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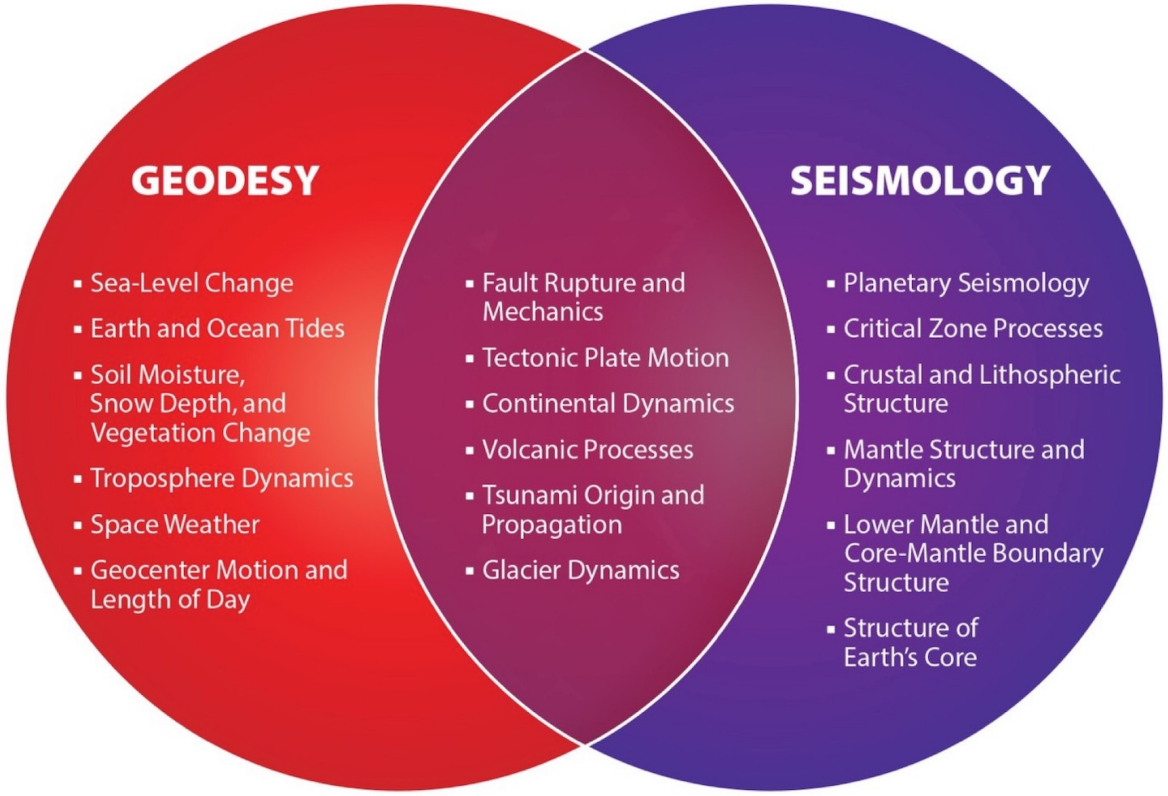
Unavco and Iris will merge in 2022/2023 to become the EarthScope Consortium

UNAVCO

Geodetic Facility



IRIS

Seismic Facility

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

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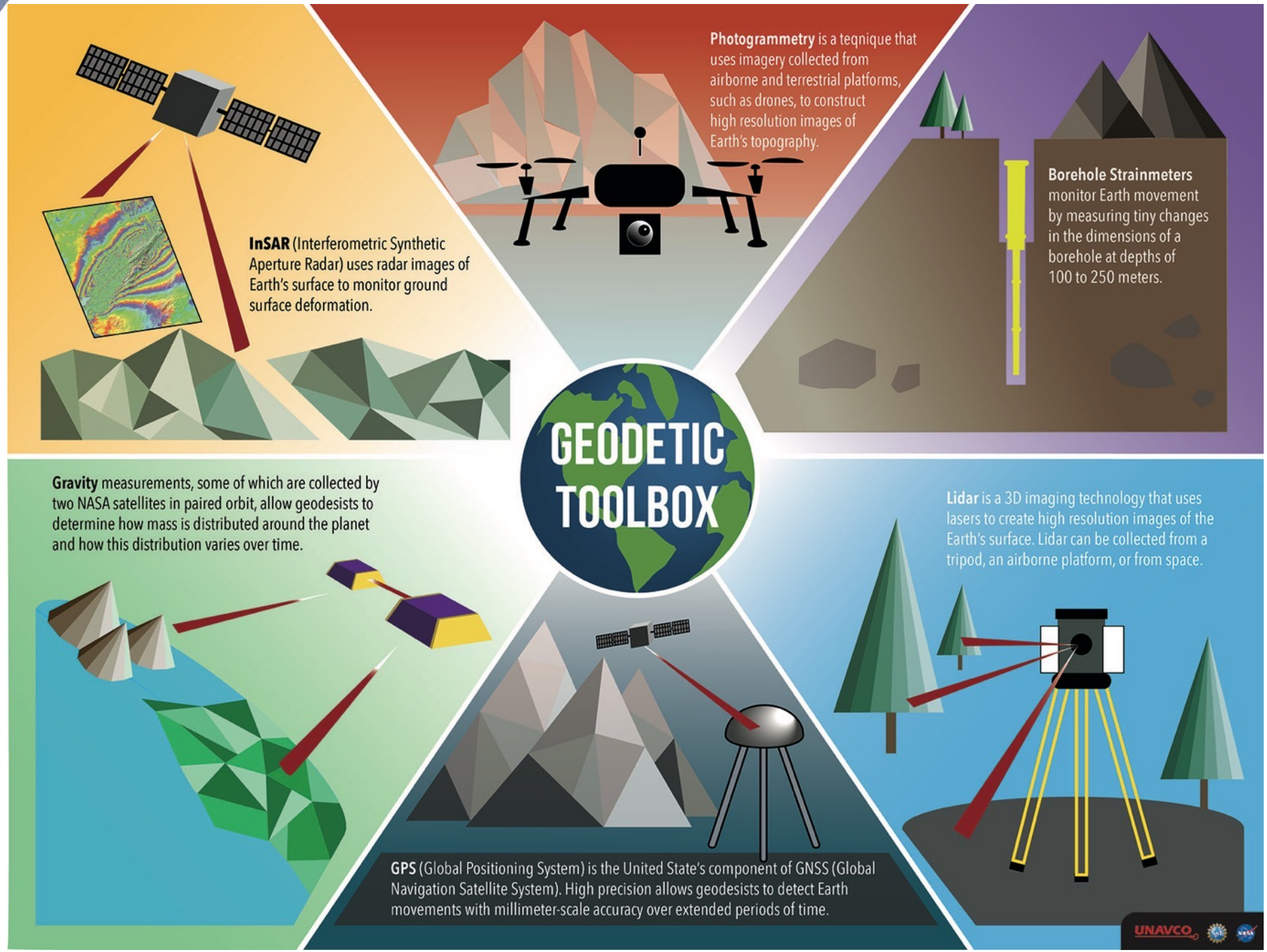
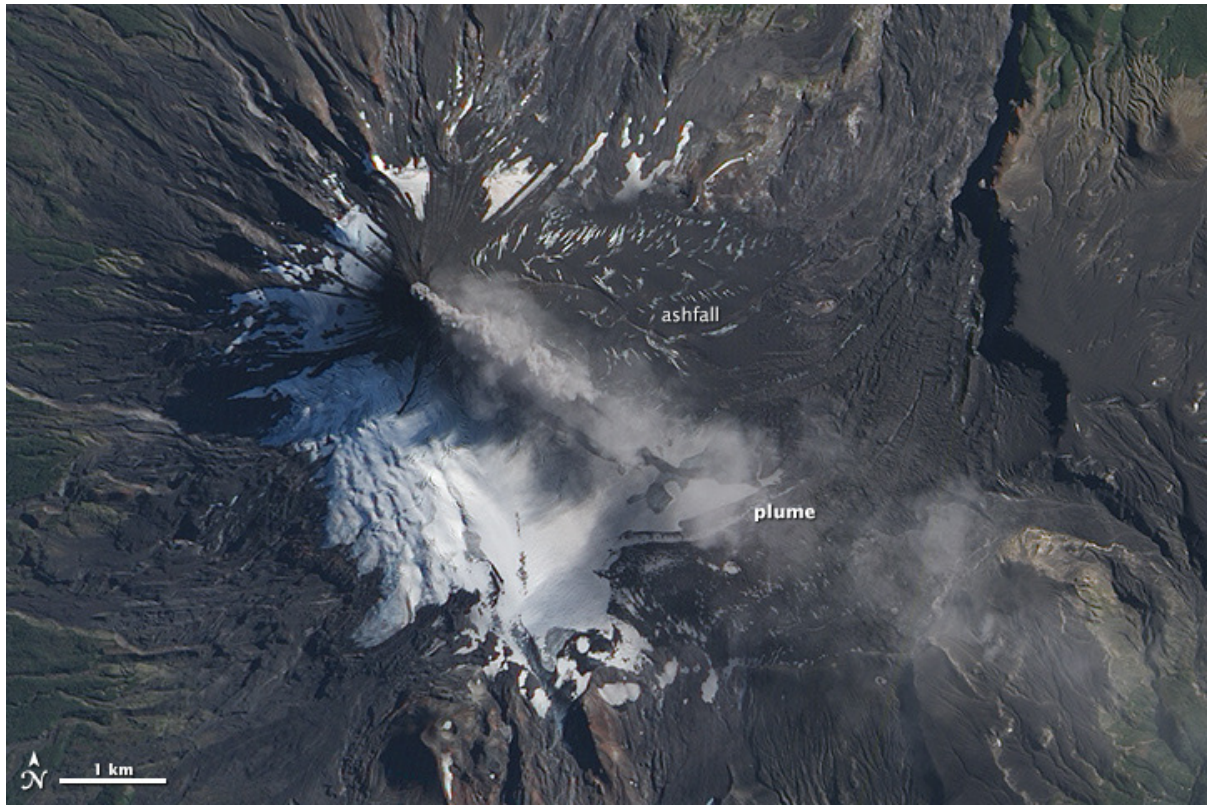
GEODETIC TOOLBOX



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



NASA Earth Observatory

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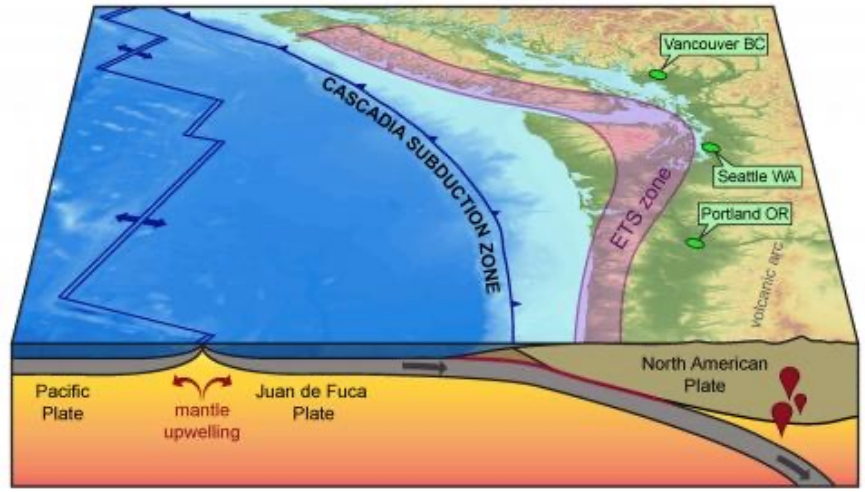
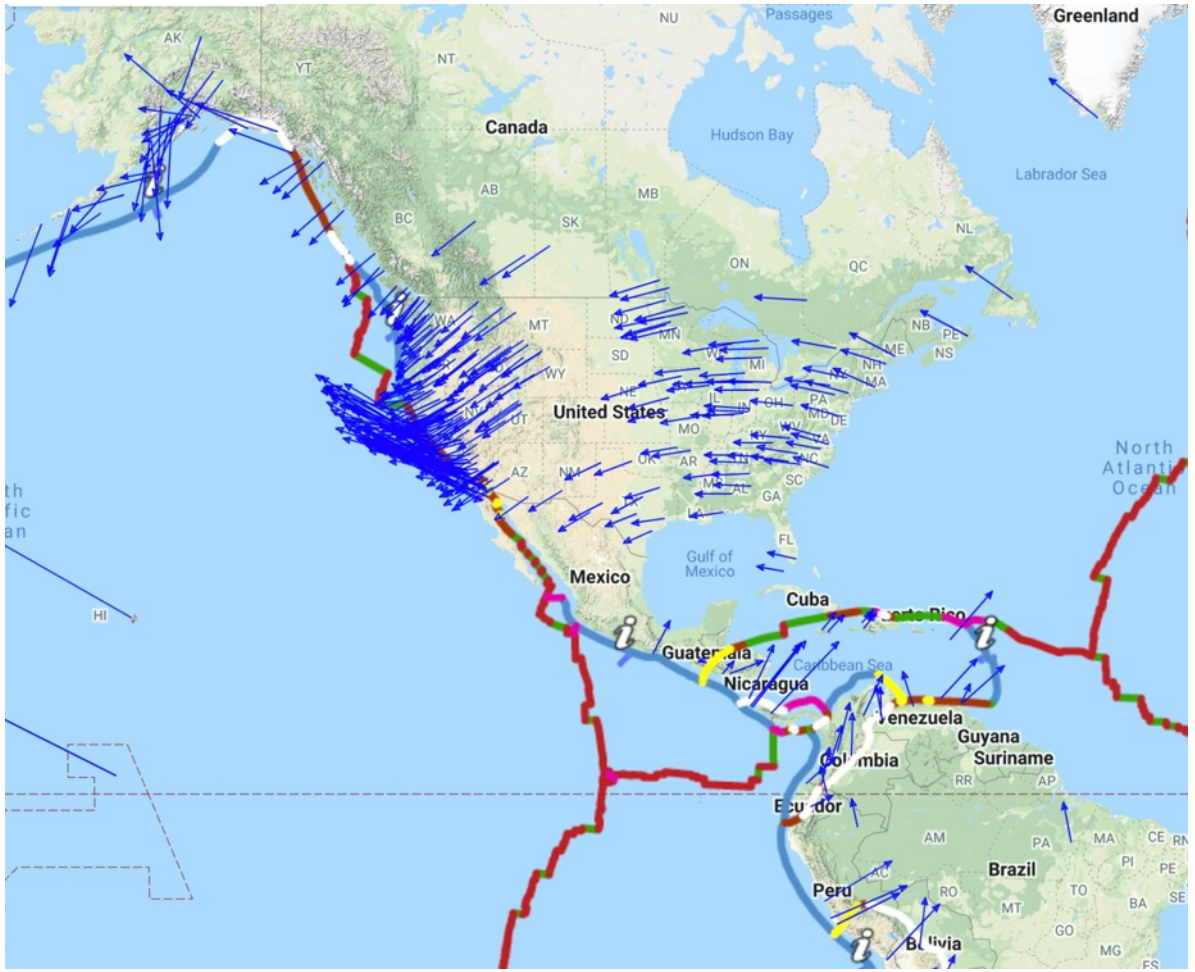
Plate tectonics

