NASA DEVELOP National Program
2023 Summer Work Plan

Georgia – Athens
Unalakleet Climate
Analyzing Permafrost Degradation and Drainage Networks in Unalakleet, Alaska

Project Overview

***Project Synopsis*:** The community of Unalakleet, Alaska is the eighth most at-risk community in the state due to coastal erosion and sea-level rise. The community is planning a managed retreat with support from the Native Village of Unalakleet and the National Renewable Energy Lab's Alaska Campus in Fairbanks, Alaska. The NASA DEVELOP team will partner with the NREL's Alaska Campus to inform its resilience planning. The team will use Sentinel-1 C-SAR, WorldView-2, WorldView-3, and ancillary LiDAR datasets to analyze permafrost degradation and drainage networks. End products will be maps highlighting permafrost deformation and drainage zones at the site designated for relocation. The NREL's Alaska Campus will use this information to better assist the Unalakleet community's managed retreat.

Study Location: Unalakleet, AK
Study Period: January 2005 – June 2023
Advisors: Dr. Marguerite Madden (University of Georgia, Center for Geospatial Research); Dr. Franz Meyer (University of Alaska Fairbanks); Dr. Simon Zwieback (University of Alaska Fairbanks)

Partner Overview

Partner Organization:

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

End User Overview

End User's Current Decision-Making Process & Capacity to use Earth Observations:
NREL's Alaska Campus researches building science and sustainable home design in extreme climates. It was recently awarded a project through the Bureau of Indian Affairs to provide housing designs for a platted subdivision in support of the Unalakleet managed retreat. To plan and prioritize for the managed retreat, its current decision-making practices include structural engineering assessments, geotechnical analysis, data on climatic conditions, and community-centered feedback on building designs. CCHRC does not currently incorporate aerial or satellite imagery into its decision making. As an organization, it has used remote sensing in past projects when partnering with organizations such as the Army Corps of Engineers. The current contacts listed are not familiar with remote sensing techniques and have limited familiarity with GIS.

Earth Observations Overview

Earth Observation:

Platform & Sensor	Parameters	Use
Sentinel-1 C-SAR	Permafrost deformation, Thermokarst detection	This dataset will assess changes in land elevation to create interferograms, which will show permafrost deformation and thermokarsts.
WorldView-2	Surface Reflectance	This dataset will be used to locate current infrastructure such as plats and roads to compare with drainage networks and permafrost deformation.

WorldView-3	Surface Reflectance	This dataset will be used to locate current infrastructure such as plats and roads to compare with drainage networks and permafrost deformation.

Ancillary Datasets:

- Alaska Division of Geological & Geophysical Surveys (DGGS), Photogrammetric DSMs and Orth imagery 2017 – analyze drainage networks and permafrost deformation
- Alaska DGGS, Photogrammetric DSMs and Orthoimage 2015 – analyze drainage networks and permafrost deformation
- Alaska DGGS, Unalakleet LiDAR 2005 – analyze drainage networks and permafrost deformation
- USGS National Map 3DEP, 5 m Alaska Digital Elevation Model – analyze drainage networks and permafrost deformation
- Alaska DGGS, Erosion exposure assessment of infrastructure in Alaska coastal communities – provides additional context for relocation by prioritizing infrastructure
  - Shoreline Change at Alaska Coastal Communities
  - Erosion Exposure Assessment - Unalakleet
- North Slope Science Initiative, Permafrost Characteristics of Alaska 2008 – provides general characteristics of permafrost
- Frozen Ground Data Center, Circum-Arctic Map of Permafrost and Ground-Ice Conditions, Version 2 – provides general characteristics of permafrost
- Global Height Above Nearest Drainage 30m – provides a coarser HAND analysis to compare against the team's
- HydroSHEDS – additional coarser resource dataset to compare against the team's hydrological outputs

Commented [1]: I have downloaded all these datasets; they are available for you on the VM Shared D drive and might be useful for permafrost or drainage analysis at a higher resolution.

Decision Support Tool & End Product Overview

End Products:

End Product	Partner Use	Datasets & Analyses
Permafrost Deformation Maps	The NREL's Alaska campus will use permafrost deformation maps to inform the Unalakleet community's managed retreat by prioritizing building construction and road expansion.	Sentinel-1 C-SAR data will be used to make interferograms and analyze permafrost deformation. LiDAR data and DEMs will be used to assess elevation change.
Drainage Network Maps	The NREL's Alaska campus will use drainage network maps to inform the Unalakleet community's managed retreat by prioritizing building construction and road expansion.	LiDAR data and the USGS 5m Alaska DEM will be used to run a height above nearest drainage analysis and create watershed, stream flow, and overall drainage networks at the Unalakleet community's relocation site.

