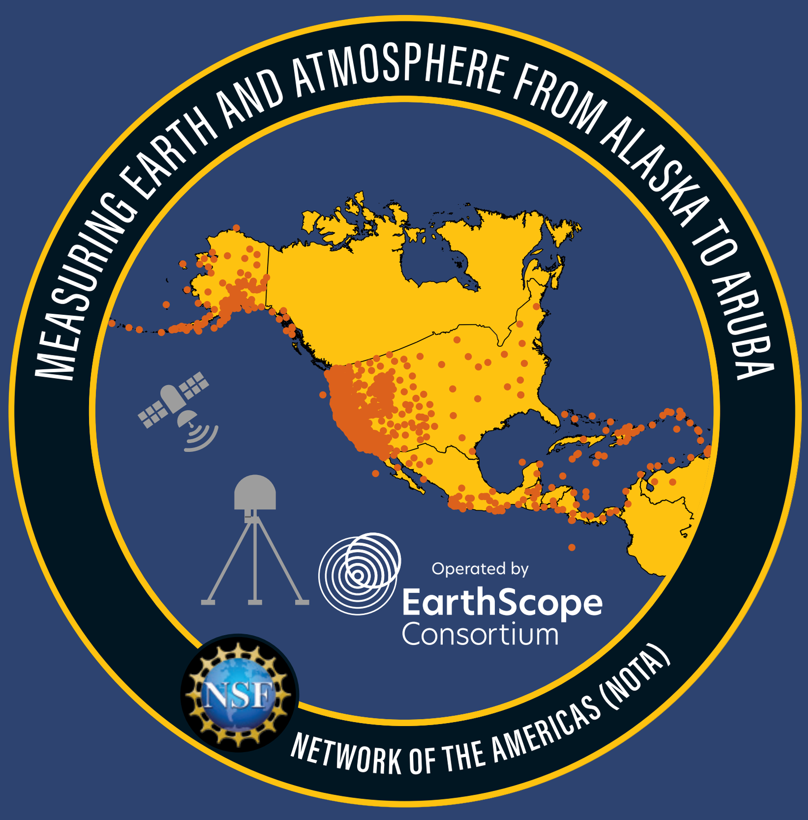
Measuring Earth

No place on Earth is stationary, and the most powerful tool we have for measuring ongoing, large-scale tectonic motions is GPS (also called GNSS). Why measure this motion? This is part of the science of geodesy—studying the shape, rotation, and gravitational field of our planet. Apart from understanding and monitoring hazards like earthquakes and volcanoes, the tools of geodesy can be used to measure melting glaciers, sea level rise, groundwater depletion, and more. Networks of GPS stations are also used to maintain the global coordinate system on an ever-changing planet, and support the accurate positioning required for surveying, autonomous vehicles, and precision agriculture.

A Network of the Americas (NOTA)

NOTA is an international geophysics sensor network spanning more than 20 countries and composed of more than 1,200 continuously operating instruments—even more than we can show on this poster—including high-precision GPS stations and borehole strain, seismic, and tilt instruments, as well as meteorological sensors. NOTA is a core component of the National Science Foundation's Geodetic Facility for the Advancement of Geoscience, operated by EarthScope.

Learn more at **earthscope.org/nota**



Who We Are

EarthScope is a non-profit university-governed consortium supporting geophysical research and education in order to explore and understand Earth systems, and to help society become more resilient to natural hazards.

