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Supplement of

The impact of the South-East Madagascar Bloom on the oceanic CO_2 sink

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Supplementary Material: Includes Figures S-1 to S-13

Figure S1: Map of monthly surface Chl-a ($mg.m^{-3}$) in the South-Western Indian Ocean in November 2019 (Top Left), December 2019 (Top Right), January 2020 (Bottom Left) and February 2020 (Bottom Right) derived from MODIS data (4x4km resolution), highlighting the SEMB bloom in this region. Figures produced with ODV (Schlitzer, 2013) from data downloaded at https://resources.marine.copernicus.eu/ (OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_093), last access, 1-June-2021.

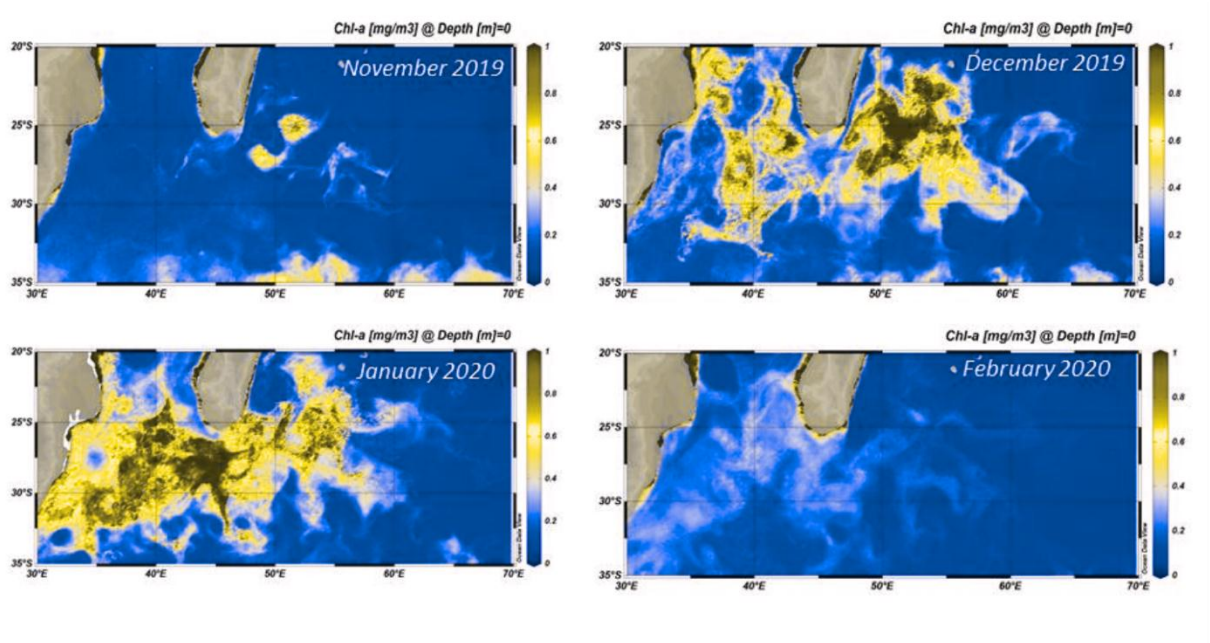


Figure S2: Map of monthly surface current ($m.s^{-1}$) for November 2019 in the South-Western Indian Ocean showing the retroflection of the South-East Madagascar Current and large cyclonic eddies at that period (both highlighted by white circles). The retroflection around 26°S/48°E is close to the location of the so-called "early retroflection" defined by Ramanantsoa et al (2021). Figure produced from https://resources.marine.copernicus.eu/ (MULTIOBS_GLO_PHY_REP_015_004) last access, 15-Dec-2021.

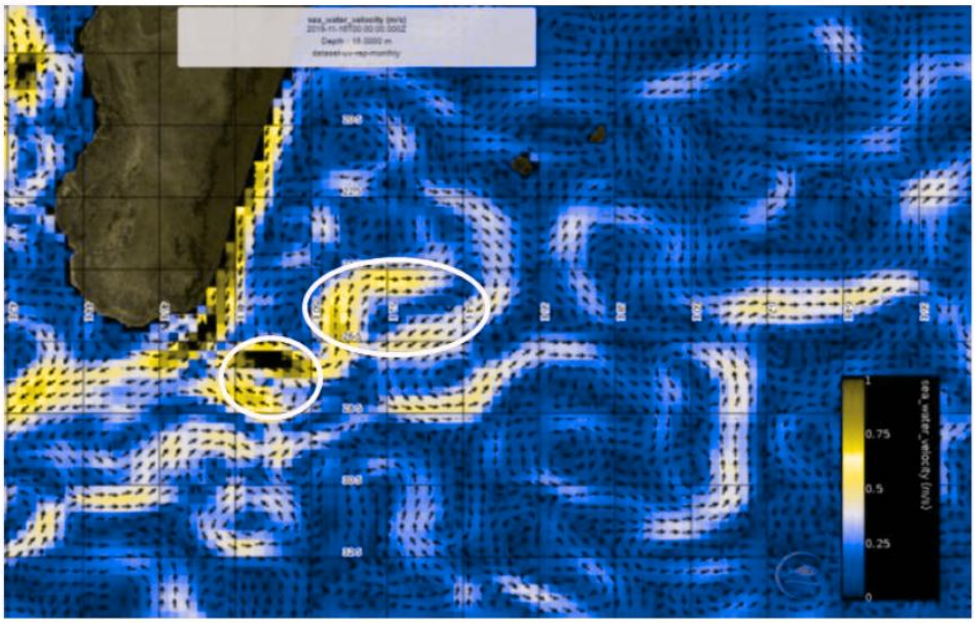


Figure S3: Sea surface temperature (SST, black circles) and salinity (SSS, open circles) in January 2020 along the OISO-30 cruise track at 54°E. The highest Chl-a concentration in the SEMB bloom were observed north of 27°S (Figure 3) in waters with lower salinity.

