Do Earth System processes affect future changes in monsoon variability?

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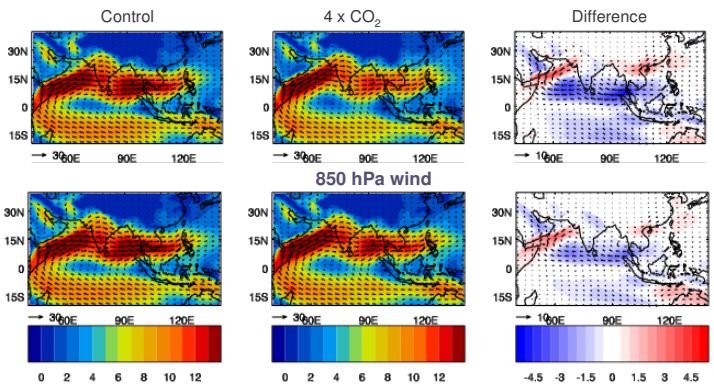
A – Introduction

Various studies have shown the importance of Earth System feedbacks in the climate system and the necessity of including these in models used for making climate change projections. We investigate whether the inclusion of such processes affects future projections of the Asian summer monsoon and on which temporal and spatial scales such effects are manifest.

The HadGEM2 family of MetUM configurations combines model components which facilitate the representation of many different processes within the climate system, including atmosphere, ocean and sea ice, terrestrial and oceanic carbon cycle and tropospheric chemistry.

We examine the impact of Earth System components on the simulation of the climatology and variability of the Asian summer monsoon in idealised climate change experiments in which a quadrupling of CO_2 is applied as a step change to a long pre-industrial control and run for many decades.

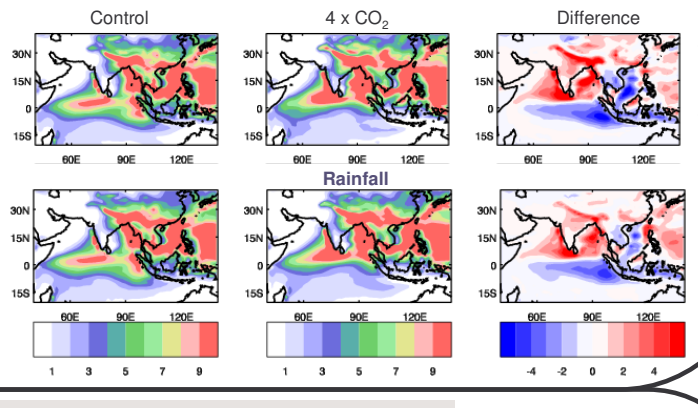
B – Impact of 4 x CO_2 on monsoon climatology



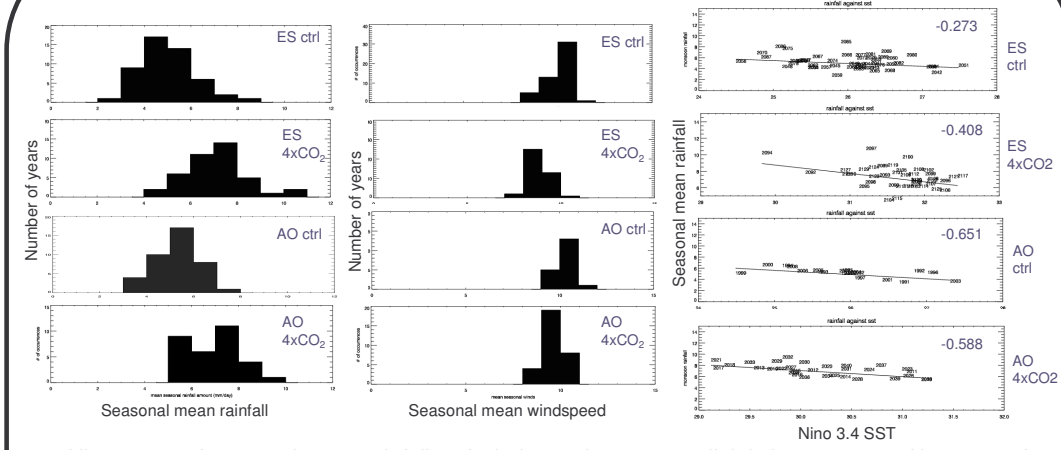
HadGEM2-ES: full Earth System including atmosphere, aerosols, land surface & hydrology, ocean & sea ice, terrestrial and ocean carbon cycle and tropospheric chemistry

HadGEM2-AO: atmosphere, aerosols, land surface & hydrology, ocean & sea ice.

