Simultaneous Determination of the Earth Rotation Parameters and Coordinates of the Optical Astrometric Stations

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ABSTRACT. The earth rotation parameters and coordinates of optical astrometric stations from 1962.0 to 1986.0 are estimated simultaneously on the assumption that the system of selected standard stations does not rotate. Longitudes and latitudes of the stations are determined every 2 months. Disagreement of the ERPs with those obtained by the space techniques decreased much compared with the published ERPs of the IPMS. It is expected that the ERPs in the whole period are also improved significantly.

1. Introduction

The accuracy of the optical astrometric ERPs is limited mainly by two factors. One is the dispersion of individual observations of time and latitude, which does not bring about systematic errors in the ERPs. The other is local systematic variations of longitude and latitude, which brings about systematic errors to the ERPs. main features of these variations are quasi-annual variations due to meteorological effects, secular variations due to inaccurate star proper motions and true station motions, and step-variations due to instrumental effects and changes of star catalogs. In this paper we determine the ERPs as free from these local variations as possible and show some of the results.

2. Data

The data used in the present calculation are UT0-UTCs and latitudes of the optical astrometric stations transmitted to the IPMS from 1962.0 to 1986.0. There are not enough time data for the period before 1967.0. Hence only the polar coordinates are estimated during this period. The total numbers of time and latitude stations are 86 and 89, respectively. Those of data are 245108 and 335753 groups for time and latitude, respectively.

A. K. Babcock and G. A. Wilkins (eds.), The Earth's Rotation and Reference Frames for Geodesy and Geodynamics, 153–158.

3. Assumptions and the Method of Computation

The computation consists of three steps. In the first step, some preliminary corrections such as trivial jumps due to movements of instruments and star catalog changes are made. Bad data are rejected in this step.

In the second step, the ERPs and errors in the adopted station longitude and latitude are simultaneously estimated. With the assumption of step-variations of the station coordinates and the ERPs, the basic observational equations are simply given by:

$$\Delta\varphi_k(t) = \Delta\varphi_{k,i} + x_{ij}\cos\lambda_k + y_{ij}\sin\lambda_k$$

$$\Delta T_k(t) = \Delta T_{k,i} + (-x_{ij}\sin\lambda_k + y_{ij}\cos\lambda_k)\tan\varphi_k + u_{ij} ,$$

where

$$\Delta\varphi_{k,i} = \Delta\varphi(t) \text{ and } \Delta T_{k,i} = \Delta T(t) \text{ for } t_i \leqq t < t_{i+1},$$

$$x_{ij} = x(t),\ y_{ij} = y(t) \text{ and } u_{ij} = u(t) = (\mathrm{UT1} - \mathrm{TAI})(t) \text{ for } t_{ij} \leqq t < t_{i\ j+1},$$

$$t_1 = t_{11} < \cdots < t_i = t_{i1} < t_{i2} < \cdots < t_{in} < t_{i+1} = t_{i+1\ 1} < \cdots < t_M .$$

k is a station code.

Lengths of the time-steps of station coordinates and the ERP are chosen to be 63 and 7 days, respectively. 63 days is short enough to identify the quasi-annual variations in the errors of station coordinates. With this choice of the periods the number of unknowns is about 18000 in total.

In each time step of the station coordinate errors the above system of equations are rank-defficient by two or three before or after 1967, respectively. In order to make the ranks full we impose the following constraints that realize zero-rotation conditions of the system of stations.

$$\sum_k \begin{bmatrix} \sin\lambda_k \\ \cos\lambda_k \\ 0 \end{bmatrix} \Delta\varphi_{k,i} + \sum_l \begin{bmatrix} -\cos\varphi_l\cos\lambda_l \\ \cos\varphi_l\sin\lambda_l \\ \cos\varphi_l \end{bmatrix} \cos\lambda_l \Delta T_{l,i} = 0 .$$

