Interactive comment on "Modelling the processes driving Trichodesmium sp. spatial distribution and biogeochemical impact in the tropical Pacific Ocean" by Cyril Dutheil et al.

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The manuscript describes model simulations without and with two different parameterizations of nitrogen fixation in the tropical Pacific. Results are compared against observations in the ocean's surface layer, and the degree of realism of the two parameterizations employed is discussed. Inferences are made about the role of diazotrophic nitrogen fixation compared to primary production by ordinary phytoplankton.

Overall, the topic is scientifically very interesting and I found the title and also the abstract very promising, but was then disappointed by the material presented in the manuscript (and the often poor way it was presented) for reasons I will explain below. I am afraid I cannot recommend publication of the manuscript in its present form and think that a very major rewrite and additional and thorough analysis is required. This is beyond what I would normally consider as major revision (and would therefore recommend reject and resubmission). As the issue is tricky with special issues, and because the scientific topic is really interesting and it would be a missed opportunity of not analysing this very carefully, I'm still OK with recommending major submission, but want to stress that 'major' should be taken very seriously.

Legend for the review :

In blue our answers.

Response to general comments:

To answer your comments we have completely rewritten the method and appendix section. The result section has also been reworked so that the speech is clearer and more precise. We have also strengthened the introduction by more accurately detailing the state of the art of nitrogen fixation in biogeochemical models.

1. It is impossible to fully understand what has been done

The explicit description of N2 fixation by Trichodesmium is provided in the Appendix. I tried hard to understand it, but admit that I failed. There may be typos or unexplained Fe terms (e.g., what is L N T ri in line 492? Why are there two different definitions of L T ri , lines 479 and 499?). It does not help, that the notation in table 1 seems to be different from the one in the appendix. There are also steps that are not explained or justified. For example line 483 - why is this procedure applied to Fe but not to P? This makes it impossible to understand what has been done and why. There are other models of diazotrophs out in the literature. How does your model relate to these? Why have you developed a new one (is it new?)? To be useful to the scientific community, this has to be presented in much more detail and put into relation to the existing literature.

Following your comments, we have significantly modified the parts presenting our set up, the context and the description of the explicit representation of *Trichodesmium*.

A paragraph about the different models used in the literature has been added in the introduction section to contextualize our study:

« Numerical models have also been used as they allow to overcome the scarcity of observations that may limit the implementation of the two previous approaches (Aumont et al., 2015; Bissett et al., 1999; Dutkiewicz et al., 2012; Keith Moore et al., 2006; Krishnamurthy et al., 2009; Monteiro et al., 2011; Moore et al., 2013; Tagliabue et al., 2008). They can notably be used to investigate the spatial and temporal variability of N_2 fixation and to study how and which environmental factors control this process. In these models, N_2 fixation has been implemented in various ways. Some models use implicit parameterizations (Bisset et al., 1999; Maier-Reimer and Kriest, 2005; Assmann et al., 2010; Aumont et al., 2015) to derive N_2 fixation from environmental conditions (mainly nitrate, phosphate and iron concentrations, temperature and light). Alternatively, other models rely on the explicit descriptions of diazotrophs (Moore et al., 2004; Dunne et al., 2013) that have mainly been developed from the knowledge derived from laboratory culture experiments focused on *Trichodesmium* sp. (Fennel et al., 2001; Hood et al., 2001; Moore et al., 2001). Noticeably, several modeling studies have been especially focused on the role of iron in controlling the distribution of diazotrophs and N_2 fixation (Keith Moore et al., 2006; Krishnamurthy et al., 2009; Moore et al., 2004; Tagliabue et al., 2008). Indeed, a realistic representation of marine iron concentrations has been stressed as a key factor to adequately simulate the habitat of diazotrophs (Monteiro et al., 2011; Dutkiewicz et al., 2012). »

The most relevant informations of the explicit modelisation of the *Trichodesmium* compartment have been added to the manuscript within a specific section:

« 2.1.3 The *Trichodesmium* compartment

For the purpose of this study, we implemented an explicit representation of Trichodesmium in the PISCES-QUOTA version. Therefore, as already stated, five living compartments are modeled including three phytoplankton groups (nanophytoplankton, diatoms, and *Trichodesmium*) and two zooplankton groups (microzooplankton, and mesozooplankton). Similarly, to nanophytoplankton (Equation 1 in Kwiatkowski et al., submitted), the equation of Trichodesmium evolution is computed as follows:

$$\frac{\partial Tri_C}{\partial t} = \left(1-\delta^{Tri}\right)\mu^{Tri}Tri - \zeta_{NO_3}^{Tri}V_{NO_3}^{Tri} - \zeta_{NH_4}^{Tri}V_{NH_4}^{Tri} - m^{Tri}\frac{Tri_C}{K_m+Tri_C}Tri_C - sh*w^{Tri}P^2 - g^Z(Tri)Z - g^M(Tri)M \quad \text{(Eq. 1)}$$

In this equation, Tri_C is the carbon Trichodesmium biomass, and the seven terms on the right-hand side represent respectively growth, biosynthesis costs based on nitrate and ammonium, mortality, aggregation and grazing by micro- and mesozooplankton.

In our configuration, the photosynthesis growth rate of *Trichodesmium* is limited by light, temperature, phosphorus and iron availability. Photosynthesis growth rate of *Trichodesmium* (μ^{Tri}) is computed as follows: $\mu^{Tri} = \mu_{FixN_2} + \mu_{NO_3}^{Tri} + \mu_{NH_4}^{Tri}$ (Eq. 2)

where $\mu FixN2$ denotes growth due to N_2 fixation, $\mu^{Tri}NO3$ and $\mu^{Tri}NH4$ represent growth sustained by $NO3^-$ and $NH4^+$ uptake, respectively. Moreover, a fraction of fixed nitrogen is released back to seawater, mainly as ammonia and dissolved organic nitrogen, by the simulated Trichodesmium compartment. Berthelot et al., (2015) estimated this fraction to be less than 10% when considering all diazotrophs. We set up this fraction at 5% of the total amount of fixed nitrogen. For the other nutrients (i.e. iron and phosphorus), the same fraction is also released.

N_2 fixation is limited by the availability of phosphate, iron and light and is modulated by temperature.

Loss processes are natural mortality, and grazing by zooplankton. Natural mortality is considered to be similar to the other modeled phytoplankton species. Grazing on *Trichodesmium* is rarely described, but it is admitted that *Trichodesmium* represents a poor source of food for zooplankton (O'Neil and Romane, 1992) especially because they contain toxins (Hawser et al., 1992). On the other hand, few species of copepods have been shown to be able to graze on *Trichodesmium* despite the strong concentrations of toxins (O'Neil and Romane, 1992). For these reasons we applied two different coefficients for the grazing preference by mesozooplankton and microzooplankton (Table 1). For microzooplankton, grazing preference is halved to account for Trichodesmium toxicity, and

for mesozooplankton the grazing preference is similar to that of the other phytoplankton species. The complete set of equations of *Trichodesmium* is detailed in Appendix 1. Table 1 presents the parameters that differ between Nanophytoplankton and Trichodesmium.

This setup reproduces N_2 fixation through an explicit representation of the Trichodesmium biomass (to be compared with often used implicit parameterizations (Assmann et al., 2010; Aumont et al., 2015; Dunne et al., 2013; Maier-Reimer et al., 2005; Zahariev et al., 2008)) that links directly environmental parameters to N_2 fixation without requiring the Trichodesmium biomass to be simulated). »

In addition to those changes within the manuscript, we significantly modified the appendix :

« *Trichodesmium* preferentially fixes di-nitrogen at temperature between 20-34°C (Breitbarth et al., 2007). The temperature effect on the growth rate is modeled using a 4th order polynomial function (Ye et al., 2012):

$$L_T^{Tri} = \frac{2{,}32.10^{-5} \times T^4 - 2{,}52.10^{-3} \times T^3 + 9{,}75.10^{-2} \times T^2 - 1{,}58 \times T + 9.12}{0.25} \quad \text{(Eq. 3)}$$

where $0.25 d^{-1}$ is the maximum observed growth rate (Breitbarth et al., 2007). Hence, at 17°C the growth rate is zero and maximum growth rate is reached at 27°C. The Trichodesmium light limitation is similar to nanophytoplankton (Aumont et al. (2015)).
From equation 2, we distinguish 2 cases for the growth rate due to N_2 fixation.
if phosphorus is limiting the equation 2 becomes :

$$\mu_{Fix} = \mu_{max}^{Tri} . L_I^{Tri} . L_P^{Tri} - \left(\mu_{NO_3}^{Tri} + \mu_{NH_4}^{Tri} \right) \quad \text{(Eq. 4a) with} \quad L_P^{Tri} = min\left(1, max\left(0, \frac{\left(\theta^P - \theta_{min}^P \right) \times \theta_{max}^P}{\left(\theta_{max}^P - \theta_{min}^P \right) \times \theta^P} \right) \right) \quad \text{(Eq. 4b)}$$

if iron is limiting :

$$\mu_{Fix} = \mu_{max}^{Tri} . L_I^{Tri} . L_{Fe}^{Tri} - \left(\mu_{NO_3}^{Tri} + \mu_{NH_4}^{Tri} \right) \quad \text{(Eq. 5a) with} \quad L_{Fe}^{Tri} = min\left(1, max\left(0, \frac{\left(\theta^{Fe} - \theta_1^{Fe} \right) \times \theta_{opt}^{Fe}}{\left(\theta_{opt}^{Fe} - \theta_0^{Fe} \right) \times \theta^{Fe}} \right) \right) \quad \text{(Eq. 5b)}$$

In equation 4b, θ^{Fe}_1 and θ^{Fe}_0 are computed as follows :

$$\theta_1^{Fe} = \theta_0^{Fe} + \alpha . \mu_{FixN_2} \quad \text{(Eq. 6a)}, \quad \theta_0^{Fe} = \theta_{min}^{Fe} + m \quad \text{(Eq.6b), and} \quad \alpha = \frac{1}{\beta} \quad \text{(Eq. 6c)}$$

$\theta^{Nutrients}$ represents the nutrient quota for Fe and phosphorus (i.e, the ratio between iron and carbon

concentrations in *Trichodesmium*, for instance). θ_{min}^{P}, and θ_{opt}^{Nut} are constants, whereas $\theta^{Nutrients}$ varies with time. The mimimum of L^{Tri}_{Fe} and L^{Tri}_{P} defines the limiting nutrient. L_I is the limiting function by temperature and light.

m represents the difference between the maintenance iron (i.e, the intracellular Fe:C present in the cell at zero growth rate) under diazotrophic growth and growth on ammonium (Kustka et al., 2003). β is the marginal use efficiency and equals the moles of additional carbon fixed per additional mole of intracellular iron per day (Raven, 1988; Sunda and Huntsman, 1997).