Find us at **earthscope.org**

Not Your Cell Phone's GPS

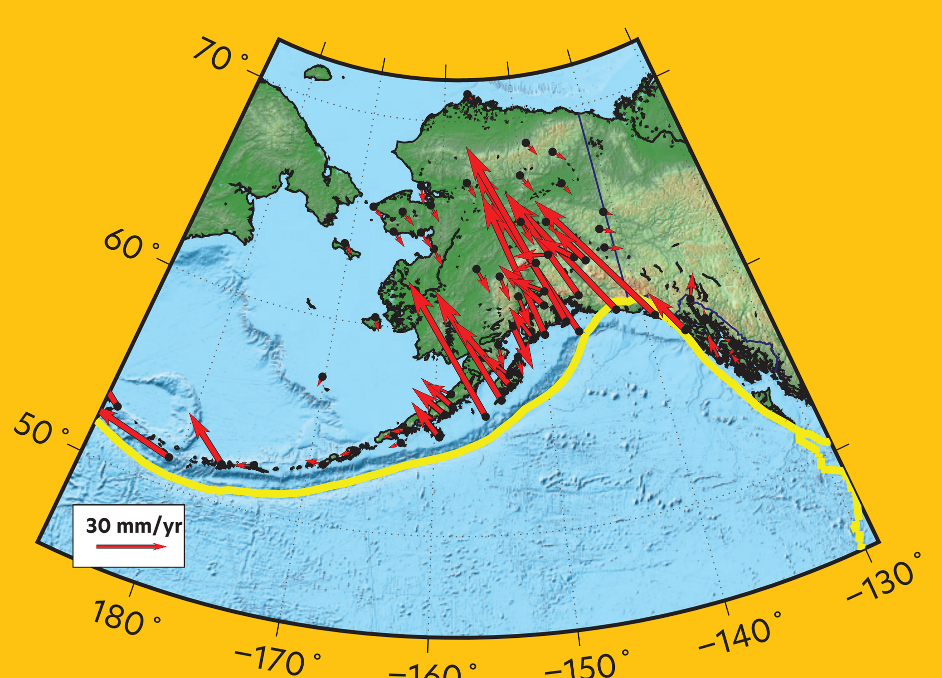
The GPS stations used to measure the shifts and bulges of our planet rely on the same technology as our cell phones. However, these stations are about 300 times more precise—the difference between knowing our position to within 3 meters (10 feet) versus knowing it to within less than a centimeter (0.4 inches). How do we do it? These instruments are anchored securely into the ground, use more parts of the satellite signal than our phones do, and do some better math. This high precision is what allows us to measure ground movement as slow as a millimeter (0.04 inches) per year by recording positions day after day and year after year.

Seismic Shift

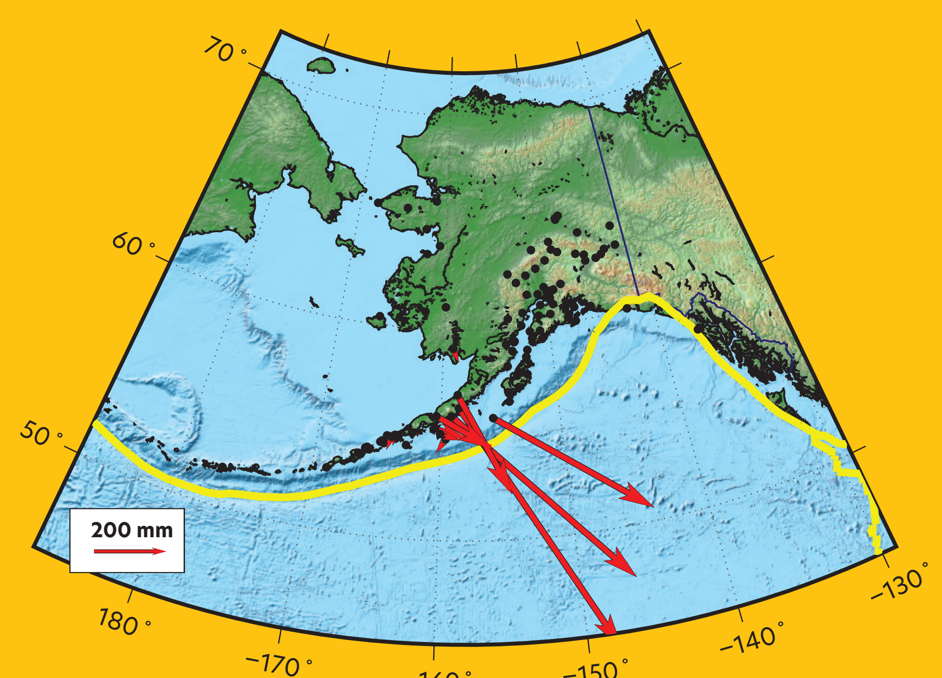
At faults like the boundaries where tectonic plates meet, stress builds up as the plates try to move in differing directions or differing rates. This causes the rock to slowly deform like a spring until the friction of the fault can no longer resist it. The fault then "slips" as all that built-up stress is released as seismic energy that shakes the ground.

