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In Situ Data Assessment: An Offline Tool for viewing Argo Data and Data Products

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Abstract: In this paper, we focus on implementation of research, and the efficient management of resulting Indian ocean data. Data management and integration consider the careful collection, management and dissemination of research data is taken to provide vast ocean information integration. In order to develop robust ocean information system, the data from in-situ ocean observing systems such as Argo floats, drifting buoys, moored buoys, XBT surveys, tide gauges, coastal radars, current meter mooring array, bottom pressure recorders has been considered to design by implementing data acquisition, processing, quality control, and database generation. The diverse data sets has been acquired from in-situ platforms needs to be quality controlled, organized and disseminated in real time to data users. This paper on ODIS provides ocean data management and web-based ocean information system and its visualization functions for oceanographic data. An integrated observing system will also require improved combination of data from in-situ platforms which observations depends on their parameters and data types.

Keywords: Heterogeneous data, Oceanography, Visualization, Data Management, Integration, Argo Data products.

I. INTRODUCTION

INCOIS, being the central repository for marine data in India, receives voluminous oceanographic data in real time, from a variety of in-situ and remote sensing observing systems. ODIS provides information on physical, chemical, biological and geological parameters of ocean and coasts on spatial and temporal domains that is vital for both research and operational oceanography [1].

Large amount of data has been generating from various Ocean Observing Systems such as in-situ platforms and remote sensing satellites established in the Indian Ocean. ODIS (Ocean Data Information System) is receiving huge amount (more than ~5 Tb per year) and it is dynamic and highly heterogeneous oceanographic data in real time. ODIS is a development system, which is dealing with data archiving, visualizing and sharing heterogeneous data. Thus the ODIS serves the information to the user community by delivering data and preliminary information services at lower costs, manpower and time-scales than has been associated with ocean state monitoring and management [2]. The real issues for data management are standardization, collaboration and enabling knowledge-based decision-making. The use of traditional method of handling ocean data using flat files was difficult to handle, as it is increased in receiving huge inflow of data from ocean observing systems. So, now as the technology has developed rapidly which can assist with diversity and volume of data flows. Obviously, the technology-driven ecosystem for providing ocean information visualization tool is more helpful for future predictions of ocean state and its operational oceanographic services.

The heterogeneous ocean data integration, which has been articulated by its physical, chemical, biological and geological parameters of ocean on its spatial and temporal domains. Integration of the many aspects and elements into an observing system will make it vastly more powerful, compelling, and effective. We are providing one stop shop for ocean related information along with its parameters and details for forecasting and various operations to perform by researchers.

Modern data management is a form of information technology. Recent developments in technology assist in coping with both the diversity and volume of data flows. The internet provides data at very low – cost. Electronic publishing is the method to know about research results and other information. Database systems are becoming more and more sophisticated, which is helping scientists and data managers to concentrate on subject matter rather than technical knowledge. Computer systems are becoming faster, hard disk and other storage space is becoming cheaper, and information technology is making it possible to conduct data management, and devise information products, that could only be dreamed of just a couple of years ago [3].

The main challenge for data managers is now to remain in control of developments, and not to let marine data management become technology-driven. Obviously, recent technical developments should be monitored, and put to

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good use whenever and wherever relevant. But it is more important to continuously re-evaluate what the role of the data centers should be, rather than how objectives are being realized. The real issues for data management are standardization, collaboration and enabling knowledge-based decision-making.

II. OCEAN OBSERVING SYSTEMS

The ocean is complex, many processes are involved. There are two types of Ocean Observing Systems, they are: In-situ Observing System and Remote Sensing Observing Systems. These Systems are used to observe real time Ocean behavior in terms of its spatial and temporal domains. The observing System will detect, track, and predict changes of Ocean physical, biological, geological and chemical processes. These observations are made for scientific research purpose and some special calculations such as:
(a) To determine the role of ocean and climate change
(b) To quantify the change in heat, water, momentum and gases of the ocean and its atmosphere
(c) To determine the cycling of carbon in the oceans the increase in atmospheric carbon dioxide
(d) To improve models of large-scale ocean circulation
(e) To understand the patterns and controls on biological diversity of the oceans
(f) To determine the origin, development and impact of episodic coastal events such as harmful algal blooms
(g) To assess the health of the coastal ocean region
(h) To determine the nature and extent of microbial life in the deep crustal biosphere
(i) To study subduction zone thrust faults, tsunami-generating earthquakes
(j) To improve models of global earth structure and core-mantle dynamics ant etc.,

