GSFC VLBI Analysis Center

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Abstract

This report presents the activities of the GSFC VLBI Analysis Center during 2004. The GSFC Analysis Center analyzes all IVS sessions, makes regular IVS submissions of data and analysis products, and performs research and software development activities 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. It submits updated EOP files and daily Sinex solution files for all IVS sessions to the IVS Data Centers immediately after analysis. The group also submits the analyzed databases to IVS for all INT01 NEOS Intensive, R1, RDV, R&D, and APSG sessions. During 2004, the group processed and analyzed 152 24-hr (54 R1, 51 R4, 6 RDV, 3 R&D, 11 T2, 16 CRF, 6 OHIG, 4 EURO, and 1 APSG) sessions and 257 1-hr UT1 (212 INT01, and 45 INT02) sessions. The group also generated and submitted 3 quarterly updated TRF solutions to the IVS Data Centers using all suitable VLBI sessions.

2.2. Research Activities

The GSFC analysis group performs research aimed at improving the VLBI technique. The primary research activities undertaken during 2004 include the following:

- Gilcreek post-seismic behavior: Since the Denali fault earthquake in November 2002, Gilcreek's horizontal motion has shown roughly exponential transient behavior. Exponential time constants computed after about 2 years are 0.82 years and 0.62 years for eastward and northward displacement respectively. The horizontal rates have nearly returned to their long-term values prior to the earthquake but still differ by about 1.5 mm/year in both the east and north directions. Such a model was applied in the group's standard terrestrial reference frame solutions. Comparison of polar motion from the R1 sessions with the IGS series shows that the WRMS agreement is not significantly different before and after the earthquake, indicating that the model is performing reasonably well.

- Ny-Ålesund displacements and gravity: Ny-Ålesund vertical rates from VLBI and GPS, and gravimetry measurements were studied and compared. VLBI and GPS vertical rates and the rate of gravity change do not agree well with model rates that account for post-glacial rebound, present day ice melting, and relative sea-level change. A possible explanation is that the observed rate of change of gravity is in error (too large by about 50%) due to a sparsity of data (4 measurements over 5 years). Another possible explanation is that the rate of present day ice melting is significantly greater (by perhaps 50-70%) than what was nominally used in the model. The analysis models and observations are discussed in a paper submitted to Geophysical Journal International ("A Geophysical Interpretation of the Secular Displacement and Gravity Rates Observed at Ny-Ålesund, Svalbard in the Arctic", by T. Sato, J. Okuno, J. Hinderer, D. MacMillan, H. -P. Plag, O. Francis, R. Falk, Y. Fukuda).
- Reference frame scale rate: Comparison of rates from 25 co-located GPS and VLBI antennas shows that, on average, GPS vertical rates (from the JPL solution) are about 1.5 mm/yr greater than VLBI rates. Further analysis indicates a rate difference between the VLBI and GPS reference frame scales of 0.2-0.25 ppb/yr, which corresponds to the observed vertical rate difference. Both the VLBI and GPS solutions were aligned to ITRF2000, with the GPS solution also aligned in scale as well as rotation and translation. A likely source of this discrepancy is GPS error due to uncorrected orbit errors. Any scale rate difference is obviously important for resolving such effects as global sea level rise, which has been estimated to be 1-2 mm/yr. This work was presented at the Fall 2004 AGU meeting.
- Source monitoring program: Most geodetic schedules are made using sources from a catalog of ~100 sources considered the best "geodetic" sources, often with a few "non-geodetic" sources added from other lists. It was found that many of the non-geodetic sources were being observed too infrequently. Beginning in February 2004, a program was begun to systematically monitor 307 of these non-geodetic sources. This list includes all ICRF defining sources plus all sources identified by Martine Fiessel as potentially stable sources not already in the geodetic catalog. A goal of observing each of these at least twice per year was set. A database was developed to keep track of when a source was scheduled and the number of successful observations. It is updated twice for each session – before the session using the schedule, and after the session using the analyzed results. Only the R1's and RDV's are being used in this source monitoring program. This effort has been very successful. Before starting this program, ~160 of the sources had not been successfully observed during the preceding year, and only 70 had been successfully observed twice. By December 2004, only 5 had not been observed during the preceeding year, and over 250 had been observed twice.
- VCS3: A third set of VLBA calibrator sessions were observed and processed by GSFC and NRAO personnel in order to fill holes in the current geodetic/astrometric catalog. In three VCS3 sessions, positions were obtained for 360 new sources. The geodetic/astrometric catalog now contains 2262 sources with positions known to better than 5 mas. With the VCS3 data, there is now a suitable phase calibrator within 4 degrees of any point over 95% of the sky north of -45 degrees declination. A paper describing this work was submitted to the Astronomical Journal ("The Third VLBA Calibrator Survey", by L. Petrov, Y.Y. Kovalev, E. Fomalont, and D. Gordon). The full geodetic/astrometric catalog is available at http://gemini.gsfc.nasa.gov/vcs/, http://magnolia.nrao.edu/vlba_calib/index.html, or http://www.vlba.nrao.edu/astro/calib/index.html (search tool).

- Antenna thermal deformation: A simple model of antenna thermal expansion based on antenna dimensions, expansion coefficients, and measured site temperature was tested in standard VLBI analysis. Baseline length variance was reduced for nearly all baselines by as much as 20 mm^2 and on average by 8 mm^2. This improvement corresponds to 1-3 mm in station vertical precision. This model will be added to the Solve analysis program.

