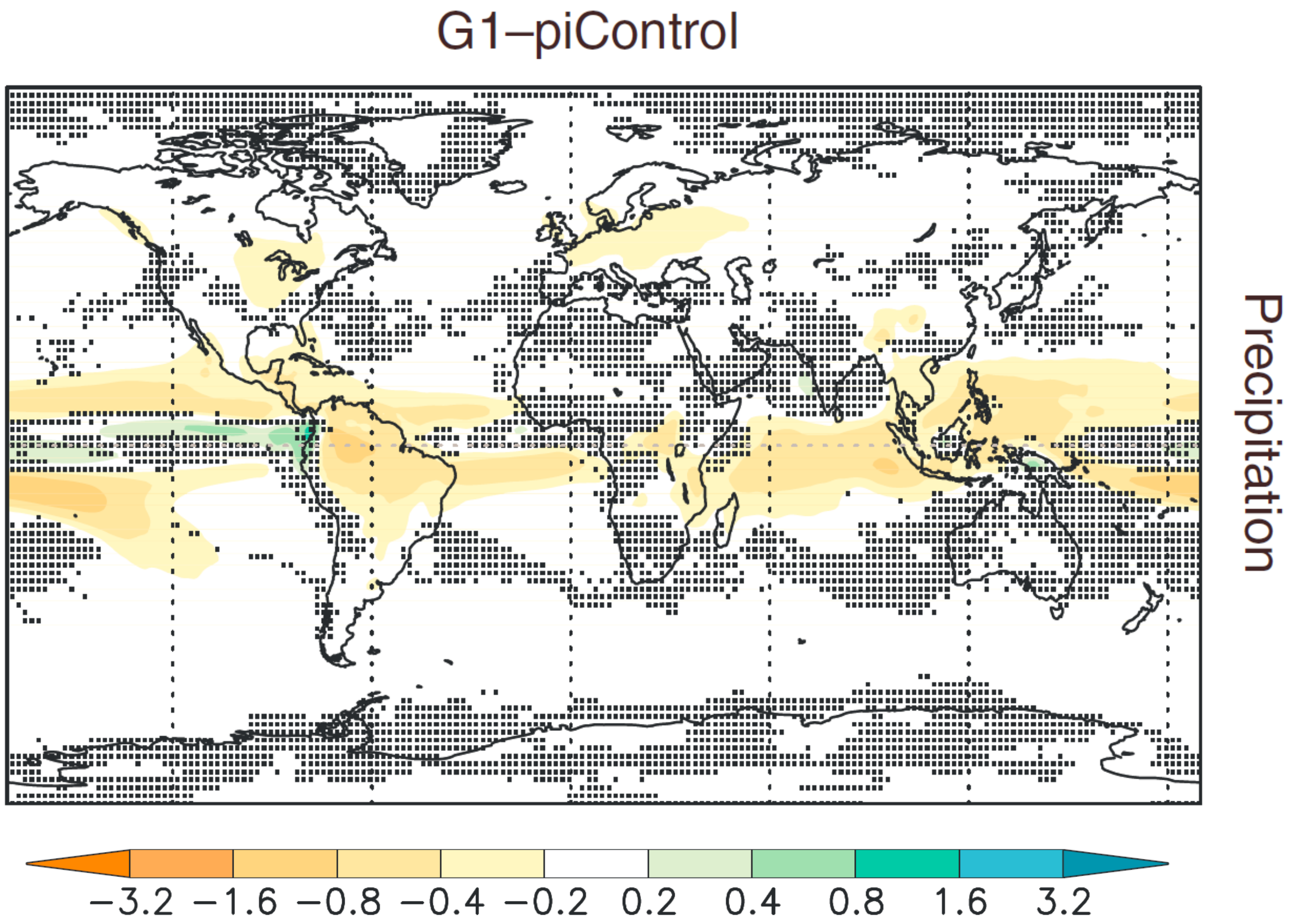
G1: Participating Models
(fully coupled atmosphere-ocean GCMs)

Model	Country	Solar constant reduction	Global mean temperature change (K)
BNU-ESM		4.4 %	0.03
Can-ESM2		4.0 %	-0.01
CCSM4		4.1 %	0.23
CESM1-CAM5.1-FV		4.7 %	-0.16
CSIRO-Mk3L-LR		3.2 %	0.03
GISS-E2-R		4.5 %	-0.29
HadGEM2-ES		3.9 %	0.24
IPSL-CM5A-LR		3.5 %	0.11
MIROC-ESM		5.0 %	-0.07
MPI-ESM-LR		4.7 %	-0.01
NorESM1		4.0 %	-0.04

Map of precipitation change

Global mean precipitation is reduced because sunlight reduction reduces surface evaporation.