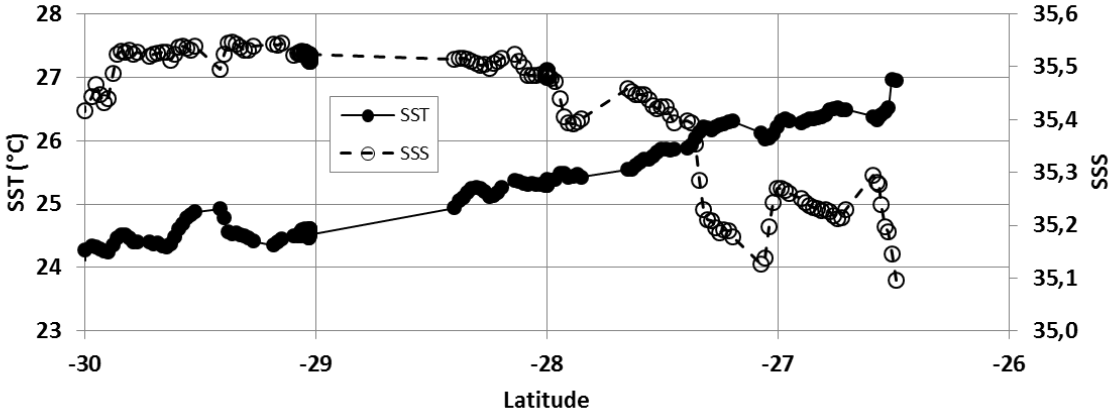
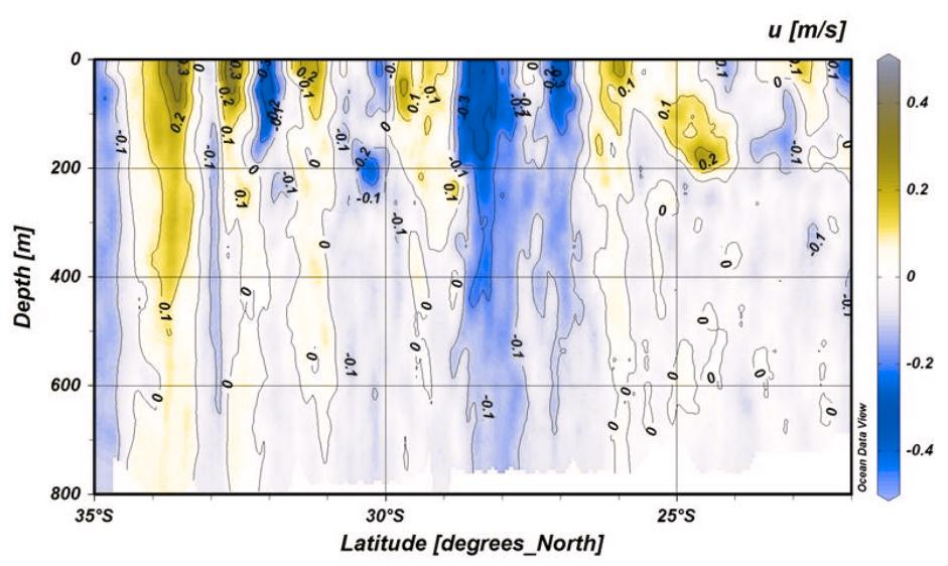


Figure S4: Top: Meridional section (Latitude/Depth) of zonal current (U in $m.s^{-1}$) observed from ADCP data collected in January 2020 in the South-Western Indian Ocean (OISO-30 cruise, see the track in Bottom). A strong westward current down to 600m is identified around 27-29°S. Figure produced with ODV (Schlitzer, 2013). Bottom: Map of monthly surface current for January 2020 in the South-Western Indian Ocean showing the retroflection of the East Madagascar Current here around 24°S (one of the forms of the EMC retroflection defined by Ramanantsoa et al 2021) and its complex meandering structure deflecting southward and recirculating northward around 54°E. Bottom Figure produced from https://resources.marine.copernicus.eu/ (MULTIOBS_GLO_PHY_REP_015_004) last access, 15-Dec-2021.



