Evaluation of ESA's Extended Timing Annotation Dataset Product for Sentinel-1 InSAR Applications

Victor NAVARRO SANCHEZ[a], **Christoph GISINGER[a]**, Ramon BRCIC[a], Steffen SUCHANDT[a], Ulrich BALSS[a], Thomas FRITZ[a], Antonio VALENTINO[b], Muriel PINHEIRO[c]
christoph.gisinger@dlr.de
[a] German Aerospace Center (DLR), Oberpfaffenhofen, Germany
[b] Rhea for European Space Agency (ESA), Frascati, Italy
[c] European Space Agency (ESA), Frascati, Italy

SAR images allow for excellent geometric accuracy due to accurate time measurements in range and precise orbit determination in azimuth [1]. Moreover, the interferometric phase of each single pixel can be exploited for differential range measurements to reconstruct surface topography or to observe Earth surface deformation. However, these measurements are affected by the spatial and temporal variability of the atmospheric conditions, by solid Earth dynamic effects, and by SAR processor approximations, which may lead to spurious displacements shifts of up to several meters [1,2].

To facilitate straightforward correction of these perturbing influences in Sentinel-1 (S-1) SAR data and its applications, the Extended Timing Annotation Dataset (ETAD) was developed in a joint effort by ESA and DLR [3][4]. The ETAD product contains ready-to-use gridded timing corrections but the data can also be converted to differential phase screens for compensating atmospheric and solid Earth effects in InSAR time series. Regular ETAD production as part of S-1 ground segment has now started in 2023 and public product dissemination is foreseen in Q3/2023.

As a part of an ongoing ETAD scientific evolution study, we investigate the formation of accurate and consistent interferometric phase corrections from ETAD, both for conventional and multi-temporal InSAR applications (e.g. persistent scatterer interferometry). As already discussed in [4], this involves translating annotated time delays into phase offsets, and evaluating the corrections at the reference grid defined by the InSAR processing workflow.

For InSAR applications, only corrections resulting in a differential phase term between acquisitions are relevant. Some ETAD corrections might cancel out on interferogram formation, or be compensated during co-registration to the reference image geometry. There is, however, a set of correction layers available in ETAD that are considered relevant for the majority of scenarios [1]: tropospheric range delay correction, ionospheric range delay related to ionospheric activity, and timing corrections related to solid Earth tidal deformations caused by the gravitational force of the Sun and Moon. Ocean tidal loading is another well-known source of solid Earth deformation signal with a significant impact on InSAR time series in many coastal regions [5]. It is not a part of ETAD yet but the effect is investigated in our scientific evolution study as a possible future ETAD product extension.

While most relevant correction layers generally vary smoothly in space (e.g. solid Earth tides or ionospheric range delay), tropospheric corrections have a strong dependence on the topography. When applying ETAD corrections to high resolution S-1 InSAR data with minimal or no multi-looking, accurate interpolation of the tropospheric corrections to the output grid is required, which involves accounting for the dependence on topography at the interpolation stage. Findings from the ETAD pilot study groups, and in particular from the IREA-CNR team, confirmed that neglecting this step results in artefacts in the (differential) ETAD tropospheric phase screens when applying the product to full-resolution Sentinel-1 interferograms.

Our experiments confirmed that local estimates of the tropospheric range-delay-to-height-derivative can reliably compensate for height effects during spatial interpolation of ETAD-based differential tropospheric corrections, mitigating any height-induced artefacts. Therefore, the possible future addition of such a "tropospheric delay to height gradient" layer is also investigated in our ETAD scientific evolution study.

In the final publication we plan to showcase the described additional ETAD correction layers, including the tropospheric delay to height gradient as well as ocean tidal loading corrections. Study cases in the European Alps (strong topography) and French Brittany region (ocean tidal loading) will be shown to assess the use of ETAD for corrections in S-1 InSAR applications.

Acknowledgement

The authors thank all the research groups that participated in the ETAD pilot study for their valuable feedback on the product when applying it in SAR applications. List of participating institutions in alphabetical order: Caltech, DIAN srl, DLR, ENVEO, IREA-CNR, JPL, Joanneum Research, NORCE, PPO.labs, TRE ALTAMIRA, University of Jena, University of Leeds, University of Strasbourg.

The S1-ETAD scientific evolution study, contract No. 4000126567/19/I-BG, is financed by the Copernicus Programme of the European Union implemented by ESA.

Views and opinion expressed are however those of the author(s) only and the European Commission and/or ESA cannot be held responsible for any use which may be made of the information contained therein.

[1] Gisinger, C., Schubert, A., Breit, H., Garthwaite, M., Balss, U., Willberg, M., Small, D., Eineder, M., Miranda, N.: In-Depth Verification of Sentinel-1 and TerraSAR-X Geolocation Accuracy using the Australian Corner Reflector Array. IEEE TGRS, vol. 59, no. 2, pp. 1154-1181, 2021. doi: 10.1109/TGRS.2019.2961248

[2] Yunjun, Z., Fattahi, H., Pi, X., Rosen, P., Simons, M., Agram, P., Aoki, Y.: Range Geolocation Accuracy of C-/L-Band SAR and its Implications for Operational Stack Coregistration. IEEE TGRS, vol. 60, pp. 1-19, 2022. doi: 10.1109/TGRS.2022.3168509

[3] ESA: Sentinel-1 Extended Timing Annotation Dataset (ETAD). Data product website on Sentinel-1 webpage: https://sentinel.esa.int/web/sentinel/missions/sentinel-1/data-products/etad-dataset

[4] Gisinger, C., Libert, L., Marinkovic, P., Krieger, L., Larsen, Y., Valentino, A., Breit, H., Balss, U., Suchandt, S., Nagler, T., Eineder, M., Miranda, N.: The Extended Timing Annotation Dataset for Sentinel-1 - Product Description and First Evaluation Results. IEEE TGRS, vol. 60, pp. 1-22, 2022. doi: 10.1109/TGRS.2022.3194216

[5] Yu, C., Penna, N. T., Li, Z., “Ocean tide loading effects on InSAR observations over wide regions,” in Geophysical Research Letters, 47, 2020. Doi: 10.1029/2020GL088184