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Special Issue: Seven research highlights from the ASF SAR DAAC* User Working Group

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* Synthetic Aperture Radar Distributed Active Archive Center
Insights into Aleutian Volcanism from InSAR Observations

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Conceptual models of the magma plumbing systems and behaviors of many volcanoes in the Aleutian arc have been made possible by combining interferometric synthetic aperture radar (InSAR) data with information from the geologic record, accounts of historical eruptions, and data from seismology, petrology, gas geochemistry, and other sources.

With its global coverage, all-weather imaging capability and unprecedented spatial resolution, InSAR has become an important technique for studying magma dynamics in remote regions.

To study Aleutian volcanism, we processed nearly 12,000 SAR images, most of which were provided by ASF, acquired by ERS-1, JERS-1, ERS-2, Radarsat-1, Envisat, ALOS, and TerraSAR-X from the early 1990s to 2010.

We combined these images to produce about 25,000 interferograms, which were analyzed for evidence of surface deformation at most of the arc’s Holocene volcanoes. Where surface displacements were sufficiently strong, we used analytical models to estimate the location, shape, and volume change of deformation.

We summarized that these processes include: (1) time-variant volcanic inflation and magmatic intrusion,
(2) deformation preceding and accompanying seismic swarms, (3) persistent volcano-wide subsidence at calderas that last erupted tens of years ago, (4) episodic magma intrusion and associated tectonic stress release, (5) subsidence from a decrease in pore-fluid pressure in active hydrothermal systems, (6) subsidence of surface lava and pyroclastic flows, and (7) no deformation at some frequently erupting volcanoes where deformation might be expected. Among the inferred mechanisms are magma accumulation in and withdrawal from crustal magma reservoirs, pressurization/depressurization of hydrothermal systems, and thermoelastic contraction of young lava or pyroclastic flows. This work demonstrates that deformation patterns and associated magma supply mechanisms at Aleutian volcanoes are diverse and vary in both space and time.

Finally, we compared the InSAR observations from the Aleutians with those from the Andes and Indonesia to highlight similarities and differences between volcanic arcs.


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ALOS-Based Constraints on Tree Heights in the Pacific Northwest

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Our team explored the use of ALOS PALSAR data in developing a potential proxy for biomass in the Pacific Northwest1 (Figure 1). The Pacific Northwest, with its high rates of precipitation, tall trees2,3, and steep relief, presents challenges to the use of interferometric synthetic aperture radar (InSAR). It is also home to dense population centers, industries ranging from fishing to technology to logging, and associated hazards from landslides, earthquakes, and volcanism.

We examine InSAR time series covering the region, focusing on variations in the height of the phase-scattering center between areas with tall trees and bare ground where logging occurred (Figure 1a,b). Focusing on short spatial scales between these two area types minimizes the contributions from the atmosphere and orbital errors (which have larger spatial scales). The linear relationship (Figure 1c) between the interferometric phase change between the clearcut and surrounding trees and the perpendicular baseline of each interferogram has a slope proportional to the height of the center. This approach requires accurate, time-dependent maps of the clearcuts and standing forest,

Figure 1: Small region in one interferogram (a) showing rectilinear pattern of clearcuts, visible in optical imagery (b). (c) Phase change in bare regions vs. perpendicular baseline (black dots, error bounds), has a slope proportional to the inferred height of phase scattering center height (blue line); red dots indicate interferograms with rainfall within six hours before SAR acquisitions. InSAR image © JAXA / METI 2009.
which we generate using Landsat imagery.

Several of the interferograms in our dataset violate the linear relationship between baseline and phase change across the clearcut (red dots, Figure 1c); at relatively high baselines there is essentially zero difference in interferometric phase across clearcut boundaries. Further inspection shows that these all include dates where there was heavy rainfall immediately preceding the SAR acquisition; the resulting wet ground then contributes to the returned signal. Culling those dates using data from local weather stations results in stronger constraints on heights for the phase scattering center heights within the trees – a potential proxy for biomass that can be derived from the ALOS PALSAR catalog.


