

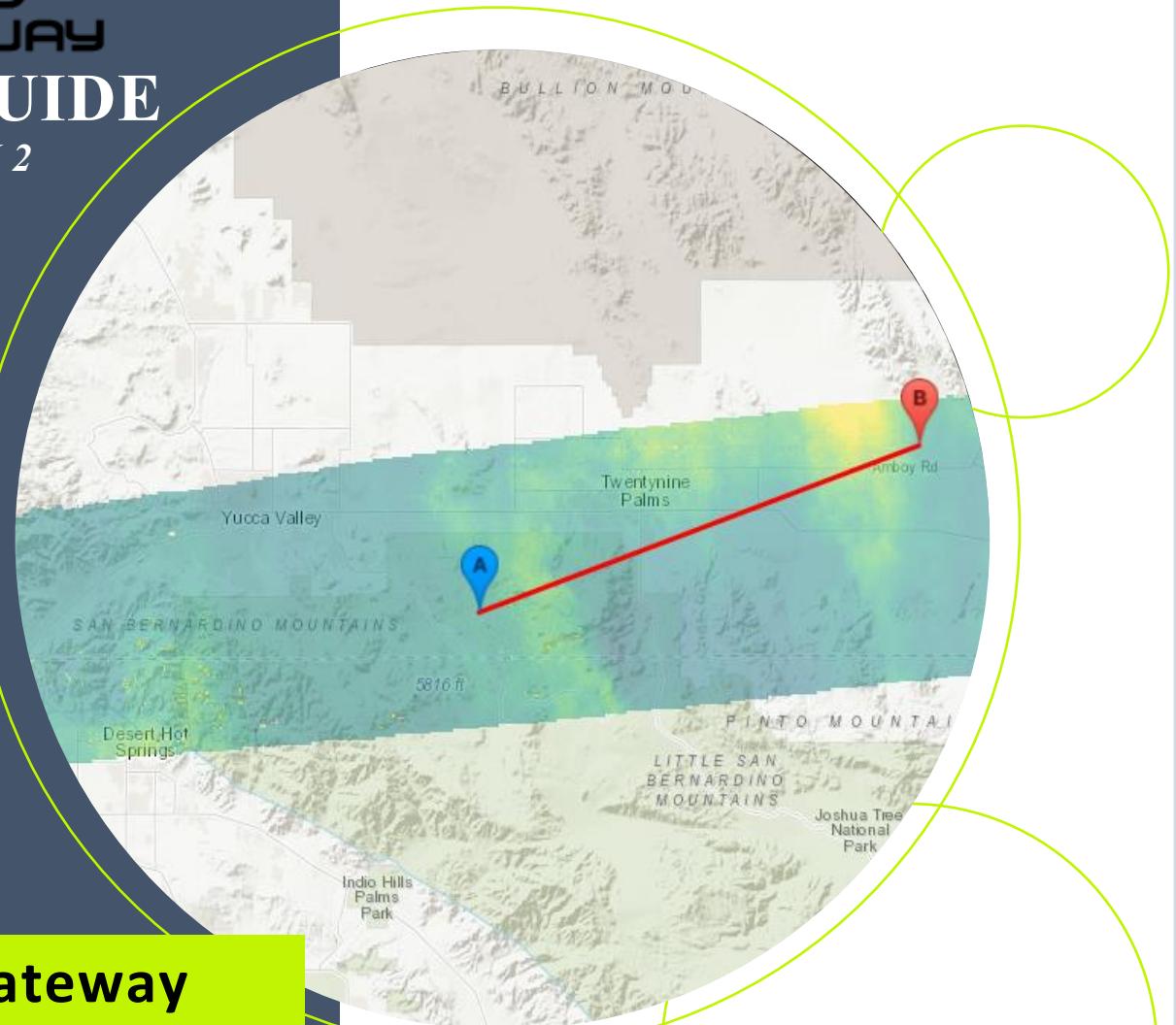
# **GEO** GATEWAY

## USER GUIDE

VERSION 2

**GeoGateway**

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



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# Overview

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

GeoGateway consists of NASA's geodetic imaging products including InSAR (interferometric synthetic aperture radar) and GNSS (Global Navigation Satellite 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 GNSS products from USGS to enable researchers to explore and integrate these data products.

Figure 1: UAVSAR Science Aircraft. (Figure adapted from Jet Propulsion Laboratory (JPL))

## 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



Figure 2: UAVSAR Science Aircraft. (Figure adapted from Jet Propulsion Laboratory (JPL))

geo-gateway.org

GEO GATEWAY Tools for Analysis, Modeling, and Response Using Geodetic Imaging Products

# Welcome to GEO GATEWAY

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

To access GeoGateway click on the provided link (<http://geo-gateway.org>).

The screenshot shows the GeoGateway homepage. At the top, there is a header with the URL "geo-gateway.org" and the "GEO GATEWAY" logo. Below the header, the text "Welcome to GEO GATEWAY" is displayed. The main content area features a large world map with a focus on North America. To the left of the map, there is a sidebar with the text "Tools display option" and two red arrows pointing to the "Zoom In" and "Zoom Out" buttons. Below the sidebar is a list of 11 tabs: Maptools, UAVSAR, GNSS, Seismicity, Nowcast, Magnitude, Disloc, Studies, 3D Imaging, Feedback, and Help. The "Maptools" tab is currently selected. The map itself shows state/province boundaries and major cities in the United States and Mexico. A scale bar indicates distances up to 200 km/mi. The bottom right corner of the map area contains the text "MÉXICO Leaflet | Map data: © Esri".

Tools display option

Zoom In

Zoom Out

Maptools UAVSAR GNSS Seismicity  
Nowcast Magnitude Disloc Studies  
3D Imaging Feedback Help

GeoGateway includes 11 tabs

1. Map Tools
2. UAVSAR
3. GNSS
4. Seismicity
5. Nowcast
6. Magnitude
7. Disloc
8. Studies
9. 3D Imaging
10. Feedback
11. Help

Pacific Ocean

GEO GATEWAY

NORTH DAKOTA  
SOUTH DAKOTA  
NEBRASKA  
KANSAS  
OKLAHOMA  
TEXAS  
MONTANA  
IDAHO  
WYOMING  
UTAH  
COLORADO  
NEW MEXICO  
ARIZONA  
CHIHUAHUA  
COAHUILA  
SAN LUIS POTOSI  
GUANAJUATO  
JALISCO  
MICHOACAN  
MORELOS  
ESTADOS UNIDOS  
MÉXICO

Leaflet | Map data: © Esri

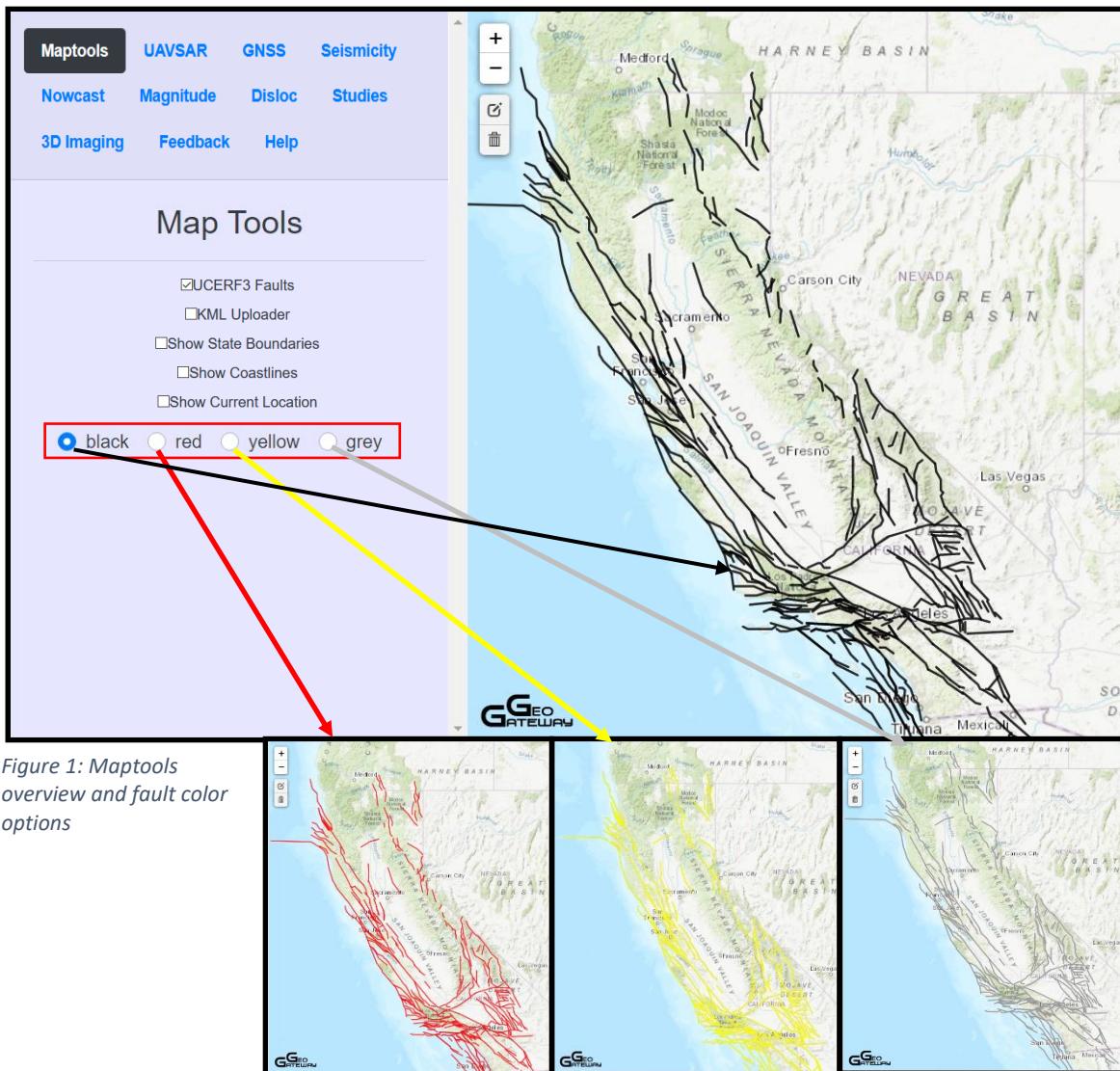
Figure 3: Overview of GeoGateway's tabs

# Maptools

## UCERF3 Faults

### (Uniform California Earthquake Rupture Forecast, version 3)

The United States Geological Survey ([USGS](#)) UCERF3 faults allow users to insert California's fault lines onto the map. To insert the fault lines, check the box next to "UCERF3 Faults." Users are given the option to choose from either black, yellow, red, or grey faults. To obtain more information regarding a particular fault, click on the fault and a popup with information pertaining to the selected area of the fault will appear.



## KML Uploader

KML (Keyhole Markup Language) is a file format used to display geographic data.

For *example*, visiting the USGS website below,

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

allows for users to search through an earthquake catalog in which the selected earthquake data can be downloaded as a KML file and uploaded into GeoGateway as shown in *figure 2*.

Once uploaded into GeoGateway, the KML file(s) are displayed.

By clicking the box next to the uploaded KML file, the file will be displayed on the map.

In this case, the KML file named “USGS\_Earthquakes” is displayed on the map.

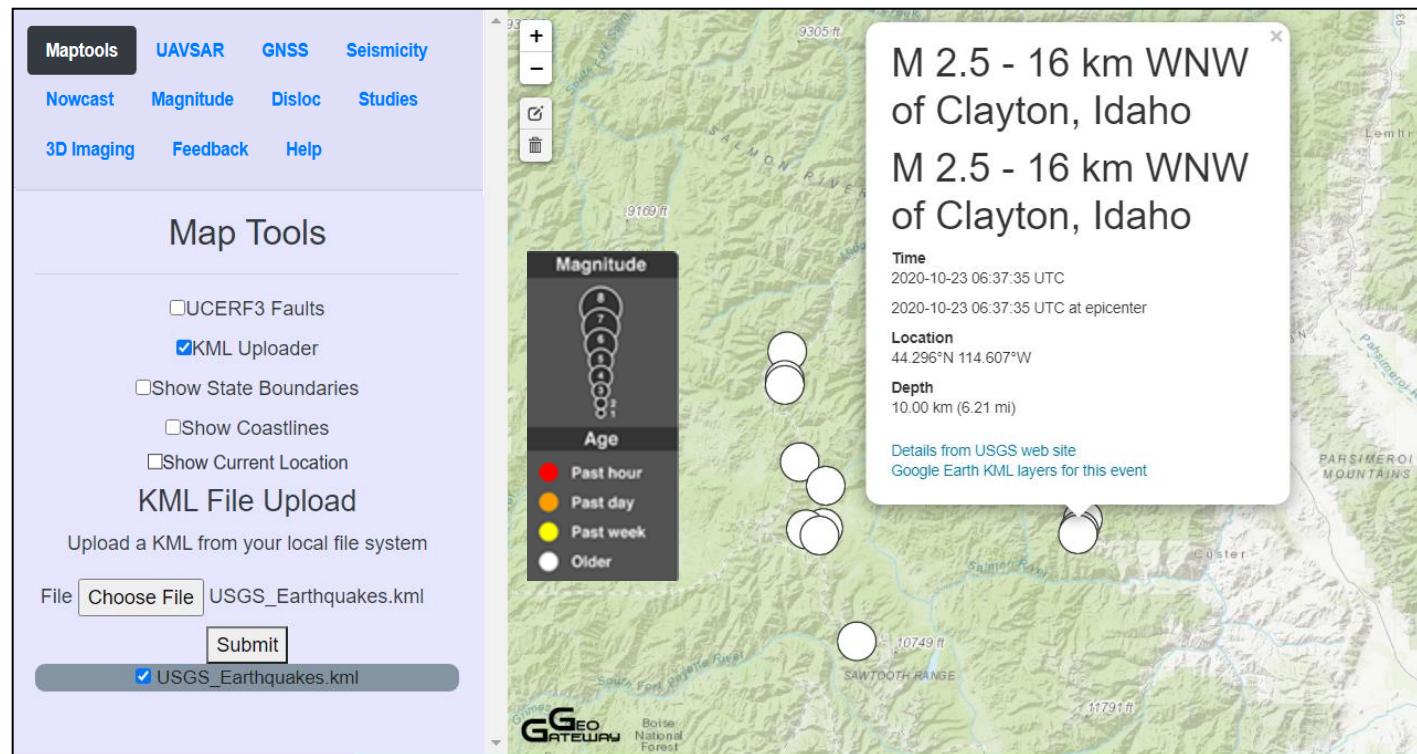


Figure 3: Downloaded KML file from USGS displayed on the map

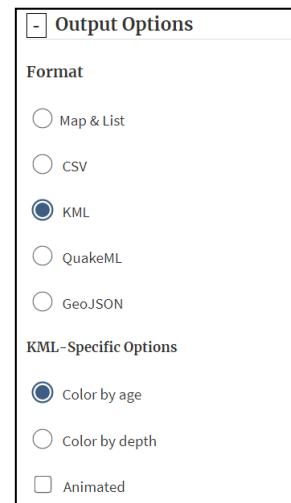


Figure 2: USGS earthquakes catalog output options



## Show State Boundaries

To display state boundaries within the United States, check the box next to “Show State Boundaries.”

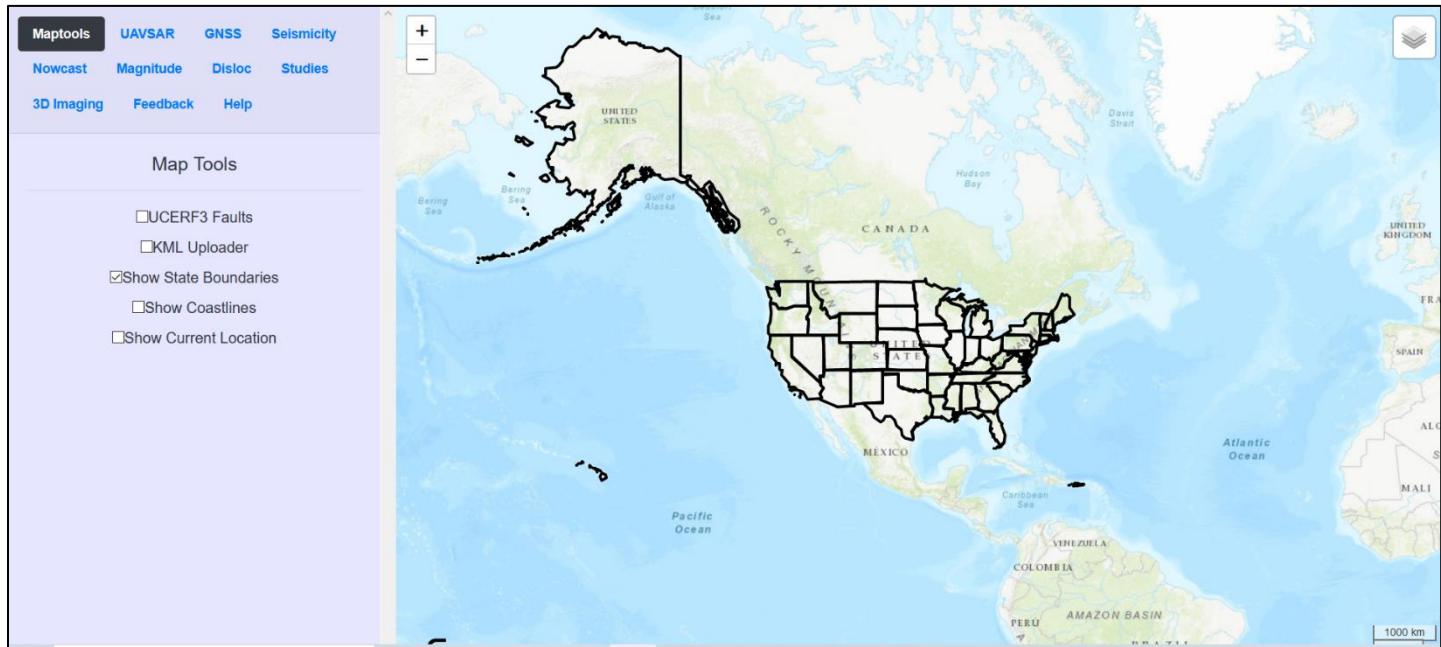


Figure 4: Maptools, United States boundary layer

## Show Coastlines

To display coastlines, check the box next to “Show Coastlines.”



Figure 5: Maptools, global coastlines layer



## Show Current Location

By clicking on “Show Current Location” users are able to view their current location on the map.

