Challenges of the TerraSAR/TanDEM-X formation

K. Snopek, L. Grunwaldt, R. Koenig
Helmholtz Centre Potsdam,
GFZ German Research Centre for Geosciences
snopek@gfz-potsdam.de

Abstract

In September 2009 TanDEM-X will be launched to fly with TerraSAR-X in a very close formation called helix. The helix means close approaches of the two spacecrafts down to approximately 200 meters at one time in along-track direction, at another time in radial direction. Orbit predictions for both spacecrafts will exhibit the usual accuracy of 2 to 3 m in radial and cross track, and something below 10 ms in along-track within 12 hours after release. Due to the very close formation, the stations need to distinguish between the two targets. We will present the formation scenario and highlight the parts where the constellation exhibits extreme positions for tracking. From this, conclusions are drawn on the difficult situations and possible remedies for the various station types

1. Introduction

TerraSAR-X (TSX) is a German radar satellite launched on June 15th 2007 to provide high quality topographic information for commercial and scientific applications. It flies on a polar, sun-synchronous orbit at the altitude of 514 km. The design lifetime of TSX is 5 years. TanDEM-X (TDX) is a TerraSAR-X add-on for Digital Elevation Measurements (DEM). Its launch is planned for fall 2009 with design lifetime 5 years where 3 years overlap with TSX.

The primary goal of the TSX/TDX mission is to deliver high quality elevation data by means of SAR interferometry. To achieve this, the two satellites will fly in a very close formation called helix. The distances between the two spacecrafts will vary between ±200 m in cross, ±300 m in radial and ±600 m in along track direction. TSX will fly on a stabile orbit and TDX, by means of frequent maneuvers, will fly around TSX. The absolute distance between the two satellites, the baseline, will vary from ~300 to ~600 m. (see Figure 1).

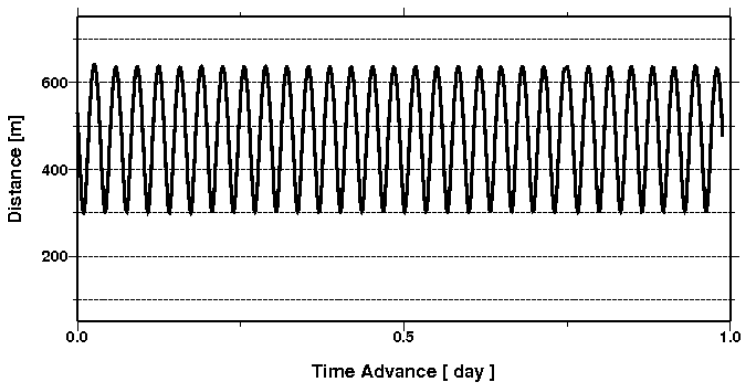

Figure 1. Baseline between TerraSAR-X and TanDEM-X.

Such a close formation imposes new challenges for SLR tracking. Accurate orbit predictions will be needed to allow the stations to distinguish between the two satellites. The stations will probably need to adapt their software and to develop dedicated tracking strategies.

The efforts put into the preparation of the TSX/TDX mission will be rewarded by the unique opportunity of simultaneous tracking of two spacecrafts. Data from simultaneous tracking will be used for the validation of the baseline between the two satellites at millimeter accuracy. The baseline will be determined solely by means of GPS measurements. The millimeter accuracy is the prerequisite to achieve the DEM accuracy requirements. The validation by SLR will be a significant input to the mission.

In the following we present the current prediction quality for TSX and results of performed simulation of SLR tracking of the TSX/TDX formation.

2. TSX Prediction Quality

Good orbit predictions are the basis for successful SLR tracking. GFZ delivers predictions for TSX and will deliver them for TDX. The two satellites are nearby identical from the construction point of view and they will fly in the same orbits. Hence, the analysis of the quality of the predictions for TSX allows us to examine if it will be possible to separate the two satellites in space. We analyzed how much the predicted orbits (PRD) differ from the precise orbits, the so called Rapid Science Orbits (RSO) that we also generate operationally with an accuracy of a few centimeters. We calculated the residuals between PRD and RSO as a function of time. The analysis period covered two months (July and August) in 2008. We also calculated histograms of residuals between PRD and RSO 12 h after the release of the prediction. The predictions are being computed twice a day; therefore 12 h is the longest period of PRD validity. The results of the analysis are given in Figure 2.

