CYCLOGENESIS AND FLOODS ASSOCIATED WITH STAGNANT COLD LOW, MARCH 25–30, 1953

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INTRODUCTION

Prior to March 25, 1953 a cold trough aloft moved eastward across the United States and during the next few days was partially responsible for the development of a series of storms along the East Coast. These storms, the result of cyclogenesis associated with the cold Low aloft which broke off from the southern end of the cold trough, deepened to various degrees at sea level and four of them brought heavy rains to New England. Even before these rainstorms, many stations in New England had already received more than normal total rainfall for March. The additional rainfall set several new precipitation records in the area and brought damaging floods along several rivers. The excessive rainfall and consequently the severe floods occurred principally in southern and western Maine.

In the following paragraphs, the rainfall and flooding during the period March 25–30 will be summarized and the synoptic conditions which produced them will be analyzed.

TABLE 1.—*Precipitation in New England for selected periods, March 1953*

A. Precipitation totals (inches) based on 24-hour amounts ending midnight EST, at first order stations

Station	Ground elevation (ft.)	Precipitation				
		Monthly normal	March 1–23	March 24–29	March 30–31	March 1–31
Bridgeport, Conn	7	3.60	6.52	2.23	0.65	9.40
New Haven, Conn	6	4.12	7.18	2.95	.65	10.78
Hartford, Conn	15	3.53	5.90	2.37	.94	9.21
Block Island, R. I	33	3.54	4.78	1.45	.29	6.52
Providence, R. I	55	3.58	5.78	1.48	.66	7.92
Nantucket, Mass	43	4.05	3.33	2.32	.57	6.22
Boston, Mass	15	3.43	5.89	2.29	2.82	11.00
Pittsfield, Mass	1,153	3.22	3.69	2.53	.61	6.83
Concord, N. H	289	3.04	4.48	2.21	1.12	7.71
Burlington, Vt	340	2.19	.96	1.09	.98	3.03
Mount Washington, N. H	6,262	5.55	2.04	3.44	1.91	7.39
Portland, Maine	61	4.03	5.49	3.55	.93	9.97
Eastport, Maine	33	2.88	2.83	4.19	.40	7.42
Caribou, Maine	628	2.40	2.51	1.82	.80	5.13
B. Precipitation totals (inches) based on 24-hour amounts ending 0730 EST						
Worcester, Mass	460	4.08	4.86	3.28	0.35	8.49
Lebanon, N. H	570	--------	2.38	2.46	.24	5.08
Rumford, Maine	674	3.44	3.23	7.22	.98	11.43
Augusta, Maine	353	--------	3.42	5.42	.33	9.17
Old Town, Maine	162	3.01	2.39	3.02	.32	5.73
Houlton, Maine	476	2.75	2.92	2.42	.84	6.12

RAINFALL

The geographic distribution of the rainfall over the 7-day period March 25–31 is shown in figure 1 which is based on an analysis of data from 235 stations in New England made by J. K. McGuire and Samuel Penn of the Boston Weather Bureau Office. During the period between the 24th and 28th the centers of heaviest rain in general progressed northeastward along a path stretching from Virginia to northern Maine. The heavy rainfall of the 29th, 30th, and 31st was confined mainly to the coastal area of New England. Vermont and the extreme western portions of Massachusetts and Connecticut received only light rain during these last three stormy days. In Maine all stations south of 46° N. reported 5-day storm rainfall totals which equalled or exceeded the amounts received during the first 23 days of the month. Rumford, Maine received double the amount received in the first 23 days.

These heavy downpours came at the end of a month which had already produced normal or above normal precipitation at most of the stations in New England. Table 1 gives a comparison of rainfall amounts reported at a number of cities in New England for the two parts of the storm period, the first 23 days of the month, and for the entire month. The normal March precipitation is also given for stations where available. The periods for which rainfall was totalled are not all the same in table 1 since the published station data are the amounts for calendar days whereas our charts and material are for the 24-hour periods ending at 0730 EST. Many of the stations in New England reported record-breaking precipitation for the month of March. New Haven, Conn., with 10.78 in., had the greatest amount in its 81 years of record. Boston broke an 82-year record and reported the highest total for any month there since July 1921. The total of 11.69 in. is 7.57 in. more than Boston's normal for March. The 24-hour total of 3.09 in. for the period ending at 1900 EST, March 30 is 0.05 in. greater than any previous 24-hour total in March. The previous record was set on March 26–27, 1877. March precipitation records were broken also at Hartford, Conn., Pittsfield and Blue Hill, Mass., and Portland, Maine.

It is of interest to compare the observed rainfall with amounts computed from an analysis of the air flow in the vicinity of New England. These computations were

