GNSS

Global Navigation Satellite System (GNSS) is any satellite constellation which provides positioning, navigation, and timing (PNT) services on a global or regional basis (*Other Global Navigation Satellite Systems (GNSS)*, 2020). One of the systems GNSS includes is the United States-owned Global Positioning System (GPS).

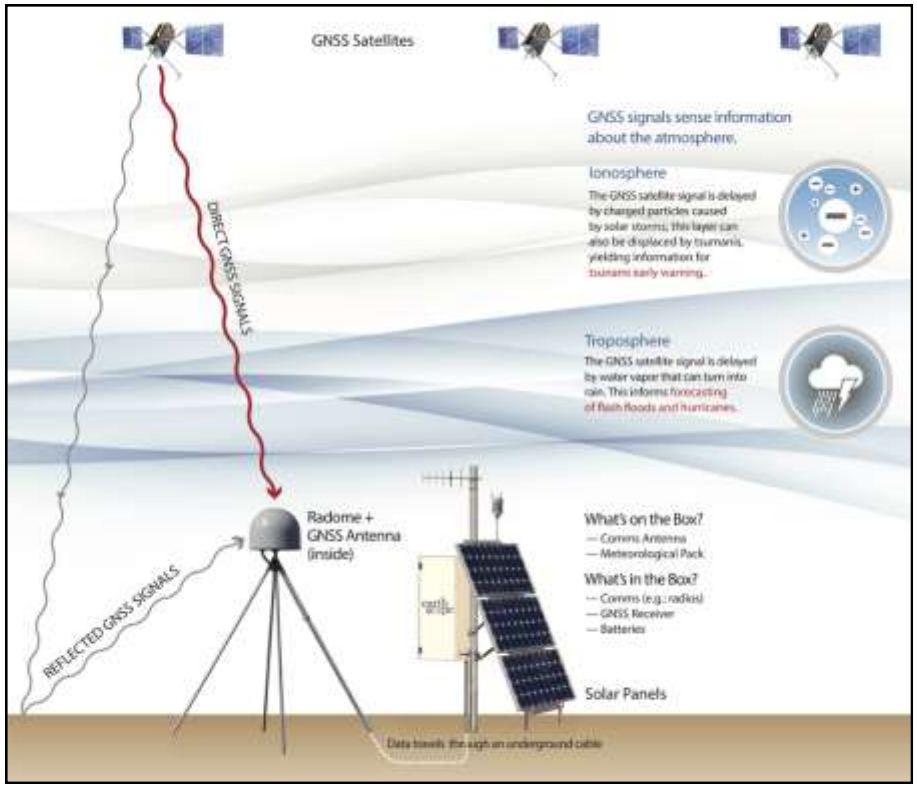


Figure 1: Network of the Americas (NOTA) GNSS station portraying the primary components of the platform. (Figure adapted from (UNAVCO, 2020))

GNSS operates via satellites sending information on two radio-frequency carriers to the receivers on earth as shown on *figure 1*. The GNSS receivers have both an antenna and processing unit. The antenna receives the satellite signals, and the receiver processes the information and turns it into measurements.

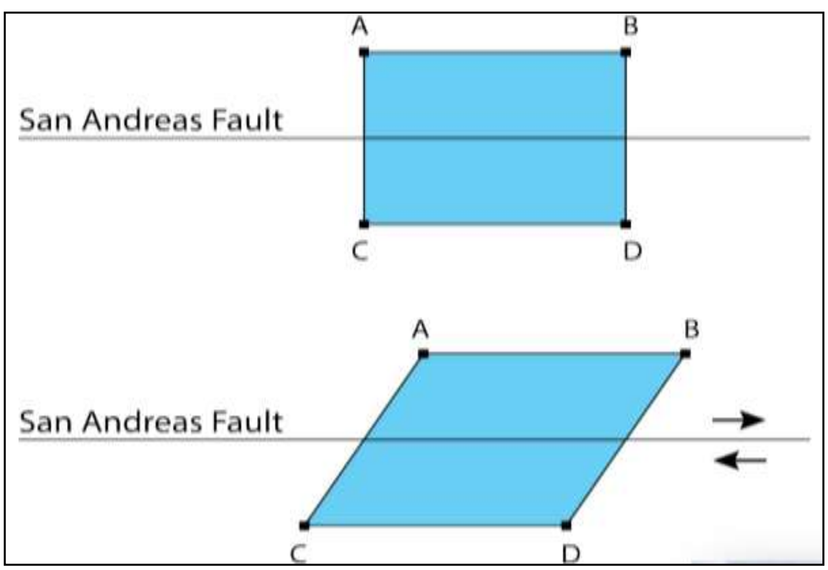


Figure 2: Demonstrates how GNSS data detects fault movement along the San Andreas Fault. (Figure adapted from (USGS, n.d.))