Strongest in tropics, except equatorial Atlantic/Pacific.

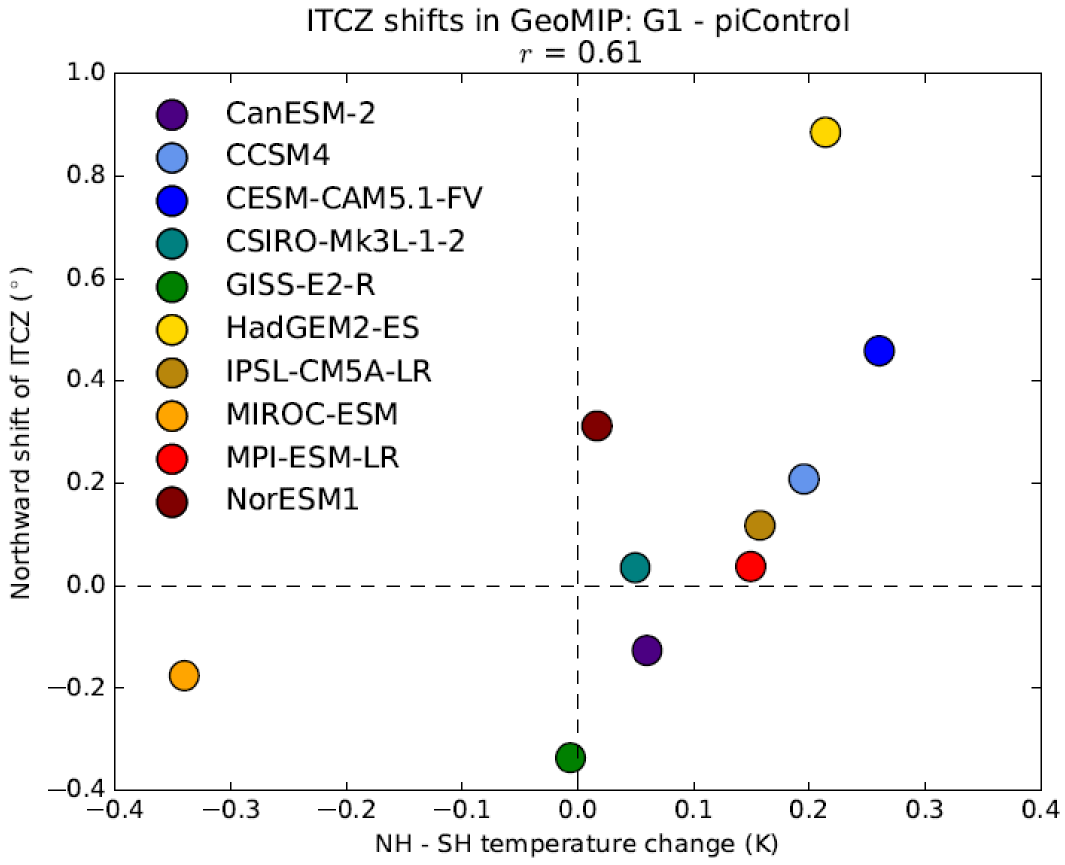


Multi-model mean map: hatched where fewer than 9 of 12 models agree on sign of change

(Kravitz et al., *J. Geophys. Res. Atmos.*, 2013a)

