Sub-daily Antenna Position Estimates from the CONT11 Campaign

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Abstract The CONT11 campaign was observed by the International VLBI Service for Geodesy and Astrometry (IVS) during 15 days from 15 to 29 September 2011. In this study, we divided the observation files of the 24 hour sessions of the CONT11 campaign into 2 h sessions. These sub-daily sessions were analyzed with the Vienna VLBI Software (VieVS) to obtain coordinate time series with 2 h resolution for each station. We found that the coordinate repeatability from the 2 h sessions is clearly reflected in a change of the tropospheric parameters like zenith delays and gradients, an effect being boosted by the non-uniform sky distribution at the stations over 2 h segments.

Keywords VLBI, CONT11, TRF, sub-daily antenna coordinates, zenith wet delays

1 Introduction

The continuous VLBI campaign, CONT11, was carried out by the International VLBI Service for Geodesy and Astrometry (IVS, Schuh and Behrend (2012)) over two weeks, from 15 to 29 September 2011, to demonstrate the highest accuracy of the VLBI system. In this study, we investigated the possibility to estimate reliable antenna coordinates every 2 hours (2 h).

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2 Data Analysis

We divided the observation files of the 24 hour sessions of the CONT11 campaign into 2 h sessions. These were then analyzed using the Vienna VLBI Software (VieVS, Böhm et al. (2012)), which is developed at the Department of Geodesy and Geoinformation at the Vienna University of Technology. The a priori terrestrial reference frame (TRF) catalogue, nutation offsets, and Earth rotation parameters (ERP) were obtained as follows:

1. First, we estimated a CONT11 specific TRF catalogue from a global TRF solution with the observations of CONT11 (named in this paper as TRF11). In this global TRF solution we applied No-Net-Rotation (NNR) and No-Net-Translation (NNT) conditions w.r.t. VTRF2008 (Böckmann et al. (2010)) and we fixed velocities to those of VTRF2008. Those datum conditions were not imposed on the antennas TSUKUB32, HOBART12, YEBES40M, and TIGOCONC since VTRF2008 coordinates of these antennas are not available for the CONT11 period.
2. We then estimated nutation offsets for CONT11 at 1 day intervals in a global solution (named in this paper as NUT11) of which a priori values were taken from the IERS 08 C04 corrections (Bizouard and Gambis (2009)) in addition to the IAU2006 precession-nutation model.
3. The ERP for CONT11 (named in this paper as ERP11) were estimated at 2 h intervals, i.e. at 1, 3, 5, ..., 21, 23 UT, in a global solution where a priori nutation offsets were fixed to daily NUT11 and a priori ERP were taken from IERS 08 C04 plus high frequency corrections. The high frequency ERP variations were modeled as recommended by the IERS Conventions 2010 (Petit and Luzum (2010)).

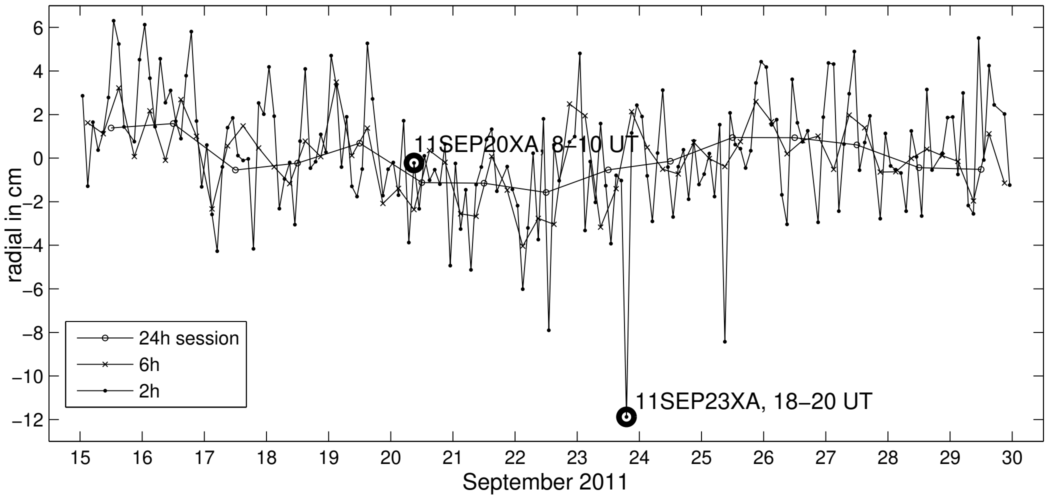

Fig. 1 KOKEE antenna TRF position time series in radial direction from the analyses of 24 h, 6 h, and 2 h sessions during CONT11 campaign. 11SEP20XA, 8-10 UT and 11SEP23XA, 18-20 UT are the examples of 2 h sessions with good (right plot of Fig. 3) and bad (left plot of Fig. 3) sky coverage of observations.

