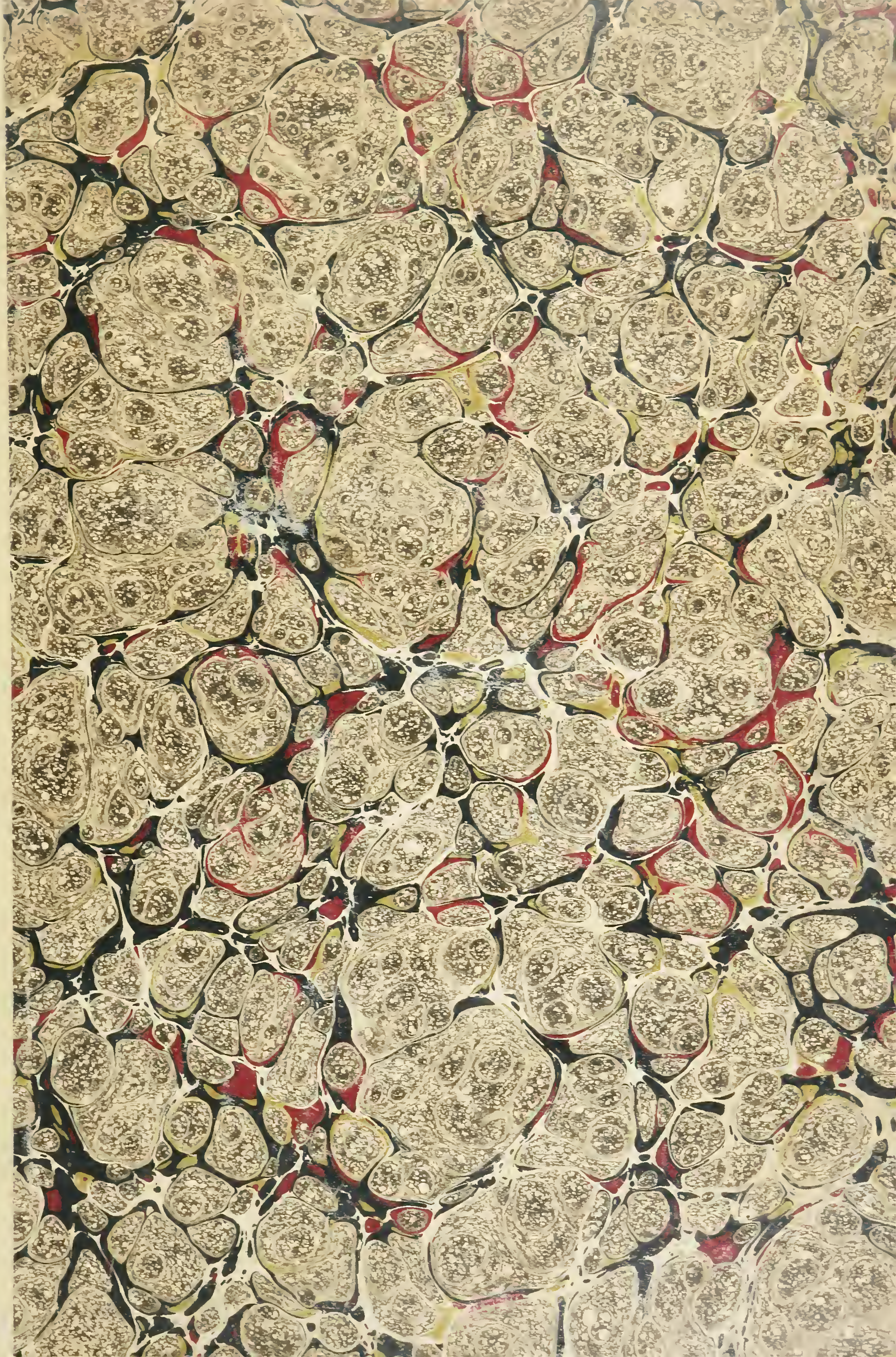

W. B., No. 63

U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

STUDIES

OF

WEATHER TYPES AND STORMS

BY PROFESSORS AND FORECAST OFFICIALS OF THE WEATHER BUREAU.

UNDER THE DIRECTION OF
WILLIS L. MOORE,
CHIEF OF WEATHER BUREAU.

No. I.—TYPES OF STORMS IN JANUARY.

BY

E. B. GARRIOTT.

1862 1889

WASHINGTON:
WEATHER BUREAU
1895.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture, Weather Bureau,
Washington, D. C., July 26, 1895.

Sir: I transmit herewith the manuscript of a paper entitled "Types of Storms in January," and respectfully recommend its publication for distribution to the Officials of this Bureau.

Very respectfully,

Willis L. Moore,
Chief of Bureau.

Hon. J. Sterling Morton,
Secretary of Agriculture.

LETTER OF SUBMITTAL.

U. S. Department of Agriculture, Weather Bureau,
Washington, D. C., July 26, 1895.

Sir: During the last two years the officials on duty in the Forecast Division have, at my suggestion and under my direction, prepared a series of reports on weather types and storms of the United States. These papers embrace studies of types of storms for each month of the year, of West Indian cyclones, and storms which first appear in the Southwest, and of storms that have caused unusually heavy snow in the several sections of the country. They also treat of the north Pacific coast and St. Lawrence Valley areas of high pressure, and discuss the cold waves of the Southern States.

The object of these investigations has been to determine facts relating to storms and their movements and characteristics, and to present certain conclusions and general rules for forecasting, which the experience and special studies of the Forecast Officials of this office have discovered to be of value in this very important line of work.

As the papers now completed contain much valuable data, and papers in course of preparation which treat of abnormal weather types, and those which may be prepared in the future, promise to add to the value of this fund of information, I recommend that the papers be published, either as a part of the Monthly Weather Review, or as separate pamphlets, or in both forms; and that when all the papers shall have been printed, they be issued in one or more volumes in shape suitable for ready reference and furnished the different Forecast Officials and Observers of the Bureau for their information and guidance.

Herewith is the first of these papers, entitled "Types of Storms in January," by E. B. Garriott, Forecast Official.

Very respectfully,

H. H. C. Dunwoody,
Assigned to duty as A. A. C.,
In charge of Forecast Division.

Willis L. Moore,
Chief of Weather Bureau.

[Extract from Monthly Weather Review, January, 1895.]

TYPES OF STORMS IN JANUARY.

By E. B. Garriott, Forecast Official.

Classified with reference to the regions in which they first appeared, the January storms traced in the Monthly Weather Review during the last ten years fall under the following general heads:

Region in which storms first appeared.	Total number of storms in ten years.
Saskatchewan Valley	32
Southwestern States	21
North Pacific coast	20
Northeast Rocky Mountain slope	8
Middle-Western States	7
Ohio Valley and Tennessee	3
Southeastern States	2
South Pacific coast	0
Total number in ten years	94

About 80 per cent of these storms belonged to what may be termed three principal types. One type, which presented the greatest number, embraced storms that advanced from the Saskatchewan Valley; another included storms that first appeared in the Southwestern States, and the third, storms which moved eastward from the North Pacific coast. The remaining storms, which were generally secondary developments to low areas of the three principal types named, were widely distributed, and while their relatively limited number will not justify their acceptance as independent types, the fact that they collectively composed one-fifth of the storms of the month, calls for a consideration of their characteristics as secondary types.

STORMS FROM THE SASKATCHEWAN VALLEY.

Chart 1 shows the tracks of all January storms that entered the region of observation north of Montana and North Dakota during the last ten years. Twenty-one, or fully two-thirds of these storms reached the Atlantic coast, and all but three of this number passed to sea north of the fortieth parallel. The plotted paths show that the usual path of storms of this general type is east-southeast over the Canadian Maritime Provinces, and it may be assumed that similar and well-marked weather and temperature changes and conditions will attend storms of seasonal severity and average speed that follow the average track. It may also be assumed that unusual and particularly notable changes and conditions will be presented in connection with storms that depart from the usual path. The principal problem in practical forecasting is to calculate the direction of movement, speed, and intensity of a storm at the time of its first appearance in a defined district. In the case of Saskatchewan Valley storms we know that two out of three of these storms pass east-southeast to the Atlantic coast north of the fortieth parallel, and that their average velocity is about 37 miles per hour. In discussing these storms, an effort will be made to connect their movements with the general distribution of pressure and temperature, and to point out those conditions which favor normal movements and the causes which seemed to occasion abnormal movements.

A storm remarkable both as regards its direction of movement and speed swept rapidly southeastward from Alberta to Arkansas, and thence off the Atlantic coast January 13–15, 1893. This storm appeared over Alberta the morning of January 13, and the general conditions which obtained at that time are shown on Chart 9. It is evident that the distribution of pressure and temperature positively prohibits an early eastward movement of the storm. The barometric gradient in that direction is steep, and the temperature is some 50° lower over Manitoba than near the storm's center. In a previous paper the statement was made that isotherms are the leading strings of a storm, and attention was called to the recognized inclination of storms to advance in the direction of least barometric resistance. In the case of this storm both of these conditions favor a movement of the storm down the eastern Rocky Mountain slope, and, as the isobars loop far to the southward, an unusually rapid movement may be anticipated. Chart 10 of the morning of the 14th shows the 12 and 24 hour movement of the center. It will be observed that the rapidity of the storm's movement, which was at the rate of about 54 miles per hour, did not permit a warming up of the air in the east quadrants of the low area, and upon its arrival in the southwest the isotherms still ran southeastward across its line of advance, with freezing temperature as far south as northern Florida.

Although a sudden and marked rise in temperature might be expected to precede, and very low temperature to follow, the passage of the storm over the east-central districts, the colder air which appeared in its front the morning of the 14th rather favored a loss of strength. The report of the following morning, Chart 11, shows that the low area flattened or divided against the cold area, and that the separate low areas reunited off the middle Atlantic coast. This storm is an excellent example of the influence of low temperature upon a storm's movement. It was opposed by much lower temperature in its front until it reached the southwest, and in endeavoring to skirt the cold area, nearly perished for lack of warmth, which is one of the sustaining elements of a storm. It followed the path of least barometric resistance, and, encountering but slight opposition in that respect, traveled at a high rate of speed. Owing to its great velocity, low temperature, which is unfavorable to precipitation, preceded and attended its passage, and no precipitation occurred save in the eastern districts where sharp temperature changes and gradients in a moist atmosphere produced a heavy fall of snow throughout the Atlantic coast States north of Florida.

A typical storm of the Saskatchewan Valley type appeared over Alberta, January 20, 1892, and reached the Canadian Maritime Provinces January 23, traveling over the most frequented track of storms of this class at an average velocity of about 39 miles per hour. The daily progress of this storm and the conditions which attended its passage are shown on Charts 12 to 15. The morning reports of the 20th, Chart 12, present conditions which prevailed just before the full development of this storm within the region of observation. At that time a storm occupied the Lake Superior region, and the trend of the isobars and isotherms favored a rapid eastward movement of the Alberta storm. By the morning of the 21st, Chart 13, the Lake Superior storm had moved eastward to a position north of Lake Huron, and the northwest low area had moved eastward over the Saskatchewan Valley a corresponding distance. Between the low areas the pressure had risen. The appearance of a crest of high pressure between low areas moving over the northern districts can, as a rule, be expected, and the lower temperature and higher pressure can, as in this case, be relied upon to rapidly give way and follow in the wake of the eastern low, allowing the western low area to advance at a normal velocity. In the present instance the high area disappeared during the 31st, and the northwest storm moved eastward over Manitoba, and by the morning of the 22d, Chart 14, had reached Lake Superior. Its after course to the Maritime Provinces was unobstructed, and its passage was unattended with noteworthy features.

Storms of this type, which follow the most frequented path over the northern Lake region, are seldom attended by precipitation until they reach the Lake region, and during their passage thence eastward the rain area is usually confined to the Great Lakes, New York, and New England. Neither are they, as a rule, attended by cold waves, save in the case of the slower moving storms of marked intensity which produce high temperatures in the east quadrants and are followed by a strong sweep of northerly winds. The storms which pursue a more southern course are, however, often attended by areas of precipitation which extend to the Gulf States and by cold waves which reach the southern limit of the barometric trough.

NORTH PACIFIC COAST STORMS.

These storms present characteristics similar to those noted in connection with the Saskatchewan Valley type. A majority of the storms of both types doubtless spring from the extreme eastern limit of the permanent winter low area of the North Pacific Ocean. The North Pacific type of storms as herein classified, however, strikes the American coast farther south, and a reference to Chart 3 will show that their tracks are more widely distributed and, on the whole, run farther south than those of the Saskatchewan Valley type. Of the 20 storms of this class traced for the last ten years, 10 reached the Atlantic coast, all, save one, passing to sea north of the fortieth parallel. In this connection it is interesting to note that this result compares closely with figures found in Bulletin A of the Weather Bureau. During the ten years covered by that report an average of 1.8 storm per month appeared on the north Pacific coast and traversed the North American continent in January. The tables found in the Bulletin show that the storms that appear on the north Pacific coast of the United States in winter possess greater vitality than any other class of storms traced over the Northern Hemisphere, and that in a 10-year period 18 storms from that region traversed successively the North American continent and the North Atlantic Ocean during the three winter months.

These storms usually cross the continent in about three days, at an average velocity of 35 to 40 miles per hour. After passing east of the Rocky Mountains they assume the characteristics noted in connection with storms of the Saskatchewan Valley type. The storms that pass well to the southward of the forty-fifth parallel carry precipitation to the Gulf States, and the cold-wave areas, depending upon the storm's intensity and previously existing temperatures, usually cover districts included within the low barometer troughs which are swept by the northerly winds of the storm's west quadrants.

NORTHEAST ROCKY MOUNTAIN SLOPE STORMS.

The northeast Rocky Mountain slope type of storms, Chart 4, also belongs to this general class, but, owing either to unusually rapid movements, which carry them across the mountains between reports, or to slight intensity, they do not appear as fully developed storms until they reach the eastern slope.

SOUTHWEST STORMS.

Probably the most important winter storms of the eastern half of the United States are those which first appear in the Southwestern States. About one-half of the storms that reach the Atlantic coast belong to this and kindred southern types, and the rain and temperature change areas are more extended, general, and pronounced than in any other class of storms that traverse districts lying east of the one-hundredth meridian. Storms of this type almost invariably move northeastward, and, unless the conditions are complicated by northwest low areas, they reach the Atlantic coast within forty-eight hours. Storms of average intensity which appear over the interior of the west Gulf States or on the extreme southern Rocky Mountain slope usually cross the Ohio Valley and the Lake region, attended by general rain or snow over the eastern half of the country, and those which advance from the immediate Gulf coast or from over the west part of the Gulf of Mexico move almost due northeast, producing areas of general rain over the Southern and Atlantic States, the upper and middle Ohio Valley, and the eastern Lake region, and are often attended by cold waves and dangerous gales in those districts. During the last ten years 21 storms have appeared in the southwest in January, and in all but one instance they reached the Atlantic. About one-half of this number crossed the Lake region and passed thence over or north of the St. Lawrence Valley; the others traversed the Atlantic coast States. The general features and characteristics of these storms can best be shown by discussing subtypes of the general type referred to.

A storm of the class that first appears on the extreme southern Rocky Mountain slope advanced from Texas to southern Lake Michigan from the morning of January 8 to the morning of January 9, 1889, crossed Lake Huron and reached a position far to the northeast of Georgian Bay by the morning of the 10th, and passed eastward over Labrador during the 11th. This storm was faintly outlined over the southern Rocky Mountain region on the 7th, and by the morning of the 8th had reached the position shown on Chart 16. By the evening of the 7th rain had set in over the southwest, and by the time this storm had become well marked over Texas the rain area had extended over the Mississippi and lower Ohio valleys. A study of Chart 16 shows that the pressure and temperature distribution favors an almost due northeast movement of the center of disturbance. The path of least barometric pressure resistance lies in that direction, and the northward loop of the isotherms over the Mississippi and lower Ohio valleys shows the region of increasing temperature toward which the storm is likely to move with the favorable pressure conditions presented. As is usual in storms of this class, the rain area which covers the Mississippi Valley can be expected to reach the Atlantic coast within twenty-four hours. It has been observed, however, that when a storm is central in Texas about thirty hours are required for the rain area to overspread New England. The high area over the northern plateau region will move rapidly southeastward and replace the low area in the southwest, causing a decided fall in temperature within the cyclonic area which appears on this chart; in fact, a cold wave can safely be anticipated within the storm area, say within the area covered or surrounded by the isobar of 29.70. Chart 17 shows the movement of the storm during the succeeding twenty-four hours. A notable feature is the rapid deepening of the barometric depression. The other conditions are as outlined in remarks relating to Chart 16. The high area has moved rapidly southeastward, the temperature is some 20° lower in the southwest, and the rain area has extended to the Atlantic coast south of New England, and will extend over that district during the next few hours. As the storm center will now move well to the northward of the St. Lawrence Valley, and the sweep of the northerly winds will not be strong, save over extreme northern districts, temperature falls sufficient to constitute a cold wave can not be expected within the next twenty-four hours, and rapidly rising barometer in the south and southwest point to a rapid clearing of the weather in the central and southern districts. The report of the following morning, Chart 18, shows the storm well beyond our region of observation, and its further influence will be in the form of diminishing westerly gales along the middle Atlantic and New England coasts and over the eastern Lake region.

The second class of this type of storms first appears near the immediate west Gulf coast, and moves northeastward, parallel with, and generally somewhat to the westward of the Appalachian range, and crosses eastern New York and New England, the average time of transit being about forty-eight hours. A good example of a storm of this class appeared on the Louisiana coast the morning of January 26, 1889, and the conditions which obtained at that time are exhibited by Chart 19. As rain had been falling over the southern and southeastern districts during the preceding two days, the actual rain area controlled or occasioned by this storm can not well be determined. A study of these storms has shown, however, that when fair weather prevails over the central and eastern districts at the time of the first appearance of the low area on the Gulf coast, the rain area spreads rapidly from the Gulf and covers districts east of the Mississippi and south of the Great Lakes within twenty-four hours and extends over New England within thirty-six hours.

When this storm appeared on the Louisiana coast the morning of the 26th, a trough of low pressure extended thence over the eastern Lake region and the St. Lawrence Valley, and the isotherms looped northward over the Ohio Valley and the lower Lakes. These conditions plainly indicate the direction of the storm's advance, and, as neither pressure gradients nor low temperature oppose the advance of the center, it may be assumed that the movement will be rapid. The rain area, which covers districts south of the Ohio River, may be expected to cover New England within twenty-four hours, and the barometer will rise rapidly with a decided fall in temperature in the Southwestern States, the fall constituting a cold wave in the west Gulf States. Chart 20 shows the progress made by the center of disturbance during the succeeding twenty-four hours. The storm has increased in intensity and rain has fallen throughout the central valleys and in the Atlantic coast States. The conditions presented the morning of the 27th seem, at first glance, unfavorable to a normal northeast advance of the storm center. It will be observed that a well-marked area of high pressure has appeared over the Canadian Maritime Provinces, with a decided fall in temperature in that region. Under certain conditions high areas of this class retard and even force back storms advancing from the interior. When this occurs the northeast high area is usually one of gradual growth and apparently well anchored, and the barometer is relatively low in the north-central districts with a gentle barometric gradient and high temperature for the season in that direction. When, as in the present instance, the western and northwestern districts are covered by an unbroken high area of great magnitude, with much lower temperature to the west and northwest of the low area, the center of disturbance can scarcely recurve in that direction, and may be expected to increase in intensity, warm up the cold area in the northeast by a strong indraught of ocean air, and force a passage along the usual path. So far as January storms are concerned the tracks plotted on Chart 2 show that during the last ten years the southwest type of storms have, without an exception, continued a northeast course after leaving the Gulf States. The morning report of the 28th, Chart 21, shows that this storm increased greatly in strength and advanced in a direct line toward the Canadian Maritime Provinces, either forcing eastward or dissipating the high area which occupied that region the preceding morning. In the meantime the center of the high area in the west remained nearly stationary and the pressure in the Northwest and over the western Lake region decreased instead of increased, as might have been expected, and increased but slightly in the southwest. The effect of these minus pressure changes in the west and northwest was to delay the clearing of the weather which generally closely follows the passage of these storms, and the cloud and rain area lingered over the Ohio and middle Mississippi valleys, and a decided fall in temperature occurred only in the cleared region which covered the interior of the Southwestern States.

A representative storm of the third class of low areas of this type (that is, those storms which appear farthest south and cross the west part of the Gulf of Mexico and pass thence northeastward over the east Gulf, south and middle Atlantic States) first appeared near the mouth of the Rio Grande River the morning of January 23, 1891, advanced to central Alabama by the morning of the 24th, moved thence northeastward off the middle Atlantic coast during the early morning of the 25th, and disappeared in the direction of Nova Scotia during the latter-named date, traversing the territory lying between the mouth of the Rio Grande and a point off the southeast New England coast in forty-eight hours. Chart 22 shows the first indications of the presence of this storm off the mouth of the Rio Grande River. The exact location of the center can only be surmised, but a calculation based upon the well known persistency and uniformly rapid movement of this class of storms, and the absence of a pressure gradient to the northeastward, would give the storm a movement to the middle Gulf States within twenty-four hours, and as precipitation is one of the first well-marked features of these disturbances, rain could be expected over a large area of the Southern States. Within twenty-four hours the center of this storm had advanced to Alabama, and Chart 23, of the morning of the 24th, presents no material obstacle calculated to prevent the storm from continuing a northeast course. The area of high pressure on the middle Atlantic coast has shifted to that position from the south Atlantic coast and is moving; it will not, therefore, oppose the advance of the storm, more especially as the temperature is high and the direction of the isotherms is northeast from the storm center. As the barometer has risen rapidly in the rear of the storm, forming a high area in the southwest, a rapid rise of pressure and rapidly clearing weather will follow closely in the wake of the storm. Like storms that traverse the Atlantic coast States from the Gulf, this low area was unattended by marked changes in temperature in the Atlantic coast districts. The storms that appear over the east Gulf and the east Gulf States in January generally belong to the type herein considered, and do not, therefore, call for individual mention.

GENERAL REMARKS.

From the foregoing charts and remarks it would appear that the storms of January belong to three, and possibly to but two, general types which may be subdivided into a limited number of classes. We have seen that fully one-half of our January storms advance from the Saskatchewan Valley and the north Pacific coast, and that of these types the storms of the first-named type are the most numerous. Many, if not all, of the Saskatchewan type are of Pacific coast origin, and the two types can, therefore, be properly combined and termed the north Pacific type, the difference being merely that the storms traced on Chart 10 reach the coast farther south than those of the Saskatchewan Valley type. A large proportion of these storms doubtless originate near the American coast, and do not advance from the Bering Sea permanent winter low area. The plotted tracks of storm in

Weather Bulletin A show that at least four-fifths of the storms that appeared on the Pacific coast north of the mouth of the Columbia River during a period of ten years first appeared near the coast, and did not actually travel eastward from the north Pacific or Bering Sea low area. The Bering Sea low area loops far to the eastward and reaches the Alaska coast in the neighborhood of Sitka in January, and this circumstance, taken in connection with the fact that the cold Arctic current flowing southward through Bering Sea Straits and the warm Pacific drift current meet south of the Alaska Peninsula, presents conditions which doubtless largely contribute to the development of storms off the Alaska coast south of the Alaska Peninsula.

The three branches representing the average paths of the north Pacific type of storms are shown on Chart 25. The north, or Saskatchewan branch, and the north Pacific branch converge and meet in the St. Lawrence Valley, and the northeast Rocky Mountain branch swings slightly to the southward of the north Pacific branch over the Northwestern States, and crosses and passes to the northward of the Saskatchewan Valley branch northeast of Georgian Bay. A result of the more southern path of the north Pacific and northeast Rocky Mountain slope storms is to carry precipitation and marked temperature change areas farther south, and these storms are more liable to be attended by secondary developments still farther to the southward, thereby causing general rain or snow over a great extent of country.

The second principal type, which embraces storms that first appear in the southwest, is also divided into three branches, all of which run almost due northeast. Storms of this class doubtless develop in the lee of the southern Rocky Mountains in the United States and to the eastward of the mountain ranges of Mexico, and an important element of their origin is found in the meeting over those regions of the warm, moist, easterly winds, which blow off the Gulf of Mexico, and which are really the western edge of the North Atlantic trade winds and the cold, dry, northwest to north winds which sweep southeastward and southward along the eastern Rocky Mountain slope. As before stated, the storms of this principal type are the most important that traverse the eastern half of the United States in January. They are attended by widespread and abundant precipitation and decided temperature changes, and are the most methodical storms as regards their direction and velocity of movement that appear within the region of observation.

COLD WAVES.

A discussion of winter storms and weather would be incomplete without a reference to cold waves. The conditions producing and attending these phenomena are so complicated, however, that even a general discussion of the subject, calculated to prove instructive to forecasters, is attended by marked difficulties. The resolving into types of the innumerable combinations presented in connection with the development and appearance of cold waves is an extremely difficult if not an impossible task, and the scope of this paper will admit of only a general discussion of their more prominent characteristics, and of a few remarks touching upon recognized conditions favorable to their entry into and progress over the United States. The visible mechanism of a cold wave embraces the cyclonic and anticyclonic areas which traverse the United States from west to east. The low areas warm up the surface air by the southerly winds in their east quadrants, and the cold, dry, northerly winds in their west quadrants that usher in the succeeding high area from the British Northwest Territory, occasion a marked fall in temperature which is termed a cold wave. It is evident, therefore, that generally speaking, the region covered by a cold wave must be successively subjected to the wind circulation of the east and west quadrants of a well-marked low area. It is also evident that the cold waves of the several sections are practically dependent upon the passage of low areas followed closely by unbroken high areas.

Thus far the mechanism seems simple and easily understood, and if the movement and strength of the high and low areas could be accurately foreseen, the forecasting of cold waves would be one of the simplest instead of one of the most difficult features of weather forecasting. As a matter of fact each of the many districts of the United States presents geographical and topographical features calculated to modify or intensify approaching cold waves. The probable intensity of a cold wave must be calculated for the varying conditions peculiar to each of the districts, and in many instances for conditions peculiar to localities. Unlike warm waves, which often produce in the central and northern districts temperatures higher than those noted in more southern latitudes to the windward, cold waves are not attended in the central and southern districts by temperatures lower than those noted to the north and west. On the contrary, the cold waves diminish in intensity as they sweep south and east, so far as the degree of actual cold is concerned, although the temperature may be relatively lower with reference to the normal temperature. As cold waves approach the moist regions of the Great Lakes and the Gulf and Atlantic coasts, conditions must be very marked to insure their overspreading those districts. For, as cold waves follow general storms, and as areas of precipitation, and even of cloudiness, are generally fatal to the advance of a cold wave, the forecaster should be very certain that the weather will clear up in a district before ordering cold-wave signals for that district.

Herein lies the difficulty of verifying cold-wave signals in the coast and Gulf regions; for the weather is often slow to clear up in the Gulf and Atlantic coast States, and in addition, there sometimes appears to be a slight fœhn effect produced in districts to the leeward of the Appalachian range of mountains; this, however, has not been proven. In the Southern States cold waves can rarely be successfully forecasted unless a well-defined low area crosses that region, followed by a well-marked and unbroken high area which has occasioned a decidedly cold wave in districts to the west or northwest. Twenty-four to thirty-six hours are usually required for a cold wave to advance from Texas to the south Atlantic coast. In January the cold waves of the central and northern districts attend the passage of the general type of storms that pass eastward from the north Pacific coast and the Saskatchewan Valley. As these cold waves drop down from the British Northwest Territory in the rear of and immediately follow the storms of this type, they assume corresponding velocities. The average time for a cold wave to advance from the British Northwest Territory to the middle Atlantic and New England States, would, therefore, be sixty to seventy-two hours. But as the storms vary in velocity, so would the time required for a cold wave to sweep the northern regions vary. In all cases the velocity of cold waves must be governed by the velocity of the low areas and of the succeeding high areas, and their intensity upon the observed temperature distribution, and the intensity of the low and high areas which promote, sustain, and propel them.

Chart 1.

Saskatchewan Valley.

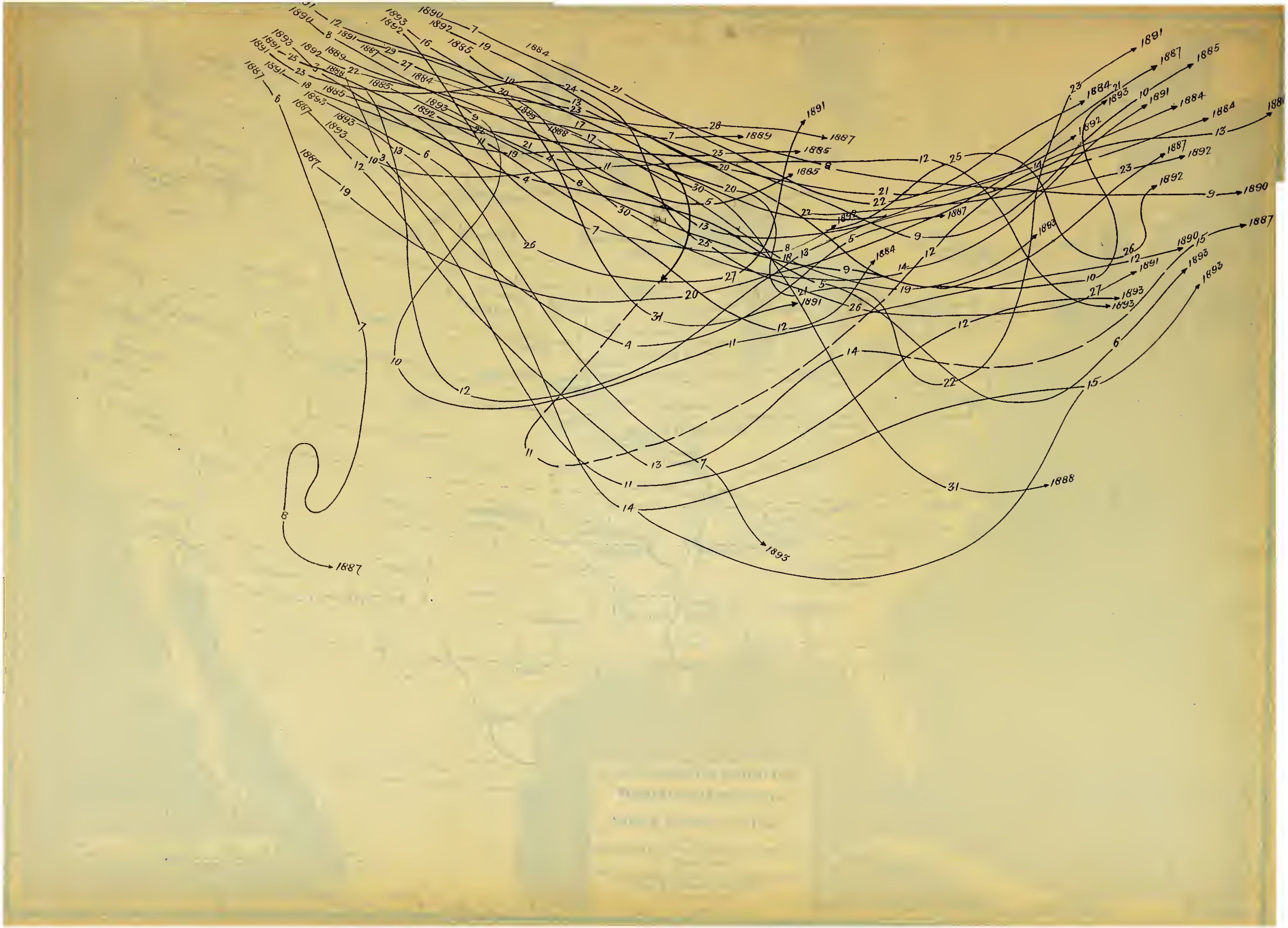


Chart 2.

Southwestern States.

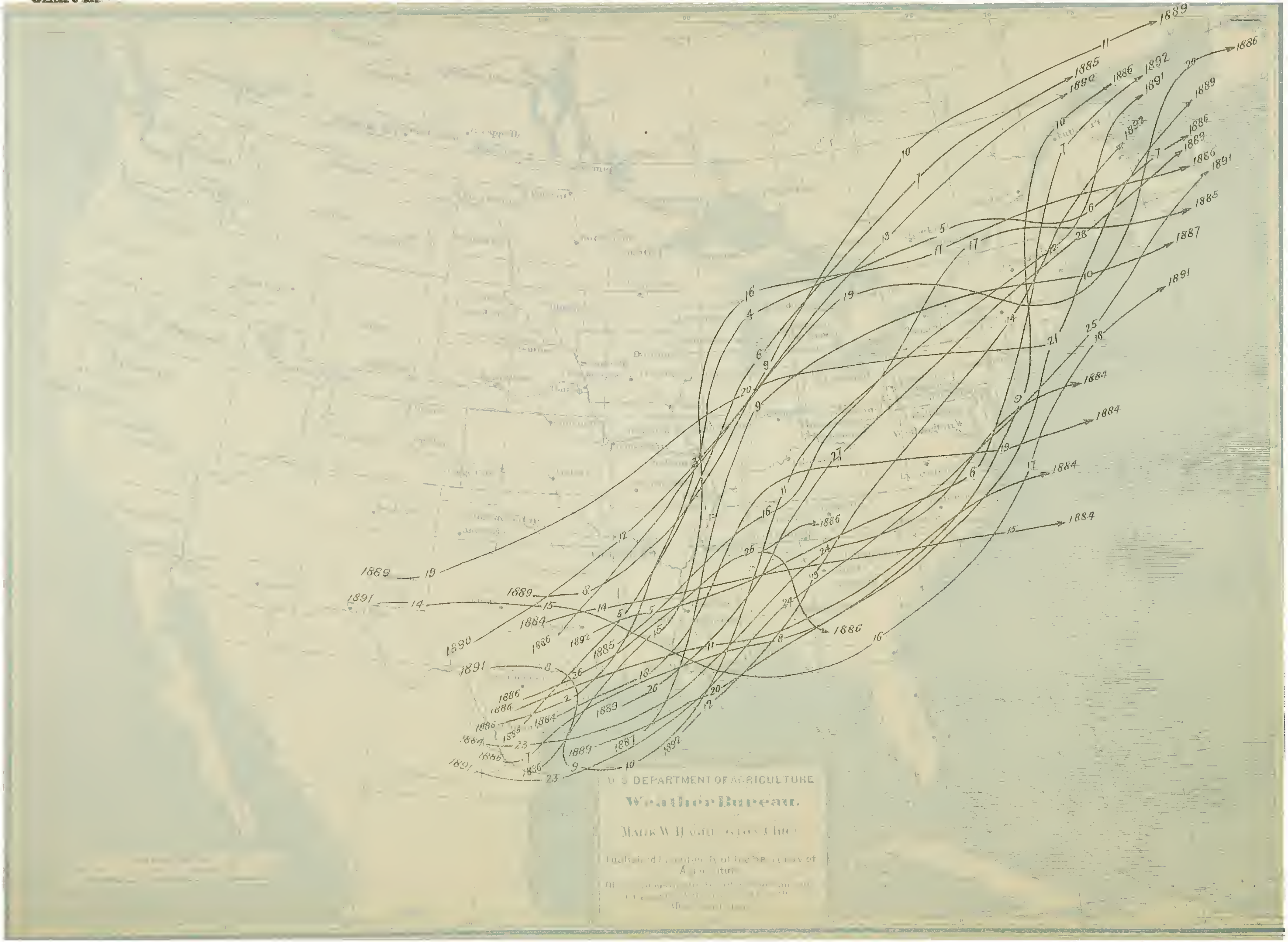


Chart 3.

North Pacific Coast.

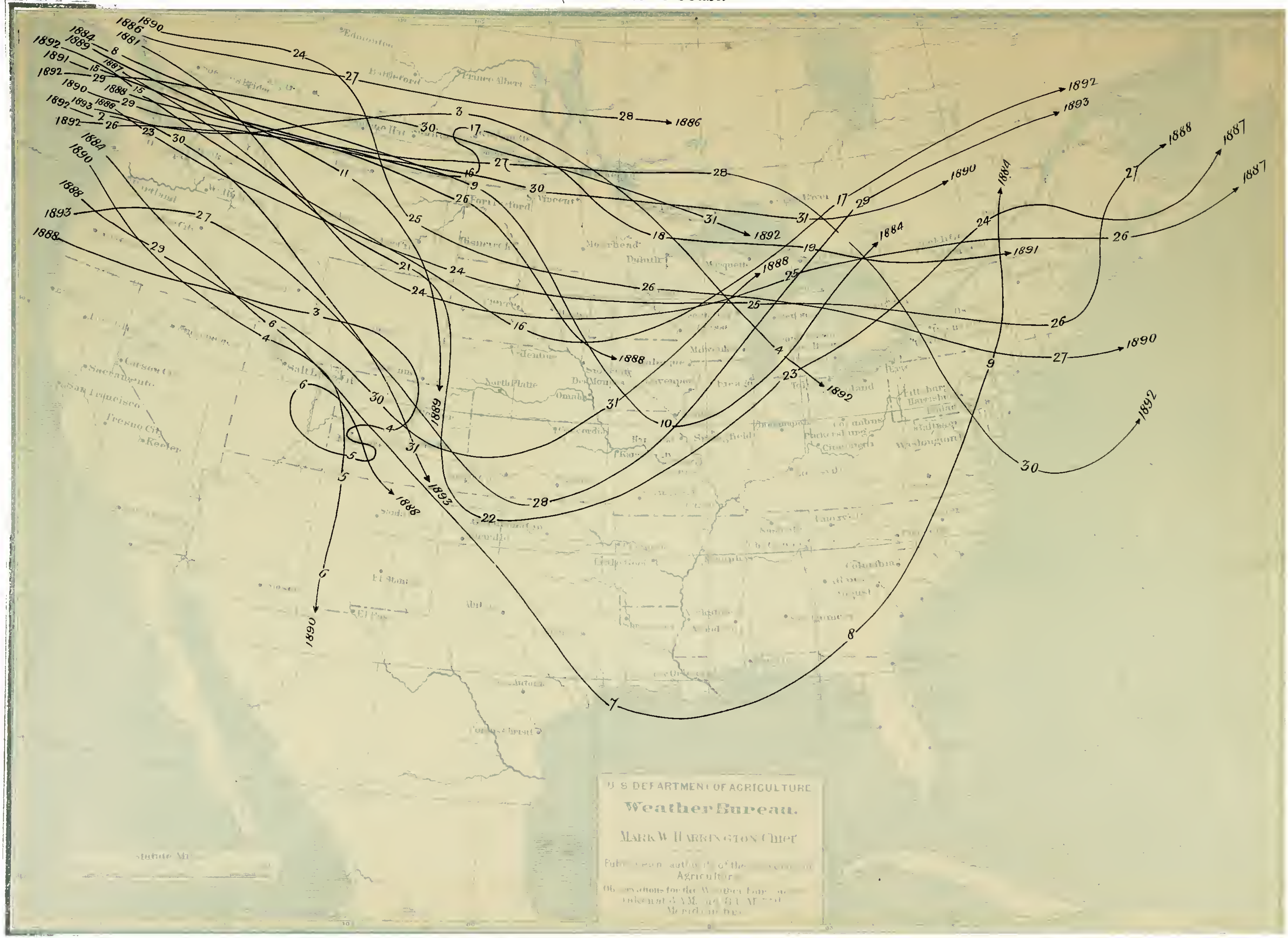


Chart 4.

Northeast Rocky Mountain Slope.

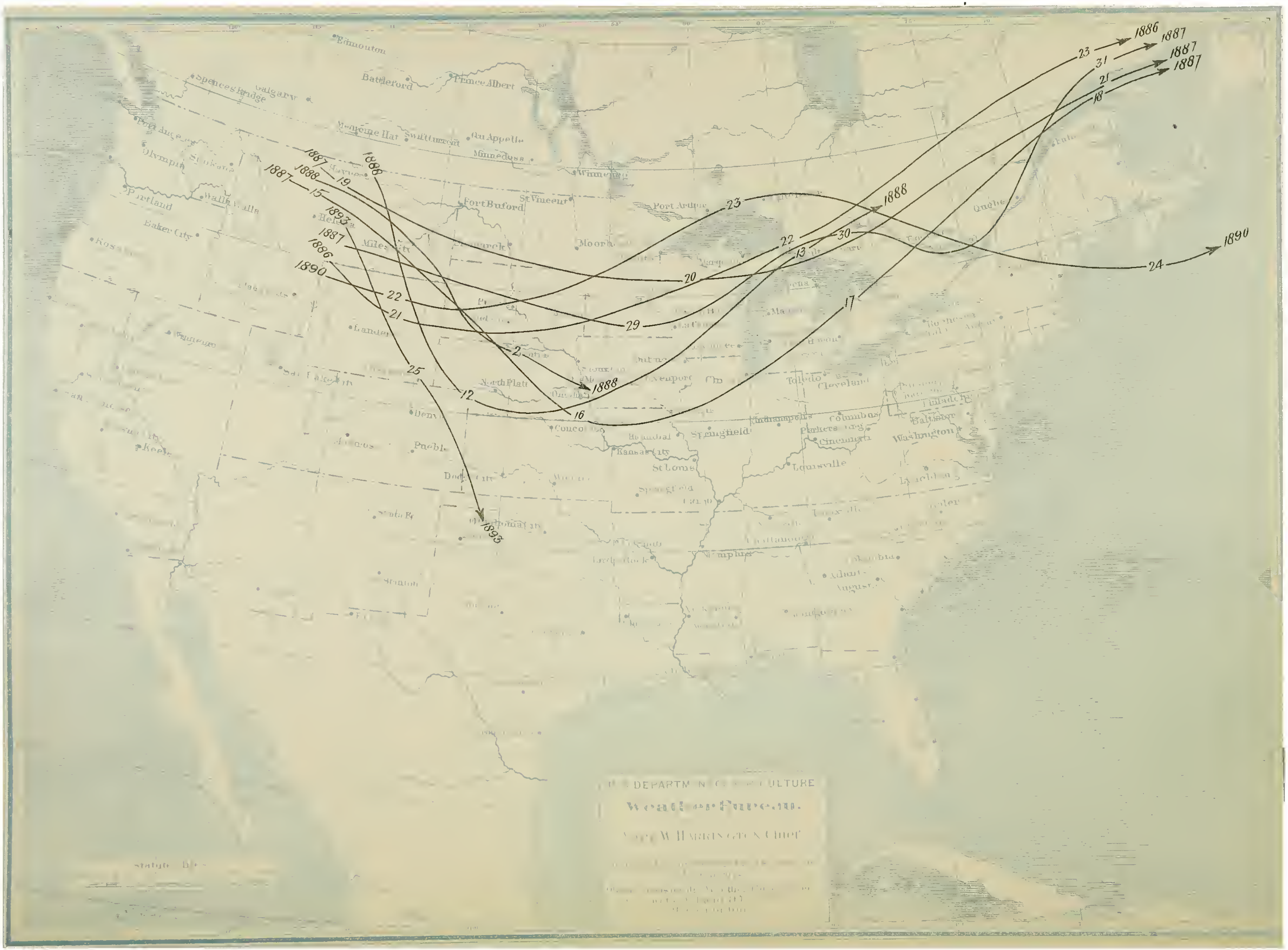
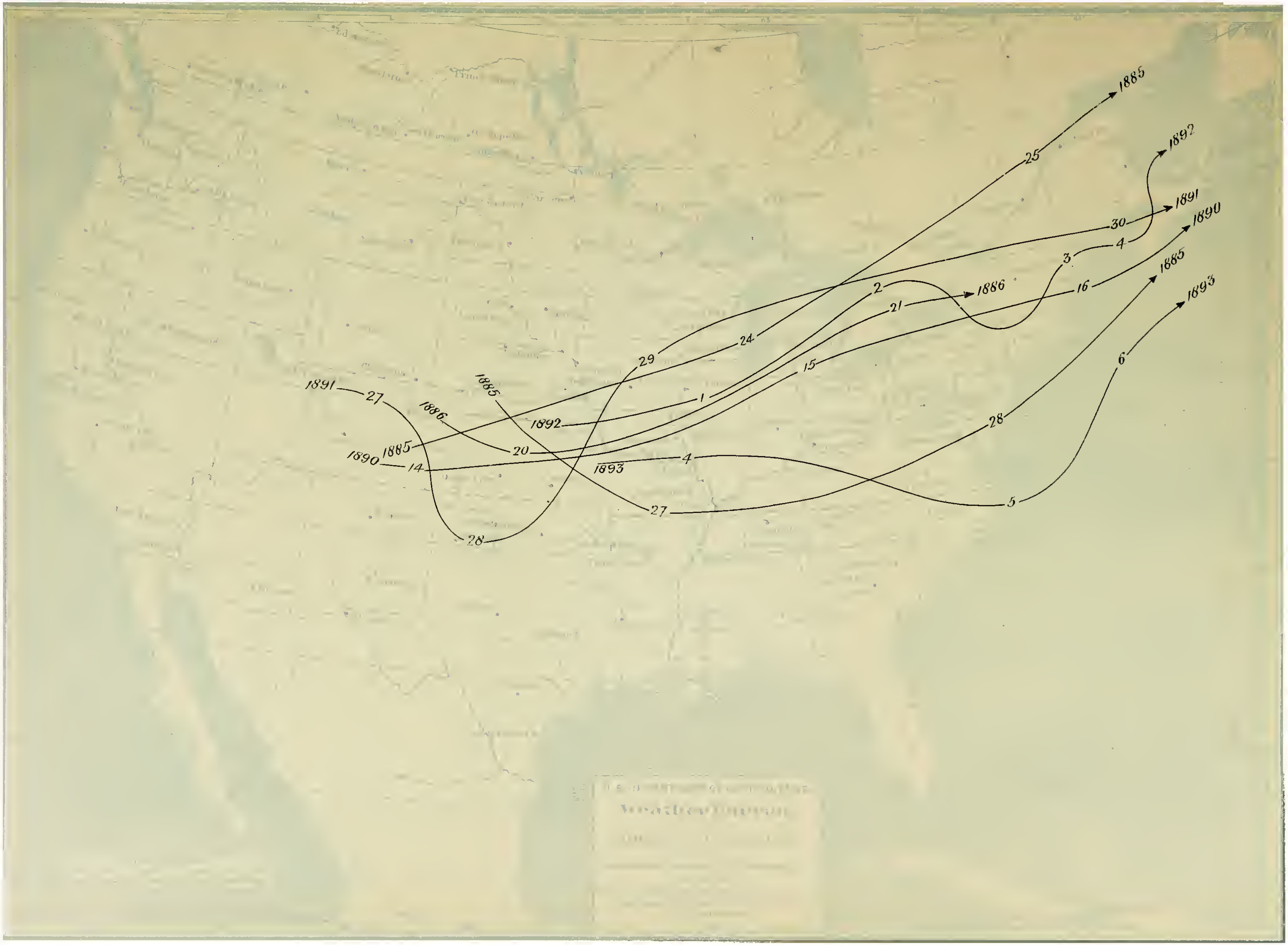


Chart 5.

Middle-Western States.



Ohio Valley and Lake Region.

Chart 7.

Southeastern States.

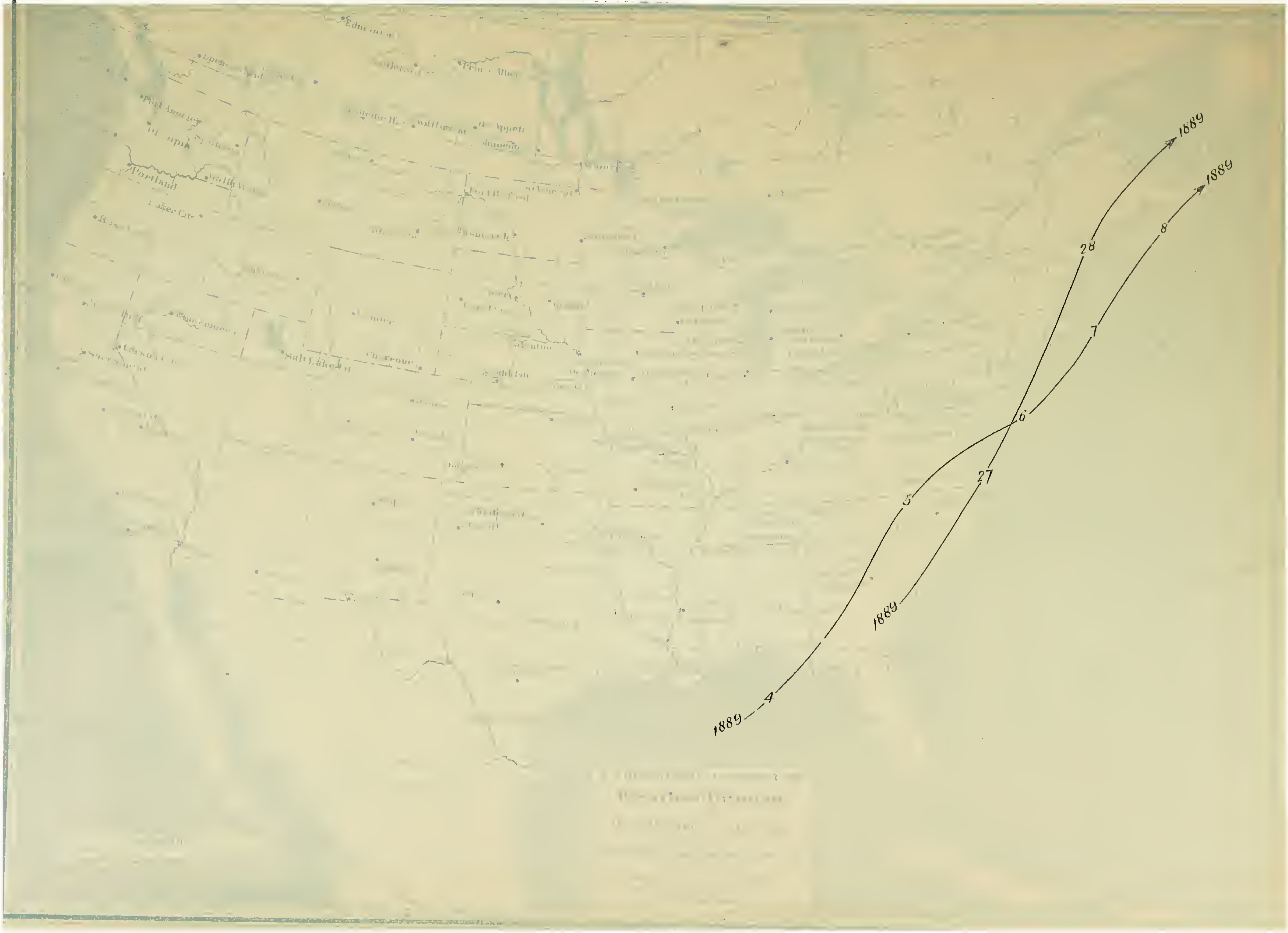
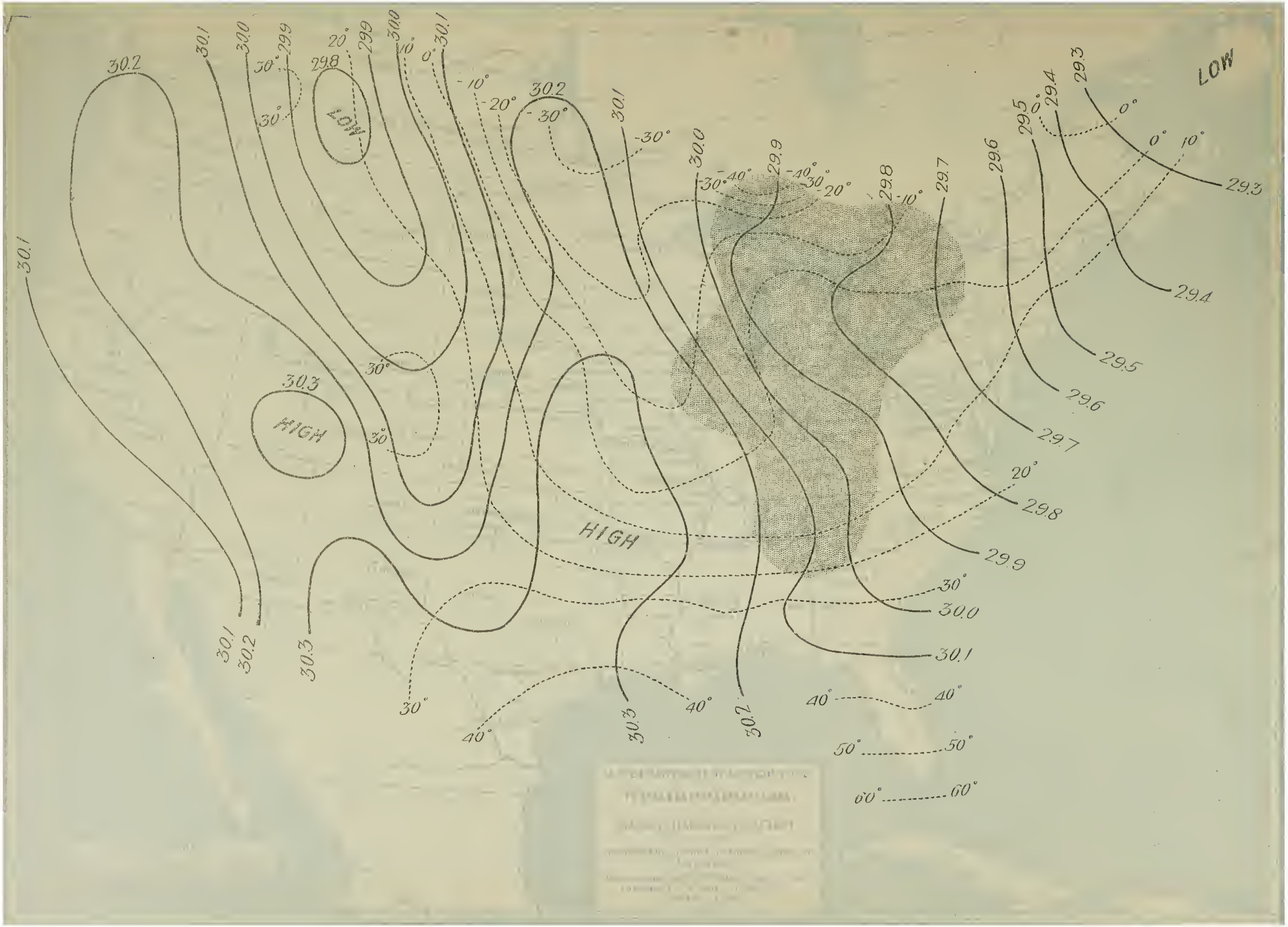


Chart 8.

South Pacific Coast.

Chart 9.

January 13, 1893—8 a. m.



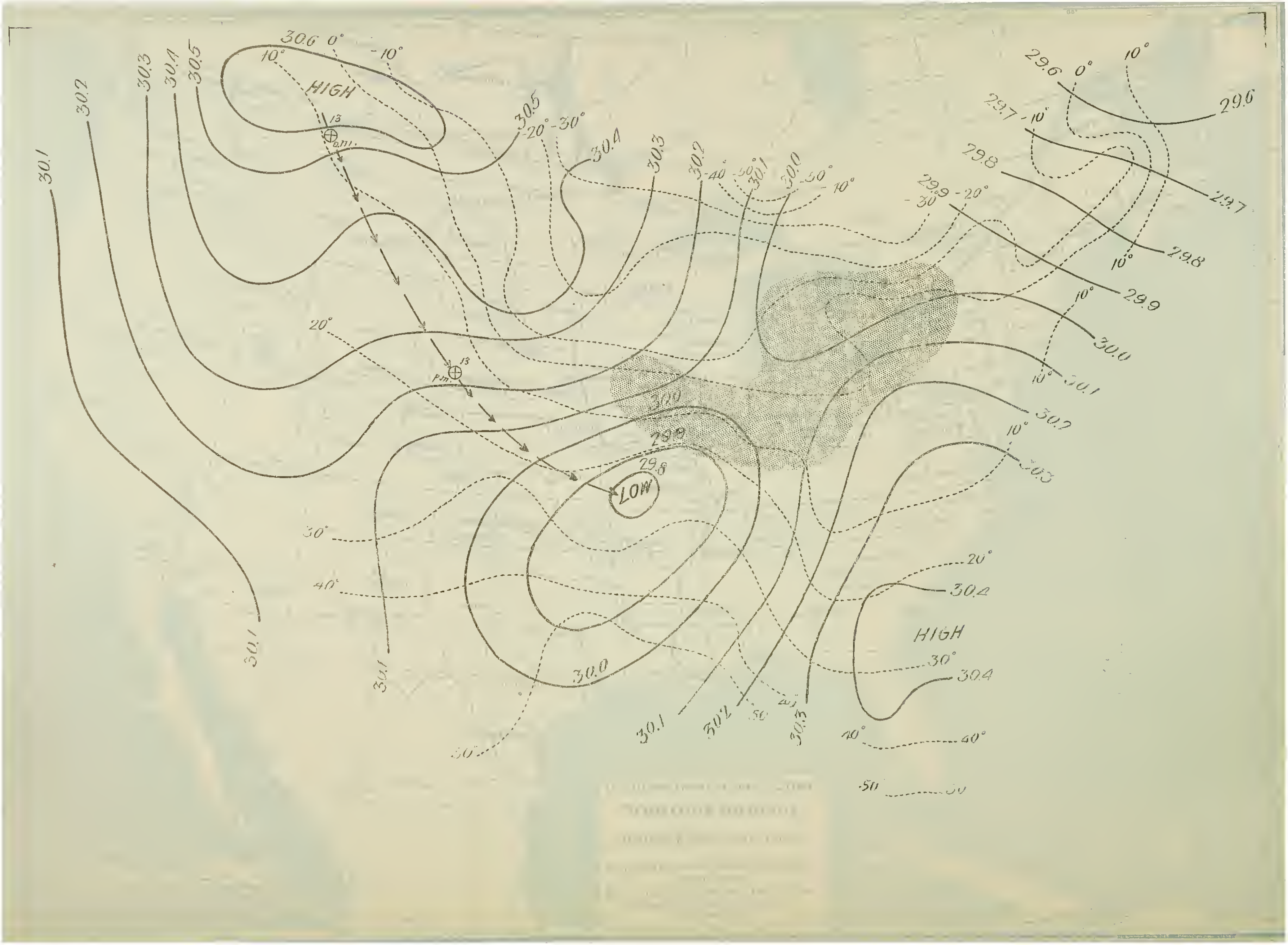

HIGH
LOW
HIGH
30.6
30.5
30.4
30.3
30.2
30.1
30.0
29.9
29.8
29.7
29.6
0°
10°
-10°
-20°
-30°
-40°
-50°
20°
30°
40°
50°
13 a.m.
13 p.m.

Chart 11.

January 15, 1892—8 a. m.

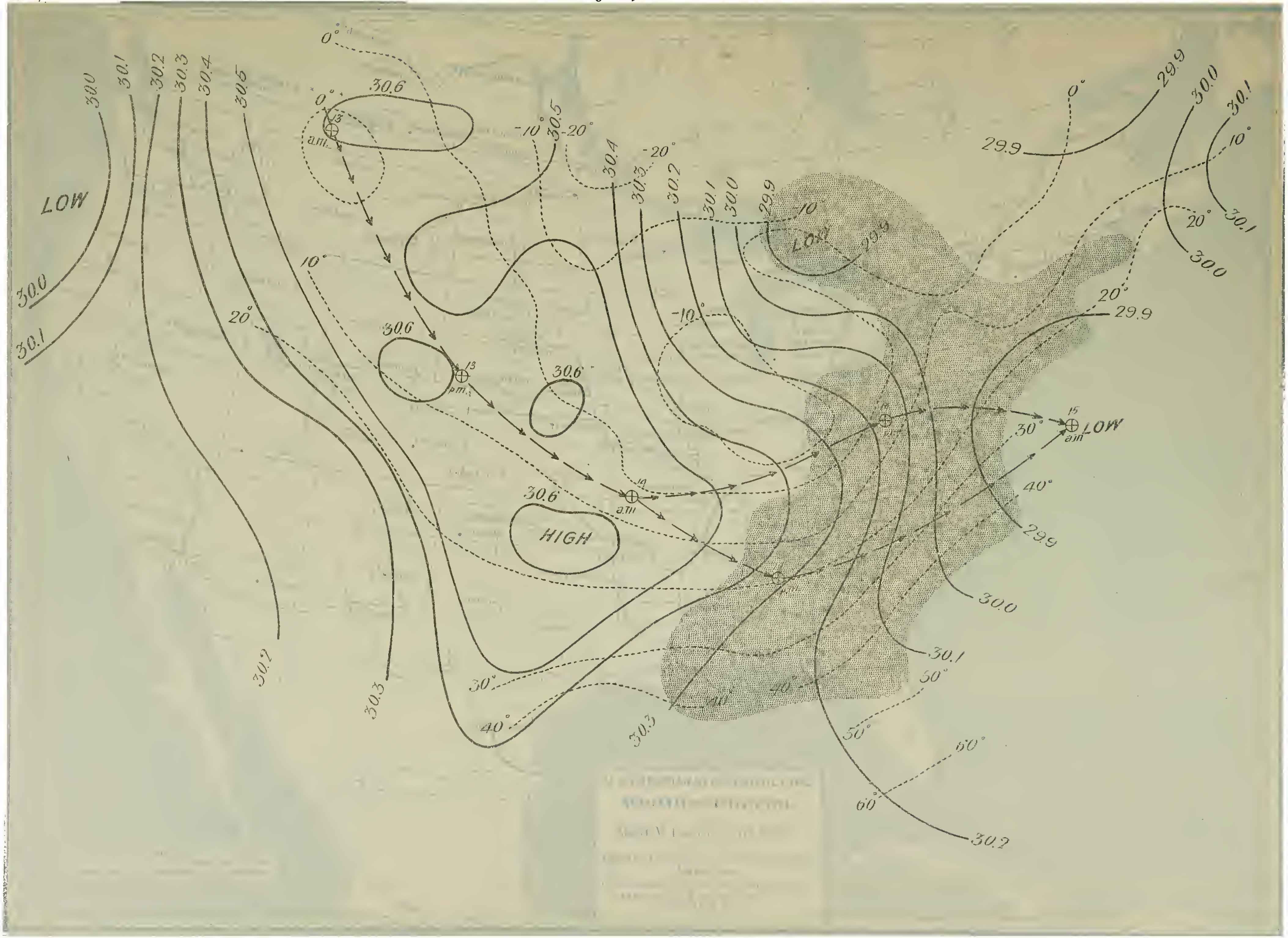


Chart 12. January 20, 1892—8 a.m.