The demands for iron in phytoplankton are for photosynthesis, respiration and nitrate/nitrite reduction. Following Flynn and Hipkin (1999), we assume that the rate of synthesis by the cell of new components requiring iron is given by the difference between the iron quota and the sum of the iron required by these three sources of demand, which we defined as the actual minimum iron quota:

$$\theta_{min}^{Fe} = \frac{0.0016}{55.85}\theta_{Tri}^{Chl} + \frac{1.2110^{-5} \times 14}{55.85 \times 7.625} L_P^{Tri} + \frac{1.1510^{-4} \times 14}{55.85 \times 7.625} L_{NO_3}^{Tri} \quad \text{(Eq. 7)}$$

In this equation, the first right term corresponds to photosynthesis, the second term corresponds to respiration and the third term estimates nitrate and nitrite reduction. The parameters used in this equation are directly taken from Flynn and Hipkin (1999).

The authors claim that implicit parameterizations of N_2 fixation are often used in biogeochemical models (line 32, line 154, in the final sentence of the manuscript they even say ‘more commonly’), but do not provide a single reference to support this claim. I think this strong statement that is used and certainly requires references and also a detailed description of this implicit parameterisation in order to allow the reader to understand some of the results (see below), and possibly repeat what has been done here.

We added references (L187-188) for the models that we know use implicit parameterization of N_2 fixation. Martinez-Rey (2015) presents in his thesis a list of the parameterizations of N_2 fixation used in the biogeochemical models embedded in the CMIP5 models. On 10 CMIP5 models, 2 biogeochemical models use an explicit description of N_2 fixation, 6 use an implicit formulation of N_2 fixation and 2 have no representation of N_2 fixation.

As already stated, the introduction has been modified and we followed the reviewer's recommendation and replaced the two sentences referring to numerical models (L119 to 121 in the submitted manuscript) by the paragraph already given at the beginning of this review.

We also added the main characteristics of the implicit N_2 fixation scheme used in our study in the

section « experimental setup »:

« In a third experiment “N2_imp”, the explicit dinitrogen fixation module is replaced by the implicit parameterization described in Aumont et al. (2015) where fixation depends directly on water temperature, nitrogen, phosphorus and iron concentrations and light (no nitrogen fixers are simulated). »

We did not feel that more details were needed as a specific description has already been published in Aumont et al., (2015).

The set-up of the physical model is unclear as well. line 111 states that it is based on a nested version. Is there a nested version used here? If so, what is the parent and what the child model? Then, in line 116 open boundary conditions are introduced. Do these replace the nesting? What does the sentence in line 118 mean “The use of similar ROMS configurations. . .is validated. . .”?

Indeed, the wording used in this section was confusing and some information about our simulations were missing. We use a regional model with open boundaries. Thus, there is no nest in this configuration. The confusing sentence referring to the « nested version » have been removed and we now only refer to the ROMS-AGRIF version of the model. The sentence « The use of similar ROMS configurations. . .is validated. . . » means that some validation of the physical conditions of the South Pacific region produced by this ROMS configuration (e.g vertical resolution, mixed active/passive scheme, turbulent vertical mixing parameterization) has been already published (Jullien et al., 2012, 2014; Marchesiello et al., 2010).

The whole section has been extensively modified in order to take your comments into account:

« **2.1.1 ROMS**

In this study, we used a coupled dynamical-biogeochemical framework based on the regional ocean dynamical model ROMS (Regional Oceanic Modeling System, (Shchepetkin and McWilliams, 2005)) and the state of the art biogeochemical model PISCES (Pelagic Interactions Scheme for Carbon and Ecosystem Studies). The ocean model configuration is based on the ROMS-AGRIF (Penven et al., 2006) informatic code and covers the tropical Pacific region [33°S-33°N;110°E-90°W]. It has 41 terrain-following vertical levels with 2-5 m vertical resolution in the top 50 meters of the water column, then 10-20 m resolution in the thermocline and 200-1000 m resolution in the deep ocean. The horizontal resolution is 1°. The turbulent vertical mixing parameterization is based on the non-local K profile parameterization (KPP) of (Large et al., 1994). Open boundaries conditions are treated using a mixed active/passive scheme (Marchesiello et al., 2001). This scheme is used to force our regional configuration with monthly climatological large-scale boundary conditions from a ½° ORCA global ocean simulation (details available in Kessler and Gourdeau (2007)), while allowing anomalies to radiate out of the domain. The use of similar ROMS

configurations (e.g vertical resolution, mixed active/passive scheme, turbulent vertical mixing parameterization) in the WTSP is largely validated through studies demonstrating skills in simulating both the surface (Jullien et al., 2012, 2014; Marchesiello et al., 2010) and subsurface ocean circulation (Couvelard et al., 2008).

To compute the momentum and fresh water/heat fluxes, we also use a climatological forcing strategy. Indeed, documenting the inter-annual to decadal variability is beyond the scopes of our study, which justifies using climatological forcing fields. A monthly climatology of the momentum forcing is computed from the 1993-2013 period of the ERS1-2 scatterometer stress (http://cersat.ifremer.fr/oceanography-from-space/our-domains-of-research/air-sea-interaction/ers-ami-wind). Indeed, ERS derived forcing has been shown to produce adequate simulations of the Pacific Ocean dynamics (e.g, Cravatte et al., (2007)). A monthly climatology at 1/2° resolution computed from the Comprehensive Ocean–Atmosphere Data Set (COADS; Da Silva et al. 1994) is used for heat and fresh water forcing. In our set-up, ROMS also forces on line a biogeochemical model using a WENO5 advection scheme (i.e. five order weighted essentially non-oscillatory scheme; Shchepetkin and McWilliams, 1998). After a one year spin-up we stored 1-day averaged outputs for analysis. »

The configuration of the biogeochemical model is not well described. E.g., line 134: a modified version, which differs in the use of a full quota formation. How is it modified? How does it differ? 'variable' Redfield ratios. The Redfield ratio is always constant and always the same (i.e. the one that Redfield used). Replace by variable C:N:P (:Si : Fe:. . .?) ratios. Is the effect of N2 fixation (and denitrification) on alkalinity included in the model? This would be another biogeochemical impact of N2 fixation that should be reported.

This whole section, describing the PISCES-QUOTA model, has been revised. Careful attention has been paid not to refer to « variable Redfield ratio » and to stress differences between the PISCES common version and the quota version. To answer your particular question, N_2 fixation is indeed impacting alkalinity for both the implicit and explicit parameterization.

« 2.1.2 PISCES

In this study, we use a quota version of the standard PISCES model (Aumont and Bopp, 2006a; Aumont et al., 2015), which simulates the marine biological productivity and the biogeochemical cycles of carbon and the main biogenic elements and micronutrient (P, N, Si, Fe). This modified model, called PISCES-QUOTA, is extensively described in Kwiatkowski et al. (2018, in press). Our version is essentially identical to Kwiatkowski's version that included an additional picophytoplankton group, except that this latter group has been removed and replaced by the Trichodesmium compartment. Here we only highlight the main characteristics of the model and the

specifics of our model version. Our version of PISCES-QUOTA has then 39 prognostic compartments. As in the standard PISCES version, phytoplankton growth is limited by the availability of five nutrients: nitrate and ammonium, phosphate, silicate and iron. Five living compartments are represented: Three phytoplankton groups corresponding to nanophytoplankton, diatoms, and *Trichodesmium* and two zooplankton size-classes that are microzooplankton and mesozooplankton. The elemental composition of phytoplankton and non-living organic matter is variable and is prognostically predicted by the model. On the other hand, zooplankton is assumed to be strictly homeostatic, i.e. its stoichiometry is kept constant (e.g., Meunier et al., 2014; Sterner & Elser, 2002). Nutrients uptake as well as limitation of growth rate are modeled according to the chain model of Pahlow and Oschlies (2009). The P quota limits N assimilation which in turns limits phytoplankton growth. The phosphorus to nitrogen ratios of phytoplankton are described based on the potential allocation between P-rich biosynthesis machinery, N-rich light harvesting apparatus, a nutrient uptake component, the carbon storage, and the remainder (Daines et al., 2014; Klausmeier et al., 2004). This allocation depends on the cell size and on the environmental conditions.

Nutrients are delivered to the ocean through dust deposition, river runoff and mobilization from the sediment. The atmospheric deposition if iron is derived from a climatological dust simulation (Tegen and Fung, 1995). The iron from sediment is recognized as a significant source (Johnson et al., 1999; Moore et al., 2004). This iron source is indeed parameterized in PISCES as, basically, a time-constant flux of dissolved iron (2 $\mu mol.m^{-2}.day^{-1}$) applied over the whole sediment surface and modulated depending on depth. A detailed description of this sedimentary source is presented in Aumont et al. (2015). The initial conditions and biogeochemical fluxes (iron, phosphorus, nitrate, ...) at the boundaries of our domain are extracted from the World Ocean Atlas 2009 (https://www.nodc.noaa.gov/OC5/WOA09/woa09data.html). »

In addition to an improved description of N2 fixation, there should also be a description of the growth of diazotrophs as well as their loss terms (grazing, mortality,. . .) and the fate of the fixed N (loss to DOM? Lifetime?)

Indeed, the added section « Trichodesmium compartment » (already given at the beginning of this review) is describing the explicit simulation of *Trichodesmium* with information given, noticeably, on the grazing preferences of zooplankton groups towards *Trichodesmium*. The time-evolution equation of *Trichodesmium* biomass with the sources and sinks is also given in this section.

2.1.3 Trichodesmium compartment

For the purpose of this study, we implemented in the PISCES-QUOTA version an explicit representation of Trichodesmium. Therefore, as already stated, five living compartments are

modeled with three phytoplankton groups (nanophytoplankton, diatoms, and *Trichodesmium*) and two zooplankton groups (microzooplankton, and mesozooplankton). Similarly to nanophytoplankton (Equation 1 in Kwiatkowski et al., submitted), the equation of Trichodesmium evolution is computed as follows:

$$L_{Tri}^{T} = \frac{2{,}32.10^{-5} \times T^4 - 2{,}52.10^{-3} \times T^3 + 9{,}75.10^{-2} \times T^2 - 1{,}58 \times T + 9.12}{0.25} \quad \text{(Eq. 1)}$$

In this equation, Tri_C is the carbon Trichodesmium biomass, and the seven terms on the right-hand side represent respectively growth, biosynthesis costs based on nitrate and ammonium, mortality, aggregation and grazing by micro- and mesozooplankton.