In the example below, compare the long-term tectonic plate movement along Alaska's plate boundary, where the seafloor plate is being pushed beneath Alaska, with the sudden motion during the July 28, 2021 magnitude 8.2 earthquake.

GPS stations allow us to measure both the gradual accumulation of stress in the time between earthquakes and the sudden slip that releases stress during earthquakes. This is important for understanding and monitoring earthquake risks for communities located near faults so effective protective measures can reduce damage and harm when the next earthquake occurs.



Long-term tectonic plate movement



Movement during earthquake

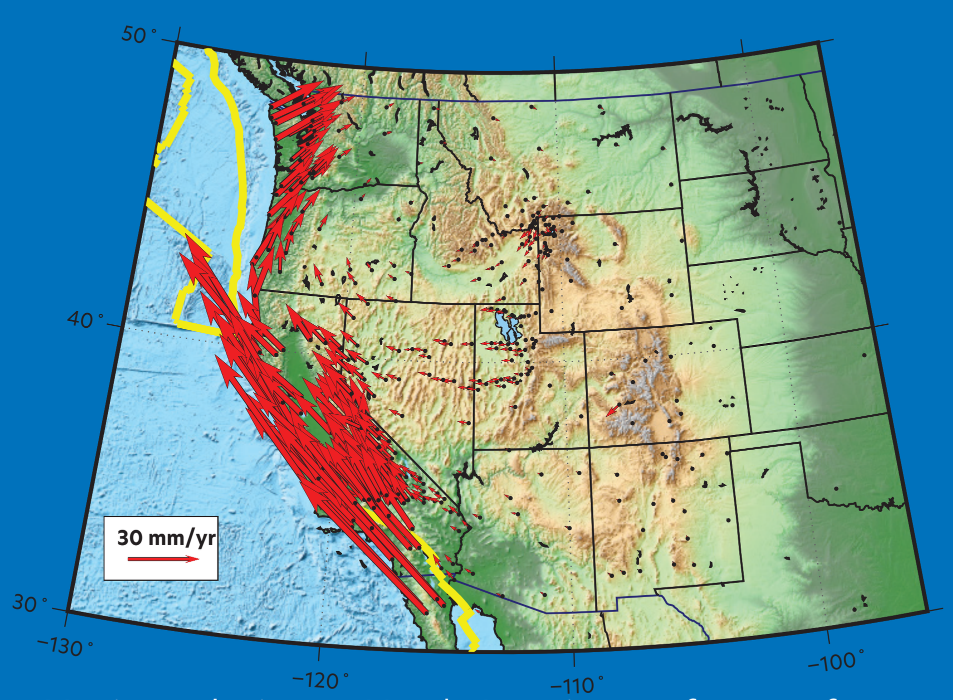
Everything is Relative

Relative motions are important. Regions with the greatest contrast in motion (long arrows near short ones or arrows pointing different directions) indicate areas where stress is building up and providing energy for earthquakes. Imagine two people holding opposite ends of a bungee cord. If they walk in the same direction and at the same speed, the cord won't be affected. But if one person is faster than the other, or if they walk in different directions, the cord will start stretching.

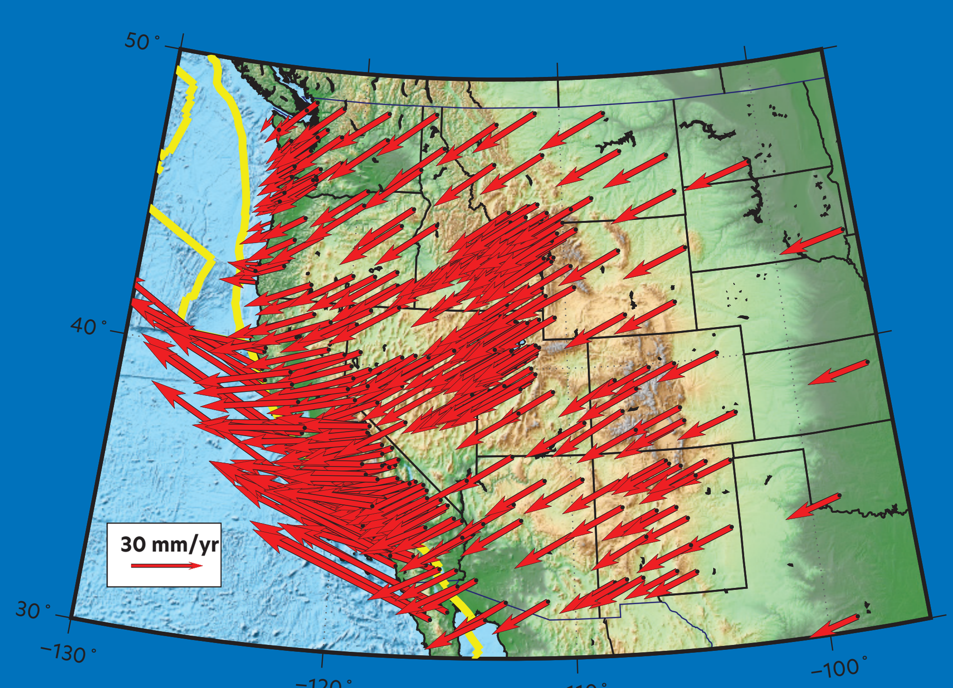
On the front side of this poster (and the top map to the right), motions are shown relative to the interior of the North American plate, which is far from plate boundaries and fairly stable. In other words, the arrows on the US West Coast show how this portion of the plate is slowly changing shape.

