OPERATIONAL DEMONSTRATION OF ERS-1 SAR IMAGERY AT THE JOINT ICE CENTER

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ABSTRACT

Synthetic Aperture Radar (SAR) imagery from the European Space Agency's ERS-1 satellite are used to determine sea ice types, ice motion and to identify ice camp location in the Alaska region. These functions are made possible by a cooperative effort between NASA, NOAA and Navy that enables the Alaska SAR Facility to transmit same day SAR imagery to the Navy/NOAA Joint Ice Center in Suitland, Maryland. There ice analysts interpret the imagery with the aid of ice classification and ice motion algorithms. Derived products are then used to support field operations and improve current analysis products. Algorithm results are discussed with particular attention to future SAR applications to global sea ice analysis in the RADARSAT timeframe.

INTRODUCTION

The Navy/NOAA Joint Ice Center (JIC) was organized in 1976 to bring together Navy and NOAA resources for the analysis and forecasting of sea ice conditions on a global basis. The JIC is tasked with providing sea ice support to government, private and foreign users. Routine products include weekly sea ice analyses for the Arctic and Antarctic, thrice weekly analyses for the Alaskan and Great Lakes regions, 7 Day and 30 Day forecasts for the Arctic and Seasonal Outlooks for the Alaskan North Slope, Baffin Bay and Western Ross Sea regions. Special support for vessels and field programs are provided upon request, in as much detail as ice observing sources permit.

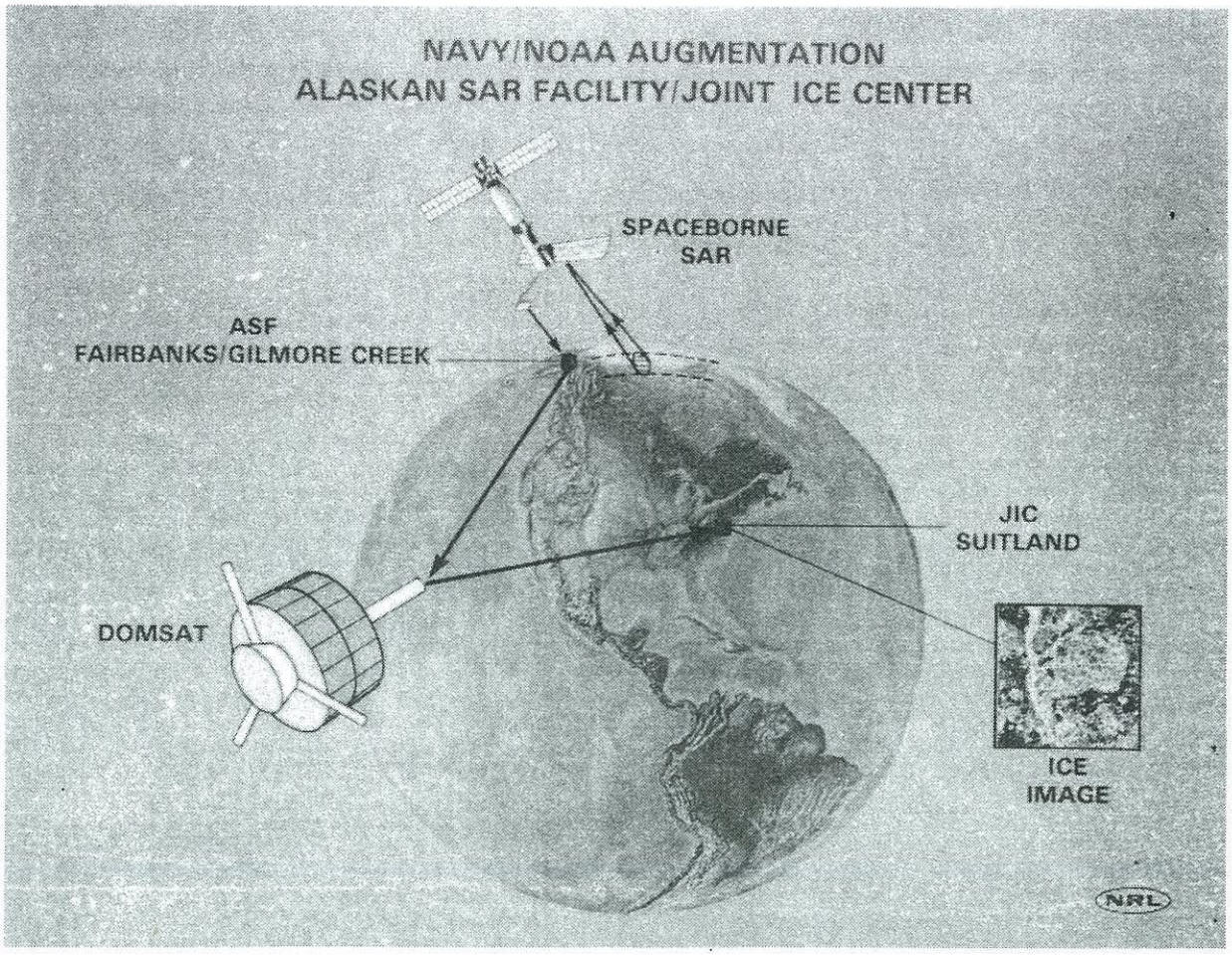
Every effort is made to employ all sources of operational sea ice information. Imagery from the NOAA polar orbiting satellites, the Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS) and the Special Sensor Microwave Imager (SSMI), and GOES satellite data (for the Great Lakes) are the primary sources. The JIC makes use of first-hand airborne reconnaissance observations provided by Navy personnel, Canadian ice observers and occasional reports from other sources.

