Visualizing Earthquake Data To Improve Communication About Seismic Hazards

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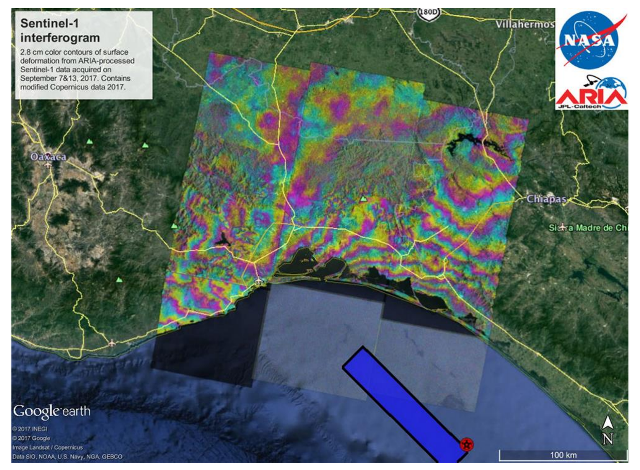
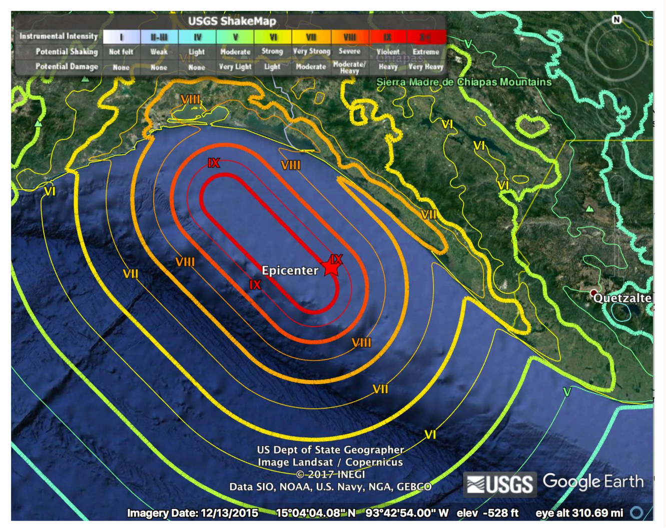
The USGS, IRIS, and NASA

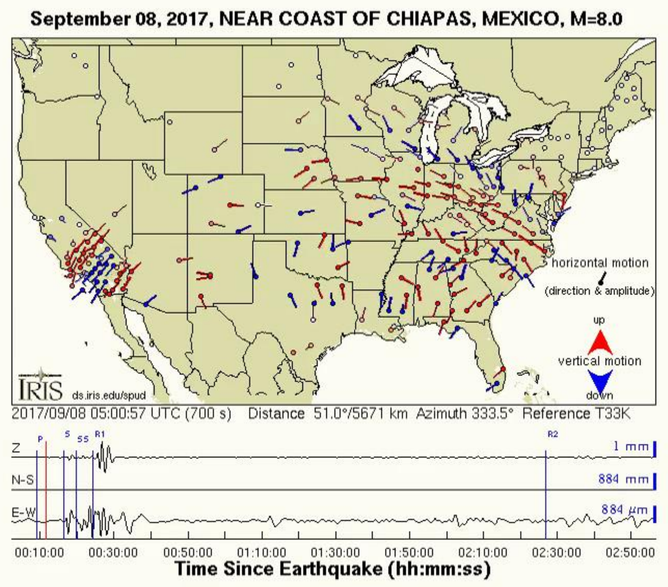
Within the event pages for the magnitude 8.2 earthquake located offshore of Chiapas, Mexico, the USGS synthesized analytics and data from many different sources and included links to the IRIS event page. Some of these resources are generated almost automatically, like the NASA image on the right, showing surface displacement. Some are fairly straightforward to interpret, like the USGS shake map below. Others are quite complex, like the frame from the IRIS vector map model in the lower right corner. Each of these attempts to show one aspect of the multifaceted data set created by an earthquake. But one characteristic is common to all three images, a focus on the surface.



