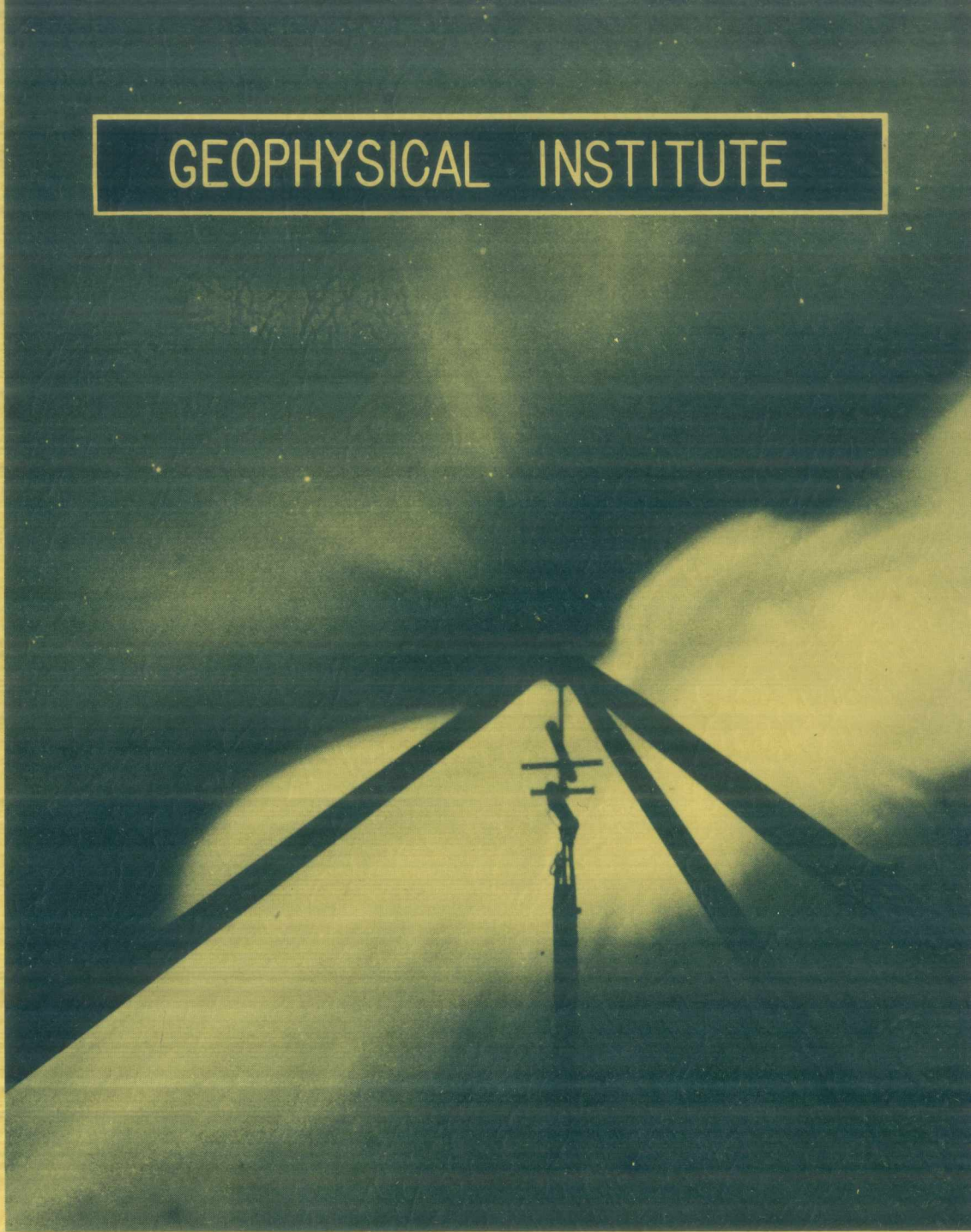


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A Study of the Aurora of 1859

by

D. S. Kimball

Scientific Report No. 6

NSF Grant No. Y/22.6/327

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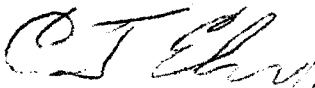
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Principal Investigator:



C. T. Elvey, Director

## ABSTRACT

The two great auroral displays of August 28-29 and September 1-2, 1859 are studied from a collection of world-wide descriptive observations. Both auroras reached to unusually low latitudes. Red glows were reported as visible from within  $23^{\circ}$  of the geomagnetic equator in both north and south hemispheres during the display of September 1-2. It is shown that by using graphic symbols, descriptive reports may be used to indicate the significant features of an auroral display. A series of world-wide maps show the hourly locations and lowest latitude limits of auroral visibility and overhead aurora for the most active hours. They illustrate how the progress of an aurora may be followed throughout the night. Both auroras seen in North America reached their southern limits near local midnight. During the larger display of September 1-2 the aurora moved to lower latitudes and also covered a wide range in latitudes. This indicates that during great displays the auroral activity appears to expand in latitude until local midnight, at the same time moving towards the geomagnetic equator. Over large areas both displays were predominantly red. Magnetic records indicate that there were two distinct disturbances associated with the two displays. A tabulation of all known available auroral observations reported from August 28 to September 5, 1859 illustrates that by using a letter code, significant auroral activity may be recorded for use in auroral catalogues.

## Introduction

In a discussion of outstanding tropical auroras, Chapman<sup>1</sup> wrote: "One of the greatest auroras on record occurred on 1859 September 1. Among places in the tropics from which it was seen was Honolulu (Hawaii). For a few nights before and after this remarkable event, the aurora was intermittently widespread over the globe, in the subauroral and subtropical belts. The period was one of exceptional activity on the sun, as indicated by great sunspots and solar flares. It is interesting to note that the first recorded observation of a solar flare was made visually by Carrington in the forenoon of 1859 September 1. Carrington pointed out that a moderate but very marked magnetic disturbance (which was of the type now known as a crochet) was shown on the Kew magnetograms at the time of observation. Toward four hours after midnight a great magnetic storm commenced. Carrington's observation is almost unique, for a flare must be of exceptional intensity to be observed in integrated light."







Elias Loomis,<sup>2,3,4,5</sup> Professor of Natural Philosophy at Yale University, realizing the great scientific interest of this rare tropical aurora, collected accounts of this great display. The reports ranged from newspaper descriptions and personal letters to reports from astronomical observatories. He also obtained magnetic records from the United States, Canada, England, Russia and Australia. However, he did not publish any comprehensive study of the reports.

Using the data collected by Loomis, a synoptic study has been made to determine the geographical location and movement of the auroral displays associated with the period of magnetic disturbance from Aug. 28 to Sept. 2.

## Graphic Representation of Auroral Activity

Auroras were seen and reported each night from August 28 until September 6, but the greatest auroral activity occurred on the nights of August 28-29 and September 1-2. The descriptive reports collected by Loomis have been converted to a graphic form with the auroral activity shown for 15 minute intervals. Individual reports sometimes spanned a time interval of several hours. In order to make the comparison of observations easier, the graphic plots were pasted into strips - a single strip for each observer. Fig. 1 is a plot of the report from Havana (Cuba) for the display of Sept. 1-2. The box for each 15 minute interval represents the sky centered along the observer's meridian as viewed from outside the earth. The bottom of each column represents the southern horizon with the northern horizon at the top. The auroral activity was recorded by placing the proper pictorial symbol at the reported position in the sky. When estimated positions were given in degrees, by the observer, they are noted adjacent to the forms, for example see the 0645 box of Fig. 1. The strips were then spread out on a table and could be arranged for comparison of the same time intervals. The symbols used are shown in Table I.

Table I. Symbols used for plotting observations

	= Glow	R	= Red Aurora
	= Homogeneous Arc		= Through clouds
	= Rayed Forms	(A)	= Aurora present, no details
	= Corona (Aurora overhead)	↑	= Flaming aurora
	= Diffuse surface.	↑	=

The aurora of August 28-29 was seen in Europe, North America, Australia and at sea. Reports from 109 observers were used in the analysis of this display. The display of September 1-2, seen in Europe, North and South America, Australia and at sea, was reported by 82 observers.

### Locations of the Auroras

The data used in this study are from written descriptive reports collected by Loomis, Fritz<sup>6</sup>, Angot<sup>7</sup>, The Sydney (Australia) Morning Herald<sup>8</sup>, The Meteorological Office<sup>9</sup>, Washburn Observatory<sup>10</sup>, Matsushita<sup>12</sup>, Wochenschrift für Astronomie, Meteorologie and Geographie<sup>13</sup>, Corzo and Adem<sup>14</sup>. Table II lists places where displays were reported from August 28 to September 5, 1859.

Hourly plots of stations recording visibility or observed overhead presence of aurora were made on large scale world maps for the two nights when the auroras were greatest (Aug. 28-29 and Sept. 1-2). By "visibility" is meant that an aurora was seen only to the north of an observer in the northern hemisphere, or to the south of places reporting auroras at southern latitudes. If auroral forms reached the zenith or beyond, they were plotted as "overhead".

For the night of August 28-29, 1859, Fig. 2 shows the locations where auroral visibility (open circles) and overhead aurora (closed circles) were reported during the most active hours, when the aurora reached its greatest equatorial extent. The geomagnetic equator is shown for reference. The position of the antisun indicated local time at each location.

In Fig. 3 the hourly locations for visibility and overhead aurora are plotted from 05<sup>h</sup> to 08<sup>h</sup> UT for the night of Sept. 1-2. A few observations from South America were reported for this display. During the hours 6<sup>h</sup> and 7<sup>h</sup>, an aurora (glow) in the north was seen from a ship at 88° 28'W and 12° 23'N (23° north geomagnetic latitude). An auroral glow in the south was also reported during this time at Santiago (Chile), 71°W and 33° 26'S (22° south geomagnetic latitude). It was during these hours that the display attained its greatest extent. The aurora had moved from north and south polar regions until it was visible from geomagnetic latitudes 22°-23° in both northern and southern hemispheres.

