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MaMeAt - A tool for visualizing
marine meteorological data for Naval applications

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Abstract

This report discusses various functionalities of tool developed for use by Naval Operations Data Processing and Analysis Centre (NODPAC) a wing of Indian Navy. The data for this tool is obtained from

the Indian Meteorological Department (IMD), Naval Operations Data Processing and Analysis Centre (NODPAC) and individual records of International Comprehensive Ocean-Atmosphere Dataset (ICOADS). These data sets are processed, quality controlled and merged to form a unique data set for enhancing the marine met climatology of Indian Ocean. The IMD and NODPAC data are compared with the unique records from COADS and duplicates are eliminated. With addition of around 12% unique records to ICOADS data, enhanced climatology is regenerated. With this base data, Graphic User Interface (GUI) based tool is build for visualizing parameters viz., SST, SLP, Wind, Relative Humidity, SSS and bathymetry. This tool has capability to generate climatology dynamically between any chosen periods apart from visualizing various plots which are useful for Navy while at sea. Also provision for adding newly observed marine met data is provided making this most robust tool for use by the Indian Navy.

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ABSTRACT

This report discusses various functionalities of tool developed for use by Naval Operations Data Processing and Analysis Centre (NODPAC) a wing of Indian Navy. The data for this tool is obtained from the individual records of International Comprehensive Ocean-Atmosphere Dataset (ICOADS), Indian Meteorological Department (IMD) and Naval Operations Data Processing and Analysis Centre (NODPAC). These data sets are processed, quality controlled and merged to form a unique data set for enhancing the marine met climatology of Indian Ocean. The IMD and NODPAC data are compared with the unique records from COADS and duplicates are eliminated. With addition of around 12% unique records to ICOADS data, enhanced climatology is regenerated. With this base data, Graphic User Interface (GUI) based tool is built for visualizing parameters viz., SST, SLP, Wind, Relative Humidity, SSS and bathymetry. This tool has capability to generate climatology dynamically between any chosen periods apart from visualizing various plots which are useful for Navy while at sea. Also provision for adding newly observed marine met data is provided making this most robust tool for use by the Indian Navy.

1 INTRODUCTION

The most important elements that affect the weather and climate are the atmosphere and oceans, and in particular ocean-atmosphere interaction processes. Oceans occupy 70% of the Earth's surface and hence it is important to understand how oceans interact with the atmosphere. To realize this worldwide efforts are being made, to obtain as many observations of the ocean and meteorological parameters over the oceans which are also known as marine meteorological parameters. However, vast areas of the oceans are still considered as the data sparse regions. To address this issue, numerous observational programs were designed and implemented over the years, such as ARGO (Array of Real-time Geostrophic Oceanography), IOGOOS (Indian Ocean Global Ocean Observing System), GOOS (Global Ocean Observing System), RAMA (Research moored array for African-Asian-Australian Monsoon Analysis), WOCE TOGA (World Ocean Circulation Experiment - Tropical Ocean and Global atmosphere), etc. All these programs use observational systems such floats, moored buoys, drifting buoys, ships etc. One of the oldest method is the ship observations dating back to 1800s.

Measuring meteorological parameters and marine parameters across oceans facilitates the air-sea interaction research. Air-sea interactions form a part of any weather phenomenon be it a low pressure system or a hurricane or storm surge or upwelling in the sea or even general circulation in atmosphere and oceans. Numerous field experiments since 1950s were carried out exclusively for flux measurements, which are the key variables in the study of air-sea interaction. Wangara, Bomex (Barbados Oceanographic and Meteorological Experiment 1969), BLX83 (Boundary Layer interaction Experiment 1983), BOBMEX (Bay Of Bengal Monsoon Experiment 1999), etc. are some of the field experiments over land and oceans. These experiments involve measurements of bulk variables namely Temperature (Dry bulb temperature-DBT), Moisture (Specific humidity-SPHUM), wind speed and direction (WS and WDIR), SST and sometimes direct measurements of surface fluxes. These field experiments and the results found are the backbone of the fundamentals in air-sea interaction study and they provide the datasets against which theories and models are tested.

In the Indian ocean, air-sea interaction process is specifically more important. The North Indian ocean (NIO) is always considered unique in its characteristics both in marine met and oceanic perspective. The monsoon reversal of winds, the number of rivers that discharge fresh water into the seas are some of the primary reasons behind the unique characteristic. As the atmosphere and ocean are always coupled, the air-sea interaction process are distinctly affected and in turn affect the weather phenomenon over NIO. The regular weather phenomenon across NIO are the tropical cyclones and the

monsoon circulation (Indian summer monsoon-ISM). Several studies discussed the influence of air-sea interaction on ISM. Any amount of data available from any reliable source is always beneficial. Owing to this fact, a tool was developed to combine the ship observations obtained from IMD, NODPAC to the already existing collection of ship observations (ICOADS) within Indian ocean region (30E - 100E , 30S - 30N), with an aim of providing a dynamical tool for visualizing on the fly graphs for decision making by person onboard the ship out in the sea.

The description of all the datasets namely, IMD data, ICOADS records, NODPAC records, their format are discussed in detail in Kameshwari et al., (2016). The format of records of the datasets are different and the extraction process, complications faced during extraction, quality control are also discussed in details.

2 Data and Methodology

The data mainly used in this tool are the marine-met observations made onboard VOS. ICOADS is the first climatology of marine-met parameters utilizing mainly the ship observations (Slutz *et al.* 1985). As of now, the number of individual observations used in ICOADS are 261 million observations. These ship records are all available in a standard International Marine Meteorological Archive (IMMA) format. The strenuous endeavor of the ICOADS team to process such huge amounts of data and making it available is well recognized in the scientific community. The second dataset is the ship records obtained from IMD which is spanning from 1961 to 2012. The observations comprise a set of 59 lakh records as measured and obtained from IMD. The format of the entire data except those records observed during the period 1961-1981 is according to IMMT format. The third dataset is the records obtained from NODPAC, which are in standard GTS format spanning the period 2010-2013. The variables present in the raw ship records are given in table 1. NODPAC data are basically observations made onboard Indian Navy ships. The NODPAC data is in GTS format and majority of data is concentrated in North Indian ocean only. This data was spanning from 2010 to 2013. For the current tool, data from 2010 to 2012 was only used. Figure 1a show the spatial distribution of the data from IMD while Figure 1b show the yearly distribution of the same data. The methods of extraction of the data from the individual records and application of quality control methods on the data are well documented in Kameshwari et al., (2016).

S. No	Variable name	S.No	Variable name
1	Air Pressure (SLP)	7	Swell wave parameters
2	Dry Bulb Temperature (DBT)	8	Weather and cloud conditions
3	Dew point Temperature (DPT)	9	Details of ship position
4	Sea surface Temperature (SST)	10	Time of observation
5	Wet bulb Temperature (WBT)	11	Details of the ship
6	Wind speed and direction (WS, WDIR)	12	Quality Control flags of all the parameters

