Using Google Earth to Teach Complex Earth Science Concepts

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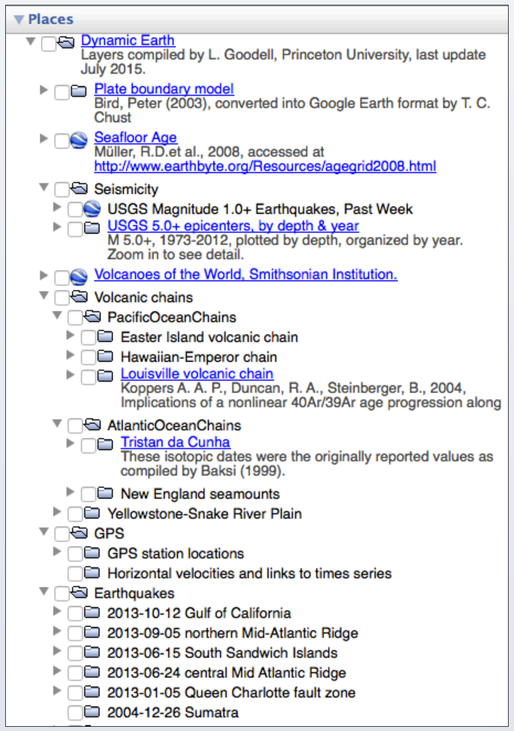
Introduction

Google Earth is a visualization tool that enables users to manipulate a "Virtual Globe" in order to examine imagery, display geographic data, and use basic tools measurement. ArcGIS has more powerful analytical capability, but a much steeper learning curve and less intuitive interface.

For the purpose of teaching plate tectonics and related concepts, I have compiled a number of Google Earth resources from free and publically available sources. These data layers, combined with simple spreadsheet and graphing tools, can be used for a wide variety of inquiry-based, data-rich exercises adaptable for introductory and upper-level activities.

These layers and the exercises that use them, are in the process of being updated. When complete, all will be posted and freely available for non-commercial adaptation and use at http://serc.carleton.edu/sp/library/google_earth/examples/49004.html (Previous versions are currently available on the website.)



Lab 1: Plate Tectonics I

Today is something of a crash course in plate tectonics, to set the stage for labs which focus on natural hazards related to plate tectonics. So don't let yourself be overwhelmed; this lab gives a broader view of hazards we will be exploring in detail over the next few weeks.

Objectives :

- To become experienced with Google Earth and use it to explore plate tectonic data sets.
- To identify and characterize convergent and divergent plate boundaries in terms of topography/bathymetry, earthquakes, volcanism and relative plate motion.
- To use geologic data to determine long-term average plate motions, by using Excel (or similar) to make distance vs. time graphs and analyze linear trends.

Lab 2: Plate Tectonics II

In Lab 1, you tracked long-term average rates of plate motion using geologic data (sea floor age and volcanic chain ages). This week, you will be analyzing plate motion using another type of data: high-precision Global Position Satellite (GPS) data collected over the last decade. Today we will be focusing on the boundary between the Pacific and its boundary with several neighboring plates. You will be assigned to a team that will analyze a particular plate boundary.

Objectives:

- To learn how to read and interpret GPS time series data.
- To characterize the boundaries between the Pacific plate and its neighboring plates.
- To compare modern plate motions (this Lab 2) to long-term average plate motions (Lab 1).

Lab 3: Information from Seismograms

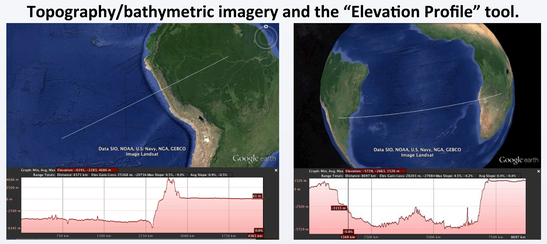
Objectives:

The class will be analyzing an earthquake that occurred on July 15, 2013. Each student will analyze seismograms from one seismic station; then the analyses from everyone will be combined to:

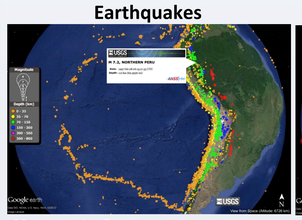
- Understand how to read seismograms and identify P-waves, and S-waves.
- Locate the epicenter of the earthquake and determine its body-wave magnitude.
- Analyze the first P-wave motions to determine the focal plane solution for the earthquake, and thereby understand the nature of the fault and plate boundary along which the earthquake occurred.

Plate Tectonic Data Sets

Topography/bathymetric imagery and the "Elevation Profile" tool.