The equatorward extent of visibility and overhead presence of aurora is illustrated in Fig. 4. The lowest latitudes for visibility of aurora are shown by solid lines. The dotted extensions indicate the probable longitude and latitude limits. The reported lowest latitude limits of overhead aurora are shown by short vertical lines crossing solid lines, with probable extensions indicated by crosses. The extensions were drawn approximately parallel to the geomagnetic equator. Fig. 4a, shows the location of aurora every two hours from 22<sup>h</sup> UT Aug. 28 to 12<sup>h</sup> UT Aug. 29. The hourly equatorward extent for Sept. 2 from 05<sup>h</sup> to 10<sup>h</sup> UT is illustrated in Fig. 4b. Such a series of hourly maps show the world-wide progress of an aurora during the night.

In addition to making a graphical analysis of the displays of August 28-29 and September 1-2, a code was devised (Table III) to record the events of an auroral display. The descriptive reports for all known observations of auroras reported from August 28 to September 5, 1859 were converted to the code and are tabulated in Table IV. The following examples illustrate how the coded data may be read:

Aug. 28-29 (line 5), Station 90 (London, Eng.)

A glow at 2330 UT; at 0015 rays reached to the zenith and flames and a glow were seen; the aurora ended at 0230 (or observations stopped)

Aug. 28-29 (line 19), Station 78 (Key West, Fla.)

A faint glow at 0550; a faint homogeneous arc 30° above the northern horizon at 0630; aurora ended (or observations stopped) at 0715.

Such a coded system could be used in auroral catalogues because it has the advantage of describing significant events in a minimum of space.

### Latitude Distribution of Auroral Activity

In order to study the latitude distribution of auroral activity during each hour, the graphic plot-strips were arranged by hours and latitudes. Reports for the auroras of August 28-29 and September 1-2 seen from the Eastern United States and the West Indies were numerous enough to enable the hourly auroral activity to be shown at most latitudes. Auroral-form symbols were plotted for each hour at the various latitude-degree zones where auroral activity was reported. In some cases the drawings represented a single observation, in others they were a composite of several reports. This procedure is illustrated in Fig. 5, which shows auroral activity for the Eastern United States at geographic latitudes  $28^{\circ}\text{N}$  to  $32^{\circ}\text{N}$  during the night of September 1-2, 1859.

When elevations were given, they are indicated in the diagrams adjacent to the particular form. If no elevations were reported, the positions of the forms on the plots represent the best estimates derived from the written descriptions. In a few cases, a short horizontal line was drawn near the top of a particular form to show its approximate elevation above the northern horizon; these were cases in which no angular positions were reported but the description indicated the upper limit to be about as shown. In a number of cases it was possible to compute overhead locations of arcs from reports of elevations by assuming a height of 100 km. This may lead to some inconsistencies, since both displays were predominantly red, suggesting a greater height. The observers did not report the color of the few arcs used to locate overhead positions from elevations, so the normal height was used. It is obvious that the chart represents an incomplete picture of what actually happened, but it suggests a procedure for studying a particularly interesting display.

### Position and Hourly Change of Equatorward Extent of Auroral Activity.

The rate at which the southern limit of the aurora seen in eastern United States moved south and then north for the two principal nights is shown in Fig. 6. During the first hour the Aug. 28-29 display moved rapidly south and remained at its greatest southern extent for several hours before retreating northward during the early morning hours. This curve does not indicate greatest southern extent at local midnight (05<sup>h</sup> UT) as found by Bless et. al.<sup>14</sup> and Davis and Kimball<sup>15</sup>. This may be because the number of observations was insufficient, and the curve for overhead aurora is uncertain for the same reason.

Reports for the night of Sept. 1-2 from most places in the eastern United States indicated cloudiness during the early evening hours. The rate at which the aurora moved south is uncertain, but during the first two hours the zone of auroral visibility may have moved 30° in latitude. This display had a southern limit for auroral visibility around local midnight, but the curve for overhead aurora is uncertain.

### The Southern Extent and Range of Auroral Forms

The probable extent and latitude range of the auroral activity for the peak hours of the two principal nights reported by observers in the United States is illustrated in Fig. 7. The upper diagrams show areas where the auroras were seen to the north of the observers (visibility) while the lower pair indicate the latitude range where the forms were reported overhead and/or to the south. If these maps show the approximate areas where the southern part of the auroras were seen they would indicate that the zones of auroral activity widen in a north-south direction during great displays. For Sept. 1-2

the regions of glows, rays and overhead forms are wider and extend farther south than for the night of Aug. 28-29. There were no observations to indicate what happens at the northern edge of the auroral activity. An unpublished study by the author of 28 auroras seen in the United States from 1939 to 1946 using observations collected as part of the National Geographic Society-Cornell University Auroral Program indicates a similar widening of the latitude range of auroral activity for the larger displays.

#### The Extent of Red Auroral Forms

One characteristic of the aurora of 1859 and other great displays is the presence of notable color in the display. Observers reported white, straw color, yellow, orange and red. The predominant color, red, was observed in glows, rays (some red tipped), arcs, pulsating and diffuse surfaces. A red glow and a red arc were reported as far south as Havana (Cuba), and Santiago (Chile) reported a red glow in the southern sky for the display of September 1-2. Fig. 9, which shows the distribution of the red auroral forms for the nights of August 28-29 and Sept. 1-2, 1859, results from a compilation of the locations reporting colored aurora and the colors seen.

#### Magnetic Activity (August 28 to September 4, 1859).

The period from Aug. 28 to Sept. 6, 1859 was one of continuing magnetic disturbance. Numerous reports of magnetic activity associated with the 1859 auroras were collected by Loomis and were published by him in tabular form and as written descriptions.

The greatest disturbance during this period began on Sept. 2, 1859 at 0450 UT, about 18 hours after Carrington observed a bright flare on the sun. Carrington "fixes the first outburst as being not 15 seconds different from

11<sup>h</sup> 18<sup>m</sup> GMT; 11<sup>h</sup> 25<sup>m</sup> was the time of disappearance."<sup>11</sup> At the same time that he observed this phenomena the three magnetic elements at Kew Observatory were simultaneously disturbed.<sup>17</sup>

Table VI lists the times of great magnetic disturbances on Aug. 28 and Sept. 2, 1859. With the exception of the Kew report, all observations were abstracted from the data collected by Loomis. There were two distinct disturbances; one on the evening of Aug. 28, and the second during the early morning of Sept. 2. These were associated with the great displays.

### Summary

Some auroral displays of the past have been widely observed. In a few cases valuable descriptions in great detail are available. This study illustrates how the significant features of a display may be readily studied from such materials by using graphic symbols.

The aurora reached low latitudes on the two nights Aug. 28-29 and Sept. 1-2. During the hours 6<sup>h</sup> and 7<sup>h</sup> UT of the second night, glows were reported as being visible from within 23° of the geomagnetic equator in both the north and south hemispheres. A series of world-wide maps showing the lowest latitude limits of visibility and overhead presence of aurora illustrates how the progress of an aurora may be followed throughout the night.

The southern limit of the aurora as seen in North America rapidly moved southward during the early hours of each display, and slowly retreated northward after local midnight. The aurora moved to lower latitudes in the larger display of Sept. 1-2 than during the display of Aug. 28-29; and the regions where glows, rays and forms overhead were present were wider for the greater display. This would seem to indicate that the auroral activity expanded in latitude for the larger display, at the same time moving towards the geomagnetic equator until local midnight.

Over large areas both displays were predominantly red, and a red arc was seen from as far south as Havana (Cuba). Santiago (Chile), 23° geomagnetic latitude, reported a red glow in the southern sky for over two hours.

Magnetic records from Canada, Europe, Russia and Australia indicate that there were two distinct magnetic disturbances associated with the two displays.

A tabulation of all known available auroral observations reported from Aug. 28 to Sept. 5, illustrates that by using a letter code, the important features of the auroras seen at various locations may be briefly recorded for use in auroral catalogues.

#### ACKNOWLEDGEMENT

The author wishes to express his appreciation to Sydney Chapman for his many helpful suggestions towards improving the manuscript.

TABLE II

LOCATIONS FROM WHICH AURORAS WERE REPORTED FROM AUG. 28 TO SEPT. 5, 1859.

Location No.	Location	Geographic Lat.	Long.	Geomagnetic Lat.
1	Adelaide, Austl.	35 S	138 E	45 S
2	Albury, Austl.	36 S	147 E	46 S
3	Aldershot, Eng.	51 N	1 W	54 N
4	Athens, Greece	38 N	24 E	36 N
5	Asheville, N.C.	36 N	82 W	47 N
6	Auburn, Cal.	39 N	121 W	46 N
7	Aurora, Ind.	39 N	85 W	50 N
8	Bahama, Isls, W.I.	26 N	79 W	37 N
9	Ballaret, Austl.	37 S	144 E	47 S
10	Bamberg, Ger.	50 N	11 E	51 N
11	Basel, Switz.	48 N	8 E	49 N
12	Bathurst, Austl.	33 S	150 E	42 S
13	Beechworth, Austl.	36 S	147 E	45 S
14	Belfast, Austl.	37 S	145 E	47 S
15	Benalla, Austl.	36 S	146 E	45 S
16	Bentonville, Ark.	36 N	94 W	46 N
17	Bermuda	33 N	65 W	44 N
18	Biala, Pol.	52 N	23 E	50 N
19	Bloomington, Ind.	39 N	86 W	50 N
20	Boden, Switz.	48 N	9 E	49 N
21	Bodenbach, Czech.	51 N	14 E	51 N
22	Boston, Mass.	42 N	70 W	53 N
23	Brighton, Eng.	51 N	0 W	54 N
24	Brisbane Co., Austl.	32 S	151 E	41 S
25	Brussels, Belg.	51 N	4 E	54 N
26	Burlington, Minn.	47 N	92 W	58 N
27	Burlington, N.J.	40 N	75 W	51 N
28	Burlington, Wis.	47 N	92 W	57 N
29	Cahaba, Ala.	32 N	87 W	42 N
30	Cape Otway, Austl.	31 S	144 E	40 S
31	Carlisle, Pa.	40 N	77 W	51 N
32	Cedar Keys, Fla.	28 N	88 W	40 N
33	Charleston, S.C.	33 N	80 W	44 N
34	Cleveland, Ohio	42 N	82 W	53 N
35	Clifton, Eng.	55 N	3 W	58 N
36	Cohe, Cuba	20 N	82 W	31 N
37	College Hill, Ohio	39 N	84 W	51 N
38	Concepcion, Chile	37 S	73 W	26 S
39	Corpus Christie, Tex.	28 N	98 W	38 N
40	Cranz, Ger.	53 N	20 E	52 N
41	Crawfordsville, Ind.	40 N	87 W	51 N
42	Dallas, Tex.	33 N	97 W	43 N
43	Davenport, Iowa	42 N	91 W	53 N

TABLE II (CONT'D.)

