

ON THE OBLIQUITY OF THE ECLIPTIC

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1. Introduction

This study was originally motivated from the discussion of the obliquity of the ecliptic, ϵ , in the work of Needham (1959) and his collaborators, and the article, "An 8-th Century Meridian Line," by Beer *et al.* (1961). A search in the historical records yields values of ϵ in addition to the published values in the literatures.

The gnomon-shadow lengths of the sun at noons on the solstitial days as recorded in the Chinese Annals were collected. Each summer-winter pair was used to compute the latitude of the observing site and the value of ϵ . The values of ϵ , determined in the Orient and in the Occident, are used to show the variation of ϵ in the three thousand years of recorded history.

2. The Observations

The heights of the Chinese gnomon were given as 8 *chi*; except the 9-*chi* gnomon used for the first listed set of observations at Jiankang, and the 40-*chi* gnomons used in Beijing. The calculated values are not corrected for the effects of atmospheric refraction and local height from the sea level. They are listed in Table 1. Column 2 lists the places of observation, column 3 the calculated values of latitudes and obliquity, column 4 the altitude of the sun at noon of the summer solstice. The latitudes and longitudes in the last column were copied from the *Gazetteers* of the U. S. Office of Geography, except those of Gaocheng which were measured in the twentieth century for the gnomon of the Duke of Zhou (*d* 1036 *B.C.E.*). This monumental stone gnomon was erected by the astronomer royal Nangong Shuo in 723 *C.E.*. In Table 1, the angles are given in degrees, and the latitudes and longitudes are measured to the north and to the east, respectively.

The land of the State of Linyi has been known to China since the Han dynasty. Its capital is said to be near the ancient city of Hue. The value of 0.57 *chi*, which is recorded in the *Tang Annals* for gnomon-shadow length as measured by Da Xiang and Yuan Tai in Linyi on the summer-solstice day, does not appear to be correct. Instead, the value of 0.91 *chi*, which was obtained after a military campaign of Liu Song against Linyi in 433 *C.E.*, is used here. The land of Tiele was known as the land of Xiongnu in the Han dynasty. The calculated latitude of the place is not as far north as that of Lake Baykal. On his journey to Samarkand, the Taoist Qui Chu-ji measured the gnomon shadow of the sun on the summer-solstice day along the shore of the Kerulen river. The longitude of the place of the observation is estimated to be about 112°E according to the event written in *The Journey West* by Li Zhi-chang.

The correlation between the calculated latitudes and the geographic latitudes of the modern cities is an indication of the accuracy of the calculated values, including ϵ . Using the regression analysis, one finds that $Latitude_{calc} = 1.055 + 0.961 \times Latitude_{geo}$, with the correlation coefficient of 0.998. Similarly, one obtains that $Latitude_{calc} = 23.596 + 1.003 \times alt.\odot$, with the correlation coefficient of 1.000.

Other published values of ϵ are collected and listed in Table 2. Again, the latitudes and longitudes in the last column are from the *Gazetteers*, except that of the first entry, in which the values were derived from *Artha-sastra* (ref. Y. Ohashi's article in this *Joint Discussion*).

TABLE 1. Chinese Records with Gnomon Measurements

Year	Place	Latitude/Obliquity	Altitude \ominus	City	Lat./Long.
<i>ca</i> 1100 <i>B.C.E.</i>	Yangcheng	34.51/23.89	79.38	Gaocheng	34.41/113.14
442 <i>C.E.</i>		–	79.38		
724		34.15/23.68	79.52		
822		34.16/23.69	79.53		
1024		34.15/23.68	79.53		
442	Jiaozhou	–	87.85	Hanoi	21.03/105.85
442 <i>C.E.</i>	Linyi	–	83.51	–	–
<i>ca</i> 300 <i>B.C.E.</i>	Luoyang	35.05/23.73	78.69	Luoyang	34.68/112.47
115-120 <i>C.E.</i>		34.51/23.89	79.38		
508		–	78.83		
581-584		34.24/23.76	79.52		
596-597		33.94/23.69	79.73		
544	Jiankang	31.90/23.55	81.67	Nanjing	32.05/118.78
544		–	81.66		
721-725	Linyi	17.14/23.63	85.93	–	–
	Jiaozhou	21.21/23.57	87.64	Hanoi	21.03/105.85
	Langzhou	29.14/23.64	84.50	Changde	29.03/111.68
	Caizhou	33.24/23.74	80.35	Runan	33.02/114.37
	Xuzhou	33.83/23.62	79.80	Fugou	34.07/114.38
	Bianzhou	34.46/23.63	79.17	Kaifeng	34.85/114.35
	Huazhou	34.75/23.65	78.90	Huaxian	35.58/114.50
	Weizhou	39.63/23.65	74.03	Weixian	39.80/114.40
	Tiele	51.01/23.70	62.70	–	–
	Henanfu	34.18/23.63	79.45	Luoyang	34.68/112.47
1049-1052	Junyi	34.60/23.48	78.88	Kaifeng	34.85/114.35
1064		34.60/23.50	78.90		
1092		34.60/23.50	78.90		
1106		34.55/23.51	78.97		
1221	Kerulen R.	–	65.47	–	–
1277	Da Du	39.86/23.54	73.68	Beijing	39.93/116.40
1368 <i>C.E.</i>	Beijing	39.85/23.54	73.68		

TABLE 2. Other Oriental Records

Year	Obliquity	Place	Lat./Long.
<i>ca</i> 300 <i>B.C.E.</i>	23.7	India	23.7/–
230 <i>B.C.E.</i>	23.86	Alexandria	31.20/29.90
830 <i>C.E.</i>	23.56	Baghdad	33.30/44.60
832	23.55	Damascus	33.50/36.25
869	23.55	Baghdad	33.30/44.60
880	23.58	ar Raqqah	36.00/39.00
970	23.58	Shiraz	29.60/52.53
970	23.58	Cairo	30.05/31.25
987	23.58	Baghdad	33.30/44.60
994	23.54	Shahr Rey	35.58/51.42
1009	23.58	al-Mugattam	30.03/31.28
1259	23.50	Maragha	37.33/46.38
1424 <i>C.E.</i>	23.52	Samarkand	39.40/66.58

3. The Saeculum of Decline

A 2-degree polynomial is used to express the secular variation of the values of ϵ as listed in Tables 1 and 2, together with the value of 23.439° for the epoch 1976.0. Using the method of least squares,

one find that $\epsilon = 23.73757813 - 0.00014623 \times T - 0.00000001 \times T^2$, where T is the number of years elapsed since the first year *C.E.*. The quantity, defined as *the unexplained variation/the number of degrees of freedom* and called β here, is equal to 0.00341321. If the values of Ptolemy and Copernicus, and the 27 occidental observed values (Wittmann, 1984) are used together with the 38 oriental values and the 1976 value, one obtains the 2-degree polynomial with the use of the method of least squares $\epsilon = 23.73989867 - 0.00015320 \times T$, which is a linear function representing the secular decline in the value of ϵ at the rate of 0.01532° per century. The value of β is 0.00235874.

References

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