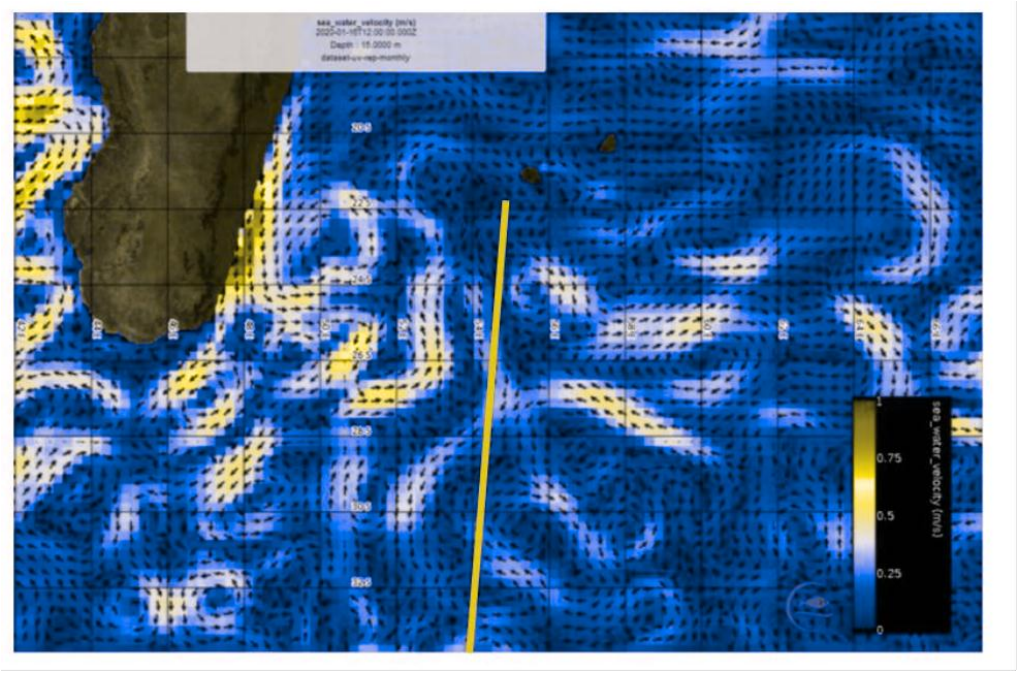


Figure S5: Top (a): 6-hour wind speed ($m.s^{-1}$) at location 27°S-54°E in January 2020 (dashed line is the average, 7.8 $m.s^{-1}$). Bottom (b): Average monthly wind speed ($m.s^{-1}$) in the region 25-30°S/45-60°E from 1991 to 2020 (orange line is the 12 month running mean). Top: data downloaded at https://resources.marine.copernicus.eu/ (WIND_GLO_WIND_L4_NRT_OBSERVATIONS_012_004), last access 20-April-2021. Bottom: data downloaded at https://giovanni.gsfc.nasa.gov/giovanni/ (GMAO, 2015), last access 19-April-2021.

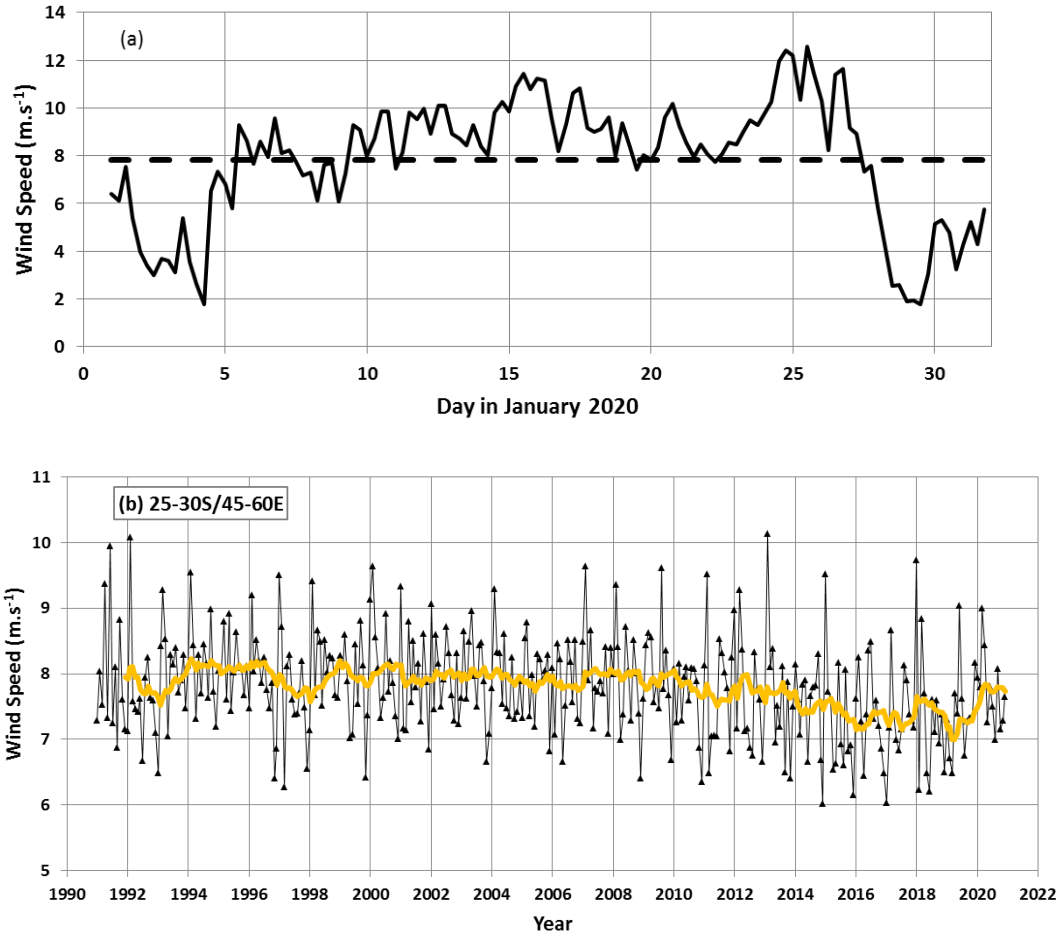


Figure S6: Map of monthly surface Chl-a (mg.m^{-3}) in the South-Western Indian Ocean in January 2005 (Top) and February 2005 (Bottom) derived from MODIS data (4x4km resolution). The OISO-12 cruise tracks in January and February 2005 used to compare with January 2020 are shown by orange lines. Note the Chl-a scale (0-0.5 mg.m^{-3}) is different from the one used in Fig. 1 and Fig. S1. The extension of the bloom in the central Indian Ocean is likely linked to the South Indian Counter Current (SICC) around 25°S observed in 2005 (Fig. S7). Figures produced with ODV (Schlitzer, 2013) from data downloaded at https://resources.marine.copernicus.eu/ (OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_093), last access, 1-June-2021.

