THE ALASKA SAR DEMONSTRATION: RADARSAT-1 EXPERIENCE AND ENVISAT PLANS

William G. Pichel[(1)], Pablo Clemente-Colón[(1)], Karen S. Friedman[(1)], Xiaofeng Li[(1)], Francis Monaldo[(2)], Robert Beal[(2)], Christopher Wackerman[(3)], Erick Malaret[(4)], Fritz Funk[(5)], William Tseng[(1)], Ralph Meiggs[(1)], Michael Hopkins[(1)]

[(1)]NOAA/NESDIS
Room 102 WWBG, 5200 Auth Road, Camp Springs, MD 20746-4304 USA, Email: William.G.Pichel@noaa.gov

[(2)]The Johns Hopkins University Applied Physics Laboratory
11100 Johns Hopkins Rd., Laurel, MD 20723-6094 USA, Email: f.monaldo@jhuapl.edu

[(3)]Veridian ERIM International
P.O. Box 134008 Ann Arbor MI 48113-4008 USA, Email: wacker@erim-int.com

[(4)]Applied Coherent Technology Corporation
112 Elden St., Suite K, Herndon, VA 20170 USA, Email: malaret@actgate.com

[(5)]Alaska Department of Fish and Game
P.O. Box 25526, Juneau AK 99802-5526 USA, Email: Fritz_Funk@fishgame.state.ak.us

ABSTRACT

The U.S. National Oceanic and Atmospheric Administration (NOAA) National Environmental Satellite, Data, and Information Service (NESDIS) ENVISAT project is focused on a pre-operational demonstration of wind and vessel position products using, predominately, the Wide-Swath Mode of the ENVISAT Advanced Synthetic Aperture Radar (ASAR). The necessary scientific algorithms, data management techniques, and product production and dissemination procedures are being prototyped using Canadian RADARSAT-1 SAR data. A near real-time demonstration of SAR product production, the Alaska SAR Demonstration (AKDEMO) has been underway since October 1999 for the waters surrounding Alaska. Wind speed, wind vector (with 180 degree ambiguity) and vessel position products are generated within about 6 hours of satellite acquisition and provided to operational agencies for evaluation and validation. Wind validation is accomplished by comparing SAR-derived winds with model output in Alaska and with buoy measurements from the NOAA moored meteorological buoys in the Atlantic off the U.S. East Coast. For validation of vessel positions, fishery observer reports are being paired with SAR-derived positions to ascertain vessel detection success. ENVISAT data will first be taken over the U.S. East Coast buoys to test and validate the wind algorithm. The vessel detection algorithm will be tailored for the ENVISAT ASAR imagery and tested as well. Once the algorithms are operating properly, ENVISAT data will then be taken over Alaska (in near real-time if possible) and made available to AKDEMO users. If RADARSAT or Japanese Advanced Land Observation Satellite (ALOS) SAR data are available as well, a two-satellite demonstration will be attempted.

INTRODUCTION

This paper summarizes progress and current status of the Alaska Synthetic Aperture Radar (SAR) Demonstration (known as the AKDEMO), a near real-time applications demonstration of pre-operational products derived from satellite SAR data. The AKDEMO currently utilizes predominately RADARSAT-1 SAR data (although some ERS-2 SAR data have been used experimentally in the past). Presented first is a description of the AKDEMO using RADARSAT-1 imagery including its goals, products and their validation, users, and data system. A sketch of the plans to add products derived from ENVISAT Advanced SAR (ASAR) imagery to the AKDEMO after appropriate research, development, and validation activities have been concluded follows this description. The various modes and polarization options of the ENVISAT ASAR will be explored in order to optimize the performance of the product algorithms by making use of the unique capabilities of the ASAR instrument.

THE ALASKA SAR DEMONSTRATION (AKDEMO)

The AKDEMO, sponsored by the U.S. National Environmental Satellite, Data, and Information Service (NESDIS) of the National Oceanic and Atmospheric Administration (NOAA) is a multi-year demonstration of the pre-operational production and use of SAR quantitative and qualitative products [1]. The AKDEMO region of interest includes the Gulf of Alaska, the Bering Sea, and portions of the Beaufort and Chukchi Seas along the Alaska coast (see Fig. 1). The region chosen contains 54% of the U.S. coastline, as well as an extensive region of ocean within the U.S. Exclusive Economic Zone requiring fisheries management and enforcement. There is a severe lack of conventional ship and buoy meteorological and ocean observations in these waters. In addition, the region is characterized by long periods of cloudiness and darkness, severe winter weather, extensive sea ice cover, and large rivers prone to flooding during spring ice breakup. These characteristics make Alaska and its adjacent seas an attractive candidate for experimentation with using SAR as a remote sensing tool to assist operational agencies in carrying out their missions of providing forecasts and warnings for safety of life and property, protecting endangered species, managing fisheries, and enforcing U.S. fishing regulations.

Demonstration Goals

There are three major goals for the Alaska SAR Demonstration:

(a) Develop, test, and validate prototype SAR products that respond to critical data needs of operational users not satisfied with present observational data in the Alaska region.

(b) Provide sustained automatic production and near-real time delivery of SAR and ancillary data and products via the Internet for trial use by operational agencies in Alaska.

(c) Familiarize the operational user community in the region with the interpretation and use of SAR image data and derived products.

