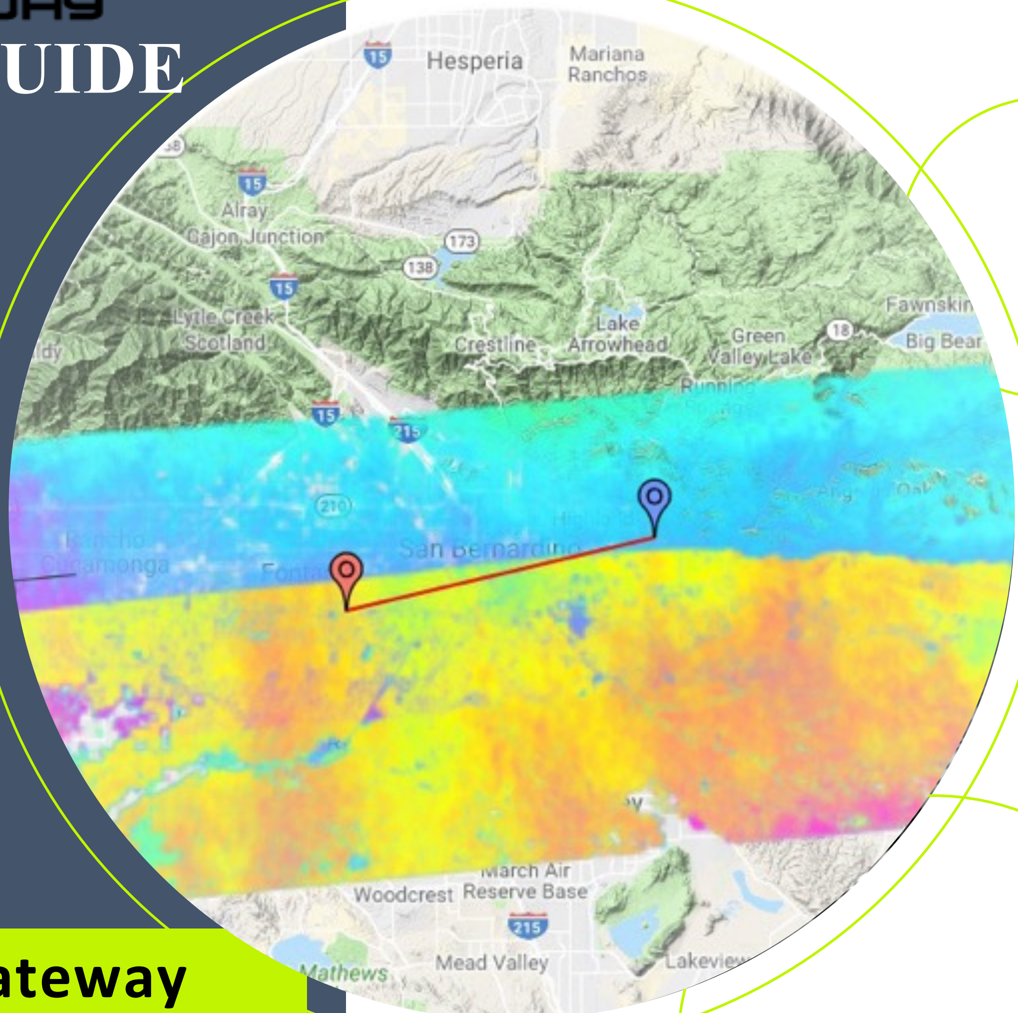
GeoGateway

USER GUIDE



GeoGateway

Tools for **Analysis**, **Modeling**, and Response Using **Geodetic Imagining** and **Global Positioning System** Products.

Government Sponsorship Acknowledgement

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Acknowledgments

This User Guide was prepared for the Seismological Society of America (SSA) workshop by the GeoGateway team. The workshop **Measuring Fault Parameters and Slip from Geodetic Imaging Data using GeoGateway Online Tools**, took place at the 2019 SSA Annual Meeting, in Seattle, Washington, on April 23, 2019.

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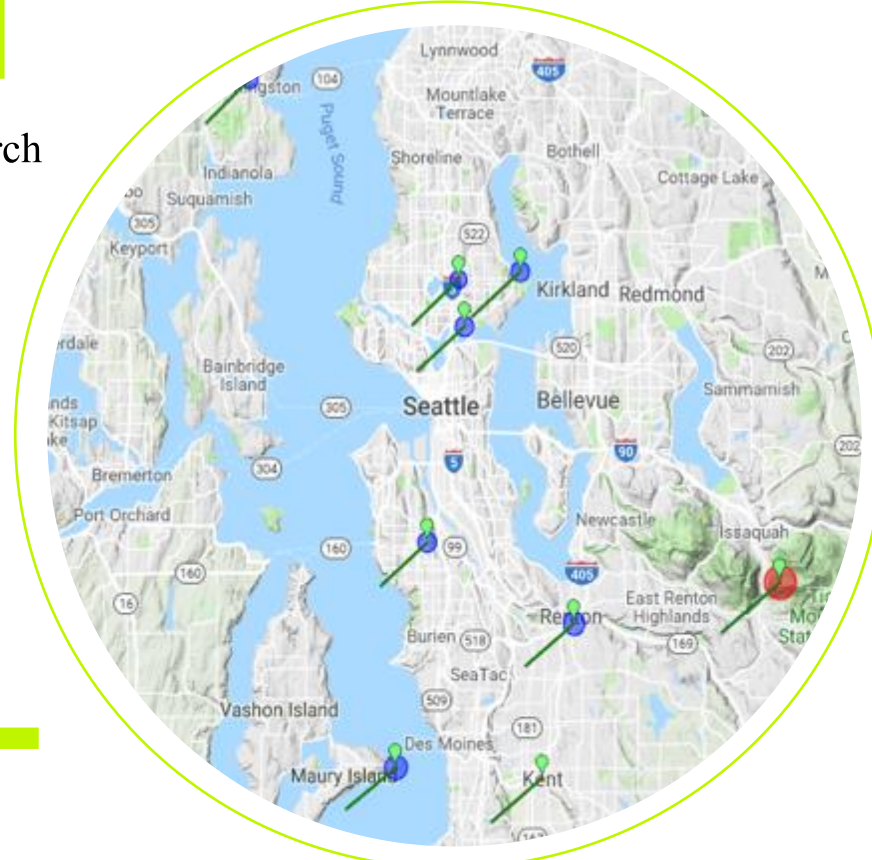
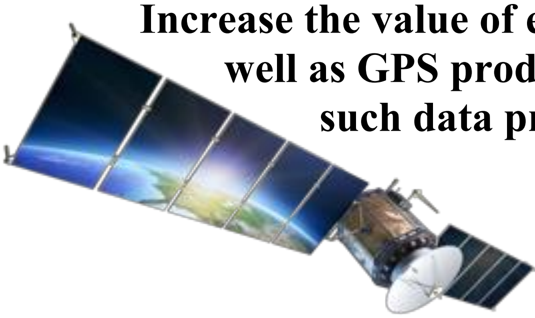
GeoGateway Overview



GeoGateway is a data product search and analysis gateway for scientific discovery, field use, and disaster response.

GeoGateway focuses on NASA's geodetic imaging products from InSAR (Interferometric synthetic aperture radar) and GPS (Global Positioning System) integrated with earthquake faults datasets, seismicity, and models.

The purpose of GeoGateway is to



Increase the value of existing geodetic imaging products from NASA as well as GPS products to enable research to explore and integrate such data products.

Goals

• Bridge the gap between production and end-use of data products
• Simplify discovery of geodetic imaging and GPS data products
• Enable researchers to explore and integrate data products
• Allow researchers to easily share, publish, and collaborate

GeoGateway is a web map-based science gateway supported by NASA's ACCESS program.

The gateway can only be accessed via internet at (http://geo-gateway.org).

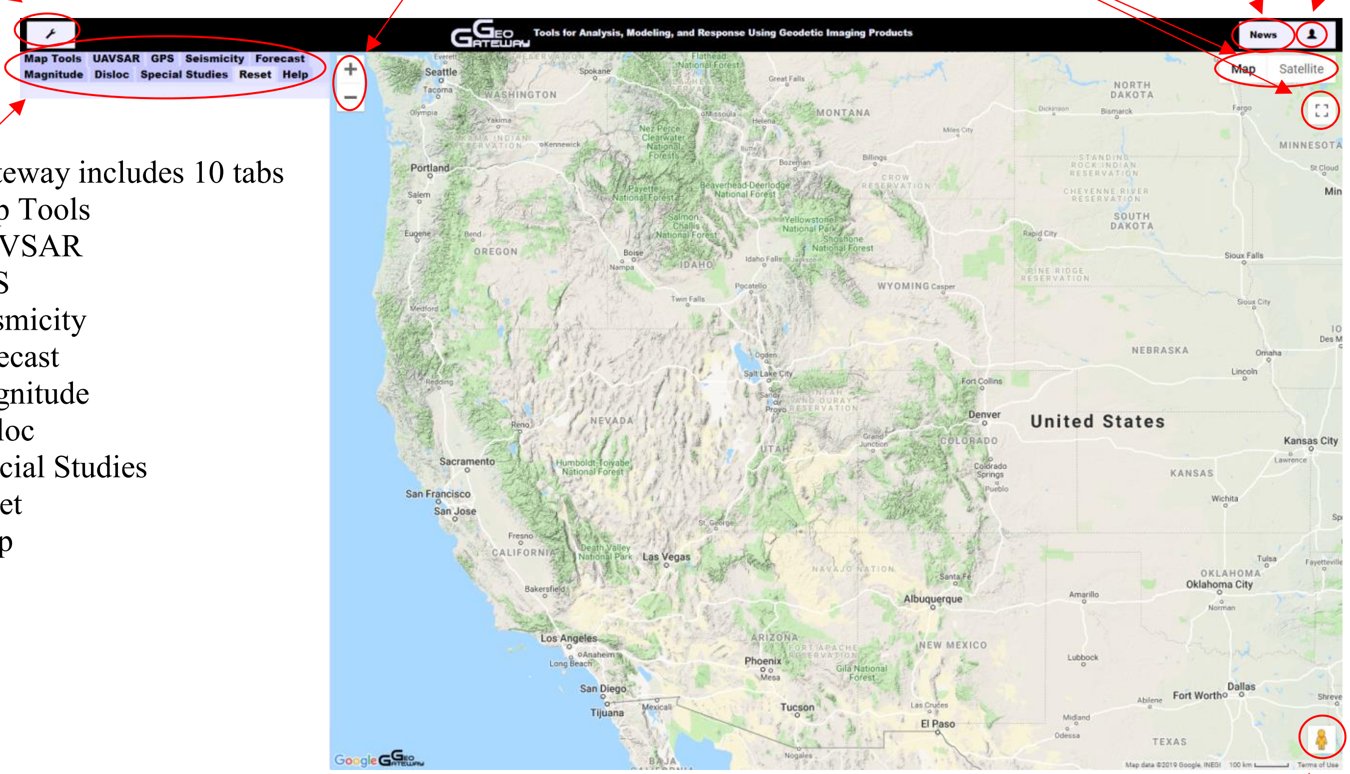
Tools display option

Zoom In
Zoom Out

Viewing Option

News

Login



Street View

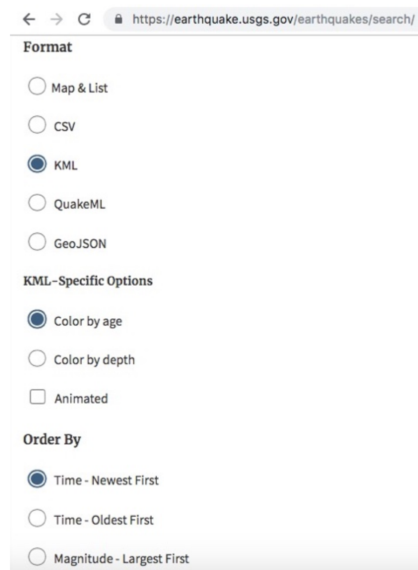
GeoGateway includes 10 tabs

1. Map Tools
2. UAVSAR
3. GPS
4. Seismicity
5. Forecast
6. Magnitude
7. Disloc
8. Special Studies
9. Reset
10. Help

Map Tools

KML Mapper

KML (Keyhole Markup Language) Mapper is a file format used for viewing geographic modeling information.



For *example*, siting the USGS website below,

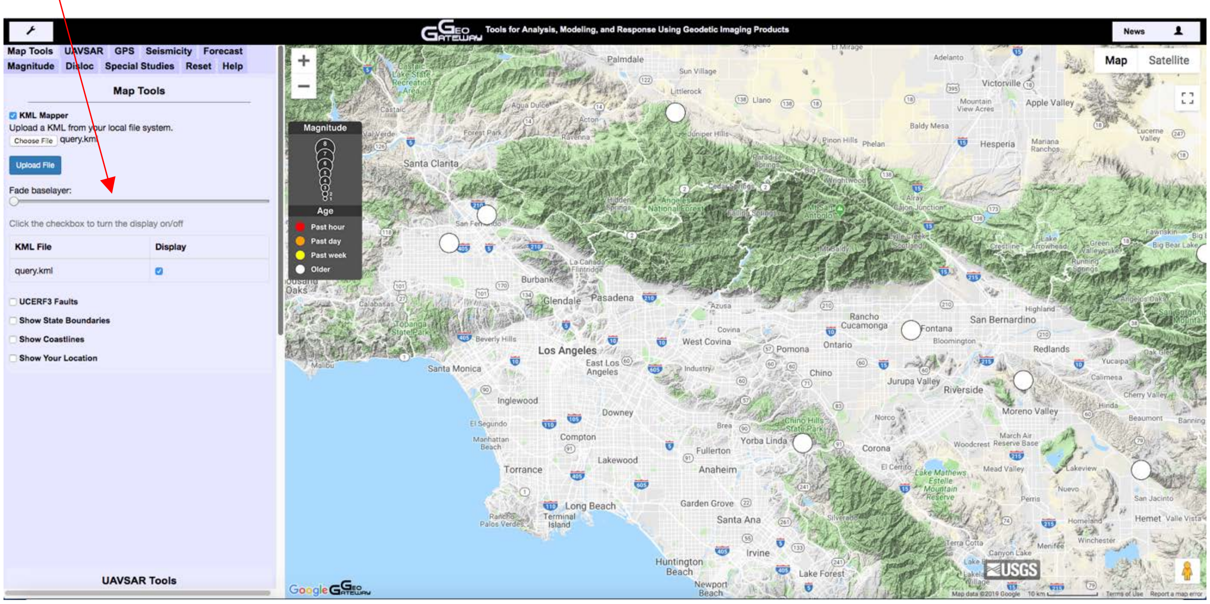
https://earthquake.usgs.gov/earthquakes/search/

allows for a user to search through an earthquake catalog in which the selected earthquake data can be downloaded into a KML file and uploaded into GeoGateway as shown in the image below.
Once uploaded into GeoGateway, the KML files are displayed.

By clicking the box in the "Display" section, next to the chosen KML File, the file will be displayed on the map.

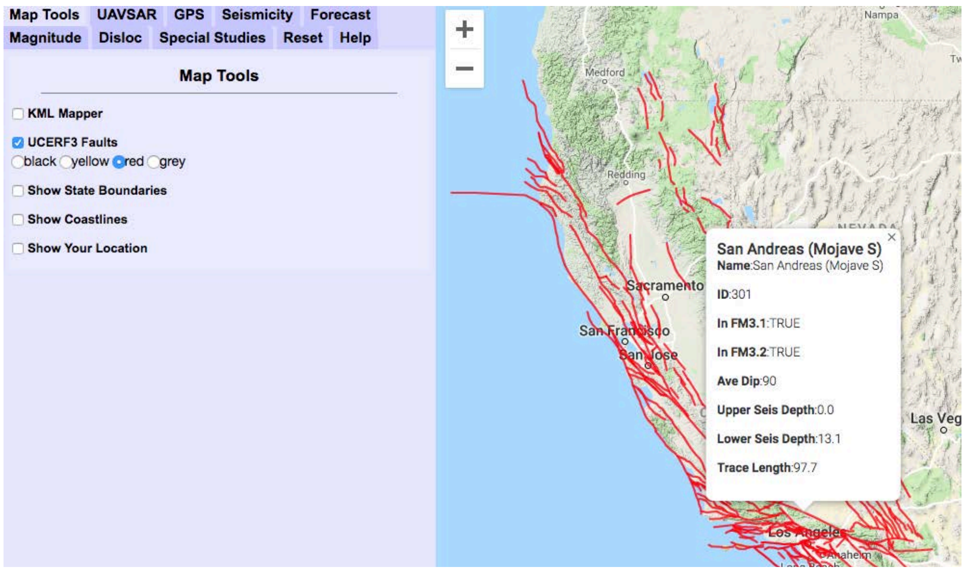
In this case, the KML file named "query" is displayed on the map.

The "Fade baselayer" option fades the background map, while the KML file does not fade.

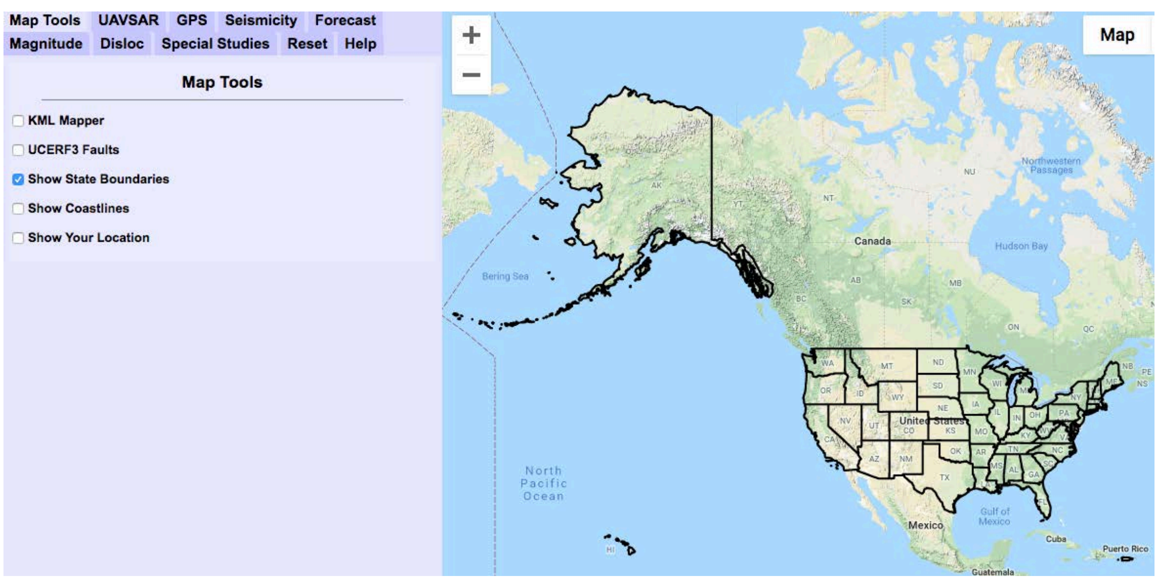


UCERF3 Faults
(Uniform California Earthquake Rupture Forecast, version 3)

The United States Geological Survey (USGS) UCERF3 faults allows users to insert California's fault lines. To input these fault lines, check the box next to "UCERF3 Faults". To choose the color of the fault lines click on the circle referring to either black, yellow, red, or grey. To understand more about a fault line, click on the fault.

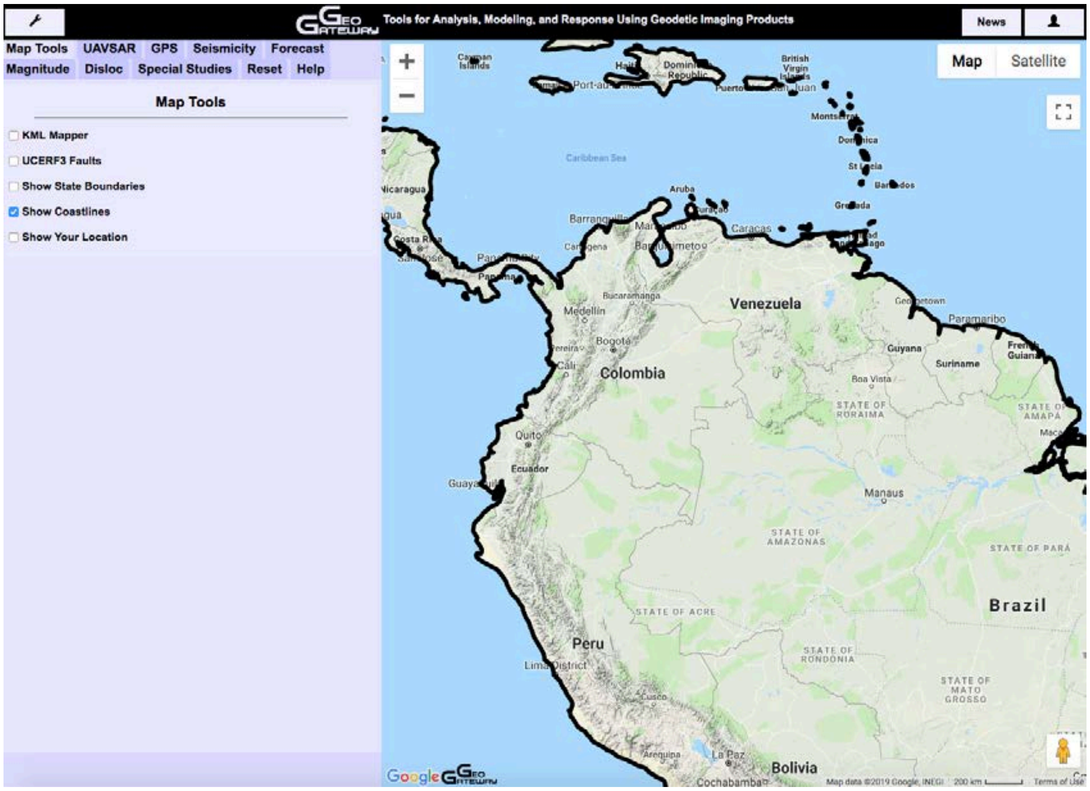


Show State Boundaries
To show state boundaries within the United States check the box next to "Show State Boundaries".



Show Coastlines

To show coastlines, check the box next to "Show Coastlines".



UAVSAR

The NASA/JPL UAVSAR (Uninhabited Aerial Vehicle Synthetic Aperture Radar), is an airborne, L-band, fully polarimetric radar, housed in a pod that is mounted to the belly of a piloted Gulfstream III aircraft. Interferometric radar images, or interferograms, are generated from repeat passes flown over a site of interest. Interferometric radar observations are made from the swaths received, which are
approximately 22 km wide and typically between 100 and 300 km long (Donnellan, A., et al., 2010)

Below is an image of how the swath is determined by a UAVSAR flight.

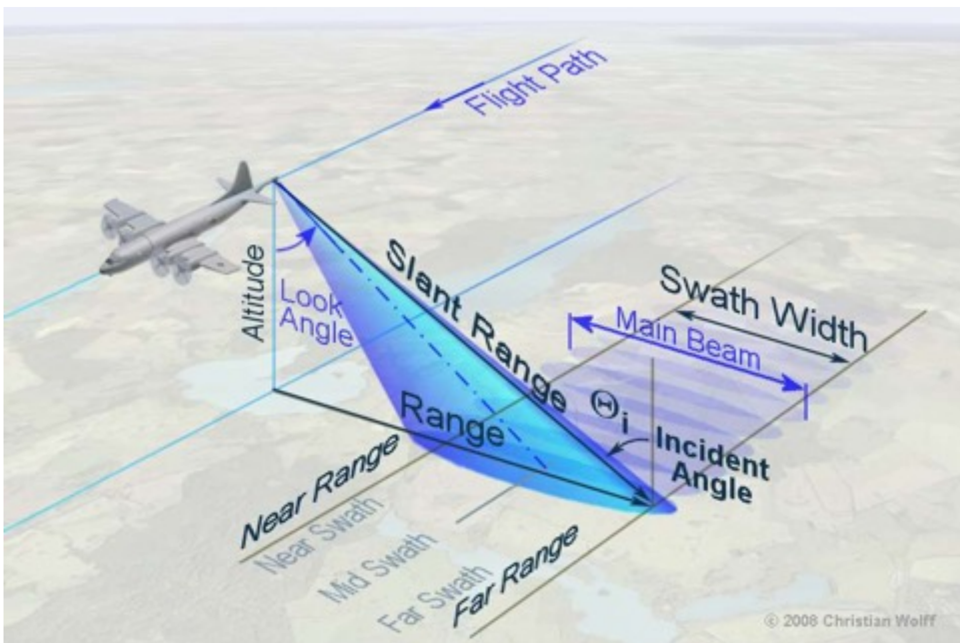


Figure adapted from (Jensen, 2000).

The wide swath of the UAVSAR instrument results in a large incidence angle variation across the swath. Near range incidence angles are approximately 25° whereas far range incidence angles are approximately 65° resulting in a 40° incidence angle variation across the swath.

Since repeat pass radar interferometric measurements only capture the component of surface motion along the line-of-sight vector, it is important to account for imaging geometry variations. Thus, a constant vertical displacement will exhibit a line-of-sight displacement that varies as the cosine of the look angle (angle between aircraft nadir vector and line of sight) and a constant cross-track displacement will exhibit a line-of-sight displacement that varies as the sine of the look angle.

Different fault geometries and types of slip produce different surface motions and project differently onto a line-of-sight change between points on the ground and instrument.

