Tree cross-section from one of the avalanche paths around Juneau showing scars from avalanche events in 1818, 1974, and 2012. Credit: Daniel Stahle

From *blogs.scientificamerican*, Molly Tankersley, 20191031

> *"Cookies are then flown a few thousand miles away to the USGS Northern Rocky Mountain Science Center, where USGS researcher Danny Stahle will analyze the rings under a microscope. The records traced in the wood can span as long as 300 years. One sample shared by Hood from this summer marked an avalanche event in 1818."*

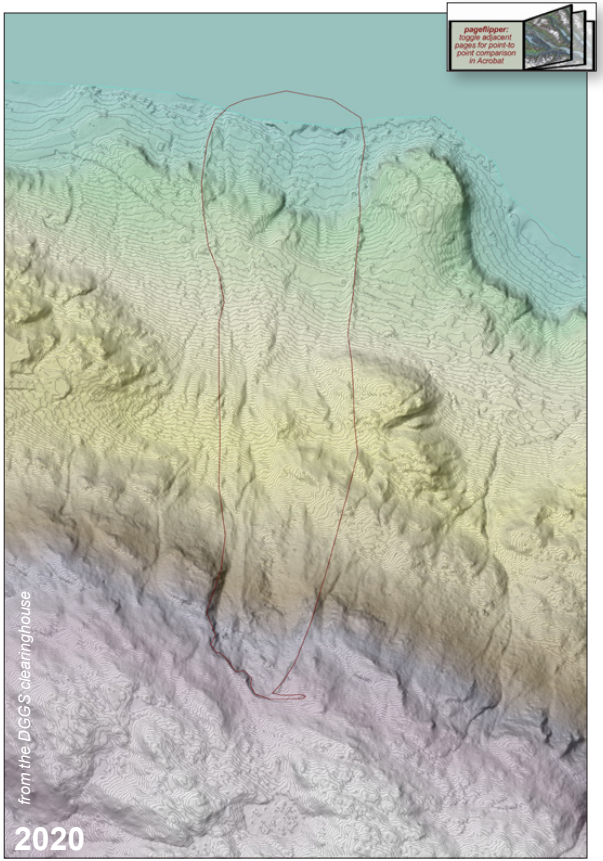
Jilk̲oot example: Beach Road Our first stop after getting off the ferry on Friday, 20220916 was at the catastrophic Beach Road Land Slide (BRLS). It's been intensively studied by an interagency team including our friend Jim Baichtal, co-author on a great multidisciplinary summary published earlier this year.

On December 2nd, 2020, Haines received 6.62 inches of rain, (previous

First of 8 pageflippers showing topography and successional change at Beach Road Land Slide (BRLS). LiDAR was shot within days of the Dec_02 event in 2020, revealing a distinct crown at 863 feet, which I traced in red on this hillshade. A crack extended eastward from that headwall. And above *that*, on my enlargement below, I've marked another possible stress fracture.

Here's from the metadata explaining this mission:

Abstract: The Alaska Division of Geological & Geophysical Surveys (DGGS) used aerial lidar to produce digital terrain (DTM) and surface models (DSM), and intensity image for Haines as part of emergency operations in response to the December 2, 2020, landslide that claimed the lives of two residents. Airborne data were collected December 8-12, 2020, and processed in Terrasolid and ArcGIS. Ground control were collected December 15-16, by the DMLW. This data collection is released as a Raw Data File with an open end-user license. All files can be downloaded free of charge from the DGGS website