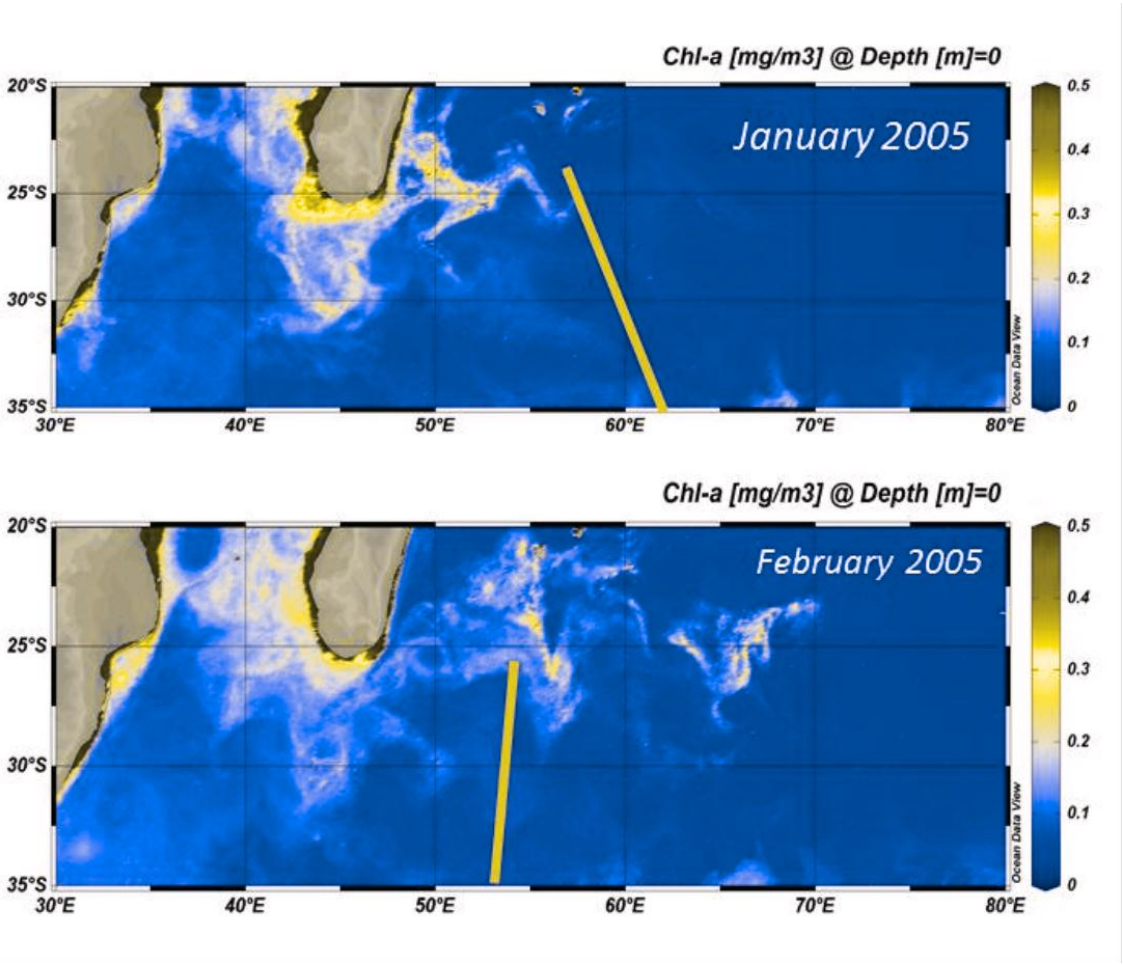
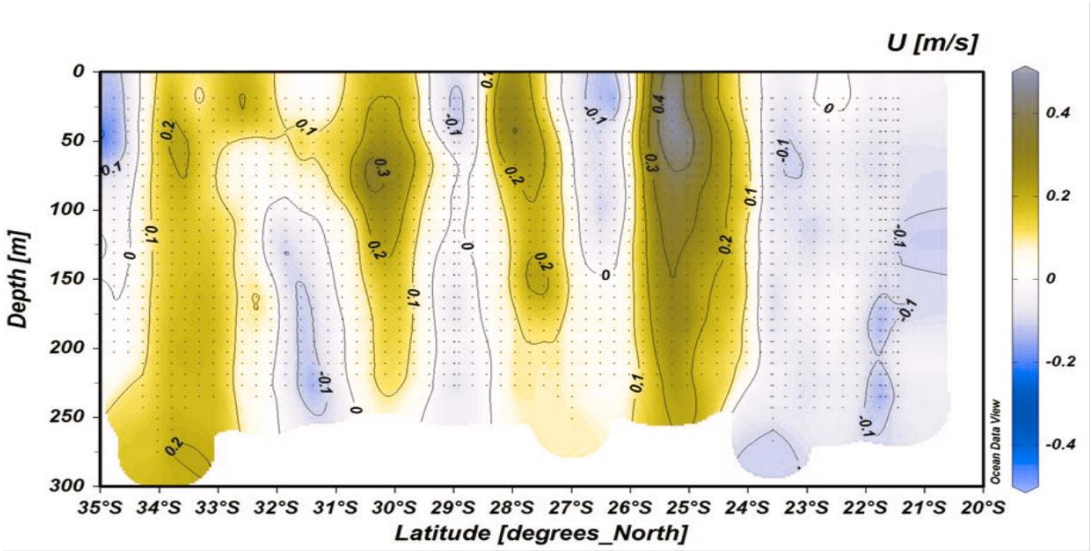


