Advanced GPS Activity—Locked & Loading

Using Plate Boundary Observatory (PBO) data to determine elastic compression of the Pacific Northwest Active Continental Margin.

   The big-picture result of this activity is that coastal stations of Oregon and Washington are being pushed toward the northeast at about ½ the velocity of Juan de Fuca Plate motion with respect to interior North America. Urban corridor stations are being pushed toward the northeast at about ¼ of the velocity of Juan de Fuca Plate motion with respect to interior North America. Stations on the east sides of Oregon and Washington are not moving at all. The clear implication is that coastal areas are moving towards eastern areas as the active continental margin is being compressed in SW – NE direction. Strain is building within the Pacific Northwest margin of the North American Plate as the Juan de Fuca Plate pushes the North American Plate margin toward the northeast. This accumulating strain will eventually be released in the next great earthquake on the Cascadia Subduction Zone. The plate boundary regions of the Juan de Fuca and North Amer ican plates are "locked and loading".

Materials

*Files needed for this activity are on the **CEETEP DVD** noted in the box below left.*

Map of 10 Plate Boundary Observatory GPS stations. The yellow blocks show the three regions reflecting GPS motion at different distances from the plate boundary. Coastal stations are being pushed towards the northeast faster than are the stations in the urban corridor and the stations east of the Cascades are basically not moving
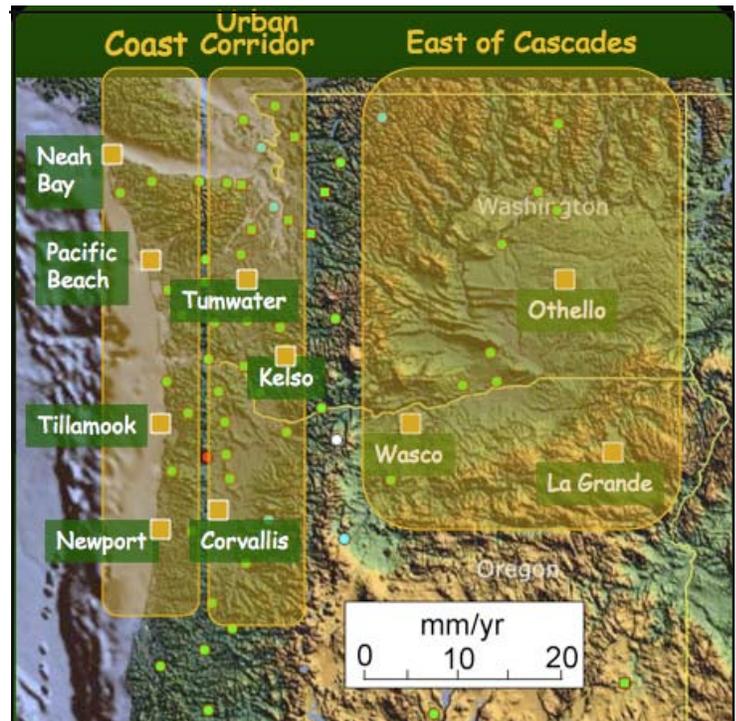
Science Standards (NGSS; pg. 287)

- From Molecules to Organisms—Structures and Processes: MS-LS1-8
- Motion and Stability—Forces and Interactions: HS-PS2-1, MS-PS2-2
- Energy: MS-PS3-1, MS-PS3-2, HS-PS3-2, MS-PS3-5
- Waves and Their Applications in Technologies for Information Transfer: HS-PS4-2, MS-PS4-3, HS-PS4-5
- Earth's Systems: HS-ESS2-1, MS-ESS2-2, HS-ESS2-2, MS-ESS2-3, HS-ESS2-3
- Earth and Human Activity: HS-ESS3-1, MS-ESS3-2

Files needed are on the DVD in the folder:

> **4. ACTIVITIES Cascadia Earthquakes & Tsunamis**
>> **Cascadia GPS**
>>> **CascadiaActivity2_ADVANCED_PBOdata**

KEY to STATION NAMES

Coast:
NEAH = Neah Bay, WA
PABH = Pacific Beach, WA
CHZZ = Tillamook, OR
NEWP = Newport, OR