ITCZ shifts in individual models

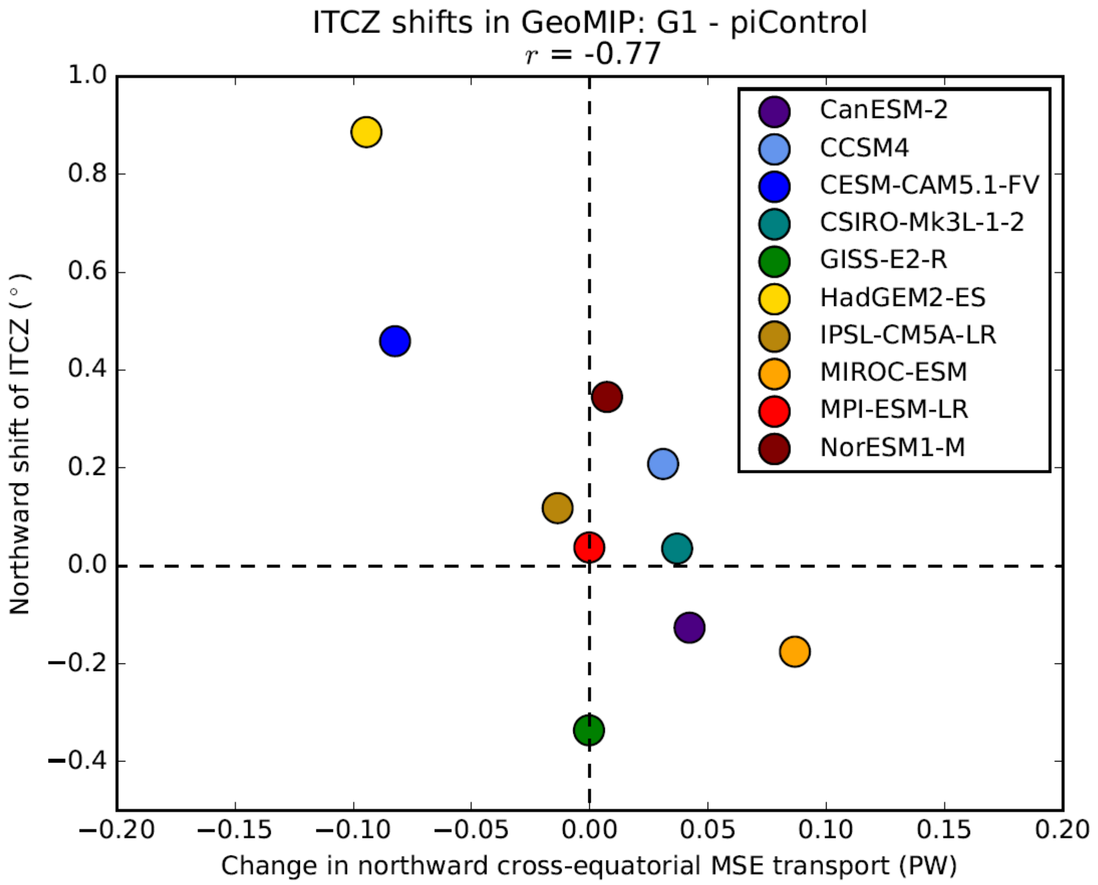
If one hemisphere is preferentially cooled, tend to have ITCZ shift towards other hemisphere.



Russotto and Ackerman, *Atmos. Chem. Phys.*, 2018

Anticorrelation with cross-equatorial energy transport

Useful for attributing sources of inter-model spread.



