Tropical Cyclone Triggers PSC Shifts in the Arabian Sea

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Abstract. Of the many oceanic ecosystems experiencing seasonal and climate-driven changes worldwide, the Arabian Sea (AS) stands out as the one with the most dramatic and extreme changes of all. However, the phytoplankton community distribution pattern and environmental adaptation to the extreme events in the Arabian Sea are less explored. Hence these features of the Arabian Sea and the fact that no comprehensive studies have been attempted to investigate the phytoplankton structure based on their size (micro- >20 μm, nano- 2 – 20 μm and picoplankton- < 2 μm) in this regional basin provided an opportunity to explore and understand the tropical cyclone influence on the phytoplankton size classes (PSC) distribution in the AS. The aim of this study is to investigate the phytoplankton size classes (PSC) distribution pattern in the AS during tropical cyclone events through a three-component approach and reconstructed chlorophyll-a datasets. The study revealed interesting results not reported earlier. The cyclone influences PSC variations observed in the AS revealed that the short extreme events regulate the PSC changes in the Arabian sea by controlling the physical drivers.

1. Introduction

The Arabian Sea (AS) is regarded as the most productive ecosystem located in the western part of the north Indian Ocean, is a semi-enclosed basin experience diurnal and seasonal change due to the seasonally reversing monsoon winds [1], [2]. This characteristic driving factor significantly influences the Arabian Sea marine ecosystem structure [3], [4]. As a sensitive ecological indicator, the phytoplankton is distributed with a definite pattern corresponding to the monsoonal changes throughout the year [5], [6]. However, extreme weather events such as tropical cyclones might appear transient, but that would cause a sudden dramatic change in the phytoplankton distribution[7], [8]. Such changes occur due to biogeochemical variability affected by the cyclone [9].

Phytoplankton communities are susceptible to environmental conditions dictated by nutrient and light availability, which certainly impacts the primary production and the marine food web [10]–[12]. Many studies have recorded phytoplankton response to extreme events primarily using the oversimplified representation of the phytoplankton community as a single group through biomass expressed as chlorophyll-a (chl-a) concentration[13], [14]. Such generalized presumption leads to discrepancies in monitoring the ecosystem structure and function [13], [15]. Besides, the chl-a concentration provides limited information compared to the community-wise approach to determining the impact of a tropical cyclone on phytoplankton distribution [7], [16]Few such studies incorporate taxonomically, size, or functional-based phytoplankton classification methods to assess their distinct role in the marine ecosystem and the specific response to the environmental conditions [13], [17].

Unusual mono-specific and multi-species phytoplankton blooms have been reported in the Arabian Sea in past decades [18], [19]. Over the past few years, countries bordering the Arabian Sea, including India, have been experiencing episodic occurrences of dead fish washing up on their shores, which might be related to the blooms and associated hypoxic events [20], [21]. The consequences of blooms have been debated from positive and negative points of view. The positive aspect of phytoplankton blooms is that they are beneficial to fisheries and primary production, and they are essential in maintaining the biogeochemical cycles of the sea [11]. The negative aspects are that some blooms can negatively affect fisheries and human health [22]. Therefore, identifying the environmental adaptations of PSC in the AS helps to understand the AS ecosystem efficiently. Further, the extreme event's investigation of phytoplankton groups helps to observe the community shift and dominance of phytoplankton communities and the response of phytoplankton communities in the AS.

In this work, the impact of the cyclonic event on the PSC dynamics was assessed by retrieving the PSC using the reparametrized model and examined the relative biogeochemical changes due to the cyclonic events. The PSC variability due to the tropical cyclone event is studied in detail to investigate the potential impact of the tropical cyclonic event on the variability in physical and chemical properties and its role in corresponding PSC shifts in the passage regions.

Table 1. Summary of 42 cyclone cases that occurred in the Arabian Sea from 2003 to 2019

