GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2010. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development 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. We maintain a Web site at http://lupus.gsfc.nasa.gov.

2. Activities

2.1. Analysis Activities

The GSFC Analysis Center analyzes all IVS sessions, using the *Calc/Solve* system, and performs the *AIPS* fringe fitting and *Calc/Solve* analysis of the VLBA-correlated RDV sessions. The group submits the analyzed databases to IVS for all R1, RDV, R&D, APSG, INT01, and INT03 sessions. During 2010, GSFC analyzed 149 24-hour (53 R1, 53 R4, 5 RDV, 6 R&D, 5 EURO, 7 T2, 1 APSG, 8 OHIG, 4 CRF, and 7 JADE) sessions, five 3-hour (TQuak) sessions, and 366 1-hour UT1 (229 INT01, 92 INT02, and 45 INT03) sessions, and we submitted updated EOP and daily Sinex files to IVS immediately following analysis. As part of the RDV program, we also observed 51 requested sources for the astronomy community and determined precise positions for most.

2.2. Research Activities

- R&D Intensives: We continued studying an alternative scheduling strategy for the INT01 Intensives, begun in 2009, by running 5 additional R&D Intensive sessions. In these sessions, Kokee and Wettzell observed a series of 1-hour pseudo-Intensives that alternated between the current strategy (using a small list of strong sources) and an alternative strategy (using all mutually visible geodetic sources). As a result of preliminary analysis, the USNO began using the alternative strategy on alternating days beginnning in July 2010.
- IYA2009 Session: For the celebration of the International Year of Astronomy in 2009, GSFC scheduled the largest astrometric VLBI session ever attempted. This involved 34 globally distributed stations and used 243 of the 295 ICRF2 defining sources. Correlation was done at Haystack in 2010. Thirty-two stations performed adequately and were made into X and S databases. We analyzed these using a test version of *Solve* which was updated to handle 32 stations, and the analyzed databases were submitted to IVS.

- ITRF2008: GSFC participated in studying and evaluating the two versions of ITRF2008, provided by IGN (France) and DGFI (Germany). The IGN TRF shows a scale difference of -0.39 ppb compared to a GSFC *Calc/Solve* solution. This is due to a scale difference of -1.05 between SLR and VLBI solutions. Removing rotation and translation differences, the WRMS position and velocity differences between the IGN or DGFI solutions and a GSFC solution were 2-3 mm and 0.3-0.4 mm/yr for the 40 most frequently used stations. When the TRF was fixed to the IGN or DGFI TRF's, the resulting X-pole and Y-pole estimates were not significantly different from a standard *Calc/Solve* solution in which positions and velocities were estimated. We also studied the Allan variances of the EOPs differenced from IGS EOPs. The two ITRF2008 solutions and the GSFC solution show the same level and type of noise, with no significant differences. Our results were reported at the IAG Symposium "Reference Frames for Applications in Geosciences".
- High Frequency EOP: We generated a new empirical high frequency EOP tidal model. Comparisons with other empirical models derived from VLBI and GPS data show good agreement. We also compared the new model and other HF-EOP empirical models against models derived using satellite altimetry data and found small but significant differences.
- Comparisons of Wet Zenith Delays: We compared tropospheric parameters derived from three independent radio techniques (VLBI, GPS and WVR) for the CONT05 campaign. These comparisons showed very good agreement, with path length WRMS residual differences at the level of 5-10 mm.
- VLBA HW/SW Correlator Comparison: A detailed comparison was made of the RDV77 session, as correlated on both the VLBA hardware correlator and the new VLBA-DiFX software correlator. Group delay differences agreed at an average WRMS of 4.2 psec, with a noise floor of $\sim$2.5 psec on the shortest baselines. These results compare well to other correlator comparisons and essentially validate the VLBA-DiFX correlator for geodetic processing.
- Chilean Earthquake: We studied the motion of the VLBI station TIGOCONC in Concepción, Chile, near the epicenter of the 8.8 magnitude earthquake of February 27, 2010. We found coseismic offsets of -45, -3040, and -678 mm in the Up, East, and North directions. Also, post-seismic transient motion was seen in the East component during the months following, but after 10 months, the East rate has nearly returned to its previous value. We presented our results at the Fall AGU Meeting.
- VLBI2010 Simulations: We investigated the geodetic performance of the future VLBI2010 network, focusing on expected accuracy and possible systematic effects. We performed simulations of several different error contributions: 1) troposphere mapping function error, 2) antenna gravitational deformation, 3) site pressure error, and 4) latitude-dependent tropospheric turbulence. Biases at the 1-2 mm level in site positions can result from the first three error sources. Vertical uncertainty due to tropospheric turbulence has latitude dependence, but no significant bias. These results were reported at the Fall AGU Meeting.
- ICRF2 Effects: A study was made of the effects of the switchover to ICRF2. Only small differences are seen in the TRF, CRF, and EOPs from VLBI solutions. The most obvious effect is an $\sim$40 μasec rotation of the CRF, mostly about the Y-axis. This is primarily a result of the small overlap of the ICRF and ICRF2 defining sources and the subsequent

difficulty of aligning them. We compared EOPs from an ICRF and an ICRF2 solution to IGS EOPs, using Allan variances, and found no significant differences.