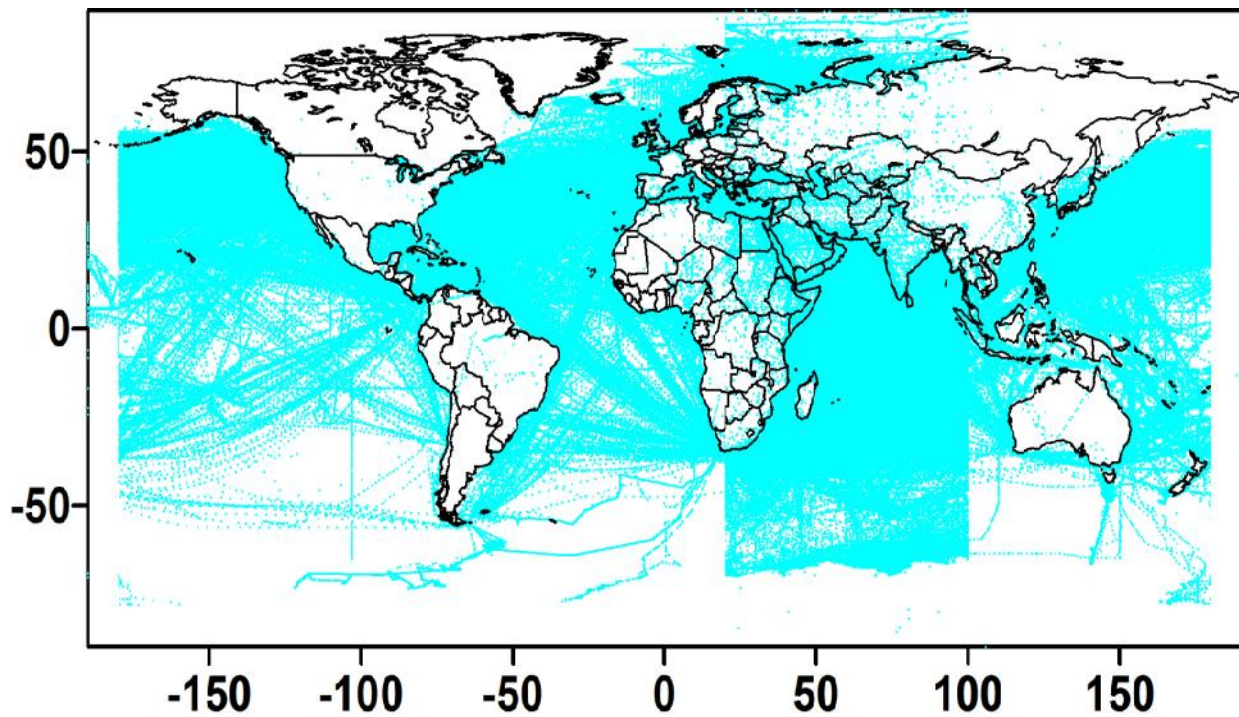Table 1 Marine Met variables available with the IMD data

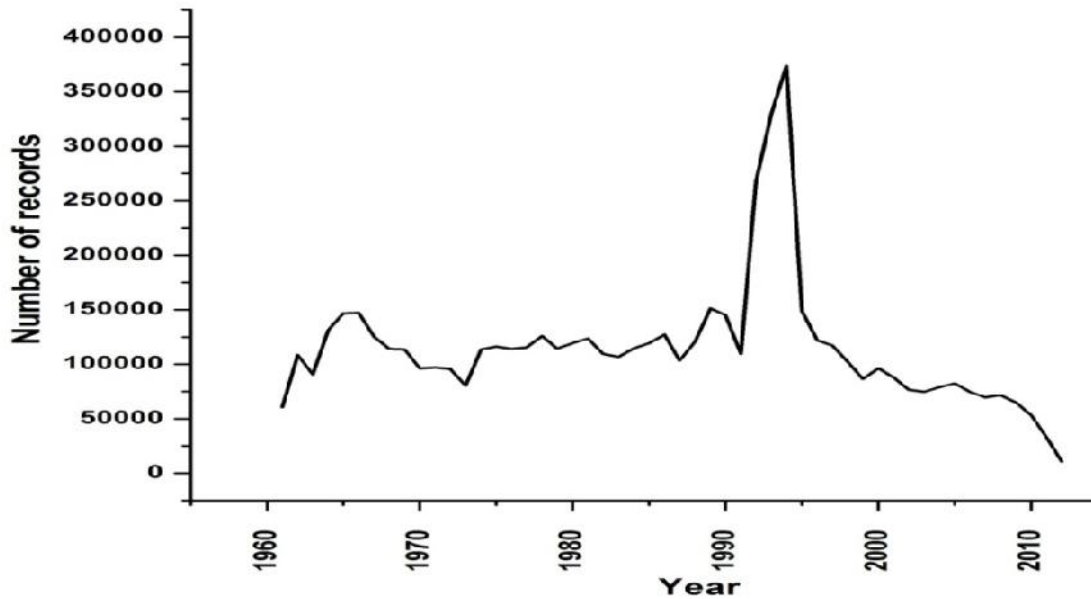Figure 1a Spatial coverage of the entire dataset given by IMD

Figure 1b : Number of records (year wise) in IMD data

3. Overview of the MaMeAT tool

Once the required parameters are extracted and quality controlled, these data are ready for use with the MaMeAT tool. Using these data records Graphical User Interface (GUI) is designed to visualize the data in various forms. As per the request of NODPAC, the following visualization functionalities are designed and incorporated into the tool.

S. No	Parameter	Visualization forms
1.	Wind speed and direction (WS, WDIR)	a. Rose plots depicting the direction of wind. b. Time series plots for a point and averaged over an area. c. Climatology generation and visualizing spatial contour plots. d. Plots along a designated ship track. e. Data density statistics plots.
2.	Sea Level Pressure (SLP)	a. Time series plots for a point and averaged over an area.

3.	Sea Surface Temperature (SST)	b. Climatology generation and visualizing spatial contour plots.
4.	Dry Bulb Temperature (DBT)	
5.	Sea Surface Salinity (SSS)	c. Plots along a designated ship track.
6.	Relative Humidity (RH)	d. Data density statistics plots.
7.	Bathymetry	a. Depth at a chosen point.
		b. Depth between two point.
		c. Area averaged depth for a chosen area.

Table 2. List of functionalities for each of the parameters provided in MaMeAT tool.

The default interface (home page) to visualize the marine met data is given in Figure 2.
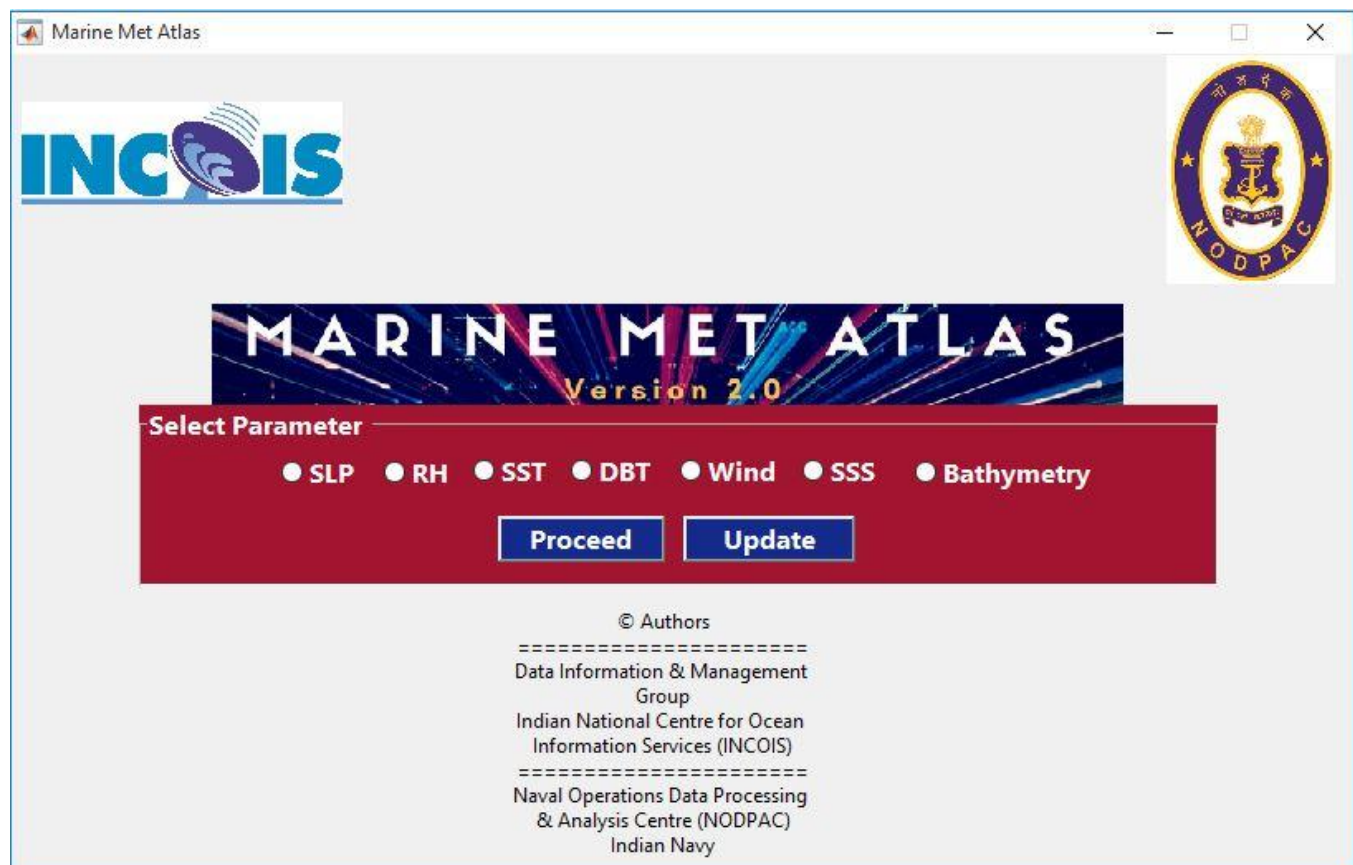

Figure 2. Home interface of the MaMeAT tool.

