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UNIVERSITY OF SOUTHAMPTON AND NATURAL ENVIRONMENT RESEARCH COUNCIL

Development of SAR Altimetry Mode Studies and Applications over Ocean, Coastal Zones and Inland Water (SAMOSA)

ESRIN Contract No. 20698/07/I-LG

WP7.3 Technical Note

Assessment of Envisat RA-2 Individual Echoes over ocean

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1. PURPOSE OF THIS DOCUMENT

This Technical Note represents the deliverable for SAMOSA WP7.3 and documents the work undertaken in SAMOSA WP7.1 on the experimental testing of Delay Doppler Processing of Envisat RA-2 Individual echoes over the ocean. The task was foreshortened to focus remaining resources in the contract on the work in SAMOSA WP 5.3.

2. IDENTIFYING ENVISAT RA-2 INDIVIDUAL ECHOES FOR DELAY DOPPLER PROCESSING

Delay Doppler processing relies on consecutive echoes being correlated. In the case of the RA-2 pulse limited altimeter, the PRF was chosen deliberately low to ensure decorrelation between successive echoes. This is so that noise reduction can be achieved by incoherent averaging.

Thus RA-2 pulses will generally be uncorrelated over ocean surfaces, except possibly in very low sea state. This hypothesis was examined using RA-2 Individual Echo (IE) Bursts in the course of CCN3 to the ESA RAIES contract 17900/03/I-LG [RD1].

Three complete cycles of RA-2 IE bursts data were processed to L1B and L2 with the RAIES processor at NOCS. We calculated the pulse-to-pulse auto-covariance for all IE over all surfaces, to identify bursts featuring pulse-to-pulse coherence. Figure 1 shows the location of IE bursts and the magnitude of the pulse-to-pulse covariance of IE amplitude and phase. The highest coherence values were obtained in regions affected by sea ice.

Using a criterion based on the significant wave height, peakiness and latitude given in the collocated Level 2 GDR, we developed the means to discriminate IE bursts over very calm ocean from IE bursts over sea ice. Figure 2 shows the IE amplitude and phase pulse-to-pulse covariance plotted against Hs, for IE obtained over ocean (blue and green) and sea ice. We see that the coherence for IE over ocean is largest at very low Hs and disappears for Hs larger than 2m. We also note that IE over sea ice is often very highly coherent.

