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Utility of SAR and Forward-Looking Infrared (FLIR) Imagery for Identification of Salmon Spawning Habitat During Winter in a Large, Glacial River

By Lisa Wirth, Alaska Satellite Facility

The large, glacial rivers that characterize the Alaskan interior are extraordinarily dynamic: glacial flow regimes, combined with heavy sedimentation, create a complex habitat template for the variety of fish species that use these systems. The remoteness and size of interior rivers present difficulties for characterizing the availability, dynamics, and use of critical habitats. Traditional methods of mapping and quantifying riverine habitats are typically limited to a small spatial and temporal extent (e.g., foot-based surveys conducted on reach scales with a single-site visit), and fail to capture important multi-scale ecological and physical processes that contribute to fish productivity (Geist and Dauble, 1998; Baxter and Hauer, 2000; Fausch, et al., 2002). However, by integrating traditional methods of habitat data collection with the use of remote-sensing technologies, it is possible to characterize fish habitat at intermediate spatial and temporal grains (e.g., river segments, years to decades), scales that are most relevant for fish populations (Fausch, et al., 2002; Torgersen, et al., 2006).

In winter, ice-free areas (i.e., open water) in the Tanana River are thought to be a result of upwelling water that prevent surface freezing, even when ambient temperatures reach −50° C. Tanana River fall chum-salmon spawn in late October and early November, and thereby have limited time for egg incubation (Salo, 1991). Warm, upwelling water would shorten this incubation time, allowing for successful fall spawning. The potential importance of upwelling means identifying open-water areas as an important step for chum-salmon management and research on the Tanana River. However, assessing the location and persistence of these areas through time is a particular challenge for this large and remote system. Although the physical process of upwelling and biological process of fish incubation is thus far unobservable using remote-sensing techniques, areas of open water can be identified using synthetic aperture radar (SAR) imagery (Figure 1). This phenomenon can be observed and monitored through time at intermediate spatial and temporal scales. The goal of this study was to evaluate the potential for SAR imagery to monitor the presence and persistence of open-water areas that are spawning habitat for fall chum salmon in

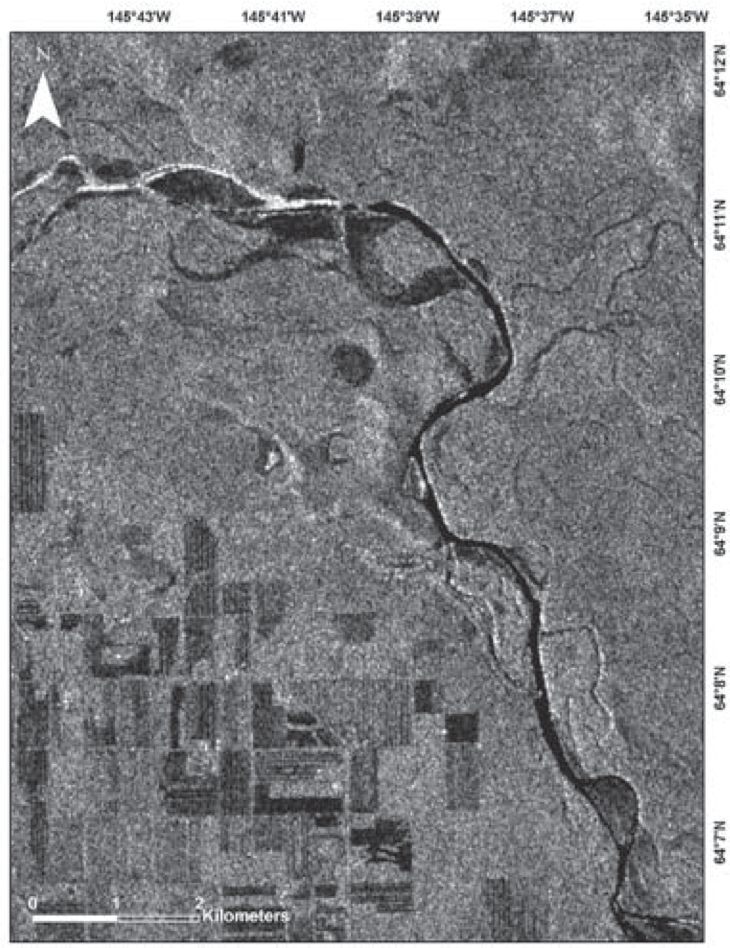

Figure 1: March 1997, RADARSAT-1 image of the Tanana River near Big Delta, Alaska, showing open water in dark tones due to low backscatter.

the mainstem Tanana River and model habitat selection from spatial distributions of individuals through the use of radio-telemetry.