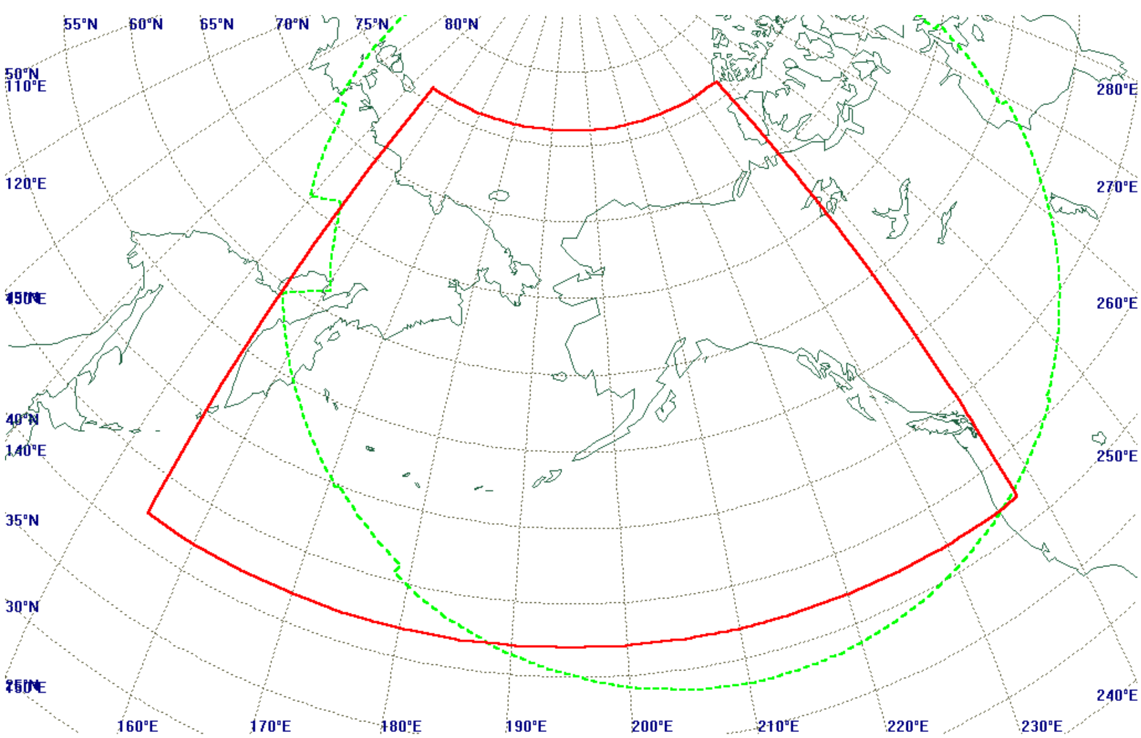


Fig. 1. Alaska SAR Demonstration region of interest (outlined in red) and the Alaska SAR Facility station mask for RADARSAT-1 (dashed green line).

Progress has been made toward meeting all three of these goals. A number of unique prototype SAR products have been developed and partially validated. Some of these products have been produced routinely from RADARSAT-1 data since October 1999 and delivered via the Internet for evaluation by operational agencies. NOAA/NESDIS sponsored a two-day training course in September 1999, given in Anchorage and Juneau, Alaska in order to teach the basics of SAR interpretation to potential AKDEMO users. In September 2000, a one-day AKDEMO User Meeting was held in Fairbanks, Juneau, and Anchorage to assess the success of the first year of the AKDEMO and to obtain suggestions for product and system improvements.

Demonstration Users

There are three major operational agencies in the State of Alaska for which the Alaska SAR Demonstration products were developed. These are:

(a) The NOAA National Weather Service (NWS) offices in Alaska including the Weather Service Forecast Offices in Anchorage, Fairbanks, and Juneau; the River Forecast Center in Anchorage; and the Alaska CoastWatch Regional Node in Anchorage. NWS responsibilities include weather forecasts and warnings, river hazard advisories, and sea ice analyses and forecasts. SAR applications of interest to these offices include ice analysis, coastal winds, storm location, river ice analysis, and flood mapping.

(b) The U.S. Coast Guard (USCG) 17^{th} District Office in Juneau. The Coast Guard is responsible for enforcing U.S. fishing regulations in U.S. waters, protection of endangered species, oil spill response, and rescuing those in peril at sea. They are interested mainly in vessel detection using SAR imagery, although winds and oil spills are also of interest.

(c) The Alaska Department of Fish and Game (ADF&G) in Juneau, Anchorage, Kodiak, and Dutch Harbor. The ADFG is responsible for managing the Alaska coastal fisheries including salmon, herring, and crab. Their primary interest in SAR applications is vessel detection.

Other users in Alaska who are experimenting with the Alaska SAR Demonstration products include the Alaska SAR Facility of the University of Alaska, Fairbanks; the Alaska North Slope Borough in Pt. Barrow; the NOAA National Ocean Service in Anchorage; weather offices of the U.S. Air Force at Elmendorf Air Force Base, Anchorage; and the NOAA National Marine Fisheries Service (NMFS) in Juneau.

Demonstration Data System

The AKDEMO relies on RADARSAT-1 (and sometimes ERS-2) data acquired by the Alaska SAR Facility (ASF) reception station located at the University of Alaska, Fairbanks. Data received are obtained from the ASF Station Mask (see Fig. 1) and processed in near real-time with the quick-look processing capability of the ASF. A large portion of the AKDEMO acquisitions is shared with the Navy/NOAA/Coast Guard National Ice Center and/or the Geophysical Processor System at the ASF. Quick-look processing uses predicted ephemeris for image formation and earth location information and is thus less accurate than processing after the final ephemeris is available, a few days after acquisition. Having the data available quickly, however, is more valuable than the improvement in earth location realized by waiting for the final ephemeris. The ASF is able to acquire the RADARSAT-1 data, scan the data into the ASF catalog system, initiate processing of the data, and complete image formation typically within 3-4 hours after acquisition. After SAR image formation, the imagery is sent automatically to the NOAA Satellite Active Archive in Suitland, Maryland where it is catalogued and distributed automatically to near real-time users including the AKDEMO (see Fig. 2). When a frame of SAR data is received by the AKDEMO, it is processed automatically into products that are stored on the AKDEMO web site (http://orbit35i.nesdis.noaa.gov/orad/sar). Typically, products are accessible to users via a personal computer (PC) Internet web browser in Alaska within 6 to 7 hours after satellite overpass. At the same time that products are being produced, the SAR imagery is also being ingested by a web-based interactive data and product browsing system known as the World Wide Web Image Processing Environment (WIPE). Developed by Applied Coherent Technology (ACT) Corporation, WIPE ingests SAR imagery and derived products, numerical weather fields, other satellite data such as visible and infrared imagery from the Geostationary Operational Environmental Satellites (GOES), and buoy reports and provides access to all these data in a georeferenced environment via a normal web browser operating on the user's PC. All data manipulation occurs on the AKDEMO web server with only small display images transferred to the user over the Internet. Thus, WIPE allows use of SAR data without requiring a user to have

