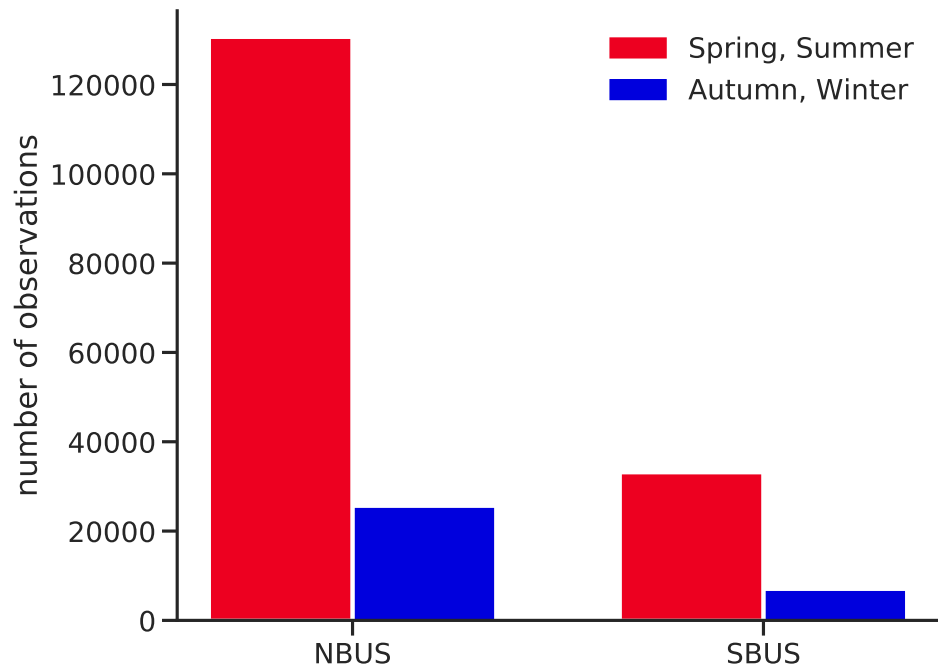


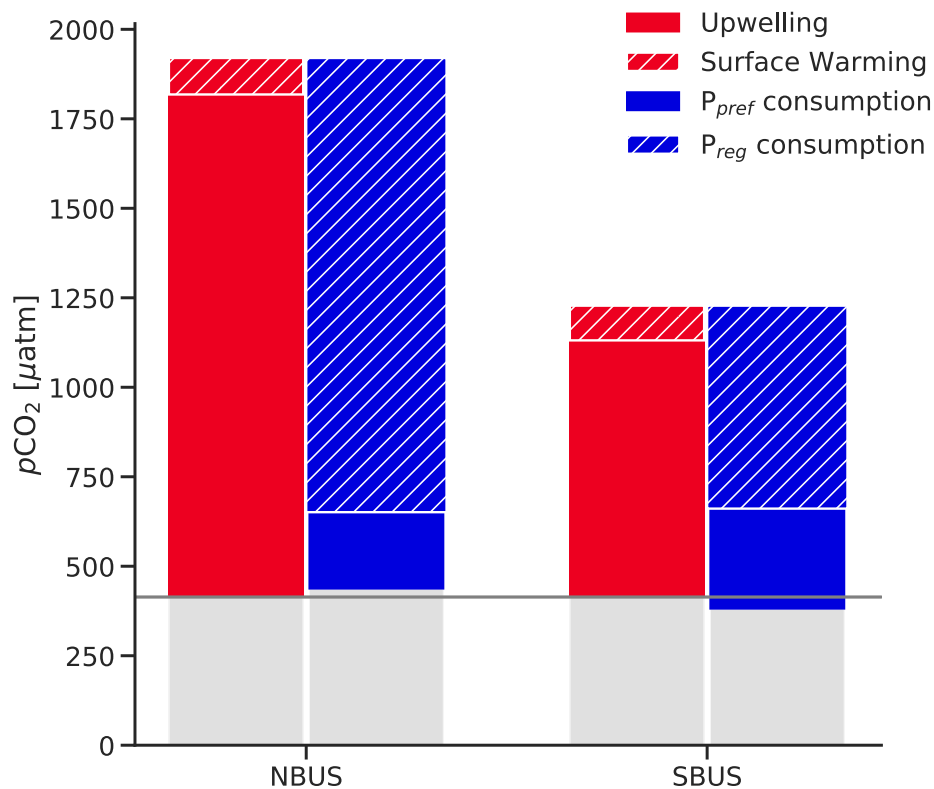
Supplementary Material

**Figure S1: Data coverage of sea surface pCO<sub>2</sub> measurements within the Benguela Upwelling System.**



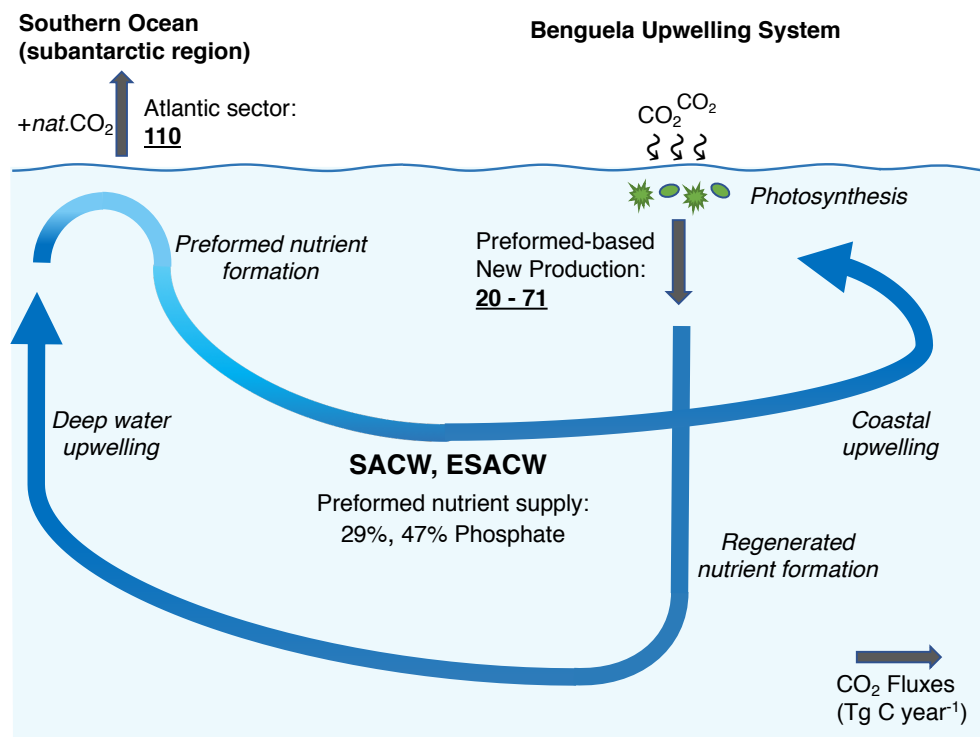
Number of observations on sea surface pCO<sub>2</sub> records per season within the northern (NBUS) and southern (SBUS) subsystem. During the spring/summer (Sept.-Mar., red) and autumn/winter season (Apr.-Aug., blue), observations amount to ~130,000 and ~25,000 in the NBUS, while the SBUS covers ~32,500 and ~6,400 measurements, respectively. The difference in number of pCO<sub>2</sub> records between the subsystems can partially be attributed to the defined upwelling area of the SBUS (177,600 km<sup>2</sup>), which is ~53% smaller than the NBUS (377,400 km<sup>2</sup>).

**Figure S2: Thermal and biological controls on sea surface pCO<sub>2</sub> based on CO2SYS simulations.**



Estimated sea surface pCO<sub>2</sub> (in μatm) during coastal upwelling, regenerated (*reg*) and preformed (*pref*) phosphate (P) consumption through biologically-mediated CO<sub>2</sub> uptake, based on CO2SYS<sup>1,2</sup> calculations using source water mass characteristics (Table 2) for the northern part of the BUS (NBUS). The coloured areas mirror the biological effect (blue), the upwelling and surface warming effect (red). The grey line represents the atmospheric pCO<sub>2</sub> of the reference year 2020 based on Mauna Loa records (414 μatm). Sea surface pCO<sub>2</sub> concentrations below (above) the atmospheric level indicate a source (sink) of atmospheric CO<sub>2</sub>.

