

MONTHLY WEATHER REVIEW.

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No. 4.

INTRODUCTION.

The REVIEW for April, 1894, is based on reports from 3,215 stations occupied by regular and voluntary observers. These reports are classified as follows: 153 reports from Weather Bureau stations; 41 reports from U. S. Army post surgeons; 2,165 monthly reports from State weather service and voluntary observers; 30 reports from Canadian stations; 223 reports through the Southern Pacific Railway Company; 567 marine reports through the co-operation of the Hydrographic Office, Navy Department, and "New York Herald Weather Service;" weekly or monthly reports from

36 U. S. Life-Saving stations; 18 reports from navigators on the Great Lakes; monthly reports from local services established in all States and Territories; and international simultaneous observations. Trustworthy newspaper extracts and special reports have also been used.

The WEATHER REVIEW for this month has been prepared under the general editorial supervision of Prof. Cleveland Abbe. The statistical tables are furnished by the Division of Records and Meteorological Data, in charge of Mr. A. J. Henry, acting chief of that division.

CHARACTERISTICS OF THE WEATHER FOR APRIL, 1894.

The most notable feature of the weather was the slow motion of the storm center off the coast of New Jersey and New England on the 11th to the 15th, and the attending extensive snowfall in the Middle States. The temperatures were decidedly above the normal in the Lake region and the entire eastern slope of the Rocky Mountains. The precipitation

was above the normal on the north Pacific coast and in North Dakota, but was generally below the normal.

The rivers were high in Arkansas and Louisiana and were rising in Oregon and Washington.

The ice on the coasts of Newfoundland and Nova Scotia was driven far west of the ordinary limit and was unusually heavy.

ATMOSPHERIC PRESSURE.

[In inches and hundredths.]

The distribution of mean atmospheric pressure reduced to sea level for April, 1894, as determined from observations taken daily at 8 a. m. and 8 p. m. (seventy-fifth meridian time), is shown by isobars on Chart II, which also gives the so-called resultant wind direction for this month; these resultants are also given numerically in Tables VIII and IX of the present REVIEW. The pressures here charted are those shown by mercurial barometers as affected by local gravity and need to be reduced to standard gravity. That part of this reduction that depends on latitude is shown by the numbers printed on the border of Chart II; it should be applied and new isobars drawn by those engaged in special researches.

During the current month of April the pressures at sea level have been highest (30.17 to 30.10) on the coast of northern California, Oregon, and Washington, and nearly as high (30.12 to 30.10) on the coasts of Florida, Georgia, South Carolina, and North Carolina; these two regions of high pressure evidently represent, respectively, the northeastern border of the high pressure over the Pacific and the southwestern border of the high over the Atlantic. The regions of low pressure were 29.90, or less, from Yuma, Ariz., southward, as also 29.90, or less, in eastern Montana, and northward over Alberta, Assiniboia, and Saskatchewan.

The normal distribution of atmospheric pressure and normal resultant wind direction for the month of April were approximately shown on Chart VIII of the REVIEW for April, 1893, as computed by Prof. H. A. Hazen, and are not

now reproduced. As compared with the normal for April, the mean pressure for the current month was in excess at all stations in the Pacific and Atlantic States, the Lake region, the Mississippi Valley, and the Gulf States, but was below the normal on the east and north Rocky Mountain slopes. The principal excess was 0.10 to 0.15 in New England, Nova Scotia, and New Brunswick; also 0.05 to 0.09 in Washington and Oregon. The principal deficit was 0.05 to 0.10 in Assiniboia. The line of no departure passed from Alberta southeast to New Mexico, thence west into southern California; it reappeared in central Texas and ran northward to the center of Lake Superior.

As compared with the preceding month of March the mean pressure of April was lower at all stations, except in a portion of the Lake region and Washington and Oregon. The line of no change passed through Nova Scotia, Maine, northern New York, western Pennsylvania, southern Michigan, northern Illinois, central Wisconsin, Minnesota, and Manitoba; it reappeared in western Alberta, passed through central Idaho, Nevada, and northern California westward to the Pacific. The principal fall was from 0.10 to 0.12 in eastern Montana, and the principal rise was 0.10 to 0.17 on the coasts of Oregon and Washington.

The systematic periodic diurnal variations of pressure are shown by the hourly means given in Table VI.

AREAS OF HIGH AND LOW PRESSURE.

The following sections give details as to the general phe-

nomena attending the individual areas of high and low pressure; the storm warnings officially issued by the Weather Bureau are also enumerated in connection with the respective disturbances.

MOVEMENTS OF CENTERS.

The following table shows the date and location of the center at the beginning and ending of each area of high or low pressure that has appeared on the U. S. Weather Maps during the month, together with the average daily and hourly velocities. The monthly averages will differ according as we consider each path as a distinct unit, or give equal weight to each hour of observation; in the first case the monthly average is taken by paths, in the latter case by hours:

Movements of centers of areas of high and low pressure.