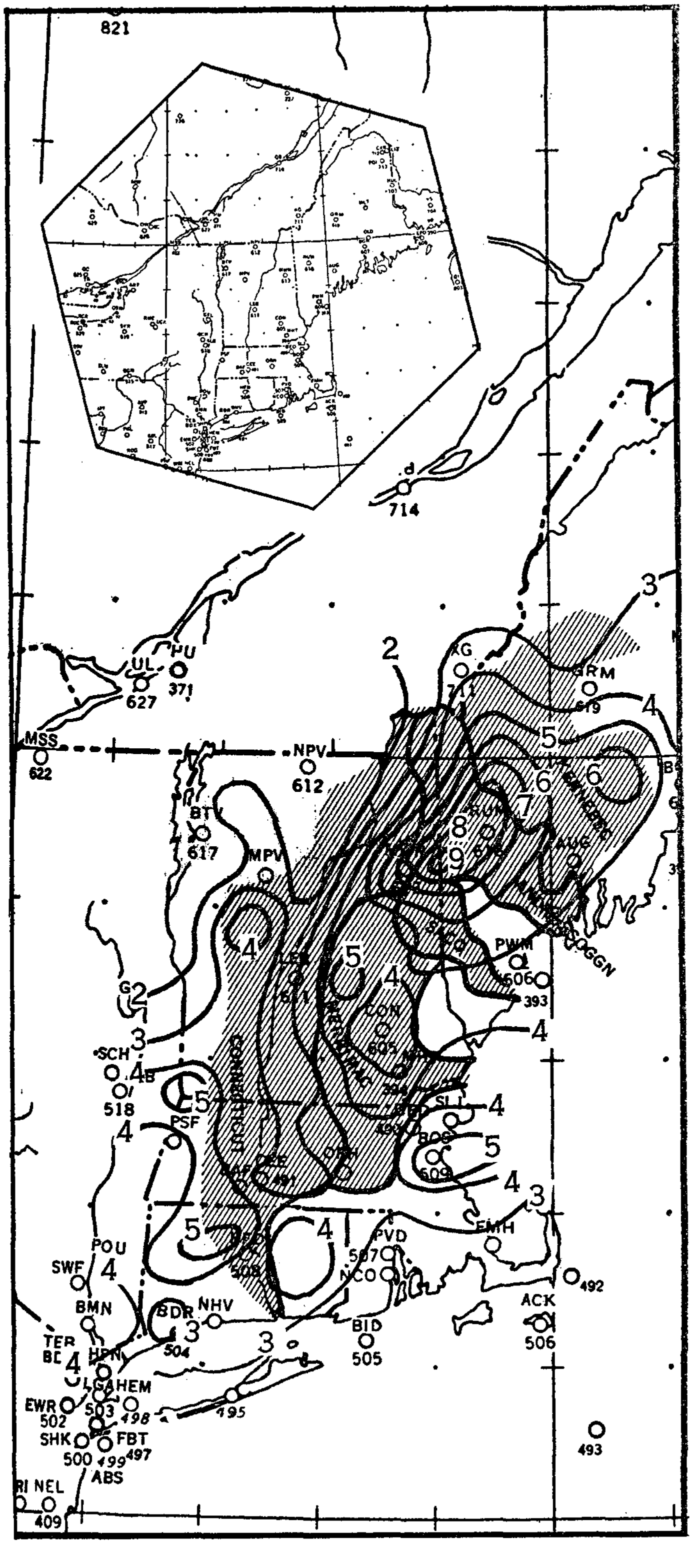

FIGURE 1.—Isohyetal map (in inches) for March 24–31, 1953, based on 24-hour rainfall amounts measured at 0730 EST. River basins are shaded and outlined. The hexagon inset outlines the area of the six triangles used in the Bellamy method to compute convergence. (See tables 1 and 2.)

made in collaboration with P. M. Kuhn of the Weather Bureau's Short Range Forecast Development Section. Kuhn [1] in connection with the work of Thompson and Collins [2], has adapted Bellamy's [3] method for computing vertical velocities to a more elaborate procedure to compute precipitation amounts. The area enclosed by the six triangles used in the Bellamy method to compute the convergence is shown in the inset in figure 1. The results of the computations are shown in table 2. Although the vertical velocities were not sufficient to account for the excessive precipitation reported at Rumford, Maine for the 24-hour period ending at 0730 EST on the 27th, they were sufficient to account for the average amount for the entire area for that period.

TABLE 2.—*Computed divergence, D, vertical velocity, W, and precipitation. Subscripts to D and W indicate pressure surfaces to which data pertain*

March (GMT)	Divergence (10^{-5} sec.$^{-1}$)					Vertical velocity (cm. sec.$^{-1}$)						12-hour precipitation (in.)
	D_{950}	D_{850}	D_{700}	D_{500}	D_{300}	W_{sfc}	W_{950}	W_{850}	W_{700}	W_{500}	W_{300}	
26, 1500	−1.8	−2.3	−2.0	−2.1	−0.2	3.0	3.9	6.3	11.0	20.1	35.6	0.86
27, 0300	−1.6	−1.0	−.7	−.5	−1.1	3.0	3.8	5.3	7.6	12.2	21.7	
27, 1500	−2.4	−.1	−2.0	−.4	−2.0	2.0	3.2	4.6	6.9	13.0	24.0	1.10

FLOODS

The base map in figure 1 includes outlines of the basins of the rivers which were affected by floods and shows that the maximum rainfall during this period covered the upper portions of the Saco and Androscoggin Rivers in New Hampshire and Maine; Rumford, Maine, which received 8.20 in. of rain from March 25–April 1, is on the upper portion of the Androscoggin. The flood was of record proportions in the Saco and Androscoggin but their smaller tributary streams were in relatively greater flood. The Kennebec, the Merrimack, and the Connecticut Rivers were also in flood during the period. The recorded flow data for some of the rivers are given in figure 2, the curves of which are based upon data sent by E. W. G. Kliemann of the Weather Bureau Office, Portland, Maine.

