ON REFERENCE COORDINATE SYSTEMS USED IN POLAR MOTION DETERMINATIONS

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ABSTRACT

A short review of the reference pole presently used in polar motion determinations by classical astrometric methods is followed by a discussion of the systematic differences between systems of polar coordinates and the influence of the mean latitude of stations on pole position. The importance of homogenous processing astrometric data is stressed.

INTRODUCTION

Different reference poles have been defined for use in determination of polar motion and variations of Earth's rotation velocity by astrometric methods. These observations have been obtained since the beginning of regular activity of the International Latitude Service (ILS) in 1899 and of the Bureau International de l'Heure (BIH) and, later, the International Polar Motion Service (IPMS), as shown in Table 1 (BIH, 1968, Cecchini, 1970, IPMS, 1962). At present the Conventional International Origin (CIO) and reference poles of BIH, 1968, and IPMS systems are used.

CIO was defined by adoption of the conventional latitudes of 5 ILS stations and introduced into practice on January 1, 1968, according to the resolutions of General Assemblies of the IAU and IUGG (IAU, 1967, IUGG, 1967).

E. M. Gaposchkin and B. Kolaczek (eds.), Reference Coordinate Systems for Earth Dynamics, 165–173.

https://doi.org/10.1017/S0252921100081215 Published online by Cambridge University Press

BIH, 1968, system was defined by determination of latitudes and longitudes of the instruments participating in time and latitude determination during the years 1966.50 - 1967.45 and located at 50 stations (BIH, 1968). The following instruments participated in these observations of latitude: VZT-19(22), A-11(12), PZT-9(14); and of time: IP-16(13), A-15(14), PZT-9(14), IPP-8(12). Numbers in parenthesis denote numbers of instruments cooperating with BIH in 1979. A system of weights characterizing the long period stability of instruments was adopted by BIH. The coincidence of the reference pole of the BIH, 1968, system with CIO and continuity of UT1 in 1968.0 were assured. In 1979 the improved system BIH, 1979, was adopted by introducing the conventional annual and semi-annual corrections to x and UT1 obtained from comparisons of BIH astrometric results with DMA and EROLD results (BIH, 1979, Feissel, 1980).

Table 1. Reference Poles Used in Determination of Polar Motion

Service	Period	Reference Pole
ILS	1899 - 1949	Mean poles of different epochs
	1949.0 - 1968.0	The new system, 1900 - 1905*
	1968.0 -	CIO
BIH	1955 - 1958	Cecchini pole**
	1958.65 - 1959.15	Transformation for Cecchini pole to the mean pole of the date
	1959.2 - 1968.0	Mean pole of the date
	1968.0 -	CIO
IPMS	1962.0 - 1968.0	The new system, 1900 - 1905*
	1968.0 -	CIO

*Mean position of the true celestial pole in 1900 - 1905 (IUGG, 1960).

**Mean terrestrial pole of 1949 - 1958 (Cecchini, 1970).

Coordinates of the pole (x,y) and UT0 in the BIH, 1968, system are computed by known equations:

$$x \cos L_{0,i} + y \sin L_{0,i} + z = \theta_i - \phi_{0,i}$$
$$x \tan \phi_{0,i} \sin L_{0,i} + y \tan \phi_{0,i} \cos L_{0,i} + t = UT0 - TAI \qquad (1)$$

The residuals of latitude and universal time R and S of individual series, referred to the BIH, 1968, system are added respectively in order to preserve the system. Here $\phi_{0,i}$ and $L_{0,i}$ denote the latitude and longitude of a station adopted by BIH.

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The residual R and S, are expressed by BIH as follows:

$$R_j = a_j + b_j \sin 2\pi\Theta + c_j \cos 2\pi\Theta + d_j \sin 4\pi\Theta + e_j \cos 4\pi\Theta$$
$$S_j = a'_j + b'_j \sin 2\pi\Theta + c'_j \cos 2\pi\Theta + d'_j \sin 4\pi\Theta + e'_j \cos 4\pi\Theta \qquad (2)$$

and are determined every year for every instrument by least squares solutions of residuals during the four preceding years. This has been the procedure since 1975 (Feissel, 1980). The values of coefficients of the equation (2) are denoted by A,B,C, etc. and published in BIH Annual Reports.