Increasingly, the JIC has been called upon to assist ships at sea in navigating near the ice edge for scientific research and to assist US Coast Guard icebreakers and other ships in penetrating the ice cover in a safe and efficient manner. This direct ship support requires the most detailed sea ice imagery possible in order to accurately portray sea ice conditions to the vessel's crew who are concerned with ice features on scales of 10's to 100's of meters for maneuvering and 10's of kilometers for transiting through the ice. Surface vessels require detailed forecasts, especially of convergence/divergence of the ice cover, in order to plan activities. The JIC has requirements for reliable, local scale (10's to 100's of meters) sea ice data to provide support to those vessels. Prior to the launch of the European Space Agency's European Remote Sensing Satellite (ERS-1), only costly first-hand aerial reconnaissance provided such information. Preliminary analysis of satellite Synthetic Aperture RADAR (SAR) data from SEASAT indicated that SAR should provide the high quality local scale data [1] required for direct ship support, including detailed information concerning the amount of leads and very thin ice that is important for efficient ship routing.

The JIC'S SAR SYSTEM

A joint NOAA/Navy/NASA program was designed to demonstrate the utility of SAR imagery and products to the JIC. To meet the JIC's operational demands a communications system, SARCOM, was designed by the Navy and installed at the Alaska SAR Facility (ASF), University of Alaska in Fairbanks. The ASF receives, processes and archives SAR imagery in cooperation with NASA. SARCOM is used to retrieve archived SAR imagery and to access Quick-Look imagery that is processed within 6 hours of acquisition on request of the JIC.

SAR images are stored at the ASF until a "window" becomes available on the NOAA/NESDIS satellite link between its Gilmore Creek Ground Station and the central receiving site near Washington, DC. SAR data are then sent to Gilmore Creek where they are forwarded to the JIC (Figure 1).



SAR WORKSTATION

Upon arriving at the JIC, SAR imagery is automatically fed into a workstation designed by NASA for digital SAR analysis. The workstation software maps the SAR imagery to a polar stereographic grid (the same used for meteorological products) and enters pertinent information into a relational database. Users can access the imagery by entering date/time, orbit number or location parameters. Searches for imagery can be expedited using an application that allows users to establish "sites" and narrowing the dates for acceptable imagery.

The workstation displays the location of all images selected for each search on a World Vector Shoreline base map then permits the user to display the actual image at several scales. Standard Low Resolution image products from the ASF are available at 240 meter resolution (Figure 2). Full resolution (30 meter) products are available on a more limited basis due to greater image size. SARCOM applies a sophisticated 32:1 compression algorithm at the ASF to speed communications and the JIC workstation automatically reconstructs these images. Besides user controlled image enhancements, the workstation includes algorithms to automatically classify sea ice type and to determine sea ice motion between image pairs [2,3]. The user can interact with the ice classification application and create a different "backscatter" based Look-Up Table if desired. Similarly an application exists for "supervised" sea ice motion detection from selected image pairs.

