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LATITUDE REDETERMINATIONS

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LATITUDE REDETERMINATIONS

INTRODUCTION

During the summer of 1930, the Coast and Geodetic Survey redetermined the value of latitude at three of its old latitude stations. The reason for this work is explained in a letter dated May 5, 1930, from Dr. Frank Schlesinger, Director of Yale Observatory, to the Director of the Coast and Geodetic Survey. The letter reads in part as follows:

As you are doubtless aware, the problem of variations of latitude has recently taken on a new aspect of interest, owing to the possibility of a secular change, as well as periodic changes, in the position of the pole. This is one reason why the resumption of observations at Gaithersburg has become so important. An independent way in which considerable light can be thrown upon this question occurred to me several years ago, and I have discussed it with a number of my colleagues, including Doctor Bowie, chief of your division of geodesy. The plan is to reoccupy, for one or two nights each, a number of the stations at which observations for latitude were made 20 or more years ago by the Talcott method. The same stars should be observed now as were used then. From the results obtained in this way we may reasonably expect light to be thrown upon the following questions: (1) The actuality of a secular motion of the pole; (2) the possibility of slow continental, or at least general, drift; (3) a better determination of the systematic errors in our adopted systems of proper motions of the fixed stars.

The following three latitude stations were chosen for the test: Mount Tom (Edward Goodfellow, 1862) in Massachusetts (latitude $42^{\circ} 14'5$, longitude $72^{\circ} 38'9$); Mount Pleasant (G. W. Dean, 1851) in Maine (latitude $44^{\circ} 01'6$, longitude $70^{\circ} 49'4$); and Des Moines (E. P. Austin, 1869) in Iowa (latitude $41^{\circ} 35'0$, longitude $93^{\circ} 37'3$). The latitudes at these stations had been observed with great care and accuracy, the same zenith telescope had been used at all three, and the probable errors of the results were small. The Talcott method was used in all cases.

R. L. Pfau was instructed to reobserve latitude at stations Mount Tom and Mount Pleasant, and E. B. Latham to reobserve latitude at station Des Moines. The work was so planned that the observations could be made at about the same time of year as originally made, in order that the same stars could be used as in the original determinations. In the instructions it was stipulated that as far as possible the same pairs of stars should be used as in the original observations at these stations.

As the Coast and Geodetic Survey now uses the Boss Catalogue,¹ and as the stars used in the original latitude observations were taken from the British Association Catalogue, it was necessary to find which of the observed stars are given also in the Boss Catalogue. To do this the approximate mean places of the stars for each station were computed for the epoch 1900.0 using the British Association Catalogue. These places were then compared with the mean places in the Boss Catalogue, and a list made for each station of all the stars used at that station which are common to both catalogues. These lists were furnished the observers concerned.

¹ Lewis Boss, Preliminary General Catalogue of 6,188 Stars for the Epoch 1900, Carnegie Institution of Washington. Publication No. 115. 1910.

As stated above, the astronomical parties made their observations at very nearly the same time of year as the original observations; namely, in the months of July and August. Both at Mount Tom and at Mount Pleasant the old observations had been reduced to a geodetic station. Accordingly at each of these stations the new observations were carefully connected with the previously used geodetic point. At Des Moines the new observations were connected with the old latitude station.

In what follows, the results of the old observations at each of the three stations, both as derived from the mean declinations used in the revised computations of 1870-1872 (see p. 3), and as derived from the mean declinations taken from the Boss Catalogue, are given and compared with the results of the new observations, the latter being derived from mean declinations taken from the Boss Catalogue.

Since the declinations of the stars used in the observations changed as much as several minutes of arc between the dates of the old determinations of latitude at the three stations and 1930, several of the pairs of stars observed during the old determinations were not, in 1930, within the prescribed limit of 20 minutes of arc for the difference between the zenith distances of the north and south stars of the pair. Ordinarily such pairs would not be used for latitude determinations, but in order to obtain complete sets for comparison with the old work, several pairs which were somewhat outside this limit were used in the redeterminations of 1930.

Because of the present lack of definite data and the uncertainty of the values used in the old computations, no attempt has been made to make corrections for the position of the pole.

The writer wishes to acknowledge the helpful suggestions of Dr. William Bowie, C. H. Swick, and W. D. Lambert, and the able assistance furnished by J. A. Duerksen and C. A. Whitten in the preparation of this publication.

Chapter I.—MOUNT TOM LATITUDE

DESCRIPTION OF STATION

Station of 1862.—This station is located in Hampshire County, Mass., on Mount Tom, about $2\frac{3}{4}$ miles north-northwest of Holyoke, and distant 27.95 meters (91.7 feet) or $0^{\circ}91'$ of latitude south and 12.8 meters (42.0 feet) west of Mount Tom triangulation station. This latter station is situated near the center of the summit ridge and is marked by a copper bolt set in the rock within a triangle with the letters "U. S." near by. Four reference marks, each a drill hole in the rock with a square around it and with an arrow pointing toward the triangulation station, are located, respectively, 19.21 meters (63.0 feet) southwest; 6.53 meters (21.4 feet) north-northwest; 6.90 meters (22.6 feet) east-northeast; and 6.15 meters (20.2 feet) southeast of the station. The latitude station was marked by a block of pine.

Station of 1930.—This station is located on Mount Tom 27.55 meters (90.4 feet) or $0^{\circ}89'$ of latitude south and 8.40 meters (27.6 feet) east of the triangulation station described above. It is not marked.

OBSERVATIONS OF 1862

The original observations were made from July 18 to August 11, 1862, inclusive, by Observer Edward Goodfellow, attached to the party of A. D. Bache. A total of 172 observations were taken on 36 pairs of stars with the Wurdemann zenith telescope No. 5. The average number of observations per pair was 4.8. A description of this instrument may be found in Appendix 14, Report of the Superintendent of the Coast Survey for 1880, page 246.²

A revision of the original latitude computation for this station was made in 1870-71. This revision was effected by the use of mean declinations that were considered more reliable than those used in the original computation. The declinations used in the revision were taken from the catalogues listed below:

- Greenwich 12, 6, and 7 Year Catalogues.
- Radcliffe Catalogue for 1845.
- Second Radcliffe Catalogue for 1860.
- Armagh Catalogue.
- British Association Catalogue.
- Gould's Standard Places of Fundamental Stars.
- And various catalogues available in 1870.

Discovery of an error in the computation increased the seconds of the mean latitude for the pair (5944, 5997) from $28^{\circ}12'$ to $28^{\circ}33'$. For the same reason, the seconds of the mean latitude for the pair (6862, 6882) were increased from $27^{\circ}67'$ to $28^{\circ}27'$. These two changes caused an increase in the mean observed latitude for the station of

² Chauvenet's Spherical and Practical Astronomy, vol. 2, Ch. VIII, contains a complete discussion of the method and result of latitude observations made in 1852 by G. W. Dean, at Rosslyn, Va., with zenith telescope No. 5. The instrument is described, and excellently illustrated.