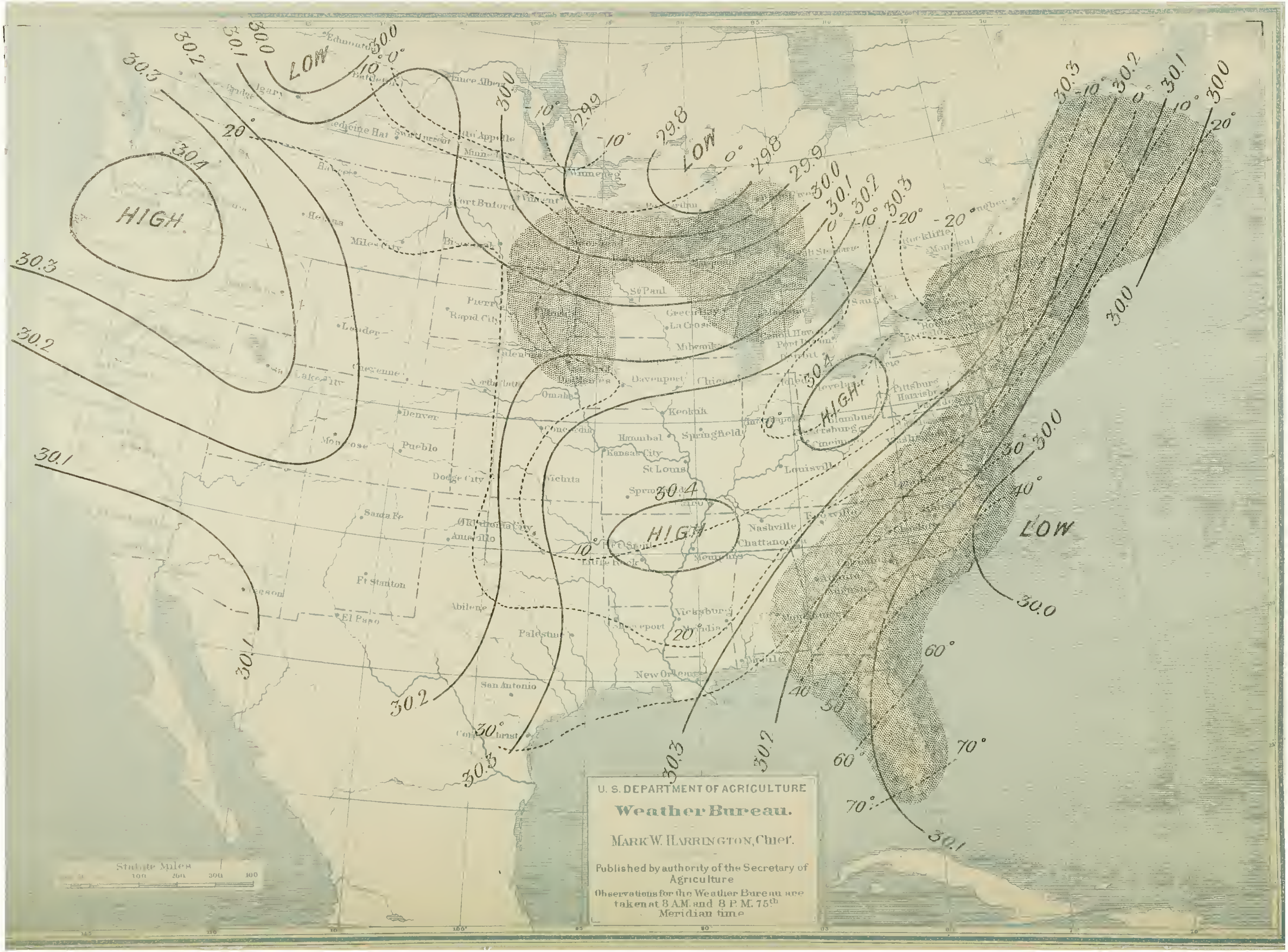


Chart 13.

January 21, 1892—8 a.m.

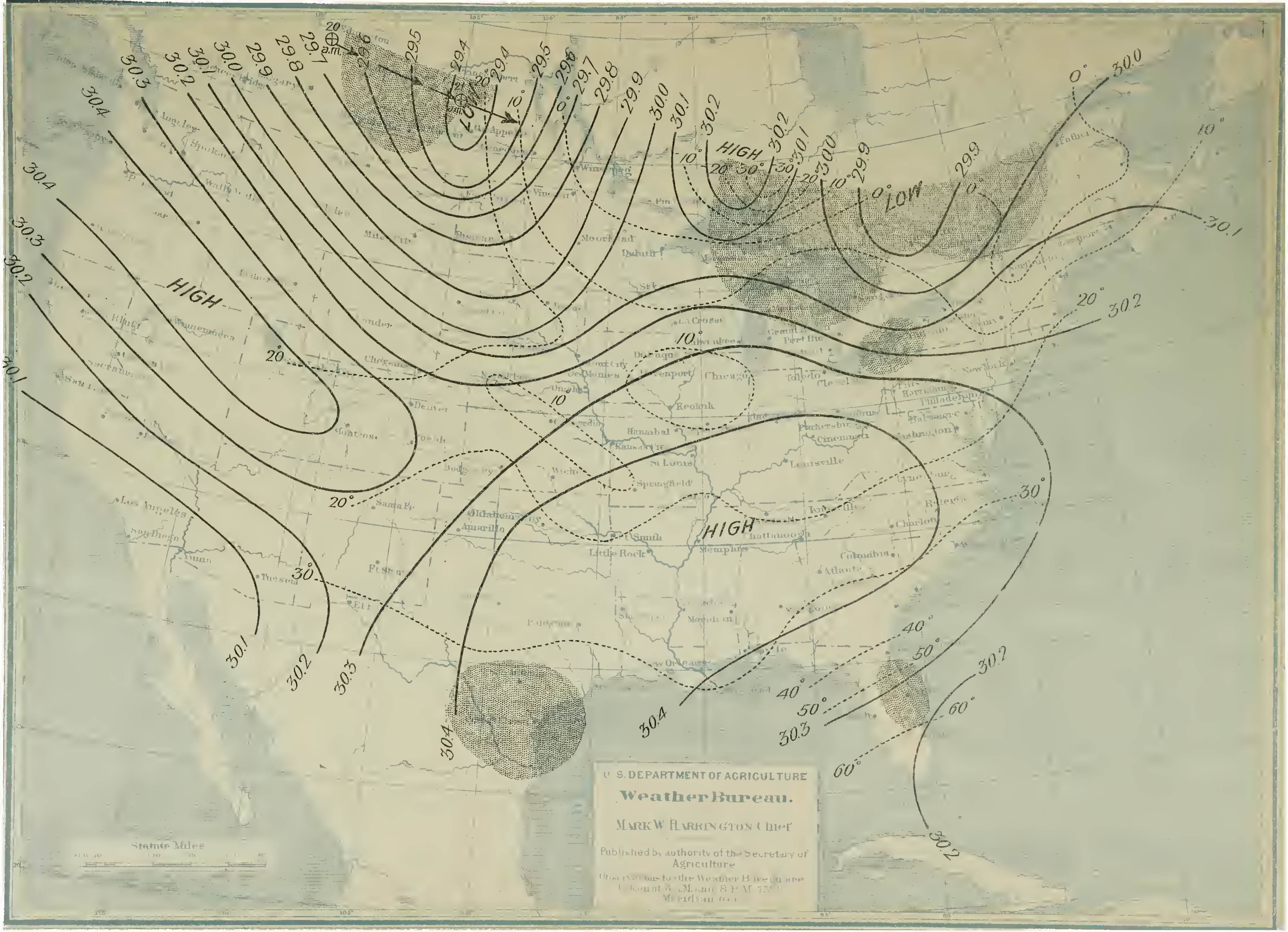


Chart 14. January 22, 1892—8 a. m.

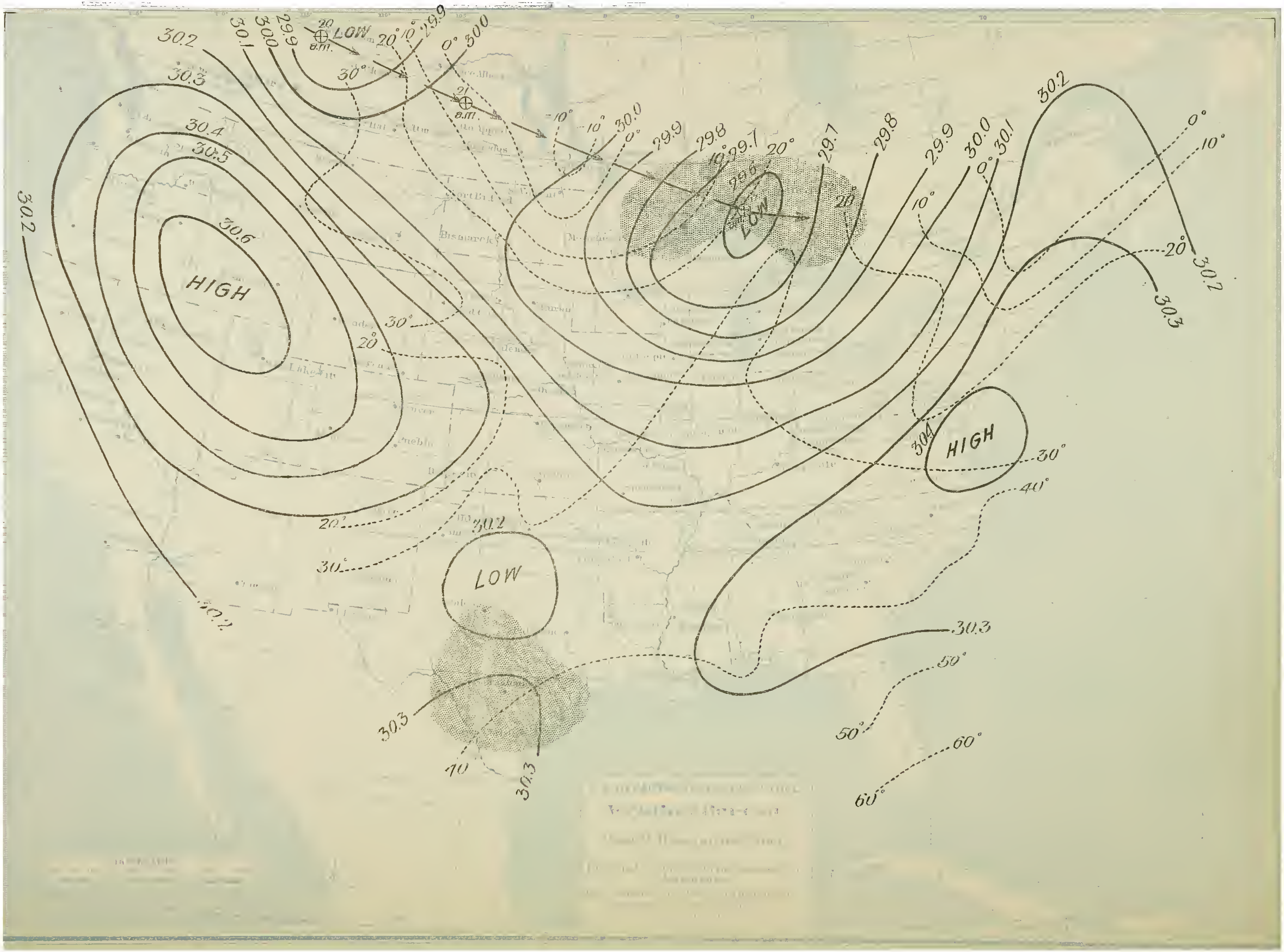


Chart 15.

January 23, 1892—8 a. m.

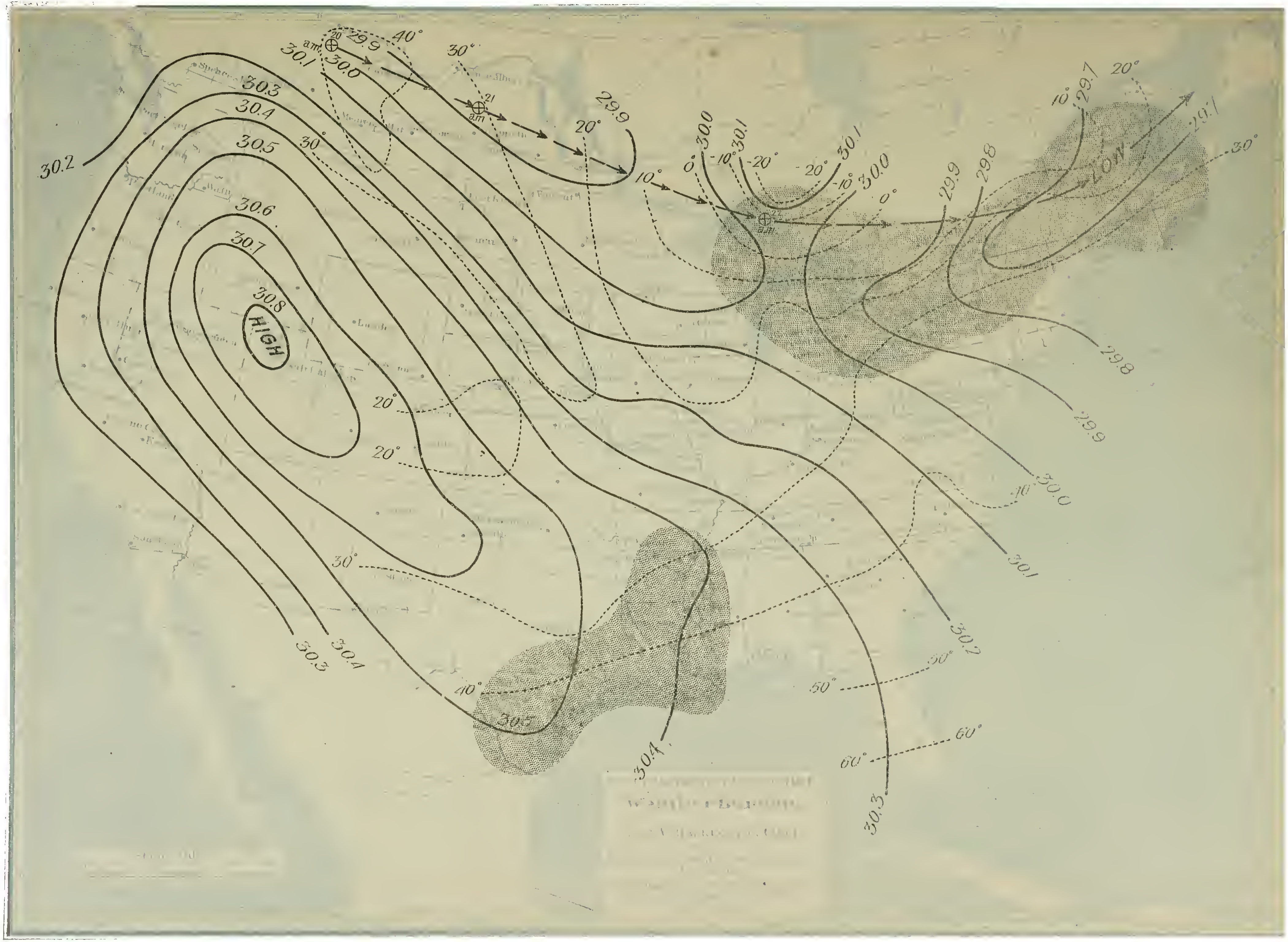


Chart 16.

January 8, 1889—8 a. m.

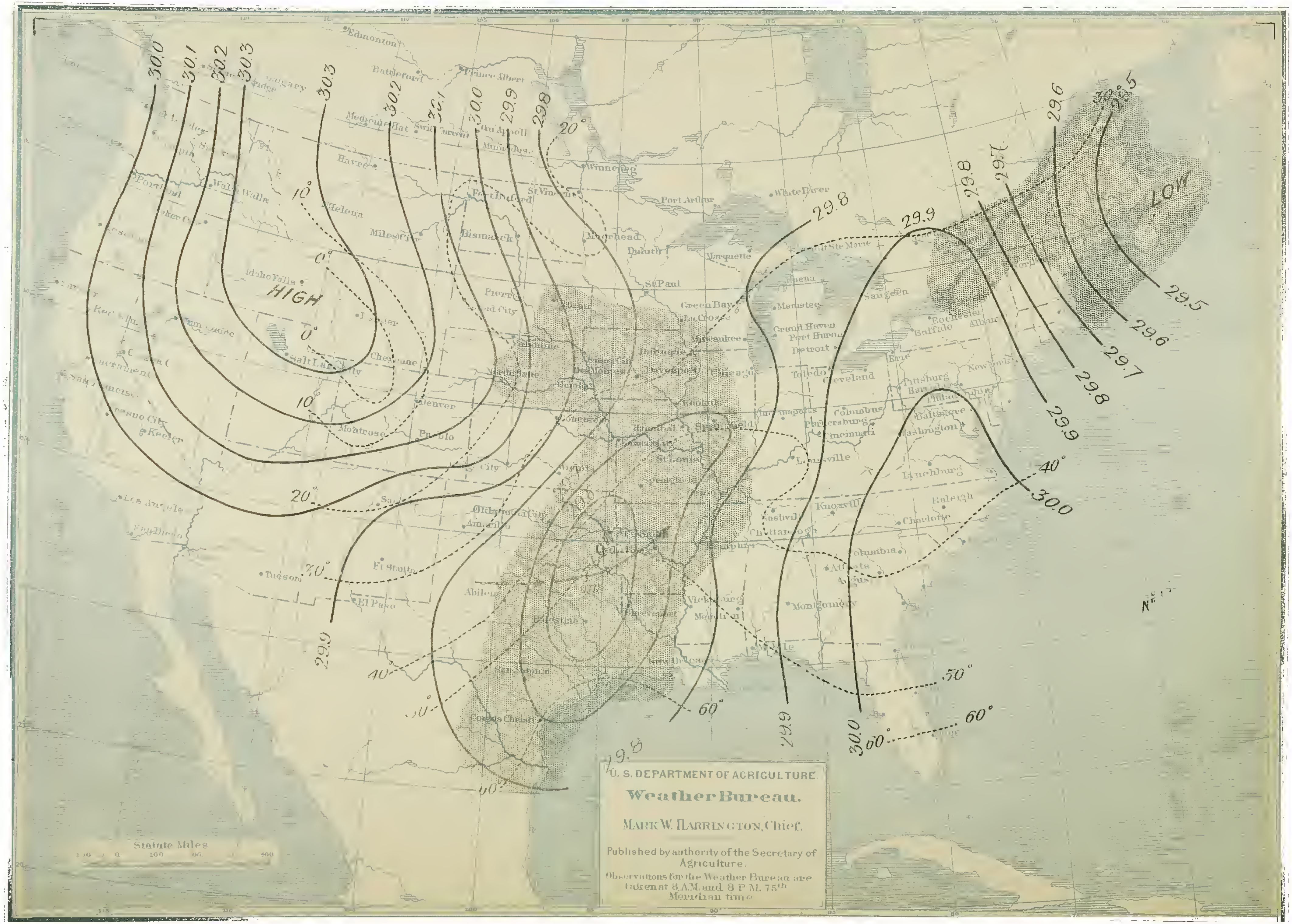


Chart 17. **January 9, 1889—8 a.m.**

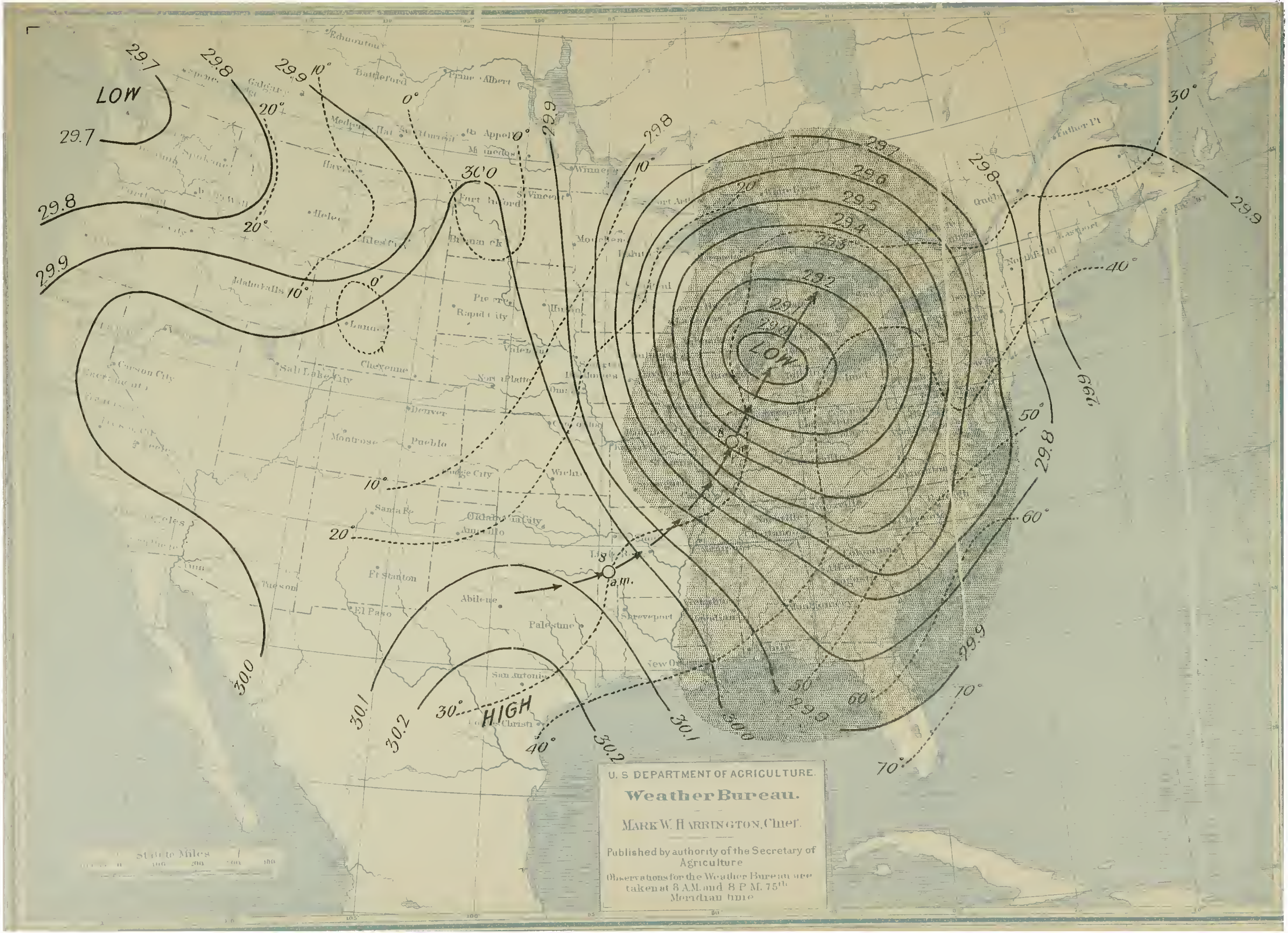


Chart 18.

January 10, 1889—8 a. m.

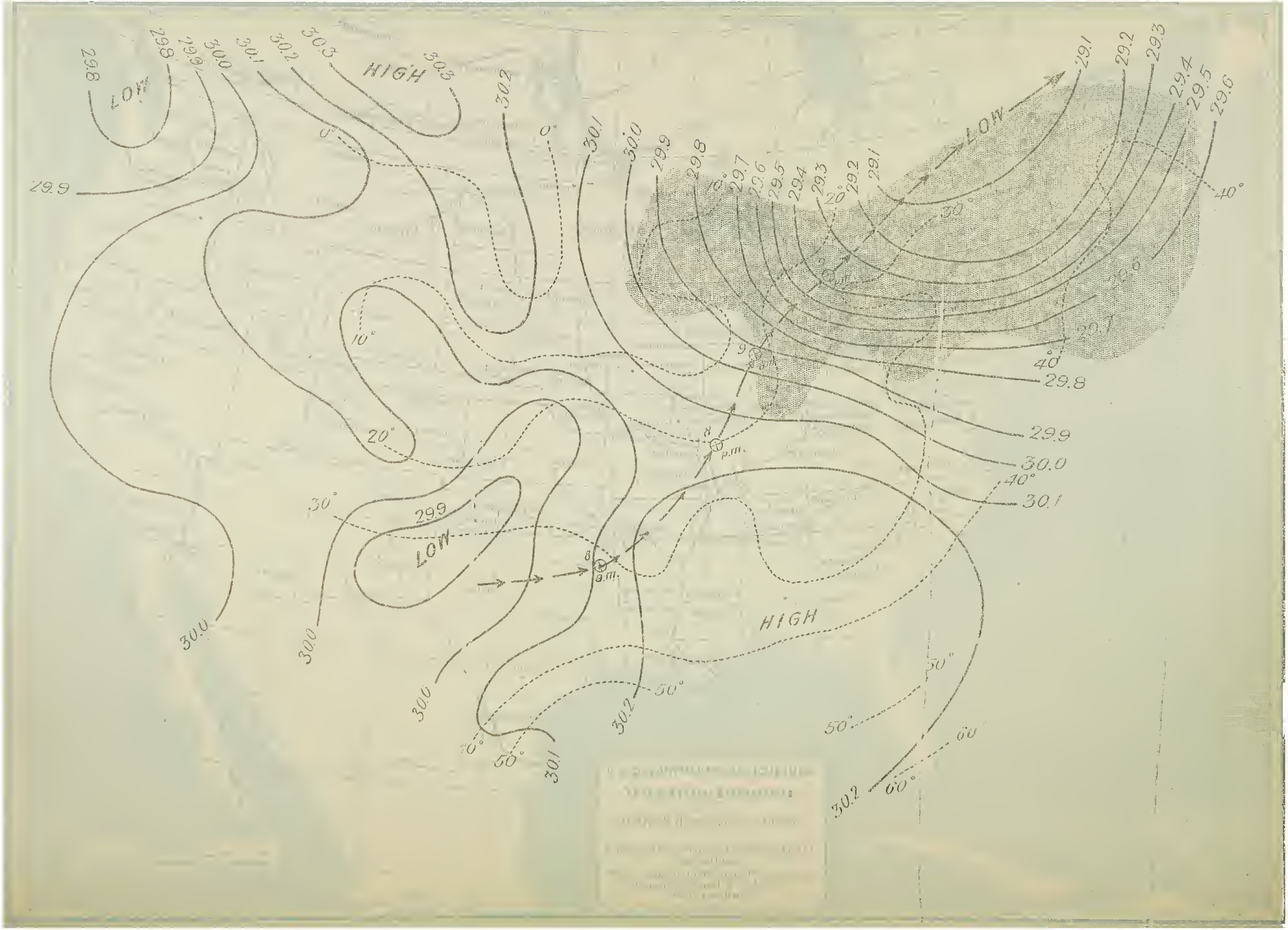


Chart 19.

January 26, 1889—8 a. m.

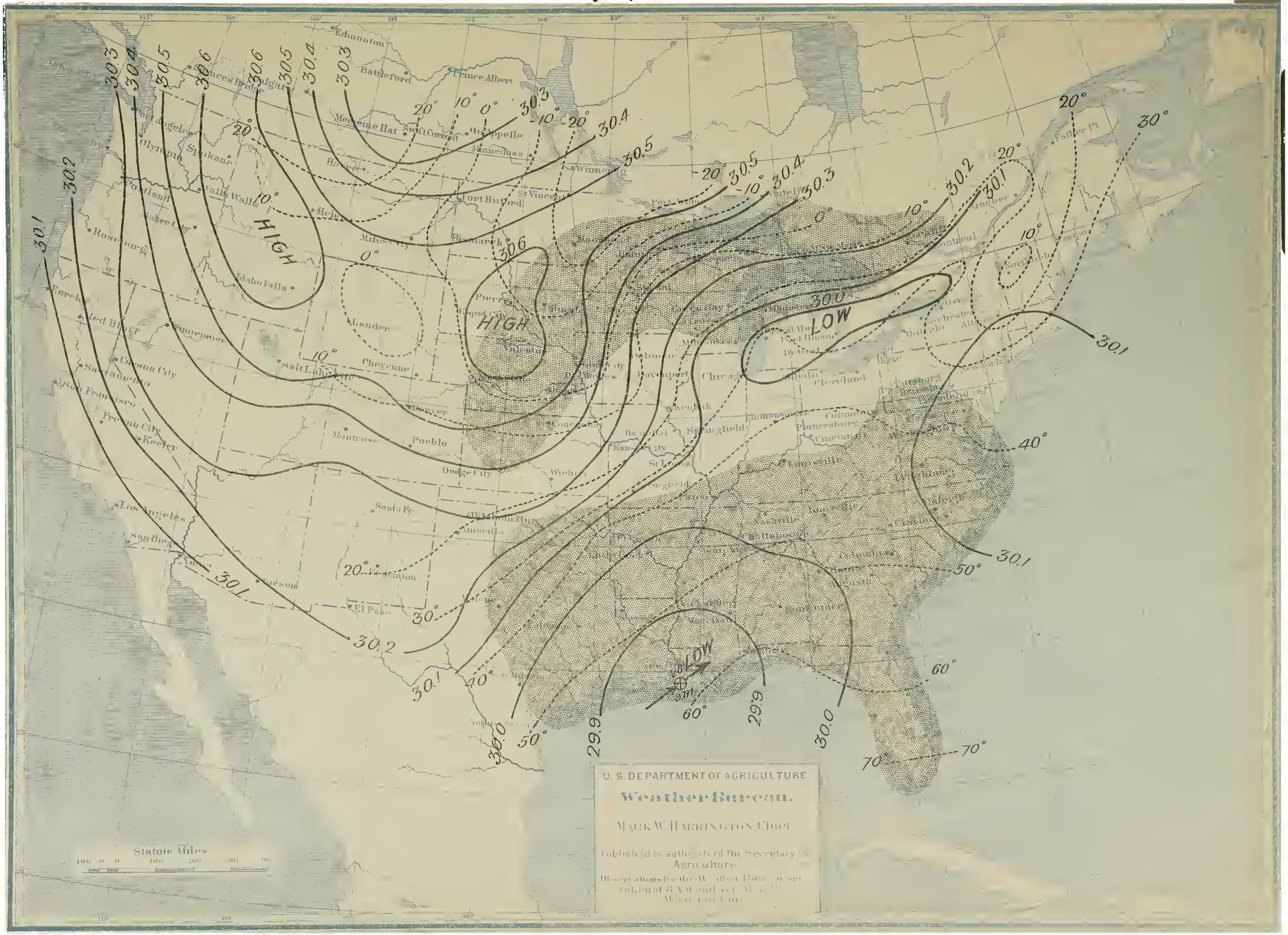


Chart 20.

January 27, 1889—8 a. m.

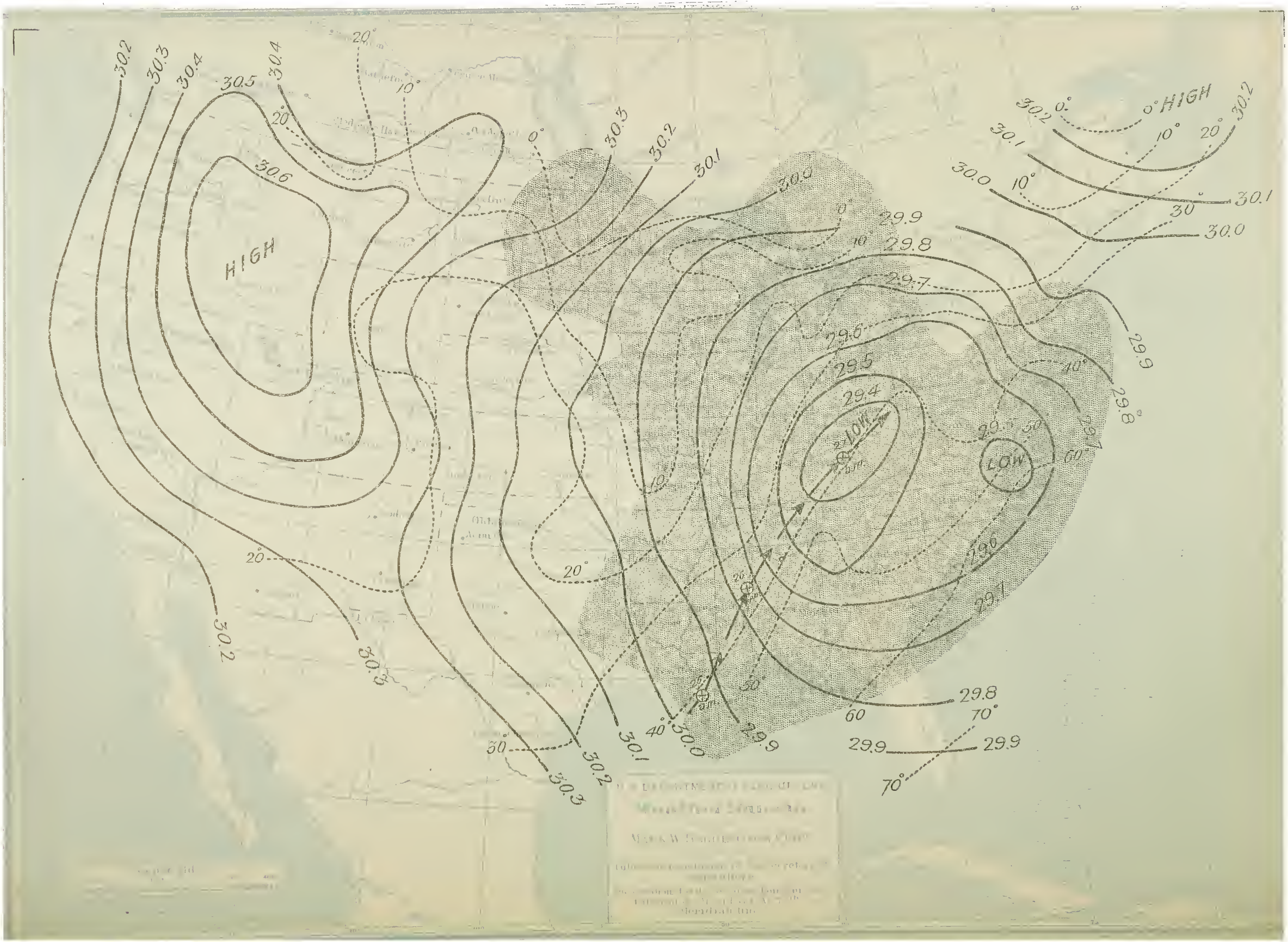


Chart 21.

January 28, 1889—8 a. m.

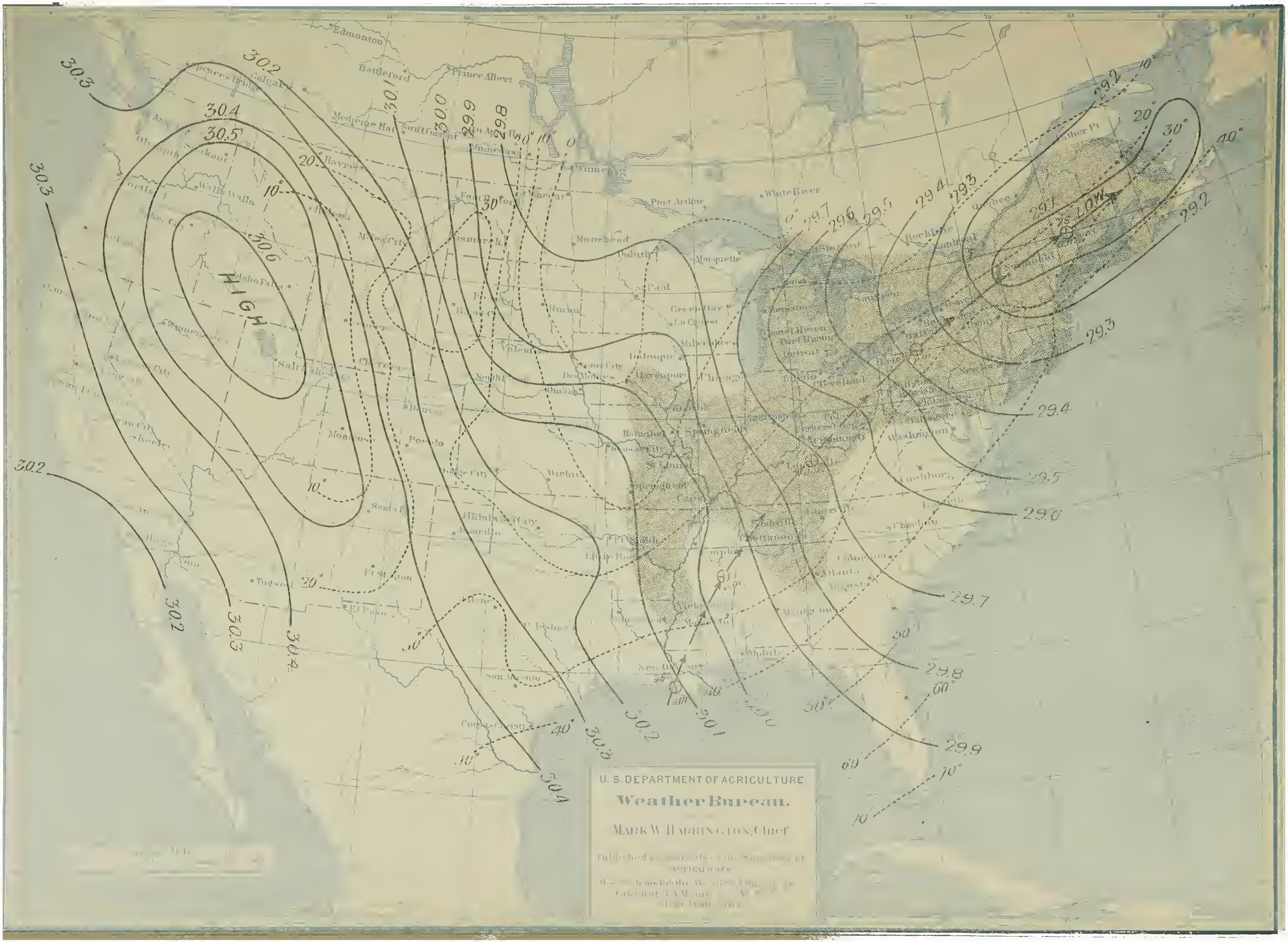


Chart 22. January 23, 1891—8 a. m.

Chart 23. **January 24, 1891—8 a. m.**

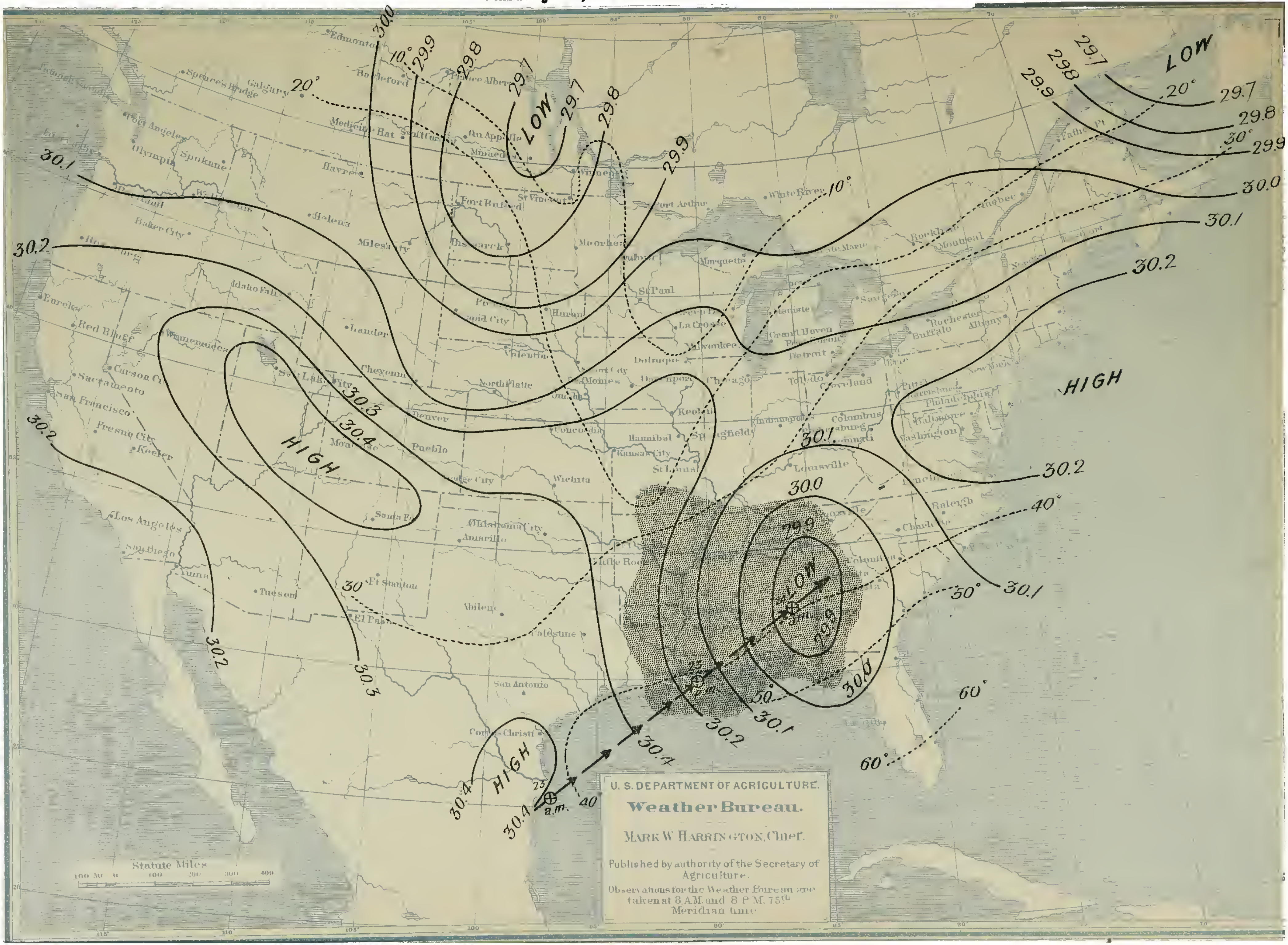


Chart 24. January 25, 1891—8 a. m.

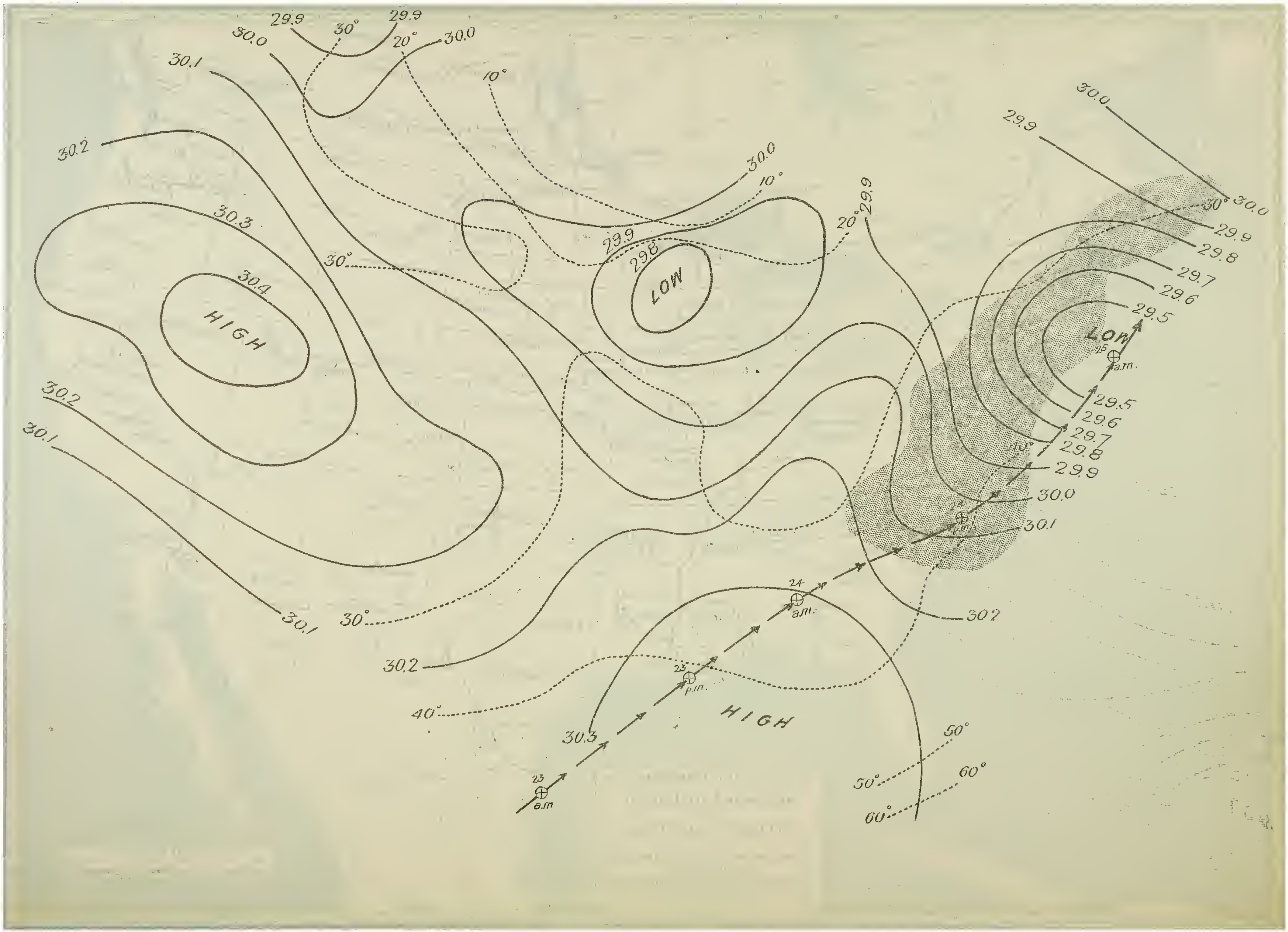
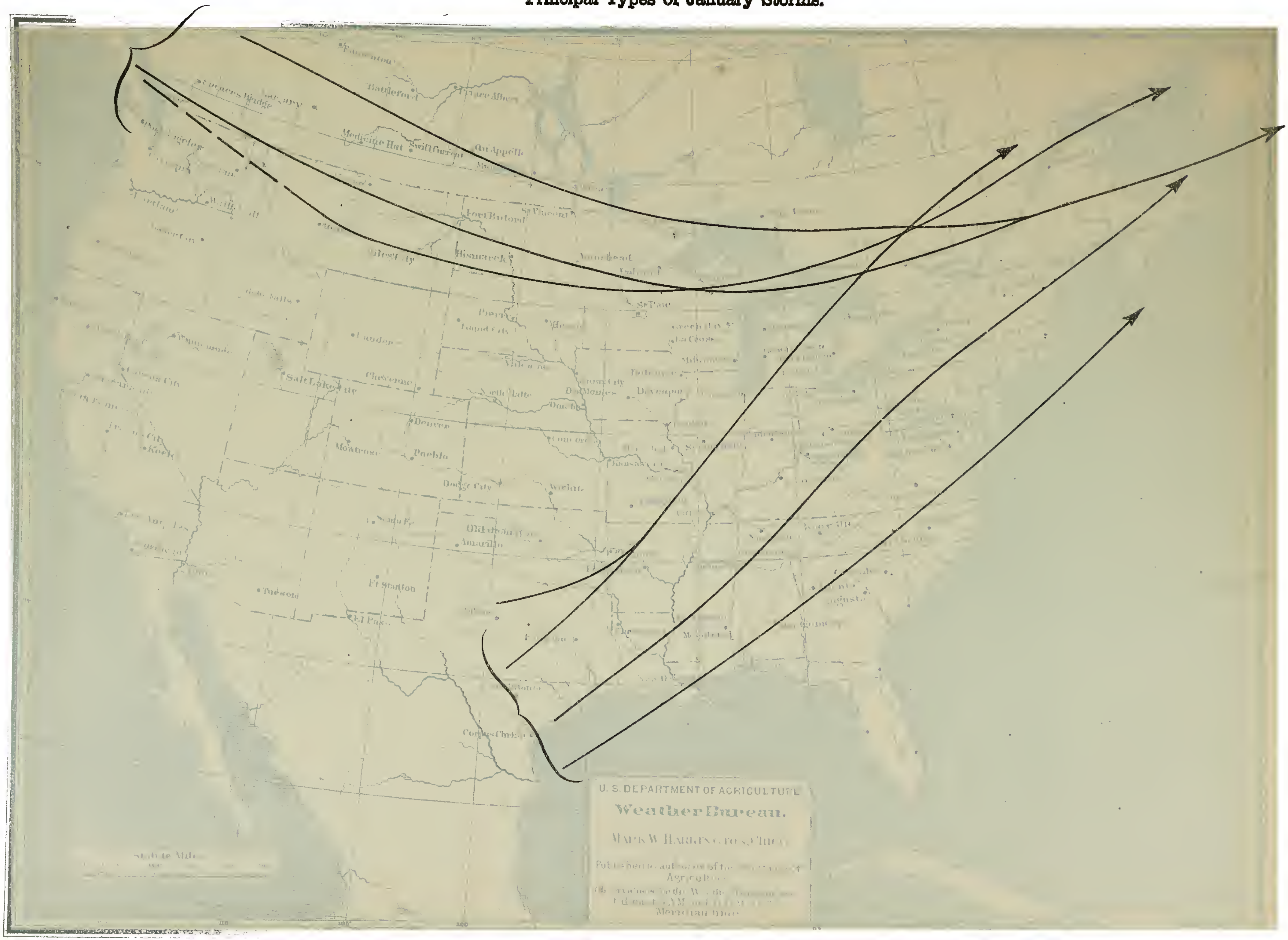


Chart 25.

Principal Types of January Storms.



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No. 2.—STORMS IN TEXAS.*

By Prof. H. A. HAZEN.

The following is "An examination of the low areas which formed over Texas, or on the Texas coast, during October, November, and December, with a view of determining the conditions which preceded their development, their probable movement, and the time required for the weather conditions attending them to extend to the Atlantic coast."

At the very first of this study it was found that the low areas which formed in Texas, or on the coast, were very few, and it was decided to add a study of all cases of rainfall which began in Texas. It is easy to see that, after all, what is most needed is a study of the occurrence of rain, and it was found that nearly half the cases in October, and almost as many in November, were with an advancing high area. The maps studied were those prepared in the Forecast Division for the years 1880–'88, inclusive, making nearly 2,400 maps. Some puzzling cases of rainfall were found at Brownsville, and, to elucidate these, all the observations made at Tlacotalpan, in Mexico, on the Gulf of Mexico, were studied in connection with the United States maps. The motions of lower and upper clouds were also studied to determine their influence, if any.

In going through the maps copious notes were made of each map under study, and while these have been freely used in making up this report, it was not deemed advisable to transcribe them fully. The number of cases of rainfall and the number of maps from which notes were taken are given in the following table:

Number of cases of rainfall and number of maps studied.

Year.	October.		November.		December.	
	Cases.	Maps.	Cases.	Maps.	Cases.	Maps.
1880	2	21	7	30	8	22
1881	5	16	5	21	5	37
1882	4	26	4	33	9	47
1883	1	8	4	18	6	32
1884	0	0	3	12	6	30
1885	2	7	2	16	3	20
1886	2	10	5	20	4	24
1887	5	31	2	20	8	52
1888	4	10	4	24	6	35
Total	25	129	36	194	55	299
Average	2.8	14.3	4.0	21.6	6.1	33.2

This table shows at once the gradual progression of the phenomena under study as the winter draws on. In fact, the driest month of the year at New Orleans is October (rainfall, 3.49, November giving 4.81, and December, 4.95). At Palestine, also, October is the driest of the three months. This is not the case, however, at Galveston, Brownsville, and San Antonio, but these studies included the Gulf and south Atlantic States. The rain at Galveston per storm was less in the later months, and this gave a slightly less rainfall, although the number of storms actually increased.

It is a little difficult to give a satisfactory summary of all these cases, and it should be remembered that what are given are the salient features of the precipitation as a whole.

OCTOBER.

In this month, more than in the others, there is a tendency to a diminished rainfall, with a *southerly wind*. A well-defined storm may originate in Texas, or traverse that State, and yet it is a curious fact that the south wind blowing off the great body of water in the Gulf does not give an abundance of rain. It is probable that nearly two-thirds of the cases of rain on the Texas Gulf in this month come with the north winds in the front of a high area or in the rear of the storm. This may be due in part to the fact that the rather cool gulf wind has its moisture or relative humidity diminished by the heated land. This rule is gradually overcome as the winter comes on, and in December most of the rain comes in front of the storm, while in the rear the north wind is rather drying. There are some difficulties in this explanation, and I merely present it as a working hypothesis.

RAIN FROM HIGH AREAS.

One of the peculiarities of the weather in October is the occurrence of rain, more or less severe, in the rear of a storm, or at other times in the front of a high area. Under these conditions, usually we have clear weather and the absence of rain. This phenomenon seems analogous to the occurrence of rain in the rear of storms in the Missouri Valley, which has been noted and commented on before. I could not find that the varying motion of clouds brought about the result. The rain is usually far more abundant at the shift of the wind or just at the beginning of the north wind, and the effect disappears when the high area wind has full sweep or is well established. It is probable that the upper current shifts a little before the lower, also the conditions left by the south wind may have brought about the rain with the oncoming colder north wind. I still regard this rainfall as difficult to explain.

The largest number of lows in October seem to come to Texas from the west or south, though a very few recurve from the Gulf. As a general thing, they are not marked by a great depression of air pressure, and, in fact, this may be said of nearly all the lows in this region during the three months. The most difficult conditions to forecast are those accompanying troughs of low pressure extending from Texas to Minnesota or the Lakes. Usually the northern part of this trough separates from the southern and goes on as an independent storm, leaving a disturbed condition in the Gulf. The motion of this disturbance is exceedingly irregular, but, in general, it moves very slowly along the Gulf coast to the south Atlantic and then up the coast. One peculiarity is that with this low there is not the usual clearing up in the rear, but rain may continue for thirty-six or even forty-eight hours.

Perhaps the most important condition to be watched under any circumstances is the behavior of the high area on the Atlantic coast. This high area is almost invariably found and often remains stationary on the middle Atlantic coast for thirty-six hours. If this moves off to sea the tendency is for the storm to develop and move after it. If the high area moves to the Nova Scotia coast, the storm will then begin to develop and will move rather slowly either along the Atlantic coast or from the middle Gulf to the upper Ohio Valley. If the high area gradually moves to the south Atlantic coast,

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* Extract from Monthly Weather Review, February, 1895.

the storm will move up the Mississippi Valley and the Atlantic coast will not get rain, except sometimes New England. I have devoted special attention to the movement of this high area, but can not lay down any rule as to when or under what circumstances it will settle over the south Atlantic coast or move to the northeast over Nova Scotia. It is possible that the observation at Bermuda might help out the study of this problem. At all events it would be a great advantage if a twice-daily observation were sent by mail from Bermuda and the record entered on the map.

NOVEMBER AND DECEMBER.

The storms in these months have about the same rate of motion as in October, but they develop into much more extensive storms and at times cover enormous regions. The trough conditions are especially marked in these months and are very difficult to positively forecast until they reach the Alleghanies. The prediction of rain with a north wind in Texas can not be ventured upon in these months, as there is a greater tendency for rain with south than with north winds.

I should say that rain is very difficult to forecast in Texas in the three months under study. The danger is of giving too much weight to threatening conditions. There is a certain condition of pressure which is invariably followed by clearing weather, i. e., a rise in pressure to the south of Texas, or sometimes over the State. This is almost an infallible sign and should be looked for with great care.

It is probable that the weather over the Gulf remains rather unsettled during these three months, though this occurs oftener in November and December than in October. The wind arrows frequently show such disturbance long before the pressure has been markedly affected.

In the course of my studies I have had occasion to examine critically all the storms of the Gulf that have approached the coast of Texas and the Southern States, and the list then prepared was published in the WEATHER REVIEW (see the REVIEW for November, 1893). The total number of these storms that reach the west Gulf is exceedingly small. I have found that in these months the Gulf storm frequently loses its intensity very rapidly. This was especially so in the case of the storm of October 12 and 13, 1886. The pressure at Galveston at 11 p. m. of the 12th was 29.35, but this was quickly diminished on the land, though giving a wind of 55 miles per hour from the southwest.

No. 3.—THE CONNECTION BETWEEN SUN SPOTS AND THE WEATHER.*

By Prof. **Frank H. Bigelow.**

At the request of the Chief of the Weather Bureau an attempt was made in June, 1894, to take photographs of the sun spots on clear days. The only telescope available for this work was a 4-inch Clark visual objective, and, after some experiments, it was concluded that the pictures thus obtained were not sufficiently superior to screen diagrams to justify the time and labor of making them. Accordingly the series for the past year consists of hand-drawn diagrams of the approximate relative positions and sizes of the spots, the diameter of the image of the sun being 85 millimeters.

In order to determine whether there is any law that controls the production of spots on the several meridians of the sun, it is necessary to resort to a long series of observations. For this purpose the Carrington "Observations of the Spots on the Sun, November, 1853, to March, 1861, made at Redhill;" the "Beobachtungen der Sonnenflecken zu Anclam und Potsdam, von G. Spörer, January, 1861, to December, 1879;" the "Photographic Results of the Greenwich Observatory, 1878 to 1891" (the last volume received), are available. The gap—1892 to June, 1894—has not been conveniently filled, though it can be done in due time. If spots have a tendency to form on certain solar meridians, then, in order to classify these as they appear, rotation after rotation, it is necessary to know the exact period of the rotation of the sun itself. In the October number, 1893, of Astronomy and Astrophysics, I published (page 9) my final result of the discussion of the periodic action in the European magnetic field, namely, 26.67928 days, and have in other places explained its connection with the sun's angular motion at the equator. This period has been tested, so that it can now be stated that the same periodic action was found in 1841 and other years up to 1895 and that this period, departing from the epoch June 12.22, 1887, does not fall short more than one-tenth of a day in fifty years. The spots have been grouped according to the accurate ephemeris instead of using the approximation 26.68.

Since the Carrington and Spörer series, and the Spörer and Greenwich series each overlap each other a little, it is possible to reduce the diagrams of Carrington and Spörer to the scale of the Greenwich series, so that a set of numbers, consistent, from 1854 to 1895, can be tabulated to show the amount of spotted areas that have occurred on the several days of the 26.68-day period in about forty years. A result that shows a definite tendency to group the spots on certain meridians becomes at once a test of the value of this period, and also points to many conclusions important in solar physics, terrestrial physics, and meteorology. For convenience the unit of area is the one hundred thousandth of the visible surface instead of one millionth. Each spot area is entered once for all, either as occurring on the central meridian or else at a date whose interval from this meridian can be computed from the available data. Hence, the tables show the total area of the sun-spot groups for forty years, arranged strictly in the 26.68-day period. The Northern and the Southern Hemispheres were kept separate throughout the compilation, and the final sums are wholly independent of each other.

The table and diagram (see Chart IX) give the sums for each of the four series specified and the sum of all, and also the curves displaying this last summation.

In plotting the curves for the Northern and the Southern Hemispheres it is seen that they are inverted curves of the same type. On comparing them with the magnetic curve derived from the European magnetic field (Amer. Met. Journ., January, 1895), it is clear that the sun-spot curve for the Southern Hemisphere gives back the *direct* type, and the sun-spot curve for the Northern Hemisphere the *inverse* type of the terrestrial magnetic curve. This computation has been arranged throughout on the ephemeris with epoch June 12.22, 1887. The curves of the accompanying diagrams give the magnetic field direct for the Southern Hemisphere, and inverted for the Northern Hemisphere. The number and sequence of the maxima and minima, in spite of some looseness in the curves, point unmistakably to a fundamental physical process.

It will be remembered (Amer. Journ. Sci., Dec., 1894,) that this same primary periodic curve was found in the temperatures of the American meteorological system, together with the phenomenon of inversion, for which no cause was assigned. The lines of force of the solar magnetic field as they pass through the earth have been fully explained (Amer. Journ. Sci., Aug., 1895). The discussion of the sun-spot formations, herewith presented, makes it evident that during certain intervals the atmosphere of the earth is under the controlling influence of the southern magnetic hemisphere of the sun; and again, the transition being usually abrupt, it is under the control of the northern hemisphere of the sun. Since the sequence or procession of the highs and lows crossing the United States corresponds always to either the direct or the inverse types, allowing for the inevitable looseness of structure in the circulation, it follows that the solar action has the power to invert the entire atmospheric movement, not only in the United States but also over the whole hemisphere of the earth (Amer. Met. Journ., Sept., 1893, curve 15). The inference seems very simple that if this polar magnetic field can maintain an order of highs and lows and can invert the order, then this magnetic field either directly or indirectly is chiefly concerned in the production of the cyclonic and anticyclonic systems. By as much as this is true, grave doubt is thrown upon the soundness of the convectional hypothesis of Ferrel, and the dynamic or driven-eddy theory of Hann to account for our primary meteorological phenomenon. The truth seems to be that the atmosphere of the earth is under the influence of four great systems of impressed forces:

1. The stress of the earth's gravitation.
2. The deflecting forces of the earth's rotation.
3. The equatorial radiant energy of the electromagnetic field.
4. The polar magnetic radiant energy from the polar regions of the sun.

The first and second are constant forces; the third has a steady diurnal and annual period from astronomical conditions; the fourth is very variable and loosely constructed, depending upon solar action, and yet is the system by which weather conditions are chiefly produced. Heretofore the meteorological problem has sought its solution by combinations of the three systems of forces mentioned, but it is clear that one of the most influential sets of impressed forces has been entirely neglected.

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* Extract from Monthly Weather Review, March, 1895.

No. 4.—LOWS NORTH OF IDAHO AND MONTANA.*

By Prof. H. A. Hazen.

The following is a report "on the probable effect of the occurrence during September of low pressure areas to the north of Idaho and Montana in determining the weather conditions in the Upper Mississippi Valley and Upper Lake region within the next thirty-six to forty-eight hours."

In the following statement a careful study has been made of the three-times-daily and twice-daily manuscript maps of the forecast division for the 16 Septembers from 1877 to 1892. In this report a small subscript figure indicates the map used, whether a. m. ($_1$), p. m. ($_2$), or night ($_3$). Since 1888 there have been only two maps, a. m. ($_1$) and p. m. ($_2$).

DESCRIPTION OF THE MAPS.

1877.

Sept. 6_1. Low in Montana; slow motion.
9_1. Moved to north Missouri.
9_3. In Illinois.
10_1. In Indiana; rain in Lower Lakes; none in upper.

1878.

Sept. 7_1. Low in Dakota; slow motion.
9_2. Rain in Upper Lakes.
17_3. Low in Dakota.
19_1. Moved to Upper Lakes, with rain.
23_2. Low in Montana.
24_1. In western Iowa; first rain in Upper Lakes.

1879.

Sept. 8_2. Low near Montana; slow motion.
11_2. Moved to eastern Minnesota, with rain.

1880.

Sept. 18–21. Marked low moving from north of Montana to north of Lakes; no rain. High to southeast, and later to south and southwest.
24–27. Another low above Lakes without rain.

1881.

Sept. 8_2. In Montana.
9_3. Rain at St. Paul.
10_1. Rain, 1.31, La Crosse; 1.37, Omaha; 1.02, Dubuque.
13_2. Trough from Manitoba to Texas.
15_2. Formed or collected in a single storm in Indiana.
16_1. Western Wisconsin.
16_3. Northern Minnesota.
17_2. In Manitoba, moving a little northwest; heavy rain.
22_3. Northern Montana.
24_1. Minnesota; rain Upper Lakes; none lower.
25_3. In eastern Montana with trough south. General storm from Lakes to Texas with highs southeast and northwest.
Sept. 28_1. In Montana; moved slowly to the north of Upper Lakes.
30_2. No rain.

1882.

Sept. 10_1. Low in Montana; moving very slowly; no rain in Upper Lakes.
13_3. Low in Montana.
18_3. Reached Upper Lakes, where there was light rain.

1883.

