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Biogeosciences Discussions

Ideas and perspectives: Ushering Indian Ocean into the UN Decade of Ocean Science for Sustainable Development (UNDOSSD) through Marine Ecosystem Research and Operational Services – An early-career's take

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Abstract.

The Indian Ocean-rim hosts many of the underdeveloped and emerging economies that depend on the ocean resources for livelihood of the populations of millions residing. Operational ocean information services cater to the requirements of managers and end-users to efficiently harness those resources, and to ensure safety. However, fishery information isn't the only operational services that will be needed empower such communities in the coming decades. Coral bleaching alerts, SCUBA-assist advisories, conservation or ecotourism assist services (e.g. Turtle-watch/Whale-watch), poaching/bycatch reduction support, jellyfish/microplastic/oil-spill watch are to name a few, but not an exhaustive list. This paper reviews existing tools, and explores the ongoing research that has potential to convert the findings into operational services in near-to-mid term.

Keywords:

Ecosystem, Operational Services, UN Decade of Ocean, Perspectives

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1. Introduction

About a third of the world population reside in the Indian Ocean (IO)-rim countries. This is projected to increase and may reach to 50% of global population by year 2050 (Doyle, 2018). Their lives and livelihoods are inherently intervened with the IO and its dynamics. These countries have very diverse cultures and philosophies. Their financial capabilities vary widely and so are their aspirations and world-views. The IO-rim (IOR) countries thus present a confluence of ideologies to a manager, with their vivid and vibrant demographics that have very different challenges and opportunities. Majority of the IOR countries have either expansive of stationary population pyramid profile, with limited land resources. Their nutritional and employment needs will have more reliance on the IO in coming decades. Marine ecosystems are promising source for the nourishment of populations and at the same time, are under serious threats than ever before. As more people are brought up from the poverty, consumerism is poised to extend to larger part of the population, which will create concerns for the health of the adjoining ocean ecosystems.

The IO is one of the relatively poorly studied oceans of the world. It is thus important to ensure that the resources in this unique, land-locked from the north ocean, are harnessed in harmony with the sustainability and with the equal opportunities. For the successful planning and execution, it is imperative for the resource managers to have community participation (Martini et al., 2017). It is especially important for the IOR countries to chart right path at the eve of the United Nations Decade of Ocean Science for Sustainable Development (UNDOSSD, 2021-2030). Advancement of geosciences in last century has provided us many tools to cope with the changing environment and associated challenges. The same role for the twenty first century is shifting to operational oceanography. Robust combination of observations and modelling, artificial intelligence, effective tools of interpretation and user-friendly dissemination of information can change millions of lives depending on the oceans. This paper hypothesize that the best possible approach to win the community attention (and to invoke the responsible ownership of the resources) is to engage the communities with the operational ecosystem related services. Further, this paper explores the regional needs and solutions based on presently available data and technologies.

2. Marine Ecosystem Research and operational Services (MERS)

The marine ecosystem related operational ocean information and forecasts services (or products as a service) can be grouped into three major categories based on their prime objectives. First type of services is related to the resource management, conservation and support to livelihood. Second type comprises of service that deal will threats to the ecosystem. The third group is of solutions for community engagement and dissemination.

Under the decadal initiative the UN Sustainable Development Goal (SDG)-14 (Life below water) will receive significant attention, which heavily relies on the remote sensing data in general and in particular, Ocean Color (OC) observations. In late 90's, the OC science achieved operational status (after a decade long hiatus post-CZCS era) due to adequate satellite coverage. Since then researchers have made extensive use of these data despite often encountering spatial (clouds and sun-glint), temporal (daily once, daytime only coverage) or spectral (fixed, limited bands) limitations. The applications range wide from fisheries and aquaculture to Harmful Algal Bloom (HAB) monitoring to estimating productivity and carbon budgeting (Wilson, C., 2011).

However, there are limitations with regard to predictability of the base of the food pyramid itself. There are global products for primary production such as VGPM (Vertically Generalized Productivity Model) that are developed with relatively low observations of the P-I (Photosynthesis-Irradiance) parameters from the IO. It is thus very much important for the IOR countries to have a regional Primary Productivity (PP) model for operational applications. This could be taken up as a priority during the UNDOSSD.

This decade is chiefly important due to the planned launch of operational hyperspectral mission such as PACE (Plankton, Aerosol, Cloud, ocean Ecosystem) by NASA in the early 2020's. A hyperspectral sensor scans oceans with high-resolution of as much as 1nm wavelength for whole the visible spectrum, that enables the researchers to begin a new era in the OC sciences due to its potential of developing a plethora of applications. This includes but does not limit to better resolving phytoplankton functional types, fishery resource management and ecosystem health monitoring. The latter is more important especially for the second type of services and is discussed in detail in subsequent section.

At the same time, the temporal limitations seem to be negated through various approaches such as using the Day-Night Band (DNB) data or OC data from the geostationary orbit such as GOCI (Geostationary Ocean Color Imager) (Miller et al., 2013; Ruddick et al., 2014). When OC science follows the footsteps of other satellite types, we may also have a "swarm" of nano-satellites or cubesats – further improving temporal and up to some extent, spatial coverage as well. Placement of HICO (Hyperspectral Imager for Coastal Ocean) on International Space Station (ISS) reminds us that the OC science may not limit to satellite remote sensing in coming decades (Huemmrich et al., 2017). Validations, sampling protocols (SOPs), inter-comparison exercises and training for all of these will be needed. Modelers are putting efforts to assimilate data products into numerical models or, making use of surface information for better resolving subsurface characteristics. Others strive for carbon, or heat-budgeting. With more than two decade of uninterrupted observations, (applying the rule of thumb of minimum 30 years time-series) we are a few years away of making use of OC data for climate applications.

