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COMMUNICATION FROM THE OBSERVATORY AT LEIDEN.

A discussion of the determination of declinations from azimuth measures made near the equator, by *C. Sanders* and *J. H. Oort*.

The following is an account of azimuth observations made at Matuba, Cabindæ, Portuguese Congo, with the special purpose of determining declinations free from refraction. Although it is realized that the possibility of a small refraction in azimuth should not be dismissed, there seems little doubt about the importance of the determination of a set of declinations independent of any errors in the vertical refraction, and with an instrument in all respects different from the meridian circle, especially now that KAPTEYN and others have drawn attention to the serious consequences of our uncertainty about the systematic errors of the declinations in the existing fundamental catalogues. The great perfection of the modern meridian circle and the apparent difficulty of reaching a comparable stability in any other type of instrument, may be the reason why, with the exception of some observations in the prime vertical, all fundamental determinations of declination have been made by meridian circles. Yet, as far as declinations only are concerned, the meridian circle has two considerable disadvantages, owing to the fact that different declinations are observed at different zenith distances, where flexure of the telescope and the circles, as well as atmospheric refraction are different. These difficulties do not exist with the altazimuth observations described below, as different zones of declination are measured at the same zenith distance.

The method.

A description of the method may be found in *The Observatory*, **40**, 271, 1917 *). It consists in measuring azimuths and zenith distances near the horizon. Could we measure *at* the horizon, and from a station on the equator, we should find the absolute declinations from the azimuths independent of uncertainties in the zenith distance or in the latitude of the station. As it is, it does not seem advisable to measure at zenith distances larger than 80°, and the average zenith distance for the measures treated in this paper is only 67°. But even then with suitable stars the errors in the zenith distances and the adopted corrections for refraction have only a negligible influence on the computed declinations. The declination is computed by the formula

$$\sin \delta = \sin \varphi \cos z - \cos \varphi \sin z \cos A.$$

The influence of small errors in φ, z and A on the declination is shown by the differentiated formula

$$d\delta = \cos t \, d\varphi - \cos q \, dz + \sin z \sin q \, dA$$

in which t is the hour angle and q the parallactic angle between the great circle through the star and the North pole and that through the star and the zenith, counted clockwise from the pole.

For Matuba, 5°17′ South, the coefficient of dz is smaller than one tenth from $-26°$ to $+1°$ declination, when working at a zenith distance of 67°. The coefficient of $d\varphi$ assumes higher values however, the average being about 0.35. Therefore the uncertainties due to latitude variation, or to ignorance of the amount of systematic error in the declinations used for the determination of the latitude, enter only to a third of their amount.

The instrument used is a "broken" altazimuth theodolite by SARTORIUS. *) It has 54 mm. aperture, a focal length of 65 cm., and circles of 35 cm. diameter. The axis cannot be reversed.

The graduation of the circles.

The circles show four-minute graduations and are read by two microscopes to seconds, and estimated to tenths. Only a very preliminary investigation of

*) See also *The Observatory*, **42**, 90, 1919.

*) From 1917 to 1919 a series of rather concordant observations of latitude variation was obtained with the same instrument. An account of these observations, together with a description of the instrument, may be found in *Monthly Notices R. A. S.* 80, 455, 1920.

the errors of graduation has been made, there being no opportunity for a thorough determination of them in Matuba. Because of their great importance in the discussion of the present results we give a short account of what has been done:

For every ten degrees careful measures were made by both microscopes of two adjacent divisions of the circle. Calling the reading at the first microscope A, at the second B, it is possible to get some idea of periodic and accidental errors of graduation by plotting the differences $B—A$ against the circle readings, z. After subtracting the constant angle between the two microscopes and correcting for excentricity, the residuals for the horizontal circle are as shown in the following table.

TABLE 1. Errors of graduation of the azimuth circle.

z	Res.	z	Res.	z	Res.	z	Res.
°	″	°	″	°	″	°	″
0	+ 0.7	90	+ 0.4	180	— 1.5	270	— 0.7
10	+ 0.6	100	+ 0.2	190	— 1.7	280	+ 0.8
20	+ 0.1	110	+ 0.4	200	— 0.8	290	— 0.6
30	— 0.2	120	— 0.4	210	+ 0.8	300	— 0.3
40	— 0.2	130	— 0.6	220	— 0.5	310	+ 0.2
50	— 0.7	140	0.0	230	— 0.3	320	+ 0.2
60	— 0.8	150	— 1.1	240	+ 0.7	330	— 0.2
70	— 0.3	160	+ 2.1	250	+ 0.5	340	— 1.2
80	+ 0,1	170	+ 1,3	260	+ 0.8	350	0.0

The mean error is ± 0″.81, whereas, the mean error of *measurement* of a difference $B—A$ is found to be ± 0″.53. The only probably real discordance shown by the table is from 150° to 190°, where five out of the six residuals larger than 1″ are crowded together. There is evidence that these large residuals around the azimuth 170° have something to do with the manner in which the circle was graduated. As at each z the distance to two consecutive graduations has been measured, we have a means of comparing the "run" at different parts of the circle. It appears that this run is constant, except at 170°, where the distance to the graduation 170°4′ is about 2″.6 above the average. In the same manner a point was found on the vertical circle where the run was 5″.8 above the average. *) It seems probable that these two exceptional deviations indicate the points from which the graduations were started. The two residuals were therefore treated as closing errors, and were equally divided over the circles and applied as corrections to the readings.