Sept. 2_3. Low north of Montana.
3_3. Upper Lakes; no rain; moved north of Lakes with traces of rain only.
5_1. Low north of Montana.
6_2. Moved to eastern Dakota.
6_3. To southern Minnesota; rain in Upper Mississippi and Lakes.
8_1. North of Montana; very slow motion.
13_3. Trough from Manitoba to Texas; rain at St. Paul; did not develop.
14_1. North of Montana.
15_2. In northern Minnesota; light rain Upper Lakes.
17_1. North of Montana.
20_1. Trough from Minnesota to Texas; no rain.
25_1. North of Montana.
26_2. Lake Superior; no rain; high southeast.

1884.

Sept. 20_1. North of Montana.
21_2. Lake Superior; no rain.
21_3. Light rain rear of this storm.
26_2. North of Montana.
27_2. Formed trough with low in Kansas.
28_2. Merged in single low north of Lakes; rain from Lower Lakes east.

1885.

Sept. 1_2. North of Montana.
2_2. North of Lake Superior; light rain at St. Paul.
9_2. North of Idaho.
11_2. Trough from north of Montana to Colorado.
11_3. Developed in a storm in eastern Dakota; rain in Upper Mississippi.
12_1. Rain on Upper Lakes; low remained north of Dakota till 13th.
13_2. No rain; moved north of Lakes.
14_3. No rain.
19_1. In Montana.
20_2. North of Lakes; no rain.
21_2. North of Montana.
21_3. Upper Lakes; no rain.
22_3. North of Montana.
26_1. Upper Lakes; no rain.
27_2. North of Montana.
28_3. In northern Minnesota; 0.03, La Crosse.

1886.

Sept. 8_1. Low north of Montana.
9_2. In Manitoba.
9_3. Upper Lakes; rain.

1887.

Sept. 5_1. Low north of Montana (ill defined).
6_2. Over Lake Superior; light rain.
9_2. Low north of Montana.
12_3. Moved to Manitoba; rain on Upper Lakes.
25_2. Trough from Montana to Texas.
30_3. Most of rain due to Gulf cyclone.

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* Extract from Monthly Weather Review, March, 1895.

1888.

Sept. 4_2. Low in Montana; moving slowly.
7_2. In Manitoba, with rain in Upper Lakes.
11_2. North of Montana; slow motion.
15_1. Lake Superior.
15_2. Trough to Gulf which gives light rain.
25_1. North of Montana.
26_1. Lake Superior; light rain.

1889.

Sept. 2_1. North of Montana.
4_1. Trough from Minnesota to northern Texas; light scattered rain.
27_2. Disturbed region north of Montana.
29_2. Moved to Manitoba.
30_1. Sprinkle of rain southeast of low.

1890.

Sept. 1_1. Low in Nebraska.
4_1. Moved to Manitoba; light rain. No low to north of Idaho and Montana this month.

1891.

Sept. 9_1. Low in Montana.
12_1. Moved to Upper Lakes; light rain.
24_2. North of Montana; very slow.
27_2. In Dakota; sprinkle.

1892.

Sept. 8_2. Low north of Montana.
9_2. Trough from Dakota to Kansas; sprinkle.
22_2. Low north of Montana.
25_1. Moved to Upper Lakes, with light rain.

CONCLUSIONS.

The above facts lead to the following conclusions:

1. The motion of lows in the extreme northwest is very markedly affected by the position of high areas to the east and southeast. In general, this motion is remarkably slow, often requiring three, four, or more days to reach the Upper Mississippi Valley and Upper Lake region.

2. The amount of rain from well-defined lows in the extreme northwest is very small, probably not more than 5 per cent, or at most 10 per cent, of the total in the regions under consideration.

3. When this low forms a trough to the south, or when it moves first toward southeast and northeast, there is a good deal of rain usually. This motion is usually very slow.

4. It is not at all possible to forecast rain for the Upper Mississippi and Upper Lakes when a low appears in the extreme northwest. In general, if the motion is to the north of the Upper Lakes there will be no rain or only sprinkles. In some cases, with a strong north or northwest wind in the rear of a low, rain may be expected for the Upper Mississippi Valley, but this forecast must be made with great caution.

APPENDIX.

While investigating the above points it was decided to pay particular attention to the cause of abnormally dry or wet months.

The greatest dryness ensues when a well-marked high moves across the country from Dakota to Florida. A second cause of dryness is when a high area is rather permanent over any region. When a low area is followed by a high, if the after-winds are north or northwest, the tendency is toward a ragged clearing up, but if the after-wind is southwest there will be a quick clearing.

The heaviest rainfalls occur in connection with low areas coming from the Gulf and passing either directly over the region or to the south of it. The next heaviest are produced by troughs running nearly north and south and moving broadside on. In many cases heavy rains occur with a high area to the north and a disturbed region to the south but without a well-defined storm.

1877.

Dry.—Cause: 1st, highs moved from northwest to southeast; 2d, a few highs moved slowly over the Lakes and swung around to the southeast on the Atlantic coast; 3d, lows starting in the west filled up before reaching the Lakes.

1878.

Wet.—Cause: 1st, much rain came from Gulf cyclones; 2d, there seemed to be also a locus of low areas in Minnesota.

1882.

Dry.—Due to the persistency of high areas over the Lake region and just a little south.

1886.

Wet.—Due, 1st, to a tendency to a permanent low area much disturbed in the north; 2d, most rain from troughs reaching across country to Texas and Gulf; 3d, there was a permanent and well-marked high area over the south Atlantic, and this may have assisted in giving rain in connection with the northern low disturbed region.

1888.

Dry.—Due to a passage of high after high over the Lakes and to a delay or sluggishness of highs as they moved alone.

1890.

Wet.—Due, 1st, to a disturbed region over the Lakes; 2d, some troughs; 3d, marked storms passed over the Lakes; 4th, there seemed a remarkable tendency to rain from north winds blowing out of highs but without any storm conditions to south.

1891.

Dry.—It is an interesting fact that the monthly mean isobars and wind directions for 1891 are almost exactly the same as for 1878 and 1890, both of which were very wet. Cause: 1st, wide extended highs moved over the Lakes and then to the south Atlantic States. The high in this region can hardly be said to have been permanent as in the wet September of 1886, but it was rather continually added to by fresh and dry highs coming from the north, i. e., the permanency was not sufficient to cause a strong flow of rather damp air from the Ocean or Gulf northward; 2d, there was a rather persistent low in the extreme northwest, from which, however, very few disturbed areas passed out, but these drew up the dry, warm air from the south; 3d, winds were mostly south and dry from dry highs.

It is not thought that there is much that is new in what has gone before. It is rather a collection of views which have been picked up from time to time but now brought together. It is impossible to lay down any but the broadest generalizations. Each map will need a treatment by itself, especially when any one map happens to show a combination of all or nearly all the points here assembled from a study of 1,290 maps.

No. 5.—TROPICAL STORMS OF THE GULF OF MEXICO AND ATLANTIC OCEAN IN SEPTEMBER.[*]

By E. B. Garriott.

The first indications of the approach of a cyclone in the West Indies are abnormally high barometric pressure and unusually cool, clear weather. These conditions may continue several days. The nearer approach of a cyclone is indicated by slowly falling barometer and the appearance in the upper atmosphere of thin, hazy, cirrus clouds. The cirrus clouds thicken, change to cirro-stratus, and, at sunrise and sunset, present dark red and violet tints. The air becomes moist and heavy and the heat oppressive. Following these conditions the cloud bank of the cyclone appears, the barometer falls rapidly, and squalls of wind and rain occur, increasing in intensity as the storm center approaches. Before the recurve the diameter of West India cyclones is 500 to 1,000 miles and their average velocity is 15 to 18 miles per hour. After the recurve they assume larger dimensions and the velocity increases. About 80 per cent of the cyclones traced in the last fifteen years appeared during the months of August, September, and October.

It is the purpose of this paper to deal with West India cyclones that have appeared in September during the last fifteen years, and to state the conditions that have preceded their occurrence in the Gulf of Mexico and on the southern coasts of the United States. As a first step in the direction of discussing the storms of this class the tracks of September cyclones for the fifteen years, 1878 to 1892, inclusive, have been plotted [see Chart VII], and some of the more prominent features shown by the plotted tracks are given in the following table:

Table showing cyclones occurring in September from 1878 *to* 1892, *inclusive.*

Year.	Appeared.	Recurved.	Disappeared.
	° °	° °	
1878	N. 11, W. 60. East of Windward Islands......	N. 24, W. 81. Florida	South of Iceland.
1878	N. 15, W. 71. Caribbean Sea..................	N. 19, W. 73. North of Haiti.................	Northeast of Bahamas.
1878	N. 14, W. 49. East of Windward Islands......	N. 25, W. 60. West of Windward Islands.....	North Sea.
1879	N. 15, W. 68. Caribbean Sea..................	N. 23, W. 87. Gulf of Mexico	Mid ocean.
1881	N. 25, W. 70. North of Haiti..................	N. 33, W. 76. North Carolina coast...........	New England coast.
1882	N. 21, W. 72. North of Haiti..................	N. 25, W. 88. Gulf of Mexico	Near Iceland.
1883	N. 15, W. 66. Caribbean Sea..................	N. 30, W. 79. South Atlantic coast...........	South of lower lakes.
1884	N. 14, W. 77. East of Windward Islands......	N. 20, W. 58. Northeast of Windward Islands.	Northeast of Windward Islands.
1885	N. 27, W. 56. Northeast of Windward Islands.	No recurve	South of Nova Scotia.
1885	N. 24, W. 89. North of Yucatan..............	N. 25, W. 93. Gulf of Mexico	Mid ocean.
1885	N. 23, W. 97. West Gulf.......................	N. 23, W. 97. West Gulf......................	Northwest of British Isles.
1886	N. 22, W. 66. North of Puerto Rico	No recurve	West of Bermuda.
1886	N. 14, W. 62. Windward Islands	N. 22, W. 97. Gulf of Mexico	Middle Missouri Valley.
1887	N. 13, W. 57. East of Windward Islands......	No recurve	Northern Mexico.
1888	N. 20, W. 67. North of Puerto Rico...........	No recurve	Southern Mexico.
1888	N. 26, W. 80. South of Florida	N. 28, W. 83. East Gulf	Mid ocean.
1888	N. 21, W. 79. Southeast of Florida............	....	West Gulf of St. Lawrence.
1889	N. 20, W. 55. East of Windward Islands......	N. 25, W. 56. Northeast of Windward Islands.	Near Azores.
1889	N. 14, W. 56. East of Windward Islands......	No recurve	Virginia coast.
1889	N. 14, W. 69. Caribbean Sea..................	N. 25, W. 92. Central Gulf...................	East Canada.
1891	N. 24, W. 57. Northeast of Windward Islands.	N. 34, W. 64. Near Bermuda	Near Grand Banks.
1891[*]...	....	....	
1892	N. 27, W. 91. Gulf of Mexico	....	Northeast Labrador.
Mean...	N. 19, W. 69.	N. 25, W. 79.	N. 44°, W. 54°.

[*] Two storms of slight energy appeared over the central Gulf, and two storms advanced east of north from the subtropical region north of the West Indies in 1891.

The chart and table show that 22 cyclones were traced for September during the last fifteen years, an average of about 1.5 per month. This average is somewhat less than the average for August and October. Of this number 5, or about 23 per cent of the cyclones traced, recurved east of the sixty-fifth meridian, and were not felt on the coasts of the United States. A second class embraced those cyclones that recurved between the sixty-fifth and ninetieth meridians. This class may be considered as having followed a normal course, and included 45 per cent of the cyclones traced. A third class, to which 32 per cent of the cyclones belonged, comprises those cyclones that passed west of the ninetieth meridian or reached the United States coasts without a recurve.

In connection with the storms of the first class, i. e., those that recurved east of the sixty-fifth meridian, it will be observed by referring to the chart that they first appeared either east of the fiftieth meridian or north of the twentieth parallel. But two of the storms traced in that region, those of September 12–18, 1878, and September 3–11, 1884, appeared far enough south to render their advance over or near the West Indies a probability. As storms liable to influence the weather conditions of the United States coasts, these two storms only of the first class will be considered. The cyclone of September 12–18, 1878, appeared while a West India storm of great energy occupied the south Atlantic coast. From the 12th to the 15th the cyclone east of the Windward Islands moved westward. During that period the south Atlantic coast storm moved northward, and was replaced by an area of high pressure which covered the Southern States and the Gulf of Mexico. The pressure continued high over the Southern and Southeastern States from the 15th to the 18th. This area of high pressure extended eastward off the southern coast of the United States, and *apparently obstructed* the westward advance of the cyclone referred to, and *forced* a recurve to the northward. The cyclone of September 3–11, 1884, moved westward from the 3d to the 5th. During that period the

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[*] Extract from Monthly Weather Review, May, 1895.

pressure continued high and 0.10 to 0.15 inch above the normal over the southeastern districts of the United States. During the 6th the high area over the southeastern part of the United States moved eastward, and the cyclone began to recurve to the northward. During the succeeding three days the pressure continued high off the southern coasts of the United States. *In each instance the westward movement of the cyclones which recurved east of the sixty-fifth meridian was apparently prevented by anticyclonic areas which moved eastward over the southern coasts of the United States.*

The second class of storms, i. e., those that recurved between the sixty-fifth and ninetieth meridians, will be considered in connection with the distribution of atmospheric pressure. Forty-five per cent., or 10 of the 22 cyclones traced, belonged to this class. Of this number 5 appeared over the Caribbean Sea, 4 east of the Bahamas, and 1 near the southern extremity of the Florida Peninsula. A study of the charts of the last fifteen years shows that when these storms appeared over the eastern Caribbean Sea or the eastern West India Islands the pressure was above the normal over the western West Indies and the Florida Peninsula. *This high pressure does not appear to have been translated from over the American Continent, but was the result of a slow and steady increase of pressure due possibly to the overflow of air, or the upper currents, from the advancing cyclone.* When the cyclones reached the longitude of eastern Cuba the pressure began to decrease over western Cuba and the southern part of the Florida Peninsula, and, in cases where the storms recurved east of the ninetieth meridian, the pressure increased over the western part of the Gulf of Mexico and over the Southwestern States. Until the cyclones reached the American coast the attendant rain area was small. After the United States coast was reached the rain area extended rapidly, and in some instances the storm center occupied the south Atlantic coast and the rain area covered the Atlantic coast States. When storms of this class reached the longitude of western Cuba the pressure began to give way and rain began to fall over the Florida Peninsula and the eastern Gulf. Over the western Gulf the pressure continued to rise. *The recurve of these cyclones was apparently due to the obstruction offered to a westward course by anticyclonic areas which had advanced or had been drawn from the continent over the west Gulf and the Southwestern States.*

Thirty-two per cent of the cyclones traced did not recurve to the northward, and had no easterly movement. A large proportion of the cyclones of this class advanced from the eastern West Indies. Upon their arrival in about longitude W. 80°, the average longitude in which September cyclones recurve, the pressure over the west Gulf began to *decrease*, and rain set in, and the interior-eastern districts of the United States were occupied by an extensive anticyclonic area. As storms prefer to follow the path of least resistance, the centers moved toward the region of decreasing pressure and avoided the high and increasing pressure to the northward. When the pressure continued high over the eastern districts of the United States the storms were unable to recurve and were penned in over Mexico or the Southwestern States. In such cases the cyclones usually developed great violence before dissipating. Similarly cyclones of this class that advanced northwestward toward the middle or south Atlantic coasts of the United States were apparently prevented from recurving by high pressure over the ocean to northward and northeastward. Description of storms of this class will be found in the MONTHLY WEATHER REVIEW for September, 1888, and September, 1889. The storm of September, 1888, raged with fearful violence over Cuba and passed thence to southern Mexico. The storm of September, 1889, was exceptionally severe, and dissipated off the middle Atlantic coast.

It may be assumed that with a nearly normal distribution and movement of atmospheric pressure September cyclones will recurve near longitude W. 80° and between latitudes N. 25° and 28°. When a cyclone is central east of Cuba and an area of high pressure is advancing eastward over the Gulf and south Atlantic States, the cyclone will probably recurve east of the Bahamas. When the cyclone reaches central Cuba or longitude W. 80°, and an area of high pressure is advancing over the west Gulf and Southwestern States, the cyclone will probably recurve over Florida or the east Gulf. When the cyclone reaches the seventy-fifth meridian and an area of high pressure is overspreading the interior and eastern districts of the United States, with stationary or falling barometer over the west Gulf and the Southwestern States, the cyclone will probably advance westward over the Gulf of Mexico. When cyclones are moving northwestward toward the south or middle Atlantic coasts of the United States, and the pressure is abnormally high over the Northeastern States and the Canadian Maritime Provinces, the chances are that the storm will not recurve but will be crowded in upon the coast and develop destructive energy.

No. 6.—THE BAROMETRIC TROUGHS OF THE PLATEAU REGION.*

By Prof. H. A. HAZEN.

A study of the barometric troughs covering the plateau region from the Colorado Valley northward to the British Possessions, to determine what influence such pressure conditions have in connection with the Mississippi Valley thirty-six hours after a well developed trough is observed. Also, to ascertain in what portion of the trough the depressions which move eastward are likely to form, and to determine the probability of the formation of low centers in the extreme southern portion of the trough, and the chance of such disturbances crossing eastward over low latitudes and affecting the weather in the Mississippi Valley.

In order to fully comprehend the general discussion to follow it is necessary to examine briefly the broader features of pressure distribution in the portion of country west of the Rocky Mountains during the autumn months. As is well known, in summer there is a rather permanent area of low pressure covering this whole region, from which there is almost no precipitation. During this same period there is an area of high pressure over the Pacific Ocean. The winds are mostly westerly and blowing toward the land. Even though they may be saturated, the relative humidity is quickly and greatly diminished by the high land temperature, and the possibility of precipitation is almost nothing.

On the other hand, in winter these conditions are exactly reversed. Now, the permanent high area is situated in the plateau region, and a permanent low pressure exists over the Pacific. It is easy to see that the autumn, being the time of transition from one state or condition to the other, would partake of both, and this commingling at first sight seems quite complex.

More particularly I find in each month the following facts:

SEPTEMBER.

On the whole a dry month in the region under discussion. Troughs in the plateau region advance rather slowly toward the Mississippi Valley. The indications are that summer influences are still potent during the month, and for this reason there is little rain either in the plateau region or to the eastward; that is, the depressed region travels eastward in a rather dry state, and I do not find that the air becomes much damper in the Mississippi Valley. I am also inclined to the opinion that the month is rather dry in the Mississippi Valley. Sometimes there is a slight concentration of energy or an increased barometric gradient around an oval area both in the extreme north at Dakota and in the south at Texas, after this trough has moved eastward; in these cases there is a tendency to a slightly increased rainfall in the upper Mississippi and in the west Gulf. This is the exception, however, and it is impossible to tell under what conditions this concentration takes place.

On the whole I would say that it is best not to place much dependence upon such a trough in the month of September, except that one may be reasonably certain that no trouble in the line of rain will come from it. As it moves eastward care should be taken to watch for a possible concentration in the extreme north or south, almost never in the center.

OCTOBER.

In this month there is a great deal more rain in this region under discussion and troughs increase in number and definiteness. The increase of rain in Arizona and New Mexico is especially noteworthy. These troughs have rather a peculiar tendency of moving on Arizona as a pivot, that is, the upper end moves to Manitoba and the trough extends across from Arizona to Manitoba. Under these conditions rain often occurs in Arizona, and generally in the rear of the trough in the extreme north. A little later the south end swings to Texas and then rain falls in the west Gulf. Generally the rain is confined to the north and south, but sometimes it extends over the whole Mississippi Valley. The motion is rather slow, seldom less than forty-eight hours to the west Gulf. As to forecasting I would say, such a trough is much more threatening than in September. However, care must be exercised, as in some Octobers the conditions are the same as in September, and I am inclined to think that this can be usually told by watching the maps. That is, there is a sort of persistency in these conditions and if the troughs begin the month with little rain they are likely to continue so. It is very difficult to determine beforehand under what conditions rain will form in these troughs as they move eastward, and one must watch as in September, forecasting very little rain until it begins to show itself. Rain is certainly the exception in these troughs.

NOVEMBER.

This month begins to show winter conditions, and is the easiest of the three to handle with respect to these troughs. Even if a trough forms in this region it will be found that generally it will be broken in two by the development of a high area in its center, or by a high extending out to southwest from the north. Rain from such troughs is very rarely experienced in the Mississippi Valley, and in fact the trough rarely moves to the Mississippi. It may be said that the trough in November is usually due to the permanent low area of the Pacific moving upon the land, and its life is almost wholly dependent upon this low area. Rains are quite frequent on the Pacific slope, but they seldom extend inland. The beginning of the permanent high area just west of the Rocky Mountains is well shown in this month. Sometimes there are concentrated lows which cross the central plateau region and give rain after reaching the middle Mississippi Valley. These lows have to be considered by themselves and are hardly a part of this trough phenomenon.

To review the whole, I would say, troughs as far west as the Colorado Valley and northward are dry and seldom increase in moisture. They move rather slowly; in October the north end moving faster than the south. Sometimes there is a concentration which will give rain in twenty-four hours. No safe forecast of rain can be made in any case till rain has begun, and even then west of the Mississippi it will be light. In a few cases there is a peculiar tendency to a fall of rain in the rear of the trough, and this takes place most frequently in the concentrated lows at the north. No rule can be laid down regarding this rain in the rear. The following lists comprise the troughs taken from the maps. In October and November, maps from 1877 to 1882, were not used, as the curves for this region were not drawn, and it was thought that enough cases could be obtained from the other years.

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* Extract from Monthly Weather Review, June, 1895.

Troughs from Colorado Valley to the British Possessions and their movement (rainfall is given in inches). When the location of the trough is not specified, it is understood to be over the plateau region.

1877.

Sept. 3_1. Pressure 29.43 at Boise City.

6_2. 29.50 at Bismarck, no rain.

7_2. Rain at St. Vincent and Moorhead.

11_3. 29.56 at Salt Lake City.

13_1. Bismarck, 29.34; rain, 0.01.

14_1. Moorhead, rain.

18_2. Boise City, 29.60.

19_2. St. Paul, no rain anywhere.

20_2. No rain, Mississippi Valley.

23_1. Rain at Marquette.

25_3. Boise City, pressure 29.43.

26_1. Rain at St. Paul far in front of trough.

1879.

Sept. 6_1. Sort of trough, but did not move east of Rockies.

8_3. Concentrated at Omaha.

10_1. No rain.

11_1. Light rain at La Crosse.

1882.

Sept. 15_1. 29.67, Winnemucca; 0.06 rain at Prescott only.

16_2. 29.56, Pioche.

17_3. Concentrated in North Dakota; no rain to speak of.

24_3. Rain at north end of trough.

26_1. Secondary formed at Deadwood with rain in its rear.

27_2. Trough from Texas to Dakota.

27_3. Rain in northern Texas, Yankton, Bismarck, and Fort Buford.

29_1. Disturbed region extends over whole country west of Mississippi, with very light rain.

1886.

Sept. 1_1. Salt Lake City, rain, 0.19.

2_2. From Texas to Dakota, little scattered rain.

13_3. Slight trough, no rain.

15_1. Trough moved and stretches from Texas to Manitoba, almost split in two; rain in lower Mississippi Valley and Minnesota.

1887.

Sept. 2_3. Disturbed region in plattau; rain north Pacific coast and North Dakota.

5_2. Disturbed region west of Mississippi; rain Minnesota and Wisconsin, none south.

6_3. Trough; rain at Boise City, 0.04, and in rear of trough on middle Pacific coast. This moved.

8_3. Trough from Arizona to Manitoba; rain, 0.06 at Cheyenne, and 0.70 at Deadwood.

9_2. Trough, but without motion at first; moved.

11_3. Stretches from Arizona to Manitoba; rain, 0.20 at Montrose, and 0.02 at Denver.

12_3. Stretches from western Texas to Manitoba; rain in Iowa, Minnesota, and North Dakota.

15_2. Trough; no rain.

16_3. Stretches from Arizona to Manitoba, with 0.04 rain at Fort Stanton.

17_1. Texas to Lake Superior; rain in middle and east Gulf only.

17_2. Trough; no rain.

19_2. Stretches from Texas to Manitoba; rain, at Concho 0.04, and trace at Minnedosa.

1888.

Sept. 2_2. Trough; rain, 0.02 at Montrose, and 0.08 at Fort Benton.

Sept. 5_1. Stretches from Arizona to Manitoba; no rain.

8_2. Trough; no rain.

9_2. From New Mexico to Swift Current.

11_2. Trough, and rain, 0.02 at Santa Fe.

13_2. Stretches from Arizona to Manitoba; rain, 0.01 at Buford.

17_1. Trough, with 0.02 rain at Winnemucca and on Pacific.

19_1. Stretches from west Texas to Manitoba; no rain.

1883.

Oct. 5_3. Low pressure in Arizona and slight north of Montana; no trough.

7_1. Marked trough, Arizona to Manitoba; no rain.

8_1. Concentrated in Manitoba with rain in Wisconsin, Upper Michigan, and Manitoba.

16_2. Trough from Arizona to North Dakota; light rain at Santa Fe, Dodge City, and North Platte.

17_2. Slight changes, with rain in Missouri and upper Mississippi valleys.

25_2. Marked low, north Pacific coast; rain on Pacific coast only.

26_2. Concentrated in Colorado; rain on west Gulf and lower Mississippi.

27_1. Trough from New Mexico to north of Montana, not definite; rain in Missouri and Mississippi valleys.

28_1. Trough stationary, with rain in Ohio, Missouri, middle and upper Mississippi.

1884.

Oct. 1_1. Broad trough; rain in Texas and upper Mississippi only.

2_1. Trough stretches from Arizona to Manitoba; rain in west Gulf, Minnesota, and upper Lakes, none in central Mississippi Valley.

2_2. Concentrated in Minnesota; rain in west Gulf, Lake Superior, Manitoba, and North Dakota.

4_1. Trough, but pressure rather high in center; rain, at El Paso and Elliott.

5_1. Concentrated in Minnesota; rain there and North Dakota, none in the Gulf.

9_2. Trough; rain at Prescott only; pressure, 29.08 at Calgary.

10_2. Stretches from Arizona to Manitoba; rain at Grant only.

11_1. Concentrated over Lake Superior; no rain; a little in rear (next map).

18_3. Trough stretches Arizona to Manitoba; rain at Grant and Prescott.

19_2. Concentrated over Lake Superior; no rain.

24_2. Trough; rain in Texas.

25_2. Stretches from New Mexico to north of Montana; rain in Texas, none north.

26_1. Stretches from Texas to Manitoba, rain in Mississippi Valley and Gulf.

28_3. Trough from Arizona to Manitoba; rain in upper Mississippi.

29_2. Texas to Lake Superior; rain in Ohio Valley, not steady.

30_3. Trough, but no rain.

31_3. Stretches from New Mexico to North Dakota; light rain in North Dakota only.

1885.

Oct. 8_1. Trough; no rain.

10_1. Stretches from Arizona to Manitoba; no rain.

11_1. Texas to Manitoba; light rain in Missouri Valley rear, none in south.

1886.

Oct. 1_1. Trough; no rain.

Oct. 2_2. Stretches from Arizona to Manitoba; no rain.

3_2. Arizona to Lake Superior; no rain.

3_3. Trough; light rain in New Mexico and east Arizona.

4_3. Stretches from Arizona to north Montana; rain in New Mexico and extreme west Texas only.

6_2. Stretches from west Texas to Manitoba; rain stopped.

7_2. Stationary; no rain anywhere.

7_3. Concentrated, north Texas; light rain there.

9_2. Still nearly stationary; no rain.

16_2. Trough, with rain north Pacific only.

16_3. Light rain at Montrose and West Las Animas.

18_3. Moved to New Mexico and Manitoba; light rain in North Dakota.

19_2. Stretches from New Mexico to Minnesota; light rain in rear extreme north.

27_3. Trough; no rain.

30_1. Nearly stationary; no rain; great high in middle Minnesota.

1887.

Oct. 3_3. Trough; no rain.

4_3. Stretches from New Mexico to North Dakota; rain in North Dakota only.

5_2. New Mexico to Minnesota; no rain.

5_3. Trough; no rain.

7_1. Stretches from New Mexico to Manitoba; light rain in North Dakota only.

7_3. Stretches from New Mexico to Lake Superior; light rain in Minnesota and Dakota.

8_1. Northern Texas to Lake Superior; rain in Texas and middle and upper Mississippi valleys.

14_1. Trough, no rain.

15_2. West Texas to Manitoba; light rain in Dakota only.

16_2. Texas to Lake Superior; light rain in middle Gulf and upper lakes.

1888.

Oct. 2_1. Trough.

3_1. Stretches from New Mexico to Minnesota; light rain in Colorado.

17_1. Trough; rain in north Pacific.

17_2. Arizona to Montana; light rain in Montana.

18_1. Concentrated in Iowa; light rain in Missouri, middle and upper Mississippi valleys.

Oct. 30_2. Trough.

31_2. Light rain in Montana only; trough not well formed.

1884.

Nov. 21_1. Trough.

21_2. Rain at Calgary and in Arizona, broken up by high to the north of Montana.

1885.

Nov. 4_2. Marked low, north Pacific, with rain there.

4_3. About stationary; rain in Utah, Wyoming, and western Colorado.

5_3. Stationary; rain, 0.42 at Salt Lake City; trough gradually filling up.

20_1. Trough, with rain in Arizona.

20_3. Filling up; rain at Salt Lake City, 0.12.

21_1. Concentrated, Colorado; no rain.

22_1. In middle Mississippi Valley; rain in rear.

24_3. Disturbed region, with rain on Pacific coast.

25_3. Not well defined; rain, 0.48 at Salt Lake City, and 0.19 at Prescott.

26_3. Stretches from Texas to Manitoba; rain in Texas, Colorado, and Nebraska.

27_1. Concentrated in Texas, with rain there and in lower Mississippi Valley.

1886.

Nov. 7_1. Trough.

7_2. Rain at Santa Fe and Elliott.

9_1. Concentrated in Minnesota; rain in Mississippi Valley.

20_2. Mostly in Idaho, with rain in rear.

21_2. Concentrated at Salt Lake City, with rain in Utah.

22_2. Concentrated in South Dakota; rain in Missouri, Ohio, middle and upper Mississippi valleys.

1888.

Nov. 17_1. Disturbance on Pacific coast, with rain there.

19_2. Still stationary on Pacific coast, with rain north; no motion east.

22_2. Disturbance on Pacific; rain on middle and north Pacific.

25_2. Still stationary, Pacific, with rain in Arizona and north Pacific.

26_2. Stretches from Arizona to Manitoba; rain in Texas; none north; disturbance disappearing.

No. 7.—HIGH AREAS OF THE NORTH PACIFIC COAST IN SEPTEMBER, OCTOBER, AND NOVEMBER.*

By E. B. Garriott.

The high areas of the North Pacific Coast in September, October, and November are associated with low areas which occupy the north-central districts of the United States. Low areas of this type usually move eastward over, or north of the Great Lakes, and are seldom attended by precipitation south of the Ohio River and the more northern of the Middle Atlantic States (see Charts VI, VII, and VIII). With the eastward movement of a low area from the north-central districts the high area on the North Pacific Coast moves east-southeastward attended by marked changes in temperature from the middle-eastern and northeastern slopes of the Rocky Mountains over the Missouri and upper Mississippi valleys and Lake Region. When a high area appears on the North Pacific Coast, and the low area is located over or east of the Great Lakes, a secondary disturbance generally develops over the central valleys. If a high area appears on the North Pacific Coast and a low area is not shown in the Northwest, one will probably develop within twelve hours.

The Pacific Coast high areas of September advance to the upper Mississippi Valley in about seventy-two hours at an average velocity of about 21 statute miles per hour. During that period the low areas which appear in the Northwest pass eastward over the northern Lakes and reach Newfoundland traveling at an average velocity of 28 miles per hour. In September, when the pressure rises above 30.20 on the North Pacific Coast and falls below 29.80 between Lake Superior and the upper Missouri Valley, rain may be expected within an area extended from the western Lakes over the extreme upper Mississippi Valley in twenty-four hours; over the middle, southern, and eastern Lake Region in thirty-six hours; and over New York, northeastern Pennsylvania, northern New Jersey, and New England in forty-eight hours. A temperature fall of 10° or more will probably be experienced on the northeast slope of the Rocky Mountains and over the western half of the Dakotas in twenty-four hours; from the eastern half of the Dakotas over the extreme upper Mississippi Valley and western Lake Superior in thirty-six hours; and over the Lake Region in forty-eight hours. Occasionally a September high area will appear on the North Pacific Coast showing pressure above 30.20, with a rather weak low area over or north of the upper Missouri Valley. The high area will remain nearly stationary for a period of one, two, or three days, with increasing pressure, and the low area will gradually deepen. When the low has gathered sufficient strength to overcome the obstruction (generally a high area to the eastward) which has prevented its eastward advance the eastward movements of the high and low areas begin. In such cases the low area generally increases in intensity as it passes over the Great Lakes. Again, a deep low area will appear in the Northwest and remain nearly stationary for several days, while the pressure gradually increases over the North Pacific Coast Region. When the pressure on the North Pacific Coast reaches 30.20 an eastward movement of the high and low areas may be expected. In cases where the pressure does not rise to 30.20 on the North Pacific Coast the low area in the Northwest will dissipate.

In October the movements of the high and low areas are somewhat more rapid than for the preceding month. The high areas from the North Pacific Coast advance to the middle Ohio Valley in seventy-two hours and the low areas traverse a path extending from the one hundredth meridian to a point southeast of Newfoundland in the same period of time. In October, when the pressure rises to 30.20 or above on the North Pacific Coast and falls to or below 28.80 in the Northwest, rain or snow may be expected over the Red River of the North Valley, over the extreme upper Mississippi Valley, and the northwestern Lake Region in twenty-four hours; in the Lake Region and upper Mississippi and northern Ohio valleys in thirty-six hours, and in the Middle Atlantic and New England States in forty-eight hours. The temperature will probably fall 10° or more in the middle and upper Missouri valleys in twenty-four hours; over the Red River of the North Valley, over the extreme upper Mississippi Valley and the western Lake Region in thirty-six hours, and over the central and eastern Lake Region and the interior of Pennsylvania, New York, and New England in forty-eight hours.

In November there is a marked change in the character of the high areas that appear over the northwestern part of the United States. In that month a majority of the high areas advance from the British Northwest Territory and enter the region of observation on the northeast slope of the Rocky Mountains. The high areas that advance from the North Pacific Coast often settle southeastward and become a part of the permanent high that commences to build up over the middle plateau region with the advent of the colder months. Many of the high areas that appear over the British Northwest Territory show pressure above 30.50 and sometimes 30.70 and 30.80. High areas of this class often extend westward over the North Pacific Coast. This class of high areas is not considered in the present paper.

In November, when a high area appears on the North Pacific Coast with a low area east of the ninetieth meridian, rain or snow will probably fall in New England within twenty-four hours. When high areas advance from the British Northwest Territory the preceding low areas are seldom attended by precipitation west of the Great Lakes. When the pressure on the North Pacific Coast rises to or above 30.30 and falls to or below 29.80 in the Northwest, precipitation may be expected in the middle and upper Missouri and extreme upper Mississippi valleys and the upper Lake Region in twenty-four hours; in the lower Lake Region, New York, and northern Pennsylvania in thirty-six hours, and from the eastern Lakes over the Middle Atlantic and New England States in forty-eight hours. The temperature will probably fall 10° or more over the Missouri Valley, and the extreme upper Mississippi Valley, in twenty-four hours; in the upper Lake Region and the upper Mississippi and lower Ohio valleys in thirty-six hours, and from the lower Lake Region over the interior of the Middle Atlantic and New England States in forty-eight hours.

[Note.—Three charts, Nos. VI, VII, and VIII, accompanied the preceding article and are reproduced herewith.]

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* Extract from Monthly Weather Review, July, 1895.

No. 8.—HEAVY SNOWFALLS IN THE UNITED STATES.

By Prof. E. B. GARRIOTT.

In order to determine the types of storms that occasion heavy snow in various parts of the United States, charts have been prepared, which show for a period of ten years the paths of areas of low barometric pressure that have been attended by snowstorms of unusual severity; and additional charts have been prepared which show the barometric conditions that prevailed twenty-four hours before the beginning of heavy snow in the several sections considered. As the course and character of storms change as the winter advances, the tracks of low areas that have been attended by exceptionally heavy snow have been plotted by months.

The paths of January low areas that have been attended by heavy snow appear on Chart 1. As these low areas belong to unusually well-marked types, their general character from the time of their first appearance to their arrival off the Atlantic coast is shown by additional charts. These charts exhibit the distribution of pressure and temperature over the United States, and the shaded areas show the regions in which rain or snow have fallen since the last observation. An examination of the tracks presented on Chart I shows that in the middle Atlantic and New England States the heavy snowstorms of January are usually produced by twin storms; that is, by storms that advance from the southwest and from the west or northwest in paths that converge and unite near the middle Atlantic or south New England coasts. In two instances only, in the last ten years, have single January southwest storms been attended by heavy snow in the Northeastern States, and in no instance during that period has a heavy January snowstorm been noted in those districts, in connection with a storm from the west or northwest, which was unattended by a low area from the southwest, or by a secondary development near the middle Atlantic coast.

Chart 2 shows the first appearance of a storm that swept the Southern and Atlantic coast States in January, 1886, attended by heavy snow in the central valleys, and thence to the Atlantic coast, and by one of the severest cold waves on record in the Southern States. When this storm first appeared, the morning of the 6th, the principal center of disturbance occupied the Rio Grande Valley, and the barometer was low over Colorado.

With much higher pressure and decidedly lower temperature over the northwest districts, a southward movement of the Colorado low area could be expected, and the report of the following morning, Chart 3, shows the united storms central and gathering strength over southern Texas. Attending the southward movement of the Colorado low area during the 6th, a severe "norther" set in over Nebraska and extended as far south as northern Texas during the 7th. The eastward movement of the storm center began the morning of the 7th. The conditions at that time, as exhibited by Chart 3, indicate a prompt and normal northeast advance of the storm. The high area in the northwest had shifted position to the westward, and the pressure was increasing rapidly, with a marked fall in temperature and high winds northwest of the center of disturbance. During the 7th and 8th the center traversed the east Gulf and the interior of the south Atlantic States; heavy snow fell in the upper Mississippi and Ohio valleys during the day, in the east Gulf States in the evening, and in the Atlantic coast States the night of the 8th, and an intense cold wave covered Texas, carrying the line of zero temperature to the central portion of that State and the line of 10° over the west part of the Gulf of Mexico. During the 9th the storm raged with great violence on the middle Atlantic and New England coasts, with heavy snow in those districts, and a severe cold wave covered the Southern States. During the next two days the cold continued intense over the Southern States, with temperature below 20° over the northern part of the Florida Peninsula, and the loss to fruit, fish, and oyster interests in that State was estimated at $2,000,000.

Another storm of this general type, which caused heavy snow over the Northeastern States, appeared over the upper Rio Grande Valley the morning of January 19, 1889, and the general conditions that obtained at that time are shown by Chart 7. This storm divided the morning of the 19th, one part passing to Illinois and the other over the Gulf of Mexico by the morning of the 20th, and snow set in on that date over the middle Atlantic and New England States. Chart 8 presents the conditions at that time, and shows the twin storms or the elongated north and south low area with two cyclonic centers before referred to. By the morning of the 21st the storm centers had united on the south New England coast, and during that day heavy snow was followed by clearing weather in New England.

A storm of the purely southwest type appeared near the mouth of the Rio Grande River the morning of January 1, 1891, as shown on Chart 10. On that date rain set in over the Gulf States and, as usual in the case of these storms, the area of precipitation extended rapidly and reached the middle Atlantic States by night, and changed to snow in that district the night of the 24th, attending the passage of the center of disturbance northeastward off the middle Atlantic coast. During the 25th the storm center passed rapidly over Nova Scotia, heavy snow fell in New England, and heavy snow was followed by clearing weather in the middle Atlantic States.

The heavy snow in the middle Atlantic and New England States of January 6, 1892, followed and attended the conditions shown on Charts 13 and 14, respectively. The chart of the morning of January 5 presents a trough of low pressure extending from Lake Superior to the west part of the Gulf of Mexico, with two low areas or twin storms, one central over Lake Superior and the other over Arkansas and Louisiana. Storms of this formation may be expected to cause heavy rain or snow in the districts to the eastward. By the morning of the 6th the storm centers had united off the middle Atlantic coast, as shown on Chart 14, and heavy snow continued during that date over the middle Atlantic and New England States, attending the northward movement of the center of disturbance.

The heavy snowstorm of January 4–5, 1893, in the middle Atlantic and New England States attended conditions shown on Charts 15 and 16. When the main center of this storm occupied the middle Mississippi Valley a secondary or additional storm development appeared off the south Atlantic coast, and the morning of the 5th, Chart 16, a trough of low pressure extended from the upper Lake region to and off the the middle Atlantic coast. Although this storm differed in general character from those previously referred to, it presented the twin low-area feature which commonly attends the more severe snowstorms of the Northeastern States in January.

Charts 17, 18, and 19 present an excellent specimen of a double or twin storm which traversed the eastern portion of the United States, January 28–30, 1894, one of the centers advancing from the west and the other from the southwest in paths which converged and united on the middle Atlantic coast. This storm caused heavy snow in the middle Atlantic and New England States on the 30th.

HEAVY SNOW IN THE SOUTHEASTERN STATES.

The infrequency of heavy snow in the Southeastern States adds to the importance of forecasting its occurrence. Perhaps the heaviest snowstorm in that district in January in the last ten years commenced the night of January 17, 1893, and continued the 18th and 19th. This storm attended twin low areas which advanced eastward in parallel paths, one over the extreme northern and the other over the extreme southern districts of the country. The conditions which prevailed the day before snow began in the Southeastern States and the conditions which obtained during the prevalence of the storm are shown by Charts 21 to 23. In this case, the northern low area was not, apparently, an active agent in producing the snowfall in the Southern States. The southern low area furnished the conditions which caused the precipitation, and, in this case, the precipitation, which is always abundant during the passage of Gulf or southern low areas, assumed the form of snow in the presence of unusually low temperature over the Gulf and south Atlantic States. It may be assumed that any well-marked low area which moves eastward over the Gulf of Mexico or near the Gulf coast, attended by temperature below freezing, will cause snow in the districts which lie to the northward of its track.

HEAVY SNOW IN THE LOWER LAKE REGION AND OHIO VALLEY.

As the occurrence of unusually heavy snow in an interior districts can not, as a rule, be foreseen for a period greater than twenty-four hours, charts illustrative of the low areas which caused the heavy snow will show in each instance the conditions which attended the first appearance of the center of disturbance and its subsequent track.

Chart 24 shows the track of three low areas which were attended by heavy snow in the upper Mississippi valley, and thence over the Ohio valley and lower lakes in January. The conditions which attended the first appearance of one of these low areas is shown by Chart 25. The morning of January 15, 1885, this low area was central over Louisiana, and the bend of the isobars and isotherms clearly indicated a normal northeast path over the upper Ohio Valley. As snow set in over the regions above referred to the night of the 15th and continued during the greater part of the following day, it will be observed that, like the low areas that produce snow in the Eastern States, this storm was attended by heavy snow in its west and northwest quadrants. Chart 26 shows the path of a storm which developed over the Western States, January 26, 1885, and moved thence eastward, attended by heavy snow in the districts above named. The morning of the day the snow began the storm center occupied southern Missouri, and its subsequent eastward movement carried it somewhat south of the Ohio River, and heavy snow fell in its northern quadrants. The Gulf storm traced on Chart 27 moved northeastward parallel with and slightly to the westward of the Appalachian Range, attended the night of the 13th and during the following day by heavy snow in the west quadrants.

UPPER MISSISSIPPI VALLEY SNOWSTORMS.

Chart 28 shows the tracks of January low areas that have been attended by exceptionally heavy snow in the extreme upper Mississippi Valley. The path of the first of these storms and the conditions which attended it before the beginning of heavy snow are shown on Chart 29. Closely following this low area a second storm passed over the upper lakes. The first low area was, however, the snow-producing storm, and its path ran south of the region of heavy snowfall.

Chart 30 exhibits the path of a January low area which was attended by heavy snow, from the extreme upper Mississippi Valley over the upper Lake region, and Chart 31 shows the general character of the storm the morning the snow began. This storm also passed south of the region of heavy snowfall.

HEAVY SNOW IN THE NORTHWESTERN STATES.

The paths of storms that have been attended by unusually heavy snow in the Northwestern States in January appear on Chart 32. Chart 33 shows the conditions which prevailed before the beginning of the heavy snow in the northwest of January 11 and 12, 1890. In this instance the low area which advanced from the southwest the day after the passage of the northwest depression merely supplemented the disturbed conditions which existed to the westward of the latter-named low area and caused a continuation of heavy snow in the lower Missouri Valley, Iowa, Minnesota, and Wisconsin.

SUMMARY OF CONDITIONS ATTENDING JANUARY SNOWSTORMS.

From the foregoing remarks and charts it will be observed that snowstorms of exceptional severity generally occur in the west and northwest quadrants of low areas and seldom or never to the southward of the storm track. The heavy snowstorms of the Atlantic and Gulf States attend energetic low areas which pass *south* of the districts in which the snow occurs, and the chances of heavy snow in those districts are furthered when two low areas approach, one from the southwest and the other from the west. In all cases the southern low area seems necessary, and when low areas of this class are confined to the coast districts by high pressure over the ocean to the eastward heavy snow will occur without the aid of the northern low area, when the temperature is below the freezing point. In nearly all of the instances considered, save in the case of some of the northwest snowstorms, the low areas advanced from the southwest and were followed by much lower temperature. The heavy snowstorms of the Northwestern States usually occur in the form of "blizzards." They follow the passage of warm, moist low areas which move south of east over and from that region.

HEAVY SNOW IN FEBRUARY.

The paths of areas of low pressure that have been attended by heavy snow in February during the last ten years are plotted on charts herewith, and the distribution of pressure at the time of the first appearance of the low areas is shown on additional charts.

HEAVY FEBRUARY SNOWSTORMS IN THE MIDDLE ATLANTIC AND NEW ENGLAND STATES.

The tracks of low areas that have been attended by exceptionally heavy snow in the middle Atlantic and New England States in February are traced on Chart 34. The distribution of pressure at the time of the appearance of the first of these low areas is shown by Chart 35. This storm moved eastward over the Gulf and south Atlantic States, February 2 and 3, 1886, with heavy snow on those dates in Arkansas, Tennessee, and northern Mississippi, and passed northeastward off the middle Atlantic and New England coasts during the 4th, attended by exceptionally heavy snow in the middle Atlantic States on the 3d and 4th, and in New England from the 3d to 5th. This was a storm of the southwest type and carried heavy snow in its north and west quadrants in a belt extending from Arkansas over the Canadian Maritime Provinces.

On the 26th and 27th of the same month, February, 1886, unusually heavy snow fell in Maine, attending the passage of a storm which advanced from Manitoba and passed off the New England coast south of Maine during the 26th, as shown on Chart 36. It will be observed that the storm center passed south of the region of heavy snowfall.

Chart 37 shows the track of a storm from the northwest, which caused heavy snow over northern New England and northern New York, February 11 and 12, 1892.

On February 17 and 18, 1893, heavy snow fell in eastern Pennsylvania, eastern New York, and New England, attending the advance and development of low areas, whose paths appear on Chart 38. The snowfall in this case was doubtless due to the development of a secondary disturbance off the Virginia coast on the 17th, which moved thence northeastward to Nova Scotia the night of the 17th and during the 18th.

Heavy snow fell in New England, February 12–13, 1894, attending the advance from the southwest, during the 11th and 12th, and the passage south of that region on the 13th, of a storm of the regular southwest type, whose track is given on Chart 39.

The morning of February 25, 1894, Chart 40, a storm appeared over northern Florida and moved thence northeastward along the immediate coast line, attended by heavy snow in the middle Atlantic States on the 25th, and over southern New England during the 26th.

HEAVY SNOW IN THE SOUTHEASTERN STATES IN FEBRUARY.

The track of the last-mentioned storm is also traced on Chart 41, as indicating the class of storms which cause the very infrequent heavy snowstorms noted in the Southeastern States. In this instance heavy snow fell in the south Atlantic States, while the storm center was moving northeastward along the coast line of that district.

HEAVY SNOW IN THE UPPER LAKE REGION AND EXTREME UPPER MISSISSIPPI VALLEY.

Chart 42 shows the paths of low areas that have been attended by heavy snow in the upper Lake region and extreme upper Mississippi Valley in February. The first of these storms was of the southwest type and appeared over Texas the morning of February 8, 1885, from which region it moved northeast, attended by heavy snow in the districts named on the 9th and during the early morning of the 10th.

Heavy snow fell in Iowa and the extreme upper Lake region February 5 and 6, 1893, attending and following the passage of a low area which appeared over Colorado the morning of February 5, Chart 44, and passed thence over the upper lakes by the morning of the 6th.

Chart 45 shows the character and course of a storm which advanced from Kansas to Lake Superior, February 27–28, 1893, attended by heavy snow during the latter-named date in Wisconsin and Upper Michigan.

HEAVY SNOW IN THE MIDDLE ROCKY MOUNTAIN DISTRICTS.

The heavy snowstorms of February in the middle Rocky Mountain districts usually follow the passage southeastward over that region of well-marked low areas from the northwest. Chart 46 shows the path of a storm of this type, which was attended by heavy snow, on the middle-eastern slope of the Rocky Mountains, February 7–8, 1891, and Chart 47 exhibits the distribution of pressure and the location of the storm-center the morning of the 6th, fully twenty-four hours before the beginning of the heavy snow. This distribution of pressure shows a second low area over the southern Rocky Mountain districts, which moved southeastward over Texas, and recurved thence northeastward over the Ohio Valley and the Great Lakes, and finally united with the northwest low area north of the lower lakes. The presence and influence of the Texas low doubtless contributed to the abnormal southerly movement of the northwest low area.

HEAVY SNOW IN THE SOUTHERN ROCKY MOUNTAIN DISTRICTS.

The heavy snowstorms of the southern Rocky Mountain districts attend the passage eastward of warm, moist low areas from the upper Rio Grand Valley, which draw over that region air whose temperature is below the freezing point; when the temperature is above the freezing point heavy rain attends this class of storms. Chart 48 shows the track of a low area of this type, which was attended by exceptionally heavy snow in the southern Rocky Mountain districts, and Chart 49 shows the distribution of pressure the morning of the day the heavy snow began and the subsequent course of the storm.

GENERAL REMARKS CONCERNING FEBRUARY SNOWSTORMS.

The tracks of February storms, given on the charts, show that in all districts the heavy snowfalls of that month, like those of January, occur to the north and west of the centers of general storms or areas of low barometric pressure. In the more southern districts the storms that cross or skirt the Gulf of Mexico moving in an easterly direction are invariably attended by abundant precipitation; when the temperature is above freezing the precipitation falls in the form of rain, and when at intervals, which commonly embrace years, temperature below freezing is noted in that district in connection with the passage of a southern low area heavy snow falls.

HEAVY SNOW IN MARCH.

Although heavy falls of snow in March have not been reported in the Southern States and are of infrequent occurrence in the northern districts, some very remarkable and memorable snowstorms have visited the northern districts in that month, during the last ten years, principal among which may be classed the "blizzard" of March, 1888, which proved so destructive to life and property in the Northeastern States.

The tracks of March low areas that have been attended by very heavy snow in the middle Atlantic and New England States during the last ten years have been plotted on Chart 50. These storms are seven in number, and this number represents an average of less than one snowstorm per year in March in the northeastern districts. Three of these disturbances were typical southwest low areas; one, the severe storm of March, 1888, developed as a secondary over the Southeastern States, two first appeared off the south Atlantic coast, one developed off the Carolina coast as a secondary to one of the Southwest storms, and one moved eastward from the middle Mississippi Valley over the Ohio Valley, and passing off the middle Atlantic coast moved thence to Nova Scotia.

Chart 51 shows the first appearance of a storm in the Southwest which caused heavy snow in Virginia, March 22, 1885.

Chart 52 shows the distribution of pressure March 10, 1888, the day before the beginning of the severe "blizzard" in the Northeastern States. The peculiar distribution of pressure shown by this chart can be depended upon to produce heavy precipitation from the central valleys to the Atlantic coast. The trough of low pressure extending from the Gulf of Mexico to the Great Lakes is bounded by well-marked areas of high pressure, one in its front and the other in its rear, whose wind circulation causes strong opposing currents of warm, moist air from the Gulf and cold air from the northwest to produce abundant precipitation, and the great length of the trough favors the development or breaking off of a secondary storm over the Southern States. The chart of the following morning, number 53, shows an eastward drift of the trough and high areas and the appearance of a secondary development over the Southeastern States. The movement of the barometric trough was attended by very heavy rain in the Southern States, and by rain changing to snow in the Lake region and Ohio Valley, and was followed by a cold wave. From this time the strength of the northern storm diminished and it disappeared north of the region of observation, while the southern storm increased in intensity and reached the Carolina coast during the 11th. By the morning of the 12th the storm center had moved to a position off the New Jersey coast, increasing rapidly in energy, and by the morning of the 13th had crossed the southern New England coast line with pressure below 28.90, after which date it apparently partly filled up and passed eastward over the ocean. The well-remembered exceptional severity of this storm was doubtless largely due to the fact that its eastward advance upon reaching the coast was blocked by much higher pressure to the eastward. With its advance checked, the eastward movement of the western high area with its much lower temperature produced remarkably steep pressure and temperature gradients both to the east and west of the center of disturbance, causing heavy precipitation, severe gales, and very marked changes in temperature. A detailed description of this storm was given in the MONTHLY WEATHER REVIEW for March, 1888.

Chart 56 shows the tracks of twin storms, one from the southwest and the other from the south Atlantic coast, which caused heavy snow in New England, March 3–5, 1891.

Chart 57 shows the distribution of pressure attending the appearance in the Southwest, and the track of a storm that was attended by heavy snow in the middle Atlantic States, March 27–28, 1891.

The latest heavy March snowstorm noted in the Northeastern States was caused by a low area that moved eastward over the Ohio Valley and Virginia, February 28–29, 1892, and moved very slowly northeast off the coast during the first five days of March.

HEAVY SNOW IN THE OHIO VALLEY AND TENNESSEE IN MARCH.

The only specially heavy snowstorm noted in this section in March during the last ten years occurred March 17, 1892, attending the eastward passage of a low area over the northern part of the Gulf of Mexico; in the more southern districts the precipitation was in the form of heavy rain. Chart 58 shows the track of this low area from the west Gulf, and Chart 59 the distribution of pressure the morning of the day preceding that upon which the storm appeared over the Gulf. Storms of this class seldom cause general precipitation over the Ohio Valley, although the rain area frequently reaches the Ohio River and the Alleghany Mountain districts. In this instance the snow attended a cold wave, whose approach is indicated by the distribution of pressure on Chart 59, and the depth of snowfall amounted to about two feet in parts of central and southwestern Iowa. This low area was also attended by heavy snow over the Eastern States.

HEAVY SNOW IN THE MISSOURI VALLEY IN MARCH.

Probably the principal snowstorm of March in this region in the period under consideration occurred March 29, 1891. The low area that caused this storm traveled the track plotted on Chart 60, and the distribution of pressure the morning before the snow began is shown on Chart 61. The track of the low area passed far to the southward and then recurved northward over the region of heavy snowfall. In South Dakota and Nebraska the snowfall was reported the heaviest in years. Chart 61 indicates heavy precipitation for the far Western States and the southward movement and strength of this storm area, which was closely followed by the high area from the north Pacific, caused a marked fall in temperature below the freezing point over the States named.

HEAVY SNOW IN THE NORTHWEST STATES IN MARCH.

Chart 62 shows the paths of two low areas which caused the heaviest March snowstorms of recent years in the Northwestern States. Both of these storms were noted in 1893.

Chart 63 shows the pressure distribution the morning before the heavy snow of March 13 began, and Chart 64 the distribution of pressure the morning of the 22d, about the time of beginning of snow. In each case the low area apparently moved southeastward over the northern Rocky Mountain districts and the heavy snow followed the passage of the centers and was confined to the north and northwest quadrants of the low areas.

HEAVY SNOWSTORMS IN DECEMBER.

Heavy snowstorms in December are of rare occurrence and in the last ten years notably heavy falls of snow have been confined to the Northeast and extreme Northwestern States.

HEAVY SNOW IN THE MIDDLE ATLANTIC AND NEW ENGLAND STATES IN DECEMBER.

Four heavy snowstorms have occurred in the middle Atlantic and New England States in December, during the last ten years, attending low areas whose paths are plotted on Chart 65. It will be observed that all of these low areas passed northeastward off, and parallel with, the Atlantic coast line, north of the Carolinas. Chart 66 shows the position over the Gulf of Mexico of the first of these storms two days before heavy snow fell in the middle Atlantic States, and three days before its full force was felt in New England.

Chart 67 shows the track of another storm of this type which followed a more rapid course and snow began in the middle Atlantic States twenty-four hours and in New England thirty-six hours after the appearance of the storm in the position given.

Chart 68 presents the pressure distribution December 16, 1890, which preceded heavy snow in the middle Atlantic States, December 17, and in New England, December 18. This storm passed from the Ohio Valley to the Carolina coast and moved thence northeastward along the coast, its passage being retarded by high pressure over the ocean and the Canadian Maritime Provinces.

Chart 69 shows a type of Southwest storm which was followed within twenty-four and thirty-six hours by heavy snow in the middle Atlantic States and New England, respectively.

The storm shown by Chart 70 passed off the south Atlantic coast and moved northeastward far to the east of the coast line the night of December 26, 1892, attended by heavy snow in Virginia and the Carolinas and by snow in northern Florida. The snowfall at Norfolk, Va., was reported 19 inches in depth, and the snow in northern Florida was reported the first that had fallen in that section in twenty-five years.

HEAVY SNOW IN THE NORTHWEST IN DECEMBER.

A notable December snowstorm in the Northwest set in the night of December 2, 1891, and continued during the following day, attending the passage of a low area from the middle Rocky Mountain districts to and over Lake Superior. The course of this low area and also the track of a low area which moved eastward over the British Northwest Territory, the 1st and 2d of the same month, are shown on Chart 71, and the distribution of pressure the morning of the 2d is shown by Chart 72.

General conclusions concerning heavy snowstorms in the various districts.

In all districts heavy snow falls north of the path of areas of low pressure.

In the central and eastern districts a majority of the heavy snowstorms are caused by low areas which advance from the southwest. Storms of this type are almost invariably attended by heavy precipitation, and when the temperature is below the freezing point the precipitation assumes the form of snow. Therefore, when a storm of this class appears, all points immediately north of the trajectory of its track will be visited by heavy snow, provided the temperature falls to or below freezing. The snow will begin with north to northeast winds and will cease closely following the passage of the storm center.

When heavy snow in the central and eastern districts is caused by low areas from the west and northwest the storm center passes south of the region of heavy snowfall; snow usually begins when the storm center is to the southwest of of the section, continues during the passage of the center to the southward, and until it has passed well to the eastward.

In the far west, southwest, and northwest districts heavy snow follows the passage of moist storm or low pressure areas and is generally attended by a cold wave.

The heavy snowstorms of the southern Rocky Mountain districts are caused by low areas which advance from the south Pacific or southern Arizona or the Mexican Territory to the southward, or by secondary disturbances which develope over the upper Rio Grande Valley. Heavy snow is very rare in this region, however.

The heavy snowstorms of the middle Rocky Mountain districts are usually caused by low areas from the north Pacific coast, which move southwestward over that region, and, in rare instances, by low areas passing eastward over the southern Rocky Mountain districts.

The heavy snowstorms of the northern Rocky Mountain districts follow the passage of low areas southeastward from Alberta or the north Pacific coast over the district, and are sometimes caused by the development of secondary disturbances over the middle Rocky Mountain districts.

No. 9.—HIGH AREAS NORTH OF THE ST. LAWRENCE VALLEY IN OCTOBER, NOVEMBER, AND DECEMBER.*

By Prof. E. B. GARRIOTT.

The areas of high barometric pressure that appear north of the St. Lawrence River in October, November, and December usually advance to that region from Minnesota or the Dakotas in twenty-four hours. A large proportion of the high areas of this class pass from western Quebec to the Canadian Maritime Provinces in twenty-four hours; a less frequent path, and one that is followed in exceptional cases only in November and December, is from western Quebec southeastward off the middle Atlantic coast. The Saint Lawrence high areas generally show pressure 30.20 to 30.30; as the fall advances, however, higher pressures appear, and values above 30.50 obtain about once a month in November and December.

With the appearance north of the St. Lawrence of a high area in October an area of low pressure usually occupies the Canadian Maritime Provinces, and another the extreme northwest. If a low area is not shown in the Northwest one will appear within twelve hours. Twenty-four hours before the high area reaches the region north of the St. Lawrence River, and when it occupies a position in the Northwest, a temperature fall of 10° or more occurs in the upper Lake Region and the Ohio Valley, and rain falls from the eastern Lake Region over the Atlantic Coast States north of Virginia. Twelve hours before the high area reaches western Quebec, and when it is central over the upper Lake Region, a temperature fall of 10° or more occurs from the lower Lakes over the interiors of New York, Pennsylvania, and New England, and the western limit of the rain area reaches the Middle Atlantic and New England States. Twenty-four hours after the high area appears north of the St. Lawrence the rain area has passed to sea and the temperature has begun to rise over the interior of the Middle Atlantic and New England States. Within thirty-six hours after the appearance of the high area north of the St. Lawrence fine weather with rising temperature obtains over the Middle Atlantic and New England States, and a fall in temperature is noted only over the Canadian Maritime Provinces. When October high areas pass southeastward from the St. Lawrence Valley a marked fall in temperature occurs over the South Atlantic States. When the high area passes eastward over northern New England and the St. Lawrence Valley easterly winds will be attended by cloudy weather and sometimes by rain along the immediate middle Atlantic and south New England coasts.

In November the relative positions and movements of the high areas and their attending low areas are practically the same as noted for the preceding month, and no material difference is shown in the temperature and rain conditions which attend them. In December, however, the greater magnitude of the high areas occasions marked differences in conditions and effects when compared with those noted for the fall months. Twenty-four hours before a December high area appears north of the St. Lawrence, and when it occupies Minnesota or the Dakotas, a low area appears on the north Pacific Coast, rain or snow falls over the lower Lakes, and in 60 per cent of the instances noted a marked fall in temperature occurs over the Middle Atlantic and New England States. Twenty-four hours after the high area appears north of the St. Lawrence (and when it has advanced to Nova Scotia, and the north Pacific Coast low area has advanced to the northwestern Lake Region) rain or snow falls along the middle Atlantic and New England coasts and the temperature continues low over the Atlantic Coast States from Virginia to Maine. Within thirty-six hours after a high area appears north of the St. Lawrence in December fine weather with rising temperature prevails over the middle Atlantic and New England States.

In conclusion, it may be stated that the high areas of the type above referred to average about two per month, or about one-fourth of the high areas traced for the months of October, November, and December. Their appearance north of the St. Lawrence is preceded by rain or snow and falling temperature over the Middle Atlantic and New England States, and is followed within thirty-six hours by fair weather and rising temperature over those districts.

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* Extract from Monthly Weather Review, August, 1895.

No. 10.—COLD WAVES ON THE MIDDLE GULF COAST.*

By Prof. E. B. GARRIOTT.

Practically, all of the important cold waves of the United States first appear over British America and advance thence over districts in the United States which are covered by the sweep of northerly winds in the west quadrants of areas of low barometric pressure. The cold waves of the middle coast of the Gulf of Mexico follow in the wake of areas of low pressure which reach the lower Mississippi Valley.