In the data analysis of the 2 h sessions we did not remove observations below a certain elevation angle, nor did we down-weight observations at low elevation angles. Source coordinates were fixed to IRCF2 (International Celestial Reference Frame 2, Fey et al. (2009)) except for sources not in the ICRF2 catalogue which were estimated. We did not estimate Earth orientation parameters (EOP) when analysing 2 h sessions. Tidal and non-tidal atmospheric loading (Petrov and Boy (2004)) as well as tidal ocean loading corrections based on the ocean model FES2004 (Lyard et al. (2006)) were introduced for each observation prior to the adjustment. Troposphere zenith hydrostatic delays (ZHD) were computed using surface pressure values recorded at the sites (Saastamoinen (1972); Davis et al. (1985)) and mapped down with the hydrostatic Vienna Mapping Functions 1 (VMF1, Böhm et al. (2006)). Antenna 2 h TRF coordinates were estimated at the epochs 1, 3, 5, ..., 21, 23 UT (see e.g. Fig. 1) using NNR and NNT conditions w.r.t. TRF11 (see the first item of this section) coordinates of the participating antennas. In the 2 h session analyses, zenith wet delays (ZWD) were estimated as piece-wise linear offsets at 1 h intervals with loose relative constraints as 1.5 cm after 1 h. Troposphere east and north horizontal total gradients were estimated as piece-wise linear offsets at 2 h intervals with absolute constraints as 1 mm in addition to tight relative constraints as 0.01 mm after 2 h. We used the wet VMF1 and the gradient mapping function as introduced by Chen and Herring (1997).

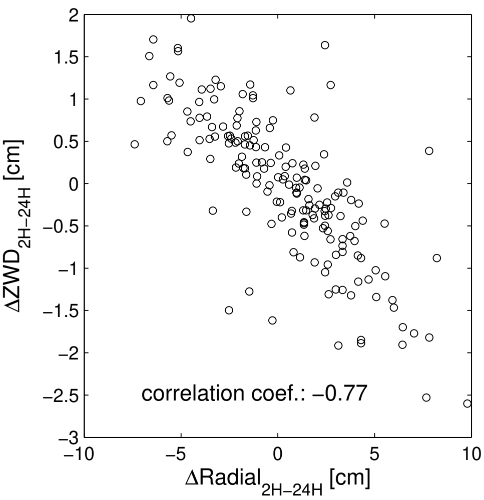

Fig. 2 The circles show the correlations between ZWD and radial position differences estimated once for each 2 h session at TIGOCONC for common epochs, i.e. 1, 3, 5,..., 23 UT.

3 Correlations between estimated coordinates and ZWD

We subtracted the 24 h radial coordinates from those estimated from the 2 h sessions (radial(2 h)-radial(24 h)) and did the same for zenith wet delays, ZWD(2 h)-ZWD(24 h). The differences of antenna TRF 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 (see e.g. Fig. 4 for TIGOCONC). Troposphere delay estimates and antenna TRF positions are highly correlated when

Antenna	Standard deviation		Correlation
	ΔZWD (cm)	Δradial (cm)	coefficient
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

Table 1 Correlations between ΔZWD and Δradial at the VLBI sites contributing to CONT11 campaign

inhomogeneous sky distribution of the observations are in 2 h sessions (see e.g. Fig. 5 for TIGOCONC). Due to small number of observations (less than 30) and inhomogeneous sky distribution (see e.g. left plot of Fig. 3) the least squares adjustment cannot de-correlate the parameters of troposphere delays and antenna TRF positions completely. Thus, troposphere delays propagate into antenna TRF positions. A ZWD offset of 1 to 2 cm propagates to antenna radial coordinates in opposite direction from 2 to 8 cm for a 2 h session depending mainly on the sky distribution of the observations. From Table 1 one can infer that the number and the sky distribution of the observations of KOKEE and TSUKUB32 are better than that of FORTLEZA and TIGOCONC during CONT11 2 h sessions.