NASA JPL-Caltech ARIA team



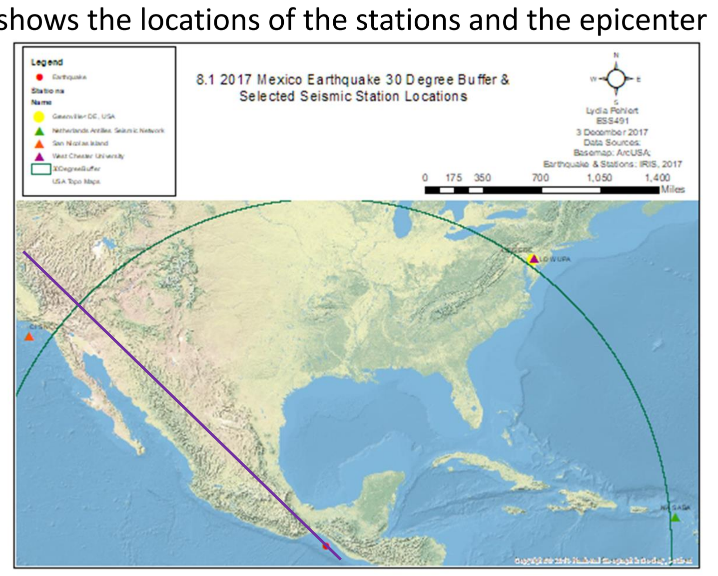
USGS



IRIS

The Stations

The stations were selected to match as closely as possible the 29.59 degree distance from the event that the West Chester University station, LDWUPA, had from the earthquake. CISNCC was selected as approximately along strike while NASABA was chosen to lie approximately in the dip direction. LDGEDE was selected as the station closest to LDWUPA and might have the most similar record. The map below shows the locations of the stations and the epicenter along with a green buffer at 29.59 degrees. A purple annotation line rotated 314 degrees from North was added. Both the CISNCC and NASABA stations are on islands.

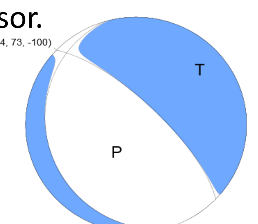


The Earthquake

Research was focused around the earthquake that ocurred offshore of Chiapas, Mexico, on September 7, 2017 at 11:49 local time (September 8 at 04:49UTC). The USGS calculated the magnitude at 8.2 Mww with a moment of 2.162e+21 N-m and a depth of 45.5 km. The W-phase moment tensor.

