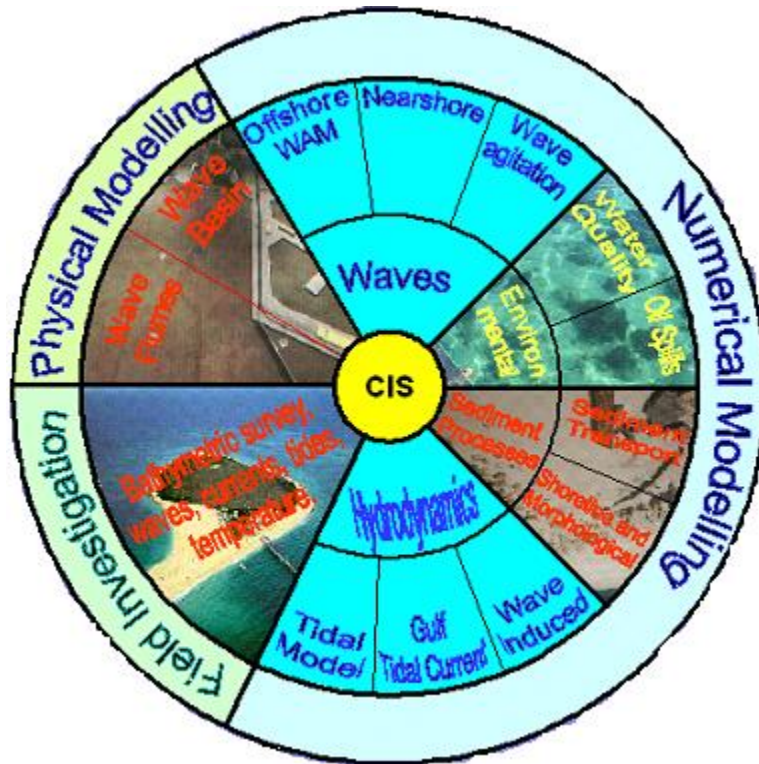


C.I.S. Interface



Description Manual For Coastal Information System Interface

C.I.S.

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COASTAL MANAGEMENT PROGRAM
KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH



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1. System Description

A number of marinas, harbors, ports, power plants, and other projects are being constructed or planned for future construction along the shoreline of Kuwait and Arabian Gulf. Such projects require data on the water levels, currents, and extreme wave conditions for the purpose of designing coastal structures. Also, the risk associated with different extreme wave conditions is also essential in designing coastal structures. Therefore, updating and upgrading the Kuwait Institute for Scientific Research (KISR) Coastal Information System (CIS) database from 1979 to 2018 is needed for long-term hydrodynamic data in Kuwait and Arabian Gulf waters. In this study a third-generation wind-driven wave model (WAM) was used to model the wind waves in the Arabian Gulf. The WAM model was validated using a Global Wave model data (ECEMF) or field measurements to ensure its accuracy. The updated database has better commercial value and will be useful for the optimal design of marine structures in the Arabian Gulf. It will also be useful for any future coastal research projects.

1.1 Background

The Digital oceanographic Atlas provides a valuable source of data. This Interface model as shown fig. 1 linked with oceanographic and met ocean databank will provide a new comprehensive hydrodynamic atlas for Kuwait's waters that can be a valuable source of information for the met ocean and oceanographic atlas of Kuwait and the Arabian Gulf. Time series of wind, wave, water levels and tidal currents are provided for last 40 years (1979 to 2018). The data generated and stored in a digital Coastal Information System C.I.S as shown in Fig. 1, that will provide a useful tool for the extraction data and analysis for (time series, summary tables, roses). The model interface system divide into several options as: -



Figure 1. Coastal Information System Interface [C.S.I]

1.2 Wind Analysis Methodology

In this study, sources of wind data covering the Gulf were purchased from the European Center for Medium-Range Weather Forecasts (ECMWF). The ECMWF wind fields have been utilized by Cavaleri et al. (1991) for wave hindcast in the western Mediterranean Sea and Sulisz et al. (2000) in the Arabian Gulf. ElDeberky et al. (2002) found that the National Centers Environmental Prediction (NCEP) data provided better results than the ECMWF data for some cases over the Mediterranean Sea. ElDeberky et al. (2002) however compared three sources of wind fields for the Mediterranean basin, the NCEP satellite blended data, the NCEP reanalysis, and the ECMWF wind fields.

Their results showed that the short available period of NCEP satellite blended data was not sufficient to judge on its accuracy for the area of study; while the NCEP reanalysis and the ECMWF wind fields showed almost similar results; while the NCEP reanalysis winds from the wave modeling point of view succeeded to simulate the extreme wave conditions compared to the measurements of the wave buoys. Benoit and Lafon (2004) however found that the ECMWF data provided better results than the NCEP data for the European continental shelf. They also had corrected the ECMWF data based on some calibration of the wind data. They also mentioned that the NCEP data provided results higher than the ECMWF data. In this study, a number of years of ECMWF wind data were used on a grid size of 0.5° with a three-hour interval. The wind data cover an area over the Arabian Gulf from Longitude 47.0° and Latitude 23.5° to Longitude 57.0° and Latitude 30.5° .

1.3 WAM Model Methodology

For most locations, it is difficult to find long-term wave data, essential for the design of any coastal project. Hindcasted wave data are usually used for such purposes. Different wave hindcasting methods are available, ranging from simplistic empirical formulas to complex two-dimensional wave models. Many organizations around the world sell hindcasted data obtained from advanced offshore wave models, e.g., British Met Office (BTO). Many other centers provide wave forecasts based on advanced offshore wave models (e.g., <https://www.fnmoc.navy.mil>). These forecasts range from global forecasts to local forecasts. The Naval Oceanographic Office in the USA uses the WAM model for forecasting waves in the Arabian Gulf (Johnson et al. 1995).

The Arabian Gulf is almost 900 km long and has a maximum width of about 360 km. The width of the Strait of Hormoz is about 100 km. The Arabian Gulf is predominantly shallow with the bottom sloping gently from the Arabian peninsula into an elongated basin attaining maximum depths of 80 to 100 m close to the more linear and mountainous Iranian coast on the east. Due to the shape of the Gulf as shown in Fig.1, it is sufficient to model the wind waves in the Gulf only with part of the Gulf of Oman.

[Sulisz and Al-Salem 2000] used a third-generation wind-driven wave model WAM (WAMDI Group, 1988) to model the wind waves in the Arabian Gulf with emphasis on Kuwait's territorial waters. The WAM model is a third-generation ocean wind-wave model. The model is based on the discrete spectral action balance equation that is a generalization of the energy balance equation in the presence of currents. In the model, this balance is formulated for propagation over a sphere using longitude λ and latitude ϕ coordinates.

$$\frac{\partial N}{\partial t} + \frac{1}{\cos \phi} \frac{\partial}{\partial \phi} (\dot{\phi} N \cos \theta) + \frac{\partial}{\partial \lambda} (\dot{\lambda} N) + \frac{\partial}{\partial k} (\dot{k} N) + \frac{\partial}{\partial \theta} (\dot{\theta} N) = \frac{S}{\sigma} \quad [1]$$

with short hand notation N for $N(k, \theta)$, which is the wave number action density spectrum of the waves, defined as the energy density divided by the relative frequency σ ; S is the source term, and θ is the wave direction.

The left hand side represents the advection term. The first term on the left hand side of the balance equation represents the local rate of change of wave action density. The second and the third terms represent propagation along great circles in geographic space. The fourth term represents shifting of wave number due to time variations in depth and currents. The fifth term represents refraction. The right hand side of the above balance represents the overall effects of the physical processes that add or take energy to or from a given spectral component. The physical processes included in the model are wind-wave interaction (generation), wave-wave interaction (quadruplet), dissipation (white capping), and shallow water bottom dissipation (bottom friction). For the calculation of waves in the surf zone and in shallow water a nearshore wave model with a fine grid should be used to transform the offshore wave roses generated by this study. More details on the model can be found in Sulisz et al. (2000), WAMDI Group (1988), and Al-Salem et al. (2005)

[Sulisz and Al-Salem 2000] showed that the use of simple empirical techniques assuming stationary and homogeneous wind fields over the Gulf often results in poor wave predictions. They also verified the ability of the WAM model to predict the wave conditions at three different locations in Kuwait. Their study indicated that the wind data obtained by the ECMWF underestimated the wind speed for some of the storms. This was shown by comparing measured winds at the buoy location with the ECMWF data for these storms. The comparison showed that for the storms with an underestimation in the wave heights, the winds used were lower than the values measured at the buoy as shown by Al-Salem et al. (2005).

The model covers the entire Gulf from the 47.4° until the 56.8° Longitude and 23.8° until 30.5° Latitude with a grid spacing of 0.1° . Fig 2 provides the grid used for the WAM model over the entire Gulf; Fig. 3 provides a closer view for the Kuwait's territorial waters. The bathymetry digitized from the admiralty charts used in Sulisz et al. (2000) was used. Twenty-five logarithmically distributed frequencies ($f_{n+1} = 1.1f_n$) with an initial frequency of $f_1 = 0.0505$ Hz were used to represent the wave spectrum. The directional spectrum has a resolution of 15° with 24 directions, which will provide data that can be used for sediment transport calculations. A time step of 5 min was used in the model (Table 1).

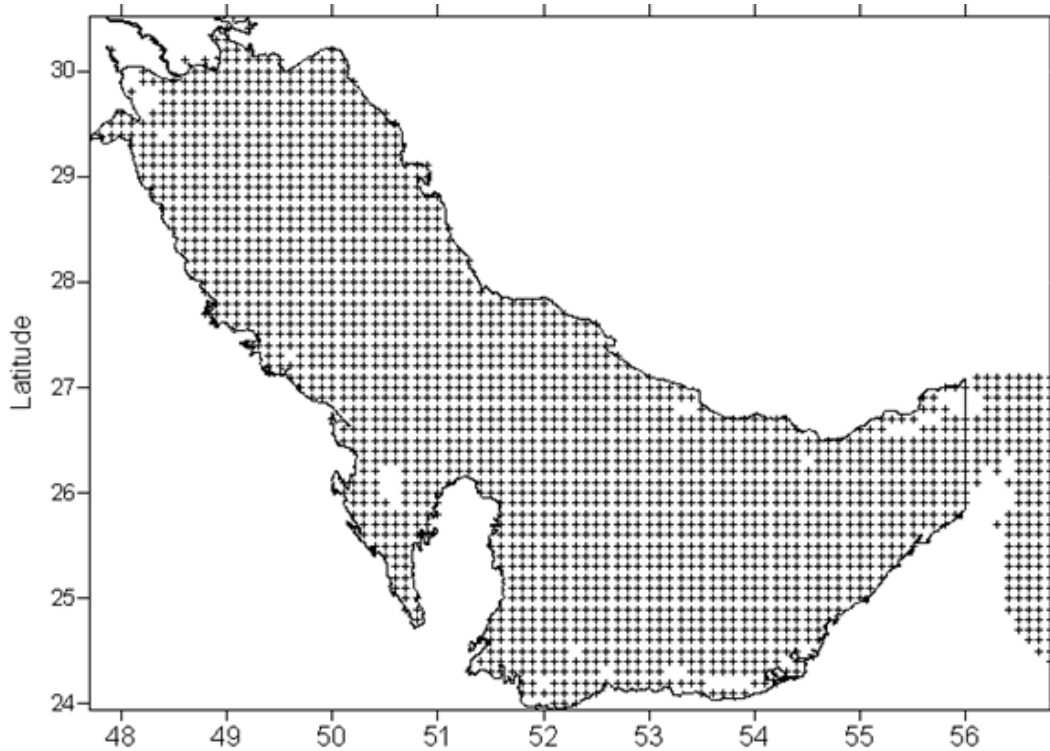


Figure 2. Grid used for the Arabian Gulf WAM model.

Table 1. WAM Model Setup Parameters

Parameter	Value / Range
Spatial grid resolution	0.1°
Frequency resolution	25 frequencies (starting from 0.0505 Hz)
Directional resolution	15° (24 directions)
Propagation time step	300 s
Source time step	150 s
Output time step	1 h
Time step for wind data	3 h for ECMWF and 6 h for NCEP
Shallow water terms	On
Depth refraction	On
Current refraction	Off

2. Wind Speed 1D/2D Database Analysis

The model covered the entire Arabian Gulf from (longitude 47.4, Latitude 23.8 deg) till (longitude 56.8, Latitude 30.5 deg.) with grid spacing of (0.1 deg). Data record covered From 1979 to 2018. Wind data at 10m above sea level. User must select this option From Fig. 1; Then Fig 3 will display to user a number of sub-option as follows:

Option 1:

2.1 Wind Extracting 1D Data at Grid

User must Select To extract wind speed data at select grid in Arabian Gulf as shown in Fig 3. Fig 4 will display for user To enter require Grid Information as follows

- Enter the Year of select data [By Select **Directory File**]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract.

Then Select **Extract** to Start collect the data require. As shown Fig. 6

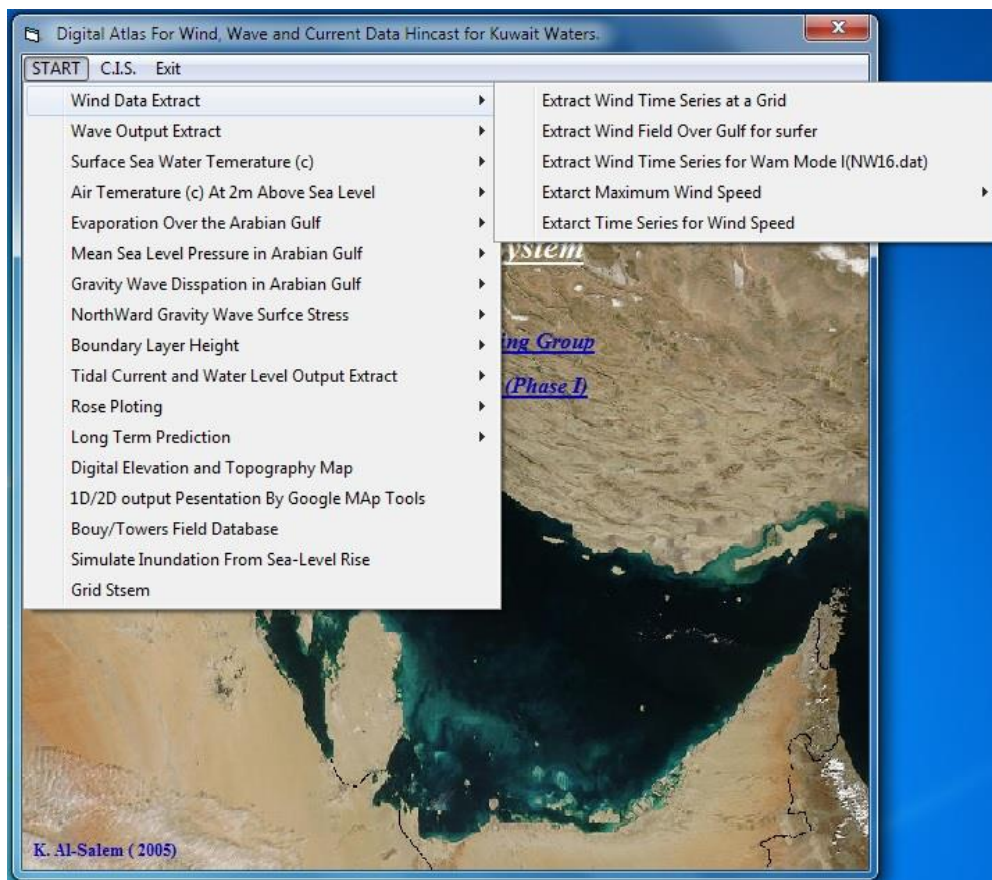


Figure 3

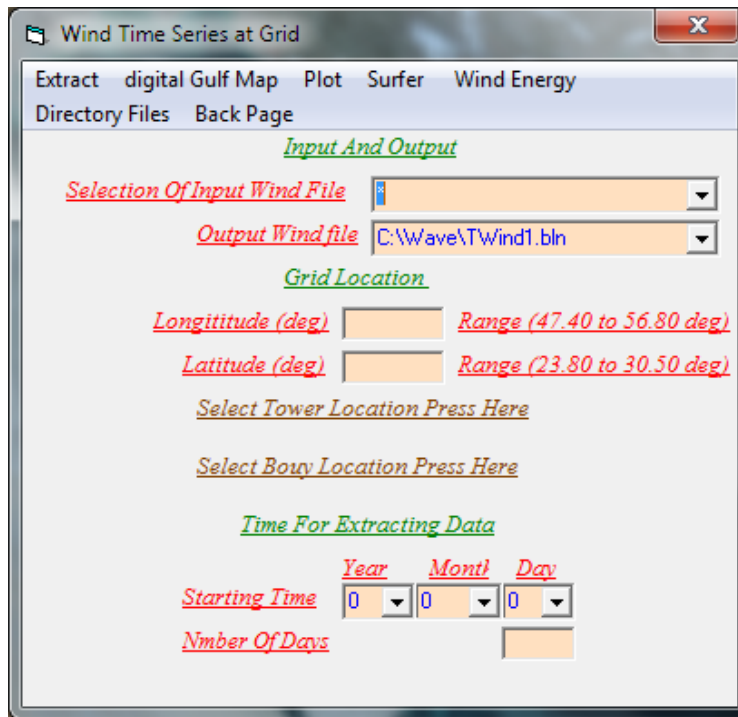


Figure 4



Figure 5

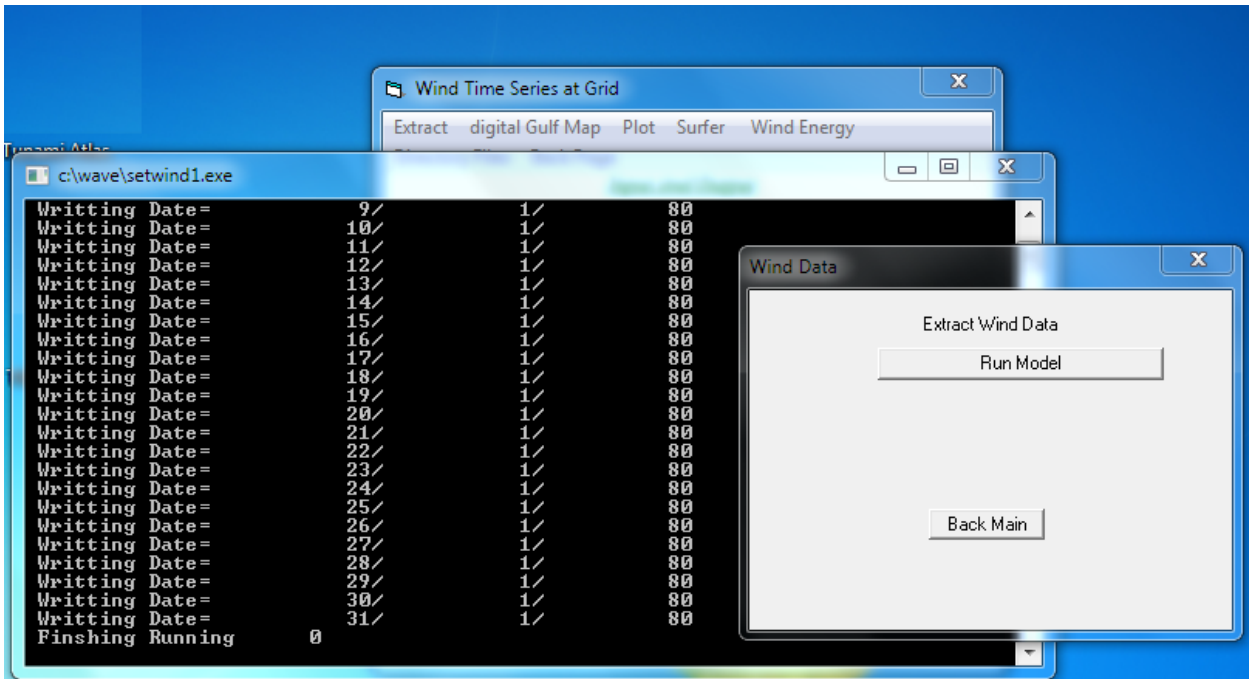


Figure 6

From 4 Data Analysis in this option as follows:

- 1- Plot Wind Speed Data [Plot] as shown in Fig 7
- 2- Plot wind Speed Data by Surfer Program [Surfer]
- 3- Wind Energy Analysis as shown in Fig. 8

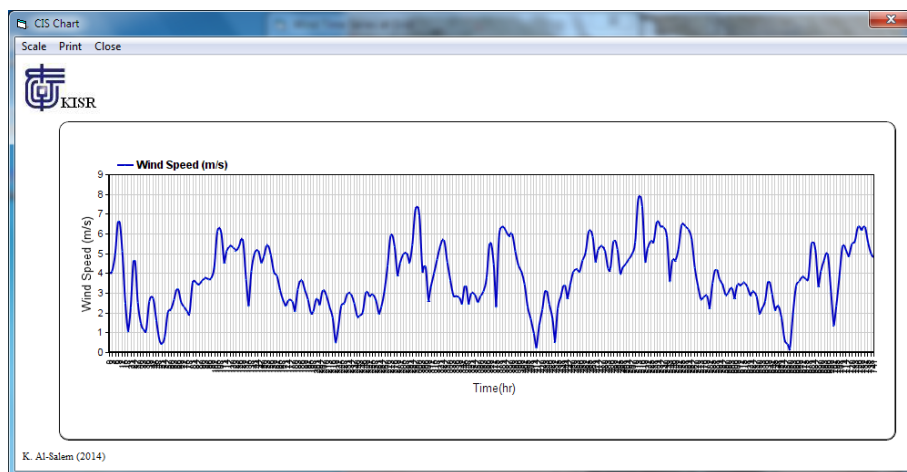


Figure 7

2.1.1. Wind Energy Analysis

Wind Energy Study and Calculating Tool. It a valuable tool to study and calculate the wind energy at any select location in Kuwait and al Arabian Gulf. User Should Selection Wind Energy from Fig. 4 after the wind data extract is finished.

Fig. 8 will display then user should select **Run** in Fig. 8 to plot all extracted wind data and the corresponding wind energy. Then user characterized the wind data as follow:-

1. Select roughens for the train.
2. Select Dray air temperature.
3. Select Hub Height.
4. Select Wind Direction
5. Select Wind Mill starting speed

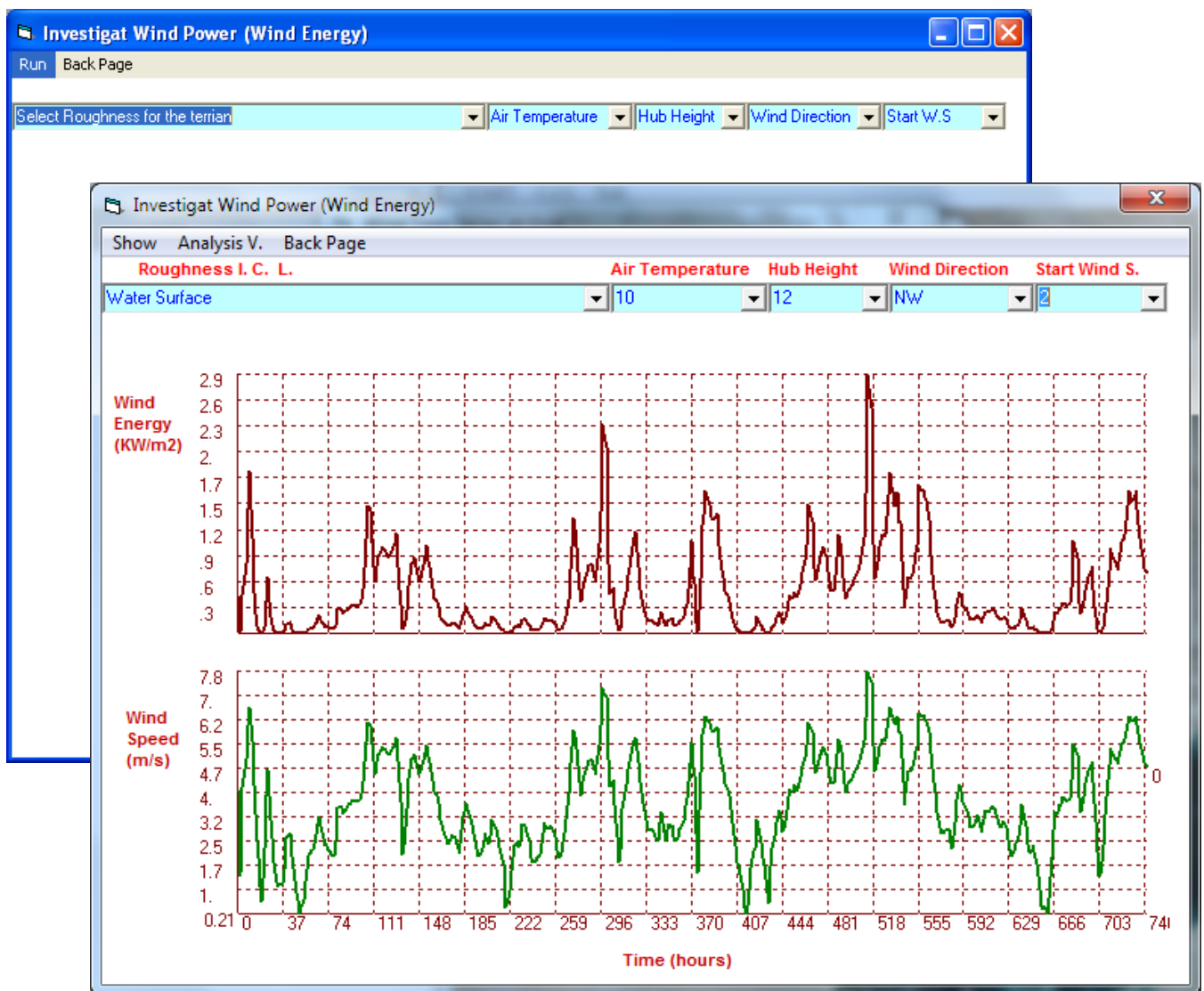


Figure 8

Then after all selection is made user should click on **Show** in Fig 8. Fig 9 will display for user to show the amount of wind energy will be produced for this wind data record and user selection. If user click on the **Analysis V.** as shown in Fig 9 a drop down list will display for user to see some calculated variables as show in Fig 9. as follow:-

- 1- Total Energy (kw/sq.m)
- 2- Mean Wind Energy (kw/sq.m)
- 3- Mean Wind Speed (m/s)
- 4- Total hours pre year (energy will produce)
- 5- Percentage of wind energy pre year (percentage energy produced pre year)

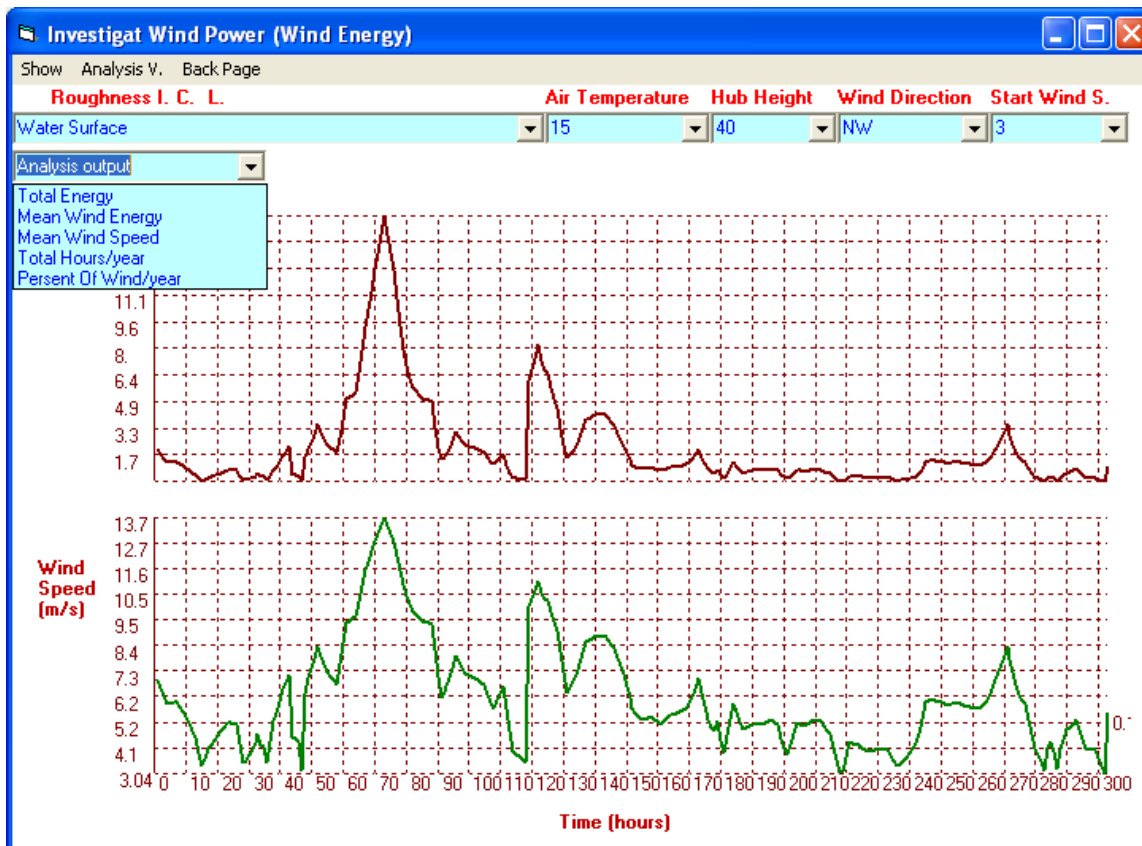


Figure 9

Option 2:

2.2 Wind Extracting 2D Data over Arabian Gulf for Surfer Format

If user select Option 2 from Fig. 3 Then Fig.10 will display. User should fill the input information and then submitted by click on Extract to receive output required information. The procedure like is:

First enter the input data file name from the storage bank by 3 ways as

- 1- Type data file input name manually as in Fig. 10.

2- Use The Drop down option then select the data name then change the required year number as in Fig. 10.

3- Click on **Directory Files** then select the data name by click on the name as in Fig. 10.

User must Enter Output File name as shown in Fig 10

User must Enter Day/Month/Year and Time[hour number in A select day] Information as shown in Fig 10.

Then after all data entered user must select **Extracts.**

To Display Then selected 2D wind speed data by Surfer program user must select [**Plot into Surfer**]. Figure 11 will display 2D wind speed at selected hour.

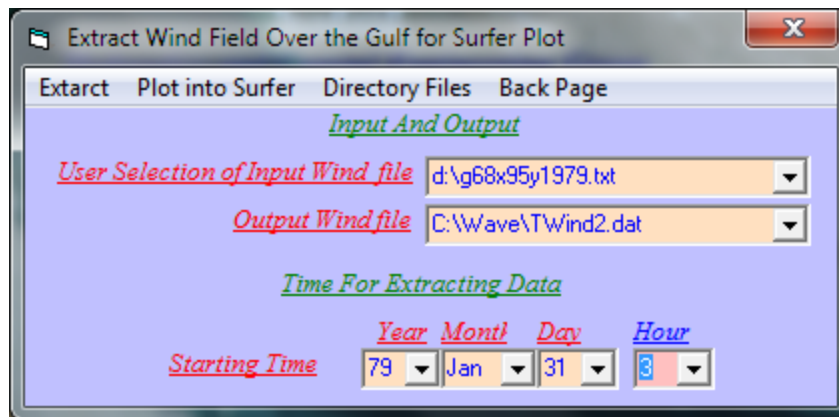


Figure 10

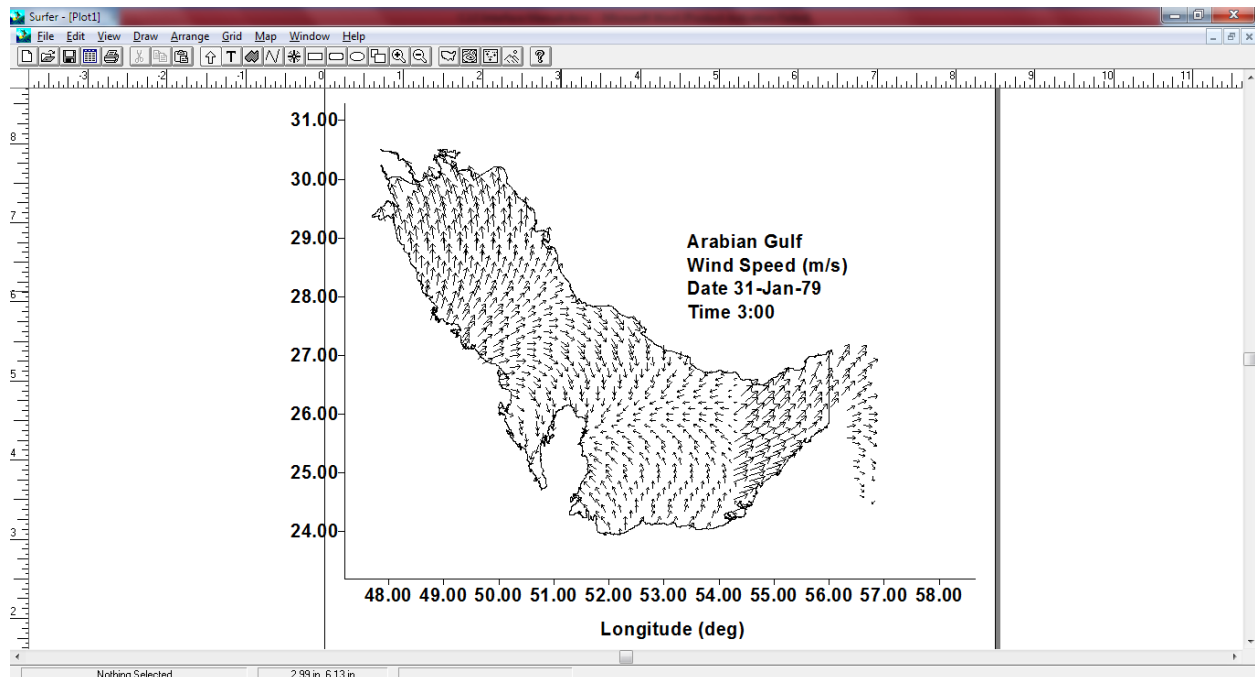


Figure 11

Option 3

2.3 Extract 2D wind Speed time series for KISR WAM Model as [NW16.dat]

To Simulation the Wind\Wave model [KISR WAM model] user must generate 2D wind speed input data in model require formatted as [NW16.dat].

Select Option 3 from Fig. 3 then Fig.12 will display. User should fill the input information and then submitted by click on Extract to receive output required information.

The procedure like is:

First enter the input data file name from the storage bank by 3 ways as

- 1- Type data file input name manually as in Fig. 12.
- 2- Use The Drop down option then select the data name then change the required year number as in Fig. 12.
- 3- Click on Directory Files then select the data name by click on the name as in Fig. 12.

User must Enter Output File name as shown in Fig 12 default name [NW16.dat]

User must Enter Day/Month/Year and Time[hour number in A select day] Information as shown in Fig 12. As (30 day is a month 365 day is a year).

Then after all data entered user must select **Extract**.

To Display selected 2D wind speed data user must click on **Edit**

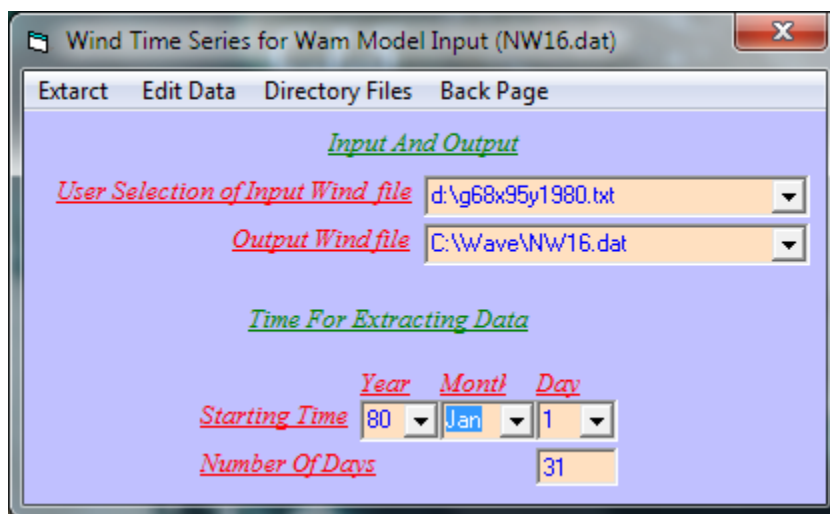
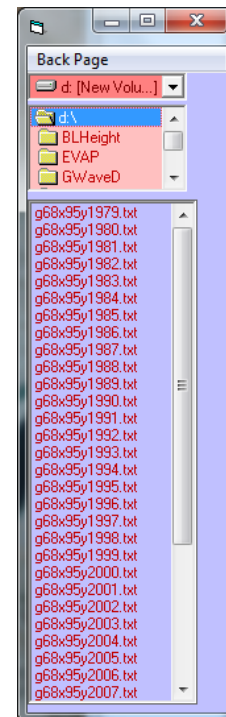


Figure 12



Option 4:

2.4 Extracting Maximum Wind Speed

To analysis maximum wind speed in 1D\2D data over Arabian Gulf. User has a number of analysis as a Sub-options as shown in Fig 13.

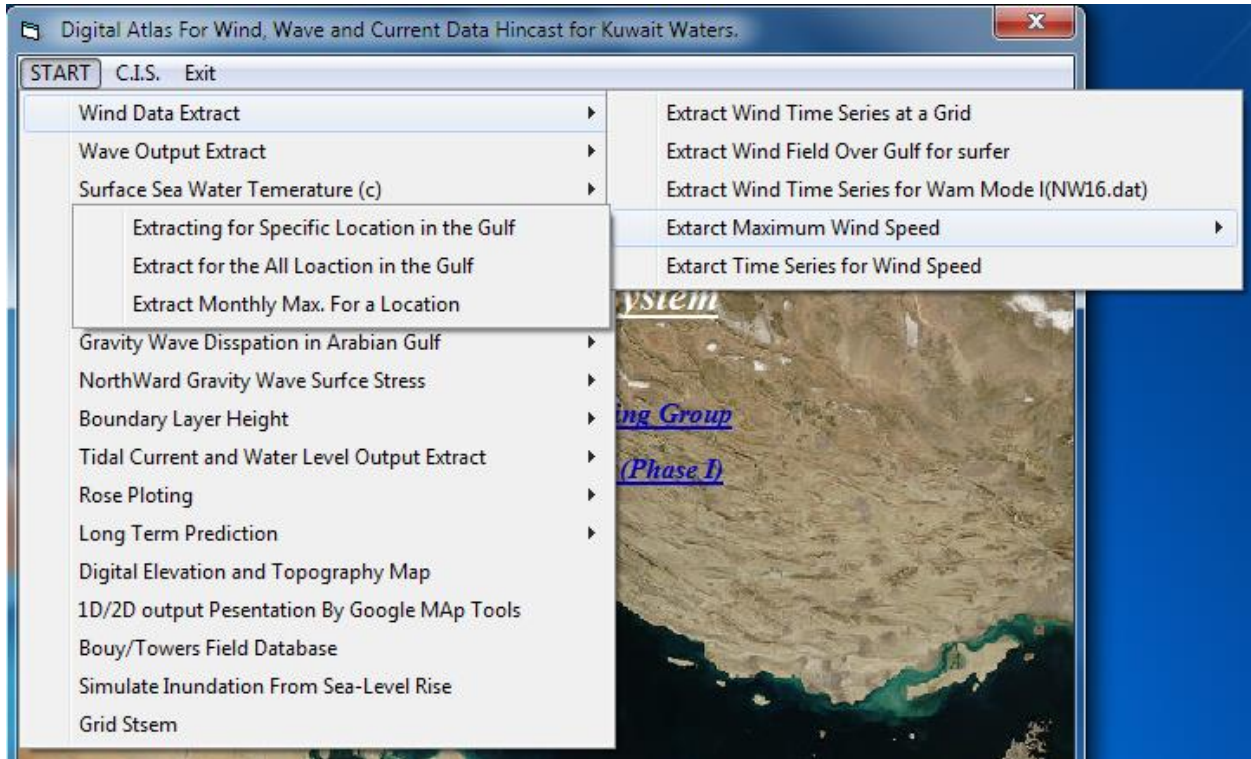


Figure 13

Sub-Option 4

2.4.1 Extract for Specific 1D grid Location in Arabian Gulf

To extract 1D wind speed data at select grid in Arabian Gulf to locate and show the maximum value and at what wind direction.

From Fig 13 a sup-option will display for user to select.

Figure 14 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select ***Digital Gulf map*** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select ***Extract*** to Start collect the data require as in Fig 14.

In Fig 14 a new Button Will Appear [***Show Max.***]. User should select To display the analysis result as shown in Fig 15.

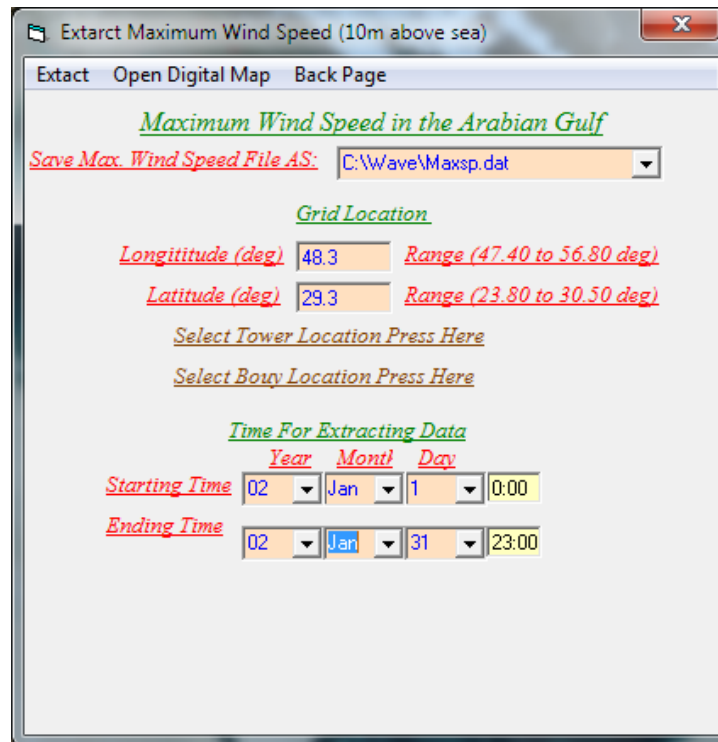


Figure 14

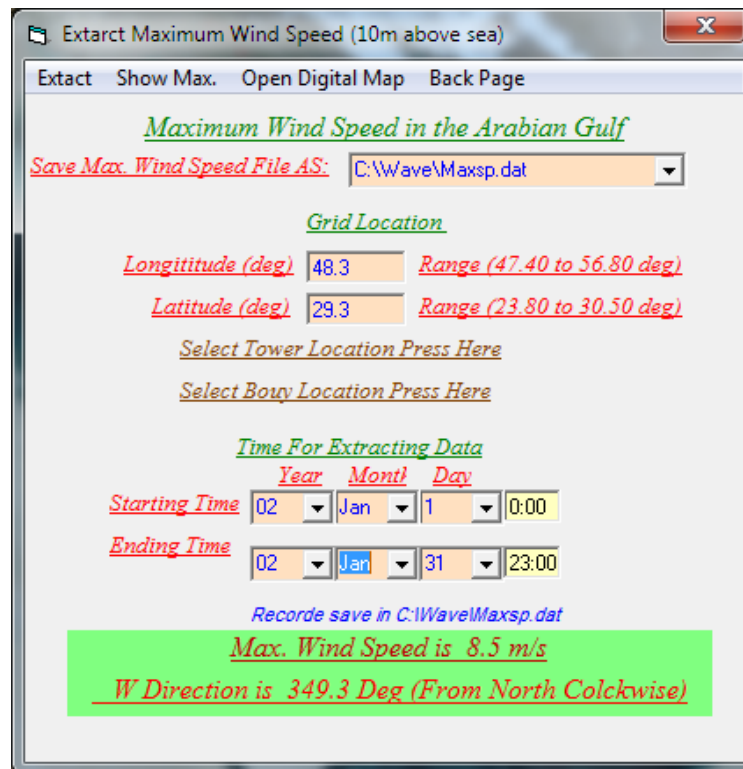


Figure 15

Sub-Option 4

2.4.2 Extract for All 2D grids Location in Arabian Gulf

To extract 2D wind speed data over Arabian Gulf to locate and show the maximum value From Fig 13 a sup-option will display for user to select.

Figure 16 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select **Extract** to Start collect the data require.

From Fig 16 user should select [*Open Surfed Plot*] to Activate Surfer software Program.

In Surfer program User should generate the grid information and contour result of wind speed.

The analysis result as shown in Fig 17 from Surfer 2D plots.



Figure 16

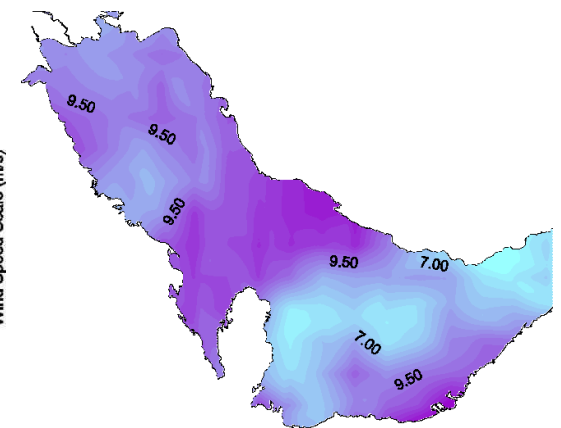
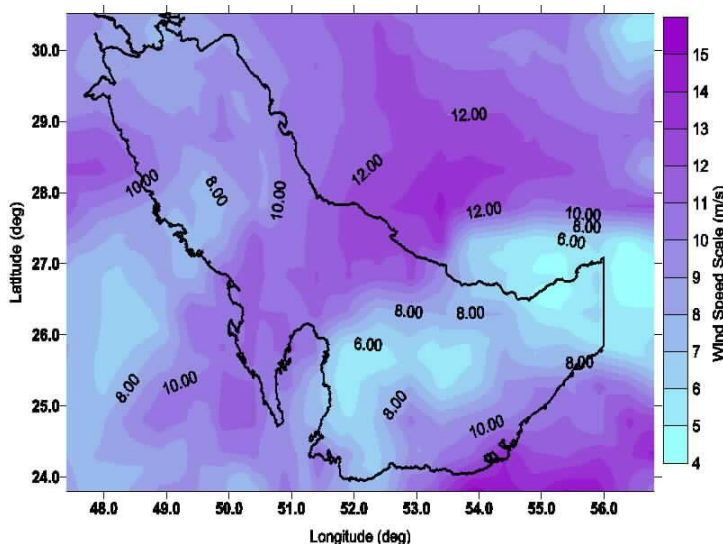
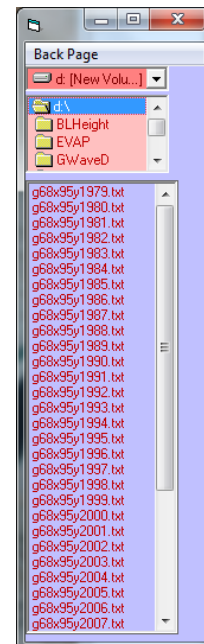


Figure 17

Sub-Option 4

2.4.3 Extract for monthly maximum 1D grid Location in Arabian Gulf

To extract 1D wind speed data at select grid in Arabian Gulf to locate and show the monthly maximum value and at what wind direction.

From Fig 13 a sup-option will display for user to select.

Figure 18 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Check Wind Speed option
- Enter Grid Location by two way as
 - Select ***Digital Gulf map*** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select ***Extract*** to Start collect the data require as in Fig 18.



Figure 18

From Fig. 18 user should Select [Show] to display the monthly wind data speed analysis result as follows as in Fig. 19:

- Monthly Max from time limits selected.
- Bar graph for monthly max.

Monthly Max. for Wind Speed (m/s) From 1/Jan/02 To 31/Dec/02											
Back Page	Dis. M										
<u>January</u>	<u>February</u>	<u>March</u>	<u>April</u>	<u>May</u>	<u>June</u>	<u>July</u>	<u>August</u>	<u>September</u>	<u>October</u>	<u>November</u>	<u>December</u>
8.47	8.91	9.22	9.42	8.17	10.28	9.19	9.43	9.45	8.11	7.51	7.85
349.31	328.47	302.07	117.81	119.45	142.81	141.74	147.59	143.55	179.29	137.14	139.27

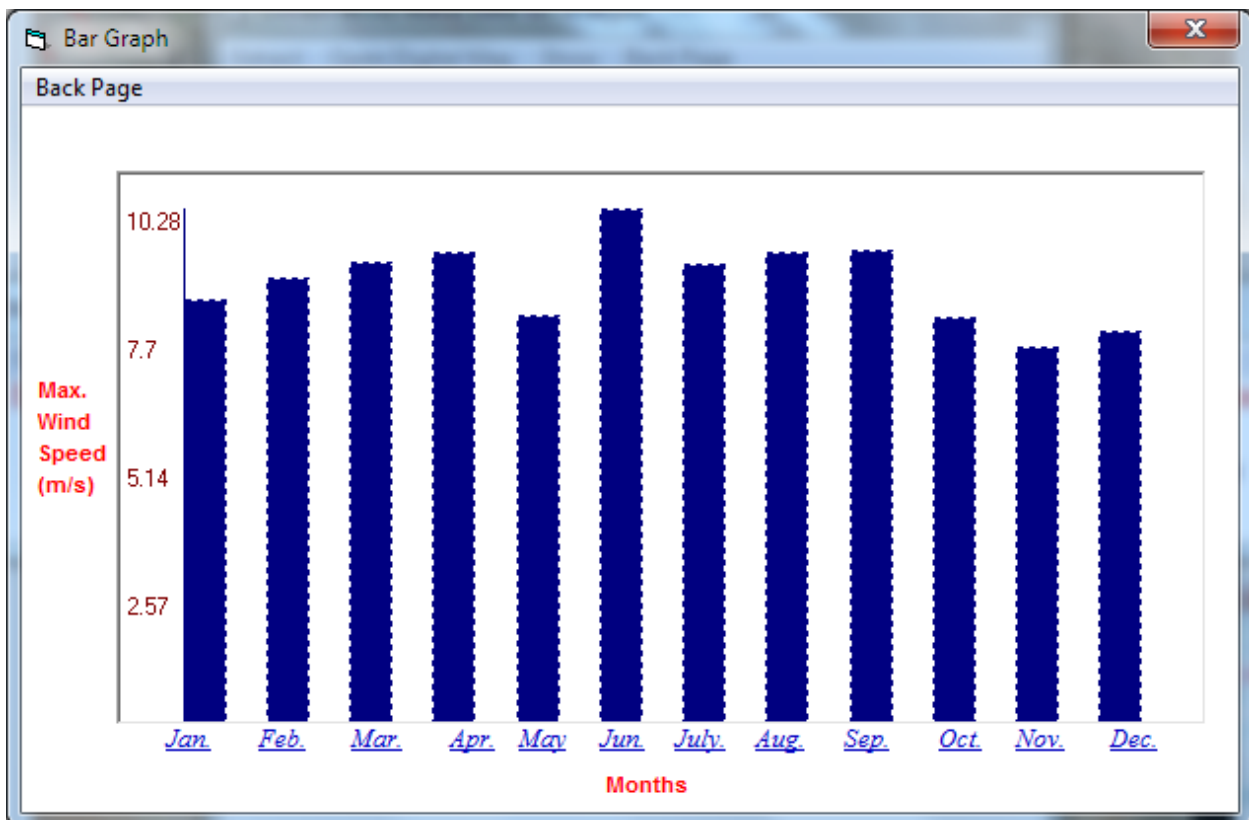


Figure 19

Option 5:

2.5 Long Terms Extracting Time Series 1D Wind Speed

The Long Terms extract 1D wind speed data (10m above sea level) at select grid in Arabian Gulf For different kind of analysis.

From Fig 13 a sup-option will display for user to select.

Figure 20 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select **Extract** to Start collect the data require as in Fig 20.

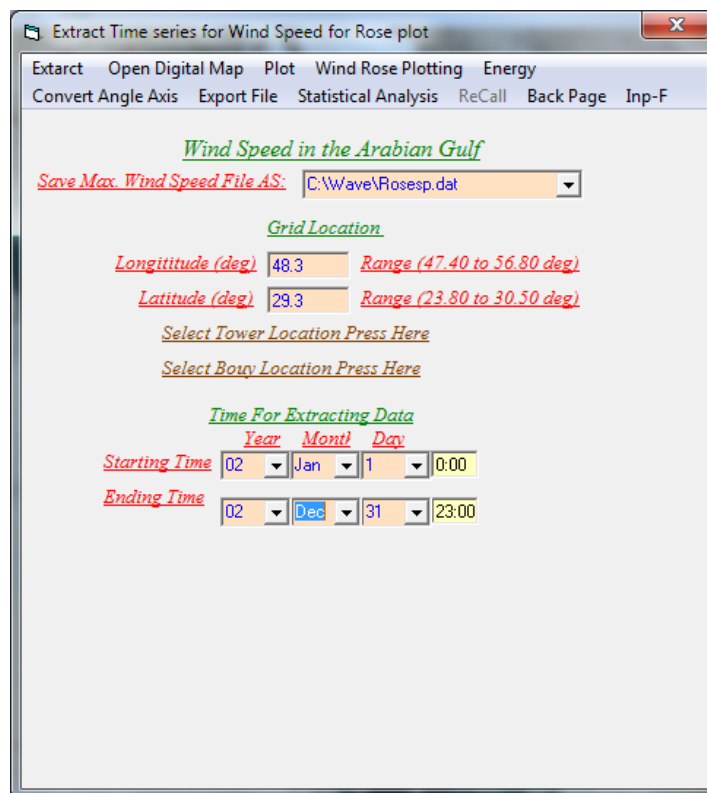


Figure 20

A number options for user to select for data reformat and plotting as follows:

- [**Plot**] To Plot extracted data Fig 21.
- [**Convert angle Axis**] to convert how wind speed direction to be read and stored Fig 22.
- [**Export File**] To Setup printing File of the extract data Fig 23.

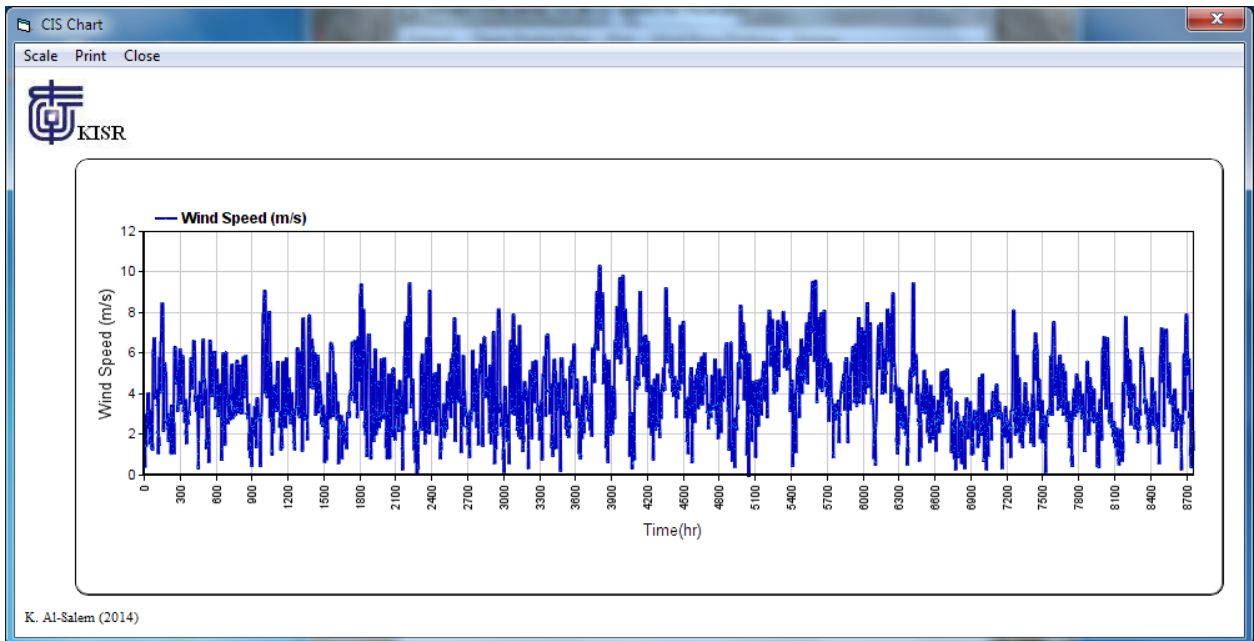


Figure 21

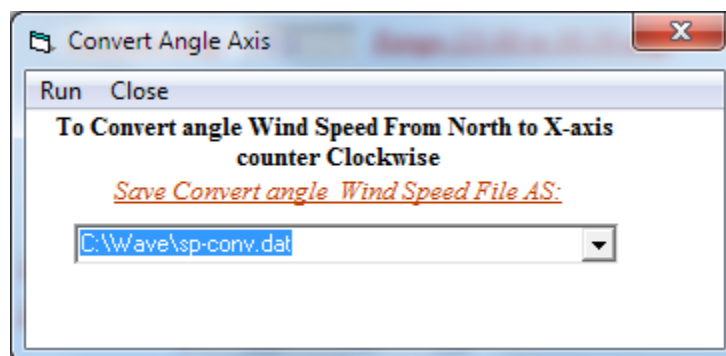


Figure 22

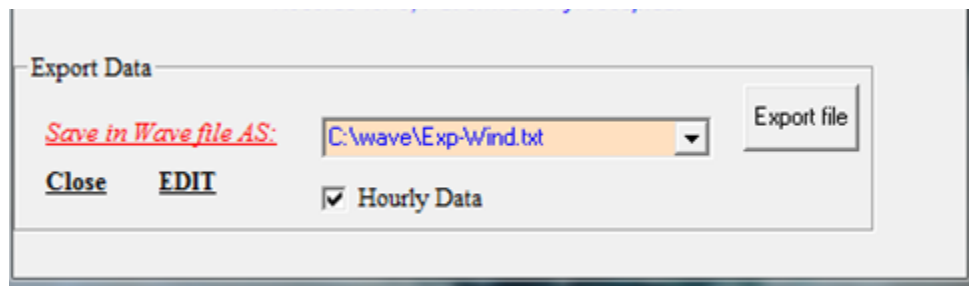


Figure 23

Sub-Option 5

2.5.1 Wind Energy Analysis

Kuwait possesses a potential of renewable energy, such as solar and wind energy. Wind energy is an alternative clean energy source compared to fossil fuel, which pollute the lower layer of the atmosphere. Wind speed is the most important parameter in the design and study of wind energy conversion systems.

To Do this data Extracting and analysis the amount of wind energy at any selected over the Arabian Gulf and over GCC countries. User must do the following from Fig 20 user must Select [**Energy**] option then Fig 24 will display to allow user to setup the following parameter for wind energy calculation at select location which:

- Terrain Roughness L.C.L.
- Air Temperature (c)
- Hub Height (m)
- Wind Direction
- Start Wind speed (m/s)

To update the parameters then select [Reload] to recalculate the amount of wind energy based on new parameters as shown in Fig 24.

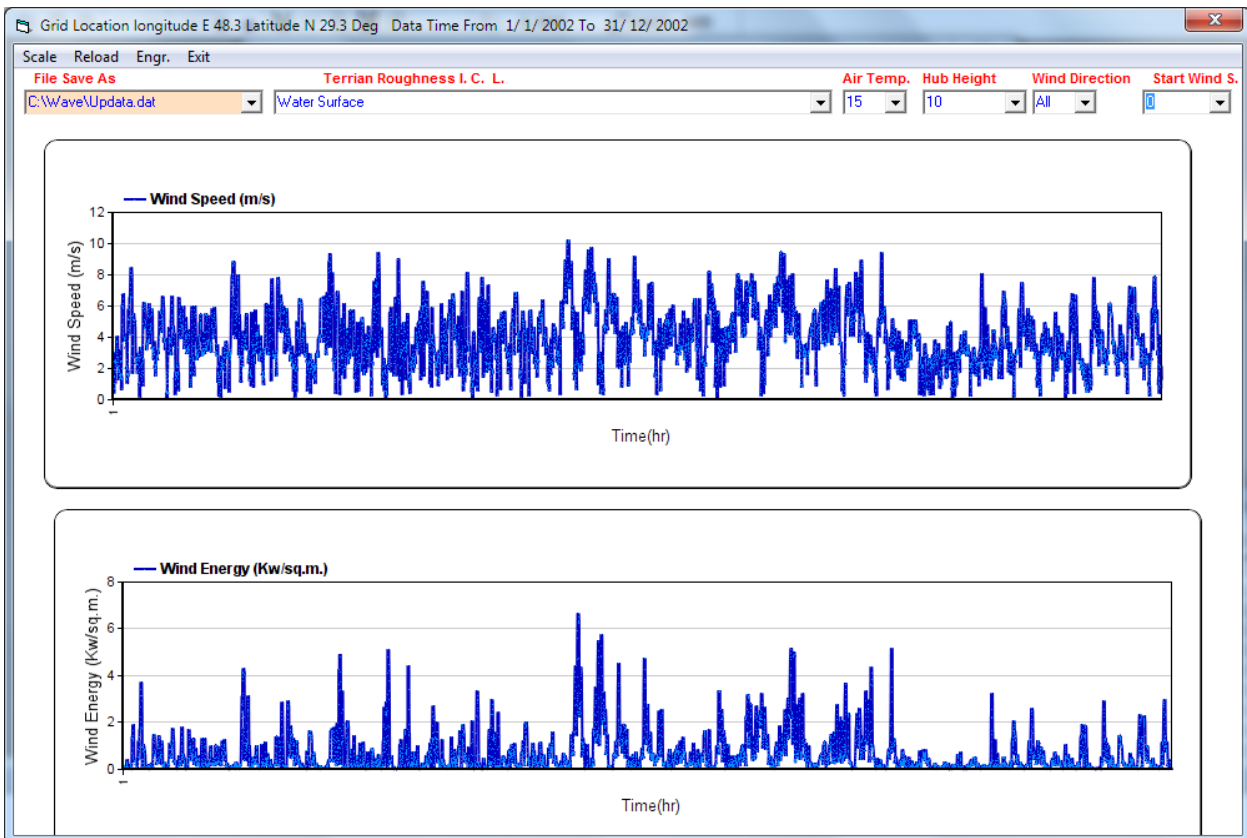


Figure 24

To Display the result analysis user must select [**ENG.**] from Fig 24 to display new window for the statistical analyses for the amount of wind energy as shown in Fig 25.

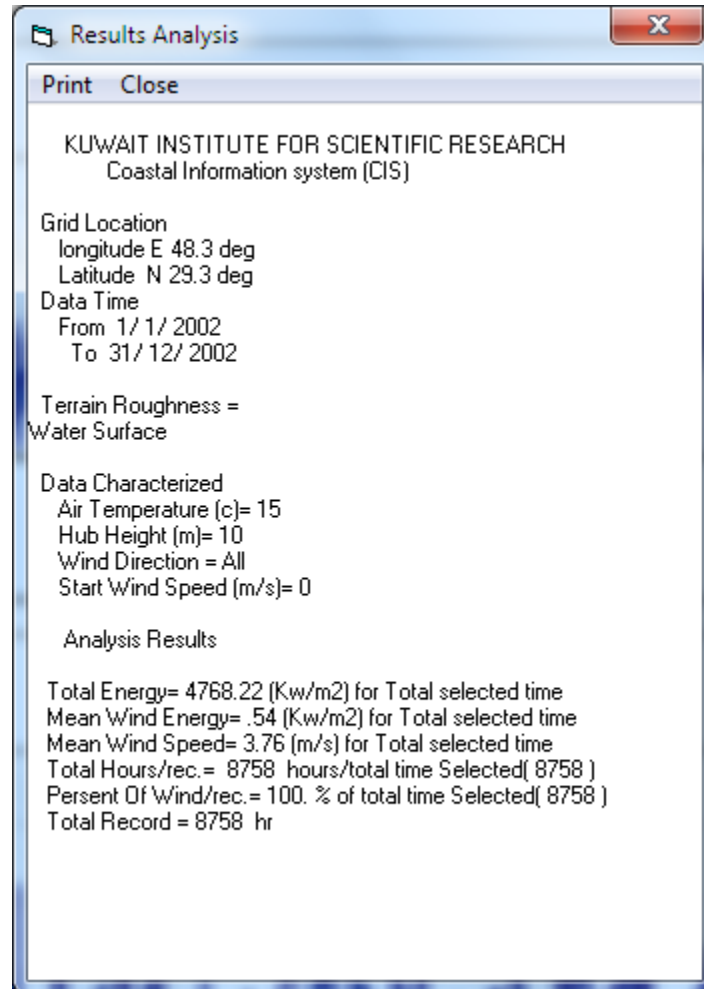


Figure 25

Sub-Option 5

2.5.2 Wind Speed Rose Plotting

User can display the wind speed rose plot by select [**Wind Rose Plotting**] from Fig 20.

The description of Wind Rose Presentation Go to [Section 11.1 Page 82]

Sub-Option 5

2.5.3 Wind Speed Statistical Analysis

Numerical Tools for Statistical and Theoretical Analysis of 2-D Wind Speed Data [Al-Salem 2016].

Effective utilization of wind energy entails a detailed knowledge of the wind characteristics at a particular location. The distribution of wind speeds is important for the design of wind farms and power generators. It is not an easy task to choose a site where wind energy conversion systems may be installed, because several factors have to be taken into account. The most important factors are the wind speed and the energy of the wind. However, wind energy is among the potential alternatives of renewable clean energy sources which could contaminate the lower layers of the troposphere, because of its cleanness.

Probability Density Distribution of Wind Speed Tool.

The wind speed probability density distributions and the functions representing them mathematically are the main tools used in the wind-related literature.

The probability density function of the Weibull distribution is given by

$$f(v) = \left(\frac{k}{c}\right) \left(\frac{v}{c}\right)^{k-1} \text{Exp}\left[-\left(\frac{v}{c}\right)^k\right] \quad (2)$$

The corresponding cumulative probability function of the Weibull distribution is given as

$$F(v) = 1 - \text{Exp}\left[-\left(\frac{v}{c}\right)^k\right] \quad (3)$$

The probability density function for the Rayleigh distribution can be simplified as

$$f_R(v) = \frac{2v}{c^2} \text{Exp}\left[-\left(\frac{v}{c}\right)^2\right] \quad (4)$$

Wind Power Density Tool.

It is worth noting two important things about this expression; one is that, the power is proportional to the cube of the wind speed. The other is that, by dividing power by the area, there is an expression on the right that is independent of the size of a wind turbine's rotor. In other words, $\frac{P(v)}{A}$ only depends on the following:

- Density of the air
- Wind speed.

WPD is a calculation of the effective power of the wind at a particular location. A map showing the distribution of WPD is a first step in identifying possible locations for wind turbines. It is well-known that the power of the wind that flows at speed v through a blade sweep area A increases as the cube of its velocity which can be expressed as the following

$$P(v) = \frac{1}{2} \rho A v^3 \quad (5)$$

Monthly or annual WPD per unit area of a site based on a Weibull probability density function can be expressed as follows:

$$P_w = \frac{1}{2} \rho c^3 \left(1 + \frac{3}{k}\right) \tag{6}$$

Setting k equal to 2, the power density for the Rayleigh density function is found to be as follows:

$$P_R = \frac{3}{\pi} \rho v_m^3 \tag{7}$$

The probability density distributions have been derived from the time-series data at CIS database. Also, the two probability density functions have been developed for a monthly or yearly basis. The wind energy potential at any location can be studied based on the Weibull and the Rayleigh models.

The power densities calculated from the CIS wind database for monthly or yearly distributions display.

From Fig 20 user must Select [**Statistical Analysis**]. Then Figure 26 will display.