The flooding in Maine was comparable to the March 1936 flood during which 5 persons lost their lives, 25 million dollars in property was lost, 125 bridges were

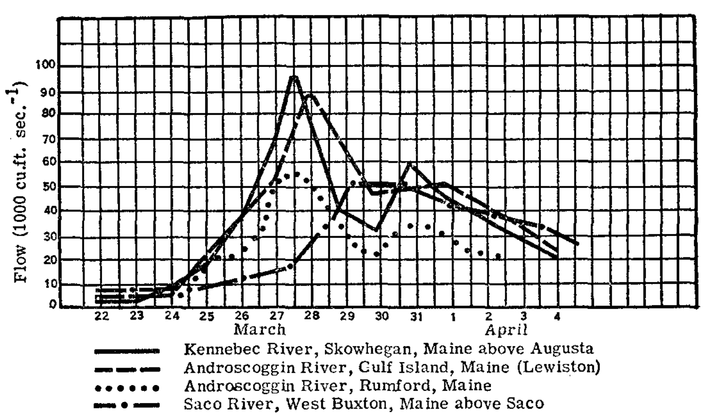

FIGURE 2.—Stream flow for March 22 to April 4, 1953.

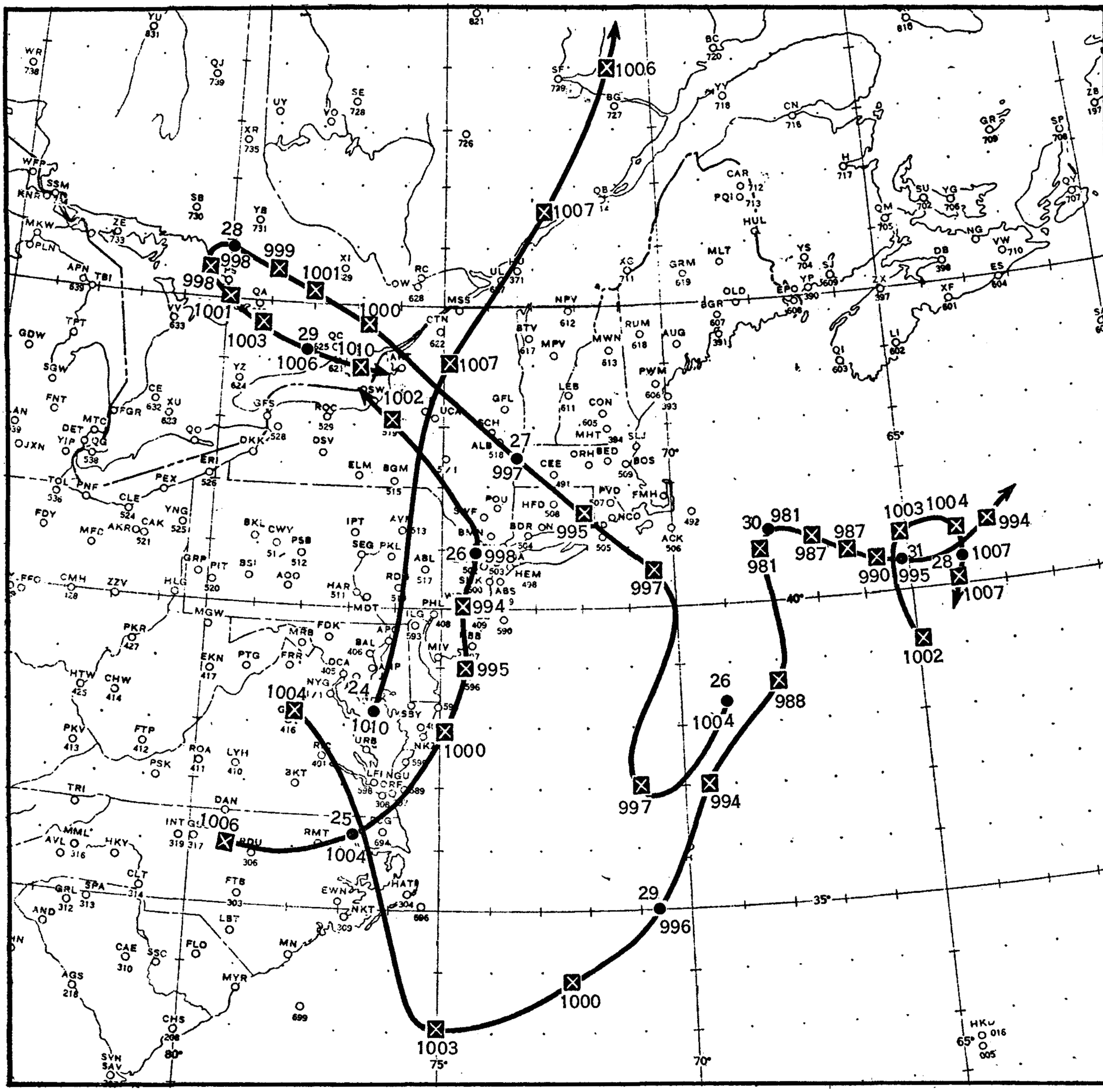

FIGURE 3.—Six-hour positions of Low centers with the central pressure, March 24–31, 1953. The black dot indicates the position at 1230 GMT for the day of the month shown; crosses indicate intermediate positions.

swept away, and 10,000 people were made homeless. However, at the time of the 1936 flood the ground had a heavy snow cover and the rivers were frozen with a thick layer of ice. The flooding rains combined with the melting snow and ice to double or triple the runoff on rivers jammed with ice floes. These conditions were not present in March 1953 and therefore, although Portland, Maine, received 9.97 in. of rain in March 1953 compared with 7.48 in. in March 1936, the floods were not so severe. The following report, quoted in part, was received from E. W. G. Kliemann of the Portland Weather Bureau Office: "The State estimated that $500,000 damage was caused to State roads and bridges and an equal amount to town-owned roads and bridges. And it is estimated that $9,000,000 damage was caused, mostly by silt and by work stoppage and ruined furniture. The total estimate of flood damage is therefore $10,000,000. . . . The major rivers did not approach the stages reached during the record flood of 1936 but several of the smaller rivers exceeded their previous records."