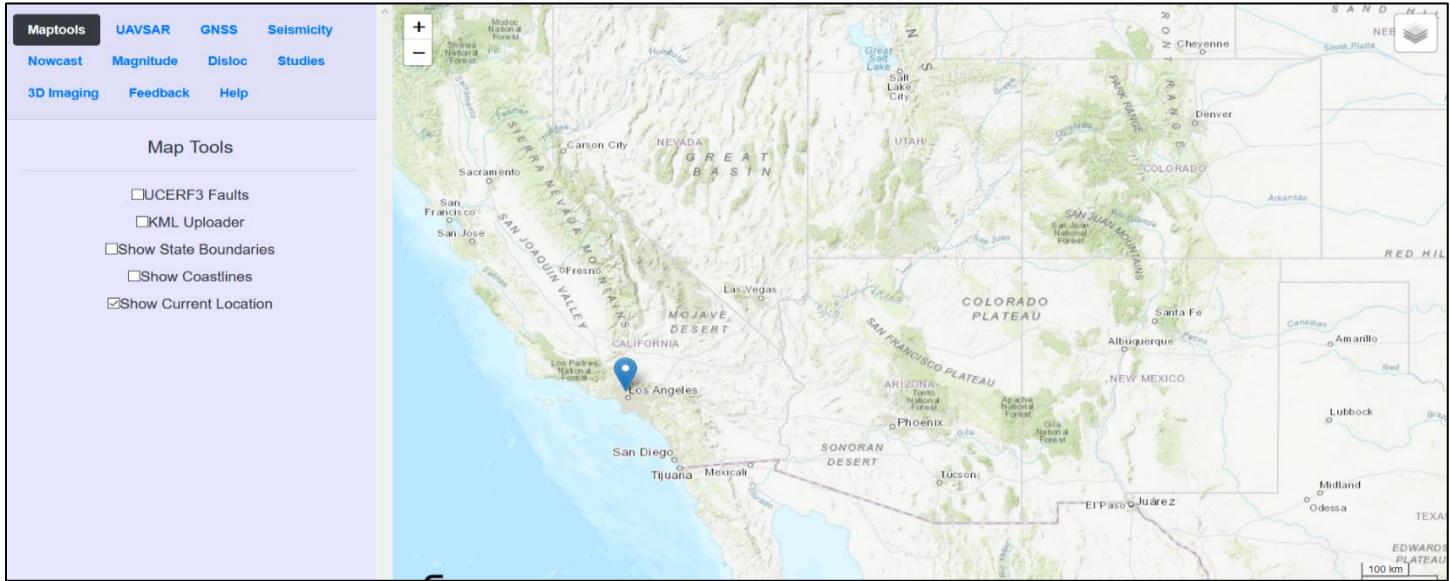


Figure 6: Maptools, show current location option

## View map in different modes

By toggling over to right corner, choose either “ArcGIS Topo Map,” “ArcGIS Light Map,” “ArcGIS Dark Map.”

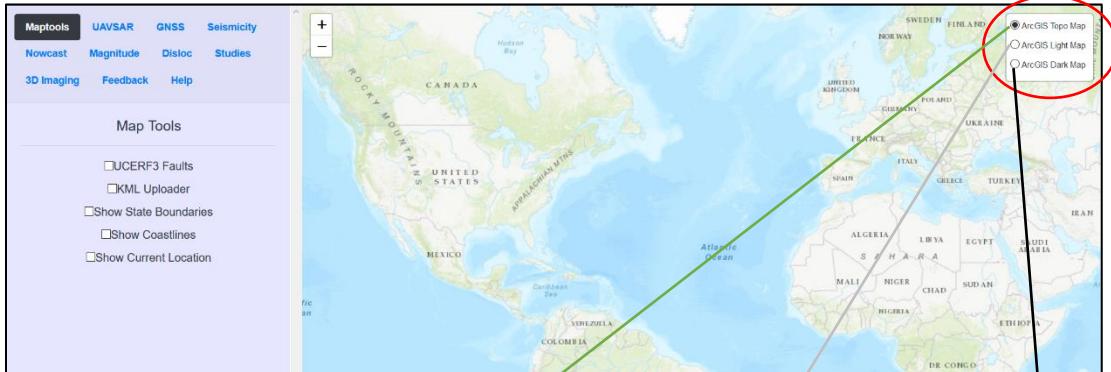
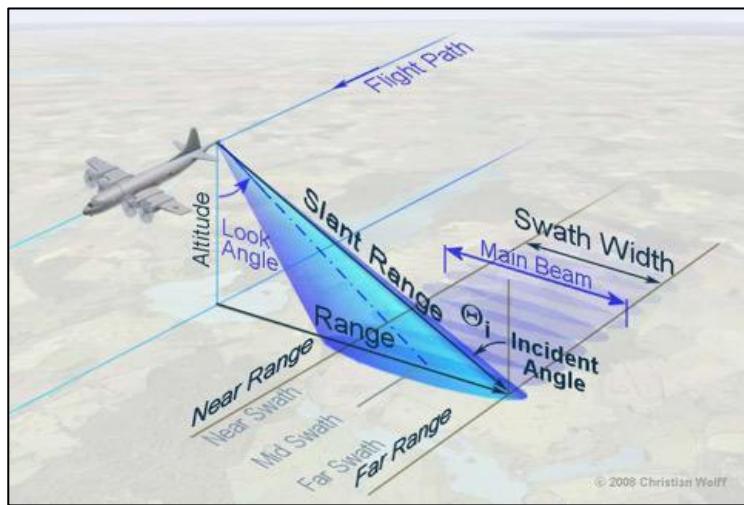


Figure 7: Maptools, different map coloring options



# UAVSAR

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 et al., 2014).



*Figure 1: Demonstration of the uninhabited aerial vehicle flight path and how the swath path is determined. (Figure adapted from (Christian Wolff, 2008))*

The wide swath of the UAVSAR instrument results in a large incidence angle variation across the swath. Near range incidence angles are approximately  $25^\circ$  whereas far range incidence angles are approximately  $65^\circ$  resulting in a  $40^\circ$  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 et al., 2014).

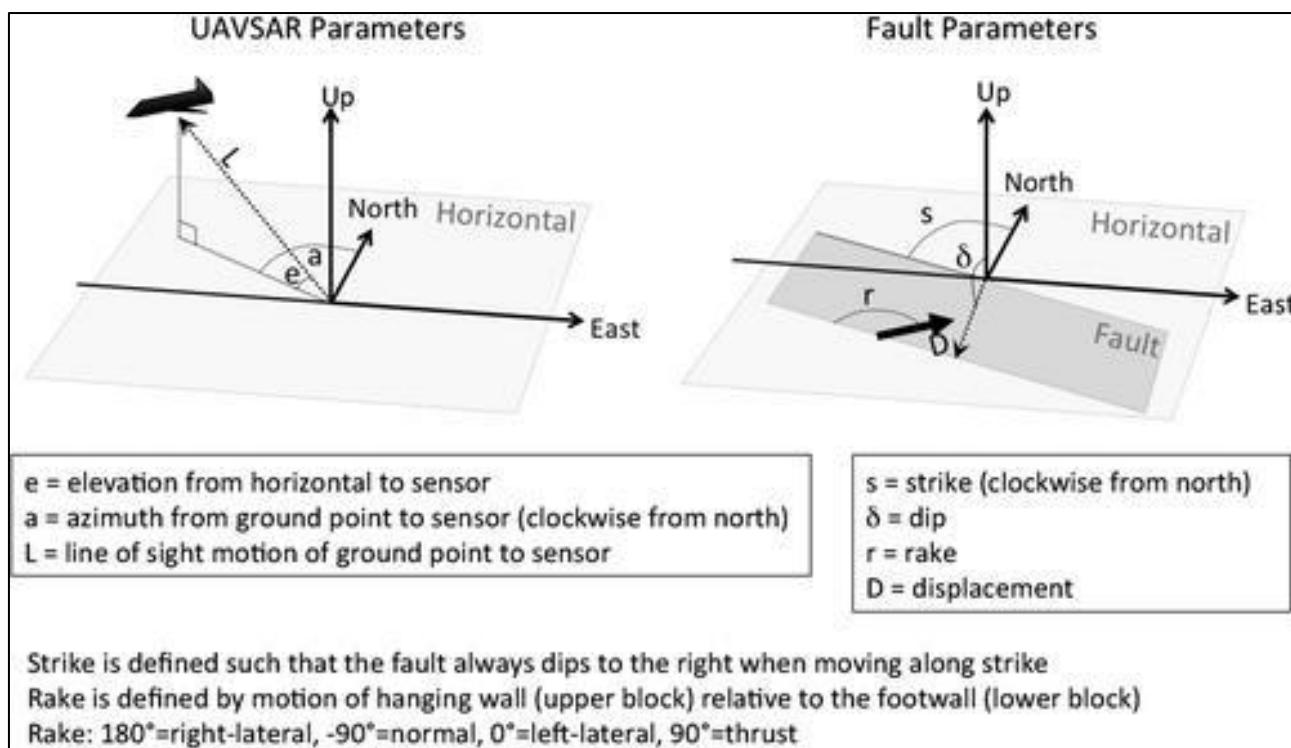


Figure 2: UAVSAR Parameters and Fault Parameters. (Figure adapted from (Donnellan et al., 2014))

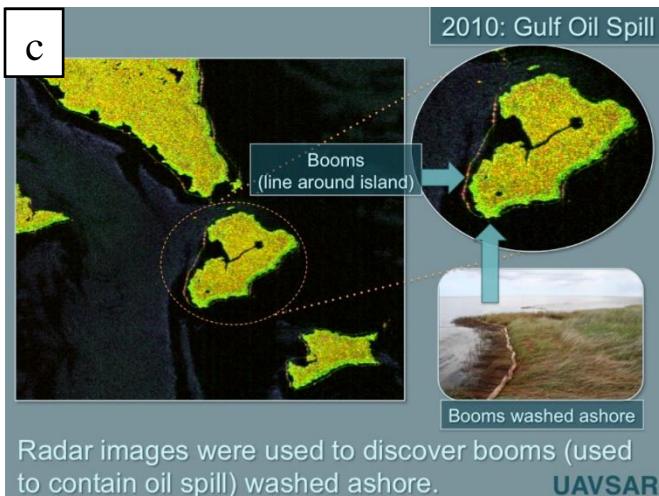
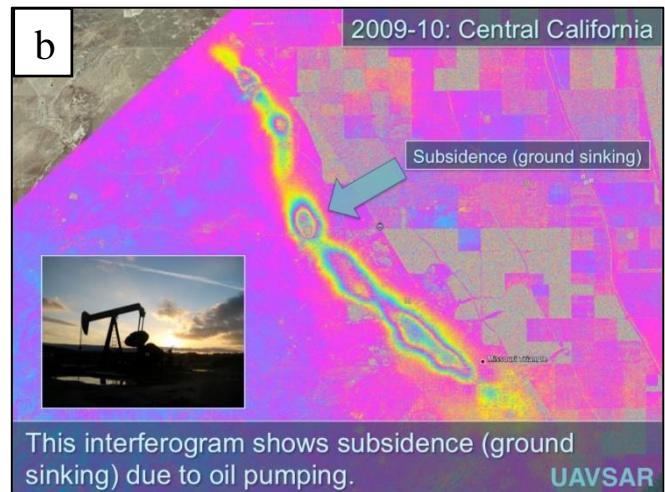
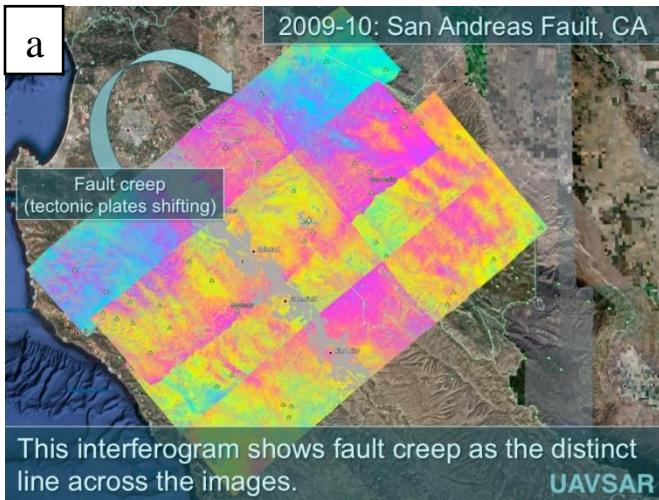
To the right, we see two different radar images creating the interferogram (shows the change or difference from each radar image).



Figure 3: Demonstration the difference between two swaths in the same location on two different dates, which results in an interferogram. (Figure adapted from (Jet Propulsion Laboratory, 2014))



## Example UAVSAR uses:



To upload UAVSAR interferograms, follow either method (1) or (2)

1. The “flight name/path” directly finds the flight name and path wanted
2. The “latitude, longitude” option returns all flight swaths crossing paths with those coordinates.



\*Note options to draw an area or drop a pin can assist users to finding an interferogram

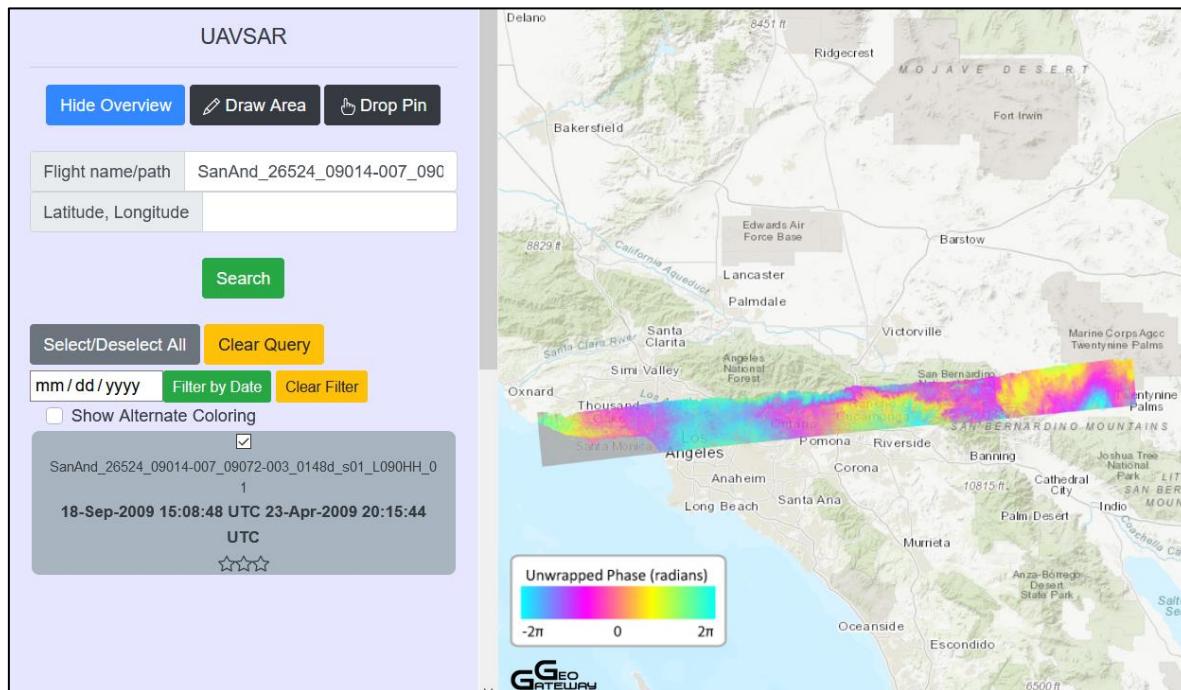


Figure 4: Demonstrates option 1 (inputting flight name/path)

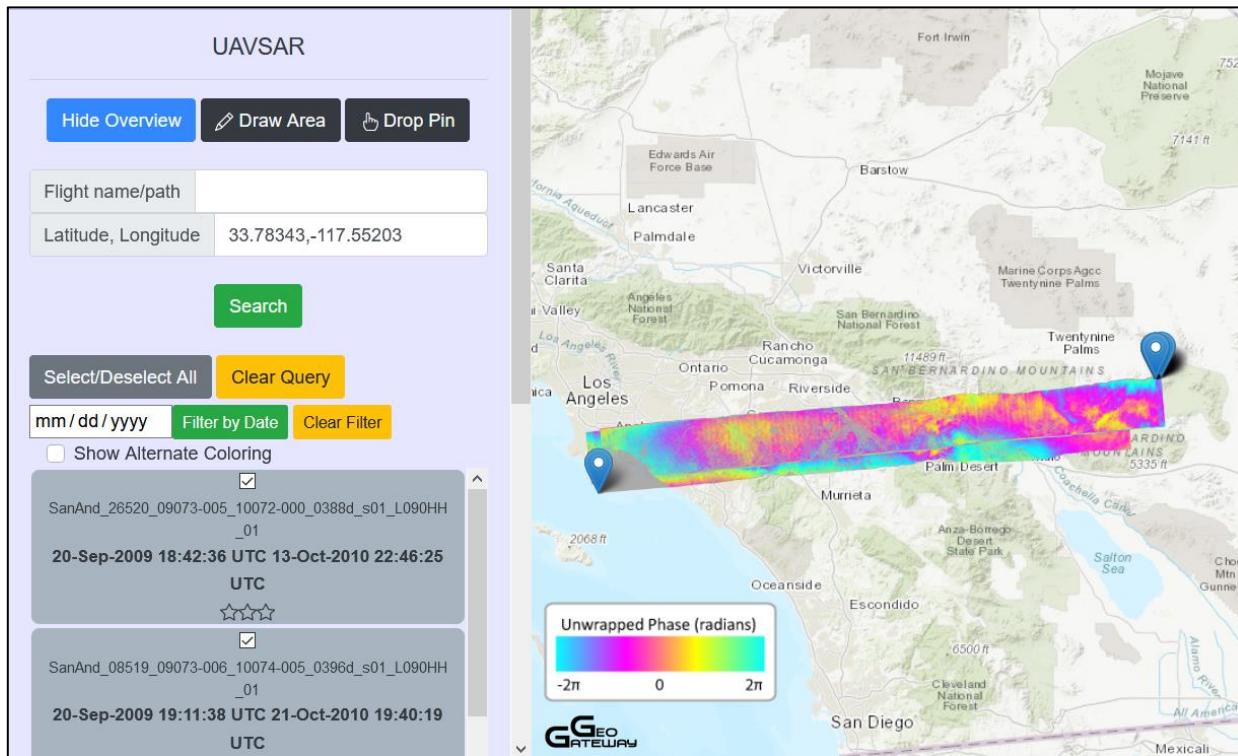


Figure 5: Demonstrates option 2 (inputting a latitude and longitude)

As shown in figure 5 the option is given to filter by date by inputting (mm/dd/yyy), narrowing the selection.

To further look into the surface fracturing, click on “Show Alternate Coloring” below the “Filter by Date” option. Notice the units of displacement change to “cm.”

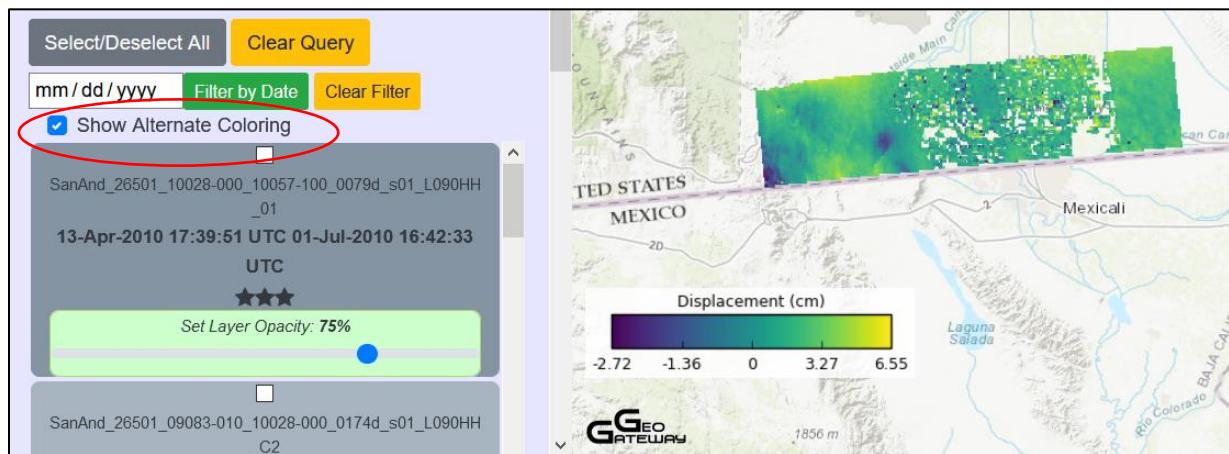


Figure 6: Demonstrates the change from the original unwrapped phase from figure 5, to displacement.



To look closer into the UAVSAR swaths,

1. Search for a flight path.
2. Select the flight path by clicking on it (flight path selection should be a darker color from the unselected paths).
3. Click on the UAVSAR flight path that is shown on the map, allowing the Line-of-Sight (LOS) tool to appear.

