Marrying Quantitative and Graphic Tidal Analysis Tools with HF Radar Current Map Outputs

Don Barrick, David James and Jimmy Isaacson
CODAR Ocean Sensors, Ltd.
1000 Fremont Avenue, Suite 145
Los Altos, CA 94024
(408) 773-8240
don@codaros.com

ABSTRACT -- Separating off the tidal portion of flow from measured data and resolving into its individual constituents is an important part of coastal oceanographic analyses. HF radar surface-current maps taken hourly over many weeks or months offer a wealth of tidal information. Recent findings by several groups -- based on HF current maps -- show striking relations for the M2 tidal constituent strengths and ellipse axes with near-shore bathymetry.

We have married the classic and popular Foreman tidal analysis MATLAB package directly to CODAR SeaSonde current map outputs via convenient graphical user interfaces. These algorithms allow one to resolve time series of total surface-velocity vectors at each map grid point into tidal constituents. Alternatively, the user can click to select specific points where such analyses are to be done, for example at an offshore structure or ADCP mooring. Based on measurements accumulated into a folder over any period of time, the algorithms will display the energy and signal-to-noise ratio of the extracted constituents, allowing the user to select which to retain for further analysis, display, or prediction. Ellipses for any of the constituents can be plotted over the Cartesian grid or at the specific points of interest. Movies of individual or summed tidal components can be made over any period from the past into the future. Finally, these tidal flows can be subtracted from the HF mapped current maps to give the de-tided residual circulation.

I. BACKGROUND

The first and most important step in the analysis of current time-series data is resolution of the tidal flows. The moon and sun-forced sinusoidal frequencies of the individual constituents of tidal heights and currents are well known from nearly two centuries of observations and analytical attacks.

What is not known are the amplitudes and phases of these harmonics -- until they are measured at a given location. They vary spatially, even over small distances, as constrained by the coasts and bathymetry. Often the dominant constituent is the M2, i.e., the semi-diurnal component caused by the moon's gravitational influence. Near shore, the axes of the vector trace for the M2 constituent -- called its tidal ellipse -- tend to align with the bathymetry contours, even for the surface flows. Even though one may not be interested in the tidal portion of flow, this strong signal must be removed in order to study the other contributors to circulation.

The most widely accepted tool for resolution of tidal current and height into its constituents is the Foreman package. Developed in 1978 [1] by Foreman as a FORTRAN package, it uses an overdetermined least-squares approach to fit the constituents of known frequency but unknown amplitudes to measured time series. The method robustly handles data gaps, which are common in most measurements. These tools have been converted to MATLAB form by S. Lentz and B. Beardsley of Woods Hole, and improved by R. Pawlowicz of UBC and Mike Cook of the Naval Postgraduate School.

HF radar is now an accepted tool for mapping surface currents over areas hundreds of square kilometers from shore. Over 120 SeaSonde systems have been sold, of which 70 or more operate continuously at permanent locations in real time. SeaSonde software allows plotting and analysis of total surface current fields, showing the local coastline and even bathymetry along with the vectors. These outputs are all manipulated by easy-to-use graphical user interfaces (GUIs). Although many SeaSonde and other HF radar users have performed tidal analyses on current-map data outputs, the procedure of going from radial velocity maps, to total velocity time series at selected locations, running the Foreman tidal analysis, and plotting tidal ellipses, time-series, or making movies of tidal-vector ouputs has been tedious and generally time consuming for each user.

We illustrate here a tool now being distributed to SeaSonde users to make their lives easier as far as the tidal analysis is

concerned. It marries the friendly GUI structure of SeaSonde data analysis and plotting with the MATLAB version of the Foreman tidal analysis package. One can analyze the constituents at a single user-selected point, at many selected points, or at all of the Cartesian grid points where vector data have been measured. The ellipse parameters of the tidal constituents are outputted and can be plotted for any selected constituent. Time series of the u/v components, amplitudes, or directions based on the fitted tidal constituents can be plotted for any period of time. These can be compared in plots or statistically with the input measured time series. Finally, 'QuickTime' movies can made of tidal vectors for any or all constituents.

