DERIVATION OF POLE COORDINATES IN A UNIFORM SYSTEM FROM THE PAST ILS DATA

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ABSTRACT

The recomputation of the past ILS observations has been carried out at Mizusawa and partly at Cagliari. Preliminary reduction of the observations at the northern stations has been completed. The coordinates of the pole were calculated preliminarily and were compared with those by Vicente and Yumi (1969, 1970). It is known that the coordinates of the pole in the past ILS reports require considerable corrections which are probably mainly due to errors of the micrometer values. Magnetic tapes of the original observational records and of the individual latitudes are now available on request.

1. DATA

Transformation to machine readable form (cards and magnetic tapes) of the original records of the past ILS observations on the northern parallel of 39°8' has been completed. The stations and the periods are: MIZUSAWA (1899-present), KITAB (1930-present), CARLOFORTE (1899-1943, 1946-present), GAITHERSBURG (1899-1914, 1932-present), UKIAH (1899-present), CINCINNATI (1899-1915) and TSCHARDJUI (1899-1919). Meteorological records and readings of the levels and the micrometer are stored, together with other various notes, on magnetic tapes in a format convenient for reduction.

2. PRELIMINARY REDUCTION

Positions and motions of the stars are taken from the catalog by Melchior and Dejaiffe (1969). Apparent places of the stars are computed after the method by Yumi, et al. (1974). The nutation is based on Woolard's (1953) table for the rotation axis. Instrumental constants other than the micrometer value (level constants, inequality of the micrometer, etc.) are based on those in the past reports of the ILS, since these quantities can not be reproduced anymore, nor can we derive corrections

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to them from the observations. Provisional micrometer values are determined from the past ILS reports taking into account their drastic changes. Corrections to the provisional micrometer values are determined by a new method which is different from the traditional one.

3. ERROR SOURCES

An observed latitude reduced through the procedure mentioned above is considered to include various kinds of errors. The following three are the most important error sources: i) errors of the micrometer value, ii) declination and proper motion errors, and iii) errors in the nutation. Since the three quantities above are closely interrelated, separation of them from one another is one of the most troublesome problems in the course of the reduction. There are two points to be resolved for determining the above three quantities independently.

First, the absolute corrections to the provisional values of the micrometer should be determined instead of the traditional relative ones. The relative correction is expressed as $dM^s - d\overline{M}$, where dM^s and $d\overline{M}$ denote the absolute correction to the provisional micrometer value of the station s and the mean of dM^s averaged over all the stations, respectively. Individual latitudes corrected for the relative micrometer corrections, are affected by $d\overline{M}$ multiplied by the observed zenith distances, which gives rise to spurious non-polar latitute variation common to all the stations. This has made a precise determination of the nutation amplitudes difficult. Furthermore, for the purpose of eliminating the effect of $d\overline{M}$ in the declination and the proper motion errors, the method of successive approximation has been traditionally adopted. Adoption of our new method makes it possible to omit this complicated process.

Second, since one of the important purposes of the project of the recomputation of the past ILS data is in the precise determination of the nutation amplitudes, a new method should be devised for separating the nutation errors from the errors of the star places. If the nutation errors are not taken into account in application of the chain method, derived group corrections are affected by the nutation errors. For example, the semiannual nutation error is absorbed in the position correction and the principal nutation error is absorbed in the proper motion correction if the data span does not cover 18.6 years. Recently, Manabe, et al. (1978) devised a new method for determining corrections to the star places together with the corrections to the nutation amplitudes of arbitrary frequencies. The results of the test calculation with this method proved that both the nutation amplitudes and the corrections to the star places could be determined simultaneously with satisfactory accuracies. We are now intending to extend this method to derive corrections to the star places of all the programme star pairs since 1899 in a uniform system by solving a set of equations with more than one thousand unknowns (more than 500 star pairs and two unknowns for each, that is, position and proper motion corrections).

4. DETERMINATION OF ABSOLUTE MICROMETER CORRECTIONS

Let us explain the method briefly, since details are given in the Vol. XII of the ILS results (Yumi and Yokoyama 1978).