Location		Geographic		Geomagnetic
No.	Location	Lat.	Long.	Lat.
44	Dubuque, Iowa	42 N	91 W	53 N
45	Dunkerque, Fr.	51 N	3 E	53 N
46	Durham, Eng.	55 N	2 W	56 N
47	Durham, N.H.	55 N	72 W	56 N
46a	Echuca, Austl.	36 S	147 E	36 S
47a	Ft. Bridger, Wyo.	41 N	110 W	49 N
48	Ft. Jefferson, Fla.	25 N	83 W	36 N
49	Fredericksburg, Va.	38 N	78 W	49 N
50	Galveston, Tex.	29 N	95 W	39 N
51	Gardiner, Mc.	44 N	70 W	55 N
52	Geneva, Switz.	46 N	6 E	48 N
53	Gettysburg, Pa.	40 N	77 W	51 N
54	Godthaab, Green.	64 N	52 W	72 N
55	Gothenberg, Swe.	58 N	12 E	58 N
56	Goulburn, Austl.	35 S	150 E	44 S
57	Grafton, Ont., Can.	44 N	78 W	55 N
58	Grantham, Eng.	53 N	1 W	56 N
59	Green Bay, Wis.	44 N	88 W	55 N
60	Guadeloupe, W.I.	16 N	62 W	27 N
61	Guanajuato, Mex.	21 N	102 W	31 N
62	Halifax, N.S.	45 N	64 W	56 N
63	Hamburg, Ger.	54 N	10 E	55 N
64	Hamilton, Ger.	32 N	65 W	43 N
65	Hamilton, Ont., Can.	43 N	80 W	54 N
66	Havana, Cuba	23 N	82 W	34 N
67	Henry Co., Ind.	40 N	85 W	51 N
68	Highland, Ill.	38 N	90 W	50 N
69	Hobart, Austl.	43 S	148 E	51 S
70	Honolulu, Hawaii	20 N	157 W	20 N
71	Inagua, Bah. Isl.	21 N	78 W	32 N
72	Iristen, Aust.	-	-	-
73	Indianapolis, Ind.	40 N	80 W	51 N
74	Jacksonville, Fla.	30 N	82 W	41 N
75	Jefferson Co., Miss.	32 N	91 W	43 N
76	Kanosha, Neb.	41 N	96 W	51 N
77	Kapunoa, Neb.	34 S	138 E	44 S
78	Key West, Fla.	25 N	82 W	36 S
79	Kingston, Jam.	18 N	77 W	29 N
80	Konisberg, Ger.	53 N	14 E	53 N
81	Krakow, Pol.	50 N	20 E	49 N
82	Kremsir (Kremsmunster) Ger.	49 N	18 E	48 N
83	Laibach, Yugos.	46 N	14 E	46 N
84	Launceston, Austl.	42 S	147 E	51 S
85	La Union, El Salvador	14 N	88 W	25 N
86	Leon, Mex.	21 N	102 W	31 N
87	Leipzig, Ger.	51 N	12 E	52 N
88	Lewiston, Me.	44 N	70 W	55 N

TABLE II (CONT'D.)

Location		Geographic		Geomagnetic
No	Location	Lat.	Long.	Lat.
89	Linz, Ger.	48 N	14 E	48 N
90	London, Eng.	52 N	0 W	55 N
91	Longwood, Austl.	37 S	146 E	46 S
92	Louisville, Ky.	38 N	86 W	49 N
93	Lunenburg, Mass.	43 N	72 W	54 N
94	Lyon, Fr.	46 N	5 E	48 N
95	Maitland, Austl.	42 S	146 E	51 S
96	Marquette, Mich.	46 N	87 W	57 N
97	Maryborough, Austl.	37 S	143 E	46 S
98	Melbourne, Austl.	38 S	145 E	47 S
99	Memphis, Tenn.	35 N	90 W	48 N
100	Micanopy, Fla.	30 N	82 W	41 N
101	Milwaukee, Wis.	43 N	88 W	54 N
102	Mitterdorf, Aust.	48 N	14 E	48 N
103	Mobile, Ala.	31 N	85 W	42 N
104	Moneka, Kan.	38 N	98 W	48 N
105	Monroe, Mich.	42 N	83 W	53 N
106	Montego Bay, Jam.	18 N	77 W	29 N
107	Monterey, Cal.	37 N	123 W	43 N
108	Montpellier, Fr.	44 N	4 E	46 N
109	Montreal, Que., Can.	46 N	74 W	57 N
110	Mt. Gambier, Austl.	38 S	141 E	48 S
111	Munster, Ger.	48 N	14 E	48 N
112	Natchez, Miss.	32 N	91 W	43 N
113	Naugard, Ger.	54 N	15 E	54 N
114	Nebraska	(42 N)	(110 W)	(50 N)
115	Neuchatel, Switz.	47 N	7 E	49 N
116	Neuenkirchen, Ger.	48 N	16 E	48 N
117	Neuerburg, Pol.	54 N	19 E	53 N
118	Neutra Hung.	48 N	18 E	47 N
119	New Albany, Ind.	38 N	86 W	49 N
120	Newburyport, Mass.	43 N	71 W	54 N
121	New Haven, Conn.	41 N	73 W	52 N
122	Newmark, Eng.	52 N	0 W	55 N
123	New Mexico	(36 N)	(106 W)	(45 N)
124	New Orleans, La.	30 N	90 W	41 N
125	New York, N.Y.	41 N	74 W	52 N
126	Newark, Ohio	40 N	82 W	51 N
127	Nottingham, Eng.	53 N	0 W	56 N
128	Novelles, Fr.	50 N	2 E	53 N
129	Ogdensburg, N.Y.	45 N	75 W	56 N
130	Olmütz, Ger.	50 N	17 E	50 N
131	Oregon	(44 N)	(125 W)	(50 N)
132	Oslo, Nor.	60 N	10 E	60 N
133	Paducah, Ky.	37 N	87 W	48 N
134	Paris, Fr.	49 N	2 E	52 N
135	Parma, Italy	45 N	10 E	46 N
136	Paulding, Miss.	32 N	89 W	43 N

TABLE II (CONT'D.)

Location		Geographic		Geomagnetic
No.	Location	Lat.	Long.	Lat.
137	Pekin, Ill.	41 N	90 W	52 N
138	Philadelphia, Pa.	40 N	75 W	51 N
139	Pikes Peak, Colo.	39 N	105 W	47 N
140	Pittsburgh, Pa.	40 N	80 W	51 N
141	Portland, Austl.	38 S	142 E	48 S
142	Prague, Czech.	50 N	14 E	50 N
143	Preston, Eng.	54 N	0 W	57 N
144	Princeton, Minn.	46 N	94 W	56 N
145	Puebla, Mex.	19 N	98 W	29 N
146	Pulkova Sov. Un.	60 N	30 E	56 N
147	Queenscliffe, Austl.	38 S	144 E	47 N
148	Rafz, Switz.	48 N	8 E	49 N
149	Raleigh, N.C.	36 N	79 W	49 N
150	Riga, Sov. Un.	57 N	24 E	53 N
151	Riley Co., Ind.	42 N	89 W	53 N
152	Rochester, N.Y.	43 N	73 W	54 N
153	Rome, Italy	42 N	13 E	42 N
154	Rome, N.Y.	43 N	75 W	54 N
155	Rzeszow, Pol.	50 N	22 E	49 N
156	Sachsen Prov. Ger.	(51 N)	(14 E)	(51 N)
157	Sacramento, Cal.	39 N	122 W	44 N
158	Sag Harbor, N.Y.	41 N	72 W	52 N
159	St. Georges, Belg.	51 N	6 E	53 N
160	St. Johns, Nfd.	48 N	53 W	59 N
161	ST. Louis, Mo.	39 N	90 W	48 N
162	St. Pascal, Que., Can.	48 N	68 W	59 N
163	St. Vallery, Fr.	50 N	2 E	53 N
164	Salem, Ore.	45 N	123 W	50 N
165	Salt Lake City, Utah	41 N	111 W	49 N
166	Sandhurst, Austl.	37 S	144 E	46 S
167	Sandwich, Ill.	42 N	88 W	53 N
168	Sandy Spring, Mo.	39 N	77 W	50 N
169	San Francisco, Cal.	38 N	122 W	45 N
170	San Salvador, El Salvador	13 N	62 W	24 N
171	Santa Clara, Cal.	37 N	122 W	44 N
172	Santiago, Chile	33 S	71 W	22 S
173	Sauk City, Wis.	43 N	90 W	54 N
174	Savannah, Ga.	32 N	81 W	43 N
175	Saxony prov. Ger.	(51 N)	(13 E)	(51 N)
176	Schemnitz, Hung.	48 N	19 E	47 N
177	Schussle, Ger.	50 N	14 E	50 N
178	Selma, Ala.	32 N	87 W	43 N
179	Spuren	-	-	-
180	Stark Co., Ill.	41 N	90 W	52 N
181	Steubenville, Ohio	40 N	80 W	51 N
182	Stockholm, Swe.	59 N	18 E	57 N
183	Stockton, Cal.	38 N	121 W	44 N
184	Stuttgart, Ger.	40 N	9 E	41 N
185	Sydney, Austl.	34 S	151 E	43 S

TABLE II (CONT'D).

