Seals on Ice: Developing an image classification workflow to produce thematic maps of ice calving into several tidewater glacier fjords in Kenai Fjords National Park

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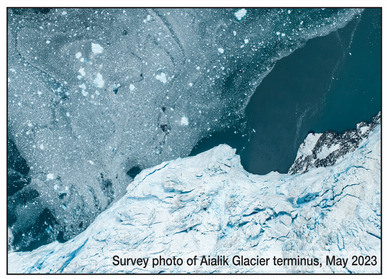
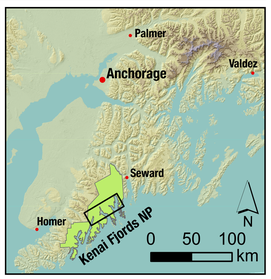
Abstract

Glaciers in Alaska are melting rapidly, changing environmental conditions and necessitating a higher frequency of monitoring to maintain an understanding of current conditions for informed natural resource management. We developed an image classification workflow that processes large amounts of monitoring data to map harbor seal habitat (icebergs) from imagery using ArcGIS segmentation tools. Icebergs are used as habitat by seals in Alaska fjords. Using normalized difference indices and pixel brightness characteristics, we implemented an automated object-based segmentation method that allows scientists to efficiently process large quantities of remotely collected image data to map changing seal habitat. In 2023, we conducted aerial photo surveys in Kenai Fjords National Park using a belly-mounted camera in a fixed-wing aircraft, producing thematic maps of ice cover via ArcGIS Pro and Jupyter Notebook. This approach is adaptable for generating ice estimates across multiple acquisitions, making it applicable to broader conservation projects. Results of our classification show the effectiveness of using normalized band indices to accentuate differences in ice/water and pixel brightness to refine preliminary outputs. The notebook demonstrates how programmatic implementation can leverage geoprocessing tools, inline annotations, and scripting to simplify data management, test classification methods, and strengthen science communication. Furthermore, our seal habitat monitoring goal fits within the larger scope of ice cover assessment in the Arctic, an important element of risk assessment and land management for varying uses from competing stakeholders. With continued developments of automated mapping methods for fixed-wing and UAV systems, traditional environmental monitoring protocols can be replaced with robust, scalable techniques to support adaptive natural resource management in the era of climate change.


Survey photo of Aialik Glacier terminus, May 2023



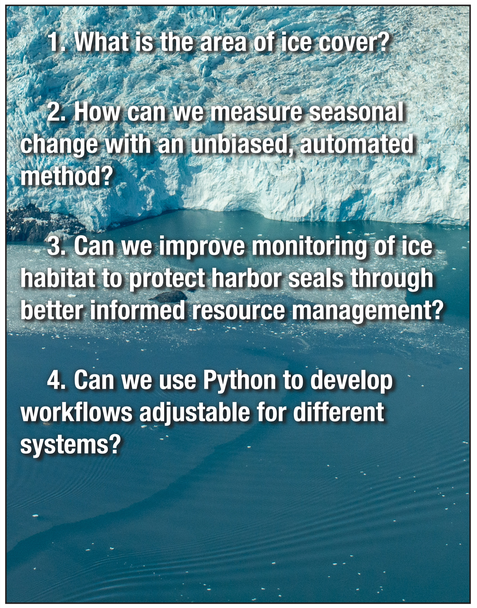
Why Improve Monitoring Methods?

- Research insights inform natural resource management decisions.
- Climate change necessitates more frequent surveys of dynamic systems.
- Existing field methods limit scope due to access difficulties, labor demands, and the need to balance detail with coverage.
- Available aviation and SfM mapping resources support the development of new imagery workflows and strengthen research collaborations.
- Management for overlapping stakeholder interests benefits from long-term, comprehensive data coverage and availability.

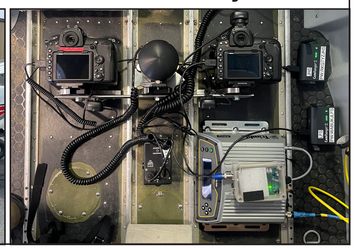
Remote Sensing of Ice Habitat

- Ice habitat surveys support conservation of harbor seals by documenting seasonal availability and impacts from tidewater glacier recession.
- Available satellite approaches are currently limited by temporal frequency, spatial resolution, and high costs.
- Field methods present logistical challenges.
- Monitoring of fjord ecosystems remains globally relevant for understanding both marine wildlife and glaciers in the context of climate change.
- Alaska NPS researchers already use drone (UAS) surveys to measure seal abundance, distribution, and habitat trends in Glacier Bay National Park.
- AKRO is developing an integrated SfM imagery solution to monitor seasonal ice abundances from several tidewater glaciers in Kenai Fjords National Park.

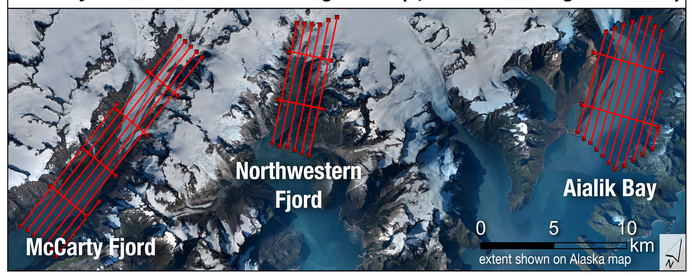
Image Classification Methods/Results



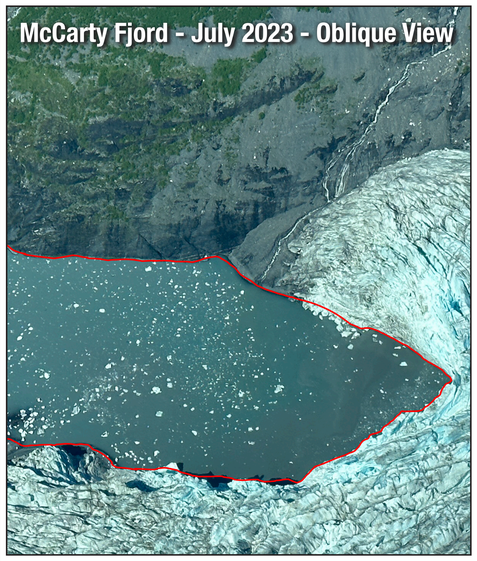
Aerial Acquisition with Cessna 206 with AKRO SfM system