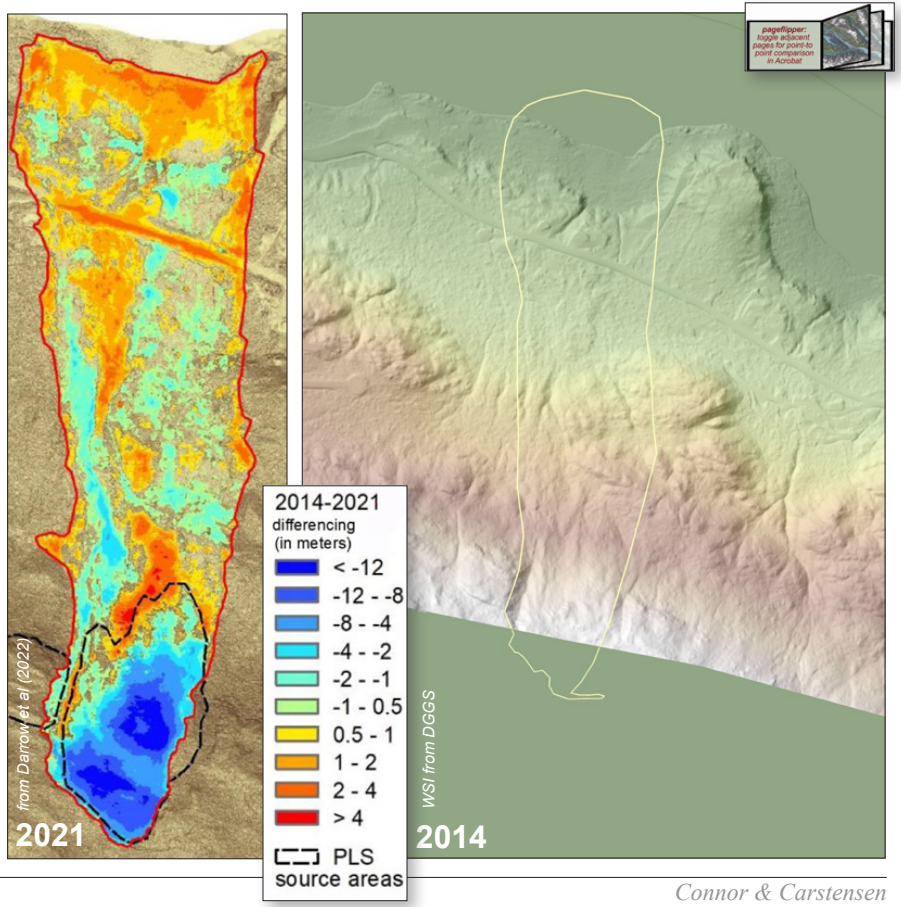
record 1.37 inches), lubricating a catastrophic slope failure that swept through Beach Road east of town, burying homes and killing 2 people. It began as a debris avalanche, soon transitioning into a debris flow. Witnesses could hear it for 20 to 30 seconds. Search parties were unable to safely access the runout due to concerns about further slope failure.

For Jessica and the *Atlas* team, shortly after the event, I prepared a 4-panel map, mostly from our growing collection of georeferenced historical air photos. A key question when trying to 'backtrack' events like these is whether vegetation suggests stability or prior disturbance, either widespread or small & patchy. Further clues to forest type and successional history can be deciphered by carefully matching forest type to underlying landforms.

Although side-by-side historical panels are effective means of comparison, these pageflippers allow more

Far right: 2nd of 8 pageflippers. Toggle against previous post-slide hillshade, searching for changes in topography. • LiDAR shot in 2014 and downloadable from the DGGS portal unfortunately didn't extend south quite to where the crown detached. However, Darrow *et al* (2022) included maps from a 2014 Lidar DTM that continued to the hilltop. Apparently Watershed Sciences Inc. (WSI: since merged to form Quantum Spatial) was able to retrieve 'fringe' data that were clipped away to form this deliverable to the state clearinghouse?

Near right: ArcPro 'minus' tools subtract one terrain model (DTM) from another—in this case June, 2021 [1] from 2014. Blue-to-red spectrum indicates more than 12 vertical meters of soil and rock were removed near the headwall (blue tones) while Beach Road was covered with more than 4 meters of debris. Darrow *et al's* red outline is more accurate than my yellow border on the pageflippers; I've adjusted to their perimeter only for the last two maps in this series.

