

MARINE MET ATLAS

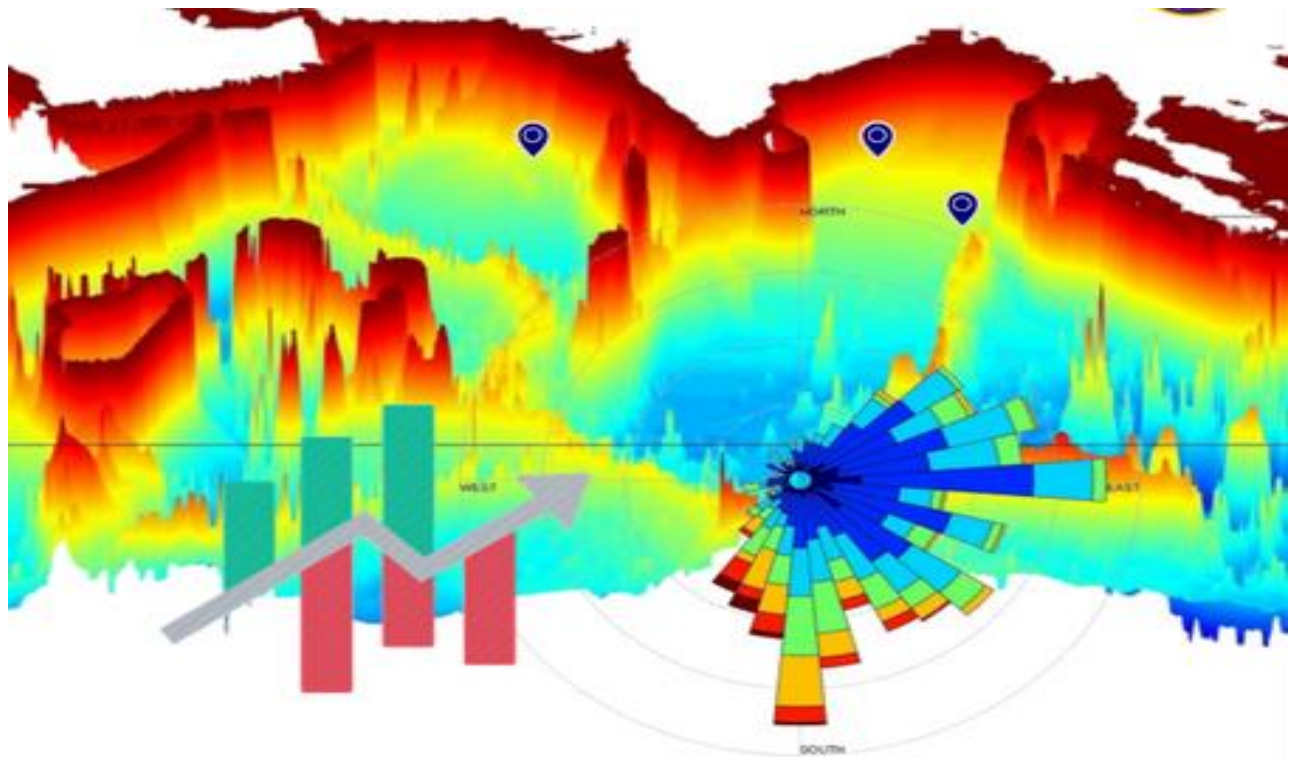
A Tool for Visualizing Marine Meteorological data for Naval Applications

INCOIS

Marine Met Atlas Tool

The Official MaMeAT

USER GUIDE 1.0



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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 ICOADS 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, EVD 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.

I 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 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, an atlas 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). This atlas goes into the background of this GUI tool with an aim of providing a dynamical access for on the fly visualization 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 all 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 v2.5 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. For the database of this tool, the individual records of ICOADS v3 spanning from 1961 to 2017 are utilized. 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 and IMMT format spanning the period 2002-2017. NODPAC data are basically observations made onboard Indian Navy ships. The NODPAC data is concentrated in North Indian ocean. The data utilized in the tool has a spatial range of 20⁰E - 120⁰E , -30⁰S - 30⁰N. The variables present in the raw ship records are given in table I. Figure 1a show the spatial distribution of the data from IMD which 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 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 2.1 Variables available in the IMD data

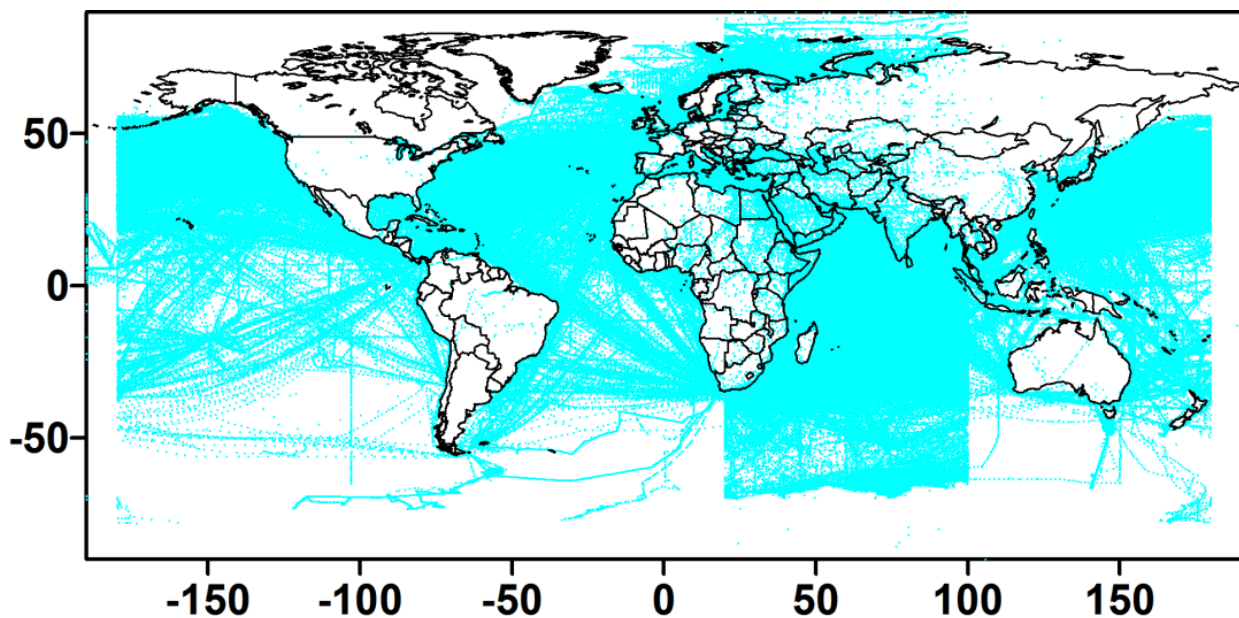


Figure 1a Spatial coverage of the entire dataset given by IMD

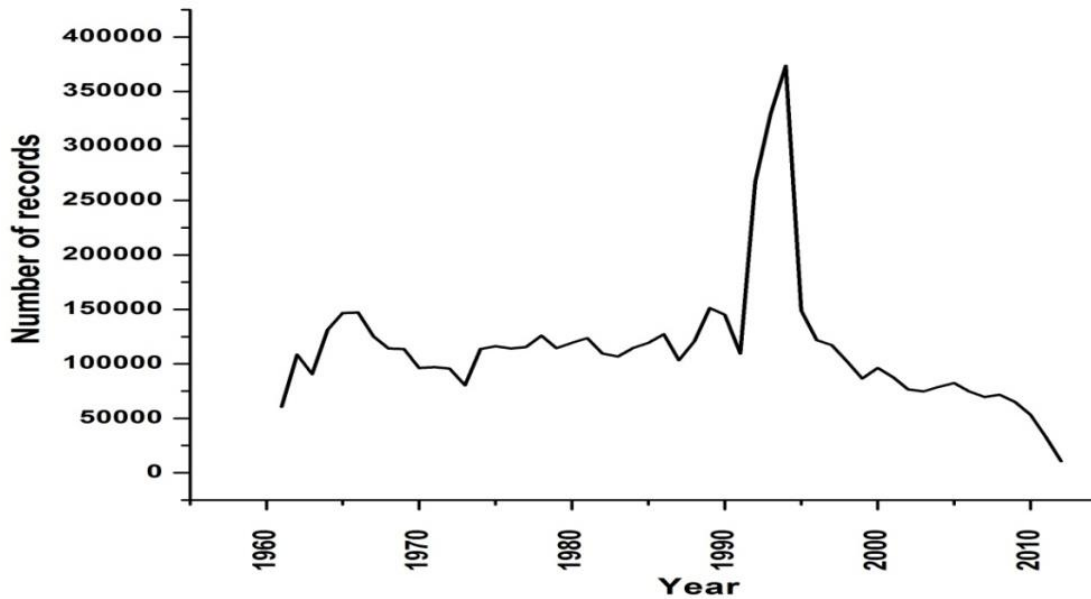


Figure 1b : Number of records (year wise) in IMD data

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
I.	Wind speed and direction (WS, WDIR)	<ul style="list-style-type: none"> 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. Statistics

2.	Sea Level Pressure (SLP)	a. Time series plots for a point and averaged over an area. b. Climatology generation and visualizing spatial contour plots. c. Plots along a designated ship track. d. Statistics
3.	Sea Surface Temperature (SST)	
4.	Dry Bulb Temperature (DBT)	
5.	Sea Surface Salinity (SSS)	
6.	Relative Humidity (RH)	
7.	Evaporation Duct height (EVD)	
8.	Bathymetry	

The default interface to visualize the marine met data is given in Figure 2.