GeoGateway's GNSS tool can be used to measure plate motion and strain accumulation across faults. *Figure 2* demonstrates how fault motion is measured along a segment of the San Andreas Fault. The top of the figure (square shape) demonstrates the initial state of the fault at the date of observation, while the bottom of figure (parallelogram) shows how at a later date of observation, the fault has moved.

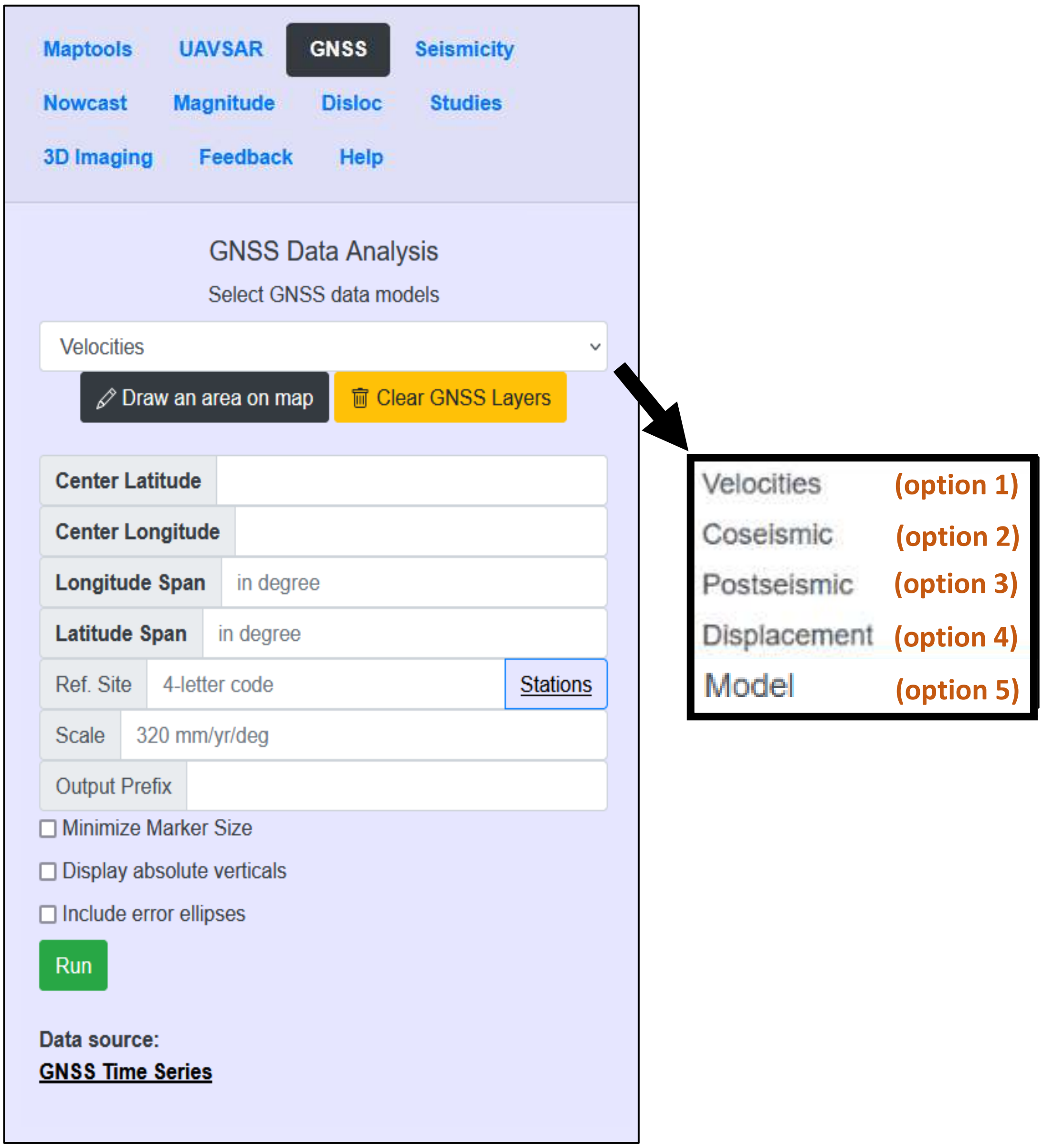


Figure 3: GeoGateway's GNSS tab, which includes five options of analysis; Velocities, Coseismic, Postseismic, Displacement, and Model.

GeoGateway offers five tools for analyzing GNSS data as shown in *figure 3*. Note the parameters in bold are required and the remaining parameters that are not in bold use default values set by GeoGateway which will be discussed within this section.