Here the user is given the option to chose one among the available marine met parameter using the radio buttons. Once the parameter is chosen, the user is shown with multiple options to plot the graphs on the fly. Various options available to the user for visualizing the data are shown in Figure 3.
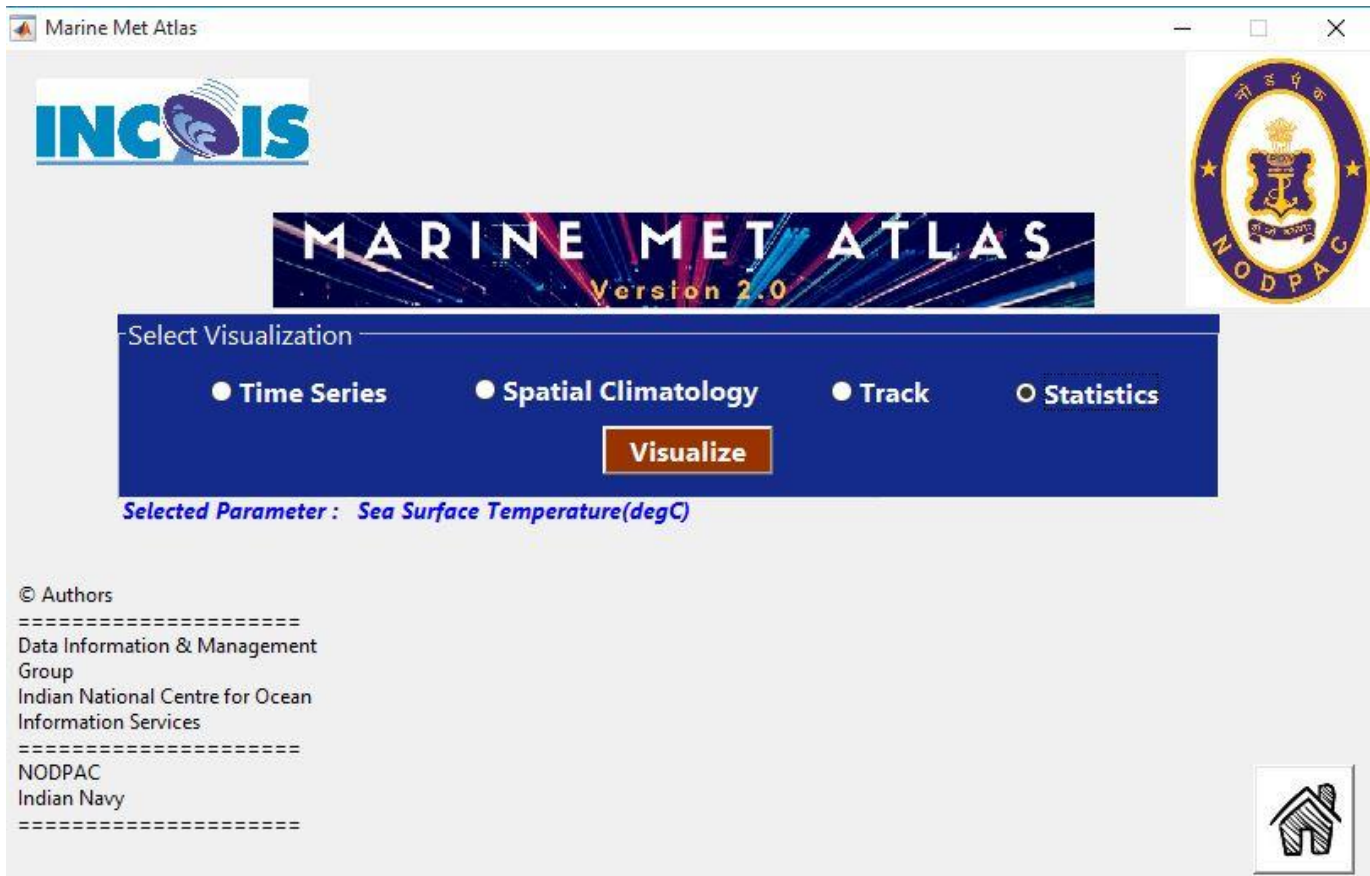

Figure 3. Types of plots available for visualizing the marine met parameter SST.

Here the user is given the options to plot (i) Time Series (ii) Spatial Climatology (iii) Track plots and (iv) Data density plots for checking the availability of data. For plotting the time series plots the user is given the option to choose his desired months (Jan - Dec) and the time zones of the day vis., 00 - 06 Hrs, 06 - 12 Hrs, 12 - 18 Hrs, 18 - 24 Hrs. For the rest of the sections all possible plots are demonstrated for Sea Surface Temperature (SST) parameter only.
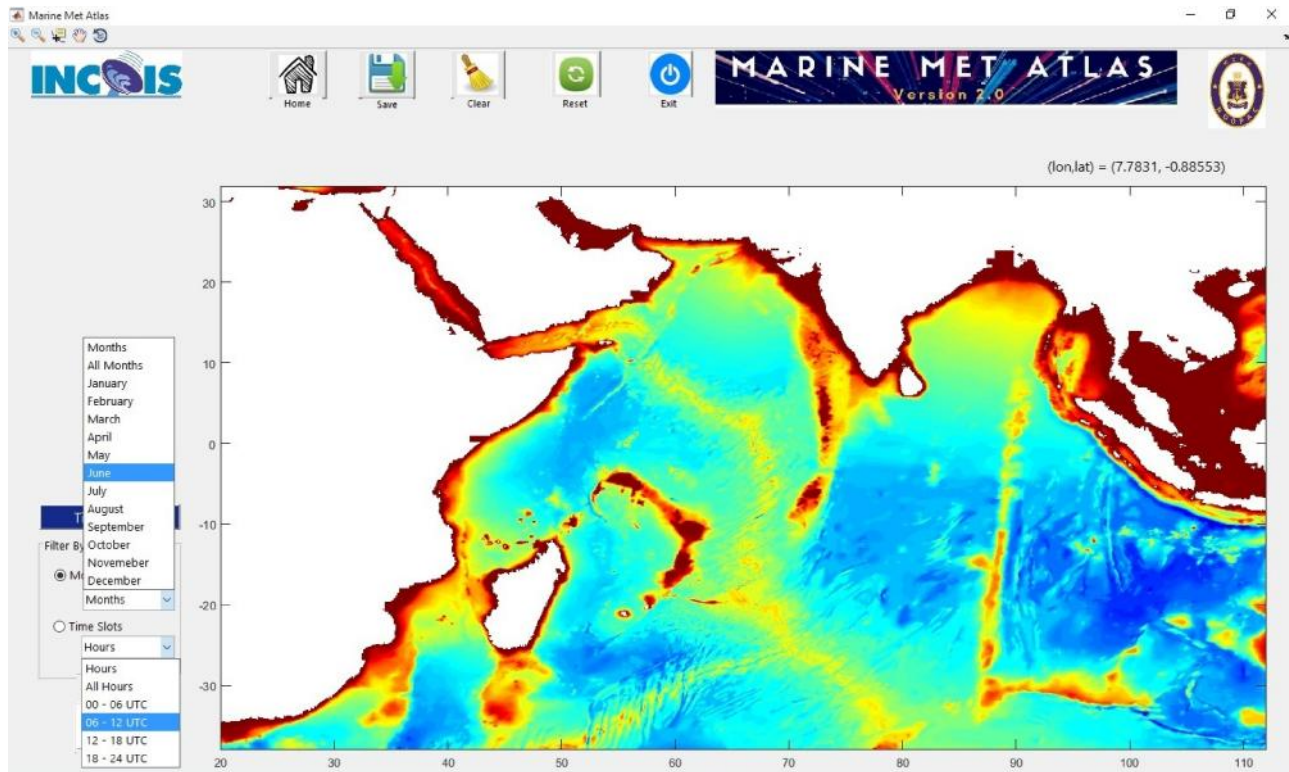
Figure 4. Options for choosing the desired month and Time zone.