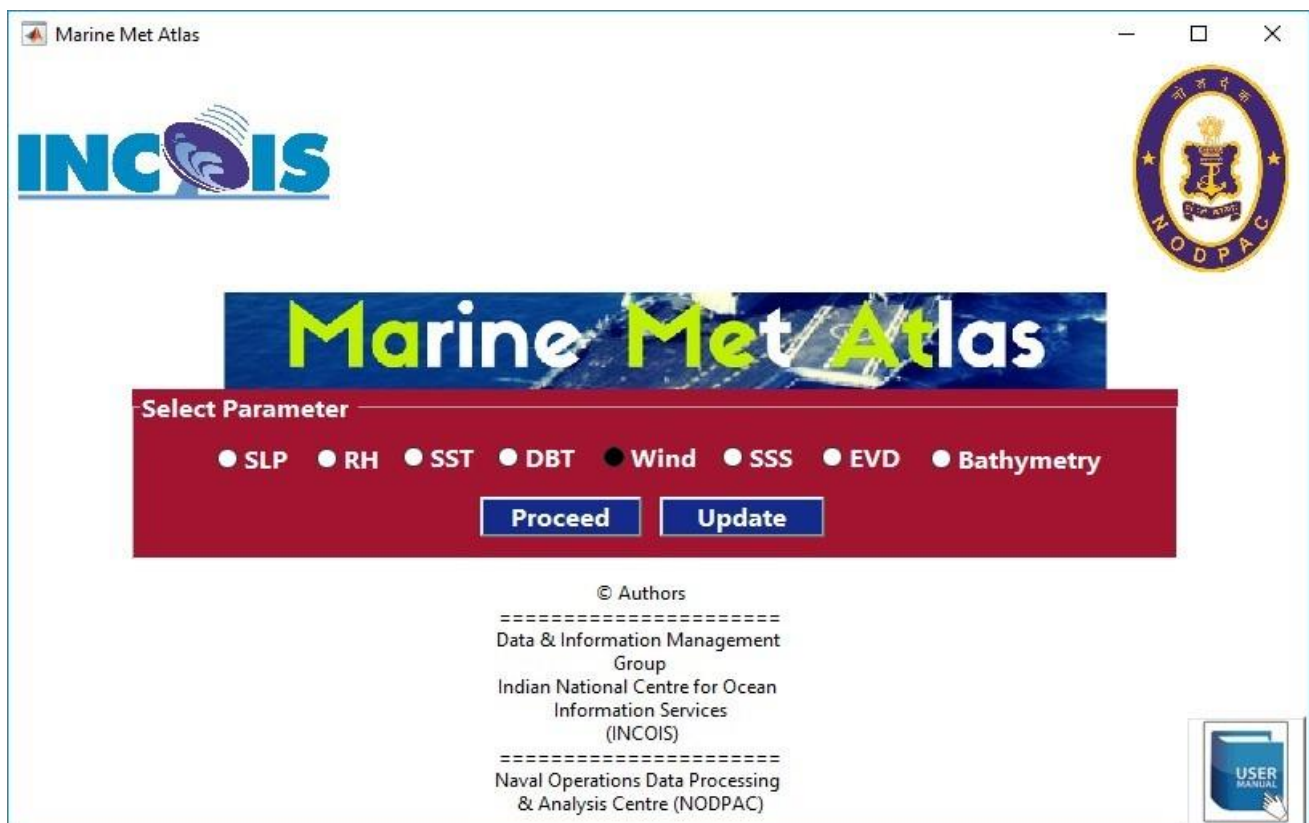


Figure 2. Home interface of the MaMeAT tool.

Here the user is given the option to choose one among the available marine met parameter using the radio button. 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.

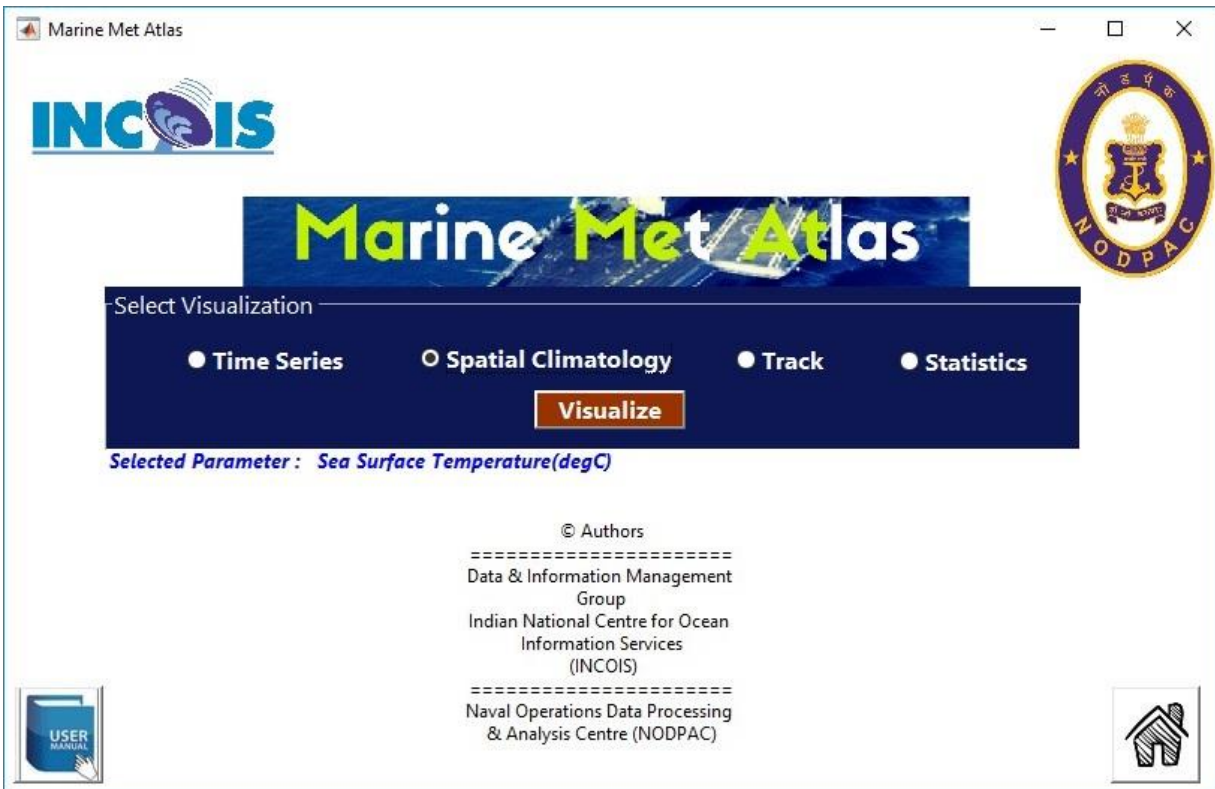


Figure 3. Types of plots available for visualizing the marine met parameter SST.

Here the user is given the options to plot (i) Time Series (ii) Spatial Climatology (iii) Track plots (iv) Statistics. For the rest of the section all possible plots are demonstrated for Sea Surface Temperature (SST) parameter only.

