On the Calibration of TanDEM-X Precise Baselines via SLR

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ABSTRACT

The TanDEM-X mission strives for the generation of a digital elevation model of the Earth from SAR measurements taken by the TerraSAR-X and TanDEM-X satellites. As a requirement to achieve height accuracies of a few meters, the baseline between the two satellites needs to be known with millimeter accuracy. The baseline is operationally derived solely from the GPS measurements of the geodetic grade IGOR receivers onboard both satellites. Quality assessment is possible via comparison of results by independent solutions within GFZ and from outside institutions. It was foreseen from the beginning of the mission to also validate the GPS based baselines via SLR. As SLR data are sparse in time and space, they may not be used in operational baseline generation. However as the SLR technique may provide range measurements with millimeter accuracy, they may advantageously be used for validation of the GPS based baseline. With the newly developed interleaving technique at Herstmonceux, a method to range to both satellites by switching from one to the next without loss of time, and in use also at Potsdam, a means of measuring the differential motion of the two satellites is available. The data of the two stations are analyzed and results and conclusions with view on baseline validation are given.

1 Introduction

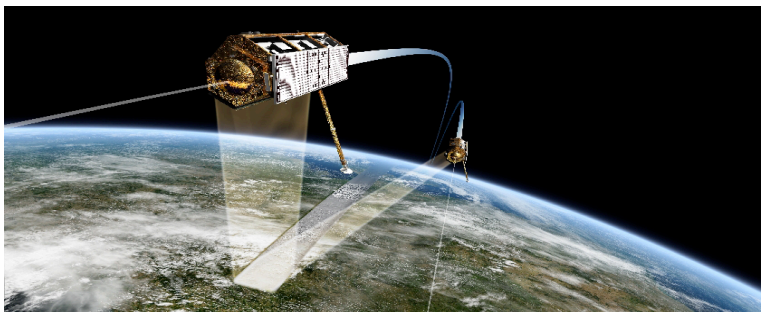

Figure 1 TanDEM-X artist's view (courtesy DLR)

The TanDEM-X (**T**erraSAR-X **a**dd-o**n** for **D**igital **E**levation **M**easurement) mission (Fig. 1, Krieger et al., 2007) is based on two nearly identical satellites, TerraSAR-X (TSX) and TanDEM-X (TDX). TSX was launched on June 15, 2007, TDX on June 21, 2010. Since then both satellites are flying in a close formation forming a Synthetic Aperture Radar (SAR) interferometer in space in order to generate a global digital elevation model (DEM). Mission goal is to reach meter level DEM accuracies in height, for this the relative position between the two spacecrafts, the "baseline", has to be known with millimeter accuracy. The GFZ German Research Centre for Geosciences has supplied the geodetic grad, two-frequency Integrated GPS and Occultation receiver (IGOR, Rothacher et al., 2007) to both satellites. By these data, the baseline can be inferred with millimeter accuracy as was demonstrated for the GRACE mission firstly by Kroes et al., 2005 and independently by Jaeggi et al., 2007.

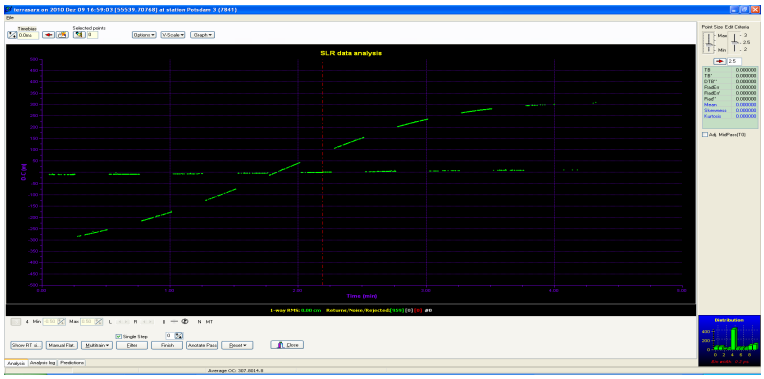

Figure 2 Screen shot of ranging residuals in the interleaving mode

Within the TanDEM-X mission ground segment the baseline is operationally generated from the IGOR data only. Also in this case the baselines are determined with millimeter accuracies as can be concluded from comparing independent solutions and from calibrating the baselines via SAR data