*) For the vertical circle the run has also been measured at nearly 400 points but nowhere an irregularity like the one found at 350° was indicated.

As the measured azimuths lie roughly between 274° and 296° in the East, between 64° and 86° in the West, the irregularities near 170°, shown in Table 1, do not influence the results. The influence of the graduation correction mentioned is small. If it were omitted the mean differences given in Table 3 would only be increased by + 0″.08 for the first 7 groups and by + 0″.02 for the last 4 groups. The residuals for the separate stars in Table 4 would be changed by + 0″.18 for the most southern star, and would remain unchanged for a star near the equator.

The position of the instrument and the corrections applied to the observations.

The instrument is mounted about 110 meters above sea level on a pier composed of cement and masoned bricks extending 3.5 m. below the surface. The upper surface of the pier, on which the instrument rests, is about 2.8 m. above the ground and 1.35 m. above the floor of the observing shed. The lower part of the pier is surrounded by a brick wall entirely isolated from the pier itself; the upper part is protected by a wooden wall; the space between it and the pier is filled up with loose sheets of paper. The roof of the shed can be shifted off towards the South.

A window in the Eastern wall of the shed allows observation of an azimuth mark. The mark is painted on an old wall about 995 m. away and can still be measured at the stellar focus. As a rule zenith point, collimation and correction to the zeropoint of the azimuth circle were determined by means of this mark in the late afternoon as well as in the early morning, and had to be interpolated for the time of observation as it was not practicable to illuminate the mark during the night. It was found that the changes in zenith point and collimation depend primarily upon temperature changes; they were therefore interpolated between the afternoon and morning values to correspond with the temperature at the time of observation. The collimation ranges from 3″ to 5″, one degree C. rise of temperature corresponding to a decrease of 0″.26. The zenithpoint was further corrected by means of an alhidade level read in each position of the instrument. One division of this level equals 2″.22.

The azimuth reading of the mark was supposed to change gradually with the time from evening to morning and was interpolated accordingly. Usually the mark was observed three times in each position. When the atmosphere is steady the mean error of one observation is only about 0″.4, but on some days deviations of over 1″ occur, apparently not of instrumental origin. In several cases the different observations of a star could have been made to agree better by assuming that the zero point of the horizontal circle had remained constant.

The azimuth of the mark was assumed to be 269°45′ 28″.51. In October 1923 a new mark was painted, and after careful measurement of the distance to the old mark was taken into use on November 7th with an assumed azimuth of 269° 48′ 31″.60. It appears from the observations that both these azimuths are about 1″.00 too mall, but it is an easy matter to apply the correction in the derivation of the results. In March new trouble with the azimuth mark arose as the old wall on which it was painted was taken down. A new wall and mark could not be secured before the middle of April, and the observations from March 23 to April 9 had to be reduced on the assumption of a constant position of the azimuth circle. The assumption is not very dangerous to our results, for observations East and West were regularly mixed, the average being therefore practically independent of the zero point.

On the whole the position of the instrument has been remarkably stable: thus e. g. from February to June 1923 the average zero point hardly changed more than half a second. The levelling screws have only been touched a very few times during the period discussed in this paper.

The inclination, b, of the horizontal axis has been determined with the aid of a striding level of which each division corresponds to 7″.5. It was found that the axis usually changed its inclination in the same sense during the evening: and accordingly a systematic difference of about 0.″40 was found between the observed declinations on nights when observations were started in position I and those for which position II preceded (in which the instrument is reversed through 180°). As the order of the two positions of the instrument was changed regularly, the averages are not affected by this error.

The observations.

When a star is observed near its greatest elongation its motion in azimuth is naturally quite slow. The observations are therefore most conveniently made in the following way: the vertical circle being so fixed that the star is soon going to pass the horizontal wire, the star is followed in azimuth till it reaches this wire, at which point both circles are read. In this manner from 3 to 7 pointings were made in one position of the instrument, after which it was reversed about the vertical axis, and the other half of the pointings were made. The average number of pointings for one night's observation of a star is 10.

The poor weather conditions of Matuba caused occasional long gaps in the observations; they had moreover to be limited to the early evening hours because the atmosphere gets very damp a few hours after sunset. If possible two stars were observed on a night, one West and one East, but there were many nights on which only one star could be finished. Table 2 gives a summary of the observing nights with the stars measured and the number of pointings made on each.

