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Characterizing and Correcting Residual RFI Signatures in Operationally Processed ALOS-PALSAR Imagery

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Radio-frequency interference (RFI) has long been identified as a problem in L-band Synthetic Aperture Radar (SAR), as it is limiting the application, performance, and data quality of SAR at many areas around the globe. Several algorithms for RFI mitigation have been developed throughout the recent decades (Le, et al., 1998; Reigber and Ferro-Famil, 2005; Rosen, et al., 2008) in response to this problem.

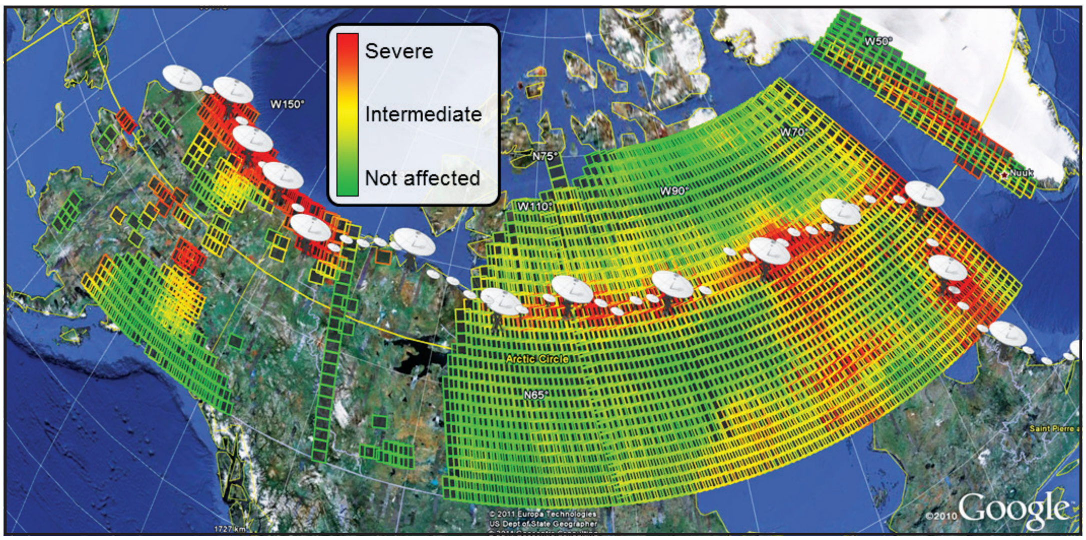

Figure 1: Spatial distribution and strength of RFI signatures in the American Arctic analyzed from a set of ALOS-PALSAR images. The bounding boxes show the geographic location of ALOS-PALSAR data that has been analyzed for RFI. The color of the bounding box classifies the strength of the RFI interference. Several areas of high RFI can be identified across the Arctic coast.

Especially in the American Arctic, RFI distortions in L-band SAR data are a widespread problem (Doulgeris and Meyer, 2011), (Meyer, et al., 2011). Areas affected by severe RFI are shown in Figure 1. Here RFI levels in Advanced Land Observing Satellite-Phased Array L-band SAR (ALOS-PALSAR) data were quantified using a data screening method (Meyer, et al., 2011) and color coded according to their magnitude. This screening method was greatly facilitated by the ASF datapool and the new datapool Application Programming Interface (API), allowing easy and rapid download of thousands of images. Strong RFI presence can be identified particularly along the Arctic coast. In these areas, high-quality RFI filtering is necessary to provide consistently well calibrated L-band radar data to the user community.

It was also shown (Meyer, et al., 2011) that in the American Arctic, many operationally processed ALOS-PALSAR images show distortions that can be attributed to residual RFI that was not completely removed by the Japan Aerospace Exploration Agency's operational filtering algorithms. Figure 2 shows two examples of RFI-induced artifacts for images acquired over Barrow, Alaska, in April 2009. Pauli decomposition images derived from operationally processed

