Nooksack River Channel Migration and Comparison Using LIDAR and UAS Elevation Data

An Analysis by Skyler Elmstrom for ESCI 442

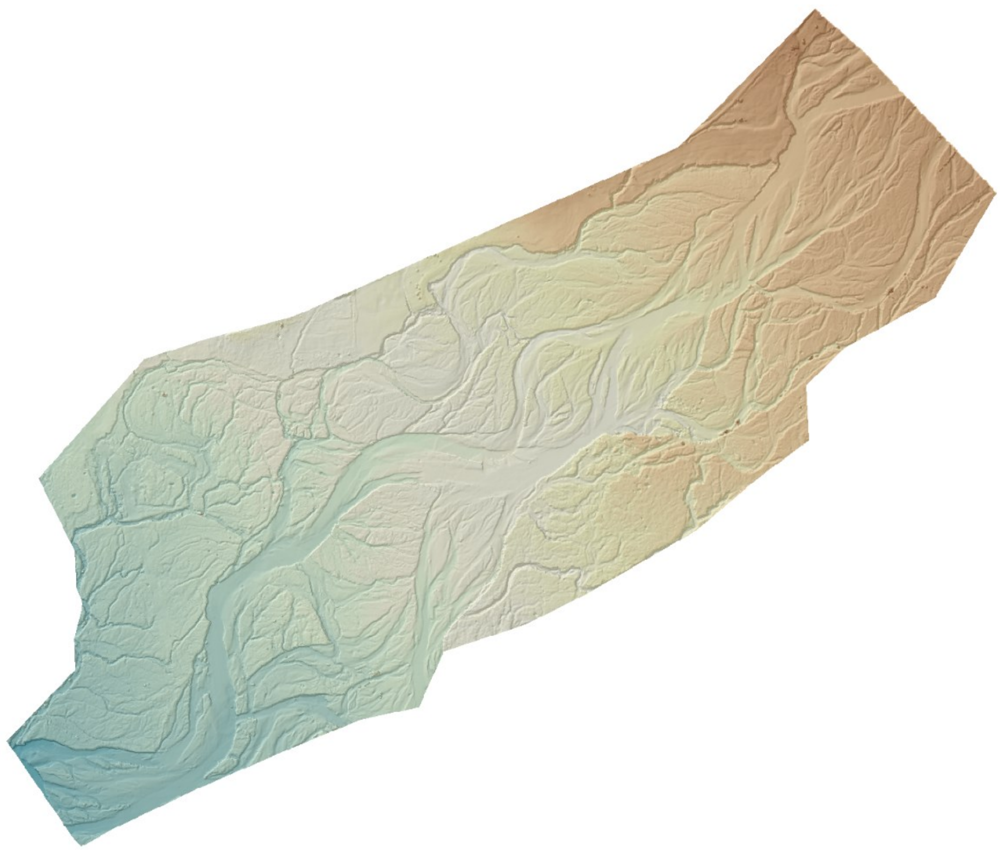

Figure 1. Bare-earth digital elevation model based on 2009 LIDAR data showing historical stream channels along a section of the Nooksack river. Elevation models such as the one above serve as the basis for identifying channel migration between time periods in this analysis.

Abstract

This analysis utilizes LIDAR and UAS datasets to evaluate and quantify channel migrations from 2005 to 2016 along a segment of the Nooksack river in Washington State. Significant alterations in channel flow were able to be identified using changes in canopy elevation of banks and islands and sediment deposition and withdrawals were able to be identified using changes in bare-earth elevations. While visualizing differences of shallower changes in elevation was possible, I excluded those values in favor of moderate and extreme changes to highlight the effects of channel migration in the study area and reduce the complexity of my analysis.

Methods

The procedure of this analysis mostly follows the guidance provided by Wallin (2018). I completed a series of functions for LIDAR datasets from 2009 and 2005 using FUSION – a LIDAR analysis suite developed by the United States Forest Service (USFS)— including catalog, ground filter, grid surface, canopy model, and export to ASCII. I then converted my ASCII exports in ArcMap into raster elevation and surface models representing bare-earth and canopy, respectively. An additional surface model from a 2016 unmanned aerial systems (UAS) dataset was provided by Wallin. Lastly, I performed several raster subtractions to evaluate temporal elevation changes within the Nooksack river's channel boundaries for bare-earth using 2009 and 2005 data and canopy using 2016, 2009, and 2005 data.