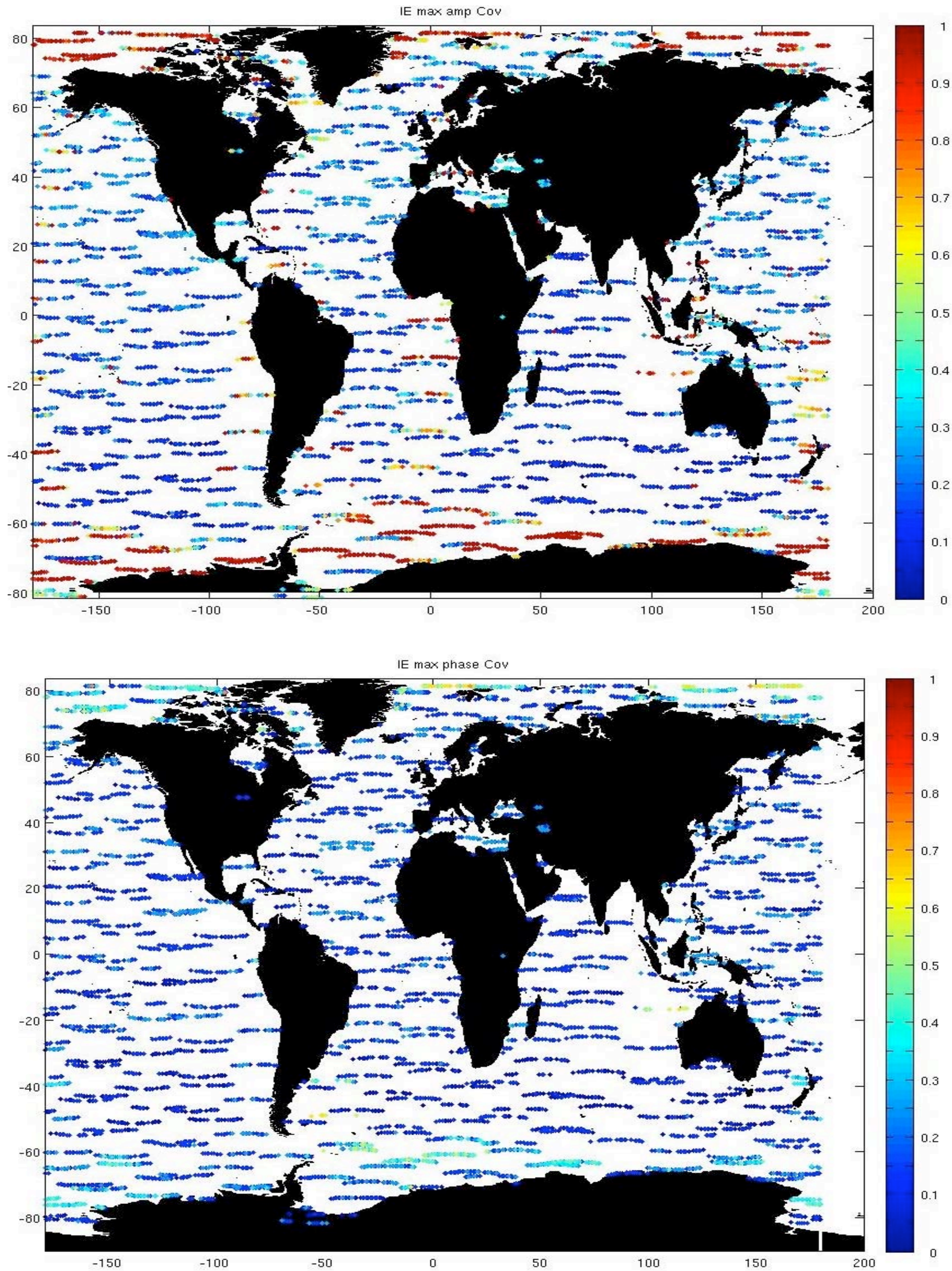
