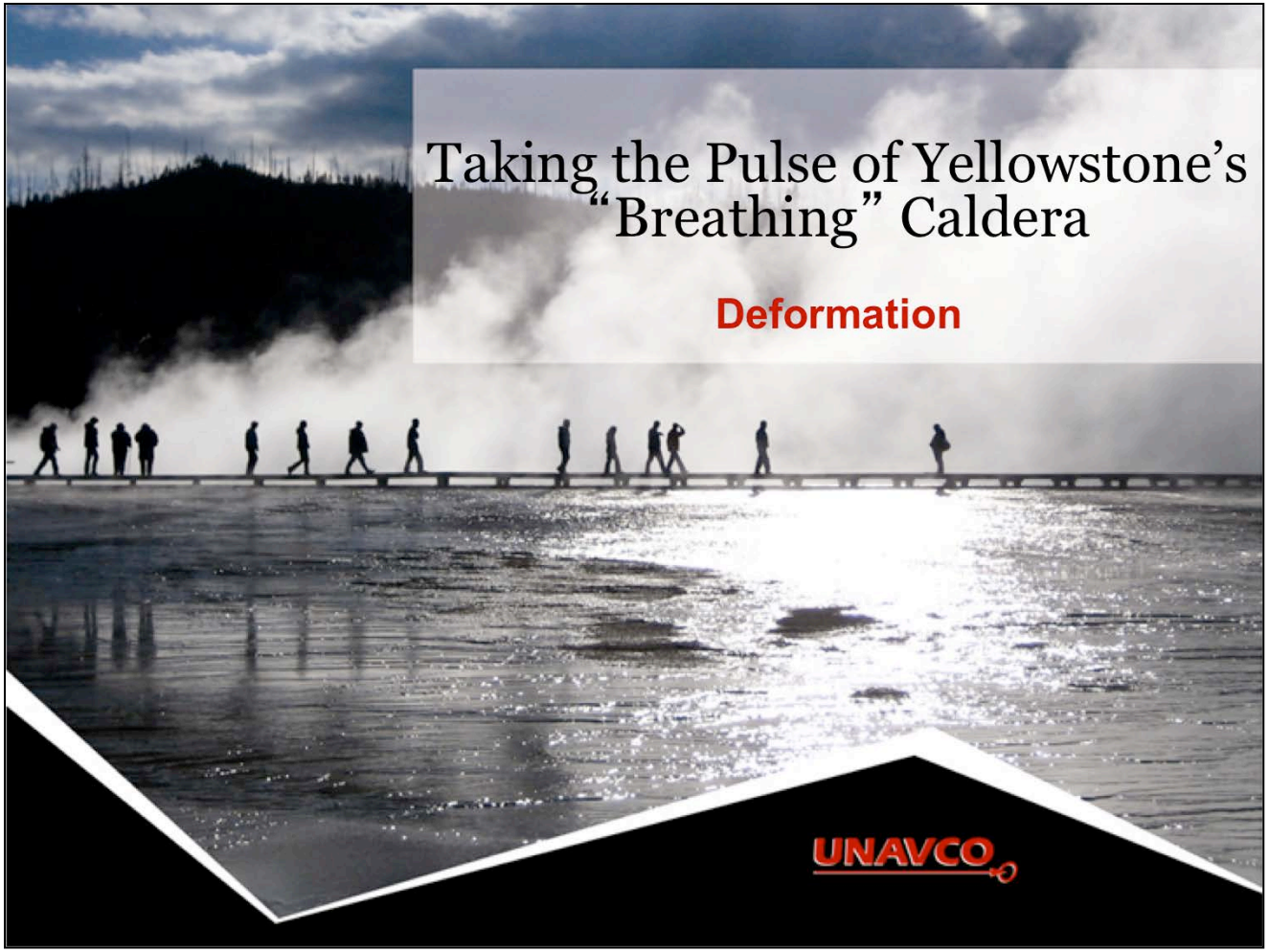


This presentation has links to extra content embedded in the slides – best viewed in Presentation Mode!

This presentation focuses on how the ground rises and falls and moves horizontally in Yellowstone region. You will also learn how scientists measure the motion.

Taking Yellowstone's Pulse
Ground deformation

Measuring deformation in ancient times

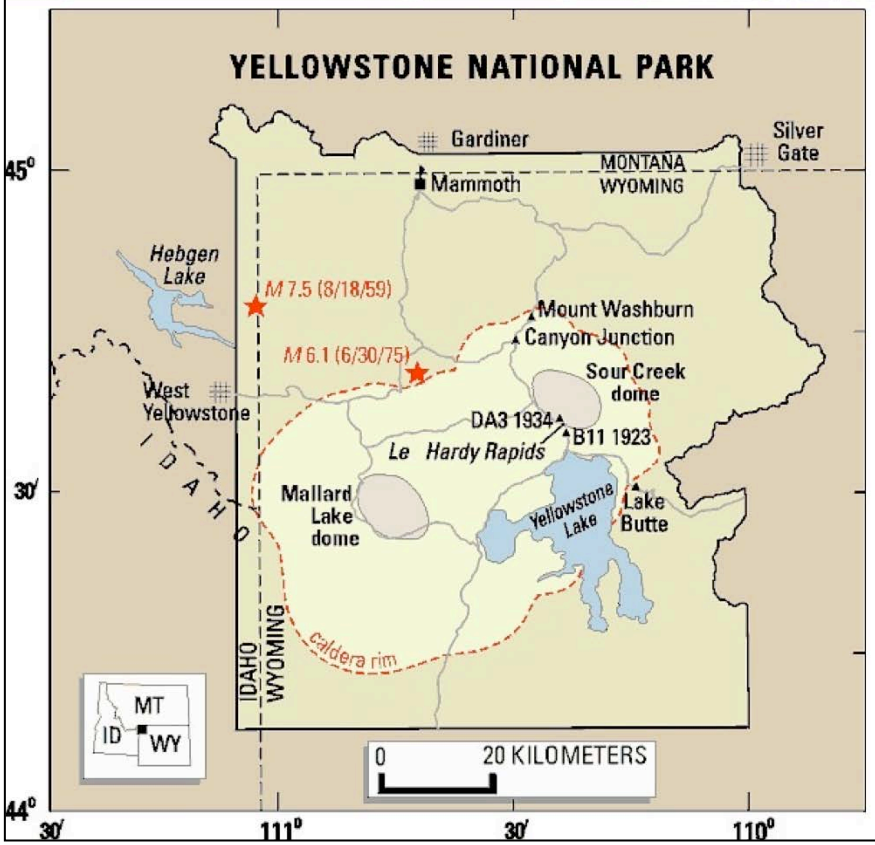
At Yellowstone, scientists began monitoring changes in ground level in 1923 using old-fashioned surveying equipment like that seen in the photos. This was decades before GPS was invented. They continued surveying this way until 1996. They had to survey every year, a time consuming task, but in gorgeous surroundings.