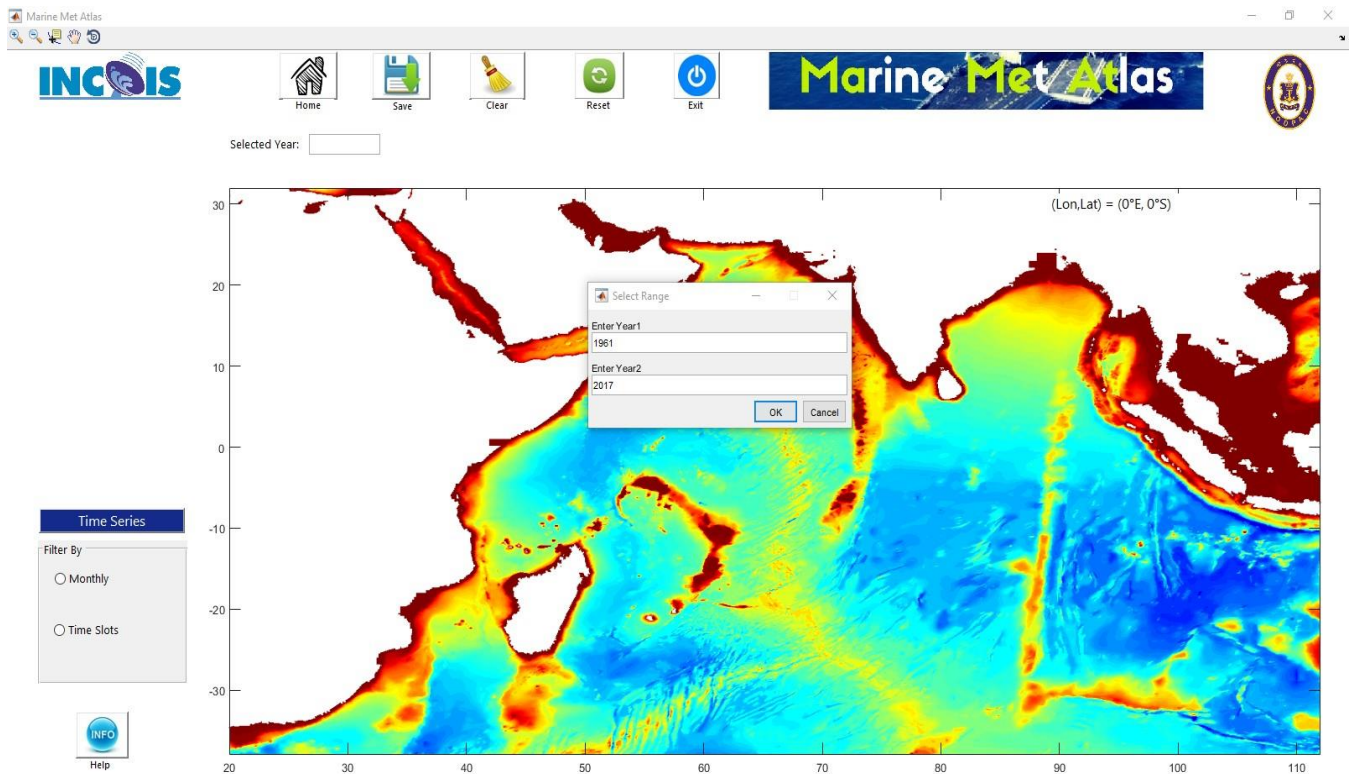


Figure 4. Radio buttons for selecting desired month and time slot are available on the left. Also, range of number of years can be given in the dialogue box.

(i) Time Series Plots: 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. Figure 4 shows that selection of years range, month and time zone from the dropdown menus for generating the time series plots. Once the user selected the year range, month and the time zone, he can select any location in the map which fires a query from the data stored, which results 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 06 - 12 Hrs . 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 capture for the choice of specific month and all time zones.

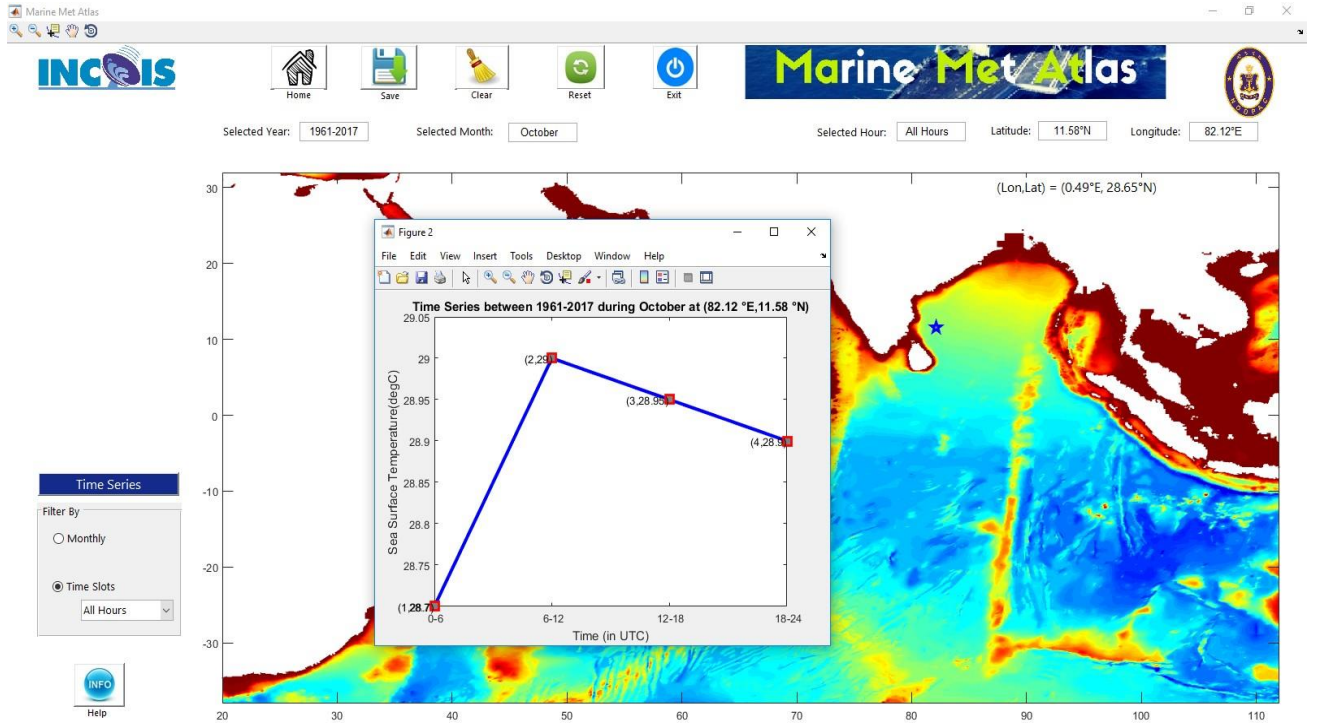
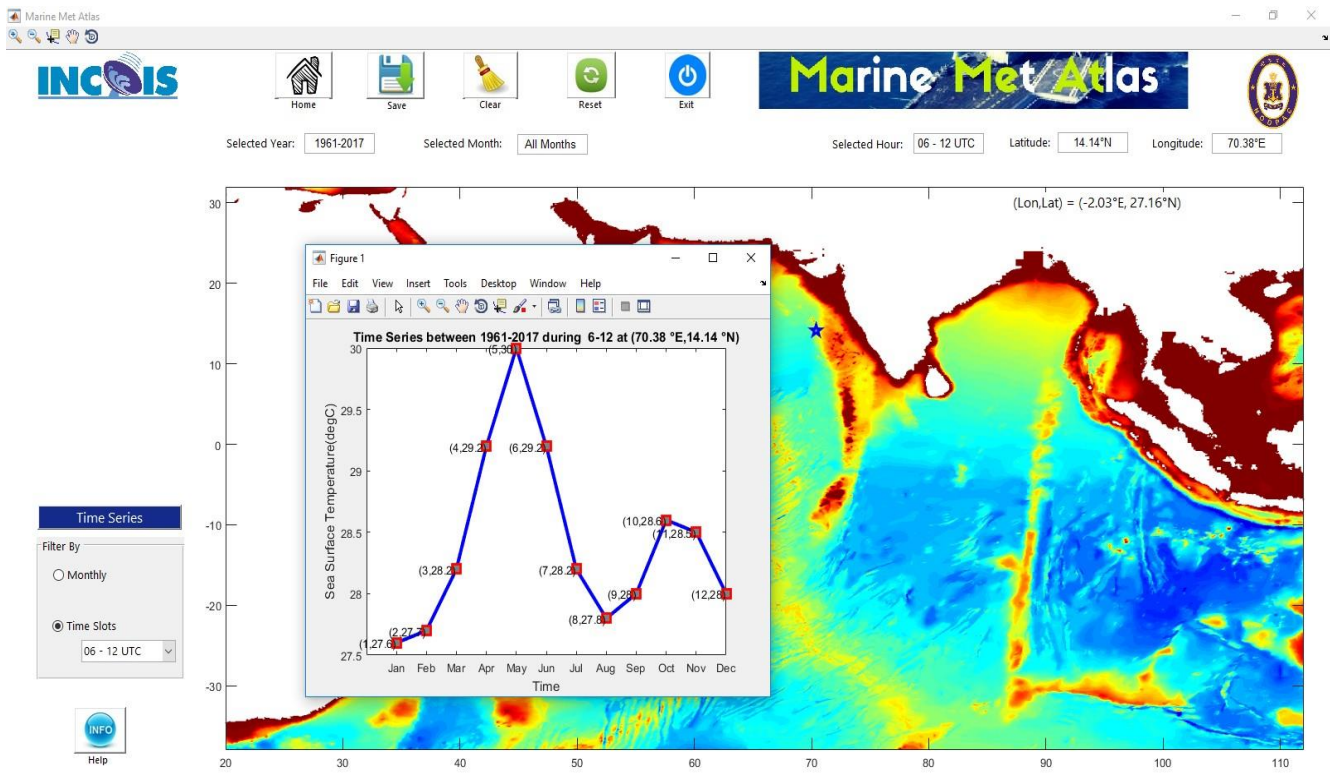


Figure 5. (Top) Time series plots of SST at 70.38 longitude and 14.14 latitude in the Arabian Sea. SST variability for all months and time zone of 06 - 12 Hrs and SST variability for January for all time zones are depicted. (Bottom) Time series plot of SST for January and all time zones at 82.12 longitude and 11.58 latitude

(ii) **Spatial Climatology** : Several options are provided to plot spatial contour plots. Detailed discussion about the generation of spatial climatology is described in Section 5. A sample plot is shown in Figure 6.