Earthquakes

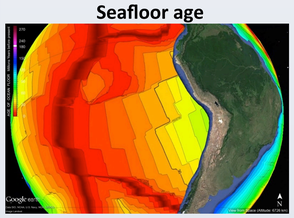


30 years of M≥5 earthquakes, plotted by depth. Clicking on a dot brings up an information box about that quake. **Source:** USGS Earthquake Archives search engine.

Volcanoes

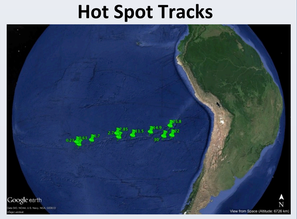
Holocene "Volcanoes of the World" layer. Clicking on a volcano brings up an information box about that volcano. **Source:** Smithsonian Global Volcanism Program.

Seafloor age

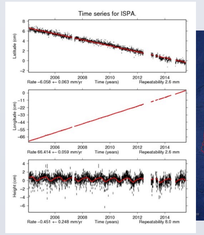


Seafloor age, 5 Ma isochrons. **Source:** Müller, R.D.et al., 2008, accessed at http://www.earthbyte.org/Resources/agegrid2008.html

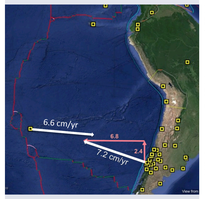
Hot Spot Tracks

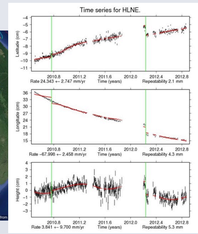


Hot spot locations and age data (in Ma) from published literature.



GPS time series





This data set consists of 2000+ GPS stations that have been collecting data for up to 17 years; clicking on a station brings up a link to the time series for that station. Students can plot their own GPS vectors from the 3-component data using basic trigonometry (above), or interpret a layer with GPS vectors already compiled (below left). **Source:** JPL and NASA, accessed at http://sideshow.jpl.nasa.gov/post/series.html

Horizontal GPS velocities (in cm/yr) derived from the GPS time series.

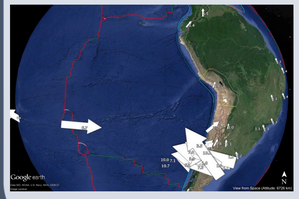
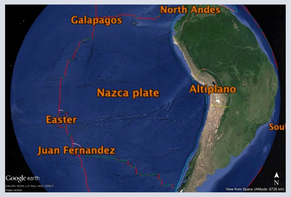


Plate boundary model by Bird, Peter (2003), converted into kmz by T. C. Chust.

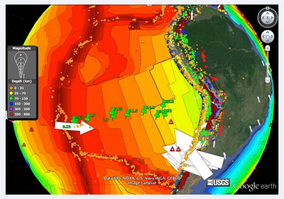


Using the Data Sets

Exploring the characteristics of and motion across plate boundaries

By navigating the globe and turning layers on and off, users are able to freely explore relationships between topography, bathymetry, earthquake locations and depth, volcanoes, seafloor age and hot spot tracks – and discover the characteristics of different types of plate boundaries for themselves.

Paper versions of this type of exercise do exist,* but GE promotes experimentation with combinations of layers and exploration at different scales. The very busy image below, for example, is a GE view of the Nazca plate with ALL the Dynamic Earth layers turned on.

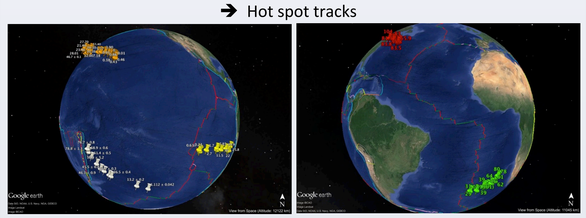


Where would you put the plate boundaries, and why?

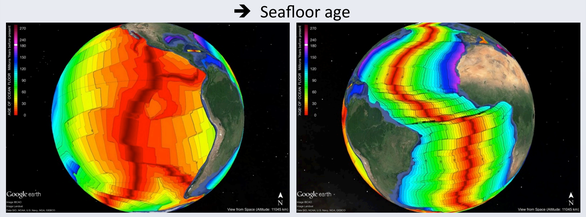
What is the nature of the motion across those boundaries?