No	Cyclone events	Start date	End date	Duration in days
1	ARB_2003_1	12/11/2003	15/11/2003	4
2	ARB_2004_1	05/05/2004	10/05/2004	5
3	ARB_2004_2	10/06/2004	13/06/2004	3
4	ONIL	30/09/2004	03/10/2004	4
5	ARB_2004_3	02/11/2004	07/11/2004	6
6	AGNI	29/11/2004	02/12/2004	3
7	ARB_2005_1	21/06/2005	22/06/2005	2
8	ARB_2006_1	13/01/2006	14/01/2006	2
9	MUKDA	21/09/2006	24/09/2006	4
10	GONU	02/06/2007	06/06/2007	5
11	YEMYN	25/06/2007	05/06/2007	1
12	ARB_2007_1	28/10/2007	2/11/2007	6
13	ARB_2008_1	05/06/2008	06/06/2008	2
14	PHYAN	9/11/2009	11/11/2009	3
15	BANDU	19/05/2010	22/05/2010	4
16	PHET	31/05/2010	7/06/2010	8
17	KEILA	29/10/2011	03/11/2011	6
18	ARB_2011_1	06/11/2011	09/11/2011	4
19	MURJAN	23/10/2012	25/10/2012	3
20	ARB_2012_1	22/12/2012	24/12/2012	3
21	ARB_2013_1	08/11/2013	10/11/2013	3
22	NANAUK	10/06/2014	13/206/2014	4
23	NILOFAR	26/10/2014	31/10/2014	6
24	ASHOBAA	07/06/2015	11/06/2015	5
25	ARB_2015_1	22/06/2015	24/06/2015	3
26	ARB_2015_2	09/10/2015	11/10/2015	3
27	ARB_2015_3	29/10/2015	05/11/2015	8
28	ARB_2015_4	06/11/2015	10/11/2015	5
29	ARB_2016_1	27/06/2016	29/06/2016	2
30	ARB_2016_2	17/12/2016	18/12/2016	2
31	OCKHI	30/11/2017	04/12/2017	5
32	ARB_2018_1	13/03/2018	14/03/2018	2
33	SAGAR	16/05/2018	19/05/2018	4
34	MEKNU	21/05/2018	26/05/2018	6
35	LUBAN	06/10/2018	14/10/2018	9
36	ARB_2019_1	10/06/2019	17/06/2019	8
37	ARB_2019_2	22/09/2019	25/09/2019	4
38	ARB_2019_3	24/10/2019	02/11/2019	10
39	ARB_2019_4	30/10/2019	07/11/2019	9

40	ARB_2019_5	02/12/2019	07/12/2019	6
41	ARB_2019_6	03/12/2019	05/12/2019	3
42	ARB_2019_7	08/12/2019	10/12/2019	3

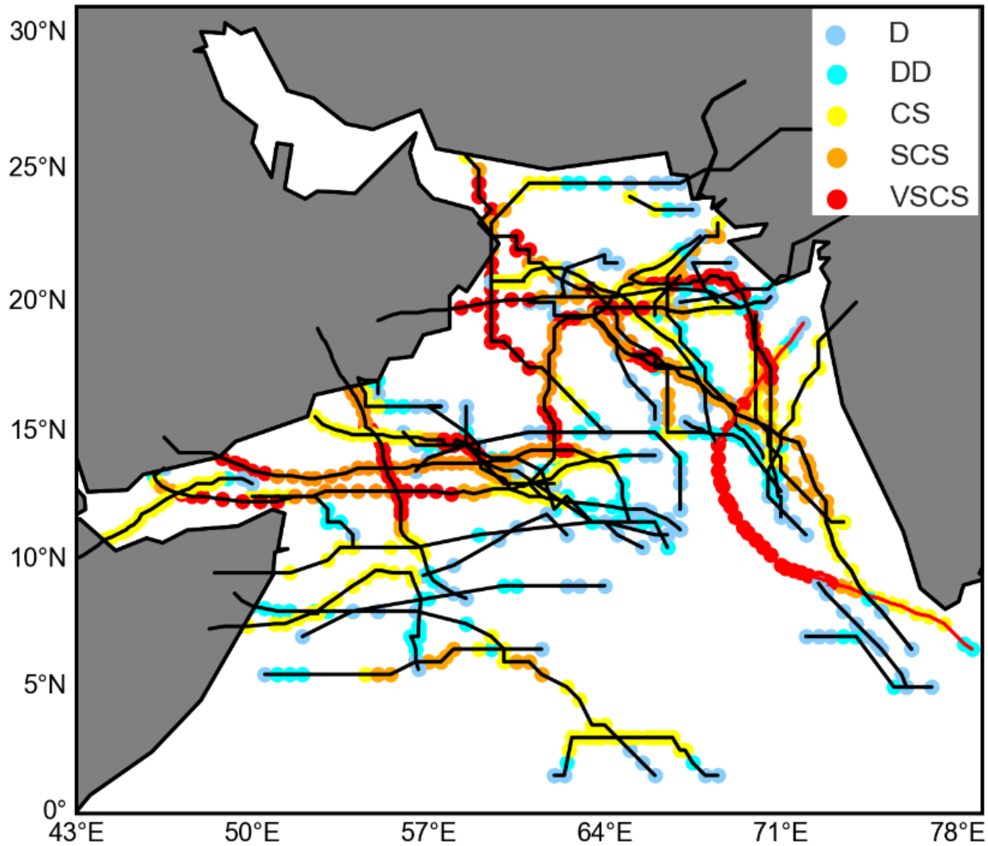

Figure 1. Tracks of tropical cyclones observed between 2003-2019 in the Arabian Sea.

