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Linking diverse nutrient patterns to different water masses within anticyclonic eddies in the upwelling system off Peru

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Abstract. The supplementary information presents details of the methods used in the main text. It is composed by three sections, where additional description of the biogeochemical model, region extent of the model domain, the particle release experiment as well as the water mass properties at the instant following the eddy A_{sim} and B_{sim} formation.

1 Biogeochemical model

BioEBUS is a nitrogen-based model, developed from the $N_2P_2Z_2D_2$ by Kone et al. (2005). This model contains 12 compartments (Gutknecht et al., 2013). As described in Gutknecht et al. (2013), marine biota are represented by four compartments and comprise the first trophic level of the food web, small (nano/ picophytoplankton and microzooplankton) and large (diatoms and mesozooplankton) organisms. The phytoplankton growth is limited only by the availability of fixed nitrogen in the water column. The nitrogen cycling includes denitrification, nitrification and anammox processes, as well as uptake by phytoplankton in the sun-lit surface layer and subsequent cycling and re-cycling by the planktonic ecosystem,. The model also represents dissolved oxygen, allowing a separation of respiration processes occurring under oxic and suboxic conditions.

1.1 Model parameters

To simulate the biogeochemical dynamics of the *ETSP*, we essentially used the same parameters as in previous studies Gutknecht et al. (2013) and Montes et al. (2014). Some parameters are adjusted, in order to obtain a better agreement with the observed dynamics of the *ETSP* (Table (1)). These parameters include the half saturation constant for nutrient (ammonium, nitrate and nitrite) uptake by both small and large phytoplankton classes, zooplankton (including small and large classes) feeding preferences, half saturation constant for zooplankton (including small and large classes) ingestion. The constants for nutrient uptake by phytoplankton and the zooplankton ingestion are adjusted to the values presented in Kone et al. (2005). The rate of first and second stage of nitrification consist of parameter values used in Gutknecht et al. (2013) and in Montes et al. (2014) respectively. The adjustment of the phytoplankton nutrient uptake and the zooplankton dynamics constants led to a reduction of both phytoplankton and zooplankton production, and consequently export production, and an improved agreement with vertical nutrient and oxygen profiles. Adjustments of the rates of nitrification allowed a better reproduction of nitrite and nitrate distributions in our model configuration.

2 Model domain

Figure SI-1 shows the extension of the model domain used in the 2 way-nesting procedure to simulate the high-resolution biophysical dynamics of the Eastern Tropical South Pacific (*ETSP*). As the *ETSP* is strongly influenced by equatorial dynamics (Montes et al., 2010), a larger model domain with a coarser grid, covering the relevant current systems of the *ETPS*, is used to force the high-resolution model centered on the oxygen minimum zone off Peru.

3 Variation in eddy A_{sim} and B_{sim} volume during their propagation

Figure SI-2 illustrate the evolution of the eddies A_{sim} and B_{sim} volume during its propagation. The eddy volume, which is mainly controlled by the horizontal structure of the eddy, vary as the eddies A_{sim} and B_{sim} move. Significant increase in volume occurs from early stage of the eddy life, period following its formation. Different from the eddy A_{sim} (Fig. SI-2-a), the volume of the eddy B_{sim} (Fig. SI-2-b) does not vary much after the first month following its formation.

4 Particle release experiment

In Figure SI-3 are illustrated the locations of particle release (light blue) as well as the tracked anticyclonic eddies (filled circles and triangles) during the model particle-release experiments. The particle-release experiments, which consisted of releasing inactive Lagrangian particles along the shelf and off Peru, are conducted to investigate the capability of anticyclonic eddies to exchange water masses with the surrounding environment. In order to cover possible seasonality effects, the particles were released in both summer and winter seasons of the southern hemisphere.

5 Water masses properties following the eddy A_{sim} and B_{sim}

The present section aims to analyse the the environmental conditions at the eddies A_{sim} and B_{sim} formation place. Figure SI-4 presents the water mass and nutrient distribution following the eddy A_{sim} formation. At that instant, the eddy interior was dominated by the water masses from the offshore region. These water masses presented distinct properties which varies with depth. At the surface layer down $100\ \mathrm{m}$ depth, the offshore waters were warmer and saltier. Both nitrate and nitrite concentrations were lower than the shelf waters. Below this layer, the offshore waters were cooler and fresher, with low nutrient concentrations. Is visible in the $100\ \mathrm{m}$ and $250\ \mathrm{m}$ a limb of shelf nitrite-rich waters in the northern edge of the structure, suggestive of entrainment by the eddy stirring.

