

## ***Interactive comment on “Nitrous oxide distribution and its origin in the central and eastern South Pacific Subtropical Gyre” by J. Charpentier et al.***

**J. Charpentier et al.**

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### **General comments**

We are most appreciative of L. Codispoti for the useful comments made on this paper. All his comments have been considered to enhance the revised version of this paper.

### **Specific comments**

Response to specific items:

1. The possibility that a highly productive coastal zone could export a particular isotopomer signature seems to me (if it actually exists) to be negligible. The latitudinal influence of Ekman transport along eastern margins due to alongshore winds can be calculated from the horizontal velocities of upwelling systems.

$$U_k = \phi_k \frac{u_*^2}{f} \left(1 - e^{-\frac{x}{R_k}}\right) \quad (1)$$

where  $U_k$  is the westward transport due to upwelling,  $\phi_k$  is a non-dimensional parameter depending on the density distribution,  $u_*$  is the friction velocity,  $f$  is the Coriolis parameter,  $x$  is the distance from the coast, and  $R_k$  is the Rossby radius of deformation. Latitudinal transport decreases exponentially from the coast and belongs to zero when  $x = R_k$ . That is equivalent to saying that the maximum reach of Ekman transport is equal to the Rossby radius of deformation (Csanady 1982). At mid latitudes, the value of the Rossby radius is within 200 to 300 km for very unstratified waters and tends to be much smaller as the stratification increases. Studies of water masses show that the first 500 m of the South Pacific Gyre are dominated by East South Pacific Central Water (ESPCW), characterized by wide temperature and salinity ranges; this water mass is formed in the middle of the South Pacific close to 40° S (Emery and Meincke 1986).

Even in the case of considerable horizontal transport at oceanic stations, the advection of waters from coastal, highly productive waters can be discarded. Density and salinity transects, as well TS diagrams shown that oligotrophic upwelling area is not connected to the oceanic stations. A small paragraph has been added to the final version to clarify this point.

- Effectively, the N:P ratio doesn't prove that nitrification is the main source of nitrous oxide. We say that the observed N:P ratio "agrees" with this nitrification and not denitrification. This paragraph has been changed to enhance the understanding of this idea.
- We have redraw the Figure 6 to enhance the discussion at this point, now we use the data from 200 to 600 m to restrict the discussion to the area where the minimum of SP is found, also we separate the linear regression for each station to

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give a better picture of the biogeochemical situation. The values given by Cohen and Gordon (1979) are cited because this is one of the few measurements made in a similar oceanographic zone. Due to the slow northward circulation and the origin of the water masses present in the first 500 m of the South Pacific Gyre, it is unlikely that the remains of an oxygen-depleted situation would be found in the water mass.

4. I am not sure why you say that Brunt Vaisala frequency (BVF) data are over-smoothed. The BVF only helps to view the high stability zones where the speed of sinking particles must be slower and, for me, the high stability zones coincide with the density gradients. In any case, the density parameter indicates whether a particular zone is stratified or not. The importance of particles in the nitrogen reductive processes in pelagic environments has been invoked previously to explain abnormal isotopic and isotopomeric values of  $\text{N}_2\text{O}$  found in the North Subtropical Pacific (Popp et al. 2002; Yoshida et al. 1989). Our work takes this hypothesis and shows that particles can be important in the pelagic environment, not supporting denitrification, but nitrifier denitrification. We have no conclusive evidence about the occurrence of nitrifier denitrification, but the available information about the biochemical process and its effect on the isotopomeric signal, and the occurrence of particulated material in such oligotrophic environments support our proposed hypothesis.
5. You are right; our work does not demonstrate that nitrifier denitrification can be an important source of nitrous oxide. The right word is “suggest” and not “demonstrate”. In any case, if we assume that our hypothesis is correct, this two-end member model can provide an important approximation to the relative importance of two cited sources. The same model has been used with a similar aim several times (Dore et al. 1998; Popp et al. 2002; Toyoda et al. 2002).
6. We address several points in this item, by order of appearance.

- (a) Certainly Archaea could be an important source of primary nitrification in the ocean, as has been suggested by several recent studies (Francis et al. 2007). Because of that, a small discussion about the role of archaeal ammonium oxidation has been added to the corresponding introduction paragraph. Nevertheless, our work is oriented to the mechanism of nitrous oxide production and its signature in the isotopomeric configuration of  $N_2O$  and not the specific role of each organism or group.
- (b) On page 1674, line 18, the oxygen-deficient condition in the coastal zone is compared to the oceanic stations. This has been changed to clarify this point.
- (c) We agree that “anammox” (i.e. ammonium oxidation to nitrogen) can be found in marine environments and is an important part of the nitrogen cycle. New evidence provided by Kartal et al. (2007) shows that small amounts of nitrous oxide can be produced by anammox bacteria. This statement has been added to the Discussion.
- (d) The paper of Wolgast et al. (1998) suggests the occurrence of denitrification within microsites of the particles deposited over the seafloor in the NE Pacific (California coast). In such cases, the speed of the particles is zero. Therefore, the advection-diffusion balance described by Kiørboe et al. (2001) and Ploug (2001) should be governed by diffusion, allowing the occurrence of such anoxic microsites. The benthic and pelagic environments are completely different, and in mid-shallow waters, the advection of substances over particles can be still important, making those microsites anoxic enough to allow nitrifier denitrification.
- (e) This statement is just part of the introduction and tries to show as simply as possible the relation between nitrous oxide and oxygen in the ocean. In this part of the analysis, AOU and the oxygen concentration can be considered to be equivalent.

- (f) The latitude and longitude data have been corrected to standard units.
- (g) This point needs to be clarified. For very low concentrations (nM range), we use the method described in Raimbault et al. (1990) and, for higher concentrations ( $\mu\text{M}$  range), we use the method described in Armstrong et al. (1967).
- (h) At this point, there is a wrong citation. The right citation is Oudot et al. (1990). In that work, the authors suggest the production of nitrous oxide during assimilatory nitrate reduction by phytoplankton in the mixed layer. We use that argument just to show that nitrous oxide production in the shallowest part of the water column can be more complicated than the known scheme of bacterial nitrous oxide production. However, our data do not allow us to deal with this part of the water column.
- (i) This is a misunderstanding probably caused by poor writing. Effectively, Poth and Focht (1985) suggest that nitrifier denitrification can be a detoxification pathway. The statement about the speed of particles is part of the discussion. The speed of the sinking particles is a function of the density gradient (and, therefore, the buoyancy of the particles) and gravity, so the conclusion that the particle movement is slower in zones with higher gradients seems to me to be logical. As for the content of the particles, our data show that, although the particle abundance at the oceanic station is low, particles do exist in a wide range of sizes. We are not discussing the abundance of nitrous oxide generated by nitrifier denitrification in particles, just the isotopomeric signature.
- (j) In coastal regions, horizontal circulation is much more important than in oceanic regions. Because of that, the results of the coastal station must be carefully interpreted and the influence of water masses running along the shoreline cannot be discarded. At oceanic stations, horizontal circulation is much slower and its influence can be neglected on small time scales.

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- (k) The discussion about how the particles can accumulate in high stability zones is supported by the particle counts made by an underwater video profiler (UVP). Despite the lack of particle sinking speed measurements, it is logical to suppose that the speed of particles is determined by a density gradient, as has been mentioned.

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