Parameters

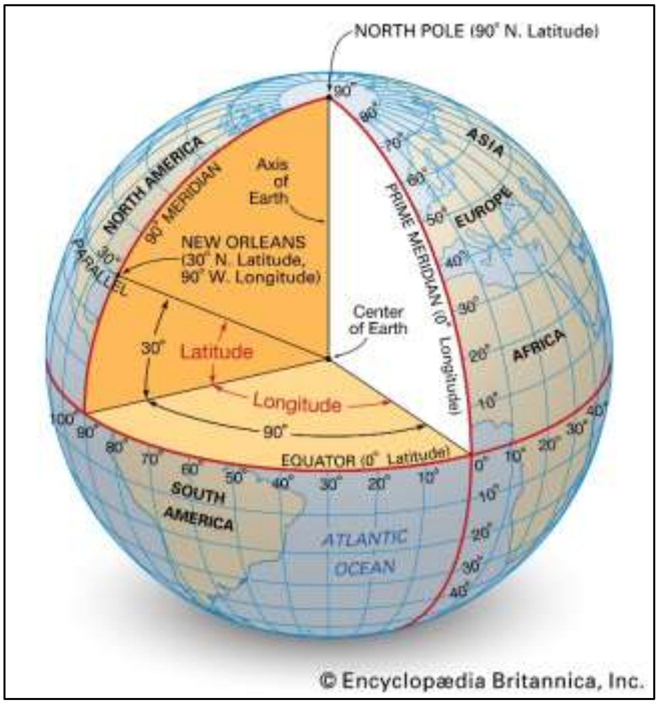


Figure 4: Overview of the geographic coordinate system (Figure adapted from (Britannica, n.d.))

Center Latitude (see *figure 4*) in decimal degrees
Center Longitude (see *figure 4*) in decimal degrees

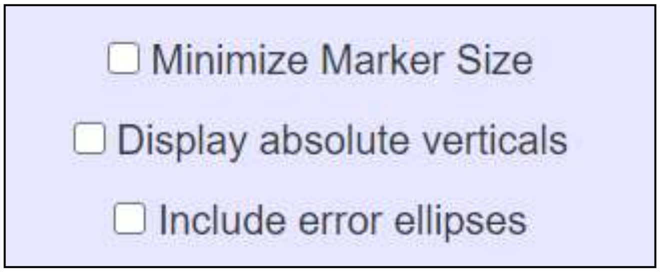
*Positive latitude is above the equator (N), and negative latitude is below the equator (S). Positive longitude is east of the prime meridian, while negative longitude is west of the prime meridian.

Longitude Span and **Latitude Span** are measured in degrees, allowing the user to create a specified parameter.
Ref. Site is the GNSS station site that the velocity vector data will be referenced to. A map with the sites can be located through the website listed below, or users may access the list of sites by clicking on "**Stations"** in the Ref. Site section of the GNSS tab. Once a location is chosen, type the 4-letter code in the box.

https://sideshow.jpl.nasa.gov/post/series.html

Scale allows the user to control the velocity vector length scaling.
Recommend setting to **320** mm/yr/deg.

Output Prefix allows users to name the dataset output.

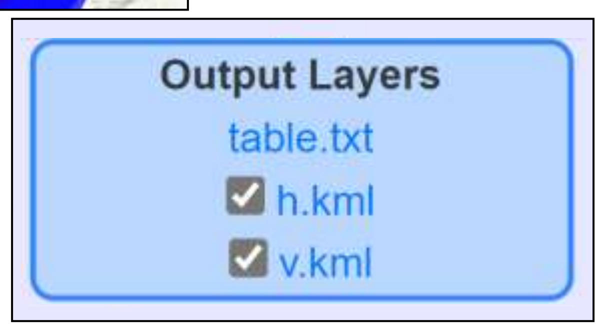


"Minimize marker size"  allows users to make GNSS site markers smaller as shown in the image below.

"**Display absolute verticals**"

Error bars are graphical tools used to illustrate the pair-wise correlation that exists between computed values (Error Ellipses). By checking the box **"Include error ellipses,"** a black ellipse at the tip of the velocity vector, representing error is displayed, as shown in the image below.

Once data is inputted, click on "Run". There is an option to download the velocity text table and the horizontal and vertical KML files as shown in the image on the right.



By selecting the “Velocities” option, the velocities of different GNSS stations are seen relative to the reference frame.

As shown in *figure 5* below “CCCC” is set as the reference point.

