UAVSAR Analysis of Beaver Pond Impacts on Adjacent Permafrost Stability

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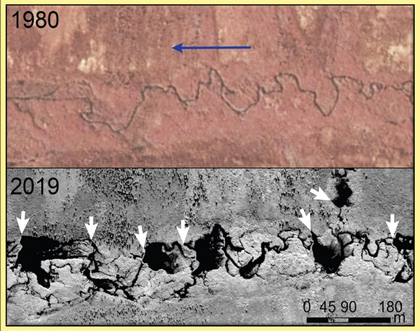
Background

- Beavers are following favorable habitat expansion into Alaskan tundra regions[1].
- Water-impounding specialists, beavers construct ponds and interconnected complexes, rapidly expanding riparian zones, and extending tundra surface water area[1][2].
- The landscape modifications they produce raise questions about the ecological impact of beaver engineering on permafrost-affected regions.
- The impoundment of water by beaver dams can have profound repercussions on permafrost, leading to increases in soil temperatures that drive thaw and, in ice-rich soils, subsidence[2][3].

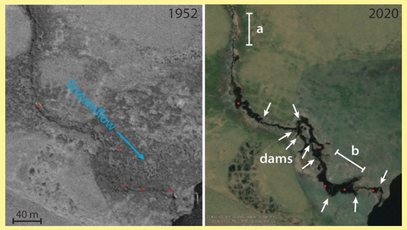
Credit: WildOn



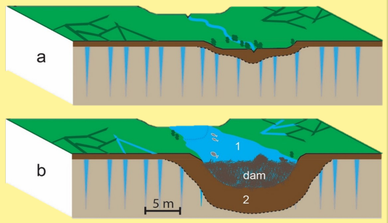
Credit: Ken Tape

- Quantifying the extent to which beaver expansion impacts permafrost stability, triggering permafrost thaw, is yet to be rigorously investigated at a regional scale.
- Here, we quantify subsidence surrounding beaver ponds and beaver-free ponds on Alaska's Seward Peninsula using radar interferometry.
- This study expands previous local-scale analyses, aiming to enhance our ability to predict permafrost stability in heterogeneous conditions.

Impact of Beaver Expansion in Permafrost Environments



1955 aerial photo: Stream flowing through ice-rich permafrost into a lake (left). 2020 GeoEye satellite image (© 2022 Maxar, Inc.) showing multiple beaver dams and ponds (right)[1].



a & b portray observed impoundment by beaver dams and theoretical changes resulting from increased heat absorption, enhanced groundwater flow, permafrost thaw, and subsidence (right)[1].

InSAR is a powerful tool for the detection and quantification of permafrost degradation driven by beaver engineering in ice-rich permafrost landscapes.

Literature Cited

[1] K. D. Tape et al., "Expanding beaver pond distribution in Arctic Alaska, 1949 to 2019," *Scientific Reports*, vol. 12, no. 1, May 2022, doi: https://doi.org/10.1038/s41598-022-09330-6.

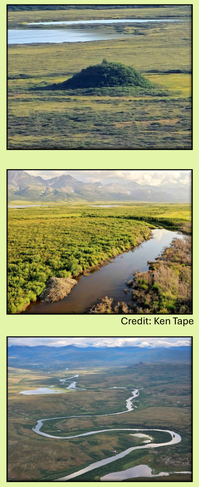
[2] B. M. Jones et al., "Multi-Dimensional Remote Sensing Analysis Documents Beaver-Induced Permafrost Degradation, Seward Peninsula, Alaska," *Remote Sensing*, vol. 13, no. 23, p. 4863, Nov. 2021, doi: https://doi.org/10.3390/rs13234863.

[3] V. E. Romanovsky and T. E. Osterkamp, "Effects of unfrozen water on heat and mass transport processes in the active layer and permafrost," *Permafrost and Periglacial Processes*, vol. 11, no. 3, pp. 219–239, 2000, doi: https://doi.org/10.1002/1099-1530(200007/09)11:3%3C219::aid-ppp352%3E3.0.co;2-7.

[4] S. Hensley, H. A. Zebker, C. E. Jones, T. Michel, R. Muellerschoen, and B. Chapman, "First deformation results using the NASA/JPL UAVSAR instrument," Oct. 2009, doi: https://doi.org/10.1109/apsar.2009.5374246.

[5] E. Fairfax et al., "EEAGER: a neural network model for finding beaver complexes in satellite and aerial imagery," J. Geophys. Res. Biogeosci., vol. 128, no. 6, 2023, doi: 10.1029/2022JG007196.

Teller_04901 UAVSAR Flightline



Credit: Ken Tape

Figure 1. Study area map. The flightline extent covers a heterogeneous terrain featuring dynamic surface hydrology, both discontinuous and continuous permafrost landscapes, and diverse geographical features.

