



What controls the initiation of phytoplankton bloom during the winter monsoon in the Arabian Sea ??

^{1,2}R. S. Lakshmi, ¹Satya Prakash, ¹A. A. Lotliker, ¹S. K. Baliarsingh, ¹A. Samanta, ^{1,2}Teesha Mathew, ¹Abhisek Chatterjee, ³Biraja Kumar Sahu, and ¹T. M. Balakrishnan Nair

1. Indian National Centre for Ocean Information Services, Ministry of Earth Sciences, Government of India, Hyderabad-500090, India
2. Kerala University of Fisheries and Ocean Studies (KUFOS), Kochi-682506, India
3. Atal Centre for Ocean Science & Technology for Islands, National Institute of Ocean Technology, Ministry of Earth Sciences, Government of India, Port Blair-744103, Andaman and Nicobar Islands, India



Introduction

- The productivity regime of the Arabian Sea is predominantly governed by seasonally reversing monsoonal winds and associated physical modulation in the water column.
- North-easterly continental cold-dry wind enhances evaporation and consequent densification of the surface waters resulting in strong convective mixing.
- The primary production in the Arabian Sea is mainly driven by the availability of nutrients, and absence of which can cause a decrease in the phytoplankton biomass.
- Availability of light : Regulates primary productivity.
- The critical depth criteria formulated by Sverdrup (1953) analyses the relationship between irradiance and mixed layer depth in determining productivity.

Objective

To understand the physical, chemical, optical and biological water column properties of the northeastern Arabian Sea during winter monsoon and to understand the interplay of physics and biology on the initiation of phytoplankton bloom.

Data & Methods

- Insitu Sampling : 4th to 13th February 2019
- Water samples were collected at six hours interval per day at each station up to 1000 m depth with upper 100 m being sampled at an interval of 10 m.
- The downwelling irradiance (E_d) and photosynthetically available radiance (PAR) was measured at each station using a hyperspectral optical profiler

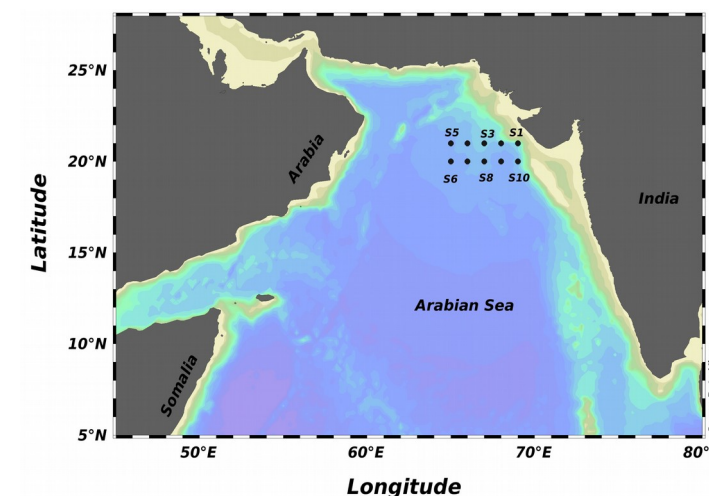


Figure 1. Map of the Arabian Sea showing sampling locations (S1 to S10).

- The Euphotic depth (Zeu), the depth at which the light intensity decreases to 1% of that at the surface, was calculated using the equation as follows.

$$Z_{eu} = 4.61/k_{PAR} \quad (1)$$

Where, k_{PAR} is the diffuse attenuation Coefficient based on Lotliker et al (2016),

$$K_{PAR} = 0.0168 + 0.97 k_d(490) \quad (2)$$

Result

Background environmental and biological condition

- Sea Surface Temperature : ~24°C
- Salinity : ~36.5-36.7 PSU
- MLD : > 100 m
- 23oC isotherm : ~110-125 m

- These physical characteristics clearly indicate an active phase of convective mixing.

