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Temporal and spatial analysis of dissolved oxygen, sea surface temperature and sea surface salinity in northern Indian Ocean: Implication for environmental trends and variability

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ABSTRACT

The Indian Ocean, a vital part of the world's climate system, influences both local and global environmental trends. Dissolved Oxygen (DO), Sea Surface Temperature (SST) and Sea Surface Salinity (SSS) in the northern Indian Ocean, are three crucial oceanographic parameters that provide a comprehensive temporal and spatial analysis. The main goal is to examine environmental trends and variability in this region, shedding light on the potential impacts of anthropogenic activities and climate change. Using data from the Copernicus Marine Environment Monitoring Service, with resolution of 0.25°, spanning from 1998 to 2020, we aim to understand the physical and biogeochemical dynamics of the Arabian Sea and the Bay of Bengal. The analysis reveals significant temporal and regional patterns in DO, SST, and SSS across the Indian Ocean basin, including clear seasonal variations, temporal long-term trends, and notable annual cycles. Variations in DO concentrations underscore the vulnerability of marine life to hypoxic or anoxic conditions, which could negatively affect biodiversity. Our results and statistical analyses emphasize the critical importance of ongoing monitoring and research in the northern Indian Ocean to understand the environmental changes occurring in this region. This study provides valuable insight into the intricate interplay of environmental trends and variability through a detailed examination of the temporal and spatial dynamics of DO, SST and SSS in the Northern Indian Ocean. It highlights the urgent needs for proactive measures to mitigate the impacts of climate change and human activities on this essential marine environment.

INTRODUCTION

Over the past few decades, global warming has significantly impacted weather, climate, human society and the economy (IPCC, 2018). Understanding the dynamics of critical oceanic parameters in these regions is essential for grasping their complex interactions and ecological processes. SSS, SST and DO are fundamental parameters that greatly influence the physical and biological properties of these oceanic areas (Smith et al., 2020). Detailed long-term studies of dissolved oxygen concentrations in the ocean, reveal a steady decline over the 50 years (Bushinsky and Emerson, 2018; Schmidtko et al., 2019). Decreasing DO levels are particularly evident in coastal oceans, leading to the proliferation and expansion of 'dead zones'. The oxygen cycle is associated with changes in ecosystem dynamics, nutrient availability and ocean circulation by global climate models (Emerson and Bushinsky, 2014).The loss of DO can have far-reaching consequences, affecting pelagic and benthic fisheries, tourism, ocean nutrient cycling, and the oceanic production of N_2O, a potent greenhouse gas.

The ocean obtains DO primarily through air-sea gas exchange and photosynthesis. DO is a critical parameter for marine organisms, as it reflects the availability of oxygen in seawater and is essential for their respiration and metabolic processes. The Arabian Sea and the Bay of Bengal, exhibit significant temporal and spatial variations in dissolved oxygen due to several factors. Subsurface dissolved oxygen is advected via water mass distribution pathways and mixed into adjacent water masses. Other contributing factors include surface solubility (affected by warming), decreased ventilation (due to increased stratification), and enhanced deep ocean respiration (driven by higher surface primary production and increased particle flux), all of which can result in de-oxygenation(Diaz and Rosenberg, 2008; Keeling et al., 2010; Peña et al., 2010). Physical, chemical and biological variables also play a crucial role in the dynamics of DO (Menzel and Spaeth, 1962). These include ocean currents, temperature, salinity, nutrient availability and biological productivity. Large-scale variability in seasonal average atmospheric inputs is reflected in the temporal and spatial variability of sea surface temperature, sea surface salinity and dissolved oxygen. Lower sea-surface oxygen concentrations, reduced mid-water ventilation due to ocean warming, and local eutrophication episodes, contribute to the expansion of marine dead zones (Stramma et al.,2008; Diaz and Rosenberg,2008).

Sea Surface Temperature (SST) refers to the temperature of the ocean's uppermost layer, while Sea Surface Salinity (SSS) denotes the concentration of dissolved salts in the same layer. Both SST and SSS are fundamental oceanographic indices critical for understanding the physical and chemical properties of the ocean and their influence climate and ecosystems (Schmidt et al., 2019). SST variability is a multidimensional phenomenon driven by various natural and anthropogenic factors. SST oscillations are influenced by solar radiation, air-sea heat exchanges, monsoonal circulation patterns, oceanic forcing mechanisms and human activities (Smith et al., 2020). These intricate interactions of mechanisms, underscore the need for comprehensive research into the complex dynamics of SST and its implications for climate and ecosystems. SSS concentration is regulated by multiple factors, including river freshwater discharge, precipitation, evaporation, climate variability, and oceanic currents (Rao and Sivakumar, 2003).