(i) <u>Time Series Plots</u>: Figure 4 shows the selection of month and time zone from the dropdown menus for generating the time series plots. Once the user selects the desired month and the time zone, he can select any location in the map which fires a query to the data stored, resulting in filtering the data so as to match the query and the output is generated in the form of a line plot.

The user is also provided with an option to choose and plot the SST variations for all the month and one specific time zone and for a specific month and all time zones respectively. The tool is also capable of throwing errors if the choice of filtering is wrong eg: choice of all months all time zones. This type of choice results in a error box indicating "wrong choice" and the user is asked to recheck his selection and change it for getting a valid output. Figure 5 shows the time series plots for a choice of all month and time zone 18 - 24 Hrs and for a choice of August and all time zones. The two peaks of SST which is a common phenomenon in Arabian Sea is clearly captured from all the available data. Also the diurnal variation of SST is also clearly captured for the choice of specific month and all time zones.
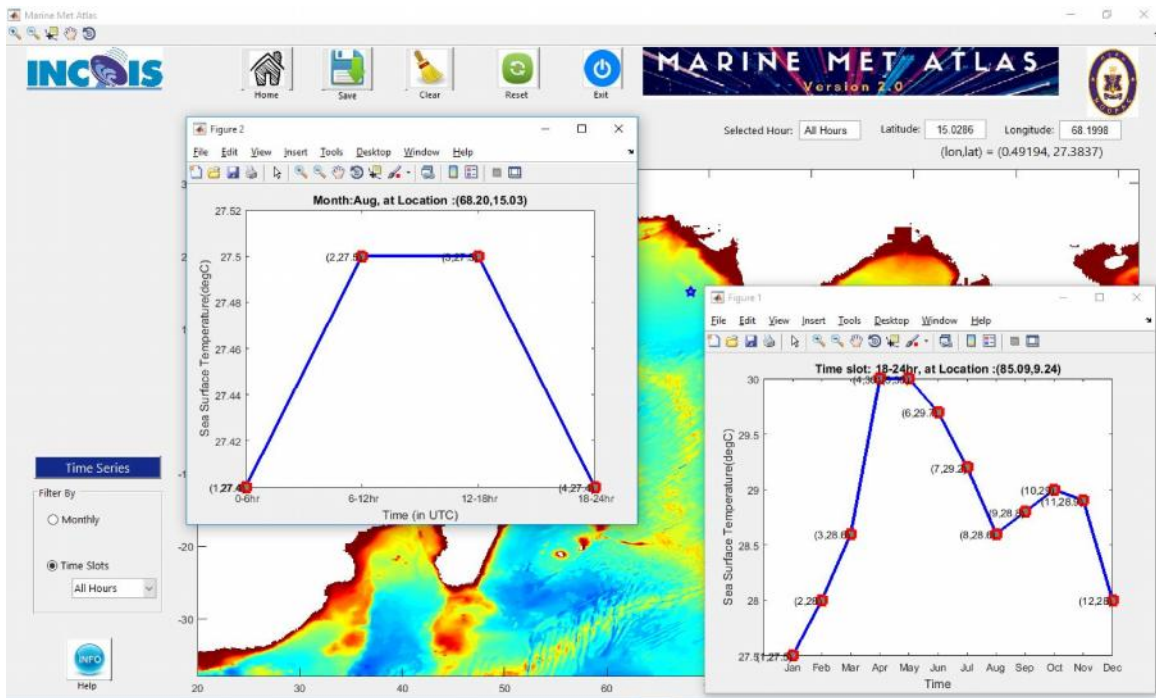
Figure 5. Time series plots of SST at 64.86 longitude and 16.80 latitude in the Arabian Sea. SST variability for all months and time zone of 18 - 24 Hrs and SST variability for August for all time zones are depicted.
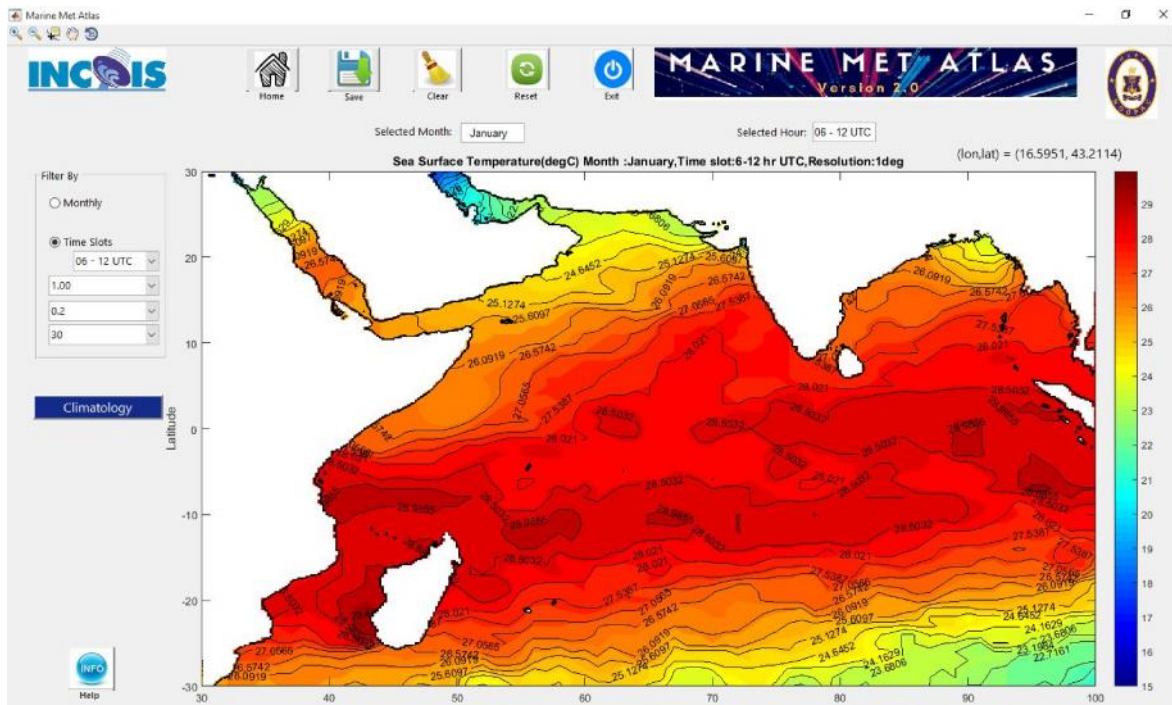

Figure 6. Spatial variation of SST for the month of January and time zone 00 - 06 Hrs dynamically generated from all available data in the data base.

