The Influence of Subtropical Mode Water in Nutrients in the South Atlantic

Paula Birocchi[1], Piero S Bernardo[1], and Olga T Sato[1]

[1]Affiliation not available

November 27, 2023

Abstract

The South Atlantic subtropical mode water (STMW) is characterized by a volume of water confined between the seasonal and permanent thermoclines. It is formed during the months of winter to early spring, July to October, near the Brazil-Malvinas Confluence region and the Brazil Current recirculation gyre. The STMW presents a homogeneous temperature (T) and salinity distribution in the horizontal and vertical, on average reaching up to 170 m of layer thickness. We investigate the impact of STMW in the nutrient's distribution and the nutricline depth in the western South Atlantic. Three data sets were used to identify the mode water and determine nutrients concentration:i) My Ocean biogeochemical model reanalysis; ii) World Ocean Atlas 2013 (WOA13) monthly climatology; and iii) the In Situ Analysis System (ISAS) data. Based on WOA13, during the summer (January, February and March) the STMW is found at subsurface from 100 m to 225 m deep; it has a mean layer thickness of 112 $\pm$ 5.0 m, reaching a maximum of 145 m. During the winter, the maximum layer thickness is 250 m while the mean is 155 $\pm$ 20.3 m. In the summer, STMW is in subsurface from 100 m to 225 m deep. As expected, the formation of mode water occured mostly in the winter to mid-spring. Using the model and ISAS data, we found a correlation between a deepening of the surface layer of minimum nitrate concentration and the mode water formation period (from June to October) in vertical profiles. From 2002 to 2012, greater nutrients concentration were found during the STMW formation period, from surface to 200 m depth, than in other periods with STMW absence. We also found a peak chlorophyll-a concentration during STMW formation period, suggesting that STMW presence in the southwest South Atlantic is important for biological processes in the upper ocean.

The Influence of Subtropical Mode Water in Nutrients in the South Atlantic

Paula Birocchi, Piero S. Bernardo, Olga T. Sato

Oceanographic Institute, University of Sao Paulo (IOUSP), Sao Paulo, Brazil
contact: paula.birocchi@gmail.com

Abstract ID:87665
PO24C-2968

Introdution

- Subtropical Mode Waters (STMW) are extensive volume of water in the oceanic upper layers. In the South Atlantic it forms from winter to mid-spring (from July to October) and persists throughout the year.
- Temperature (T) and salinity (S) are homogeneous horizontally and vertically. The STMW is usually formed in the warm side of west boundary currents in the subtropical gyres and in oceanic fronts (Figure 1).

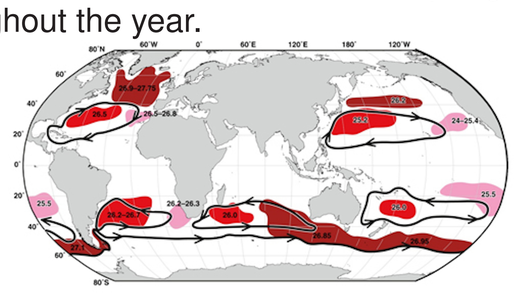

Figure 1. Global distribution of the STMWs. Talley et al., 2011.

- The STMW formation and its advection can influence biogeochemical processes in the subtropical gyre by introducing variability in the subsuperficial nutrients reservoir (Palter et al., 2005).

Objetives

We aim is to determine how STMW in the southwest South Atlantic influences the concentration of nutrients in the region. Our specific goals are to:

- Detect the STMW in the South Atlantic;
- Correlate nitrate concentration during the formation of STMW in vertical profiles;
- Determine how nutrients and chlorophyll-a (Chl-*a*) concentrations vary in interannual scale due to the formation of STMW.

