Assessment of Ionospheric Effects Mitigation Techniques on Space-borne Low-Frequency SAR data

Sébastien Angelliaume[a], Aymeric Mainvis[b], Vincent Fabbro[b], Hélène Oriot[c] and Joel Lemorton[b]

[a]DEMR, ONERA F-13661 Salon cedex Air – France
[b]ONERA/DEMR, Université de Toulouse F-31055 Toulouse – France
[c]DEMR, ONERA, Université Paris Saclay F-91123 Palaiseau – France

Synthetic Aperture Radar (SAR) imagery has been used for decades to monitor the Earth's surface. Space-borne instruments can be operated day and night and in almost all weather conditions while covering large areas with a fixed revisit time. Historically, radar sensors launch into space operated mainly in the high part of the electromagnetic spectrum, namely in C-band and X-band. At these frequencies, the EM signal is slightly disturbed by the ionospheric layer. But the recent and planned launch of radar instruments operating in the lower part of the electromagnetic spectrum has made it necessary to develop mitigation techniques for compensating the disturbances on the EM signal.

The objective of the study reported herein is to consolidate the understanding, assessment and correction of ionospheric effects (spatial TEC variation) on space-borne low-frequency radar observations. First, we simulated SAR data by focusing on the future ESA Earth observation missions, BIOMASS (UHF-band) and ROSE-L (L-band). The simulation consists in producing references data (without ionospheric effects) and data disturbed by a canonical ionospheric phase screen (3-order polynomial variation of TEC value in azimuth direction). Then we apply two mitigation techniques published in the literature, namely the *Azimuth Shift Method* [1] and the *Phase Compensation Method* [2]. The first one [1] is applied to INSAR processing to correct the phase advance induced by the ionosphere. The correction is based on an approximate linear relationship between the ionosphere-induced azimuth offset and the ionospheric delay. Regarding the second mitigation technique [2], the correction is based on the integration of the slant TEC into the SAR processing to directly mitigate the phase distortion induced by the ionosphere. In order to compensate the phase and time-Doppler history distortions, the correction is performed at the slant range of the ionospheric layer, i.e., on partially focused single-look complex data.

Finally, we evaluate the performances of these mitigation techniques by comparing the spatial TEC gradient at the input of the simulator and at the output of the correction methods. Fig. 1 below gives an illustration of the performances obtained with the *Azimuth Shift Method* applied to both BIOMASS and ROSE-L simulated data. We observe the efficiency of the mitigation technique (low RMSE value between actual and estimated TEC gradient) to estimate and correct the overall ionospheric effect on the simulated SAR images. As expected, the impact of the TEC gradient is significantly greater on the BIOMASS data than on the ROSE-L data with azimuth shift up to about $^{+}/\text{-}$ 4 resolution cells at UHF-band with TEC gradient limited to about 0.04 TECU/km.

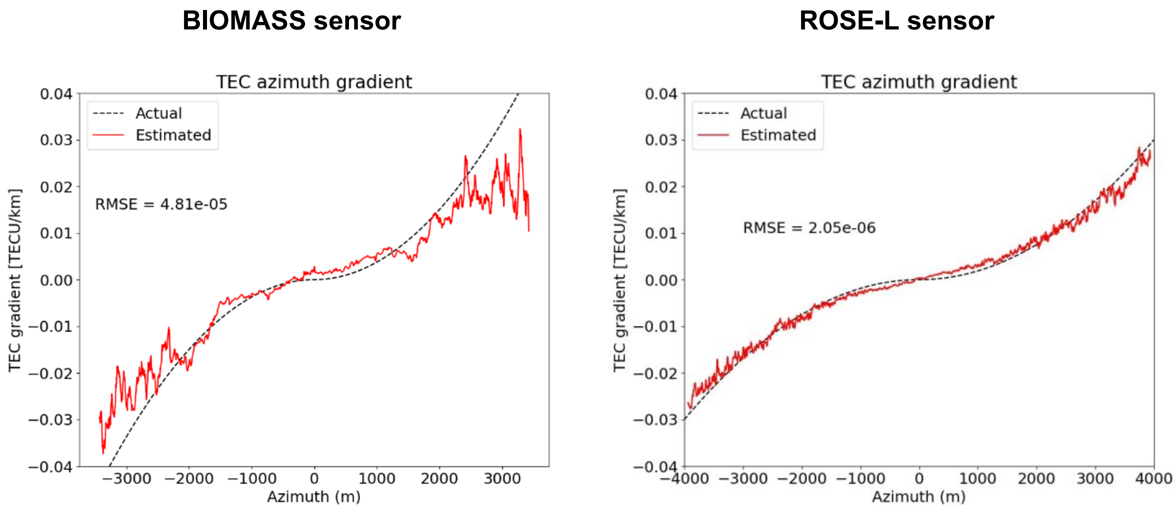

Fig. 1: estimation of azimuth TEC gradient for both BIOMASS (left) and ROSE-L (right) simulated SAR data.

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[1] He, Y. F., W. Zhu, Q. Zhang, and W. T. Zhang. « Compensation of the Ionospheric Effects on SAR Interferogram Based on Range Split-Spectrum and Azimuth Offset Methods - A Case Study of Yushu Earthquake ». *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences* XLII-3 (30 April 2018).

[2] S. Kim, K. P. Papathanassiou, R. Scheiber and S. Quegan, "Correcting Distortion of Polarimetric SAR Data Induced by Ionospheric Scintillation," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 53, no. 12, pp. 6319-6335, Dec. 2015.