Interpreting line-of-sight changes for fault motions requires assumptions for the style of faulting. Slip of a certain orientation, corresponding to fault slip, can be projected onto line-of-sight between the ground and instrument using the following parameters (Donnellan, A., et al., 2014).

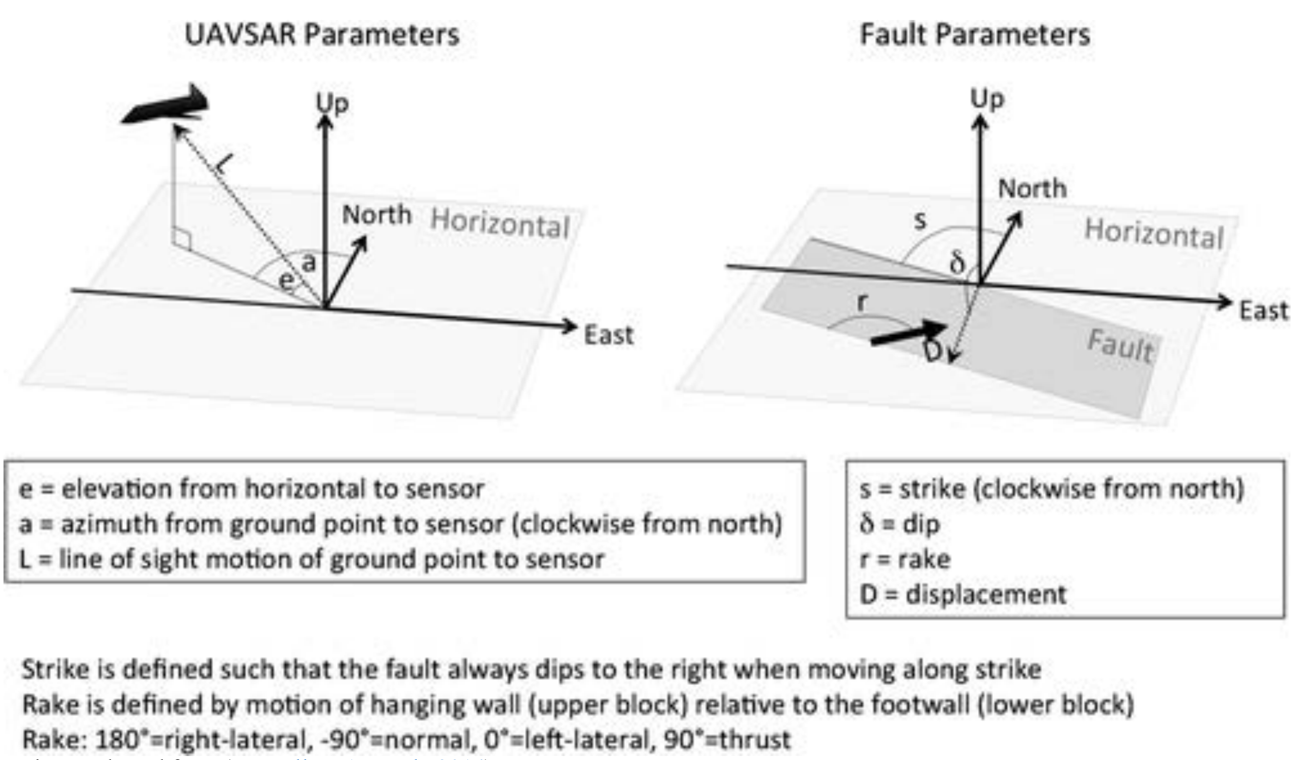


Figure adapted from (Donnellan, A., et al., 2014).

To the right, we see two different radar images creating the interferogram (shows the change or difference from each radar image).

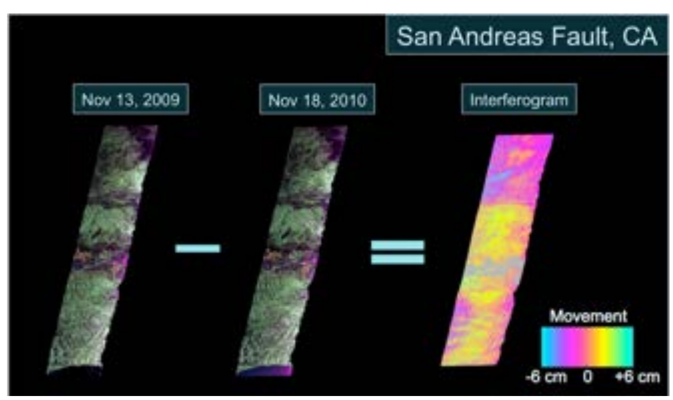


Figure adapted from (NASA, 2014).

Interferograms allow a user to see how the difference in fringes portrays an uplift within a location, as seen in the image on the right.

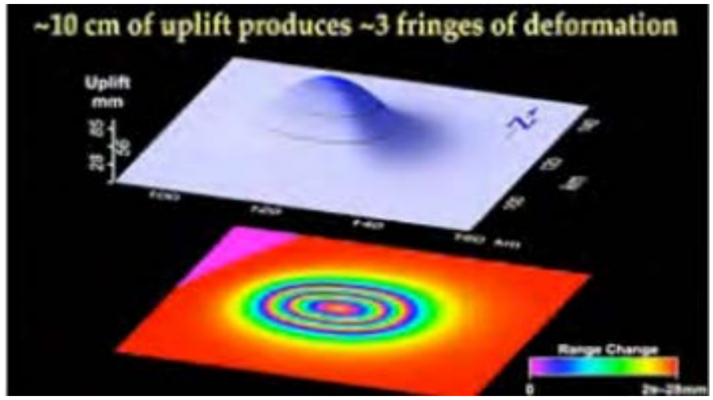


Figure adapted from (NASA, 2014).

Example UAVSAR cases:

a.

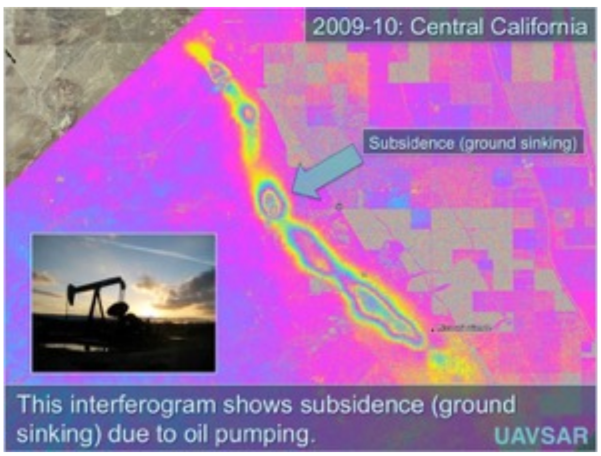


Figure adapted from (NASA, 2014).

b.

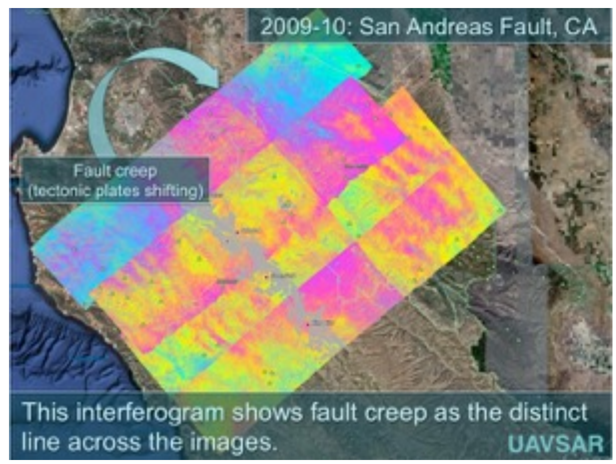


Figure adapted from (NASA, 2014).

c.

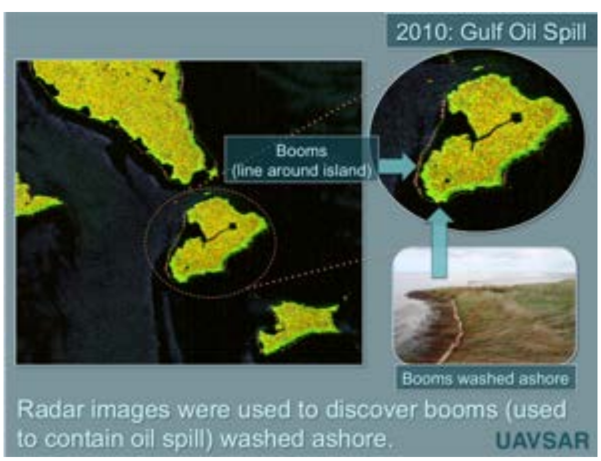
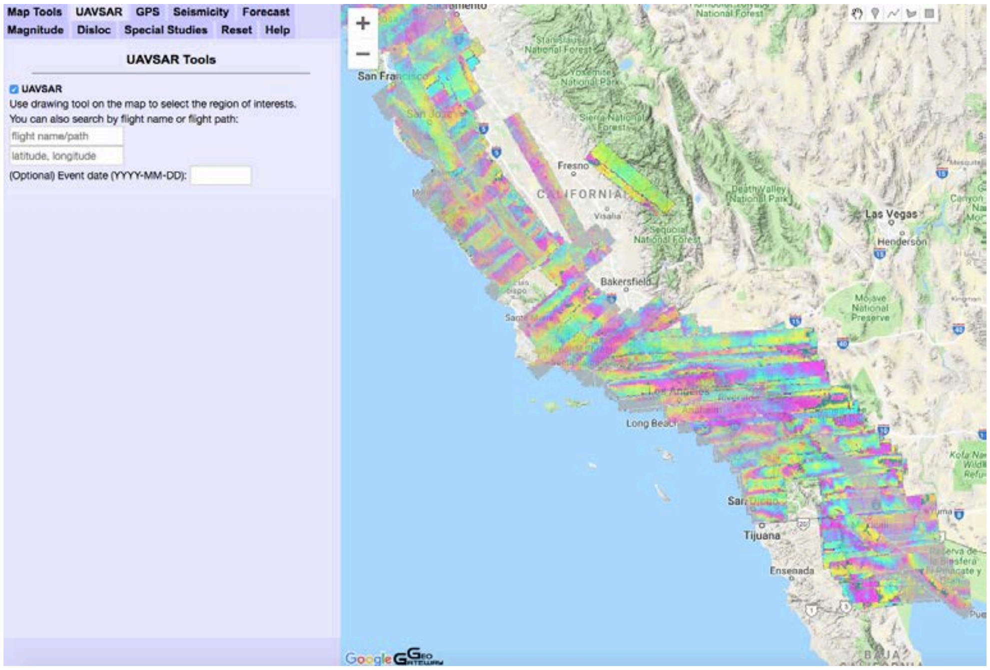


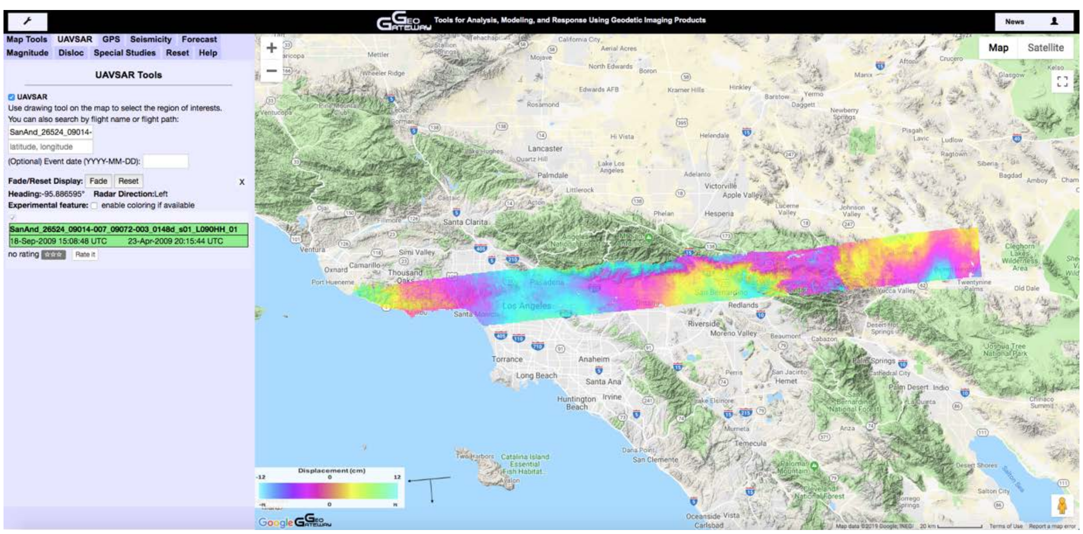
Figure adapted from (NASA, 2014).

By checking the “UAVSAR” box in the “UAVSAR” tab, various UAVSAR strips will show.

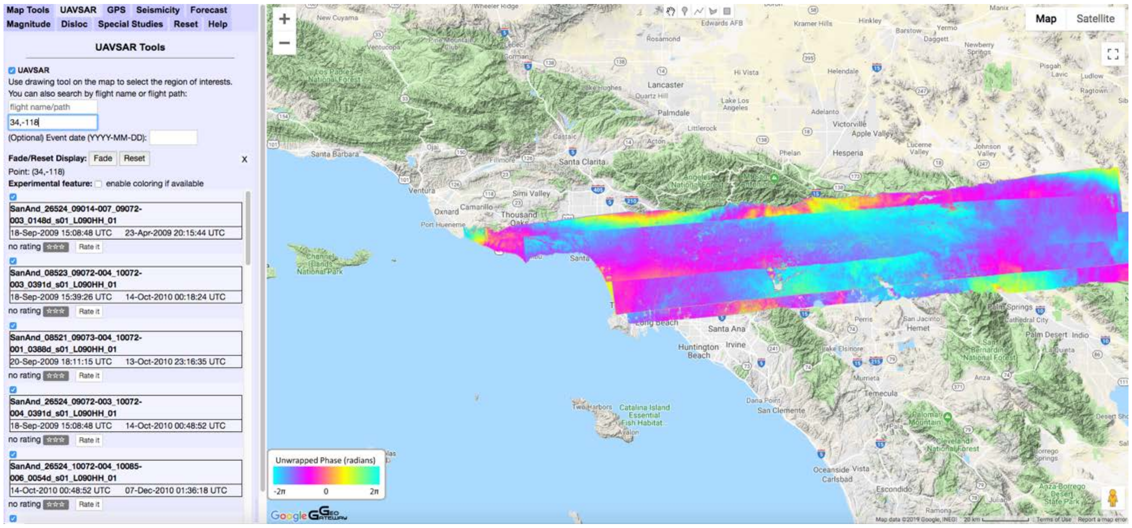


To individually select a UAVSAR flight path choose either method (1) or (2).

1. Insert the flight name in the “flight name/path” section.



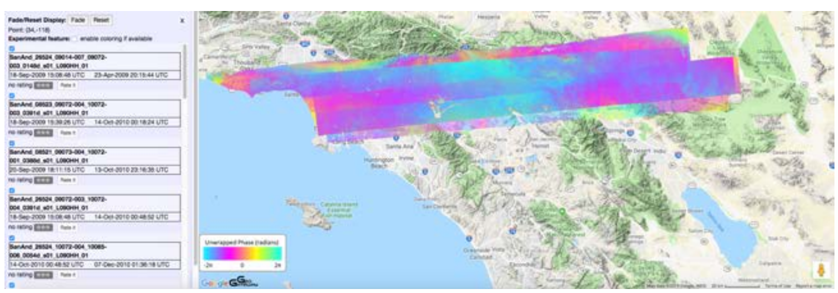
2. Insert “latitude, longitude” of the region of interest. And choose a strip from the region.



It is optional to put in an event date (YYYY-MM-DD) in order to narrow the selection.

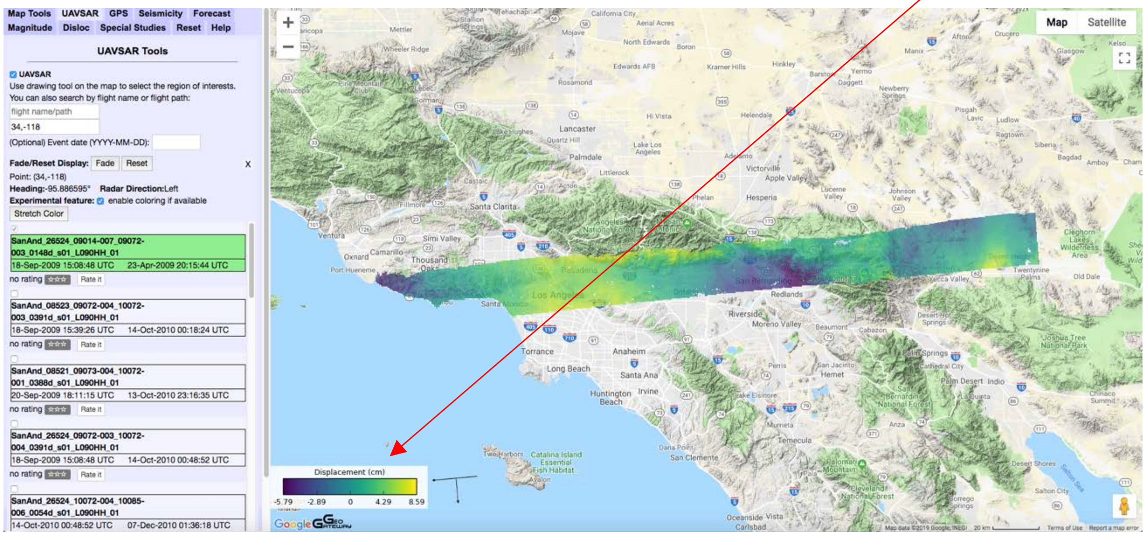
The option is given to (a) “Fade” the UAVSAR strip(s) and (b) “Reset” the strip(s) to their orginal format.

a.

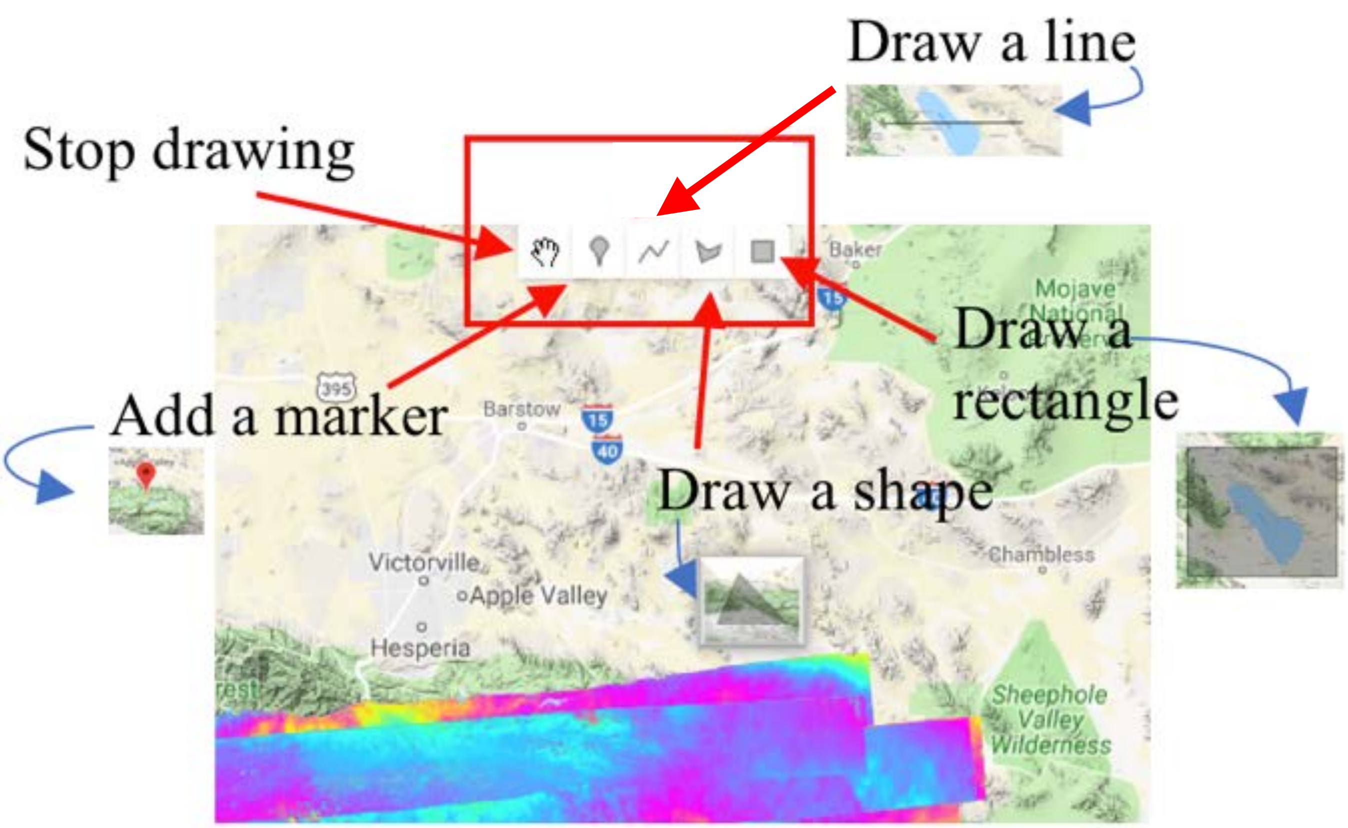


b.

c. To further look into the surface fracturing, click on "enable coloring if available". Notice the units of displacement change to "cm".



Within the "UAVSAR" section, users are given **five** tools, as shown by the arrows below in the image.

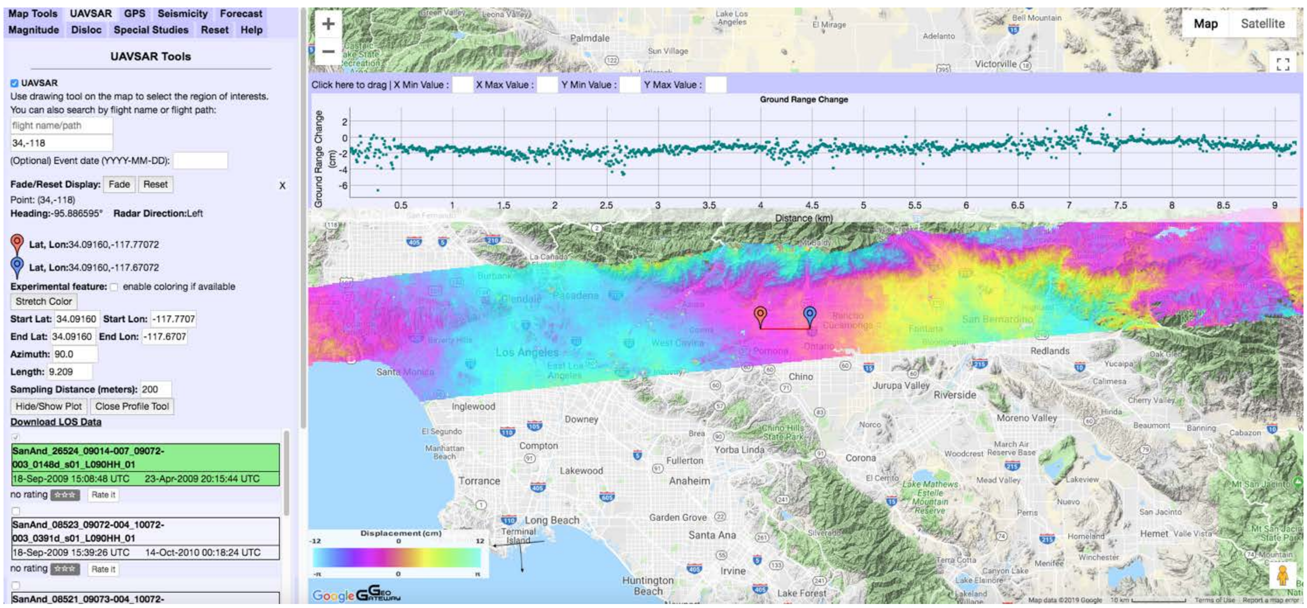


To look closer into the UAVSAR strip,

1. Search for a flight path.

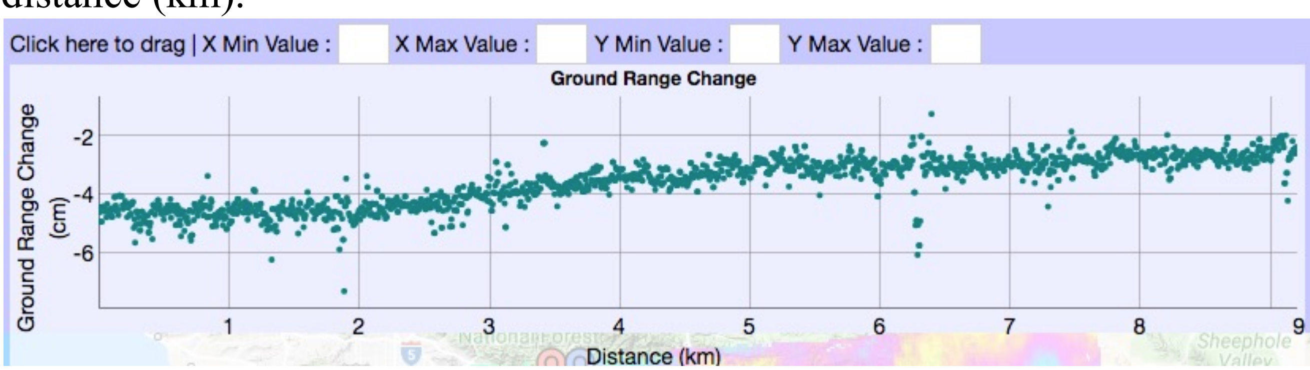
2. Select the flight path by clicking on it (flight path selction should be highlighted in green).

