Sea Surface Nitrate and Nitrate Based New Production - two innovative research products from SGLI on board GCOM-C

ALGORITHM THEORETICAL BASIS DOCUMENT

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I. Introduction:

Ocean ecosystems play a critical role in the Earth's carbon (C) cycle through net primary production (NPP) processes that fix dissolved CO_2 into organic matter in the well-lit, surface oceans, and C export into the deep ocean via the biological pump (*Siegel et al., 2015*). A major fraction of this C transported (export carbon) into the oceans' interior is associated with allochthonous nitrogen inputs, primarily inorganic nitrate into the euphotic zone *(Eppley and Peterson, 1979; Dugdale and Goering, 1967)*. In oceanic regions outside of coastal marginal zones, and away from the influence of terrestrial inputs, inorganic nitrate inputs from below the euphotic zone represent a very important source of new nitrogen. Hence, understanding the spatial and temporal variations of inorganic nitrate in the euphotic layer over basin and global scales is an important requirement for ocean biogeochemical process studies *(Fasham et al., 2001)*.

Despite its importance, nitrate data obtainable by traditional shipboard techniques fall far short of the spatial and temporal scales required for global climate research. This is especially true for high latitude areas which continue to remain chronically under sampled, particularly in winter when shipboard expeditions are difficult to conduct. Yet high latitude regions are important sinks for atmospheric CO_2. Most observational and modeling studies of C export (*Strass and Woods, 1991; Glover et al., 1994*) rely on nitrate maps constructed using multi-year data sets such as that of the NOAA National Oceanographic Data Centre (NODC) Atlas (*Garcia et al., 2010*). For climate-change and ocean C cycling studies, when the purpose is to study interannual variations in C export, the utility of these climatological maps is rather limited.

Satellites have been suggested as a useful alternative, but although they can provide frequent, large-scale, near surface views of several variables relevant to phytoplankton ecology such as incident radiation, chlorophyll *a* and sea surface temperature (SST), nitrate measurements from space have remained elusive as most nutrients including nitrate lack an electro-magnetic signal that can be exploited from space.

This document presents the algorithm theoretical basis for deriving sea surface nitrate and nitrate based new production from satellite data.

II. Sea surface nitrate algorithm

There have been previous attempts to estimate seawater nitrate concentrations using proxies, one being temperature which bears a strong inverse relationship with N (*Kamykowski and Zentara, 1986*). This is because seawater temperature and nitrate concentrations are tightly coupled as major inputs of nutrients into the euphotic zone occur through the intrusion of colder, nitrate-rich waters from deeper depths. Although empirical algorithms based on SST and nitrate relationships have been in existence for quite a while (*Chavez et al., 1996*) their application over large temporal and spatial domains has been frustrated by the time and space varying nature of the relationship (*Garside and Garside, 1995; Chavez et al., 1996*). One reason for these variations is that SST-nitrate relationships, is that the algorithms do not account for changes in nitrate that arise from phytoplankton photosynthesis and growth (*Goes et al., 1999; 2000;Silio-Calzada et al., 2008; Hutahaean et al., 2010*).

We have shown previously (*Goes et al., 1999; 2000*), that if biologically mediated changes in the character of temperature-nitrate relationships are taken into account, remote sensing can be exploited to provide high-resolution maps of sea surface nitrate that are valid over much larger scales than previously possible. Chlorophyll *a* was chosen as a predictor biological variable, largely, because of its known relationship with sea surface nitrate in the euphotic zone, and its accessibility from space in conjunction with SST. In our earlier studies we used data from several cruises to the North Pacific Ocean, covering different water types and different seasons were used to develop a set of algorithms that could predict SSN from T and Chl a.

The algorithms for nitrate take the general form as follows:

$$\text{Sea surface nitrate} = f_1(\text{SST}) - f_2(\text{Chl a})$$

III. Nitrate-based new production algorithm

In *Goes et al. (2000)*, we show how SSN maps could be exploited to estimate new production fueled by the supply of nitrate inputs during winter convective mixing in the subarctic Pacific Ocean. In high latitude regions this input of nutrients supports the largest fraction of new production occurring annually in the world's major ocean basins (*Strass and Woods, 1991; Glover et al., 1994*). By estimating the drawdown of nitrate within the euphotic zone over the growth season, we showed that it was possible to obtain estimates of C export that compared well with traditional shipboard sediment trap C export flux measurements. Although these new production estimates represent a lower bound estimate for total global ocean export production (as it does not account for C export that could result from other new nitrogen inputs into the system such as from N_2 fixation or aerosol dust inputs into the ocean etc.), they do provide a synoptic view of high-C export areas and regions where the dominant drivers are convective overturning and coastal upwelling.

The algorithm for nitrate based new production, takes the following form

$$\text{Nitrate based new production} = [\Sigma_{ED} [NO_3(0) - NO3(t)] * R]/t$$

Where $=\Sigma_{ED} [NO_3(0) - NO3(t)]$ is the amount of nitrate drawn down from the euphotic zone over the growth season (for instance from the start of the spring bloom in March, to the end of the summer bloom in Sept. in the North Atlantic or North Pacific) of phytoplankton and R is the factor for converting nitrogen into C units and t is the time interval over which nitrate drawdown is calculated.

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