2632088

Pulse-Pair (Doppler) Processing of Envisat Individual Echoes

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The Envisat 'Individual Echoes' (IE) recording mode provides a 1-second burst of 1984 individual complex echo returns every 1 minute (the rest of the time the data stream is processed into 20 Hz bursts). One record of IE data is 1984 pulses x 128 range bins. This collection mode was designed for experimentation beyond the conventional burst processing. This paper follows on several other research publications discussing various possibilities for exploiting complex IE data. We investigate Doppler processing and the potential for increasing in-range resolution through Doppler focusing. We processed IE data with Fourier transforms. Envisat PRF of 1800 is intended for a maximum number of independent (uncorrelated) echoes. If the echoes where indeed uncorrelated, the spectra would be featureless. But instead there was immediate evidence of significant spectral lines, indicating coherence in Envisat pulse train. This is not a contradiction of the Envisat goal for independent samples. The coherence levels are small and the samples are almost uncorrelated. However with 1984 samples a coherence as small as 0.05 is statistically significant and sufficient to obtain some of the benefits of Doppler processing. Borrowing an idea from the meteorological radar community, we also use Pulse Pair Processing (PPP), which under certain conditions provides more accurate estimates of the spectral moments than the Fourier Transforms. PPP uses lagged products of echoes, conj(z(n))z(n+k). The magnitude of the sum with k=0 is the usual incoherent power. A new and possibly more useful 1-lag power can be produced. Doppler velocity and coherence are also obtained from such lagged products. Doppler and PPP are demonstrated on IE data time series over open ocean. A companion poster titled Examples of Pulse-Pair (Doppler) Processing of Envisat Individual Echoes In Coastal and Inland Waters will provide additional case-studies. Coherence levels are 0.05 to 0.3 and are in inverse proportion to sea state (calm seas has the highest coherence). The measured Doppler velocities correspond to the satellite vertical velocity, with an rms of 0.26 m/s. The peaks in 1-lag power and 1-lag coherence appear to sharply focus on the water surface. The accompanying figure illustrate PPP for one IE data set. A dashed red line at range bin 50 indicates the alignment of the Brown waveform (top), a peak in one-lag power, Doppler velocity, and a peak in coherence (bottom). In summary benefits of Doppler processing, similar to those being reported with the newer CryoSat-2, are possible with Envisat. CryoSat-2 has a PRF of 17,800 which is 10 time greater than Envisat, and specifically designed for Doppler processing. But our results suggest that there is a possibility for Doppler processing on Envisat's longer operational time span, beginning with IE collections in September 2004 up to the present. Figure 1. PPP spectral moments vs. range bin