GSFC VLBI Analysis Center

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

Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2005. 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 Mark IV/5 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, CONT05, APSG, and NEOS Intensive INT01 sessions. During 2005, the group processed and analyzed 164 24-hr (51 R1, 51 R4, 15 CONT05, 6 RDV, 11 R&D, 7 T2, 7 CRF, 8 CRDS, 2 CRFS, 4 EURO, and 2 APSG) sessions and 309 1-hr UT1 (226 NEOS INT01, and 83 INT02) sessions. We also submited updated EOP files and daily Sinex solution files for all IVS sessions to the IVS Data Centers immediately after analysis. The group also generated and submitted two TRF solutions to the IVS Data Centers using all suitable VLBI sessions. The Analysis Center maintains a web site (http://lupus.gsfc.nasa.gov/) which underwent major revisions during 2005.

2.2. Support Activities

Over the years, the GSFC Analysis Center has directly or indirectly supported numerous missions and projects of other groups and agencies. For instance, our rapid Intensive session UT1 turnaround has played crucial roles in determining precise maneuvers required for various planetary spacecraft, such as Cassini and others. We have also provided valuable support for the Gravity Probe B mission for several years. This has included generating and calibrating databases of the guide star and phase reference sources from VLBA astrometry sessions, and determination of the precise position of the phase reference sources from our own RDV observations. This is allowing GP-B scientists to accurately measure the proper motion of the guide star, a prerequisite for accurate measurement of the satellite's precession. We also have provided a source position service as part of the RDV program since 1997. Observations of 18 requested sources were made for members of the astronomical community in 2005, and precise positions were obtained where possible.

2.3. Research Activities

The GSFC analysis center performs research aimed at improving the VLBI technique. The primary research activities undertaken during 2005 include the following:

- Hydrology loading: The effect of hydrology loading was further investigated. Model site displacements calculated from the most recent version of the Milly et al. (J. Hydrometeorology, 3, 283-299, 2002) model were applied in analysis. For most baselines the observed variance reduction (1-8 mm^2) was greater than the model variance (1-5 mm^2) because the hydrology signal is seasonal and correlated with other unmodeled seasonal effects (even after removing antenna thermal deformation and using the IMF mapping function). This can also be seen from estimates of hydrology loading site vertical admittances that are mostly larger than 1.5.
- CONT05 analysis: A preliminary analysis of the 15 CONT05 sessions was made. Initial conclusions are: 1) RMS differences between CONT05 and IGS are 55 and 36 μas for X-pole and Y-pole, which are $\sim$50% of the R1/R4 IGS differences, and are likely a result of the larger CONT05 network, 2) Subdaily EOP residuals to the JMG96 high frequency EOP tidal model have RMS $\sim$180 μas, which is somewhat greater than the formal uncertainties ($\sim$120 μas) and similar to the level of residuals from previous CONT series, 3) Baseline length repeatabilities are $\sim$0.8-1 ppb.
- Unstable sources: Analysis of source position time series shows that a significant number of geodetic sources show unstable behavior. EOP estimates are improved if the apparent motions of unstable sources are estimated as multinode splines (rather than treating them as fixed). This is seen by reduced polar motion and nutation differences in the simultaneous CORE-A/NEOS-A sessions (1997-2000). Future work will include identifying all unstable sources that should be removed from the geodetic catalog, identifying other stable sources that should be added, and determining the best analysis strategy for treating unstable sources.
- Source Monitoring: 2005 marked the second year of our source monitoring program. Our goal is to systematically monitor all sources in regular use 1) in the geodetic catalog; 2) in the ICRF; and 3) that Martine Feissel classified as potentially stable. The total number of sources in this combined list is 302. The observational target is inclusion in at least 12 sessions per year for geodetic sources, and at least 2 sessions per year for other sources. Most geodetic sources meet these targets automatically in the regular scheduling of experiments. But for those sources that do not, a certain amount of observing is scheduled using the R1 sessions, where each R1 can include up to 10 sources from the monitoring list. The monitoring program has been very successful. At its start, there were $\sim$160 sources not observed during the previous 2 years, and $\sim$70 sources observed only once. By the end of 2005, only 1 source had not been observed and only 16 had been observed less than twice during the prior year. Based on the above success, we are expanding the program to include imaging this same set of sources using the RDVs. The goal will be to image each geodetic source at least 3 times per year and other sources at least once every two years.
- Correlation between VLBI observations: A key assumption in VLBI parameter estimation has been that all observations can be treated as independent. There is anecdotal evidence though that this is not the case. For example, analysts have noticed that within a scan, all of the residuals involving a common station appear to be correlated. We examined several

RDV sessions to verify if this was indeed the case. It was found that, on average, station dependent residuals ranged from about 5 to 15 ps in an RMS sense. This is much larger than would be expected by chance, indicating that there is real station dependent noise which is correlated. The parameter estimation strategy in program SOLVE needs to be modified to correctly account for this noise. We expect that this will result in two effects—the parameter estimates will change and the formal errors will get larger.

- VCS4/5: A fourth and fifth set of VLBA calibrator sessions were observed and processed by GSFC and NRAO personnel in order to fill the remaining holes in the current geodetic/astrometric catalog north of -40 degrees declination. Positions were obtained for 836 new sources in three VCS4 and three VCS5 sessions, and 580 of these were found to be suitable as calibrators. The geodetic/astrometric catalog now contains 3481 detected sources, with 2892 suitable as calibrators. This work will be published in the Astronomical Journal in 2006. For more details see http://vlbi.gsfc.nasa.gov/vcs/.
- Higher frequency CRF: Members of the analysis group are working with associates at JPL, USNO, NRAO and elsewhere, 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. A K band session and a K/X/S VLBA session were observed and analyzed in 2005. To date, the group has conducted 8 VLBA sessions and developed a catalog of 259 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 2005. Calc/Solve development work was concentrated on the development of a Linux/HP-UX compatible version. At year's end, it was in use at GSFC and several other Analysis Centers. The next release of Calc, version 10, is in final testing and will be released early in 2006. It is updated for compliance with the IERS Conventions (2003), and uses the non-rotating origin system. Further work was done on program GEODYN to develop algorithms and software for computation of path delays for near zone objects for processing VLBI observations of the Cassini/Huygens lander.

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: release the Calc10/Solve Linux/HP-UX version; oversee the re-Calcing of all data bases in the IVS Data Centers; incorporate correlations between observations in standard VLBI processing; participate in development of the next VLBI ICRF; participate in additional K/Q observations and reference frame development; continue development of GEODYN for analysis of spacecraft VLBI observables; and perform further research aimed at improving the VLBI technique.

5. Publications

"The Third VLBA Calibrator Survey", L. Petrov, Y.Y. Kovalev, E. Fomalont, D. Gordon, Astronomical Journal, vol. 129, 1163-1170, 2005.