Surface Process Hazards Unit 4: Oso Landslide case study student exercise

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In this exercise we will combine the skills and content knowledge we have covered so far to look closely at one recent mass-wasting event near Oso, WA. You have already looked at the broader region of northwestern Washington during Units 2 and 3.

Take a few minutes to think about what you know of this region from the previous units. Here are small versions of the maps to jog your memory (Figure 1); the blue square shows the location of the Oso slide and the coverage of the lidar hillshade image shown in Figure 2.

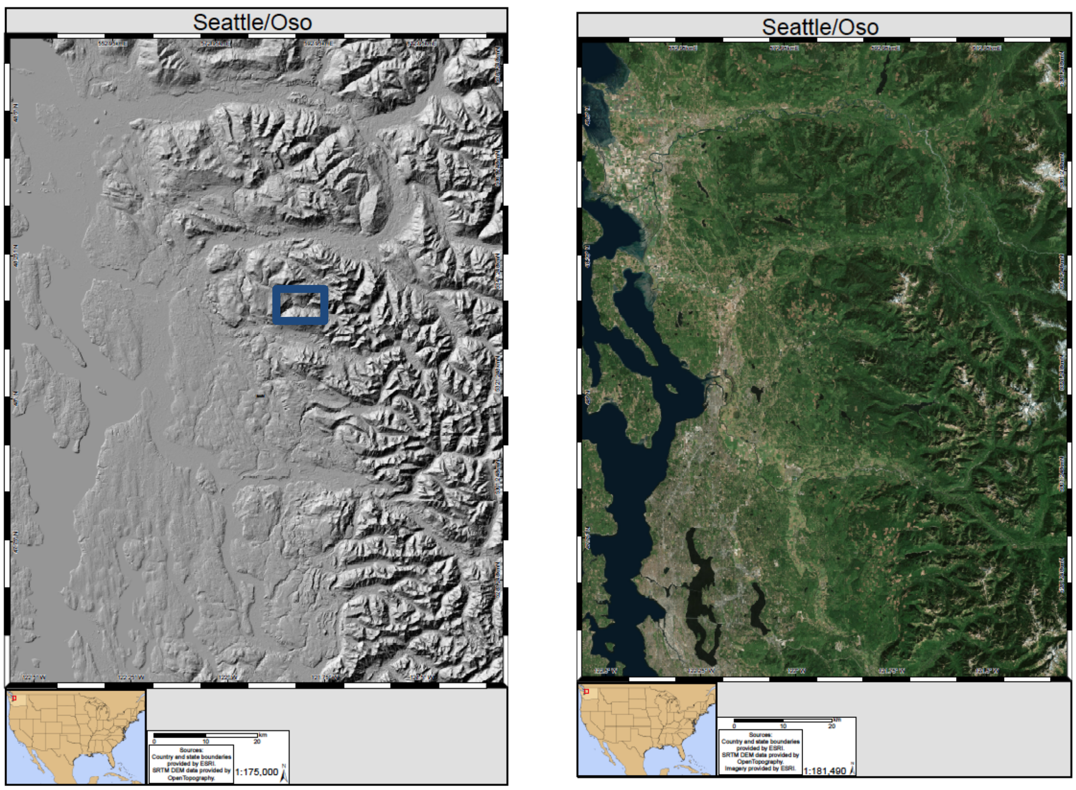


Figure 1: SRTM-based hillshade image (left) and Aerial imagery (right) of northwestern Washington state. The blue box shows the location of the lidar hillshade coverage shown in Figures 3 and 4. Country and state boundaries and satellite imagery from ESRI. SRTM hillshade data from OpenTopography.

1. Name some of the characteristics of the natural landscape (climate, tectonics, etc.) that lead to increased risks of landslides in this region.

Figure 2 below shows a labeled schematic block diagram showing the main components of a rotational landslide (head-scarp, toe, unit surface, hummocky section, crown). Figures 3 and 4 illustrate the symbology used to show landslides in map view.