As mentioned in the 1921 Report of the director of the Observatory at Leiden *) the programme for the observations was drawn up at Leiden during Mr. SANDERS' latest visit to Europe. Preliminary observations were started in the early part of 1922 in January 1923 was it decided to observe only near but only the greatest elongations. The latter observations are discussed in the present paper.

The reductions.

The computation of the declination from azimuth and zenith distance was carried out for each pointing separately. The zenith distances were corrected for refraction (by means of BESSEL's tables), for level, etc. To the azimuth a correction $\pm\, b \cot z \pm \dfrac{c}{\sin z}$ was applied to correct for the inclination of the horizontal axis, b, and for the collimation, c.

In order to eliminate remaining errors in the inclination of the horizontal axis the means of the pointings in the two positions of the instrument were combined with weights proportional to $\sin q \cos z$, being the coefficient of b in the formula for $d\delta$ (p. 201). The difference caused by this weighting seldom exceeds 0″.30; no weights have been applied when the averages of the two positions differed by less than 1″.

In an unpublished discussion of observations in 1922 professor DE SITTER has found that, although the results gave a distinct indication of systematic errors in the Boss declinations, a large error proportional to the cosine of the parallactic angle made them unreliable. It was indicated that the error could be either interpreted as a personal error proportional to the rapidity of the star's motion in azimuth or else as a large systematic error in the zenithdistances. On the advice of professor DE SITTER observations were afterwards made exclusively very near greatest elongation. As appears from Table 4 the highest value of $\cos q$ occurring is 0.132; the average even if taken without regard to sign is only 0.042, so that an error of 2″ in the computed correction for refraction (corresponding to a temperature difference of about 2½°C. or to a barometer error of 8 mm.) would have no appreciable influence on the declinations. There is no regular progression of the residuals with $\cos q$ in the present results.

The latitude used.

The mean latitude used in the calculations is

*) *B. A. N.* Vol. I, 2, p. 7, 1921.

TABLE 2. Stars observed for declination programme.

Group	Date	East	Number of settings	West	Number of settings
	1923				
I.	Jan. 20			δ Aqr	10
	21			»	10
	Feb. 8			η Cet	3
	12	δ Crt	12	β Cet	12
	13	»	12	»	13
	15			»	14
	19			τ Cet	13
	20	γ Crv	12	»	14
	21	»	12	»	14
	22	»	12		
	Mar. 23			δ Eri	13
	24			»	13
	25	α Vir	13	»	8
	27	»	13	»	8
	30	»	13	»	8
II.	Apr. 2	α Lib	7		
	13	»	11	γ Eri	10
	14	»	12	»	12
	16			β Lep	15
	17	γ Sco	8	α Lep	8
	18	δ Sco	10	β Lep	10
	21	»	9	»	10
	25	»	10	»	11
	28			»	10
III.	May 15	θ Oph	11	β C Ma	10
	17			»	11
	20	θ Oph	10	δ C Ma	10
	22			»	10
	25			»	10
	29	θ Oph	10	»	8
	Jun. 1	»	11		
	5	λ Sgr	8	ρ Arg	11
	8	»	10	»	11
	9	»	10	»	11
IV.	26	σ Sgr	11		
	27	»	11		

Group	Date	East	Number of settings	West	Number of settings
	Jul. 3	σ Sgr	9	δ Crt	11
	4	»	9	»	11
	7	λ Aql	10	δ Crt	11
	8	»	10	»	11
	17	β Cap	12	γ Crv	11
	20	»	11	»	12
V.	Aug. 25	δ Aqr	6	α Vir	6
	28	»	6	»	6
	Sept. 1	»	10	α Lib	11
	3	»	10	»	11
	12	β Cet	10	δ Sco	10
	17	»	8		
	19	»	10	δ Sco	11
	Oct. 14	ζ Cet	10	θ Oph	9
	18	»	10	»	11
VI.	Nov. 7	γ Eri	10	σ Sgr	6
	8	»	9		
	11	»	7		
	12	»	8	σ Sgr	13
	13	β Lep	12	λ Sgr	14
	14	»	11	»	13
	24	α Lep	12	»	9
	25	»	12	»	9
VII.	Dec. 23			δ Cap	13
	26	δ C Ma	11		
	30	»	16		
	31			δ Cap	13
	1924				
	Jan. 4			δ Aqr	11
	5	α Hya	10	»	11
	11			»	7
	15	α Hya	6		
	Feb. 2			β Cet	14
	5	α Hya	6	»	15
	7			»	6