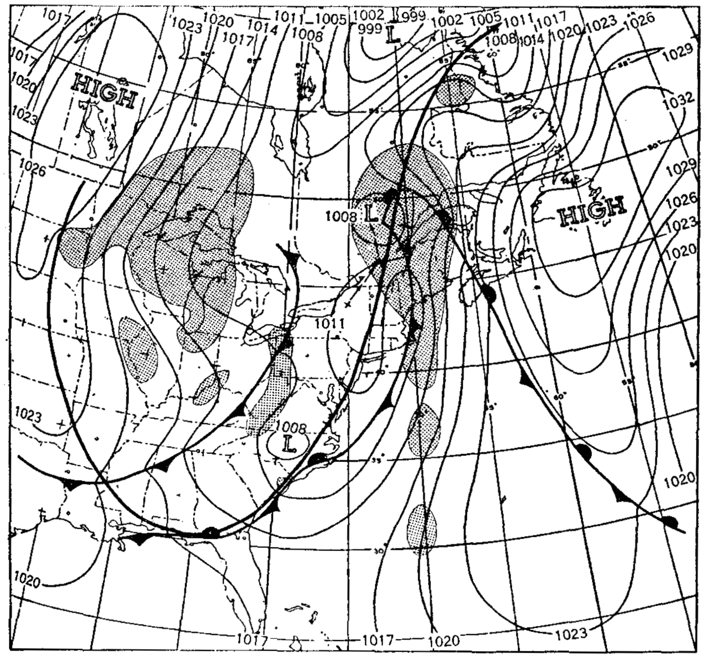

FIGURE 4.—Surface weather chart for 0630 GMT, March 25, 1953. Shading indicates areas of active precipitation. Small "x's" indicate the past positions of the Low at 6-hour intervals. The heavy curved arrow is the axis of the jet stream at 300 mb.

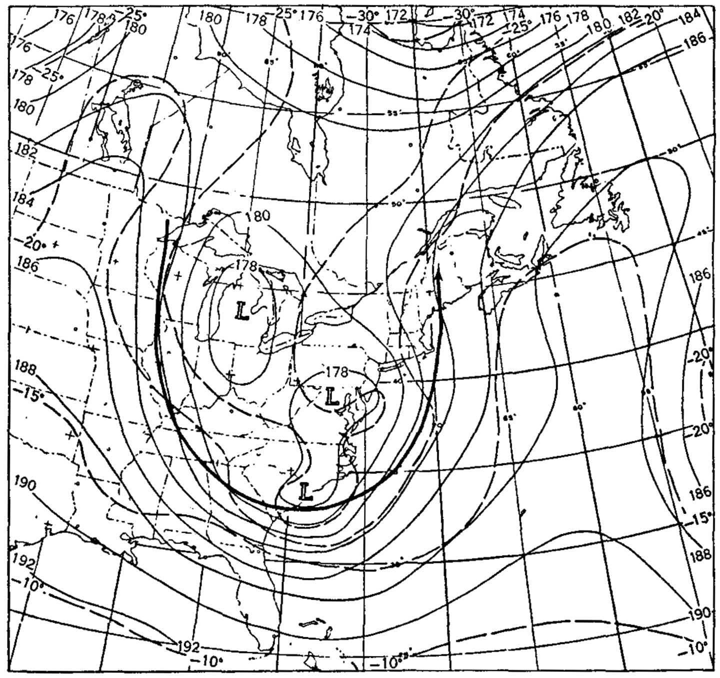

FIGURE 6.—500-mb. chart for 0300 GMT, March 26, 1953.

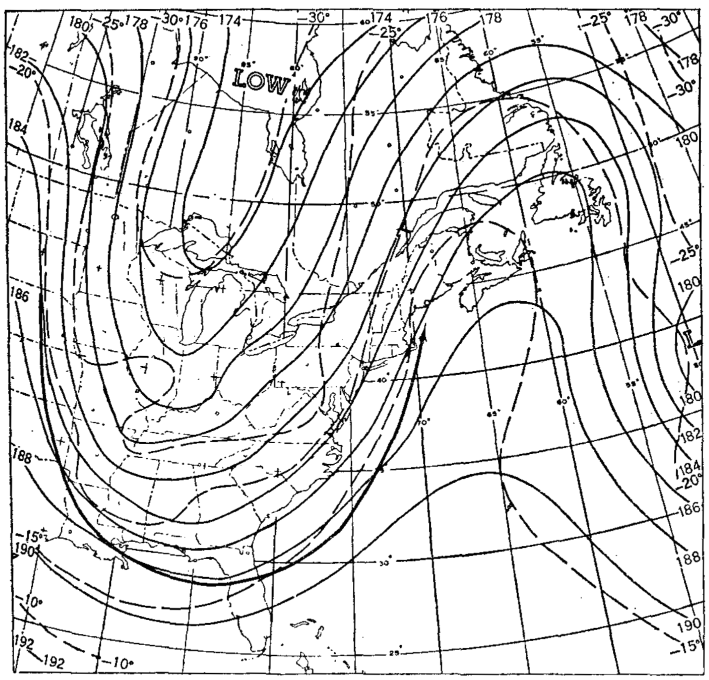

FIGURE 5.—500-mb. chart for 0300 GMT, March 25, 1953. Contours (solid lines) at 200-ft. intervals are labeled in hundreds of geopotential feet. Isotherms (dashed lines) are in intervals of 5° C. The heavy curved line is a constant absolute vorticity trajectory.

