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Phytoplankton community structure at the juncture of the Agulhas Return Front and Subtropical Front in the Indian Ocean sector of Southern Ocean: Bottom-up and top-down control

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ABSTRACT

The juncture of the Agulhas Return Front (ARF) and Subtropical Front (STF) in the Indian Ocean sector of Southern Ocean (SO) is characterized by high mesoscale turbulence, which results in sporadic, short lived phytoplankton proliferation. The biota, mainly the phytoplankton community from such a complex hydrodynamic region and its response to the mesoscale turbulence, are areas of interest for investigation. Hence, during the sixth Indian expedition to SO, a two-day time series was occupied at the ARF and STF merged region (40°S 58°30′E) from 13 to 15 January, 2012. The vertical profiles of phytoplankton (based on pigment indices) indicated variation in the percentage contribution of phytoplankton functional groups (Micro, Nano and Pico). Though the overall community structure was dominated by nanoplankton, as exhibited by pigment indices and CHEMTAX analysis, drastic shifts in the community were observed at 120 m depth at six hourly intervals. The oscillation between Flagellates (nanoplankton) to prokaryotes (picoplankton) and then to diatoms (microplankton) at this depth in three consecutive observations coincided with the significant variations in phosphate and nitrate concentrations, along with increase in abundance of the grazer community (ciliates and heterotrophic dinoflagellates). From the present study, it is evident that the flagellate group is the ideal one to survive in such a complex regime. However, the observed small interval oscillation in the phytoplankton community could be a coupled effect of bottom-up (vertical advection that alters the nutrient flux), and top-down (increased abundance of microzooplankton) factors.

1. Introduction

Phytoplankton, keystone microscopic algae are important players in aquatic systems due to their role in primary production, biogeochemical cycling of elements and regulation of global carbon budget in oceans through export production. The qualitative and quantitative analyses of phytoplankton are the basic steps towards understanding their community structure in a given region (Holligan, 1992). Phytoplankton community structure may vary from one place to another and also within the same water body (Fogg and Thake, 1987), based on the hydro-biological complexities prevalent in the given region. The knowledge from the marine pelagic system on the species-specific roles of phytoplankton, i.e., resource competition (bottom-up) versus mortality factors (top-down) is very scant (Verity and Smatacek, 1996). Such factors influence the food chain and biogeochemical cycles (Banse, 1995) by determining the phytoplankton biomass and the fate of produced material. In majority of the research efforts attempting to explain the factors controlling phytoplankton growth rates, mortality factors have been neglected (Smetacek et al., 2004).

The present study area is the juncture of the Agulhas Return Front (ARF) and Subtropical front (STF) in the Indian Ocean sector of Southern Ocean which is the boundary between warm, saline, nutrient-poor, subtropical, surface water and cooler, fresher, nutrient-rich sub-Antarctic surface water. In the Indian Ocean sector of SO, Agulhas return current flows parallel or juxtaposed to the STF (Lutjeharms and Ansorge, 2001). Owing to the presence of Agulhas return current which is dynamically very unstable, the ARF and the STF in the Indian Ocean sector of SO are characterized by high mesoscale turbulence (Ansorge and Lutjeharms, 2005) that results in intermittent and short lived phytoplankton blooms in this region (Llido et al., 2005). It is, therefore, of interest to study

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what kind of phytoplankton community could dominate in such a highly turbulent region and what are the critical factors supporting their dominance.

In view of this, the objective of this time series (48 h at 6 hourly interval) observation was to study the phytoplankton community structure in the merged ARF and STF region of the Indian Ocean sector of SO by characterizing the pigment composition and also to evaluate it in relation to the prevailing physico-chemical variables (growth factors) and microzooplankton community (mortality factor). The information obtained from the present study would be useful for developing biogeochemical models for similar regions.

2. Materials and methods

As part of the sixth Indian Expedition to the Southern Ocean, a two day time series station was occupied at the ARF region (40°S 58°30′E) in the Indian Ocean sector of SO from 13 to 15 January 2012 (Fig. 1). Water samples were collected from standard depths (0, 10, 30, 50, 75, 100 and 120 m) at six hourly intervals (00, 06, 12, 18, 24, 30, 36, 42, 48 h), using Niskin samplers (5 L) mounted on a carrousel unit along with the CTD. The collected water samples were used for the analysis of chlorophyll *a*, phytoplankton diagnostic pigments, microzooplankton and macro nutrients. In addition, physical data were collected using different sensors and remote sensing techniques (details under Section 2.1).

