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सत्यमेव जयते

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Dear Sir/Madam,

In response to your communication dated 14th December, 2021 to Ministry of Earth Sciences, inputs were sought on the topic "Ocean observing" to be included in the Secretary General's Report for twenty-second Meeting of the United Nations Open-ended Informal Consultative Process on Oceans and Law of the Sea. Please find enclosed a brief report on the said theme.

The Report has been prepared by the Ministry of Earth Sciences, the nodal Ministry administratively in charge of the subject matter.

Best Regards,

(Dr. Kajal Bhat)

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Ministry of Earth Sciences (MoES), Government of India

Indian National Centre for Ocean Information Services (INCOIS)

Report on Ocean Observations by India

Reference: Antarctic Treaty Secretariat Circular No. 18 / 2021 - Invitation to contribute to the SG Report on the topic of focus (Ocean Observing) for the Twenty-Second meeting of the United Nations Open-ended Informal Consultative Process on Oceans and Law of the Sea.

Sustained ocean observations are crucial to understand complex oceanic processes, its variability, its interaction with the atmosphere and development of operational ocean services for the benefit of the society. The Ministry of Earth Sciences (MoES), Government of India leads the national ocean observation programs along the Indian coast and in the Indian Ocean through its autonomous institutions, the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad and the National Institute of Ocean Technology (NIOT), Chennai. Data from these observing network are efficiently and effectively utilised for generation of ocean information and advisory services viz., potential fishing zone advisories, harmful algal bloom information, coral bleaching alerts, ocean state forecast, tsunami, cyclone and storm surge early warning services, etc. that support blue economy initiatives and enhance safety of life. The data forms critical component in ocean modelling, calibration and validation of remote sensing data. India is now embarking on Ocean Climate Change Advisory Services to understand and provide future projections of the important ocean climate change indicators on decadal to longer time scales and associated impact on the coastal regions by developing suite of dynamical / statistical models and techniques and establishing dedicated observational system. The data generated from the observational network help in developing products and support the blue economy initiatives. The scientific rationale of all these observing programmes is to contribute towards supporting the greater goal of sustainable development and ecosystem restoration, expanding biological observing networks and marine biodiversity observations, innovation and making use of advanced technologies for low-cost, multidisciplinary observations and to improve global ocean observation networks.

Several of India's ocean observing networks form integral part of the Global Ocean Observing System (GOOS) programme of the Intergovernmental Oceanographic Commission (IOC/UNESCO). INCOIS serves as the National Oceanographic Data Centre (NODC), designated by the International Oceanographic Data Exchange Programme (IODE) of the IOC/UNESCO. INCOIS maintains data compatibility, interoperability and follows data sharing protocols as part of the international observation programs, and in other national level programs. It is important that ocean observing programmes be sustained and further strengthened with regional and global collaborations for achieving the goals as envisioned in UN Sustainable Development Goals (in particular SDG14) and the UN Decade of Ocean Science for Sustainable development (2021-2030).

1. India's contribution to international Ocean observing programs

In this section, the Ocean Observation Programs maintained by INCOIS and NIOT and part of international programs, and data shared with other international partners are described.

1.1. Indian Argo Program

Argo program is a collaborative partnership of more than 30 countries to collect hydrographic observations of the top 2000m of the ocean and forms the major component of the Global

Ocean Observing System (GOOS) led by the Intergovernmental Oceanographic Commission (IOC) of UNESCO. INCOIS, representing India, actively participates in this global ocean observation program since 2001 by deploying Argo floats in the Indian Ocean and processing the data by following the globally approved protocols. INCOIS has deployed 494 floats so far in the Indian Ocean. Data from these floats are relayed in real-time mode enabling data assimilation in models at the Ocean Data Analysis/Reanalysis centers globally. Delayed mode quality-controlled data are used for generating value-added products for weather and climate research.

With recent enhancements in Argo float technology, now we can include biogeochemical sensors in the Argo float, thus enabling collecting physical, biological, and chemical data from the upper 2000 m of the ocean. In-situ data products from this program enable the monitoring of ocean biogeochemistry and health, and monitor major processes such as ocean deoxygenation, acidification and warming and their effect on phytoplankton, the main source of energy of marine ecosystems.

1.2. Drifting Buoy Program

As part of the Global drifter program (GDP) under GOOS, INCOIS participates and deploys lagrangian drifting floats in the Indian Ocean. The primary objective of this program is to maintain a global 5°x5° array of ~1300 satellite-tracked surface drifting buoys to meet the need for an accurate and globally dense set of in-situ observations of sea surface temperature, atmospheric pressure and mixed layer currents (derived from drifter positions) for the scientific and operational use of these data. Global drifter data enables the modelling of marine garbage in the world oceans and helps us to take contingency plans to make the oceans garbage free in line with the UN Sustainable Development Goals (SDG) 14, in target 14.1. As part of this program, INCOIS plan to deploy 30 drifters per year in the North Indian Ocean (1 drifter in 5°x5° box) at a measurement frequency of 1 hour.