Results

The bare-earth subtraction between the elevation models from 2009 and 2005 yielded a range of elevation changes from -35m to 70m. I refined this result to exclude extreme outlier elevations that may have been caused by errors in the generation of the surface models. I also excluded values within 0.5m to -1m to emphasize the larger changes in elevation (Figure 2). My final extrapolation in figure 2 shows deposition of sediment from .5m to >5m and the withdrawal of sediment from -1m to <-15m within the channel boundary. Withdrawal of sediment is likely an indicator of recent channel migration whereas sediment deposition may indicate a recent change in channel flow. Sediment withdrawal is found primarily along channel banks while sediment deposition is found between channels or along high points created by multiple channels (Figure 2).

The canopy subtraction from 2009 to 2005 appears to corroborate trends found in the bare-earth subtraction: areas depicted in red show a reduction in elevation and are found mostly along existing channel banks and one major channel migration change near the left-center of the study area; light blue areas show elevation changes between 0 and 2m and generally match the output of the bare-earth subtraction (Figure 3).

Canopy change from the 2016 UAS data and 2009 LIDAR data shows that the outward channels reduced elevations along stream bends by 1m to 5m (Figure 4). The amount of change from 2009-2016 appears to be significantly higher than 2005-2009 but 2009-2016 lacks major deviations in channel flow as is seen in the 2005-2009 model.

My final canopy change model for 2005-2016 shows that this portion of the Nooksack had lasting changes to its channel flow matching the changes in the other two time periods of this analysis: one major change in the channel flow occurred during 2005-2009 and can be seen center-left and most other reduction in elevations along the channels occur along the outward banks of stream bends (Figure 5).

Discussion

LIDAR and UAS provide convenient and comprehensive data for identifying channel migration that is normally difficult to discern using other ground-based methods. This analysis shows that bare-earth and canopy returns of LIDAR data can be used to answer questions about channel sediment flow as well as river bank erosion. Both the bare-earth and canopy models had some flaws resulting in extraneously large values, but some extreme values were useful in identifying landslides.

The bare-earth subtraction performed better than expected for identifying changes in channel morphology: reductions and increases in channel elevation were easily distinguished from subtle changes that exist beyond the river. However, it failed to show whether the changes to channel flow are eroding outward banks or just shifting sediment between historical channels. The canopy subtractions showed the erosion of the outward or vegetated banks more clearly. Vegetation loss around channel migrations were most useful for identifying major changes in channel flow, such as the new channel created between 2005 and 2009 and the erosion of the outward banks from 2005 to 2016. Canopy subtractions were less useful in identifying changes to channel elevations likely due to the range of elevations being compared. The bare-earth models had more subtle differences than vegetation models which allowed me to create color schemes for narrower ranges of data. Highlighting channel differences would likely require masking out mature vegetation and land beyond the outer banks of the river.

My decision to refine the results of each model by excluding certain values has visual benefits but also information loss. The subtraction analysis of raw elevation data showed that many upland areas had similar elevation changes as the river channels. By excluding information close to 0 to reduce the noise of upland ground or vegetation elevation changes, I lost some information regarding shallower channel elevation changes. Overall, showing only moderate or extreme changes in my analysis adequately portrayed channel migrations. I considered excluding extreme values, but I noticed one important feature would excluded: a landslide indicated by sloped elevation changes from high (red) to low (orange) found right of center in figure 2. Other extreme values are small areas and are most likely errors or misclassified returns during the LIDAR returns extraction.

This analysis was a great starting point for identifying channel migration but could easily be expanded to attempt to model the size of channels, create vector paths of the stream flow, approximate change in sediment, or quantify rates of erosion or vegetation loss. Additionally, a comparison could be made using precipitation rates to investigate the channel deviation observed and erosion of the river banks: high precipitation rates may have increased the height of the river's flow, resulting in erosion of the river banks; low flow may have concentrated into a single channel that created a new path.

