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Efficient thermal noise removal of Sentinel-1 image and its impacts on sea ice applications

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Wide swath SAR observation from several spaceborne SAR missions played an important role in studying sea ice in the polar region. Sentinel 1A and 1B are producing dual-polarization observation data with the highest temporal resolution ever. For a proper use of dense time-series, radiometric properties must be qualified. Thermal noise is often neglected in many sea ice applications, but is impacting seriously the utility of dual-polarization SAR data. Sentinel-1 TOPSAR image intensity is disturbed by additive thermal noise particularly in cross-polarization channel. Although ESA provides calibrated noise vectors for noise power subtraction, residual noise contribution is significant considering relatively narrow backscattering distribution of cross-polarization channel.

In this study, we investigate the noise characteristics and propose an efficient method for noise reduction based on three types of correction: azimuth de-scalloping, noise scaling, and inter-swath power balancing. The core idea is to find optimum correction coefficients resulting in the most noise-uncorrelated gentle backscatter profile over homogeneous region and to combine them with scalloping gain for reconstruction of complete two-dimensional noise field. Denoising is accomplished by subtracting the reconstructed noise field from the original image. The resulting correction coefficients determined by extensive experiments showed different noise characteristics for different Instrument Processing Facility (IPF) versions of Level 1 product generation. Even after thermal noise subtraction, the image still suffers from residual noise, which distorts local statistics. Since this residual noise depends on local signal-to-noise ratio, it can be compensated by variance normalization with coefficients determined from an empirical model. Denoising improved not only visual interpretability but also performances in SAR intensity-based sea ice applications. Results from two applications showed the effectiveness of the proposed method: feature tracking based sea ice drift and texture analysis based sea ice classification. For feature tracking, large spatial asymmetry of keypoint distribution caused by higher noise level in the nearest subswath was decresed so that the matched features to be selected evenly in space. For texture analysis, inter-subswath texture differences caused by different noise equivalent sigma zero were normalized so that the texture features estimated in any subswath have similar value with those in other subswaths.