Scientists measured distance and elevation between points on "leveling lines." The photos show scientists surveying leveling lines in 1905 and 1981. The black and white photo is of scientists on Mount Whitney, California, at 14,500 feet elevation. The color one is of geologists working in the crater of Mount St. Helens on 6 November 1981.

Right-hand image from Department of Agriculture, Experiment Stations, Berkeley. 1905. US Geological Society Photographic Library. "ID. Topography A 240." http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20Topography%20A%202402 Retrieved 2 January 2012.

Left-hand photo from Topinka, L. 1981. USGS. U.S. Geological Survey Earthquake Information Bulletin, v. 16, no.2, p. 77. March-April 1984. Accessed from US Geological Society Photographic Library. "ID. CVO-F. 87ct." http://libraryphoto.cr.usgs.gov/cgi-bin/show_picture.cgi?ID=ID.%20CVO-F.%20%2087ct Retrieved 2 January 2012.

Measuring Elevation Changes: the Leveling Line



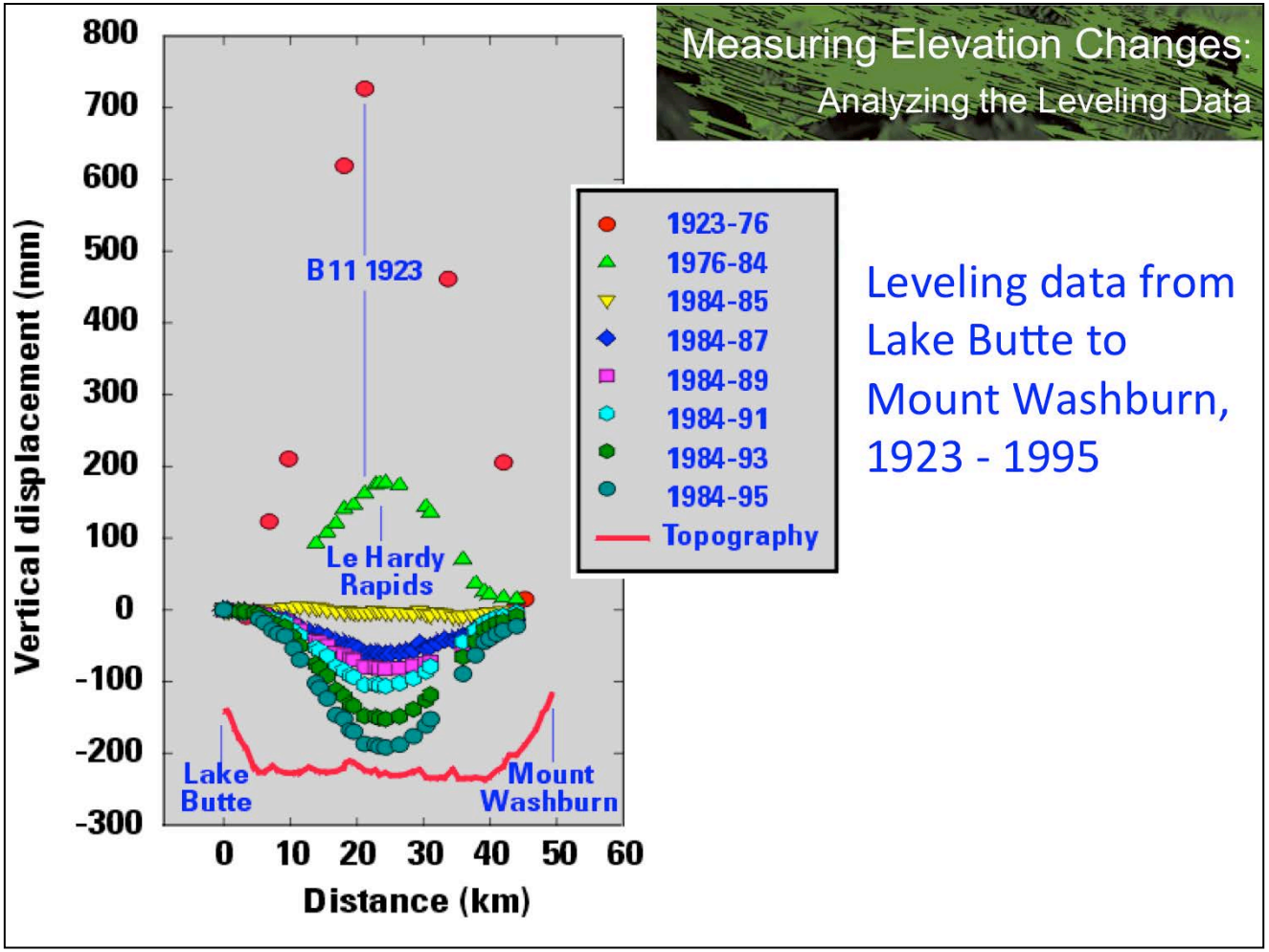
Reference map for leveling data

On your paper map, draw a line between Lake Butte and Mount Washburn. This will be like a leveling line. We have surveyed ("leveling") data from Lake Butte, Mount Washburn, and from many other stations, including at the Le Hardy Rapids and where B11 1923 is. Mark those four points on your map.

Where is this line compared to the caldera? Discuss this as a group.

You will now work with the survey data—shown on the next slide.

Map from Yellowstone Volcano Observatory: Map of Yellowstone Caldera and Leveling Benchmarks. http://volcanoes.usgs.gov/yvo/LvlMap.html Retrieved 30 December 2011.



This graph shows how the elevation has changed at survey locations on the leveling line from Lake Butte to Mount Washburn. from 1923 to 1995.

