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RADARSAT-1 Observations of Circulation Features Associated With a Bowhead Whale Feeding Hotspot Near Barrow, Alaska

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Satellite imagery acquired by earth-orbiting satellites provides spatial and temporal reference frames for illustrating the character of and changes to oceanographic features and phenomena. In the Arctic, where persistent cloud cover limits usable visible-band imagery of the ocean, radar imagery is often the best visualization tool for the ocean surface. This all-weather capability was exploited as part of an interdisciplinary study of a bowhead whale feeding hotspot that develops in late summer and early autumn of most years near Point Barrow, Alaska (Figure 1). The intensity of this feeding hotspot varies with wind-driven changes to the local ocean circulation. When winds are weak (less than 5 m s-1, ~10 kts), a strong oceanographic front forms along the southern edge of Barrow Canyon where the Alaska Coastal Current flows east-northeastward adjacent to the southern flank of the canyon. This front is of particular local interest because it is indicative of aggregation and retention of zooplankton prey in the shallow coastal waters of the western Beaufort Sea and, as a result, is a locus for bowhead whales pausing to feed during their westward fall migration.

Free-floating sea ice serves as a proxy for the distribution of zooplankton prey and is a convenient tracer to illustrate the location of this oceanographic front and the attendant aggregation and retention of zooplankton in the shallow coastal waters of the western Beaufort Sea under weak wind conditions. For example, a RADARSAT-1 image, acquired on 23 October 2007 (Figure 2a),

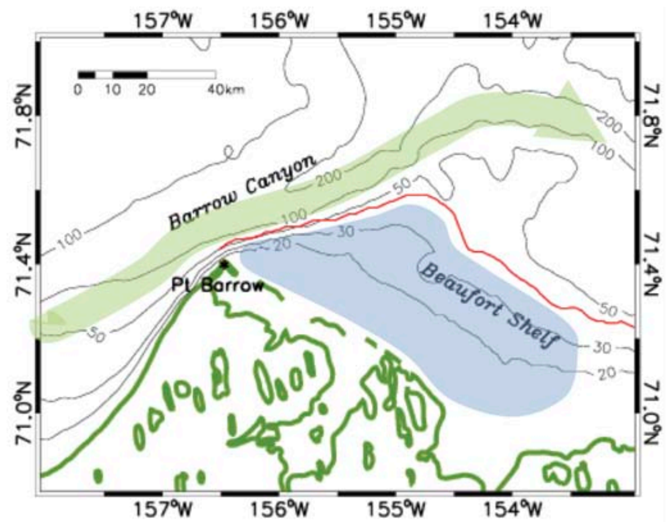

Figure 1: Schematic of the Barrow, Alaska, area. The green arrow shows the idealized trajectory of the Alaska Coastal Current. The blue-shaded area shows the location of the Barrow area bowhead-whale feeding hotspot. The red line delineates the nominal seaward boundary of the shallow inner Beaufort Shelf.

when average winds were weak (4.2 m s−1) clearly shows a frontal boundary along the southern edge of Barrow Canyon separating open water over the canyon from grease/new ice that is largely confined to the shallow western Beaufort Shelf. A second front separates more consolidated sea ice from less consolidated sea ice. A second RADARSAT-1 image, acquired on 30 October 2007 (Figure 2b, i.e., one week after the Figure 2a image), during strong winds (7.4 m s−1) from the east shows the grease/new ice that was previously confined to the western Beaufort Shelf