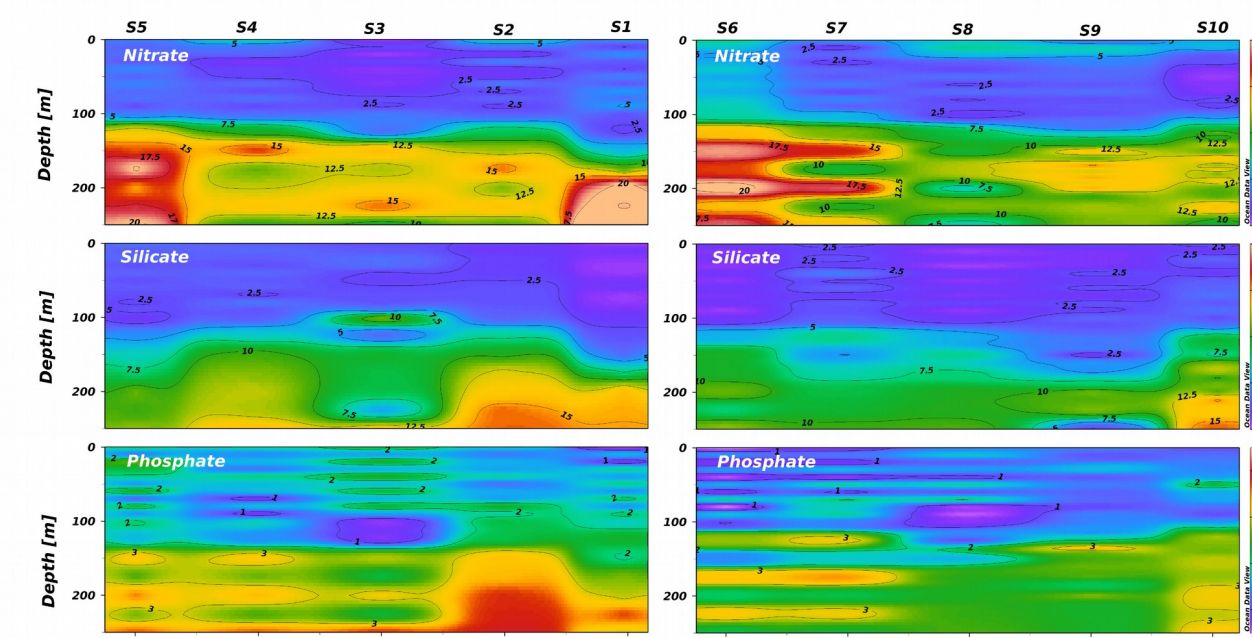


Figure 3. Vertical section of nitrate (µM), silicate (µM) and phosphate (µM) along 21°N and 20°N transects.

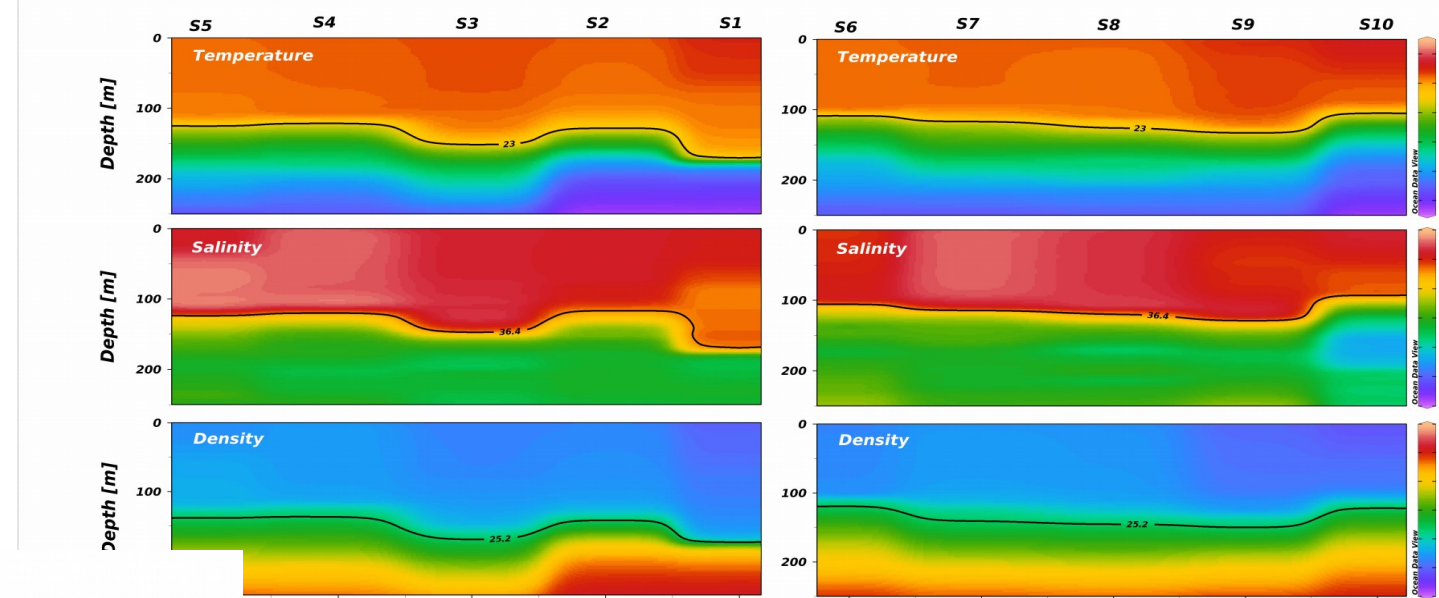


Figure 2. Vertical section of temperature, salinity and density along 21°N and 20°N transects.