Number.	First observed.			Last observed.			Path.		Average velocities.		
	Date.	Lat. N.	Long. W.	Date.	Lat. N.	Long. W.	Length.	Duration.	Daily.	Hourly.	
High areas.											
I.	1, a. m.	0	0	7, a. m.	33	78	4,200	6.0	700	29	
II.	1, a. m.	56	96	3, p. m.	37	74	1,600	2.5	640	27	
III.	7, a. m.	44	129	10, a. m.	30	100	1,900	3.0	633	26	
IV.	7, a. m.	57	89	12, a. m.	49	56	1,850	5.0	370	15	
V.	11, a. m.	40	127	12, a. m.	43	126	300	1.0	300	12	
VI.	12, a. m.	53	114	14, a. m.	47	86	1,350	2.0	675	28	
VII.	12, a. m.	46	93	16, a. m.	49	65	1,050	4.0	413	17	
VIII.	16, a. m.	42	126	22, a. m.	43	91	1,500	6.0	250	11	
IX.	24, a. m.	50	86	29, a. m.	30	80	1,700	5.0	340	14	
X.	24, p. m.	44	115	25, a. m.	44	109	400	1.0	400	17	
XI.	27, a. m.	43	129	30, a. m.	42	108	50	3.0	166	7	
XII.	28, a. m.	50	90	30, p. m.	36	71	1,500	2.5	600	25	
Sums							18,000	41.0	5,487		
Mean of 12 paths									457	19.0	
Mean of 41 days									439	18.3	
Low areas.											
I.	1, a. m.	49	66	2, a. m.	49	53	700	1.0	700	29	
II.	1, a. m.	54	115	6, a. m.	47	55	2,900	5.0	580	24	
III.	1, a. m.	33	95	1, p. m.	34	84	300	0.5	600	25	
IV.											
V.	6, p. m.	52	114	7, a. m.	54	109	300	0.5			
VI.	7, p. m.	43	101	10, p. m.	44	85	1,750	3.0	583	24	
VII.	6, p. m.	42	93	9, p. m.	44	60	2,000	3.0	667	28	
VIII.	10, p. m.	36	75	14, a. m.	42	65	700	3.5	200	8	
IX.	10, a. m.	53	116	13, p. m.	30	100	1,900	2.5	760	32	
X.	13, a. m.	53	117	16, a. m.	47	87	1,500	3.0	500	21	
XI.	16, a. m.	41	108	21, p. m.	48	73	2,000	5.5	364	15	
XII.	22, a. m.	41	74	25, a. m.	47	58	1,300	3.0	433	18	
XIII.	17, p. m.	48	113								
XIV.	21, a. m.	52	115	25, p. m.	47	95	1,300	4.5	289	12	
XV.	22, p. m.	32	102	25, a. m.	26	97	1,200	2.5	480	20	
XVI.	26, a. m.	49	123	30, p. m.	51	87	1,600	4.5	356	15	
XVII.	27, p. m.	43	105	30, p. m.	42	98	900	3.0	300	13	
Sums							20,350	45.0	6,812		
Mean of 14 paths									487	20.3	
Mean of 45 days									452	18.8	

HIGH AREAS.

I.—This was apparently the eastern end of the so-called tropical area over the Pacific Ocean. After pushing eastward over the Rocky Mountain plateau on the 1st, the highest pressure seems to have retreated to the west and extended northeastward toward Oregon, but by the morning of the 3d it had again pushed eastward over the Rocky Mountains, and on the morning of the 4th the highest pressure extended from British Columbia southeast over Wyoming, and was entirely east of the Rocky Mountain Divide. Severe frosts occurred on the mornings of the 3d, 4th, and 5th in northern California, Washington, Oregon, Idaho, and western Montana. The highest pressure moved south and east, being central on the 5th, a. m., in Kansas; 6th, a. m., in Tennessee, with severe frosts in adjoining States, and on the 7th, a. m., off the south Atlantic coast, with light frosts in North Carolina, South Carolina, and Tennessee, after which this high area disappeared over the ocean.

II.—This was a continuation of high area No. XIX from March. It appeared on the 1st, a. m., in Manitoba, while low

area No. II was developing between it and high area No. I; it moved rapidly southeastward; the 2d, a. m., it was central near Lake Superior; 3d, a. m., in eastern Pennsylvania, and 3d, p. m., was off the middle Atlantic coast, where it disappeared.

III.—On the 7th, a. m., pressure rose off the coast of Oregon, apparently due to the motion northeastward of a high area from the Pacific Ocean. Just as in the case of high area No. I, we have here also a low area, No. V, developing apparently in British Columbia, while the high area, No. IV, develops to the eastward of it and high area No. III to the southwest. During the 7th and 8th the high pressure pushed eastward into Idaho and Montana, and by the 8th, p. m., was central in Utah; 9th, a. m., Colorado; 9th, p. m., the area of high pressure extended from Oregon and Idaho to Texas without much difference of pressure over this region, and this very rapid southeastward extension was accompanied by high north and northwest winds as well as by low pressure to the south and east, one of which developed into low area No. VI, which was central on the morning of the 10th in southern Michigan, while high area No. III was then central in western Texas, after which it disappeared.