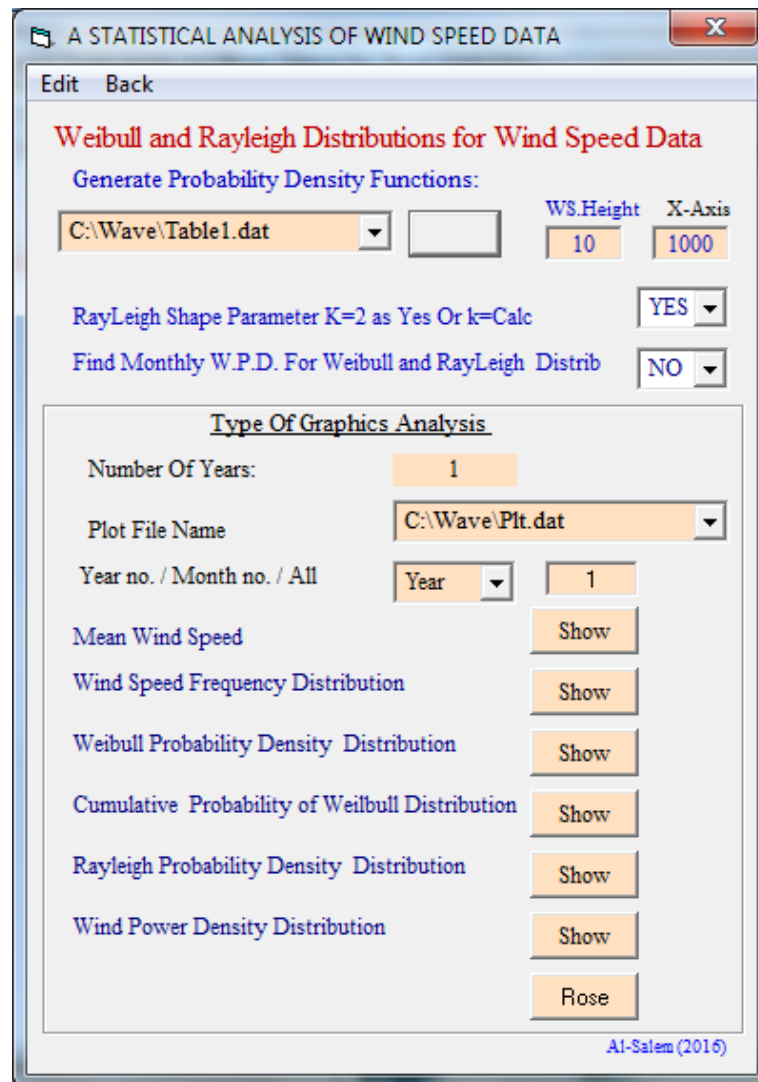


Figure 26

User must to recalculate by select [**Generate Probability Density Function**] to display the type of graphics analysis to let user to select any the analyzed parameters list as in Fig 26 for following selection:

- Option of display Yearly / Months No / All analysis
- Mean Wind Speed as shown in [Fig 27, 28 and 29 for Year/Month/All option]
- Wind Speed Frequency Distribution [Figs 30 for All Option]
- Weibull Probability Density Distribution [Figs. 31,32 for All/Year option]
- Cumulative Probability of Weibull Density Distribution [Figs 33,34 for All/Year option]
- Rayleigh Probability Density Distribution [Figs 35,36 for All/Year option]
- Wind Power Density Distribution [Fig 37,38 for All/Year option]

Rose Option Plot [[The description of Wind Rose Presentation Go to \[Section 11.1 Page 82\]](#)]

Figure 27

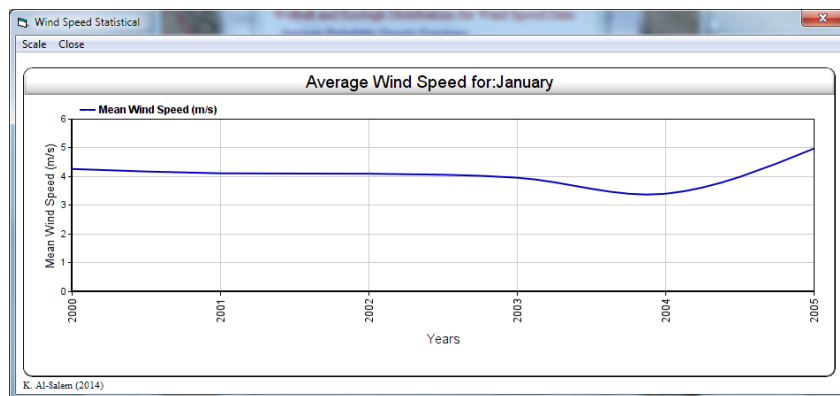


Figure 28

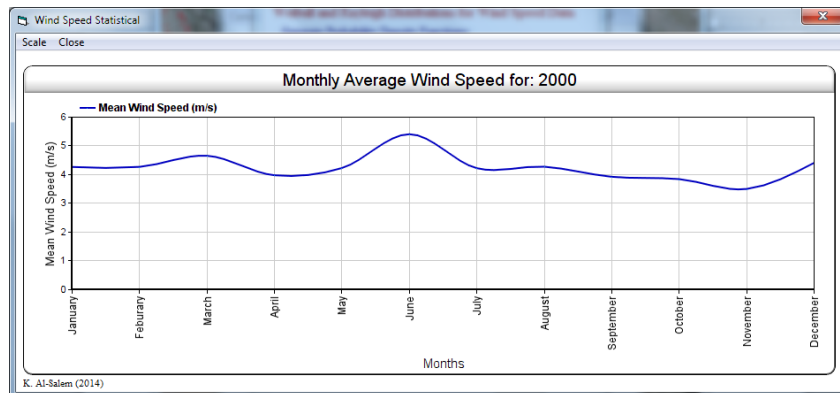
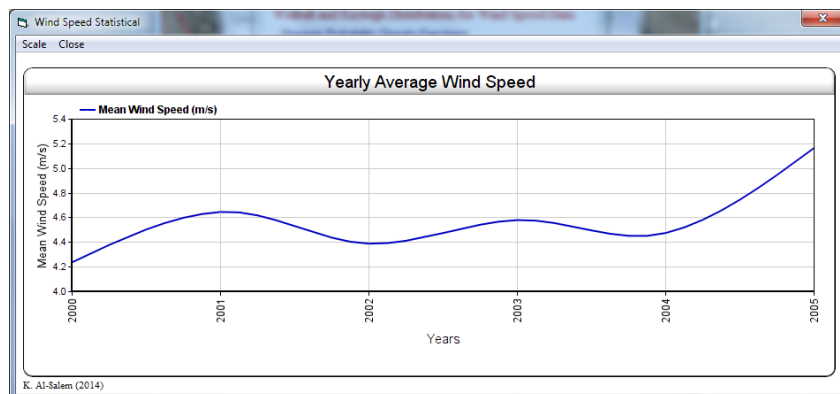


Figure 29



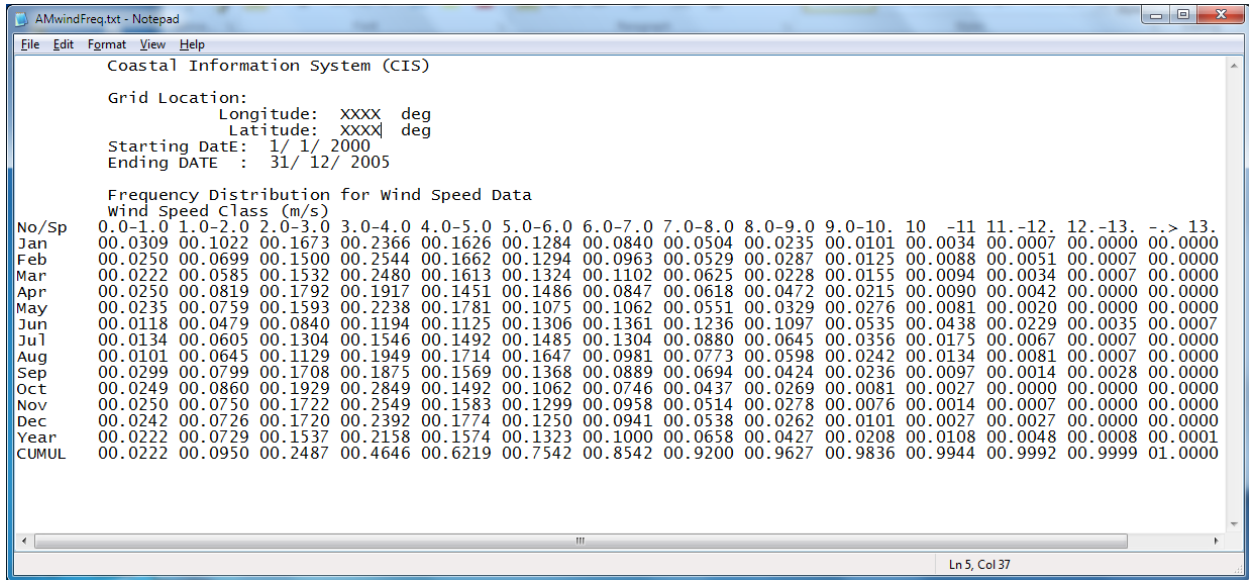


Figure 30

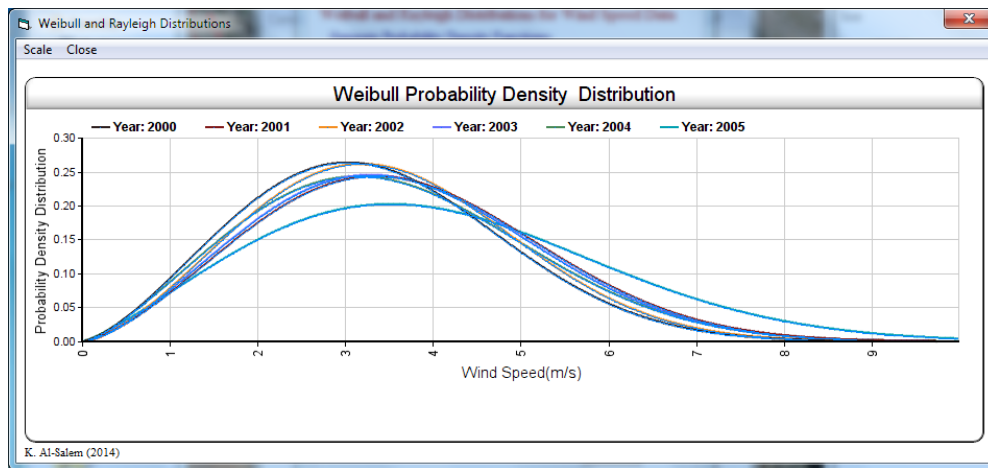


Figure 31

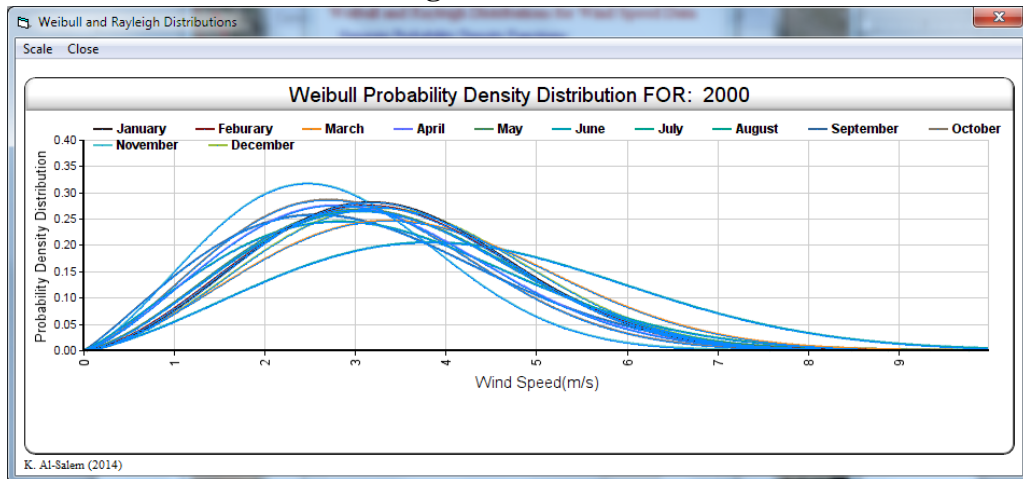


Figure 32

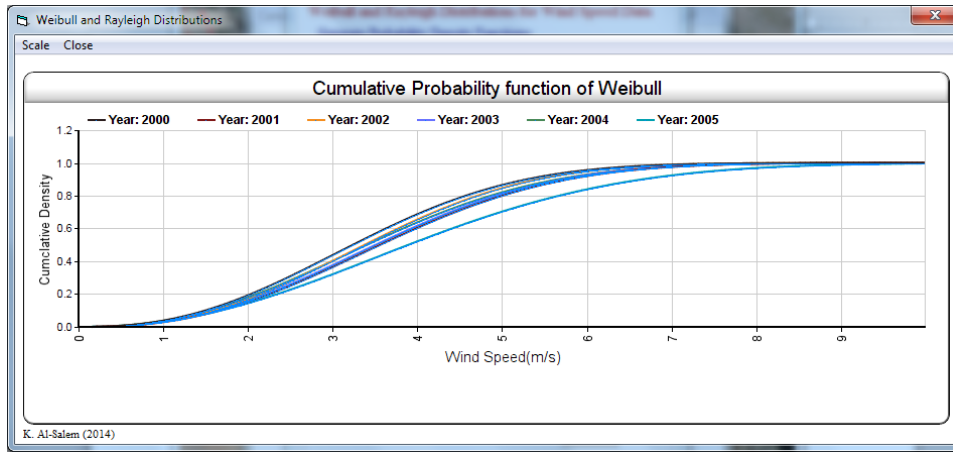


Figure 33

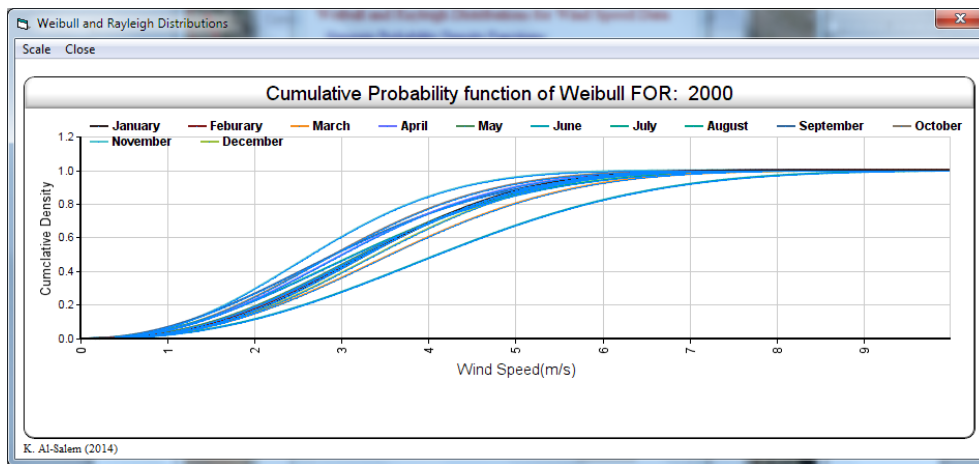


Figure 34

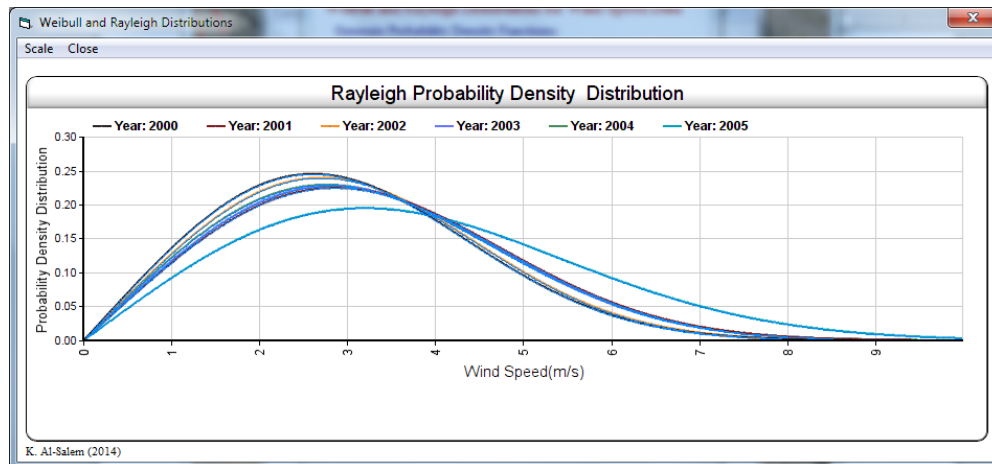


Figure 35

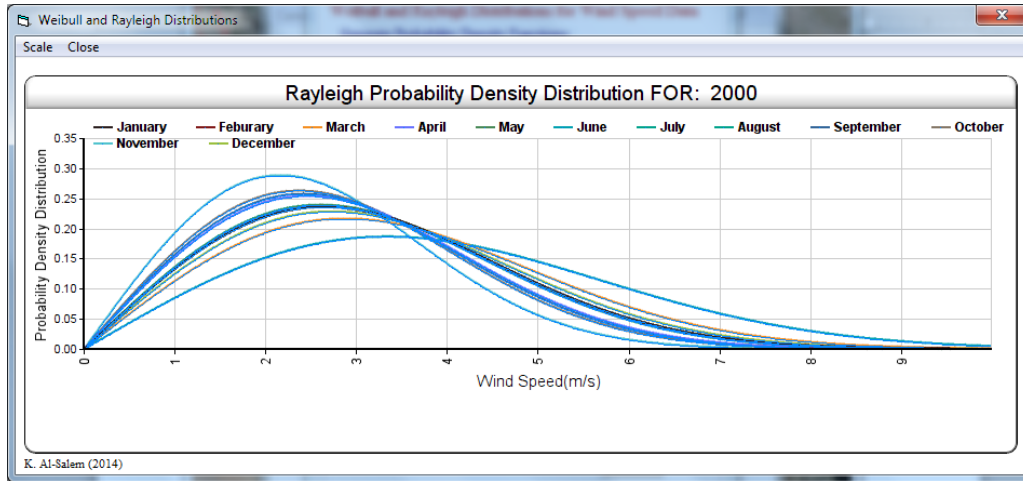


Figure 36

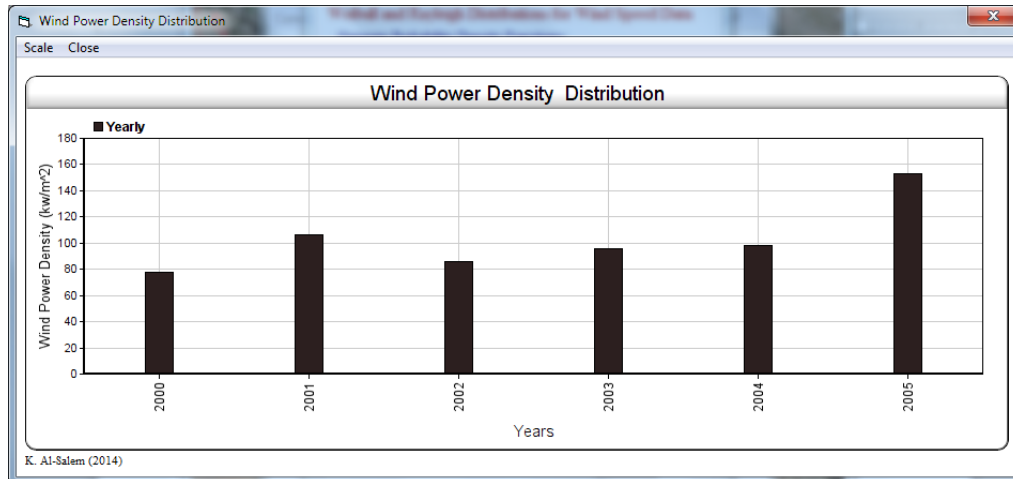


Figure 37

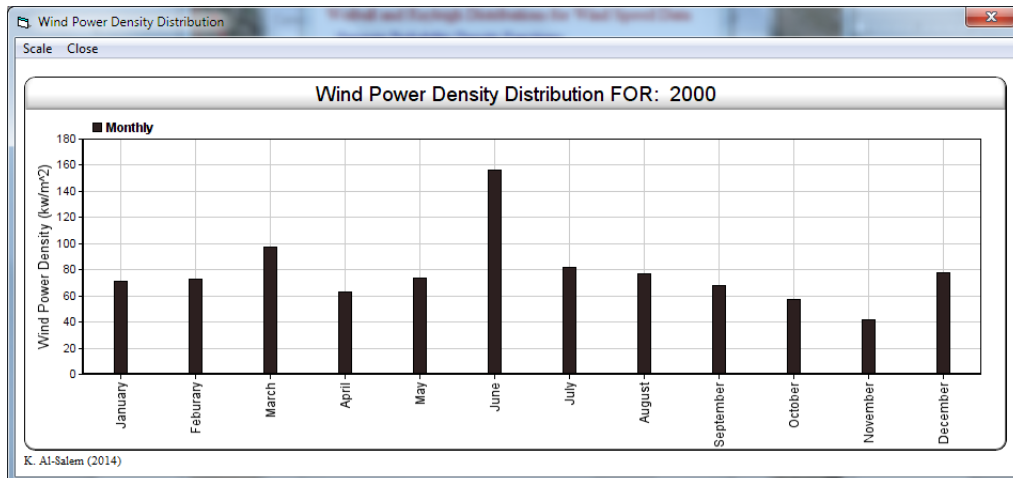


Figure 38

3. Significant Wave Height 1D/2D Database and Analysis

Digital Oceanographic Gulf Data for (Arabian Gulf). (Extracting Wave data records). Sulisz and Al-Salem K. et al. (2000) used a third-generation wind driven wave model WAM (WAMDI Group, 1988) to model the wind waves in the Arabian Gulf with emphasis on Kuwait's territorial waters. The model covered the entire Arabian Gulf from (longitude 47.4, Latitude 23.8 deg) till (longitude 56.8, Latitude 30.5 deg.) with grid spacing of (0.1 deg). Data record covered from 1979 to 2018 which about 40 years. User must select this option From Fig.39.

Figure 39 display to user a number of sub-option as follows:

- Monthly Significant Wave Height 1D\2D Extract
- Time Series Significant Wave height 1D Extract
- Maximum Significant Wave Height in Arabian Gulf

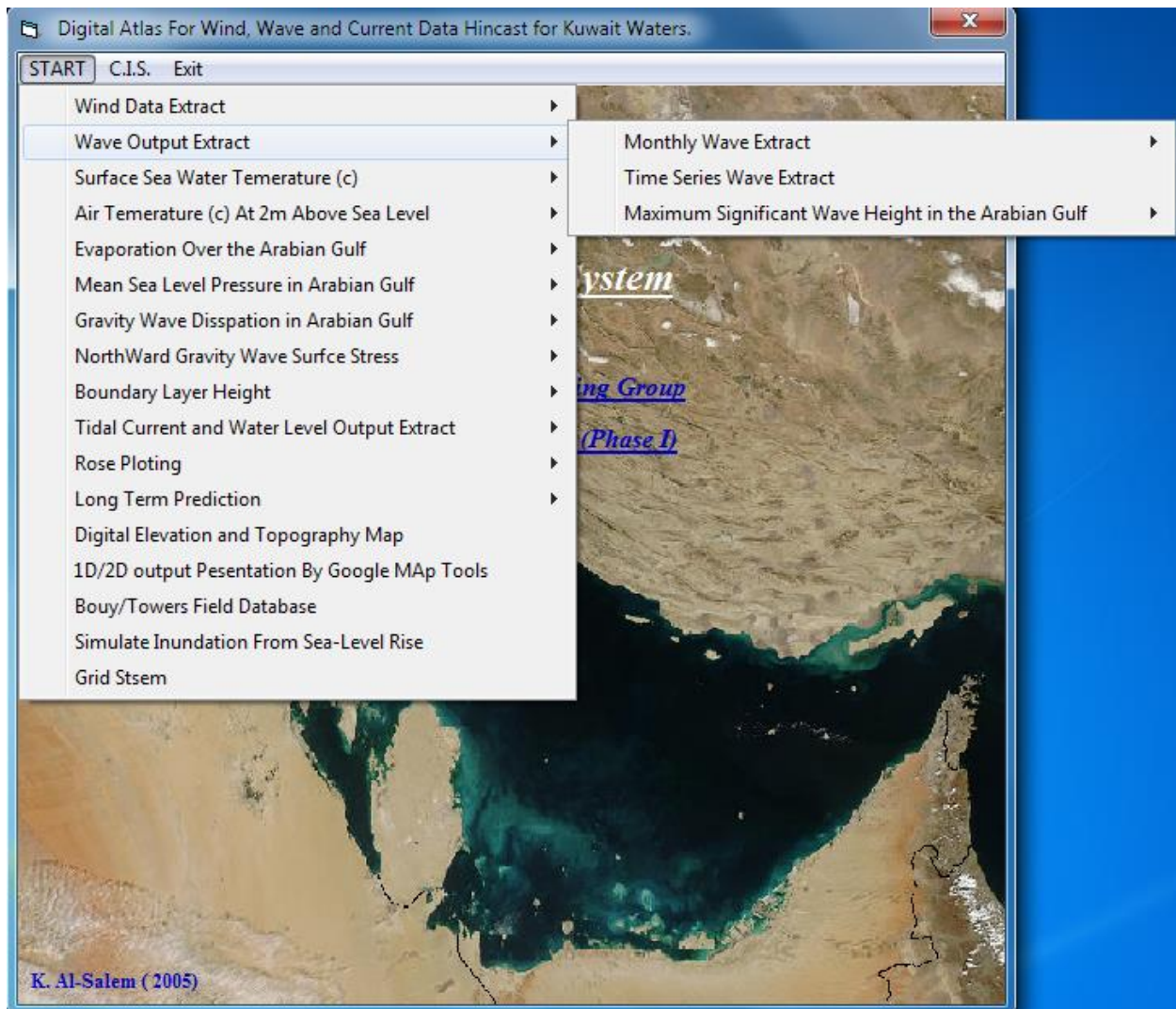


Figure 39

Sub-Option 1:

3.1 Monthly Significant Wave Height 1D\2D Extract

If user select extract wave height data by selecting [*Monthly wave Extract*] from Fig 39. A sub-option will display to user as shown in Fig 40 to select from which

- i. Extract Wave, Direction and Period at Grid*
- ii. Extract Wave Field over Gulf for Surfer*
- iii. Store Wave, Direction and Pried [OFF not activate]*



Figure 40

If Option [*Extract Wave, Direction and Period at Grid*] selected from Fig 40. User must Select To extract Significant wave data at select grid in Arabian Gulf as shown in Fig 40. Fig 41 will display for user To enter require Grid Information as follows

- Enter WAM model output file name where data will extract from as input File. This can be done in 2 ways as follow:
 - Manual Enter File name with correct Path
 - By select [*Directory files*] new directory window will open to select the file.
- Enter Output file name where extracted data will store in.
- Variable selection to be Extract
- Enter Grid Location by two way as
 - Select Digital Gulf map [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)

- Enter Select Day / Month /Year

Data will extract for all one month hourly records.

Then Select Extract to Start collect the data require. As shown Fig. 41.

To display the Extracted data is by

- [Plot] to diplat data in 1D plot image as shown in Fig 42.
- [Plot Into Surfer] to generate output extracted records if surfer program format.
- [Export] To setup printable extract data file. If user selected this option a file name will appear at bottom of Fig 41.

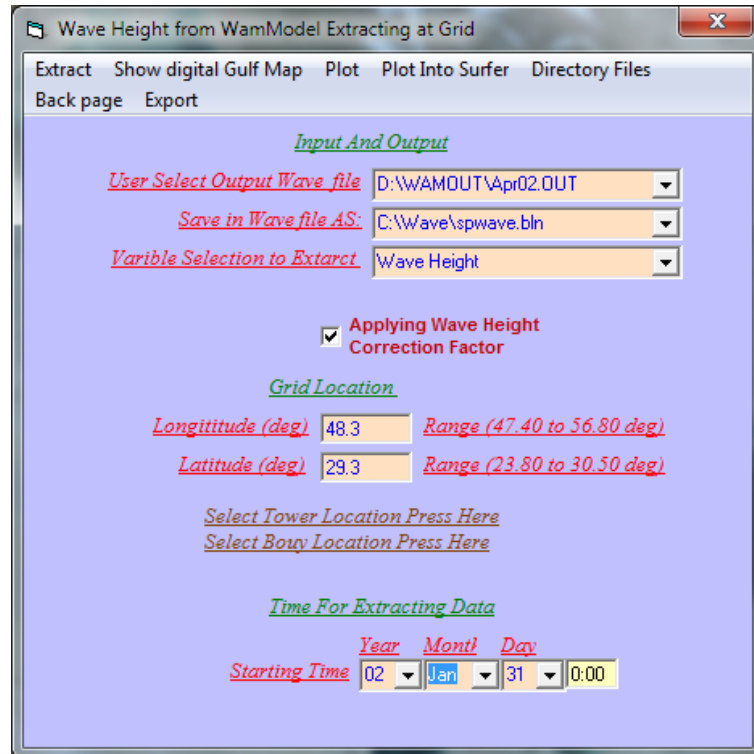


Figure 41

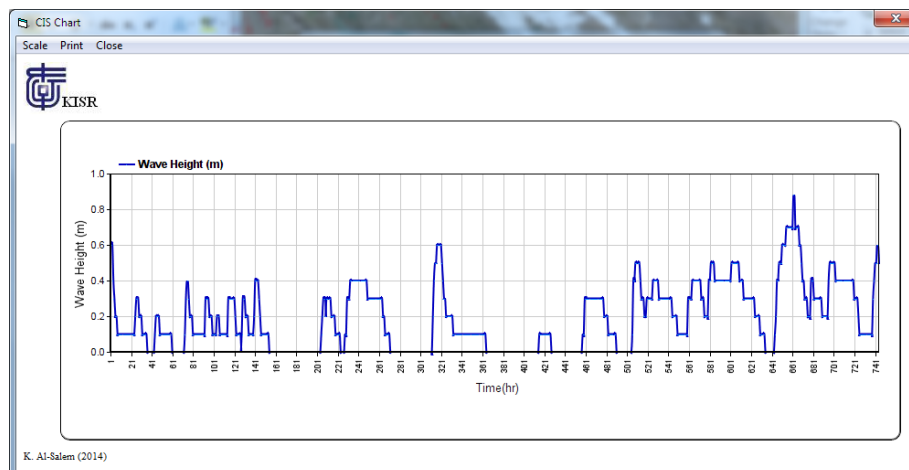


Figure 42

Extract Wave Field over Gulf for Surfer

If Option [***Extract Wave Field over Gulf for Surfer***] selected from Fig 40. User must select To extract Significant wave field data over Arabian Gulf as shown in Fig 40. Fig 43 will display for user to enter require Grid Information as follows

- Enter WAM model output file name where data will extract from as input File. This can be done in 2 ways as follow:
 - Manual Enter File name with correct Path
 - By select [***Directory files***] new directory window will open to select the file.
- Enter Output file name where extracted data will store in.
- Variable selection to be Extract
- Enter Select Day / Month /Year and must select the hour number in day

Then Select [***Extract***] to Start collect the data require. As shown Fig. 43.

To display the Extracted data is by

- [***Plot Into Surfer***] to generate output extracted records if surfer program format as shown in Fig 44 and 45.

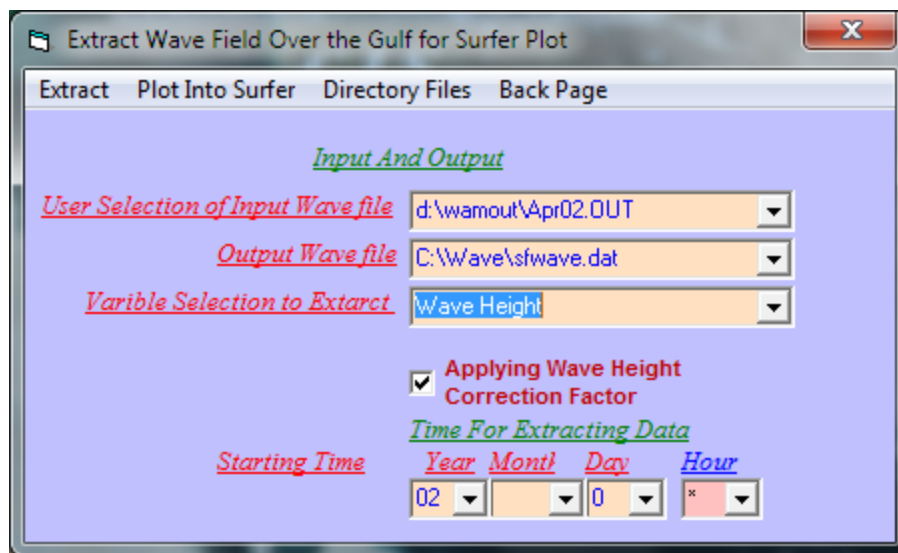


Figure 43

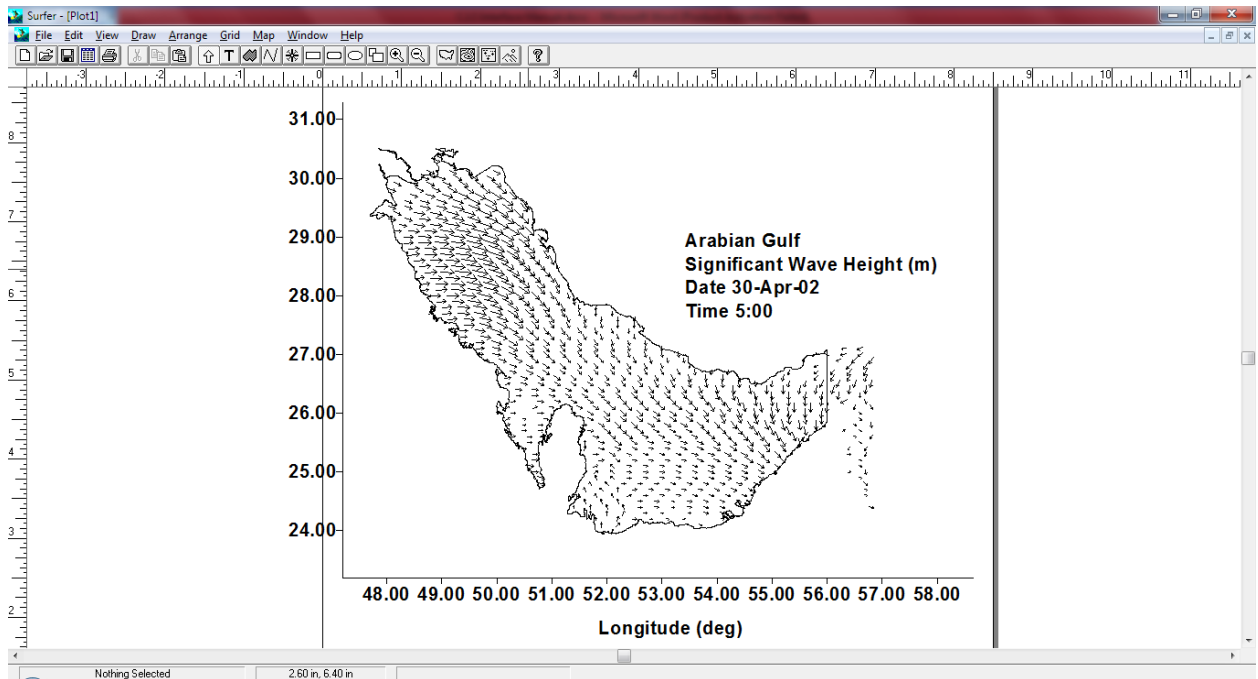


Figure 44

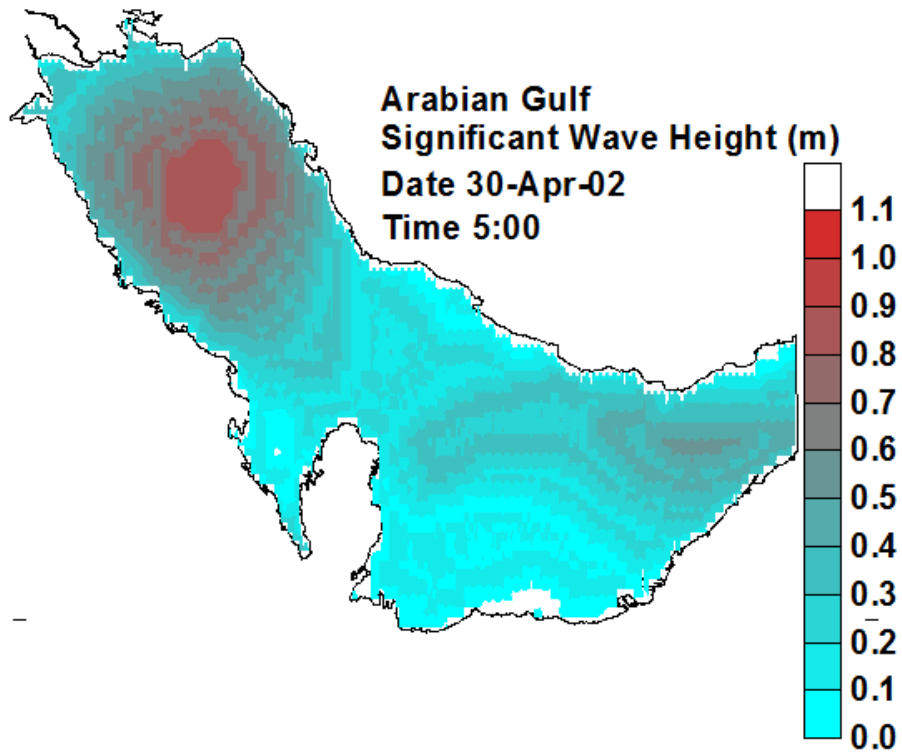


Figure 45

Sub-Option 2:

3.2 Time Series Significant Wave height 1D Extract

To extract 1D Significant wave height data at select grid in Arabian Gulf waters as Fig 39.

From Fig 39 a sup-option will display for user to select.

Figure 46 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Variable Selection to Extract
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Day / Month /Year and Time:0.00hr
- Enter End Day / Month / Year and Time:23.00hr

Then Select **Extract** to Start collect the data require as in Fig 46.

In this section a number numerical models for Wave Data Analysis and presentation were setup for user to select as follows:

- I. **[Plot]** to Plot wave data as 1D plot [aS shown in Figure 47
- II. **[Plot Wave Rose]** [**Description Wave Rose Presentation Go to [Section 11.2 Page 85]**
- III. **[Wave Scatter Diagram]**. Display 3D wave statistical analysis as in diagram and table.
- IV. **[Wave Energy/Power]**. Display analysis of optional energy and power from wave data.
- V. **[Statistical Analysis]**
- VI. **[Export File]** to generate formatted printable output file.

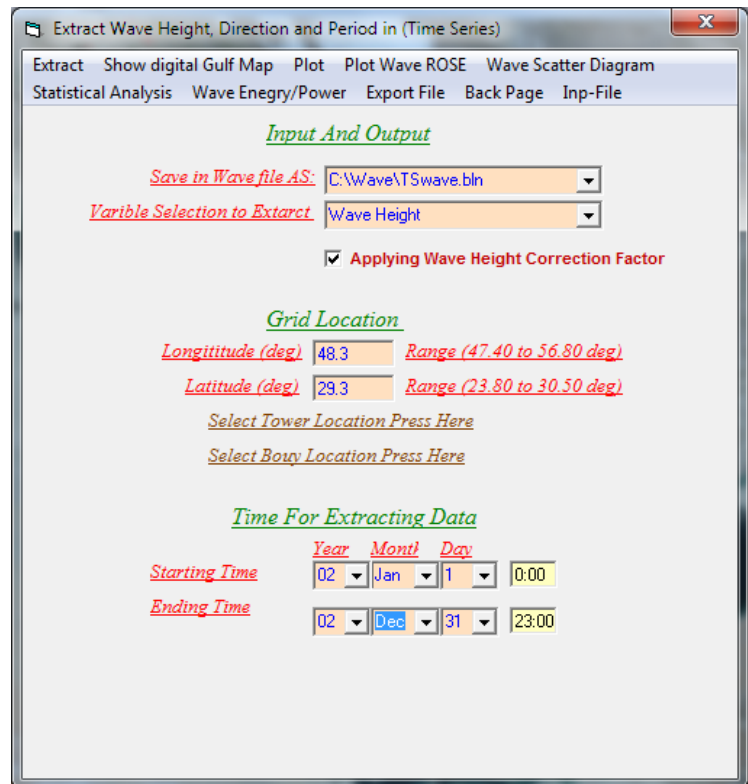


Figure 46

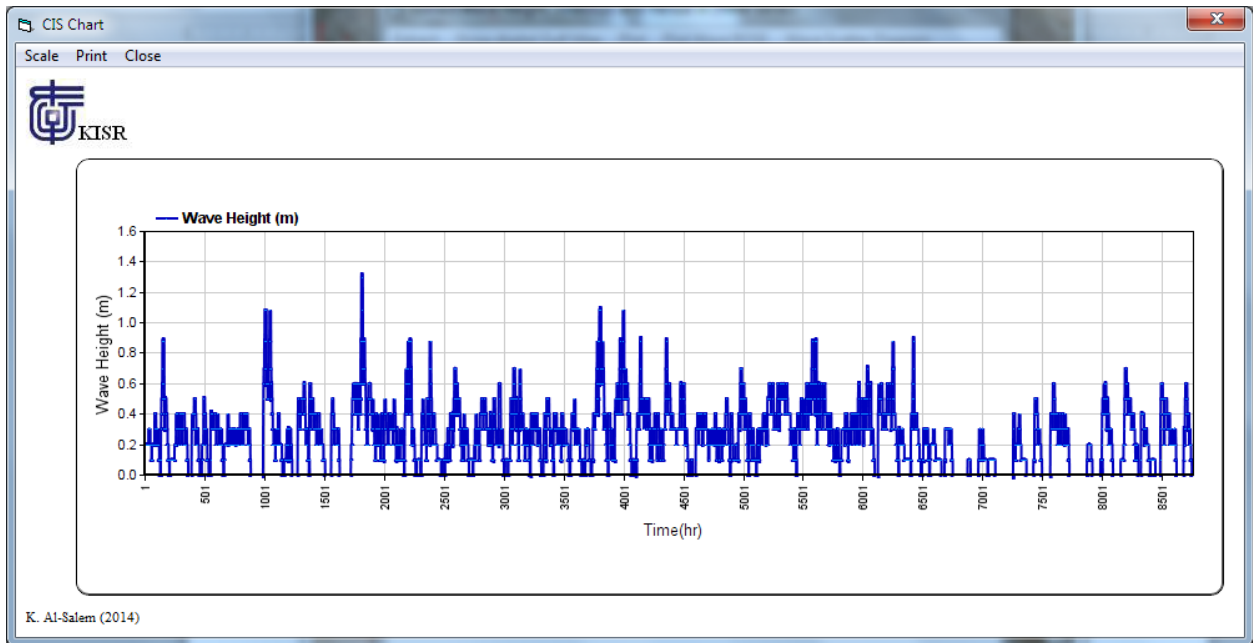


Figure 47

A Statistical and Theoretical Analysis of 2-D Waves Data Tools

3.2.1 Wave Scatter Diagram Analysis model

Scatter Diagram Analysis for 2-D Wave Height [Developed by Al-Salem 2005]. Scatter diagrams are used to demonstrate correlation between two quantitative variables; where often, this correlation is linear. Scatter diagrams are summarizing the wave climate and are typically representing the joint probability of wave height and wave period combinations during the time period they are encompassing. Typical time periods are annual or seasonal. For marine energy applications, scatter diagrams provide the distribution of H_s , T_r , recommended as shown in Fig. 49. Alternatively, T_p , T_{02} , or T_z can be used instead of T_e . They are presented in tabular form and are specific to the site where they have been established. Each bin of the table displays the cumulative occurrences of the H_s , T_e pairs. H_s (wave height) bins are defined in 0.4-m intervals, ranging from 0 to 4.4 m. H_s values are representing the center of the bins and take values of 0.2, 0.6...4.2. T_r (wave period) bins are defined in 0.8-s intervals, ranging from 0 to 8.8 s. T_r values are representing the center of the bins and take values of 0.4, 1.2., 2.0, ..., 8.4 as shown in Fig 48.

From Fig 46 user must Select [*Wave Scatter Diagram*] to start the program analysis.

Figure 48; Display scale input adjustment for the data analysis then select [*Hs Scatter Digram*]

Figure 49; Display Wave scatter table for joint probability of significant wave height and wave Period (source: Al-Salem, 2008).

Figure 50,51 display Two types of 3-D wave height scatter diagram for significant wave height, wave Period, and present of occurrences (Hs,Tr, %) (source: Al-Salem, 2008).

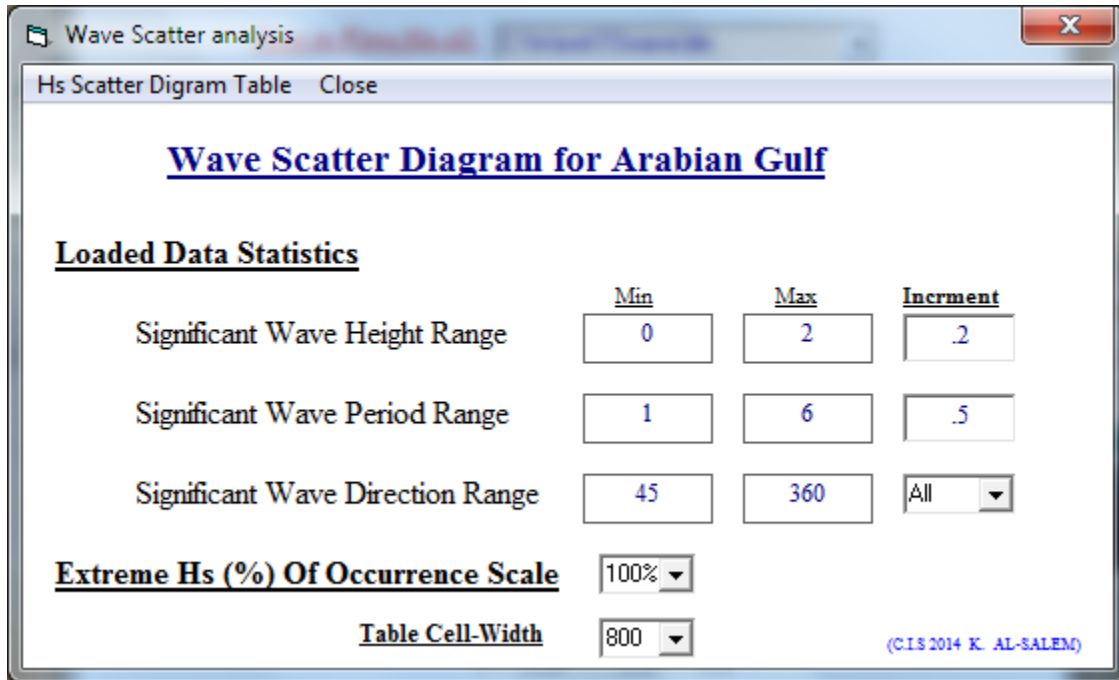


Figure 48

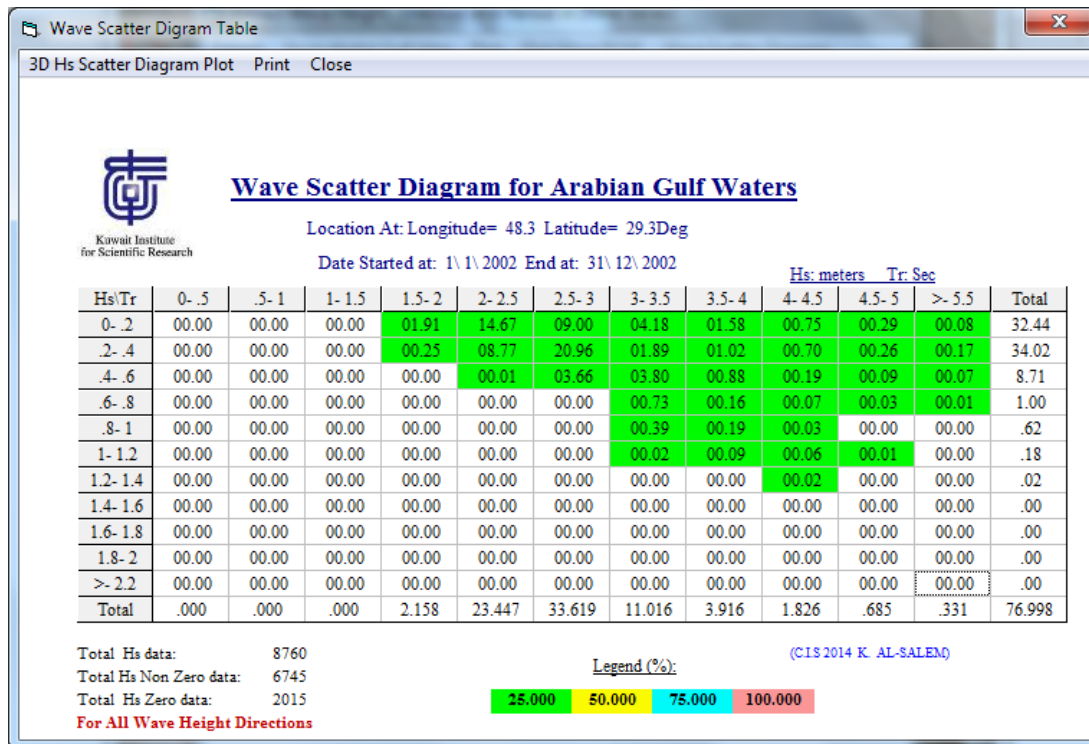


Figure 49

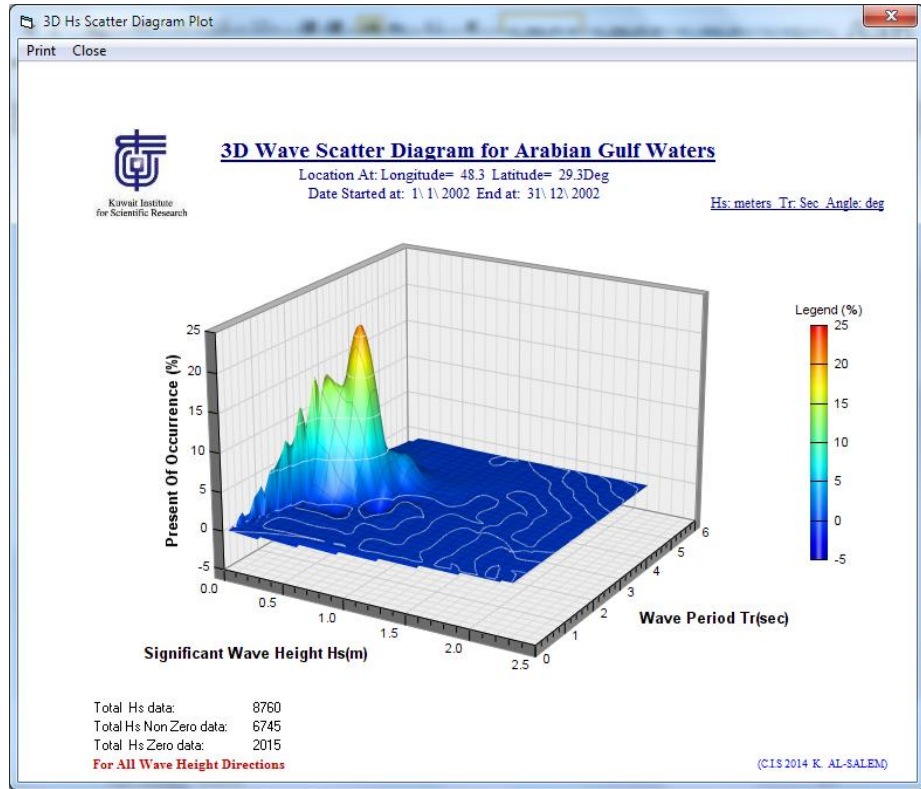


Figure 50

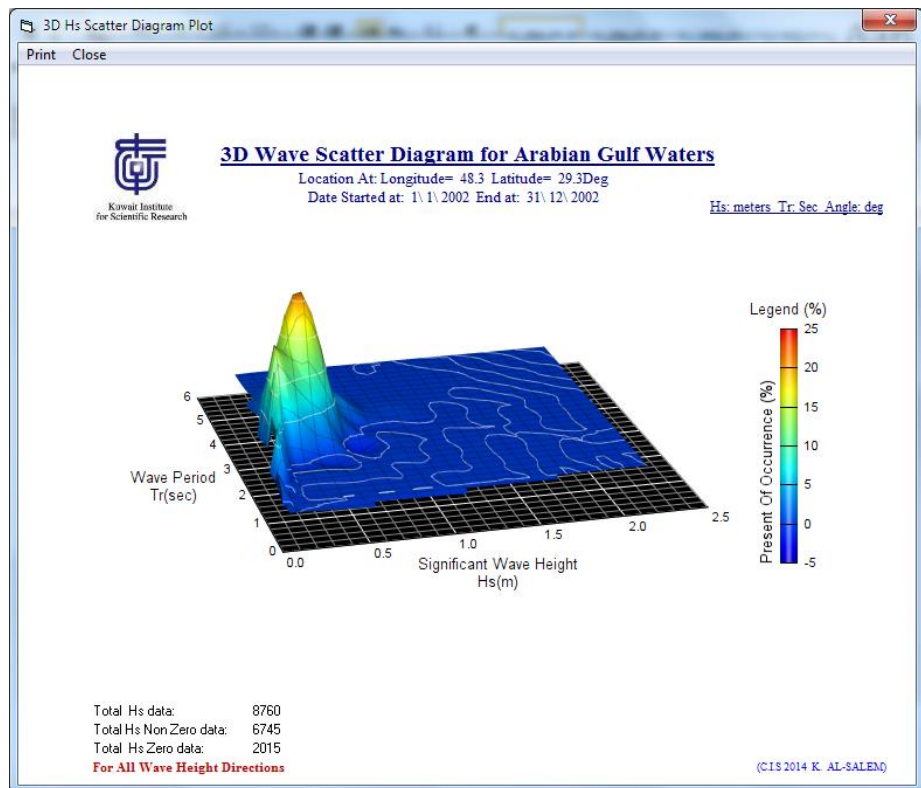


Figure 51

3.2.2. Wave Energy\Power Analysis

Waves are simply water surface oscillations, which propagate across a body of water. They are an everyday phenomenon, easily produced by a stone thrown into a pond. Though in nature waves can take on very different forms, they will all have the same basic properties. These are:

- Wavelength: Distance from one crest to the next
- Peak or Crest: The highest point of a wave
- Trough: The lowest point of a wave
- Height: Difference between trough and crest
- Period : Time taken for one wave to pass a fixed point
- Frequency : Number of waves per second that pass a fixed point
- Velocity : Speed with which the waves are moving past a fixed point
- Steepness: The ratio of height to width

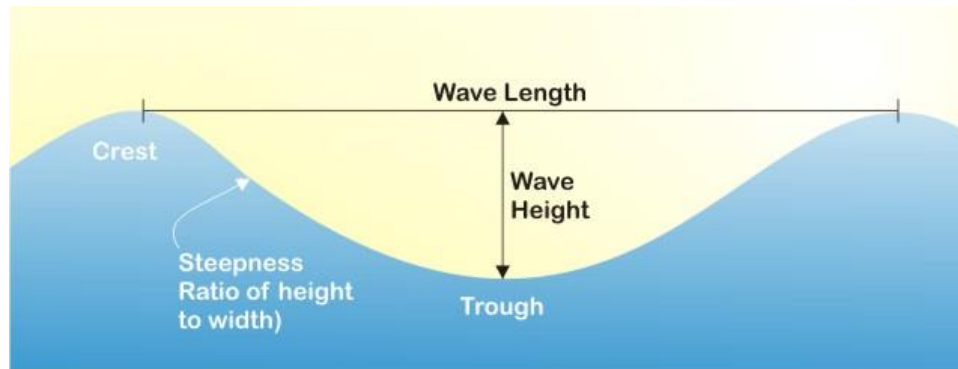


Figure 52

Wave Power Formula [*base on standard*]

Wave power is the energy carried by the wind waves and consumption of that energy to do useful work, for example, electricity generation, pumping of water into the reservoirs or water desalination. A machine capable of exploiting wave power is known as wave energy converter. Wave power is different from diurnal flux of tidal power and steady gyre of ocean currents. On a whole, the wave power is the energy transport by the wave surface of the ocean.

The Wave power formula is given by,

$$P = \frac{\rho g^2 T h^2 l}{32\pi}$$

Where,

P = power of water wave present in depth (Watts),

ρ = water density (1.025 kg/m³),

g = acceleration due to gravity (9.81 m/s²),

T = wave period,

h = wave height,

l = length of wave front.

Wave Power Formula [Based on Significant wave height]

In general, larger waves are more powerful but wave power is also determined by wave speed, wavelength, and water density. How powerful a wave is is determined by the ‘Wave Power Formula’. In this case, the ‘power’ does not refer to the power that would be produced by a wave power machine, rather it means the ‘wave energy flux’, or the transport rate of wave energy. In deep water where the water depth is larger than half the wavelength, the wave power is found using the following equation:

$$P = \frac{\rho g^2}{64\pi} H_{m0}^2 T \approx \left(0.5 \frac{\text{kW}}{\text{m}^3 \cdot \text{s}} \right) H_{m0}^2 T,$$

Where P is the wave energy flux per unit of wave-crest length, H_{m0} the significant wave height, T the wave period, ρ the water density and g the acceleration by gravity. The above formula also says that wave power is proportional to the wave period and to the square of the wave height. If the significant wave height is given in meters, and the wave period in seconds wave power has units of kilowatts (kW) per meter of wave front length.

Wave energy

In average ocean conditions, the average energy density per unit area of sea surface waves is proportional to the wave height squared, shown in the following equation:

$$E = \frac{1}{16} \rho g H_{m0}^2,$$

where E is the mean wave energy density per unit horizontal area (J/m^2), the sum of kinetic and potential energy density per unit horizontal area. The potential energy density is equal to the kinetic energy, both contributing half to the wave energy density E.

Waves in Shallow and Deep Water

Ocean waves behave differently depending on the depth of the water they have formed in. ‘Deep’ water is generally considered to be when the water has a depth larger than half a wavelength, which is usually the case in the open ocean. In deep water:

- Velocity of wave through water determined by wavelength
- Longer waves move faster
- Typical speed=28 mph

In shallow water:

- Velocity of wave determined by water depth
- Speed (m/sec) = 3.1 x square root (depth)
- When a deep water wave moves into shallow water it slows down
- If wave=28 mph in deep water, in 1 meter deep water speed is 7 mph

More uniform ‘Deep’ water waves offers the opportunity for the development of technology that will not get damaged as heavily as near-shore machines.

To Analysis wave energy from Extract Wave data User must Select from Fig. 46 [**Wave Energy\Power**].

Then Figure 53 will display for user to select [Year/Month/All Option] analysis parameters from Dropdown list. Then [**Show**] To Display the analysis Wave Energy\Power Graph as shown in Figs 54 and 55.

[**Scale option**] Let user to reform the Graph Color Typ

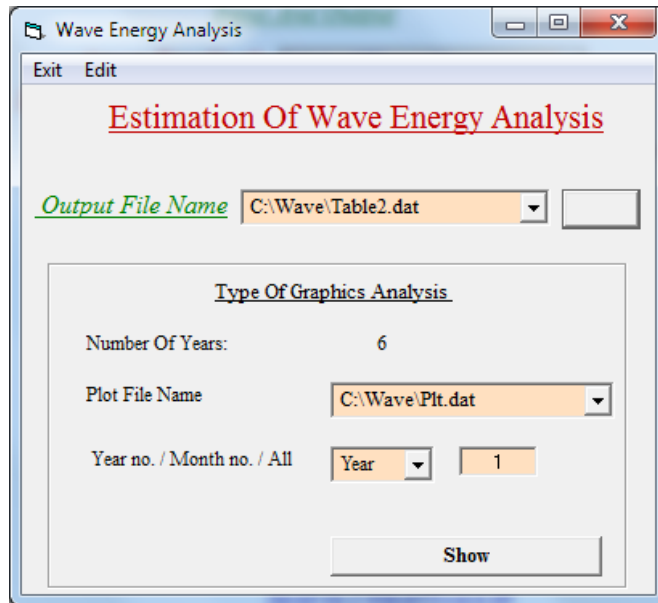


Figure 53

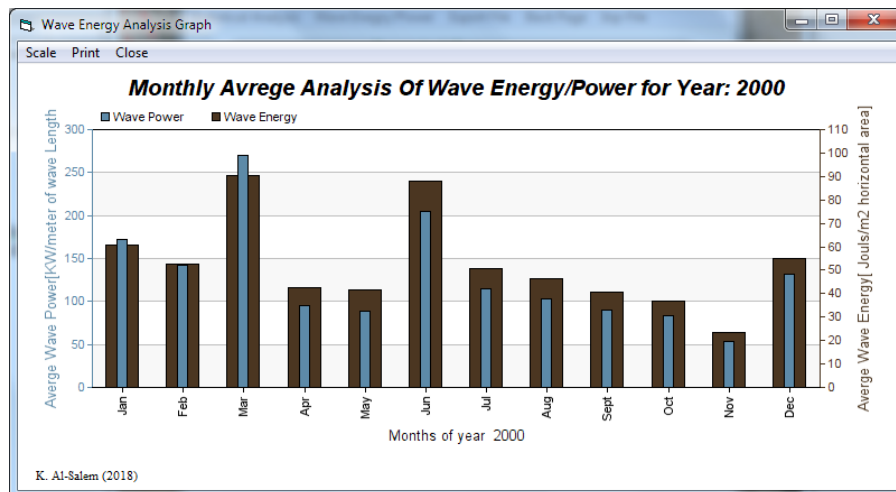


Figure 54

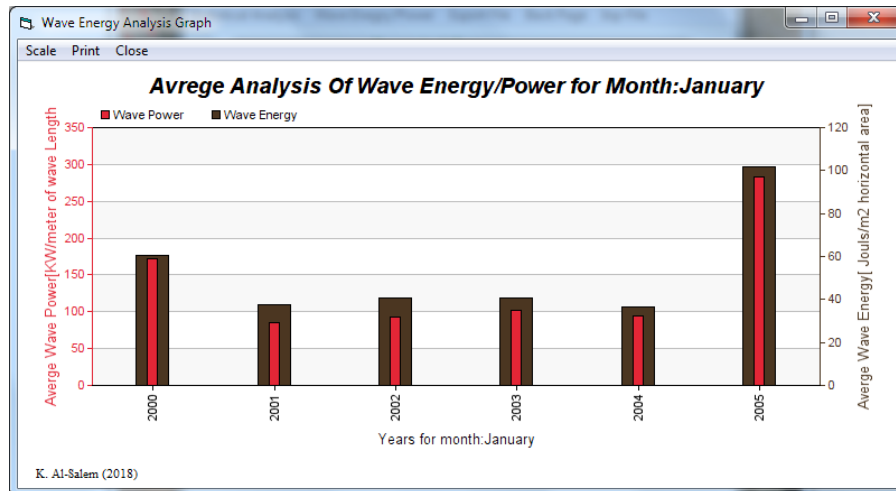


Figure 55

3.2.3 Statistical Analysis and Wave Height Spectrum model

Model Forms for Wave Spectra. The concept of a wave spectrum is commonly used for modeling the sea state. Models of the spectrum enable the spectrum to be expressed as some functional form, usually in terms of frequency, frequency and direction, or alternatively in terms of the wave number as the wave number and frequency are related by the dispersion, the frequency and wavenumber forms can be transformed from one to the other.

Models of the spectrum are used to obtain an estimate of the entire wave spectrum from known values of a limited number of parameters such as the significant wave height and wave period. These may be obtained by hindcast calculations, direct measurement, or visual observation. To give an idea of the various factors which need to be taken into account, a few models are given as examples and controlled by CIS analysis tools as shown in Fig 56. In all cases, S is used to represent the variance density spectrum.

Pierson-Moskowitz Spectrum Distribution. The Pierson-Moskowitz spectrum (Pierson and Moskowitz, 1964) is often used as a model spectrum for a fully developed sea, an idealized equilibrium state reached when duration and fetch are unlimited. The mathematical forms of $S^+(w)$ are in terms of the significant wave height, $H_{1/3}$. ($H_{1/3} = \zeta$ m), w Frequency, $g=9.82 \frac{m}{s^2}$. Fetch limitations are displayed in the formulation as follows:

$$S^+(w) = \frac{8.1}{10^3} \frac{g^2}{w^5} e^{\alpha} \quad (8)$$

Where:

$$\alpha = -0.032 \left(\frac{g}{\zeta w^2} \right)^2$$

ζ Significant wave height ($H_s/3$) in meter

$S^+(w)$ Spectral Density ($\frac{m^2}{rad \cdot sec}$)

w Angular frequency (rad/sec)

Bretschneider Spectrum Distribution. The ISSC spectrum (also known as Bretschneider or modified Pierson-Moskowitz) is defined as:

$$S^+(w) = \frac{1.25}{4} \frac{w_m^4}{w^5} \zeta^2 e^{\alpha} \quad (9)$$

Where:

$$\alpha = -1.25 \left(\frac{w_m}{w} \right)^4$$

ζ Significant wave height (m) ($H_{\frac{1}{3}} = 4\sqrt{M_0}$)

w_m Peak frequency: $\frac{2\pi}{T_p}$

T_p Peak period of the spectrum (sec)

The peak period of the spectrum T_p corresponds to the frequency at the mode of the spectral density, the peak frequency w_p :

$$T_p = \frac{2\pi}{w_p}$$



JONSWAP Spectrum Distribution. The JONSWAP spectrum extends the Pierson-Moskowitz spectrum to including fetch-limited seas. This spectrum is based on an extensive wave measurement program (Joint North Sea Wave Project) carried out in 1968 and 1969 in the North Sea. The JONSWAP (1973) spectrum, received almost instant recognition and became very well-known in international literature. The resulting spectral model is taken as the following form (Hasselmann et al.,1973):

$$S^+(w) = \frac{ag^2}{w^5} \text{Exp}\left(\left(-\frac{5}{4}\right)\left(\frac{w_p}{w}\right)^2\right) \gamma^k \tag{10}$$

Where frequency at peak values of wave period

$$w_p = \frac{2\pi}{T}$$

$$a = \frac{5.061H_s^2}{T^4} B$$

Where

$\gamma = 3.3$ Peak enhancement parameter that describes the degree of peakedness of the spectrum.

$S^+(w)$ JONSWAP spectral density in $\left(\frac{m^2}{rad/s}\right)$

$$B = [1 - 0.287Ln(\gamma)] \tag{11}$$

$$k = \text{Exp}\left(-0.5\frac{\left(\frac{w}{w_p}-1\right)^2}{\sigma}\right)$$

Where:

w Angular frequency (rad/s)

T Wave Period (s)

H_s Significant wave height (m)

$\sigma = 0.07 \quad w \leq w_p \quad \text{or} \quad \sigma = 0.09 \quad w > w_p$

From Fig 46 user must Select [**Statistical Analysis**]. Then Figure 56 will display.

User must to recalculate by select [**Generate Probability Density Function**] to display the type of graphics analysis to let user to select any the analyzed parameters list as in Fig XX for following selection:

- I. Mean Significant Wave Height analysis
- II. Mean Significant wave Periods
- III. JONSWAP distribution spectrum
- IV. Bretschneider distribution spectrum
- V. Pierson-Moskowitz distribution spectrum

Figure 57 and 58 display Monthly and Yearly average significant wave height and wave period. Figure 59 shows three types of wave energy spectral diagrams for (monthly and yearly) analysis) by applying Pierson-Moskowitz spectrum equation as shown in equation (8).

Figure 60 presents three types of wave energy spectral diagrams for (monthly and yearly) analysis) by applying Bretschneider spectrum equation as shown in equation (9).

Figure 61 shows three types of wave energy spectral diagrams for (monthly and yearly analysis) by applying JONSWAP spectrum equation as shown in equation (16) (Hasselmann et al. 1973).

A STATISTICAL ANALYSIS OF WAVE HEIGHT DATA

Edit Back

Estimation Of Wave Spectra From Wave Height and Period

Generate Spectrum Distribution

C:\Wave\Table2.dat

Jonswap Spectral Peak Enhancement Function 3.3

Total x-axis frequency with interval of 0.01 500

Resize X-Axis Increment 0.01 Start Tick 1

Type Of Graphics Analysis

Number Of Years: 16

Plot File Name C:\Wave\Plt.dat

Year no. / Month no. / All Month 6

Mean Significant Wave Height(m) All Year Month Show

Mean Significant Wave Period(sec) Show

JONSWAP Spectrum Distribution Show

Pierson-Moskowitz Spectrum Distribution Show

Bertschnider Spectrum Distribution Show

Figure 56

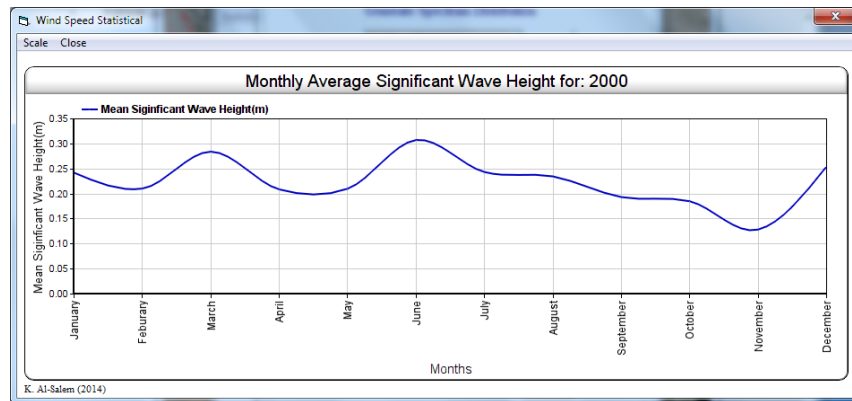


Figure 57

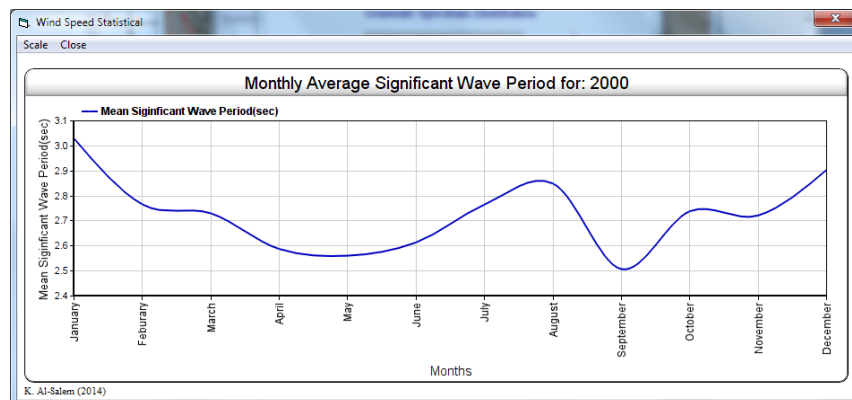


Figure 58

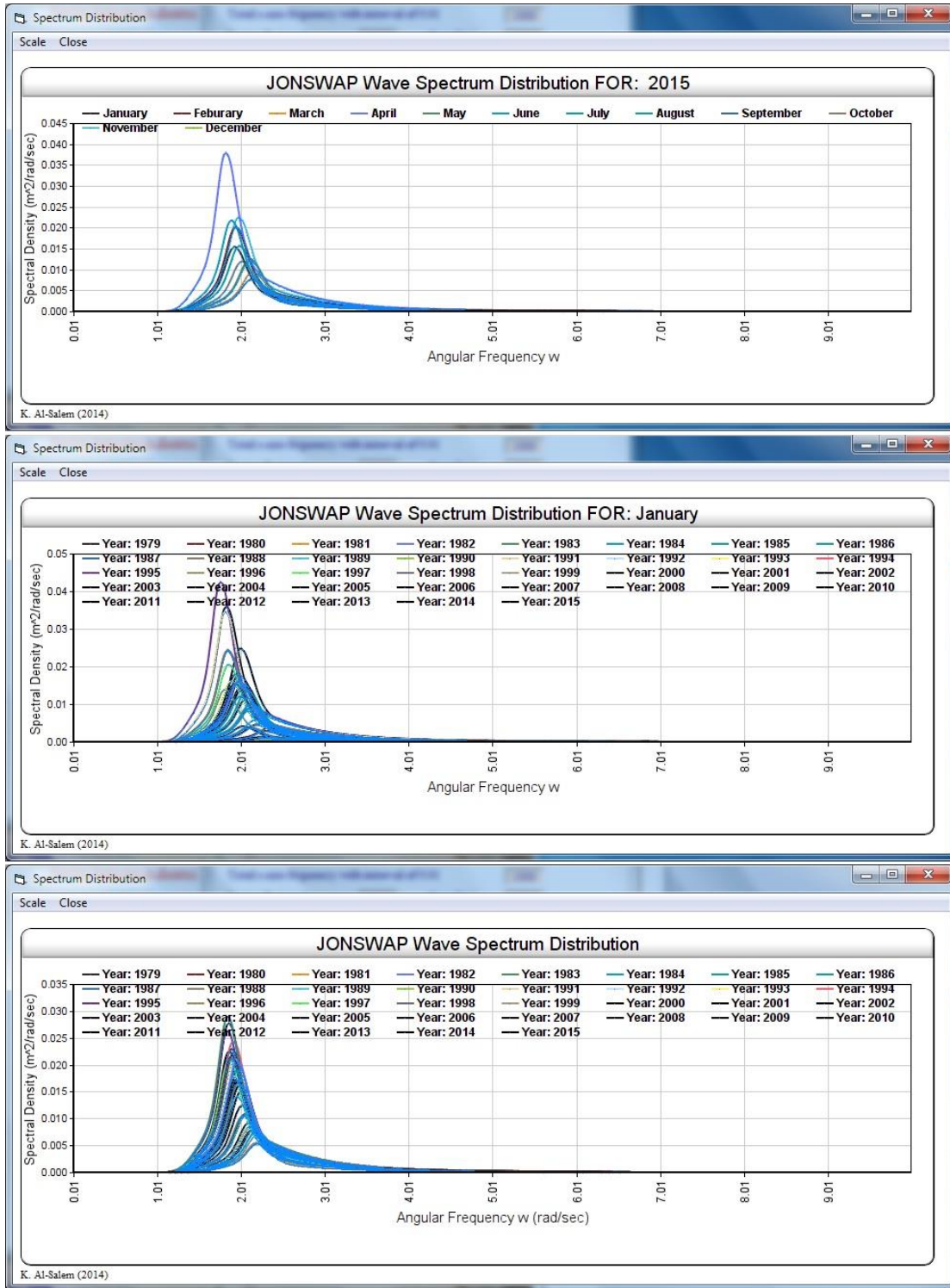


Figure 59

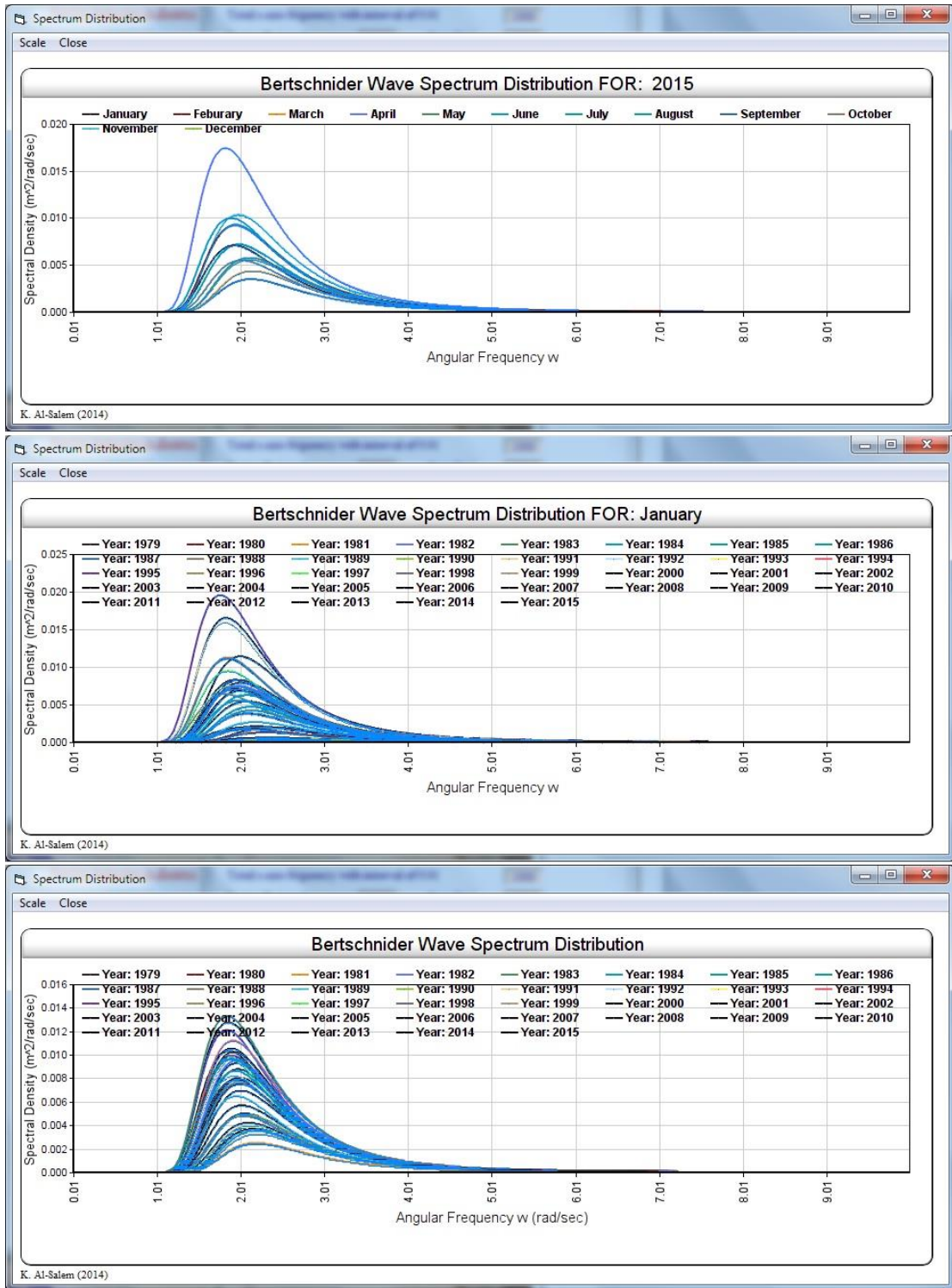


Figure 60

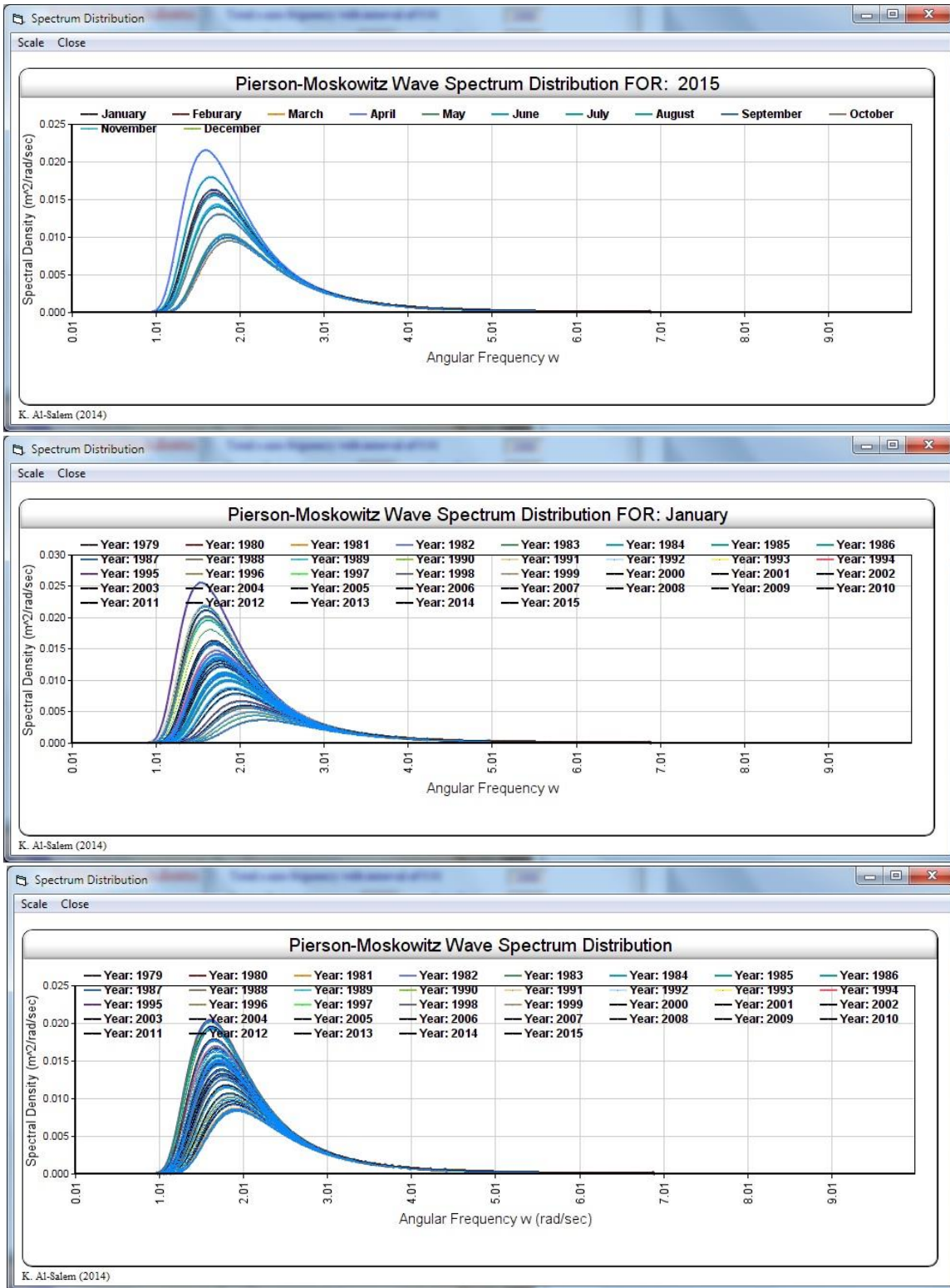


Figure 61

Sub-Option 3:

3.3 Maximum Significant Wave Height in Arabian Gulf

To analysis maximum wave height in 1D\2D data over Arabian Gulf. User has a number of analysis as a Sub-options as shown in Fig 62. A List of option as

- I. Extract for Specific 1D grid Location in Arabian Gulf
- II. Extract for All 2D grids Location in Arabian Gulf
- III. Extract for monthly maximum 1D grid Location in Arabian Gulf

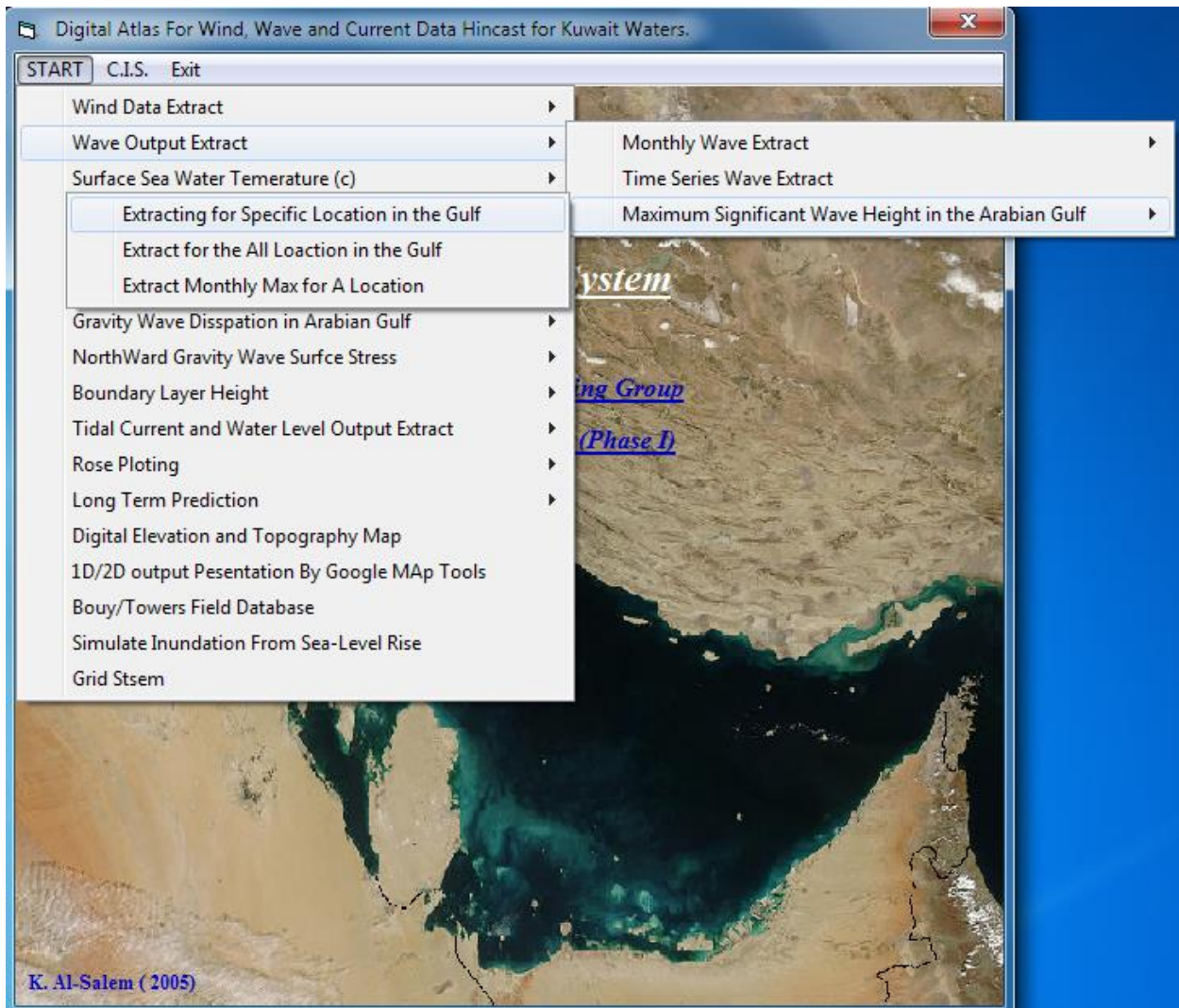


Figure 62

3.3.1 Extract for Specific 1D grid Location in Arabian Gulf

To extract 1D wave height data at select grid in Arabian Gulf to locate and show the maximum value and at what wave direction.

