SURFACE CURRENT RETRIEVAL FROM TERRASAR-X DATA USING DOPPLER MEASUREMENTS

Cristian Rossi, Hartmut Runge, Helko Breit, Thomas Fritz

Remote Sensing Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany

1. INTRODUCTION

Common techniques to measure surface currents are HF radars (CODAR), acoustic Doppler profilers, surface drifters or satellite altimetry. It has also been demonstrated that Synthetic Aperture Radar (SAR) data is suitable for this kind of measurements, providing a global coverage thus an high potential [1]. A current, as a moving target at the water surface, causes a Doppler frequency shift of the backscattered signal making straightforward a line-of-sight velocity retrieval; the *Doppler speed* can then be related to the geophysical parameters describing the surface wave motion [2].

Two different techniques have been used for the estimation of the Doppler shift: direct Doppler measurements [3] and Along Track Interferometry (ATI) [4]. On the one hand, ATI is a powerful technique for the detection of moving targets in SAR images; the concept is to compare the phase from two receive antennas displaced in along-track direction: since the phase differences between two complex images are proportional to the Doppler shift, ATI can be used for our purposes. On the other hand, Doppler shift can be estimated directly from single channel data. In this paper, a magnitude-approach based on a spectral analysis of focused SAR data is used and some quality measures assessing the goodness of the estimation are provided. The reference Doppler is computed in a geometrical approach using the satellite attitude parameters, taking into account possible mispointing errors. When dealing with river scenes, or generally with coastal scenes, azimuth ambiguities and ships bias the estimation: a post-processing on the focused data is proposed for avoiding these kind of outliers.

Section 2 deals with the algorithmic description of the novel processor and a performance analysis; sample results are shown in Section 3.

2. DOPPLER SHIFT RETRIEVAL FROM FOCUSED DATA

In Fig. 1 a block scheme of the developed *TerraSAR-X Doppler-Shift Processor* is shown. It is composed by five processing blocks, providing as output the Doppler speed map.

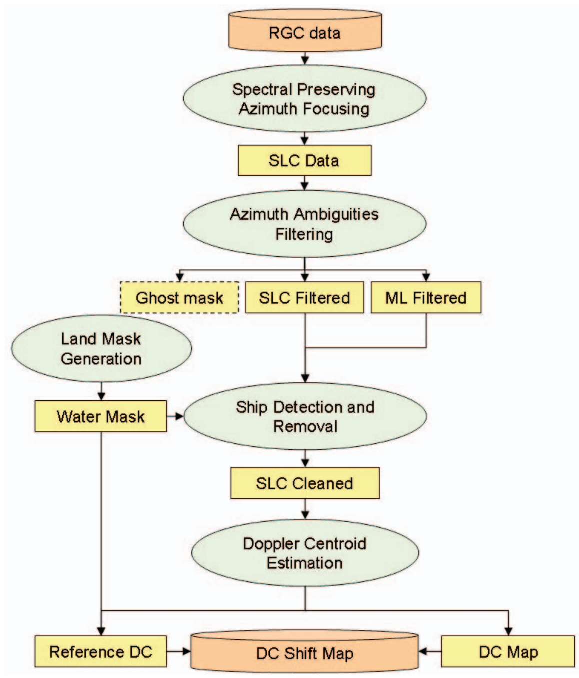


Fig. 1: Block Scheme of the Doppler Shift Processor.

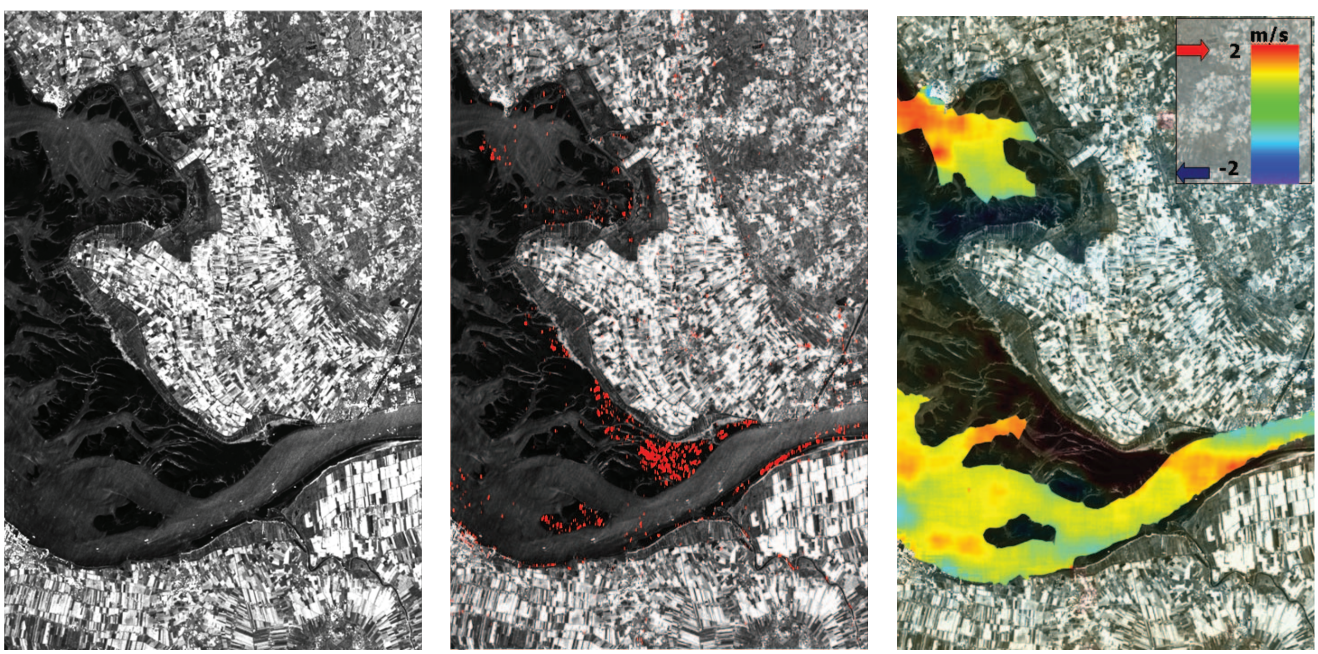
- **Spectral Preserving Azimuth Focusing**: although the azimuth spectrum of a TerraSAR-X SSC data fully fulfills the satellite radar performance requirements, it is not suitable for a Doppler analysis as the raw spectrum is modified by the processing. An unweighted matched filter azimuth focusing transfer function is thus applied to the range compressed data, for the preservation of the spectral proprieties.