- Observed Nitrate : ~2.5 µM
- Silicate Concentration : ~2.5 µM
- Phosphate Concentration : 1-2 µM
- DIN (Dissolved Inorganic Nitrogen; nitrate + nitrite + ammonium) : ~5 µM

Primary productivity and Observed Stoichiometric ratio of nutrients

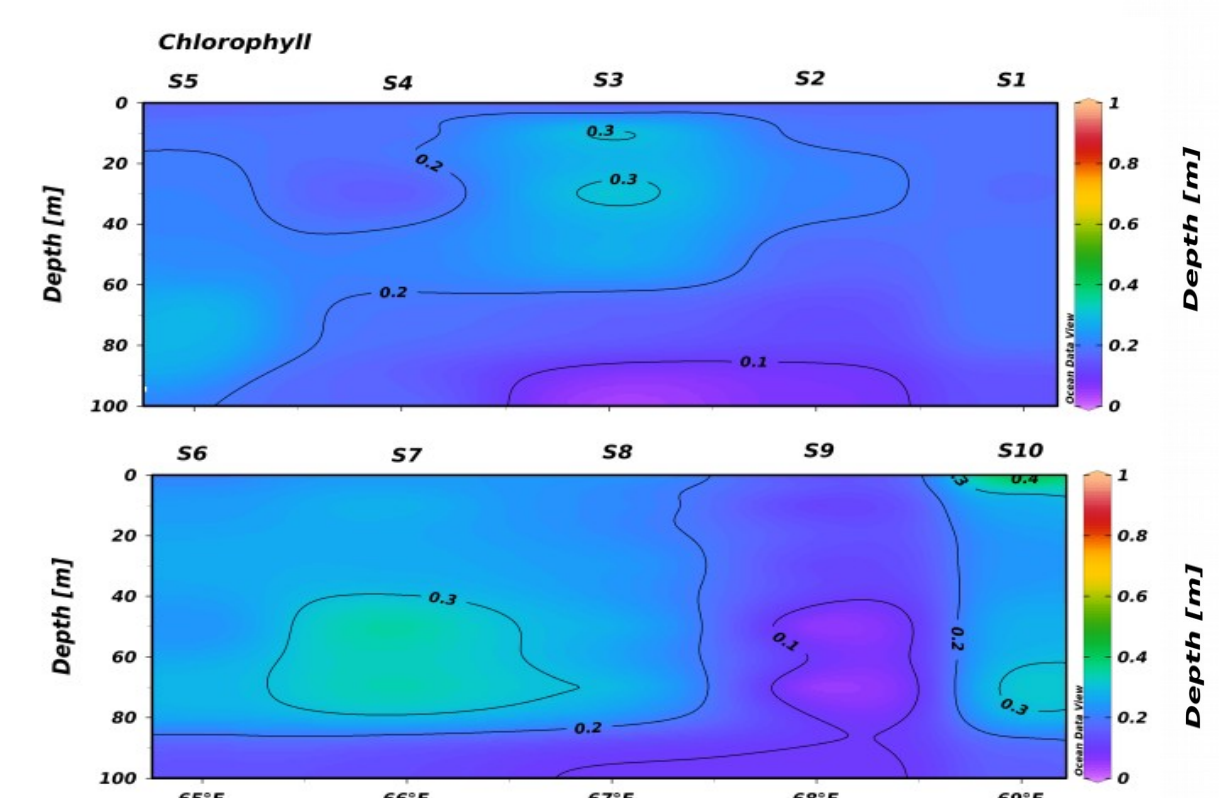


Figure 4. Vertical section of chl-a (µg/l) along 21°N and 20°N transects.

