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Inter-agency comparison of TerraSAR-X and TanDEM-X baseline solutions

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Introduction

TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) is the first Synthetic Aperture Radar (SAR) mission using close formation flying for bistatic SAR interferometry. The primary goal of the mission is to generate a global digital elevation model from the configurable SAR interferometer with space baselines of a few hundred meters. As a key mission requirement for the interferometric SAR processing, the relative position, or baseline, of the two satellites must be determined with an accuracy of 1mm (1D RMS) from GPS measurements collected by the onboard receivers.

Operational baseline products for the TanDEM-X mission are routinely generated by the German Research Center for Geosciences (GFZ) and the German Space Operations Center (DLR/GSOC) using different software packages (EPOS/BERNESE, GHOST) and analysis strategies. For an independent performance assessment, TanDEM-X baseline solutions are, furthermore, generated at the Astronomical Institute of the University of Bern (AIUB) on a best effort basis using the BERNESE software.

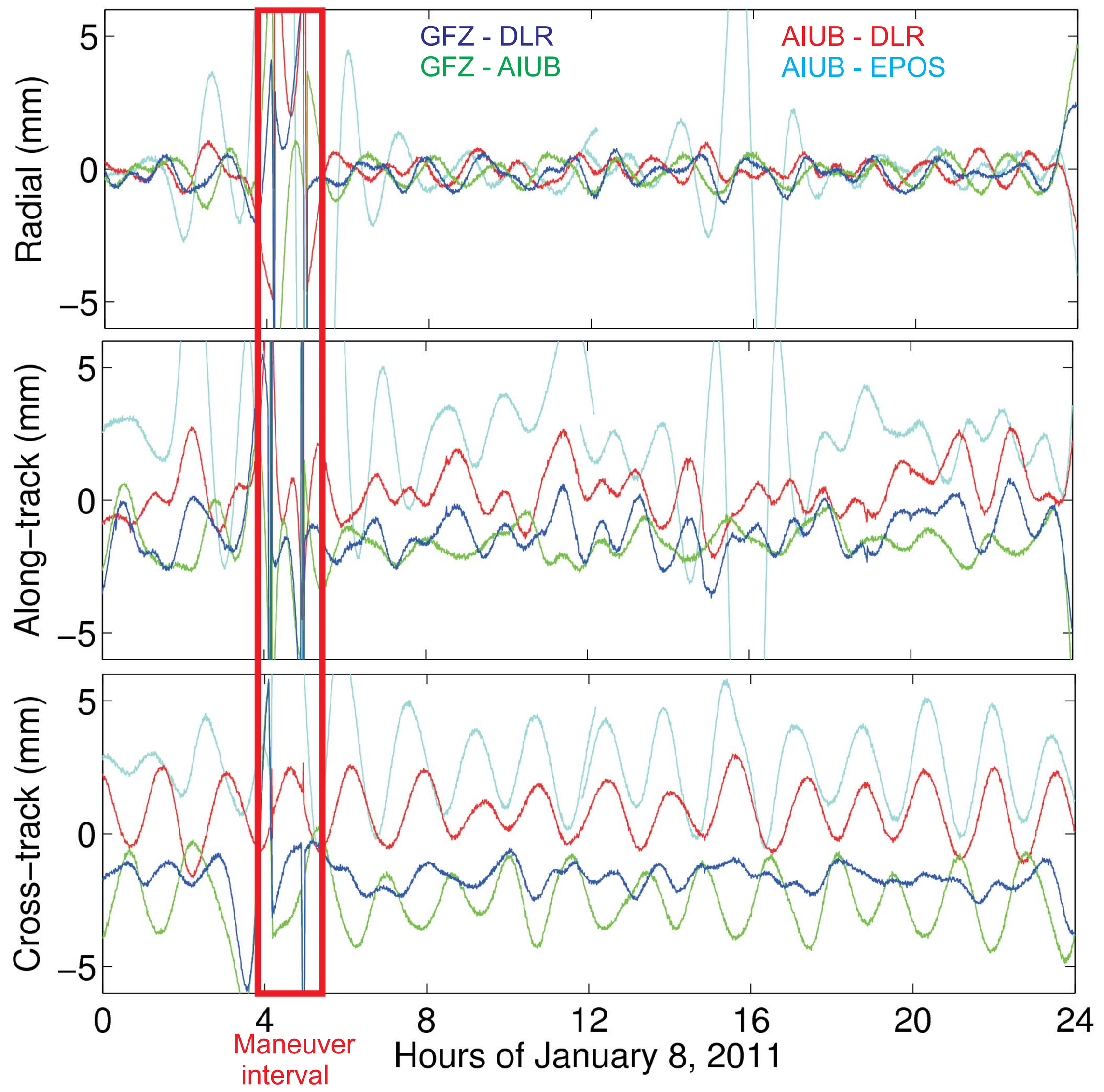

Figure 1: Baseline differences obtained from the different software packages for one example day (GFZ denotes the BERNESE solution computed at GFZ). Around the maneuvers (red box) the differences are largest. Small biases are present between the solutions.