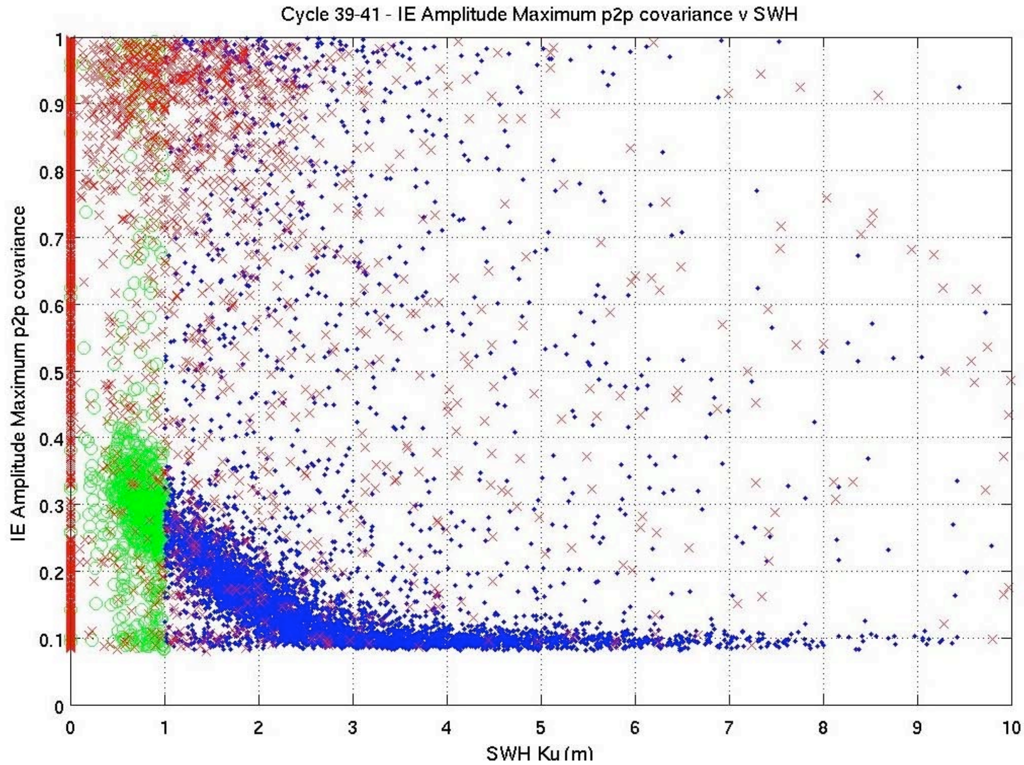


