GSFC VLBI Analysis Center

David Gordon, Chopo Ma, Dan MacMillan, John Gipson, Karen Baver

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2008. 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 aimed at improving the VLBI technique.

2. Activities

2.1. Analysis Activities

The GSFC analysis group analyzes all IVS sessions using the Calc/Solve system, and it 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, CONT08, NEOS INT01, and INT03 sessions. During 2008, the group processed and analyzed 189 24-hour (49 R1, 53 R4, 6 RDV, 18 R&D, 5 CONT08, 6 EURO, 9 T2, 10 OHIG, 5 CRF, 8 CRDS, 3 CRMS, 2 CRFS, 1 CRD, and 14 JADE) sessions and 366 1-hour UT1 (230 NEOS INT01, 95 INT02, and 41 INT03) sessions. We also submitted updated EOP files and daily Sinex solution files for all IVS sessions to the IVS Data Centers immediately following analysis. The group also generated and submitted one TRF solution to the IVS Data Centers using all suitable VLBI sessions. The GSFC Analysis Center maintains a Web site at http://lupus.gsfc.nasa.gov, where the latest solutions and velocity plots can be found.

2.2. Research Activities

The GSFC Analysis Center performs ongoing research aimed at improving the VLBI technique. Several of these research activities are described below:

- ICRF2 Preparations: The analysis group is participating in the development of the next realization of the International Celestial Reference Frame (ICRF2). Source time series solutions were made to study the stability of the VLBI sources. Time series position plots and various statistical quantities were studied to identify stable and unstable sources. Two methods were developed to select stable candidate sources for use in defining the axes of ICRF2. In the first, we picked 300 sources evenly distributed in declination with the lowest WRMS position variation in 17 declination zones. Second, we picked 386 apparently stable sources based on examination of their time series plots and their WRMS positions and Chi-squares per-degree-of-freedom. Also, numerous source catalog solutions were generated to study the best ways to generate the final catalog and to try to determine what its noise level and noise floor will be. The solutions included: tests of observation and session decimation; tests using different data ranges (starting in 1979, 1990, and 1993); tests using different session types (with and without small and regional networks); tests with unstable sources treated as global vs. arc parameters; tests with pressure loading on vs. off; tests with axis offsets estimated vs. not estimated; and tests treating site positions as global vs. arc parameters. The decimation studies indicated that the source formal errors should be increased by $\sim$50%. Little difference was found in starting with 1990 vs 1979, but the 1993 start showed a noticeable increase in source formal errors. Adding the small networks (mobiles, regionals, and ties) degraded the source time series solutions, but had little effect on the source catalog solutions.

- VLBI2010 Simulations: VLBI2010 network simulation studies were made for the IVS VLBI2010 committee. Specifically, we investigated different strategies for improving geodetic performance: 1) optimized observing schedules, 2) more observations due to faster antenna slewing rates, 3) improved analysis strategies, and 4) larger antenna networks. It was found that the 3D WRMS position errors are reduced from current best levels (e.g., CONT sessions) by a factor of 2-3 when the antenna slew rate increases by a factor of 3-4 over current average rates. It was also found that applying elevation dependent weighting reduces the 3D WRMS position errors by 20-30%. Accounting for correlated site-dependent noise between observations in each scan yielded an additional reduction of about 10%. Simulations of global networks show that scale and EOP scatter is reduced by about a factor of 2 as the network size increases from 8 to 32 sites. We also found generally good agreement of our results with those obtained with the OCCAM and point-positioning software packages at Vienna Technical University. Additional work is needed to resolve differences between our results—for example, in comparisons of simulations versus observed data results and model sensitivities to observation noise and switching interval.

- SLR/VLBI Network Design: We continued simulation work on the design of a network of co-located VLBI and SLR antennas. The goal is to define and maintain the terrestrial reference frame at a level of 0.1 mm/yr to support global change monitoring. For VLBI, we generated daily observing schedules and simulated delay noise. Observation files and session parametrization files were generated and input to the GSFC software Geodyn package for combination. We are currently investigating the performance of networks of 8 to 32 sites similar to the networks used for VLBI2010 work.

- Ny-Ålesund Site Motion: We have investigated the motion of Ny-Ålesund as observed by VLBI as part of a paper submitted to Journal of Geodynamics [1] which compares coordinate time series and velocity estimates from VLBI, GPS, and DORIS. The observed uplift of Ny-Ålesund is twice that predicted by postglacial rebound and present day ice melting of nearby glaciers. The GPS and VLBI uplift rates show an increase of 3-4 mm/yr between measurements before 2003 and after 2003.

- Antenna Thermal Deformation: We implemented antenna thermal deformation as a contribution that can be applied in Calc/Solve analysis. The contribution can be in the form of 1) a measured height series (such as an invar wire length time series that provides a direct measure of the vertical variation of the reference point position) or, (2) antenna reference point variation derived using a model. The model for each antenna consists of antenna dimensions, antenna material expansion coefficients, reference temperature, and observed temperature.

We ran baseline solutions applying the model using antenna information compiled by A. Nothnagel and found improvement in length repeatabilities of up to 1 mm. The level of improvement was similar to previous tests using less complete antenna information. Based on TRF solutions, the effect of thermal deformation on the terrestrial reference frame is insignificant, where the effect on the scale was ~0.01 ppb.

