GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2011. 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.

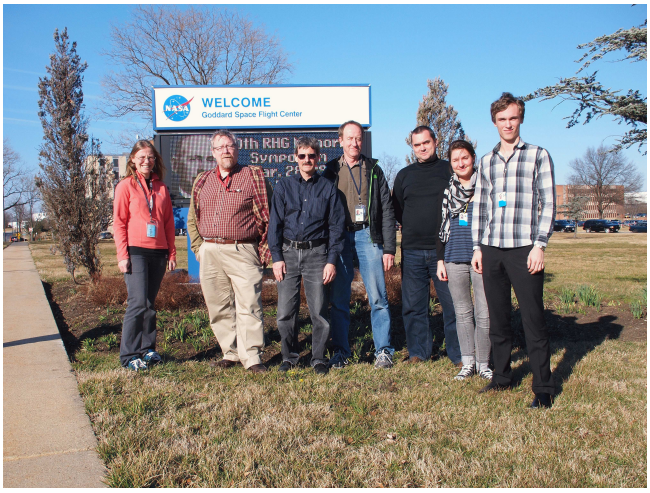

Figure 1. Members of the GSFC VLBI Analysis Center.

2. Activities

2.1. Analysis Activities

The GSFC VLBI Analysis Center analyzes all IVS sessions, using the *Calc/Solve* system, and 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, CONT11, INT01, and INT03 sessions. During 2011, GSFC analyzed 153 24-hour (52 R1, 49 R4, 5 CONT11, 6 RDV, 5 R&D, 6 EURO, 7 T2, 3 APSG, 3 OHIG, 3 CRF, 3 CRDS, 1 AUST, 4 JADE, and 6 JAXA) sessions, and 406 1-hour UT1 (280 INT01, 88 INT02, and 38 INT03) sessions, and we submitted

updated EOP and daily Sinex files to IVS immediately following analysis. Two updates were made in 2011 of our 24-hr and Intensive EOP series. Also, as part of the RDV program, we observed 24 requested sources for the astronomical community.

2.2. Research Activities

- Intensive Scheduling: We continued studying the alternative INT01 scheduling strategy that we proposed in 2009 and tested in several 2009 and 2010 R&D sessions. This strategy consists of using all mutually visible geodetic sources, and it is now called the Uniform Sky Strategy (USS). It was used in INT01 sessions on alternating days continuously since Dec. 2010. An analysis of the first five months showed that while it improves the sky coverage, it also yields higher UT1 formal errors and session fits, indicating a need for further analysis. With the first full year of continuous data now available, we will begin this analysis in early 2012.
- *Fourfit* Processing of RDV Sessions: A transition from *AIPS* post-correlation processing of RDV sessions to *Fourfit* processing was begun. An RDV session was *fourfit* processed at both Haystack and USNO and was compared to an *AIPS* version. The *fourfit* processing was shown to result in greater sensitivity, better detection of weak sources, and fewer subambiguity errors. All new RDVs will now be *fourfit* processed at GSFC.
- Meteorological Data Analysis: The geodetic VLBI data set is known to have many cases of missing, biased, and inaccurate meteorological data that impacts the quality of the VLBI processing. We developed statistical tools to detect bad and missing met data, and we compared the met data to other sources. To homogenize the met data, we used pressure and temperature time series derived from the ECMWF model, interpolated and extrapolated to the VLBI stations. For this purpose, we modified *Solve* to allow use of an external meteorological time series. Use of our ECMWF derived time series instead of the database met values showed noticeable improvements in the solutions. We also implemented an option that uses a time lag in the thermal deformation model that can be chosen by the user.
- Analysis of LOD Time Series with the SSA: We studied the length-of-day time series derived from the GSFC 2011a solution with the Singular Spectrum Analysis (SSA) tool. This allowed us to extract different significant components and to compare them with the Multivariate ENSO Index (MEI). We first studied the time series with the long-term tendency removed. The time-varying amplitudes of the annual and semi-annual components, as well as a secondary tendency extracted by the SSA, show a very strong correlation with the MEI time series. In a second study, we removed the long-term tendency, and annual and semi-annual signals at constant amplitude with time. A correlation study of the principal component of the remaining signal of the LOD with the MEI showed that they correlate strongly with each other for a time delay of 31 days, which is in agreement with other studies.
- Source Monitoring: Together with USNO we continued our program of monitoring all ICRF2 defining sources. Our goal is to observe geodetic sources at least 12 times and non-geodetic sources at least 3 times during a 12 month period. The R1, R4, and RDV sessions participate in the monitoring program.
- VLBI2010 Systematic Errors: We investigated the level of error of VLBI2010 geodetic measurements by simulating the effect of tropospheric turbulence, clock error, observation noise, hydrostatic troposphere mapping function error, antenna gravitational deformation, and site

