MONITORING PHYTOPLANKTON BLOOM OCCURRENCE AND ITS ASSOCIATED PARAMETERS IN THE NORTH EASTERN ARABIAN SEA USING GHRSST DATA

GUIDED BY,

DR. RANJIT KUMAR SARANGI

SCIENTIST-SG

EPSA/BPSG/MED

SPACE APPLICATIONS CENTER (SAC) AHMEDABAD

PRESENTED BY,

GREESHMA K U

SUMINA

NIT-SURATHKAL

KARNATAKA, INDIA

INTRODUCTION

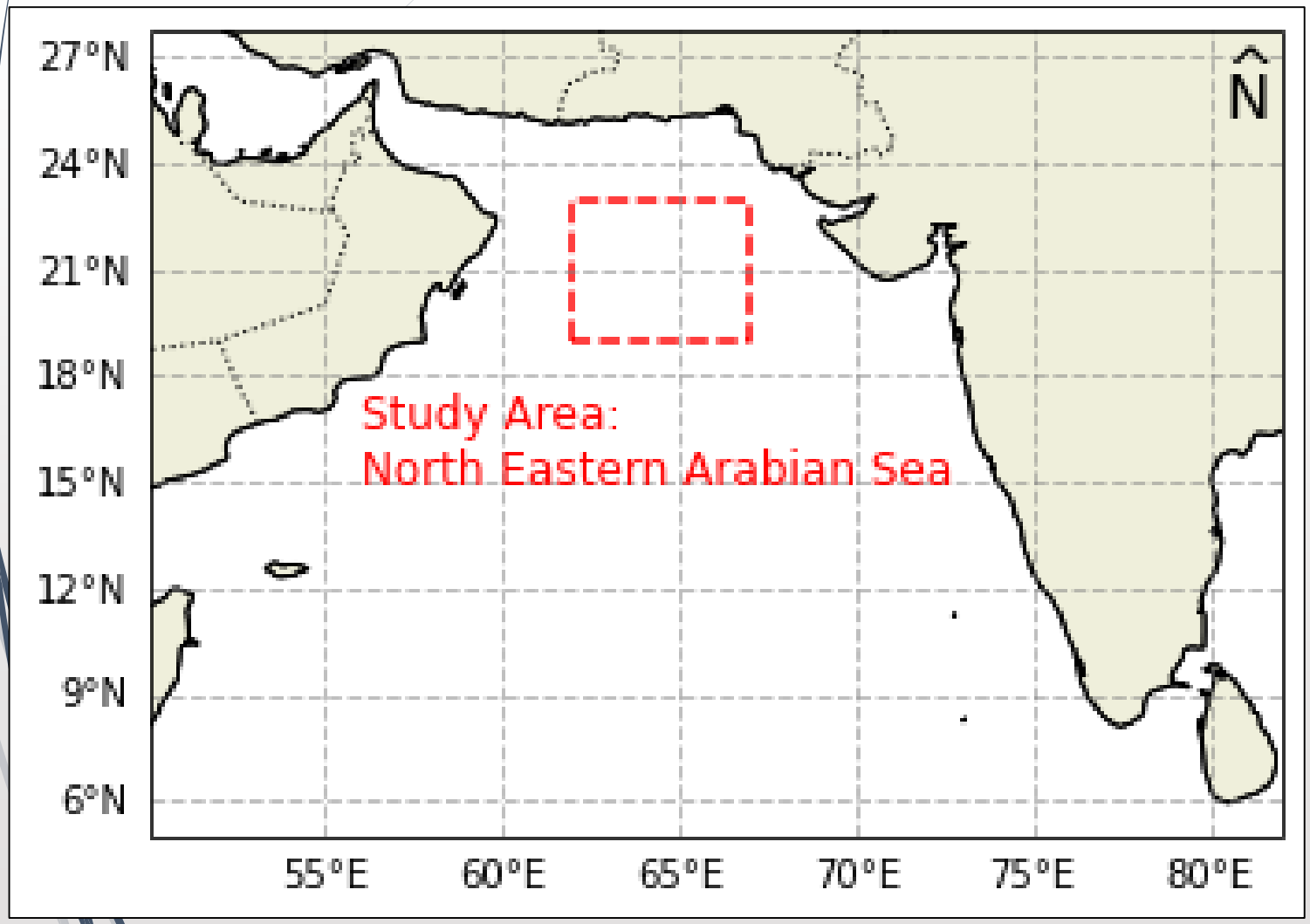
- The Arabian Sea is recognized as one of the world's most productive ocean regions, primarily because of the circulation driven by the monsoon.
- Over the last decade, there has been an increase in spatial distribution of phytoplankton bloom due to changing climatic conditions and seasonal patterns.
- Chlorophyll concentration is often used as a proxy for phytoplankton biomass.
- The synergistic analysis of chlorophyll and associated parameters holds the potential to unlock;
  - a deeper comprehension of oceanic dynamics
  - driving advancements in fisheries management
  - ecosystem conservation
  - climate change mitigation strategies

- SST is the proxy parameter to collocate and link with the upwelling phenomenon in seawaters.
- The chlorophyll-based productivity is enhanced due to upwelling and convection of nutrients in surface waters.
- Hence, SST plays a crucial role in identifying the existence of the upwelling phenomenon.
- **GHRSST** stands for the Group for High Resolution SST products mainly;
  - Level 2 pre-processed ("L2P") on the original swath projection
  - Level 3 composite (gridded with gaps) products formed using SST from either a single swath/scene (“L3U”), a single sensor but multiple swaths/scenes (“L3C”) or multiple sensors (“L3S”)
  - Level 4 analysed (gridded, gap-free) SST from multiple sensors/platforms ("L4")

OBJECTIVES

- To monitor the occurrence of algal bloom along the North Eastern Arabian Sea (19- 23°N & 62-67°E) for five years (2018-2022).
- To analyze the oceanic conditions that may trigger the algal bloom through parameters such as
    - Sea Surface Temperature (SST)
    - Chlorophyll-a concentration (Chl-a)
    - Sea Level Anomaly (SLA)
    - Wind speed
    - Photosynthetically Available Radiation (PAR)

STUDY AREA



- North Eastern Arabian Sea (19°N - 23°N & 62°E - 67°E)
- Algal Bloom Information Service (ABIS), INCOIS portal

Global Ocean Colour (Copernicus-GlobColour), Bio-Geo-Chemical, L4 (monthly and interpolated) from Satellite Observations (Near Real Time) – Chlorophyll a

- Spatial Resolution – 4*4 km
- Temporal resolutions: daily, **monthly** plus, for some variables, **daily gap-free** based on a space-time interpolation to provide a cloud-free product.
- Upstream sensors used are SeaWiFS, MODIS-Aqua & Terra, MERIS, VIIRS-SNPP & JPSS1, OLCI-S3A & S3B.
- Mass concentration of various algae species expressed as chlorophyll in seawater, **Phytoplankton Functional Type (PFT) and Phytoplankton Size Classes (PSCs);**

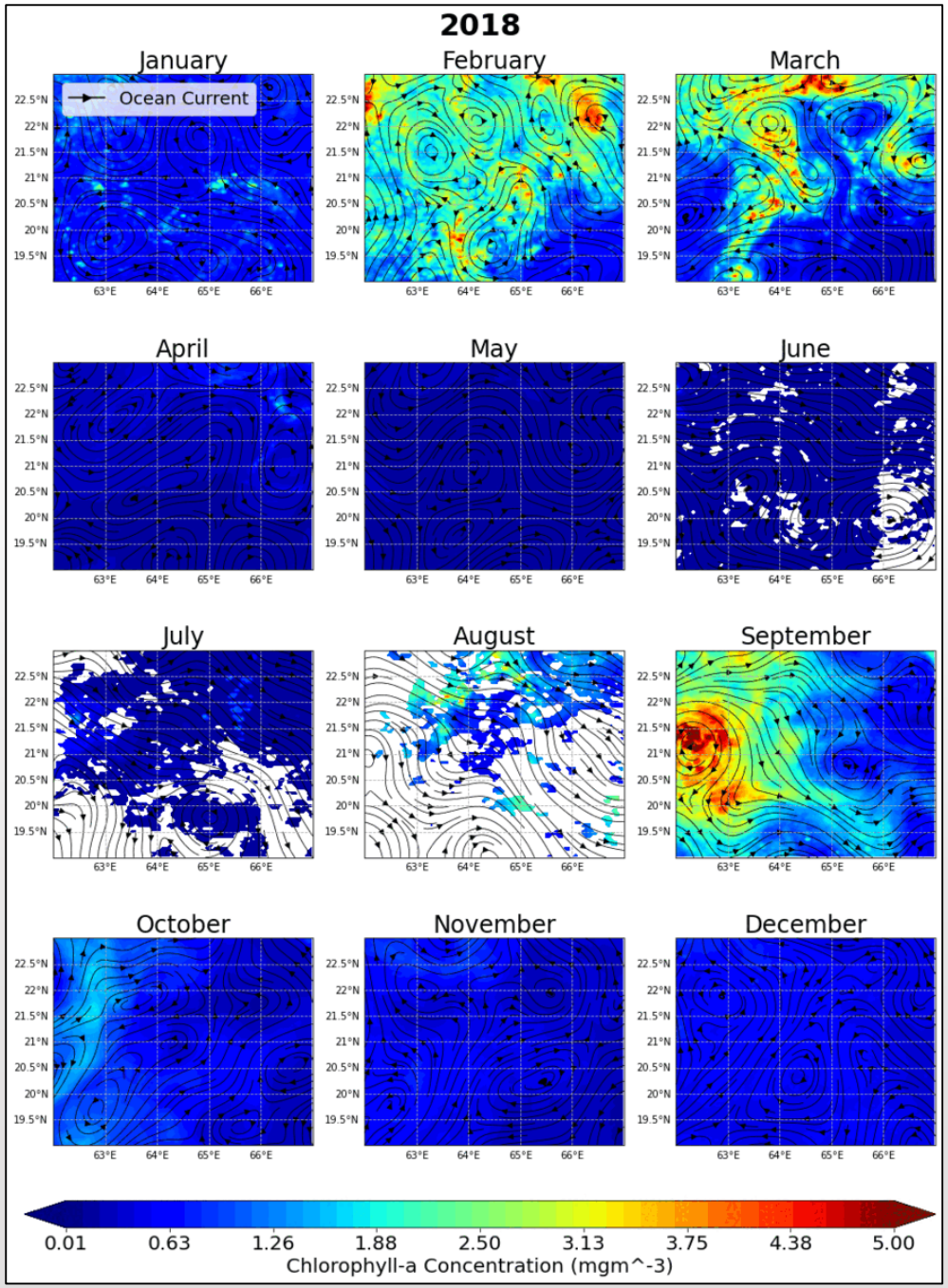
• Green algae	• Diatoms	• Micro phytoplankton	• Prokaryotes	• Picophytoplankton
• Haptophytes	• Dinophytes	• Nano phytoplankton	• Prochlorophytes	

OSCAR third-degree resolution ocean surface currents

- Data was accessed from NASA's PODAAC JPL website.
- Data are on a 1/3 degree grid with a 5-day resolution.
- OSCAR (Ocean Surface Current Analysis Real-time) contains near-surface ocean current estimates, derived using quasi-linear and steady flow momentum equations.
- The horizontal velocity is directly estimated from sea surface height, surface vector wind and sea surface temperature.

GLOBCOLOR CHLOROPHYLL MONTHLY ANALYSIS 2018 TO 2022 OVERLAID WITH OSCAR OCEAN CURRENTS

- For the study area; algal bloom was much observed over the chl-a range of 0.01 to 5 mg/m^3
- Algal bloom as chlorophyll patches was observed mainly during the months of February and March throughout the five years.
- Compared with other years, March 2019 showed a very high chl-a concentration.
- During the Southwest monsoon period July-September, chlorophyll patches were observed distinctly, especially for the year 2018.
- Current is moving the boom features in its direction with the bloom peak at the center of the ocean circulation features.