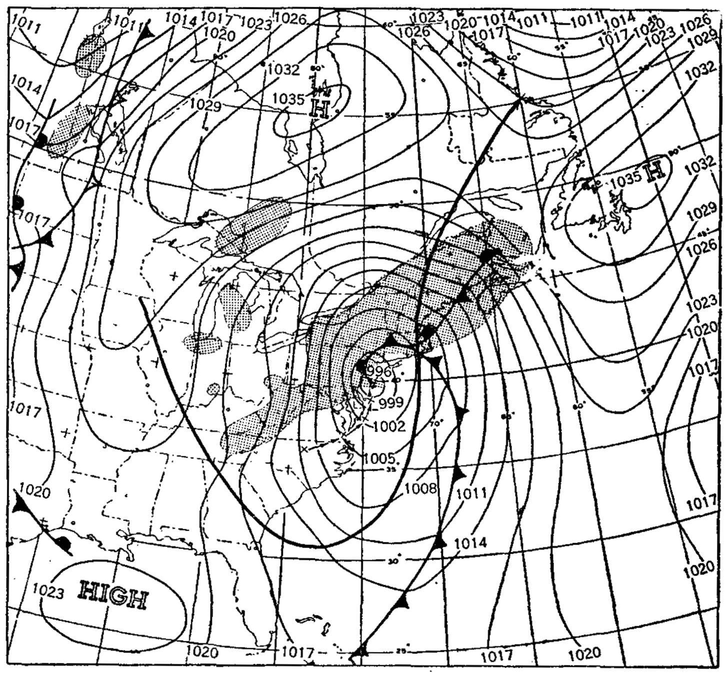

FIGURE 7.—Surface weather chart for 0630 GMT, March 26, 1953.

SYNOPTIC ANALYSIS OF THE CYCLONES

The tracks and central pressures of the storms that brought the excessive rainfall to New England are shown in figure 3. The first storm of the series had a poorly defined center but produced rain in New England on March 24–25. The second storm, which developed in North Carolina early on the 25th, moved up the coast and then northwestward into New York State, producing additional rain in New England on the 25–26th. A third center developed offshore about 200 miles south of Nantucket on the 26th and moved northwestward through southern New England; as it passed through, the heaviest rains for a 24-hour period were reported at 0730 EST on the 27th in New Hampshire and Maine. Still another storm, in some respects the most interesting of the series

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from the dynamic point of view, developed in Virginia on the 28th, moved offshore, and deepened into a major cyclone which dominated the weather along the New England coast for several days. These storms were similar to those of November 1950 and November 1952 [4] in that they also were connected with cold troughs which could not move far offshore because of the existence of a "blocking" High in the Atlantic.

It is always difficult in meteorology to determine definitely whether a certain feature in the large-scale flow pattern is the control for all the other portions of the flow. However, in the charts to be presented, a blocking High in the Atlantic may be recognized as controlling the flow and as the steering mechanism moving the storms northward along the coast rather than eastward across the Atlantic. This blocking High, which had been in mid-Atlantic, began to show up in the western Atlantic as the westward progression of anticyclogenesis continued in accord with typical blocking action.[1] Thus the ridge off the coast of the United States continued to build northward and the westerly component of the wind which was rather pronounced north of 50° N. at 0300 GMT on the 25th (figs. 4 and 5) became progressively weaker on the succeeding charts. With this general picture in mind, some more specific details of the synoptic developments associated with the series of storms will be examined.

The first storm had no well-defined closed circulation at sea level and started from a weak center in Virginia on the 24th. It moved rapidly north-northeastward through Pennsylvania and New York State into Canada (fig. 4) producing 0.50 in. to nearly 2 in. of rain over most of New England except northern Maine. This rain was evidently due to convergence in the long fetch of southerly winds as indicated by the sea level isobars extending from about latitude 25° N. to the latitude of northern Maine, about 48° N.

A further factor favoring convergence and the consequent vertical motion necessary for precipitation was the movement of the jet stream maximum over the area. The axis of the 300-mb. jet stream is indicated on figure 4. The jet maximum was over New Jersey and moving northward. Thus from Riehl's [5] ideas on the dynamics of the advection of vorticity and the vorticity tendency equation, one would expect the vertical motion necessary to produce rain to occur in the lower strata over the New England area. However, if the jet maximum moved along the axis of the jet as shown in the analysis, it would be too far west to conform to theory. At this time the cold trough aloft (fig. 5) was pushing eastward with the cold air advection over New England coming from the southwest with 40-knot winds; consequently the trend was for the jet to be displaced eastward. A displacement of only 100 miles in 12 to 18 hours would have been sufficient for the jet stream and its maximum to be in

