

UNAVCO: Network of the Americas (NOTA)

Chad Pyatt

NOTA Northwest

Oregon GNSS Users Group - June 17, 2022



GAGE

National Science Foundation's Geodetic Facility
for the Advancement of Geoscience

Operated by

UNAVCO

What we do

- UNAVCO supports geodesy research to understand Earth processes and help society become more resilient to natural hazards.
 - Operates networks of instruments that continuously collect data
 - Maintains instruments for researchers to use
 - Archives and provides access to data
 - Offers geoscience education resources and internships



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UNAVCO's Northwest Region



- Ken Austin – Regional Manager based in Ellensburg Washington. Ken manages operations in the Pacific Northwest, including Northern California, Oregon, Washington and Alaska
- Chad Pyatt – Engineer based in Lincoln City Oregon. I primarily focus on northern Oregon, Washington and Alaska. I occasionally work in other regions (central America and the Caribbean).
- Adam Woolace – Engineer based in Fortuna California. Adam primarily focusses on northern California and southern Oregon. Adam also works in the rest of the region; he helped build the GNSS network in Mexico (TlalocNet) and works in the Caribbean as needed.
- Liz Van Boskirk – Project Manager based in Portland Oregon (Manages Borehole Geophysical Instrument Network). Liz helped build the Borehole network and occasionally supports the GNSS network in the northwest and Caribbean.



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Geodetic Facility for the Advancement of Geoscience (GAGE)

- UNAVCO operates GAGE—one of the National Science Foundation’s two premier geophysical facilities in support of geoscience and geoscience education.
 - Formerly the Plate Boundary Observatory, part of Earthscope. The Earthscope Program formally ended at the end of FY’2018, when the new NSF Geophysical Facility Award took effect.
- Funding provided by the National Science Foundation, NASA, and the United States Geological Survey



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Major Partnerships in the PNW

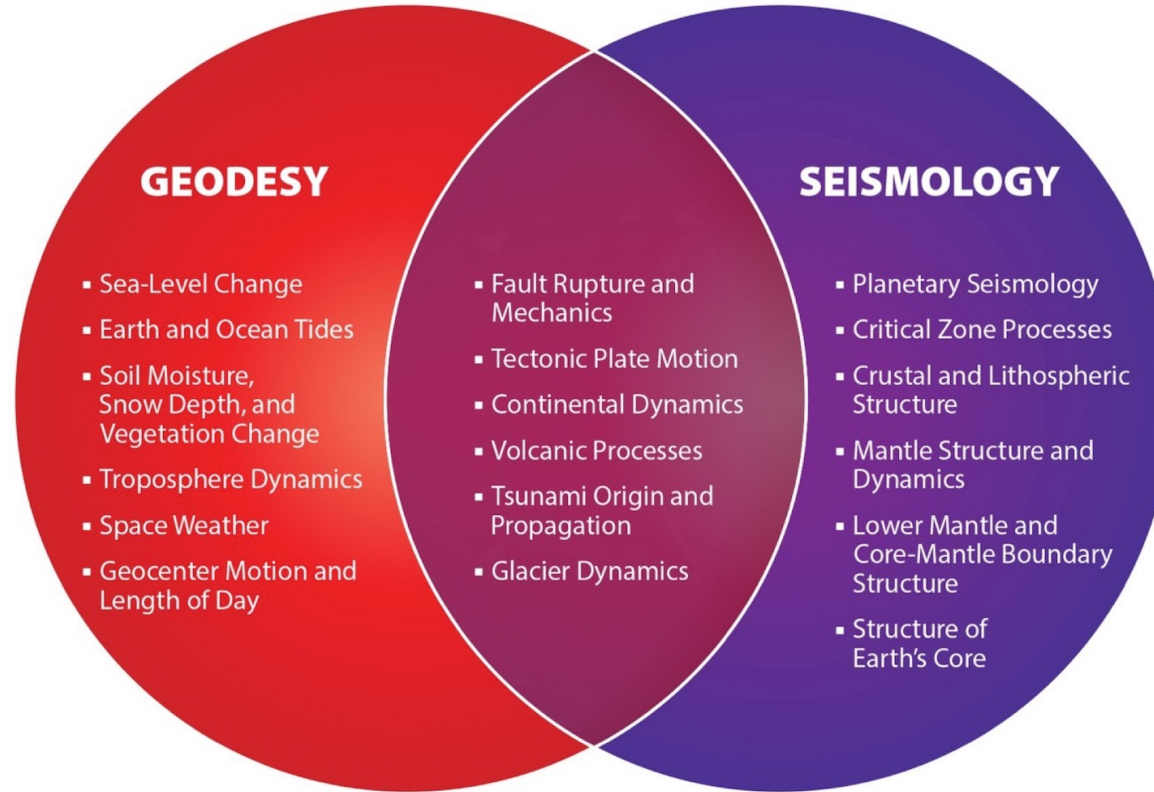
- In Oregon:
 - ODOT – ORGN, Geometronics Department
 - University of Oregon – Earth Hazards Lab, Pacific Northwest Seismic Network (PNSN)
- In Washington:
 - USGS Cascade Volcano Observatory
 - University of Washington – PNSN
 - Central Washington University – Pacific Northwest Geodetic Array
- In Alaska:
 - USGS Alaska Volcano Observatory
 - Alaska Earthquake Center
 - University of Alaska Fairbanks – Geophysical Institute



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Unavco and Iris will merge in 2022/2023 to become the EarthScope Consortium

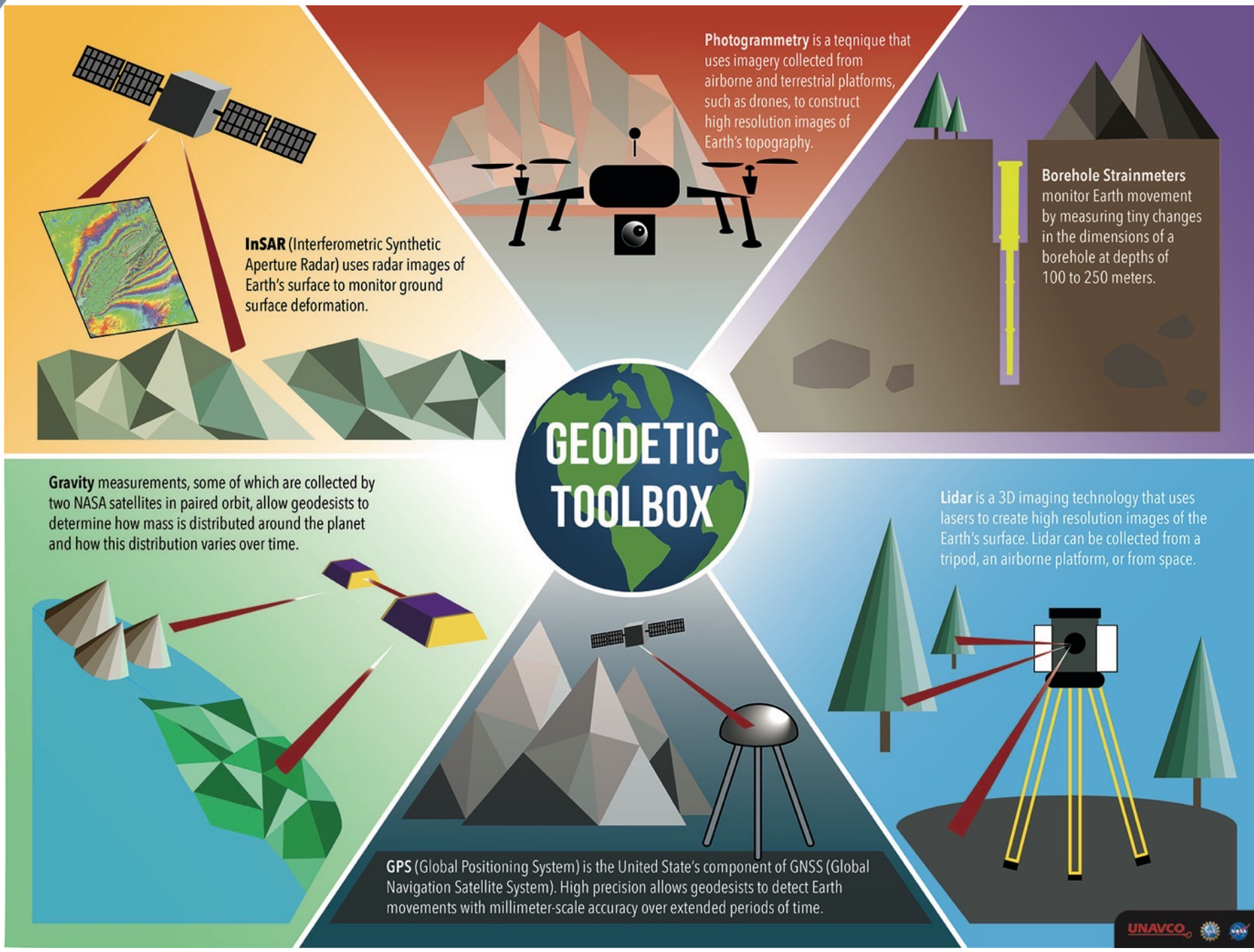
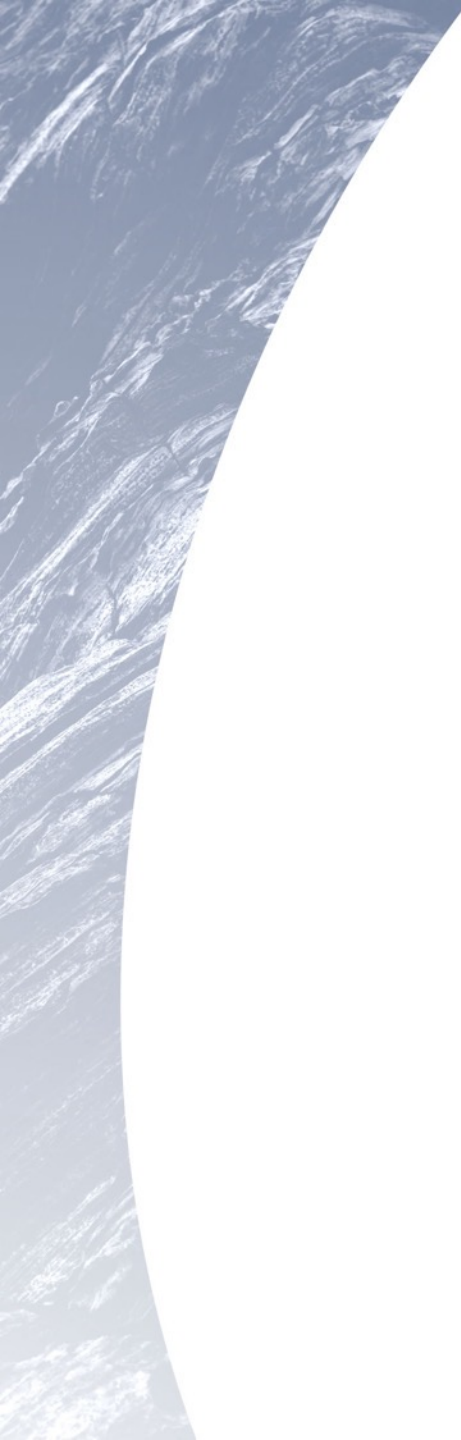


2025 : Open competition for new cooperative agreement with NSF to operate a Geophysical Facility (including NOTA)



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InSAR (Interferometric Synthetic Aperture Radar) uses radar images of Earth's surface to monitor ground surface deformation.

Photogrammetry is a technique that uses imagery collected from airborne and terrestrial platforms, such as drones, to construct high resolution images of Earth's topography.

Borehole Strainmeters monitor Earth movement by measuring tiny changes in the dimensions of a borehole at depths of 100 to 250 meters.

Gravity measurements, some of which are collected by two NASA satellites in paired orbit, allow geodesists to determine how mass is distributed around the planet and how this distribution varies over time.

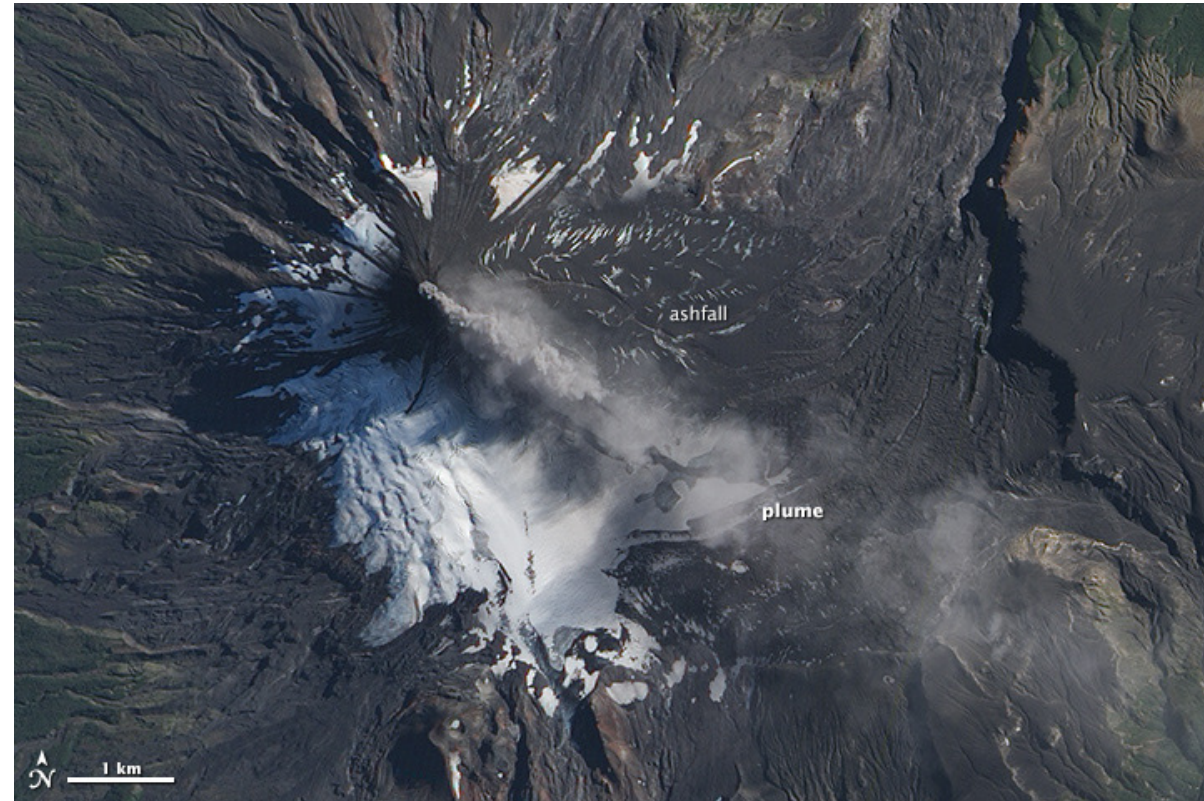
GEODETTIC TOOLBOX

GPS (Global Positioning System) is the United State's component of GNSS (Global Navigation Satellite System). High precision allows geodesists to detect Earth movements with millimeter-scale accuracy over extended periods of time.

Lidar is a 3D imaging technology that uses lasers to create high resolution images of the Earth's surface. Lidar can be collected from a tripod, an airborne platform, or from space.

Geodesy—Deformation

- Deformation is a change in shape (which we can measure!)
- Earth's crust and the ground surface can deform in different ways and for different reasons
 - Fault movement
 - Volcanic activity
 - Ice sheet mass change
 - Groundwater depletion/recharge
 - Landslides

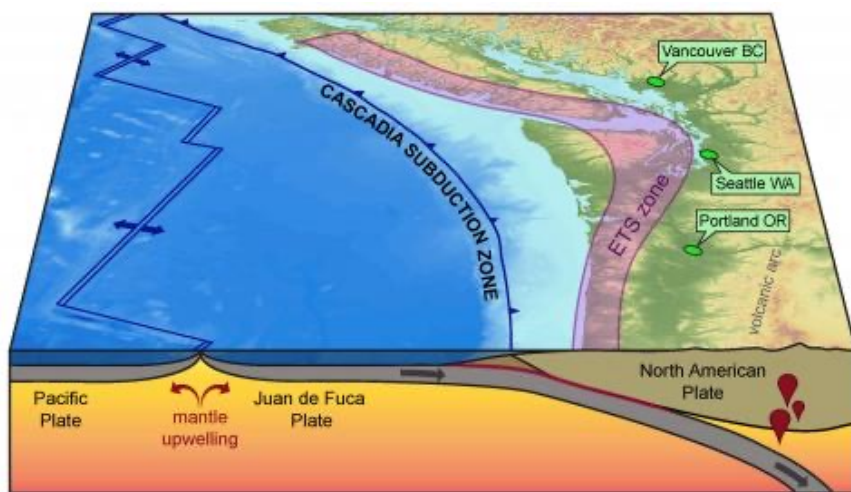


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Plate tectonics

- Networks of instruments measure the slow movement of Earth's tectonic plates—and the hazards at boundaries between plates

