GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2001. The center's primary analysis activities, research activities, and software development activities are reported, and the analysis staff members are described.

1. Introduction

The GSFC VLBI Analysis Center is located at NASA's Goddard Space Flight Center in Greenbelt, Maryland. The GSFC group processes all 24-hour sessions from the Mark-4 correlators and submits EOP values derived from each session to the IVS within one working day of correlation. The group also analyzes all NEOS-Intensive experiments and submits the UT1 values within 3 working hours. The group has primary responsibility for the analysis and timely submission of databases and data products to IVS for the CORE, NEOS-A, NEOS-Intensive, SURVEY, and CONT sessions. The analysis group also processes all VLBA RDV sessions using the NRAO AIPS program and analyzes them with Solve. Additionally, GSFC periodically submits updated TRF and CRF solutions to IVS from global solutions using all available VLBI observations. GSFC uses, maintains, develops, and distributes the Calc/Solve analysis system. The group also engages in research and analysis activities aimed at improving the measurement and understanding of Earth rotation, improving VLBI analysis techniques and modeling, improving troposphere modeling, and maintaining and refining the celestial and terrestrial reference frames.

2. Activities

2.1. Analysis Activities

The primary analysis activities during 2001 included:

- Routine processing and analysis of:

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 52 NEOS-A sessions
 74 CORE sessions
207 NEOS-Intensive sessions
  2 SURVEY sessions
  5 CONT sessions
  5 RDV sessions
 18 IRIS-S sessions
  5 EUROPE sessions
 10 CRF sessions
  2 NAVEX sessions
  1 CORE-OHIG sessions
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- Analysis of the VLBA Calibrator Survey Experiments. These were 10 VLBA sessions made by NRAO staff (Tony Beasley, Ed Fomalont, et. al) between 1994 and 1997 to obtain positions

and X/S fluxes of 1822 candidate calibrator sources. The GSFC group processed them into Mark-3 databases using AIPS and performed the astrometric analysis using SOLVE. The astrometric analysis detected 1686 sources in both X and S bands, of which 1332 were new. Of the new 1332 sources, positions were obtained to better than 1 m-asec for 53%, and better than 10 m-arcsec for 92%. A paper announcing this work and the new source catalog (the VCS1 catalog) has been submitted to the Astronomical Journal (T. Beasley, et. al, 2002). The new catalog is available at http://www.nrao.edu/vlba/VCS1.

- Analysis of the first GBT-ties experiment, in cooperation with Dr. F. Ghigo (NRAO). This VLBA correlated experiment between the new GBT antenna and the NRAO20 antenna, both in Green Bank, was processed through AIPS and analyzed with SOLVE to get an initial position accurate to ∼1 cm horizontally and ∼2–3 cm vertically.

2.2. Research Activities

The primary research activities during the period included the following:

- Made extensive comparisons of VLBA session RDV22 as correlated on the VLBA correlator and fringed with AIPS vs. correlation on the Haystack Mark-4 and fringed with fourfit. Systematic, elevation dependent differences in the behaviour of the VLBA station phase cal tones at BBC frequencies of 10 kHZ and 7010 kHZ were found. It was found that, using manual phase cals, there is no significant difference in the group delays from AIPS fringing vs. Mark4/Fourfit fringing. However, the AIPS processing may be inherently noisier than the Mark4, and the delay sigmas may be significantly underestimated. This work is continuing.
- Obtained position variations of 40 VLBI stations at 32 tidal frequencies from the analysis of 3 million group delay measurements over the period 1980 to 2002. Residual displacements after the removal of solid Earth tides were studied. It was revealed that the estimates of vertical and horizontal station displacements are in generally good agreement with the ocean loading computed on the basis of ocean tide models for the main diurnal and semi-diurnal tides. Moreover, VLBI results allow us to discriminate between different ocean tide models: displacements for the M2 tide are much closer to the modern GOT00 model than to the old Schwiderski model. At the same time discrepancies between VLBI results and models of ocean loading for K1, K2 and S2 tides exceed both the errors of the estimates and the errors of ocean loading displacements based on reported formal uncertainties of ocean tide models. It was found that there is a significant non-tidal signal at diurnal and annual frequencies. Applying a model of hydrological loading reduces the residual signal at annual frequency. Using an empirical model of harmonic site position variations in VLBI processing provides a better fit and improves baseline length repeatability. It was found that ocean loading admittance is not smooth across a tidal band, and the recommendation of the IERS Conventions to compute ocean loading for minor tides by interpolating across each tidal band is not warranted.
- Compiled a Master Astrometric Catalog, using sources from the ICRF Ext-1, the VLBA calibrator survey catalog, and a recent CRF solution.
- Investigated the contribution of hydrologic loading on VLBI site positions. The average vertical variation of VLBI sites due to loading calculated from a hydrology model [Milly and Schmakin, 1999] is about 2-3 mm rms and the signal is generally annual. Application of the

model in VLBI analysis reduces site vertical scatter by an average of about 2.5 mm rms for most sites.