An observed latitude of the station s at the epoch t, $\phi^s(t)$, is expressed as,

$$\phi^s(t) = \phi^s_p(t) - d\delta(t) - D(t)\cdot dM^s(t), \qquad (1)$$

$\phi^s_p(t)$: true latitude including the non-polar common variation,
$d\delta(t)$: correction to the adopted declination,
$D(t)$: observed zenith distance in micrometer turns, which is considered to be common to all the stations for each pair,
$dM^s(t)$: correction to the provisional micrometer value per ½ turn.
Each of the above quantities is considered to be a monthly mean in the following discussions. Let us solve, by the method of least squares, the following equation with two unknowns, $A^s(t)$ and $B^s(t)$, for each of the two or three groups every month,

$$\phi^s(t) = A^s(t) + \gamma\cdot D(t)\cdot B^s(t) \qquad (2)$$

where γ is a normalizing factor to be taken into account if the provisional micrometer value is far from 40"/turn. The number of equations (2), equivalent to the number of pairs in a group is six or eight. One of the solutions $A^s(t)$ has the same meaning as the control latitude (Markowitz 1961), but in a slightly modified way. We deduce the absolute micrometer correction from the solution $B^s(t)$. The quantity $B^s(t)$ can be expressed as

$$B^s(t) = - dM^s(t) - \varepsilon(t). \qquad (3)$$

$\varepsilon(t)$ is a quantity peculiar to each group, since it depends only on $d\delta(t)$ and $D(t)$ of the star pairs in each group. Therefore, $\varepsilon(t)$ can be estimated by the ordinary chain method on the assumption that $dM^s(t)$ does not vary drastically among the evening, intermediate and morning series. The chain method gives the solution in a form,

$$E(t) = \varepsilon(t) - \overline{\varepsilon}(t), \qquad (4)$$

where $\overline{\varepsilon}(t)$ is considered to be the mean of $\varepsilon(t)$ of all of the twelve groups, which is caused inevitably by an application of the chain method. $\overline{\varepsilon}(t)$ is an unknown at present. Combining equations (3) and (4), we have

$$'B^s(t) = B^s(t) + E(t) = -dM^s(t)/\gamma - \overline{\varepsilon}(t). \qquad (5)$$

The observed latitude of equation (1) corrected for $'B^s(t)$ is written as

$$'\phi^s(t) = \phi^s_p(t) - d\delta(t) + D(t)\cdot\overline{\varepsilon}(t)\cdot\gamma. \qquad (6)$$

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For estimating $\overline{\varepsilon}(t)$, we use the reduction to group mean. Assuming that $d\delta(t)$ is not correlated with $D(t)$, we can neglect $d\delta(t)$ included in the reduction to group mean and can infer $\overline{\varepsilon}(t)$. Thus, the effects of the errors of the star places could be eliminated from $B^S(t)$ of equation (3). Through this procedure, the absolute corrections to the provisional micrometer values can be determined independently for each station. The final values of $E(t)$ and $\varepsilon(t)$ which are principally independent of localities are determined from $B^S(t)$ of all the stations. Actually, $E(t)$ and $\varepsilon(t)$ derived for each of the ILS stations independently, agree very well among all the stations. The only exception during all the ILS observations, which gives values of $E(t)$ and $\overline{\varepsilon}(t)$ divergent from the other stations is CINCINNATI from 1912 through 1922. In this period, estimated corrections of the CINCINNATI micrometer show very unstable variations.

Most of the temperature coefficients of the micrometers adopted in the past ILS reports require considerable corrections. Consequently, the past reductions may have yielded spurious annual variation of latitude. The individual latitudes are corrected by a linear interpolation of $dM^S(t)$, first taking into account the corrections to the temperature coefficients.

5. DETERMINATION OF THE CORRECTIONS TO THE STAR PLACES

In order to test whether or not the correction to the micrometer values was done well, corrections to the star places were derived following the traditional method using the reduction to group mean and the group correction, based on the individual latitudes and taking into account the absolute micrometer corrections. Derived results agree generally very well among all the ILS stations. The point to be emphasized from this fact is that the micrometer correction of our method was done quite accurately. If the micrometer correction is not accurate, the correction to proper motion, $d\mu'$, especially will deviate remarkably, since the zenith distances become large due to precession at the beginning and the end of the observing program.