- **Azimuth Ambiguities and Ship Filtering**: in our processing the Azimuth Ambiguity to Signal Ratio (AASR) could be higher than the one measured in standard TerraSAR-X data due to the lack of the azimuth processing window. For minimizing the impact of the filtering on the azimuth spectrum of the region to consider, a space varying filter, just on the ambiguity positions, is applied, with an approach similar to the one in [5]. The output of the filter is a *cleaned* image, with the only disturbing signatures recognized as ships or strong targets, removed with a detection from the ML image and a replacement with the median of the window used.

- **Doppler Shift Estimation**: for the estimation of the Doppler centroid a magnitude-based approach that simply looks for the the frequency of the peak of the Doppler magnitude spectrum is used. The observed azimuth spectrum is averaged over a certain number of range cells: a window of (N_{az}, N_{rg}) samples is exploited for the estimation for every data sample. A 4th-order model is used for the spectrum fitting and the estimation is refined through a parabolic interpolation. The root mean square error is an output parameter stating the goodness of the model; it can be seen as a ”quality parameter” of the estimation. The reference Doppler is computed from the satellite attitude; this measure is affected by pointing errors: any mispointing of the antenna may lead to a shift of the Doppler centroid. TerraSAR-X introduced a new method, named Total Zero Doppler Steering, for reducing the Doppler centroid to 0 Hz, with a nominal accuracy of ± 100 Hz. The measured accuracy is however well beyond this value (about ± 16 Hz) , as demonstrated in [6]. In the processor, the additional Doppler shift due to mispointing error is corrected with measures over land (where Doppler shift should be zero). The *line-of-sight* velocity of surface currents projected on the water surface is easily derived from the Doppler shift definition:

$$v_g = \frac{\lambda \Delta f_{DC}}{2 \sin \theta} \tag{1}$$

where Δf_{DC} is the estimated Doppler shift and θ is the radar look angle.



(a) *MultiLook of the spectral preserving azimuth focused image*.

(b) *Azimuth ambiguities mask*.

(c) *Doppler speed map*.

Fig. 2: Example of results from the *TerraSAR-X Doppler Shift Processor*. On the left the ML of the spectral preserved azimuth focused image is shown. It is an acquisition over the Elbe estuary made on the 26th October, 2008, after the low tide. The center image is the azimuth ambiguities mask superimposed to the ML. The ambiguities are shown in red: they spread over the whole data, and they are present also in the main river flow. On the right the Doppler speed projected on the river surface is shown just over the water areas. The mean current on the navigable canal is 0.85 m/s from West to East, varying sensibly probably due to the wind. Moving away from the estuary the current decreases its intensity.

3. SAMPLE RESULTS

The Elbe estuary was chosen as a test site for its strong currents mostly caused by a mix of three phenomenons: tides, winds and river flow. The scene analyzed is a stripmap TerraSAR-X acquisition made on the 26th October, 2008 over this area. This acquisition was made about two hours after the low tide, which occurred at 4:53, in a normal river flow condition without precipitations and, using the Beaufort wind scale classification, with a light breeze from South-West. What is easy to expect from these information is a surface river current from West to East, due primarily to the passage from low to high tide and strengthened by the wind. The wavelets moving from South-West are also visible from the ML image. In Fig. 2 some sample results from the processor are shown; all the results are in slant-range coordinates.

4. CONCLUSIONS

TerraSAR-X data was demonstrated suitable for surface currents retrieval: its high resolution allows the estimation over small and complex areas like the one studied in this paper. The quality of the data and the accuracy of the geometric Doppler computation provide reliable surface current estimations made with Doppler measurements. The *TerraSAR-X Doppler-Shift Processor* can be also used for less complex river scenes or ocean scenes: some more results and a cross-validation with other estimation techniques will be provided.

5. REFERENCES

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