II. EXAMPLES OF HOW IT'S USED

There are three separate procedures executed sequentially. We assume two or more sets of contemporary SeaSonde radial vector ASCII files have been stored in their respective directories, as is standard on the Central Site computers. These are usually produced at hourly or half-hourly intervals. In the case of bistatic radars, these would be elliptical velocity files. The first step is to produce time series of total velocities (u/v) at desired points. This is done by running the `CombineBIGUI launcher`, within the `CombineBI` folder. The user will be queried for setup preferences. This will include locations (latitude/longitude) at which tidal analyses are desired, presumably at points of interest where other measurements are available (e.g., ADCP). Or, the user can request tidal analyses at all of the Cartesian grid points where total vectors are computed and plotted. The user has several choices to select how the scalar components from the available sites are combined: (i) least-squares fitting of all available components from each site within a circle of specified radius; (ii) average of nearest four points from each site within a circle of specified radius; (iii) nearest neighbor from each site within a circle of specified radius. Upon execution, this tool produces time series, matching up data available from the various sites within a user-specified time interval, e.g., 0.5 hours. If there is no data from at least two sites near the desired point, a gap at that time results.

Next, one runs the tidal analysis tool on the u/v components by launching `TidalAnalysisGUI launcher` from the `Tidal Analysis` folder. The user is queried for setup inputs in the lower left window of Fig. 1.

After running the tidal analysis tool, one can plot time series or frequency spectra of the resulting constituents. Suppose one wants to plot tidal time series. The window to the right in Fig. 1 shows the largest ten constituents, sorted by SNR (signal-to-noise ratio). Here the user chooses which to include, e.g., up through M4 in the example here. Then one plots the predicted u/v time series, and by zooming and scrolling via the controls in the upper left window, selects the segment to view. Also available are simultaneous plots of measured and tidally fitted time series. We analyze a data set from the Gulf of Fonseca in Central America that is dominated by strong semi-diurnal tides. A plot of outputs are illustrated in Fig. 2.

Finally, with a third set of tools one can make a movie of the ellipses and vectors for a selected constituent. Here we focus on seven points in the Gulf of Fonseca at which other measurements were taken. As before, a GUI called `TidalMovieGUI launcher` from inside the `Tidal Movie` folder is launched and used to select user preferences. This is shown to the left of Fig. 3.

The 'Project Settings' window to the right organizes paths to the files needed, including the coastline and sea background on which the plots will be made. The M2 constituent is selected, and animation parameters are set. The resulting map graphic for a single movie frame is shown in Fig. 4. The two radar sites in Honduras are shown as red dots, approximately 25 km apart. The measurements were made during March and April of 2001.