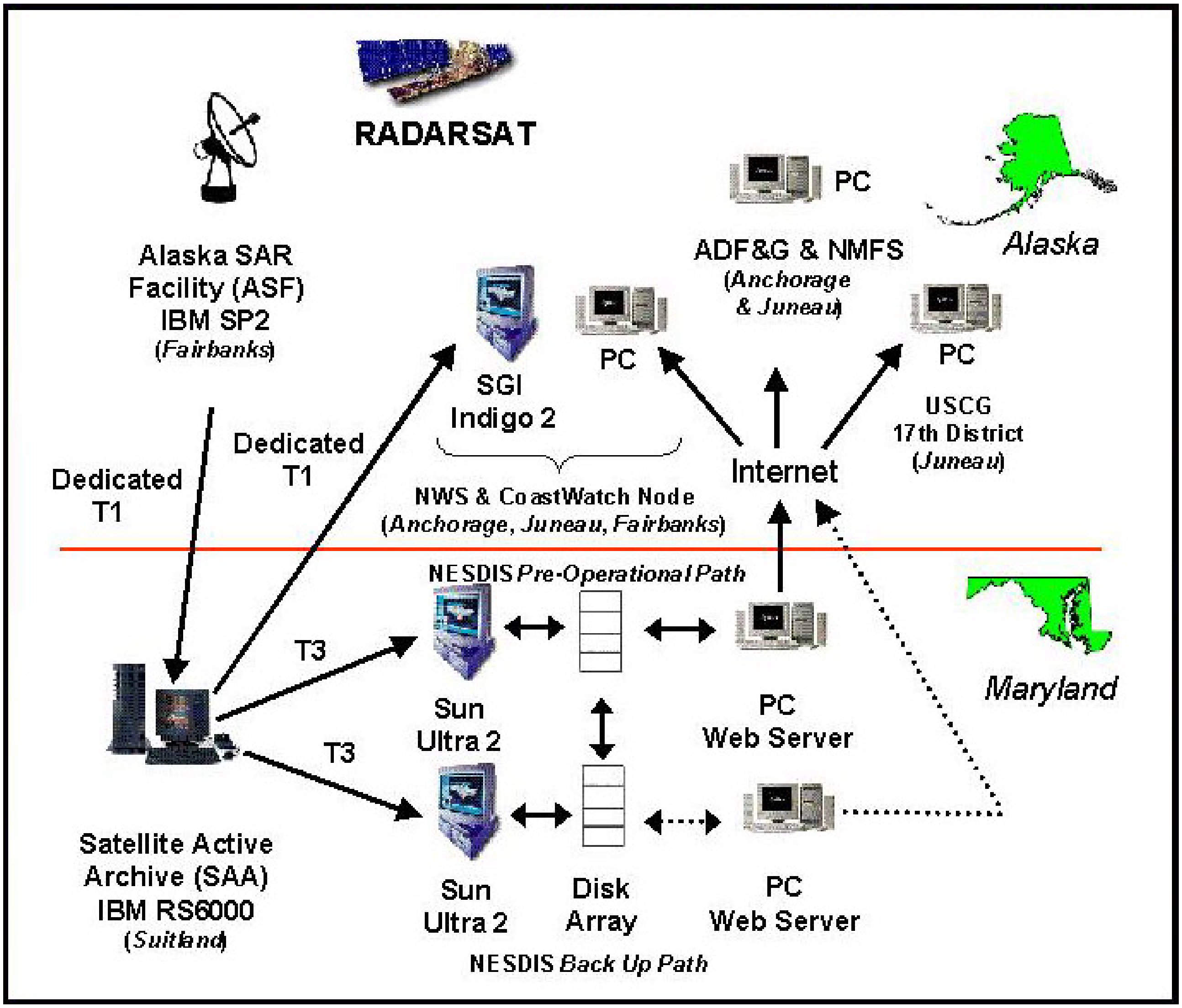


Fig. 2. Alaska SAR Demonstration Data System

access to large bandwidth Internet connections or sophisticated workstations (see http://www.actgate.com for a full description of WIPE).

WIPE stores data and products in a Structured Query Language (SQL) database. Authorized users can start WIPE from within their Internet browser, select a region and time period of interest, select data to display, examine single SAR frames or mosaics, display derived image products or other satellite imagery, superimpose vector products like model

wind data on top of the SAR imagery or image products, zoom, display profiles, make two or three dimensional plots, drape imagery over topography or bathymetry, create animations, and output images.

Demonstration Products

Table 1 lists the AKDEMO data and products stored on the web site and in the WIPE system. The first four products shown in Table 1 are generated for each frame of SAR data. Products are stored on the AKDEMO web site and ingested to WIPE for access by users via either system. The algorithms used to produce these products are summarized below.