Once a basic product is created (either an enhanced image, ice type or ice motion product) the user can use several graphic applications to annotate, color code, affix a map grid, draw a ship route or draw boundaries. The final version can be saved to disk and printed on either a high quality color printer or a laser printer.

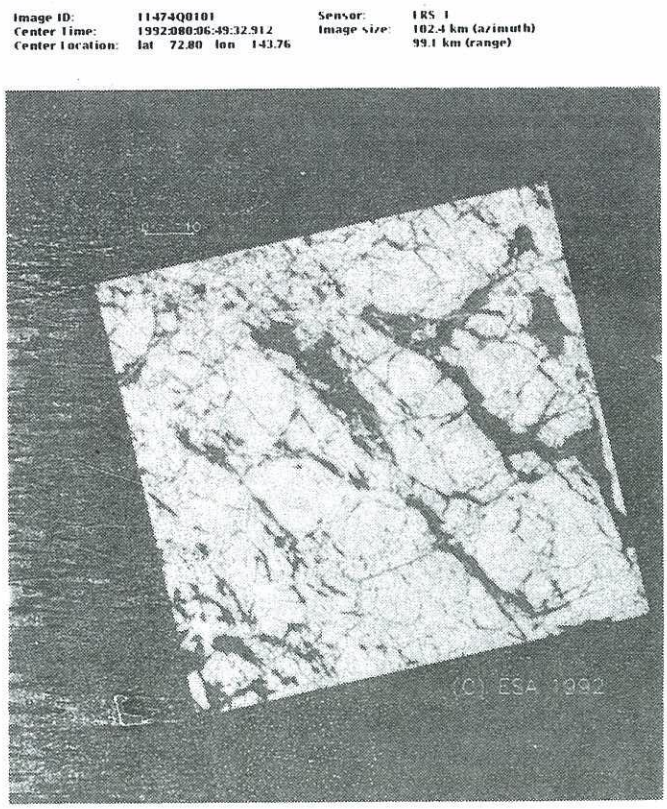


Figure 2 ERS-1 SAR Image 20 Mar 92

OPERATIONAL SUPPORT FOR LEADEX

During March 1992, immediately following installation of the SAR system, the JIC actively supported LEADEX field operations. The LEADEX project involved scientific studies of new and young sea ice in leads in the Southern Beaufort Sea. A camp was established on a multiyear floe and numerous flights and snow-machine runs were made to nearby leads. The project requested that the JIC provide support for the initial search for a suitable camp location and continuing support to locate leads close to the camp, especially new features that might develop during the field program.

The JIC requested repetitive SAR coverage of the LEADEX camp location from the ASF. Fortunately the camp was located within a SAR swath though the 3-Day repeat cycle (Ice Phase orbit) limited coverage to once every third day. The ASF provided Quick-Look coverage throughout the entire project. SAR swaths adjacent to that containing the camp were also processed in order to obtain a more complete description of the sea ice environment.

Communications to the LEADEX camp were not direct. The JIC sent products to the logistics base at Deadhorse (Prudhoe Bay), Alaska via telefax. JIC analysts used the supervised ice classification application to create an ice type product whose color coding was compatible with fax transmission (Figure 3).

