Machine learning estimates of nitrogen fixation in the global oceans and comparison to other models

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Introduction

• Marine nitrogen (N₂) fixation is an important biogeochemical process, which supplies “new” nitrogen to the global oceans, supporting oceanic uptake and sequestration of carbon (1-2). Despite the central role of N₂ fixation, its controlling factors remain elusive and estimates of its magnitude vary substantially (3).


• Machine learning techniques have increasingly been applied to marine sciences, e.g. simulating global net community production (6).

• Aim: To identify strong predictors of N₂ fixation, to predict N₂ fixation distribution using machine learning methods and finally to compare our estimates to the ones derived by other models.

Methods and data

1. Global N₂ fixation dataset (Figure 1) is updated, representing ~80% increase in the size of observations compared to Luo et al (2012) dataset.

2. Deep-integrated N₂ fixation rates are matched with various environmental factors spatiotemporally (Figure 2).

Primary studies used to compare with our estimates:

- Daily: solar radiation, wind speed (NCEP/NCAR)
- Monthly: sea surface temperature, photosynthetically available radiation, chlorophyll a concentration (NASA Ocean Color)
- Annual: oxygen concentration (WOA); mixed layer depth (7)

Data are binned into 2°×2° resolution after matching.

3. Random forest (RF) and support vector regression (SVR) are applied to simulate N₂ fixation using compiled environmental factors. Models were trained with randomly selected training dataset (70% of total) and evaluated using the test dataset (30% of total), shown in Figure 3.

4. Other model outputs (Figure 4)

CMIPS: CanESM, CNRM, GFDL, IPSL, MPI, CESM-BGC

Literature: Richer and Christian (2018); Jickells et al (2017); Paulsen et al (2017); Landolfi et al (2015); Luo et al (2014) (4, 8-11). All the model outputs are re-gridded into 2°×2° resolution.

Results

No single predictor is strongly correlated with N₂ fixation rates at global scale.

Machine learning methods can predict observed N₂ fixation fairly well.

Large discrepancies exist among various models in terms of the predicted distribution and magnitude of marine N₂ fixation.

Conclusions

• Weak correlation between N₂ fixation rates and single environmental factor suggests N₂ fixation may be controlled by a complex interplay of multiple factors.

• Modeled N₂ fixation fluxes by RF and SVR at 59 and 82 Tg N yr⁻¹ respectively from 50°S to 50°N are in line with previous estimates but in the lower end of other models.

• Large uncertainties in model predictions argue for increased and more coordinated efforts to explore oceanic N₂ fixation using geochemical tracers, modeling, and observations over broad oceanic regions.

References


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