



**HAL**  
open science

# Hot spot of N<sub>2</sub> fixation in the western tropical South Pacific pleads for a spatial decoupling between N<sub>2</sub> fixation and denitrification

Sophie Bonnet, Mathieu Caffin, Hugo Berthelot, Thierry Moutin

## ► To cite this version:

Sophie Bonnet, Mathieu Caffin, Hugo Berthelot, Thierry Moutin. Hot spot of N<sub>2</sub> fixation in the western tropical South Pacific pleads for a spatial decoupling between N<sub>2</sub> fixation and denitrification. Proceedings of the National Academy of Sciences of the United States of America, 2017, 114 (14), pp.E2800 - E2801. 10.1073/pnas.1619514114 . hal-01621724

**HAL Id: hal-01621724**

**<https://amu.hal.science/hal-01621724>**

Submitted on 21 Mar 2019

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution 4.0 International License



# Hot spot of N<sub>2</sub> fixation in the western tropical South Pacific pleads for a spatial decoupling between N<sub>2</sub> fixation and denitrification

Sophie Bonnet<sup>a,b,1</sup>, Mathieu Caffin<sup>b</sup>, Hugo Berthelot<sup>b</sup>, and Thierry Moutin<sup>b</sup>

Nitrogen (N) is the building block of life. Quantifying the sources and sinks of N to the ocean is essential for predicting its productivity and potential carbon sequestration. In his paper, Gruber (1) seeks for “elusive marine nitrogen fixation” following results from Knapp et al. (2), who measured unexpectedly low N input through N<sub>2</sub> fixation in the eastern tropical South Pacific (ETSP), seriously bringing into question the proposed close spatial coupling between N input (through N<sub>2</sub> fixation) and loss (through denitrification) (3). Here, we compile data from recently published and unpublished studies revealing a hot spot of N<sub>2</sub> fixation in the western tropical South Pacific (WTSP) arguing for a spatial decoupling between N sources and sinks in the South Pacific.

Based on four cruises performed between 2012 and 2015 during austral winter and summer conditions, with a total of more than 600 <sup>15</sup>N<sub>2</sub> incubations-based measurements, and particularly a 4,000-km zonal transect at ~20°S in 2015 (OUTPACE cruise: [dx.doi.org/10.17600/15000900](https://doi.org/10.17600/15000900)), we report N<sub>2</sub> fixation rates of 570 μmol N·m<sup>-2</sup>·d<sup>-1</sup> on average over the WTSP (Fig. 1). They are far higher than model predictions for the area (~150–200 μmol N·m<sup>-2</sup>·d<sup>-1</sup>) (1) and in the upper range (100–1,000 μmol N·m<sup>-2</sup>·d<sup>-1</sup>) of rates gathered in the global N<sub>2</sub> fixation Marine Ecosystem Data (MAREDAT) database (4).

The close spatial coupling between N sources and sinks in the Pacific was hypothesized because denitrification in the oxygen minimum zones (OMZs) creates excess phosphorus (P) surface waters (nitrate-poor but phosphate-rich), that is, potential ideal niches for N<sub>2</sub> fixation. Downstream of the OMZs, surface waters were supposed to gradually lose this excess P through N<sub>2</sub> fixation, restoring the system to a “Redfieldian” balance (3). However, predicted and actual measurements of N<sub>2</sub> fixation in the South Pacific

are not in agreement (1): unexpected low N<sub>2</sub> fixation rates are measured in the ETSP (2) and in the South Pacific Gyre (2, 5), and we report here high N<sub>2</sub> fixation rates in the WTSP (Fig. 1). Such a hot spot of N<sub>2</sub> fixation in the WTSP is likely due to the alleviation of iron limitation, a major component of the nitrogenase enzyme that catalyzes N<sub>2</sub> fixation (6), when waters originating from the east reach the WTSP through the South Equatorial Current (SEC) (Fig. 1). Surface iron concentrations are indeed higher in the WTSP [average, 0.57 nM (7)] than in the central and ETSP [~0.10–0.30 nM (8)], where it limits N<sub>2</sub> fixation (9). The WTSP appears to provide optimal environmental conditions for diazotrophs to bloom extensively, but this region deserves special attention to better identify the reasons for such an ecological success.

Such a hot spot in the WTSP sheds light on the elusive marine nitrogen fixation in the Pacific (1) and indicates that this region may play an obvious role in replenishing the Pacific Ocean in N, which could partly counterbalance the N losses in the ETSP.

## Acknowledgments

This research is a contribution of the OUTPACE project ([dx.doi.org/10.17600/15000900](https://doi.org/10.17600/15000900)) managed by the MIO funded by the Agence Nationale de la Recherche (Grant ANR-14-CE01-0007-01), the Les enveloppes fluides de l'Environnement (LEFE)-CyBER program [CNRS-Institut National des Sciences de l'Univers (INSU)], the IRD, the Grand Observatoire du Pacifique Sud (GOPS) program (IRD), and the Centre National d'Etudes Spatiales (CNES) (BC T23, ZBC 4500048836), MoorSPICE (DOI: 10.7284/903044), PANDORA ([dx.doi.org/10.17600/12010050](https://doi.org/10.17600/12010050)), and BIFURCATION ([dx.doi.org/10.17600/12100100](https://doi.org/10.17600/12100100)) projects managed by Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS) and SCRIPPS Institution of Oceanography, part of the Climate and Ocean: Variability, Predictability and Change (CLIVAR)/Southwest Pacific Ocean Circulation and Climate Experiment (SPICE) International Program, and funded by NSF Grant OCE1029487, Agence Nationale de la Recherche Grant ANR-09-BLAN-0233-01, and INSU/LEFE projects Solwara and SPICEMoor.