4 Conclusions

From our analyses of the CONT11 sub-daily (2 h) sessions, the following results were drawn:

- All negative correlations between the ΔZWD, [ZWD(2 h)-ZWD(24 h)] and Δradial, [radial(2 h)-radial(24 h)] at the VLBI sites are statistically significant (p values < 0.05).
- 1 cm ΔZWD variation corresponds to approximately 2 to 4 cm Δradial when 2 h sessions are analyzed.
- Due to the large correlations between the troposphere delay estimates and the antenna TRF positions for CONT11 2 h sessions (see Table 1), troposphere delays propagate into antenna positions in parameter estimation. Correlations between the two parameters can be mitigated if homogeneously distributed adequate number of observations are carried out at each antenna at each sub-daily session e.g. 2 h.
- We are planning for the future to reduce troposphere delays estimated from 24 h sessions from the observations of 2 h 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 effects on the antenna positions at sub-daily tidal frequencies.

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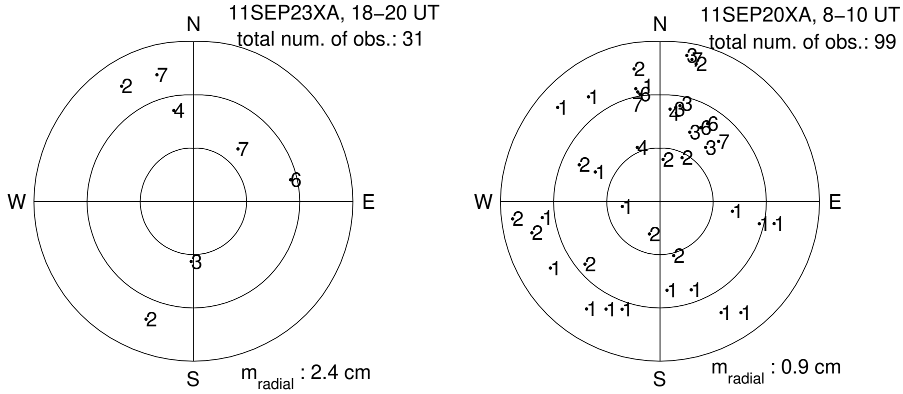

Fig. 3 Sky plots at KOKEE for the 2 h sessions observed during 11SEP23XA, 18 - 20 UT (left plot) and 11SEP20XA, 8 - 10 UT (right plot) illustrate bad and good sky coverage of observations in 2 h segments which results in inaccurate and better antenna position estimates. The number of observations per scan with the total number of the observations of the sessions and the formal errors of the estimated antenna coordinates in radial direction are written on the sky plots.

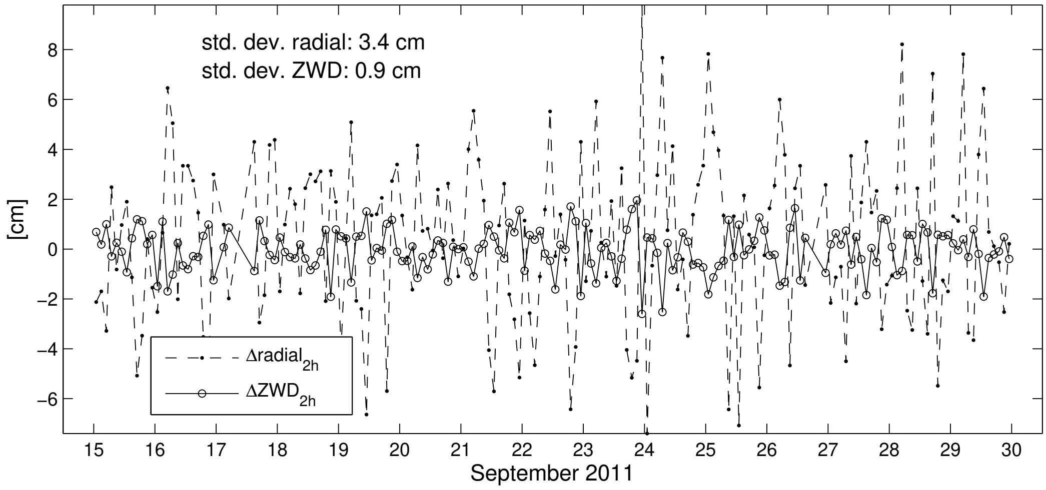

Fig. 4 The circles on solid lines and dots on dashed lines show ZWD and antenna radial coordinate differences between those estimated from 2 h and 24 h sessions of CONT11 campaign at TIGOCONC for the common epochs, i.e. 1, 3, 5,..., 23 UT.

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