0^o.01 and in the weighted mean latitude of 0^o.02. The result of the revision of 1870, with the two changes noted above, follows:³

Mean observed latitude of latitude station.....	42	14	27. 63	±0. 06
Weighted ⁴ mean observed latitude of latitude station..	42	14	27. 64	±0. 06
Reduction to sea level.....			-0. 06	
<hr/>				
Latitude of latitude station.....	42	14	27. 58	±0. 06
Reduction to geodetic station.....			+0. 91	
<hr/>				
Latitude of geodetic station.....	42	14	28. 49	±0. 06

In the original observations at Mount Tom, observations were made on each of 35 of the 36 pairs of stars on several different nights, usually 3 to 6. The agreement of the results of the different observations on the same pair should be a fairly good indication of the accuracy of the individual observations. At least, errors of star places are not involved. Refraction errors should have small effect on the residuals, since the Talcott method was used. For each pair observed more than once, the latitude was computed for each night's observation. Then a mean latitude for that pair from the results of the different nights' observations was taken, and the residuals from this mean were formed.

There were 171 residuals for the 35 pairs observed more than once at Mount Tom in 1862. The average size of these residuals is 0^o.45. This would indicate that observations on a single pair on one night will on the average give the latitude of the station within 0^o.45, if there are no errors in the star places. The maximum residual is 1^o.79.

OBSERVATIONS OF 1930

The observations of 1930 were made on 15 of the pairs of stars used in 1862, each pair being observed only once. The instrument used was the Bamberg broken-telescope transit No. 20, a description of which may be found on pages 3-7 of Special Publication No. 109, Wireless Longitude.

Table 1 contains the results of the observations of 1930. Column 1 contains the Boss Catalogue numbers of the stars; column 2, the date of observation; column 3, the position of the star whether north or south of the zenith; column 4, the position of the telescope, whether the ocular is east or west; column 5, the apparent declination; column 6, one-half the sum of the declinations; column 7, one-half the difference of the zenith distances in arc, corrected for inclination of the instrument, refraction and reduction to meridian; column 8, the observed latitude of the latitude station as derived from each pair of stars; and column 9, the corresponding latitude of the geodetic station. The following results were obtained.

³ To investigate the reliability of the earlier reductions from mean to apparent declination, the apparent declinations for the 15 stars common to the two sets of latitude observations (1862, 1930) were recomputed for 1862 by means of the Finlay Cape Meridian Tables. The results, however, differed little from apparent declinations computed 68 years earlier by means of Bessel's Star Places and Star Constants and the formula $\delta - \delta_0 = A\alpha' + B\beta' + C\gamma' + D\delta' + \tau\mu'$. In fact the mean effect was to change the mean observed value of latitude by only 0^o.01. Consequently, the reductions from mean to apparent declination used in the earlier computations were accepted for all three stations.

⁴ See Special Publication No. 14, pp. 119-121.

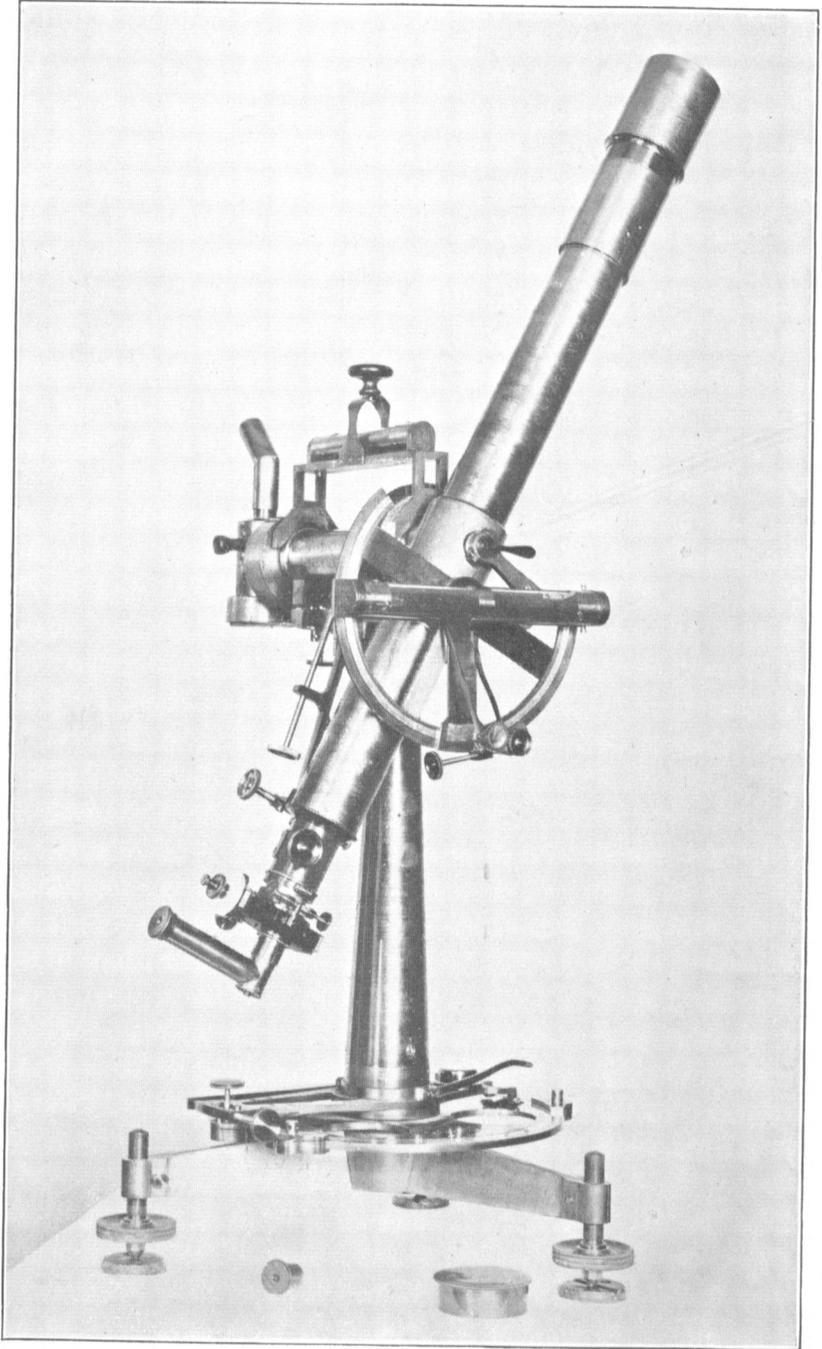


FIGURE 1.—ZENITH TELESCOPE

This instrument was used for the original latitude determinations.