Remote Sensing provides us with the only global view of the oceans on synoptic timescales. For ocean carbon, remote sensing capabilities can be broken down into three main thematic categories: Quantifying upper ocean biomass and ocean primary productivity, Providing a synoptic link between the ocean ecosystem and physical processes, Quantifying air-sea CO_2 flux. Satellite Remote Sensing provides critical information on high-frequency variability, large-scale spatial patterns, and seasonal-to-internal signals. However, only a few parameters can be measured from satellites and for most properties, ocean color and its biomass, primary productivity, community structure, physiology, colored dissolved organic matter. Another property like air sea-gas transfer consists of wave characteristics, wind speed and friction velocity, sea surface temperature, atmospheric pressure.

In-situ observing systems have both Eulerian (based on fixed locations) and Lagrangian (whose location varies with time) systems. The elements of in-situ observing system in terms of their principle, capability to observe the ocean, technology and some of the applications pertaining to physical variables are considered. Modern data management is a form from information technology. Recent developments in technology assist in coping with both the diversity and volume of data flows. The internet provides data and information at a very low – cost. Electronic publishing is more preferred for communicating research results and other information. Database systems are becoming more sophisticated, which allows scientists and data managers to concentrate on subject matter rather than technical. Computer systems are becoming faster, hard disk and other storage space is becoming cheaper, and information technology is making it possible to conduct data management, and devise information products, that could only be dreamed of just a couple of years ago.

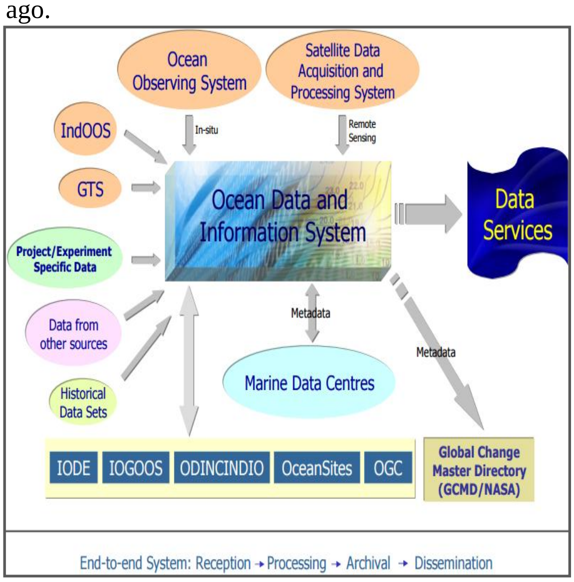

Fig 1 : An end-to-end system of ODIS

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III. DATA INTEGRATION SYSTEM – IN-SITU PLATFORMS

It is an experiment in which a comprehensive, integrated observing system would be established and held in place for several years and the data assimilated into state- of- the art models of the global ocean circulation in near real-time. It is a system to implement operational observation programs for the oceans and coastal areas. It is a program designed to improve the ocean models necessary for predicting decadal climate variability and change.

An in-situ observing system consists many elements such as tide gauges, ship based marine meteorology from Voluntary Observing Ships(VOS), Ships of Opportunity (SOOP) based XBT/XCTD sections, repeat hydrography, drifting and moored buoys, acoustic tomography, argo profiling floats, gliders, etc. Each element has some advantages and disadvantages in terms of temporal and spatial resolutions. Integrating all the elements, sustaining and improving the different components of observing system to meet the evolving needs for societal benefits is an imperative need for ocean observing system. Though the sensors used in these platforms/elements records primarily physical variables, the time has come to have multi-disciplinary approach to understand the total system.