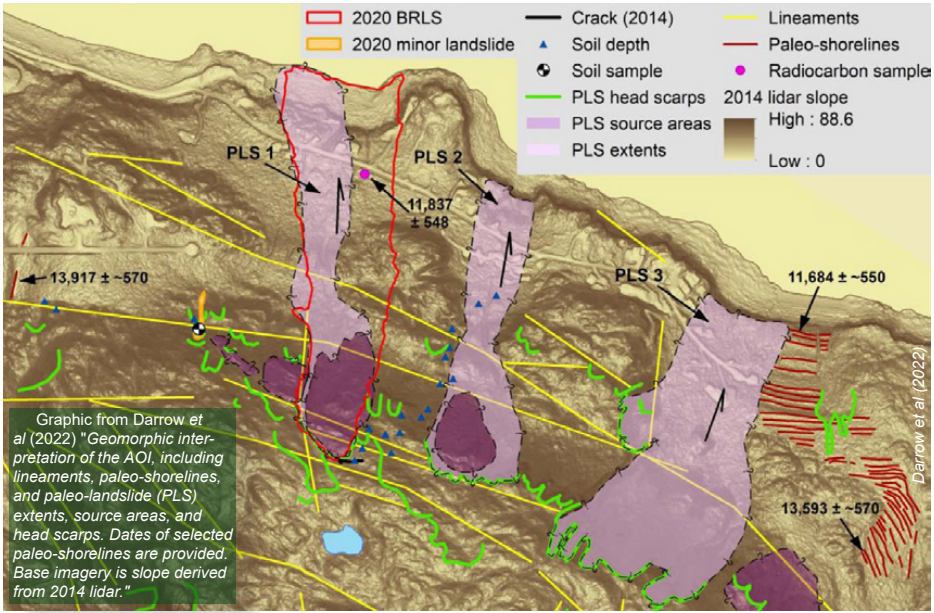


1 I first suspected the team's post-slide LiDAR dated 2021 was in error; DGGS data were released 20210213 but LiDAR was actually *acquired* between December 8 & 12, 2020. Turned out, however that the authors contracted their own UAV survey the following June using "*a Phoenix LiDAR Systems MiniRanger un-crewed laser scanner and high-res imagery from DJI Matrice 210 V2 RTK UAS. Leica GS18 (GNSS) receivers gave high-res georeferencing and post-processing, with lidar ground resolution of 0.1m & imagery resolution of 0.03m.*"

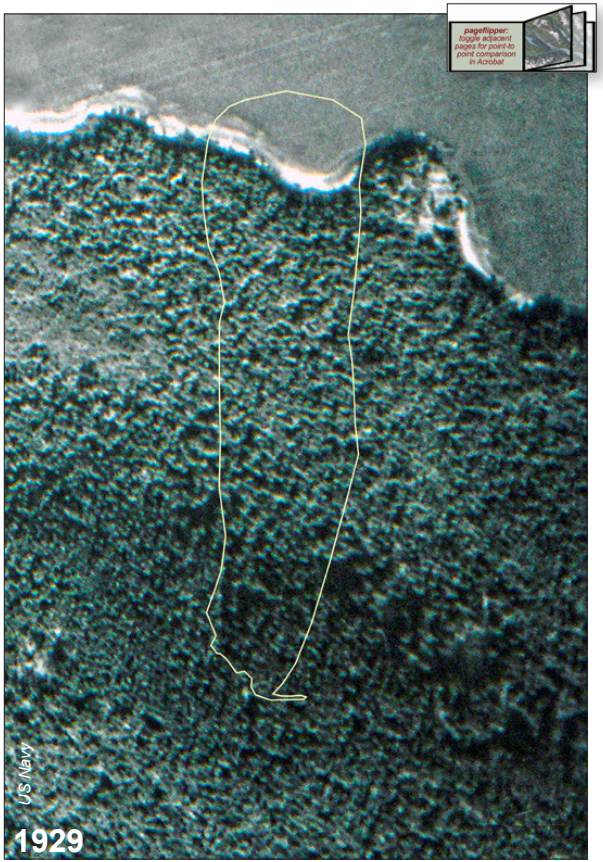
careful point-to-point overlay. I'm doubling the 4x series to 8 precisely fitted panels in the following pages, adding a new post-BRLS orthophoto from AOL, and more products from the State's emergency mission, flown within a week of the landslide.