2. Data and Methods

The present study is based on a chl-a [mg m^{-3}] MODIS-Aqua Level-3 products, obtained from the NASA ocean color daily and 4-km resolution from the website (https://oceancolor.gsfc.nasa.gov/). The analyzed series covers the period from 2003 to 2019 for the Arabian Sea (43 °E to 79°E and 0°N to 31°N). The satellite-based data products are generally prone to missing data values due to overcast conditions. Missing values of chl-a were reconstructed by Data Interpolation Empirical Orthogonal Function (DINEOF) developed by [23]. The DINEOF method is based on Empirical Orthogonal Function (EOF), which fills the missing data values with the number of EOF modes on an iterative basis. It is a freely available method that can be obtained from http://modb.oce.ulg.ac.be /mediawiki/index.php/DINEOF. Many studies have incorporated this method and proved successful in reconstructing oceanographic datasets like chl-a [5], [24]. Further the reparametrized three component model of Shunmugapandi et al. (2022) is applied on the reconstructed chl-*a* to retrieve the PSC time-series datasets.

3. Results

3.1 Cyclone induced phytoplankton community shift

The mesoscale variability of PSC due to cyclonic events is examined using reconstructed chl-a data. For an in-depth understanding of PSC due to cyclones, a total of 42 cyclone cases occurred in the AS from 2003-2019 is taken for analysis (shown in Table. 1 and Figure 1). Cyclone track data from

IMD is used to extract corresponding PSC on each transit point for all 42 cyclone cases under three stages (pre, during and post-cyclone). Through reconstructed chl-a, the above extraction process was efficiently achieved. The percentage change of each PSC is calculated to estimate the short-term PSC changes affected by the cyclonic events (Figure 2). In comparing the 42 cyclone cases shown in Figure 1, it is found that the tropical cyclone could initiate phytoplankton community shift with high intensity compared to other cyclones. The percentage change of specific PSC is high due to the impact of the extreme tropical cyclone compared to other cyclonic events in the AS shown in Figure 2. On noticing the microplankton, the overall percentage change is + 15 % in the cyclone transect. Whereas the percentage change of picoplankton reduced to -16 % in the same cyclone transect region. There are no substantial changes in the nanoplankton noticed. The impact of the tropical cyclone on the physical and biogeochemical in the cyclone passage region and the corresponding effect on the PSC distribution is studied.

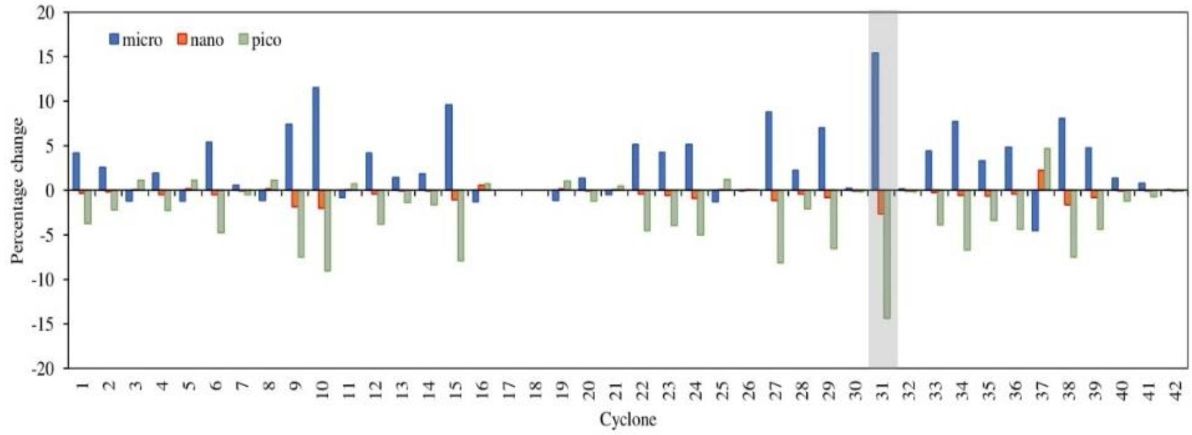

Figure 2. Observation of PSC before, middle and after the passage of 42 cyclone tracks. The cyclone case information is specified in Table 8.1 in ascending order as per the year occurred.

5. Discussion and conclusion

Our study finds that the intensity of the cyclones and the cyclone-induced PSC shifts are high in the post-monsoon in the Arabian Sea. The duration of the PSC shifts is longer based on the intensity of the cyclone for about 7-14 days. Further, the southern part of the Arabian Sea experiences massive community shifts compared to the northern part. The strong winds associated with cyclonic event induces upwelling of nutrients in the oligotrophic waters in the southern part, which creates a favourable condition for the microplankton to proliferate. This process led to dominance and community shift from picoplankton to microplankton in the cyclone passage region. This study provides the outlook of cyclone-induced PSC community shifts in the Arabian Sea.

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