3. Click on the UAVSAR flight path that is shown on the map, allowing the Line-of-Sight (LOS) tool to appear.



Place the two markers on any location along the UAVSAR strip, to look at different ground range change.

The LOS tool allows users to study ground range change (cm), along a distance (km).



As shown above, users are open to put in X and Y values of their choice.

Exercise : Model and Analyze Interferograms

Go to http://geo-gateway.org

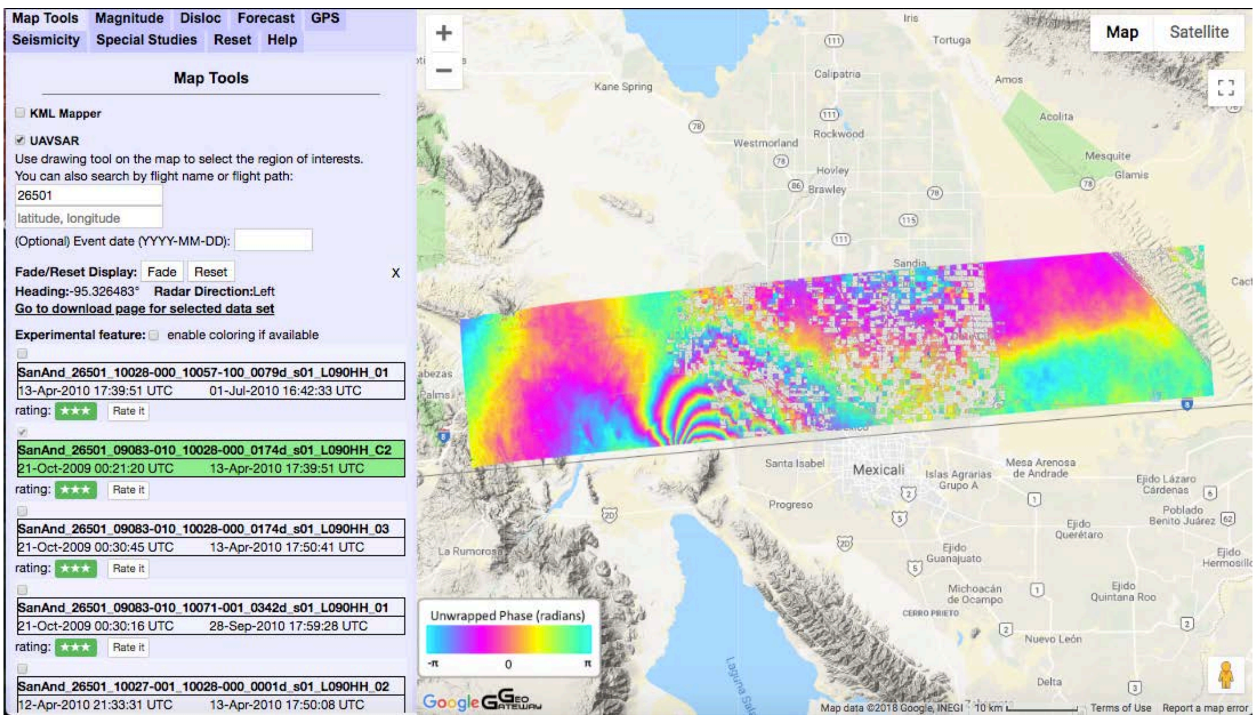
Click the "**Map Tools**" tab on the top left.

Check UAVSAR box

There are two methods a user may use to search for a UAVSAR Interferogram.

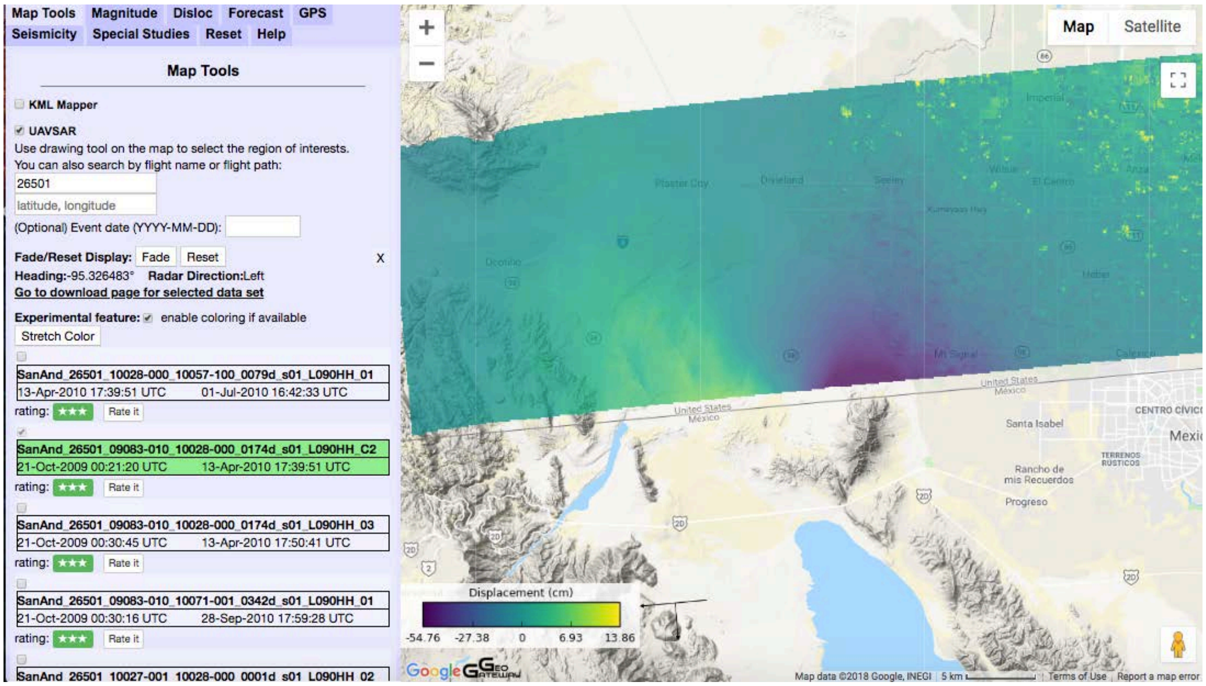
1. The "flight name/path" directly finds the flight name and path wanted
2. The "latitude, longitude" option returns all flight paths crossing paths with those coordinates.
   In the case of this exercise, enter 26501 (flight name/path) in the search window and hit return.

Select second line in list
(Name is SanAnd_26501_09083-010_10028-000_0174d_s01_L090HH_C2, should end in C2)



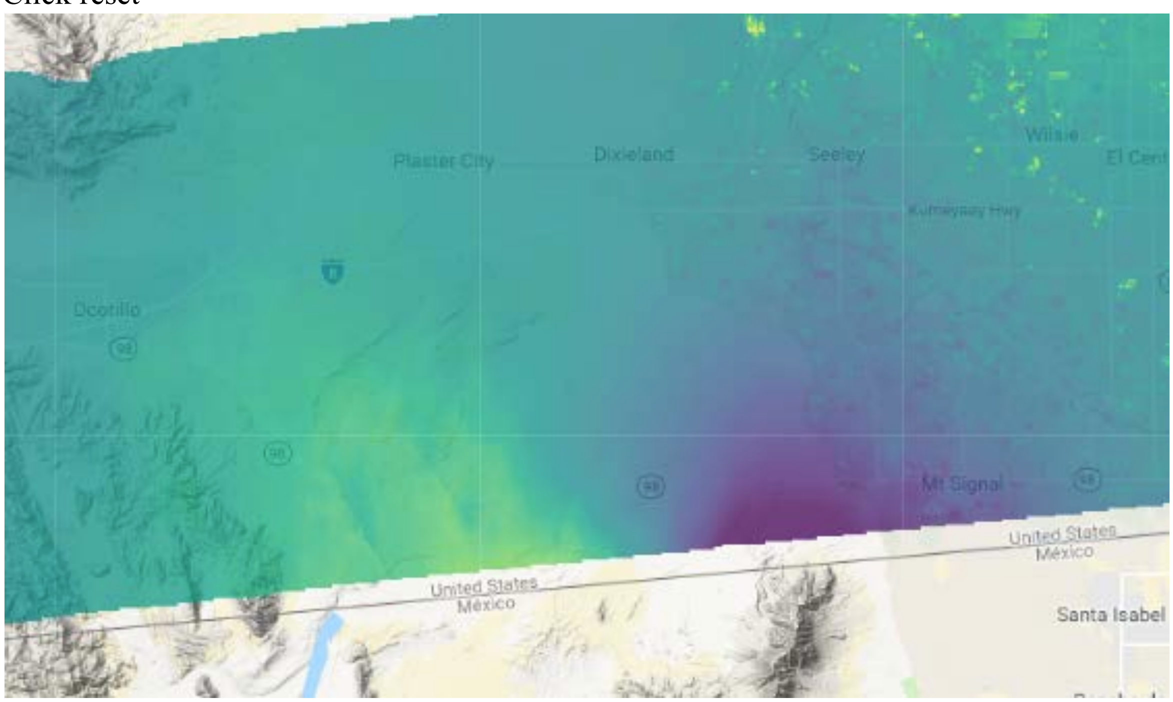
Click on "**Experimental feature: enable coloring if available**" just above the list of repeat pass interferometry (RPI) products

Re-select second line in list
(Name is SanAnd_26501_09083-010_10028-000_0174d_s01_L090HH_C2, should end in C2)



Zoom into area of the two lobes that are green/yellowish and purple.

- **a.** Click fade
- **b.** Click reset

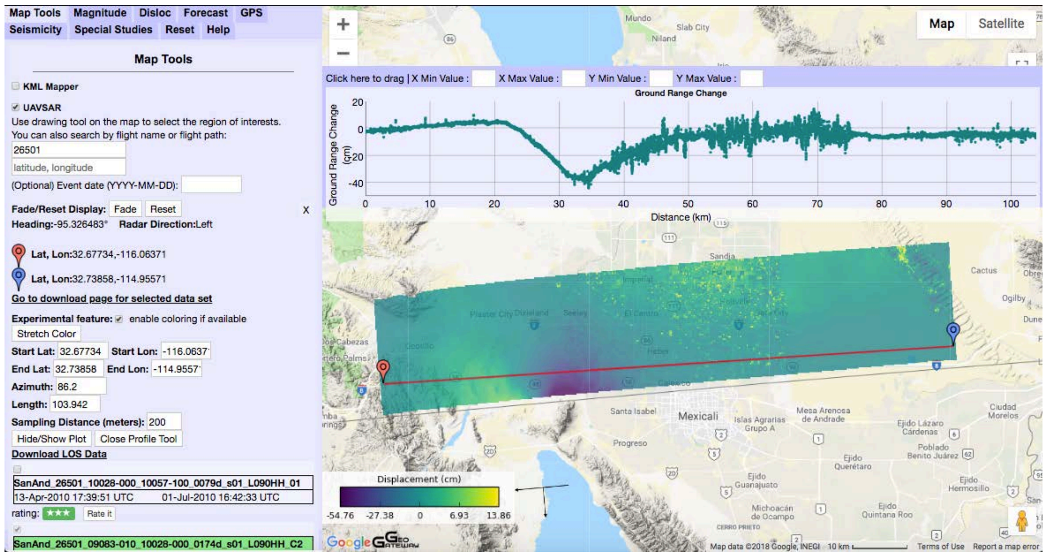


Yellow lobe shows more surface fracturing

Click on the map.

a. Adjust the endpoints of the profile to be on the product, but parallel the south end of the product through the largest color difference.
b. Mouse over the plot and read the maximum and minimum ground range change from the upper right corner of the plot

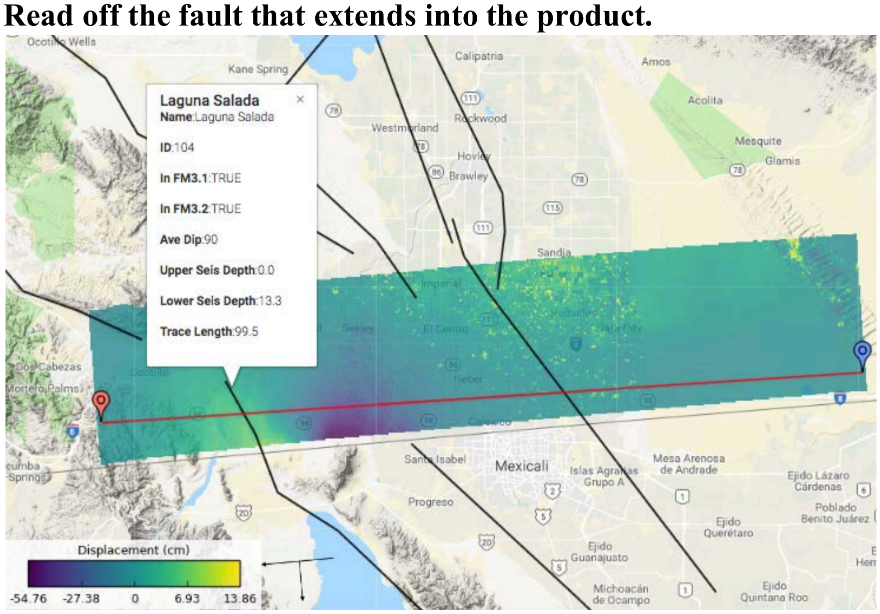
Ground range change occurred across the two lobes as shown below.



The purple lobe moved away from the instrument on the aircraft as we see that the negative (darker color) implies that the ground moved away from the instrument on the aircraft.

Scroll to the very bottom of the left panel and click the "UCERF3 Faults" check box

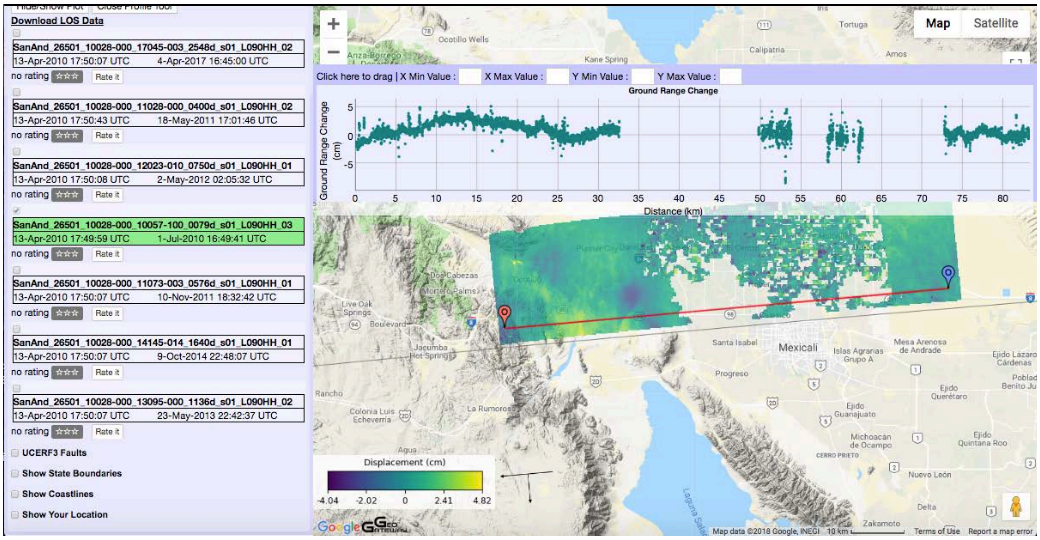
a. Click on the black line (fault)
b. **Read off the fault that extends into the product.**



c.

The mapped fault ruptured in the earthquake.

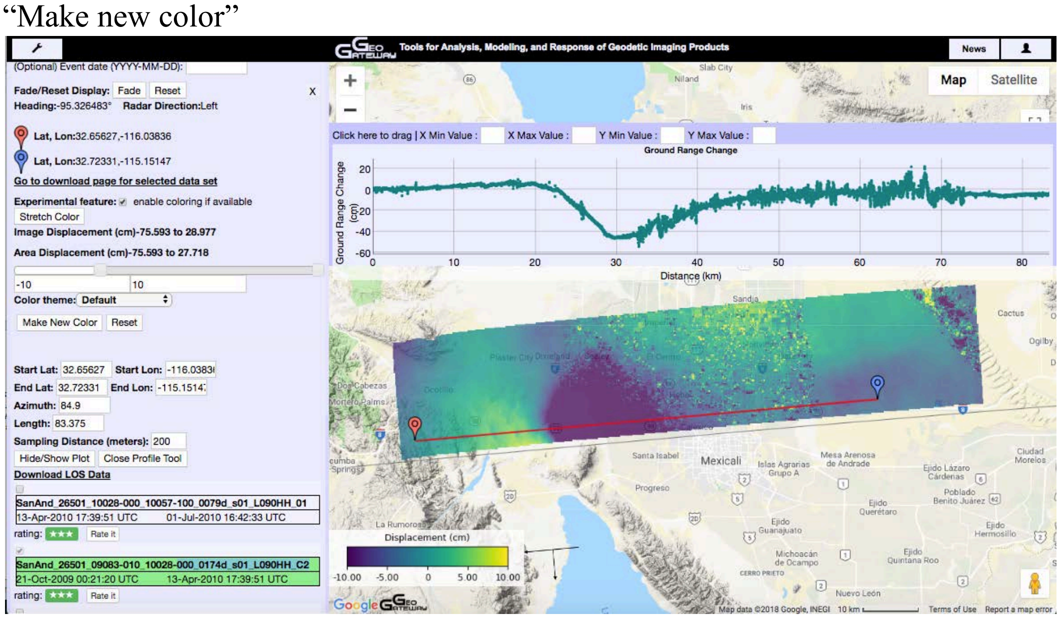
d. Scroll down and find line SanAnd_26501_10028-000_10057-100_0079d_s01_L090HH_02 with dates 13-Apr-2010 17:49:59 UTC 1-Jul-2010 16:49:41 UTC



We see a difference when selecting a different time frame, also some slips have error as shown from the absence in color.

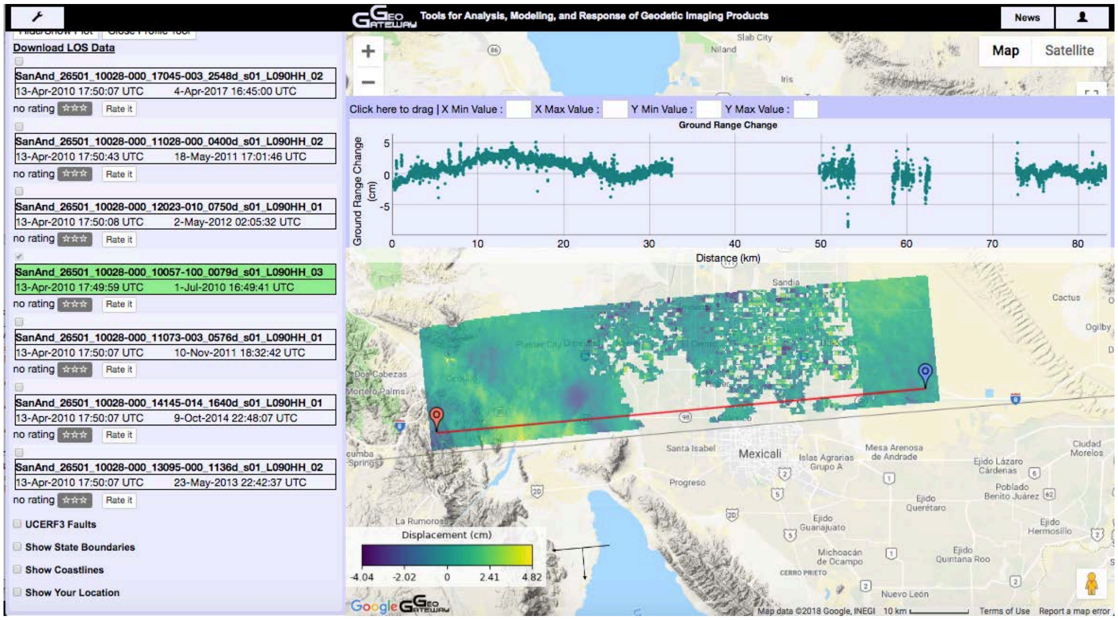
Re-select second line in list
(Name is SanAnd_26501_09083-010_10028-000_0174d_s01_L090HH_C2, should end in C2)

a. Adjust the endpoints to cover the yellow lobe only
b. Zoom into the yellow lobe
c. Click on "Stretch color"
d. Click on "Make new color"
e. Slide the color bars to roughly -10 and 10 or enter -10 and 10 into the fields and "Make new color"



Scroll down and find line SanAnd_26501_10028-000_10057-100_0079d_s01_L090HH_02 with dates 13-Apr-2010 17:49:59 UTC 1-Jul-2010 16:49:41 UTC

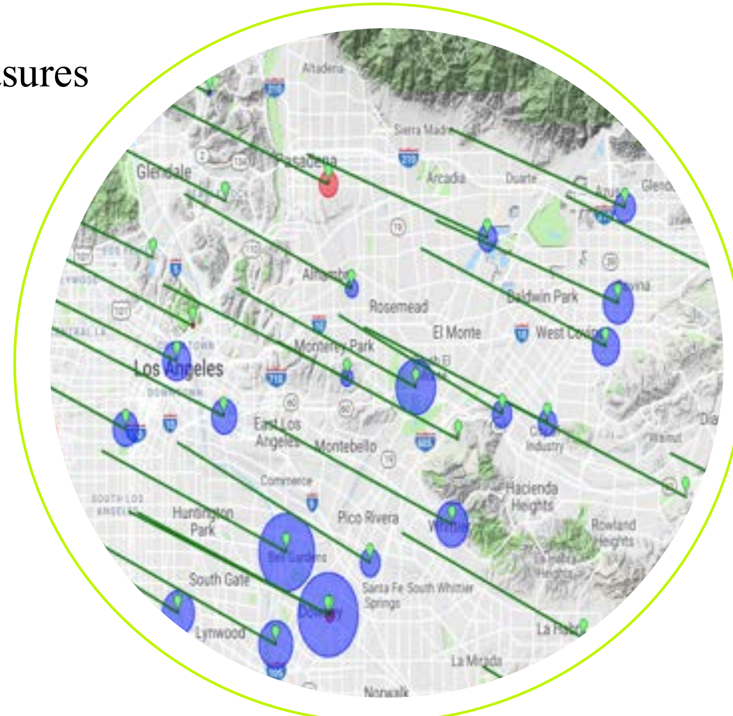
a. Leave color stretch as it was (-10 to 10) and select “Make new color”

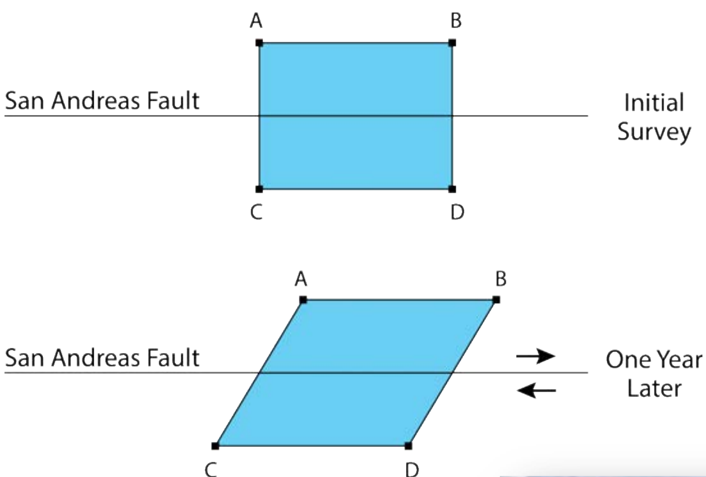


Coseismic offset, and postseismic slip is visible.

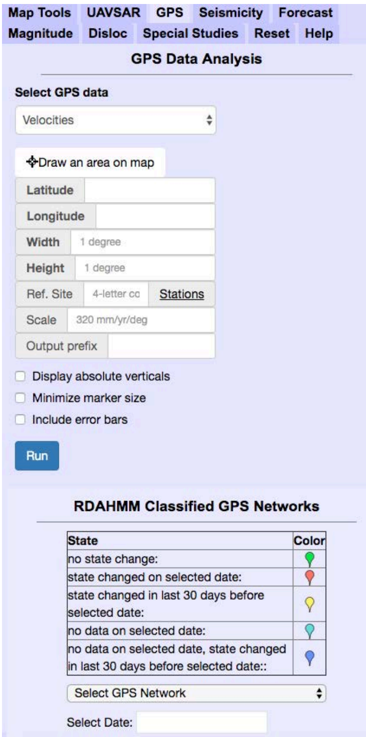
Global Positioning System (GPS)

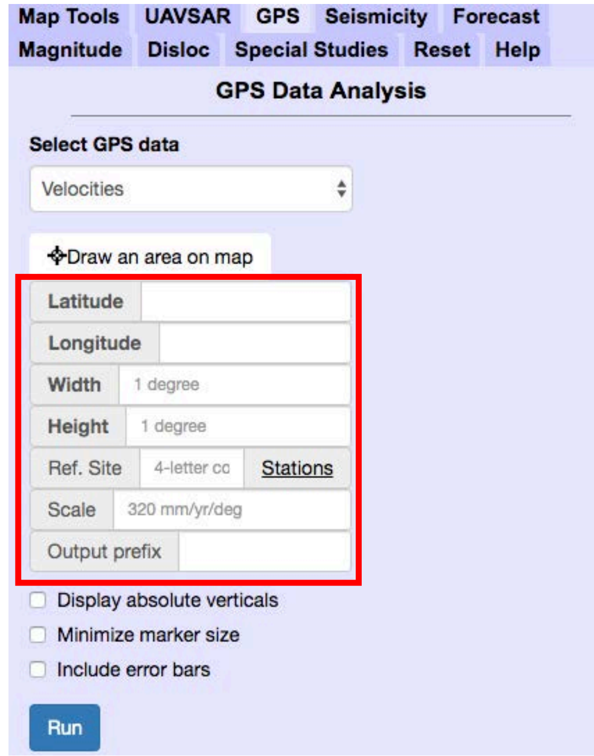
Global Positioning System (GPS) measures geolocation and time. GPS stations measure crustal deformation and fault movement through the communication of satellites. GeoGateway’s GPS tool can be used to measure plate motion and strain accumulation across faults.