Standard deviations of baseline differences

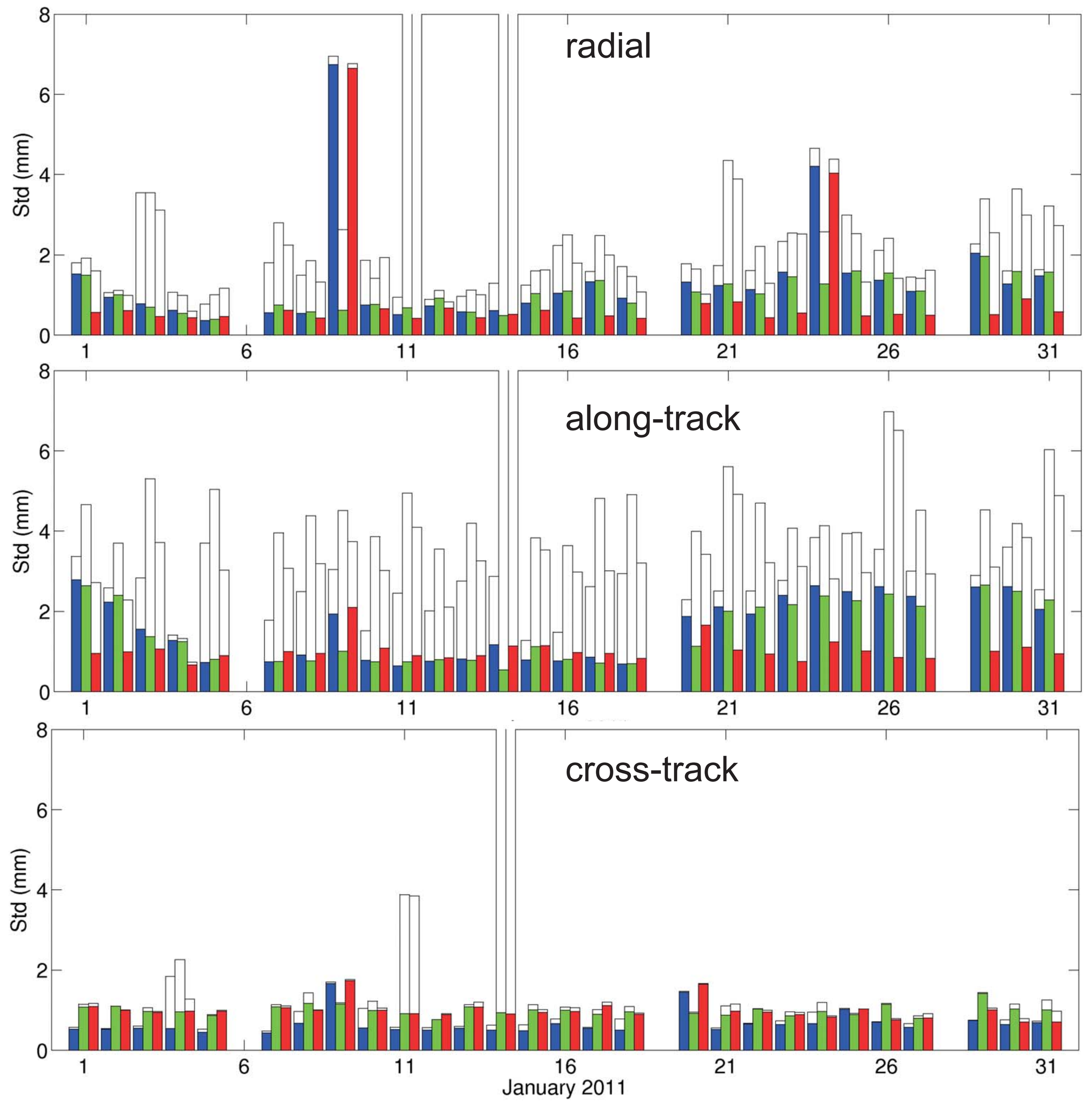

Figure 2: Standard deviations of inter-agency baseline comparisons for January 2011. Empty bars indicate the statistics for entire 24h arcs, whereas colored bars exclude the time between 20 min before the first and 20 min after the second maneuvers performed daily on TanDEM-X. Days with maneuvers performed on TerraSAR-X and TanDEM-X simultaneously are excluded (Jan. 6, 19, 28).