IV.—On the 7th, a. m., pressure was rising with northeast winds on Lake Superior, while low No. V was central in Saskatchewan. Subsequent maps show that an area of high pressure must at that time have been central over Hudson Bay and moving southeastward, so that by the 8th, a. m., it was south of James Bay, while the central region of high pressure moved eastward. An area of low temperature moved more rapidly southward; on the 8th, a. m., pressure continued highest in Ontario, but temperature had fallen most decidedly in North Carolina; by the 10th, a. m., pressure was highest in the St. Lawrence Valley, Maine, and New Brunswick, but temperature had continued falling in North Carolina. On the 11th, a. m., pressure was highest over the Gulf of St. Lawrence, and by the 12th, a. m., over Newfoundland, after which this high area disappeared in the presence of low No. VIII, which was at that time moving along the New England coast.

V, VI, and VII.—On the 11th, a. m., pressure was highest off the coast of Oregon, but at the same time the extreme western portion of area No. IV, reaching from Manitoba into Minnesota, began its southward movement and may be called area No. VII; by the 12th, a. m., beside these two areas of high pressure, there was also an appreciable rise, with northerly winds and cooler air, in Assiniboia and Saskatchewan, which is called area No. VI, so that pressure was at or above the normal across the entire continent from Oregon to Nova Scotia, while to the southward pressures were low in Texas and on the middle Atlantic coast. The high pressure over Oregon (No. V) disappeared by the 13th, a. m., but that in Minnesota (VII) continued and was joined by that from Saskatchewan (VI), so that by the morning of the 14th a moderate high prevailed from Lake Superior southward. This high pressure moved eastward, passing over the mouth of the St. Lawrence on the 16th, a. m., after which it disappeared.

VIII.—The high area over the Pacific west of Oregon began pressing eastward on the 16th, a. m., while low area No. XI, which had for several days been prevailing throughout the Rocky Mountain region, advanced eastward, reaching Iowa on the 18th, p. m. From the 16th to the 18th pressure was high over northern California, Washington, and Oregon, apparently as the eastern edge of the high pressure on the Pacific, but by the 19th, a. m., pressure was highest in Idaho and stretched southeastward as a ridge that reached from Wyoming into Texas and the Gulf of Mexico by the morning of the 20th, while at the same time stretching northeastward into Manitoba. By the morning of the 21st the highest pressure was in Minnesota, extending thence southwest to California, south

into Texas, and southeast over Florida. By the 22d, a. m., although the highest pressure was in Iowa, yet pressure was so uniform that we must consider high area No. VIII as having disappeared.

IX.—On the 21st and 22d pressure rose in Saskatchewan and Manitoba, in the rear of low area No. XIV, which was moving southward, and on the 24th, a. m., pressure was highest north of Lake Superior; the front moved rapidly southeastward, and by the 26th, a. m., the highest pressure was central in North Carolina, and remained on the south Atlantic coast until the 28th, a. m., and over Florida on the 29th, a. m., after which it disappeared. In connection with this high area high northeast winds occurred on the Atlantic coast, and signals were ordered, on the 25th, 3.30 p. m., for northeast winds from Norfolk section to Savannah.

X.—On the 23d and 24th an area of high pressure pushed eastward from the Pacific, and on the morning of the latter date a ridge extended from southern Utah to Washington, while low area No. XIV was central in Montana. On the 24th, p. m., this ridge of high pressure was central in Idaho, and on the 25th, a. m., in Wyoming. By the 25th, p. m., this area of high pressure had entirely disappeared, evidently owing to the decided rise of temperature in the full sunshine over the Rocky Mountain plateau, and the rapid extension southeastward of the low pressure, No. XVI, that was then approaching Oregon.

XI.—On the 27th pressure rose decidedly on the Pacific coast, while low area No. XVI moved eastward over British Columbia, and from that date until the 30th, a. m., pressure rose steadily and slowly throughout the Pacific States and Rocky Mountain plateau region. As the highest pressure continued always off the coast of Oregon this general rise represented the northeasterly extension of the high pressure over the Pacific Ocean. During this period the areas of rainfall that were at first near the Pacific coast were gradually pushed further eastward, so that on the last day of the month the Pacific coast and Rocky Mountain plateau generally had clear dry weather, and the rainy areas were east of the Rocky Mountain Divide.

XII.—On the 28th pressure rose north of Lake Superior, while low area No. XVI extended from Athabasca southeast to Colorado; 29th, a. m., the central high pressure had moved southeast into the St. Lawrence Valley, and by the 30th, a. m., still further southeast, until it was off the middle Atlantic coast, after which its progress was more southerly.

LOW AREAS.

I.—This was a continuation of low area No. XXI of the March REVIEW; it was central on the 1st, a. m., at the mouth of the St. Lawrence; the 2d, a. m., apparently northeast of Newfoundland. Signals for high southwest winds were ordered on the 12th, 11 a. m., at Eastport and Narragansett.