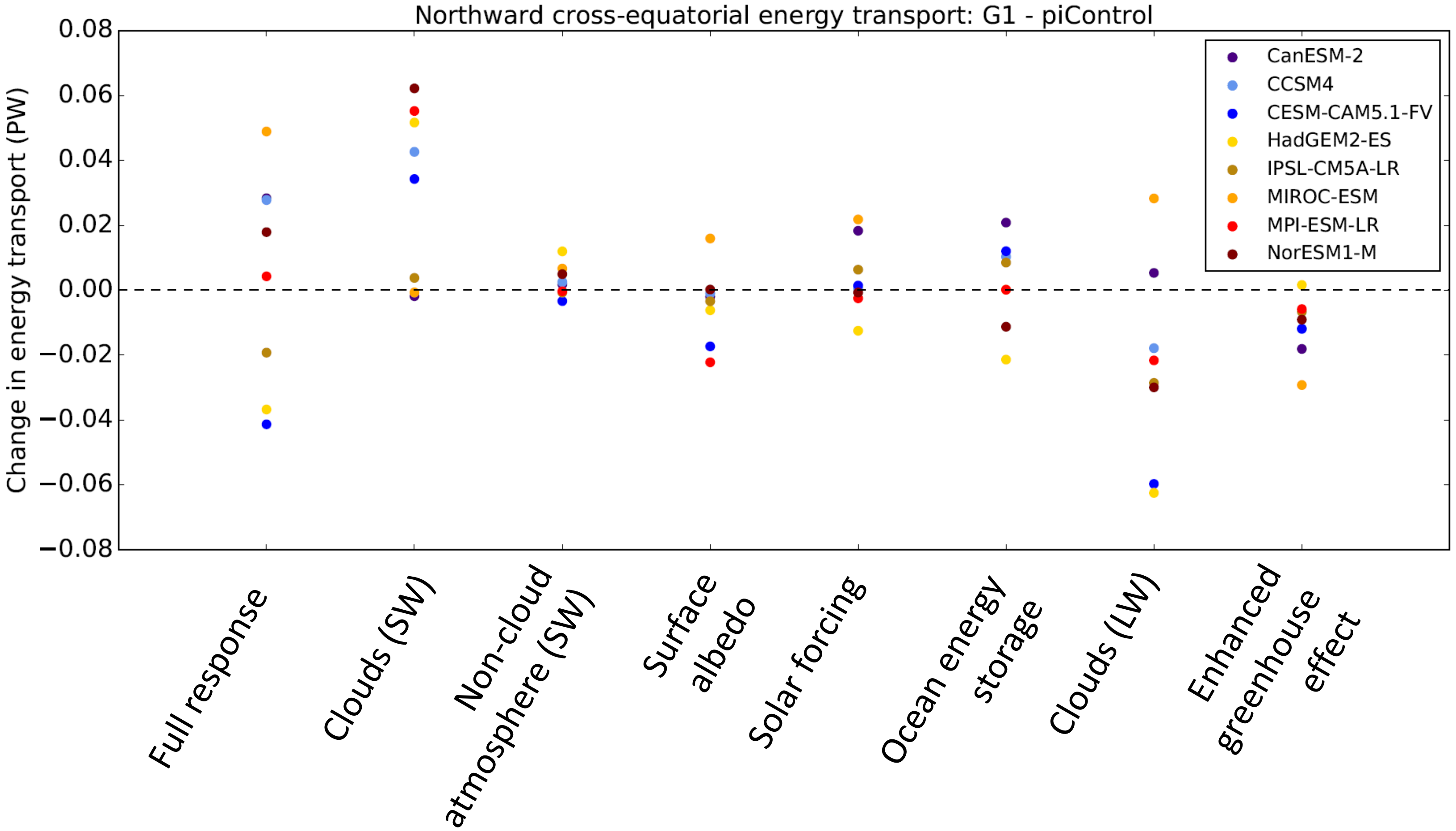
Russotto and Ackerman, *Atmos. Chem. Phys.*, 2018

Attribution experiments with moist EBM

Following procedure of, *e.g.*, Frierson and Hwang (2012)

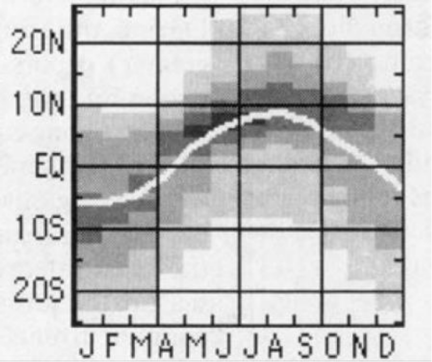
Plug TOA radiation changes associated with various physical processes into EBM. How does cross-equatorial MSE transport respond?

Cloud adjustments largest source of inter-model spread.