IPMS determines polar motions with respect to the CIO continuing computations of pole coordinates in the ILS system. The IPMS determines pole coordinates in two other systems, $IPMS_L$ and $IPMS_{L+T}$, based respectively on latitude data from about 70 instruments and the combined latitude and time data of about 120 instruments. Mean latitudes and longitudes of all instruments are determined with respect to CIO and Zero Point of the BIH, 1968, system, respectively, using data from several years. These are occasionally changed due to change of instruments or programs. Pole coordinates are computed in the IPMS systems using equation (1) without any additional systematic corrections. In the case of differences of UT0-TAI the empirical term τ is added.

The present accuracies of pole coordinates of BIH and IPMS systems are of order of 3 to 4 and 10 to 15 milliseconds of arc, respectively. Systematic differences between pole coordinates of these systems are two to three times larger.

DISCUSSION OF THE SYSTEMATIC DIFFERENCES BETWEEN POLE COORDINATES OF DIFFERENT SYSTEMS

Differences of polar coordinates computed in different systems were developed by BIH using formula (2). Variations of the coefficients A of the differences of ILS-BIH and IPMS-BIH are plotted in Figures 1 and 2 together with coordinates of the barycenters of ILS and IPMS polar orbit in respect to CIO (BIH, 1979, IPMS, 1977). Correlation of these two curves in the case of ILS system shows that there are no secular variations of relative positions of the BIH reference pole and that of CIO. Large variation of the coefficient A and of positions of the barycenters of ILS polar orbit are connected with latitude variations of stations and not with secular polar motion because a coefficient A contains only systematic differences between systems. In the case of IPMS there is some discrepancy between variations of IPMS barycenters and variations of the coefficient A. This can be seen in the relative motion of CIO with respect to reference poles of the BIH and IPMS systems. It should be mentioned that motion of the mean

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pole computed by the Orlov filter for ILS (A. A. Korsuń, 1980) is in agreement with the variation of the coefficient A presented here.

The variations of coefficients of individual stations that cooperate with BIH in the last 12 years are of order of 0.1 seconds of arc for the 12 latitude stations and of order of 0.01 - 0.02 seconds of arc for the 20 stations. This is roughly the BIH weights. Variations of the A coefficients of stations correlate with their mean latitude variations computed by the Orlov's filter (Figure 3).