Group	Date	East	Number of settings	West	Number of settings
VIII.	22	β Vir	10	ζ Cet	12
	24			»	16
	Mar. 5	β Vir	16	o Cet	4
	10	γ Vir	17	»	6
	11	»	16	»	6
	14	ζ Vir	14	η Eri	16
	23			»	12
	25	β Crv	4	»	9
	27	ζ Vir	12	»	12
	April 1	»	10	δ Ori	12
	2	»	10	»	12
	9	κ Vir	10	»	8
IX.	May 6	δ Oph	10	ι Ori	10
	9			»	6
	11	δ Oph	11		
	12	»	8	ι Ori	6
	17	μ Ser	9	30 Mon	9
	19	»	10	»	10
	21	»	8	»	10
	22	»	8	»	10
	24			»	10
X.	Jul. 28	β Aqr	10	β Vir	8
	29	»	8	»	8
	31	»	8	»	8
	Aug. 8	»	10		
	13	α Aqr	11		
	18	»	10		
XI.	Oct. 16	θ Cet	10	141 G Oph	6
	Nov. 5	γ Cet	10	θ^1 Ser	10
	6	»	10	»	10
	10	α Cet	10	δ Aql	11
	11	»	12	»	11

— 5°16′59″.54 corresponding to the mean latitude derived from Talcott observations in 1919 *). The present pier is 0″.14 South of that from which the latitude observations were made.

The latitude rests largely on Boss declinations of stars between — 29° and + 19°. As we have seen above about one third of the error of the latitude, that is of the systematic error of the stars used in the latitude programme, enters into our declinations, so that these are still affected by part of the systematic error which we want to determine. The latitude stars extend about 15° North of the zone in which the azimuth observations lie and we cannot rigorously assume their systematic errors to be the same, and eliminate them in that way. This procedure may however be followed as soon as a redetermination of the latitude has been made from the pairs culminating within 8° of the zenith.

All differences given in Tables 3 and 4, of our declinations with Boss' Preliminary General Catalogue and with the Nautical Almanac, rest on the assumption that the above latitude is correct. An alternative would be to assume that the declinations used in the latitude programme are subject to a systematic error of say — 0″.60 *), in which case about 0″.20 should be subtracted from all the differences given on the follow ingpages (except Table 5). If we assume the mean systematic error of the latitude stars to be the same as that of the stars observed for azimuth, we find that our residuals require a correction of — 0″.18, which may not be far from the true correction.

The mean latitude has been corrected for latitude

*) *Monthly Notices R. A. S.* 80, 462, 1920.

*) See for instance KAPTEYN, *B. A. N.* Vol. I, 14, p. 72, 1922.

variation by applying the results for Greenwich which were very kindly communicated to Leiden in advance of their publication. In 1919 it was found that the variation of latitude at Matuba was very nearly the same as at Greenwich. The corrections, mean latitude — observed, are shown in column (6) of Table 3.

On the assumption that the amplitude of the polar motion in the meridian of 90° longitude has been roughly equal to that found in the meridian of Greenwich estimates were made of the azimuth variation in Matuba; the corresponding corrections to the azimuth of the mark are given in column (12) of the same table.

Results for different periods.

Table 3 gives the results combined into groups of about equal weights, covering from two to eight weeks each. The different groups are indicated in Table 2.

TABLE 3. Mean differences with Boss' P. G. C. and with the Nautical Almanac.

Group	Date	Number of stars	Number of obs.	Average decl.	$\Delta\varphi$ Greenw.	$\delta_B - \delta_{obs.}$ East	$\delta_B - \delta_{obs.}$ West	$\Delta\delta$ Boss	$\Delta\delta$ N.A.	ΔA_o	Corr. for az. var.	ΔA_o corrected
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
I	1923.2	6	17	− 14°.5	+ 0″.23	+ 0″.70	− 1″.23	− 0″.26	+ 0″.01	− 1″.07	0″.00	− 1″.07
II	.3	6	14	− 18.8	+ 0.23	+ 0.34	− 1.72	− 0.69	− 0.40	− 1.10	− 0.10	− 1.20
III	.4	5	16	− 23.7	+ 0.20	+ 0.08	− 1.22	− 0.57	− 0.26	− 0.71	− 0.17	− 0.88
IV	.5	5	14	− 15.6	+ 0.12	− 0.22	− 1.21	− 0.72	− 0.40	− 0.55	− 0.20	− 0.75
V	.7	7	17	− 17.0	− 0.12	+ 0.78	− 1.08	− 0.15	+ 0.18	− 0.99	− 0.03	− 1.02
VI	.9	5	14	− 20.9	− 0.01	+ 0.46	− 1.43	− 0.48	− 0.44	− 0.98	+ 0.15	− 0.83
VII	1924.0		12	− 17.1	+ 0.04	+ 1.01	− 1.07	− 0.03	+ 0.21	− 1.13	+ 0.15	− 0.98
VIII	.2	7	18	− 4.1	+ 0.15	+ 1.31	− 1.03	+ 0.14	+ 0.70	− 1.12 − 1.46	+ 0.08	− 1.04 − 1.38
IX	.4	4	14	− 4.1	+ 0.12	+ 0.61	− 1.19	− 0.29	+ 0.15	− 0.99	− 0.05	− 1.04
X	.6	3	9	− 1.5	0.00	+ 0.91	− 1.26	− 0.18	+ 0.22	− 1.01	− 0.10	− 1.11
XI	.8	6	10	+ 1.3	(− 0.02)	+ 1.18	− 1.84	− 0.33	− 0.12	− 1.48	(+ 0.10)	− 1.38
Average		42	155	− 12°.4				− 0″.32	− 0″.01			

