62. Local Non-Polar Variation of Latitude

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1. Introduction. The existence of an annual variation of latitude, independent of the polar motion, was first found by H. Kimura in 1902. This term is so-called Kimura's z term. The discussion on the problem, whether the existence of a local variation in latitude which is not common to all the ILS stations is possible or not, has been made by many investigators since 1902. Most of previous discussions, however, have been made on the basis of some assumptions that only one station has a local term and errors in star places used for latitude observations are sufficiently small. Therefore, we could not detect the local non-polar term from the ILS data definitely. Utilizing the ILS data of mean latitudes published by S. Yumi and Y. Wako, the author tried to deduce the local non-polar variation of latitude for each station for the period from 1936 to 1963.

The following principle for the deduction of local non-polar variation of latitude has been adopted. If the observed variation of latitude for each station would contain only the term dependent on the polar motion and z term common to all the stations, a set of consistent values for x, y and z within the range of observational error ought to be obtained uniquely from the solutions either for 5 stations or 4 stations. The differences between these values, if exist, should be eliminated. Among them the coefficients of \( \Delta \phi_i \) for computing z term are always positive and so their contribution factors to the observed variation of latitude are convenient for the study of the local non-polar term. The elimination of the differences between z terms obtained for 5 stations and each combination of 4 stations within the range of observational error lead automatically to an approach to the correct values of x and y for 5 stations and each combination of 4 stations. This means that we have only one instantaneous pole and common z term for any each.

2. Method of Deduction. The variation of latitude at the ILS stations, Mizusawa (M), Kitab (K), Carloforte (C), Gaithersburg (G) and Ukiah (U) are given as follows.

\[
\Delta \phi_i = \phi_{i, \text{obs}} - \Phi_i,
\]

where \( \phi_{i, \text{obs}} \) is the observed value of latitude at the \( i \)-th station and \( \Phi_i \) the mean latitude of the \( i \)-th station referred to the adopted system of
coordinates. In this paper the CIO° is taken as the origin. The coordinates of the instantaneous pole at any epoch, \( x \) and \( y \), are calculated by the following relation for the ILS stations:

\[
\Delta \varphi_i = x \cos \lambda_i + y \sin \lambda_i + z,
\]

where \( z \) is a term independent of the polar motion and common to each station. For the purpose of eliminating the Chandler motion with the period of about 1.2 years and annual motion, we have taken six year running average for \( x \), \( y \) and \( z \). In general the solutions of \( x \), \( y \) and \( z \) for the 5 stations (MKCGU) and for each combination of 4 stations by the method of least squares are written as follows.

\[
x = \sum a_i \Delta \varphi_i, \quad y = \sum b_i \Delta \varphi_i, \quad z = \sum c_i \Delta \varphi_i.
\]

The coefficients, \( a_i \), \( b_i \) and \( c_i \), are the constants which will be given by the distribution of the stations and the following relations hold among them.

\[
\sum a_i = 0, \quad \sum b_i = 0, \quad \sum c_i = 1.
\]

Computed values of \( x_5 \), \( y_5 \) for 5 stations and \( x_4 \), \( y_4 \) for each combination of 4 stations are far beyond the range of observational errors which are estimated approximately as 0.002–0.003 for six year running average of the annual mean values of \( \Delta \varphi_i \). We are unable to explain such large discrepancies between \( x_5 \), \( y_5 \) and \( x_4 \), \( y_4 \), if the observed \( \Delta \varphi_i \) would contain only the components of the polar motion and \( z \) term common to all the ILS stations. Consequently, it is quite reasonable to consider that the observed variation of latitude for each station must include a local non-polar term.

For the deduction of this term we have compared \( z_5 \) from 5 stations with those \( z_4 \) from each combination of 4 stations since the coefficients of this term, \( c_i \), is most adequate for the extraction of a local variation. The results of the comparison are shown in Fig. 1. It is to be noticed that the differences between \( x_5 \), \( y_5 \) and \( x_4 \), \( y_4 \) are very small when the differences between \( z_5 \) and \( z_4 \) are negligibly small. The reason for this fact should be considered as follows. As we have only one instantaneous pole for any epoch, the polar motion should be naturally represented by the same value of \( x \), \( y \) either for 5 stations or each combination of 4 stations. \( Z \) term should be common and the same value for all the stations. Therefore, the differences between \( z \) terms ought to be considered as an indication that local non-polar variation must be included in \( \Delta \varphi_i \).