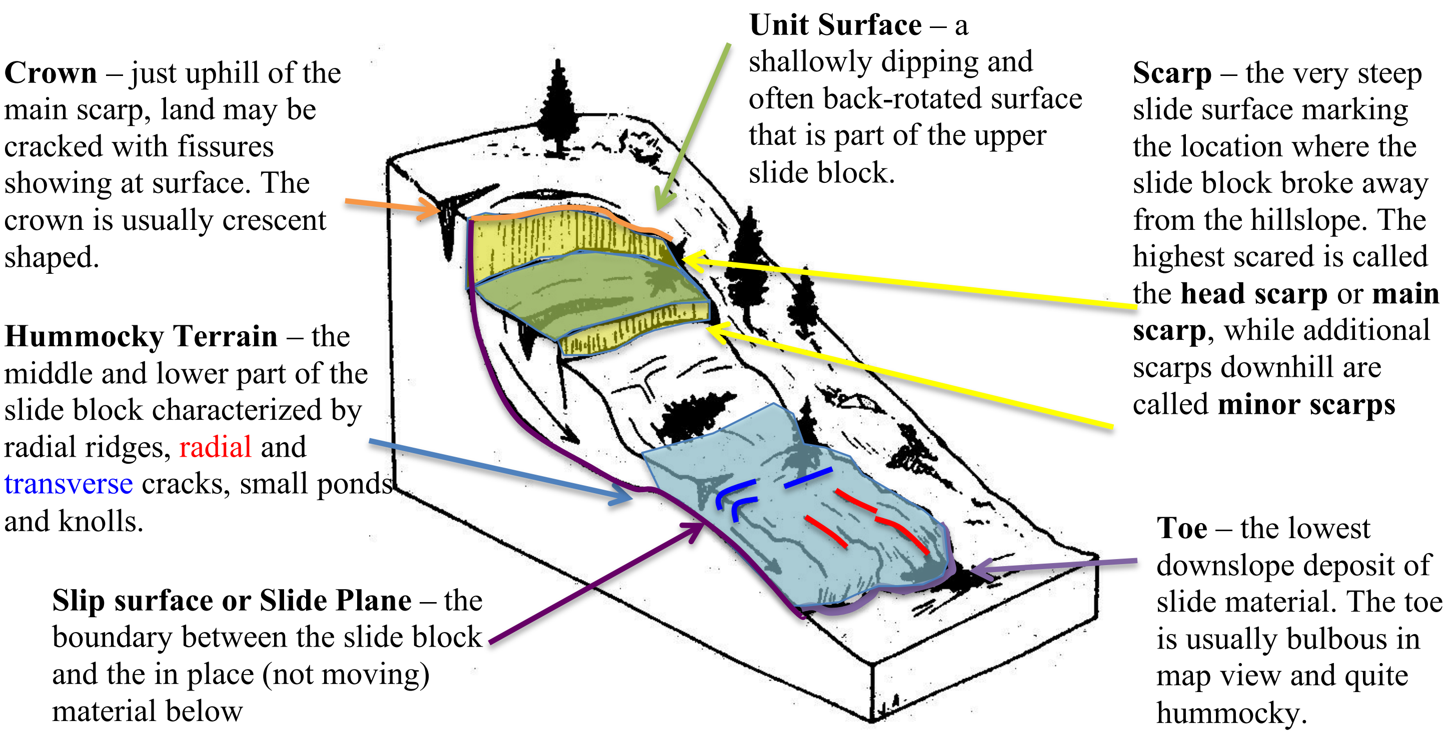


Figure 2: Schematic block diagram of a rotational complex slide with morphological components labeled (modified after http://www.conservation.ca.gov.)

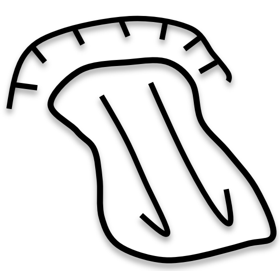


Figure 3: Symbology used in landslide mapping. The slide material is outlined in either a solid (known) or dashed line (inferred). Arrows are used to show the direction of flow.

