GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2012. The GSFC VLBI 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. We also provide a pressure loading service to the geodetic community at http://gemini.gsfc.nasa.gov/results/aplo. We now provide additional services described below for hydrology loading, nontidal ocean loading, and meteorological data. These time series can be found by following the links on the GSFC VLBI group Web site: http://lupus.gsfc.nasa.gov/dataresults_main.htm.

2. Activities

2.1. Analysis Activities

The GSFC VLBI Analysis Center analyzes all IVS sessions, using the *Calc/Solve* system, and it performs the 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, AUST, CONT11, INT01, and INT03 sessions. During 2012, GSFC analyzed 189 24-hour (54 R1, 55 R4, 15 CONT11, 11 RDV, 9 R&D, 3 AUST, 1 APSG, 5 EURO, 4 T2, 5 OHIG, 7 CRF, 9 CRDS, and 11 JADE) sessions, and 371 one-hour UT1 (244 INT01, 83 INT02, and 44 INT03) sessions, and we submitted updated EOP and daily Sinex files to IVS immediately following analysis. One update was made in 2012 of our 24-hr and Intensive EOP series. Also, as part of the RDV program, we observed 17 requested sources for the astronomical community.

2.2. Research Activities

- Meteorological Data Analysis: Because of the inhomogeneity of the pressures and temperatures in the Mark III databases, we derived a set of meteorological data time series, named G-ECM, from the ERA-Interim reanalysis model of the ECMWF for all VLBI stations. These series are available online (http://lacerta.gsfc.nasa.gov/met) and are updated when new data becomes available from ECMWF. When applied as a replacement for met data in VLBI databases, VLBI solutions are improved. For the R1 and R4 sessions from 2002 to 2011, use of the G-ECM pressures a) reduces baseline length weighted RMS for 55% of the baselines, with an average reduction of 0.06 mm, and b) reduces position weighted RMS for nine out of 19 stations by an average of 0.22 mm, with no conclusive improvement or degradation for eight stations. Using the G-ECM temperatures, a) 47% of the baseline lengths have a reduced weighted RMS and an average reduction of 0.01 mm, b) ten out of 19 stations show reduced weighted RMS position scatter of up to 0.08 mm, with five stations showing no conclusive improvement or degradation, and c) the amplitudes of the annual signal are significantly reduced, by up to 0.27 mm.

- Analysis of LOD Time Series with SSA: In [1], we studied an LOD time series obtained from VLBI measurements and extracted its principal components using Singular Spectrum Analysis (SSA). After removing the long-term trend, which explains 73.8% of the signal, three remaining components explain a further 22.0% of the signal: an annual and a semi-annual signal as well as a second trend. Using the complex demodulation method, we obtained the variations in the amplitudes of the annual and semiannual components. We compared the Multivariate ENSO Index (MEI) with these series and with the second trend obtained by the SSA. The correlations are significant: 0.58 for the annual component, -0.48 for the semi-annual component, and 0.46 for the second trend.
- Nutation Analysis: We focus on the two nutation parameters. We developed nutkal2012.f, a FORTRAN routine that uses the Kalman filter to regularize these irregular time series into a daily time series. The model is defined by a linear trend and specified harmonics, and we included an indicator of the quality of the estimate (goodness of fit). After investigating the various characteristics of the initial time series (Free Core Nutation component, periodic components, level and type of noise), we set up the parameters of the Kalman filter to fit the nutation data [2].
- Source Monitoring: Together with USNO we continued monitoring all ICRF2 defining sources. Our goal is to schedule and observe each geodetic source in at least 12 sessions over the preceding 12 months. In April 2012 the observing target for non-geodetic sources was increased from three to five sessions per year. The R1, R4, and RDV sessions participate in the source monitoring program.
- Intensive Scheduling: We continued to study the Uniform Sky Strategy (USS), the alternative INT01 scheduling strategy proposed and tested in 2009 and 2010 and in use for the INT01s operationally on alternating days since mid-2010. We compared the 2011 USS sessions to the non-USS 2011 sessions, and we found that the USS provided better overall protection against source loss and noise than the original strategy did. The USS also improved the UT1 formal errors at a time of the year (early October) that typically has bad sky coverage and high UT1 formal errors. But during some periods of the year, the USS produced a larger average UT1 formal error than the original strategy, generated higher UT1 formal errors, and provided worse protection against noise. We investigated the effect of schedule characteristics (e.g., the temporal distribution of the observations) on results, as a first step towards refining the USS.
- Astronomical Source Catalog and Source Time Series: A new astronomical source catalog, gsf2012a_astro, was generated. This catalog contains positions of 3708 sources, of which 3589 are X/S sources, 103 are X/GPS-ionosphere sources, and 16 are X-only sources. A new source time series, gsf2012a_ts, was also generated. It contains single session positions of 1563 sources in the ICRF2 time series format. Both files will be updated regularly and are available at http://lupus.gsfc.nasa.gov/dataresults_main.htm.

