National Aeronautics and Space Administration

The NISAR-ISRO SAR Mission

Terrestrial Permafrost

NISAR will observe changes in permafrost landscapes globally. Biweekly measurements of permafrost surface deformation will characterize this major hazard to infrastructure, projected to have a large economic impact by the end of this century.

Ground ice in permafrost

As permafrost remains below freezing throughout the year, it may contain water in its solid form: ice. The amount of ground ice varies widely. In certain locations, the ground can contain more than 90% of ice by volume. When such materials thaw, the melting of ice and drainage of its meltwater cause the ground to settle or collapse, as seen in the rapidly retreating bluff on the right.

Ground ice comes in a bewildering variety of types, which reflect how the ice happens to be stored in the ground: Massive ice accumulates in impressively large subsurface bodies of ice. Wedge ice appears within tension cracks that form repeatedly during winter to 'wedge' the rock or soil apart. Ice also commonly occurs within pores in the soil, essentially cementing the soil together, or as 'lenses' of ice that accumulate in localized zones below ground.

Photo: G. Iwahana

Permafrost monitoring

Permafrost soils, which remain frozen throughout the year, underlie approximately 15% of the Earth's terrestrial surface. Widespread changes in permafrost conditions have recently been observed, such as increasing ground temperatures and deeper seasonal thaw. Where the soils are rich in ground ice, permafrost thaw can induce surface settlement and cause damage to homes, roads, and other critical infrastructure. Changing permafrost conditions also impact water resources, ecosystem services, and the global carbon cycle.

The NISAR Mission – Reliable, Consistent Observations

The NASA–ISRO Synthetic Aperture Radar (NISAR) mission, a collaboration between the National Aeronautics and Space Administration (NASA) and the Indian Space Research Organization (ISRO), will provide all-weather, day/night imaging of nearly the entire land and ice masses of the Earth repeated 4-6 times per month. NISAR's orbiting radars will image at resolutions of 5-10 meters to identify and track subtle movement of the Earth's land and its sea ice, and even provide information about what is happening below the surface. NISAR will also provide information on crop area and forest biomass over time and with enough detail to reveal changes on field scales. Products are expected to be available 1-2 days after observation, and within hours in response to disasters, providing actionable, timely data for many applications.

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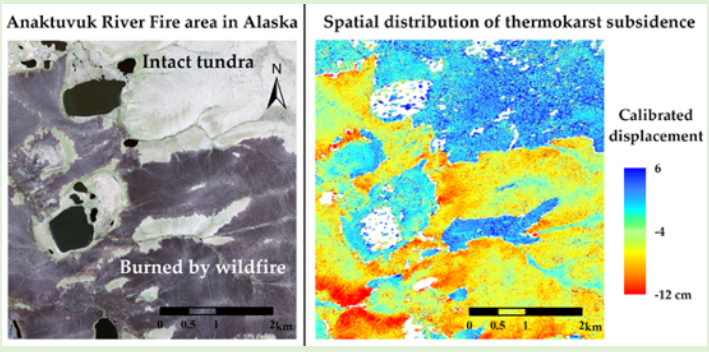
Permafrost degradation has major implications for the economy. As permafrost thaws and ground ice melts, the soils lose strength and the surface can subside and collapse. The costs to maintain and repair infrastructure affected by thaw-induced soil failure and subsidence are projected to continue to increase rapidly in Alaska and across the Arctic. Transportation is particularly affected, as roads and airstrips may require increased maintenance or relocation. Permafrost thaw also contributes to increasing rates of coastal and fluvial erosion, which threaten numerous Arctic communities. Permafrost degradation and thaw-induced subsidence further change local drainage and wetness. Consequently, changes in permafrost conditions in a warming world will have complex, multi-faceted impacts on transportation conditions, water resources, and ecosystem services, such as the provision of fish, game, and timber.

Monitoring ongoing and predicting future changes in permafrost landscapes is critical for the economy, local residents, and the scientific community. However, such assessments are complicated by the sparsity of observations and by the complex interactions between permafrost soils, wildfire, ecosystems, and hydrology. To address the paucity of ground observations in these vast, sparsely populated regions, satellite observations such as those from NISAR are critical. They are also crucial for documenting and understanding the complex interactions that determine the vulnerability and resilience of permafrost. For instance, wildfires constitute a major disturbance that can induce permafrost degradation and, ultimately, disappearance. However, depending on the local conditions, permafrost may recover aided by the rapid regrowth of reflective vegetation and insulating organic soils.

NISAR will enable unprecedented insights into changing permafrost landscapes. It will provide precise measurements of subsidence induced by the melting of subsurface ice as permafrost thaws, and of annual frost heave and settlement, which occurs as water expands upon freezing and contracts upon thawing. Using a technique called synthetic aperture radar interferometry, the radar observations can be turned into maps of surface elevation changes. Infrastructure planners, businesses, and residents alike will be able to access critical information on subsidence and associated hazards related to frozen ground dynamics, thanks to NISAR's open data policy. NISAR's frequent radar observations will further provide a detailed record of changes in surface vegetation, soil moisture, lake and river ice, and inundation, all of which are vital to transportation conditions, water resources, and provision of food and raw materials. In summary, NISAR will enable unprecedented insight into the hazards, as well as the resources, of these rapidly changing regions.

Fire-induced permafrost degradation

At more than 200,000 acres, the Anaktuvuk River Wildfire on Alaska's North Slope triggered widespread degradation of the underlying ice-rich permafrost. InSAR analyses revealed pronounced subsidence within the fire perimeter in 2008-2009. The comparison between a high-resolution optical image (left) and the SAR deformation map (right) clearly shows that the distribution of intense subsidence was restricted to the burned area. Fieldwork and high-resolution imagery corroborate the interferometric findings of pronounced and spatially variable subsidence. InSAR techniques have great potential for quantifying subsidence induced by permafrost degradation with a high spatial and temporal resolution.



SAR deformation analyses reveal that the areas of large post-fire subsidence (shown in yellow red in the right panel) coincide with the burn scar (dark patches in the left panel)