As cold waves are a product of the cyclonic circulation of winds about areas of low pressure, a consideration of the habits and characteristics of the low areas of the colder months, and more especially of those which have been attended by cold waves, is necessary to a determination of the several types of cold waves and of the conditions which contribute to their development and movement.

A well-defined low area presents a warm and a cold side. In the east or warm side southerly winds are attended by the higher temperature of lower latitudes; in the west, or cold side of the low area west to north winds carry southward the cold of higher latitudes. At any given point in the east quadrants of the low area warm, southerly winds will prevail. As the center of disturbance passes to the eastward the cold, northerly winds of the west quadrants are experienced. When, therefore, abnormally high temperature obtains in the front, and abnormally low temperature in the rear, of a low area, a decided fall in temperature will be experienced within the area of active cyclonic disturbance following the passage to the eastward of the storm center, and in cases where a decided and specified fall to the freezing or frost temperature occurs, a cold wave is noted.

The cold waves of the middle Gulf Coast belong to two fairly well-defined types. They either follow the passage of a low area from the northwestern States to the lower Mississippi Valley, or follow a low area which develops or appears in the extreme southwest. The southwest low area may develop in the southern part of a trough of low pressure which extends southward between the Rocky Mountains and Mississippi River, or it may appear near the west Gulf Coast and move thence over the middle Gulf States. A necessary condition to the southward sweep of the cold waves, whether they depend upon the northwest or the southwest low areas, is an unbroken area of high barometer extending over the Rocky Mountain and Plateau regions. It is also necessary to the verification of a cold-wave signal on the middle Gulf Coast, in cases where a fall of 16° to 42° is required, that a 24-hour fall in temperature of 20°, or more, shall have occurred in the middle-western States, and that a gradient of at least 25° shall appear between the Gulf Coast and the thirty-fifth parallel. When, therefore, the weather maps show a well-defined low area over the lower Mississippi Valley, with temperature 60°, or below, at New Orleans, and an area of high pressure of great magnitude covering the Rocky Mountain and Plateau regions, with a 24-hour fall in temperature of 20°, or more, in States lying between the lower Missouri River and the middle Rocky Mountains, and a temperature gradient of 25°, or more, between New Orleans and Oklahoma, a fall in temperature of at least 16° may be expected along the middle Gulf Coast within twenty-four hours.

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* Extract from Monthly Weather Review, September, 1895.

No. 11.—WEATHER FORECASTS IN THE STATE OF MISSOURI.

By H. C. Frankenfield, Local Forecast Official, St. Louis, Mo. (Dated December 5, 1895.)

The elevation of the State of Missouri above the level of the sea varies from 275 to over 2,000 feet. The least elevation is in the southeast corner of the State. In the northern half the elevation varies generally between 500 and 1,000 feet, except in the extreme northwest corner, where it is over 1,000 feet. The southern half, except for a small section on either side, is generally from 1,000 to 2,000 feet above the sea level and is mountainous.

The Missouri River enters the State at the extreme northwest corner and flows along the western boundary about one-third of its length until Kansas City is reached, when it turns to the eastward and flows generally in that direction until it empties into the Mississippi River which forms the eastern boundary of the State.

Topographical conditions, however, may be considered as fairly uniform, the only noticeable influence exercised being that of the Ozark Mountains in the southern part of the State, which sometimes shield the northwest portion of the State from the full intensity of storms moving northeastward through eastern Arkansas to the Ohio Valley. They also exercise a slight retarding influence upon storms and cold waves from the Northwest.

In compiling the data upon which to base the following deductions regarding the successful forecasting of Missouri weather, the observations and maps for a limited number of years have been used, namely, from July, 1889, to June, 1894, inclusive. It would, of course, have been preferable to have used more, but lack of time prevented, and, in any event, it was thought that the different storm types are so distinct, both as to locality and season, that fairly accurate results could be obtained with but five years' data.

PRECIPITATION.

In all 549 more or less well-defined lows were studied, and of these all but three, or one-half of 1 per cent, originated somewhere to the westward of the State of Missouri. Of these three, two moved westward from the south Atlantic Coast bringing precipitation, local in one case and general in the other, and comparatively light in both. The other originated within the State. It was only of moderate energy, not very well defined, and caused general thunderstorms with a substantial amount of rain.

By far the greater portion of the lows which moved over the country first appeared in the British Northwest Territory in the Province of Alberta. Twenty-six per cent were of this type, but only 32 per cent of these caused precipitation in the State of Missouri. A considerable number, 9 per cent, came from the north Pacific Coast region, and of these 49 per cent caused precipitation in Missouri. An almost equal number originated in the middle Plateau, and 80 per cent of these caused precipitation. Seven per cent originated in the southern Slope, and 87 per cent of these caused precipitation. Nine per cent also originated in the northern slope, but only 49 per cent of these caused precipitation in Missouri. Six per cent originated in the southern Plateau and 91 per cent of these caused precipitation. Only 2 per cent originated in Mexico or the west Gulf States, but 92 per cent of these caused precipitation. Rain or snow also followed fifty-six cases of irregular and unsettled conditions, indicated on the weather maps by the curving away from each other of the isobars and isotherms, leaving an open space between. These usually caused rain within a reasonable time, and 10 per cent of them developed into well-defined lows, one in April, 1893, becoming a storm of exceptional severity by the time it reached the middle Slope. These irregular arrangements of the isobars and isotherms, when they occur in the Southwest and West, indicate the presence of conditions which will almost invariably cause precipitation in Missouri in from twenty-four to thirty-six hours; the interval depends upon the distance of the irregular conditions from the State when first noticed.

No precipitation at all occurred from the lows originating in Manitoba and the Missouri Valley.

The seasonal distribution of the lows was found to be as follows: Spring, 25 per cent; summer, 23 per cent; autumn, 22 per cent; and winter, 30 per cent. The percentages with precipitation were: Spring, 64; summer, 64; autumn, 50; and winter, 61. It will be noticed that the seasonal distribution of the lows was fairly uniform except in the winter. There was a deficiency in the precipitation percentage in the autumn, but those of the remaining three seasons were almost exactly alike.

The monthly distribution of the lows varied from 6 per cent in June to 11 per cent in December. Ten per cent occurred in January, and from 7 to 9 per cent during the remaining months. Notwithstanding the low percentage in June, 80 per cent of the lows of that month caused precipitation in Missouri, while November, with a percentage of 8, or 2 higher than that of June, had precipitation with only 47 per cent of its lows. April, with a percentage of 7, had precipitation with 71 per cent of its lows. The five months from February to June, inclusive, with 40 per cent of the lows, had precipitation with 68 per cent of these, while the seven months from July to January, inclusive, had precipitation from 54 per cent of the remainder.

The localities from which the lows move also appeared to have a considerable effect upon the amount of precipitation. The Alberta lows, which were 26 per cent of the total, furnished only 13 per cent of the precipitation, while the southern Plateau lows, which were 6 per cent of the total, furnished 10 per cent of the precipitation or, relatively, over three times as much as the Alberta lows. The middle Plateau lows, 9 per cent of the total, produced 14 per cent of the precipitation, and the north Pacific Coast lows, with the same percentage, produced 12 per cent. The southern Slope lows, being 7 per cent of the total, produced 9 per cent of the precipitation. Six per cent of the precipitation was caused by the irregular conditions before mentioned. The lows from the Saskatchewan Valley produced but little precipitation. Those from the central Pacific Coast Region, although few in number (only 1 per cent) produced 4 per cent of the precipitation, a greater proportionate amount than those from any other section. The entire Pacific Coast Region, with 12 per cent of the lows, produced 20 per cent of the precipitation, while the Plateau Region, with 17 per cent of the lows, produced 27 per cent, the proportionate amounts being almost equal, but slightly in favor of the Pacific Coast Region. The Slope Region, with 12 per cent of the lows, produced 17 per cent of the precipitation.

It will be seen from the above that the Pacific Coast and Plateau and Slope regions produced 41 per cent of the lows and 64 per cent of the precipitation. The seasonal distribution of the amounts of precipitation with reference to the localities of the lows does not present any interesting features, except in the cases of Columbia and Alberta lows. Generally there is a direct relation between the number of lows and the amount of precipitation, except during the summer months, when the irregular conditions produce about one-third of the precipitation through the medium of thunderstorms. There was also a considerable amount of the precipitation, about 5 per cent, caused by high pressure to the northwest of the State of Missouri, and this was no doubt due to the condensation indirectly produced by the cold air of the highs. This precipitation from highs is liable to occur in any month, and is extremely difficult to forecast on account of its uncertainty. A detailed study of the different types of lows reveals the following facts:

Columbia lows.—As a rule no precipitation resulted from these lows unless they moved southeastward down as far as southern South Dakota after crossing the mountains. When they followed this path 88 per cent of them brought precipitation in Missouri, the only failure being a weakly defined storm which was dissipated in South Dakota. The greatest amount of precipitation occurred when the lows moved down as far as the fortieth parallel. After they reached this latitude, and unless joined by other lows from the southwest, the precipitation did not last more than a day. When joined by lows from the southwest it lasted from two and one-half to three days, but it was not of excessive amount. These lows may be looked for only from November to March, inclusive.

Alberta lows.—These lows are liable to occur in any month, but those with precipitation were more frequent from November to May, inclusive, the percentage being 42 as against 23 for the other six months. Thirty-eight per cent of the Alberta lows moved eastward across the country north of the forty-fifth parallel without causing any precipitation in Missouri. They usually brought precipitation when they moved southeastward to the middle Plateau and middle Slope in the shape of a long trough extending in a northeast and southwest direction. In these cases precipitation occurred from 91 per cent, the reason for failure in the remaining 9 per cent not being ascertainable from a thorough study of the map conditions. These Alberta lows sometimes remain nearly stationary for three or four days, or even longer, before they take up their easterly or southeasterly movement. When they move southeastward precipitation usually follows in from thirty to forty-eight hours, generally in about eighteen hours after the centers pass below the forty-fifth parallel. Slow movements obtain from the late spring until the early autumn, and after the lows once reach the middle Plateau and the Slope Regions, showers are probable for several days. In winter the movement is occasionally so rapid that precipitation will occur in Missouri in less than twenty hours. Another tendency of these Alberta lows is to cause precipitation only in the northeast half of the State, and often only in the southeast quarter. This is probably due to the deflecting influence of the mountains in the southern portion of the State. Of the lows which caused precipitation 30 per cent were of this nature, and with no discrimination in favor of any particular season. Another feature of the precipitation with this type is its persistence for a considerable time after the low has passed to the eastward and the winds have shifted to the northwest. Clearing weather should be forecasted with caution, and not as soon as the map conditions would seem to indicate.

Assiniboia lows.—Fifty-five per cent of these lows moved directly east over Canada and none of that number caused precipitation in Missouri. Only those which moved southeastward to South Dakota, Nebraska, or Minnesota, did so, and in all cases the amounts were small, the maximum amount at St. Louis being only 0.12 inch. Sixty-four per cent of the lows which moved southeastward brought precipitation, which usually followed in forty-eight hours, and it is worthy of note that none of them moved farther south than the fortieth parallel.

Saskatchewan lows.—The movements and effects of these lows were similar to those of Assiniboia, except that the amounts of precipitation were decidedly greater. There was no precipitation in Missouri unless they moved down near to the fortieth parallel and the majority moved directly east over the extreme north. Precipitation attended 33 per cent of these lows, and all that moved as far south as the fortieth parallel. It usually followed in thirty-six or forty-eight hours.

Manitoba lows.—These lows moved in the usual due eastward path of the British Territory lows and caused no precipitation in Missouri.

North Pacific lows.—These lows followed the usual rule of the northwest lows, being very rarely attended by precipitation unless they came down below the fortieth parallel before reaching the Mississippi Valley. They were most prevalent from November to May, inclusive. Thirty-seven per cent of them moved eastward across the northern part of the country, and none of these caused precipitation in Missouri. Fourteen per cent were dissipated before reaching the Slope Region and but one of these caused precipitation. The remaining 49 per cent moved southeastward and all of them brought precipitation in from forty-eight to seventy-two hours, although some of the storms moved so rapidly that precipitation occurred in twenty-four hours. Others moved so slowly that it did not occur for four days. A rather remarkable instance of absence of precipitation from one of these lows was that of the storm which appeared on the north Pacific Coast on April 6, 1890. This storm moved eastward to Manitoba in thirty-six hours, the pressure at the center at that time being 29.4 inches. It then moved southeastward to Iowa and northern Illinois in twelve hours, with a pressure at the center of 29.5 inches, and then continued eastward over the lower Lakes. The only precipitation reported from Missouri was a trace at Kansas City.

Central Pacific lows.—Eighty-three per cent of these lows caused precipitation in the State of Missouri. Their movement was directly east and usually very rapid, bringing precipitation in from twenty-four to thirty-six hours. There was generally a high quite close to the northward, causing the precipitation to be frequently quite heavy.

Southern Pacific lows.—Seventy-three per cent of these lows were accompanied by precipitation in Missouri and their movement was usually, first, slightly north of east, then east over the track followed by the central Pacific lows. Occasionally they moved eastward to the Gulf of Mexico, over which they disappeared, or else turned northward through the east Gulf States. When they turned northward very violent storms frequently resulted. A few of these lows were dissipated just after crossing the Rocky Mountains. Storms of this type also moved very rapidly and precipitation usually occurred in about thirty-six hours. It was generally quite abundant, a characteristic of nearly all the Pacific Coast lows.

Northern Slope lows.—Forty-nine per cent of these lows brought precipitation to Missouri. About one-half moved eastward across the northern portion of the country, while the other half moved southeastward, frequently in the shape of a long and narrow trough, extending in a northeast and southwest direction, causing southeast winds for a considerable time. Ninety-eight per cent of the latter type brought precipitation, while only 2 per cent of the former were so favored. One well-defined low, which moved southeastward, failed to bring precipitation, and a few were dissipated in the extreme west. The amounts of precipitation were generally slight, but the lows which moved down the Missouri Valley to southeast Nebraska or northern Missouri occasionally produced a substantial rain. Precipitation, when it occurs from these lows, usually comes in about thirty-six hours, sometimes as much as twenty-four hours later, but rarely sooner.

Middle Slope lows.—Eighty-seven per cent of these lows brought precipitation to Missouri. Their easterly movement varied to the northward or southward, but being so close to Missouri precipitation nearly always resulted in from twelve to twenty-four hours, sometimes a little sooner. A few turned so sharply toward the north that there was no precipitation.

Southern Slope lows.—Precipitation also followed 87 per cent of these lows. Their points of origin were so close to the State that almost all of them passed through some portion of it. For the same reason precipitation followed very soon, usually in twenty-four hours, and in a few cases sooner. It follows, therefore, that precipitation from these lows can not be forecast with certainty thirty-six hours in advance. All that can be done is to watch carefully for falling pressures and irregular wind conditions with considerable rises in temperature that appear somewhat abnormal. These remarks apply with equal force to the middle Slope lows. The few southern Slope lows that did not cause precipitation moved southeastward or were dissipated in a short time.

Northern Plateau lows.—Seventy-three per cent of these lows caused precipitation in Missouri, and in a great majority of cases their paths lay southeastward through Colorado to Oklahoma or Texas, and then northeastward through the southern portion of Missouri, the Ohio Valley, the lower Lakes, and the St. Lawrence Valley. Usually the amount of precipitation was comparatively light, and it did not commence until after the lows turned to the northeastward from Oklahoma or Texas, generally in from sixty to seventy-two hours.

Middle Plateau lows.—About 80 per cent of these lows caused precipitation in Missouri, and generally in substantial quantities. The average interval from the first appearance of the lows until the commencement of precipitation was thirty-six hours. Occasionally, it was forty-eight, and very rarely, twelve hours. At the outset these lows rarely moved eastward, but southeastward or northeastward until the Slope Region was crossed, when they turned more nearly eastward, those in the south going through the Ohio Valley to the lower Lakes, and those in the north moving over the upper Lakes to Canada.

Lows from Wyoming appear to move very rapidly. In December, 1893, one traveled from Wyoming to eastern New York, a distance of over 2,000 miles in forty-eight hours. Those of the middle Plateau lows that did not cause precipitation were generally crowded out by highs, or occasionally by other lows in the north. Only one or two moved so far north as to leave the State of Missouri beyond their influence.

Southern Plateau lows.—Ninety-one per cent of these lows caused precipitation in Missouri. Their favorite path was eastward to Texas, then northeastward through Iowa or Missouri; some moved northeastward through the Ohio Valley, and occasionally one would move directly eastward. In these latter cases there would be precipitation from the high to the northward. Precipitation usually followed in from thirty-six to forty-eight hours; sometimes twelve hours earlier, but rarely later. These lows as a rule moved quite rapidly after leaving Texas, and the precipitation lasted from twenty-four to thirty-six hours, clearing weather following shortly after that time.

Mexican lows.—Only two per cent of the total number of lows originated in this section, but 92 per cent of them brought precipitation. They usually moved northeastward through the Southwestern States to the Ohio Valley and the lower Lakes, but sometimes their direction was eastward to the Atlantic Coast and then northward. One moved directly north from Louisiana to Minnesota. Precipitation may be expected in from twenty-four to thirty-six hours, but rarely later. Whenever precipitation follows in twelve hours, it is probable that a more careful examination of the wind directions and barometric changes would have indicated the approach of the low from the Gulf about twelve hours sooner. The amount of precipitation averaged about one-half inch.

Irregular formations.—Precipitation from these formations occurred usually in summer, less frequently in the spring and autumn, and rarely in winter. It generally occurred when the barometer was high north of the forty-second parallel, with a lesser high in the extreme southeast, and with low pressure in the West and Southwest. The pressure within the State was usually between 29.95 and 30.05 inches, except in winter, when higher pressures were the rule. Pressures lower than 29.90 were rare with this type. The temperatures averaged from 70° to 75° at 8 a. m., seventy-fifth meridian time, during the summer, but differed widely during the winter. These irregular formations are characterized by the small number and irregular arrangement of the isobars and isotherms. The isobars form parabolas with their apices toward each other, leaving a three or four sided open space between, and the isotherms cross them in various directions. Precipitation usually occurred in from twenty-four to thirty-six hours after the appearance of these conditions, but was sometimes twelve hours earlier or later. It took the form of brief showers, and the showery conditions continued about twenty-four hours, although at times the irregular conditions persisted for several days with frequent showers. The amount of precipitation was generally quite moderate, although heavy showers sometimes occurred, particularly in the western half of the State.

Precipitation from high areas.—Precipitation in Missouri from high areas is comparatively uncertain, and a careful study of previous conditions does not afford any conclusions that are as reliable as could be desired.

It appears that at times precipitation was caused usually within twenty-four hours, by high areas, mostly of decided character, in the Slope or Plateau regions. The pressure was generally above the normal over the remainder of the country, although there were sometimes slight depressions moving across the Gulf of Mexico, or else over the extreme north, particularly in the winter. In nearly all the cases the amounts of precipitation were light, and, except in summer, were evidently indirectly caused, as stated before, by the low temperatures accompanying the highs, the high area forcing its cold air underneath the warm air and lifting it up to a sufficient height to cause cooling by expansion to a temperature below the dew-point. In the summer the conditions were generally unsettled and somewhat confused, causing local showers, principally thunderstorms.

It is worthy of note that the highs rarely moved across the Mississippi River, except with greatly decreased energy. Many were dissipated west of the river.

The following conditions usually preceded precipitation from high areas:

(*a*) High of decided character in the northern or middle Slope or middle Plateau, and pressure elsewhere normal or above.

(*b*) Cold wave covering the central valleys, northern and middle Slopes, except in summer.

(*c*) Isothermal gradients usually quite steep, about 10° per 100 miles (except in summer), either in southeast Nebraska and southwest Iowa, or in Missouri, or in western Kentucky and western Tennessee, and less than one-half as steep to the northwestward, with the isotherms extending in a northeasterly direction.

(*d*) Frequently in winter slight depressions over the Gulf of Mexico, sometimes depressions in the extreme north, although these latter do not appear to have any effect on the result.

(*e*) Northeasterly winds, shifting later to easterly and southeasterly. One peculiar form of high pressure area, with conditions somewhat different from the above, caused precipitation in Missouri in about 83 per cent of the cases investigated. The pressure was generally high over the whole country east of the Rocky Mountains, but the belt of highest pressure extended in oval form over the States immediately north of Missouri, sometimes reaching farther west to Nebraska and as far east as West Virginia, but with the highest belt extending from eastern Nebraska to western Illinois. The weather was cloudy, with northerly winds, and the temperatures ranged from 30° to 40° within the State of Missouri, although much lower in one case. The isotherms extended across the State in a horizontal direction parallel to the long axes of the oval isobars above mentioned. Precipitation from high areas always followed in twenty-four hours and was usually light in amount.

Precipitation under the influence of lows advancing from Florida, or the extreme southeast into the east Gulf States, has not been considered, owing to the extreme rarity of its occurrence; only two cases have been noted during the five years, neither resulting in much precipitation in Missouri.

The following general deductions may be drawn from the foregoing:

I.—During the summer months, although the lows may be fairly well defined and persistent in the Northwest, there will be no precipitation as a rule in Missouri until highs follow the lows and reach the northern and middle Slopes.

II.—During the summer months when lows appear in the Northwest and settle down over almost the entire West with no well-defined formation, thunderstorms and warm waves are persistent with short intervals of dry and slightly cooler weather.

III.—Whenever, except in summer, any section of the western or southwestern country is open—that is, with isobars and isotherms curving away from each other, leaving an open space between—and the temperatures in the open section show a considerable rise as compared with the surrounding country, a low may be expected to develop in that section in from twelve to twenty-four hours which will move eastward and cause precipitation in Missouri. Storms of exceptional intensity sometimes originate in the southern Plateau from these conditions.

IV.—When a long, narrow trough of low pressure extending in a general north and south direction is moving eastward, it will frequently break in two in the Slope Region, the upper section passing off to the northeastward, and the lower one, with its original center in Kansas, continuing eastward, bringing precipitation in Missouri within twenty-four hours.

V.—In winter, after warm southerly winds have been blowing for some time into a low area, a slight fall of snow may be expected during the first part of the following cold wave when the pressure commences to rise and the temperature to fall rapidly.

VI.—Heavy snows are comparatively rare in Missouri; when they occur they are usually preceded by the following conditions:

(*a*) An area of low pressure in the West or Southwest moving eastward.

(*b*) High pressure over the Northwest and from the Mississippi Valley eastward.

(*c*) Temperature within the State usually from 28° to 34°, although occasionally slightly lower.

VII.—When a moderate depression, viz, one having a pressure at the center of from 29.7 to 29.9 inches, moves slowly southeastward from the extreme northwest, and, after reaching the eastern end of the middle Plateau or the middle Slope, remains nearly stationary for the next twenty-four or thirty-six hours, there is reason to expect (1) a decided increase in intensity within the succeeding twelve or twenty-four hours; (2) a sharp change in direction to the eastward, usually through some portion of Missouri; (3) a rapid movement; (4) precipitation in the State lasting about a day; (5) in winter the usual cold wave quickly following. About 4 per cent of the lows from the northwest, which brought precipitation in Missouri, were of this description.

VIII.—The following points may be of some value in forecasting when the forecasts are based upon map conditions at 8 a. m. and 8 p. m., seventy-fifth meridian time:

(*a*) The same general conditions will rarely prevail over the entire State of Missouri at the same time. Precipitation and decided changes in temperature will occur in the northwest half twelve hours sooner than in the southeast half, and often twenty-four hours sooner than in the extreme southeast portion of the State. The same is true of clearing conditions. Whether this is due to the retarding influence of the Ozark Mountains, or to a pause in the natural rhythm of storms is a question for further study. The facts are as stated, with the probabilities in favor of the first suggestion as being the correct one.

(*b*) Conditions in the extreme southeast portion of Missouri will persist through one or more maps after they have entirely disappeared from the remainder of the State. This is particularly true of precipitation and falling temperature. Some effect produced by the junction of the two great river valleys of the Ohio and Mississippi is no doubt largely responsible for this peculiarity.

TEMPERATURE.

The temperature investigations have been confined almost entirely to the study of cold waves, the causes of warm waves in summer are so uniform that they may be dismissed with the following brief remarks: "High temperatures in Missouri are caused by the passage of lows through Iowa and Minnesota, especially in summer when the movement is slow." (Hammon).

Warm waves in summer persist until a high appears back of the prevailing low pressure, and moves eastward to the Slope Region. Frequently a high will be located in the Southeast and will remain there for a number of days, being constantly reinforced by cool air from the ocean. This bank of cool and heavy air will prevent the eastward movement of any low area, and the warm waves in Missouri will continue until the high in the southeast disappears, notwithstanding any indications of cooler weather to the northwestward.

The following general conclusions were deduced from a study of the origin and progress of cold waves:

I.—The severity of the cold wave depends largely upon the lowest reading of the barometer within the area of low pressure, the proximity of the center of the low to the State, its direction with reference to the State, and the intensity of the succeeding high.

II.—Owing to the latitude of Missouri and the rapid easterly movement of the lows from November to April inclusive, nearly all the cold waves are of comparatively short duration.

III.—"The most marked cold waves occur with a low in Missouri and a high in Montana or North Dakota." (Hammon.)

IV.—When a low passes to the southeast and west of Missouri there will be no marked fall in temperature, as the winds will blow from some northerly direction in advance of the low, and there will not be much rise in temperature. In cases of this sort it is perhaps better to forecast colder weather in twenty-four hours, followed by warmer within twelve hours after, as the high following the low will cause warmer southerly winds without regard to the intensity of the former, and the extent of the cold wave in the West and Northwest.

V.—"A low in Missouri and a high in Minnesota affect eastern Missouri, but not materially western Missouri." (Hammon.)

VI.—A Mexican low passing through Missouri produces a severe cold wave lasting at least from thirty-six to forty-eight hours.

VII.—A low in Colorado moving rapidly eastward, e. g., to the upper Lakes in twenty-four hours, causes a decided cold wave of short duration in about thirty-six hours. After this a considerable rise in temperature may be expected within thirty-six hours, unless the high is reinforced by another coming down from the extreme north, in which case the low temperature will persist for a day or two longer.

VIII.—When a low moves across the extreme north the fall in temperature in Missouri will not be very great, but if the temperature is already comparatively high, the fall is likely to be sufficient to justify a cold wave warning. These cold waves are in all cases of very short duration.

IX.—When a low covers the entire West with its center in the extreme north, and a high is coming down from the extreme northwest, a cold wave may be expected in from forty-eight to sixty hours, but it will be of short duration, and not very severe. If a second low follows, however, a severe cold wave is probable after it passes.

X.—In forecasting cold waves that follow lows and pass eastward to the north of Missouri, a careful watch should be kept for another low that may come in by way of the middle or southern Plateau. In this case there will be but little change in temperature, with the chances in favor of a rise instead of a fall.

XI.—When a low moves northeastward keeping southeast of Missouri, there will not be much fall in temperature unless the following high is of a very decided character with very low temperatures in the Northwest. As the lows in these cases pass south of the State, the prevailing winds will be from the cold northwest quarter.

XII.—When there is a low in Missouri and a high in the West or Southwest, the fall in temperature will not be so marked as if the high were in Montana or the Dakotas, although at times there will be a considerable fall, especially in the western portion of the State. These cold waves are also of short duration, the high usually passing to the south of Missouri, causing a rise in temperature within twenty-four hours.

XIII.—"When a low passes through or north of Iowa the effect in Missouri is not very marked, no matter how cold it may be on the Canadian border." (Hammon.)

XIV.—A constant watch should be maintained, particularly in January, for lows from Alberta, which move southeastward very rapidly, often from Alberta to Missouri or Illinois in twenty-four hours, or at the rate of from 60 to 65 miles per hour. In these cases the temperature will rise considerably for twenty-four hours, will commence to fall shortly afterward, and by the time thirty-six hours have passed will have fallen decidedly. A still greater fall may be expected in forty-eight hours, and the turning point a few hours later. When a storm of this character moves over the country, it is not improbable that one or two similar ones will follow almost immediately after.

XV.—With a decided high in the Northwest and a low stationary in the middle Plateau, a severe cold wave may be expected in twenty-four hours.

XVI.—With a low on the Lakes and another in the Southwest, with a high coming down between the two, expect a cold wave in twenty-four hours.

XVII.—When a high is coming down from the north and a low is central in the middle Plateau, the latter having previously warmed up the State of Missouri, the cold wave will progress slowly (the low interfering with the free movement of the high), but will be severe, as the high will probably spread over the entire West, crowding out the low. These cold waves usually last two or three days.

XVIII.—With a high in Kansas and Nebraska with a southeastward movement, and a cold wave already covering Missouri, it is usually safe to forecast warmer weather within twenty-four hours, although it may still be much colder west of Missouri. The shifting of the winds to the south with the passage of the high will explain this.

XIX.—With a high in the Dakotas following a low, and another low coming in from the central or north Pacific Coast, if a considerable fall in temperature has already taken place with a further fall indicated by higher pressure and more cold to the northwestward, do not forecast colder, but warmer weather within twenty-four hours, as these latter lows will generally move in very rapidly and drive the high to the northeastward.

XX.—With a stationary high in the middle Plateau, and another coming down from the north, the temperature is likely to fall gradually for a day or two until the northern high moves into the Dakotas, when a cold wave may be expected in Missouri within twenty-four hours. The high will usually spread over the west, causing a severe cold wave which will last a few days.

XXI.—When a cold wave covers the State, and there is no falling pressure to the northwestward, cold weather will probably continue (sometimes for as long as two or three weeks) until a low of marked intensity again moves in somewhere from the west or northwest.

XXII.—When a high covers the State, and the temperature has fallen considerably within twenty-four hours, and the pressure remains high from the Plateaus eastward, with the prevailing winds very light, a further slight fall in temperature may be expected during the succeeding night.

XXIII.—When a high appears in Manitoba without the usual preceding low, and spreads southward and eastward, causing a severe cold wave, the effect will be much more marked in eastern than in western Missouri. Cold waves of this description are rare, but severe.

THUNDERSTORMS.

I have found the forecasting of thunderstorms for a period of from twenty-four to thirty-six hours in advance to be a comparatively unsatisfactory and thankless undertaking, and I fully agree with Mr. Strong's conclusion from his experience in Ohio, (Weather Bureau Bulletin No. 9, page 53,) that, owing to the great variation in the direction and velocity of the thunderstorm belts, it is almost impossible to make a direct forecast as to time and place. The weather map may show the unmistakable presence of thunderstorm conditions, but whether the storms will occur in one section of the State, or in another, or in neither, is always an open question. When thunderstorms have occurred in the State of Missouri, they have generally been preceded from twenty-four to thirty-six hours by some of the following conditions:

I.—An area of moderately low pressure, usually in the southwest or west, but quite frequently in the northwest.

II.—Southerly winds, mostly southeasterly, but sometimes easterly.

III.—Comparatively high temperatures, especially in summer.

IV.—Morning temperatures in summer between 66° and 78°, and pressure about normal, varying between 29.8 and 30.2 inches.

V.—The presence of irregular or "open" conditions to the west or southwest, before noted as indicating the approach of precipitation.

VI.—Isotherms in the shape of inverted troughs.

VII.—Isotherms trending north and south in the Slope

Region, and turning sharply to the eastward somewhere north and west of Missouri, generally in Nebraska or South Dakota.

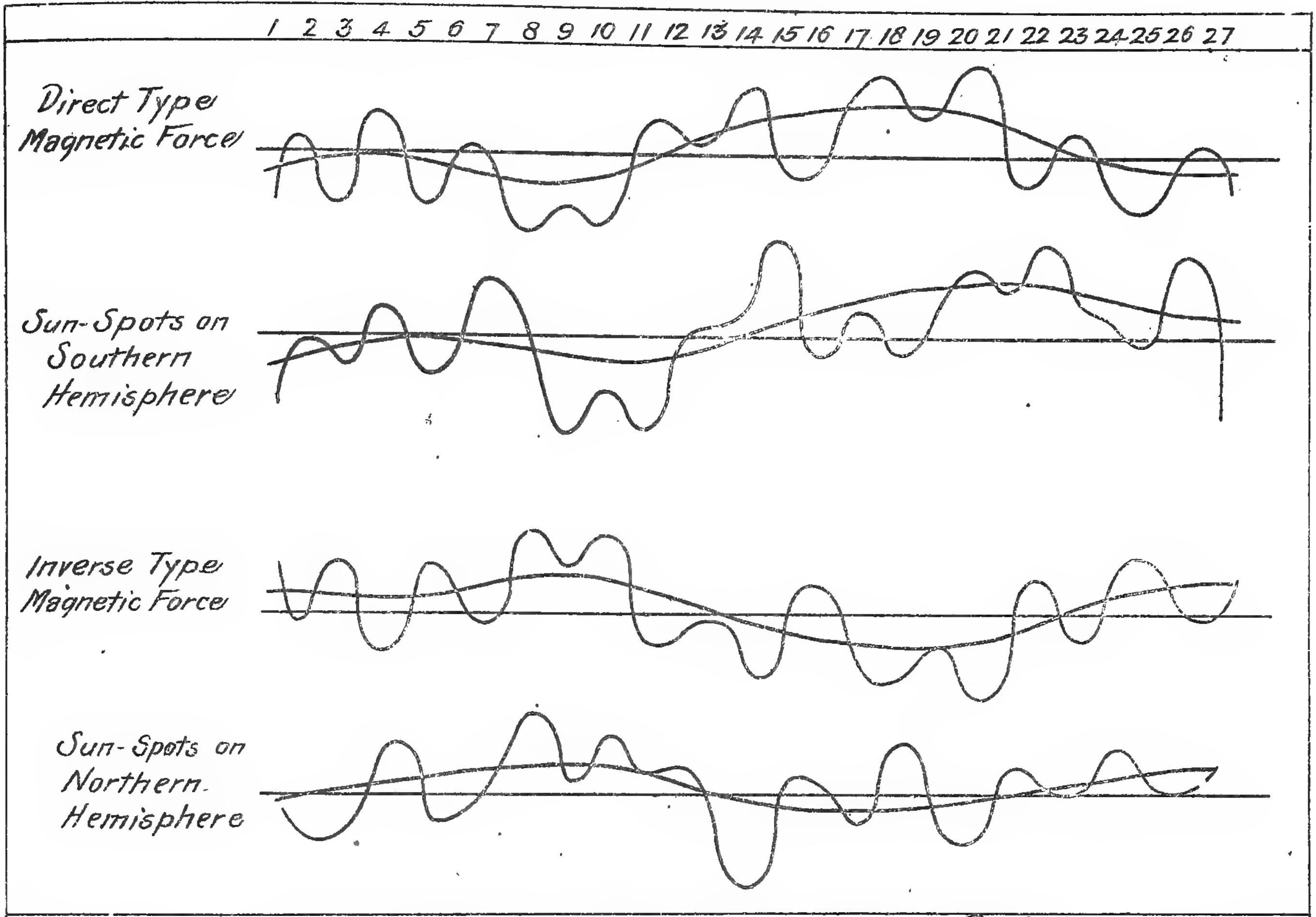
VIII.—Isotherms and often isobars very wavy, the former frequently forming numerous loops.

IX.—Isotherms cutting isobars sharply, often at right angles.

X.—Winter thunderstorms occur generally when the isotherms nearest the State are in the shape of irregular parabolas with their apices toward the north, and when there has been a considerable rise in temperature during the past twenty-four hours with a low in the west and lower temperature close at hand.

XI.—Thunderstorms rarely occur at the center of a low, especially when the pressure is below 29.7 inches. If they occur at all they may be looked for on the eastern and southeastern edges of the disturbance.

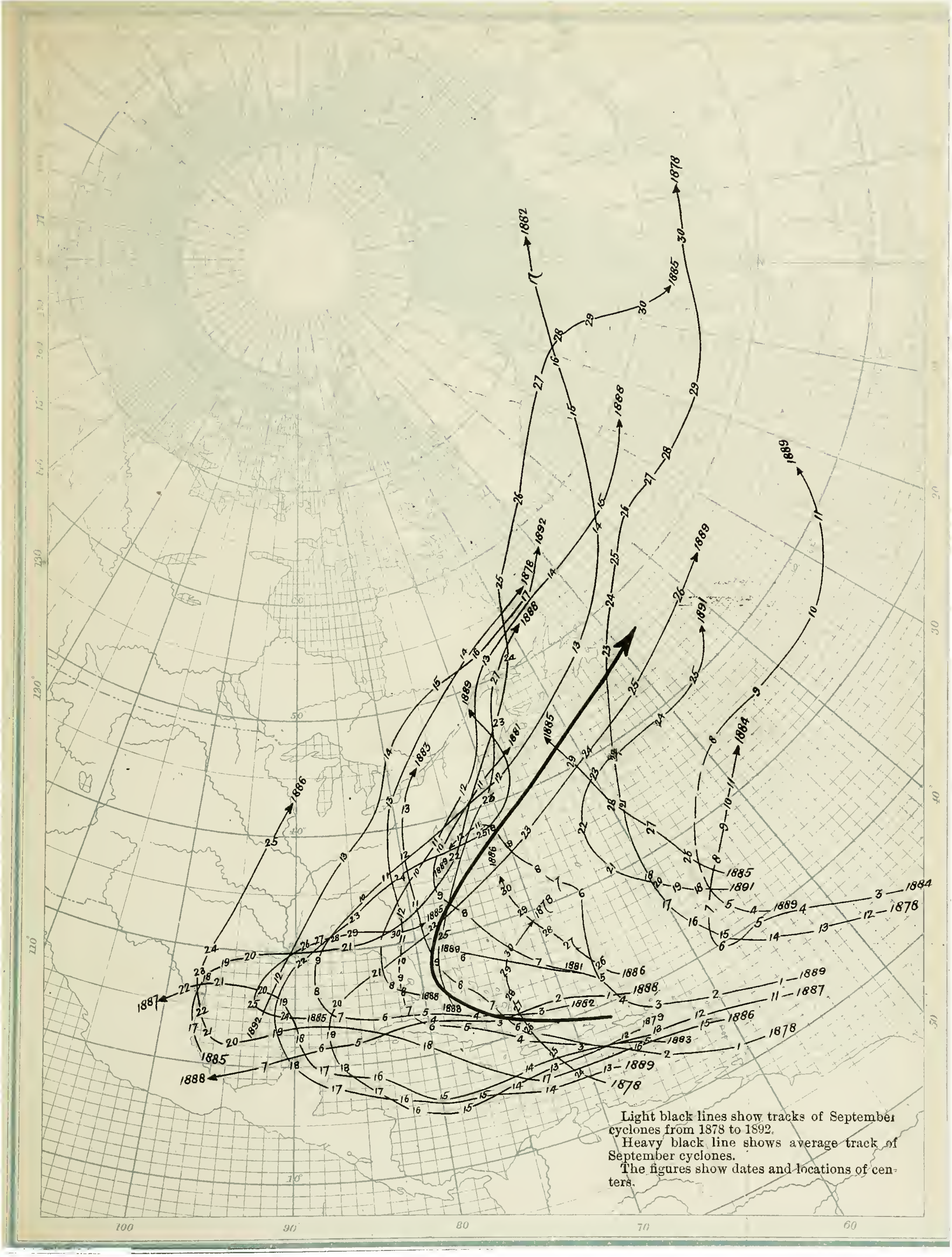
Chart IX. Comparison of the Total Sun Spot Areas, 1854–1895, with the European Magnetic Field, in the 26.68 day period.



Sun-Spot areas arranged in the 26.68 day Period.
1854-1895.

26.68 Days	Southern Hemisphere.						Northern Hemisphere.					
	Car.	Spö.	Gr.	W.	Sum.	Var.	Car.	Spö.	Gr.	W.	Sum.	Var.
1	504	526	341	0	1371	-394	417	699	531	0	1647	-93
2	367	788	477	90	1722	- 43	261	815	334	80	1490	-250
3	221	977	369	35	1602	-163	364	810	429	0	1603	-137
4	283	1174	428	30	1915	+150	562	943	509	30	2044	+304
5	275	877	311	75	1538	-227	470	764	371	5	1610	-130
6	362	604	653	30	1649	-116	390	921	371	30	1712	- 28
7	408	1117	430	125	2080	+315	400	1101	342	30	1873	+133
8	270	946	449	85	1750	- 15	348	1042	658	125	2173	+433
9	274	689	230	0	1193	-572	410	834	417	135	1796	+ 56
10	398	724	273	40	1435	-330	425	1251	300	55	2031	+291
11	159	677	309	100	1245	-520	405	1035	332	80	1852	+112
12	356	872	282	150	1660	-105	398	806	598	55	1857	+117
13	316	977	487	0	1780	+ 15	378	825	236	25	1464	-276
14	347	955	510	75	1887	+122	249	738	210	0	1197	-543
15	584	1092	620	10	2306	+541	317	850	643	30	1840	+100
16	278	842	519	30	1669	- 96	272	1072	388	40	1772	+ 32
17	383	794	653	50	1880	+115	281	883	356	40	1560	-180
18	215	833	535	75	1658	-107	452	811	674	70	2007	+267
19	233	1033	561	0	1887	+122	450	558	531	32	1571	-169
20	388	1004	667	30	2089	+324	311	707	376	50	1444	-296
21	323	919	711	59	2011	+246	384	986	376	120	1866	+126
22	344	1005	857	80	2286	+521	240	962	415	145	1762	+ 22
23	327	833	698	80	1938	+173	310	1027	332	70	1739	- 1
24	415	968	435	35	1853	+ 88	515	966	409	70	1960	+220
25	326	1026	300	47	1699	- 66	415	922	362	45	1744	+ 4
26	223	1010	959	35	2227	+462	292	914	536	15	1757	+17
27	191	700	437	0	1328	-437	212	720	599	80	1611	-129
				Mean -	1765					Mean -	1740	

Chart VII. Tracks of Cyclones in September.



Light black lines show tracks of September cyclones from 1878 to 1892.

Heavy black line shows average track of September cyclones.

The figures show dates and locations of centers.

High Areas of the North Pacific Coast Region and their Associated Phenomena.

Chart VI. September.

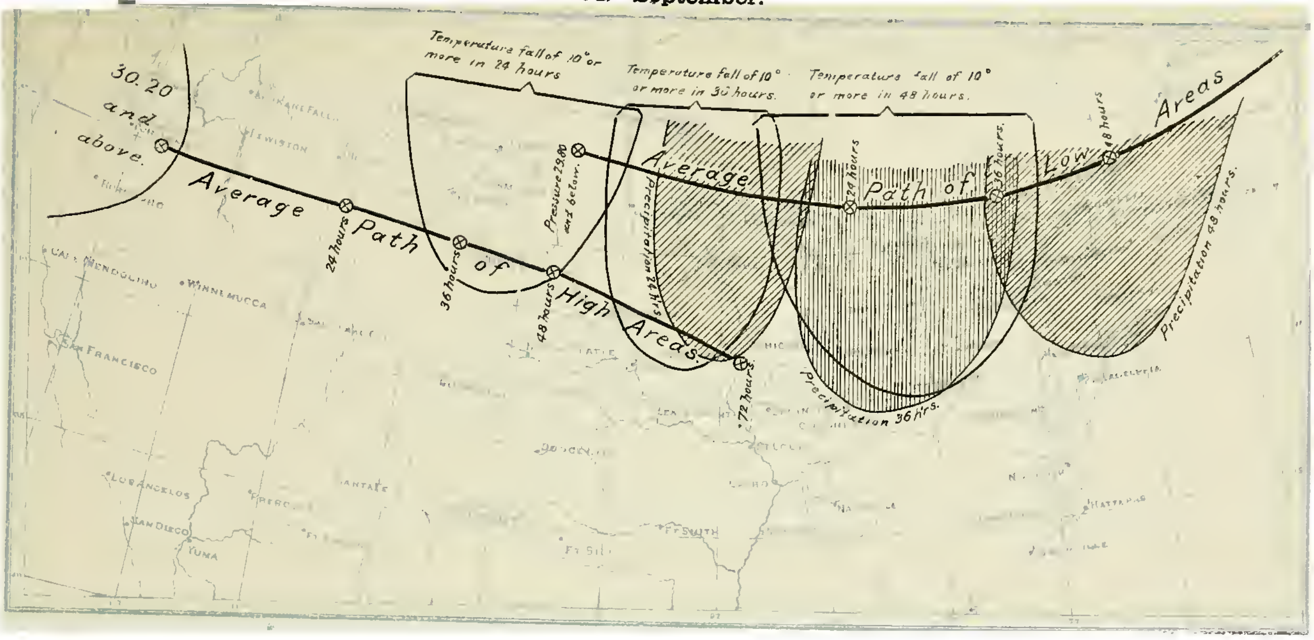


Chart VII. October.

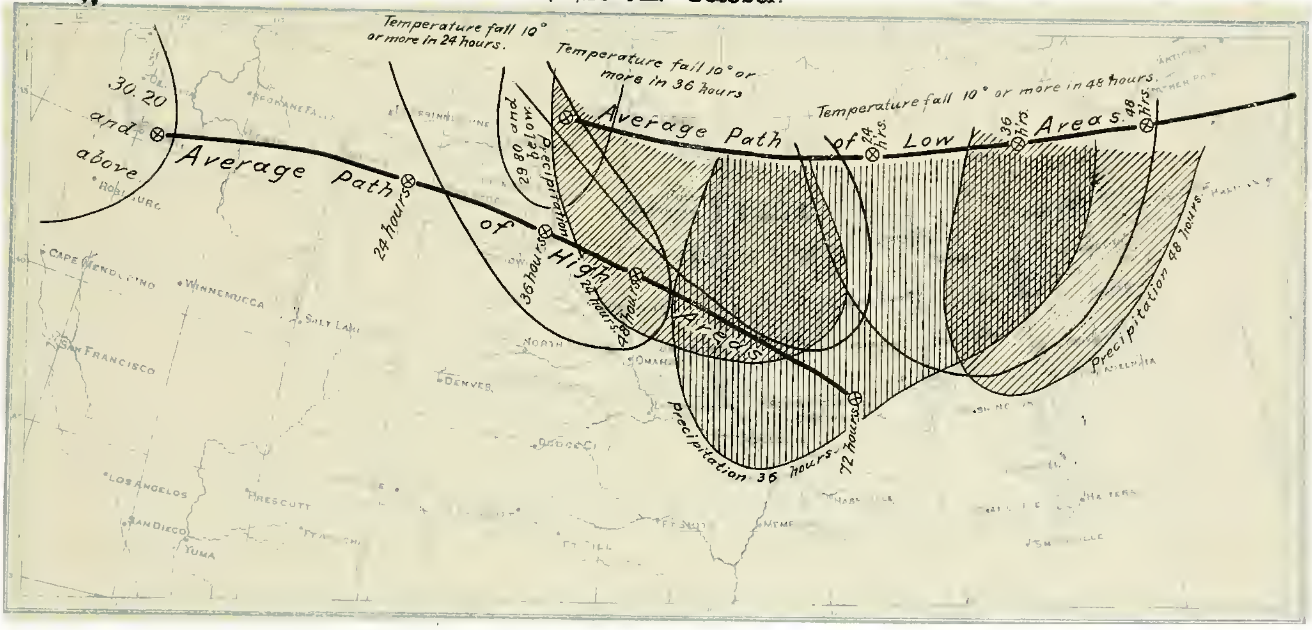
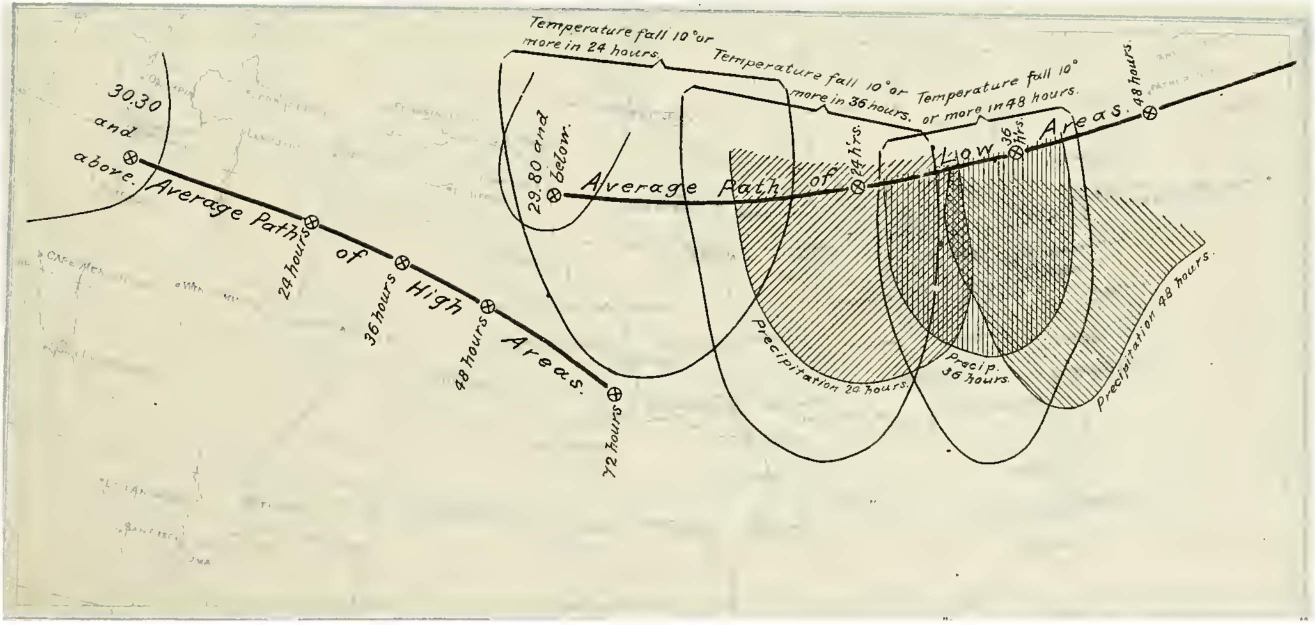


Chart VIII. November.



MIDDLE ATLANTIC AND NEW ENGLAND STATES.

CHART 1.

JANUARY.

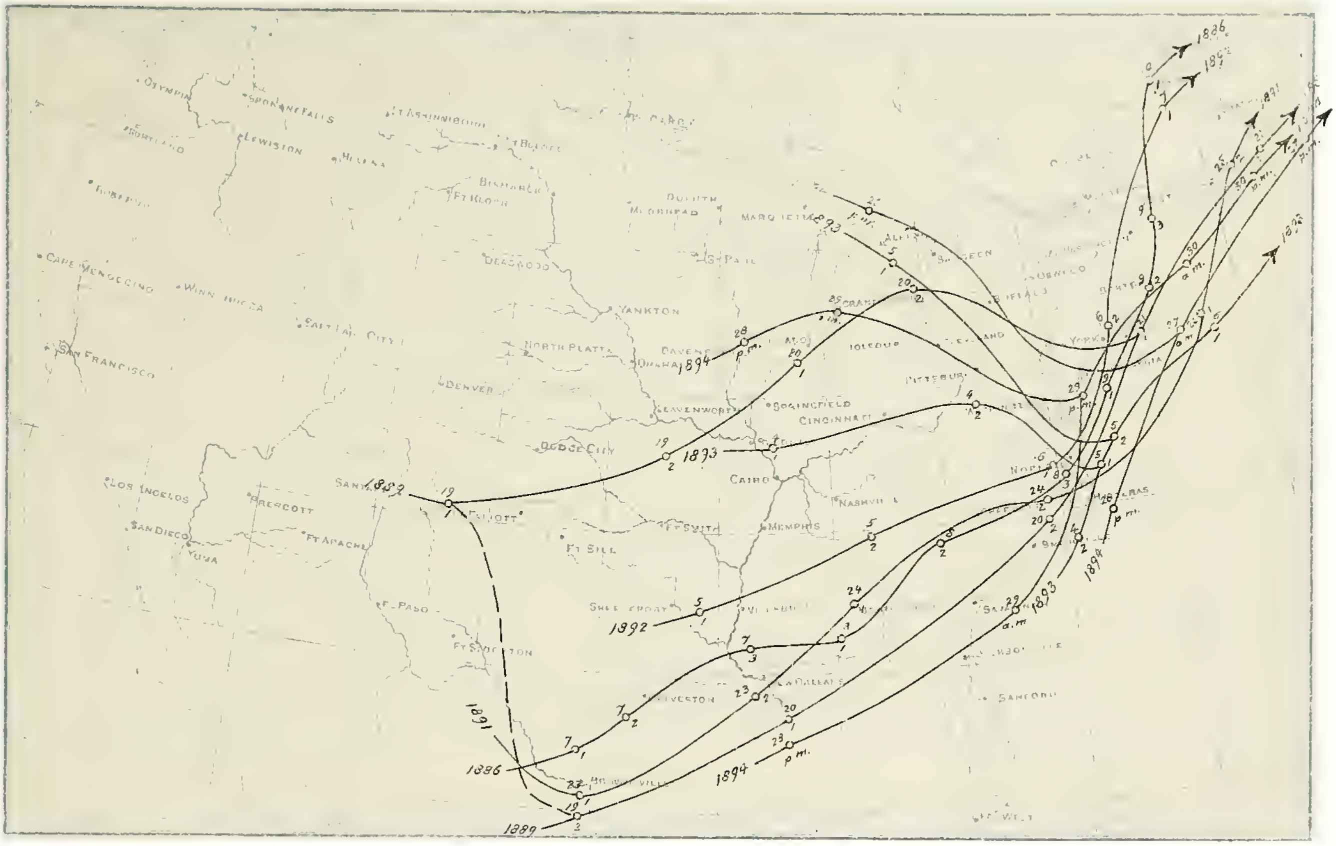
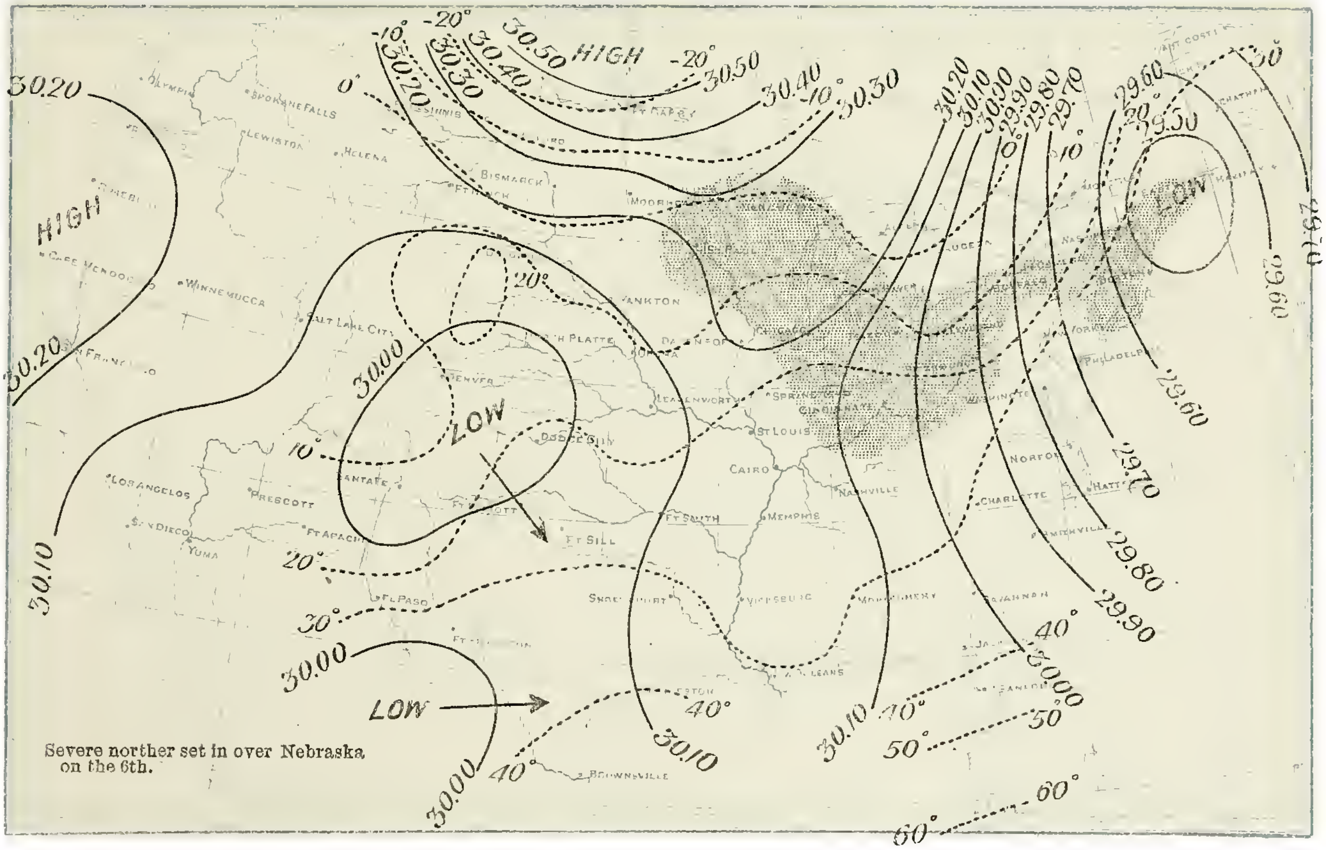


CHART 2.

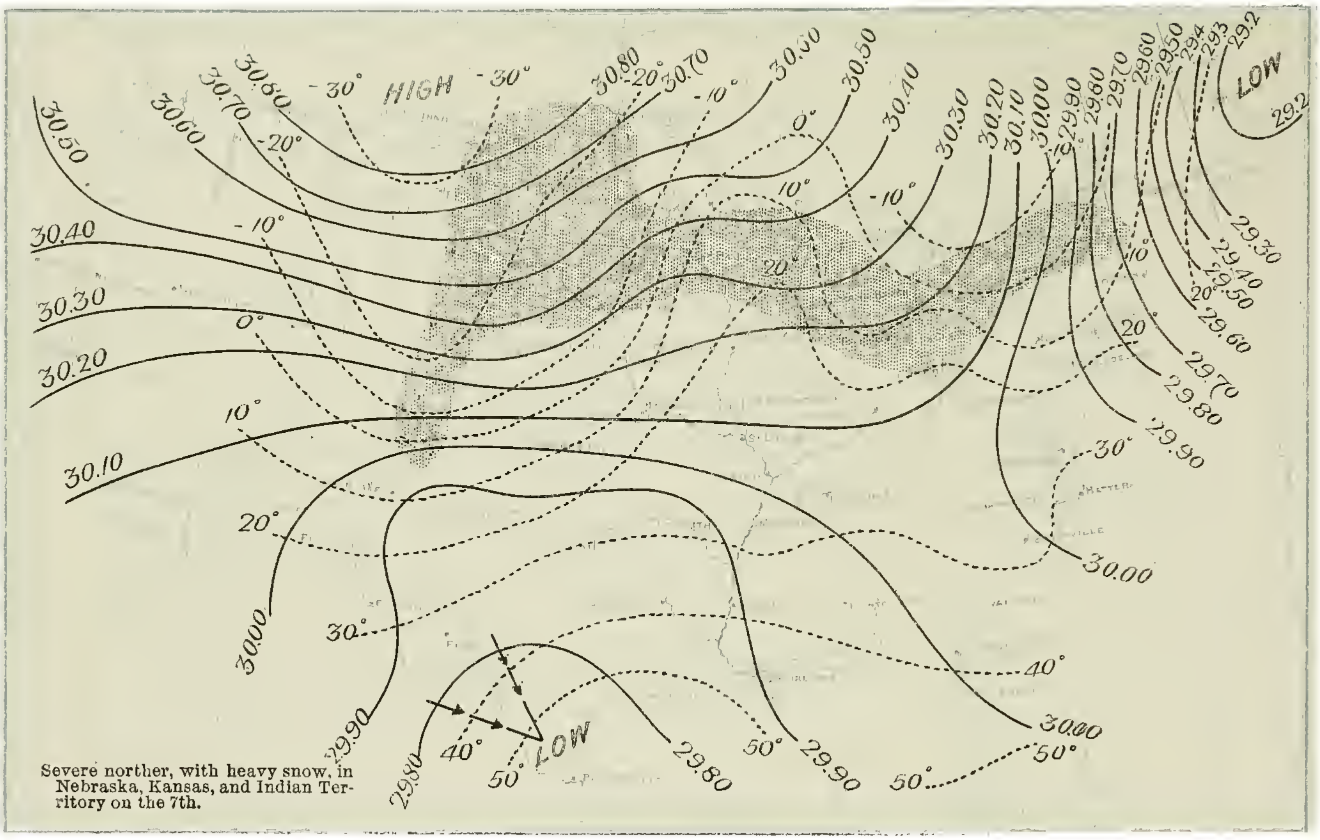
January 6, 1886—7 a. m.



Severe norther set in over Nebraska on the 6th.

CHART 3.

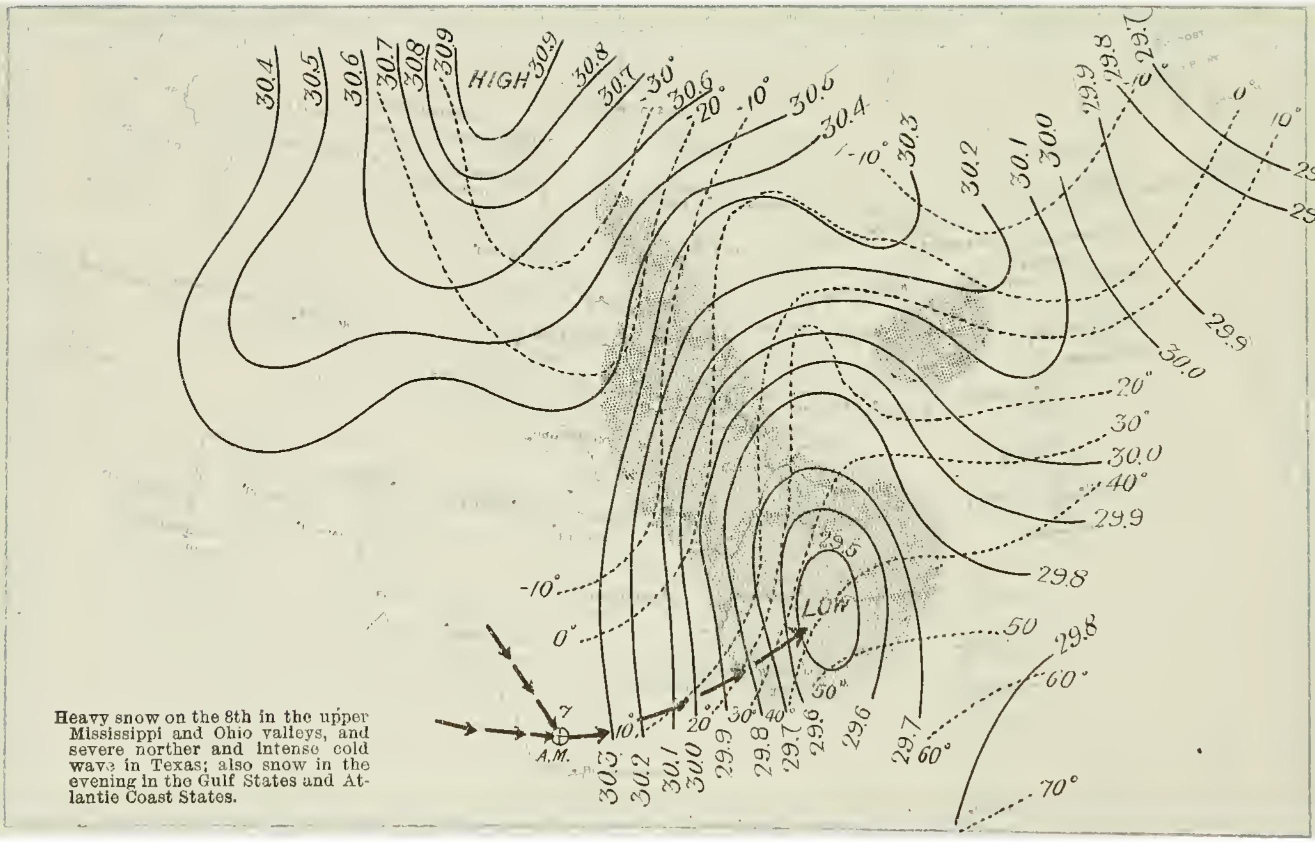
January 7, 1886—7 a. m.