Table 1 – Alaska SAR Demonstration Products [2]

Product	**Web Site Display**	**WIPE Display**
RADARSAT-1 SAR Imagery	Low resolution image	Full resolution image
SAR-derived wind speed image	Image – 1 km resolution	Image – 1 km resolution, Graphics overlay
SAR-derived wind vectors	Graphics on SAR image, text file	Graphics overlay
SAR-derived vessel positions	Graphics on SAR image, text file	Graphics overlay
Geostationary visible and IR imagery	-	Full resolution image
AVHRR-derived SST field	Image – 14 km resolution	Image – 14 km resolution
Passive microwave (SSM/I) wind speed	Image – 50 km resolution	Image – 50 km resolution
Meteorological Model Output (FNMOC NOGAPS model) including winds, SWH, air temp., SST, air pressure, dominant wave period and direction	Image – 1^o grid	Image - 1^o grid and wind vector graphic overlay
Scatterometer winds (from ERS-2)	Graphics	Graphics overlay
Buoy observations – winds, air temp., SST, air pressure, SWH	Text file	Graphics overlay

Note: SWH = Significant wave height, SST = sea surface temperature, SSM/I = Special Sensor Microwave/Imager, FNMOC = Fleet Numerical Meteorology and Oceanography Center, NOGAPS = Navy Operational Global Atmospheric Prediction System

SAR Imagery

The current AKDEMO uses predominately data from the Canadian Space Agency's RADARSAT-1 satellite, which carries a multi-mode C-band (5.3 cm wavelength) SAR with horizontal transmit and receive (HH) polarization. Two modes are used by the AKDEMO: ScanSAR Wide B (480 km swath, 100 m resolution, 50 m pixels) and Standard (100 km swath, 25 m resolution, 12.5 m pixels). For the ScanSAR Wide B imagery, the resolution has been degraded further to 200 m resolution (100 m pixels) and the imagery has been mapped to polar stereographic projection before the AKDEMO receives the imagery (Standard Mode data is received unmapped at full resolution). Each image is stored on the AKDEMO web site in a password protected section of the site as a low resolution (subsampled by 10) flattened image (i.e., variations in backscatter due only to changing incident angle have been removed). Imagery is also ingested by the WIPE system at full resolution and remapped to a linear latitude/longitude format for co-registration with other image and vector data.

Wind Images

Wind images are calculated for the AKDEMO from RADARSAT-1 SAR imagery using the CMOD4 algorithm (1) developed for the VV polarization of the ERS-1 scatterometer [3], modified for the HH polarization of RADARSAT-1 with the functional relationship proposed in [4] and shown in (2).

$$F_0^V = a(2)\, f(U)^{(}\, [1 + b(2)\cos N + c(2,U)\cos 2N]^{1.6} \quad (1)$$

where F_0^V is the vertical polarization radar cross section (RCS); 2 is the local angle of incidence; U is the wind speed, a, b, c, and (are empirically determined coefficients; and N is the angle between the SAR look direction and the local wind direction.

$$F_0^H = F_0^V \frac{(1 + " \tan^2 2)^2}{(1+ 2 \tan^2 2)^2} \quad (2)$$

where F_0^H is the horizontal polarization RCS calculated from calibration routines available from the ASF along with information in the RADARSAT Committee on Earth Observing Satellites (CEOS) Leader File for each frame of SAR data, " is a parameter that is still an area of research and has been empirically estimated to be 0.6 [4, 5], and the other parameters are defined the same as in (1).

Wind estimates are obtained from SAR imagery by calibrating to horizontal polarization RCS; averaging to 1 km resolution; using (2) to find vertical polarization RCS; using a wind direction obtained from the Fleet Numerical Meteorology and Oceanography Center (FNMOC) Navy Operational Global Atmospheric Prediction System (NOGAPS) wind forecast closest in time to the SAR overpass time (interpolated to the position of the SAR pixel) to determine the angle between the SAR look direction and the local wind direction; and inverting (1) to obtain wind speed from wind direction, angle of incidence, and vertical polarization RCS. Fig. 3 is an example of one of the resulting wind speed images. In order to validate the SAR winds, they have been compared with coincident model wind estimates as well as buoy wind data. NOAA U.S. East Coast moored buoy wind data were compared with SAR-derived wind estimates. From a database of 291 comparisons, closely matched spatially and temporally, it was found that there is a mean difference between SAR-derived and buoy-derived winds of -0.90 m/s with a standard deviation of 2.02 m/s. The ScanSAR imagery processed at ASF has a severe near-range (below an angle of incidence of 25^{o}) underestimation of RCS [6], which leads to an underestimation of wind speed by about 3 m/s [7]. A correction for this near-range problem is being developed at the ASF. Experimentation with an empirical correction for the near-range problem as well as a correction for bias that is a function of wind speed have indicated that root-mean-square errors (RMSE) in the range of 1.9 m/sec are possible.

