A NEW RESEARCH FOR THE SECULAR POLAR MOTION IN THIS CENTURY

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ABSTRACT. A new research for the secular drift of the Earth's pole was made based on nine long sequences of latitude observations and led to the following conclusions.

1. During this century, the Earth's pole has been moving with a mean rate of about $0''.0016$/yr along the meridian about 70° (W). This drift rate is much less than the $0''.0035$/yr derived from the ILS sequence.
2. Relative to the North American continent, the Ukiah station located on the west coast of the U.S. shows a local drift of about 6 cm/yr northward, which coincides well with that determined by new techniques.
3. Referring to the Europe-Asia plate, the whole North American continent shows a drift northward with a rate of about 8 cm/yr. The Mediterranian shows a similar drift of about 6 cm/yr. Perhaps these drifts are the consequences of plate motion and/or deflection of local vertical. It is useful for ascertaining the sources of the drifts to intercompare longer sequences observed with different techniques, including classical and new ones.
4. Three of five ILS stations, Ukiah, Gaithersburg, and Carloforte, show significant local drifts. Therefore, the Conventional International Origin (CIO), which is defined by the 1903.0 mean latitudes of five ILS stations, is far from fixed on the Earth's surface. It is necessary to re-define an origin of the pole of the Conventional Terrestrial System (CTS).
5. The quasi-30-year libration showed by the ILS data is not the real pattern of the Earth's polar motion, but results from both the irregular polar motion over some period and the local motion of Ukiah.

1. INTRODUCTION

So far, the main conclusion on the secular polar motion is that in this century the Earth's pole has a drift with a rate of about $0''.003$/yr in the direction near the meridian of 70° (W) and a quasi-30-year libration[1−14]. The existence of secular polar motion led to the resolution of IAU Symposium No. 32, held in 1967 [15], in which the CIO was defined.

It has not been ascertained whether this secular polar motion is real or apparent because of the paucity of ILS stations. In some periods, only three ILS stations were in operation. The secular polar motion of the ILS obviously must be affected by the local latitude variation of any one of these stations. The number of ILS stations is too small to allow different station combinations in order to separate the local latitude variations from the polar motion.

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Therefore, more latitude sequences are necessary.

2. THE SECULAR VARIATIONS OF LATITUDES

In this work, nine longer latitude sequences including those of five ILS stations have been collected. The information about them is shown in Table I.

Table I. Information about latitude sequences used in this paper.

No	station	Inst.	code	Duration	a	b	$\sqrt{P}$	Long.
1	Mizusawa	VZT	MIZ	1900-1978	3″.6630	−0″.00138	1.44	141.13
2	Mizusawa	FZT	MIF	1943-1978	3.5228	−0.00106	0.52	141.13
3	Kitab	VZT	KIT	1930-1978	1.9371	−0.00089	0.85	66.88
4	Pulkovo	VZT	PUZ	1904-1978	17.1194	−0.00078	0.98	30.33
5	Carloforte	VZT	CAR	1900-1978	9.0180	0.00242	1.28	8.31
6	Greenwich	FZT	GRF	1911-1936	0.0048	0.00126	0.62	0.34
7	Washington	PZT	WAP	1915-1978	17.1415	0.00429	1.02	−77.07
8	Gaithersburg	VZT	GAI	1900-1978	13.3004	0.00419	1.27	−77.20
9	Ukiah	VZT	UKI	1900-1978	12.1408	0.00558	1.54	−123.20

In this table, a and b are the parameters of the linear expression

$$\phi(t) = a + b(t - 1903.0)$$

where ϕ is the observed latitude. P is the normalized weight of b, determined by

$$P = P_1 \times P_2.$$

$$P_1 = 1/\sigma^2, \text{ and } P_2 = DT,$$

where σ is the noise level of the latitude sequence and DT is the observation duration.

3. ANALYSIS OF THE LINEAR TERM OF LATITUDE

In Figure 1, the distribution in longitude of rate b of the latitude sequences is shown. It is obvious that the distribution is systematic. The differences among b values are small for stations in the same region and significant for those in different regions, which suggests that observational error is not a primary element of b. The rate b of a sequence may include the following parts:

$$b = b_p + b_s + b_c \tag{1}$$

where (1) b_p is the part caused by the drift of the pole, which is related to secular polar motion $\dot{X}$ and $\dot{Y}$ by the equation

$$b_p(i) = \dot{X}\cos L_i + \dot{Y}\sin L_i. \tag{2}$$

Here L_i is the west longitude of the station. When equation (2) is substituted into

$$\dot{X}\cos L_i - \dot{Y}\sin L_i + \dot{Z} = b_s \tag{3}$$

the result $\dot{Z} = 0$ should be obtained.