Figure S7: Top: Meridional section (Latitude/Depth) of zonal current (U in $m.s^{-1}$) observed from ADCP data collected in January 2005 in the South-Western Indian Ocean (OISO-12 cruise, see the track in Fig. S6). The eastward South Indian Counter Current (SICC) is well identified at 25°S down to 250m. Figures produced with ODV (Schlitzer, 2013). Bottom: Map of monthly surface current for January 2005 in the South-Western Indian Ocean showing the retroflection of the East Madagascar Current and the SICC around 25°S bounding the Chl-a distribution (Fig. S6). Figure produced from https://resources.marine.copernicus.eu/ (MULTIOBS_GLO_PHY_REP_015_004) last access, 15-Dec-2021. ADCP data from OISO-12 cruise available at JAS-ADCP database (http://uhslc.soest.hawaii.edu/sadcp/DATABASE/01545.html)



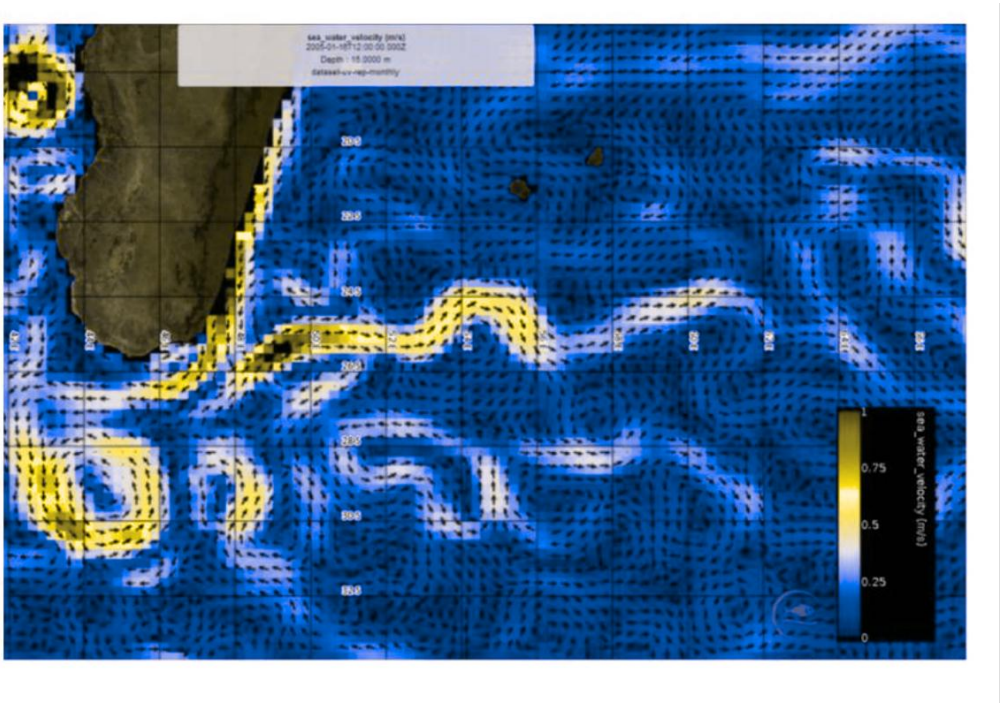


Figure S8: Temperature (black) and salinity (grey) profiles in the top 100m at 28°S-54.33°E (station 1, cruise OISO-30 on 6/1/2020) showing a strong stratification in the bloom area (mixed-layer is 22m).