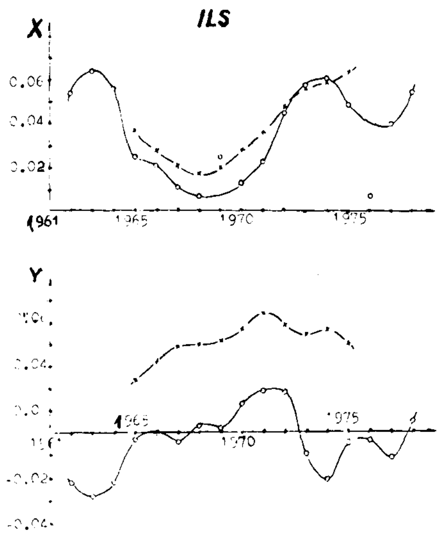

Figure 1. ILS Barycenters x-x and Coefficients A_{BIH}o-o

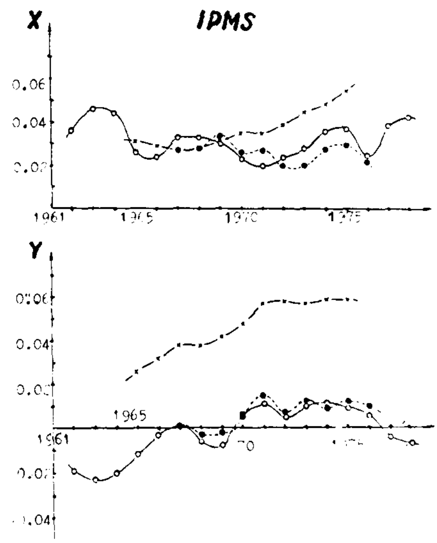

Figure 2. ILS Barycenters x-x and Coefficients A_{BIH}o-o

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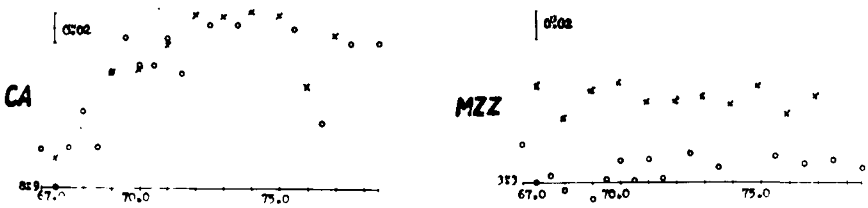

Figure 3. Orlov's Mean Latitudes (x-x) and Coefficients A_{BIH} (o-o) of Carloforte and Mizusawa.

The influence of mean latitude variation on ILS polar orbit was analysed by computation of ILS polodia for the period of 1968-1974 using the differences of latitudes (θ) and mean latitudes (θ_m) and comparing these results with polodia computed from latitude data themselves. Computations were also made for different subsets of 5 to 20 stations (given in the Table 2).

Table 2. List of Stations Considered in the Analysis of the Effect of Large Variations of a Mean Latitude on Derived Polar Coordinates

I. Stations with small variations of mean latitudes in 1968-1974.		II. Stations with large variations of mean latitudes in 1968-1974.	
Mt. Stromlo	Greenwich	Richmond	Turku
Blagovestchensk	Paris	Washington	Neuchatel
Irkoutsk	Pulkovo	Gaithersburg	Hamburg
Warsaw	Poltava	Mizusawa	Uccle
Pecny	Tokio	Belgrade	Kitab

Mean square error of polar coordinates x,y and the error of a single observation ($\delta\varepsilon$) computed from the θ-θ_m data are much smaller than for the θ data themselves (Figure 4). The systematic differences $(O-C)_{IPMS}$ are much smaller for θ-θ_m data than for θ data in the case of small number of stations and stations with large mean latitude variations (Figure 5).

There is noticeable difference between ILS polodia computed from θ-θ_m and θ data in the period of 1962-1968 (Figure 6). ILS polodia computed from θ-θ_m data is much closer to IPMS polodia computed by IPMS in this period.

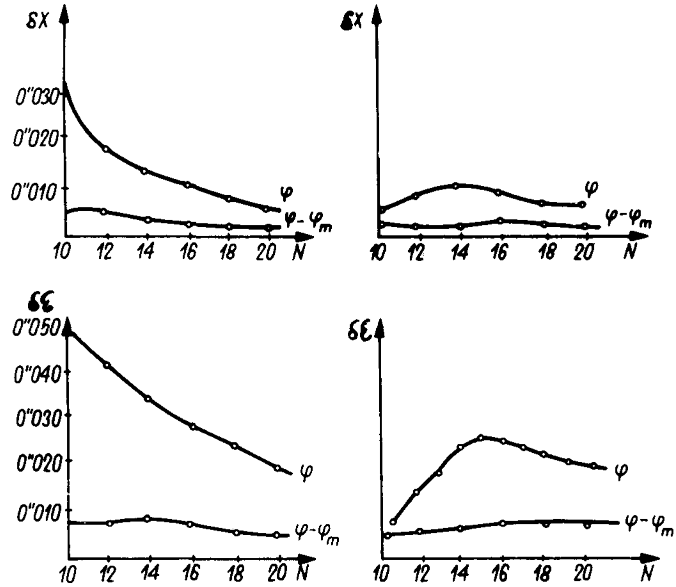

Figure 4. Mean square errors of x and of a single observation:
a) the II set of stations plus n stations of the set I (Table 2).
b) the I set of stations plus n stations of the set II (Table 2).