(2) b_s is the part caused by the local drift of the station, which is independent of secular polar motion. When this b_s is substituted into equation

$$\dot{X}\cos L_i - \dot{Y}\sin L_i + \dot{Z} = b_s(i) \tag{4}$$

generally, $\dot{X} \neq 0, \dot{Y} \neq 0$, and $\dot{Z} \neq 0$ should be obtained and the $\dot{X}, \dot{Y}$, and $\dot{Z}$ are the apparent rates caused by the local drifts of the stations.

(3) b_c is the part caused by the mean systematic error of proper motion of declination. For ILS stations there is

$$b_c(i) = b_c = constant.$$

When such a group of b_c is substituted into equation

$$\dot{X}\cos L_i - \dot{Y}\sin L_i + \dot{Z} = b_c(i)$$

the solution $\dot{X} = 0, \dot{Y} = 0, \dot{Z} = b_c$ should be obtained.

In Table I, it is shown that the values of b of ILS stations are far from a constant. In fact, so far no significant error with such form has been found to exist in the proper motion system of fundamental catalogues. Therefore, the b_c can be neglected. Then there are

$$b(i) = b_p(i) + b_s(i) \tag{5}$$

and

$$\dot{X}\cos L_i - \dot{Y}\sin L_i + \dot{Z} = b(i) - b_s(i). \tag{6}$$

Given b_s, $\dot{X}$ and $\dot{Y}$ can be solved for with equation (6). Meanwhile, the solved $\dot{Z}$ should be null if the given b_s are appropriate. Therefore, $\dot{Z} = 0$ can be regarded as the restraint condition for solving equation (6).

4. EVALUATION OF THE DRIFT PARAMETERS OF THE POLE

4.1. Evaluation 1

Using the b of ILS, and letting $b_s(i) = 0, (i = 1, 2 \ldots 5)$, equation (6) can be solved and the solutions

$$\dot{X}_1 = 65, \dot{Y}_1 = 345, \dot{Z}_1 = 187, S_1 = (\dot{X}_1^2 + \dot{Y}_1^2)^{\frac{1}{2}} = 351,$$

$$sita_1 = \arctan(\dot{Y}_1/\dot{X}_1) = 79°(W)$$

$$\sigma_1 = 129, \text{(all numbers in units of } 0''.00001)$$

can be obtained. Where σ_1 is the standard deviation for unit weight of $b(i)$. These drift parameters of the pole coincide well with those given by other authors in the past [1–6]. However, for this evaluation, $\dot{Z}$ is far from null. This suggests that the $\dot{X}$ and $\dot{Y}$ are obviously affected by the local drift of some ILS stations.

4.2. Evaluation 2

Using the b of all nine sequences and supposing $b_s(i) = 0, (i = 1, 2, \ldots 9)$, the solution of equation (6)

$$\dot{X}_2 = 25, \dot{Y}_2 = 361, \dot{Z}_2 = 163,$$

$$S_2 = 362, sita_2 = 89^\circ(W), \sigma_2 = 121$$

can be obtained. For both evaluations above, $\dot{Z}_1$ and $\dot{Z}_2$ are significant. This suggests that the supposition of $b_s(i) = 0$ is not appropriate.

4.3. Evaluation 3

According to the determination with SLR[16], it is known the west coast of the U.S. shows a drift of about 6 cm/yr northwards relative to the North American continent. Therefore, subtracting this drift of 6 cm/yr = 0″.002/yr, the rate of Ukiah should be b(9) = 0″.00358/yr instead of 0″.00558/yr. Then the three U.S. stations can be regarded as on the same plate. Their rates should be

$$b(7) = 0''.00429/\mathrm{yr} \text{ (of Washington)}$$

$$b(8) = 0''.00419/\mathrm{yr} \text{ (of Gaithersburg)}$$

$$b(9) = 0''.00358/\mathrm{yr} \text{ (of Ukiah)}$$

Obviously, comparing them with the stations on the Eurasian plate, the three U.S. stations show a common larger drift rate. Let

$$b_s(7) = b_s(8) = b_s(9) = d$$

and

$$b_s(i) = 0, (i = 1, 2, \ldots 6).$$

It can be seen from Table I that the Carloforte station has a large rate of b(5) = 0″.00242/yr, which is obviously different from those of stations located on the Eurasian plate. It may be caused by the position of the station on the joint of the African and Eurasian plates. We do not have the accurate parameters of its drift determined with new techniques. Therefore, we have to let p(5) = 0.

