A New Milestone in Radar Remote Sensing of Earth's Oceans, Land Waters, Cryosphere, and Seafloor

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Radar remote sensing of Earth was first demonstrated by Seasat launched 48 years ago. The synthetic aperture radar (SAR) carried onboard showed high resolution images of Earth's oceans, land surface, and sea ice. The radar altimeter of Seasat showed the variability of sea surface height caused by ocean surface currents as well as marine gravity anomalies. However, the spatial resolution of radar altimeters is limited by the large radar footprint (~10 km) and measurement noise, making it difficult to study small-scale, rapidly changing ocean processes, especially near coasts. The coarse resolution has also limited the capability of observing land surface waters.

While SAR provides high-resolution images of many features of Earth's surface, it is difficult to derive quantitative information to study the underlying geophysical processes. Analysis of the phase difference of consecutive SAR observations (a technique called radar interferometry) has allowed determination of the slow movement of ice sheets since the early 1990s. The concept of applying radar interferometry onboard a satellite for oceanography and land hydrology was developed in the 2000s. Twenty years later the global mission called Surface Water and Ocean Topography (SWOT) was launched in December 2022.

The fundamental advancement of SWOT is the capability of observing the elevation of Earth's waters with spatial resolution never achieved before, close to that of SAR.
This unprecedented capability allows the measurement of sea surface height at scales of 1 km versus 50 km from previous radar altimeters, as well as the elevation of water surface of rivers wider than 30 m and lakes larger than 1 hector, representing an order of magnitude improvement over the previous capability from radar altimeters. These measurements have been used to compute ocean current velocity at small scales for understanding the vertical exchange of heat and carbon between the atmosphere and the ocean, a key process governing the changing weather and climate. The increased resolution will also advance the study of near shore processes to assess the coastal impact of sea level rise and severe weather. SWOT data are also used to compute the flow rate of the world's rivers wider than 30 m, and water storage of lakes larger than 1 hector. These unprecedented data have helped water managers to assess fresh water supplies and improve prediction of flood and draught. Marine gravity anomalies derived from the slopes of sea surface height are used to map seafloor topography with findings of tens of thousands of previously undetected seamounts, as well as abyssal hills, which are the most common form of sea floor revealing the past evolution of marine tectonics. The measurement of the elevation of sea ice (the free board) is used to estimate the volume of sea ice, which is a key parameter for understanding the cryosphere in response to climate change.