Group number and average date are given in the first two columns. The third column contains the number of stars used; the groups are so chosen that the numbers of stars observed East and West are practically equal. If a star is observed on one night only it has been assigned half weight; all the others have equal weights. The total number of observations is given in the fourth column, a complete night's result for a star being counted as one observation. The number of pointings would be about ten times as large. Columns (7) and (8) contain the mean differences, East and West, of the Boss declinations with those found from the present observations. As most of the stars occur in the Nautical Almanac the reduction to apparent place was obtained from these except for a correction for diurnal aberration. The difference between the two columns (7) and (8) is due to a constant error, ΔA_o, in the assumed zero point of the azimuths, which error is shown in column (11). It has been computed by dividing the difference (8) — (7) by the sum of the average coefficients of dA East and West. These coefficients, $\sin z \sin q$, are not given in the table. The last column of the table gives the same quantities corrected for azimuth variation. It appears from these that the mark has been quite constant during the period covered by the observations.

The column $\Delta\delta$ Boss represents the average systematic error of the Boss declinations used, if we assume the present observations to be correct. It is simply the mean of columns (7) and (8) so that no uncertainty as to the exact azimuth of the mark enters into these numbers. The next column of the table gives the corresponding differences with the Nautical Almanac (four stars which did not occur in the N. A. were omitted).

Il should be mentioned that a few observations with less than three pointings in each position, as well as the observations of the double star γ Virginis, have been excluded. The observation of γ Corvi on Feb. 12, 1923, has been excluded on account of its being marked doubtful. The first two observations of δ Aquarii, which stand rather apart from the first group, have also been omitted.

TABLE 4. Separate deviations from BOSS arranged in order of declination.

Name of star	θ[1] Ser	α Cet	δ Aql	γ Cet	β Vir	ζ Vir	δ Ori	α Aqr	μ Ser	ο Cet	δ Oph	30 Mon	141 Oph.	λ Aql
α 1900	18h 51m	2h 57m	19h 20m	2h 38m	11h 45m	13h 30m	5h 27m	22h 1m	15h 44m	2h 14m	16h 9m	8h 21m	17h 21m	19h 1m
δ 1900	+4° 4'	+3° 42'	+2° 55'	+2° 49'	+2° 20'	−0° 5'	−0° 22'	−0° 48'	−3° 7'	−3° 26'	−3° 26'	−3° 35'	−5° 0'	−5° 2'
Group number		XI		XI	VIII	VIII		X	IX		IX			IV
Residuals East		+0".45 −0.31		−0".43 −0.80	−1".19 +0.40	+0".21 −0.17 +0.80 +0.21		−0".41 +0.19	−0".01 −0.85 −0.71 −0.51		−0".45 −0.78 −0.15			−1".13 −1.77
Average res.		+0".07		−0".62	−0".40	+0".26		−0".11	−0".52		−0".46			−1".45
Average *z*		70°		67°	68°	74°		70°	67°		70°			68°
Average cos *q* sin *A*		+.120		+.118	+.094	+.094		+.094	+.077		+.077			+.066
Group number	XI		XI		X		VIII			VIII		IX	XI	
Residuals West	−0".59 −0.64		−0".62 −0.61		−0".21 +0.78 −0.71		−0".04 +0.89 −0.25			−0".04 −0.50		+0".20 +0.67 −0.56 +0.90 −0.22	+0".13	
Average res.	−0".62		−0".62		−0".05		−0".20			−0".27		+0".20		
Average *z*	64°		64°		63°		67°			67°		57°	63°	
Average cos *q* sin *A*	−.132		−.126		−.122		−.097			−.076		−.069	−.060	
Total average $\delta_B-\delta_{Obs.}$	−0".62	+0".07	−0".62	−0".62	−0".19	+0".26	+0".20	−0".11	−0".52	−0".27	−0".46	+0".20	(+0".13)	−1".45
$\delta_{N.A.}-\delta_{Boss}$ (1924)		−0.13	+0.42	+0.16	+0.64	+0.70	+0.29	+0.35	+0.25	+0.63	+0.87	+0.43		+0.72