The Asian monsoon climatology and the pattern of change with 4 x CO_2 is very similar in the two configurations. Increases in monsoon rainfall are slightly larger in HadGEM2-ES.



C – Interannual variability and teleconnections

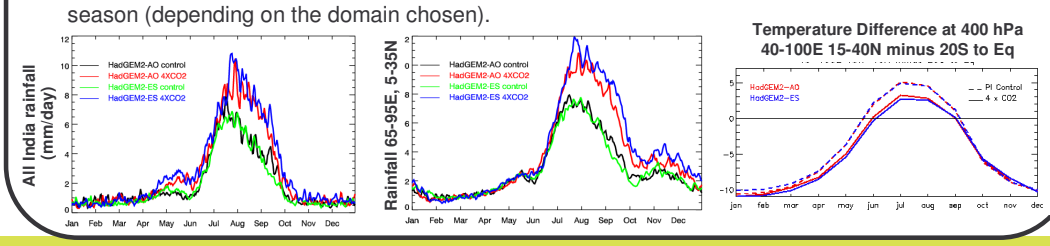


Histograms of seasonal mean rainfall and wind speed suggest a slightly larger range of interannual variability of seasonal mean rainfall in the ES control, and that this increases with 4xCO$_2$ in both AO and ES. In the ES control there was a very weak negative correlation between AIR and Nino3.4 SSTs, however this is strengthened by 4xCO$_2$. The correlation was stronger in the AO control and is slightly weakened for 4xCO$_2$. The overall increase in Nino3.4 SSTs is greater in ES than AO.

D – Seasonal cycle

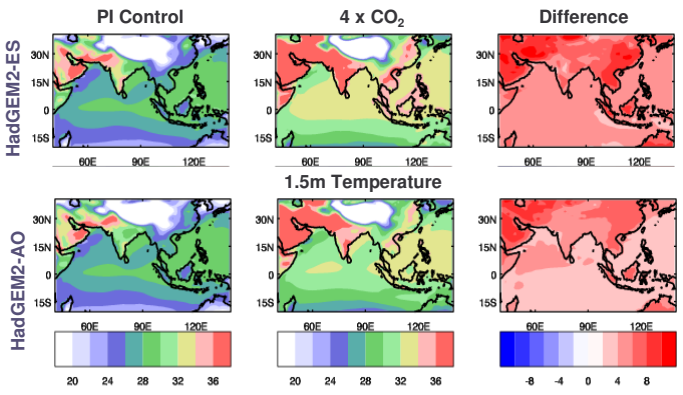
There is initial relative weakening of the tropospheric meridional temperature gradient with 4xCO$_2$ due to pronounced heating over the equator in June and July. This is associated with a slight delay in the peak of the monsoon rainfall.

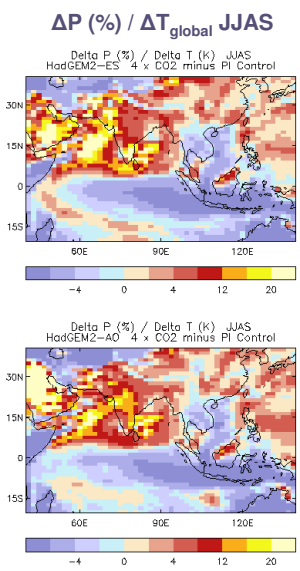
This relative weakening reduces towards end of monsoon season due to enhanced heating (reduced cooling) over Indian land. This is associated with a slight lengthening of monsoon rainy season (depending on the domain chosen).