- chl-a concentration : 0.1 -0.3 µg/l, in the upper water column
- Si:N integrated for photic depth : ~ 0.52

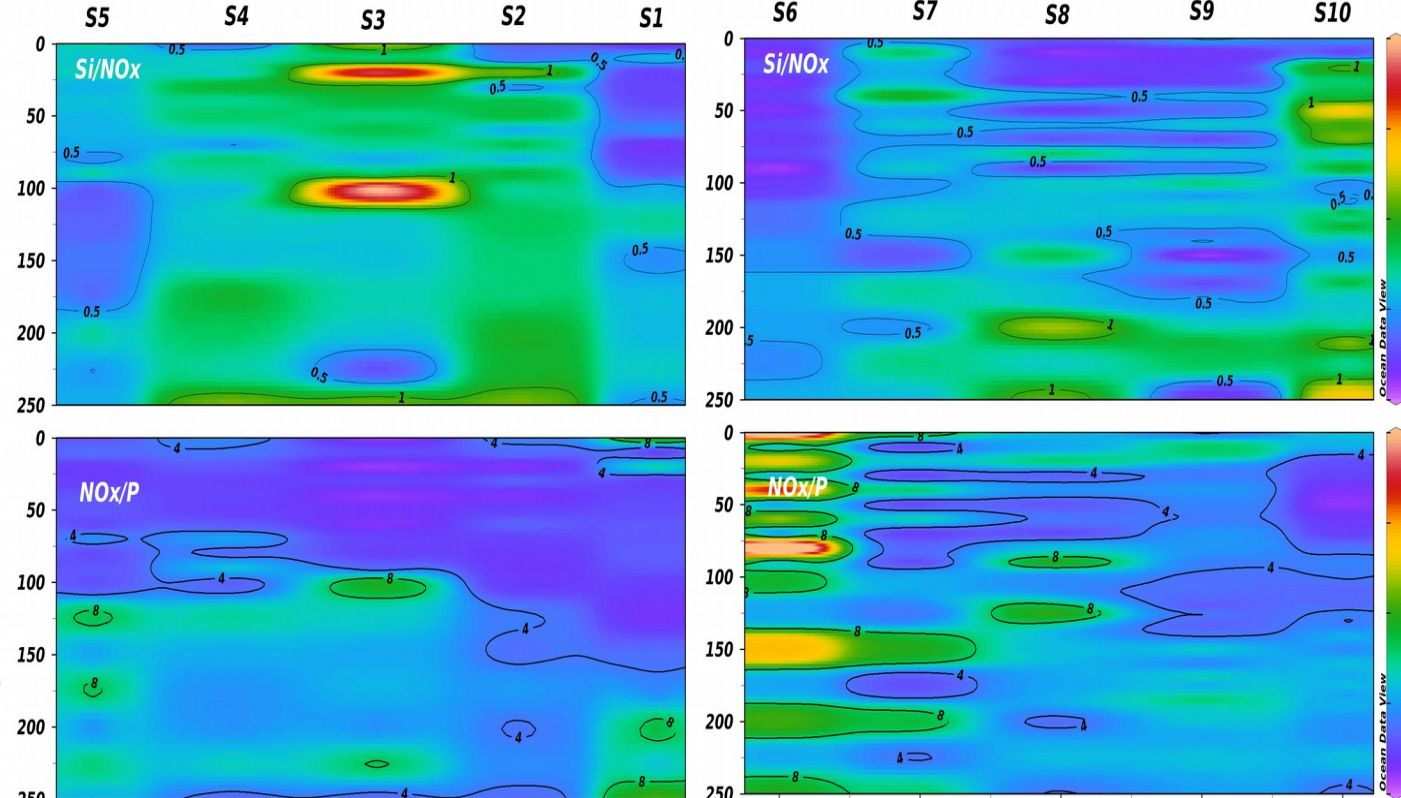


Figure 5. Vertical section of Si/DINNOx and DIN/P along 21°N and 20°N transects. DIN includes nitrate, nitrite and ammonium.

- Oxygen Saturation : 95:103%
- Diatoms and Noctiluca were absent, instead picophytoplankton dominated

Role of light limitation on the reduction of productivity

- The integrated chl-a concentration upto euphotic depth was very less (~40 mg/m²) despite of having very high nitrate concentration in the column (~200-300 µmol/kg).