If we instead show motions relative to the planet as a whole (lower map to the right), we can see how Earth's tectonic plates move in relation to each other. North America is generally moving towards the Pacific Ocean—while the western side of California's San Andreas fault plate boundary is moving a different direction.

You can investigate these reference frames yourself (and zoom in!) using our interactive map at **earthscope.org/velocity-viewer**



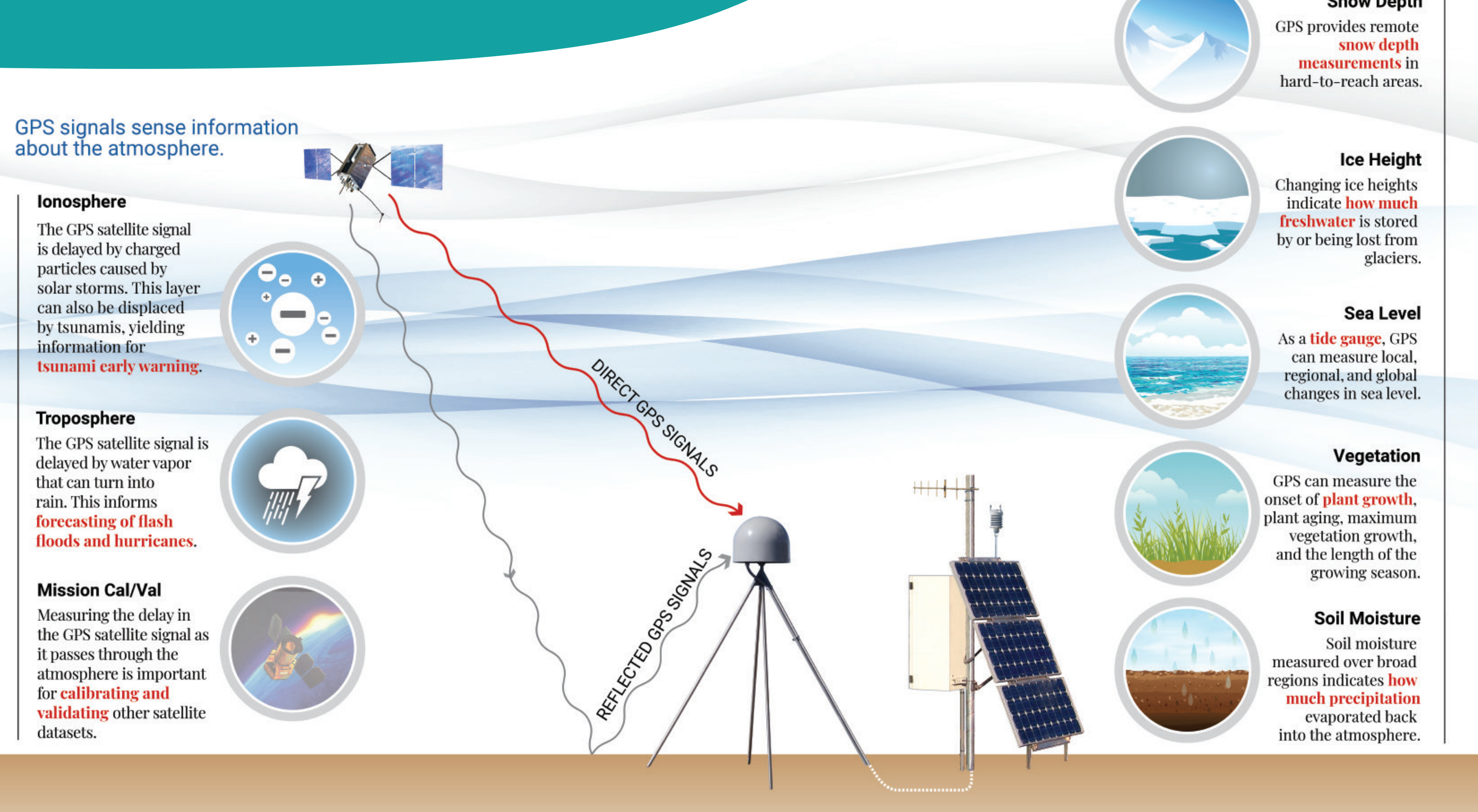
Motion relative to North American reference frame