In this case, given a value of d, a group of drift parameters of the pole can be obtained. Taking $d = 265$, the drift parameters are

$$\dot{X}_3 = 52, \dot{Y}_3 = 150, \dot{Z}_3 = 0$$

$$S_3 = 159, sita_3 = 71^\circ(W), \sigma_3 = 32 = min.$$

The simultaneity between $\dot{Z}_3 = 0$ and $\sigma_3 = min.$ is very interesting. It suggests that by removing the local drift of 0″.00265/yr of the American stations, the rates of mean latitudes of all stations can be explained well by a linear drift of 0″.00159/yr of the pole. We think, therefore, this result is more believable than the past result of 0″.003/yr.

5. ON THE LIBRATION OF THE POLE

Based on the data of ILS, a libration of the pole with a quasi-30-year period and an amplitude of about 0″.03 was found by some authors[7–11]. In this paper, we try to ascertain

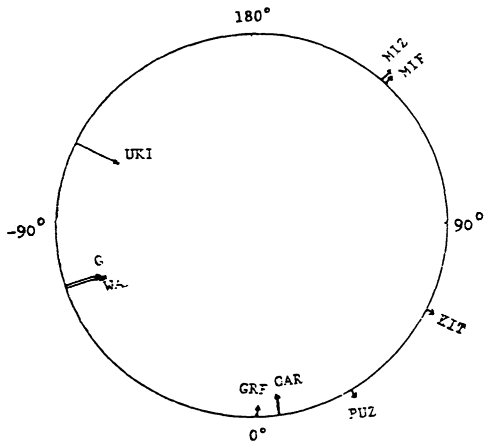

Fig. 1 The distribution of the drift rates of the stations in longitude

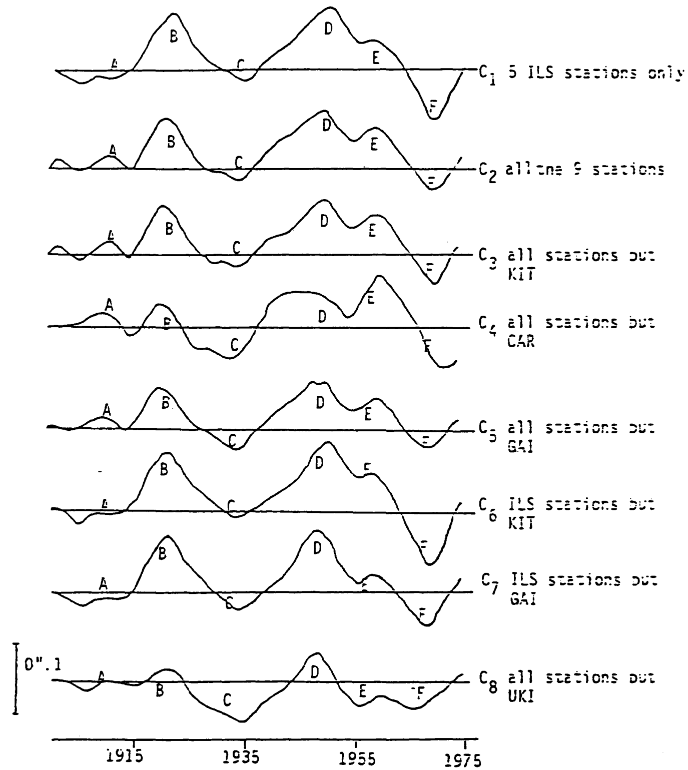

Fig.2 The shapes of the decades fluctuations of x-component based on different combinations

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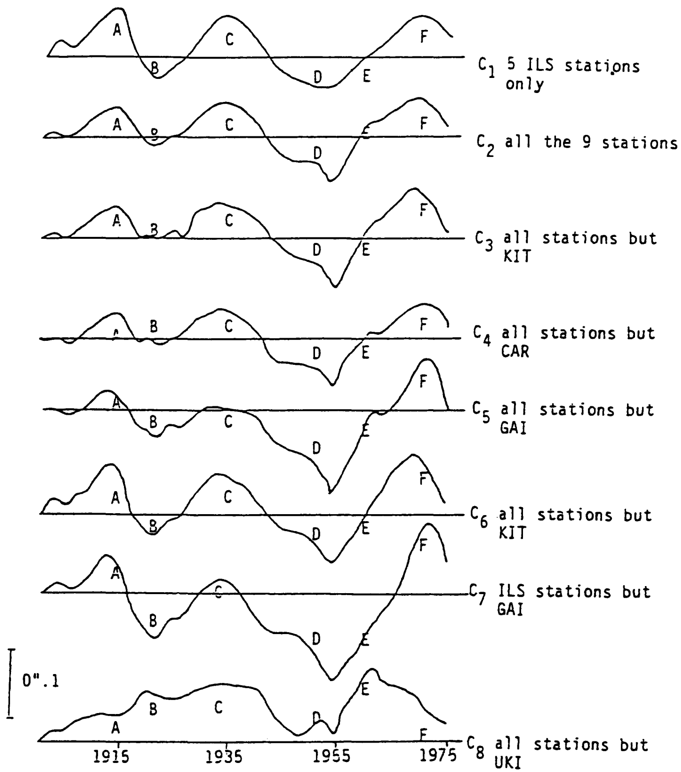