In our configuration, the photosynthesis growth rate of *Trichodesmium* is limited by light, temperature, phosphorus and iron availability. Photosynthesis growth rate of *Trichodesmium* (μ^{Tri}) is computed as follows: $\mu^{Tri} = \mu_{FixN_2} + \mu_{NO_3}^{Tri} + \mu_{NH_4}^{Tri}$ (Eq. 2)

where μ_{FixN2} denotes growth due to N_2 fixation, μ^{Tri}_{NO3} and μ^{Tri}_{NH4} represent growth sustained by NO_3^- and NH_4^+ uptake, respectively. Moreover, a fraction of fixed nitrogen is released back to seawater, mainly as ammonia and dissolved organic nitrogen, by the simulated Trichodesmium compartment. Berthelot et al., (2015) estimated this fraction to be less than 10% when considering all diazotrophs. We set up this fraction at 5% of the total amount of fixed nitrogen. For the other nutrients (i.e. iron and phosphorus), the same fraction is also released.

N_2 fixation is limited by the availability of phosphate, iron and light and is modulated by temperature.

Loss processes are natural mortality, and grazing by zooplankton. Natural mortality is considered to be similar to the other modeled phytoplankton species. Grazing on *Trichodesmium* is rarely described, but it is admitted that *Trichodesmium* represents a poor source of food for zooplankton (O'Neil and Romane, 1992) especially because they contain toxins (Hawser et al., 1992). On the other hand, many species of copepods have been shown to be able to graze on *Trichodesmium* despite the strong concentrations of toxins (O'Neil and Romane, 1992). For these reasons we applied two different coefficients for the grazing preference by mesozooplankton and microzooplankton (Table 1). For microzooplankton, grazing preference is halved to account for Trichodesmium toxicity, and for mesozooplankton the grazing preference is similar to that of the other phytoplankton species.The complete set of equations of *Trichodesmium* is detailed in Appendix 1. Table 1 presents the parameters that differ between Nanophytoplankton and Trichodesmium.

This setup reproduces N_2 fixation through an explicit representation of the Trichodesmium biomass (to be compared with often used implicit parameterizations (Assmann et al., 2010; Aumont et al., 2015; Dunne et al., 2013; Maier-Reimer et al., 2005; Zahariev et al., 2008) that links directly

environmental parameters to N_2 fixation without requiring the Trichodesmium biomass to be simulated).

line 163. Explain why 156E was chosen as western boundary of the test regions without sedimentary iron input? Doesn't this ensure that there is always iron being supplied from the western boundary of the Pacific Ocean?

We chose 156°E as the western boundary to remove the sedimentary iron source only in the south western Pacific islands, and to evaluate the impact of these islands and of iron from these islands on N_2 fixation.

2 . The presentation of the results is often poor and not as convincing as is could and should be

Part of this a language problem. Despite the impressive author list, no careful proof reading seems to have taken place before submission. There are many typos, incorrect words, wrong grammar and incomplete sentences. This can (and should) be improved. Some explanations are very vague and, at closer inspection, are not that convincing. For example, line 231/232: The bias 'beyond' (presumably 'eastward of'?) 170W is explained by a bias in iron concentrations, which, however occurs mostly west of 150W according to Fig.2.

The revised manuscript has undergone a thorough proof reading to look for typos and grammatical errors. About your specific example, an undersestimation of the simulated iron concentration in TRI is displayed east of 170°W in figure 2 when compared to data from the 20°S transect (~0.2 in observations and ~0.4 in TRI simulation). The figure 9 strengthen the assumption that the iron biais is responsible to the N2 fixation biais in the south Pacific gyre. In addition we replaced 'beyond ' by 'eastward of'.

Fig. 4 Why show the vertical integral and the vertical average in separate panels?

The information looks very similar. Explain what differences the reader should see and understand.

We added text to explain the reason of these two integration layers:

« Some areas are sampled only in the surface layer (0-30m) while others have been sampled deeper. To overcome this sampling bias we compared the observations with N2 fixation rates simulated integrated over two different layers (0-30m and 0-150m). »

One motivation mentioned in the introduction was the comparison of biogeochemical controls and impacts between implicit and explicit representation of N2 fixation. The only comparisons shown are for surface chlorophyll (quite different) (Is the implicit diazotrophic biomass of the implicit representation included here?) and primary production (very similar). Both variables are

biogeochemically among the less relevant ones. Showing a comparison for N2 fixation rates, nutrient concentrations, export production, pCO2 and possibly oxygen would be much closer to the original goal of the paper. In my view, such a comparison is essential.

The main goal of this study is to evaluate the impact of explicit N_2 fixation on the tropical Pacific production (a change of the title of the study suggested by an anonymous reviewer now better reflect that main goal). However, we followed your recommendation to look at the N_2 fixation rates and carbon export in TRI and TRI_imp simulations.

Figure supp. 1 represents the carbon export (under the euphotic layer, in µmol $N.m^{-2}d^{-1}$) comparison and the figure supp. 2 represents the N_2 fixation rate comparison (integrated over top to 150m, panel a in mmol C. $s^{-2}.d^{-1}$ and panel b in percentage). We observe a carbon export greater in TRI simulation, the average across the Pacific of this difference is 0.1mmol $C.m^{-2}.d^{-1}$ or 4 %, and in LNLC regions the increase varies between 6 and 10 %. The N_2 fixation rates are greater in TRI simulation except in the warm pool, in the equatorial upwelling, and in Peru upwelling.

Fig. 2. Why does the run N2_imp have more chlorophyll along the eastern boundary and along the equator than run TRI? This is interesting and might point to some feedbacks in the system.

The nitrogen fixation rates

Indeed, this may be an indirect effect of the increased production of TRI (compared to N2_imp) notably within the gyres (Fig 2 & 10). This increased production drives a decrease in iron concentration within the euphotic zone in TRI (vs. N2_imp). Then, this negative iron anomaly (still compared to N2_imp) will, through the 3D circulation, impacts the sub-surface iron concentration. Then the water masses upwelled in the equatorial Pacific and along the eastern boundary have lower concentration in iron. Hence, less chl in TRI in these iron limited regions.

The comparison among modeled and measured iron concentrations in Fig.2 is very difficult to see. Try different figure types (larger blobs, overly observed ’blobs’ on modeled map,...) Same for Fig.4

The goal of this comparison is to validate the spatial structure and the means. We have made the dots larger on the figure.

Fig. 9. Are currents on panels c and d different?

No, it's the same physical configuration, so the currents are identical. This is now acknowledged in the figure caption.

3. minor points

line 326 ‘cools temperature’ is wrong either lowers temperature or cools the water.

Following your suggestion, we have modified the text.

line 349. What is meant by high islands?

They are the islands with high orography. We have modified the text.

Table 1 : Models parameters for Trichodemium and nanophytoplakton.

Parameters	Symbol	Unity	Value	Reference
Maximum growth rate for Tricho.	μ^{Tri}_{max}	d^{-1}	0.25	Breitbarth et al. (2007)
Maximum growth rate for Nano.	μ^{Nano}_{max}	d^{-1}	1.0	
Initial slope P-I tricho	αI	$(W.m^{-2})^{-1}.d^{-1}$	0.072	Breitbarth et al. (2008) and Hood et al. (2002)
Initial slope P-I nano	αI	$(W.m^{-2})^{-1}.d^{-1}$	2.0	
Microzoo preference for Tricho.	pItri	-	0.5	
Microzoo preference for nano	pIP	-	1.0	
Maximum Fe/C in Tricho.	θFe,Trimax	mol Fe.(mol C)$^{-1}$	1.10^{-4}	Kustka et al. (2003)
Maximum Fe/C in nanophyto	θFe,Imax	mol Fe.(mol C)$^{-1}$	4.10^{-5}	
Maintenance iron	m	mol Fe.(mol C)$^{-1}$	$1.4.10^{-5}$	Kustka et al. (2003)
Marginal use efficiency	β	mol C.(mol Fe)$^{-1}$.day^{-1}	$1.4.10^{-4}$	Kustka et al. (2003)

Table 2 : List and description of the different experiments.

Name configuration	N_2 fixation	Iron from sediment
TRI	explicit	yes
TRI_NoFeSed	explicit	no
N2_imp	implicit	yes
Wo_N2	no	yes

Figures caption :

Fig. 1 : Annual mean concentrations in µmol L^{-1}: a) PO4 data from CARS b) PO4 simulated by the ROMS-PISCES model c) NO3 data from CARS d) NO3 simulated by the ROMS-PISCES model. On panels (a) and (b), the black contours show the annual mean patterns of the temperature preferendum from observations (a) and the model (b). The red contours display the 25°C isolign in austral winter (plain) and in austral summer (dash). On panels (c) and (d) the red boxes represent the LNLC regions (defined as region where $[NO^-_3] < 1$ µmol L^{-1} and [Chl] < 0.1 mg $Chl.m^{-3}$).

Fig. 2 : Left : Boxplots of the 0-150m averaged Iron (nmol $Fe.L^{-1}$) data (blue) and the equivalent for the model (red) colocalised with the observations in space and time. The coloured box represents the 25-75% quartile of the distribution, the whiskers the 10-90% percentile distribution. The line inside the coloured box is the median.

Right : Iron concentrations (nmol $Fe.L^{-1}$) as observed (b) and as simulated by the model (c). Iron concentrations have been averaged over the top 150m of the ocean. Model values have been sampled at the same location, the same month, and the same depth as the data.

Fig. 3 : Top : Annual mean surface Chlorophyll concentrations (in mg $Chl.m^{-3}$) from (a) GLOBCOLOUR data (b) TRI simulation and (c) TRI_imp simulation. Bottom panel (d) shows the the annual mean surface chlorophyll concentrations of Trichodesmium in the TRI simulation.

Fig. 4 : Nitrogen fixation rates (µmol $N.m^{-2}d^{-1}$) as observed (left) and as simulated by TRI simulation (right). In the top panels, nitrogen fixation rates have been integrated over the top 150m of the ocean. In the bottom panels, the vertical integration has been restricted to the top 30m of the ocean. Model values have been sampled at the same location, the same month (climatological month vs real month), and the same depth as the data.