	radial	along-track	cross-track
GFZ - DLR	1.3 (2.0)	1.6 (2.7)	0.7 (0.8)
GFZ - AIUB	1.1 (2.7)	1.5 (5.8)	1.0 (1.9)
AIUB - DLR	0.9 (2.6)	1.0 (4.7)	1.0 (1.8)

Table 1: Mean values (in mm) of the standard deviations shown in Figure 2 without (or with) considering maneuver intervals.

Excluding maneuvers, Figure 2 and Table 1 show

- an almost constant agreement of about 1mm in all components between AIUB - DLR using different software packages
- larger differences between AIUB - DLR on Jan. 9 and 24 due to a bug in the GHOST software (corrected in the meantime)
- a varying agreement of about 1-2mm in the radial and along-track components between GFZ - AIUB and GFZ - DLR
- an almost constant agreement of about 0.7mm in the cross-track component between GFZ - DLR using different software packages

Including maneuvers, Figure 2 and Table 1 show

- a significant impact of maneuver intervals in the radial and along-track components for all solutions, almost no impact for the cross-track component
- larger differences between AIUB - DLR and GFZ - AIUB in all components – the optimum maneuver handling is currently a topic of further research at AIUB

Conclusions:
None of the presented solutions is perfect, which underlines the need of inter-agency comparisons for generating a consolidated baseline product serving the high accuracy demands of the interferometric SAR processing.