The figure on the left shows how GPS stations around San Andreas Fault recorded data displaying measured movement of the fault within a time span of a year.





To define an area for analysis, fill in the parameters within the red box.

Latitude (see image below) in decimal degrees
Longitude (see image below) in decimal degrees

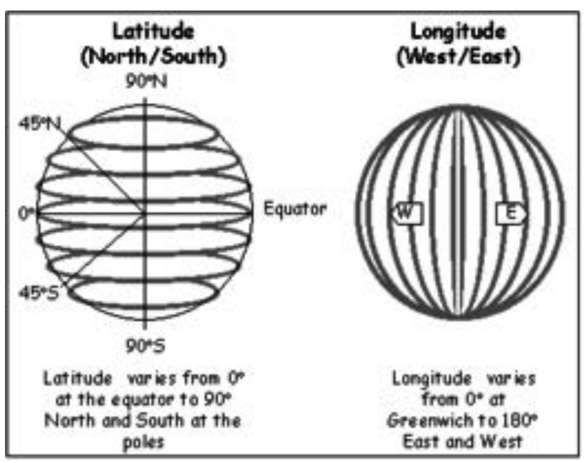


Figure adapted from (www.fedstats.gov)

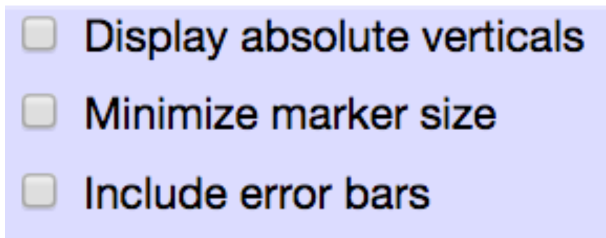
*Positive latitude is above the equator (N), and negative latitude is below the equator (S). Positive longitude is east of the prime meridian, while negative longitude is west of the prime meridian.)

Width and **Height** are measured in degrees, allowing the user to create a specified parameter.

Ref. Site is the GPS station site where the velocity vector data will be referenced to. A map with the sites can be located through the website below. Once a location is decided, type the 4-letter code in the box.

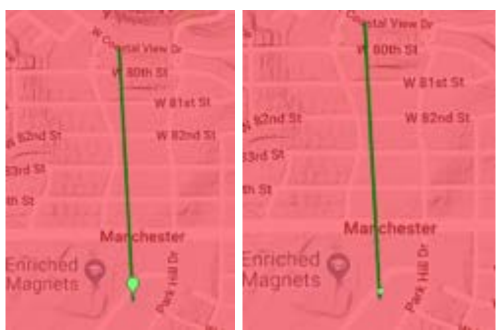
https://sideshow.jpl.nasa.gov/post/series.html

Scale allows the user to control the velocity vector length scaling.
Recommended to set at **320** mm/yr/deg.

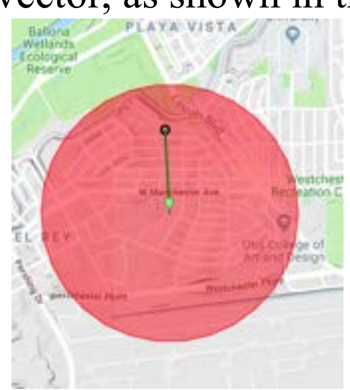


Click the box to "Display absolute verticals".

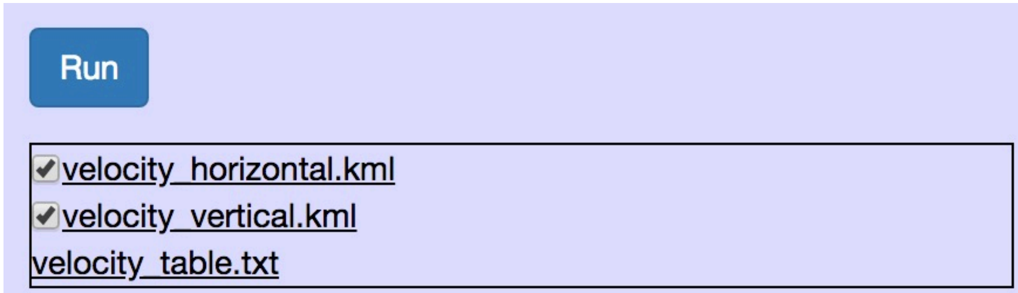
"Minimize marker size"  allows users to make GPS site markers smaller as shown in the image below.



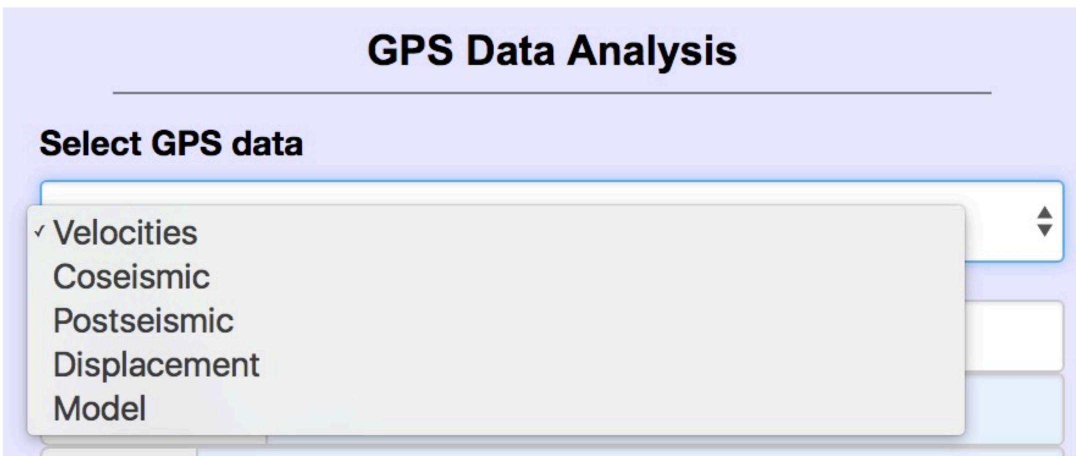
Error bars are a graphical tool used to illustrate the pair-wise correlation that exists between computed values (Error Ellipses). The error is represented by a black ellipse at the tip of the velocity vector, as shown in the image below.



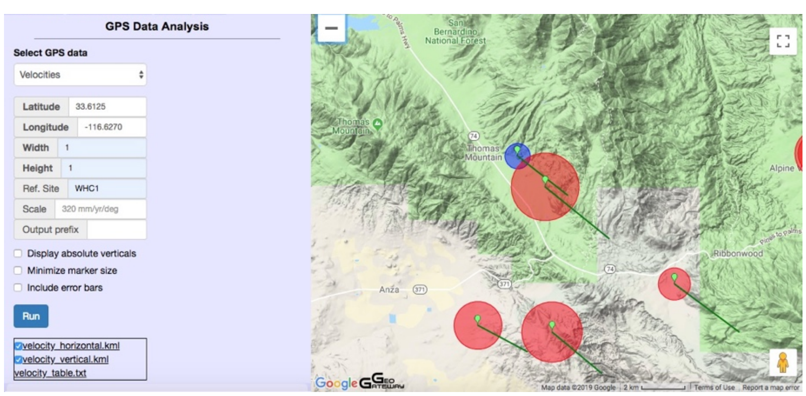
Once the steps to inputting data are complete, click on “Run”. There is an option to download kml and text files as shown below.



The GPS Data Analysis section allows users to select for Velocities, Coseismic, Postseismic, Displacement, and Model Analysis.



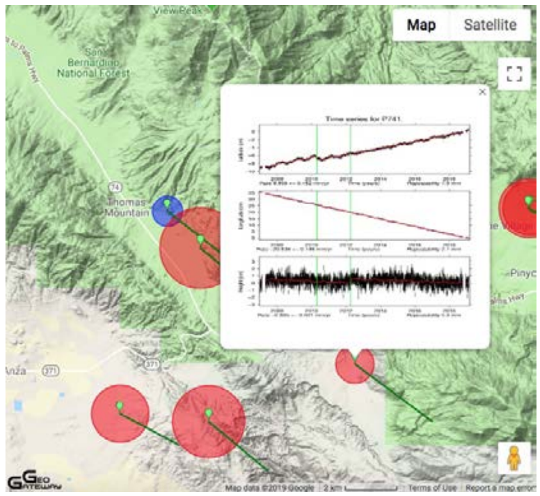
Selecting the “Velocities” option, the velocities of different GPS stations are seen relative to the reference frame.
As shown in the image below “WHC1” is set as the reference point.

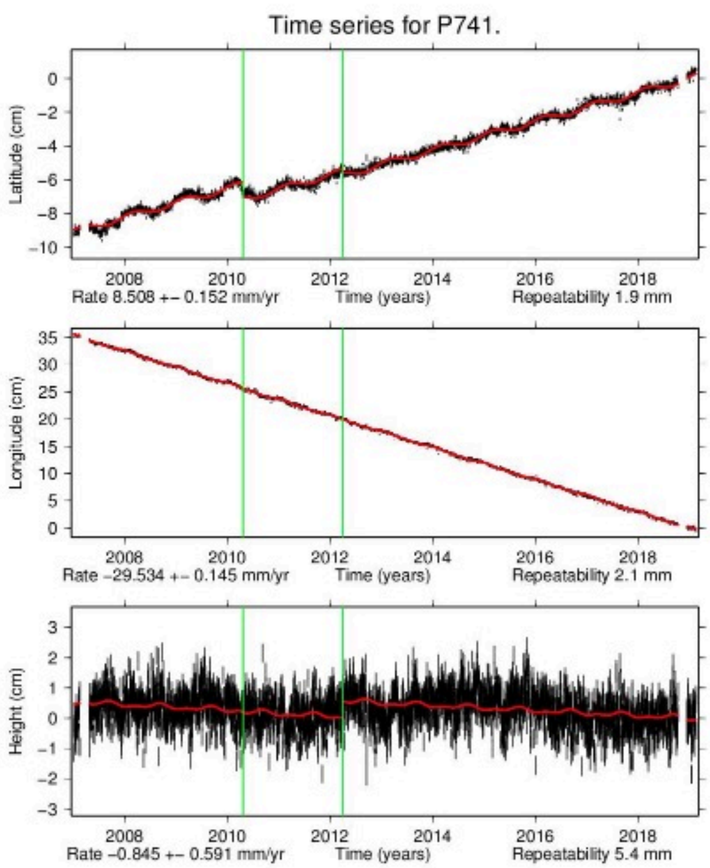


Each vector shows the velocity of a single GPS station as the Earth moves. The tail of the vector is pinned at the GPS station, and the length of the vector shows how fast the GPS station is moving. The other end of the line, away from the marker, is the direction the GPS station is moving.

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

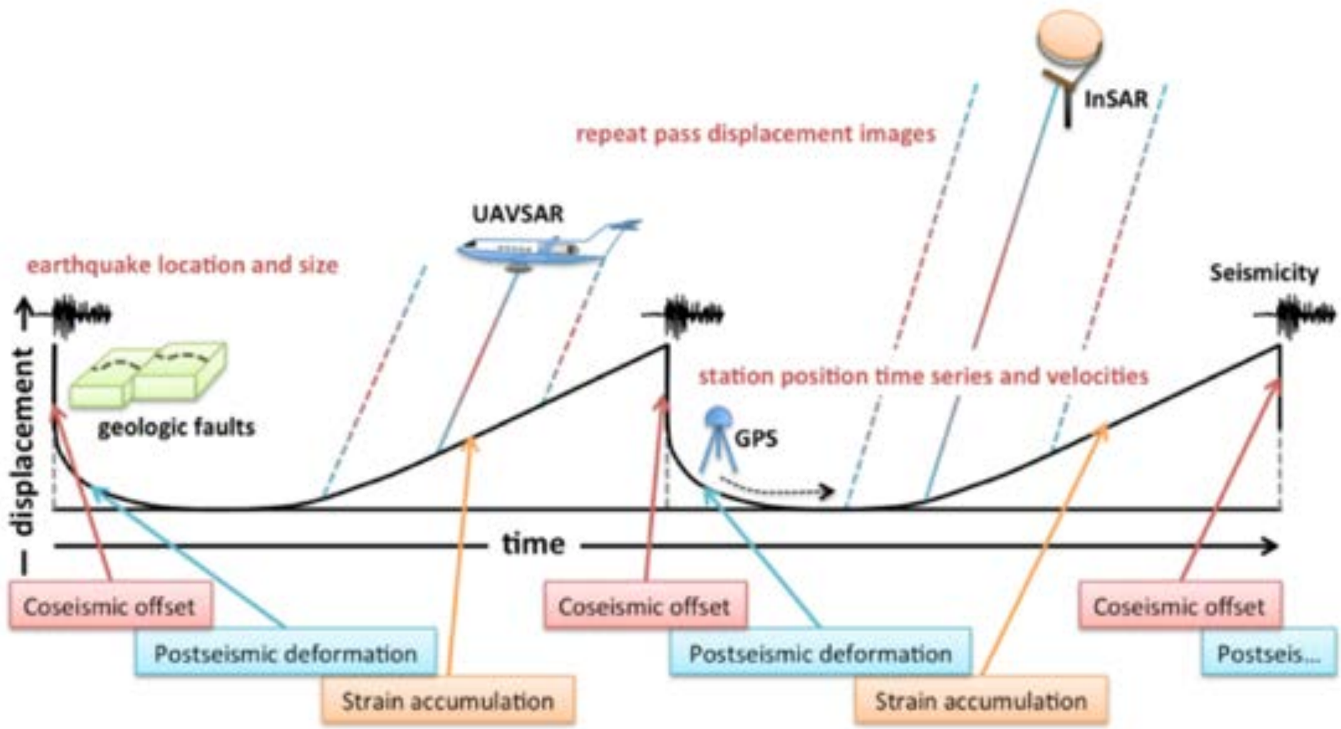
Clicking on a GPS station, three time series graphs appear.





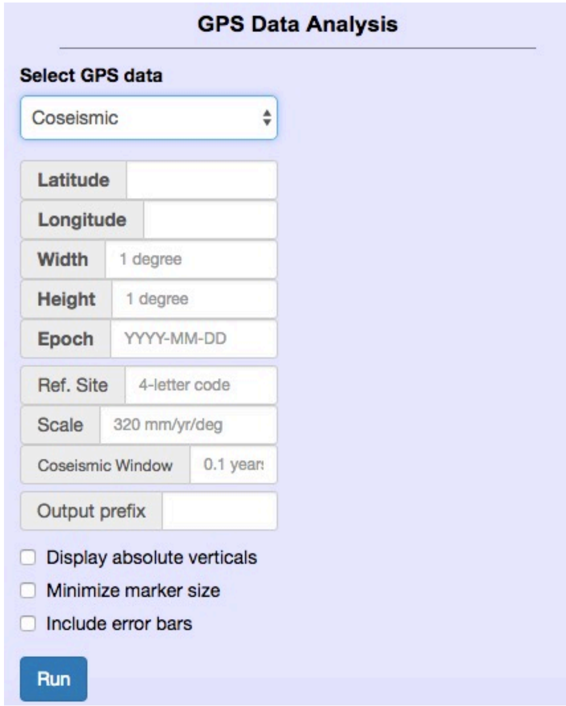
The time series shows how far the station has moved. The top graph shows latitude (cm) versus time (years). The black dots are the data points and the red line is the best fit line to the entire dataset. In this example, we see as time goes by the station moves closer to the North. For the longitude versus time graph (middle graph) we see that the GPS station is moving to the West. The bottom graph shows the vertical height versus time which is relatively constant. 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.

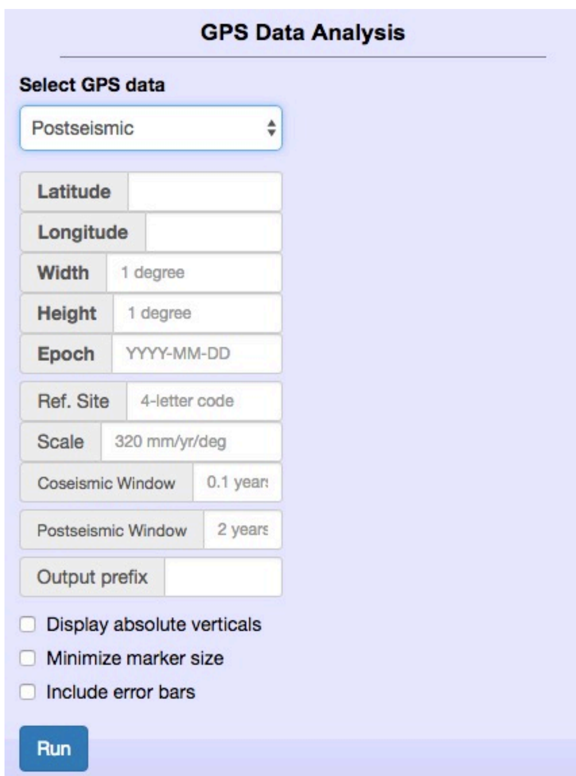


The image above illustrates the earthquake cycle, and typical rates of deformation in the coseismic and postseismic periods.

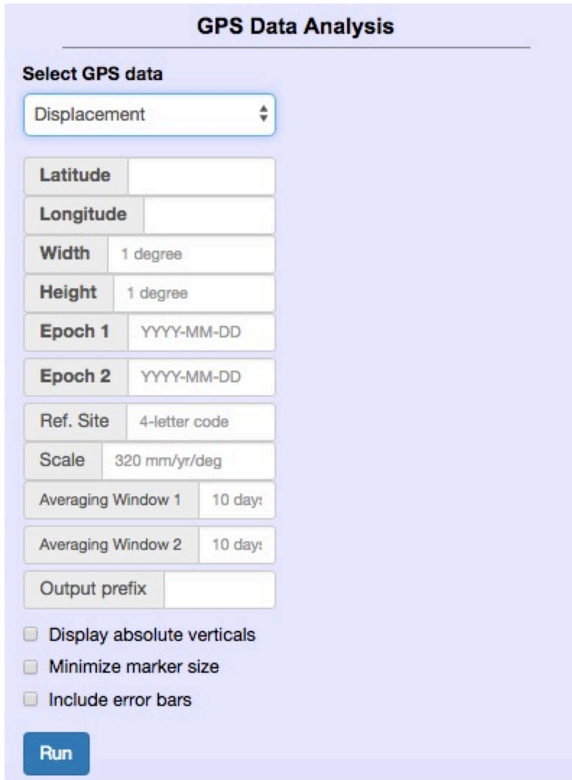
Coseismic offset refers to the time during an earthquake until a rupture ends.



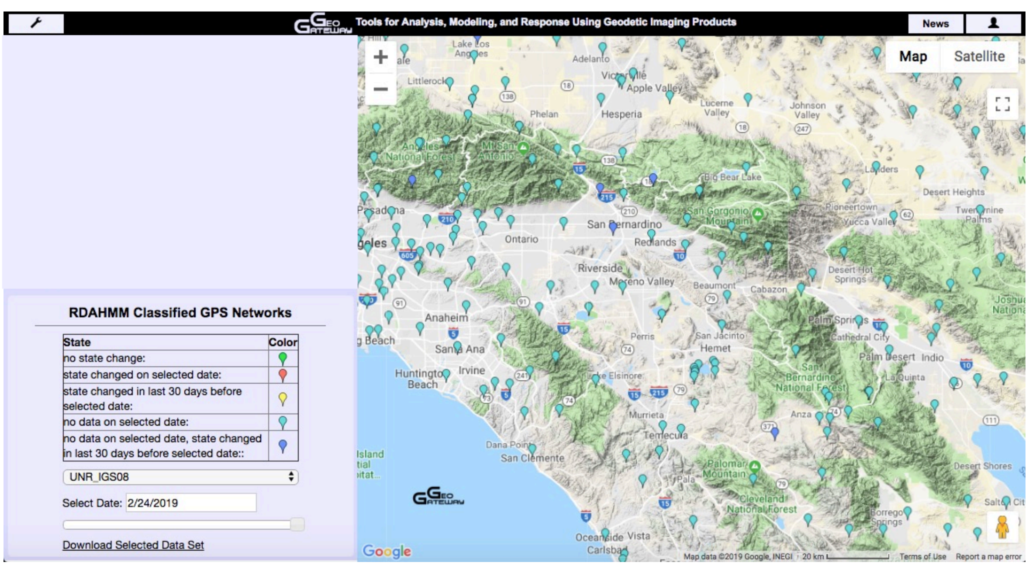
Postseismic deformation refers to the time after a large earthquake when deformation occurs.



When considering coseismic and postseismic data, 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.
Looking at displacement data, we must choose a time period for analysis.



Below “GPS Data analysis” is the “RDAHMM Classified GPS Networks”, allowing one to choose different GPS Networks and a specific date.

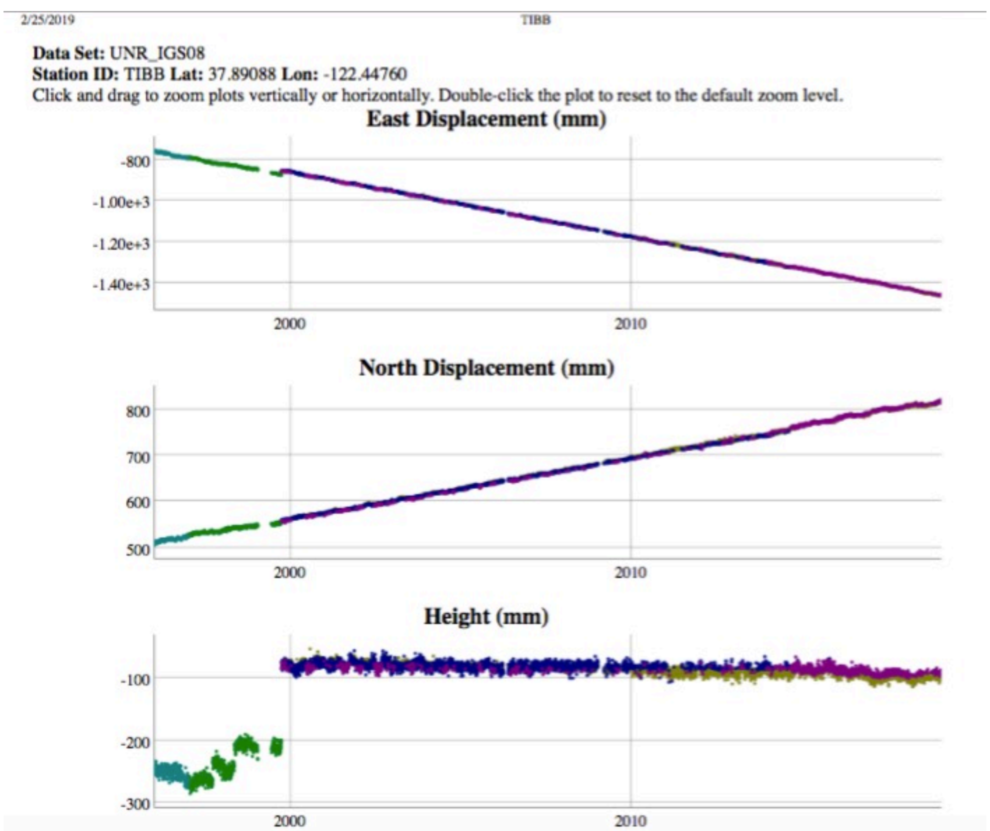


As shown in the image above, the GPS station markers have different colors unlike the “GPS Data analysis” section. The colors indicate change of state.

The representation of the colors is seen in the box below.

State	Color
no state change:	
state changed on selected date:	
state changed in last 30 days before selected date:	
no data on selected date:	
no data on selected date, state changed in last 30 days before selected date::	

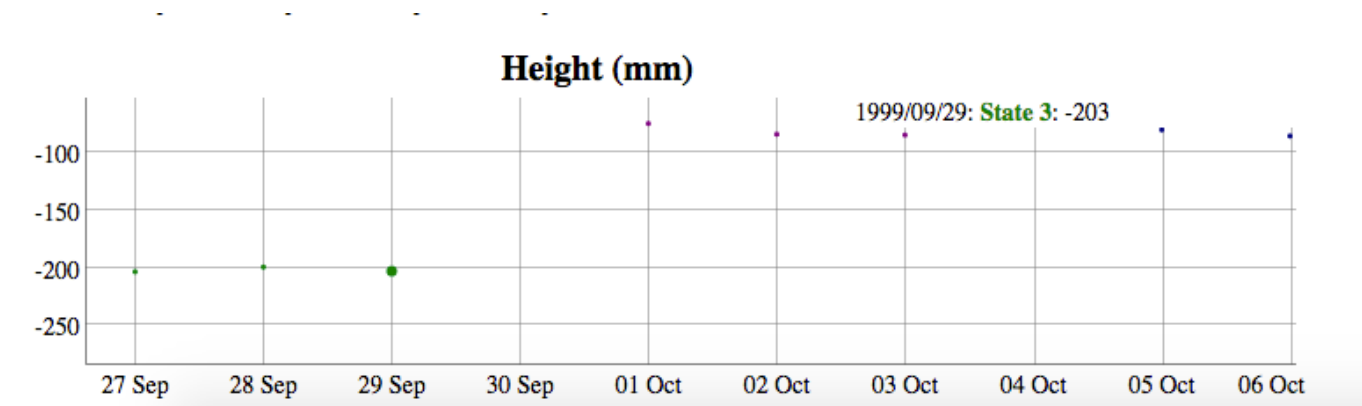
Clicking on a GPS station, will open three graphs that show displacement (mm) with time.