Severe norther, with heavy snow, in Nebraska, Kansas, and Indian Territory on the 7th.

CHART 4.

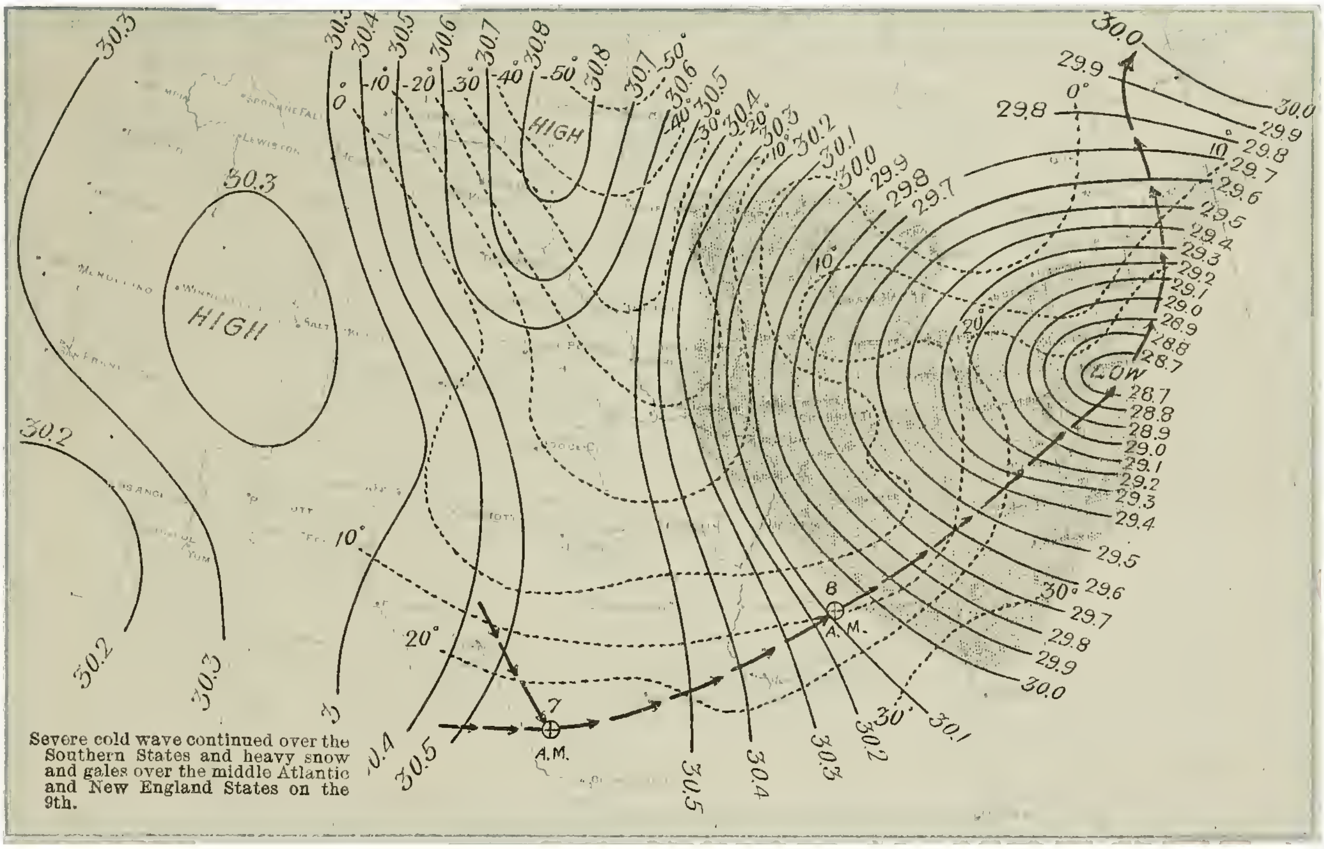
January 8, 1886—7 a. m.



Heavy snow on the 8th in the upper Mississippi and Ohio valleys, and severe norther and intense cold wave in Texas; also snow in the evening in the Gulf States and Atlantic Coast States.

CHART 5.

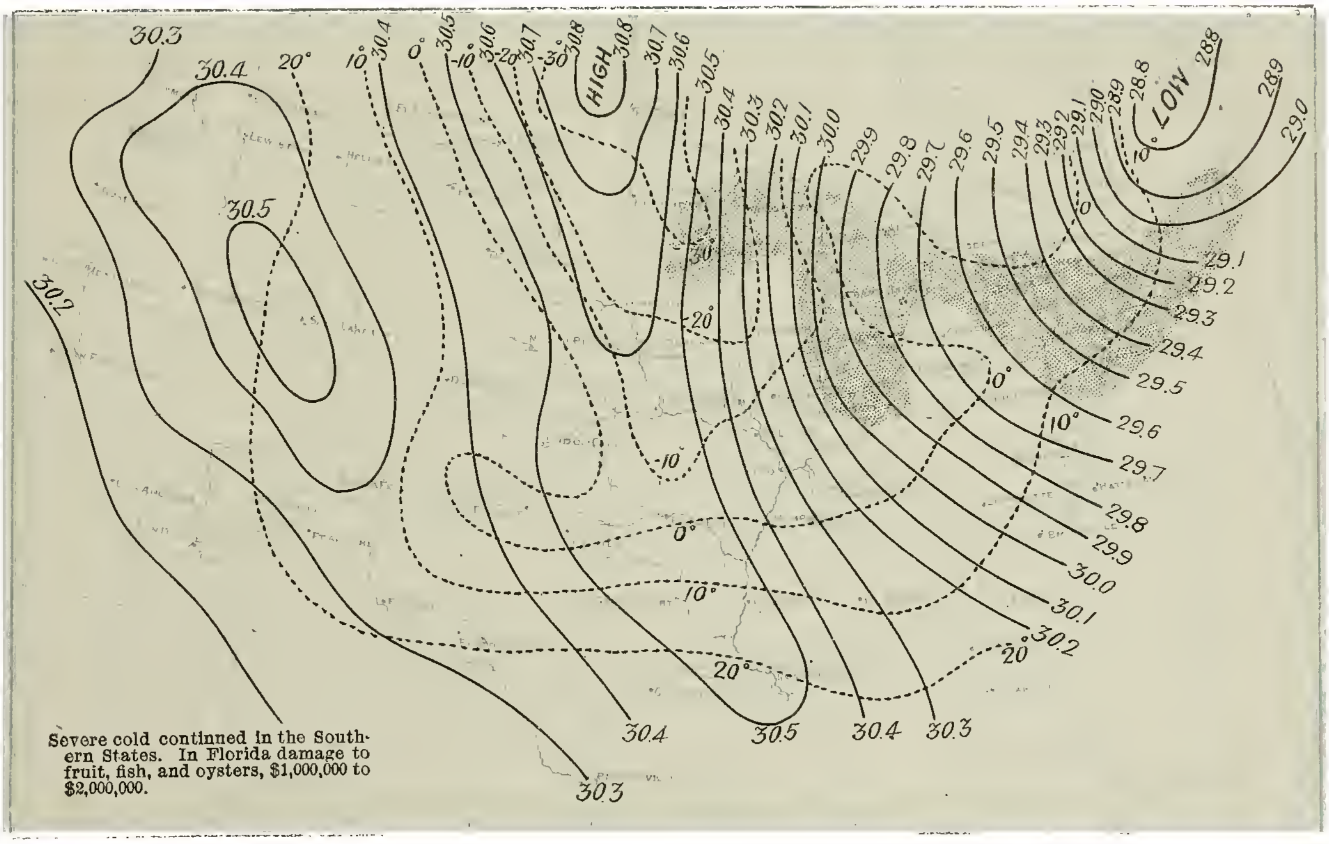
January 9, 1886—7 a. m.



Severe cold wave continued over the Southern States and heavy snow and gales over the middle Atlantic and New England States on the 9th.

CHART 6.

January 10, 1886—7 a. m.



Severe cold continued in the Southern States. In Florida damage to fruit, fish, and oysters, $1,000,000 to $2,000,000.

CHART 7. January 19, 1889—8 a. m.

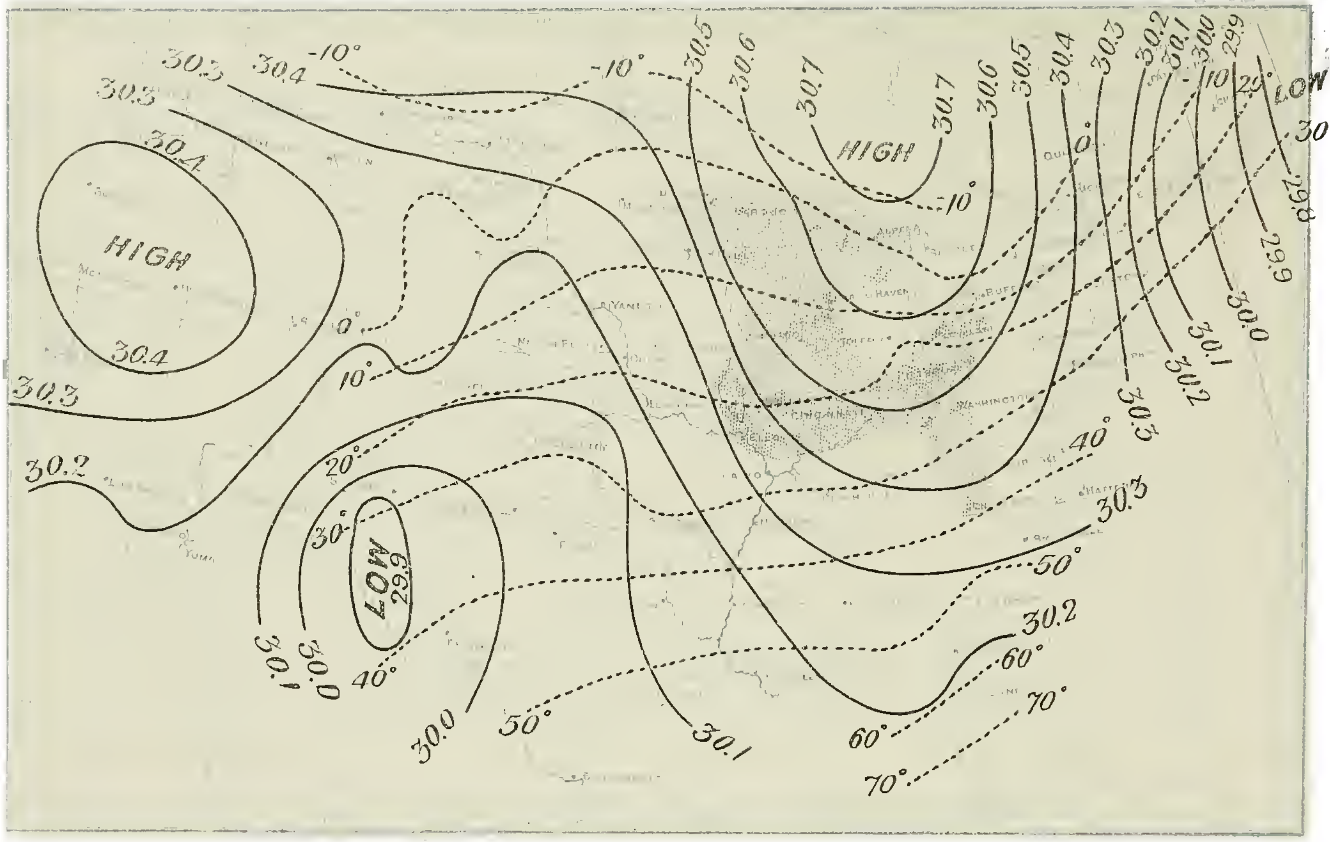
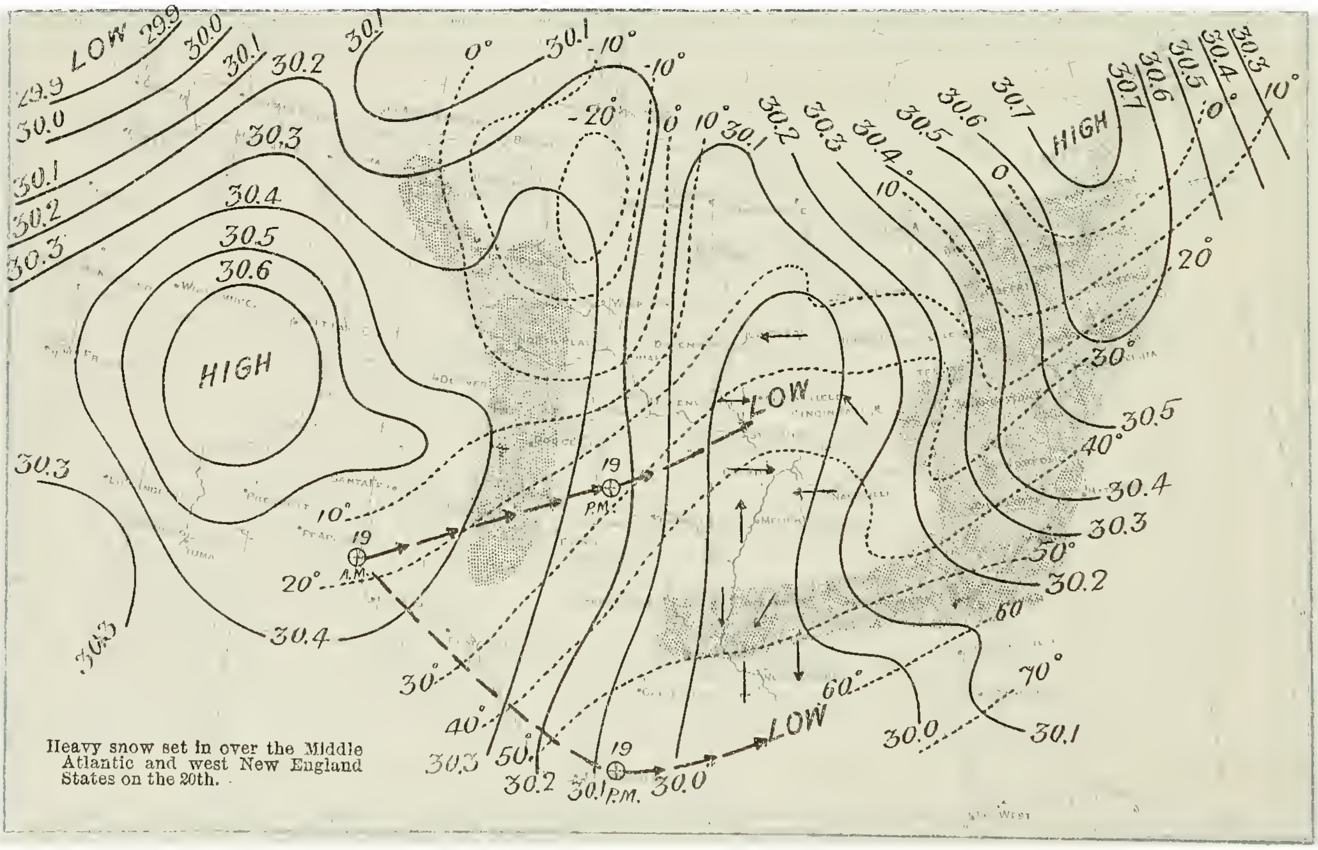
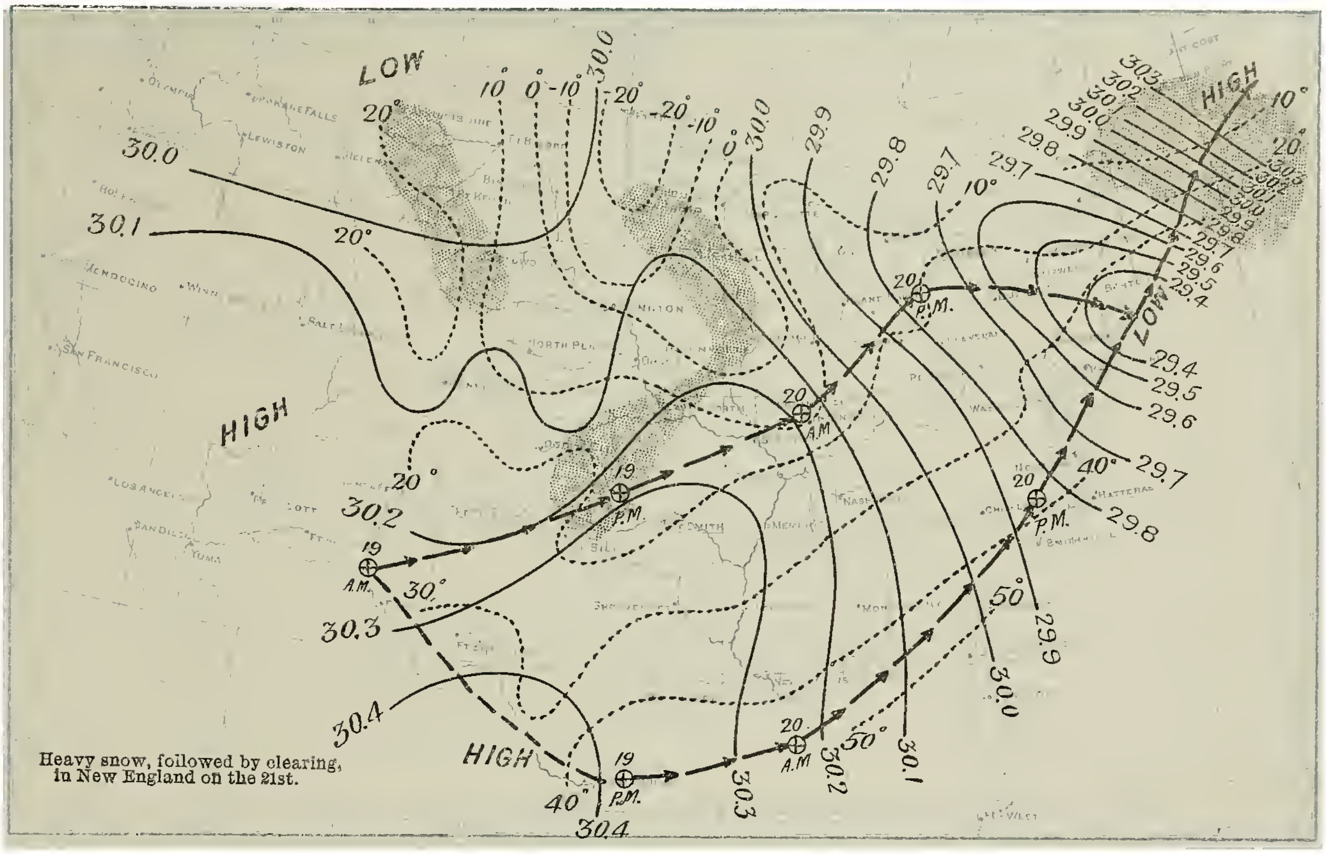


CHART 8. January 20, 1889—8 a. m.



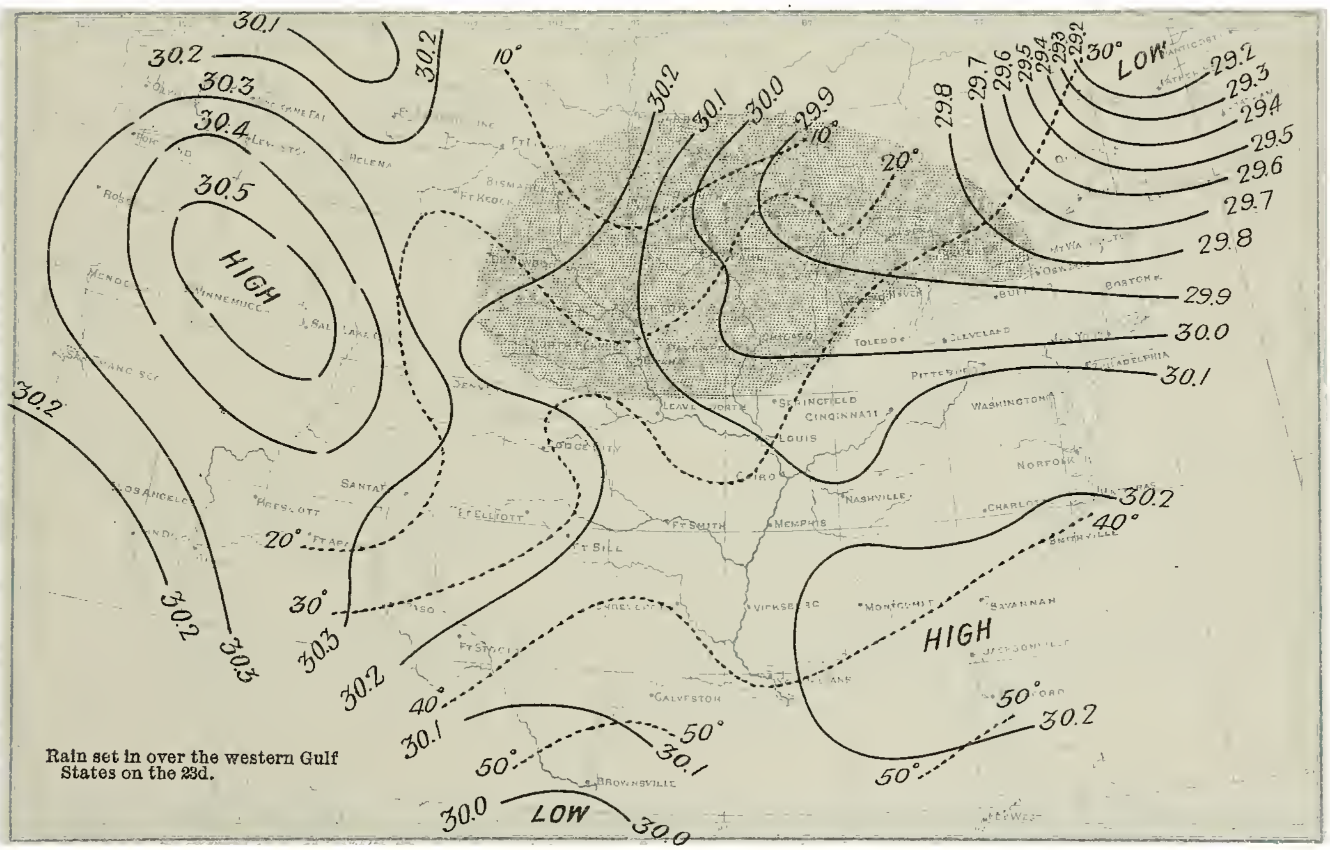
Heavy snow set in over the Middle Atlantic and west New England States on the 20th.

CHART 9. January 21, 1889—8 a. m.



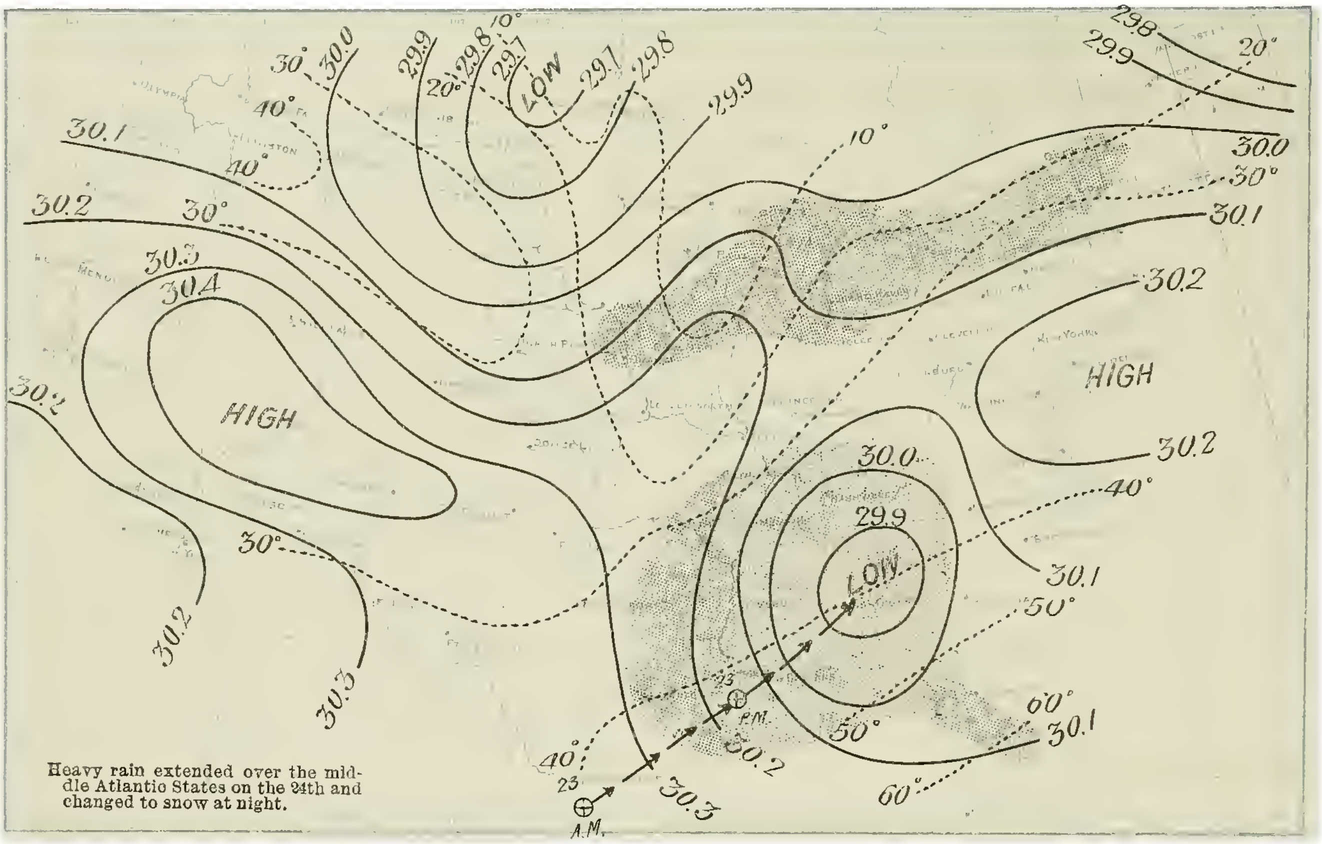
Heavy snow, followed by clearing, in New England on the 21st.

CHART 10. January 23, 1891—8 a. m.



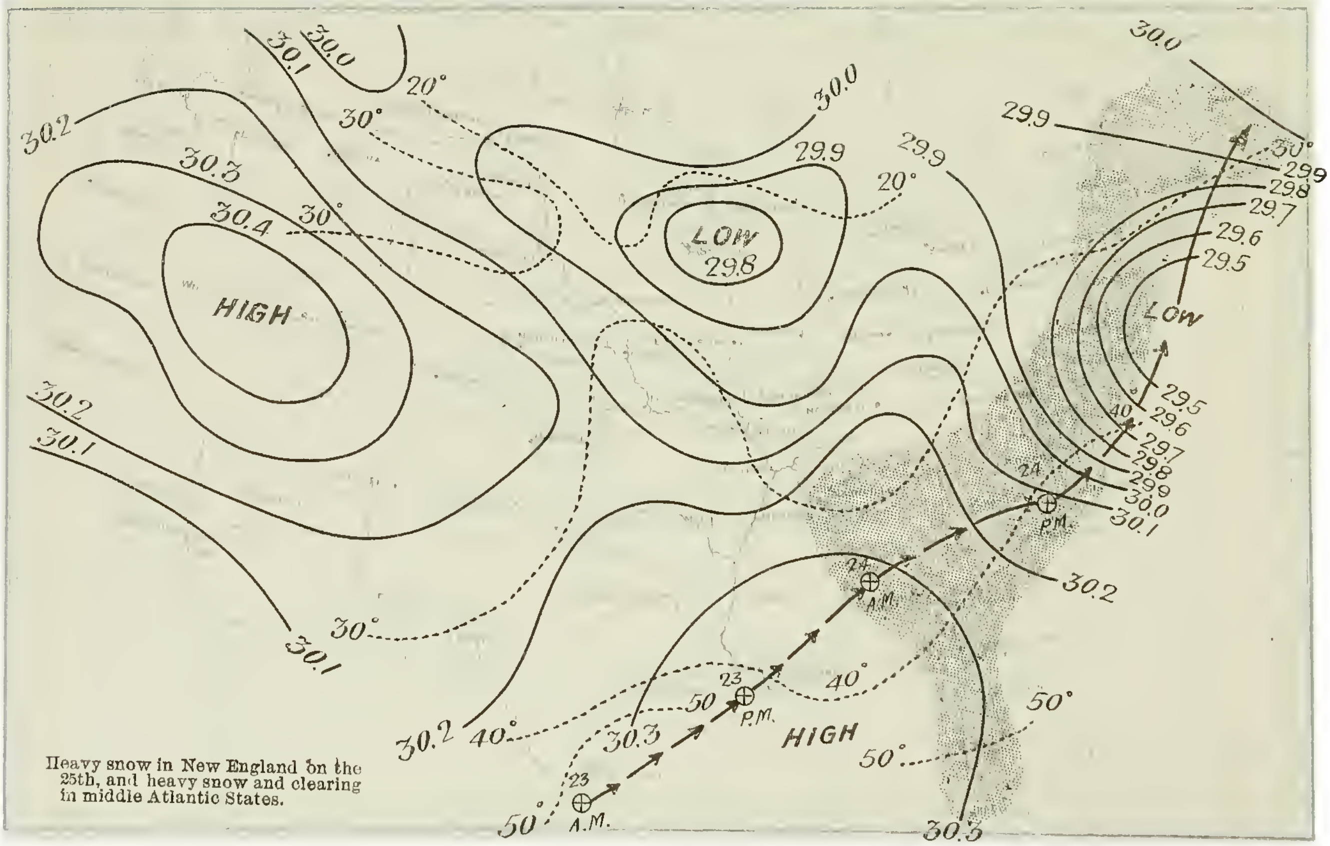
Rain set in over the western Gulf States on the 23d.

CHART 11. January 24, 1891—8 a. m.



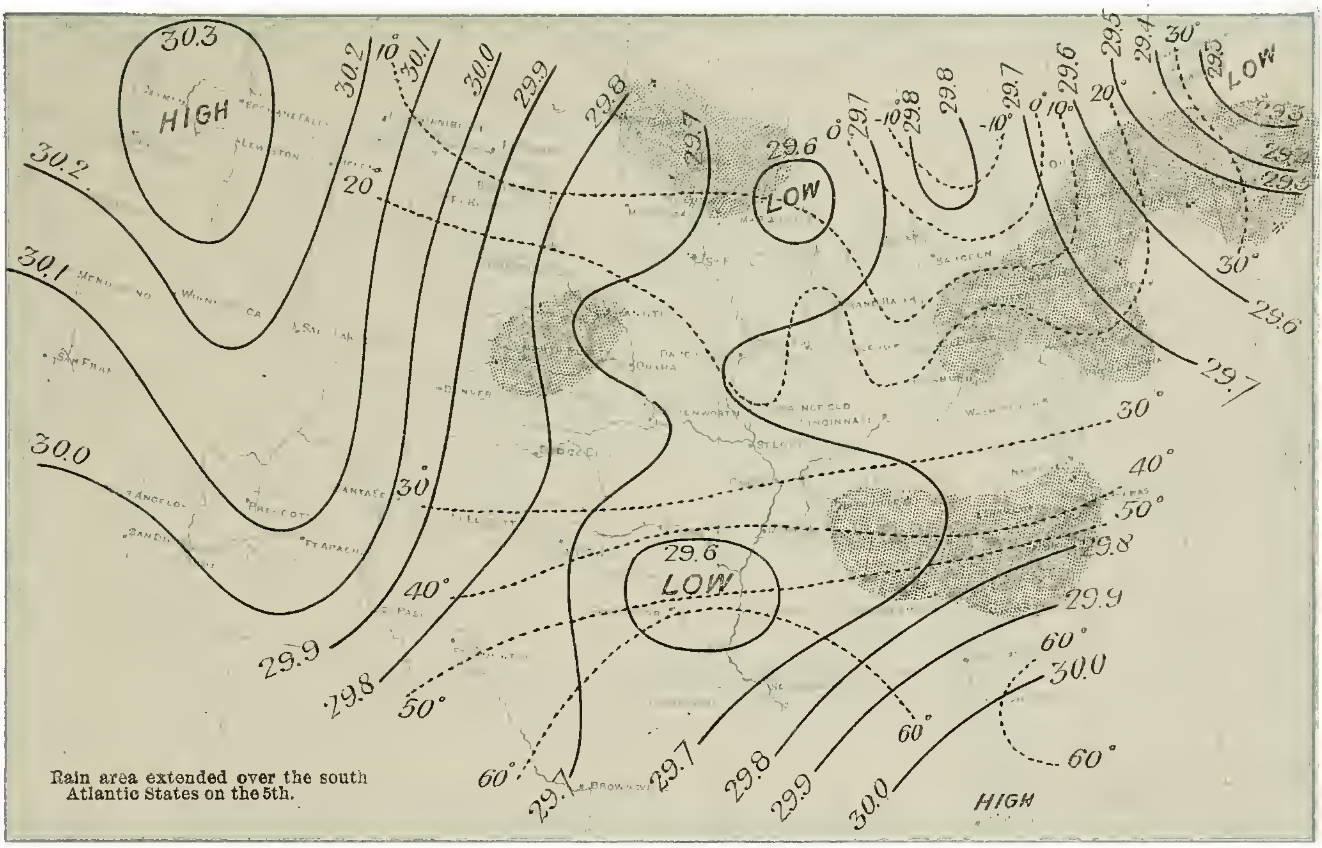
Heavy rain extended over the middle Atlantic States on the 24th and changed to snow at night.

CHART 12. January 25, 1891—8 a. m.



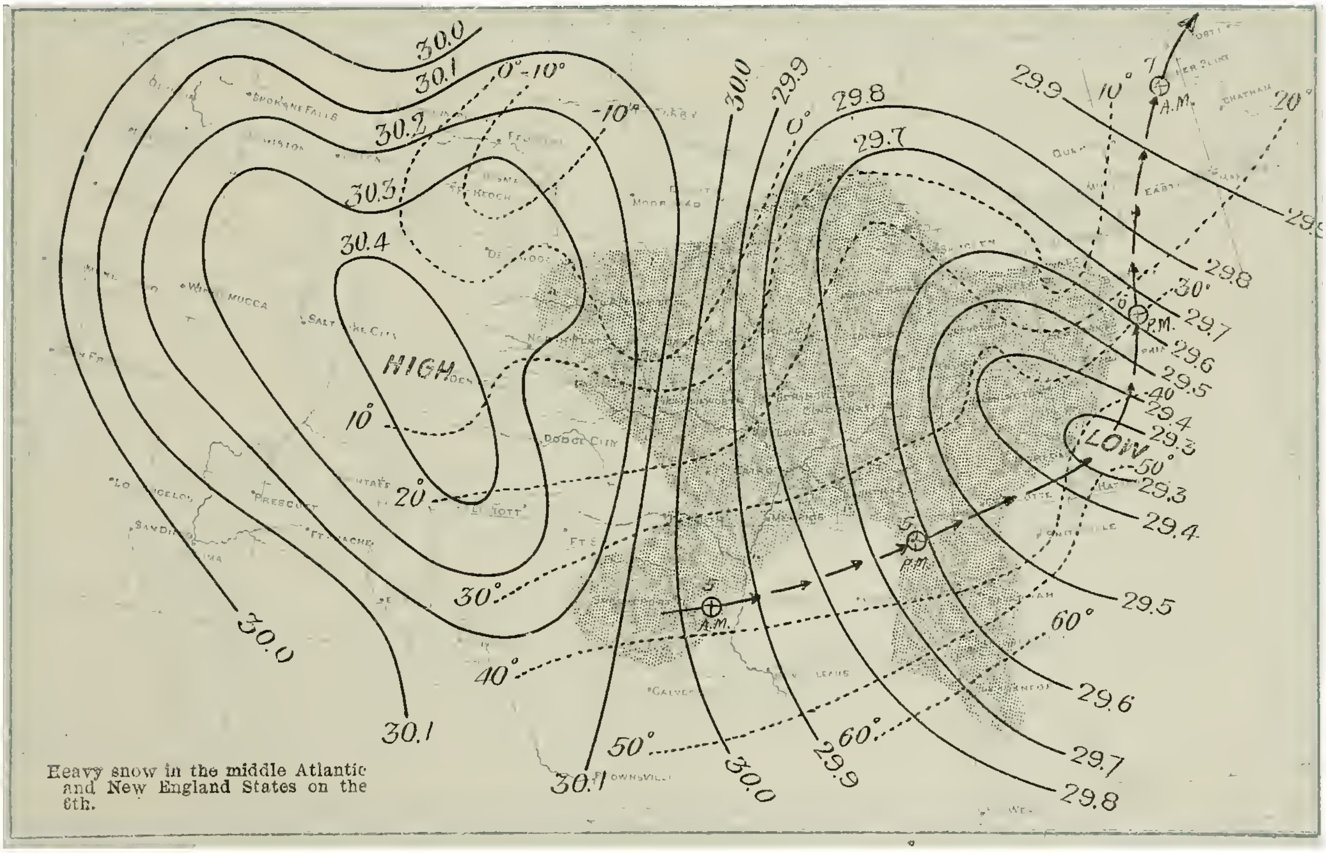
Heavy snow in New England on the 25th, and heavy snow and clearing in middle Atlantic States.

CHART 13. January 5, 1892—8 a. m.



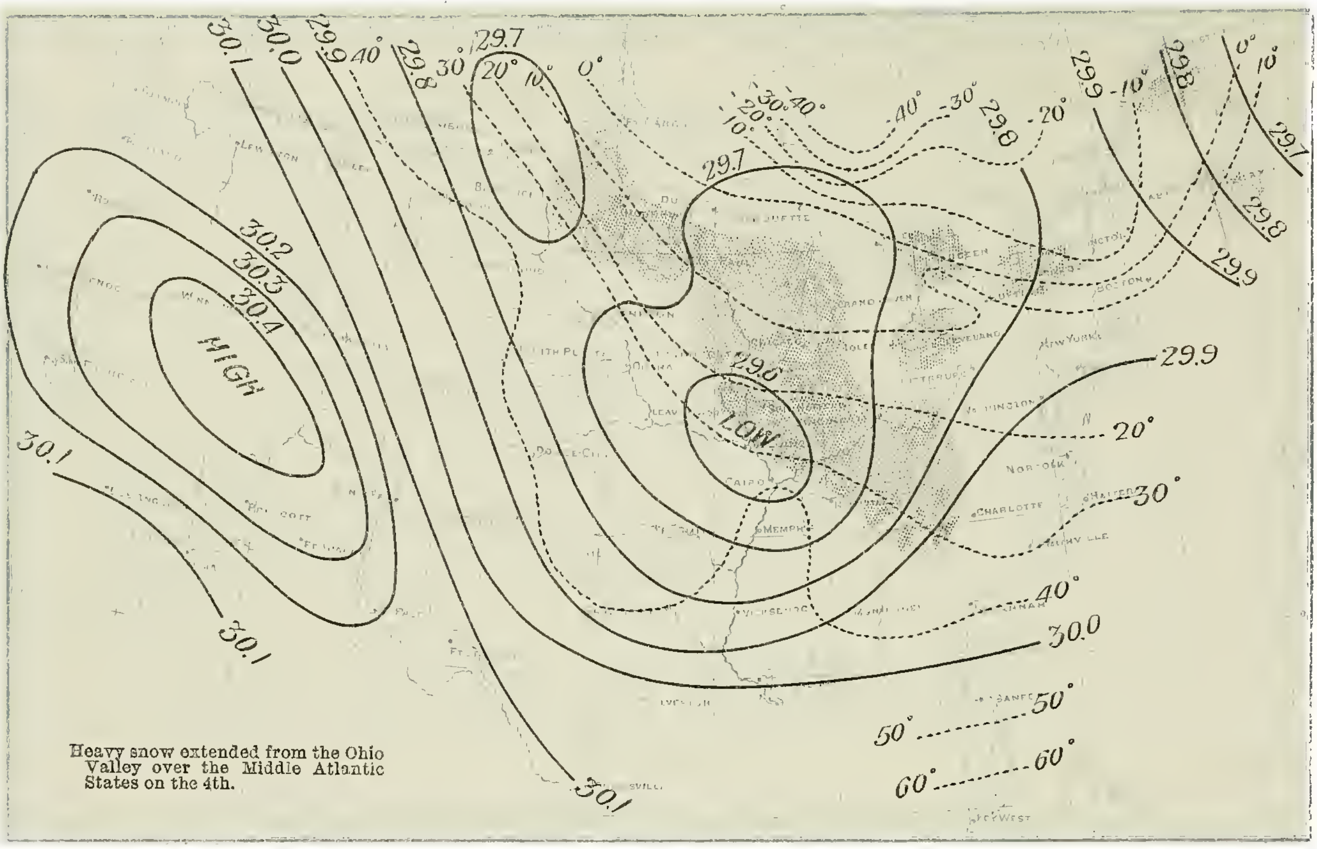
Rain area extended over the south Atlantic States on the 5th.

CHART 14. January 6, 1892—8 a. m.



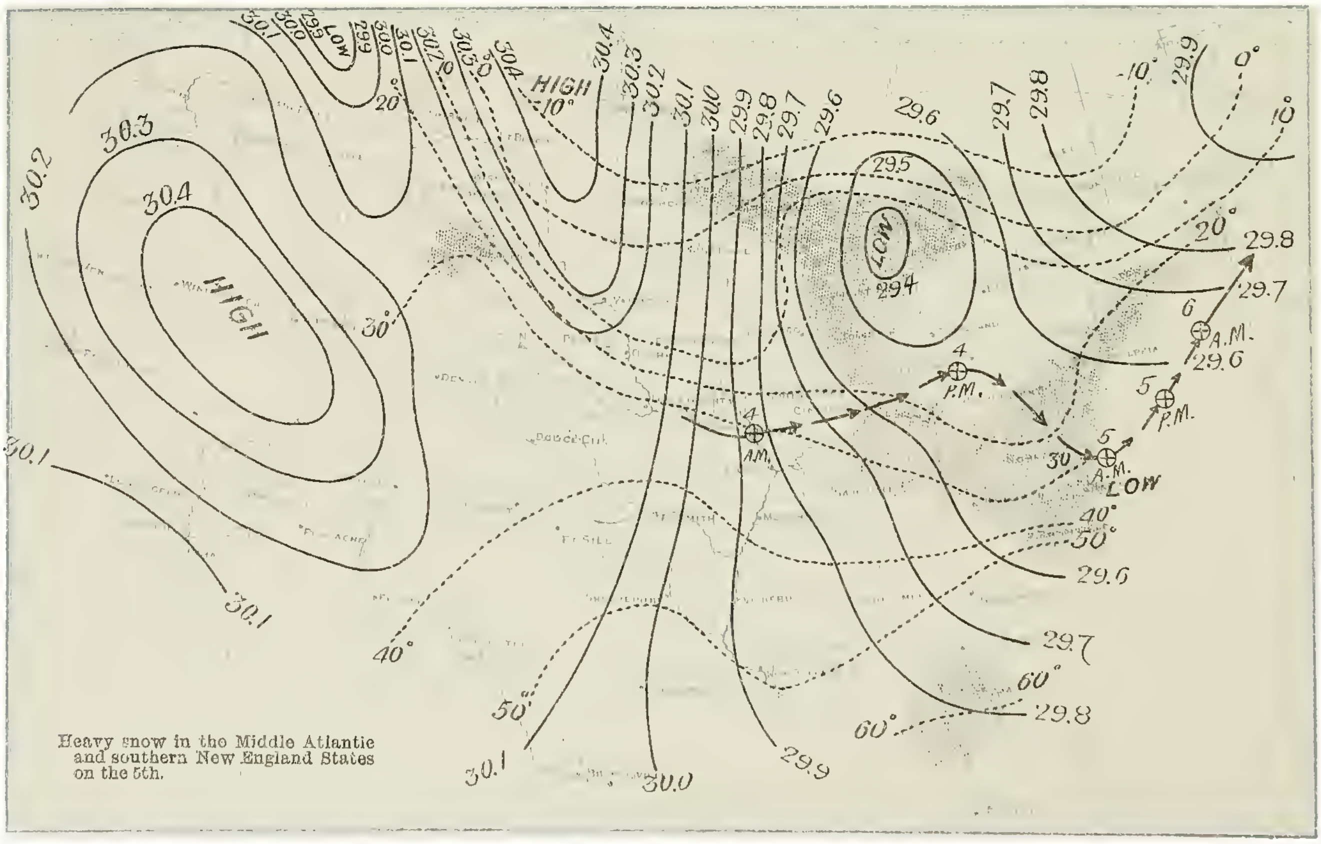
Heavy snow in the middle Atlantic and New England States on the 6th.

CHART 15. January 4, 1893—8 a. m.



Heavy snow extended from the Ohio Valley over the Middle Atlantic States on the 4th.

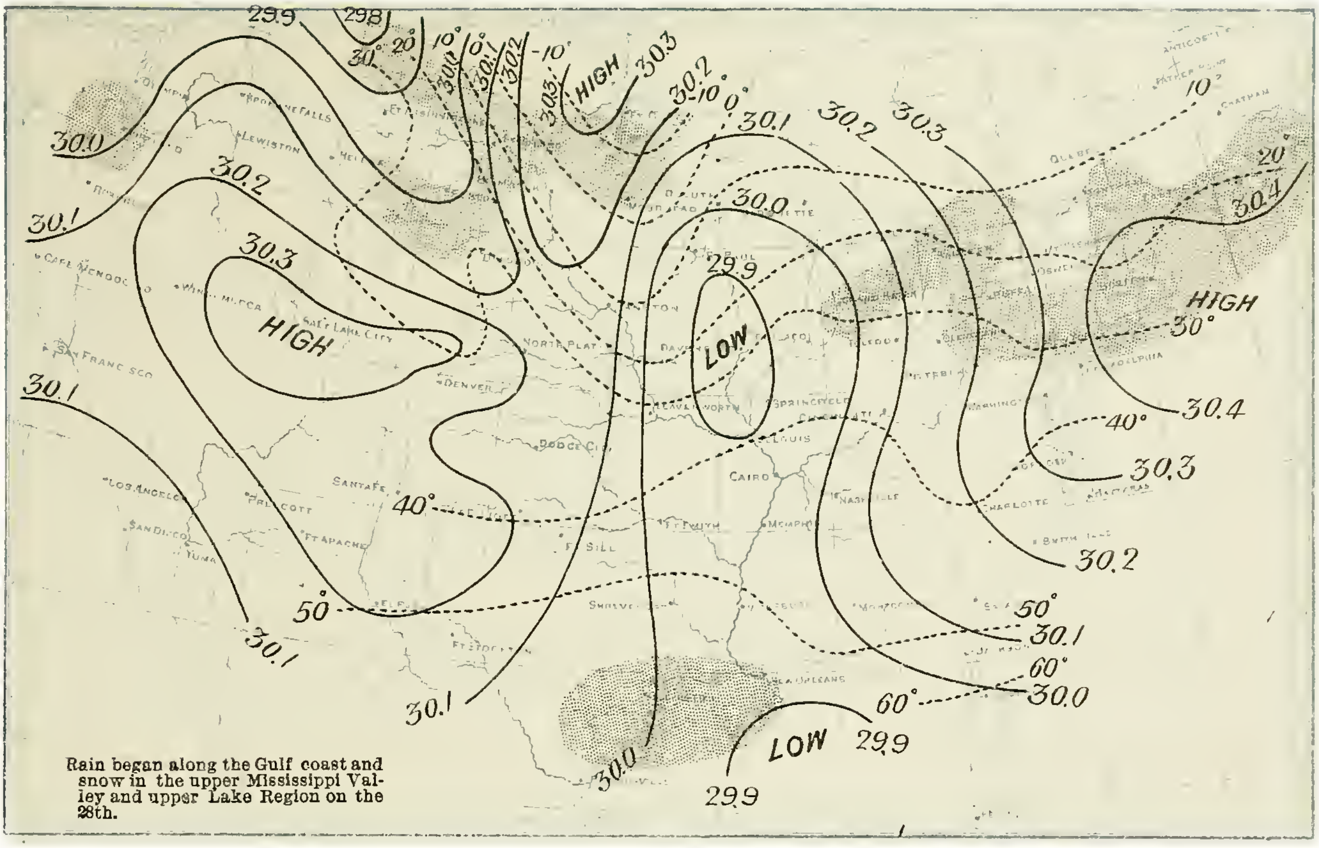
CHART 16. January 5, 1893—8 a. m.



Heavy snow in the Middle Atlantic and southern New England States on the 5th.

CHART 17

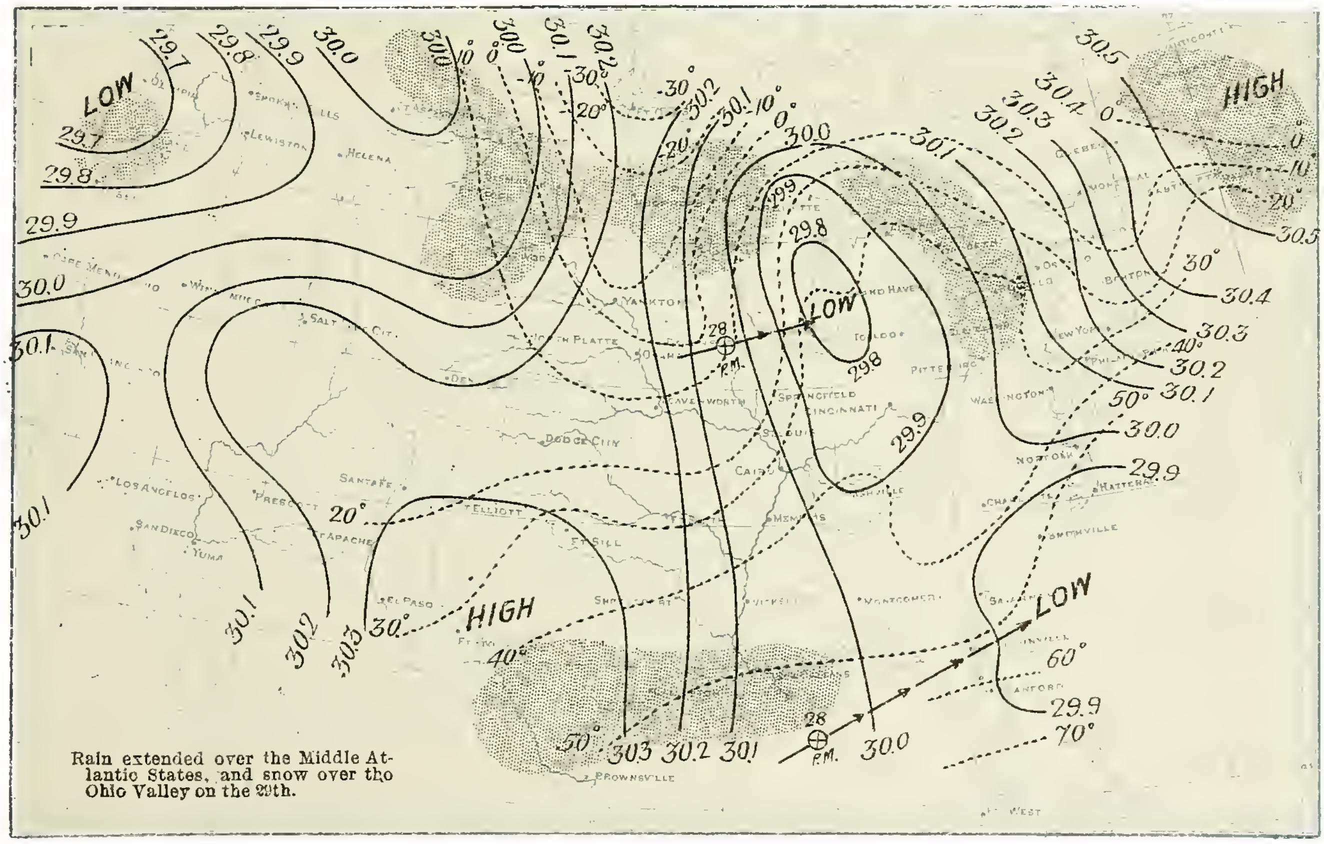
January 28, 1894—8 p. m.



Rain began along the Gulf coast and snow in the upper Mississippi Valley and upper Lake Region on the 28th.

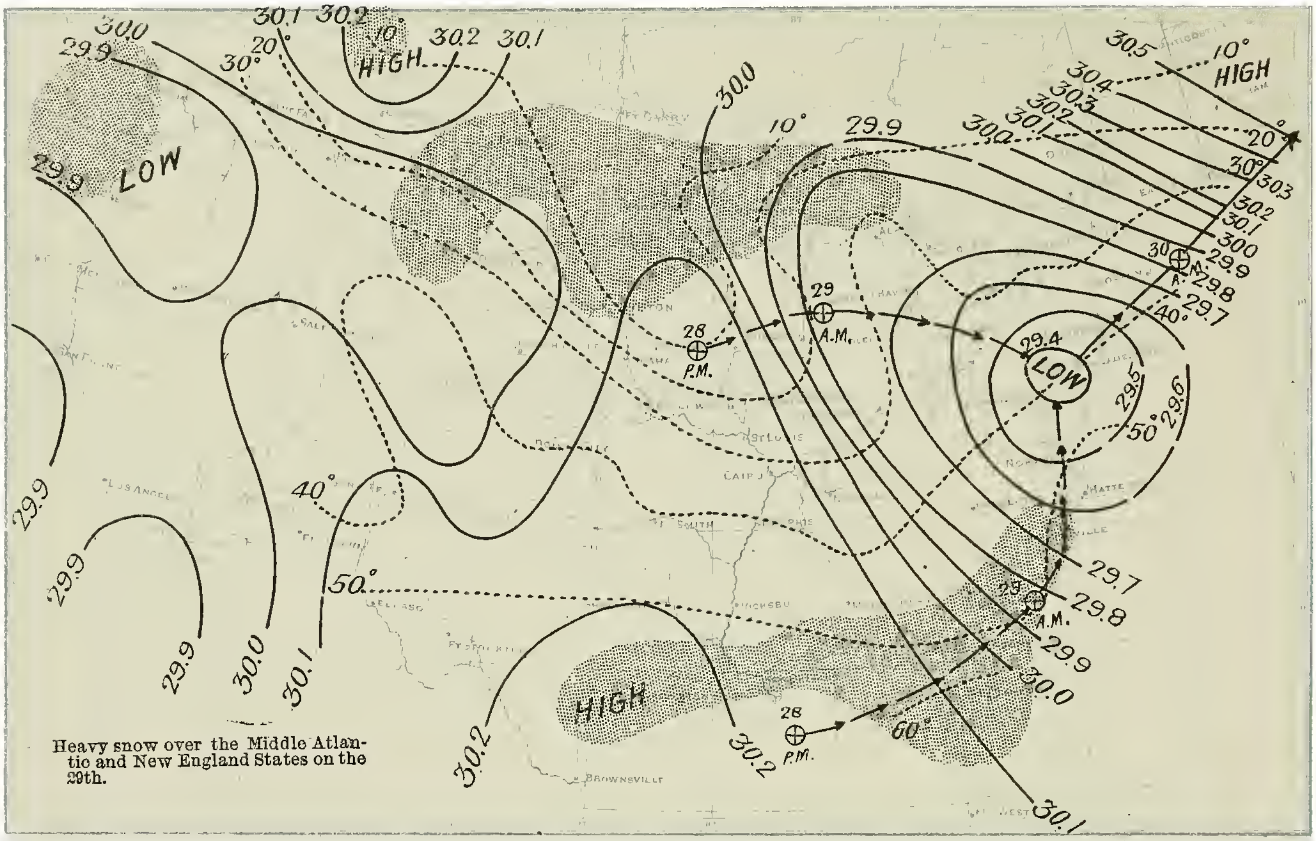
CHART 18.

January 29, 1894—8 a. m.



Rain extended over the Middle Atlantic States, and snow over the Ohio Valley on the 29th.

CHART 19. January 29, 1894—8 p. m.



Heavy snow over the Middle Atlantic and New England States on the 29th.

CHART 20. SOUTHEASTERN STATES.

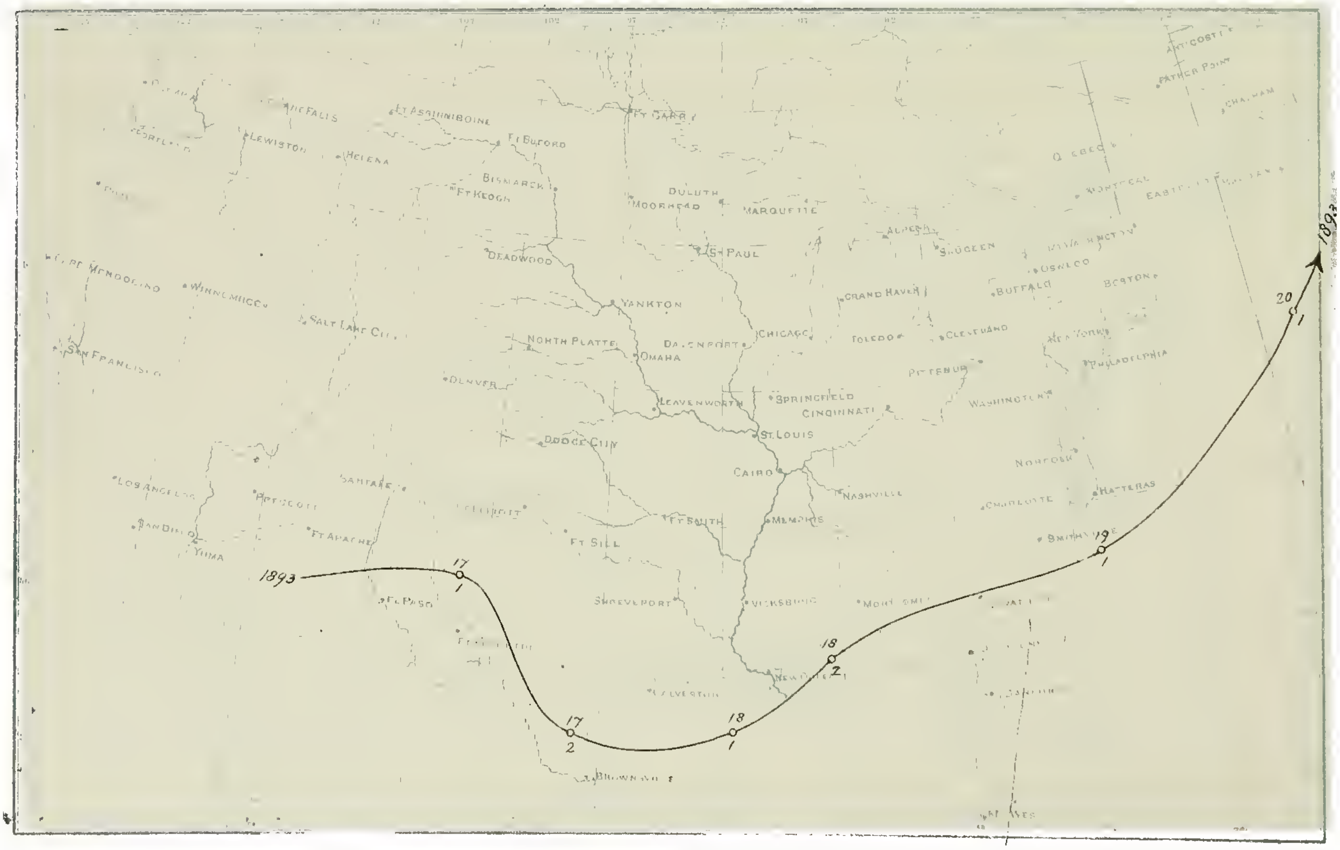
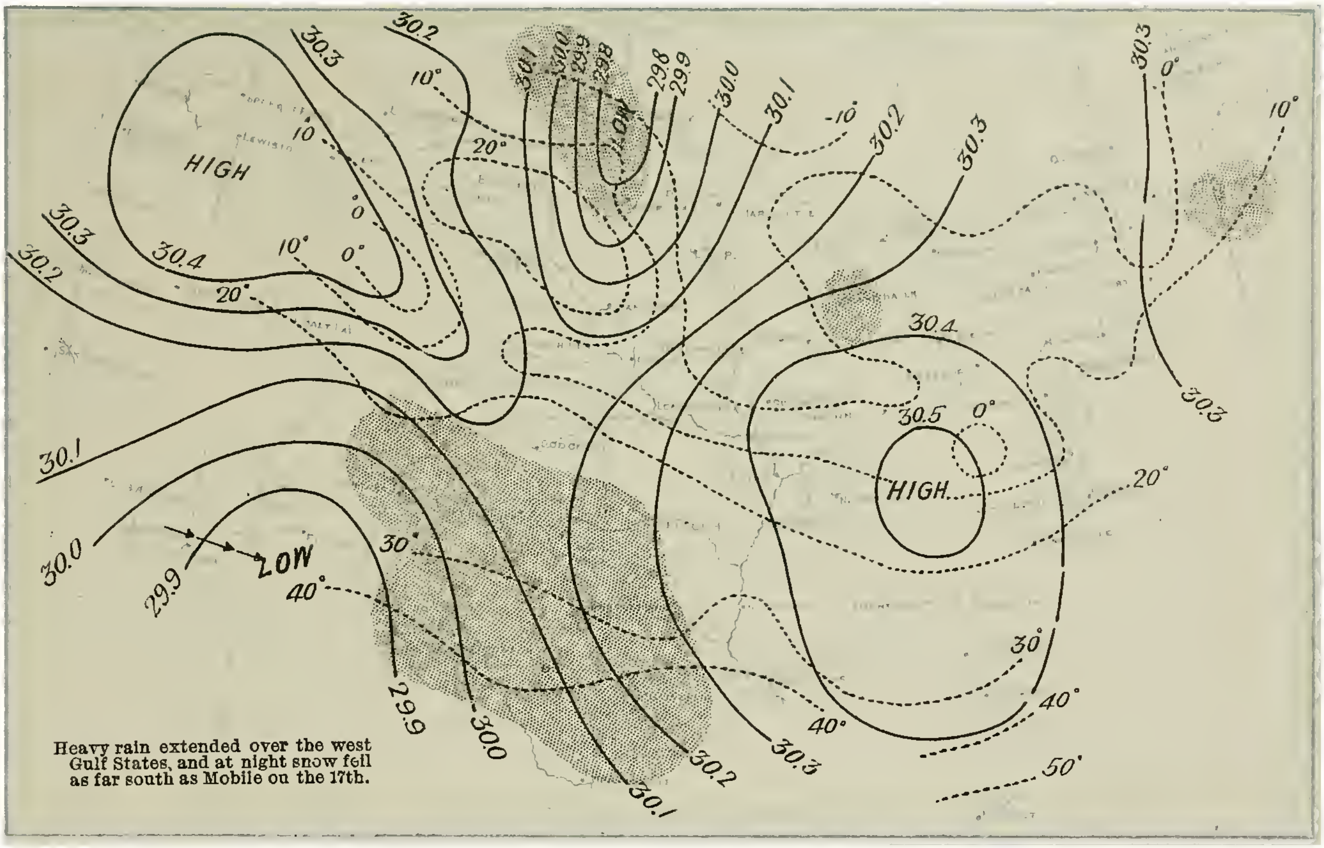
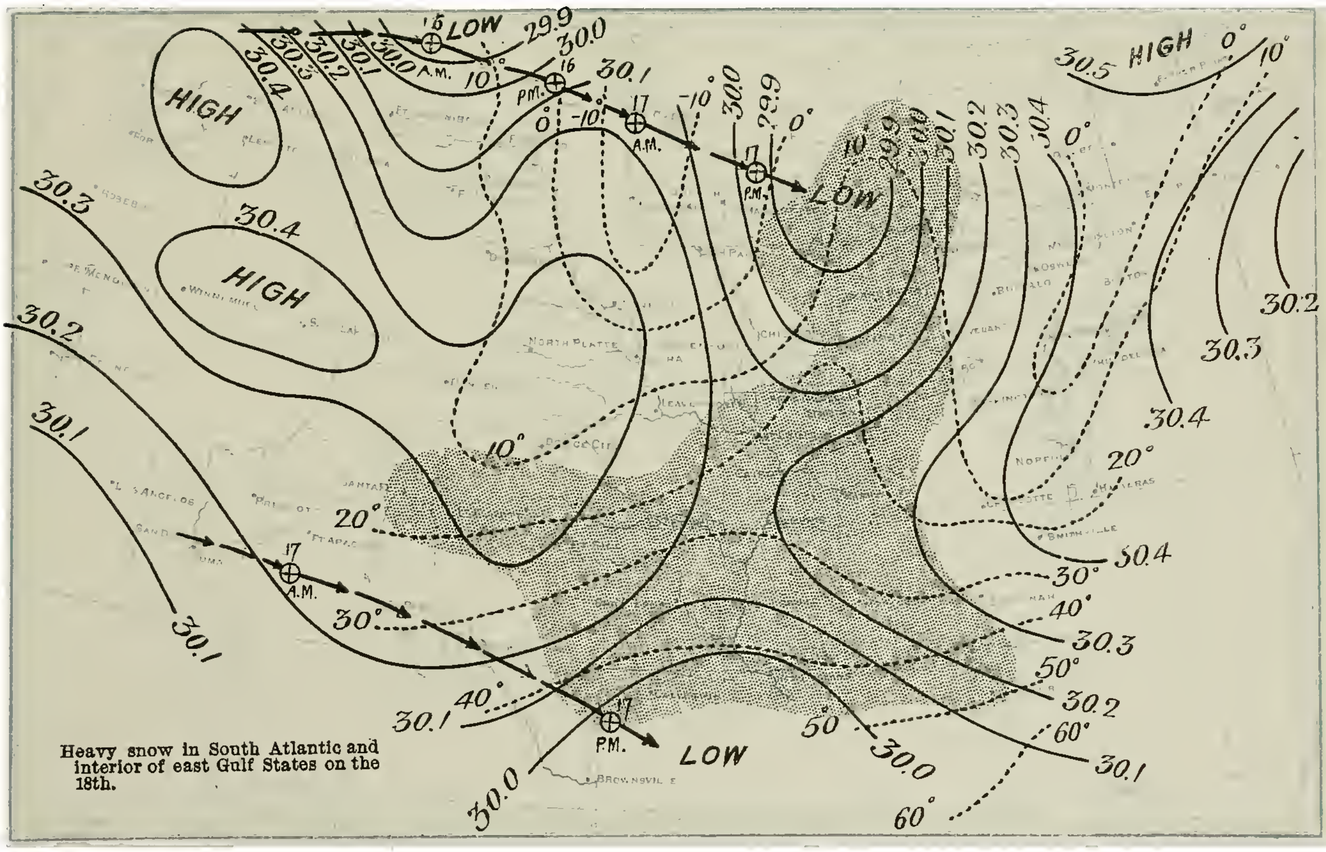


CHART 21. January 17, 1893—8 a. m.