Motion relative to global reference frame

And for my next trick...

GPS stations can measure even more than the motion of the ground (or glacier!) beneath them. As the satellite signal passes through the atmosphere on the way to a station, it is affected by the ionosphere and by water vapor in the troposphere. The satellite signal can also bounce off the surface near the station before reaching the antenna, and scientists have learned how to use this reflected signal to measure changes in nearby water levels, soil moisture, and other characteristics.

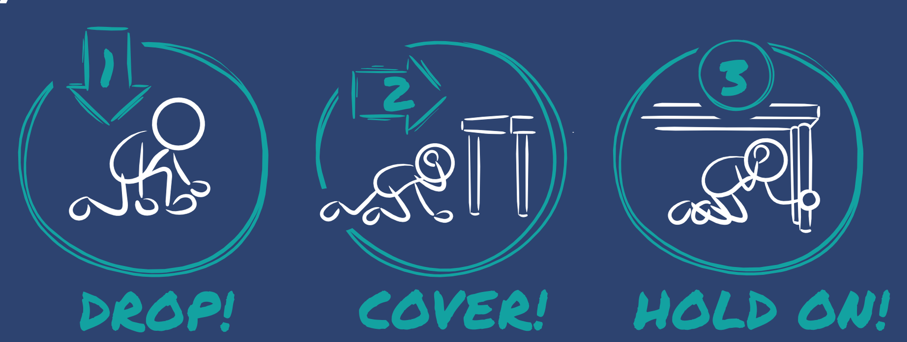


Staying Safe

NOTA stations are part of the United States Geological Survey's ShakeAlert® Earthquake Early Warning system. When earthquake shaking reaches the nearest seismometers and GPS stations, the ShakeAlert system detects the earthquake so an alert can be issued to other areas before strong shaking arrives. For example, with just a few seconds of warning individuals can Drop, Cover, and Hold On to protect themselves, and automated actions like slowing down trains, stopping elevators, and opening firehouse doors can occur.

Learn where alerts are available and how to ensure you receive them at **usgs.gov/ShakeAlert**

If you FEEL SHAKING or GET AN ALERT...



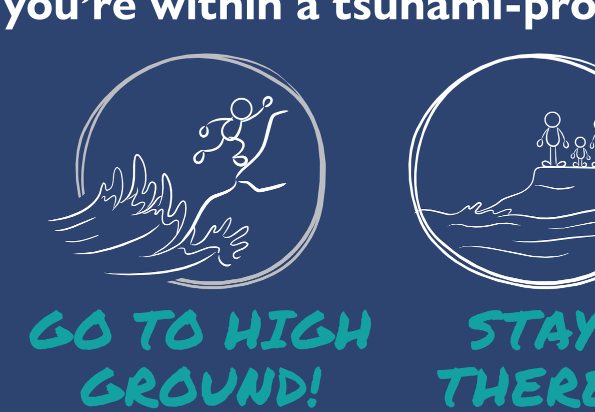
Know what to do before, during, and after...

an earthquake

a tsunami

a volcanic eruption

If you're within a tsunami-prone area:



The shaking is your tsunami warning. Tsunami waves may arrive for hours.

ShakeAlert