There are some proven (e.g. telemetry) and emerging (e.g. eDNA) tools that can help researchers for the services related to higher trophic levels (Costa et al., 2010; Stat et al., 2017). These tools are very useful in providing vital information habitat utilization, migration, environmental preferences and presence-absence analysis. The research can then support to the operational services that cater to sustainable resource management, prevention of bycatch or help reduce accidental mortality. National Oceanic and Atmospheric Administration (NOAA)'s TurtleWatch is the best suited example for majority of the IO countries (Howell et al., 2015). Other species for which such products are very much needed in the operational mode are Cetaceans, Sharks and marine mammals.

The operational services that can predict the movement and presence of these animals are required for conservation authorities who can then effectively design protected areas, do better marine spatial planning or monitor potential hotspots for poaching or IUU (Illegal, Unreported and Unregulated) fishing. Additionally these can also support the ecotourism (e.g. WhaleWatch) as an alternate livelihood for the fishermen that face capture fishery as less lucrative occupation. Ecotourism needs support from operational services monitoring mangroves and corals as well. Innovative ideas that put together existing observations and forecasts (e.g. water clarity, currents and wave-height, coral health i.e. no-bleaching/stress alert), and generate novel products (e.g.

SCUBA-buddy advisories), will support dive operators in the many of the IOR-countries, especially to the SIDS (Small Island Developing States). Mariculture (open ocean cage culture) is emerging as another area of livelihood as an alternate to the capture fishery and is poised to be more feasible at wider areas with newer designs of submerged cages (Korsøen et al., 2012).

Acoustics is another such tool that can support development of operational services for various stakeholders. Acoustic telemetry is useful for the species to which satellite telemetry isn't suitable due to various reasons (Crossin et al., 2017). Whereas, the field of bioacoustics has been furthered into many sub-branches. The estimation of zooplankton biomass with the help of acoustic backscatter isn't only limited to moored buoys and these techniques have transcended to AUVs (Autonomous Underwater Vehicles), aptly called as zooglider (Ohman et al., 2019). Such surveys are vital for zooplankton and ichthyoplankton distribution monitoring, and for ecosystem models that would connect the regional PP products to the higher trophic levels. Bioacoustics is also used in terms of monitoring the marine animals' movements by listening to the underwater sounds, often through Passive Acoustic Monitoring (PAM), which would be one of the less intrusive ways of study (Brwoning et al., 2017). Human activities can be nuisance to the marine environment in many ways and sound is one of the ways (Williams et al., 2015). Future operational services will need to account for developing ways to monitor the oceanic soundscape.

Another common anthropogenic impact to the marine ecosystems is transport and introduction of alien (non-native) species through the ballast water. These species when lack natural predators, are often turn out to be invasive species and throw off the local ecological equilibrium (Bailey S.A., 2015). Oil spill is yet another source of pollution from the ships. These can be addressed up to certain extent by monitoring vessel AIS (Automatic Identification System) data and applying artificial intelligence-machine learning (AI-ML) tools to identify the ship behavioural patterns prior to such discharges; and then use it as predictive model (Soares et al., 2019).

Plastic adversely impact the marine environment in multiple ways. The known pathways include ghost fishing (entanglement), ingestion, bioaccumulation and allied effects, as well as transport of alien species and pollutants. Among the top-20 countries globally with inadequately managed plastic as a source to the ocean, half are the IO-rim countries. All of the Bay of Bengal (BoB) peripheral countries face the issue of land-plastic management (Jambeck et al., 2015). Thus, the BoB needs to be prime focus to monitor the oceanic and beach debris in the operational mode, with the help of latest remote sensing techniques (Martínez-Vicente et al., 2019).

On the other hand, mass sink of jellyfish swarming have been reported the Arabian Sea (AS) (Billet et al., 2006). Jellyfish swarms are known to be disruptive to fisheries, and to cooling water intake facilities of coastal industries with causes little known, and thus calls for development of predictive capabilities. The AS also witness large scale blooms of *Noctiluca scintillans* and research in recent years may provide the foundation for the bloom forecasting (Xiang et al., 2019). Crashing of jellyfish swarms or algal blooms have implications to the deep sea ecology, particularly in the regions such as the AS which has prominent oxygen minimum zone (OMZ). The stratified waters such as of the northern IO basins have implications for large pelagic which may face additional fishing pressure with the expansion of the OMZs due to shrink of the habitat (Nimit et al., 2020).

While it is important to have robust observations and modelling capabilities in order to generate operational services and products, it is equally important to have effective dissemination. Presently, the IOR countries rely on information dissemination through conventional modes which are almost entirely land-based. This results in episodes such as cyclone Ockhi wherein lack of timely alerts cost many lives (Roshan M, 2018). Dissemination of operational services onboard has benefits during fair weather as well in terms of fuel saving. Due to limitation of cellular signal support at sea, it is imperative that a full-fledge dissemination system should be supported through satellite communication (Singh et al., 2016). Such dissemination systems are to be provided along with feedback mechanism so to validate the services in real or near-real time. The feedbacks also open new avenues of data collection. Crowdsourcing of data gathering could play an essential role in making seafarers eyes and ears of the scientists (Kelly et al., 2020).

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