GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2003. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development activities aimed at improving the VLBI technique.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. It is part of a larger VLBI group which also includes the IVS Coordinating Center, the Core Operation Center, a Technology Development Center, and a network station. The analysis center participates in all phases of geodetic and astrometric VLBI analysis, software development, and research aimed at improving the VLBI technique.

2. Activities

2.1. Analysis Activities

The GSFC analysis group routinely analyzes all Mark 4 IVS sessions using the Calc/Solve system, and performs the AIPS post correlation analysis (phase calibration and fringe fitting) and the Calc/Solve analysis of the VLBA-correlated RDV sessions. It submits updated session EOP files and daily Sinex solutions for all IVS sessions to the IVS data centers immediately after analysis. Timeliness goals are 3 working hours after correlator release for Intensive submissions, and 1 working day for 24-hr Mark 4 submissions. The group submits analyzed databases to IVS for all INT01 NEOS Intensive, R1, RDV, CONT02, R&D, and APSG sessions. During 2003, the group processed and analyzed 168 24-hr sessions (49 R1, 53 R4, 6 RDV, 5 CONT02, 13 T2, 12 CRF, 6 OHIG, 12 R&D, 5 EURO, 4 APSG, and 3 SURVEY sessions), 179 1-hr INT01 NEOS Intensive sessions, and 29 INT02 Intensive sessions. The group also generates and submits quarterly updated TRF and CRF solutions to the IVS data centers using all suitable VLBI sessions.

2.2. Research Activities

The GSFC analysis group performs research aimed at improving VLBI analysis and modeling techniques, improving tropospheric and other geophysical modeling, improving the measurement and understanding of Earth orientation, maintaining and refining the celestial and terrestrial reference frames, and other related scientific investigations. The primary research activities undertaken during 2003 include the following:

- Mass loading: Observed VLBI site position variations have significant contributions at seasonal frequencies. To explain these variations, staff investigated the effect of various mass loading signals on crustal displacements measured by VLBI. Specifically, the effects of hydrological loading, atmospheric pressure loading, and non-tidal ocean loading were considered. Applying loading models for these three effects reduced annual vertical site amplitudes for

~70% of the most frequently used VLBI sites by up to 2-3 mm, where the total observed amplitudes were generally 3-6 mm. Use of these models also improves baseline length repeatabilities except for some northern latitude sites where it is suspected that the snow component of the hydrologic model is not correct.

- Atmospheric pressure loading: Detailed investigations of atmospheric pressure loading were carried out. A rigorous procedure for computing atmospheric pressure loading was developed. A model for atmospheric tides was included. For all VLBI and SLR stations, the 3-D displacements due to atmospheric pressure loading were computed using the 6-hr surface pressure fields from the National Centers for Environmental Prediction (NCEP). The error budget of the pressure loading time series was quantitatively estimated and the errors were found to be below 15%. The loading series were validated by comparing them with a dataset of 3.5 million VLBI observations for the period of 1980–2003. It was shown that, on average, only 5% of the amount of power present in the loading time series was not also present in the VLBI data. For the first time, horizontal displacements caused by atmospheric loading have been detected. Correction for atmospheric loading in VLBI produces a significant improvement in baseline length repeatability, except for the annual component. A paper on pressure loading was presented at the GPS meeting in Luxembourg in April 2003 (see Petrov and Boy, http://arXiv.org/abs/physics/0401117), and a refereed paper (see Petrov and Boy, http://arXiv.org/abs/physics/0311096) was submitted to and accepted by JGR, to appear in 2004. On 18 March 2003, an atmospheric pressure loading service for VLBI and SLR was established. Series of 3-D displacements due to atmospheric pressure loading for all VLBI and SLR stations are updated daily. They are available at http://gemini.gsfc.nasa.gov/aplo.
- IMF: The impact of using an isobaric mapping function on VLBI analysis was investigated. The use of the NCEP Numerical Weather Model (NWM) to provide in situ atmosphere information for atmosphere delay mapping functions was evaluated using VLBI data spanning 11 years. Parameters required by the IMF mapping functions were calculated from the NWM and incorporated into Calc/Solve. Compared with the NMF mapping functions, the application of IMF in global solutions demonstrates that the hydrostatic IMF mapping function, IMFh, provides both significant improvement in baseline length repeatability and noticeable reduction in the amplitude of the residual harmonic site position variations at semidiurnal to long-period bands. For baseline length repeatability, the reduction in the observed mean square deviations achieves 80% of the maximum expected for the change from NMF to IMF. On the other hand, the wet IMF mapping function, IMFw, as implemented using the NCEP data, results in a slight degradation of baseline length repeatability, probably due to the large grid spacing used by the NWM. A paper on this subject was presented at the GPS meeting in Luxembourg in April 2003 (see Niell and Petrov, http://arXiv.org/abs/physics/0401118).
- Antenna thermal deformation: Antenna thermal expansion and contraction can contribute significantly to a site's annual vertical variations, with amplitudes as large as 3-4 mm. A simple model based on antenna dimensions and material expansion coefficients was applied in the VLBI analysis, along with the mass loading models. For many sites, the thermal expansion correction helps to reduce the annual vertical amplitudes.
- Quasar proper motions: When proper motions are estimated in the VLBI standard solutions, about 100 quasars are found with position uncertainties less than 50 μas/yr and apparent proper motions greater than 50 μas/yr. The weighted RMS of apparent proper motion is