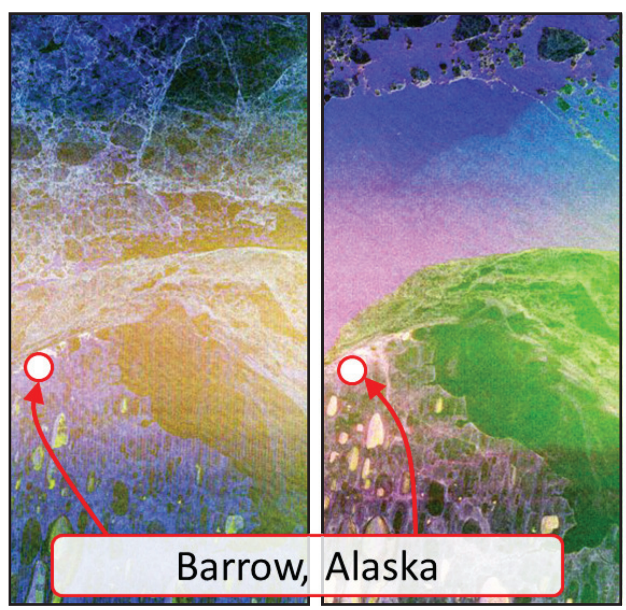

Figure 2: Pauli RGB images of sea ice near Barrow, Alaska. Note the unrealistic variation of polarimetric signatures over similar looking sea-ice floes and the green and purple image artifacts.

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Level-1.1 ALOS-PALSAR scenes are shown. Significant polarimetric signature variations can be identified over regions that appear to have similar surface characteristics. The strong color changes in the polarimetric decomposition would indicate strong changes in scattering properties, which appear unrealistic. Additional small-scale artifacts are visible. Both signal patterns are typical for RFI-affected data (Reigber and Ferro-Famil, 2005).

From an analysis of ALOS-PALSAR Level-1.0 data, it was found that the RFI signal in this area is characterized by high-power, wide bandwidth, temporarily narrow signatures, where center frequency is randomly changing with time. In such complex RFI environments, simple notch-filtering algorithms, such as the one implemented in the ALOS-PALSAR processor, fail, resulting in residual artifacts in the SAR image, polarimetric signature, and phase (Rosen, et al., 2008).

In order to obtain consistent data quality, a new RFI filter method was developed that is optimized to remove residual RFI signatures from ALOS-PALSAR imagery that were not corrected by the notch-filtering algorithm implemented in the operational processor. The new approach analyzes SAR data in azimuth time rather than range frequency and uses statistical methods to detect and remove RFI signatures.

After range compression, sections of ~2,000 azimuth lines are transformed into the range-frequency azimuth-time domain. A specific range frequency slice is extracted from the two-dimensional data. The extracted frequency slice is log transformed to generate data of approximate Gaussian distribution and a statistical outlier test is used to identify interference signals using a Z-test approach. This new RFI filter was embedded in a customized SAR processor, where it is used in combination with a traditional notch filter to capture a wide range of RFI signatures.

To demonstrate the effectiveness of the new RFI filter, RFI-affected, full-polarimetric ALOS-PALSAR data acquired near Barrow, Alaska, were processed using both the operational and the customized processor. To quantify performance, processed data were analyzed for image quality, polarimetric signature, and Interferometric SAR (InSAR) coherence.

The improvement of SAR image quality is exemplified in Figure 3, where both the operationally (top panel) and custom focused (bottom panel) HV channel of an ALOS-PALSAR image near Barrow, Alaska, are shown. The image quality improvement achieved by the customized algorithm is clearly evident.

To visualize improvements of polarimetric signature, full-polarimetric ALOS-PALSAR scenes were processed to Pauli RGB images using both the operational (Figure 4a) and customized processor (Figure 4b). The RFI-induced color distortions evident in Figure 4a are corrected in Figure 4b to virtually flat Pauli RGB images. Classification results based on these data are shown in Figure 4c and d. They provide additional evidence that the custom processor (Figure 4d) produces more distinct and realistic results.