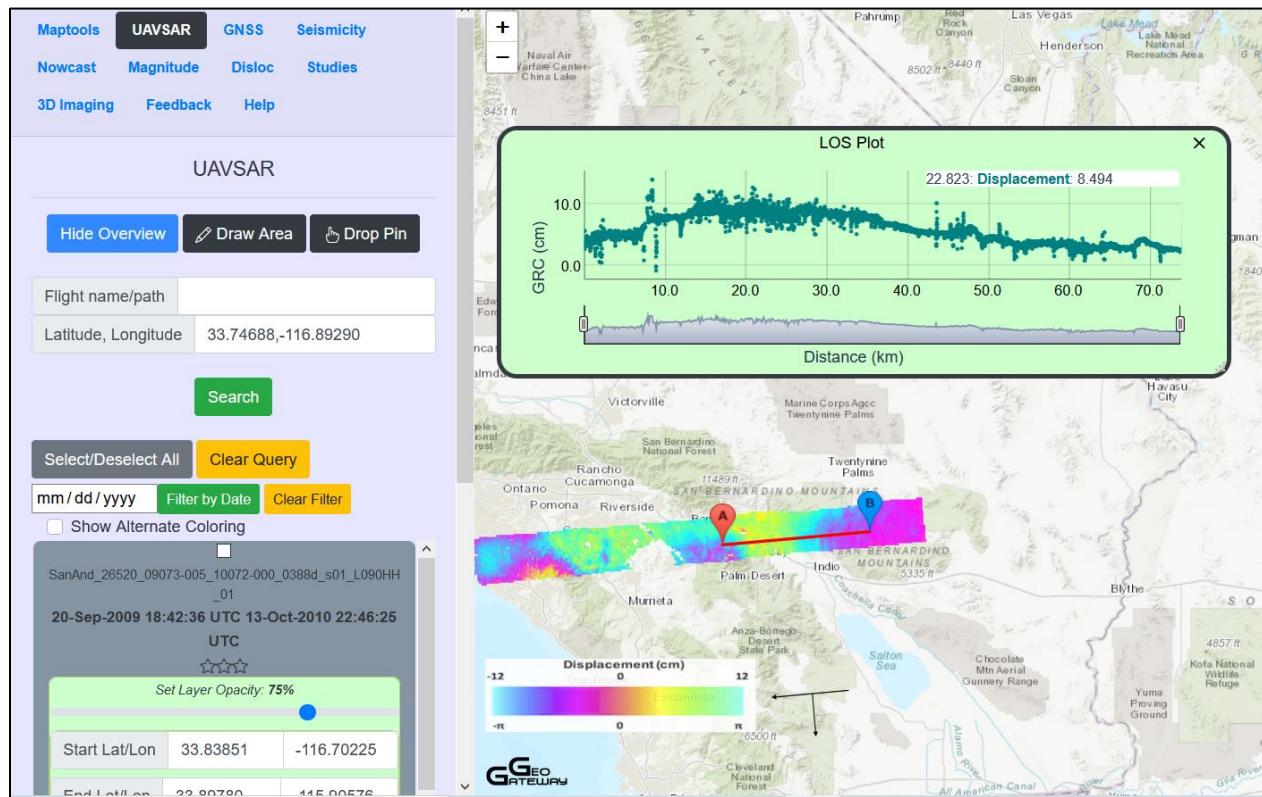


Figure 7: Line-of-Sight tool

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

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



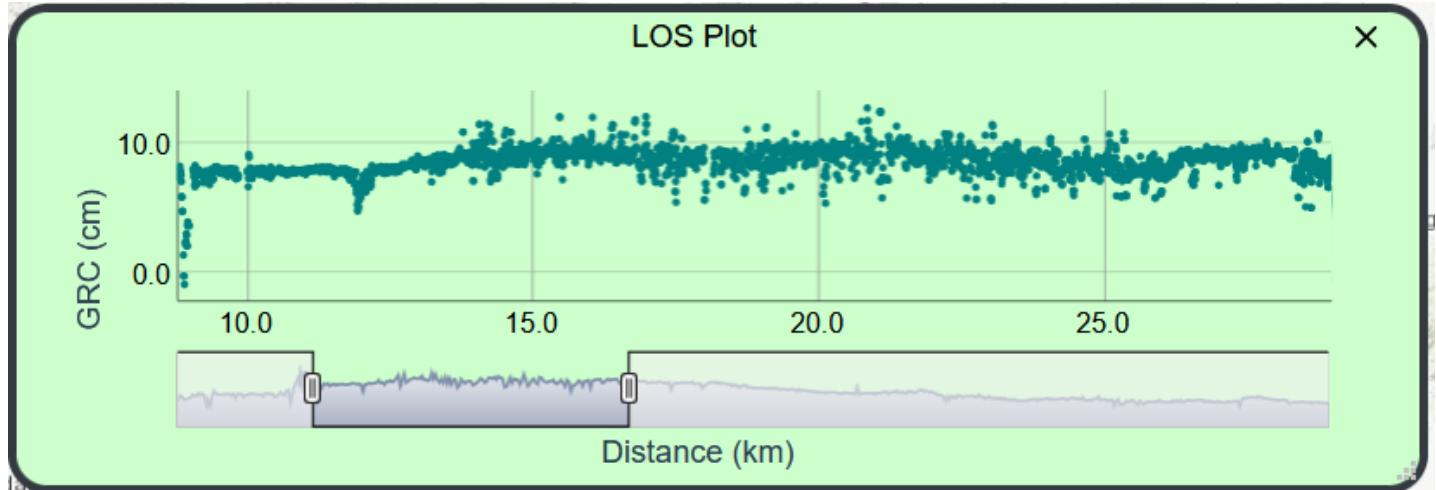


Figure 8: Line-of-Sight tool set to specific distance

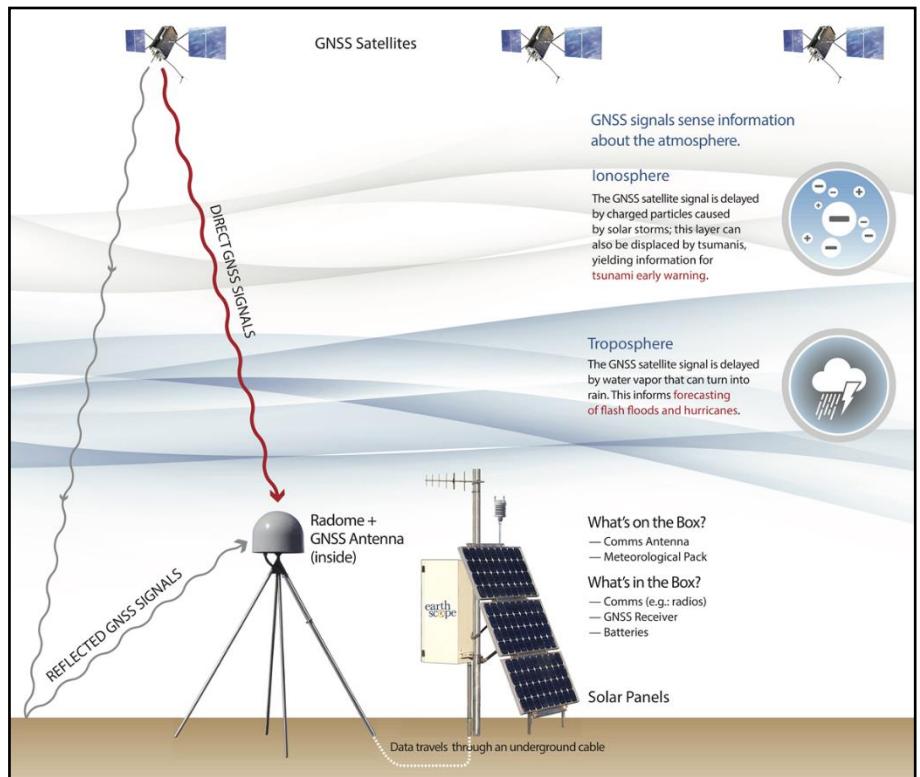
Users are able to choose a distance of focus by moving as shown in figure 8.



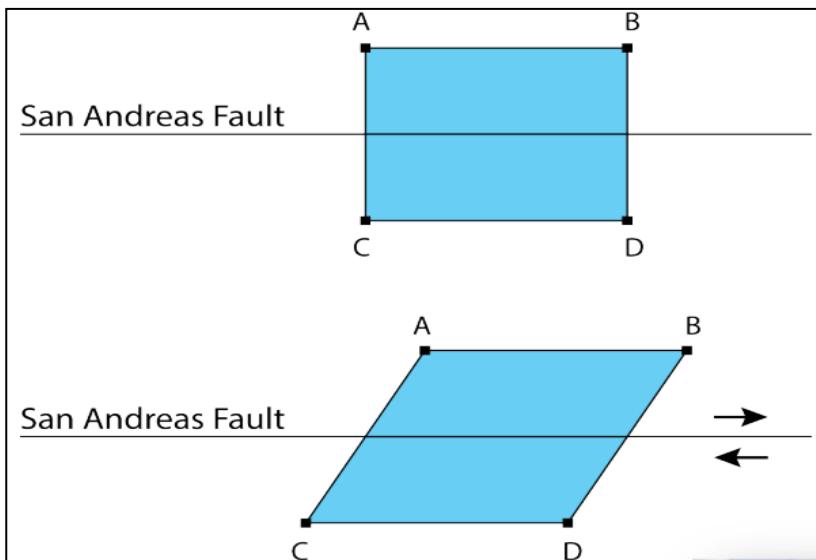
# GNSS

Global Navigation Satellite System (GNSS) contains satellite constellation which provides positioning, navigation, and timing (PNT) services on a global or regional basis (*Other Global Navigation Satellite Systems (GNSS)*, 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 1: Network of the Americas (NOTA) GNSS station portraying the primary components of the platform. (Figure adapted from (UNAVCO, 2020))*



*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.

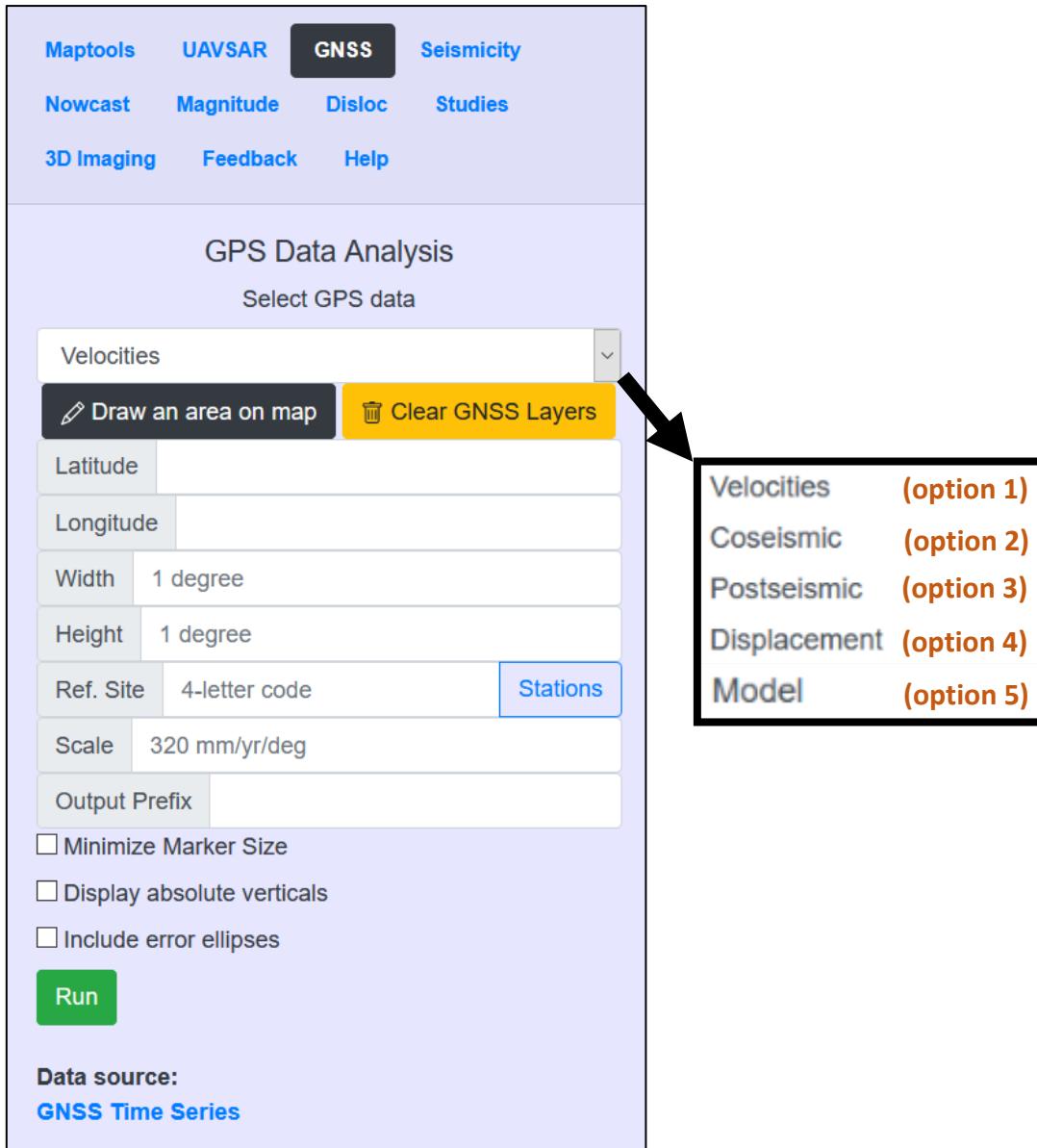


Figure 3: GeoGateway's GNSS tab, which includes five options of analysis; Velocities, Coseismic, Postseismic, Displacement, and Model.

GeoGateway allows users to analyze GNSS data for velocities, coseismic, postseismic, displacement, and model. Specific parameters must be filled in order to obtain a result.

## Parameters

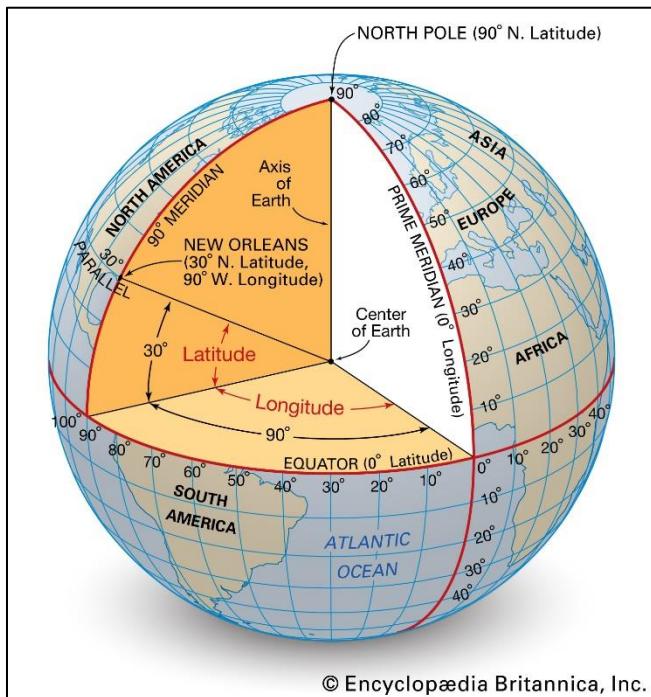


Figure 4: Overview of the geographic coordinate system (Figure adapted from (Britannica, n.d.))

**Latitude** (see *figure 4*) in decimal degrees  
**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.

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

**Ref. Site** is the GPS 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.

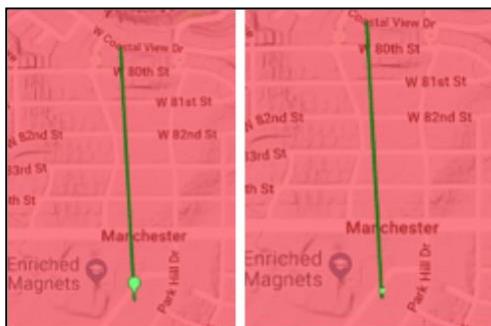
**Output Prefix** allows users to name the dataset output.



- Minimize Marker Size
- Display absolute verticals
- Include error ellipses

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

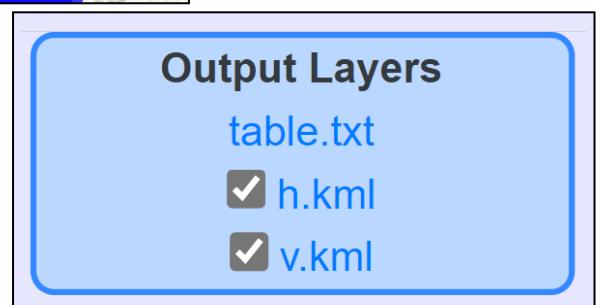
### “Display absolute verticals”



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 GPS stations are seen relative to the reference frame.

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

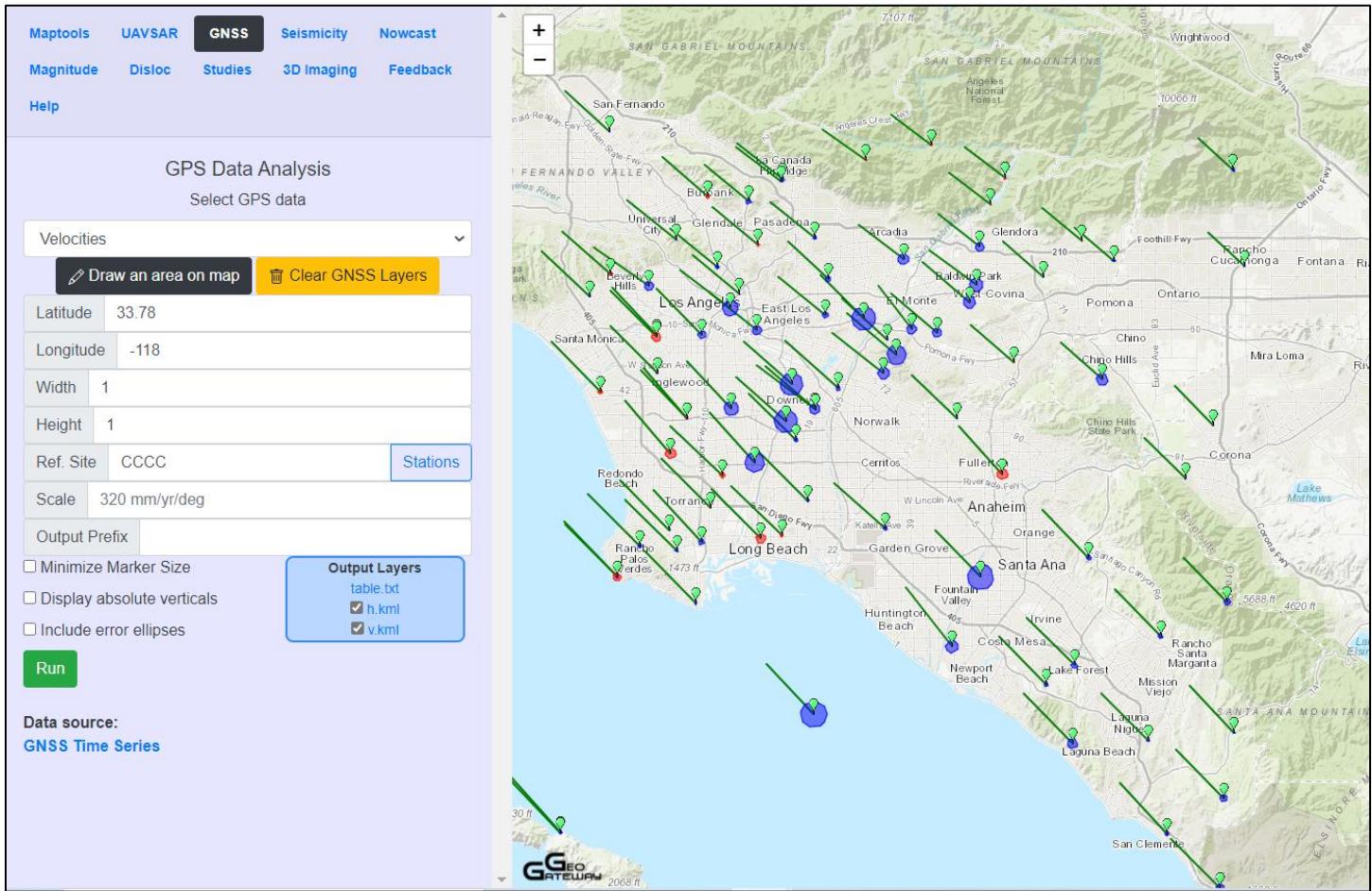


Figure 5: Velocities Analysis

Each vector shows the velocity of a single 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.