Location No.	Location	Geographic Lat.	Long.	Geomagnetic Lat.
186	Tartu (Dorpot) Sov. Un	58 N	27 E	55 N
187	Tasmania, Austl.	42 S	146 E	51 S
188	Thomasville, Ga.	31 N	84 W	41 N
189	Tobolsk, Sov. Un.	58 N	63 E	49 N
190	Toronto, Ont. Can.	41 N	79 W	54 N
191	Tottenham, Eng.	54 N	0 W	57 N
192	Union Hill, Tex.	30 N	97 W	40 N
193	Upsala, Swe.	60 N	18 E	58 N
194	Urbana, Ohio	40 N	83 W	51 N
195	Utah	(37 N)	(110 W)	(45 N)
196	Valparaiso, Chile	33 S	71 W	22 S
197	Vienna, Aust.	48 N	16 E	48 N
198	Vischel, Ger.	50 N	7 E	52 N
199	Wakayama, Japan	34 N	135 E	23 N
200	Waltham, Mass.	42 N	71 W	53 N
201	Wangaratta, Austl.	36 S	146 E	45 S
202	Washington (State)	(49 N)	(122 W)	(56 N)
203	Washington, Tex.	31 N	96 W	40 N
204	West Point, N.Y.	42 N	74 W	53 N
205	Willow Creek, Ind.	42 N	89 W	53 N
206	Winona, Minn.	44 N	92 W	55 N
207	Wyandott, Kan.	39 N	95 W	49 N
At Sea				
208	Atlantic Ocean	67 N	55 W	66 N
209	" "	51 N	10 W	53 N
210	" "	51 N	13 W	54 N
211	" "	45 N	17 W	51 N
212	" "	34 N	33 W	42 N
213	" "	34 N	44 W	53 N
214	" "	30 N	45 W	40 N
215	" "	28 N	80 W	34 N
216	" "	27 N	35 W	36 N
217	" "	27 N	46 W	37 N
218	" "	26 N	29 W	35 N
219	" "	26 N	27 W	34 N
220	" "	24 N	35 W	33 N
221	" "	15 N	24 W	23 N
222	" "	13 N	88 W	24 N
223	" "	50 S	80 W	39 S
224	" "	67 S	66 W	56 S
225	Pacific Ocean	54 S	144 W	51 S

TABLE III

Code for Description of AurorasPresence of Aurora

(A) Aurora present, no details

Form

GL = Glow, DS (Diffuse surface)

HA = HA, (Homogeneous arc),  
HB (Homogeneous band)RF = RA, (Rayed arc), RB (Rayed band),  
D (Drapery)

RY = Isolated rays

PS = Pulsations

FL = Flames

CA = Corona

Motion (M)MN = To north, MN = Fast motion to NMS = To south, MS = " " " SME = To east, ME = " " " EMW = To west, MW = " " " WMRA = Random Motion, MRA Fast.Intensity (I)

IF = Faint

IM = Medium

IB = Bright

IVB = Very bright

Color (C)

CYG = Yellow-green, white

CRU = Red upper border

CRL = Red lower border

CRA = Red all over

CRP = Red (partial)

CBL = Blue

CVGR = Violet-green

CALL = All Colors

Changes

PS = Pulsations start

PT = Pulsations end

FS = Flames start

FT = Flames end

RFS = Ray forms start

SQ = Sequence (ex.:HA change to RA,  
SQHARA)Time

S = Start of display

P = Peak

T = End of Display

DU = Duration

DUAN = Duration all night

TDN = Ends at dawn

AF = Event after a certain time

T? = Continued after last observations

Height (H)

HZ = To zenith

HNZ = From north to zenith

HLN = Low in north

HLS = Low in south

HN..<sup>o</sup> = Height above NorthHS..<sup>o</sup> = Height above SouthHE..<sup>o</sup> = Height above EastHW..<sup>o</sup> = Height above WestExtent (XX)

XN = North only

XS = South only

XE = East only

XW = West only

XALL = Covers sky

XP = Partial, spotty

X = Extensive

XENW = In east, north, west, etc.

Special Forms (SF)

SFH = Hooked Band

SFD = Dark segment, etc.

Weather

CL = Cloudy

PCY = Partly cloudy

CLRN = Clouds and rain

CLSN = Clouds and snow

LU = Moon interferes

HZ = Haze interferes

HZALL = Haze over sky

TABLE IV.

LOCATIONS AND DESCRIPTIONS OF THE AURORAS  
REPORTED FROM AUGUST 28 TO SEPTEMBER 5, 1859

<u>Serial No. of Place of Observation</u>	<u>Time and Information Recorded</u>	<u>Reference to Source*</u>
<u>August 28-29, 1859 (UT)</u>		
176	2000-0100 (A)	L,A,F
10	2200S;2237RF,CR	F,A,Wo
132	2215 CA,FL,CR;2300T,PCL	L
177	2300-0030 (A)	L,A,F
90	2330 GL;0015RFZN,FL,GL;0230T	L,A,F
163	2345-0115RF,GL,CR;0245T	L,A,F
21	0000-0100 (A)	L,A,F
25	0015-0200GL,RFZN;0130PS,CR	L,A,F
209	0030 (A),CRA	L,F
127	0045-0315;0230RFZN,CA,PCL	L
142	0100RF,IB	L,A,F,Wo
23	0130HAZN,CR	L,A,F
134	0200-0415;HAHN150°,CR	L,A,F,Wo
211	0200 (A),CR	M
214	0300-1000;0330RFHN30°,CR	L,F
219	0315-0415GL,CRA	L,F,M
62	0500-0700;CA0615;RAHN168°	L
204	0515-1245; CA,RFZN,GL,CR	L
78	0530GL,IF;0630HAHN30°,IB;0715T	L
100	0530-1145;RFHN80°,CR	L
121	0530-0815T;HAHN168°,CA,FL,CL	L
200	0530-1300;RFZN,GL,CRA	L
49	0600-1115T;GL,CR	L
64	0600T;CA,XENW,IB	L
65	0600-0700;CA,HAHN170°,CRA	L
74	0600-1200RF	L
125	0600-TDN;RFZN;0715CA,CR	L
158	0600-0700;CA,RFZN,FL,CR	L
50	0615-1400;1400RFHN85°,FL,GL	L
88	0615-1200;HAHN175°,RFZN,FL,IB	L
93	0615-1430;0730RFZN,CRA,IB	L
103	0615-0830;RF,GL	L
190	0615CA,RFZN,CRA	L
27	0630HAHN160°,RFZN;0715CA	L
39	0630RA,CRL	L

\* See Table V for meaning of symbols

TABLE IV (CON'T)

Serial No. of Place of Observation	Time and Information Recorded	Reference to Source
41	0630-1200RFZN;1245CA,FL	L
57	0630-0700CA;1130-1200GL	L
138	0630HAHN158°	L
53	0700-0800;0730RFZN,GL,CRA	L
66	0700-1400;1400RFZN,GL,CRA	L,Wo
109	0700-0800;RFZN,CA,CRA,IB,PCL	L
120	0700HAHN173°;0800CA,FL,CR	L
124	0700-0800;RF,XN	L
168	0700HAHN130°	L
137	0715-0800;0745RFZN,HA	L
149	0715-0900 (A)	L
59	0730-1000RFZN;0900CA,GL,CR	L
167	0730-1100RFZN;1000CA,HA,FL	L
19	0800-0830RFZN,HAZN,CR	L
28	0800-1000RF,CR,IB	L
29	0800-0900GLHN90°	L
37	0800-1315;1000CA;1315RFZN	L
44	0800-1100;RF,GL,CRA	L
92	0800FL,GLZN,CRA	L
101	0800-1200;0245RFZN,CA,IB	L
162	0800CA,IB	L
178	0800HAHN20°;0830RA;1000RF	L
34	0830-1200;0830HAHN120°,RFZN,CR	L
161	0830-1330;RFZN;1315CA,GL,CRA	L
105	0845HAHN160°,RFZN;0900CA,GL,CRA	L
67	0900GL,RFZN,CA;1000RFHN25°	L
68	0900HA,RFZN;1300CA;1400HA	L
194	0915HAHN140°,RFZN,CR	L
206	0930RFZN;1200CA	L
91	1000-1115;1030RFZN,GL,CRA	S,Wo
98	1000-1615;1045RFZN,HA,CR,PCL	L,Wo
139	1000RFZN,GL,CR	L
152	1000CA	L
201	1015-1130 (A)	S
95	1100 (A),CR	S
147	1100,XS,CR	S,Wo
165	1100-1445;1300RFZN,HA,CR	L
166	1100IB	L,S
185	1100GL,CRA,HA	L,S,Wo
141	1100-1300T,RF;1200CA	L

TABLE IV (CON'T)

Serial No. of Place of Observation	Time and Information Recorded	Reference to Source
207	1130CA;1330T	L
110	1200RF,XE,IB	S
133	1200-1300;IB,PCL	L
195	1200-1300GL,RF,CR	L
202	1200-1800;1415HAZN;1600RFZN,FL	L
33	1215GL	L
77	1230RAHS30 <sup>0</sup> ,CR	L
76	1300RFZN,GL,CRA	L
157	1300RF,CR	L
171	1300GL;1330RFHN40 <sup>0</sup> ; 1530T	L,A
182	1300GL;1315RFHN50 <sup>0</sup> ,CR	L
107	1330-1530 (A),IB	L
169	1400-TDN;1400RFZN,GL	L
225	1900GL,CR,RFHS140 <sup>0</sup> ,IB	M
1	RFXS	S
17	RFXN,CR	L,F
32	RFHN30 <sup>0</sup> ,CR	L
42	RAHN45 <sup>0</sup> ,RF,CR,TDN	L
71	GL,CR,IB	L,F
97	XS,ZN	S
116	RF,CR	F,A,Wo
130	RF,CR	F,A,Wo
153	RFZN,GL,CR	L,A,F,Wo
173	RFZN,XNEW	W
174	RFHN45 <sup>0</sup> ,CRXN	L
181	RFZN,2HAZN,FL,CR	L
217	GL,CRA	L,F

Aurora reported - no details (Locations & Sources)  
 3(L,F),4(F,A),8(F),11(F),20(A),22(L),47(F),52(F,A),  
 56(S),58(L),72(L,F),87(F,A),94(F,A),108(F,A),113(F),  
 115(A),117(F),128(A),135(F,A),140(L),148(F),156(F),  
 159(F),175(A),184(F,A),187(L),197(F,A),198(F),218(A),  
 210(A),224(L).