Nodal Planes

Plane	Strike	Dip	Rake
NP1	164°	20°	-61°
NP2	314°	73°	-100°



USGS National Earthquake Information Center , PDE

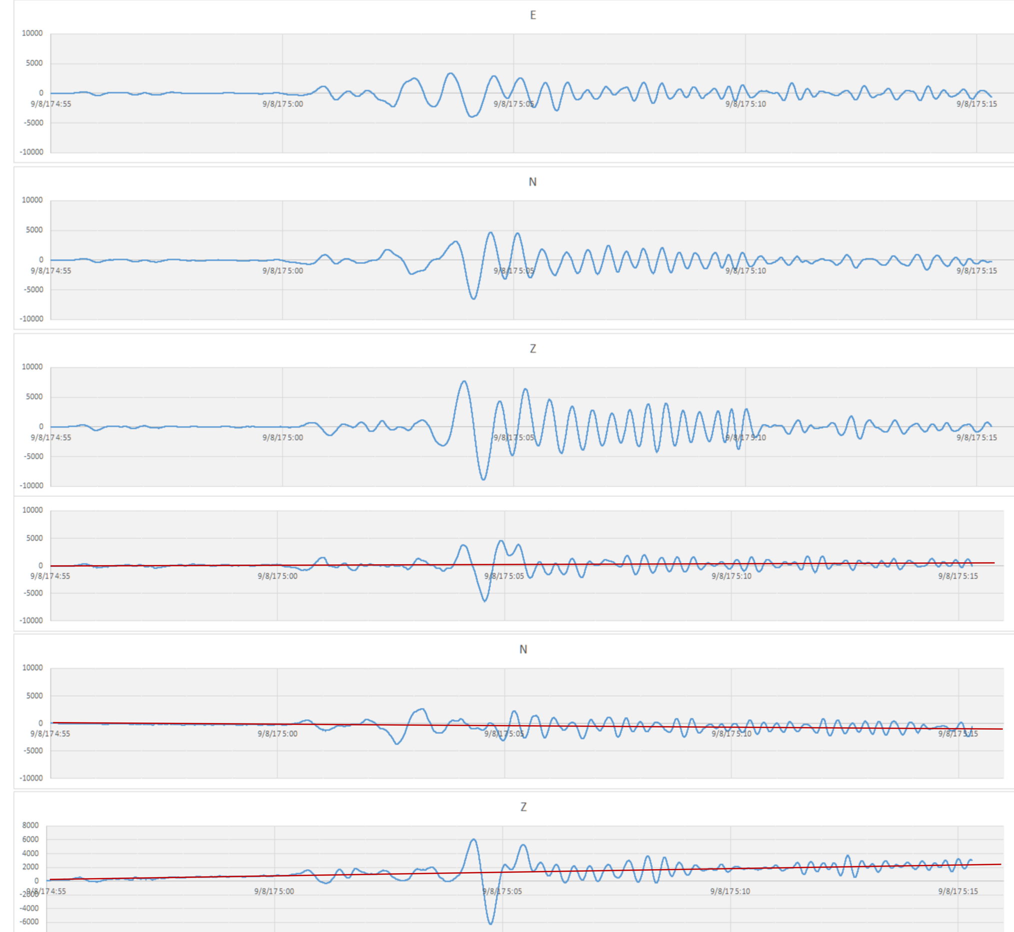
Principal Axes

Axis	Value	Plunge	Azimuth
T	2.184e+21 N-m	27°	52°
N	-0.044e+21 N-m	9°	317°
P	-2.140e+21 N-m	61°	210°

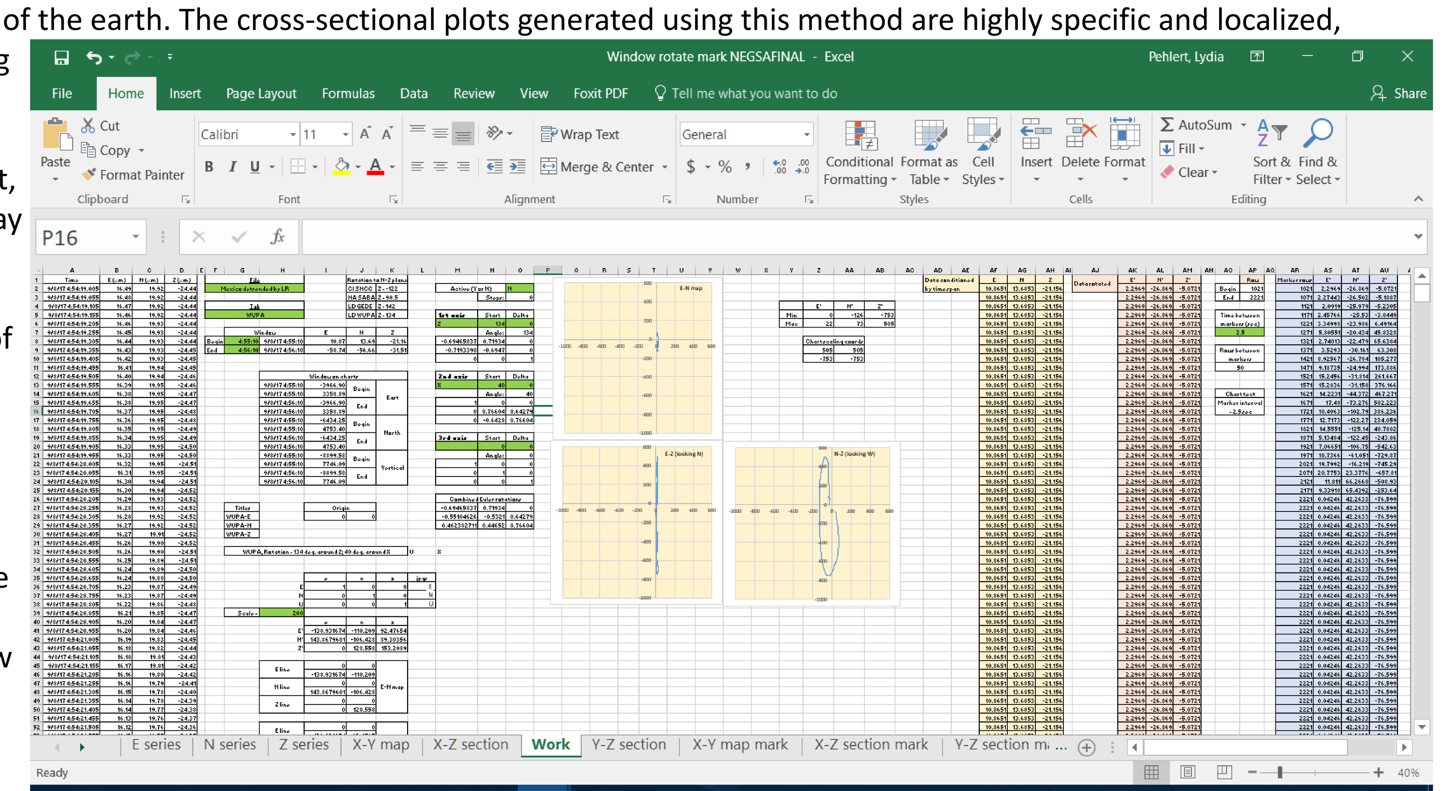
All values calculated by the USGS National Earthquake Information Center , PDE

Excel Processing

The time series data for each station were requested using the IRIS Wilber3 tool. The data were converted from counts to nanometers per second and then integrated to find displacement in micrometers. This displacement was plotted as shown to the right with data from WUPA. The WUPA component plots are nicely centered around zero. The data from CISNCC, LDGEDE, and NASABA showed a linear drift over time. The plots of NASABA are shown with red annotation lines to highlight this linear trend. The angle is not consistent from one component to the next. It is unclear what causes this linear trend, but it seems likely that it is some kind of systematic error. Because it is linear, it is relatively easy to eliminate.