RADARSAT-1 images, collected from C-band (5.7-cm wavelength) taken from the standard-beam mode, acquired by the Alaska Satellite Facility (ASF), collected in March 1997, 2000-2003, 2005, 2006, and 2008, proved useful for identifying the presence and persistence of open water through time. Results from the stacked layering of the standard-beam data showed spatially persistent open-water areas in the Big Delta, Alaska, region. Results showed that nearly half of the tagged

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spawning salmon chose to spawn in mapped open-water areas that accounted for less than 5% of the habitat that was available, demonstrating the preferential use of these areas as spawning habitat. FLIR images of persistent open-water areas mapped from SAR imagery were collected in November 2009 to show surface-temperature patterns and localized hotspots. This allowed for the identification of areas with strong groundwater inputs and complex thermal heterogeneity, creating a suitable thermal environment for egg incubation (Figure 2).

Fish populations carry out life-history events at intermediate spatial and temporal scales, and this scale is said to be the most difficult to survey (Fausch, et al., 2002). Previously, satellite imagery was used to study stream habitat at the basin scale and only to analyze one-dimensional channels that do not show habitat features required by fish (Fausch, et al., 2002). Using SAR imagery, identified in spatially and temporally persistent ice-free areas, is important for fall chum-salmon spawning at the intermediate scale. The information was combined with a more focused intermediate analysis using FLIR imagery that identified thermal heterogeneity within persistent open-water areas. This approach created an opportunity for a view of a system at a watershed scale – the scale for which lands are managed and salmonids carry out life-history events (Rieman and Dunham, 2000). Technological advancements and the use of remote sensing, in part, circumvent spatial and temporal constraints in traditional freshwater ecological studies for assessing fish habitat.