- Correlated Noise: We implemented station dependent correlated noise in Calc/Solve. Tests of the effects of correlated noise using good VLBI data sets, such as CONT05 or the R1's and R4's for 2005-2006, show that including mapping function-like correlated noise improves the VLBI solutions in the following ways: 1) reduced baseline scatter; 2) reduced scatter in source positions; 3) better agreement between simultaneous independent VLBI measurements of EOP; and 4) better agreement between VLBI and IGS measurements of EOP.
- New Geodetic Sources. The Goddard VLBI group expanded the geodetic source catalog by 189 sources. These sources were chosen by L. Petrov based on compactness, lack of structure, and source strength. Since many of these sources had not been observed recently, we decided to observe them in a series of four R&D sessions prior to regular inclusion in the R1's. The first of these R&D's was scheduled for April 2008 and the last for September 2008. After verifying that these sources were successfully observed and updating the flux catalog, we gradually added these sources to the regular geodetic catalog starting in October 2008.
- RDV Paper: A paper on the use of the VLBA for geodesy [2] was prepared and submitted to the Journal of Geodesy. It reports on 14 years of geodetic observations and presents station displacements due to crustal motion, earthquakes, and antenna axis tilts. It will be published in 2009.
- Higher Frequency CRF: Members of the analysis group continued working with associates at JPL, USNO, NRAO, and Bordeaux Observatory to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands (~24 and ~43 GHz). The primary goals are to build up a reference frame for use in planetary spacecraft navigation at Ka band (~33 GHz), and to build a reference frame less affected by source structure and potentially more precise than the current X/S frame. The K/Q group prepared and submitted two papers on this work to the Astronomical Journal. Paper I [3] presents and discusses the K-band reference frame and Paper II [4] presents and discusses the K and Q band imaging results.

2.3. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Calc/Solve is a package of approximately 120 programs and 1.2 million lines of code. Several updates were released during 2008.

2.4. Support Activities

The GSFC VLBI Analysis Center has provided a source position service as part of the RDV program since 1997. Observations of 76 requested sources were made in 2008 for members of the astronomy and astrometry community, and precise positions were obtained for most of them.

3. Staff

The Analysis Center consists of a GSFC civil servant, Dr. Chopo Ma, and four NVI, Inc. employees who work under contract to GSFC. Table 1 lists these staff members alphabetically, except for Dr. Ma, who oversees the entire GSFC VLBI project for GSFC, and Dr. John Gipson, the GSFC VLBI Project Manager. Dr. Ma is also the IVS representative to the IERS, the current chair of the IERS directing board, and the chair of the IVS/IERS ICRF2 working group. Dr. Gipson is also the chair of IVS Working Group 4 on VLBI Data Structures. Dr. David Gordon and Dr. Daniel MacMillan lead contract tasks that support the Analysis Center.

This year, after eight productive years at the Analysis Center, Leonid Petrov left to join another GSFC project. His many responsibilities are being divided among the remaining group members. To learn the new point of contact for a specific task, please contact John Gipson (John.M.Gipson@nasa.gov) or Dan MacMillan (Daniel.S.MacMillan@nasa.gov).

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

Dr. Chopo Ma	CRF, TRF, EOP, K/Q reference frame development
Dr. John Gipson	source monitoring, station dependent noise, parameter estimation
Ms. Karen Baver	Intensive analysis and monitoring, software development, Web site
Dr. David Gordon	Analysis of 24-hour sessions, RDV processing and analysis, K/Q reference frame development, VLBA calibrator surveys, Calc development, ICRF2 development
Dr. Daniel MacMillan	CRF, TRF, EOP, mass loading, antenna deformation, apparent proper motion, post-seismic studies, ICRF2 development

4. Future Plans

Plans for the next year include: participation in the development of the ICRF2, participation in VLBI2010 development efforts, participation in the development of a new VLBI data structure, participation in additional K/Q observations and high frequency reference frame development, and performing further research aimed at improving the VLBI technique.

References

[1] "The Kinematics of Ny-Ålesund from Space Geodetic Data", H. Kierulf, B.Pettersen, D. MacMillan, and P. Willis; submitted to Journal of Geodynamics.

[2] "Precise Geodesy with the Very Long Baseline Array", L. Petrov, D. Gordon, J. Gipson, D. MacMillan, C. Ma, E. Fomalont, R. C. Walker, and C. Carabajal; submitted to Journal of Geodesy.

[3] "The Celestial Reference Frame at Higher Radio Frequencies. I. Astrometry from VLBA Observations at 24 and 43 GHz", G. Lanyi, D. Boboltz, P. Charlot, A. Fey, E. Fomalont, B. Geldzahler, D. Gordon, C. Jacobs, C. Ma, C. Naudet, J. Romney, O. Sovers, and L. Zhang; submitted to Astronomical Journal.

[4] "The Celestial Reference Frame at Higher Radio Frequencies. II. VLBA Imaging at 24 and 43 GHz", P. Charlot, D. Boboltz, A. Fey, E. Fomalont, B. Geldzahler, D. Gordon, C. Jacobs, G. Lanyi, C. Ma, C. Naudet, J. Romney, O. Sovers, and L. Zhang; submitted to Astronomical Journal.