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Contributions of GPS and VLBI for understanding station motions

P.J. Mendes Cerveira *, R. Heinkelmann, J. Boehm, R. Weber, H. Schuh

Vienna University of Technology, Institute of Geodesy and Geophysics, Advanced Geodesy, Gusshausstrasse 27-29, A-1040 Vienna, Austria

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Abstract

The occurrence of non-secular signals in site positions is well known. Since a few years, a main objective of research has been the separation of apparent motions from real geophysical motions and deformations. We investigated eight weekly Global Positioning System (GPS), one daily solution from Scripps Orbit and Permanent Array Center (SOPAC), and two Very Long Baseline Interferometry (VLBI) station coordinate time series and the corresponding baselines. One major hurdle in our investigation was the handling of constraints imposed on the GPS solutions. Seasonal signals in the height component with amplitudes of up to 9 mm for a few sites on the Asian continent were recovered. For baselines longer than 5000 km, the precision of the GPS technique is superior to the VLBI technique from the point of view of repeatability. The improvement on VLBI baseline repeatability after applying the atmospheric pressure loading time series provided by the Goddard Space Flight Center (GSFC) VLBI group reaches 3.3% (median value). Coordinate time series or baseline lengths derived from GPS and VLBI Analysis Centers (ACs) solutions have not yet achieved an unambiguously assessment of sub-cm agreement.

Keywords: GPS; VLBI; IGS; Reference frame; Geodetic baseline

1. Introduction

Space geodetic techniques observe electromagnetic waves propagating from quasars or from satellites. The observation equations are differential, defining a family of solutions. To obtain one solution, boundary conditions are applied. Different Analysis Centers (ACs) use different boundary conditions, which is one of the reasons why their solutions do not match. Nevertheless, baseline lengths time series obtained from Global Positioning System (GPS) and Very Long Baseline Interferometry (VLBI) measurements show coherent transient signals. Both techniques apply a multitude of corrections to the raw observables for effects such as tropospheric refraction, pole tide, solid Earth tides, and ocean tide loading.

The effects of atmospheric pressure (van Dam et al., 1994) and hydrological loading on station positions have been investigated for several years. Dong et al. (2002) discuss seasonal signals in GPS position time series, whereas Petrov and Ma (2003) analyze harmonic VLBI site variations. Penna and Stewart (2003) show that mismodelled diurnal or

* Corresponding author. Fax: +43 1 58801/12896.
E-mail addresses: mendes@mars.hg.tuwien.ac.at (P.J. Mendes Cerveira), rob@mars.hg.tuwien.ac.at (R. Heinkelmann), jboehm@mars.hg.tuwien.ac.at (J. Boehm), rweber@mars.hg.tuwien.ac.at (R. Weber), hschuh@mars.hg.tuwien.ac.at (H. Schuh).

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semi-diurnal tidally induced station height variations can map into annual or semi-annual terms. In the most recent study on atmospheric pressure loading, Petrov and Boy (2004) propose a new model for routine processing of space geodetic observations.

In this paper, we focus on site coordinate changes with special treatment of the constraints and reference frame realization considering various solutions from the International GPS Service (IGS) ACs. Then, we investigate baseline lengths repeatabilities for GPS and VLBI. Our aim is to improve the agreement (within the sub-cm level) between GPS and VLBI solutions, from which global geophysical investigations, e.g., used for tectonophysics, would undoubtedly benefit. The motivation of this paper is to show the limitations and deficiencies of space geodetic solutions, on which geophysical interpretations are based.

2. Observations

Eight ACs of the IGS produce global weekly station coordinate solutions in the Software Independent Exchange (SINEX) format, which can be downloaded from the Crustal Dynamics Data Information System (CDDIS) server ftp://cddisa.gsfc.nasa.gov/pub/gps/products/. This format contains parameter vectors, a so-called "full" estimated covariance matrix and sometimes also its a priori covariance matrix. As described in Davies and Blewitt (2000) and Altamimi et al. (2002), these matrices should allow us to remove a priori constraints to restore a free network solution. For our investigations, all available AC solutions from GPS week 1021 till week 1275 (August 1999 till August 2004) were used. We tried to deconstrain the station coordinate solutions and estimated a new set of seven transformation parameters with respect to the updated IGb00 reference frame (Ray et al., 2005), for each GPS week. The weekly AC solutions were aligned to IGb00. The seven Helmert parameters were estimated using only those stations for which the deviation to their IGb00 position was smaller than 3 cm (this step was done iteratively). This precision limit corresponds to maximum apparent seasonal and transient variations of the GPS coordinate time series. Thus, the number of chosen stations was typically from 40 to 70 out of the 99 possible ones. Besides, we also downloaded geocentric daily coordinate solutions (in the ITRF2000) from the Scripps Orbit and Permanent Array Center (SOPAC) located at the server ftp://garner.ucsd.edu/pub/timeseries/. We did not choose the topocentric solutions, because these files did not enable us to recover the geocentric positions of the stations. Only 359 IGS stations were selected for our analysis (see Fig. 1(a)).

Concerning VLBI analysis, we calculated two long-term solutions with VLBI sessions covering more than 20 years. An observation model with conditions between the parameters, as implemented in the OCCAM 6.0 software (Titov et al., 2001), was used. From November 1981 till June 2004 more than 3800 24-h X/S-band sessions were observed including 155 stations. Twenty percent of sessions were discarded for our solutions, e.g., single-baseline sessions, sessions with small (national) networks, and sessions that provided major problems in the analysis. The total number of retained sessions was 3045, containing 50 stations (see Fig. 1(b)) that show small residuals and have stable a priori coordinates (ITRF2000). Our two VLBI solutions differ by one feature: in the first solution we did apply atmospheric

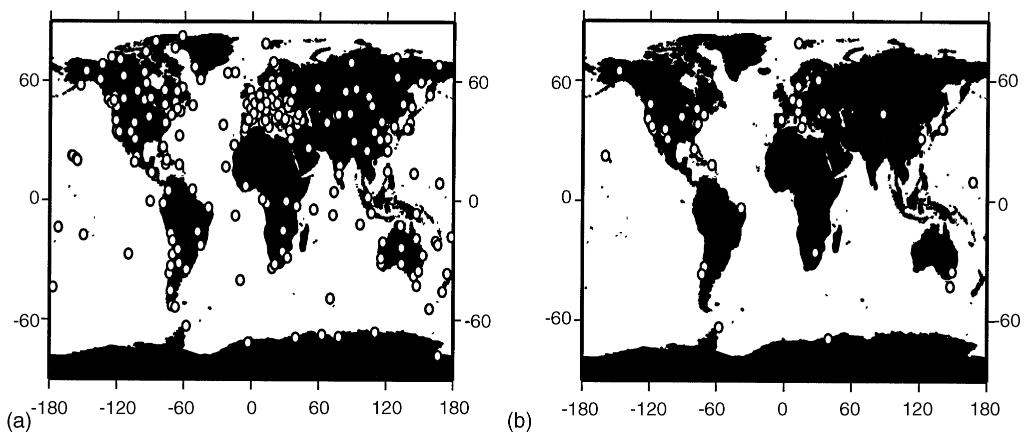

Fig. 1. (a) Distribution of the 359 IGS stations used in this investigation and (b) distribution of the 50 chosen VLBI stations.