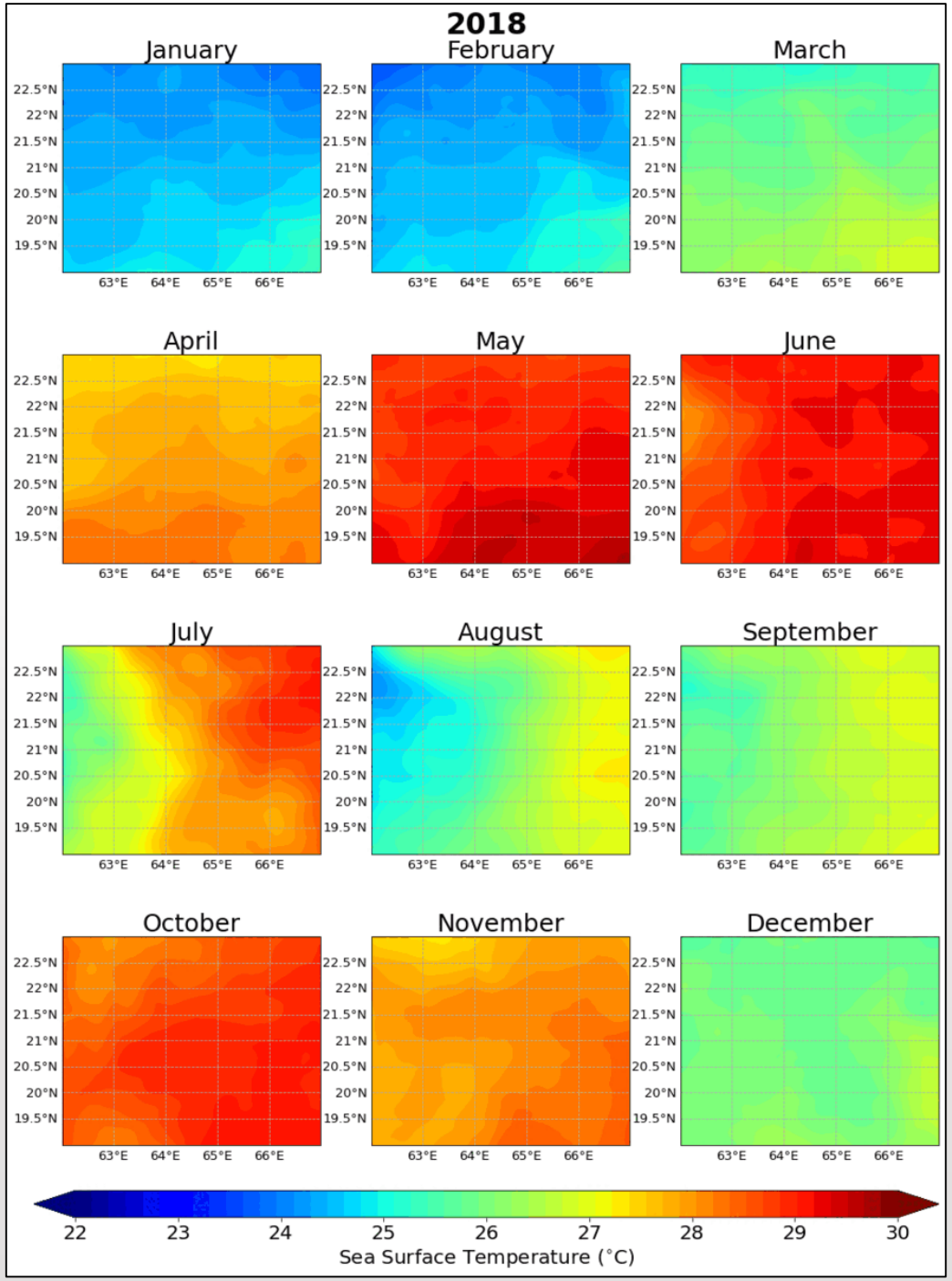


GHRSST Level 4 DMI_OI SST (DMI_OI-DMI-L4-GLOB-v1.0)

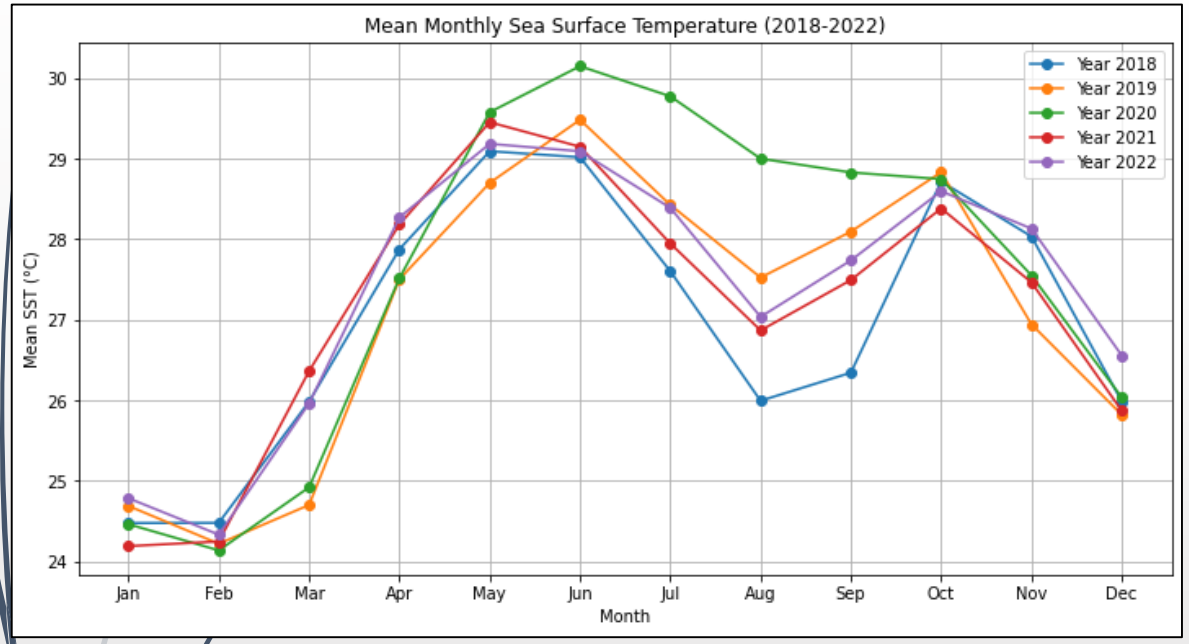
- Produced daily on an operational basis by the Danish Meteorological Institute (DMI) using an optimal interpolation (OI) approach on a global **0.05 degree** grid.
- The analysis is based upon nighttime GHRSST L2P skin and subskin SST observations from several satellites.
- The sensors include the Advanced Very High Resolution Radiometer (AVHRR), the Spinning Enhanced Visible and Infrared Imager (SEVIRI), the Advanced Microwave Scanning Radiometer 2 (AMSR2), the Visible Infrared Imager Radiometer Suite (VIIRS), and the Moderate Resolution Imaging Spectroradiometer (MODIS) on Aqua.

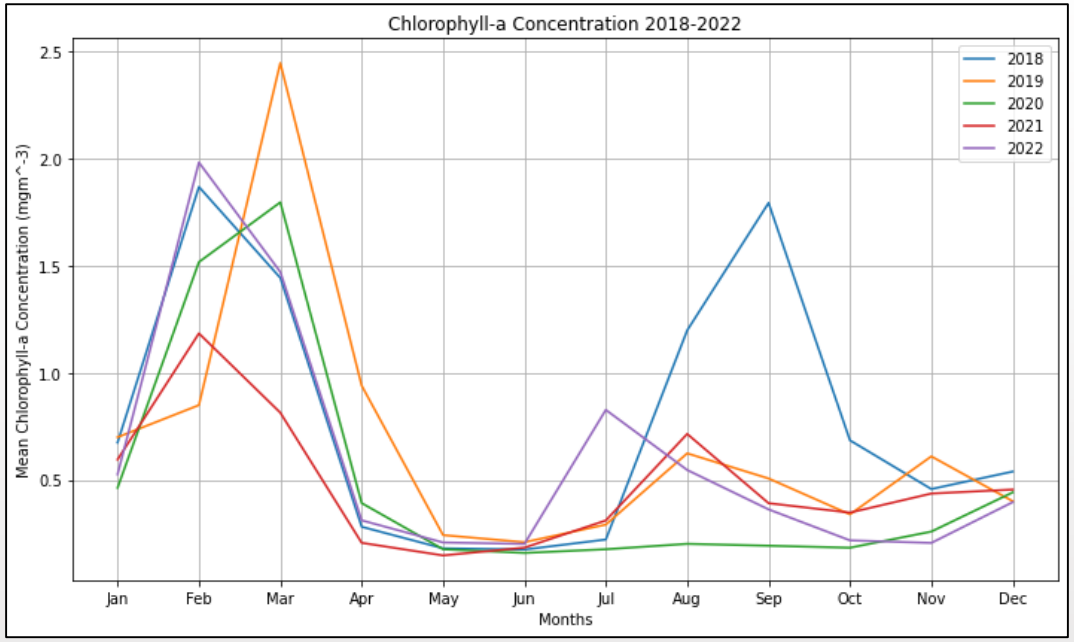
GHRSST SEA SURFACE TEMPERATURE MONTHLY ANALYSIS 2018-2022

- The general SST range observed for the studied Arabian Sea was between 22 to 30 ℃.
- The variation of SST over the months for the defined years was converse to the variation of chlorophyll.
- Compared with other years, high SST was observed for the year 2020 and low SST was observed for the years 2018 and 2019.



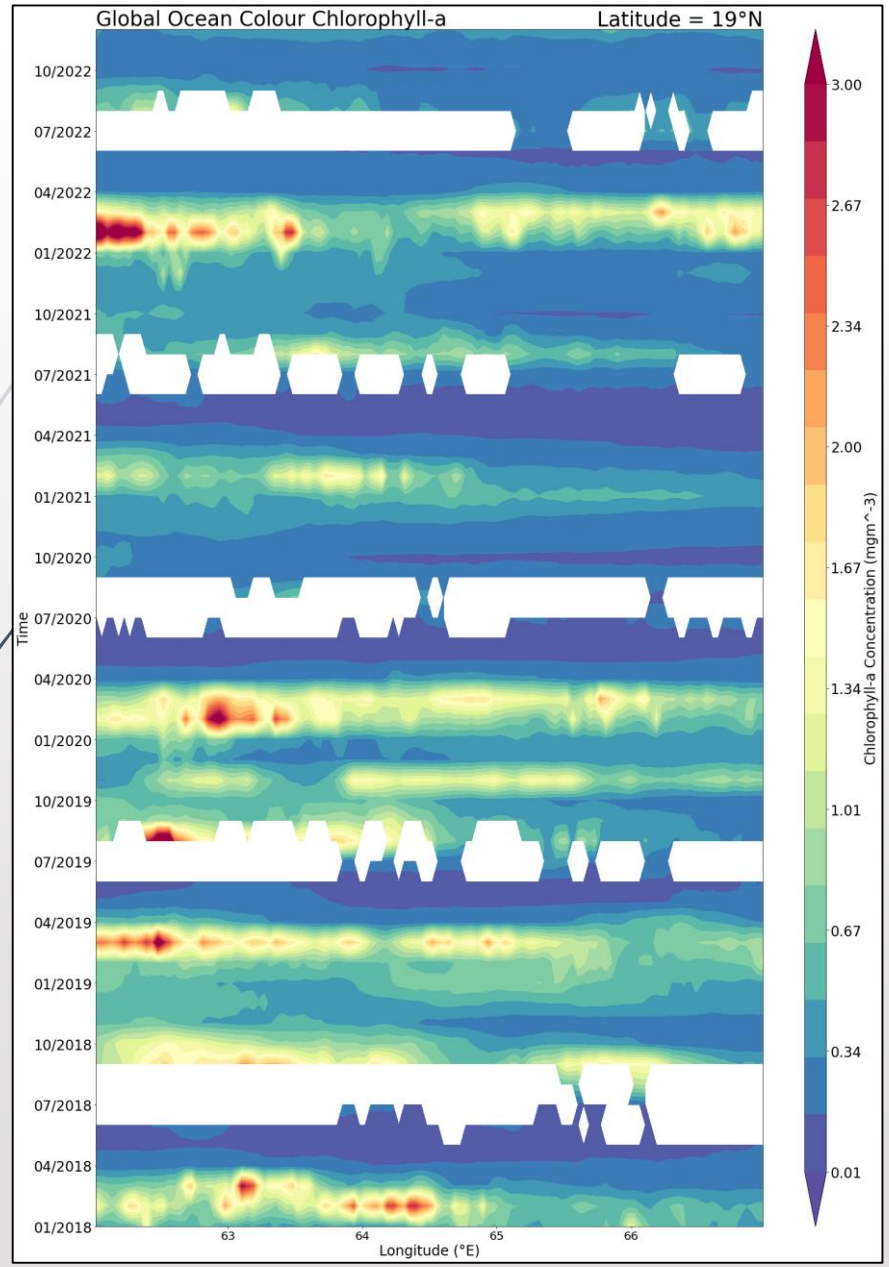
MEAN MONTHLY SST & CHLOROPHYLL VARIATION (2018-2022)