- VLBA Correlator Support: D. Gordon spent three weeks at NRAO in Socorro, N.M. as a 'resident shared risk observer' (RSRO). While there, he set up a script for automated conversion of DiFX correlator output into Mark IV format, and he modified an existing script to archive the Mark IV files. VLBA observers can now request Mark IV output for further processing with *fourfit* in addition to the normal fits.idi output.
- Non-tidal ocean loading: We computed non-tidal ocean loading series at VLBI sites using ocean bottom pressures from the ECCO model maintained at JPL. At coastal VLBI sites, typical peak-to-peak vertical loading variations are 3-6 mm, and vertical annual amplitudes are 1 mm. When these loading series are applied in VLBI analysis, the baseline length scatter, the site position scatter, and the annual vertical amplitude are reduced at these sites.
- Loading services: We set up hydrology loading (http://lacerta.gsfc.nasa.gov/hydlo/) and non-tidal ocean loading (http://lacerta.gsfc.nasa.gov/oclo/) services at GSFC. Monthly hydrology loading series based on the NASA/GSFC GLDAS hydrology model are available with a latency of about 1.5 months for 170 VLBI stations as well as for a 1x1 degree gridded map with loading series for each lattice point. Non-tidal ocean loading series derived from the JPL ECCO ocean model are available with a latency of about two months for 170 VLBI stations with 12-hour resolution.
- Tsukuba postseismic motion: To compute an a priori position for TSUKUB32 in analysis, we set up a Tsukuba position service that provides a post-earthquake nonlinear correction series based on GPS position data generated by JPL. The series is updated every day with the latest GPS data with a latency of 8-14 days depending on the day of the week and when GPS final orbits were available for the JPL solution. The service location is ftp://gemini.gsfc.nasa.gov/pub/misc/dsm/tsukuba/.

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. Work began on Calc 11 for compliance with the IERS 2010 Conventions and will be finished in 2013.

We continued developing and refining the new "openDB" data format to store VLBI data. We modified *Solve* to use the openDB format instead of superfiles, and we reproduced our 2011a (and other) solutions in the new format. Large solutions using most of the VLBI data take about the same amount of time using the openDB format or superfiles. In timing tests with larger data sets, such as the CONT11s, *Solve* runs about twice as fast using the openDB format. In addition, we wrote several utilities which produce, use, and modify the openDB format. We also began work on *openDBmake*, a partial replacement for *dbedit*, to make "version 1" openDB sessions from *fourfit* fringe files. We also began work on *openDB96*, a plug-compatible replacement library for the *dbase96* library. The goal is to allow programs which use the Mark III database handler to use openDB files with no or minimal changes to the code.

Developing the new VLBI data analysis software νSolve has reached its final stage. After thorough comparisons of SOLVE and νSolve, we started using νSolve in our routine data processing of Intensive and IVS-R4 sessions. Currently we are focused on the implementation of openDB in all parts of CALC/SOLVE. νSolve can now import and analyze a VLBI session in openDB format.

3. Staff

During 2012, the Analysis Center staff consisted of one GSFC civil servant, Dr. Chopo Ma, six NVI, Inc. employees who work under contract to GSFC, and four half-year student interns from Chalmers University of Technology (Sweden). Dr. Ma oversees the GSFC VLBI project for GSFC, and he is also the IVS co-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 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; quarterly nuvel updates.
Dr. Sergei Bolotin	Database analysis, ν*Solve* 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 ITRF updates.
Dr. Karine Le Bail	Time series statistical analysis (EOP, nutation, 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, VLBI2010 and SGP simulations, VLBI/SLR/GPS combinations.
Mr. David Eriksson	Mass loading, troposphere raytracing (through June).
Ms. Johanna Juhl	Meteorological data analysis, troposphere ray tracing (through June).
Ms. Julia Ringsby	openDB development (starting in June).
Mr. Ronny Videkull	openDB development (starting in June).

4. Future Plans

Plans for the next year include ICRF2 maintenance, astronomical catalog expansion in preparation for ICRF3, participation in VLBI2010 development, continued development of ν*Solve* and the new "openDB" data format, upgrade of program *Calc* for the IERS 2010 Conventions, and further research aimed at improving the VLBI technique.

References

[1] K. Le Bail, J. M. Gipson, and D. S. MacMillan, Quantifying the Correlation Between the MEI and LOD Variation by Decomposing LOD with Singular Spectrum Analysis, accepted for publication in IAG Symp. 139, Earth on the Edge: Science for a Sustainable Planet, Chris Rizos, Pascal Willis (Eds), ISBN 978-3-642-37221-6, 2012.

[2] K. Le Bail, J. M. Gipson, and S. Bolotin, Regularization of Nutation Time Series at GSFC, (submitted to the proceedings of the 7th IVS General Meeting in Madrid, Spain), 2012.