**The Urban Corridor =
Willamette Valley/Puget Lowlands**
CORV = Corvallis, OR
KELS = Kelso, WA
TWHL = Tumwater, WA

Eastern WA or Eastern OR
PO22 = La Grande, OR
P451 = Othello, WA
P445 = Wasco, OR

Activity:

1. Introduce EarthScope project. This leads to showing the map of PBO stations over the Pacific Northwest on which you indicate the stations from which data will be analyzed. Map file = **PBOMap. pdf.**

2. Using the **PBOData09.ppt** PowerPoint, print out time series of all the stations you wish students to analyze. Students are given PBO data time series binned by regions (coastal, urban corridor, east of Cascades). You can have different groups of students do a set of stations that are approximately along a west to east transect across Oregon or Washington. For example, one set could be Neah Bay, Tumwater, and Othello.

3. Fit trend lines for the available time interval.

4. Compute slopes for northward and eastward positions to determine the north and east velocities of motion. Typical results: Newport station is moving 9 mm/yr north and 7 mm/yr east. Velocities for stations east of the Cascades will be essentially zero compared to the coastal and urban corridor stations.

5. Plot the velocities as arrows on the Cascadia GPS Analysis Grid.doc. Graphically add the north and east velocities to get the net velocity. This is adding vectors but doing it graphically makes it simple and avoids dealing with the trigonometry. Can always add the mathematical computations to add the vectors if you want to enhance the math portion of the exercise. Typical result for a coastal station would be a velocity of about 15 mm/yr toward the northeast. An urban corridor station will yield a velocity of around 7 mm/yr.

6. Open the **PBOData09.ppt** PowerPoint file, plot the individual station vectors on the blank PBO Station Map. For each station, use the tool to draw arrows (from the Drawing Toolbar) and the mm/year scale on PBO Map to draw an arrow of the correct length. Then, rotate arrow to match the final velocity direction determined from time series. Move the base of the arrow to the station location on the map. Pattern that emerges is velocities around 15 mm/yr for coastal stations, 7 mm/yr for urban corridor stations, and essentially zero for stations on the east sides of Oregon and Washington.

*If you want to download the latest available data directly from **UNAVCO**, follow instructions below.*

Accessing PBO plots and data:

1. Go to table of Plate Boundary Observatory GPS stations at URL below

http://pboweb.unavco.org/shared/scripts/ stations/?page=station_type&groupid=1

2. Find the listing for the station that you want to analyze. Example: NEAH is a "Nucleus GPS" station at Neah Bay, Washington. Search for "NEAH" under the listing of stations labeled "Nucleus GPS – (219 stations)".

3. In the row labeled NEAH in left column, locate the column labeled "Time Series Plots" and click on that column. This will take you to the GPS Station: NEAH – Data Products page at URL listed below.

http://pboweb.unavco.org/shared/scripts/station s/?checkkey=NEAH&sec=data_products

4. Under "Static Plots", click on "Unfiltered". This will take you to the URL listed below where the North, East, and Height of station NEAH is plotted against date from January 2004 until the date you access the page. Copy and past the time series plot into a graphics program and save in format of your choice (e.g. TIFF or JPG or PDF).

http://pboweb.unavco.org/shared/scripts/st ations/?checkkey=NEAH&sec=timeseries_ plots&timeseries=raw

5. If you are interested in mathematical analyses of GPS station coordinates, you can access tabulated data that can be read into Excel for analysis. To do this, return to step #3 and access the Data Products page at URL listed below. To download the daily coordinates of GPS station NEAH, locate the column labeled "Unfiltered" under "Station Position Time Series" and click on the "CSV" link. This will download a file "NEAH.pbo.csv" that you can read into Excel for analysis.

http://pboweb.unavco.org/shared/scripts/station s/?checkkey=NEAH&sec=data_products

Velocities determined by UNAVCO.

These can be accessed by "Detrended" tab when you are viewing the Time Series Plots for a station.