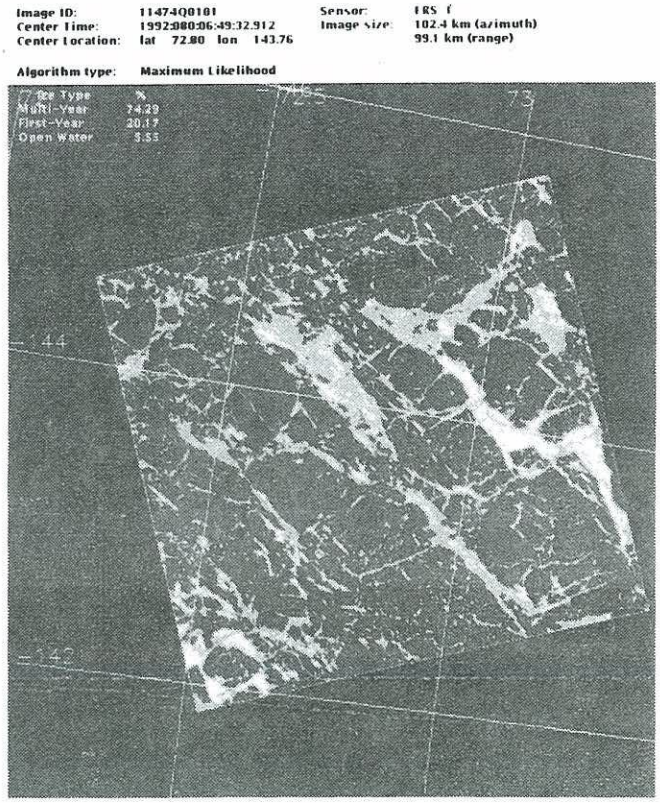


Figure 3 Classified SAR Image

Although some degradation was inevitable, a useful product was received at Deadhorse. These products displayed leads close to the camp and highlighted new features. A grid was overlaid and annotation added routinely. Although these products, derived from standard low resolution images, were adequate for most purposes we found that they were not useful for locating short ice runways (1000-1500 feet). In addition, corner reflectors deployed by LEADEX were visible only on Full Resolution products. Camp buildings and the runway were not detectable on either Full or Low Resolution images. Identification of the corner reflectors and a map of the camp sent by LEADEX to JIC validated the accuracy of the geolocation of Quick Look products (300-500 meters).

AUGMENTATION OF ROUTINE PRODUCTS

Prior to the advent of SAR the highest resolution data source for routine ice analysis was 550 meter resolution DMSP OLS

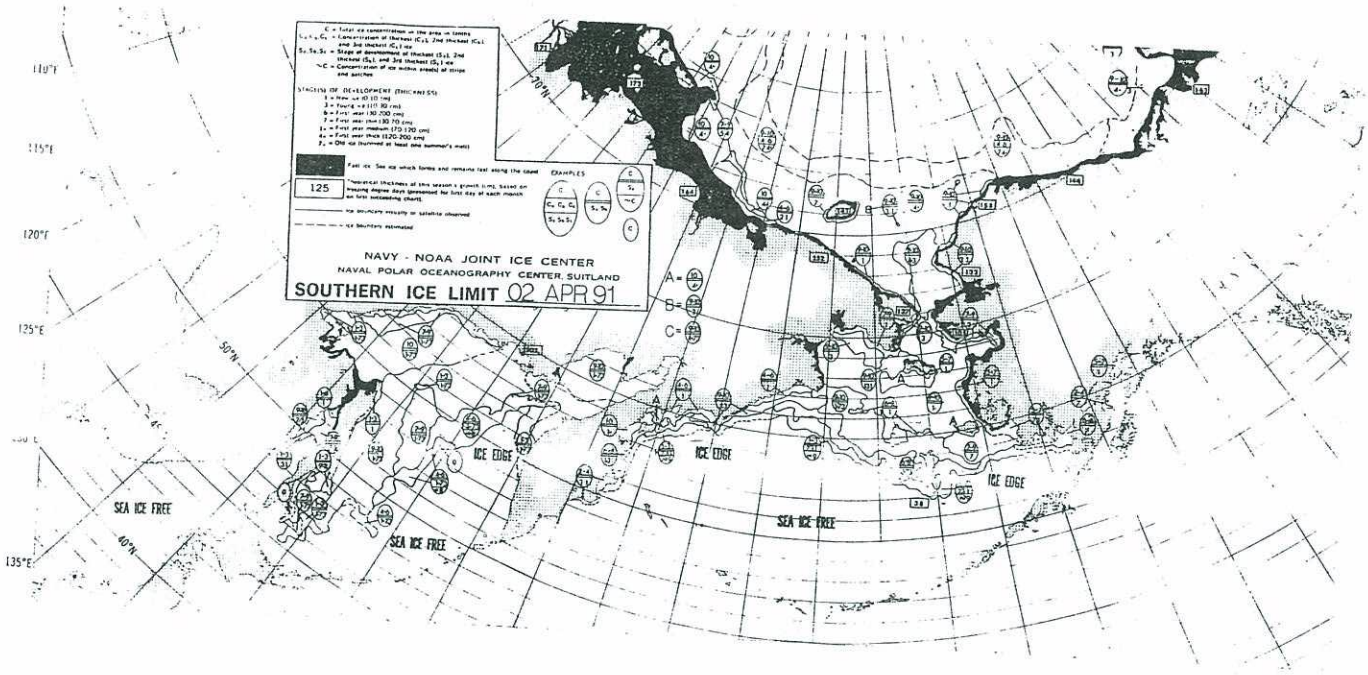
image products which arrive at the JIC some 48 to 96 hours after acquisition. Since OLS operates in the visual and infrared bands, these images are frequently cloud covered and of limited use for ice analysis. In contrast, SAR data acquisition is unaffected by weather or daylight and its resolution is at least twice as fine. In fact, the operational resolution is even greater because the backscatter of individual pixels can be distinguished whereas a group of several visual or infrared pixels are required for ice discrimination.