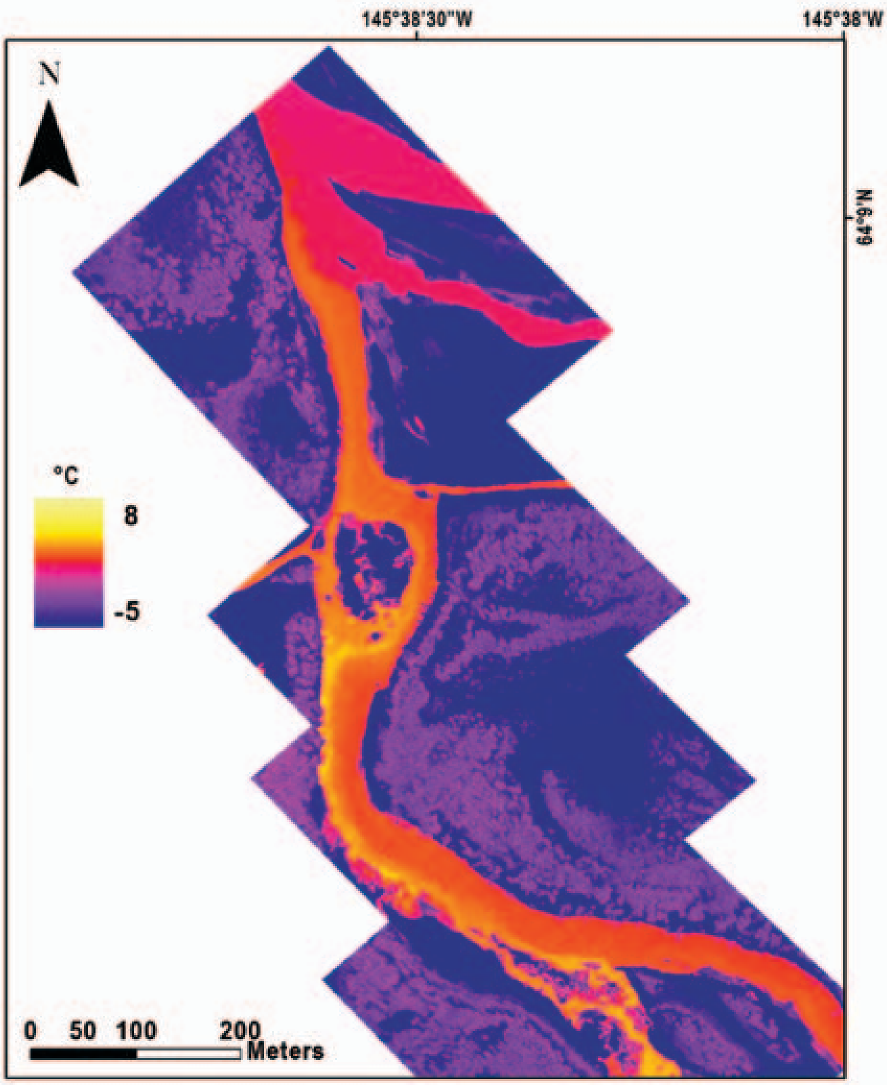

Figure 2: FLIR image of persistent open-water area mapped from SAR imagery showing thermal heterogeneity of upwelling groundwater influx. Yellow shades (warmer water) indicate upwelling groundwater. Pink shades (cooler water) indicate surface water.

Information on obtaining SAR data is available online at http://www.asf.alaska.edu/. This research was funded through the Arctic Yukon Kuskokwim Sustainable Salmon Initiative, the Alaska Department of Fish and Game-Commercial Fisheries Division, and the Tanana Chiefs Conference.

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INTERFEROGRAM: A Bold New Direction

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Figure 1

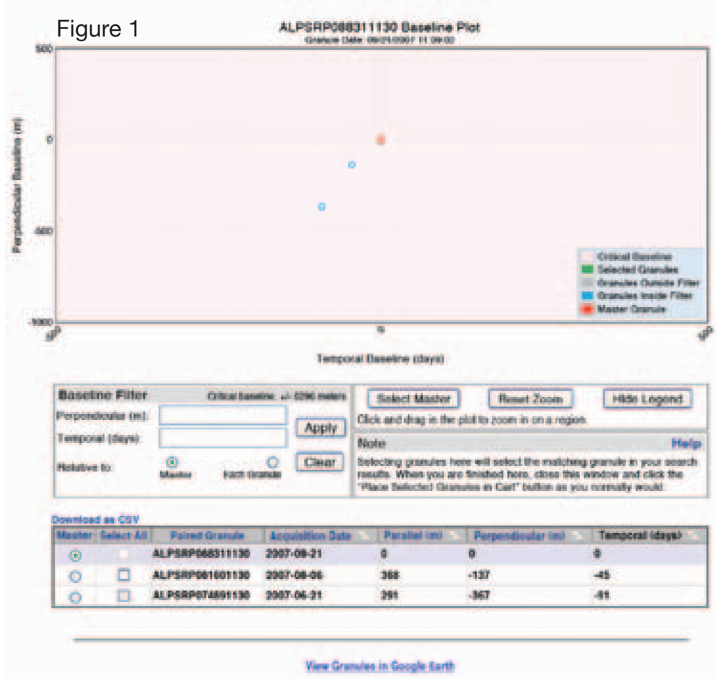
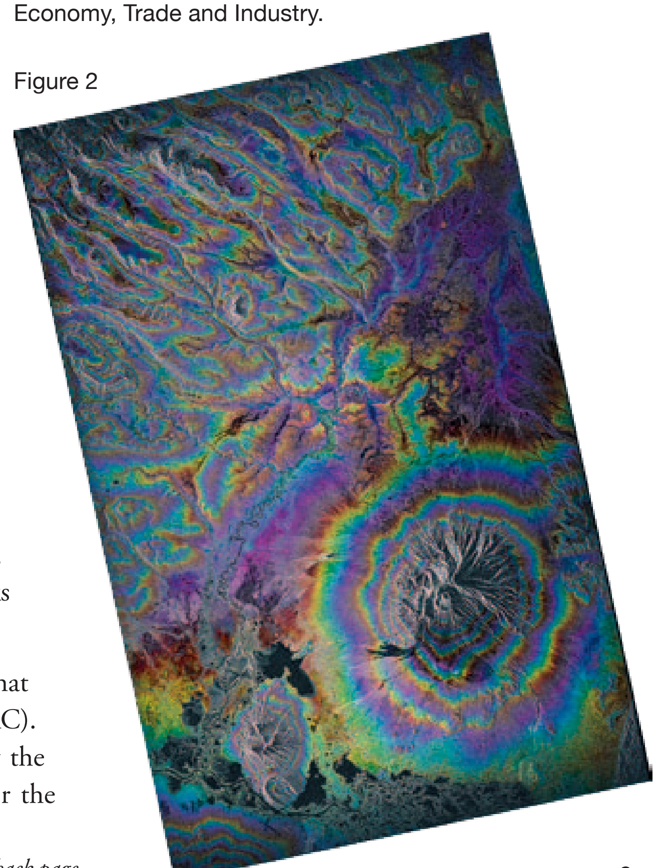


Figure 1: An example of the URSA baseline plot. Users are provided with the capability to observe the perpendicular and temporal baseline distribution of an InSAR stack based on the selection of a desired master, filter granules, and select granules to order.