The eddy B_{sim}, which is an open ocean eddy, also shown different water masses properties with depth (Fig. SI-5). A remarkable difference is observed between $100\ \mathrm{m}$ and $250\ \mathrm{m}$ depth, where is visible an increment up to 20 $\mu\mathrm{mol\,l^{-1}}$ of nitrate.

Table 1. Adjusted parameter used in the biogeochemical model.

Parameter	Units	Value
Half saturation constant for NH4 uptake by largephytoplankton	mmol N m^{-3}	0.7
Half saturation constant for NO2+NO3 uptake by small phytoplankton	mmol N m^{-3}	1.0
Preference of small zooplankton to small phytoplankton	mmol N m^{-3}	0.75
Preference of small zooplankton to large phytoplankton	mmol N m^{-3}	0.25
Preference of large zooplankton to large phytoplankton	mmol N m^{-3}	0.5
Preference of large zooplankton to small zooplankton	mmol N m^{-3}	0.24
Half saturation constant for ingestion by small zooplankton	mmol N m^{-3}	1.0
Half saturation constant for ingestion by large zooplankton	mmol N m^{-3}	2.0
Rate of first stage of nitrification	d^{-1}	0.9
Rate of second stage of nitrification	d^{-1}	0.025

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Figure SI- 1. Model bathymetry of the Eastern Tropical South Pacific. The black square denotes the zoom into the eastern tropical south Pacific oxygen minimum zone. The color denotes depth in meters. The topography is derived from the GEBCO 1' data set.

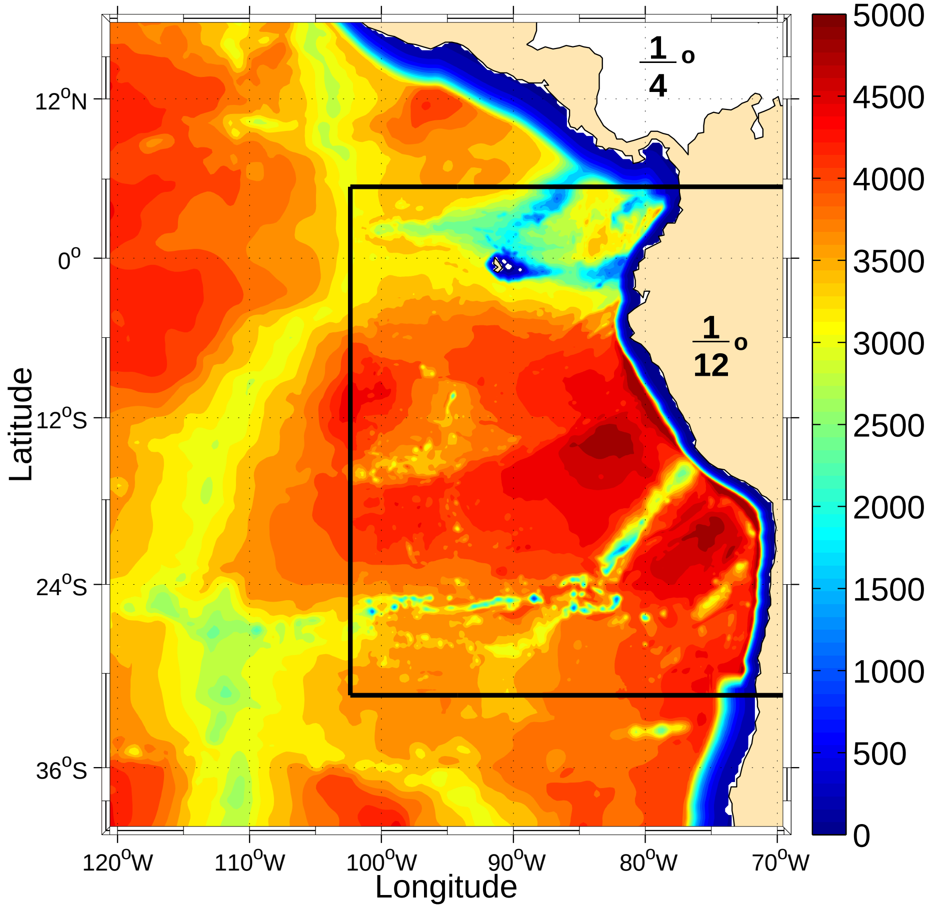

Figure SI- 2. Volume evolution of the eddy A_{sim} (a) and B_{sim} (b) during their propagation.