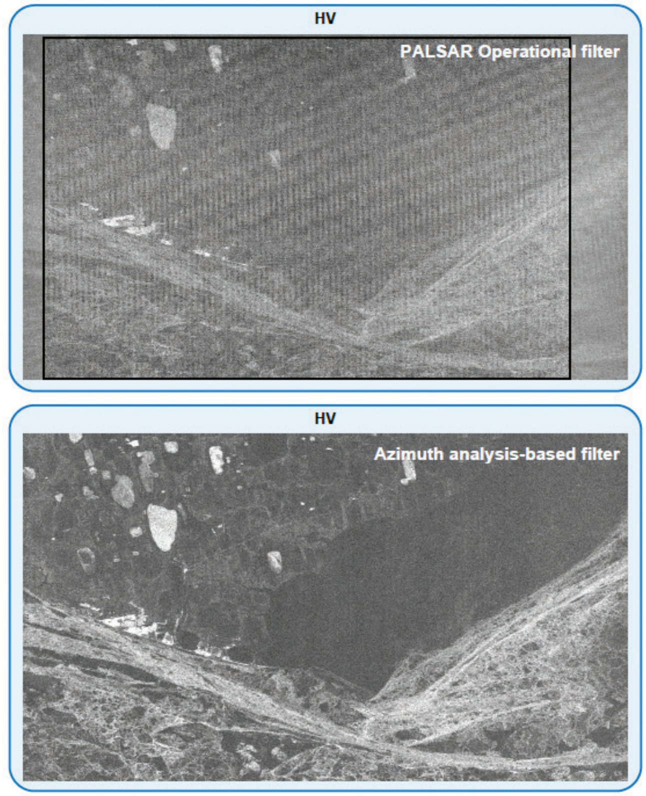

Figure 3: HV operational filtered (top), and new azimuthal filtered (bottom) focused images. The operational filter does not remove image artifacts, while the proposed filter restores the original image quality.

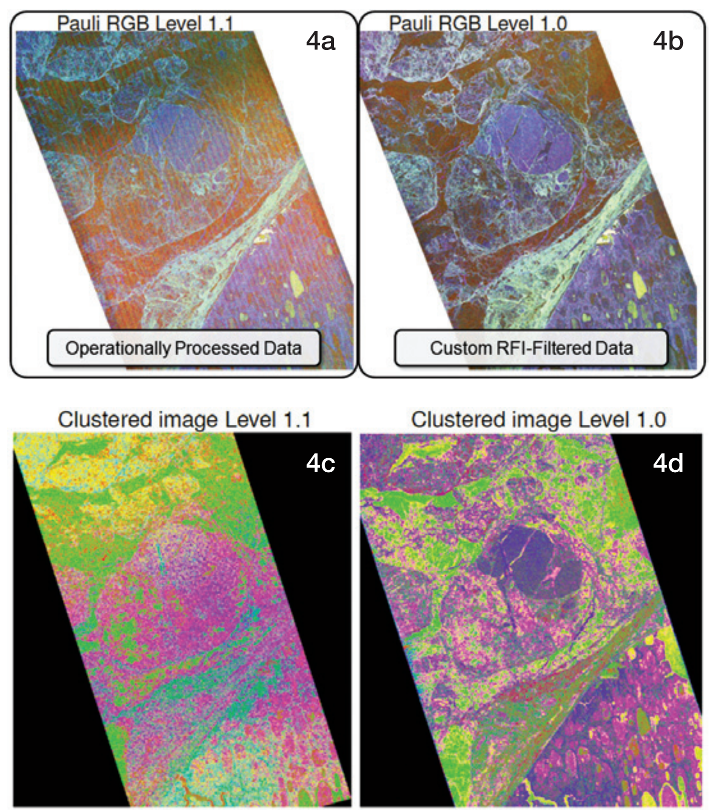

Figure 4: Improvement of polarimetric signature exemplified by a polarimetric clustering example: a) and b) before-and-after Pauli RGB images; c) and d) before-and-after segmented class images. The proposed filtering algorithm results in flatter response, sharper detail, and better defined clusters.

Probability density functions (PDF) of the coherence of a SAR interferogram acquired near Barrow, Alaska, are shown in Figure 5 for both operationally and custom-processed data. A comparison of the coherence distribution indicates clearly higher coherence in the custom-processed data.

In conclusion, RFI is a severe and growing issue in L-band radar remote sensing that affects data quality in many areas around the globe. It was shown that ALOS-PALSAR data over the American Arctic coast is consistently affected by complex RFI signatures, whose effects cannot be sufficiently removed using traditional notch-filter algorithms. A novel processing scheme was presented that is capable of effectively removing RFI artifacts. Examples have shown that the developed technique leads to improved image quality, polarimetric integrity, and InSAR coherence.