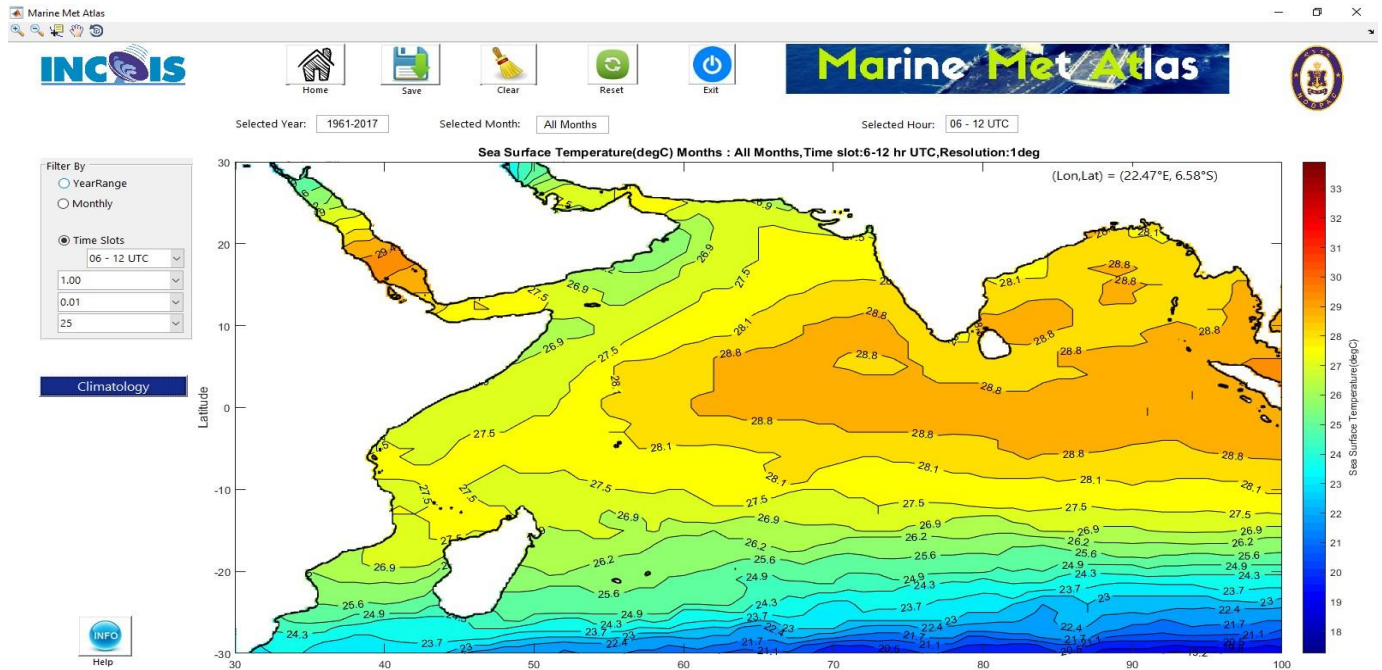


Figure 6. Spatial variation of SST for all months, all years and time zone 06 - 12 Hrs dynamically generated from the available data in the data base.

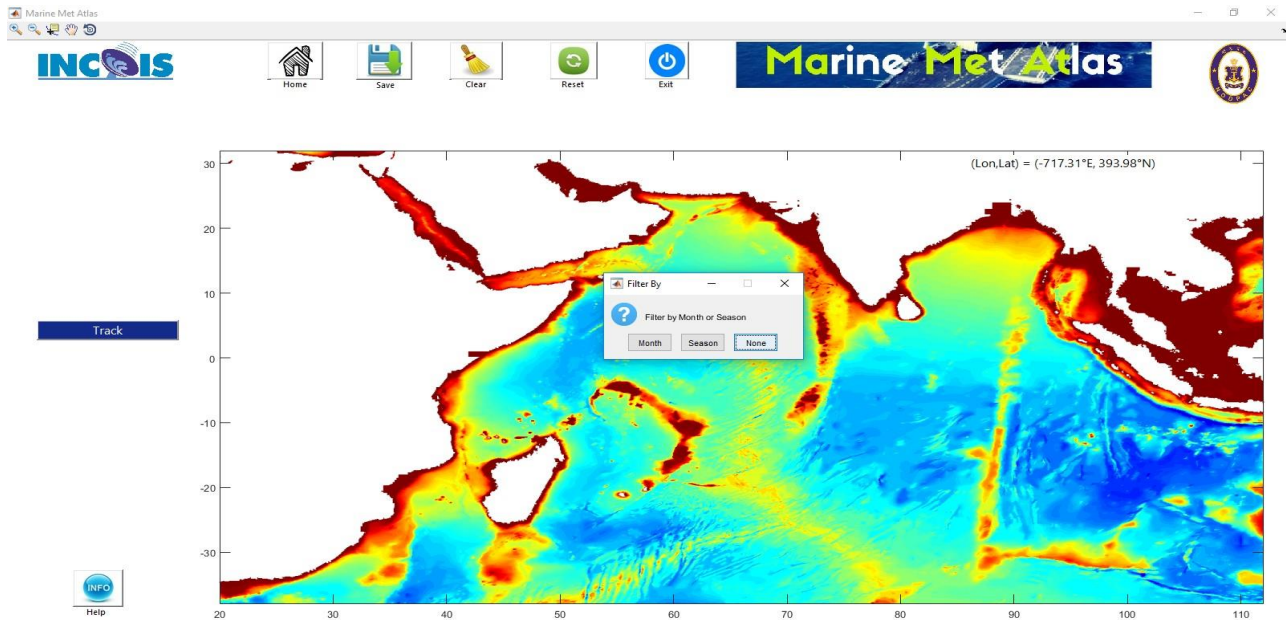


Figure 7 Option to select specific season or month during which the parameter value along the track is to be visualized

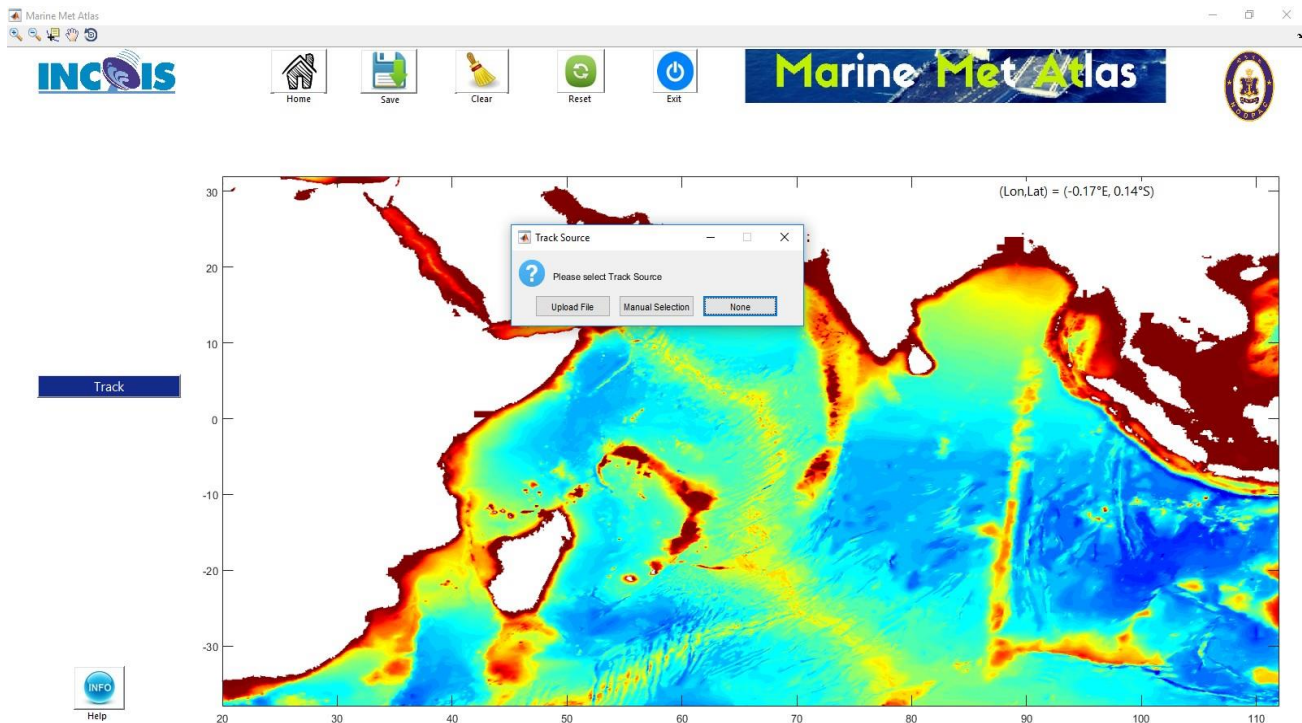


Figure 8. Options to provide cruise positions to obtain the parameter value along the track