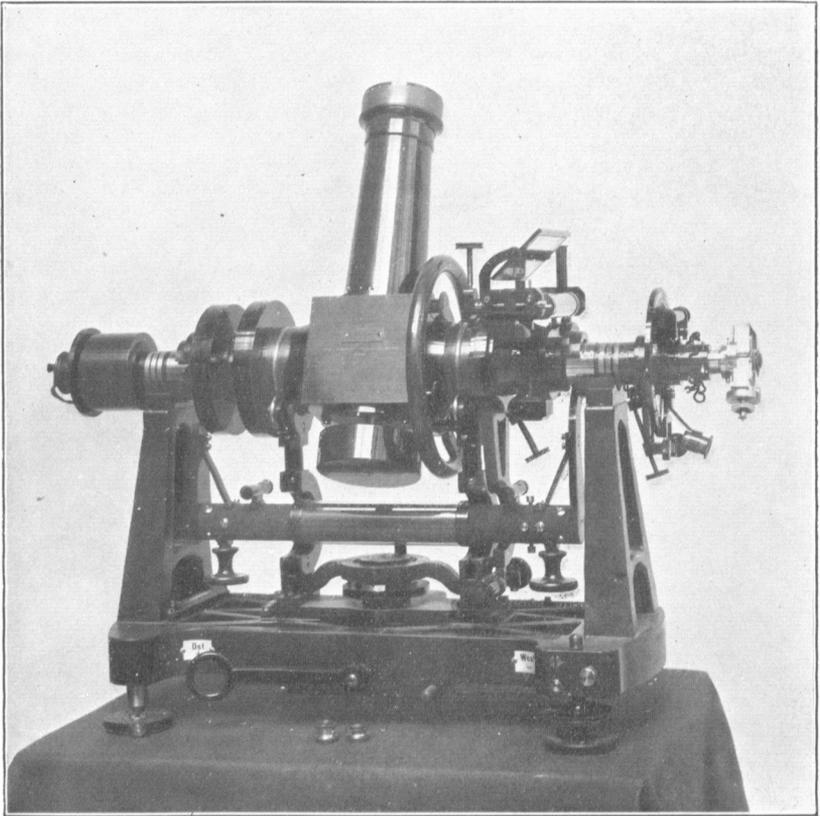


FIGURE 2.—BAMBERG BROKEN-TELESCOPE TRANSIT
This instrument was used for the recent latitude redeterminations.

	°	'	''	'''
Mean observed latitude of latitude station, 1930	42	14	26.50	±0.09
Reduction to sea level			-0.06	
<hr/>				
Latitude of latitude station	42	14	26.44	±0.09
Reduction to geodetic station			+0.89	
<hr/>				
Latitude of geodetic station	42	14	27.33	±0.09

COMPARISON OF OBSERVATIONS OF 1930 AND 1862

For purposes of comparison, the latitude of 1862 was recomputed, using only the 20 pairs of stars found in the Boss Catalogue and taking the data for the mean declination from that catalogue. The result of using the data of the Boss Catalogue was found to decrease the mean latitude derived from these pairs by 0".18. The decrease is 0".26 when only the 15 pairs used in the 1930 observations are considered.

Next, from the recomputed results above, the latitudes derived from the 15 pairs of stars reobserved in 1930 were compared, by means of Table 2, with the corresponding determinations of 1930. In this table columns 1 and 2 give the British Association and Boss Catalogue numbers, respectively, of the stars; column 3, the latitudes from the 1930 observations; column 4, the latitudes from the 1862 observations based on the Boss Catalogue; column 5, the difference, column 3 less column 4.

To test the reliability of using the results from only 15 pairs, the mean latitude derived from the 1862 observations for all 36 pairs was compared with the mean latitude derived from only the 15 pairs reobserved in 1930, both based on the revision of 1870. The former was found to be 0".10 less than the latter.

RECAPITULATION OF DATA OF COMPARISON

	[At geodetic station]			
	°	'	''	'''
Final latitude:				
Determination of 1862 (36 pairs), using data of 1870	42	14	28.49	±0.06
Determination of 1930 (15 pairs), using Boss data	42	14	27.33	±0.09
<hr/>				
Difference (1930-1862)			-1.16	
Mean observed latitude: ⁵				
Determination of 1862 (15 pairs), using Boss data	42	14	28.38	
Determination of 1930 (15 pairs), using Boss data	42	14	27.39	
<hr/>				
Difference (1930-1862)			-0.99	

⁵ Uncorrected for elevation of station above sea level.

TABLE 1.—Results of observations of 1930 at Mount Tom

[R. L. Pfau, observer; Bamberg broken-telescope transit No. 20.]

Boss Catalogue No. of star	Date, 1930	Direction of star	Position of ocular	Apparent declination	One-half sum of declinations	One-half difference of corrected zenith distances	Observed latitude	
							Latitude station, 1930	Reduced to geodetic station
				° ' "	° ' "	' "	° ' "	"
4021	July 23	N.	E.	62 49 02.28	42 00 07.18	+14 19.42	42 14 26.60	27.49
4031	do.	S.	W.	21 11 12.09				
4057	do.	S.	W.	38 08 56.34	42 11 24.57	+ 3 02.50	27.07	27.96
4089	do.	N.	E.	46 13 52.80				
4860	July 24	S.	W.	31 38 21.04	42 27 50.44	-13 23.79	26.65	27.54
4869	do.	N.	E.	53 17 19.83				
4957	do.	N.	E.	50 08 01.46	42 13 06.78	+ 1 19.92	26.70	27.59
4992	do.	S.	W.	34 18 12.09				
5002	do.	S.	W.	42 15 31.23	42 27 25.95	-13 00.57	25.38	26.27
5024	do.	N.	E.	42 39 20.67				
5097	do.	N.	E.	57 20 21.84	42 26 57.82	-12 31.26	26.56	27.45
5132	do.	S.	W.	27 33 33.79				
5185	do.	S.	W.	28 28 55.13	42 25 02.72	-10 36.56	26.16	27.06
5191	do.	N.	E.	56 21 10.31				
4104	July 25	S.	E.	17 23 23.34	41 58 15.20	+16 11.98	27.18	28.07
4152	do.	N.	W.	66 33 07.06				
4162	do.	N.	W.	46 28 49.23	42 01 00.06	+13 25.97	26.03	26.92
4184	do.	S.	E.	37 33 10.89				
4247	do.	S.	E.	27 03 02.64	41 58 45.16	+15 41.87	27.03	27.92
4270	do.	N.	W.	56 54 27.67				
4349	do.	N.	W.	43 54 25.57	42 15 26.12	- 0 59.40	26.72	27.61
4359	do.	S.	E.	40 36 26.66				
4497	do.	S.	W.	27 45 37.88	42 19 20.11	- 4 53.66	26.45	27.34
4531	do.	N.	E.	56 53 02.34				
4582	do.	S.	E.	30 33 03.57	42 24 30.25	-10 04.59	25.66	26.55
4609	do.	N.	W.	54 15 56.93				
4708	do.	S.	W.	23 32 52.16	42 15 39.13	- 1 12.65	26.48	27.37
4765	do.	N.	E.	60 58 26.10				
4855	do.	N.	W.	52 09 32.88	42 16 29.30	- 2 02.53	26.77	27.66
4872	do.	S.	E.	32 23 25.73				
Mean							42 14 26.50	27.39

TABLE 2.—Comparison of the results of 1930 with those of 1862 at Mount Tom

[In this table all values of the latitude are reduced to the geodetic station.]

