Mapping of monthly climatology of global ocean surface nutrient by a feed forward neural network

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Feed forward neural network (FNN) is one of neural network families and a software applicable for oceanographic mapping has been developed by Zeng et al. [1]. The method has already been applied for sea surface fCO_2 mapping with SOCAT data products [2] and reasonable performance was obtained [1]. Since seasurface nutrients, such as phosphate, nitrate and silicate, are important parameters for ocean biogeochemical cycles, we tried application of FNN to global mapping of these nutrients combining several observational datasets. The dataset, having global coverage, is World Ocean Database 2013 by NODC/NOAA. In Pacific region, we have more detailed surface ocean datasets from ship-of-opportunity programs by NIES (National Institute for Environmental Studies, Japan) and IOS (Institute of Ocean Science, Canada). In this study we combined these data sets and some were added from Pacific hydrographic data set, PACIFICA (Pacific Ocean Interior Carbon dataset). Relationship between sea surface temperature, sea surface salinity, mixed layer depth and satellite observed chlorophyll-a were put into a coordinated format and the FNN was trained with the nutrient data sets with temporal and locational variables (month, latitude and longitude). Monthly climatological maps with 1x1 degree latitude and longitude resolution for phosphate, nitrate and silica were obtained and error of estimation was examined by comparison with the training datasets. The evaluation was feasible for oceanic regions of relatively high nutrient concentrations such as North Pacific, Southern Ocean, North Atlantic, and East Pacific Equatorial upwelling regions. The nitrate biases were -0.24 ± 0.62, -0.27 ± 0.72, -0.57 ± 0.81, and -1.21 ± 0.88 micro M, respectively for these oceanic regions. The performance was comparable for another mapping study using different neural network scheme by Yasunaka et al. for North Pacific [3], even this study was the global mapping. The larger bias and standard deviation for Equatorial Pacific should be caused by ENSO variability. Avoiding lack of high latitude coverage caused by missing satellite chlorophyll-a dataset in winter season, FNN estimation without chlorophyll-a dataset was evaluated for the three nutrients. Errors for nitrate and silicate changed seasonally, which were larger in summer and smaller in winter. This is due to relatively uniform distribution of the nutrients in winter overturning period and increasing patchness in productive summer period. However, error in phosphate estimation showed no seasonal change. Estimated map with and without chlorophyll-a showed some differences related probably due to biological productivity. We compared maps of silicate/nitrate ratio with and without chlorophyll-a dataset in the North Pacific. Higher silicate/nitrate ratio areas were detected in the subarctic north western Pacific HNLC region in late summer only in the maps with chlorophyll-a dataset. Figure 1 shows silicate/nitrate molar ratio for global ocean (upper panel), where silicate and nitrate concentrations are more than 4 and 2 micro M, respectively. Uniform ratio around 1.5 is observed in the high latitude North Pacific but more variability in the southern ocean of summer. Increasing silicate/nitrate ratio is observed in the western high latitude North Pacific in August and September. This may be related to the changing control of diatom productivity by micro nutrient supply.

[1] Zeng et al. (2014) JAOT 31, 1838-1849. [2] Pfeil et al. (2013) ESSD 5, 125-143. [3] Yasunaka et al. (2014) JGR 119, 7756-7771.

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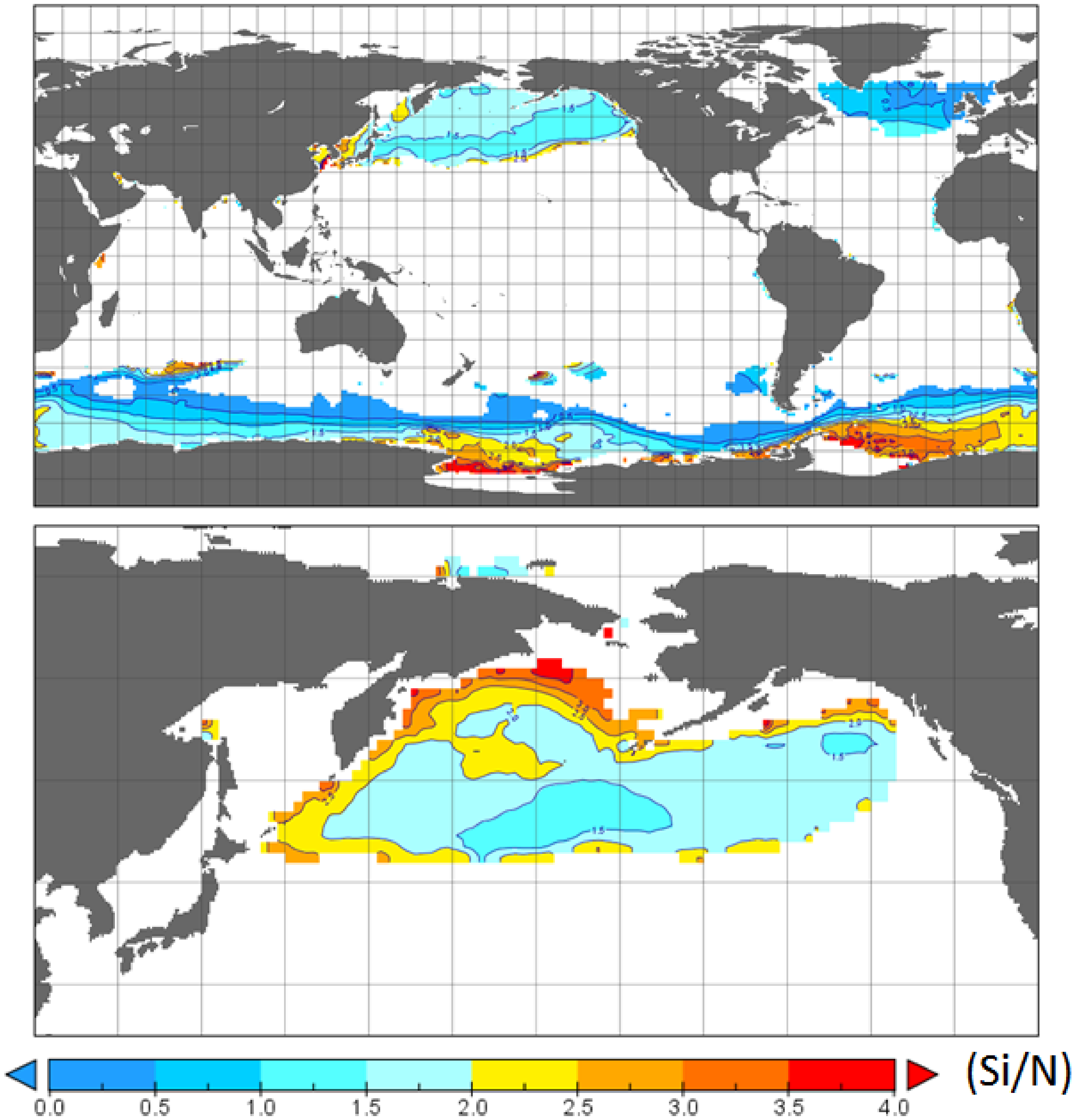

Figure 1. Silicate/nitrate molar ratio map of February for global ocean (upper panel) and August for North Pacific (lower panel) estimated by FNN