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# 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 Here, we compile data from recently published and unpublished studies revealing a hot spot of N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.

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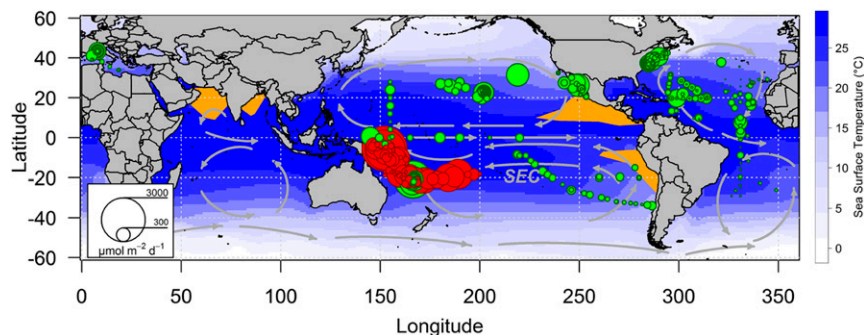


Fig. 1.  $N_2$  fixation in the world's oceans quantified using  $^{15}N_2$  incubation-based measurements. Green dots: integrated  $N_2$  fixation rates (in micromoles of nitrogen per square meter per day) from the MAREDAT database (4) and Knapp et al. (2). Red dots:  $N_2$  fixation rates quantified 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.

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