Right: 3rd of 8 pageflippers beginning a successional change series. A century ago, forest was already mature. See, however, comments below on even-aged stands in the runout portion.

Below: After the BRLS, scrutiny of 2014 & 2020 LiDAR revealed diagnostic signatures of what the Darrow team called "paleo landslides" (PLS)—both runout zones (pink) and steep starting zones above them (purple). Jim Baichtal & John Norton had already mapped ancient shoreline features. In addition to obvious wave-cut scarps, marine surfaces can be distinguished from till-&-bedrock outcroppings by their smooth texture.



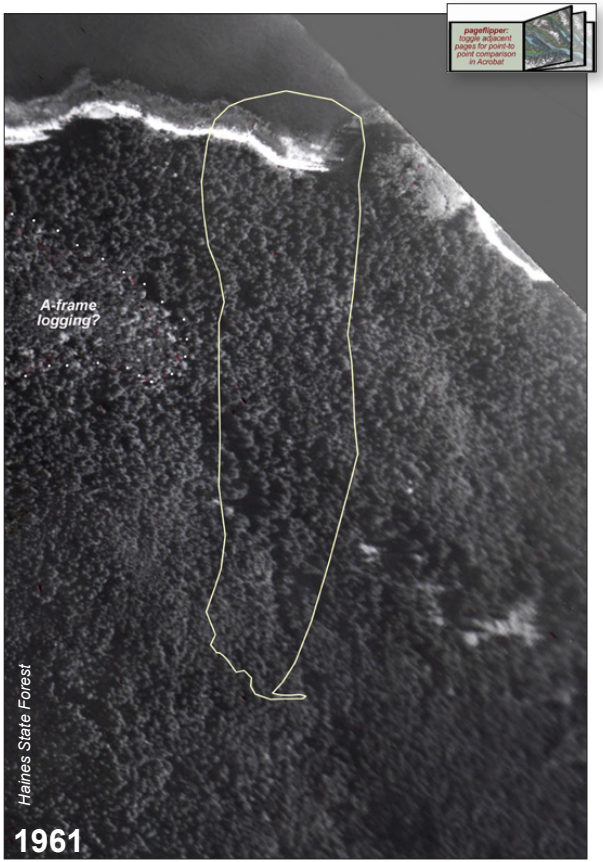
Graphic from Darrow *et al* (2022) "*Geomorphic interpretation of the AOI, including lineaments, paleo-shorelines, and paleo-landslide (PLS) extents, source areas, and head scarps. Dates of selected paleo-shorelines are provided. Base imagery is slope derived from 2014 lidar.*"



Avalanche forecaster Erik Stevens flew the head scarp immediately after the landslide and took the most revealing image we have, below. (*20220920: I'd hoped for some drone aerials on our Chilkat tour, but this site is in a no-fly zone due to proximity to the airport.*)

Forest at this headwall looks like small, fairly even-aged hemlock. Probably not old growth. Photo-resolution's not good enough in my copy to identify the smooth sediments in the head scarp. If it's marine, that's *way* above highest marine deposits so far documented by Norton & Baichtal in Greater Chilkat Watershed.

4th of 8 pageflippers. For 1961, my scanned imagery from the DOF collection in the Juneau office just barely reached the future landslide. I wish I'd scanned the next photo in this flightline, because it's low elevation and high-res, providing great stereo. The 1998 DOF collection probably also covers this slope, and could be scanned. (My crystal ball was out of commission in winter 2019-20 when copying these images) • On left I've outlined the only substantial patch of young growth. Off-photo, this stand narrows and drops to the beach—a pattern typical of coastal-access A-frame logging.