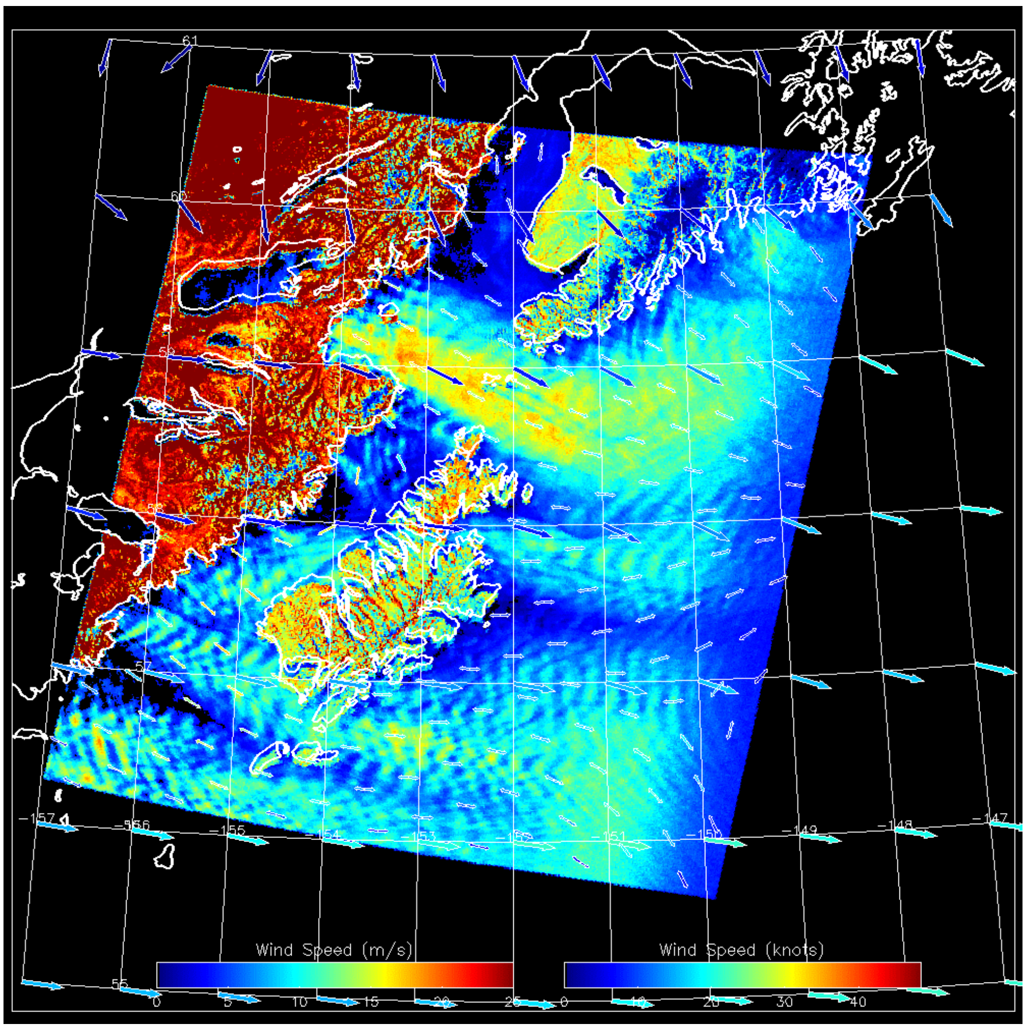


Fig. 3 – Wind speed image calculated from RADARSAT-1 ScanSAR Wide B imagery using a modified CMOD4 algorithm for 16:33 GMT 9/8/00. Wind speed is indicated by the color of the wind image. The resolution is 1 km. Larger arrows are the FNMOC NOGAPS model winds with the direction indicated by the arrow and the speed indicated by the color inside the arrow. SAR Wind Vectors are also plotted as smaller double-headed arrows with the arrowheads indicating direction with 180^{o} ambiguity and the color inside the arrow indicating speed. Kodiak Island is in the middle left of the image with the Alaska Peninsula at the far left and Cook Inlet in the top middle of the image.

Wind Vectors

Since the accuracy of the SAR-derived wind images can vary substantially with errors in model wind direction, alternative methods of obtaining wind direction information have been studied. This has led to the implementation of a completely separate approach to wind calculation which is run in parallel to the wind image algorithm described above. In this second algorithm, wind direction is obtained from the SAR image itself by locating wind-aligned features. The basic approach of the algorithm is to first estimate wind direction by locating large-scale (3-16 km) linear features in the image that approximately line up with the surface wind. These could be wind rows caused by vortices in the planetary boundary layer, changes in wind flow coming off of land features due to topographical variations, changes in wind speed across wind fronts, or surfactant features aligned with the wind flow. Once the local wind direction is estimated, the local RCS is calculated and used to estimate wind speed by inverting a model that predicts RCS from the local wind speed, wind direction (with respect to the SAR look direction), and angle of incidence. A single wind vector (with 180^o directional ambiguity) is estimated for each 32 km region over the ocean within the SAR image.

The wind direction algorithm first averages the SAR image down to a 500 m sample size. This helps to reduce the speckle noise in the image and decreases the sizes of the Fourier transforms that will be calculated. The averaged image is then broken into subsets of about 48 km on a side (spaced 32 km apart), and a wind direction is estimated for each subset. This is done by: (a) generating a spectrum from each subset by averaging the intensities of Fourier transforms calculated from portions of the subset and then smoothing the averaged spectra, (b) fitting a quadratic polynomial to the low wavenumber region of the spectrum and estimating a direction of elongation of the polynomial, and (c) spatially smoothing the direction estimates with a weighted average where the weights come from the mean RCS of the subset (averaging is done over 3X3 samples of the wind direction grid, repeated twice) [8]. A comparison of directions obtained from this algorithm with 51 coincident buoy wind directions yields a RMSE of 41 degrees. After applying a metric that attempts to eliminate lee waves and convection cells and after spatial smoothing, the RMSE was reduced to 32 degrees.

After generating the grid of wind directions, an estimate of wind speed is calculated at each grid location. This is accomplished by using a RCS model that predicts the RCS of the ocean given the local wind speed, the local wind direction, the angle of incidence of the SAR, and the look direction of the SAR. Since the wind direction and the mean radar cross section for each grid point are known, the model can be used to find the wind speed that generates the closest model RCS to the actual RCS. An analytical model to predict RCS for RADARSAT HH polarization imagery based on a two-scale approach has been developed [9]; however, it is computationally intensive and not suited for a near real-time demonstration. Various alternatives to the analytical model were investigated and a polynomial approximation to the analytical model was chosen:

$$F_0^H = F_0^V \ (a_3 \tan^3(2) + a_2 \tan^2(2) + a_1 \tan(2) + a_0) \qquad (3)$$

where F_0^H is the RADARSAT horizontal polarization RCS, F_0^V is the CMOD4 model result for vertical polarization from (1), 2 is the angle of incidence, and a_0, a_1, a_2, a_3, are parameters generated by fitting to a RADARSAT validation data set consisting of a series of RADARSAT images containing NOAA moored buoys paired with the coincident buoy wind measurements.

Wind speed is calculated by finding the wind speed that generates the closest model radar cross section, F_0^H, to the actual radar cross section for the RADARSAT image. This is done by looping over wind speeds from 1 to 25 m/s every 0.2 m/s and picking the wind speed that generates the smallest error in radar cross section. RCS is calculated for each wind speed guess by using (1) to obtain F_0^V and (3) to obtain F_0^H. With the same 51 coincident buoy pairs used for measuring directional error, a wind speed RMSE of 4.0 m/s was obtained. Upon examining the data it was found that there was a linear relationship between the wind speed error (SAR-derived wind speed minus buoy wind speed) versus the SAR-derived estimated wind speed. If this error is removed, the RMSE is 1.6 m/s [8]. Additional work is needed to determine the cause of this linear relationship; and the larger database of buoy and SAR image matches used for wind image validation should be incorporated in the wind vector validation.