Metodology

The study area extends from 60°W to 10°W and 25°S to 50°S. Three monthly resolution datasets were used:

- T and S from WOA13 (Garcia et al 2014; Locarnini et al. 2013) with a spatial resolution of 1°×1°;
- NO_3, SiO_2 e PO_4 concentrations from Bio Analysis 018 reanalysis model from CMEMS (Paul et al., 2015) with a spatial resolution of 0.5° x 0.5°;
- T and S from the In Situ Analysis System (ISAS) (Gaillard et al., 2009) from 2002 to 2012 with a resolution in longitude of 0.5°.

The data were selected for the study area and interpolated in the same spatial grid. The STMW was identified through T, S and potential vorticity (q) values determined by Sato and Polito (2014):

T(°C)	S	q ($m^{-1}s^{-1}$)
14.1 - 15.9	35.4 - 35.8	1.5×10^{-10}

The NO_3 vertical profiles in regions with and without STMW formation were compared (Figure 3) based on Palter et al. (2005). The mean concentration of NO_3, SiO_2, PO_4 and Chl-a were computed between 0 and 200 meters in the water column from 2002 to 2012 (Figure 4), for the STMW formation area: 42.5°W to 47°W and 35°S to 37°S .

Finding the STMW in the climatology

- STMW mean thickness is 112 ± 5 m in the summer and 155 ± 20 m in the winter;
- The STMW can only be detected in the subsurface in summer and autumn. From winter to mid-spring, the STMW outcrops at the surface due to its formation.

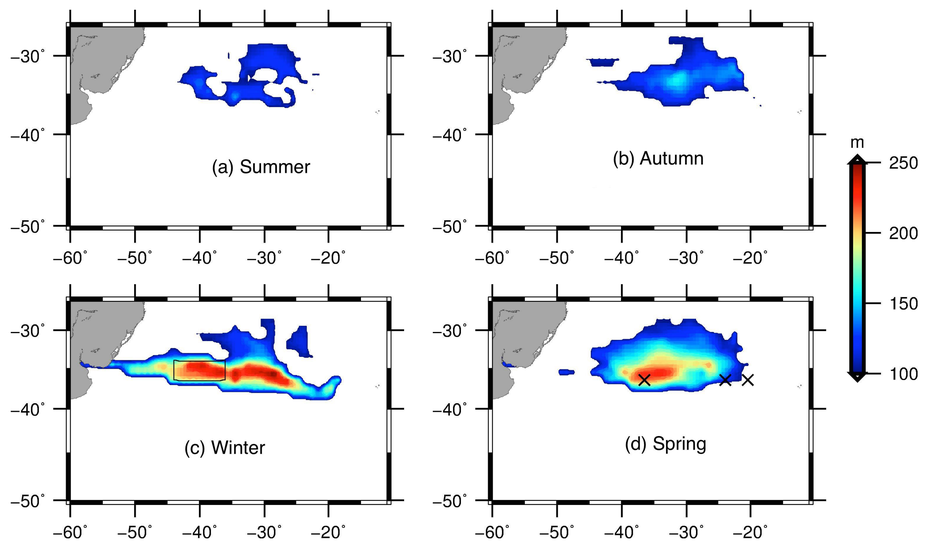

Figure 2. Seasonal mean thickness of STMW (WOA13). Rectangle: area where the mean concentrations of nutrients and Chl-a were calculated (Figure 4). The X position indicates the vertical profiles on Figure 3.

Deepening of the nutricline

- Analysis of the mean vertical profiles of T (ISAS) and NO_3 (CMEMS) indicates that the NO_3 nutricline deepens in regions where a thicker STMW was found (Figure 3a) compared to regions with thinner STMW (Figure 3b) or regions without STMW (Figure 3c);
- The nutricline mean depth is of the order of 230±8 m in regions with formation of STMW (Figures 3a and 3b) and 150±8 m outside.