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





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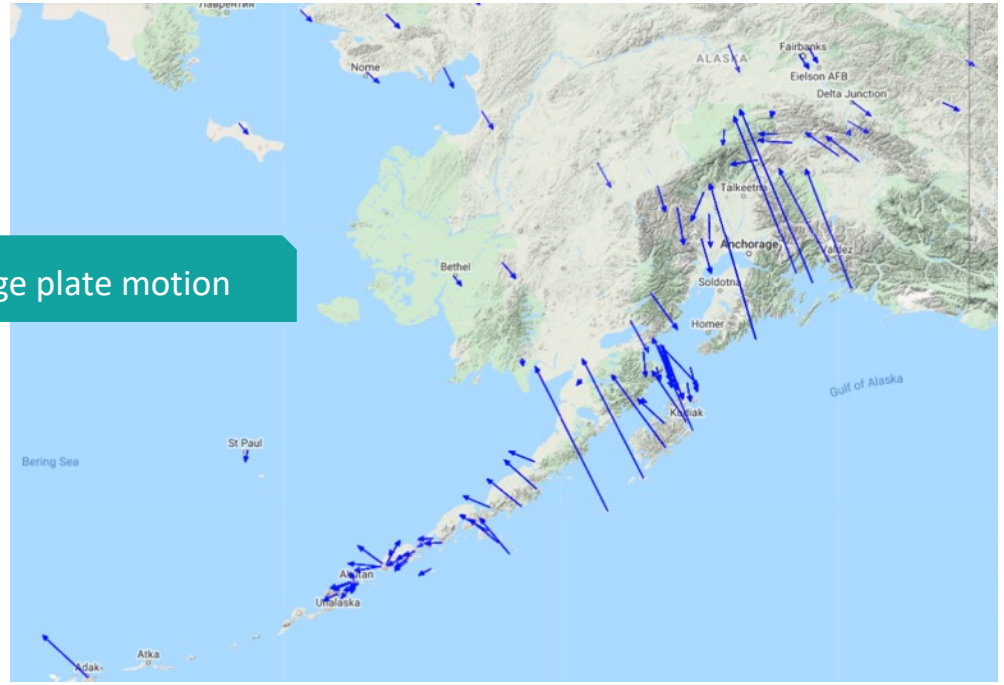
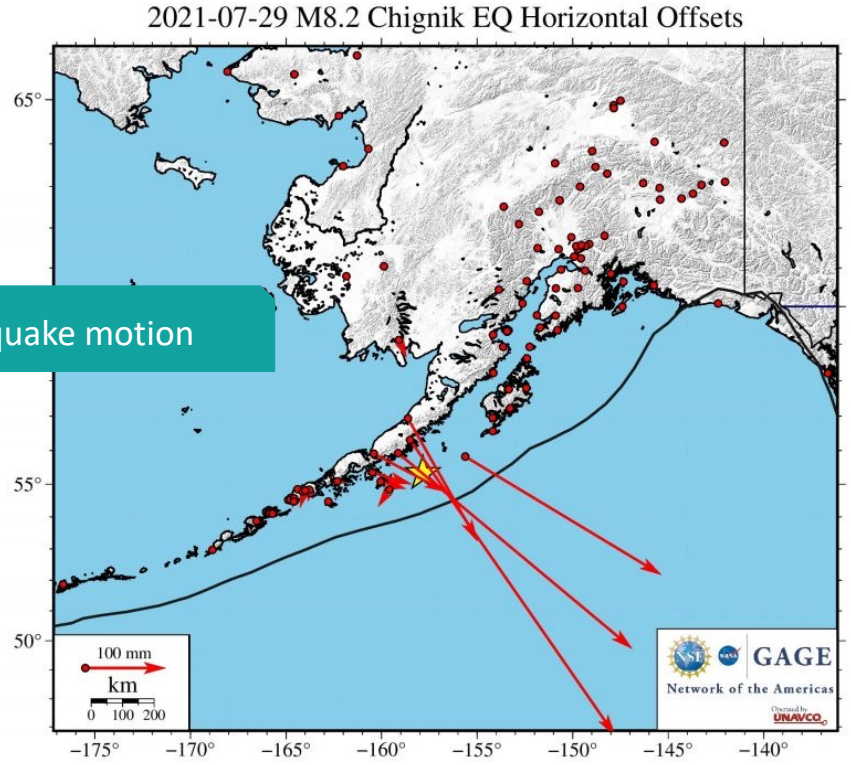
Earthquakes

- 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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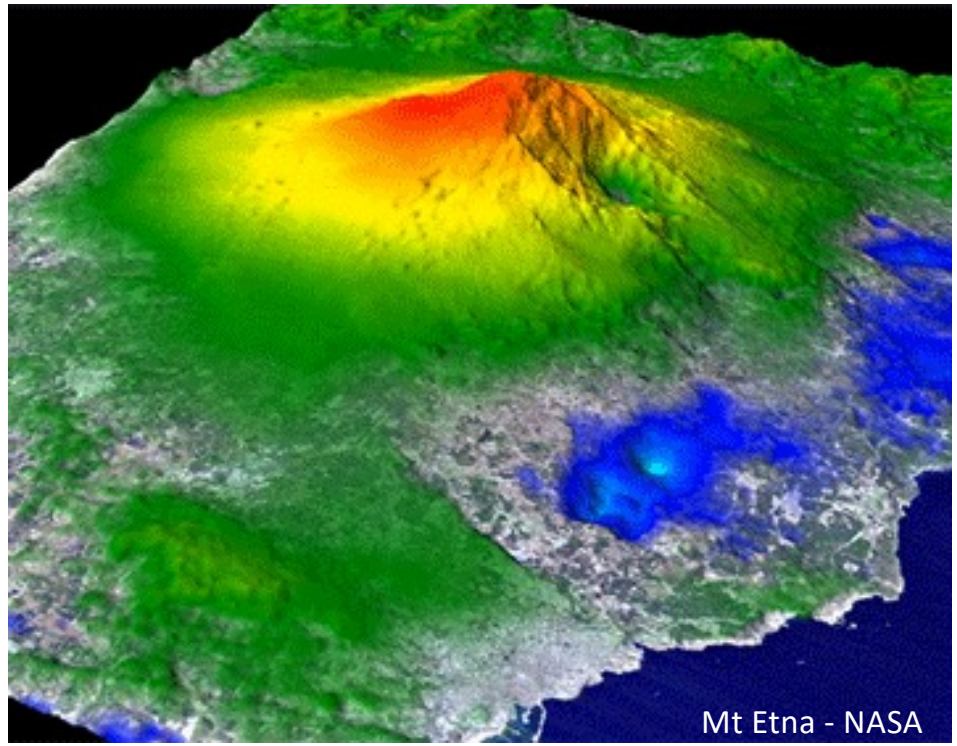
Volcanoes

- 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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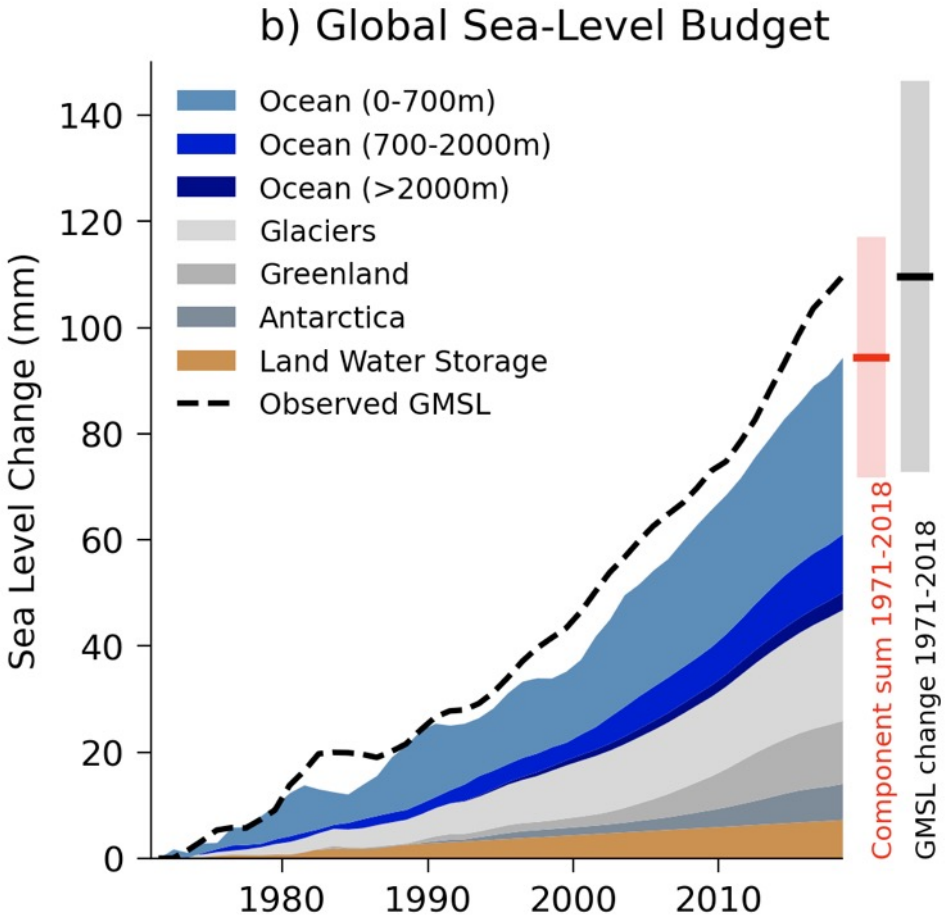
Sea level rise

- 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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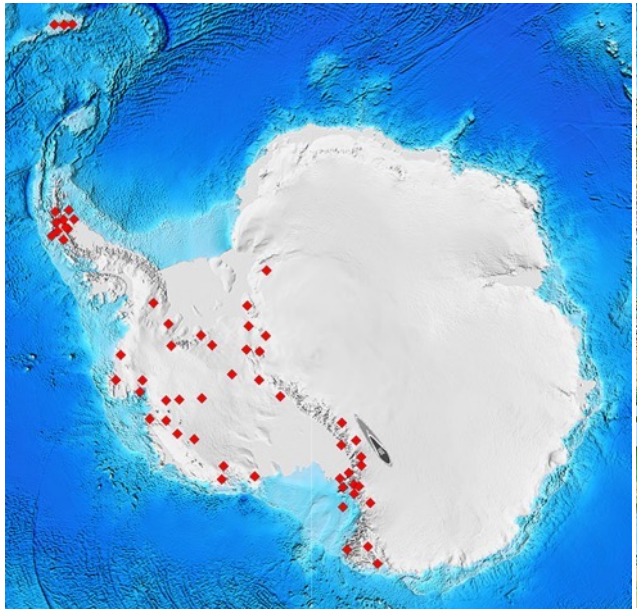
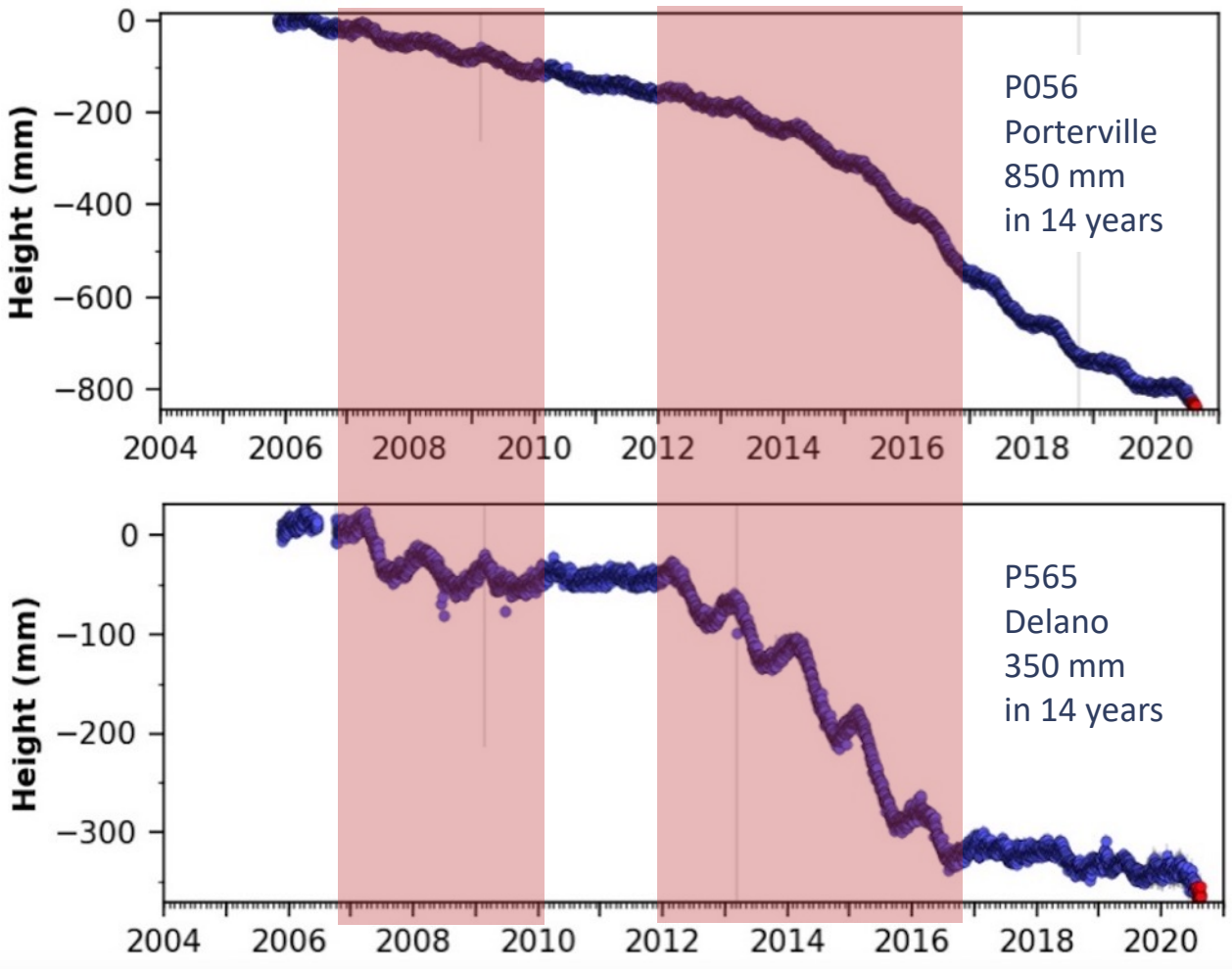
Polar science support