Star Nos.		Latitude of geodetic station (based on Boss data)			Star Nos.		Latitude of geodetic station (based on Boss data)		
British Association Catalogue	Boss Catalogue	Results of 1930	Results of 1862	(1930) minus (1862)	British Association Catalogue	Boss Catalogue	Results of 1930	Results of 1862	(1930) minus (1862)
5249	4021	42 14 27.49	28.12	-0.63	6341	4708	27.37	28.46	-1.09
5252	4031				6410	4763			
5265	4057	27.96	28.67	- .71	6534	4860	27.54	28.29	- .75
5338	4089				6551	4869			
5376	4104	28.07	27.88	+ .19	6533	4855	27.66	27.43	+ .23
5453	4152				6553	4872			
5463	4162	26.92	28.33	-1.41	6659	4957	27.59	27.92	- .33
5496	4184				6698	4992			
5602	4247	27.92	28.14	- .22	6718	5002	26.27	28.57	-2.30
5643	4270				6745	5024			
5775	4349	27.61	28.17	- .56	6847	5097	27.45	28.43	- .98
5790	4379				6879	5132			
6021	4427	27.34	29.17	-1.83	6957	5185	27.05	28.40	-1.35
6079	4531				6976	5191			
6147	4582	26.55	29.68	-3.13	Mean		42 14 27.386	28.377	-0.991
6185	4609								

Chapter II.—MOUNT PLEASANT LATITUDE

DESCRIPTION OF STATION

Station of 1851.—This station is located in Oxford County, Me., near the summit of Mount Pleasant, about 6 miles west of Bridgton, and is marked by a granite pillar resting on a granite ledge 1.52 meters (5.0 feet) or $0^{\circ}05'$ of latitude south and 5.70 meters (18.7 feet) west of the original Mount Pleasant triangulation station. The latter is on the summit and is marked by a copper bolt set in the rock about a foot below the surface of the ground. Later, another triangulation station was established, which is also marked by a copper bolt set in rock and covered by soil. The more recent station is at an elevation 4 feet lower than the original one, and 16.922 meters (55.52 feet) southeast. It is 26.262 meters (86.16 feet) from the southwest corner of the hotel and 35.256 meters (115.67 feet) from the southeast corner of the bowling alley. When visited in 1930, the 1851 latitude station could not be found.

Station of 1930.—This station is on Mount Pleasant 13.29 meters (43.6 feet) or $0^{\circ}43'$ of latitude south and 14.11 meters (46.3 feet) east of the original triangulation station described above.

OBSERVATIONS OF 1851

These observations were made by G. W. Dean between July 20 and August 19, 1851, inclusive, with Würdemann zenith telescope No. 5. A total of 236 observations were made on 44 pairs of stars, the average number of observations per pair being 5.4. As in the case of Mount Tom, the computation of this latitude was revised at a later date, 1870, by means of adopted mean declinations considered more reliable than those originally used. They were also taken from the catalogues listed on page 3. In this revision $41^{\circ}40'$ was taken as the value of one turn of the micrometer in place of $41^{\circ}45'$, the value used in the original computation. The result of this revision computation follows:

	°	'	"	"
Mean observed latitude of latitude station.....	44	01	36.42	± 0.04
Weighted ^o mean observed latitude of latitude station..	44	01	36.44	± 0.04
Reduction to sea level.....			-0.11	
Latitude of latitude station.....	44	01	36.33	± 0.04
Reduction to geodetic station.....			+0.05	
Latitude of geodetic station.....	44	01	36.38	± 0.04

For the same reason and in the same manner as at Mount Tom (see p. 4), residuals were formed for the 43 pairs of stars observed on more than one night (usually 5 or 6). There were 235 residuals, whose average size is $0^{\circ}31'$. This would tend to show that the latitude derived from a single observation on a pair would, on the average, be accurate within $\pm 0^{\circ}31'$ if there were no errors in star places. The maximum residual is $1^{\circ}47'$.

^o See Special Publication No. 14, pp. 119-121.

OBSERVATIONS OF 1930

R. L. Pfau observed on 19 of the 44 pairs used in the 1851 observations on August 17, 18, and 22, 1930, observing each pair only once. The data for the computation of latitude from the 1930 observations are given in Table 3, tabulated as in Table 1 (see p. 4). The results are as follows:

Mean observed latitude of latitude station, 1930.....	°	'	"	"
Reduction to sea level.....	44	01	35.96	±0.06
			-0.11	
Latitude of latitude station.....	44	01	35.85	±0.06
Reduction to geodetic station.....			+0.43	
Latitude of geodetic station.....	44	01	36.28	±0.06

COMPARISON OF OBSERVATIONS OF 1930 AND 1851

As in the case of Mount Tom, the latitude of 1851 for Mount Pleasant was recomputed from the observations on the 34 pairs of stars found in the Boss Catalogue, using the data of that catalogue to obtain the mean declinations.

The effect of using the Boss Catalogue is to decrease the latitude based on the data of 1870 by 0".25, the same 34 pairs being used in both cases. When only the 19 pairs used in 1930 are considered, the effect is to decrease the latitude by 0".24.

The latitude of 1851 was then derived from the 19 pairs of stars used in the observations of 1930, using the data of the Boss Catalogue. These results and those for 1930 are compared in Table 4, which is formed in the same way as Table 2 in Chapter I and needs no further explanation. (See p. 5.)

It was found that the mean observed latitude of 1851, based on the data of 1870 when derived from the 19 pairs used in 1930, was 0".13 less than that derived from the entire set of 44 pairs.

RECAPITULATION OF DATA OF COMPARISON

[At geodetic station]

Final latitude:				
Determination of 1851 (44 pairs) based on data of 1870.....	°	'	"	"
Determination of 1930 (19 pairs) based on Boss data.....	44	01	36.38	±0.04
	44	01	36.28	±0.06
Difference (1930-1851).....			-0.10	
Mean observed latitude: ⁷				
Determination of 1851 (19 pairs) based on Boss data.....	44	01	36.10	
Determination of 1930 (19 pairs) based on Boss data.....	44	01	36.39	
Difference (1930-1851).....			+0.29	

⁷ Uncorrected for elevation of station above sea level.