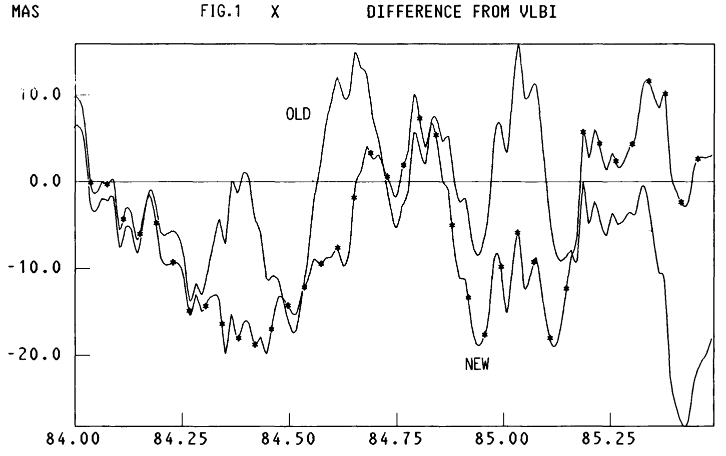
The summations are taken over selected standard stations which satisfy such conditions as wide and even coverage of geographic area and long period of observations. The numbers of the standard stations are 14 and 23 for time and latitude, respectively.

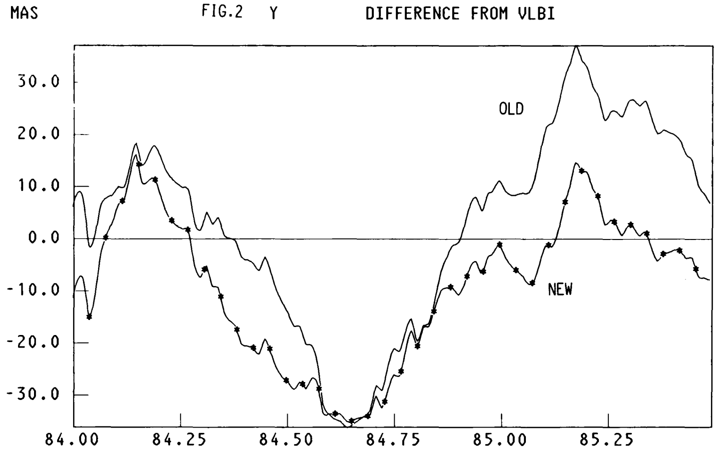
The terrestrial reference frame defined by the above equation is stabilized by imposing the smoothness conditions given by:

$$\Delta\varphi_{k,i} - \Delta\varphi_{k,i+1} \approx 0 \text{ and } \Delta T_{k,i} - \Delta T_{k,i+1} \approx 0$$

We assume equal smoothness of the time and latitude variations for all the stations and its optimum value is determined so as to minimize ABIC (Ishiguro 1982). This smoothing procedure gives suitably interpolated coordinates of the standard stations even when they have no observations in a certain time step.

In the final step, daily values of the ERPs are re-computed on the basis of the station coordinate corrections computed in the second step. The method is the same as the one used in computating the Monthly Notes of the IPMS (Manabe et al. 1982). The daily values thus computed are essentially the same as the 7 day values obtained in the second step.