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

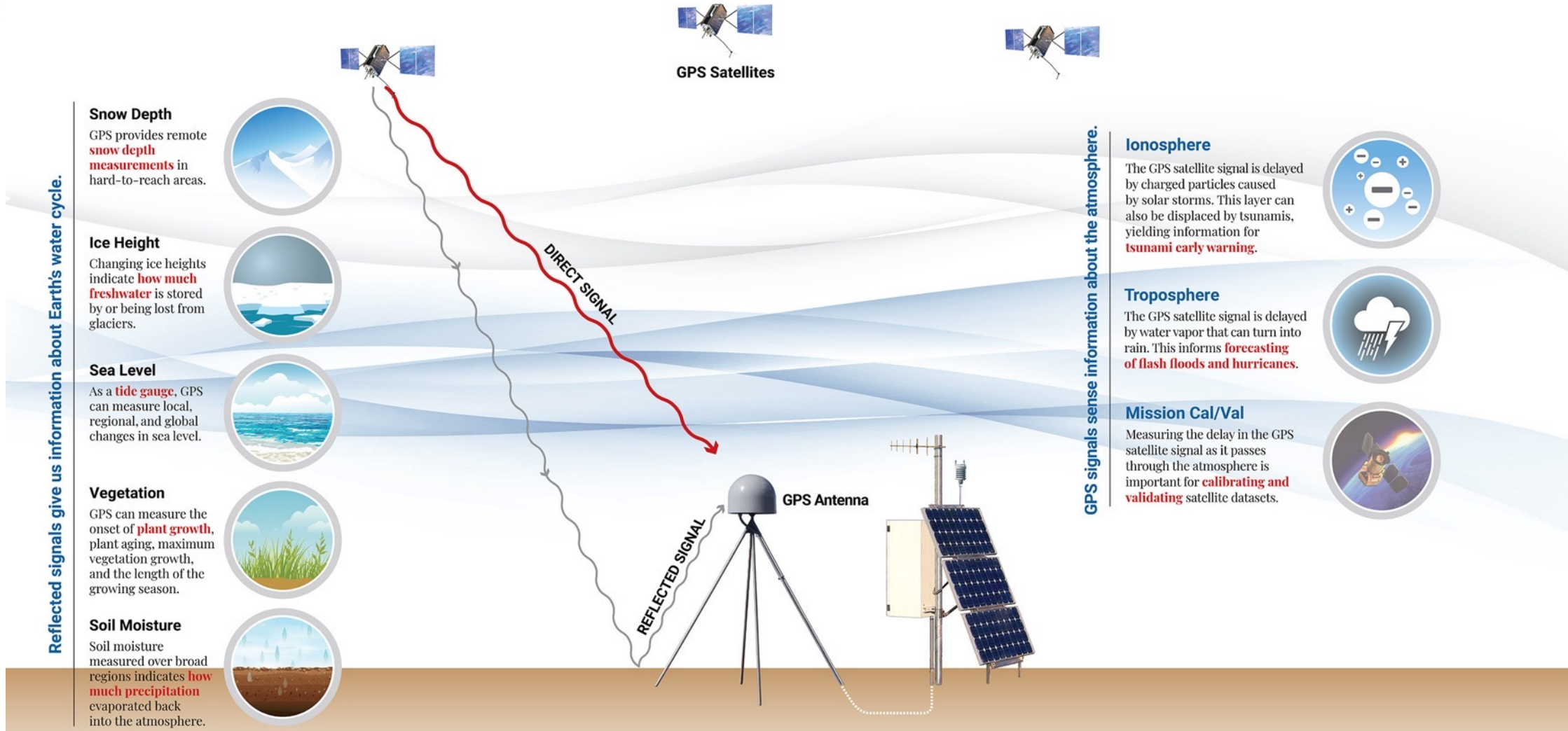


Groundwater

Ground subsidence during drought

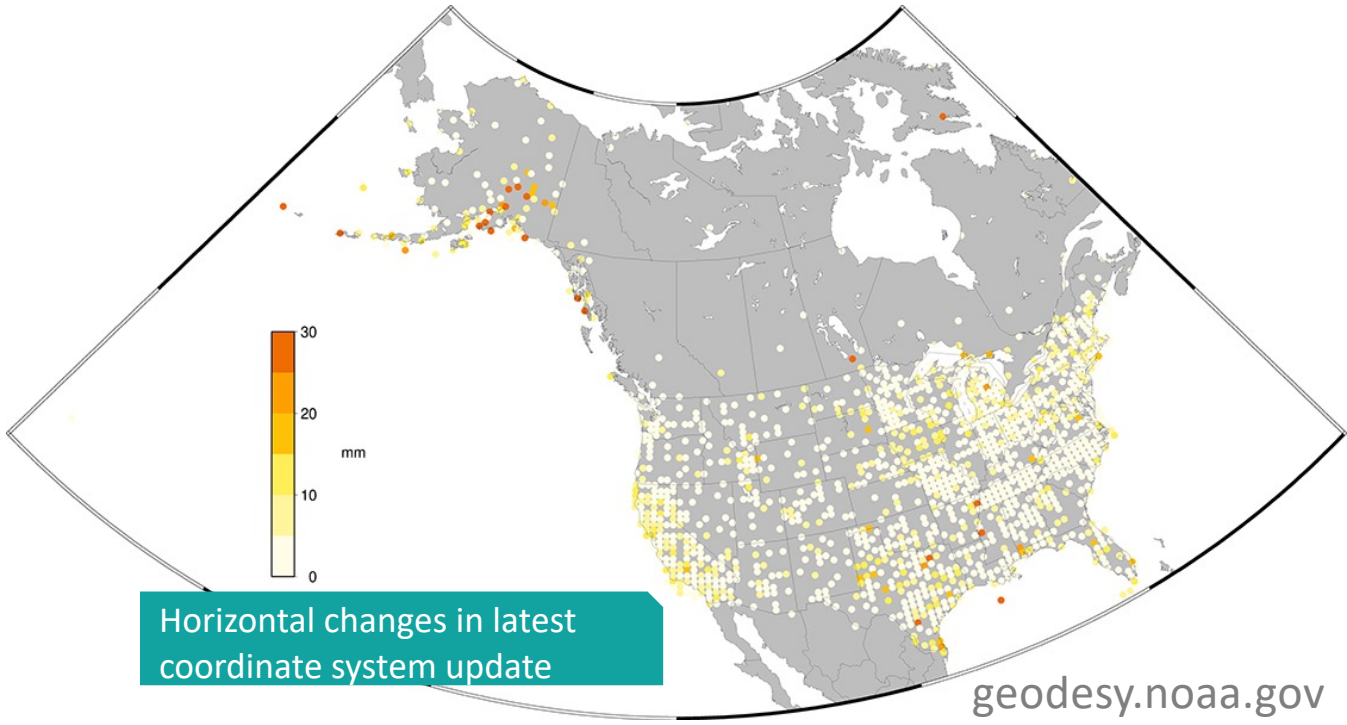


Atmosphere and More



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



Horizontal changes in latest coordinate system update

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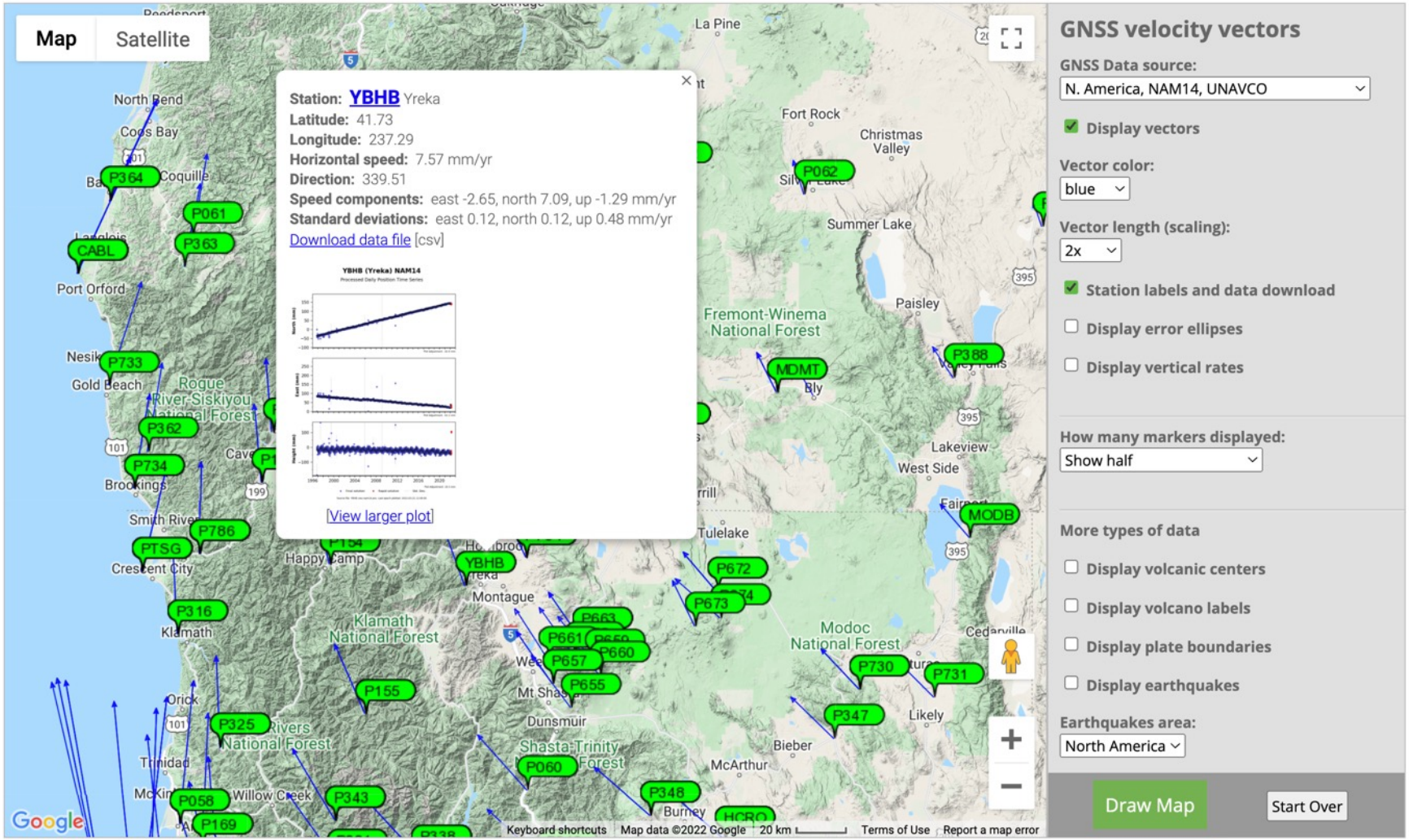
geodesy.noaa.gov

How to find stations and view data

unavco.org/velocity-viewer



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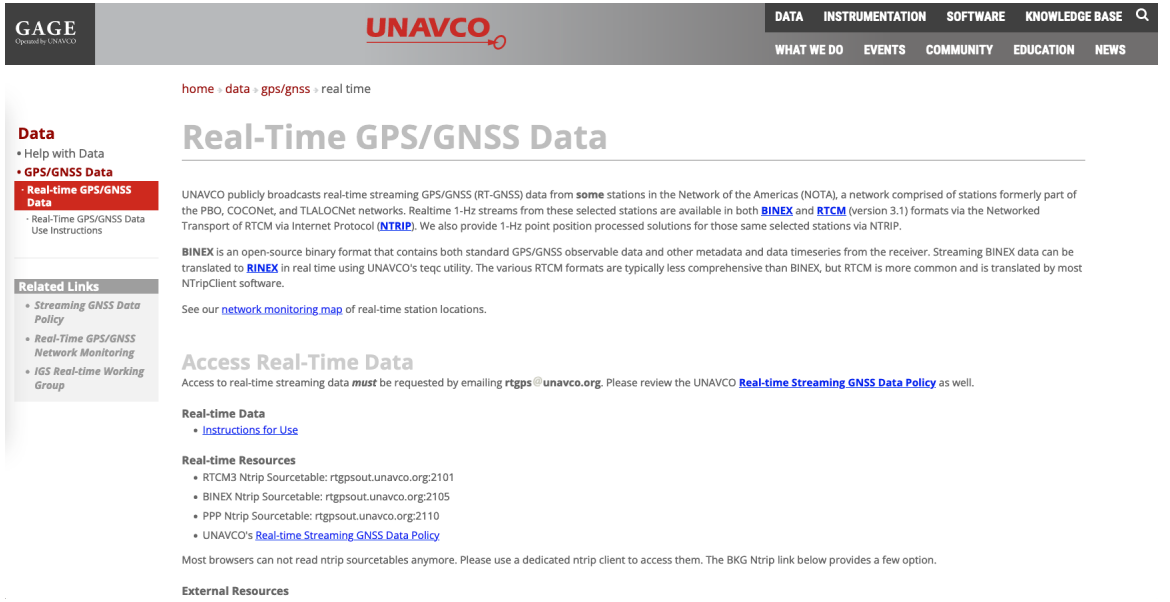
Real-Time Data Availability

- 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



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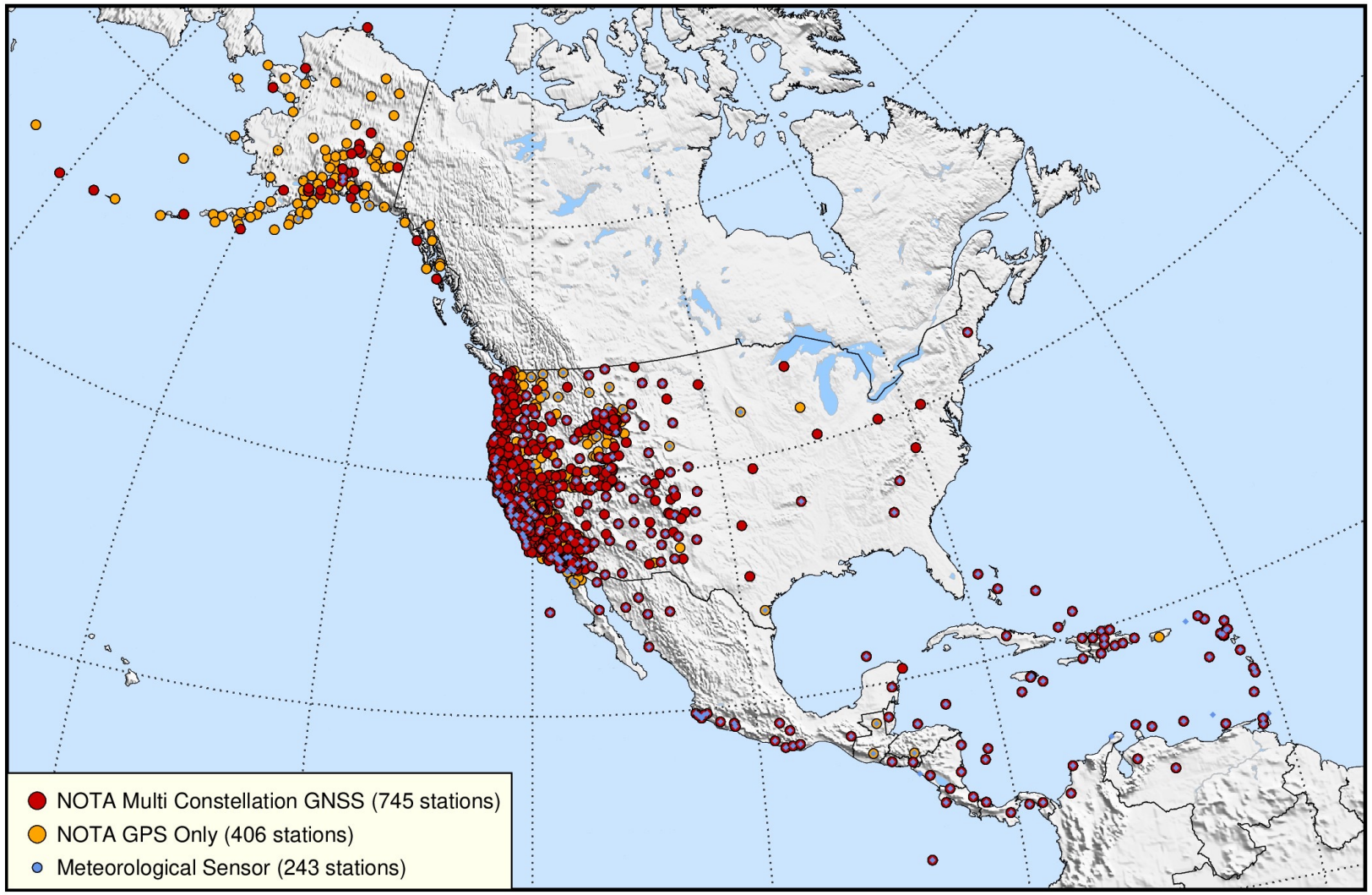
Network of the Americas (1150 GNSS stations across US, Mexico, Caribbean)



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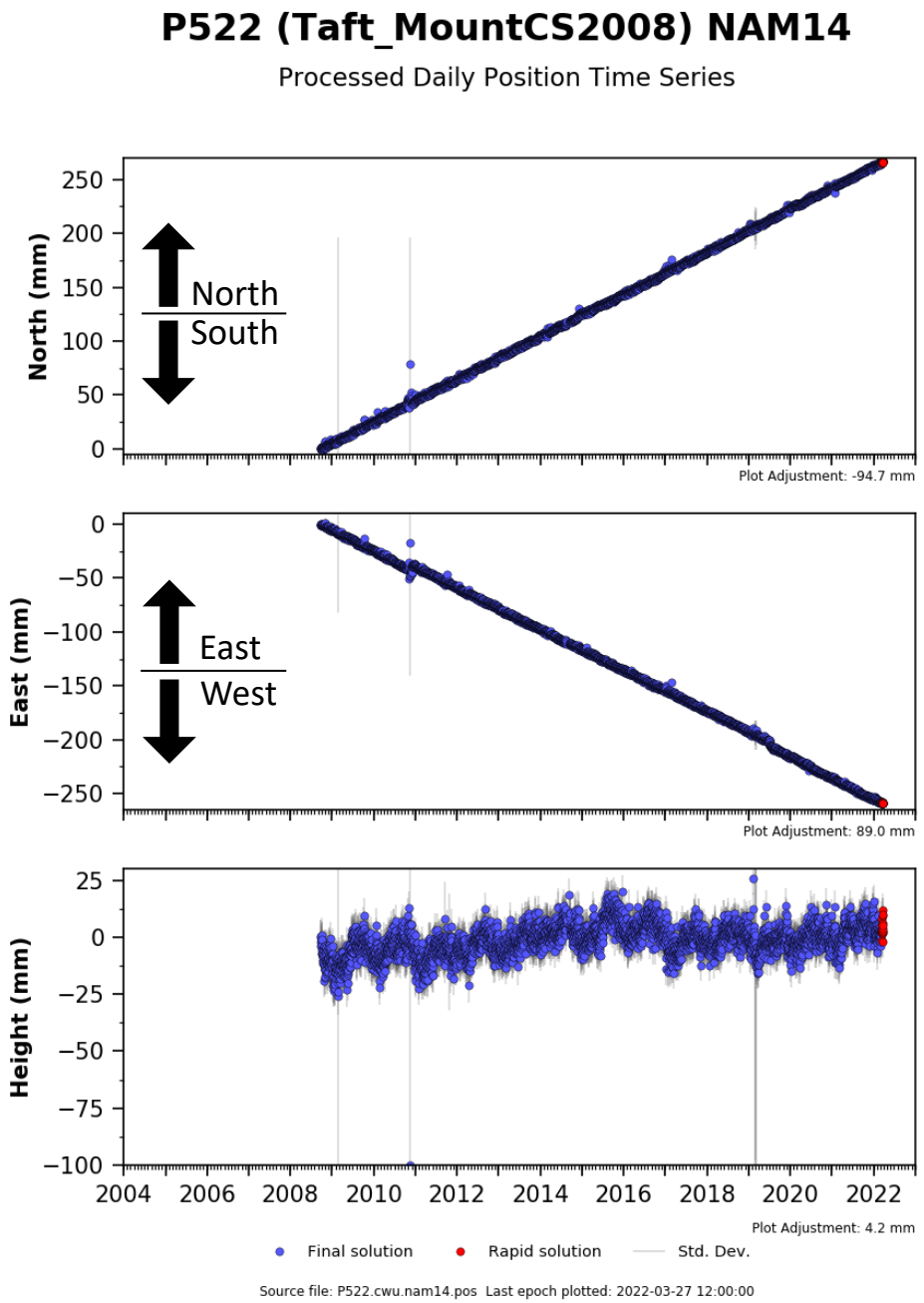
High-precision GPS