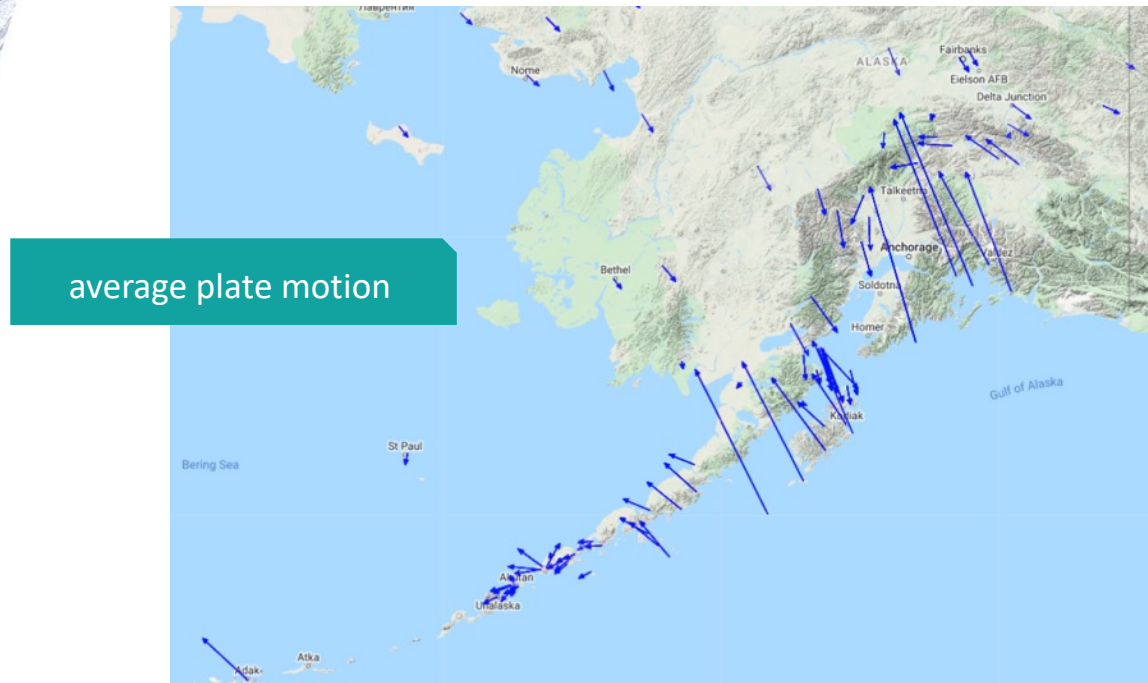


GAGE

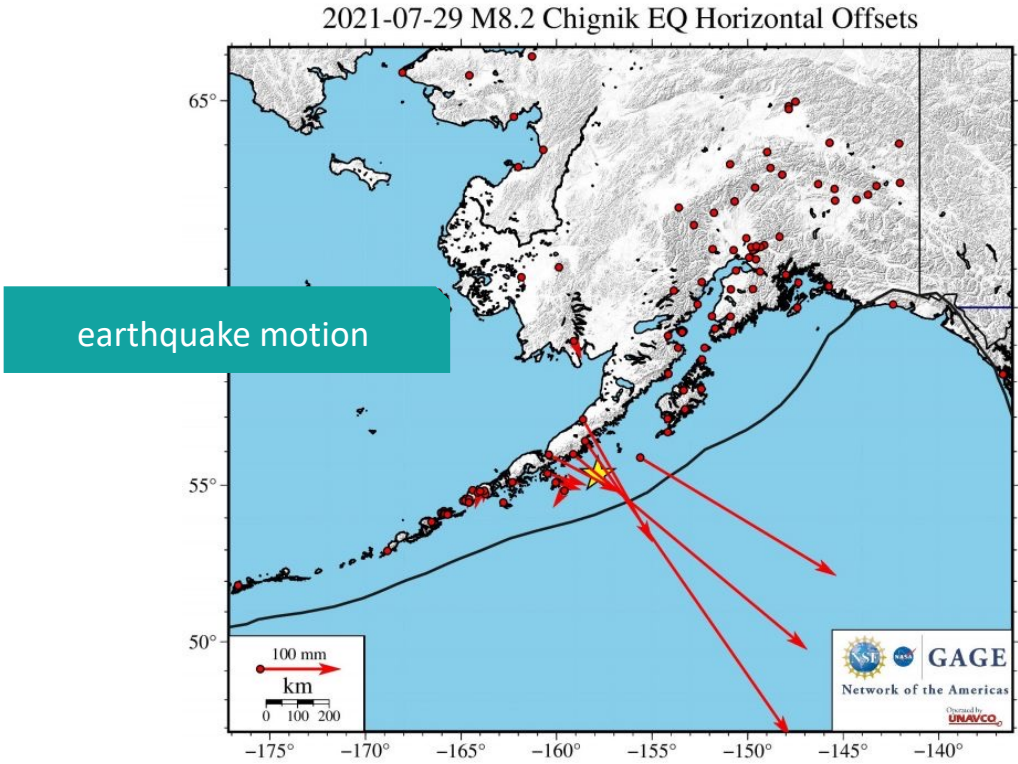
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Earthquakes

- Measurements show where—and by how much—faults moved during an earthquake



average plate motion



earthquake motion



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Earthquakes

- After the 2021 magnitude 8.2 Chignik Alaska earthquake, UNAVCO downloaded high-rate data from stations in the region and sent instruments and staff to support post-event research

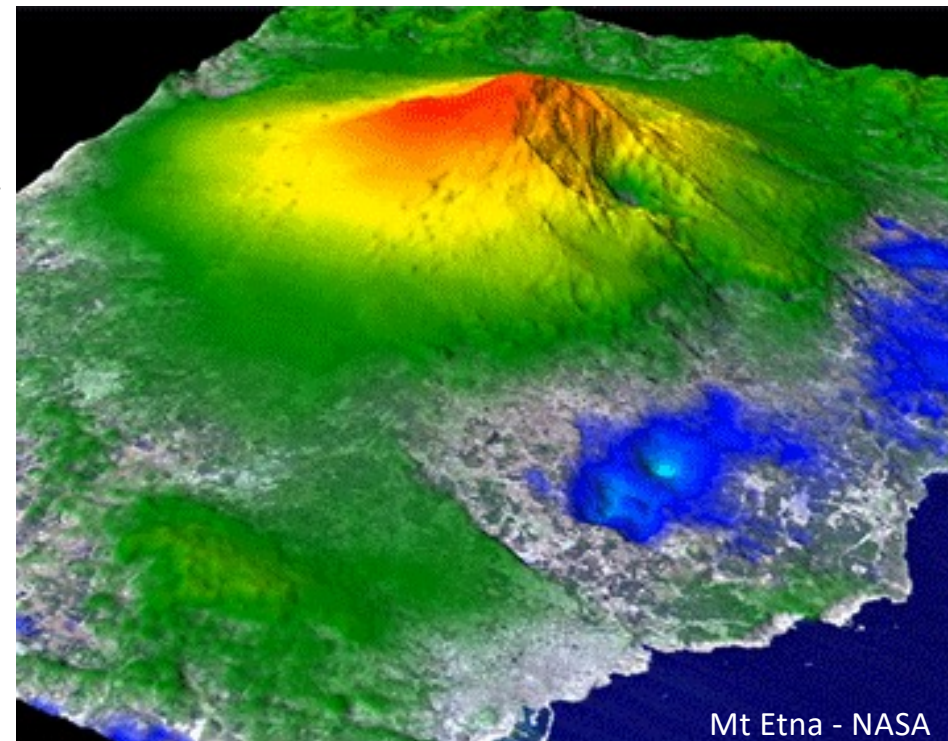


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Volcanoes

- Monitoring deformation of volcanoes provides insight into activity deep below the surface—such as “inflation” due to the arrival of magma from deeper sources

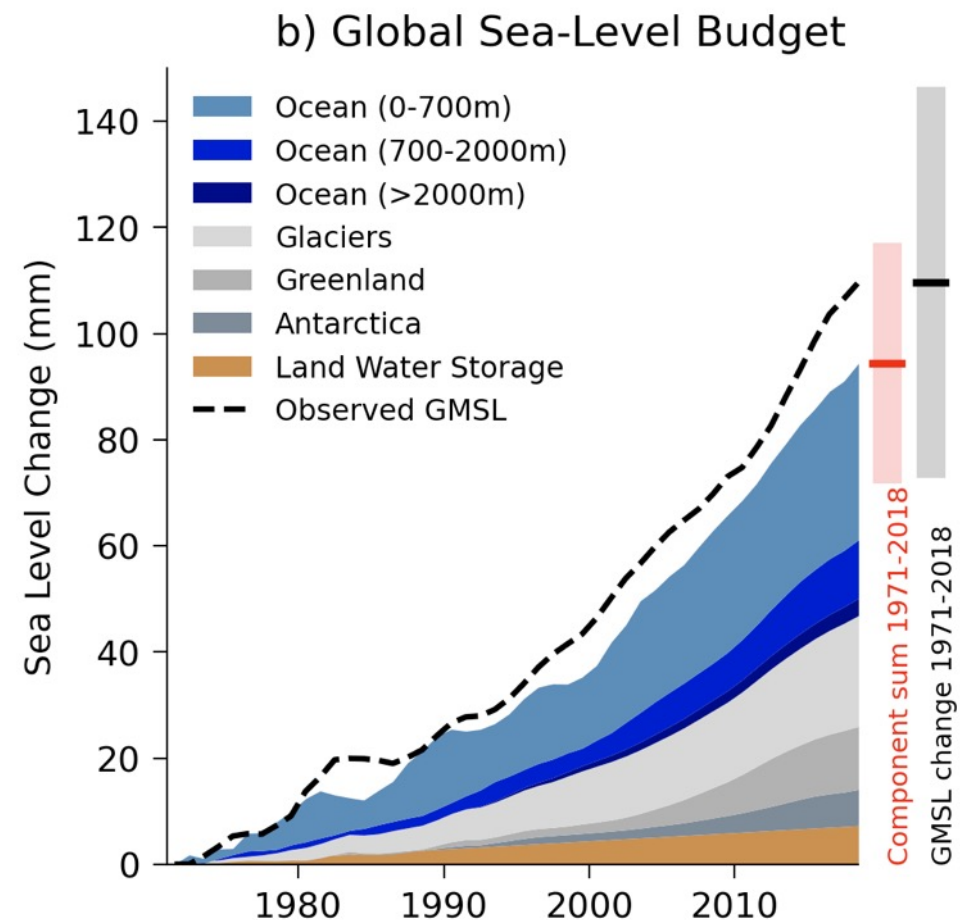


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Sea level rise

- Geodesy enables precise satellite measurements of sea level height
- Gravity satellites measure ocean and ice sheet mass changes
- GPS stations measure glacier movement, bedrock uplift as weight of ice declines
- GPS stations can also serve as tide gauges
- All these pieces of the puzzle combine to show contributors to sea level rise



Source:
IPCC

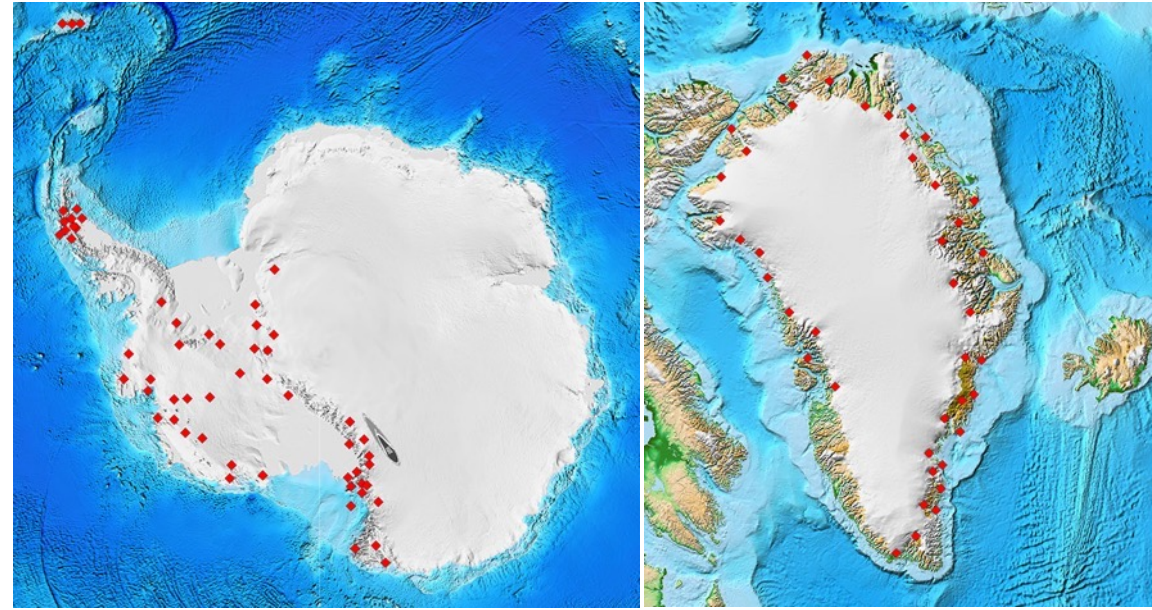


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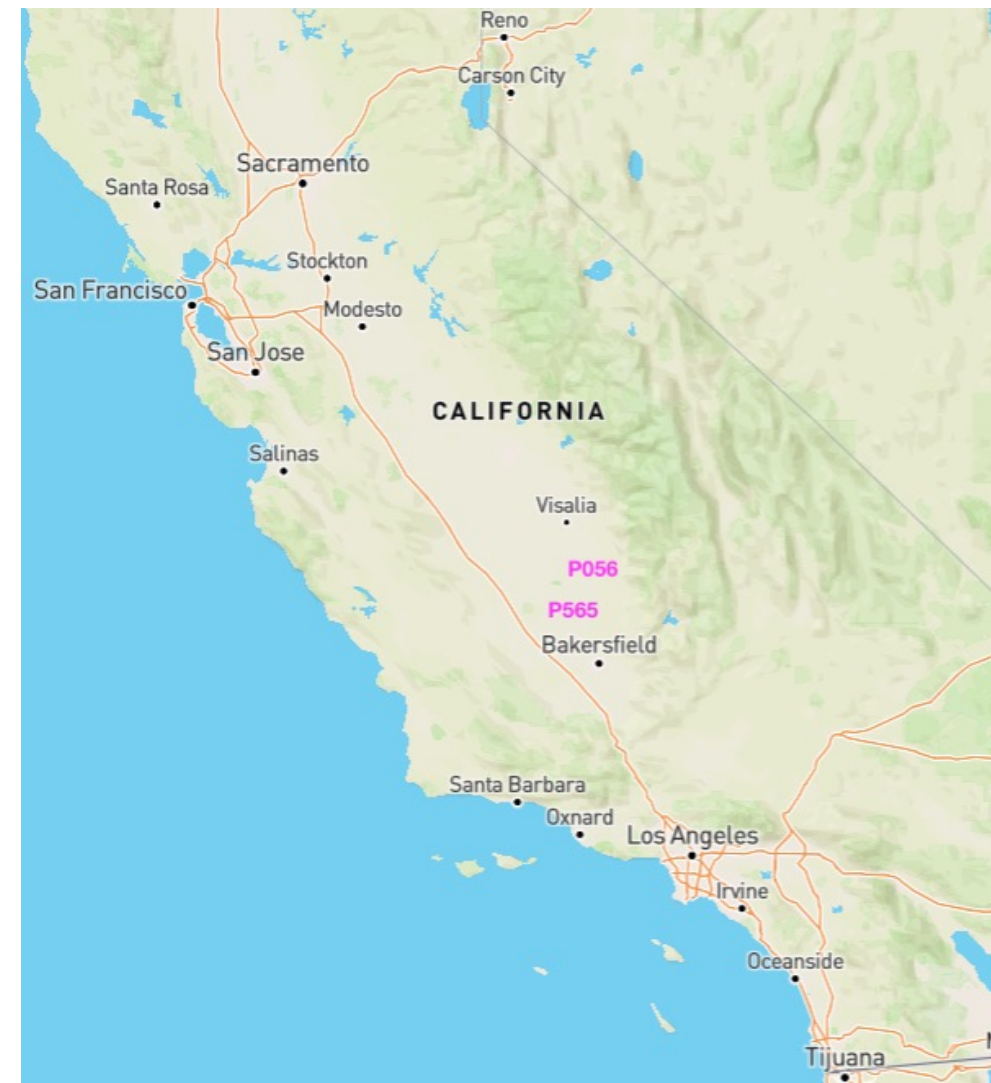
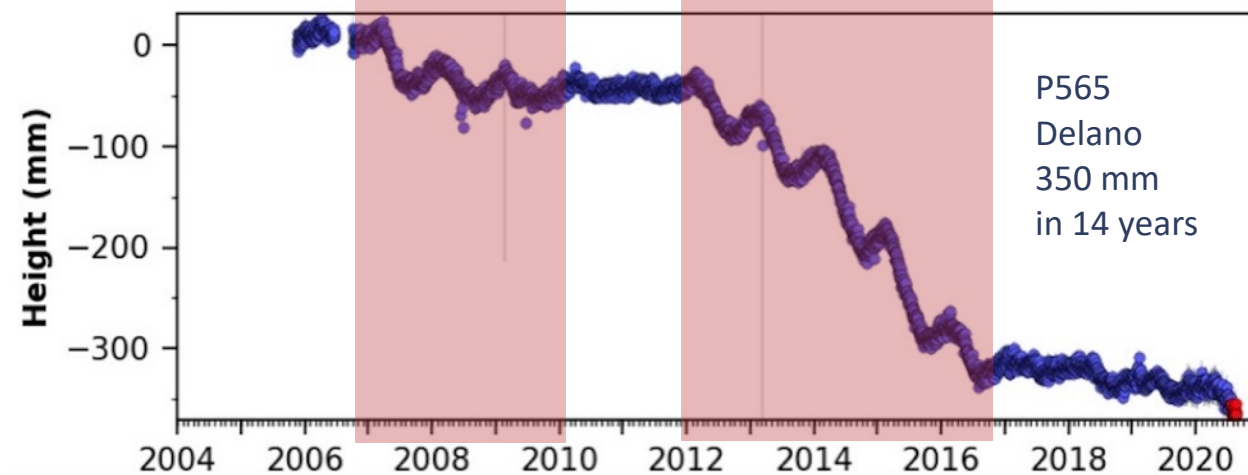
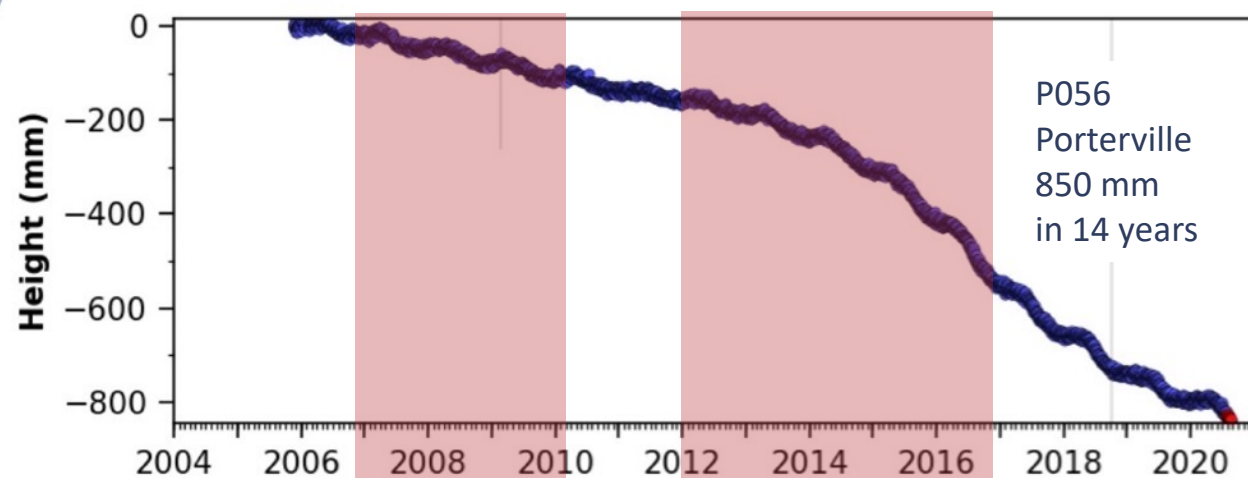
Polar science support

- UNAVCO supports networks of continuous GPS stations in Antarctica and Greenland
- Assists with instrumentation for wide range of polar research

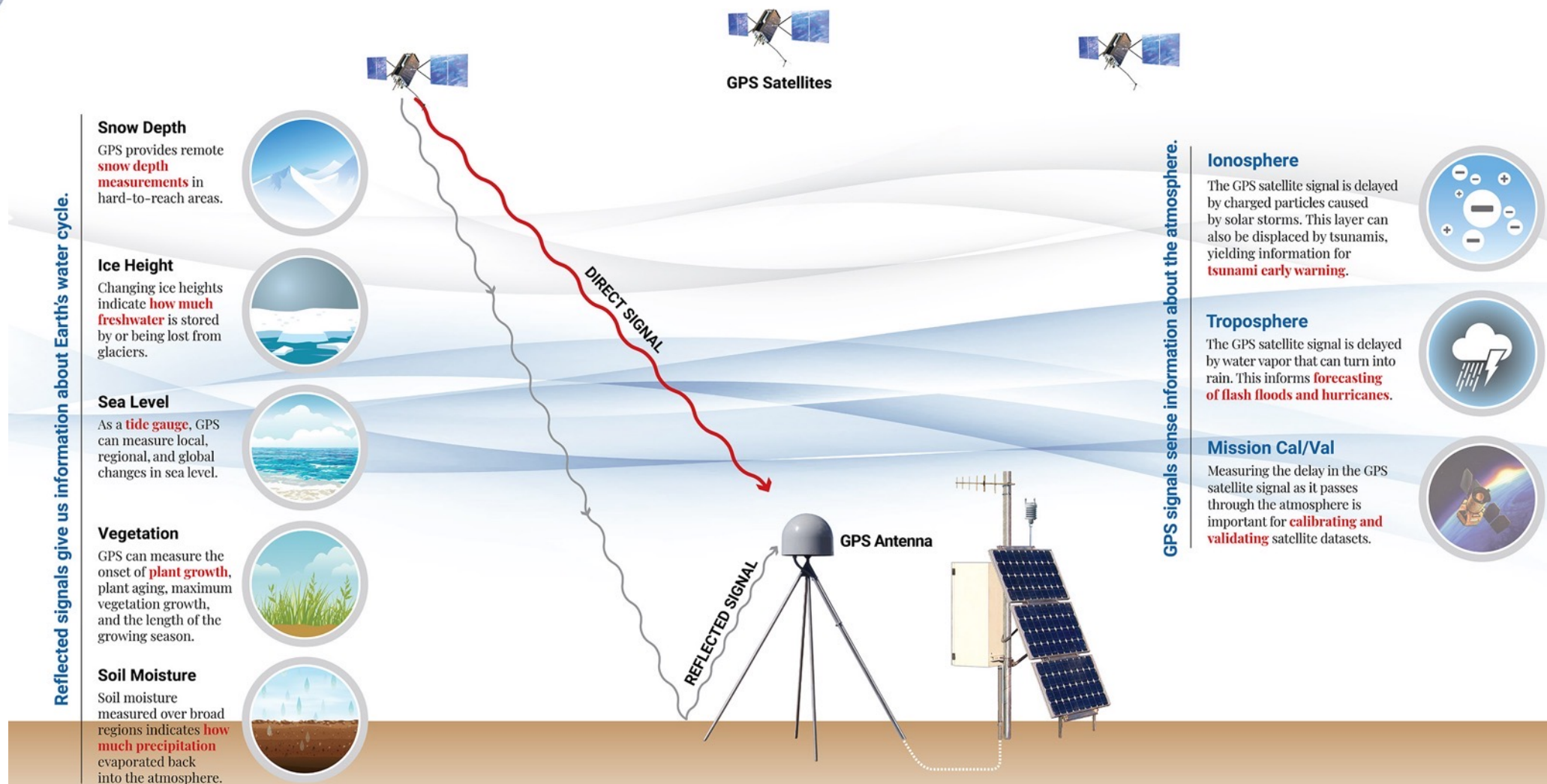


Groundwater

Ground subsidence during drought



Atmosphere and More



Reflected signals give us information about Earth's water cycle.