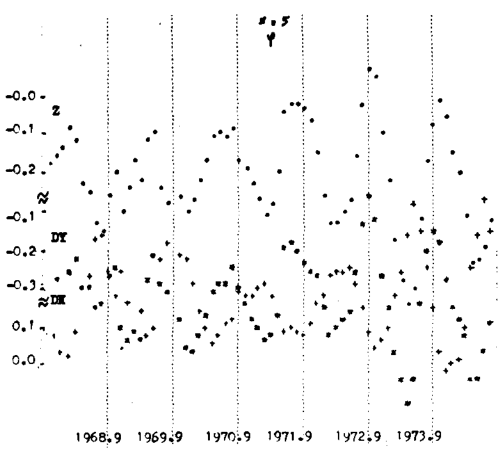

Figure 5a

Variations of (O-C) computed for x,y and term z from θ data of five stations.

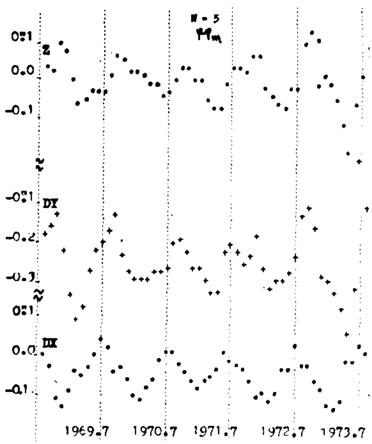

Figure 5b

Variations of (O-C) computed for x,y and term z from $\theta-\theta_m$ data of five stations.

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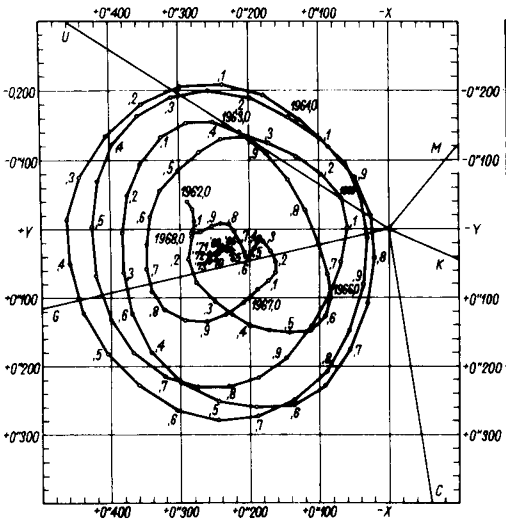

Figure 6a. IPMS Polodia in 1962-1968.