1.3. Moored Ocean Observing Network by NIOT

NIOT established the Moored Ocean Observation Network comprising of Met Ocean, CAL-VAL and Tsunami buoys for data collection and to disseminate real time data. The present buoy network comprises of twelve OMNI buoys, four coastal buoy systems, one CAL-VAL buoy system and two tsunami buoys. Besides, one (1) IndARC mooring at Kongsfjorden, Norway, one ADCP mooring and a Directional Wave Rider buoy off Chennai is also being maintained by NIOT.

The OMNI Buoy network transmits high resolution real-time upper ocean vertical profiles of temperature, salinity and currents along with surface meteorological data of winds, humidity, pressure, temperature, rainfall and radiation. The data are being received at NIOT and disseminated to INCOIS for further transmission on GTS in real-time for its utilisation by operational agencies globally. The OMNI programme contributes to the Global Ocean Observing System (GOOS).

MoES supports Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA) programme of NOAA/PMEL under the INDO-US collaboration. NIOT and INCOIS are extending operational support to NOAA/PMEL for RAMA buoys in the Indian Ocean since 2008. A Joint OMNI-RAMA Indian Ocean Data Portal was developed by INCOIS jointly with NIOT and PMEL-NOAA. The joint data portal showcases the large inventory of meteorological and oceanographic data sets with direct access for data display and delivery.

1.4. Ship-based Automated Weather Stations (AWS)

INCOIS installed a network of 34 AWSs onboard vessels owned by different Indian agencies and report the data in real-time at the INCOIS data reception center and further disseminated on GTS. The primary objective of the AWS program is to measure the surface met-ocean parameters to validate and refine the forcing parameters (obtained from different met agencies) for the Indian Ocean Forecasting System (INDOFOS) which is being operated at INCOIS. This AWS network measures all the basic weather parameters like wind speed and direction, air and sea surface temperature, barometric pressure, downwelling shortwave and longwave radiations, surface humidity etc. These measurements enable to compute the fluxes of heat, water (E-P) and momentum across the air-sea interface and provide precious ground truth data for model forcing validation. The programme contributes to the Ships Observations Team (SOT) of WMO.

1.5. Wave Rider Buoy Network

INCOIS maintains a network of 16 wave rider buoys for monitoring the state of the ocean as well as the online/offline validations of the ocean state forecasts. Accurate forecasting of the nearshore wave conditions, including high swell events, surges, cyclone induced waves etc, is a very crucial part of the coastal zone management that plays a vital role in the Government of India's developmental policies. In-situ wave parameters from the coastal regions provide valuable ground truth for model validation and model assimilation purposes. To achieve this goal, INCOIS started the Wave Rider Buoy (WRB) program of strategically deploying the WRB's in climatologically important Indian coastal locations. Data from the WRBs are used for assimilation and validation, to investigate the wind-wave and wave-wave interactions, and to track long-term wave climate trends. The programme contributes to the Data Buoy Cooperation Panel of WMO.

1.6. Tide Gauge Network.

INCOIS maintains a network of 36 real-time tide gauge stations around the Indian coastal regions and island stations to continuously monitor the sea level variations around the coasts. This network forms a major component of the Indian Ocean Tsunami Warning System (IOTWS) located at INCOIS besides the Tsunami detecting buoys. IOTWS is one of the three regional Tsunami warning providers for the Indian Ocean region mandated and coordinated by IOC, UNESCO. Out of the 36 stations, 8 station data are shared with IOC Sea Level Monitoring Facility (http://www.ioc-sealevelmonitoring.org/index.php). The long-term sea level observations are critical for understanding the decadal climate variability at local and regional scale in the context of sea level rise due to global warming and its impact on the coasts.

1.7. Tsunami Buoy Network

INCOIS maintains a network of 05 Tsunami Buoys with surface buoys (03 in the Bay of Bengal and 02 in the northern Arabian Sea). NIOT maintain 2 Tsunami Buoy Systems in the north Indian Ocean and data being transmitted to INCOIS in real-time. These open ocean tsunami buoy systems equipped with bottom pressure sensors can provide warning to coastal areas that will be first impacted by a tsunami, before the waves reach them and nearby tide gages. Since the tsunami waves will not yet be modified by local bathymetry, open ocean buoys often provide a better forecast of the tsunami strength than tide gages at distant locations. The data from these tsunami buoys are shared with the National Buoy Data Centre (NDBC) of NOAA.