Each survey location was measured repeatedly using surveying methods like those shown in the photos adding more locations through time.

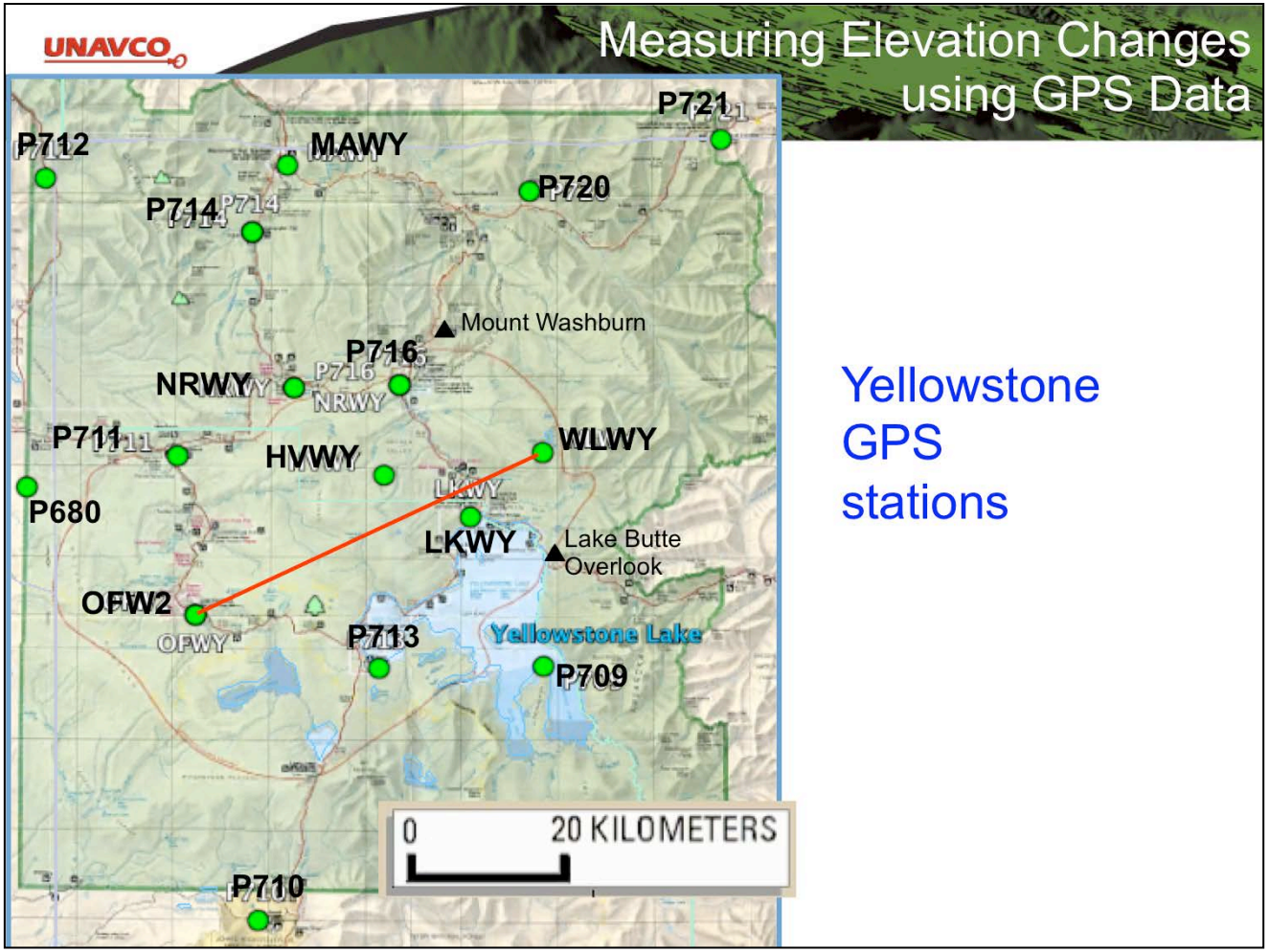
The symbols show each location's average elevation for the time periods shown.

To read this graph, look at one location such as Le Hardy Rapids, closely. Extend the short blue line above the "H" to the x-axis.

Starting with the green triangle symbol above the H – what was the average elevation of Le Hardy Rapids for 1976 to 1984? What was its average elevation in 1984 to 1985 (yellow inverted triangle symbol)? Continue to follow your line through time to see how the elevation changes at Le Hardy Rapids.

Study the graph then discuss the questions on your worksheet.

Image from Dzurisin, D., Savage, J.C., and Fournier, R.O., 1990, "Recent crustal subsidence at Yellowstone Caldera, Wyoming." Bulletin of Volcanology, v. 52, p. 247-270. Accessed from Yellowstone Volcano Observatory. http://volcanoes.usgs.gov/yvo/LvlData1923-1995.html Retrieved 2