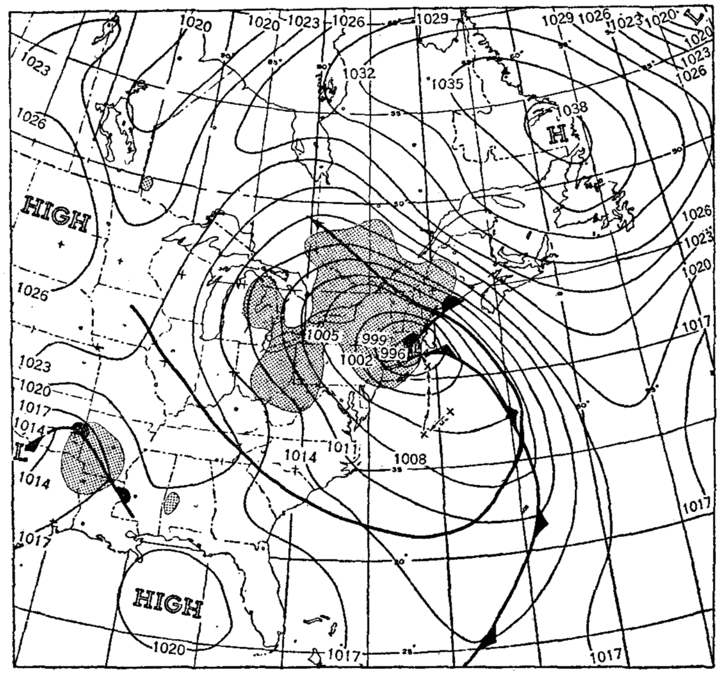

FIGURE 8.—Surface weather chart for 0630 GMT, March 27, 1953.

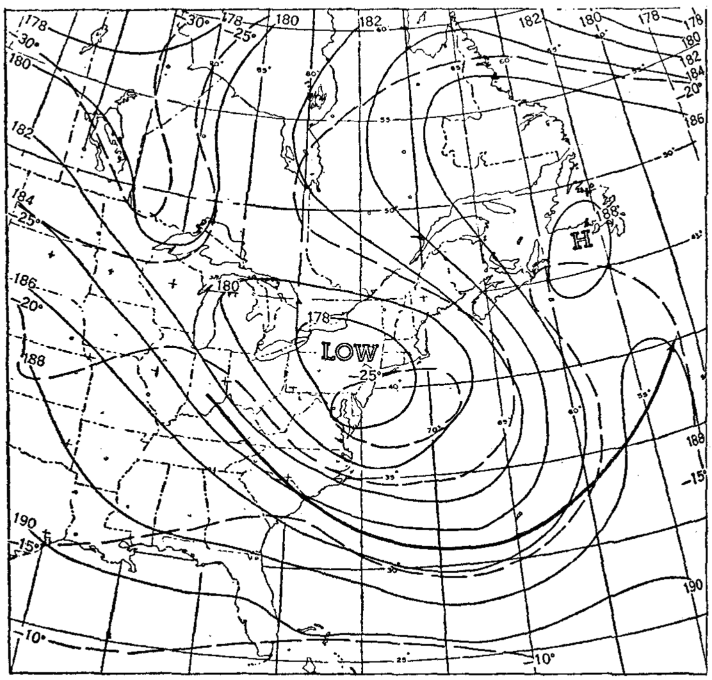

FIGURE 9.—500-mb. chart for 1500 GMT, March 27, 1953.

position to take part in the rain-producing mechanism. This easily could have occurred, for the speed of the trough was actually about 17 knots.

The southern part of the cold trough as shown on the 500-mb. chart for 0300 GMT on the 25th (fig. 5) broke off into a cold Low by 0300 GMT on the 26th (fig. 6). This cold Low continued to dominate the developments in the northeastern United States for at least the next six days.

[1] See discussion of blocking and references cited by Sanders in the article on pp. 67–74.

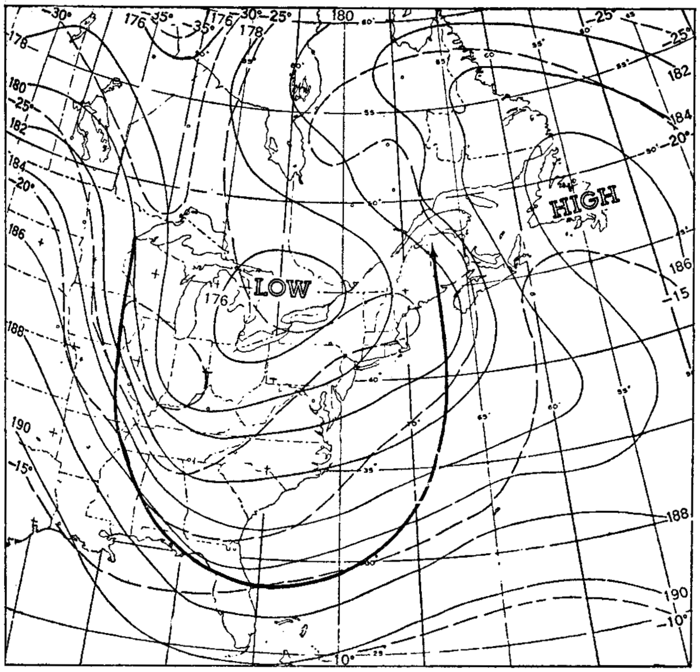

FIGURE 10.—500-mb. chart for 1500 GMT, March 28, 1953.

