Sub-daily VLBI antenna position estimates derived from the CONT11 campaign

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1. INTRODUCTION

The International Very Long Baseline Interferometry (VLBI) Service for Geodesy and Astrometry (IVS) observed the continuous CONT11 campaign from 15 to 30 September 2011. The goal of this campaign was to assess the current capabilities of the VLBI technique, e.g. the accuracy of geodetic parameters. In this study, we investigate the possibility of estimating sub-daily antenna TRF (terrestrial reference frame) positions from the VLBI observations. First, we divided the 15 24-hour sessions of CONT11 into two hour (2h) and six hour (6h) observation files and analyzed them with the software VieVS (Vienna VLBI Software). We optimized the parameterization according to the 2h and 6h sessions, e.g. by excluding antennas from the sessions of which the number of observations is not enough for performing a regular solution and by fixing celestial pole offsets. The a priori TRF coordinates and daily Earth Orientation Parameters (EOP) were obtained from a global solution for CONT11. Then, we estimated one offset per antenna per 2h and 6h session, applying no-net-translation and no-net-rotation conditions with respect to the TRF derived from our global solution. A noteworthy result from our study is that the sky distribution of the observations per antenna per sub-daily session should be homogeneous to derive reliable antenna positions, because homogeneous sky coverage allows for a good separation of the coordinates and the tropospheric delays in the data analysis. The spectra of the position time series of certain antennas include significant amplitudes at sub-daily tidal frequencies which are discussed.

2. PARAMETERIZATION FOR THE ANALYSES 2 HOURLY CONT11 SESSIONS