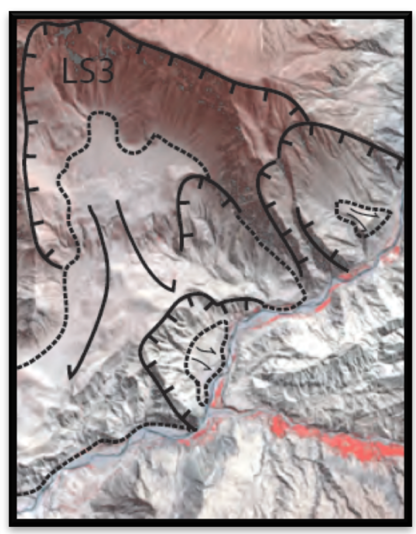


Figure 4: Example of landslides mapped on a field photo (left; photo by Sarah Hall) along the Rio Marañon, Peru and on a false-color ASTER satellite image (right) along the Rio Tambo.

The next two maps show high-resolution hillshade images (derived from airborne lidar data) of the location of the March 22, 2014 Oso slide event (Figure 5) which buried ~35 homes and a highway. Forty-three people were killed in this event, making it the deadliest landslide in US history, and caused ~$150 million in damages. Spring 2014 was one of the wettest in recorded history with March receiving ~200% the average monthly precipitation in a few weeks. Figure 6 was flown in 2014 shortly after the event. Figure 7 was flown in 2011 before the most recent slide event.

Figure 5: An oblique aerial view of the Oso slide (By Spc. Matthew Sissel/Spc. Samantha Ciaramitaro - http://www.dvidshub.net/image/1209685/oso-mudslide, Public Domain)

2. Locate the recent slide event in the morphology visible on the hillshade in Figure 6. Draw right on this figure to highlight the different landslide components. Use the appropriate mapping symbology according to the example in Figure 3 and 4 above. You may find evidence for additional landforms related to previous landslides besides the recent slide just left of center. Map these landforms as well.