- 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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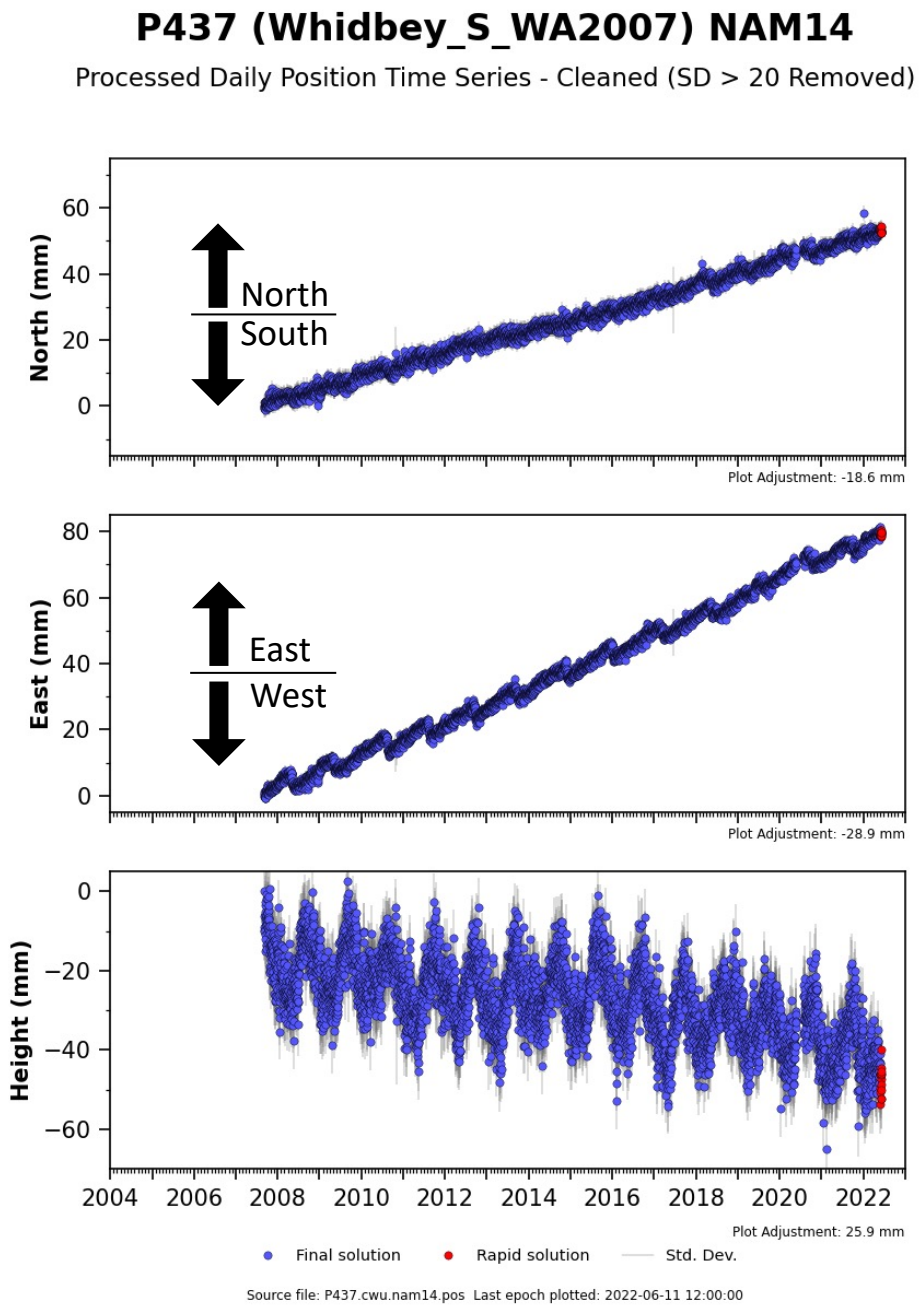
High-precision GPS

- 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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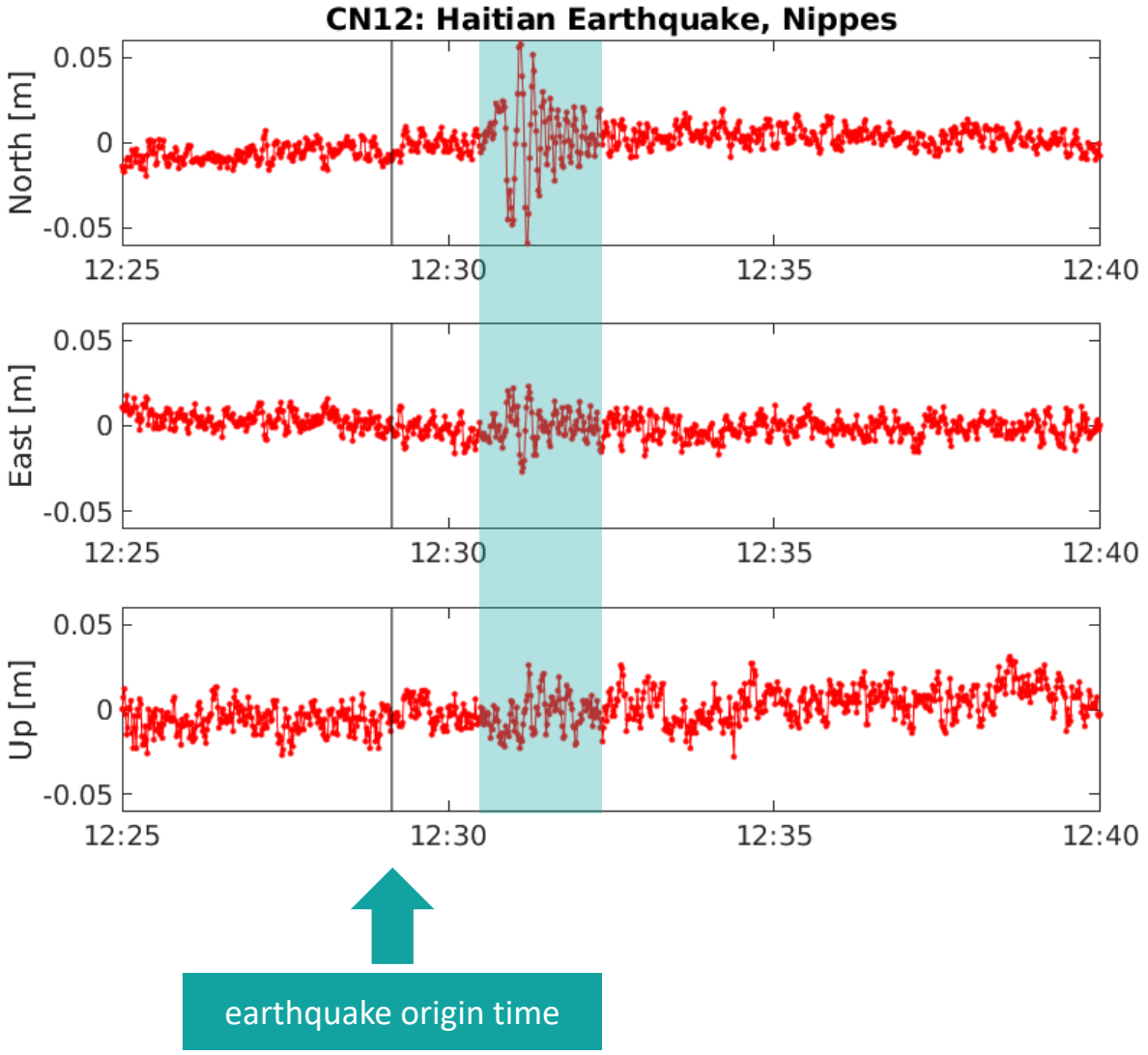
High-precision GPS

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



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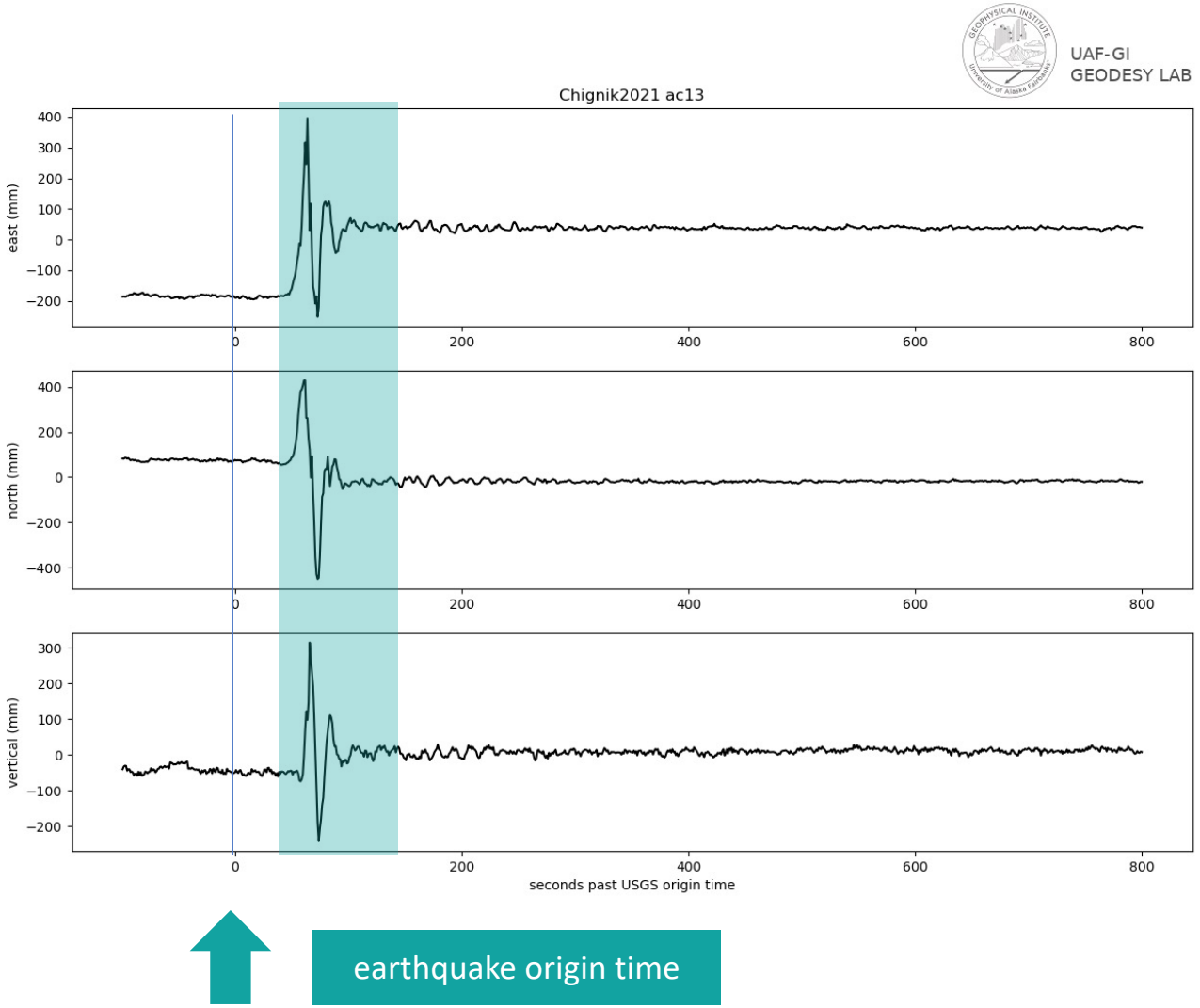
High-precision GPS

- 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



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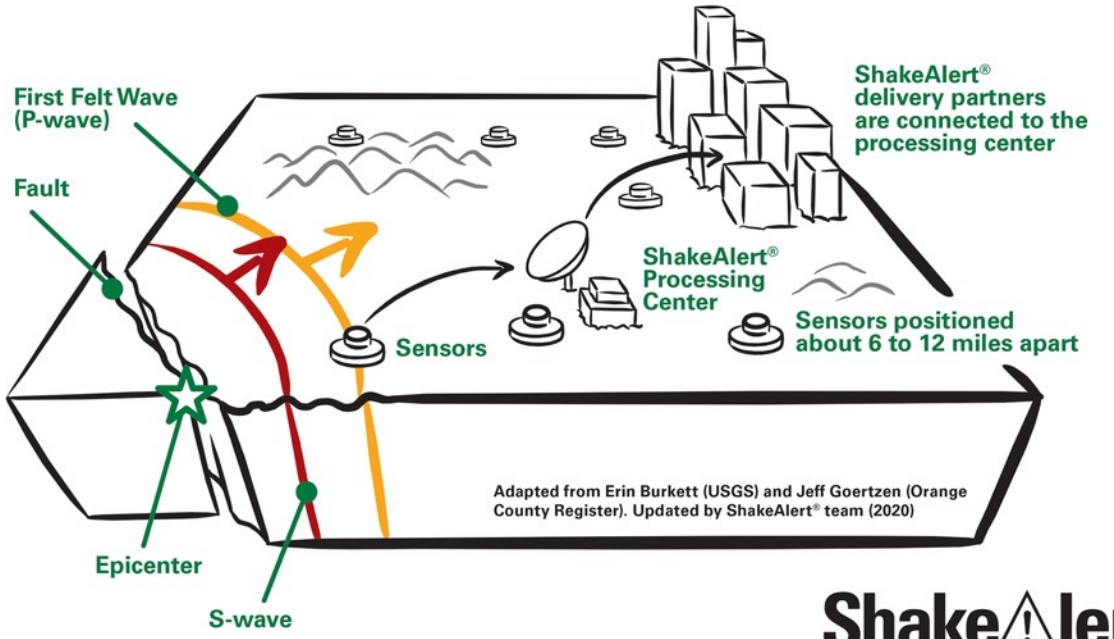
ShakeAlert® Earthquake Early Warning System