Vessel Positions

The positions of offshore and coastal fishing vessels are determined by locating bright targets in the SAR imagery. The core of the detection algorithm is a local process to locate regions of bright image samples that are statistically different from the surrounding ocean clutter. This procedure is often referred to as a constant false alarm rate (CFAR) process since it is a relative measure based on the local statistics of the background clutter and thus keeps the number of false alarms constant as the mean of the clutter varies. The algorithm uses a set of nested windows that are moved efficiently throughout the image. The innermost window, the signal window, is sized to contain the smallest ship expected. A buffer window, containing the signal window is sized to contain the largest ship expected. And finally the background window, which contains both the signal and buffer windows, is sized to give a good statistical measure of the image background when there is no ship. These windows are moved throughout the image as a set, shifting by one image sample each time they are moved. At each position, the mean image value within the signal box is calculated, m_s, along with the mean and standard deviation of the image values within the background box but not within the buffer box (m_b and F_b, respectively). A detection statistic, d, is then calculated as in (4).

$$d = (m_s - m_b) / F_b \tag{4}$$

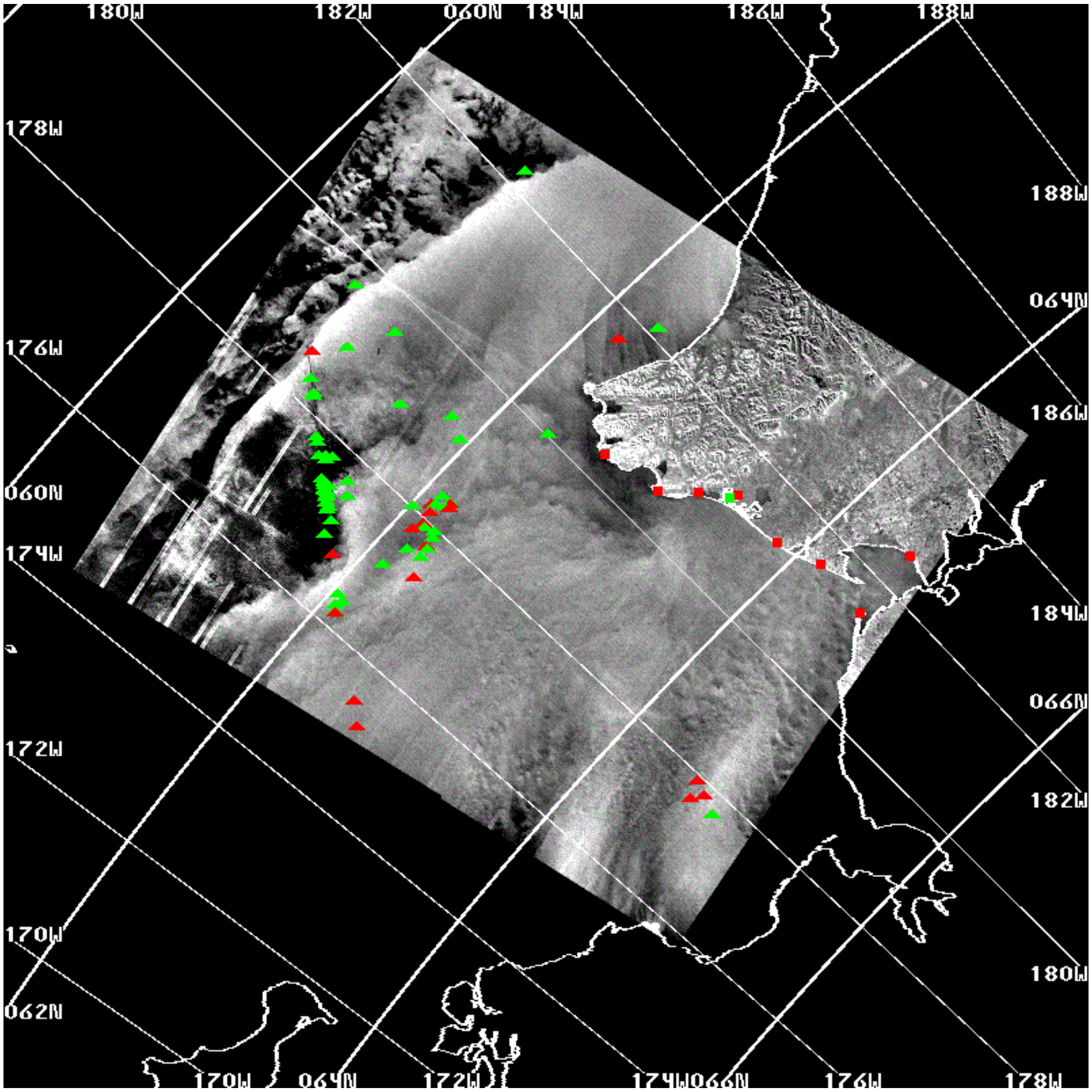
Finally, a threshold, T_0, is applied to d: if $d \geq T_0$ then a ship has been detected within the signal box, if $d < T_0$ then no ship has been detected. This approach is computationally efficient and can be applied to a whole RADARSAT-1 ScanSAR image within about 10 minutes on a modest workstation.