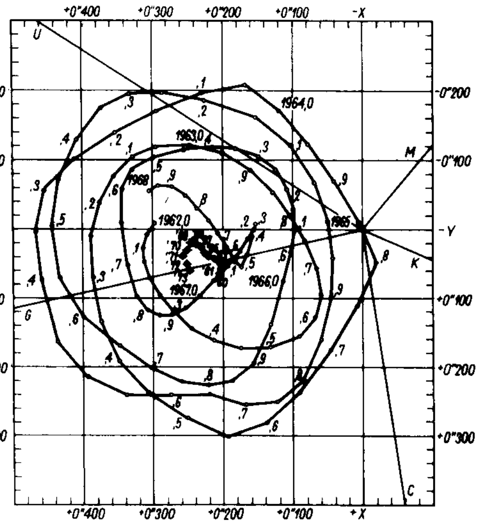

Figure 6b. ILS Polodia in 1962-1968

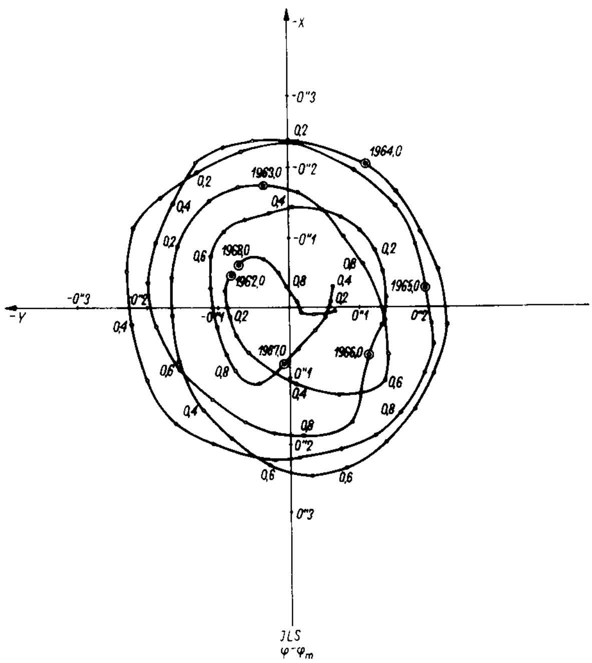

Figure 6c. ILS Polodia computed from $\theta-\theta_m$ data in 1962-1968.

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These experimental results show that the influence of mean latitude variations on ILS polar motion is noticeable due to the large variation of mean latitude of 5 ILS stations (Figure 3), and small number of stations. Computations of ILS polodia from $\theta-\theta_m$ data (the BIH practice) could improve the ILS results. We have only one set of ILS data for polar motion determination in the past. Some improvement of their accuracy can be achieved by improvements of processing these data.

The definitions of the CIO and the reference pole of the BIH, 1968, system are accidental in some respects. The choice of the location of the ILS stations was made at the end of the last century with little knowledge of geophysics. BIH, 1968, system was defined on the base of stations participating at the service in the years 1964-1967 without analysis of geophysical properties of station environments, long stability of instruments and their distributions in longitude. Some aspects of the choice of stations used for determinations of polar motion and UT were discussed by Djurovič (1978) and Kołaczek (1978). Now we should consider the establishment of the best astrometric system taking into account present geophysical knowledge and the experience of the BIH and IPMS services.

REMARKS ON PROCESSING OF ASTROMETRIC DATA IN POLAR MOTION DETERMINATIONS

The celestial and terrestrial reference systems based on astrometric observations are the final results of processing these measurements. The reference pole and the zero point defined statistically as the BIH, 1968, system is the result of the adjustment of many individual observations obtained by different methods at many stations and weighted arbitrarily. The same situation exists in the case of the fundamental catalogues FK4 or FK5 (Tucker, Teleki, 1978). The final results are the sum of real physical parameters used in the processing of that data but not enough is yet known. The results are dependent on applied methods of data reduction and on the transformations to the common systems. The final results usually are not free from influences of systematic errors which are complex functions of time and other factors, e.g., temperature, and which cannot be eliminated by purely statistical methods. Applying statistical principles, we must seek to increase the accuracy of individual observations. At present, a common program ought to be obligatory for each participating station. Such a program would describe separately each kind of instrument, would establish uniform observational methods and treatment of instruments and pavilions, would specify determination of critical instrument constants, would detail measurements of important geophysical and atmospheric parameters, and would establish uniform processing of observations.

At present, methods for the basic processing of observational data differ from station to station and are usually not described completely. Observational data are smoothed in different ways, creating arbitrary deformation of data. In transformation of data to one common system an arbitrary system of weights and some empirical corrections are adopted without understanding the physical character of all interfering phenomena. In requiring more accurate data to calculate more realistic parameters of physical phenomena it is necessary to assure homogeneity of methods of data processing. It is constantly accentuated but not fulfilled (e.g., Kołaczek, Weiffenbach, 1974).

New observing techniques promising much higher accuracy of determinations of polar motion and UT open the new epoch in studies of the Earth's rotation. At the threshold of this epoch the Merit Program is being organized in order to compare possibilities of all available techniques and to outline the future plans of regular determination of polar motion and UT. At this moment it is necessary to reopen discussion concerning the practice of the classical astrometric methods in order to improve their accuracy by improving the processing of these data. More attention to all perturbing physical phenomena ought to be paid in astrometric methods as they are in modern techniques.

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NOTE: This work is supported in part by the Smithsonian Institution Foreign Currency Program Grant, No. FR-6-50015.