- 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

shakealert.org



ShakeAlert™

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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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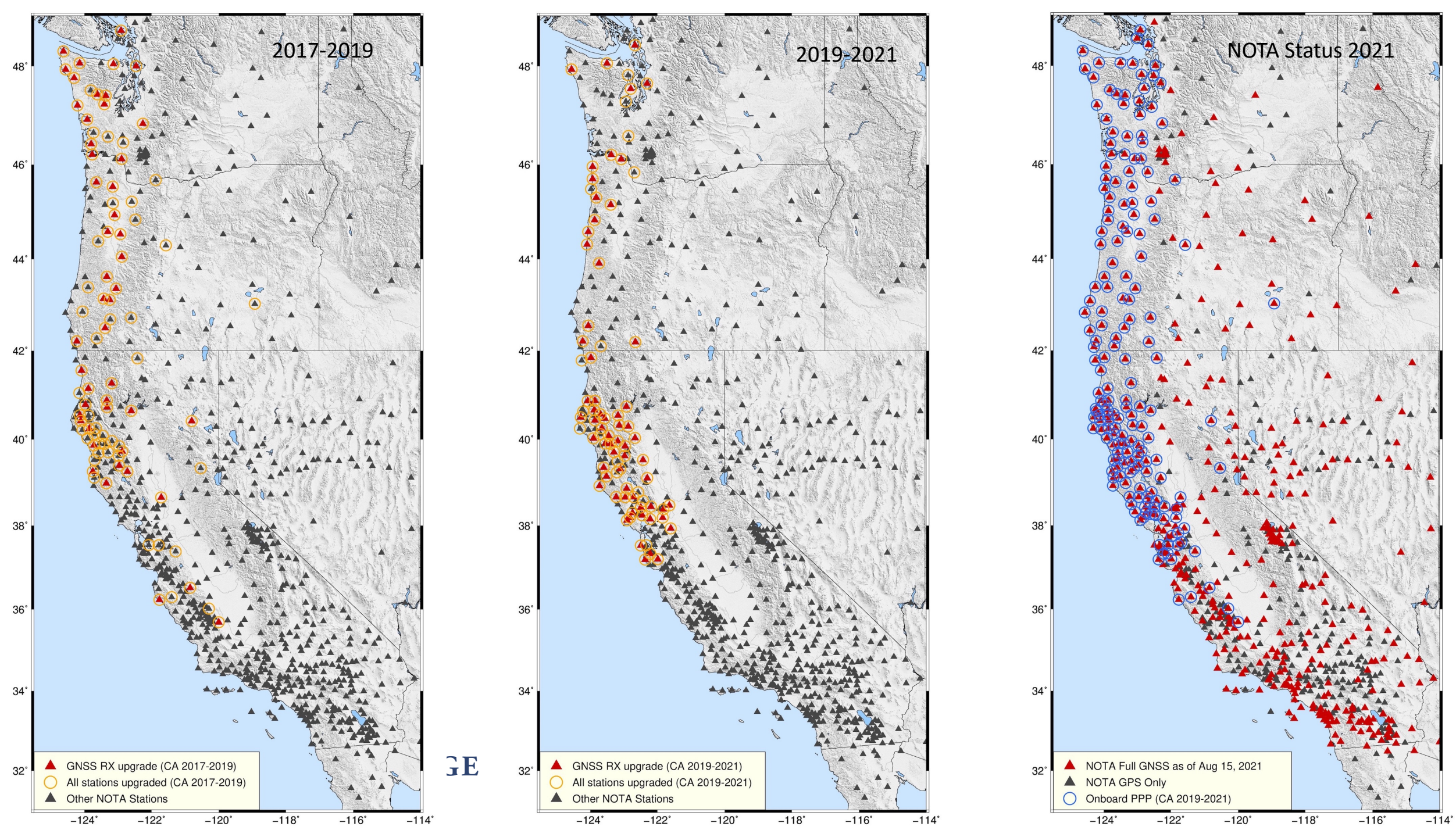
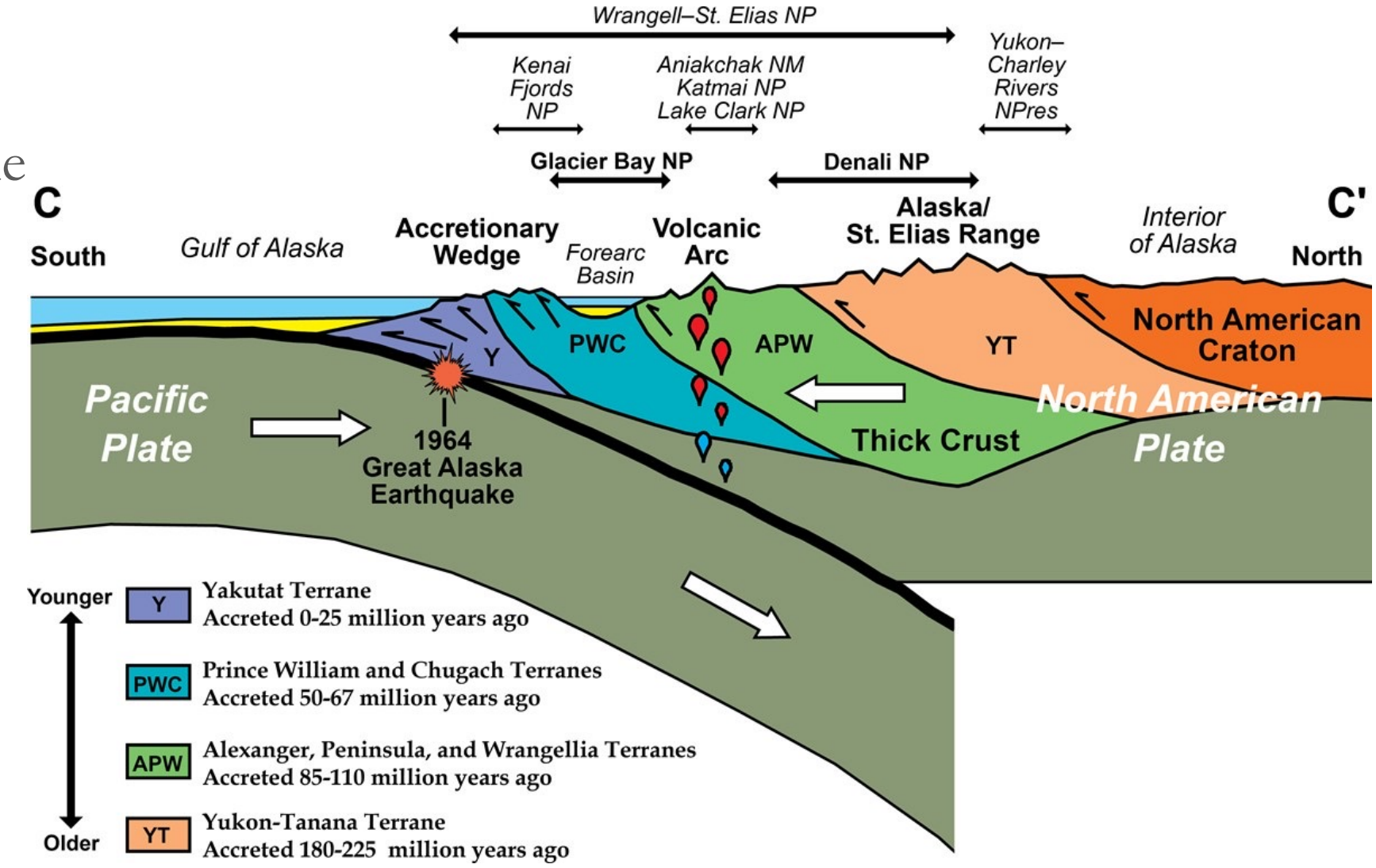

2017-2019
GNSS RX upgrade (CA 2017-2019)
All stations upgraded (CA 2017-2019)
Other NOTA Stations
2019-2021
GNSS RX upgrade (CA 2019-2021)
All stations upgraded (CA 2019-2021)
Other NOTA Stations
NOTA Status 2021
NOTA Full GNSS as of Aug 15, 2021
NOTA GPS Only
Onboard PPP (CA 2019-2021)
48°
46°
44°
42°
40°
38°
36°
34°
32°
−124°
−122°
−120°
−118°
−116°
−114°

Regional focus: Alaska

- Aleutian Subduction Zone
  - earthquakes
  - tsunamis
  - volcanoes

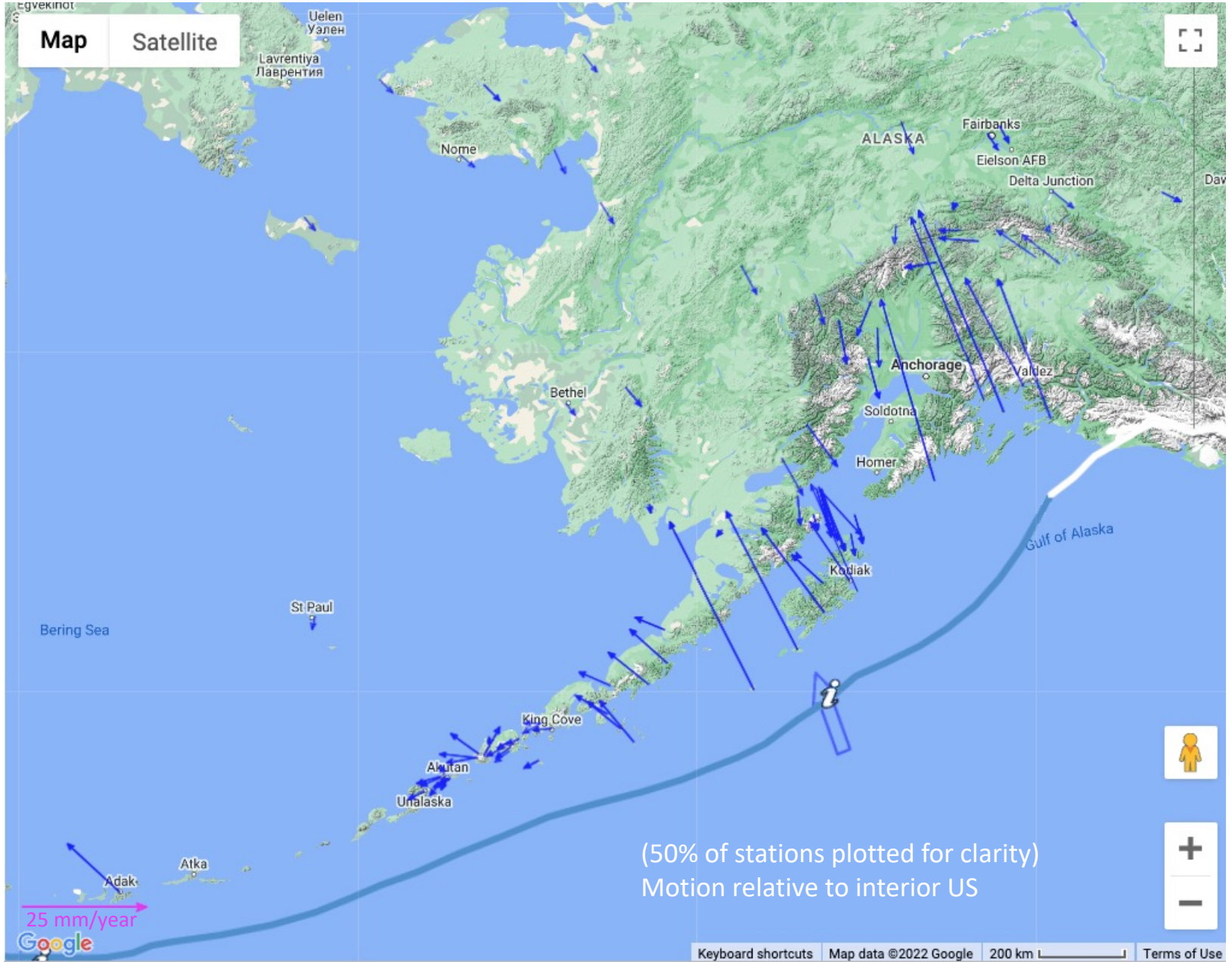


USGS/Robert J. Lillie

Regional focus: Alaska

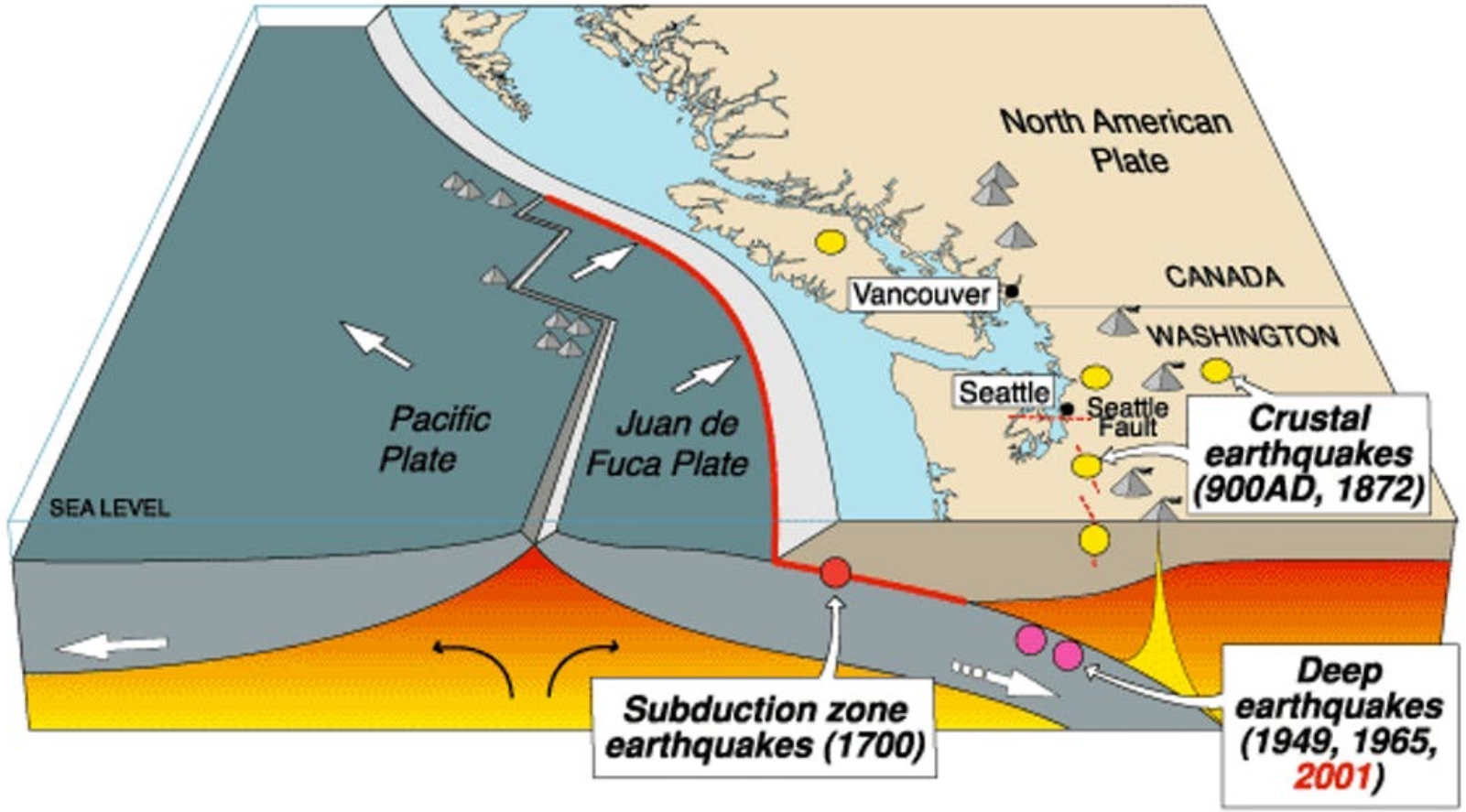
- North American plate moving
- Pacific plate moving