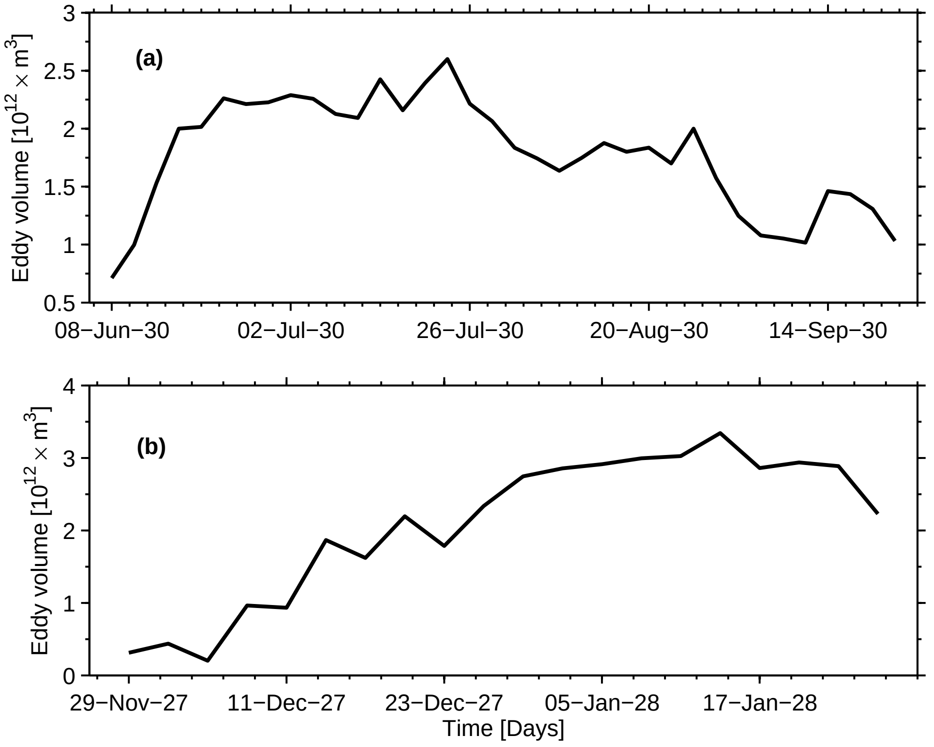

Figure SI- 3. Particle release sites (light blue) and the trajectory of tracked anticyclonic eddies (filled circles and triangles) during the particle release experiment. Colour in tracked eddies correspond to model years, with black for year 28, red for year 29 and blue for year 30. Eddies tracked during summer and winter are represented in filled circles and triangles respectively.