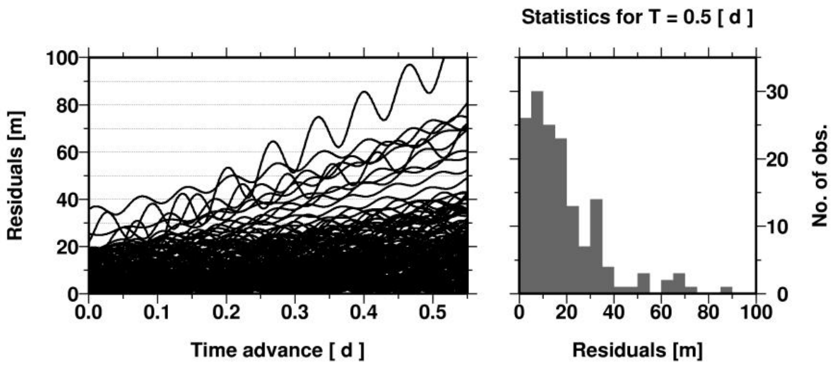

Figure 2. Accuracy of predictions for TerraSAR-X.

It can be seen that the residuals 12 h after release remain usually below 40 m. This is several times smaller than the anticipated distance between the two satellites. So we conclude that the stations will be in the position to easily distinguish between the two satellites.

3. TSX/TDX Simulation

In order to check how the TSX/TDX formation will look from a SLR station point of view we simulated several passes over selected stations locations. Our goal was to answer the following questions: (1) how large will be the angular difference between the two spacecrafts and (2) will it be possible to track both satellites simultaneously. We assumed that the possibility for simultaneous tracking will occur if the angular difference between TSX and TDX is smaller than 60 arc seconds (as). We simulated SLR passes for 11 SLR stations: Yarragadee, Washington, Arequipa, San Juan, Zimmerwald, Mount Stromlo, Graz, Herstmonceux, Potsdam, Matera and Wettzell. The period of the simulation was one day, which resulted in 35 passes (minimum elevation was 20 deg) and 555 observations. We used the GFZ precise orbit determination software EPOS for our calculations. A sample pass over Potsdam is presented in Figure 3Figure 3.