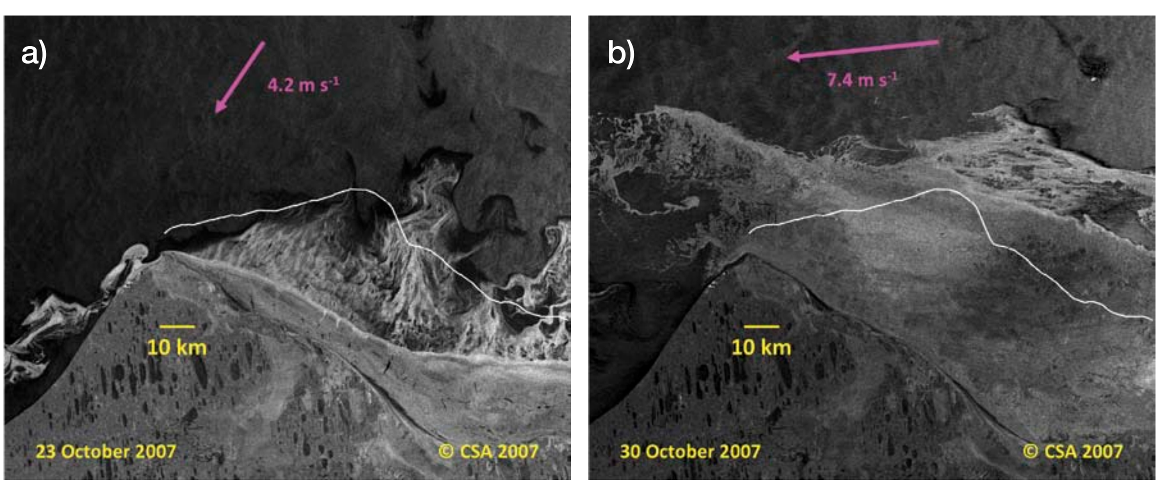

Figure 2: The white line in each image delineates the nominal seaward boundary of the shallow inner Beaufort Shelf. The annotated pink arrow in each image identifies the wind speed and direction.

Continued on page 2

Continued from front page

has been pushed northwestward off-shelf into the deeper waters across Barrow Canyon. The fronts along the southern edge of Barrow Canyon and parallel to the Beaufort Coast that were present during weak wind conditions are no longer present.

Based on the spatial distributions of sea ice shown in these two synthetic aperture radar (SAR) images, it is inferred that the local ocean circulation promotes the aggregation and retention of zooplankton prey in the shallow waters of the western Beaufort Sea when winds are weak, but that local circulation is altered by strong easterly winds so as to not retain or aggregate zooplankton on the western Beaufort Shelf. If the ocean circulation associated with the weak wind regime, in fact, concentrates and retains zooplankton in sufficient quantities to support efficient feeding by groups of bowhead whales, then whale groups should more likely be observed over the Beaufort Shelf when winds are weak. Conversely, if, as indicated by Figure 2b, strong winds from the east do not promote accumulation and retention of zooplankton on the western Beaufort Shelf, then observations of whale groups should be less common during these windier conditions.

These inferences were validated by parsing aerial observations of bowhead whales, obtained during September-October 1982-2009, by the Bowhead Whale Aerial Survey Project (BWASP) according to the wind regime associated with each observation. Figure 3a shows that 62 large groups (4 or more individuals) of whales were observed when winds were weak (<5 m s-1) and only three large groups of whales were observed (Figure 3b) when winds were from the east and were moderate to strong (>5 m s-1). Accordingly, it is reasonable to infer that weak winds lead to the establishment of a shelf-break front adjacent to Barrow Canyon and that the presence of this front is both an indicator and promoter of better feeding opportunities for bowhead whales on the western Beaufort Shelf.