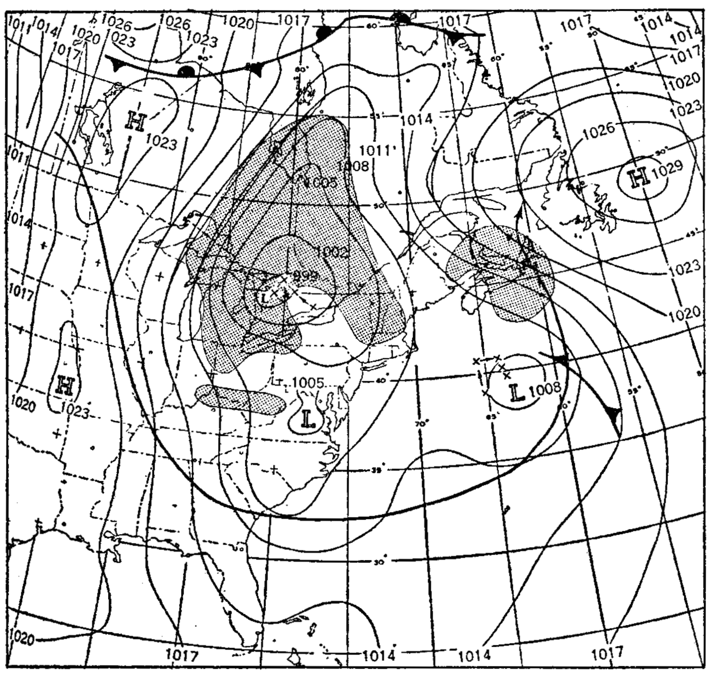

FIGURE 11.—Surface weather chart for 1830 GMT, March 28, 1953.

The Low centered over New Jersey at 0630 GMT on the 26th (fig. 7), the second of the series, had deepened 13 mb. in 24 hours to a central pressure of 994 mb. This is reflected in the obvious increase in gradient at 500 mb. in the southern portion of the trough (fig. 6). The curvature of the field of flow at 500 mb. had not increased noticeably in this region but the shear had increased with the increase in gradient; that is, the cyclonic vorticity had increased. The prognostic charts of the advection (extrapolation) of the constant-absolute-vorticity field, based on barotropic concepts, did not indicate an increase of this magnitude. However, by noting the temperature-height solenoids on the 500-mb. chart for 0300 GMT of the 25th (fig. 5) the advection of the minor cold trough from the vicinity of Memphis to near Hatteras in 24 hours could be anticipated although deepening to the degree which actually took place was unexpected. Thus both the vorticity approach and the direct approach of height-temperature solenoid consideration had shortcomings. The constant-absolute-vorticity trajectory indicated that the trough line would not move appreciably. Thus any advection into the trough which would tend to increase the contour gradient in the southern portion of the trough would have the effect of increasing the cyclonic vorticity in this region of maximum curvature of the flow.

After this second storm had deepened the center followed a curved path northwestward from New Jersey and passed through New York State into Canada (fig. 3). It was this storm which was instrumental in bringing the moist air into New England, but a third storm developed offshore about 1230 GMT on the 26th and produced important effects.

Storm number three moved into New England near Block Island about midnight EST of the 26th (fig. 8). The heavy rains in southern Maine occurred between 0730 EST on the 26th and 0730 EST on the 27th. The cyclogenesis was apparently associated with the dynamic factors inherent in the 300-mb. jet stream maximum which was over Georgia at 0300 GMT on the 26th. This maximum was difficult to follow on the analyses but could logically be expected to progress around the Low; this inference is borne out by the report at 300 mb. of an 85-knot wind from the southeast at Nantucket at 1500 GMT on the 27th. The previous cyclonic circulation had prepared the fields of temperature and moisture before the development and movement of the deepening Low into the New England area. This third center produced accelerated flow of the moist air as it moved onshore toward a stubborn High and consequently produced convergence and vertical motion which gave the record rainfall over the upper parts of the Saco and Androscoggin basins in New Hampshire and Maine as described earlier.

On the 500-mb. chart for March 27 at 1500 GMT (fig. 9) the flow over the Central States had a very pronounced component from the west. However, the flow 24 hours later, March 28 at 1500 GMT (fig. 10), had veered with more pronounced northerly components, and the speeds had increased from approximately 40 knots on the average to over 60 knots. This veering of the flow and increasing speed were significant factors in the cold advection into the western portion of the trough which in turn was followed by an increase in the gradients of temperature and of height at 500 mb. in the southern portion of the trough. This of course implies that the trough deepened somewhat in the southern portion also.

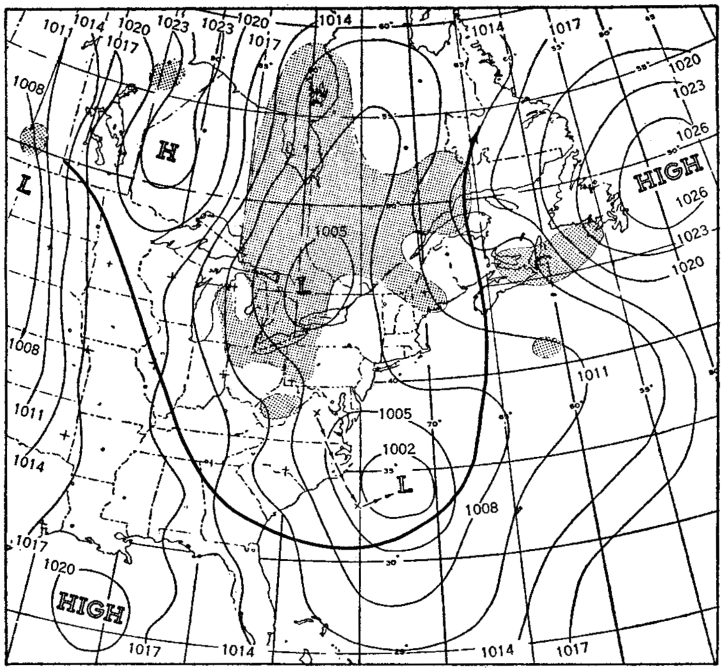

FIGURE 12.—Surface weather chart for 0630 GMT, March 29, 1953.