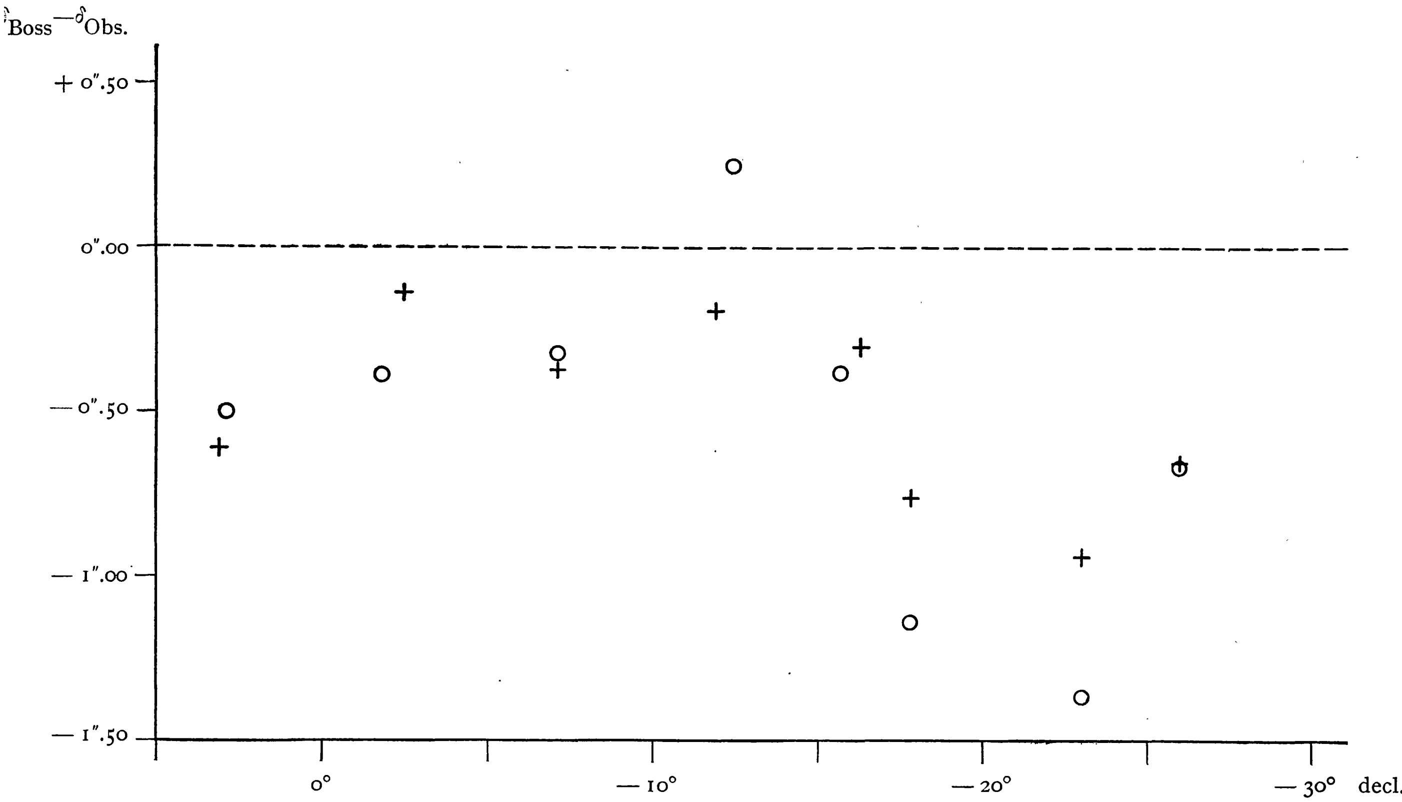
Name of star	ι Ori	β Aqr	α Hya	θ Cet	η Eri	κ Vir	δ Eri	α Vir	ζ Cet	γ Eri	δ Crt	β Cap	α Lib	δ Aqr.
α 1900	5h 31m	21h 26m	9h 23m	1h 19m	2h 52m	14h 8m	3h 38m	13h 20m	1h 47m	3h 53m	11h 14m	20h 15m	14h 45m	22h 49m
δ 1900	−5° 59'	−6° 1'	−8° 14'	−8° 42'	−9° 18'	−9° 49'	−10° 6'	−10°38'	−10°50'	−13°48'	−14°14'	−15° 6'	−15°38'	−16°21'
Group number		X	VII	XI		VIII		I	V	VI	I	IV	II	V
Residuals East		−0".65 −0.99 −0.30 +0.25	+0".79 +0.20 +0.87	+0".18		+1".22		+0".69 +0.22 +0.73	+1".05 +0.73	+0".36 −0.40 +0.79 +0.35	+0".03 −0.04	−1".32 −0.33	+0".48 +0.41	+0".06 +0.09 −0.37 −0.70
Average res.		−0".42	+0".62					+0".55	+0".89	+0".28	0".00	−0".82	+0".44	−0".23
Average *z*		67°	72°	67°		70°		64°	70°	74°	67°	70°	74°	68°
Average cos *q* sin *A*		+.058	+.051	+.036		+.034		−.039	+.028	+0.29	+.004	+.001	+.018	−0.12
Group number	IX				VIII		I	V	VIII	II	IV		V	VII
Residuals West	+0".16 −0.85 −0.72				−1".52 +0.52 +0.79 −0.03		−0".05 +0.40 −0.78 −1.28 −0.95	+0".82 +1.16	−0".16 +0.64	−0".64 −0.50	−0".07 +0.01 −0.85 +0.18		−1".01 −0.21	−0".42 +0.85
Average res.	−0".47				−0".06		−0".53	+0".99	+0".24	−0".57	−0".18		−0".61	+0".22
Average *z*	72°				67°		57°	62°	64°	67°	64°		67°	66°
Average cos *q* sin *A*	−.063				−.031		+.004	−.010	−.012	−.002	+.018		+.016	+0.29
Total average $\delta_B-\delta_{Obs.}$	−0".47	−0".42	+0".62	(+0".18)	−0".06	(+1".22)	−0".53	+0".72	+0".56	−0".01	−0".12	−0".82	−0".08	−0".08
$\delta_{N.A.}-\delta_{Boss}$ (1924)	+0.21	−0.04	+0.45	+0.15		+0.40	+0.13	+0.58	+0.42	+0.24	+0.29	+0.34	+0.42	+0.01