LATITUDE REDETERMINATIONS

TABLE 3.—Results of observations of 1930 at Mount Pleasant

[R. L. Pfau, observer; Bamberg broken-telescope transit No. 20]

Boss Catalogue No. of star	Date 1930	Direction of star	Position of ocular	Apparent declination			One-half sum of declinations			One-half difference of corrected zenith distances	Observed latitude				
				°	'	"	°	'	"		°	'	"	"	
5220	Aug. 17	S.	E.	39	10	61.39	44	10	05.28	-8	20.23	44	01	36.05	36.48
5251	do	N.	W.	49	09	09.16									
5270	do	N.	W.	62	45	36.87	44	12	01.78	-10	26.06			35.72	36.15
5287	do	S.	E.	25	38	26.69									
5469	do	S.	E.	39	06	09.34	44	09	32.22	-7	56.33			35.89	36.32
5478	do	N.	W.	49	12	55.09									
5806	do	S.	E.	32	12	58.31	44	14	24.08	-12	48.15			35.93	36.36
5821	do	N.	W.	56	15	49.84									
4438	Aug. 18	S.	E.	26	09	47.86	44	02	48.47	-1	12.06			36.41	36.84
4470	do	N.	W.	61	55	49.08									
4606	do	S.	W.	31	23	17.71	43	58	38.12	+2	58.57			36.69	37.12
4622	do	N.	E.	56	33	58.54									
4644	do	S.	E.	28	50	13.52	44	10	14.60	-8	38.66			35.94	36.37
4688	do	N.	W.	59	30	15.67									
4747	do	S.	W.	39	35	51.85	44	08	35.58	-6	59.95			35.63	36.06
4770	do	N.	E.	48	41	19.30									
4878	do	N.	W.	50	15	08.13	44	07	52.14	-6	16.41			35.73	36.16
4912	do	S.	E.	38	00	36.14									
4972	do	S.	E.	36	10	42.36	44	10	43.87	-9	07.63			36.24	36.67
4980	do	N.	W.	52	10	45.38									
5102	do	S.	W.	38	18	06.10	44	06	23.16	-4	47.56			35.60	36.03
5137	do	N.	E.	49	54	40.22									
5165	do	N.	E.	61	47	38.28	44	14	44.22	-13	09.03			35.19	35.62
5173	do	S.	W.	26	41	50.15									
5177	do	S.	W.	28	36	03.77	44	14	04.83	-12	28.64			36.19	36.62
5184	do	N.	E.	61	52	05.89									
4382	Aug. 22	N.	E.	62	57	22.88	43	45	45.60	+15	50.28			35.88	36.31
4402	do	S.	W.	24	34	08.32									
4653	do	N.	W.	49	05	16.44	43	57	48.00	+3	48.02			36.02	36.45
4715	do	S.	E.	38	50	19.56									
4749	do	S.	E.	39	32	26.80	44	06	53.44	-5	16.99			36.45	36.88
4770	do	N.	W.	48	41	20.07									
4855	do	N.	W.	52	09	40.36	44	04	34.93	-2	58.38			36.55	36.98
4873	do	S.	E.	35	59	29.50									
4912	do	S.	E.	38	00	36.95	44	04	23.28	-2	48.11			35.17	35.60
4957	do	N.	W.	50	08	09.61									
5157	do	S.	E.	35	46	51.53	44	22	14.78	-20	38.75			36.03	36.46
5163	do	N.	W.	52	57	38.04									
Mean												44	01	35.96	36.39

TABLE 4.—Comparison of the results of 1930 with those of 1851 at Mount Pleasant

[In this table all values of the latitude are reduced to the geodetic station]

Star Nos.		Latitude of geodetic station (based on Boss data)			Star Nos.		Latitude of geodetic station (based on Boss data)								
British Association Catalogue	Boss Catalogue	Results of 1930	Results of 1851	(1930) minus (1851)	British Association Catalogue	Boss Catalogue	Results of 1930	Results of 1851	(1930) minus (1851)						
		° ' "	" "	" "			° ' "	" "	" "						
5840 ----	4382 ----	} 44 01 36.31	} 35.95	} +0.36	6667 ----	4972 ----	} 44 01 36.67	} 36.54	} +0.13						
5860 ----	4402 ----				6687 ----	4980 ----									
5922 ----	4438 ----				} 36.84	} 36.46				} +.38	6849 ----	5102 ----	} 36.03	} 36.01	} +.02
5978 ----	4470 ----										6895 ----	5137 ----			
6178 ----	4606 ----				} 37.12	} 36.09				} +1.03	6915 ----	5157 ----	} 36.46	} 36.23	} +.23
6216 ----	4622 ----										6928 ----	5163 ----			
6238 ----	4644 ----				} 36.37	} 36.50				} -.13	6932 ----	5165 ----	} 35.62	} 36.63	} -1.01
6318 ----	4688 ----										6940 ----	5173 ----			
6255 ----	4653 ----										} 36.45	} 35.82			
6349 ----	4715 ----				6970 ----	5184 ----									
6390 ----	4747 ----				} 36.06	} 36.23				} -.17	7008 ----	5220 ----	} 36.48	} 36.34	} +.14
6428 ----	4770 ----										7062 ----	5251 ----			
6391 ----	4749 ----				} 36.88	} 35.49				} +1.39	7098 ----	5270 ----	} 36.15	} 36.02	} +.13
6428 ----	4770 ----										7117 ----	5287 ----			
6530 ----	4855 ----				} 36.98	} 36.00				} +0.98	7398 ----	5469 ----	} 36.32	} 35.78	} +.54
6556 ----	4873 ----	7411 ----	5478 ----												
6566 ----	4878 ----	} 36.16	} 35.95	} +.21	7843 ----	5806 ----	} 36.36	} 35.56	} +.80						
6599 ----	4912 ----				7871 ----	5821 ----									
6599 ----	4912 ----	} 35.60	} 36.02	} -.42	Mean.....		44 01 36.394	36.096	+0.298						
6659 ----	4957 ----														

Chapter III.—DES MOINES LATITUDE

DESCRIPTION OF STATION

Station of 1869.—This station is located at Des Moines, Polk County, Iowa, in the courthouse grounds on the west side of the Des Moines River, 2.96 meters (9.7 feet) due east of the Des Moines longitude station. This latter station was marked by a block of stone, 12 inches square and 4½ feet long, sunk into the ground to within 4 inches of the top and filled in with sand. In this stone, the top of which was lettered “U. S. C. S. 1869,” was set a copper bolt 8 inches long and three-fourths inch in diameter, marked with a cross. The longitude station is 39.26 meters (128.8 feet) or 1°27' of latitude south and 18.56 meters (60.9 feet) or 0°81' of longitude east of the courthouse dome. In 1930, the longitude station was described as 1 meter east-northeast of the southeast corner of the concrete block at the east end of the steps leading to the south entrance of the courthouse, the mark projecting 8 inches above the ground and being half way up the slope between the courthouse and the sidewalk. On the opposite side of the courthouse yard is a similar stone, about 8 inches square and 3½ feet long, marked also by a copper bolt with a cross, 90.10 meters (295.6 feet) due north of the longitude station and, as found in 1930, 2 meters (7 feet) southwest of the edge of the Mulberry Street sidewalk and 13.64 meters (44.8 feet) northeast of the north-east corner of the courthouse.

