Interannual Rock Glacier Surface Elevation Changes using UAS in Great Basin National Park, Nevada.

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Abstract

Critical freshwater resources lying within mid-latitude mountain glaciers are vulnerable to a rapidly changing climate. The Lehman Rock Glacier is the only extant glacier mapped within the Great Basin National Park in Nevada. As part of an effort to understand this specialized alpine environment, we have been studying this area and conducting observations with annual student research visitations since 2005. Deploying mixed methods including an embedded sensor network, paleoclimate reconstructions, hydrological observations, and unmanned aerial system (UAS) operations, our team has documented diverse evidence of climate change over interannual to millennial scales. Starting in 2015, we conducted annual surveys of the rock glacier to measure topographic changes. Initially, we used balloon-borne photogrammetry, capturing 600+ images over about 0.1 km2 at an altitude of 500m above ground level (AGL). Despite impartial terrain coverage (50-80%) caused by limited control of the balloon rig in the air, digital elevation modeling (DEM) differencing resolved a net volume loss of 5,300m3 between 2015 and 2016. Submission of a Certification Of Approval (COA) granted our team permission to fly a UAV for the first time within the National Park in 2018 and 2019 to map the rock glacier. UAS surveying over successive days in August with $>$ 80% horizontal and vertical overlap helped achieved 100% coverage with 900+ photos. Using previous year's DEMs, we have optimized autonomous flight planning at 80m AGL and 168m AGL at 8.5mh and 20kmh, respectively. We will present our most recent computations of the glacier changes from years 2018 and 2019 and discuss how UAS instrumentation techniques are helping us observe changing glacier conditions at centimeter-scale resolution, better understand ecosystem relationships, and improve capabilities to model future landscapes all while mitigating mountain safety issues.

Inter-annual Rock Glacier Surface Elevation Changes in Great Basin National Park, Nevada using UAS Photogrammetry

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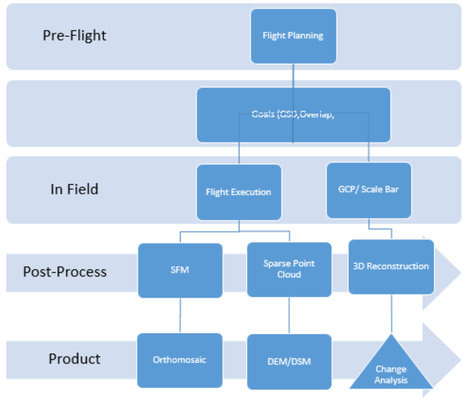
MOTIVATION:

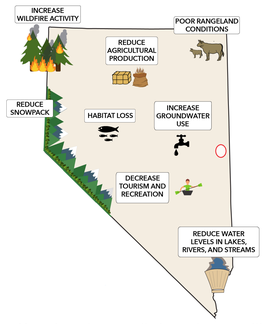
This undergraduate research project stems from annual student research trips made to Great Basin National Park (GBNP). Beginning in 2005, the Great Basin Expedition (GBEX) is a collaborative initiative conducted with park staff that seeks to annually document the diverse impacts of climate change. One park feature of intense observation is the Lehman Rock Glacier, where we have conducted annual photogrammetric surveys since 2015. We began with a balloon and camera; now we are using a UAV. Student researchers constrain surface elevation changes in order to better understand and make inferences about a) climatic controls on topography; b) future volume changes; and c) the hydrological impacts to the ecological and agricultural communities below. The Lehman Rock Glacier, Nevada's only exant ice feature, is ripe for developing burgeoning geomorphological inquiry via hands-on learning.

METHODS:

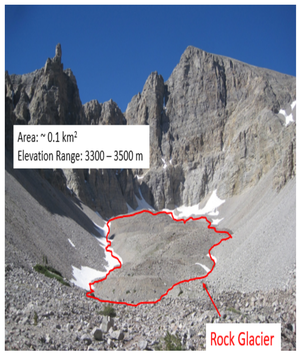


STUDY SITE:

The Lehman Rock Glacier located in GBNP, Nevada is situated at ~3400 m asl. It's placement within a cirque limits insolation most of the day thus preserving this hydrological feature.

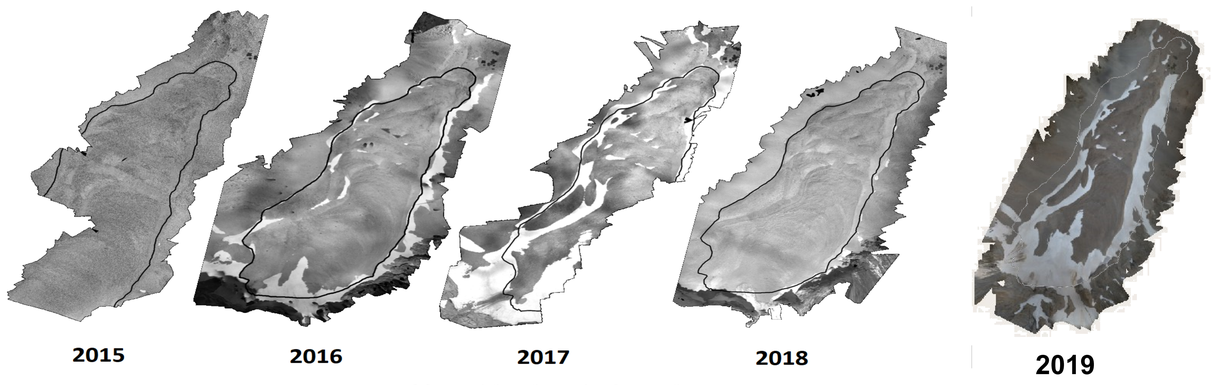


Nevada water scarcity impacts map with red dot marking location of GBNP.