From Fig 62 a sub-option will display for user to select.

Figure 63 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select **Extract** to Start collect the data require as in Fig 63.

In Fig 63 a new Button Will Appear [**Click.**]. User should select To display the analysis result as shown in Fig 64

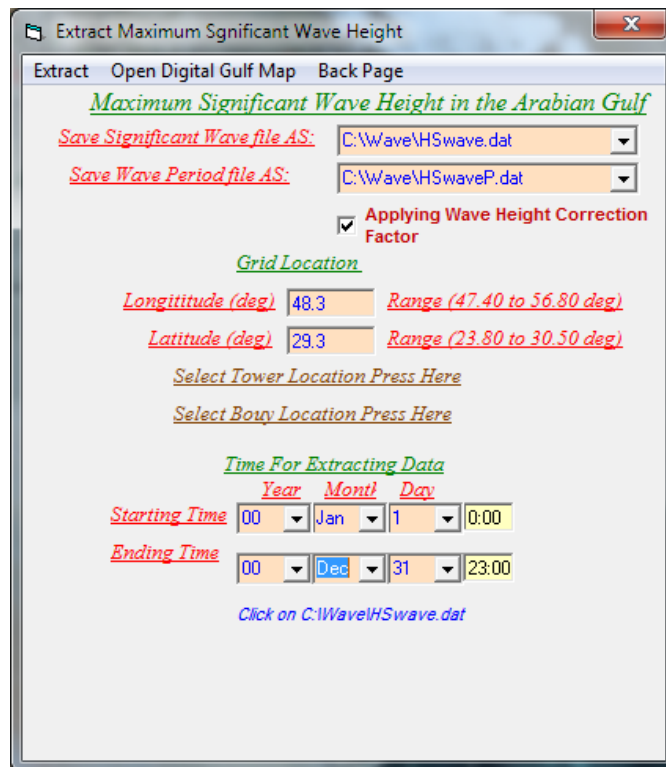


Figure 63

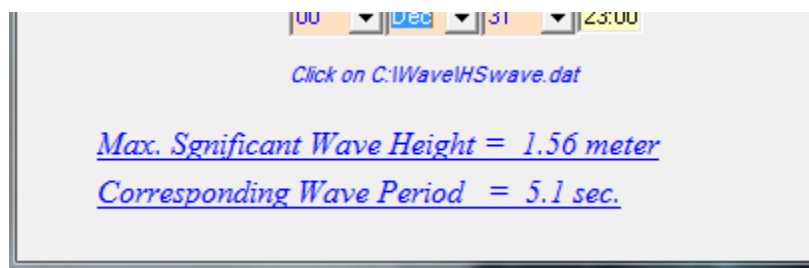


Figure 64

3.3.2 Extract for All 2D grids Location in Arabian Gulf

To extract 2D Wave Height data over Arabian Gulf to locate and show the maximum value From Fig 62 a sub-option will display for user to select.

Figure 65 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract wave height and stored in.
- Enter output file name where data will extract wave Period and stored in.
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select **Extract** to Start collect the data require as in Fig 65.

From Fig 65 user should select [**Open Surfed Plot**] to Activate Surfer software Program.

In Surfer program User should generate the grid information and contour result of wave height.

The analysis result as shown in Fig 66 from Surfer 2D plots

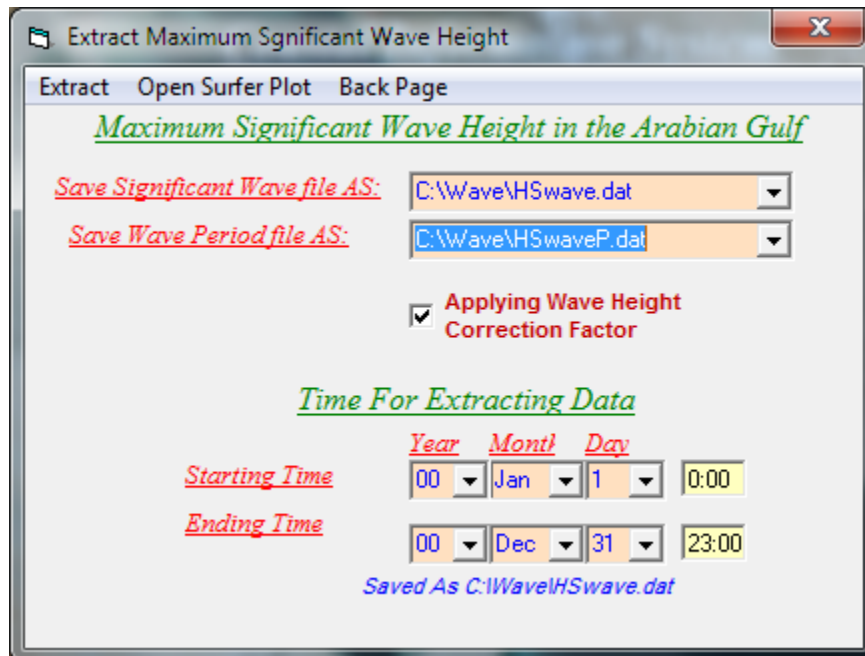


Figure 65

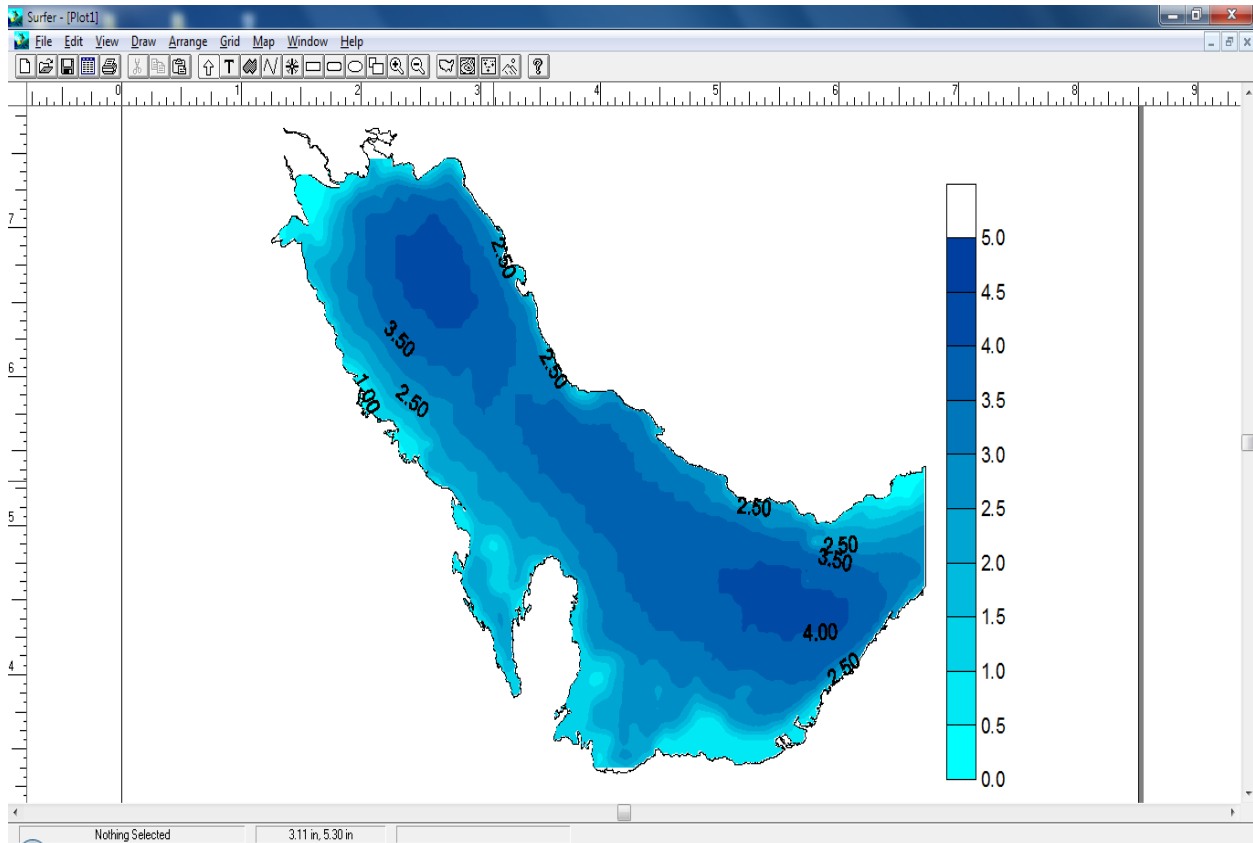


Figure 66

3.3.3 Extract for monthly maximum 1D grid Location in Arabian Gulf

To extract 1D wave Height data at select grid in Arabian Gulf to locate and show the monthly maximum value and at what wave direction.

From Fig 62 a sup-option will display for user to select.

Figure 67 will display for user to enter require Grid Information as follows:

- Enter output file name where data will extract and stored in.
- Check Wind Speed option
- Enter Grid Location by two way as
 - Select ***Digital Gulf map*** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Day / Month /Year and Time
- Enter End Day / Month / Year and Time.

Then Select ***Extract*** to Start collect the data require as in Fig 67.

Figure 68 will display to monthly maximum Significant wave height with corresponding Wave Direction.

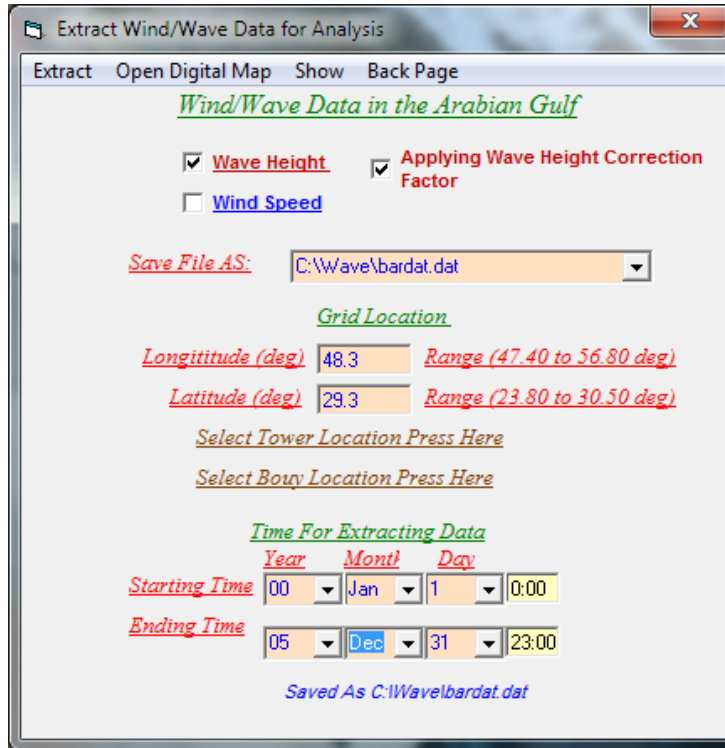


Figure 67

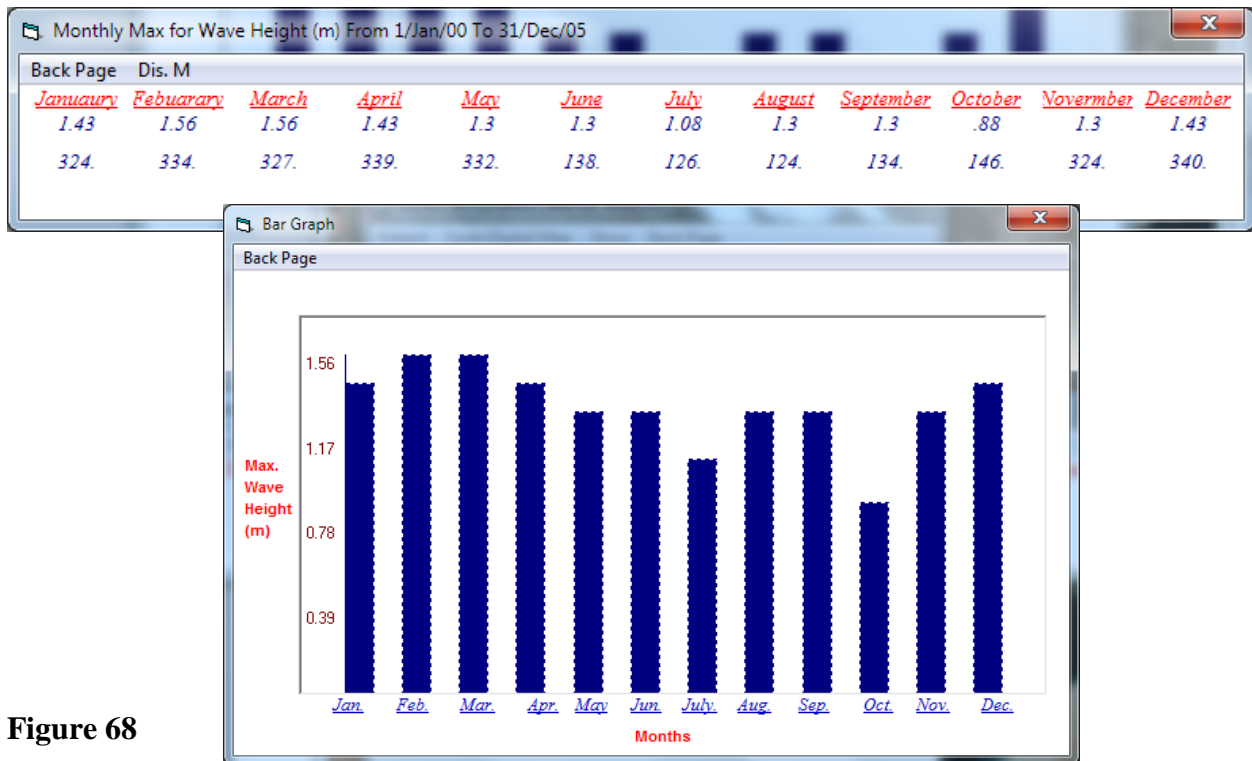


Figure 68

4. Surface Sea Water Temperature Database

Sea surface temperature (SST) is the water temperature close to the Sea surface. The exact meaning of surface varies according to the measurement method used, but it is between 1 millimeter and 20 meters below the sea surface.

User must Select To extract Surface Sea Temperature data at select grid in Arabian Gulf as shown in Fig 69. Where a number of Sub-options analysis was setup as shown in Fig 69. A List of option as:

- I. *Extracting 1D Water Temperature time Series at Grid*
- II. *Extracting 2D Water Temperature Field over Arabian Gulf for Surfer*
- III. *Program Format*
- IV. *Extracting 1D Time Series For Sea water Temperature*



Figure 70

Sub-Option 1

4.1 Extracting 1D Water Temperature time Series at Grid

. To extract 1D water temperature data user must select from Fig 69. Fig 70 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select **Directory File**]. As input file
 - Enter output file name where data will extract and stored in.
 - Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
 - Enter Select Day / Month /Year
 - Enter Start Day number and number of Days user want to Extract [365 a year]
- Then Select **Extract** to Start collect the data require. As shown Fig. 70
To display the extracted data by 1D plot as shown Fig 71

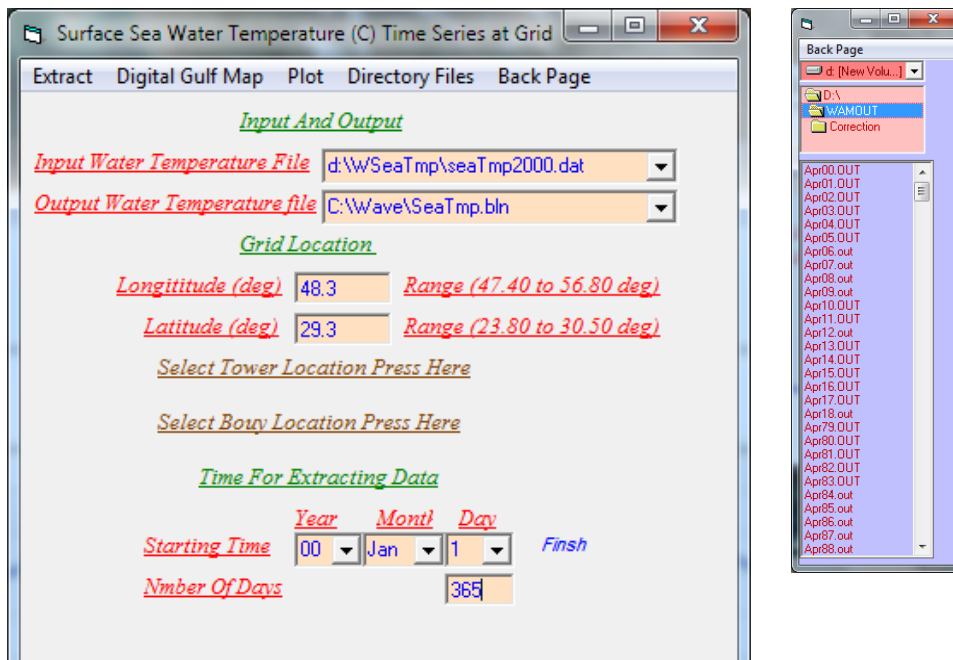


Figure 70

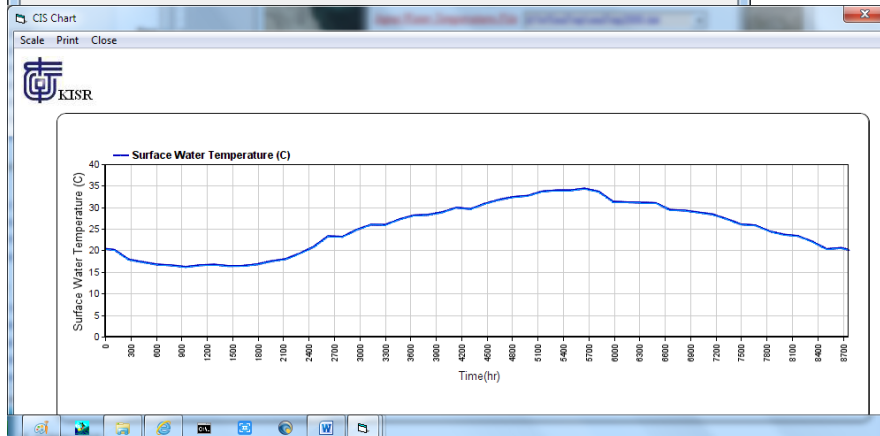


Figure 71

Sub-Option 2

4.2 Extracting 2D Water Temperature Field over Arabian Gulf for Surfer Program Format

. To extract 2D water temperature data user must select from Fig 69. Fig 72 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 72

To display the extracted data by Surfer program in 2D plot as shown Fig 73

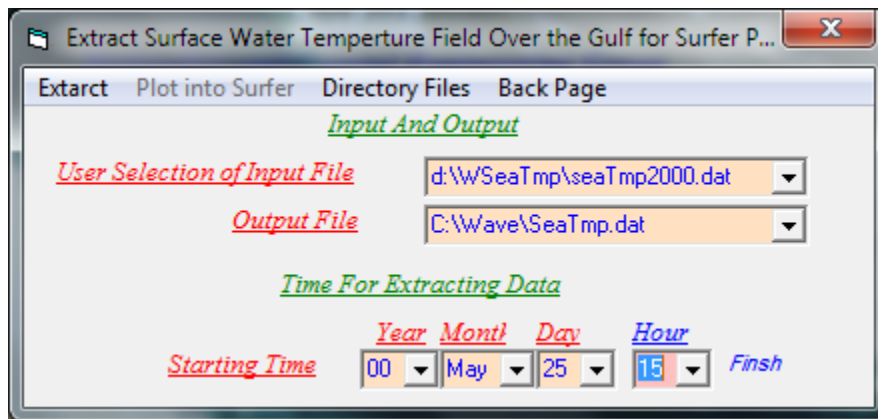


Figure 72

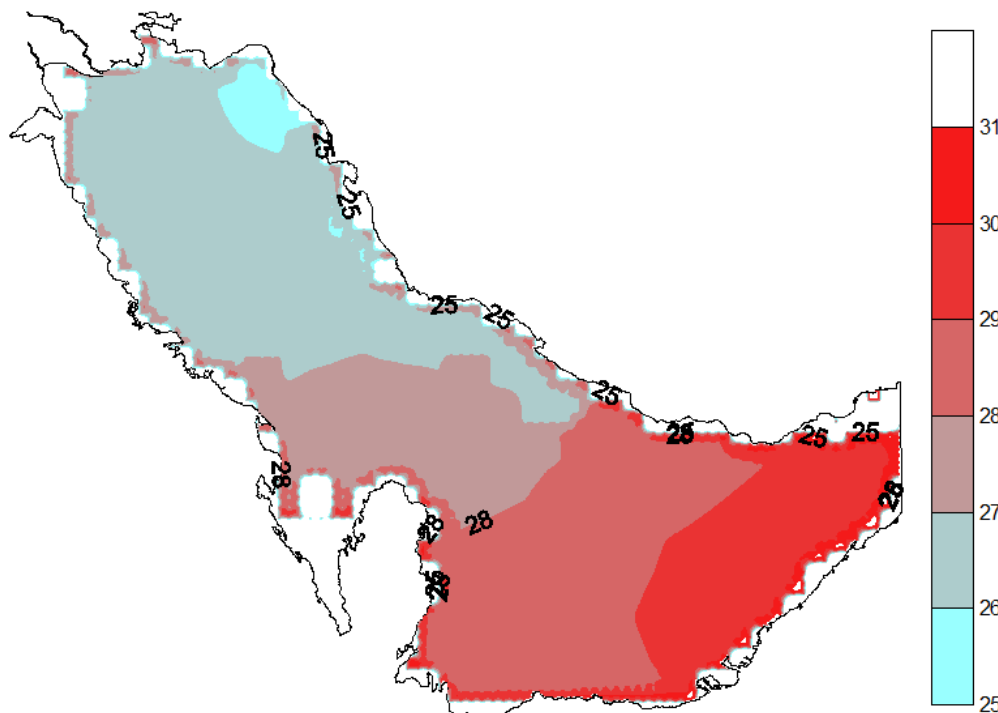


Figure 73

Sub-Option 3

4.3 Extracting 1D Time Series For Sea water Temperature

. To extract 1D time series water temperature data user must select from Fig 69. Fig 74 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 74

To display the extracted data by 1D plot as shown Fig 75

To Generat Printable file user must select [**Export File**] as shown in Fig 74

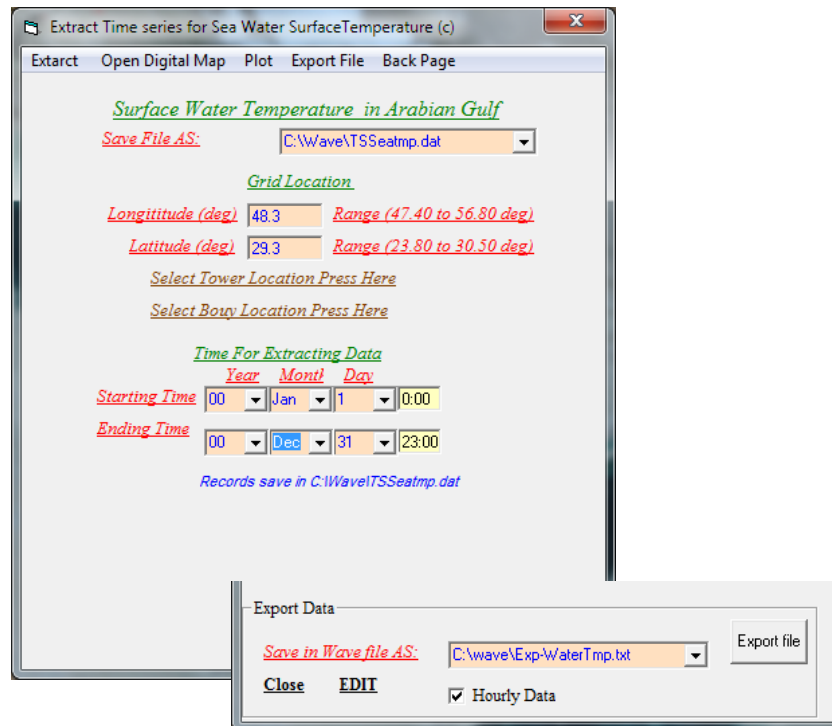


Figure 74

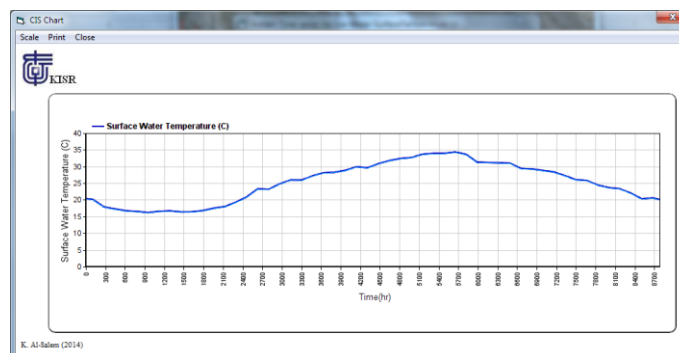


Figure 75

5. Air Temperature at 2m above Sea Level Database

User must Select To extract Air Temperature at 2m above sea level data at select grid in Arabian Gulf as shown in Fig 76. Where a number of Sub-options analysis was setup as shown in Fig 76. A List of option as:

- I. *Extracting Air Temperature time Series at Grid*
- II. *Extracting Air Temperature Field over Arabian Gulf for Surfer Format*
- III. *Extract Time Series Air Temperature over Arabian Gulf*

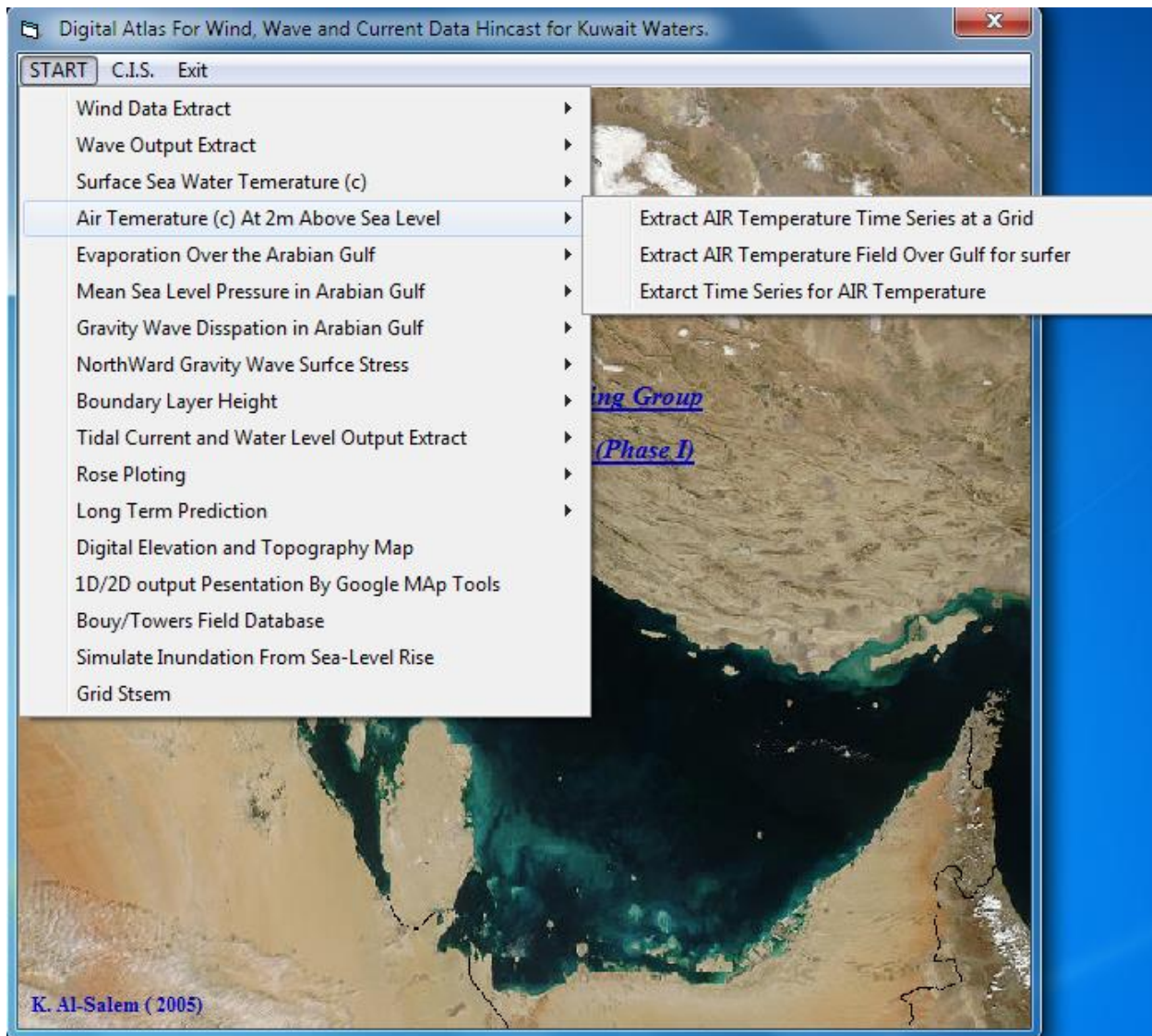


Figure 76

Sub-Option 3

5.1 Extracting Air Temperature time Series at Grid

. To extract 1D Air temperature data user must select from Fig 76. Fig 77 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select Digital Gulf map [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract [365 a year]

Then Select Extract to Start collect the data require. As shown Fig. 76

To display the extracted data by 1D plot as shown Fig 78

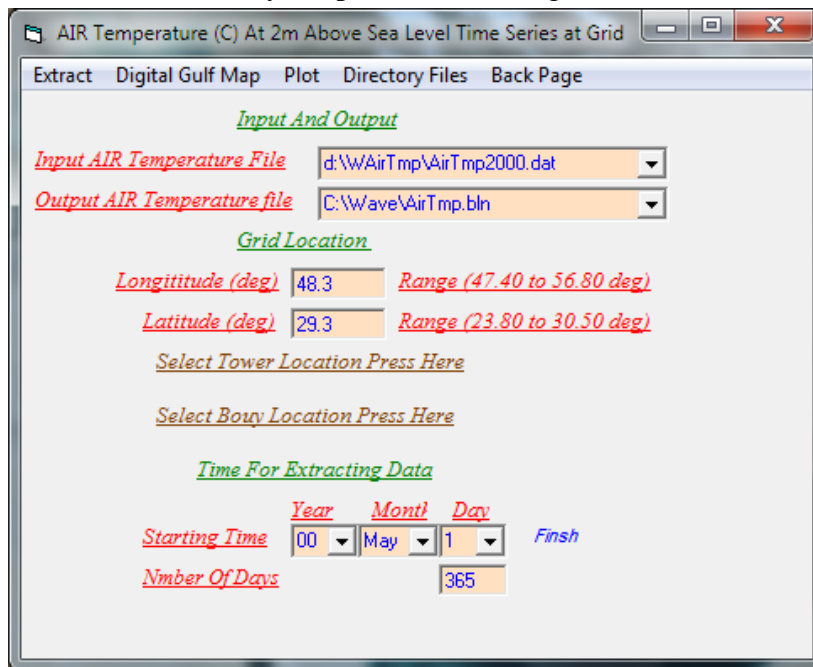


Figure 77

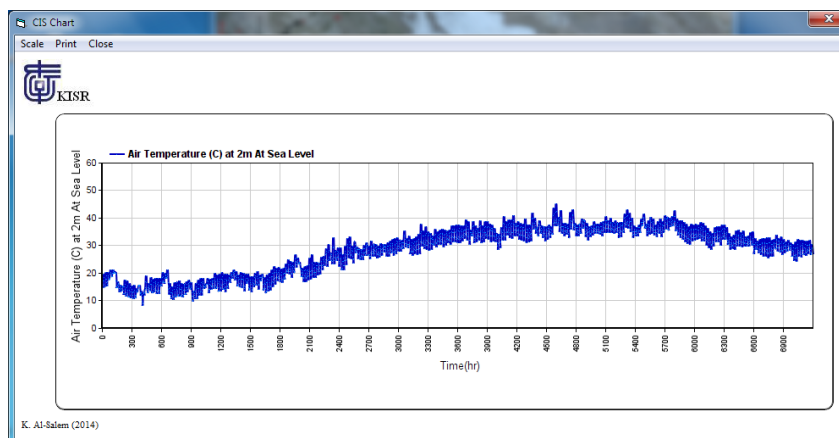


Figure 78

Sub-Option 3

5.2 Extracting Air Temperature Field over Arabian Gulf for Surfer Format

To extract 2D Air temperature data user must select from Fig 76. Fig 79 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 76

To display the extracted data by Surfer program in 2D plot as shown Fig 80

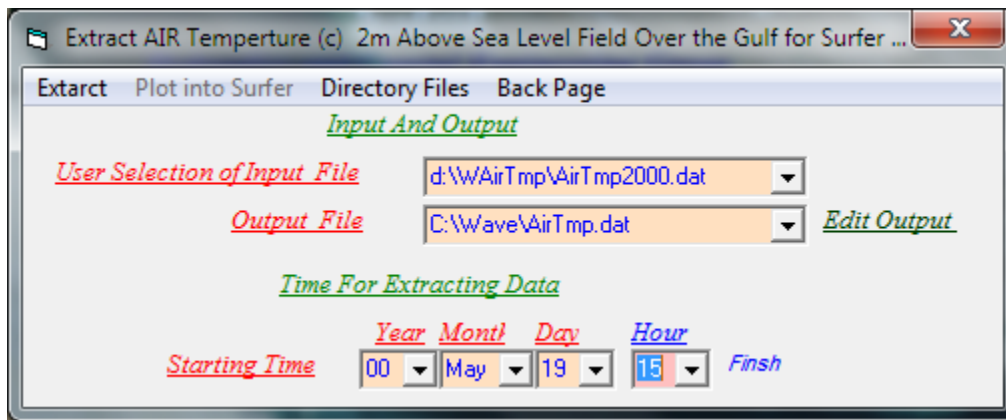


Figure 79

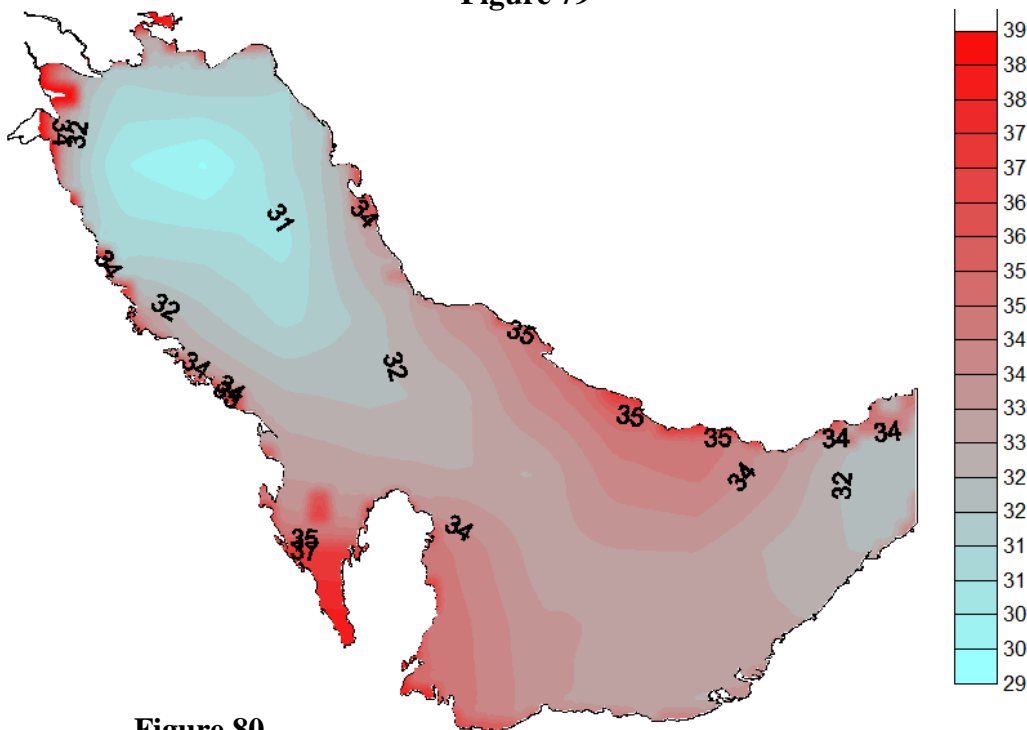


Figure 80

Sub-Option 3

5.3 Extract Time Series Air Temperature over Arabian Gulf

To extract 1D time series Air temperature data user must select from Fig 76. Fig 81 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 76

To display the extracted data by 1D plot as shown Fig 82

To Generat Printable file user must select [**Export File**] as shown in Fig 76

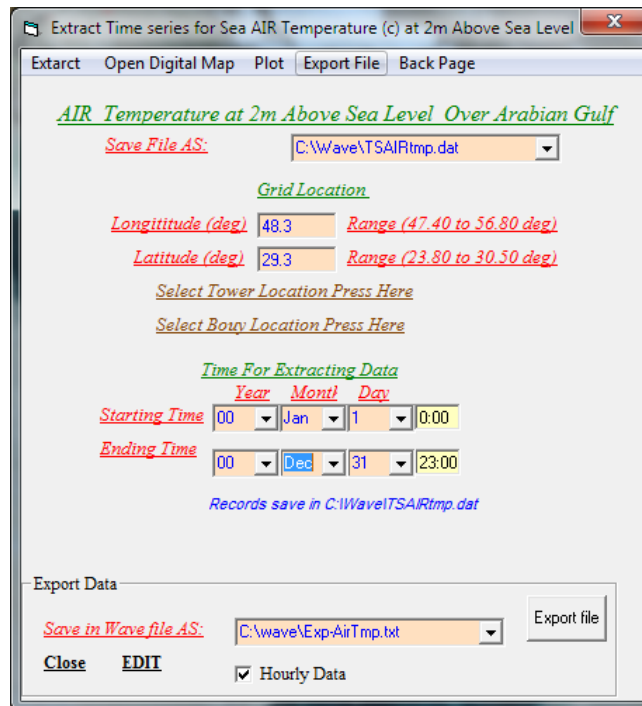


Figure 81

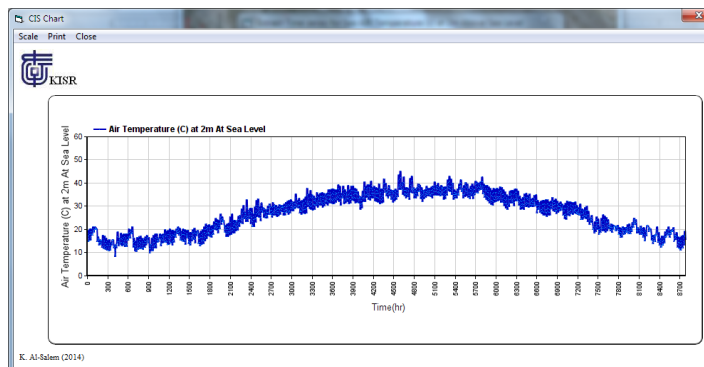


Figure 82

6. Evaporation over Arabian Gulf Database

User must Select To extract Evaporation rate above sea level data at select grid in Arabian Gulf as shown in Fig 83. Where a number of Sub-options analysis was setup as shown in Fig 83. A List of option as:

- I. *Extracting Evaporation at Grid*
- II. *Extracting Evaporation Field over Arabian Gulf for Surfer Format*
- III. *Extract Time Series Evaporation Process over Arabian Gulf*

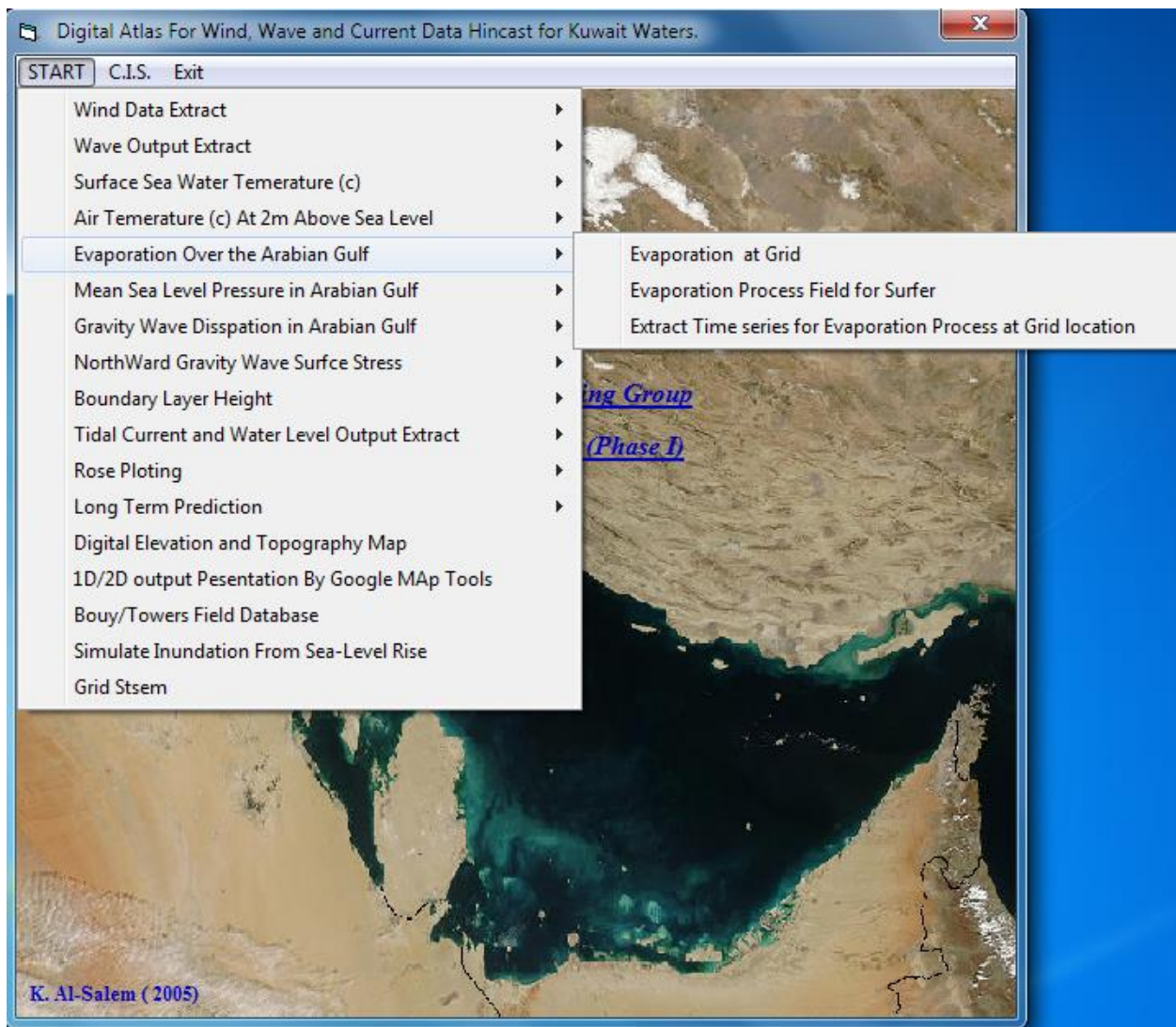


Figure 83

Sub-Open 1

6.1 Extracting Evaporation at Grid

To extract 1D Evaporation Rate data user must select from Fig 83. Fig 84 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select **Directory File**]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract [365 a year]

Then Select **Extract** to Start collect the data require. As shown Fig. 84
To display the extracted data by 1D plot as shown Fig 85

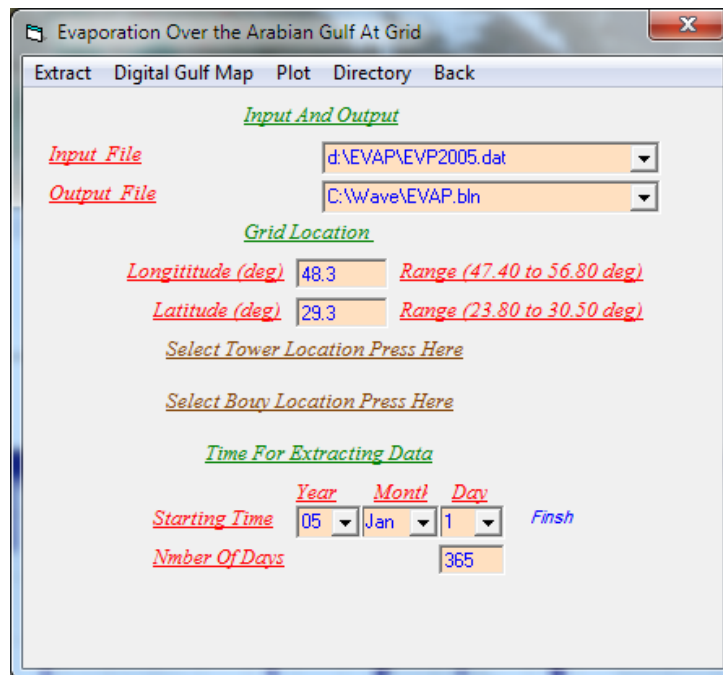


Figure 84

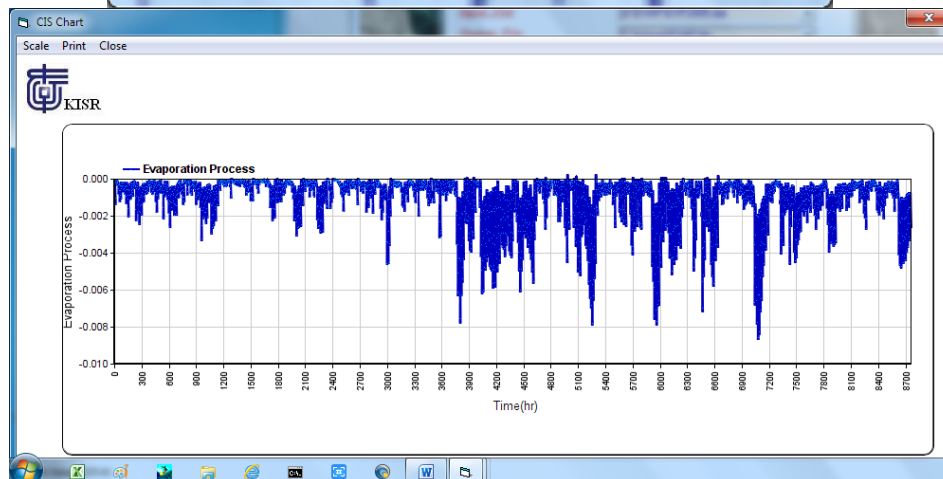


Figure 85

Sub-Open 2

6.2 Extracting Evaporation Field over Arabian Gulf for Surfer Format

To extract 2D Evaporation data user must select from Fig 83. Fig 86 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 86

To display the extracted data by Surfer program in 2D plot as shown Fig 87

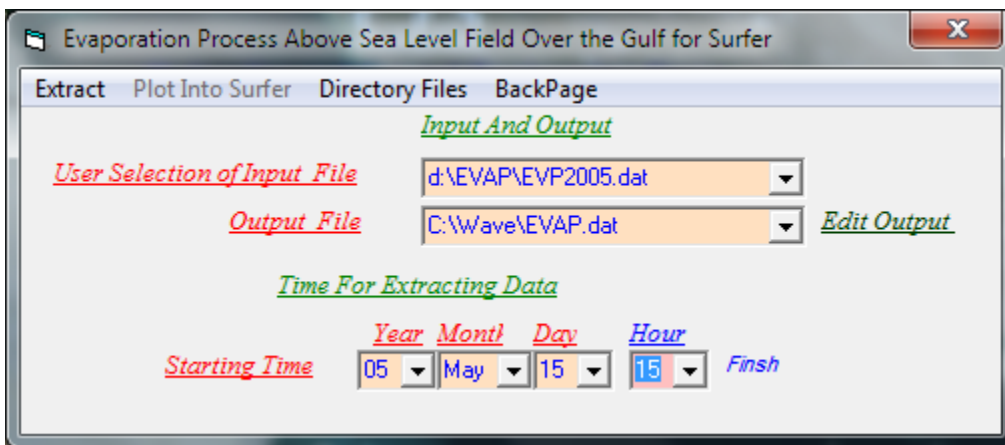


Figure 86

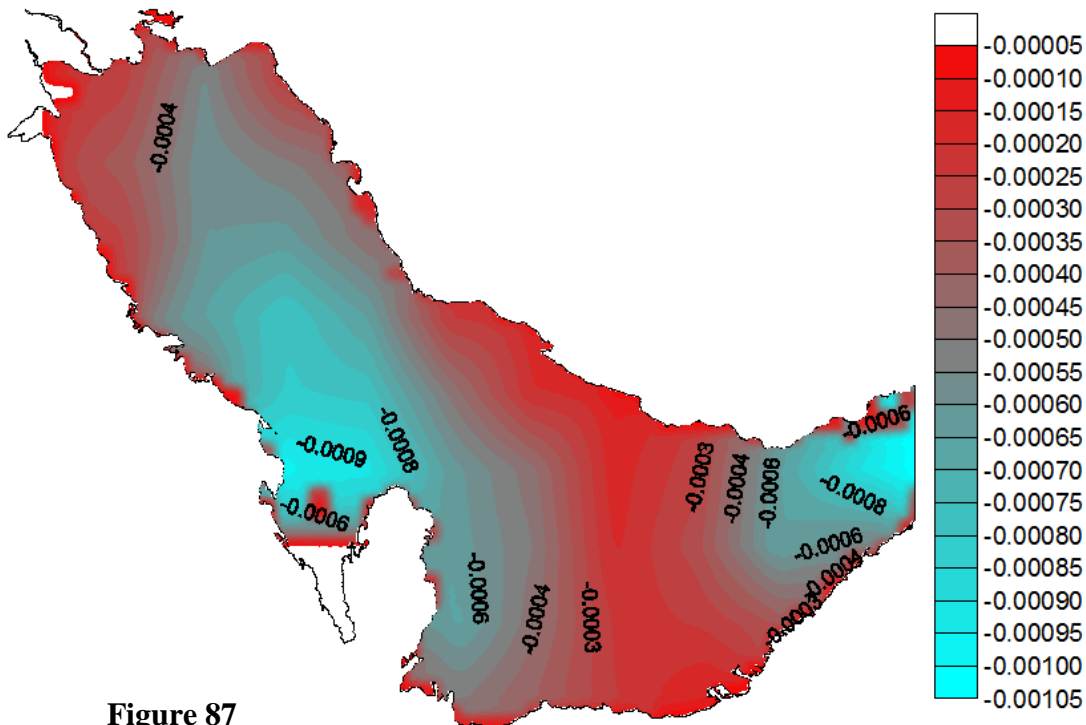


Figure 87

Sub-Open 3

6.3 Extract Time Series Evaporation Process over Arabian Gulf

To extract 1D time series Evaporation data user must select from Fig 83. Fig 88 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 88

To display the extracted data by 1D plot as shown Fig 89

To Generate Printable file user must select [**Export File**] as shown in Fig 88

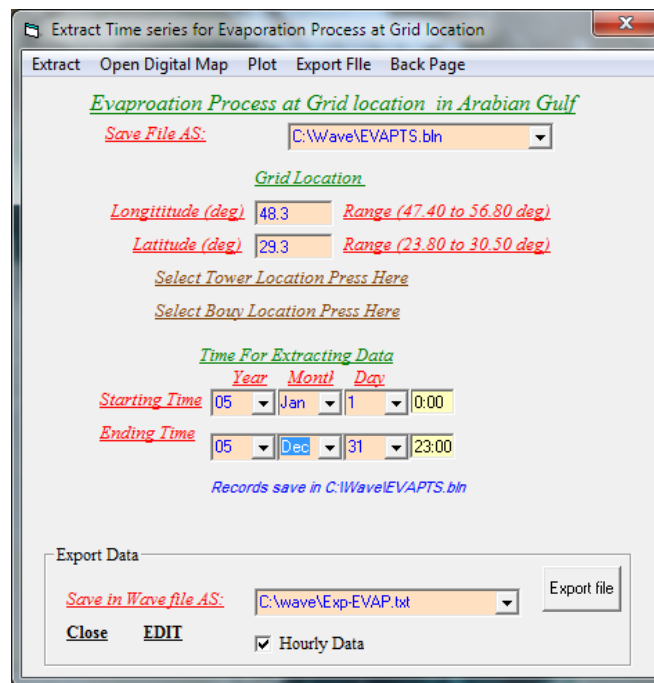


Figure 88

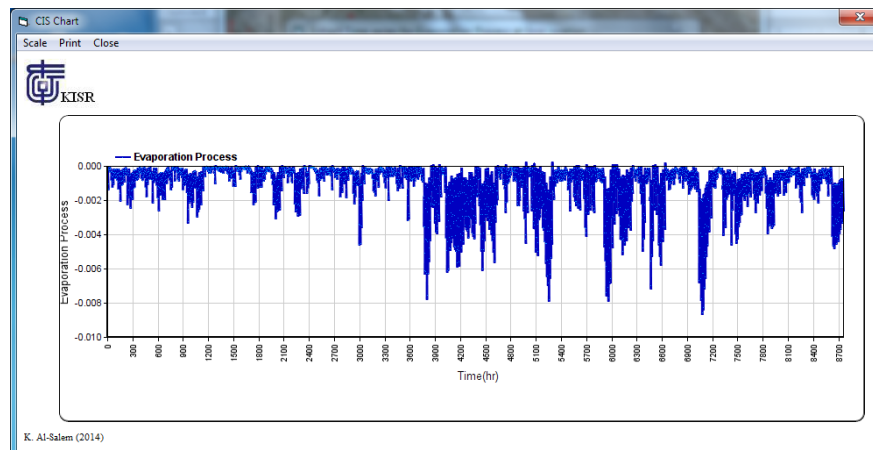


Figure 89

7. Mean Sea Level Pressure over Arabian Gulf Database.....

User must Select To extract mean Sea-Level Pressure data at select grid in Arabian Gulf as shown in Fig 90. Where a number of Sub-options analysis was setup as shown in Fig 90. A List of option as:

- I. *Extracting Mean Sea Level Pressure at Grid*
- II. *Extracting MSL Pressure Field over Arabian Gulf for Surfer Format*
- III. *Extract Time Series MSL Pressure over Arabian Gulf*

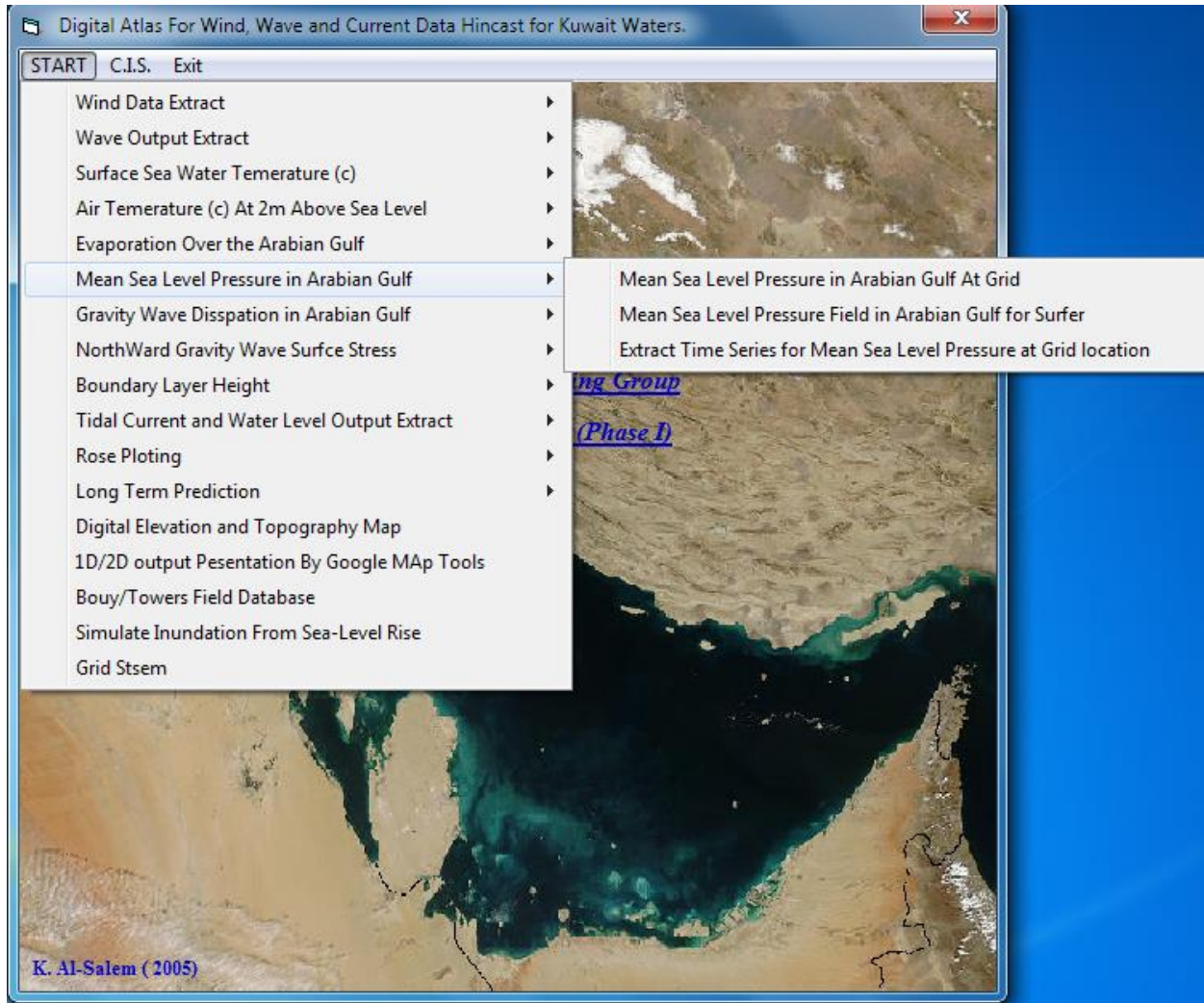


Figure 90

Sub-Open 1

7.1 Extracting Mean Sea Level Pressure at Grid

To extract 1D Mean Sea Level Pressure data user must select from Fig 90. Fig 91 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select **Directory File**]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract [365 a year]

Then Select **Extract** to Start collect the data require. As shown Fig. 91

To display the extracted data by 1D plot as shown Fig 92

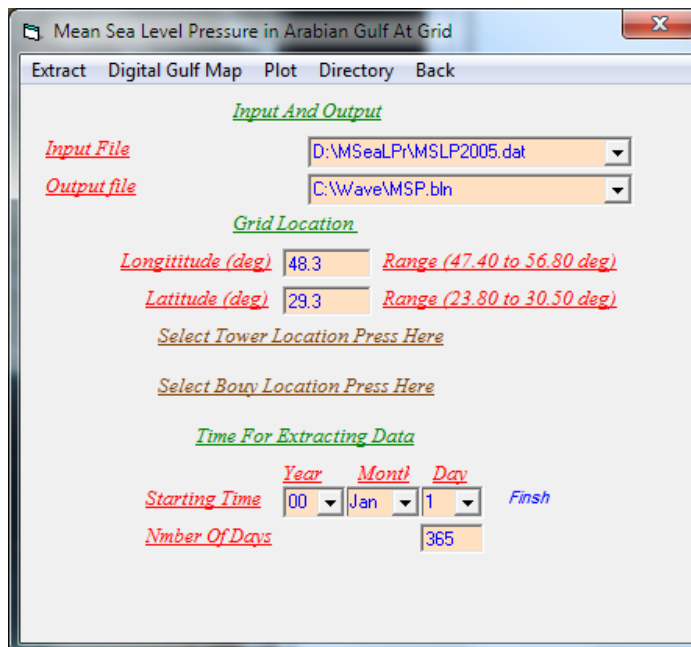


Figure 91

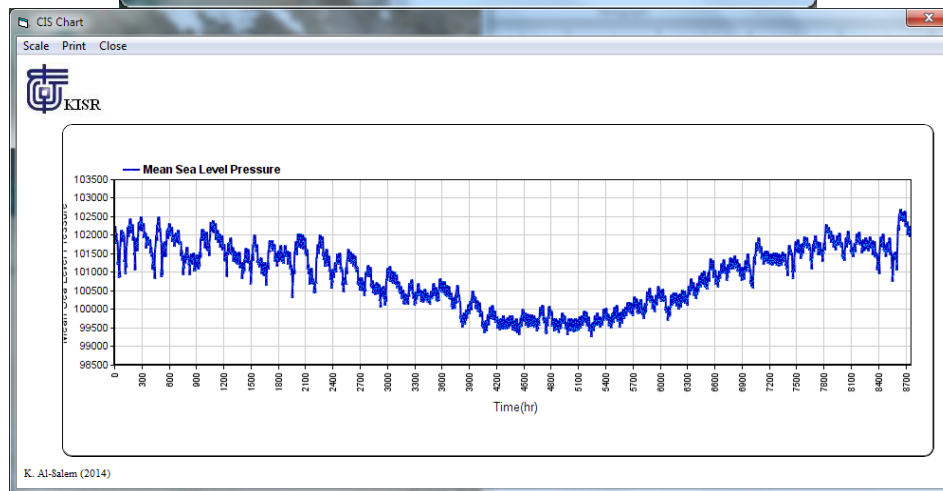


Figure 92

Sub-Open 2

7.2 Extracting MSL Pressure Field over Arabian Gulf for Surfer Format

To extract 2D Mean Sea Level Pressure data user must select from Fig 90. Fig 93 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 93

To display the extracted data by Surfer program in 2D plot as shown Fig 94

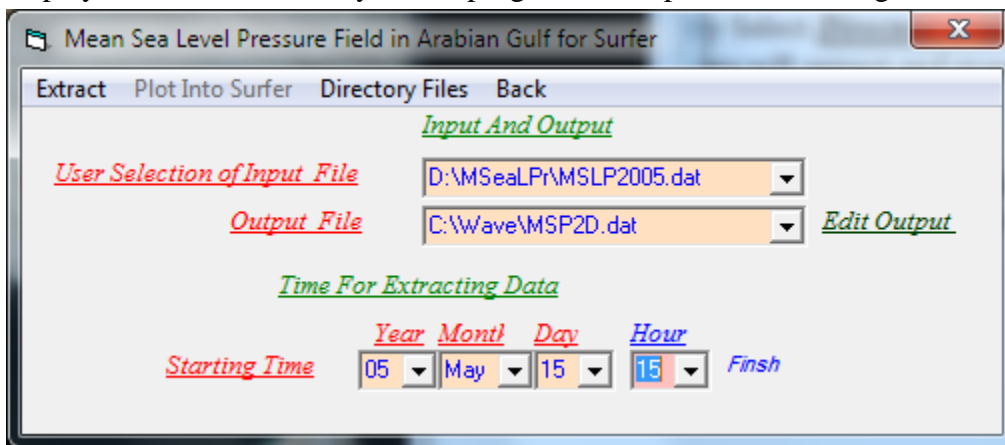


Figure 93

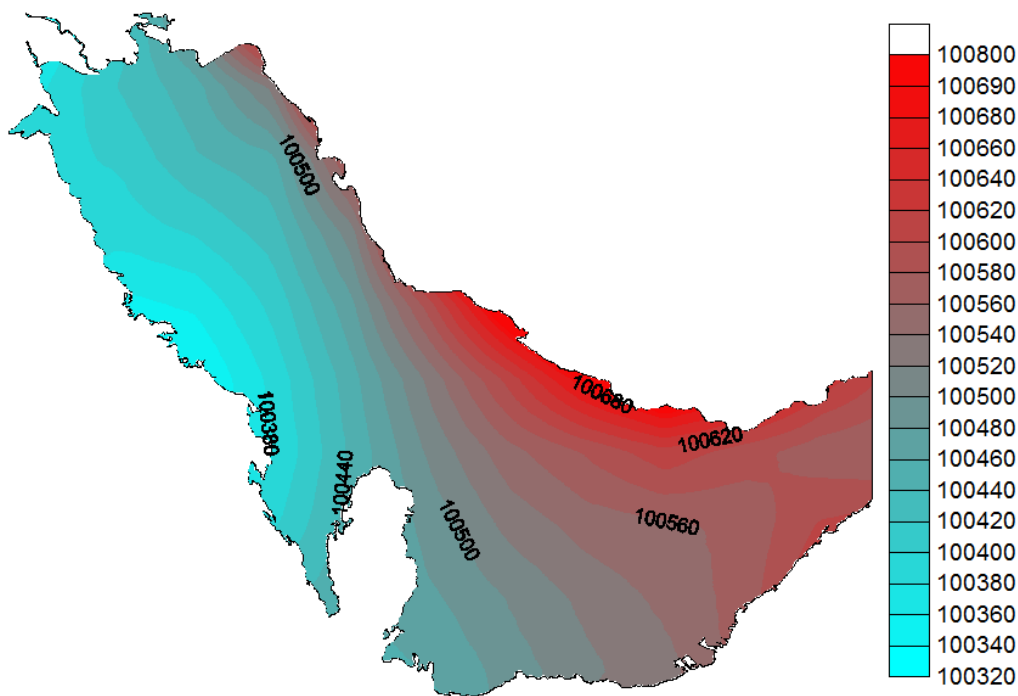


Figure 94

Sub-Open 3

7.3 Extract Time Series MSL Pressure over Arabian Gulf

To extract 1D time series Mean Sea Level Pressure data user must select from Fig 90. Fig 95 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 90

To display the extracted data by 1D plot as shown Fig 96

To Generat Printable file user must select [**Export File**] as shown in Fig 95

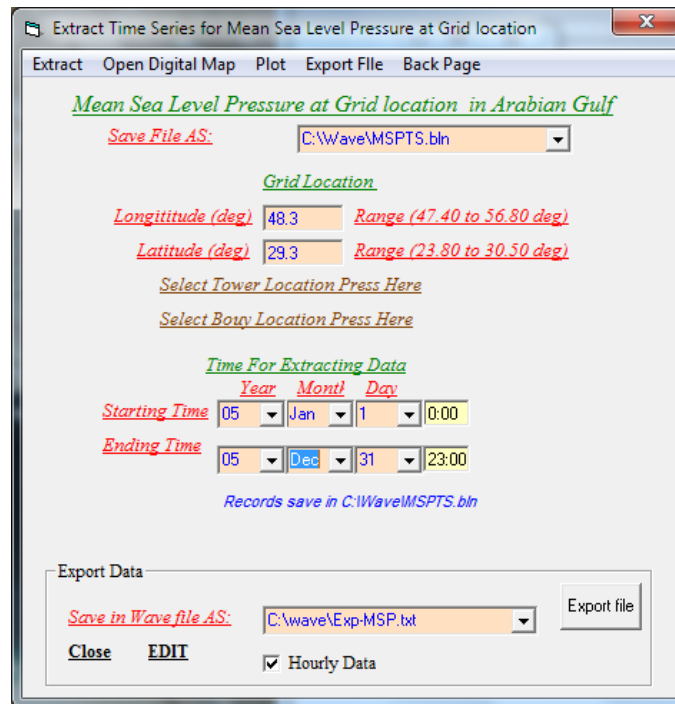


Figure 95

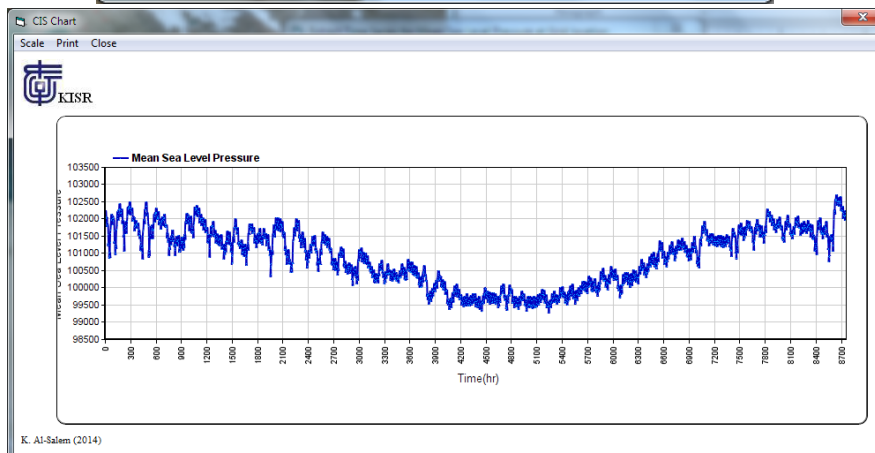


Figure 96

8. Gravity Wave Dissipation in Arabian Gulf Database

User must Select To extract Gravity Wave Dissipation data at select grid in Arabian Gulf as shown in Fig 96. Where a number of Sub-options analysis was setup as shown in Fig 96. A List of option as:

- I. *Extracting Gravity Wave Dissipation in Arabian Gulf at Grid*
- II. *Extracting Gravity Wave Dissipation Field over Arabian Gulf for Surfer*
- III. *Extract Time Series for Gravity Wave Dissipation over Arabian Gulf*

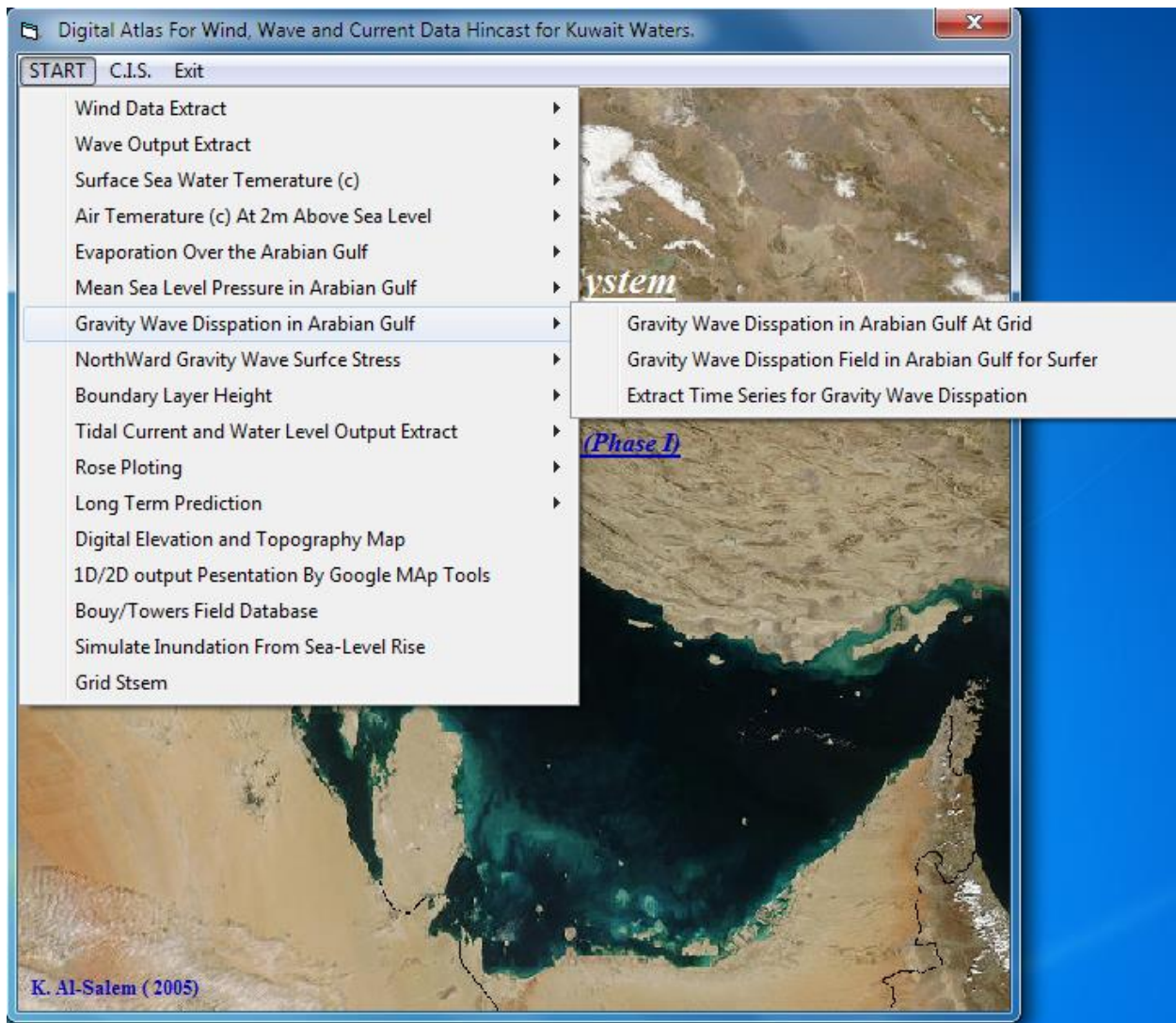


Figure 96

Sub-Option 1

8.1 Extracting Gravity Wave Dissipation in Arabian Gulf at Grid

To extract 1D Gravity Wave Dissipation data user must select from Fig 96. Fig 97 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select **Directory File**]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract [365 a year]

Then Select **Extract** to Start collect the data require. As shown Fig. 97

To display the extracted data by 1D plot as shown Fig 98

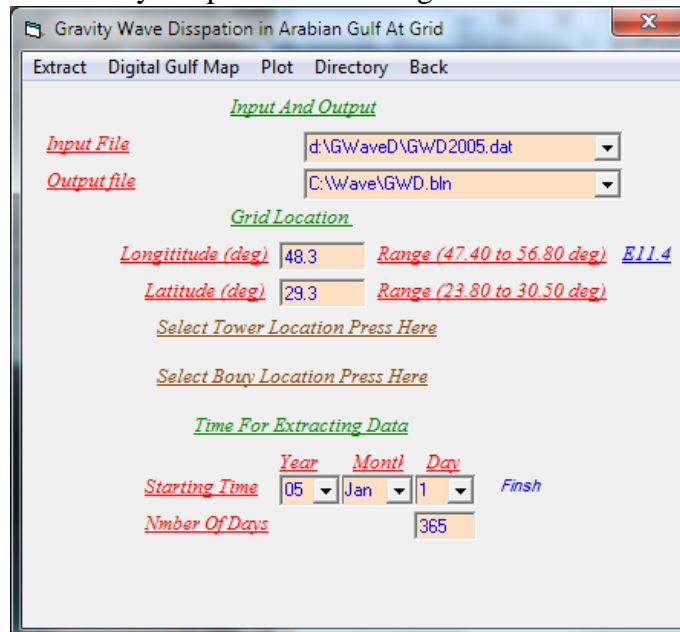


Figure 97

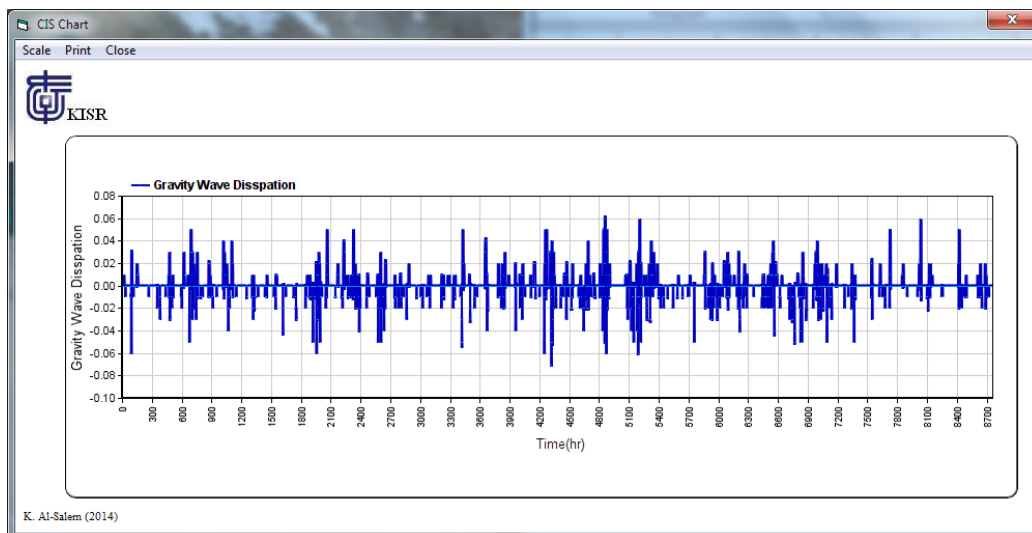


Figure 98

Sub-Option 2

8.2 Extracting Gravity Wave Dissipation Field over Arabian Gulf for Surfer

To extract 2D Gravity Wave Dissipation data user must select from Fig 96. Fig 99 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 99

