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The Seasonal Cycle of CO_2 in the Southern Ocean: Diagnosing Anomalies in CMIP5 Earth Systems Models

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The Southern Ocean forms a key component of global carbon budget: taking up about a third (1.0±0.5 PgC yr-1) of the total global oceanic annual uptake of anthropogenic CO_2 and accounting for most of the uncertainty in the global ocean CO_2 fluxes. A recent synthesis study (Lenton et al., 2013), showed that although ocean biogeochemical models agree on the mean annual flux of CO_2 in the Southern Ocean, they disagree on both amplitude and phasing of the seasonal cycle and compare poorly to observations. In this study, we used a diagnostic analysis based on the representation of the seasonal cycle of CO_2 air-sea fluxes (FCO_2), (Mongwe et al., 2016) on 10 CMIP5 earth system models. Our approach shows how an understanding of the seasonal variability of drivers of CO_2 at a seasonal scale helps explain the anomalies between observations and CMIP5 models. In this study, we show that the model –observations FCO_2 seasonal cycle anomalies are due to differences in the magnitude of the seasonal cycle of dominant drivers of pCO_2 i.e. thermal and physical-biogeochemical drivers. We found that 6 of the 10 CMIP5 models overestimate the role of solubility (temperature driven) during autumn, which delays the impact of winter sub-surface DIC entrainment to surface pCO_2 and thus causing a divergence from observations FCO_2. We found that 3 of the 10 overestimate the physical –biogeochemical driver on pCO_2 due to overestimation of the net CO_2 biological uptake. We found that convective CO_2 winter entrainment, as well as the impact of summer biological CO_2 uptake, have a compound effect on the amplitude of the seasonal cycle of DIC and hence FCO_2.