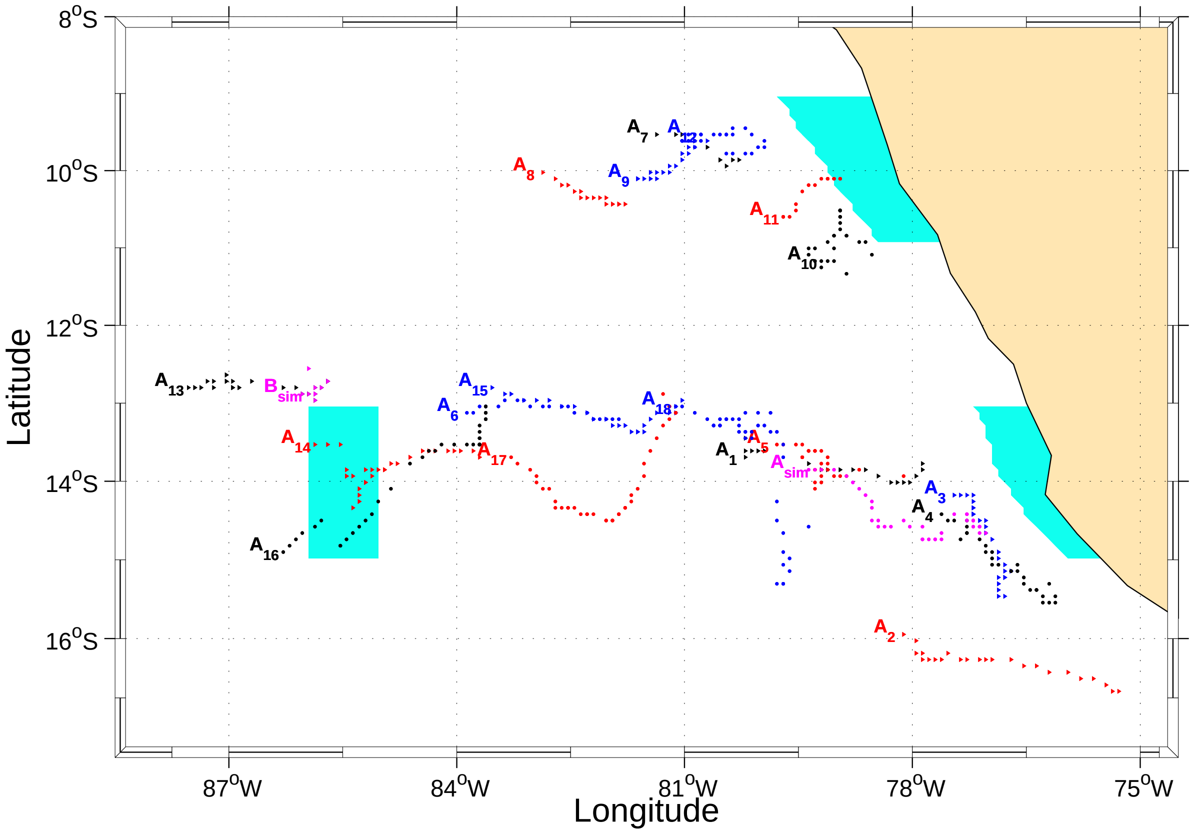

Figure SI- 4. Water masses properties and nutrients distribution at an instant following the eddy A_{sim} formation. *Left panels:* Spatial distribution of simulated salinity at surface (upper panels), 100m (middle panels) and 200 m depth (bottom panels). *Middle left panels:* The same as left panel, but for temperature. *Middle right panels:*The same as left panel, but for nitrate. *right panels:* The same as left panel, but for nitrite. The arrows represent the circulation patterns at the eddy's edge.

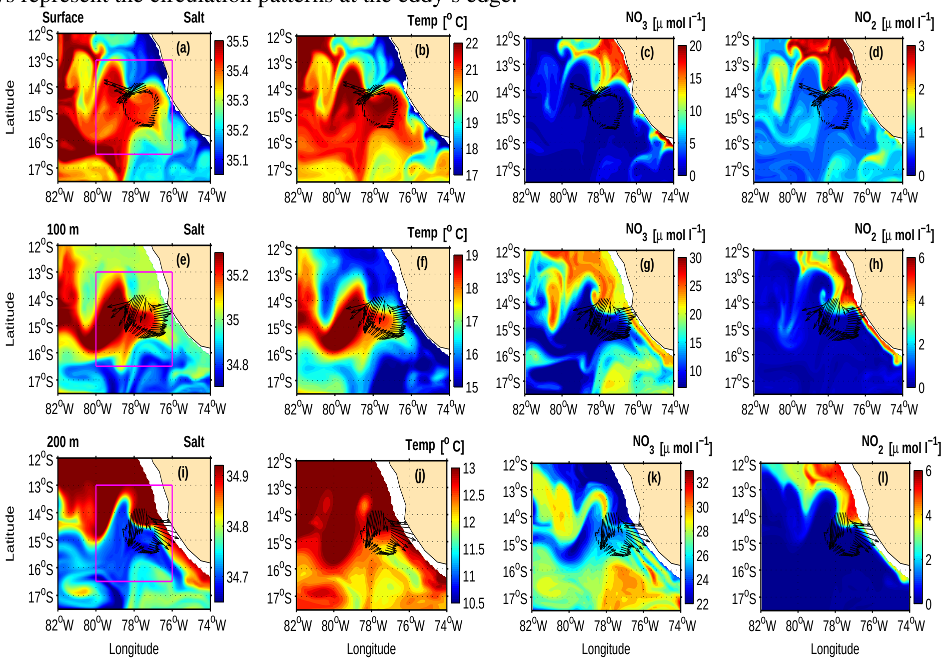

Figure SI- 5. Water masses properties and nutrients distribution at an instant following the eddy B_{sim} formation. *Left panels:* Spatial distribution of simulated salinity at surface (upper panels), 100m (middle panels) and 200 m depth (bottom panels). *Middle left panels:* The same as left panel, but for temperature. *Middle right panels:*The same as left panel, but for nitrate. *right panels:* The same as left panel, but for nitrite. The arrows represent the circulation patterns at the eddy's edge.