E – Precipitation response to surface warming

The monsoon in the model responds to the increase in surface warming in 4 x CO_2 runs, with an increase in monsoon rainfall despite a slight weakening of the tropospheric temperature gradient and a weaker monsoon circulation, thereby agreeing with multi-model ensemble from AR4.





Globally, the ES model warms more than the AO model, and the change of precipitation with temperature is larger.

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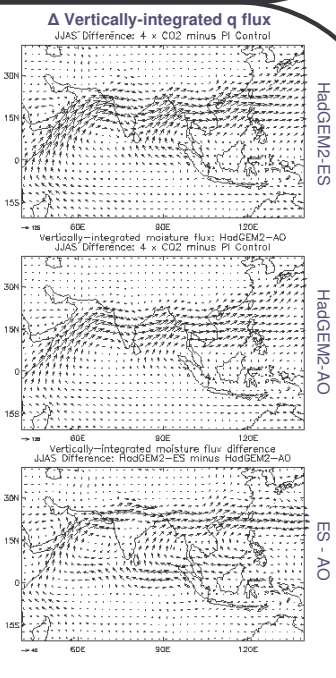
Configuration	ΔP_{global} (%)	ΔT_{global} (K)	$\Delta P / \Delta T_{global}$
HadGEM2-ES	7.7	6.6	1.17
HadGEM2-AO	4.4	5.3	0.83

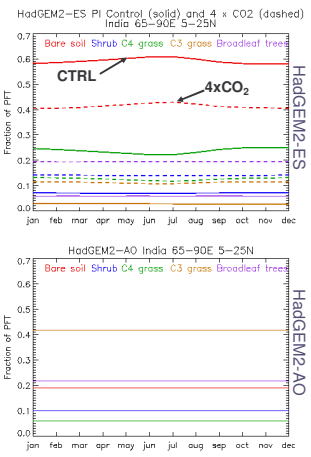
This is reflected in slightly larger $\Delta P / \Delta T_{global}$ values in the Asian monsoon region in the ES configuration.

F – Moisture transport

The increase in monsoon rainfall is associated mainly with enhanced moisture fluxes from the Arabian Sea due to surface warming.

Moisture fluxes over the northern Arabian Sea, India and East Asia are enhanced more in ES than AO.

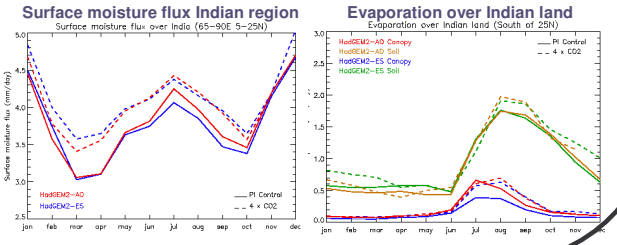




The vegetation distribution over India is rather different in ES than AO in both PI Control and 4xCO$_2$, with far more bare soil and C3 grass, rather than C4 grass and broadleaf trees.

With 4xCO$_2$, some bare soil is replaced by shrubs and broadleaf trees.

Surface moisture fluxes locally are smaller during summer in the ES Control as there is less canopy evaporation. Thus, the ES sees more enhancement of moisture fluxes with 4xCO$_2$ as the vegetation cover increases.



G – Implications

The changes in the monsoon between 4xCO$_2$ and control are similar in HadGEM2-ES and HadGEM2-AO, but are slightly larger in HadGEM2-ES. This may be partly related to the presence of rather different, and varying, vegetation distribution in HadGEM2-ES.

This suggests that, at least on the timescales examined here, the Earth system processes play a role in determining the projection of future monsoon rainfall.

However, the signal over land may also be larger if there was not a general underestimation of rainfall over the Indian land in this model.

Also, the moisture flux enhancement over Arabian Sea would likely be even larger if not for the large Arabian Sea cold SST bias seen in both configurations' pre-industrial (and present day) simulations *(see Martin et al. poster M243A)*.

This suggests that the influence of Earth system processes on the future projections of monsoon rainfall may be smaller than that of the systematic biases, particularly in SST, that are present in both configurations. This will be examined in future work.

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Acknowledgements
The authors would like to thank Susanna Stephenson for her contribution to this work.