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Space Geodesy at Yebes: Station Motion from VLBI and GPS

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Abstract. Analysis of VLBI sessions and GPS time series has been performed for the 14-m radiotelescope at Yebes site from 1995 to 2003. The best a priori geophysical models and auxiliary weather information from European Center for Medium-Range Weather Forecasts (ECMWF) have been used for the VLBI analysis. The results derived from VLBI measurements are consistent with the plate tectonic motion and no significant movements are detected. The GPS results might detect a deviation in the horizontal components, which is not supported by the VLBI results. We appear to detect a small relative motion between the VLBI and the GPS monuments.

1. Introduction

The National Geographical Institute (IGN) of Spain is active in space geodesy with VLBI and GPS observations using the instrumentation at the National Astronomical Observatory (OAN) at Yebes.

Between 1995 and 2003 the Yebes 14-m radiotelescope was used successfully in 32 geodetic VLBI experiments, including 19 European sessions. The 14-m telescope is not used anymore since 2005 and it will be replaced by the newly constructed 40-m radiotelescope in 2008. Additional to the geodetic VLBI data, there are GPS data from the Yebes site available since 1999.

Fig. 1 shows an aerial picture of the Yebes station. The GPS antenna is located on the roof of a building.

A local tie survey performed in 1999 [1] determined the distance between the 14-m radiotelescope and the GPS antenna to be 106.496 m $\pm$ 0.012 m. The approximate distance between the two radiotelescopes is 225 m.

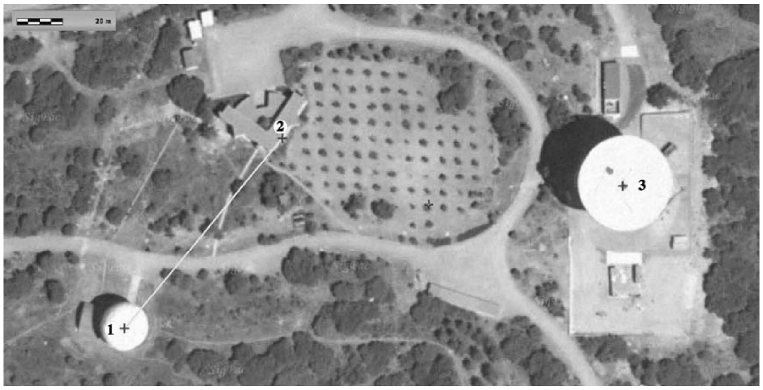

Figure 1. The IGN facilities at Yebes (Guadalajara, Spain). Displayed are (1) the 14-m radiotelescope used in VLBI observations, (2) the GPS antenna of the IGS station, and (3) the new 40-m radiotelescope

2. Analysis

The current project focuses on the analysis of Yebes station geodetic position using VLBI and GPS. The goal is the comparison, combination and interpretation of VLBI and GPS time series for Yebes. We focus on the European VLBI experiments from 1995 to 2003. In future work, we will include all the experiments in the analysis, not only European, in which the 14-m radiotelescope in Yebes participated in those years. For the GPS analysis we use all available data between the middle of 1999 and the end of 2007.

We use the Calc/Solve software package [2] for the analysis of the VLBI sessions and introduce the best a priori geophysical models. The FES2004 ocean model is used as the best a priori model for the ocean tide loading for all the European VLBI sites. The FES2004 tidal charts were computed using a variational assimilation strategy. The assimilated data are the tidal constants coming from the tide gauge and satellite sea level analysis [3].

We introduce auxiliary information from the European numerical weather model ECMWF (European Center for Medium-Range Weather Forecasts) [4] for experiments where we detected that weather data was missing or was obviously wrong. We make a comparison between solutions with original data and solutions in which we include ECMWF auxiliary data. We detected station position changes on the order of 2 mm in the vertical component in the worst case, and sub-millimeter changes for the horizontal positions.

For the estimation of the geodetic position for Yebes 14-m radiotelescope we treated all the other stations involved in the experiments so that their position and velocity were fixed in ITRF2005. Station coordinates for Yebes were estimated for every VLBI session, resulting in time series in a geocentric coordinate system. The station coordinates were transformed into a local geodetic coordinate system, and plate tectonic motion according to the Nuvel-1