These SAR attributes have enabled JIC analysts to significantly increase the detail and information of routine ice charts of the Alaska region. Specific improvements included more precise location of the sea ice edge in the Bering Sea during breakup and detection of multiyear sea ice boundaries across the Beaufort, Chukchi and East Siberian Seas (Figure 4). Accurate position of the ice edge has obvious benefits for fishing and shipping interests. SAR derived ice edges were added to the JIC's Alaska Regional and West Arctic ice analyses.

Multiyear ice detection was used to modify the JIC's seasonal outlook (3 month prediction) for shipping along Alaska's North Slope [4]. In a climatic context, multiyear ice forms the so-called permanent Arctic pack ice. Changes in multiyear ice concentration and extent may be an indicator of climate change. Short term weather forecasting models could use multiyear ice information to adjust their Arctic Ocean heat flux parameterization. The multiyear ice edge drawn on JIC charts was in large part derived from SAR imagery analyzed during Spring and early summer of 1992.

OPERATIONAL SUPPORT FOR USCGC POLAR STAR

During August and September, 1992 the Coast Guard Icebreaker Polar Star will operate in the northern Chukchi Sea. Their mission is seismic and requires ship routing through the ice to specific stations and accurate ice movement forecasts for station keeping. SAR will be used to derive near real time ship routing tracks through the ice cover and ice motion algorithm products will be used to aid the ice forecasters. Products from the JIC will be sent via satellite to the ship and will be used and verified aboard by scientists and a JIC ice observer. This project will test the effectiveness of polar communications links for computer to computer transfer of derived products and the ability of the JIC to provide timely support whenever SAR swaths cover the Polar Star's operating location.



SUMMARY

SAR products have expanded JIC capabilities into previously unattainable functions. The very high resolution imagery, with apparently excellent radiometric qualities, enabled the JIC to produce fine resolution support products for several field activities. Ice classification by simple radar backscatter has proven effective and has been very successfully employed to detect the presence or absence of multiyear sea ice over a wide area. Sea ice motion algorithm products have been employed to detect lead formation and areas of ridge building. These direct measurements of opening and closing are vital for efficient ship routing through ice covered waters.

Considerable progress in the application of SAR to operational sea ice analysis and forecasting has been made during the past few months. The SAR workstation and algorithms were derived from the research community, and after some revision have proven robust and well suited for operational applications. Perhaps the most difficult problem the JIC has encountered is related to transmitting high resolution products to field activities.

The JIC will pursue the application of digital analysis capabilities, especially backscatter based Look-Up Tables for different geographic and temporal venues. Work with ERS-1 SAR (C-band) will be applied to JERS-1 SAR (L-band). The experiences from these two research satellites will make planning for RADARSAT, the first operational SAR satellite, more rigorous and should aid in the rapid exploitation of these data in an operational environment.

References

[1] Carsey, F., "Review and Status of Remote Sensing of Sea Ice," IEEE J. Oceanic Eng., Vol.14, No.2, 127-138, 1989.

[2] Kwok, R., E. Rignot, B. Holt, R. Onstott, "Identification of Sea Ice Types in Spaceborne SAR Data," J. Geophys Res., Vol.97, No.C2, 2391-2402, 1992.

[3] Kwok, R., J. Curlander, R. McConnell, S. Pang, "An Ice Motion Tracking System at the Alaska SAR Facility," IEEE J. Oceanic Eng., Vol.15, No.1, 1990.

[4] Navy/NOAA Joint Ice Center, "Seasonal Outlook, Western Arctic Ice, 1992" issued by Navy/NOAA Joint Ice Center, 1992.