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On the coherence of nadir altimeter signals over water with ENVISAT RA-2 Individual Echoes

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The ENVISAT Radar Altimeter (RA-2) offers a range of innovative features, including measurements at a second lower radar frequency (S-band), easy access to high-rate (18Hz) ocean waveforms and bursts of un-averaged complex altimeter returns (˜2kHz) at Ku-band. RA-2 is the first space borne altimeter to provide such bursts of individual echoes (IE). This mode of acquisition has been operational on ENVISAT since the beginning of the mission, resulting in a global dataset now spanning over 5 years. More details about RA-2 Individual Echoes and their processing can be found at http://earth.esa.int/raies/.

This paper presents results of scientific investigations within the recently-concluded ESA RAIES contract of the correlation properties of RA-2 altimeter signals using bursts of individual echoes over water surfaces in the open ocean and the coastal zone. Studies of RA-2 individual echoes (IE) revealed that IE bursts contain a wealth of new information about the Earth's surface and about the performance of the RA-2 instrument. The IE data used here were processed at NOCS using the RAIES IE processor v4.2 developed by SciSys Ltd within the ESA RAIES contract.

Analyses of the IE bin-to-bin correlation properties (within altimeter waveforms) revealed (i) systematic spurious data in the 1984th waveform for all bursts examined in Cycle 39-41, (ii) the performance of RA-2 is as expected for de-correlated pulses once the 1984th waveform is removed, (iii) interesting subtle effects in higher order IE phase comparisons that are consistent in ocean returns, but somewhat different over

land surfaces (iv) marked change in phase characteristics between the thermal noise region and the main ocean return originating at least in part from other weak instrumental effects.

Access to IE bursts collocated with Level2 GDR information through the SciSys RAIES v4.2 processor permitted extensive data mining exercise of the IE dataset based on L2 GDR geophysical data. It was possible to identify and select IE over specific surface conditions to examine their pulse-to-pulse correlation properties. The prime motivation for this work was to determine if pulse-to-pulse coherence could be observed with ENVISAT RA-2 over water surfaces despite RA-2's low PRF.

A number of criteria were used to identify IE for calm water surfaces, with particular care given to discriminating altimeter echoes over calm water from altimeter echoes over sea ice, which show similar highly specular waveform characteristics but have markedly different coherence properties. Maximum pulse-to-pulse correlation for IE over water surfaces was observed for both IE amplitude and phase at or near the nominal tracking point (gate 46 for RA-2) and decrease with significant wave height.

These studies have major implications for future altimeter missions, in particular the next generation of phase-enabled altimeters (Cryosat, Sentinel), which have the ability to return un-averaged complex echoes over the ocean at a much higher rate. This will open up a range of opportunities for higher-performance altimeters and new ocean altimetric applications of interest to space agencies and scientists.