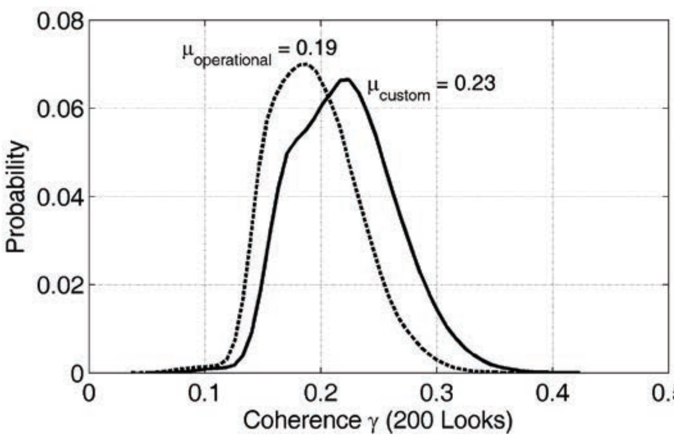

Figure 5: Coherence PDFs for an InSAR pair of RFI-affected ALOS-PALSAR images processed by both the operational (black dashed line) and the custom (black solid line) processor. Through customized RFI processing, a coherence improvement can be achieved.

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Rosen, P.A., Hensley, S., and Le, C., 2008. Observations and mitigation of RFI in ALOS-PALSAR SAR data: Implications for the DESDynI mission, Radar Conference, 2008. RADAR '08. IEEE, pp. 1-6.

Vertex: ASF's Data Portal *by Jessica Garron, ASF, UAF, U.S.A.*

ASF has developed and deployed a new user interface to highlight the contents of the ASF SAR datapool. Vertex (Figure 6) is an intuitive user interface that facilitates the search for and visualization of ASF datapool assets, delivery of relevant metadata about those assets, as well as facilitating the bulk delivery of those ASF data. Vertex is designed to familiarize users with SAR data without requiring prior knowledge of SAR platforms, beam modes, or processing parameters. Required search parameters are limited to a geographic region of interest or a defined granule list. A Vertex search returns thumbnail imagery of SAR products and basic metadata for granules within the search region. In the search results list, you can click on a given returned cell and access the product profile page for that particular granule, which contains a low-resolution browse image, expanded metadata from the return

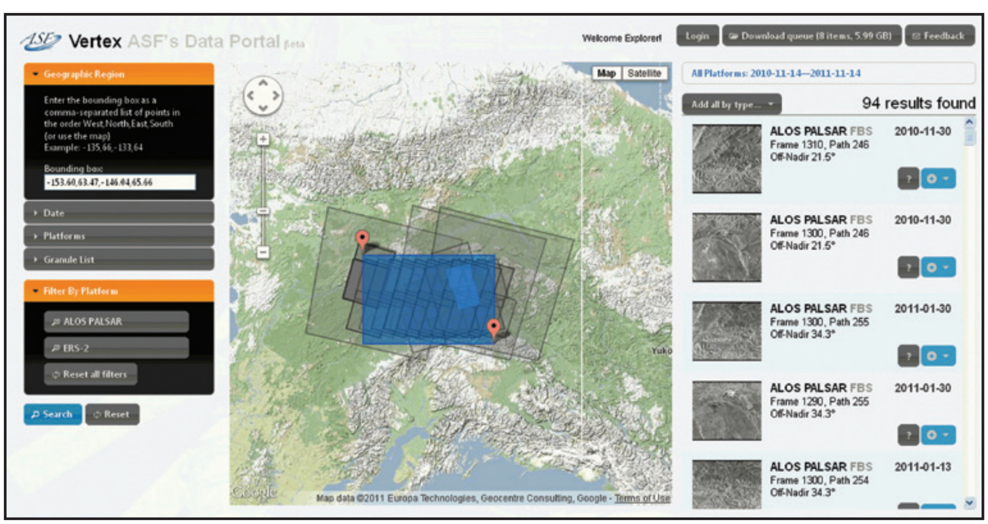

Figure 6: Example of an unfiltered search, returned through Vertex.

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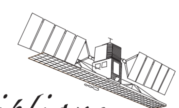
cell, as well as the capability to add processed products to your download queue.

ASF Distributed Active Archive Center users with a user ID and password have full access to download SAR data through Vertex, either as individual granules or via a bulk delivery method available through the download queue. The registration button within the interface provides the information on how to acquire a National Aeronautics and Space Administration-approved account, which grants access to restricted data from the ASF datapool for download.

Vertex includes an integrated feedback mechanism, accessible by selecting the Feedback button at the top of the Vertex page. Through this feedback mechanism, users are able to submit feedback that is both recorded in the ASF database, as well as recorded in the forum that is monitored by ASF staff who are working to improve the user experience through Vertex, which is directly accessible via e-mail at: asf-vertex@googlegroups.com. Users can also provide feedback either by e-mail to uso@asf.alaska.edu or by phone at 907-474-6166.



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