Sources

Wallin, D. 2018. *Lab X: Using LIDAR Data to Monitor Channel Migration.* Retrieved from http://myweb.facstaff.wwu.edu/wallin/envr442/ENVI/442_segmentation_ENVI___Orfeo_acme4.htm. Accessed on 3/14/2018.

Figures

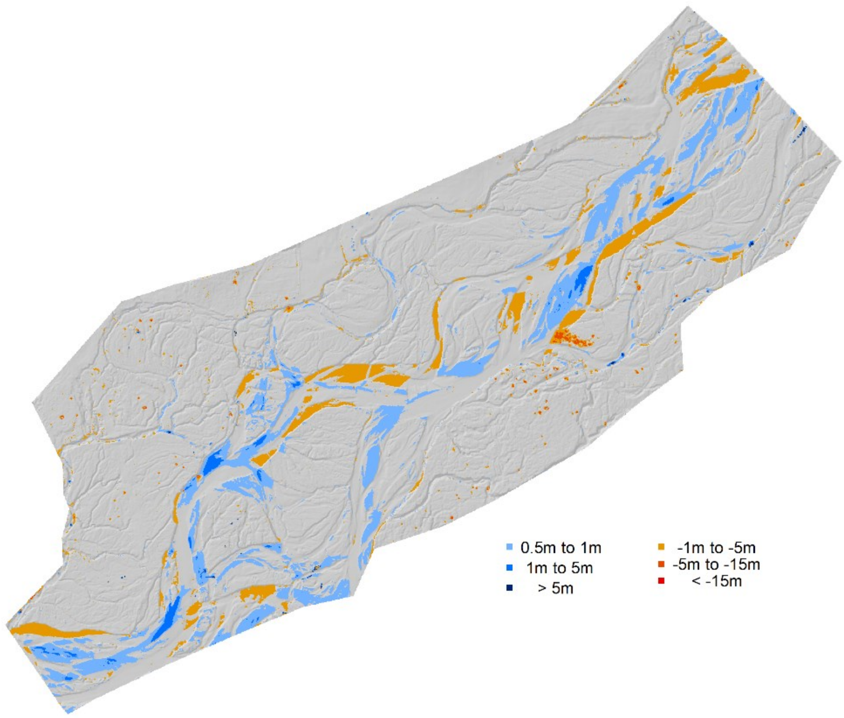

Figure 2. Bare-earth subtraction between 2005 and 2009 Nooksack river LIDAR elevation models emphasizing moderate to extreme changes. Increases in elevation are represented in blue and decreases represented in orange-red; light color indicates moderate change while dark indicates extreme change.

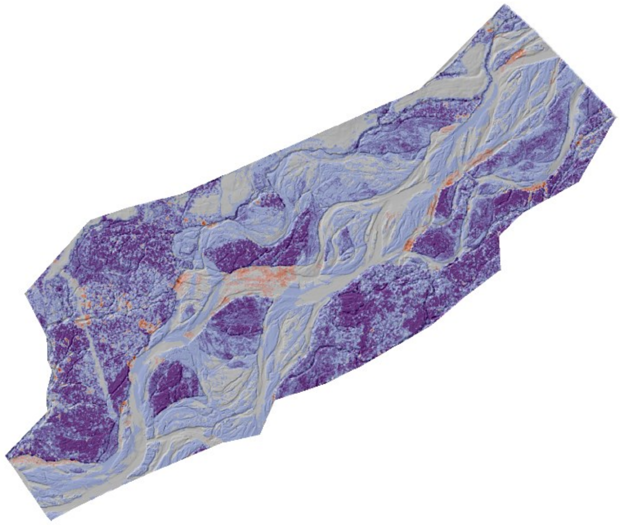

Figure 3. Canopy subtraction between 2005 and 2009 LIDAR surface models. Decreases in canopy are shown in red and increases are shown in blue; light color indicates shallow change while dark indicates extreme change. Some outward bank erosion occurred as well as a new channel being formed left of center, indicated by wide decreases in surface/vegetation elevation.