(iii) Along a Track plot: 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 (Figure 7). The user can create a cruise track file a priori 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 8 shows the available options to give the track positions. After selecting the option and the locations the user is given an option to save this cruise track for later use. The positions of the cruise track are shown as p_1, p_2, \dots, p_n where p_n is the n th location 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 9 shows the line plot of SST along the cruise positions.

(iv) Data Statistics: The user is given an option to view the number of records available in the atlas database. The user can view the bar chart either yearly or monthly. Figure 10 shows the data availability of SST parameter for all years and all months.

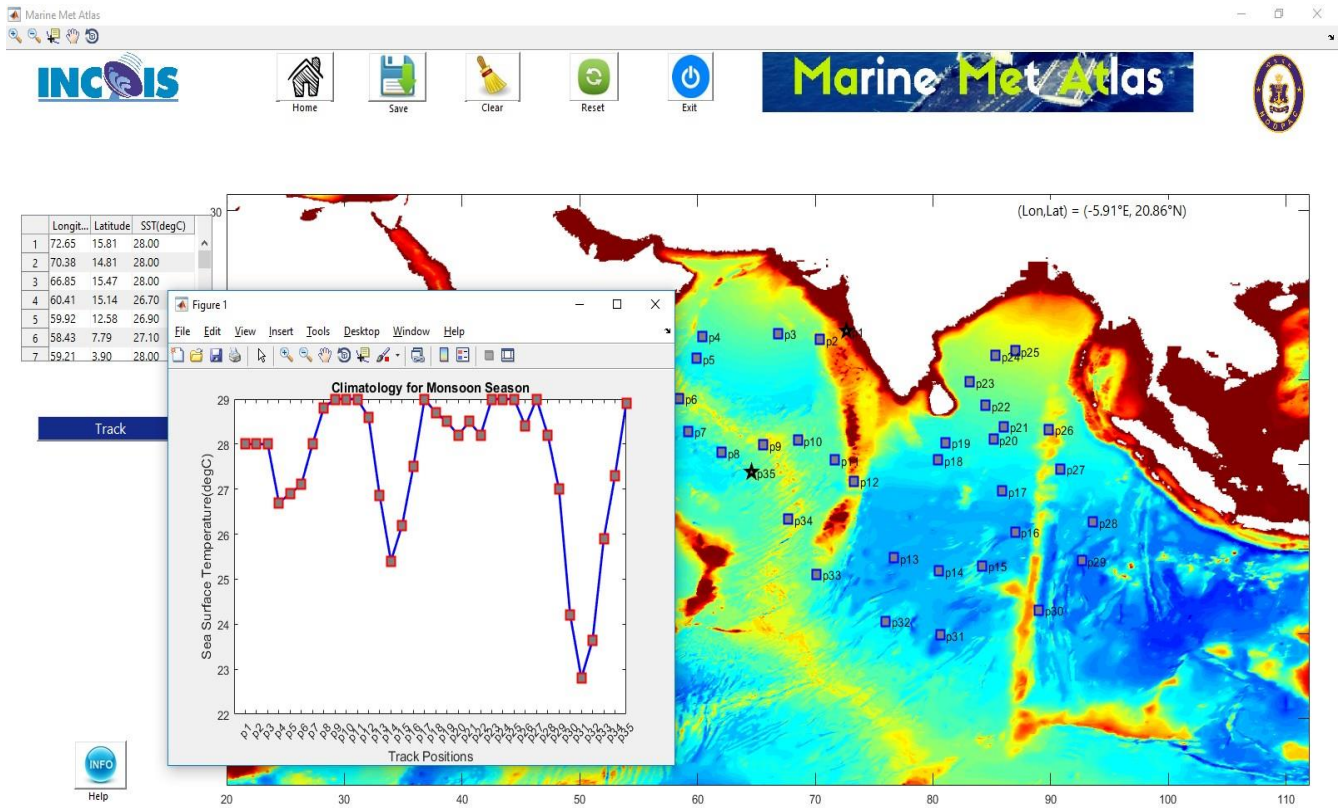


Figure 9. Plot of SST along the cruise track positions for the Monsoon Season.

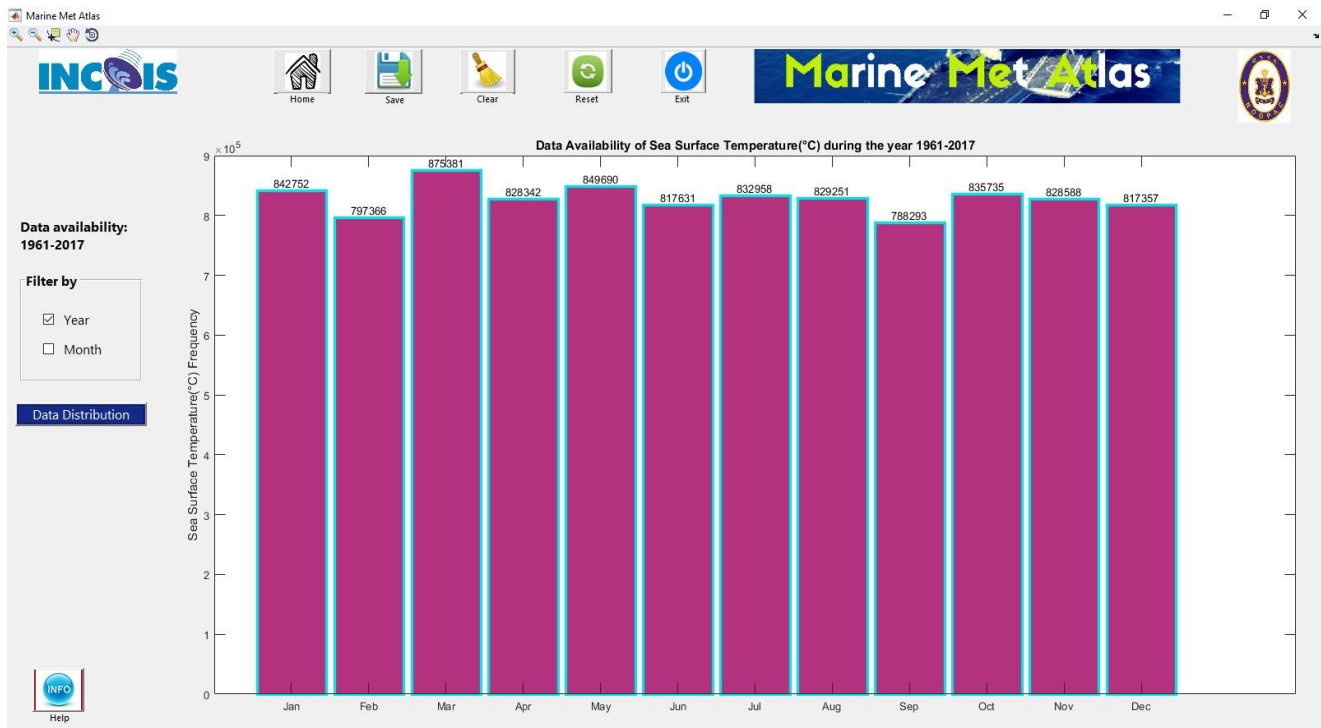


Figure 10 Data availability of SST parameter for all years and all months

4 WIND ROSE PLOTS OF WIND:

Apart from options like time series, climatology and track 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 11 shows the GUI for choosing options for plotting the wind rose plots. Figure 12 shows the rose plots for the locations 62.96 E longitude and 14.25 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. Except for this all other plots for winds parameter are similar to that of other parameters like SLP, SST etc.