A. References

1. Foreman, M.G.G., *Manual for Tidal Currents Analysis and Prediction,* Pacific Marine Science Report 78-6 Institute of Ocean Sciences, Victoria, BC Canada, 1978.
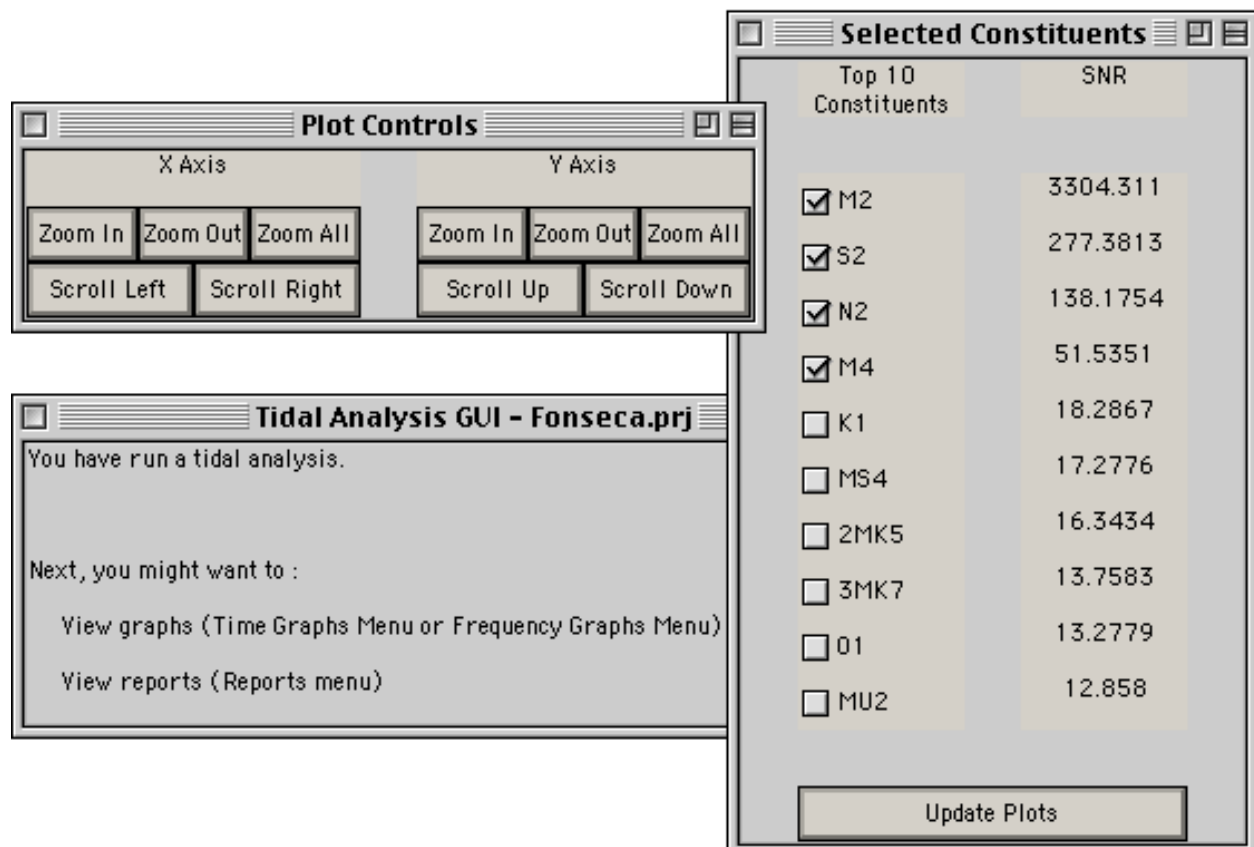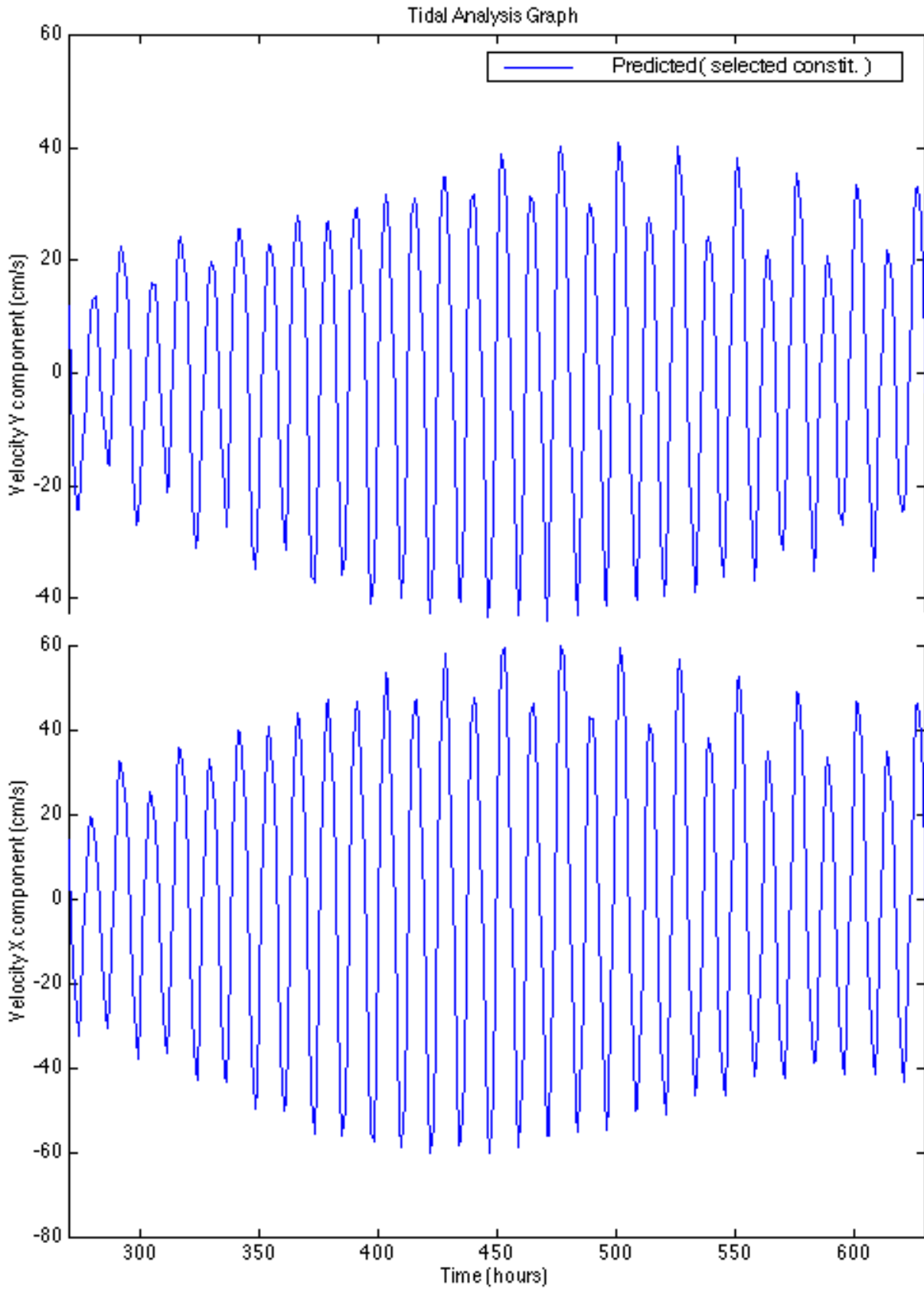
Figure 1. GUI windows for tidal analysis.