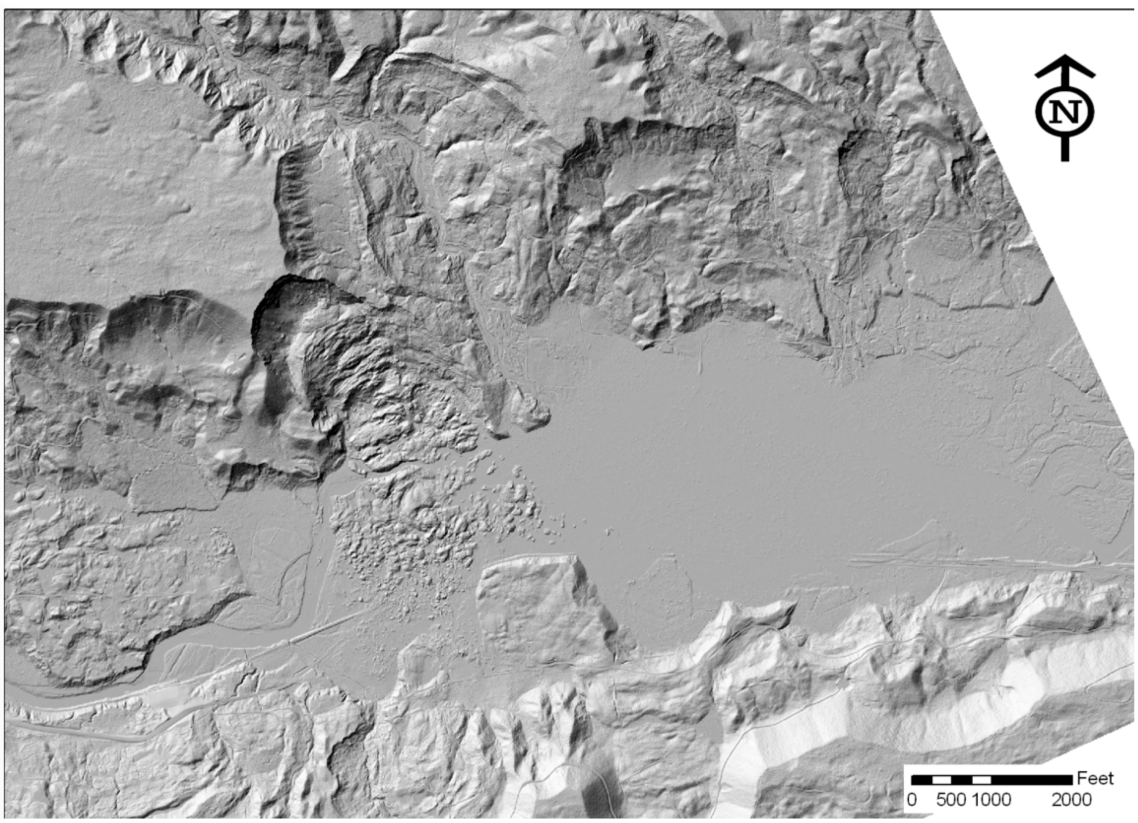


Figure 6: Lidar-based hillshade image of the Oso, WA region. These data were collected post March 2014 by the Washington State DOT, the map was provided by http://gis.ess.washington.edu/areas/oso/.

3. Now compare your morphological interpretation of Figure 6 to the hillshade image based on data collected before the slide event (Figure 7). Besides the obvious mass redistribution along the path of the slide, do you see any other changes in the landscape between the 2013 and 2014 images, Figures 7 and 6 respectively? Draw and label them on Figure 6.

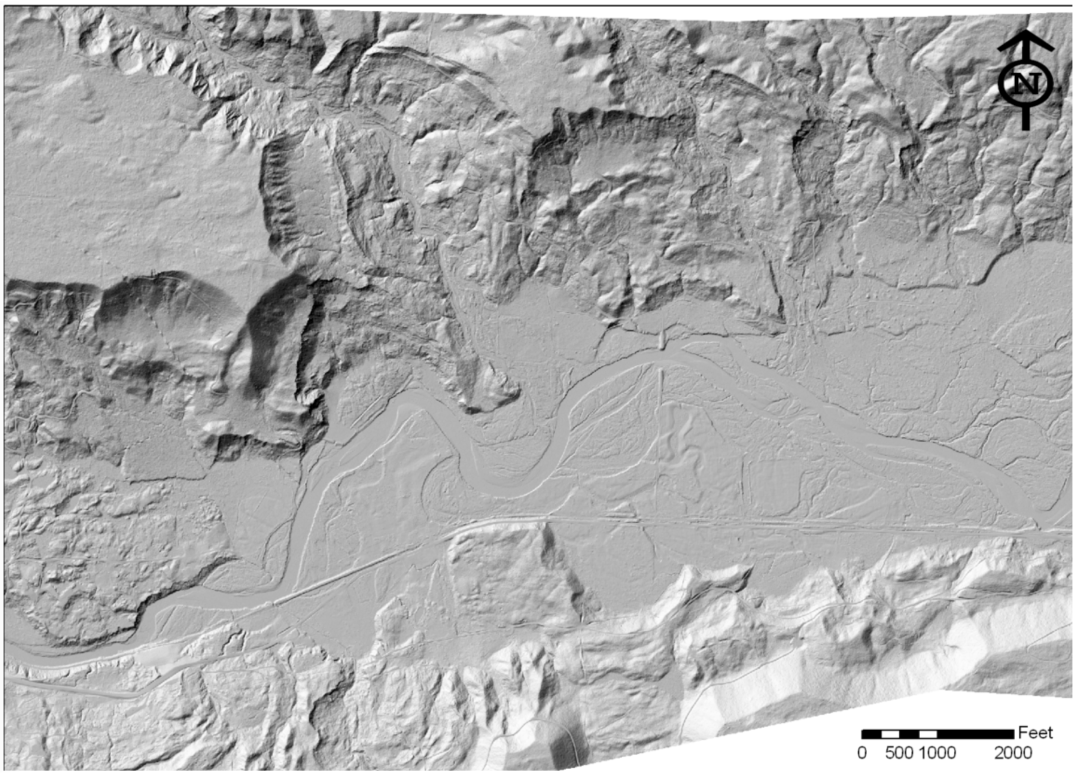
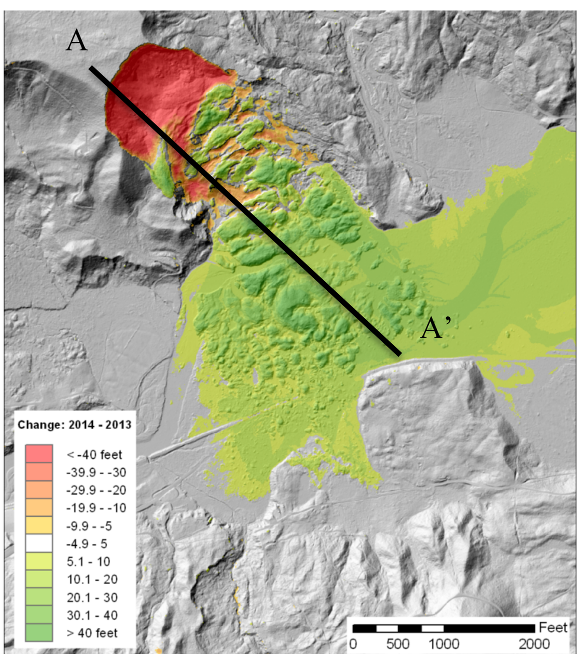