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

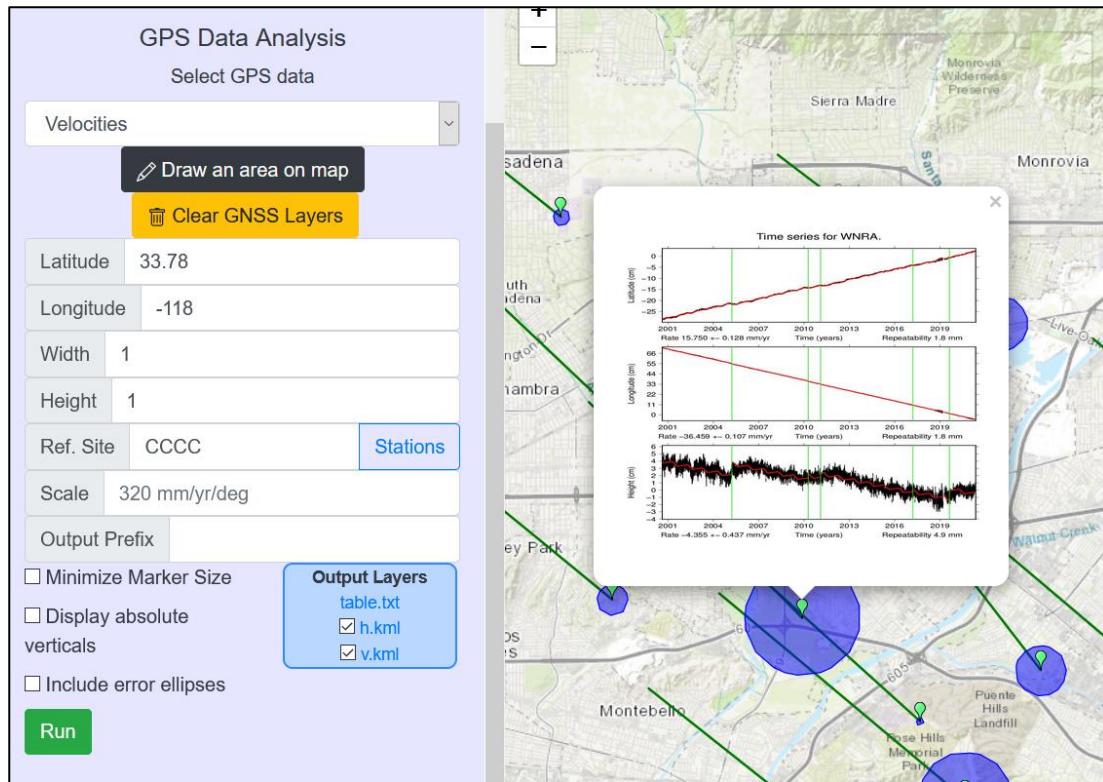


Figure 6: Time Series for WNRA station

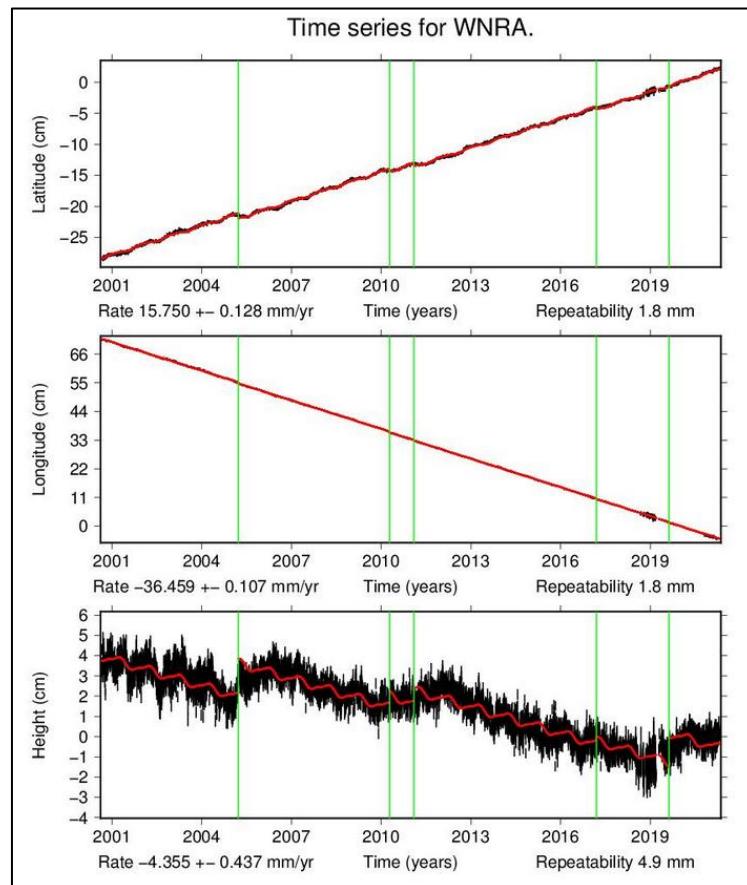


Figure 7: Time series tables, including latitude, longitude, and height



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 GPS 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.

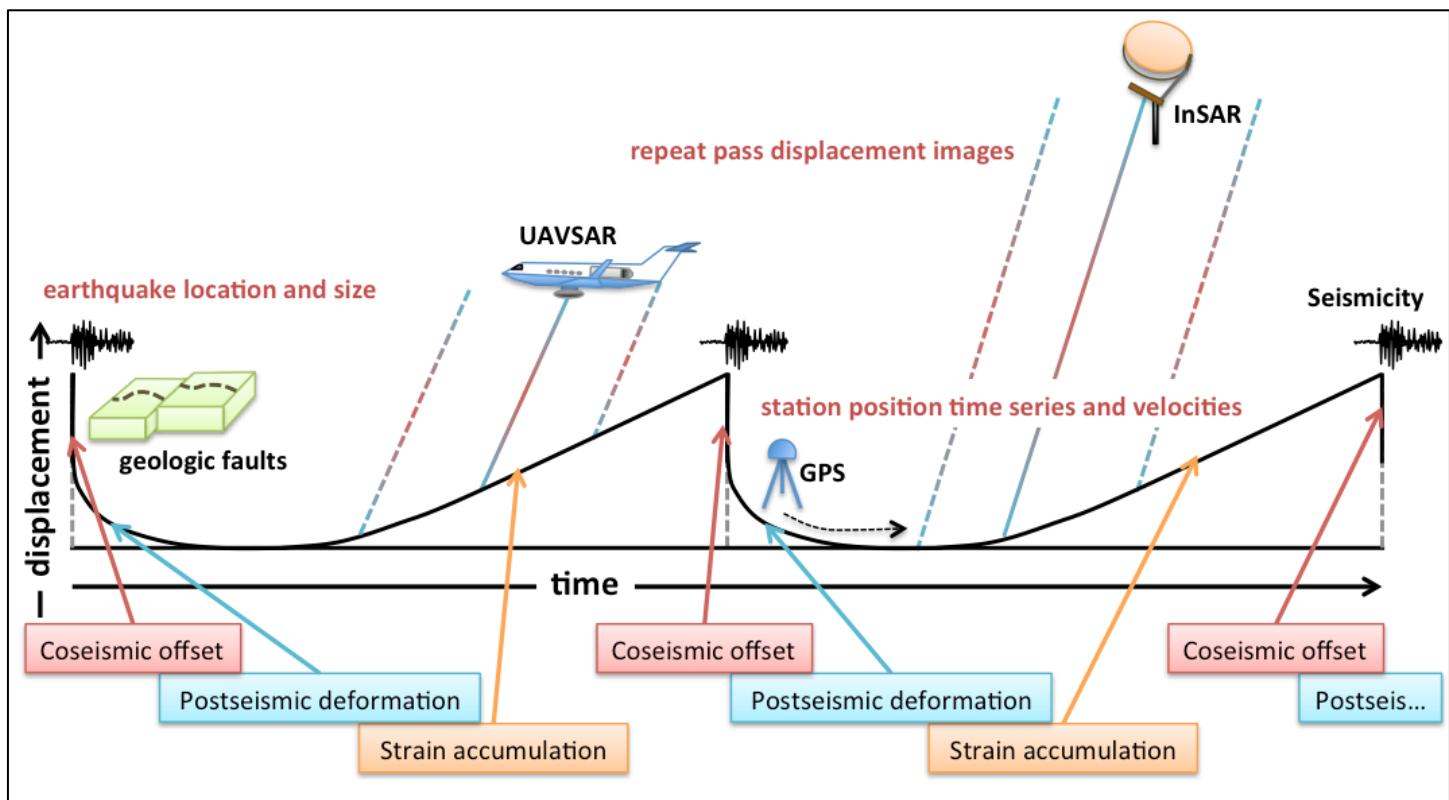


Figure 8: Crustal deformation is spatially and temporally non-uniform as strain accumulates over prolonged time scales, where it later rapidly released as earthquakes, and readjusts post-seismically. Numerous types of data from different sections of the earthquake cycle (as shown in the figure above)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

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

### GPS Data Analysis

Select GPS data

Coseismic

Latitude		
Longitude		
Width	1 degree	
Height	1 degree	
Epoch	YYYY-MM-DD	
Ref. Site	4-letter code	<input type="button" value="Stations"/>
Scale	320 mm/yr/deg	
Coseismic Win.	0.1 years	
Output Prefix		
<input type="checkbox"/> Minimize Marker Size		
<input type="checkbox"/> Display absolute verticals		
<input type="checkbox"/> Include error ellipses		
<input type="button" value="Run"/>		
<b>Data source:</b>		
<a href="#">GNSS Time Series</a>		

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

### GPS Data Analysis

Select GPS data

Postseismic

Latitude		
Longitude		
Width	1 degree	
Height	1 degree	
Epoch	YYYY-MM-DD	
Ref. Site	4-letter code	<input type="button" value="Stations"/>
Scale	320 mm/yr/deg	
Coseismic Win.	0.1 years	
Postseismic Win.	2 years	
Output Prefix		
<input type="checkbox"/> Minimize Marker Size		
<input type="checkbox"/> Display absolute verticals		
<input type="checkbox"/> Include error ellipses		
<input type="button" value="Run"/>		
<b>Data source:</b>		
<a href="#">GNSS Time Series</a>		

Figure 10: 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.

**GPS Data Analysis**

Select GPS data

Displacement

Draw an area on map   Clear GNSS Layers

Latitude		
Longitude		
Width	1 degree	
Height	1 degree	
Epoch 1	YYYY-MM-DD	
Epoch 2	YYYY-MM-DD	
Ref. Site	4-letter code	<b>Stations</b>
Scale	320 mm/yr/deg	
Av. Win. 1	10 days	
Av. Win. 2	10 days	
Output Prefix		

Use NGL data  
 Minimize Marker Size  
 Display absolute verticals  
 Include error ellipses

**Run**

**Data source:**  
**GNSS Time Series**

Figure 11: Displacement Analysis

## GPS Data Analysis

Select GPS data

Model

Latitude	
Longitude	
Width	1 degree
Height	1 degree
Epoch 1	YYYY-MM-DD
Epoch 2	YYYY-MM-DD
Ref. Site	4-letter code
Scale	320 mm/yr/deg
Output Prefix	

Minimize Marker Size  
 Display absolute verticals  
 Include error ellipses

**Data source:**  
**GNSS Time Series**

Figure 12: Model Analysis



# Seismicity

The seismicity tab allows users to display earthquakes in a region over a specified period. *Figure 1* displays GeoGateway’s Seismicity tab. The tab is split into two sections, “Recent Earthquakes from USGS” and “Search Earthquake Catalog.”

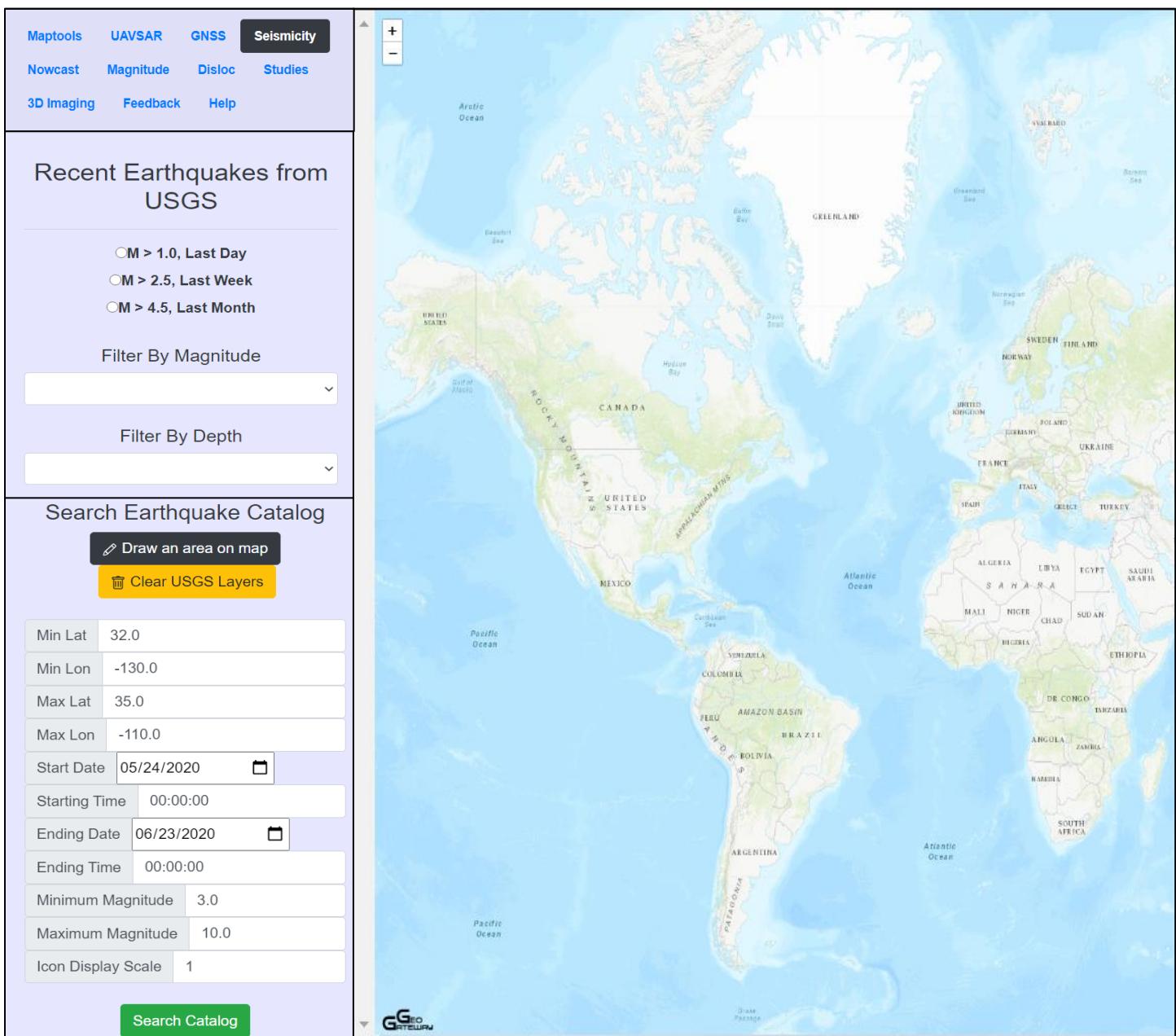


Figure 1: GeoGateway’s Seismicity tab



The tab allows users to view recent earthquakes from USGS data. The USGS data can also be found on the USGS website [earthquake.usgs.gov/earthquakes/map/](http://earthquake.usgs.gov/earthquakes/map/). As shown in *figure 2*, the displayed earthquake events are color coded with the hotter colors representing recent events and the cooler colors representing less recent events.

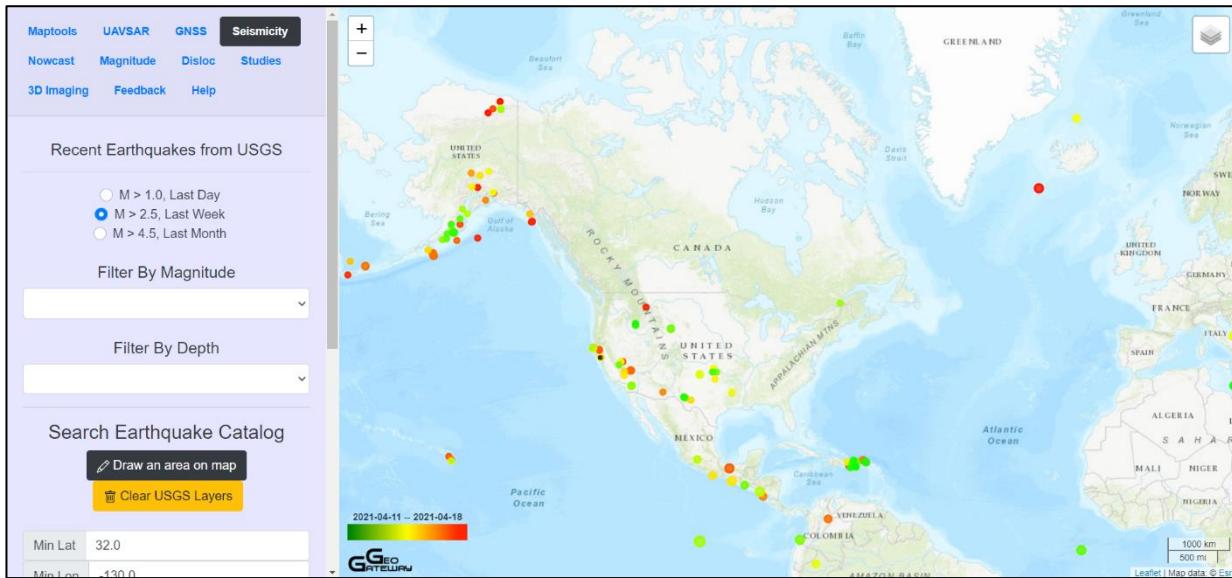


Figure 2: GeoGateway's Seismicity tab - displaying seismic events greater than magnitude 2.5 in the last week.

Filters, such as **M > 1.0, Last Day**, **M > 2.5, Last week**, and **M > 4.5, Last Month** can be selected as shown in *figure 2*. As shown below, additional filters may be applied to generate recent earthquakes. The **Filter By Magnitude** (*figure 3b*) option allows users to choose additional filters, such as  $M > 5$  and  $M > 6.5$ . The **Filter By Depth** (*figure 3c*) option allows users to filter for a Depth  $\leq 30$  km.

Figure 3:  
(3a) USGS recent earthquake's additional filter options (Filter By Magnitude and Filter By Depth)  
(3b) Filter by magnitude greater than 5 or greater than 6.5.  
(3c) Filter by depth less than or equal to 30 km

Filter By Magnitude

Filter By Depth

Filter By Magnitude

No Filter  
M > 5  
M > 6.5

Filter By Depth

No Filter  
Depth  $\leq 30$ km

To search for a particular earthquake event, input specific parameters pertaining to the event in the **Search Earthquake Catalog** section.