Biases of baseline differences

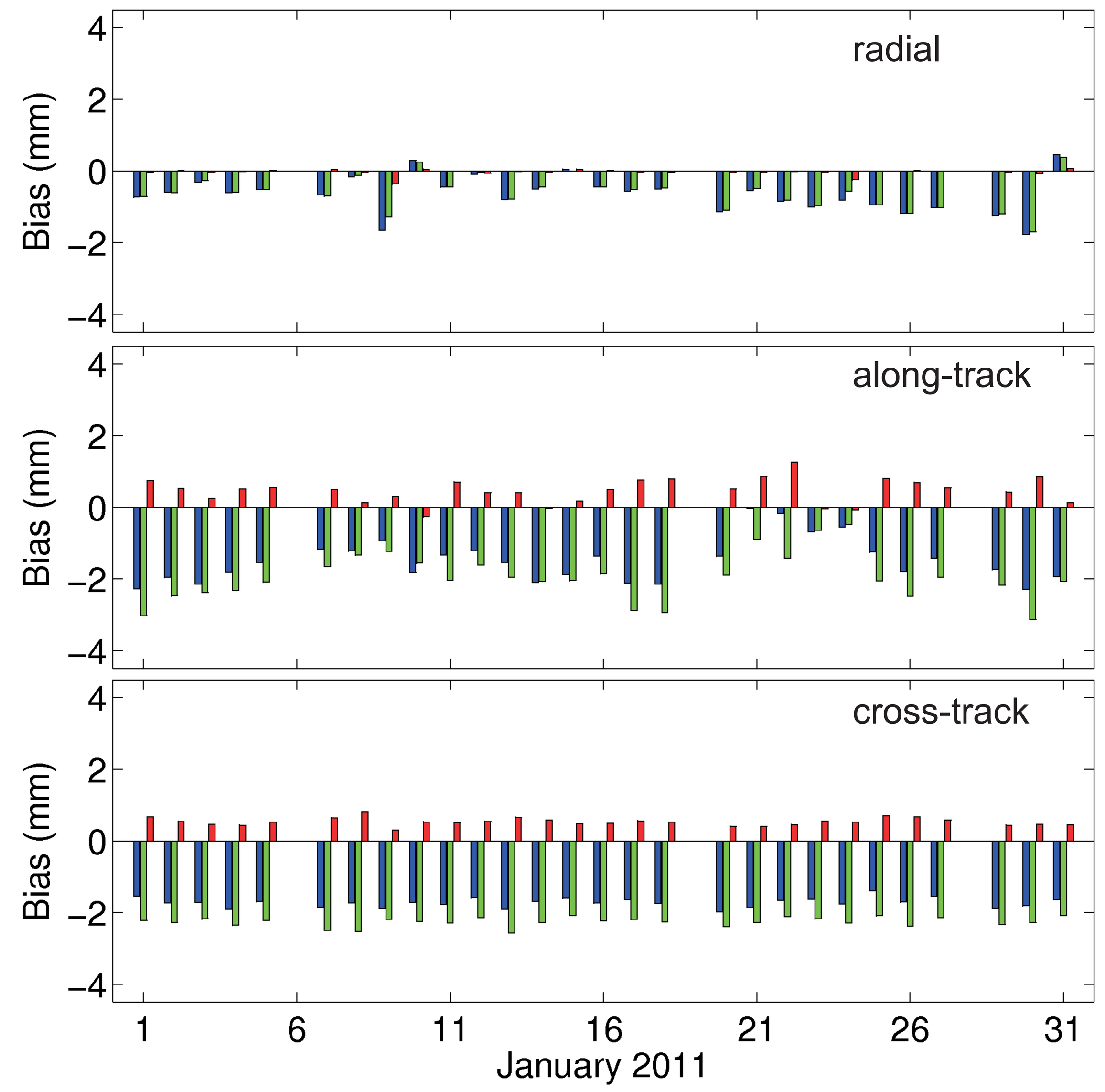

Figure 3: Mean biases of inter-agency baseline comparisons for January 2011 (maneuver intervals excluded). Almost the same results are obtained when maneuver intervals are considered (not shown).

	radial	along-track	cross-track
GFZ - DLR	-0.7 (-0.6)	-1.5 (-1.5)	-1.7 (-1.7)
GFZ - AIUB	-0.6 (-0.6)	-2.0 (-1.9)	-2.3 (-2.2)
AIUB - DLR	0.0 (0.0)	0.5 (0.4)	0.5 (0.5)

Table 2: Mean values (in mm) of the biases shown in Figure 3 without (or with) considering maneuver intervals.

Excluding or including maneuvers, Figure 3 and Table 2 show

- biases that are smaller than 0.5mm in all components between AIUB - DLR using different software packages
- biases of up to 2.3mm that exist between GFZ - AIUB using the same software package

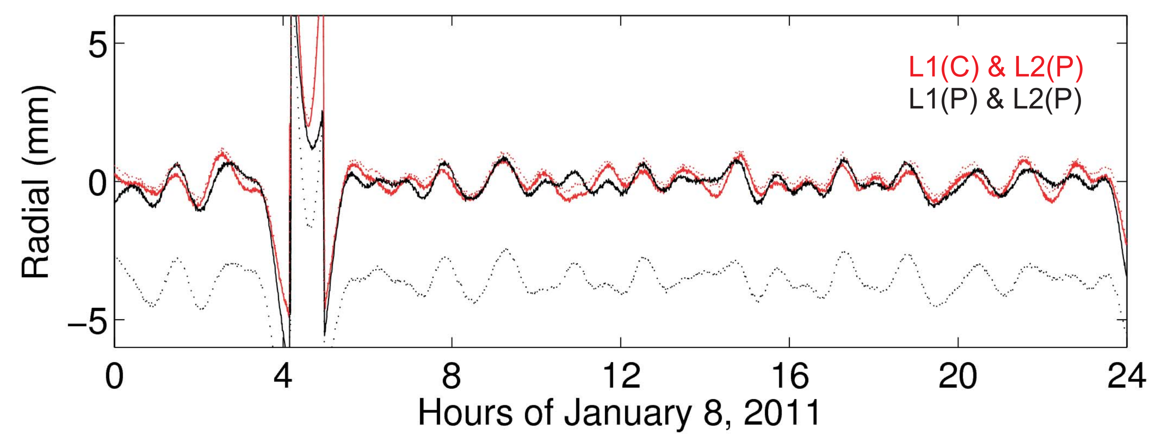

Figure 4: Radial baseline differences between AIUB - DLR for one example day using different carrier phase observations together with tightly constrained relative dynamics (solid lines, nominal case) or more relaxed (kinematic-like) relative dynamics (dotted lines).