<sup>a</sup>Aix Marseille Université, Toulon Université, CNRS, Institut de Recherche pour le Développement (IRD), Observatoire des Sciences de l'Univers Pythéas, Mediterranean Institute of Oceanography (MIO), Unité Mixte 110, 98848 Noumea, New Caledonia; and <sup>b</sup>Aix Marseille Université, Toulon Université, CNRS, IRD, Observatoire des Sciences de l'Univers Pythéas, MIO, Unité Mixte 110, 13288 Marseille, France

Author contributions: S.B. and T.M. designed research; S.B., M.C., and H.B. performed research; S.B. and M.C. contributed new reagents/analytic tools; S.B. and M.C. analyzed data; H.B. and T.M. added suggestions on the paper; and S.B. wrote the paper.

The authors declare no conflict of interest.

<sup>1</sup>To whom correspondence should be addressed. Email: [sophie.bonnet@univ-amu.fr](mailto:sophie.bonnet@univ-amu.fr).

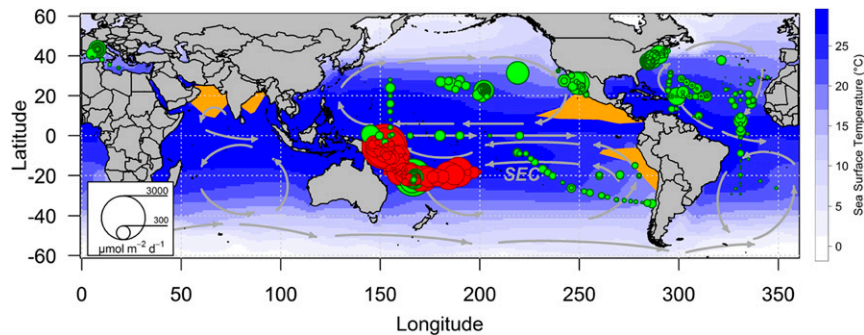


Fig. 1.  $N_2$  fixation in the world's oceans quantified using  $^{15}N_2$  incubation-based measurements. Green dots: integrated  $N_2$  fixation rates (in micromoles of nitrogen per square meter per day) from the MAREDAT database (4) and Knapp et al. (2). Red dots:  $N_2$  fixation rates quantified at 57 stations (WTSP) including data from Bonnet et al. (2015), DOI 10.1002/2015GB005117, using either the  $^{15}N_2$  bubble addition method or the enriched seawater method (10). To ensure accurate rate calculations, the  $^{15}N/^{14}N$  ratio of the  $N_2$  pool in the incubation bottles was systematically measured. Discrete rate measurements were depth integrated over the photic layer using trapezoidal integration. Gray arrows: main surface currents. SEC: South Equatorial Current. Orange shaded areas: main OMZs.

- 1 Gruber N (2016) Elusive marine nitrogen fixation. *Proc Natl Acad Sci USA* 113(16):4246–4248.
- 2 Knapp AN, Casciotti KL, Berelson WM, Prokopenko MG, Capone DG (2016) Low rates of nitrogen fixation in eastern tropical South Pacific surface waters. *Proc Natl Acad Sci USA* 113(16):4398–4403.
- 3 Deutsch C, Sarmiento JL, Sigman DM, Gruber N, Dunne JP (2007) Spatial coupling of nitrogen inputs and losses in the ocean. *Nature* 445(7124):163–167.
- 4 Luo YW, et al. (2012) Database of diazotrophs in global ocean: Abundances, biomass and nitrogen fixation rates. *Earth Syst Sci Data* 5(1):47–106.
- 5 Moutin T, et al. (2008) Phosphate availability and the ultimate control of new nitrogen input by nitrogen fixation in the tropical Pacific Ocean. *Biogeosciences* 5(1): 95–109.
- 6 Raven JA (1988) The iron and molybdenum use efficiencies of plant growth with different energy, carbon and nitrogen source. *New Phytol* 109:279–287.
- 7 Campbell L, Carpenter EJ, Montoya JP, Kustka AB, Capone DG (2005) Picoplankton community structure within and outside a *Trichodesmium* bloom in the southwestern Pacific Ocean. *Vie Milieu* 55:185–195.
- 8 Blain S, Bonnet S, Guieu C (2008) Dissolved iron distribution in the tropical and subtropical South Eastern Pacific. *Biogeosciences* 5:269–280.
- 9 Dekaezemacker J, et al. (2013) Evidence of active dinitrogen fixation in surface waters of the eastern tropical South Pacific during El Nino and La Nina events and evaluation of its potential nutrient controls. *Global Biogeochem Cycles* 27:1–12.
- 10 Mohr W, Grosskopf T, Wallace DW, LaRoche J (2010) Methodological underestimation of oceanic nitrogen fixation rates. *PLoS One* 5(9):e12583.