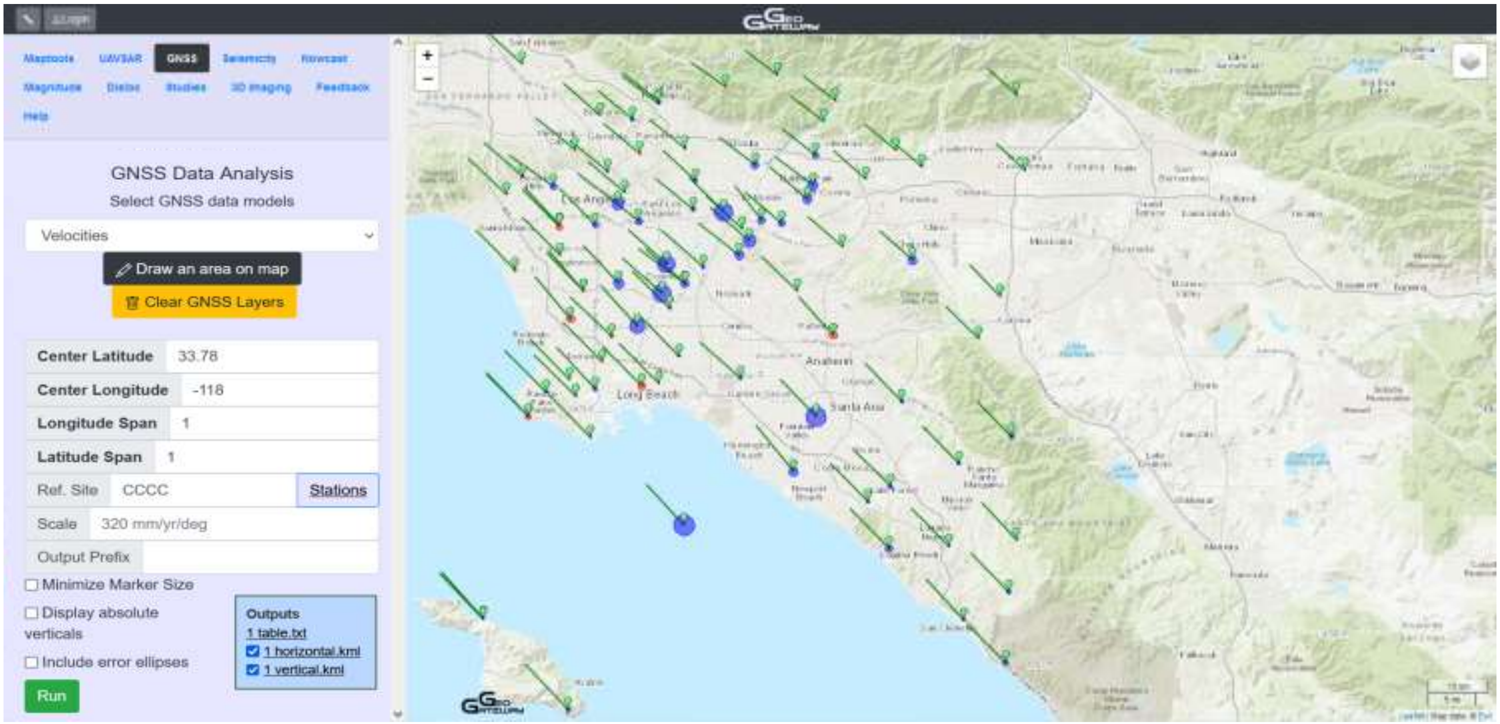


Figure 5: Velocities Analysis

Each vector shows the velocity of a single GNSS station as the Earth moves.

The tail of the vector is pinned at the GNSS station, and the length of the vector shows how fast the GNSS station is moving. The other end of the line, away from the marker, is the direction the GNSS station is moving.

Vertical displacements are shown by red (uplift) or blue (subsidence) circles. The larger the circle, the more displacement.

By clicking on a GNSS station, three time series graphs appear.