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



Regional focus: Pacific Northwest

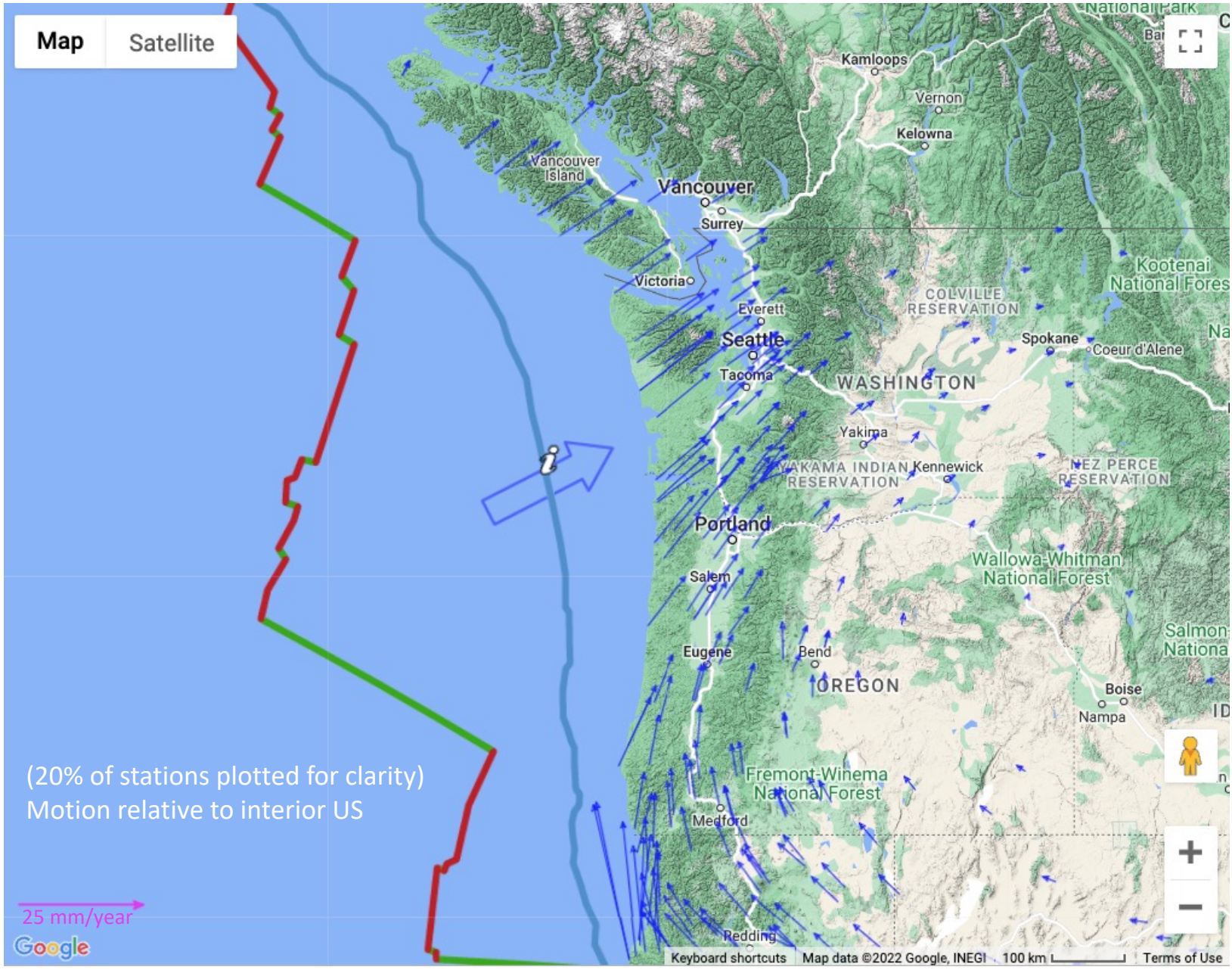
- Cascadia Subduction Zone
  - earthquakes
  - tsunamis
  - volcanoes



USGS

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!

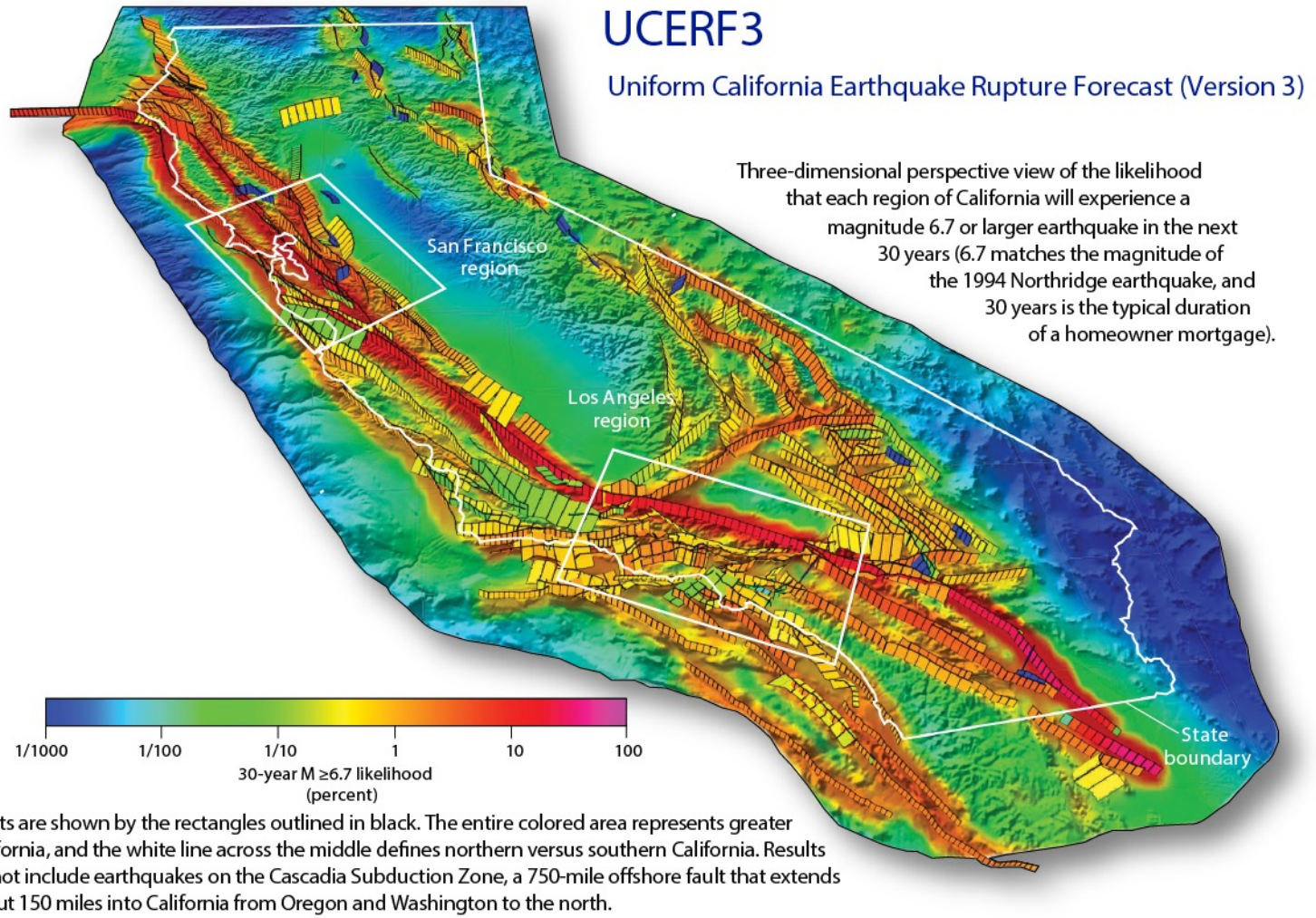


Regional focus: California

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

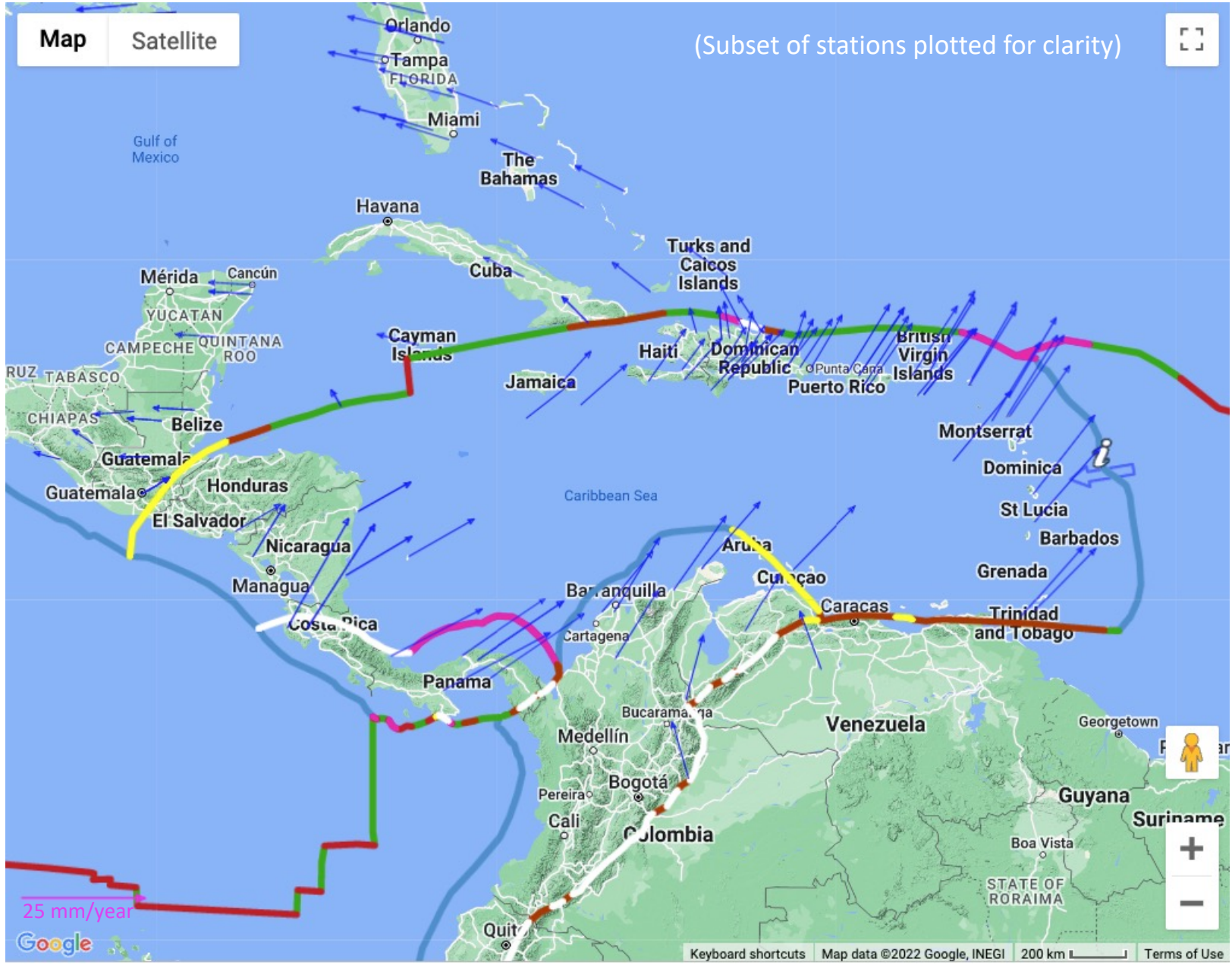
Regional focus: California

- California seismic hazard is complex!



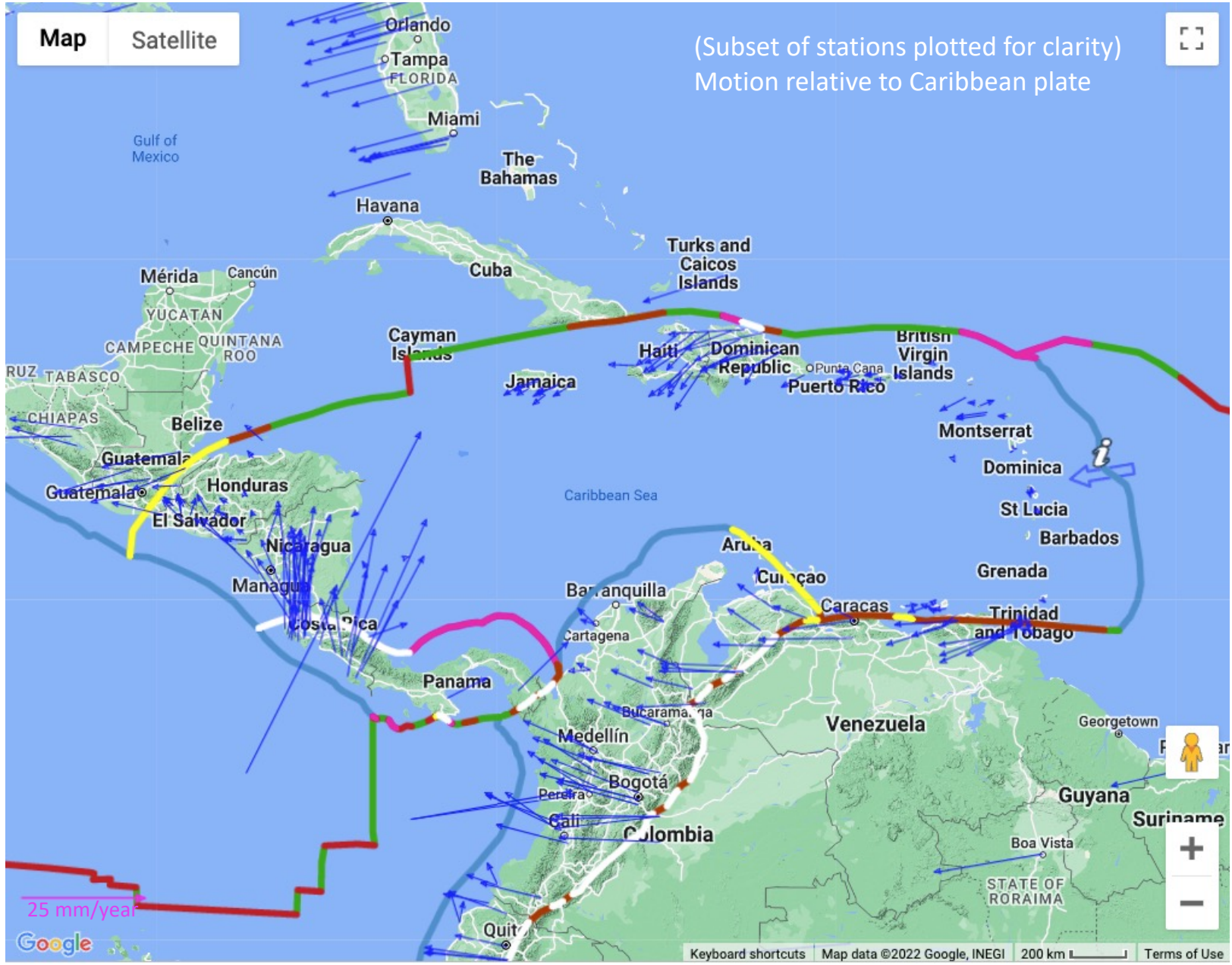
Regional focus: Caribbean

- 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!