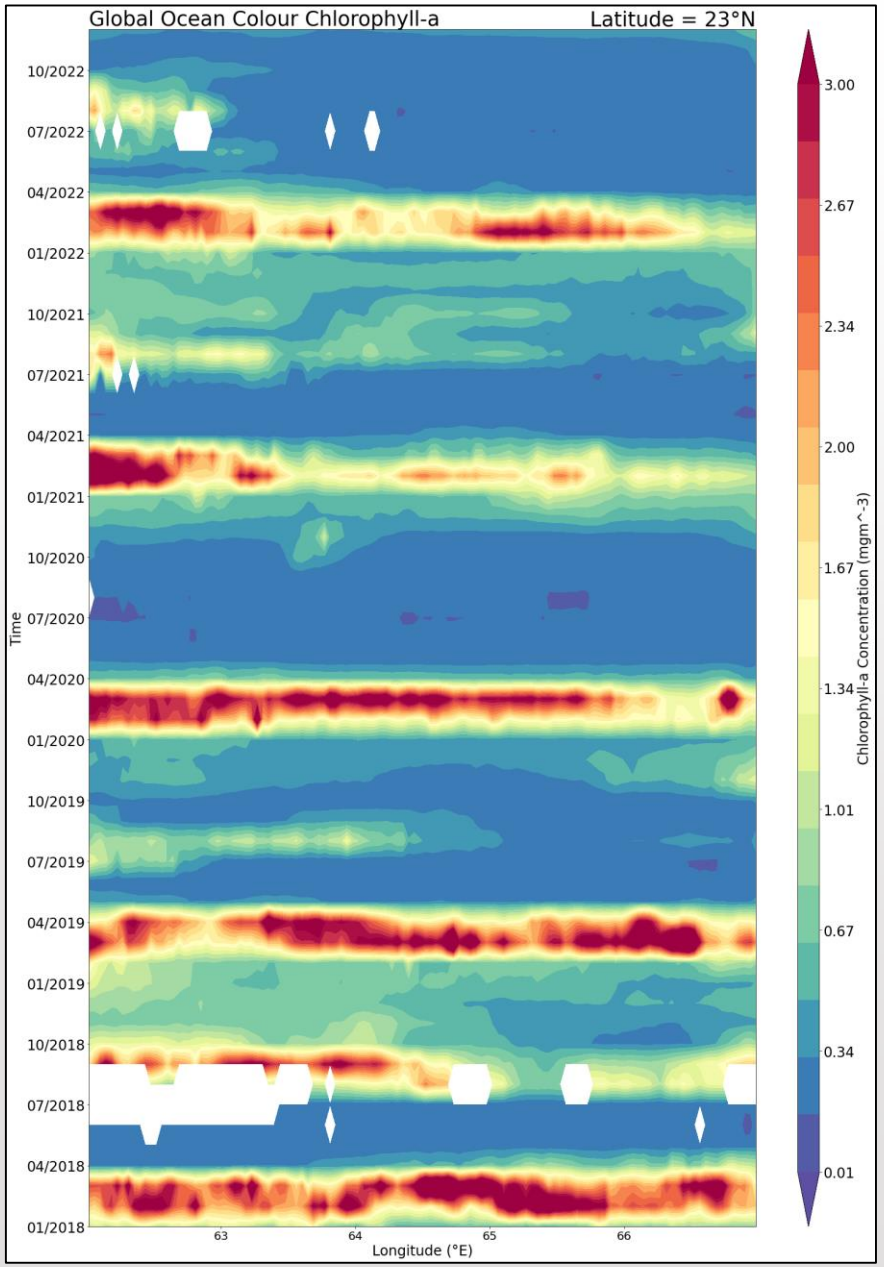




- May and June which has the lowest mean monthly chlorophyll, is found to have the highest SST.
- From April to June, SST is very high due to solar radiation, therefore the chlorophyll concentration gets reduced over ocean.
- Then during the SW monsoon (July–Sept), chlorophyll values are extremely high, while SST is low.
- During October, SST value again raises (post monsoon).
- Then, during NW monsoon (Nov-Dec), SST value again reduces till March whereas the Chl-a concentration increases to the peak.
- Then by March, as solar radiation increases SST value raises decreasing the chl-a over ocean surface.

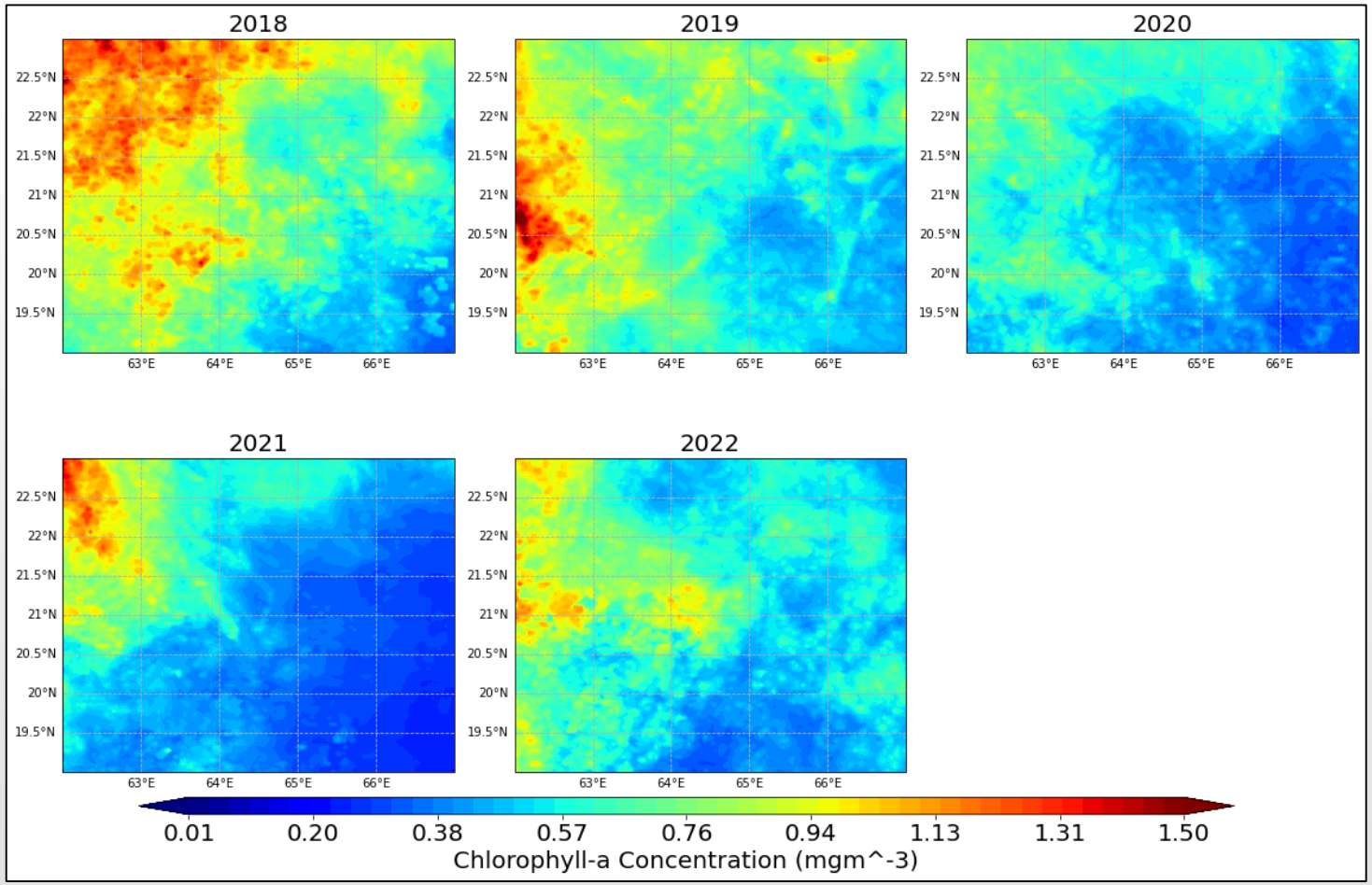
CHLOROPHYLL HOVMOLLER PLOTS (2018-2022)





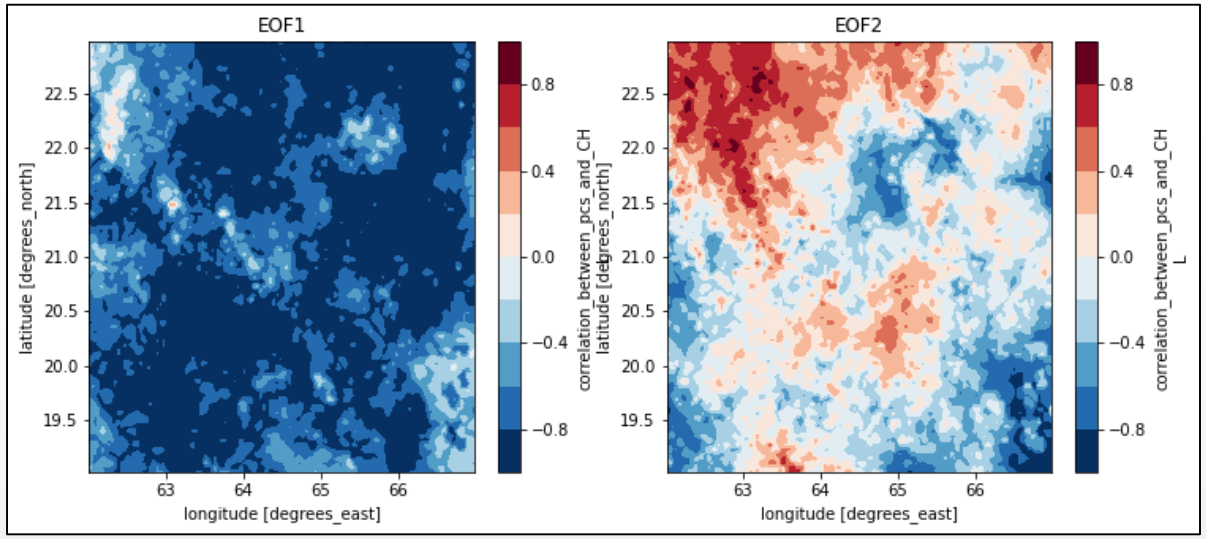
GLOBCOLOR CHLOROPHYLL ANNUAL ANALYSIS 2018 TO 2022

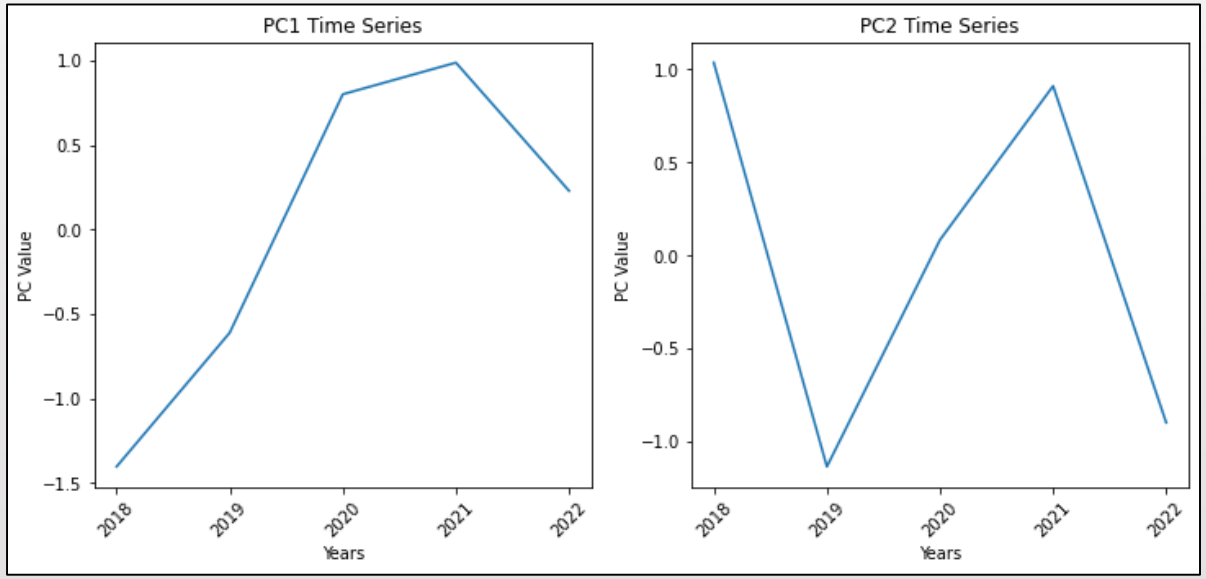
- The algal bloom was observed higher in 2018 and reduced year-wise subsequently.
- This high chlorophyll-a concentration during 2018 may be to low SST during the respective year.