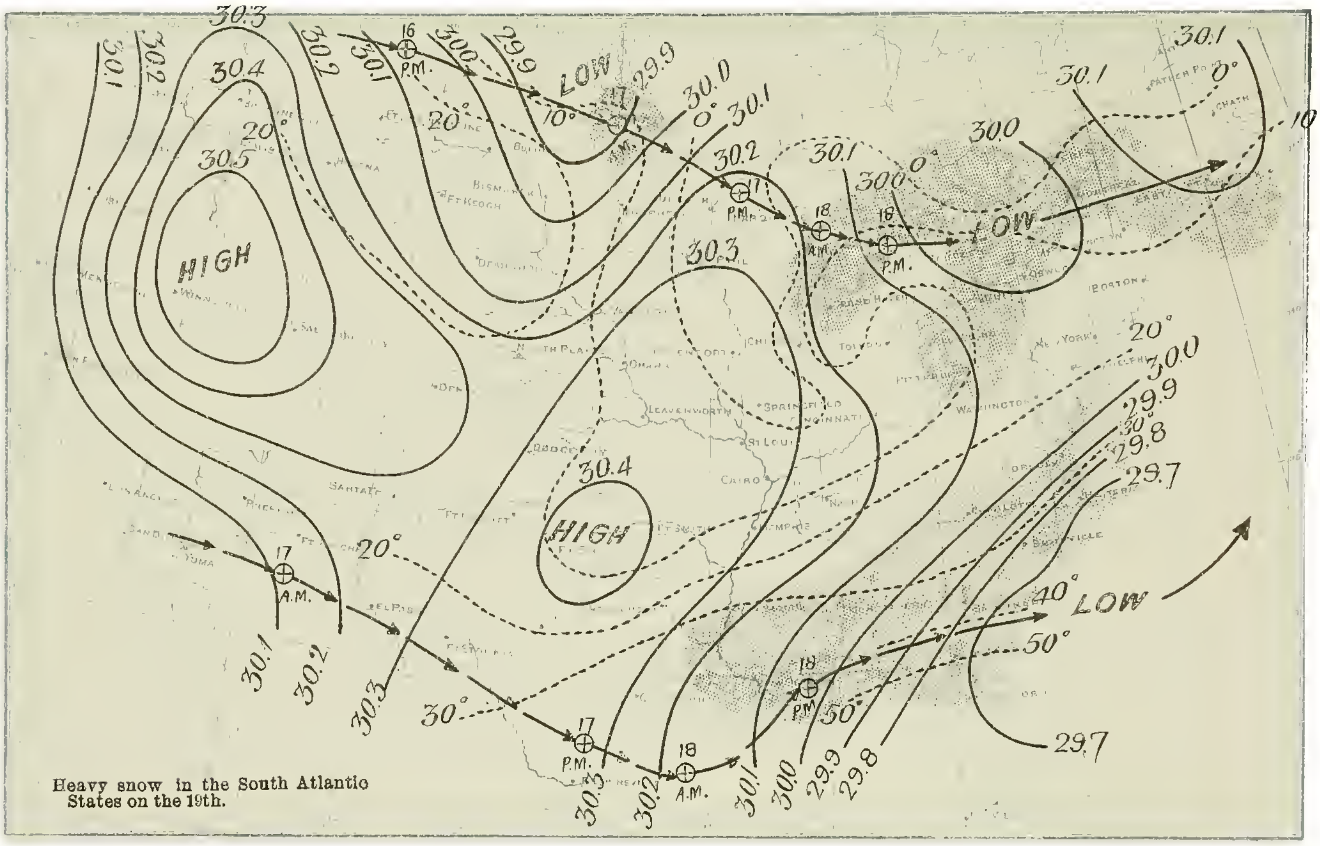
Heavy rain extended over the west Gulf States, and at night snow fell as far south as Mobile on the 17th.

CHART 22. January 18, 1893—8 a. m.



Heavy snow in South Atlantic and interior of east Gulf States on the 18th.

CHART 23. **January 19, 1893—8 a. m.**



Heavy snow in the South Atlantic States on the 19th.

CHART 24. **UPPER MISSISSIPPI AND OHIO VALLEYS AND LOWER LAKES.**

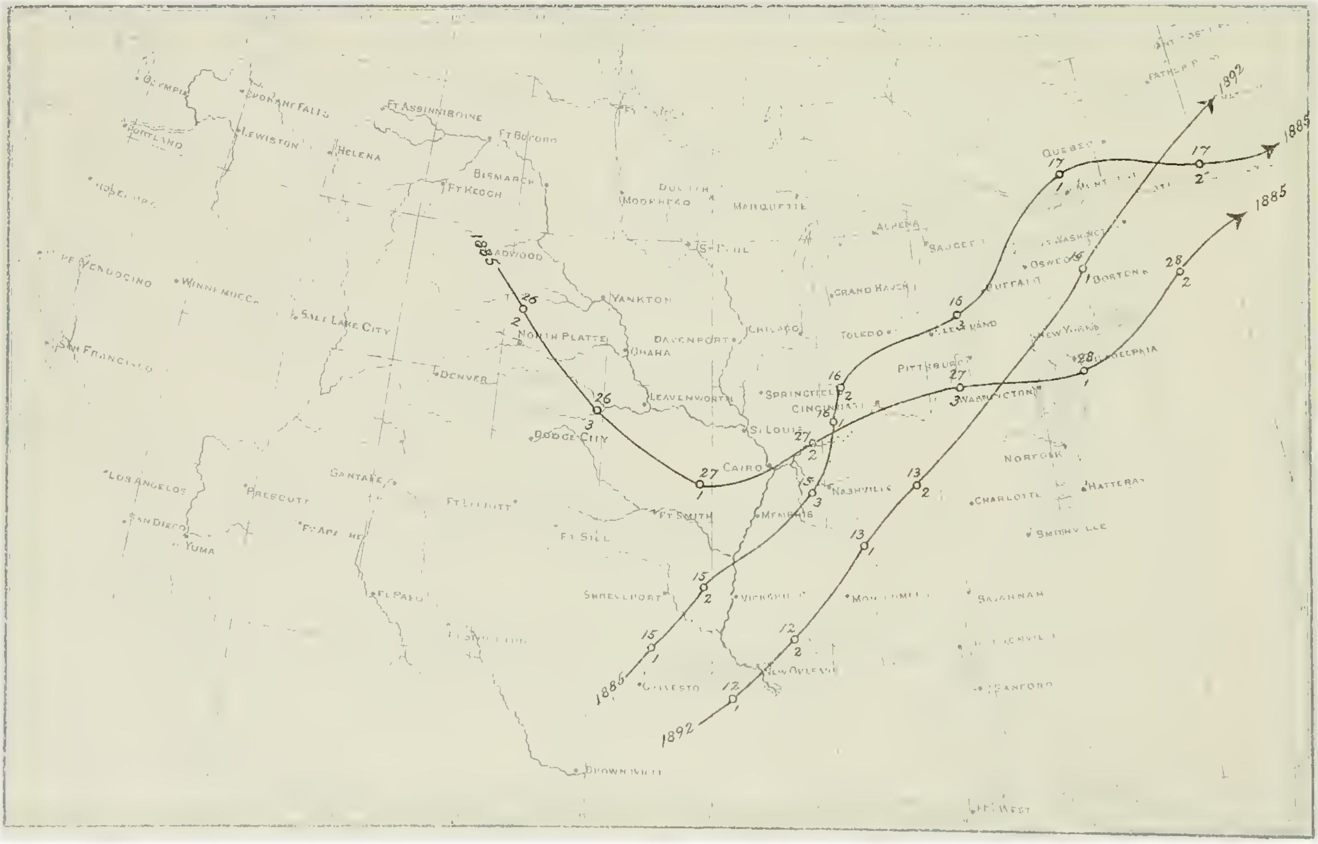
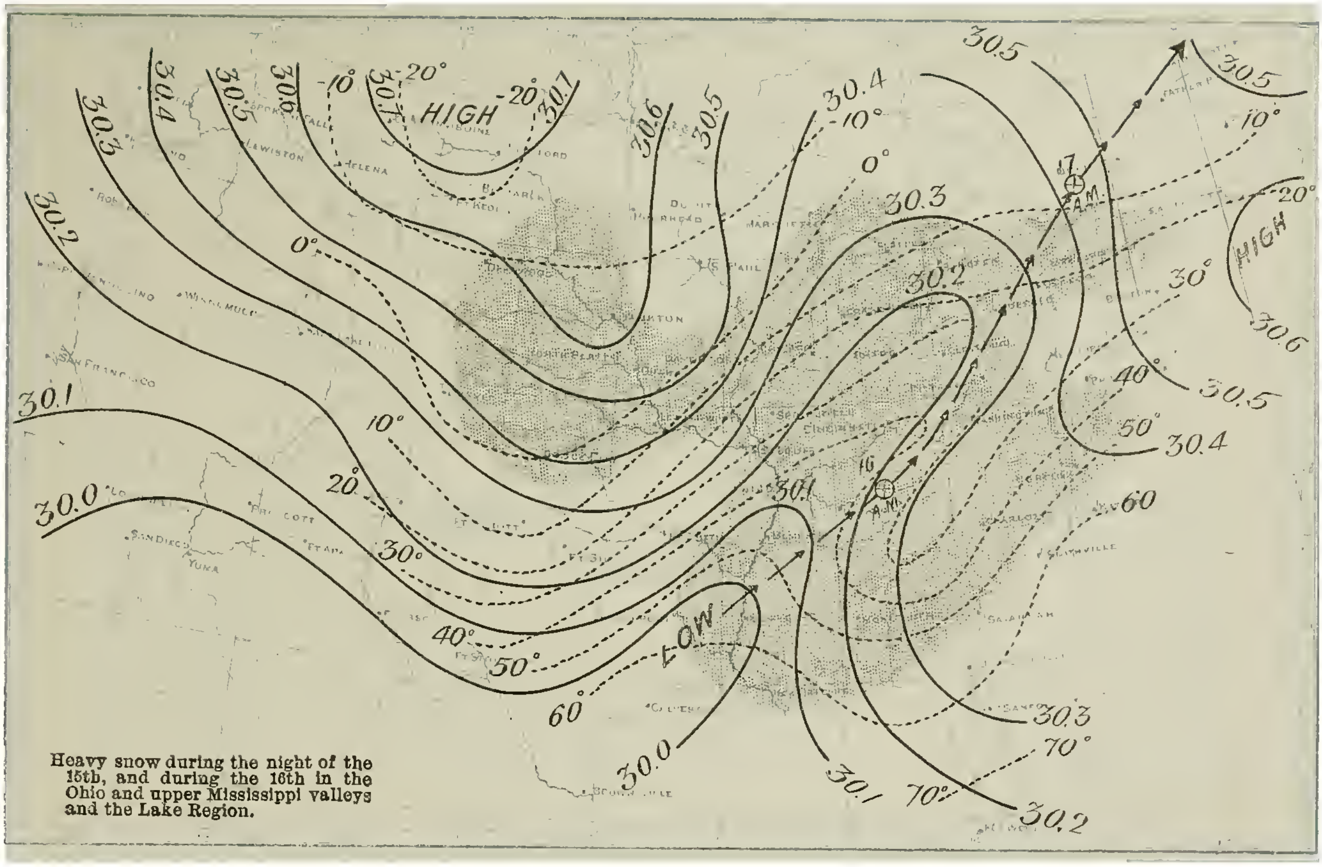
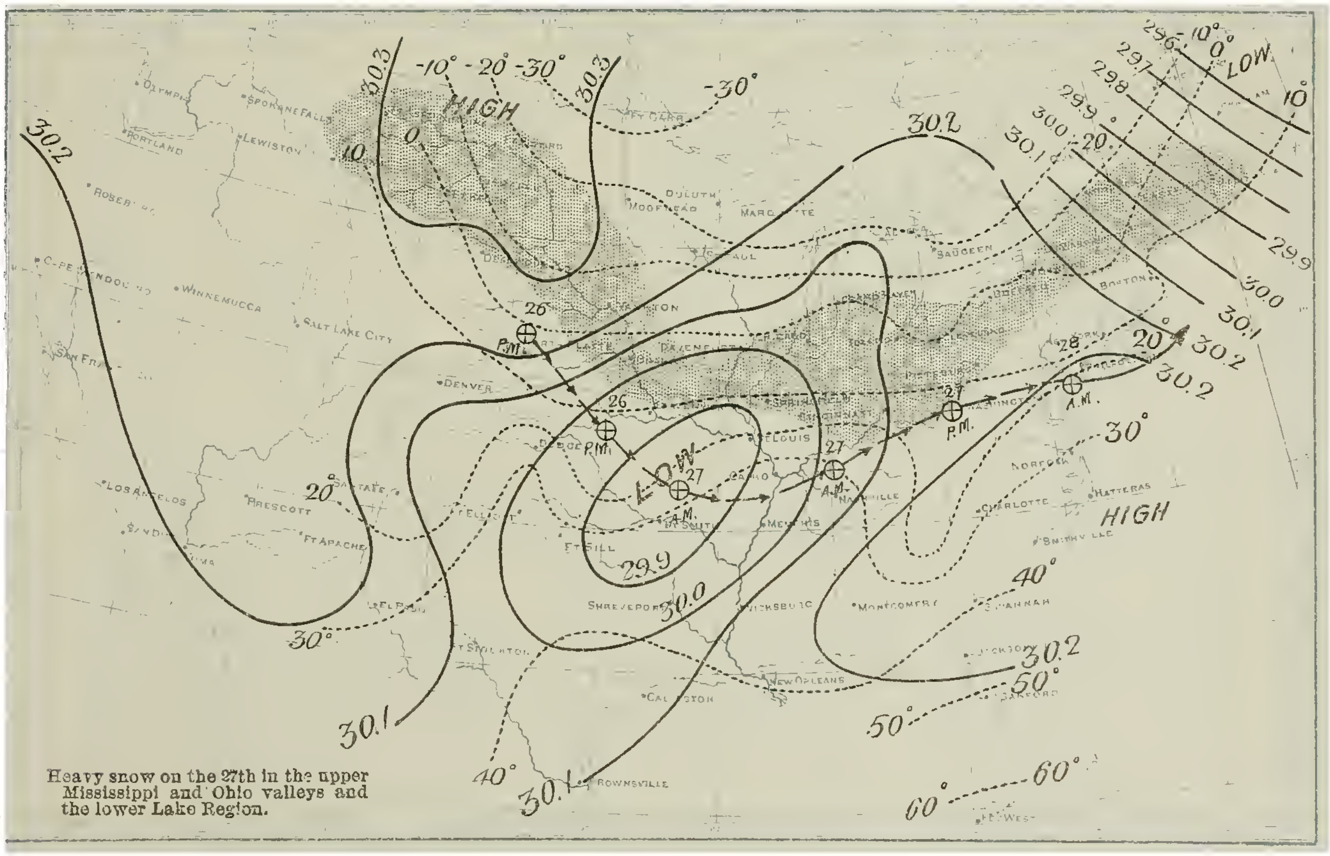


CHART 25. **January 15, 1885—7 a. m.**



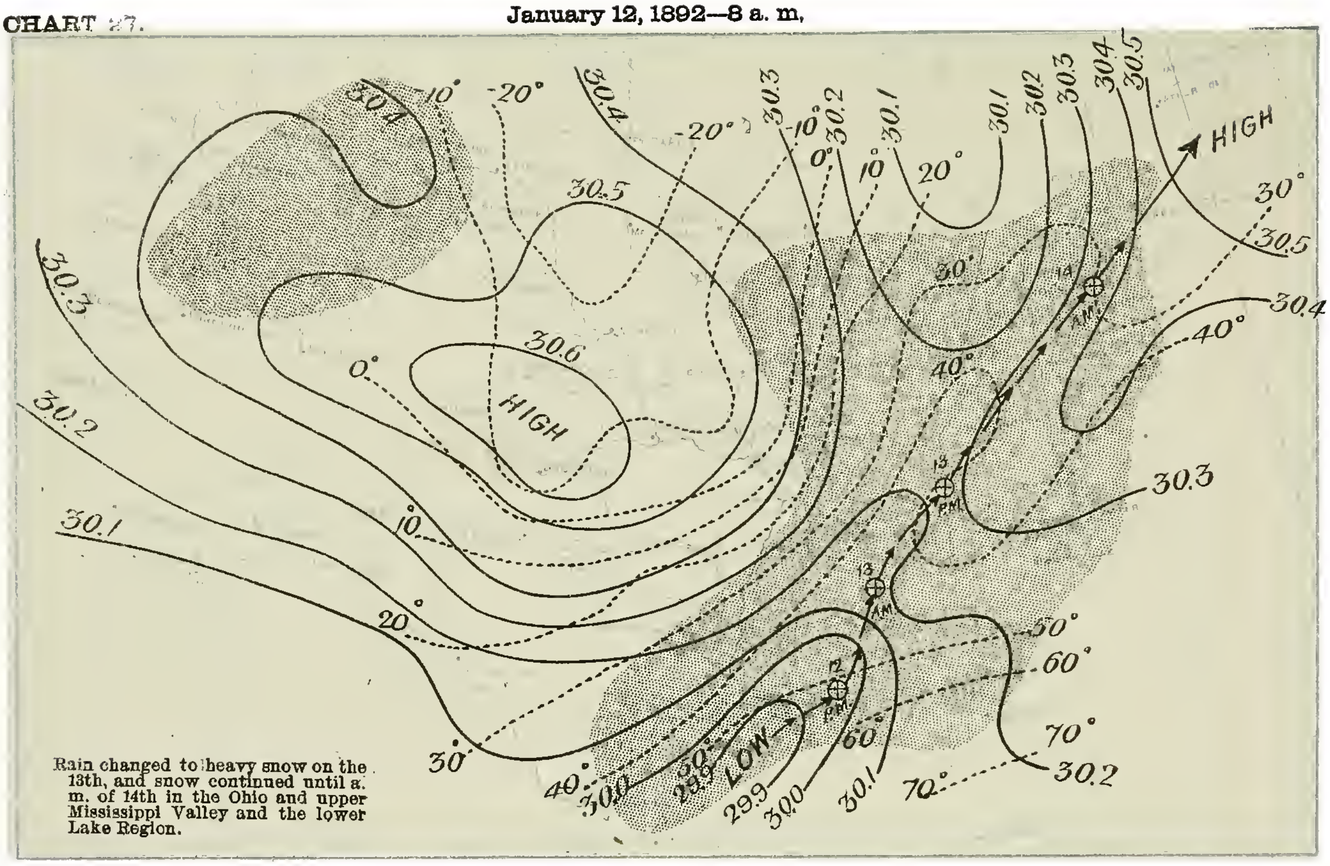
Heavy snow during the night of the 15th, and during the 16th in the Ohio and upper Mississippi valleys and the Lake Region.

CHART 26. **January 27, 1885—7 a. m.**



Heavy snow on the 27th in the upper Mississippi and Ohio valleys and the lower Lake Region.

CHART 27. January 12, 1892—8 a. m.



Rain changed to heavy snow on the 13th, and snow continued until a. m. of 14th in the Ohio and upper Mississippi Valley and the lower Lake Region.

CHART 28. UPPER MISSISSIPPI VALLEY.

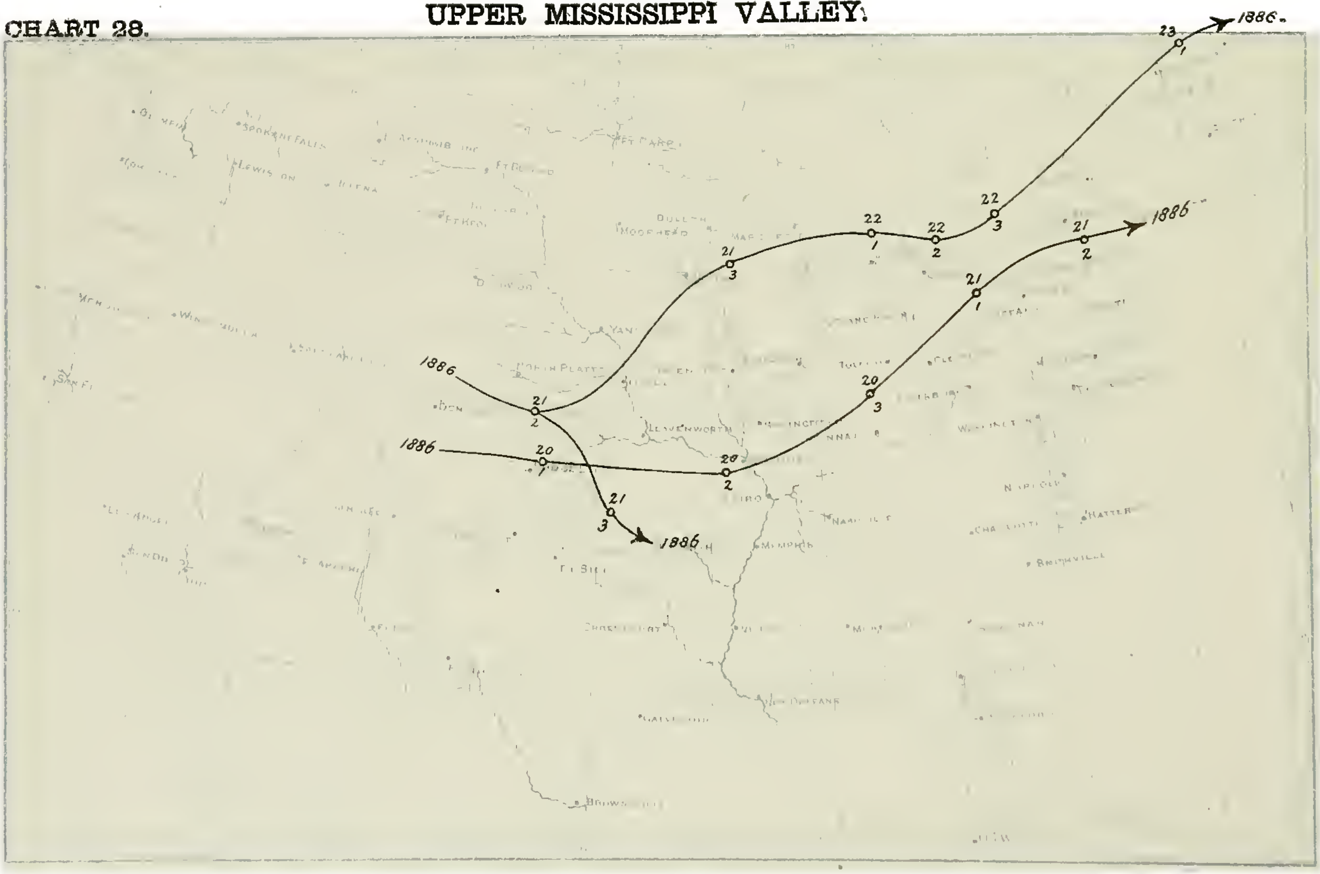
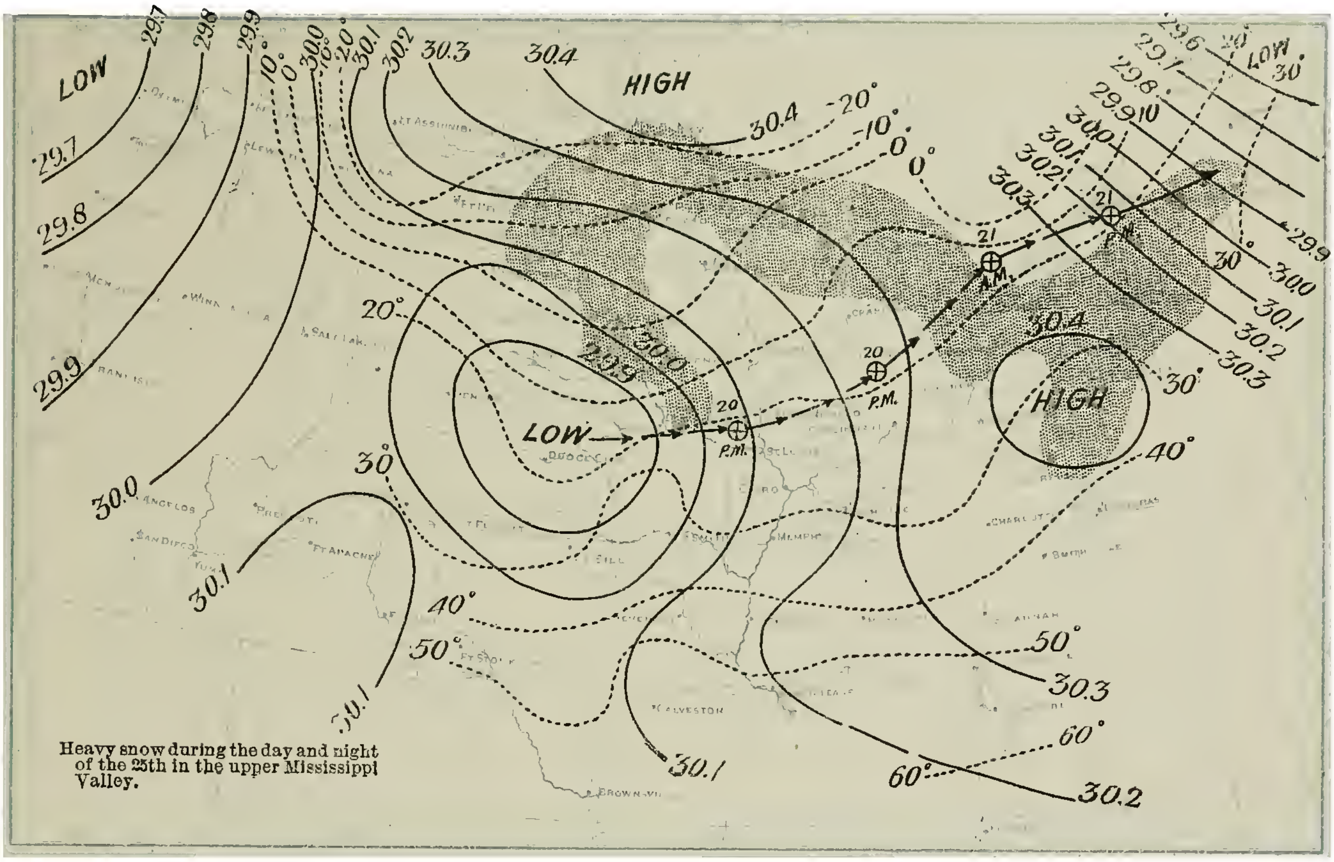


CHART 29. January 20, 1886—7 a. m.



Heavy snow during the day and night of the 25th in the upper Mississippi Valley.

CHART 30. UPPER LAKES AND UPPER MISSISSIPPI VALLEY.

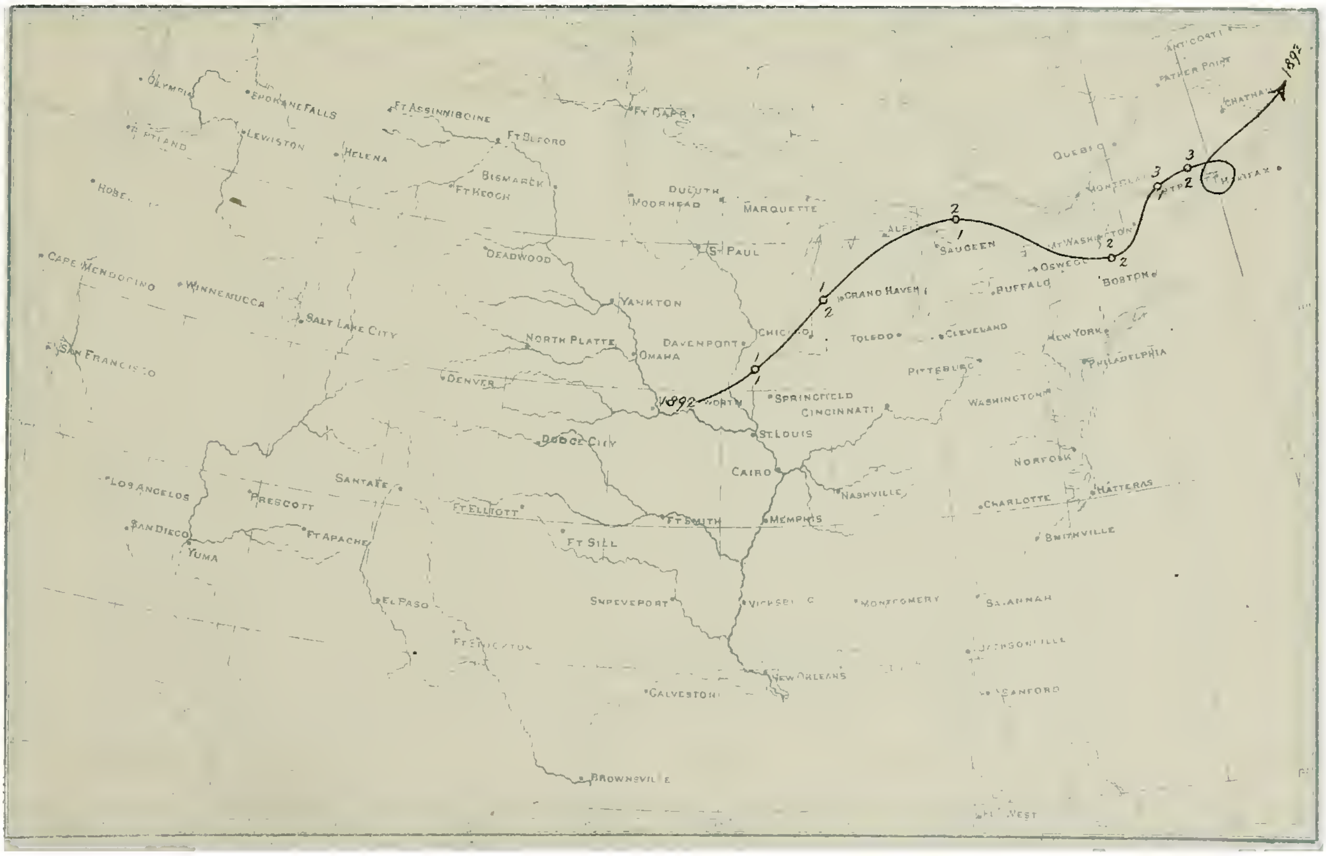
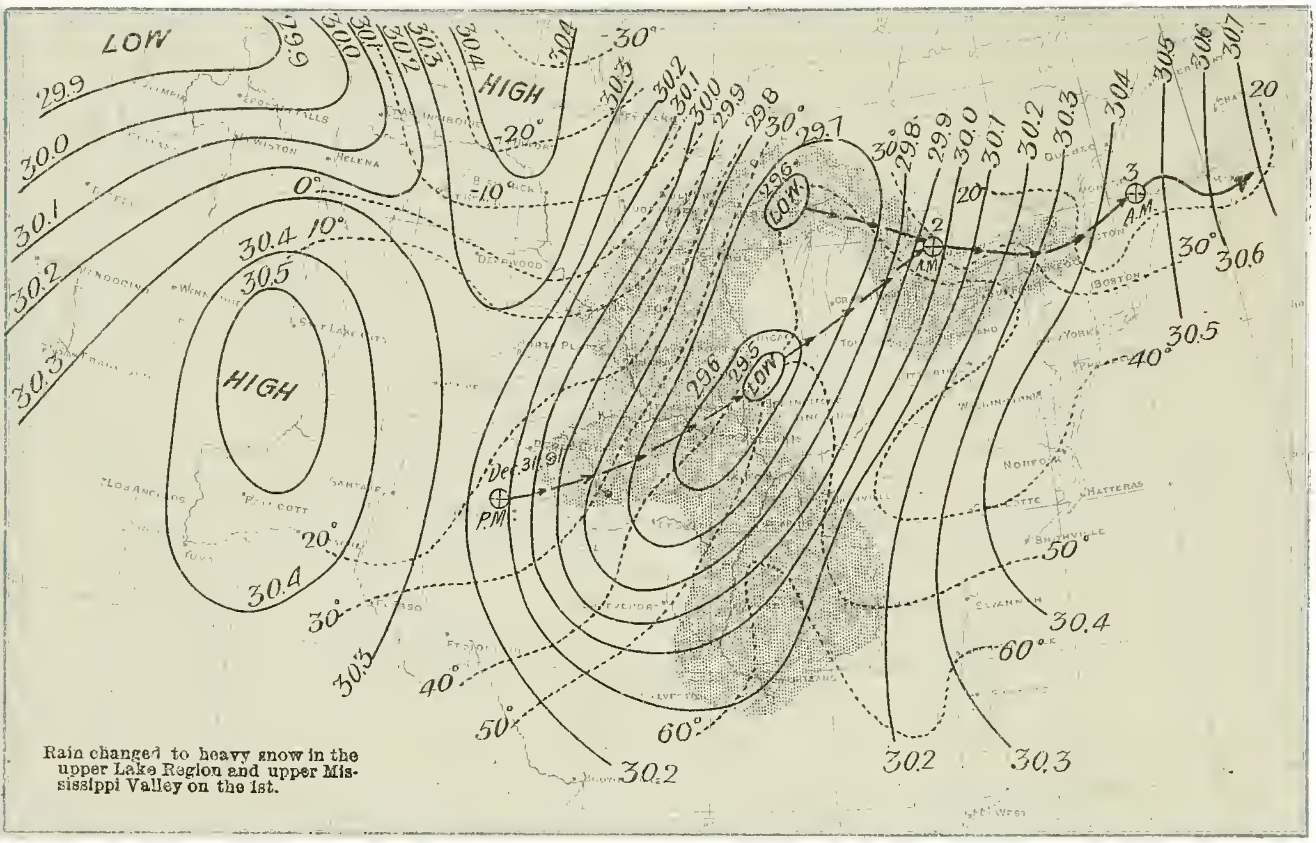


CHART 31. January 1, 1892—8 a. m.



Rain changed to heavy snow in the upper Lake Region and upper Mississippi Valley on the 1st.

CHART 32. NORTHWESTERN STATES.

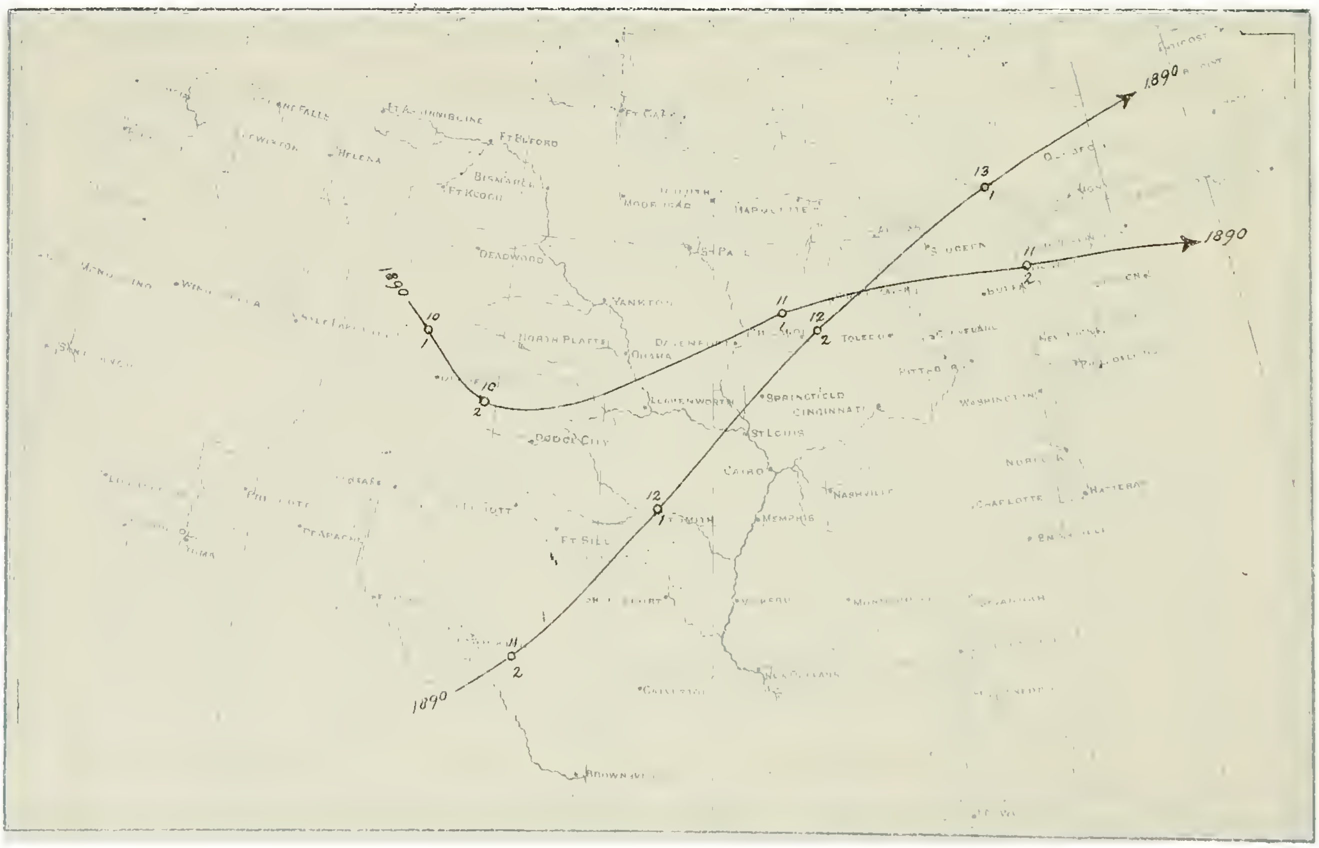
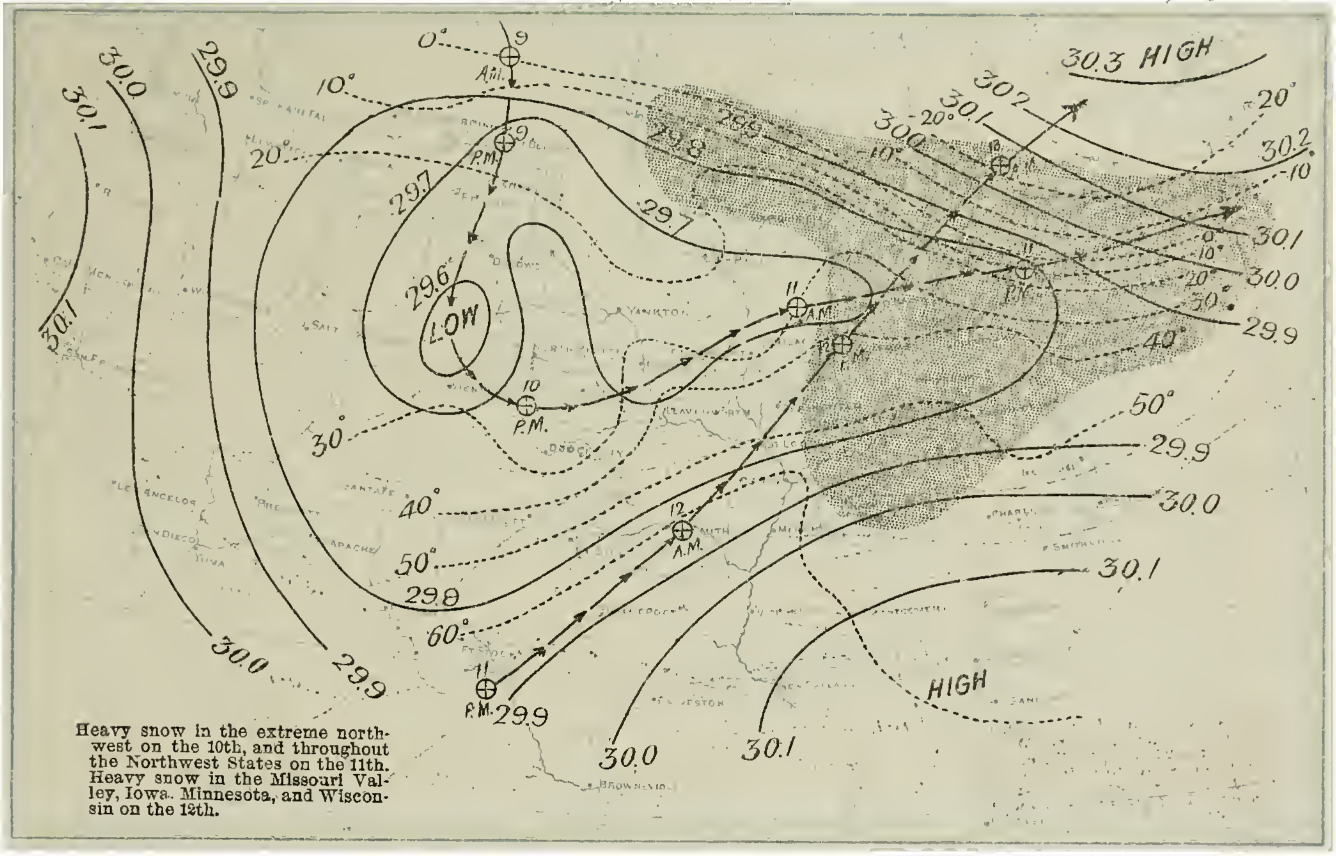


CHART 33. January 10, 1890—8 a. m.



Heavy snow in the extreme northwest on the 10th, and throughout the Northwest States on the 11th. Heavy snow in the Missouri Valley, Iowa. Minnesota, and Wisconsin on the 12th.

MIDDLE ATLANTIC AND NEW ENGLAND STATES.

CHART 34. FEBRUARY.

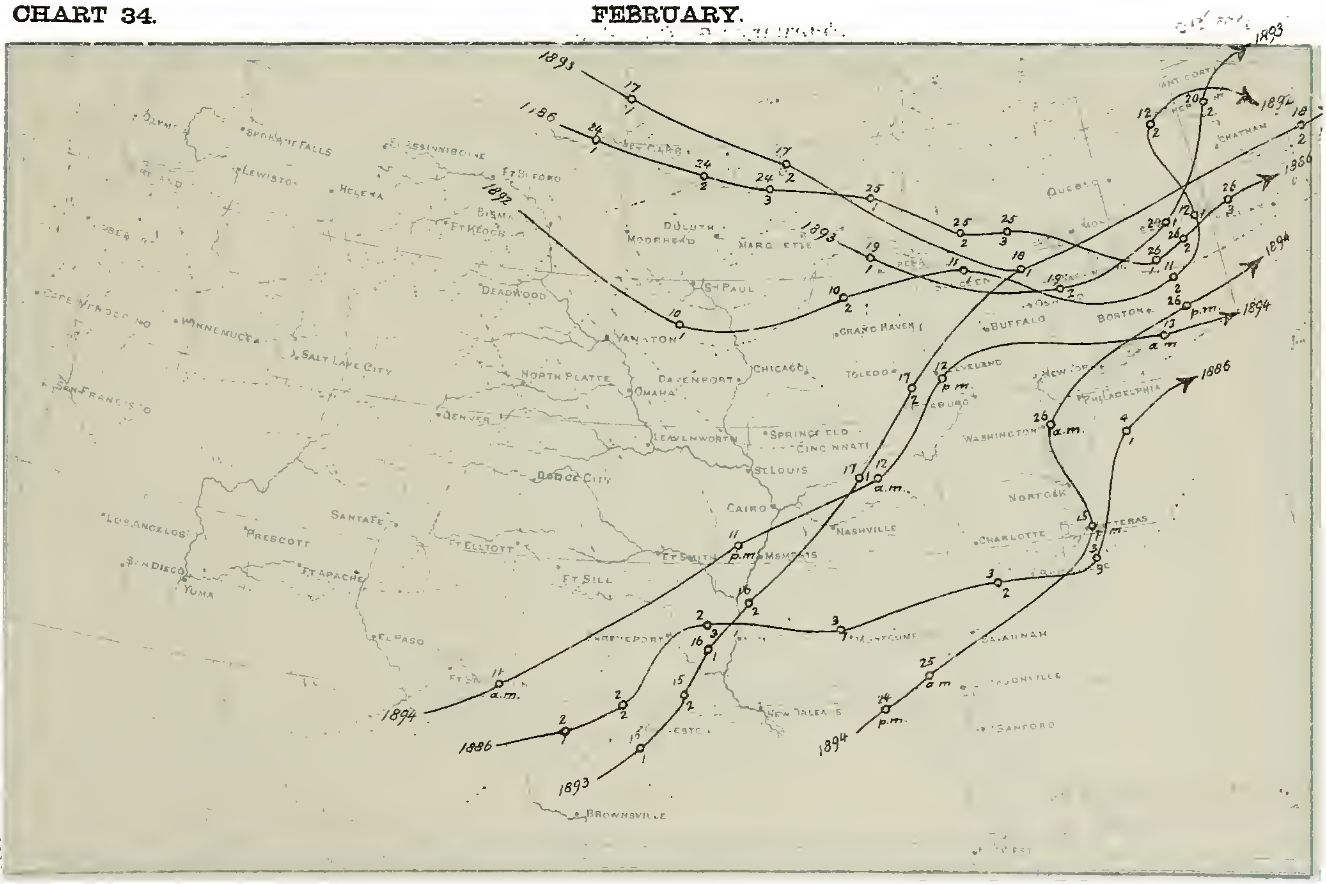
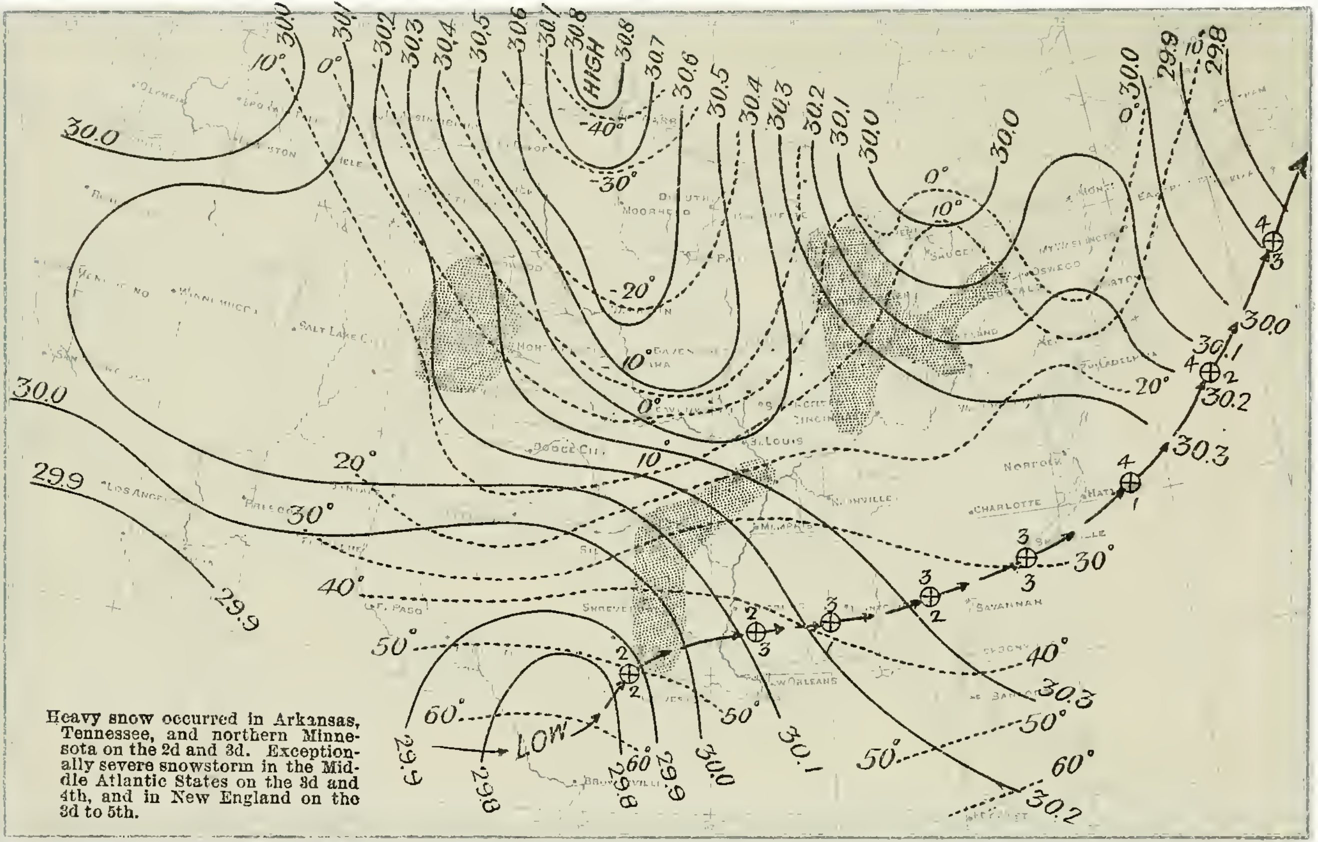
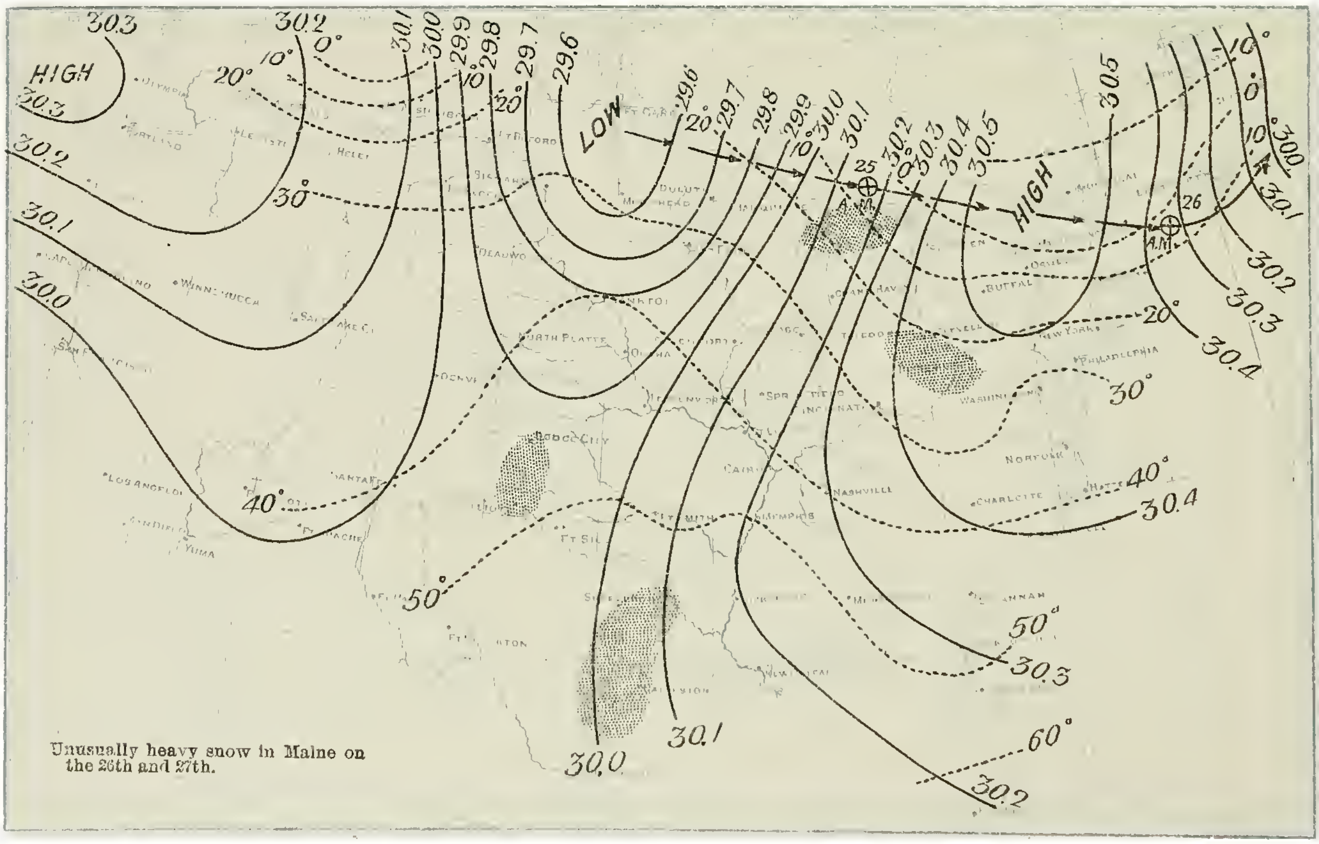


CHART 35 **February 2, 1886—7 a. m.**



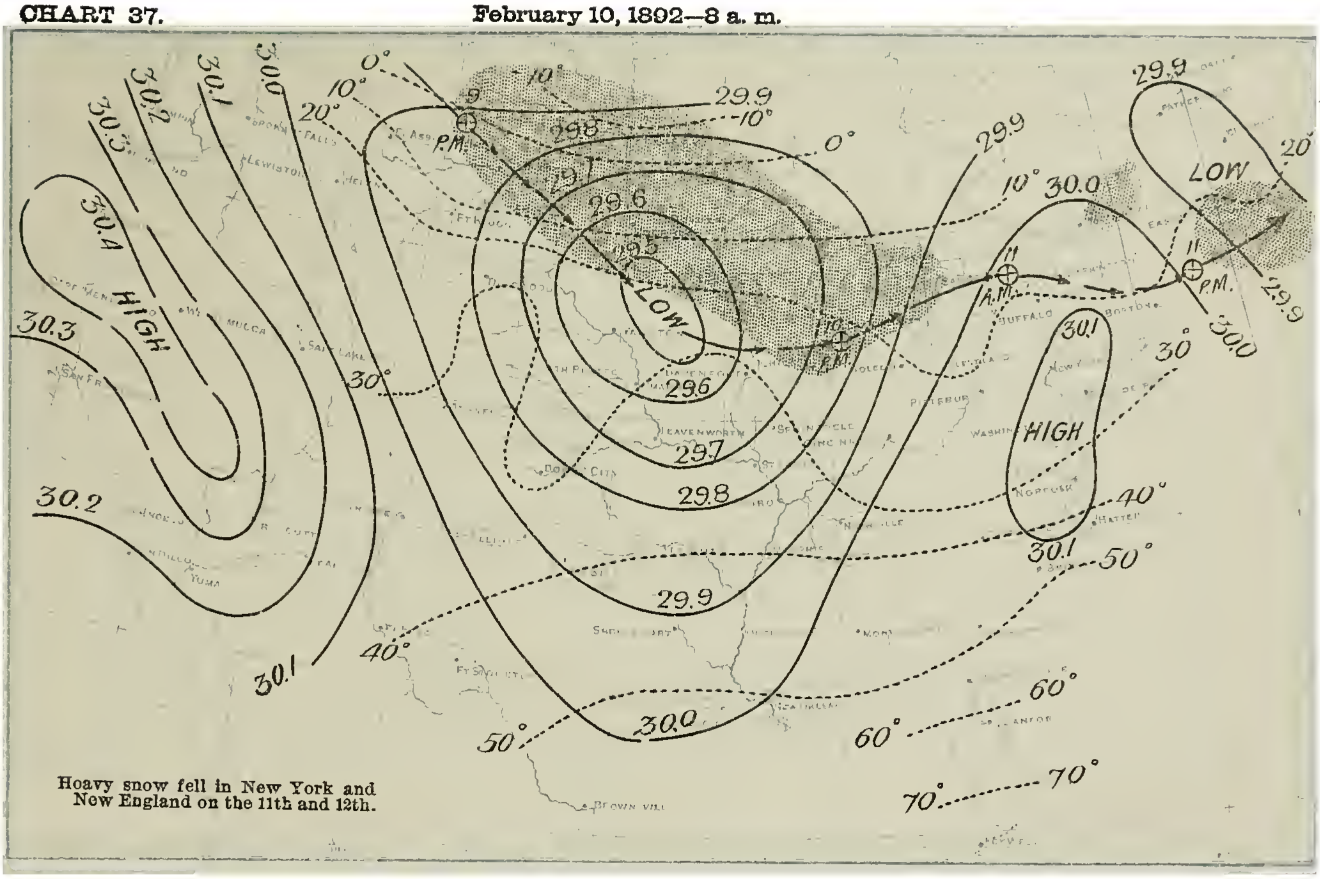
Heavy snow occurred in Arkansas, Tennessee, and northern Minnesota on the 2d and 3d. Exceptionally severe snowstorm in the Middle Atlantic States on the 3d and 4th, and in New England on the 3d to 5th.

CHART 36. **February 24, 1886—7 a. m.**



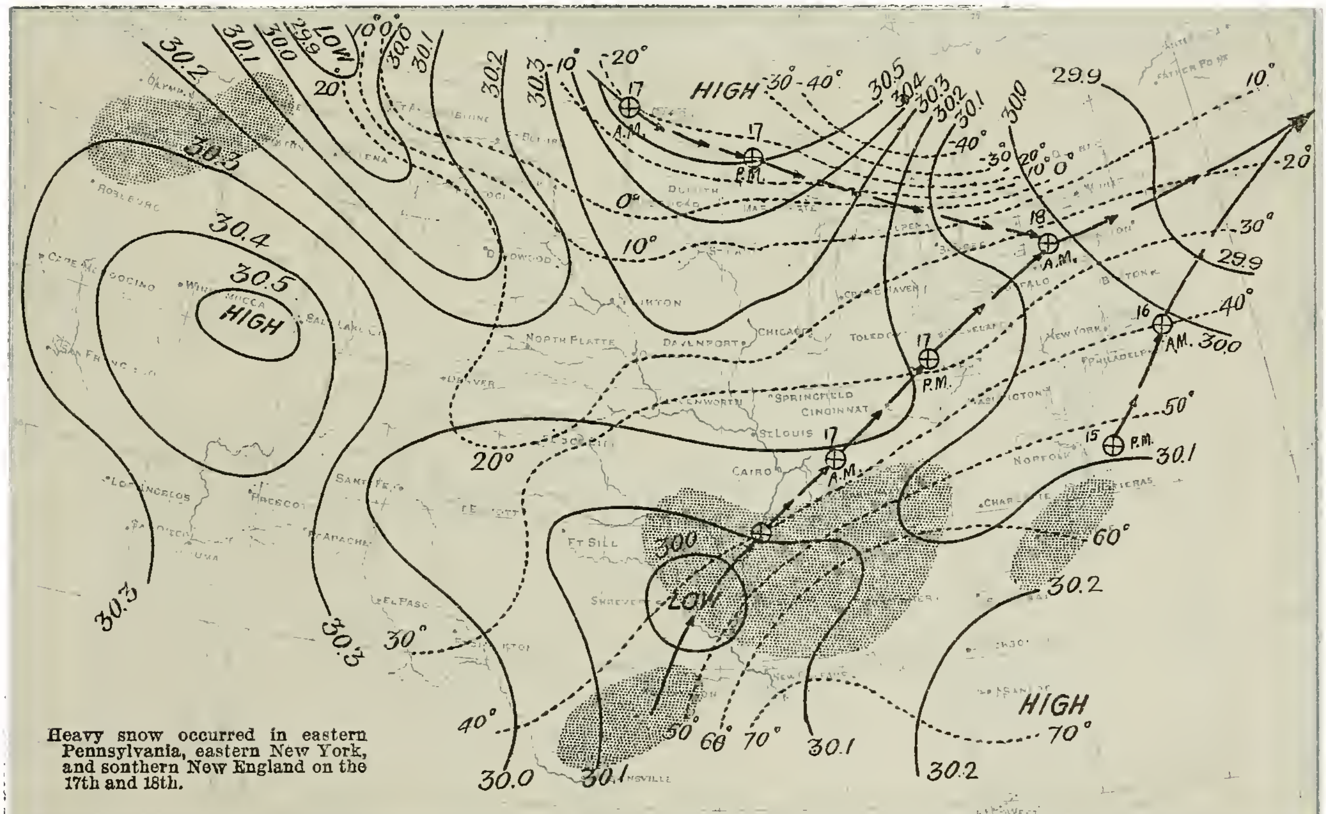
Unusually heavy snow in Maine on the 26th and 27th.