**Box 1-4** require users to input the latitudes and longitudes of the specified region. Users have the option to use the “Draw an area on map” feature to generate earthquake events onto the map based on the region drawn by the user.

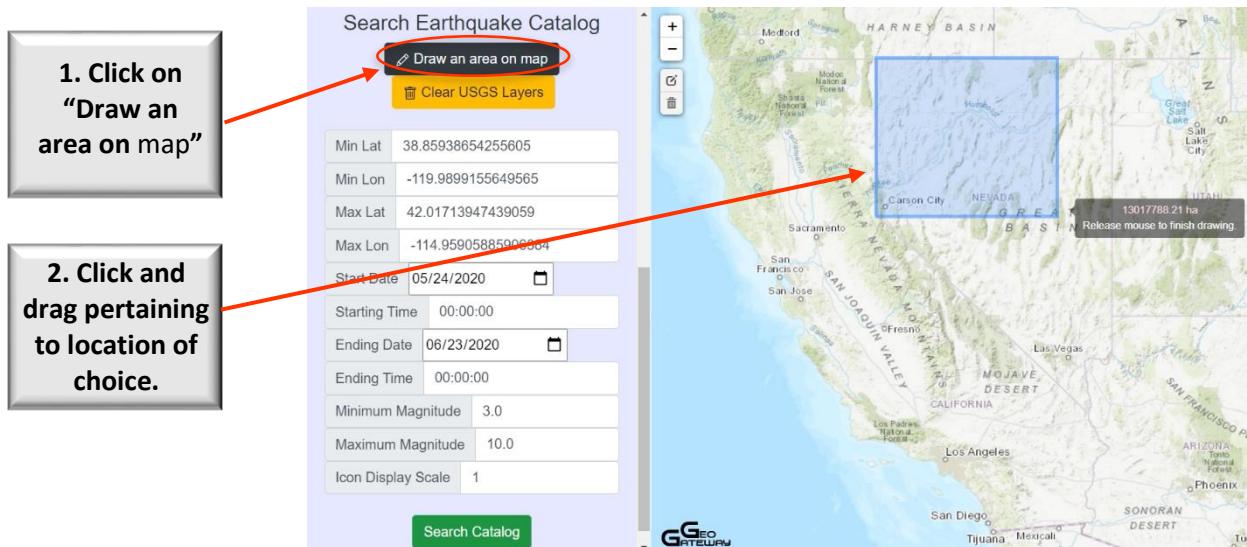


Figure 4: Draw an area on map option

**Box 5-8** require data regarding the range of date and time of interest.

**Box 9-10** require the range of chosen magnitude.

**Box 11** requires the user to scale the size of the icon of the earthquake event, by inputting a number (larger number = larger icon).

By clicking on **Search Catalog** earthquake events based on the given parameters inputted by the user are shown on the map.

To clear the inputted USGS data, click on **Clear USGS Layers** right below to **Draw an area on map** option.

Moreover, users are given the option to download “USGS KML” and “GeoJSON.”

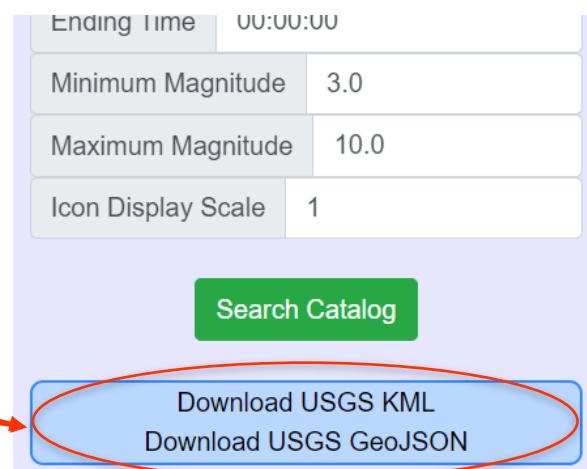


Figure 5: Download USGS KML and GeoJSON.



# Nowcast

GeoGateway's Nowcast tab consists of useful tools to evaluate earthquake hazard and risk generated by the [Open Hazards Group](#).

Users have the option to choose from

- Global Forecast
  - Heat Map (M>6.5, 1 Year)
  - Warm colors represent high risk and cool colors represent low risk
- California Forecast
  - Heat Map (M>5, 1 Year)
  - Warm colors represent high risk and cool colors represent low risk
- Display California faults
- Display Global Disaster Alerting Coordination System (GDACS) Data
- Generate Nowcast Plots, resulting in earthquake potential scores

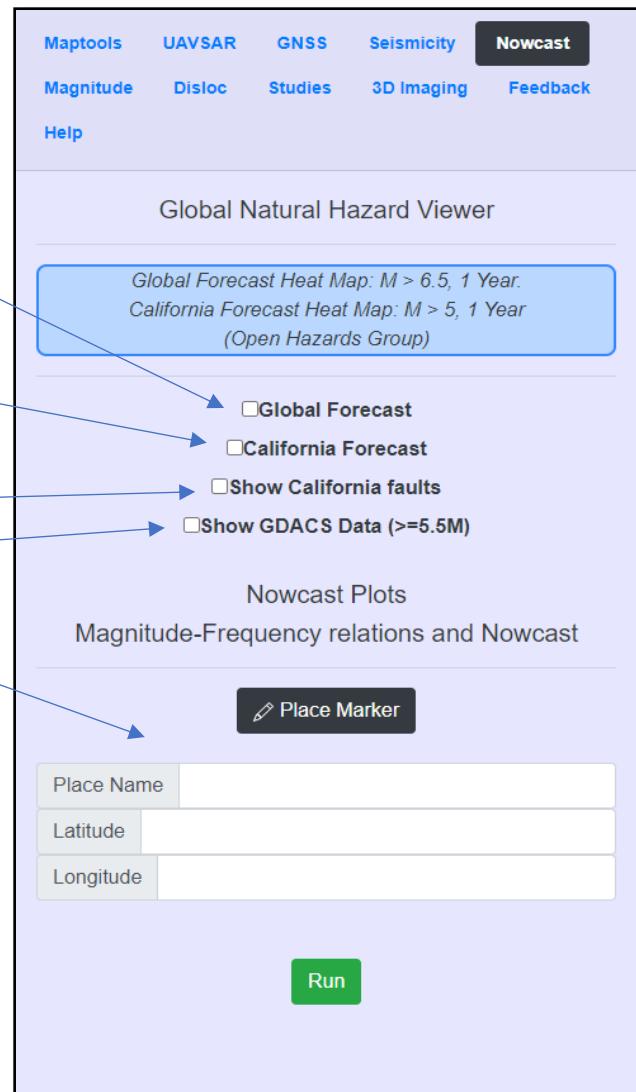


Figure 1: Nowcast tab

By clicking on the “Global Forecast” option, users are able generate a heat map which forecasts magnitudes greater than 6.5 in a year. *Figure 2* displays the risk associated for such forest along portions off the coast of Alaska, Canada, northern United States. High risk is represented through warm colors and low risk is represented as cool colors. By clicking on any part of the layer, users are able to see the risk associated with the location of interest.



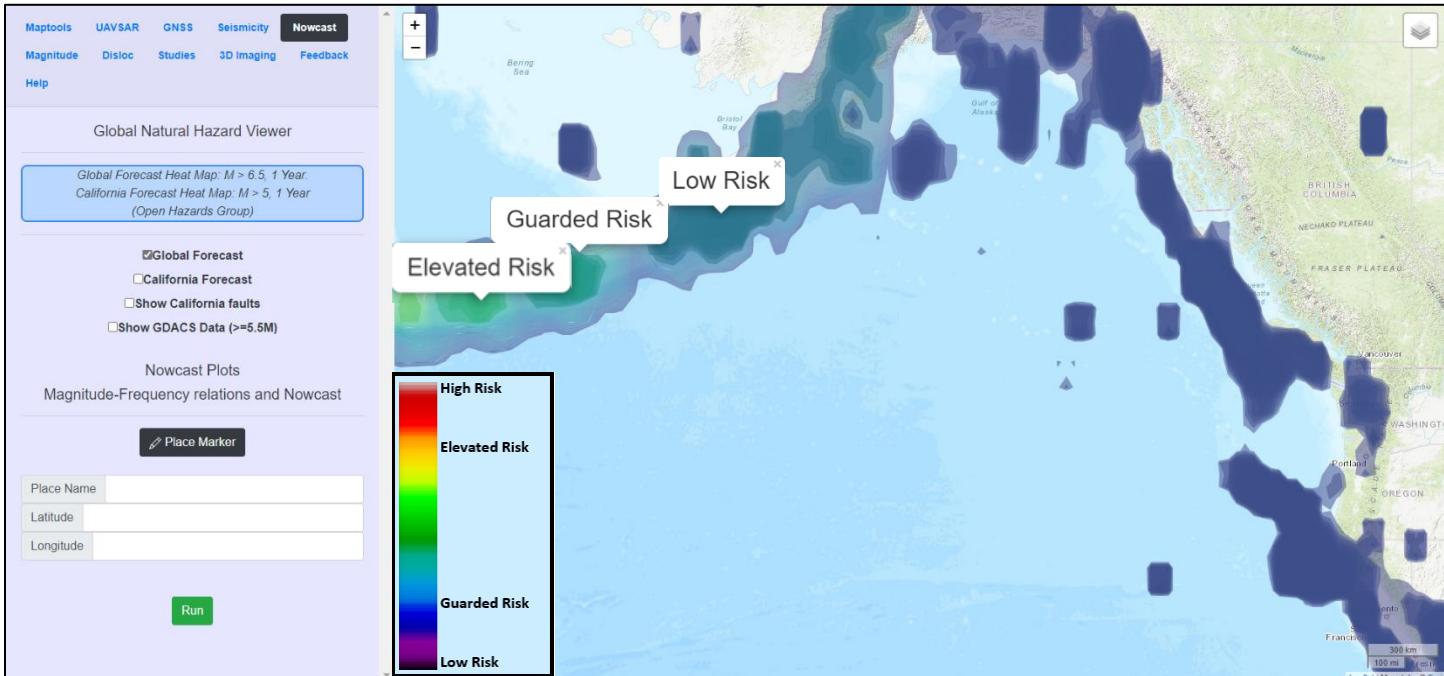


Figure 2: Display of global forecast heat map along the coast of parts of Alaska, Canada, and Northern United States

By clicking on the “California Forecast” option, users are able generate a heat map which forecasts magnitudes greater than 5 in a year. *Figure 3* displays the risk associated for such forest within California and parts of Nevada.

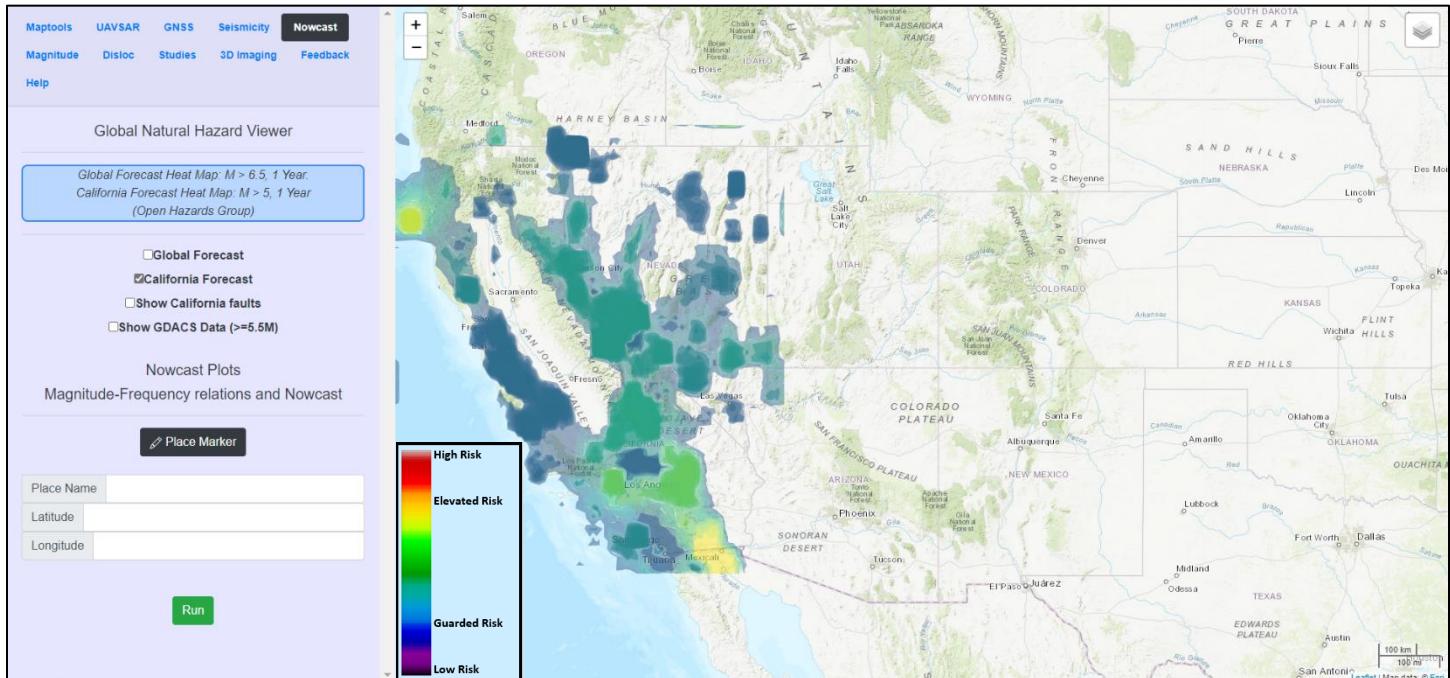


Figure 3: Display of California forecast heat map within California and parts of Nevada



By clicking on “show GDACS Data ( $\geq 5.5M$ )” option, Global Disaster Alerting Coordination System (GDACS) data for earthquakes greater than or equal to 5.5 is displayed. *Figure 4* displays GDACS data off the coast of Fiji.

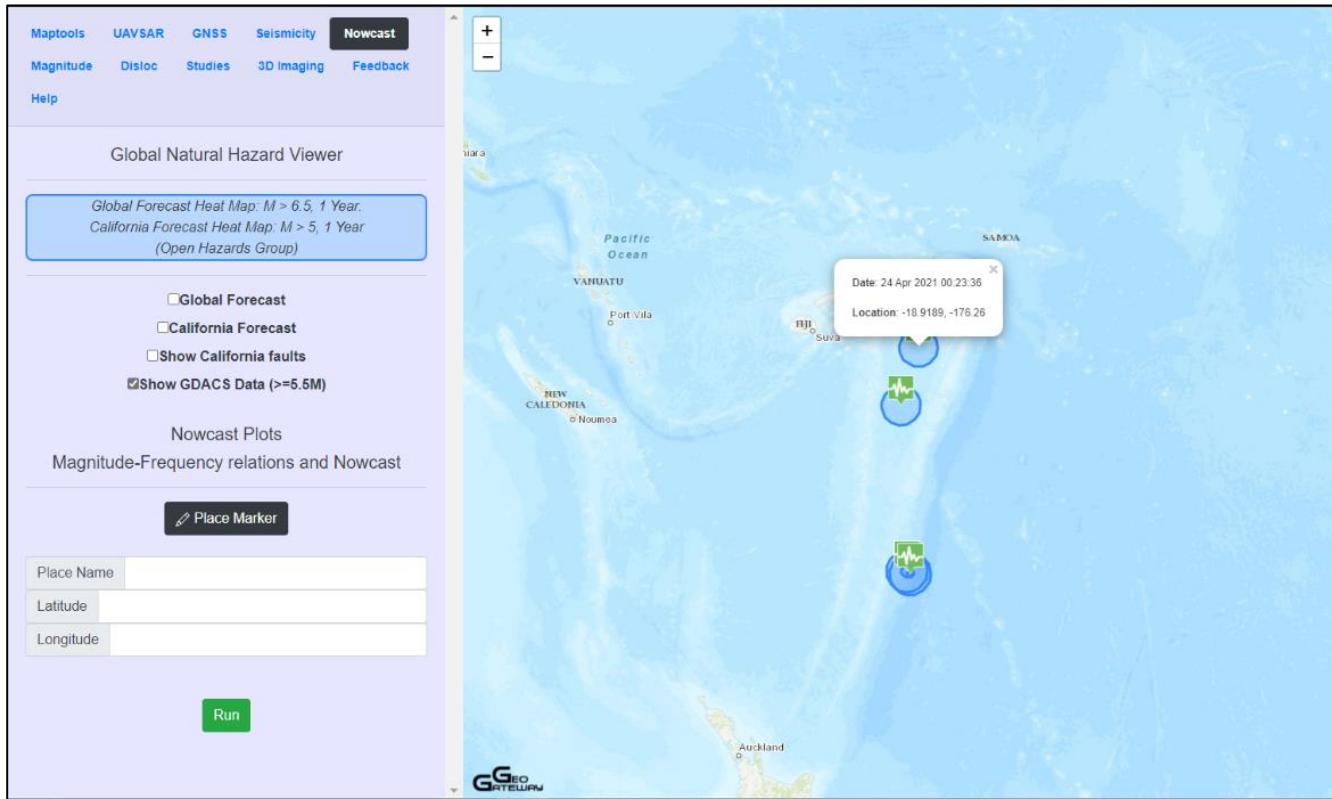


Figure 4: Global Disaster Altering Coordination System data off the coast of Fiji

The second section of the tab allows for users to generate Nowcast Plots pertaining to the potential score that characterizes the current state of progress of a defined geographic region through its normal earthquake “cycle.” Nowcasting is the prediction of the present, the very future and the very recent past, and it uses proxy data to estimate the current dynamical state of a driven complex system such as earthquakes, neural networks, or the financial markets (Donnellan et al., 2021).

Seismic nowcasting uses counts of small earthquakes as proxy data to determine the natural time. The count of small earthquakes since the last large earthquake is the natural time that has elapsed in the last large earthquake. The proxy data allows for an estimate of the current dynamical state of an earthquake fault system.