Fig. 5 : a) Depth-integrated (0 to 125m) rates of nitrogen fixation (µmol $N.m^{-2}d^{-1}$) at ALOHA for the data (blue) and TRI simulation (red). b) Depth-integrated (from 0 to 150m) rates of nitrogen fixation (µmol $N.m^{-2}d^{-1}$) in the south Pacific (red box, Fig. 1c) in the data (blue) and in the TRI simulation (red). The blue curve is the average of all the model points inside the south Pacific zone (red box, Fig. 1c), whereas the green curve corresponds to the average of the model points where data are available..

Fig. 6 : Relative contribution (in percentage) of *Trichodesmium* to total primary production.

Fig. 7 : *Trichodesmium* biomass (mmol $C.m^{-2}$) in (a) austral summer and (b) austral winter, integrated over the top 100m of the ocean.

Fig. 8 : Seasonal cycle of the limitation terms of *Trichodesmium* production in a) the South Pacific and b) the North Pacific. The right scale represents the total limitation.

Fig. 9 : Top : Minimum, mean and maximum in the South box (Fig 1c) of (a) the iron concentrations, and (b) of the chlorophyll concentrations of Trichodesmium.

Bottom : Annual mean iron concentrations (shading ; in nmol $Fe.L^{-1}$) and current velocities (vectors ; in $m.s^{-1}$) for c) the TRI_NoFeSed simulation and d) the TRI simulation. Annual mean Chlorophyll concentrations of *Trichodesmium* (mg $Chl.m^{-3}$) for e) the TRI_NoFeSed simulation and f) the TRI simulation. The concentrations have been averaged over the top 100m of the ocean. The current velocities are identical on the panels a and b.

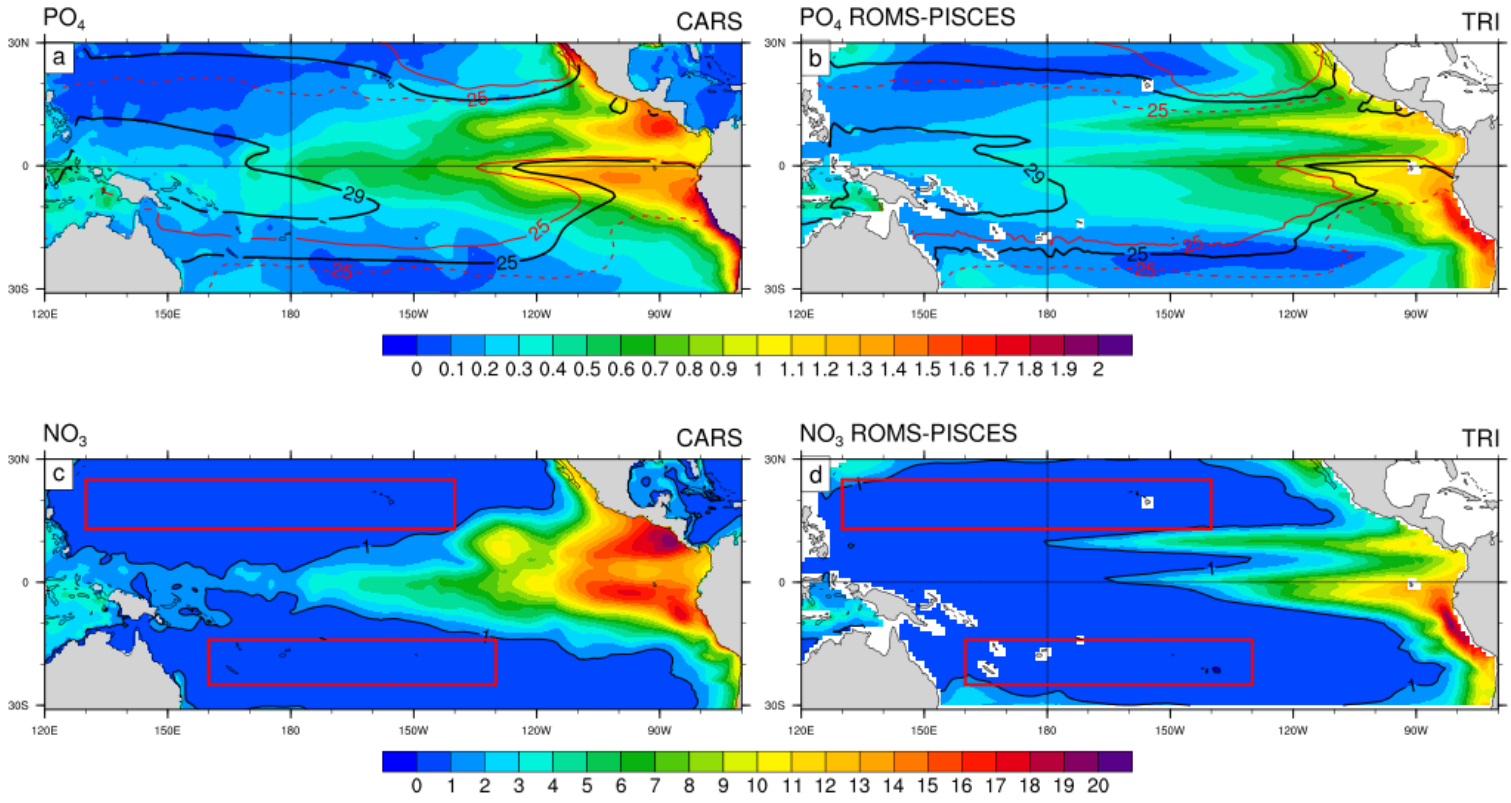
Fig. 10 : Percentage increase of primary production between the TRI simulation and the Wo_N2 simulation (top) and the N2_imp simulation (bottom); The left panels show total primary production including the contribution of Trichodesmium whereas in the right panels, primary production only includes the contribution of diatoms and nanophytoplankton.

Fig. Supp. 1 : Difference of fluxes of carbon export at euphotic layer between TRI simulation and TRI_imp simulation in mmol $C.m^{-2}.d^{-1}$ (a) and in percentage (b).

Fig. Supp. 2 : Depth-integrated (from 0 to 150m) rates of nitrogen fixation (μmol $N.m^{-2}d^{-1}$) in a) TRI simulation and b) TRI_imp simulation.

Fig. Supp. 3 : Physic balance of depth-integrated (from 0 to 150m) rate of iron concentrations (in mol $Fe.m^{-2}.d^{-1}$) averaged on south Pacific (red box, Fig. 1).

Fig. Supp. 4 : Seasonal cycle of Trichodesmium rate change (in mol $C.m^{-2}.s^{-1}$) in the South Pacific.


PO4
CARS
a
PO4 ROMS-PISCES
TRI
b
30N
0
30S
120E
150E
180
150W
120W
90W
25
29
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2

NO3
CARS
c
NO3 ROMS-PISCES
TRI
d
30N
0
30S
120E
150E
180
150W
120W
90W
1
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Figure 1

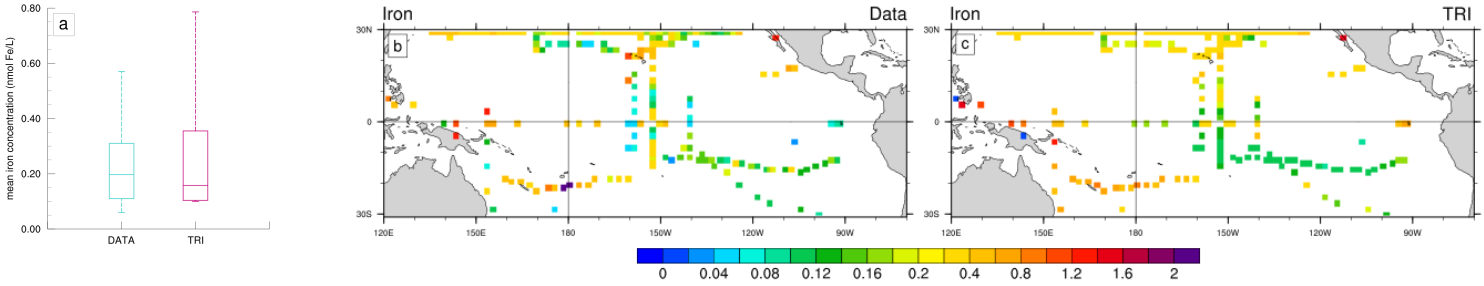
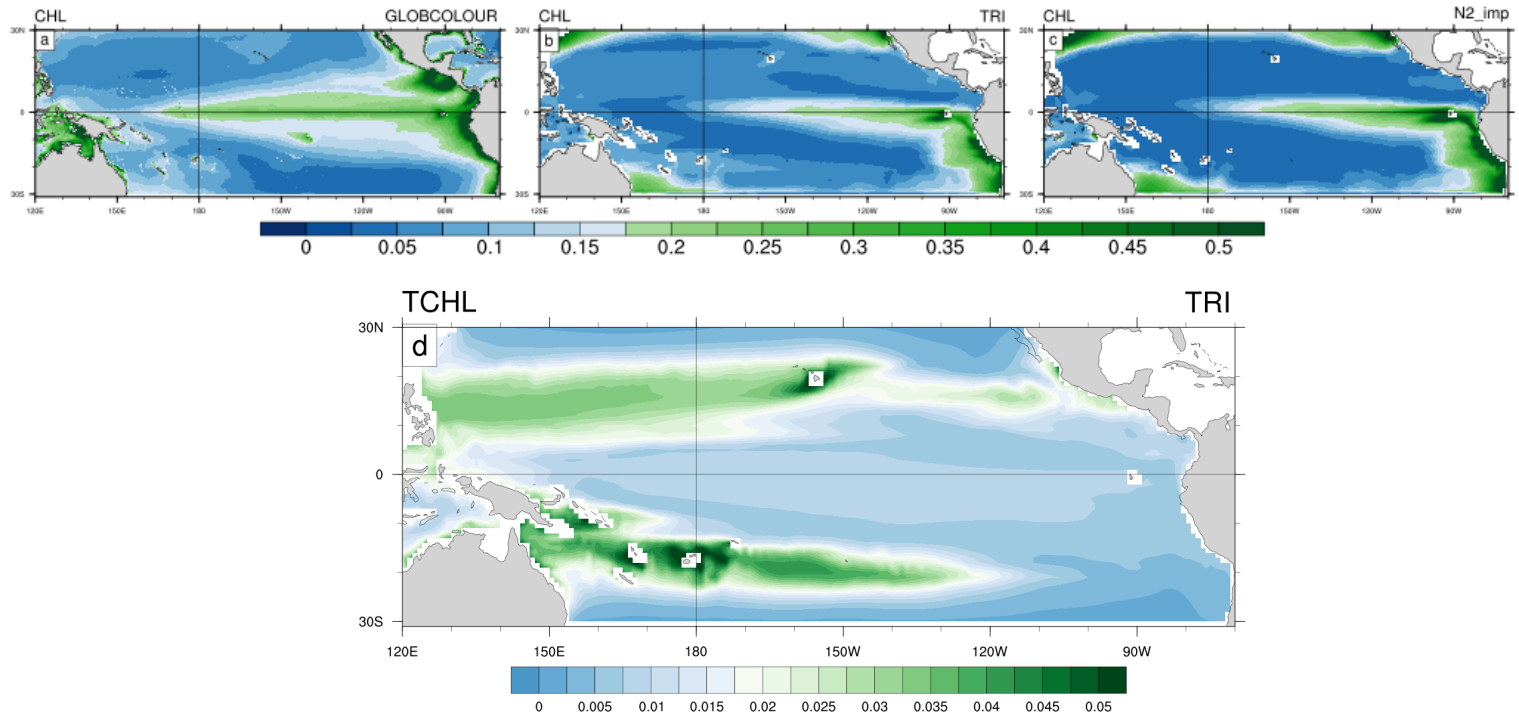