(ii) <u>Spatial Climatology plot</u>: In this option the user is given a choice to generate a plot depicting the spatial variability of chosen parameter (SST here) from all the available data for a specific month and time zone of interest. Median filter is applied to obtain the climatological value from all the available data. As the data has variabilities viz., diurnal, day to day, monthly, seasonal and inter annual median is a better choice to get the central value indicating more or less a climatological value. Figure 6 shows the spatial distribution of SST for the month of January and for the time zone 06 - 12 Hrs. Also the user is provided with the option of generating the grid resolution of his choice among 1.00, 0.75, 0.50 and 0.25 degrees. The use is also provided with a option to control the filled as well as the line contours overlaid on them. The user is also given option to chose the beginning and ending years with in which the data can be fetched and climatology can be generated along with other option for plotting.
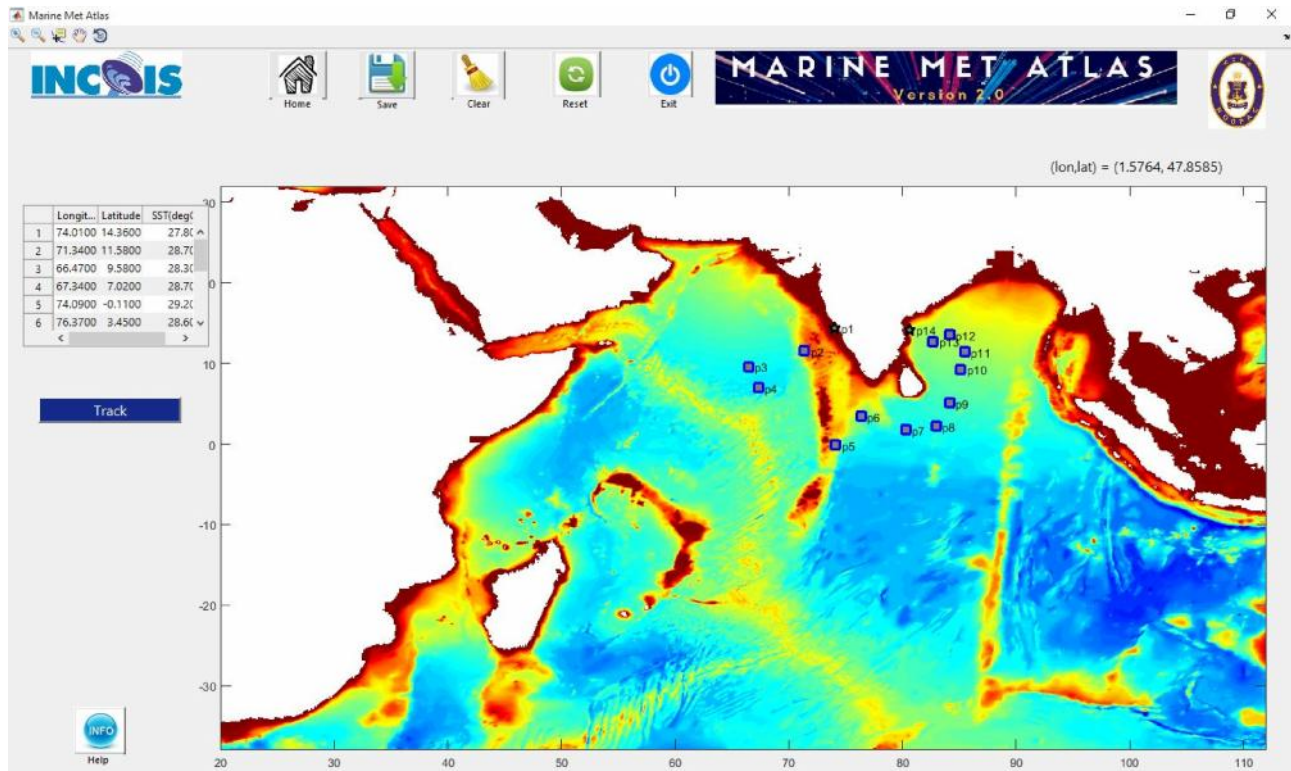

Figure 7. Manual selection of cruise positions to obtain the parameter along this track.

(iii) <u>Along a Track plot</u>: In addition to the time series and spatial contour plots, the user is also given an option to generate the line plots along any specified ship tracks for any specific month or season. The user can create a cruise track file apriori which can be uploaded or the track of his choice can also be created with manual selection of (longitude, latitude) points which can be eventually saved into the desired locations and can be used at a later stage. Figure 7 shows the location of the track chosen to
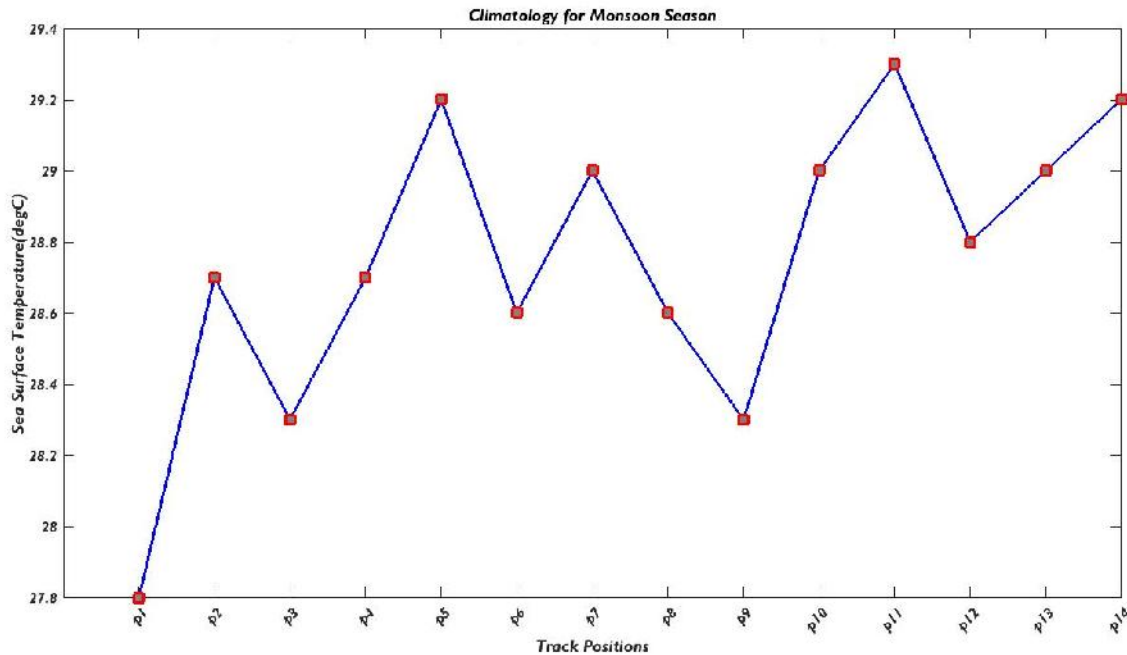
Figure 8. Plot of SST along the cruise track positions for the Monsoon Season.

display the SST values along its path. Once the locations are chosen the user is given an option to save this cruise track for later use. The positions of the cruise track are shown as p1, p2, ... pn where pn is the nth position of the track. The values along these positions are computed from the data and then displayed in the left hand side frame which can be copied and used for any purpose. Also the line plot of the parameter chosen (here it is SST) is shown for all the position along the track. Figure 8 shows the line plot of SST along the cruise positions.

(iv) Data density plots: This option is given to the user to check the spatial and temporal coverage of data which is used in generation of the plots and also to know that amount of data that has gone into generation of climatology. There are options like (a) to see the distribution of data varying each month between the chosen year(s) and (b) to see the distribution of data for a chosen month varying for all the years and (c) to see the spatial distribution of data corresponding to the parameter which give a confidence of the spatial contours drawn for the parameter based on the data. The first option of monthly distribution of data is given in figure 9. Here a sample year 1987 is chosen for which the monthly distribution of the data is given in the figure. The second option of yearly variability of SST for a chosen month is shown in Figure 10. Here the distribution of SST data for the month of January for all the years 1960 to 2012 is given. One can clearly see the increase in the amount of data records with the passage of time from more and more ships. The third option of plotting and checking the spatial distribution of SST