To display the extracted data by Surfer program in 2D plot as shown Fig 100

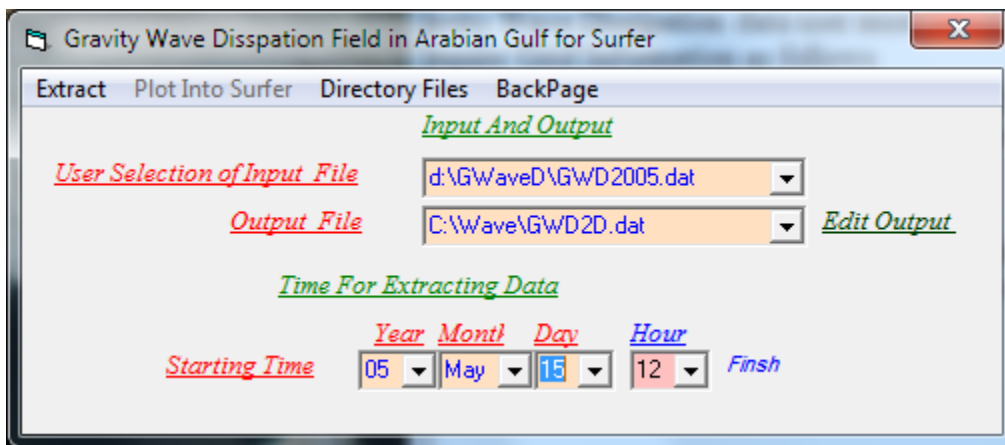


Figure 99

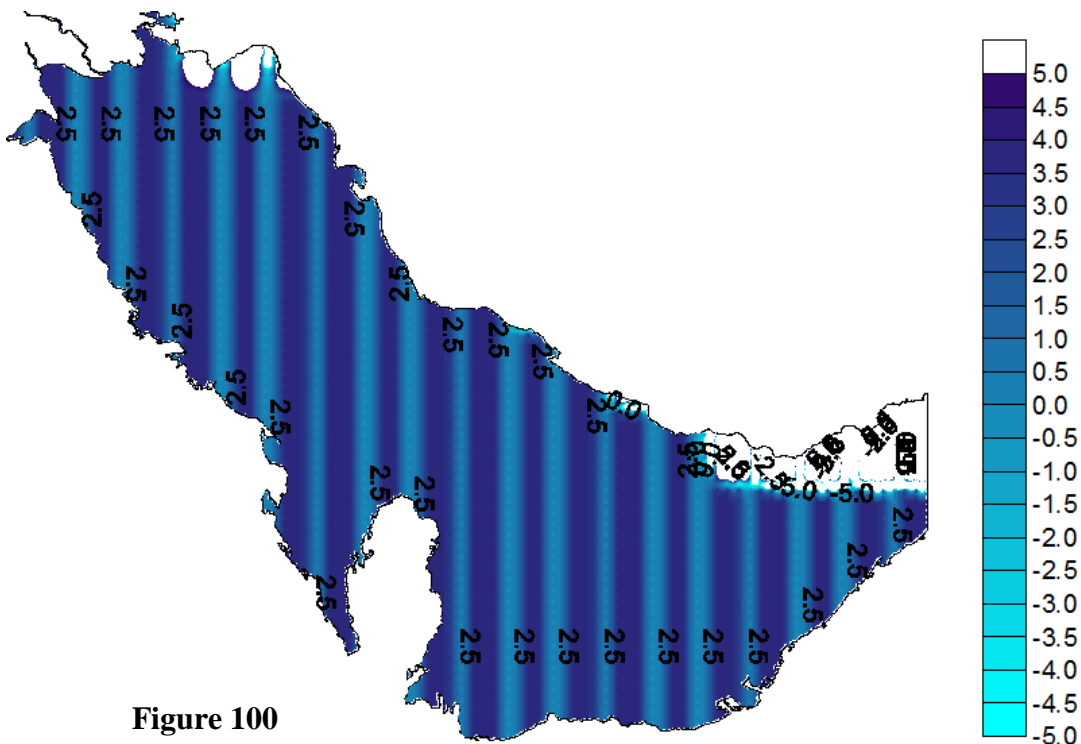


Figure 100

Sub-Option 3

8.3 Extract Time Series for Gravity Wave Dissipation over Arabian Gulf

To extract 1D time series Gravity Wave Dissipation data user must select from Fig 96. Fig 101 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 101

To display the extracted data by 1D plot as shown Fig 102

To Generat Printable file user must select [**Export File**] as shown in Fig 101

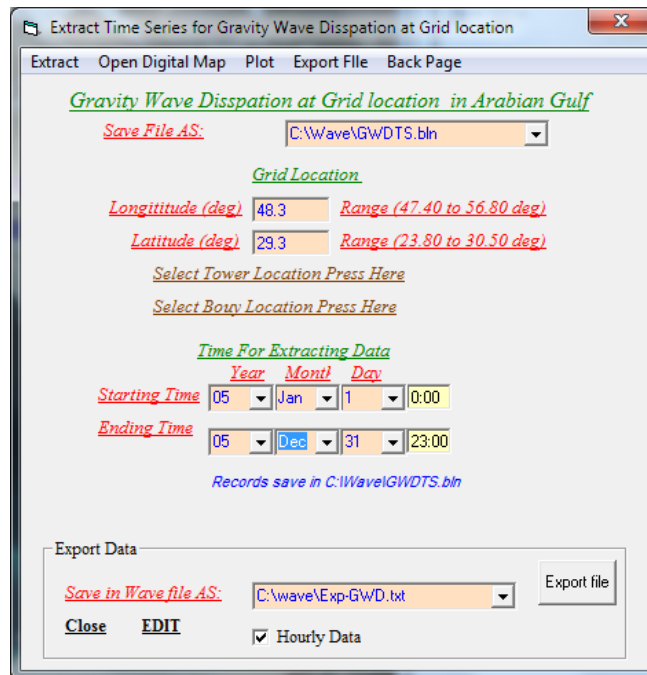


Figure 101

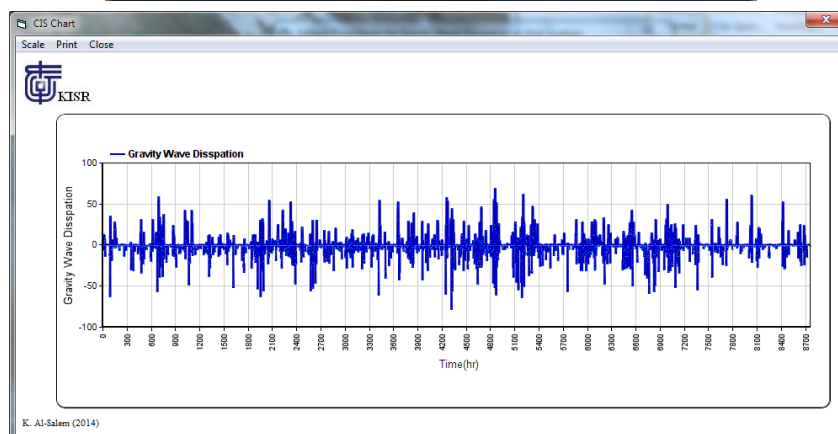


Figure 102

9. Northward Gravity Wave Surface Stress in Arabian Gulf

User must Select To extract Northward Gravity Wave Surface Stress data at select grid in Arabian Gulf as shown in Fig 103. Where a number of Sub-options analysis was setup as shown in Fig 103. A List of option as:

- I. *Extracting Northward Gravity Wave Stress in Arabian Gulf at Grid*
- II. *Extracting N.G. Wave Stress Field over Arabian Gulf for Surfer Format*
- III. *Extract Time Series for N. G. Wave Stress in Arabian Gulf*

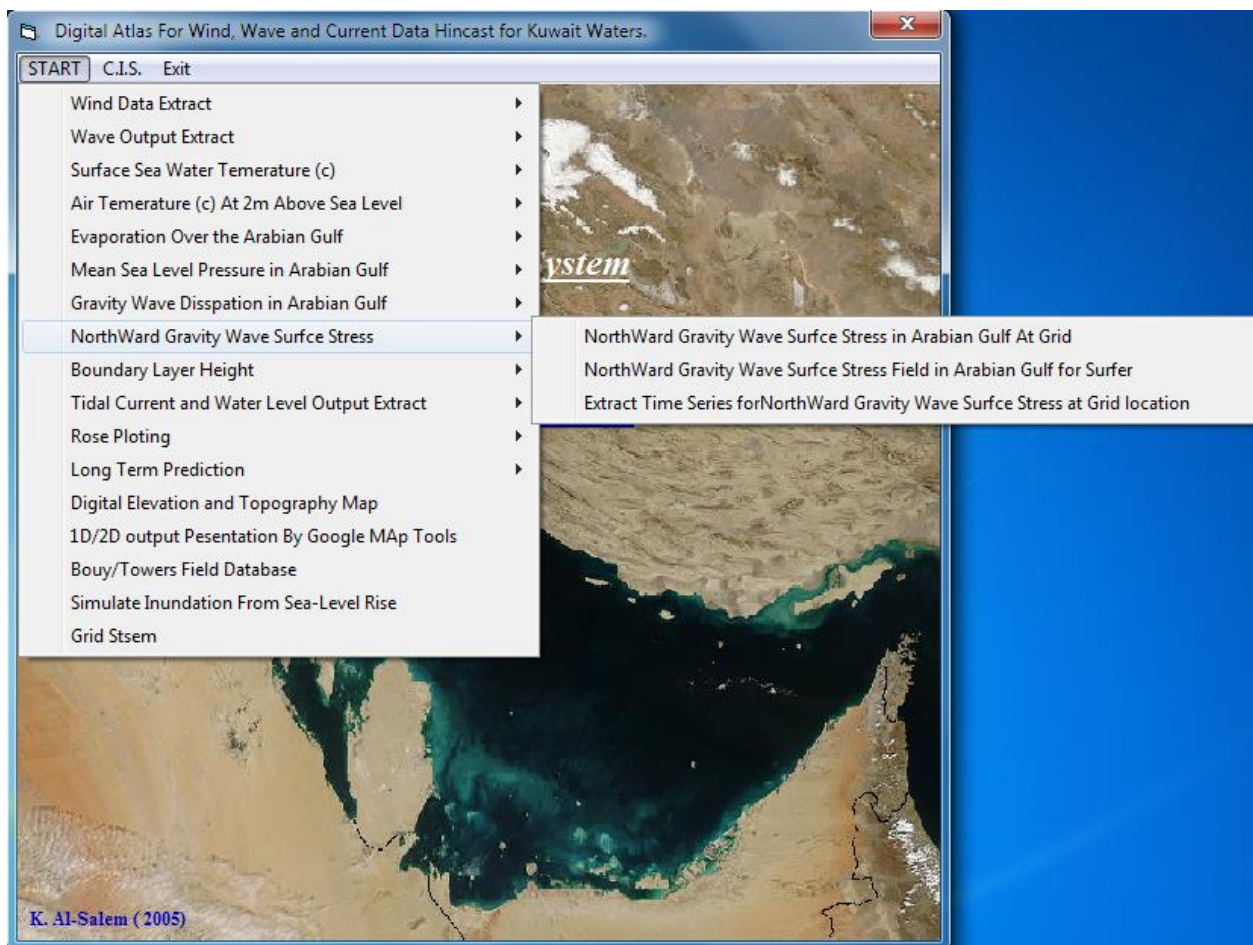


Figure 103

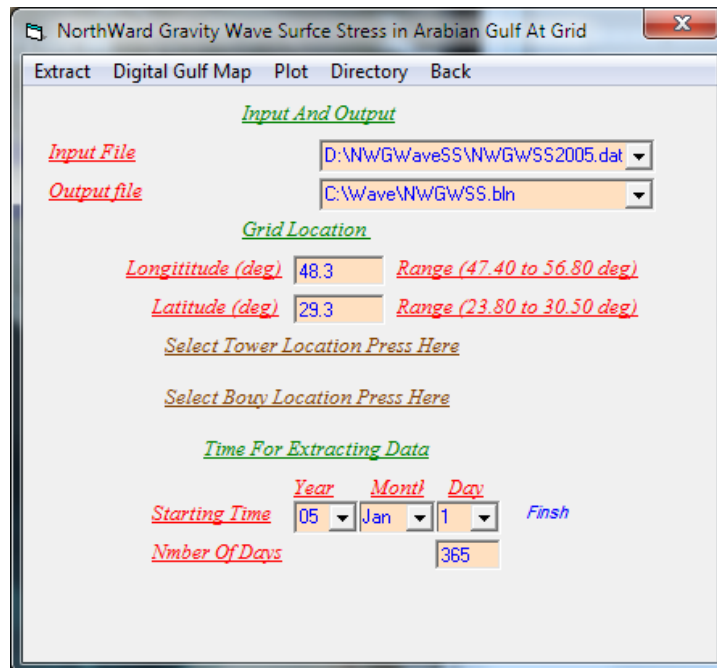
Sub-Option 1

9.1 Extracting Northward Gravity Wave Stress in Arabian Gulf at Grid

To extract 1D Northward Gravity Wave Surface Stress data user must select from Fig 103. Fig 104 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select ***Directory File***]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select ***Digital Gulf map*** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract [365 a year]

Then Select ***Extract*** to Start collect the data require. As shown Fig. 14
To display the extracted data by 1D plot as shown Fig 105



NorthWard Gravity Wave Surface Stress in Arabian Gulf At Grid

Extract Digital Gulf Map Plot Directory Back

Input And Output

Input File D:\NWGWaveSS\NWGWSS2005.dat

Output file C:\Wave\NWGWSS.blm

Grid Location

Longitude (deg) 48.3 *Range (47.40 to 56.80 deg)*

Latitude (deg) 29.3 *Range (23.80 to 30.50 deg)*

Select Tower Location Press Here

Select Bouy Location Press Here

Time For Extracting Data

Starting Time Year: 05, Month: Jan, Day: 1 *Finsh*

Number Of Days 365

Figure 104

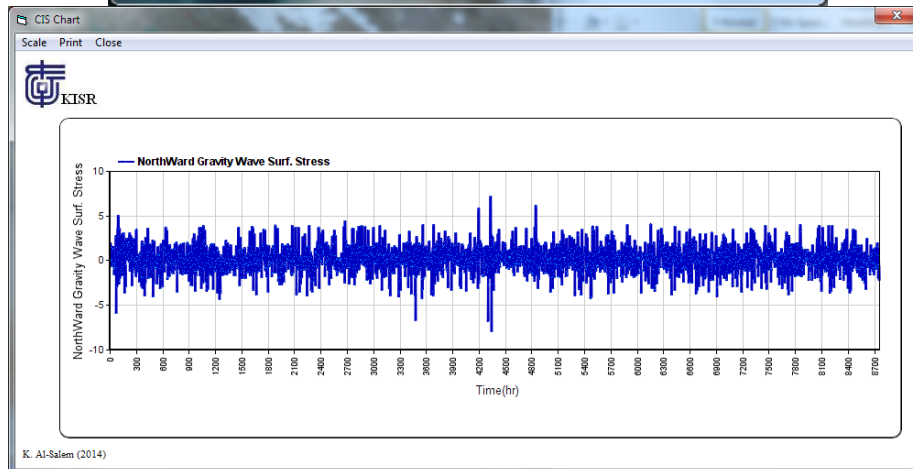


Figure 105

Sub-Option 2

9.2 Extracting N.G. Wave Stress Field over Arabian Gulf for Surfer Format

To extract 2D Northward Gravity Wave Surface Stress data user must select from Fig103. Fig 106 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 106

To display the extracted data by Surfer program in 2D plot as shown Fig 107

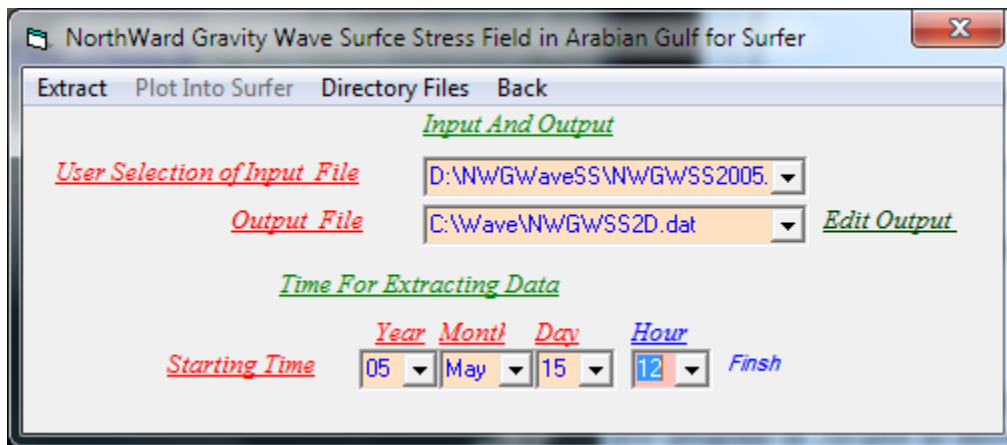


Figure 106

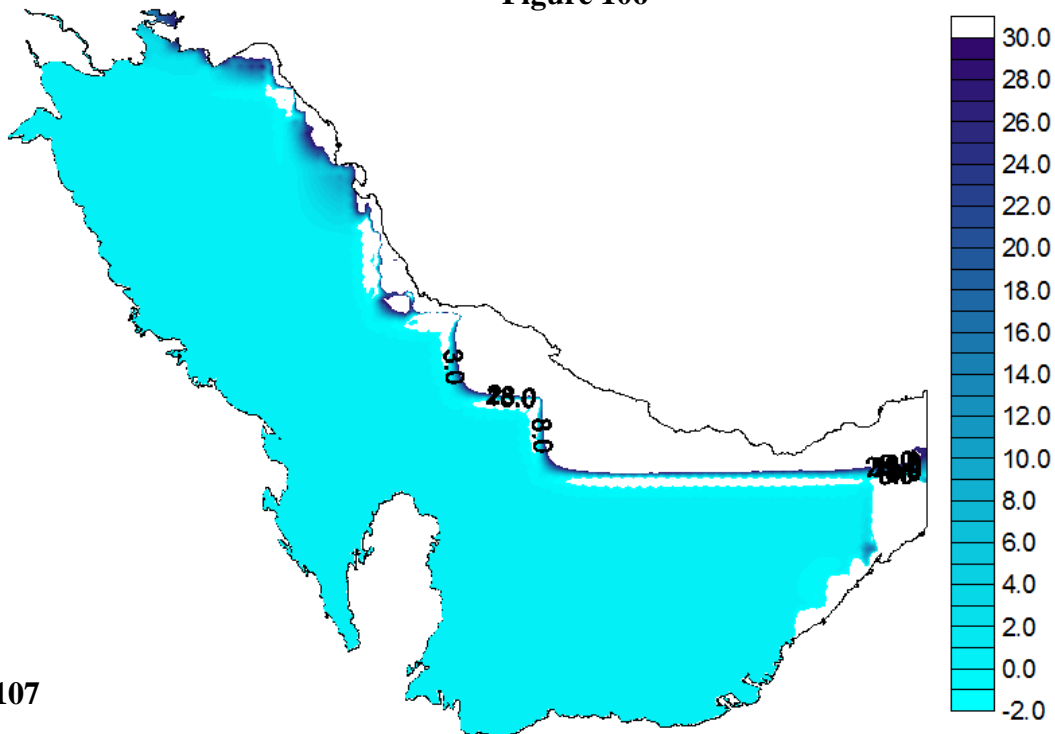


Figure 107

Sub-Option 3

9.3 Extract Time Series for N. G. Wave Stress in Arabian Gulf

To extract 1D time series Northward Gravity Wave Surface Stress data user must select from Fig 103. Fig 108 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 108

To display the extracted data by 1D plot as shown Fig 109

To Generate Printable file user must select [**Export File**] as shown in Fig 108

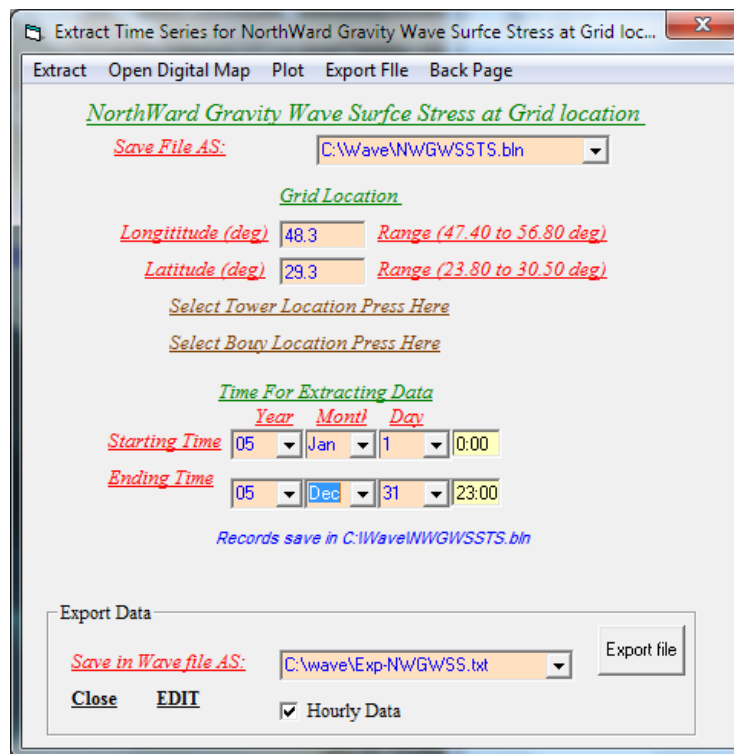


Figure 108

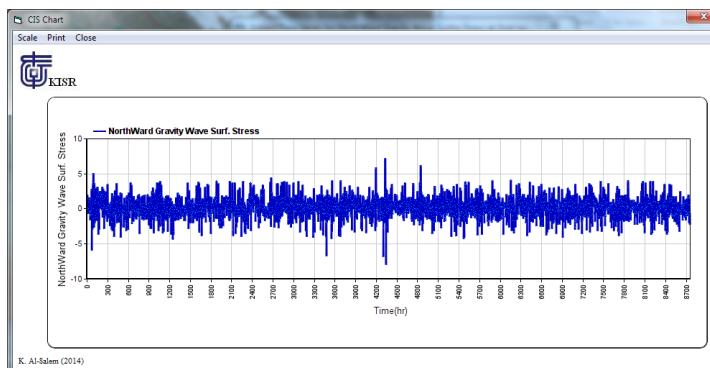


Figure 109

10. Boundary Layer Height Over Arabian Gulf Database

User must select To extract **Boundary** Layer Height data at select grid in Arabian Gulf as shown in Fig 110. Where a number of Sub-options analysis was setup as shown in Fig 110. A List of option as:

- I. *Extracting Boundary Layer Height in Arabian Gulf at Grid*
- II. *Extracting Boundary Layer Height Field over Arabian Gulf for Surfer*
- III. *Extract Time Series for Boundary Layer Height over Arabian Gulf*

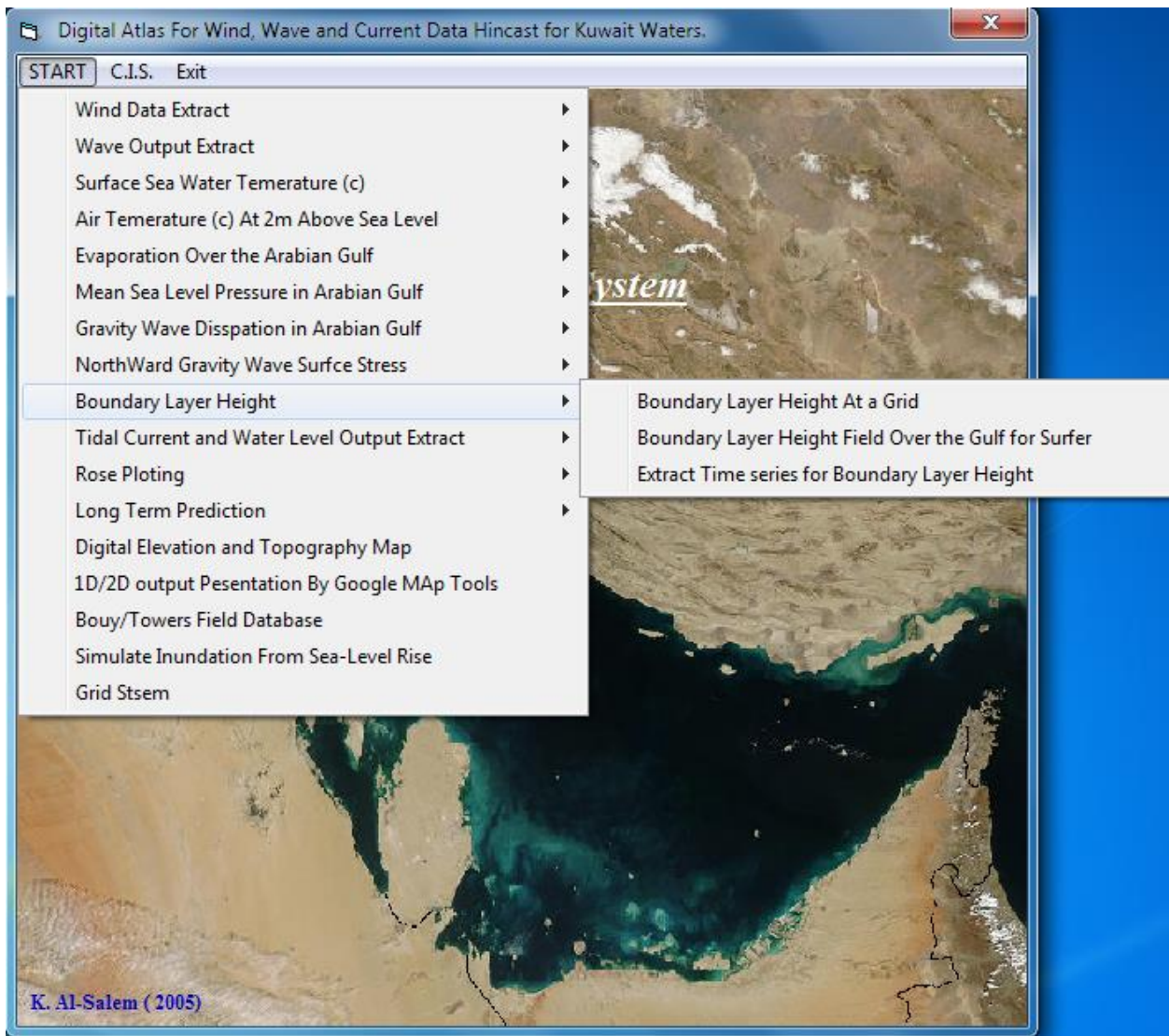


Figure 110

Sub-Option 1

10.1 Extracting Boundary Layer Height in Arabian Gulf at Grid

To extract 1D Boundary Layer Height user must select from Fig 110. Fig 111 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select **Directory File**]. As input file
- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Select Day / Month /Year
- Enter Start Day number and number of Days user want to Extract [365 a year]

Then Select **Extract** to Start collect the data require. As shown Fig. 111

To display the extracted data by 1D plot as shown Fig 112

Figure 111

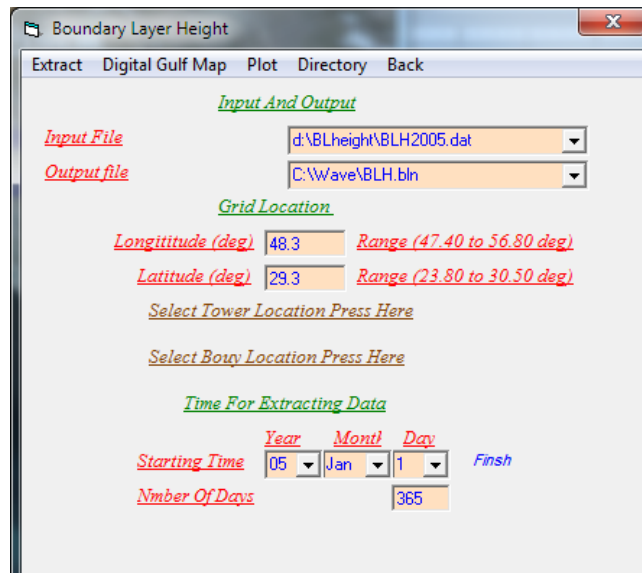
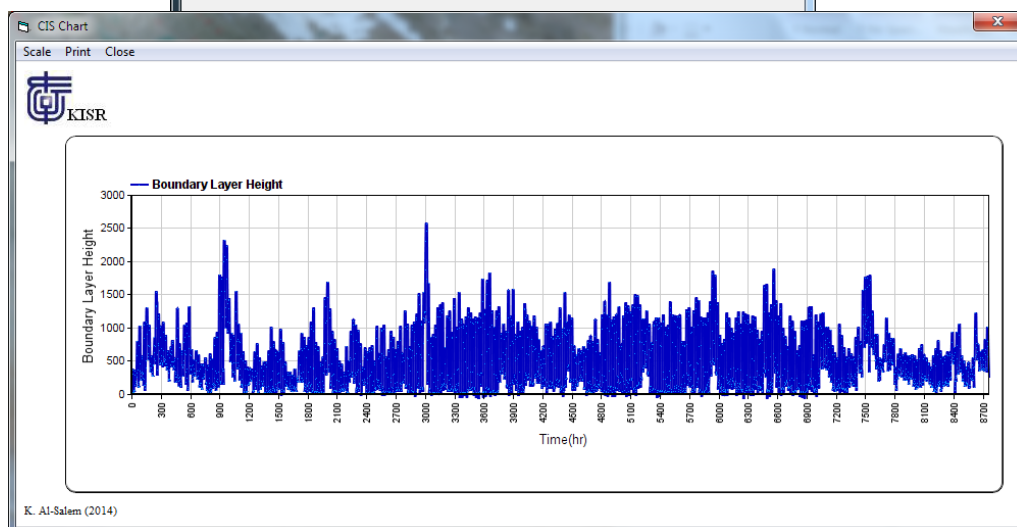


Figure 112



Sub-Option 2

10.2 Extracting Boundary Layer Height Field over Arabian Gulf for Surfer

To extract 2D Boundary Layer Height data user must select from Fig 110. Fig 113 will display for user to enter require Grid Information as follows

- Enter the Year of select data [By Select Directory File]. As input file
- Enter output file name where data will extract and stored in.
- Enter Select Day / Month /Year
- Enter Time in number of Hour in A day

Then Select Extract to Start collect the data require. As shown Fig. 113

To display the extracted data by Surfer program in 2D plot as shown Fig 114

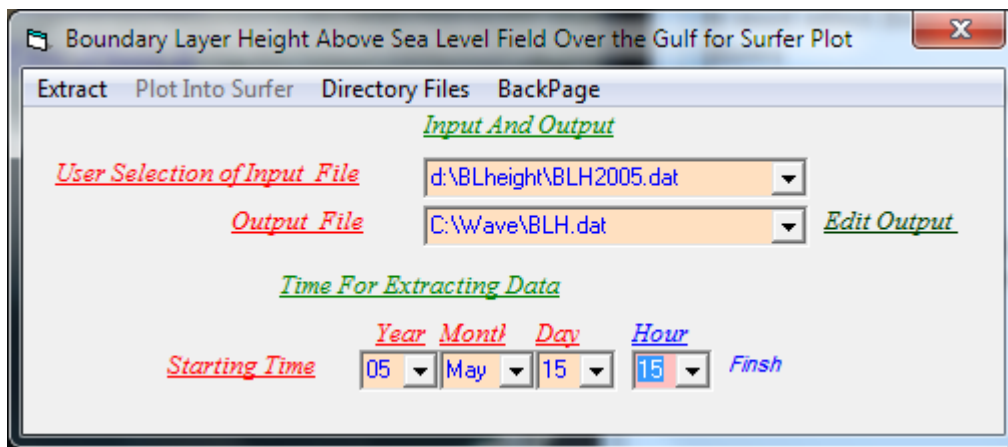


Figure 113

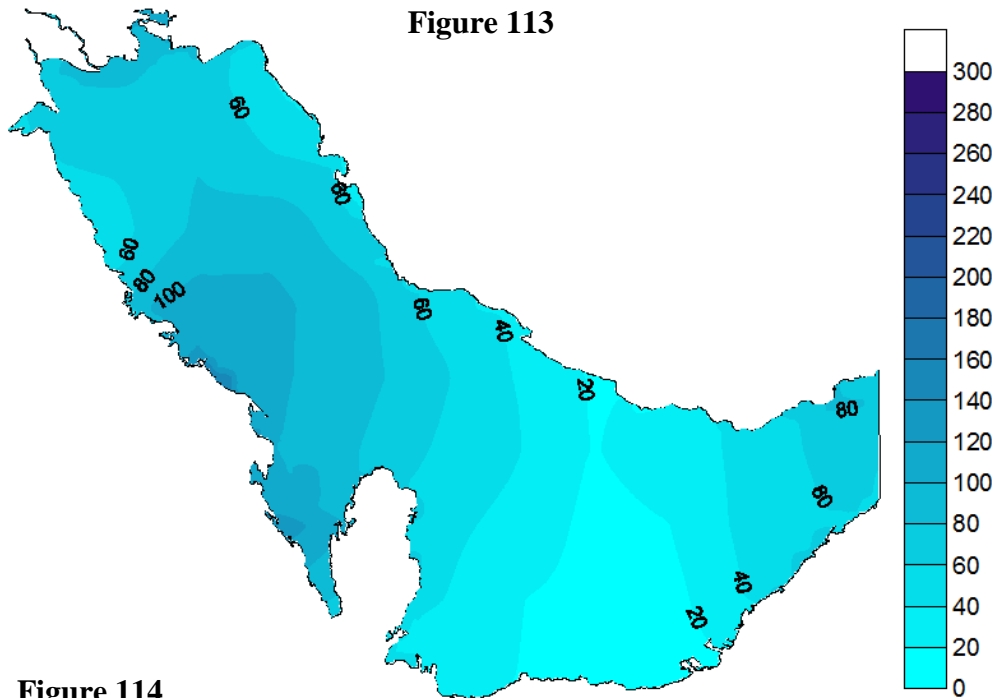


Figure 114

Sub-Option 3

10.3 Extract Time Series for Boundary Layer Height over Arabian Gulf

To extract 1D time series Boundary Layer Height data user must select from Fig 110. Fig 115 will display for user to enter require Grid Information as follows

- Enter output file name where data will extract and stored in.
- Enter Grid Location by two way as
 - Select **Digital Gulf map** [As shown in Fig. 5]
 - Manual Enter Longitude/Latitude in (deg)
- Enter Start Select Day / Month /Year at 0.00
- Enter End Select Day /Month/Year at 23.00

Then Select **Extract** to Start collect the data require. As shown Fig. 115

To display the extracted data by 1D plot as shown Fig 116

To Generate Printable file user must select [**Export File**] as shown in Fig 115

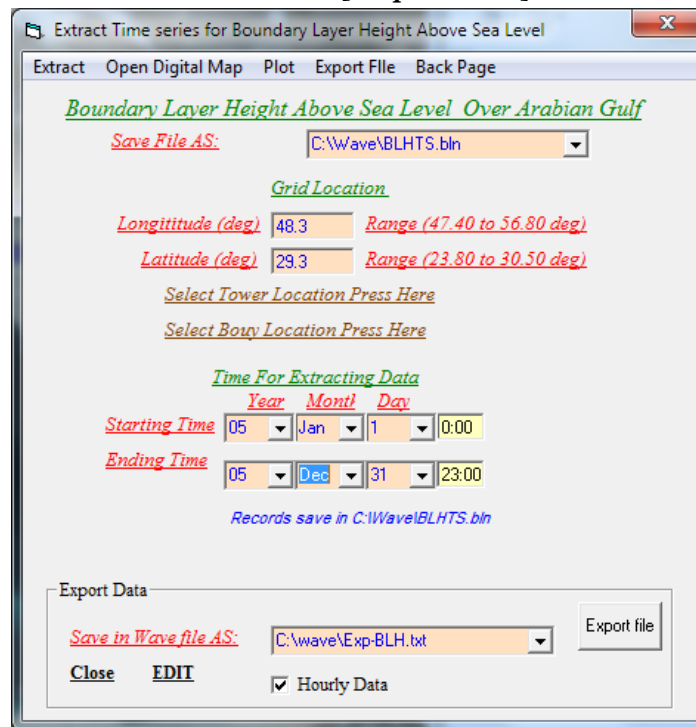


Figure 115

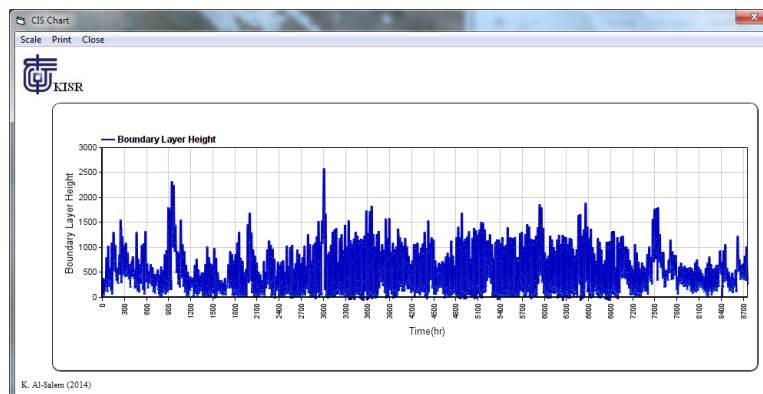


Figure 116

11. Rose Program Plotting [KROSE Model]

Rose Plotting Tool [Named: KRose was Developed by Al-Salem k 2005]. It's a valuable tool for user to create a rose plot and the statistical of frequency table for wave height, wind speed and tidal current for any location and time period in the Arabian Gulf. Where a number of Sub-options analysis was setup as shown in Fig 117. A List of option as:

- I. *Extracting Wind Speed For Rose Plot*
- II. *Extracting Significant Wave Height For Rose Plot*

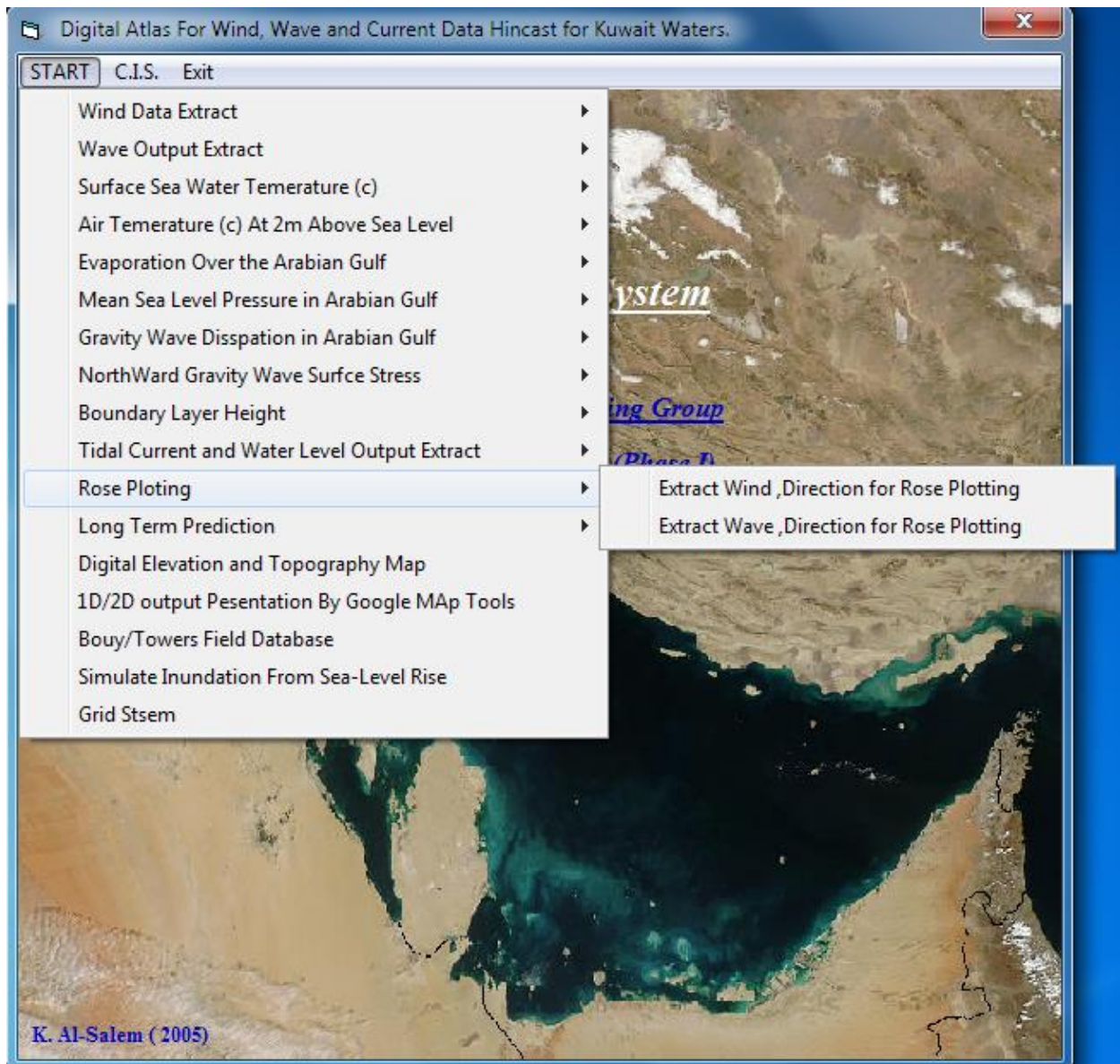


Figure 117

To plot data using Rose Plotting Software click on **Plot Wave Rose** as shown in Fig. 118 a new window titled (**Rose Plot Configuration**) will display for user to Configure the plot as: -

- Data Record file** (Input Data Extract Name)
- Save Statistical Table** (output Statistical table)
- Type Of Plot TO Select** (plot type Wind, Wave, Or Tidal Current)
- Select Magnification Number** (Data Zoom in/out)
- Select Increment Class** (Data Range)
- Select Plot Width Number** (Rose Wing Width)

Then Click in **Show** as shown in fig 118. Fig.68 and 69 will display the **frequency of statistical distribution table** and the corresponding **Rose Plot** of the data frequency.

Sub-Option 1

11.1 Extracting Wind Speed for Rose Plot

If Select to plot wind data from Fig 117 user must select or any wind speed analysis sub-Program all Linked with the **KROSE Program**.

Fig 118 will display for user to Extract Wind Data as follow:

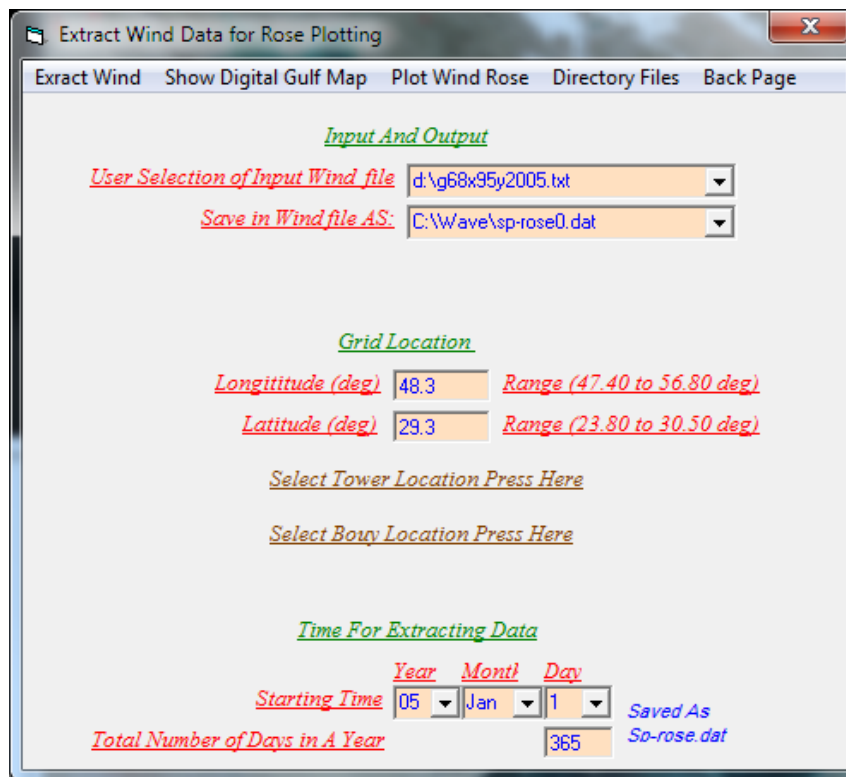


Figure 118

User must Select [Plot Wind Rose] from Fig 118. Then Fig 119 will display for user to enter the Rose Plot Configuration information require.

Fig 119 it part of KROSE program it linked with all Wind Speed Data Analysis in The C.I.S System. Then To; display the Result [*Frequency of Statistical Wind Seep and Direction Table*] by Select [*Show*] in fig119. Fig 120 will display. To Display Rose Plot Select [*Graph*] in Fig 120 Fig 121 will display in new window as Rose Plot.

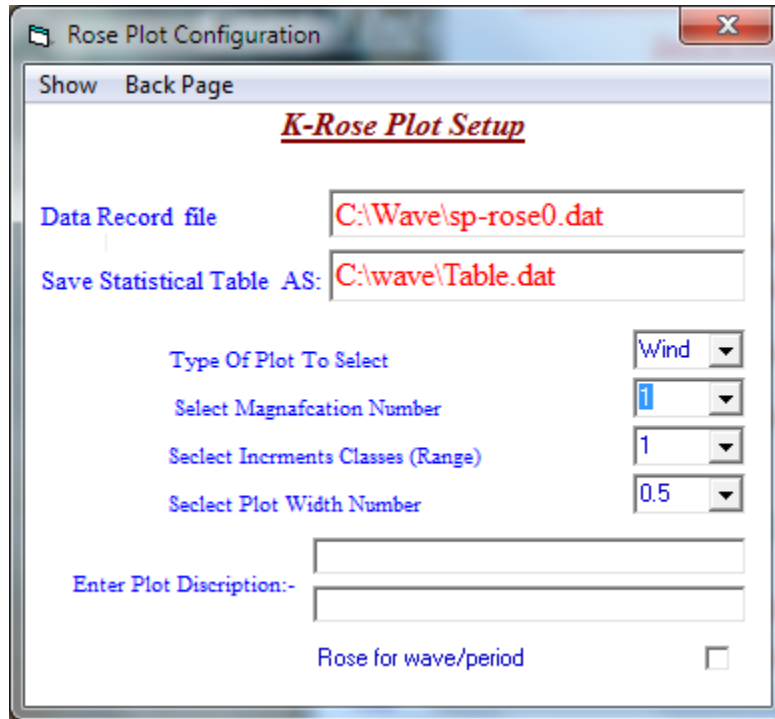


Figure 119

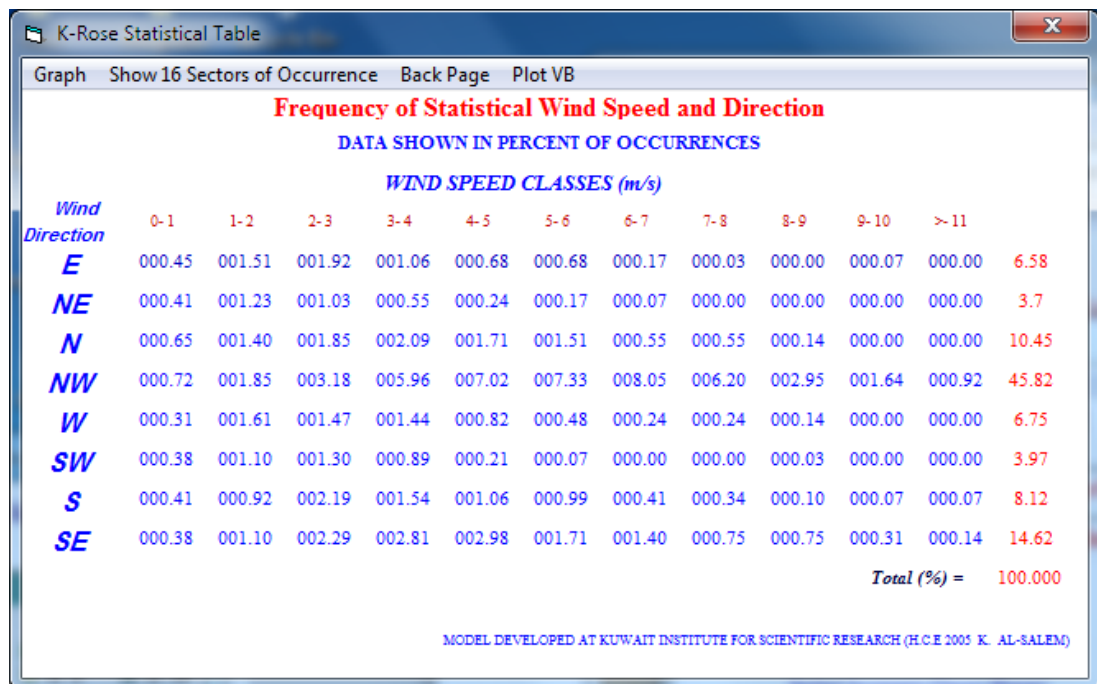


Figure 120

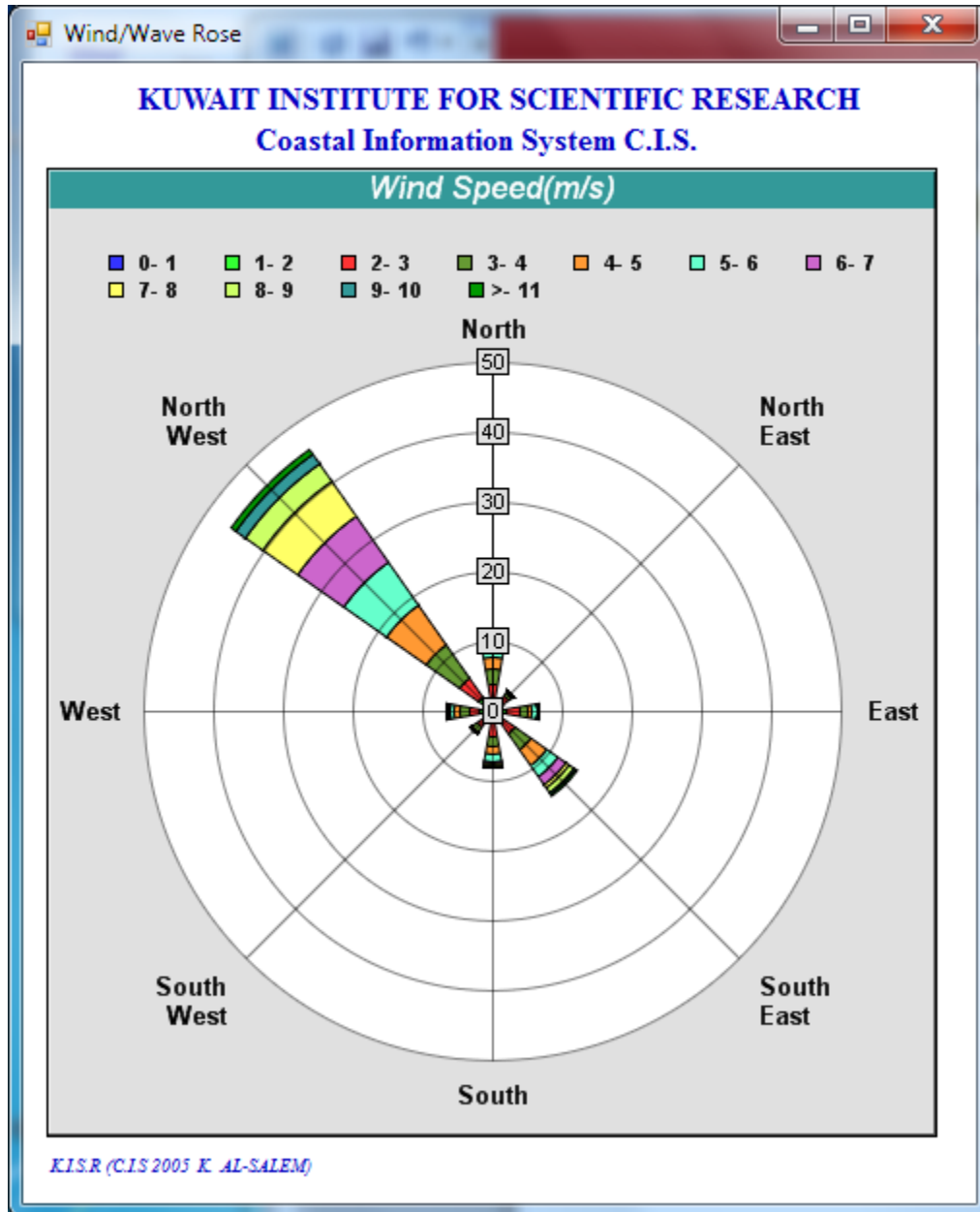


Figure 121

Sub-Option 2

11.2 Extracting Significant Wave Height For Rose Plot

If Select to plot Significant wave height data from Fig 117 user must select or any Wave Data analysis sub-Program all Linked with the **KROSE Program**.

Fig 122 will display for user to Extract Wave Data as follow:

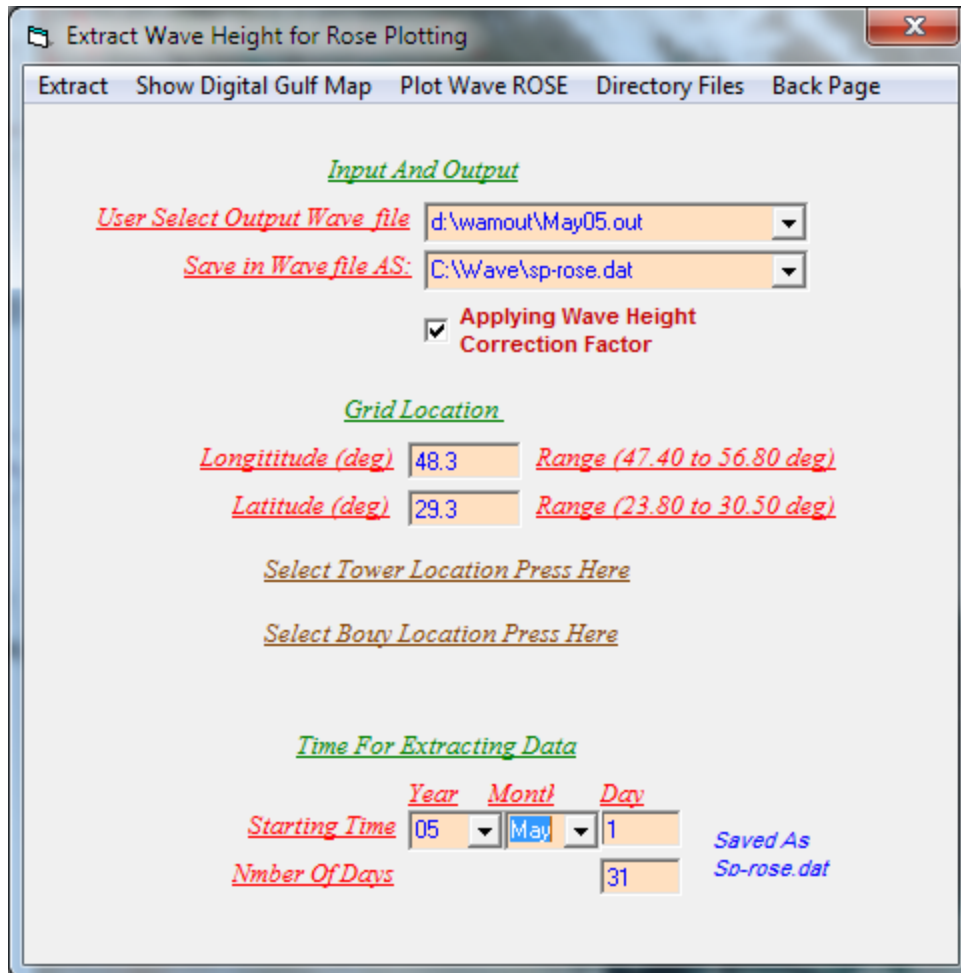
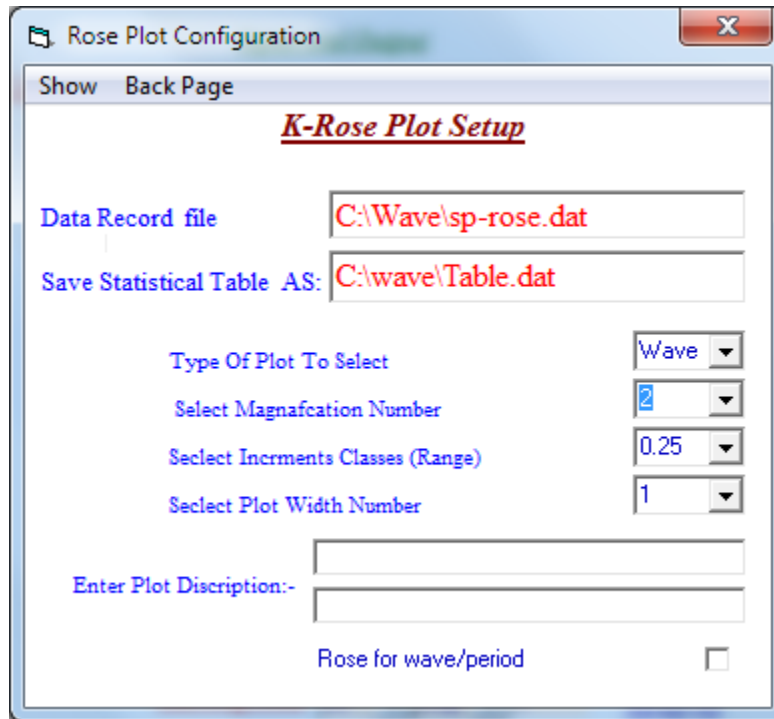


Figure 122

User must Select [Plot Wave Rose] from Fig 122. Then Fig 123 will display for user to enter the Rose Plot Configuration information require.

Fig 123 it part of KROSE program it linked with all Wave data Data Analysis in The C.I.S System. Then To; display the Result [*Frequency of Statistical Wind Seep and Direction Table*] by Select [**Show**] in fig123. Fig 124 will display. To Display Rose Plot Select [**Graph**] in Fig 124 Fig 121 will display in new window as Rose Plot as in Fig 125.



Rose Plot Configuration

Show Back Page

K-Rose Plot Setup

Data Record file: C:\Wave\sp-rose.dat

Save Statistical Table AS: C:\wave\Table.dat

Type Of Plot To Select: Wave

Select Magnafcation Number: 2

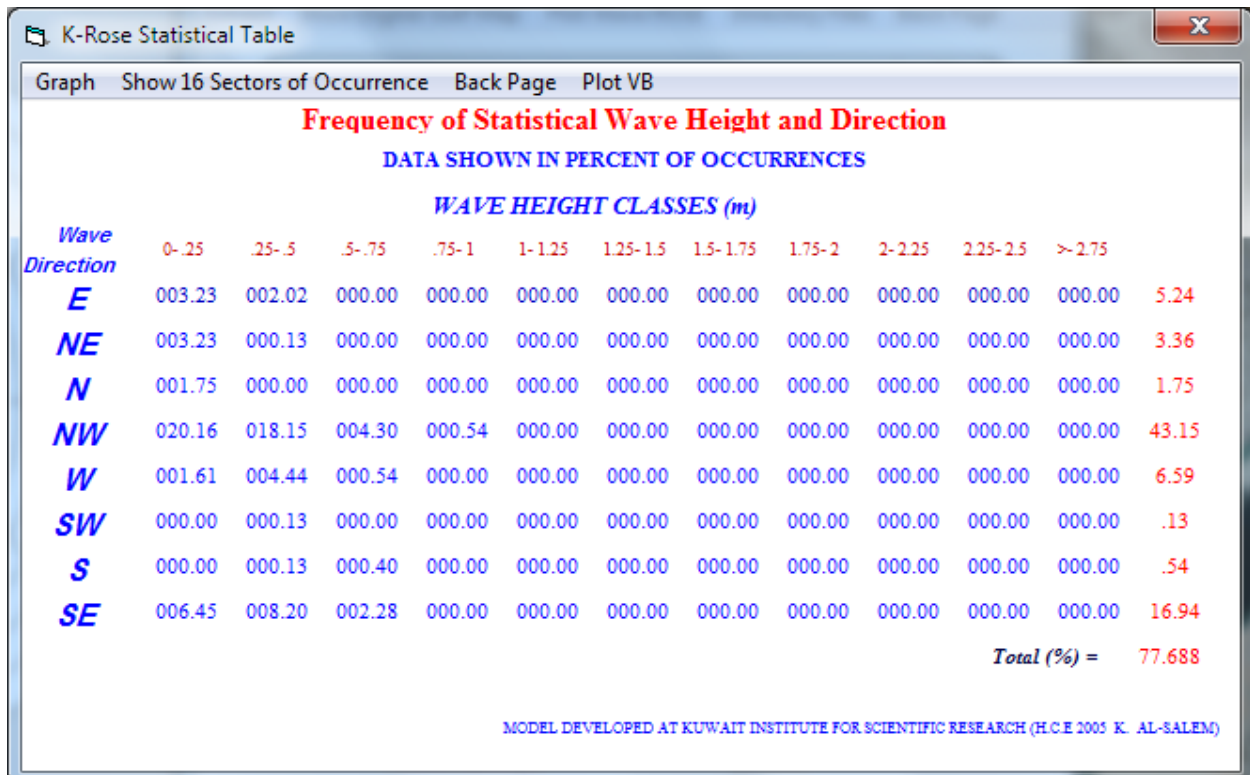
Select Incrments Classes (Range): 0.25

Select Plot Width Number: 1

Enter Plot Discription:-

Rose for wave/period

Figure 123



K-Rose Statistical Table

Graph Show 16 Sectors of Occurrence Back Page Plot VB

Frequency of Statistical Wave Height and Direction

DATA SHOWN IN PERCENT OF OCCURRENCES

WAVE HEIGHT CLASSES (m)

Wave Direction	0-.25	.25-.5	.5-.75	.75-1	1-1.25	1.25-1.5	1.5-1.75	1.75-2	2-2.25	2.25-2.5	>-2.75	
E	003.23	002.02	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	5.24
NE	003.23	000.13	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	3.36
N	001.75	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	1.75
NW	020.16	018.15	004.30	000.54	000.00	000.00	000.00	000.00	000.00	000.00	000.00	43.15
W	001.61	004.44	000.54	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	6.59
SW	000.00	000.13	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	.13
S	000.00	000.13	000.40	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	.54
SE	006.45	008.20	002.28	000.00	000.00	000.00	000.00	000.00	000.00	000.00	000.00	16.94
Total (%) =											77.688	

MODEL DEVELOPED AT KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH (H.C.E 2005 K. AL-SALEM)

Figure 24

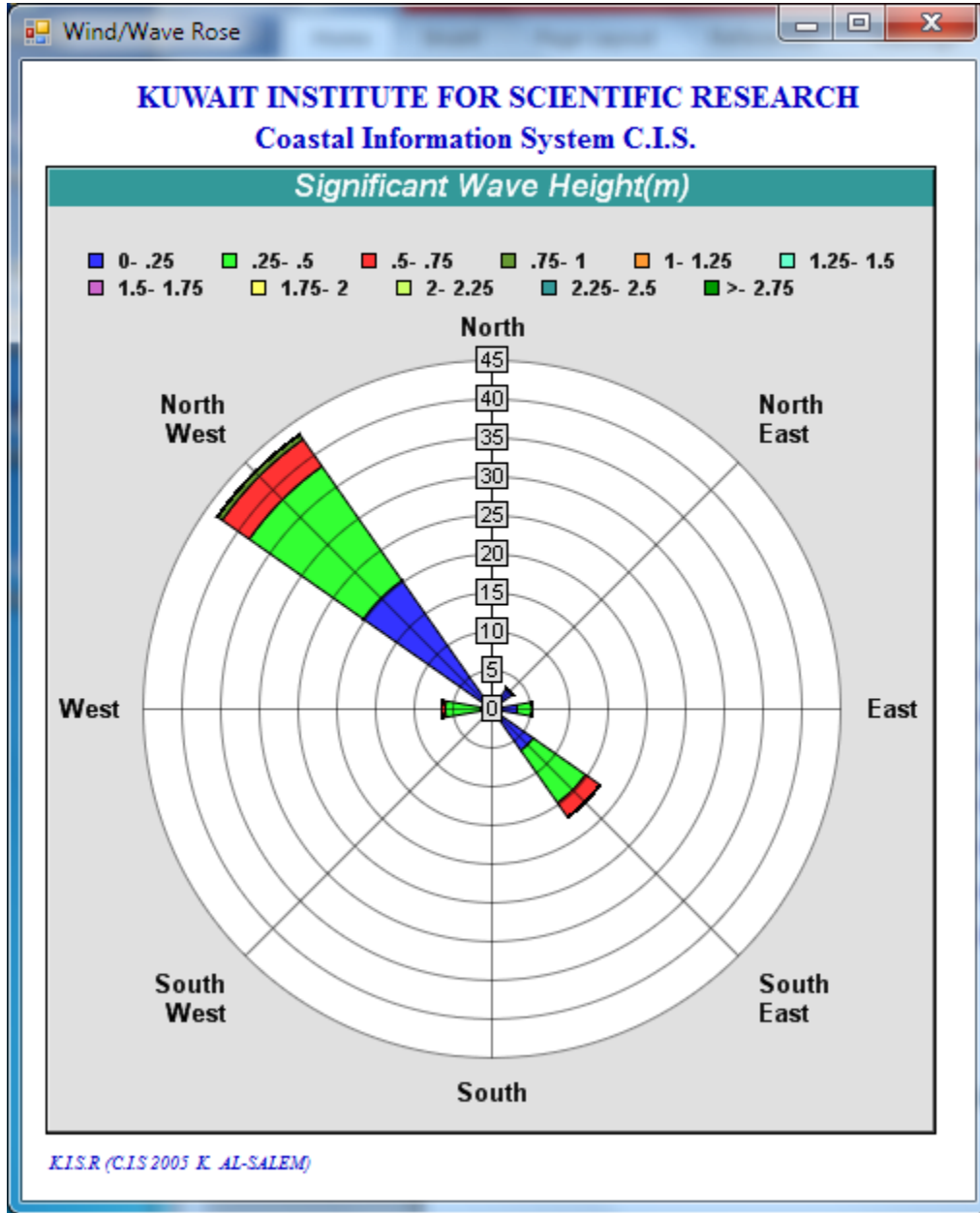


Figure 125

12. Long Term for Extreme Wind/Wave Prediction

Methodology used in [LPT model Developed by Al-Salem 2005] Analysis

The Gumbel and Weibull distribution was used for the extreme value prediction. The input data point selection was done using the POT method with a 1 m threshold wave height. The data points for each location are arranged in the descending order. The probability of exceedence, Q is calculated using the formula

$$Q = \frac{(i - c_1)}{(N + c_2)} \quad (11)$$

where i is the Rank, N is the total number of data points, and the constants c_1 and c_2 are as follows,

$c_1=0.44$ and $c_2 = 0.12$ for Gumbel distribution

$c_1=0.20 + (0.27/\alpha)$ and $c_2 = 0.20 + (0.23/\alpha)$ for Weibull distribution,

where α is a shape parameter that varies from 0.8 to 1.3.

The detailed description of Gumbel and Weibull distribution can be found from many sources (for example, see Kamphuis (2000)). For the purpose of quick reference and use for the readers, the salient details of these distributions are provided below.

Gumbel distribution

The Gumbel distribution is described by

$$P = e^{-e^{\frac{(H-\gamma)}{\beta}}} \quad (12)$$

where

P is the probability of non exceedence ($P=1-Q$), γ is a location parameter and β is a scale parameter.

Eq. 3 can be linearised by taking logs on both sides twice resulting in,

$$-\ln \left[\ln \left(\frac{1}{P} \right) \right] = \frac{(H - \gamma)}{\beta} \quad (13)$$

The L.H.S. of Eq. 4 is called the reduced variate of the Gumbel distribution.

For the data set described, a least square best line fit is made and the value of β and γ is obtained from the slope and intercept of the best line fit.

Weibull distribution

The Weibull distribution is a three parameter distribution described by,

$$P = e^{-\left(\frac{H-\gamma}{\beta}\right)^\alpha} \quad (14)$$

This may also be expressed as,

$$Q = e^{-\left(\frac{H-\gamma}{\beta}\right)^\alpha} \quad (15)$$

For the purpose of linear transformation, taking logarithm on both sides and after reorganization the following is obtained,

$$\left[\ln \left(\frac{1}{Q} \right) \right]^{\frac{1}{\alpha}} = \frac{(H - \gamma)}{\beta} \quad (16)$$

The L.H.S. of Eq. 7 is called the reduced variate of the Weibull distribution.

Again, for the data set described, a least square best line fit is made and the value of β and γ is obtained from the slope and intercept of the best line fit. The shape parameter α is varied from 0.8 to 1.3 with an increment of 0.05. The value of α , which gives best fit for the data, is selected (based on the highest value of correlation coefficient).

Prediction of Wave Heights for Specified Return Periods

The return period, T_R and the probability of exceedence are linked by the following expression:

$$Q = \frac{1}{lT_r} \quad (17)$$

where l is the number of events per year. For the present study, the total number of storm events exceeding threshold value of $H_s = 1.0$ m for each location is known. Since the data is for a total duration of 12 years, the value of l can be easily calculated.

According to Gumbel distribution, the wave height expected for a selected return period H_{TR} can be estimated from,

$$H_{TR} = \gamma - \beta \ln \left[\ln \left(\frac{1}{P} \right) \right] = \gamma - \beta \ln \left[\ln \left(\frac{lT_R}{lT_R - 1} \right) \right] \quad (18)$$

According to the Weibull distribution, the wave height expected for a selected return period H_{TR} can be estimated from the following formula:

$$H_{TR} = \gamma + \beta \left[\ln \left(\frac{1}{Q} \right) \right]^{\frac{1}{\alpha}} = \gamma + \beta \left[\ln(lT_R) \right]^{\frac{1}{\alpha}} \quad (19)$$

To run Extreme Wind/Wave Analysis program user must select option shown in Fig 125. Where a number of model Sub-Option are list as follows:

- I. Extreme Wind speed / Wave height Prediction [Based on Monthly Max].
- II. Extreme Wind speed/Wave height Prediction [Based on Threshold Value]
- III. Extreme Wind speed / Wave height Prediction [Airport Monthly Data].

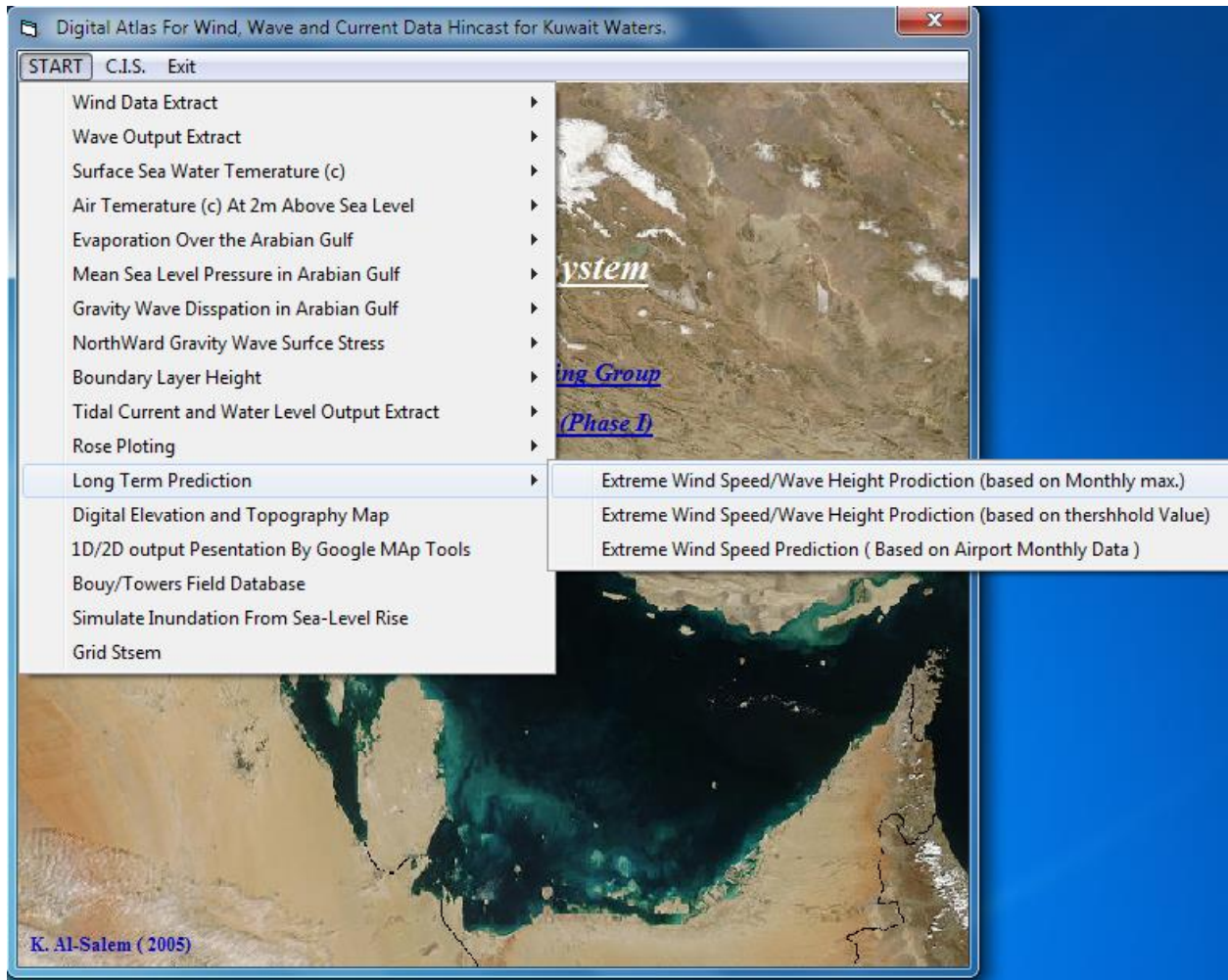


Figure 126

Sub-Option 1

12.1 Extreme Wind speed / Wave height Prediction [Based on Monthly Max].

If user select from Fig 126 the extreme wind/wave analysis based on monthly max data generate for C.I. Interface. Figure 127 will display for user to select the parameter for extreme analysis

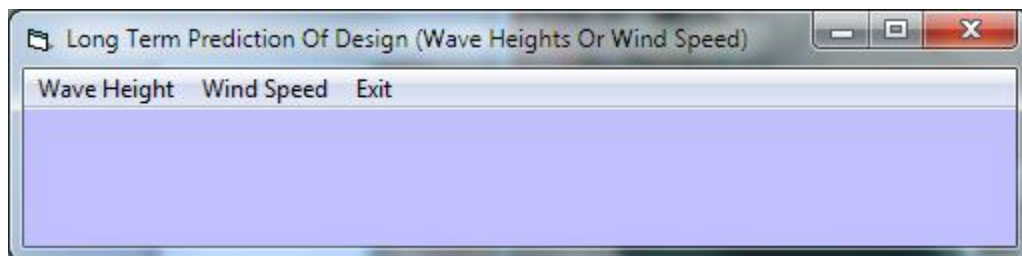


Figure 127

If user Select Wind Speed Analysis from Fig 127,

Figure 128 will display. User must enter the input information as follows:

1. *Name of output file name*
2. *Number of year to extract for analysis [Start from 1979 to 2018] about 40*
3. *Grid location [Longitude/Latitude]*
4. *Name of Directory where Wind Speed Database Stored in*

Then User must select [**Extract**] to load the select data.

