EGU22-4919
https://doi.org/10.5194/egusphere-egu22-4919
EGU General Assembly 2022

A Method for the Correction of Non-Closure Phase Artefacts in Triplets of Multi-look SAR Interferograms

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Multi-temporal interferometric synthetic aperture radar (InSAR) algorithms represent nowadays mature tools to analyze the Earth's ground deformation with high accuracy. Among them, a significant role is played by those algorithms based on the use of small-baseline (SB) multi-look interferograms, which are less affected by decorrelation noise artefacts. Recently, there is a great concern on the studying the sources of some inconsistencies in the InSAR products (i.e., ground deformation time-series and mean deformation velocity maps) that happen when sets of multi-look SAR interferograms with very short temporal baselines are processed, compared to those obtained using interferograms with longer temporal baselines. Concerning the interferometric SAR analyses for the study of the Earth's surface displacements, such spurious signals lead to systematic biases that, if not adequately compensated for, might lead to unreliable InSAR ground displacement products.

In this study, we propose a methodology to estimate and correct a set of multi-look SB interferograms that is based on computing and analyzing sets of (wrapped) non-closure phase triplets. The developed phase estimation method works on every single SAR pixels independently, assuming the (unknown) phase bias signal could be approximated as the sum of a constant phase velocity term v and a time-dependent (i.e., dependent on the interferograms temporal baseline) phase velocity difference terms $\Delta v(\Delta t_i)$, where Δt_i is the temporal baseline of the generic i-th interferogram. Once the whole set of triplets that could be formed using short baseline ML interferograms is identified, and considering the mathematical properties of the triplets non-closure phases, we can write an overdetermined system of linear equations, where the known terms are the measured wrapped non-closure phases over the set of identified triplets, namely $\mathbf{\Delta\Phi}^{triplets}$, and the unknowns are the temporal-baseline-dependent phase velocity difference terms $\mathbf{\Delta v}$. For example, considering the Sentinel1-A/B sensors, the temporal baseline is sampled with an atomic sampling time of six days; accordingly, if we accept, for instance, a threshold of 96 days for the maximum allowed temporal baseline of the selected SB interferograms, we have 16 unknowns to be estimated. Once the linear system is solved in the Least-Squares sense, the phase biases at the different temporal baselines, namely $\mathbf{\Delta\Phi}^{bias}$, are iteratively retrieved by integrating the phase acceleration terms, assuming as the initial condition that the phase bias at the maximum considered temporal baseline is zero, that is $\Delta\varphi^{bias}{}_{max\_baseline} = 0$.

Preliminarily experiments, performed on sets of Sentinel1-A/B SAR data in different geo-morphological conditions, demonstrate the effectiveness of the developed methodology. Additionally, we performed some simulations and experiments to test the validity of an extension of the developed method to the non-stationary case, e.g., when the phase bias signals depend on the specific single time acquisitions of the SAR images involved in the SB interferograms generation, and not only on their temporal baselines. Our work is propaedeutic for further investigations aiming at retrieving/analyzing the ground properties of the imaged targets on the terrain, such as the soil moisture content or other local ground properties that are usually not considered appropriately by conventional InSAR analyses.