II.—On the 1st, a. m., the weather maps show a high pressure over the Rocky Mountain plateau, a slight diminution in eastern Texas, and a definite low in Athabasca; these two depressions represent, respectively, the edges of the Mexican or tropical low and the Bering Sea or Alaskan low, and from these two regions there continued to emanate during the month a series of areas of low pressure which generally, at first, stretched toward each other along the eastern Rocky Mountain slope and then moved eastward.

On the 1st, a. m., pressure was lowest in Athabasca; this depression stretched rapidly southeast, while the center moved at first southeast into Minnesota and thence east over New Brunswick. On the 2d, p. m., its southward extension into Kansas, formed one or more subsidiary lows, and northwesterly gales prevailed from Montana to Texas and Kansas. On the 3d and 4th the center passed over Lake Superior, and southeast to southwest gales prevailed over the Lake region.

On the 4th and 5th, while the center was moving eastward through Ontario, severe southwest and northwest gales prevailed over the Lakes. In connection with this storm center special warnings of severe local storms were sent on the 3d, 10.30 a. m., to the observers at Chicago, Ill.; Sault Ste. Marie, Mich.; Des Moines, Dubuque, and Keokuk, Iowa; La Crosse, Green Bay, and Milwaukee, Wis.; and Duluth and St. Paul, Minn. On the 4th, 2.30 p. m., a special warning, "Dangerous storm on the coast," was sent to the secretaries of the Maritime Exchanges at New York and Philadelphia, and also to the local observers between Baltimore, Md., and Eastport, Me., inclusive. In connection with this low area signals for high winds were ordered as follows: 3d, 10.20 a. m., southwest at Grand Haven, Mich.; 3d, 11 p. m., southwest at Woods Holl section to Atlantic City, N. J.; 4th, 10.50 a. m., at Boston, Mass., to Eastport, Me.; 4th, 11 a. m., continue southwest at Grand Haven, Mich.; 4th, 2.45 p. m., southwest at Norfolk section to Breakwater.

III.—This slight depression was central on the morning of the 1st in Arkansas and eastern Texas; it soon dissipated into an area of rain over the interior of the Gulf States on the afternoon of that day.

IV.—This represents the low pressure that frequently extends up the Gulf of California into Arizona and Mexico; the pressure was lowest at Yuma, Ariz., on the 3d, 7th, 11th, 14th, 20th, 27th, and 30th. From the 6th to the 11th pressure was also low to the northward, even as far as Athabasca, and the low area that had moved southeastward over British Columbia on the 5th and was central in Athabasca on the 6th, p. m., seems finally to have joined with the northward extension of low area No. IV, forming the well-defined depression No. V.

V and VI.—This area, No. V, passed over British Columbia on the 5th, extending rapidly southeastward over the Rocky Mountain plateau, and on the 6th, p. m., was central in Alberta, while a minor depression, No. VII, was central in Iowa, where it had apparently developed during that day. During the 7th the former depression, No. V, considered as a distinct whirl, virtually disappeared in Manitoba, but at its southern extremity a new depression and cyclonic whirl, No. VI, developed in western Nebraska and South Dakota, while the minor depression, which is numbered VII, moved from Ohio into West Virginia and began its more important development. Meanwhile the depression No. IV also deepened and increased its area, so that it, together with No. VI and what remained of No. V, virtually constituted a large depression which extended from Mexico to Manitoba. No. VI moved to the south-southeast, reaching Oklahoma on the 8th, p. m.; its northern end was, on the 9th, a. m., central in Missouri, and on the 10th it passed northeastward over the Lake region as a very severe storm. After the 10th, p. m., this area, No. VI, was rapidly broken up.

In connection with area No. VI signals for high winds were ordered as follows: 8th, 11 p. m., southeast at Grand Haven; 9th, 11 p. m., continue Grand Haven southeast and order Milwaukee northeast; 9th, 11.20 p. m., southeast at all stations on lakes Erie and Huron; 9th, 11.20 p. m., northwest at Chicago; 10th, 11.50 a. m., southeast on Lake Ontario; 10th, 11.50 a. m., southeast, Baltimore to Newport section; 10th, 1 p. m., southeast, Boston and Boston section; 10th, 1 p. m., southeast, West Point, Va., to Wilmington section; 10th, 1 p. m., change to northwest at Milwaukee, Grand Haven, Lake Huron, and Lake Erie.

VII.—On the 8th, a. m., No. VII was off the middle Atlantic coast, while high area No. IV was central north of the Lake region; the flow of the cold air from the northeast over New England and New York, with rain and snow during the 8th, caused No. VII to rapidly develop into a well-marked cyclonic storm, which moved northeastward along

the coast, and was central on the 9th, a. m., south of Halifax, but on the 9th, p. m., east of Halifax, after which it disappeared from our coast.

In connection with this low area, No. VII, signals for high winds were ordered as follows: 8th, 10.18 a. m., southeast, Boston and section to Eastport; 8th, 11 a. m., northeast, Sandy Hook to Narragansett section, except New York; 9th, 10.50 a. m., continue southeast at Eastport; 9th, 11 p. m., continue northeast at Woods Holl.