Then user must select [**LT Probality**] to start program. Fig 129 will display to user a number on Distribution analysis to select as follow:

- *Gumble Distribution*
- *Fretchet Distribution*
- *Weibull Distribution*

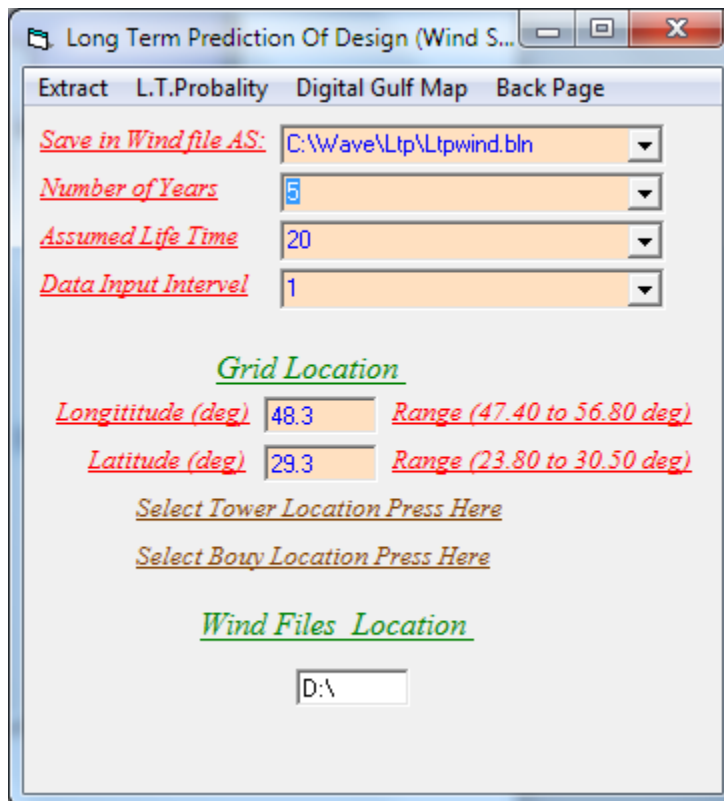


Figure 128

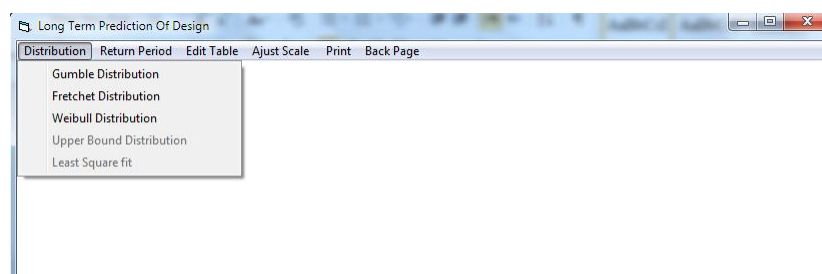


Figure 129

Example If Gumell distribution was selected

If user select Gumbell distribution from [*Distribution*] as in Fig 129.

Fig 130 and 131 will display for user all information need as follow:

- Get the analysis data Line Equation Fig 130.
- Edit the simulation output file [*Edit Table*]. Fig 130.
- Can Plot the [*Return Period*] of [12, 25, 50, 100 years] with corresponding wind speed Fig 130
- Get a corresponding Wind speed by select the probability value from dropdown list in Fig 131
- Get any Corresponding Information from select [Return Period TR year] in Fig 131 to get the following:
 - The Probability value of occurrences
 - Extreme Wind Seep (m/s)
 - Encounter Probability value

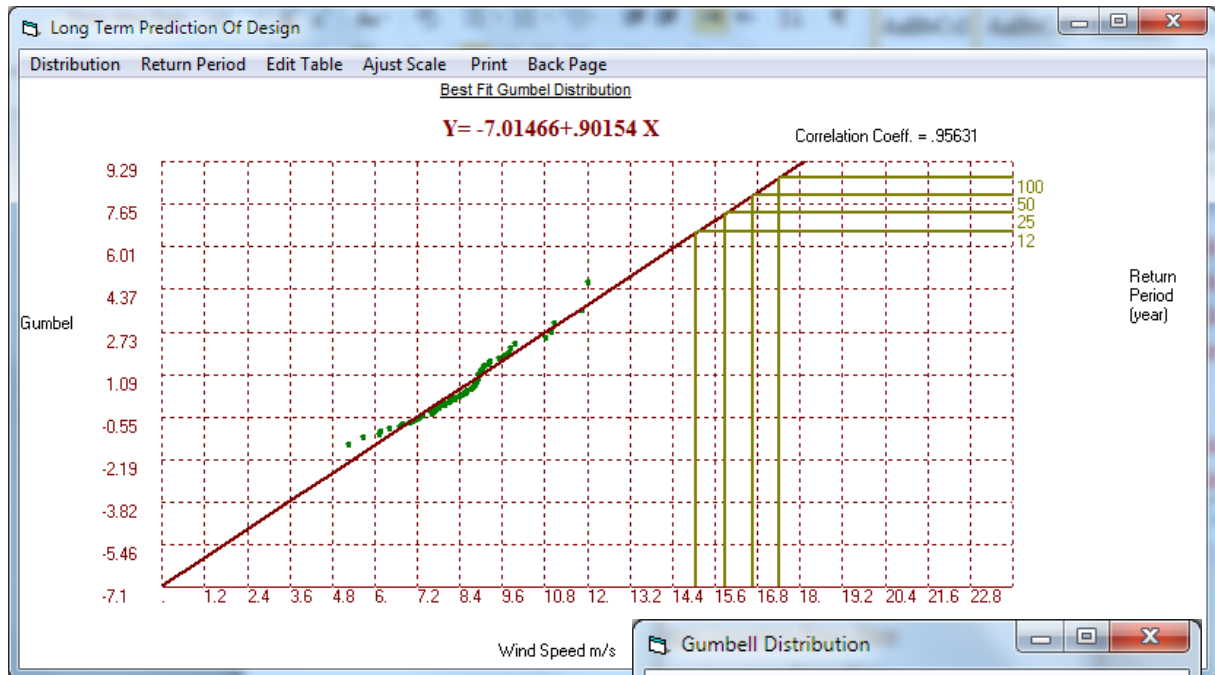


Figure 130

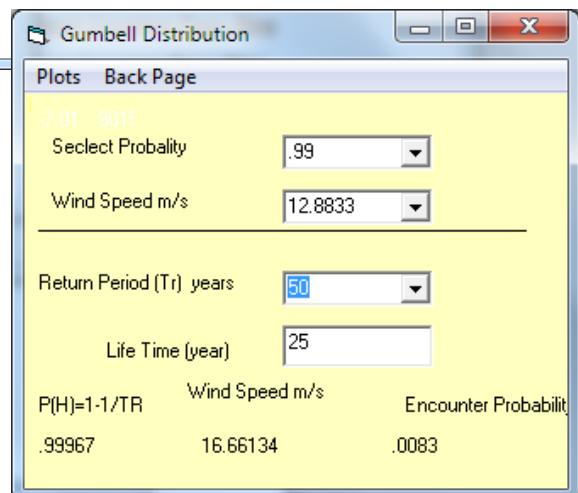


Figure 131

If user Select Wave Analysis from Fig 127.

Figure 132 will display. User must enter the input information as follows:

1. Name of output file name
2. Variables Selection to Extract
3. Number of year to extract for analysis
4. Grid location [Longitude/Latitude]
5. Start day/month/year time in a day
6. End day/month/year time in a day

Then User must select [**Extract**] to load the select data.

Then user must select [**LT Probality**] to start program. Fig 133 will display to user a number on Distribution analysis to select as follow:

- Gumble Distribution
- Fretchet Distribution
- Weibull Distribution

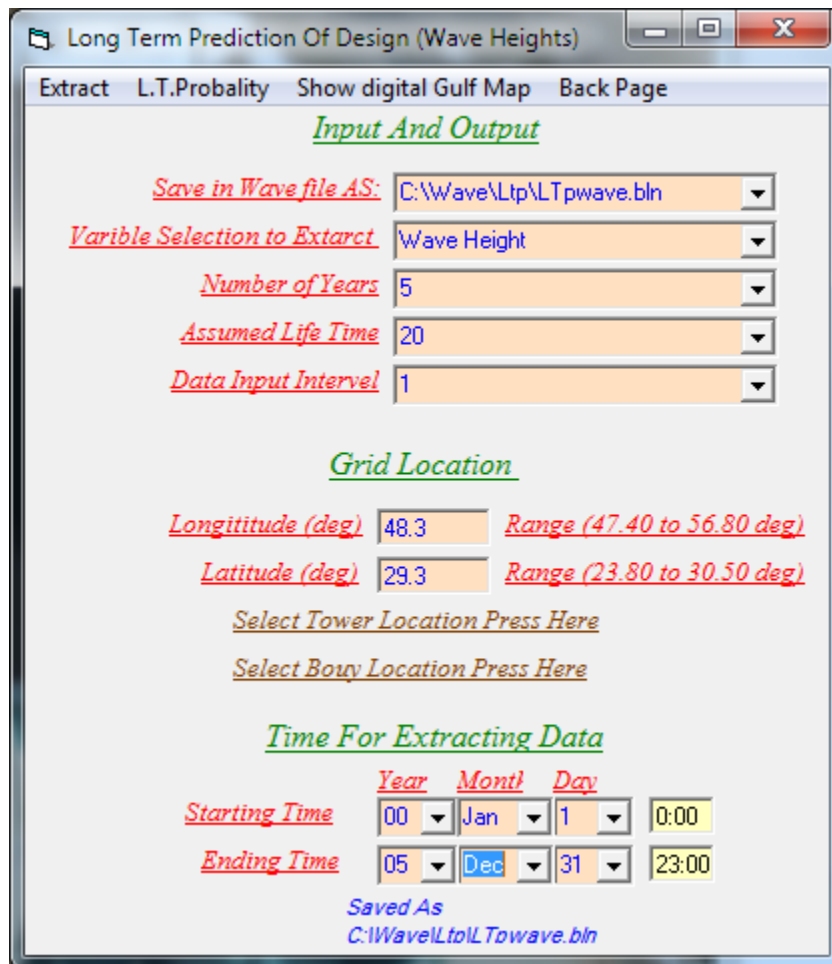


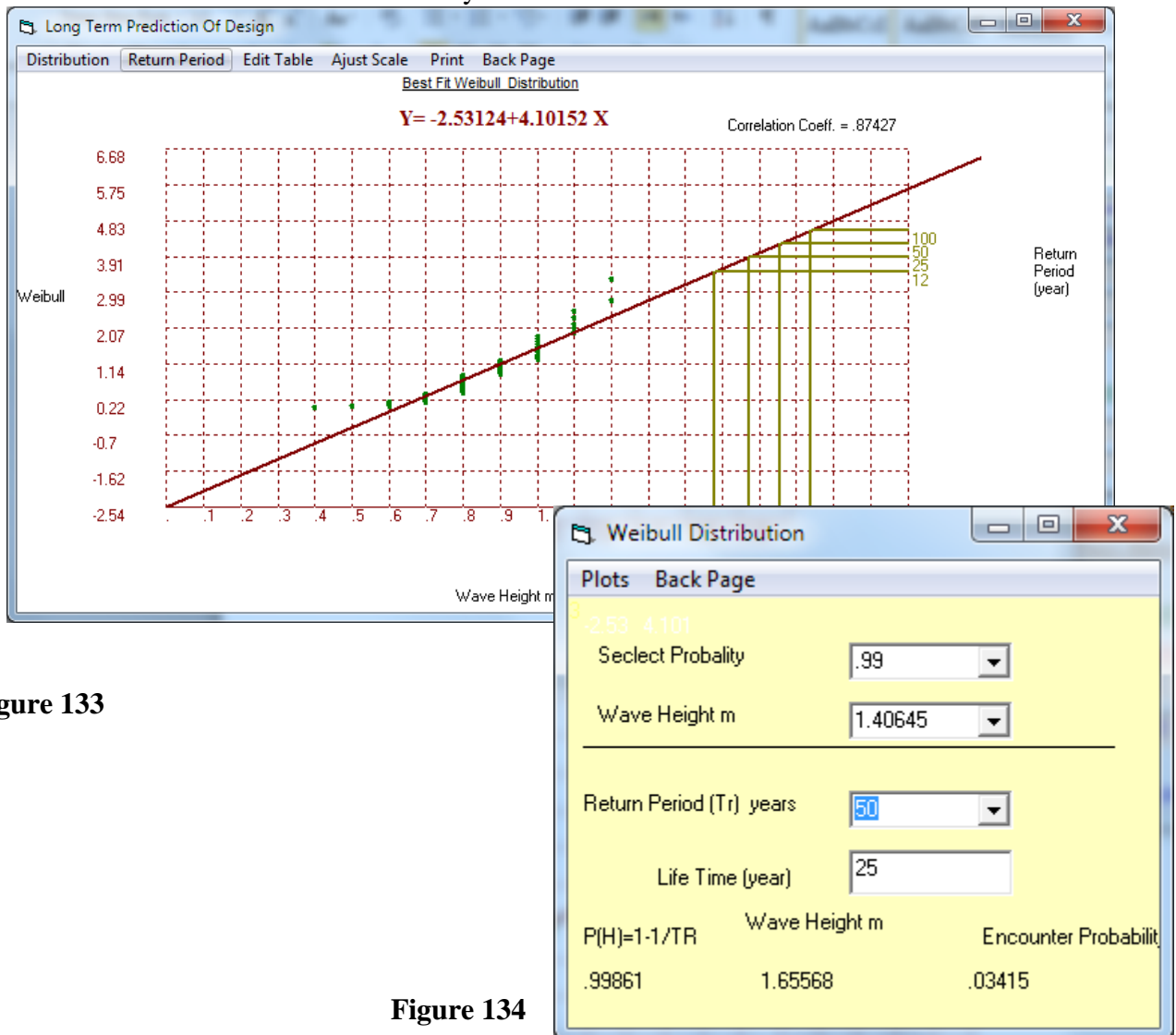
Figure 132

Example If Weibull Distribution was selected

If user select Weibull distribution from [*Distribution*] as in Fig 133.

Fig 133 and 134 will display for user all information need as follow:

- Get the analysis data Line Equation Fig 133.
- Edit the simulation output file [*Edit Table*]. Fig 133.
- Can Plot the [*Return Period*] of [12, 25, 50, 100 years] with corresponding extreme Wave Height(m) Fig 133
- Get a corresponding Extreme Wave height (m) by select the probability value from dropdown list in Fig 134
- Get any Corresponding Information from select [Return Period TR year] in Fig 134 to get the following:
 - The Probability value of occurrences
 - Extreme Wave Height (m)
 - Encounter Probability value



Sub-Option 2

12.2 Extreme Wind speed/Wave height Prediction [Based on Threshold Value]

If user select from Fig 126 the extreme wind/wave analysis based on thresholds value data generate from C.I. Interface. Figure 135 will display for user to select the parameter for extreme analysis

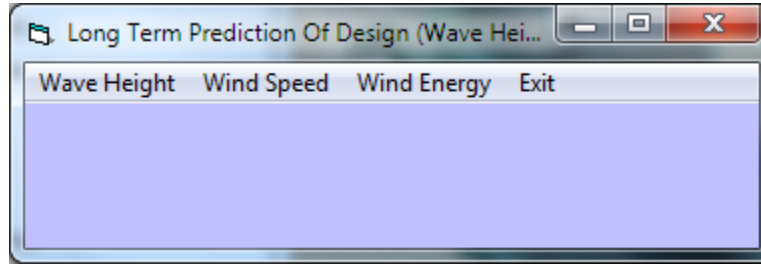


Figure 135

If user Select Wind Speed Analysis from Fig 135.

Figure 136 will display. User must enter the input information as follows:

1. *Name of output file name*
2. *Number of year to extract for analysis*
3. *Grid location [Longitude/Latitude]*
4. *Select time data option*
 - *Check All Database [1979 to 2018]*
 - *Check Random File [Data file not from CIS database]*
 - *Check Select wind Data time limit [user enter start year year/End year]*

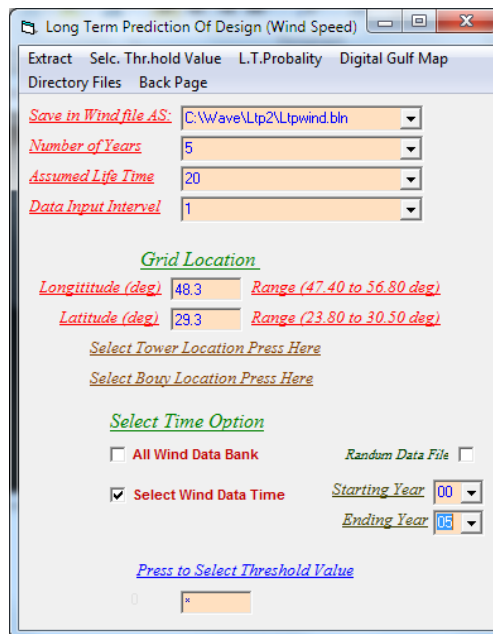


Figure 136

Then User select [**Extract**] from Fig 136.

Then when Extract Finished user must select [**Selec Thr.Hold Value**] a new threshold value will appear as in Fig 137.

User can modify the threshold value by [**Press to Select Threshold Value**]. New Screen will display for user as in Fig 138.

In Fig 138 user should reload data with inial threshold value to plot by select [**Wind**].

If user wants change the threshold value as follows:

1. Change the threshold value in fig 138
2. Select [**Wind**] to update the wind data with new threshold value.

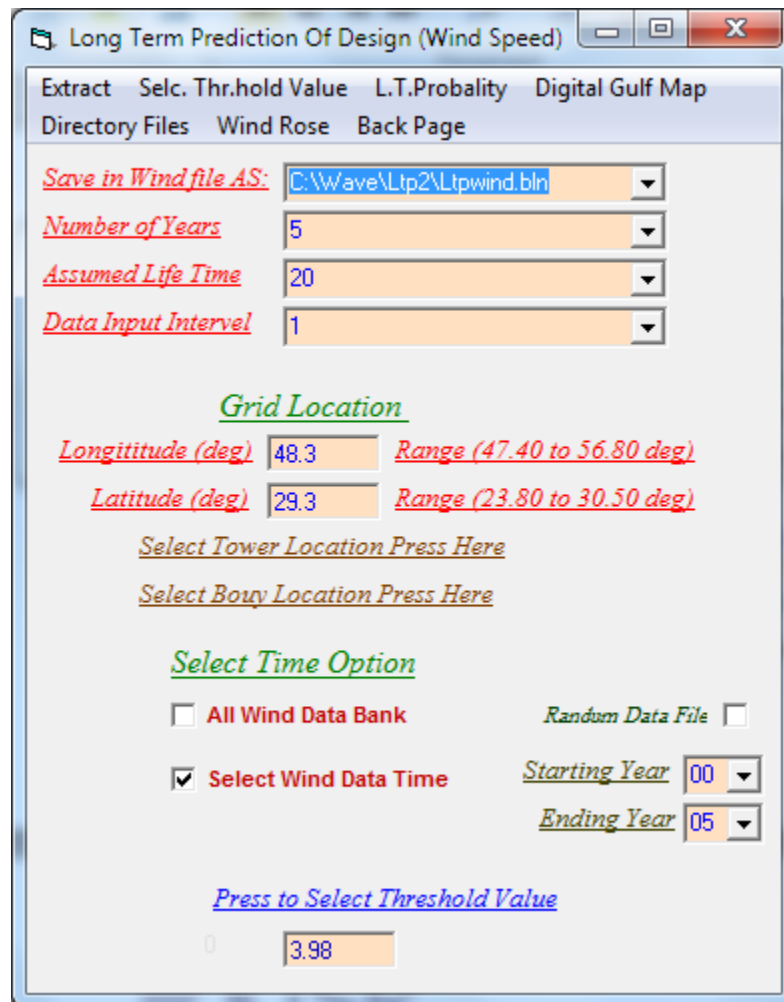


Figure 137

Then user must select [**LT Probability**] from 137 to start program. Fig 139 will display to user a number on Distribution analysis to select as follow:

- Gumble Distribution
- Fretchet Distribution
- Weibull Distribution

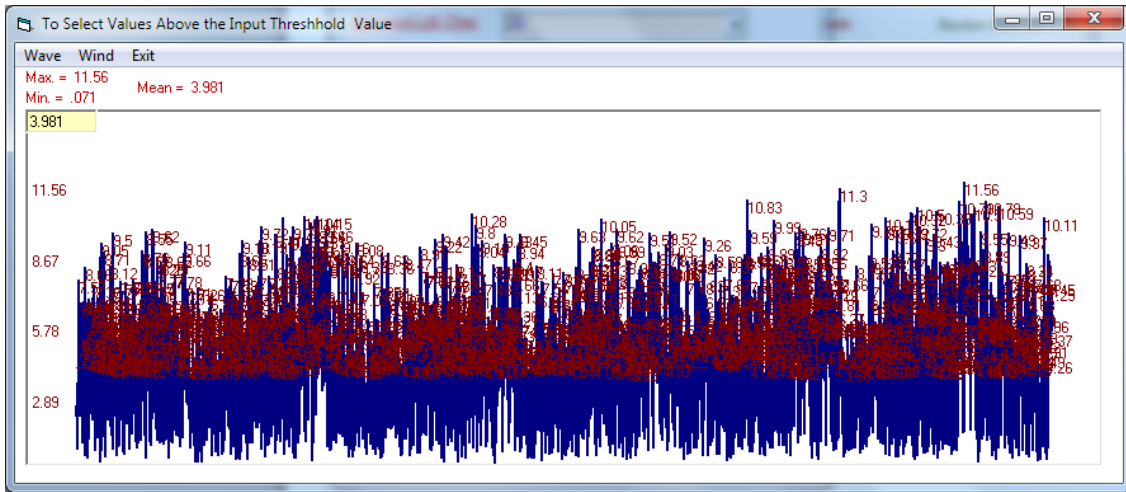


Figure 138

Example If Gumell distribution was selected

If user select Gumbell distribution from [*Distribution*] as in Fig 139.

Fig 139 and 140 will display for user all information need as follow:

- Get the analysis data Line Equation Fig 139.
- Edit the simulation output file [*Edit Table*]. Fig 139.
- Can Plot the [*Return Period*] of [12, 25, 50, 100 years] with corresponding wind speed Fig 130
- Get a corresponding Wind speed by select the probability value from dropdown list in Fig 140
- Get any Corresponding Information from select [*Return Period TR year*] in Fig 140 to get the following:
 - The Probability value of occurrences
 - Extreme Wind Seep (m/s)
 - Encounter Probability value

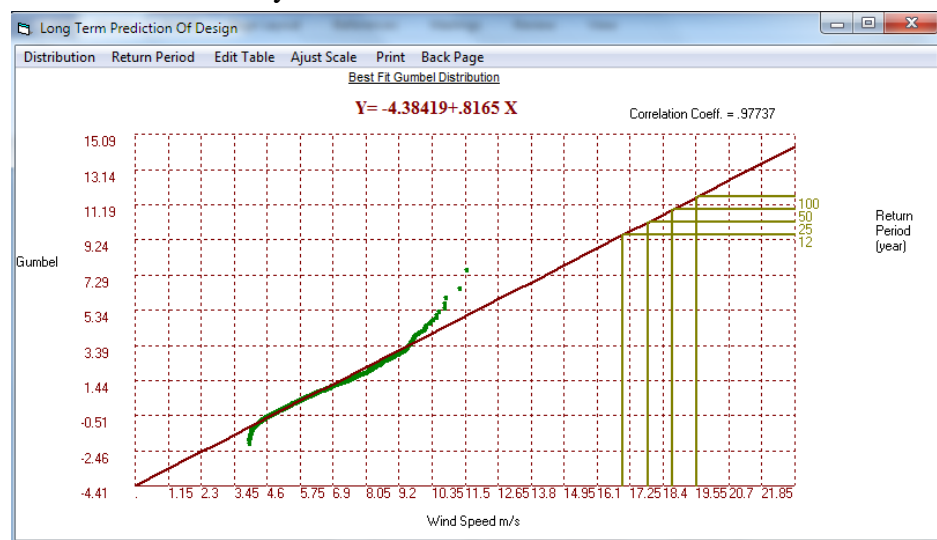


Figure 139

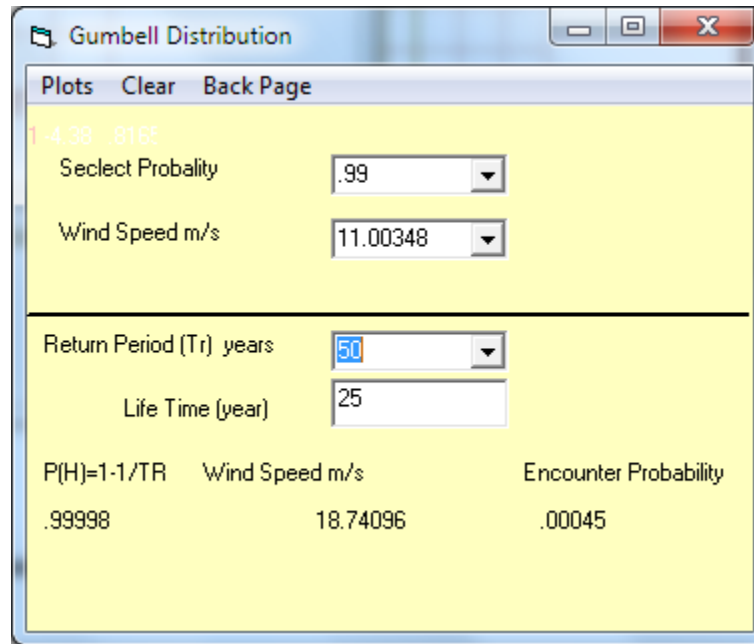


Figure 140

If user Select Wave Height Analysis from Fig 135.

Example If Weibull Distribution for Wave Height Analysis

[Same analysis description in Sub- Option 2 of section 12]

Sub-Option 3

12.3 Extreme Wind speed / Wave height Prediction [Airport Monthly Data].

[Same analysis description in Sub- Option 1 of section 12]

13. Digital Bathymetry and Topography for Arabian Gulf [AGbath model]

Kuwait Topographic and Bathymetric data

Different-high resolution satellite images and topography and bathymetry data were used. The images were either purchased or obtained from any available free source. The images were processed to obtain a new set of satellite-derived bathymetry and land elevation. The data were from local digitized navigational charts and free data available from different sources. Both data were used to create seamless elevation and bathymetry map of the Arabian Gulf region and part of the Indian Ocean/ Arabian Sea. The new data were created after interpolating (preserving the original data values), resampling, clipping, and post processing of six original data as shown subsequently:

- Satellite Derived Bathymetry for shallow water South of Kuwait Bay, 10 m grid.
- CM93 chart data (contour lines and points in various resolutions).
- GEBCO bathymetry, 30 s grid.
- Stereo Surface Model for Kuwait coastal area, 5 m grid.
- SRTM surface elevation data, 90 m grid.
- Coastline from spring 2016 (based on 10 m satellite data).

Table 2 provides the details of the data source used in this study

Table 2. Details of Different Kinds of Data Source for the Development of Digital Elevation Map

Description	Resolution	Coverage	(Satellite) Data Source
Digital Surface Model (DSM 5m)	5 m	3-km buffer to the inland from the Kuwaiti coastline	IRS P5
Satellite Derived Bathymetry	10 m	Kuwaiti shallow waters (5-12 m) from south of Kuwait to Saudi Arabia and coral atolls in the Gulf	Sentinel 2A
Satellite Derived Bathymetry	Contours	Areas in the Arabian Gulf which were purely charted	
Coastline	10 m	Entire Gulf region	Sentinel 2A
CM93	Points/Contours	Entire Gulf region	CM93
SRTM	90 m	Gulf region, excluding the areas of DSM 5 m	SRTM mission
GEBCO	30 arc seconds	Entire study area but excluding the area where other, higher resolution data were used	Gridded data based on survey data

Development Method of Digital Elevation Map

To create a seamless elevation model, different kinds of data sources were used and finally interpolated together to create the Digital Surface Model (DSM)/elevation. For the Kuwaiti area 5-m spatial resolution DSM was created for the coastal area as well as a shallow water bathymetric grid with 10-m spatial resolution was created. It is worth noting that all of the satellite data calibration was carried out with respect to the standards provided by the satellite

data provider. The measuring calibrated radiances were verified using the EOMAP radiative transfer model. The adjacency correction and sun glitter correction were done. The seafloor and water-depth calculations were performed using the WATCOR module suggested by [Heege et al. (2004) and Pinnel (2007)]. The transformation of subsurface reflectance to the seafloor albedo was based on the equations published by [Albert and Mobley (2003)].

By using the water spectra, it is possible to calculate the water column thickness and so the water depth, which can then be linked to a specific datum such as mean sea level (MSL). The 5-m DSM was created by a stereo image approach (Uttenthaler et al., 2013) using IRS P5 satellite image data. The process includes single scene stereo matching and disparity image check and bundle rational polynomial coefficient (RPC) correction. The intersection of each stereo pair image is set at 3-D points, representing the earth's surface including tree tops and buildings. The irregular point clouds are combined and converted to a regularly spaced grid with a spacing of 5 m. If the multiple points fall into the same grid cell, their heights would be calculated with median to form a new point. The remaining grids are filled with the Shuttle Radar Topography Mission (SRTM) data. This method was applied successfully in previous works at other sites [e.g., Siermann, 2014]. The 5-m DSM is accompanied by ortho layer with a World Geodetic System 84 (WGS84) Datum and the Universal Transverse Mercator (UTM) projection.

All of the source data were used as input for an interpolation method specifically designed for the creation of topographic DEMs. It is based on the Australian National University Digital Elevation Model (ANUDEM) program developed by [Hutchinson (1988)]. The satellite-derived shallow water bathymetric data were validated for vertical accuracies using the data from the single beam acoustic survey carried out data by KISR on 30 June 2016. The survey was done at clear coastal water along the southern coast of Kuwait. The comparison between field measured depth data and the derived depth data and is shown in Figure 2 as the model validation. The validation showed an overall good performance of the model. The horizontal accuracy of the 5-m grid was checked against very high-resolution optical image data (quick bird ortho mosaic) and showed an overall agreement of 3-m CE 90.

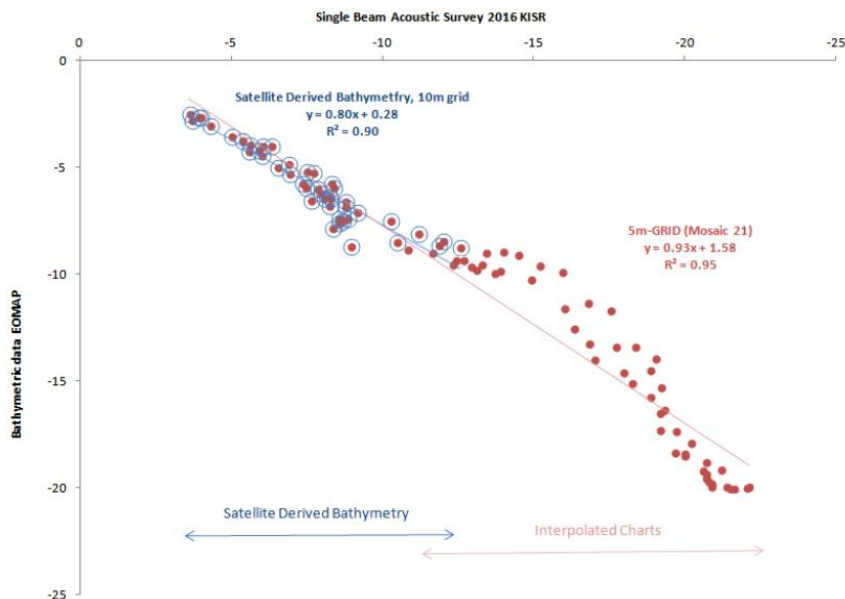


Figure 141. Validation of satellite-derived shallow water bathymetry and interpolated bathymetric data with the single beam acoustic data for southern Kuwait.

The sources of the Digital Bathymetry and topography data for Kuwait and Arabian Gulf Land/Waters Database used in [*AGbath Model Developed by Al-Salem 2016*]. *AGbath program* was linked with KISR digital elevation database In Coastal Information System Interface. From Fig 142 user active the *AGbath program*. Figure 143 will display for user the main page of *AGbath program* to start the model

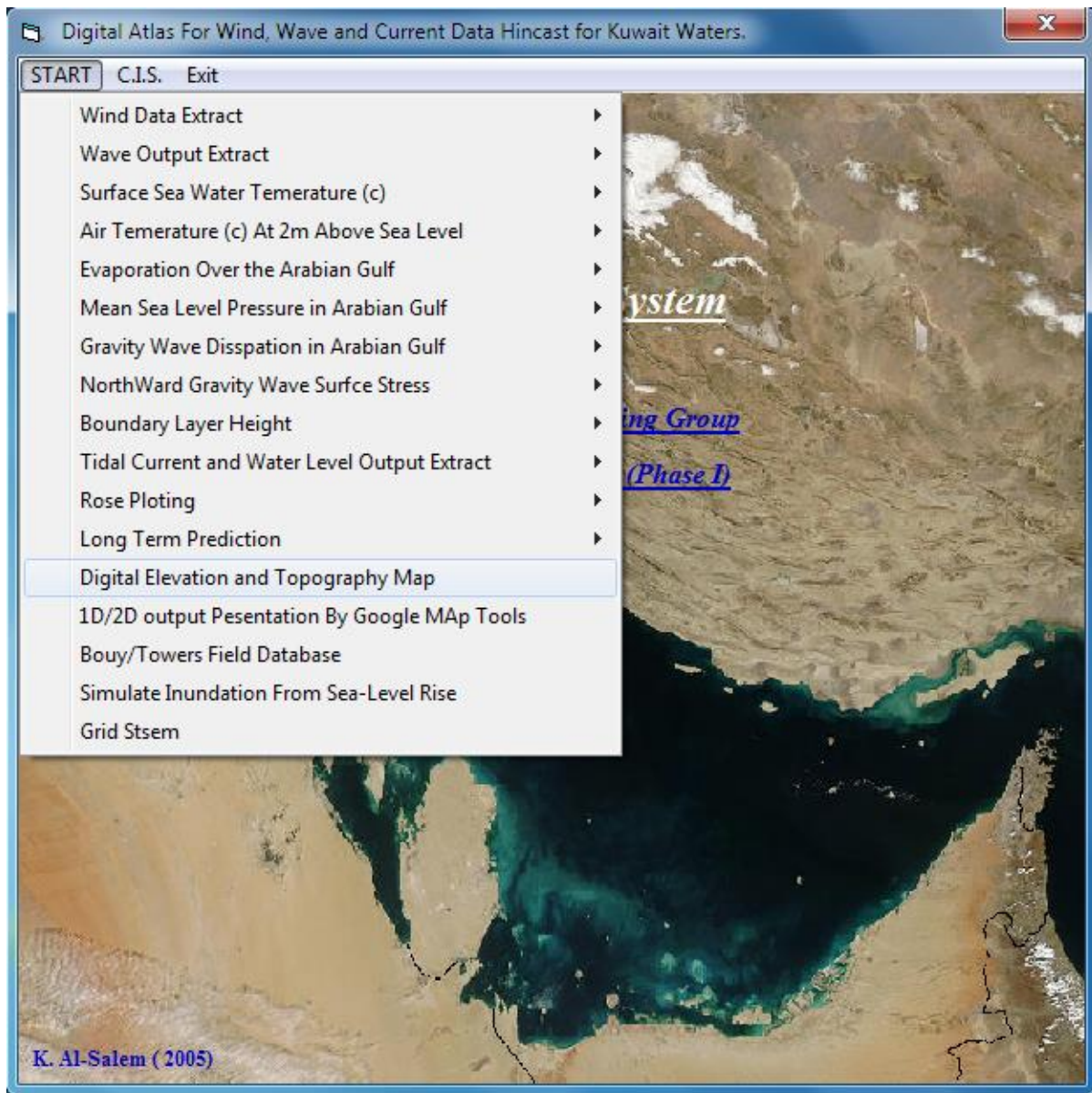


Figure 142

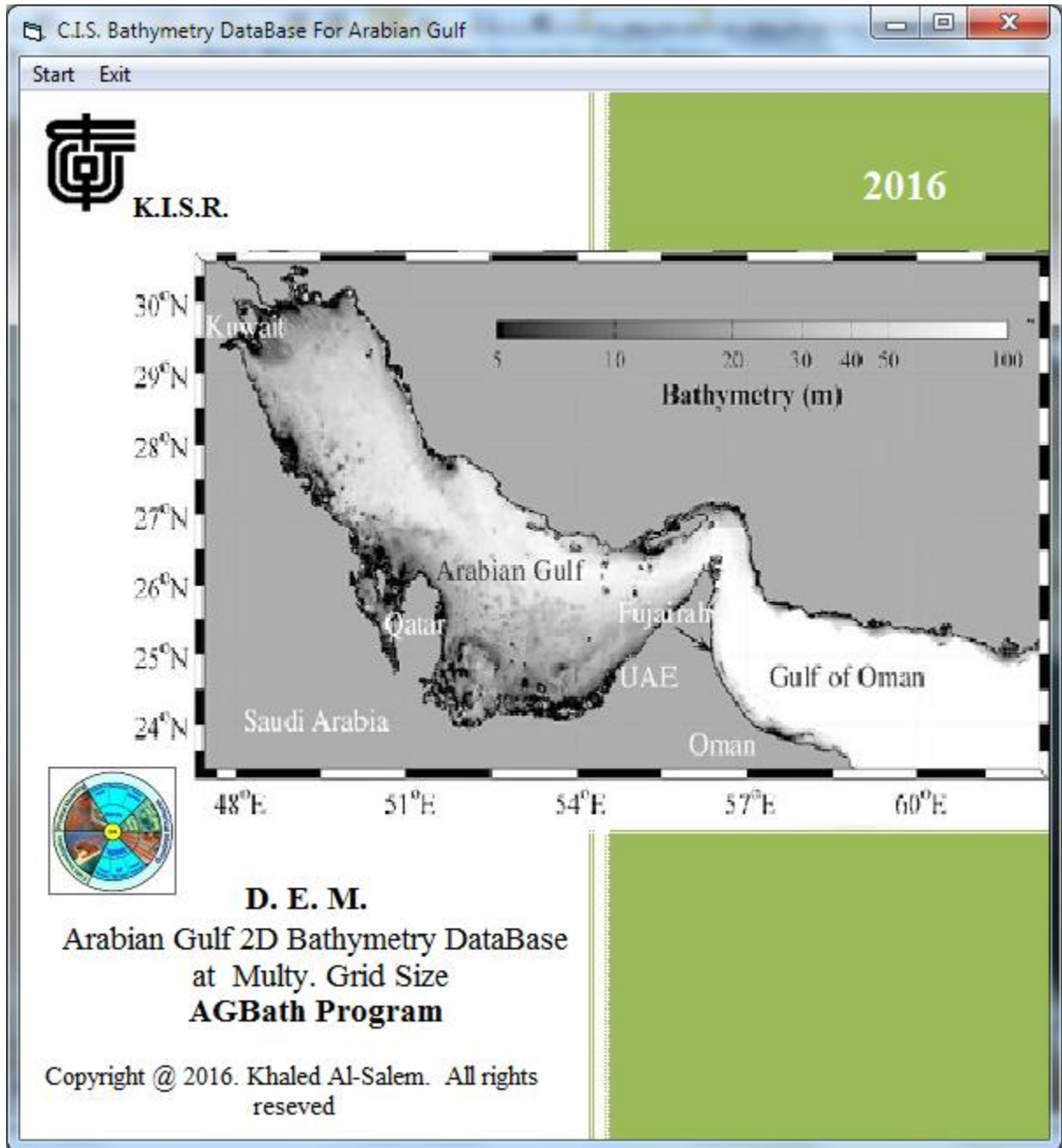


Figure 143

From Figure 143 user must select [*Start*] to Run the program. Figure 144 will display for user To start Enter the require information needed.

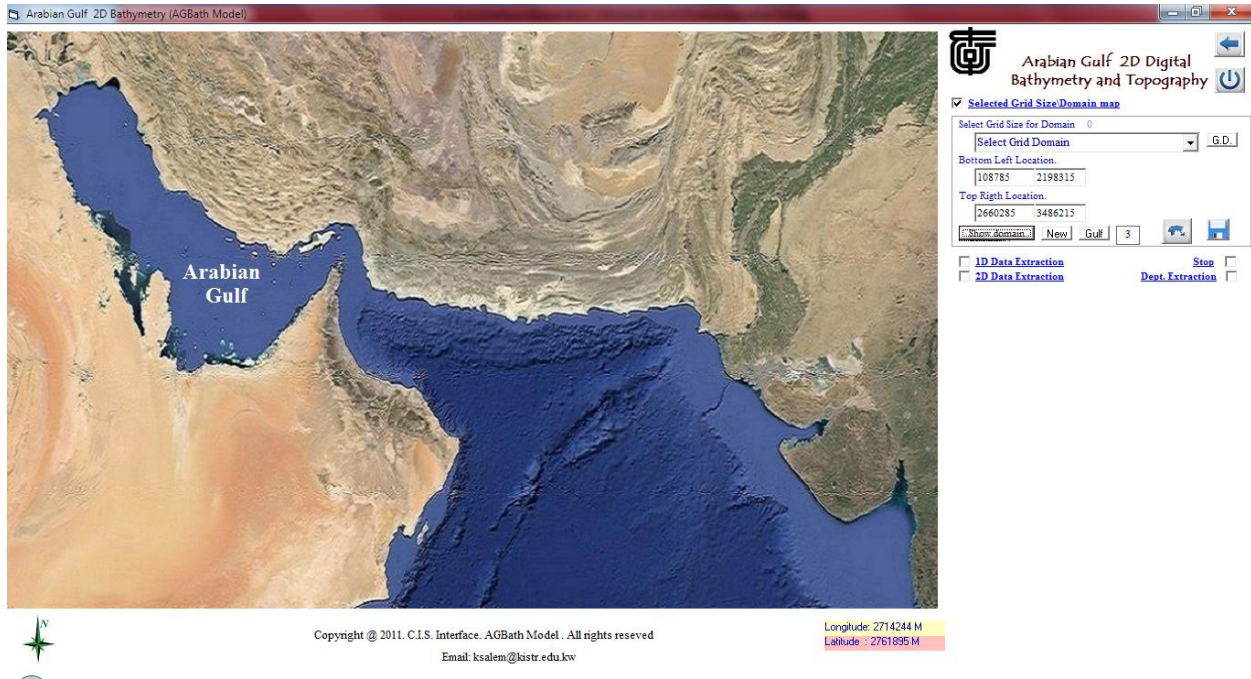


Figure 144

AGbath model has two options to extract Bathymetry data as follows:

1. Extract 1D bathymetry profile data for select Path line
2. Extract 2D bathymetry data for Select area

To start the program user must select the required digital bathymetry database area from Fig 144. As shown in the drop list option as in **[Select Grid Size for Domain]**. A list of sub-areas based on grid size varies from [1215 to 5 m] covering the Arabian Gulf and Gulf of Oman to Kuwait terminal waters. Then after area selected, information of the area will appear as follows:

- Lower left corner to upper right corner in UTM units.
- Total grids in longitude {NX} and total grid in latitude {NY}

Then to show the selected area by select **[Show Domain]**

To zoom in, user must select **[NEW]**. Then all information will clear. Then user must select lower left location by clicking on the map and upper right location by clicking on the map. Then select **[Show Domain]**

To replot the original domain, user select **[G.D]**

Then user selects the number of sub-options to use by checking the box listed in Fig 144

Bathymetry Data [**Negative values represent Water area Positive Values is Dry or land area**]

Sub_Option 1

[1D bathymetry profile]

User must select **[Show domain]** then check the box for **[1D Data Extracting]** as in Figure 144. Fig 145 will display with a new frame area for 1D Extracting Option.

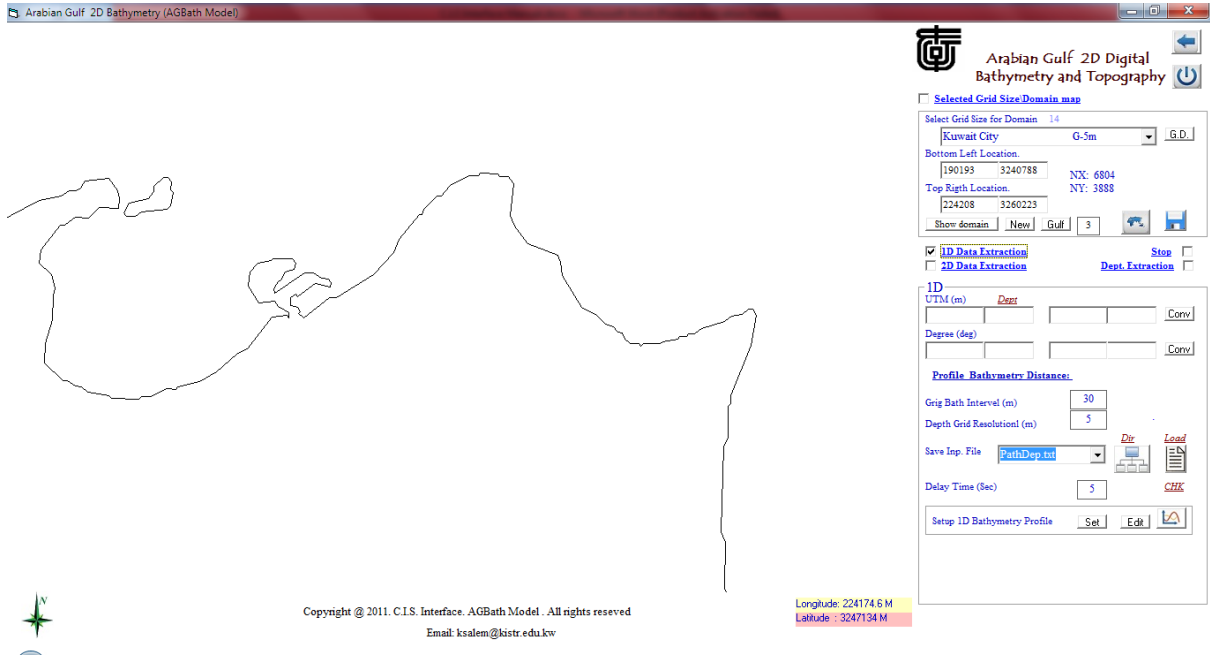


Figure 145

User now must select the path line were data will be extract as number of ways as follow:

- 1- by Click on the map Two click for Start Location And End Location
- 2- Manual enter start location and End Location has have two option as
 - Enetr inUTM [Conver to Degrees]
 - Enetr In Degrees [Convert to UTM]

Then if data location is finished and convert to Degree/UTM. User must select [**Profile bathymetry Distance**] to Calculate the profile length in meter as shown in Fig 146

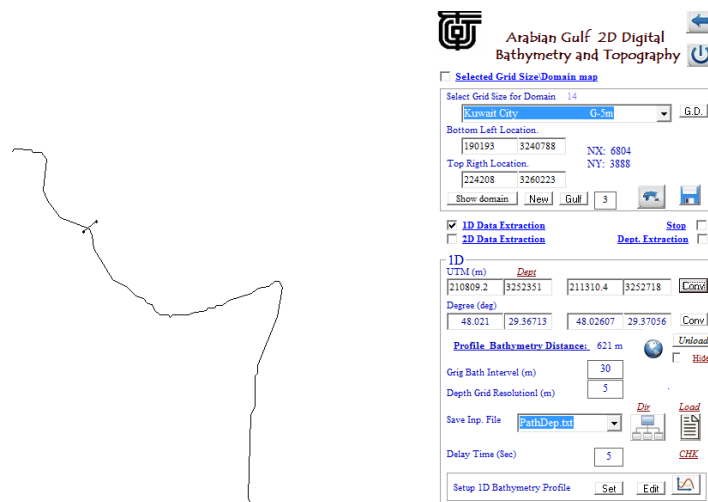


Figure 146

Then in Fig 146 user will see the following information as:

- Profile bathymetry Distance Value in meter
- Grid path interval (m). *User can Change the interval size*
- Grid Resolution Size (m) [Grid DX/DY]

To Display The Selected Profile path on Google map is select [] as Sown in Fig 147.
This option needed an *internet Connect is ON*

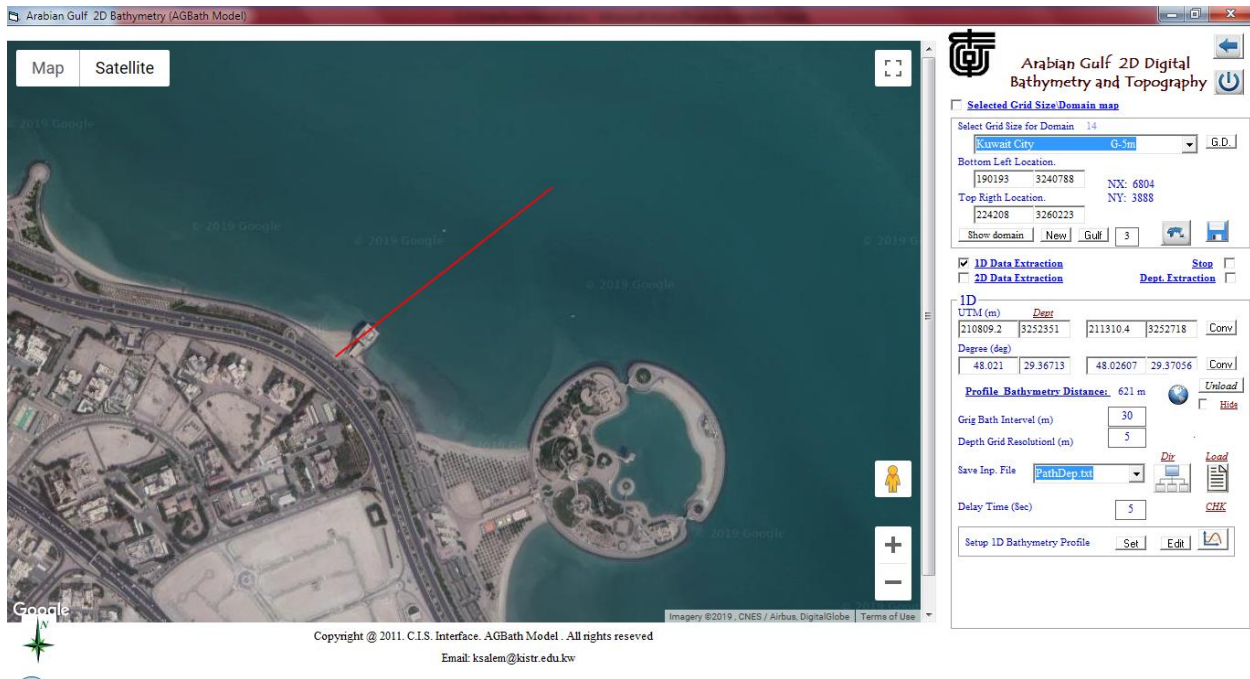


Figure 147

User must Setup the **output file name** where data will stored in


Then to start extract data user must select [] in Fig 146.

Figure 148 display plot of the select bathymetry profile as 1D plot.

Figure 149 display extract bathymetry file table data [*Edit*]

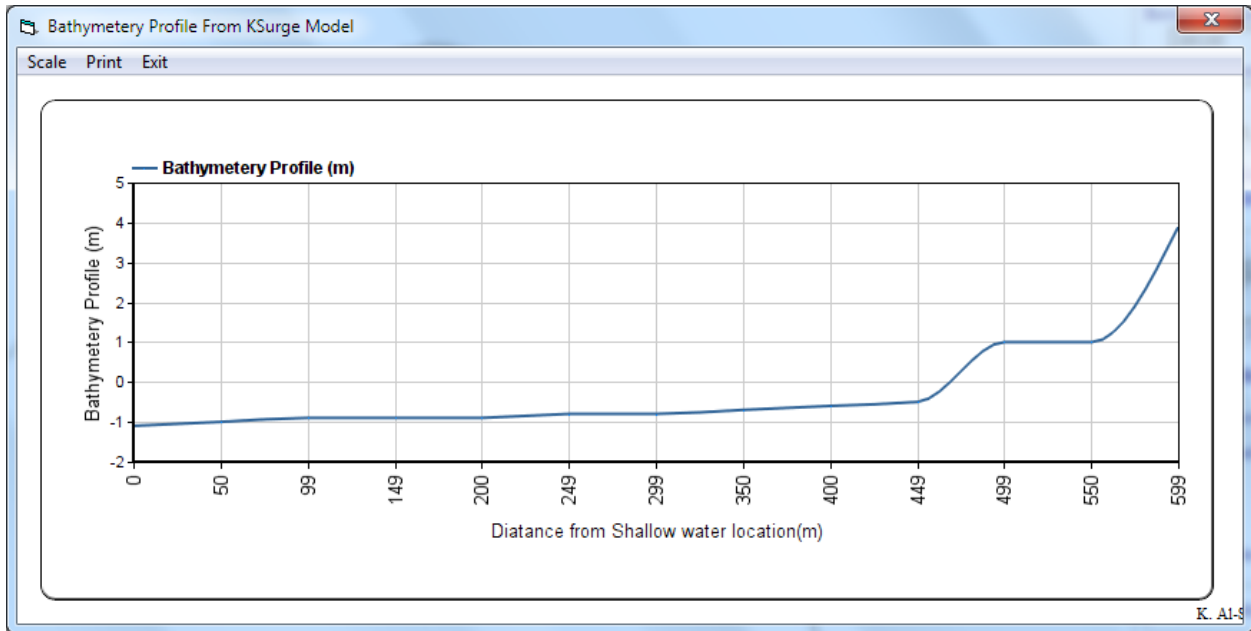
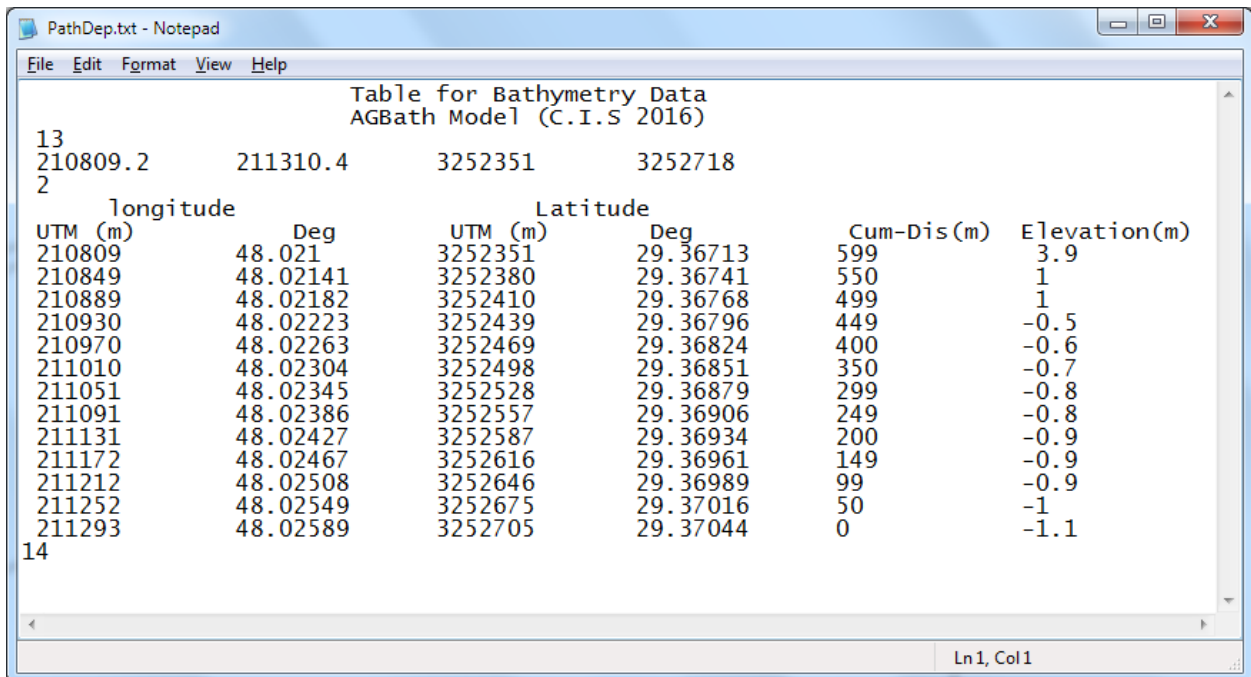


Figure 148



PathDep.txt - Notepad

File Edit Format View Help

Table for Bathymetry Data
AGBath Model (C.I.S 2016)

13
210809.2 211310.4 3252351 3252718
2

UTM (m)	Longitude (Deg)	UTM (m)	Latitude (Deg)	Cum-Dis (m)	Elevation (m)
210809	48.021	3252351	29.36713	599	3.9
210849	48.02141	3252380	29.36741	550	1
210889	48.02182	3252410	29.36768	499	1
210930	48.02223	3252439	29.36796	449	-0.5
210970	48.02263	3252469	29.36824	400	-0.6
211010	48.02304	3252498	29.36851	350	-0.7
211051	48.02345	3252528	29.36879	299	-0.8
211091	48.02386	3252557	29.36906	249	-0.8
211131	48.02427	3252587	29.36934	200	-0.9
211172	48.02467	3252616	29.36961	149	-0.9
211212	48.02508	3252646	29.36989	99	-0.9
211252	48.02549	3252675	29.37016	50	-1
211293	48.02589	3252705	29.37044	0	-1.1

14

Ln 1, Col 1

Figure 149

Sub_Option 2

[2D area Bathymetry data]

User must select [**Show domain**] then check box for [**2D Data Extracting**] as in Figure 144. Fig150 will display with a new Frame area for 2D Extracting Option.

User now must select the area where data will be extract as number of ways as follow:

- 1- by Click on the map Two click for lower left location and second click for upper right location
- 2- Manual enter lower left location and second enter for upper right location
 - Entr in UTM [Convert to Degrees]
 - Entr In Degrees [Convert to UTM]

Then if data location is finished and convert to Degree/UTM. User can see the selected area

location on Google Map by select [] as Sown in Fig 151.

This option needed an **internet Connect is ON**

User must Setup the **output file name** where data will stored in

Then to start extract data user must select [**EXTRACT**] in Fig 150.

To convert Result data from UTM TO Degree user must select [**CONERT**] in Fig150

To Send 2D bathymetry Data to Analysis the Sea-Level Rise model [Q8Sr model developed by: Al-Salem 2019] by Click on Check Box in Fig 150

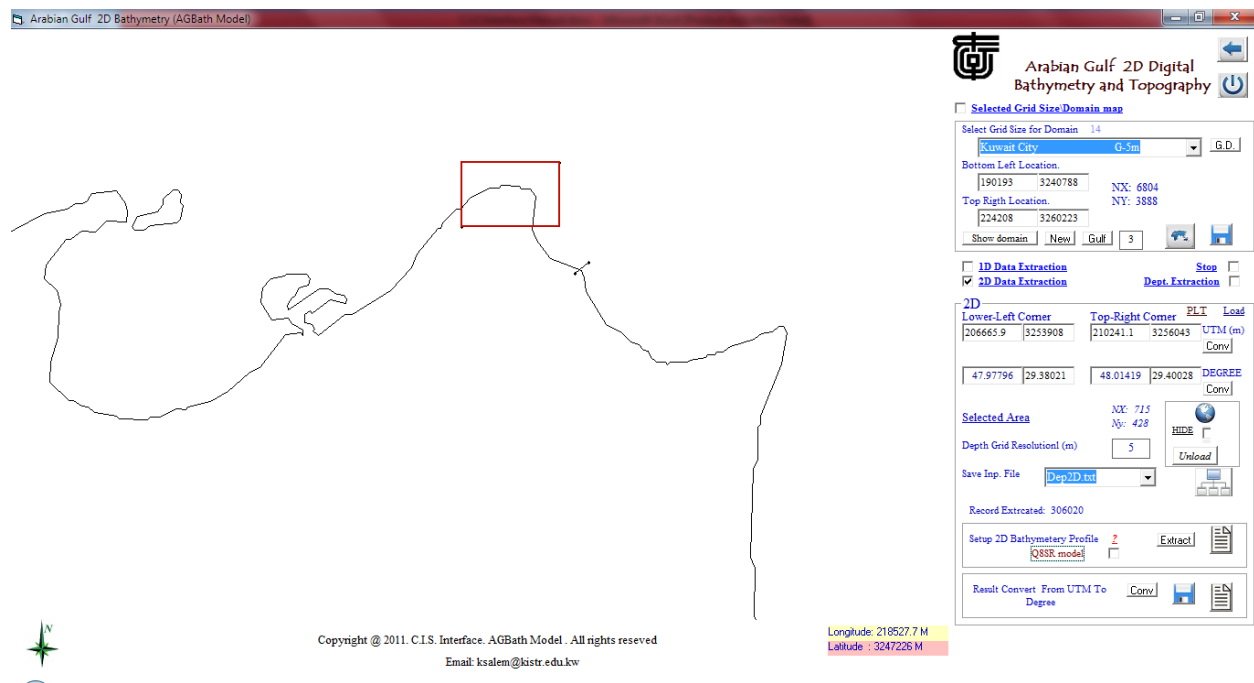


Figure 50

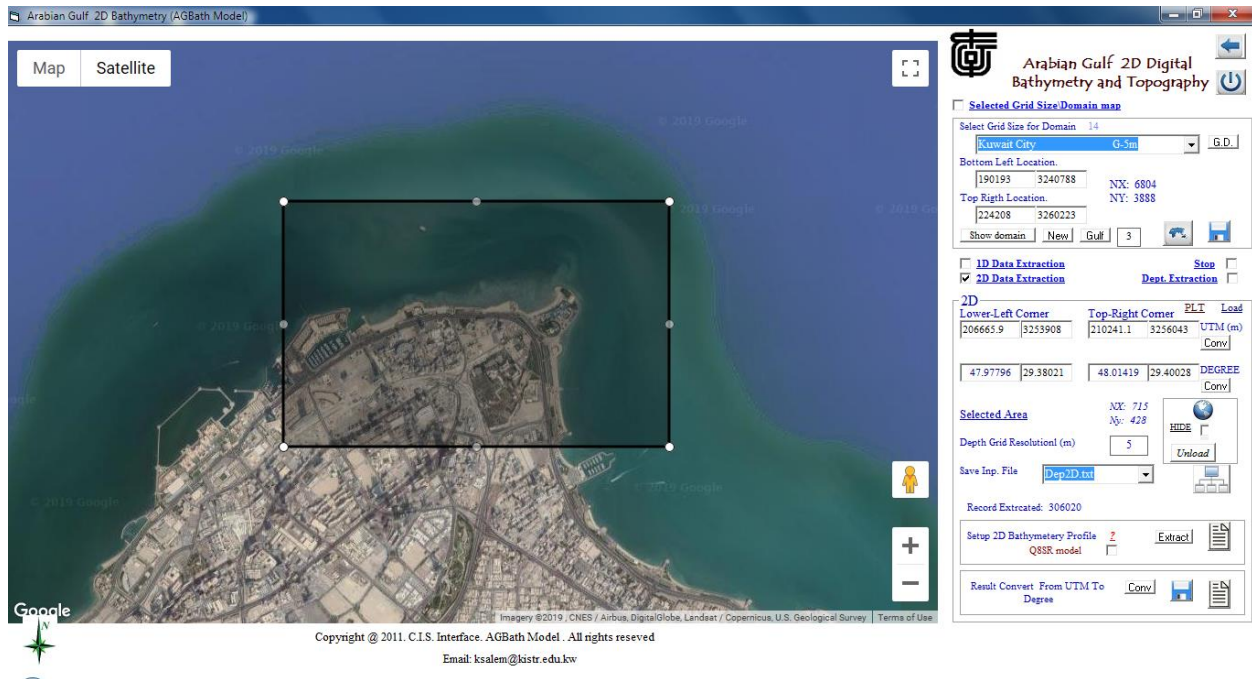


Figure 151

14. Presentation 1D/2D model f By Google Map Tools [KGMMap model]

Google Maps has been around for a while, but too many people are unaware of the full extent of the services that the service can afford.

[KGMMap model] uses Google map utilities to presents a simulated 1D/2D output result from different model in Costal Information System Interface on Satellite image. To demonstrate how to run the model is by select from Fig 152 [1D/2D output presentation by Google Map]

Figure 153 will display Main Page of KGMMap.

This model Need Internet Connection

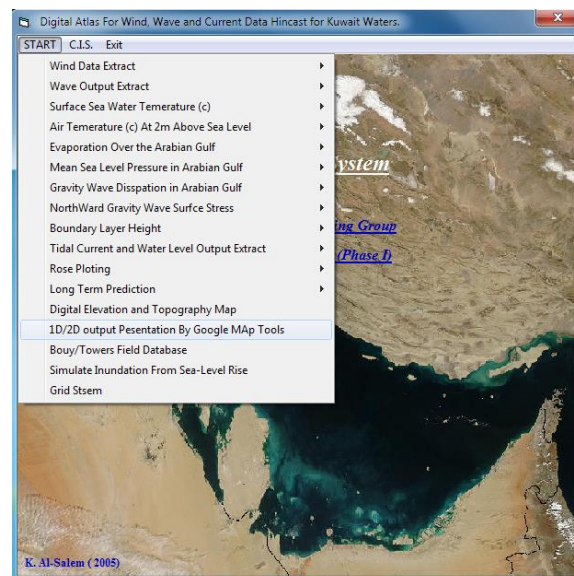


Figure 152

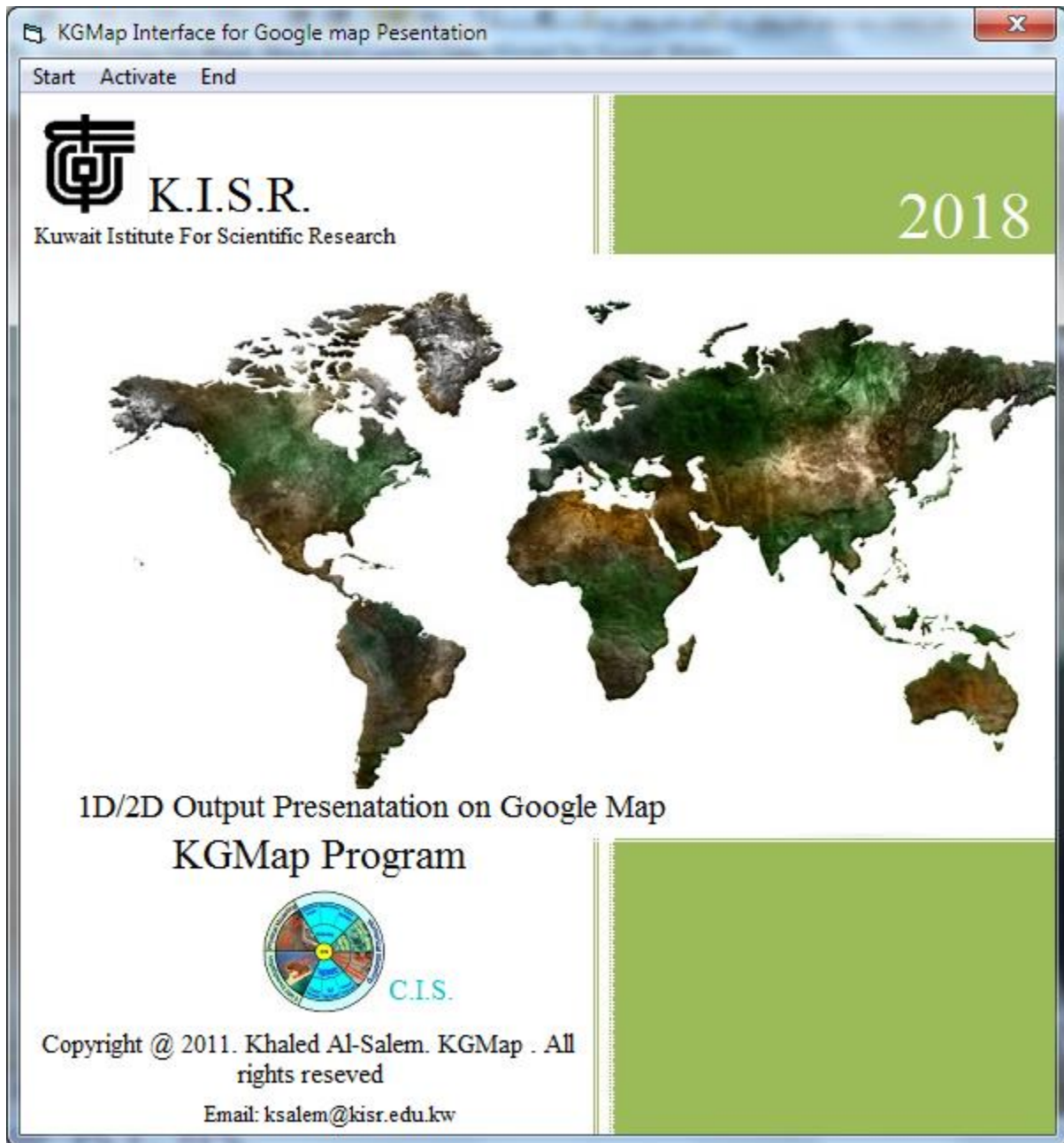


Figure 153

From Fig 153 user must select [*Start*]. Fig 154 will display a map of KISR on Google map with a number of options user should select from dropdown list as follow:

1. *1D Map*
2. *2D Map*
3. *My office*
4. *File Optimizing*

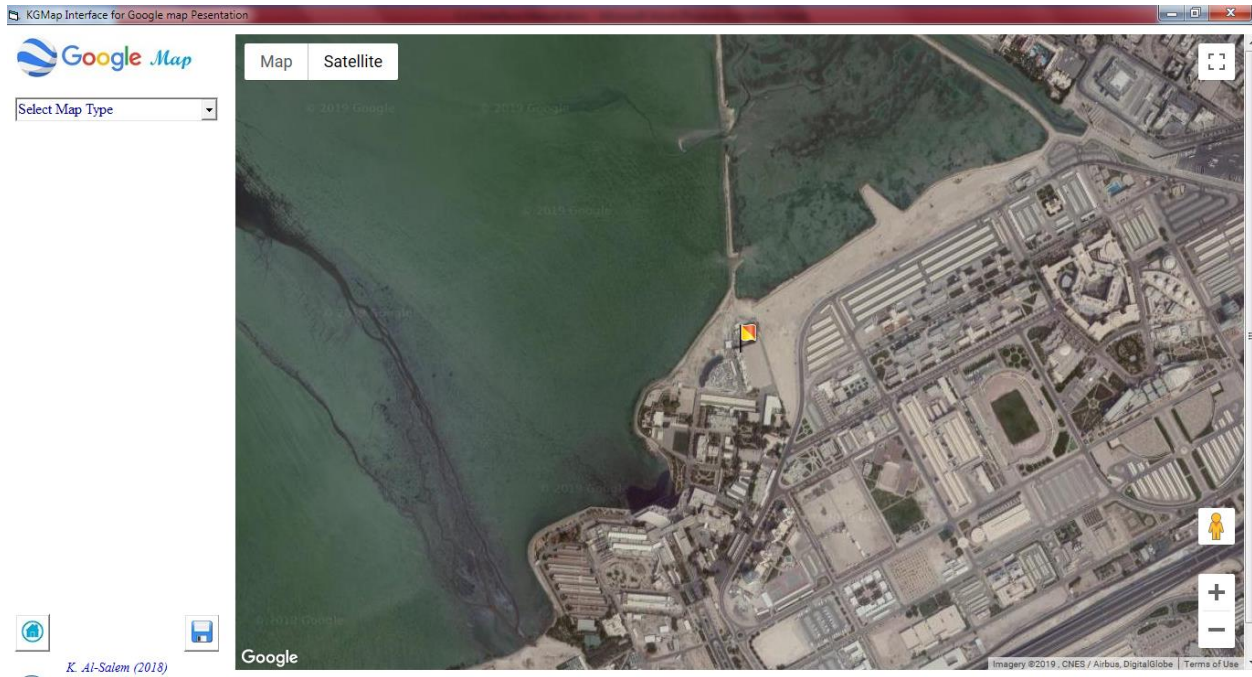


Figure 154

Sub_option 1

If user select [*ID map*] as shown in Fig 155 a number of information require to enter as follows:
User must select data format as:

- X,Y data
- X,Y,Z data

User must select [*input file name*]

User allow to set the Google map Zooming by select from dropdown list in [*Map zoom Fator*]

Then to show the data on Google map by Select [*Display Google Map*] Fig 156 will display for user the data place on Google Map and Map Center Location [Longitude/Latitude in Degrees].

To Export or print the image map user must select [*SAVE*] a new Frame will appear as shown in Fig 157 for user to Select the following:

- *Print Image*
- *Save AS HTML file [To create HTML file for present Google map as standalone file]*

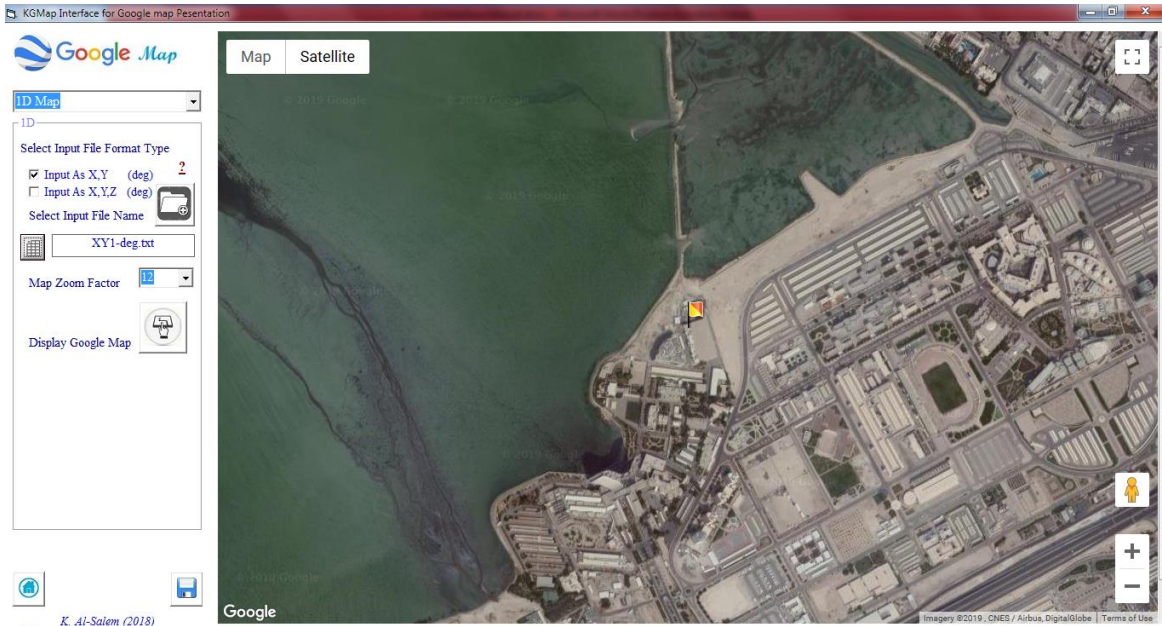


Figure 155

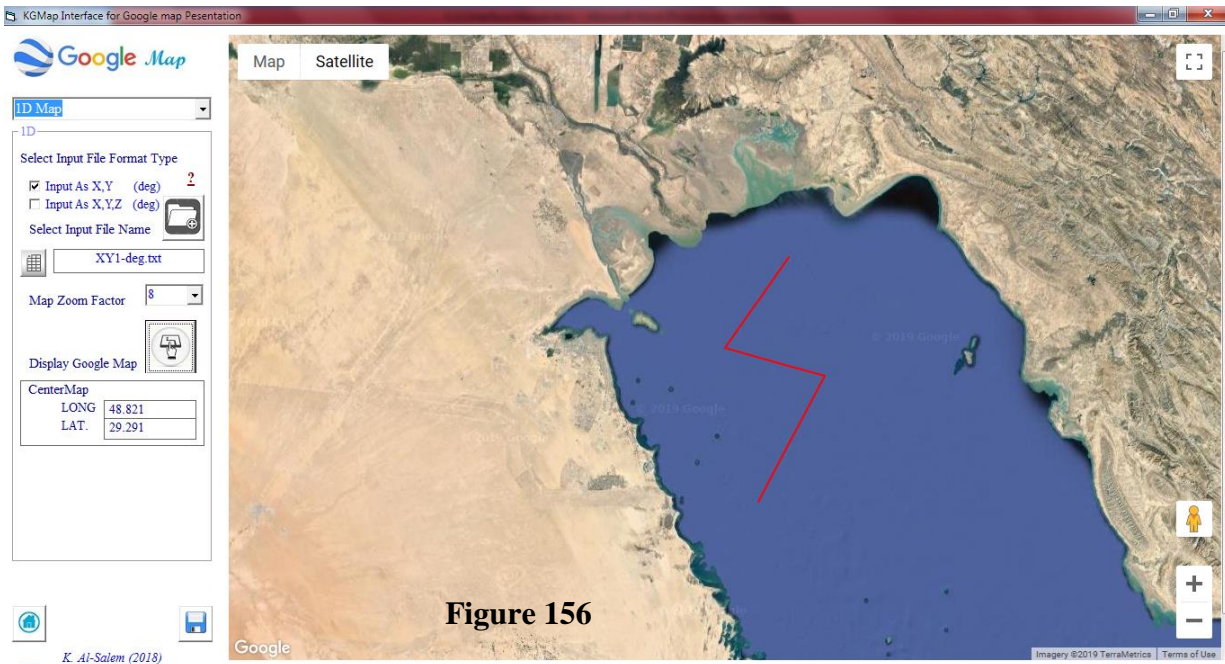


Figure 156

Figure 157



K. Al-Salem (2018)

Sub_option 2

If user select [**2D map**] as shown in Fig 154 a number of information require to enter as follows:

User must select data format as:

- X,Y data
- X,Y,Z data
- Input as 2D

User must select [*input file name*].

