NASA/CRUSTAL DYNAMICS PROJECT GEODETIC DATA ANALYSIS

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ABSTRACT. The VLBI group in NASA's Crustal Dynamics Project (CDP) maintains an integrated system for analyzing geodetic VLBI data. This system includes: CALC, calibration programs, SOLVE, GLOBL, and the Data Base System. CALC is the program which contains the models used to calculate the theoretical delay. SOLVE is used to analyze single experiments. GLOBL is used to analyze large groups of experiments. The Data Base System is a self-documenting data storage system used to pass data between programs and archive the data. Kalman filtering is being investigated for operational use in geodetic data analysis.

1. Description

The general flow of geodetic data is from the observatories where the data are recorded, to the correlator for correlation, and finally to the analysis centers, such as Goddard Space Flight Center (GSFC) for analysis. At GSFC, the data pass through CALC, calibration programs, and several housekeeping programs. SOLVE is then used by an analyst to examine the data in detail and develop models for the clock and atmosphere behavior. Once the models have been developed, the data are passed on to GLOBL where they are used in larger solutions.

CALC calculates the geometric delay for the observations including the effects of the best understood geophysical and astronomical models. Currently, the models include: J2000 precession, 1980 IAU Nutation Series, UT1/PM BIH *a priori*, solid earth tides, pole tide, Yoder UT1 tidal variations, ocean loading, gravitational deflection of light, and the PEP numerical ephemeris. CALC also calculates the partial derivatives used for estimation of station and source positions and model parameters.

SOLVE is an interactive weighted least-square analysis program used to analyze single day experiments. The most difficult part of this analysis is developing models for the atmosphere and clock behavior during experiments. Accordingly, SOLVE includes a powerful interactive plotting utility to aid the analyst in developing good

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polynomial models for these effects. Usually 5 to 15 clock or atmosphere coefficients per station must be estimated. The use of these polynomial models does not completely account for the systematic variation of the atmosphere and clocks during the experiment. In order to account for this 'noise,' SOLVE calculates 'Error Constants' that are used to modify the observation weights. SOLVE also allows adjustment of station and source coordinates, UT1/PM, daily nutation offsets or nutation model coefficients, solid earth tides, precession constant, and gamma.

GLOBL is an extension to SOLVE used to estimate parameters from large data sets. Typical large solutions use 470 experiments, 180,000 observations, and 12,000 parameters. To make this tractable, a technique called 'arc-parameter elimination' is used. This technique takes advantage of the large scale structure of the normal equations to reduce the matrix manipulation by a factor of more than 10,000 compared to a direct solution. Parameters can be estimated independently for each experiment or globally from all the experiments. The two most common types of solutions are UT1/PM and Baseline. In a UT1/PM solution, the station and source coordinates are estimated globally and UT1/PM are estimated independently for each experiment. The result is a UT1/PM series. In a Baseline solution, sources coordinates are adjusted globally, station coordinates are estimated independently for each experiment. The produces a history of baseline evolutions. Model parameters can be adjusted as part of either solution.

The Data Base System is the glue that holds the system together. It provides a standard, secure, and permanent means of passing data between programs and archiving the data. One of the goals of the Data Base System is to maintain the accountability of the data analysis. A record is kept of each step in the data analysis process, along with comments by the analyst. The Catalog System keeps track of all the data bases and where they reside on disk and tape. The Data Base System is designed to be as portable as possible and has been used successfully on HP, UNIVAC, IBM 360, and DEC VAX computers.

Kalman filtering is being investigated for use as an operational technique for data analysis. Filtering Mark III geodetic data was pioneered by Tom Herring and Jim Davis at CfA. It uses statistical descriptions of clock and atmosphere behavior to model their variation from one observation to another. The statistical model of the clock and atmosphere used by the filter is physically more realistic than the polynomials used by SOLVE. This improvement effectively removes the need to adjust the observation weights to account for unmodeled 'noise.' Because much of the analyst time in SOLVE is spent parametrizing the clocks and atmosphere, the filter has the potential to free analyst time for other work. The filter requires about two to three times as much computation as least-squares.

2. Acknowledgements

This analysis system is the result of the combined efforts of the GSFC/CDP VLBI Group over a period of more than 10 years.