Variance of Chl-a during 2018-2022

- EOF decomposition was employed to extract the interannual variance of Chlorophyll.
- The first and second EOF modes (EOF1/2) of Chl-a exhibited statistical significance in the study area.
- With a contribution of 67.11% to the total variance, EOF1 showed a striking Chl-a signal.
- EOF2 explained 14.33% of the total Chl-a variance.





- PC1 time series shows the spatial variability of chlorophyll. It can be seen increasing till 2021 and then decreasing.
- For PC2, it can be seen that gradual reduction from 2018 to 2019.
- The PCs associated with the first two modes are unimodal, that is, they show one maximum and one minimum along the year, but with different phases.
- The first mode has its maximum in November and its minimum in July, while the second mode has its maximum between Aug and Oct and its minimum in March.

GLOBCOLOR Phytoplankton Functional Type (PFT) and Phytoplankton Size Classes (PSCs) Monthly Analysis (2018-2022)

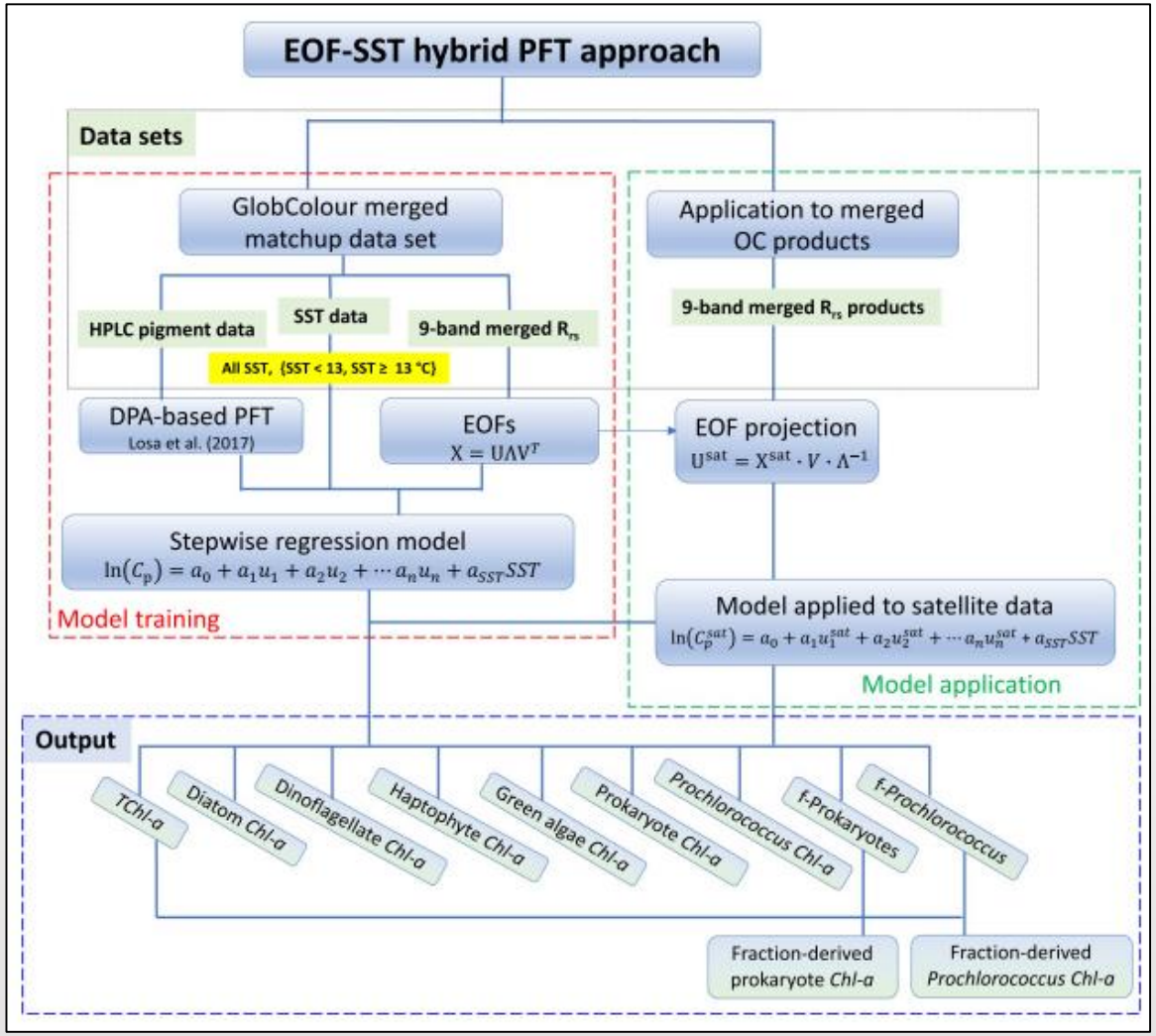
- (Xi et al., 2020) study presented an algorithm for globally retrieving chlorophyll-*a* concentrations of PFTs from multi-sensor merged ocean color (OC) products or Sentinel-3A (S3) Ocean and Land Color Instrument (OLCI) data from the GlobColor archive in the frame of the CMEMS.

- The retrieved PFTs include diatoms, haptophytes, dinoflagellates, green algae and prokaryotic phytoplankton.

- Based on empirical orthogonal functions (EOF), the algorithm was developed to retrieve Chl-a concentrations of multiple PFTs using extensive global data sets of in situ pigment measurements and matchups with satellite OC products.

- Later (Xi et al., 2020) study was retuned in 2021.
- The retuned algorithm, referred to as **EOF-SST hybrid algorithm**, which was improved by:
  - (i) using 23% more matchups between the updated global in situ pigment database and satellite remote sensing reflectance (Rrs) products
  - (ii) (ii) including sea surface temperature (SST) as an additional input parameter.

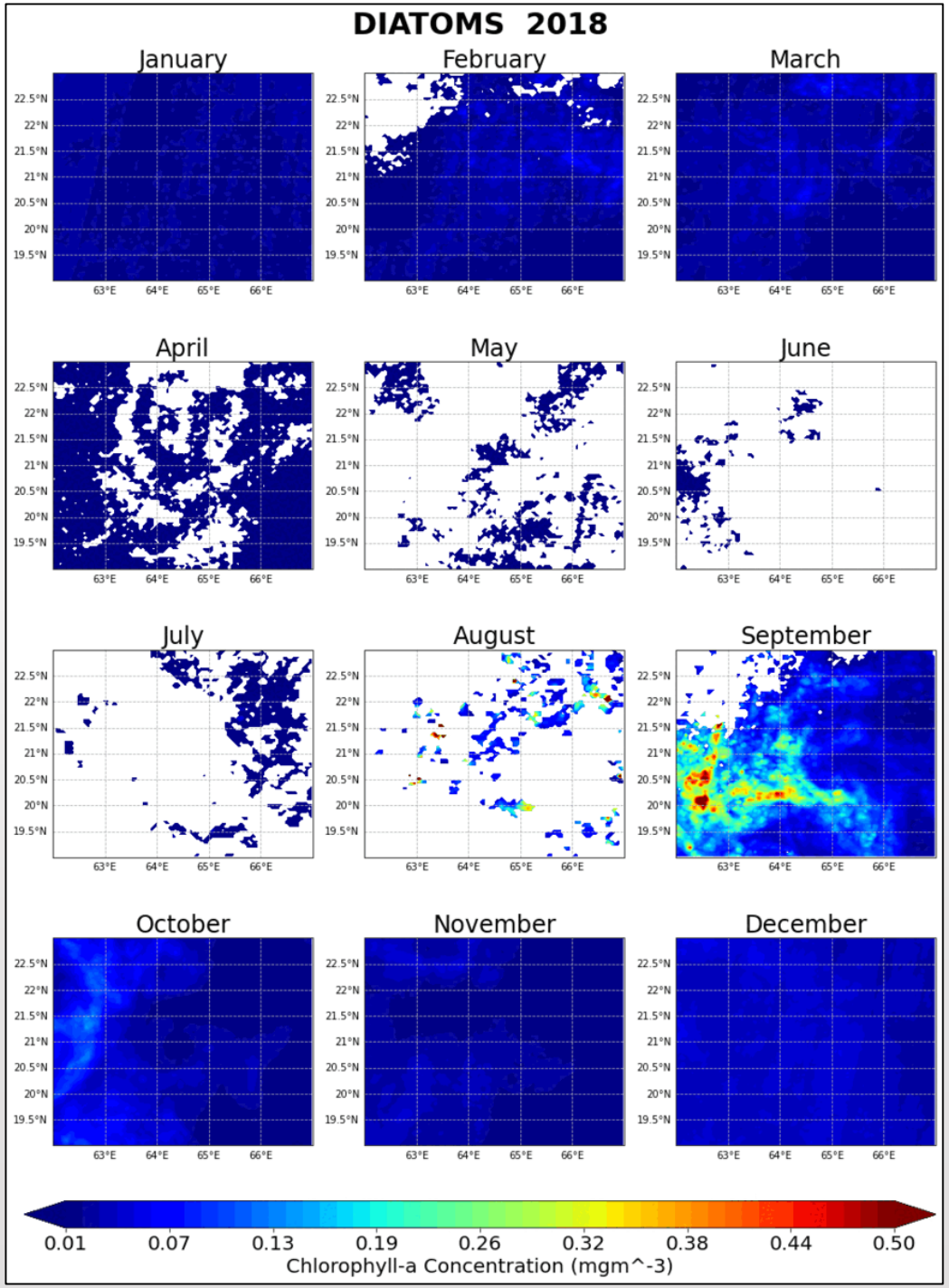
(Xi et al., 2021)



PFT and PCS retrieval Algorithm (Xi et al., 2021)

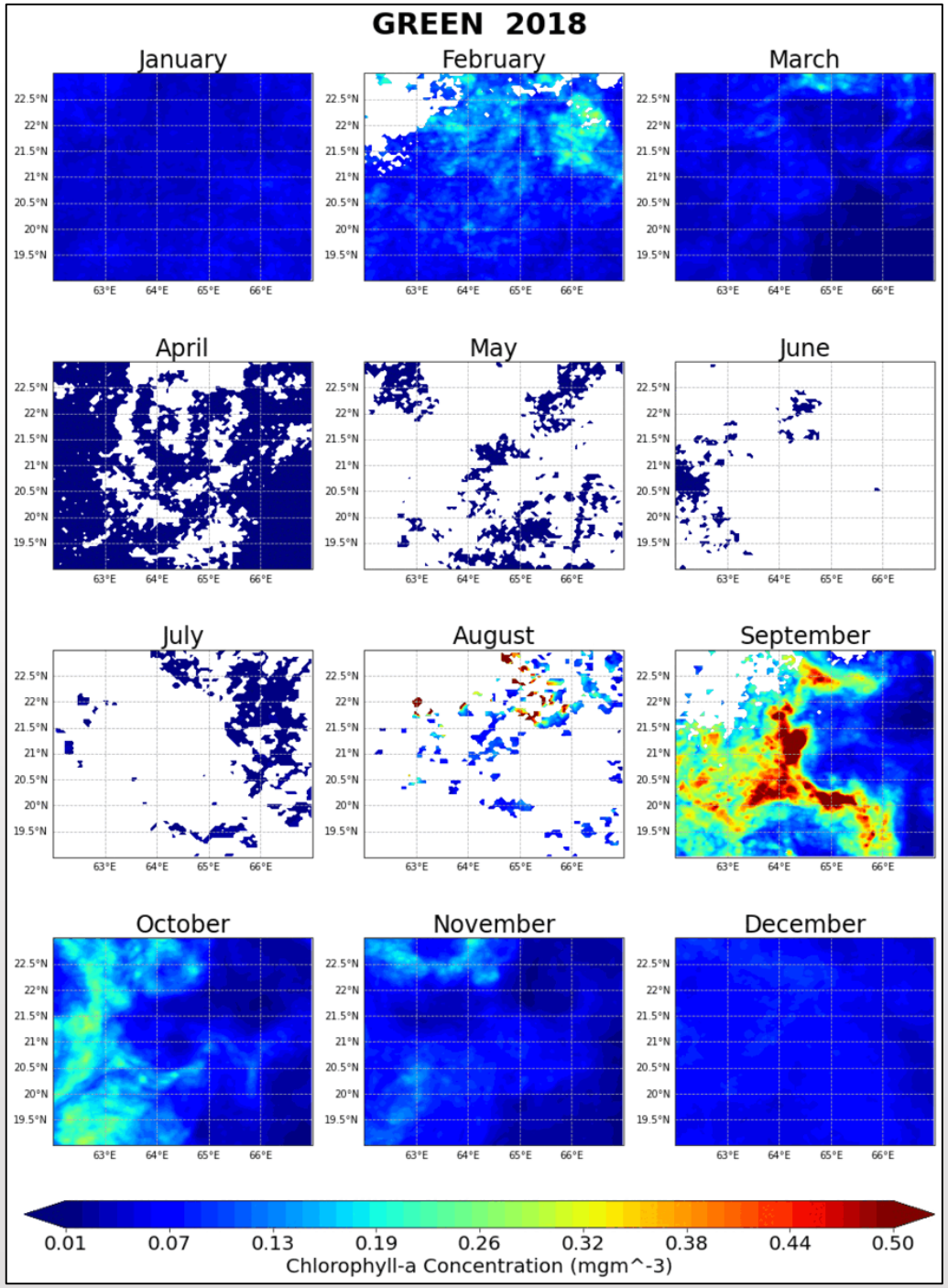
DIATOMS (2018-2022)

- Generally, dominant bloom features are observed in the range of 0.01 to 0.5 mg/m^{-3} for all considered phytoplankton.
- Dominant bloom features are observed during the southwest monsoon period (July to September) throughout the year.
- Compared with other years, during March of 2019, dominant chl-a patches can be seen.