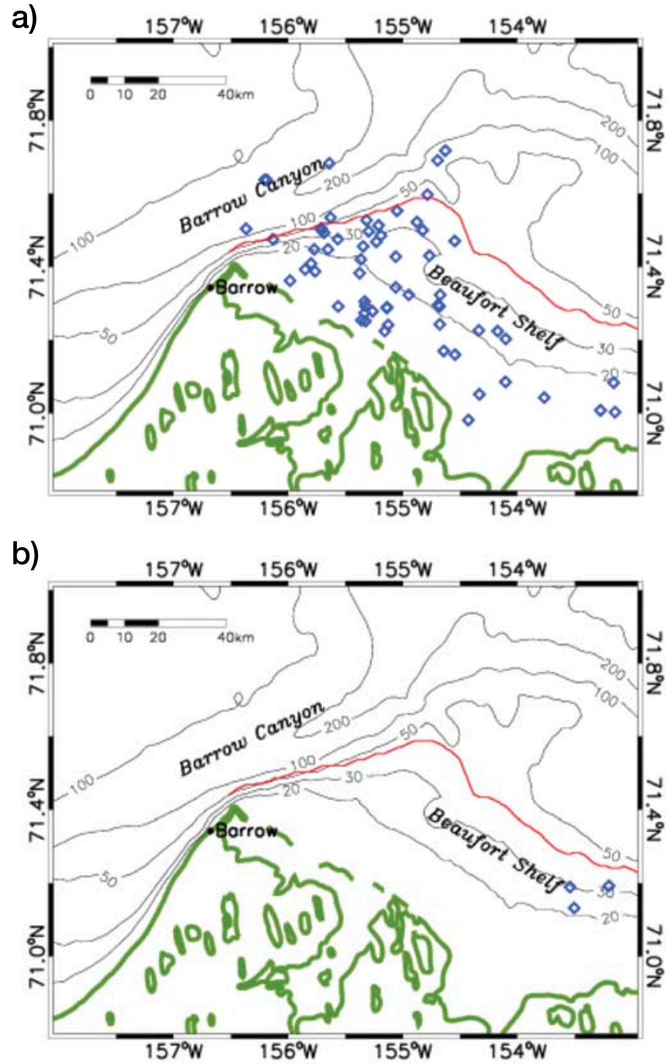

Figure 3: Locations of large groups (4 or more animals) sighted BWASP observers during **a)** weak wind conditions (<5 m s-1) and **b)** strong east wind conditions (> 5 m s-1), September-October 1982-2009. The red line in each figure delineates the nominal seaward boundary of the shallow inner Beaufort Shelf.

ASF Student Intern From Karlsruhe, Germany, Improves PolSAR Classification *by Donald Atwood, Ph.D.*

For the last 4 years, ASF has actively supported an internship program in cooperation with Karlsruhe University in Germany. For graduation, Karlsruhe engineering students must complete a 6-month internship to apply their research skills. For ASF, this program has provided an opportunity to hire highly-skilled students to perform innovative research using ASF-archive datasets. Past projects have led to research on improved detection of ships, topographic compensation of polarimetric data, and the mapping of radio-frequency interference (RFI) effects on Advanced Land Observing Satellite Phased Array L band SAR (ALOS PALSAR). The advantages of the program are numerous: The cultivation of a new generation of SAR researchers, increased community awareness of ASF datasets, the development of new SAR innovations, and the development of cross-institutional ties.

In the summer of 2010, Karlsruhe Senior, Moriz Wurth, traveled to Alaska to work on the development of Polarimetric SAR (PolSAR) applications for the Jet Propulsion Laboratory (JPL) Uninhabited Aerial Vehicle (UAVSAR). The choice of

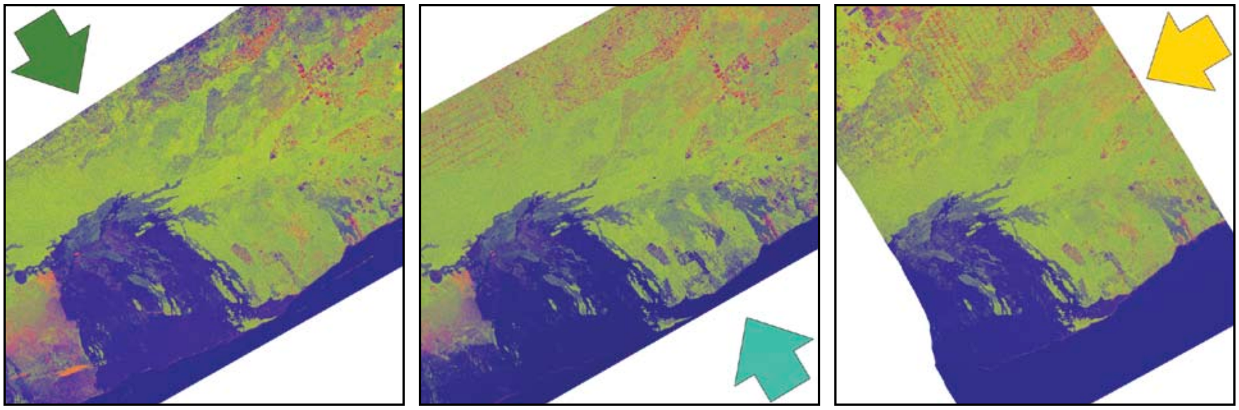

Figure 4: Color-coded VanZyl decompositions. The arrow indicates the radar look direction.

UAVSAR was a natural for an ASF-intern project. ASF has become the archive for this JPL-created dataset. In addition to being unrestricted and available for immediate download (making it somewhat unique for SAR data), UAVSAR-PolSAR data are a magnificent dataset for those seeking to perform PolSAR research. The quad-pol, L-band data have a -47 dB noise floor, are high resolution (<6 m), and have been terrain corrected.

Besides investigating oil-spill signatures for the Deepwater Horizon event and addressing dihedral rotation in urban settings, Moritz explored the way that SAR scattering mechanisms are impacted by local incidence angles. Using polarimetric decompositions, such as those developed by Freeman, VanZyl, and Yamaguchi, the interactions of SAR microwaves with land cover can be characterized as being double bounce, surface bounce, or volume scattering. Moritz' project was to follow up on results in which UAVSAR-polarimetric scattering mechanisms were shown to be strongly dependent upon local incidence angle. Moritz wanted to find out whether he could optimize PolSAR-classification accuracy by utilizing multiple view angles.