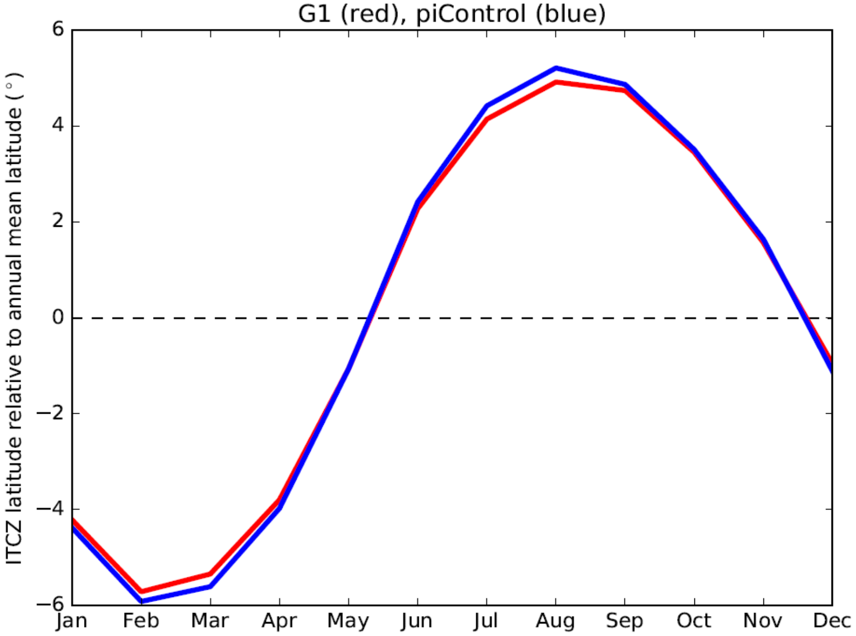


Seasonal migration of ITCZ

Climatology



Waliser and Gautier, *J. Climate*, 1993



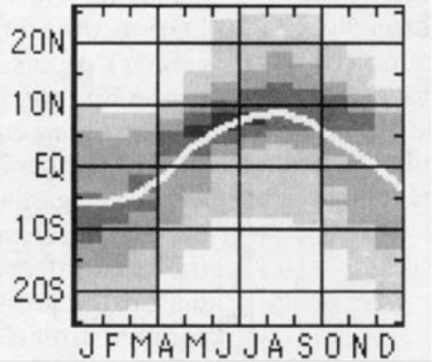
Multi-model mean ITCZ position

Seasonal migration dampened in geoengineered climate.

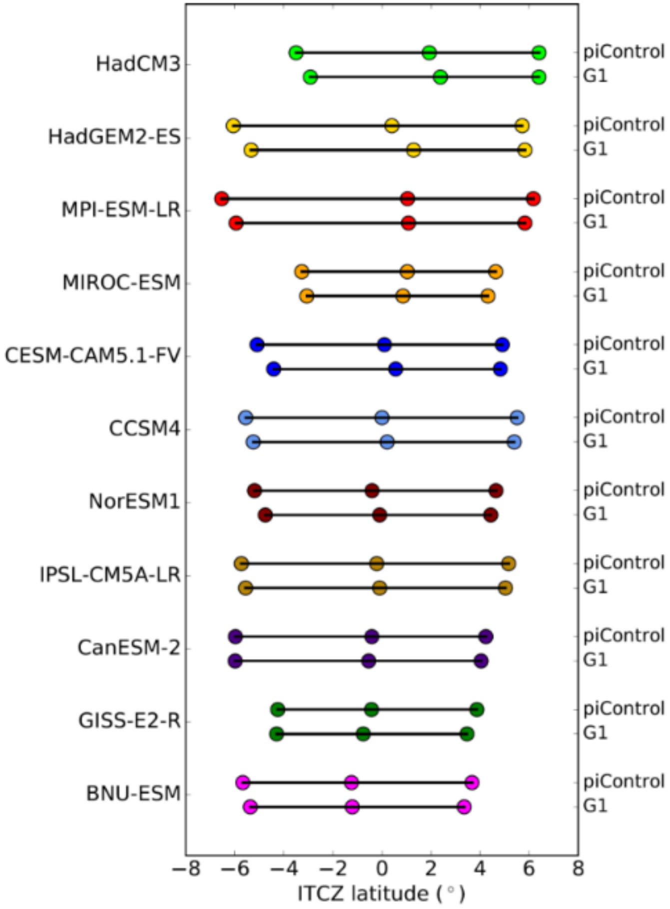
Reason: preferential cooling of summer hemisphere.

Seasonal migration of ITCZ

Climatology

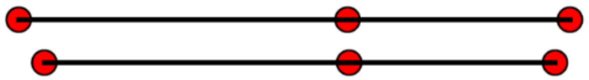


Waliser and Gautier, *J. Climate*, 1993



Damping occurs in every model.