August 29-30,1859

57	0645RF,CR	L,F
190	0830 (A),IF	L
202	1100-1600;GL,XN,IF	L,F

Aurora reported - no details (Locations & Sources)  
 45(A),58(F),109(L),142(A),198(F).

TABLE IV (CON'T)

<u>Serial No. of Place of Observation</u>	<u>Time and Information Recorded</u>	<u>Reference to Source</u>
<u>August 30-31, 1859</u>		
202	1230-1600GL,XN,IF Aurora reported - no details (Locations & Sources) 54(F),57(L,F),58(F,A),198(F,A)	L
<u>August 31-September 1, 1859</u>		
58	RF,XALL,CR,PCL Aurora reported - no details (Locations & Sources) 57(F),81(F,A),142(F,A),179(F),198(A)	L
<u>September 1-2, 1859</u>		
73	0300RA;0600CA,CR;0945T	L
75	0300HAHN25°;0430HA;0500GLZN,CR	L
106	0300GLXN	L,F
124	0300S;0700RFZN,CR	L,F
170	0300GLXN,CR;0800CL	L,F
112	0400S;0630RFHN100°	L
164	0400GL,0730GLXALL,IB;1100T	L
50	0430S;GL,CR	L,F
132	0430RF,FL,CL	L,F
203	0430GL;0600RFZN,CR;1015T	L
16	0500GLHN60°;0845T	L
19	0500-0600;GL,HAHN160°,CR,IB	L
31	0500-0700IB	L
38	0500-0700GL,XS,CR	L
74	0500-0915;RF,GLXALL,CR	L
92	0500GL,RFZN,CR;0800T	L
123	0500 (A),CL	L
151	0500RFZN;0700RFHN160°,CR	L
161	0500RFZN	L
192	0500GL;0700RFZN;0930FL;1105T	L
212	0500-0600;GLXN,CR	L,F,M
5	0530GLXALL;0830CLXALL,CR	L
6	0530-1145;0730GLXALL,CR	L
66	0530-1000;0630RFZN;0730RFHN100°	L,F,Wo
100	0530-0630;0630RFZN,CA,CR,IB	L
190	0530RF,CA	L,F
215	0530RFXN;0715HAZN	L,F
222	0530-0645GLXN;0700CL	L
48	0545HAHN25°;0630RFZN;0930T	L
7	0600GL,RFZN;0900RFXALL	L

TABLE IV (CON'T)

<u>Serial No. of Place of Observation</u>	<u>Time and Information Recorded</u>	<u>Reference to Source</u>
17	0600-0700IB	L,F
65	0600 (A),IB	L
79	0600-1015;GL	L,F
103	0600GL;0700RFZN,CR;1015T	L
126	0600-0930;0700HAHN175°;RFZN,CR	L
114	0600GL,CR;0630CA;0700T	L
120	0600RFXALL,CR,IB	L
125	0600CA;0845T	L
129	0600-0800 (A),IB	L
157	0600GLXN;0800CA,CL,XS	L,F
174	0600HAHN45°;0700HAZN;0800CA,FL	L,F
180	0600-0700;GL,XALL,CR,HAHN160°,IB	L
195	0600RFXALL,CA,HAHN160°,CR	L
224	0600-0800;GLZN,PS,CR,IB	L
78	0615RFZN,GL;1000T	L,F
36	0630 RFHN40°,CR,IB	L,F
60	0630GLXN,CR;0800RFHN20°,GL	L,F
99	0630RF,CR;1045T	L
178	0630RA,CA;1045T	L
47	0645RFXALL,GL,CR	L
152	0645GLXALL;0800RFZN,CA,CR	L
29	0700HAZN,GL	L
85	0700-1100;GLHN30°,CR	L
165	0700RF,GL,XALL	L
213	0700GL,IF	L,F
109	0715GL,CR,IB,CL	L,F
39	0730RFHN140°,CR;1015T	L
119	0730RFXALL;0830IB	L
194	0730GLXALL;0800CR,XS;0845RFXS	L
131	0800 (A) IB	L
172	0800-1100;GLXS,CR	L
188	0800RFZN,CR,IB	L
225	0800GLXALL,CR,IB;1000T	M
136	0815GLHN120°;0930T	L
98	0839RFZN,CA,CR	Wo
56	0900-1300;GLHS60°,CR,IF	S
104	0900RFXALL,CR;1045T	L
70	1000GLHN35°,CR	L,F
77	GLZNRFS40°,CR	L
143	RF,FL,DS,CR,IB	L

TABLE IV (CON'T)

Serial No. of Place of Observation	Time and Information Recorded	Reference to Source
199	CRXN, IB	Ma
220	GL, RF, CR	L, F
Aurora reported - no details (Locations & Sources)		
4(A), 12(S), 33(L), 35(L, A), 41(L), 46(A, F), 51(L), 58(A), 61(Mx), 69(L), 81(L, A, F), 82(L), 142(L, A, F), 153(A), 160(L), 179(F), 186(F), 86(Mx), 145(Mx), 196(L), 221(F), 216(F).		
<u>September 2-3, 1859</u>		
160	0000S	L
93	0050HA; 0220RF; 0330PS	L
73	0130RFN	L
109	0140RF, 3HA; 0320RFZN	L
28	0200S; 0230HAHN45°; 0330RFZN	L
31	0200HAHN20°, RF, CR, FL	L
43	0200RFHN45°, CR	L
34	0215HAHN10°; 0445RFZN, CR; 0630T	L, A, F
161	0220GL; 0320-0332RF; 0334GL, CR	L
7	0230S, FL	L
51	0230RFZN, HAHN12°, 25°	L
129	0230RFZN, CA, GL, CR	L
68	0300-0930; 0330RF, HA, CL	L
125	0300S; HA, RF; 0315FLZN, 0415T	L
194	0445S; GL; 0500RF; 0530RFZN	L
223	0530S, RFZN, GL, CR	L
4	GL	L, A, F
38	GL, XS, CR	L
132	RFZN, PCL	L, F
144	RFZN, CR	L
154	RF, FL	L
Aurora reported - no details. (Locations & Sources)		
18(L), 35(L, A, F), 40(F), 47(F, A), 57(L), 63(F), 80(F), 81(F), 82(L, A, F), 83(L), 89(L), 102(L), 118(L), 121(L), 150(F), 155(L), 182(F), 186(F), 189(F), 190(F).		

TABLE IV (CON'T)

<u>Serial No. of Place of Observation</u>	<u>Time and Information Recorded</u>	<u>Reference to Source</u>
<u>September 3-4, 1859</u>		
89	1900 (A)	L
118	2000 (A)	L
176	2000 (A)	F
18	2100 (A)	L
4	2130GLXN;0000T	L,A
57	0150S;0300CA,XN	L,F
152	0200RF;0300DS;0330CA;0400T	L
26	0230RF,IB	L
119	0245RFHN45°;0300GL	L
165	0300S;GLHN45°;0700T	L
51	RFXALL,CR,IB	L
132	RFHN30°,FL	L,F
144	HAHN20°,RFHN45°	L
190	RF,CA	L
Aurora reported - no details. (Locations & Sources)		
40(A),35(L,A,F),46(L,A,F),55(F),58(L,F),63(A),81(A),82(F,A), 83(L),90(L),122(F),127(L),146(F),155(A),191(F),194(L),204(L).		
<u>September 4-5, 1859</u>		
132	RFZN,FL	L,F
190	RF	L,F
Aurora reported - no details (Locations & Sources)		
19(L),35(A),46(A),57(L,F),58(A),113(F),121(L,F),122(A), 127(L),191(A),193(F).		
<u>September 5-6, 1859</u>		
73	0600RFXN	L
132	HAHN15°	L,F
Aurora reported - no details. (Locations & Sources)		
63(F),111(F),113(F,A),190(L),208(F).		

# TABLE V

## SYMBOLS FOR SOURCE REFERENCE

L	=	Loomis <sup>2,3,4,5</sup>
F	=	Fritz <sup>6</sup>
A	=	Angot <sup>7</sup>
S	=	Sydney Morning Herald <sup>8</sup>
M	=	Meteorological Office <sup>9</sup>
W	=	Publications of the Washburn Observatory <sup>10</sup>
Ma	=	Matsushita <sup>12</sup>
Wo	=	Wochenschrift für Astronomie, Meteorologie und Geographic <sup>13</sup>
Mx	=	Corzo and Adem <sup>14</sup>

TABLE VI  
MAGNETIC OBSERVATORIES RECORDING INTENSE DISTURBANCE  
Aug. 28 and Sept. 2, 1859

<u>Location</u>	<u>Time UT</u>	<u>Magnetic Activity</u>
<u>Aug. 28, 1859</u>		
Melbourne, Austl.	2250	Violent disturbance commenced
Sydney, Austl.	2200-2300	Very disturbed
Brussels, Belg.	2100-2200	Off scale
Paris, Fr.	2300	Very disturbed
<u>Sept. 2, 1859</u>		
Kew Observatory, Eng.	0500	H & V go off scale after 0500
St. Petersburg (Leningrad)	0500	Very disturbed from 0500
Sov. UN	0749	Off scale
	0809	" "
	1244	" "
Catherineburg, Sov. UN	0546	Off scale
	0646	" "
Barnal, Sov. UN	0616	Off scale
Nerchinsk, Sov. UN	0558	Very disturbed
Rome, Italy	0600	Very disturbed
	1525	Off scale
Christiana (Oslo) Nor.	1342	Very disturbed
	1544	" "
Paris, Fr.	1600	Very disturbed
Toronto, Can.	1332	Off scale