Figure 1: Pulse-to-pulse covariance in Envisat RA-2 IE (top) amplitude and (bottom) phase over ocean and sea ice.



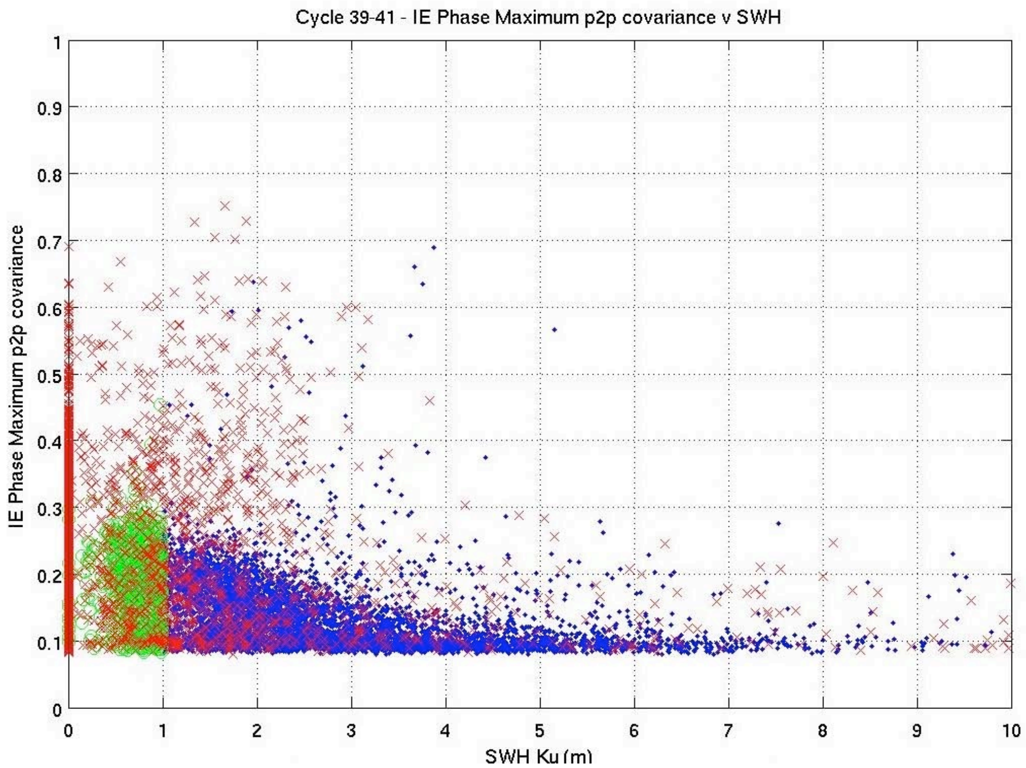


Figure 2: Pulse-to-pulse covariance in Envisat RA-2 IE (top) amplitude and (bottom) phase over ocean (blue and green) and sea ice (red).