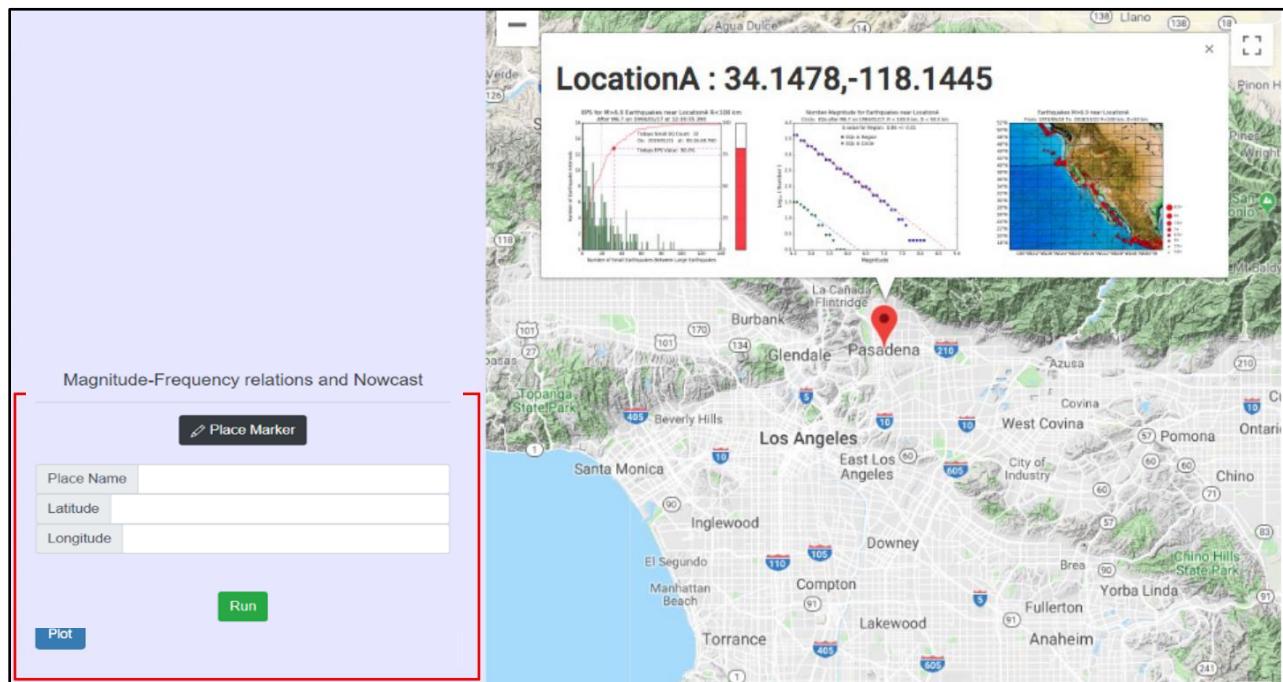


Figure 5: Nowcast plots for LocationA

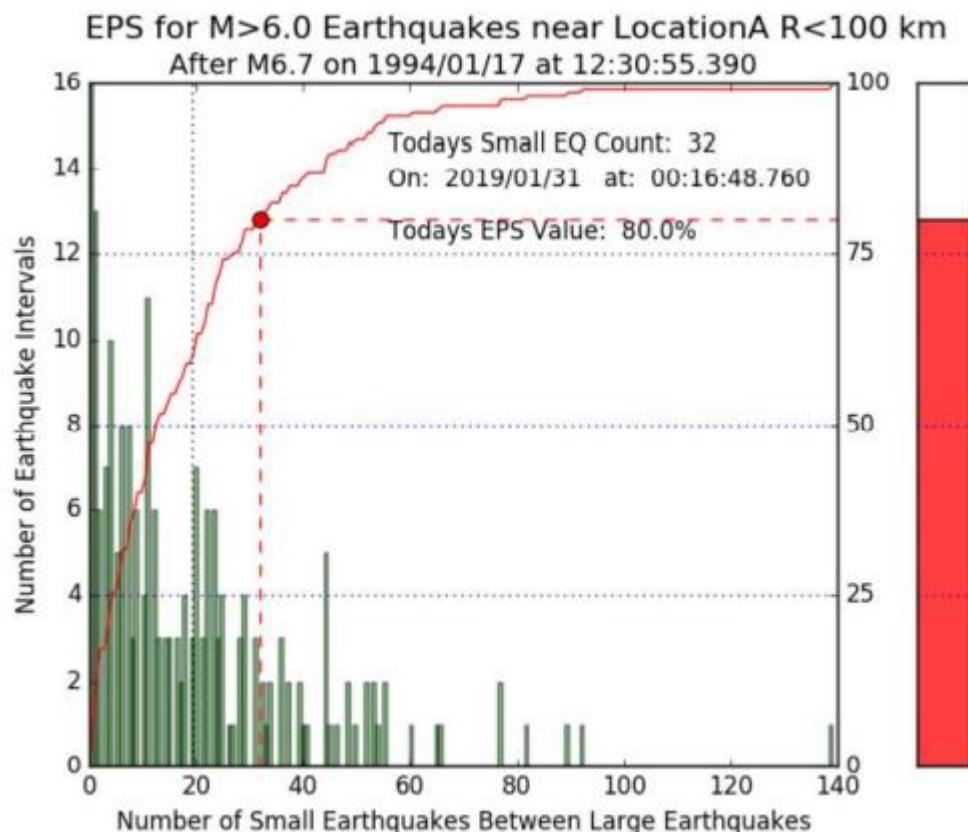


Figure 6: Earthquake Potential Score for LocationA (Pasadena, CA)



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 *figure 6* 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%.

*Figure 7*'s data displays “Number-Magnitude” statistics. The blue squares represent all the earthquakes  $\geq 3$  and the lower green circles show earthquakes  $3 \leq X < 6.5$ .

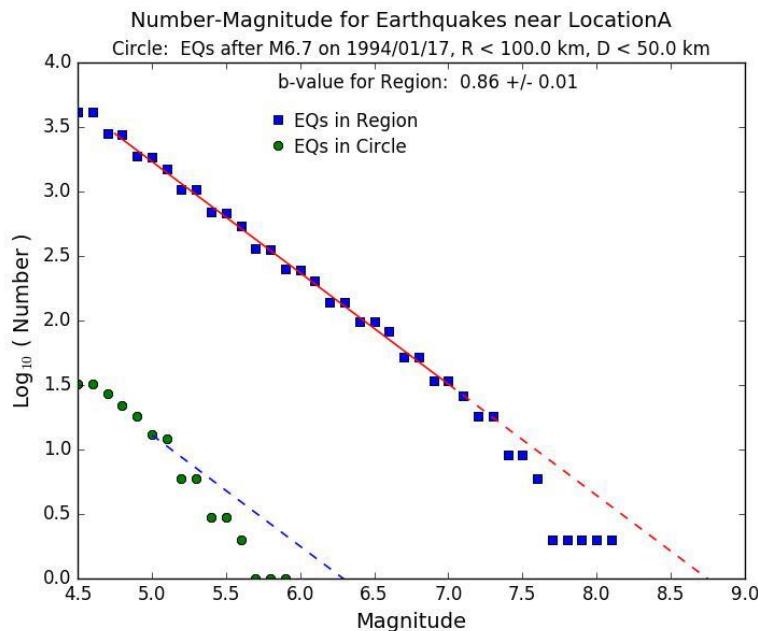


Figure 7: Number-Magnitude for Earthquakes near LocationA (Pasadena, CA)

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

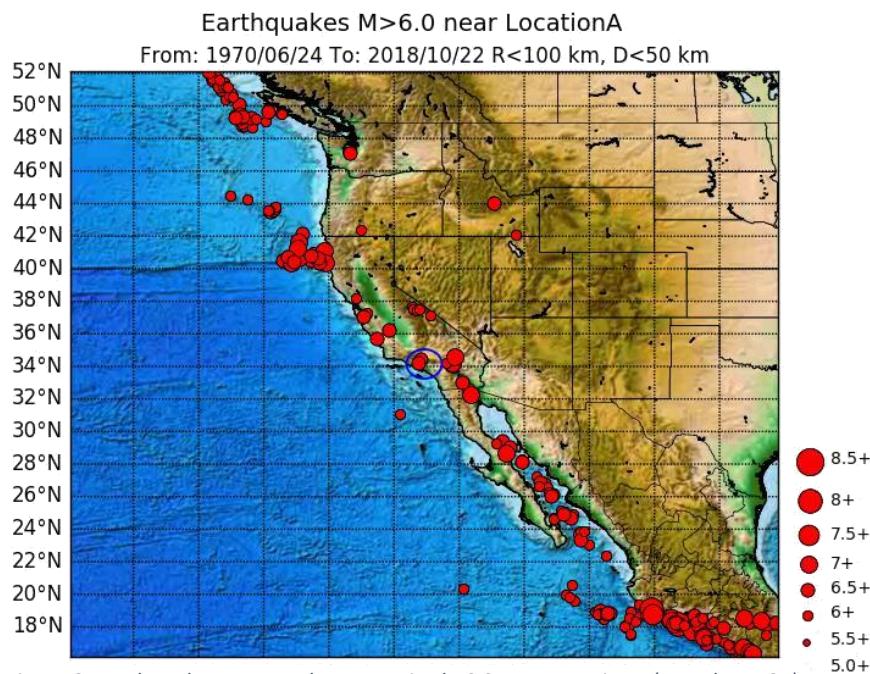


Figure 8: Earthquakes greater than Magnitude 6.0 near LocationA (Pasadena, CA) from 1970/06/24 to 2018/10/22



# Magnitude

Magnitude is the physical size of an earthquake. In *figure 1*, notice the magnitude scale in correspondence to the earthquake's energy equivalence.

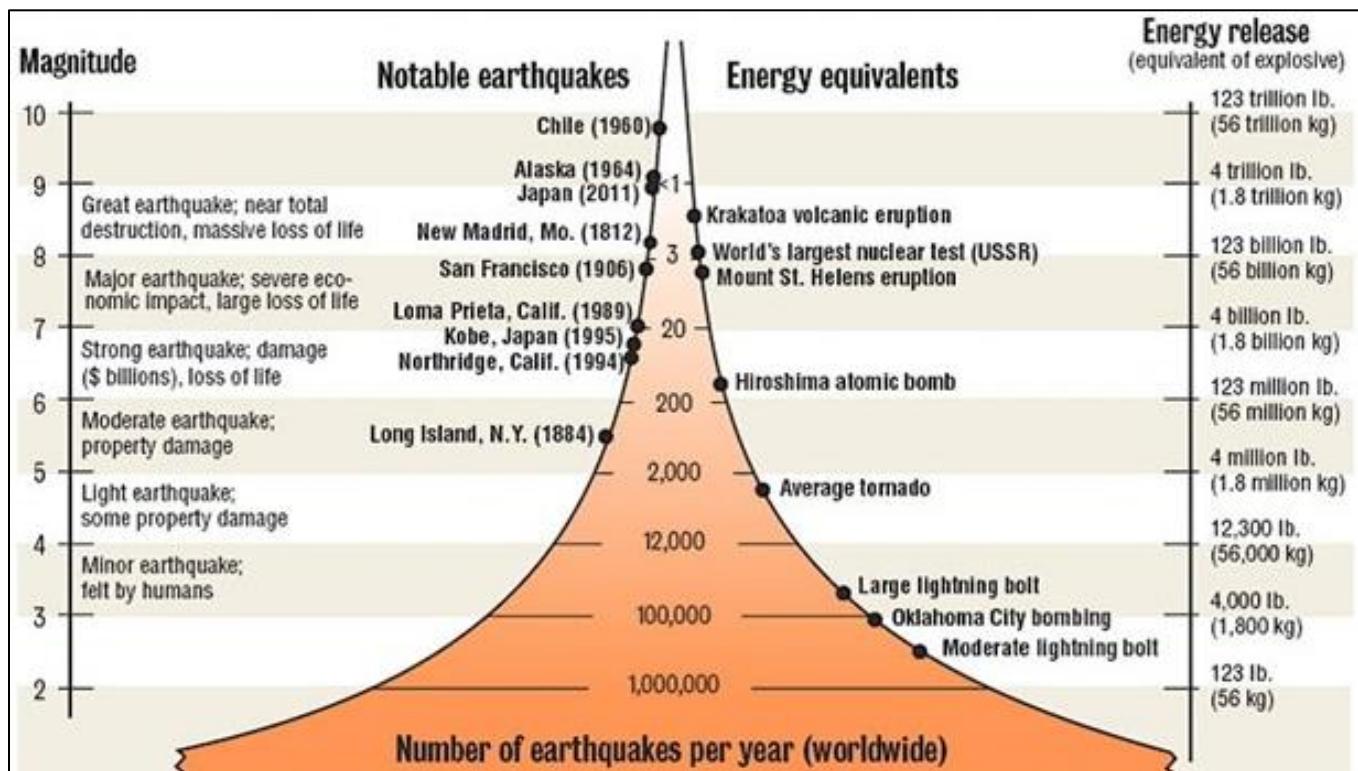


Figure 1: Seismic wave energy in earthquakes and energy equivalents. (Figure adapted from (Incorporated Research Institutes for Seismology, IRIS))

Both seismic moment and moment magnitude ( $M_w$ ) can be calculated using GeoGateway's moment magnitude calculator. As shown in *figure 2*, **seismic moment** equates to the product of the shear modulus, rupture area, and slip length, and **moment magnitude** equates to the product of two-thirds the log base of seismic moment, subtracted by 10.73.

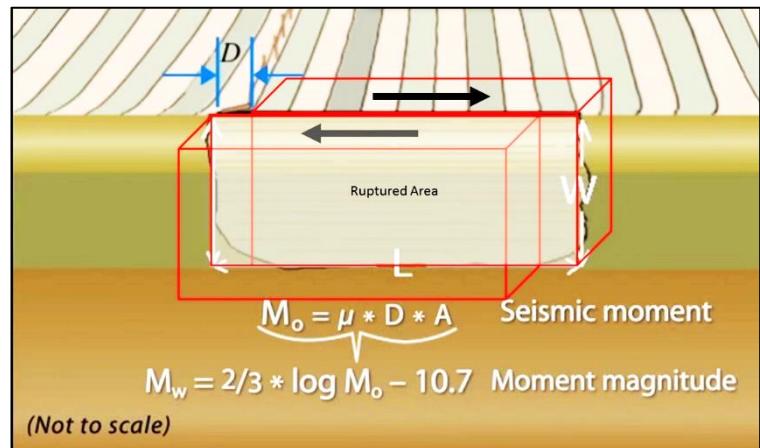


Figure 2: Represents the seismic moment and moment magnitude equations. (Figure adapted from (Vista Heights Middle School))

## The shear modulus ( $\mu$ ) is

$3.2 \times 10^{11}$  dynes/cm<sup>2</sup> in the crust  
 $7.5 \times 10^{11}$  dynes/cm<sup>2</sup> in the mantle

The area (km<sup>2</sup>) as shown in *figure 2* can be found by using the length (L) and width (W). The slip (meters) is the average displacement (D) of the rupture.

Step 1: To begin calculations,  
click on the “Magnitude” tab

Step 2: Once the tab is open, input the  
fault length that ruptured in kilometers

Step 3: Input the fault width that ruptured, in  
units of kilometers

Step 4: Input the distance the fault moved (slip),  
in units of meters

Step 5: Input the shear modulus in units of  $\frac{10^{11} \text{ dyne}}{\text{cm}^2}$

Step 6: Click on Calculate



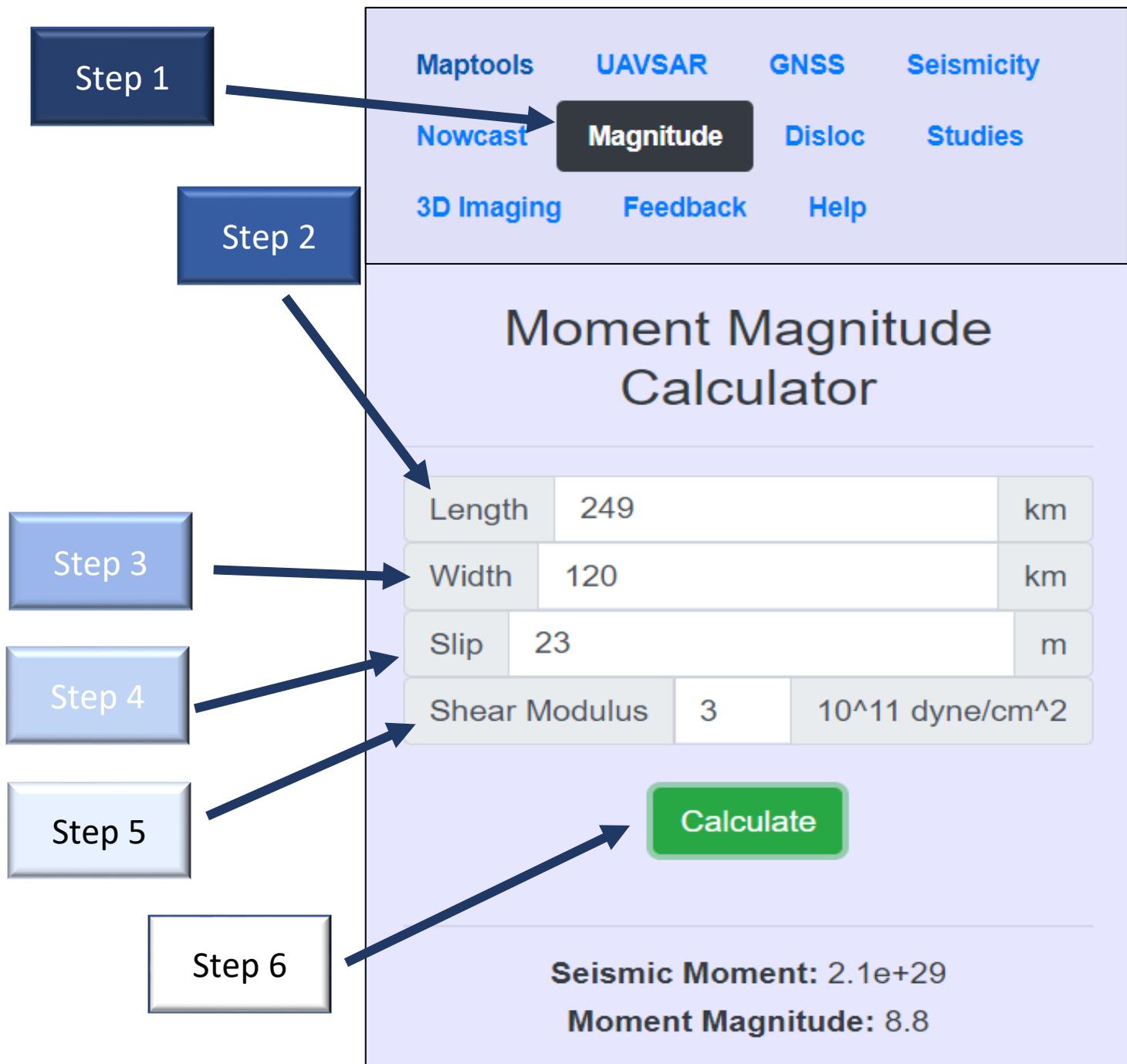


Figure 3: Calculating seismic moment and moment magnitude of 2011 Tohoku-Oki earthquake.

GeoGateway has set the moment magnitude 9.0 Tohoku-Oki earthquake as default. The results indicate a seismic moment of  $2.1 \times 10^{29}$  dyne\*cm and a moment magnitude of 8.8.



# Disloc

Elastic dislocation models are commonly used to analyze inversion on faults following the event of an earthquake (Chen et al., 2020). In 1985, Yoshimitsu Okada (Ph.D.) proposed a formula which calculated displacement in an isotropic, uniform elastic half space. The formula can calculate coseismic deformation caused by any fault within the elastic half space (Okada, 1985). Okada's dislocation theory, which is the most commonly used dislocation theory, is often used with InSAR. InSAR monitors the surface coseismic deformation field, and subsequently, Okada's theory is used to conduct fault slip inversion, calculating the coseismic strain stress field (Chen et al., 2020). Elastic dislocation models generated by Disloc can be used to geodetically measure deformation of an elastic medium due to slip from active faults (Avouac, n.d.).

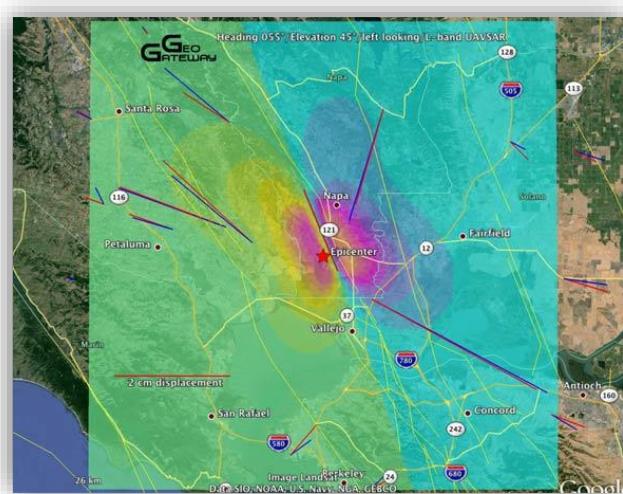


Figure 1: Example of Okada's dislocation in an elastic half space (figure adapted from NASA's GeoGateway team).