Yellowstone GPS stations

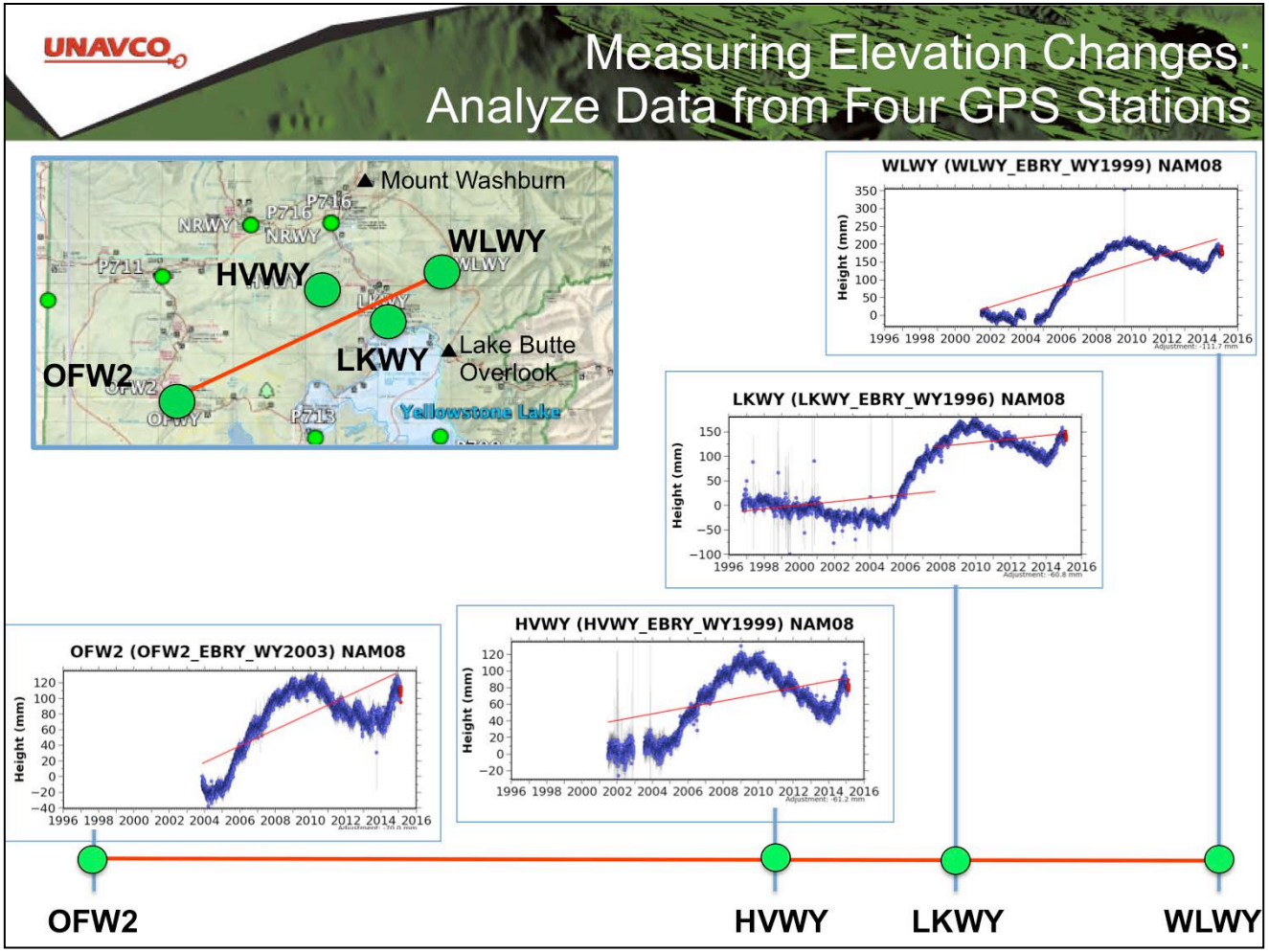
We also use ground stations that work in concert with satellites in the Global Positioning System, or GPS. Each of the stations on this map records data repeatedly every day.

The stations are set into the ground ten meters, in concrete. They measure the position of the station very precisely. If the ground moves only a few millimeters, the station can detect the change in position.

Sometimes it is useful to look at data from a new perspective. You will now work with data from GPS stations located across the length of the caldera.

This new transect crosses the old leveling line. They are: OFW2, HVWY, LKWY, and WLWY.

Draw their locations, Station ID labels, and a line that connects OFW2 & WLWY on your map.



Each graph shows the vertical change at the location of each GPS station. How has the land moved at each station? And compared to each other?

What does the horizontal axis show? The vertical axis? How do the vertical axes change between the stations?

When was the area rising? When was it falling? When did it peak? How much?

Describe the timing of the inflation and deflation of the ground at the GPS stations compared to each other.

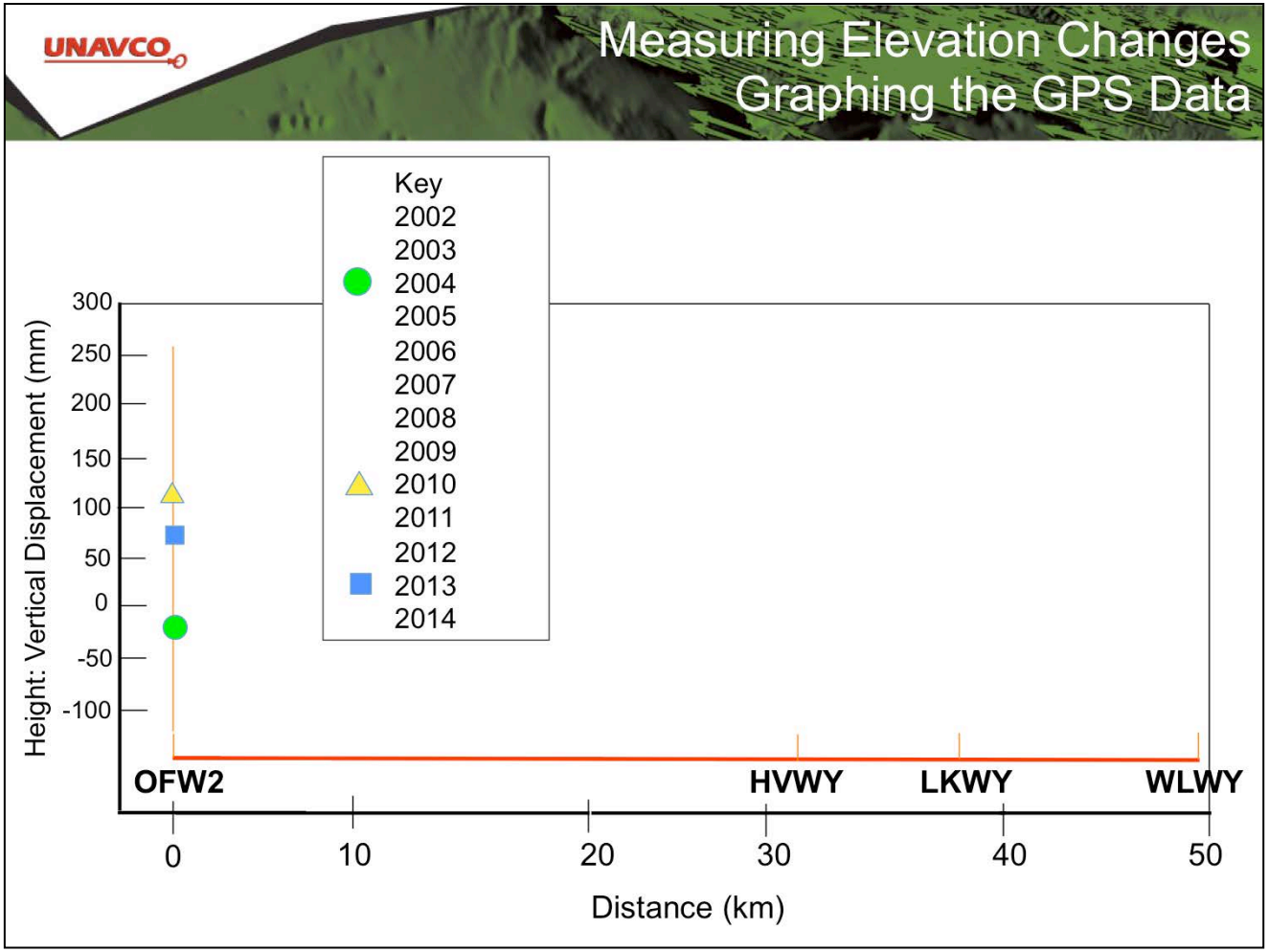
Where is this line compared to the caldera?