The longitudinal coordinate system exemplifies the **east-west** displacement, while the latitudinal coordinates exemplifies the **north-south** displacement.

To zoom into a specific time frame, pick a start point and drag the mouse to an end point.

After zooming in, the state changes are better noticed. The color change as shown in the image below, shows state change of the GPS station.



The paper by Donnellan et al. (2018a), referenced in the citations section, displays observations of the **Global Positioning System** (GPS) time series encompassing the region reveal a northward migrating pattern of deformation following the 04 April 2010 Mw7.2 El Mayor-Cucapah (EMC) earthquake.

Exercise : Produce GPS Velocities, Offsets, and Displacements

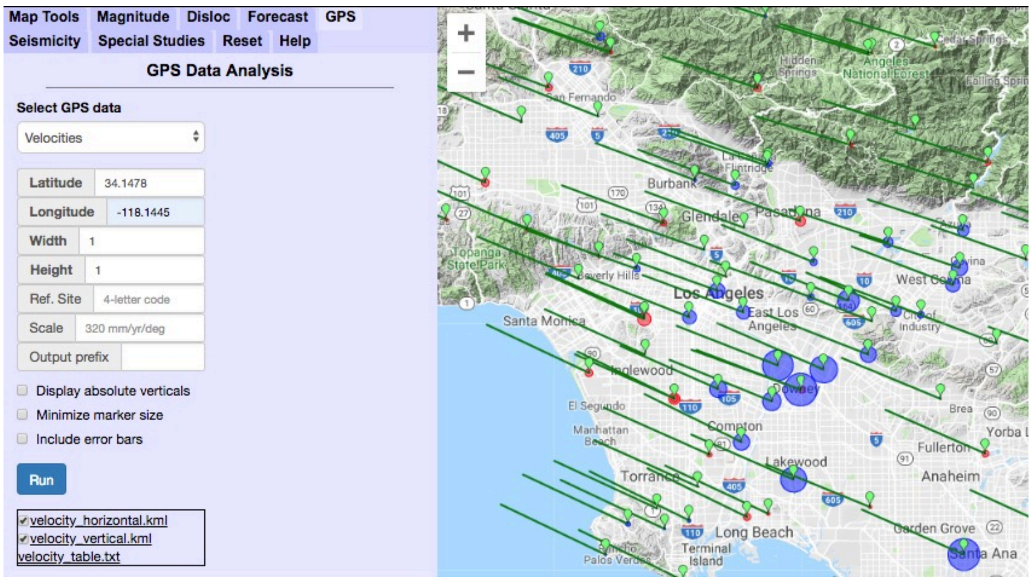
Go to http://geo-gateway.org

Click the "**GPS**" tab

In all following screen captured maps include the input window to show parameters that were used

On bottom left construct GPS velocity map with no reference

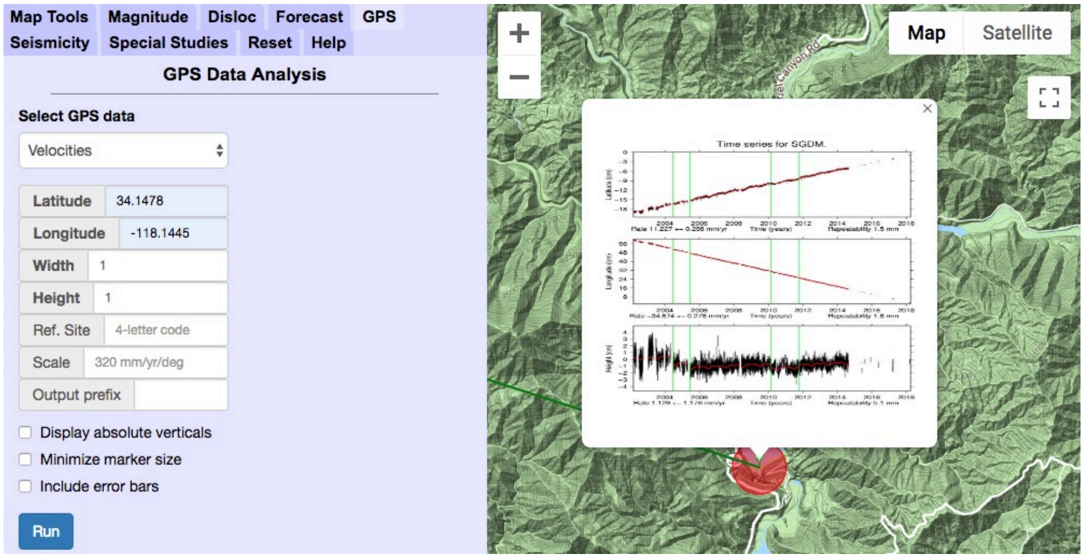
a. Select latitude and longitude of plot center in decimal degrees
b. Select width and height in degrees (try 1 degree)
c. Leave reference site blank



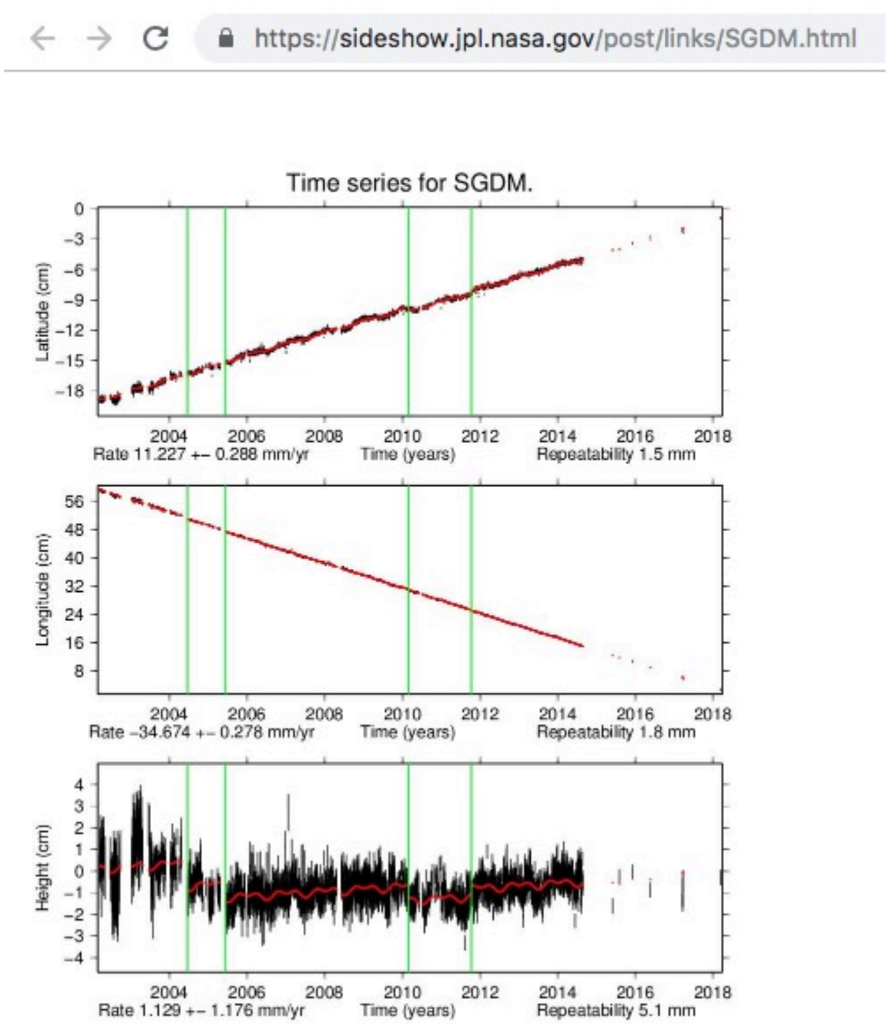
d. Run
e. **Download the velocity table**

Site	Lon	Lat	Delta E	Delta N	Delta V	Sigma E	Sigma N	Sigma V
AZU1	-117.896492	34.126020	-35.998000	11.564000	-2.179000	0.132000	0.145000	0.607000
BGIS	-118.159701	33.967119	-38.117000	14.906000	-5.755000	0.188000	0.217000	0.817000
BKMS	-118.094703	33.962260	-40.042000	17.478000	-5.153000	0.336000	0.400000	1.442000
BLSA	-118.028681	33.799545	-39.311000	16.080000	0.623000	0.529000	0.615000	2.202000
BRAN	-118.277055	34.184896	-37.323000	13.865000	-0.572000	0.157000	0.181000	0.766000
BTDM	-118.188231	34.292807	-35.512000	11.793000	1.333000	0.149000	0.155000	0.565000
CBHS	-118.629810	34.138563	-38.956000	17.556000	0.615000	0.055000	0.062000	0.237000
CCCO	-118.211202	33.876262	-36.542000	18.169000	-3.102000	0.416000	0.493000	1.768000
CCCS	-117.864947	33.862744	-37.807000	16.582000	1.277000	0.345000	0.419000	1.475000
CGDM	-117.964950	34.243994	-34.979000	11.036000	0.170000	0.139000	0.174000	0.614000
CHIL	-118.026003	34.333424	-34.183000	10.891000	0.435000	0.104000	0.120000	0.451000
CHMS	-117.827705	34.640463	-24.895000	5.370000	0.359000	0.103000	0.125000	0.426000
CIT1	-118.127290	34.136710	-35.936000	12.876000	1.905000	0.157000	0.185000	0.631000
CJVG	-118.144232	34.530321	-32.252000	9.905000	-0.988000	0.470000	0.531000	1.865000
CLAR	-117.708814	34.109929	-35.182000	11.874000	-2.351000	0.167000	0.197000	0.689000
CMP9	-118.411429	34.353181	-36.500000	12.756000	-1.502000	0.160000	0.195000	0.670000
CRHS	-118.272771	33.823506	-39.095000	17.583000	0.276000	0.286000	0.341000	1.292000
CSDH	-118.256722	33.861479	-39.775000	17.849000	0.955000	0.133000	0.159000	0.543000
CSN1	-118.523816	34.253552	-37.776000	15.955000	-0.476000	0.136000	0.164000	0.569000
CTDM	-118.613215	34.516550	-35.093000	10.691000	0.798000	0.081000	0.097000	0.335000
CVHS	-117.901722	34.082012	-37.513000	12.163000	-3.045000	0.205000	0.243000	0.862000
DAM2	-118.396869	34.334837	-36.140000	12.895000	0.779000	0.218000	0.221000	0.975000
DAM3	-118.397471	34.333992	-36.480000	12.720000	-0.344000	0.239000	0.233000	1.048000
DSHS	-118.348546	34.023933	-36.929000	16.780000	0.169000	0.497000	0.579000	2.090000
DVPB	-117.860132	34.413413	-31.540000	9.082000	0.361000	0.085000	0.108000	0.373000
DYH2	-118.127463	33.938315	-39.221000	15.001000	-6.207000	0.219000	0.260000	0.875000
DYHS	-118.125987	33.937990	-41.475000	15.214000	1.221000	0.402000	0.495000	1.760000
ELSC	-118.208437	34.029735	-37.978000	13.947000	-2.623000	0.121000	0.137000	0.515000
ELTS	-118.453765	34.599292	-30.844000	10.972000	-1.216000	0.292000	0.359000	1.188000
FVPK	-117.935719	33.662329	-38.376000	17.186000	-0.834000	0.431000	0.511000	1.756000
FXHS	-118.359483	34.080606	-40.732000	14.282000	-1.247000	0.156000	0.184000	0.723000
GVRS	-118.112898	34.047448	-37.773000	13.712000	-1.278000	0.097000	0.115000	0.388000
HBCO	-118.285799	33.783648	-37.537000	18.626000	-0.680000	0.198000	0.236000	0.845000
HOL3	-117.845130	34.458156	-29.274000	7.886000	0.716000	0.047000	0.055000	0.186000
HOLP	-118.168176	33.924541	-38.536000	15.645000	-3.524000	0.187000	0.218000	0.758000
JNHG	-117.955441	34.449064	-30.703000	9.158000	-0.147000	0.207000	0.255000	0.834000
JPLM	-118.173232	34.204822	-36.552000	12.928000	-1.234000	0.166000	0.186000	0.724000

f. Click on a station to show time series



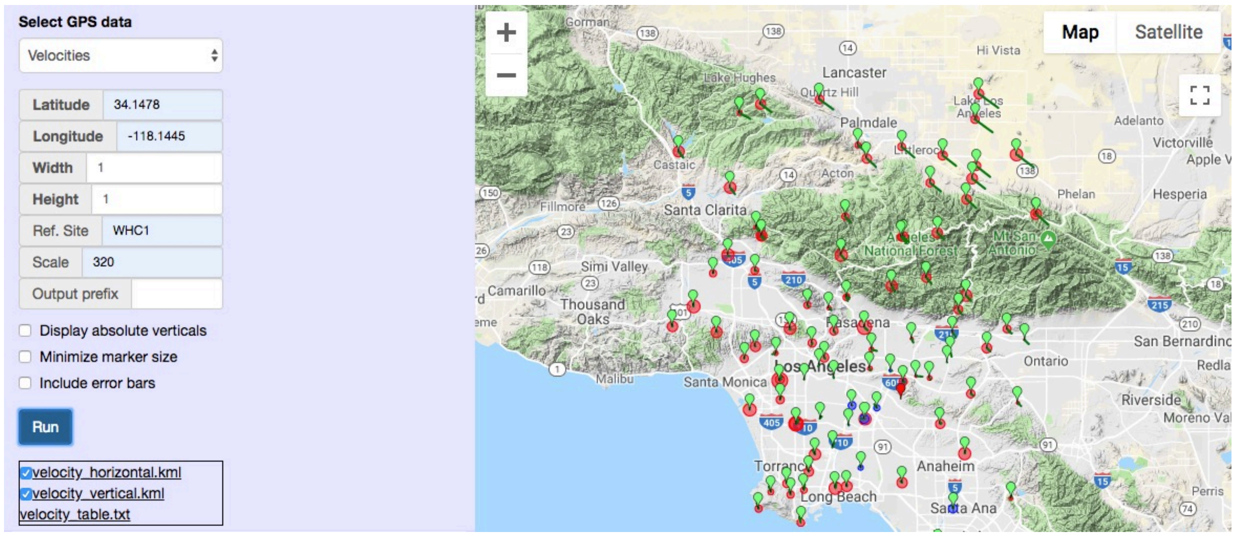
g. Click on small time series thumbnail to produce web page of result



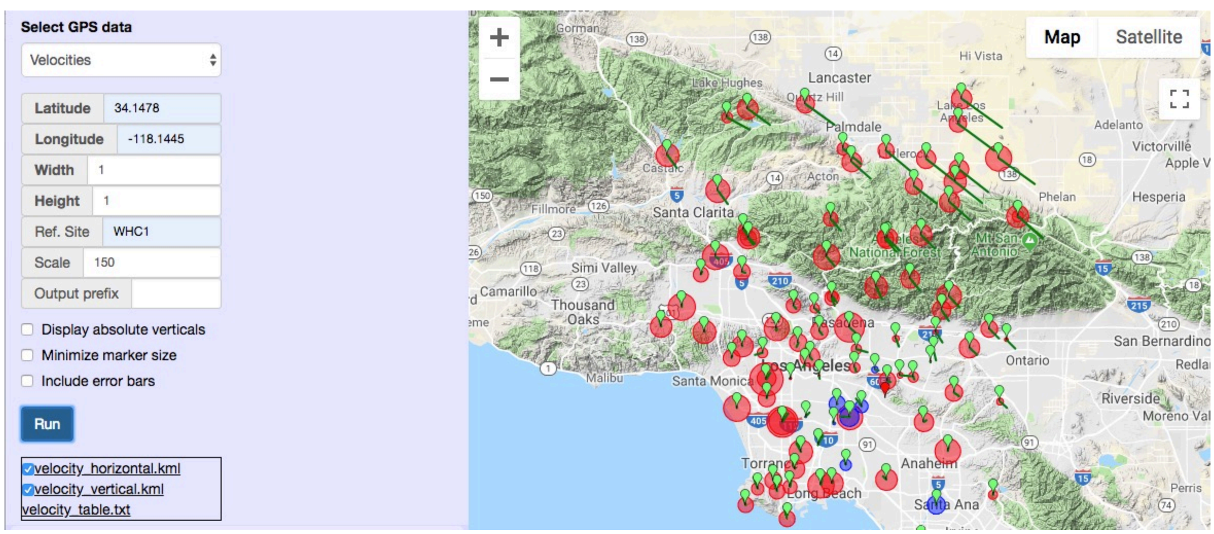
h. Download KML file if you would like to save it. This can be later plotted with the KML mapper on the map tools tab

On the bottom left construct a GPS velocity map with reference

a. Select latitude and longitude of plot center
b. Select width and height in degrees (1 degree is often good)
c. Select a reference site from previous plot
d. Run

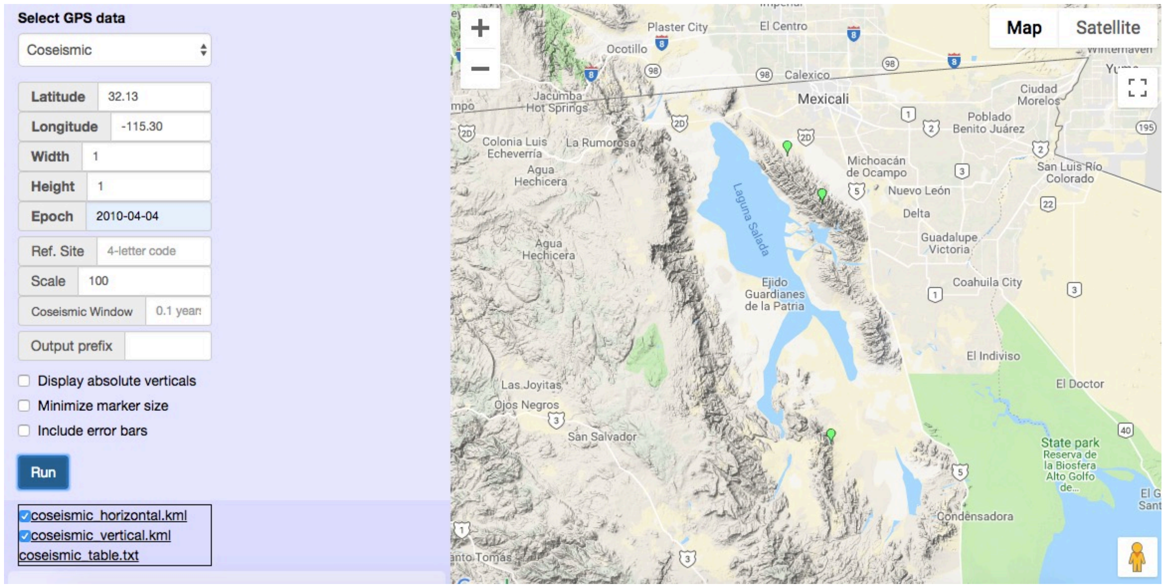


e. Vary the scale to see the result (hint – smaller number results in larger vectors).

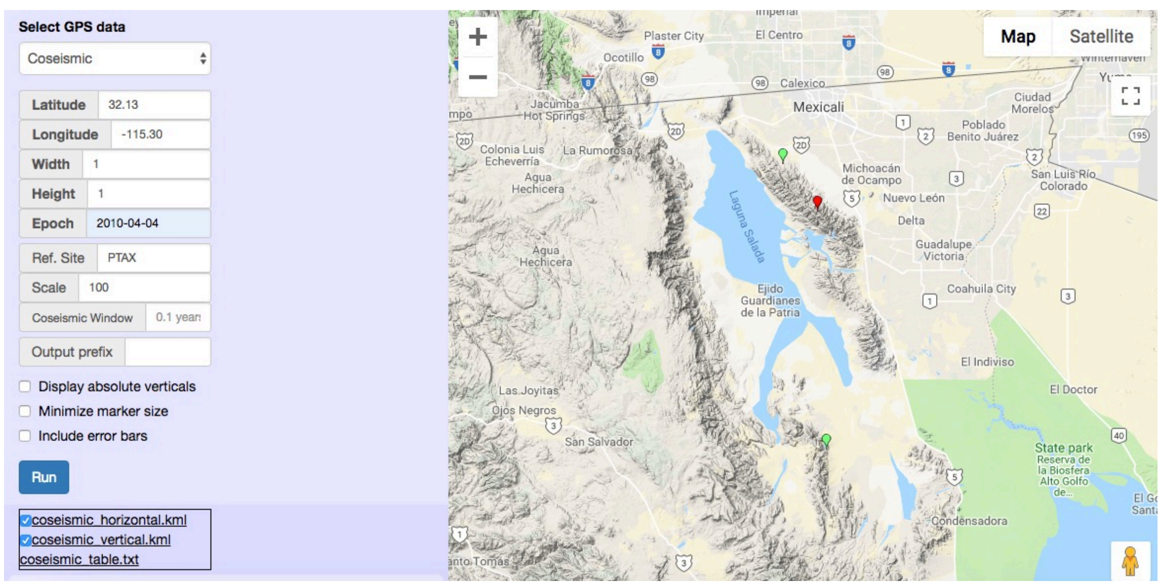


Repeat for coseismic displacements

a. Select latitude and longitude of plot center near a large event (e.g. South Napa or El Mayor – Cucapah earthquake)
b. Enter time of earthquake
c. **Print plot with no reference**

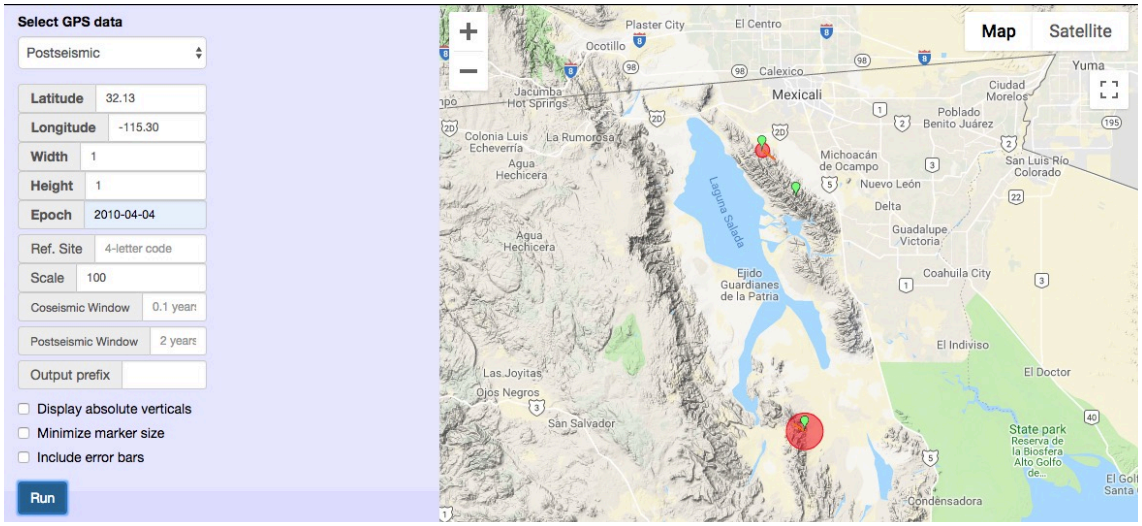


d. **Print new plot with a reference station**

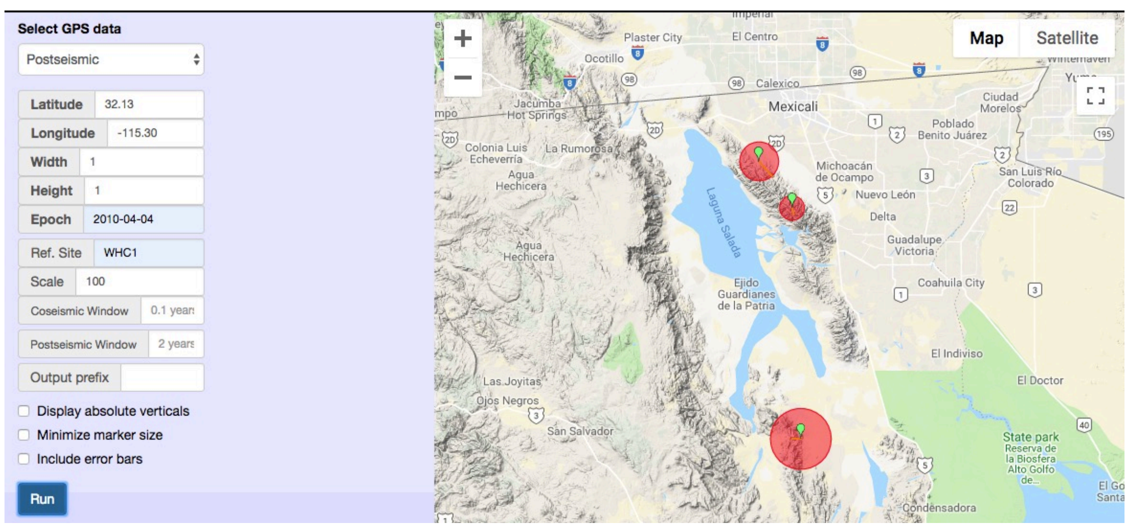


Repeat for postseismic displacements

a. Select latitude and longitude of plot center near a large event (e.g. South Napa or El Mayor – Cucapah earthquake)
b. Enter time of earthquake
c. Experiment with different postseismic windows
d. **Print plot with no reference**

