The Wavemill 2D Ocean Current Mapping System: On-Board Signal Processing and Architecture Definition

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1 - OVERVIEW

The Wavemill 2D Ocean Current Mapping System is a microwave interferometric SAR concept proposed by C. Buck (2005) to provide wide swath, high-resolution, high precision 2D maps of ocean surface topography and ocean vector currents.

This CEOI Seedcorn study focusses on estimating the on-board processing capabilitiies needed for Wavemill to deliver the scientific requirements for wide-swath ocean mesoscale and coastal zone mapping. This UK-funded study complements a recently completed ESA Wavemill project on the sampling and measurement capability of Wavemill (Márquez et al., 2010).

2 - The WAVEMILL INSTRUMENT CONCEPT

The Wavemill instrument concept is a hybrid interferometric system, which combines both across-track interferometry (for the determination of sea-surface topography) and along-track interferometry (for measurement of the total ocean surface current velocity). By means of multiple squinted beams fore and aft of the satellite, the surface can be imaged from different nearly orthogonal directions, from which true two dimensional maps of ocean surface topography and total ocean velocity may be determined over a broad swath.

The capabilities of the Wavemill concept were studied extensively in a recent ESA study (Márquez et al., 2010). The instrument specifications and measurement performance of the Wavemill system are summarised in Table 1 below.

Satellite altitude	546	km	Burst length	22.8	ms
Carrier frequency	13.3	GHz	Antenna length	4	m
Chirp bandwidth	100	MHz	Antenna height	0.2	m
Peak transmit power	2.3	kW	Effective XT baseline (co-time)	3.38	m
Noise Figure	5.7	dB	Effective XT baseline (hybrid)	1.86	m
Pulse length	74	µs	Effective AT baseline (hybrid)	12.41	m
PRF	2700	Hz	Sea current horizontal resolution	1	km
Total processed Doppler Bandwidth	1400	Hz	Sea topography horizontal res.	15	km

Ocean topography			
Better than 10 cm for 15 km spatial resolution			
Ocean surface current magnitude			
Better than 0.1 m/s for 1 km spatial resolution and over the full swath (2 x 100km)			
Ocean surface current direction			
Better than	5°	@ 0.85 m/s	for 1 km spatial resolution and over the full swath (2 x 100km)
	10°	@ 0.42 m/s	
	20°	@ 0.21 m/s	

Table 1: Wavemill instrument specifications from the ESA Wavemill study and estimated measurement retrieval capabilities for ocean surface topography and total ocean surface current vectors (from Buck et al., 2009)

3 - The WAVEMILL/JAVELIN CONCEPT

The original Wavemill concept consisted of four SAR antennas, but a more compact design, known as the Javelin, has recently been proposed and evaluated. Figure 1 shows an artist's impression of the Javelin concept, while Figure 2 shows respectively the across-track (XTI) and along-track (ATI) interferometric baselines achieved with this design.

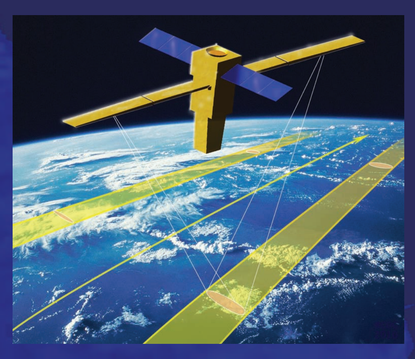

Figure 1: Artist impression of the Wavemill/Javelin concept

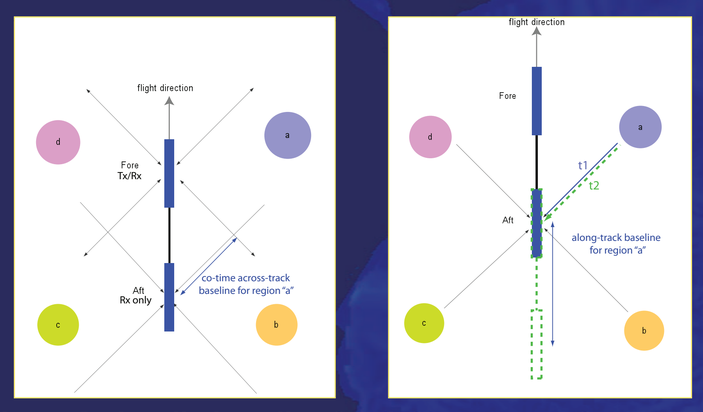

Figure 2: Javelin baseline for (left) ocean surface topography (XTI) and (right) total ocean surface velocity (ATI)

4 - RELATING SCIENCE REQUIREMENTS and DATA PROCESSING NEEDS

An essential aspect of the design of the Wavemill hardware is to ensure that the system has sufficient on-board processing capability to cope with the need to compute large numbers of complex interferograms and to handle large volume of data. This project addresses this specifically, to determine what capability is needed in order for Wavemill to deliver measurements pertinent to the needs of the oceanographic science and operational community, in the open ocean and in the coastal zone.