Snow Depth

GPS provides remote **snow depth measurements** in hard-to-reach areas.



Ice Height

Changing ice heights indicate **how much freshwater** is stored by or being lost from glaciers.



Sea Level

As a **tide gauge**, GPS can measure local, regional, and global changes in sea level.



Vegetation

GPS can measure the onset of **plant growth**, plant aging, maximum vegetation growth, and the length of the growing season.



Soil Moisture

Soil moisture measured over broad regions indicates **how much precipitation** evaporated back into the atmosphere.



GPS signals sense information about the atmosphere.

Ionosphere

The GPS satellite signal is delayed by charged particles caused by solar storms. This layer can also be displaced by tsunamis, yielding information for **tsunami early warning**.



Troposphere

The GPS satellite signal is delayed by water vapor that can turn into rain. This informs **forecasting of flash floods and hurricanes**.



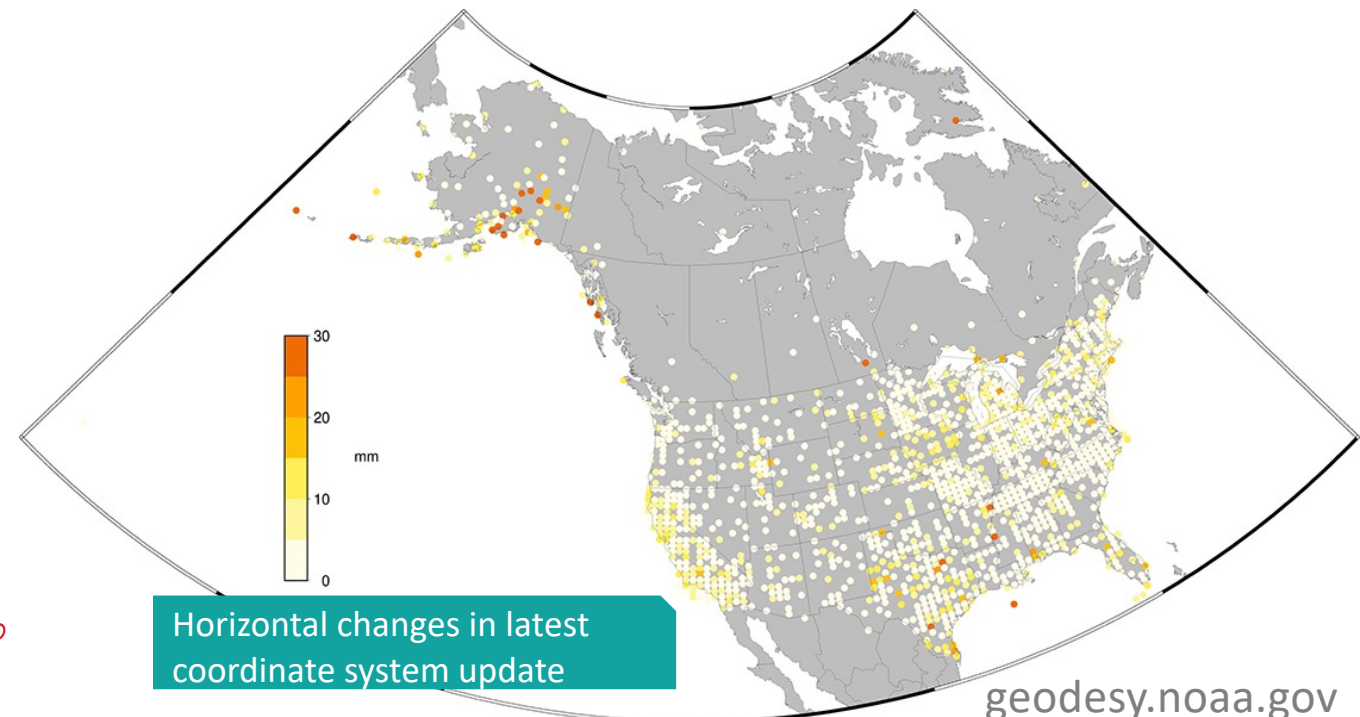
Mission Cal/Val

Measuring the delay in the GPS satellite signal as it passes through the atmosphere is important for **calibrating and validating** satellite datasets.



Applications Beyond Science

- Continuous GPS/GNSS stations around the world are used to maintain the global coordinate system on a moving planet
- Stations can also be used as reference for higher-precision RTK (Real-Time Kinematic) positioning used in surveying, precision agriculture, construction, and autonomous vehicles



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How to find stations and view data

unavco.org/velocity-viewer

Map Satellite

Station: YBHB Yreka
Latitude: 41.73
Longitude: 237.29
Horizontal speed: 7.57 mm/yr
Direction: 339.51
Speed components: east -2.65, north 7.09, up -1.29 mm/yr
Standard deviations: east 0.12, north 0.12, up 0.48 mm/yr
[Download data file](#) [csv]

YBHB (Yreka) NAM14
Processed Daily Position Time Series

GNSS velocity vectors
GNSS Data source: N. America, NAM14, UNAVCO
 Display vectors
Vector color: blue
Vector length (scaling): 2x
 Station labels and data download
 Display error ellipses
 Display vertical rates
How many markers displayed: Show half

More types of data
 Display volcanic centers
 Display volcano labels
 Display plate boundaries
 Display earthquakes
Earthquakes area: North America

Draw Map Start Over



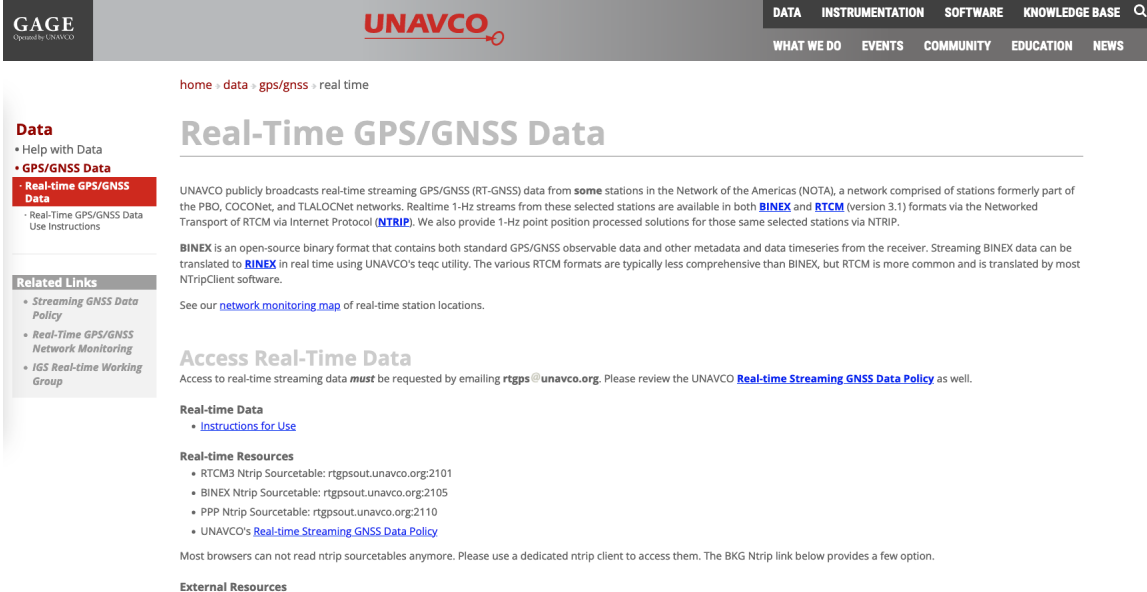
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Real-Time Data Availability

- UNAVCO publicly broadcasts 1-Hz real-time data streams from select stations in NOTA.
- We also provide processed 1-Hz point position solutions for those stations.
- Data is streamed in BINEX and RTCM via NTRIP.
- Data is free to use with attribution.

• <https://www.unavco.org/data/gps-gnss/real-time/real-time.html>



The screenshot shows the UNAVCO website's "Real-Time GPS/GNSS Data" page. The header includes the GAGE logo, the UNAVCO logo, and navigation links for DATA, INSTRUMENTATION, SOFTWARE, KNOWLEDGE BASE, WHAT WE DO, EVENTS, COMMUNITY, EDUCATION, and NEWS. The main content area features a breadcrumb trail (home > data > gps/gnss > real time) and a section titled "Real-Time GPS/GNSS Data". This section explains that UNAVCO publicly broadcasts real-time streaming GPS/GNSS (RT-GNSS) data from stations in the Network of the Americas (NOTA). It details the data formats (BINEX and RTCM) and the NTRIP protocol used for streaming. A "Related Links" sidebar on the left lists "Streaming GNSS Data Policy", "Real-Time GPS/GNSS Network Monitoring", and "IGS Real-time Working Group". The "Access Real-Time Data" section provides instructions on how to request real-time streaming data via email (rtgps@unavco.org) and references the "Real-time Streaming GNSS Data Policy". A "Real-time Resources" section lists Ntrip Sourcetable URLs for RTCM3, BINEX, and PPP. A note at the bottom states that most browsers cannot read ntrip sourcetables anymore and suggests using a dedicated ntrip client.

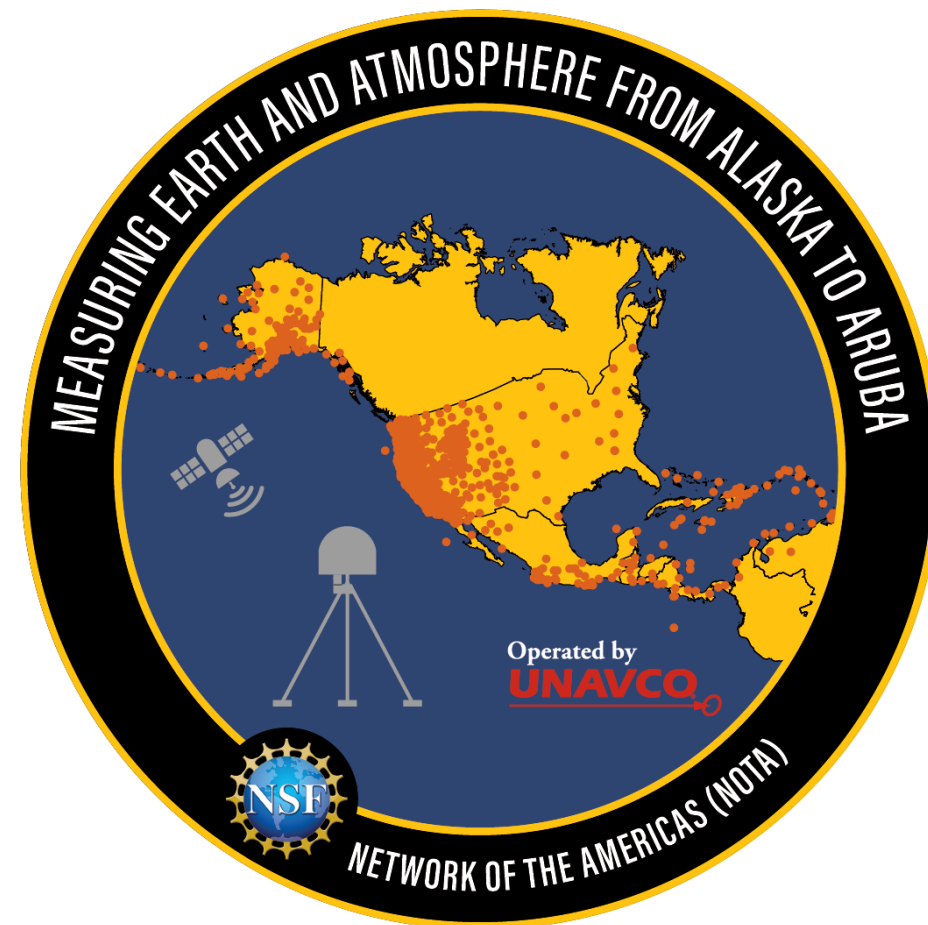


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Network of the Americas

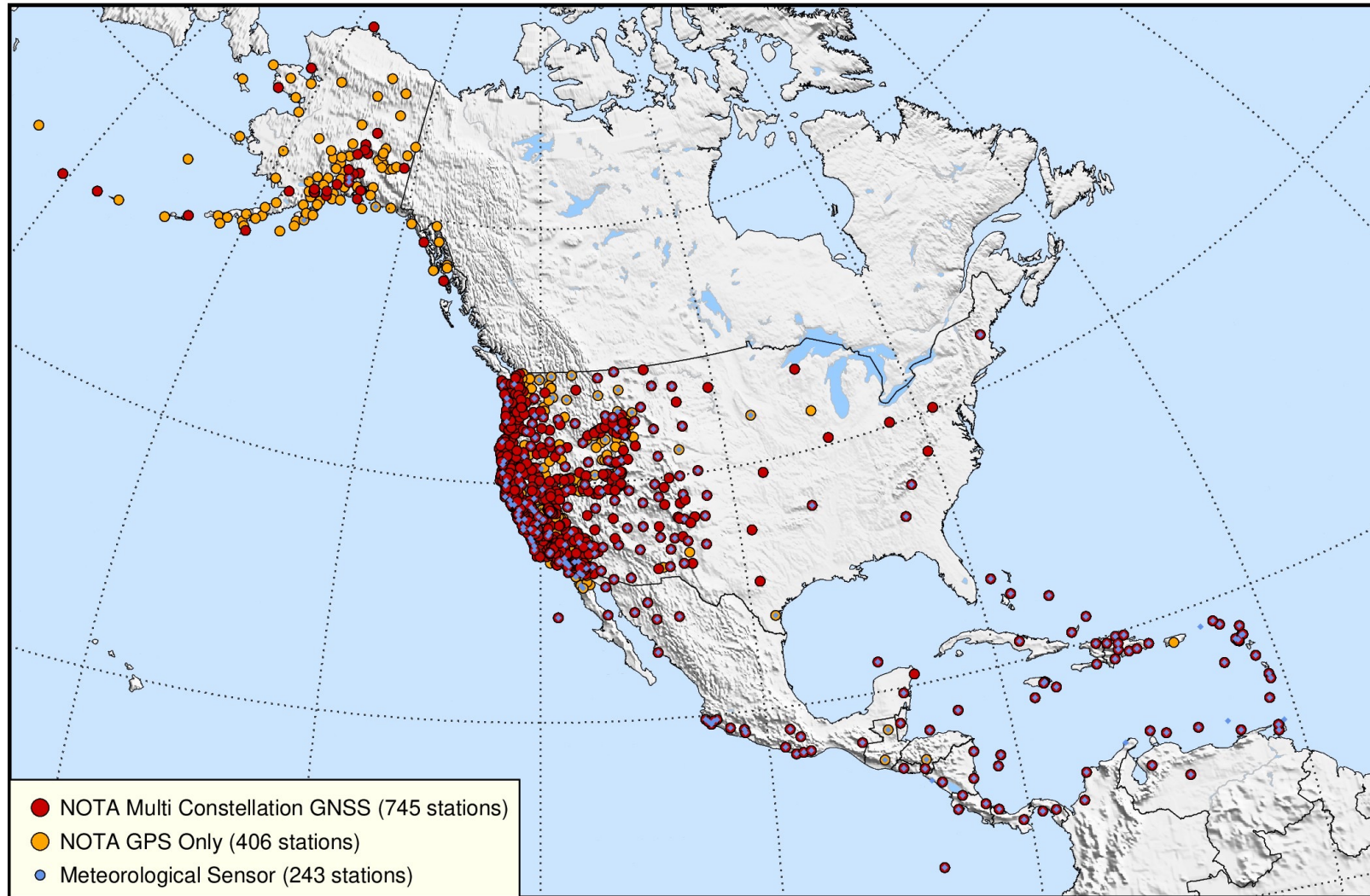
- NOTA is an international geophysics sensor network and composed of more than 1,200 continuously operating instruments, including high-precision GPS stations and borehole strain, seismic, and tilt instruments. The footprint of the network stretches from the Aleutian Islands to the Caribbean.