Key



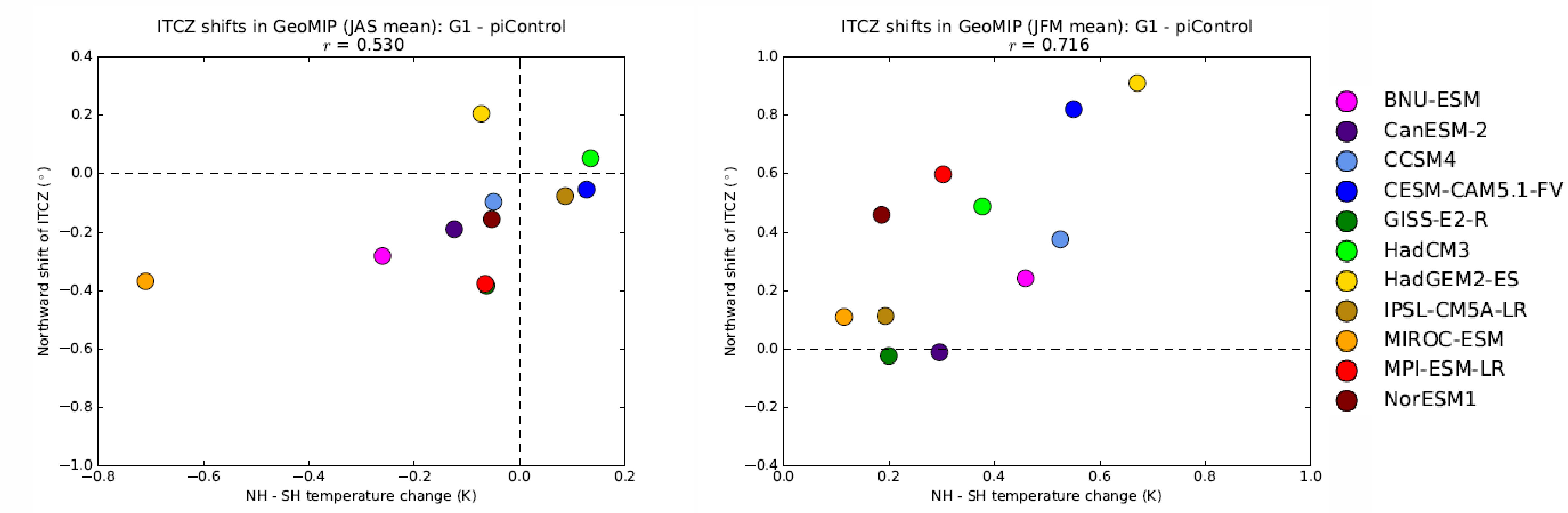
piControl
G1

JFM Annual Mean JAS

North→

Smyth et al., *Atmos. Chem. Phys.*, 2017

ITCZ shift vs. inter-hemispheric temperature change in seasons



Boreal Summer **Boreal Winter**

Smyth et al., *Atmos. Chem. Phys.*, 2017

Summary

Under 4xCO_2 and reduced solar constant, such that net forcing is zero:

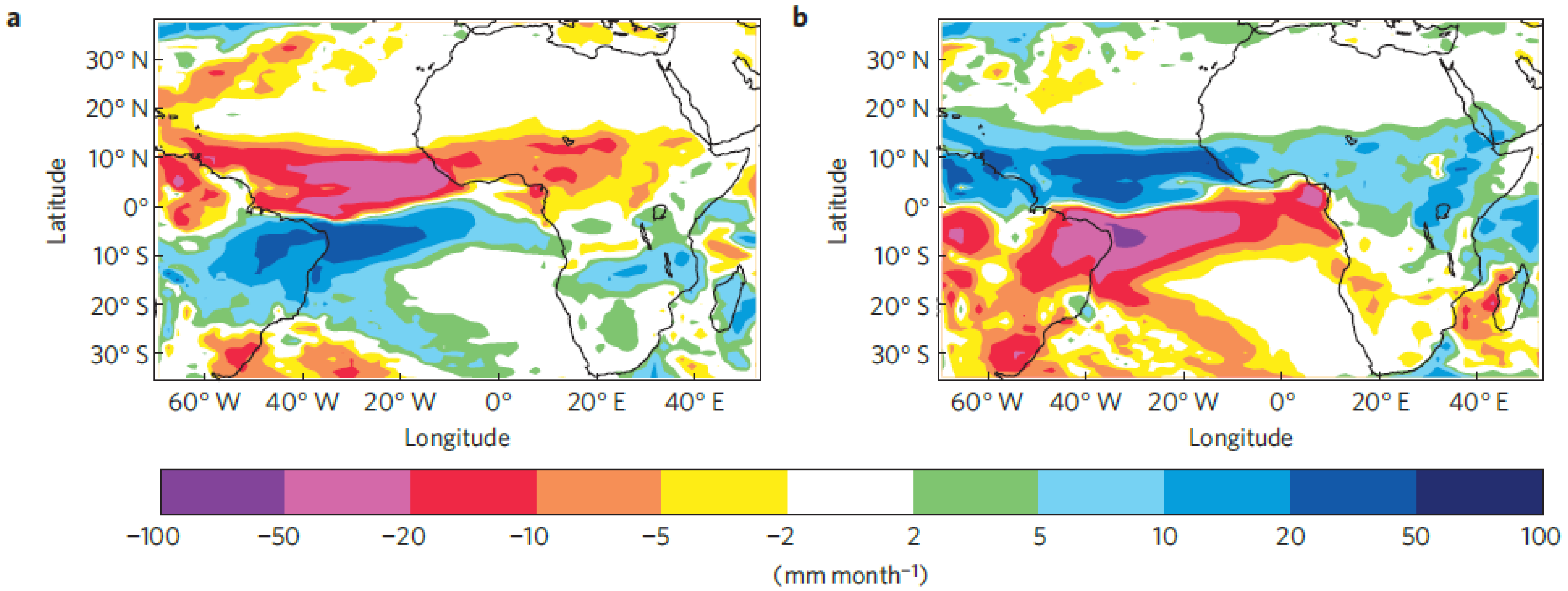
- Some models exhibit ITCZ shifts.
- The cloud response is the largest source of inter-model spread therein.
- The seasonal migration of the ITCZ is weakened
  due to preferential cooling of the summer hemisphere.

Unresolved questions:

- How much of annual mean ITCZ narrowing is due to
  the seasonal migration reduction?
- CO_2 + solar responses: how linear?