NEAH, *Neah Bay, WA:*
North velocity = 7.43 ± 0.02 mm/yr
East velocity = 10.16 ± 0.02 mm/yr
Height velocity = 4.75 ± 0.04 mm/yr

PABH, *Pacific Beach, WA:*
North velocity = 10.83 ± 0.02 mm/yr
East velocity = 13.43 ± 0.02 mm/yr
Height velocity = -0.50 ± 0.03 mm/yr

CHZZ, *Tillamook, OR:*
North velocity = 9.18 ± 0.02 mm/yr
East velocity = 7.52 ± 0.02 mm/yr
Height velocity = -0.14 ± 0.04 mm/yr

NEWP, *Newport, OR:*
North velocity = 8.85 ± 0.04 mm/yr
East velocity = 6.27 ± 0.04 mm/yr
Height velocity = 1.34 ± 0.08 mm/yr

CABL, *Port Orford, OR:*
North velocity = 11.69 ± 0.03 mm/yr
East velocity = 5.15 ± 0.03 mm/yr
Height velocity = -0.30 ± 0.05 mm/yr

CORV, Corvallis, OR:
North velocity = 6.39 ± 0.02 mm/yr
East velocity = 2.73 ± 0.02 mm/yr
Height velocity = -1.11 ± 0.03 mm/yr

KELS, Kelso, WA:
North velocity = 5.36 ± 0.03 mm/yr
East velocity = 4.36 ± 0.03 mm/yr
Height velocity = 0.41 ± 0.06 mm/yr

TWHL, Tumwater, WA:
North velocity = 5.03 ± 0.02 mm/yr
East velocity = 4.46 ± 0.02 mm/yr
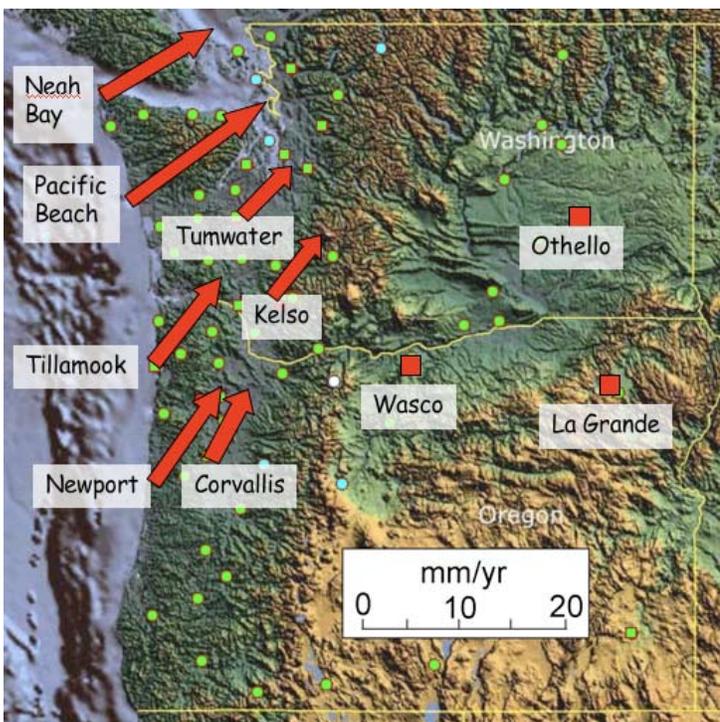*Height velocity = -1.34 ± 0.03 mm/yr*

P022, La Grande, OR:
North velocity = 0.32 ± 0.03 mm/yr
East velocity = -0.88 ± 0.03 mm/yr
Height velocity = 0.60 ± 0.06 mm/yr

P451, Othello, WA:
North velocity = 0.62 ± 0.02 mm/yr
East velocity = 0.20 ± 0.02 mm/yr
Height velocity = -1.59 ± 0.04 mm/yr

*P445, Wasco, OR:*
North velocity = 1.58 ± 0.03 mm/yr
East velocity = 0.30 ± 0.03 mm/yr
*Height velocity = -2.66 ± 0.05 mm/yr*

LEFT: Image from PowerPoint presentation shows all the motion vectors plotted on a map of Oregon and Washington.
 Notice that all the stations are moving in a northeasterly direction because this is the direction that the Juan de Fuca Plate is moving with respect to the North American Plate. The Coast Range is there because the land is deforming and rising in response to the forces pushing on it by the subducting Juan de Fuca Plate.