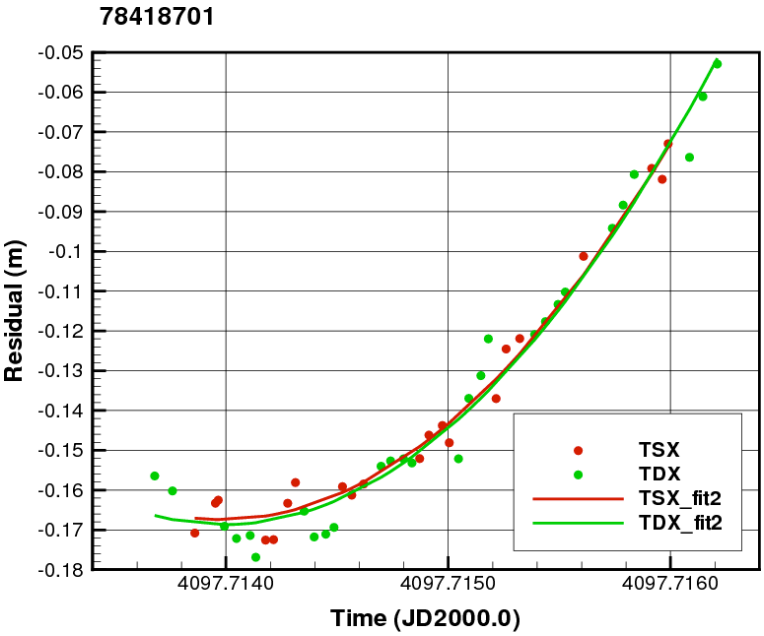

Figure 3 Degree 2 polynomials for one pass over Potsdam

takes over well known test sites.

Satellite Laser Ranging (SLR) data would be too sparse in time and space for the operational generation of baselines. However as the SLR data potentially can provide millimeter level ranging accuracy, they could be adopted to validate the GPS only based baseline. In particular the interleaving tracking technique invented recently in Herstmonceux by Gibbs, 2010, supports this idea. The interleaving technique allows to track both satellites with seamless switching between TSX and TDX within one pass (see Fig. 2).

In the following we analyze SLR interleaving data gathered at Herstmonceux and Potsdam, where this technique was implemented as well, over a recent four months period. From the results we can draw some first conclusions.

2 Analysis

In order to check the potential accuracy of recent Herstmonceux and Potsdam ranging data to TSX and TDX, residuals from Precise Orbit Determinations (POD) with GFZ's Earth Parameter and Orbit System – Orbit Computation (EPOS-OC) software (for features of the software see Zhu et al. 2004) are analyzed. POD methods and achievable orbit accuracies for Low Earth Orbiters (LEO) are discussed e.g. in Michalak and Koenig, 2010. For TSX and TDX EPOS-OC delivers orbits with accuracies of a few centimeters. From these PODs, the residuals are taken for all interleaving passes observed by Herstmonceux and Potsdam in the period January to April 2011. Due to imperfect modeling in the dynamic POD approach used, some systematics remain in the residuals that behave smooth to a large extent and can be modeled pass-wise by simple polynomials of low degree. In order to assess the impact of the degree of the polygon, Fig. 3 depicts a degree two polynomial fit to the residuals of either TSX or either TDX for one pass over Potsdam. For TSX the fit is 4.4 mm for TDX the fit is 6.2 mm. Fig. 4 shows the degree three polynomial fits for the same constellation, for TSX the fit is 4.4 mm, for TDX the fit is 4.9 mm, a slightly better performance for TDX. This behavior is observed in few more numbers of cases, so for the further analyzes the degree of the polynomial fit is restricted to three. Fig. 5 completes the resume thus far by a view on a degree three polynamial fit for one pass of range