User allow to set the Google map Zooming by select from dropdown list in [*Map zoom Fator*]

User must select [Minimum Data] as follow:

Manual Enter the minimum data values by **CHECK ON**

Model calculate the minimum value by **CHECK OFF**

To convert the input from UTM to Degree user Check On [**in main data was in UTM**]

Then user must Select [**LOAD**] to start setup the data for Google map presentation.

To show the data on Google map user have check on of the following:

- Contour Map as shown in Fig 159
- Contour Dot Map as shown in 160

To Export or print the image map user must select [**SAVE**] a new Frame will appear as shown in Fig 157 for user to Select the following:

- *Print Image*
- *Save AS HTML file [To create HTML file for present Google map as standalone file]*

Sample of HTML file AUTO-created from KGMap model list below.

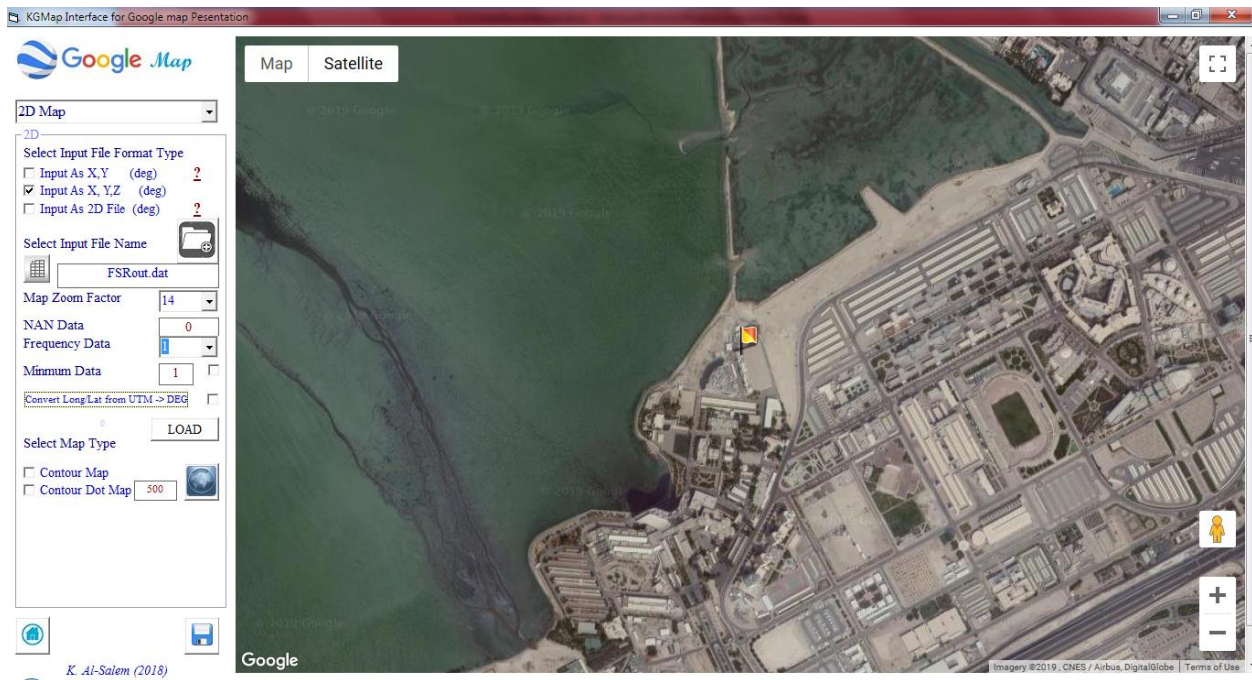


Figure 158

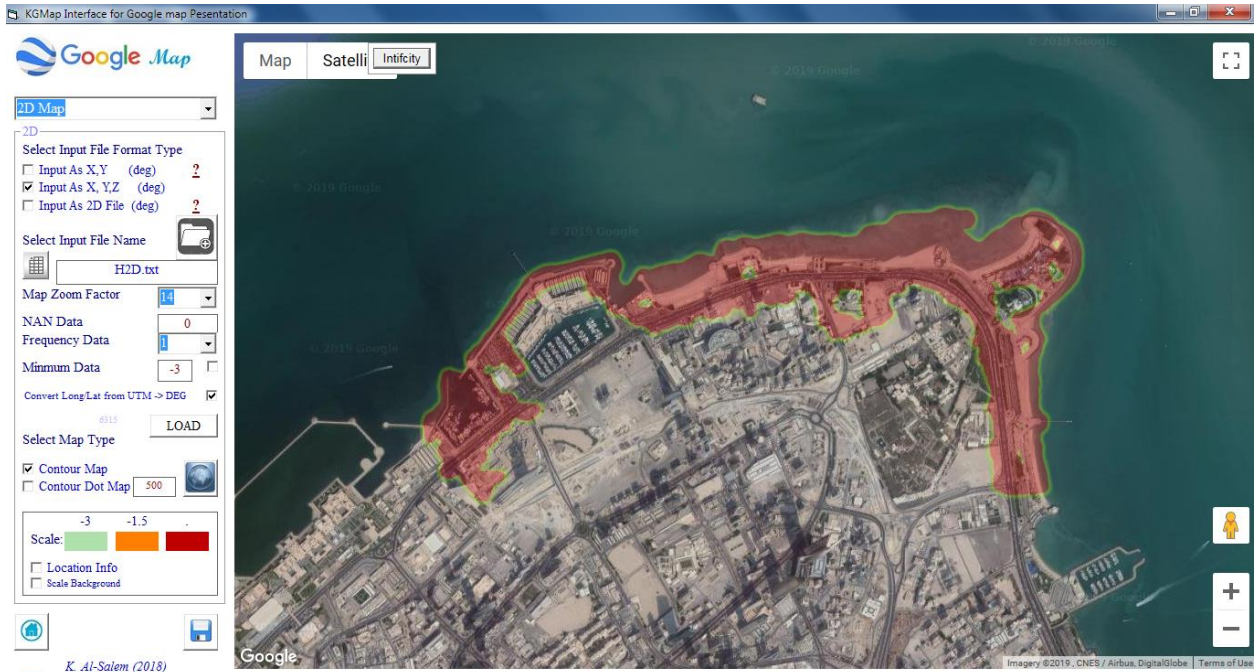


Figure 159

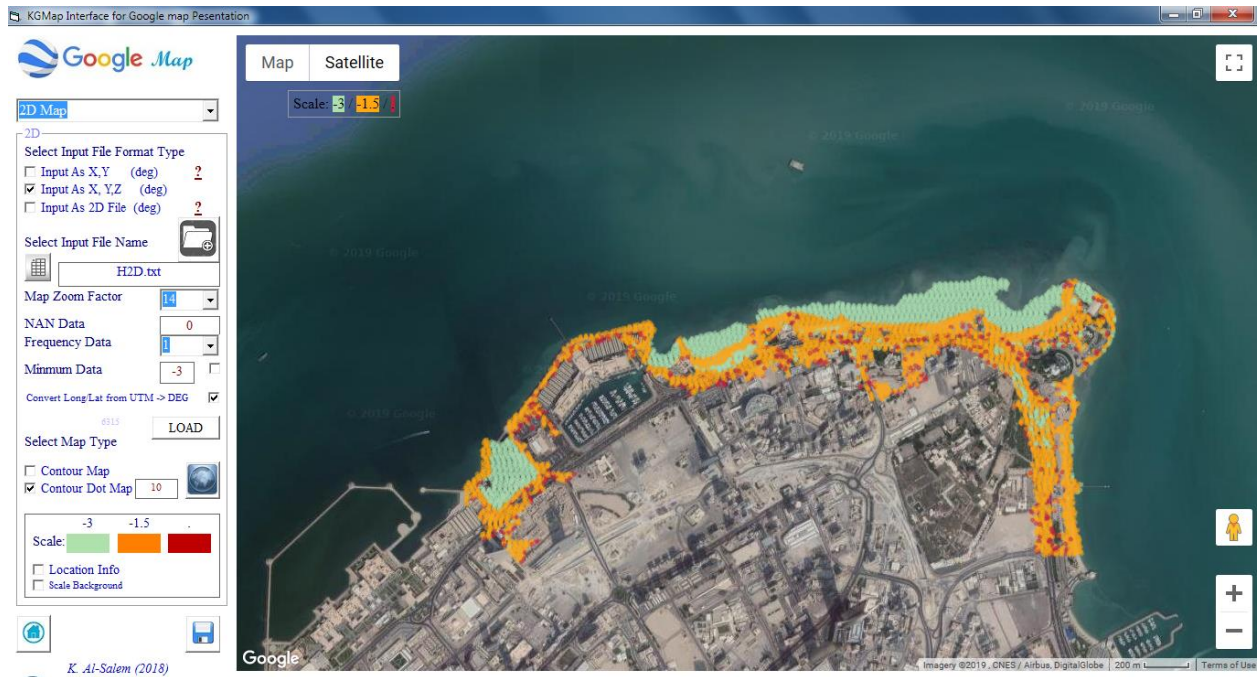


Figure 160



Sample of HTML file Created from KGMap model

```
<!DOCTYPE html>
<html>
<head>
<meta http-equiv="content-type" content="text/html;charset=utf-8"/>
<meta http-equiv="X-UA-Compatible" content="IE=edge">

<title>C.I.S.</title>
<style>
#map { height: 100%;
}
html, body {
height: 100%;
margin: 0;
padding: 0;
}
</style>
</head>
<script>
function initMap() {
var map = new google.maps.Map(document.getElementById("map"), {
zoom:8,
center: {lat: 29.291,lng: 48.821},
mapTypeId: "satellite"
});
var flightPlanCoordinates = [
new google.maps.LatLng(29.772,49.214),
new google.maps.LatLng(29.291,48.821),
new google.maps.LatLng(29.142,49.431),
new google.maps.LatLng(28.467,49.027)
];
var flightPath = new google.maps.Polyline({
path: flightPlanCoordinates,
geodesic: true,
strokeColor: "#FF0000",
strokeOpacity: 1.0,
strokeWeight: 2
});
flightPath.setMap(map);
}
</script><script src="http://maps.googleapis.com/maps/api/js?key=AIzaSyBG5W9UEomYpNK38QmpobKVRk6YKZ4ICy0"
type="text/javascript">
</script>
<body onload="initMap()" >
<div id="map" ></div>
<br clear="all"/>
<br/>

</body>
</html>
```

Sub_Option 4

File optimizing it is Toole to reduce the file data records since we are dealing with internet option with Google maple it not except large number of data to plot on Google map.

If user select [**File Optimized**] as shown in Fig 161 a number of information require to enter as follows:

User must select data format as:

X,Y data

X,Y,Z data

User must select [**input file name**]

User must select [**Output file name**]

User must select [**First line Ndata On/OFF**]

User must select the approximate minimum value [Select big –value if water example -100]

User allow to select [**Frequency Data**] that will user select how much the will reduce.

Then user must select [**Update**]. A number of information will appear in Fig 161 as follows:

- Updated Recodes
- Original Records
- Min- Z value
- Max Z Value

Then that new create output File should use in Sub-Option 1 or 2 Google map Presentation

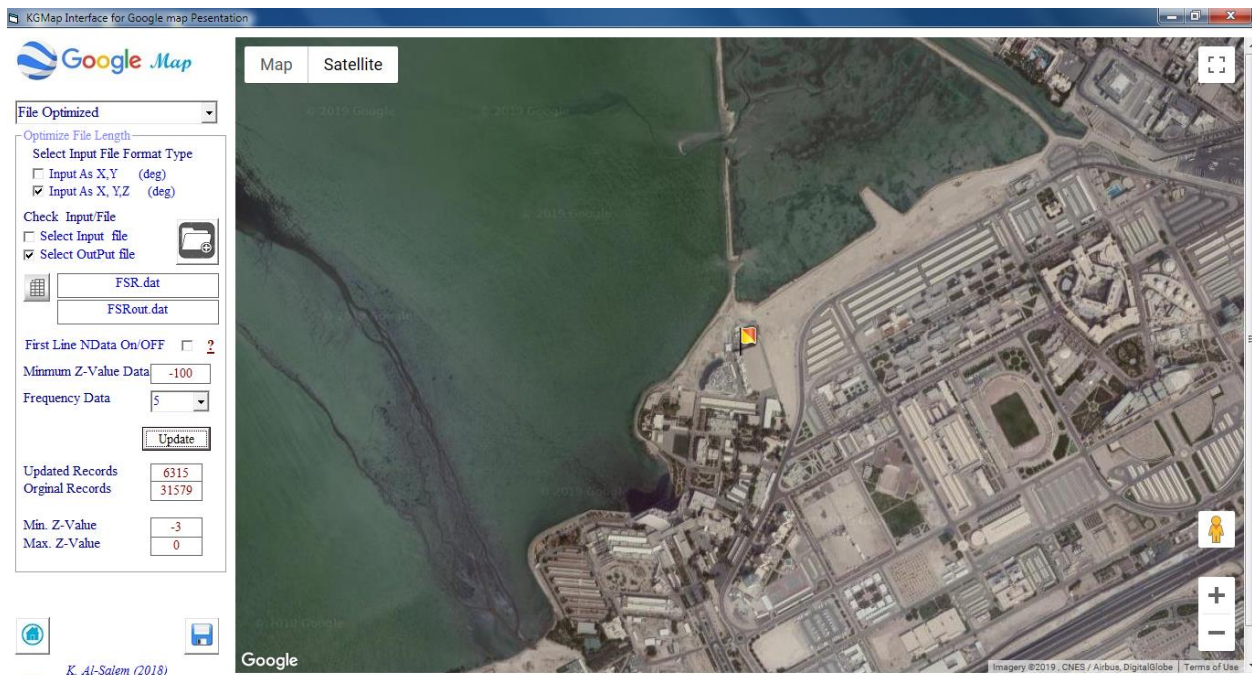


Figure 161

15.Finas Buoy and Towers Database [Measurement Data 1995-1996] [EES161 Database]

EES161 project it was project to install wave Buoy and al-Fintas coast and 5 Towers near Auha Island to Collect Hydrodynamic parameter data from 1993 to 1996. The location was set as follows:

Buoy Location (Al-Fintas Coast)

48.167 \ 29.167 Buoy depth 25 m

Towers Location (Near Auha Island)

48 26 00 \ 29 17 00 T1 depth 7.0 m

48 26 00 \ 29 19 00 T2 depth 5.0 m

48 26 00 \ 29 20 00 T3 depth 4.0 m Shallow water

48 26 00 \ 29 21 00 T4 depth 3.0 m Shallow water

48 26 00 \ 29 21 30 T5 depth 2.0 m Shallow water

To run and Extract Wave/Wind data user must select From Fig162 [*Buoy/Towers Field Database*]. Then Fig 163 will display for user to select.

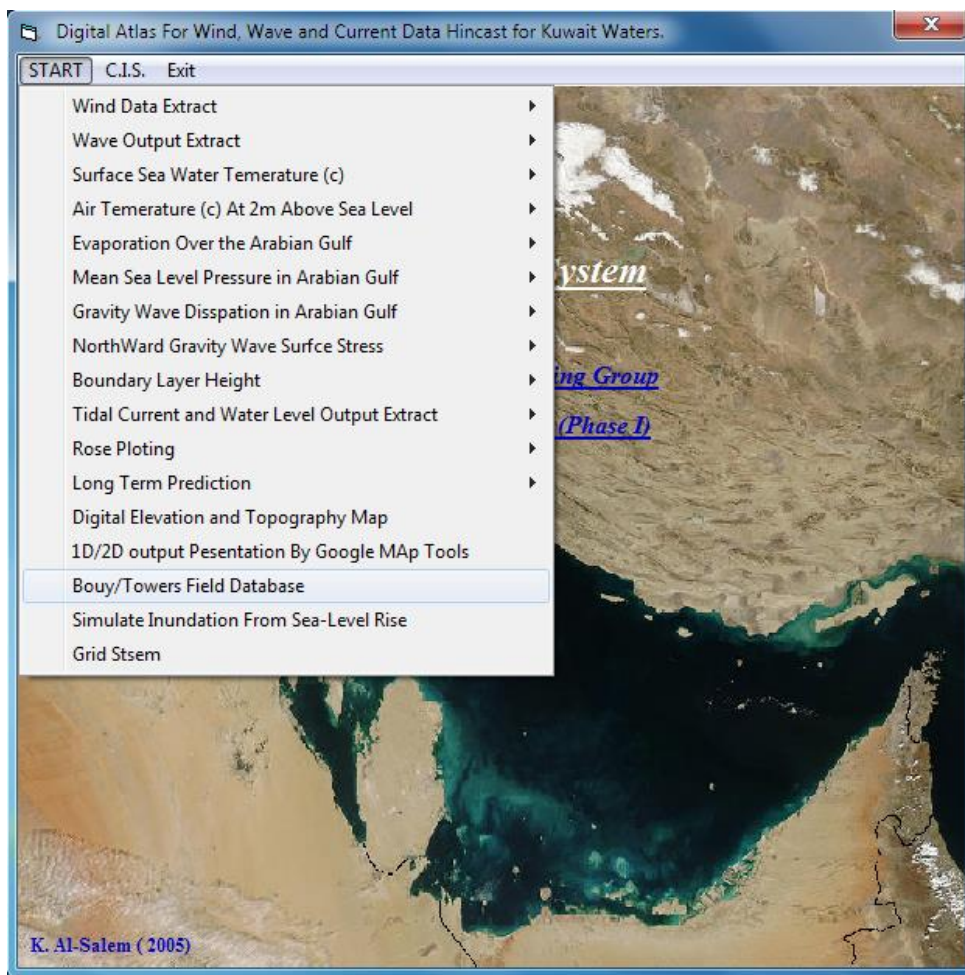


Figure 162

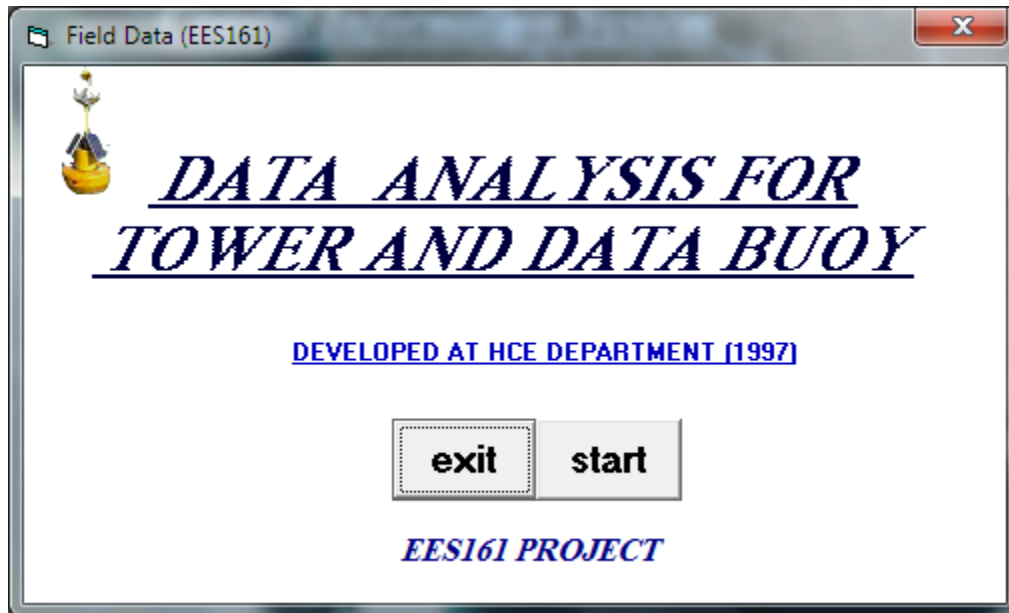


Figure 163

User must Select Start to Run EES161 Database program from Fig 163. Figure 164 will display a map with Buoy and Towers location.
User can select to extract data by Click on Buoy image or Tower image in Fig 164.



Figure 164

Option 1

If user Select Buoy image Fig.165 will display for user to the following:

- I. Wind Data Extract
- II. Wave Data Extract

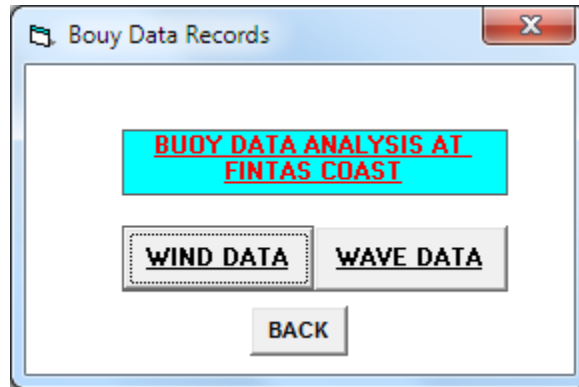


Figure 165

Sub-Option 1

If user select [*Wind data*] to display wind database. Figure 166 will display to select the following:

[*DATA AVAILABLE*] to select year of the wind data

[*MONTH LIST*] to select number of month available in database

If user selects the Year and the month to extract from Fig 167. Then Fig 168 show wind table statistics. And frequency analysis

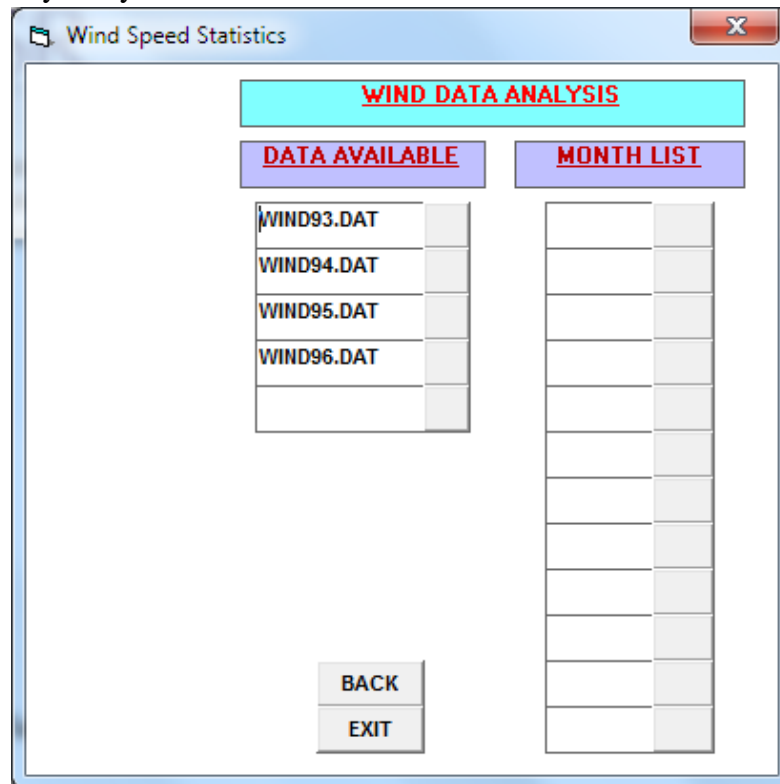
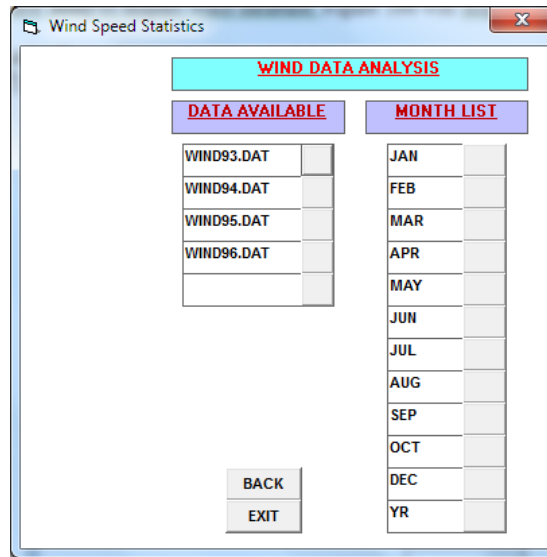


Figure 166



WIND DATA ANALYSIS

DATA AVAILABLE

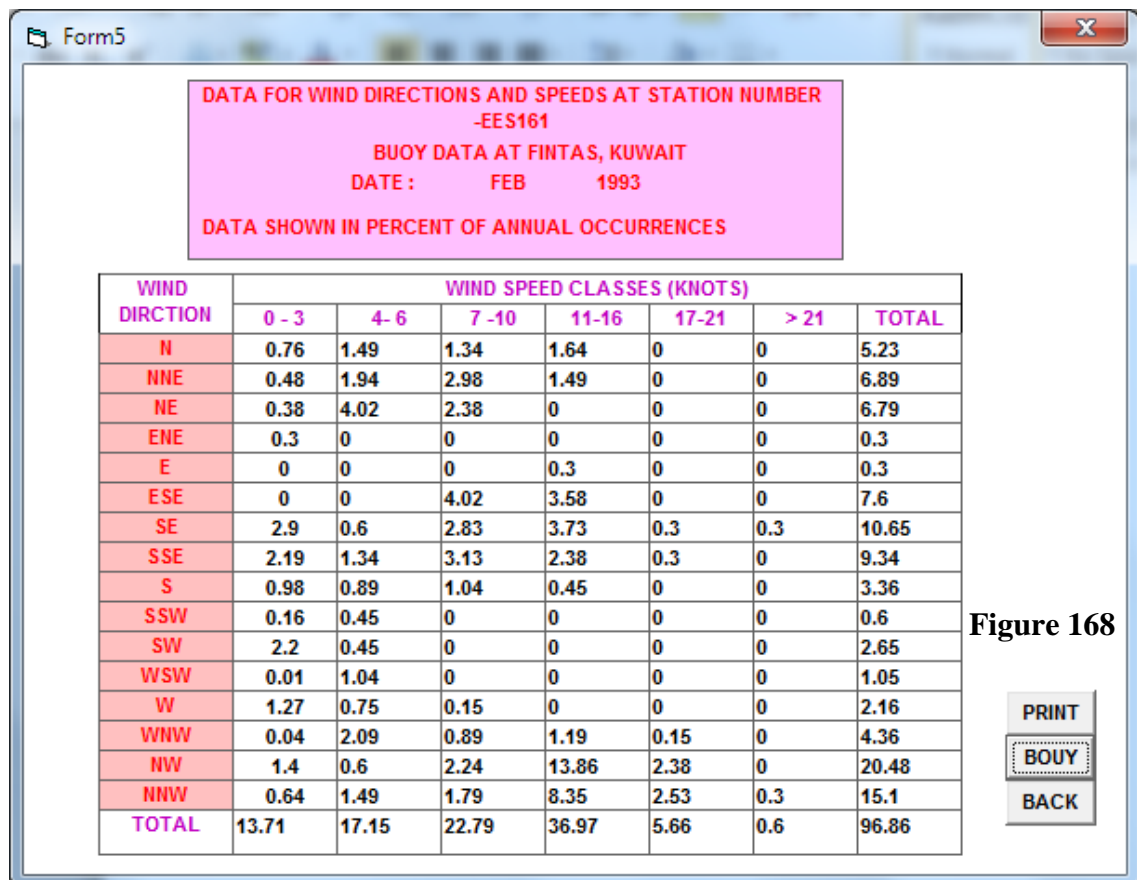
WIND93.DAT	<input type="checkbox"/>
WIND94.DAT	<input type="checkbox"/>
WIND95.DAT	<input type="checkbox"/>
WIND96.DAT	<input type="checkbox"/>
	<input type="checkbox"/>

MONTH LIST

JAN	<input type="checkbox"/>
FEB	<input type="checkbox"/>
MAR	<input type="checkbox"/>
APR	<input type="checkbox"/>
MAY	<input type="checkbox"/>
JUN	<input type="checkbox"/>
JUL	<input type="checkbox"/>
AUG	<input type="checkbox"/>
SEP	<input type="checkbox"/>
OCT	<input type="checkbox"/>
DEC	<input type="checkbox"/>
YR	<input type="checkbox"/>

BACK
EXIT

Figure 167



DATA FOR WIND DIRECTIONS AND SPEEDS AT STATION NUMBER -EES161
BUOY DATA AT FINTAS, KUWAIT
 DATE : FEB 1993
 DATA SHOWN IN PERCENT OF ANNUAL OCCURENCES

WIND DIRCTION	WIND SPEED CLASSES (KNOTS)						TOTAL
	0 - 3	4 - 6	7 - 10	11-16	17-21	> 21	
N	0.76	1.49	1.34	1.64	0	0	5.23
NNE	0.48	1.94	2.98	1.49	0	0	6.89
NE	0.38	4.02	2.38	0	0	0	6.79
ENE	0.3	0	0	0	0	0	0.3
E	0	0	0	0.3	0	0	0.3
ESE	0	0	4.02	3.58	0	0	7.6
SE	2.9	0.6	2.83	3.73	0.3	0.3	10.65
SSE	2.19	1.34	3.13	2.38	0.3	0	9.34
S	0.98	0.89	1.04	0.45	0	0	3.36
SSW	0.16	0.45	0	0	0	0	0.6
SW	2.2	0.45	0	0	0	0	2.65
WSW	0.01	1.04	0	0	0	0	1.05
W	1.27	0.75	0.15	0	0	0	2.16
WNW	0.04	2.09	0.89	1.19	0.15	0	4.36
NW	1.4	0.6	2.24	13.86	2.38	0	20.48
NNW	0.64	1.49	1.79	8.35	2.53	0.3	15.1
TOTAL	13.71	17.15	22.79	36.97	5.66	0.6	96.86

PRINT
BOUY
BACK

Figure 168

Sub-Option 2

User select [*Wave data*] to display wave database. Figure 169 display to select the following:

[*DATA AVAILABLE*] to select year of the wind data

[*MONTH LIST*] to select number of month available in database

[DAILY DATA] to select day number

Then Fig 170 Will Display for [Wave height, Period, Direction] in a table format every 3hr.

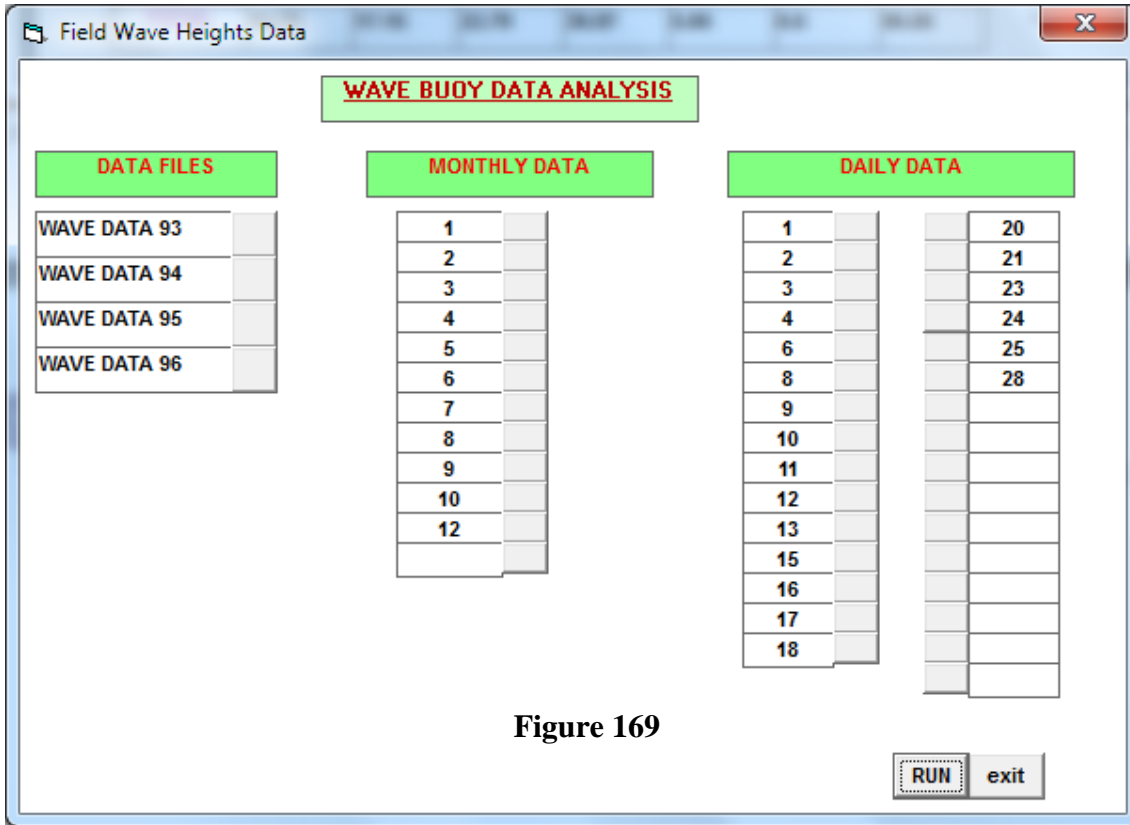


Figure 169

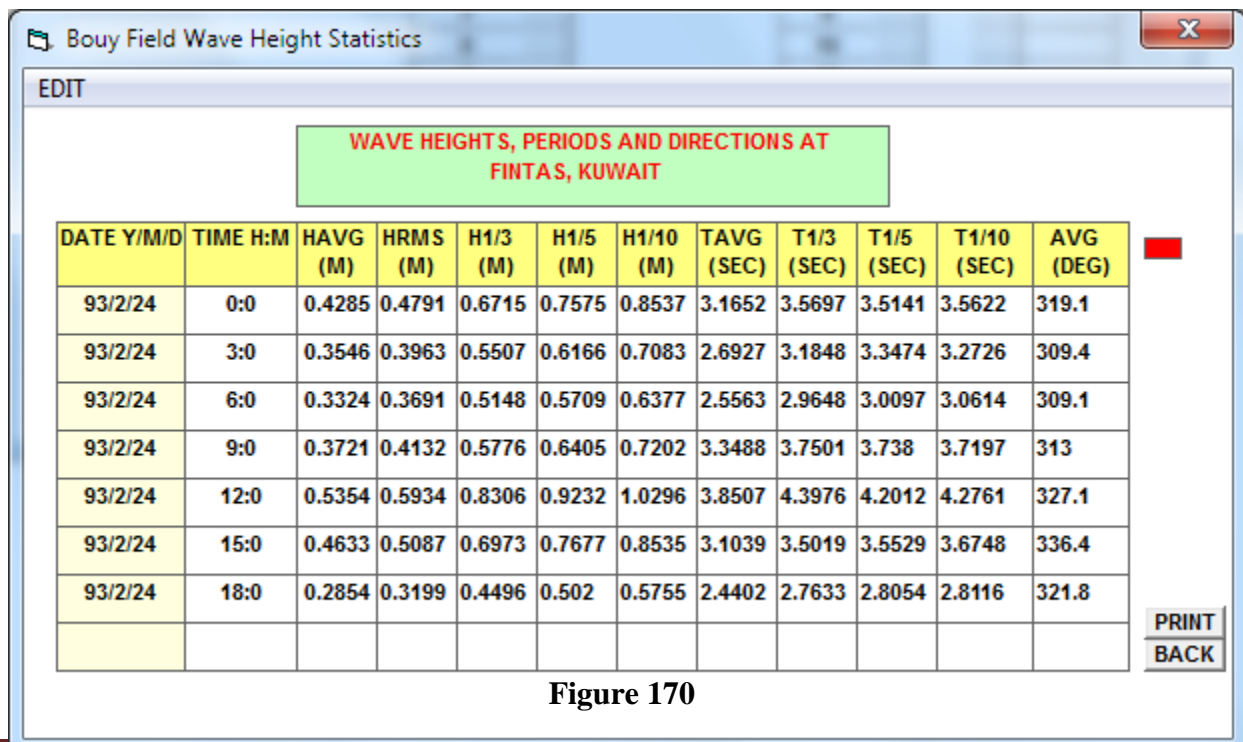


Figure 170

Option 2

If user Select Towers image from Fig.164. Figure 171 will display for user all 5 tower images to select and extract data.

If user select [*Tower 1*] in fig 171 to display wave database. Only Tower 1 have wind data recorded.

To display wave data in Tower 1 Figure 172 will display to select the following:

[*DATA AVAILABLE*] to select year of the wind data

[*MONTH LIST*] to select number of month available in database {Click on Run}

[*DAILY LIST*] to select day number {Click on Run}

If user selects the Year and month and day to extract from Fig 172.

Then Fig 173 show wave table every 3hr show.

To Display wind Same procedure as in Wind Section.

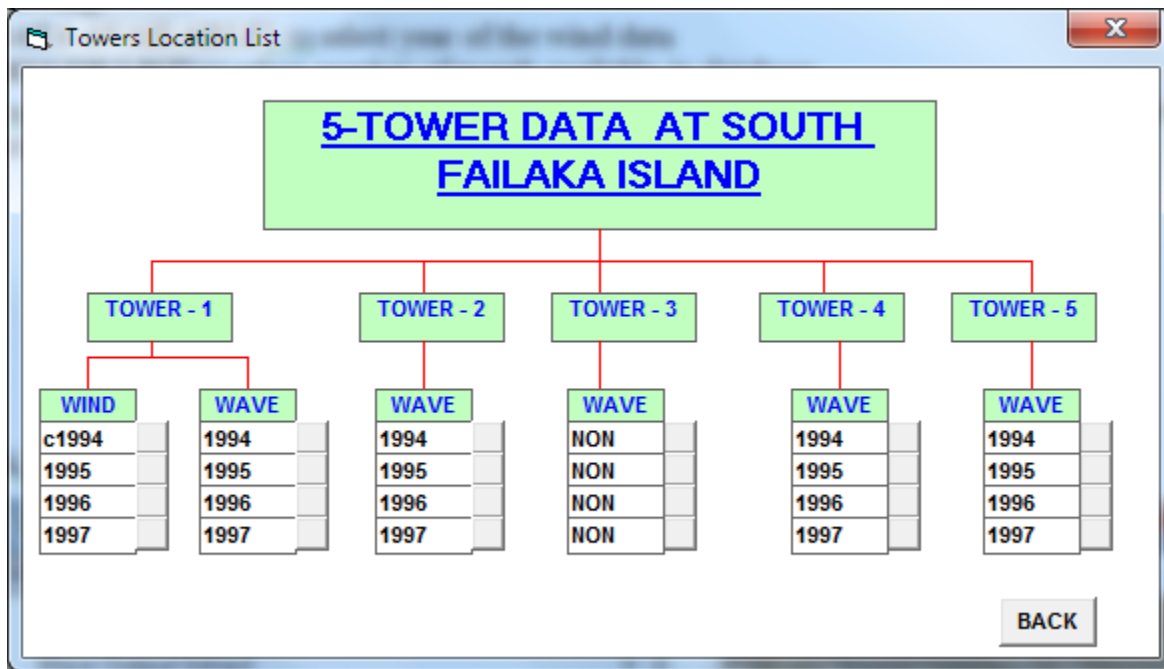


Figure 171

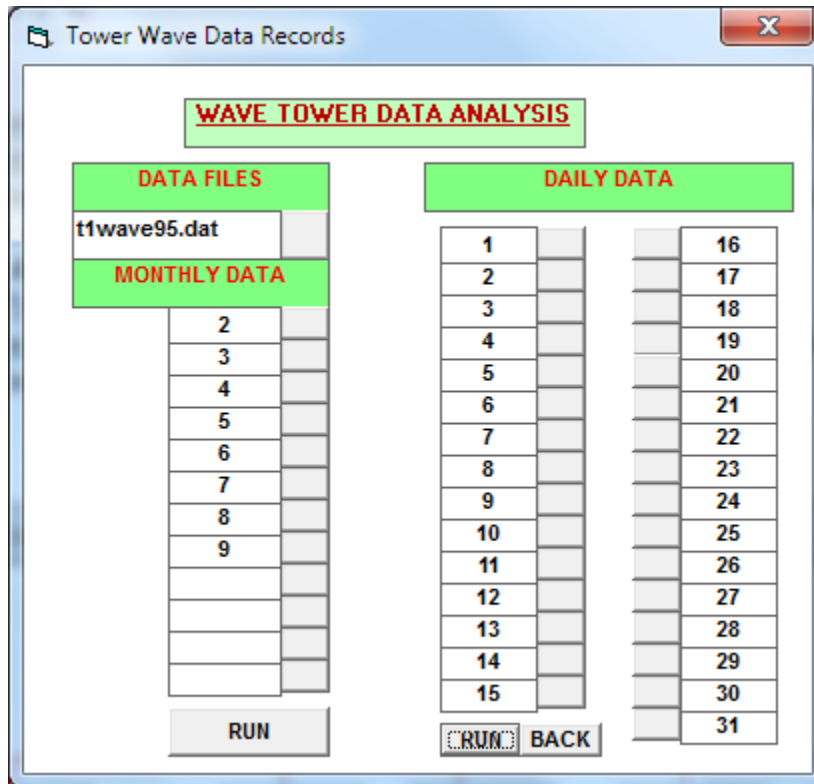


Figure 172

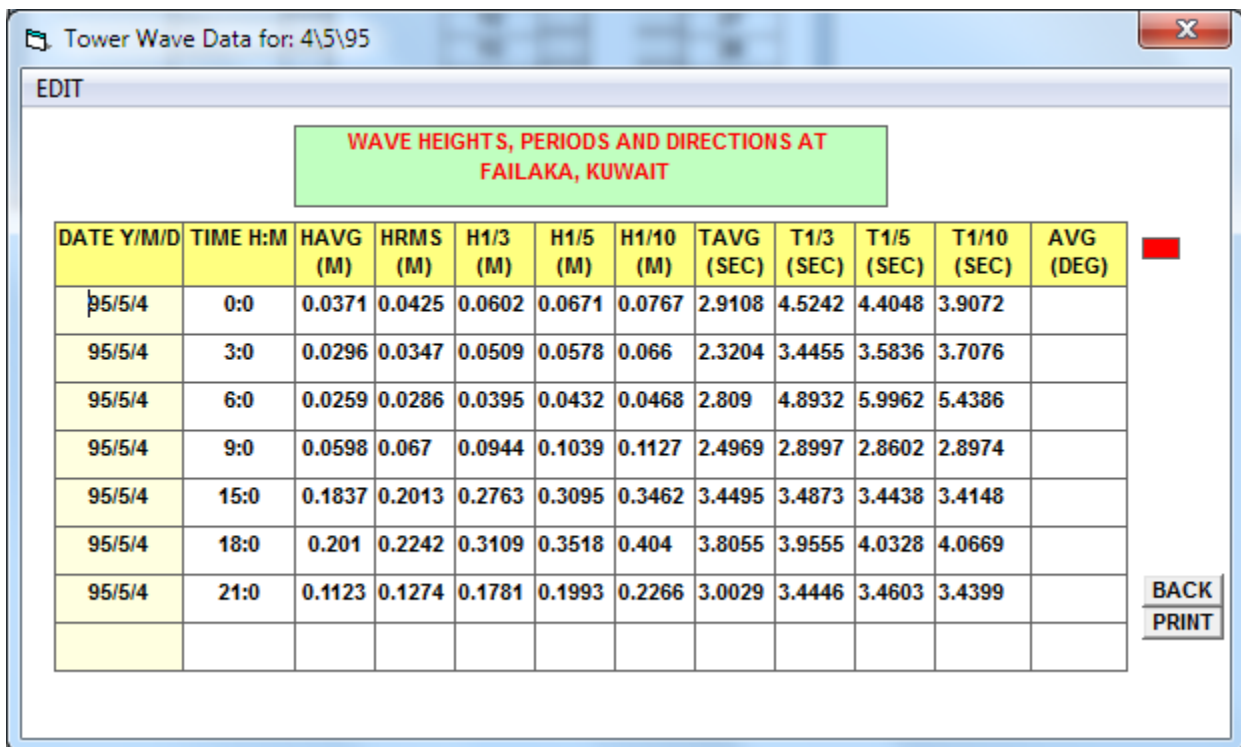


Figure 173

16. Simulation Inundation From Sea-Level Rise Program [Q8Sr model]

16.1 Methodology

Concept of the model was aimed to carry out some of the assessments of the sea rise effect on Kuwait coastal line region, using the numerical modeling technique. The sources of the topography data for Kuwait land/coast data used in this study from KISR digital elevation database from coastal information system [AL-Salem 2016, 2017]. The sea rise scenarios were identified to be possible threats at the Arabian Gulf water, and the areas along the Kuwait coast inside the Arabian Gulf.

The objectives were to achieved in the model as follows:

- To identify effect of the sea rise, with potential threats, affecting the Gulf region, Especially the coast of Kuwait.
- Selected sea rise scenarios as [0 .5, 1.0 and 2 m] above mean sea level.
- To evaluate sea rise threats and hazards, from different scenarios, to the coast of Kuwait.
- Visualize potential impacts from sea level rise through maps.

Kuwait coastline will divided in 11 different sections as shown in Figure 1. The coordinate of each section will describe in Table 1.

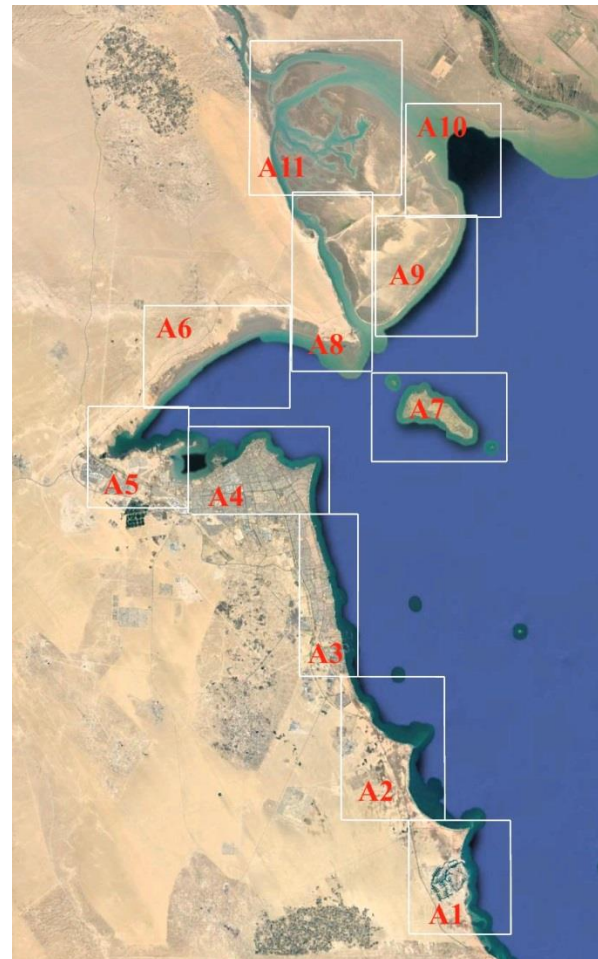


Figure 174

16.2 Concept of model Methodology

Q8Sr model developed by Finite Different technic by [Al-Salem 2019]

The model concept has some limitation as:

- Cell depth having constant depth.
- System have close boundary [no outside domain input].
- Soil Porosity $p=1$

To simulate the sea-level rise inundation is by applying the following equation [20]

$$\sum_{N_y}^{i=1} \sum_{N_x}^{j=1} H_{i,j} = P(H_{i,j} - Z_{dep})$$

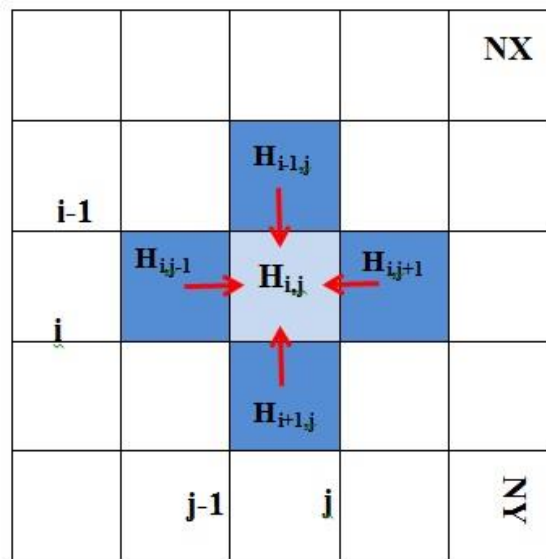


Figure 175

Model formulation

Z: sea level rise increment in [m]

H: water depth [m] at mean sea level

I grid notation along Y-axis [Ny]

J grid notation along X-Axis [Nx]

Zdep set to 0 unless change by Z $H_{i,j} = H_{i,j} - Z$

Finite Different following these Rules formulation

Where [I>1 and I<Ny]

Where [J= 1] at **left boundary**

$H_{i-1,j}$ or $H_{i+1,j}$ or $H_{i,j+1} < 0$

Zdep=Z

Where [J=NX] at **right boundary**

$H_{i-1,j}$ or $H_{i+1,j}$ or $H_{i,j-1} < 0$

Zdep =Z

Where [J < 1 and J>NX]

$$H_{i-1,j} \text{ or } H_{i+1,j} \text{ or } H_{i,j-1} \text{ or } H_{i,j+1} < 0$$

$$Zdep = Z$$

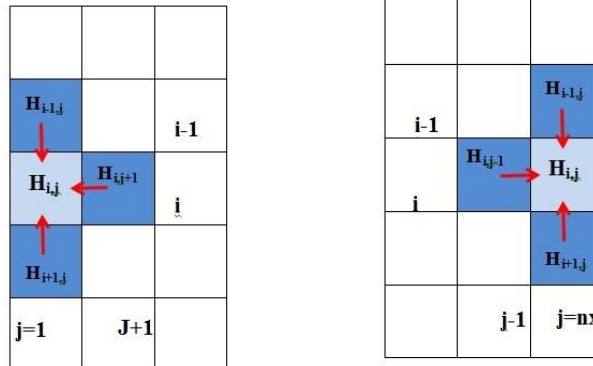


Figure 176

Where [I= 1] at Upper boundary

Where [J= 1] at **left boundary**

$$H_{i+1,j} \text{ or } H_{i,j+1} < 0$$

$$Zdep = Z$$

Where [J=NX] at **right boundary**

$$H_{i+1,j} \text{ or } H_{i,j-1} < 0$$

$$Zdep = Z$$

Where [J < 1 and J > NX]

$$H_{i+1,j} \text{ or } H_{i,j-1} \text{ or } H_{i,j+1} < 0$$

$$Zdep = Z$$

Where [I= NY] at Bottom boundary

Where [J= 1] at **left boundary**

$$H_{i-1,j} \text{ or } H_{i,j+1} < 0$$

$$Zdep = Z$$

Where [J=NX] at **right boundary**

$$H_{i-1,j} \text{ or } H_{i,j-1} < 0$$

$$Zdep = Z$$

Where [J < 1 and J > NX]

$$H_{i-1,j} \text{ or } H_{i,j-1} \text{ or } H_{i,j+1} < 0$$

$$Zdep = Z$$

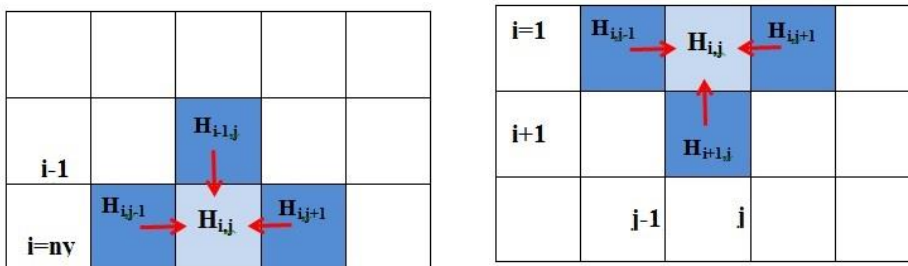


Figure 177

To Run Q8SR model for inundation prediction from Sea level Rise.

User must select [**Simulation Inundation From Sea-level Rise**] From Fig 178.

Figure 179 Will display the main Page of the Q8SR model.

User must select [**Control File**] in Fig 179 to enter or select Control file was created from [**AGBath model**].

The default file name created from AGBath was two file as

- **LocInp.txt** as control parameter file [if user used another name check inside the file the depth file name should be correct and path]
- **Dep2D.txt** as bathymetry data extract from AGBath model.

These were store in [C:\Wave\Q8Sear\Data\]

Then select [**Start**] in Fig 179 to Load the domain Bathymetry Contour map as shown in Fig 180

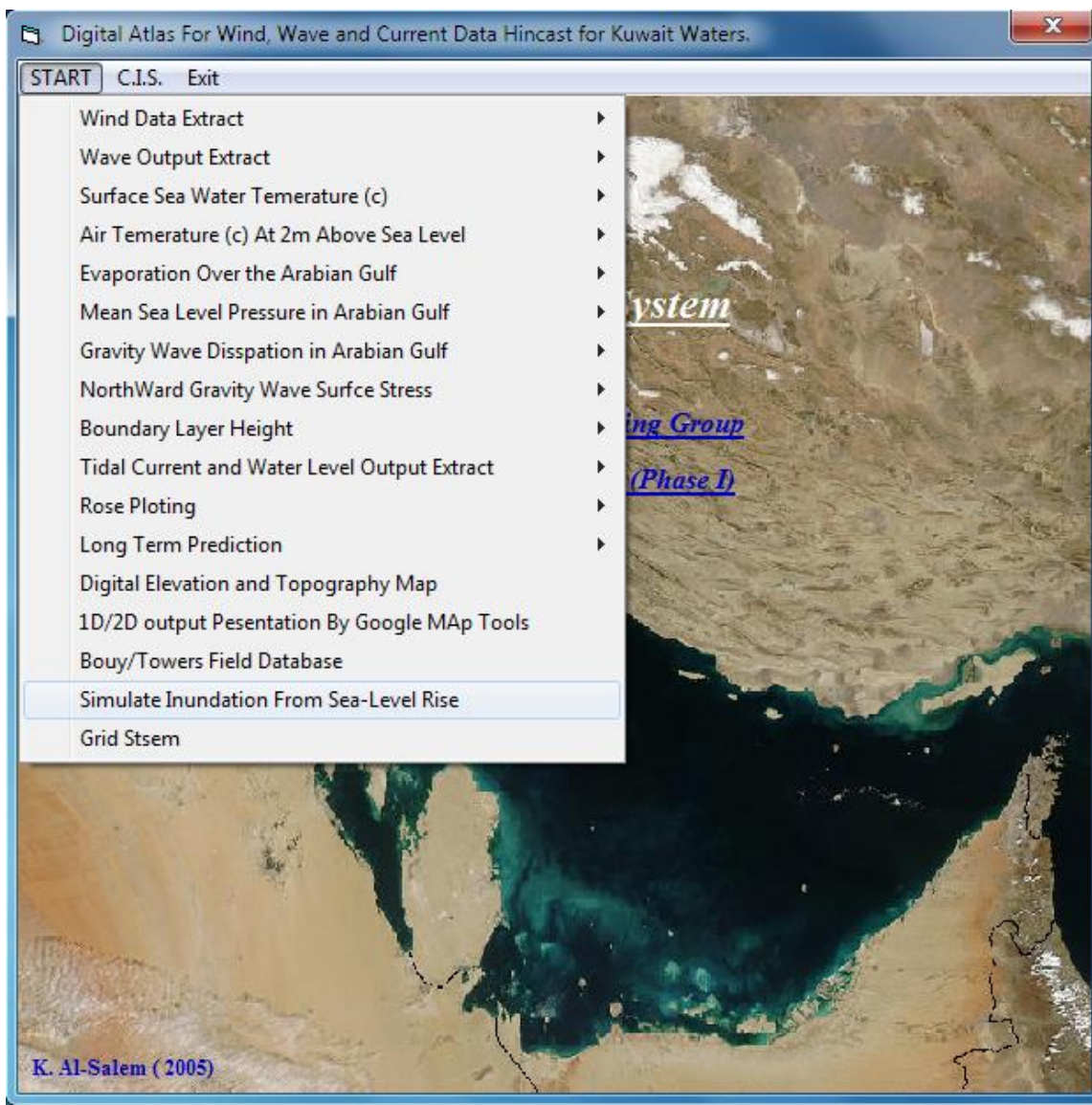


Figure 178

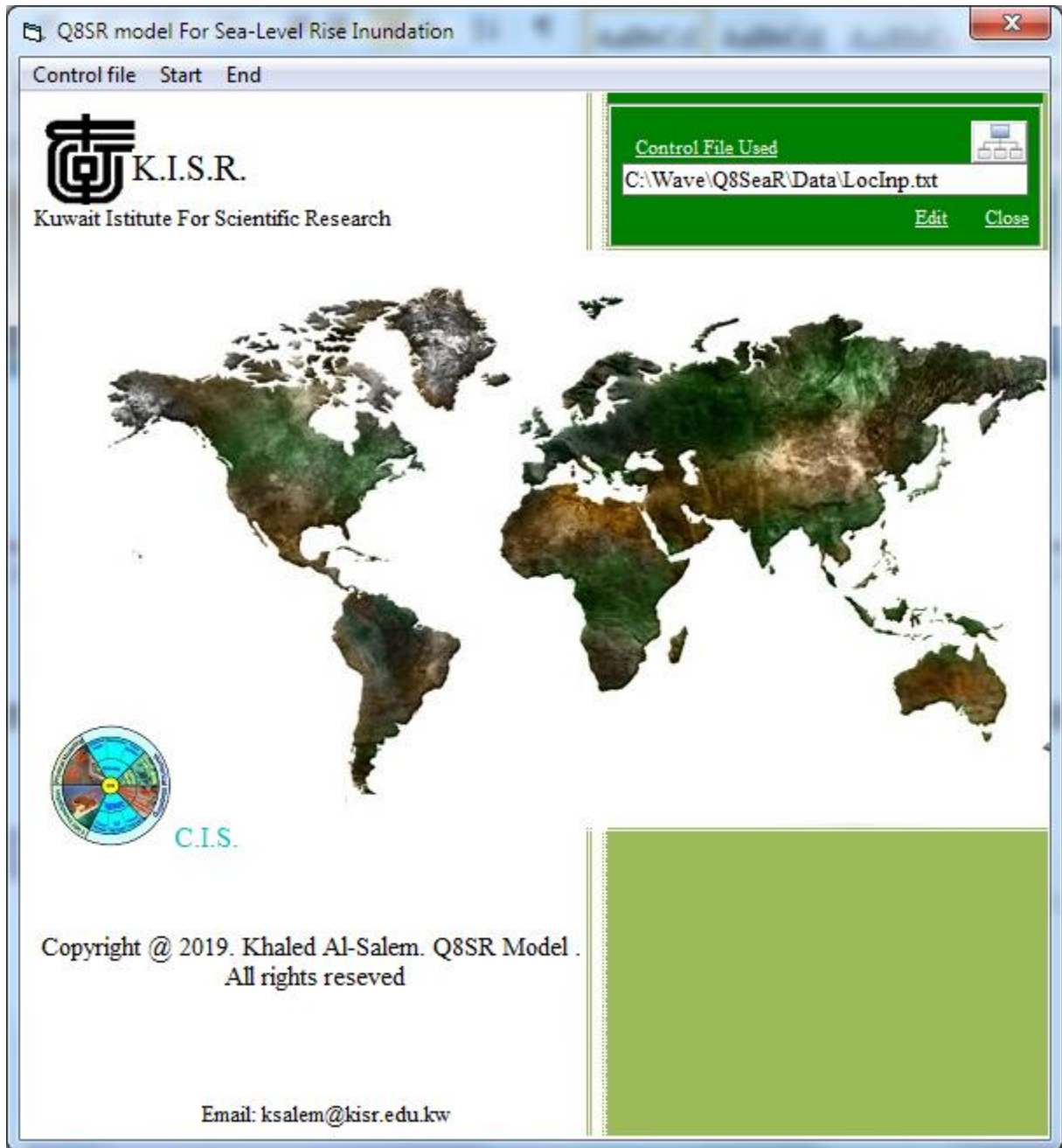


Figure 179



Figure 180

Figure 180 display a number of information on the Selected Domain area as follows:

- I. Lower-Left and Uper-Right corner on Domain Select in UTM
- II. Reload option to Recalculate and plot map
- III. Total Grid Number in Nx / Ny
- IV. Cell Grid Reslution (m)
- V. Total domain Grids
- VI. Pen color Size
- VII. Load Input depth file (m)
- VIII. Sea Level Rise Time Series as [Min/Max/Interval] (m)
- IX. Finite different Marching Simulation:
 - Top To Bottom
 - Bottom To Top
 - Right To Left

User must select the following to start

- 1- Sea-Level Rise time series [Min/Max/Interval]
- 2- Finite Different Marching Type
- 3- Check box for :
 - Check ON : for GMT output format
 - Check OFF : Surfer program Format



After All Entry Checked and entered user Select [] to start simulation the Inundation Prediction for each Sea level rise increment selected as shown in Fig 181



Figure 181

To Display the simulation Results user must select the check box [**Show Analysis**] as shown in Fig 181. A new Analysis frame will appear for following Presentation:

If user check one the following then Click on {  } to run:

- [Wet/Dry Cell Analysis [Fsat.dat] to edit final analysis file As shown in Fig 182
- [Show Out Dep File [Elr*.dat] To display Map on Inundation for Select Sea-Level Rise step. As shown Fig 181

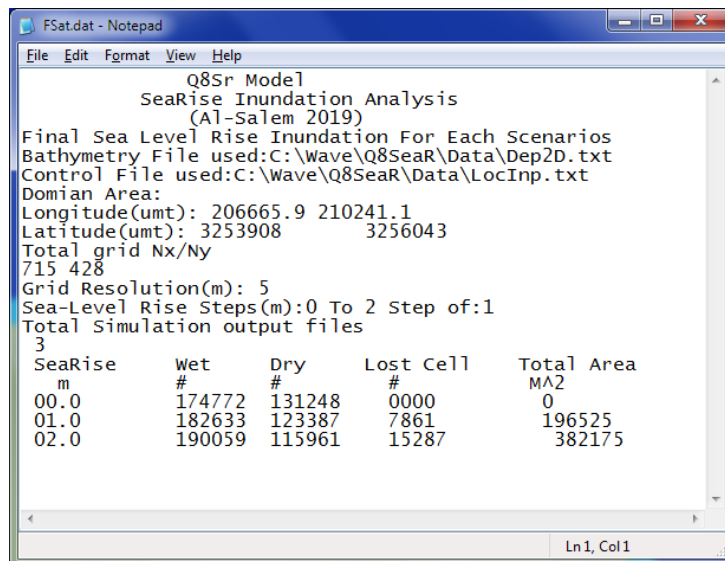


Figure 182

If user want to locate all Cell Went From Dry cell To Wet cell which show the inundation area on A map for Select Sea-Level Rise step As shown Fig 183 must select two file name as follows:

- [Load Out Dept. (Elr#.dat)]
- [Load Index (Sat#.dat)]

Then Click on  to display the map.
Two Result will allows user to select as


- [Edit] To Edit the select file as in Fig 184
-  Show inundation Perdition on Google Map {Need Internet Access} as in Fig 185

To Display the total area lost for Each Sea-Level Rise Increment as 1D plot.

User must chikc Box [**Plot Total Area**] in Fig 186

To Display the total number of Cells lost [From Dry to Wet] for Each Sea-Level Rise Increment as 1D plot.

User must chikc Box [**Cell Dry=>Wet**] in Fig 187

Then to show click on ]

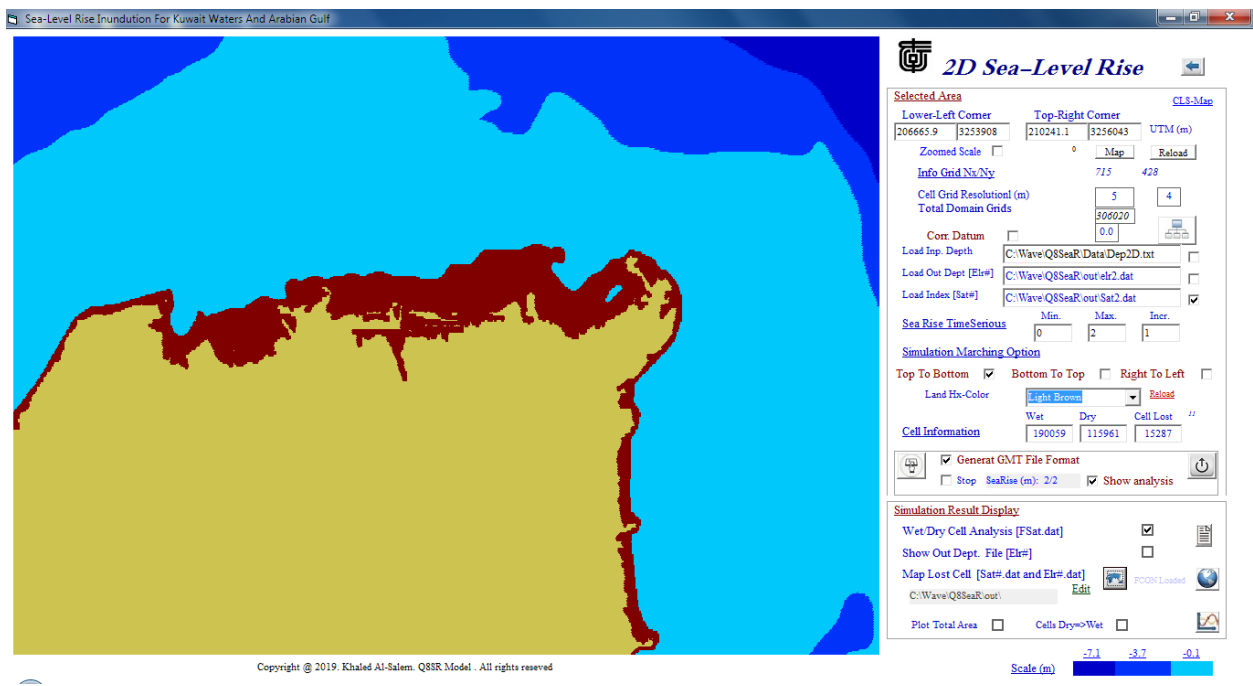


Figure 183

```

FWet.dat - Notepad
File Edit Format View Help

      Q8SR Model
      (Al-Salem 2019)
      Total Cell Becomes Wet From Dry:
      Bathymetry File used: C:\Wave\Q8SeaR\Data\Dep2D.txt
      Simulated Output Depth file used: C:\Wave\Q8SeaR\out\elr2.dat
      Related Index file used: C:\Wave\Q8SeaR\out\Sat2.dat
      Domain Area:
      Longitude(utm): 206665.9 210241.1
      Latitude(utm): 3253908 3256043
      Total grid Nx/Ny: 715 \ 428
      Grid Resolution(m): 5
      Total Domain Gris: 306020
      Sea-Level Rise Steps(m): 0 , 2 Step of: 1
      Total area Lost: 382175 MA2 at selected Steps
      15287
      Longitude      Latitude      New Dept      Old Dept
      UTM            UTM            M             M
      208808         3255323       -2            0
      208813         3255323       -2            0
      208818         3255323       -2            0
      208823         3255323       -2            0
      208828         3255323       -2            0
      208833         3255323       -2            0
  
```

Figure 184

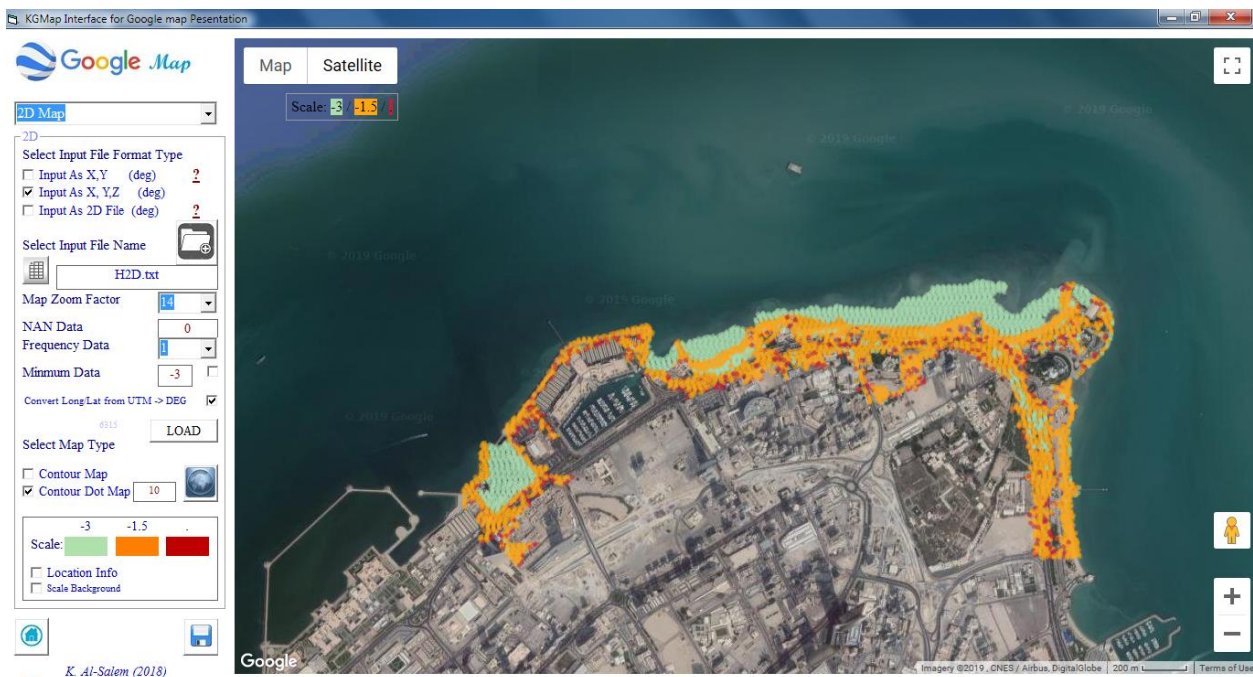


Figure 185

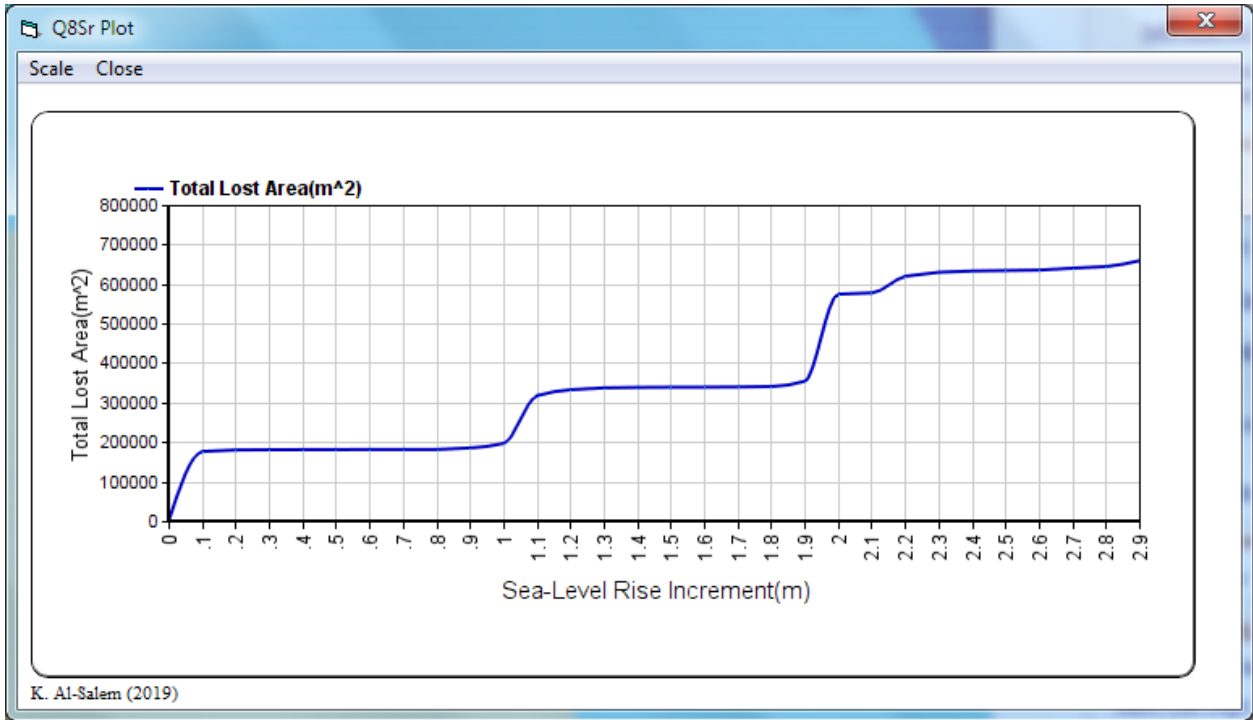


Figure 186

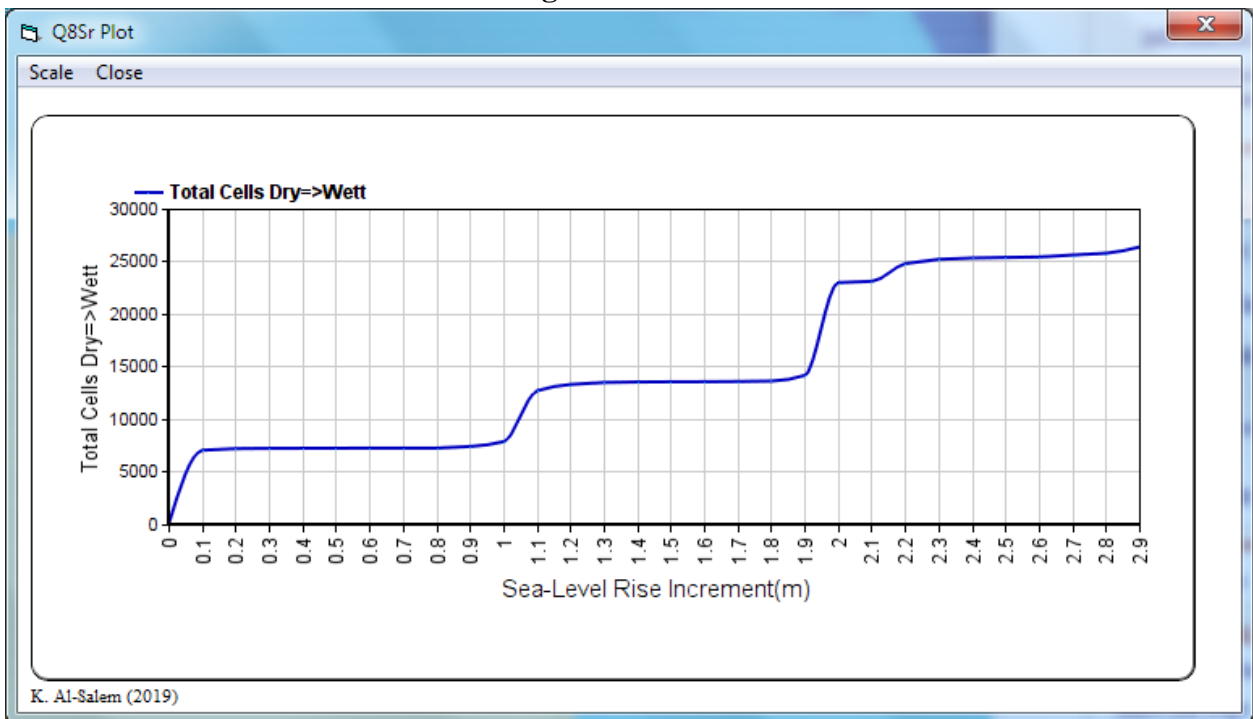


Figure 187

17. Grid system

To Show Coastal Information System Grid Domain for Wave/Wind
User should select the option from Fig 188. Figure display the Main Page for user the select.