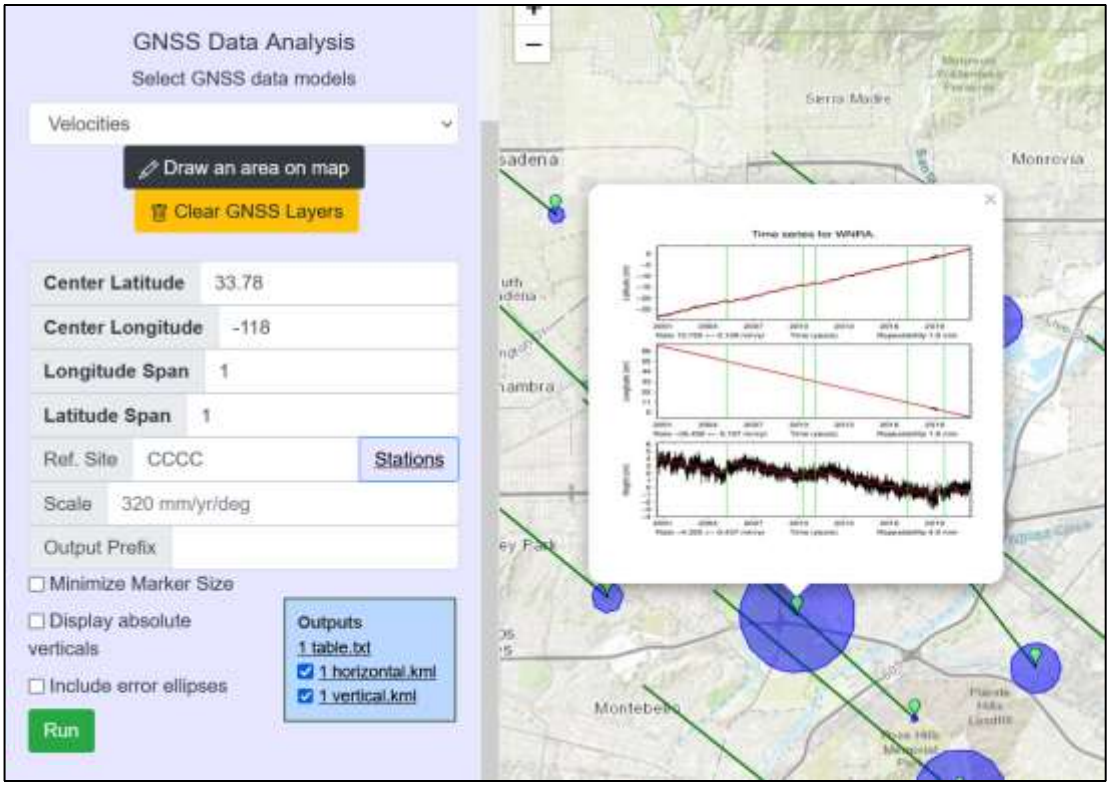


Figure 6: Time Series for WNRA station

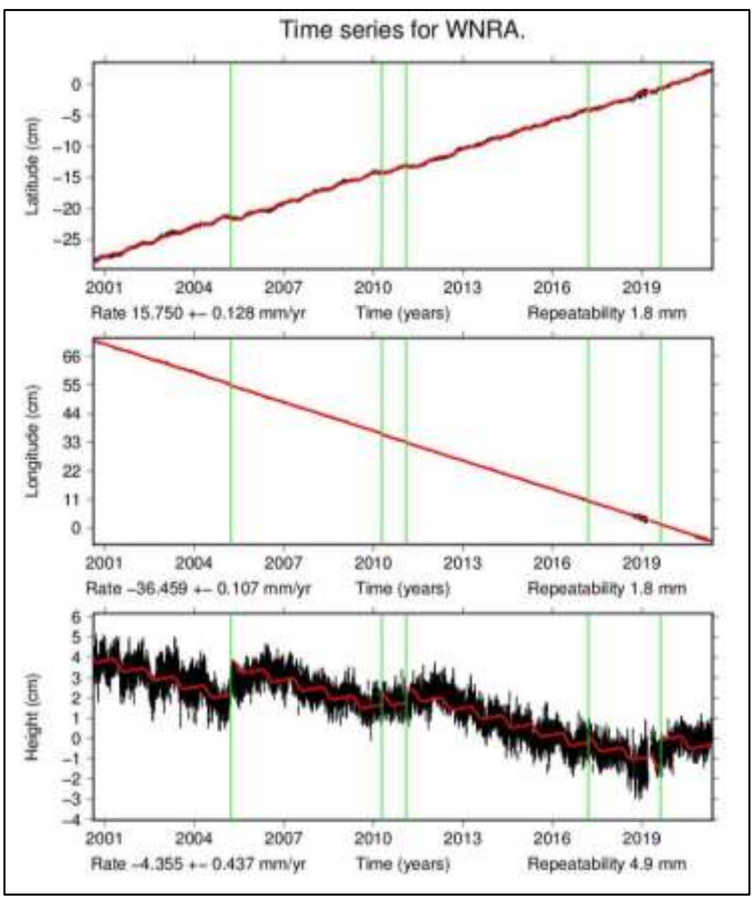


Figure 7: Time series tables, including latitude, longitude, and height

The time series shows how far the station has moved. The top graph shows latitude (cm) versus time (years). The black dots are the data points and the red line is the best fit line to the entire dataset. In this example, we see as time progresses the station moves closer to the North. For the longitude versus time graph (middle graph) we see that the GNSS station is moving to the West. The bottom graph shows the vertical height versus time which is decreasing. The green lines that intersect vertically on the graph are locations where there are jumps in the data.

Coseismic and postseismic data can be selected by specifying a time period during or after an earthquake which a user wants to focus on.

