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Southern Ocean Winds and Precipitation at the LGM: The Influence of State Dependency and Sea Surface Changes on CMIP5-PMIP3 Results

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One hypothesis to explain the apparent tight coupling of deglacial atmospheric CO_2 and Antarctic temperature is latitudinal shifts in the Southern Ocean westerly wind belt: shifts could drive changes in the ocean CO_2 inventory. PMIP2 and PMIP3 models show considerable disagreement in their simulation of deglacial, 21 ky to 0 ky, Southern Ocean wind changes. This is despite nearly all CMIP5 models exhibiting a poleward shift and all models a strengthening of the surface jet following from 1900 to 2100, following the RCP8.5 scenario. Understanding what drives modelled wind changes, and the reasons for inter-model inconsistencies, should help our understanding of large changes in past CO_2 and climate.

We find that that jet position is strongly related to the sea ice edge latitude in PMIP3-CMIP5 simulations. An equatorwards shift in the sea ice edge correlates with a poleward shift in the jet latitude (r $\sim$ -0.9). The relationship is strongest for 850 hPa winds, however similar results are obtained using 1000 hPa and τ_U. A 1° difference in the sea ice edge suggests a -0.8° shift in the 850 hPa jet. However this applies only to models which have jets which are at a realistic latitude at 0 ky; if the 0 ky modelled jet sits equatorward of 47°S this relationship does not apply. If we look at the relationship between Southern Ocean sea surface temperature changes and jet shifts, a cooling of -1 K between 0 to 21 ky over the Gersonde *et al.* (2005) Southern Ocean compilation locations results in a 3.0° poleward shift in the 850 hPa jet (r = 0.83; n=5).

The ensemble of present day CMIP5 model run data show an equatorward bias of 3.3° in the ensemble mean position of the surface zonal mean jet. We thus also calculate the impact of initial jet position, or state, dependency for Southern Ocean jet shifts and intensity changes across the various oceanic sectors. We find that state dependency explains up to 56% of the 0 to 21 ky jet shifts in the Atlantic (r=-0.75, N=9, for τ_U), and 41% in the Indian Ocean (r = -0.64, N = 9, for τ_U). State dependency is much weaker in the Pacific; here any influence is negligible. We generally find state dependence stronger for τ_U than for the 850 hPa winds. For the whole of the Southern Ocean, the variance explained by state dependency is 38% (r = -0.62, N = 9, for τ_U).

Finally we also find that state dependency has a large influence on the simulation of past observed moisture changes. In the majority of cases model-data agreements at 21 ky are highly dependent on the jet position at 0 ky, indicating that state dependence is also critical in determining model-data moisture agreements. This finding also has implications for the calculation of Southern Ocean buoyancy forcing during the deglacial.