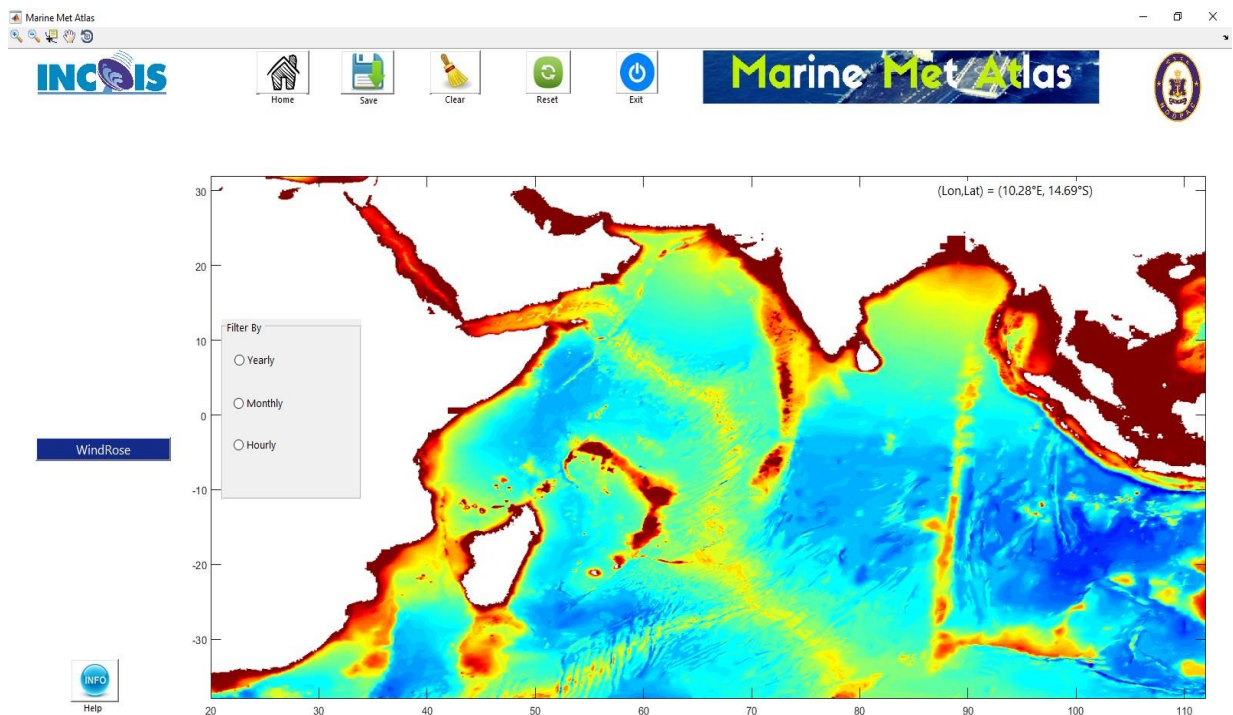


Figure 11. GUI depicting options for generation of wind plots.

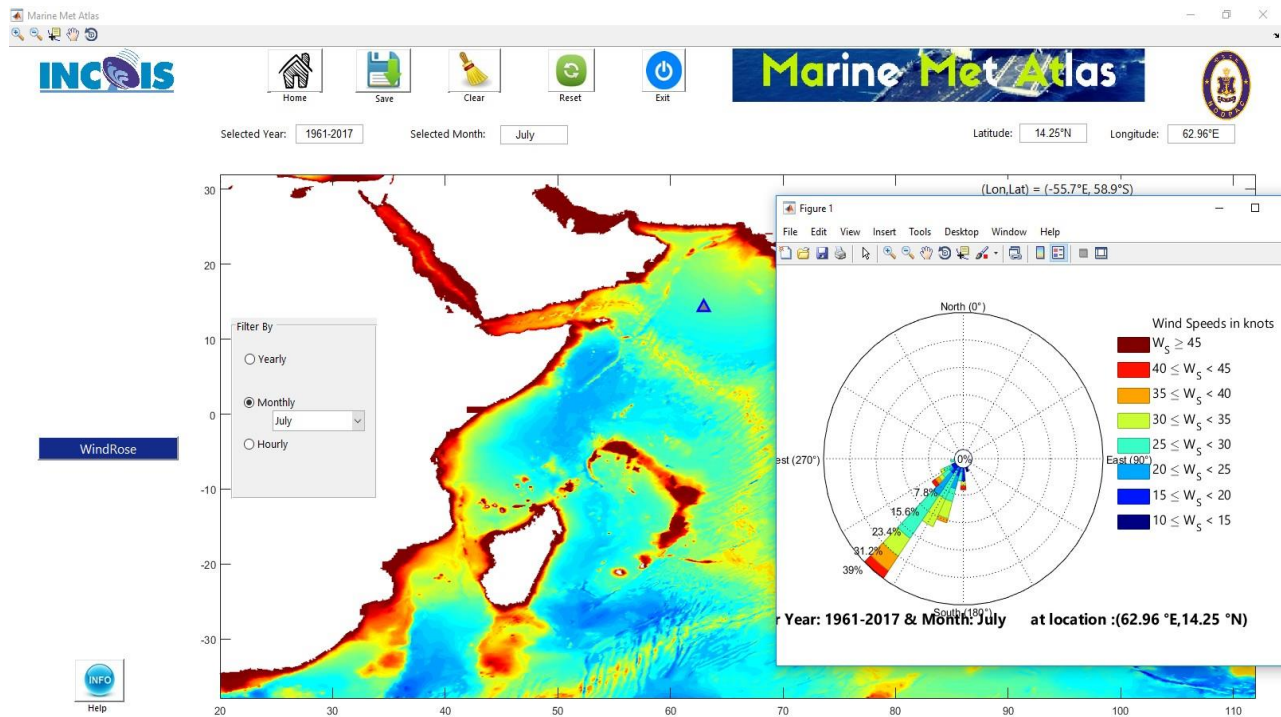


Figure 12. Rose plot of wind for the month of July obtained from all the data of 1961 - 2017.

5 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. Also, the option for choosing the number of contour lines and levels in the spatial plot that would be produced is provided. By default the climatology uses all the data for all the years available. However 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. Also provision for updating the data for years to come is also provided (Figure 14), so that this tool is not limited to the current climatology but also caters to all upcoming years too. Figure 13 shows the options of generating climatology. Figure 6 shows spatial climatology of SST of all years, all months for 6 - 12 UTC, for a grid resolution of $1^\circ \times 1^\circ$ with contour level 0.01 deg Celsius and with 25 contour lines.

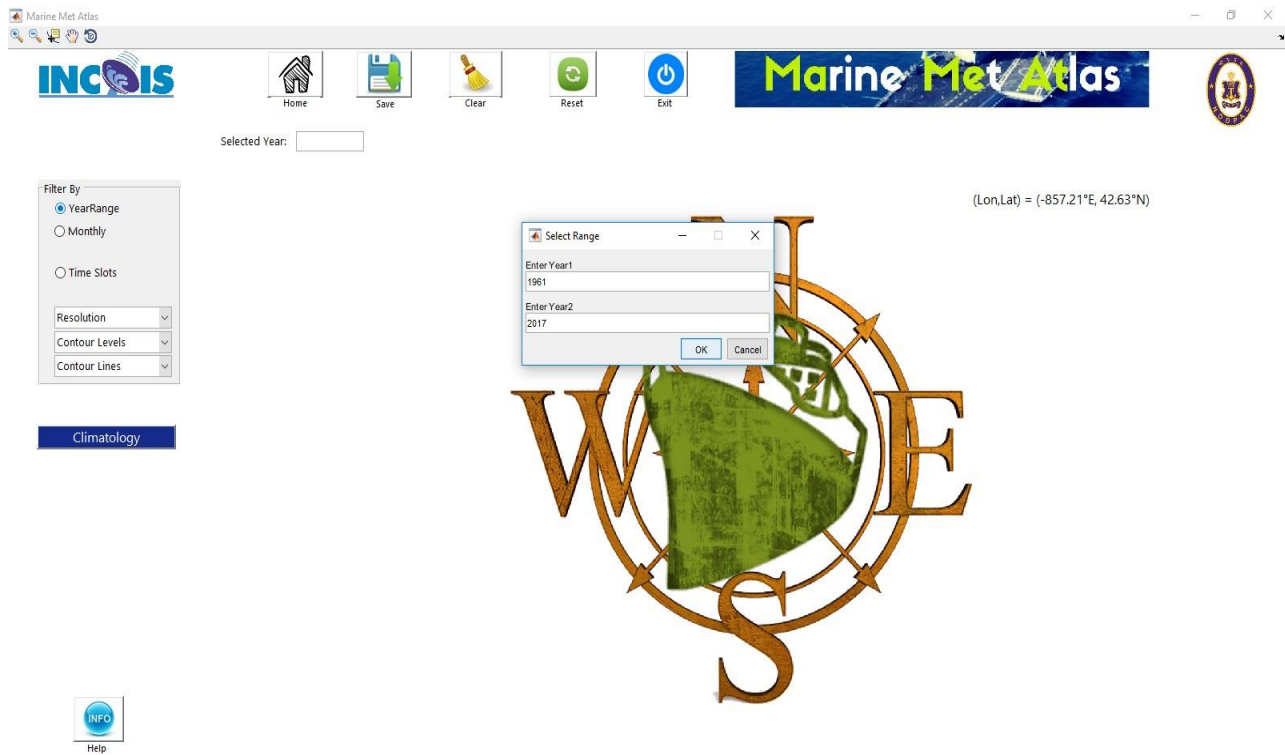


Figure 13. Options for generating climatology for a chosen period, chosen month and time zone from all the available data for visualization . Options for resolution and number of contour levels is depicted

