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The fast and slow response of Southern hemisphere midlatitude circulation to forcing

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Previous studies have highlighted the potential for different timescales of response of the mid-latitude circulation to external forcing, and have shown that many aspects of forced changes in atmospheric circulation do not scale with global surface temperature change. Here we examine the fast and slow components of the southern hemisphere midlatitude circulation response to a range of drivers using experiments from eight climate models participating in the Precipitation Driver and Response Model Intercomparison Project (PDRMIP). The perturbations are a doubling of carbon dioxide (2xCO_2), a tripling of methane (3xCH4), a five-fold increase in sulphate aerosol (5xSul), a ten-fold increase in black carbon aerosol (10xBC) and a 2% increase in the solar constant (2%Sol). We focus on the comparison between two sets of experiments, one with a fully coupled ocean and another with fixed sea-surface temperatures (fSST). The latter enables an evaluation of the midlatitude circulation response associated with rapid atmospheric adjustments in the absence of sea surface temperature (SST) changes.

We find that in the coupled experiments with evolving SSTs the eddy-driven jet (EDJ) shifts polewards and strengthens for forcings that produce global warming, with the strongest responses found in austral summer compared to winter. The fSST experiments show that for all forcings considered, substantial changes in the EDJ occur in the absence of SST changes. For black carbon, which induces only weak global surface temperature changes but relatively stronger atmospheric heating, the fSST experiments capture almost all the EDJ changes in the coupled experiment. For other forcings that induce significant SST changes (CO_2, CH4, sulphate, solar), the effect of SST changes dominates over the rapid adjustments, but the latter still contribute to the overall response. The results emphasise the need to understand the processes associated with rapid adjustments in the large-scale circulation and not only the effects from slower changes in SSTs