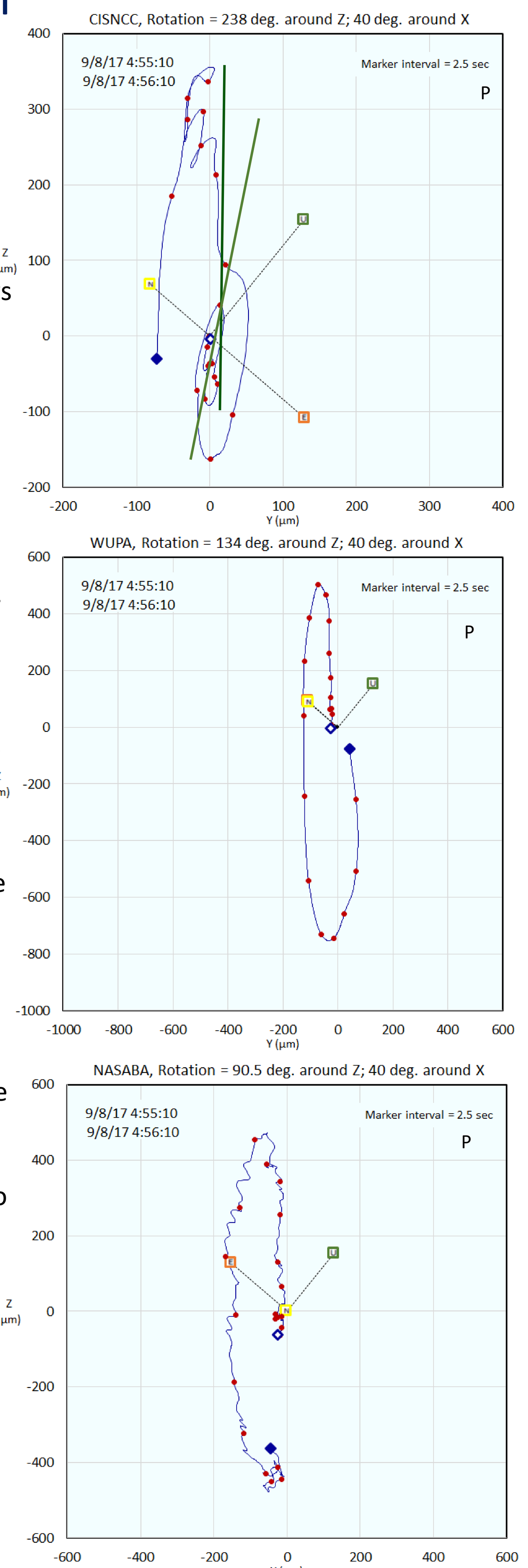


The detrended data were then rotated using the azimuth from the station to the epicenter to bring the data into an orientation where the wave arrives from the right side of the plots. While these representations are still confined to 2-dimensions, they focus on the movement of the motion of the wave rather than its trajectory along the surface of the earth. The cross-sectional plots generated using this method are highly specific and localized, contributing little to an overview of the event, but they may help to understand what kind of motion is actually occurring at a given point at a given time and to help present new questions.