Station of 1930.—The station is in the courthouse grounds, 52.28 meters (171.5 feet) or 1°69' of latitude north and 11.84 meters (38.8 feet) or 0°51' of longitude east of the old longitude station described above. It is 9.56 meters (31.4 feet) from the edge of the steps at the east entrance of the courthouse in a line toward the east almost perpendicular to the edge of the steps.

OBSERVATIONS OF 1869

These observations were made by E. P. Austin between July 12 and 19, 1869, inclusive, with Wurdemann zenith telescope No. 5.

A total of 76 observations were made on 22 pairs of stars, the average number of observations per pair being 3.5.

As at Mount Tom and Mount Pleasant and for the same reason, the computation of the latitude of 1869 at Des Moines was revised in 1872 by the adoption of mean declinations taken from the various catalogues listed on page 3. The results follow:

	°	'	"	"
Mean observed latitude of latitude station.....	41	35	02.67	±0.07
Weighted * mean observed latitude of latitude station ..	41	35	02.69	±0.07
Reduction to sea level.....			-0.04	
Latitude of latitude station.....	41	35	02.65	±0.07

Of the 22 pairs of stars observed in 1869, 21 were observed on several nights, usually from 3 to 5. As at Mount Tom and Mount Pleasant (see pp. 4 and 7) residuals were formed from the means of each of the 21 pairs. There are 75 of these residuals, the average

* See Special Publication No. 14, pp. 119-121.

size of which is 0".35. This tends to show that, on the average, a single observation on a pair at this station in 1869 gives the latitude within 0".35, provided there is no error in star places. The maximum residual is 1".34.

OBSERVATIONS OF 1930

E. B. Latham made observations on July 31 and August 1, 1930, on 10 of the star pairs used in 1869. In addition, he took observations on 8 other pairs not observed in 1869, and, therefore, of no value for comparison. Table 5 gives the data for the latitude computation for all pairs used, tabulated in the same way as in similar tables for Mount Tom and Mount Pleasant. (See pp. 4 and 8.) The last column of Table 5 contains the latitude for each pair reduced to the old 1869 latitude station, the reduction from new to old station being -1".69. The results are as follows:

	°	'	"	"
Mean observed latitude 1930 (all pairs)	41	35	01. 12	±0. 09
Mean observed latitude 1930 (10 pairs)	41	35	01. 22	±0. 12
Reduction to sea level			-0. 04	
<hr/>				
Latitude of the 1869 latitude station (10 pairs) ..	41	35	01. 18	±0. 12

COMPARISON OF OBSERVATIONS OF 1869 AND 1930

When the latitude of 1869 is derived from only the 15 pairs of stars that were found in the Boss Catalogue, first with the original mean declinations and then with mean declinations from the Boss Catalogue, the use of the Boss Catalogue declinations is found to decrease the latitude by 0".17. When only the 10 pairs reobserved in 1930 are considered, the decrease in the latitude is 0".15.

The mean observed latitude of 1869, based on the original mean declinations and derived from all 22 pairs of stars, is 0".19 less than when derived from only the 10 pairs that were reobserved in 1930.

In Table 6, formed in the same manner as Table 2 (see p. 5), are tabulated the data for comparison of the results of the observations of 1930 and of 1869 on the 10 pairs reobserved in 1930 and computed by means of mean declinations taken from the Boss Catalogue.

RECAPITULATION OF DATA OF COMPARISON

[At station of 1869]

Final latitude:				
Determination of 1869 (22 pairs), using original data	41	35	02. 65	±0. 07
Determination of 1930 (10 pairs), using Boss data ..	41	35	01. 18	±0. 12
<hr/>				
Difference (1930-1869)			-1. 47	
Mean observed latitude: ⁹				
Determination of 1869 (10 pairs), using Boss data ..	41	35	02. 71	
Determination of 1930 (10 pairs), using Boss data ..	41	35	01. 22	
<hr/>				
Difference (1930-1869)			-1. 49	

⁹ Uncorrected for elevation of station above sea level.

TABLE 5.—Results of observations of 1930 at Des Moines ¹

[E. B. Latham, observer; Bamberg broken-telescope transit No. 21]

Boss Catalogue No. of star	Date, 1930	Direction of star	Position of ocular	Apparent declination	One-half sum of declinations	One-half difference of corrected zenith distances	Observed latitude		
							Latitude station of 1930	Reduced to latitude station of 1869	
4069.....	July 31	S.	E.	36 50 32.72	} 41 32 13.19	+2 49.99	41 35 03.18	01.49	
4089.....	do.....	N.	W.	46 13 53.66					
4142.....	do.....	S.	W.	23 17 44.09	} 41 36 38.96	-1 35.72	03.24	01.55	
4159.....	do.....	N.	E.	59 55 33.83					
4204.....	do.....	S.	E.	21 38 27.17	} 41 18 21.88	+16 40.82	02.70	01.01	
4221.....	do.....	N.	W.	00 58 16.60					
4229.....	do.....	N.	W.	53 02 29.21	} 41 33 46.32	+1 15.60	01.92	00.23	
4279.....	do.....	S.	E.	30 05 03.42					
4232.....	do.....	N.	W.	53 03 57.26	} 41 29 44.32	+5 18.12	02.80	01.11	
4286.....	do.....	S.	E.	29 55 31.39					
(?)	Aug. 1	N.	E.	57.47	} 41 29 44.52	+5 18.64	02.80	01.11	
do.....	do.....	S.	W.	31.57					
4408.....	July 31	N.	W.	46 18 35.25	} 41 39 42.72	-4 38.86	03.86	02.17	
4422.....	do.....	S.	E.	37 00 50.18					
4584.....	do.....	S.	W.	28 45 07.85	} 41 30 33.12	+4 29.99	03.11	01.42	
4609.....	do.....	N.	E.	54 15 58.40					
4629.....	do.....	S.	E.	24 24 58.04	} 41 35 18.32	-0 15.92	02.40	00.71	
4671.....	do.....	N.	W.	58 45 38.59					
4763.....	do.....	N.	W.	60 58 27.78	} 41 45 54.24	-10 50.87	03.37	01.68	
4797.....	do.....	S.	E.	22 33 20.71					
4910.....	Aug. 1	N.	W.	25 50 33.11	} 41 19 02.54	+15 59.93	02.47	00.78	
4330.....	do.....	S.	E.	56 47 31.96					
4315.....	July 31	N.	E.	32 48 40.34	} 41 37 21.79	-2 19.12	02.67	00.98	
4842.....	do.....	N.	W.	50 26 03.24					
4894.....	do.....	N.	W.	56 44 24.34	} 41 26 01.70	+9 01.24	02.94	01.25	
4942.....	do.....	S.	E.	26 07 39.07					
5012.....	do.....	N.	E.	44 32 22.78	} 41 32 26.90	+2 35.57	02.47	00.78	
5069.....	do.....	S.	W.	38 32 31.03					
5115.....	do.....	N.	W.	58 39 32.09	} 41 42 00.89	-6 59.00	01.89	00.20	
5134.....	do.....	S.	E.	24 44 29.69					
5208.....	do.....	S.	W.	37 48 54.05	} 41 41 32.63	-6 30.44	02.19	00.50	
5230.....	do.....	N.	E.	45 34 11.21					
5249.....	do.....	S.	E.	38 12 36.69	} 41 37 12.29	-2 08.81	03.48	01.79	
5320.....	do.....	N.	W.	45 01 47.89					
5350.....	do.....	S.	W.	36 13 59.95	} 41 41 28.32	-6 25.14	03.18	01.49	
5389.....	do.....	N.	E.	47 08 56.70					
5453.....	do.....	N.	E.	59 41 54.01	} 41 37 47.11	-2 44.40	02.71	01.02	
5482.....	do.....	S.	W.	23 33 40.21					
Mean (10 pairs used in 1869).....							41 35 02.91	41 35 01.22	±0.12
Mean (all pairs).....							41 35 02.81	41 35 01.12	±0.09