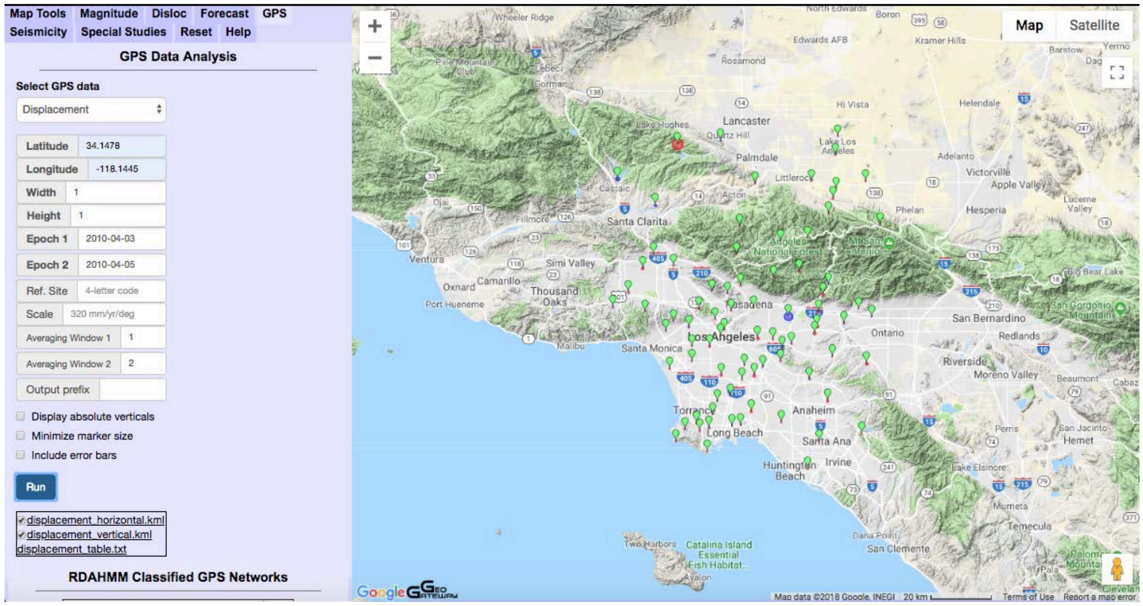


e. **Print new plot with a reference station**

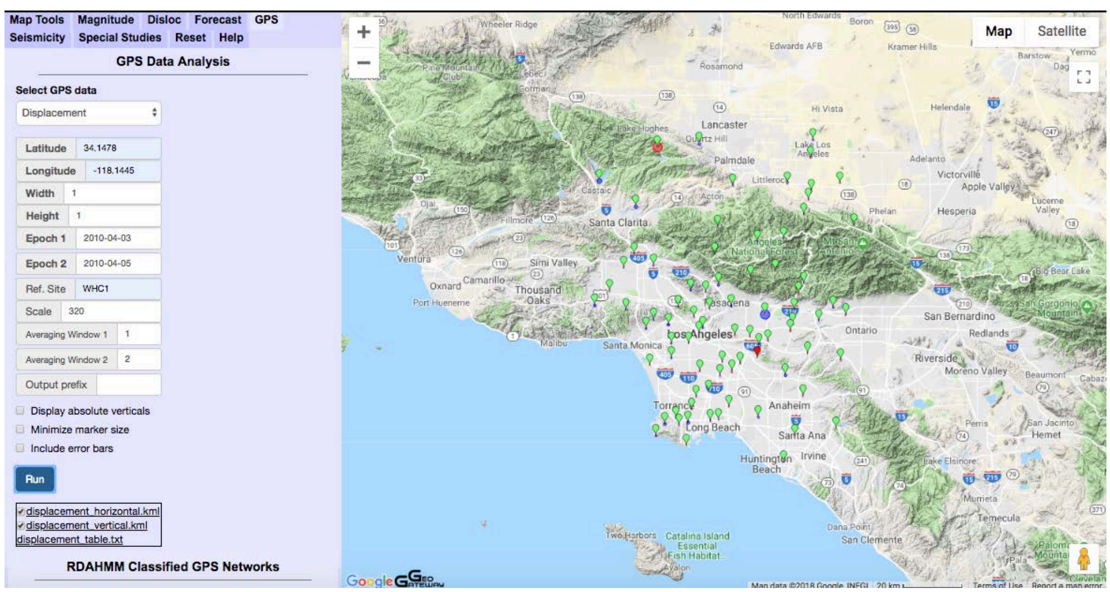


Repeat for displacements

a. Select latitude and longitude of plot center
b. Enter two times to calculate displacements between time 1 and time 2
c. **Print plot with no reference**

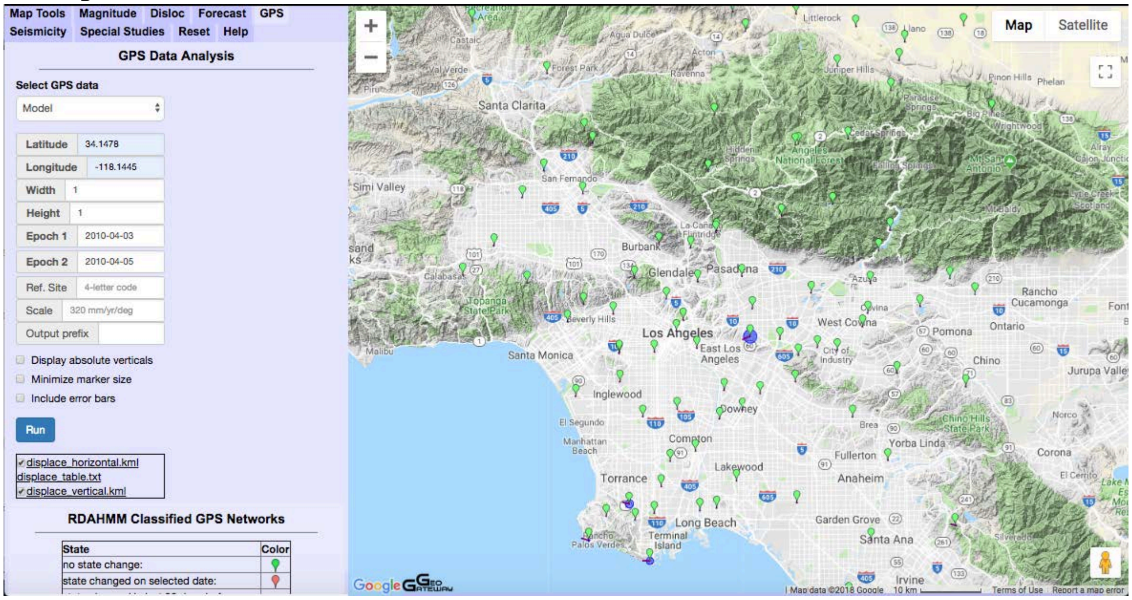


d. **Print new plot with a reference station**

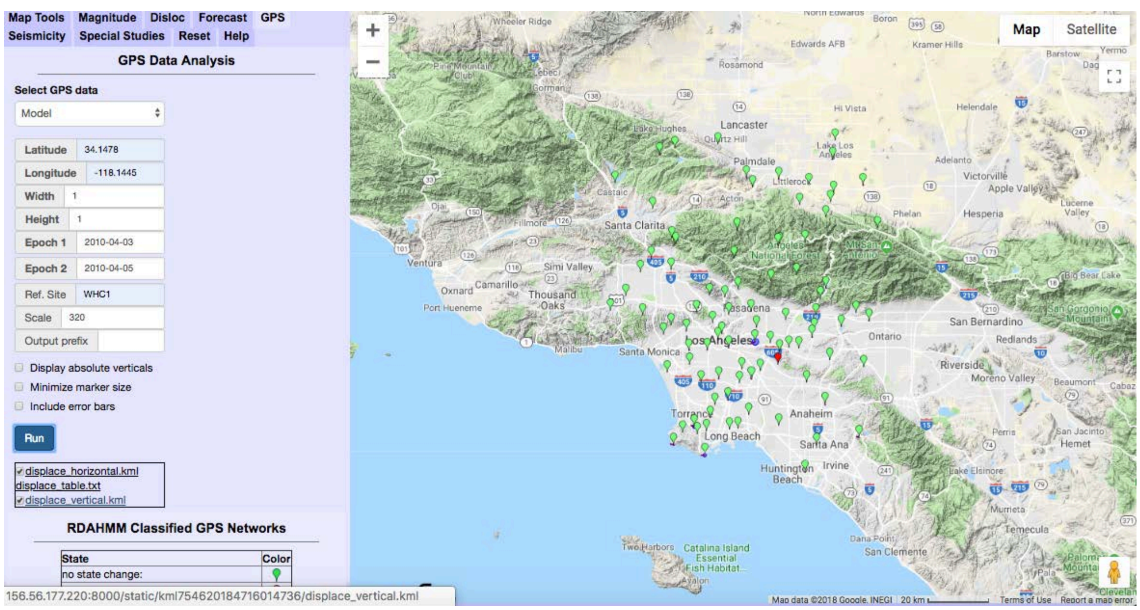


Repeat for model

a. Select latitude and longitude of plot center
b. Enter two times to calculate displacements between time 1 and time 2
c. **Print plot with no reference**

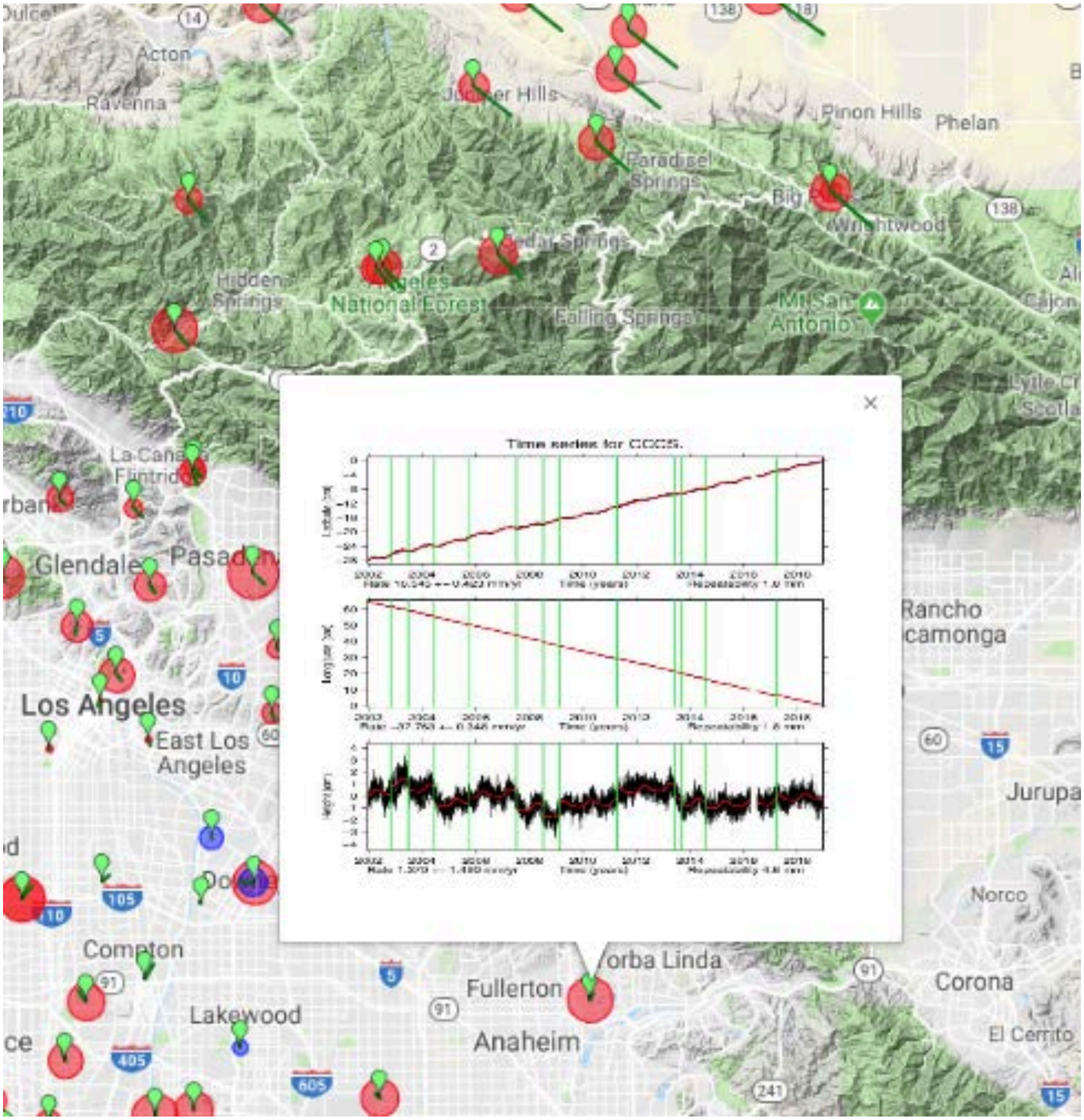


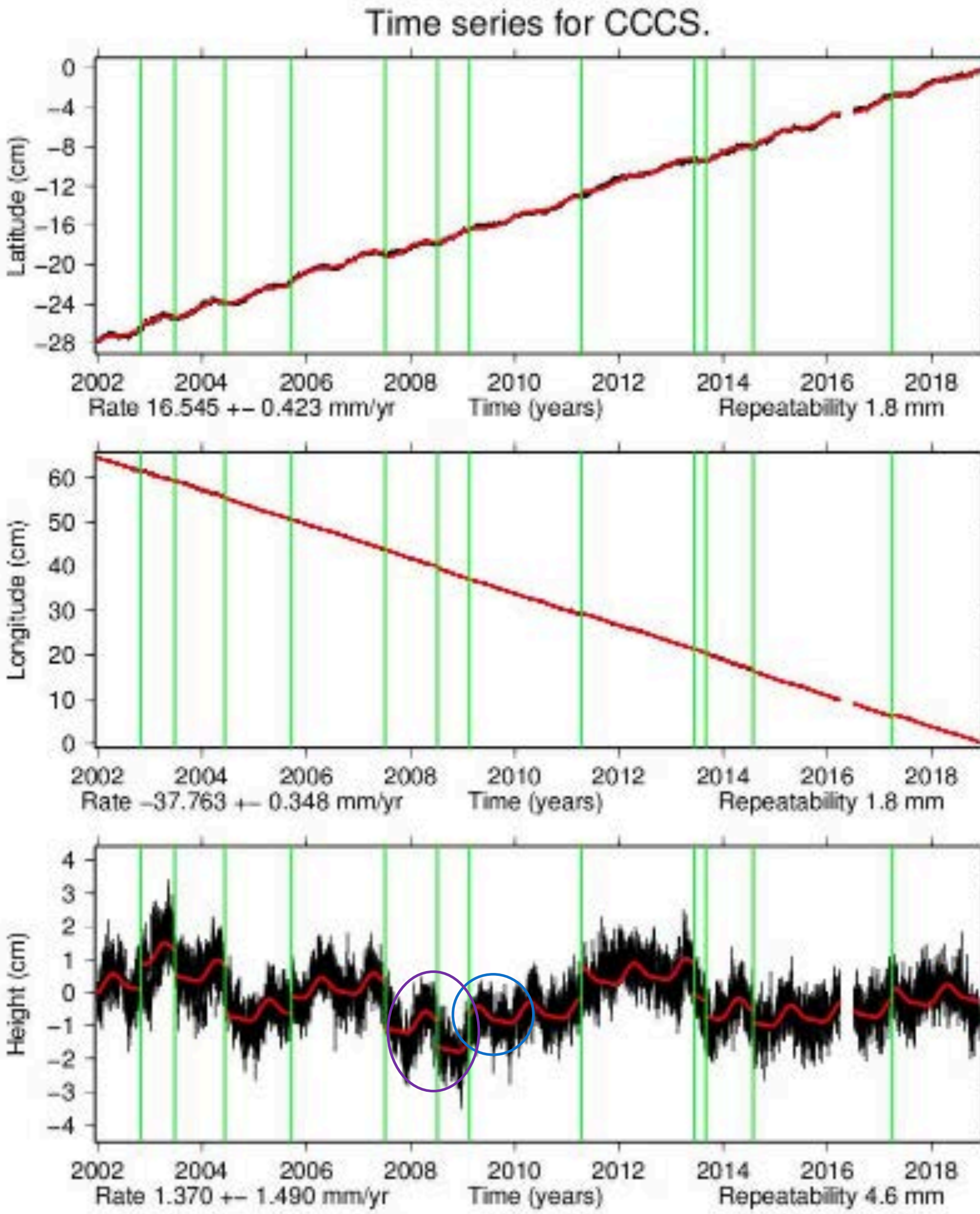
d. **Print new plot with a reference station**



Find and print a time series that shows an offset and postseismic motion

a. Label offset
b. Label postseismic motion
c. Point to time series



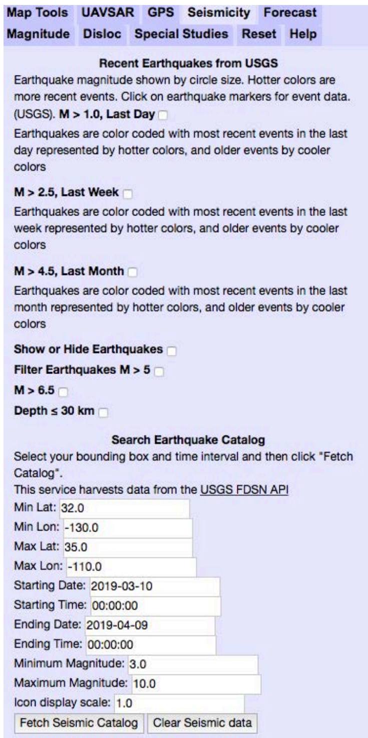


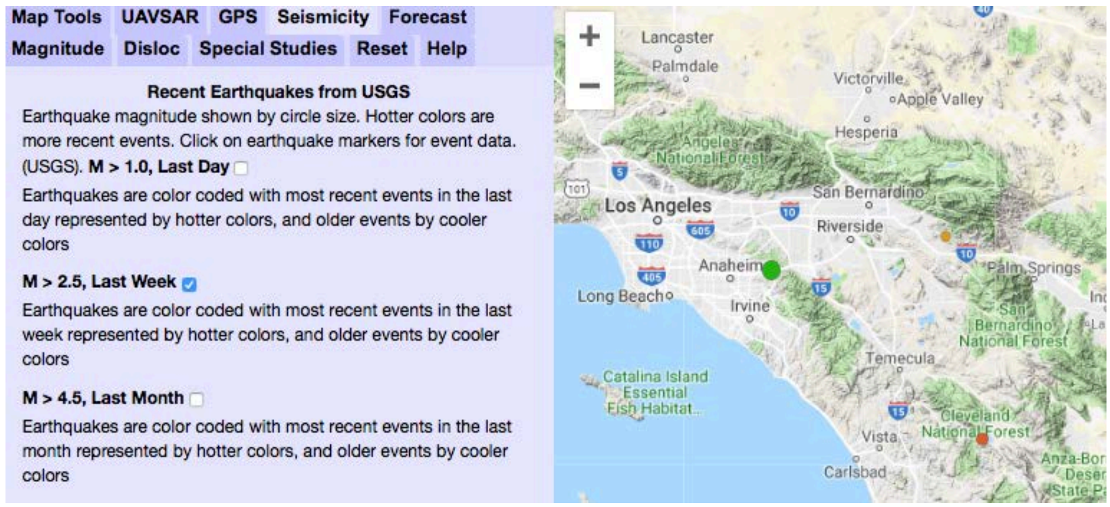
Purple oval shows offset

Blue circle shows postseismic motion

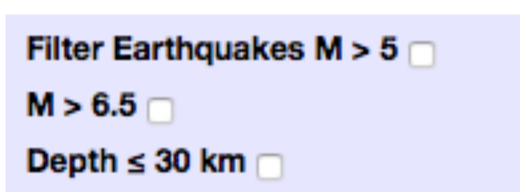
Seismicity

The Seismicity tab allows users to display earthquakes in a region over a specified time period.

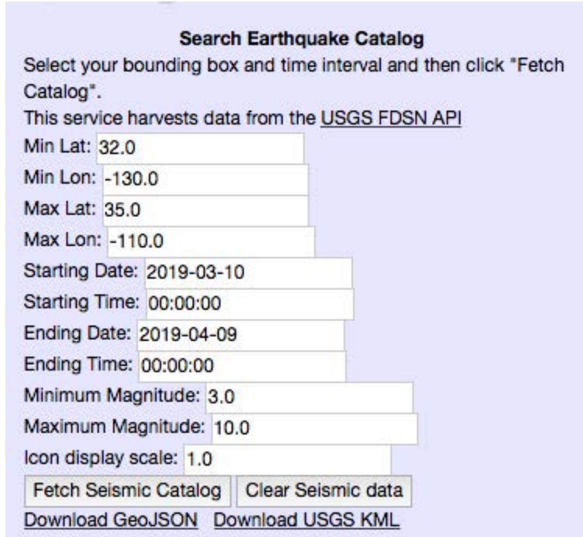




The tab allows for a selection of Recent Earthquakes from USGS data, which can be found on the USGS website https://earthquake.usgs.gov/earthquakes/map/ , as shown in the image above. The earthquake's magnitude is shown by circle size. Hotter colors are more recent events. Read the description under each checked box for further information about the data.



Additional filters, such as M > 5 and M > 6.5 and Depth ≤ 30 km can be found in the tab under Filter Earthquakes as shown above.

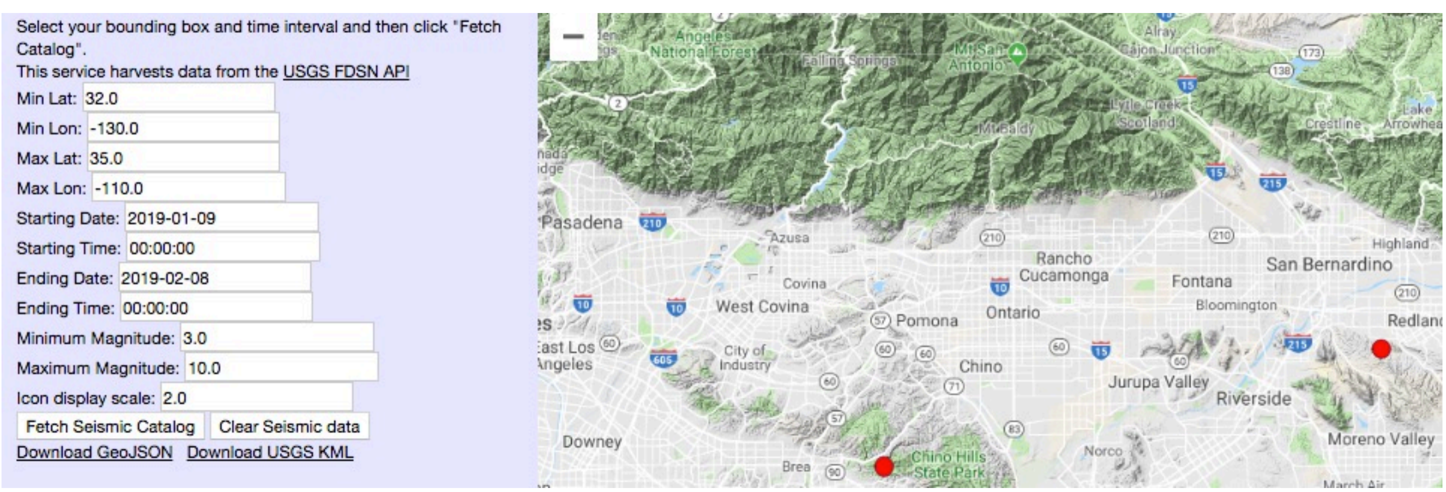


To generate the earthquake catalog, users must input data specific to what they want to produce.

Lines 1-4 require users to put the latitudes and longitudes of the specified region.
Lines 4-8 require data regarding the range of date and time of interest.
Lines 9-10 require the range of chosen magnitude.

Lastly box 11 requires the user to scale the size of the icon of the seismic event, by inputting a number (larger number = larger icon).