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YouTube

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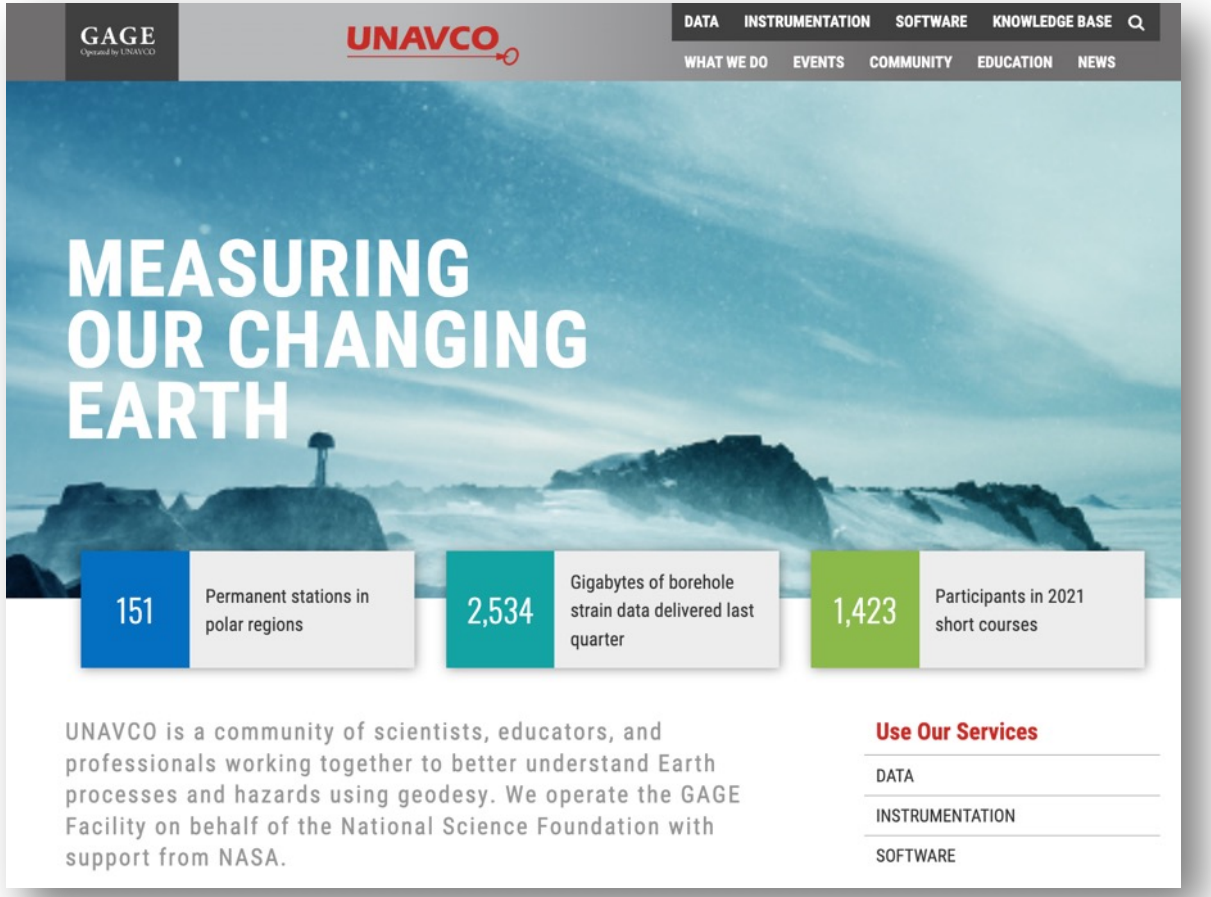

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INTERNSHIP PROGRAMS AND OPPORTUNITIES

Geo-Launchpad

Research Experiences in Solid Earth Science for Students (RESESS)

UNAVCO Student Internship Program (USIP)

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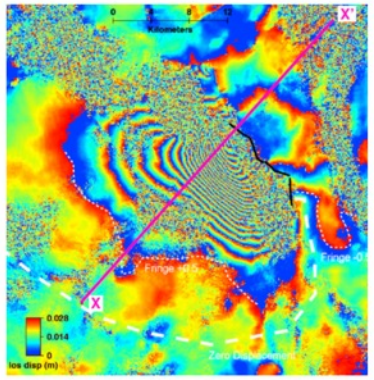
EDUCATION RESOURCES

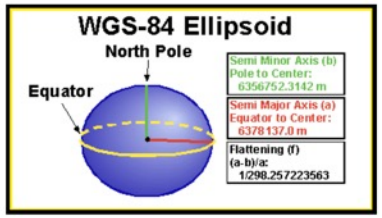


GETSI Undergraduate Modules

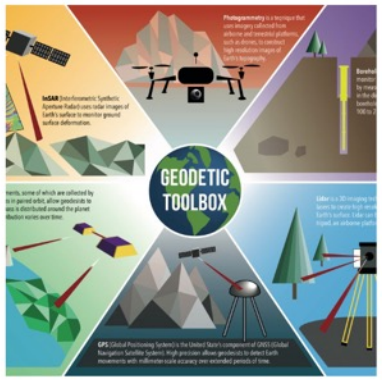
K-12 Activities & Demos

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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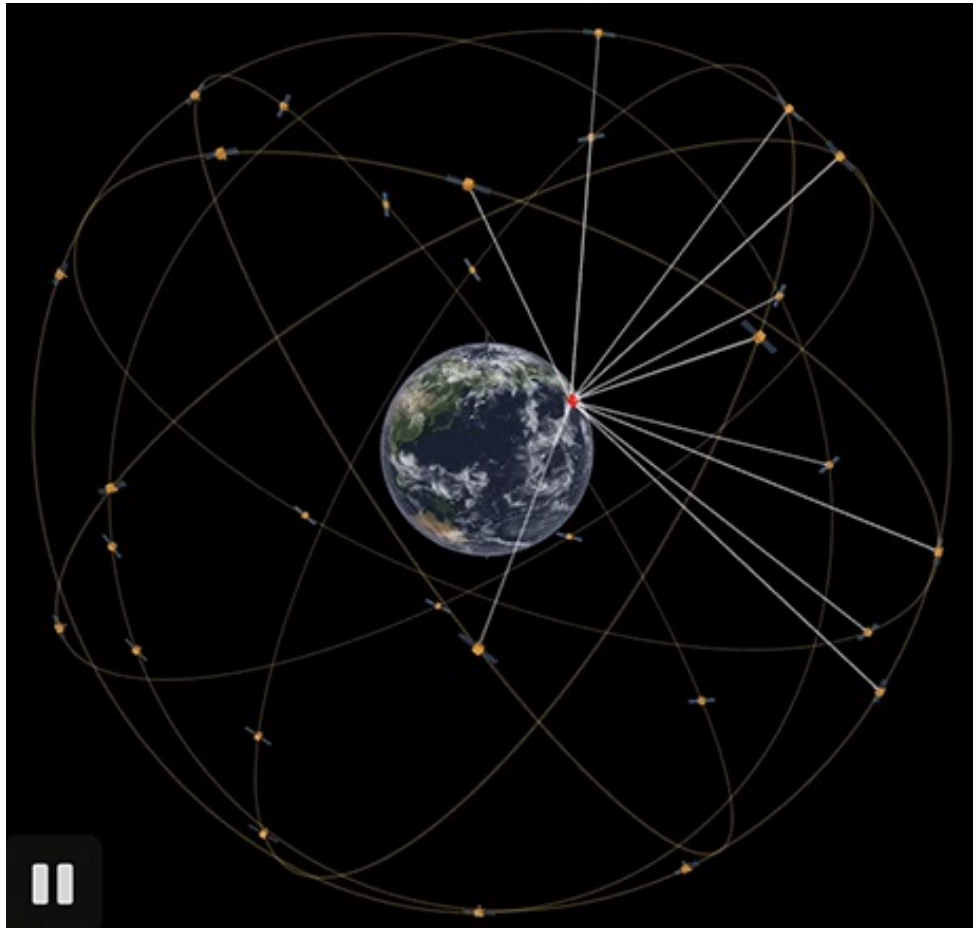
How does GPS work?

- 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)



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)

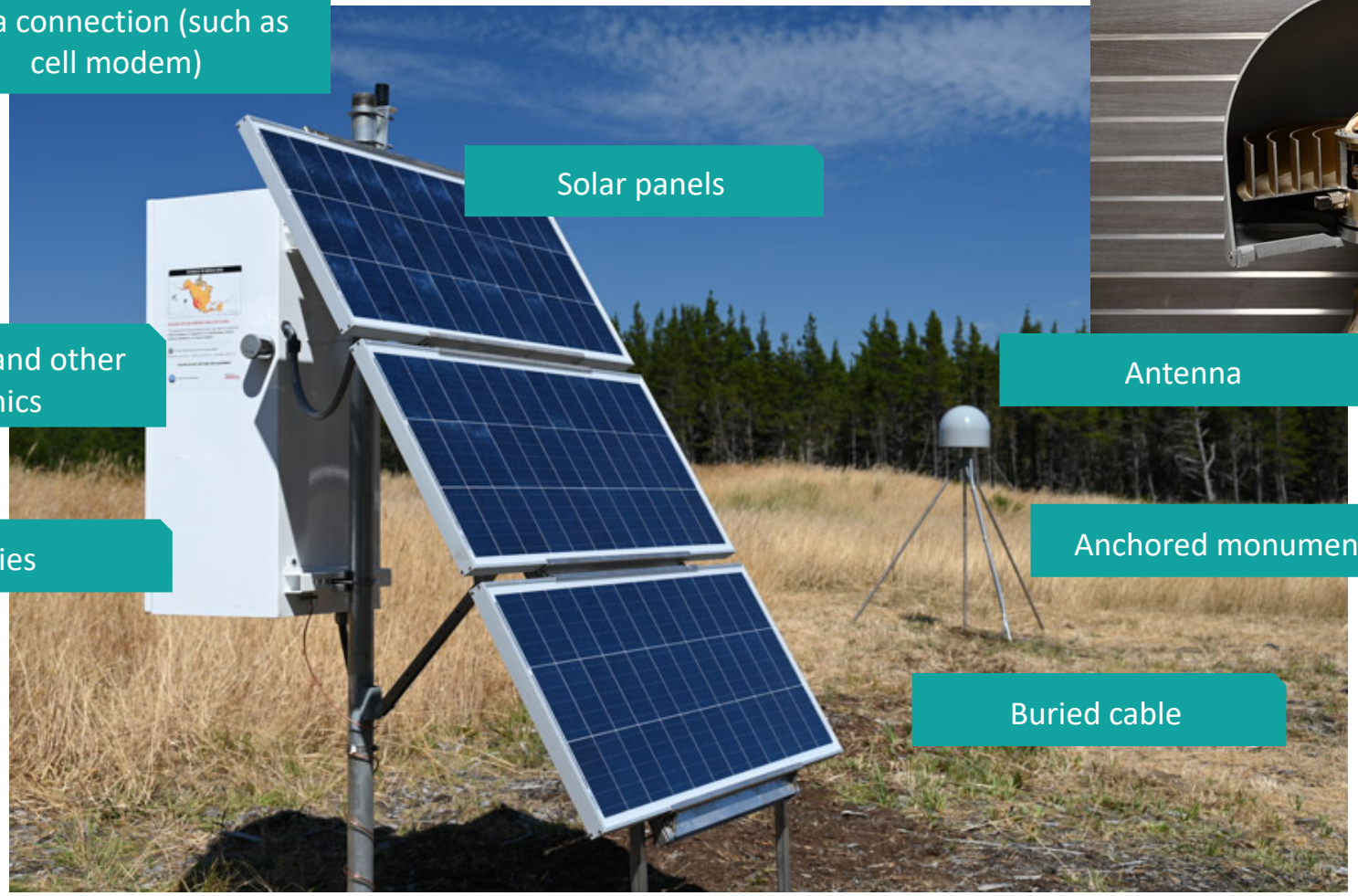
- All are examples of Global Navigation Satellite Systems (GNSS)

- Some receivers can use multiple (or all) satellite constellations

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

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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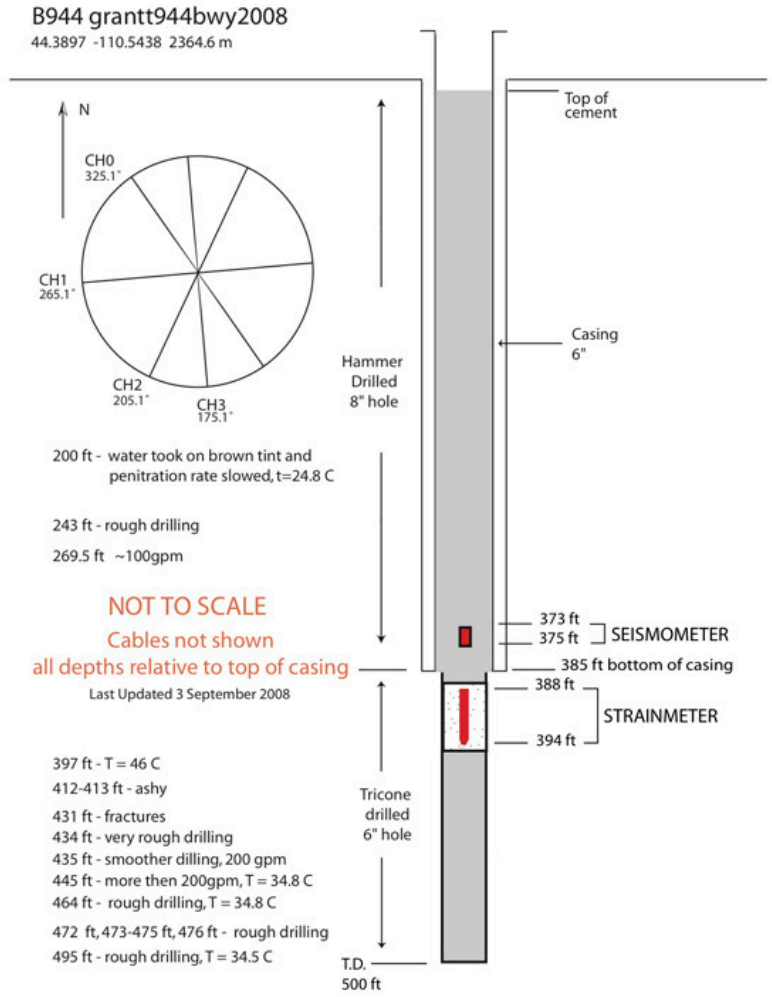
What's in a borehole station?



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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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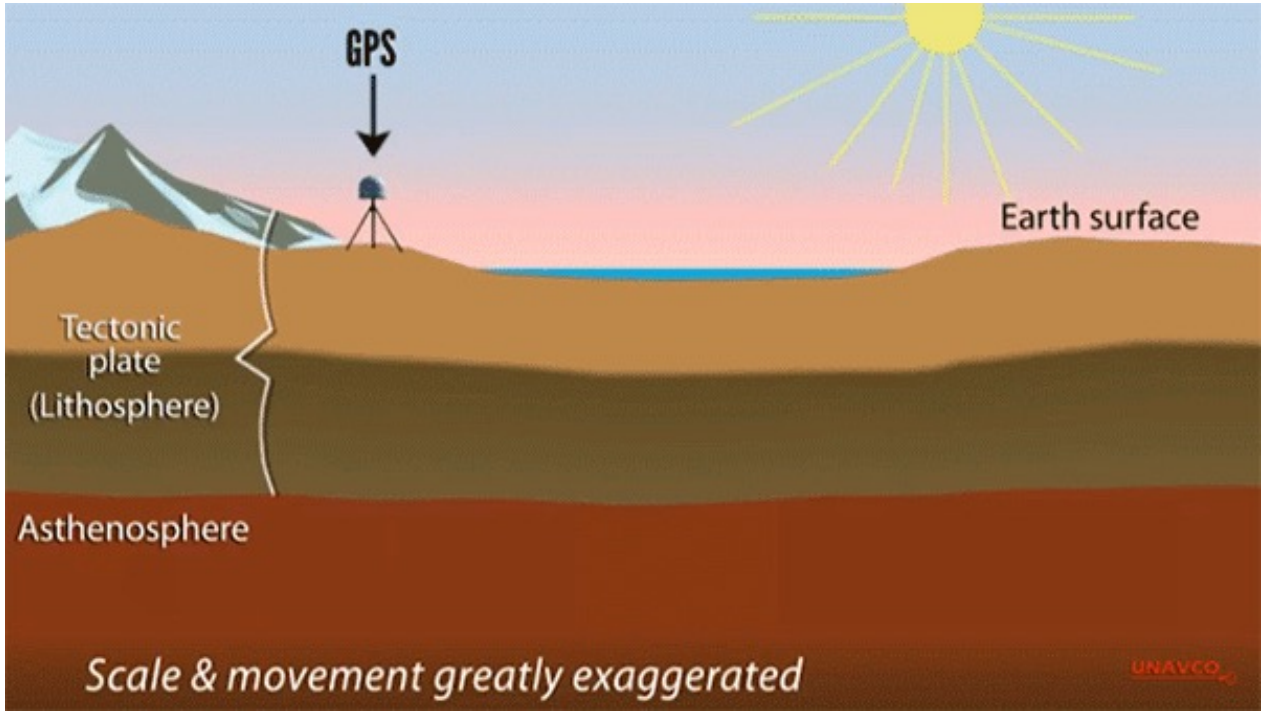
Groundwater