Figure 2. Fitted time-series tidal flow of v (upper) and u (lower) components over selected period.

TidalMovie User Interface

Welcome to the TidalMovie User Interface.

To get started:

Open an existing project (Project menu) OR

Create a new project (Project menu)

Project Settings

Input Settings

Total Time Series folder: Macintosh HD:SeaTides 1.6:TidalMovie:Projects:Sample Data FONS 1:TTS Files: [Browse]

Map file: Macintosh HD:SeaTides 1.6:TidalMovie:Projects:Sample Data FONS 1:FonsM2Tid.jpg [Browse]

SD Setup Site file: Macintosh HD:SeaTides 1.6:TidalMovie:Projects:Sample Data FONS 1:SDSite_FONS [Browse]

Tidal Analysis Settings

Tidal Constituent name: M2 [Help]

Animation Settings

Start w/ data point #: 1   Frame count: 24

Window width (pixels): 600   Window height (pixels): 450

Ellipse scaling factor: 3   Vector scaling factor: 3

Output filename: M2_TidalMovie

(If no path is specified, file will be saved in folder above the TTS folder.)

[Close (save changes)]   [Preview (save changes)]   [Cancel (discard changes)]
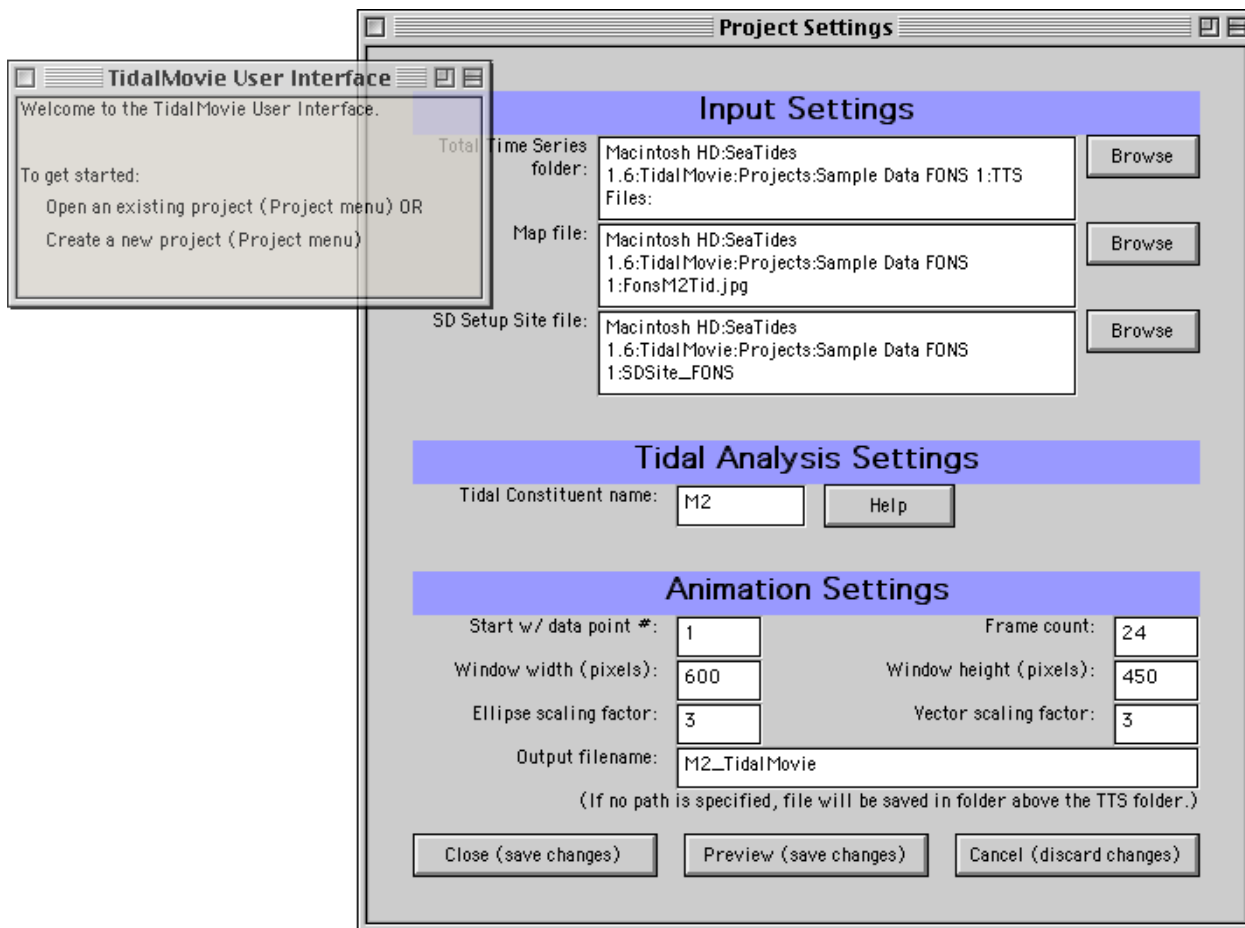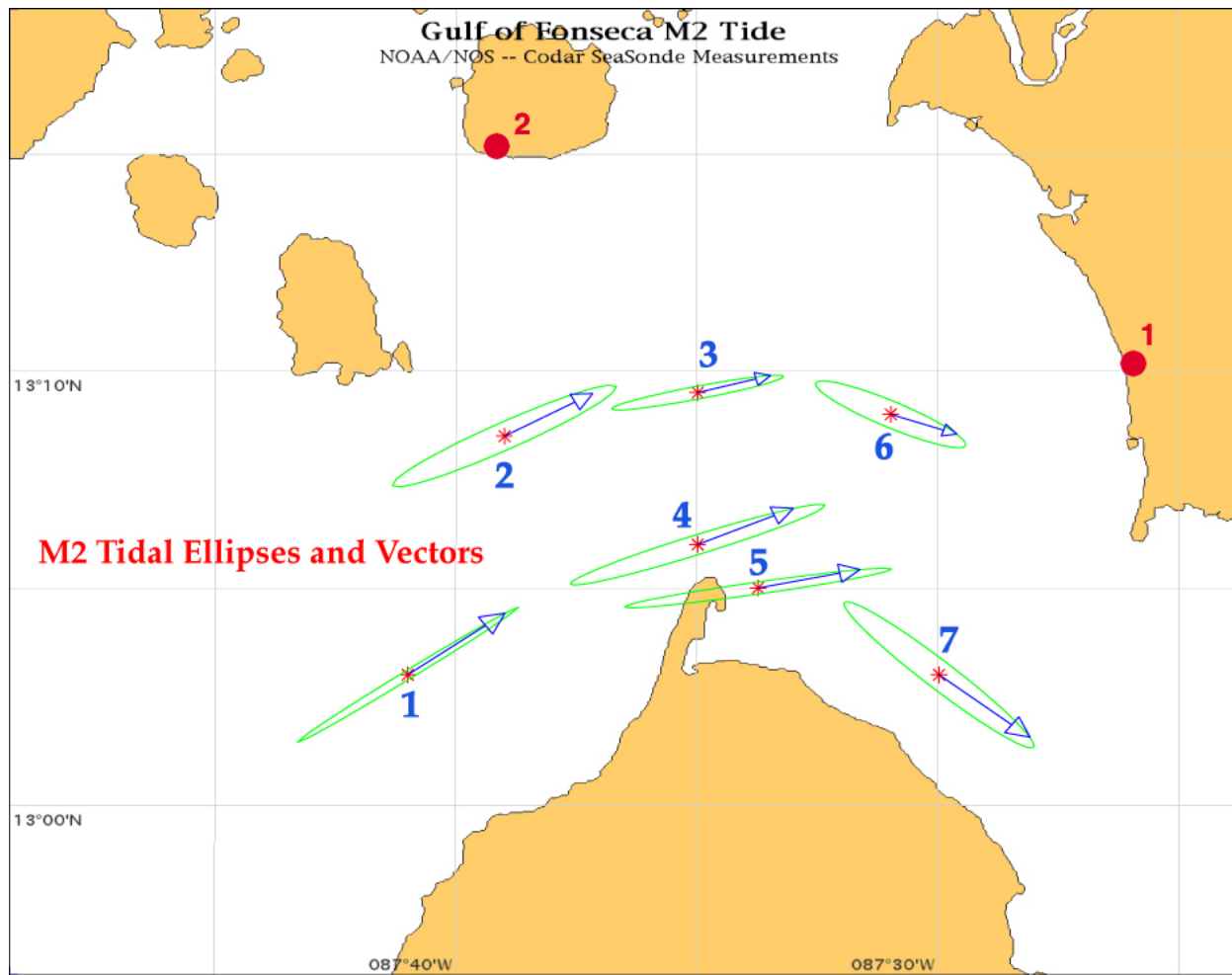
Figure 3. GUI for tidal movie making.

Figure 4. Map showing M2 tidal ellipses at seven selected points on Gulf of Fonseca.