Figure 2: ALOS-PALSAR interferogram overlaid on the amplitude of the master image, as produced by the ASF production system. Master Image: ALPSRP088311130 acquired 2007-09-21. Slave Image: ALPSRP074891130 acquired 2007-06-21. Klyuchi, Russia. The copyright for the scenes used to create this image is held by the Japan Aerospace Exploration Agency/Ministry of Economy, Trade and Industry.

Figure 2



The ASF SAR Data Center (SDC) now provides users the capability to search-and-order Interferometric SAR (InSAR) pairs through the online User Remote-Sensing Access (URSA) interface and has expanded the data-product offerings to include custom InSAR products. Users are now capable of identifying stacks of SAR granules suitable for interferometric processing, assess the perpendicular and temporal baseline distribution of a stack by interacting with the online baseline plot tool (Figure 1), and select pairs to order a number of interferometric products.

By exploiting phase differences between two SAR images, interferometric processing techniques provide estimates of topographic changes to a subcentimeter level. In principle, data from satellites in the ASF archive are suitable for InSAR, as long as the image pair adheres to some very basic rules. The data needs to be acquired by the same satellite, in the same beam mode, and with the same look direction. There are a few exceptions to this rule. The tandem mode of the European Remote-Sensing Satellite-1 (ERS-1) and ERS-2 satellites provides data very suitable for InSAR applications because both satellites are identical and meet the criteria above with a favorable temporal baseline of one day. ScanSAR data, available for RADARSAT-1 and Advanced Land Observing Satellite Phased Array L-band SAR (ALOS PALSAR), are another special case as these are formed by combining several beam modes in one swath. The interferometric processing of ScanSAR data is still on a research level that does not allow the use in a production environment. This data type has not been included in the InSAR capable datasets.

In the InSAR tab of the search results in URSA, users will find granules organized into lists of interferometrically-suitable datasets, referred to as InSAR stacks. InSAR stacks are composed of granules that cover the same geographic region, are from the same platform, and were acquired with the same beam mode, look angle, and bandwidth. Theoretically, two granules in an InSAR stack may be used to create an interferogram, however, image selection depends entirely upon the specific application of study. Often researchers will explore the distribution of baseline lengths to determine the feasibility of interferometry for a given pair and application. Baseline is the temporal and spatial distance between two satellite observations and its length provides an indication of the sensitivity to topographic height. URSA users may access baseline plots to view granule acquisition dates, parallel, perpendicular, and temporal baselines, as well as to filter InSAR stacks and observe only those granules that are within specified baseline lengths.

Users who order an interferogram from ASF will receive a beta product that has been processed using the Repeat Orbit Interferometry Package (ROI PAC). ROI PAC is an open-source software package developed and distributed by the Jet Propulsion Laboratory, with contributions from the user community, for the purpose of creating SAR interferograms (Figure 2).

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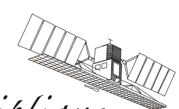
ASF offers users four processing options: UTM_GEOTIFF, COMPLEX_PAIR, COMPLEX_IGRAM, and COMPLEX_PAIR_AND_IGRAM. The UTM_GEOTIFF is the basic InSAR product and includes an interferogram, coherence image, and amplitude image geocoded to UTM (Universal Transverse Mercator) projection and stored in GeoTIFF format. InSAR product packages produced at ASF include the contents of the UTM_GEOTIFF package. For users interested in completing their own ROI-PAC processing, the COMPLEX_PAIR package contains the complex Master and Slave data in ROI-PAC format and the COMPLEX_IGRAM package provides the complex interferograms in ROI-PAC format. For those interested in the additional items contained in both the COMPLEX_PAIR and COMPLEX_IGRAM product packages, the COMPLEX_PAIR_AND_IGRAM option is offered.

As the ASF SDC strives to promote, facilitate, and participate in the advancement of remote-sensing data, ASF is pleased to announce the beta release of the InSAR product packages. Whether your interest in InSAR is for topographic mapping, deformation, glacier monitoring, volcanic observation, or other applications, ASF invites your feedback on their InSAR tools and products, and looks forward to making improvements that will better serve your research and scientific needs.



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