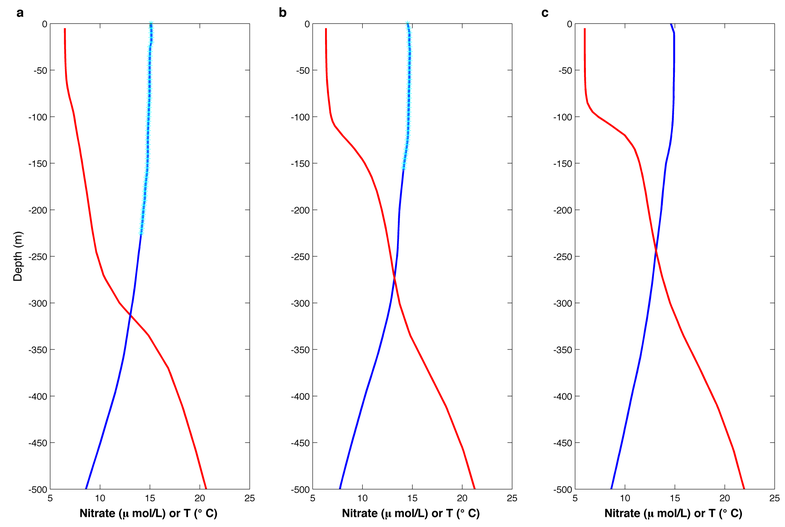

Figure 3. Vertical profiles of T (ISAS) and NO_3 (μmol/L) (CMEMS), at 36.5°SS, at different longitudes: 36.5°W (left), 24°W (center) and 20.5 °W (right), in September 2012.

Relation between STMW thickness, nutrients and chlorophyll-a

- The concentration of NO_3, SiO_2 and PO_4 decrease during the formation of STMW. The Chl-*a* concentration increases from 0.2μmol/L in summer to 0.35μmol/L during the formation period (Figure 4);
- The formation of STMW likely enhances water mixing (Figure 4 and 5), taking phytoplankton to deeper waters with low-light conditions and leading to its photoacclimation. This process can be noticed by high Chl-*a* during formation.
- Significant correlation is found between the nutricline depth and thickness of STMW (Figure 5).

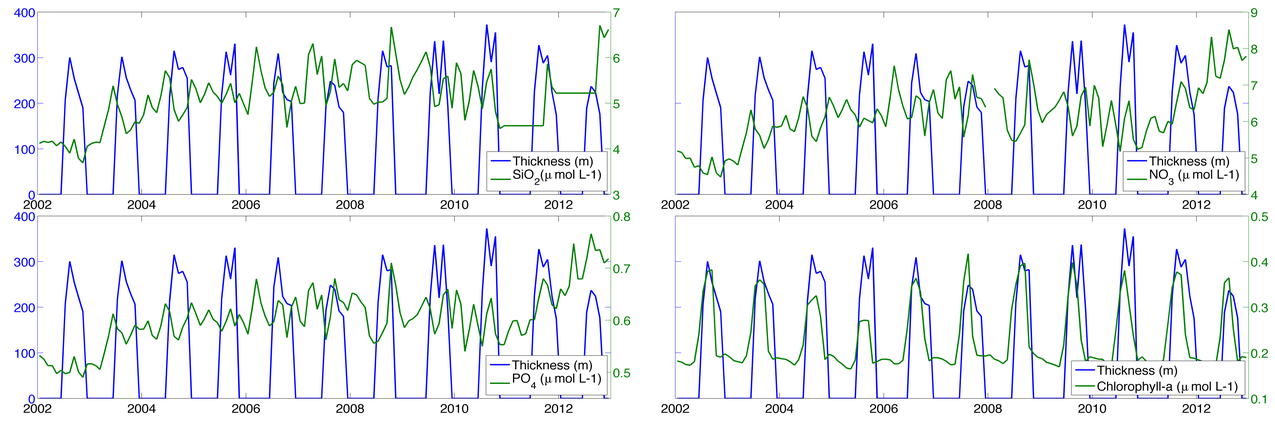

Figure 4. Interannual mean thickness of STMW (m) (ISAS), nutrients and Chl-a concentration (μmol/L) (CMEMS): SiO_2, NO_3, PO_4, Chl-a, between 0 and 200 m, from 2002 to 2012.