- Hydrology loading: The effect of hydrology loading on VLBI site position estimates was investigated. Application of model site displacements derived from the hydrology model of Milly et al. (J. Hydrometeorology, **3**, 283-299, 2002) improved baseline length repeatabilities for more than 80% of baselines and accounts for 1-5 mm in station vertical variation depending on the site.

- UT1 Intensives comparisons: A study was performed on 275 IVS-INT01 sessions (Kokee-Wettzell) and 48 IVS-INT02 sessions (Tsukuba-Wettzell) between July 2002 and December 2003. Analysis of the differences between each UT1 estimate and UT1 linearly extrapolated from the nearest 24 hour session showed that the precision of each series was 18-22 μsec. The average UT1 formal errors and session fits for the INT02 sessions (9.5 μsec and 27 μsec) were better than for the INT01 sessions (13.9 μsec and 36 μsec).

- Ter-diurnal variations: Direct estimation of harmonic EOP was performed. Several unexpected phenomena were found. There is a strong prograde narrow-band signal in polar motion around $K_1 + 2K_1^-$. There is also a narrow-band signal in UT1 at S_3 and a rather broad peak around $K_1 + 2K_1^-$ frequency. Estimates of the power spectrum around K_2 and S_2 show the presence of signal *near* these spectral lines.

- Love numbers estimation: Estimation of Love numbers from VLBI observations and their comparison with superconducting gravimetry data analysis results was performed. It was found that for diurnal and semi-diurnal bands, VLBI gives upper limit errors that are less by a factor of 2–4 than superconducting gravimetry measurements of the Earth's non-rigidity. The estimates of Love numbers at semi-diurnal bands from VLBI allows one to discriminate between theories of solid Earth tides. Also, the combination of results from VLBI and superconducting gravimetry allows estimation of the k Love number with an upper error limit for diurnal and semi-diurnal bands in the range 0.5–1.0%.

- Higher frequency CRF: Members of the analysis group are working with JPL, USNO, NRAO, and others, to extend the celestial reference frame to higher frequencies by using the VLBA at K and Q bands (~24 and ~43 GHz). The primary goal is to build up a reference frame for use in planetary spacecraft navigation at Ka band (~33 GHz). A nearly simultaneous K/X/S VLBA session was observed and analyzed. The K/X, K/S, and X/S ionospheres were computed and compared. The K band ionosphere corrections showed a maximun range of ~400 psec peak-to-peak at the longest baselines. At Ka band, about half as much should be seen; therefore the ionosphere delay at Ka band will need to be measured in some manner.

- Altimeter radiometer monitoring: VLBI and GPS wet zenith delay estimates were used to monitor and calibrate drifts in the sea surface radiometer measurements from the TOPEX and Jason-1 satellites. For the period 1993-1999, the VLBI drift calibration of TOPEX agrees very well with the GPS drift calibration, although it is five times noisier because there is much less VLBI intercomparison data. Also, two systematic jumps of 5 mm and 11 mm in the time series of Jason-1 radiometer measurements were identified using GPS and VLBI measurements. A paper describing this work was published in a special issue of Marine Geodesy on Jason-1 calibration.

2.3. Software Development

The GSFC group develops and maintains the Calc/Solve analysis system. Updates were released approximately bimonthly during 2004.

Calc/Solve development work was concentrated on the development of a Linux and HP-UX compatible version. At year's end, most of the programs were ready. This includes the catalog system and database handler, SOLVE, the new REPA plotting program, and Calc 9.13. Completion and release is expected early in 2005.

Work was also concentrated on upgrading Calc for compliance with the IERS Conventions (2003). The Fortran 77 version was essentially completed during the past year. A Fortran 90 HP-UX/Linux version will be produced early in 2005.

Efforts were begun to develop an integrated analysis system with the program GEODYN at its base, and with capabilities to integrate VLBI, SLR, GPS, DORIS, and laser altimetry measurements at the level of the observables. Initial, limited capabilities of analyzing VLBI observations were added. This work will be carried over into 2005 and 2006.

3. Staff

Members of the analysis group and their areas of activity include: Dr. Chopo Ma (CRF, TRF, EOP, K/Q CRF, IVS representative to the IERS, and newly elected chairman of the IERS directing board), Dr. Dan MacMillan (CRF, TRF, EOP, mass loading, antenna deformation, proper motion, and post-seismic studies), Dr. David Gordon (database analysis, RDV processing and analysis, K/Q CRF analysis, VLBA calibrator surveys, Calc development), Dr. Leonid Petrov (CRF, TRF, EOP, mass loading analysis, VLBA calibrator surveys, Calc/Solve development, Linux migration, GEODYN development), Ms. Karen Baver (R4 and Intensives analysis, software development, Linux migration), and Jim Ryan (retired) (Calc/Solve Linux migration).

4. Future Plans

Plans for the next year include: Finish and release the first Linux/HP-UX version of Calc/Solve; finish the update of Calc for compliance with the IERS Conventions (2003); participate in development of the next VLBI ICRF; participate in a fourth set of VLBA calibrator survey sessions; participate in additional K/Q observations and reference frame development; continue development of GEODYN for integrated analysis of VLBI, SLR, GPS, DORIS, and laser altimetry observables; and further research aimed at improving the VLBI technique.

5. Publications

MacMillan, D. S., B. D. Beckley, and P. Fang, "Monitoring the TOPEX and Jason-1 Microwave Radiometers with GPS and VLBI Wet Zenith Path Delays", Marine Geodesy, **27**, 703-716, 2004.