The images captured below show the 3 regions addressed in this activity. At left you see the "locked and loading" area with lock symbol; the slow-slip region with GPS symbol; the passive region with unlocked symbol. The graphs show the movement of each station as observed by GPS data.
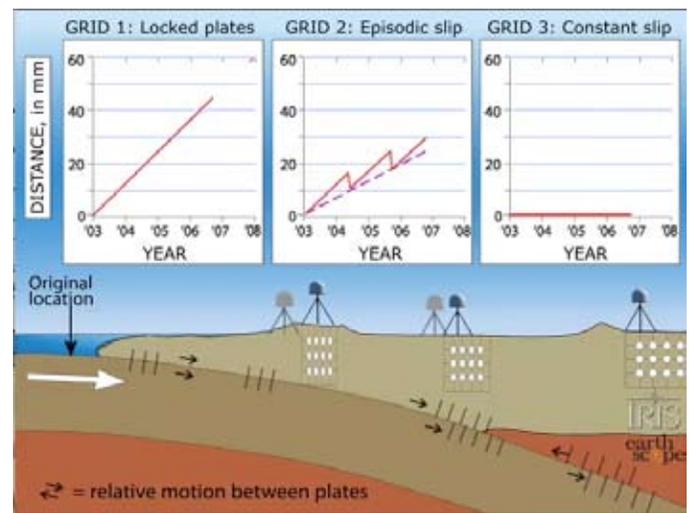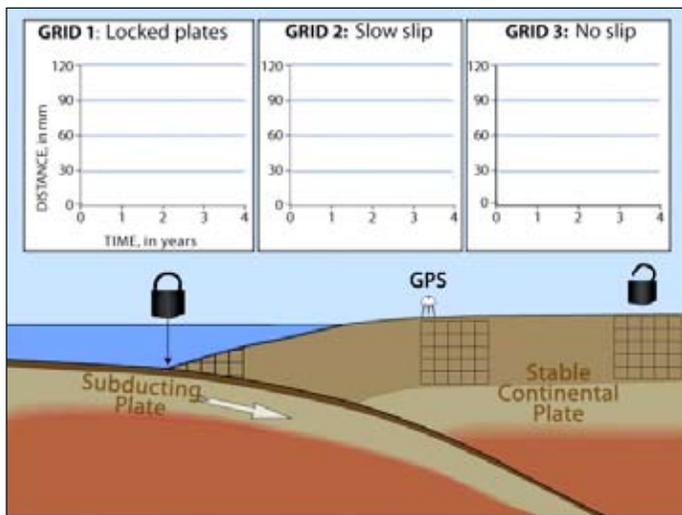
Animation depicted above is on the CEETEP DVD in the folder:

3. **Cascadia Earthquakes & Tsunamis**
   > 2. **ANIMATIONS Cascadia Earthquakes & Tsunamis**
      > **Monitoring Subduction_GPS & ETS**
         > **GPS_3grid_subduction_Groom.mov**
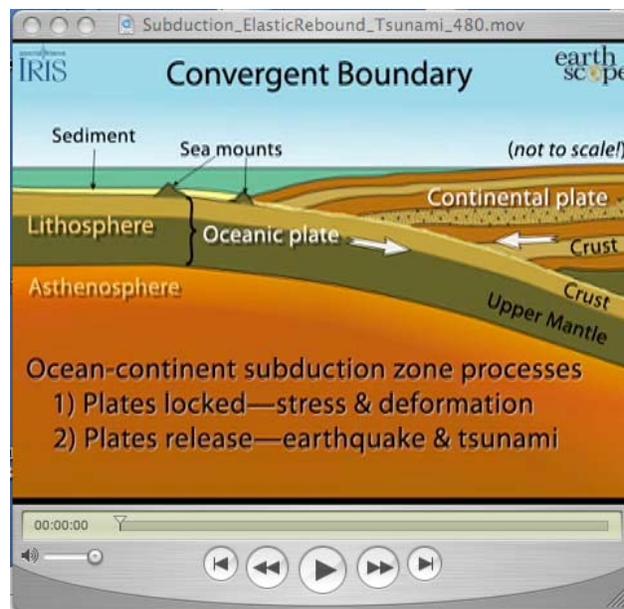
This animation shows the processes that lead to a subduction-zone earthquake.

It is on the CEETEP DVD in the folder:

2. **ANIMATIONS_Earth & Tectonics**
   > **Plate Interaction_Converge Diverge Transform**
   > **Convergent Margin_Compression**
   >**Subduction_ElasticRebound_Tsunami_480.mov**

Or on the Internet: **http://www.iris.edu/hq/programs/education_and_outreach/animations/11**