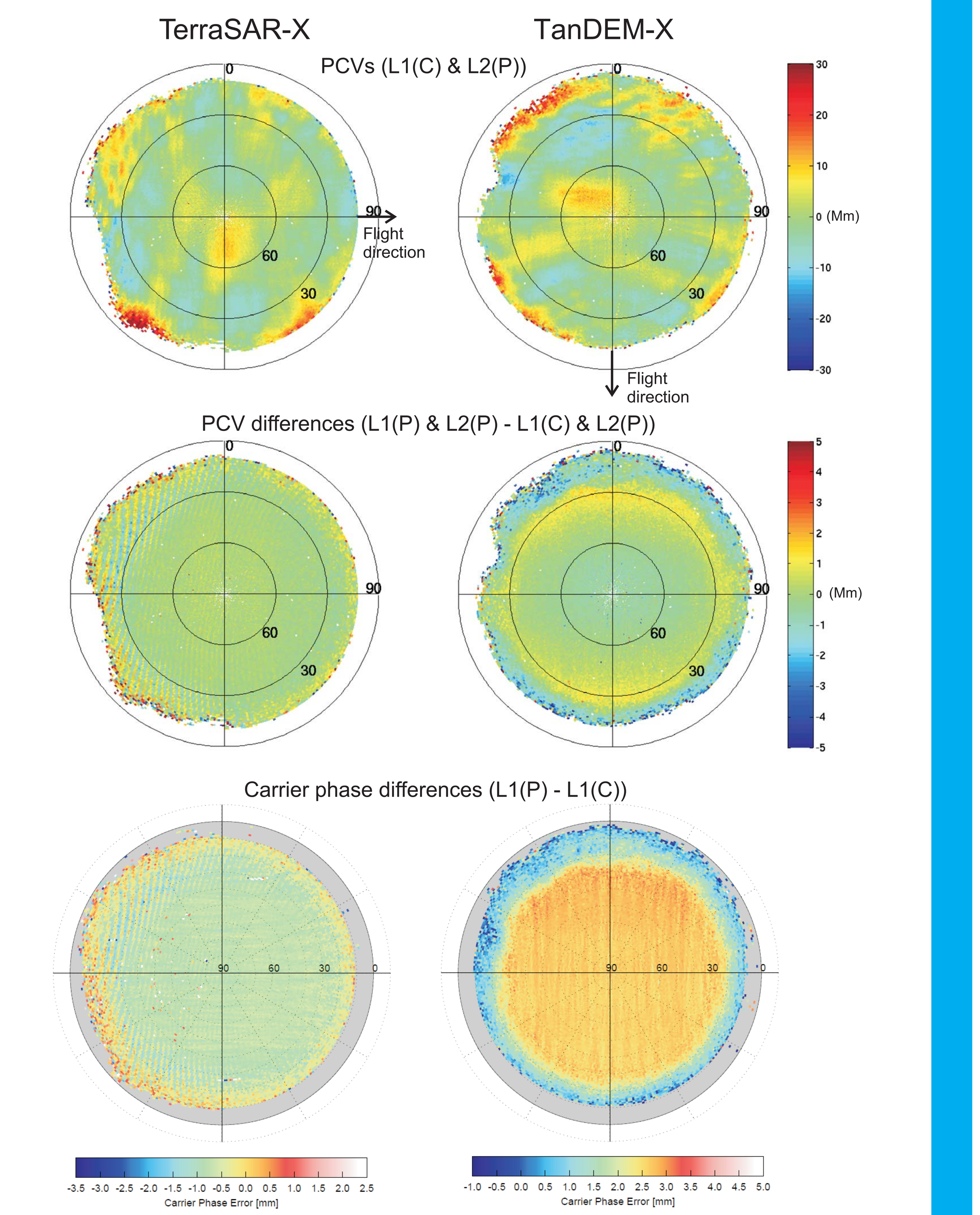

Figure 5: Empirically derived phase center variations (PCVs) of the ionosphere-free linear combination (top row), PCV differences using different carrier phase observations on the first frequency (middle row), direct differences between the L1(P) and L1(C) carrier phase observations (bottom row, quarter-cycle removed).

Observation selection, Figures 5 and 4 show

- pronounced systematic differences between the L1(P) and L1(C) carrier phase observations from the IGOR receiver on TanDEM-X
- systematic differences between the L1(P) and L1(C) carrier phase observations on TerraSAR-X due to the active occultation antenna
- a clear impact on the radial bias of baseline differences of about 3mm when using relaxed relative dynamics

Conclusions

The determination of the relative position between the TerraSAR-X and TanDEM-X satellites with an accuracy of 1mm (1D RMS, i.e., including biases) is a challenge. The inter-agency comparisons suggest that even the best agreement between AIUB - DLR (excluding maneuver intervals) yields RMS values of "only" **0.9mm**, **1.2mm**, and **1.1mm** for the radial, along-track, and cross-track components. The standard deviations between GFZ - DLR indicate that a further reduction of the cross-track RMS should be feasible in the very near future. The systematic differences between the L1(P) and L1(C) carrier phase observations and their origin need to be further investigated.

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