The Breathing Earth

Using Python to Visualize the Ups and Downs of the Ground

Gina M. Schmalzle[1,2], David White[1]
[1]Nordstrom, Seattle, WA; [2]BOS Technologies, LLC, Seattle, WA

The Data: High Precision GPS

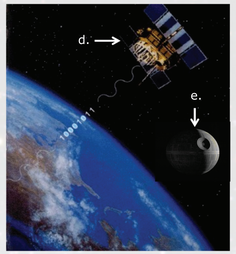
a.

b.

c.

a. GPS Monument
b. GPS antenna and receiverin its case

c. GPS antenna mounted over a Monument
d. GPS Satellite
e. the Death Star

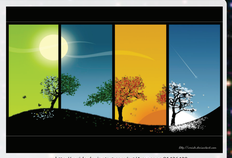


GPS sites track the 3-dimensional position of a monument over time at the millimeter level. We use the vertical component of ~1500 GPS sites in this work.

Over 1100 permanent GPS sites were installed as part of the National Science Foundation EarthScope Plate Boundary Observatory starting in 2004, adding to an already existing array of sites.

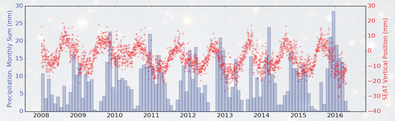
A. Precipitation

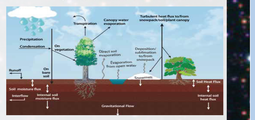
In the winter, increased precipitation saturates land, making it heavy and pushing it down. In the summer, the water evaporates or flows away, allowing the ground to rebound. The cyclical nature is much like the movement of your chest while breathing -- an inhale represents the summer, and exhale the winter.



http://vxside.deviantart.com/art/4-seasons-81436429

a) Time series of monthly summed precipitation (blue bars, mm) and vertical GPS positions (red, mm).



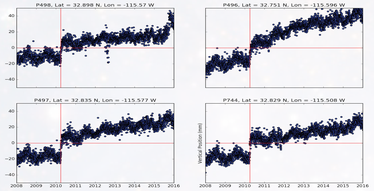


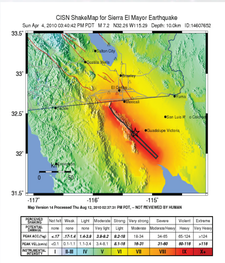
http://www.kristinelarson.net/wp-content/uploads/2015/10/sap3-1-final-al0026.png

B. Earthquakes

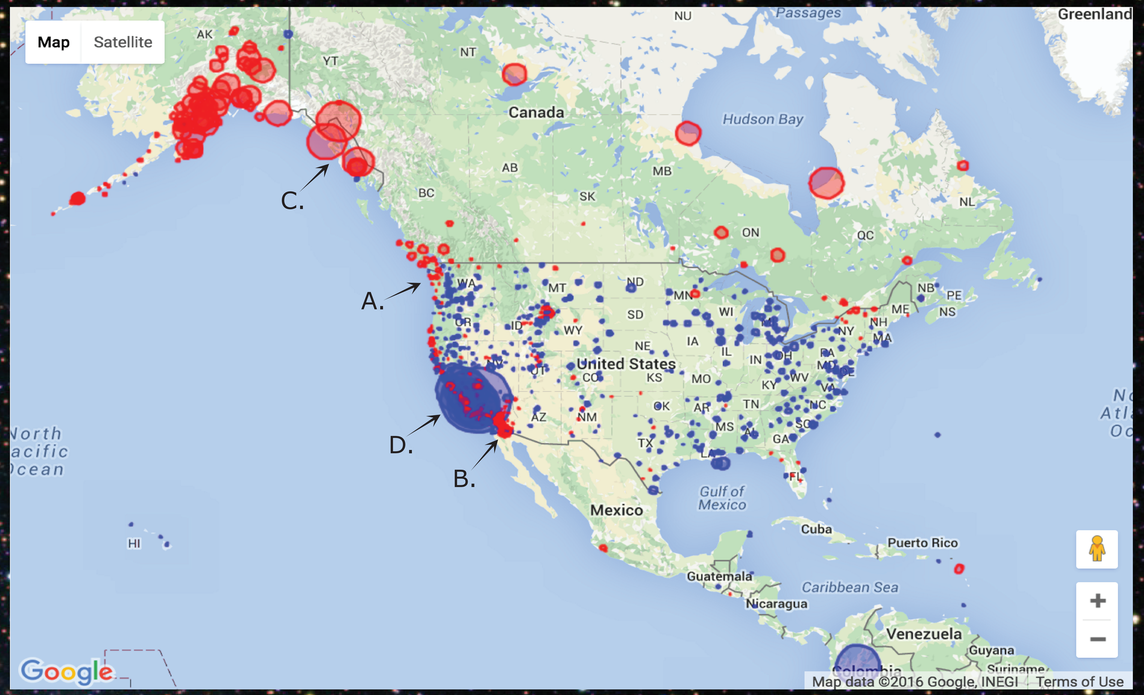
Earthquakes can cause a sudden change in position of the ground surface that may continue to influence the ground position over many years due to the viscosity of the underlying mantle.