a
mean iron concentration (nmol Fe/L)
0.80
0.60
0.40
0.20
0.00
DATA
TRI
Iron
Data
b
30N
0
30S
120E
150E
180
150W
120W
90W
Iron
TRI
c
0
0.04
0.08
0.12
0.16
0.2
0.4
0.8
1.2
1.6
2

Figure 2


CHL
GLOBCOLOUR
a
CHL
TRI
b
CHL
N2_imp
c
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

TCHL
TRI
d
30N
0
30S
120E
150E
180
150W
120W
90W
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
0.045
0.05

Figure 3

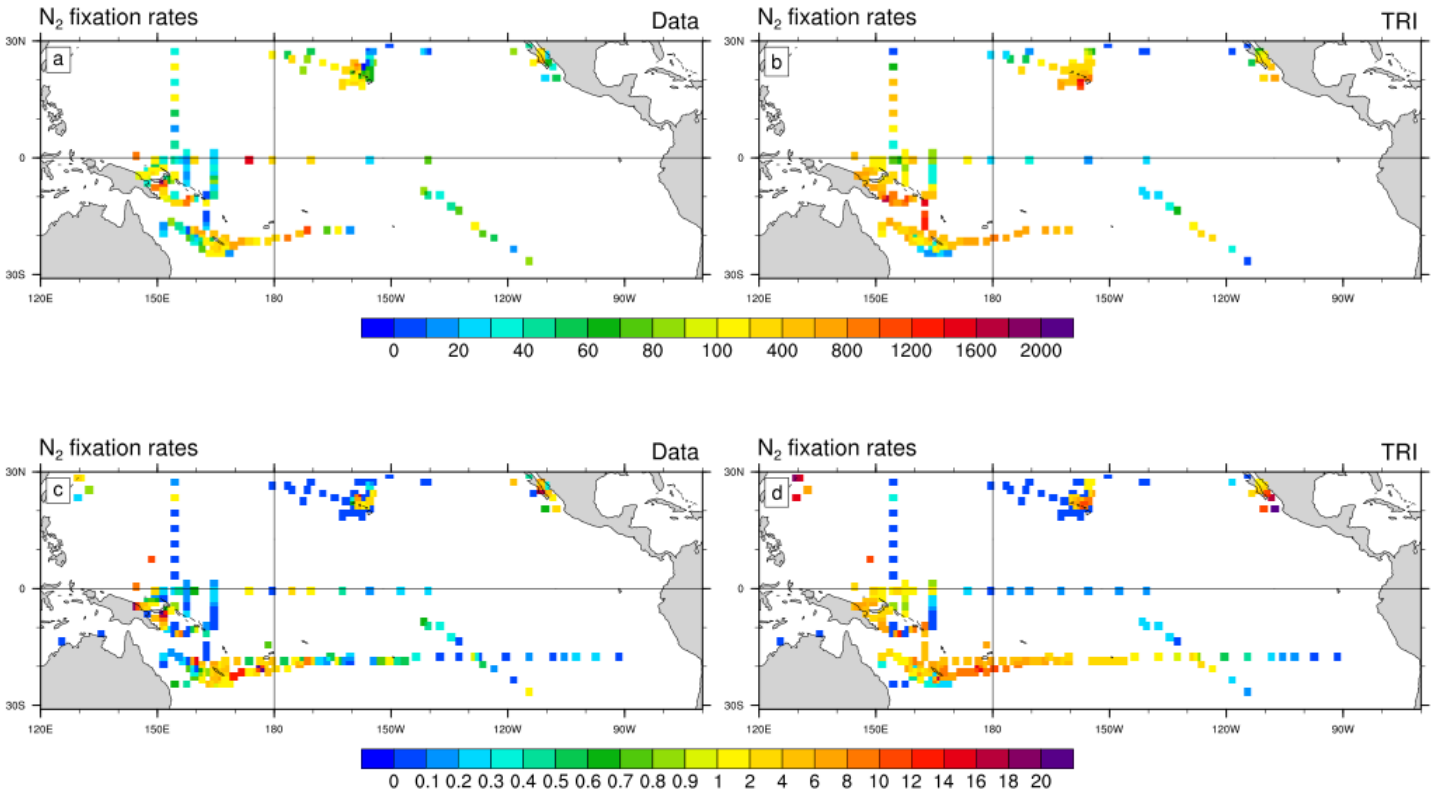
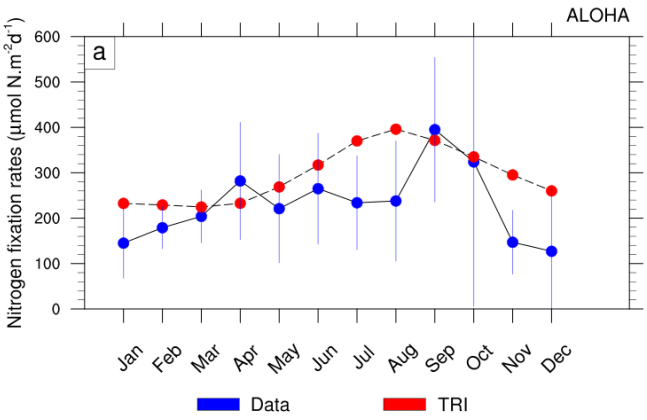

N2 fixation rates
Data
a
N2 fixation rates
TRI
b
30N
0
30S
120E
150E
180
150W
120W
90W
0 20 40 60 80 100 400 800 1200 1600 2000
N2 fixation rates
Data
c
N2 fixation rates
TRI
d
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1 2 4 6 8 10 12 14 16 18 20

Figure 4


ALOHA
a
Nitrogen fixation rates (µmol N.m-2d-1)
0
100
200
300
400
500
600
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Data
TRI

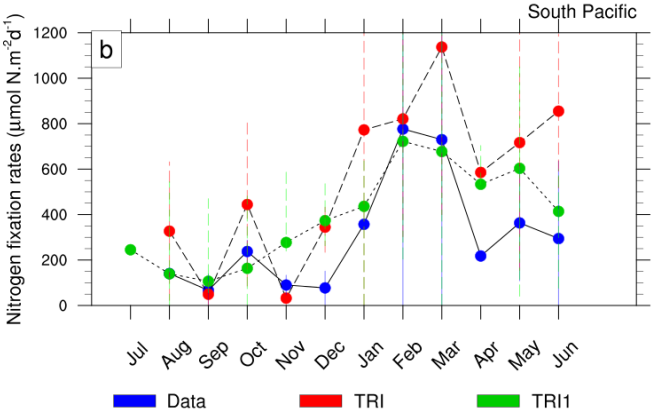

South Pacific
b
Nitrogen fixation rates (µmol N.m-2d-1)
0
200
400
600
800
1000
1200
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Data
TRI
TRI1

Figure 5

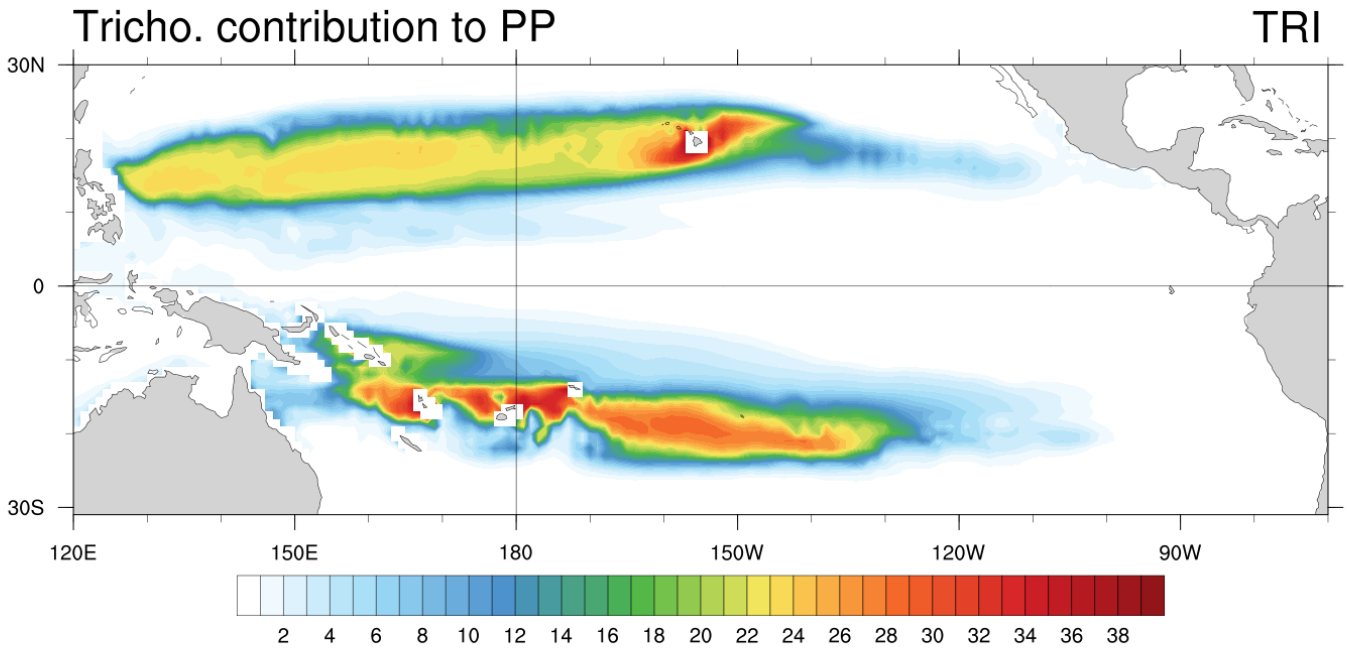

Tricho. contribution to PP
TRI
30N
0
30S
120E
150E
180
150W
120W
90W
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38