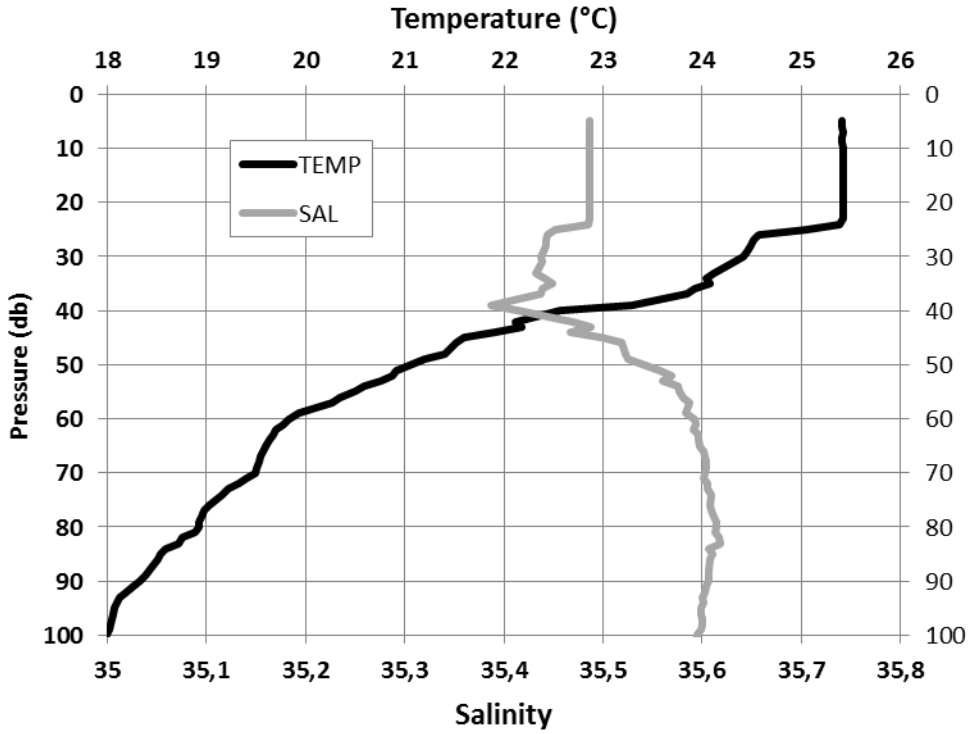


Figure S9: An ARGO float (Code 5904423) in the region of the bloom. Left: trajectory of the float from November 2019 to March 2020. Right: Potential Density (sigma-0) time-series in the top 100m recorded during this period, showing the strong stratification in January 2020 (mixed layer = 20m) when the float stayed around 27°S-52°E. Source: http://www.coriolis.eu.org/Data-Products/Data-Delivery/Data-selection. (last access, 09-Apr-2021). Figures produced with ODV (Schlitzer, 2013).

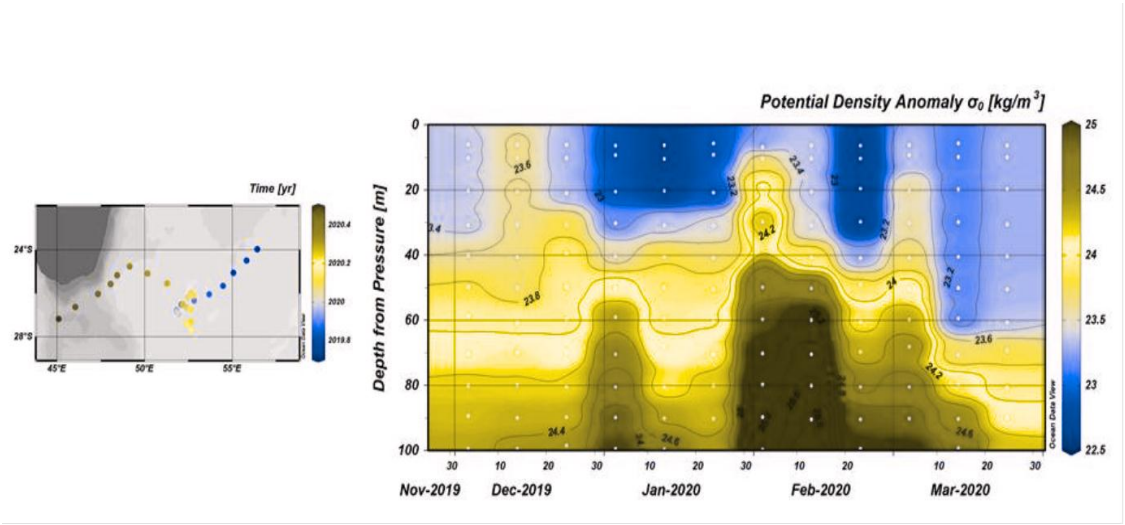


Figure S10: Top: Monthly Mixed-Layer Depth (m, in black) and Chl-a ($mg.m^{-3}$, in grey) at location 25°S-52°E for the period 2018-2020. In July-September 2019, the MLD was deep. In November 2019 when the MLD was shallow (20m), Chl-a started to increase with a maximum reached in December 2019 (1.8 $mg.m^{-3}$). Bottom: Same plot but for the period 2011-2020 showing the anomaly in both MLD and Chla in 2019 (in bottom the Chl-a is in Log scale). MLD data from https://resources.marine.copernicus.eu/ (MULTIOBS_GLO_PHY_TSUV_3D_MYNRT_015_012) last access, 21-June-2021. Chl-a data from https://resources.marine.copernicus.eu/ (OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_093), last access, 1-June-2021.