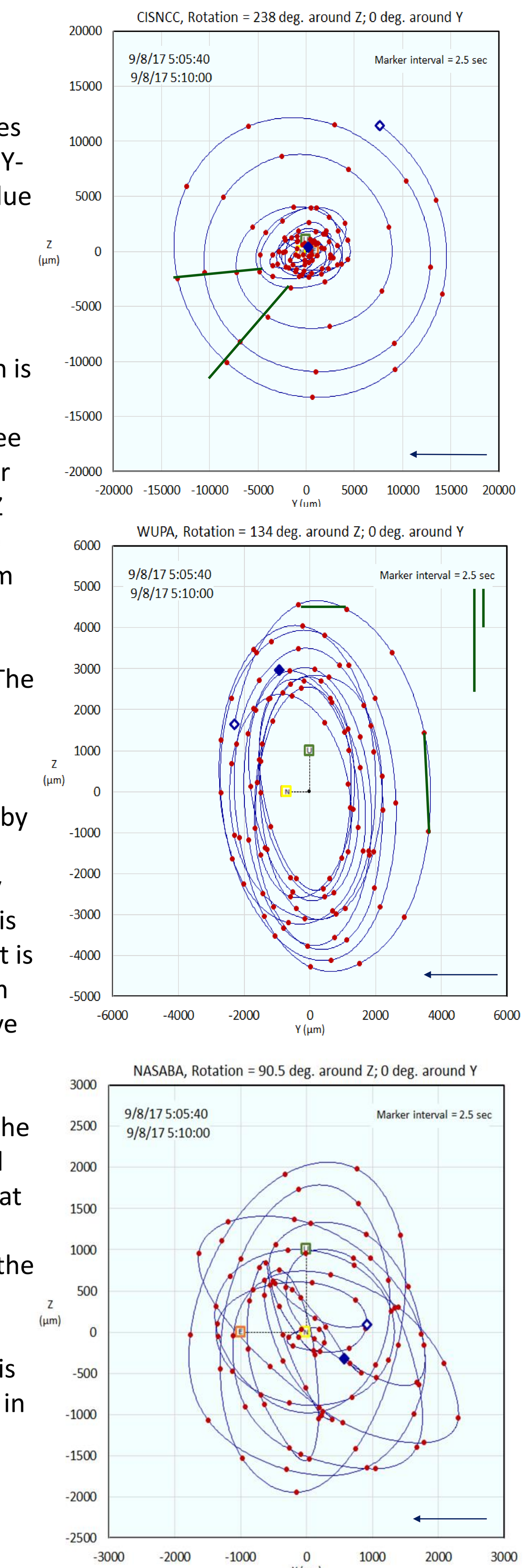
P Wave Arrival Angle

The P arrival during the 4:55:10 to 4:56:10 time interval plotted in the Y-Z section shows an emergence angle near 40° from the vertical for almost all stations. The exception is station SNCC, which seems to have a shallower angle of about 32°, highlighted with green annotation lines. It is unclear why this apparent change in emergence angle is observed. The red marker points show a similar velocity pattern to that observable in the surface wave plots above. The velocity seems to increase along the elongated sides of the plot and to decrease in velocity at the ends. This pattern is consistent for all stations but the significance is unclear.



Surface Waves

These Y-Z plots from the SNCC, SABA, and WUPA stations show surface waves arriving along the positive Y-axis, marked with a dark blue arrow. The waves at SNCC, and WUPA show clear retrograde cycles, characteristic of Rayleigh waves. At SABA the motion is more complex and more distributed among the three sections, preventing a clear cross-section view. The Y-Z plot from SNCC is closer to circular, while the plot from WUPA is elongated. Both stations show decreasing spiral patterns over time. The distance traveled between the red marker points decreases over time for station SNCC, emphasized by the green annotation lines indicating that the velocity also decreases. While this is true for WUPA and SABA, it is most clear in the data from SNCC Similar to the P wave records, the surface wave data for WUPA show an increase in velocity along the elongated sides of the oval and a decrease in velocity at the ends. The green annotation lines illustrate the differences in length. Although the WUPA data shows this most clearly, this pattern is also observable in SNCC and SABA. The SABA record is less easy to interpret, resembling a tangled knot of yarn.