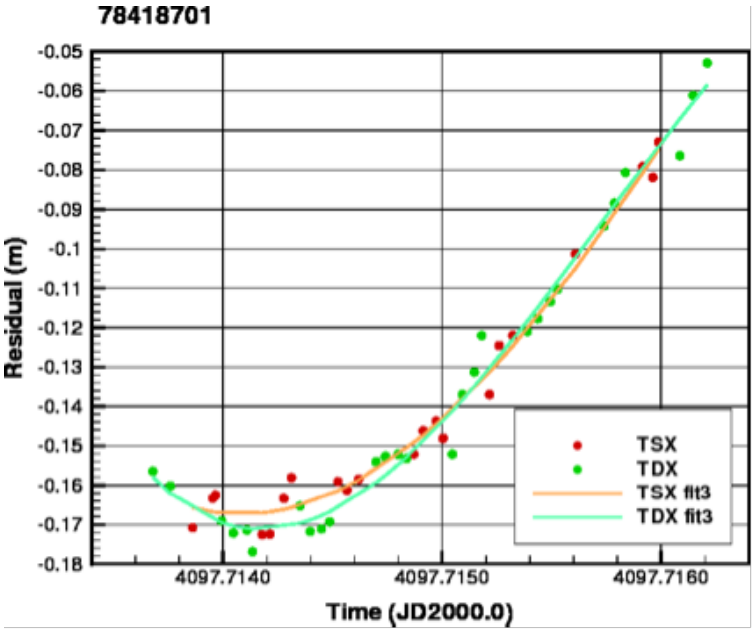

Figure 4 Degree 3 polynomials for one pass over Potsdam

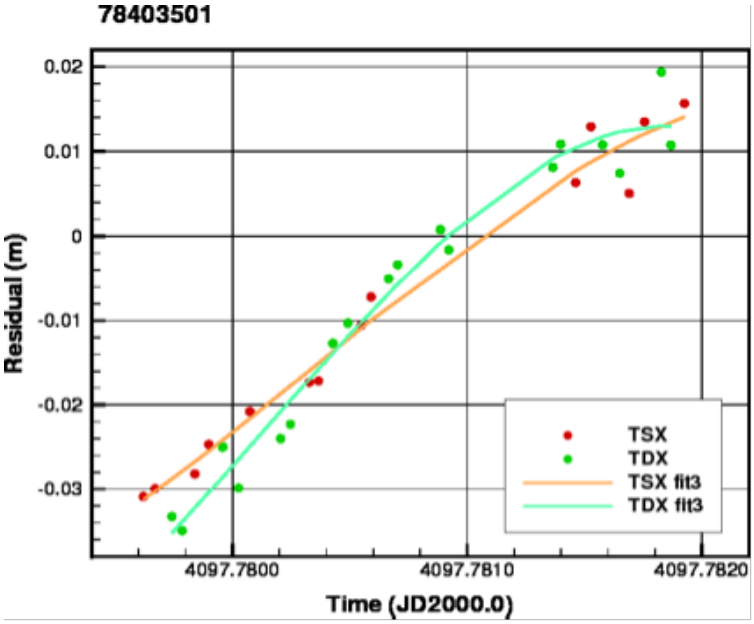

Figure 5 Degree 3 polynomials for one pass over Herstmonceux

residuals by Herstmonceux. For TSX the fit is 2.8 mm, for TDX 3.1 mm.

A graphics displaying all degree three polynomial fits of all interleaving passes tracked by Herstmonceux and Potsdam in the analysis period is given in Fig. 6. The overall fit for Herstmonceux amounts to 3.3 mm inferred from 81 passes, for Potsdam the fit results little worse with 5.6 mm inferred from 66 passes.

3 Conclusions

Within the TanDEM-X ground segment precise baselines are generated from the onboard IGOR data with millimeter accuracies. This is validated by comparisons of independent solutions and via SAR calibration over known test areas. The SLR interleaving technique implemented at Herstmonceux and Potsdam offers differential ranging to both satellites. If millimeter accuracies of the ranges would be available, SLR could validate the GPS based baselines. As however the accuracies of the analyzed SLR data is still at the few millimeter range as shown, the SLR system need to enhance their accuracy to the sub-millimeter region which is probably achievable once they migrate to kHz or few-kHz systems. The impact of the geometry has not been considered here and is going to be analyzed next.

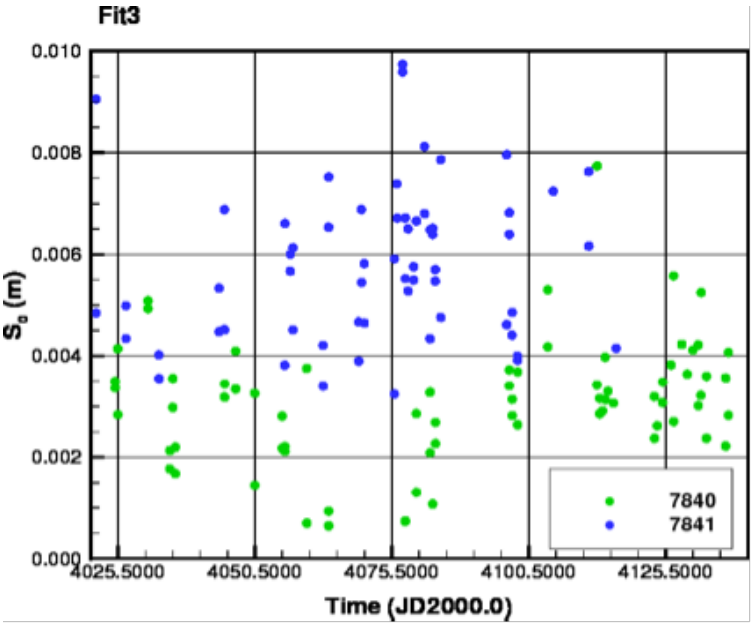

Figure 6 Degree 3 polynomial fits for all passes over Herstmonceux and Potsdam

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