Regions with large numbers of system noise floor samples and land regions are handled somewhat differently. Regions with significant numbers of system noise floor samples contain bright "dots" which cause false alarms because they look line ship signatures. False alarms in these regions are eliminated by (a) raising the value of T_0 for these regions; and (b) requiring that $m_s > m_0$ where m_0 represents the lowest energy value expected for a ship return. The latter constraint eliminates noise spikes that are significantly brighter than the local background (and thus have a d statistic larger than T_0) but by themselves do not have enough energy to represent a ship return. False detections over land are eliminated with a land mask that indicates whether each pixel is over water, over land, or along the coast in a region 2 km either side of the coastline. Detections over land are eliminated immediately, but those within the 2 km zone may be over land or water depending on the accuracy of the earth location information for the image. To decrease the land detections in this coastal zone, two additional constraints are applied: $m_b < m_1$ and $F_b < F_0$. The limit on the background standard deviation eliminates detections over rough land regions ($F_0 = 0.03$). After all detections have been done, the value of m_b for each of them is translated into a wind speed, essentially removing incident angle and range effects. The maximum wind speed for all detections over water is found and any detection for which m_b translates into a wind speed value greater than this is removed, thereby putting an upper limit on m_b [9]. Fig. 4 shows the results of the vessel detection algorithm.

Manual analysis of images with fleets of ships was employed to determine that a T_o of 5.5 maximizes ship detections while minimizing false alarms. Although very few direct comparisons between known vessel positions and vessel detections have been made, algorithm performance has been assessed with fleets of vessels of known size distribution and vessel count. Analyzing an image coinciding with the Bristol Bay red king crab fishery of October 18, 1999, it was determined that with 200 m resolution ScanSAR Wide B data, about 45% of the vessels could be detected, with vessel lengths of 35 to 38 km as the minimum length vessel detected. If 100 m resolution data are used, 60% of the vessels can be located (with minimum vessel sizes detected in the range of 33.5 to 35 m) [11].

ENVISAT PROJECT SUMMARY

The development and demonstration of near real-time products from ENVISAT ASAR data will be a natural enhancement of the Alaska SAR Demonstration. The use of ENVISAT data will allow increased temporal and spatial coverage, permit improved algorithms using dual polarization, and provide the redundancy desired for routine pre-operational product production.



(c) Canadian Space Agency, 2000

Fig. 4. Example of a product from the vessel detection algorithm for September 30, 2000 at 05:03 GMT. North is to the lower right. Cape Navarin, Russia is in the center right of the image. A triangle means the detection was over the water; a square means that the detection was within the 2 km coastal buffer. A green color means it is a "sure" detection ($T_0 > 12$) and a red color means that the detection is not so sure ($T_0 < 12$). The line of detections corresponds to vessels aligned with the U.S./Russia Maritime Boundary Line.

Project goals

The following applications will be developed and demonstrated with ENVISAT ASAR data:

(a) High resolution coastal winds and weather features: The existing RADARSAT-1 wind image and wind vector products will be combined into a single algorithm, which will use both meteorological model wind directions and wind directions derived from wind-aligned features in the SAR imagery to provide input direction to the calculation of wind vectors from ENVISAT ASAR imagery. The alternating polarization mode of the ASAR will be used to refine the HH/VV polarization ratio being used in the RADARSAT-1 wind calculation and to evaluate the relative merits of using HH or VV polarization for wind determination with ENVISAT data. The wind algorithm will be applied to the Image, Wide Swath, Alternating Polarization, and Global Monitoring ENVISAT modes. Winds will be generated first using U.S. East Coast data and paired with simultaneous NOAA moored buoy wind observations for accuracy assessment and algorithm refinement and validation. During this phase, work on the wind algorithms will be accomplished in coordination with ENVISAT Proposal #141 by Robert Beal, and Proposal #189 by Donald Thompson, both of The Johns Hopkins University Applied Physics Laboratory. After validation, the wind product developed from ENVISAT data will be generated routinely and in near real-time, if possible, using data covering Alaskan waters and provided to the NWS offices in Anchorage, Juneau, and Fairbanks in Alaska for evaluation.

(b) Vessel positions for fisheries management and enforcement: The CFAR algorithm developed for the AKDEMO will be adjusted to run with ENVISAT data. Differences in ship detection performance between HH and VV will be investigated and the different ENVISAT modes will be evaluated for ship detection effectiveness, first off the U.S. East Coast, then in Alaska. Both coastal fisheries ship detection, such as for the Togiak Bay herring fishery, and open-ocean fisheries ship detection, such as for the snow crab fishery, will be evaluated. Since the location of a fishing vessel can be constantly changing, increased coverage frequency from using both ENVISAT and RADARSAT-1 will be important to management activities.

(c) Oil spill detection and mapping: The Alternating Polarization Mode will be used to evaluate discrimination between biogenic and mineral oil slicks. The polarization signature of natural slicks occurring in the Gulf of Mexico will be compared with that of fish processing slicks from fishing vessels participating in the Bering Sea walleye pollock fishery and with slicks from plankton blooms in spring.

(d) River ice analysis: Analyzing the spring breakup of ice in the larger rivers in Alaska for ice conditions, ice runs, and ice jams and attendant flooding will be enhanced with additional coverage using ENVISAT Image Mode images of HH and VV polarization. Possible improvements in river ice determination using the Alternating Polarization mode will also be examined.

(e) Developmental Applications: Other applications, still in the research and development mode with RADARSAT-1 will be addressed with ENVISAT as well. One such application is ocean feature detection with wavelet transforms. The automatic identification of the North Wall of the Gulf Stream and Gulf Stream eddies will be evaluated. Other applications include algal bloom identification with coincident Medium Resolution Imaging Spectrometer (MERIS) data in the Gulf of Mexico, upwelling feature identification and measurement along the U.S. East Coast, and flood mapping in coastal regions after storms or during high water in river basins.

Project Phases and Schedule:

The addition of ENVISAT to the Alaska SAR Demonstration will proceed in three phases:

(a) Phase 1 is the pre-ENVISAT phase with algorithm development, validation, testing, and demonstration proceeding using predominately RADARSAT-1 imagery, but also occasionally some ERS-2 imagery. This phase began in October 1998 with algorithm development. Near real-time wind product demonstration within the Alaska SAR Demonstration began October 1999, with vessel detection products added in March 2000. Algorithm refinement is ongoing as is product evaluation by users in Alaska.

