EGU21-2957
https://doi.org/10.5194/egusphere-egu21-2957
EGU General Assembly 2021

Critical Depth Model – Primary Production by Phytoplanktons

Jayatu Kanta Bhuyan[1,2], Eiichi Furusato[3], and Subashisa Dutta[4]

[1]Department of Civil Engineering, Indian Institute of Technology, Guwahati, India (jayatubhuyan@gmail.com)
[2]Biozatra Science and Technology Pvt. Ltd., Guwahati, India (jayatu@biozatra.com)
[3]Institute for Regional Co-creation in Southern Kyusyu and the Nansei Islands, University of Kagoshima, Japan (eifurusato@km.kagoshima-u.ac.jp)
[4]Department of Civil Engineering, Indian Institute of Technology, Guwahati, India (subashisa@iitg.ac.in)

The spring bloom phenomenon in large regions of the world oceans have been studied for decades. However, the conditions necessary to trigger spring blooms remains uncertain till date. During the past decades several hypothesis appeared, the first being critical depth hypothesis - a conventional framework put forwarded by a Norwegian researcher H.U Sverdrup in the North Atlantic. His theory predicts that phytoplankton blooms occur when the mixing depth of the water column is less than a critical threshold value. This hypothesis proposed by Sverdrup (1953) to explain the occurrence of spring bloom of phytoplankton is known as critical depth (z_{cr}) in oceanography. Thus, the z_{cr} corresponds to the depth at which integral net photosynthesis is balanced by respiratory losses.

For the computation of the growth term to explain spring bloom of phytoplankton several alternative models have been proposed which are based on grazing and mixing processes, mathematical modelling and simulations, controlled and field experiments. Mathematical expressions have been extensively investigated by means of integro-differential equation models (Platt et al., 1991; Huisman and Weissing, 1994; Weissing and Huisman, 1994). Simplifying assumption such as use of linear P-I curve by Sverdrup, series solution based on a light saturation exponential model by Platt et al. (1991) and rectangular hyperbola model by Huisman (1999) are removed. Here, we focus on selecting a high accuracy P-I curve for estimating z_{cr}.

The most accurate photosynthesis-intensity relationship (P-I equation), a right-angle hyperbolic function, is proposed for critical depth evaluation. An exact analytical solution is presented by performing definite depth integrations of the right-angle hyperbolic equation and examining a method to obtain the equation by considering the mathematical characteristics. The series expansion equation including Bernoulli's number was used because the right-angle hyperbolic equation does not provide analytical solutions in definite integration. Moreover, since the integration range of this series equation is mathematically limited to π/2 or less, a new series of right-angle hyperbolic P-I equation is proposed by using polynomial approximation in the depth range up to the maximum photosynthetic rate (P_m). We, therefore present concise ideas for the estimation of z_{cr} limited to saturation type P-I curve by comparing the obtained equation with the critical water depths evaluated in previous studies. Furthermore, we suggest that future models of

bloom formation should include shape factor for water column to make realistic projections for engineering applications in inland water bodies.

References:

Huisman J (1999): Population dynamics of light-limited phytoplankton: Microcosm experiments, Ecology, 80(1), 202–210.

Huisman J & Weissing FJ (1994): Light Limited Growth and Competition for Light in Well Mixed Aquatic Environments: An Elementary Model. Ecology, 75(2), 507-520.

Platt T, Bird DF, Sathyendranath S (1991): Critical depth and marine primary production. Proc. R. Soc. Lond. B, 246(1317), 205-217.

Sverdrup, HU (1953). On Conditions for the Vernal Blooming of Phytoplankton. Cons. int. Explor. 18(3), 287-295.

Weissing FJ & Huisman J (1994): Growth and Competition in a Light Gradient. J. theor. Biol., 168, 323 – 326.