CHART 37. **February 10, 1892—8 a. m.**



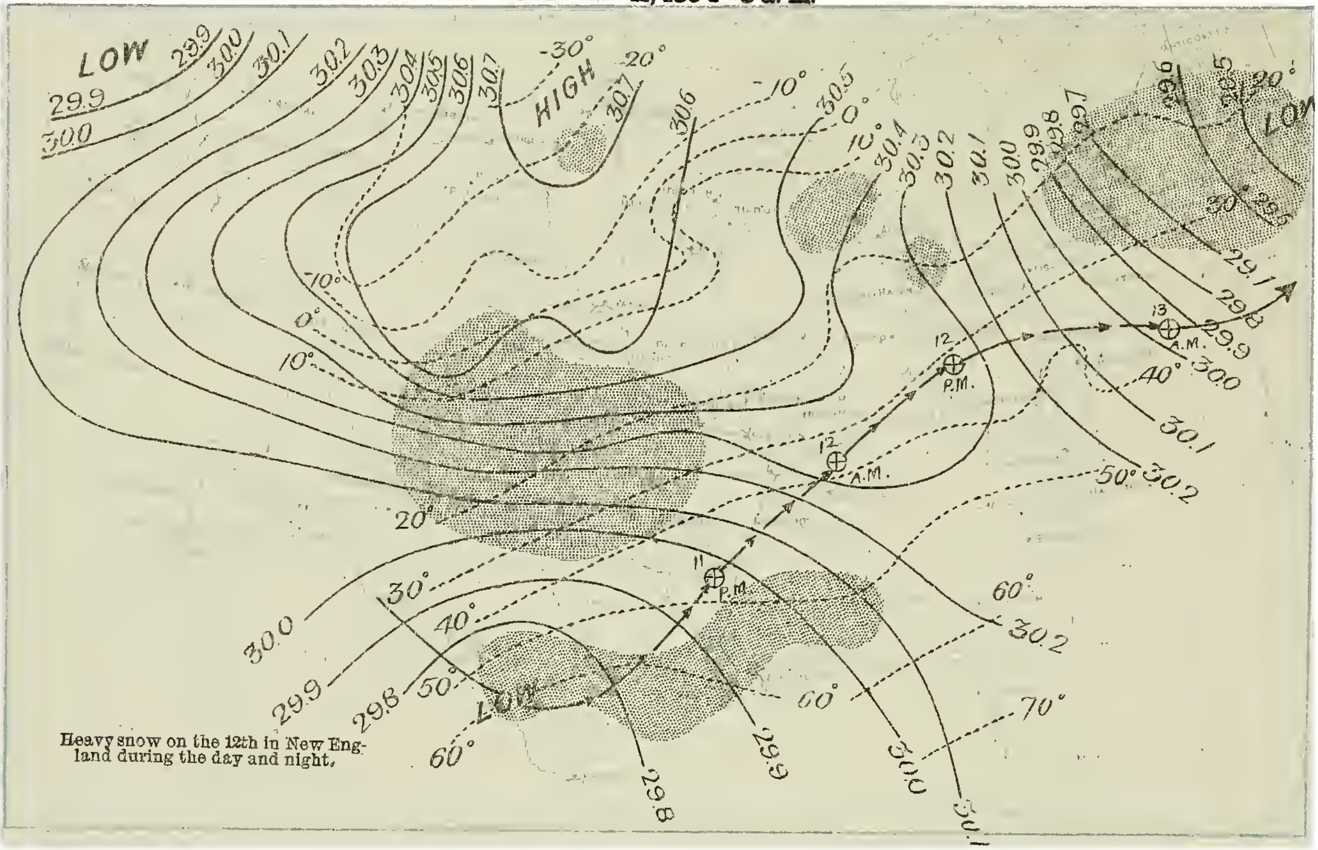
Heavy snow fell in New York and New England on the 11th and 12th.

CHART 38. **February 16, 1893—8 a. m.**



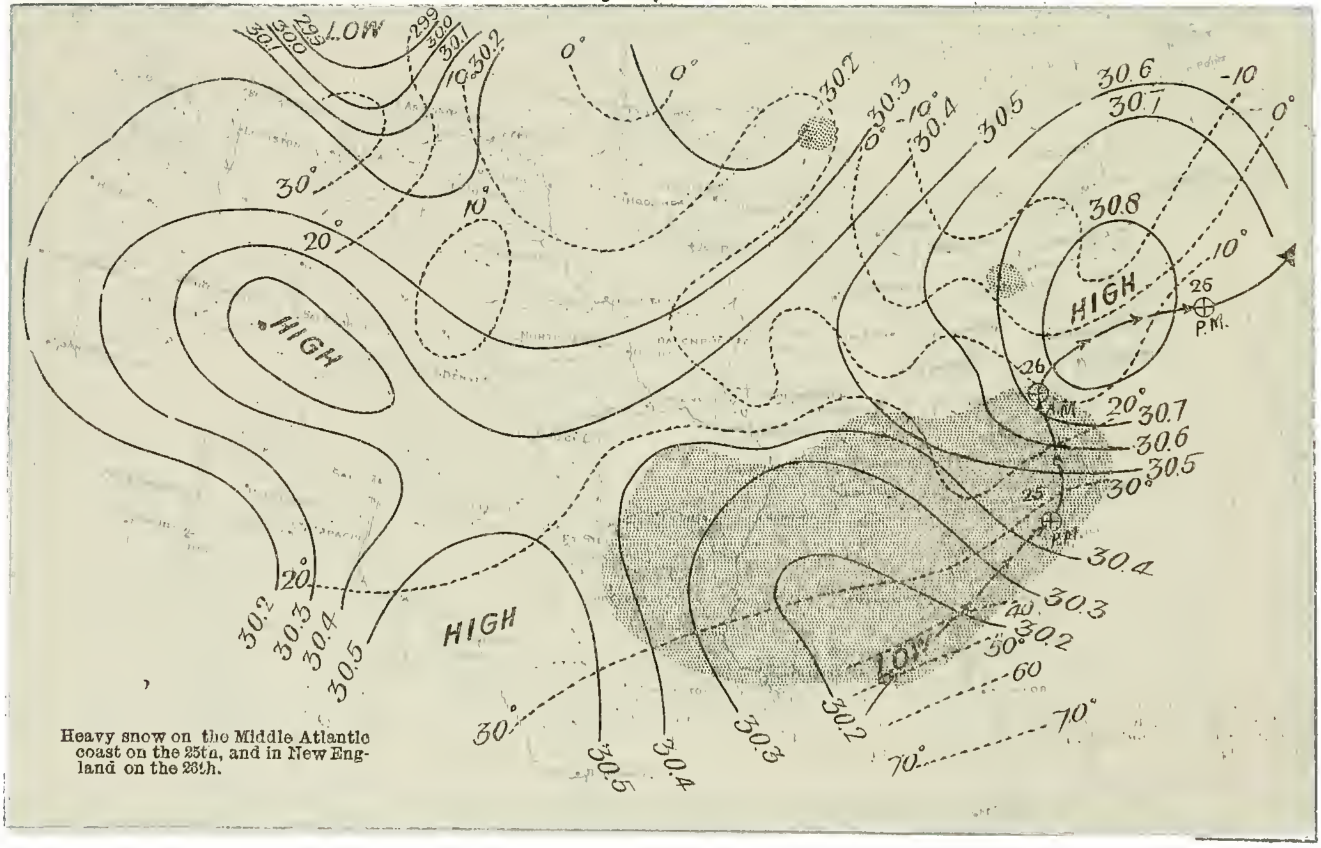
Heavy snow occurred in eastern Pennsylvania, eastern New York, and southern New England on the 17th and 18th.

CHART 39. 11, 1894—8 a. m.



Heavy snow on the 12th in New England during the day and night.

CHART 40. February 25, 1894—8 a. m.

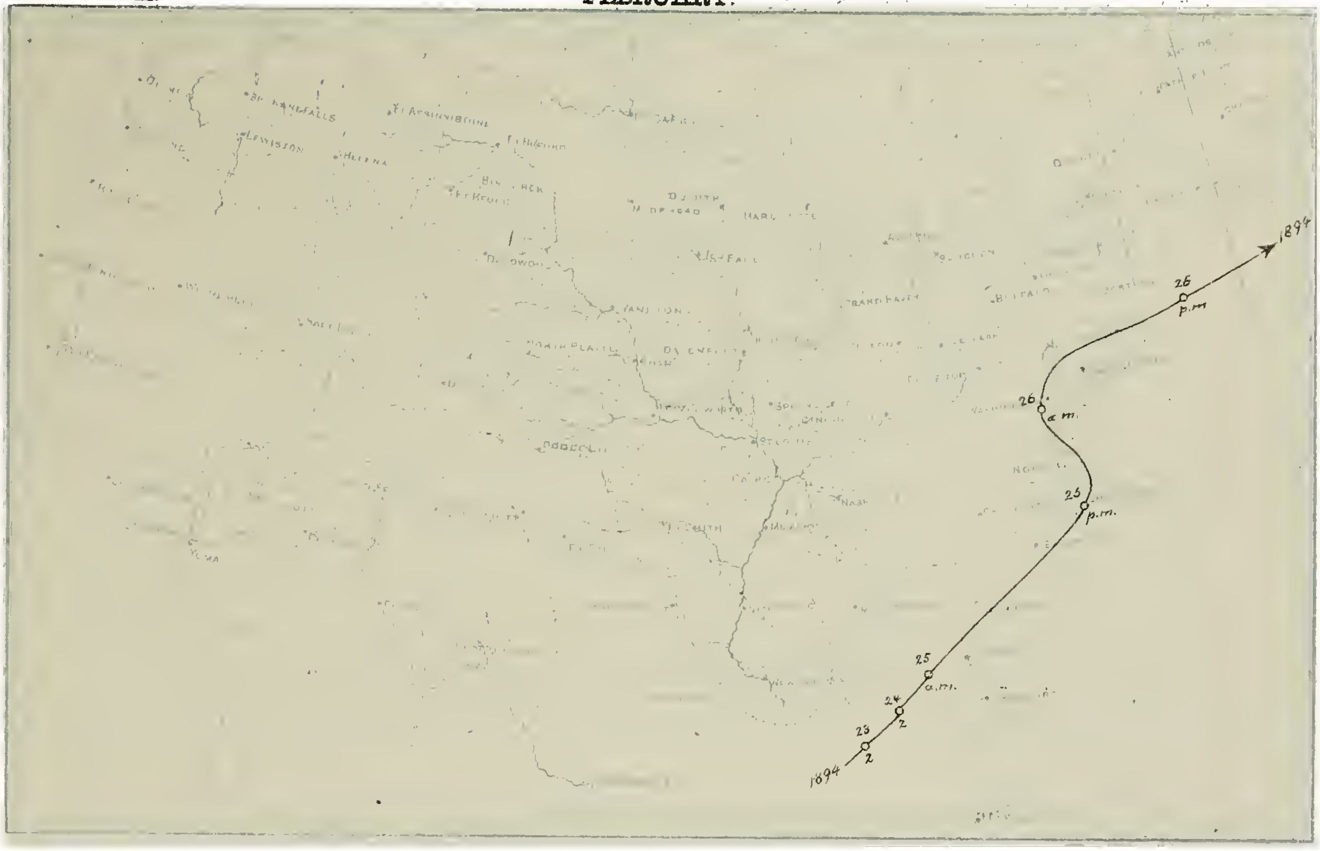


Heavy snow on the Middle Atlantic coast on the 25th, and in New England on the 26th.

SOUTHEASTERN STATES.

CHART 41.

FEBRUARY.



UPPER LAKES AND EXTREME UPPER MISSISSIPPI VALLEY.

CHART 42.

FEBRUARY.

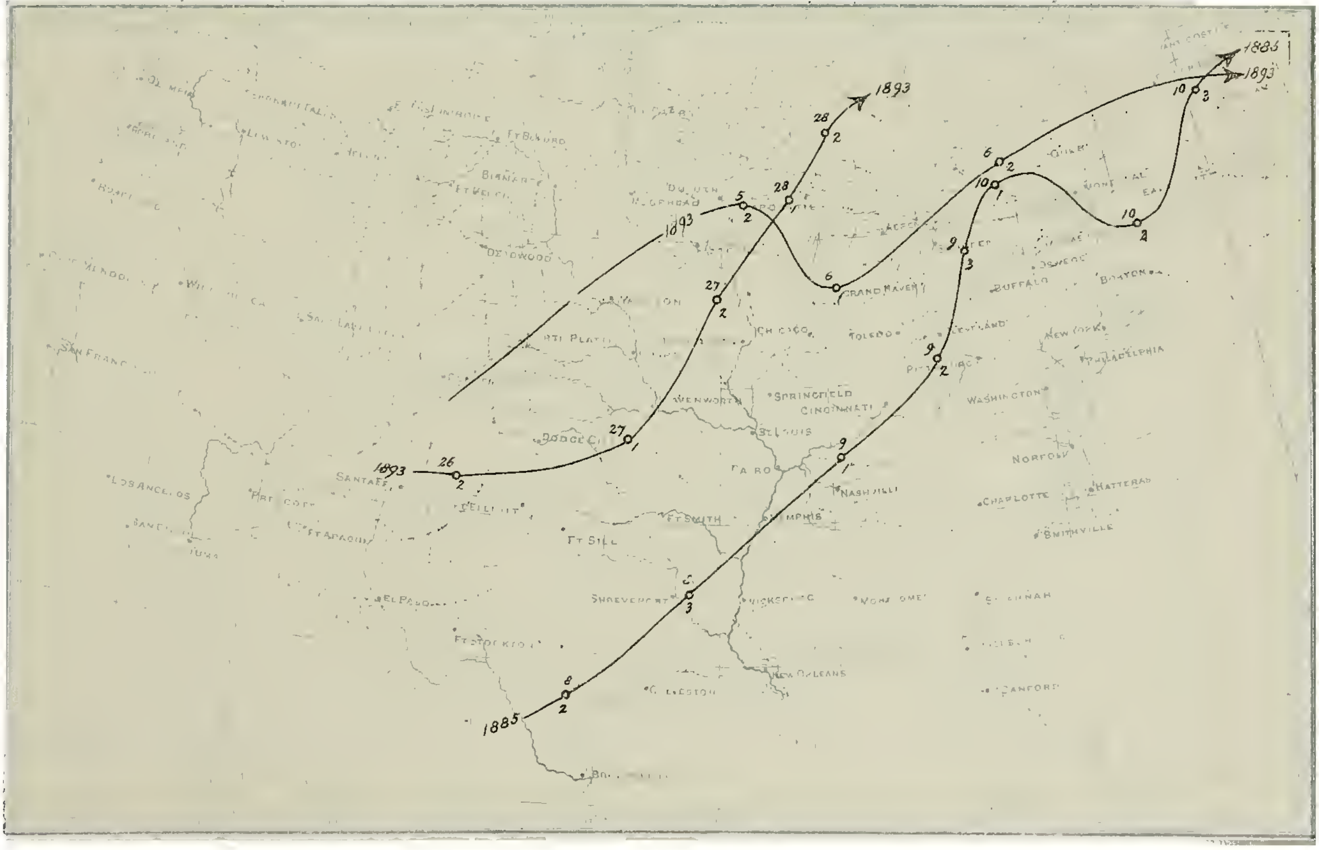
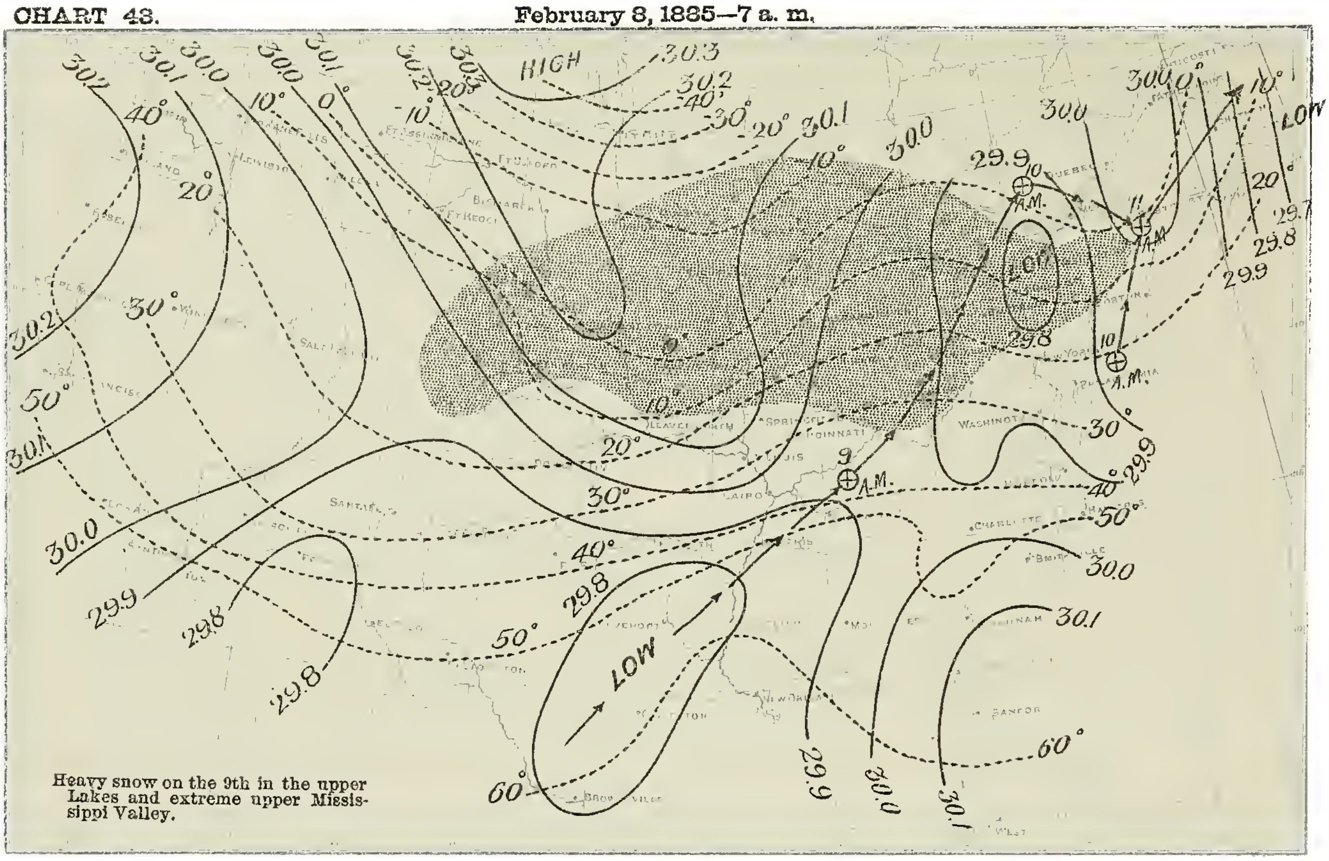
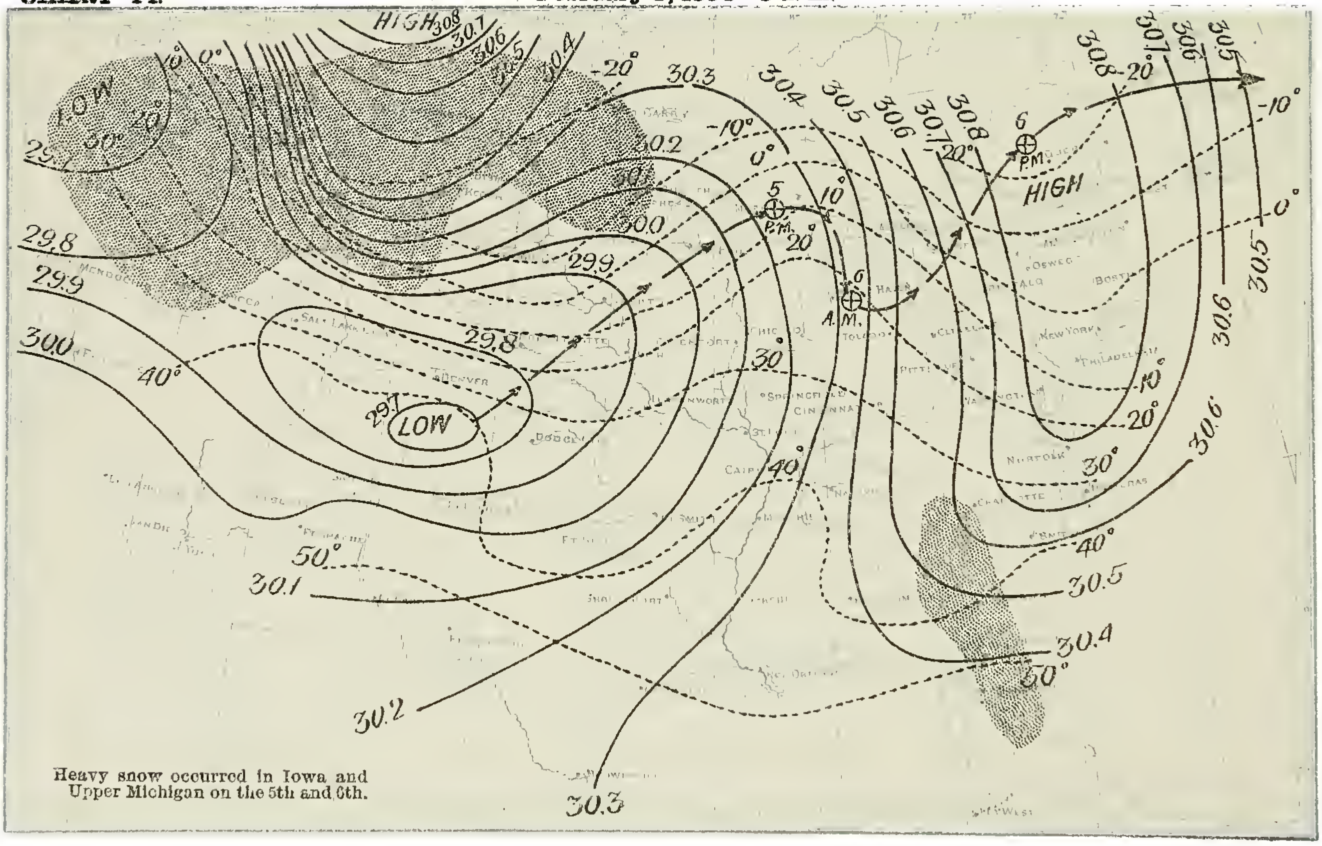


CHART 43. February 8, 1885—7 a. m.



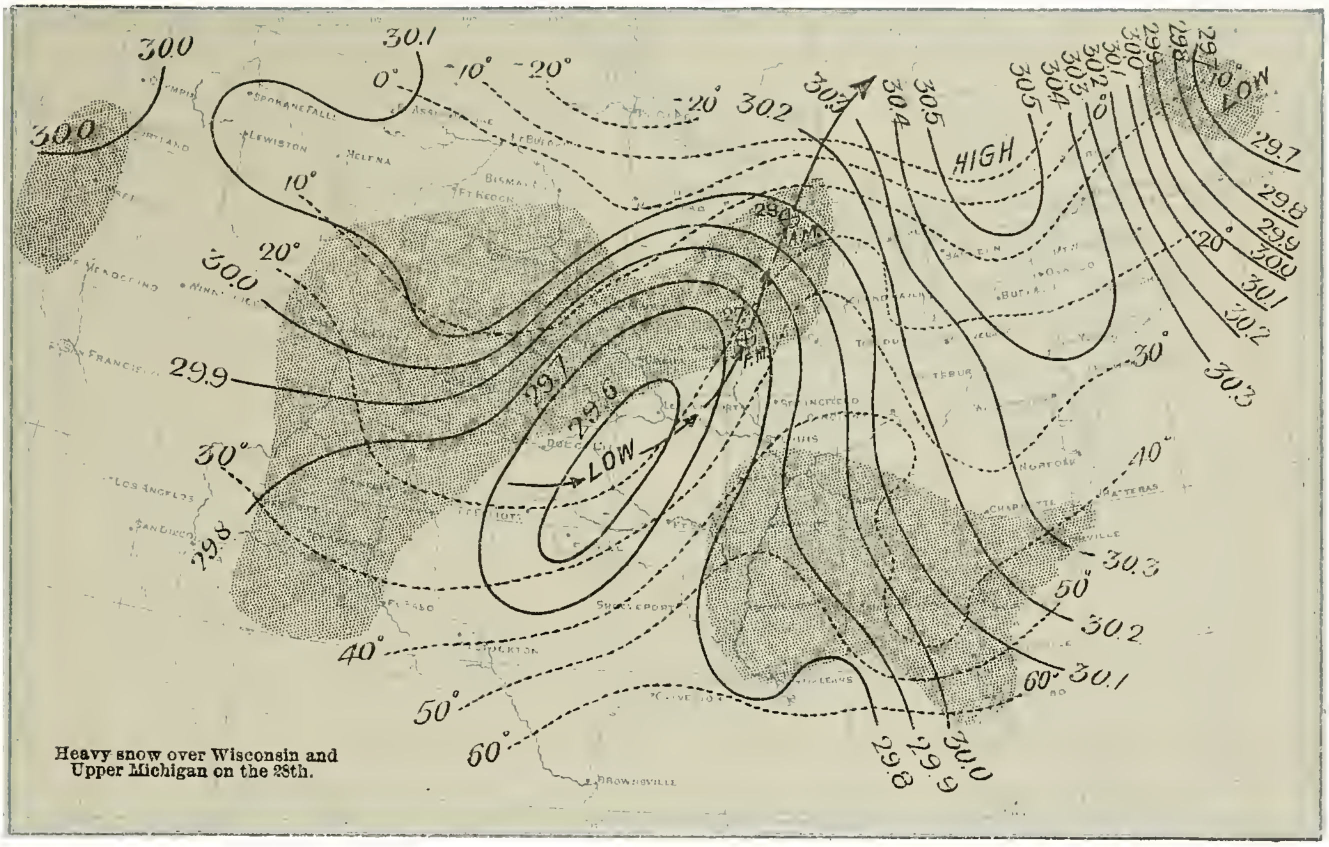
Heavy snow on the 9th in the upper Lakes and extreme upper Mississippi Valley.

CHART 44. February 5, 1893—8 a. m.



Heavy snow occurred in Iowa and Upper Michigan on the 5th and 6th.

CHART 45. **February 27, 1893—8 a. m.**



Heavy snow over Wisconsin and Upper Michigan on the 28th.

MIDDLE-EASTERN ROCKY MOUNTAIN SLOPE.

FEBRUARY.

CHART 46.

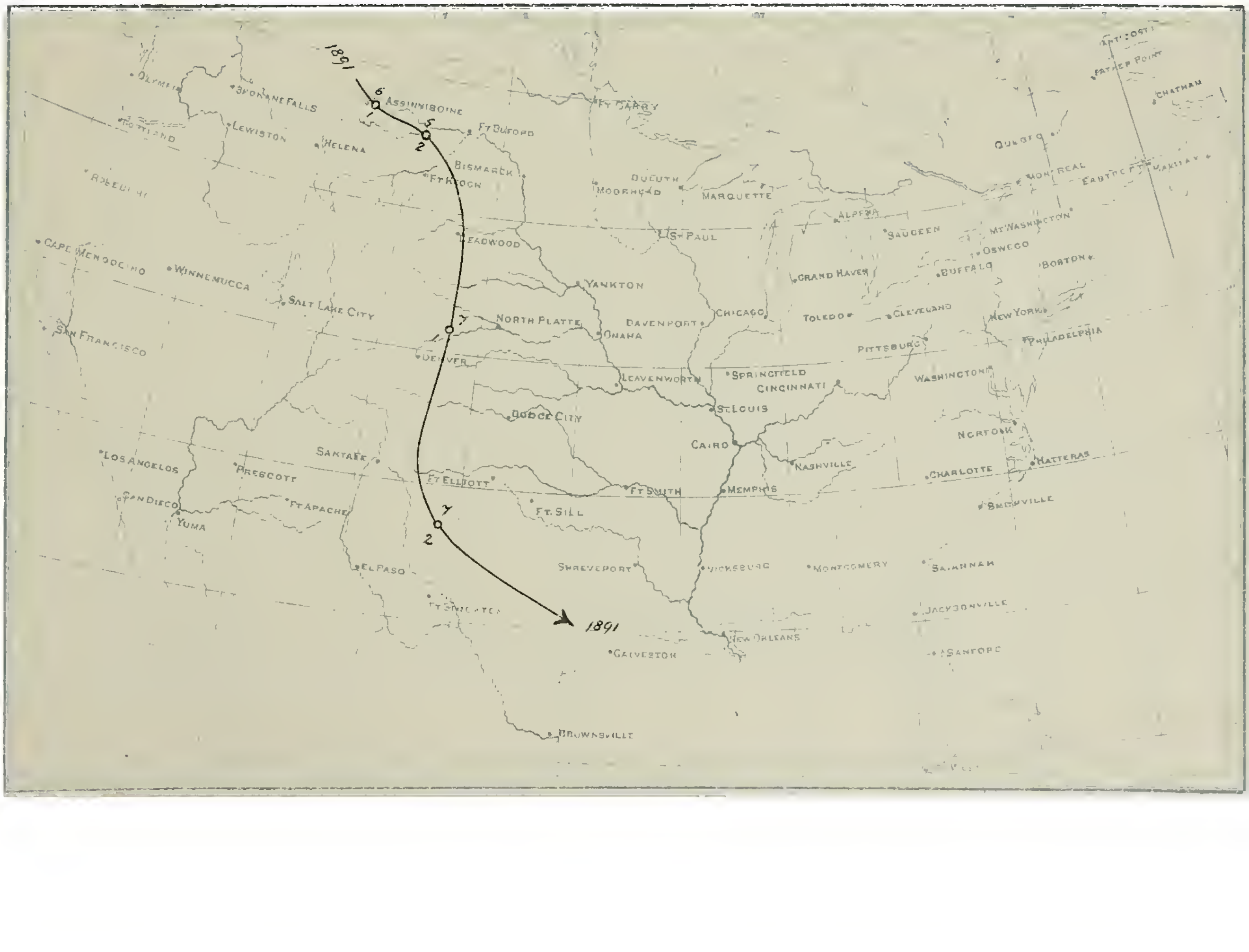
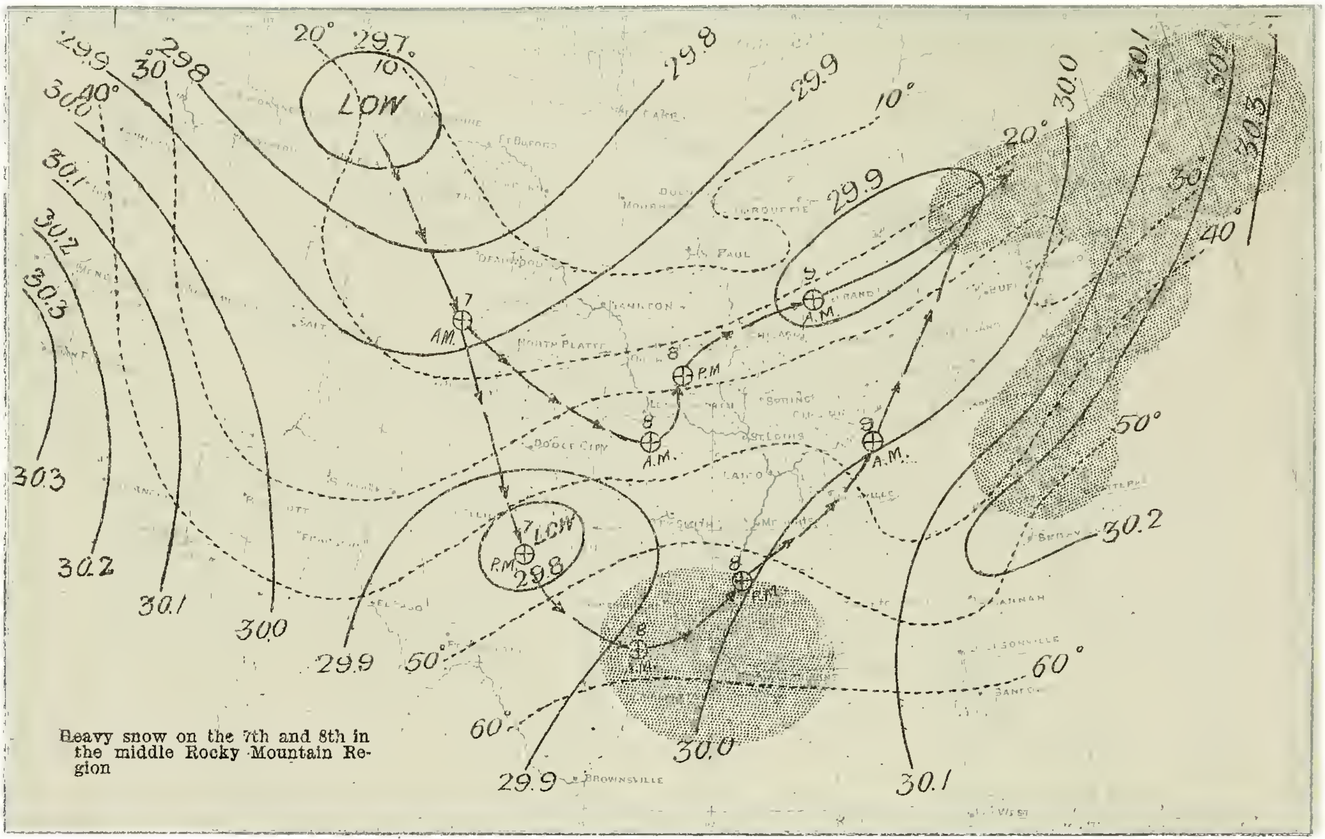


CHART 47. **February 6, 1891—8 a. m.**



Heavy snow on the 7th and 8th in the middle Rocky Mountain Region

SOUTHERN ROCKY MOUNTAIN DISTRICT.

CHART. 48. **FEBRUARY.**

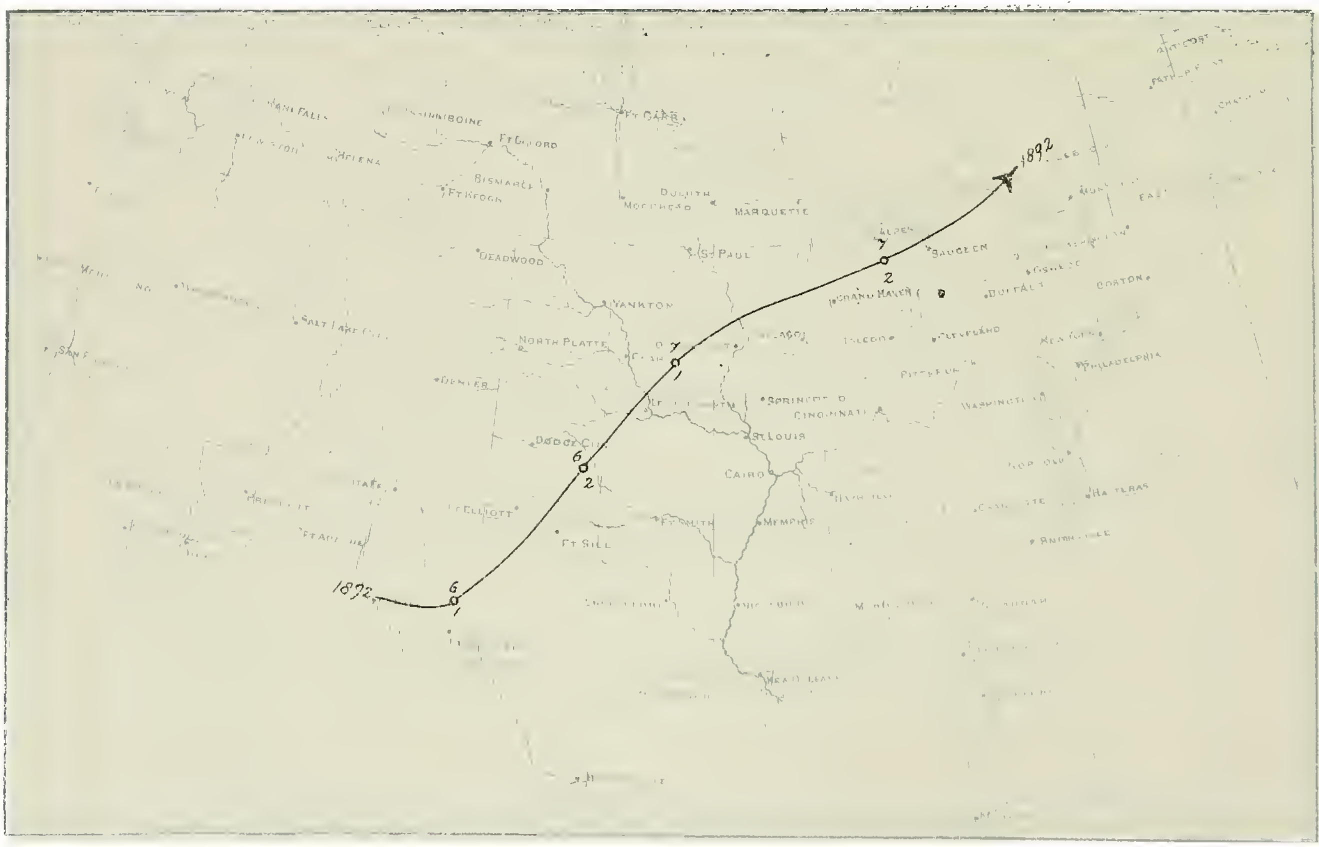
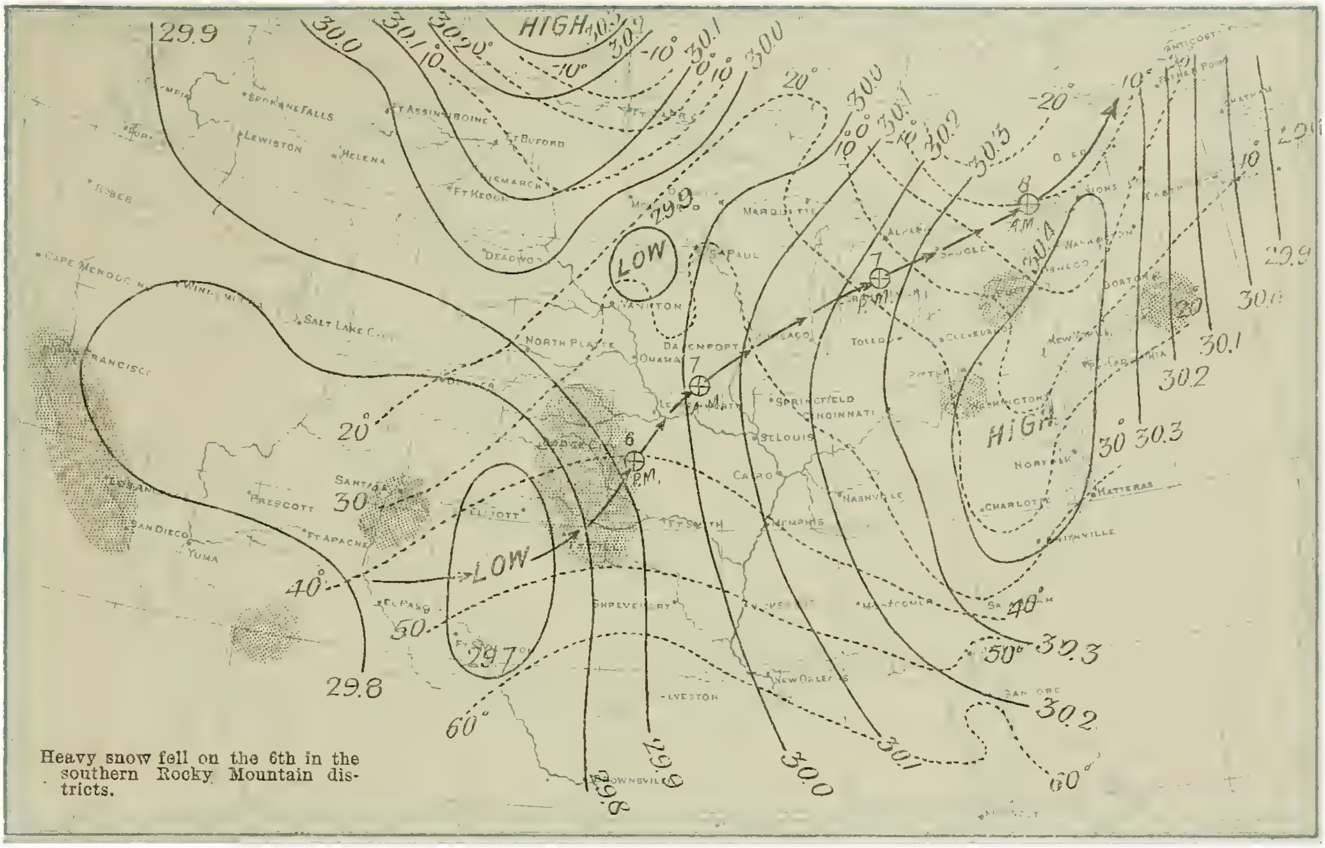


CHART 49. February 6, 1892—8 a. m.



Heavy snow fell on the 6th in the southern Rocky Mountain districts.

CHART 50.

MIDDLE ATLANTIC AND NEW ENGLAND STATES.

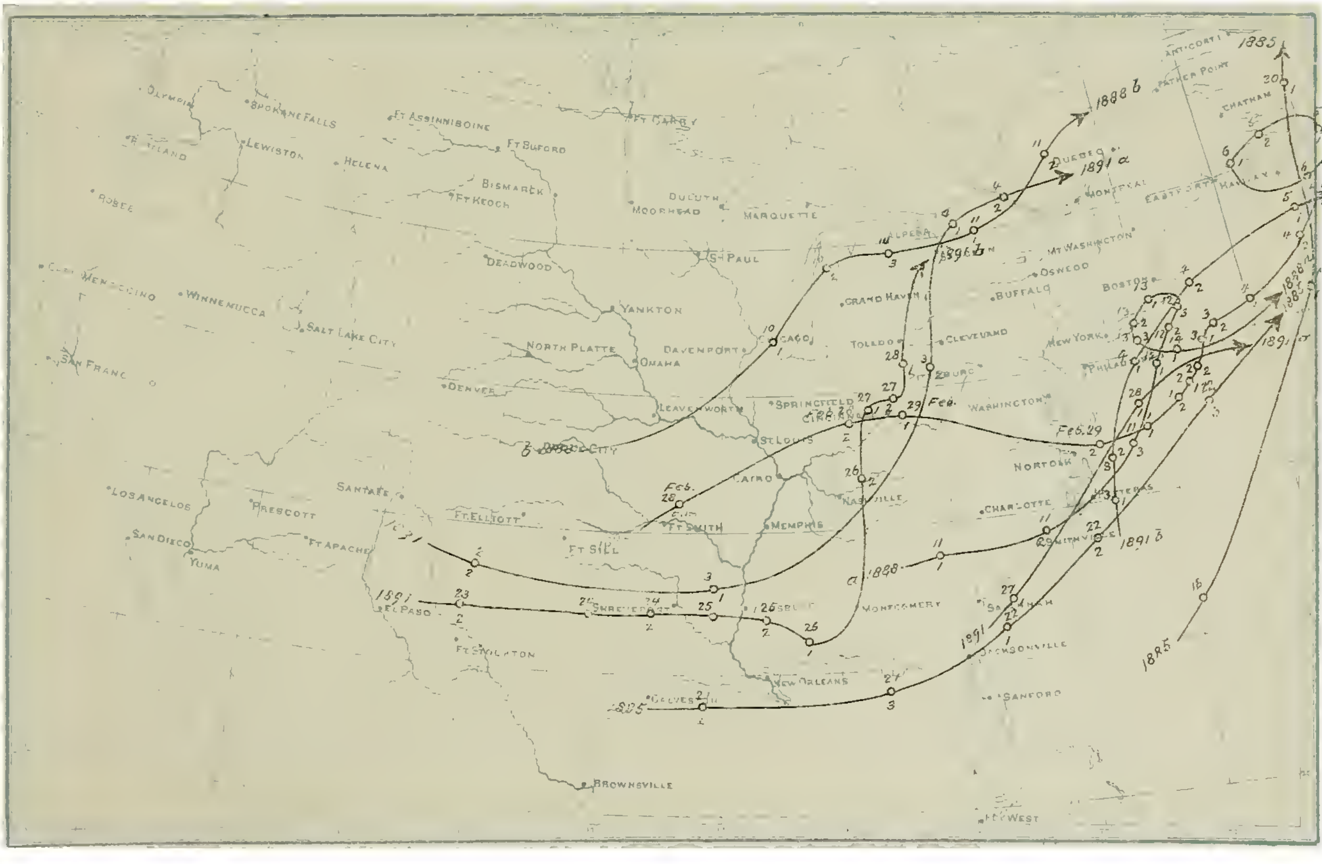
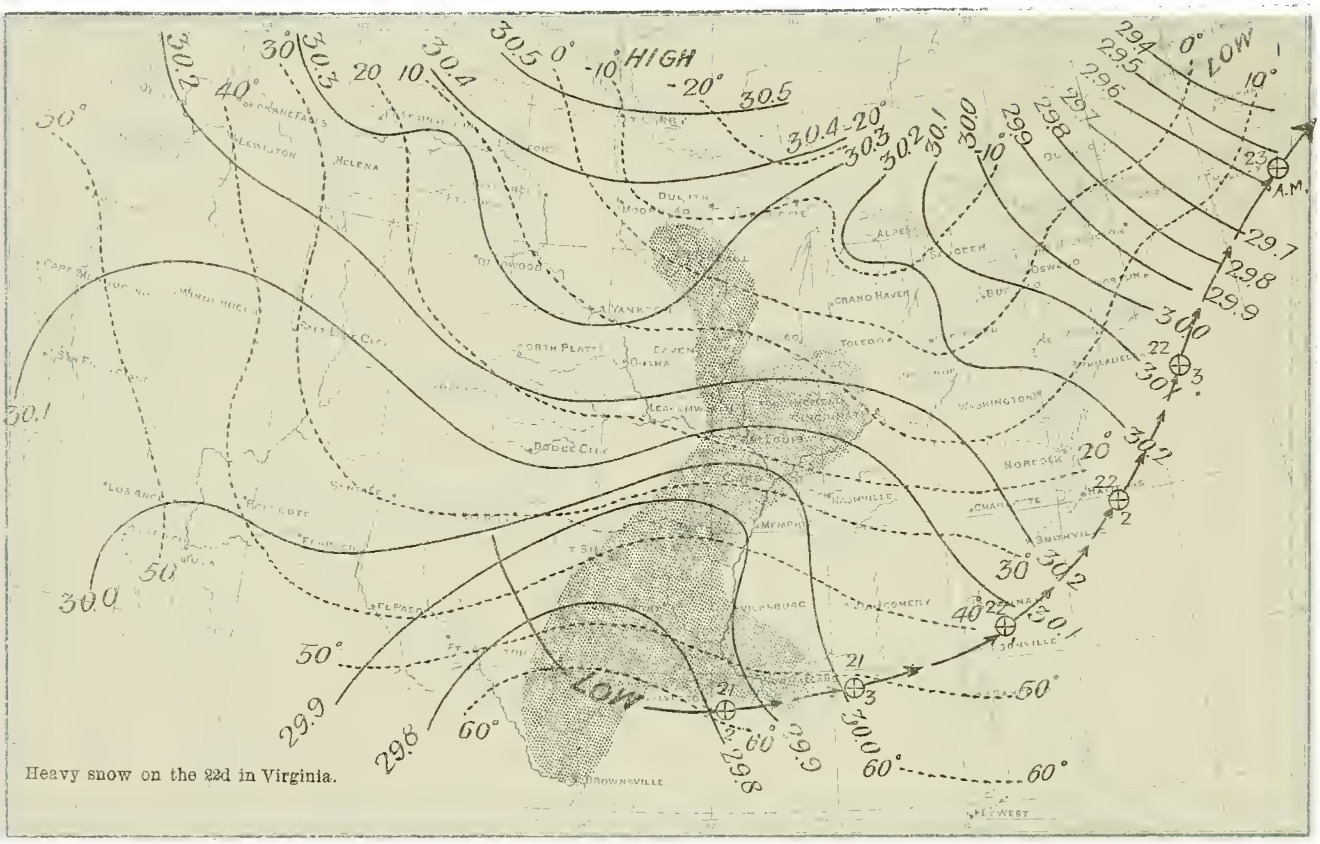


CHART 51. March 21, 1885—7 a. m.



Heavy snow on the 22d in Virginia.

CHART 52. March 10, 1888—7 a. m.

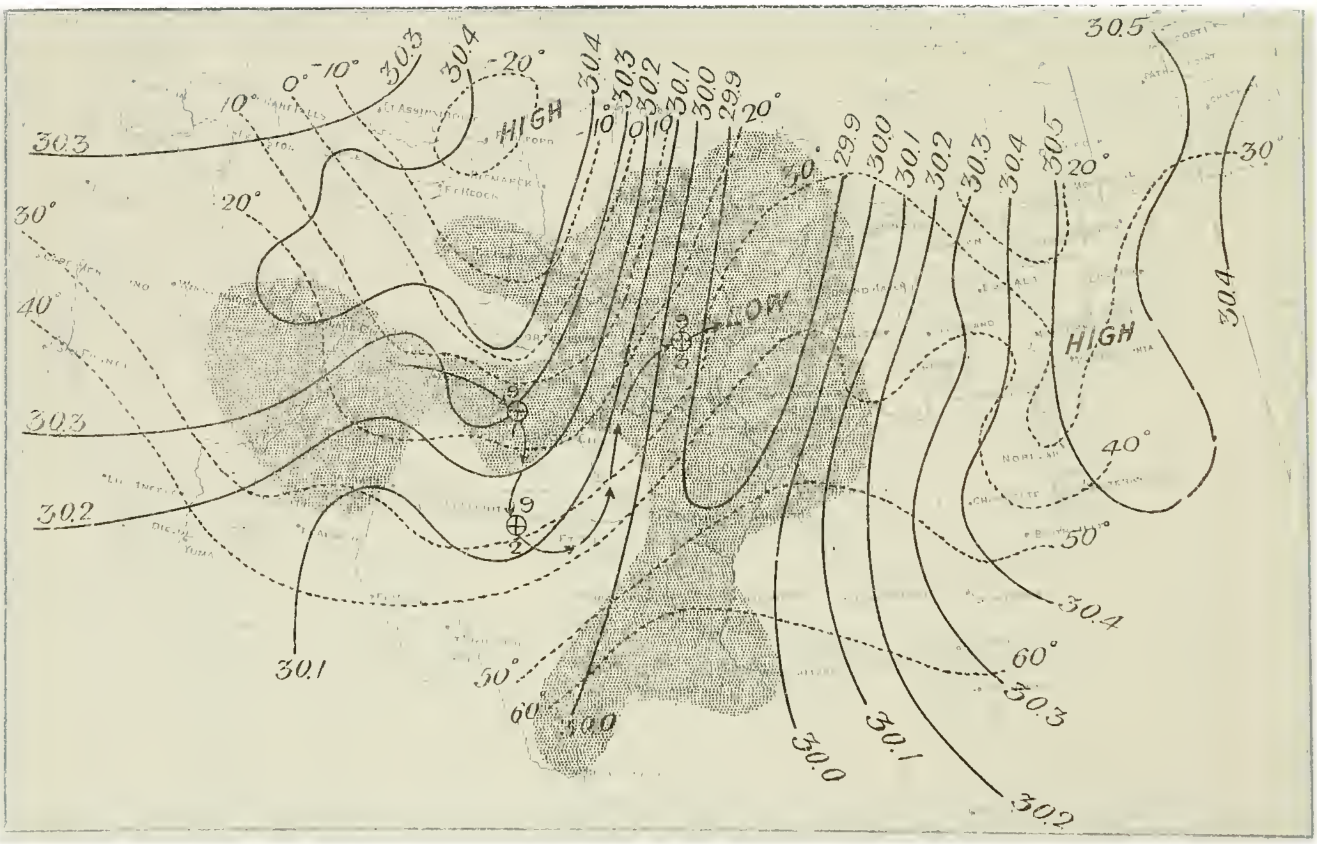


CHART 53. March 11, 1888 —7 a. m.

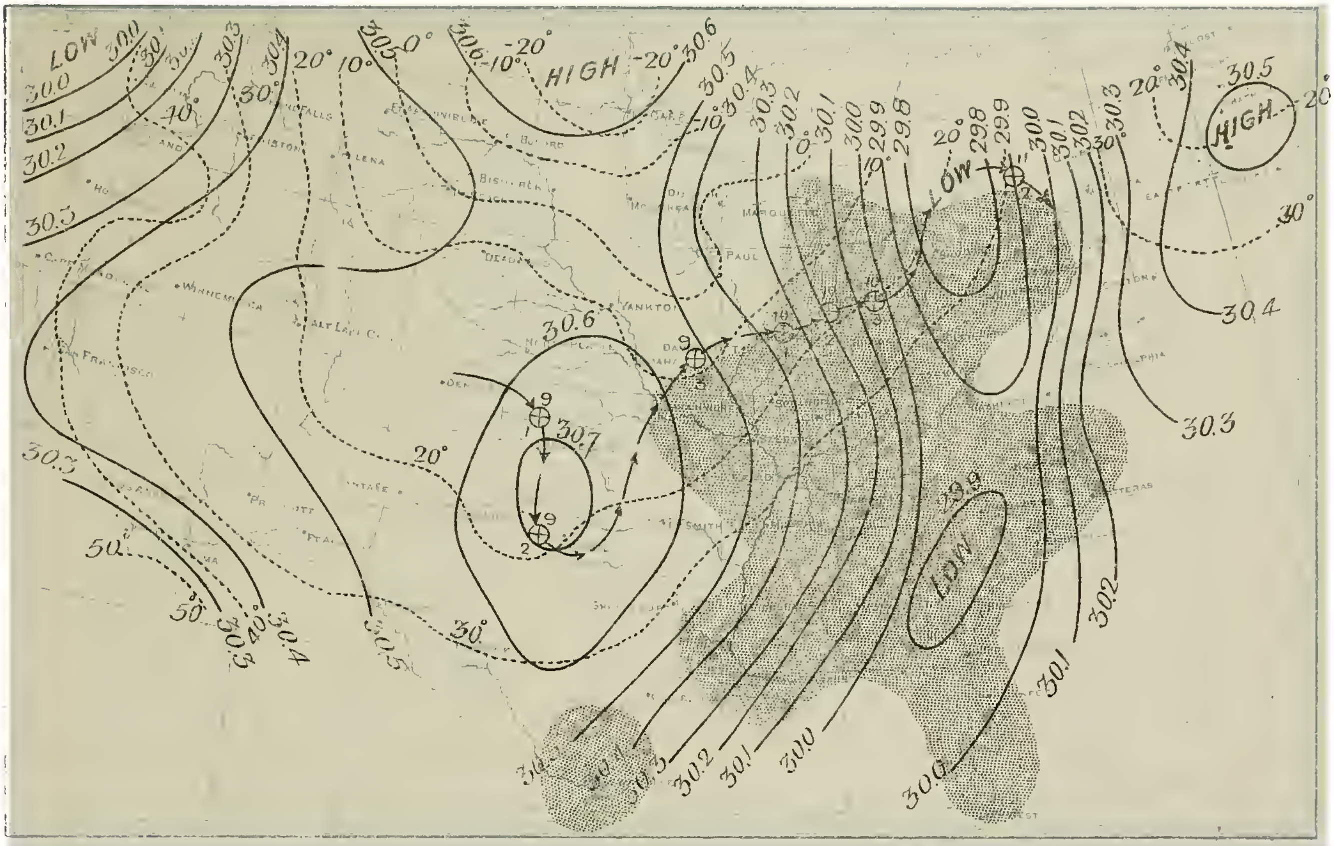


CHART 54. March 12, 1888—7 a. m.

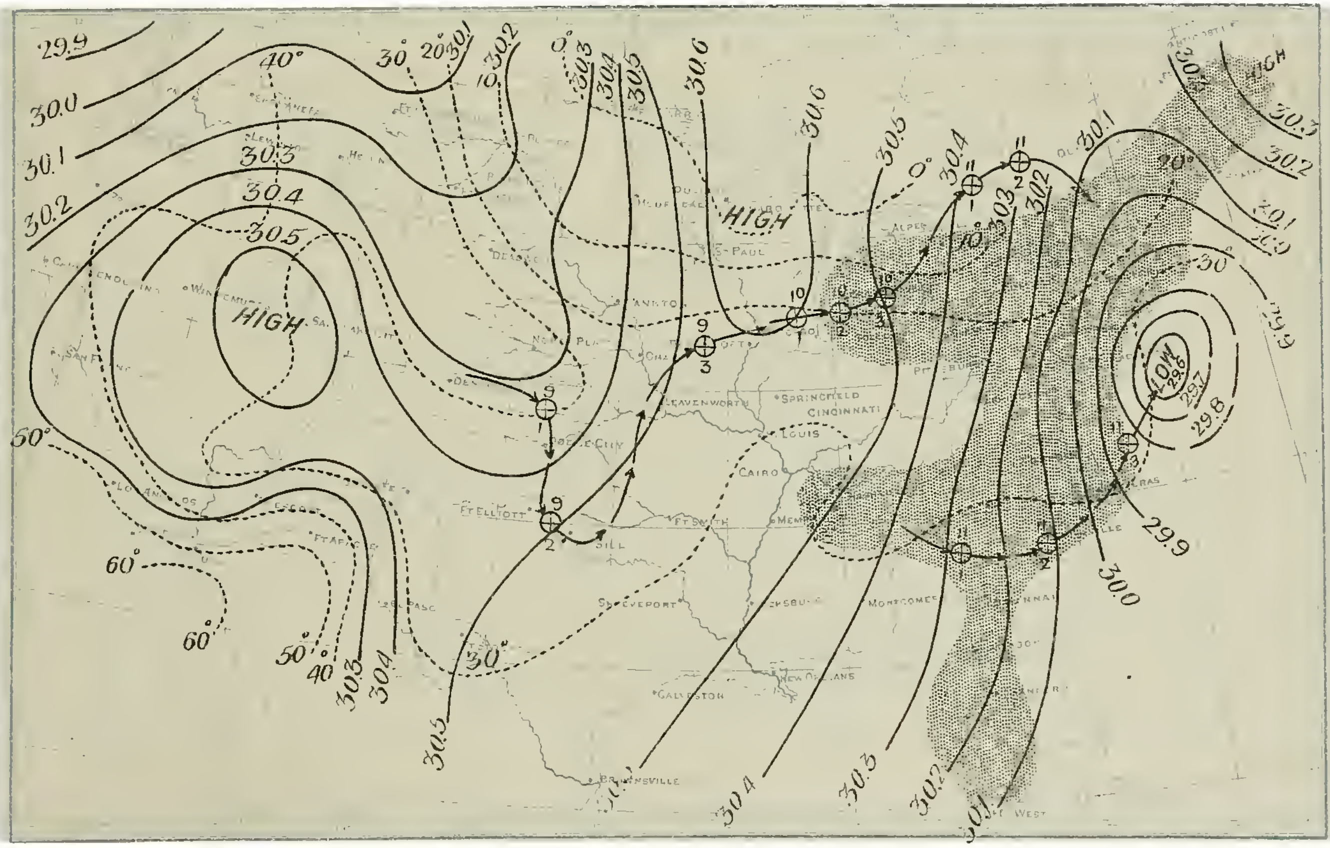


CHART 55. March 13, 1888—7 a. m.