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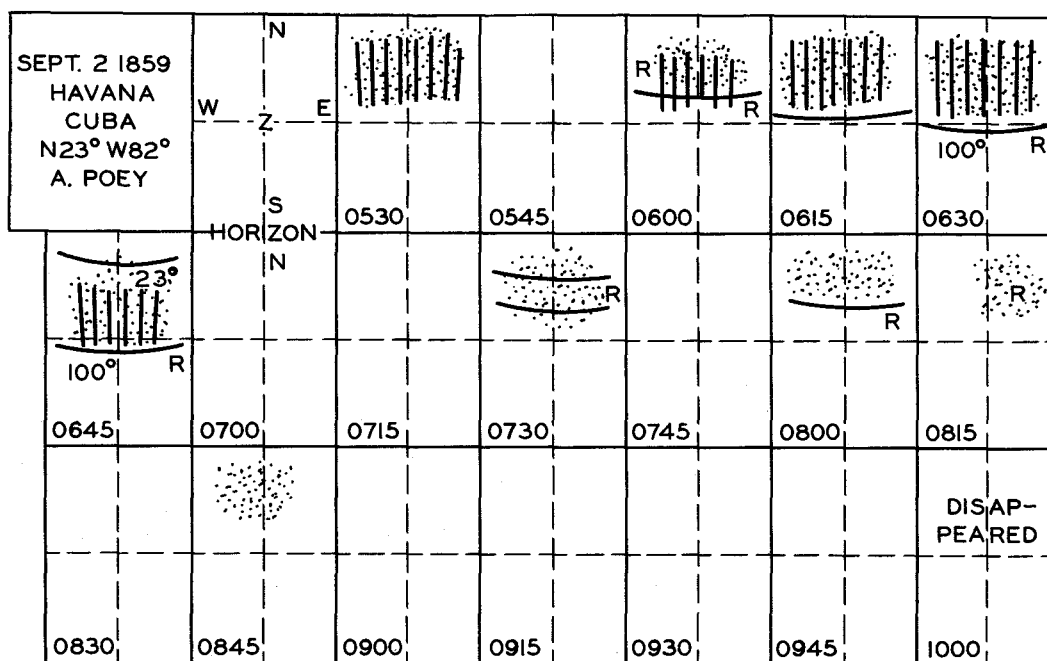


Fig. 1. Graphic Plot of the Aurora of Sept. 1-2, 1859  
Seen at Havana, Cuba.

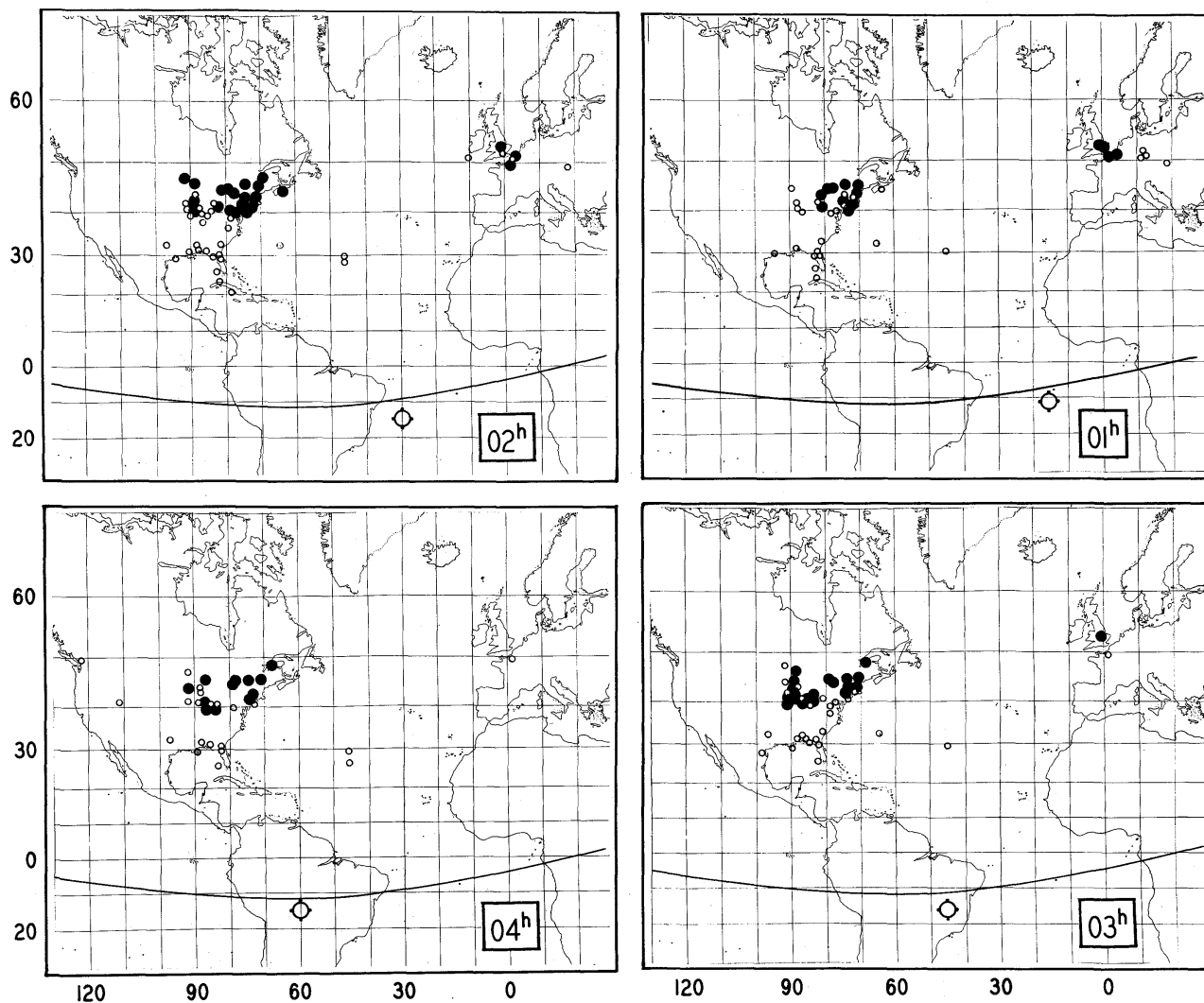


Fig. 2. Location of overhead and visibility of aurora during the four most active hours of Aug. 28-29, 1859; circles, overhead aurora; large dots, visible aurora; and large circle, antisun.

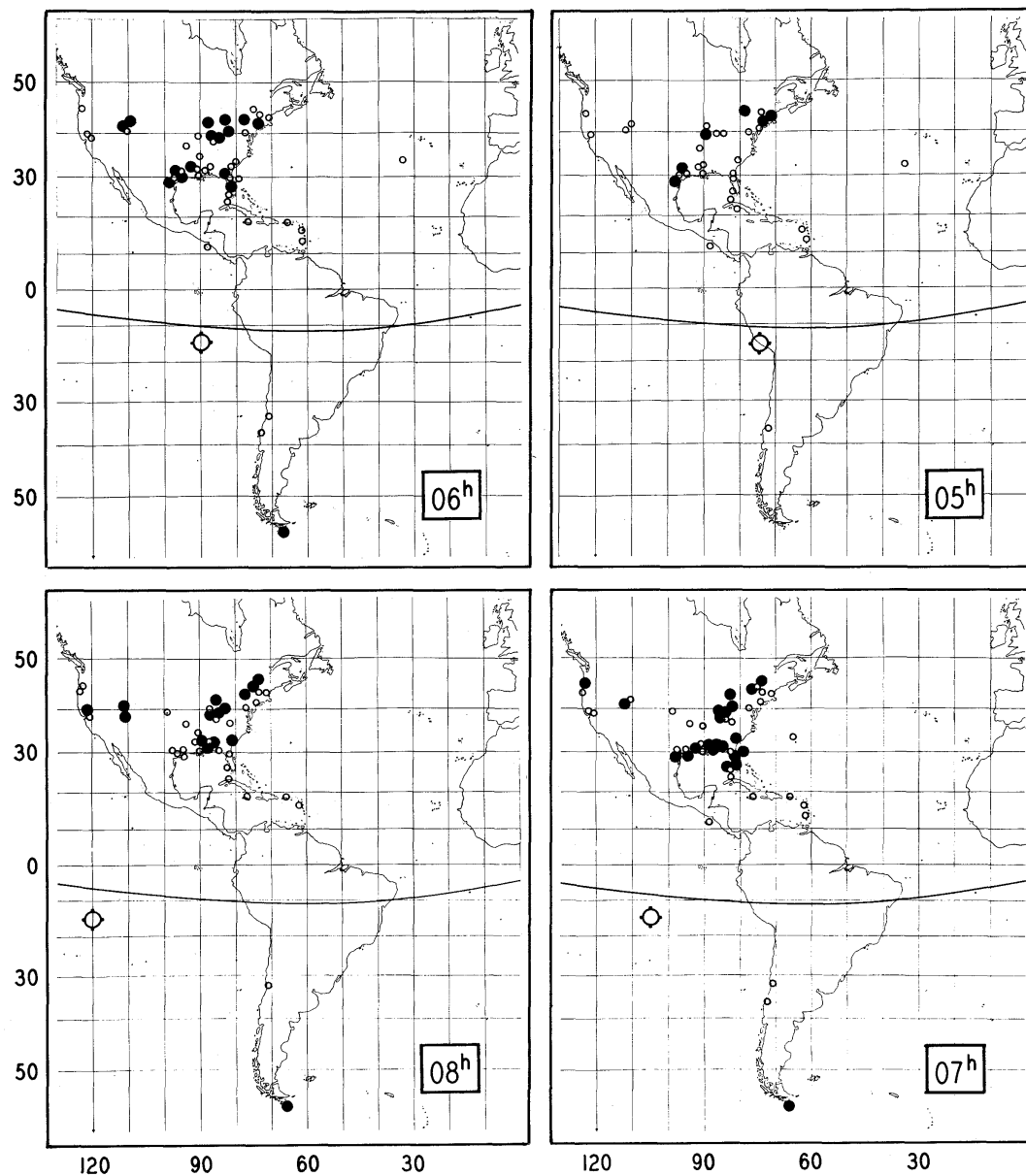


Fig. 3. Location of overhead and visibility of aurora during the four most active hours of Sept. 1-2, 1859; circles, overhead aurora; large dots, visible aurora; and large circle, antisun.