This inquiry was facilitated with multiple UAVSAR views of the Kilauea Volcano on the Big Island of Hawai'i. The area is interesting for its diversity of land cover as well as its significant topography. The latter meant that each of the three contemporaneous view angles of the same region afforded significantly different local incidence angles for each pixel on the ground. The impact of different local incidence angles on scattering mechanism was explored by performing VanZyl decomposition on each of the three images. Figure 4 shows RGB images of the three decompositions, in which red represents double bounce, blue represents surface bounce, and green is volume scattering. While qualitative agreement exists between the three images, the variability caused by differences of incidence angle is clearly evident. A relevant question becomes whether the three datasets can be merged so as to improve the classification results over any one scene.

For each given ground sample (pixel), the three VanZyl decompositions are analyzed so as to identify the one offering the strongest double-bounce component. The polarimetric properties of that pixel were then included in a new synthesized polarimetric image. Thus, pixel-by-pixel, a new polarimetric image that optimizes the double-bounce scattering mechanism was created.

Using an unsupervised polarimetric classifier in PolSARpro, the synthesized image was classified into 16 segments and using cluster-busting techniques, the 16 segments were merged into five land-cover classes: water, vegetation, lava, open area, and urban. A similar classification procedure was applied to the three original images as well; yielding a total of four land-cover classifications that can be compared for accuracy. Classification accuracy was determined by using 400 randomly sampled points whose land-cover types were determined by inspection of aerial imagery (Figure 5).

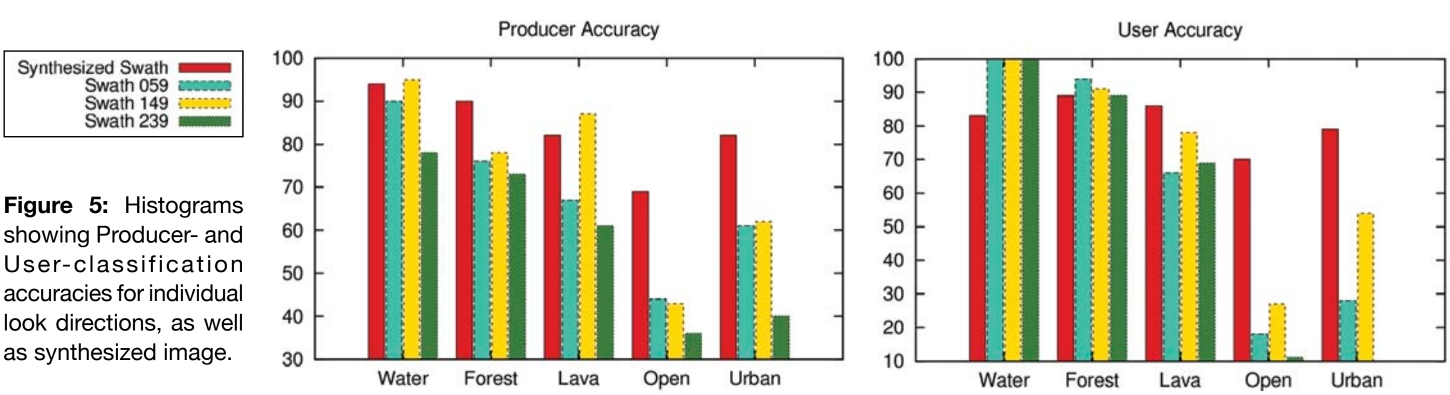

Figure 5: Histograms showing Producer- and User-classification accuracies for individual look directions, as well as synthesized image.

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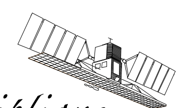
Continued from page 3

With the exceptions of water and forest classes in the User-Accuracy graph, the synthesized image yielded either the first or second highest accuracy for every other class. The improvement in the case of open land and urban is seen to be very significant, with the synthesized accuracy more than 2x greater than that of individual user accuracies. In a field where significant effort has been expended to improve classification accuracy by several percentage points, improvements on the order of 50% are indeed striking. Nevertheless, further research may yield better ways to generate synthetic images, with even higher classification accuracy.

These results will be presented at the 9th European Conference on SAR (EUSAR) 2012, in Nuremberg, Germany. The generation of significant scientific outcomes from the internship program is a win/win for the student interns and ASF. The student interns get real-world research opportunities in remote sensing and ASF gets capable young researchers who bring energy and a European perspective to their 6-month stay in Alaska.



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