VIII.—This depression appeared on the 10th, a. m., as a special local disturbance southeast of the center of No. VI. At that time, while an area of 29.55, with cyclonic winds, heavy rain, and snow, prevailed at the southern end of Lake Michigan, the isobar of 29.8 passed through eastern Tennessee and western Virginia. By the 10th, p. m., this line of 29.8 inclosed two low areas, one central in Michigan the other central on the coast of Virginia, into which position it had evidently moved from the western portion of that State, attended by high southwest winds at Wilmington and Hatteras. From this time on area No. VI rapidly died away, while No. VIII moved slowly up the coast as a violent whirling storm. On the 12th, a. m., No. VIII was central some distance east of New Jersey, but afterward moved more rapidly eastward than northward. From the 11th, a. m., until the 13th, a. m., the storm center seems to have moved only from near Cape May, N. J., to near Cape Cod, Mass., and the heavy snow and rain from New Jersey to Massachusetts with high northeast and northwest winds made this the most memorable storm for this season of the year since March, 1888.

In connection with low area No. VIII signals for high winds were ordered as follows: 10th, 11 p. m., Boston, Mass., and section, changed from southeast to northeast; 10th, 11 p. m., northeast at Portland and Eastport, Me.; 11th, 10.15 a. m., West Point, Va., to Atlantic City, N. J., changed from southeast to northwest; 11th, 10.15 a. m., Sandy Hook, N. J., to Woods Holl, Mass., section, changed from southeast to northeast; 11th, 11.10 p. m., Boston, Mass., to Eastport, Me., continue northeast; 12th, 11 a. m., Sandy Hook, N. J., to Woods Holl, Mass., section, continue northeast; 12th, 11.10 p. m., Boston, Mass., and section to Eastport, Me., continue northeast; 13th, 10 a. m., Atlantic City, N. J., to Portland, Me., change northeast to northwest; 13th, 10.20 a. m., northwest from Delaware Breakwater to Norfolk section; 13th, 10.30 p. m., Eastport, Me., continue northeast.

IX.—On the 9th, p. m., pressure began to fall in British Columbia and Alberta, and by the 10th, a. m., was lowest at Edmonton. This center moved southeastward over Assiniboia, thence southward into Montana, where it was central on the 11th, a. m.; meanwhile pressure had fallen far to the southward over and beyond Texas and northern Mexico; therefore, evidently, this central depression is to be considered only as one spot in a trough of low pressure, extending indefinitely north and south, possibly forming part of one of those great waves that must exist in the upper atmosphere and whose movements have been studied mathematically by Helmholtz and Margules. By the 11th, p. m., the principal depression was central in Colorado; 12th, a. m., northern Texas; 12th, p. m., western Texas; 13th, a. m., southwest Texas; 13th, p. m., southwest Texas. In connection with low area No. IX signals for high winds were ordered as follows: 12th, 11.10 p. m., southeast at Corpus Christi, Tex.; 13th, 10.30 p. m., continue southeast at Corpus Christi, Tex.; 13th, 11.00 p. m., southeast at Galveston, Tex.

It can scarcely be thought that this rapid southward movement represents either the movement of a whirling system of winds with low pressure or the movement of the trough of a single wave of low pressure; it is more reasonable to look upon it as the movement of a locus or node of intersection and interference of waves and troughs of pressure that are

slowly changing their positions in the atmosphere at some distance above the earth's surface. The resistances which the atmosphere experiences in its effort to move over the earth's surface may be described as follows: (1) By impinging on the irregularities of the continents and the waves of the ocean a certain amount of forward motion is annulled and a portion of the atmosphere receives a vertical or even a backward motion, so that the advancing air is mixed with other air moving more sluggishly forward or even backward; as a result the advancing air gives up a portion of its momentum to the sluggish air and both combine to move with an intermediate velocity. (2) By the heating of the surface of the earth and the ocean the sluggish-moving lower stratum is made to rise, the more rapidly moving upper stratum descends to take its place, and the resulting intermixed atmosphere moves with an intermediate velocity. As a result of these two influences, the movement of the middle portion of the atmosphere experiences a retardation that depends upon the amount of vertical convection that is determined by the roughness of the ground and the intensity of insolation; this amount is, of course, greatest over the continents and in sunlight, but least over the ocean and in darkness. Above the region of strong vertical convection the atmosphere moves with much greater smoothness, possibly even with what is known as steady flow, while between these two portions of the atmosphere may exist a third separating layer in which cylindrical atmospheric rolls with horizontal axes may exist.

