CONSISTENCY OF CDP AND IRIS VLBI EARTH ORIENTATION RESULTS

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ABSTRACT. This study compares the earth orientation results obtained by the NASA CDP and the NGS IRIS experiments. The results agree at about one combined formal error (two milliarcseconds) after small biases (one to three milliarcseconds) have been removed from each component. Furthermore the biases are found to correspond to small rotations between the reference frames, principally the terrestrial frame, for the two sets of experiments. In the past the CDP data has not been used in combined solutions of earth orientation parameters prepared by the data centers at the U.S.N.O. and the B.I.H. The authors propose that these data should be included because they are distinct from the IRIS data and represent an important supplement to those data. We also point out that the total number of observations is about equal in the CDP and IRIS experiment sets.

1. INTRODUCTION

The physical figure of the earth exhibits a small semi-periodic motion relative to its spin axis. This polar motion taken together with the phase of rotation, i.e., Universal Time (UT1), defines the Earth's orientation.

Very Long Baseline Interferometry (VLBI), as developed by NASA at Goddard Space Flight Center (GSFC), has emerged as the most precise and efficient technique for measuring earth orientation. This VLBI technique has been used by the National Geodetic Survey (NGS) for about the past five years for routine monitoring of earth orientation. Their

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program, originally termed POLARIS, was expanded in 1983 and re-named IRIS.

In the meanwhile NASA's Crustal Dynamics Project (CDP) has performed approximately 90 fixed site experiments, mainly for the study of tectonic plate motion and deformation. However, the CDP data are equally useful for obtaining earth orientation results. This paper compares the results of CDP and IRIS earth orientation results.

2. THE CDP, IRIS, AND MERIT DATA SETS

2.1. CDP Data

The CDP experiments are managed by NASA Goddard Space Flight Center. They are a heterogeneous set taken on a network of about 20 sites that span the North American, Eurasian, and Pacific plates. There have been about 90 experiments since 1980, with about 75,000 observation in all. The results considered here are from a combined solution of all the experiments, in which the site and source positions have been solved for globally and the earth orientation parameters have been solved for in each separate experiment.

2.2. IRIS Data

The IRIS experiments are managed by NGS for the purpose of monitoring earth orientation. From 1981 until 1983 the stations at Westford, Massachusetts and Ft. Davis, Texas provided UT1 and the X component of polar motion at 7 day intervals. Late in 1983 additional stations were added at Wettzell, Germany and Richmond, Florida. This system provides UT1 and both components of polar motion at 5 day intervals. The data set analyzed here was provided by D. Robertson at NGS. It contains over 300 experiments through 1 September 1986, although only data through the end of 1985 are compared below.

2.3. MERIT 1980 Data

There are 14 experiments conducted during 1980 as part of the campaign to Monitor Earth Rotation and Intercompare the Techniques (MERIT) that are common to the CDP and IRIS data. These provide the ability to tie the two systems together. The data provided six common sites, many common sources, and a reference day. The earth orientation results from both experiment sets are defined to be equal to the Bureau International de l'Heure (B.I.H.) values on 17 October 1980.

3. EARTH ORIENTATION RESULTS

The CDP and IRIS earth orientation series were compared by making a quadratic interpolation of IRIS data to CDP experiment times. Figures 1, 2, and 3 show the differences between the two sets of earth orientation results, in the sense CDP minus IRIS, plotted as a function of time. The data span the interval from the 1980 MERIT campaign until the end of 1985. The height of each vertical error bar is equal to plus and minus one formal error (unscaled) for the CDP data.

Figure 1 shows the X component of polar motion data. The weighted average bias between the two data sets is -1.7 milliarcseconds (mas). The weighted root mean square (WRMS) difference after the bias was removed is 2.2 mas. The combined formal error (CFE), 2.1 mas, is the root mean square (RMS) of the square roots of the sum of the squares of the formal errors of each technique. The WRMS is approximately equal to the CFE.

Figure 2 shows the Y component of polar motion data. The bias is -1.1, the WRMS difference is 2.4, and the CFE is 1.8 mas. The WRMS is about equal to 1.3 times the CFE.

Figure 3 shows UT1. The bias is 3.0, the WRMS difference is 2.0, and the CFE is 2.0 mas. The WRMS is equal to the CFE.

The statistics show that the scatter as measured by the WRMS difference between the two sets of results is about equal to the value that would be expected by a combination of the formal errors from the two experiment sets. Furthermore, the WRMS measurements are generous in the sense that they include a component of "analyst noise" due to parametrization by different data analysts. Mallama (1985) showed that this noise is about 0.4 to 0.7 mas.