Data retrieved (February 2015) from:

http://www.unavco.org/instrumentation/networks/status/pbo/overview/OFW2

http://www.unavco.org/instrumentation/networks/status/pbo/overview/HVWY

http://www.unavco.org/



If your teacher asks you to, you'll make a graph similar to the leveling data graph.

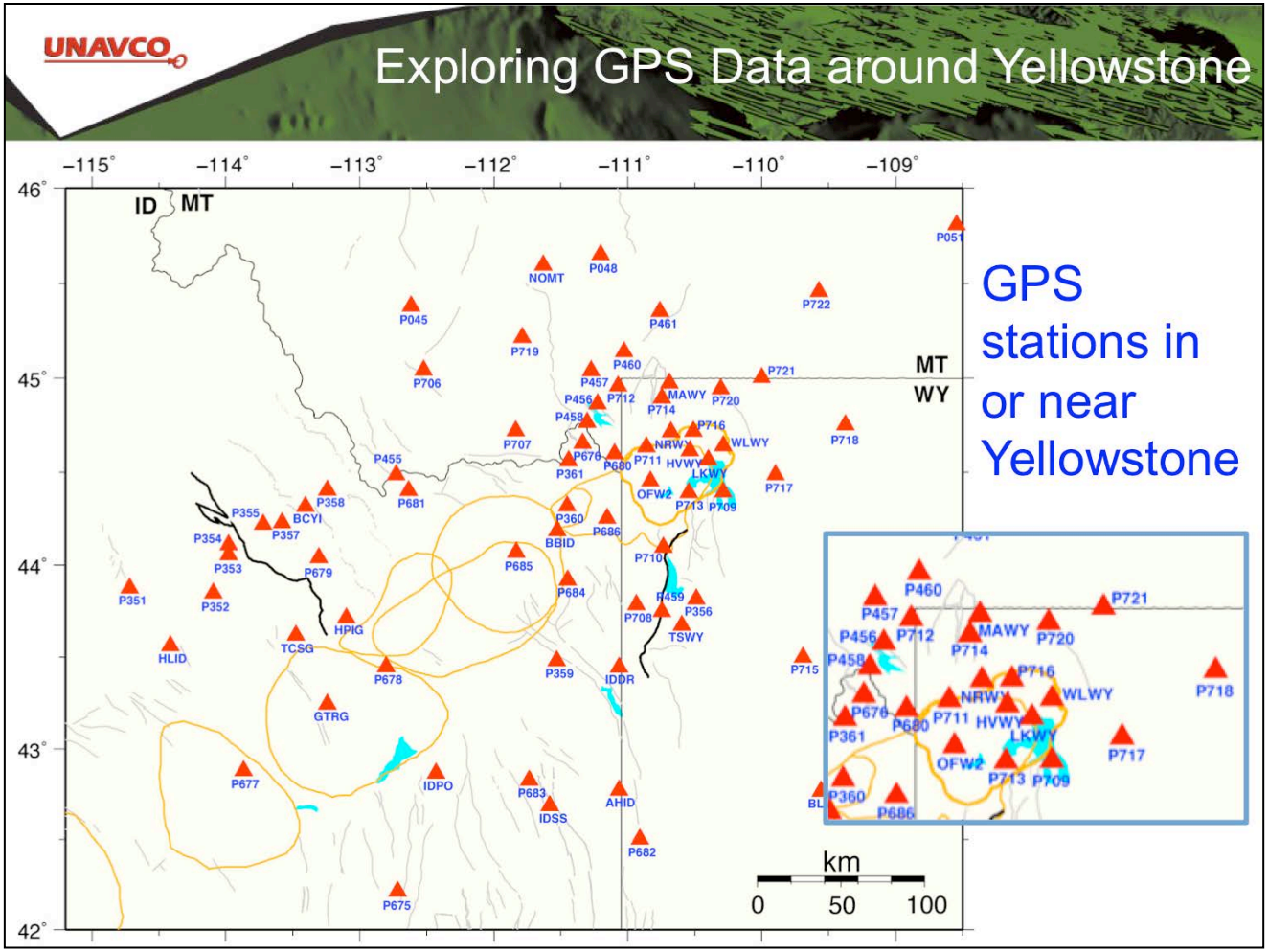
For each station, plot the height for 2004 then the years when the graph is at maximum(s) or minimums. The data from GPS station OFW2 has been graphed for three dates.

Your teacher might have you graph every year.

The data is 'messy' so use an average height for the date.

Use a different color or symbol for each year's data – but also make sure to use the same symbol and color for the same year on the different GPS stations.

Draw your colors and symbols in the key.