Figure 6

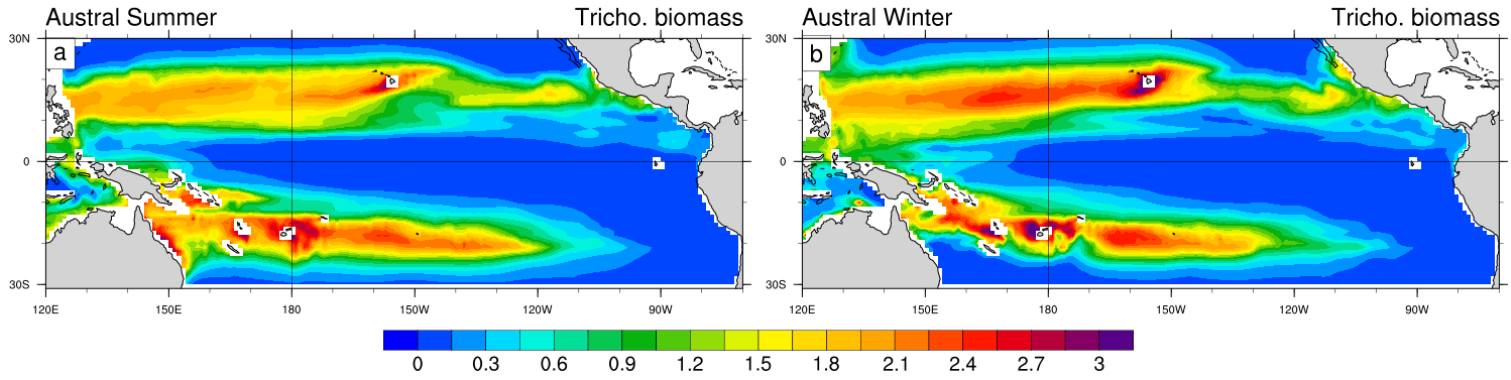

Austral Summer
Tricho. biomass
a
Austral Winter
Tricho. biomass
b
30N
0
30S
120E
150E
180
150W
120W
90W
0
0.3
0.6
0.9
1.2
1.5
1.8
2.1
2.4
2.7
3

Figure 7

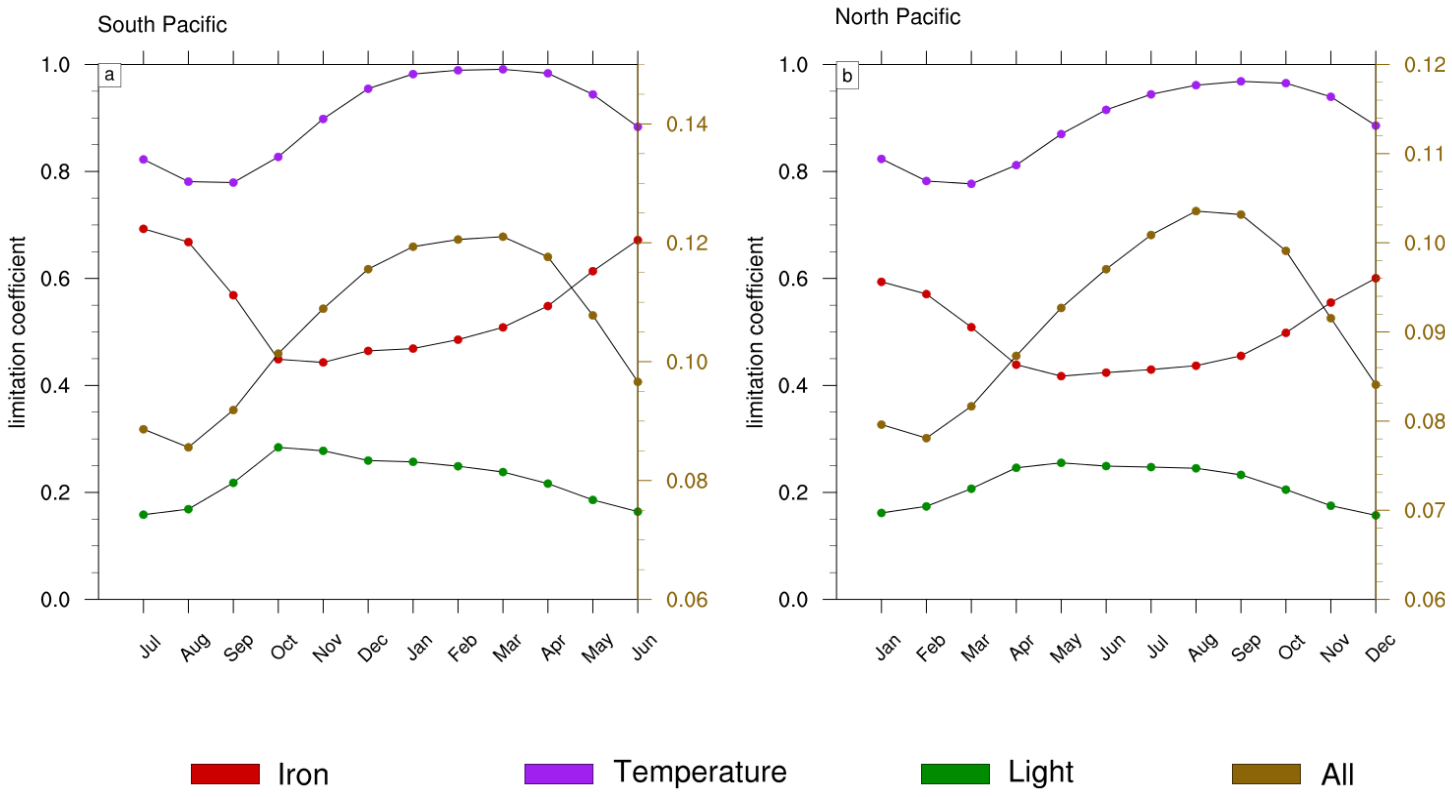

South Pacific
North Pacific
a
b
limitation coefficient
1.0
0.8
0.6
0.4
0.2
0.0
0.14
0.12
0.10
0.08
0.06
0.11
0.09
0.07
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Iron
Temperature
Light
All

Figure 8

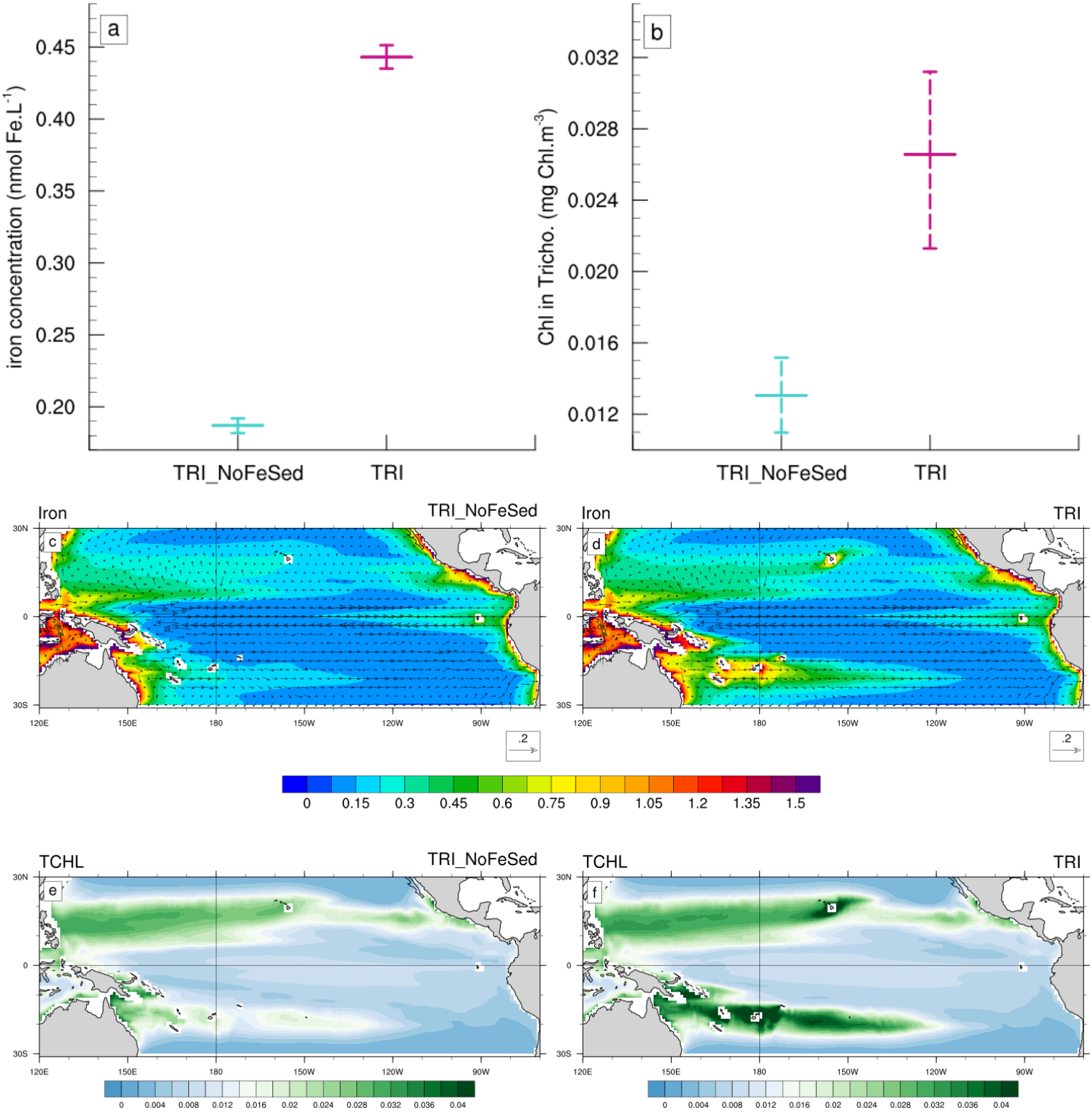

a
iron concentration (nmol Fe.L-1)
0.45
0.40
0.35
0.30
0.25
0.20
TRI_NoFeSed
TRI
b
Chl in Tricho. (mg Chl.m-3)
0.032
0.028
0.024
0.020
0.016
0.012
TRI_NoFeSed
TRI
Iron
TRI_NoFeSed
c
Iron
TRI
d
30N
0
30S
120E
150E
180
150W
120W
90W
0
0.15
0.3
0.45
0.6
0.75
0.9
1.05
1.2
1.35
1.5
TCHL
TRI_NoFeSed
e
TCHL
TRI
f
0
0.004
0.008
0.012
0.016
0.02
0.024
0.028
0.032
0.036
0.04