6. PRELIMINARY DERIVATION OF THE COORDINATES OF THE POLE

After applying the reduction to group mean and the group correction, the monthly mean latitudes were calculated, assigning weights by the number of observations. In order to compare with the coordinates of the pole given in the past ILS reports, the preliminary values of (x, y) were calculated with the same combinations of the stations as used in the past calculations. Therefore, (x, y) from 1922.7 through 1934 were derived with the three stations of MIZUSAWA, CARLOFORTE and UKIAH, and the data of CARLOFORTE from 1941 through 1943 were discarded as was done in Vol. IX. The mean latitudes of CINCINNATI and TSCHARDJUI are taken from the Band V. Weights are not assigned for computing (x, y). Although the system of the Melchior-Dejaiffe catalog is different from that of the GC catalog on which the mean latitudes defining the CIO are based, adoption of the presently used mean latitudes does not change the reference system from the CIO.

7. COMPARISON WITH THE PAST RESULTS AND EXPECTED REVISION OF THE POLAR MOTION

In order to estimate how much of the polar motion in the past ILS reports will be revised, our preliminary results were compared with (x, y) by Vicente and Yumi (1969, 1970), the origin of which is the CIO. Values of (x, y) of the present calculation show remarkable differences from those by Vicente and Yumi. Behavior of the differences consists of both irregular variation and an annual one, the amplitude of which sometimes attains 0".04. These differences change their appearance drastically, corresponding to changes of the observing program. It is reasonable to attribute these differences to insufficient micrometer corrections in the past reports, especially for the periods before 1922.7 and from 1935 through 1948 when the micrometer corrections were not applied month by month. Differences in the x component from 1949 through 1954, and those in the y component from 1922.7 through 1934 show remarkable annual variation with an amplitude of about 0".03, although the micrometer corrections were determined very carefully. However, the temperature coefficients during these periods adopted in the past calculations differ considerably from our present determinations. This is the most probable cause for explaining these annual variations in the differences. It is well known that the annual component of the polar motion during these periods shows unusual behavior when compared with other periods. It is thus expected that the annual component of the polar motion will be revised remarkably by the results of the recomputation of the ILS observations, due mainly to the detailed correction of the micrometer values.

Furthermore, there seems to be a sudden change of the system of the polar coordinates around 1918, when CINCINNATI and TSCHARDJUI stopped observations (1915 and 1919, respectively). This may suggest that the mean latitude of these stations require redetermination for defining them in the CIO system.

8. SEPARATION OF NUTATION AND STAR PLACES

Declination and proper motion corrections of all the star pairs observed since 1899 should be determined in a unique system, independent from the nutation. In other words, simultaneous determination of the star places and the nutation is preferable. A test calculation was made for the data during 1935-1954, 1955-1966 and 1967-1977, respectively. The main purpose of the test calculation is to confirm whether the theory by Manabe, et al. (1978) is applicable to the ILS data or not. The semiannual and fortnightly nutation amplitudes were determined with sufficient accuracies from the three group observations, and coincidence with other observational determinations is very good. The principal nutation (with a 18.6-year period), on the other hand, can be determined only from the data during 1935-1954, and the reasults obtained are (Sakai, 1978):

$$\Delta\varepsilon = 9''.199 \pm 0''.0035, \qquad \sin\varepsilon\Delta\psi = 6''.836 \pm 0''.0035.$$

These results may be the most reliable ones at the present stage for the principal nutation, since the data used for this analysis are reduced in a uniform system, the micrometer correction was done absolutely, and the duration of observations covers twenty years. The semiannual nutation can not be determined from the two group observations, because the right ascension covers only four hours each month and it is difficult to separate the nutation error from the position errors of the declination. In the future, we intend to add the further unknowns of the deflection of the vertical due to the luni-solar tidal forces.

9. MAGNETIC TAPES AVAILABLE ON REQUEST

The following magnetic tapes i), ii), iii) are available and magnetic tape iv) is in preparation.

i) Original records of observations with the meteorological data and the level and micrometer readings,
ii) Individual latitudes based on the provisional micrometer values,
iii) Individual latitudes based on the absolute micrometer values determined by the method in section 4 in this paper,
iv) Magnetic tapes iii) corrected for declination and proper motion corrections in the uniform system (now in preparation).

The definitive values of the coordinates of the pole since 1899 based on the recomputation will be published at the XVIIth General Assembly of the IAU, after resolving various problems stated in this paper.

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