Bathymetry using Synthetic Aperture Radar (SAR) satellites

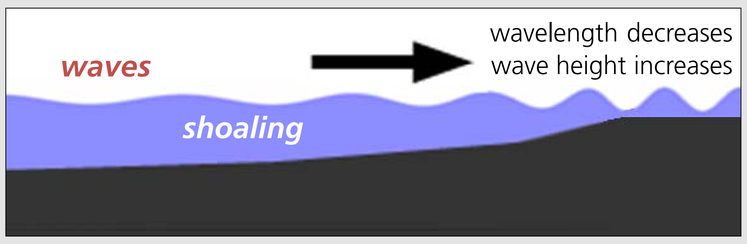
Maritime SAR applications

Synthetic Aperture Radar (SAR) is an active remote sensing technology. Radar satellites emit and receive their own signals and, hence, do not need to rely on sunlight for their acquisitions. Another benefit compared to optical satellites is SARs ability to look through clouds, which means data acquisition is very reliable.
Radar beams cannot penetrate water. However, the small ripple waves on the sea surface are enough to reflect the signals back to the satellite.
In the maritime sector, SAR is currently being used for the detections of sea state, wind, oil spills, sea ice, icebergs and ships. These detection algorithms have been developed to run automatically in the receiving station to provide results in Near Real Time (NRT). Applications are the improvement of wave and wind models by providing data across large areas, the improvement of maritime domain awareness, and the support of vessels travelling through ice-infested waters.
With the BASE-platform project, bathymetry is added to this list of maritime SAR applications.

SAR bathymetry retrieval

- **Shoaling effect**

Waves travelling into shallower waters are subject to the shoaling effect: they increase in height while their length decreases



- **Dispersion relation**

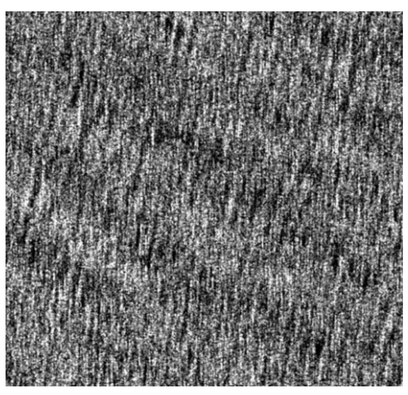
The dispersion relation describes the relation between wave length and water depth:

$$d = \frac{L}{2\pi}\tanh^{-1}\left(\frac{2\pi L}{gT^2}\right)$$

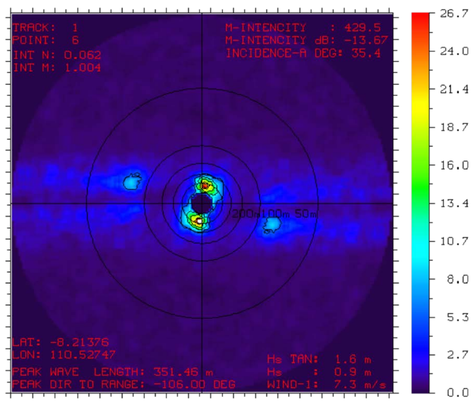
To calculate the depth, the wavelength *L* and the wave period *T* are necessary.

- **Wavelength retrieval**

The wavelength is determined from a SAR scene using 2D Fast Fourier Transformation (FFT). Automatic error filtering is applied to remove the effect of ships, buoys, wind parks, or sand banks from the resulting spectrum.



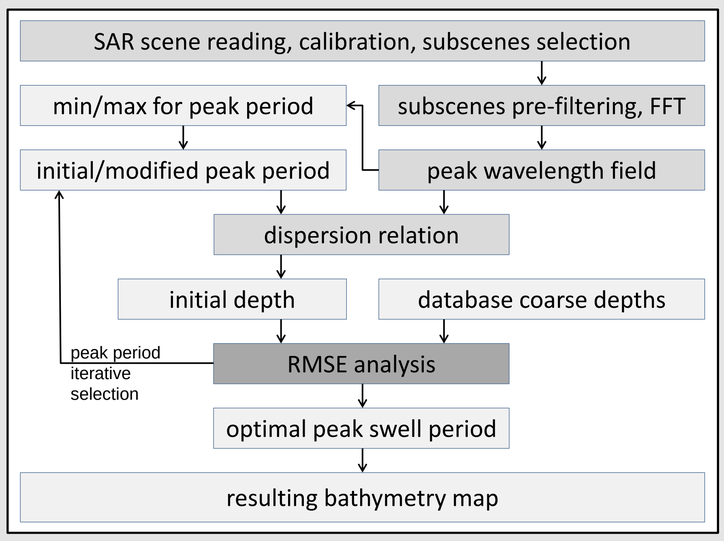
Original SAR subscene



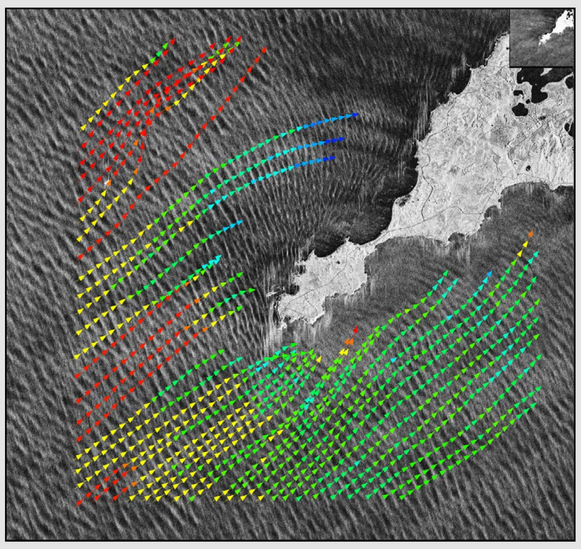
Retrieved spectrum

- **Wave period retrieval**

The wave period cannot be retrieved from the SAR scene directly since it does not contain any temporal information. Instead, it is calculated with a minimum deviation analysis using pre-existing bathymetric data from sources like GEBCO or EMODnet as first guess.