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Network of the Americas (1150 GNSS stations across US, Mexico, Caribbean)



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High-precision GPS

- Plate motion at station P522 near Bakersfield, California
- Average horizontal motion relative to central US:
 - 27.28 millimeters (1.07 inches) per year to the northwest

seasonal and long-term vertical movement can be used to monitor groundwater

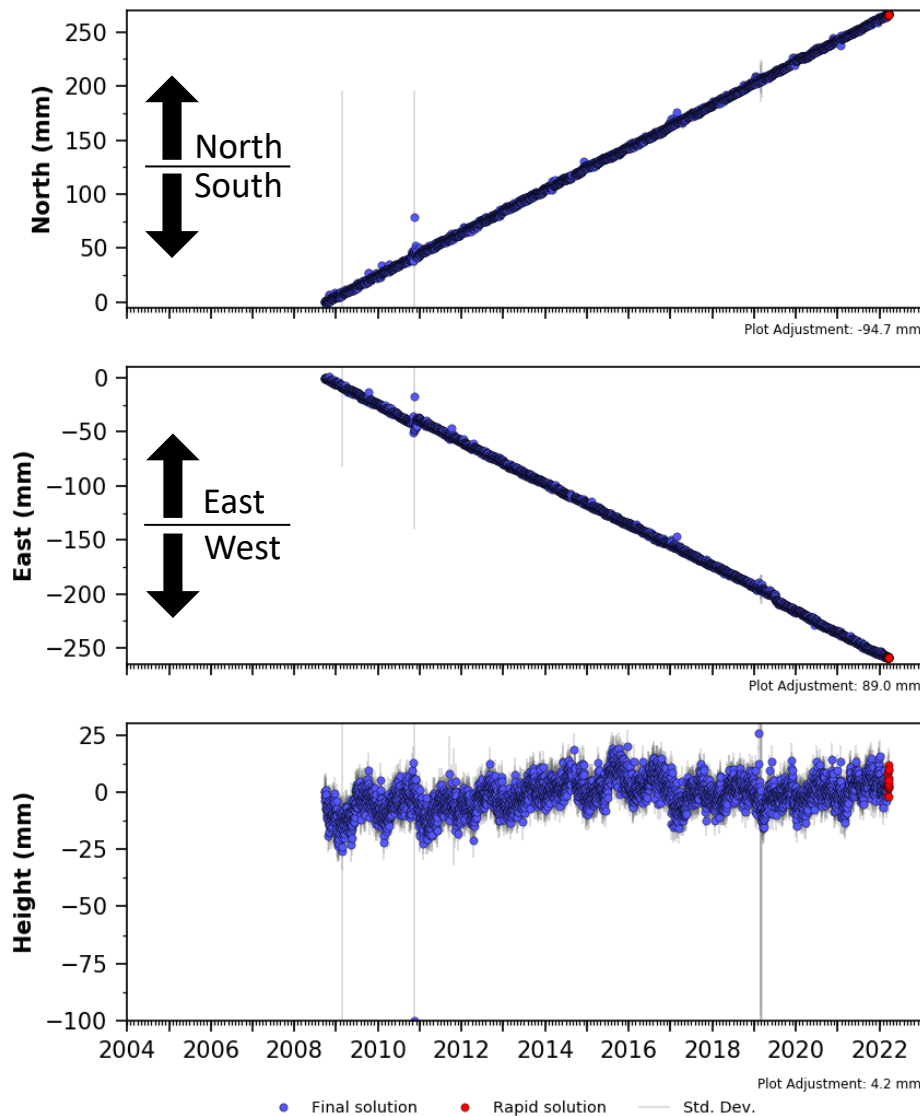


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P522 (Taft_MountCS2008) NAM14

Processed Daily Position Time Series



Source file: P522.cwu.nam14.pos Last epoch plotted: 2022-03-27 12:00:00

High-precision GPS

- Plate motion at station P437 on Whidbey Island
- Data help provide insight into previously unknown plate tectonic motion
- Episodic Tremor and Slip (ETS) – Equivalent to an ~6.5 magnitude earthquake every 14-18 months.

Sawtooth pattern in both horizontal and vertical traces clearly illustrate ETS events

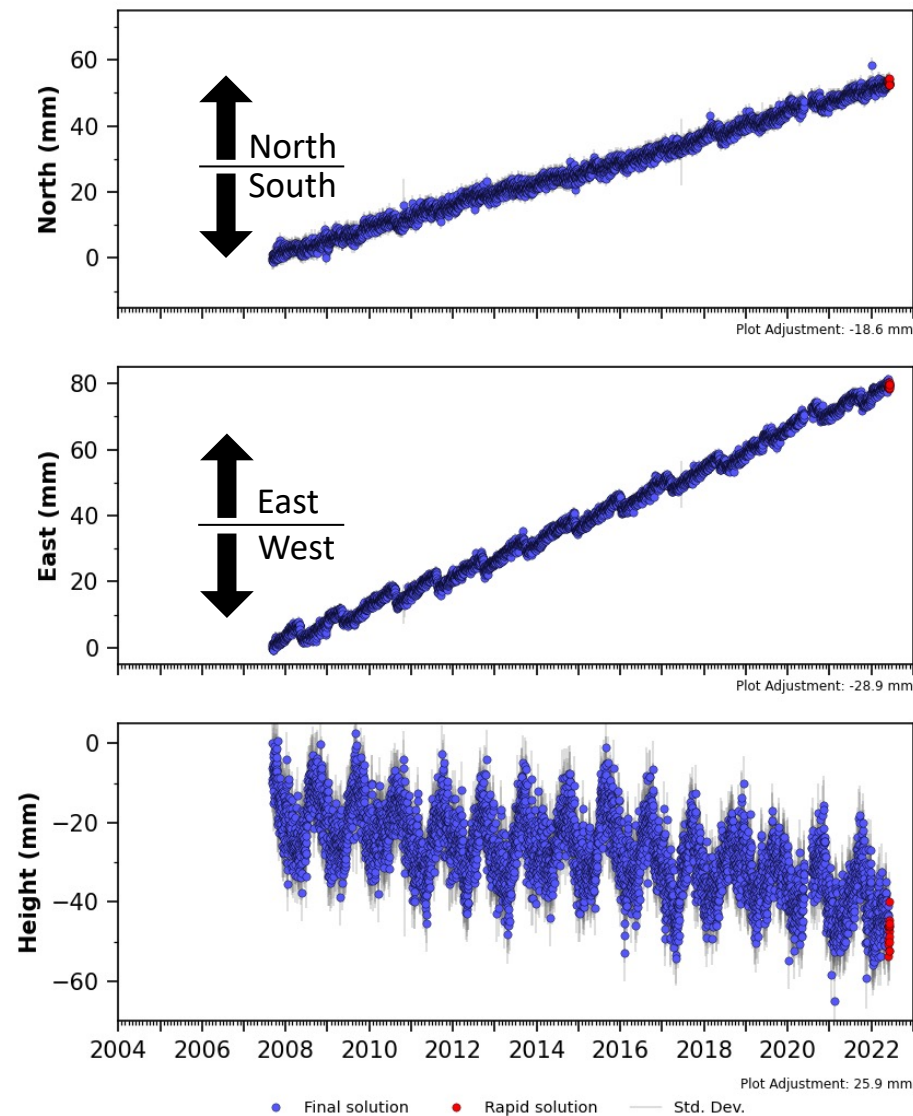


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P437 (Whidbey_S_WA2007) NAM14

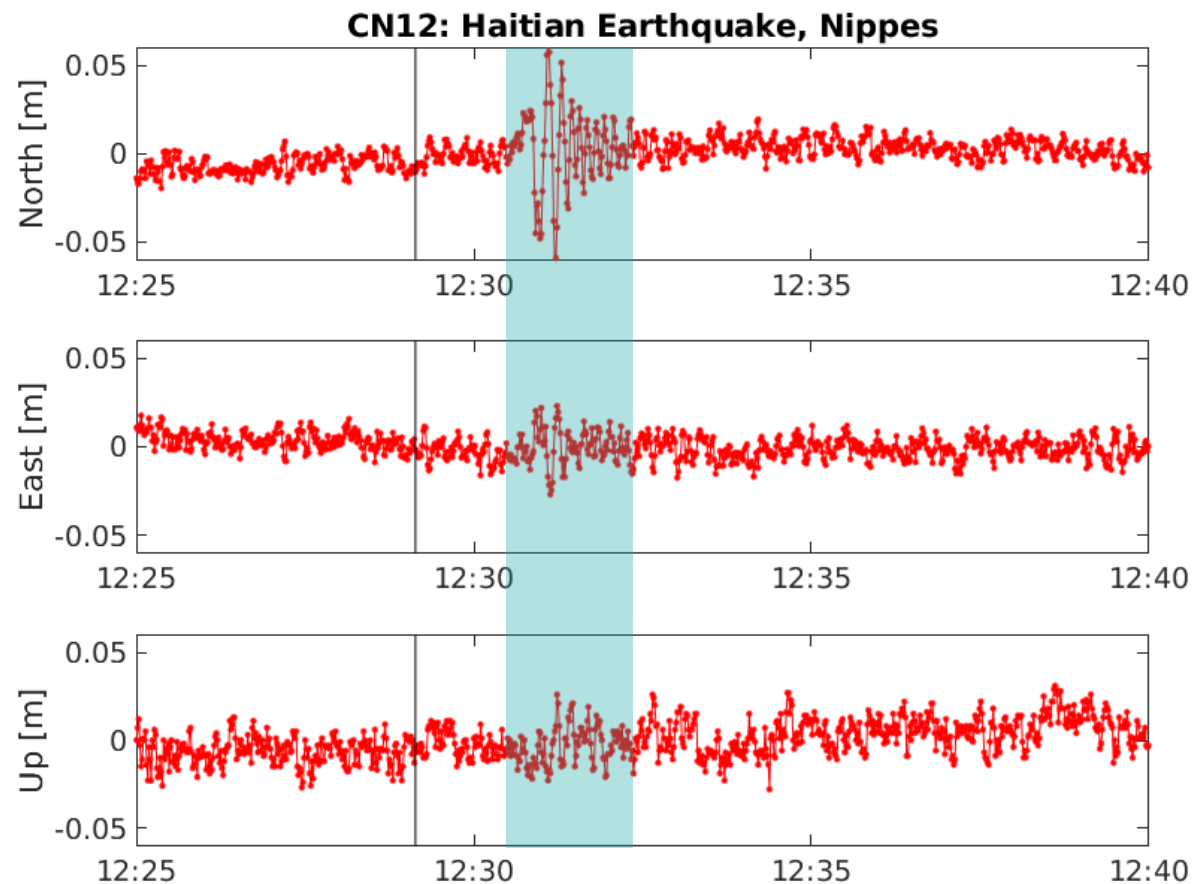
Processed Daily Position Time Series - Cleaned (SD > 20 Removed)



Source file: P437.cwu.nam14.pos Last epoch plotted: 2022-06-11 12:00:00

High-precision GPS

- 2021 Haiti magnitude 7.2 earthquake
- This station was 348 kilometers (216 miles) from the epicenter



↑
earthquake origin time



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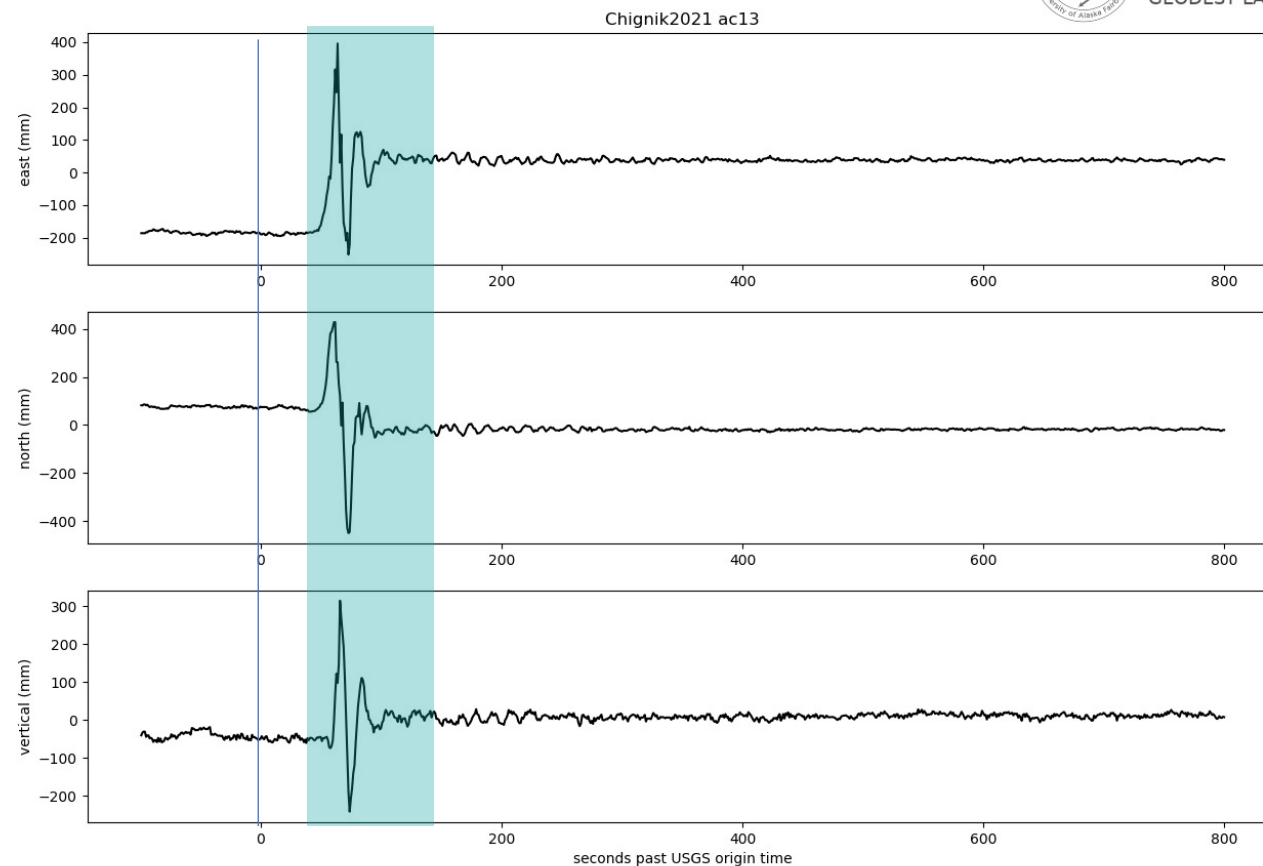
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High-precision GPS



UAF-GI
GEODESY LAB

- 2021 Chignik AK magnitude 8.2 earthquake
- Station AC13 is 152 kilometers (94 miles) from the epicenter
- ~0.5 meters vertical displacement, ~0.8 meters north and east horizontal displacement



earthquake origin time

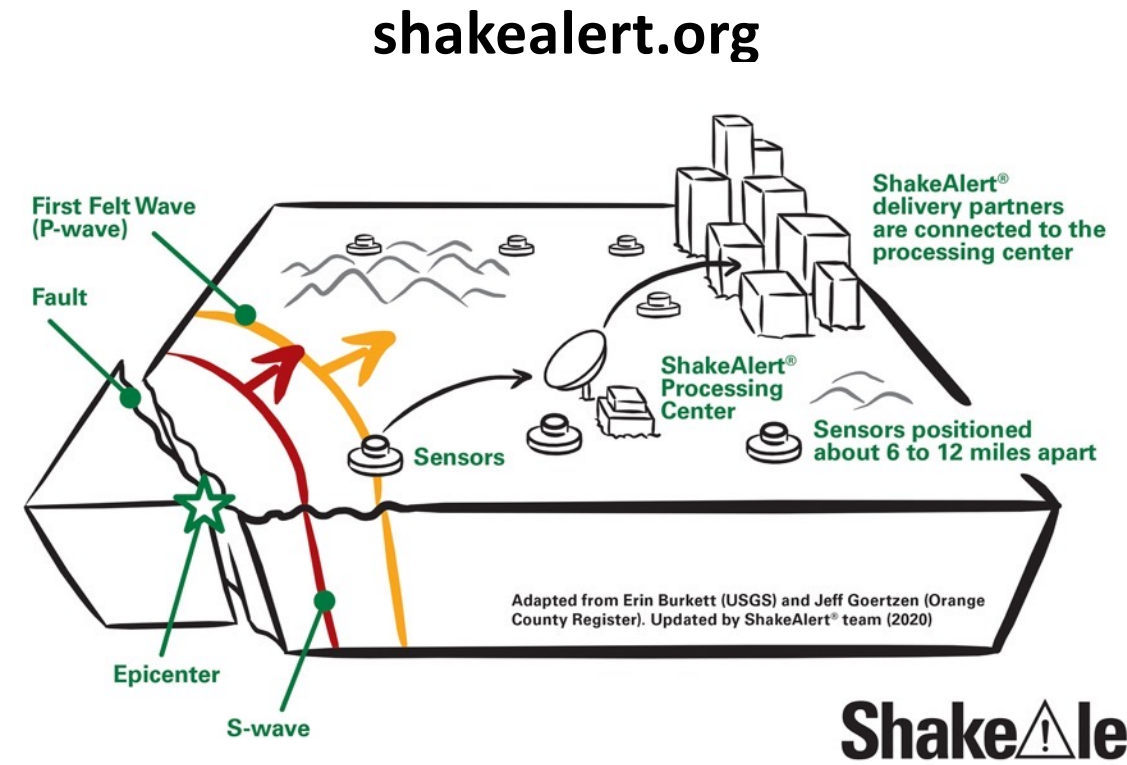


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ShakeAlert® Earthquake Early Warning System

- UNAVCO is streaming GPS station data into ShakeAlert
- Fast detection of seismic waves allows for warning before shaking reaches farther locations
- GPS stations are critical to fast and accurate warnings for the largest earthquakes



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NOTA Partnership with USGS on ShakeAlert EEW

2017-2019 (~1.2M)

- 54 collocations of existing NOTA stations with new USGS/PNSN seismic stations
- Modernization of collocated stations (Full GNSS, cell modems, power systems)
- Modernize an additional 39 NOTA stations
- Real-Time streaming to USGS