Integration of the observing system elements and programs also means to combine their data systems ultimately. This does not necessitate single joint databases or even common data formats, since modern technologies exist like distributed systems and Live Access Servers with data dictionaries and data discovery techniques that enable data access across diverse sources. Many programs have their own data system established and a future challenge then is to provide seamless and cross-linked access to all of them. Technologies exist for this, and the programs to make that reality are under development [5]. No standards (i.e. formats, QC procedures, best practices) exist currently for many biogeochemical and ecosystem parameters (in profile or time series form). OceanSITES has started to try filling that gap and is working to define format and QC/QA procedures.

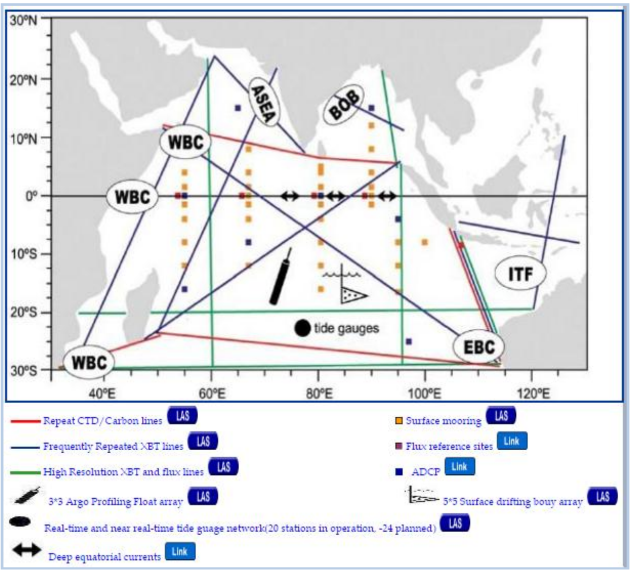

Fig 2: Integrated Observing System with basin-scale observations by moorings, Argo floats, XBT lines, Surface-drifters and tide guages

In situ observations conducted on appropriate space and time scales, Integration of these data to the surface signal measured by satellites and Improved models of the behavior of the carbon system, including data integration via inverse (diagnostic) modeling and data assimilation.

The Ocean Data and Information System (ODIS) is a system which provides an end-to-end ocean data information management system. Currently, the INCOIS archive contains more than 140000 salinity and temperature profiles and the databank holds ~17,00,000 records [6]. The data sets
available includes data from Argo floats, moored buoys, drifting buoys, XBTs, current meters, buoys, tide gauges, bottom pressure recorders, coastal radars, wave rider buoys, autonomous weather stations, etc[7]. The Live Access Server (LAS) installed at INCOIS is widely used by the oceanographic community for data selection, visualization and the generation of on-the-fly graphics[6].

The observation occurring on northern Bay of Bengal region: Generation of a high quality data on temperature, salinity, oxygen and currents in the upper ocean by deploying a single deep-sea current meter mooring at 18°N, 89°E ,

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and surface meteorological parameters from a moored buoy in the northern Bay of Bengal. Describing the sub-intraseasonal variability in the near-surface fields of temperature, salinity, oxygen and currents and the investigation of mixed layer heat budget in the northern Bay of Bengal.

The database is designed according to the data flow of the system as shown in Figure 3. The main focus in this database management system are: Data Acquisition, Data Processing, Quality Checks, and Data Archival. The best way to configure the in-situ information system is by implementing the RDBMS, which contains both data and metadata. MySQL A database is updated on an operational basis (ships and buoys reporting at synoptic hours) and the updated data is immediately available to users[2]. This system is also helps in monitoring the ship tracking and their position of mooring and drifting. This Database is incorporated with applications like input, query, retrieval, visual quality control, and reporting functions. It is a client/server based architecture, MySQL is located on a server and all other applications are on different client systems. Raw data acquired from different sources are pushed to the backup FTP Server.