about 30 μas/yr in both right ascension and declination, which is significant compared to the ICRF noise floor given that the observed proper motions are from 1-2 decades of observing. For many sources, structure effects are certainly responsible for much of the observed apparent proper motion, and structure corrections are desirable. Based on analysis of the coherence of the pattern of observed proper motion over the sky, attempts are being made to estimate the galactic rotation rate. A presentation on this topic was made at the VLBA Tenth Anniversary Meeting, in Socorro, New Mexico, in June 2003 (see http://arXiv.org/abs/astro-ph/0309826).

- Gilcreek post-seismic behavior: Analysis of the time series of VLBI horizontal positions at Fairbanks shows that, over the year following the Denali fault earthquake of November 2002, the site velocity averaged ~20 and ~8 mm/yr faster to the South and East, respectively, in comparison to the long-term rate prior to the earthquake. The position variation roughly follows an exponential transient decay with a time constant of 2-3 months. Another year of data may be needed to determine whether the horizontal rates have returned to their pre-earthquake values.
- CONT02 analysis: Analysis of the CONT02 sessions showed that the baseline length precision is at the level of the best VLBI sessions and polar motion offset and rate estimates agree with those from GPS at the level of their formal uncertainties. The variance of subdaily EOP residuals (160-200 μas for X, Y, and UT1) to tidal models are not significant compared to the formal uncertainties of the subdaily estimates. This variance is similar to that for previous CONT campaigns. However, the subdaily EOP residuals do show modulated diurnal, semi-diurnal, and 2-day variations.
- Antenna fixed axis tilt analysis: A Solve user-partial was used to estimate the tilts of all antennas with axis offsets in the RDV sessions. This study confirmed the tilt of the Pietown antenna, as first determined by NRAO using the pointing data. The pointing data shows a slowly increasing tilt, starting around 1991, and amounting to ~3.75 arc-minutes at 206 degrees azimuth, as of May 2003. Solve gives a tilt of ~2.6 arc-minutes at 202 degrees azimuth, at an averaged epoch of ~2000.0. Factoring in the difference in epochs, this is excellent agreement. The motion determined for Pietown is anomalous, showing an excess velocity of some 2 - 2.5 mm/yr to the SW, compared to Fort Davis, Los Alamos, and Kitt Peak, and cannot be explained by the geology of the region. Pietown's increasing tilt, of ~.3 arc-min/yr, translates into ~1.5 mm/year of motion to the SSW, if due to settling at the base of the antenna, and more if the settling/tilting is occuring deeper under the antenna. Thus, Pietown's anomalous motion may be entirely due to local settling effects.
- High frequency CRF: Members of the analysis group are working with JPL, USNO, NRAO, and others, to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands (~24 and ~43 GHz). The primary goal is to build up a reference frame for use in planetary spacecraft navigation at Ka band (~33 GHz). Three sessions were analyzed during the year, a K-band survey and two K/Q sessions, using AIPS and Calc/Solve. Combined with two K/Q sessions from the previous year, the CRF determined shows declination dependent offsets from the X/S CRF, indicative of ionospheric effects. Though non-simultaneous, the K and Q observations were interpolated to obtain ionosphere corrections. Though these corrections add considerable noise to the solutions, they also appear to reduce the declination dependent errors.

2.3. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Updates were released approximately bimonthly in 2003. Work in 2003 concentrated on the development of a Linux compatible version of Calc/Solve. Extensive upgrading of Calc for compliance with the IERS Conventions (2003) was begun and will be finished in 2004.

3. Staff

Members of the analysis group (and their areas of activity) include: Dr. Chopo Ma (CRF, TRF, EOP, and K/Q CRF analysis; IERS representative), Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, proper motion, and post-seismic studies), Dr. David Gordon (database analysis; RDV and K/Q CRF analysis; Calc development), Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis; Calc/Solve development), Ms. Karen Baver (R4 and Intensives analysis, software development), and Ms. Cindy Villiard (data processing).

4. Future Plans

Plans for the next year include: Finishing the update of Calc for compliance with the IERS Conventions (2003); finishing and releasing the first Linux version of Calc/Solve; participation in a third set of VLBA calibrator survey sessions; participation in additional K/Q observations and reference frame development; and further research aimed at improving the VLBI technique.

5. Publications

Fomalont, E. B., L. Petrov, D. S. MacMillan, D. Gordon, C. Ma, "The Second VLBA Calibrator Survey: VCS2", Astronomical Journal, **126**, 2562–2566, 2003.

Petrov, L., C. Ma, "Study of Harmonic Site Position Variations Determined by VLBI", J. Geophys. Res., **108**, No. B4, 2190, 2003.