Ice Velocity Mapping in Antarctica

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Ice sheets are acknowledged by the World Meteorological Organization and the United Nations Framework Convention on Climate Change as an Essential Climate Variable. Ice velocity is a crucial geophysical parameter that can be measured using spaceborne synthetic aperture radar (SAR) data. We have produced a continent wide ice velocity map based on data acquired during the International Polar Year, and are now conducting a series of regional studies analyzing data from several epochs.

On Ross Ice Shelf, our results confirm the deceleration of Mercer and Whillans Ice Streams, with a 12-year difference in speed of −16.7 % and −25.3 %, respectively. The resulting change map shows, for the first time, the entire spatial extent of the deceleration. The reduction in speed extends hundreds of km

Ice-surface velocity maps for Central Antarctica for 1997 (a) and 2009 (b) overlaid on a MODIS mosaic; (c) shows the difference in speed (2009–1997) for the entire region. Blue tones indicate a deceleration, red tones an acceleration. The two dark red regions on the ice shelf edges (Ross Ice Shelf
upstream and onto the shelf. near Roosevelt Island and Filchner Ice Shelf) indicate pre-calving. Source data © CSA 1997, 2009.

Our results contrast the relative stability of Central Antarctica with a dramatic increase in flow speed and associated mass loss in the Amundsen Sea Embayment in West Antarctica, with an increase in ice discharge (77% since 1973) into the ocean from the collective ensemble of these large glaciers. During retreat across their respective ice plains, Pine Island and Smith Glaciers underwent a rapid increase in ice discharge. However, since 2009, the ice discharge of Pine Island has remained steady. Thwaites Glacier, which had experienced a steady flow since 1992, started to speed up in 2006 and has increased its ice discharge considerably since. The acceleration of Thwaites Glacier more than compensated for the recent stoppage of the acceleration of Pine Island Glacier. Using differential SAR interferometry, we also measure a grounding line retreat of up to 35 km for these glaciers between 1992 and 2011.

Data analysis and Earth System Data Record production is conducted at the Department of Earth System Science, University of California, Irvine, under a contract with NASA’s MEaSUREs program. The velocity maps are available at NSIDC. SAR data were made available for this project courtesy of the Polar Space Task Group.


A Forest-Height Map for the State of Maine

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In order to create a forest-height map (Figure 1) for the state of Maine, we used 37 pairs of repeat-pass ALOS PALSAR images to relate the interferometric decorrelation signature to vegetation height.

An advantage of deriving heights from interferometric synthetic aperture radar (InSAR) is that the data can be collected autonomously using an orbiting satellite sensor such as ALOS PALSAR, and does not require additional information, such as the below-canopy topography, in order to estimate height. Heights were calibrated by using a 44,000-hectare map of heights obtained in central Maine from NASA's Land, Vegetation, and Ice Sensor (LVIS). Areas of overlap between adjacent PALSAR scenes were used to propagate the solution from the central region near the Howland Forest region (Figure 2) to the entire state.
Hurricane Morphology and Wind-Speed Climatology from SAR

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As the two examples below illustrate, SAR imagery offers a wealth of data for meteorology.

Cyclones and typhoons: Ever since the first generation of meteorological satellites in the 1960’s, Atlantic tropical cyclones and their Pacific counterparts typhoons have been monitored from conventional weather-satellite sensors with passive remote-sensing instruments. Many media have published striking pictures of the cloud-top structures of tropical cyclones at kilometer spatial resolution. Since the launch of the first spaceborne synthetic aperture radar (SAR) onboard Seasat in 1978, tropical cyclones have also been observed with SAR, which penetrates clouds with active microwave radar. SAR then receives radar backscatter from the ocean surface. As a result, a SAR image shows the imprint of a tropical cyclone on the water. Examples of these sea-surface imprints are shown in Figure 1, revealing shapes of tropical cyclone eyes.