Figure 3 illustrates the complex relationships between observational needs, spatial sampling, retrieval accuracy, instrument specifications and on-board data processing capabilities. Science and operational needs are often expressed in terms of spatial resolution, but it is really the ability to achieve adequate retrieval accuracy that remains the critical condition for any system. In the case of Wavemill, retrieval accuracy is intimately linked to spatial resolution, which in turn determines the requirement for on-board processing capability.

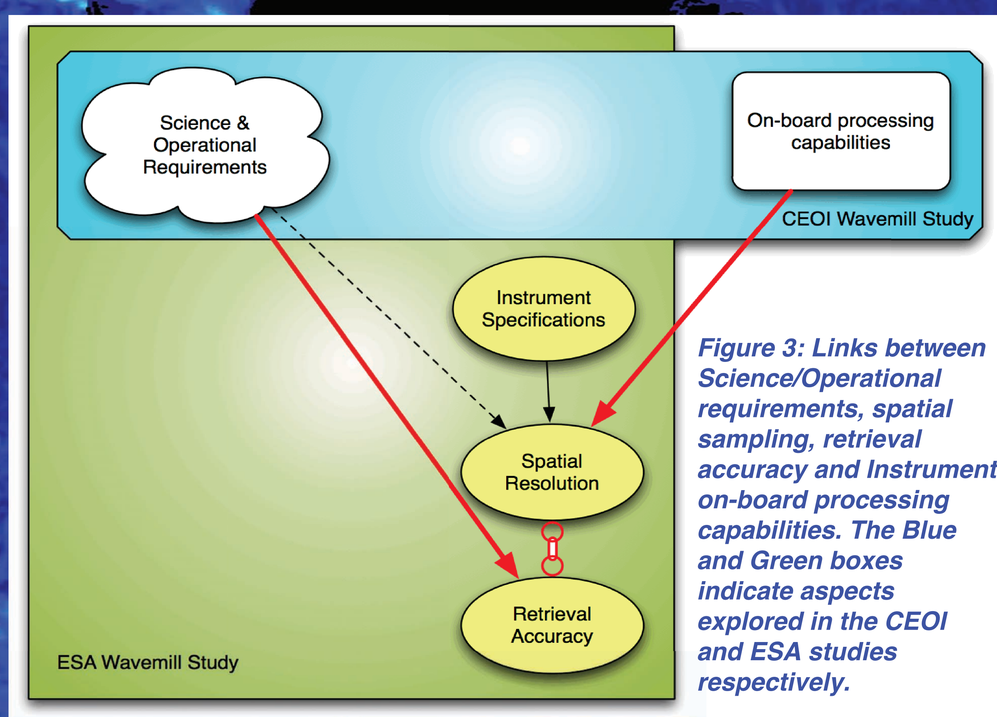

Figure 3: Links between Science/Operational requirements, spatial sampling, retrieval accuracy and Instrument on-board processing capabilities. The Blue and Green boxes indicate aspects explored in the CEOI and ESA studies respectively.

5 - CONCLUSIONS AND RECOMMENDATIONS

Operational ocean models play an essential role in delivering ocean surface topography and total ocean current velocity to users engaged in a wide range of research and operational applications. As a result, the needs of ocean models for data assimilation drive the requirements for satellite observations.

In the open ocean, requirements include satellite sea surface height data over wide swaths and at spatial scales that are finer than what can be achieved with the present constellation of nadir-pointing altimeters. Two-dimensional maps of sea surface height over 100 km swaths with ~10km spatial resolution and of order 5 centimeter accuracy would go a long way towards addressing these needs.

In the near-shore and shallow water regions, the situation is very different, as there is a strong need for high-resolution maps of total ocean current velocity and direction, including the ageostrophic components which are dominant in these regions. These needs are best addressed by along-track interferometric measurements, which can yield data with spatial resolution of 1km or less. The required retrieval accuracy for current velocity (~0.1m/s) and direction (~10 deg) are also well within the reported capabilities of past airborne and spaceborne experimental ATI SAR systems.

In summary, the Wavemill instrument concept could address user needs for ocean topography and ocean current measurements in the open ocean and the coastal zone with one single system. Thanks to in-flight re-programmable technology, the on-board processing would be optimized to maximise the duty cycle and best exploit the hybrid capabilities of the system. Ideally, the system would operate in XTI mode in the open ocean to provide sea surface height data, switching to high-resolution ATI mode over coastal and shallow water regions, to provide high-resolution data on total ocean surface currents.

References

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Background Image: Oceanic fronts derived from satellite SST© Lekouara, NOCS, 2010

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