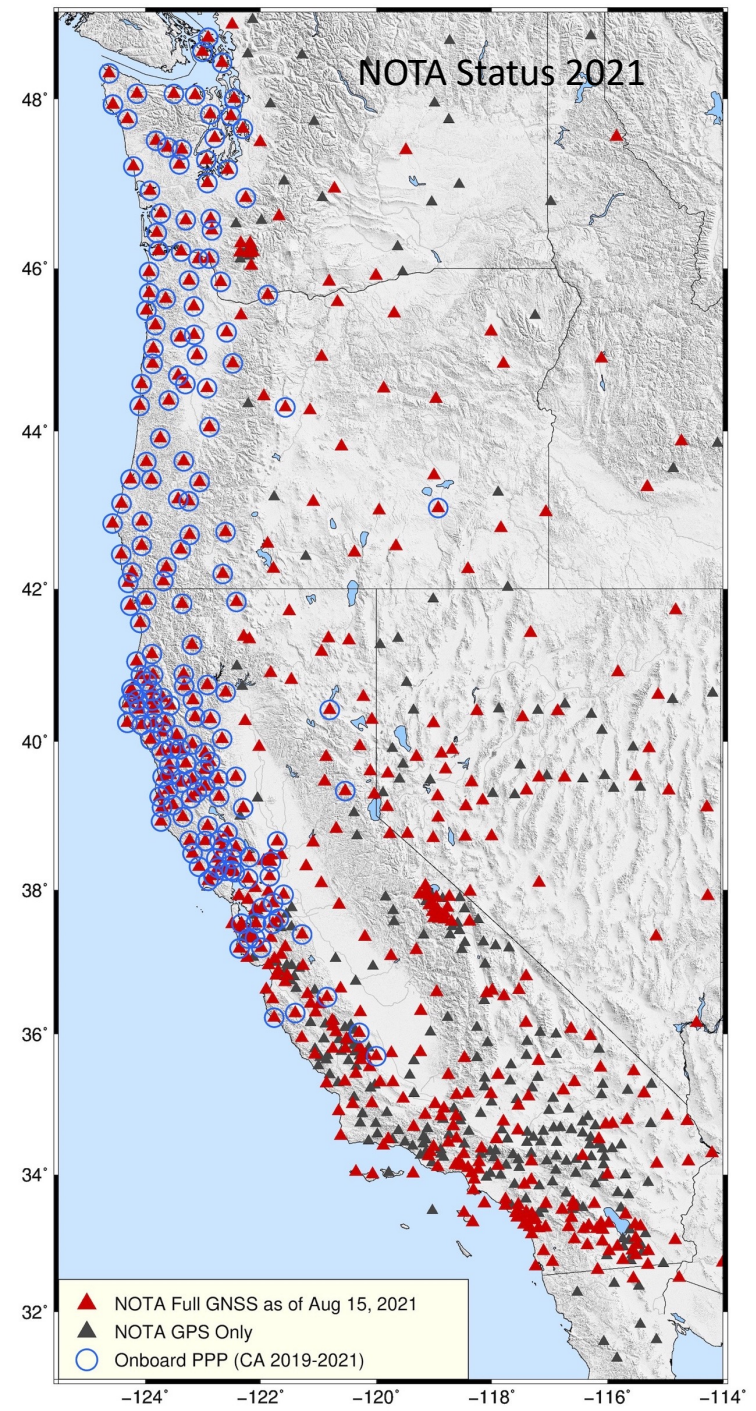
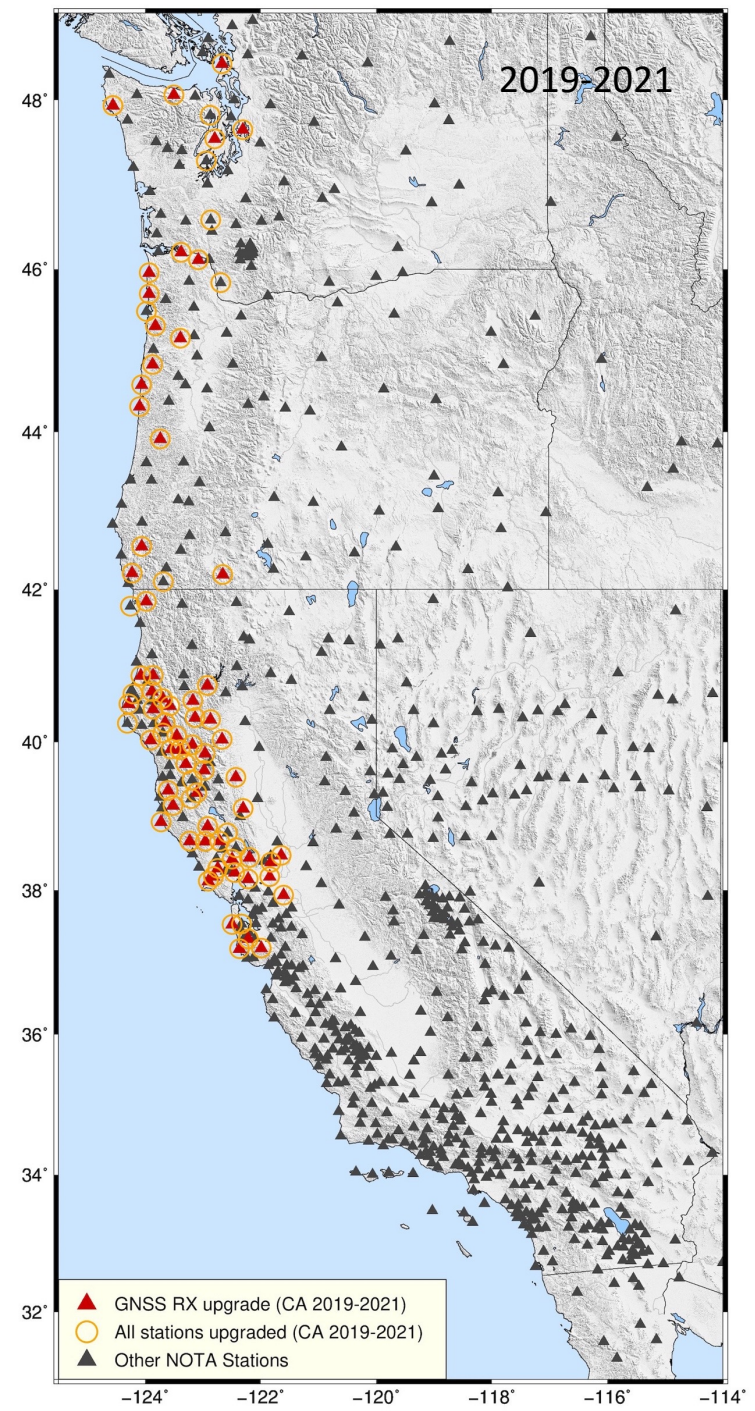
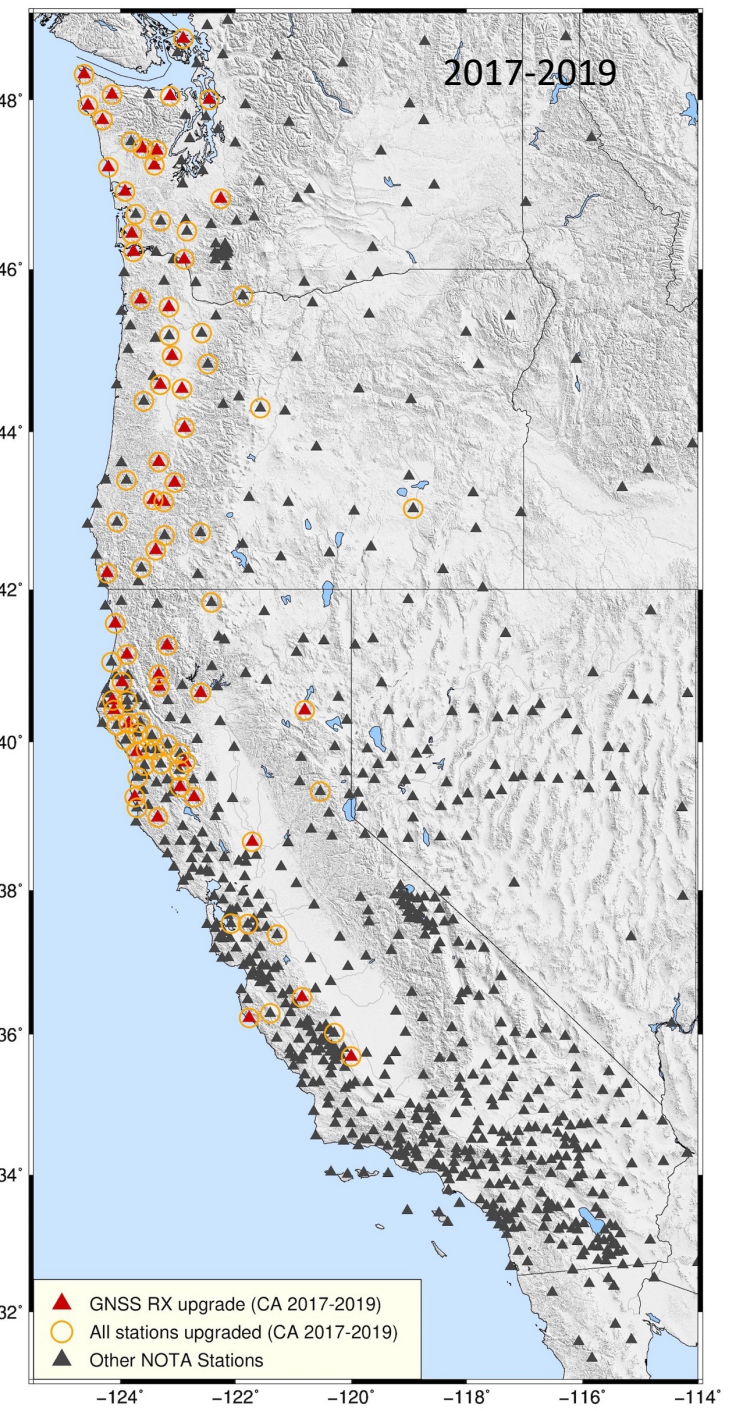
2019-2021 (~1.5M)

- Modernize remaining NOTA stations from Canadian border to SF Bay area, West of I-5
- Densify NOTA network in Oregon (5 new stations)
- Enable on-board positioning for 184 NOTA station in PNW footprint



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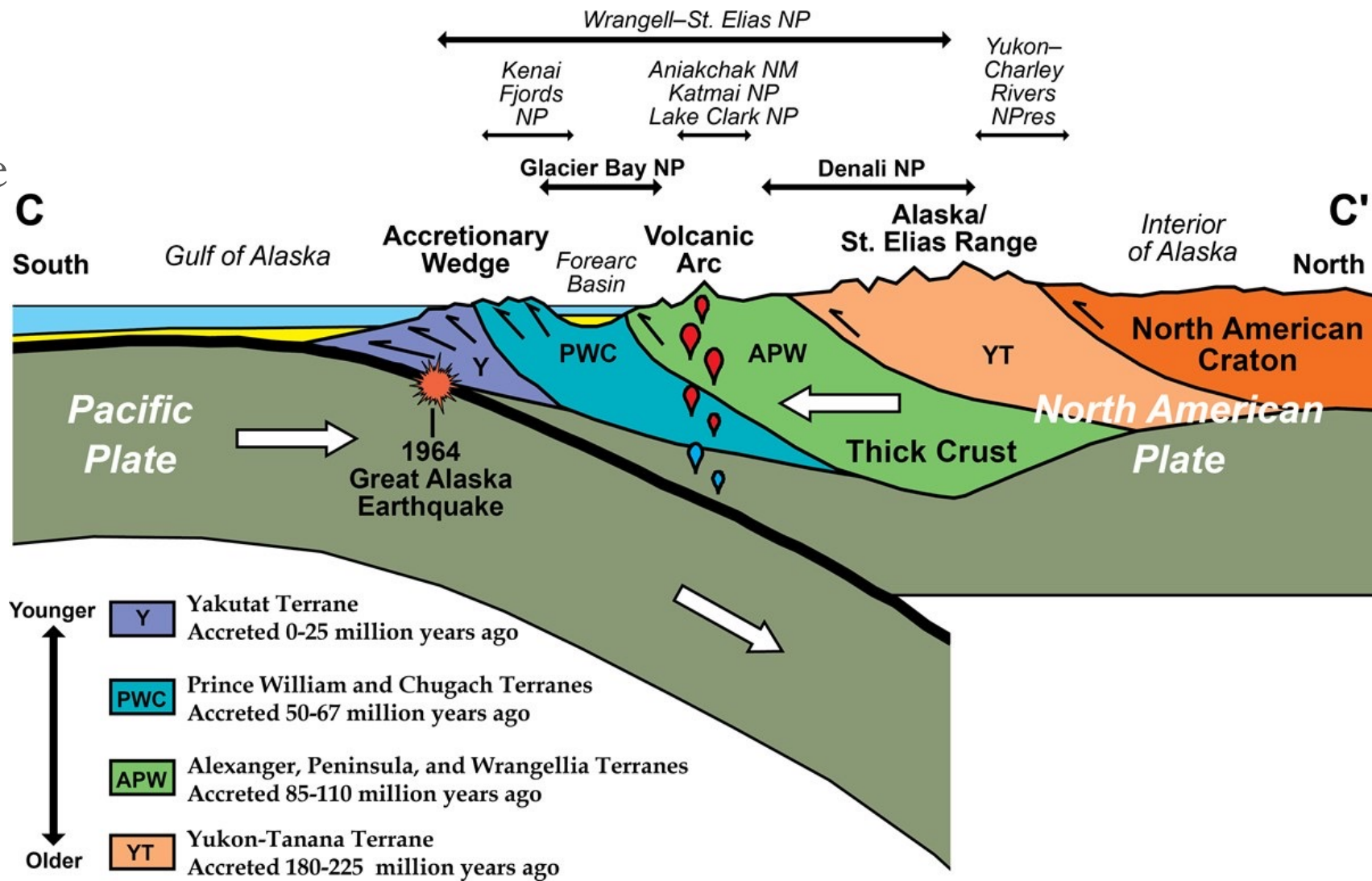
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Regional focus: Alaska

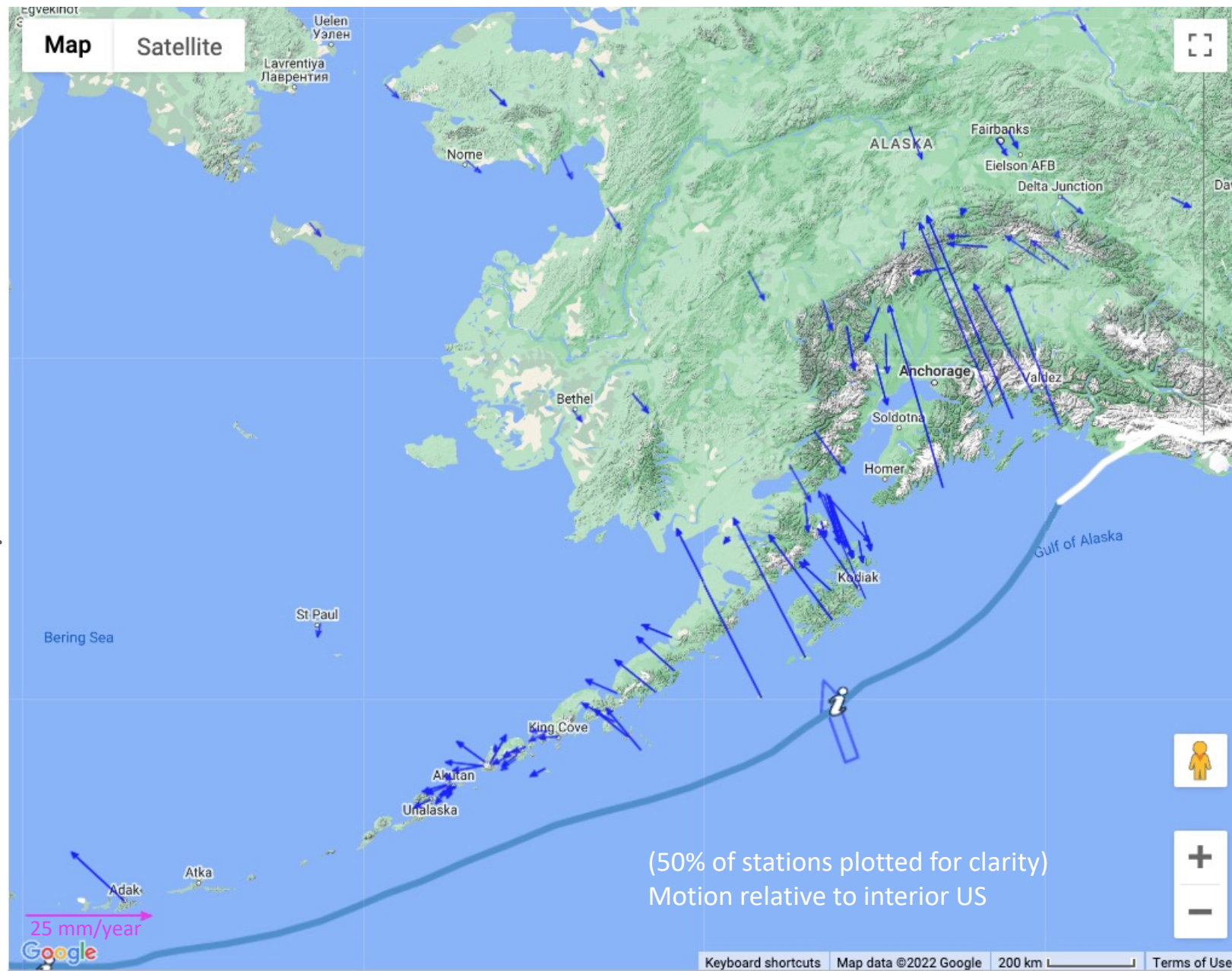
- Aleutian Subduction Zone

- earthquakes
- tsunamis
- volcanoes



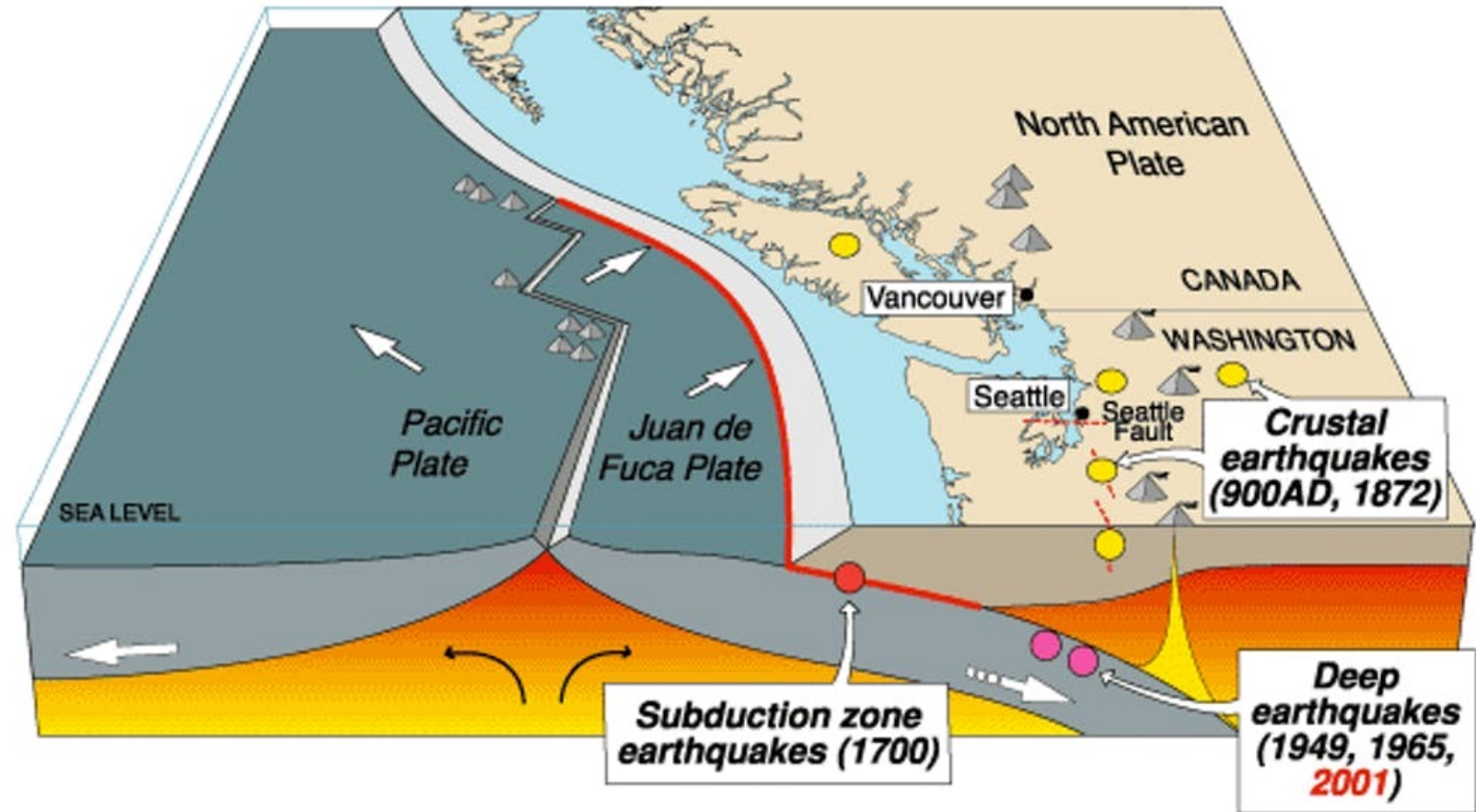
Regional focus: Alaska

- North American plate moving 
- Pacific plate moving 
- This map shows difference from interior US motion—you can see effects of plate collision at the edge!