- Investigated the effect of 3-sigma automatic editing. Compared the results of 32 CORE sessions edited manually vs. edited automatically with a 3-sigma cutoff. Global Solve solutions showed significantly better baseline length repeatability for the 3-sigma versions.
- Developed a procedure to simulate expected EOP uncertainties for designing VLBI observing networks. Databases are generated from a schedule and run in a standard terrestrial reference frame solution using average station reweight constants to simulate actual station performance. We used the procedure to study the effect of varying such parameters as network size, data rate, SNR targets, and session length.
- Studied the results of using the 1:2 fanout mode and doubling the recorded bandwidth in the NEOS-Intensive sessions. We made comparisons between five standard 1.5-hour Intensives and five 1-hour test Intensive sessions scheduled within 1.5 hours on the same day. Measures of the quality of the observations (SNR and quality codes) were similar. The differences between UT1 adjustments from the pairs of sessions were found to be statistically insignificant. Based on this analysis, the 1-hour Intensives were adopted, thereby shortening station operational time required for the Intensives.
- Examined the performance of the first 30 Mark-4 sessions and compared the geodetic results with other experiment series. Mark-4 baseline repeatabilities were $\sim$0.9 ppb compared with repeatabilities of $\sim$1.4 ppb for other series (NEOS-A or CORE-A and CORE-B). Earth orientation formal uncertainties are generally better than for these other series by $\sim$10–25%. There is better agreement in Y-pole motion from IGS and these Mark-4 sessions than the other VLBI series, but agreement for X-pole and LOD is not significantly different.
- Investigated the systematic effects of different series of experiment sessions on the EOP series and baseline length series. We found that EOP series generated from a standard terrestrial reference frame (TRF) solution were systematically affected more than expected when certain sessions were added to the solution. Specifically, this was true for the RDV and the Mark-4 sessions. The effect is caused by an adjustment of the TRF positions and velocities that propagates to EOP and primarily affects EOP from smaller networks, like the European network. Mark-4 baseline lengths were biased with respect to the trends through all other sessions. However, the latest analysis indicates that it may be the RDV sessions for these baselines that produce the apparent Mark-4 bias.
- Collaborated with Anne-Marie Gontier (Paris Observatory) to develop PIVEX (Platform Independent VLBI EXchange format) file structure and wrote a preliminary database handler.

2.3. Software Development

The primary software development activities from Jan. 1, 2001 - Dec. 31, 2001 included:

- Program Calc was upgraded to version 9.12 to handle correlator-produced databases, to read a new EOP input file, and to add U/V coordinates.
- Extensive changes in programs Dbedit and Solve were made to support new correlator/fourfit output features.

- Extensive upgrades were made to programs Snoop and Msnoop to support F-solve and batch mode processing and to improve quarterly solution output. User's guides were written.
- Program Snranal was incorporated into the Calc/Solve system. Bimonthly Calc/Solve system updates were maintained, in the form of an easy-installation distribution kit. See http://gemini.gsfc.nasa.gov/solve.

3. Staff

The GSFC analysis group is part of a larger VLBI group of civil service and contractor personnel, which also includes a Technology Development Center, three network stations, the Core Operations Center, and the Coordinating Center. This larger group saw the end of an era in 2001 with the retirement of its longtime leader, Dr. Tom Clark.

The analysis group is composed of the following six individuals who are involved full time, or nearly so, in analysis activities.

Dr. Chopo Ma leads the analysis group. His interests include astrometry, the celestial and terrestrial reference frames, extension and improvement of EOP measurement, and the improvement of analysis and modeling. He is a member of the IAU working group on the Celestial Reference System and heads the subgroup for the maintenance and extension of the ICRS. As such he has particular interest in improving the modeling and optimization of ICRF analysis as well as providing better information about source position variations. He is also one of the VLBI representatives on the IERS directing board, and is responsible for generating ITRF and ICRF products for IVS and IERS use and for improvement of consistency between them.

Dr. Dan MacMillan is involved in VLBI technique improvement and analysis system software development (Solve), particularly in the area of tropospheric delay modeling. His interests include improving the modeling of atmospheric delay gradients, deriving better mapping functions from meteorological assimilation data, and various TRF and CRF studies. He is also working on improving or adding modeling for atmospheric pressure loading, ocean loading, and hydrology loading.

Dr. David Gordon manages all initial data processing and analysis activities, performs the AIPS geodetic processing of VLBA experiments, and maintains and develops program Calc. His research interests include astrometry, tectonic motions, improving VLBI modeling, improving VLBA/AIPS processing, correlator comparisons, and phase delay development.

Dr. Leonid Petrov maintains and develops the Mark-4 VLBI analysis Calc/Solve package and the suite of programs for automated data transmission and processing. He conducts research in the fields of optimal estimation of EOP, estimation of Love numbers, improvements in the modeling of ocean loading, and investigation of instrumental errors in VLBI.

Ms. Karen Baver is the primary analyst for the NEOS-Intensive sessions. She also maintains and develops a wide range of software, including the database catalog system, the solution archive catalog system, the Snoop reporting programs, and various analysis graphics programs. She also supports the group's web page activities, assists in generating all types of TRF and CRF reports, generates site and velocity plots, assists in generating IVS publications, and provides assistance to new and current users of the analysis package.

Ms. Cindy Lonigro works on initial experiment preparation and data archiving and provides analysis support and miscellaneous support.