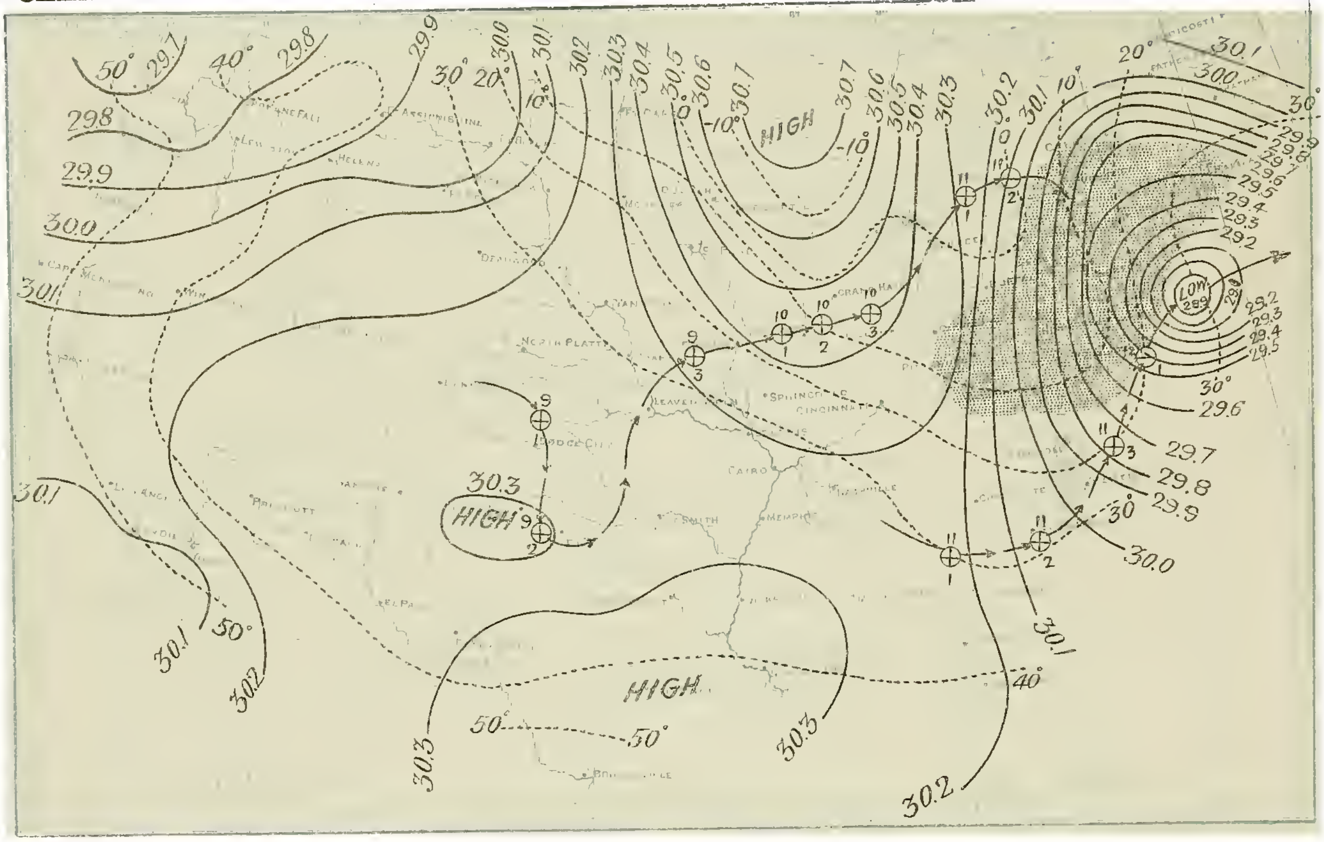
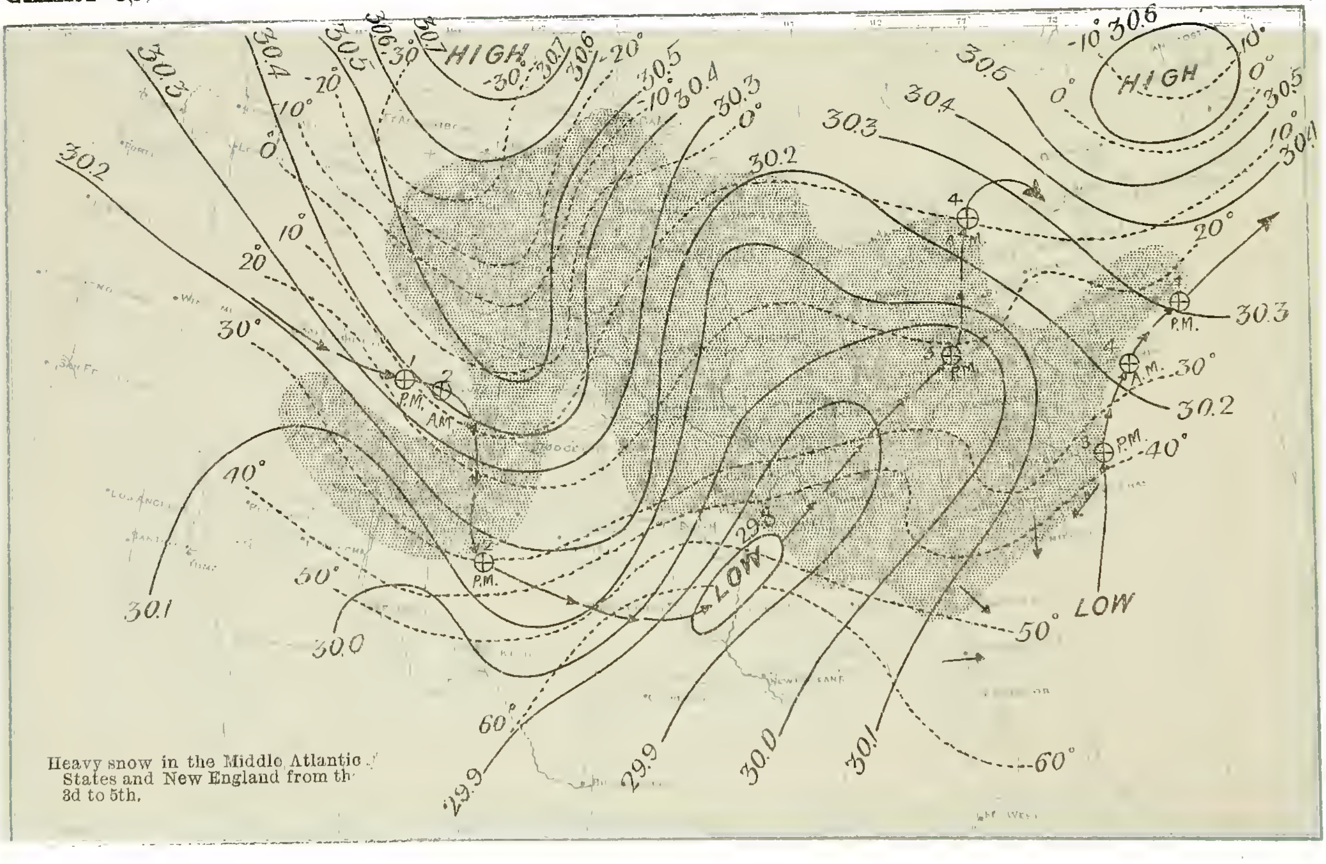
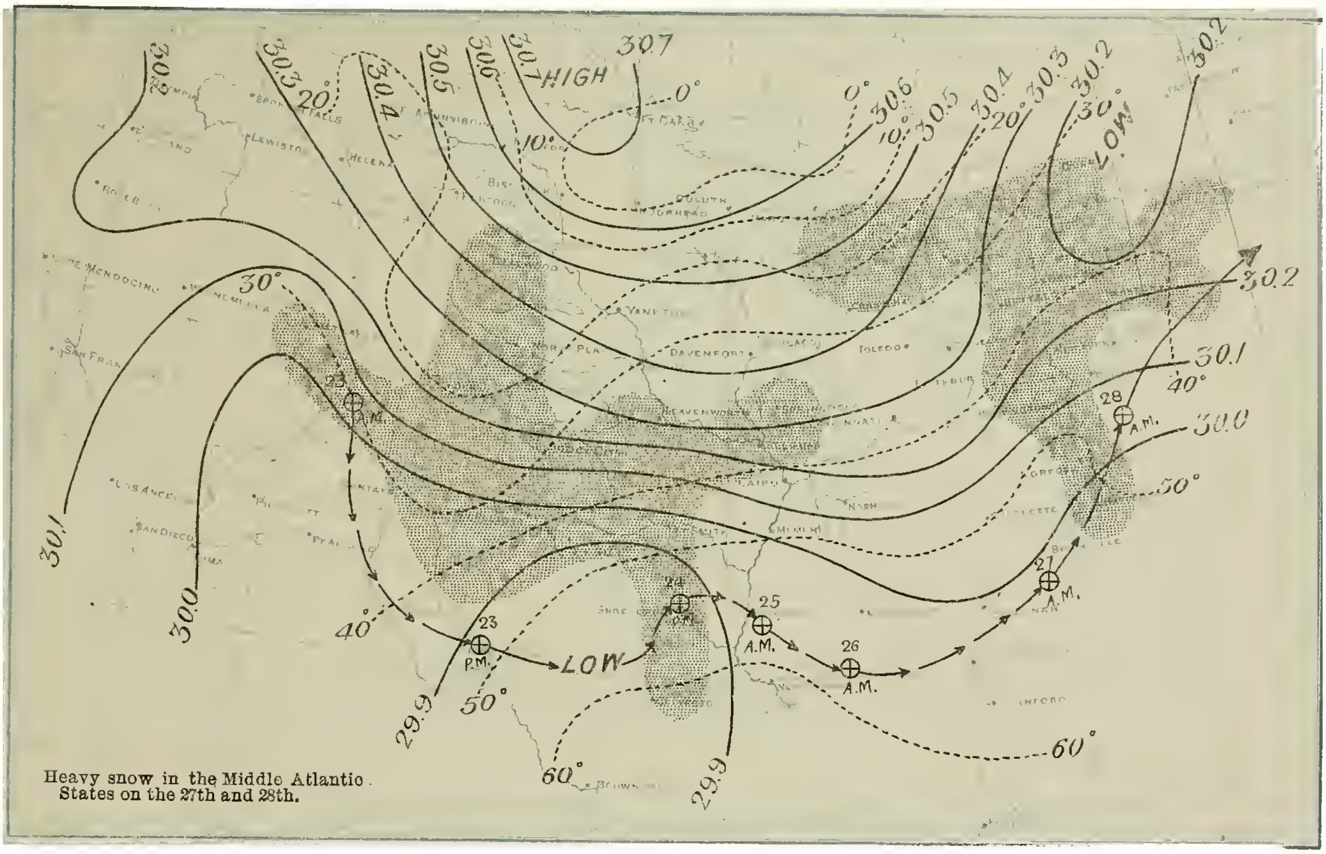


CHART 56. March 3, 1891—8 a. m.



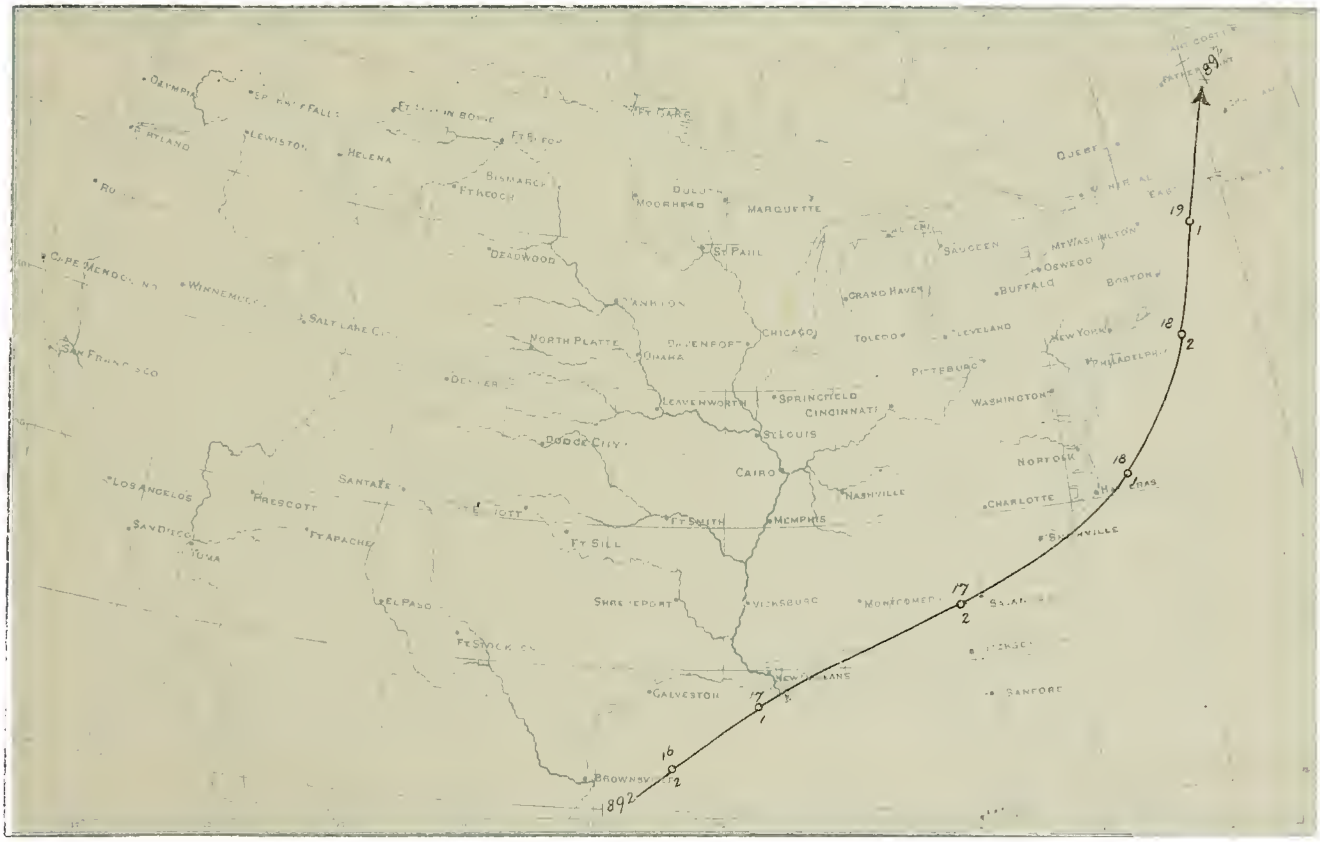
Heavy snow in the Middle Atlantic States and New England from the 3d to 5th.

CHART 57. March 24, 1891—8 a. m.

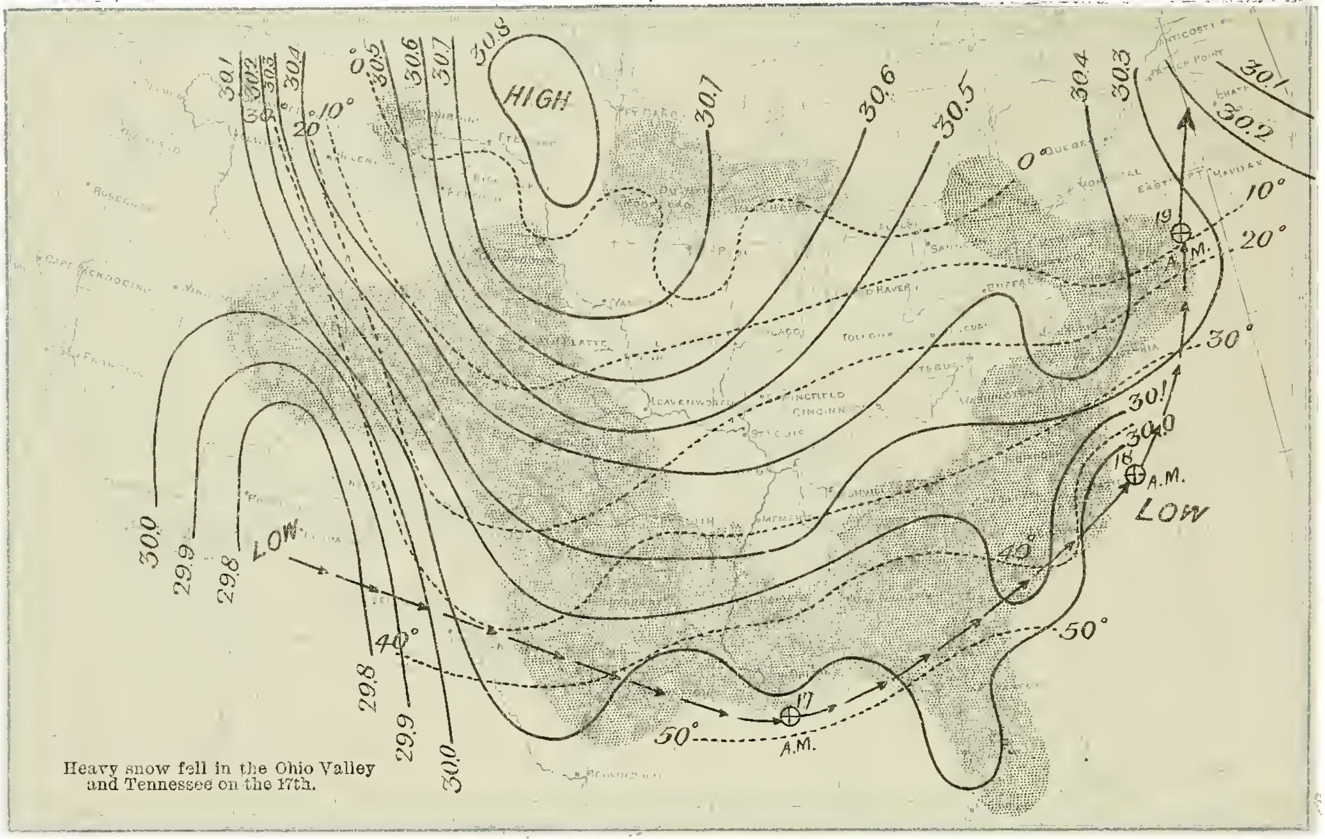


Heavy snow in the Middle Atlantic States on the 27th and 28th.

CHART 58. OHIO VALLEY AND TENNESSEE.



March 16, 1892—8 a. m.



Heavy snow fell in the Ohio Valley and Tennessee on the 17th.

MIDDLE MISSOURI VALLEY.

CHART 60.

MARCH.

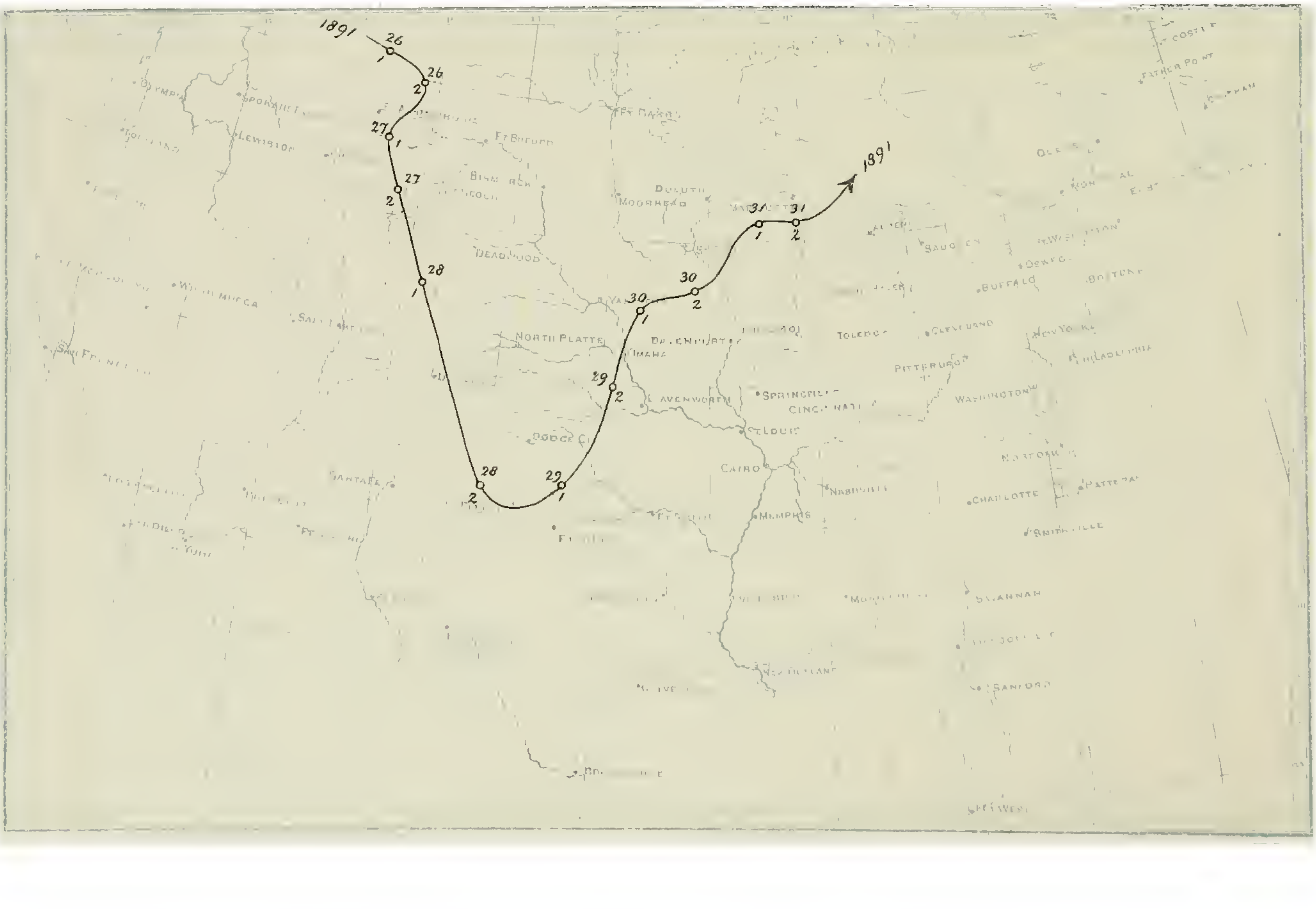
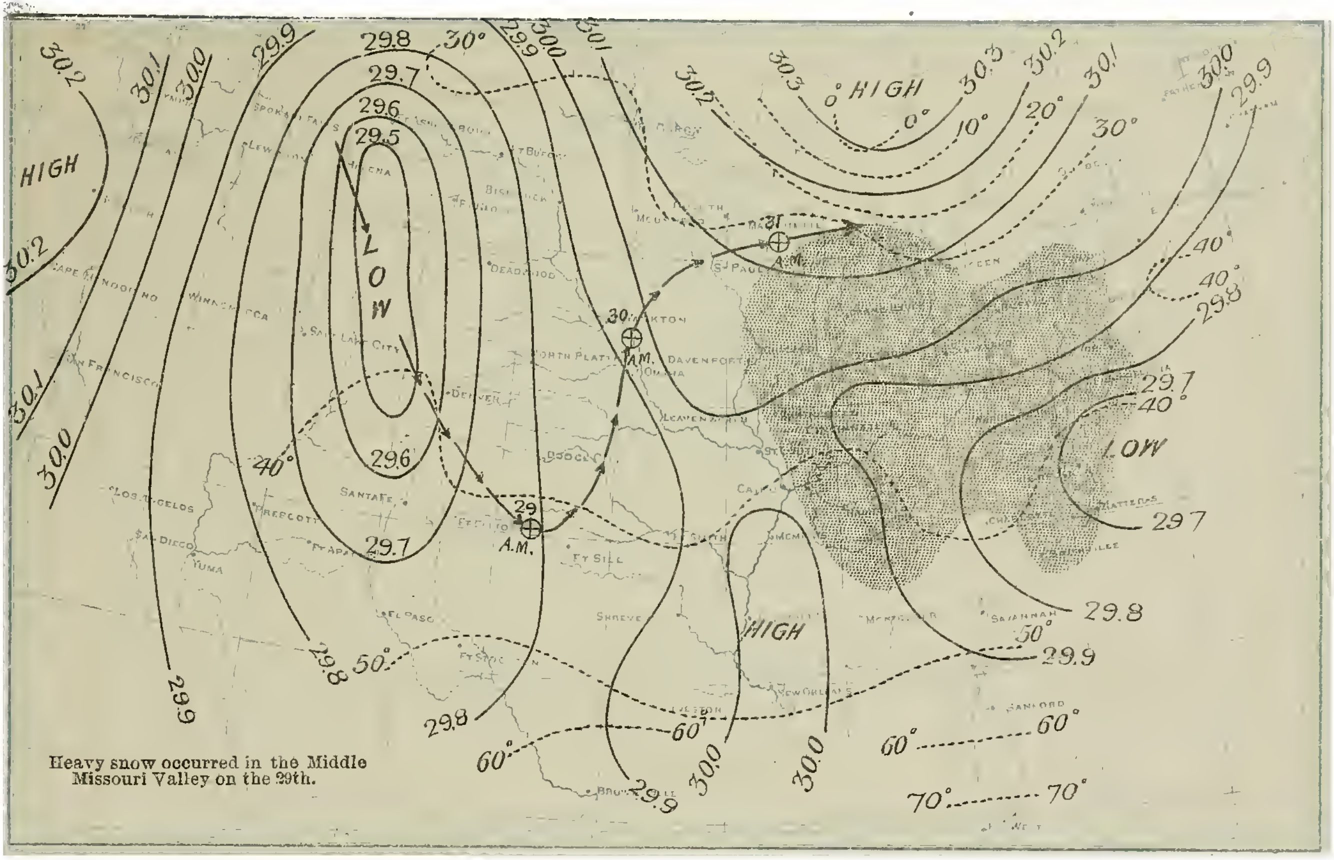


CHART 61. March 28, 1891—8 a. m.



Heavy snow occurred in the Middle Missouri Valley on the 29th.

NORTHWESTERN STATES.

CHART 62. MARCH.

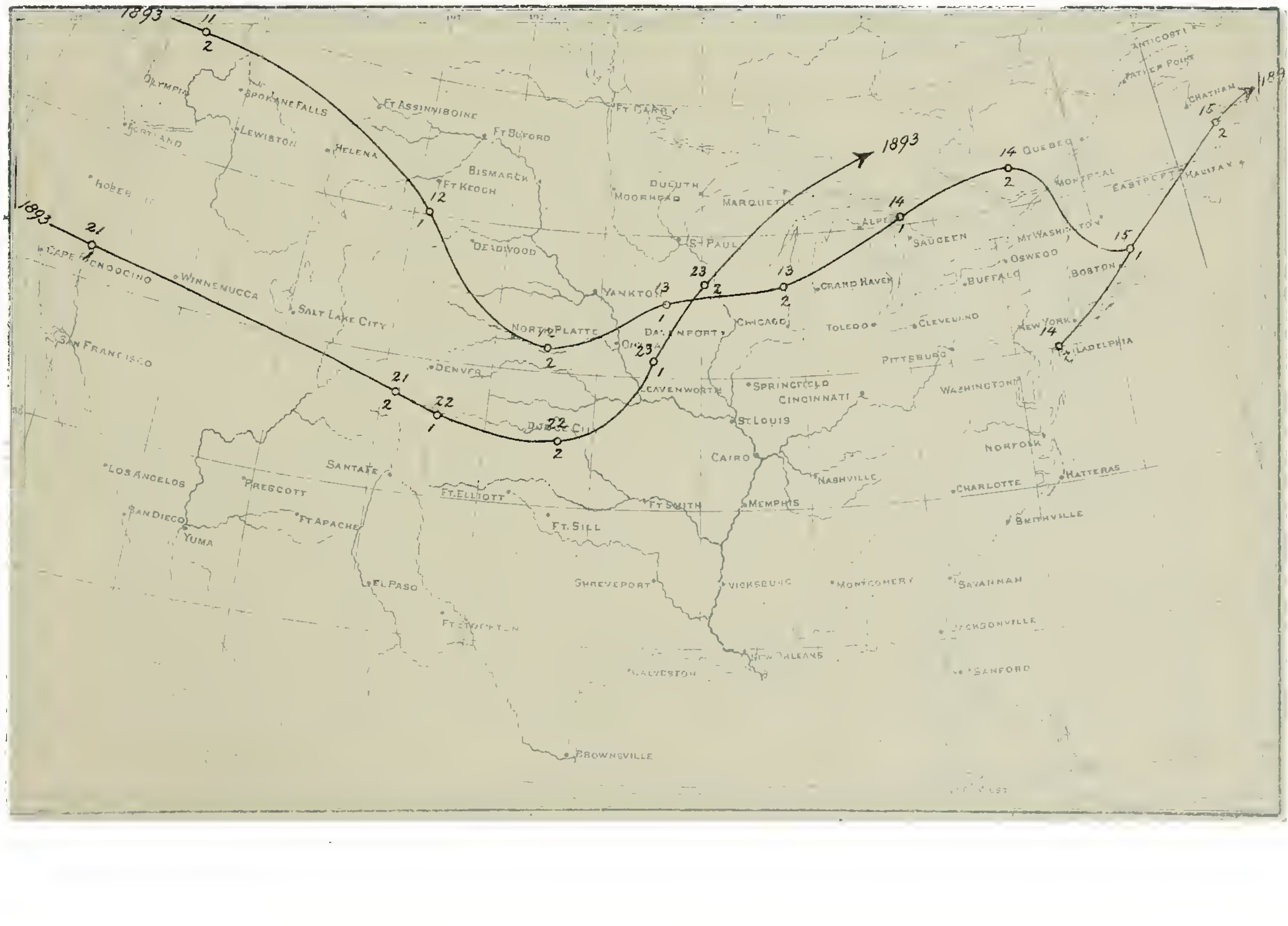
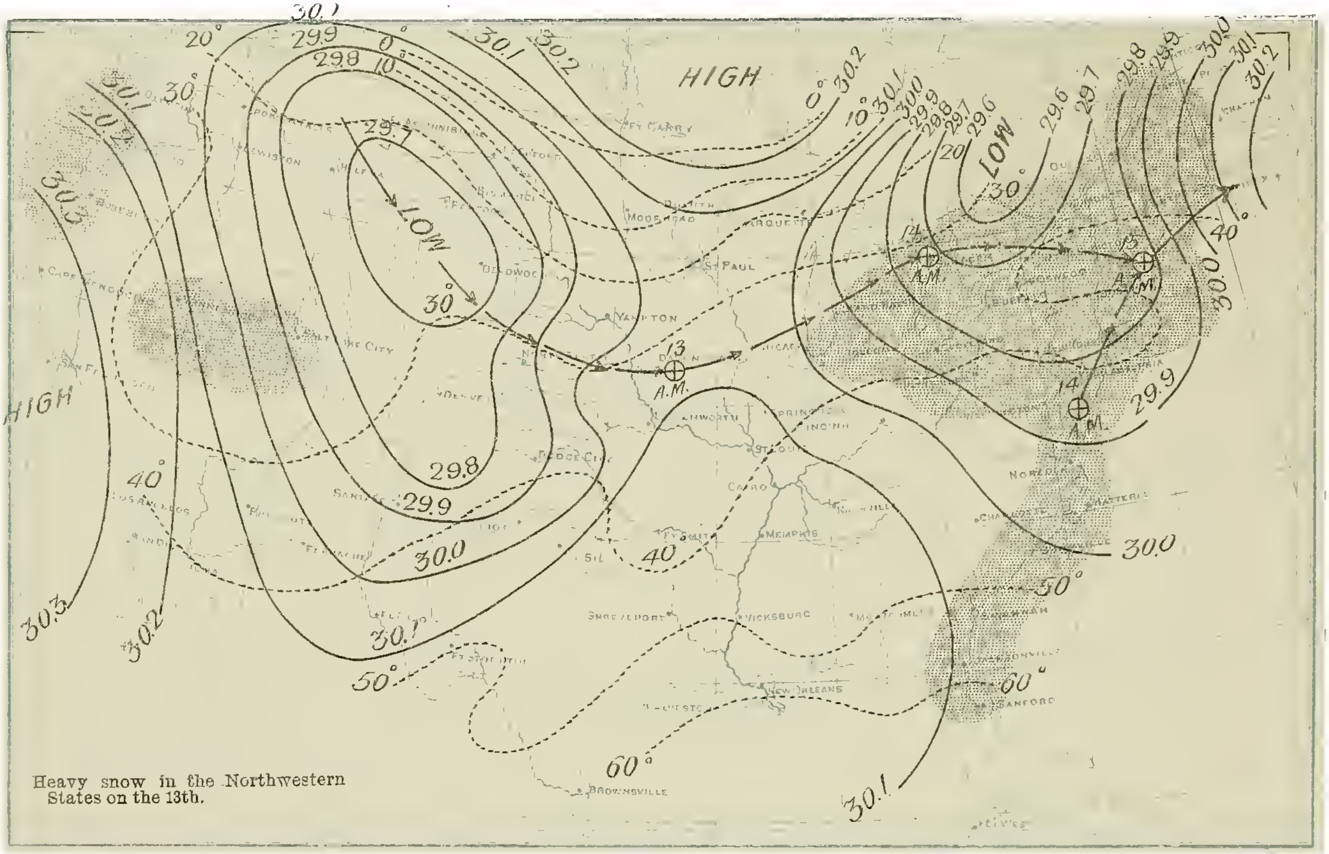
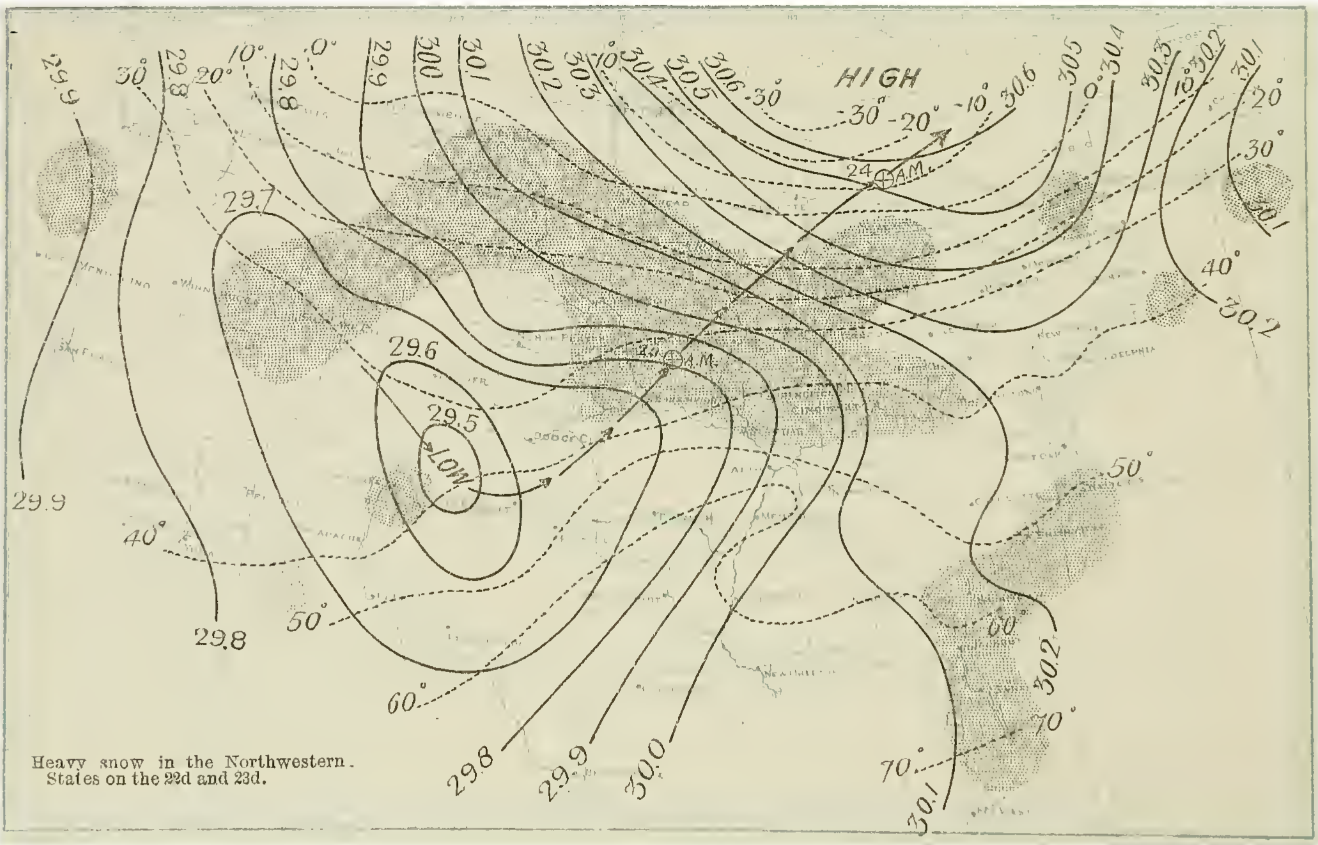


CHART 63. **March 12, 1893—8 a. m.**



Heavy snow in the Northwestern States on the 13th.

CHART 64. **March 22, 1893—8 a. m.**

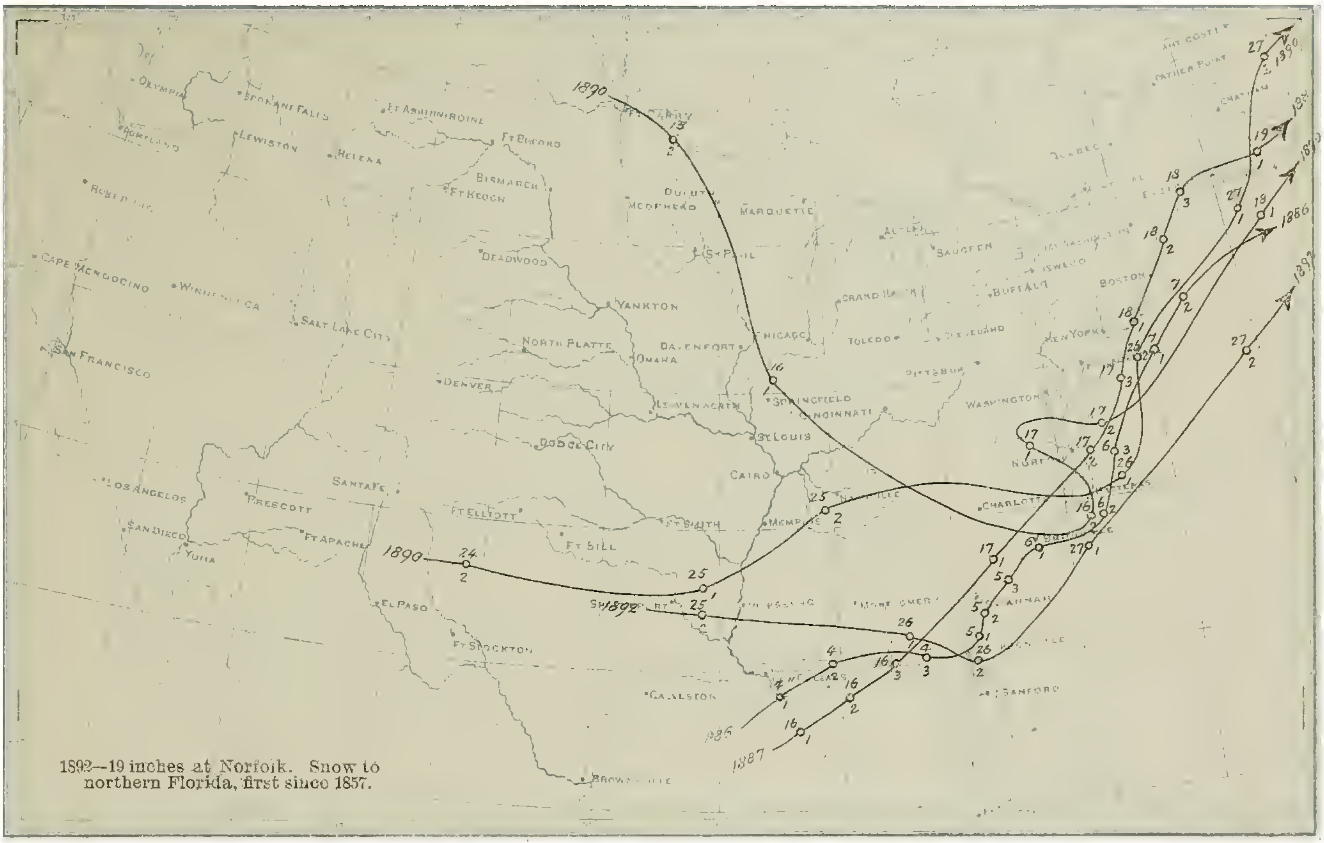


Heavy snow in the Northwestern States on the 22d and 23d.

MIDDLE ATLANTIC AND NEW ENGLAND STATES.

HART 65.

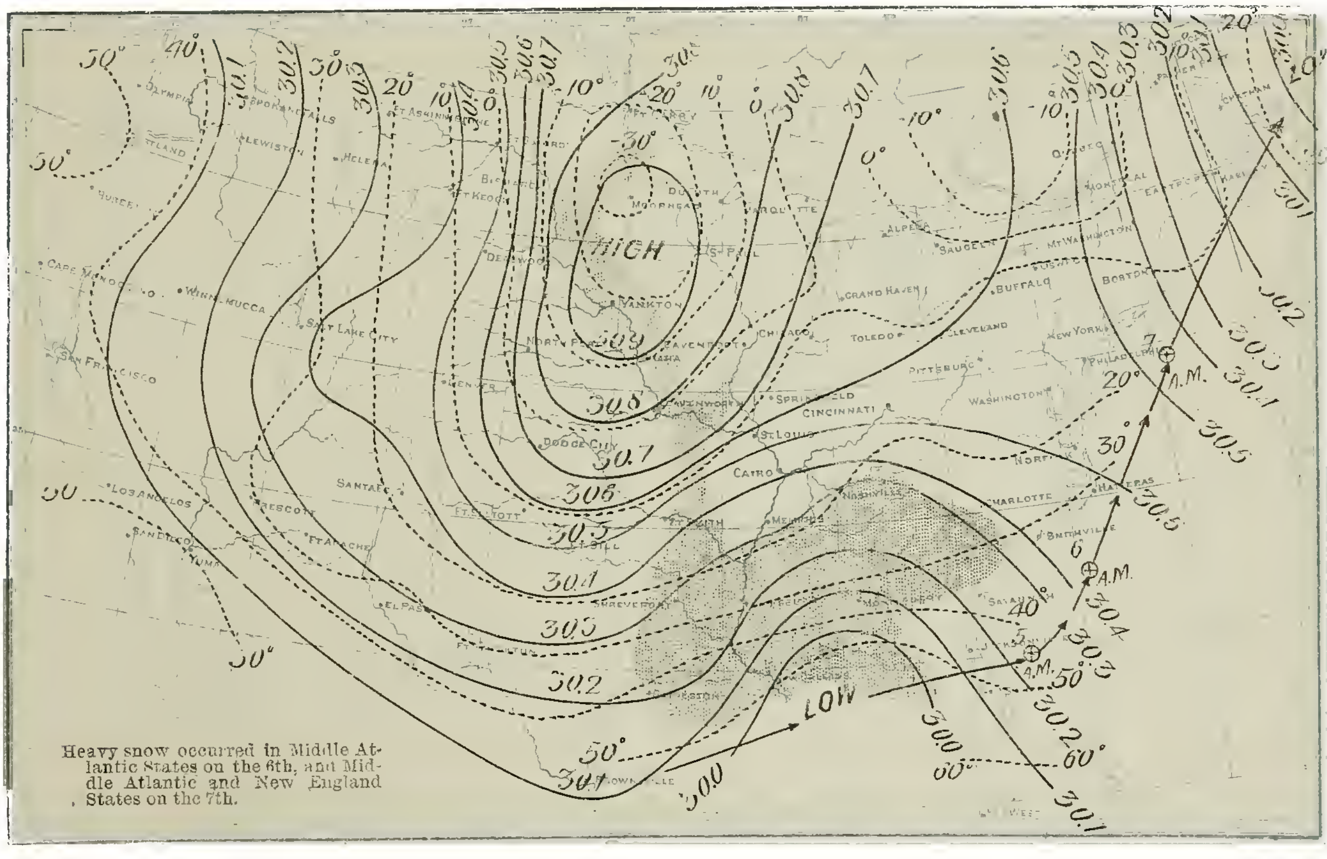
DECEMBER.



1892—19 inches at Norfolk. Snow to northern Florida, first since 1857.

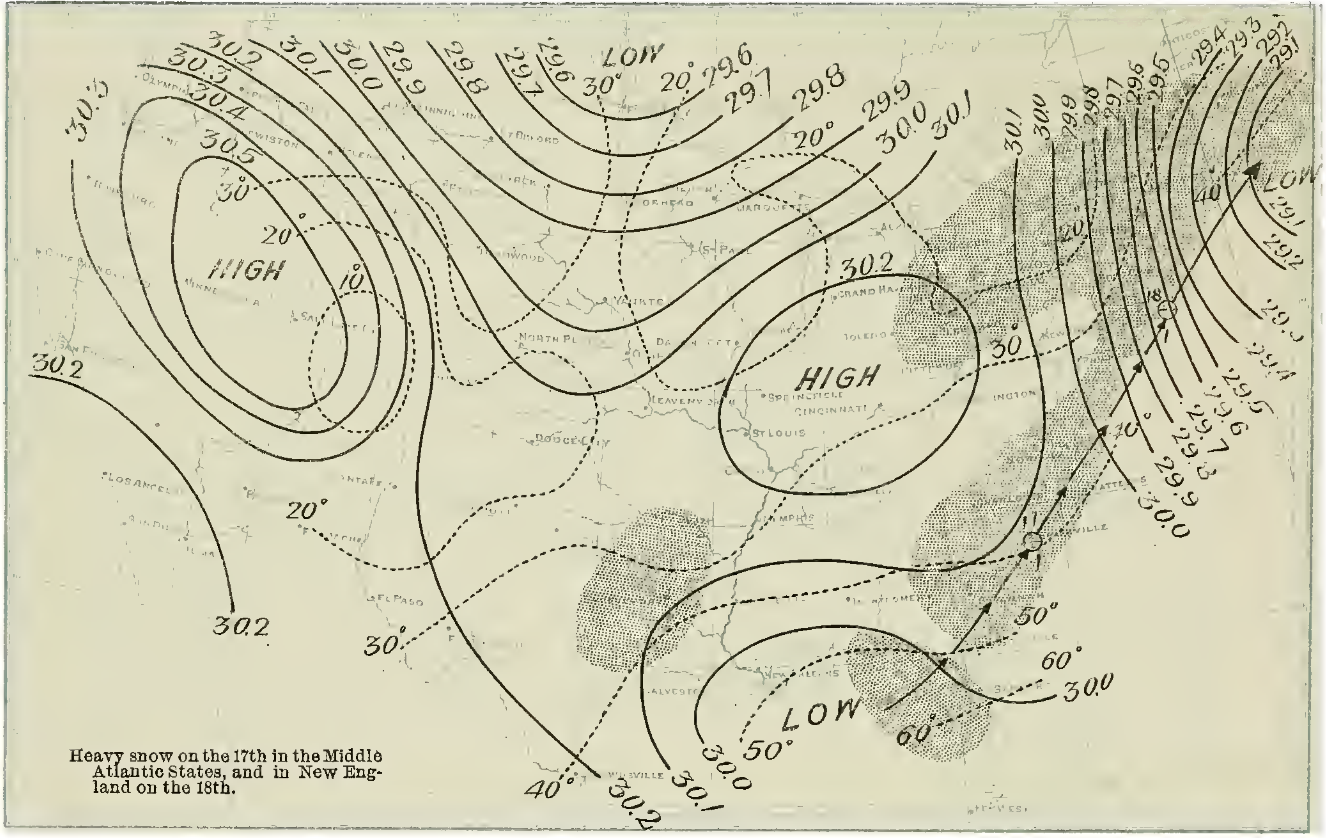
CHART 66.

December 4, 1886—7 a. m.



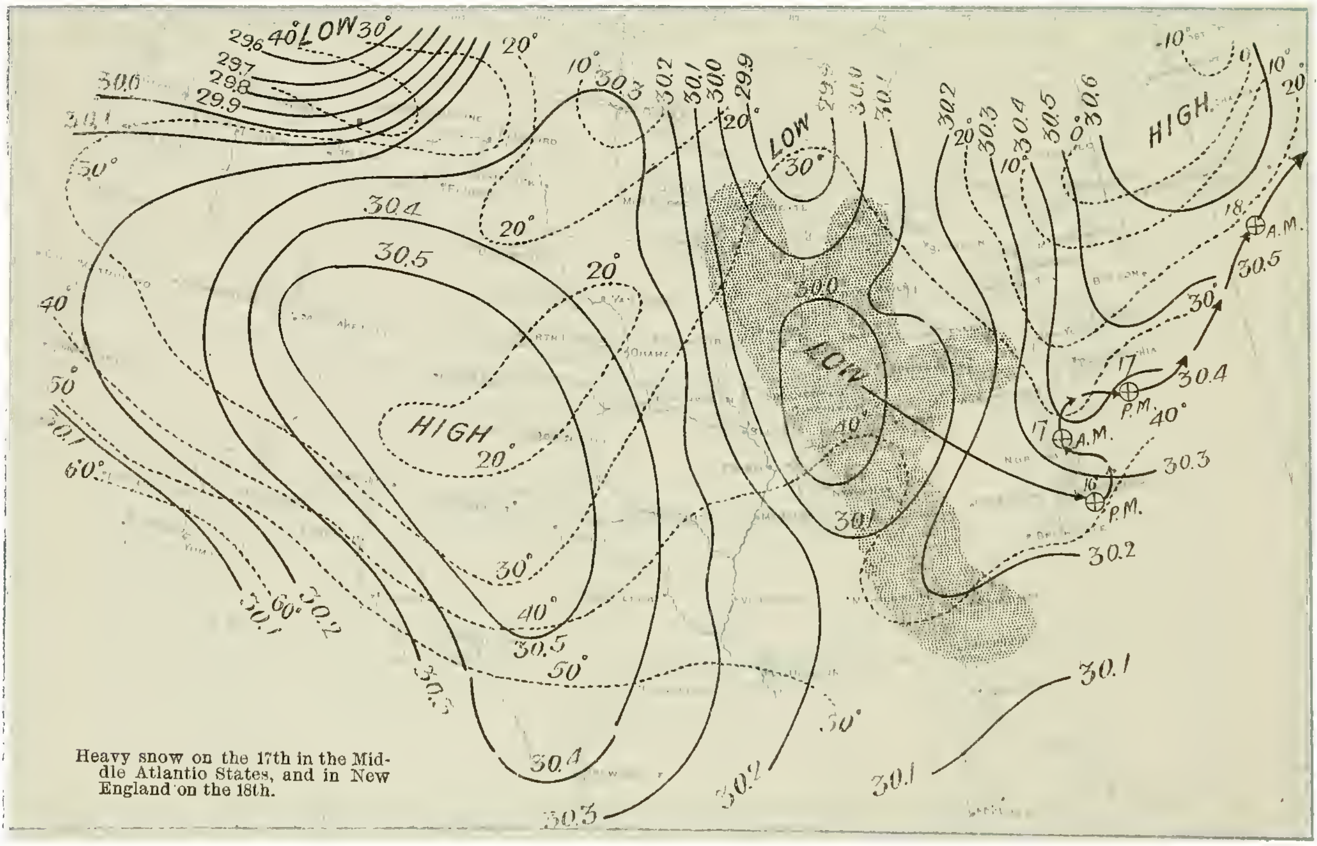
Heavy snow occurred in Middle Atlantic States on the 6th, and Middle Atlantic and New England States on the 7th.

CHART 67. **December 16, 1887—7 a. m.**



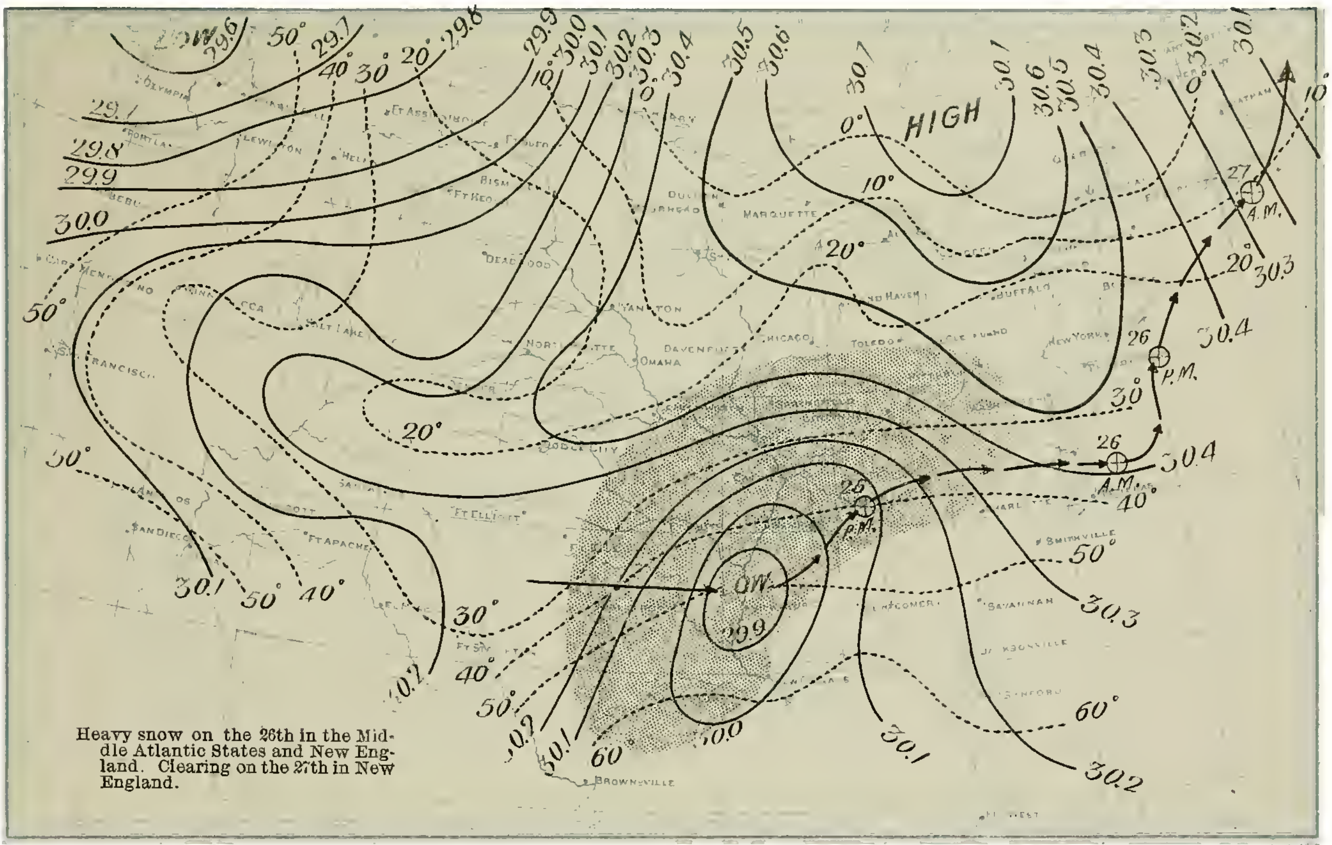
Heavy snow on the 17th in the Middle Atlantic States, and in New England on the 18th.

CHART 68. **December 16, 1890—8 a. m.**



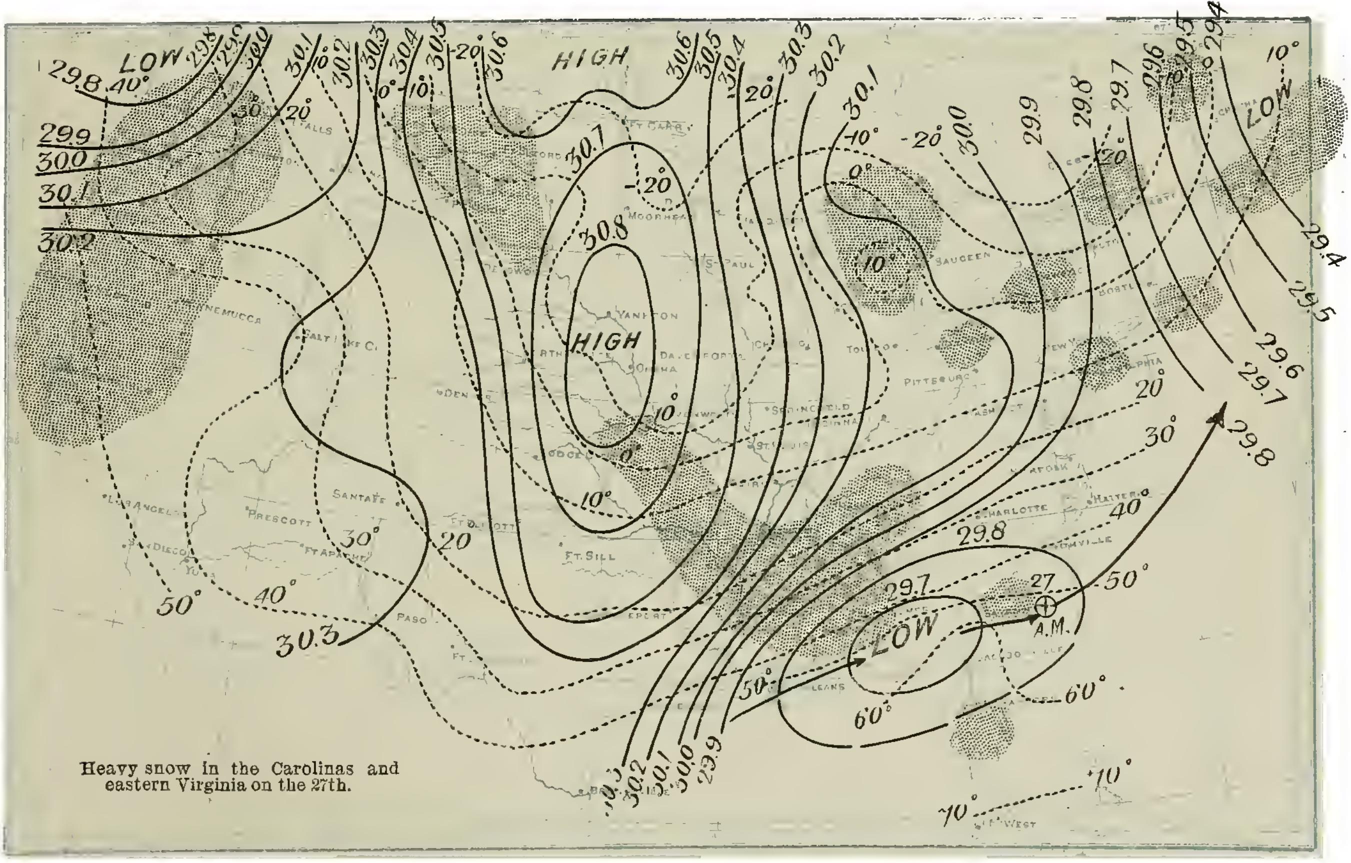
Heavy snow on the 17th in the Middle Atlantic States, and in New England on the 18th.

CHART 69. December 25, 1890—8 a. m.



Heavy snow on the 26th in the Middle Atlantic States and New England. Clearing on the 27th in New England.

CHART 70. December 26, 1892—8 a. m.



Heavy snow in the Carolinas and eastern Virginia on the 27th.

NORTHWESTERN STATES.

CHART 71.

DECEMBER.

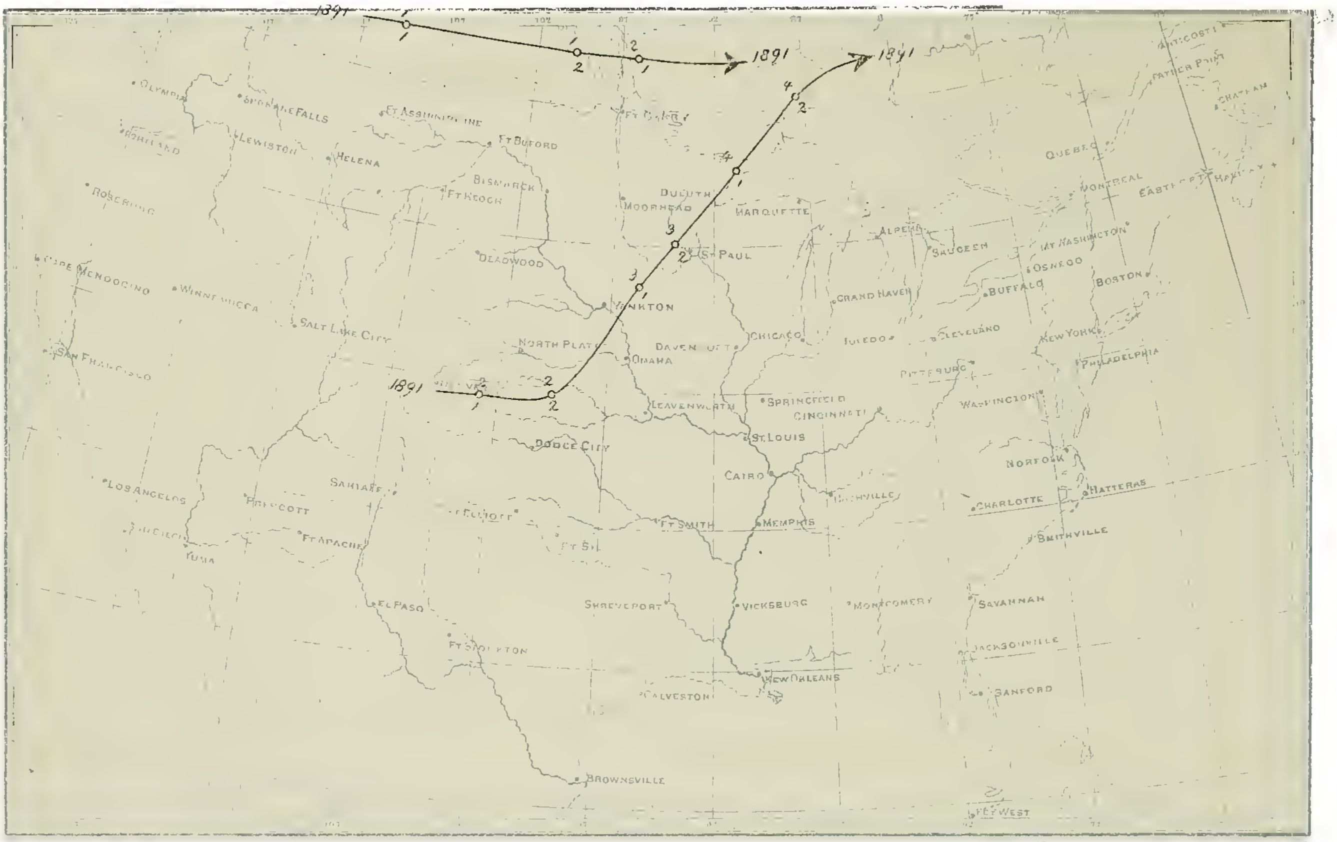
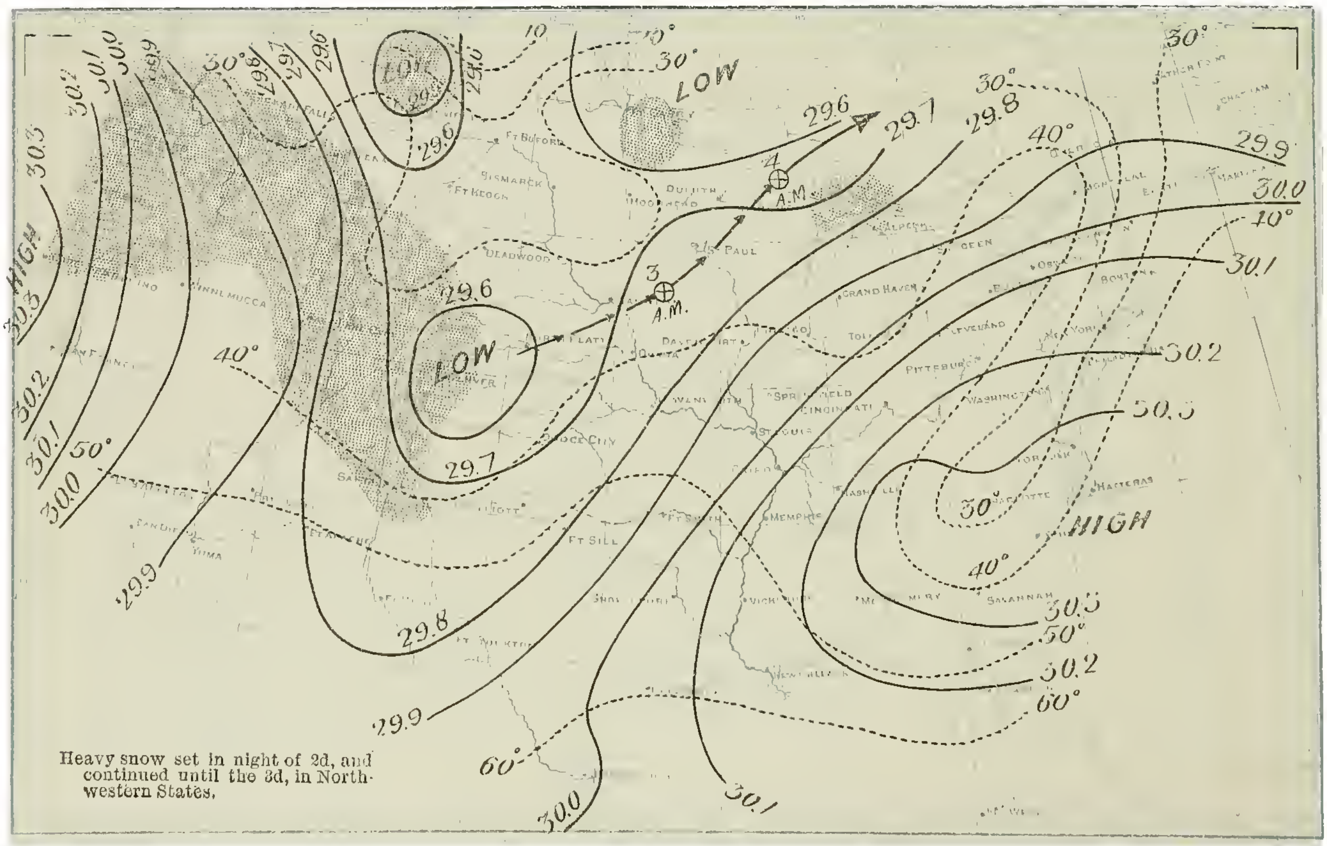


CHART 72.

December 2, 1891—8 a. m.



Heavy snow set in night of 2d, and continued until the 3d, in Northwestern States.