3. EXPERIMENTAL DELAY DOPPLER PROCESSING OF RA-2 IE BURSTS OVER OCEAN

Based on this dataset and understanding, we identified IE bursts over the ocean with maximum coherence for experimental testing of Delay Doppler processing.

Figure 3 shows the geographical location of one of the selected bursts, and a top-down view of the along-track evolution of IE waveforms amplitude and phase within the burst. Despite the high coherence, the echo still displays a Brown-type slowly decaying trailing edge, rather than the strongly specular appearance that is sought for DD processing.

The first step of Delay Doppler Processing was nevertheless applied, consisting of the along-track 1D FFT of the complex echo burst [RD2]. The procedure was applied with both N = 1983 and N = 512. The results of the FFT are shown in Figure 4. According to [RD2], the results of the FFT for N= 512 should avoid problems of aliasing, as long as coherence is sufficient. However, in both cases, aliasing due to the low PRF is still observed. Hence, no further processing was applied to IE over ocean.

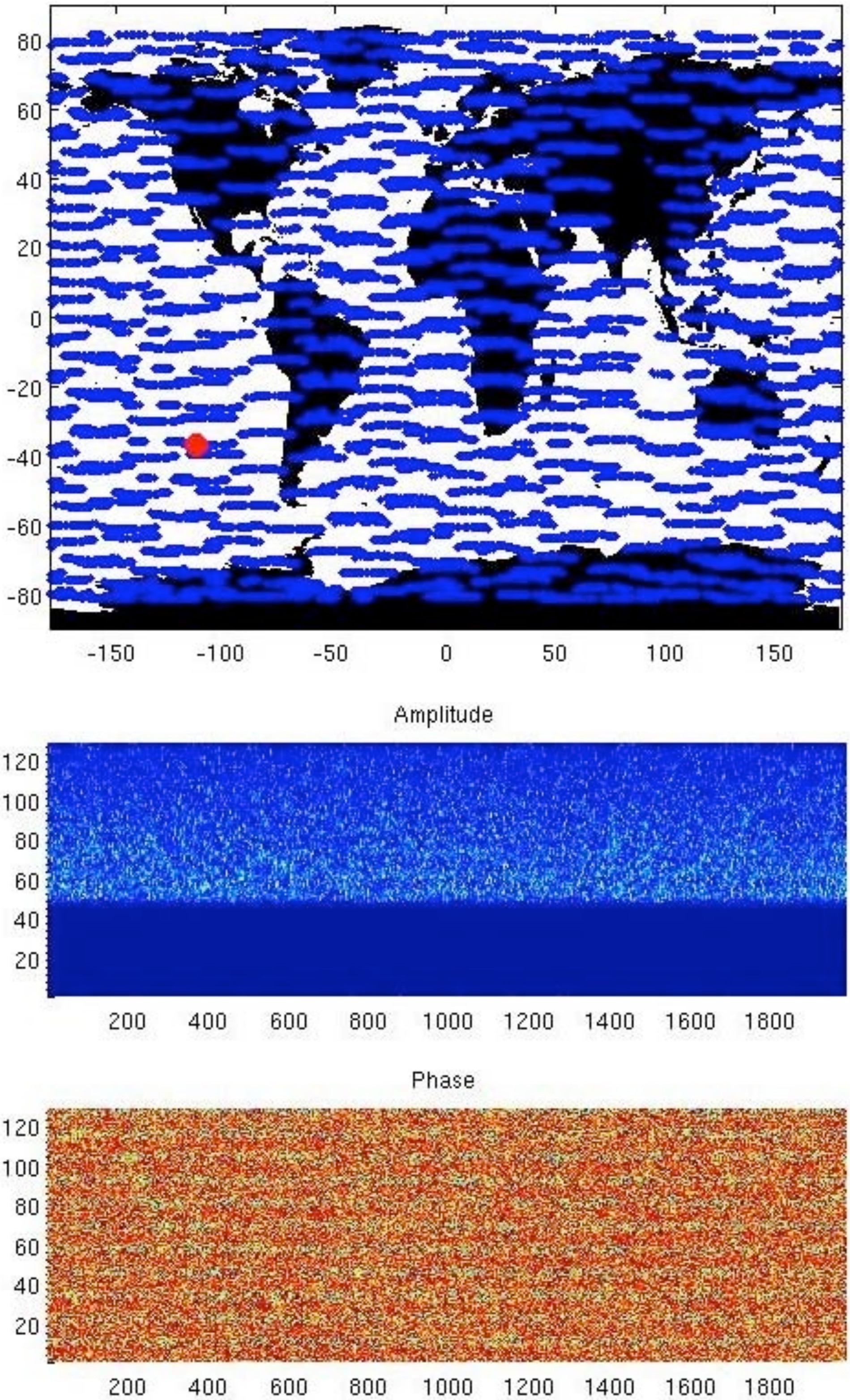


Figure 3: (Top) Location of high-coherence IE burst over ocean with (middle) IE amplitude and (bottom) phase within the 1.1 second burst (1983 echoes * 128 gates)