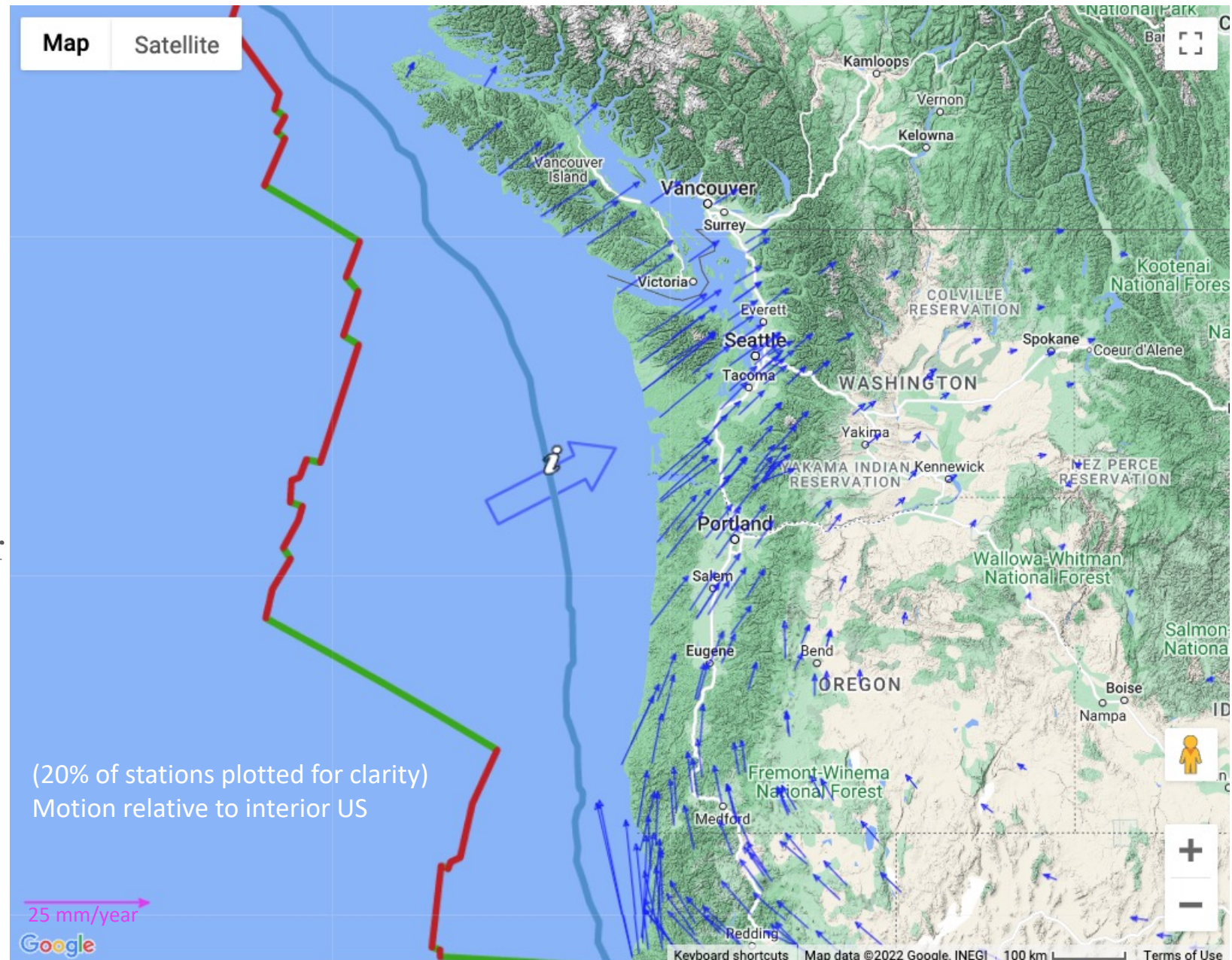
Regional focus: Pacific Northwest

- Cascadia Subduction Zone
 - earthquakes
 - tsunamis
 - volcanoes



Regional focus: Pacific Northwest

- North America moving 
- Pacific plate moving 
- This map shows difference from interior US motion—plate collision makes for complex pattern at the edge!



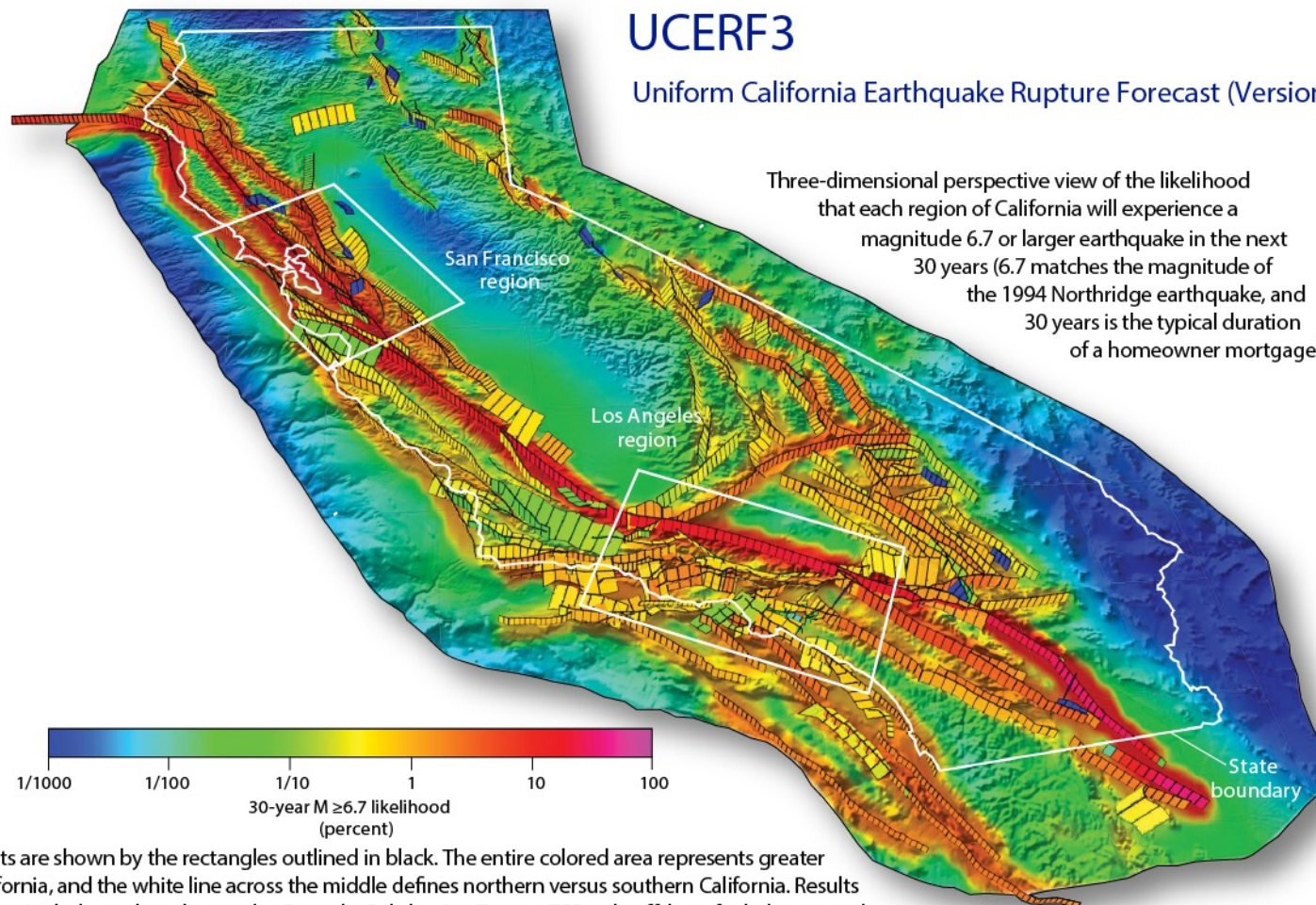
Regional focus: California

- The San Andreas fault marks a boundary between the Pacific and North American plates



Regional focus: California

- California seismic hazard is complex!



UCERF3

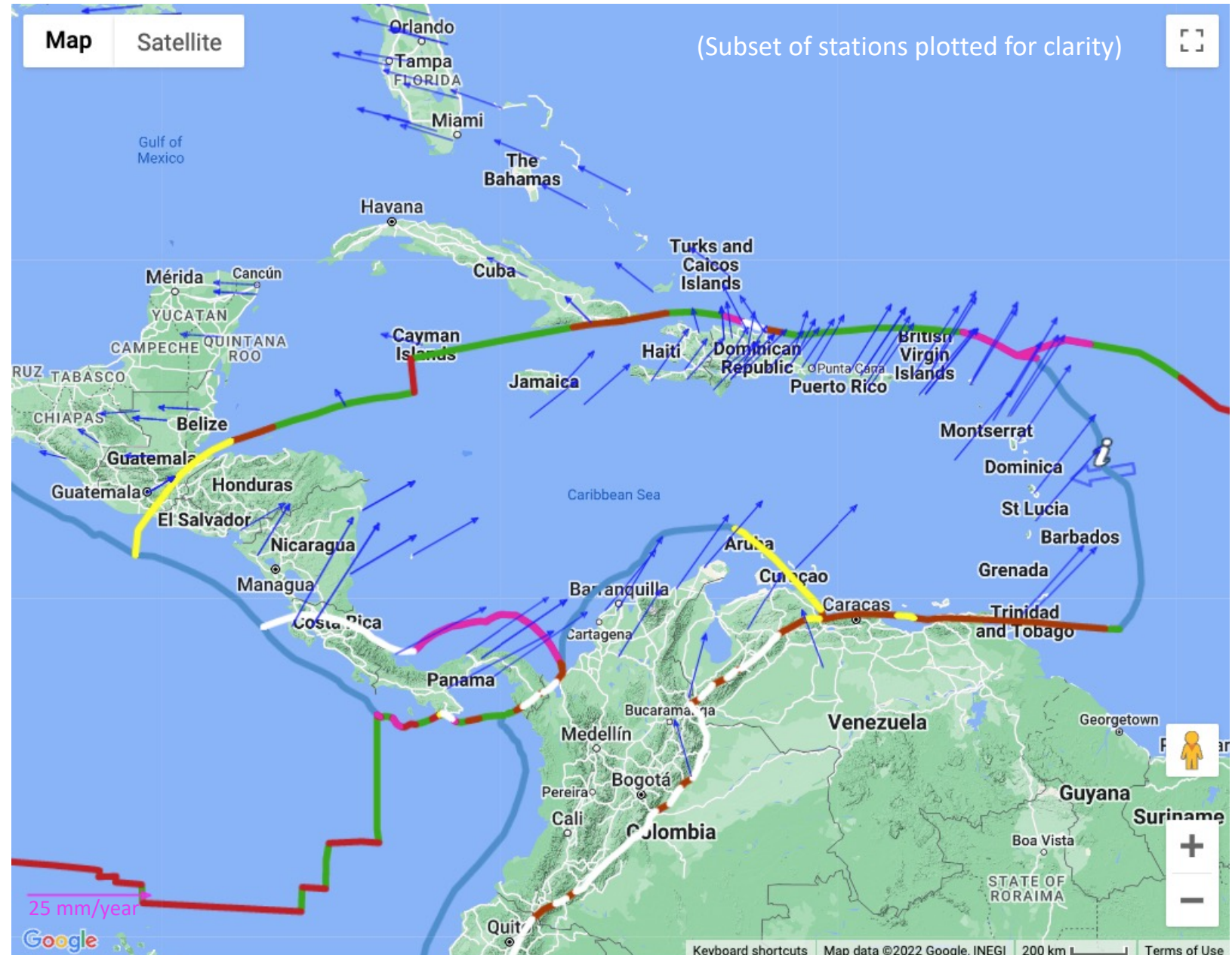
Uniform California Earthquake Rupture Forecast (Version 3)

Three-dimensional perspective view of the likelihood that each region of California will experience a magnitude 6.7 or larger earthquake in the next 30 years (6.7 matches the magnitude of the 1994 Northridge earthquake, and 30 years is the typical duration of a homeowner mortgage).

Faults are shown by the rectangles outlined in black. The entire colored area represents greater California, and the white line across the middle defines northern versus southern California. Results do not include earthquakes on the Cascadia Subduction Zone, a 750-mile offshore fault that extends about 150 miles into California from Oregon and Washington to the north.

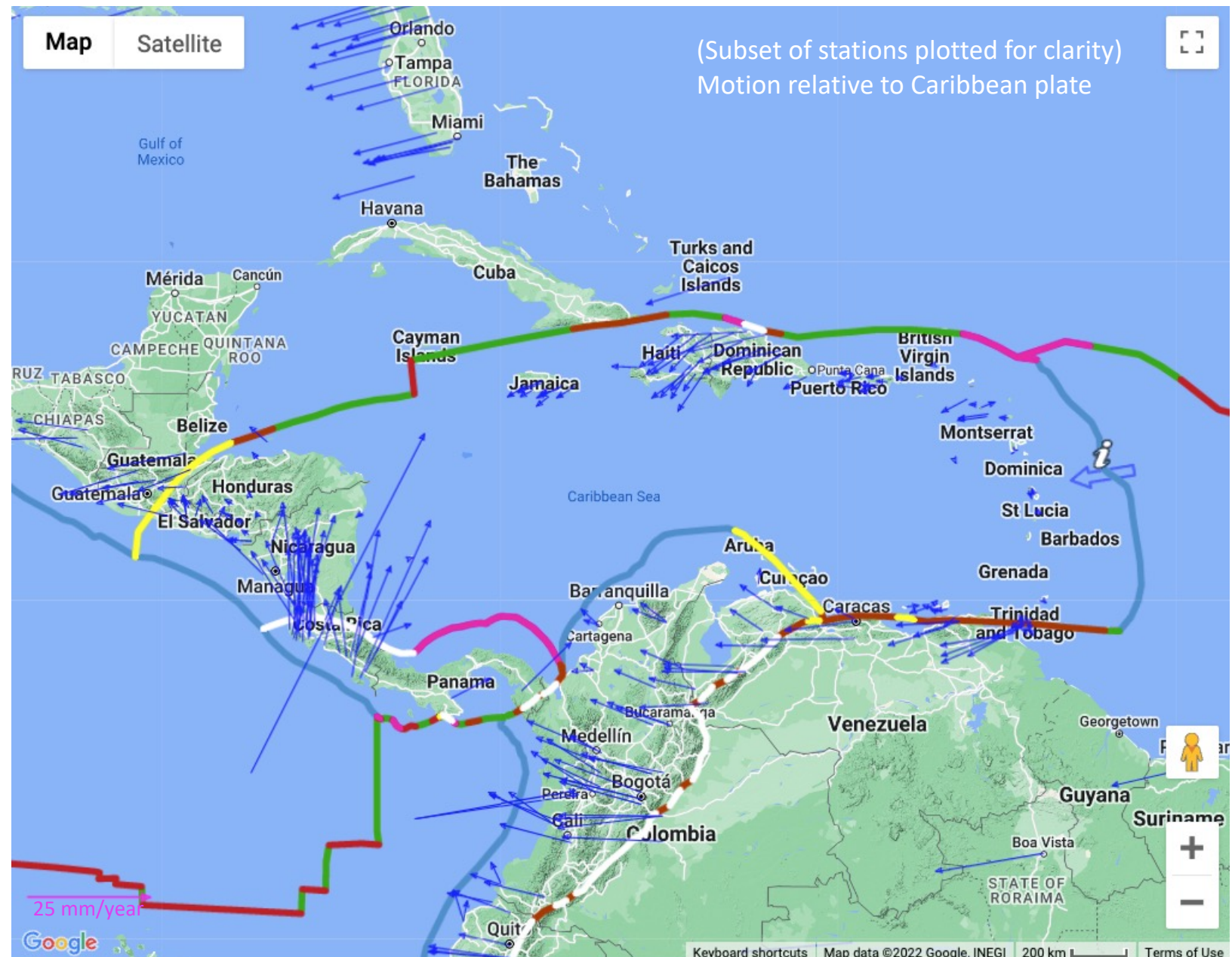
Regional focus: Caribbean

- Plate motion in the Caribbean is complex
- Subduction feeds volcanic islands of the Eastern Caribbean



Regional focus: Caribbean

- This map shows difference from average motion of the Caribbean plate
- Relative motion in Haiti & Dominican Republic results in seismic hazard



Thank You!

Find us on



Visit unavco.org



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The screenshot shows the UNAVCO website homepage. At the top, there is a navigation bar with the GAGE logo (Operated by UNAVCO) on the left, the UNAVCO logo in the center, and a search bar on the right. The search bar contains the text: DATA INSTRUMENTATION SOFTWARE KNOWLEDGE BASE. Below the navigation bar, there are links for WHAT WE DO, EVENTS, COMMUNITY, EDUCATION, and NEWS. The main content area features a large blue header with the text "MEASURING OUR CHANGING EARTH" over a background image of a rocky coastline. Below the header, there are three data points in colored boxes: 151 Permanent stations in polar regions (blue box), 2,534 Gigabytes of borehole strain data delivered last quarter (teal box), and 1,423 Participants in 2021 short courses (green box). At the bottom, there is a paragraph of text: "UNAVCO is a community of scientists, educators, and professionals working together to better understand Earth processes and hazards using geodesy. We operate the GAGE Facility on behalf of the National Science Foundation with support from NASA." To the right of this paragraph is a section titled "Use Our Services" with a list of links: DATA, INSTRUMENTATION, and SOFTWARE.

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DATA INSTRUMENTATION SOFTWARE KNOWLEDGE BASE

WHAT WE DO EVENTS COMMUNITY EDUCATION NEWS

MEASURING OUR CHANGING EARTH

| | | | | | |
|-----|-------------------------------------|-------|--|-------|------------------------------------|
| 151 | Permanent stations in polar regions | 2,534 | Gigabytes of borehole strain data delivered last quarter | 1,423 | Participants in 2021 short courses |
|-----|-------------------------------------|-------|--|-------|------------------------------------|

UNAVCO is a community of scientists, educators, and professionals working together to better understand Earth processes and hazards using geodesy. We operate the GAGE Facility on behalf of the National Science Foundation with support from NASA.