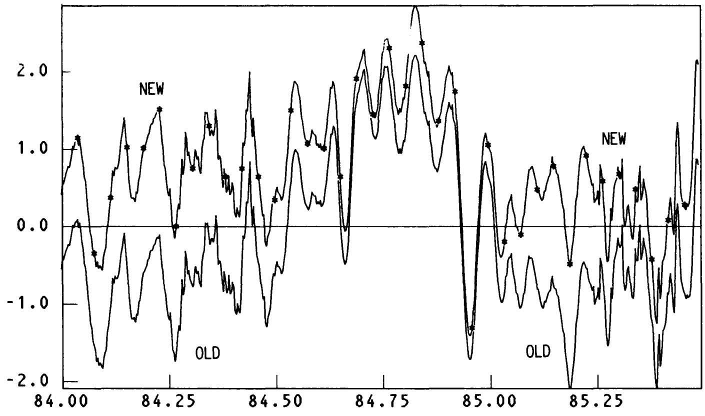




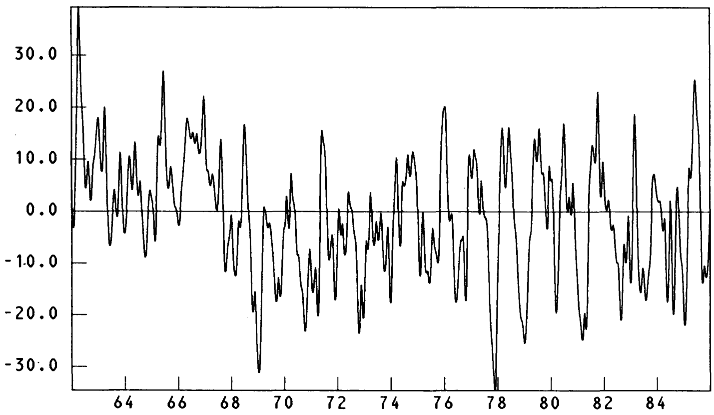
4. Results

Figs. 1-3 compare the individual components of the obtained ERPs (referred to as the new ERPs) and the published values of the IPMS

MS FIG.3 UT1-TAI DIFFERENCE FROM VLBI



MAS FIG.4 X(NEW) DIFFERENCE FROM 'OLD'



(referred to as the old ERPs) with the IRIS ERPs for the period from 1984.0 to 1985.5. This period is chosen because the current IRIS network became fully operational in the early 1984 and some of the standard stations in the optical astrometry network ceased observations around 1985.5.

It is seen in Fig. 1 that the fluctuations of the x-component with a time scale of a few months decreased. In the y-component the annual signature of the new ERPs is more stable than that of the old ERPs. Both the new and old UT1 have clear monthly signature and jumps near the end of 1985. However, the almost linear trend in 1985 is less apparent in the new UT1. Summarizing the above, the new ERPs are closer to the

ERPs obtained by the new techniques. Thus, it is reasonable to expect that the new ERPs are more accurate than the old ERPs in the whole period. In general, the new polar orbit is smoother and more round than the old one.

In the long period of time the most significant difference of the new ERPs from the old ones is the jumps of x and y at the beginning of 1967 when the time data came to use. Fig. 4 shows the x-component as an example. Annual differences are also clear in the figure. In addition all the three components of the ERPs have trends which are almost parabolic. However, linear parts do not seem large enough to be significant.

One of the possible causes of the differences between the new and old results is the differences in the systems of weighting the individual data. Both the new and old weighting systems are based on dispersions of the data in a certain time interval, which is 63 days in the new system. However, in the new system, the weights are controlled so as to avoid extremely large values, while the old system has no such control and too large weights were assigned to some stations.

The local variations of time and latitude closely follow the residuals of time and latitude computed by using the old ERPs. However, the local variations have smaller amplitudes and are more stable than the residuals, as a consequence of the smoothness condition.

References

Ishiguro, M. : 1982, On the Use of the Multiparameter Models in Statistical Techniques, Thesis, Univ. Tokyo.

Manabe, S., Tanikawa, K. and Yokoyama, K. : 1982, The Frequent Time Series of the Polar Motion and UT1 by the IPMS, Proc. General Meeting of the Tokyo IAG, 194-203.

DISCUSSION

M. Feissel: With the recent replacement of optical astrometry by the space geodesy techniques for the measurement of the Earth's rotation, one concern is the possible relative drift in the series of the ERP, which would reflect instabilities in the realisation of the reference frames involved. Does the solution presented in this paper show any significant long-term trend with respect to SLR (since 1976) or VLBI (since 1981)?

Reply by Manabe: The drift of x and y presented here does not exceed 1 mas with respect to the space techniques results. That of UT is a little bit larger, but it is smaller than 0.3 ms after 1976.

Bauersima: Optical astrometric determinations of EOP are based on the direction of the local plumb-line and so they are sensitive to *secular* wandering of the center of mass of the Earth relative to the "Earth-fixed" coordinate system. It seems to be important to investigate this contribution of optical observations as compared with the equivalent contribution of SLR observations via determination of a time–varying Earth potential.

Reply by Manabe: If the station coordinate variations obtained really reflect the geopotential variation, some common variations should be identified. Unfortunately, the optical data do not seem to be stable enough to detect such phenomena. Most of the variations seem to be due to meteorological and instrumental effects as well as to star catalogue errors.

Fallon: Can you re-reduce the IPMS observations back into past decades? That might be more valuable than for present-day data.

Reply by Manabe: I have reduced all the IPMS data from 1962.0 to 1986.0.