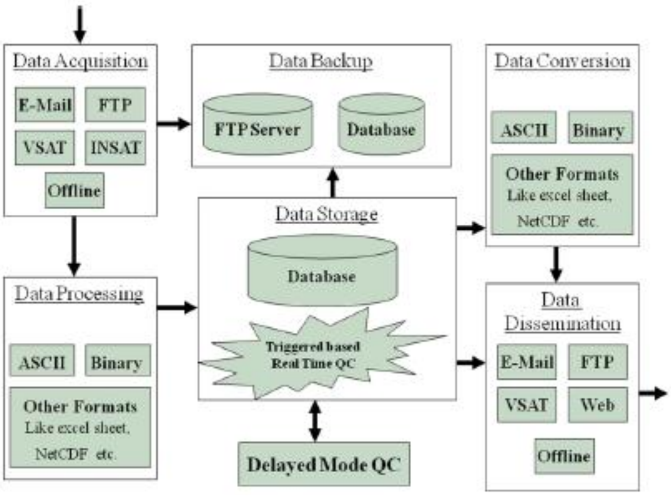

Fig 3: Flow of in situ data from various sources into the ODIS system established at INCOIS

Two types of Quality Check measures are followed based on the type of data set. For data received in real time, quality control is based on a trigger set, the data are checked for their range and possible presence of spikes and a stuck value test is done using this trigger based QC. For instance, data from moored buoys, Automatic Weather Stations, drifting buoys, and wave rider buoys are all quality controlled in this way. Apart from this, these data sets are also quality controlled in a delayed mode. The data that are received in near real time or delayed mode are received either with QC flags assigned by the agency responsible for collection of the data or are quality controlled at INCOIS. Data falling in this category are XBTs, current meters, etc. XBTs are quality controlled based on procedures laid down in the CSIRO cook book (Bailey et al., 1994). Once appropriate QC flags (table 1) are assigned, the data are pushed into the database. In any case, internationally approved standard QC procedures are used for assigning quality flags to the data[2].

The following table 2 is the various in-situ platforms and its details. Argo floats have Temperature, Salinity and geostrophic Currents (0, 75, 100, 200, 500, 100 M depths), Heat content upto 300M , Mixed layer depth, Isothermal layer depth, depth of 20° and 26° Isotherms, Dynamic Height, sea Surface Height anomaly.

QC flags:

QF Value	Meaning:
0	No QC performed
1	Good data
2	Probably good
3	Bad data that are potentially correctable
4	Bad data
5	Value changed
7	Nominal value
8	Interpolated value
9	Missing value

Table 1: QC flags

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IV ARGO DATA AND PRODUCTS FOR INDIAN OCEAN

Argo is an internationally coordinated activity directed at characterizing both the temperature and salinity structure of the mid- and upper-ocean and the advective field at mid-depth through deployment of autonomous profiling floats. It is envisioned that the resulting temperature and salinity profiles will be used to:

- initialize climate forecast models,
- detect and attribute climate change effects on the ocean,
- calibrate/validate satellite altimetric data, and
- increase understanding of the ocean and its role in global climate.

These objectives demonstrate that Argo data are to be utilized by both operational and research communities.

Argo collects salinity/temperature profiles from a sparse (average 3° x 3° spacing) array of robotic floats that populate the ice-free oceans that are deeper than about 2000m. They also give information on the surface and subsurface currents. Each profile is made up of about 200 data points. The first Argo floats were deployed in 2000. Argo data are made available to users quickly and free of restriction. The DVD contains 93202 temperature and salinity profiles, obtained from 1125 Argo floats deployed by India and other countries in the Indian Ocean (20°E – 140°E and 70°S – 30°N) during January, 2001 – December, 2008 excluding profiles in the Exclusive Economic Zone(EEZ).

This System also contains

1. Objectively analyzed Value Added Products (gif images) as listed below:
   - Temperature, Salinity and Geostrophic Currents (0, 75, 100, 200, 500, 1000 M depths)
   - Heat Content up to 300 M
   - Mixed Layer Depth, Isothermal Layer Depth
   - Depth of 20° and 26° Isotherms
   - Dynamic Height

2. MLD Climatology
   - Mixed Layer Depth
   - Median Deviation
   - Anomaly
   - Data Density

3. Argo statistics
   - Floats deployed against survived
   - Year wise floats
   - Year wise profiles
   - Age of floats
   - Floats position
   - Density maps

4. T/S plots

The grided T/S data (NetCDF) used for deriving the above products is also made available in this DVD. The data can be interactively obtained by using the interface software developed in Java. This interface works on Windows operating system. Argo distribution panel contains the image which is created by using image of Indian ocean region of 20E – 140E and 30N – 70S with the size 479 X 399.