A priori values

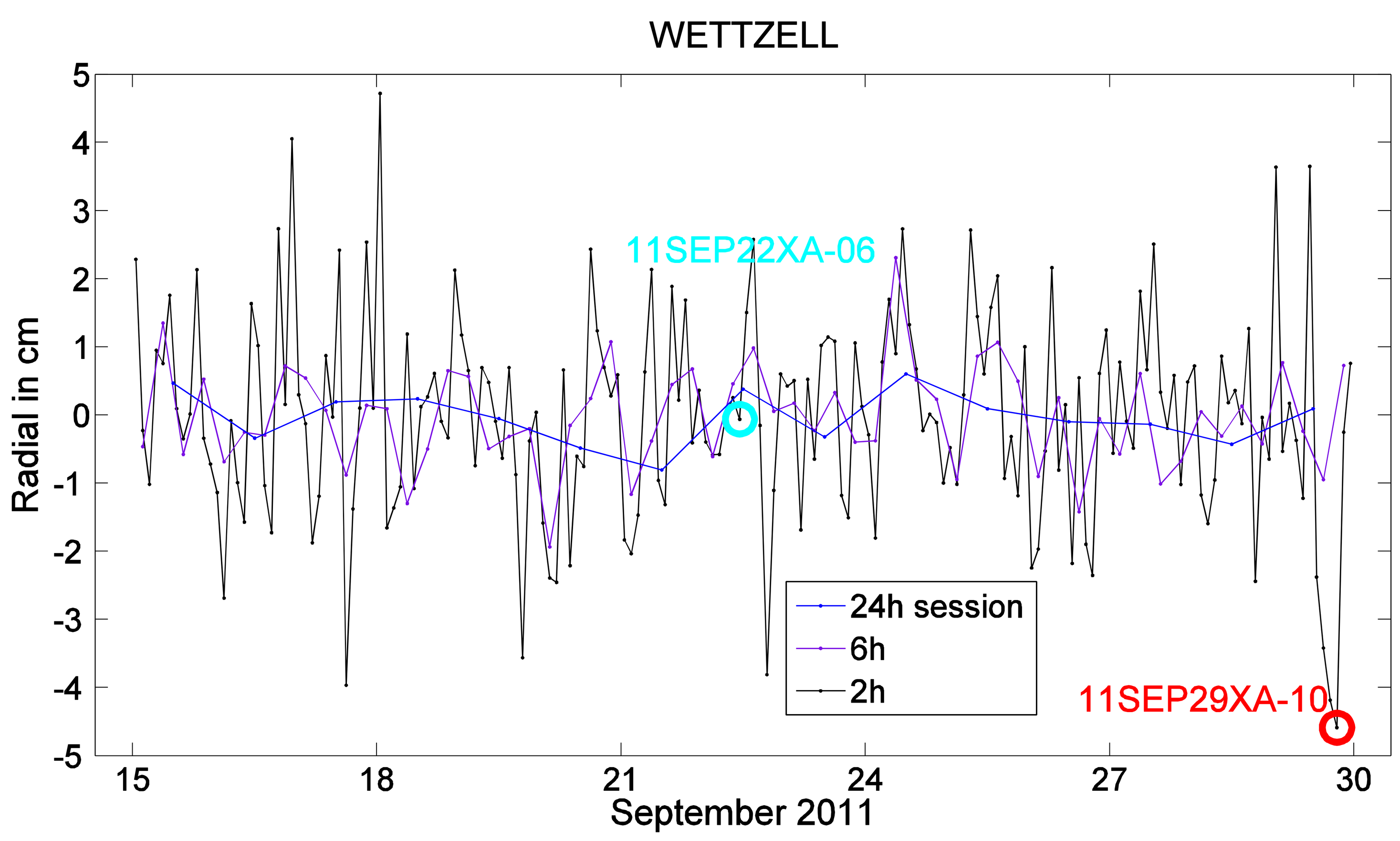
TRF (antenna coordinates)	TRF11[1] + geodynamic models + thermal antenna deformation (Nothnagel 2009) [1] The TRF catalogue provided from a global TRF solution with the observations of CONT11. NNR and NNT conditions were introduced w.r.t. VTRF2008 (Böckmann et al. 2010). Velocities were fixed to those of VTRF2008. TSUKUB32, HOBART12, YEBES40M, and TIGOCONC were excluded from TRF datum since VTRF2008 coordinates of these antennas are not available for the CONT11 period.
CRF (source coordinates)	ICRF2 (Fey et al. 2009)
Nutation (CIP in CRF)	IAU2006 + EOP11[2] [2] The Earth orientation parameter series for CONT11 were estimated at 1 day intervals in a global solution of which a priori nutation offsets were taken from IAU2006 + IERS 08 C04 and a priori ERP from IERS 08 C04 + high frequency corrections.
ERP (CIP in TRF and Earth's phase of rotation)	ERP11[3] + high frequency corrections [3] The Earth rotation parameter (ERP) series for CONT11 were estimated at 2h intervals in a global solution of which nutation offsets were fixed to IAU2006 + EOP11[2] and a priori ERP were taken from EOP11[2] + high frequency corrections.
Antenna position corrections from geodynamic models	Solid Earth tides (IERS Conventions 2010, Petit and Luzum 2010). Tidal ocean loading (FES2004, Lyard et al. 2006). Tidal and non-tidal atmosphere loading (GSFC, Petrov and Boy 2004). Pole tide and ocean pole tide (IERS Conventions 2010).
Troposphere ZHD	Calculated from surface pressure (Saastamoinen 1972, Davis et al. 1985) and mapped with VMF_h (Böhm et al. 2006).
Troposphere gradients	No a priori gradients were used.
Observations	Outlier observations were excluded ($v(i)>5*m0$). Observations were not down-weighted.