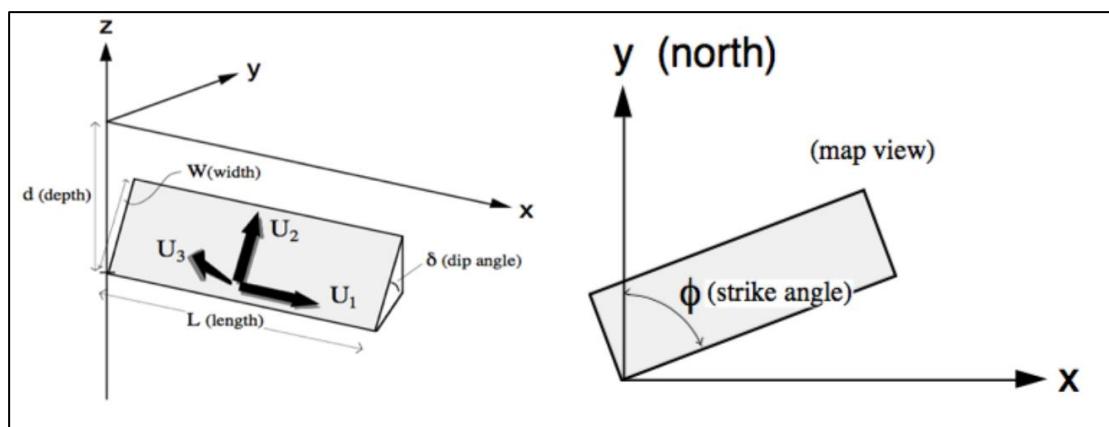


Figure 2: Elastic Dislocation Fault Parameters (figure adapted from Harvey Mudd College)

In figure 3, the **location** of the fault is defined as the surface projection of the lower-left corner of the fault plane. The **depth** is represented as the z-coordinate of the fault's bottom edge. The **dip** angle is measured from horizontal (Harvey Mudd College, n.d.).

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 (Harvey Mudd College, n.d.).

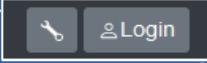
**U<sub>1</sub>** is the strike slip component of fault slip (strike-slip dislocation U<sub>1</sub> greater than 0 identifies a right lateral motion).

**U<sub>2</sub>** is the dip slip component of fault slip (dip-slip dislocation U<sub>2</sub> greater than 0 identifies a reverse motion).

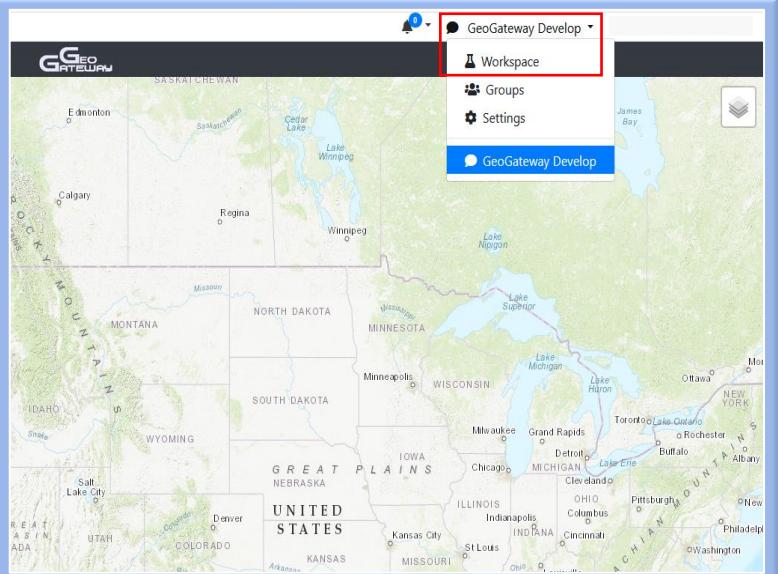
**U<sub>3</sub>** is the tensile component of fault slip (tensile dislocation U<sub>3</sub> greater than 0 identifies a tensile opening).

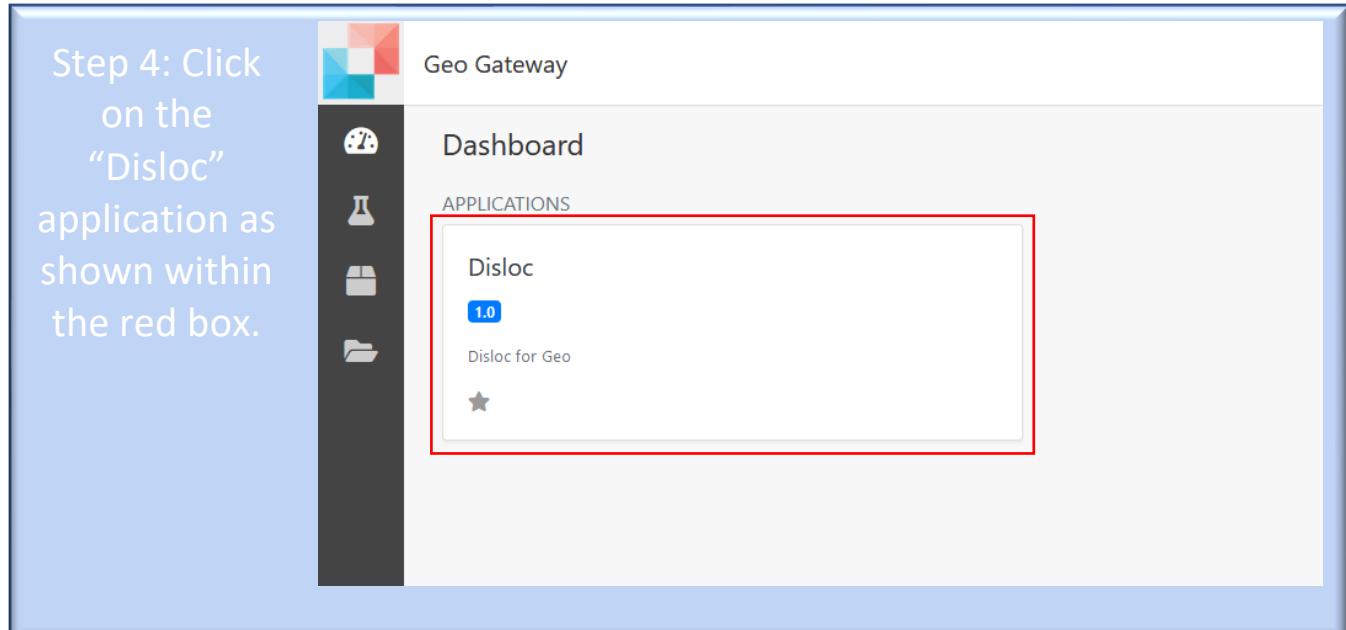
To run Disloc, visit the Disloc tab on GeoGateway and follow the following steps.

Step 1: Create an account on GeoGateway by visiting  
<https://geo-gateway.org/auth/create-account>

Step 2: Log into GeoGateway by clicking on the “” button on the left corner found on GeoGateway’s homepage.

Step 3: On the upper right corner on GeoGateway’s homepage, click on “GeoGateway Develop,” and then click on “Workspace.”





Step 5: Users must upload their Disloc files into the area shown in the red box. Users have the option to change the experiment name and add a description by clicking on “Add a description.” Users may also change the “elevation,” “azimuth,” and “radar frequency,” of their choice as shown in the image to the right. Lastly, click on the green button, “Save and Launch.” Note the data might take a couple of minutes to load.

To find the output files, click on the Erlenmeyer flask found on the left side of the page. There the output file name will be displayed. To view the output files, click on the experiment of interest.

Browse Experiments

Search Experiments Select an attribute to search by Select an experiment status to filter by Reset Search

Select a date range to filter by

Name	Application	Creation Time	Status	Actions
<a href="#">Disloc on May 12, 2021 11:49 AM</a>	Disloc	a day ago	COMPLETED	<a href="#">Clone</a>
<a href="#">Disloc on May 12, 2021 10:23 AM</a>	Disloc	a day ago	COMPLETED	<a href="#">Clone</a>
<a href="#">Disloc on May 12, 2021 9:57 AM</a>	Disloc	mmirkhan	a day ago	COMPLETED <a href="#">Clone</a>

Showing 1 - 3

In the image below, the experiment summary and output files are displayed. Now, users may download each of these files.

Geo Gateway

Experiment Summary

Share 2 Clone

- Disloc Output
- [output.csv](#)
- Disloc-Standard-Error
- [Disloc.stderr](#)
- Disloc-Standard-Out
- [Disloc.stdout](#)
- KMZ Output File
- [output.csv.insar.kmz](#)

User Input Copy

4fault.txt  
input.txt

	A	B	C
1	201 101 32.705002 -115.911331		
2	69.11097717285156 -60.93335342407227 -5		
3	14 45 1 1 -450 -600 0 33.14		
4	x y ux uy uz exx exy eyy		
5	-100.000002 -10.000000 -2.311e+00 6.078e-01 -3.776e-01 -2.695e-02 6.8		
6	-99.000002 -10.000000 -2.338e+00 6.166e-01 -3.813e-01 -2.741e-02 6.99		
7	-98.000000 -10.000000 -2.366e+00 6.256e-01 -3.850e-01 -2.787e-02 7.17		
8	-97.000000 -10.000000 -2.394e+00 6.348e-01 -3.887e-01 -2.835e-02 7.36		
9	-96.000002 -10.000000 -2.422e+00 6.442e-01 -3.925e-01 -2.884e-02 7.55		
10	-95.000002 -10.000000 -2.451e+00 6.538e-01 -3.963e-01 -2.933e-02 7.74		
11	-94.000002 -10.000000 -2.481e+00 6.635e-01 -4.002e-01 -2.984e-02 7.94		
12	-93.000000 -10.000000 -2.511e+00 6.735e-01 -4.041e-01 -3.036e-02 8.15		
13	-92.000002 -10.000000 -2.542e+00 6.837e-01 -4.081e-01 -3.089e-02 8.37		
14	-91.000000 -10.000000 -2.573e+00 6.942e-01 -4.121e-01 -3.143e-02 8.59		
15	-90.000000 -10.000000 -2.605e+00 7.048e-01 -4.162e-01 -3.199e-02 8.82		

Figure 3: output.csv

Figure 3 displays the output.csv file which shows the x, y,  $U_1$ ,  $U_2$ , and  $U_3$  (refer to figure 2), and  $exx$ ,  $exy$ , and  $eyy$  (components of the surface strain) factors. For more information regarding the parameters used please refer to (Okada, 1985).

Referring to Step 5, users must upload a text file. The figure below shows what the text file must include.

**Line 1: Latitude Longitude #** (The latitude and longitude are the model origin location, corresponding to  $x = 0, y = 0$ . The # represents 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)

Example of line 1: 32.705000 -115.911333 1

**Line 2:  $x_0 \ x_d \ x_s \ y_0 \ y_d \ y_s$**  (Represents the grid: 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.)

Example of line 2: -100 1 201 -10 1 101

**Line 3:  $x, y$  (km) from origin and strike (degrees)** ( $x$  coordinate and  $y$  coordinate of the first fault and the strike angle of the fault, measured clockwise from north)

Example of line 3: 69.110979 -60.933355 -5

**Line 4: fault type 0 for point dislocation, depth, dip (degrees), lambda ( $\lambda$ ), mu ( $\mu$ ),  $U_1$ ,  $U_2$ ,  $U_3$ , length, width**

(Provide the vertical depth to the *bottom* of the fault, followed by the dip angle in degrees (zero for horizontal; 90° for vertical). The  $\lambda$  and  $\mu$  are 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.)

Example of line 4: 1 14 45 1 1 -450 -600 0 33 14

---

Repeat the formatting from line 3 and line 4 for each additional fault.

Example of line 5 (same format as line 3): 56.877979 -45.030355 -48

Example of line 6 (same format as line 4): 1 15 75 1 1 -830 0 0 51 15

Example of line 7 (same format as line 3): 46.475979 -56.538355 132

Example of line 8 (same format as line 4): 1 14 60 1 1 -830 0 0 60 14

Example of line 9 (same format as line 3): 25.940979 -9.411355 -25

Example of line 10 (same format as line 4): 1 12 50 1 1 -100 0 0 18 12

Figure 4: Dislocation input data

To allow the output file to be shown on GeoGateway, return to the Disloc tab on the GeoGateway website and click on “Load Experiments” as shown in the image below. Once the experiments appear, click on the green highlighted text

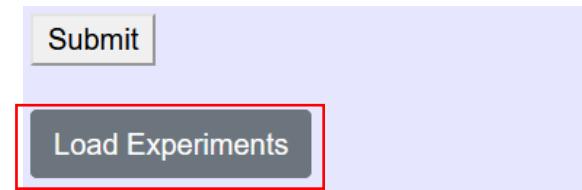




Figure 5: Dislocation output data displayed on map on GeoGateway. The image is in correspondence to line's 1-4 from figure 4.



Figure 6: Dislocation output data displayed on map on GeoGateway. The image is in correspondence to line's 1-10 from figure 4.



# Special Studies

GeoGateway's Special Studies tab comprises of listed products for demonstration purposes.

The study includes wildfire burn areas and debris flows imaged with UAVSAR following the Southern California 2018 Woolsey Fire shown in figure (2) below; and the 2017 Montecito, California fire, in figure (4) below. See *Donnellan et al. 2018* for more information on the Montecito, CA fire.



Figure 1: Woolsey Fire (figure adapted from courtesy of Wally Skalij from the Los Angeles Times)

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Special Studies

**Southern California Woolsey Fire**

Southern California's Woolsey Fire on Nov. 15 observed with UAVSAR

[Woolsey fire perimeter \(11-18-2018\)](#)

[Hill fire perimeter \(11-12-2018\)](#)

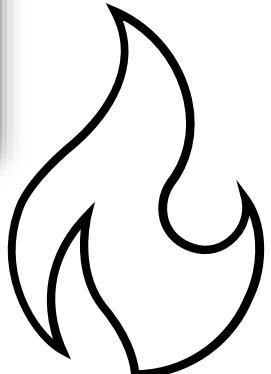
[UAVSAR Correlation Image 1 \(geotiff\)](#)

[UAVSAR Correlation Image 2 \(geotiff\)](#)

Experimental products: JPL/Caltech/GeoGateway

Wildfire and debris flows

Figure 1(a): Woolsey Fire and Hill fire perimeter



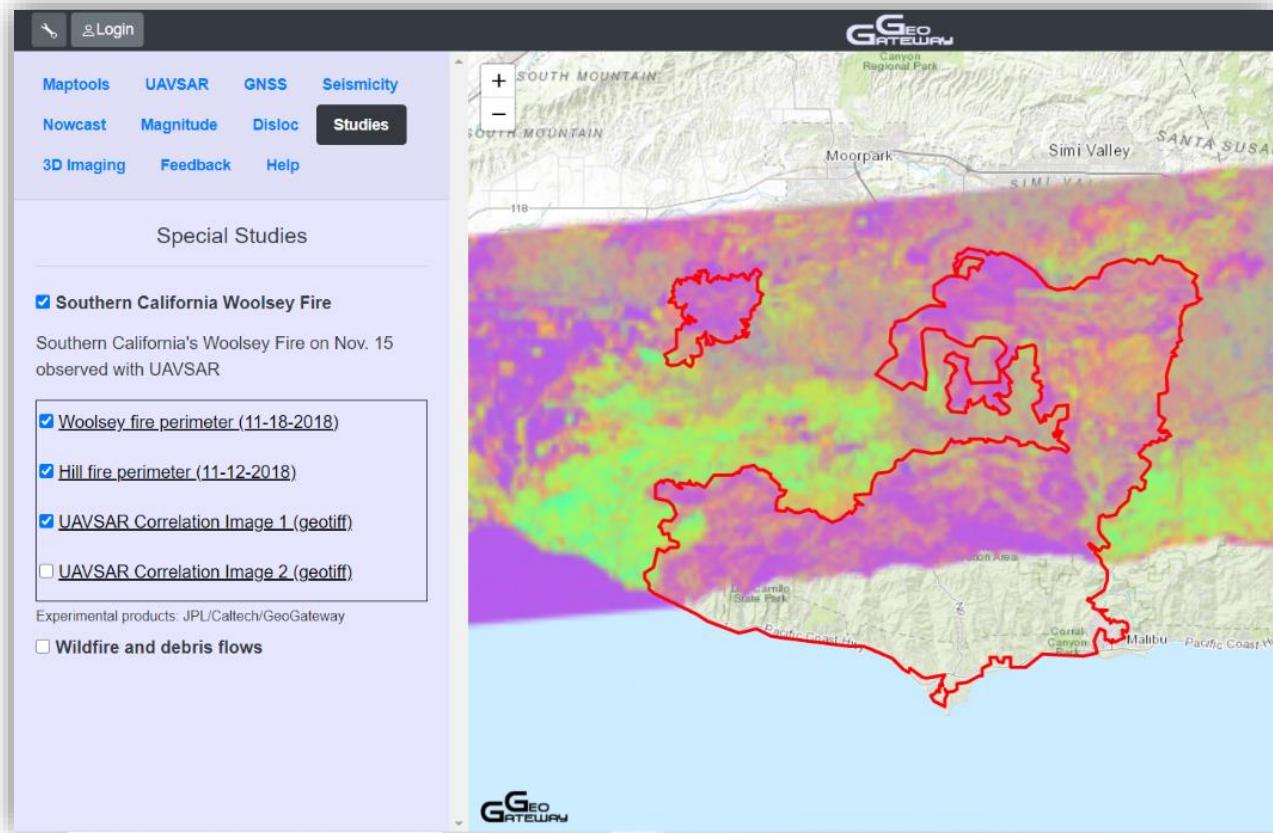


Figure 2(b): UAVSAR correlation image (1) of Woolsey fire. UAVSAR can see through smoke, clouds, and the dark of night.

