**NASA DEVELOP National Program**

**2020 Spring Project Proposal**

**California – JPL**

**Alaska Transportation & Infrastructure**

*Identifying Permafrost Subsidence Using NASA Earth Observations to Pinpoint Road & Infrastructure Vulnerability*

**Project Overview**

***Project Synopsis*:** This project will use remotely-sensed data to identify two kinds of permafrost thaw, subsidence and thermokarst formation, as they occur near major roads and infrastructure in order to enrich partners’ decision-making capabilities involving this issue. The NASA DEVELOP team will compare two means of identification of permafrost deformation: elevation change data derived from LiDAR and interferograms derived from UAVSAR and Sentinel-1 C-SAR. Using similar methodology, the team will also create interferograms to identify areas experiencing thermokarst near economically important roads and infrastructure in areas of interest in interior Alaska. Through the handoff of project results, the NASA DEVELOP team will build capacity in the partners (Army Corps of Engineers’ Cold Regions Research and Engineering Laboratory; Alaska Department of Transportation, Alaska Department of Natural Resources) to use remote sensing to highlight areas experiencing the highest severity of permafrost deformation/thermokarst and therefore better allocate resources to the areas in need.

***Community Concern:*** Permafrost, soil, and rock that remains frozen for two or more years, is a dominant terrain feature in interior Alaska. In this area, significant localized permafrost thaw is occurring, especially in places where natural insulative vegetation has been removed due to disturbances such as construction or fire. Some extremely wet years since 2014, as well as increasing average global temperatures, are increasing permafrost thaw. When ice-rich permafrost thaws, surface deformation and subsidence frequently occur. Surface deformation poses a serious threat to Alaska’s infrastructure, leading to the decreased structural integrity of the ground and subsequent damage to roads and structures. The State of Alaska is looking for better ways to remotely sense areas experiencing permafrost deformation to bolster their decision-making processes regarding these critical areas.

***Source of Project Idea:*** JPL science advisor Dr. Bruce Chapman approached the DEVELOP JPL Lead/Fellow, Cecil Byles, regarding a project idea centered around remotely sensing permafrost deformation in Alaska. He mentioned that his contacts at the US Army Corps of Engineers Cold Regions Research and Engineering Laboratory (CRREL) might be interested in serving as an end user.

***National Application Area Addressed:*** Transportation & Infrastructure

***Study Location:*** AK

***Study Period:*** 2017 – 2019 (May – September)

***Advisors:*** Bruce Chapman (NASA Jet Propulsion Laboratory, California Institute of Technology), Benjamin Holt (NASA Jet Propulsion Laboratory, California Institute of Technology)

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory** | Tom Douglas, Senior Scientist; Christopher Hiemstra, Research Scientist | End User | Yes |
| **Alaska Department of Transportation** | Garrett Speeter, Regional Engineering Geologist | End User | Yes |
| **Alaska Department of Natural Resources** | Ronald Daanen, Field Hydrologist | End User | Yes |
| **Alaska Satellite Facility** | Franz Meyer, Chief Scientist | Collaborator | No |

***End User Overview***

***End User’s Current Decision-Making Process:***CRREL currently focuses on Alaska and Greenland at their Fairbanks, AK office. They operate a permafrost tunnel in Fairbanks, which they use for research, but desire more information about permafrost melt to ensure safety within the tunnel. The Alaska Department of Transportation’s (DOT) decision-making entails assessing permafrost near major transportation routes. They have to decide whether to preserve or purposely thaw permafrost depending on the scenario and typically make their decisions based on ground-based geological and geotechnical observations. The Alaska Department of Natural Resources (DNR) is interested in the effects of permafrost on long-term groundwater quality and availability to Alaskans as well as permafrost melt causing slope movements and drunken trees. They make their decisions based on a combination of satellite imagery and ground-based detection.

***End User’s Capacity to Use NASA Earth Observations:***

*US Army Corps of Engineers, Cold Regions Research and Engineering Laboratory* – CRREL is familiar with NASA Earth observations and sometimes uses them in their decision-making. However, they have limited experience with synthetic aperture radar (SAR) and want to gain more knowledge about detecting permafrost melt using radar methods.

*Alaska Department of Transportation* – The DOT sometimes uses remote sensing products on a project by project basis but does not usually incorporate NASA Earth observations into their decision-making. However, they tend to use ground-based surficial and subsurface geologic investigations instead of remote sensing.

*Alaska Department of Natural Resources* – The DNR does not typically use NASA Earth observations in its

decision making, although they are familiar with satellite remote sensing products in general.

***Collaborator & Boundary Organization Overview***

***Collaborator Support*:**

*Alaska Satellite Facility* – The Alaska Satellite Facility (ASF) will support the team by granting them access to the cloud-based OpenSARLab resource, hosted by ASF in Jupyter Notebooks, which will be used by the team to automate Interferometric Synthetic Aperture Radar (InSAR) processing. ASF also hosts the ASF Distributed Active Archive Center (DAAC), which specializes in SAR data collection, processing, archiving, and distribution

***Dissemination by Boundary Organizations*:**

*United States Army Corps of Engineers, Cold Regions Research and Engineering Laboratory* – CRREL noted that they are willing to share results of the project with their parent organization, the US Army Corps of Engineers, as well as outside entities such as the US Army Directorate of Public Works and NASA ABoVE (Arctic-Boreal Vulnerability Experiment).