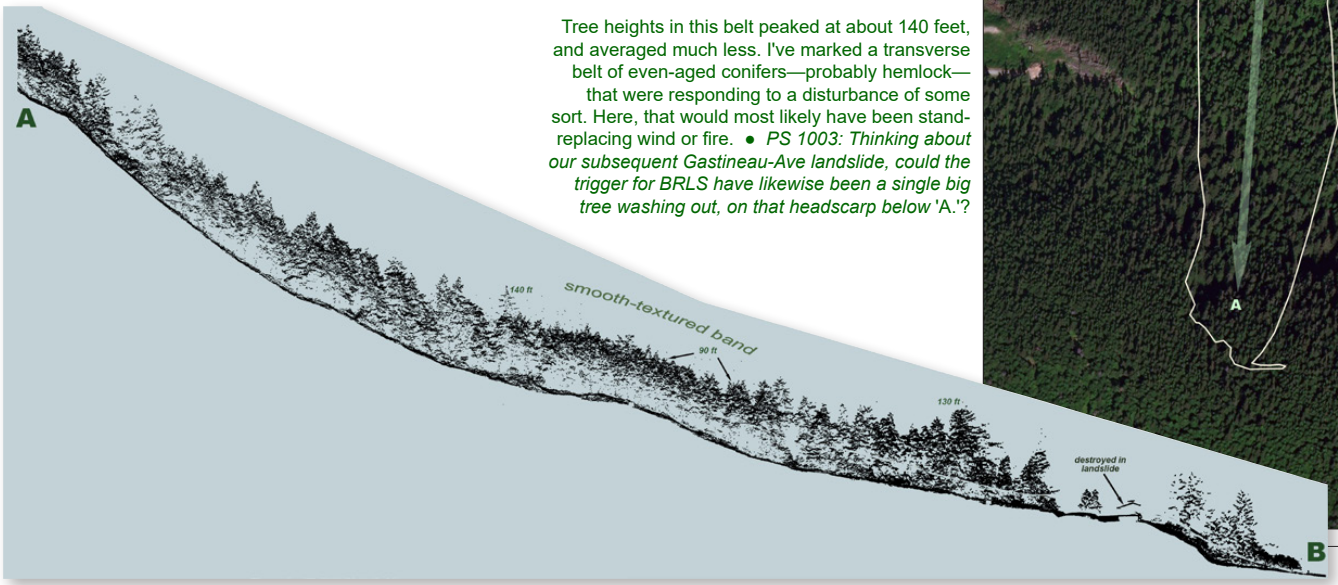
Darrow's team used change detection from DTMs to generate the previous colored map of erosion and deposition, and to put numbers on that transfer. They estimated:

> *"134,300 m³ of material loss in the landslide head region. [compared to] approximately 52,800 m³ of deposition throughout the landslide body including trees deposited along the flanks, with a total landslide volume of about 187,100 m³. Discrepancy between volume displaced and volume deposited indicates the majority of the landslide debris, roughly 81,500 m³, entered the inlet."*

Right: 5th of 8 pageflippers. In 2018 imagery, a band of smooth textured forest extended cross-slope uphill. Then, where slope steepened, larger, gappier forest grew. Thanks to LiDAR, we have a detailed record of this forest's structure.

Below: LiDAR tiles from the 2014 mission allow us to visualize the 'ghost forest' wiped out by the December 2nd landslide. Transect A-B is a 55-foot-wide belt through 2 tiles of the point cloud. This profile doesn't quite extend to the head scarp, and our DGGS portal gives nothing higher. Perhaps, though, the data exist, as did a DTM that also gets clipped here in the 'public' version.

Tree heights in this belt peaked at about 140 feet, and averaged much less. I've marked a transverse belt of even-aged conifers—probably hemlock—that were responding to a disturbance of some sort. Here, that would most likely have been stand-replacing wind or fire. ● *PS 1003: Thinking about our subsequent Gastineau-Ave landslide, could the trigger for BRLS have likewise been a single big tree washing out, on that headscarp below* 'A.'?



John holding forth in left distance, after advising students to fan out and experience the BRLS for ourselves. It's hard for many of us to properly acknowledge a tragedy until we're alone. For me, the fresh, bright green on these flush-seep fines was most poignant, like flowers on a grave. Panorama actually spans about 180 degrees, swung from ocean up to headscarp. My only decent pics of the BRLS were from the ferry. Once on-site, sun was in exactly the wrong position for photography.