Analysis

We employ high-resolution L-band UAVSAR InSAR pairs (2018-2024) to estimate surface deformation at 3 m resolution[4]. Subsidence adjacent to ponds is mapped relative to the surrounding uplands. Leveraging a GIS database of beaver pond site points compiled from satellite imagery and in situ observations, we compare subsidence near beaver-affected and beaver-unaffected ponds.

Identify Pond Pairs Beaver-affected and non-affected → **Radar Interferometry** Quantify subsidence proximal to ponds → **ANOVA Analysis** Evaluate difference in subsidence

- UAVSAR InSAR pair products (Fig. 2) were obtained from JPL and processed to derive wrapped and unwrapped phase for available acquisition years.
- Upland regions of the AOI exhibit higher interferometric coherence, facilitating subsidence analysis in these areas (Fig.3).
- Initial wrapped phase results (Fig. 3) suggest patterns consistent with subsidence
- A statistical comparative analysis between beaver-affected and unaffected ponds as a function of distance from the shoreline is employed to evaluate the differential impacts of beaver activity on permafrost stability and subsidence dynamics.

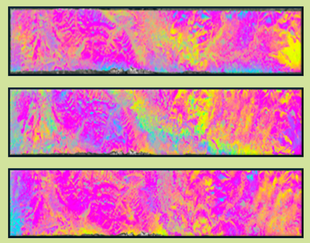
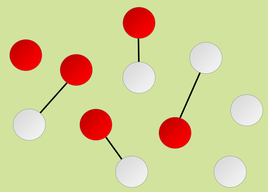


Figure 2. Interferograms covering 2018-2024 (JPL).



Acknowledgments

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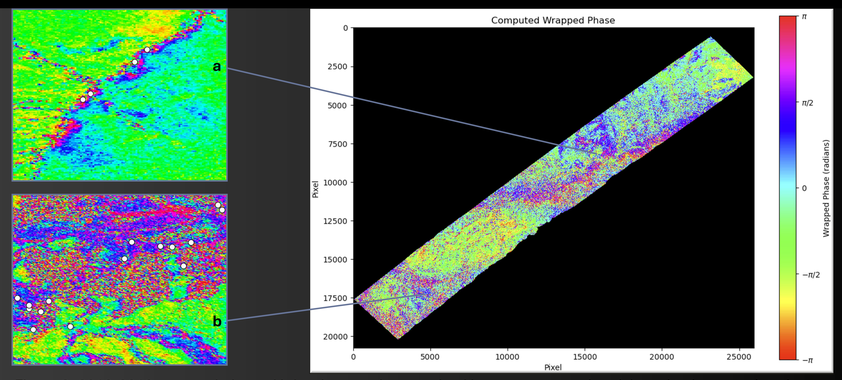
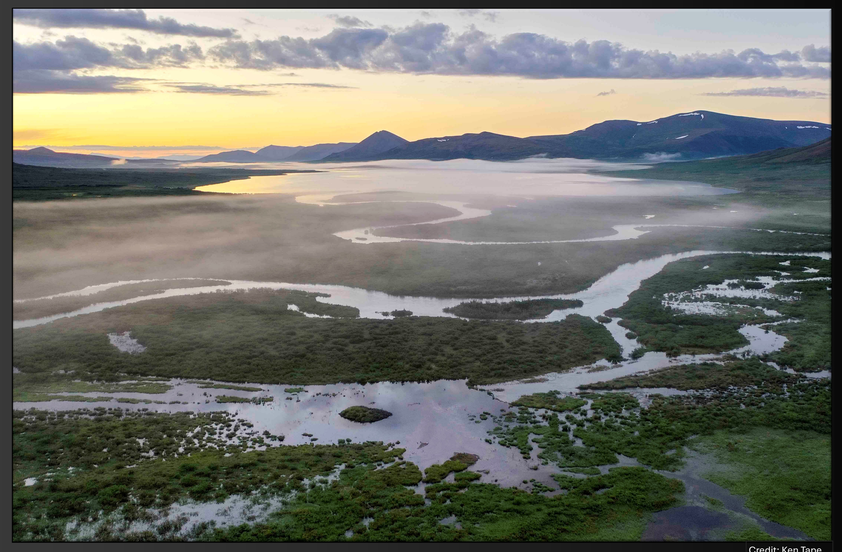


Figure 3. 2018-2019 wrapped phase. Upland areas characterized by narrower reaches (a) tend to be associated with higher coherence while lowland areas with extensive surface water (b) are associated with lower coherence values.

Key Takeaways

- The expansion of beavers into Alaska's Arctic tundra[1] raises important questions about the impacts of beaver engineering on permafrost stability[2].
- We employ UAVSAR interferometric analysis to evaluate beaver-affected and non-affected ponds on the Seward Peninsula, assessing surface change as a function of distance from the shoreline via statistical evaluation.
- Preliminary analysis suggests measurable subsidence patterns in areas with high interferometric coherence, supporting the utility of UAVSAR for estimating subsidence proximal to beaver ponds in permafrost landscapes.
- Early results indicate subsidence, an analysis of the full time series is underway to quantify it.



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