The lowest stratum is subject to violent commotions, which are, however, contained below the separating surface, technically called a discontinuous surface. This intermediate layer of rolls, separating the lower from the upper atmosphere, heaves like the billows or the swell on the surface of the ocean, and occasionally simulates the formation of breakers. Over certain regions and at certain times of the day and the year this layer is absent, but at other times and places it is well developed. The upper layer presents far swifter horizontal motions that are affected only by the exceedingly feeble viscosity of cold air, by the slight gradients up and down which it has to move, by the rotation and the gravity of the earth, and, finally, by the tidal action of the sun and moon. Under these forces the upper portion of the atmosphere, resting as it does upon the lower, affects the latter principally by slight variations of pressure, and can cause areas of high and low pressure to move in a manner different from what would have been considered probable when studying only the lower atmosphere. In the lower atmosphere, which is that studied by Espy and his disciples, we consider the effects of vertical convection, the condensation of vapor, the formation of small whirlwinds, such as waterspouts and tornadoes, but in studying the upper atmosphere, which is that to which the mathematical study of hydrodynamics has generally applied, we have to deal not only with large whirls but with forced and free tidal waves and with the standing waves due to the overcoming of obstacles. We even consider the possibility of a wave on the lower surface of the upper layer as breaking, as it were, at its inverted summit and forcibly mixing its foam, viz, the upper air, with our lower atmosphere, thereby setting up temporarily such mixtures as facilitate the formation of lows and violent winds and rain over large areas of the lower atmosphere.

From this point of view, the phenomena observed at the surface of the earth become complex combinations of those peculiar to the upper and lower atmosphere respectively, and it becomes possible to see that from April 9 to 13, a trough of low pressure, passing southeastward high above the Rocky Mountains, might be interfered with in such a way as to leave at its southern end only a small depression, as a locus moving southward and gradually filling up. A very similar occurrence took place from the 14th to the 18th, except only that in the former case the winds induced at the earth's surface

were not able to develop the low pressure into a storm center, whereas in the latter case they found the lower atmosphere in a more favorable condition and did develop rain and an increasing cyclonic whirl.

From the same point of view it is evident that the areas of high pressure over the eastern portions of the North Atlantic and the North Pacific may be, in part, due to the obstruction offered by the Eastern and Western Continents, respectively, to the general southeastward movement of masses of descending cold, dry air. The large extent of the Pacific Ocean and the abrupt height of the Rocky Mountains combine to make the high pressure over the Pacific Ocean a little more pronounced than the corresponding high pressure over the North Atlantic Ocean. These high areas owe their existence partly to static and partly to dynamic influences; they represent a sort of standing wave of pressure due to resisted motion, where the pressure accumulates until it becomes sufficient to overcome the increased resistances.

X.—On the 12th pressure fell in British Columbia, and on the 13th it was lowest in Alberta, with high pressure in Manitoba. This depression extended, like its predecessor, rapidly southward, and on the 14th, a. m., pressure had fallen throughout the Rocky Mountain region and the Missouri Valley, the lowest being in Saskatchewan, with a trough extending into Kansas, where a minor depression was central. By the 14th, p. m., pressure was lowest at Yuma, and a general depression prevailed from the Mississippi Valley to California and Oregon, and to an unknown extent north and south. By the 15th, a. m., this area had begun to fill up at its northern, and especially its northwestern side, and the lowest pressures were central in North Dakota and northern Texas, respectively. By the 15th, p. m., the eastern edge of the depression, or the isobar of 29.90, had moved a little eastward and lay between W. 85° and 90°, while on the northwestern side this isobar had moved more decidedly southeastward into Manitoba, North Dakota, and Idaho; pressure had fallen, especially in Arizona, while the original low pressure, which was now central in Minnesota, was less conspicuous. It does not seem proper to consider the lowest pressure now in Arizona as in any way the direct result of the southward movement of a low pressure from Alberta. It may have been the result of a northeastward movement of the low area off the coast of Mexico, or more likely was due to a combination of the, as yet unknown, conditions existing in the upper atmosphere. A comparison of the maps of the 13th, p. m., and the 15th, p. m., shows that so far as concerns surface temperatures and winds, no change had occurred in the lower atmosphere sufficient to cause the great change of pressure that had been brought about in these two days. The principal characteristics of this change of pressure were the development of the low in Arizona, the filling up of the low in Manitoba and Minnesota, and the rapid approach of an area of high pressure from the northwest to the coast of Oregon and Washington. By the 16th, a. m., the original area of low pressure, No. X, had moved over Lake Superior, and by the 16th, p. m., had disappeared. On the other hand the trough of low pressure over Arizona and Utah had become an isolated depression, central in northwestern Colorado, and its subsequent history is given below, while the high pressure, No. VIII, on the Pacific coast had pushed its northerly winds southward to the Gulf of California.

