**Unalakleet Climate**

*Analyzing Permafrost Degradation and Drainage Networks in Unalakleet, Alaska*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The Unalakleet Climate project team created both interactive and static subsidence and drainage network maps derived from Sentinel-1 C-SAR, WorldView-2, WorldView-3, and USGS 5 m Alaska Digital Elevation Model (DEM) data. The team’s products support the ongoing relocation efforts of the Native Village of Unalakleet in Western Alaska, in partnership with the National Renewable Energy Lab (NREL).

***Abstract:***

The coastal community of Unalakleet is currently the 8th most at-risk community in Alaska to the adverse effects of climate change that include permafrost degradation, severe coastal erosion, and sea-level rise-induced flood inundation caused by increasingly frequent storm surges. In response, the community has started a managed relocation with support from the Native Village of Unalakleet (NVU) and the National Renewable Energy Lab (NREL)’s Alaska campus in Fairbanks. The Unalakleet Climate NASA DEVELOP team partnered with NREL to provide remote sensing support and analysis for resilience planning in Unalakleet, supporting their ongoing relocation efforts and guiding future area expansion. The team utilized Sentinel-1 C-Synthetic Aperture Radar (SAR), WorldView-2, and WorldView-3 datasets from 2017 – 2023 to analyze subsidence and utilized a 2014 Ancillary USGS 5 m Alaska DEM to conduct drainage network analyses that included watershed delineation and Height Above Nearest Drainage (HAND) analysis. The team also used high-resolution WorldView images to locate stable reference points that served as quality control for the team’s analyses. The team’s end products included maps containing subsidence and drainage zones information at and surrounding the relocation site. The team’s products provide NREL with valuable data that enables them to better assist Unalakleet’s managed relocation and assists Unalakleet with adapting to the catastrophic effects of climate change and build resilience in a community on the front lines of climate change.

***Key Terms:***

Alaska, subsidence, InSAR, drainage networks, HAND, remote sensing, resilience planning, permafrost degradation

***National Application Area Addressed:*** Climate

***Study Location:*** Unalakleet, AK

***Study Period:*** 2017 to 2023 (May to September)

***Community Concerns:***

* Climate change poses dire challenges to remote coastal communities like the Native Village of Unalakleet (NVU). NVU is situated in Western Alaska, bordered by the Norton Sound to the west and the Unalakleet River to the southeast. Due to its location, Unalakleet currently experiences increasingly frequent, intense impacts of climate change like permafrost degradation, coastal erosion, melt, and sea level rise-induced flooding.
* The city is located on a 4-mile gravel spit situated ~14 ft above sea level. The Unalakleet River cuts into the land at an alarming erosion rate of ~2ft per year and poses a significant threat to the longevity of NVU’s existing infrastructure.
* The Unalakleet River is known for its multitude of salmon species that spawn there along with animals like caribou, ptarmigan, oogruk (bearded seal), and various bird species which are important for recreation and subsistence hunting. The native residents of Unalakleet also gather salmon berries, blackberries, sour dock, duck eggs, and many others from the surrounding landscape. The ecosystem and its availability of resources have been severely impacted by permafrost degradation along with coastal and riverine erosion, as habitats are degraded along with loss of access to hunting grounds.

***Project Objectives:***

* Analyze summer subsidence from 2017 – 2023
* Conduct HAND analysis and extract drainage network information
* Create interactive and static maps of subsidence and drainage networks

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** | **Sector** |
| **National Renewable Energy Lab, Alaska Campus** | Georgina Davis, Project ManagerAaron Cooke, Project Manager | End User | Federal Government |

***Decision-Making Practices & Policies:***

NREL and NVU are bound by different legislations in their decision-making process. NREL’s decision-making process is governed by the U.S. Interagency Arctic Research Policy Committee (IARPC)’s 2018 Principles for Conducting Research in the Arctic, while NVU operates under the 1971 Alaskan Native Claims Settlement Act (ANCSA). Under their principles NREL strives to stay accountable, establish effective communication, respect the Indigenous knowledge and cultures, build and sustain relationships, and pursue responsible environmental stewardship. NVU and NREL have already conducted a few preliminary geotechnical engineering tests at the relocation site. They have performed 12 moisture content tests, 12 Atterberg limit tests, 12 sieve and hydrometer analysis tests, 6 unconfined compressive strength tests, and 6 direct shear tests. With future tests planned, coupled with our end products, NREL’s guidance of NVU will enable the community to make better-informed decisions as they navigate ongoing challenges of relocation while ensuring that long-term health and community resilience continue to remain at the center of the project.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Sentinel-1 C-SAR** | Vertical displacement | Derived interferograms were used to assess the vertical displacement of the land surface over time and can show ground subsidence. |
| **WorldView-2** | Surface reflectance | This dataset was used to locate current infrastructure such as plats and roads to compare with subsidence and drainage networks results. It also served to locate reference points for quality control. |
| **WorldView-3** | Surface reflectance | This dataset was used to locate current infrastructure such as plats and roads to compare with subsidence and drainage networks results. It also served to locate reference points for quality control. |