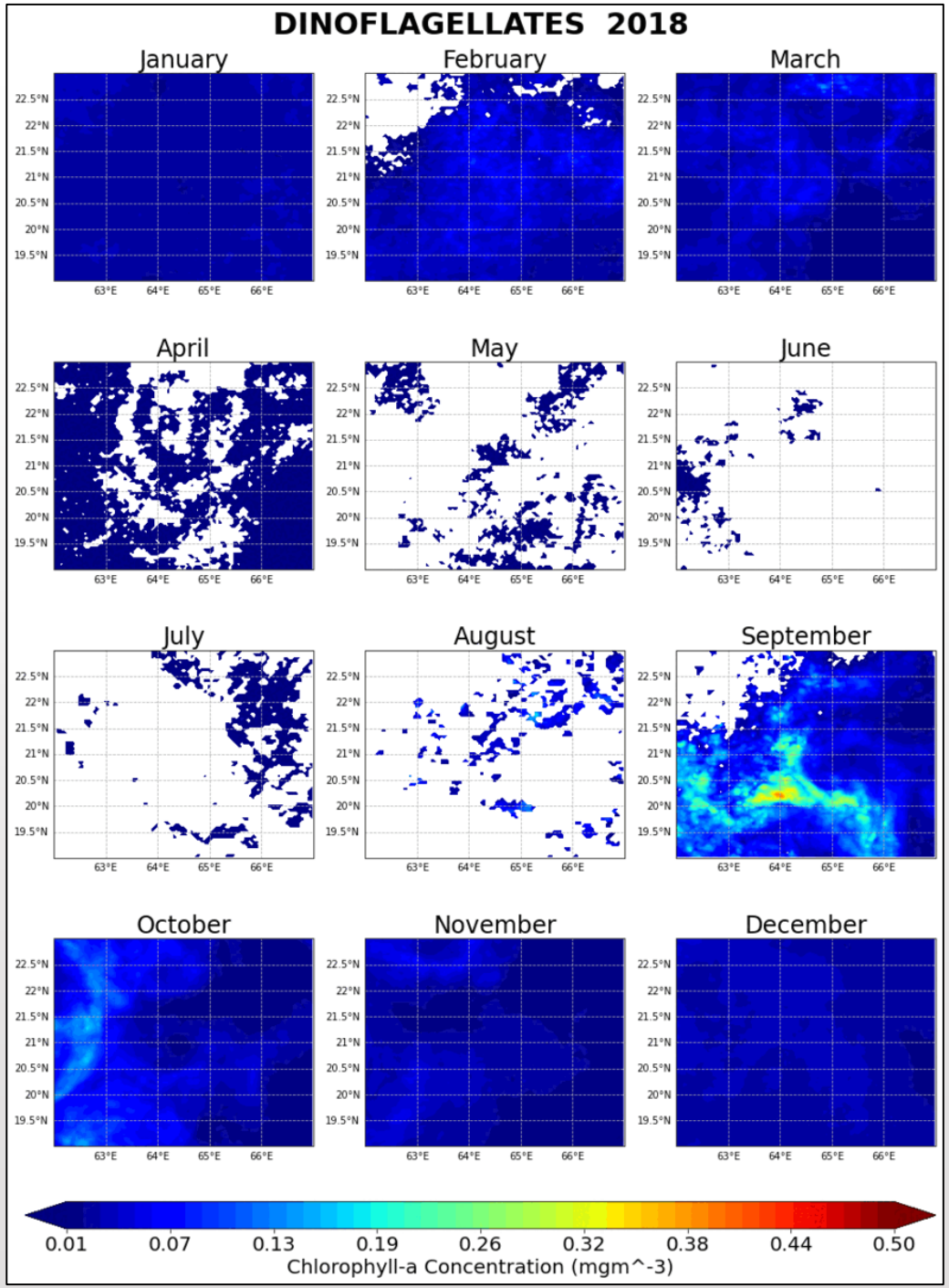
GREEN ALGAE (2018-2022)

- Similar to Diatoms, dominant bloom features are observed during the southwest monsoon period (July to September) throughout the year.
- Also, bloom patches were observed during the Northeast monsoon period (February, March).
- Distinct bloom features were absent in the April to June months, since these months have high SST.



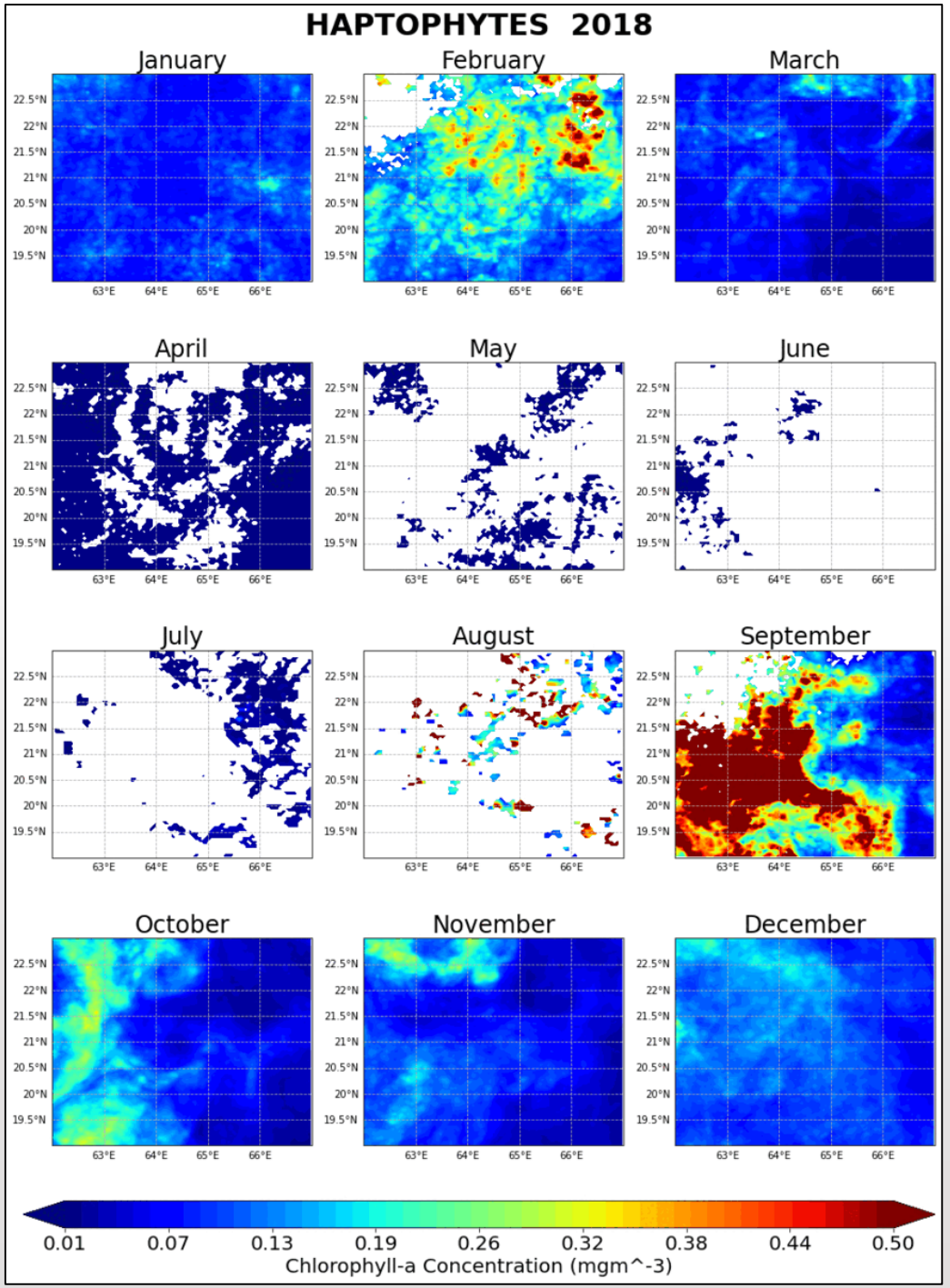
DINOFLAGELLATES (2018-2022)

- Dinoflagellates or Dinophytes were less dominant during these five years for the study area.
- These phytoplankton also show the same trend as Diatoms and Green Algae.



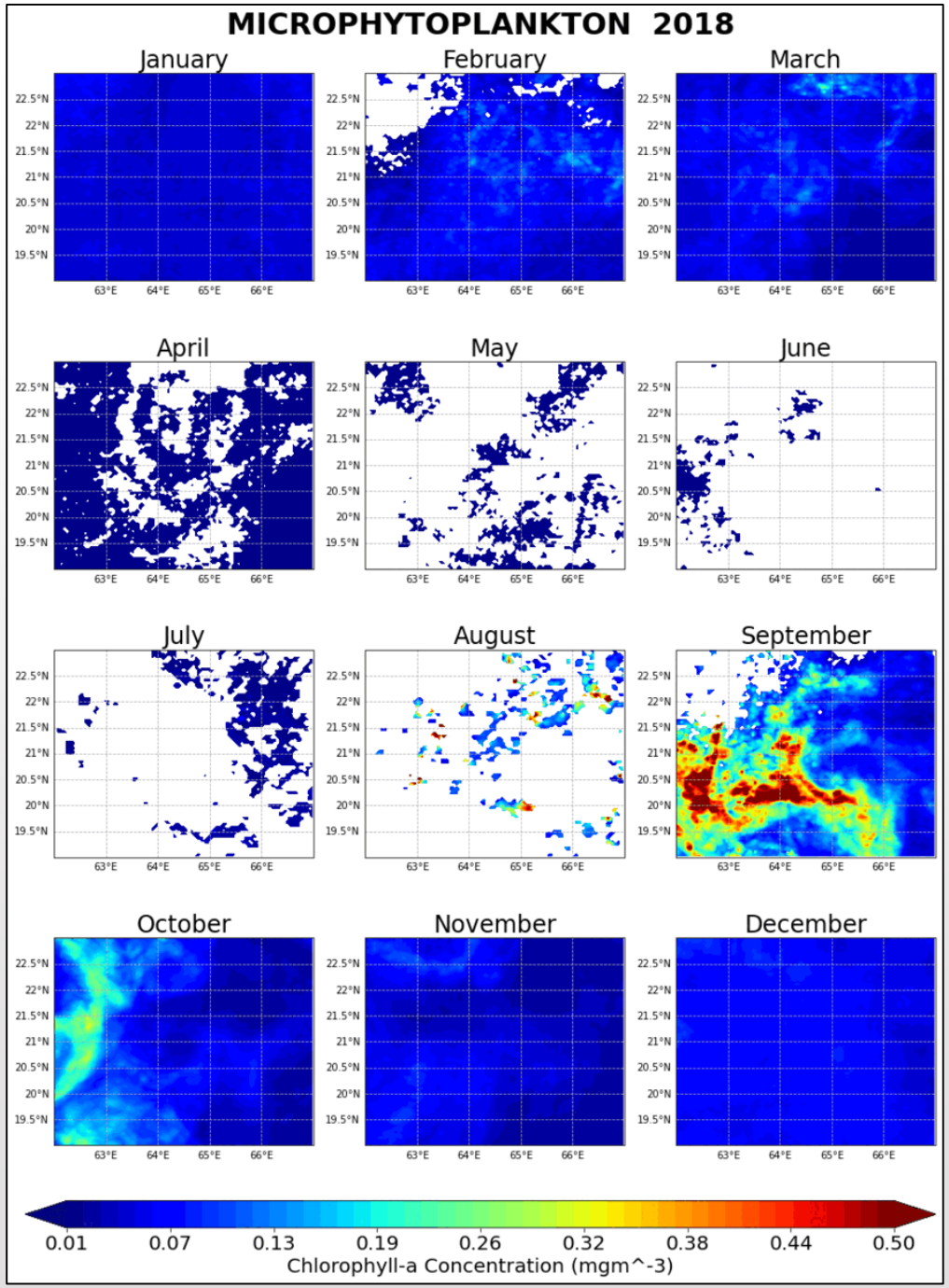
HAPTOPHYTES (2018-2022)

- Dominant bloom features are observed during both the monsoon periods.
- Throughout the months of February, the Chl-a concentration was observed above 0.5 mg/m^{-3} and for September 2018.