Project Timeline & Previous Related Work

Project Timeline: 1 Term: 2023 Summer

Similar Past DEVELOP Projects:

- 2020 Fall JPL – Central Valley Water Resources II
- 2020 Summer JPL – Alaska Transportation & Infrastructure
  - Check for updated software
  - Tutorial videos by past team and Alaska Satellite Facility
- 2019 Spring JPL – Alaska Ecological Forecasting II

Commented [2]: Once you have access to DEVELOPedia, it will be best to look these up there. Specifically the Alaska Transportation & Infrastructure project

- 2021 Spring MSFC – Cheat Water Resources

Partner Overview

Source of Project Idea: A previous GA participant, Isabella Chittumuri, works with the National Renewable Energy Lab, Alaska Campus and connected them with the GA Fellow, Sarah Payne. We have had three video calls since with partners. The GA Fellow, Dr. Madden, and Dr. Ross were put in contact with science advisors at the University of Alaska Fairbanks.

Partner Interest: The partners wrote up a proposal from their perspective. It will be extremely useful to better understand their priorities and perspective.

Datasets Overview

Datasets:

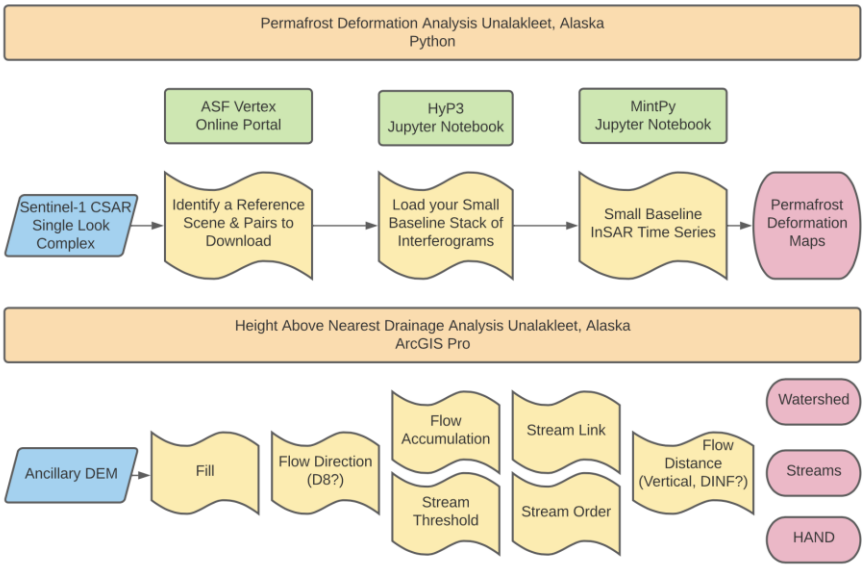
- Sentinel-1 C-Synthetic Aperture Radar, Level-1, Single Look Complex
    - The Alaska Satellite Facility Distributed Active Archive Center (DAAC) specializes in synthetic aperture radar data
    - Data coverage of Sentinel-1 is worldwide with a 6 – 12 day repeat cycle, it is two satellites in a 12 day orbit that may ascend/descend and overlap
    - SLC complex product's spatial resolution depends on how the image was acquired
- WorldView
    - Priority data from MAXAR, the Georgia Fellow (Sarah Payne) created an account through NASA's Commercial Small Sat Data Acquisition Program (CSDA) has already downloaded available imagery onto the Virtual Machine's shared D drive.
    - Standard 2A imagery "radiometrically corrected, sensor corrected, and projected to a plane using the map projection and datum of the customer's choice. Standard Imagery also has a coarse DEM applied to it, which is used to normalize for topographic relief with respect to the reference ellipsoid. The degree of normalization is relatively small, so while this product has terrain corrections, it is not considered orthorectified. All Standard Imagery products have uniform GSD throughout the entire product. " – MAXAR Product information
    - Spatial resolution from 50 cm to 2 m, revisit up to 1.1 days for WorldView
    - We cannot provide raw imagery to the public since it is proprietary, it must be processed

Potential Workflows

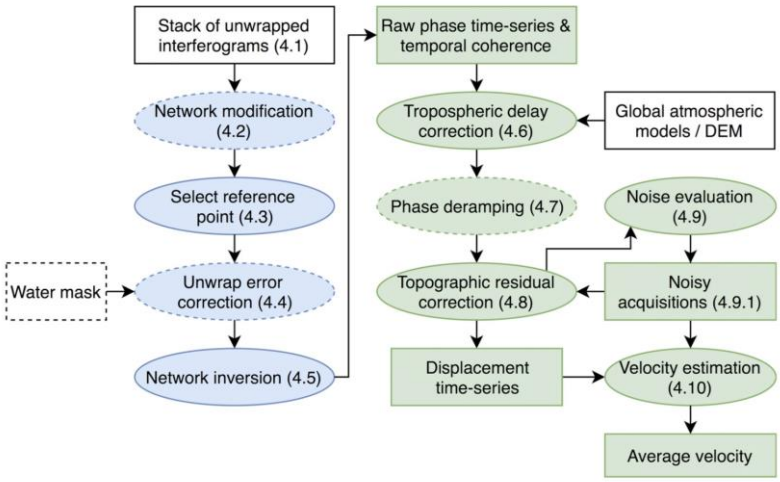
Potential Priorities:

1. **Create the Study Area Shapefile**
2. **Understand the Ancillary Datasets** provided on the VM and see if the LiDAR data may be of use to provide a higher resolution dataset for permafrost deformation analysis or drainage network analysis
3. **Understand Sentinel-1 SLC Permafrost Deformation Workflow**
    1. Understand the basics of SAR remote sensing
    2. Understand Sentinel-1 C-SAR SLC data products
    3. Explore the many tutorials through the ASF for processing, primarily in Python
    4. Investigate the old code from the Alaska T&I project
    5. Alter code specifically focused on the most recent data for Unalakleet
4. **Understand HAND**
    1. Download and understand the USGS 3DEP 5m DEM for Alaska
    2. Explore tutorials to use the hydrological analyses in ArcGIS Pro
        1. Watershed creation
        2. Stream processing
        3. Height Above Nearest Drainage Analysis

5. **Use WorldView** manual image interpretation to look at sites best suited for prioritizing relocation

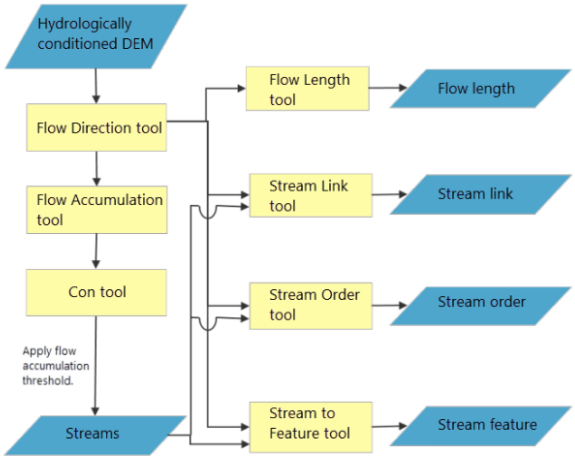


Rough Overview: Created by GA Fellow



MintPy Flowchart: "Routine workflow of InSAR time series analysis. Blue ovals: steps in the interferogram domain including unwrapping error correction and network inversion; green ovals: steps in the time-series domain including phase corrections for the tropo-spheric delay, phase ramps, and topographic residuals.

White rectangles: input data. Green rectangles: output data. Optional steps/data are marked by dashed boundaries." (Yunjun et al. 2019).



ArcGIS Pro Stream Flowchart: ArcGIS Pro Documentation

Subject Matter Training

Remote Sensing Fundamentals

- ARSET's "Fundamentals of Remote Sensing" - Session 1, Session 1A
- ARSET's "Introduction to Synthetic Aperture Radar"

Project Specific Analysis - InSAR

- USGS SAR Overview
  ASF StoryMap Tutorials
  - InSAR on Demand
- Jump-Start SAR Analysis in the Cloud with ASF's OpenSARLab
- OpenSARLab
- HyP3
  - Introduction to SAR
- MintPy

Project Specific Analysis – Drainage Networks

- ArcGIS Pro Introduction
- ArcGIS Pro Hydrology Toolset

Notes & References:

References:

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

Strozzi, T., Antonova, S., Günther, F., Mätzler, E., Vieira, G., Wegmüller, U., Westermann, S., et al. (2018). Sentinel-1 SAR Interferometry for Surface Deformation Monitoring in Low-Land Permafrost

Areas. *Remote Sensing*, *10*(9), 1360. MDPI AG. Retrieved from http://dx.doi.org/10.3390/rs10091360 Daniel

Yunjun, Z., Fattahi, H., Amelung,F. (2019) Small baseline InSAR time series analysis: Unwrapping error correction and noise reduction, Computers & Geosciences,Volume 133, 104331, https://doi.org/10.1016/j.cageo.2019.104331

Zhang, Z. et al. (2022, September). A review of satellite synthetic aperture radar interferometry applications in permafrost regions: Current status, challenges, and trends. *IEEE Geoscience and Remote Sensing Magazine*, *10*(3), 93-114. doi: https://ieeexplore.ieee.org/document/9777880 Jaweed

Zwieback, S. and Meyer, F. (2021, April). Top-of-permafrost ground ice indicated by remotely sensed late-season subsidence. *The Cryosphere, 15(4), 2041-2055*. doi: https://tc.copernicus.org/articles/15/2041/2021/ Ian