The effect of doubled CO_2 and model basic state biases on the monsoon-ENSO system: The mean response and interannual variability

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Background: Increased greenhouse forcing could not only impact the mean monsoon in Southeast Asia, but also its interannual variability, possibly leading to further devastating droughts and floods.

• Sperber & Palmer (1996) found that climatological basic state errors in the tropics could prevent accurate seasonal prediction of precipitation variability. Federov & Philander (2000) realised that such errors would have an enormous impact on projections of the future climate.

• At 1xCO_2, systematic biases lead to an excessive mean monsoon in HadCM3, together with excessive trade winds in the Pacific and confinement of convection over the Maritime Continent. The monsoon-ENSO teleconnection, essential for seasonal prediction, is improved in both its strength and timing when systematic biases are removed (Turner *et al.* 2005).

• This study assesses the impact of tropical Indo-Pacific basic state biases on projections of the monsoon at 2xCO_2.

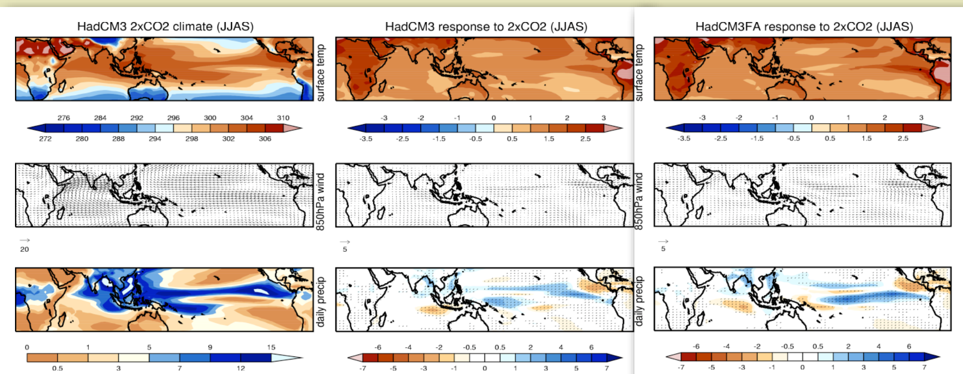


Fig 2: HadCM3 2xCO_2 mean JJAS climate (left), 2xCO_2 response in HadCM3 (middle), HadCM3FA (right).

Mean response of the Indo-Pacific: The surface temperature response to 2xCO_2 comprises an increased land-sea gradient and El Niño-like warming (Meehl & Washington 1996).

• The mean monsoon does not weaken with El Niño-like warming; instead a slight increase and northward shift in the Somali Jet occurs (in common with Hu *et al.* 2000, Kitoh *et al.* 1997, Ashrit *et al.* 2003, May 2004).

• Seasonal precipitation undergoes significant increases over India and the broad South Asia region and there is a northward shift in the Pacific ITCZ.

• The flux adjusted experiment shows the same patterns of change but with greater magnitude, suggesting that systematic model biases are masking the true impact of climate change.

TABLE 1. DAILY RAINFALL TOTALS (mm.day^{-1}) DURING THE JJAS SEASON OVER THE INDIAN LAND SURFACE, AS DEFINED BY GADGIL AND SAJANI (1998).

CO_2	CMAP	HadCM3	HadCM3IPFA	$\Delta rain_{FA}$
observed	4.60	-	-	-
$1\times CO_2$	-	4.29	3.41	−20.5%
$2\times CO_2$	-	4.44	3.84	−13.5%
$\Delta rain_{CO_2}$	-	+3.5%	+12.7%	-

TABLE 2. DAILY RAINFALL TOTALS (mm.day^{-1}) DURING THE JJAS SEASON OVER THE 5 − 40°N, 60 − 100°E REGION AFTER MEEHL AND ARBLASTER (2003).

CO_2	CMAP	HadCM3	HadCM3IPFA	$\Delta rain_{FA}$
observed	4.79	-	-	-
$1\times CO_2$	-	5.17	4.76	−7.9%
$2\times CO_2$	-	5.44	5.17	−4.9%
$\Delta rain_{CO_2}$	-	+5.2%	+8.5%	-

Method: Four century-long integrations of the UK Met Office fully coupled GCM HadCM3 are compared. The L30 version is used as it better simulates intraseasonal tropical convection and features a more realistic atmospheric response to El Niño (Inness *et al.* 2003; Spencer & Slingo 2003).

• The impact of systematic model bias is studied by applying an annual cycle of equatorial heat flux adjustments to the Indo-Pacific basin (Inness *et al.* 2003; Turner *et al.* 2005). The adjustments were calculated by relaxing SSTs in a control run back towards climatology and saving the anomalous heat fluxes required to form an annual cycle. The anomalous fluxes are then applied to the equatorial ocean in new 1xCO_2 and 2xCO_2 integrations.

• Climate change is assessed using 1xCO_2 (pre-industrial) and 2xCO_2 experiments. The 2xCO_2 experiments are initialised after 150-yr stabilized integrations, prior to which CO_2 concentration was ramped up at 1%/year.

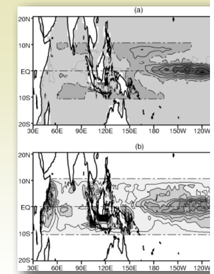


Fig 1: Annual mean (a amplitude (b) of flux

Monsoon interannual variability and its teleconnection to ENSO variability increases at 2xCO_2, in terms of dynamics (zonal windshear ind & Yang 1992) and precipitation. ENSO variability also increases in the fut The flux adjusted experiment sees the greatest increase in monsoon-ENSO

• The mean dynamical teleconnection strengthens in the future climate whil rainfall relation remains robust. Both possess a notable biennial character.

• The effects of systematic model bias on the teleconnection are larger th climate change.

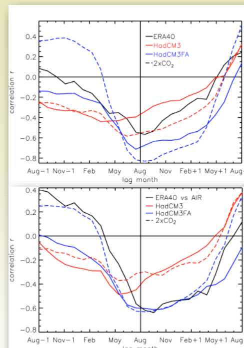
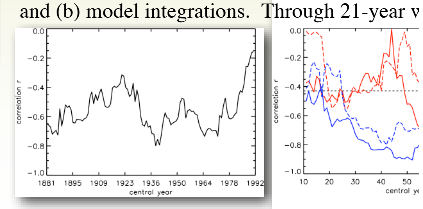


Fig. 3: Lag correlations between Nino-3 SSTs and JJAS (a) DMI (b) Indian rainfall.

• Decadal-timescale variations in the summer teleconnection are of similar magnitude to those in observations (Fig. 4) despite fixed CO_2 forcing.

• Recent weakening of the observed relationship thus cannot be distinguished from internal variation.

Fig 4: Nino-3 SST vs. Indian rainfall moving c in JJAS (a) observations (HadISST, All-India I and (b) model integrations. Through 21-year w



Implications: Both seasonal precipitation and interannual variability of the monsoon-ENSO system 2xCO_2. The future monsoon-ENSO teleconnection remains robust.

• Systematic model biases may be masking the full impact of increased CO_2 forcing on the Asian summ and the wider Indo-Pacific region.

• Removing biases has a greater impact on the monsoon-ENSO teleconnection than climate change, ho changes are within the bounds of internal variability.

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