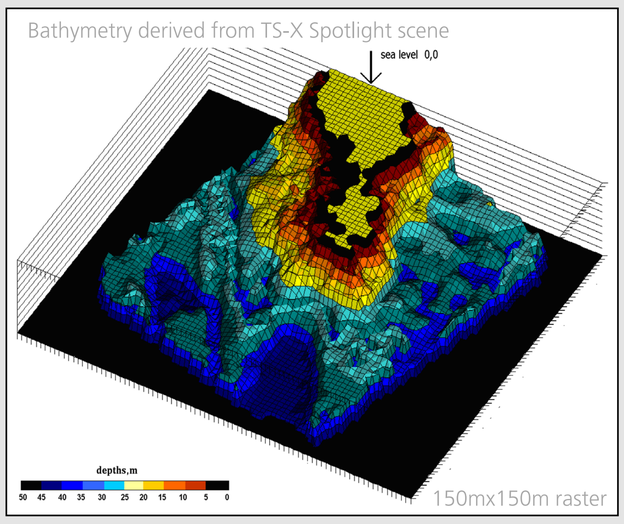


Application test site: Rottnest Island (Australia)

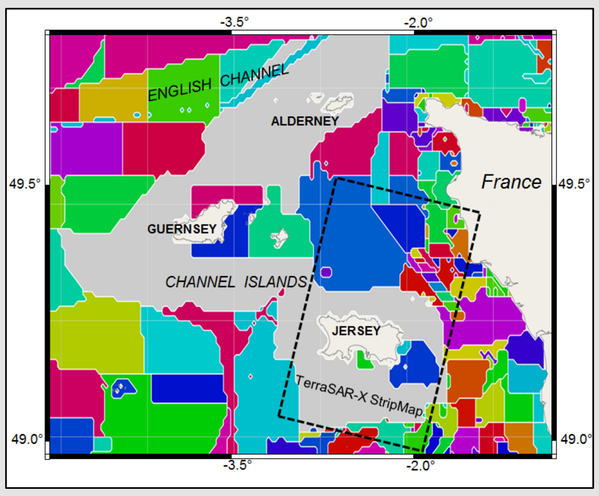


Rottnest Island is located on the west coast of Australia close to Perth. Its frequent exposure to long swell waves from the Indian ocean made is very suitable for SAR bathymetry retrieval.
The scene on the left is a high resolution TerraSAR-X SpotLight scene, © DLR 2009. Wave rays were used in this case, started at the scene boundaries and tracked until they read shallow waters. The swell waves are well visible; colours indicate the different wave lengths detected.

The retrieved SAR bathymetry was combined with optical bathymetry to cover also the shallow coastal waters. Both datasets compared favourably to in-situ measurements with echo sounders.
The right figures shows the SAR bathymetry retrieved around Rottnest Island from the scene shown above with the bathymetry calculated on a 150m grid.

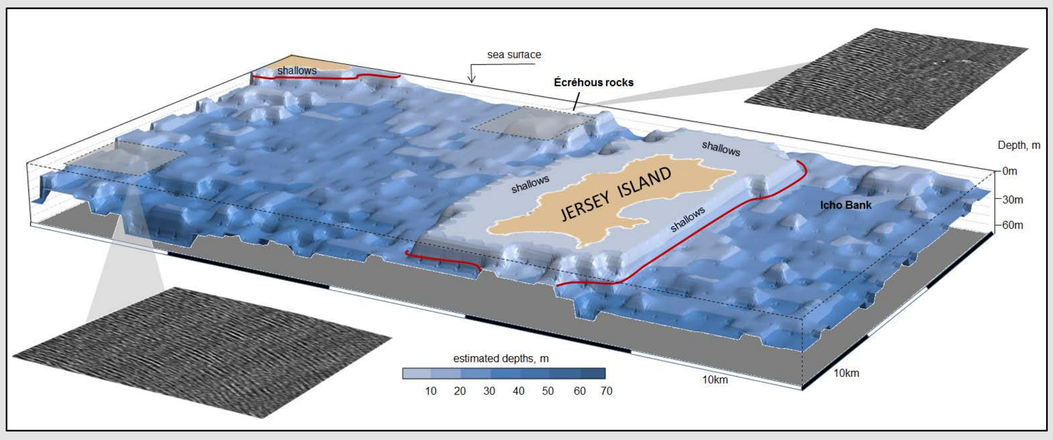


BASE-platform trial area: Channel Island (UK)



Despite their central location within Europe just south of the English Channel, the bathymetry around the Channel Islands area is poorly known. The right figure shows the source for data available in the EMODnet portal; coloured areas indicate various sources of survey data while grey areas indicate data from GEBCO, which in this area may date back to lead line measurements from the 19th century.

Within the BASE-platform project, this area was selected as one of our trial areas to improve the availability of up-to-date bathymetry data there. While altimetry cannot be used here due to the shallow waters and proximity to the mainland, optical, SAR and crowd-sourced information can be combined with water level modelling to receive an updated, high-resolution bathymetry.
The figure below shows the results of SAR bathymetry from a TerraSAR-X StripMap scene; its location is indicated in the figure above. The differences between wave lengths in deep and shallow waters is easily discernible from the two subscenes shown.



More information at:
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