4. COMPARISON OF SITE AND SOURCE CATALOGS - BIASES EXPLAINED

The site and source catalogs derived from the global CDP and IRIS solutions were investigated in order to account for the small biases between the earth orientation solutions. According to Feissel (1986) differences in earth orientation parameters are related to rotations in the respective terrestrial and celestial reference frames by the following equations:

$$DX = RY - AX * \sin T + AY * \cos T \qquad (1)$$

$$DY = RX + AX * \cos T + AY * \sin T \qquad (2)$$

$$f(DUT) = - RZ + AZ \qquad (3)$$

where DX, DY, and DUT are the expected biases in the earth orientation measurements, R(X,Y,Z) is the terrestrial rotation, A(X,Y,Z) is the celestial rotation, T is sidereal time, and f is the conversion factor to go from universal time to sidereal time. (The terms involving sidereal time, T, average to zero after because of diurnal rotation.)

The site catalogs had 9 sites in common, while 9 more sites appear in the CDP catalog only, and 3 more sites appear in the IRIS catalog only. Several of the CDP-only sites are on the Pacific plate. The source catalogs contain 26 sources in common, while 17 more are specific to the CDP catalog, and 6 more are specific to the IRIS catalog.

The site catalogs were compared using a Fortran program that makes

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a weighted least squares fit by adjusting translation, rotation, and scale (i.e., a seven parameter fit). Likewise the source catalogs were compared, but only rotation was adjusted (i.e., a three parameter fit).

Evaluation of the three equations shows excellent agreement between the earth orientation biases and the relative orientation of the reference frames. The bias DX, -1.7 ± 0.3, corresponds to a rotation around the RY axis, -1.1 ± 0.4, with an error of 0.6 mas or 1.2 CFE. The bias DY, -1.1 ± 0.3, corresponds to a rotation around the RX axis, -1.6 ± 0.5, with an error of 0.5 mas or 0.8 CFE. The bias f(DUT), 3.0 ± 0.2, corresponds to the sum of rotations around - RZ, 3.0 ± 0.2, and AZ, 0.1 ± 0.04, with an error of 0.1 mas or 0.3 CFE.

Thus all the biases can be explained at the sub-milliarcsecond level, and they correspond to rotations of the terrestrial and celestial frames at an accuracy of about one CFE or less.

5. CONCLUSIONS

The CDP and IRIS earth orientation data are in agreement at about one CFE level (two milliarcseconds), after small biases (one to three milliarcseconds) have been removed. These biases appear to result from small rotations between the CDP and IRIS reference frames. The excellent agreement between these data sets, and the explanation of the biases, make it clear that the CDP data should be included along with IRIS data in combined series of earth orientation results.

6. ACKNOWLEDGEMENTS

The authors express their thanks to E. Himwich and M. Torrence for their involvement with the data analysis; and to C. Ma for suggesting that reference frame rotation might account for the biases between CDP and IRIS data.

7. REFERENCES

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Mallama, A. (1985), 'A Comparison of Earth Orientation Data Obtained by Different Space Techniques', in Proceedings of the International Conference on Earth Orientation and the Terrestrial Reference Frame, p. 637.

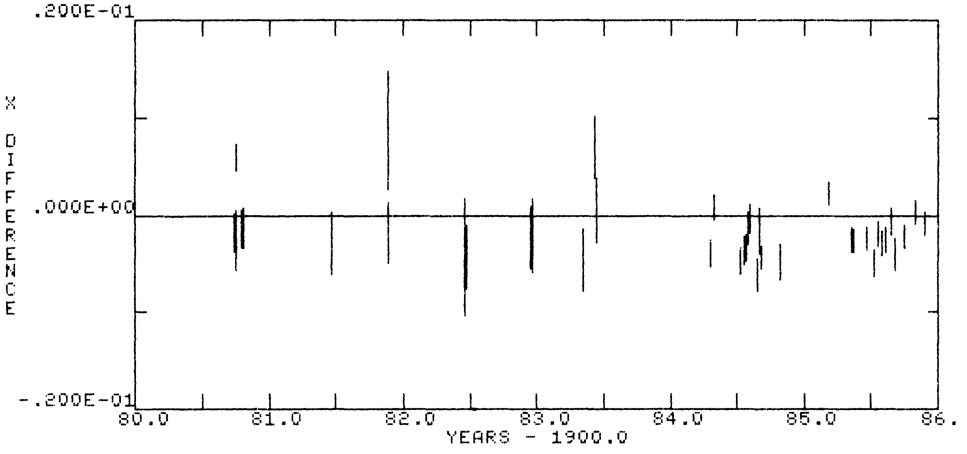

Figure 1. The difference in the X component of polar motion, in the sense CDP minus IRIS, in units of arcseconds.

