

Understanding the drivers of regional tropical rainfall changes under warming

Rob Chadwick, Duncan Ackerley, Gill Martin, Peter Good, Hervé Douville, Chris Skinner, Kate Willett, Dietmar Dommenget, Tomoo Ogura



Drivers of regional climate change under CO₂ forcing



Figure from Marion Saint-Lu



Drivers of Tropical Precipitation Change

Annual Precipitation Change HadGEM2

Coupled abrupt4xCO2



Veg Response to 4xCO2



SST Pattern-Only



SST Uniform +4K



4xCO2 Rad.





 $mm \,\, day^{-1}$

Chadwick et al. 2017, Clim. Dyn.



Large Plant Physiological Effect on Rainfall Change in Tropical Forests

HadGEM2

Coupled abrupt4xCO₂

HadGEM2

Vegetation Response to $4xCO_2$



CCSM4

Coupled abrupt4xCO₂

CCSM4

Vegetation Response to $4xCO_2$







CNRM Coupled abrupt4xCO₂







Influence of land warming on circulation change



Bayr & Dommenget, 2013, J. Climate



Sources of land warming



Land response to SST warming

Direct radiative warming from increased CO₂

Warming from plant stomatal response to increased CO₂



Experimental Design

- Atmosphere-only configuration of ACCESS1.0
- Surface temperature and soil moisture saved every 3 hours during initial amip, amip4xCO2, amip4xCO2rad and amip4K runs.
- These 3 hourly fields, interpolated and updated hourly, are then used to prescribe land surface properties in further AGCM experiments.



Direct CO₂ radiative effect

Annual Mean Precipitation Change



Total direct radiative effect

> Land warming only



Direct Atmospheric CO₂ effect on Monsoons

JJA Precipitation Inst. TOA rad. forcing а a **TOA** forcing -1.9 -1.5 -1.1 -0.7 -0.3 0.0 0.3 0.7 1.1 1.5 1.9 -9.5 -7.5 -5.5 -3.5 -1.5 0.0 1.5 3.5 5.5 7.5 9.5 Inst. sfc. rad. forcing PMSL/850hPa winds е b Surface forcing $1 m s^{-1}$ -2.85 -2.25 -1.65 -1.05 -0.45 0.0 0.45 1.05 1.65 2.25 2.85 -9.5 -7.5 -5.5 -3.5 -1.5 0.0 1.5 3.5 5.5 7.5 9.5 Inst. atm. rad. forcing Tropospheric temperature C Atmospheric forcing -7600.0 -6000.0 -4400.0 -2800.0 -1200.0 0.0 1200.0 2800.0 4400.0 6000.0 7600.0 -9.5 -7.5 -5.5 -3.5 -1.5 0.0 1.5 3.5 5.5 7.5 9.5



Direct Atmospheric CO₂ effect on Monsoons

JJA AEI Rad. AEI а b SH LH d С

-19.0 -15.0 -11.0 -7.0 -3.0 0.0 3.0 7.0 11.0 15.0 19.0 $W m^{-2}$



Plant physiological effect

Annual Mean Precipitation Change

Sum of Landonly and Vegonly

amip4xCO2phys

-1.9

-1.5

-1.1

-0.7

Total plant physiological effect

а



-0.3 0.0 0.3

 $mm \ day^{-1}$

0.7

1.1

1.5

1.9

b

Sum of land warming and transpiration change experiments

Plant transpiration change only

Land warming only





- The balance of mechanisms driving precipitation change differs by region. SST pattern change is dominant over the tropical oceans, and also influential over some land regions.
- The direct atmospheric radiative effect of CO2 strengthens the West African and Asian monsoon circulations, due to differing atmospheric adjustments over land and ocean.
- In tropical forest regions, the vegetation response to CO2 plays a major role in driving precipitation change.
- CO2-induced reductions in plant transpiration actually drive precipitation increases in some forest regions, due to associated land warming.