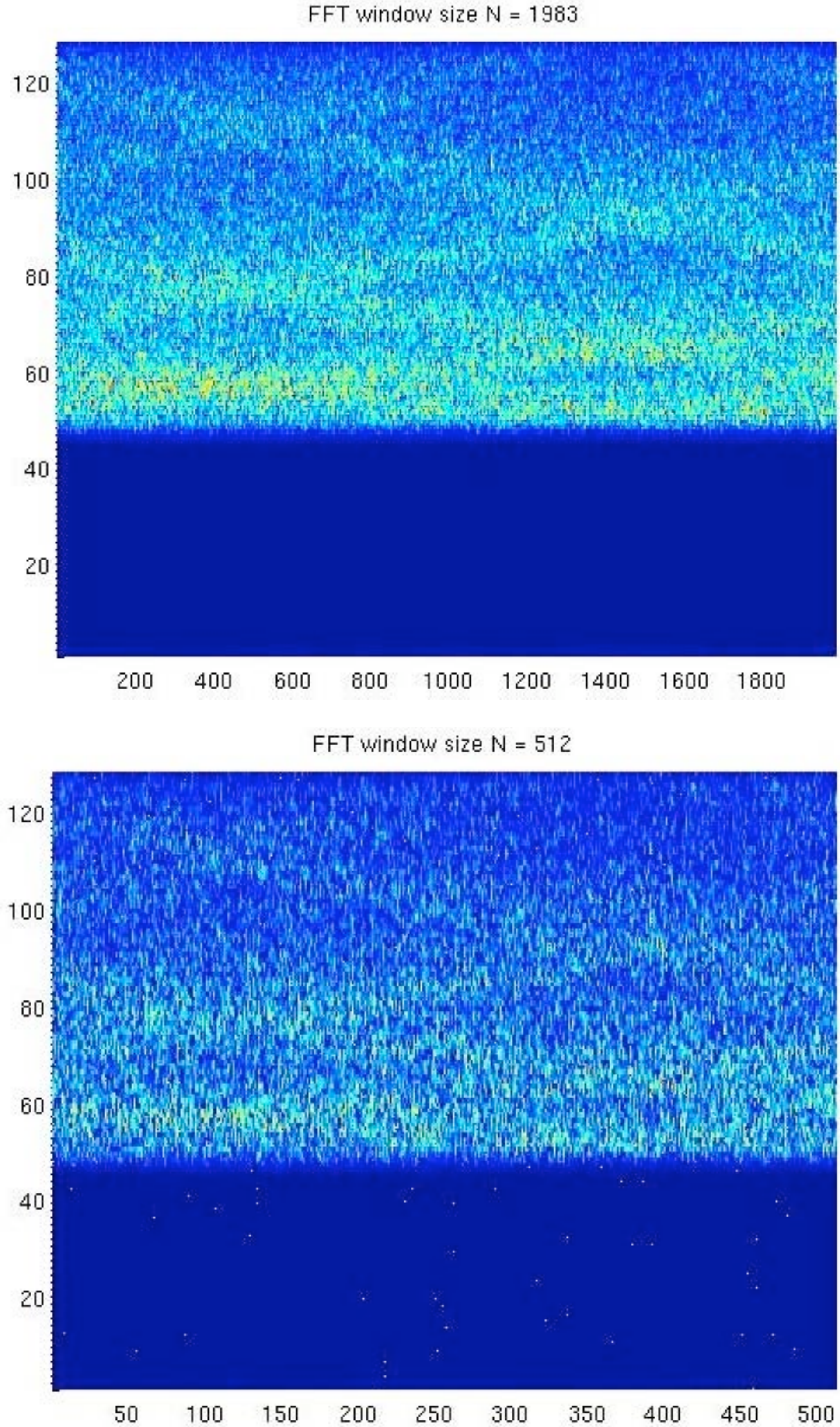


Figure 4: Along-track 1D FFT of complex IE burst for (top) N=1983 and (bottom) N = 512.

4. EXPERIMENTAL DELAY DOPPLER PROCESSING OF RA-2 IE BURSTS OVER SEA ICE

Out of curiosity, the same procedure was performed on an high-coherence IE over sea ice.

Figure 5 shows again the location of the selected burst, and the IE waveforms amplitude and phase within the burst. This time, the IE sequence shows a highly specular echo, characterised by very high amplitude, a rapidly trailing edge and coherent phase in the gates around the leading edge.

The result of the along-track 1D FFT is presented in Figure 6, again for N = 1983 and N= 512. This time, there is no evidence of aliasing in either case and the result displays a well-defined sharp peak. The horizontal axis represents Doppler frequency bins shown in FFT wrapped order, i.e. ranging from 0 (at x = 0) to PRF/2 (at x = N/2) to - PRF/2 (at x = N/2 +1) to – PRF/N (at x = N) with the interval Δf = PRF/N.

The peak displays a roll-off in frequency consistent with that seen in SAR Delay Doppler Maps [RD3], but extends only to over a few waveform gates. The benefit of further Delay Doppler processing would therefore be difficult to assess, and no further processing was performed.