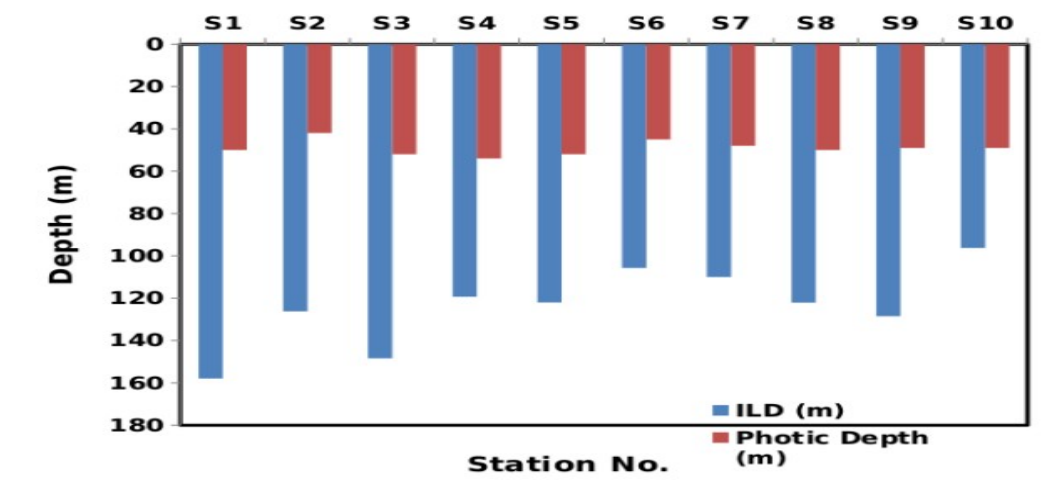


Figure 6. The bar diagram of euphotic depth (red) and mixed layer depth (blue) at 10 sampling stations.

- Our analysis of the MLD and Zeu shows that MLD was much deeper (~100-120 m) compared to the Zeu (~42-54 m).

- The surface chl-a (MODIS) varied between 0.2 to 2 µg/l.

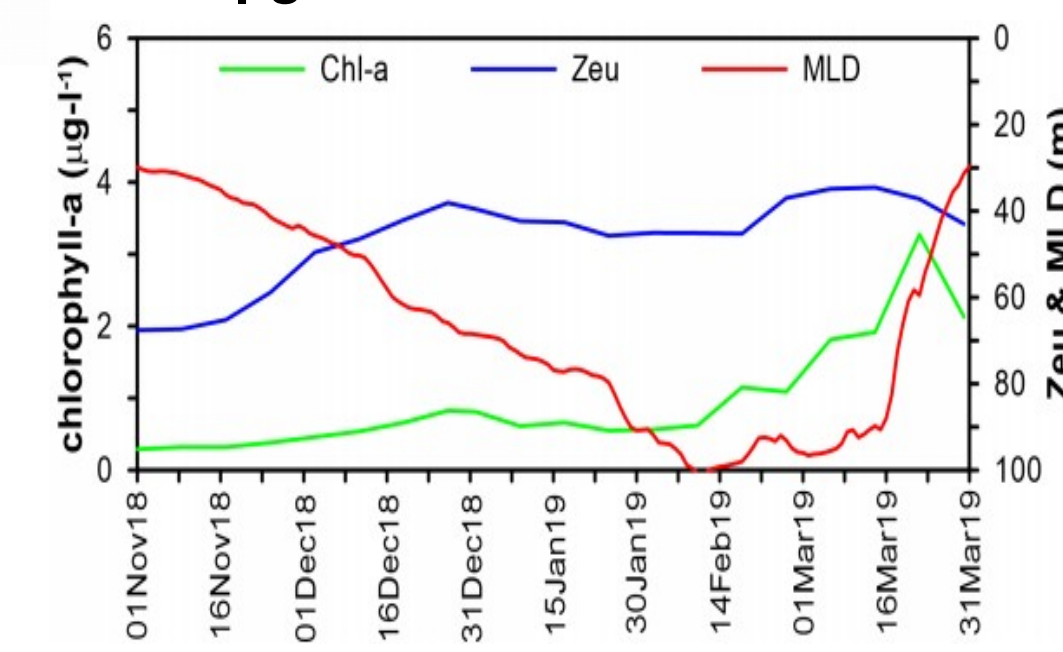


Figure 7. The time-series of simulated mixed layer depth (INCOIS- GODAS), satellite derived euphotic depth and surface chl-a.

The Sverdrup critical depth hypothesis holds true in the Arabian Sea during the winter monsoon.

- The increasing surface chlorophyll (chl-a) was concurrent with the shallowing of the mixed layer.
- The bloom appears to have occurred towards the 3rd week of March 2019.

The initiation of bloom depends on the re-stratification of the water column.

Conclusion

- The observational data show cooler, denser surface layer with a deep mixed layer and nutrient-rich upper surface layer.
- Despite harbouring higher nutrients, the chl-a concentration was lower than expected in the upper water column during the winter monsoon and was dominated by picophytoplankton, though the conditions were favourable for the Noctiluca to proliferate.