(b) Phase 2 is the ENVISAT development phase where algorithms will be tailored to utilize the different ENVISAT ASAR modes. Experimentation with different polarization modes will be undertaken in this phase along with wind algorithm validation using U.S. East Coast buoys. This phase should last for a year, starting six months after the launch of ENVISAT (now scheduled for June 2001). Thus this phase should occur between January and December 2002, and utilize data predominately from the U.S. East Coast and the Gulf of Mexico. A mid-term report detailing the ASAR version of the wind and vessel detection algorithms will be produced at the end of Phase 2.

(c) Phase 3 is the ENVISAT Alaska SAR Demonstration phase with a near real-time demonstration of applications in Alaska. It should start in October 2002 and proceed for two years to September 2004. A final report on the demonstration performance will be produced by December 2004. Proceeding in parallel with the demonstration in this phase will be the development of new applications such as algal bloom monitoring, and studies of the identification of ocean features such as upwelling and current fronts. If RADARSAT-1 continues to operate, overlap with RADARSAT-1 to provide a two-satellite demonstration should be possible from October 2002 until the launch of RADARSAT-2 sometime in 2003. If the Japanese Advanced Land Observing Satellite (ALOS) is also launched in 2003, perhaps there can be an overlap of the ENVISAT ASAR Alaska SAR Demonstration with experimental products generated from the L-band ALOS PALSAR during 2004. Phase 3 is dependent on near real-time availability of ENVISAT ASAR imagery for the waters around Alaska.

SUMMARY

The AKDEMO is now well underway with SAR imagery, coastal wind measurements, and vessel positions being provided to users (NWS, USCG, and ADF&G) within 6 to 7 hours after data acquisition by the RADARSAT-1 satellite. Products are being provided via a project web site and also via a web-based interactive browse and data analysis system called WIPE. ENVISAT ASAR data, when it becomes available, will provide an opportunity to enhance and extend work already underway. Experiments with the different modes of ENVISAT, particularly the Alternating Polarization Mode, should lead to algorithm improvements in wind calculation and vessel detection. In addition, new applications will be developed such as oil spill detection and mapping, river ice analysis, ocean feature detection, and algal bloom identification.

AKNOWLEDGMENTS

Funding for the AKDEMO is being provided by the NOAA/NESDIS Ocean Remote Sensing Program. RADARSAT data have been provided under the NASA RADARSAT Applications Development and Research Opportunity (ADRO) Project 396. ENVISAT data will be provided under the European Space Agency ENVISAT Announcement of Opportunity Project 431 ("Operational Demonstration of CoastWatch Coastal Oceanographic and Hydrologic Applications of ENVISAT ASAR Imagery"). SAR data have been processed at the Alaska SAR Facility of the University of Alaska, Fairbanks and distributed to the AKDEMO via the NOAA/NESDIS Satellite Active Archive. Mention of a commercial entity or product does not constitute endorsement by the U.S. Government.

REFERENCES

[1] W. Pichel and P. Clemente-Col\n, "NOAA CoastWatch SAR applications and demonstration," *Johns Hopkins APL Technical Digest,* vol. 21, no. 1, pp. 49-57, 2000.

[2] W. Pichel, P. Clemente-Col\n, K. S. Friedman, X. Li, and E. Malaret, "Analysis of ocean surface features with coincident SAR and radiometer data within the Alaska SAR Demonstration," *Proceedings IGARSS 2000 The Role of Remote Sensing in Managing the Global Environment, 24-28 July 2000, Honolulu, Hawaii,* 3 pp*., 2000.*

[3] A. Stofflen and D.L.T. Anderson, "Wind retrieval and ERS-1 scatterometer radar backscatter measurements," *Adv. Space Res.,* vol. 13, pp. 53-60, 1993.

[4] D. Thompson, T. Elfouhaily, and B. Chapron, "Polarization ratio for microwave backscattering from the ocean surface at low to moderate incidence angles." *Proc. 1998 International Geoscience and Remote Sensing Symposium,* pp. 1671-1673, 1998.

[5] D. Thompson and R. Beal, "Mapping High-Resolution Wind Fields Using Synthetic Aperture Radar," *Johns Hopkins APL Technical Digest,* vol. 21, no. 1, pp. 58-67, 2000.

[6] F. Monaldo, R. Beal, D. Thompson, W. Pichel, and P. Clemente-Col\n, "Validation of Wind Retrievals from the RADARSAT SAR," *Proceedings IGARSS 2000 The Role of Remote Sensing in Managing the Global Environment, 24-28 July 2000, Honolulu, Hawaii,* 3 pp*., 2000.*

[7] F. Monaldo, R. Beal, "Comparison of SAR-Derived Wind Speed with Ocean Buoy Measurements," *JHU/APL Report SRO-00-05, a report for the Satellite Ocean Remote Sensing Program, NOAA/NESDIS, 15 pp., 2000.*

[8] C. Wackerman, "Estimating Wind Vectors from Radarsat Synthetic Aperture Radar Imagery," *Veridian ERIM International Report 10032100-1T, prepared for Office of Naval Research for Contract #N00014-99-C-0439,* Veridian ERIM International, 25 pp., 2000.

[9] C. Wackerman, "An analytical two-scale model to predict C-VV and C-HH radar cross section values," *Veridian ERIM International Report 10020200-2-T, prepared for Office of Naval Research for Contract # N00014-99-C-0439,* 37 pp., 2000.

[10] C. Wackerman, "Automated Detection of Ships Using Radarsat SAR Imagery," Veridian ERIM International Report 10020200-1-T, prepared for Cooperative Institute for Limnology and Ecosystems Research (CILER), for Purchase Order # 3000026445, 40 pp., 2000.

[11] Friedman, K. S., C. Wackerman, F. Funk, K. Rowell, W. G. Pichel, P. Clemente-Colón, and X. Li,, 2000, Validation of an automatic vessel detection algorithm using in-situ positions. *Proceedings IGARSS 2000 The Role of Remote Sensing in Managing the Global Environment, 24-28 July 2000, Honolulu, Hawaii*, 3 pp.