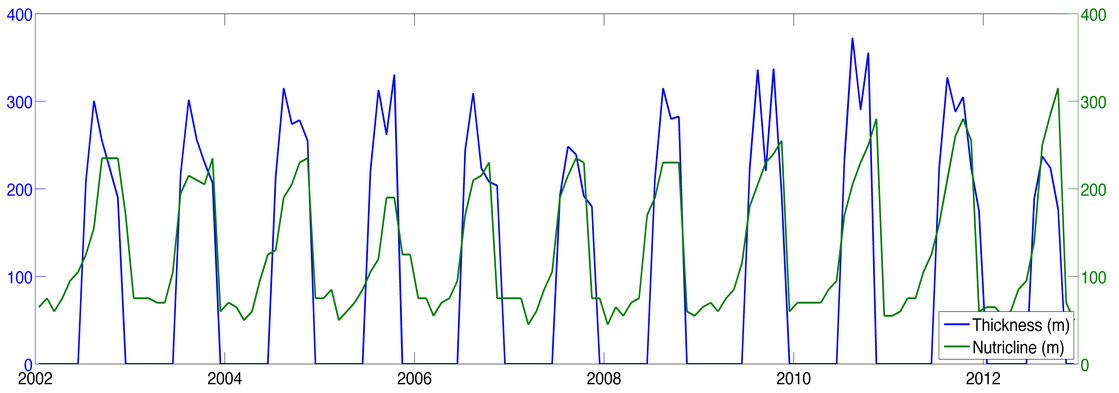

Figure 5. Monthly mean nutricline depth (m) based on the NO_3 maximum gradient (Palter et al. 2005) (in green) and monthly mean thickness of the superficial STMW (m) (in blue) for the region *A*.

Conclusion

- The STMW main formation occurs during the winter until the mid-spring;
- In the formation region, the deepening of the nutricline coincides with the occurence of the STMW which is responsible for the superficial layer mixing in the oceans and therefore changes the nutrients concentration on surface;
- The formation of STMW in the southwest Atlantic influences the concentration of nutrients and Chl-*a* due to convective mixing between layers below the nutricline and superficial waters.
- This phenomenon is key for understanding the relationship between physical and biological processes in the subtropical gyre.

References

Gaillard, F., E. Brion, and R. Charraudeau (2009). Isas–v5: Description of the method and user manual. IFREMER Rapport LPO, 09–04.

Garcia, H., R. Locarnini, T. Boyer, J. Antonov, O. Baranova, M. Zweng, J. Reagan, and D. Johnson (2014). World ocean atlas 2013, volume 4: Dissolved inorganic nutrients (phosphate, nitrate, silicate), s. A. Mishonov Technical Ed, 1–25.

Locarnini, R., A. Mishonov, J. Antonov, T. Boyer, H. Garcia, O. Baranova, M. Zweng, C. Paver, J. Reagan, D. Johnson, et al. (2013). World Ocean Atlas 2013. Vol. 1: Temperature. A. Mishonov, Technical Ed. NOAA Atlas NESDIS 73, 40.

Palter, J. B., M. S. Lozier, and R. T. Barber (2005). The effect of advection on the nutrient reservoir in the North Atlantic subtropical gyre. Nature 437(7059), 687–692.

Paul, J., C. Perruche, and A. Hameau (2015). Global ocean biogeochemistry analysis and weekly forecast: Product user manual.

Sato, O. and P. Polito (2014). Observation of South Atlantic subtropical mode waters with Argo profiling float data. JGR: Oceans 119(5), 2860–2881.

Talley, L. D. (2011). Descriptive physical oceanography: an introduction. Academic press.