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Science Story

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Development of Chlorophyll Product

Scientists in National Remote Sensing Centre (NRSC),in collaboration with INCOIS, developed a new Chlorophyll product synthesizing satellite ocean colour and *in-situ* observations

A 3-dimensional gridded chlorophyll product is generated using the BioGeoChemical Argo (BGC-Argo) float measured chlorophyll fluorescence profiles. The time period considered for this study is from 2013 to 2020.BGC-Argo chlorophyll profiles were captured in the northern Indian Ocean and were calibrated using Remote Sensing data. Generated a 1^{o} x 1^{o}gridded 3D product using the calibrated profiles on a monthly scale.

Euphotic Depth

The euphotic depth is the depth in water below the surface where photosynthesis can occur. This is important for aquatic ecosystems as it is where primary producers, such as phytoplankton, create energy through photosynthesis that supports the food chain. Light availability can limit the euphotic depth, which can have implications on the health of the water body and the organisms that rely on it.

BGC-Argo Float – Principle

Biogeochemical Argo (BGC-Argo) float provides an automated platform to collect the biogeochemical parameters like chlorophyll, dissolved oxygen, nitrate, downwelling irradiance etc., apart from the traditional parameters like the temperature and salinity profiles. BGC-Argo float network has enhanced the coverage of *in-situ* chlorophyll profile measurements during the last decade to enable the assessment of phytoplankton biomass in the subsurface on varying scales.

An Argo float is an autonomous Lagrangian instrument that measures the subsurface structure of temperature, salinity and other biogeochemical parameters in the ocean. Argo float works on the Archimedes' principle that applies the mechanism of modifying the volume while keeping the mass constant through a system of reserve oil and a bladder. A hydraulic actuator is used to deflate the bladder thereby the float sinks to the subsurface and vice-versa to ascent towards surface while measuring the ocean

parameters. The data transmission to data centres is through Argos satellite system. These pre-programmed floats are deployed from ships at different locations across the global oceans by various designated agencies. The typical measurement cycle of a float is 10 days and up to 2000m depth, however, it could be adapted based on the deployed location and requirement.

Figure 1. Schematic diagram of a BGC Float (Courtesy: Roemmich et al., 2019; https://doi.org/10.3389/FMARS.2019.00439)

Scientific Rationale

Phytoplankton biomass is a vital component in the global carbon cycle. Chlorophyll-*a* concentration (Chl-*a*) is considered as a proxy to estimate phytoplankton biomass. The spatial and temporal distribution of 'Chl-*a*' is well understood on a global scale due to the synoptic remote sensing observations by ocean colour sensors. The delicate balance between phytoplankton growth and loss processes controls the response of phytoplankton populations to environmental changes on seasonal to decadal time scales, stressing the need for a better understanding of its spatio-temporal distribution and variability in the global ocean. Monitoring the subtle changes in the phytoplankton through its proxy 'Chl-*a*' demands high precision measurements which are often cumbersome and often under sampled if not unmeasured. However, the ocean colour remote sensing is limited to the surface layer which is also called as 'euphotic layer'. To overcome this limitation, a blended product by combining both in-situ from BGC-Argo floats and satellite observations is envisaged.

The chlorophyll fluorescence measured by BGC-Argo over estimates the chlorophyll concentration at the location by factor of ~2. Thus calibration for the region is more relevant. The direct usage of these datasets might lead to ambiguous outcome / over estimation in terms of productivity of a region. The chlorophyll fluorescence measured by a BGC-Argo float is obtained using the following equation:

Equation

$$Chl\text{-}a = \alpha * (Fluoro\text{-} \beta)$$

Where,

α : scale factor or gain

β : dark counts or offset

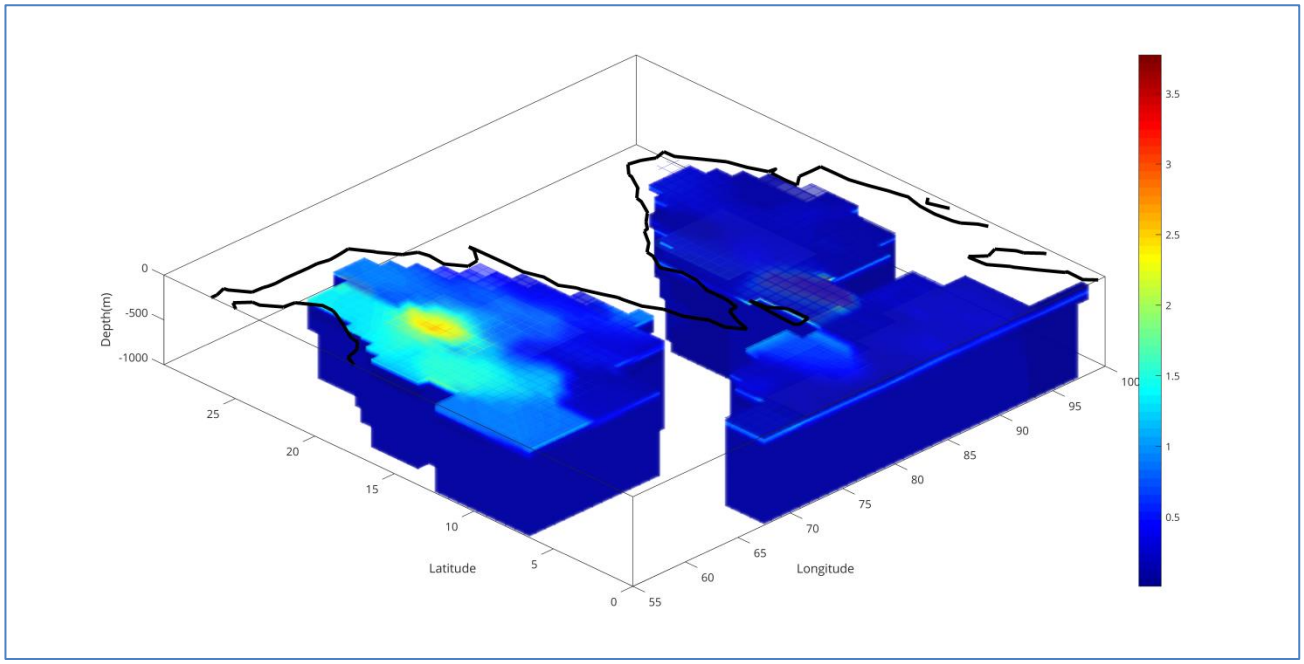
Calibration

The chlorophyll is obtained from Moderate Resolution Imaging Specroradiometer (MODIS) satellite – onboard Aqua satellite.Chlorophyll-a concentration measured by ocean color sensors is collocated with the Argo location to estimate the euphotic depth (Zeu) at the region. 63 floats deployed by ESSO-INCOIS in the northern Indian Ocean with 8263 individual profiles of Chlorophyll fluorescence were processed. Subsequently, BGC-

Argo measured chlorophyll is integrated between surface and 1.5 times the Z_{eu}. The scale factor (α) is obtained as a ratio of surface chlorophyll from remote sensing and the integrated chlorophyll for each individual profiles. The median of all the 'α' values is considered as the scale factor for that particular BGC-Argo float. Similarly, dark count (β) is obtained by taking the arithmetic mean of Chl-a values between 500 – 2000 m or the deepest depth available with each individual profile. Chl-*a* is nearly zero below 500 m, which accommodates the response of the instrument in the absence of the signal, usually the case in deeper waters. Thus, β of a particular float is determined as the median of individual means obtained from the individual profiles. Once the calibration coefficients of a float are obtained, the entire data measured by the float is re-generated.

Gridded Product

The objective analysis-based gridding was carried out in two steps. First the chlorophyll data C_n (x_n, y_n, z_n, t_n) for each profile n was linearly interpolated to standard depths (1 m from surface to 2000 m) thereby creating a modified data set C'_n (x_n, y_n, z_n, t_n). This interpolation was done only when two samples in a profile are within a selected vertical distance, which increased from 5 m in the surface to 100 between 500 – 2000 m. Second, in a separate computation at each standard depth Z0 the chlorophyll C'n were mapped from irregular grid locations (xn, yn, zn) to regular grid (x0, y0, z0) locations with a grid spacing of 1º X 1º.



The spatial variability of the Deep Chlorophyll Maximum (in terms of both depth and concentration) is mapped in the northern Indian Ocean region. Depth up to which the upwelling induced chlorophyll exists is clearly identified in the major upwelling zones of the Arabian Sea.

Takeaways

1. This method can be extended to other parts of ocean including Arabian sea and Bay of Bengal.

2. Uniform correction factor enables generation of products which can be used for inter-comparison, utilization in the initialization of biogeochemical models and assimilation of the profiles for improved model products.

3. The Chlorophyll content can be used as a proxy to characterize flora and fauna in the region as well as aquatic life.