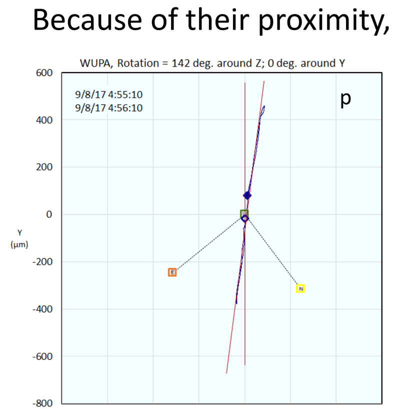


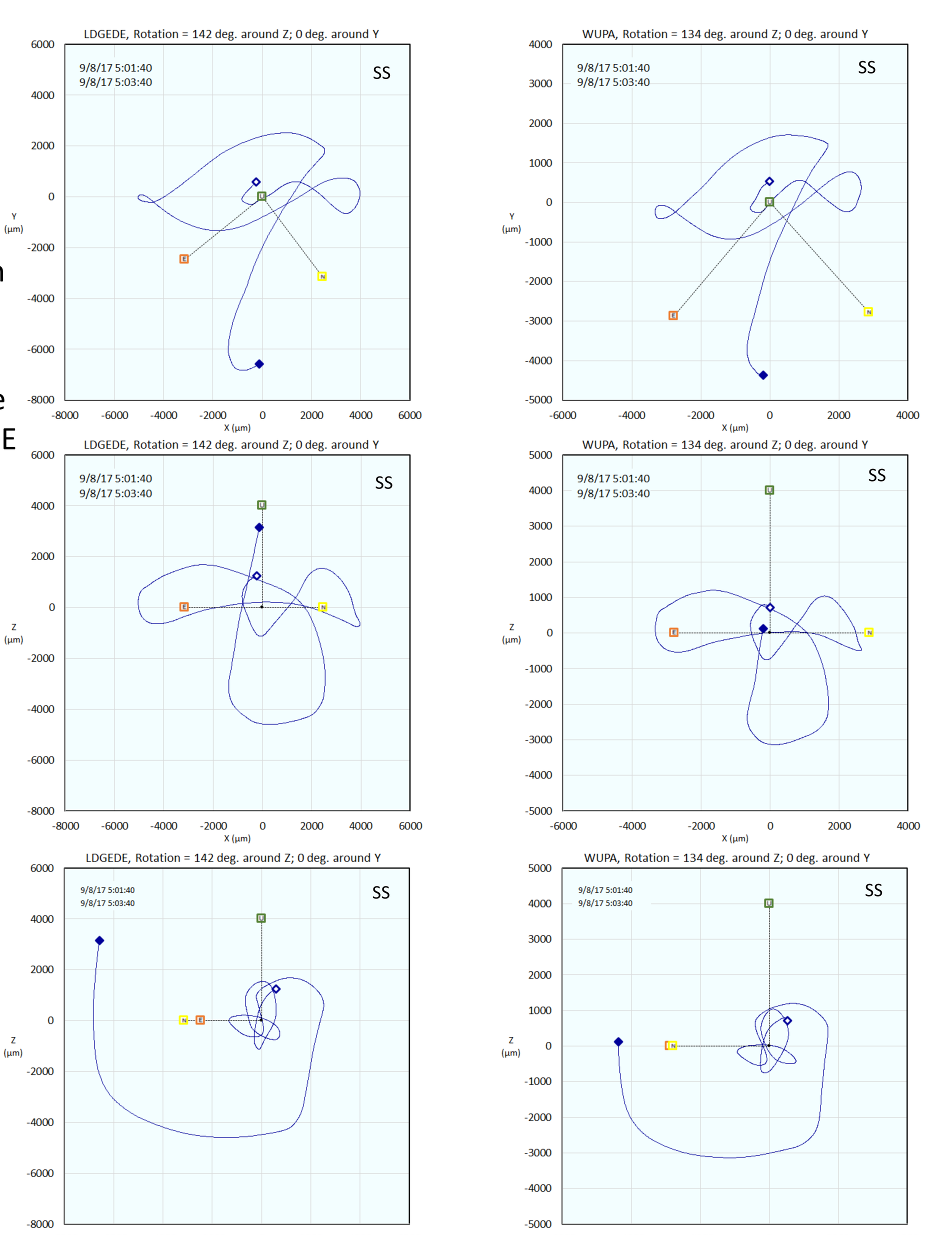
LDWUPA and LDGEDE SS Waves

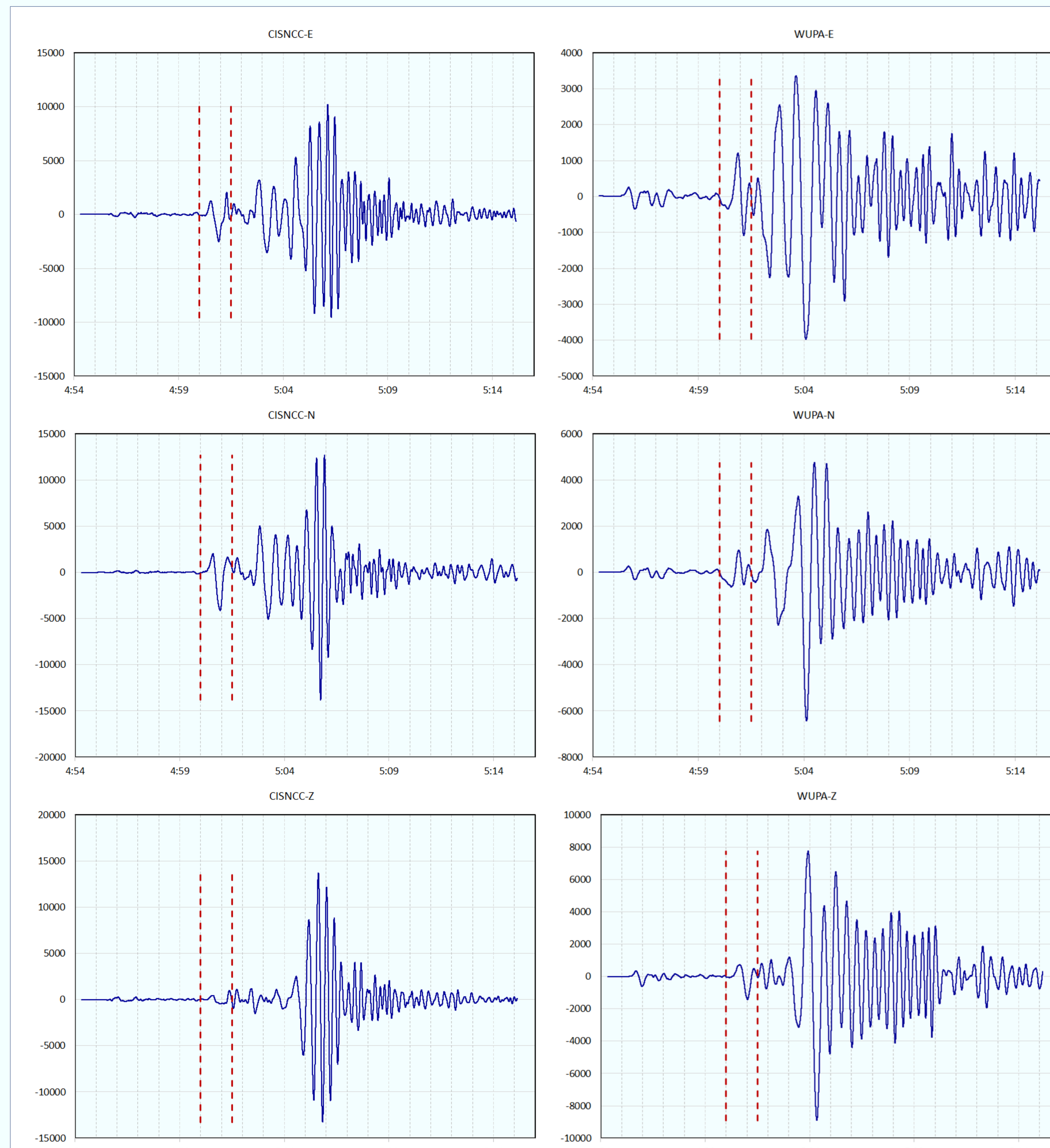
In most respects, the patterns created by the data from both WUPA and GEDE stations appear almost identical, as might be anticipated from their close proximity to each other. This similarity is demonstrated on the right with a side by side comparison of the plots during the 5:01:40 to 5:03:40 time interval, containing the SS wave arrival. Because the patterns are so similar, only the plots of WUPA data are used for comparison elsewhere on the poster. However there are a few important differences between the two stations that should be addressed. The scale of the motion at the stations does differ. As seen in the table of maximum values to the left, the GEDE station has consistently higher maximum values.

Max	E (µm)	N (µm)	Z (µm)
WUPA	3359	4753	7746
GEDE	5020	7326	11656

One potential explanation of this discrepancy is a muting or amplification of the signal based on the material the seismometer is anchored in, but this idea was not explored further. The other aspect in which the stations were observed to differ was in the optimized rotation. Rotating the data around the Z-axis by the negative of the azimuth calculated by drawing a great circle on Google Earth from the station to the epicenter, brought the wave arrivals to be parallel to the X-axis for all stations except WUPA. Because of their proximity, both WUPA and GEDE had calculated azimuths of 142°. While the GEDE data does work well with a Z rotation of 142°, the WUPA data appears to fit better at a Z rotation of 134°. This rotation discrepancy is best illustrated in the 4:55:10 to 4:56:10 time interval at WUPA, containing the P arrival. The red annotation lines show the angular trend of the data and a vertical reference.