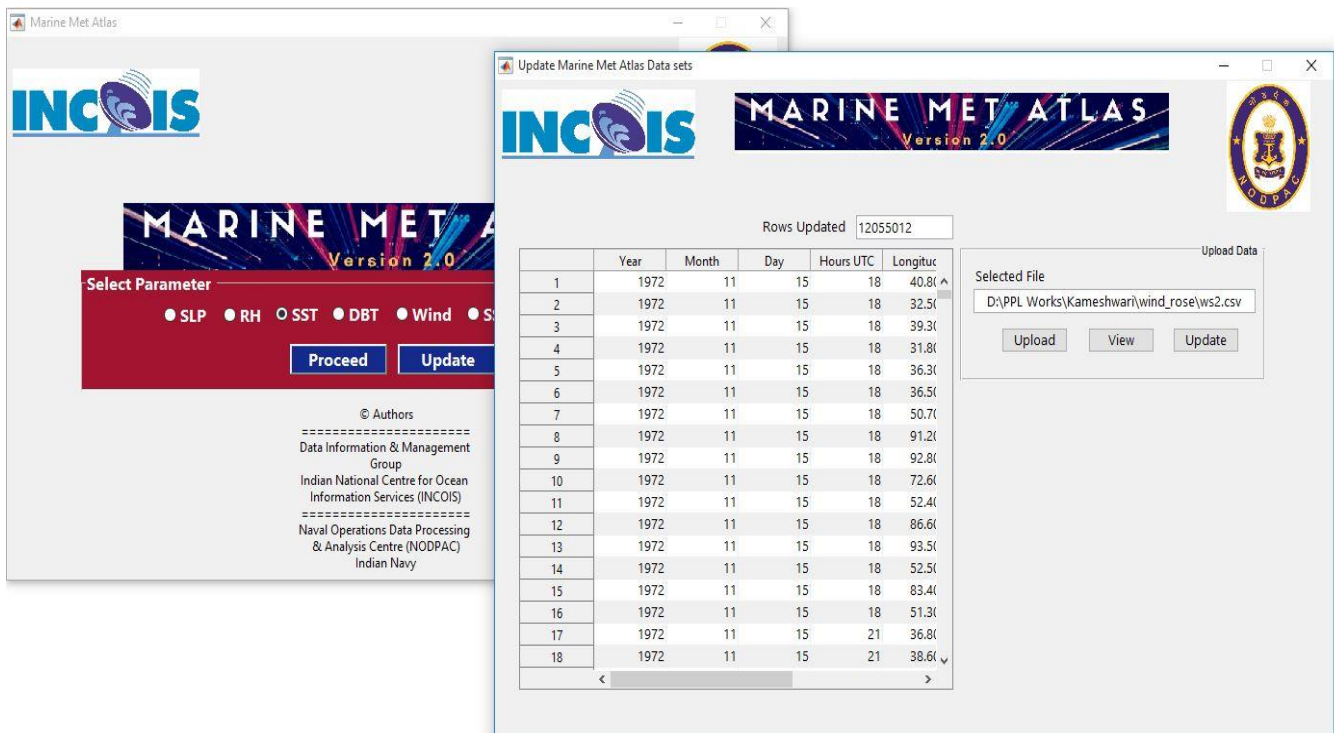


Figure 14. Option for appending of newly generated data sets to the existing parameters.

6 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. For this purpose, Etopo 5 minutes resolution bathymetry file is used as the background source. The bathymetry tool is shown with a 3D perspective view and user can get the depth value of ocean with the movement of cursor over the bathy plot. The bathy tool can be rotated in 360 degree both horizontal and vertical directions. 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 (67.15E, 5.31N) and (86.11E, 4.13N) 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. The user is also given an option to visualize the bathymetry in 3D view either by giving latitude and longitude limits or by drawing a box. Figure 17 shows the options available to give the latitude and longitude limits and Figure 18 shows the extracted bathymetry in 3D view of the box selected.

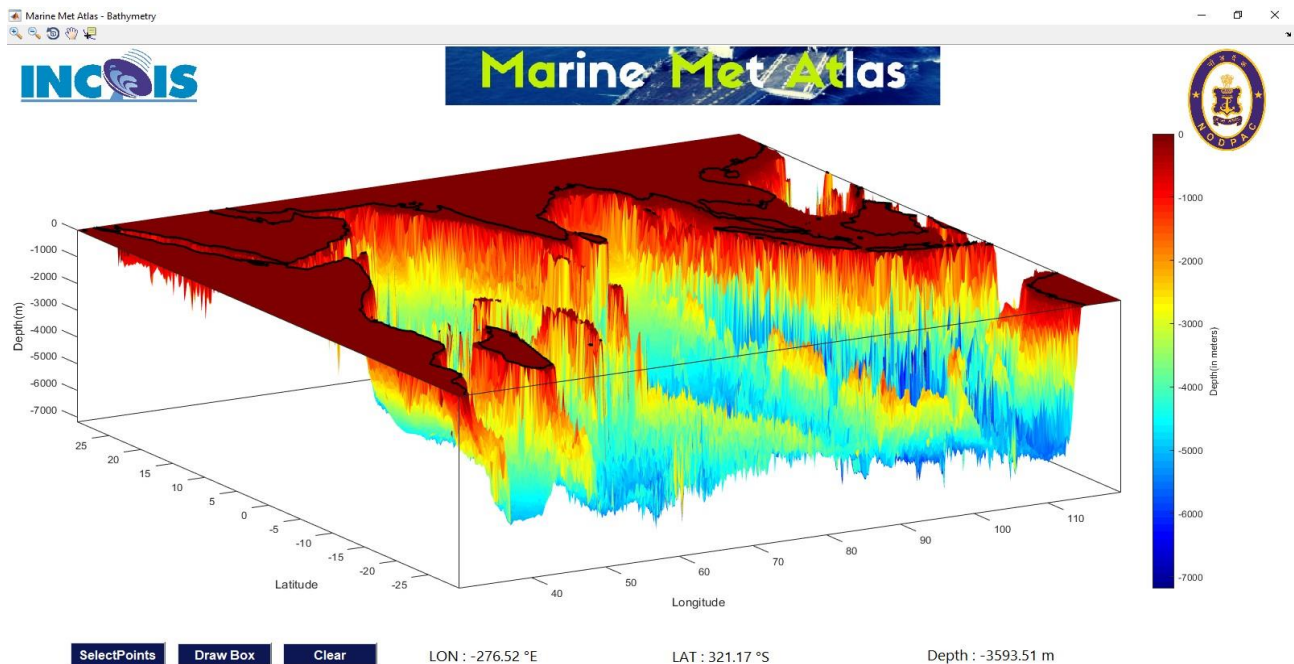


Figure 15. Bathymetry screen for visualizing and obtaining the depth of any location in the Indian ocean.