XI.—This depression was central in northwestern Colorado on the 16th, a. m., and may be considered either as an inclosure of the northerly end of the permanent depression of low area No. IV, or as a new formation in connection with the advance of high No. VIII. By the 17th, a. m., it had become an oval, stretching from northern Texas to Minnesota, having warm southeast winds with rain on its eastern side, and cold northerly winds with snow on its western. At this time two centers

of low pressure existed, in the southeastern part of Colorado and South Dakota, respectively; the former area then disappeared as such, while the high northerly winds advanced due southward into western Texas, and on the 17th, a. m., the lowest pressure was central in western Nebraska, where it remained nearly stationary for twelve hours and then moved slowly northeastward, reaching Lake Superior by the 19th, p. m.; here again it was nearly stationary for twelve hours, and by the 20th, p. m., had become a long oval over the northern portion of southern Michigan. By the 21st, p. m., the lowest pressure was central in the St. Lawrence Valley, and the storm of wind and rain had been generally broken up. On the other hand, the cold northwest winds in the rear had, both on the 20th and 21st, produced a minor local whirl and depression, which had, apparently, moved eastward, through Iowa on the 19th, into Ohio on the 20th, and into the middle Atlantic States, where it disappeared on the 20th.

In connection with low area No. XI, a special warning of severe local storms was sent, on the 16th, p. m., to the observers at Wichita and Concordia, Kans., Sioux City, Iowa; Topeka, Kans., Yankton, S. Dak., and Columbia, Mo. Again, on the 17th, 11.20 a. m., special storm warnings were sent to the observers at Fort Smith, Ark., Keokuk and Dubuque, Iowa, Minneapolis, Minn., and Springfield, Mo. Finally, on the 17th, p. m., local storm warnings were sent to Springfield, Ill., Springfield, Mo., Cairo, Ill., Hannibal, Mo., Davenport and Keokuk, Iowa, Columbia, Mo., and Fort Smith, Ark.

In connection with this depression signals for high winds were ordered as follows: 17th, 10.40 a. m., southeast on Lake Michigan; 18th, 11.10 a. m., continue southeast on Lake Michigan; 18th, 11.20 a. m., southeast at Red Wing, Minn. (Lake Pepin); 18th, 11.20 p. m., southeast at Sault Ste. Marie, Mich., to Cleveland, Ohio; 19th, 11.50 a. m., change Red Wing, Minn. from northeast to southwest; 19th, 11 a. m., southeast from Erie, Pa., to Oswego, N. Y.; 19th, 3.45 p. m., change Sault Ste. Marie, Mich., Green Bay, Wis., and section, Milwaukee, Wis., and section, Grand Haven, Mich., and Mackinaw section, Alpena and Port Huron, Mich., Sandusky, Ohio, to Buffalo, N. Y., from southeast to southwest; 20th, 11.50 a. m., continue southwest at Chicago, Ill., Grand Haven, Mich., and section, Mackinaw, Mich., and section; 20th, 2.30 p. m., southwest from Wilmington, N. C., to Fortress Monroe, Va.; 20th, 3.30 p. m., continue southwest at Sault Ste. Marie, Mich., Green Bay, Wis., to Milwaukee, Wis., Grand Haven, Mich., lakes Huron, Erie, and Ontario.

XII.—On the 22d another special depression developed in New Jersey, which moved northeast and disappeared on the coast of New England on the 23d, p. m., but revived on the 24th off the coast of Nova Scotia.

XIII.—On the 17th pressure fell in British Columbia and a trough of low pressure developed in Alberta, as this moved eastward it rapidly disappeared on the 18th, or possibly merged with No. XI, and was quickly followed by cold northerly winds.

XIV and XV.—On the 20th pressure fell over British Columbia and southern California, and low pressure developed in Alberta, where it was central on the 21st, a. m., at which time, also, a trough of low pressure extended thence southward through Nevada to the Gulf of California; evidently we have here a very long depression, while on its eastern side a corresponding long ridge extended from the region north of Manitoba to Texas and beyond, and on its western side an area of high pressure over the Pacific Ocean was beginning to push eastward. During the 21st and 22d an indefinite area of low pressure, with several subordinate centers, prevailed over the Rocky Mountain plateau and the eastern slope. Low area No. XIV had disappeared by the 23d, a. m., in Montana, but area No. XV took definite shape in Texas on the southern border of the general depression. By the 24th, a.

m., area No. XIV again appeared central in Montana, but by the 25th, p. m., it finally disappeared in Minnesota; it had, of course, during these three days gradually filled up as a barometric depression and broken up as a cyclonic whirl. At the southern end of this general depression the lowest pressure that occurred at Yuma, Ariz., on the 20th, p. m., stretched northward into Nevada on the 22d, a. m., at which time, however, an indefinite low, with opposing winds, existed in western Texas; this latter may be called low No. XV and, by the 25th, a. m., it had disappeared in southern Texas.

The indefinite nature and unimportant phenomena attending lows Nos. XIV and XV do not make them less worthy of study and of numeration in our list of lows, since under slightly different circumstances similar unimportant areas develop into the severest storms, and the reappearance of No. XIV on the 24th, a. m., is a crucial test of imperfect theories as to the cause of low pressures.