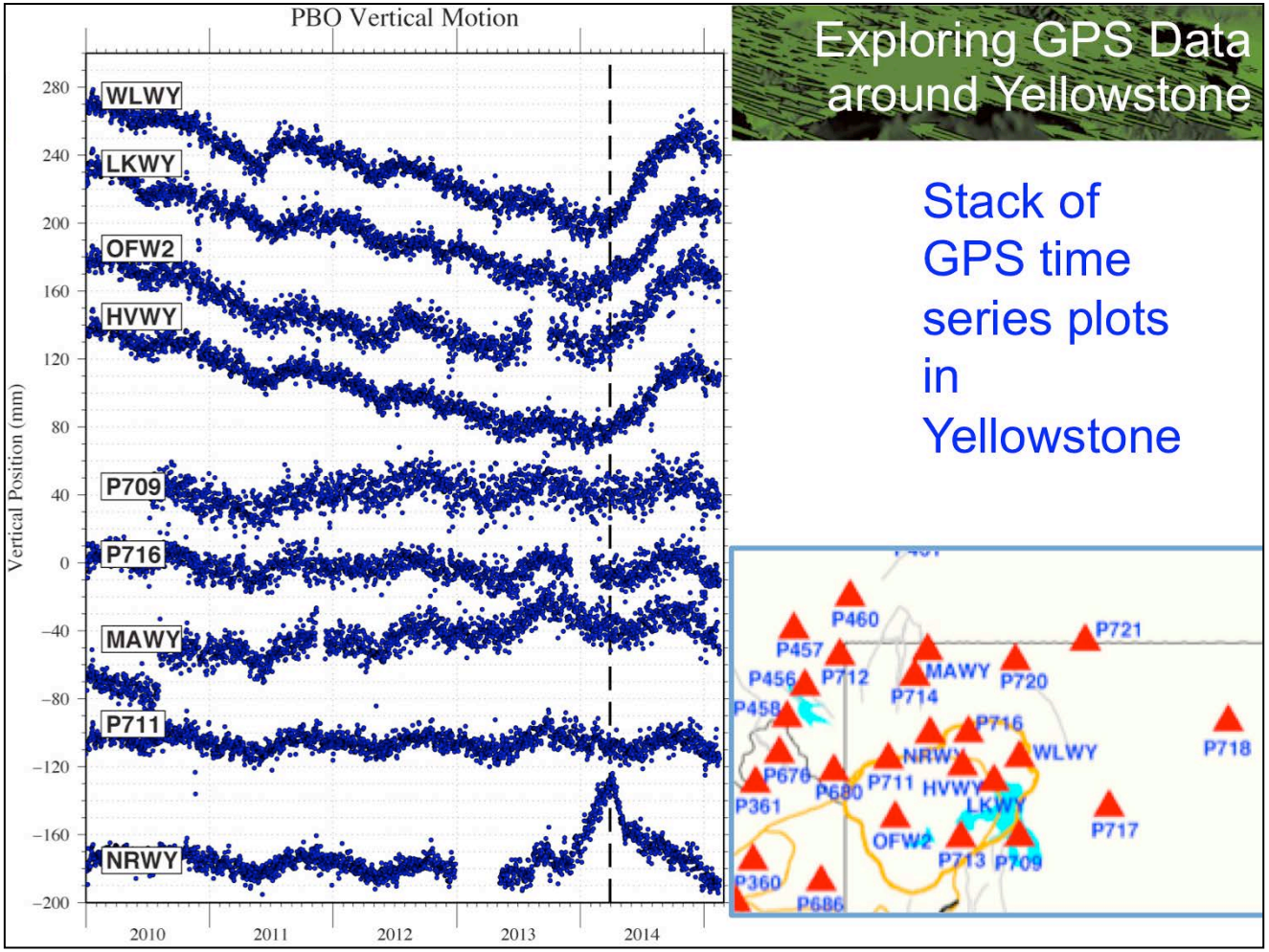


When you click on the large, regional, map, you will link to an interactive website that feeds you GPS data for the stations shown. The smaller map zooms in closer to Yellowstone. http://www.uusatrg.utah.edu/ts_ysrp.html (Search for “utah permanent gps network.”)

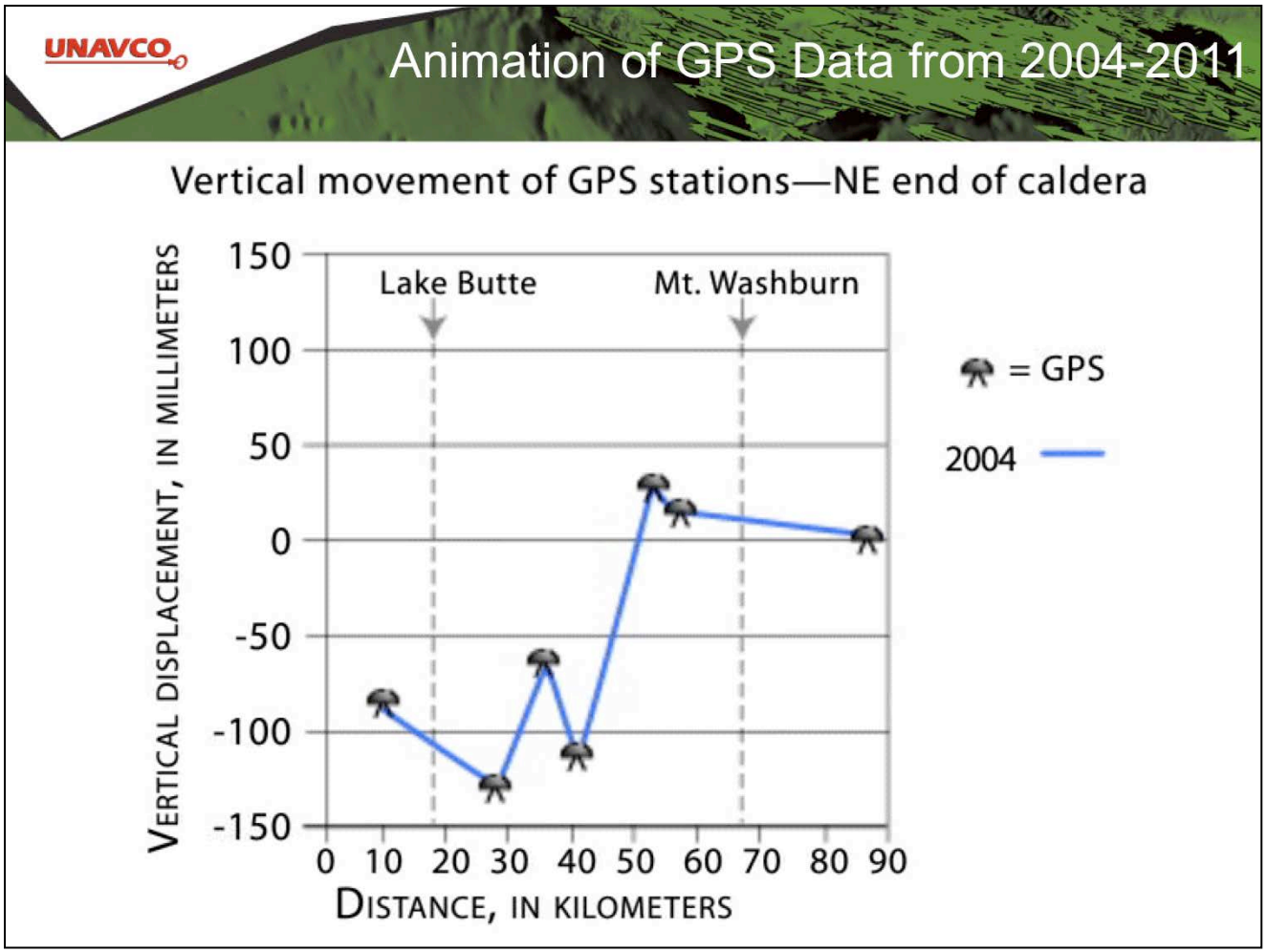
The golden loops mark calderas.