In order to deduce this variation we have utilized the differences of \( z \) terms as follows.

\[
\Delta z_i = z_5 - z_4 = \sum (c_i - \bar{c}) \Delta \varphi_i
\]

\[
= \frac{1}{2} d\varphi_i(\text{local}) - \frac{1}{2} \sum c_i d\varphi_i(\text{local}) + f_i(d\varphi_i(\text{local}))
\]
where $f_i(d\varphi(\text{local}))$ is a linear formula of $d\varphi(\text{local})$ and sufficiently small in comparison with two other terms. The 2nd term is common to 5 ILS stations. We can use $\Delta z_i^{(i)}$ as the first approximation of a local non-polar variation of latitude for the $i$-th station. Subtracting $\Delta z_i^{(i)}$ from $\Delta \varphi_i$, we obtain

$$\Delta \varphi_i^{(i)} = \Delta \varphi_i - \Delta z_i^{(i)}. \quad (6)$$

Inserting $\Delta \varphi_i^{(i)}$ instead of $\Delta \varphi_i$ in (5), we get $\Delta z_i^{(ii)}$ and so on. The differences of $z$ between 5 stations and each combination of 4 stations can be reduced less than observation errors of $d\varphi_i$, by four times repetition. The results of $\Delta z_i^{(i)}, \Delta z_i^{(ii)}, \Delta z_i^{(iii)}, \Delta z_i^{(iv)}, \sum \Delta z_i = d\varphi_i$ and $\Delta \varphi_i' = \Delta \varphi_i - d\varphi_i$ are to be used for the computation of a correct motion of the mean pole.

3. Meaning of $\sum \Delta z_i = d\varphi_i$. We can obtain the solutions $x', y'$,
\( z' \) by inserting \( \Delta \varphi'_i \) instead of \( \Delta \varphi_i \) in (2), which are the correct polar coordinates with the differences within the range of observational error of \( \Delta \varphi_i^{(3)} \) either for 5 stations or each combination of 4 stations. This means that the extracted part from the observed variation of latitude

\[
\sum_{i}^{IV} dz_i = d\varphi_i \tag{7}
\]

is the local non-polar variation for each station. Curves of \( d\varphi_i \) are shown in Fig. 2, from which we can point out the following facts:

- **Fig. 2.** Local non-polar variation of latitude.

  a) The period of variation is nearly 19 years.
  b) The phases are just the same for Mizusawa and Gaithersburg.
  c) The anti-phases are the same for Kitab and Ukiah.
  d) The variation of Carloforte is very small in comparison with other ILS stations.
  e) The mean values of local non-polar variation for each station are

\[
\begin{align*}
M & \quad K & \quad C & \quad G & \quad U \\
-0^\circ 027 & \quad +0^\circ 013 & \quad -0^\circ 004 & \quad -0^\circ 010 & \quad +0^\circ 018.
\end{align*}
\]

These values correspond to the average drift of each station during
the period from 1900.0 to 1949.5.

The local changes of latitude at the ILS stations, M. K. C. G. U., suggest that there is a rhythmic change of the earth's potential surface. Putting

$$d\varphi_i = u \cos 2\lambda_i + w \sin 2\lambda_i,$$

we can express $d\varphi_i$ as 2$\lambda$-term of the non-polar variation of latitude at the ILS station.

The phase and epoch of the variation of $u$ and $w$ which are shown in Fig. 3 coincide very well with the corrections of the Ephemeris Time with respect to the Universal Time computed by A. Stoyko

$$\Delta(\Delta T) = +0:3426 \sin \Omega - 0:1084 \sin 2(\Pi_1 - \Omega) - 0:300,$$

where $\Omega$ is the longitude of ascending node and $\Pi_1$ the longitude of perigee of the lunar orbit. This fact indicates that the inequality in the mean solar time from the tidal variation in the rotation of the earth with the period of 18.6 years ($\Omega$) just corresponds to our non-polar variation of the ILS station.
This remarkable correspondence indicates that the change in $C$, the principal moment of inertia around the rotational axis of the earth, is closely related to the changes in $(A + B)$, the sum of the principal moments of inertia in the equatorial plane of the earth, under the usual assumption, $\Delta A + \Delta B + \Delta C = 0$, by neglecting compressibility.

At present we are unable to find other correspondences in geophysical data such as changes in gravity, curvature of the earth's potential surface. The changes in longitudes of Paris, Washington, Ottawa, Tokyo, Zi-Ka-Wei and Tashkent observatories which are derived from the Bulletin of BIH, may be considered as some correspondences.

4. Conclusion. The rhythmic non-polar changes in latitude of the ILS stations suggest that there may be a global variation of the earth's potential surface due to the lunar tidal action. H. Kimura investigated the effect of the luni-solar action on the polar motion and suggested the existence of disturbing terms with the period of 18.6 years in $x, y$ coordinates of the polar motion. However, he could not arrive to the definite conclusion. The author has found these disturbing terms in the non-polar local variation in latitude of the ILS stations.

The effect of the variation of the earth's potential surface should be taken into consideration for discussing the continental drift by astronomical observations, the secular motion of the mean pole and the determination of astronomical position when we refer to the level surface of the station.

References