- The significant outcome of the present study is that two factors primarily control the phytoplankton bloom in the northern Arabian Sea during the winter monsoon: **1. the stoichiometric ratio of nutrients, mainly Si and DIN, input into the mixed layer and 2. re-stratification of the upper water column during the later winter monsoon.**

Contact me : lakshmi.s@incois.gov.in

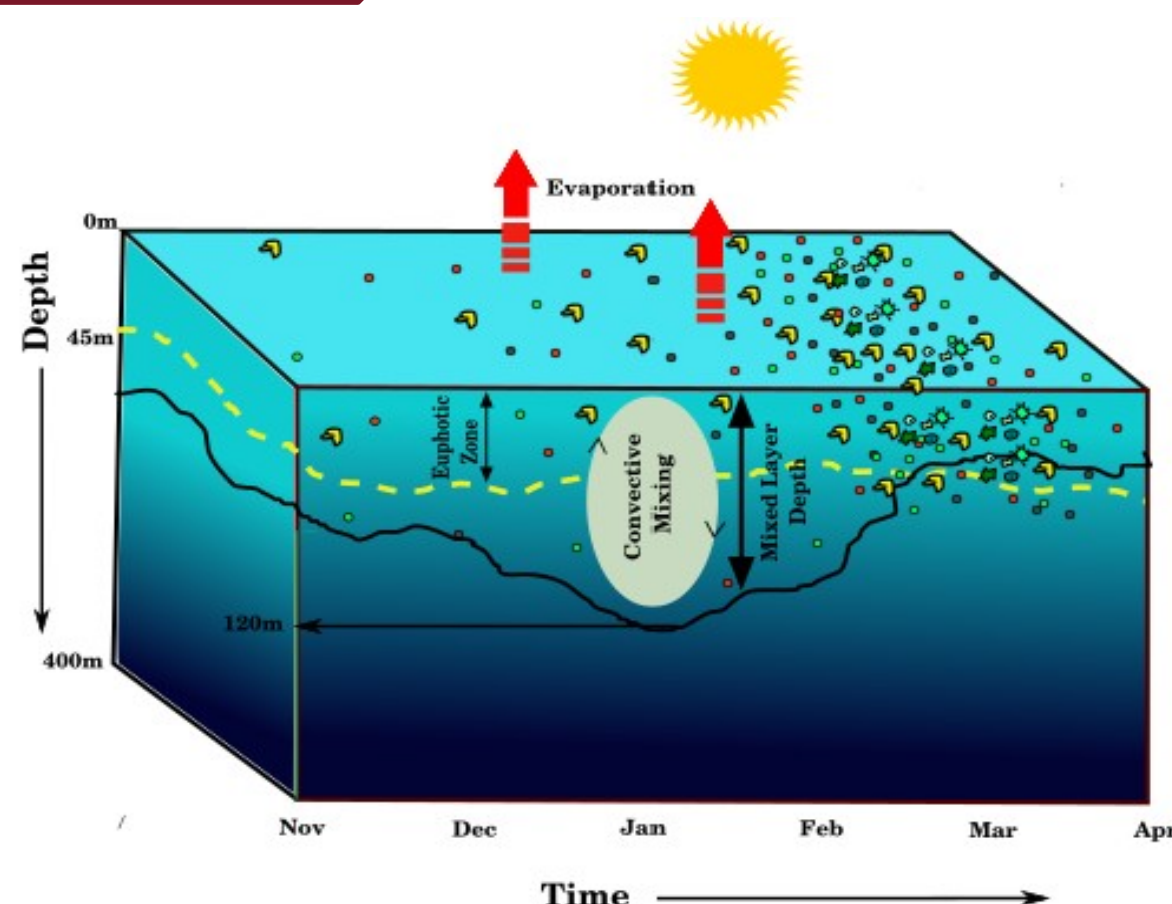


Figure 8: Schematic diagram which shows the interplay between mixed layer depth and euphotic depth on the initiation of phytoplankton blooms.

References

1. Sverdrup, H. On conditions for the vernal blooming of phytoplankton. J. Cons. Int. Explor. Mer 18, 287–295 (1953).
2. Lotliker, A. A., Omand, M. M., Lucas, A. J., Laney, S. R., Mahadevan, A., and Ravichandran, M. Penetrative radiative flux in the Bay of Bengal. Oceanography 29, 214–221 (2016).