2.1. Physico-chemical variables and chlorophyll a

During the time series observation, three hourly temperature and salinity profiles were collected using a CTD (Make: SBE 911 plus, with accuracy: temperature ±0.001 °C, conductivity ±0.0001 S/m and depth ±0.005% of full scale). The PAR (Photosynthetically Active Radiation) sensor attached with the CTD was Biospherical PAR light sensor: Model no: QSP2300. The Microstructure Profiler (MSS90L) used for the study was manufactured by Sea & Sun Technology (Trappenkamp, Germany) in collaboration with ISW Wassertechnik. It is a loosely tethered system, comprising two PNS06 shear probes; the depth rating given by the manufacturer is 500 m. The details of instrument can be found in Prandke et al. (2000). The Microstructure Profiler (MP) was operated from the starboard side beam of the ship, and the ship was allowed to drift during the operation. The ship thrusters were switched off during the operation. A special winch manufactured by ISW Wassertechnik, Germany was used to deploy the MP. The winch provided sufficient slack in the cable while the instrument was sinking. This reduced the profiler vibrations transferred from the ship. The microstructure shear data collected were used to infer dissipation rates (ε) following a method similar to that of Moum et al. (1995). At each sampling (6 h interval), 3 shear profiles extending to 500 m were collected and the dissipation rates inferred were averaged for the station at 1 m interval. Noise levels of turbulent dissipation rates from the Microstructure Profilers are better than 10^{-9} W/Kg (Prandke and Stips 1998). The euphotic depth was calculated as the depth of 1% of surface PAR. The mixed layer depth was calculated following the 0.03 kg/m^3 density difference criteria from 10 m depth. Apart from the above in situ data, the delayed time Merged Sea Level Anomaly (SLA) obtained from the AVISO live access server (http://atoll-motu.aviso.oceanobs.com) and 8 day composite MODIS chlorophyll *a* concentration for the sampling period were also used in this study.

Macro-nutrients – nitrate (NO_3), silicate (SiO_4) and phosphate (PO_4) from the standard depths were estimated using an autoanalyser (SKALAR) following the standard protocol (Grasshoff et al., 1983).

Chlorophyll *a* (Chl *a*): Three litres of seawater collected from the standard depths was filtered through GF/F Whatman filter and the filters were kept frozen (−20 °C) prior to analyses. For total Chl *a* by fluorometry, the frozen samples were placed in 15 ml centrifuge tubes and extracted overnight at 4 °C using 10 ml 90% acetone. The extracted samples were measured fluorometrically using Turner's AU 10 Fluorometer (Turner Designs Inc., USA). Calibration was carried out using standard chlorophyll *a* pigments (DHI, Denmark). Obtained Chl *a* values were correlated with the Chl *a* values obtained from a fluorescence detector attached to CTD and the relationship was found to be statistically significant ($r^2=0.46$, $n=66$, $p\leq 0.0001$). Hence, the merged values (fluorometry and CTD fluorescence) were used to plot the distribution of Chl *a* in the study area. In addition, the satellite MODIS Chl *a* data (weekly composite) for the study period was also downloaded for the study location.

2.2. Phytoplankton pigment analysis

Three litres of water sample were filtered through GF/F (47 mm) glass fiber filters. The filters were stored in liquid nitrogen until analysis. The entire process was carried out in dim light and low temperature to minimize degradation of pigments during the filtration and extraction procedure. The filters were treated with 3 mL 95% acetone for 5 min in an ultrasonic bath filled with ice water and the extracts were stored overnight at −20 °C for HPLC (High Performance Liquid Chromatography) analysis. Chemo-taxonomically similar marker pigments were grouped together based on earlier practice

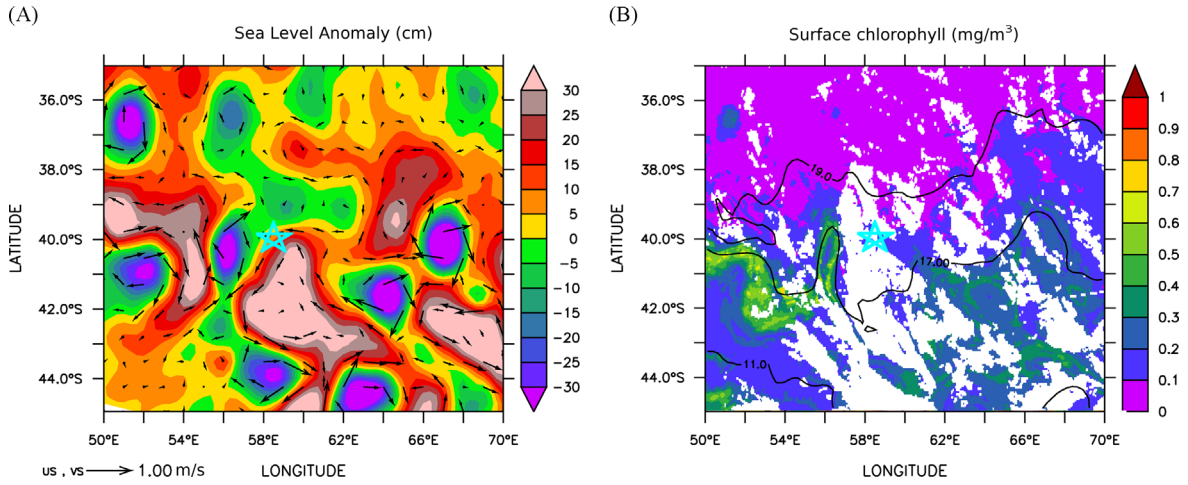

Fig. 1. (a) Study area showing time series station location (marked as star) along with sea level anomaly and (b) chlorophyll distribution at study area (weekly composite from MODIS).