Estimation of SAR Signal Penetration Depth over Snow/Ice Land Cover Areas using Volume Decorrelation computed from Geocoded TanDEM-X Products

Nerea Ibarrola Subiza[*1], Lukas Krieger[1], Marie Lachaise[1], Dana Floricioiu[1], Thomas Fritz[1]

[1]Remote Sensing Technology Institute, German Aerospace Center (DLR), Oberpfaffenhofen, Germany

*nerea.ibarrolasubiza@dlr.de

Digital elevation models (DEMs) derived from SAR interferometry (InSAR) can be significantly affected by volume decorrelation in different land cover areas. Volume decorrelation occurs when radar signals interact with multiple scattering surfaces at different heights and orientations. This effect causes the radar signals to scatter in multiple directions, leading to a loss of coherence. The scattering phase center is consequently located beneath the surface, resulting in biased elevation calculations for the actual land surface.

In bistatic radar systems like TanDEM-X, volume decorrelation can be derived from the interferometric total coherence by considering various decorrelation sources affecting the overall coherence [1]. The availability of this interferometric parameter as a layer in the TanDEM-X products is highly valuable for a range of applications, such as the estimation of penetration depth into snow or ice-covered surfaces or into forest canopy. This study presents results obtained by directly using geocoded products within the TanDEM-X DEM Change Map processing chain [2] to compute volume decorrelation for each acquisition. Applying the equations from [3], volume decorrelation, together with the height of ambiguity, are used to derive the penetration depth on ice and snow. This additional information helps to correct the bias between the actual terrain surface and the measured phase center, leading to more realistic elevation estimation.

A recent study on Aletsch glacier [4] has observed the elevation bias due to signal penetration in an X-band derived DEM by comparing it to a coincident DEM acquisition from Pléiades optical imagery. Here the elevation bias – averaged per elevation bin – can reach up to 4–8 m in the accumulation area and a mean elevation difference over of -5.59 m which can in turn reduce to about -4.29 m if additional local fine co-registration corrections are applied to this complex topography area. We use these results to validate the circumstances under which a signal penetration correction layer can be used to generate bistatic X-band DEMs that reflect the actual ice/snow surface.

Keywords: TanDEM-X DEM, Bistatic Interferometric Coherence, Volume Decorrelation, Penetration Depth, Glacier Mass Change.

[1] Rizzoli, Paola, Luca Dell'Amore, Jose-Luis Bueso-Bello, Nicola Gollin, Daniel Carcereri, and Michele Martone. "On the Derivation of Volume Decorrelation From TanDEM-X Bistatic Coherence." *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* 15 (2022): 3504–18. https://doi.org/10.1109/JSTARS.2022.3170076.

[2] Schweisshelm, Barbara, and Marie Lachaise. “Calibration of the Tandem-X Craw DEMs for the Tandem-X DEM Change Maps Generation.” In *IGARSS 2022 - 2022 IEEE International Geoscience and Remote Sensing Symposium*, 291–94. Kuala Lumpur, Malaysia: IEEE, 2022. https://doi.org/10.1109/IGARSS46834.2022.9883204.

[3] Dall, Jorgen. “InSAR Elevation Bias Caused by Penetration Into Uniform Volumes.” *IEEE Transactions on Geoscience and Remote Sensing* 45, no. 7 (July 2007): 2319–24. https://doi.org/10.1109/TGRS.2007.896613.

[4] Bannwart, Jacqueline, Livia Piermattei, Inés Dussaillant, Lukas Krieger, Dana Floricioiu, Etienne Berthier, Claudia Roeoesli, Horst Machguth, and Michael Zemp. “Elevation Bias Due to Penetration of Spaceborne Radar Signal on Grosser Aletschgletscher, Switzerland.” *Journal of Glaciology*, April 30, 2024, 1–15. https://doi.org/10.1017/jog.2024.37.