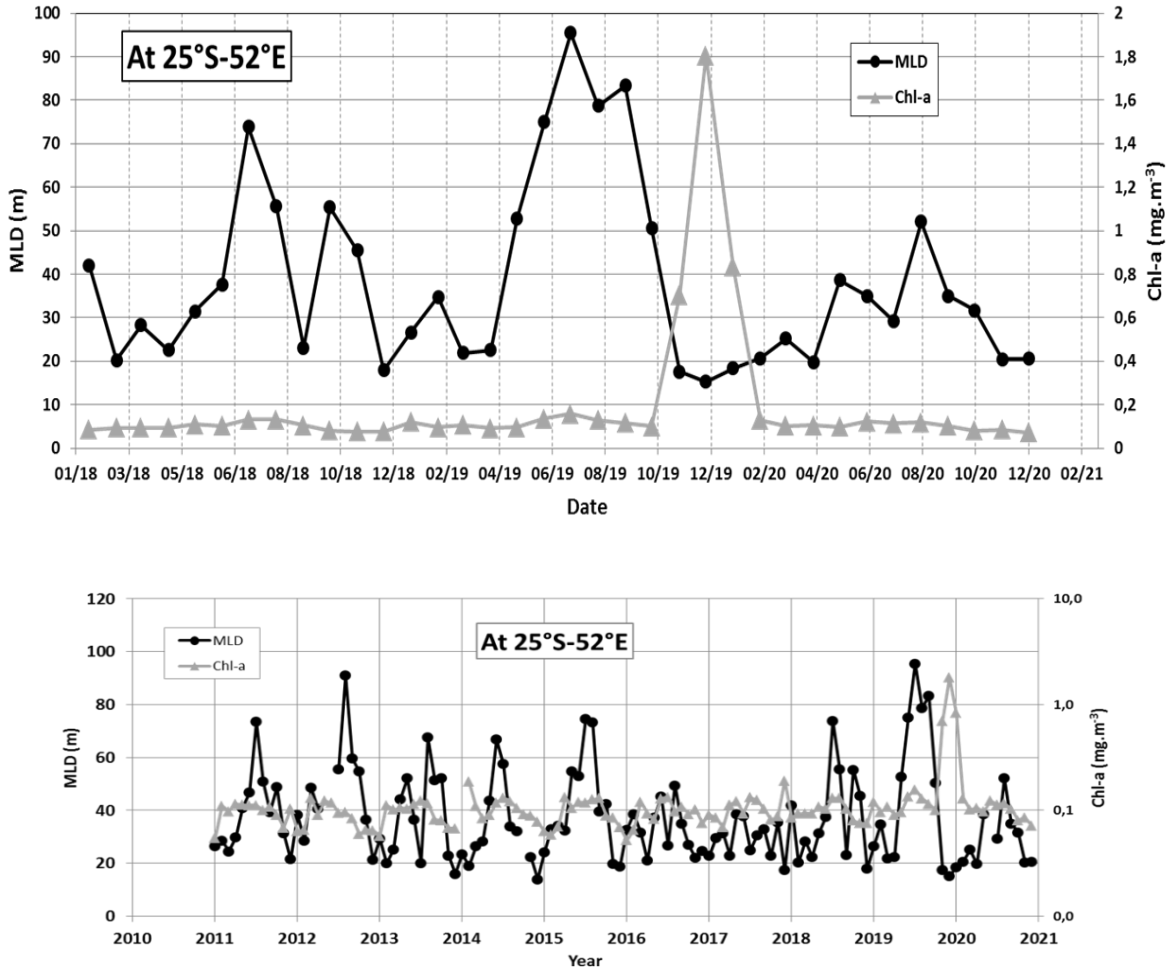


Figure S11: Time series (for December in 2002-2019) for (a) pCO_2 (µatm, black) and (b) air-sea CO_2 flux (mmol.m^{-2}.d^{-1}, black) at location 27°S-54°E from the CMEMS-LSCE-FFNN model (Chau et al, 2022). In (a) the atmospheric pCO_2 is also shown (red dashed line). In both figures the Chl-a concentration for December at the same location are also shown (mg.m^{-3}, in grey). In December 2019, when Chl-a was high, pCO_2 was relatively low and the CO_2 flux was negative (ocean sink). Chl-a data from https://resources.marine.copernicus.eu/ (OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_093), last access, 1-June-2021.