Figure 7: Lidar-based hillshade image of the Oso, WA region. These data were collected in 2013. The map was provided by http://gis.ess.washington.edu/areas/oso/.



4. Based on your interpretation of Figures 6 and 7, does this region have a history of mass-wasting events? Give evidence to support your answer.

Figure 8: This image shows the difference in surface elevation between the 2013 and 2014 data. Note the loss of elevation in the headscarp area and corresponding gain in elevation in the toe region (modified after http://gis.ess.washington.edu/areas/oso/.)

5. In the space below, draw a sketch of what you think the topographic profile looks like from A-A' (shown on Figure 8). This does not have to be perfect – just be sure to show the topographic profile reflects the redistribution of mass.

As the lidar-based hillshade image reveals (Figure 7), this region has a long history of mass-wasting events such as the 2014 Oso event. In fact, portions of the same slide block slid rapidly on six different occasions between 1937 and in 2006. We can look back at recent surface elevation changes using InSAR techniques to learn how we might recognize and prepare for future events such as the Oso slide. While this block slid catastrophically in a matter of seconds in 2014, portions of the block have been slowly slipping for a very long time. InSAR provide a way to study and plan in regions prone to slow-slip landslides.

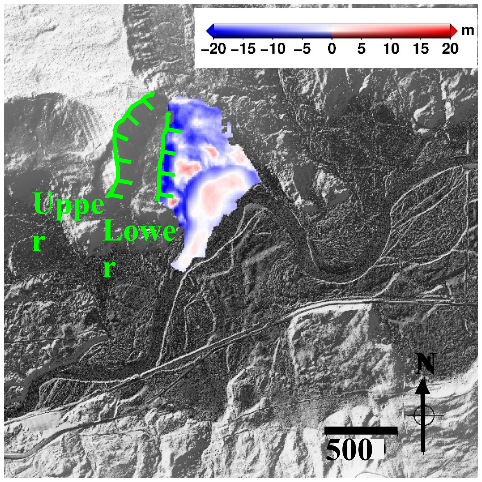
In the next part of this activity (Figure 9), you will interpret some SRTM, lidar, and InSAR data from a study by Kim et al. (2015) of the Oso slide area prior to the major 2014 event. They used a combination of these datasets to yield temporal coverage from 2000-2013. (Fun side activity – you can do the same type of study using the historical data tool on Google Earth!)