data is shown in Figure 11. For this the user need to choose both the Year and Month which will result in the generation of spatial distribution plot. The sample plot of spatial distribution is given in Figure 11 for the year 1987 and all months.
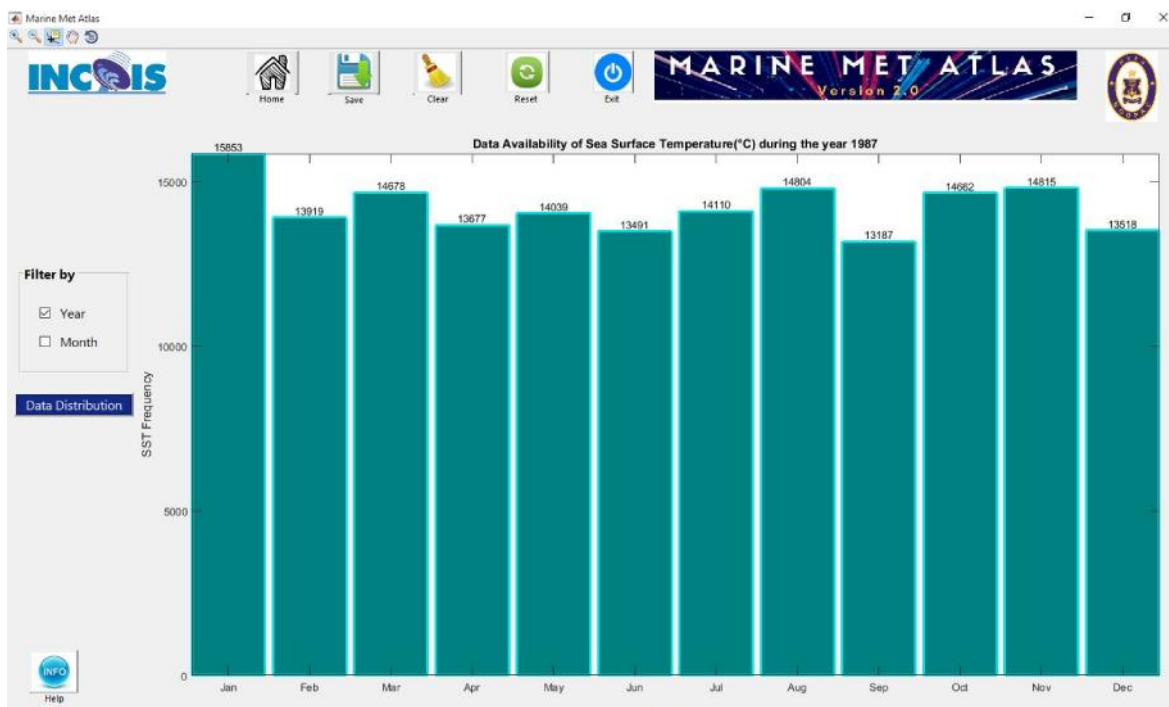

Figure 9. Monthly distribution of SST data for the sample year 1987.
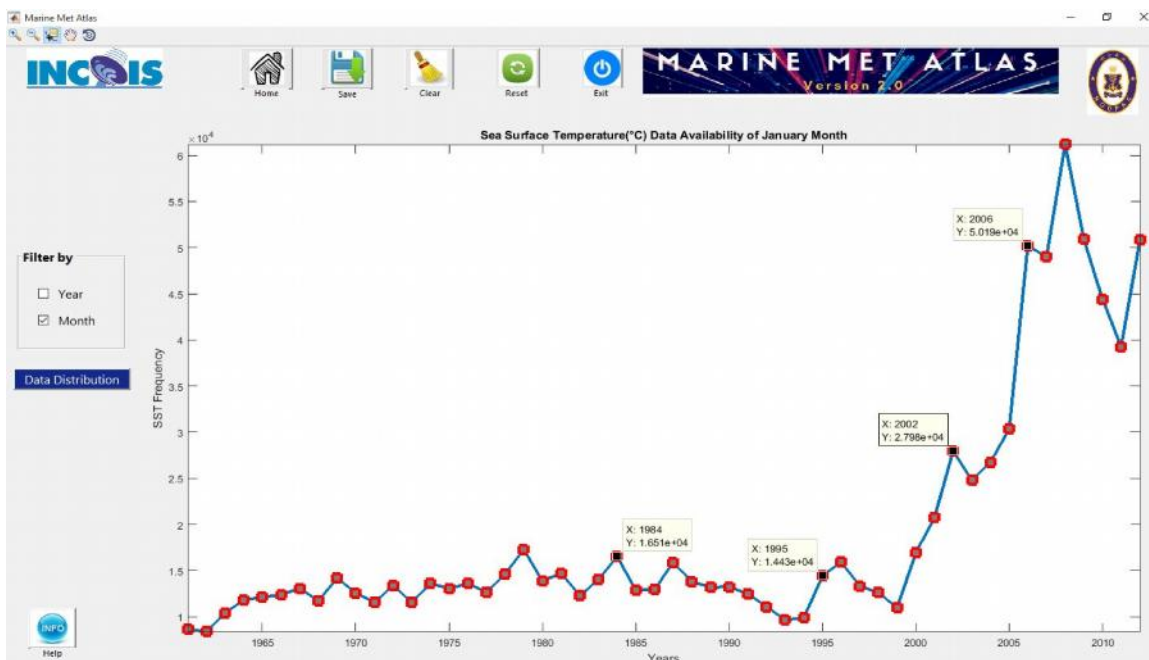

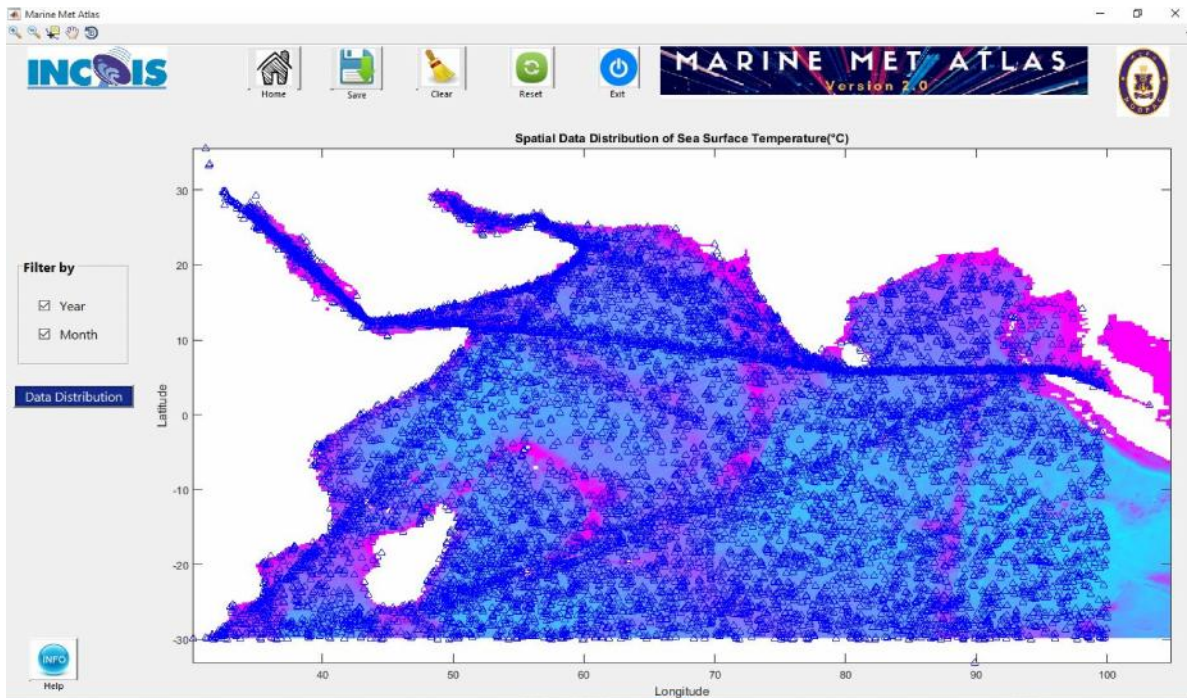Figure 10. Yearly distribution of SST data for the month of January.

Figure 11. spatial distribution of SST data for the year 1987 and all months.

The idea behind providing the statistics is that user can gain confidence about the output that is being generated dynamically based on the data that is there in the database. This also gives a confidence whether the output was generated by interpolation or all available data is used for generating the output.