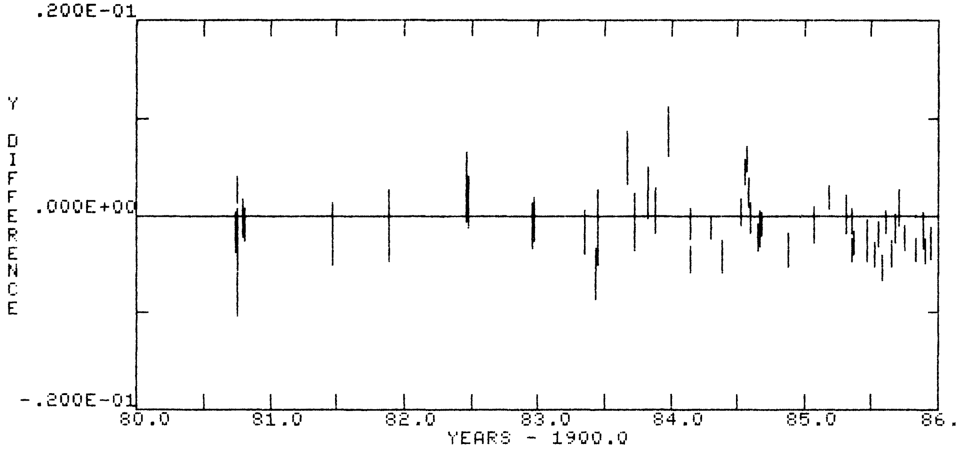

Figure 2. The difference in the Y component of polar motion, in the sense CDP minus IRIS, in units of arcseconds.

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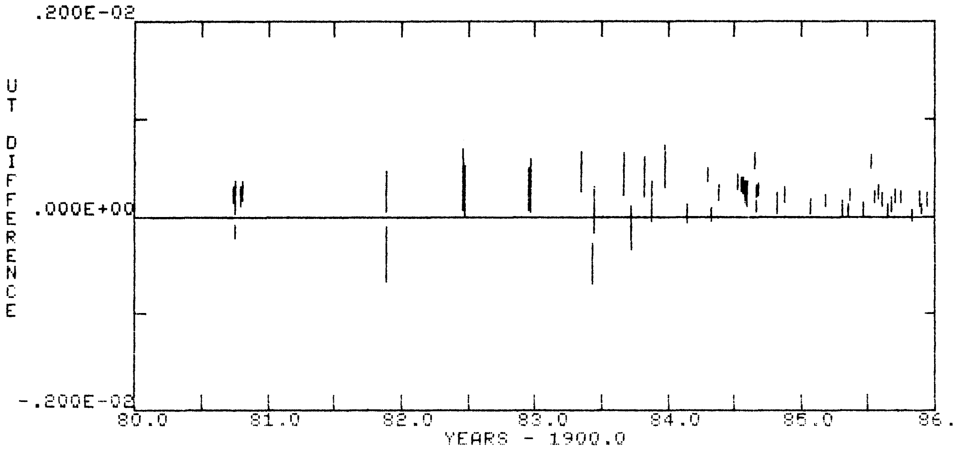

Figure 3. The difference in UT1, in the sense CDP minus IRIS, in units of seconds.

DISCUSSION

Carter: Did the reduction of the CDP observations, which span three plates including the relatively rapid Pacific plate, include a correction for plate motion, i.e. by using a plate motion model?

Reply by Mallama: The CDP analysis does not include a model for plate motion. However, we plan to add this model in the very near future. This may reduce the rotation between the CDP and IRIS terrestrial reference frames.

Feissel: You have shown that the biases in the series of ERP and the relative orientations of the reference frames of CDP and IRIS are in agreement. This is a test of the internal consistency of the two systems. The relative differences are small, however they significantly differ from zero. Can you explain this?

Reply by Mallama: I can think of 3 effects that may contribute to the rotation between the CDP and IRIS frames. 1) The analysis of the data on the reference day which ties CDP and IRIS may be different. This effect probably accounts for less than 1 mas. 2) The sites that are not in common between the CDP and IRIS data sets may be causing the rotation. This is especially true for the sites in the CDP data that are on the Pacific plate which has a rapid motion relative to the North American plate. 3) There may be a discrepancy between the way that NGS derives site coordinates from IRIS data, versus the way that GSFC derives site coordinates from CDP data. We will investigate all these possibilities. In regard to the second possibility on plate motion, we plan to enhance our software very soon to model this effect. Furthermore, we suggest that rotations between the CDP and IRIS coordinate frames are arbitrary as long as they are well-defined and consistant with ERP results.

T. Clark: Two additional comments: 1) The two data sets just discussed were of comparable size — in general CDP measurements were multi-baseline. 2) When the IRIS data set is independently analyzed at NASA/GSFC, agreement between these analyses are at the 1 σ (FSE) level.

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