¹ The first 10 pairs in this table are stars used in the observations of 1869. The remaining 8 pairs were used only in 1930.

² The above pair was observed on two nights.

TABLE 6.—Comparison of the results of 1930 with those of 1869 at Des Moines

[In this table the 1930 results are reduced to the 1869 station]

Star Nos.		Latitude of latitude station of 1869 (based on Boss data)			Star Nos.		Latitude of latitude station of 1869 (based on Boss data)					
British Association Catalogue	Boss Catalogue	Results of 1930	Results of 1869	(1930) minus (1869)	British Association Catalogue	Boss Catalogue	Results of 1930	Results of 1869	(1930) minus (1869)			
										°	'	"
5310	4069	41 35 01.49	02.79	-1.30	5871	4408	02.17	03.18	-1.01			
5338	4089											
5434	4142											
5459	4159				01.55	03.35				-1.80	6150	4584
5525	4204				01.01	02.41				-1.40	6185	4609
5560	4221											
5574	4229											
5575	4232				00.23	03.28				-3.05	6223	4629
5666	4286											
5703	4310											
5752	4330				01.11	02.62				-1.51	6410	4763
					00.78	02.22				-1.44	6453	4797
											Mean	

SUMMARY

In studying the data for this publication several different comparisons between the old and new latitude determinations at each of the three stations were made.¹⁰ Each of the comparisons for a station is based on a somewhat different method of computing, selecting, or combining the data. It is difficult to say which method is the best, but probably the most reliable comparison is obtained if both the old and new determinations are made to depend only on the pairs of stars that were common to both sets of observations. When this is done, and the old determinations are based upon the declinations adopted in 1870 or 1872 and the new determinations are based upon the Boss Catalogue declinations, we obtain the following differences in the sense, new latitude minus old latitude:

Mount Tom (15 pairs)	-1.25
Mount Pleasant (19 pairs)	+0.05
Des Moines (10 pairs)	-1.64

If, however, the old determinations, as well as the new, are based upon Boss Catalogue declinations, the following differences are obtained:

Mount Tom	-0.99
Mount Pleasant	+0.29
Des Moines	-1.49

It can be seen that the use of the Boss Catalogue data decreases the difference between the old and new determinations at both Mount Tom and Des Moines, although both differences still remain large. At Mount Pleasant the difference is made larger by the use of the Boss Catalogue data, but it is still quite small.

¹⁰ Not all of the data of these comparisons are included in this publication, but they are on file at the Coast and Geodetic Survey and may be consulted by those interested in a more detailed study of the subject.

APPENDIX

FORMULAS AND CONSTANTS USED IN THE COMPUTATION OF LATITUDE

For the observations with Wurdemann zenith telescope No. 5, which was used for the original determinations at all three stations, the formula is as follows (see Special Publication No. 14, p. 116):

$$\phi = \frac{1}{2} (\delta + \delta') + \frac{R}{2} (M - M') + \frac{d}{4} \left[(n + n') - (s + s') \right] + \frac{1}{2} (r - r') + \frac{1}{2} (m + m'),$$

in which the primed letters refer to the north star and the unprimed letters to the south star and,

δ = apparent declination,

M = micrometer reading (increased readings corresponding to increased zenith distances),

R = value in arc of one turn of the micrometer screw,

d = value in arc of one division of the level bubble,

n and s = the readings of the north and south ends of the level bubble, respectively,

r = the refraction correction, and,

m = the correction to measured zenith distance when the star is observed off the meridian.

The correction for differential refraction for a pair of stars is given by the formula,

$$r - r' = 57''.7 \sin (z - z') \sec^2 z$$

in which

$$z = RM,$$

and

$$z' = RM'.$$

(See Special Publication No. 14, pp. 117 and 118.)

The constants of Wurdemann zenith telescope No. 5 were as follows:

Mount Tom	Mount Pleasant	Des Molnes
$R = 41.380$	41.400	41.42
$d = 0.76$	0.79	0.815

For the Bamberg broken-telescope transits, the instruments used in 1930, the formula is somewhat different from the one given above and is as follows (see Special Publication No. 109, p. 52):

$$\phi = \frac{1}{2} (\delta + \delta') + \frac{R}{2} (M_E - M_W) + \frac{1}{4} \left(\frac{d + d_1}{2} \right) \frac{1}{2} \left[(n + n_1 + s + s_1)_E - (n + n_1 + s + s_1)_W \right] + \frac{1}{2} (r - r') + \frac{1}{2} (m + m'),$$

in which the symbols have the same meaning as in the preceding formula, except that the subscripts E and W refer to the position of the ocular and the subscript 1 is used to indicate the level readings and level value for the second one of the two levels, this instrument being equipped with two levels.

The constants of the two instruments used in the 1930 determinations are as follows (see Special Publication No. 109, p. 32):

Bamberg transit No. 20 "	Bamberg transit No. 21 "
$R = 78.94$	79.08
$\frac{d + d_1}{2} = 1.335$	1.286

HISTORICAL NOTE ON THE TALCOTT METHOD

The method of latitude determinations, known as the Talcott or Horrebow-Talcott method, was first publicly announced by Peter Horrebow when his *Atrium Astronomiae* was published in 1732. Very little attention, however, was paid to it until, over 100 years later, Capt. Andrew Talcott of the United States Engineers discovered and developed the method independently and demonstrated its practicality with the zenith telescope.¹¹

The Talcott method was introduced in the Coast Survey by Superintendent A. D. Bache in 1846 and after numerous trials was finally adopted as the standard for the determination of latitude by the Survey in 1851. The first complete set of observations by this method was made by T. J. Lee for the Coast Survey at Thompson, Mass.,¹² in 1846, with a zenith telescope loaned by the United States Military Academy. In 1847, the Survey acquired an instrument of its own, known as zenith telescope No. 1.

