Nitrogen transfers within an Oxygen Minimum Zone: the Namibian upwelling (South-East Atlantic Ocean)

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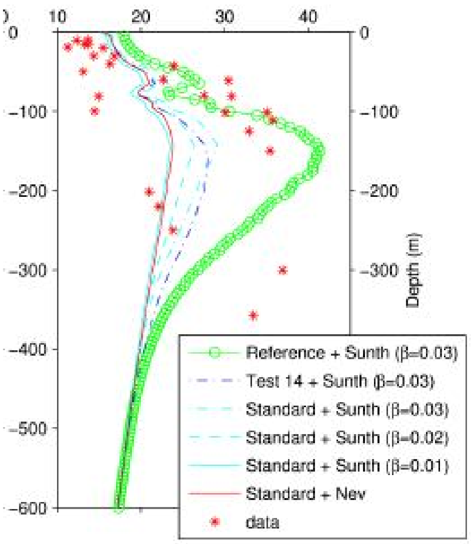
Aims of this project and methods:

In this project, the nitrogen transfers within the Namibian upwelling (Northern part of the Benguela upwelling system) were estimated: advection by the mean circulation, submesoscale activity (eddies/filaments), and flux to the atmosphere (N_2O flux). For this purpose, we developed a **Bio**geochemical model for **E**astern **B**oundary **U**pwelling **S**ystem: BioEBUS, taking into account specific processes in Oxygen Minimum Zones (OMZs): nitrification, denitrification and anammox.

Main results:

The performance of the physical/biogeochemical model (ROMS/BioEBUS) over the Namibian upwelling, after a sensitivity analysis on biogeochemical parameter values and N_2O parameterizations, was evaluated using satellite and *in situ* data, especially the first N_2O measurements offshore Namibia for a climatological simulation (Fig.1).



Based on our sensitivity analyses, biogeochemical parameter values associated with organic matter decomposition, vertical sinking, and nitrification play a key role for the low-oxygen water content, N loss, and N_2O concentrations in the OMZ. Moreover, the explicit parameterization of both steps of nitrification, ammonium oxidation to nitrate with nitrite as an explicit intermediate, is necessary to improve the representation of microbial activity linked with the OMZ.

Fig.1: (Left): Vertical profiles of maximum N_2O concentrations between 22-24°S and 10-15°E (in 10^{-3} mmol N_2O m^{-3}) for different parameterizations (Nevison et al., 2003; Suntharalingam et al., 2000, 2012), β coefficient (Suntharalingam et al., 2000, 2012) and sensitivity analyses on key parameters. Vertical profiles were 8 yr averaged. Red stars represent in situ measurements from the FRS Africana cruise in December 2009 during an active upwelling event.

The simulated minimum oxygen concentrations are driven by the poleward meridional advection of oxygen-depleted waters offshore of a 300m isobath and by the biogeochemical activity inshore of this isobath, highlighting a spatial shift of dominant processes maintaining the minimum oxygen concentrations off Namibia (Fig.2).

Anammox contributes to about 20% of total N loss, an estimate lower than currently assumed (up to 50 %) for the global ocean. (Gutknecht et al., 2013a)

In the mixed layer, the total N offshore export is estimated (see Fig. 3.a) at 10°E off the Walvis Bay area, with a positive mesoscale contribution of 20%.