***Ancillary Datasets:***

* [USGS National Map 3DEP, 5 m Alaska Digital Elevation Model](https://apps.nationalmap.gov/lidar-explorer/#/) – Input to perform watershed delineation and HAND analysis
* [Global Height Above Nearest Drainage 30 m](https://gena.users.earthengine.app/view/global-hand) – Coarser HAND analysis to compare against the team’s 5 m HAND analysis
* [Alaska Climate Research Center Weather Data](https://akclimate.org/) – Precipitation data for Unalakleet region

***Modeling:***

* MintPy (POC: Dr. Franz Meyer, University of Alaska Fairbanks) – Perform small baseline subsets (SBAS) InSAR timeseries analysis of subsidence
* Height Above Nearest Drainage (HAND) (POC: Dr. Franz Meyer, University of Alaska Fairbanks) – Perform drainage network analysis

***Software & Scripting:***

* ASF Vertex Online Portal – Selecting and downloading reference pairs for interferograms
* ASF OpenSARlab – JupyterHub for running HyP3, MintPy, and HydroSAR
* HyP3 Jupyter Notebook – Building small baseline stack of interferograms
* Miami InSAR timeseries software in python (MintPy) Jupyter Notebook – Performing small baseline subsets (SBAS) InSAR timeseries analysis of subsidence
* Python 3.7.0 – Processing the InSAR data for subsidence analysis, visualizing the MintPy results, and generating the html maps
* ArcGIS Pro 3.1.1 – Performing watershed delineation and HAND analysis, visualize subsidence and drainage network results

***End Products:***

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| --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** |
| **Interactive html and static PDF subsidence maps of study area** | Interferograms derived from Sentinel-1 C-SAR data were prepared in Hyp3 and input into MintPy to compute the subsidence at and surrounding the relocation site. | NREL will use these maps to provide NVU with an intuitive and interactive way to engage with the subsidence data in planning construction and building/road expansion at and around the designated relocation site. |
| **Interactive html and static PDF drainage network maps of study area** | USGS 5 m Alaska DEM was used to complete a HAND analysis to identify the Unalakleet River watershed, stream flows, and overall drainage networks at and surrounding the relocation site. | NREL will use these maps to provide NVU with an intuitive and interactive way to engage with the drainage network data in planning construction and building/road expansion at and around the designated relocation site. |

***Product Benefit to End User:***

The subsidence and drainage networks end products will be used by NREL to support Unalakleet’s managed relocation. Our work addresses important issues including identifying high, active subsidence below existing infrastructure (e.g., plats & roads), assessing the viability of potential expansion sites, and helping to prioritize relocation zones. Our remote sensing/GIS results help support Unalakleet Village’s resilience planning and bolster our partner’s geospatial knowledge and capacity to harness the burgeoning use of InSAR to investigate ground subsidence and drainage networks in Alaska and other regions in the future.

**References**

Nobre, A. D., Cuartas, L. A., Hodnett, M., Rennó, C. D., Rodrigues, G., Silveira, A., & Saleska, S. (2011). Height Above the Nearest Drainage–a hydrologically relevant new terrain model. *Journal of Hydrology, 404(*1-2*)*, 13-29. doi: [10.1016/j.jhydrol.2011.03.051](https://doi.org/10.1016/j.jhydrol.2011.03.051)

Saylor, P., Dudek, M., Green, J., & Lange, K. (2020). Alaska Transportation & Infrastructure Identifying Permafrost Subsidence Using NASA Earth Observations to Pinpoint Road and Infrastructure Vulnerability in Fairbanks, Alaska. <https://ntrs.nasa.gov/citations/20205007557>

Strozzi, T., Antonova, S., Günther, F., Mätzler, E., Vieira, G., Wegmüller, U., ... & Bartsch, A. (2018). Sentinel-1 SAR interferometry for surface deformation monitoring in low-land permafrost areas. *Remote Sensing*, *10*(9), 1360. doi: [10.3390/rs10091360](https://doi.org/10.3390/rs10091360)

University of Alaska Fairbanks Institute of Northern Engineering US Army Corps of Engineers Alaska District, US Army Corps of Engineers Cold Regions Research and Engineering Laboratory. (2019). Statewide Threat Assessment: Identification of Threats from Erosion, Flooding, and Thawing Permafrost in Remote Alaska Communities. [www.denali.gov/wp-content/uploads/2019/11/Statewide-Threat-Assessment-Final-Report-20-November-2019.pdf](https://www.denali.gov/wp-content/uploads/2019/11/Statewide-Threat-Assessment-Final-Report-20-November-2019.pdf)

Zhang, Z., Lin, H., Wang, M., Liu, X., Chen, Q., Wang, C., & Zhang, H. (2022). A review of satellite synthetic aperture radar interferometry applications in permafrost regions: current status, challenges, and trends. *IEEE Geoscience and Remote Sensing Magazine*. doi: [10.1109/MGRS.2022.3170350](https://doi.org/10.1109/MGRS.2022.3170350)

Zwieback, S., & Meyer, F. J. (2021). Top-of-permafrost ground ice indicated by remotely sensed late-season subsidence. *The Cryosphere*, *15*(4), 2041-2055. doi: [10.5194/tc-15-2041-2021](https://doi.org/10.5194/tc-15-2041-2021)