Explore the data from the different stations. How are the graphs similar or different to the stations you analyzed previously?

Maps from Yellowstone-Snake-River-Plain GPS Network http://www.uusatrg.utah.edu/ts_ysrp.html Retrieved 2 January 2012.

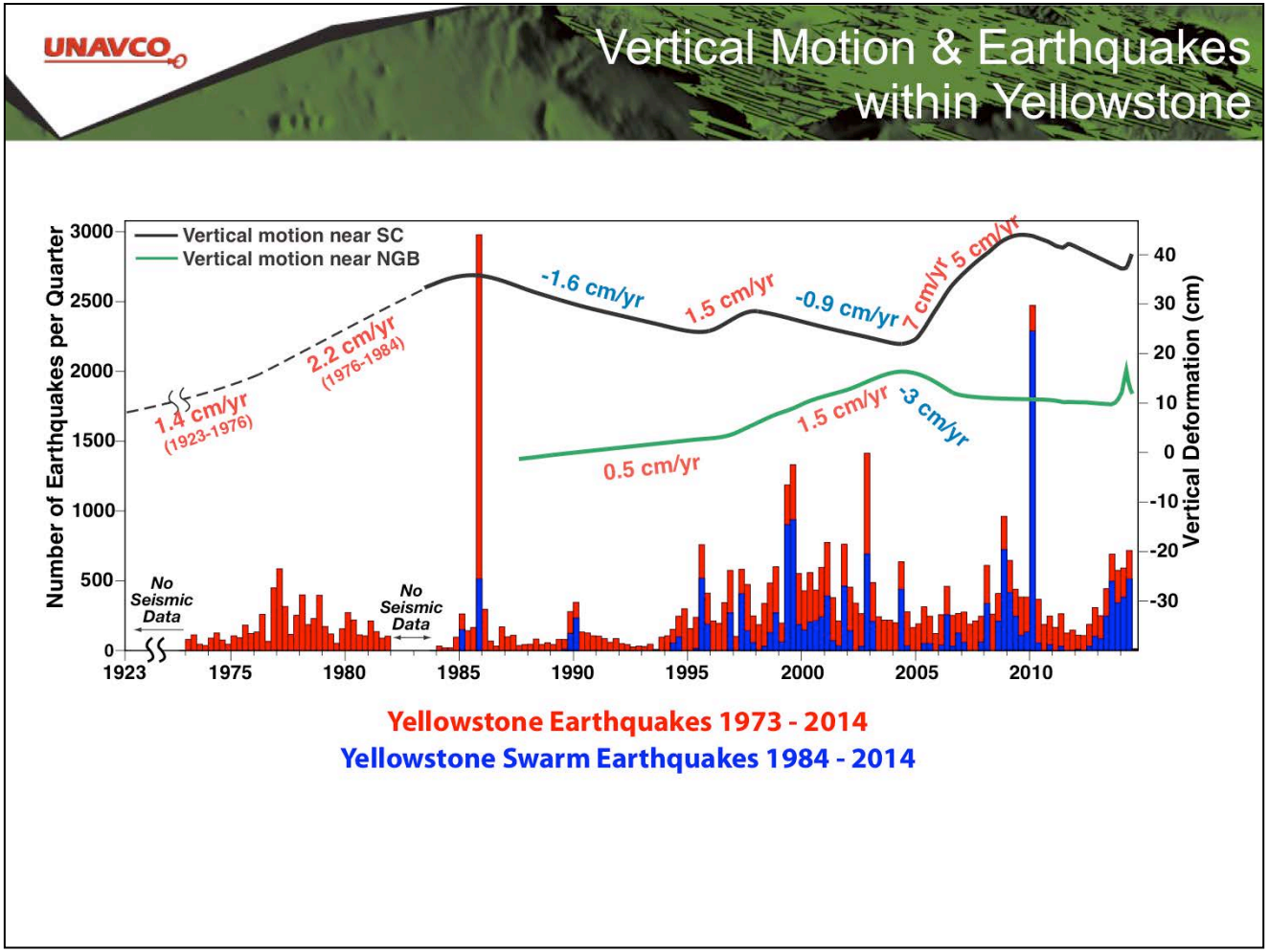


Vertical changes through time for many Yellowstone GPS stations shown as Time Series plots. Source: Christine Puskas, UNAVCO.



This animation should start on its own, try clicking on the graph. You can view an animation of the ground moving the GPS stations up and down near the leveling line.

Animation by Jenda Johnson for UNAVCO, 2013. http://www.unavco.org//education/resources/educational-resources/lesson/gps-yellowstone/module-materials/yellowstone-gps-2004-2011.mov Retrieved 20 November 2014. (Search on YouTube for “UNAVCO research P8.”)