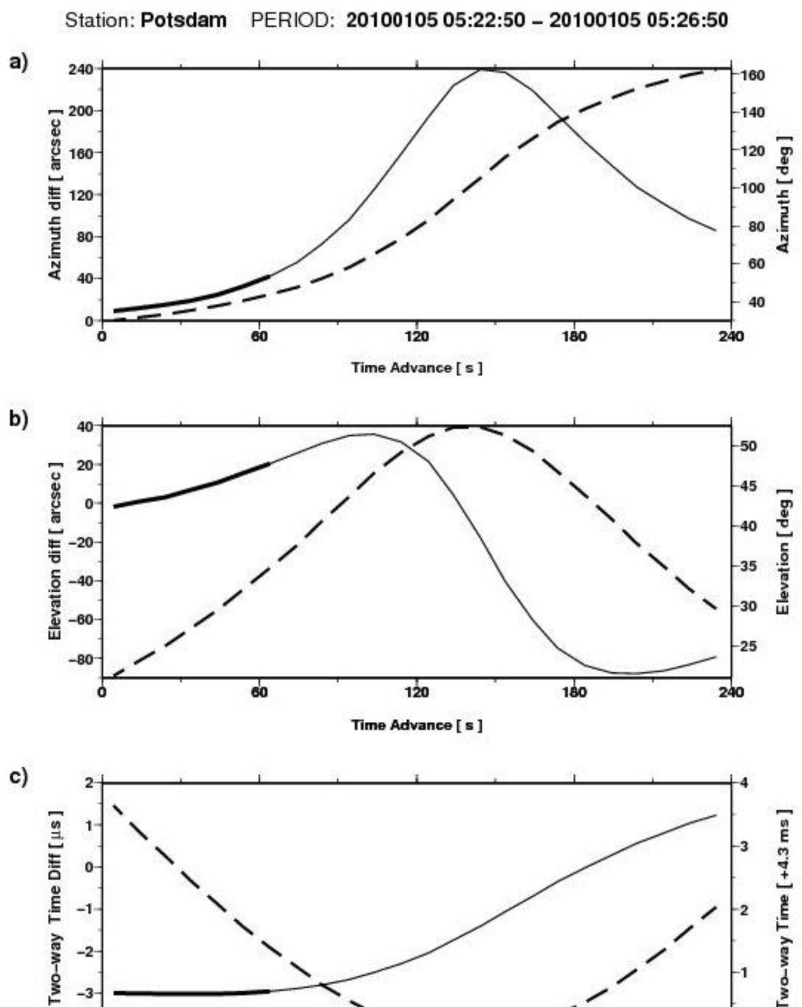

Figure 3. Simulation of a pass of the TSX/TDX formation over station Potsdam. Dashed lines indicate angular coordinates: azimuth and elevation in a) and b) respectively, and two-way travel time to TSX (c). Thin solid lines indicate angular (a,b) or time differences (c) between TSX and TDX as observed by the station. Thick solid lines indicate that the angular difference between the two spacecrafts is smaller than 60 arcs seconds.

Angular differences between TSX and TDX for the pass presented in Figure 3 vary from approximately +10 as to +240 as in azimuth, and from approximately -80 as to +30 as in elevation. Two-way travel time separation is in the order of several microseconds. There exists the possibility to track both satellites simultaneously for about 60 s. in the beginning of the pass.

Figure 4 shows statistics for all simulated passes. A simultaneous tracking is possible for about 20% of all observations. For these cases, the separation of the two satellites in the two-way travel time is more than 2000 ns. So the separation in range is significant and allows also to distinguish the two spacecrafts.

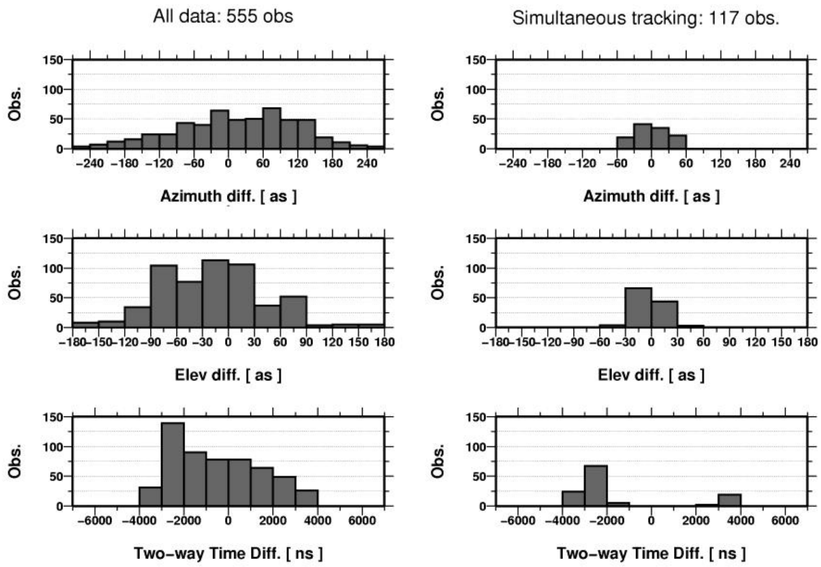

Figure 4. Left side: histogram of differences between TSX and TDX for all simulated observations. Right side: histogram of differences for observations when simultaneous tracking is possible.

4. Conclusions

Our study shows that SLR tracking of the TSX/TDX formation will be a challenging task for the SLR network. The accuracy of the predictions, with updates twice per day, should allow a separation of the two satellites in space. However, very small distances between the two spacecrafts in certain instances will probably urge stations to decide which spacecraft to track during a pass. One can imagine a scenario where stations build a cluster and decide which part of the cluster tracks TSX and which TDX.

Our simulations show also that in a certain percentage of tracks, both spacecraft will be within the transmitting beam at the same time but with a clear separation in range. In these cases, simultaneous tracking will be possible enabling the validation of the baseline between the two satellites at the milimeter accuracy.