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# Recent changes in the accumulation of anthropogenic carbon in mode waters of the Southern Indian Ocean

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The Southern Ocean plays an important role in the climate system by regulating excess $CO_2$ in the atmosphere. A large part of the anthropogenic $CO_2$ ($C_{ant}$) absorbed in surface waters of the Southern Ocean is isolated from the atmosphere at mid-latitudes through the sinking of mode waters down to 1500m. Since the Southern Ocean $CO_2$ sink and mode waters formation vary from inter-annual to decadal scales, one would expect the $C_{ant}$ content in these waters to be also variable. This has been suggested through modeling studies but it is challenging to detect these changes based on observations.  This study attempts to estimate the evolution of $C_{ant}$ accumulation in mode waters of the Southern Indian Ocean over the period 1985-2019 based on observations from the Global Ocean Data Analysis Project (GLODAPv2_2020) and the long-term monitoring program OISO (Océan Indien Service d'Observations). The comparison of three data-based diagnostic approaches showed the strength of the eMLR(C*) method (Clement and Gruber, 2018) for estimating temporal variations in the accumulation of $C_{ant}$. The increase in $C_{ant}$ estimated between 1985 and 2019 show a relatively good agreement for the three methods in the different types of mode waters identified in the Indian Ocean:  the mean trend is between +1.02 and +1.09 µmol $kg^{-1}$ $yr^{-1}$ in the Subtropical Mode Water (STMW), between +0.73 and +1.02 µmol $kg^{-1}$ $yr^{-1}$ in the Subantarctic Mode Water (SAMW) and between +0.25 and +0.51 µmol $kg^{-1}$ $yr^{-1}$ in the Antarctic Intermediate Water (AAIW). However, on shorter periods we found larger discrepancies between the eMLR(C*) method and the two other techniques (back-calculation and TrOCA), the latter showing larger uncertainties. The mean increase in $C_{ant}$ between 1994 and 2007 estimated using the eMLR(C*) is +1.34 (± 0.18) µmol $kg^{-1}$ $yr^{-1}$ in the STMW, +1.05 (± 0.05) µmol $kg^{-1}$ $yr^{-1}$ in the SAMW and +0.60 (± 0.11) µmol $kg^{-1}$ $yr^{-1}$ in the AAIW, which is consistent with previous results obtained over the same time period using the same method (Gruber et al, 2019). Interestingly, the trends estimated with this method in recent years (between 2007 and 2017) weakened by about half in all mode waters, in STMW (+0.73 (± 0.20) µmol $kg^{-1}$ $yr^{-1}$), the SAMW (+0.49 (± 0.20) µmol $kg^{-1}$ $yr^{-1}$) and AAIW (+0.26 (± 0.42) µmol $kg^{-1}$ $yr^{-1}$). Due to the important contribution of mode waters in the storage of $C_{ant}$, these results could significantly reduce the oceanic inventories of $C_{ant}$ in recent years at both the regional and global scales. The reduction in $C_{ant}$ trends in mode waters of the Southern Indian Ocean raises questions on the external/internal processes that control mode waters formation and air-sea $CO_2$ exchanges in the Southern Ocean at a decadal scale.