XVI.—Pressure fell rapidly on the 25th in Oregon and Washington, and a decided depression was evidently moving eastward or southeastward toward that coast, but as it was central in British Columbia on the 26th and was then moving southeastward, it is likely that on the 25th, a. m., the main depression was far northwest of Oregon. This depression was the most important of the month for that section of the country and brought heavy rain, with high southerly winds, on the 25th and 26th to northern California, Oregon, and Washington. A notable feature was the occurrence of a tornado at Seattle—a very rare phenomenon in Washington. By the 26th, p. m., pressure had begun to rise on the Pacific coast and the lowest pressure was central at Calgary, in Alberta, and extended as a narrow trough throughout that

province and southeastward into northwestern Nebraska. Rain continued during the 27th at most stations in the Pacific States, with increasing westerly winds and rising barometer, and the central depression remained in Alberta, while the trough steadily maintained its dimensions, and, by the 27th, p. m., had begun the formation of two separate whirls and low areas, respectively located in eastern Wyoming (XVII) and in Alberta (XVI). The latter remained nearly stationary until the 28th, p. m., as far as can be judged from the few reports that we receive from this region, but by the 29th, a. m., it had moved decidedly eastward and subsequently moved southeastward, extending as a long trough so as to maintain its connection with area No. XVII.

In connection with low area No. XVI on the 26th, a. m., the special dispatch, "Conditions favorable for severe local storms during Friday," was sent to the observers at Bismarck, Williston, Sioux City, Valentine, Rapid City, Yankton, and Pierre.

XVII.—The southern area, No. XVII, which was in Wyoming on the 27th, p. m., moved slowly eastward; it was almost entirely obliterated on the 29th, but was replaced on the 30th in Colorado by a new whirl in its own previous location, which by the 30th, p. m., was central in eastern Nebraska, and is to be considered as included in the same general depression that then extended northward, and also covered No. XVI.

In connection with the beginning of this low area, and on the 28th, p. m., when it was central in western Nebraska, a special warning of severe local storms was sent to observers at Des Moines, Sioux City, Omaha, Yankton, Huron, and Valentine.

NORTH ATLANTIC METEOROLOGY.

[*Pressure in inches and millimeters; wind-force by Beaufort scale.*]

The normal barometric pressure for April over the North Atlantic Ocean, as deduced from international simultaneous observations, is highest, 30.10 to 30.14 (764 to 766), in a belt extending from the west coast of Africa between N. 18° and N. 28°, westward to W. 49°; a corresponding so-called tropical belt prevails on the Pacific Ocean, west of the peninsula of Lower California. The region of lowest pressure, 29.80 to 29.75 (757 to 756), includes Iceland and the southern end of Greenland, and extends from N. 50° and W. 40° to N. 75° and E. 5°; a still lower area of low pressure apparently exists in the North Pacific Ocean, from the southern portion of Alaska westward along the Aleutian Archipelago to W. 165°. The average of this month shows an area of high pressure, 30.10 by 30.20, extending from the interior of British America, at N. 55°, W. 90° to 110°, northward to about N. 70°, W. 100° to 120°; another area of high pressure apparently exists at the northern end of Smith Sound, and to these areas may be added another of 30.10 to 30.20 in Siberia between N. 55° and 70°, E. 90° and 130°. It will be seen that the high pressures in these Arctic regions have steadily diminished since February and are, in April, just about to disappear and be replaced by low pressures in June. These pressures are as given by the mercurial barometer under the influence of local gravity, and need to be increased by 0.07 in order to be expressed in terms of standard gravity.

As compared with March the normal pressures in April are lower by 0.10 in a zone extending from Saskatchewan northwest to the mouth of the McKenzie, at N. 70°, W. 135, and are lower by 0.20 in eastern Siberia and northern China, but less by 0.15 in western Europe; they are higher by 0.25 at North Cape and Nova Zembla.

The departures of the monthly means for April from the

annual means for each individual station show a deficit of 0.10 over the Atlantic Ocean south and southeast of Newfoundland, and extending thence over Spain, France, and the Mediterranean, and in general a deficit exists from the equator northward to N. 50° around the whole earth, but an excess prevails north of the zone between N. 50° and N. 70°.

The normal zone of the maximum frequency of storm paths passes from the coast of China, at N. 40°, westward to Japan, thence northeastward along the Japanese and Kurile Islands, crossing Bering Sea to Alaska, attaining N. 58° at W. 152°, thence southeast over British Columbia to Utah, thence eastward to Massachusetts and northeast to Ireland, where it divides toward northern and southern Europe. The regions of maximum frequency seem to be over the Great Lakes, with an average of 2.4 storm tracks per month for each region of 5° square, and, again, east of Newfoundland, with a frequency of 3.0. Low centers occur most frequently over the Missouri Valley and eastern slope of the Rocky Mountains, but many of these are imperfectly developed and dissipated before becoming severe storms.

The normal velocity of storm centers during April is 26 miles per hour in the United States, 20 miles over the Atlantic Ocean, and 18 miles in Europe.

NORTH ATLANTIC STORMS.

The following paragraphs give some account of the areas of low pressure and strong winds on the Atlantic Ocean during April, 1894. Daily charts are compiled at the Weather Bureau showing the United States and European conditions as nearly as practicable at Greenwich noon; these are supplemented by simultaneous data for the ocean received through the co-operation of the Hydrographic Office of the