All of the maps shown in Figure 9 are *difference* maps from Kim et al. (2015). They show the change in elevation (m) between different times of data collection. Each map includes a description of the time period of data coverage and the type of data used. For each map, red represents positive elevation gains (scale max is 20 m on all except D where the max is 5 m), blue represents elevation loss (min -20 m on all except D where the min is -5 m) and no change is shown in green. The scale bar in each figure represents 300 m on the ground. Use these maps (Figure 9) to answer the following questions.

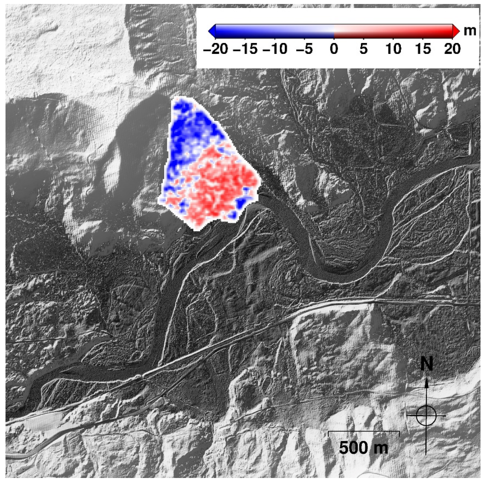
6. During 2000-2003, was elevation gain located near the toe of the slide or near the head scarp?

7. A rapid slide event occurred during this monitoring period. Do you think it occurred between 2007-2011 or 2003-2007? Explain why you think so.

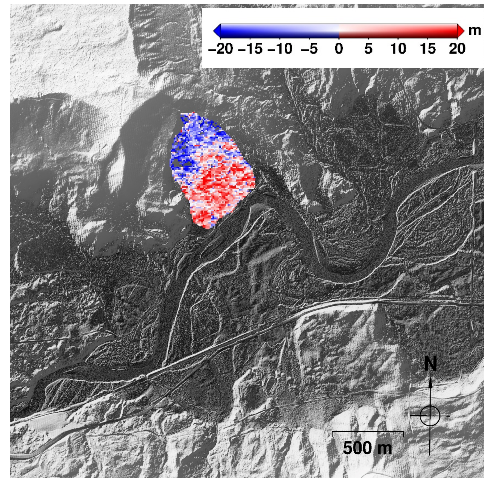
8. Estimate the area of the slide that grew by 10m or more between 2000 and 2013 (scale bar = 500 m.)



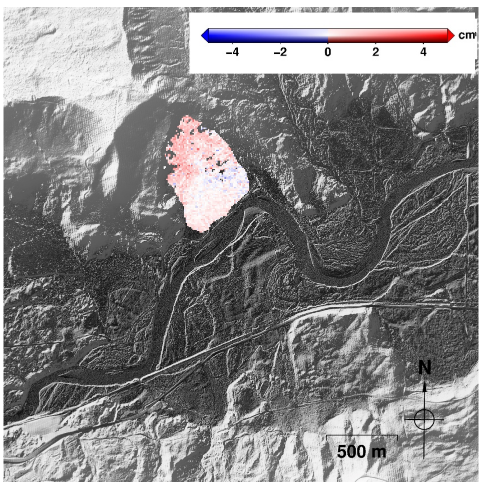
9A: Difference between 2000 SRTM data and 2003 lidar data