*Alaska Department of Transportation* – AK DOT indicated that they will be able to use the project results in

investigations and geotechnical reports that may be distributed to contractors building transportation

projects, designers using DOT data to design transportation projects, other government entities, and communities in the State of Alaska.

*Alaska Department of Natural Resources* – AK DNR noted that they can release project results to other entities interested in permafrost in the Alaska, including the National Ecological Observatory Network, which they share an office with.

***Project Communication & Transition Overview***

***In-Term Communication Plan*:** The team will maintain regular email communication with the partners throughout the term. All emails will go through the Project Lead. In addition to regular email communication, the team will have weekly telephone meetings with the partners to discuss updates and any issues encountered.

***Transition Plan*:** The team will hand off the end products at the end of the term via video conference in addition to a presentation describing the work done over the term. Partners will be able to immediately use the geospatial maps to identify areas most at risk and will also be able to replicate the team’s methodology for additional areas. Software release is anticipated, and the partners have been informed that DEVELOP node leadership will hand off the script 6-12 months after the conclusion of the project.

**Earth Observations Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter(s)** | **Use** |
| **Gulfstream III UAVSAR** | Permafrost deformation detection | This dataset will be used to create interferograms, which will show land subsidence due to permafrost thaw in the study areas. |
| **Sentinel-1 C-SAR** | Permafrost deformation detection, thermokarst detection & severity | This dataset will be used to create interferograms, which will show land subsidence due to permafrost thaw in the study areas. It will also be used to detect thermokarst in areas without UAVSAR coverage. |

***Ancillary Datasets:***

* National Science Foundation (NSF) National Ecological Observatory Network (NEON) LiDAR datasets – create elevation change products to analyze permafrost deformation near the Barrow, Caribou Creek, Delta Junction, Healy, and Toolik NEON sites
* CRREL LiDAR dataset – create elevation change products to analyze permafrost deformation near CRREL

***Software & Scripting:***

* Esri ArcGIS – data processing and map creation
* ENVI – data processing and map creation
* Sentinel Application Platform (SNAP) – data processing and interferogram creation
* Python – scripting of a tool which can automate InSAR and LiDAR processing
* OpenSARLab – scripting of a tool which can automate InSAR processing

**Decision Support Tool & End Product Overview**

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Partner Use** | **Datasets & Analyses** | **Software Release Category** |
| **Permafrost Deformation Maps** | These maps will show areas experiencing permafrost deformation as well as the severity of deformation using two different datasets: LiDAR and InSAR. This method will be used in select study areas where auxiliary LiDAR datasets already exist. | LiDAR will be used to create elevation change data from year to year. L-band UAVSAR and Sentinel-1 C-SAR will be used to create interferograms that will show land subsidence as a result of permafrost deformation. | I |
| **Thermokarst Maps** | These maps would show thermokarst presence and severity near major roads and built-up areas using InSAR. | Sentinel-1 C-SAR (and UAVSAR where available) will be used to create interferograms that will show areas experiencing thermokarst. | I |
| **Standard Operating Procedure** | This document would list out the entire methodology of the project in detail so partners can replicate the study in new areas of Alaska not touched on by the DEVELOP project. | N/A | N/A |
| **Permafrost SAR Tool** | This end product would be a script automating InSAR and LiDAR processing in user-selected study areas with recent data. | LiDAR will be used to create elevation change data from year to year. L-band UAVSAR and Sentinel-1 C-SAR will be used to create interferograms that will show land subsidence as a result of permafrost deformation. | IV |

***End User Benefit*:** From the results of this project, the end users will be able to incorporate NASA Earth observation-based methodologies into their decision-making processes involving permafrost deformation and land subsidence detection. With interactive geospatial maps, the end users will be able to identify and prioritize areas experiencing the highest intensity of permafrost deformation. Additionally, handing off a script to end users will build their capacity to continue using InSAR into the future, despite the challenging nature of InSAR processing.

**Project Timeline & Previous Related Work**

***Project Timeline:*** 1 Term: 2020 Summer

***Related DEVELOP Work:***

2018 Spring (NC) - Alaska Disasters: Development of a Snowmelt Monitoring Tool Using NASA MODIS and NOAA Climate Data Records to Aid Wildfire Managers in Alaska

2014 Spring (JPL) Global Disasters II: Utilizing the Power of Remote Sensing and Crowdsourcing for Natural Disaster Damage Assessment and Response

**References:*:***

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the Qinghai-Tibet Railway detected via jointly analysis of C- and L-band small baseline SAR interferometry. *Remote Sensing of Environment 123*. 523-540.

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permafrost and seasonally frozen ground. In C.R. Duguay & A. Pietroniro (Eds.), *Remote sensing in Northern Hydrology: Measuring Environmental Change, Volume 163.* (pp. 91-118). Washington, DC: American Geophysical Union

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