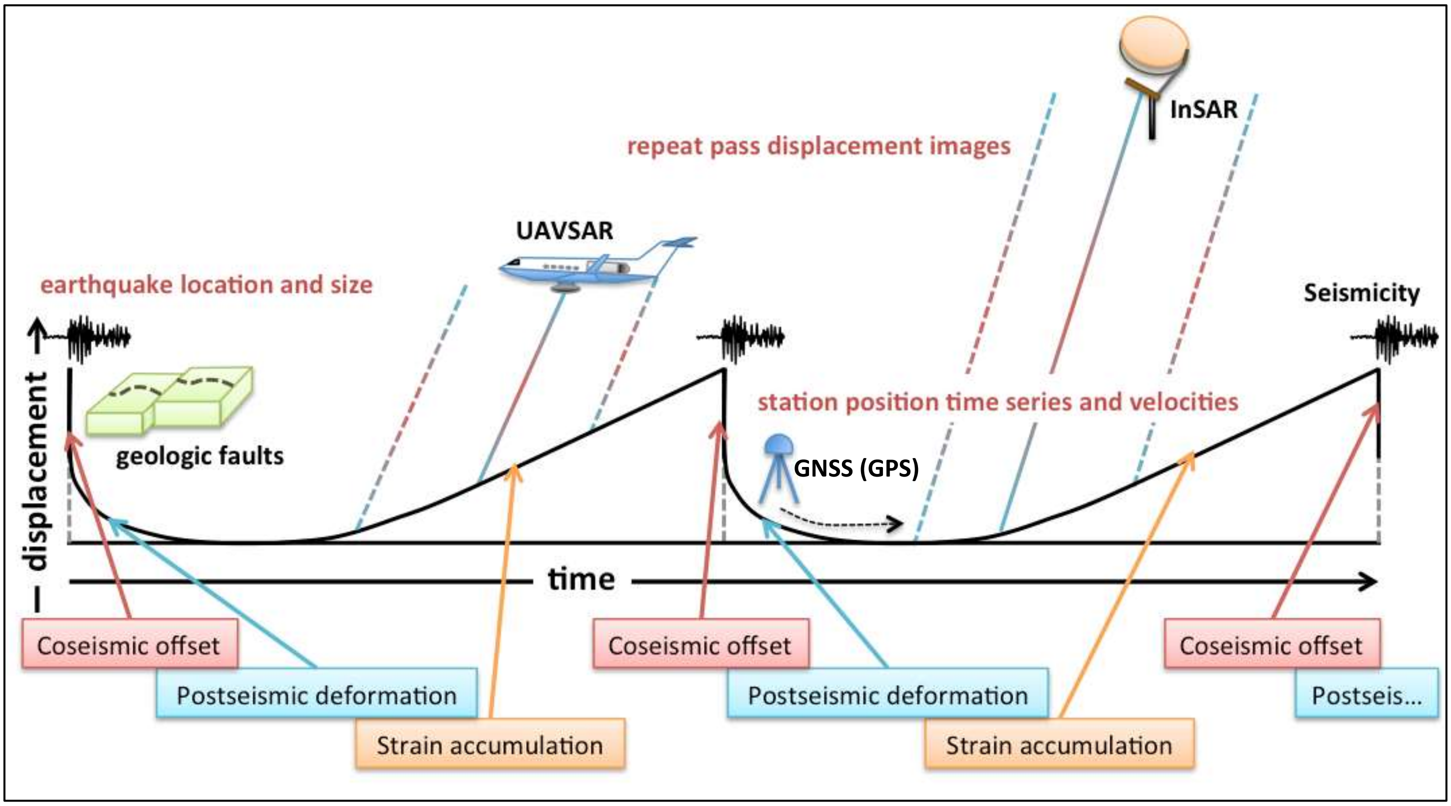


Figure 8: Crustal deformation is spatially and temporally non-uniform as strain accumulates over prolonged time scales, where its later rapidly released as earthquakes, and readjusts post-seismically. Numerous types of data from different sections of the earthquake cycle (as shown in the figure above) are required for analysis.

Figure 8 illustrates the earthquake cycle, and typical rates of deformation in the coseismic and postseismic periods.