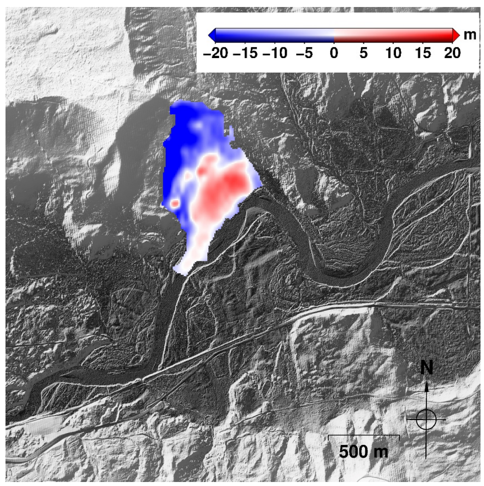
9B: Difference between 2003 lidar data and 2007 InSAR data



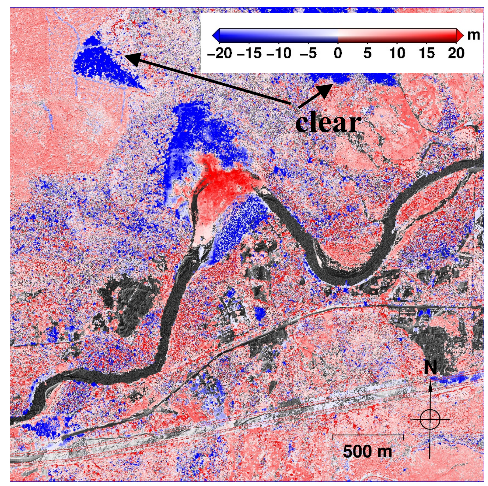
9C: Difference between 2000 SRTM data and 2007 InSAR data



9D: Difference between 2007 InSAR and 2011 InSAR data



9E: Difference between 2000 SRTM and 2013 lidar data



9F: Difference between 2003 SRTM and 2013 lidar data (lidar data includes vegetation points)

Figure 9. Difference maps of the Oso Landslide area in the 14 years preceding the major event in 2014. Images, provided by J.Kim, cover the same data sets as detailed Kim et al., 2015 (in *Geomatics, Natural Hazards and Risk*).

9. Figure 9F looks a bit different than the rest because it is based partially on lidar data that includes not only surface elevation points but also vegetation elevation points. Note the blue areas that denote loss (tree clearing). Do you think tree clearing above the head scarp would contribute to increased driving or resisting forces? If so, which? Why do you say so?

10. Describe at least three societal impacts from the Oso Landslide. Imagine that you are consulting for a community in a similar geologic setting. Make three suggestions of steps or choices the community could make to reduce the risk from landsliding.

Recently, scientists have used InSAR data to study landscape changes occurring over large areas as well as focused studies such as the one above. Some slow-slip landslides are quite small in area and are located in remote regions where few people live, however they are important indicators of how fast sediment is moving through a watershed (see Figure 10). With loose material moving slowly due to gravity, what do you think the fate of that material will be with a bit of water! High precipitation could trigger both landslides and flooding – both hazards for downstream populations to be wary of.

