Spring 2024 Project Summary

Alaska Ecological Conservation
Using NASA Earth Observations to Identify Recent Changes in River Ice Phenology and Its Impacts on Caribou Migration

Project Team

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Project Overview

Project Synopsis:
This study uses remote sensing to investigate the hypothesis that changing river ice formation periods have delayed/deflected caribou migration paths. In partnership with the National Park Service, Region 11, we analyzed fall river ice phenology from 2017 – 2023 for three river sections in northwestern Alaska. Using radar imagery, optical imagery, and spectral indices along with temperature validation, we investigated ice coverage timing to help our project partners and their community concerns, including the steep decline of caribou populations, conservation, and management strategies.

Abstract:
Each fall, caribou (*Rangifer tarandus*) in the Western Arctic Herd migrate hundreds of kilometers across northwestern Alaska to acquire seasonal resources and reach wintering grounds. Various rivers intersect migration paths, and caribou can only cross over open water or high-ice extents but are unable to cross rivers in stages of partial freezing. Recent temperature increases in Alaska can alter the timing and duration of ice formation periods, impeding migratory patterns. The Massachusetts NASA DEVELOP team partnered with the National Park Service in Alaska to detect river ice onset dates and formation periods using Landsat 8 Operational Land Imager and Landsat 9 Operational Land Imager-2, Sentinel-1 C-band Synthetic Aperture Radar and Sentinel-2A/B MultiSpectral Instrument imagery in Google Earth Engine. This feasibility analysis measured ice coverage using the Normalized Difference Infrared Index, Relative Difference River Ice, and Vertical-Vertical/Vertical-Horizontal backscatter values based on the spectral and surface characteristics of rivers. The team produced annual freezing timelines, time series plots, and maps at three river stretches to analyze river ice phenology changes. Radar imagery assessed ice coverage more accurately, while optical imagery better identified ice onset dates. Meanwhile indices were unable to robustly establish ice formation thresholds across the study period. These study results can help the National Park Service to better evaluate spatiotemporal migratory shifts and contextualize recent regional caribou declines.

Key Terms:
river phenology, *Rangifer tarandus*, caribou, remote sensing, Landsat, Sentinel, NDWI, RDRI

Application Area: Ecological Conservation
Study Location: Northwestern Alaska
Study Period: 2017 to 2023 (September to November)

Community Concerns:

- Shifting ice phenology could alter caribou migrations which can diminish reproductive success.
- The Western Arctic Herd, which in recent years has experienced population declines beyond normal fluctuations, could face further declines due to climate change.
- Communities of Alaska harvest caribou as a source of food and material, and caribou are also an integral part of northern culture and spirituality.
- Altered migratory patterns could present monitoring challenges for communities and managers.

Project Objectives:

- Capture trends in river ice phenology on the Kobuk and Colville Rivers for the fall caribou migration between early October to late November between 2017 and 2023
- Produce time series maps and plots to display timing and progression of river ice using satellite imagery and imagery analysis
- Determine capabilities and limitations of NASA remotely sensed data to inform caribou management

Partner Overview

Partner Organization(s):

Organization(s)	Contact (Name, Position/Title)	Partner Type	Sector
National Park Service, Gates of The Arctic National Park & Preserve	Dr. Kyle Joly, Biologist	End User	Federal Government

Decision-Making Practices & Policies:

Dr. Kyle Joly is a caribou biologist currently interested in research on caribou migration and harvest monitoring initiatives. As the herd is hunted year-round, this research is at the nexus of science and policy and can show that declines and migratory changes that are often attributed to hunting policy could be caused in-part by changes in river ice phenology. Dr. Joly is experienced in GIS and has worked with Landsat data previously. Additionally, he has worked for two decades with the Gates of the Arctic and the Yukon-Charley National Parks and Preserves to understand the spatial ecology of caribou in Alaska. He is interested in seeing how remote sensing can be used to understand and contextualize changing migratory behavior such as instances of river tracing, migratory deflection, etc.

Earth Observations & End Products Overview

Earth Observations:

Platform & Sensor	Parameter(s)	Use
Landsat 8 OLI	Surface Reflectance	Used to detect river ice phenology using the normalized difference water index (NDWI), Relative Difference River Ice Index (RDRI), Normalized Difference Infrared Index (NDII), near infrared (NIR)/shortwave infrared (SWIR) ratio, and true color visualization.
Landsat 9 OLI-2	Surface Reflectance	Used to detect river ice phenology using NDWI, RDRI, NDII, NIR/SWIR ratio, RBG visualization.
Sentinel-2 MSI	Surface Reflectance	Used to detect river ice phenology using NDWI, RDRI, NDII, NIR/SWIR ratio, RBG visualization.
Sentinel-1 C-SAR	VH and VV Backscatter Mean	Used to create time series maps and plots of VV and VH band values to show a correlation between backscatter and river ice formation phases.

Ancillary Datasets:

- MesoWest Fire & Fuels – Air temperature data to compare to VV and VH backscatter plots to display correlations between river ice presence and temperature
- USGS National Hydrology Dataset (NHDPlus) – River polygon shapefile including the Kobuk and Colville Rivers

Software & Coding Languages:

- Google Earth Engine JavaScript API (v0.1.388) – Acquisition and processing of optical and radar data
- R 4.3.3 – Run statistical analysis and data visualizations
- Microsoft Excel Version 2312 – Data processing to create the timeline of yearly freezing dates for each study site from 2017 to 2023
- ESRI ArcGIS ArcGIS Pro 3.2.2 – Cartography, digitization, threshold analysis and visualization

End Product(s):

End Product(s)	Earth Observations Used	Partner Benefit & Use
River Ice Timeseries Plots	Landsat 8 OLI Landsat 9 OLI-2 Sentinel-1 C-SAR Sentinel-2 MSI	This end product will visualize river ice trends across years using optical indices. These timeseries will allow the partner to compare the results of river ice formation dates with caribou data to better evaluate spatiotemporal migratory shifts and contextualize recent regional caribou declines.
River Ice Timeseries Maps	Landsat 8 OLI Landsat 9 OLI-2 Sentinel-1 C-SAR Sentinel-2 MSI	This end product will visualize river ice trends across years using optical indices. These timeseries will allow the partner to compare the results of river ice extent with caribou data to better evaluate spatiotemporal migratory shifts.

Ice Formation Timeline	Landsat 8 OLI Landsat 9 OLI-2 Sentinel-2 MSI	This end product will visualize and chart yearly ice formation across sites using optical data. These charts provide daily estimates of river ice presence that the partner can compare with caribou data to between understand the relationships between river ice formation and shifts in migration patterns.

Product Benefit to End User:

Our partner will be able to use our end products to compare ice formation periods with caribou migration data. Years with delayed or disrupted caribou migration pathways can be compared with the study site's river condition. By this analysis, they will be able to better contextualize patterns of migration anomalies with phenological data to understand developing caribou behavior in response to climate change. This in conjunction with the project's methods will be used to conduct similar freezing analyses for future years, which will better inform management and harvesting policy.

Project Continuation Plan:

This term, the team identified spatiotemporal shifts in river ice formation for the Kobuk and Colville Rivers by creating timeseries maps and plots and a river ice formation timeline. These will help the partner better understand how shifts in river ice formation have impacted this part of the Western Arctic Herd's migration path. Part II will observe the next part of the WAH's migration path: calving zone selection. This project will produce vegetation phenology timeseries charts and maps identifying optimal zones for caribou calving. Ultimately, these projects will help the partner better understand overall changes in the WAH's migration patterns.