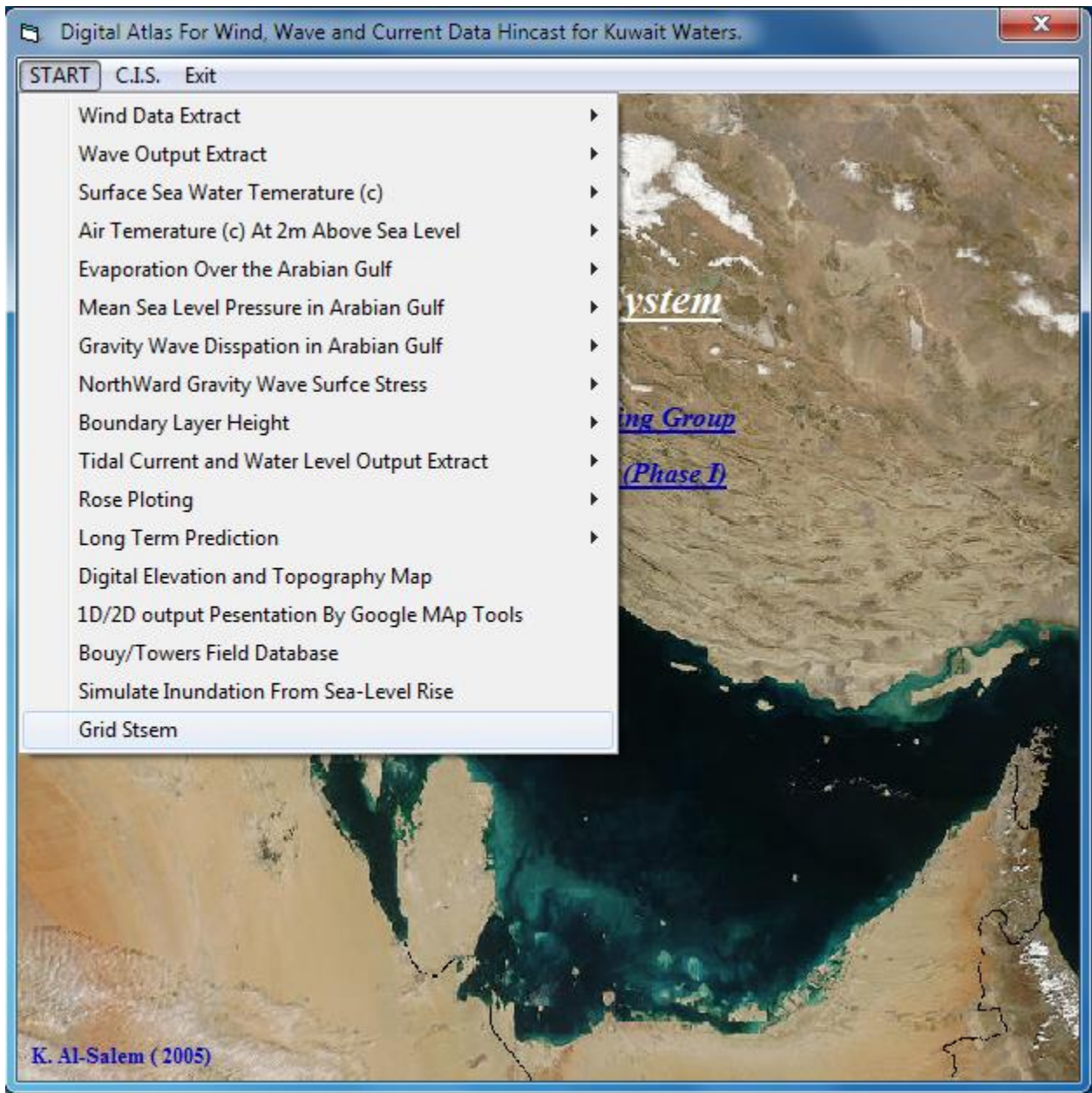


Figure 188

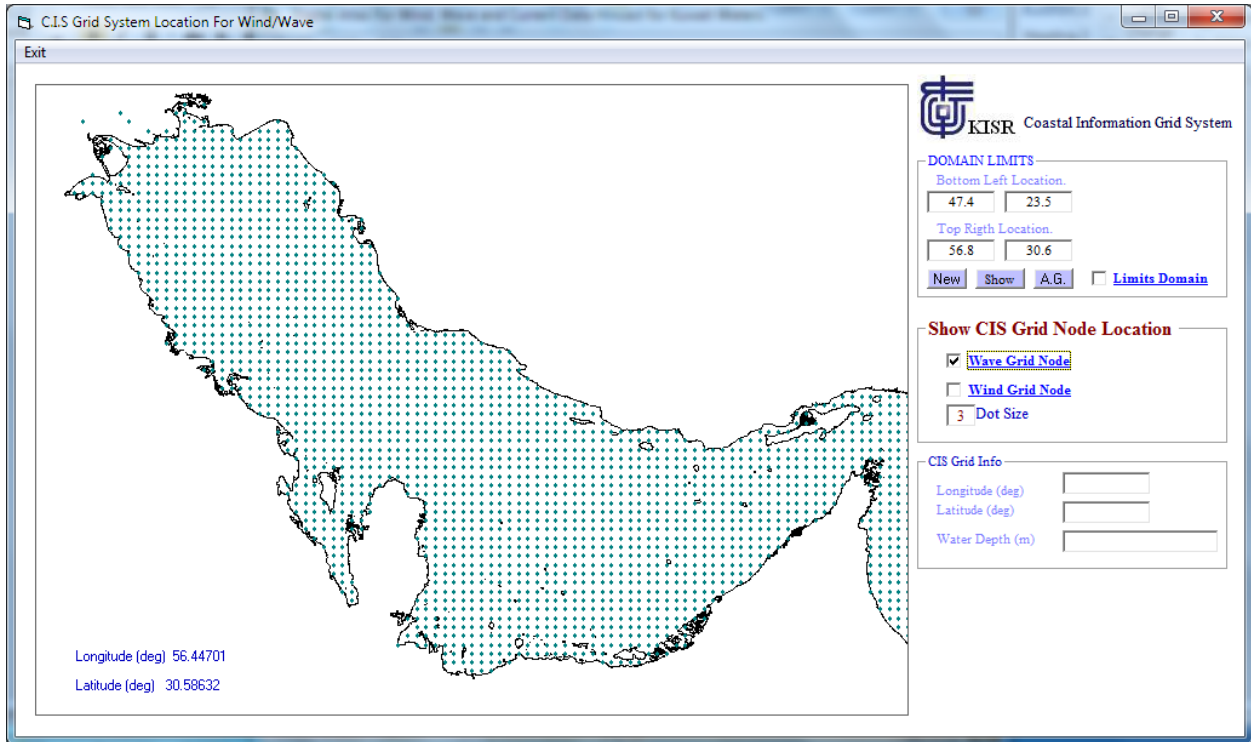


Figure 189

TUnami-N2KISR Interface Digital Manual



***EVALUATION OF TSUNAMI HAZARDS ALONG
THE KUWAITI COASTLINE DUE TO POSSIBLE
EARTHQUAKE AND LANDSLIDES***

Developed By
Khaled Al-Salem

2017

*COASTAL MANAGEMENT PROGRAM
KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH*

This report presents the progress of a scientific study to evaluate tsunami hazard to the Arabian coast with a particular interest to Kuwait. It has been identified from historical and literature reviews that tsunami for the Arabian Gulf regions, except from the extraterrestrial source, can be generated by submarine earthquake and landslide sources. The submarine earthquake can possibly occur at the Makran Subduction Zone, offshore of Oman, and the landslides, are from tall cliff along the Iranian coast. A series of numerical simulations were performed applying a well-known original tsunami modeling computer code developed at Tohoku University and low resolution and accurate elevation data. The code was further improved in this study by including the effects of natural tide by Kuwait instituted for scientific Research [Al-Salem 2017]. This report presents some preliminary simulation results showing that there are insignificant adverse effects of the tsunami to Kuwait in terms of wave height. More information was displayed at digital atlas of the Project at remote web-address at: [<http://www.hceatkuwait.net/Q8TSUnami/Q8Main.aspx>].

Tsunami-N2KISR interface Code was develop by using the Following Programing interpreter Language Code:

1. Visual Fortran F90
2. Visual Qbase 6.0
3. GMT [Generic Mapping Tools Graphics] It is high advanced Postscript coding for developing colored map by Perl postscript coding.
4. GS Scriptor program [Surfer Utility]
5. Active Script page for Remote web-coding [For Public Warning System at web-address: [<http://hceatkuwait.net/KUnami/KUnami.aspx>].
6. Objective-C for Mobile coding [For Public Warning System at web-address: [<http://hceatkuwait.net/KUnami/KUnami.aspx>].

Project Overview.

Submarine Earthquake-Generated Tsunamis

Scenario Setting Up for Makran Subduction Fault

The MSZ fault as shown in Fig 1 was considered to generate tsunami in four cases in this study. Four earthquake scenarios were established in this study. The four earthquakes replicate an actual biggest earthquake recorded in 1945 with the earthquake moment magnitude (M_w) of 8.3, according to Heidarzadeh and Satake (2014). Although there is no record of M_w greater than 8.3 in this area, this study followed a scenario analysis suggested by Heidarzadeh et al. (2009), which proposed tsunami sources from great earthquakes with M_w up to 9.0, i.e., for the running Case E2, Case E3, and Case E4. The relationship between earthquake magnitude and fault geometry previously proposed (Wells and Coppersmith, 1994) was applied as it gives a smaller rupture area but higher slip and ensures the probable worst- case scenarios. Table 1 provides details of fault parameters for each scenario considered in this study.

Scenario Setting Up for the Hypothetical Kazerun-Qatar Fault

The Kazerun-Qatar fault system is a north-trending dextral strike-slip fault zone in the Zagros mountain belt of Iran as shown in Fig. 2. It probably originated as a structure in the Pan-African basement. This fault system played an important role in the sedimentation and deformation of the Phanerozoic cover sequence and is still seismically active. No previous study has reported the

continuation of this important and ancient fault system northward across the Sanandaj–Sirjan zone. Kazerun faults were identified in the Arabian gulf. The Zagros mountain front is a reverse fault and is not situated in the sea. Therefore, the earthquake from this fault will not probably cause enough uplift or subsidence in the sea. The Kazerun–Qatar fault is a strike-slip fault. Table 3 provides more information on the strike-slip faults. Although the Kazerun–Qatar fault has some significant extension into the sea at the Arabian Gulf, as shown in Figure 2.

Table 1. Earthquake Fault Parameters for Makran Subduction Zone Considered in this Study

No.	M_w	Length (km)	Width (km)	Slip (m)	Depth (km)	Strike	Dip	Rake
Case E1	8.3	55	70	10	27	246	7	89
		55	70	10	27	246	7	89
		55	70	0	27	246	7	89
		55	70	4.3	27	246	7	89
Case E2	8.3	200	80	8.5	27	270	7	89
Case E3	8.6	500	100	13	25	280	7	90
Case E4	9	500	150	25	25	265	7	90
		400	150	25	25	280	7	90

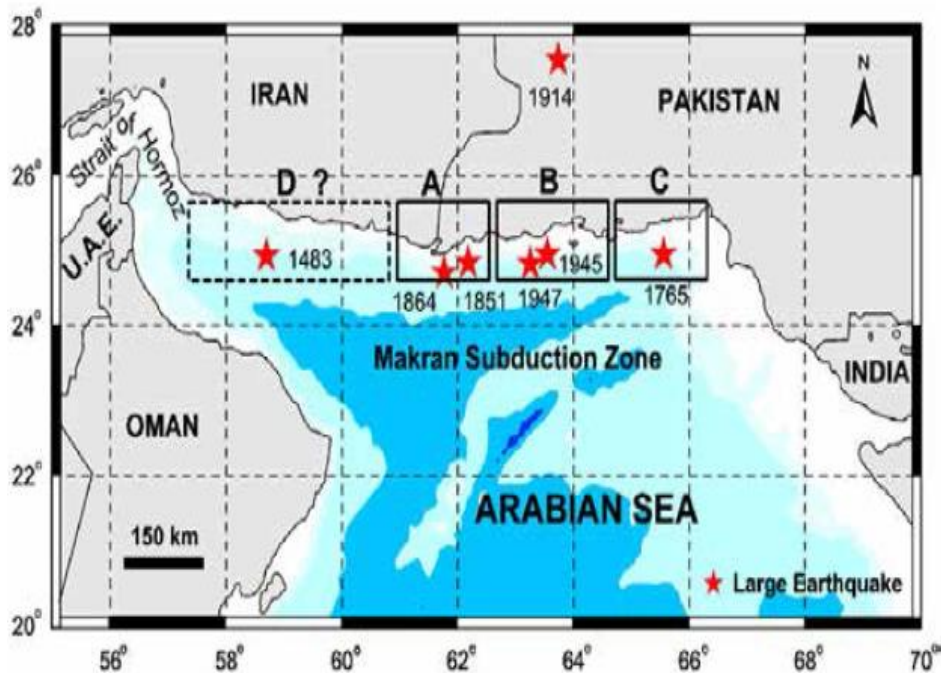


Fig. 1. Historical earthquakes in Makran Subduction Zone and the four blocks A to D as segments of the plate boundary, which ruptured due to large earthquakes.



Fig. 2. Kazerun-Qatar Fault Tsunami genic sources.

Table 2. Earthquake Fault Parameters of the Hypothetical Kazerun-Qatar Fault

N	Magnitude Mw	X (m)	Y (m)	Slip (m)	Length (m)	Width (m)	Strike (deg)	Dip (deg)	Rake (deg)	Depth (m)
1	8.7	404530	3430030	20	500000.0	50000.0	177.0	62.0	90.0	10000.0
2	8.8	404530	3430030	25	500000.0	50000.0	177.0	62.0	90.0	10000.0
3	8.9	404530	3430030	40	500000.0	50000.0	177.0	62.0	90.0	10000.0
4	9	404530	3430030	50	500000.0	50000.0	177.0	62.0	90.0	10000.0
5	9.065	404530	3430030	65	500000.0	50000.0	177.0	62.0	90.0	10000.0
6	9.2	404530	3430030	100	500000.0	50000.0	177.0	62.0	90.0	10000.0

Landslide-Generated Tsunamis

Scenario Setting Up for Landslide Source

Earthquake-induced coastal landslide might have been the cause of the large tsunami waves (Mokhtari, 2011). Even while it was not confirmed, coastal landslide triggered by seismic motion may generate future tsunamis in the Arabian Gulf region. Based on the possible landslide-generated tsunami in 1008 AD in the Gulf in Siraf, five possible areas for coastal landslides

(Cases L1 to L7) were identified at some of the Iranian coasts where the land elevations are higher than 500 m and are close to the sea. Locations of the landslide site for Cases L1 to L7 are given in Fig. 3. Coastal landslide parameters used for the seven cases considered in this study are shown in Table 3.

Table 3. Coastal Landslide Parameters for the Assumed Scenarios inside the Arabian Gulf

No.	Volume (km ³)	Length (km)	Width (km)	Thickness (m)
Case L1	1.0	20	5	10
Case L2	1.0	20	5	10
Case L3	1.0	20	5	10
Case L4	1.0	20	5	10
Case L5	0.5	10	5	10
Case L6	1.0/1.5/2.0	20	5	10/15/20
Case L7	1.0/1.5/2.0	20	5	10/15/20

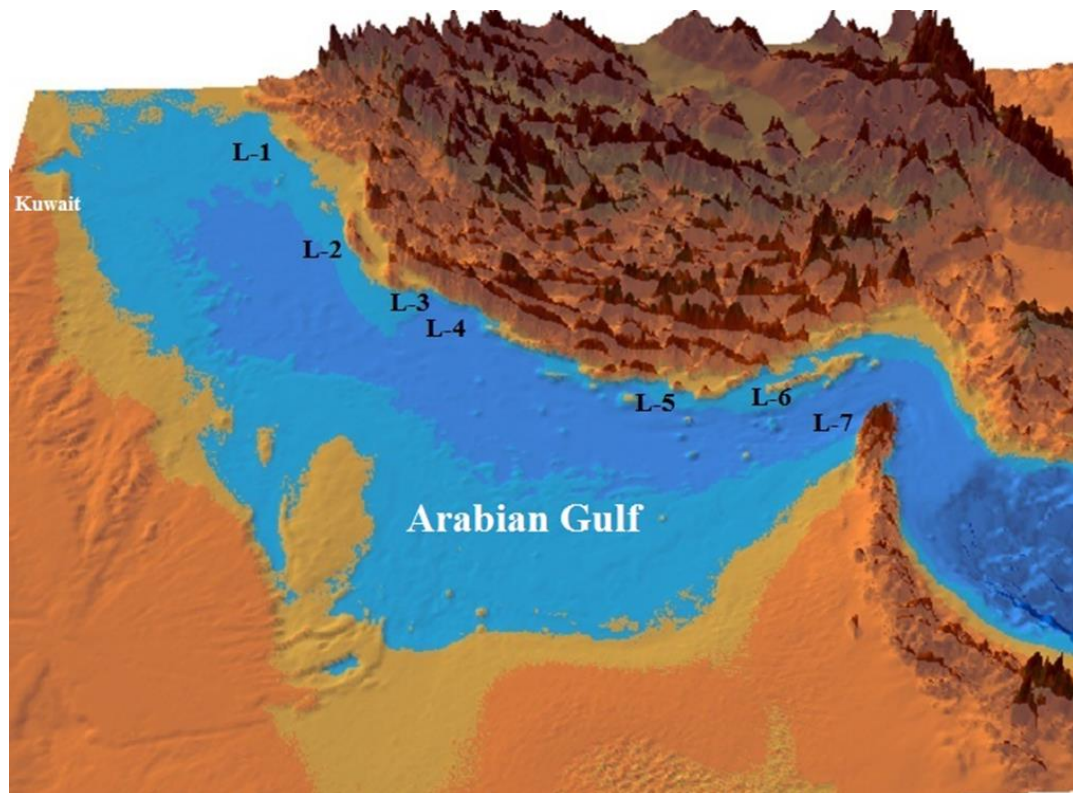


Fig. 3. Locations of coastal landslide in the Arabian Gulf region for Case L1 to Case L5.

Source of the Topography and Bathymetry Data

In this study, different-high resolution satellite images and topography and bathymetry data were used. The images were either purchased or obtained from any available free source. The images were processed to obtain a new set of satellite-derived bathymetry and land elevation. The data were from local digitized navigational charts and free data available from different sources. Both data were used to create seamless elevation and bathymetry map of the Arabian Gulf region and part of the Indian Ocean/ Arabian Sea. The new data were created after interpolating (preserving the original data values), resampling, clipping, and post processing of six original data as shown in Fig 4.

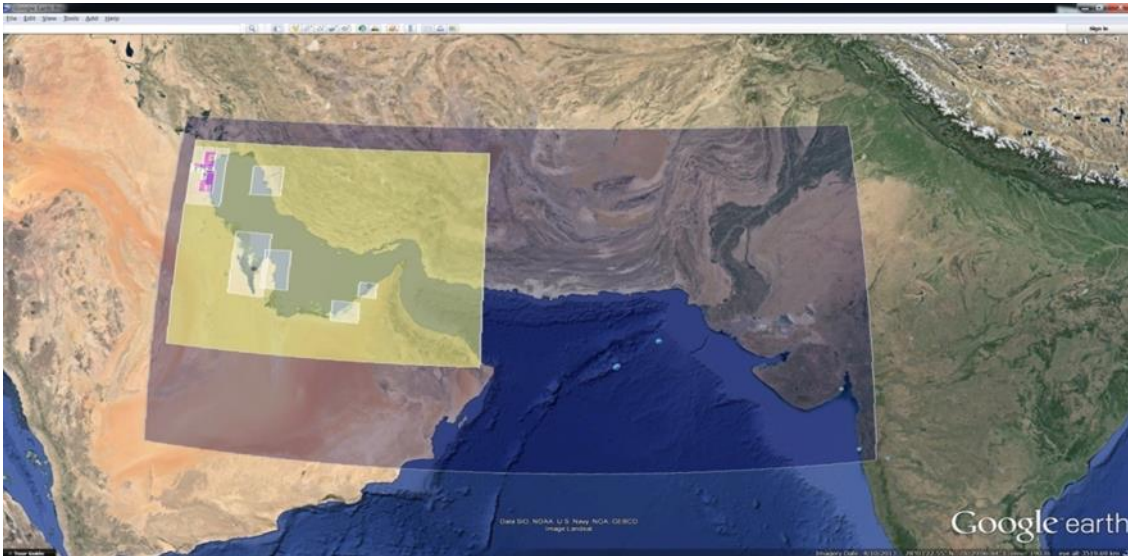


Fig 4. Multiple grids system.

Tsunami Numerical Modeling

Method for Submarine Earthquake-Generated Tsunami Simulation

Numerical simulation of far-field tsunamis was carried out using the code that was developed by Tohoku University, which was called the Tohoku University's Numerical Analysis Model for Investigation of Near-field tsunamis (TUNAMI) code (IUGG/IOC TIME Project, 1997). The model was updated by [Al-Salem K. 2017 at KUWAIT INSTITUTE FOR SCIENTIFIC RESEARCH]. New tsunami model TUNAMI-N2KISR and model interface has been successfully developed and two-dimensional (2D) Tidal level prediction was developed and coupled inside the model interface. The model has been tested successfully with the newly available DEM for prediction tsunami wave prediction with and without the effect of tidal level.

Coupled 2D Water Level Prediction Model with TUNAMI-N2KISR Model.

KISR-Coastal Management Program developed a 2D tidal model, which can predict tide level at any time covering the whole Arabian Gulf and Gulf of Oman region based on KTide model (Al-Salem, 2006, 2008 and 2012). The tide water level distribution at an hour's interval is shown. These results suggested that there are several rapid changes of the water level at different locations (especially at the head of the Arabian Gulf), which should have some significant effect

on tsunami wave propagation. Figure 5 shows Comparison of water level prediction at Al-Ahmadi-Kuwait from KTide 2D model and KTide 1D model [developed by Al-Salem] at [http://www.hceatkuwait.net/web_pas/web-ktide/default.aspx]

Figure 6 display Results of the newly developed 2D tide model showing the distribution of water level in the Arabian Gulf from tide at hourly intervals.

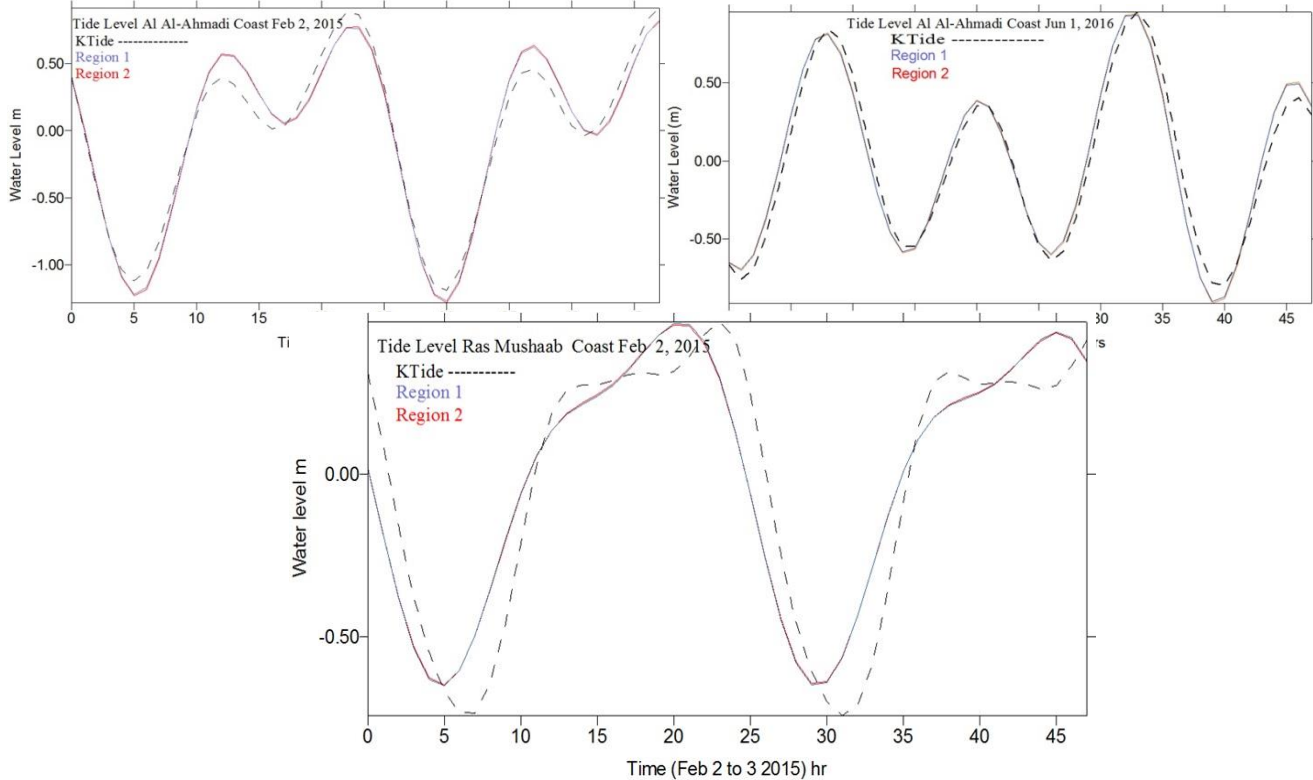


Fig. 5 Comparison of water level prediction at Al-Ahmadi-Kuwait from KTide model and 2D water level prediction on 1 June 2016 and Ras Mushaab-Saudi Arabia.

Modeling of the Landslide-Generated Tsunami

For coastal landslides, tsunami generation was simulated using the two-layer numerical model developed by solving nonlinear long-wave equations within two interfacing layers with appropriate kinematic and dynamic boundary conditions at seabed, interface, and water surface (Imamura and Imteaz, 1995). The coastal landslide was calculated by the 3D slope failure analysis method to define the actual possible failure volume in detail. The two-layer numerical model simulates landslide-generated tsunamis by modeling the interactions between tsunami generation and submarine landslides as upper and lower layers Fig. 7. The two-layer model implemented with TUNAMI-N2KISR model solves the nonlinear equations of mass and momentum conservation in two layers, which have the interactions between upper and lower layers. The initial condition of lower layer calculated from coastal landslides can generate tsunami waves in the upper layer by means of the interactions between these two layers.

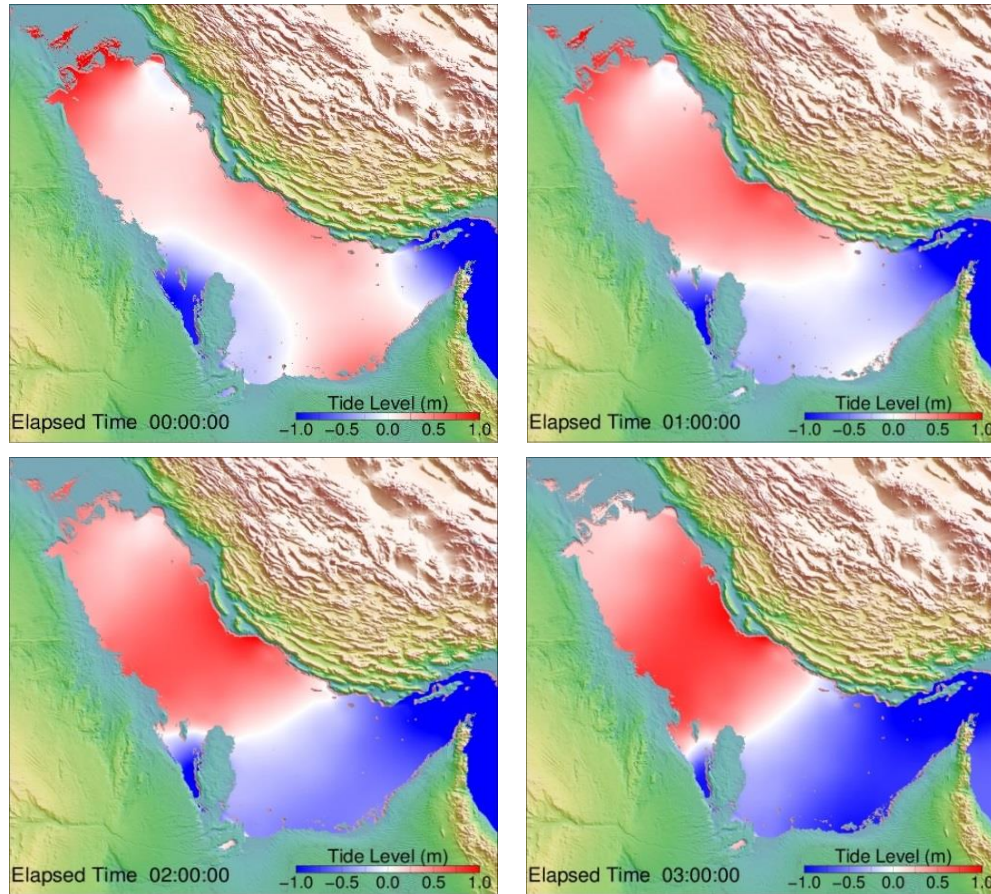


Fig 6. Results of the newly developed 2D tide model showing the distribution of water level in the Arabian Gulf from tide at hourly intervals.

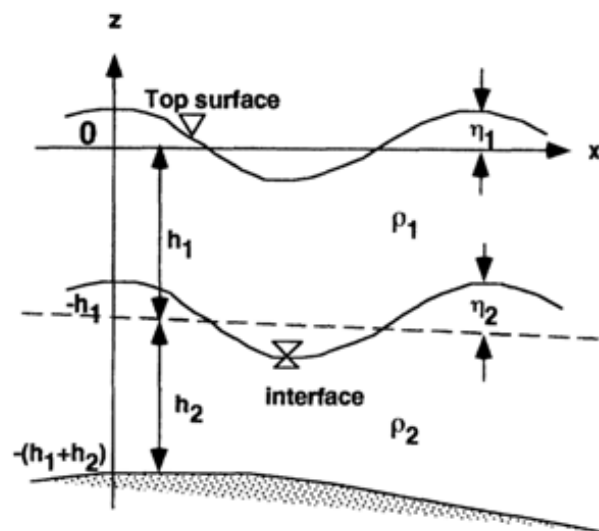


Fig.7. Definition of two-layer profile

TUnami-N2KISR Model Demonstration

*PREDICTION Of TSUNAMI HAZARDS ALONG THE ARABIAN GULF AND GULF OF OMAN
COASTLINE DUE TO POSSIBLE EARTHQUAKE AND LANDSLIDES*

[Al-Salem K 2017]

More Info. Website : <http://www.hceatkuwait.net/Q8TSUnami/Q8Main.aspx>

User can run the TUnami-N2KISR interface from [Coastal Information System CIS] interface
Then Figure 8 will display the main TUnami-N2KISR main page as follows:



Figure 8

Figure 9 will display after user select [START]. Figure 9 is main model page displays a number of options for user to selected as follows:

- Option 1: Info. Section
- Option 2. Two check box [Set Region and Resize]
- Option 3: Model Simulation
- Option 4: Analysis
-

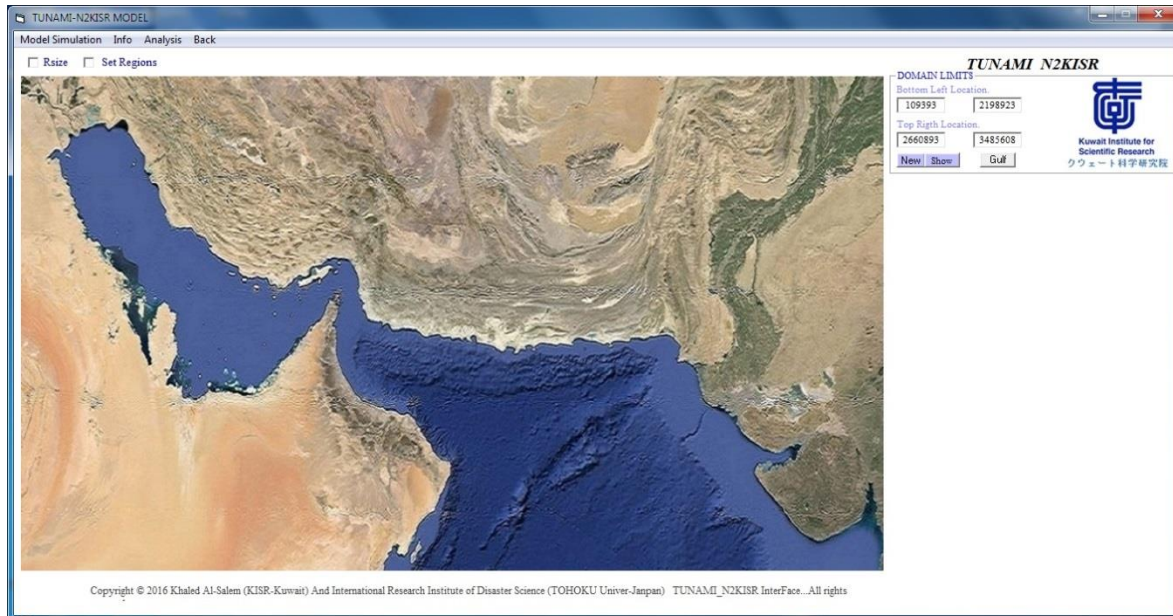


Figure 9

If user select OPTION 1

User select option 1 from Figure 9 a number of sub-option will display for user as shown in Figure 10 for the follows information as

- Show mozaics [To display sub-Grids area Location as display in Fig 11]
- Regions images [To display sub-Grids Image area Location as display in Fig 12]
- Bathymetry [To display System Area Bathymetry as display in Fig 13]
- Epicenter Location
- Pre-Scale
- -----
- Activation [System Activation Pass-Code Request from Developer]



Figure 10

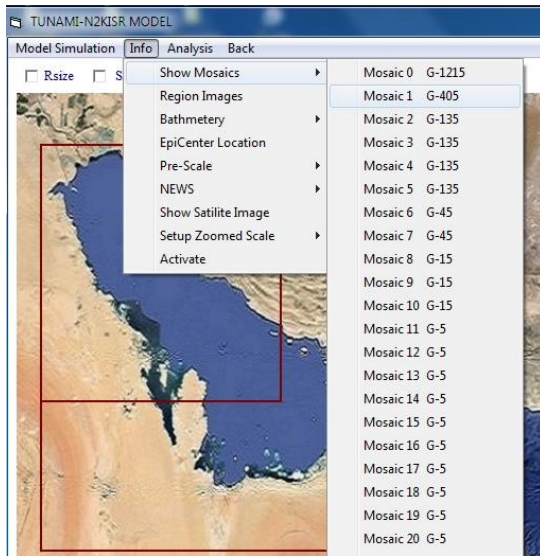


Figure 11

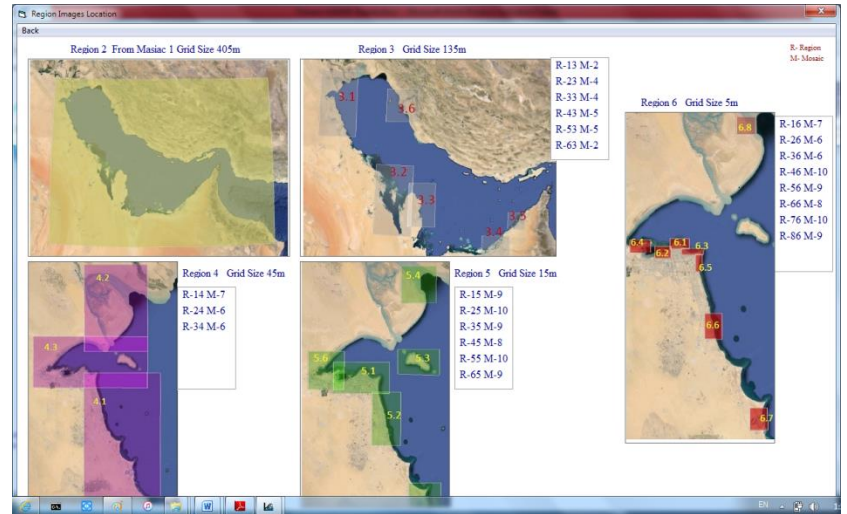


Figure 12

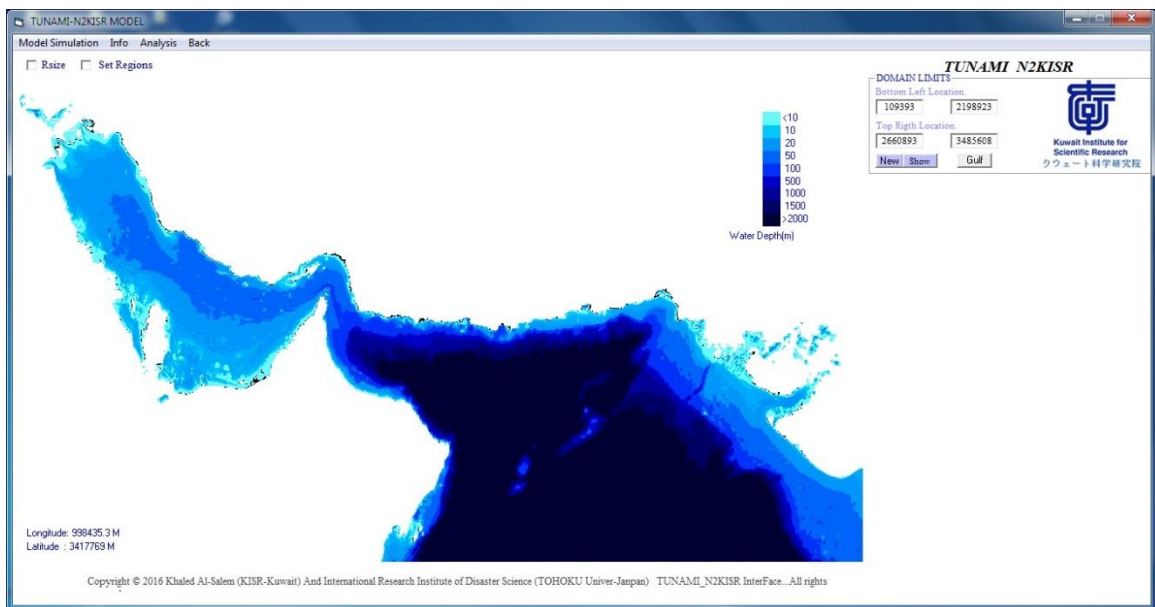


Figure 13

If Select Option 2. Check box [Set Region]

In this section user can start new project. User must check [Set Region] on Fig 13 then Figure 14 will display for user number information to start project. A number of Check boxes will display for user at Figure 14 as follows:

- SetUp Model Region
- SetUp Water Level 2D KTide model

- SetUp Region Connections
- SetUp Initial Deformation
- SetUp Output Points Location

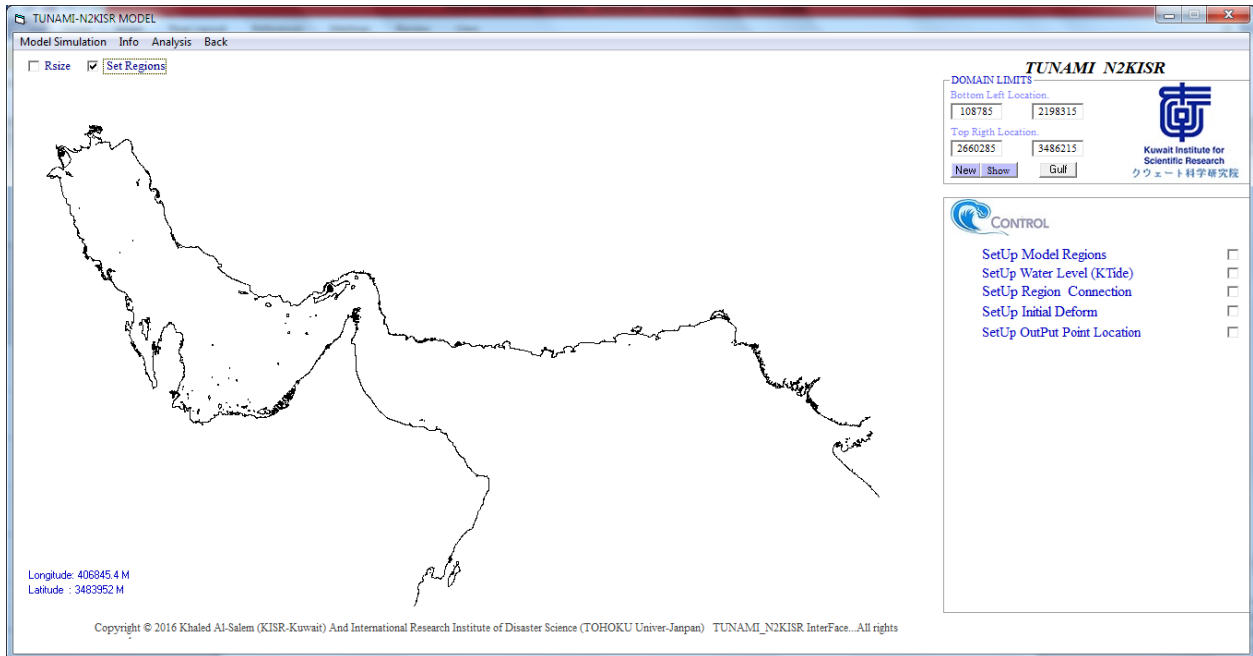


Figure 14

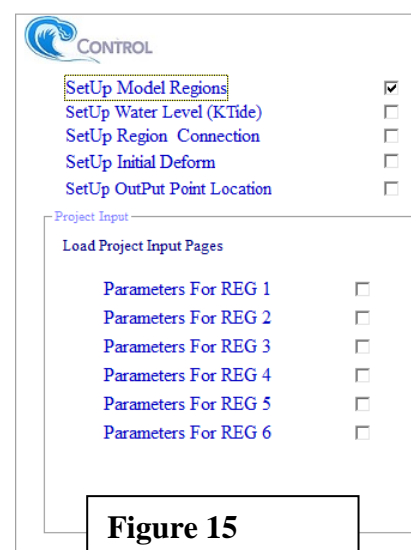
If user select: SetUp Model Region

Figure 15 will display 6 model regions for user to setup new project as:

- Parameters For Region 1 that cover area of Arabian Gulf and Gulf Of Oman

With grid size resolution of 1215m dx/dy se Figure 12

- Parameters For Region 2 that cover area of Arabian Gulf With grid size resolution of 405m dx/dy see Figure 12
- Parameters For Region 3 With grid size resolution of 135m dx/dy. divide into sub area of 6 inside Arabian Gulf see Figure 12.
- Parameters For Region 4 With grid size resolution of 45m dx/dy. divide into sub area of 3 inside Kuwait waters see Figure 12





- Parameters For Region 5 With grid size resolution of 15m dx/dy. divide into sub area of 6 inside Kuwait waters see Figure 12
- Parameters For Region 6 With grid size resolution of 5m dx/dy. Divide into sub area of 8 inside Kuwait waters see Figure 12

User must active for each grid area connection only Region 1 by default is activated.

Figure 16 show Parameters area of Region 1

Figure 17 show Parameters area of Region 2

Figure 18 show Parameters area of Region 3

Region 1 Inputs Parameters

TUnami-N2KISR Parameters Input

Region 1 Parameters

IF1: Number of X grids Dimension: 2100
 JF1: Number of Y grids Dimension: 1060
 DX1: Horizontal grid size along x direction: 1215
 Dyl: Horizontal grid size along y direction: 1215

Start X1: 108785 End X2: 2660285
 Start Y1: 2198315 End Y2: 3486215

Default Name for Region 1 file: C:\TUNAMI-N2KISR\bathymetry\Region1.dat

Figure 16

Region 2 Inputs Parameters

TUnami-N2KISR Parameters Input

Region 2 Parameters R-12

IF1: Number of X grids Dimension: 2790
 JF1: Number of Y grids Dimension: 2100
 DX1: Horizontal grid size along x direction: 405
 Dyl: Horizontal grid size along x direction: 405

From Left: Start X1: 169535 50 End X2: 1298270 980
 Index From Lower: Start Y1: 2514215 260 End Y2: 3363500 960

Border R2

Parent Grid ID Number: 1 Mosaic Number: 0
 Parent Index X1: 108785 Parent Index X2: 2660285
 Parent Index Y1: 2198315 Parent Index Y2: 3486215

Default Name for Region 2 file: C:\TUNAMI-N2KISR\bathymetry\Region2.dat

Figure 17

Region 3 Inputs Parameters

TUnami-N2KISR Parameters Input

Region 3 Parameters R-13

IF1: Number of X grids Dimension: 960 450 810 960 630 750 1000
 JF1: Number of Y grids Dimension: 1950 600 1200 1140 900 1050 1000
 DX1: Horizontal grid size along X: 135 135 135 135 135 135 135
 Dyl: Horizontal grid size along Y: 135 135 135 135 135 135 135

Index X From Left: Start X1: 0 169535 640 428735 850 513785 1460 760835 1780 890435 600 412535
 End X2: 320 299135 790 489485 1120 623135 1780 890435 1990 975485 850 513785

Index Y From Lower: Start Y1: 1450 3101465 830 2850365 600 2757215 300 2635715 580 2749115 1600 3162215
 End Y2: 2100 3364715 1130 2931365 1000 2919215 680 2789615 880 2870615 1950 3303965

Parent Grid ID Number/ Mosaic #: 2 2 2 4 2 4 2 5 2 5 2 2 2 2
 Parent Index X1: 169535 169535 169535 169535 169535 169535 169535
 Parent Index X2: 1298270 1298270 1298270 1298270 1298270 1298270 1298270
 Parent Index Y1: 2514215 2514215 2514215 2514215 2514215 2514215 2514215
 Parent Index Y2: 3363500 3363500 3363500 3363500 3363500 3363500 3363500

Generate Region Data And 2D Data: Region-13 Region-23 Region-33 Region-43 Region-53 Region-63 Region-73

Figure 18

Region 4 Inputs Parameters

TUnami-N2KISR Parameters Input

Region 4 Parameters R-34

IF1: Number of X grids Dimension: 1500 1200 1950 1000
 JF1: Number of Y grids Dimension: 1950 1500 1200 1000
 DX1: Horizontal grid size along X: 45 45 45 45
 Dyl: Horizontal grid size along Y: 45 45 45 45

Index X From Left: Start X1: 270 205985 285 208010 5 171020
 End X2: 770 273485 685 262010 655 258770

Index Y From Lower: Start Y1: 400 3155465 1215 3265490 960 3231065
 End Y2: 1050 3243215 1715 3332990 1360 3285065

Parent Grid ID Number/ Mosaic #: 13 6 13 7 13 7 13
 Parent Index X1: 169535 169535 169535
 Parent Index X2: 299135 299135 299135
 Parent Index Y1: 3101465 3101465 3101465
 Parent Index Y2: 3364715 3364715 3364715

Generate Region Data And 2D Data: Region-14 Region-24 Region-34 Region-44

Figure 19

Each Region page as shown in Figure 17,18 and 19 have plot option to the following

- **Parent map** to plot pervios region area
- **Draw**, to select the sub region to plot
- **User**, user can create sub region manually

Example connects setup

Region 1

Region 2 check

Region 3 check 3.1

Region 4 check 4.3

Region 5 check 5.1

Region 6 check 6.1

Figure 20 display user connections .

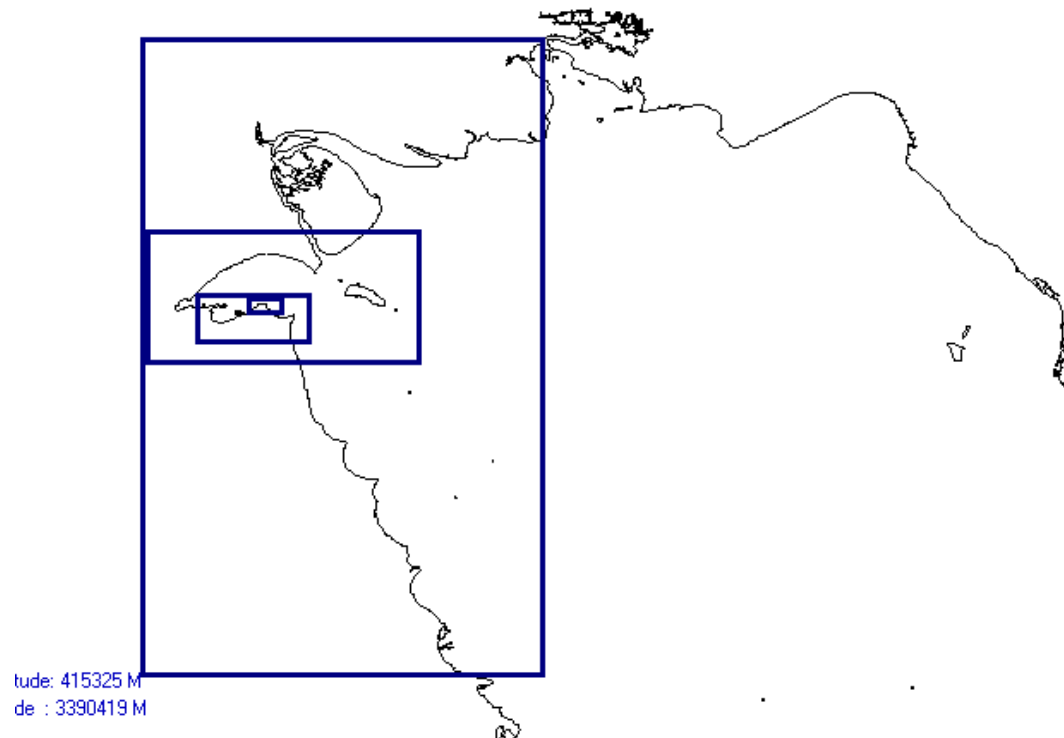


Figure 20

If user select: SetUp Water Level 2D KTide model

User after setup project connection then if user want to simulated Water level change in Tsunami simulation model. User select 2D Ktide model; Then Figure 21 will display for main page of 2D KTide model. User must select[**start**].Figure 22 will display for user with the selected connect are check. User must setup Date [day/month/year] and number of hours for tidal level prediction. All predictions data will store at sub-directory TIDE. Predicted data are Hourly. Figure 23 display after user select [Start] to complied 2D KTIDE model.



Figure 21

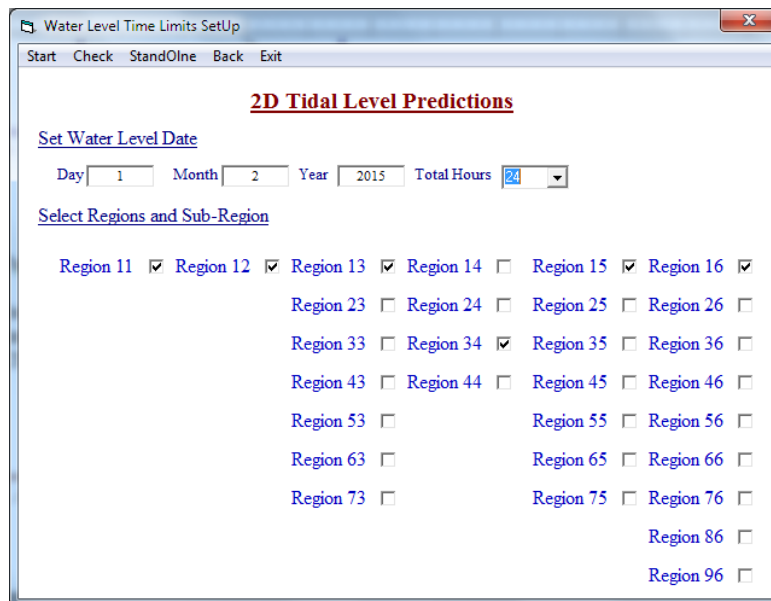


Figure 22

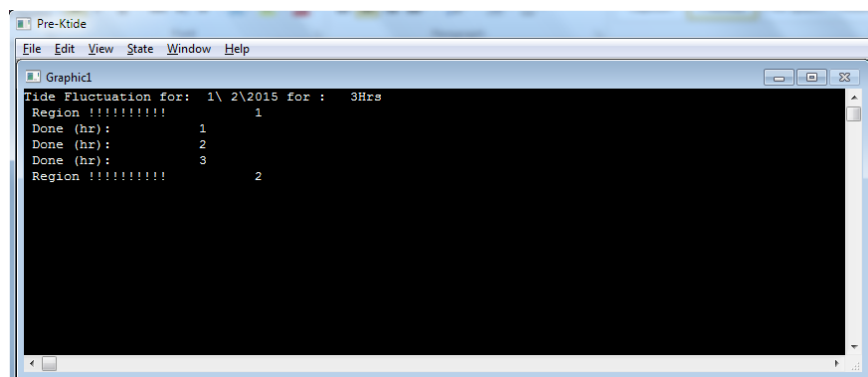


Figure 23

If user select: SetUp Region Connections

User can display and load newly set connection Or saved connection by select checkbox [**SetUp Region Connections**]. Figure 24 will display the setup new connect as shown in Figure 20. User can enter

System or project name

Target area name

User can update the connect manually

User can load old saved system connect by select file from [Directory] as shown in Figure 25 and then from [File] selected load. Figure 26 display Connection Format stored.

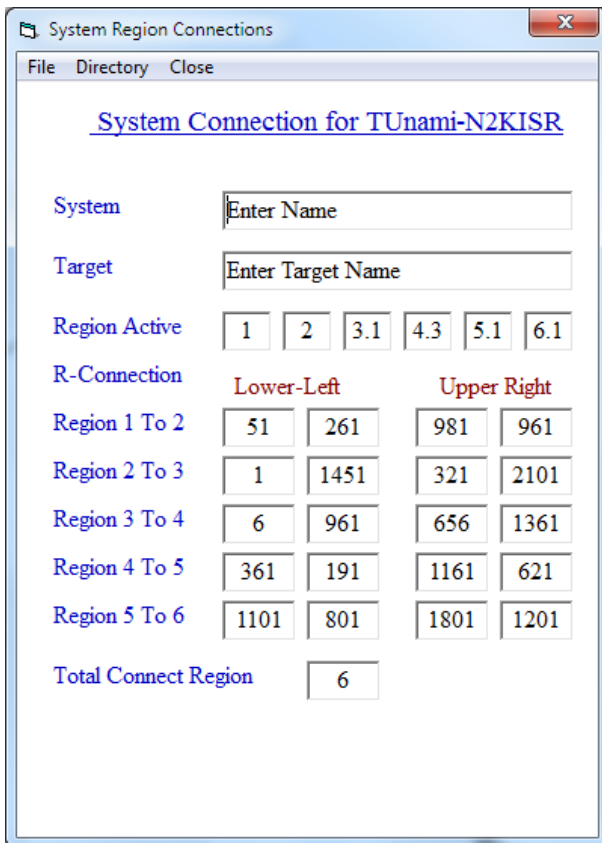


Figure 24

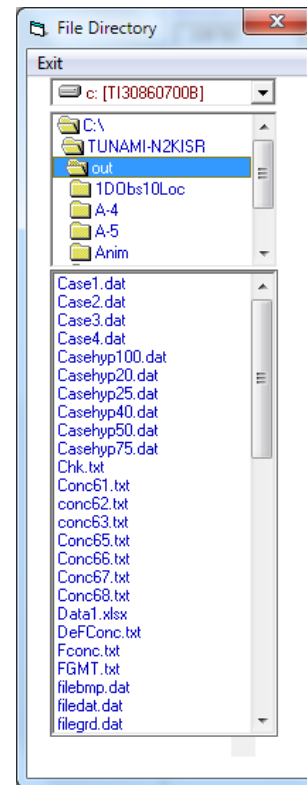


Figure 25

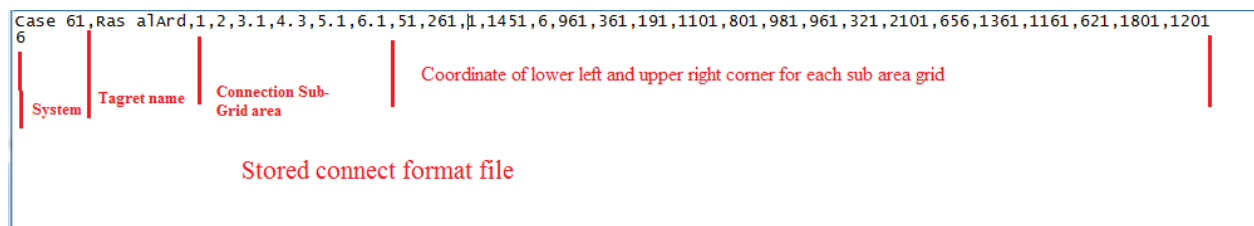


Figure 26

If user select: SetUp Initial Deformation

After all regions connection are setup then user must start initial deformation by checkbox **[Initial Deformation]** then Figure 27 will display.

To setup initial deformation user must select [setup input file].

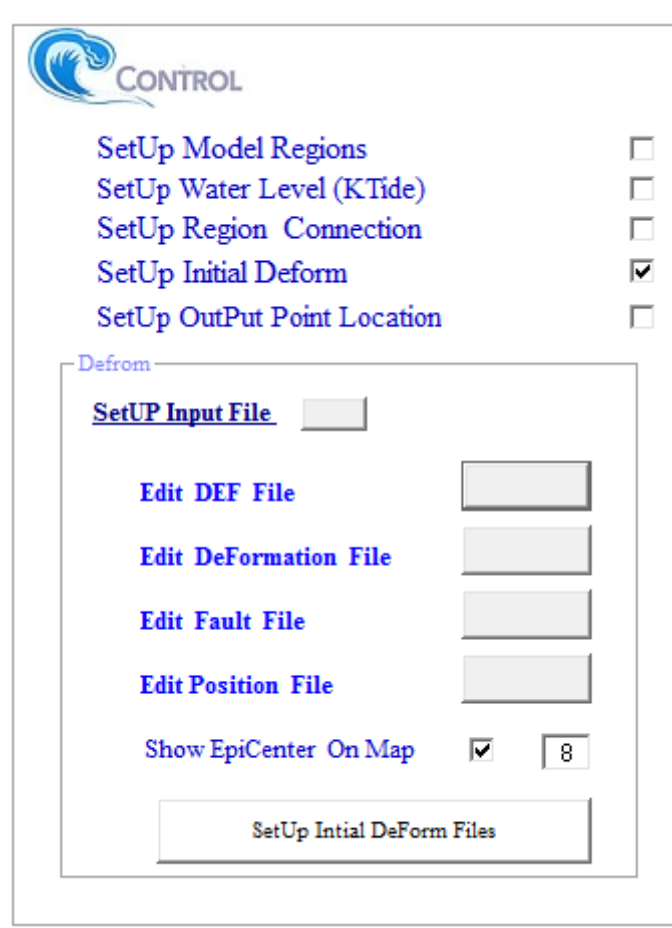
Figure 28 display the sub-area grid parameter selected . user must load saved connect file then All sub-connect area data display and Earth Quack scenarios case for user to select by checkbox **[Fault set file data]** Then user must save data. Then close page.

On Figure 27 user can see the save sub-connect data file at [Edit file].

If user want to display Epicenter earthquake location must checkbox ON.

User can start simulate initial deformation case by select **[Set Initial Deformation]**

Figure 29 will display the Epicenter location and Figure 20 display compilation page of the simulation model.



The screenshot shows a software window titled "CONTROL" with a blue wave logo. It contains a list of options with checkboxes:

- SetUp Model Regions
- SetUp Water Level (KTide)
- SetUp Region Connection
- SetUp Initial Deform
- SetUp OutPut Point Location

Below this list is a sub-section titled "Defrom" containing several file input fields and a checkbox:

- SetUP Input File
- Edit DEF File
- Edit DeFormation File
- Edit Fault File
- Edit Position File
- Show EpiCenter On Map 8

At the bottom of the sub-section is a button labeled "SetUp Intial DeForm Files".

Figure 27

DeForm SetUp Page

Save/Load Close

Faults Data

C:\TUNAMI-N2KISR\Out\Case1.dat Save Load

No Events: 1 No. Of Fault Segments: 2 Multiple Fault events=1

Fault.Set file data

Longitude(m)	Latitude (m)	Slip(m)	Lenght(m)	Width(m)	Strik(dg)	Dip(dg)	Rake(dg)	Depth(m)
<input checked="" type="checkbox"/> 2159224	2700017	25	500000	150000	265	7	90	25000
<input checked="" type="checkbox"/> 1543597	2658621	25	400000	150000	280	7	90	25000
<input type="checkbox"/> 1869647	2800932	0	55000	70000	246	7	89	27000
<input type="checkbox"/> 1917671	2829785	4.3	55000	70000	246	7	89	27000

Defdimension.Set file data

No.	No. Of Region	Index X	Index Y	Grid X	Grid Y
1	6	2100	1060	1215	1215
		2790	2100	405	405
		960	1950	135	135
		1950	1200	45	45
		2400	1290	15	15
		2100	1200	5	5

Position.Set file data

Lower Left Corner of Region

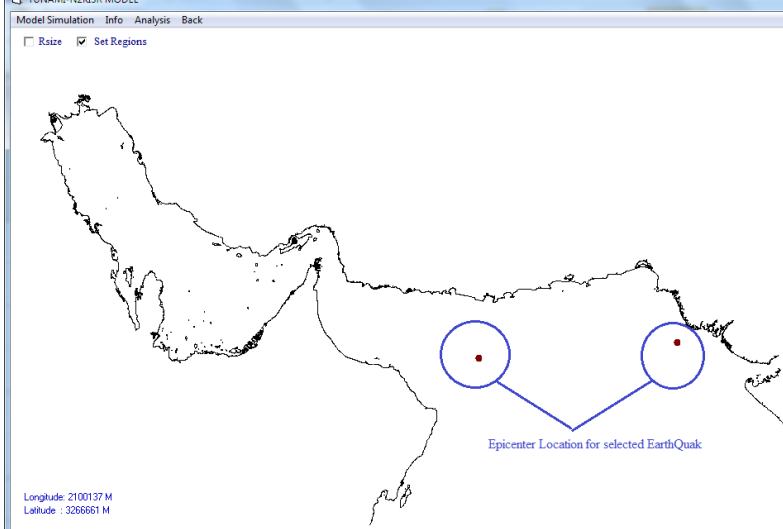
Longitude (m)	Latitude (m)
108785	2198315
169535	2514215
169535	3101465
171020	3231065
187220	3239615
203720	3251615

Figure 28

TUNAMI-N2KISR MODEL

Model Simulation Info Analysis Back

Resize Set Regions



Longitude: 2100137 M
Latitude: 3266651 M

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TUNAMI N2KISR

DOMAIN LIMITS

Bottom Left Location: 108785 2198315

Top Right Location: 2660285 3486215

New Show Gulf

CONTROL

- SetUp Model Regions
- SetUp Water Level (K.Tide)
- SetUp Region Connection
- SetUp Initial Deform
- SetUp OutPut Point Location

Deform

SetUP Input File

- Edit DEF File
- Edit Deformation File
- Edit Fault File
- Edit Position File

Show Epicenter On Map 8

SetUp Initial DeForm Files

Figure 29

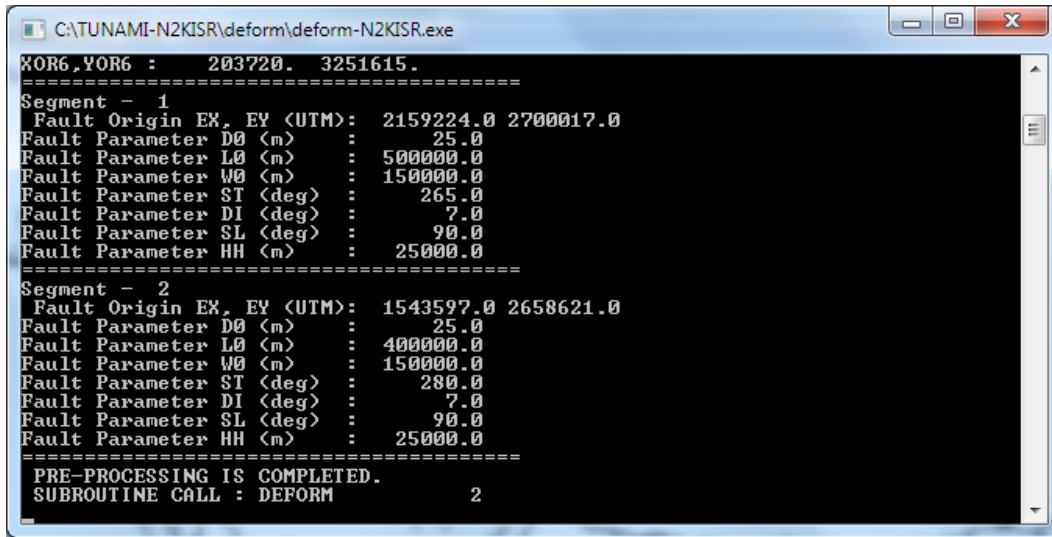


Figure 30

Deformation files format [With Default file names]

1 File name: def.set

No. event Number of fault segments Single fault event=0, Multiple fault event=1

2- File Name: defdimension.set

No. event Number of x-grids Number of y-grids x-grid size y-grid size

3-File name: fault.set

Long	Lat	Slip	Length	Width	Strike	Dip	Rake	Depth
[utm]	[utm]	[m]	[m]	[m]	[DEG]	[DEG]	[DEG]	[m]

4-File name: position.set

Long	Lat	Long	Lat
(bottom left)	(bottom left)	(top right)	(top right)

Up to this location the project connection was set and ready for main model simulation.

User must select from Figure 29 [MODEL SIMULATION].

To Start model simulation two options will display in DropList as

- 1- TUnami-N2KISR simulation
- 2- Two layer model simulation for landslide case .

User must select option 1 for TUnami-N2KISR then Figure 31 will display the following information shows and request as:

1. Option to coupled water level change in simulation [Checkbox On/Off]
2. To speed model simulation uses **OpenMP Compiling** Option then user set number of **CORE** as shown in figure 32 [from *Start Task Manger* of PC]
3. Input Total simulation time at {KL}
4. User must select [Update Input]. To refresh all parameters inputs.
5. Then user start model simulation Figure 33 shows model compiling.

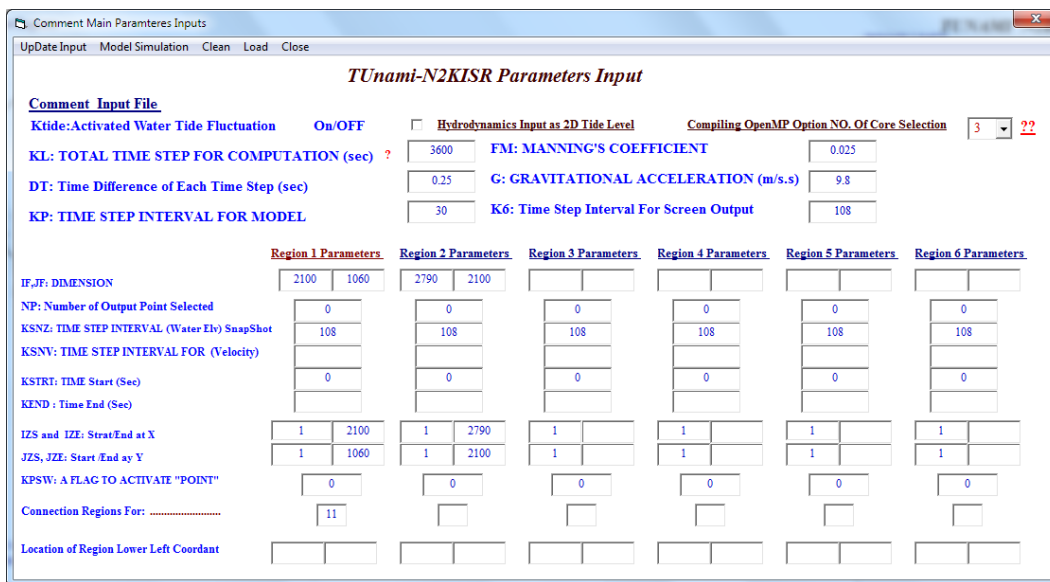


Figure 31

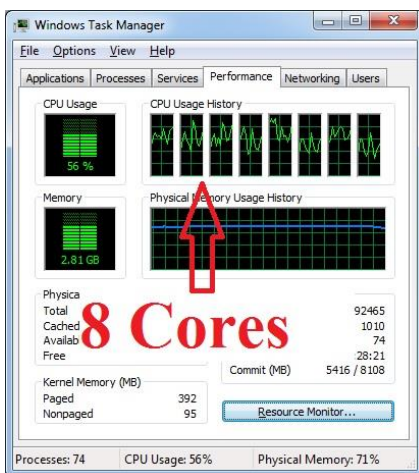


Figure 32

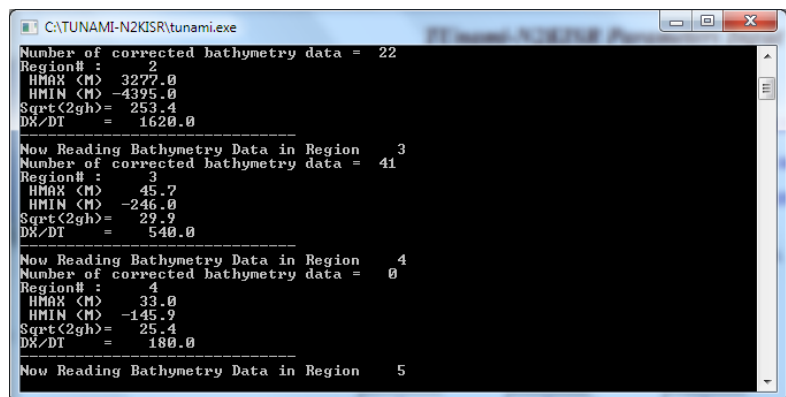


Figure 33

Simulation Output Display.

User can display model output as follow

1. 1D Elevation output display [Plot time series at a location]
2. 2D images for image/ Animation display
3. 1D Tide level display [Plot time series]

To start display output user must select from DropList at [Analysis] as shown in Figure 34.

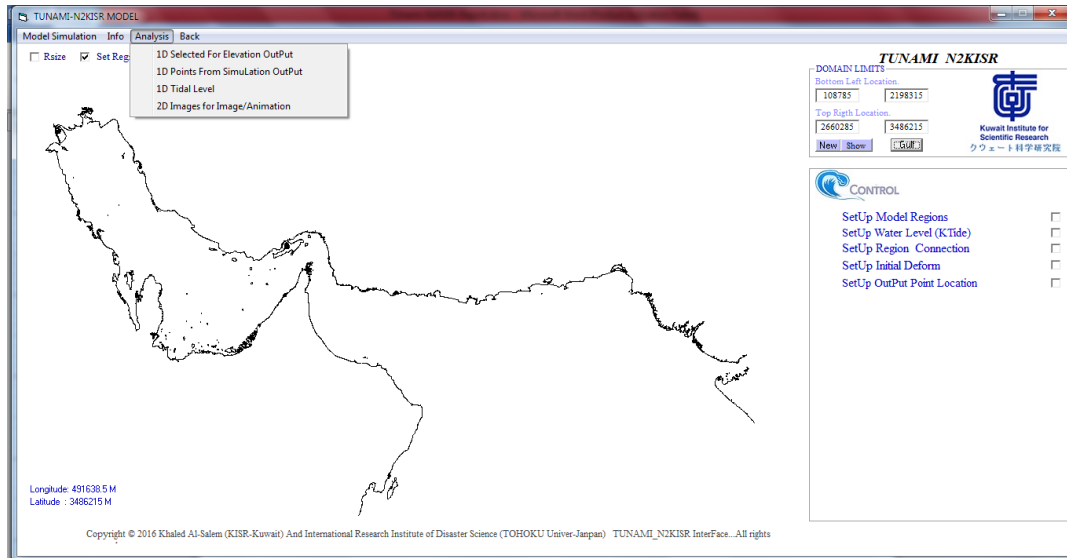


Figure 34

If user Select; 1D Elevation output display

user must select 1D Elevation plot from DropList at Figure 34 then Figure 35 will display to setup the Extraction data at selected locations and time limits as follows:

1. Select Grid Region [For Multi-Grid region simulation]
2. Select time Limit [Start to End] and interval steps.
3. Set input direction by default [C:\TUNAMI-N2KISR\result\elr\]
4. Set out directory by default [C:\TUNAMI-N2KISR\Out\]
5. Then user must select to setup files names as [Start]
6. User can select location for extracting elevation output data by Click On the map as follows:
 - User must enter location number
 - Then Checkbox [On/OFF]
 - Then user start to click on map for the location
 - User must [End and Save]

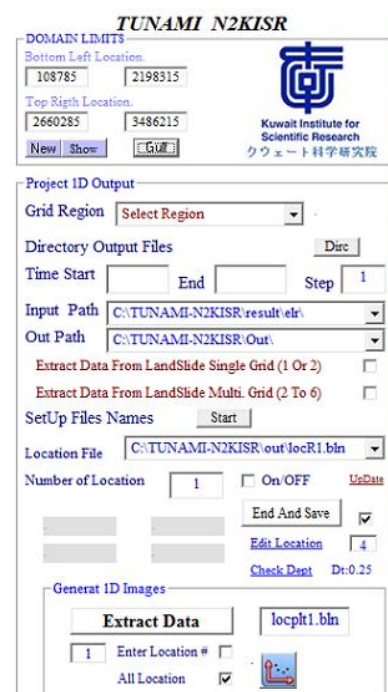



Figure 35

- User can edit location and Check the selected location depth.
7. Then user start to Extract Data by press on [EXTRACT DATA]
 8. To display 1D plot Click on []. Then Figure 36 will display the Extracted 1D plot for All location and Figure 37 for Signal location

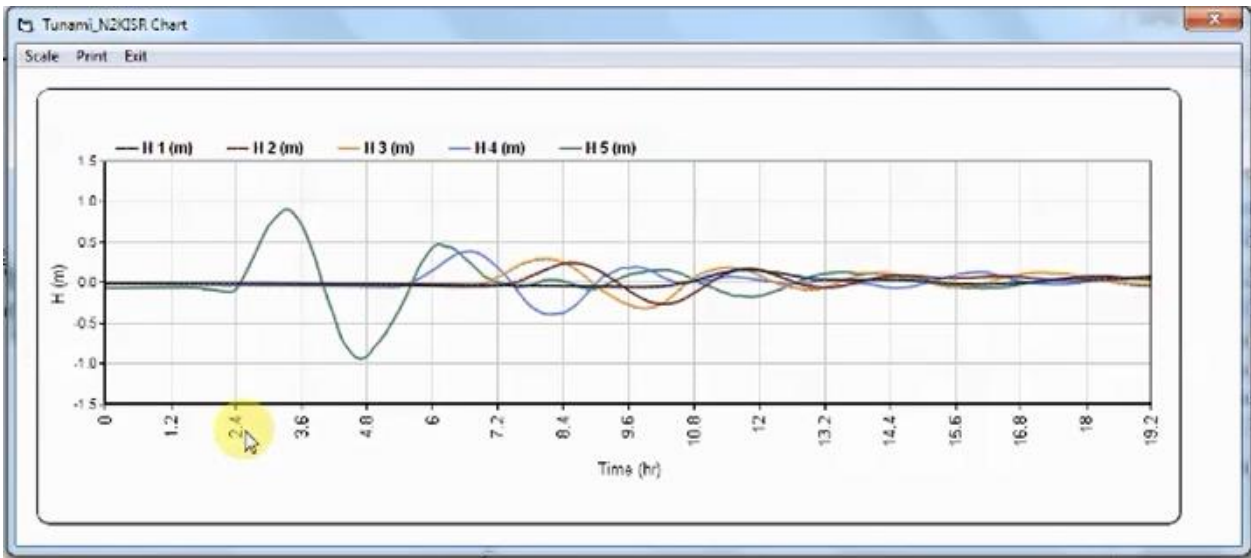


Figure 36

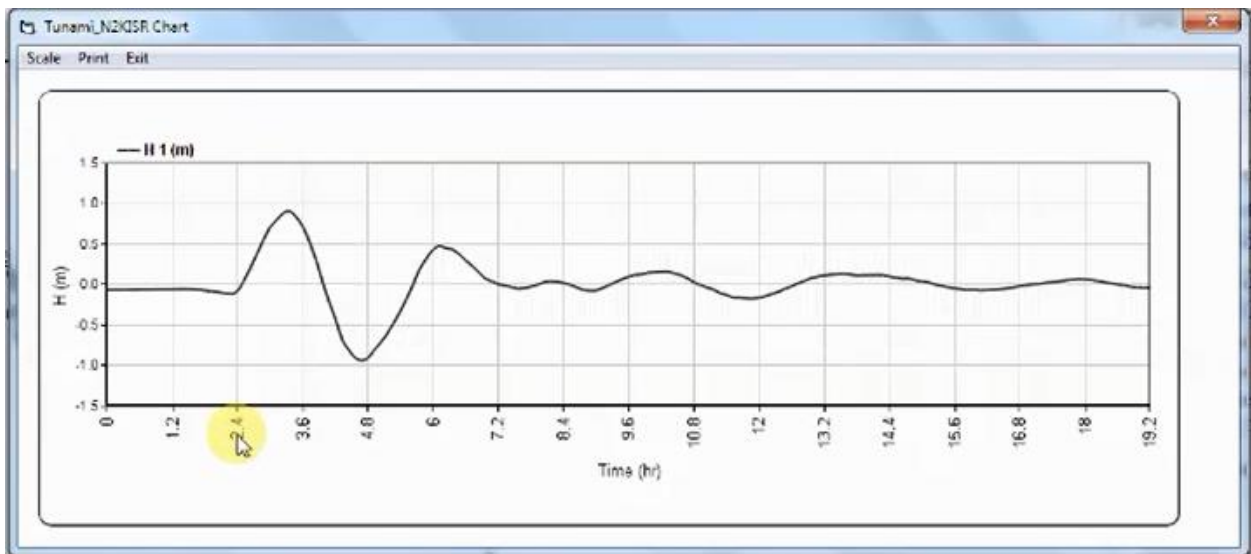


Figure 37

If user Select; 2D images for image/ Animation display.

user must select 2D image/ Animation from DropList at Figure 34 then Figure 38 will display to setup the Extraction data at selected locations and time limits as follows:

1. Select time Limit [Start to End] and interval steps.

2. Set input direction by default [C:\TUNAMI-N2KISR\result\elr\]
 3. Set out directory by default [C:\TUNAMI-N2KISR\Out\Anim\]
 4. Select Grid-Layer Number from Droplist [By default Grid-layer Region Selected]
 5. Then user must select to setup files names for Surfer to create 2D Animation []
- And enter interval time step. Figure 39 will display option of 2D/3D animation option.
6. Set Contour Level file information by default [C:\TUNAMI-N2KISR\Images\PLV02.lvl].
 7. Set SX2 Trim limit [0] / SY1 Trim Limits [0]. User can Shift Origin of View by change the numbers.
 8. User can select 2D/3D animation option by Click On follows:
 - 2D by GMT script program as shown in Figure 40
 - 3D by GMT script program as shown in Figure 41.