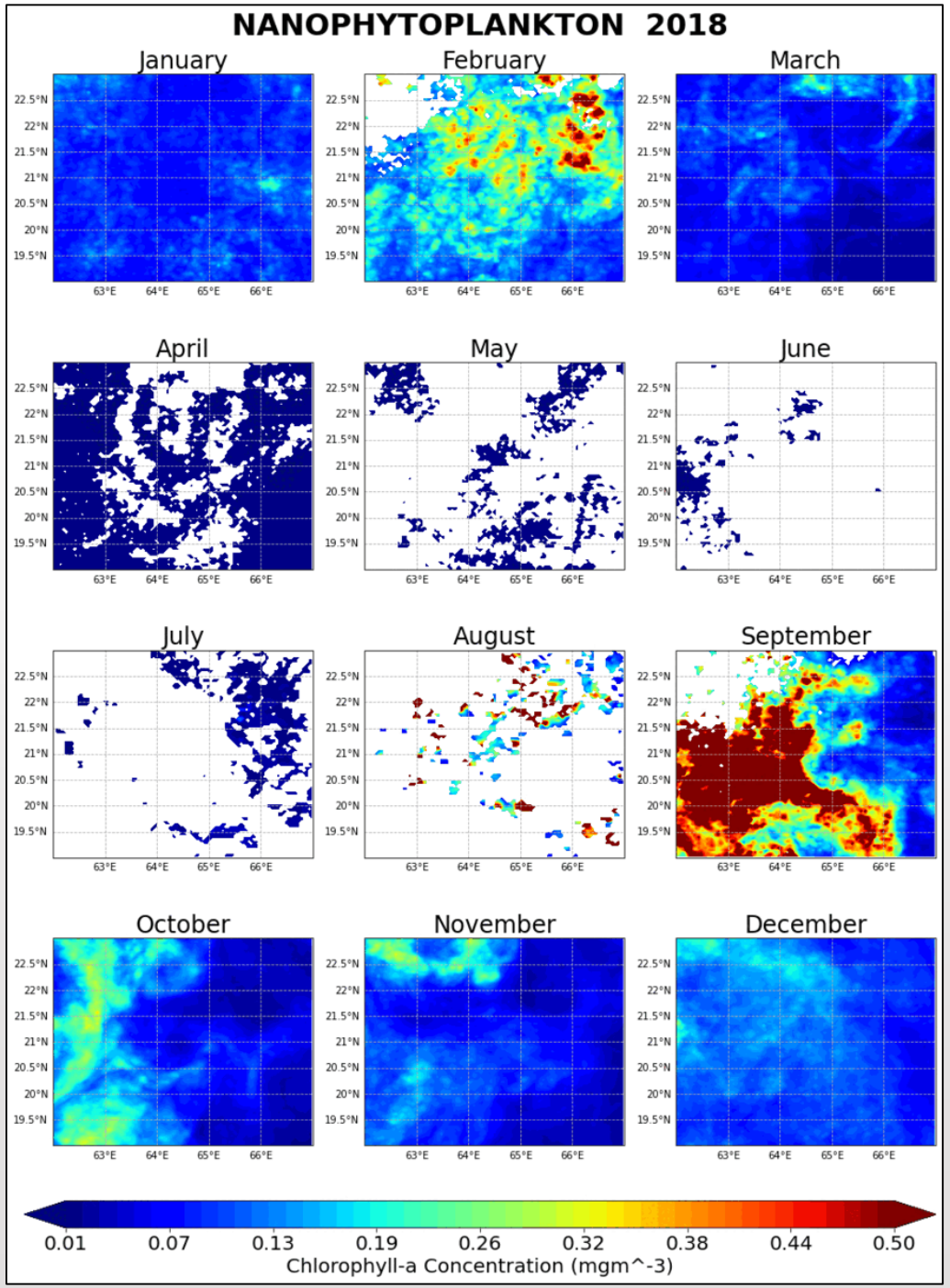
MICROPHYTOPLANKTON (2018-2022)

- Dominant bloom features are observed during the southwest monsoon season.
- Chlorophyll concentration or algal bloom was found reduced year-wise from 2018 to 2022.



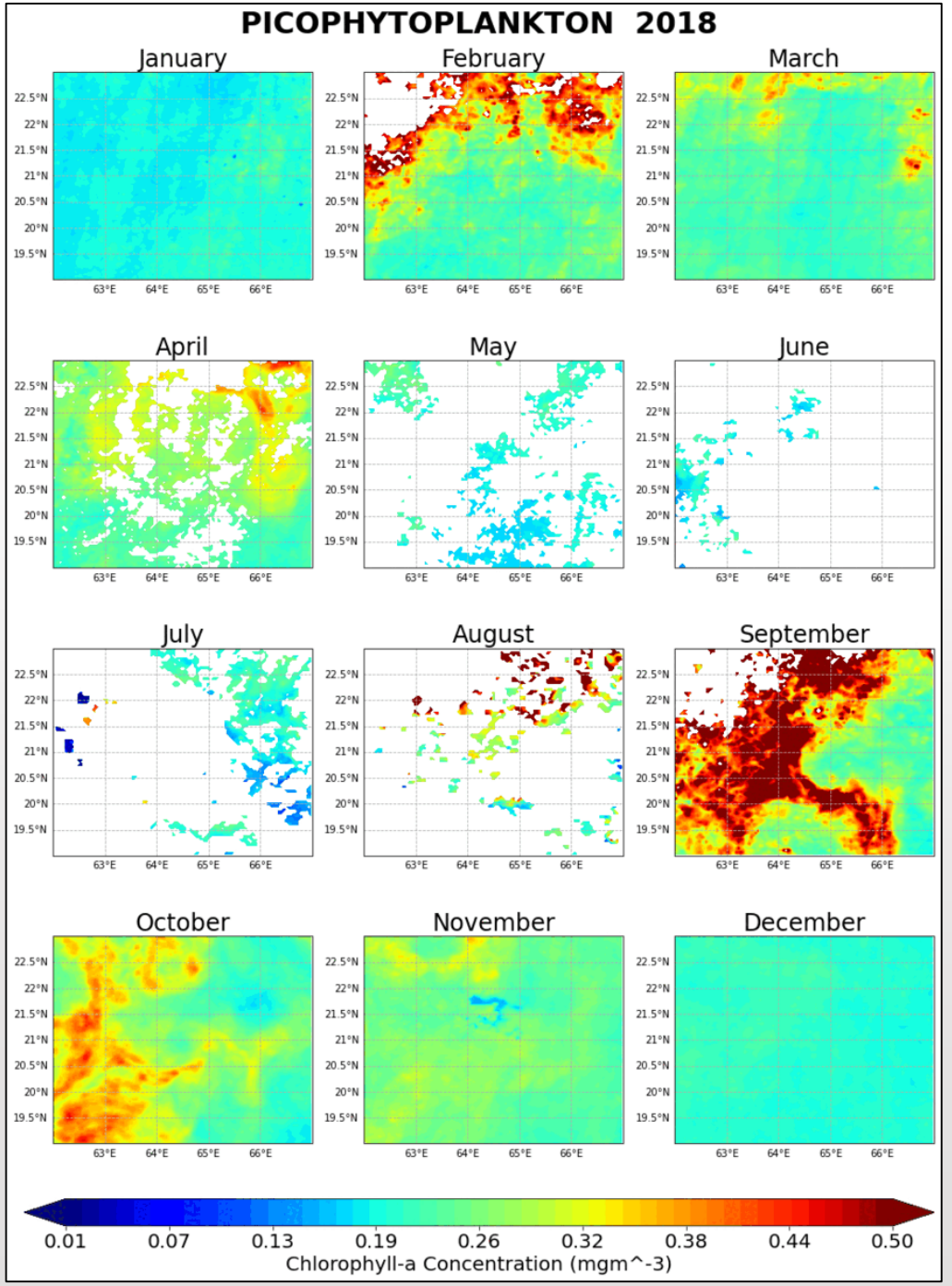
NANOPHYTOPLANKTON (2018-2022)

- Similar trend of microphytoplankton was observed.
- Dominant bloom features are observed during both the monsoon periods.
- Throughout the months of February, the Chl-a concentration was observed above 0.5 mg/m^{-3} and for September 2018.



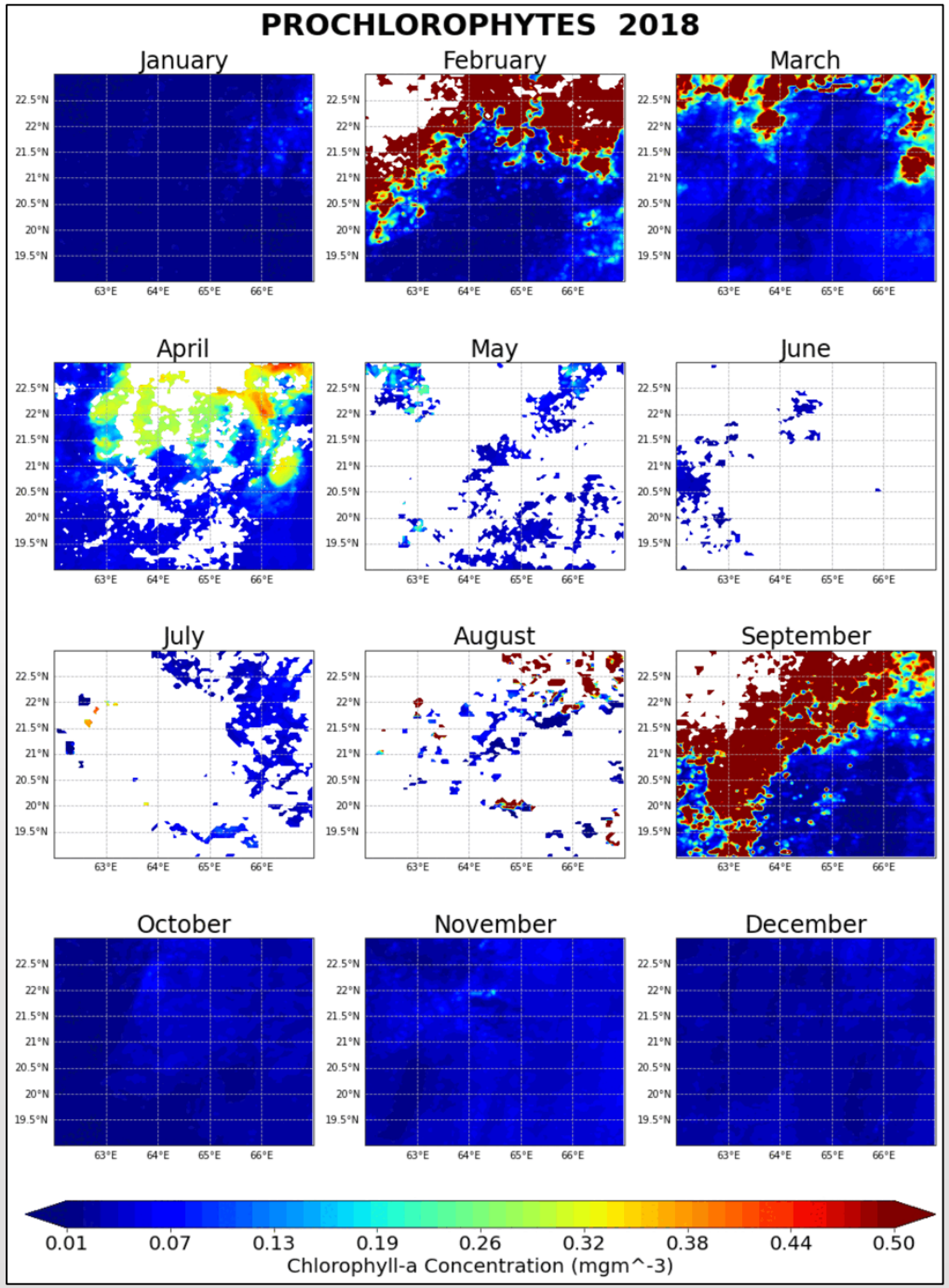
PICOPHYTOPLANKTON (2018-2022)

- This is the dominant type of phytoplankton observed in the study area.
- The chlorophyll concentration found above 0.2 mg/m^{-3}
- Dominant bloom features are observed for both monsoon periods.
- Compared with other years, April 2019 observed high algal bloom of that year.