Name of star	τ Cet	δ Cap	γ Crv	α Lep	β CMa	β Cet	β Lep	δ Sco	ρ Arg	γ Sco	θ Oph	λ Sgr	δ CMa	σ Sgr
α 1900	1h 39m	21h 42m	12h 11m	5h 28m	6h 18m	0h 39m	5h 24m	15h 54m	8h 3m	14h 58m	17h 16m	18h 22m	7h 4m	18h 49m
δ 1900	−16°28'	−16°35'	−16°59'	−17°54'	−17°54'	−18°32'	−20°50'	−22°20'	−24°1'	−24°53'	−24°54'	−25°29'	−26°14'	−26°25'
Group number			I	VI		V	VI	II		II	III	III	VII	IV
Residuals East			−1".48 −0.85	−0".93 −0.61		−1".40 −1.17 −0.32	−1".19 −1.56	−0".88 −2.16 −1.70		−0".19	−1".38 −1.15 −0.54 −1.39	−0".70 −0.04 +0.04	−1".63 +0.25	−0".59 −1.55 +0.40 −0.44
Average res.			−1".16	−0".77		−0".96	−1".38	−1".58			−1".12	−0".23	−0".69	−0".54
Average *z*			72°	76°		74°	76°	74°		76°	72°	70°	67°	72°
Average cos *q* sin *A*			−.003	+.018		+.001	+.005	−.002		+.008	−0.39	−.057	−.078	−.045
Group number	I	VII	IV	II	III	I, VII	II	V	III		V	VI	III	VI
Residuals West	−0".19 +0.46 −0.63	−0".54 +0.58	−0".91 −0.80	−0".44	−0".39 −0.70	−0".75 −0.14 −0.31 −0.15 −0.73	−1".72 −1.80 −1.08 −1.51 −1.43	−0".45 −1.38	+0".83 −1.07 −0.56		−0".80 +0.16	−0".17 −0.45 −0.57 −0.88	−0".87 −0.58 −0.62 −0.63	−0".37 −0.05
Average res.	−0".12	+0".02	−0".86		−0".54	−0".42	−1".51	−0".92	−0".27		−0".32	−0".52	−0".68	−0".21
Average *z*	66°	62°	67°	76°	68°	69°	66°	70°	64°		74°	70°	64°	74°
Average cos *q* sin *A*	+.027	+0.27	+.024	−.016	+.019	+.021	+.058	+.034	+.085		+.032	+.045	+.075	+.018
Total average $\delta_B-\delta_{Obs.}$	−0".12	+0".02	−1".01	−0".66	−0".54	−0".62	−1".47	−1".31	−0".27	(−0".19)	−0".85	−0".40	−0".68	−0".43
$\delta_{N.A.}-\delta_{Boss}$ (1924)		+0.01	+0.41	0.00	+0.55	+0.36	−0.07	+0.50	+0.74	+0.53	+0.13	+0.21	+0.26	−0.14

Separate differences with Boss' P. G. C. and their correlation with declination.

It is seen from Table 3 that the corrections obtained to Boss' P. G. C. or to the Nautical Almanac differ a great deal from one group to another. It will be shown that the difference in the declination of stars used in the various groups is the most probable cause of these discrepancies. Although the entire range in declination is only 30°, Table 4 indicates a large variation of systematic difference within this interval. The residuals in the table represent differences "Boss" minus "Observed", the latter being corrected for latitude variation and for the error in the assumed azimuth of the mark, viz. — 0″.97 for the observations up to March 23, 1924 when the azimuth mark was taken down, and — 1″.23 for the observations after this date. To these values has been added the estimated azimuth variation for each period.