Use Our Services

- DATA
- INSTRUMENTATION
- SOFTWARE

INTERNSHIP PROGRAMS AND OPPORTUNITIES



Geo-Launchpad



Research Experiences in Solid
Earth Science for Students
(RESESS)



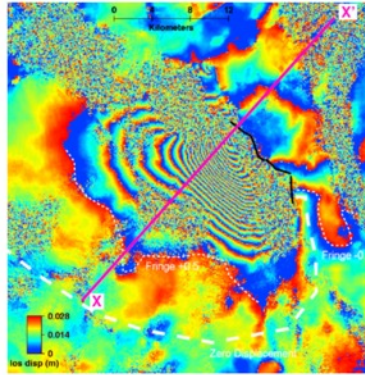
UNAVCO Student Internship
Program (USIP)



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EDUCATION RESOURCES



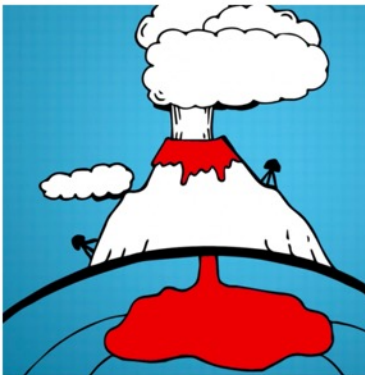
GETSI Undergraduate Modules



K-12 Activities & Demos



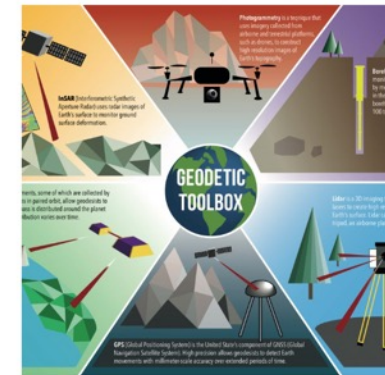
Field Learning



Videos & Animations



Tutorials



Posters & Graphics

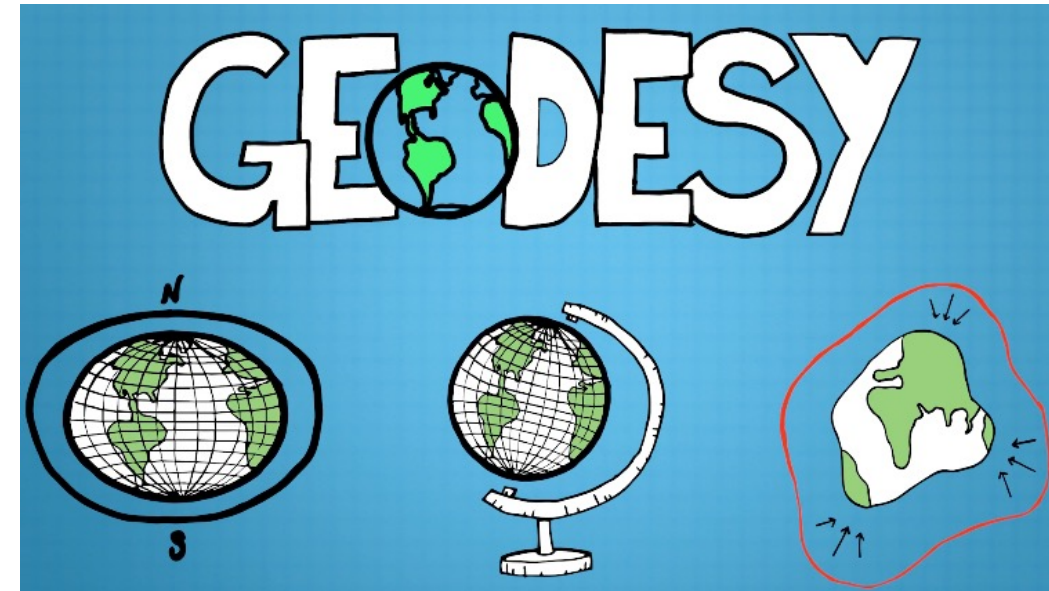


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What is geodesy?

- Geodesy is the science of extremely accurate measurements of Earth's shape, orientation, and gravity—everything from the coordinate system that underlies all navigation and positioning to detecting the warning signs of a volcanic eruption.

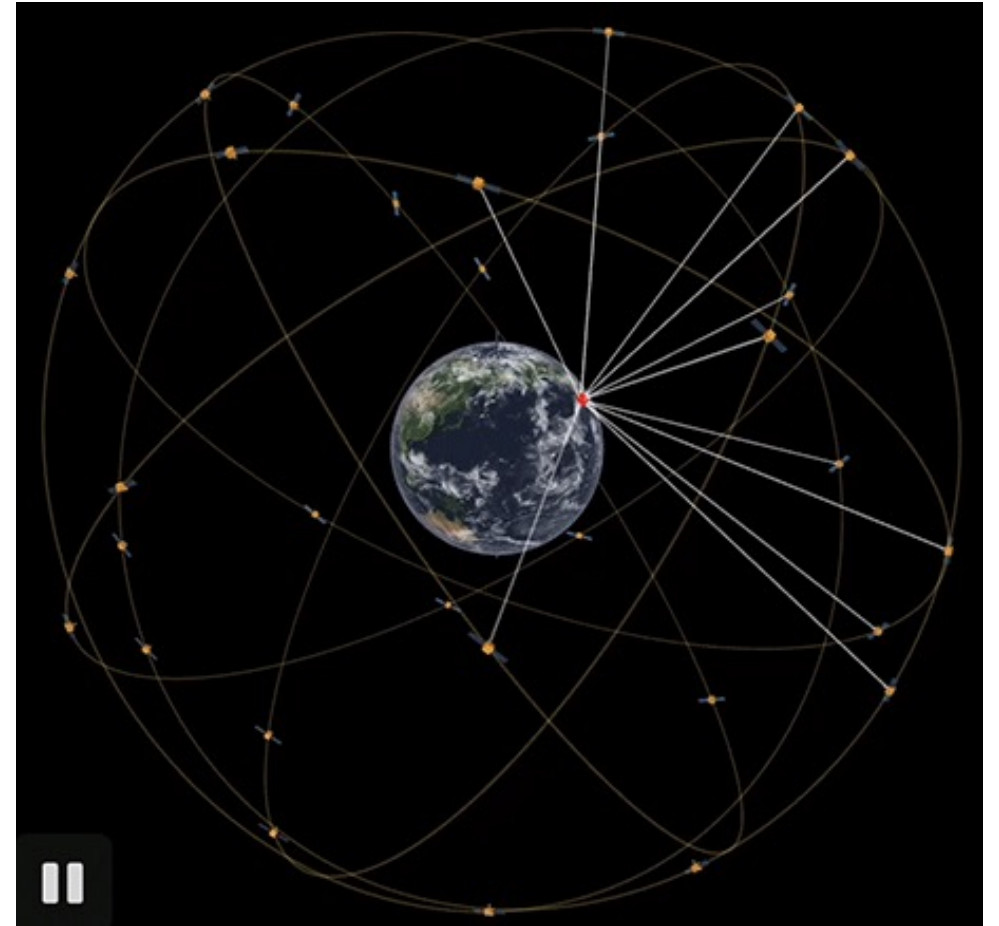


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How does GPS work?

- GPS devices read signals from satellites
- Signal includes satellite location and exact time of transmission
- Device calculates distance to satellite based on time of signal arrival
- Given distance to multiple satellites, it determines your position (trilateration)



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Source:
<https://ciechanow.ski/gps/>

What is GNSS?

- Global Positioning System (GPS) is operated by the United States
- Other satellite constellations include GLONASS (Russia), Galileo (EU), and BeiDou (China)
- All are examples of Global Navigation Satellite Systems (GNSS)
- Some receivers can use multiple (or all) satellite constellations



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High-precision GPS

- A geodetic GPS station can determine its position with sub-centimeter-level precision—sensitive enough to measure ground movement of less than a millimeter per year (the thickness of about 10 sheets of paper).
 - Stable mount securely anchored into the ground
 - Sensitive antenna that examines the satellite signal more closely than typical handheld GPS device
 - Data corrections for atmospheric conditions, satellite orbit, and satellite clocks further increase precision
 - Can use multiple navigation satellite constellations (Galileo, GLONASS, BeiDou), commonly referred to as GNSS



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What's in a GPS station?

Data connection (such as cell modem)

Solar panels

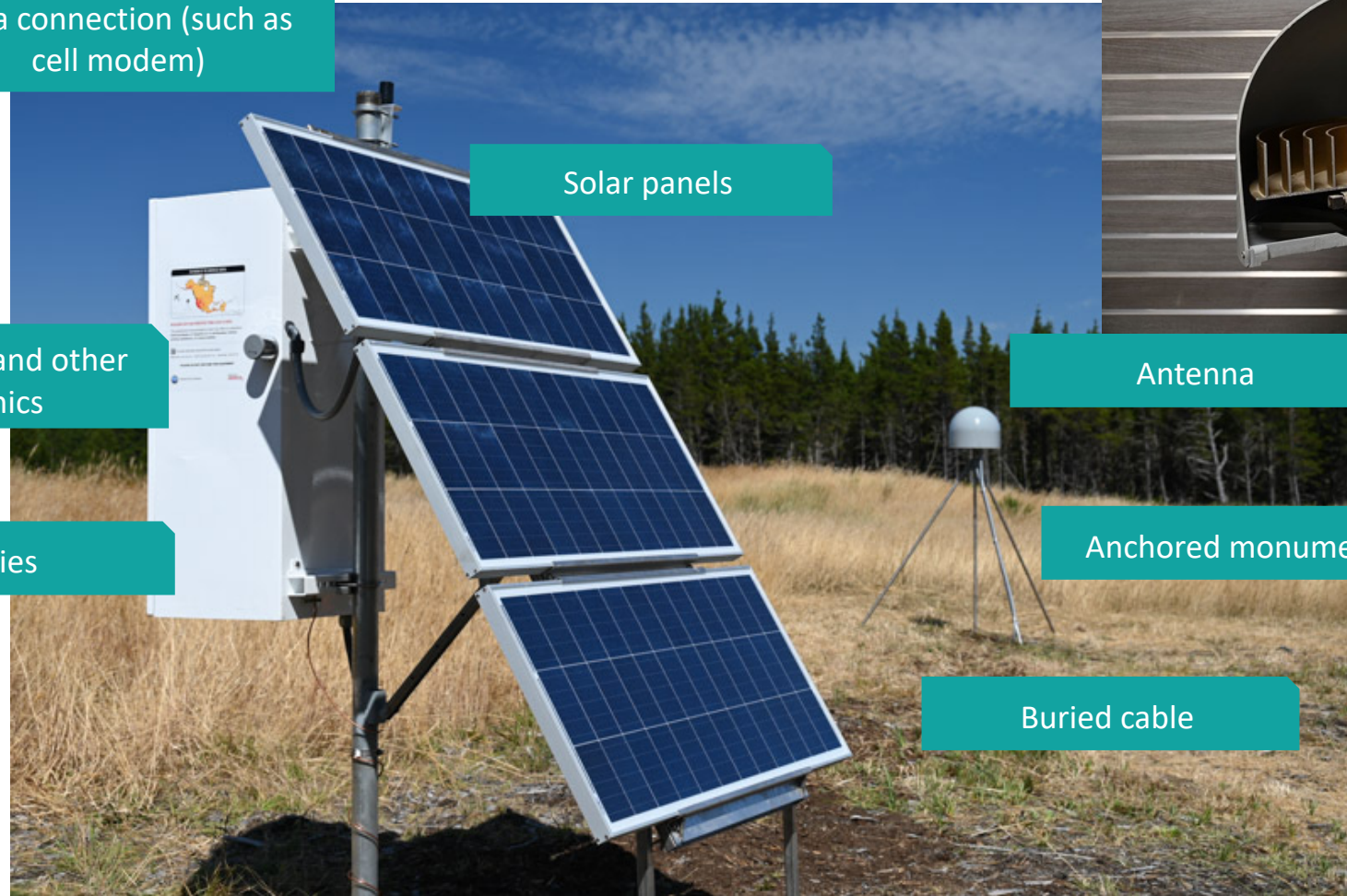
GPS receiver and other electronics

Batteries

Antenna

Anchored monument

Buried cable



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What's in a GPS station?

- Charge controller and power system
- Data connection
- GPS receiver
- Batteries



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What's in a borehole station?



power source

data connection

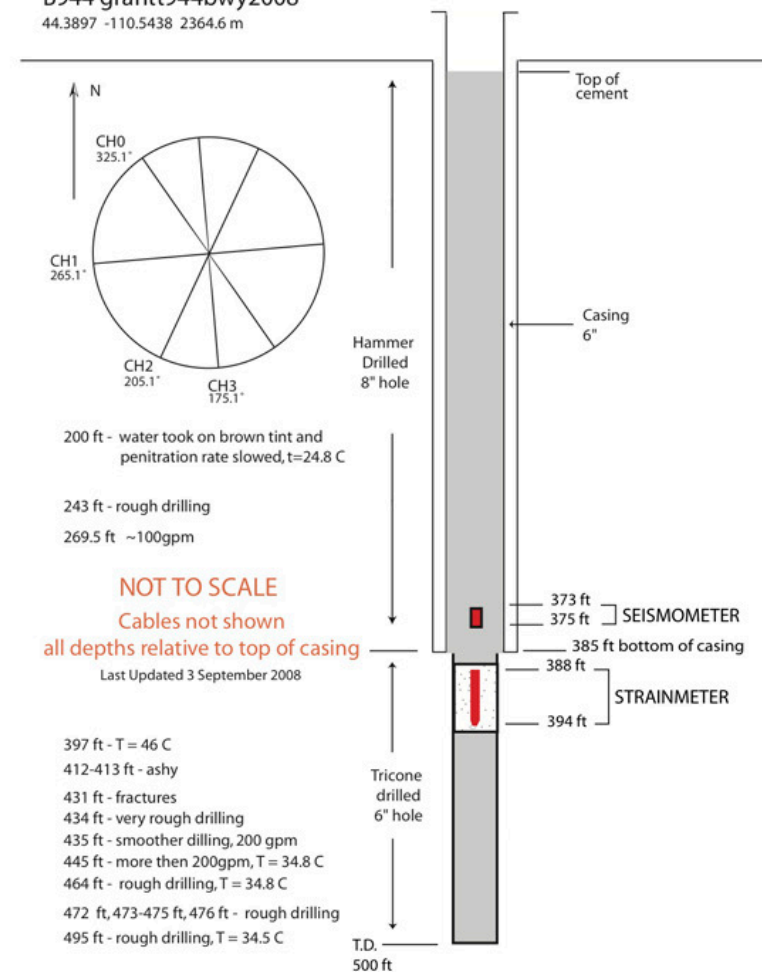
data logging devices

strainmeter

seismometer

other instruments

B944 grantt944bwy2008
44.3897 -110.5438 2364.6 m



GAGE

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UNAVCO

How do borehole strainmeters work?

- Bedrock deforms (strains) as stress accumulates, releasing this energy as seismic waves during earthquakes
- Strainmeters can measure changes in the shape of the borehole of less than one millionth of a percent
- Detects small fault movements in between those that GPS stations and seismometers focus on, filling a data gap

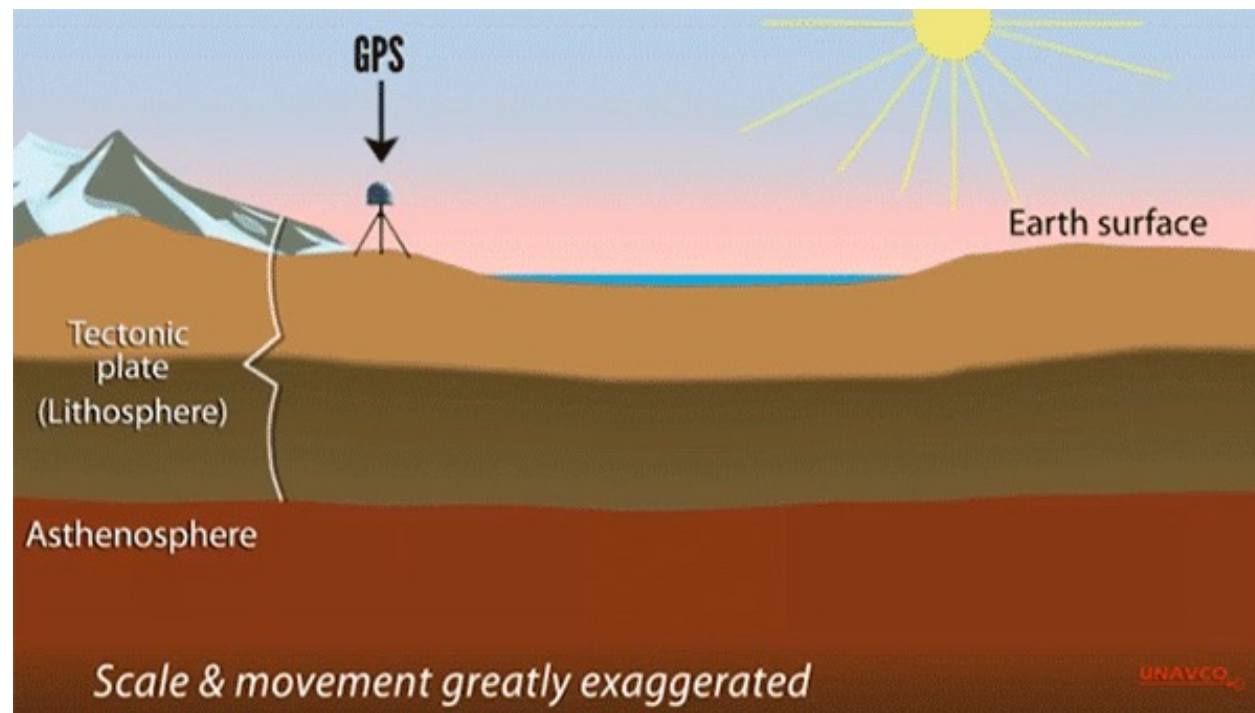


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Groundwater

- Measuring subtle surface movements can reveal seasonal or long-term changes in water resources

