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Changes to the tropical circulation in a CO2 ramp-up/ramp-down simulation

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Changes to the tropical circulation during an idealised model experiment of CO2 ramp-up and ramp-down (simulating potential future C02 mitigation measures) were analysed. The HadCM3 coupled GCM was used to simulate a transient increase from pre-industrial C02 levels to 4xC02, followed by a reduction in C02 to the original level and a stabilisation period.

Wu et al 2010 (GRL, 37, L12705) analysed the global precipitation (P) and temperature (T) responses in this experiment, and found that P exhibited a non-linear relationship with T. Whereas T begins to decrease contemporaneously with the reduction in C02, P continues to increase for several decades before slowly decreasing. This hydrological hysteresis means that two possible hydrological states are possible for the same global mean T. As changes in water vapour are seen to follow temperature closely in this experiment, this hysteresis effect would be expected to be reflected in the tropical circulation (c.f. Held & Soden 2006, J. Clim., 19, 5686-5699). Transient changes to the tropical circulation during this experiment, particularly to the Hadley and Walker circulations, were examined.

The Hadley circulation exhibited significant changes during the increasing C02 phase, particularly in DJF when the northern cell was substantially weakened. However, during the ramp-down phase the Hadley circulation returned to its pre-industrial state as C02 and T decreased, even though P remained in a substantially increased state. Similarly there was an increase in the extent of the boundaries of the Hadley cells during the ramp-up phase, but these also returned to their original state during the ramp-down phase. There were also large changes to the strength and position of the Walker cells during the ramp-up phase, but in contrast to the behaviour of the Hadley cells these did not totally return to the pre-industrial state with C02 and T during the ramp-down phase.

Similar C02 ramp-up/ramp-down experiments were performed with the more recently developed HadGEM2 GCM, also showing hydrological hysteresis behaviour. Analysis of changes to the tropical circulation in these experiments will be presented, and compared with the behaviour of HadCM3.