Figure 9

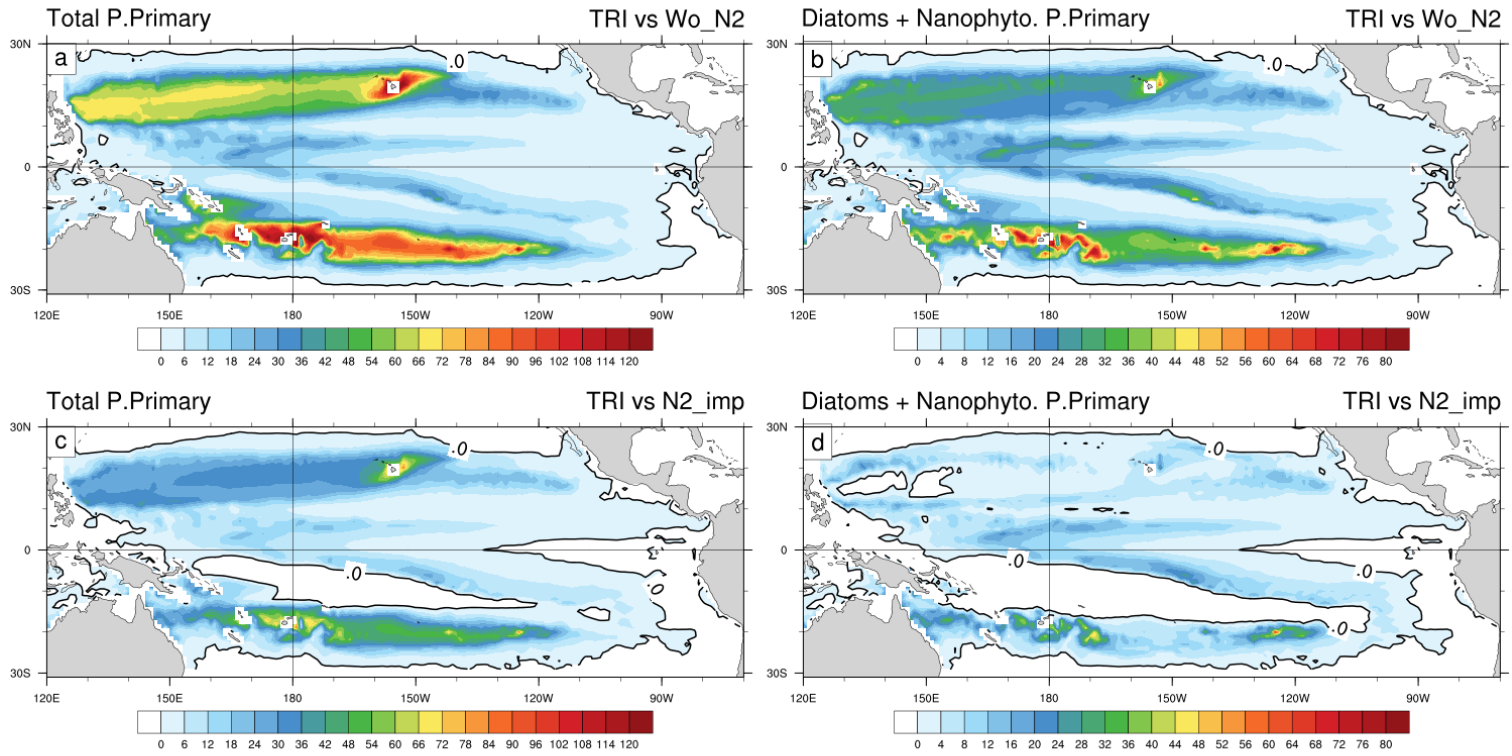

Total P.Primary
TRI vs Wo_N2
a
Diatoms + Nanophyto. P.Primary
TRI vs Wo_N2
b
Total P.Primary
TRI vs N2_imp
c
Diatoms + Nanophyto. P.Primary
TRI vs N2_imp
d
30N
0
30S
120E
150E
180
150W
120W
90W
0 6 12 18 24 30 36 42 48 54 60 66 72 78 84 90 96 102 108 114 120
0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64 68 72 76 80