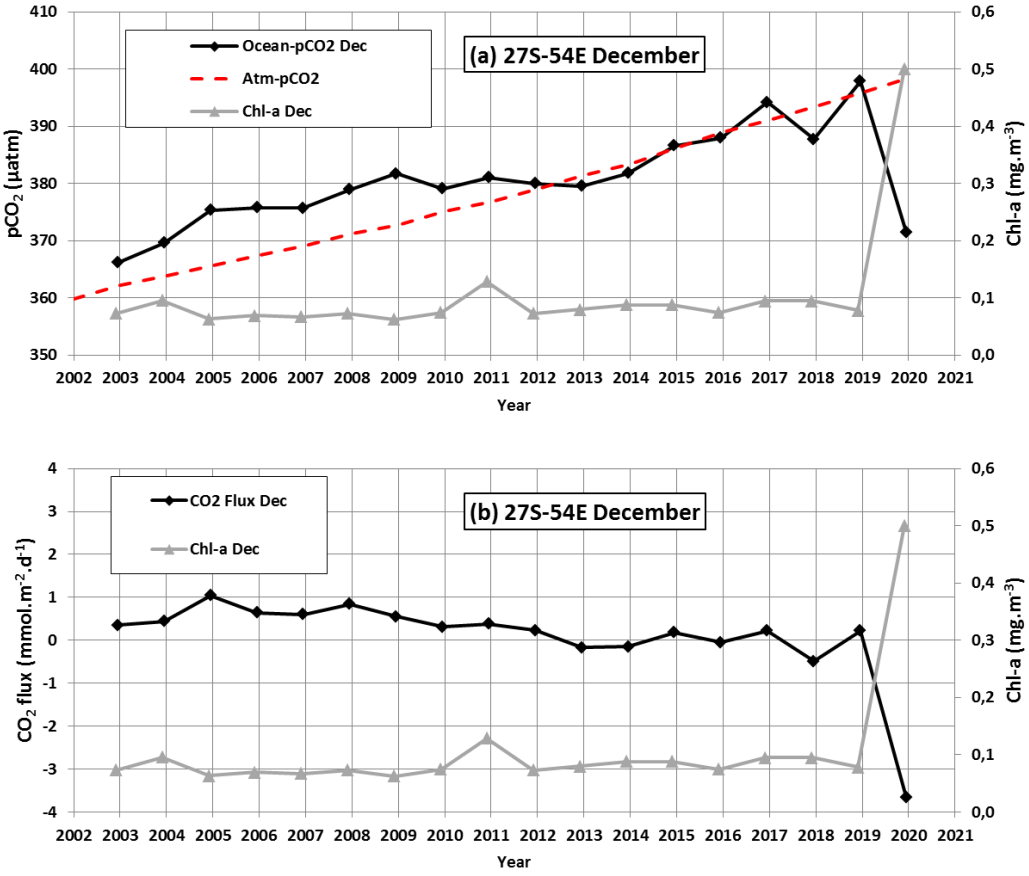


Figure S12: Time series (for December in 2002-2019) for (a) pCO_2 (µatm, black) and (b) air-sea CO_2 flux (mmol.m^{-2}.d^{-1}, black) at location 29°S-50°E from the CMEMS-LSCE-FFNN model (Chau et al, 2022). In (a) the atmospheric pCO_2 is also shown (red dashed line). In both figures the Chl-a concentration for December at the same location are also shown (mg.m^{-3}, in grey). In December 2019, when Chl-a was high, pCO_2 was relatively low and the CO_2 flux was negative (ocean sink). Chl-a data from https://resources.marine.copernicus.eu/ (OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_093), last access, 1-June-2021.

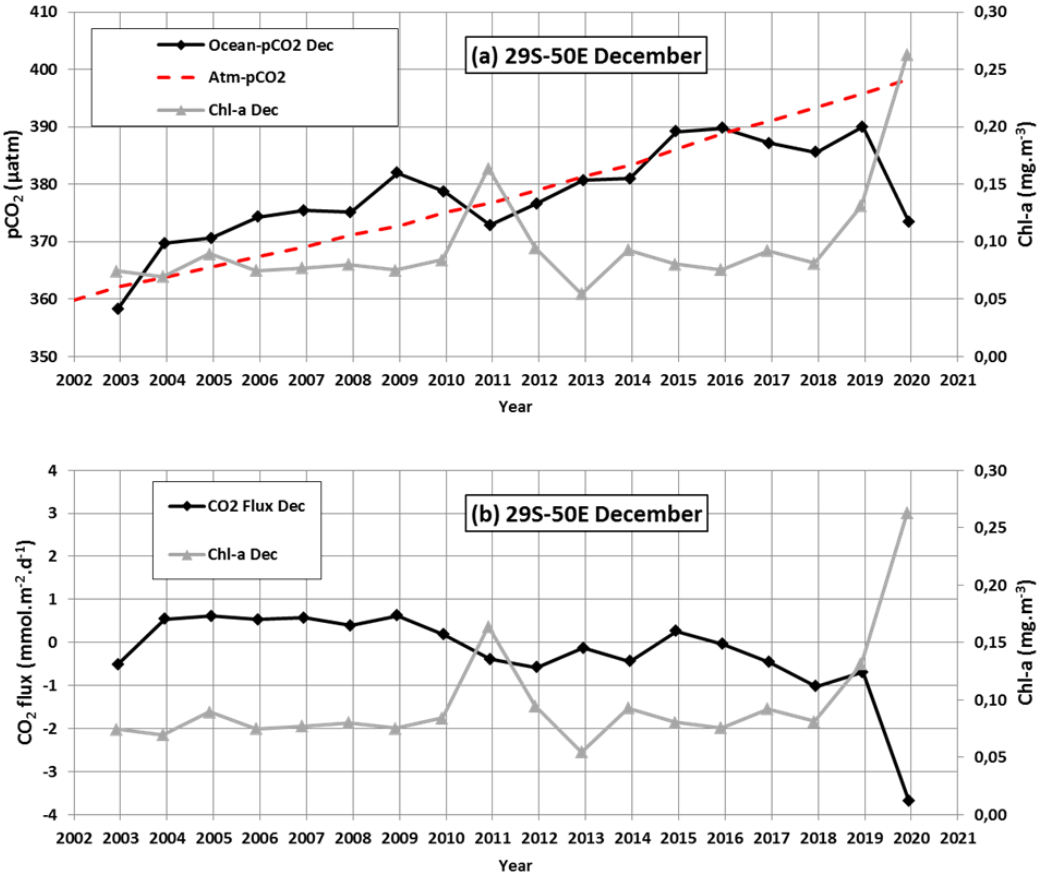


Figure S13: Top: Hovmoller time series (for December in 1996-2019) for pCO_2 (top in µatm) and air-sea CO_2 flux (bottom in $mmol.m^{-2}.d^{-1}$) along 27°S in the South Indian Ocean from the CMEMS-LSCE-FFNN model. For the flux, the blue (resp. yellow to brown) represents a CO_2 sink (resp. CO_2 source). Bottom: Monthly flux ($TgC.month^{-1}$) for December 1996-2019 integrated in the region 25-30°S/50-60°E from the CMEMS-LSCE-FFNN model. The model produced a strong anomaly in December 2019. Figures on top produced with ODV (Schlitzer, 2013).