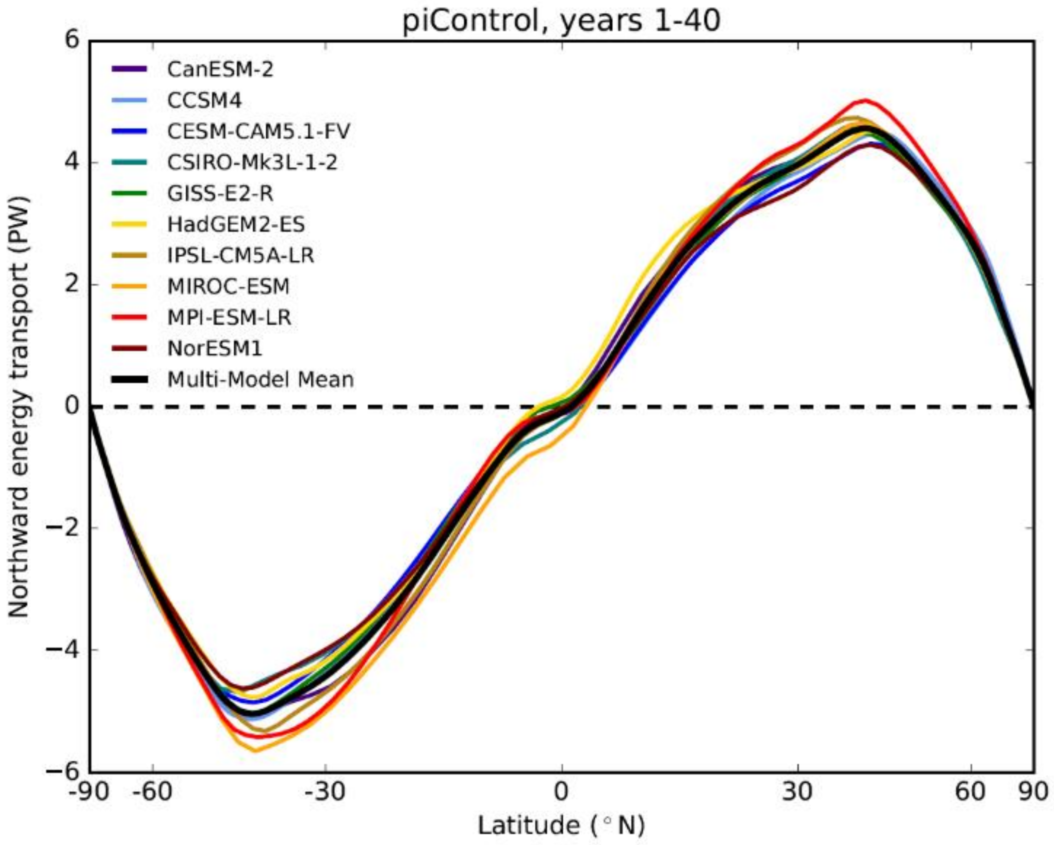
Slides taken out

What if we injected in only one hemisphere?



Precipitation change from injecting 5 Tg SO_2/year into Northern Hemisphere (a) or Southern Hemisphere (b) in HadGEM2-ES model. (Haywood et al., 2013)

Climatological Northward Energy Transport by the Atmosphere



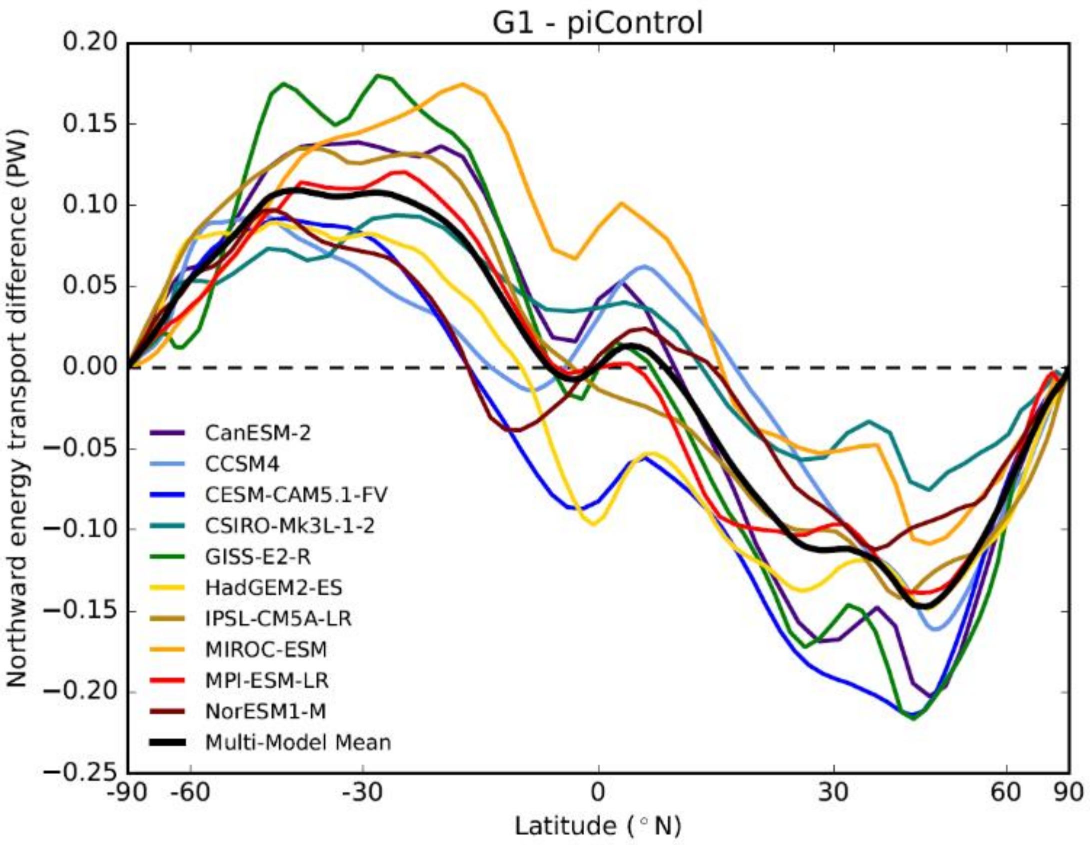
Atmosphere moves energy from equator to poles.

Change in Northward Energy Transport

Decrease in poleward energy transport!

Opposite of global warming case.

Moisture transport accounts for discrepancy.



The reduced poleward energy transport limits the polar warming.