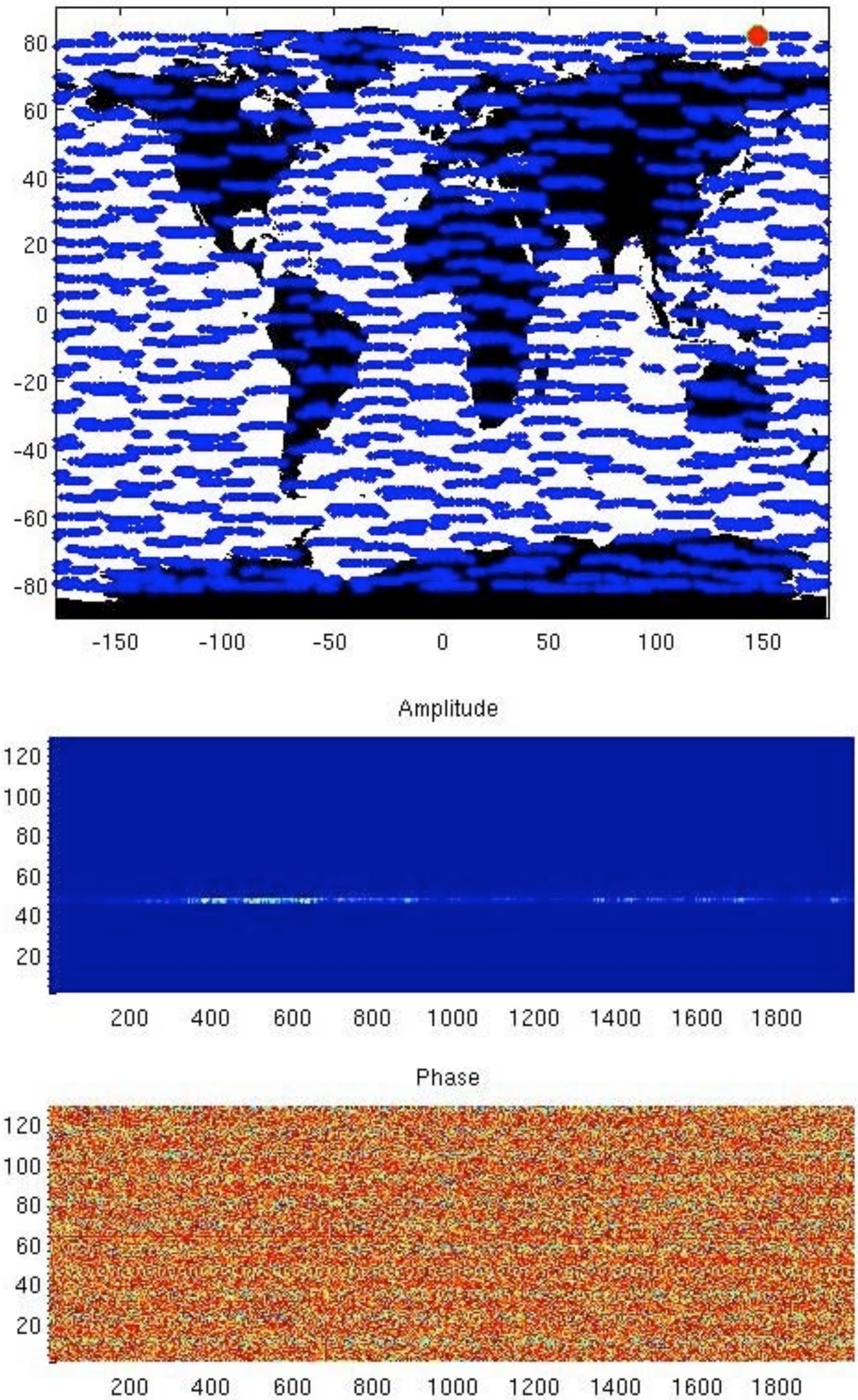


Figure 5: (Top) Location of high-coherence IE burst over sea ice with (middle) IE amplitude and (bottom) phase within the 1.1 second burst (1983 echoes * 128 gates)