The table shows the average values of the zenith distance and of the cosine of the parallactic angle. It also gives an indication of the time of observation by a reference to the groups of Table 3. The total



Differences with Boss' Preliminary General Catalogue.

Circles represent observations made in the East, crosses those made in the West.

average residuals are given at the bottom, together with the differences between the N. A. and Boss for 1924. The N. A. positions appear to be about 0″.3 higher on the average.

The agreement of the declinations of the same star on different nights is generally satisfactory, keeping in mind the relatively small dimensions of the instrument. The probable error of one observation of a star as found from an intercomparison of the different nights comes out ± 0″.33 for the Eastern and ± 0″.37 for the Western observations.

There is no definite regular progression of the residuals with either zenith distance or parallactic angle. Nor have we found any indications of a dependence on the temperature or on the time of observation.

It seems likely that the average difference with Boss is primarily a function of the declination. In Table 5 the residuals have been averaged for 7 zones of declination extending over 5° each. The zone from — 15° to — 20° has been subdivided into two parts, each of which has about the same weight as the other zones. The differences with Boss are plotted in the accompanying diagram. A correction of — 0″.18 has been applied to the residuals in the table and in the diagram in order to eliminate the main part of the error in the latitude (see page 204).

The interesting feature presented by the table is the similarity of the variation with declination of the East and West observations. The agreement of the two is quite as good as can be expected from the

TABLE 5.

Limits of declination	Δ_δ Boss East	Number of stars	Δ_δ Boss West	Number of stars	Δ_δ N.A. East	Δ_δ N.A. West
° °	″		″		″	″
+ 5 to 0	− 0.50	3	− 0.61	3	− 0.19	+ 0.02
0 » − 5	− 0.39	4	− 0.14	3	+ 0.16	+ 0.31
− 5 » − 10	− 0.32	4	+ 0.37	3	+ 0.03	(− 0.44)
− 10 » − 15	+ 0.25	4	− 0.19	5	+ 0.63	+ 0.14
− 15 » − 16.8	− 0.38	3	− 0.30	4	− 0.13	− 0.16
− 16.8 » − 20	− 1.14	3	− 0.76	4	− 0.89	− 0.39
− 20 » − 25	− 1.37	4	− 0.94	4	− 1.11	− 0.66
below − 25	− 0.67	3	− 0.65	3	− 0.56	− 0.54

small number of stars. As far as instrumental errors are concerned we should perhaps expect to find greater variation between the East and West observations of the same zone than among the East observations themselves. Of course, by the way in which the error of the azimuth of the mark has been determined, the total average of the differences East has been made approximately equal to the average West.

There is some probability that the diagram gives us a rough idea of the systematic errors of the Boss Catalogue in this zone*). The numbers of stars observed are however too small to draw any definite conclusions from, and a little uncertainty as to the absolute values of the corrections remains, as long as no computation of the latitude from Talcott pairs with smaller zenith distances has been made.

It has sometimes been argued that when working at zenith distances as large as 70° important lateral refractions should be expected. We think that there may not be so much a priori probability of such a refraction. The mass of air transversed is only three times that at the zenith; now zenith refractions seldom seem to exceed a few hundredths of a second, (compare the "night-errors" in the latitude programmes) *). If we assume relative inclinations of air layers to be of the same order in vertical and horizontal directions, the lateral refraction would certainly not be of much importance. The material at hand is rather too scanty to allow an investigation of the possible effect of these refractions. A correlation of the residuals in Table 4 with the seasons could not be made out however, and the fair agreement between the East and West observations gives some support to the view that no very large azimuthal refractions exist.

The general conclusion is that even with so small an instrument as the one employed the possibility is indicated of getting an independent check on the declinations found by meridian observations and that the method may be of special value in determining the dependance of systematic errors of existing fundamental systems upon the declination.

*) The remarkable agreement of the *Cape Fundamental Catalogue* for 1900 with the *P. G. C.* (the average difference ranging from + 0″.14 to ∓ 0″.02 in the zone from + 5° to − 25° declination) makes it rather hard to believe that the large differences found here do really indicate systematic errors in BOSS' system. On the other hand it is difficult to see how an instrumental error affecting East and West observations in the same way could have entered into the above observations, except for the possibility of a still undetermined periodic error of the circle. It should be remarked that there is a difference of about 16 years in the epochs of the Cape Catalogue and the present observations, and there is also discordant evidence from five Northern catalogues, which according to ROY (*Pop. Astr.* 30, 6, 1922) indicate an average correction of − 0″.56 to the BOSS catalogue near the equator.

*) See SCHLESINGER, *Publications A. S. P.* 18, 49, 1906, and also ALBRECHT and WANACH's comparison of the latitude from zenith pairs with that from pairs at 60° zenithdistance, *Resultate des internationalen Breitendienstes* 2, 169—188, 1906.