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# Detecting Climate Fingerprints in Southern Ocean Carbon Using a Global Ocean Biogeochemical Model and Observations

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The Southern Ocean (SO) plays an important role in the uptake, transport and storage of carbon by the global oceans. These properties are dominated by 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 in the SO using a combination of modelling and observations to identify climate fingerprints in dissolved inorganic carbon (DIC). We conduct an ensemble of hindcast model simulations using the NEMO-PlankTOM12 global ocean biogeochemical model. We use the model to isolate the changes in DIC due to anthropogenic $CO_2$ alone and the changes due to climatic drivers (both climate variability and climate change) and determine their relative roles in the emerging total DIC trends and patterns. We analyse the DIC climate fingerprint since 1995, across spatial scales in the SO, and check the extent to which they are detectable in the GLODAPv2.2020 observations. Model results were subsampled to the observations to directly compare the climate fingerprints. Results show that 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 (<55°S) and the influence of climatic drivers dominating at higher latitudes (>55°S). This pattern is present in all basins. In the subsurface ocean, climatic drivers act to decrease DIC concentration, opposing the influence of anthropogenic $CO_2$, with a stronger decrease at lower latitudes (<50°S). These patterns resulted in a climate fingerprint specific to SO change and were detectable in the observations. However, the model underestimates the surface DIC increase and the spatial and depth variability of the subsurface DIC decrease. We use the model to directly attribute the climate fingerprint to various climate drivers and discuss timescales for unambiguous detectability of the fingerprint in observations.