USE OF EQUAL ALTITUDES INSTRUMENTS FOR ACCURATE DETERMINATION OF LATITUDES (1)

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1. Because of its extremely slight amplitude, the *polhodie* (tractrix curve) of the earth's axis can be studied in empirical fashion by means of latitude observations only if this coordinate is measured with a high degree of accuracy.

To this end methods that eliminate as largely as possible the various causes of error usually encountered in determining zenith distances are used. The use of graduated circles for angle measurements is the first thing to be avoided ; errors of refraction and those due to instrument warping are next largely eliminated, and finally as accurate a connection as possible of the star sight with the observer's vertical is attempted.

2. The Talcott-Horrebow method meets all these conditions, but it is interesting to note that equal altitudes instruments do likewise.

The essential asset of these instruments, of which the prismatic astrolabe is the most wide-spread, is that they maintain the most constant instrument altitude obtainable, which requires great stability of the angle defined by the instrument's optical device as well as accurate verticality. This latter requirement is generally met by using a mercury pool, which is a more accurate method than the use of a spirit level. As to the instrumental angle usually defined by means of prisms or crossed mirrors, instrument-makers manage to obtain almost absolute rigidity within ordinary limits of temperature. Owing just to the constant altitude observation method, the instrument's position with reference to the vertical does not vary ; its mechanism distortion may be considered as being absolutely constant and does not interfere in results. Practically the same conditions apply as regards refraction where variations due to changes in temperature and pressure during observations must alone be considered ; these variations are very slight owing to the relatively high value of 60 degrees generally used for instrumental altitude.

3. With equal altitudes instruments, it is practically impossible to carry out observations directly on the meridian ; however, the observation of stars passing near the meridian is of primary importance in determining latitudes. In practice stars crossing at instrumental altitude 30 or 40 degrees from the meridian also contribute efficaciously to the determination of this coordinate ; as these stars are more numerous than the circummeridian stars, it is possible to obtain by using them a fairly large number of transits in a relatively short time. This is of course interesting from the point of view of random errors and variations in refraction ; besides, by covering a sizeable area of sky, a certain amount of compensation is achieved bewteen the coordinates of stars as supplied by tables, which sometimes show systematic zone errors.

4. Owing to facilities of transportation, speed of installation, and convenient operation, equal altitudes instruments have been considered as designed for use in the field and at temporary observatories rather than at a permanent station. Few methodical experiments have been made, therefore, to test the extreme accuracy that can be obtained with these instruments ; little research has occurred for the development of their accuracy and to fit them for use in important observatories concurrently with transit instruments.

Mention should however be made of the large type of Jobin prismatic astrolabe with a 61 millimetre aperture and × 150 magnification, which was set up in 1916 at the Paris Observatory and which our regretted colleague and friend, Madame Chandon, used for

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(1) Address at a meeting on *Latitude Variation* on 18th December, 1947.

many years in making numerous and remarkable observations. Impressed by the excellent correspondence between individual latitude values obtained, as early as 1917, she was the first to consider the possibility of using these observations in investigating latitude variation.

The 1926 and 1933 international revisions of longitudes also supply interesting data on the accuracy of determinations by prismatic astrolabe, since it was used at the same time as transit instruments at the basic stations in Paris, Algiers, San Diego, and Zi-Ka-Wei and since a large number of observations were made during the two-month period of each revision.

5. We have not had time to hunt up and to debate results obtained at each station where many observations of equal altitudes were made during a comparatively short period — we particularly regret that we are unable to cite M. Fayet's interesting work — but the figures we are quoting, relating to three observatories, seem sufficient for appraisal of the accuracy obtained.

I. — **PARIS OBSERVATORY** - Observer : M[me] CHANDON.
Jobin Prismatic Astrolabe, large model
(61 mm. object lens ; × 150 magnification).

		DATES			
		31st May to 7th Aug. 1916	October 1926	November 1926	October and November 1926
Number of series		19	13	10	23
Latitude	Intervals of extreme values	0",48	0",56	0",48	0",57
	Arithmetical means 48° 50'	9",58	11",45	11",46	11",45
Differences from the mean	Mean differences	0",12	0",16	0",15	0",16
	Number of differences under or equal to .... 0",1.	8	7	3	10
	d° 0",2.	16	7	6	15
	Other differences	All < 0",3.	All < 0",3.	All < 0",3.	All < 0",3.

The 1926 station position was different from the 1916 position. The 1916 mean latitude referred to the 1926 position is 11"43. The last column combines figures obtained for the two months in the two preceding columns. All observation series involved an average of forty stars. The Cauchy-Tisserand method of computation was used.

II. — **TOULOUSE OBSERVATORY** - Observer : M. BERTHOMIEU.

			DATES		
			28th July to 7th Dec. 1934	7th June to 30th July and 18th Oct. 1935	
Instrument			JOBIN Geodesic Mod.	S.O.M. Geodesic Mod.	Series involved from 30 to 40 stars. There were generally two series per observation night. Solutions were reached by the position line plotting method.
Object lens			40 mm.	53 mm.	
Magnification			54	71	
Number of series			11	21	
Latitude	Intervals of extreme values.		1",65	1",35	
	Arithmetical means 48° 50'.		45",67	45",62	
Difference from the mean	Mean differences		0",33	0",25	
	Number of differences under or equal to	0",1.	2	6	
		0",3.	6	14	
	Other differences		3 ⩾ 0",5	1 > 0",5	

III. — **TEMPORARY OBSERVATORY AT SAN DIEGO** - Observer : M. GOUGENHEIM.
(Date : October-November 1933).

		INSTRUMENTS.			
		S. O. M. Geodesic Model 53 mm. × 80	S. O. M. Large Model 80 mm. × 120	Previous two columns	S. O. M. Large Model (Last 31 series)
Number of series		7	39	46	31
Latitude	Intervals of extreme values	0",56	1",43	1",43	0",90
Latitude	Arithmetical means 32° 42'	34",84	35",00	34",97	34",99
Difference from the mean	Mean differences	0",11	0",19	0",19	0",13
Difference from the mean	Number of differences under or equal to 0",1.	4	19	15	17
Difference from the mean	Number of differences under or equal to 0",2.	6	25	30	24
Difference from the mean	Other differences	All < 0",4.	2 > 0",5	2 > 0",5	All < 0".5.

Each series involved about sixty stars and was treated by the least squares method. The first eight series using the large model of astrolabe were made under less favorable observation conditions than those which followed (bad weather, wind and clouds, and adjustment of the recently received instrument). The last thirty-one series, which took thirty-three days and of which twenty-nine were consecutive, have therefore been considerd separately in the last column.

6. The foregoing tables definitely show that the large type of astrolabe corresponds to a marked increase in accuracy of determinations.

If consideration is given to the fact that most of these observations were not undertaken for the purpose of obtaining latitudes, and if it is borne in mind that the individual latitude values supplied by each series are independent from one another, the results shown lead to the belief that with slight improvements in the instruments and methods of observation, equal altitudes instruments, particularly prismatic astrolabes, may well compete in the determination of latitudes with a maximum of accuracy.