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Detecting Climate Fingerprints in Southern Ocean Carbon using a Biogeochemical Ocean Model

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The Southern Ocean plays an important role in the uptake, transport and storage of carbon by the global oceans. These properties are dominated by the response to the rise in anthropogenic CO_2 in the atmosphere, but they are modulated by climate variability and climate change. Here we explore the effect of climate variability and climate change on ocean carbon uptake and storage in the Southern Ocean. We assess the extent to which climate change may be distinguishable from the anthropogenic CO_2 signal and from the natural background variability. We use a combination of biogeochemical ocean modelling and observations from the GLODAPv2020 database to detect climate fingerprints in dissolved inorganic carbon (DIC).

We conduct an ensemble of hindcast model simulations of the period 1920-2019, using a global ocean biogeochemical model which incorporates plankton ecosystem dynamics based on twelve plankton functional types. We use the model ensemble to isolate the changes in DIC due to rising anthropogenic CO_2 alone and the changes due to climatic drivers (both climate variability and climate change), to determine their relative roles in the emerging total DIC trends and patterns. We analyse these DIC trends for a climate fingerprint over the past four decades, across spatial scales from the Southern Ocean, to basin level and down to regional ship transects. Highly sampled ship transects were extracted from GLODAPv2020 to obtain locations with the maximum spatiotemporal coverage, to reduce the inherent biases in patchy observational data. Model results were sampled to the ship transects to compare the climate fingerprints directly to the observational data.

Model results show a substantial change in DIC over a 35-year period, with a range of more than +/- 30 µmol/L. In the surface ocean, both anthropogenic CO_2 and climatic drivers act to increase DIC concentration, with the influence of anthropogenic CO_2 dominating at lower latitudes and the influence of climatic drivers dominating at higher latitudes. In the deep ocean, the anthropogenic CO_2 generally acts to increase DIC except in the subsurface waters at lower latitudes, while climatic drivers act to decrease DIC concentration. The combined fingerprint of anthropogenic CO_2 and climatic drivers on DIC concentration is for an increasing trend at the surface and decreasing trends in low latitude subsurface waters. Preliminary comparison of the model fingerprints to observational ship transects will also be presented.