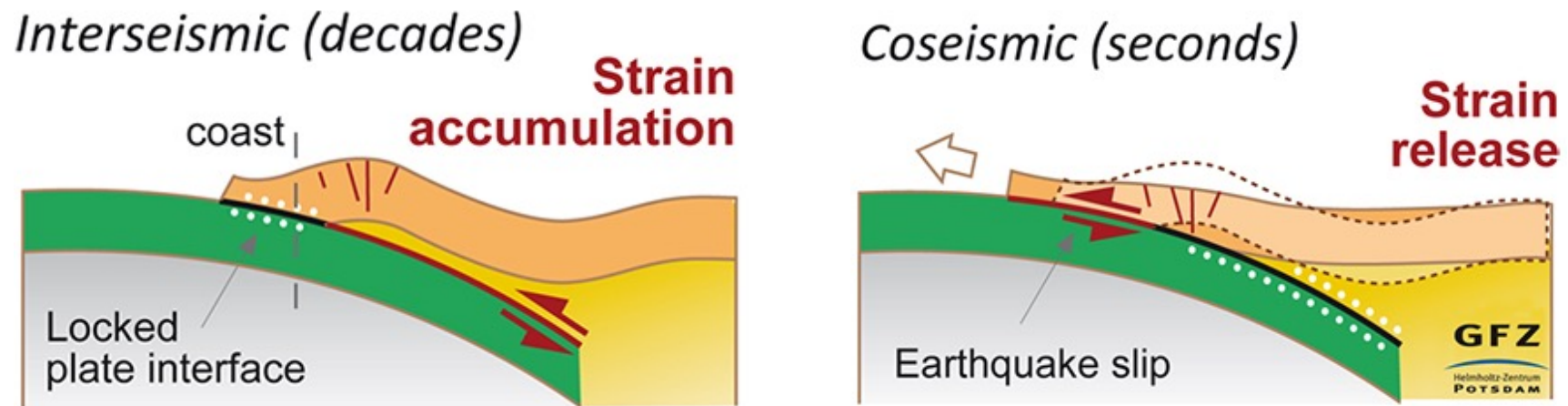


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The Earthquake Cycle

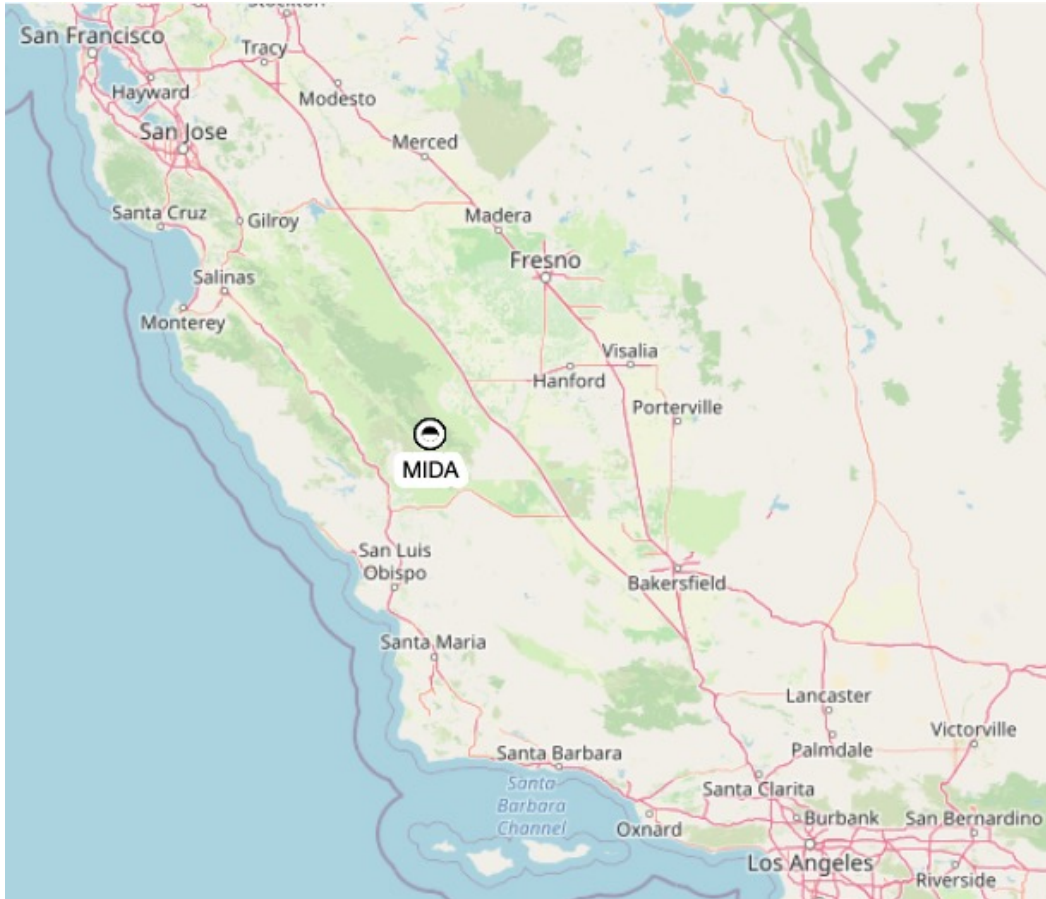
- Earthquakes occur when accumulated stress exceeds the strength of the fault, causing a portion of the fault to slip
- Rock actually deforms under this stress, bouncing back to its former shape and releasing seismic energy
- While this cycle repeats, the timing of earthquakes is not predictable



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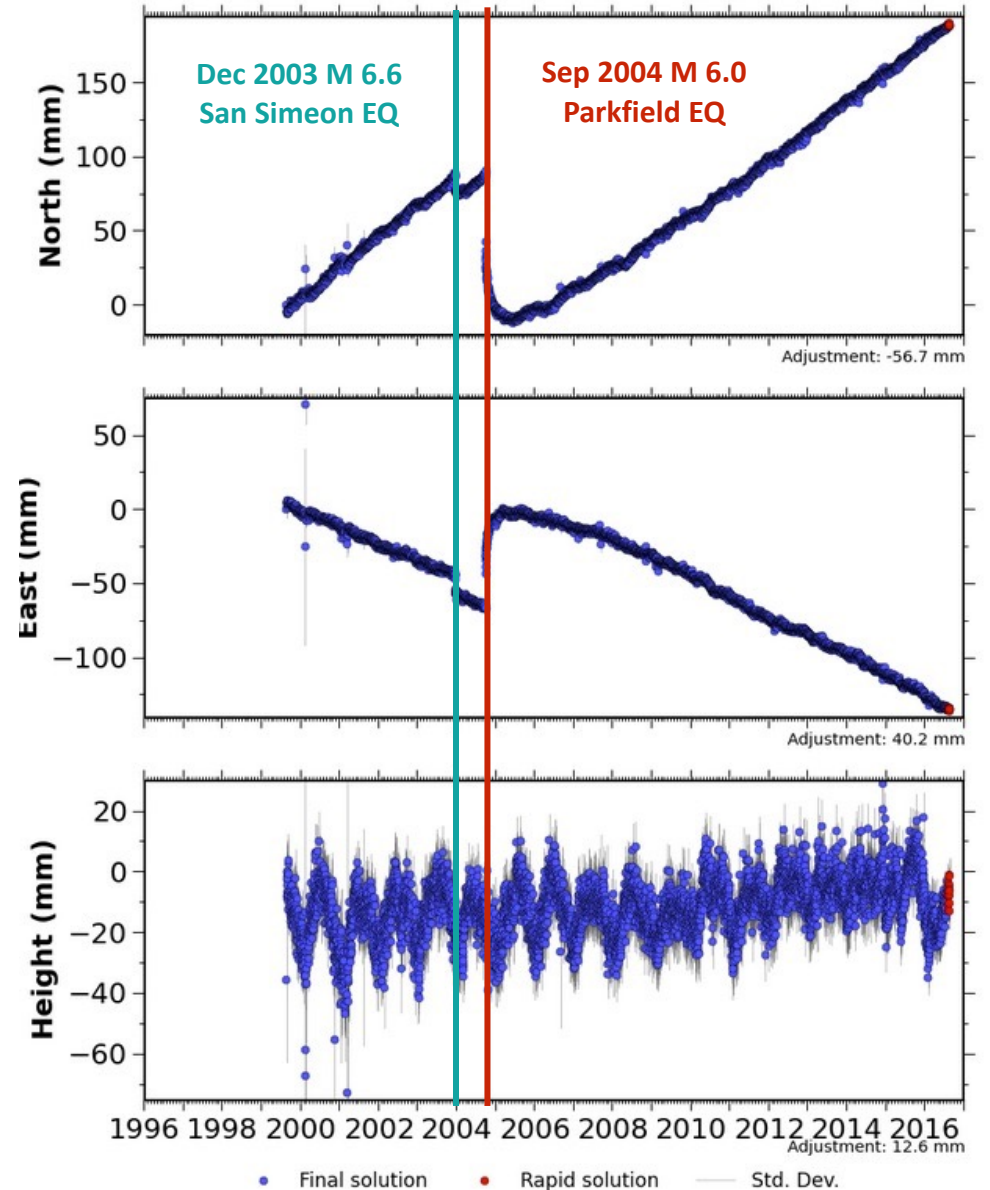
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Earthquakes



MIDA (MIDA_SCGN_CN1993) NAM08

Processed Daily Position Time Series



Source file: MIDA.pbo.nam08.pos Last epoch plotted: 2016-08-22 12:00:00



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UNAVCO

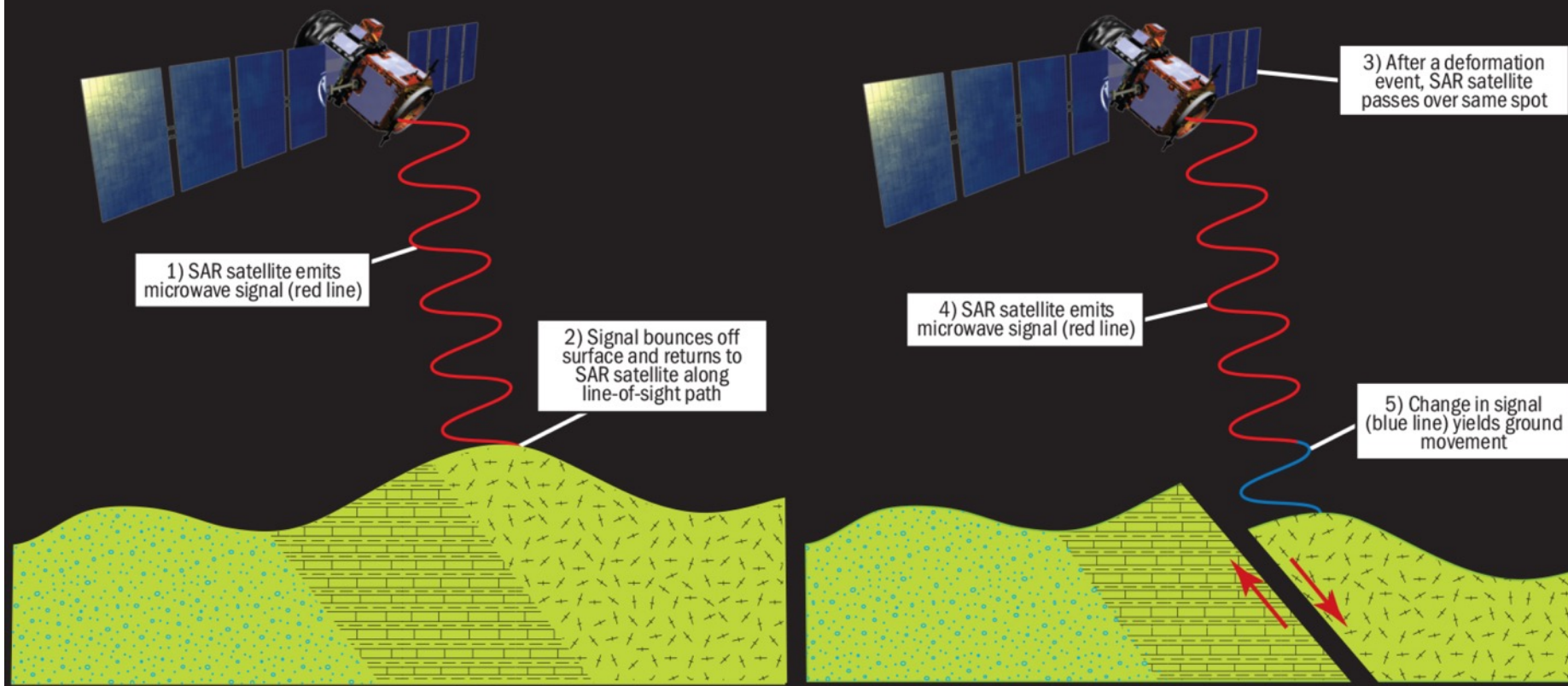
How does InSAR work?

Multiple satellite passes are needed to measure changes.

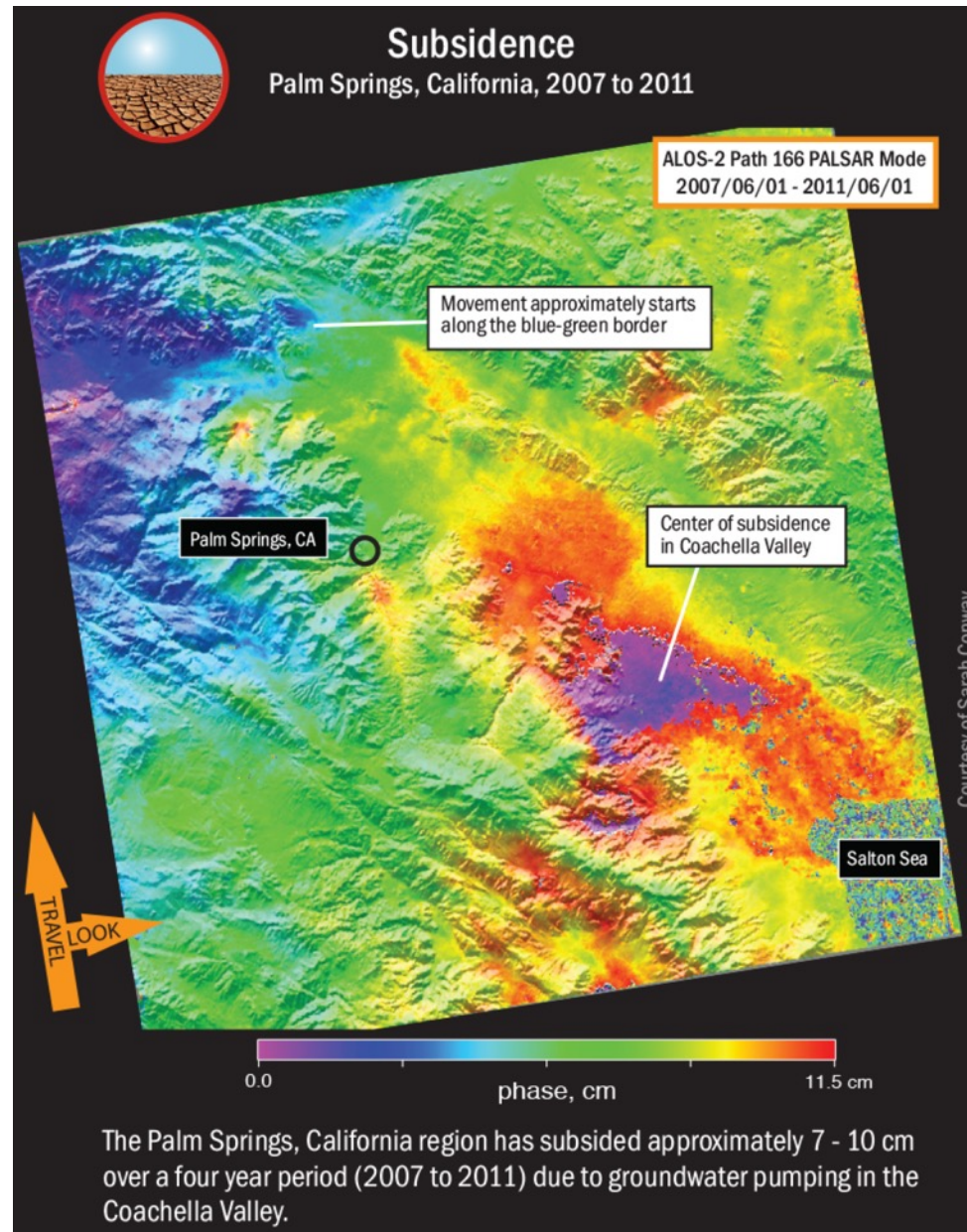
Example of InSAR detecting change
(Earthquake)

Satellite Pass #1 — Pre-deformation

Satellite Pass #2 — Post-deformation



What does InSAR do?



What does InSAR do?

Earthquake

Ms = 6.7, China, November 11, 2016



Sentinel-1, ascending track
2016/11/13 - 2016/12/07

The 2016 Akto earthquake near Xinjiang, China occurred along a strike-slip fault.

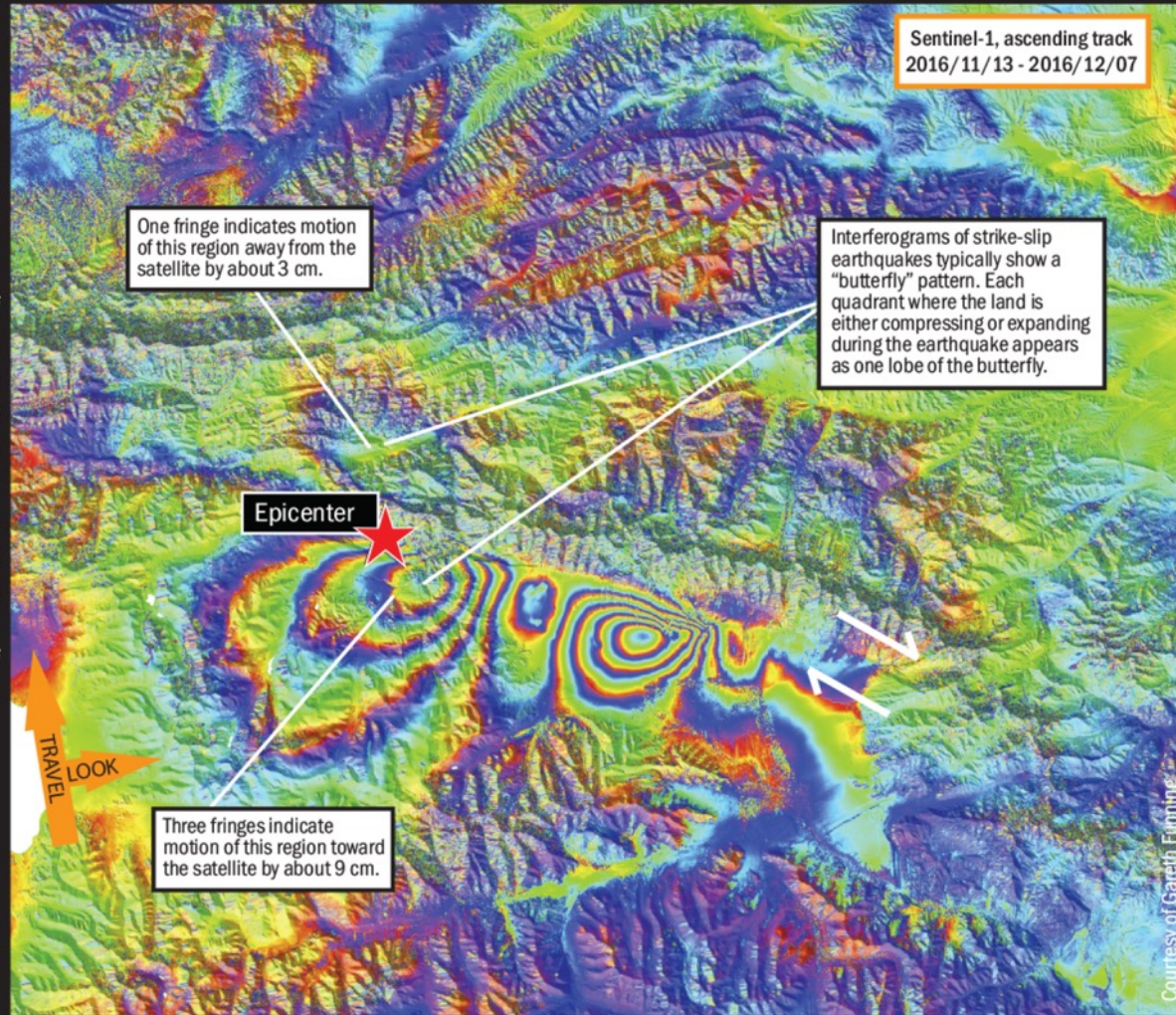
The land south of the fault moved to the west, while the land north of the fault moved to the east. Total motion amounted to about 12 cm at the surface of this blind fault, with about 1 meter of slip at depth.

One fringe indicates motion of this region away from the satellite by about 3 cm.

Interferograms of strike-slip earthquakes typically show a "butterfly" pattern. Each quadrant where the land is either compressing or expanding during the earthquake appears as one lobe of the butterfly.

Epicenter

Three fringes indicate motion of this region toward the satellite by about 9 cm.



Courtesy of Gareth Funning