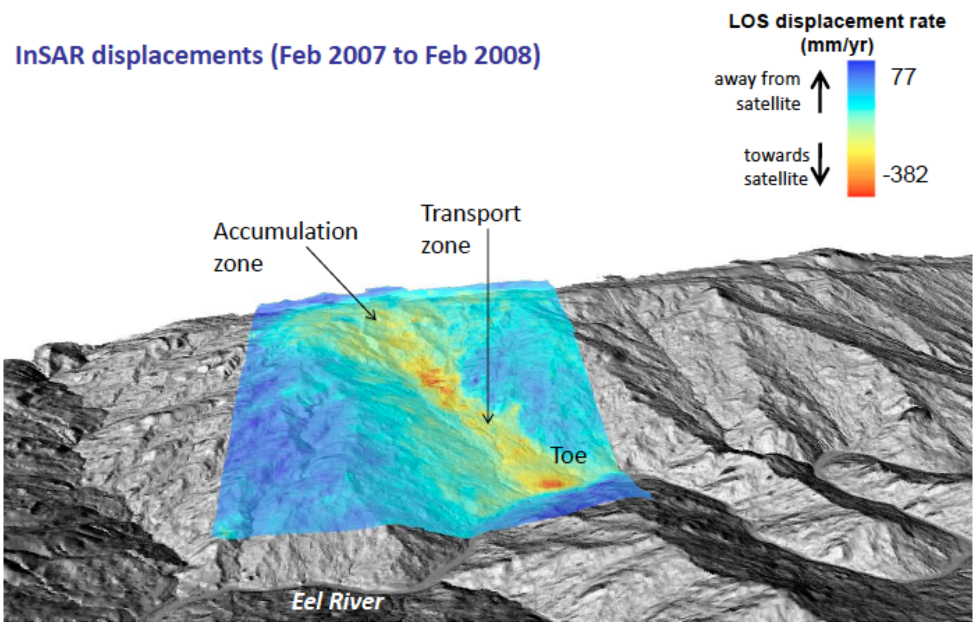


Figure 10: Oblique view of the landscape in northern California illustrating the use of InSAR in tracking the velocity of sediment moving down a slow-slip in a slow-moving landslide. Image by J. Roering and used with permission. More information in Roering et al., 2012. Note the sign indicates the motion of the material towards or away from the observation satellite.

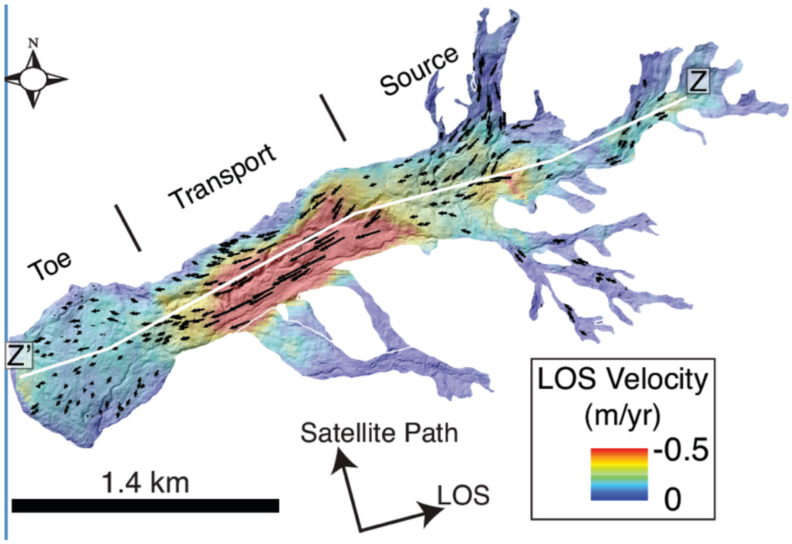


Figure 11: Boulder Creek is a landslide in northern California, a part of the Eel River watershed. It is one of many slow-moving landslides in this region (By A. Handwerger. Used with permission. More about the study in Handwerger et al, 2013).

11. About how fast, in the fastest part of the slide, is the material in the Boulder Creek slide moving in cm/yr (Figure 11)? Just for reference, fingernails grow at about 4cm/yr.

References:

Jin-Woo Kim, Zhong Lu, Feifei Qu & Xie Hu (2015) Pre-2014 mudslides at Oso revealed by InSAR and multi-source DEM analysis, Geomatics, Natural Hazards and Risk, 6:3, 184-194, DOI: 10.1080/1947705.2015.1016556
(GNHR is an open journal that allows reproduction http://www.tandfonline.com/doi/abs/10.1080/19475705.2015.1016556#.VuxqMxIrLN0)

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Josh Roering, Ben Mackey, Alex Handwerger, Adam Booth, David Schmidt, and Corina Cerovski-Darriau, 2012. Tectonic forcing and geomorphic response along Cascadia and the Mendocino Triple Junction, GeoPrisms Lecture.