Estimated parameters

Clocks (First LS)	One offset and rate per-clock for each 2h session were estimated and reduced from the observations
Clocks (Main LS)	Continuous piece-wise linear offsets (CPWLO) (2h intervals, loose relative constraints as 2.1 cm after 2h)
ZWD	CPWLO estimated with VMF_w (1h intervals, loose relative constraints as 1.5 cm after 1h).
Troposphere east and north horizontal total gradients	CPWLO estimated with the gradient mapping function from Chen and Herring (1997). (2h intervals, absolute constraints as 1 mm in addition to tight relative constraints as 0.01 mm after 2h)
Nutation	fixed to a priori nutation offsets i.e. EOP11[2]
ERP	fixed to a priori ERP i.e. ERP11[3]
Antenna TRF coordinates	• One offset for each 2h sessions (NNR and NNT w.r.t. TRF11[1]) were estimated at epochs e.g. 1, 3, 5, ..., 21, 23 UT. • NNR and NNT conditions were imposed on all antennas participating in 2h sessions.

3. RESULTS

3.1. Sky distribution of the observations and antenna radial position estimates at WETTZELL



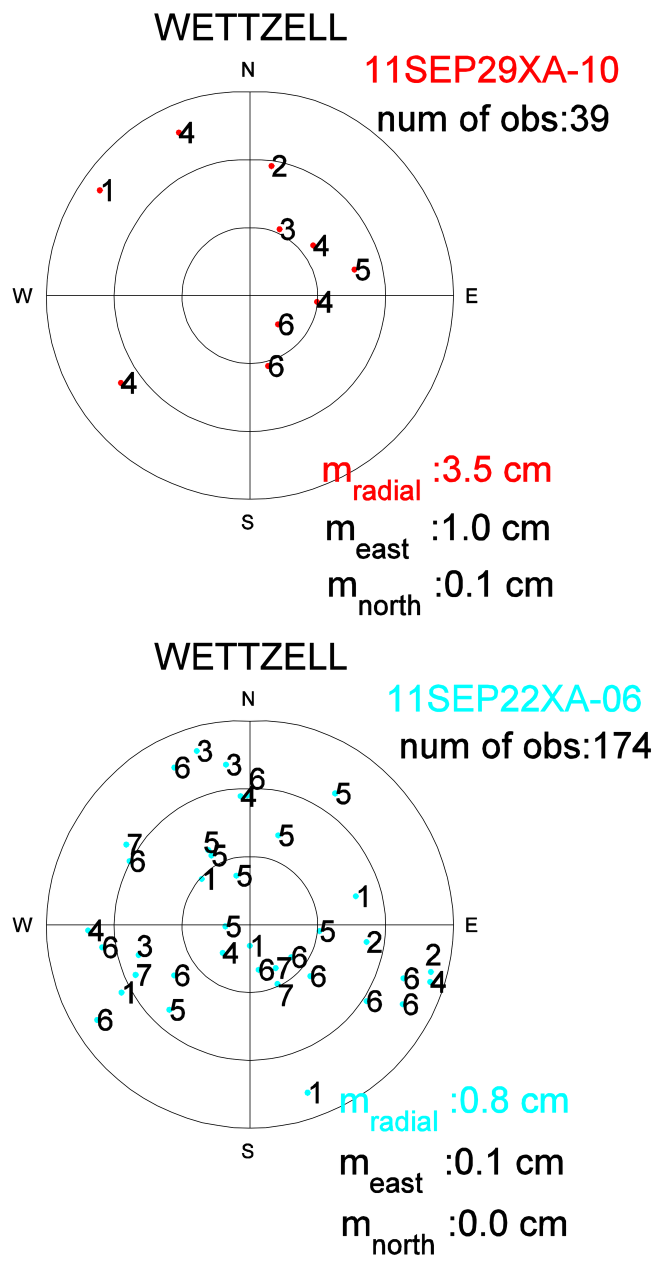


Figure 1 The blue, purple and black dotted lines (upper plot) show antenna TRF position estimates in radial direction from 24h, 6h, and 2h sessions of CONT11, respectively. The 2h sessions of which names are written in red and cyan provide inaccurate and good antenna radial position estimates, respectively. Sky plots of WETTZELL (Germany) for these sessions observed during 10 – 12 UT (cyan) and 18 - 20 UT (red) are shown to the right. The number of observations at WETTZELL per scan with the total number of the observations of the 2h sessions and the formal errors of the estimated antenna coordinates are written on the sky plots.