pressure error. Biases at the 1-2 mm level in vertical site position estimates can be caused by troposphere mapping function error, gravitational antenna deformation, or site pressure errors. Errors due to tropospheric turbulence decrease with latitude, leading to 1-3 mm RMS site vertical error but no significant bias. Given the precision and stability of high quality meteorological sensors, vertical bias errors due to pressure (used to compute hydrostatic delay) and temperature (used to compute antenna thermal deformation) errors should be much less than 1 mm.

- Tsukuba Postseismic Motion: The observed motion of the TSUKUB32 antenna after the Tohoku earthquake was nonlinear following a coseismic displacement of about 700 mm, primarily in the eastward direction. Six months after the earthquake, the eastward displacement rate was about 15 cm/yr greater than the long term rate before the earthquake. Analysis of the single baseline Tsukuba-Wettzell Intensive sessions requires very accurate site positions since they cannot be estimated along with UT1. We used GPS post-earthquake positions from the co-located GPS antenna TSKB to correct the TSUKUB32 positions after the earthquake. After correction, the Tsukuba-Wettzell and Kokee-Wettzell UT1 estimates agree with the USNO UT1 combination solution with the same level of WRMS and bias error.
- Hydrology Loading: Continental hydrology loading causes peak-to-peak vertical site displacements of 3-8 mm that are strongly seasonal. We have computed the hydrological loading using both the GSFC GLDAS hydrology model data and GRACE data. Applying either loading series in *Calc/Solve* analysis reduces the UEN site position and baseline length scatter. We are working on starting a hydrology loading service to provide site loading series to the VLBI user community.
- Astronomical Source Catalog and Source Time Series: A new astronomical source catalog, gsf2011a_astro, was generated. This catalog contains positions of 3671 total sources, of which 3522 are X/S sources, 123 are X/GPS-ionosphere sources, and 26 are X-only sources. A new source time series, gsf2011a_ts, was also generated. It contains single session positions of 1366 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.

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 April 2011.

Also, we continued refining the new data structure which stores VLBI data in netCDF files organized by an ASCII 'wrapper' file. We wrote software to convert from the Mark III database format into this new format. The software converts around 80% of the data included in a database, including all of the data currently contained in NGS cards. We are in the process of modifying *Calc/Solve* to use this new format and successfully ran a large global solution, producing results essentially identical to the standard processing.

We also continued work on a new software system. A replacement for the interactive part of *Solve*, *νSolve*, is being developed using C++. *νSolve* is currently able to read in a pair of X/S databases, resolve ambiguities, deal with clock breaks, evaluate ionospheric corrections, and edit outliers. It performs analysis of VLBI sessions using the Square Root Information Filter

and can treat estimated parameters as local (one value for a session), arc (multiple values for a session), piece-wise linear, and stochastic. It can write out a processed session in Mark III database format and can work either in a standalone mode or interacting with the Mark III catalog system. Currently we are making comparisons of *νSolve* and *Solve* analysis. We expect to make the first public release of this software in early 2012.

3. Staff

The Analysis Center staff consists of one GSFC civil servant, Dr. Chopo Ma, six NVI Inc. employees who work under contract to GSFC, and two student interns from Chalmers University of Technology. Dr. Ma oversees the GSFC VLBI project for GSFC and 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, *νSolve* 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, apparent proper motion, VLBI2010 simulations, VLBI/SLR/GPS combinations.
Ms. Johanna Juhl	Meteorological data analysis, ray tracing.
Mr. David Eriksson	Hydrology loading, topographic errors in pressure loading.

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, upgrade of program *Calc*, creation of a hydrology loading service, creation of a pressure and temperature service using ECMWF data, and further research aimed at improving the VLBI technique.