**Figure S3: Schematic overview on the coupling between Southern Ocean CO<sub>2</sub> loss and CO<sub>2</sub> uptake in the Benguela Upwelling System through the biological carbon pump.**



CO<sub>2</sub> fluxes (grey arrows) of the biological carbon pump at the air-sea interface and subsurface, regulated by the effects of preformed-based new production in the Benguela Upwelling System and natural outgassing of CO<sub>2</sub> in the Atlantic sector of the Southern Ocean. The transport of water masses from Southern Ocean across the South Atlantic (blue arrows) shapes the supply of preformed nutrient inventories of the upwelling source water masses (South Atlantic Central Water, Eastern South Atlantic Central Water) of the northern and southern Benguela subsystem.

**Table S1: List of expeditions to the Benguela Upwelling System with description of ID and timing of the cruises included in the pCO<sub>2</sub> database of this study.**

| Research Vessel | Cruise ID | Time period             |
|-----------------|-----------|-------------------------|
| Maria S. Merian | MSM07/2   | 10/03/2008 – 20/03/2008 |
| Meteor          | M76/2     | 15/05/2008 – 05/06/2008 |
| Africana        | A258      | 02/12/2009 – 16/12/2009 |
| Discovery       | D356      | 10/09/2010 – 19/10/2010 |
| Maria S. Merian | MSM17/3   | 20/01/2011 – 07/03/2011 |
| Maria S. Merian | MSM18/4   | 24/07/2011 – 20/08/2011 |
| Maria S. Merian | MSM19/1b  | 02/10/2011 – 11/10/2011 |
| Meteor          | M99       | 31/07/2013 – 23/08/2013 |
| Meteor          | M100/1    | 31/08/2013 – 01/10/2013 |
| Meteor          | M100/2    | 04/10/2013 – 21/10/2013 |
| Meteor          | M101      | 23/10/2013 – 04/12/2013 |
| Meteor          | M102      | 06/12/2013 – 23/12/2013 |
| Meteor          | M103/1    | 27/12/2013 – 18/01/2014 |
| Meteor          | M153      | 15/02/2019 – 31/03/2019 |

- 1 Humphreys, M. P. *et al.* PyCO2SYS: marine carbonate system calculations in Python. Zenodo., doi:10.5281/zenodo.3744275 (2020).
- 2 Lewis, E. & Wallace, D. Program Developed for CO<sub>2</sub> system Calculations. doi:10.15485/1464255 (1998).