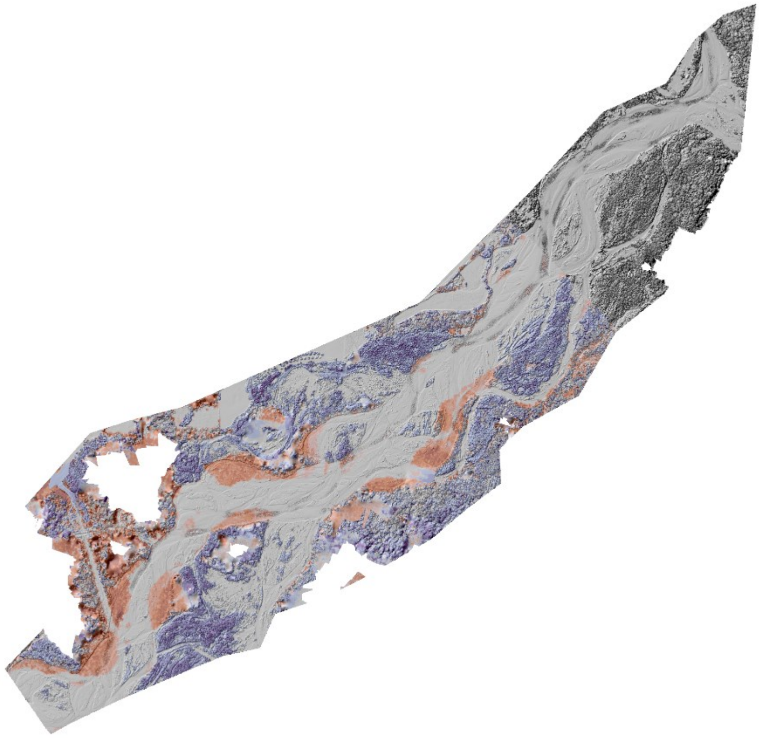

Figure 4. Canopy subtraction between 2009 LIDAR and 2016 UAS surface models. Decreases in canopy are shown in red and increases are shown in blue; light color indicates shallow change while dark indicates extreme change. The new channel observed in the 2005-2009 subtraction can be seen here with additional erosion of the outward banks. Outward bank erosion is more significant than the previous 2005-2009 period as well.

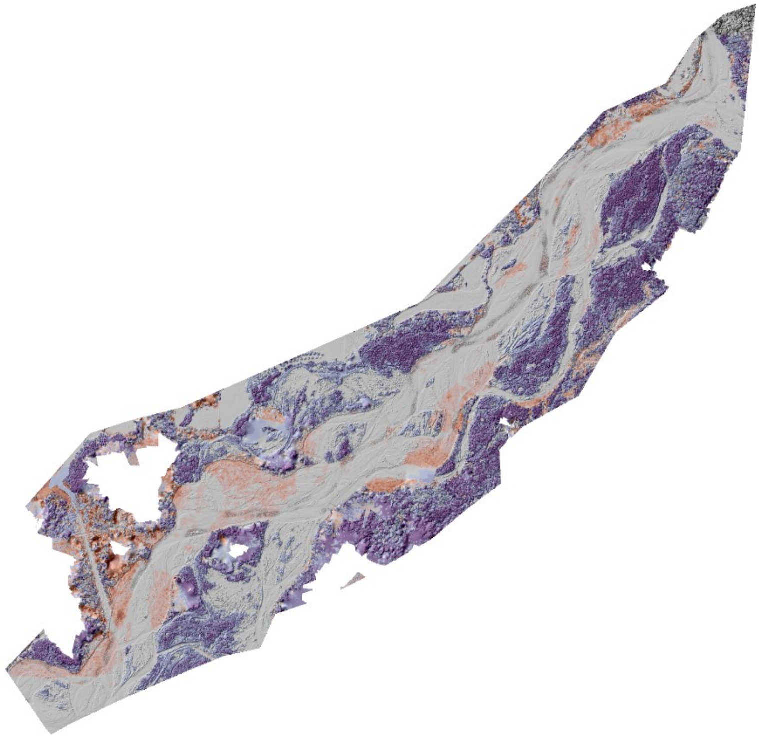

Figure 5. Canopy subtraction between 2005 LIDAR and 2016 UAS surface models. Decreases in canopy are shown in red and increases are shown in blue; light color indicates shallow change while dark indicates extreme change. This model shows cumulative vegetation loss caused by channel migration and both the new channel and outward bank erosion of stream bends are observable.