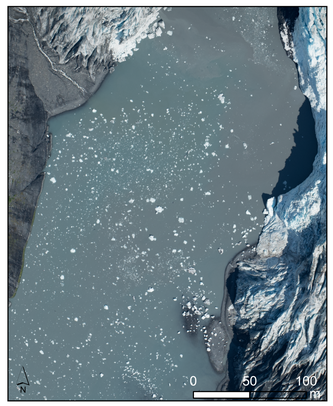
Kenai Fjords 2023-2025 AOIs & Flightlines (4,200 feet above ground level)



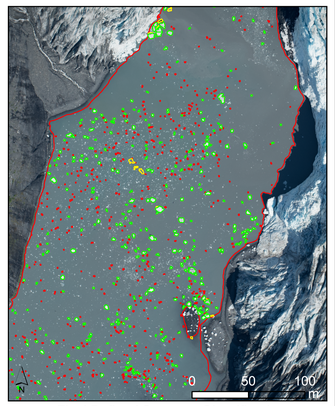
McCarty Fjord - July 2023 - Oblique View



McCarty Fjord - July 2023 - Classification Results from Segmentation



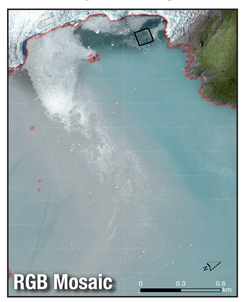
Mosaic RGB Image from SfM-derived DSM

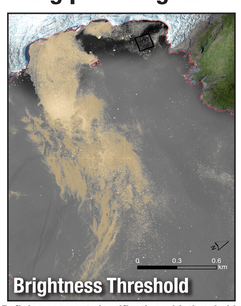


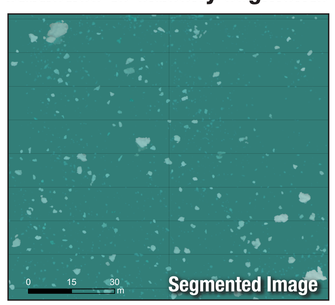
Final Refined Segment Classification

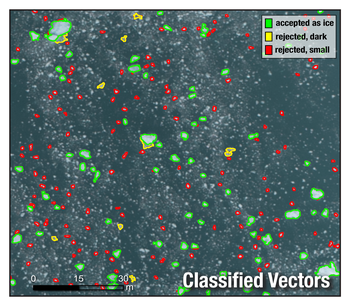
Acquisitions were processed in ArcGIS Pro using Mean Shift Segmentation and a classification stage that incorporates zonal statistics of pixel brightness for vectors to differentiate between ice, water, submerged ice, silt, etc. Compared to using training points and defining binary thresholds, object-based segmentation more strongly differentiates suitable ice habitat (> 1.6 m²) from multiple scenes with set tool parameters.

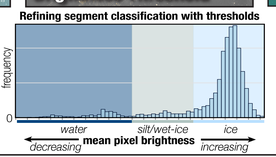
Aialik Fjord July 2023: Using pixel brightness statistics to classify segments









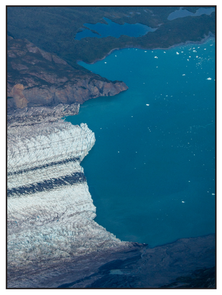


ArcGIS Jupyter Notebook

0 Run photogrammetry workflow
1 Derive value, spectral index rasters
2 Segment band stack using mean shift algorithm
3 Classify vectors with size, pixel brightness
4 Visualization

Discussion

- Inconsistent lighting and silt plumes during acquisition limited the success of using brightness thresholding with AKRO's uncalibrated imagery.
- Object-based segmentation produced consistent iceberg outlines across various scene types and environmental conditions.
- Python in ArcGIS aids method development for projects with large datasets and multiple acquisitions of the same type.
- Jupyter Notebooks integrate data analysis with annotation through scripting.
- Facilitate collaboration and revision with shareable Jupyter Notebooks.
- SfM photogrammetry remains a diverse tool for remote Alaska parklands.
- Automated mapping workflows are applicable and adjustable for UAS, fixed-wing, and satellite monitoring programs.
- Tidewater glaciers' role in human-nature interaction links improved ice monitoring to risk assessment for subsistence, ecotourism, and shipping.
- Low-cost, reliable, unbiased, remote methods help strengthen long-term, frequent monitoring programs.



Impacts and Relevance

- Python in ArcGIS helps users build modular, scalable, adjustable workflows.
- Alaska Region NPS improves in-house capabilities for ice habitat mapping to support conservation efforts of harbor seals in Kenai Fjords.
- Thematic mapping from SfM imagery continues to bring supplemental insights to risk management discussions in the remote Arctic.
- Jupyter Notebooks support collaboration and tailoring of geoprocessing toolsets for multiple acquisition systems and research goals.
- Automated tools expand wildlife monitoring alongside improvements in UAS technology, machine learning, and sensor accessibility.
- Adaptive management strategies benefit from enhanced data-driven tools.
- Monitoring constitutes a crucial component of environmental stewardship.

Acknowledgements

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