1.8. XBT/XCTD Program

The XBT/XCTD program is part of the Ship Of Opportunity Program (SOOP), a component of the GOOS, whose mission is to provide a global platform to deploy and operate oceanographic instrumentation from cargo ships and research vessels. INCOIS is part of the 19 institutions joint XBT program where we maintain eXpendable BathyThermographs (XBT) lines along select sea routes around India. This is one of the longest ongoing observational programs jointly executed by INCOIS and the National Institute of Oceanography (NIO, Goa, India). Under the XBT (XCTD) program temperature (temperature and salinity) profiles of the upper ~800 m of the ocean along regular commercial shipping routes is collected and processed for analysis. These long-term measurements are critical to improve our understanding of the interannual to decadal-scale volume transport in the oceans.

2. National level programs

In this section, observation programs of INCOIS, mainly to augment the service mandate of the institution, are described.

2.1. Coastal Water Quality Monitoring

As a part of 'Coastal Monitoring' programme, INCOIS will establish buoy based autonomous water quality observatories at six select locations in Indian Coastal waters along West (Veraval, Goa, Kochi) and East (Chennai, Visakhapatnam and Digha) coast of India. The first phase deployment is at Visakhapatnam and Kochi which will be subsequently scaled up at other locations. These observatories will continuously record a multitude of physical and biogeochemical parameters. The data recorded by the observatories is aimed at monitoring water quality parameters, developing an understanding of coastal processes, assessing the health of the coastal waters, model validation, assimilation, and forecasting of water quality parameters.

2.2. Deep Ocean Observing System

India has initiated efforts to develop Ocean Climate Change Advisory Services (OCCAS) under the Deep Ocean Mission (DOM) and R&D towards to understand and provide future projections of the important ocean climate change indicators on decadal to longer time scales and associated impact on the coastal regions.

The existing observation platforms alone are not suitable to monitor and detect any changes in the circulation patterns (meridional overturning circulation, Indonesian throughflow etc.) in the Indian Ocean at climate scale, as there is no observing platform below 2000 m water depth. To monitor critical climate variables, particularly the deep-sea circulation and associated long-term signatures, a dedicated observational system will be developed while sustaining and augmenting the existing network of moored buoys, Argo floats, drifters, etc. As part of OCCAS, INCOIS will establish the Deep Ocean Observing System comprising Gliders (8), Deep Argo Floats (48) and Wave Drifters (150), during the next 5 years.

2.3. Coastal HF Radars

The Indian Coastal Ocean Radar Network (ICORN) comprising of 10 HF radars along mainland coastal locations and Andaman islands was established by NIOT. Out of 10 sites, 6 are located along the east coast of India, a pair covering the Gulf of Khambhat, Gujarat in the west coast of India, and the remaining two are in the Andaman Islands. These HF radar systems map surface currents, wave characteristics, and spectra in wide swaths of coastal

waters up to 200 km offshore, 24 hours a day, and in all weather conditions. These surface observations are then reported to the data reception centers at NIOT and INCOIS. Main users of these high-quality data include academia, research institutes, and ocean information service providers.

2.4. Equatorial Current Meter Mooring Array

INCOIS has set up and continues to maintain 03 equatorial subsurface current meter moorings in the Indian Ocean with a collaboration with the National Institute of Oceanography (NIO, Goa, India). Long-term time series of current data from the equatorial Indian Ocean form a rare in situ data record for model simulation validations, and to study the cross-equatorial flow and its interannual to decadal-scale variations.

2.5. Coastal ADCP Network

INCOIS, in collaboration with NIO, Goa, maintains a network of 18 coastal Acoustic Doppler Current Profilers (ADCP) along the Indian coastal regions. This is one of its kind measurements of coastal currents around the Bay of Bengal and Arabian Sea and provides valuable in situ current records of more than a decade for model simulation validation, basic research on Indian Ocean coastal currents etc.

2.6. Ship-based process specific observations

INCOIS conducts regular cruises in the ocean to collect physical, biological, chemical and meteorological data from Indian Ocean. These observation campaigns are aimed at collecting in situ observations to study specific processes that are important to improve in the ocean forecast models for better forecasts. INCOIS utilizes state of the art observation tools like ocean gliders, lagrangian floats, ASIMET systems, eddy covariance flux system, underway CTD systems, conventional and lowered ADCP systems etc to collect data.

2.7. GNSS and SMA network in the Islands

A real-time network of 35 collocated Strong Motion Accelerometers (SMA) and Global Navigation Satellite System (GNSS) receivers are established in the Andaman Nicobar Islands with real-time satellite connectivity. This real-time GNSS and SMA data will be used for estimation of Moment Magnitude which is critical indicator of tsunamigenic potential of an earthquake. Also, the directly measured rupture area and vertical and horizontal displacements of the sea floor gives the information to force the tsunami propagation and inundation models. The estimated run-up heights will be more accurate with real source parameters compared with worst-case scenario slip distribution, which is current operational strategy for fast tsunami warnings. These observations together with the tsunami monitoring buoys and costal tide gauge stations form the observation component of the Indian Ocean Tsunami Warning System.

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