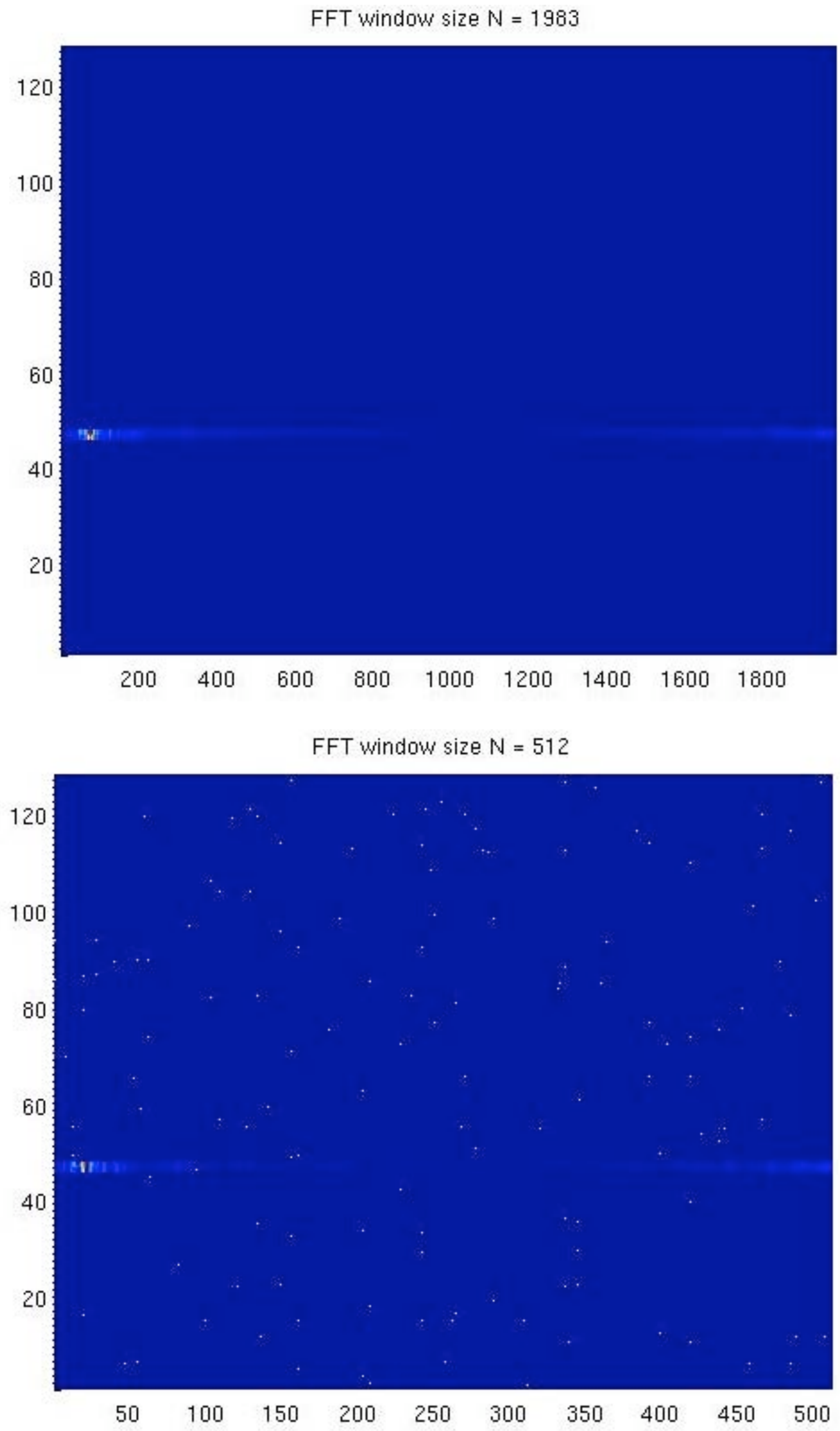


Figure 6: Along-track 1D FFT of complex IE burst for (top) N=1983 and (bottom) N = 512.

5. CONCLUSIONS

The first step of Delay Doppler processing was applied to high coherence IE over the ocean and over sea ice. In the case of IE over ocean, even the highest observed coherence was not sufficient to warrant delay doppler processsing. Results over sea ice showed more promise but were not pursued due to insufficient resources remaining in the contract.

6. REFERENCES AND APPLICABLE DOCUMENTS

[RD1] Gommenginger C.P. & G. Quartly, RAIES Third and Final Contract Change Note update of Task 5 Technical Note on “Scientific exploitation of Individual Echoes for ocean applications”, ESA Contract 17900/03/I-LG: Exploitation of the ENVISAT radar altimeter individual echoes and S-band data for ocean, coastal zone, land and ice/sea-ice altimetry (RAIES), 55 pages, Dec 2007.

[RD2] Gommenginger C.P. & P. Cipollini, SAMOSA WP7 Technical Note on “Delay Doppler Processing of Envisat RA-2 Individual Echoes”, ESRIN Contract No. 20698/07/I-LG: Development of SAR Altimetry Mode Studies and Applications over Ocean, Coastal Zones and Inland Water (SAMOSA), 13 pages, February 2009.

[RD3] Gommenginger C.P. & M.A. Srokosz, SAMOSA WP5.3 Technical Note on “Development & Testing of SAR Altimeter waveform theoretical retracker”, ESRIN Contract No. 20698/07/I-LG: Development of SAR Altimetry Mode Studies and Applications over Ocean, Coastal Zones and Inland Water (SAMOSA), 34 pages, July 2009.