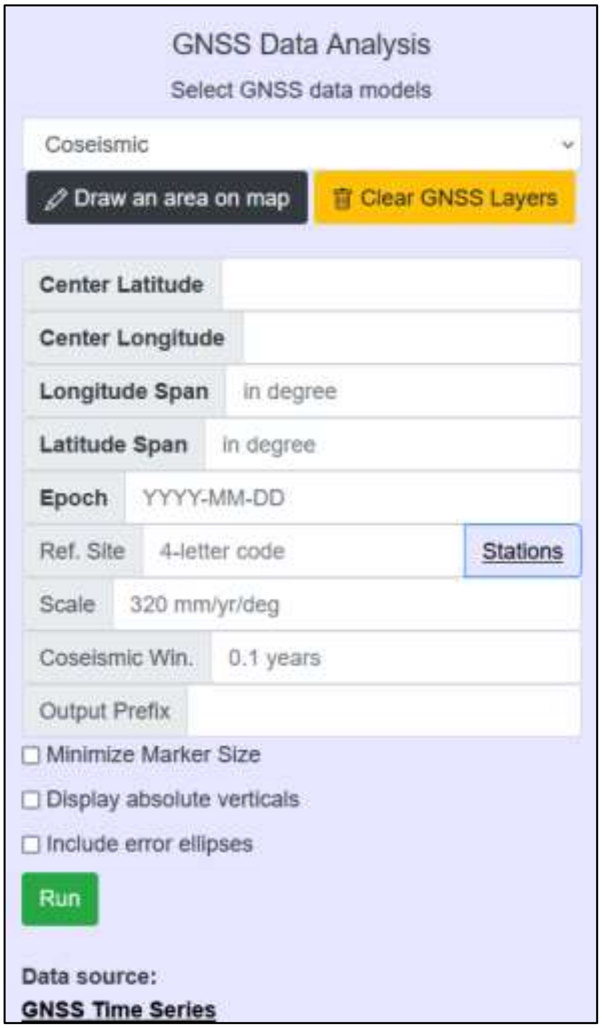


Figure 9: Coseismic offset refers to the time during an earthquake until a rupture ends.

Figure 10: Postseismic deformation refers to the time after a large earthquake when deformation occurs.

To generate coseismic and postseismic displacements, the user must consider “Epoch” and “Coseismic Window” and “Postseismic Window.” The Epoch is the time of the event and the window is any time period of choice.

The displacement tool avoids use of any fit parameters and instead uses daily time series data to directly compute displacements between any two times which have measurements (Heflin et al., 2020).