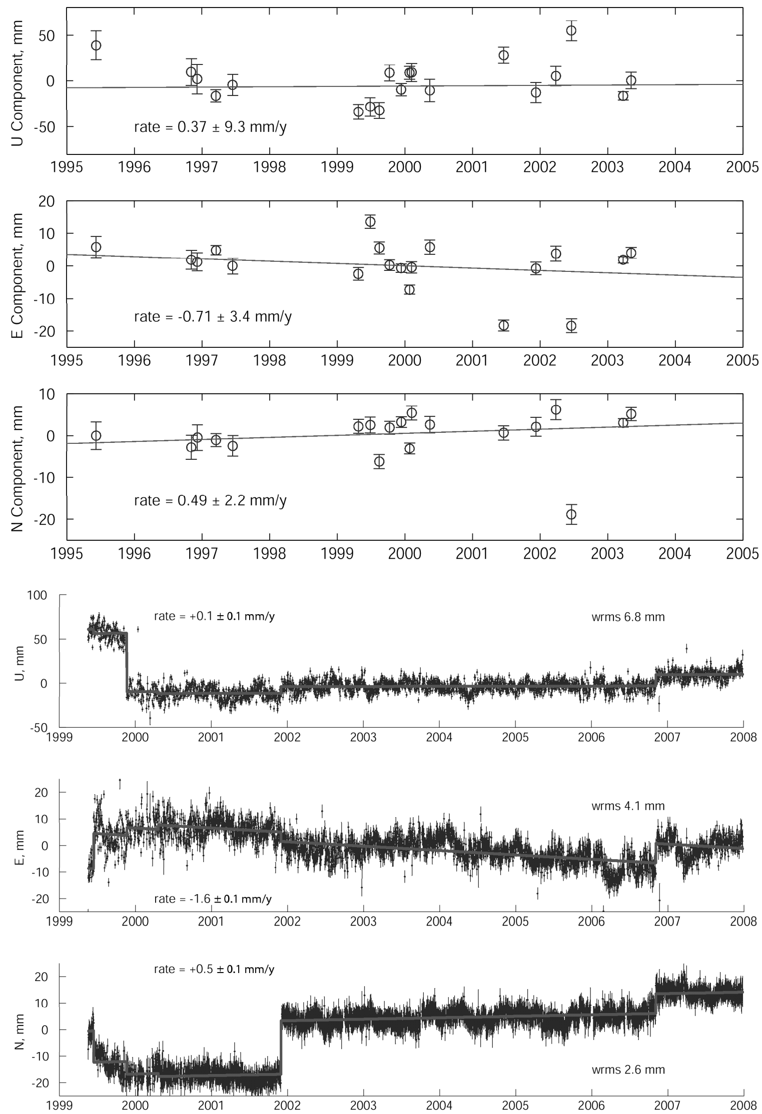

Figure 2. Time series of topocentric station position for the Yebes VLBI station (top) and GPS station (bottom). Plate motion according to Nuvel-1 has been subtracted

[5] was subtracted. The top graphs in Fig. 2 show time series of the resulting three-dimensional topocentric station position.

The GPS data analysis was performed with the Gipsy-Oasis-II software package [6] using the precise-point positioning (PPP) strategy. The resulting cartesian geocentric station positions were transformed into a local geodetic reference system, and the plate tectonic motion was removed according to

Nuvel-1 NNR [5]. The bottom graphs in Fig. 2 show the corresponding time series.

Based on the VLBI and GPS time series, we determined linear changes of topocentric station position. These station rates were estimated by a least-squares fit. For the GPS time series we took into account breaks in the time series, for example due to antenna replacements, according to the information given in the log-file on the IGS webpage [1]. Tabl. 1 shows the results.

Table 1. Topocentric rates from VLBI and GPS

Component	VLBI rate, mm/y	GPS rate, mm/y
Up	$+0.37 \pm 9.3$	$+0.1 \pm 0.1$
East	-0.71 ± 3.4	-1.6 ± 0.1
North	$+0.49 \pm 2.2$	$+0.5 \pm 0.1$

3. Discussion and Outlook

The determined topocentric station rates from VLBI are not significant. The statistical uncertainties are much larger than the determined rates. In the GPS case, the horizontal rates are significant in a statistical sense, while the vertical rate is not. Even though the standard deviations are probably too optimistic due to the large number of observations, we see in particular a significant westward motion by 1.6 mm/y relative to the plate motion model. The corresponding northward motion by 0.5 mm/y is less significant. The results indicate that we might detect a deviation from the plate tectonic model, which is not supported by the VLBI results.

We therefore also investigated the distance between the VLBI and GPS monument. Here we used the station positions in the cartesian geocentric system, i.e. ITRF05. We interpolated the GPS positions to the exact epochs of the few VLBI results and calculated the cartesian distance between the reference points. Unfortunately, there are only 12 common epochs between 1999 and 2003. The time series of distance between VLBI and GPS is shown in Fig. 3. We analyzed the time series and determined average values for the distance and its linear change with time. Again we used the epochs given on the IGS webpage [1] to introduce breaks in the time series. There are three sections in the time series and the average distances are 106.476 ± 0.001 m, 106.485 ± 0.001 and 106.495 ± 0.001, and the rate is -1.9 ± 0.1 mm/y. The distance corresponds reasonably well with the local tie results, however, the decrease in distance is surprising. The decrease in distance is consistent with the detected westward motion of the GPS station.

This result might indicate that there is some local motion at the Yebes station, possibly related to the building on where the GPS station is mounted.

Currently we work on a homogeneous reanalysis of all geodetic VLBI

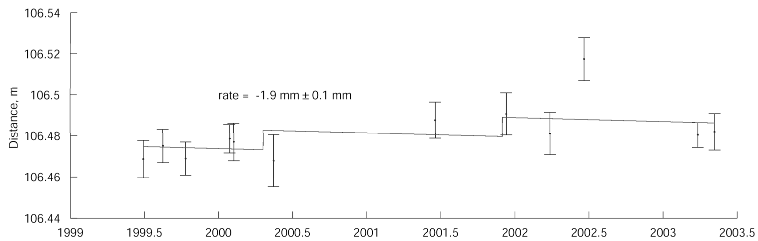

Figure 3. Time series of distance between VLBI and the GPS antenna at YEBES

sessions in which the Yebes 14-m radiotelescope participated, not only European experiments. We use auxiliary information from a numerical weather model as well as the best a priori geophysical models. In particular we are curious whether the results for local motions between the GPS and VLBI equipment at the station can be confirmed when we include more VLBI data. A complete reprocessing, together with planned local-tie measurements, is of major importance for the combination of the historic VLBI observations performed with the 14-m radiotelescope and the future observations with the new 40-m radiotelescope. Future geodetic VLBI sessions with the new 40-m radiotelescope will help to improve the results for the station position and velocity at Yebes.

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