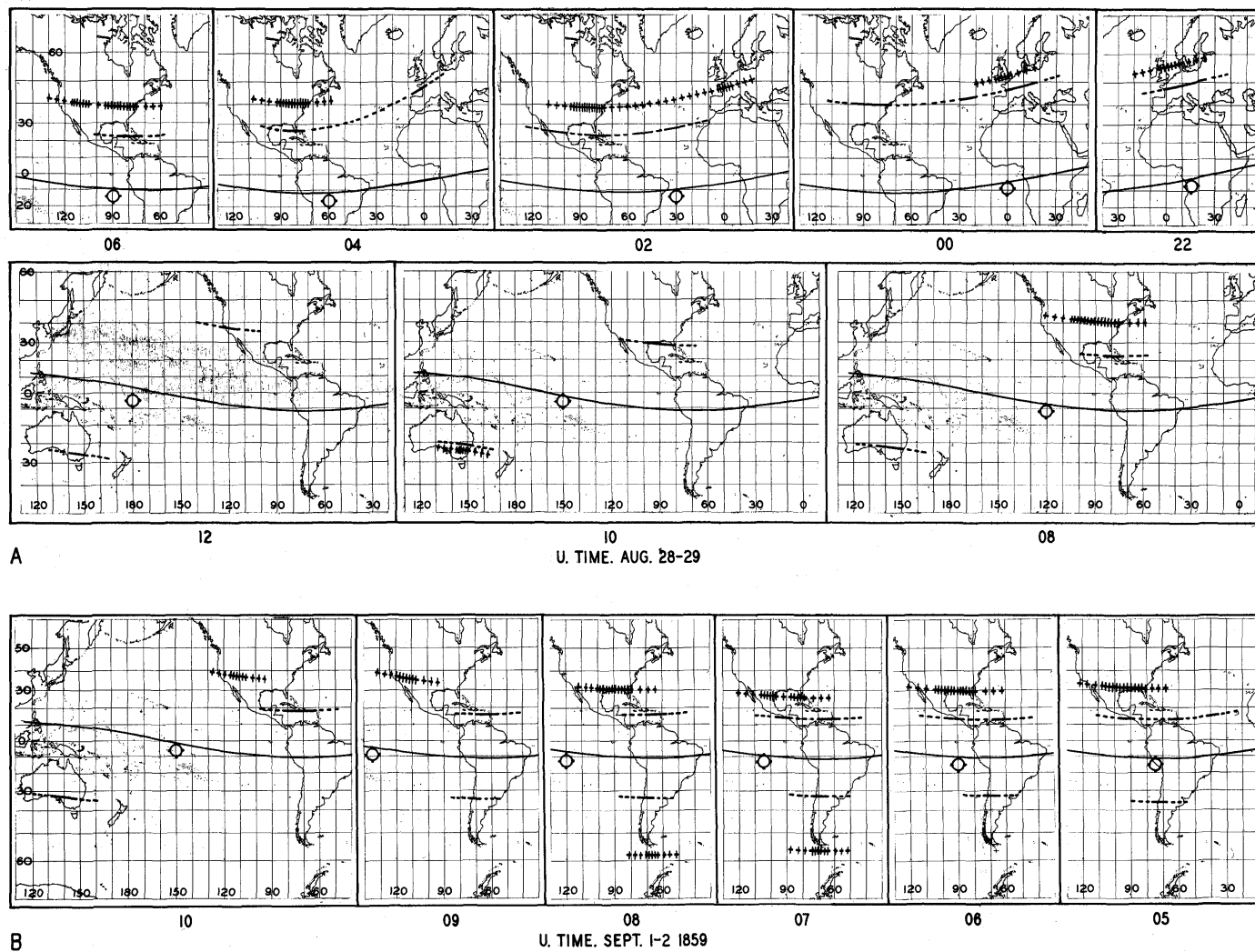


Fig. 4. Equatorial Limit of Overhead and Visibility of Auroras Aug. 28-29, 1859 (22<sup>h</sup> to 12<sup>h</sup> UT) and Sept. 1-2, 1859 (05<sup>h</sup> to 10<sup>h</sup> UT).

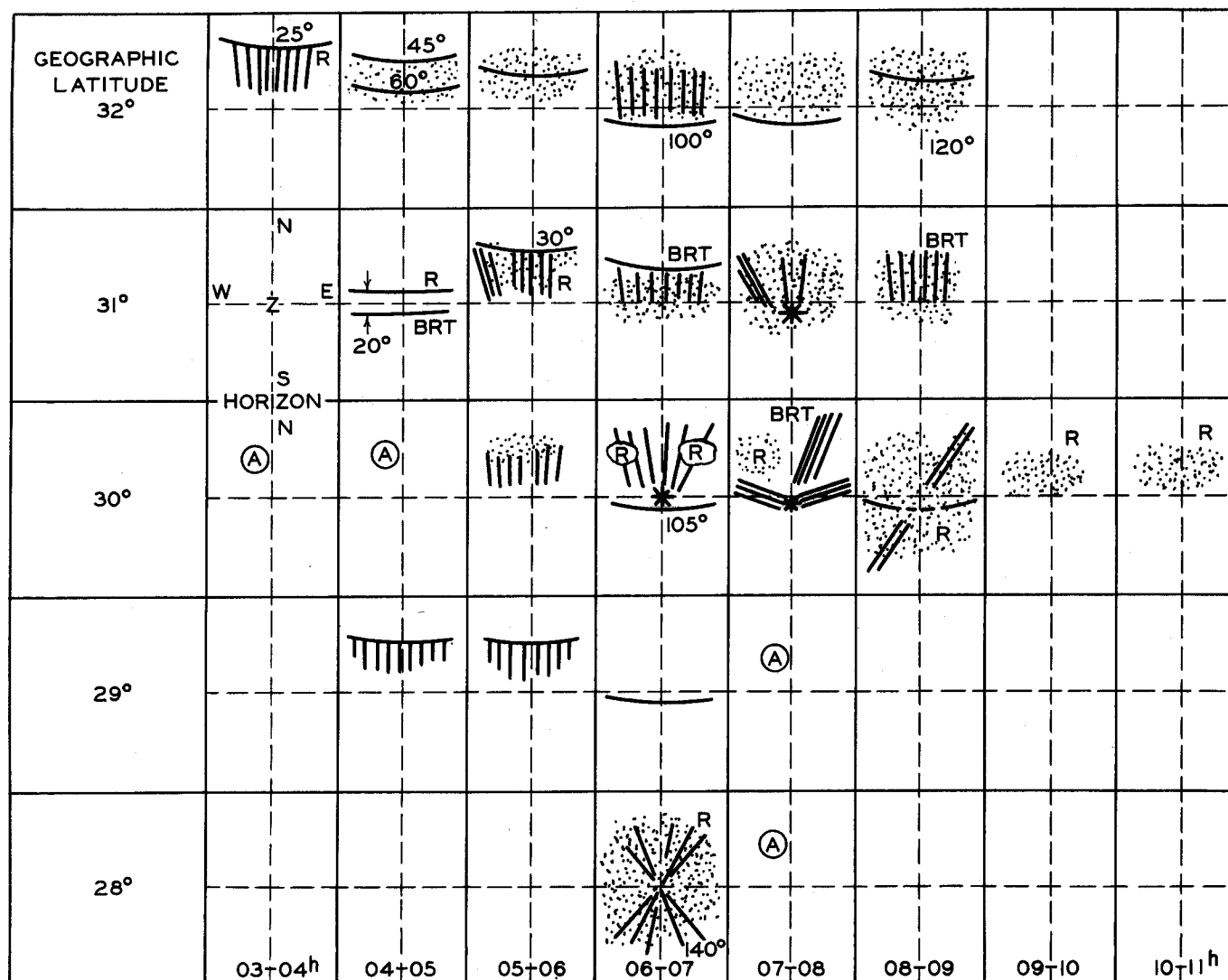


Fig. 5. Method of Representing the Auroral Activity at Different Degrees of Latitude During Each Hour, Sept. 1-2, 1859 for Eastern United States.