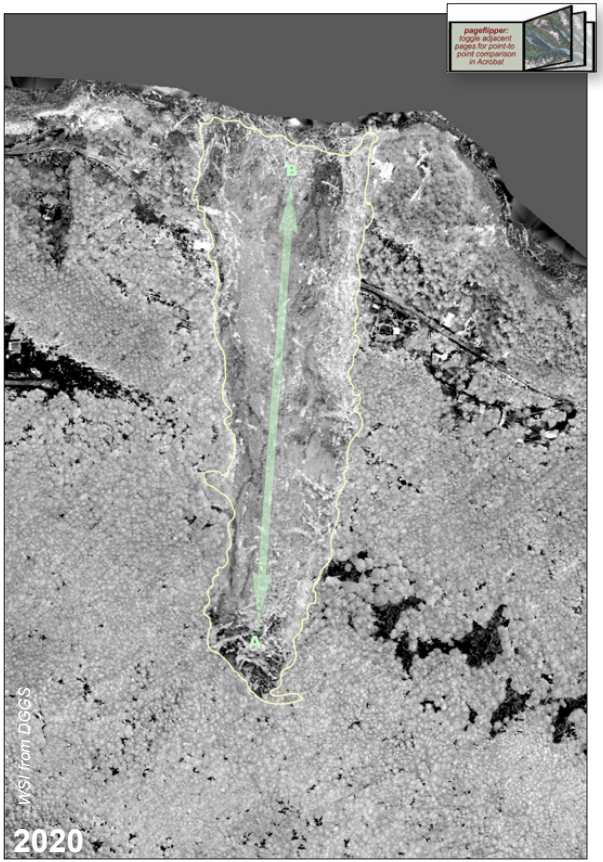
Cassie and others were intrigued by patterns of revegetation. Although I'm a decent regionally-grounded botanist, most green stuff here stumped me. It's as if natives were so shocked by the violence of this belch that they left the rubble to globetrotting, earthmover-riding invaders.

And many that may have been local were still in early cotyledon growth-stages that I'm not good at identifying. I experienced this also above my home in Áak'w Aaní, at mid-levels of Nettleslide, where a much smaller snow avalanche dumped fines over slopes around 500 feet above Service Road. Had to ask Koren Bosworth to scramble up there to help me put names on them.

6th of 8 pageflippers. In summer 2020 there was almost nothing growing in the fresh scarp, at least not visible from this elevation. Arc from photo-point 49 shows span of iPhone sweep-pano, below.

Still requiring heavy retouching in Photoshop to bring up detail from the nearly backlit image, this telephoto from in-bound ferry at least shows fines in the headscarp, and still-unsettled debris-dams, poised to flush more soil downslope. Presumably in 'whimpers' not 'bangs'? Encompassing forest looks quite even-aged.

7th of 8 pageflippers. DGGS delivered an intensity image along with the DTM, DSM, and classified points (*ie*. the point cloud through which preceding profile was cut). Largest crowns and gappiest forest are on steepest slopes.



There's a little more detail on the BRLS in our *Part II* journal for 0916. But I've chosen to group these 8 Jilk̲oot pageflippers with preceeding views of Áak'w downtown upfront in *Part I>Surf-geo*, because, collectively, they're my first close look at a landform I've long admired but never analysed in detail.

Below: Zooming in on the headscarp gives better views of one-meter contours. I've added a blue line over what could be yet another incipient detachment.

Last of 8 pageflippers. DGGS portal offers both DTM (bare earth, or ground), and DSM, (including vegetation surface). Subtracting DTM away from DSM gives canopy height. Tallest trees frame the upper (southern) end of the transect. By standards of my homeland in Áak'w and T'aak̲ú Aaní, where some Nettleslide-framers reach 200 feet, these are not super-trees. But size is relative, and that gappy colluvial patch just east of BRLS headscarp with lots of brick-tinted crowns >140 feet is Jilk̲oot's answer to Áak'w's cliffhanging Landmark Trees.