Fig. 3 The shapes of the decades fluctuations of y-component based on different combinations

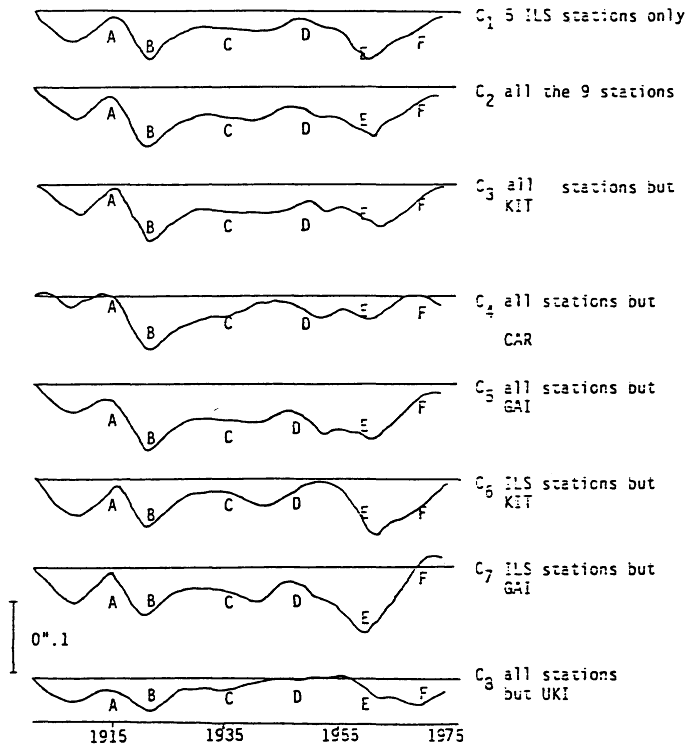

Fig. 4 The shapes of the decades fluctuations of z-component based on different combinations

whether the libration is true or false. By removing the linear tendency of the nine latitude sequences and filtering their high frequency fluctuations, the decade fluctuations of the latitude sequences were obtained. Then, based on different combinations of the filtered sequences, the X, Y and Z, which have decade fluctuations only, can be obtained. The aspects of X, Y, and Z by different combinations are shown as Figures 2, 3, and 4, respectively, on which sections A, B, C, D, E, and F are their main fluctuations. In these figures, curve C_1 shows ILS polar motion. It shows a significant quasi-30-year fluctuation. Comparing C_1 with other curves, it is found that

1. In Figures 2 and 3, the shapes of sections A,B,E, and F of $C_1 - C_7$, which entirely include the Ukiah station, are similar to each other. On the contrary, these sections of C_8, which does not include Ukiah, are very different from those of $C_1 - C_7$. These suggest that the fluctuations of section A,B,E, and F are caused by the local latitude variation of Ukiah.
2. The amplitudes and shapes of section C and D of all curves $C_1 - C_8$ in Figures 2 and 3 are similar to each other, which suggests that these sections depend on station combinations. They are real polar motion.
3. In Figure 4, sections C and D do not have significant fluctuations for all combinations $C_1 - C_8$. Meanwhile, sections A,B,E, and F have similar fluctuations for all combinations except C_8. These also suggest that the fluctuations C and D are caused by real polar motion, and A,B,E, and F are caused by the local variations of the Ukiah station. Therefore, it can be concluded that the quasi-30-year libration included in ILS polar motion is not real regular polar motion. It is only an accidental mixture of both irregular polar motion in some period and the local variation of latitude of the Ukiah station.

6. CONCLUSIONS

1. In this century, the Earth's pole has been drifting with a mean rate of $0''.00159$/yr in the direction of the 71° (W) meridian. This rate is much less that $0''.0035$/yr evaluated by ILS only.
2. Referring to the Eurasian plate, the whole North American continent shows a relative mean drift of about 8 cm/yr in latitude towards north.
3. The quasi-30-year libration of the pole, which was included in the ILS data, is not real regular polar motion but only an accidental mixture of both the irregular polar motion in some period and the local latitude variations of the Ukiah station.

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