The time series below are for sites in southern CA affected by the April 4, 2010 El Mayor Earthquake.





https://en.wikipedia.org/wiki/2010_Baja_California_earthquake#/media/File:April_2010_Baja_California_earthquake_Intensity_USGS.jpg



How We Did It

DATA PREPARATION AND BACKEND

1. Download data: ftp://data-out.unavco.org/pub/products/position/

For each site:
2. Vertical position, latitude and longitude --> sqlite3 database
3. 7 day rolling median calculated
4. Select only sites with data on 2008-01-01
5. The median value on 2008-01-01 is subtracted from the time series
6. One value every 30 days written to JSON file.

Future work:
1. Send data to Amazon Relational Database Service for time series API service.

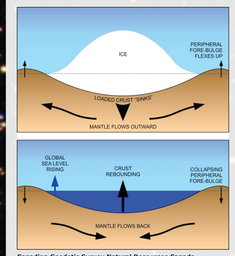
VISUALIZATION

1. Python Flask Application
2. Deployed on AWS Elastic Beanstalk
3. Javascript Frameworks: jQuery, Google Maps API
4. Data from JSON file

Future Work:
1. Add time series plot using API service -- click on point, retrieve time series
2. Reduce latency -- Currently split up into regions to reduce the data size

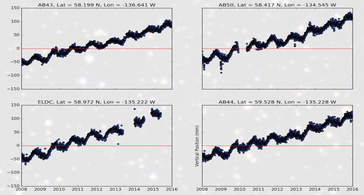
https://github.com/ginaschmalzle/BreathingEarth

C. Glaciers and Snow Melt



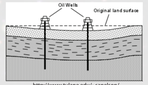
Canadian Geodetic Survey Natural Resources Canada

The heavy weight of glaciers and ice sheets cause the ground to depress. When the ice melts, the crust rebounds causing uplift. The sites shown here are located in Glacier Bay National Park and Preserve, North of Juneau, Alaska.



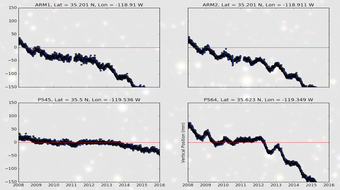
D. Water/Oil/Gas Pumping

http://www.wateredu.com/aquapedia/land-subsidence



http://www.tulane.edu/~sanelson/Natural_Disasters/subsidence.htm

Permeable rock can hold fluids, such as oil, gas and water. When these liquids are pumped it reduces the fluid pressure in the surrounding rock, causing it to subside. The photo to the left shows the massive amounts of subsidence that occurred from water pumping in CA. GPS sites on the right from southern CA.



Takeaways

High precision GPS are used to monitor vertical motions of the earth's crust at mm level accuracy.

Ground level changes with the seasons -- lots of precipitation in the winter makes the ground heavy, depressing it. In the summer the water evaporates or flows away, allowing the earth to rebound.

Other causes of vertical motion are earthquakes, glacial melt, and oil, gas and water pumping. This is not a complete list.

This is still a work under construction! Comments and suggestions welcome.