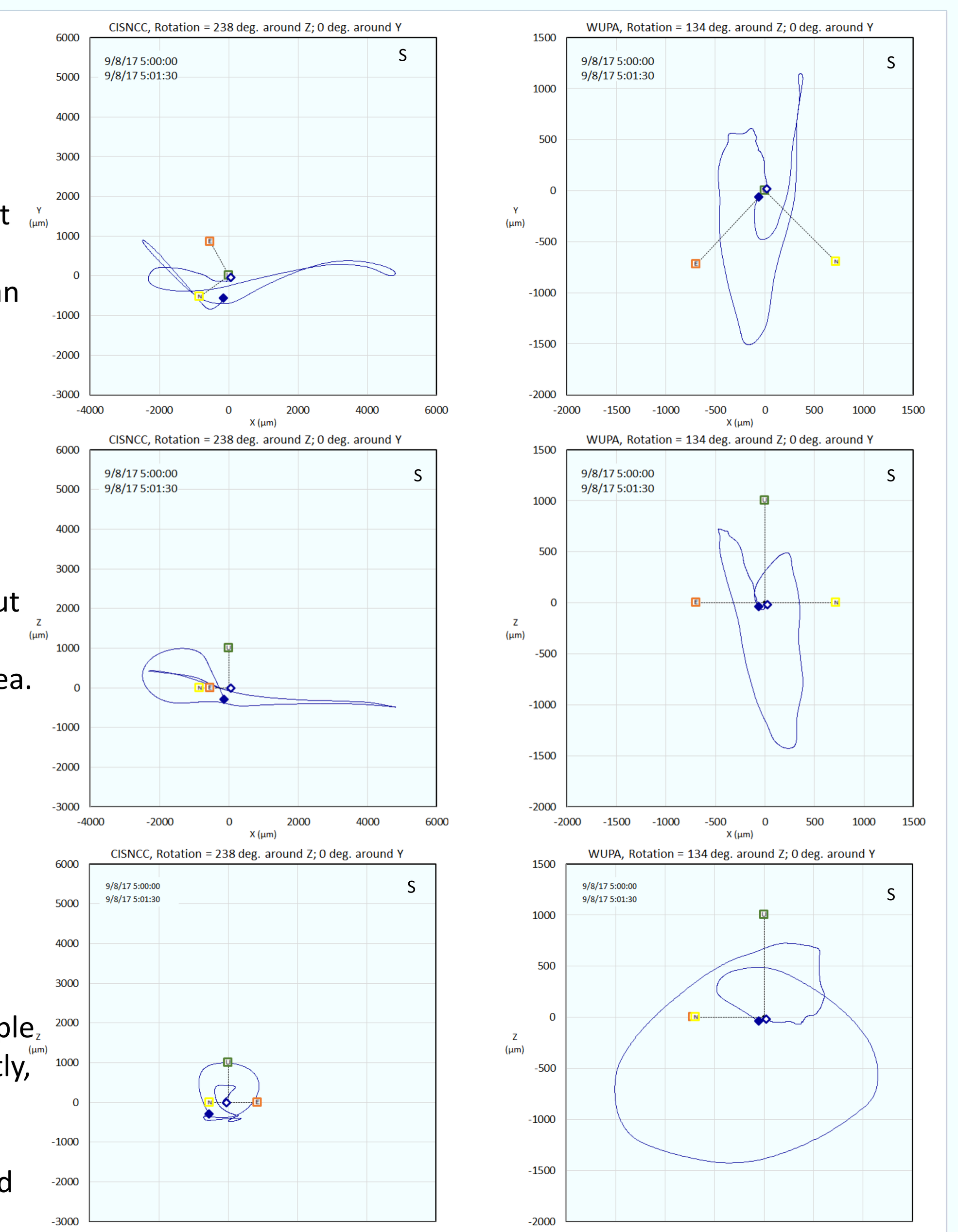






CISNCC and LDWUPA S Waves

The data from SNCC and WUPA from 5:00:00 to 5:01:30, which includes the predicted S arrival at about 5:00:10, show strong contrasts. SNCC seems to show an almost polarized wave while the data from WUPA are more complex. One conjecture is that the orientation of the stations relative to the fault and the earthquake location may have influenced this pattern, since CISNCC is roughly along strike, but much more research would be necessary to substantiate this idea. While it is often difficult to differentiate arrival times in the more traditional seismic record, sometimes comparison of these component records can yield interesting observations and it is still a useful way to orient the viewer to the relative time at which a particular arrival or sample interval is occurring. Consequently, sampling time intervals were marked in the traditional 3-component displays using dashed red lines as shown on the right.



Conclusions

Earthquakes are complex and multidimensional events that no single image, model, or illustration can possibly hope to describe. One objective for this research project was to reintegrate seismic velocities recorded as North, East, and vertical components into waveforms that can be rotated in three dimensions to reveal the arrival directions and characteristic motions of body and surface waves via animation. Not only does the complex nature of the data present challenges to understanding and viewing, but also presenting the results of the analyses can be problematic. It is difficult to preserve the information from a time lapse animation within a program on a static poster. While isolated frames from Excel plots proved a more informative method of conveying results than attempts to replicate the animations created within Excel and ArcGlobe, these less interactive and exclusively visual presentations have significant limits. In the process of exploring different modes of presentation of seismic data, many interesting observations were made, such as the apparent change in P wave emergence angle and the seeming polarization of the S wave travelling along strike, but these observations were not rigorously explored. As anticipated, station location relative to the fault seemed to influence data patterns with those roughly along strike and dip having strongly contrasting patterns and seismometers in close proximity to each other showing similar patterns.