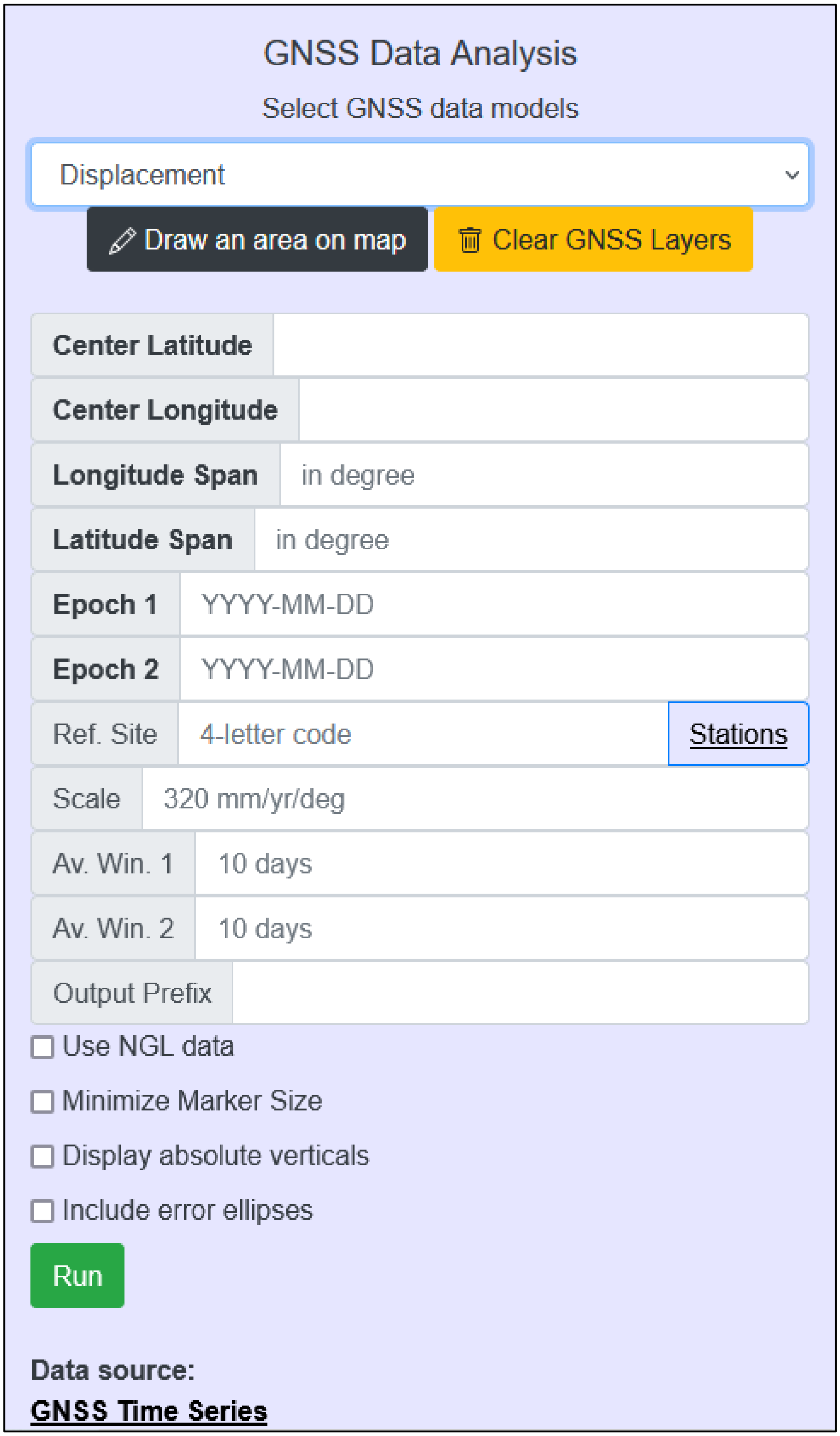


Figure 11: Displacement Analysis

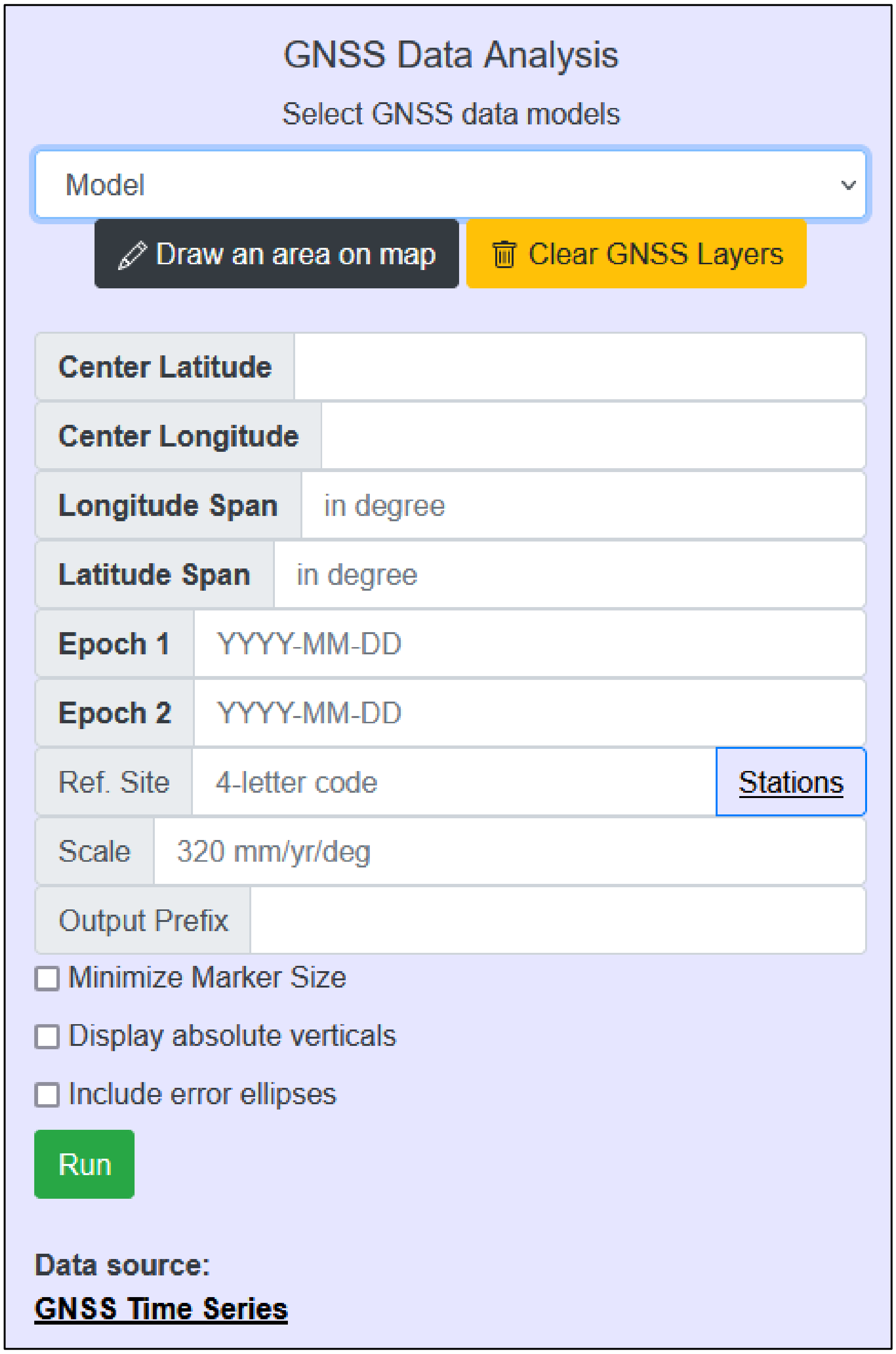


Figure 12: Model Analysis

The model tool uses all fit parameters to compute a displacement between two user specified times (Heflin et al., 2020).