- Source Monitoring: We continued our successful source monitoring program using the R1 and RDV sessions. In May we switched over from monitoring the ICRF defining sources to the ICRF2 defining sources. In July USNO joined this program with the R4 sessions.
- Astronomical Source Catalog: An astronomical source catalog in the ICRF2 frame was compiled. This catalog contains positions of 3658 total sources, of which 3468 are X/S global sources, 39 are X/S arc sources, 125 are X/GPS-ionosphere sources, and 26 are X-only sources. It is available at http://lupus.gsfc.nasa.gov/dataresults_main.htm.
- Source Position Time Series Studies: We continued our analysis of source position time series. We analyzed and compared the VLBI data from the last 20 years (1989.5–2009.5) and from the last 10 years (1999.5–2009.5). Data over the last 10 years shows greater stability, pointing to network improvements. The selection of a set of stable sources is not unique: compared with an OPA solution, the overlap is at 85% of the sources. The analysis of various sources showed that the time series noise is not a stationary process. We compared time series of ten different analysis centers using five different software packages, for data through mid-2008. We found that the correlation in source stabilities depends somewhat on the analysis strategy and the software package used.
- Regularization of VLBI Time Series: VLBI sessions are typically not spaced at regular intervals, making analysis difficult with basic statistical tools. We developed a tool to construct a regular data span using Singular Spectrum Analysis (SSA). For source time series, prediction using this tool has been studied and has shown efficiency in the short-term (one to two years). The SSA method has permitted us to decompose the UT1-TAI time series into tendencies, periodic signals, and white noise.
- Geodetic Catalog: We analyzed the sources in the geodetic catalog, and some show different behavior over the last ten years than over the entire VLBI period. A signal can be detected easily for such sources as an apparent proper motion (local drift, jump, and/or periodic signal). The sources identified have since been removed from the geodetic catalog.
- Meteorological Data: We have looked for discrepancies in the meteorological data in CONT08 and all 2008 R1 and R4 sessions. Station pressures in the databases can differ by up to 10 hPa from ECMWF data, which can produce vertical differences of up to 1 mm. Also, some stations have no met data, requiring *Calc/Solve* to use constant default values. Replacing these constant values with ECMWF values resulted in better performance. However, a consequence of the use of ECMWF values is loss of the diurnal variations of the met signals (due to the 6-hr smoothing), which can increase the RMS of fit.

2.3. Software Development

The GSFC VLBI Analysis Center develops and maintains the *Calc/Solve* analysis system, a package of approximately 120 programs and 1.2 million lines of code. A new version of *Calc/Solve* was released in May 2010. Among other changes, it uses X/Y nutation partials and allows the use of the 2006 IAU nutation model as an á priori. We also continued work on a new software system. A replacement for the interactive part of *Calc/Solve*, *νSolve*, is being developed using C++. We expect first public release of this software in 2011.

3. Staff

The Analysis Center staff consists of one GSFC civil servant, Dr. Chopo Ma, and six NVI, Inc. employees who work under contract to GSFC. Dr. Ma oversees the GSFC VLBI project for GSFC and is also the IVS representative to the IERS and the current chair of the IERS Directing Board. Dr. John Gipson is the GSFC VLBI Project Manager and also the chair of IVS Working Group 4 on VLBI Data Structures. Table 1 lists the seven staff members and their main areas of activity.

Table 1. Staff members and their main areas of activity.

Ms. Karen Baver	Intensive analysis, monitoring, and improvement; software development; Web site development.
Dr. Sergei Bolotin	Database analysis, next generation software development.
Dr. John Gipson	Source monitoring, high frequency EOP, parameter estimation, new data structure, station dependent noise.
Dr. David Gordon	Database analysis, RDV analysis, ICRF2 and astronomical catalogs, K/Q reference frame, *Calc* development, quarterly updates.
Dr. Karine Le Bail	Time series statistical analysis (EOPs, source positions), database meteorological data analysis.
Dr. Chopo Ma	ICRF2, CRF/TRF/EOP, K/Q reference frame.
Dr. Daniel MacMillan	CRF/TRF/EOP, mass loading, antenna deformation, apparent proper motion, VLBI2010 simulations, VLBI+SLR combination.

4. Future Plans

Plans for the next year include: ICRF2 maintenance, astronomical catalog expansion, participation in VLBI2010 development, continued development of the new VLBI data structure and the new analysis software, K/Q observations and high frequency reference frame development, further analysis of the meteorological data and replacement of missing and bad data, continued study of various VLBI time series (such as LOD) with the SSA and other statistical tools, and further research aimed at improving the VLBI technique.

References

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