These images are from a study of sea-surface imprints of 84 hurricanes over 10 years, from 74 RADARSAT-1 SAR and 10 Envisat ASAR images containing tropical cyclone signatures. Their features include eye structure, mesovortices, rain bands, and arc clouds, as well as rarities such as high winds within an eye.

Wind speed: The retrieval of wind speed from SAR imagery has matured significantly over the past decade. Estimating wind speed from SAR imagery depends on the calibration of normalized radar cross section (NRCS). Soon after the launch of RADARSAT-1 in 1995, ASF began producing calibrated imagery in near real time. During the 17 years of RADARSAT-1 data, the speed and precision of processing improved. The mission’s cessation offered an opportunity for ASF to re-process the data, incorporating the knowledge gained from previous processing. This reference set provided data for the analysis pictured in Figure 2 of the wind-power flux density off the coasts of Delaware and Maryland, derived from over 1,400 RADARSAT-1 images.

Monitoring Land Subsidence and Floodplains

Brian D. Conway - Arizona Department of Water Resources

Since 2005, more than 25 land-subsidence features in Arizona, collectively covering more than 1,200 square miles of the state, have been monitored with the use of interferometric synthetic aperture radar (InSAR) data by the Arizona Department of Water Resources (ADWR). One striking example is McMullen Valley in west-central Arizona, site of both the town of Wenden and Centennial Wash, a watershed of the Gila River.

ALOS-1 PALSAR InSAR data from the Alaska Satellite Facility has been a critical resource in identifying both land subsidence in the valley and changes to the natural flow pattern around the town and the watershed. We first delineated land subsidence in the valley in 2008 with InSAR data.

In 2010, Centennial Wash flooded Wenden for the second time in 10 years. Wenden is within a land-subsidence bowl, which has exacerbated the recent flooding.
The department has documented land subsidence of 2.7 feet in the center of the bowl using recent GPS survey data compared to survey data from 1991.

The InSAR data have provided the department and floodplain managers a three-dimensional view of how the subsidence has changed the natural flow pattern around Wenden. We continue to collect InSAR data to monitor the valley.

**Extent of Inundated Wetlands from ALOS SCANSAR Data**

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**ALOS PALSAR**, an orbiting L-band SAR launched by the Japanese Aerospace and Exploration Agency (JAXA) in 2006, pursued a global observation strategy through the mission’s end in mid-2011. The PALSAR instrument most often operated in a subset of its available modes: fine beam HH polarization, fine beam HH and HV polarization, and SCANSAR HH. Restriction of both the mode and the look angle for many of the observations produced a time sequence of regionally consistent imagery.

The need for improved wetland characterization motivated the creation of an Inundated Wetlands Earth System Data Record (IW-ESDR) as part of NASA’s Making Earth System Data Records for Use in Research Environments (MEaSUREs) program. The program has generated maps of wetland extent and inundation dynamics at two scales: 100 m, using ALOS PALSAR ScanSAR imagery; and 25 km, using multiple satellite datasets. Data inputs for IW-ESDR 100 m products were 350-km-wide ScanSAR strips acquired and processed through JAXA. These strips were calibrated, geocoded to the SRTM DEM, and assembled into regional mosaics.

Some processing of this data, particularly orthorectification, has been conducted on “Pleiades” at the NASA Advanced Supercomputing Division (NAS) at the NASA Ames Research Center.

**South America multi-temporal ALOS PALSAR ScanSAR image mosaic (2007-2010). This L-band HH polarization image has been radiometrically terrain corrected using the SRTM DEM. © JAXA/METI 2007-2010.**
inundation classification based on a simple image brightness threshold was generated. Examination of sequences of image classifications reveals the dynamic nature of the Pacaya-Samiria wetlands in Peru.

This research was within the framework of the ALOS Kyoto & Carbon Initiative. ALOS data were provided by JAXA EORC. Supporting resources were provided by the NASA NAS High-End Computing Program. This work was partially performed at the Jet Propulsion Laboratory, California Institute of Technology.

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