Exploring plate velocities with multiple independent data sets

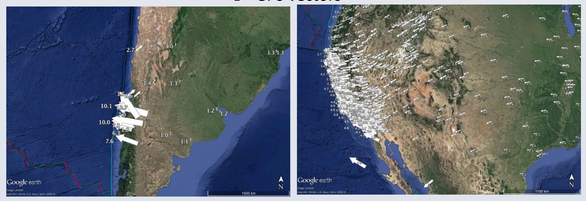
➔ Hot spot tracks



➔ Seafloor age



➔ GPS vectors



Students discover the basics of plate tectonics in the course of this exploration. But importantly, they also develop a deeper, nuanced understanding of more complex concepts such as:

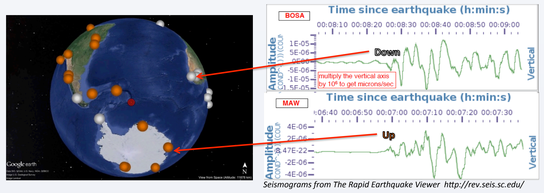
- Plate boundaries are *not* the narrow lines shown in textbooks or on blackboard diagrams, but instead are complex zones over which activity is distributed.
- The velocity of a given plate varies over time, as show by comparing long-term average plate velocities (derived from seafloor age data and hot spot tracks), and "near real-time" velocities (derived from GPS times series).
- Different plates move at different rates.
- A single hot spot track could be explained by a moving plate over a stationary hot spot OR a stationary plate over a moving hot spot. By having students to work with multiple hot spot tracks, they discover the first explanation matches the data best. This is further supported by seafloor age and GPS velocity vectors that are consistent with that explanation.
- Hot spots do not supply a constant pin-point source of magma to the overriding plate.
- Subducting plates start to melt at depths of 150-200km, based on the depth of the earthquakes under subduction zone volcanoes.
- Not all plate boundaries are well-defined. E.g. where is the boundary between the North American and Eurasian plates (between Alaska and Russia?)

*e.g. *"Discovering Plate Boundaries," http://www.plateboundary.rice.edu*

Visualizing Focal Plane Solutions

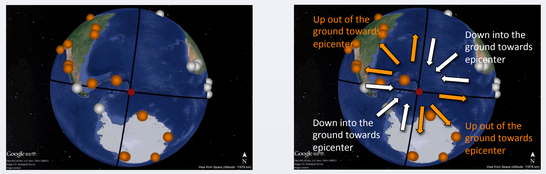
(under development)

- After locating the general vicinity of the epicenter using conventional P and S wave analysis, students plot 1st P-wave motions: **Ups** and **Downs**.

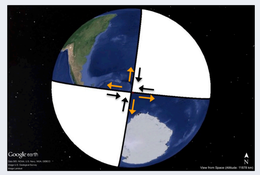


Seismograms from The Rapid Earthquake Viewer http://rev.seis.sc.edu/

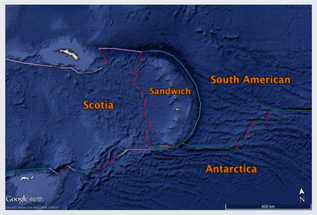
- Then, draw two great circles that divide the globe into 4 quadrants, each of which has only one type of P-wave motion (**Up** or **Down**). Visualize the motion.



Two possible solutions: *"The July 15, 2013 Mw7.3 South Sandwich Islands earthquake occurred as a result of either east-west left-lateral or north-south right-lateral strike slip motion at shallow oceanic crustal depths. The earthquake occurred ~100km east of a complex plate triple junction between the South America, Antarctica, and Sandwich plates..." http://earthquake.usgs.gov/earthquakes/eqarchives/poster/2013/20130715.php*

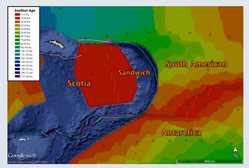


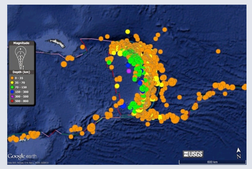
Analyze the plate boundary setting to determine which is most likely:



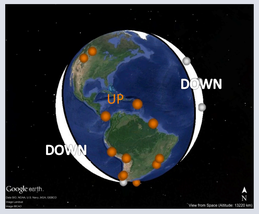
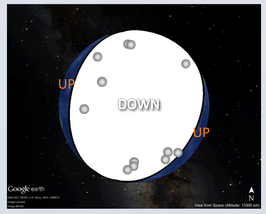
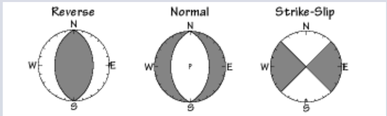
Along which plate boundary did this earthquake occur?

Justify your reasoning.





How would your answer change if the epicenter was in the Caribbean?



How would your answer change if the epicenter was in the Middle East?