Global export flux and regional functionality of biological pump; a result from JGOFS sediment trap programs since 1982

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It has become clear that the export of atmospheric CO_2-carbon to the ocean interior by biological pump is a result of the interplay of all the oceanic particles. The removal of particulate organic and inorganic carbon from the productive ocean layers to the interior sink is the most critical process in the operation of the biological pump that contributing to the CO_2 cycles. However, the gross specific gravity of highly hydrated photosynthetic organic carbon particles is lighter or equivalent to that of the seawater. Particulate organic carbon (Corg) is only allowed to depart from the upper ocean layers in aggregates whose gross specific gravity is ballasted by substantially heavier particles. We found that $CaCO_3$ particle flux is taking the critical role to remove organic carbon from upper oceans to the deeper sink as ballast. In regard to the ballasting effect, export flux of biogenic silica in opal (Sibio) is not as important as we suspect; the amount of transfer efficiency of settling particles (TECorg) that contained >30 % of $CaCO_3$ is far greater than the amount of settling particles with >50 % of Sibio. Lithogenic particles are efficient ballasts for bringing the TEC-org to similar a level as what $CaCO_3$ does, however, the area where large quantities of lithogenic particles are limited in the world ocean therefore its global effect is insignificant. Thus we reached to an algorithms to estimate organic carbon flux based on ballasting effects of other oceanic particulate matters (Francois et al., this meeting).

The algorithms for Cinorg (C in biogenic $CaCO_3$) and Sibio fluxes were modeled directly from the sea surface temperature and primary production. Sibio in the moderate climatic zones where seasonality was recognized were calculated from the sea surface concentration of SiO_2 in winter. Sibio in the Equatorial Oceans and Arabian Sea was estimated from primary production. Algorithms for Cinorg and Sibio were optimized using the observational flux data as Corg. Global distribution of the three elements in 250 km-grid were composed and the global fluxes of these elements at 2,000 m were estimated by summing the fluxes representing all individual cells.

Thus our estimate of annual global fluxes of Corg, Cinorg and Sibio using the data since 1983 are 36.2, 33.8 and 34.6 Tera-Moles, respectively. The range of annual global organic carbon is about 0.2 to 25 gC m^{-2}. Global distribution of annual Cinorg is less variable than the other two criteria and ranges from 0.2 to 10 gC m^{-2}. The range of annual Sibio was as wide as 0.5 to >100 gSi m^{-2}. The global biogeochemical ratios, Corg/Cinorg, Sibio/Corg and Sibio/Cinorg are amazingly similar, approximately 1.1, 1.0 and 1.0 in our estimate. Global distribution of Corg/Cinorg is monotonous ranging from 0.5 to 6, except in a part of the Southern ocean where this value reaches >10. The range of Sibio/Cinorg is 0.2 to 50 and by far the largest among the above mentioned biogeochemical ratios. The oceanic region where Sibio/Cinorg is maintained consistently at >10 is clearly demarcated from low latitudinal, moderate ocean and forming clear zones what can be identified as silica ocean in the higher latitudinal regions in the North Pacific and in the Southern ocean.

We thus propose to distinguish three functional oceanic provinces based upon the ternary mole ratio among Corg Cinorg and Sibio: the Organic Carbon Ocean (the Polar Oceans) Carbonate Ocean and Silica Ocean. The removal of photosynthetically produced $CaCO_3$ also withdraws alkalinity from the surface ocean reducing that ocean's capacity to absorb the atmospheric CO_2. A silica ocean situation, defined as oceanic regions where the ratio of biogenic silicon flux (Sibio) to inorganic carbon flux (Cinorg) is larger than 1 (in mol-ratio), reduces the surface alkalinity in far less extend. However, TEC-org is smaller than in the case of the carbonate ocean where Sibio/Cinorg is <1. This indicates that fewer organic carbon particles penetrate the Mesopelagic layer under a silica ocean than under a carbonate ocean. Therefore, hypothetically, the settling organic carbon in the silica ocean would be more remineralized in the Mesopelagic layer thus an intermediate layer can be a significant CO_2 sink. However, more organic carbon particles can reach the deeper oceanic interior under a carbonate ocean condition.