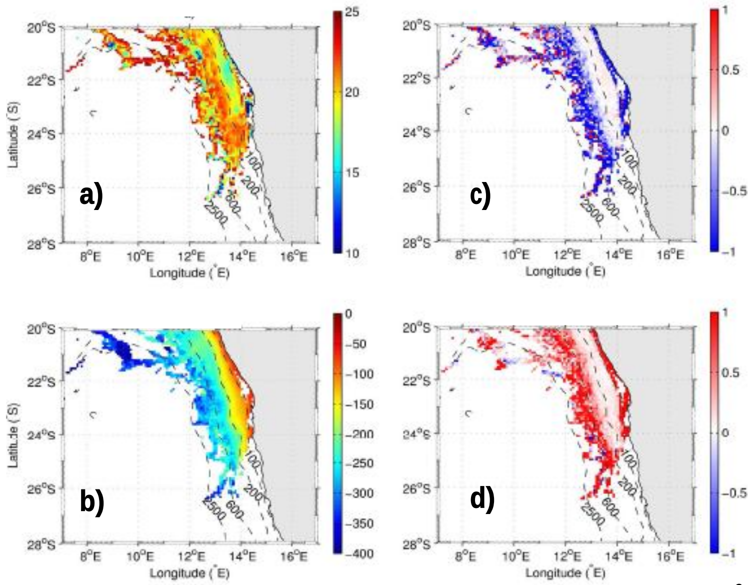


Fig.2 (Above):(a) Minimum oxygen concentrations (mmol O_2 m^{-3}) simulated in the OMZ, (b) depth (m) of these minimum oxygen concentrations (c) oxygen advection term and (d) oxygen mixing term (mmol O_2 m^{-3} d^{-1}).

Extrapolated to the whole BUS, the coastal N source for the subtropical gyre corresponds to 0.1±0.04 $molNm^{-2}$ yr^{-1}. This N flux represents a major source of N for the gyre compared with other N sources, and contributes 28% of the new primary production estimated for the South Atlantic subtropical gyre.

Export production (see Fig.3.a) helps to maintain an OMZ off Namibia in which coupled nitrification, denitrification and anammox processes lead to losses of fixed N and N_2O production. However, neither N losses nor N_2O emissions significantly impact the main N exports of the Walvis Bay area.

The studied area does not significantly contribute to N_2O emissions (0.5 to 2.7 %) compared to the global coastal upwelling emissions. Locally produced N_2O is mostly advected southward by the poleward undercurrent.

Over the slope, submesoscale dynamics represent a sink of nutrients due to a secondary circulation (Fig.3.b). (Gutknecht et al., 2013b)

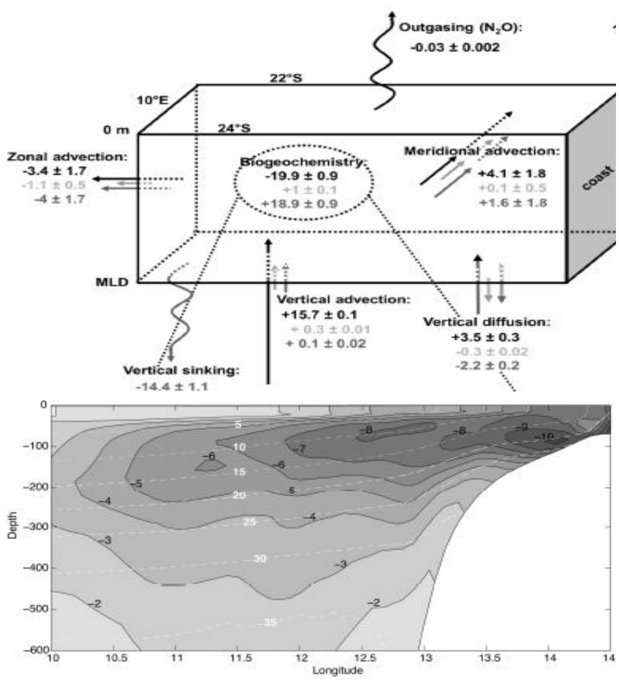


Fig.3 (Right): (a) Full nitrogen budget in the mixed layer (10^{10} $molNyr^{-1}$). Fluxes of DIN are indicated in black, DON are in light grey and PON in dark grey. (b) Nitrate deficit ($mmolNm^{-3}$) between the eddy-resolving simulation and a non eddy-resolving simulation, featuring the role of eddies on vertical distribution of nutrients in the Benguela upwelling system. Dashed lines represent nitrate isocontours for the eddy-resolving simulation. Fluxes: 8 yr means, averaged between 22 and 24° S.

Publications:

Gutknecht, E., 2011. « Interactions côte-large dans le système de l'upwelling du Benguela par modélisation couplée physique/biogéochimique », PhD Thesis, Paul Sabatier University, 259 pp.

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