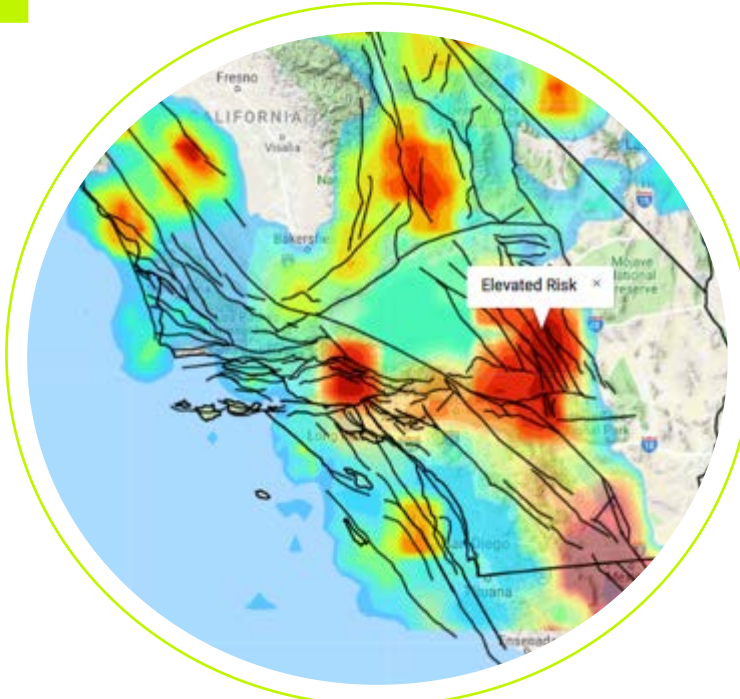
Click “Fetch Seismic Catalog” in order to display the result of the seismicity on the map. Moreover, users are given the option to download “GeoJSON” and “USGS KML”.

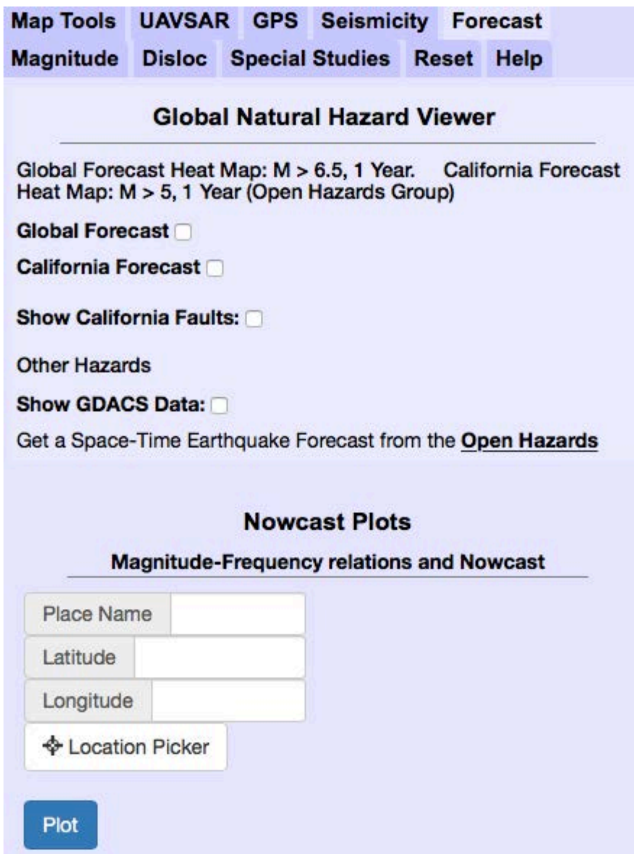


Right next to the “Fetch Seismic Catalog” is the “Clear Seismic data” where the data inputted clears.

Forecast

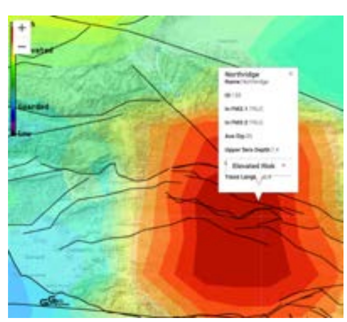
The Forecast tab allows users to select earthquake forecasts from the Open Hazards Group, and display them in a "Forecast Heat Map" format which uses warm colors to identify areas with elevated risk.



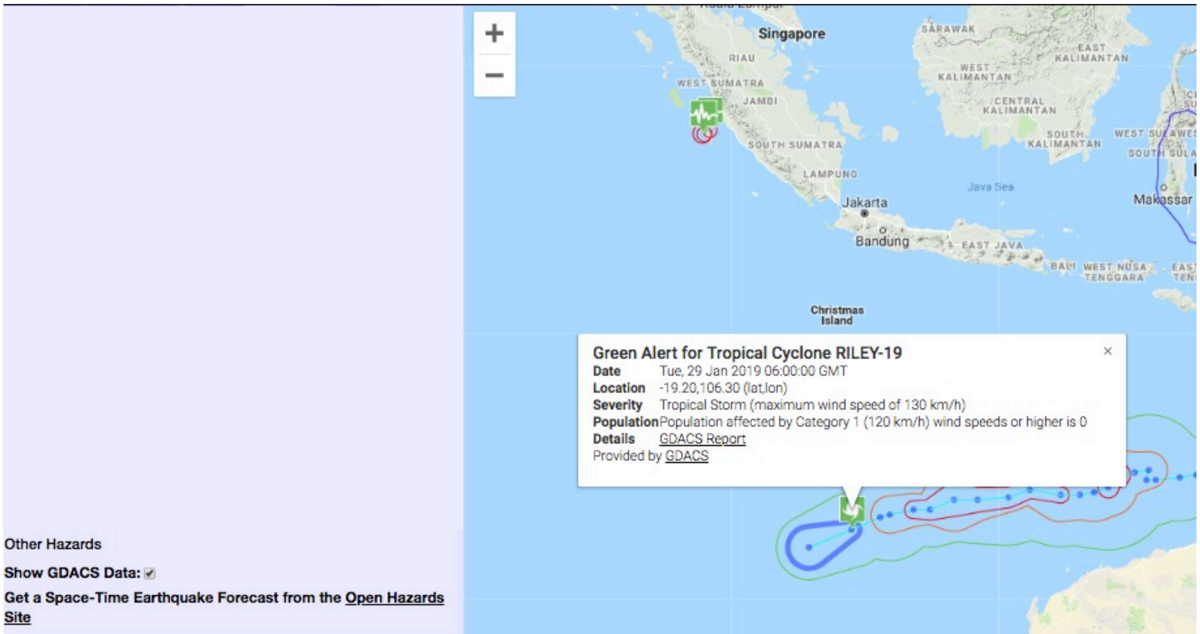


The Global Forecast option allows for a selection of either a Global Forecast Heat Map (M > 6.5, 1 Year) or a California Forecast Heat Map (M>5, 1 Year) as shown in the image above.

Global Forecast Heat Map



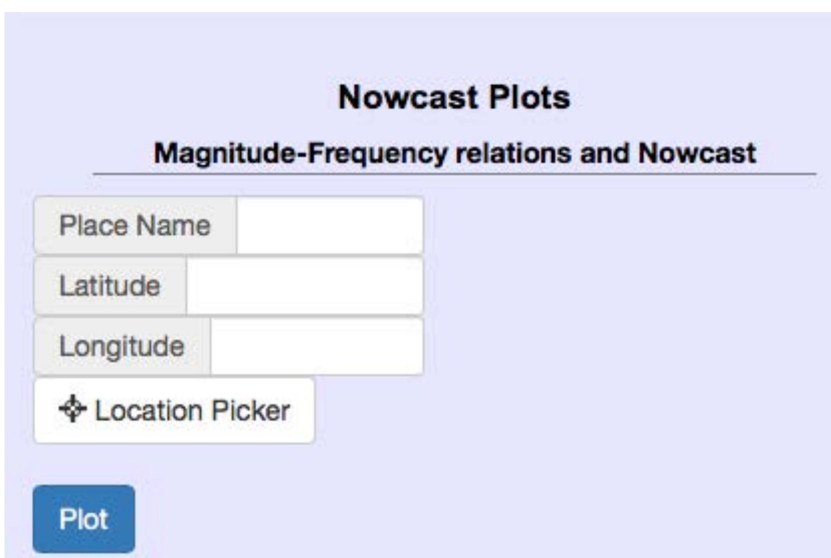
California Forecast Heat Map



Other Hazards through the Global Disaster Alerting Coordination System (GDACS) data can be selected. For example, the image above shows a Green Alert for a Tropical Cyclone.

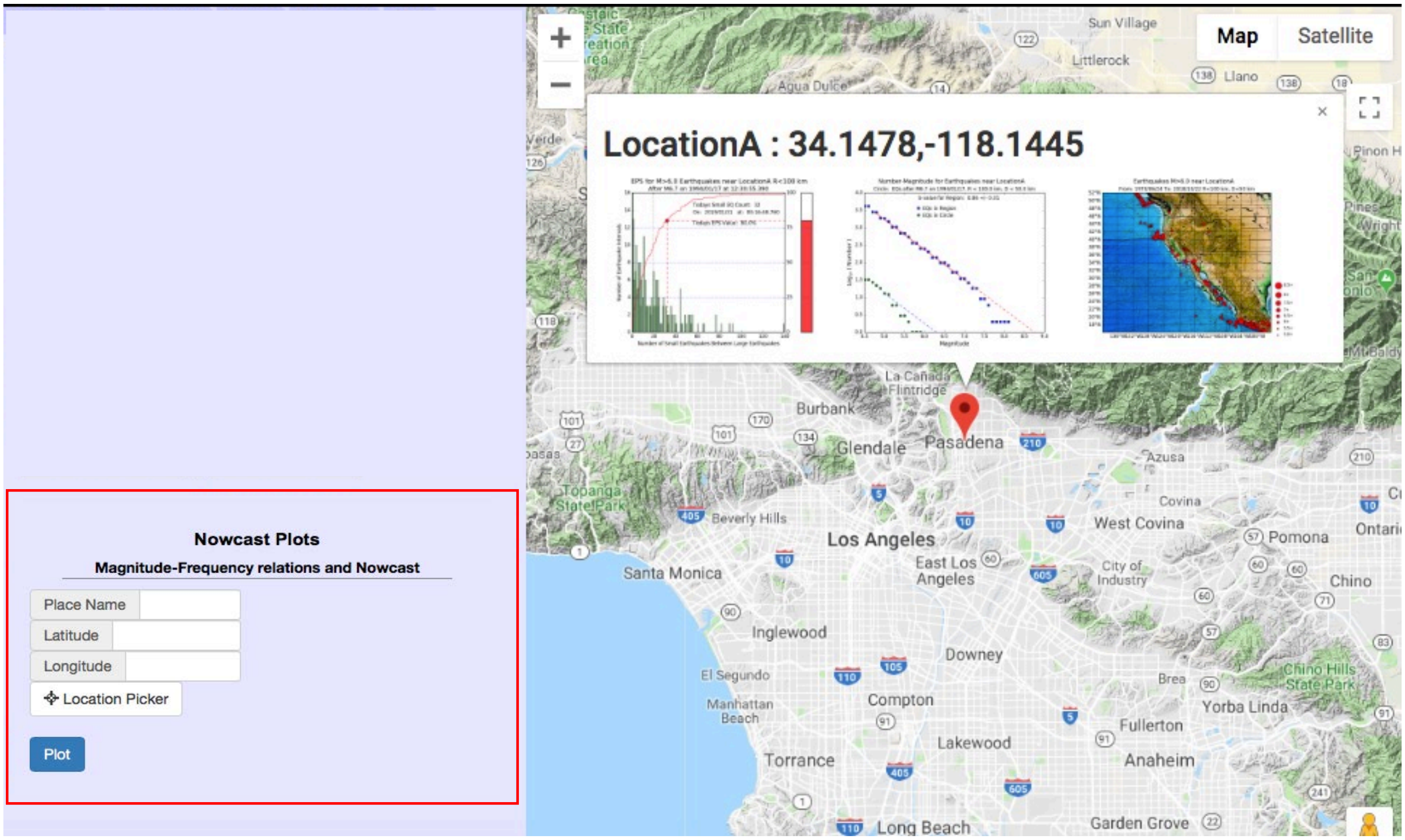
For Space-Time Earthquake Forecast Data, click on the Open Hazards Site below the GDACS Data, found on https://www.openhazards.com/viewer.

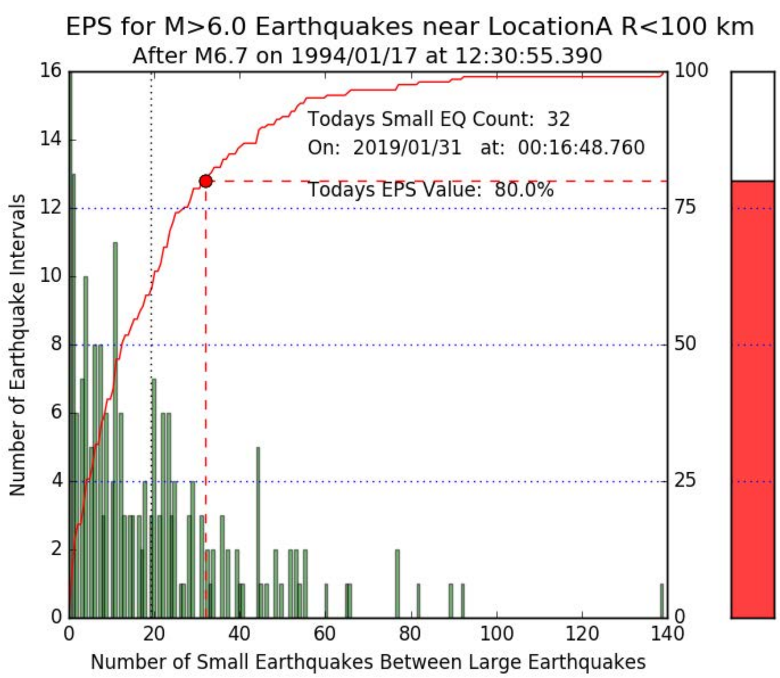
Below the Global Natural Hazard Viewer is the "Nowcast Plots" generator.



Here, users may create plots by naming a location and inputting a latitude and longitude, either manually or by using the location picker to choose a location.

When finished inputting data, press “plot” which will show different figures associated with the chosen location.





The Earthquake Potential Score (EPS) data for the chosen location, in this case "LocationA" can be viewed.

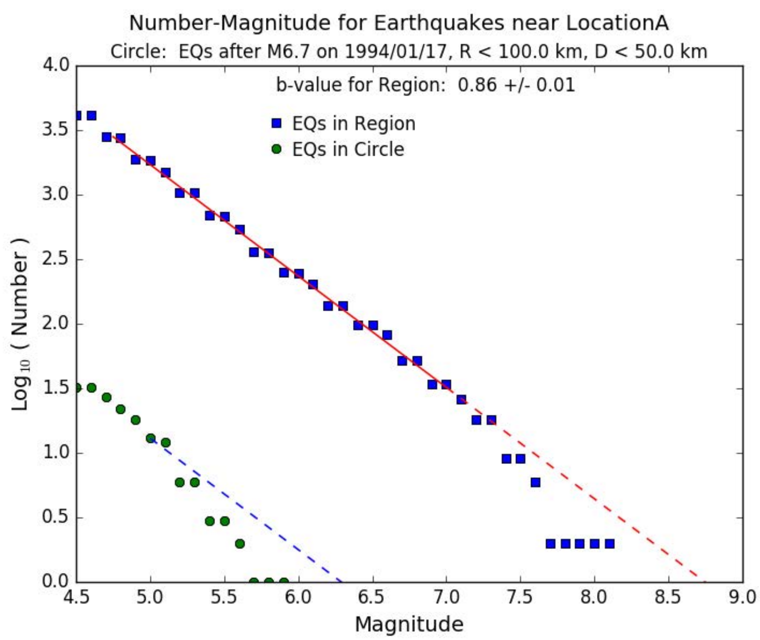
$$\text{EPS} = P\{n \leq n(t)\}$$

P = Cumulative Distribution Function (CDF) of small earthquakes occurring between large earthquakes

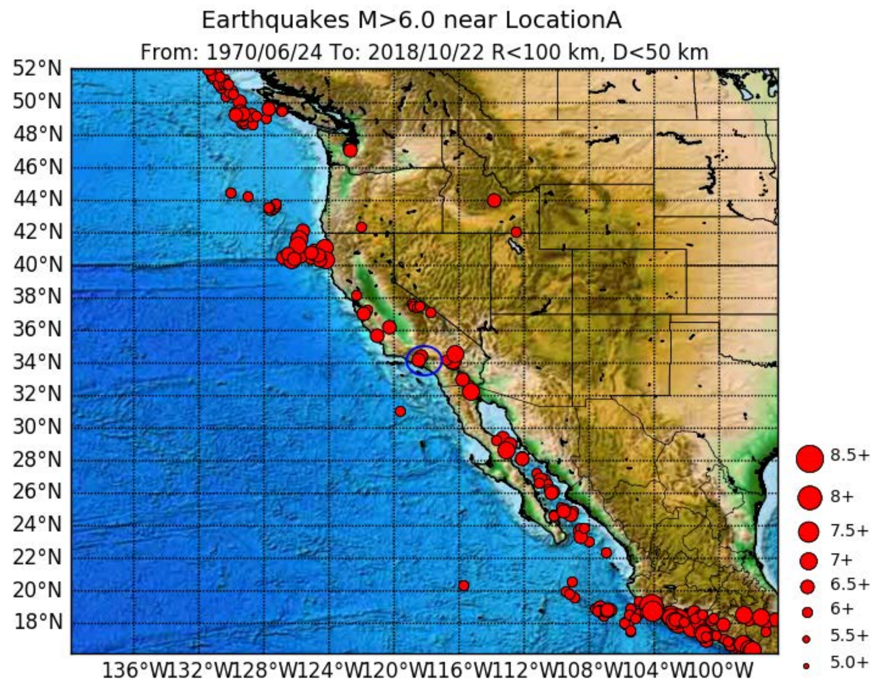
n(t) = the number of small earthquakes since the last large earthquake
n =small earthquakes since the last large earthquake.

EPS values for the figure on the left column portray magnitudes greater than $M\lambda = 6$, 100 km within the specified region
The figure portrays that the small earthquakes count for today is 45 and the EPS Value is 89.30%.

The figure to the right of the EPS data displays "Number-Magnitude" statistics. The blue squares represent all the earthquakes ≥ 3 and the lower green circles show earthquakes 3 ≤ X < 6.5.



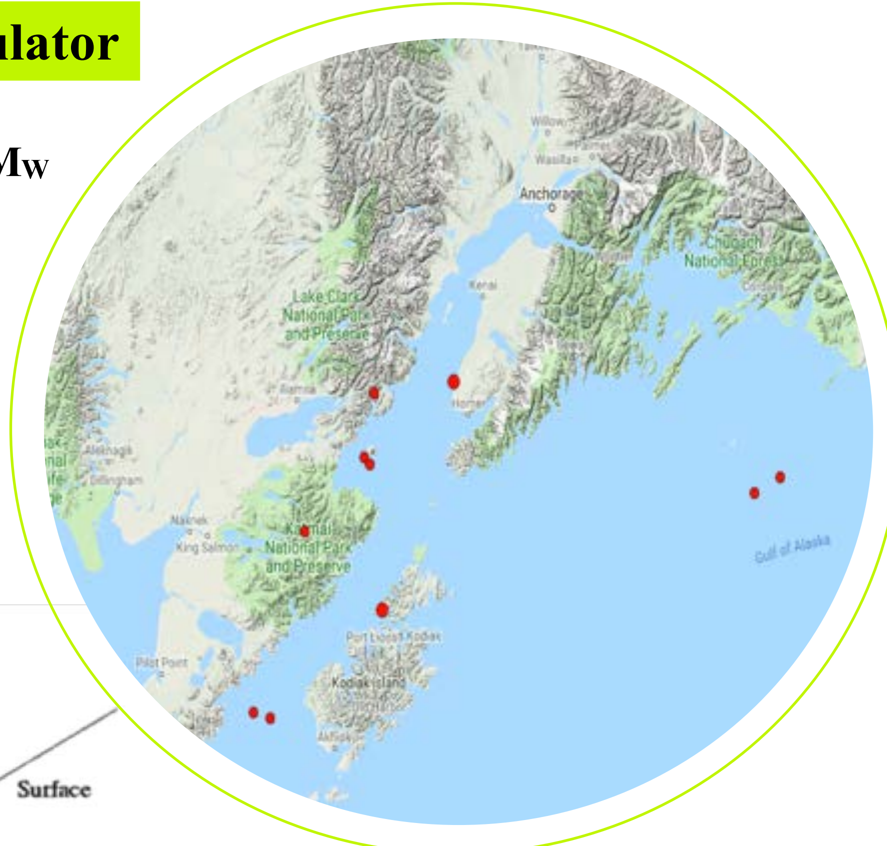
The last figure located on the far right displays a map of earthquakes with a magnitude ≥ 6.0 near San Bernardino as of 1970. The blue circle centered on San Bernardino has a radius equal to 100 km.

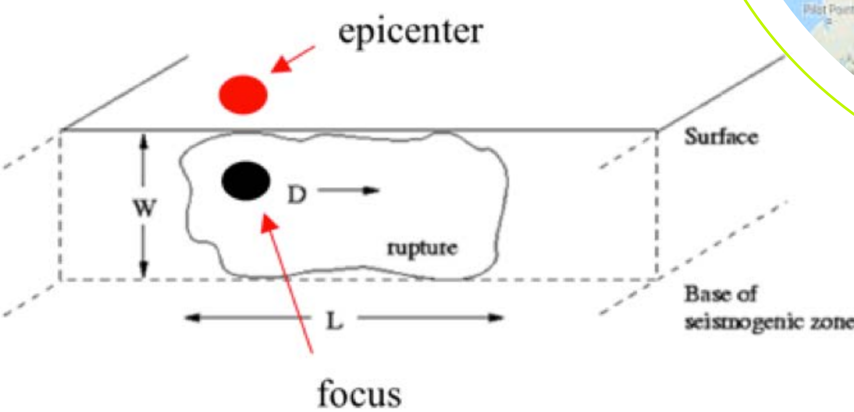


To analyze another location, click on the reset tool in the “Reset” tab.

Moment Magnitude Calculator

Moment Magnitude abbreviated **Mw** is the total moment release of an earthquake. The moment is measured as the product of the distance moved by the fault slip and the force needed to move the fault. The data is found and derived from multiple stations near and around the epicenter.





“Earthquake Glossary-Seismic Moment.” *U.S. Geological Survey*.

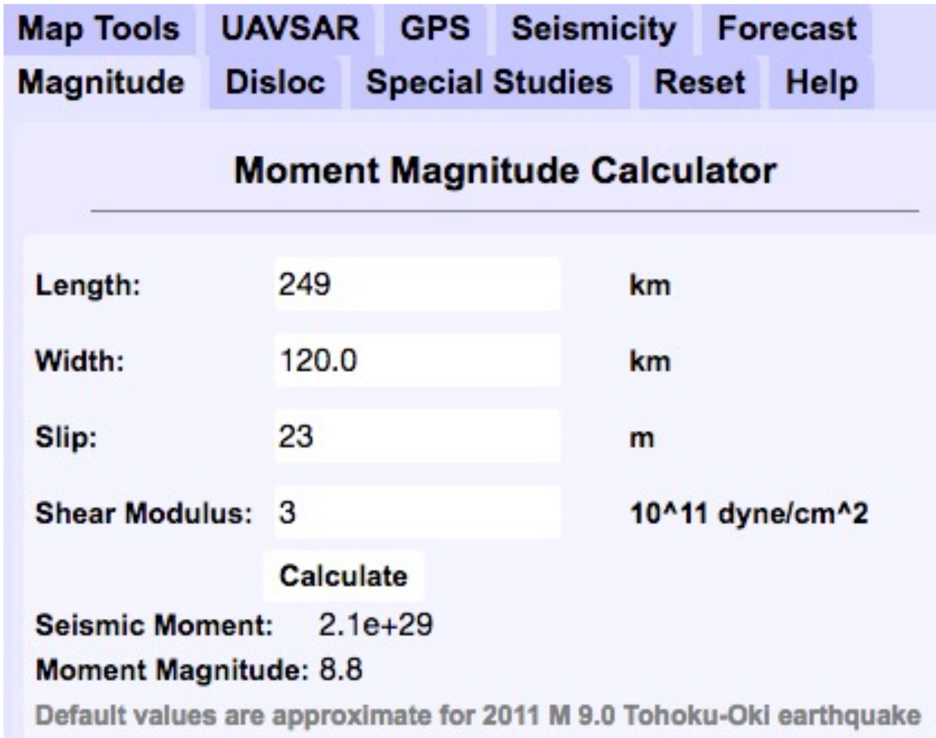
In the diagram on the lower left we see an example of an earthquake, with the epicenter representing the red dot and the focus representing the black dot.

The shear modulus or μ is

3.2×10^{11} dynes/cm^2 in the crust

7.5×10^{11} dynes/cm^2 in the mantle

The area (km^2) can be found as shown in the diagram by using the length (L) and width (W). The slip (meters) is the average displacement (D) of the rupture.



Within GeoGateway, the moment magnitude can be calculated by clicking on the "Magnitude" tab. Once the page is loaded, insert the **length**, **width**, **slip**, and **shear modulus** (in units shown) to calculate the moment magnitude as shown in the image above of an example of the M_W 9.0 Tohoku-Oki earthquake.

Exercise : Calculating Moment Magnitude

GeoGateway allows users to calculate the moment magnitude by clicking on the “Magnitude” tab and further inputting data. Within this exercise you will create a M6 earthquake.