The Talcott method for the determination of latitude superseded the methods formerly used which depended on the measurement of absolute zenith distances with the zenith sector or on the observations of the transits of stars over the prime vertical with a prime vertical transit.¹³

METEOROLOGICAL DATA

The material in the tables which follow has been taken from the field records of the respective stations. Unfortunately, the old field record for Des Moines could not be located and so no information is available regarding the meteorological conditions in 1869 at this station.

¹¹ See A Question of Priority in Originating a Very Important Astronomical Method. By J. E. McGrath. *Journal of the Royal Astronomical Society of Canada*, vol. 8, No. 8, January-February, 1914, pp. 36-40.

¹² See Capt. T. J. Lee, U. S. Corps Topographical Engineers, assistant on the survey of the coast, *On the Use of the Zenith and Equal-Altitude Telescope in the Determination of Latitude*, Topographical Bureau of the War Department, 1848.

¹³ See Coast and Geodetic Survey Special Publication No. 14, p. 103, Special Publication No. 110, pp. 47-48, and Appendix 14, Report of the Superintendent of the Coast Survey for 1880, p. 245.

TABLE 7.—*Meteorological conditions at Mount Tom in 1862*

Date, 1862	At beginning of observation			At end of observation			Weather conditions
	Ba- rom- eter	Temperature (F.)		Ba- rom- eter	Temperature (F.)		
		Inside	Outside		Inside	Outside	
July 18	<i>Inches</i> 29.032	° 60.8	° 60.8	<i>Inches</i> 29.025	° 58.8	° 56	Clear and calm.
19	28.940	57.4	50.8	28.857	56.2	56	
25	28.748	76.8	76.9	28.751	63.5	65	Very hazy; wind fresh from south.
27	29.887	68.5	68	28.885	63	63.7	
28	28.896	71.8	70.8	28.870	67.3	67.1	Clear and calm; flying clouds. Wind fresh from northwest.
30	28.860	72.8	71	28.852	66.9	-----	
Aug. 1	28.853	71.8	69.8	28.860	65.6	65.5	Moderately clear and calm; wind light from southeast.
1	28.885	73.6	70.5	28.884	67	66.5	
2	28.951	78.2	76	28.960	70.6	70.9	Moderately clear, sky hazy; wind fresh from south.
3	28.966	71.9	71.5	28.965	67.8	67.8	
4	28.941	77.2	75.8	28.945	74	72.6	Wind light from northwest; partly clear; wind fresh from northwest.
6	28.958	73.1	73.9	28.995	69.5	69.2	
7	28.980	68.6	68.9	28.992	67.4	*82.0	Clear, horizon hazy; wind fresh. Cloudy; wind moderate from northwest.
8	28.720	78.8	79.0	-----	-----	-----	
10	28.854	66.5	67.0	-----	-----	-----	Clear; wind strong from north. Clear; wind strong from south.
11	28.848	71.0	70.0	-----	-----	-----	

* Probably an error in recording.

TABLE 8.—*Meteorological conditions at Mount Tom in 1930*

Date, 1930	At beginning of observation			At end of observation			Weather conditions
	Ba- rom- eter	Tem- pera- ture (C.)	Time (eastern standard time)	Ba- rom- eter	Tem- pera- ture (C.)	Time (eastern standard time)	
July 23	<i>Inches</i> 29.07	° 22.4	8.00 p. m.	<i>Inches</i> 29.10	° 20.0	10.50 p. m.	Cloudy. Increasing cloudiness.
24	29.02	19.0	10.30 p. m.	29.01	18.5	12.10 a. m.	
25	29.05	24.0	7.50 p. m.	29.09	20.0	10.45 p. m.	

TABLE 9.—*Meteorological conditions at Mount Pleasant in 1851*

Date, 1851	At beginning of observation			At end of observation			Weather conditions
	Barom- eter	Temperature (F.)		Barom- eter	Temperature (F.)		
		Inside	Outside		Inside	Outside	
	<i>Inches</i>	°	°	<i>Inches</i>	°	°	
July 20.	28.08	67.4	67.0	27.83	59.5	59.5	Wind fresh from west-northwest.
21.	28.08	67.4	67.0	27.78	61.5	61.5	
22.	28.09	67.0	66.7	27.99	64.0	63.8	
23.	28.09	67.0	66.7	28.10	61.0	61.0	Calm and clear p. m.; flying clouds 3 a. m.
28.	28.09	67.0	66.7	27.60	62.0	62.0	Cloudy; aurora visible.
27.	28.09	67.0	66.7	27.54	59.8	58.5	Cloudy.
30.	28.09	67.0	66.7	28.11	52.5	53.0	
31.	28.09	67.0	66.7	28.14	53.0	53.0	
Aug. 2.	28.09	67.0	66.7	28.04	61.5	61.2	Clear, scattering clouds; wind moderate from northwest; aurora visible.
3.	28.09	67.0	66.7	28.18	60.3	58.5	Hazy; fresh breeze from northeast.
5.	28.09	67.0	66.7	28.08	58.5	58.5	Cloudy in early evening; atmosphere damp.
8.	28.09	67.0	66.7	28.08	58.5	58.5	Increasing cloudiness.
13.	28.09	67.0	66.7	27.89	66.0	64.5	Increasing haziness.
14.	28.09	67.0	66.7	27.83	56.2	55.5	Increasing cloudiness.
15.	28.09	67.0	66.7	27.83	50.8	51.0	Do.
16.	28.09	67.0	66.7	27.89	53.1	53.0	Wind strong from northwest; flying clouds.
18.	28.09	67.0	66.7	27.90	51.2	51.2	
19.	28.09	67.0	66.7	28.14	54.0	53.8	

No temperature or barometer readings were recorded at Mount Pleasant in 1930. The record merely states that it was cloudy on August 21.

As stated previously, no meteorological data are available for Des Moines for the determination of 1869. No temperature or barometer readings were recorded at this station in 1930. The record states only that the air was smoky on July 31 and August 1 and prevented the completion of the observations on the latter date.

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- 109-F. Hydrography.
- 109-G. Leveling.
- 109-H. Nautical Charts.
- 109-I. Oceanography.
- 109-J. Traverse.
- 109-K. Seismology.
- 109-L. Terrestrial Magnetism.
- 109-M. Tides.
- 109-N. Topography.
- 109-O. Triangulation.
- 109-P. Cartography.
- 109-R. Airway maps.

(Name)-----

(Address)-----