GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2006. 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 routinely 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, and NEOS Intensive INT01 sessions. During 2006, the group processed and analyzed 196 24-hr (50 R1, 53 R4, 14 CONT05B, 6 RDV, 1 VLBA/Quake, 7 old VLBA, 8 R&D, 5 T2, 8 CRF, 8 CRDS, 1 CRFS, 6 EURO, 13 OHIG, 3 APSG, 8 E3, and 5 JADE) sessions and 307 1-hr UT1 (223 NEOS INT01 and 84 INT02) 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 two TRF solutions to the IVS Data Centers using all suitable VLBI sessions. A special effort was also made to process six old VLBA sessions from the CONT96 campaign. Inadequate software had prevented their processing when originally released. They were successfully fringed using the NRAO AIPS program, analyzed using Calc/Solve and submitted to IVS. 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. Support Activities

The GSFC VLBI Analysis Center has provided a source position service as part of the RDV program since 1997. Observations of 17 requested sources were made in 2006 for members of the astronomy/astrometry community, and precise positions were obtained where possible. The Analysis Center also continued its support of the Gravity Probe B mission by generating VLBA astrometric databases of the guide star for CFA researchers and by observing the phase referencing calibrator in several RDV sessions.

2.3. Research Activities

The GSFC Analysis Center performs research aimed at improving the VLBI technique. The primary research activities undertaken during 2006 include the following:

- Unstable Sources: The source position time-series for many of the frequently observed radio sources in the NASA geodetic VLBI program show systematic, non-linear as well as linear variations of as much as 0.5-1.0 mas, due mainly to source structure changes. If these apparent source position variations are not modeled, they produce corresponding systematic variations in estimated Earth orientation parameters (EOP's) at the level of 0.02-0.04 mas in nutation and 0.01-0.02 mas in polar motion. We examined the stability of position time-series of the 107 radio sources in the current NASA geodetic source catalog. We looked at different ways of handling source instabilities where the positions of unstable sources are either estimated for each session, or spline parameters are estimated for them. We found that some of these strategies improve EOP accuracy by reducing the biases and WRMS differences between EOP measurements from the independent but simultaneous CORE-A and NEOS-A VLBI networks from 1997 to 2000. These results are discussed in a paper accepted for the Journal of Geodesy special issue for VLBI. [MacMillan, D.S. and Ma C., 'Radio Source Instability in VLBI Analysis', J. Geod, 2007, in press.]
- CONT Campaigns: Relative to tidal models, high frequency EOP residuals from the various CONT campaigns all have WRMS's of 0.18 to 0.20 mas, compared with formal uncertainties ranging from about 0.20 mas for CONT94 to 0.12 mas for CONT05. We investigated whether or not there is any signal in these residuals. We found evidence of a possible terdiurnal signal in the VLBI polar motion hourly series for CONT02, but it was not present in CONT05. However, it is not clear what the source of such a signal may be. AAM is a possible source, but the size of the signal from the polar motion residuals was at least 2 orders of magnitude larger than what is expected from AAM. It is likely that the terdiurnal signal, as well as other spurious peaks at other multiples of 1 cpd, are artifacts of analysis, but further investigation will be required to resolve this.
- Simulations: We developed procedures for simulating the performance of a network of VLBI antennas. The procedure consists of generating a simulation database from an observing schedule for the network and then performing a Monte Carlo simulation by running a SOLVE solution over a large number of repetions of the database. In each repetition, observed delay residuals are generated as random clock and atmosphere noise. Repeatability of parameter estimates (e.g., baseline lengths or station positions) from the solution gives a measure of parameter precision. We have used this simulation tool to analyze different options for the VLBI2010 design.
- Source Monitoring: We continued the source monitoring program which began on February 1, 2004. Its goals are to observe all geodetic catalog sources at least 12 times and all non-geodetic catalog sources at least twice in every 12 month period. This is done by including the sources which have not met their targets in either the weekly R1's or the bi-monthly RDV's. The maximum number of monitored sources is restricted to no more than 10 in the R1's, and 30 in the RDV's. Overall, the observing goals were met with only a few exceptions. Only 1 geodetic source (0530-727) did not meet its target in 2006. And only 10 non-geodetic sources were not observed in 2006, all being weak sources with fluxes less than 0.1 Jy in

either S or X-band. Another 22 non-geodetic sources were observed only once. These were also weak sources, but not quite as weak, typically 0.15-0.20 Jy.

- Correlated Noise: A key assumption of VLBI parameter estimation is that observations on different baselines are independent. If this assumption is false, then the parameter estimates will be incorrect and the formal errors too small. One simple alternate assumption is that at each epoch, all observations involving a common station are correlated due to station dependent noise. This effect can be accounted for by modeling the normal equations by introducing station-dependent correlations between the observations in a given scan. The functional form of the correlation depends on its source. For example, correlation due to atmosphere mis-modeling increases at lower elevations. We looked at the effect of including unmodeled correlated errors on two datasets: 1) the R1 and R4 sessions during 2005 (an example of good operational stations over a prolonged period of time), and 2) the CONT05 sessions (an example of a very-good VLBI network over a short period of time). We found that incorporating different kinds of atmosphere mis-modeling improved both data sets in the sense that 1) baseline scatter was reduced and 2) agreement with external EOP was improved. For example, in our tests using the CONT05 data set we found that the scatter in 48 out of 55 baselines was improved with an average reduction of 10%.
- Quake VLBA Session: The GSFC Analysis Center obtained VLBA time for a special session on November 8 to measure any possible displacements resulting at the Mauna Kea VLBA site resulting from an October 15 earthquake on the island of Hawaii. Results will be published in 2007.
- 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 ($\sim$24 and $\sim$43 GHz). The primary goals are to build up a reference frame for use in planetary spacecraft navigation at Ka band ($\sim$33 GHz), and to build a reference frame less affected by source structure and apparent proper motion and potentially more precise than the current X/S frame. One K band session was observed and analyzed in 2006, concentrating on weaker sources and ecliptic sources. To date, the group has conducted 9 VLBA sessions and developed a catalog of 267 sources at K-band and 132 sources at Q-band, with sub-mas positions. Future work will concentrate on observing weaker sources, and densifying the catalog along the ecliptic and in the regions needed for several upcoming Mars missions.

2.4. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Several updates were released during 2006. Specifically, Calc version 10.0 and the Linux/HP-UX compatible version of Calc/Solve were released in Spring 2006. Calc 10 complies with the IAU 2000 Resolutions and the IERS Conventions (2003), and uses the non-rotating origin system. The GSFC Analysis Center now does all of its database processing and analysis on Linux PC machines. Near the end of 2006, program Dbedit was also converted to allow writing Mark IV databases on Linux PC (Little Endian) machines, a feature that will allow the correlators to phase out their HP systems.

3. Staff

Members of the analysis group and their areas of activity include: Dr. Chopo Ma (CRF, TRF, EOP, K/Q reference frame development, IVS representative to the IERS, and current chairman of the IERS directing board), Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, apparent proper motion, and post-seismic studies), Dr. David Gordon (database analysis, RDV processing and analysis, K/Q reference frame development, VLBA calibrator surveys, Calc development), Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis, VLBA calibrator surveys, Calc/Solve development, Linux migration, GEODYN development), Dr. John Gipson (source monitoring and improved parameter estimation), and Ms. Karen Baver (R4 and Intensives analysis, software development, Linux migration, web site development and maintenance).

4. Future Plans

Plans for the next year include: participation in development of the next VLBI ICRF, participation in additional K/Q observations and reference frame development, participation in VLBI2010 development efforts, and performing further research aimed at improving the VLBI technique.