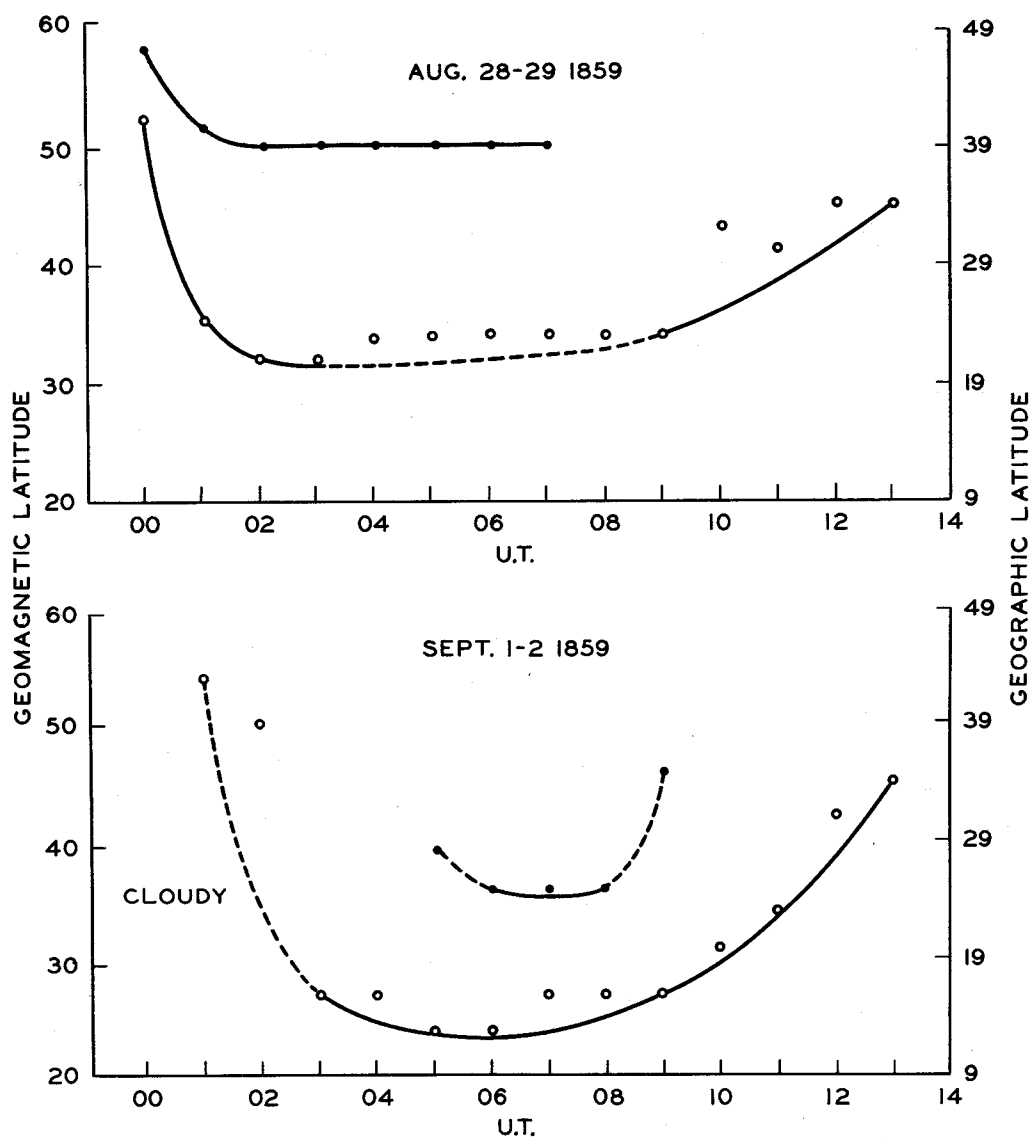


Fig. 6. Southern Extent of Visibility and Location of Overhead Aurora at Each Hour for Eastern United States.

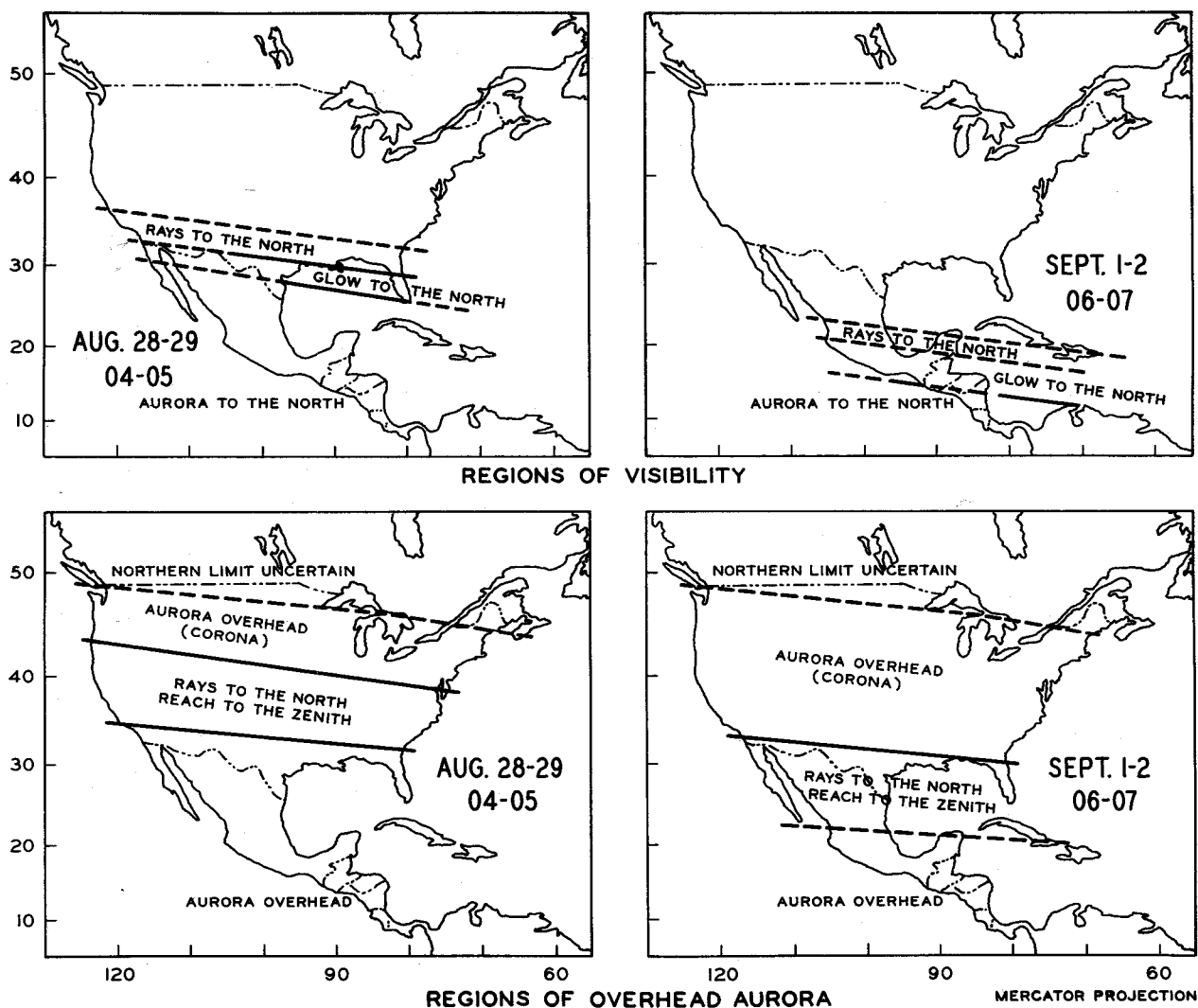


Fig. 7. Extent and Latitude Range of Auroral Visibility and Overhead Location of Aurora During Maximum Activity for Aug. 28-29 and Sept. 1-2, 1859.

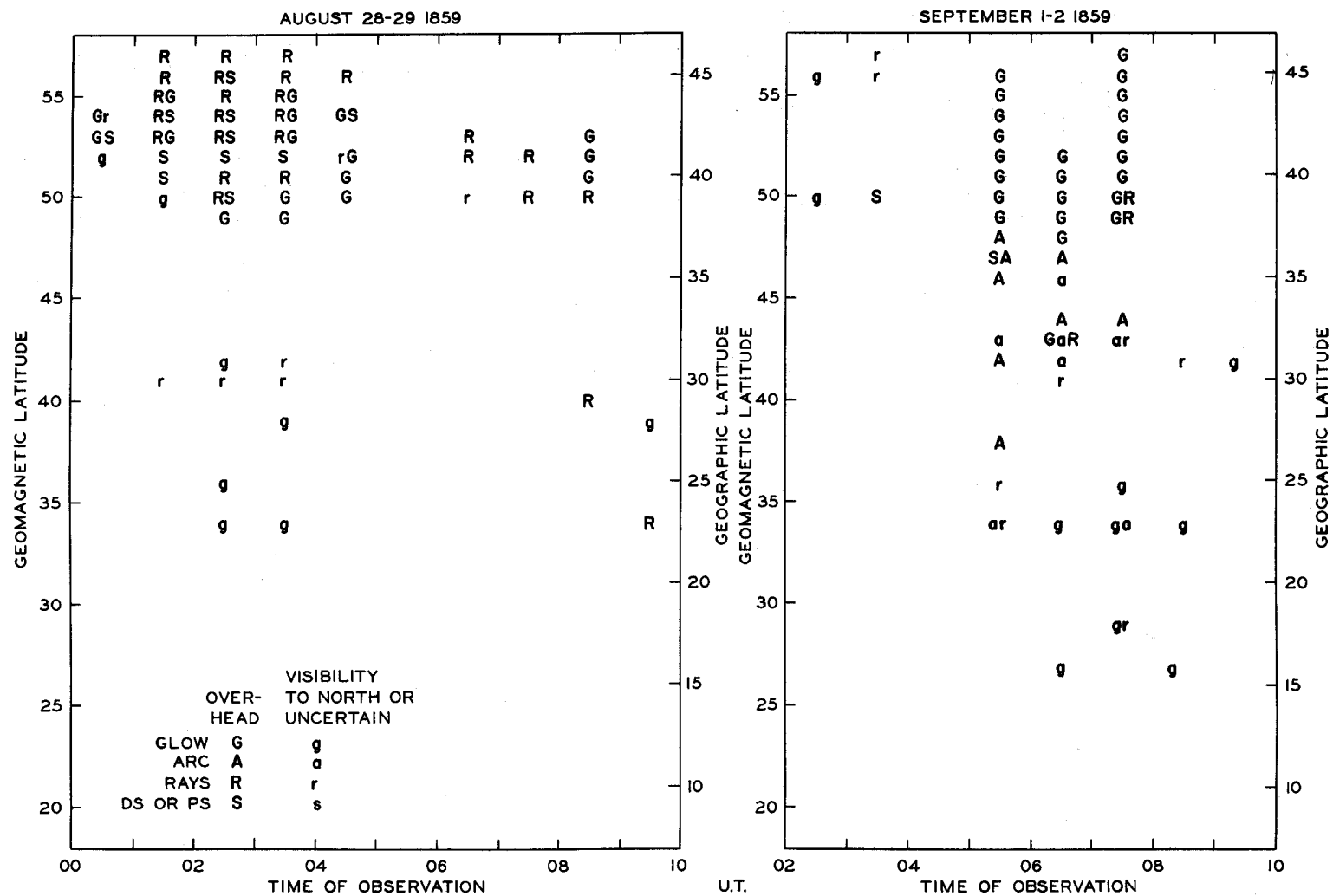


Fig. 8. Latitude Extent of Red Auroral Forms Observed in Eastern United States.