Since the Argo floats usually do not obtain observation at the sea surface, the present study evaluates the MLD using 10 m-depth data, which has been used as a reference depth for the MLD by many previous studies [7]. When the shallowest observation level of a profile is deeper than 10 m, the profile is not used for estimating MLD. Profiles whose deepest observation level is shallower than 100 m are also excluded, since deeper MLD values greater than 100 m are observed during winter [8] . Profiles whose vertical resolution is finer than standard depth levels in the traditional hydrographic observations are chosen for estimating MLD. These steps removed 6582 profiles a reduction of 10.6% of total profiles used for generating the climatology. Since temperature and salinity data sets are not available at regular depths for all the floats, we have uniformly interpolated them linearly to 1 m depth resolution until 1000 m for all the observations. For each profile, density is calculated using the high-pressure equation of state[9].

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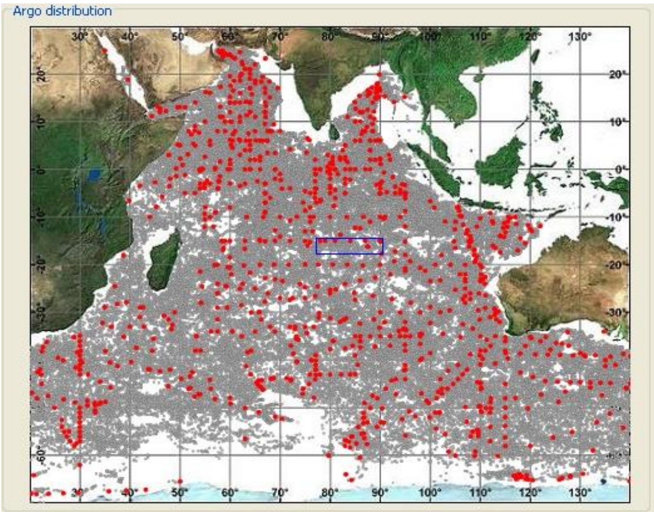


Fig 4: Argo Distribution Table

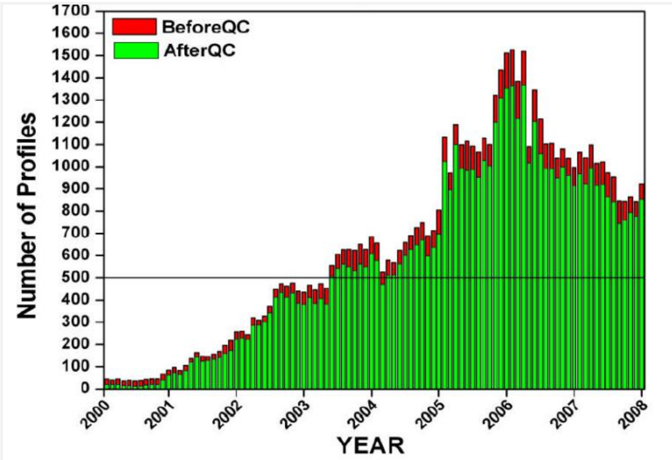
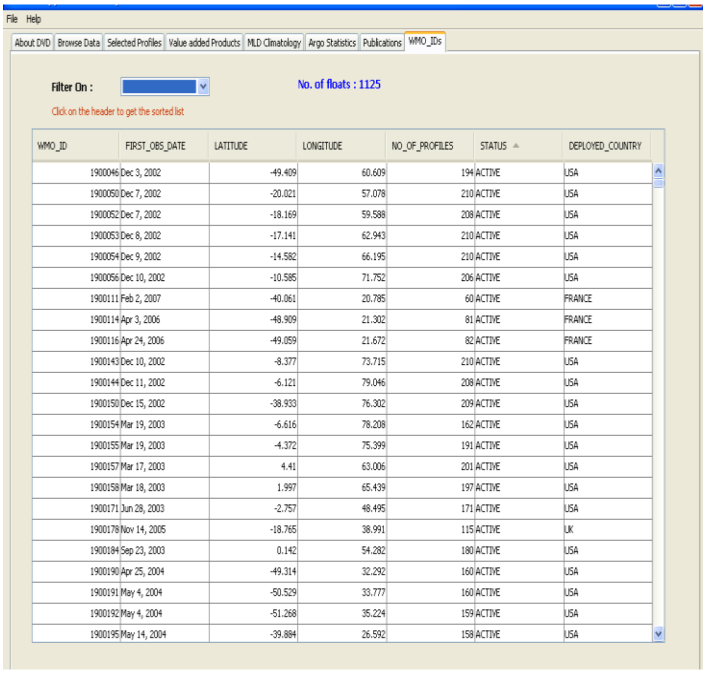