3.2. Correlations between ΔZWD(2h-24h) and Δradial(2h-24h) during CONT11 at HARTRAO

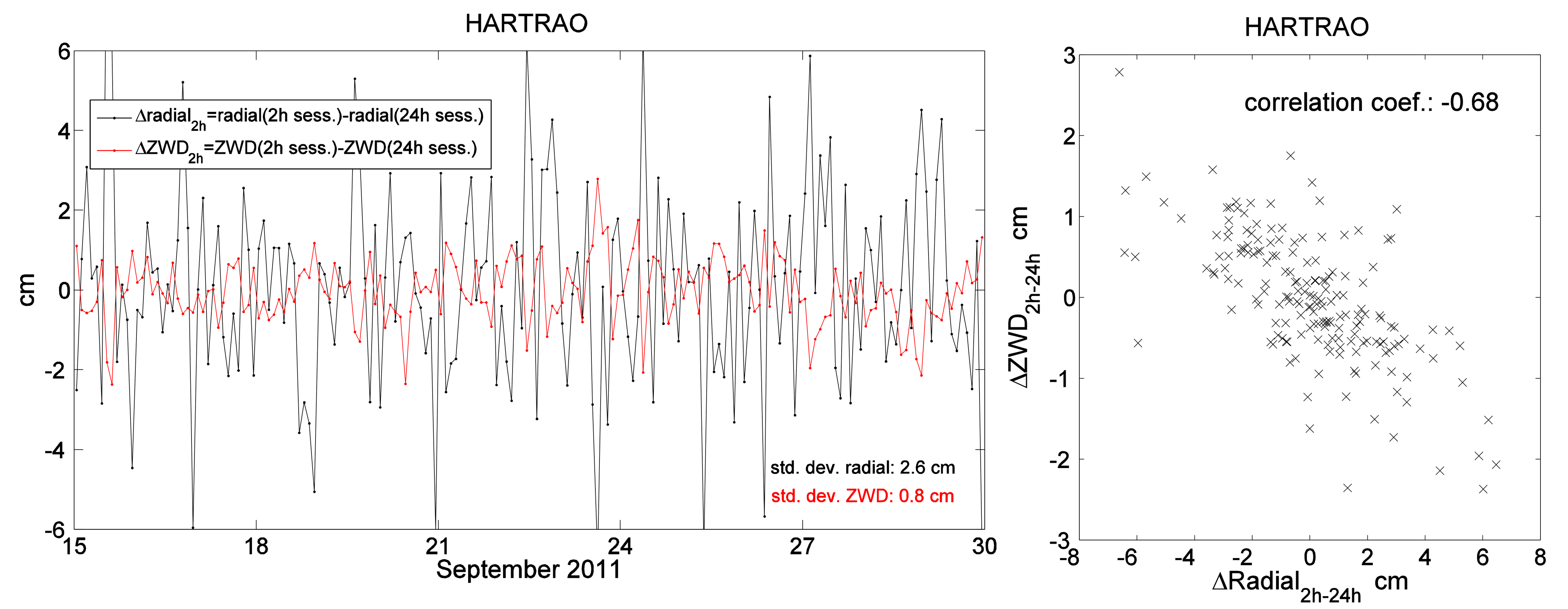


Figure 2 The red and black dotted lines (left-side plot) show ZWD and antenna radial coordinate differences between those estimated from 2h and 24h sessions of CONT11 campaign at HARTRAO (South Africa). The black crosses (right-side plot) show the correlations between ZWD and radial position differences estimated once for each 2h session at common epochs of e.g. 1, 3, 5, ..., 23 UT.

3.3. Correlations between ΔZWD(2h-24h) and Δradial(2h-24h) at the VLBI sites of CONT11

Acronyms of CONT11 VLBI antennas (ordered by latitude)	Standard deviations of ΔZWD (cm)	Standard deviations of Δradial (cm)	Correlation coefficients between ΔZWD and Δradial
NYALES20	0.4	1.5	-0.54
ONSALA60	0.7	1.8	-0.52
BADARY	0.7	2.3	-0.71
WETTZELL	0.5	1.5	-0.51
WESTFORD	0.7	2.2	-0.61
YEBES40M	0.6	1.7	-0.50
TSUKUB32	0.8	2.4	-0.35
KOKEE	0.7	2.5	-0.38
FORTLEZA	1.5	4.3	-0.77
HARTRAO	0.8	2.6	-0.68
TIGOCONC	0.9	3.4	-0.77
HOBART12	1.1	4.0	-0.70

- We subtracted the 24h radial coordinates from those estimated at 2h (radial(2h)-radial(24h)) and did the same for zenith wet delays, ZWD(2h)-ZWD(24h).
- The differences of radial coordinates vary in [-2 +2] cm to [-8 +8] cm and the differences of ZWD in [-1 +1] cm to [-4 +4] cm for all VLBI sites for CONT11.
- Due to few observations (less than 40) and inhomogeneous sky distribution (see e.g. Figure 1) the least squares adjustment can not de-correlate the parameters of troposphere delays and antenna TRF positions completely.
- Thus, troposphere delays propagate into antenna TRF positions.
- 1 to 2 cm ZWD propagate to antenna radial coordinate in opposite direction from 2 to 8 cm (see e.g. Figure 2) for a 2h session depending mainly on the sky distribution of the observations.

4. CONCLUSIONS and OUTLOOK

- All negative correlations between the ΔZWD , [ZWD(2h)-ZWD(24h)] and Δradial, [radial(2h)-radial(24h)] at the VLBI sites are statistically significant (p values < 0.05).
- 1 cm ΔZWD variation corresponds to approximately 2 to 4 cm Δradial when 2h sessions are analysed.
- Troposphere delays and antenna TRF positions are highly correlated by an inhomogeneous sky distribution of the observations in 2h sessions. Due to these large correlations, troposphere delays propagate into antenna positions in parameter estimation. Correlations between the two parameters can be mitigated if homogeneously distributed observations are carried out at each antenna at each sub-daily session, e.g. within 2h sessions.
- In future, we plan to reduce troposphere delays estimated from 24h sessions from the observations of 2h sessions before the parameter estimation. Thus, other effects than troposphere on the antenna coordinates will be unveiled, e.g. residual displacements to the a priori geodynamic models on the antenna positions at sub-daily periods.

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