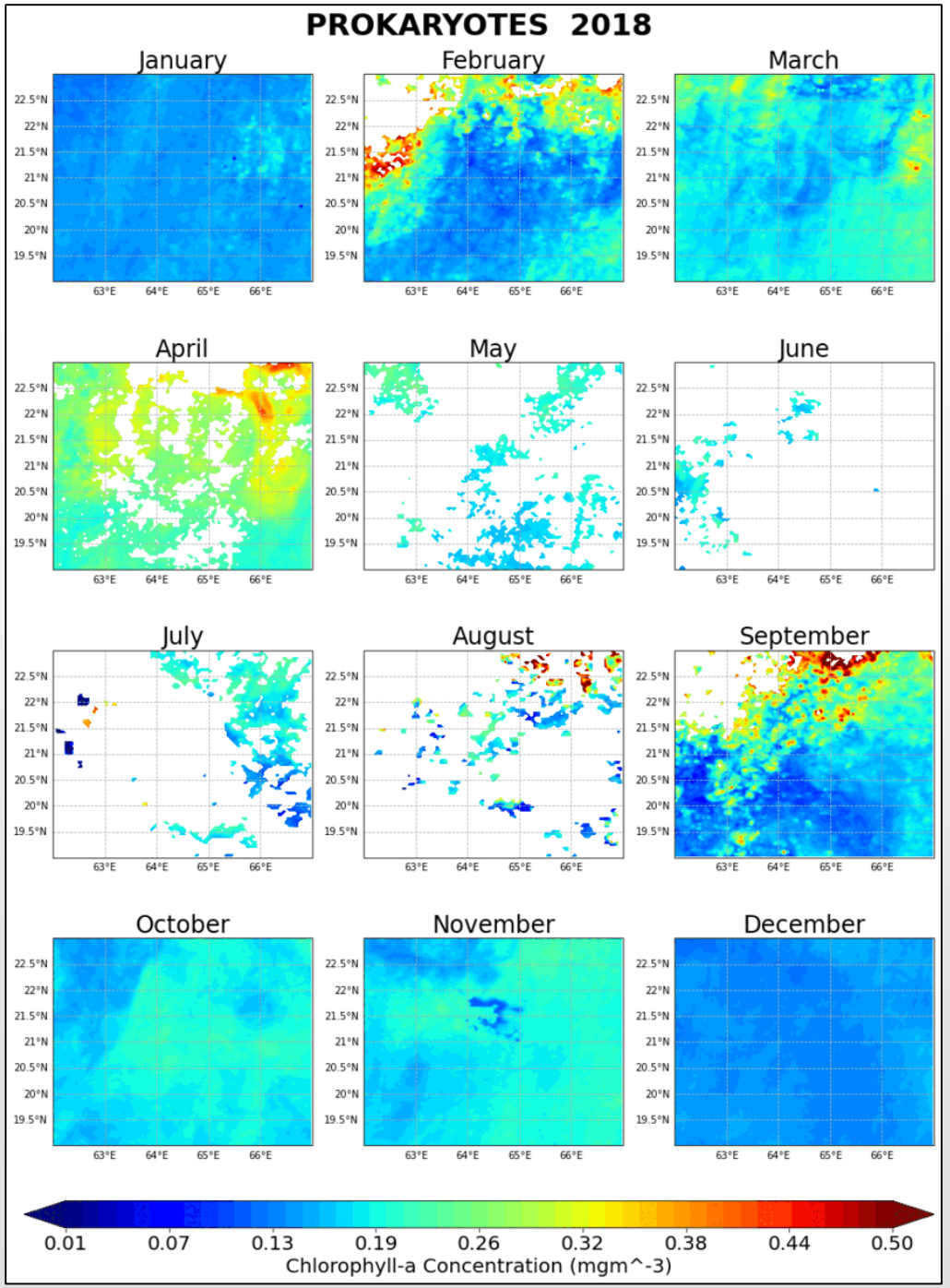
PROCHLOROPHYTES (2018-2022)

- Dominant bloom features are observed from the month of January to September throughout the five years.
- Observed that algal bloom starts in January, growth proceeds, and declines by the month of October.
- Algal bloom was found to reach its peak by the month of March, especially for the years 2019,2020 and 2022.



PROKARYOTES (2018-2022)

- This is the dominant type of phytoplankton after picophytoplankton.
- Chlorophyll concentration was found almost above 0.13 mg/m^{-3}
- Except for April 2019 and March 2022, chlorophyll concentration was found almost below 0.45 mg/m^{-3}

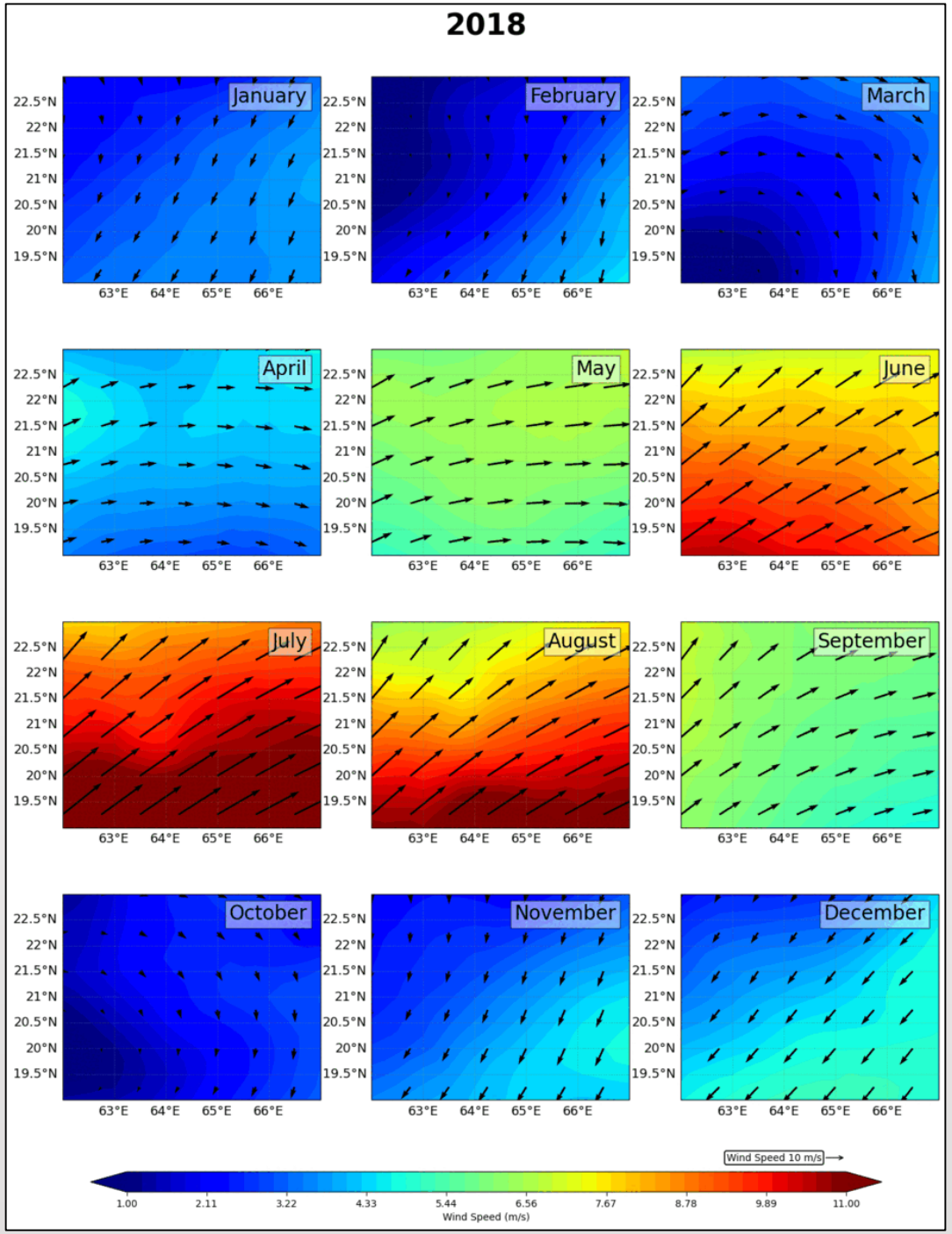


ERA5 monthly averaged wind speed data

- This study utilized 10m wind speed, 10m u component of wind and 10m v component.
- 10m wind speed parameter is the horizontal speed of the wind, or movement of air, at a height of ten meters above the surface of the Earth.
- The 10m u component the of wind parameter is the eastward component of the 10m wind.
- The 10m v component the of wind parameter is the northward component of the 10m wind.
- The units of these parameters are meters per second.

WIND Speed (2018-2022)

- Wind speed variation over the studied Arabian Sea ranged between 1 to 11 m/s.
- During the southwest monsoon period, high wind speed has been observed (>10 m/s).
- Especially for the year 2018 (Jun-Aug), experienced a high wind compared with other years.
- By the month of September, the SW monsoon retrieves and the wind speed magnitude reduces below 8 m/s.
- During October (post-monsoon), the wind speed almost reduces below 4 m/s.

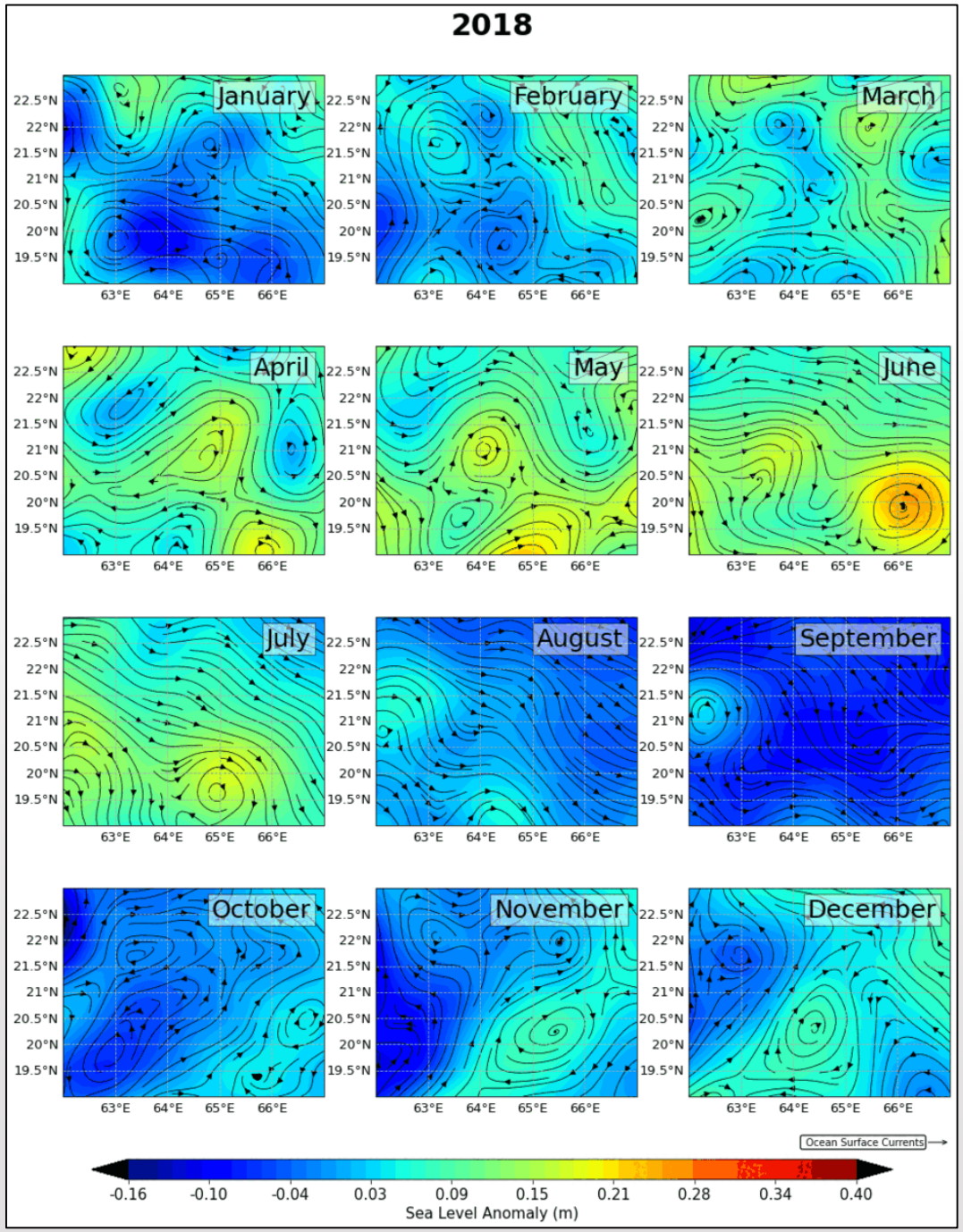


Sea level Anomaly and Geostrophic Currents, multi-mission, global, optimal interpolation, gridded data

- 0.25-degree longitude/latitude level-3 daily data was accessed from the NOAA Coastal Watch website.
- Applying optimal interpolation to along-track satellite observations over the global ocean from a constellation of radar altimeter missions.
- These grids are produced with near-real-time (3-5 hours latency) data. Currently, Jason-3, AltiKa, Cryosat-2, Sentinel-3A, and Sentinel-3B data are used in the processing of the NRT dataset.
- Geostrophic Currents are produced from the SLA and are included in the dataset.