Rose plots of Wind:

Apart from options like time series, climatology, track plots and density plots, an additional option for plotting is provided for wind parameter named "Rose plots". A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. Using a polar coordinate system of gridding, the frequency of winds over a time period is plotted by wind direction, with color bands showing wind speed ranges. The direction of the longest spoke shows the wind direction with the greatest frequency (Wikipedia). Figure 12 shows the GUI for choosing options for plotting the wind rose plots. It also shows the rose plots for the locations 63.14 E longitude and 10.21 N latitude for the month of July. From the figure South Westerly winds are clearly depicted which are trade mark of the monsoon winds during the months of June - September each year. The user is also given an option to chose a combination of months and years, days and time of day etc. This is one of important parameter for people sailing on ships, as the direction of the winds can be used to save fuel if the cruise course is in the same direction of the winds. This will also indicate the

presence of Ekman currents which are derived from winds and the current direction can also be used smooth sailing of ships.
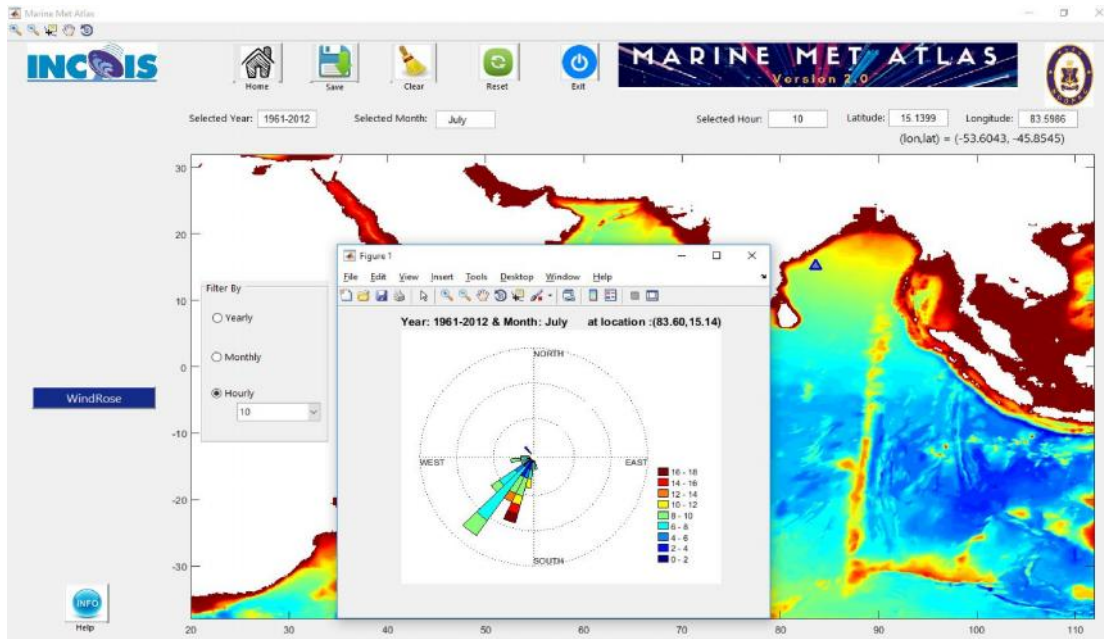

Figure 12. Rose plot of wind for the month of July obtained from all the data of 1961 - 2012.

Except for this, all other plots for winds parameter are similar to that of other parameters like SLP, SST etc.
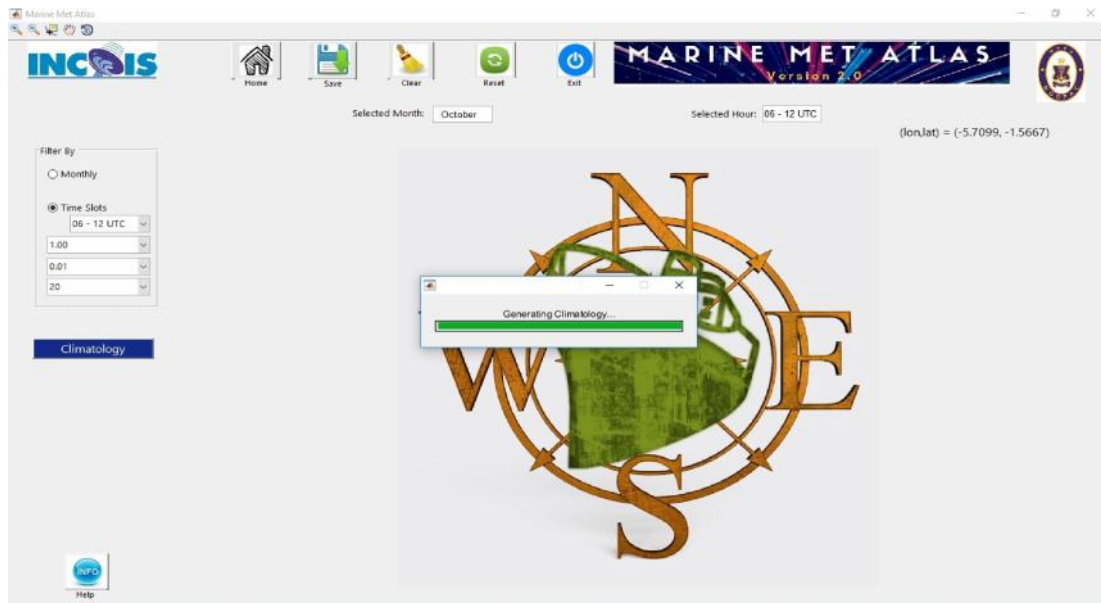

Figure 13. Option for generating climatology for a chosen period, chose time zone from all the available data for visualization .

4. Dynamic climatology generation.

One of the biggest attractions of this tool is that it is dynamic. Unlike climatologies which are generated once and all the analysis is derived based on it, here the climatology generation is made dynamic. The user is given an option to generate climatology for any resolutions like, 1.0°, 0.75°, 0.50° and 0.25° degrees and also for period of his choice. By default the climatology generation uses all the data for all the available years. However in this tool an option is given to the user to choose the time range (year x_1 - year x_2) so that all the data available between this period is obtained and climatology is generated. Figure 13 shows the option of generating climatology for a grid resolution of 1° x 1°. Also provision for updating the data for years to come is also provided, so that this tool is not limited to the current climatology but also caters to all upcoming years too. The GUI pages corresponding to the updation of the new data measured by the ships is shown in Figure 14. As long as the data corresponding to the marine met parameters are maintained in the format provided, the updation can be done with just click of a button and all future visualization can be done with the new data inclusive.
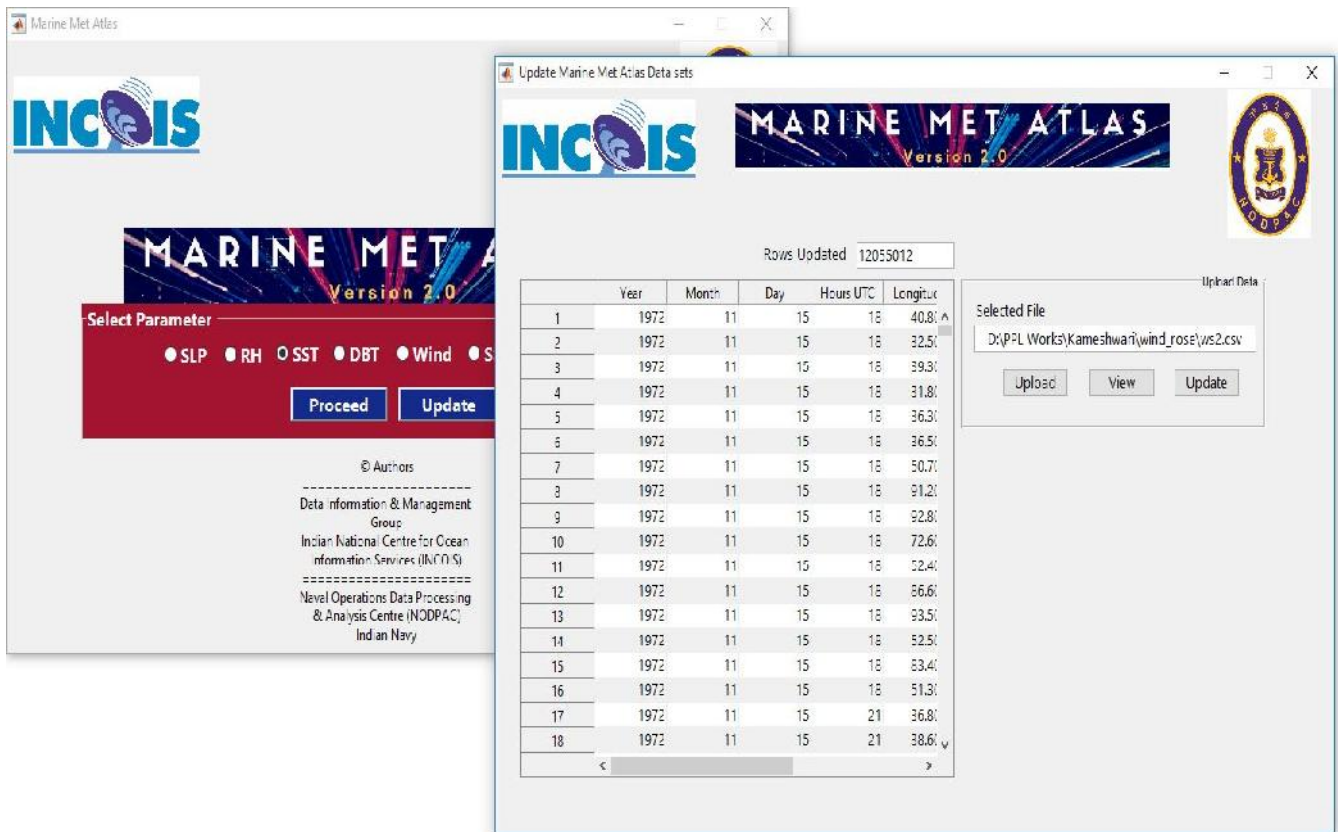

Figure 14. Option for appending of newly generated data sets to the existing parameters.