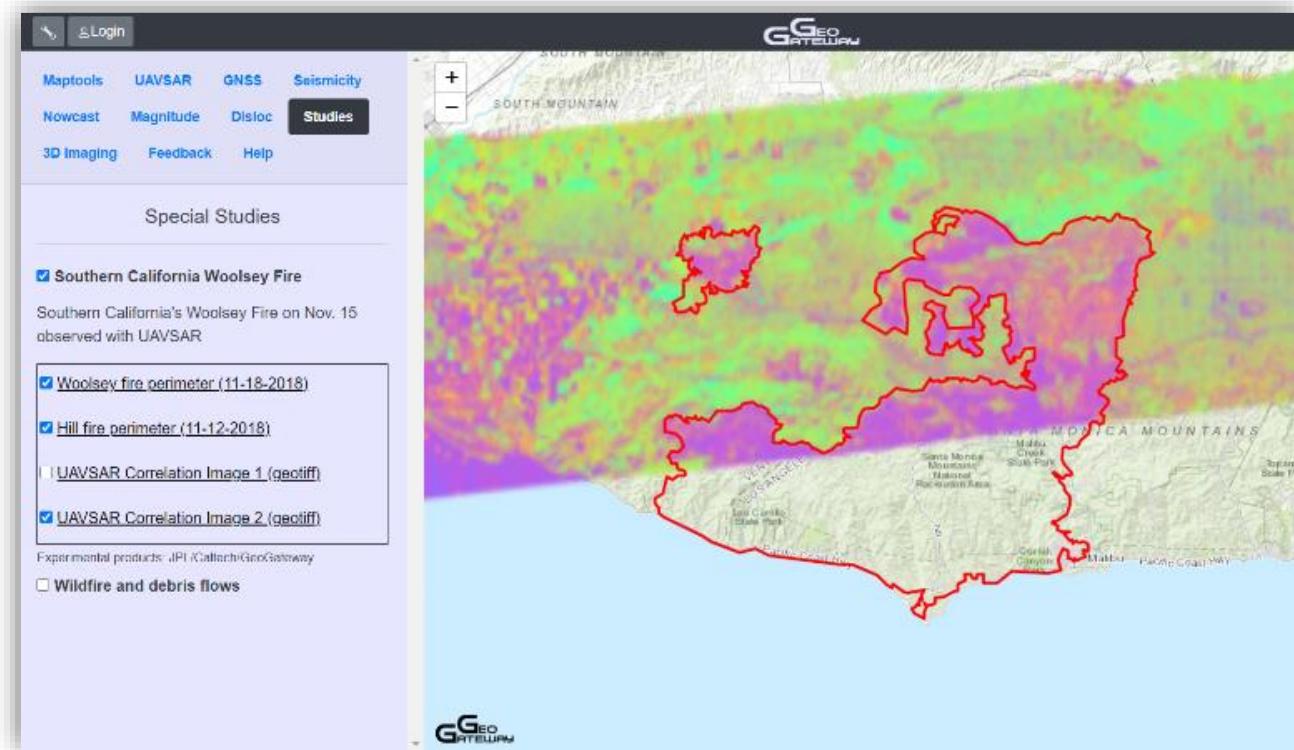
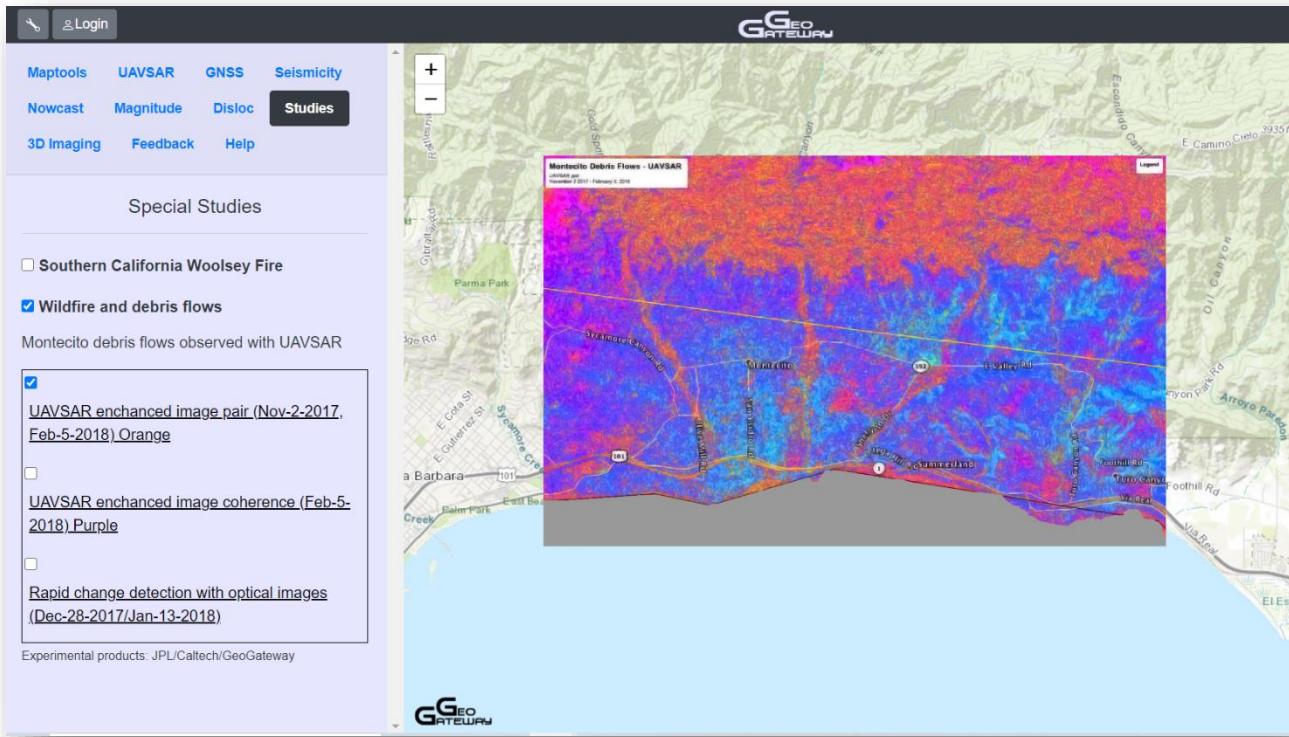


Figure 2(c): UAVSAR correlation image (2) of Woolsey fire.





*Figure 3: Debris flow on Highway 101 following the Thomas Fire in Montecito (figure adapted from courtesy of Trevor Hughes, USA TODAY)*



*Figure 4(a): The image displays UAVSAR high-resolution interferogram that has been despeckled, converted to four colors and contrast increased. Orange represents the disturbed areas, and debris flows can be seen extending from the fire scar south of the*



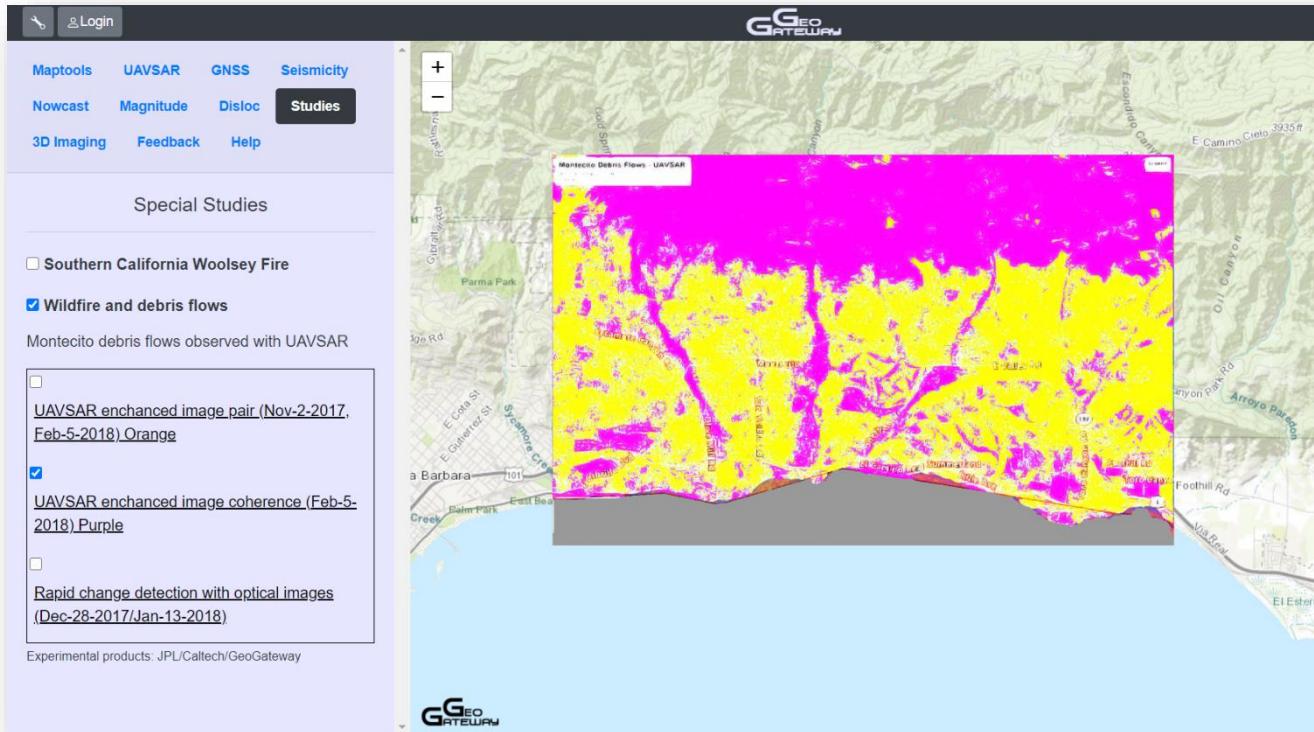


Figure 4(b): The image displays UAVSAR high-resolution correlation image that has been despeckled, converted to two colors and contrast increased. Purple represents the disturbed areas and are decorrelated, and debris flows can be seen extending from the fire scar.

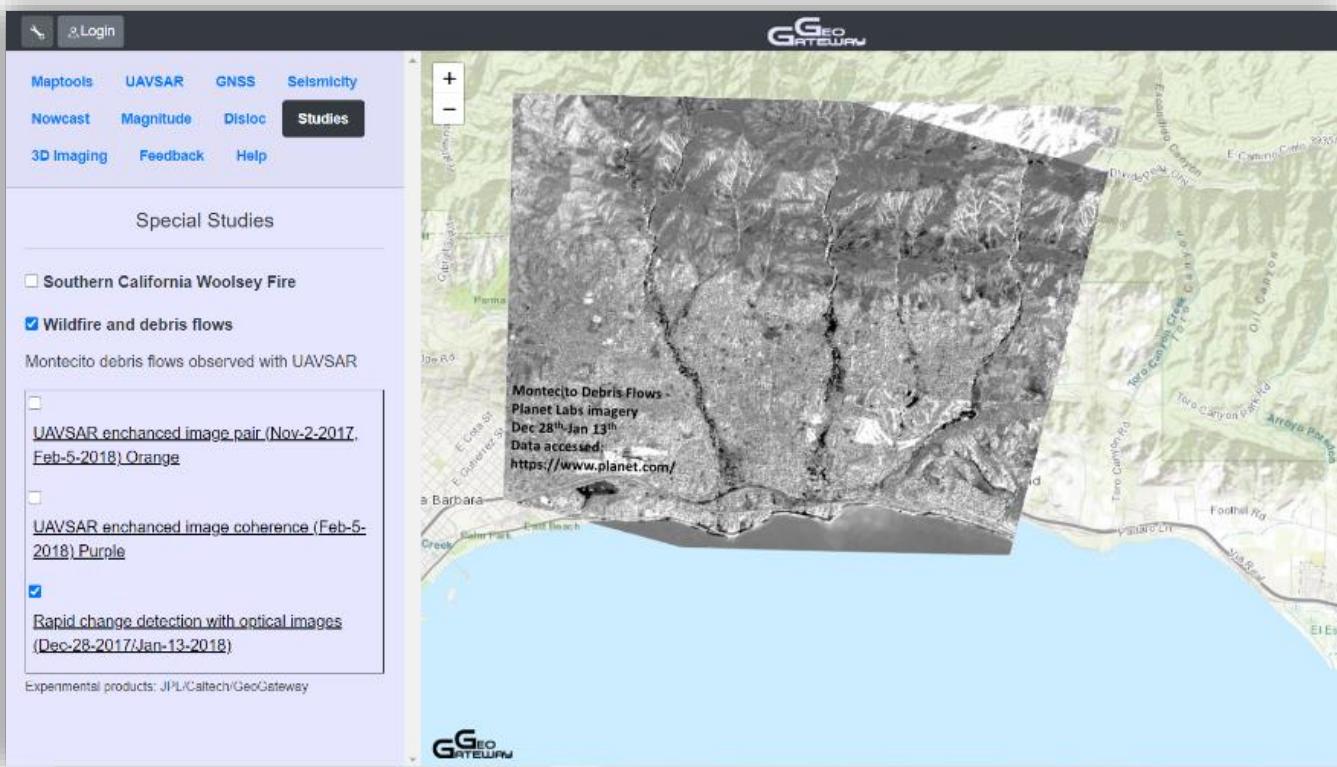


Figure 4(c): Montecito debris flow optical image.



# 3D Imaging

Users can locate postseismic products of the Ridgecrest Earthquake (M6.4 (July 4, 2019) and M7.1 (July 5, 2019)) by navigating to the “3D Imaging” tab and clicking on the box labeled “Postseismic Products of Ridgecrest Earthquake.”

The data was collected by Andrea Donnellan and Gregory Lyzenga.



Figure 1: Earthquake Damage on California Hwy 178  
figure adapted by (Ben Brooks, USGS)

More information regarding the data can be obtained by clicking on the citation below  
[Andrea Donnellan, Gregory Lyzenga, Adnan Ansar, Christine Goulet, Jun Wang, Marlon Pierce; Targeted High-Resolution Structure from Motion Observations over the M<sub>w</sub> 6.4 and 7.1 Ruptures of the Ridgecrest Earthquake Sequence. Seismological Research Letters doi: <https://doi.org/10.1785/0220190274>](#)

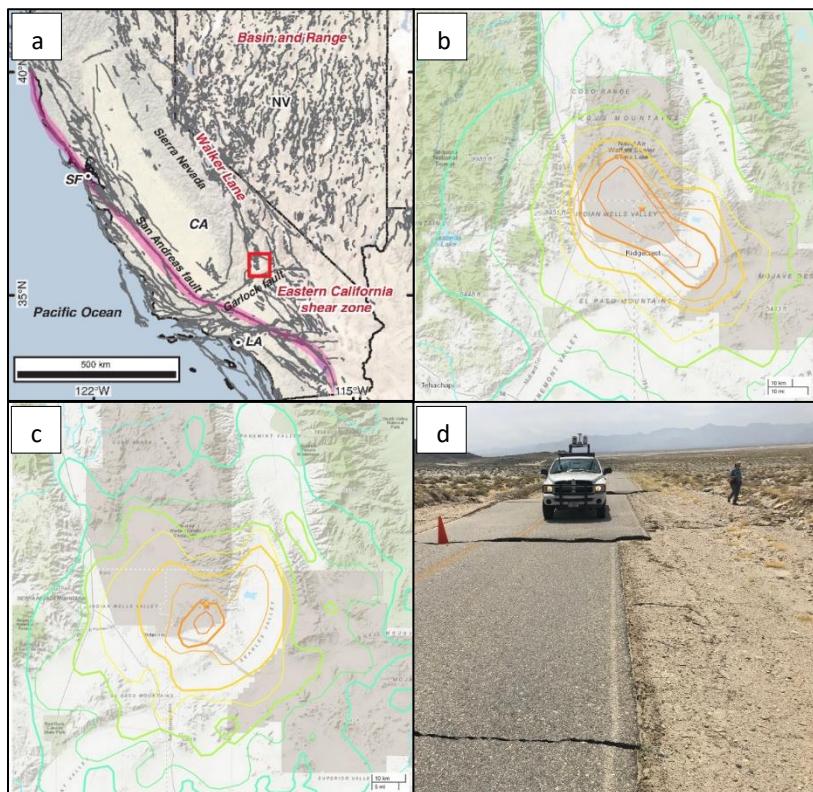


Figure 2: Figures from 2019 Ridgecrest earthquake

2(a) Boxed location shows location of the Ridgecrest earthquakes. Picture adapted from (Jobe et al., 2020)

2(b) Shaking intensity levels associated with each contour color shown for Mw 7.1 earthquake event. Warm colors represent higher intensity and color colors represent lower intensity. Picture adapted from (USGS, 2020).

2(c) Shaking intensity levels associated with each contour color shown for Mw 6.4 earthquake event. Warm colors represent higher intensity and color colors represent lower intensity. Picture adapted from (USGS, 2020).

2(d) Road offset on the road at Naval Air Weapons Station China Lake (NAWSCL) from the M7.1 rupture (Ben Brooks, USGS).



The products included in the 3D Imaging tab comprise of,

1. **Inferred rupture traces and orthomosaic images** for the M6.4 earthquake and M7.1 earthquake, which can be selected by clicking on the corresponding box. The inferred rupture traces can be downloaded as a KML.
2. **Six point cloud** (in LAZ format), which can be downloaded for each earthquake by clicking on “Point Cloud” across the listed dates which range from 2019/07/09 to 2019/09/27. Further, clicking on the “2cm DSM” option will download a 2 cm Digital Surface Model (in LAZ format). A quality report can be accessed by clicking on “Report.”
3. **Digital Surface Model (DSM) and orthomosaic image**, which can be downloaded as a KMZ by clicking on “Products overview (kmz).”
4. **Data from Potree**, a viewer for large point cloud/LIDAR data sets, which can be accessed and viewed by clicking on "View Point Clouds." Potree allows for users to adjust the appearance, clip, measure, export, and complete several other actions to the orthomosaic images.
5. An **animated GIF** of the M7.1 earthquake, which can be accessed by clicking on the “Animated Gif” button under M7.1 products.

Date	Type	Format	Action
2019/07/09	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/07/11	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/07/15	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/07/22	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/08/08	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/09/27	Point Cloud	2cm DSM	<a href="#">Report</a>
<a href="#">Products overview (kmz)</a>		<a href="#">View Point Clouds</a>	

Date	Type	Format	Action
2019/07/09	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/07/11	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/07/15	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/07/22	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/08/08	Point Cloud	2cm DSM	<a href="#">Report</a>
2019/09/27	Point Cloud	2cm DSM	<a href="#">Report</a>
<a href="#">Products overview (kmz)</a>		<a href="#">View Point Clouds</a>	
<a href="#">View Animated Gif</a>			

Figure 3: 3D Imaging tab content



**Maptools UAV/SAR GNSS Seismicity Nowcast Magnitude**

**Disloc Studies 3D Imaging Feedback Help**

Postseismic Products of Ridgecrest Earthquake

High-Resolution Targeted 3D imaging Postseismic Products of the Ridgecrest M6.4 (July 4, 2019) and M7.1 (July 5, 2019) Earthquake Sequence. Collected by Andrea Donnellan and Gregory Lyzenga

The point clouds (in LAZ format) are released with [research article](#). If using these products, please cite Donnellan, A., Lyzenga, G., Wang, J., Pierce, Ma., Goulet, C., 2019. High-resolution Targeted 3D Imaging Postseismic Products of the Ridgecrest M6.4 and M7.1 Earthquake Sequence, DOI: 10.5967/5sq2-v6g0. Full record

Inferred Rupture Traces M6.4

Overview of orthomosaic image M6.4

Inferred Rupture Traces M7.1

Overview of orthomosaic image M7.1

**M 6.4 products**

2019/07/09	Point Cloud	2cm DSM	Report
2019/07/11	Point Cloud	2cm DSM	Report
2019/07/15	Point Cloud	2cm DSM	Report
2019/07/22	Point Cloud	2cm DSM	Report
2019/08/08	Point Cloud	2cm DSM	Report
2019/09/27	Point Cloud	2cm DSM	Report

[Products overview \(kmz\)](#) [View Point Clouds](#)

**M 7.1 products**

2019/07/09	Point Cloud	2cm DSM	Report
2019/07/11	Point Cloud	2cm DSM	Report
2019/07/15	Point Cloud	2cm DSM	Report
2019/07/22	Point Cloud	2cm DSM	Report
2019/08/08	Point Cloud	2cm DSM	Report
2019/09/27	Point Cloud	2cm DSM	Report

[Products overview \(kmz\)](#) [View Point Clouds](#)

[View Animated Gif](#)

SALT WELLS VALLEY

300 m 1000 ft Leaflet Map data © Esri

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# Feedback

GeoGateway's feedback tab is designed for users to submit reports on a bug or feature, provide enhancement ideas or any suggestions, or report any other concerns pertaining to GeoGateway.

The screenshot shows the 'Feedback' tab of the GeoGateway interface. At the top, there is a navigation bar with tabs: Maptools, UAVSAR, GNSS, Seismicity, Nowcast, Magnitude, Disloc, Studies, 3D Imaging, Feedback (which is highlighted in black), and Help. Below the navigation bar is a 'Bug Report Form' section with the sub-section title 'Open form in separate window'. The form includes fields for 'Email (Optional)', 'Report Type' (with options: Bug, Feature, Enhancement, Other), 'Related Tool' (with options: Map Tools, UAVSAR, GNSS, Seismicity, Nowcast, Magnitude, Disloc, Help, Other), 'Description' (a large text area), and 'Screenshots' (a section for uploading files). A note says 'Use screenshots of related tool to help us solve the problem'. At the bottom, there is a 'Drop files or click here to upload' field and a blue button with a right-pointing arrow. The footer says 'Powered by Qualtrics'.

**Navigate to the “Feedback” tab.**

**Input email (optional).**

**Choose the report type. Users may also provide recommendations for the GeoGateway team by selecting “other.”**

**Choose the tool or tab to file the report on**

**Users should include a description on what they want to report.**

**Include screenshots if need be.**

**Left click on the blue box with the arrow to send in the report.**



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