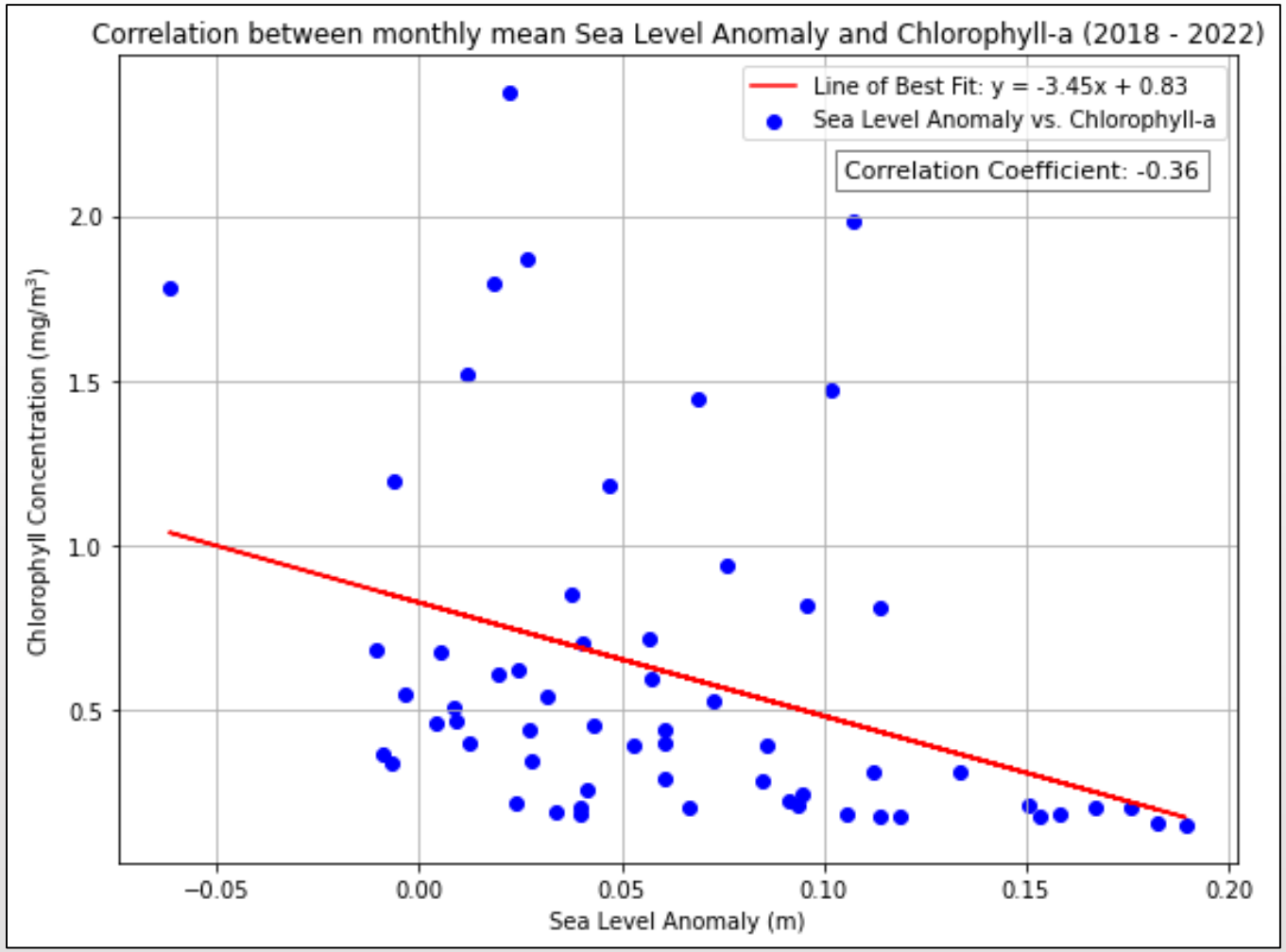
SEA LEVEL ANOMALY(2018-2022)

- SLA observed effectively ranged between the values -16 to 40 cm.
- Increment in SLA values was observed year-wise, from 2018 (<27 cm) to 2022 (>40 cm).
- Throughout five years, the months of April, May and June observed high SLA.
- Monsoon seasons which mainly contribute to algal bloom biomass are showing less SLA range (<27 cm).
- During the SW monsoon (Jul-Sept), more negative SLA has been observed.



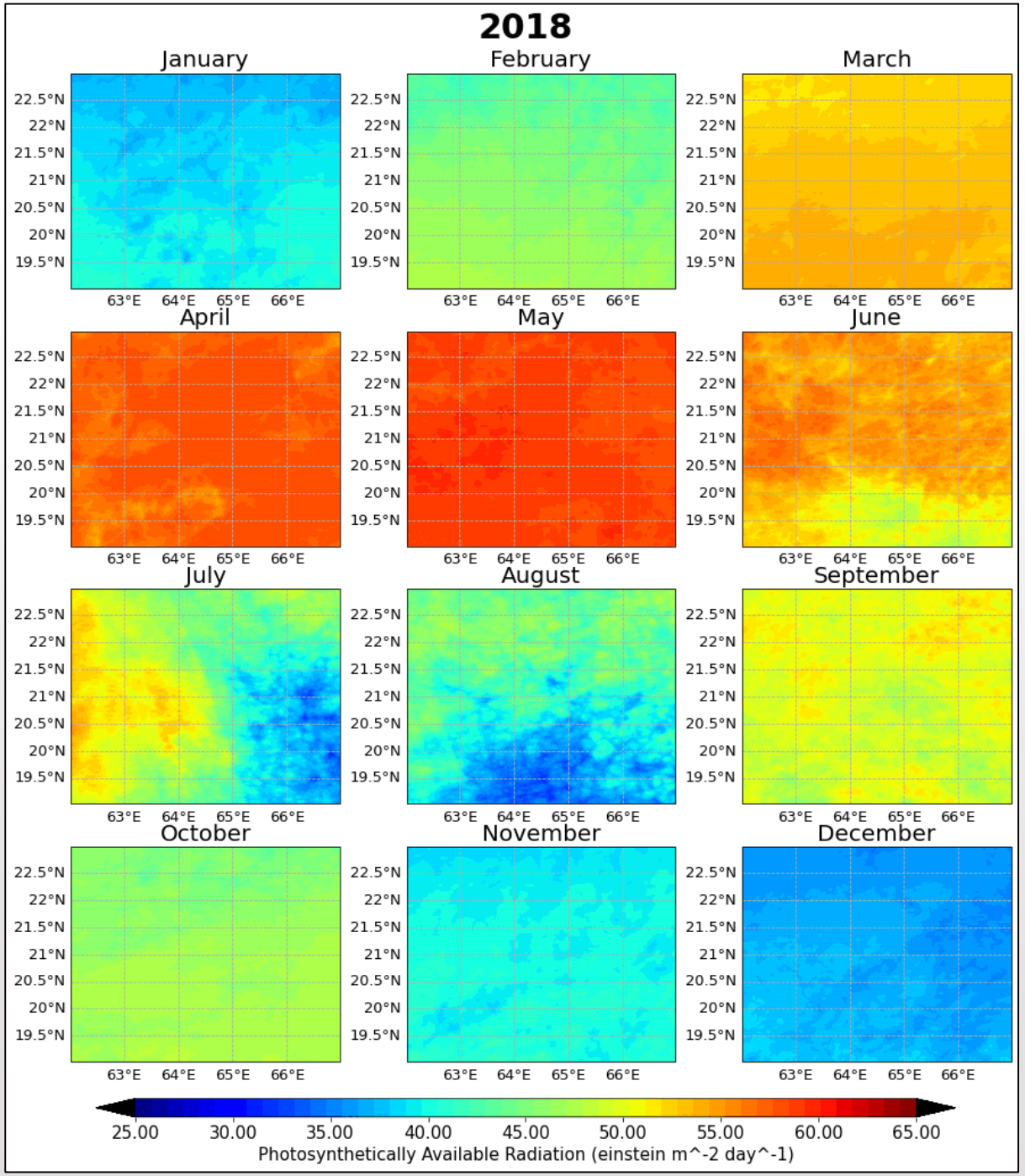
CORRELATION ANALYSIS BETWEEN MEAN CHLOROPHYLL & SEA LEVEL ANOMALY (2018-2022)

- The negative correlation between sea level anomaly and chlorophyll suggests that higher sea level anomalies may be associated with lower chlorophyll levels.
- This could imply that in regions with elevated sea level anomalies, the conditions for algal blooms might be less favorable.
- Thus, SLA is linked as such; low SLA (negative trend) is linked to low SST and high nutrient and high chlorophyll, thus algal bloom growth.



PHOTOSYNTHETICALLY AVAILABLE RADIATION (2018-2022)

- Expect both monsoon periods, PAR values range above 45 einstein $m^{-2}day^{-1}$
- High PAR values are observed for months having high SST and low Chl-a which is an intriguing fact.
- Different algal species have varying requirements for light; it was observed that the species Picophytoplankton, Prochlorophytes and Prokaryotes are dominant over high PAR ranges.
- Also observed that for the study area considered, high PAR values are associated with high SLA values.



CONCLUSION

- From the Five-year monthly analysis; the most favourable condition for algal bloom growth in terms of ocean surface chlorophyll concentration either links with low SST or high wind speed or low sea level anomaly or low PAR conditions.
- For the study area; algal bloom was much observed over the chl-a range of 0.01 to 5 mg/m^{-3}
- The general SST range observed for the study area was between 22 to 30 ℃.
- Ocean Current is moving the boom features in its direction with the bloom peak at the center of the ocean circulation features.
- The annual chlorophyll plots show that the algal bloom was observed higher in 2018 and reduced year-wise subsequently.
- Picophytoplankton was the dominant type of phytoplankton observed in the study area (0.2 mg/m^{-3}) and then Prokaryotes (0.13 mg/m^{-3}).
- From the Hovmoller plots, at higher altitudes chl-a concentration was found to be high between the months of January and April.

- Increment in SLA values was observed year-wise, from 2018 (<27 cm) to 2022 (>40 cm).
- Wind speed variation over the studied Arabian Sea ranged between 1 to 11 m/s.
- The negative correlation between sea level anomaly and chlorophyll. This could imply that in regions with elevated sea level anomalies, the conditions for algal blooms might be less favorable.
- Expect both monsoon periods, PAR values range above 45 einstein $m^{-2}day^{-1}$
- High PAR values are observed for months having high SST and low Chl-a which is an intriguing fact.
- Different algal species have varying requirements for light; it was observed that the species Picophytoplankton, Prochlorophytes and Prokaryotes are dominant over high PAR ranges.
- Also observed that for the study area considered, high PAR values are associated with high SLA values.

THANK YOU…