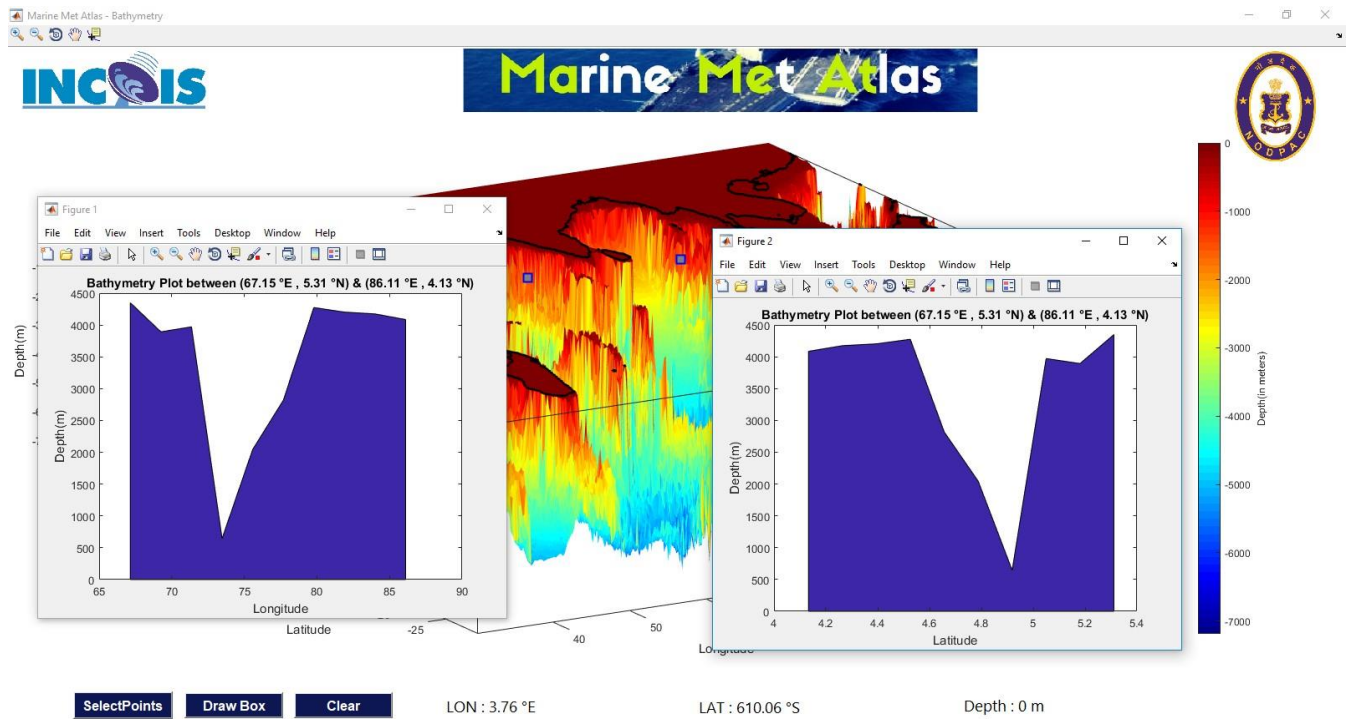


Figure 16 Bathymetry variation along longitude and latitude between two chosen points.

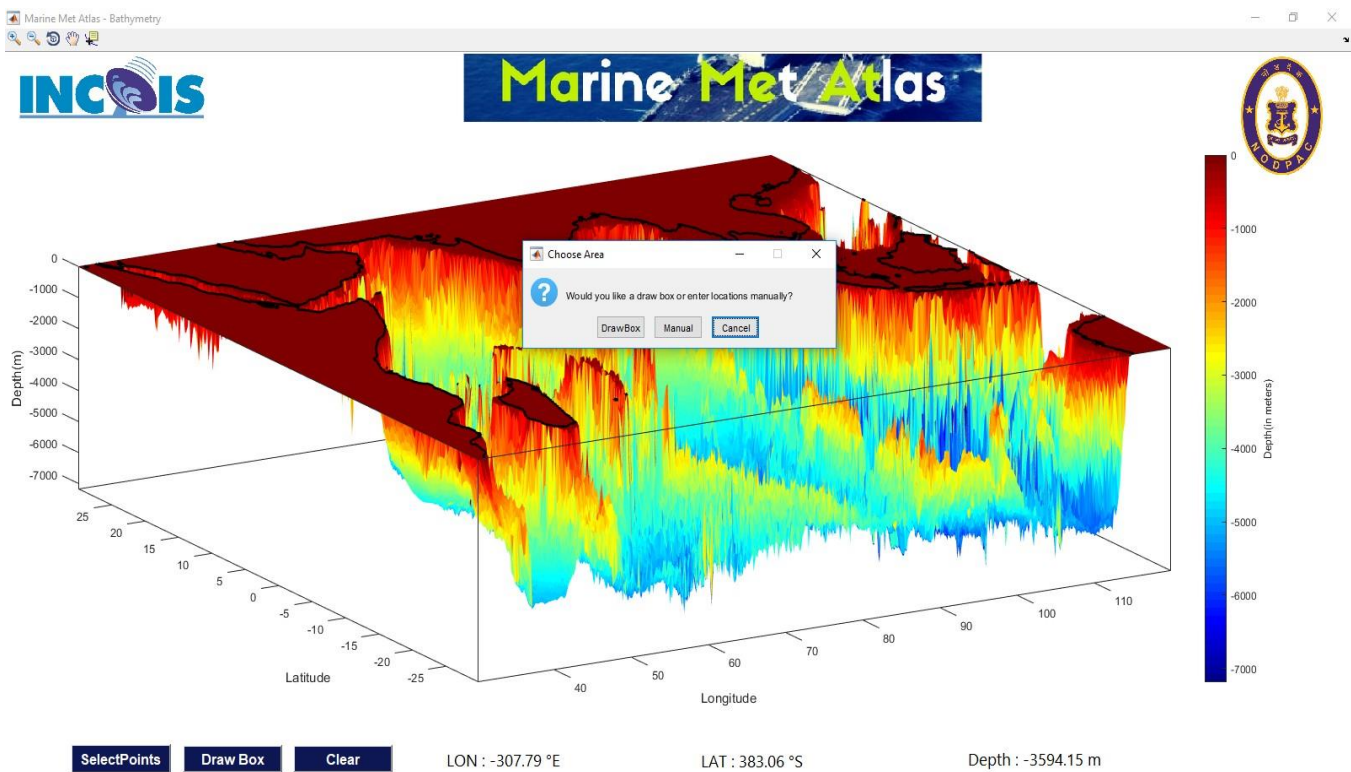


Figure 17 Options for extracting bathymetry in 3D view

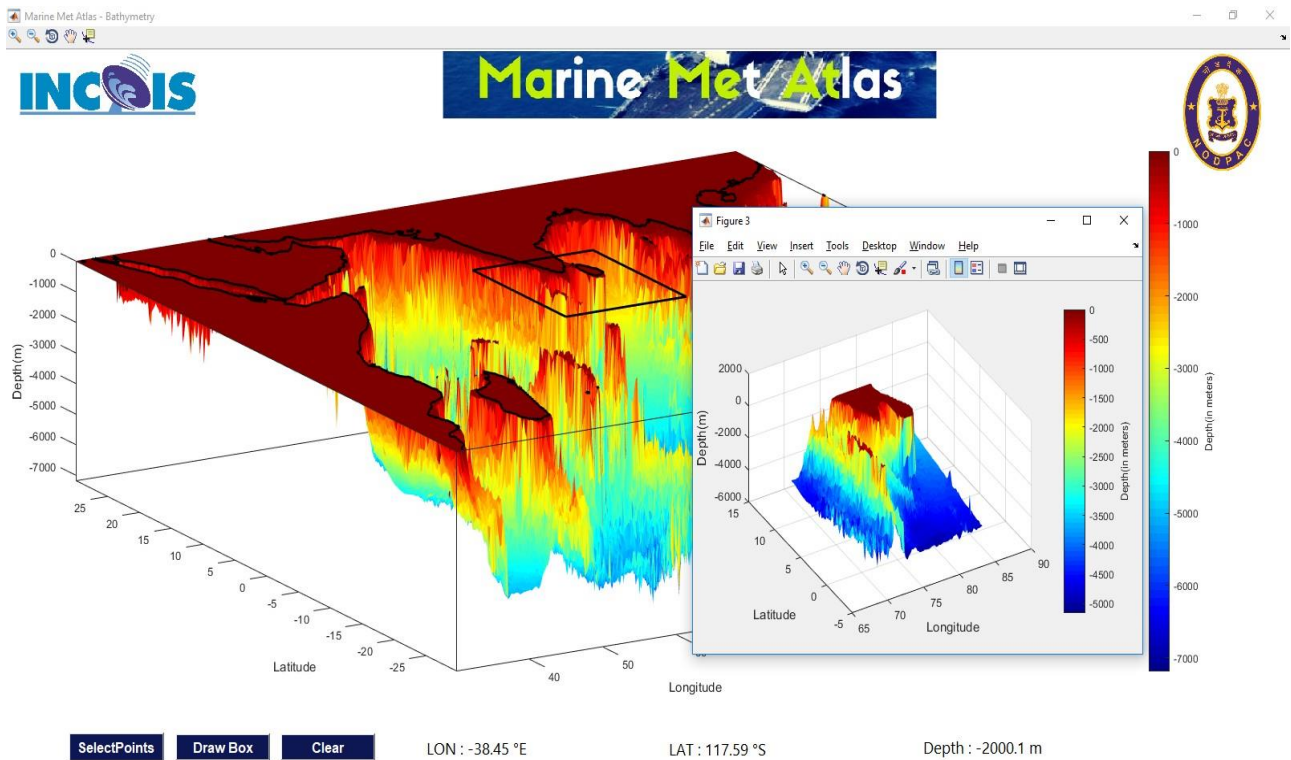


Figure 18 Bathymetry extracted in 3D view within the region of the box drawn

7 SUMMARY AND CONCLUSION

A tool was developed for use by Naval Operations Data Processing and Analysis Centre (NODPAC) a wing of Indian Navy. Data 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) are all collectively used for this purpose. 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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