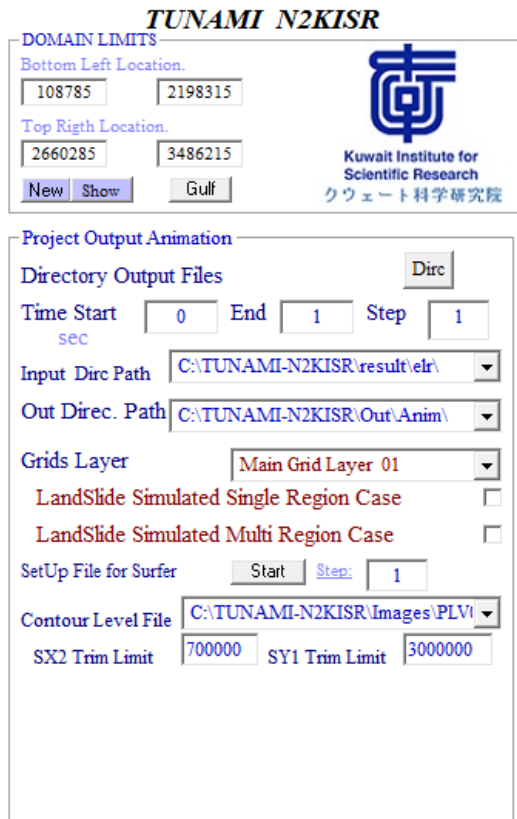


Figure 38



Figure 39

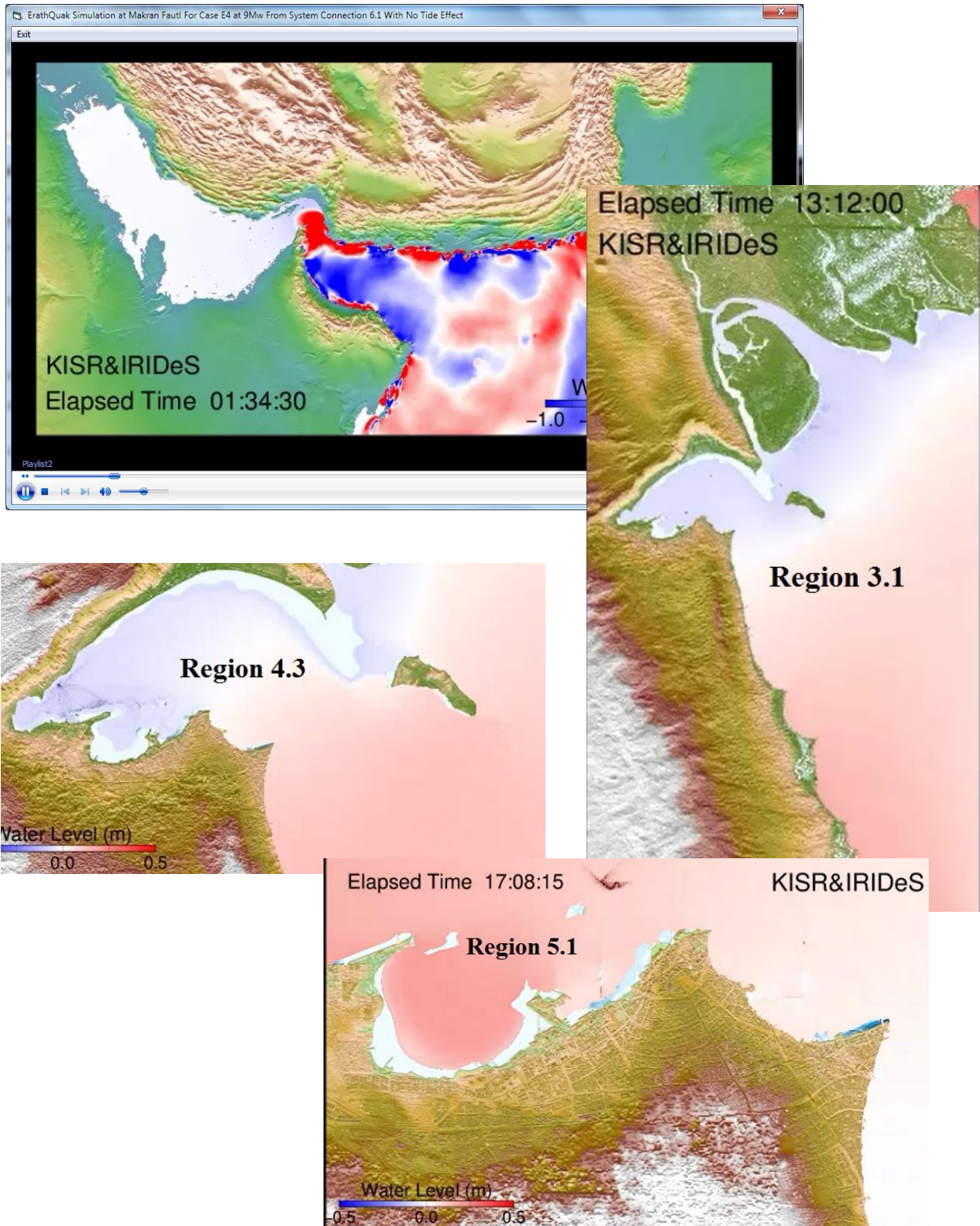


Figure 40

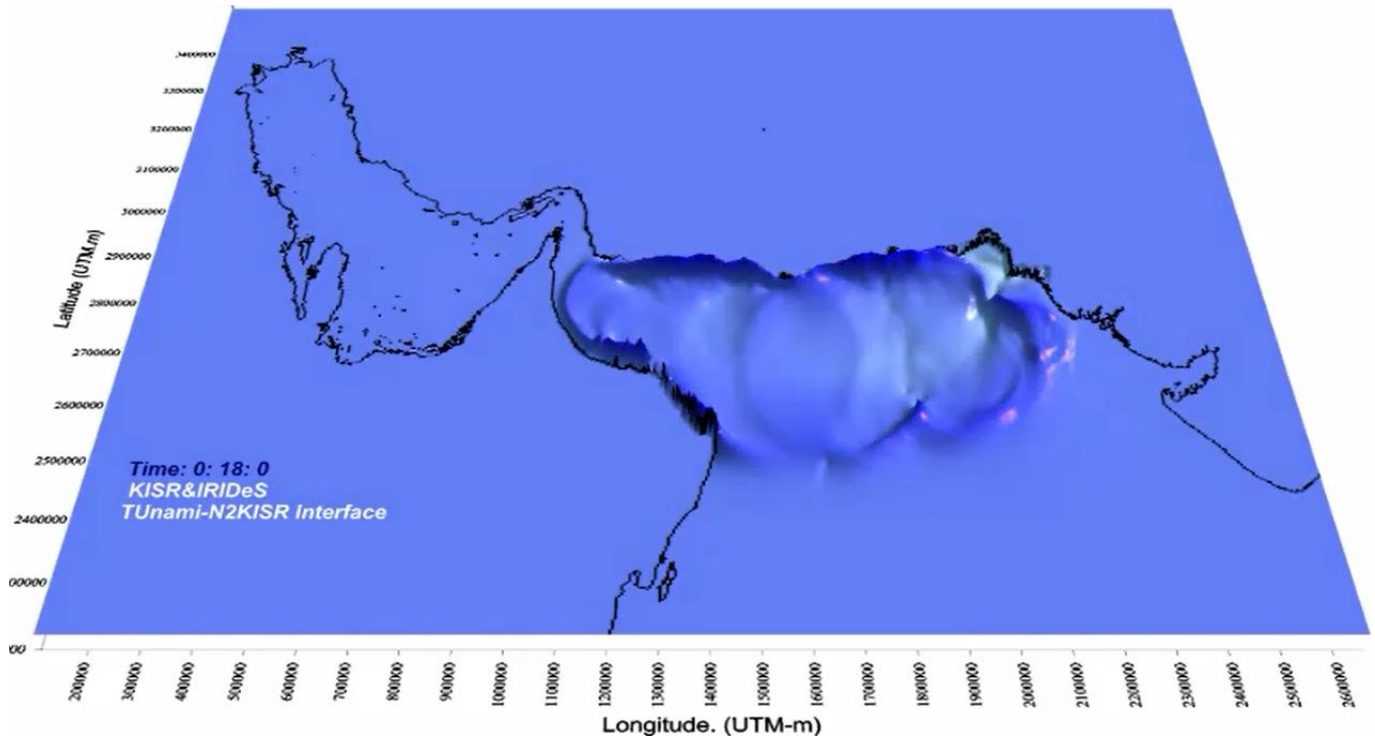


Figure 41

If user Select; 1D Tide level display [Plot time series].

user must select 1D Tide level display from DropList at Figure 34 then Figure 41 will display to setup the Extraction data at selected locations and time limits as follows:

- Select Grid Region [For Multi-Grid region summation].
- Select time Limit [Start to End] and interval steps.
- Set input direction by default [C:\TUNAMI-N2KISR\Tide\].
- Set out directory by default [C:\TUNAMI-N2KISR\Out\].

Then user must select [] to set file names.

Then user must enter number of location to extract water level data. Then CheckBox to ON to start click on map to setup location.

To Edit select location data by [EDIT LOACTION] as shown in Figure 42.


To Display water level time series data extracted by select [] to plot for all location as shown in Figure 44 and Single location as shown in Figure 44.


Figure 45 show 2D Water level prediction at different sub-regions.

TUNAMI N2KISR

DOMAIN LIMITS

Bottom Left Location

Top Right Location


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 كويتي للعلوم والدراسات

Project ID Water Level

Select Region

Directory Output Files

Time Start End Step

Input Path

Out Path

SetUp Files Names

Location File

Number of Location On/OFF

Generat ID Images

Enter Location #

All Location

Figure 42

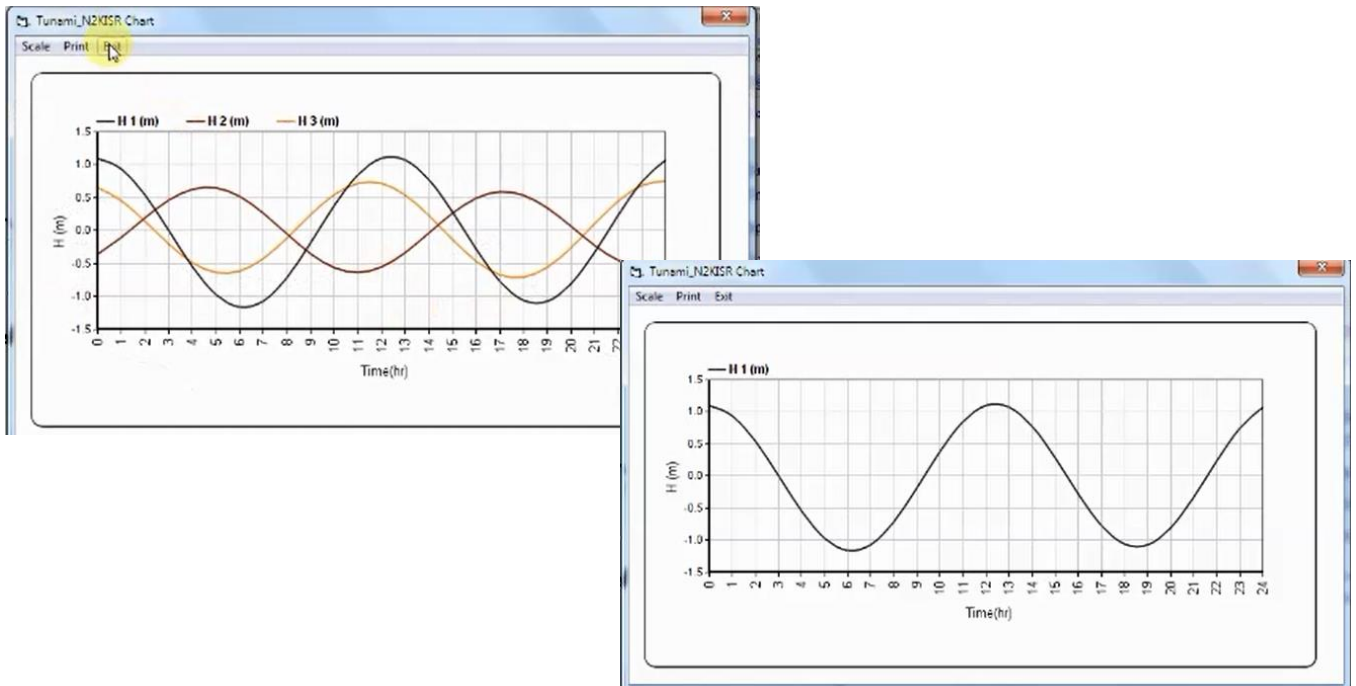


Figure 44

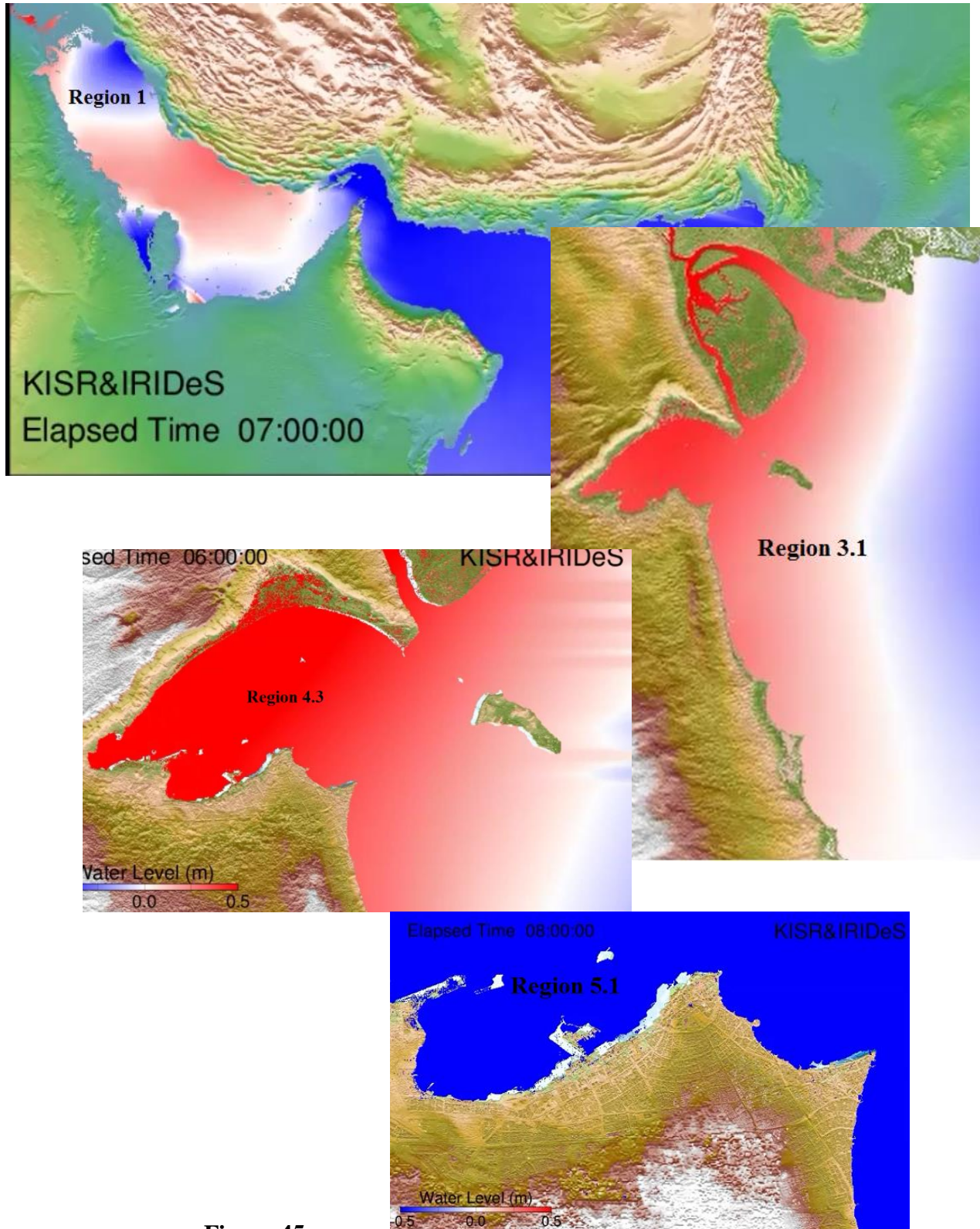


Figure 45



Modeling of Coastal Landslide Generated Tsunami By TWO-LAYER MODEL

To run Coastal Landslide Generated Tsunami model user has 2 options for simulation which are the following:

1. Single Region [Single Grid region simulation]
2. Multi-Regions [Nest- Grid region simulation]

Single Grid Region Simulation

To run this option user from Figure 8 must start the model

Then user must checkbox for **[SET REGION]** to Activate the model Grid Region as shown in Figure 15.

Then user must checkbox to activate Region 2 as shown in Figure 17.

Then user must select **[Model Simulation]** as shown in Figure 14. Then a Droplist will display for user to select.

Select **[Single Grid Region Simulation]** Figure 46 will display for user to enter the require model parameters as follows:

1. From Figure 46 user select [Region 1 or 2]
2. Enter Total time step computations [Total HrS*3600sec]
3. Enter Number of Core for OpenMp compiling as shown in Figure 32.
4. Enter [KSNZ] for Time step for computation.

In Landslide simulation option DON'T USE Activate Water level Fluctuation option.

To Setup Initial deformation Files for a new project the model have two options:

1. Then user must select from Figure 47 **[UpDate]**.

Then Droplist will display for user to select the **[Load Pre-Saved Initial Deformation Files]** new widow will option as shown in Figure 46.

Then user must select from Droplist option in [Pre-Save Initial Deformation Files]. In this model there are 7 Landslide scenarios were saved at inside Arabian Gulf Water [Landslide Case 1 to 7].

User must PRESS [] to load pre-saved data. Then From **[UDATE]** select **[Landslide Area]** to display the landslide area on MAP as shown in Figure 47

2. If user want create new landslide area from Figure 48 do the following:

- activate [ON]
- Select Region [1 or 2].
- Select landslide Plate Thickness[+ for remove , - Backfill]
- Select new Landslide area by enter the corner location of landslide.**[In Counter Clockwise direction]**. For each location must checkbox then click on map.
- Then select **[Landslide area]** to calculation area and Volume of landslide.
- Then user must Select [] to Generate the initial Deformation file.

- To display The new landslide area on map by Select [UDate] then select [LandSlide Area] as shown in Figure 49

User now ready to Start Simulation by Select [**Model Simulation**]. Then figure 50 display the computation window.

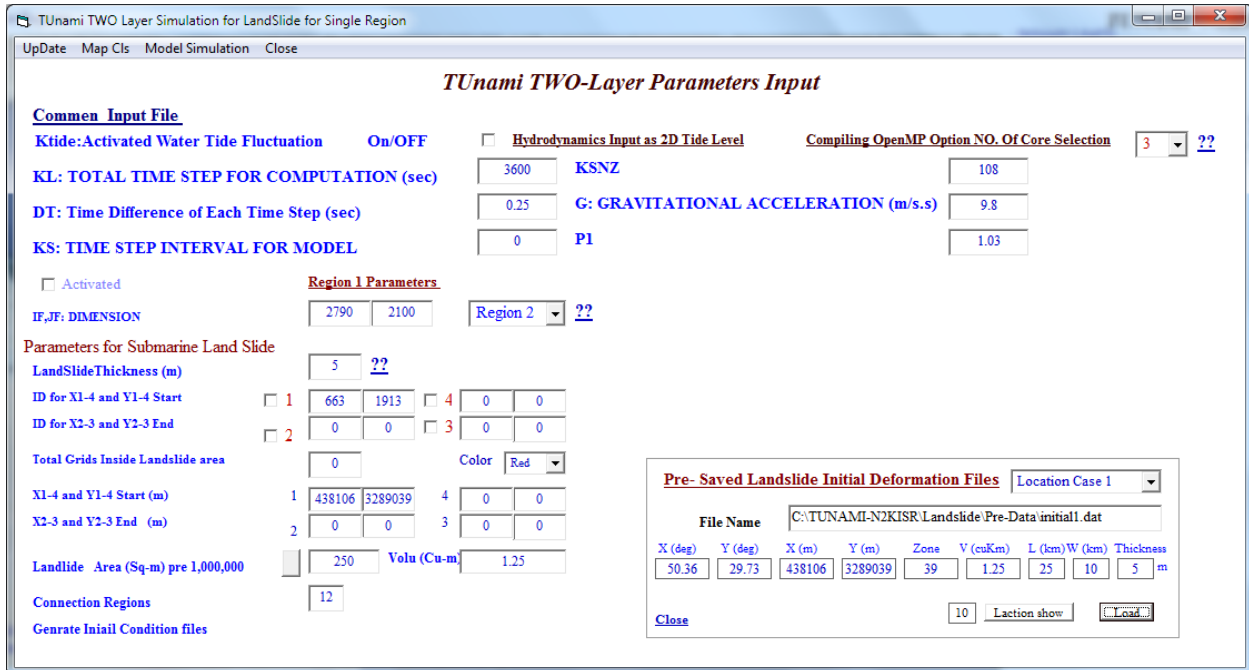


Figure 46

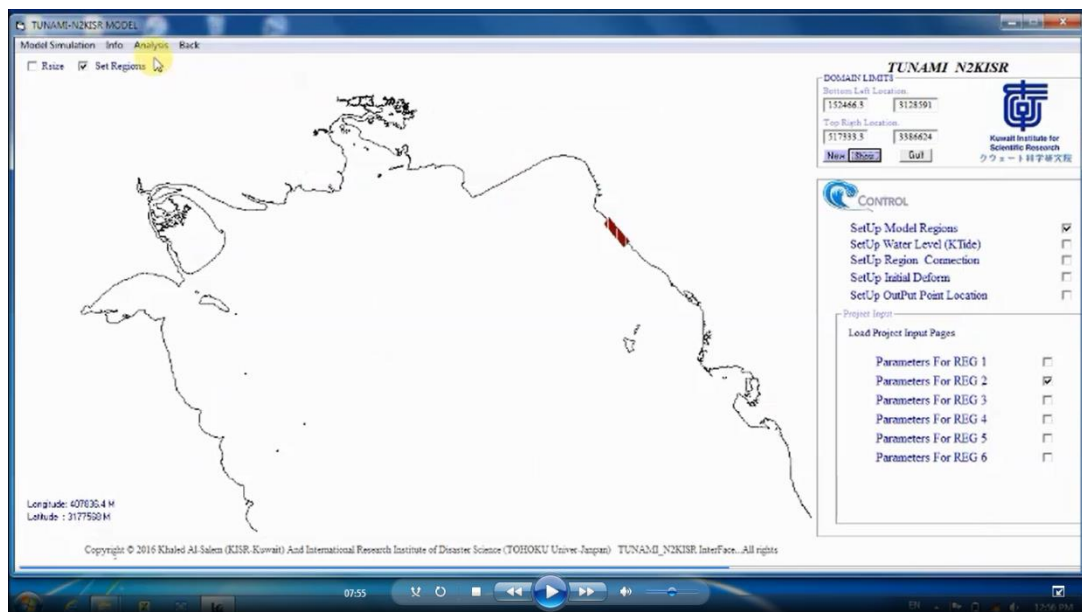


Figure 47

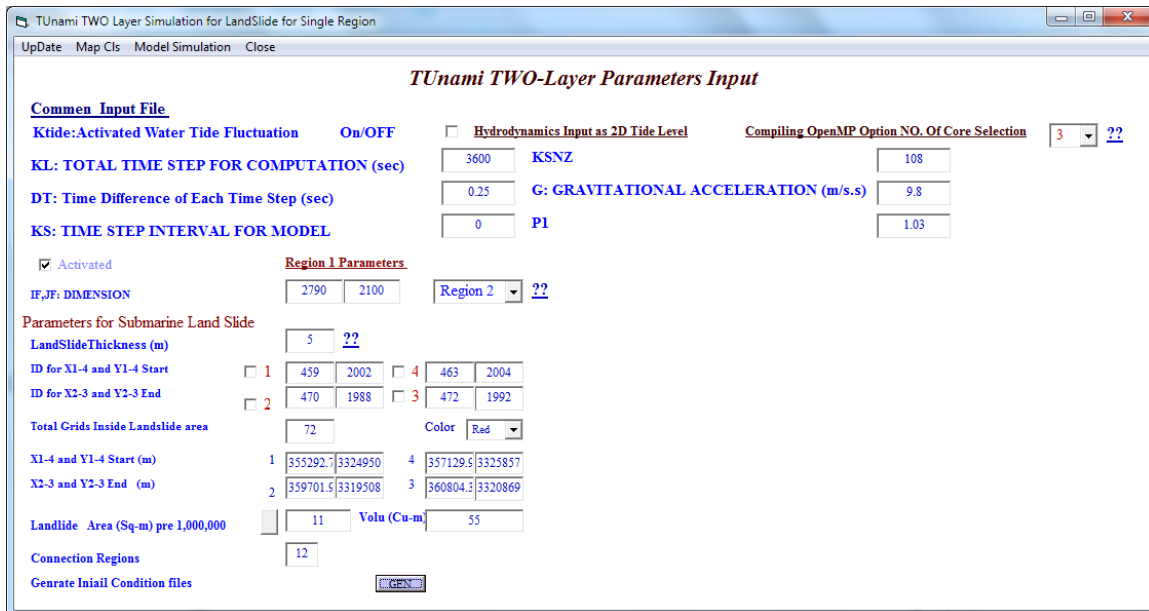


Figure 48

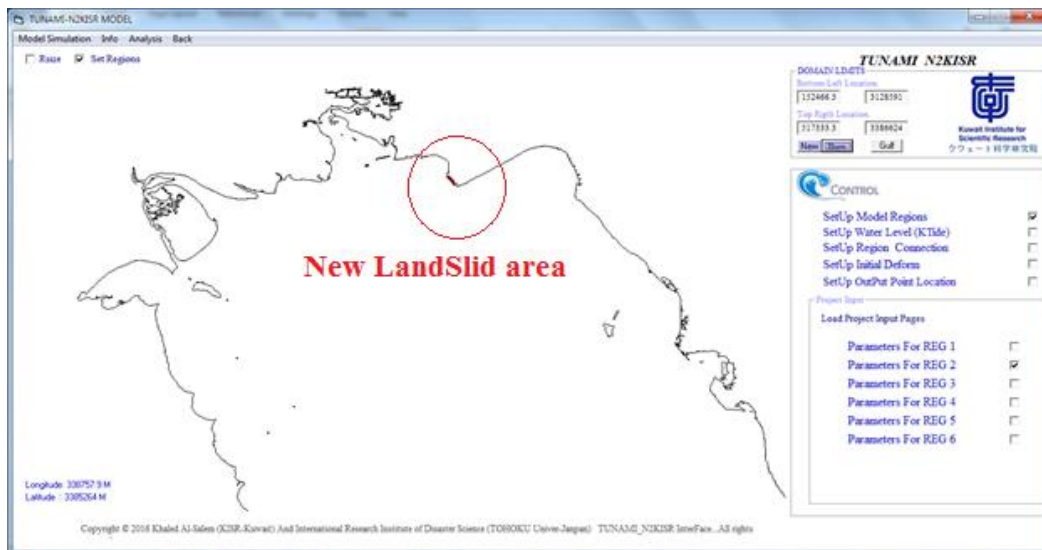


Figure 49

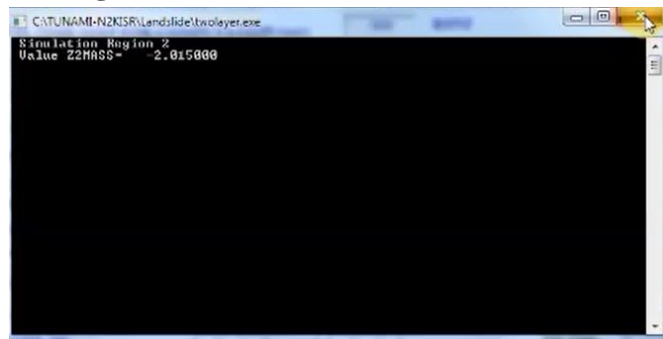


Figure 50



Multi-Grid Region Simulation

To run this option user from Figure 8 must start the model

Then user must checkbox for **[SET REGION]** to Activate the model Grid Region as shown in Figure 15.

Then user must checkbox to activate Regions Connection Sub-Grid Area [Nest-Grid area] as shown in Figure 51

Then user must select **[Model Simulation]** as shown in Figure 14. Then a Droplist will display for user to select.

Select **[Multi-Region for TWO-LAYER Simulation]** Figure 52 will display for user to enter the require model parameters as follows from Droplist at **[UPDate]**:

1. User must Select The setup Connect of Nest-Region at [Setup System Connection].

Figure 53 will display for to select/load System Connection as :

- From droplist in Figure 53 user select **[File]=>[Set new Conc]**. System will automatically will display as in Figure 53
- From Droplist in Figure 53 user select **[File]=>[Save Conc]**. If any change I title or sub-title.
- From Droplist in Figure 53 user select **[File]=>[Load/Save]**. New window will open with a default file name [Fconc.txt] user click on Save as shown in Figure 53.

2. User must Select **[Load/Saved Regions Parameters]** as in Figure 54. Multi-Regions parameters connect will display as shown in Figure 54 .

3. User from Droplist at Figure 54 must select the **[Load Pre-Saved Initial Deformation Files]** new widow will option as shown in Figure 54.

4. Then user must select from Droplist option in [Pre-Save Initial Deformation Files]. In this model there are 7 Landslide scenarios were saved at inside Arabian Gulf Water

[Landslide Case 1 to 7]. User select] to load data.

5. From Droplist in Figure 54 at [Updat] user select **[Load landslide area]** to find out the total area and display the location on Map as shown in Figure 49.

6. Enter Total time step computations [Total HrS*3600sec].

7. Enter Number of Core for OpenMp compiling as shown in Figure 32.

8. Enter [KSNZ] for Time step for computation.

In Landslide simulation option DON'T USE Activate Water level Fluctuation option.

To Setup Initial deformation Files for a new project the model have two options:


- 1- Then user must select from Figure 52 **[UpDate]**.

Then Droplist will display for user to select the **[Load Pre-Saved Initial Deformation Files]** new widow will option as shown in Figure 55.

Then user must select from Droplist option in [Pre-Save Initial Deformation Files]. In this model there are 7 Landslide scenarios were saved at inside Arabian Gulf Water [Landslide Case 1 to 7].

- 2- If user want create new landslide area from Figure 48 do the following:

- activate [ON]

- Select Region [1 or 2].
- Select landslide Plate Thickness[+ for remove , - Backfill]
- Select new Landslide area by enter the corner location of landslide.*[In Counter Clockwise direction]*. For each location must checkbox then click on map.
- Then select [**Landslide area**] to calculation area and Volume of landslide.
- Then user must Select [] to Generate the initial Deformation file.
- To display The new landslide area on map by Select [UPDATE] then select [LandSlide Area] as shown in Figure 49

User now ready to Start Simulation by Slect [**Model Simulation**]. Then figure 56 display the computation window.

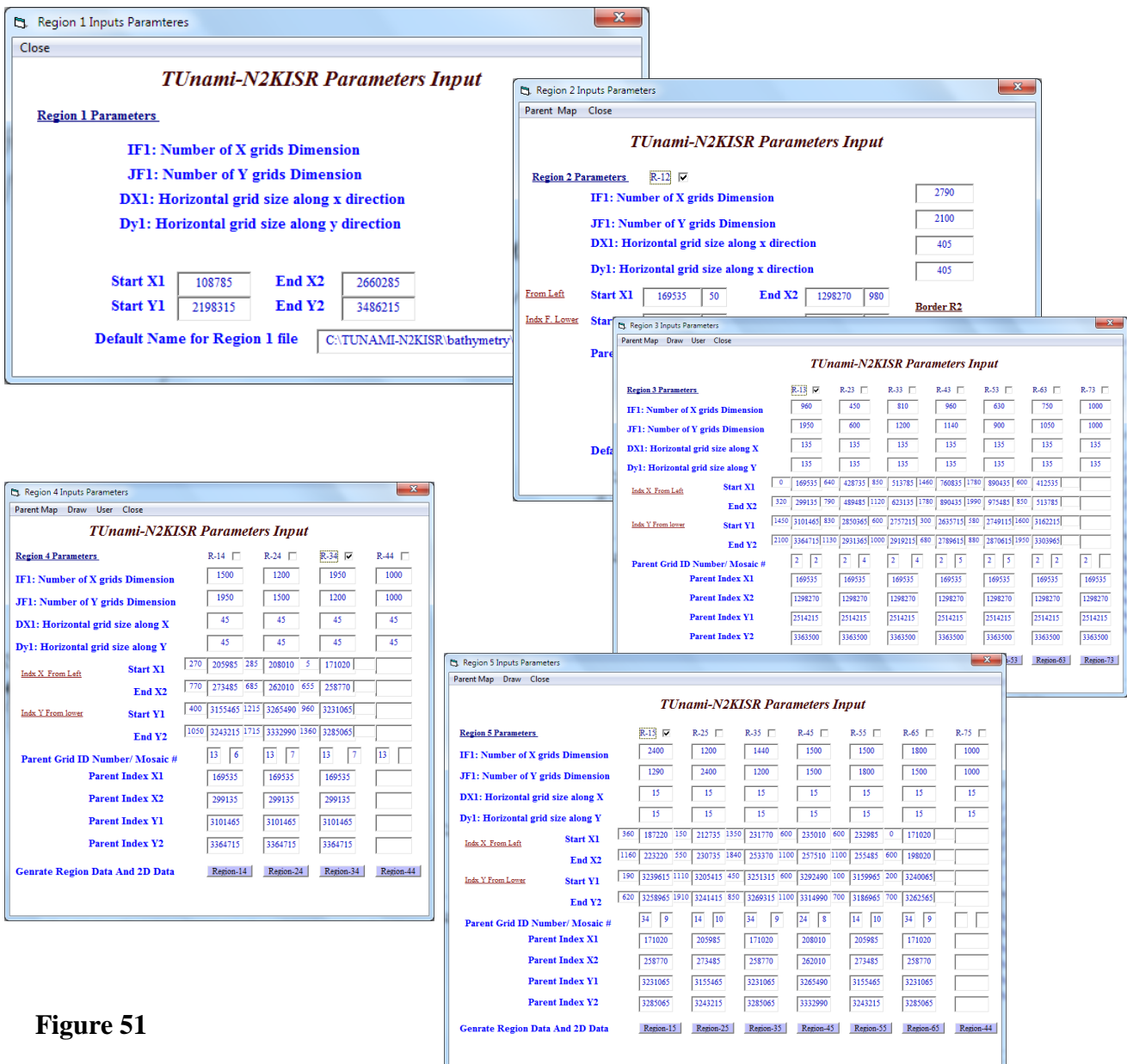


Figure 51

Tsunami TWO Layer Simulation for Landslide for Multi Region

UpDate Map Clear Model Simulation Close

Tsunami Multi Region TWO-Layer model Parameters Input

Common Input File

Compiling OpenMP Option NO. Of Core Selection: ??

KL: TOTAL TIME STEP FOR COMPUTATION (sec): G: GRAVITATIONAL ACCELERATION (m/s.s):

DT: Time Difference of Each Time Step (sec): FM: MANNING'S COEFFICIENT:

K6: Time Step Interval For Screen Output: KS: KSNZ:

Activated

	Region 1 Parameters	Region 2 Parameters	Region 3 Parameters	Region 4 Parameters	Region 5 Parameters
IF, JF: DIMENSION	<input type="text" value="2790"/> <input type="text" value="2100"/> Default	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
Parameters for Submarine Land Slide		Region#			
LandslideThickness (m)	<input type="text" value="-5"/> ??	X1(utm)	<input type="text"/>	<input type="text"/>	<input type="text"/>
ID for X1-4 and Y1-4 Start	<input type="checkbox"/> 1 <input type="checkbox"/> 4	Y1(utm)	<input type="text"/>	<input type="text"/>	<input type="text"/>
ID for X2-3 and Y2-3 End	<input type="checkbox"/> 2 <input type="checkbox"/> 3				
Total Grids Inside Landslide area	<input type="text" value="0"/> Color: <input type="text" value="Red"/>				
X1-4 and Y1-4 Start (m)	1 <input type="text"/>				
X2-3 and Y2-3 End (m)	2 <input type="text"/>				
Landslide Area (Sq-m) pre 1,000,000	<input type="checkbox"/> <input type="text"/> Volu (Cu-m) <input type="text"/>				
Default Regions	<input type="text" value="12"/> Total Connection Regions				
Genrate Iniail Condition files	<input type="text" value="1"/>				

Figure 52

System Region Connections

File Directory Close

System Connection for Mult TWO-Layer model

System:

Target:

Region Active: 2 3.1 4.3 5.1

R-Connection: Lower-Left Upper Right

Region 2 To 3	<input type="text" value="1"/>	<input type="text" value="1451"/>	<input type="text" value="321"/>	<input type="text" value="2101"/>
Region 3 To 4	<input type="text" value="6"/>	<input type="text" value="961"/>	<input type="text" value="656"/>	<input type="text" value="1361"/>
Region 4 To 5	<input type="text" value="361"/>	<input type="text" value="191"/>	<input type="text" value="1161"/>	<input type="text" value="621"/>
Region 5 To 6	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

Total Connect Region:

File Name:

Figure 53

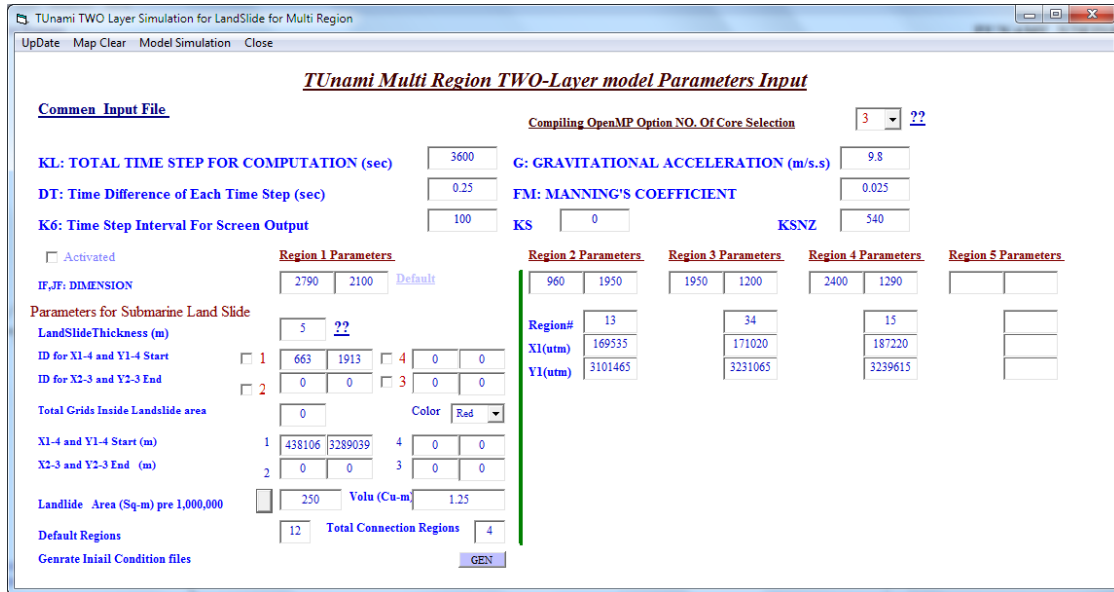


Figure 54

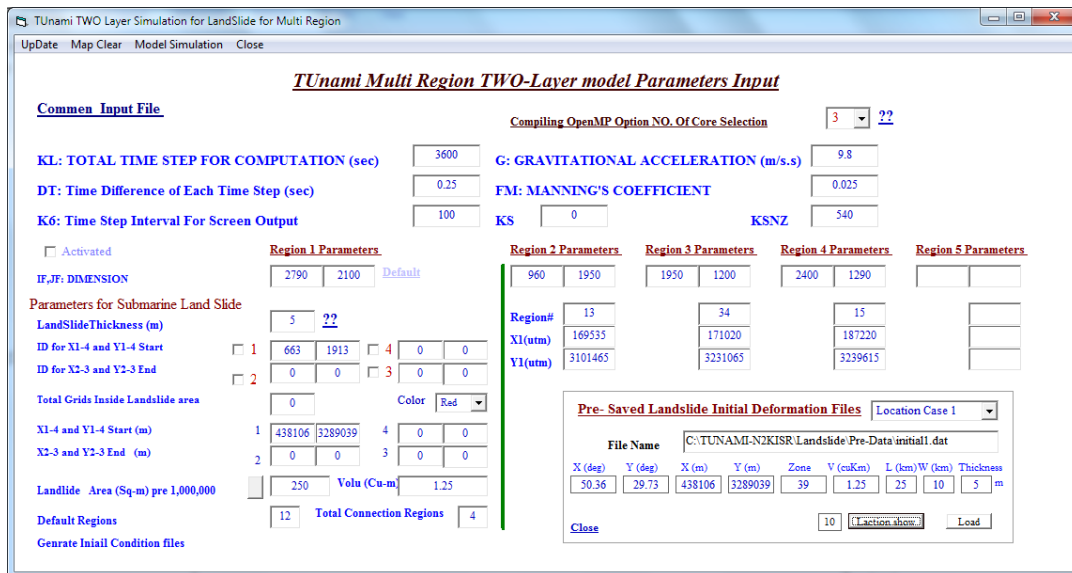


Figure 55

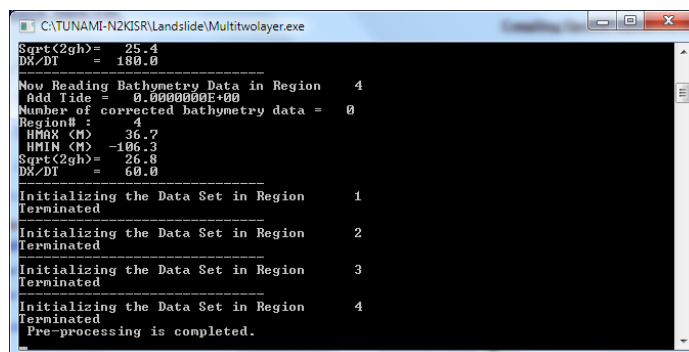


Figure 56

Simulation Output Display.


User can display model output as follow

1. 1D Elevation output display [Plot time series at a location]
2. 2D images for image/ Animation display

To start display output user must select from DropList at **[Analysis]** as shown in Figure 57.

If user Select; 1D Elevation output display

user must select 1D Elevation plot from DropList at Figure 57 then Figure 58 will display to setup the Extraction data at selected locations and time limits as follows:

1. Select Grid Region [For Grid region simulation]
2. Select time Limit [Start to End] and interval steps.
3. Set input direction by default [C:\TUNAMI-N2KISR\result\elr\]
4. Set out directory by default [C:\TUNAMI-N2KISR\Out\]
5. User must one of the checkboxes:
 - If single Region simulation [Extract data from Landslide Single Grid 1 or 2]
 - If Multi-region simulation [Extract data from Landslide Multi-Grid 2 or 6]
6. Then user must select to setup files names as [Start]
7. User can select location for extracting elevation output data by Click On the map as follows:
 - o User must enter location number
 - o Then Checkbox [On/OFF]
 - o Then user start to click on map for the location
 - o User must [End and Save]
 - o User can edit location and Check the selected location depth.
8. Then user start to Extract Data by press on **[EXTRACT DATA]**
9. To display 1D plot Click on . Then Figure 59 will display the Extracted 1D plot at selected locations.

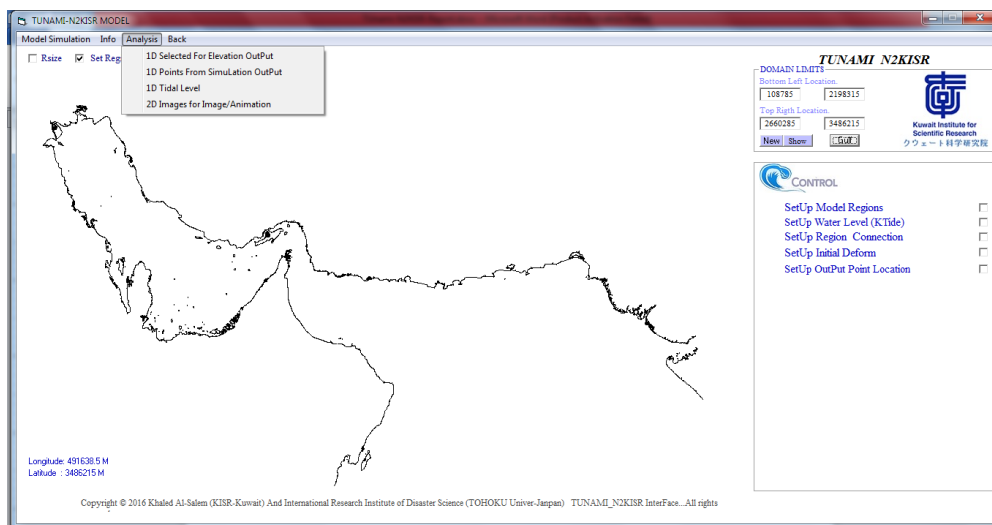


Figure 57

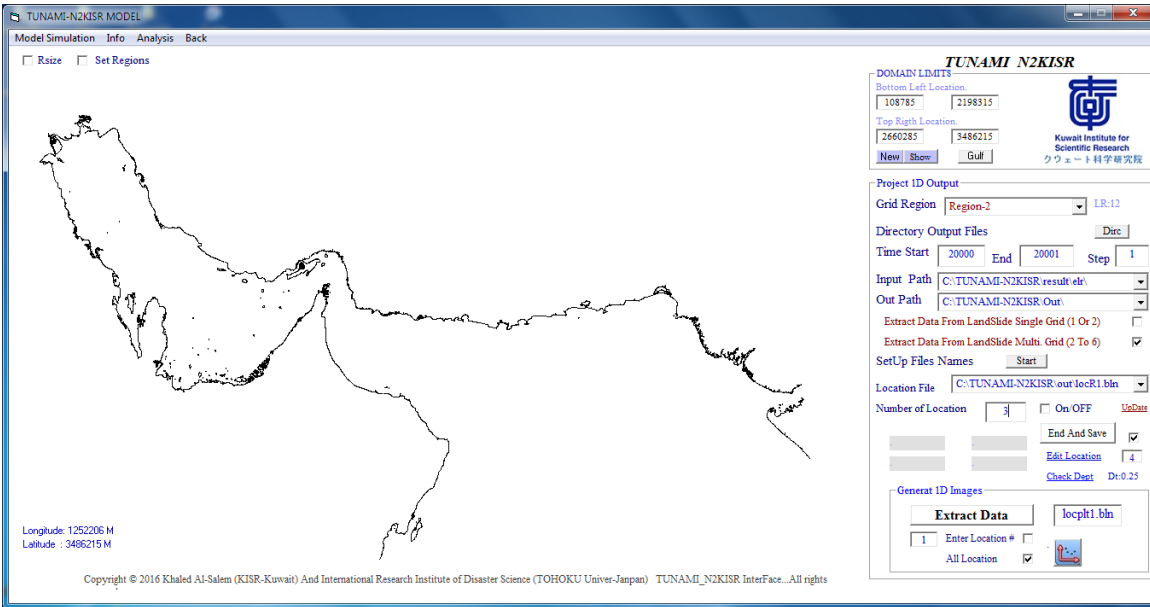


Figure 58

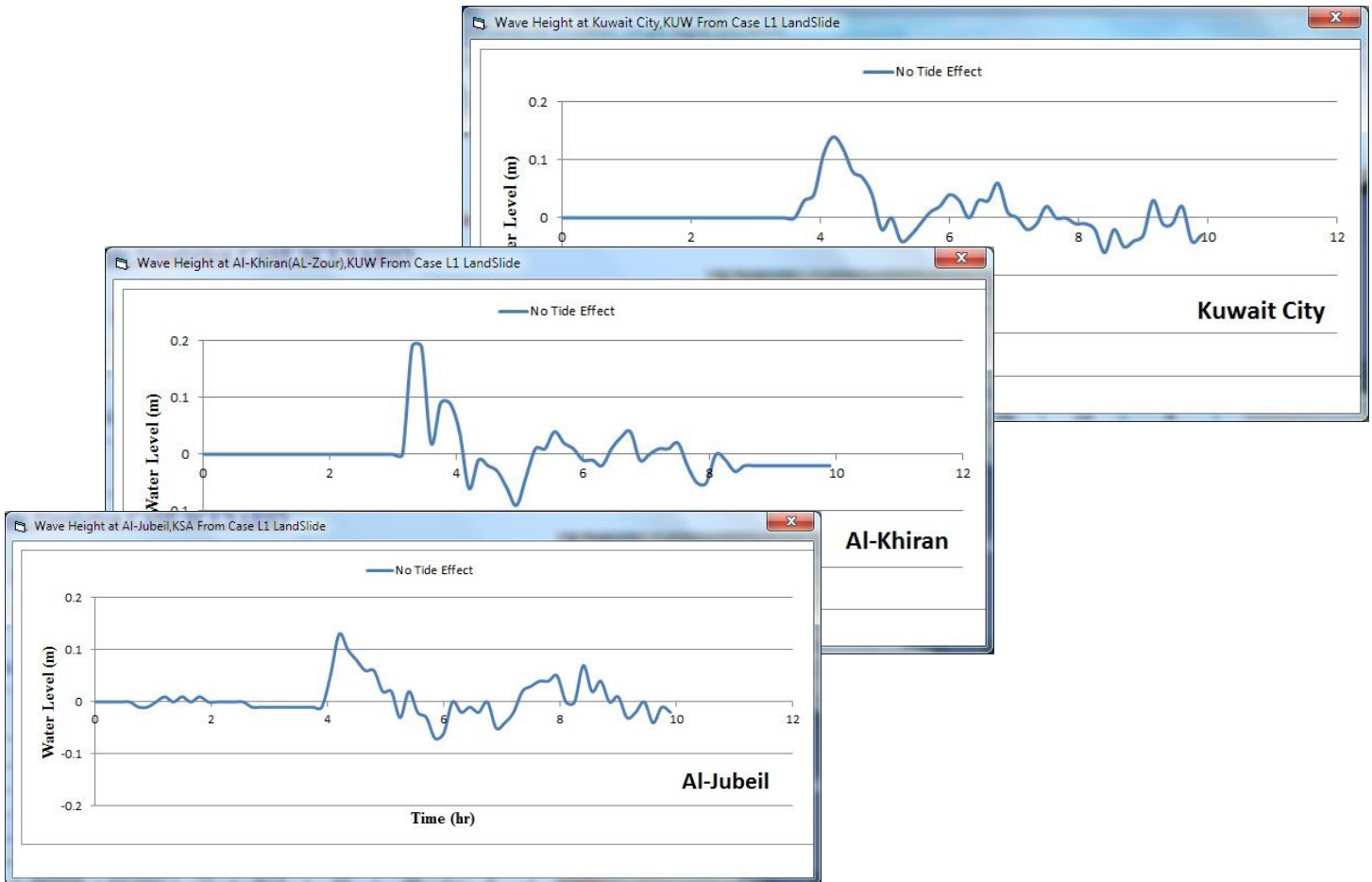


Figure 59

If user Select; 2D images for image/ Animation display.

user must select 2D image/ Animation from DropList at Figure 57 then Figure 60 will display to setup the Extraction data at selected locations and time limits as follows:

1. Select time Limit [Start to End] and interval steps.
2. Set input direction by default [C:\TUNAMI-N2KISR\result\elr\]
3. Set out directory by default [C:\TUNAMI-N2KISR\Out\Anim\]
4. Select Grid-Layer Number from Droplist [By default Grid-layer Region Selected]
5. User must one of the checkboxes:
 - If single Region simulation [Extract data from Landslide Single Grid 1 or 2]
 - If Multi-region simulation [Extract data from Landslide Multi-Grid 2 or 6]
6. Then user must select to setup files names for Surfer to create 2D Animation []
And enter interval time step. Figure 39 will display option of 2D/3D animation option.
7. Set Contour Level file information by default [C:\TUNAMI-N2KISR\Images\PLV02.lv1].
8. Set SX2 Trim limit [0] / SY1 Trim Limits [0]. User can Shift Origin of View by change the numbers.
9. User can select 2D/3D animation option by Click On follows:
 - 2D by GMT script program as shown in Figure 61
 - 3D by GMT script program as shown in Figure 61.

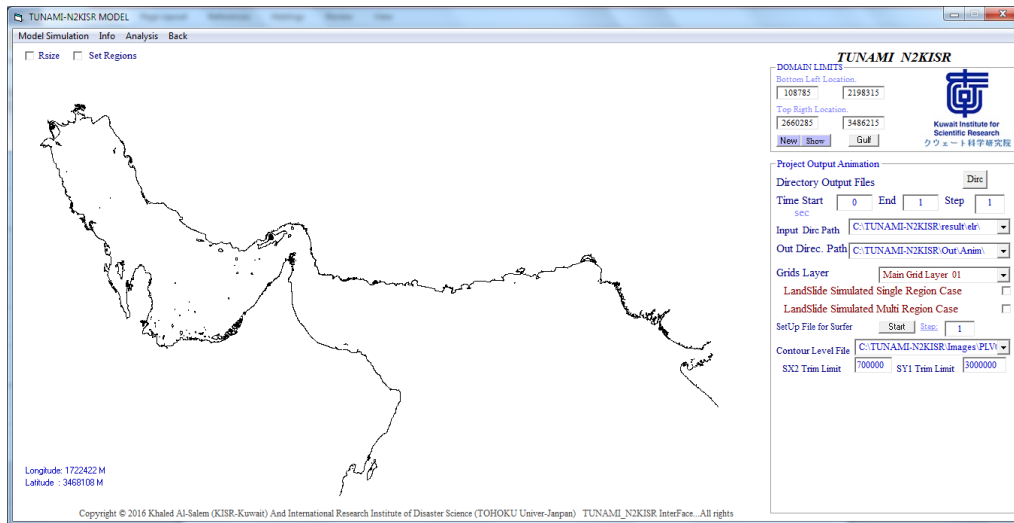


Figure 60

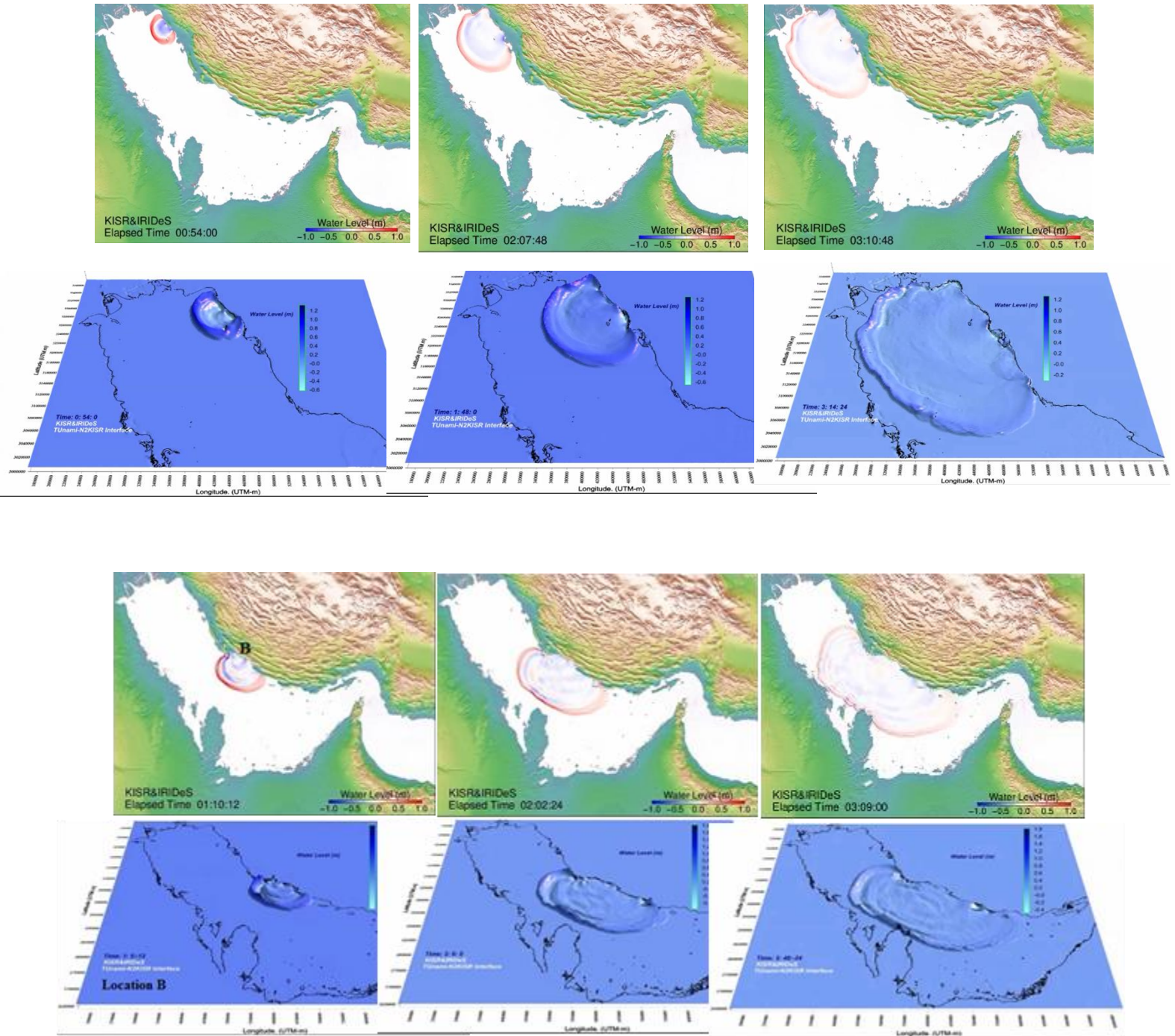


Figure 61

Awareness System for Tsunami Wave Height in Arabian Gulf , Gulf of Oman and the Arabian Sea Through Smart Mobil Technology and Internet Website by TUNami-N2KISR Interface

The interface Of Tsunami Warning System

As known, the prediction of an earthquake is still not satisfactory with today's technologies, and in fact, for most earthquakes, is unsuccessful. Detection and prediction of tsunamis is only half the work of the system. Of equal importance is the ability to warn the populations of the areas that will be affected. The TUNami-N2KISR warning systems feature lines of communications (such as internet website and smart mobile technology as shown in Figure 62). The awareness system capable of issuing warnings to the general public in less than 15 minutes for known location and initial data input of epicenter and moment magnitude of an underwater quake and the probable tsunami arrival times can be quickly calculated and posted for any selected location from the main domain area in TUNami-N2KISR interface. The internet website address was display the tsunami hazard at website address

:(<http://www.hceatkuwait.net/KUnami/kunami.aspx>) [Al-Salem Khaled. 2016. "Awareness System for Tsunami Wave Height in Arabian Gulf , Gulf of Oman and the Arabian Sea Through Smart Mobil Technology and Internet Website by KUnami Interface". *International Conference on Information and Communication Technologies for Disaster Management (ICT-DM'2016)*, Dec. 13, 2016.Vienna,Austria]. Also it will display on smart mobile system and it will be posted at Apple Store in future [The mobile wave preliminary version was already developed].




Figure 62

Procedures for using of (TUnami-N2KISR Interface)

TUnami-N2KISR interface is an efficient and easy-to-use data entry and model simulation. This version is sufficiently user-friendly and can provide the basic information of simulation for tsunami wave prediction. In this section of the report, step-by-step instructions are given for using the model interface.


The procedures outlined here consist of number of steps which can be summarized as the model can be run after model simulation finished or from Per-saved Result for 2D wave elevation scenarios. Then from Figure 63 user must Select [ANALYSIS] then [1D SELECTED FOR ELVATION OUTPUT] Figure 64 will display for user to setup Select location for extract time series Tsunami Wave Prediction for Public Broadcast though Remote Website or Model application. User must following the following steps as:

1- From Figure 64 user select:

- Region from Droplist
- Enter start output file number to End File number
- Select [DIRC] To setup Input File Path
- Enter Output file path [Or use the default Path]
- User Select [] to Form Input File Names File.
- User must select the output Target location as
 - Enter number of Location to extract
 - User Select [**CHECKBOX ON/OFF**]
 - Based on the location number user **CLICK on MAP** of the select location unlit the [CKECKBOX On/OFF will uncheck]
 - Then must select [**END and SAVE**]
 - Then user must select [**EDIT LOCATION**]
 - Then USER must select [**CHECK DEPT**]


2- Then user Start to Extract Data by select [**EXTRACT DATA**]

3- User can Display 1D plot of the select locations

Now user ready to upload output data to Remote website for public Awareness by select [] at Figure 64. Figure 65 will display for user to enter the following information as :

1. Enter Earthquake Date [**Day Month YEAR**]
2. Enter Earthquake Occur Time [**Hour Minute Second**]
3. Enter Earthquake Magnitude [Mz]
4. Enter Posting Time In Remote Website.

This is the time in hours is time that data will be stay display on Public Website

5. Then user must start to from the file for upload to website by select []

6. To edit the file select []

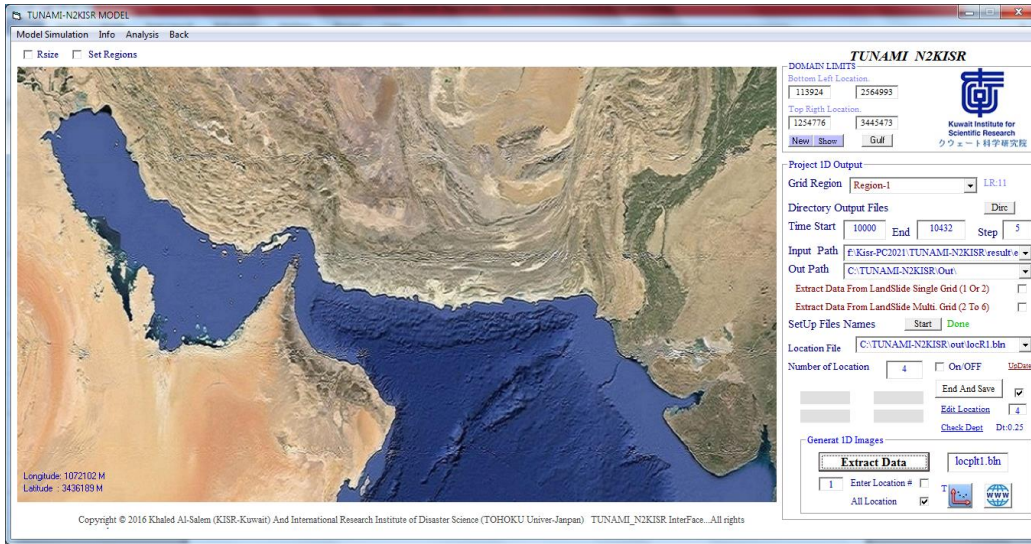


Figure 63.

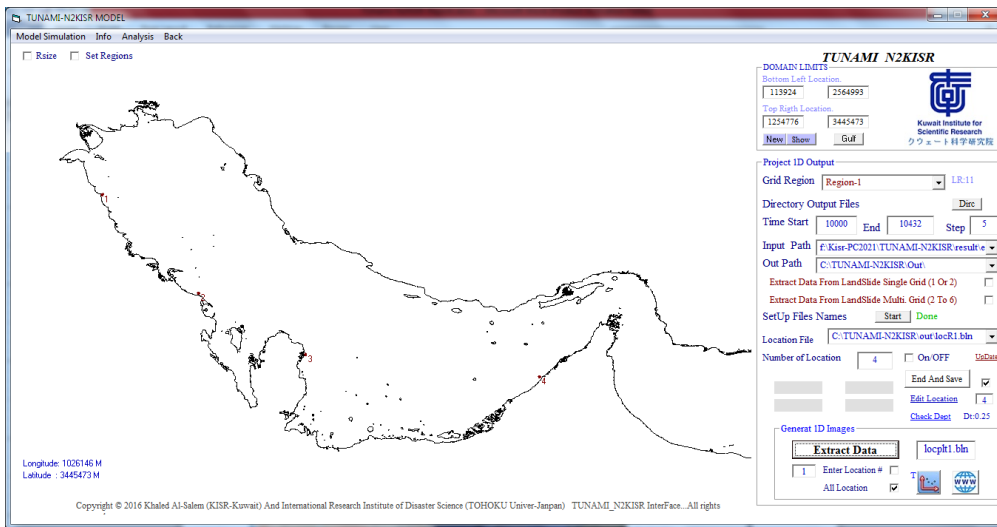


Figure 64

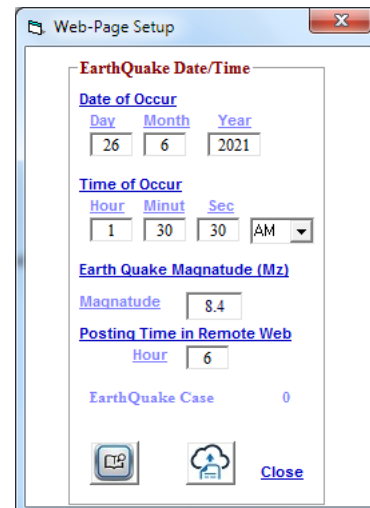


Figure 65

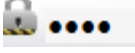

Procedures for uploading setup file by (TUnami-N2KISR Interface)

[Operator Only]

To upload the setup data is assign to remote website at address

[\[http://hceatkuwait.net/KUnami/KUnami.aspx\]](http://hceatkuwait.net/KUnami/KUnami.aspx)


Then user must do following:

- User must Enter Password [Operator only] at [] as in Figure 66
- User Select [] in Figure 66 to open the upload section for user the select the file.
- User can select refresh page or wait number seconds for AUTO-Refresh for data will appear on GOOGLE MAP as shown in Figure 67.

Remote website Display

Figure 67 display for the select target data time series of wave height for a number of hours select by operator.

User can display for each select Target location as 1D time series plot by select from Figure 67 at

[] then Figure 68 will display

User enter Location number then select [] to form a plot file then select [SHOW] to

display the plot file as in figure 68. User can download data by select []

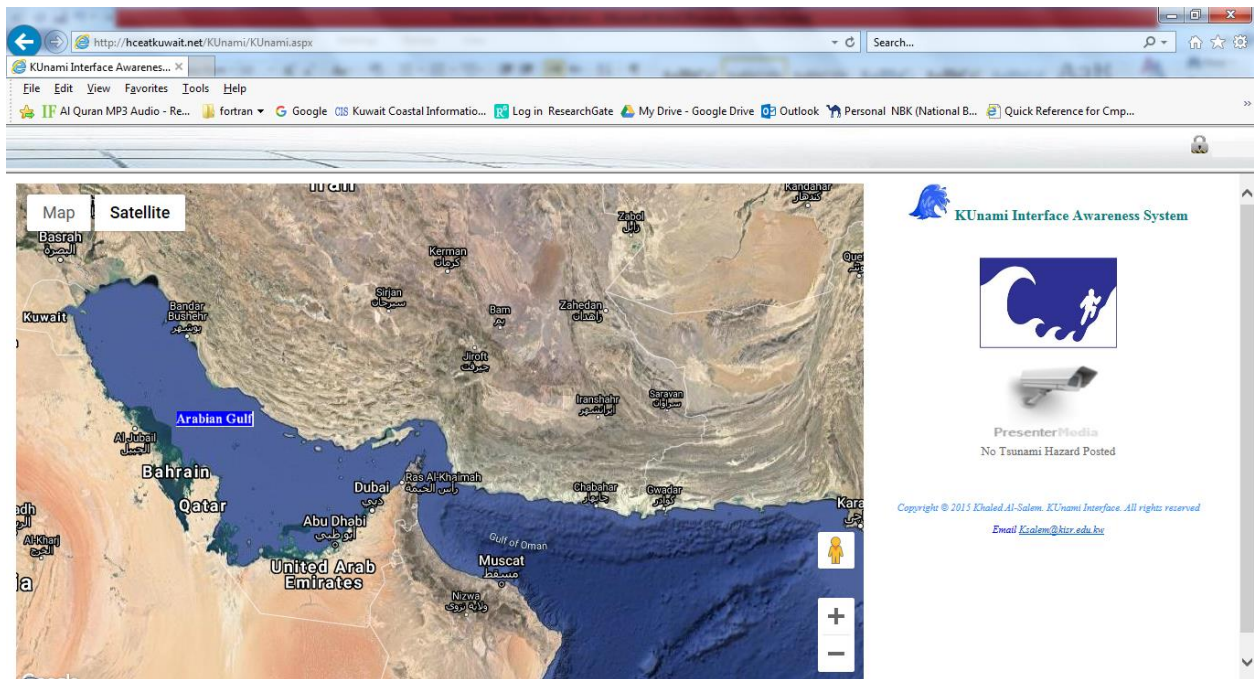


Figure 66

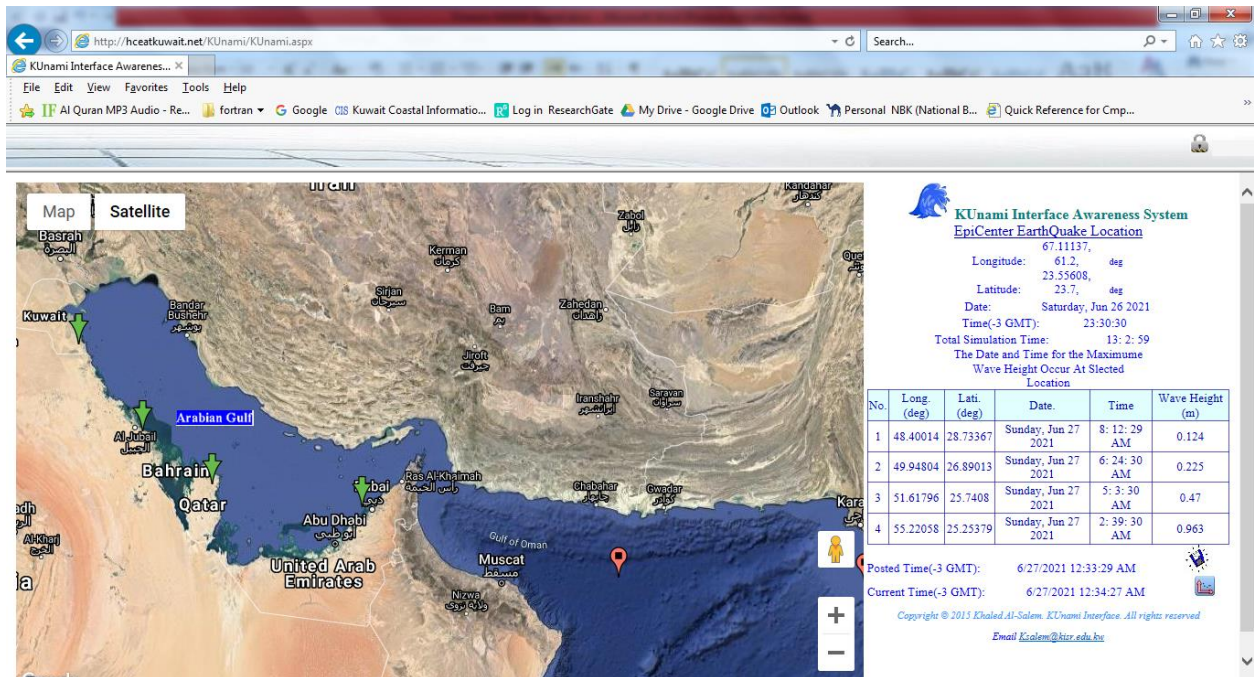


Figure 67

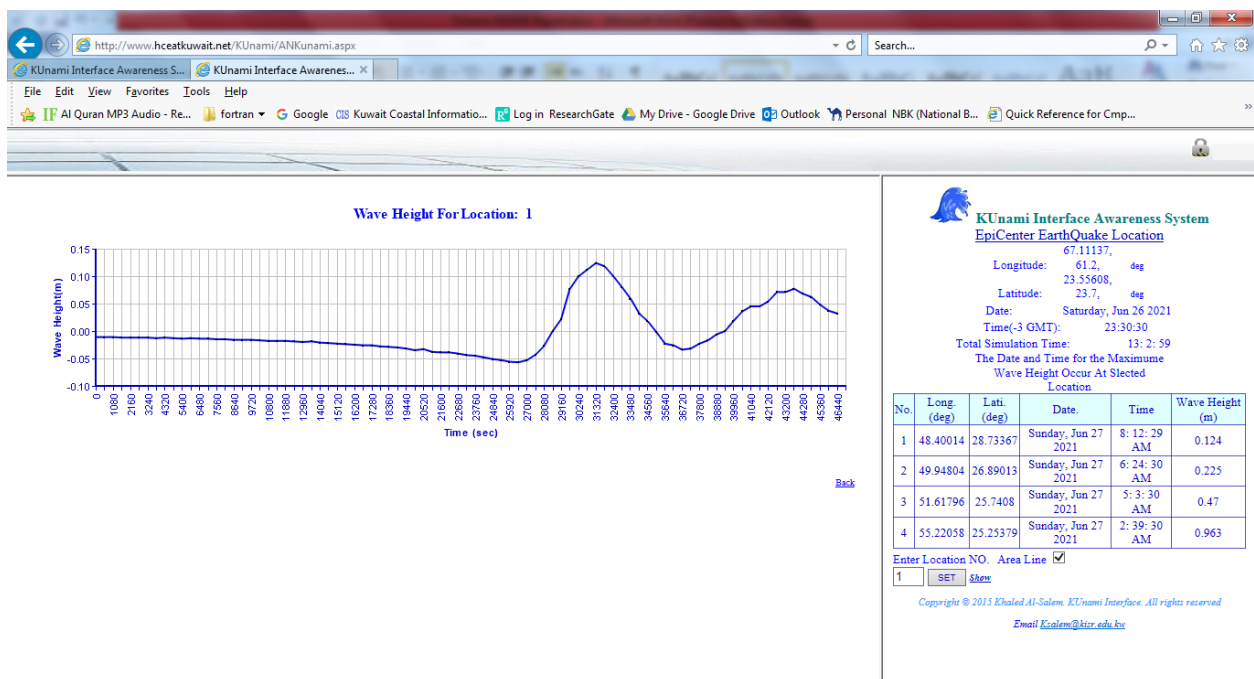


Figure 68

Awareness System for Tsunami Wave Height by Mobile Application Display

A Mobile apps was developed by [Al-Salem K. 2016] to display for public awareness of Tsunami wave height on Google map as shown in Figure 69. The mobile apps can run by the following:







- User can start the apps by select [] then select []
- Figure 70 will display if there are a posted data is [ON] if now post data the apps will stay on until post warning in On again.
- User can display any of select target time series data by select [] as shown in Figure 70.
- Then Figure 71 will display for user to enter location number to display 1D Time series plot and enter [x scale can be set as 1 for Sec 60 for minutes 3600 for hours].
- Then user must select [] to display 1D plot as shown in Figure 72
- User can send data information by Email and Message from selection [] at Figure 70.
- Then Figure 73 will display for user to select option of data sending as [] For Email option or [] For Message option



Figure 69



Figure 70



Figure 71

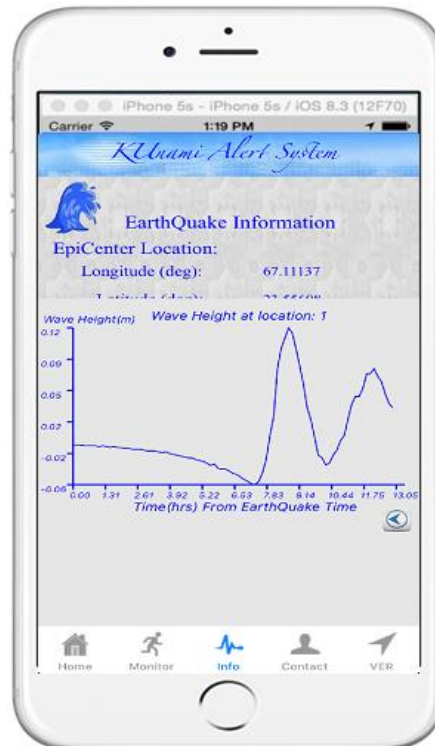


Figure 72



Figure 73