Fig 5: Profiles data distribution



WMO_ID	FIRST_OBS_DATE	LATITUDE	LONGITUDE	NO_OF_PROFILES	STATUS	DEPLOYED_COUNTRY
1900046	Dec 3, 2002	-49.409	60.609	194	ACTIVE	USA
1900050	Dec 7, 2002	-20.021	57.078	210	ACTIVE	USA
1900052	Dec 7, 2002	-18.169	59.588	208	ACTIVE	USA
1900053	Dec 8, 2002	-17.141	62.943	210	ACTIVE	USA
1900054	Dec 9, 2002	-14.582	66.195	210	ACTIVE	USA
1900056	Dec 10, 2002	-10.585	71.752	206	ACTIVE	USA
1900111	Feb 2, 2007	-40.061	20.785	60	ACTIVE	FRANCE
1900114	Apr 3, 2006	-48.909	21.302	81	ACTIVE	FRANCE
1900116	Apr 24, 2006	-49.059	21.672	82	ACTIVE	FRANCE
1900143	Dec 10, 2002	-8.377	73.715	210	ACTIVE	USA
1900144	Dec 11, 2002	-6.121	79.046	208	ACTIVE	USA
1900150	Dec 15, 2002	-38.933	76.302	209	ACTIVE	USA
1900154	Mar 19, 2003	-6.616	78.208	162	ACTIVE	USA
1900155	Mar 19, 2003	-4.372	75.399	191	ACTIVE	USA
1900157	Mar 17, 2003	4.41	63.006	201	ACTIVE	USA
1900158	Mar 18, 2003	1.997	65.439	197	ACTIVE	USA
1900171	Jun 28, 2003	-2.757	48.495	171	ACTIVE	USA
1900178	Nov 14, 2005	-18.765	38.991	115	ACTIVE	UK
1900184	Sep 23, 2003	0.142	54.282	180	ACTIVE	USA
1900190	Apr 25, 2004	-49.314	32.292	160	ACTIVE	USA
1900191	May 4, 2004	-50.529	33.777	160	ACTIVE	USA
1900192	May 4, 2004	-51.268	35.224	159	ACTIVE	USA
1900195	May 14, 2004	-39.884	26.592	158	ACTIVE	USA

Fig 6 Observations based on WMO_ids

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WMO_IDs section shows the unique wmo_id's details in a table. We can also filter the data by country wise. And also have the sorting on columns by clicking the required column header.

The data is retrieved as unique wmo_ids and the first observation date is obtained as the floats's first observation date , the latitude and longitudes are taken at the first observation date, the STATUS, represents the present status of the float which is evaluated as "INACTIVE" if the data is not receiving from the past 60days , otherwise set as "ACTIVE". The Deployed country is the country which deployed the float.

CONCLUSION

To cater to wide users of the oceanographic data suffering with low bandwidth connections, DMG, INCOIS has come up with a Argo Data Explorer on " In situ data Assessment: An offline tool for viewing Argo data and data products ". The ADE provides efficient data sharing and integration, easy to access to and long-term archiving of Argo data sets. It demonstrates that the Tool products and services are responsive to needs of the Indian Ocean region communities, universities and research organizations. And this Desktop tool has been designed with much care with the intension easier and more complexity involved is presented in simple and lucid style.

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