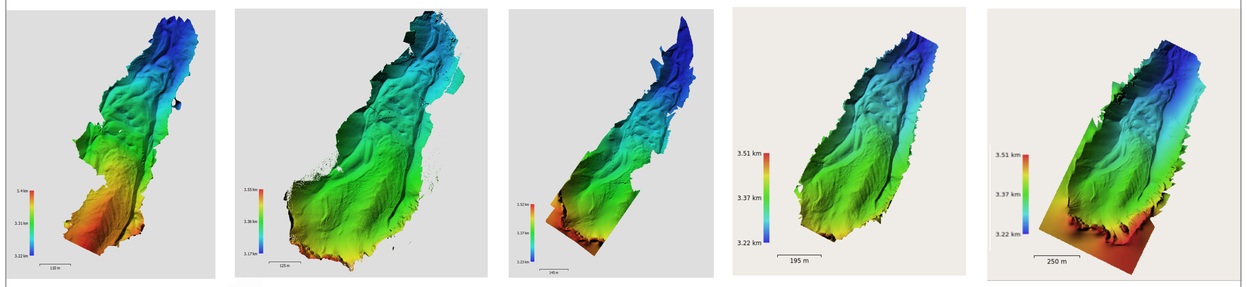


Extent of the Lehman Rock Glacier

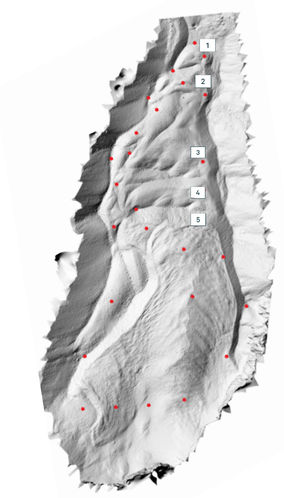
TIME SERIES 2015 - 2019



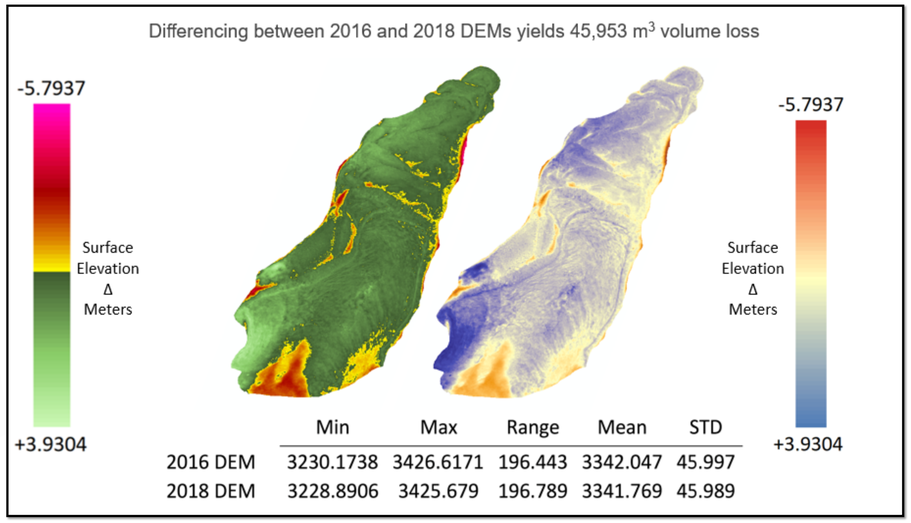
2-3cm resolution orthomosaics of consecutive survey years



10cm resolution DEM"s of consecutive survey years

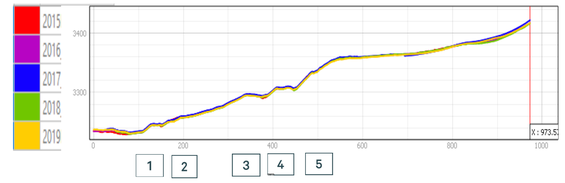


4cm resolution hillshade of the 2018 DEM with red dots indidcating location of control points



Differenced 2016/2018 DEMs. Pronounced changes near headwall are result of snow layers which were later masked out.

Transect Elevation Profile:



Elevation (Y) v. Position (X) chart using a transect line through DEM's

Year	2015	2016	2017	2018	2019
Images Taken	696	830	651	903	952
Images Used	606	627	575	850	921
GCP's Used	5	13	12	27	27
Accuracy points used	14	19	21	19	18
Tie points	537682	337676	570,388	171,660	333,673
GCP Horiz. RMS (M)	0.018	0.005	0.095	0.001	0.001
GCP Vert. RMS (M)	0.019	0.001	0.014	0.002	0.002

Comparison chart of 2015-2019 digital models

TAKEAWAYS:

- UAV photogrammetry and structure-from-motion algorithms provide a unique, hands-on opportunity to study geomorphological changes
- These methods can be effectively implemented in the alpine change monitoring toolkit while also reducing risk to research personnel.
- The Lehman Rock Glacier is more dynamic than previously thought. 3 distinct lobes are moving and lowering/rising at different rates.
- Combining remote sensed data and in-situ observational data helps to develop undergraduate research potential in physical geography

FUTURE STUDENT OPPORTUNITIES:

- Improved UAV platforms with modular sensor payloads will diverse avenues of scientific inquiry.
- Leverage increasing student interest in machine learning and AI for in-flight change detection and mapping techniques.
- Real Time Processing in the field vs Post Processing in the lab

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