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Introduction to the Special Issue on Ocean Remote Sensing with Synthetic Aperture Radar

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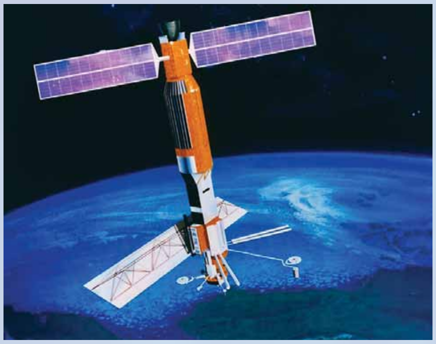
Seasat (Seafaring Satellite) was launched 35 years ago on June 26, 1978, with the first civilian synthetic aperture radar (SAR) dedicated to ocean science. Unfortunately, the excitement of sending images of the ocean, ice, and Earth lasted only 100 days when Seasat abruptly stopped operation due to a power failure. Nevertheless, it ushered in the dawn of space-based remote sensing, demonstrating the feasibility of observing and researching oceanic and atmospheric processes from space.

SAR is truly an innovative measurement device. It is extremely sensitive to small changes in roughness and to motion effects because it utilizes the relative motion between the antenna and the target area to synthesize an aperture that is kilometers long in space. Thus, it creates much finer spatial resolution than is possible with the satellite's physical antenna. Carl A. Wiley, a mathematician working for Goodyear Aircraft Company, invented the concept of synthetic aperture in June 1951 while working on a correlation guidance system for the Atlas Inter-Continental Ballistic Missile program. In early 1952, Chalmers Sherwin and other researchers at the Control Systems Laboratory of the University of Illinois independently performed experiments with radar systems that had the potential to focus at all ranges simultaneously because of greatly improved angular resolution.



Artist's concept of Seasat. *Image Credit: NASA/JPL*

Many developments that resulted from related work by researchers at the University of Michigan's Willow Run Research Center eventually led to the first successful focused airborne SAR image of the Willow Run Airport and vicinity in August 1957. The data were processed on an optical analog computer that could perform large-scale scalar arithmetic calculations in many channels simultaneously. Although the first operational SAR was put on an F-4 Phantom jet during the Vietnam War, the images failed to impress due to low resolution and the presence of speckle, an artifact that is still characteristic of SAR data and that makes interpretation of the images more challenging compared to optical photos. Speckle is the main reason that SAR has not been widely accepted for scientific, commercial, military, and civilian government applications.

Further airborne experiments and tests with antennas in the 1960s led to the recognition that SAR is better suited on a platform circling Earth in a low orbit of a few hundreds of kilometers. Complementary inventions in the field of lasers and digital processors (i.e., computers) allowed the rapid processing of multiple channels of SAR data at once.

In the 1970s, NASA's Jet Propulsion Laboratory began to develop a dedicated ocean measuring satellite called Seasat. When launch time approached, the expected digital processor for the SAR was not ready and an optical recorder and processor were quickly constructed. During the launch year, the Canadian company MacDonald, Dettwiler and Associates developed the first digital processor, but it took hours to produce an image from just a few seconds of radar data. However, the quality of the image was significantly better than that of the optically processed images.

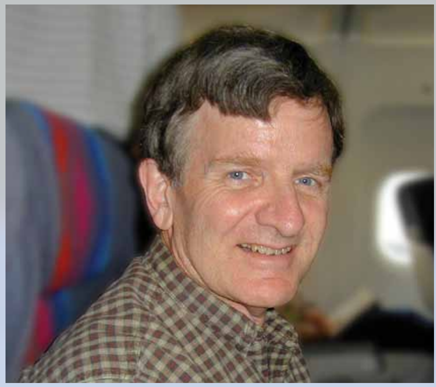
Encouraged by these results and those from several missions with the Shuttle Imaging Radar in the 1980s, the European Space Agency embarked on a project to put a dedicated SAR satellite in orbit. The first European Remote-Sensing Satellite (ERS-1) was launched in 1991, followed shortly by RADARSAT-1 in 1995 by the Canadian Space Agency. These trend-setting SARs (both C-band) based on Seasat technology were eclipsed with more capable and higher resolution SAR systems in the mid-2000s—RADARSAT-2 (C-band), ALOS/PALSAR (L-band), and TerraSAR-X and TanDEM-X (X-band), as well as the first constellation of SAR satellites called COSMO-SkyMed (X-band).

In this special issue, we provide an overview of current innovative applications of SAR data to exploring and understanding ocean processes and phenomena. **Ager** leads off with an introduction to synthetic aperture radar, providing detailed, yet basic, descriptions of how this complex system works and of the different SAR sensors and modes available today. Next, **Monaldo et al.** trace the history of SAR wind speed retrieval from the first Seasat SAR images to today's NOAA/NESDIS RADARSAT-2 operational wind speed products.

Horstmann et al. present the latest developments with respect to tropical cyclone winds retrieved from SAR, and show that useful information on tropical cyclone wind fields can be acquired in either co-pol or cross-pol modes. **Foster** describes a novel approach to providing geophysically consistent surface winds and their associated pressure fields. **Jackson et al.** explain how SAR can image oceanic phenomena, such as nonlinear internal waves, that propagate tens of meters below the surface. **Lehner et al.** describe how high-resolution SAR images a variety of coastal processes, and **Romeiser** presents a cutting-edge approach to extracting surface currents from SAR data. Moving into colder waters, **Dierking** discusses the challenges of using SAR for sea ice monitoring.

Detection of surface phenomena such as man-made and natural slicks is of high interest since the Deepwater Horizon incident. The papers by **Caruso et al.** and **Garcia-Pineda et al.** discuss the challenges of detecting oil spills, while **Gade et al.** describe how these slicks can be markers of coastal dynamics. The final paper, by **Mallas and Graber**, is related to maritime security and discusses how SAR is used to detect ships at sea.

On a very sad note, we would like to remember with this special issue our friend and colleague Donald Robert Thompson, who passed away unexpectedly on December 1, 2011. Don started his career as a nuclear physicist. In 1980, he joined the Applied Physics Laboratory of the Johns Hopkins University as a principal staff physicist. Here, Don applied his exceptional skills in nuclear scattering calculations to gain a better understanding of radar backscatter from the ocean surface. He quickly became an international leader in using radar measurements to observe the ocean's internal waves, surface waves, and currents, as well as marine surface winds. Don's work remains significant to understanding the capabilities as well as limitations of these measurements. He was one of the first to accurately predict radar cross-section variations across ocean internal waves. He helped explain high-frequency radar measurements of currents and current measurements from SAR. He also elucidated the expected reflections of GPS signals from the ocean surface, and helped develop geophysical model functions that relate ocean surface winds to radar cross sections based on simulations of electromagnetic scattering. His scientific productivity never faltered, extending to completion of a paper on measuring ocean winds at X-band that was published posthumously. Don, we miss you, and *Du bist immer in unseren Gedanken*!



Donald Robert Thompson.

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