

Investigation of Residual Shift Effects in Azimuth Geolocation Results of Sentinel-1 TOPS Data by Leveraging SAR Calibration Sites in Argentina

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Sentinel-1 (S-1) single-look complex (SLC) synthetic aperture radar (SAR) images allow for a very high geolocation accuracy down to centimetric levels, if one makes use of the mission's precise orbit products and if the known perturbing effects are compensated for in post-processing. These perturbing effects involve the path delays of troposphere and ionosphere, the Earth's tidal deformation signals, and residual systematic effects associated with the S-1 SAR data processor, all of which have been studied and validated extensively by the S-1 SAR Mission Performance Cluster (SAR-MPC) [1]. The SAR-MPC is an international consortium of SAR experts and is in charge of the continuous monitoring of the S-1 instruments status, as well as the monitoring of the quality of the L1 and L2 products. This monitoring also includes the geolocation quality of S-1 mission. Therein, non-critical but nevertheless noteworthy residual offsets between 0.1 to 0.3 meters are still present to various degrees in azimuth geolocation residuals of reference corner reflectors (CRs) measured with S-1A/B/C satellites [1]. They are considered to be at least partly related to SAR antenna characteristics of the particular spacecraft [2]. Investigation and possible mitigation of these effects is an ongoing effort at SAR-MPC.

As part of SAR-MPC's contribution to the S-1C and S-1D in-orbit commissioning activities, geolocation analyses have been performed over a multitude of calibration sites, including El Sosneado and Casleo in northern Argentina, which are operated by CONAE for the SACOM mission [3]. These two sites offer several unique features which make them very interesting for our S-1 data analysis: The sites are equipped with eight or more very large CRs of 3 m inner-leg size, which are differently oriented to support both the ascending and descending passes. Even with the medium resolution S-1 IW C-band data, they enable precise azimuth geolocation measurements of 0.1 m or better due to their large dimensions. Moreover, the sites are situated in the high-altitude terrain of the Andes, and are located some 30 degrees south of the geomagnetic equator, a region that is strongly affected by ionosphere dynamics. Finally, the sites happen to show up at burst edges or the burst overlap of the tightly maintained S-1 IW data footprints, where the SAR Doppler gets largest and thus any TOPS data focussing limitations or antenna effects become more evident. All these features make it challenging to perfectly accommodate the S-1 azimuth geolocation results of the CRs for the various

available pass geometries, exposing any shortcomings in the S-1 TOPS data processing and the ionospheric corrections.

Currently, we are investigating three different effects that should allow us to even further enhance the azimuth geolocation accuracy of S-1 TOPS data and possibly resolve the dcm-level residual azimuth shifts among the sub-swaths: Firstly, there is the impact of the azimuth antenna pattern. The loss of isolated transmit-receive-modules (TRMs), which at some point occurred for each of the S-1 satellites, or of an entire antenna tile such as for S-1A in June 2016 [2], can alter the azimuth antenna phase pattern and therefore introduce sub-swath-dependent shifts if not considered during the processing. Secondly, the hyperbolic sensor-to-ground distance function, which has to be assumed when analytically modelling the azimuth filter during spectral focussing, deviates from the true distance function. For S-1 TOPS data, the deviation towards the edge of the bursts becomes large enough to cause residual shifts of up to 0.1 m. Thirdly, there are the azimuth shifts introduced by the ionosphere if strong along-track ionospheric gradients are present in the scene. In principle, this effect is well understood but the coarse resolution of ionospheric total electron content (TEC) maps makes it difficult to accurately determine the effect. SAR-based interferometric methods such as split-spectrum offer a mean to derive relative ionospheric azimuth shifts, but they operate on image pairs and require good coherence for stable results [4]. Again, the CONAE sites are favourable in that regard, as they are located in the arid regions of the Andes that provide high long-term-stable coherence in SAR data, which allows us to compare both methods.

In summary, the large CRs of the two CONAE sites provide a mean to test modelling of these three azimuth shift effects against ground truth. In our conference contribution, we plan to present them in more detail and report on the status of our analysis. Eventually, the outcomes will also contribute to further advancement of the S-1 Extended Timing Annotation Dataset (ETAD) product, which offers post-processing corrections for all the consolidated S-1 perturbation effects in a comprehensive product in-line with the S-1 level-1 data [5].

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