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



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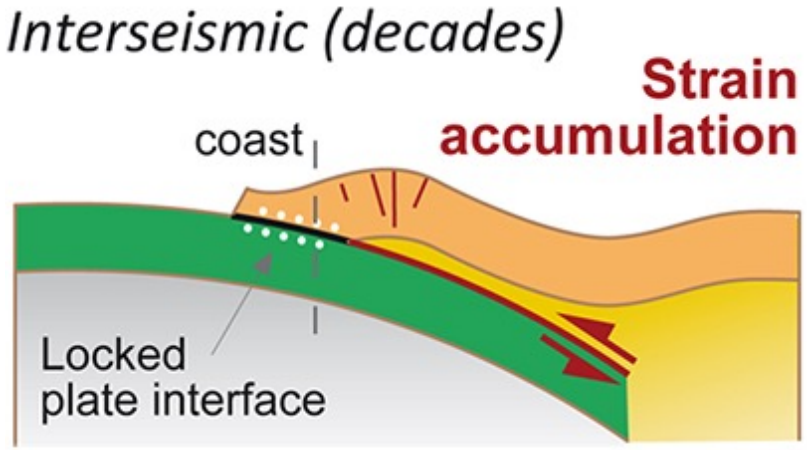
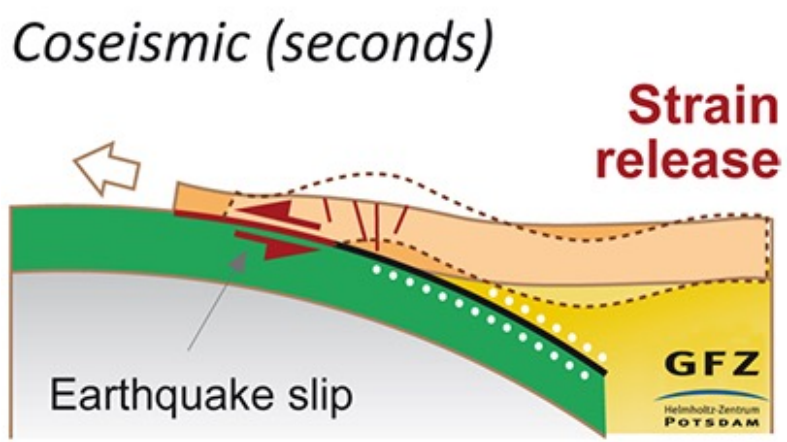
The Earthquake Cycle

- 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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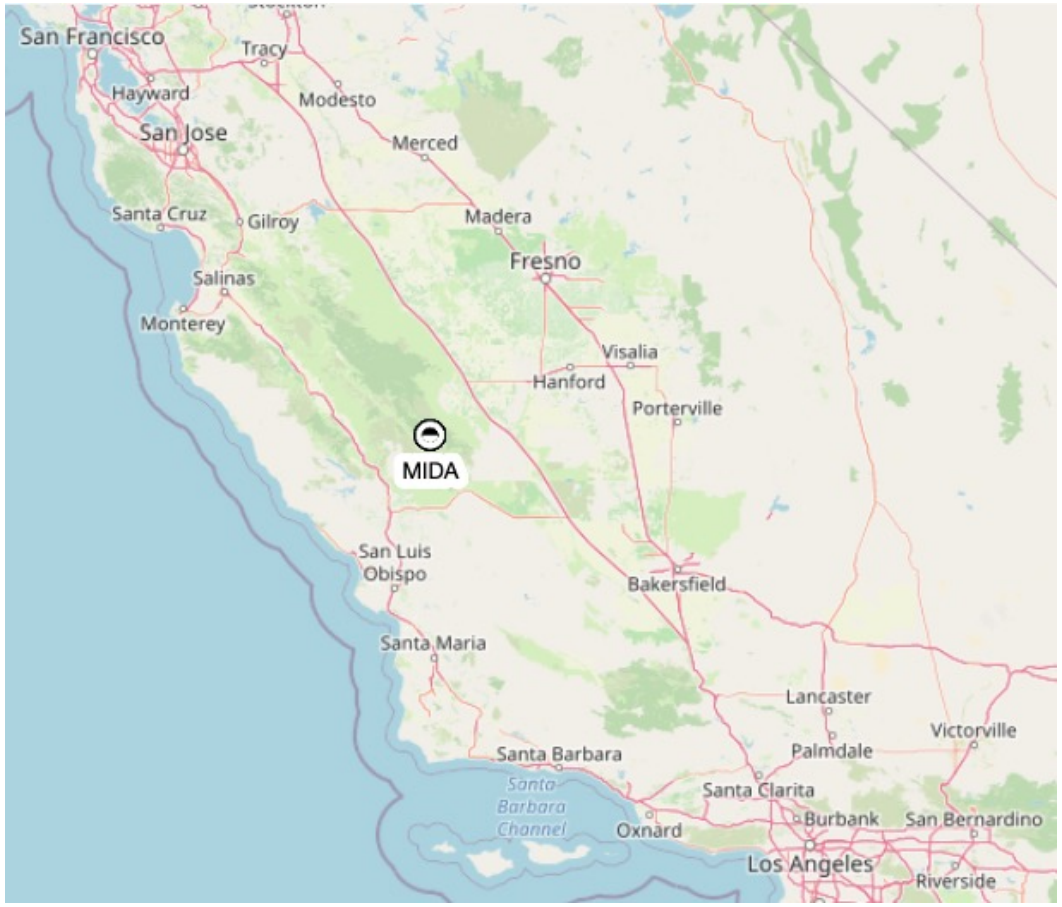
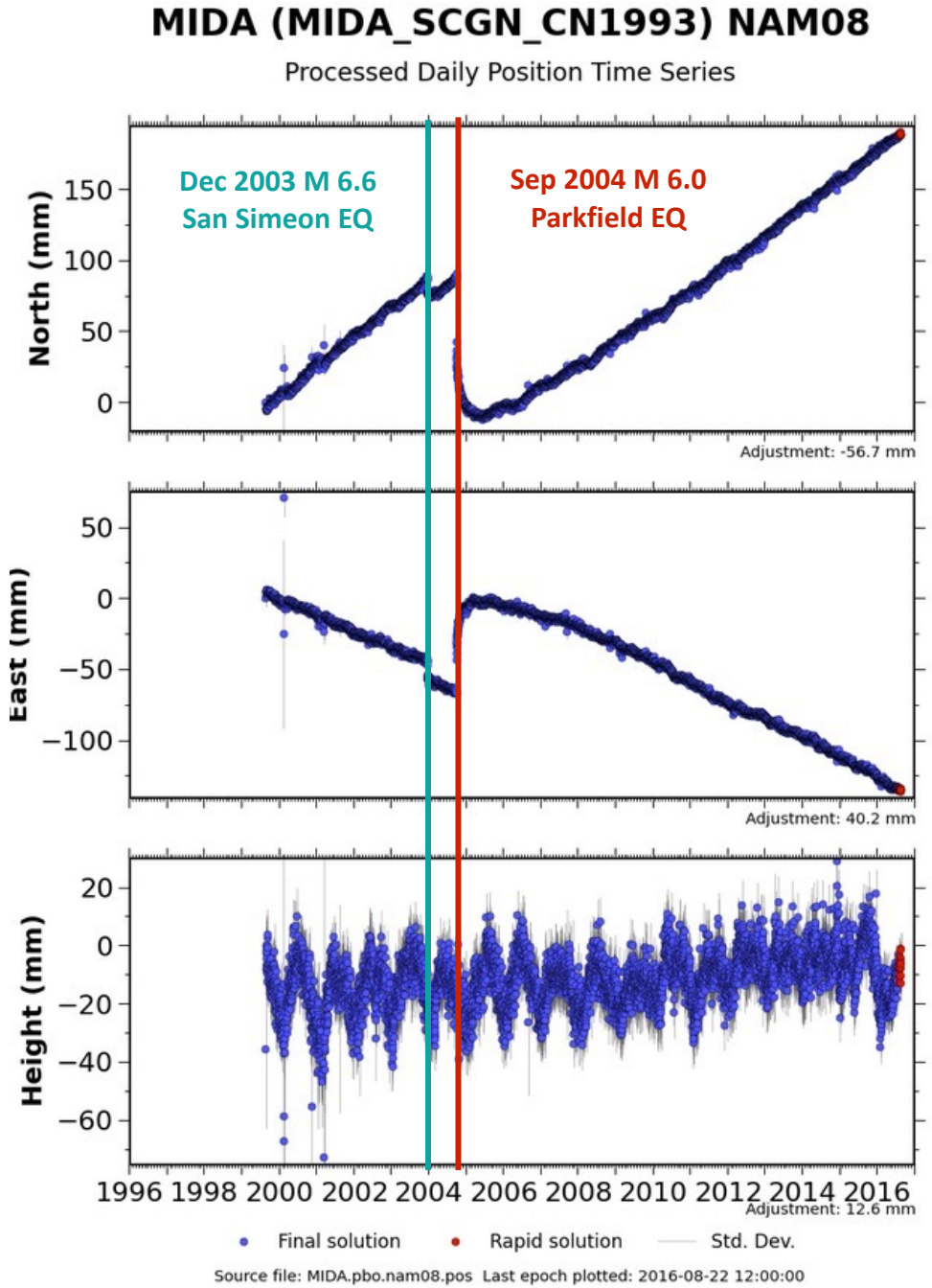
Earthquakes





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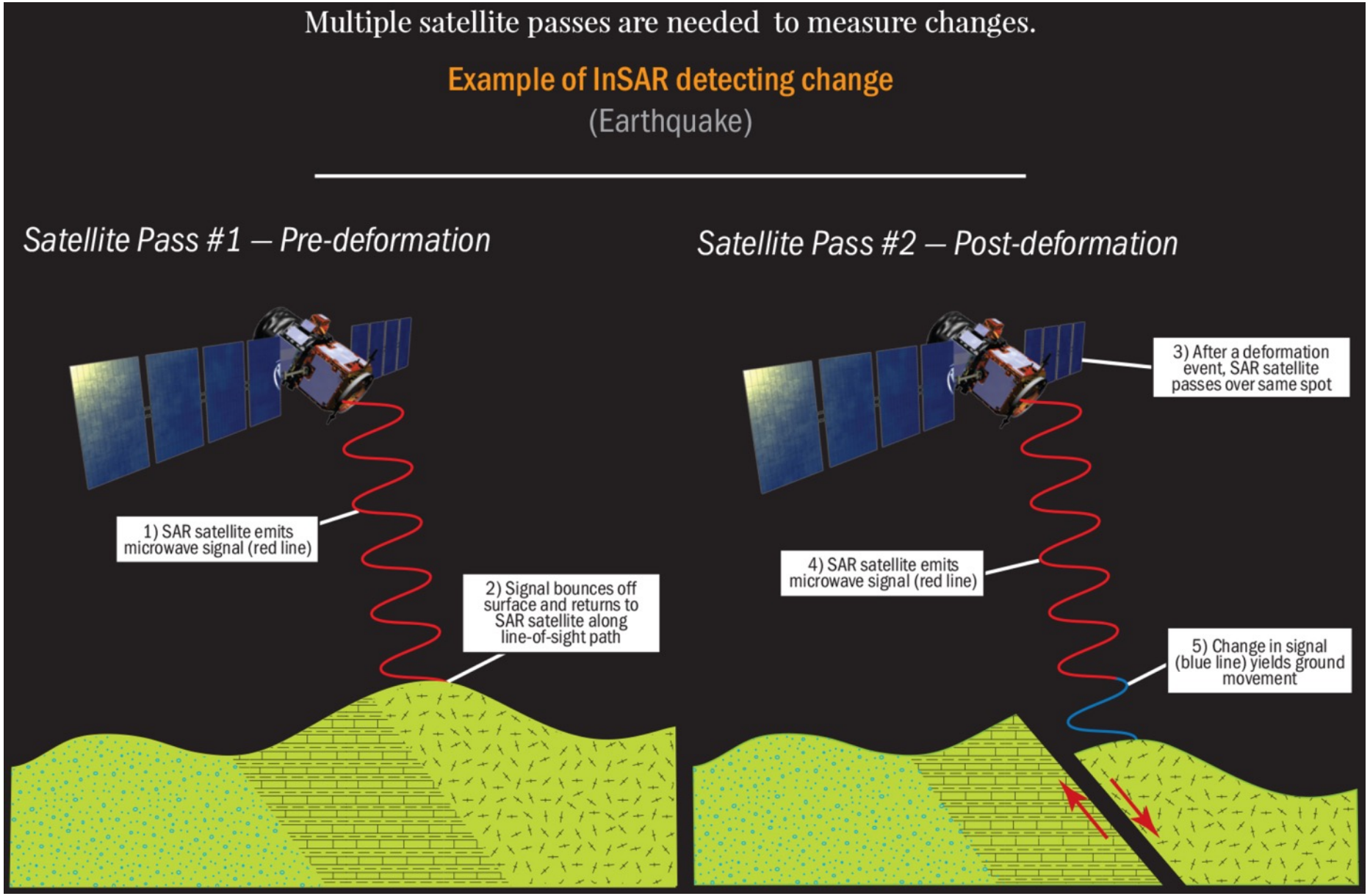
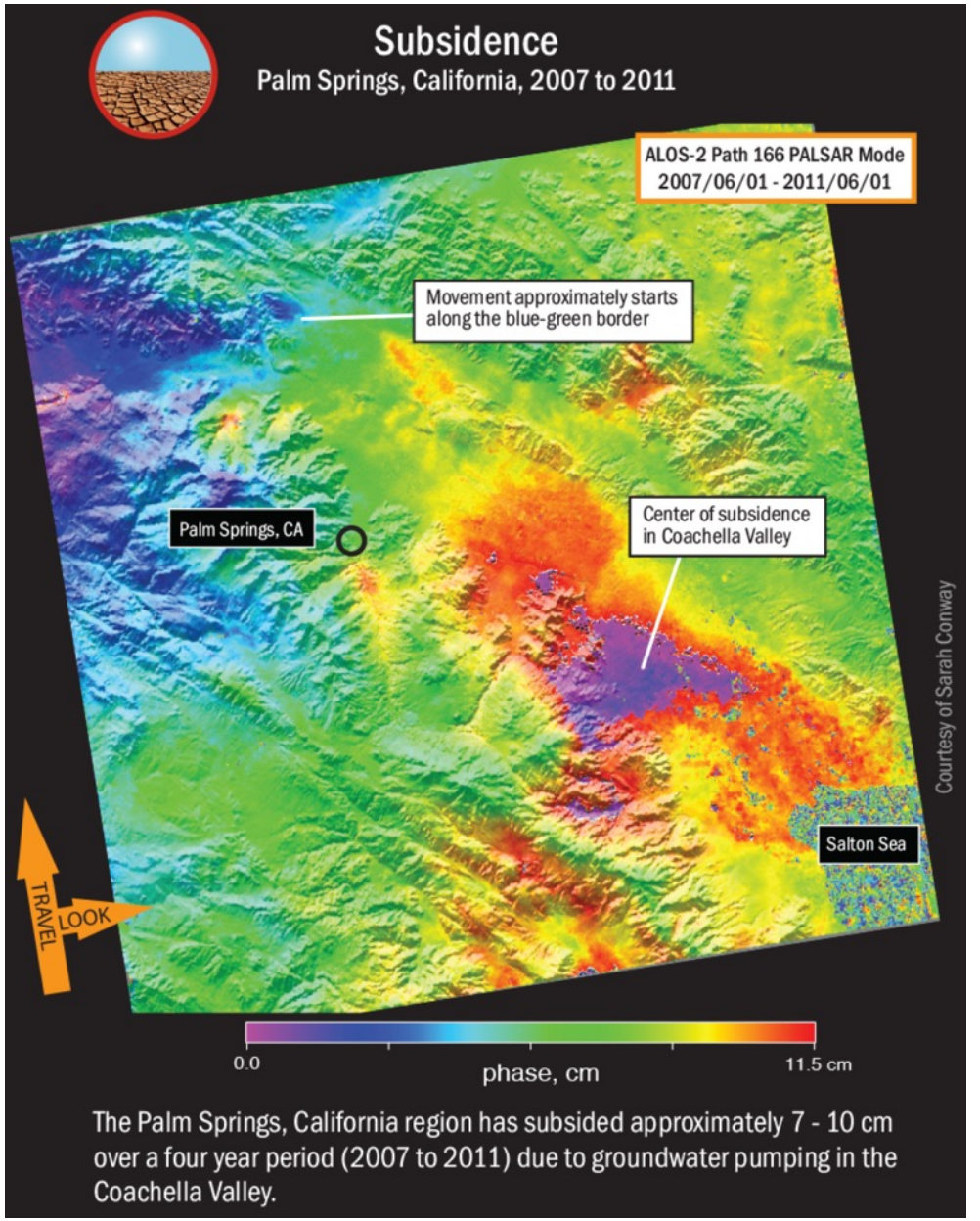
How does InSAR work?



What does InSAR do?



What does InSAR do?