Go to http://geo-gateway.org

Click on the “**Magnitude**” tab

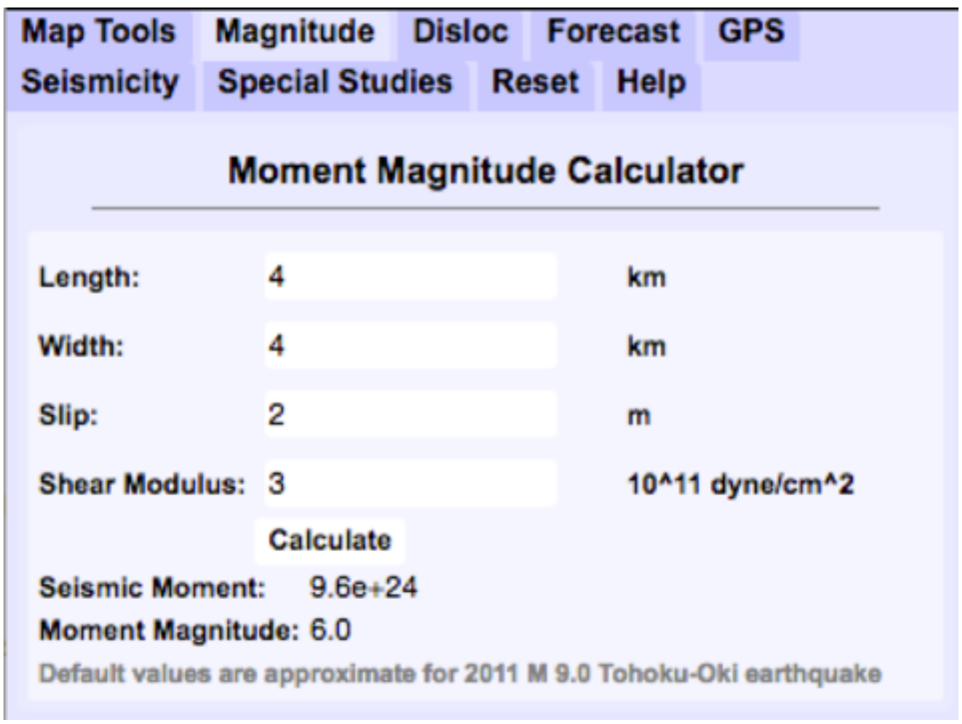
Enter parameters to create a M6 earthquake and list the parameters used (hint: length and width should be equal)

a. Length (km): 4

b. Width (km): 4

c. Slip (m): 2

d. Shear Modulus (10^{11} dyne/cm^2): 3



Extra: Use the GeoGateway Moment Magnitude Calculator to estimate the number of earthquakes.

Assume a San Andreas fault slip rate of 35 mm/yr. Use the above slip to estimate the number of M6 earthquakes that should occur over 100 years at that slip rate

Answer →

35 mm/yr x 100 years = 3,500 mm

3,500 mm to m = 3.5 m

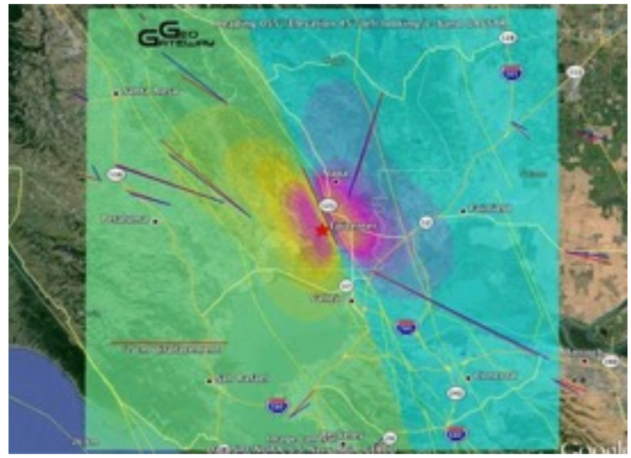
Slip is 2 m

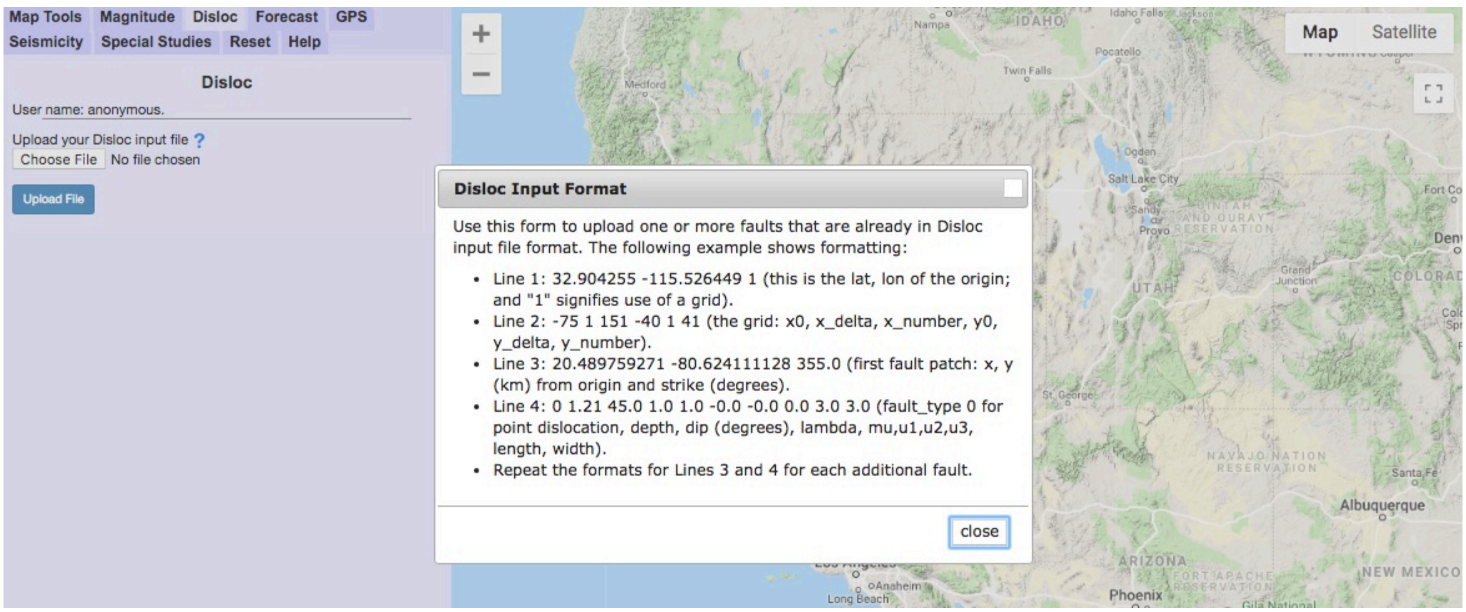
2 m / 3.5 m = **0.57 earthquake(s)**

Dislocation (Disloc)

Elastic dislocation models generated by Disloc can be used to geodetically measure deformation, strain, and tilt, due to slip from active faults.

When running *Disloc*, several parameters are needed to characterize each fault.





The ***location*** of the fault is defined as the surface projection of the lower-left corner of the fault plane (shown as the origin in the diagram). The ***depth*** is the z-coordinate of the fault's bottom edge. The ***dip*** angle is measured from horizontal (as shown).

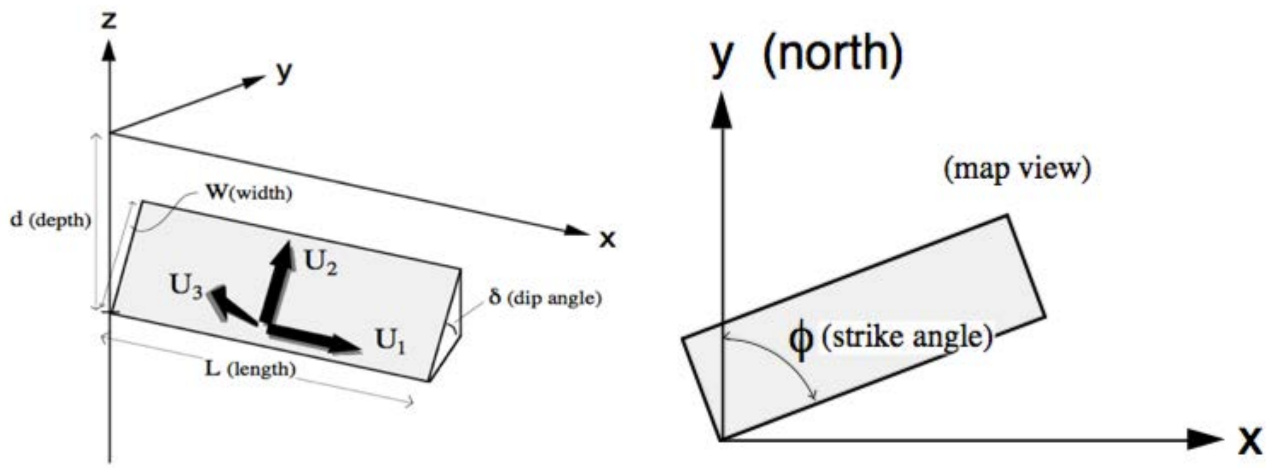


Figure adapted from (Donnellan, A., et al., 2014).

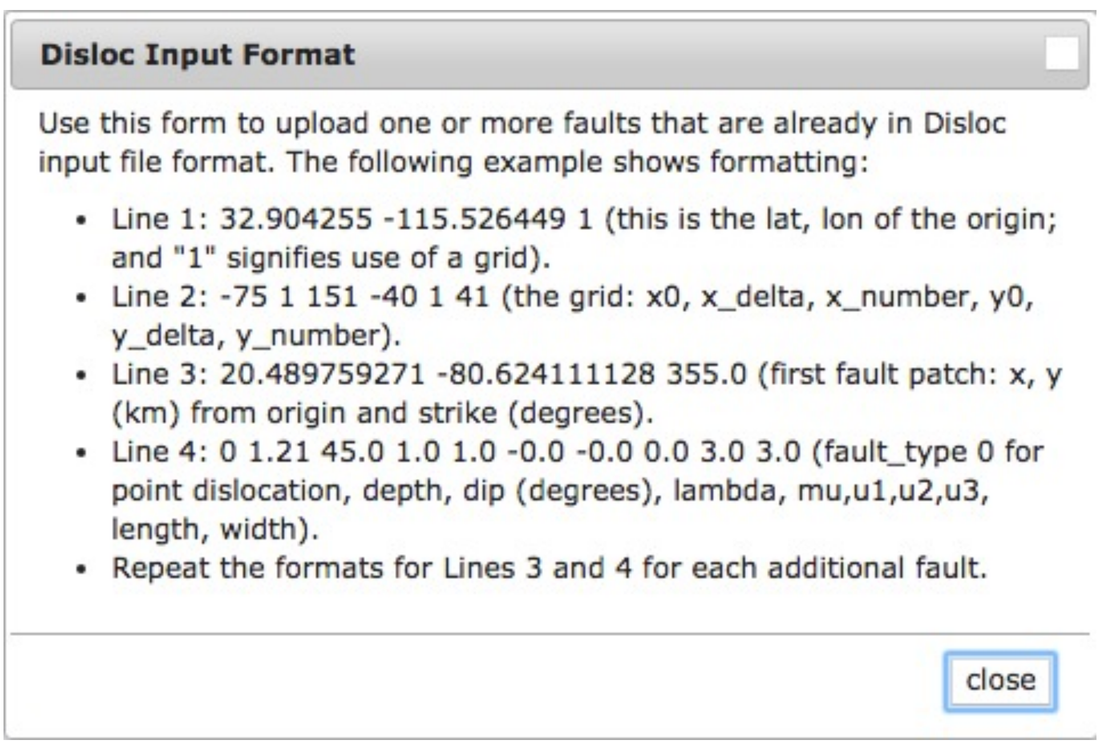
The ***strike*** angle is the orientation (measured clockwise from north) of the surface projection of the fault's horizontal edges. The ***length*** and ***width*** are the dimensions of the rectangular fault.

U_1 is the strike slip component of fault slip (positive for left-lateral).

U_2 is the dip slip component of fault slip (positive for thrust).

U_3 is the tensile component of fault slip (positive for opening).

For Disloc source code follow these steps below
Start by opening a text file.



Disloc Input Format

Use this form to upload one or more faults that are already in Disloc input file format. The following example shows formatting:

- Line 1: 32.904255 -115.526449 1 (this is the lat, lon of the origin; and "1" signifies use of a grid).
- Line 2: -75 1 151 -40 1 41 (the grid: x0, x_delta, x_number, y0, y_delta, y_number).
- Line 3: 20.489759271 -80.624111128 355.0 (first fault patch: x, y (km) from origin and strike (degrees).
- Line 4: 0 1.21 45.0 1.0 1.0 -0.0 -0.0 0.0 3.0 3.0 (fault_type 0 for point dislocation, depth, dip (degrees), lambda, mu,u1,u2,u3, length, width).
- Repeat the formats for Lines 3 and 4 for each additional fault.

close

Line 1:

You will first be asked to supply the "latitude" and "longitude" of the origin. These actually do nothing, and should be set to zero.
Next enter the generation parameter. This tells how you will specify the points at which you want calculated displacements. If it is 0, this means you will be giving it a list of arbitrary x,y points (good for irregularly distributed sites). If it is 1, this means you are asking for output at regularly spaced points on a rectangular grid (good for uniform coverage of an area if you want to later plot).

Line 2:

Next is either the list of x, y points, or a description of how to generate the rectangular grid. In the latter case, this consists of: starting x-coordinate, increment in x direction, number of steps in x direction, starting y-coordinate, increment in y direction, number of steps in y direction.

Line 3:

You will next be asked to supply the x coordinate and y coordinate of the first fault. You should enter the location of the fault's reference corner (see illustration) measured in units of distance (e.g. kilometers, not degrees). Next is the strike angle of the fault, measured clockwise from north as viewed from above (see diagram).

Line 4:

Next you give the vertical depth to the *bottom* of the fault, followed by the dip angle in degrees (zero for horizontal; 90° for vertical). Next are λ and μ, the Lamé elastic parameters.

Their absolute values are not important, only their ratio. $\lambda=\mu$ is the most common assumption for typical rocks.

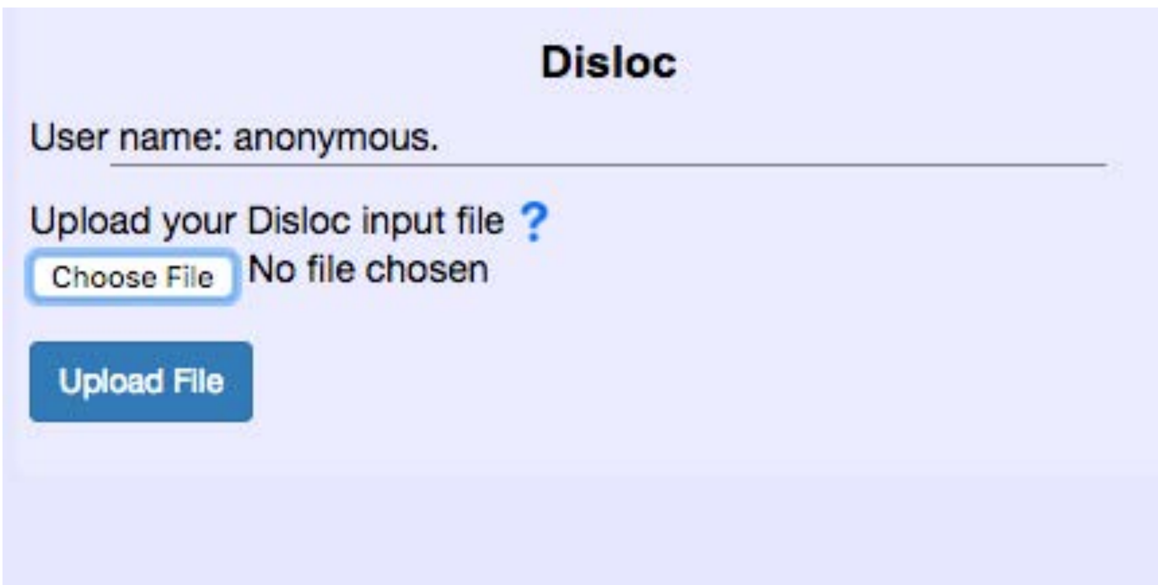
U_1, U_2, and U_3 are the amounts of relative slip to apply to the fault surface in the strike slip, dip slip and tensile directions, respectively.

Positive U_1 corresponds to *left-lateral motion* (opposite in sense to the San Andreas fault for example).

Positive U_2 corresponds to *thrusting motion* with the hanging wall riding up over the foot wall (like the San Gabriel mountains for example).

U_3 will not normally be used, since ordinary earthquake faults involve motion only tangential to the fault plane.

Finally the length and width of the rectangular fault surface (as illustrated) are entered. If you wish to model the effects of more than one fault, or build up a complex compound fault from rectangular "tiles", the input is simply repeated, starting with the next fault's x coordinate and y coordinate. When done entering faults, you signal the end to *setupdis* by typing <control-D>.

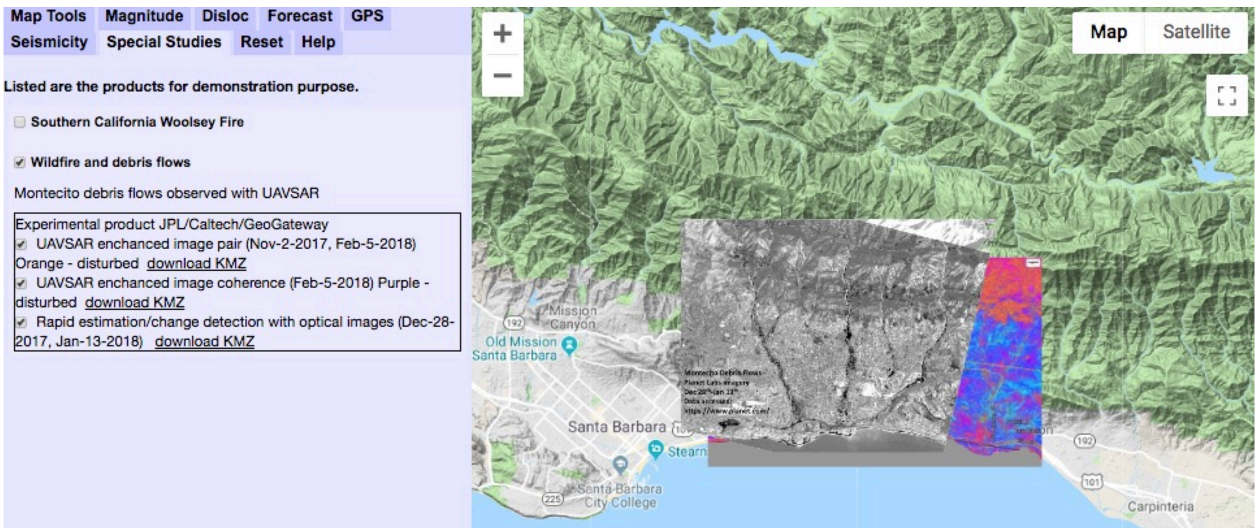


Lastly upload the file on the "disloc" tab.

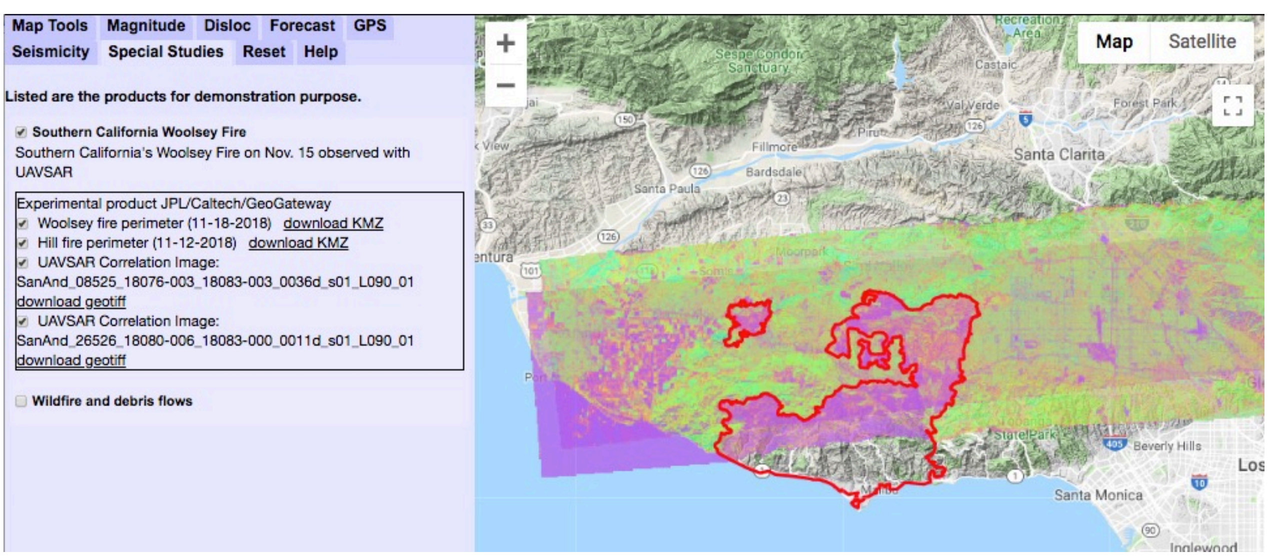
Special Studies

GeoGateway's Special Studies tab, includes listed products for demonstration purposes.
The study includes wildfire burn areas and debris flows following the 2017 Montecito CA fire, imaged with **UAVSAR** in figure (a) below; and Southern California 2018 Woolsey Fire shown in figure (b) below. See Donnellan et al. 2018b for more information.

(a)

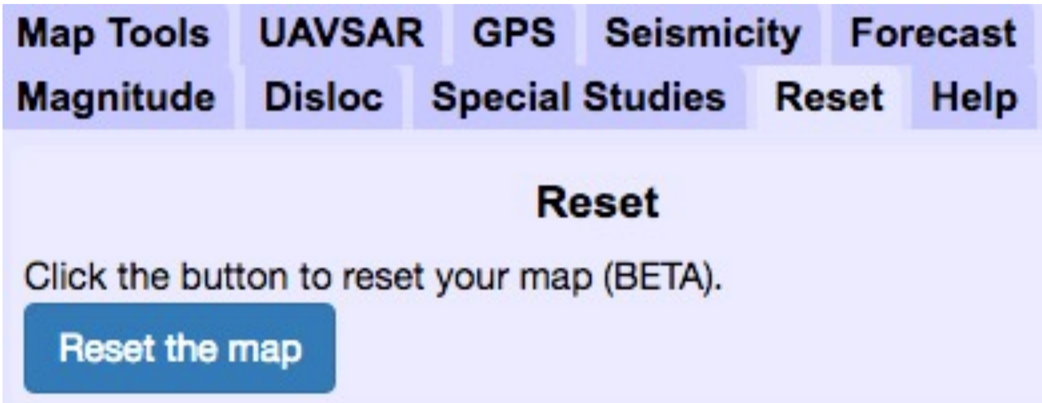


(b)



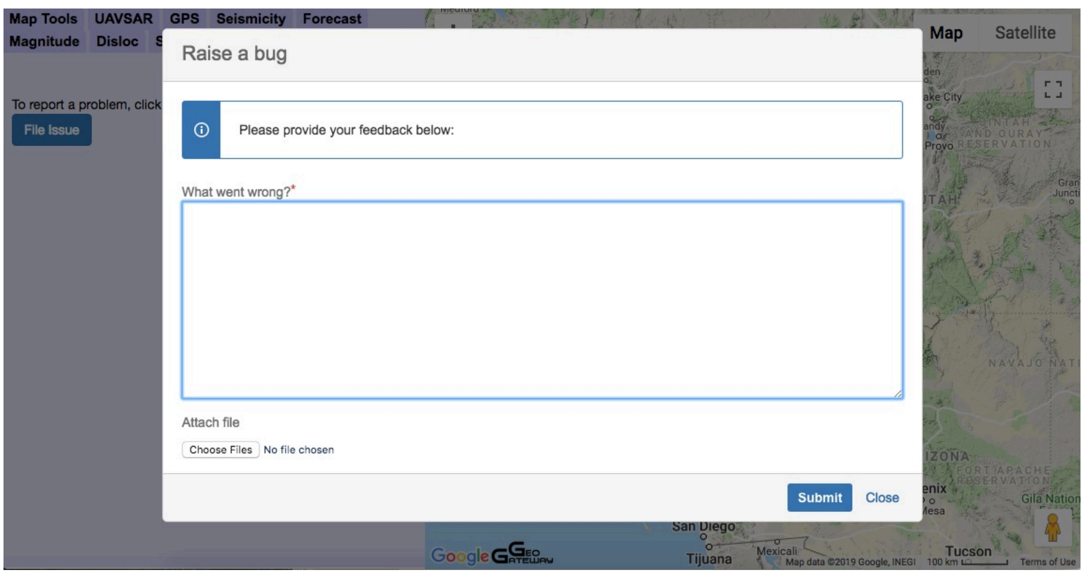
Reset Tab

By clicking on “Reset the map” button, all data on the map will clear.



Help Tab

Click on the “File Issue” button in order to raise awareness of a problem encountered on GeoGateway.



Citations

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Donnellan A, Parker J, Hensley S, Pierce M, Glasscoe M, Pierce M, Wang J, Ma Y, Rundle J (2014) “UAVSAR observations of triggered slip on the Imperial, Superstition Hills, and East Elmore Ranch Faults associated with the 2010 M 7.2 El Mayor-Cucapah earthquake” *Earth and Space Science* Volume 15, Issue 3.
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Donnellan A, Parker J, Ludwig L, Glasscoe M, Granat R, Pierce M, Wang J, Ma Y, Rundle J (2016) "GeoGateway: A system for analysis of UAVSAR data products," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing. pp. 210-213.
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Website: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016EA000185