5. Bathymetry visualization

Figure 15 shows the bathy tool in a 3D perspective view for viewing the depth of any location in the Indian Ocean. This provision to view the depth data is provided in addition to all these marine met parameters which is handy while operating at sea. For this purpose, Etopo 5 minutes resolution bathymetry file is used as the background source. The bathymetry tool is show with a 3D perspective view and user can get the depth value of ocean with the movement of curser over the bathy plot. Also an option to get the bathymetry between two points is also provided. This can be very useful in case of search and rescue operations. For instance during the search and rescue operations of AN-32 Air force flight there was requirement of bathymetry between set of points for conducting search and rescue operations. This kind of tool provided along with the marine met data can be handy to the operator onboard ship for their naval operations. An example of bathymetry variation between two locations (63.45, -0.30) and (76.73, -1.11) is shown in Figure 16. This type of plots gives an indication of possibility of search operation based on the depth below the search area.
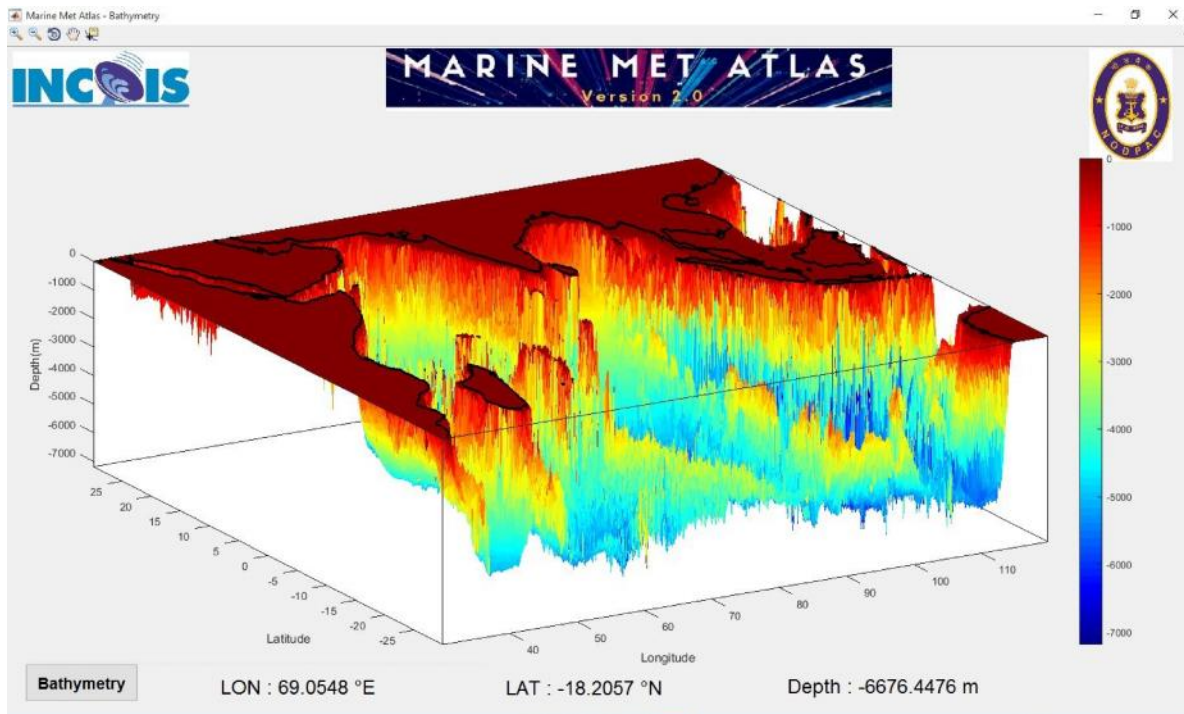

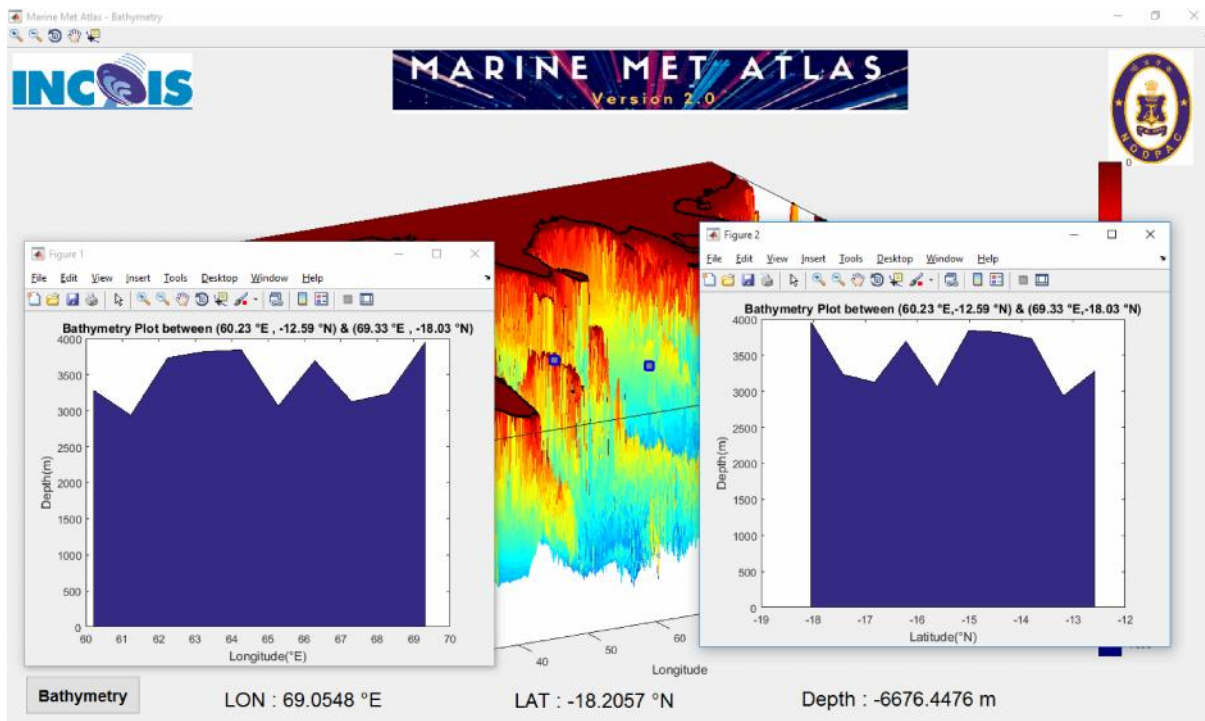Figure 15. Bathymetry tool for visualizing and obtaining the depth of any location in the Indian ocean.

Figure 16. Bathymetry variation along longitude and latitude between two chosen points.

6. Summary and conclusion

In this work tool developed for use by Naval Operations Data Processing and Analysis Centre (NODPAC) a wing of Indian Navy was described. Data from IMD, NODPAC and individual records of ICOADS are all together used for generating database and visualization purpose. The data from these centers are processed, quality controlled and merged to form a unique data set for enhancing the marine met climatology of Indian Ocean. Around 12% unique records were added to already available ICOADS data, enhancing the regenerated climatology. With the use of this base data, Graphic GUI tool is built for visualizing parameters viz., SST, SLP, Wind, Relative Humidity, SSS and bathymetry. This tool is capable for generating climatology dynamically between any chosen periods apart from visualizing various plots which are useful for Navy while at sea. Also provision for adding newly observed marine met data is provided making this most robust tool for use by the Indian Navy.

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https://en.wikipedia.org/wiki/Wind_rose