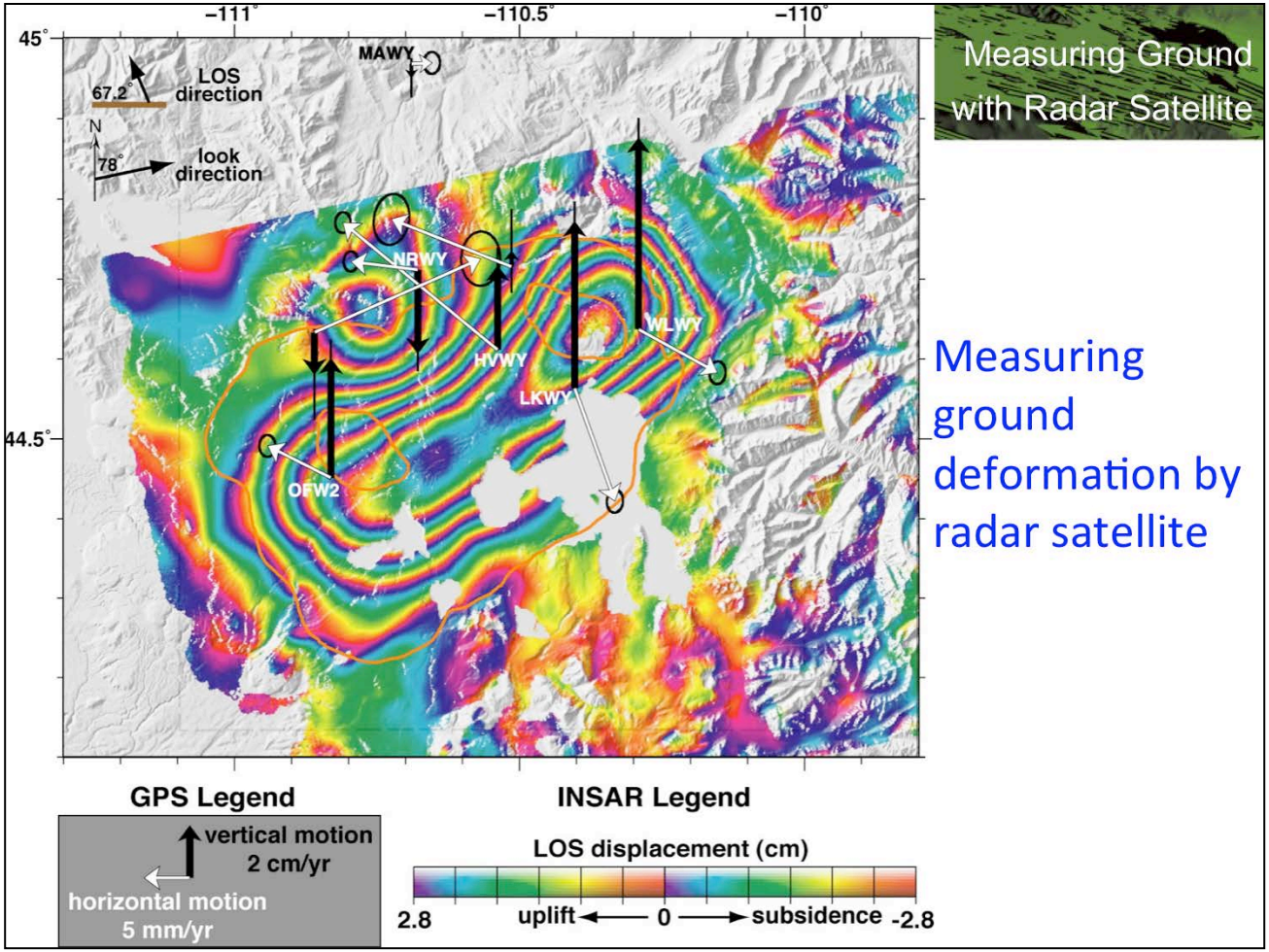
This graph pulls together leveling and GPS data while also showing earthquakes and earthquake swarms from 1923 through 2014. Two regions of Yellowstone deform in approximate opposite oscillation. We have been studying the GPS and leveling data associated with the Norris Geyser Basin (the lower green line on the graph).

How do these graphs compare to the data you analyzed?

SC: Sour Creek Dome,

NGB: North Geyser Basin

Farrell, J., D. Shelley, R. B. Smith, P. Puskas, W-L Chang. (2014), The Mw4.8 Norris Geyser Basin Earthquake of 30 March, 2014 and its Relationship to Crustal Deformation and Seismic Activity of the Yellowstone Volcanic System, S11E-4400 presented at 2014 Fall Meeting, AGU, San Francisco, Calif., 15 Dec. 2014.



Scientists can also collect data about how the ground has deformed using a satellite-based instrument called Interferometric Synthetic Aperture Radar (InSAR). Computers compare two radar images of the area taken at different times and show changes in elevation with the colors you see.

Each repetition of a color from a red band to another red band) represents 28 mm (2.8 cm) of uplift. This image shows changes between 2004 to 2006.

How much uplift was there? Compare and contrast leveling, InSAR, and GPS data for this area.

Other features: Orange lines shows the caldera outlines. Black arrows are vertical motion and white arrows are horizontal velocity measured by GPS from 2004 and 2006.

Click on the image to link to a brief article about ground deformation in Yellowstone. http://volcanoes.usgs.gov/yvo/publications/2007/upsanddowns.php (Search for “yvo ups downs.”)

Image from Chang, W.-L., et al. (2007). "Accelerated Uplift and Magmatic Intrusion of the Yellowstone Caldera, 2004 to 2006." Science **318**(5852): 952-956.. Retrieved from The University of Utah Seismology and Active Tectonics Research Group. http://www.uusatrg.utah.edu/ Retrieved 24 February 2015.

Taking Yellowstone's Pulse
Sources

UNAVCO: Johnson, Jenda. 2013. "Vertical Movement of GPS Stations—NE End of Caldera." http://www.unavco.org//education/resources/educational-resources/lesson/gps-yellowstone/module-materials/yellowstone-gps-2004-2011.mov Retrieved 20 November 2014. (Search on YouTube for "UNAVCO research P8.")

USGS, Volcanic Hazards Program, Yellowstone Volcano Observatory. 2007. "Recent Ups and Downs of the Yellowstone Caldera—2007 article." http://volcanoes.usgs.gov/yvo/publications/2007/upsanddowns.php Retrieved 20 November 2014. (Search for "yvo ups downs.")

All retrieved 6 November 2014.