Figure 10

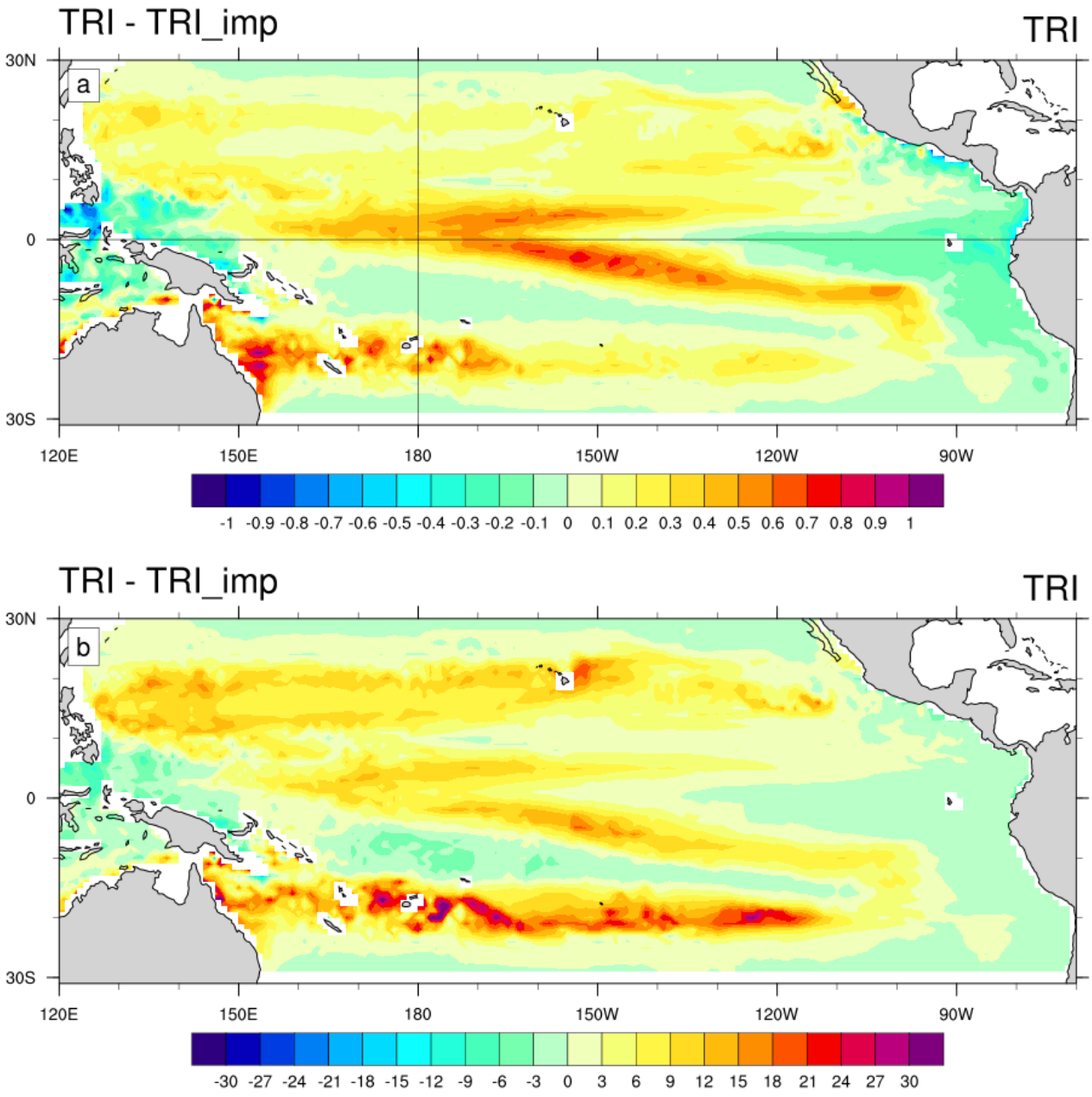


Figure Supp. 1

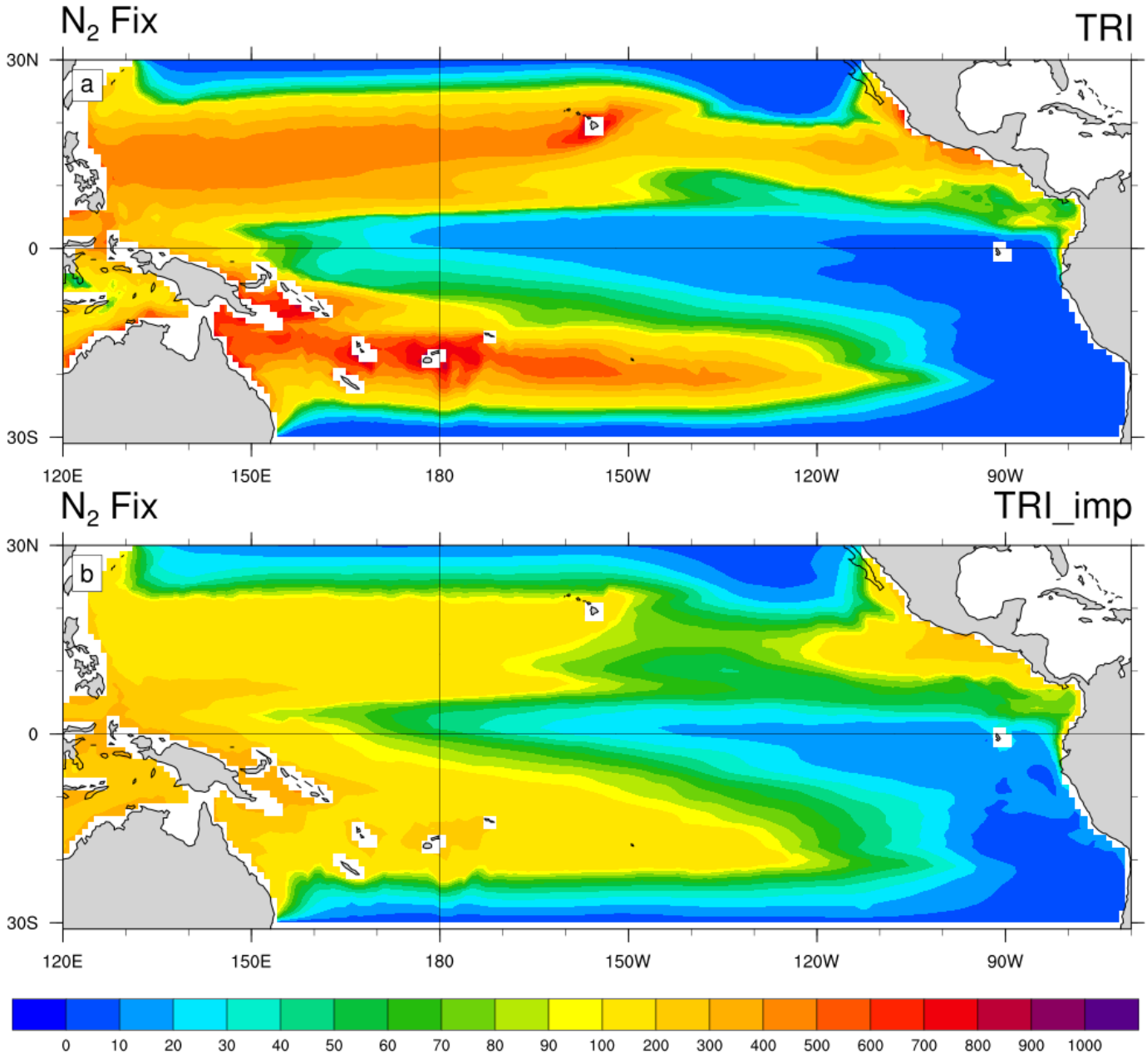


Figure Supp. 2

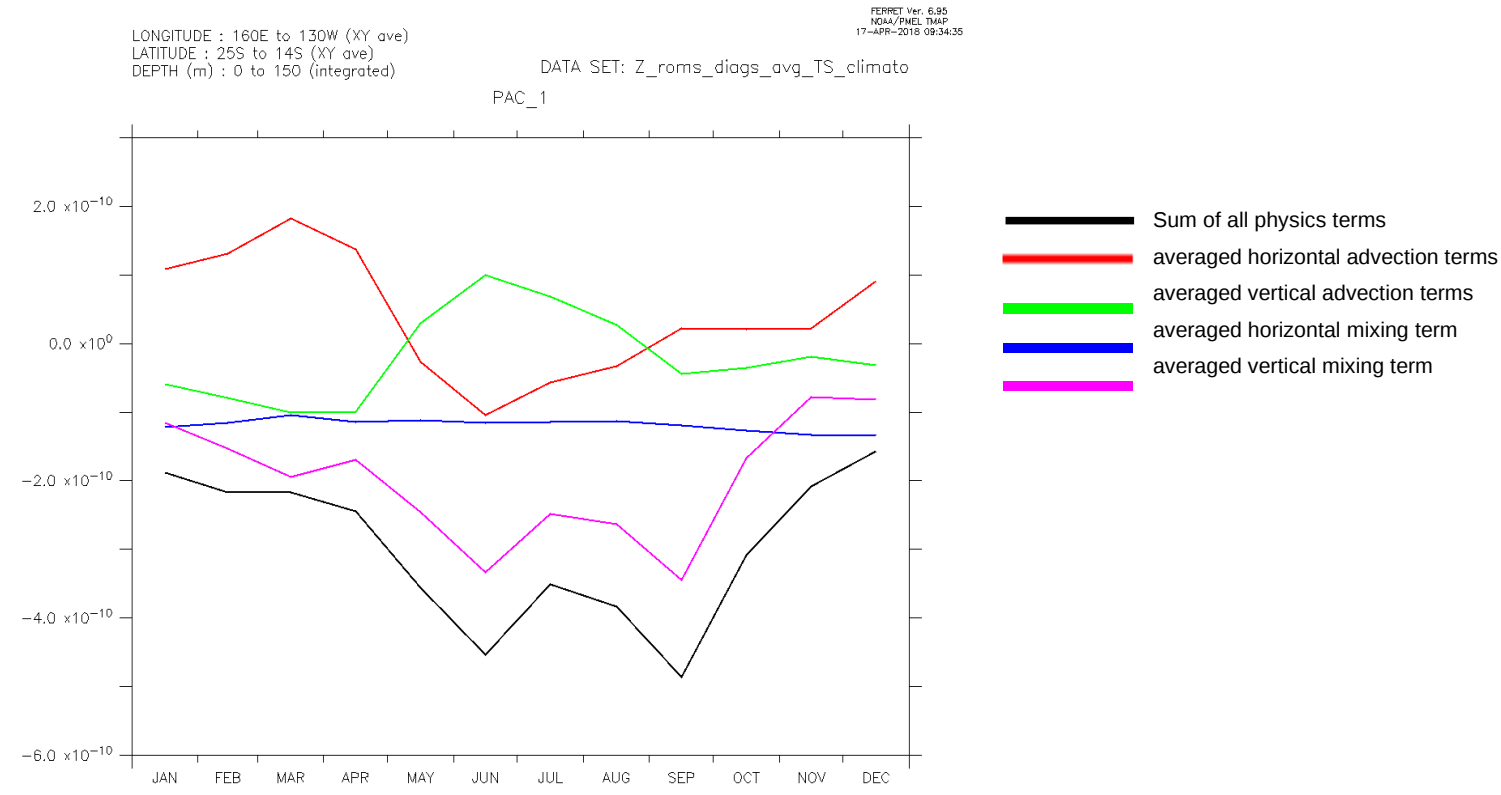


Figure Supp. 3

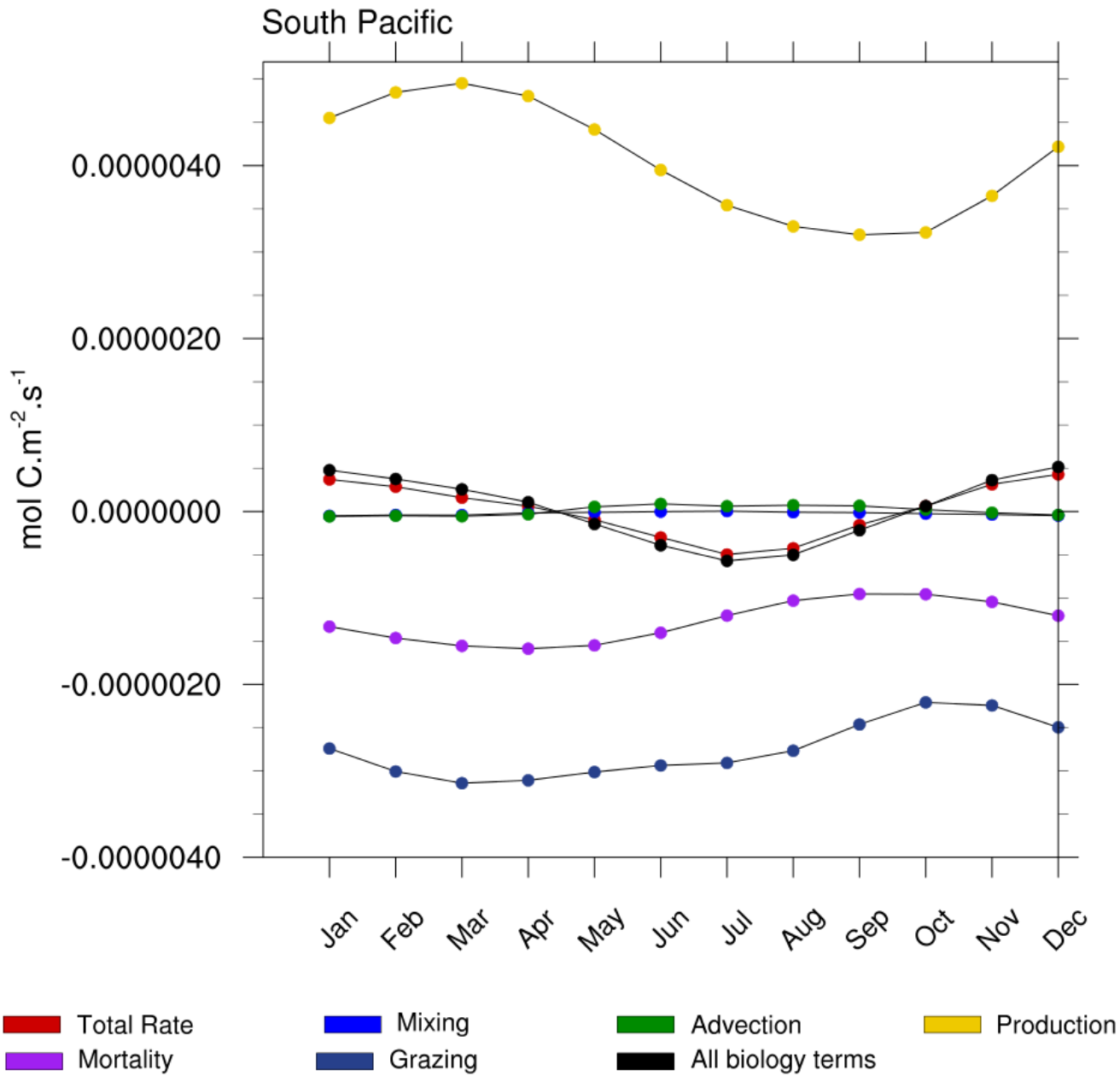


Figure Supp. 4