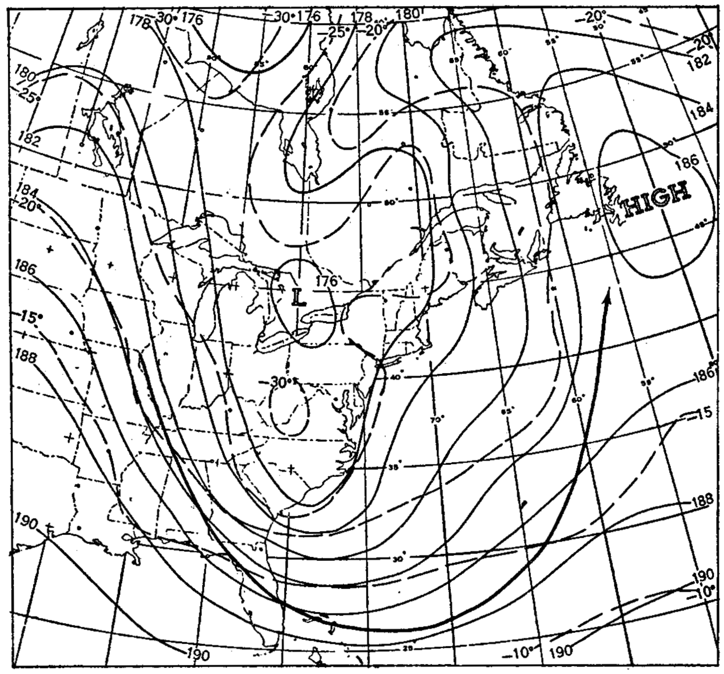

FIGURE 14.—500-mb. chart for 0300 GMT, March 29, 1953.

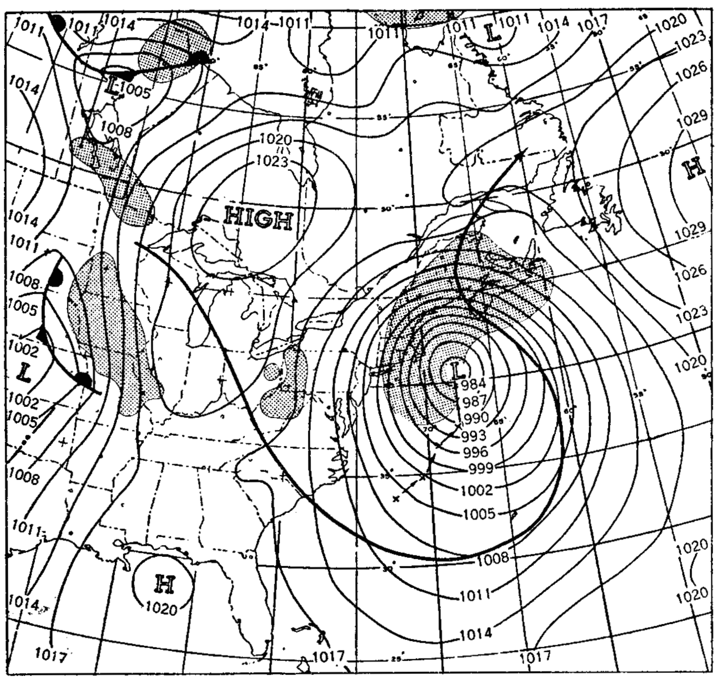

FIGURE 13.—Surface weather chart for 0630 GMT, March 30, 1953.

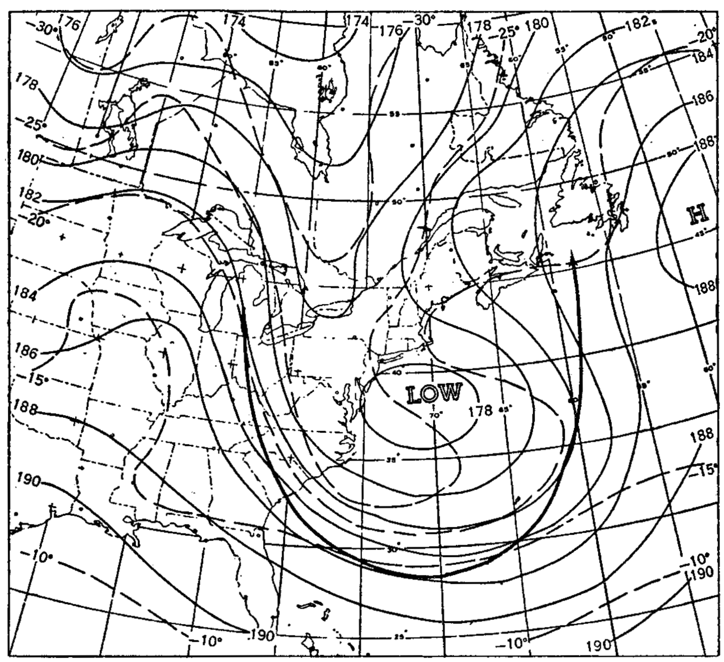

FIGURE 15.—500-mb. chart for 0300 GMT, March 30, 1953.

It is difficult to say in a particular case which phenomenon was the first to appear; or in other words to predicate a definite causal relationship between two observational facts. However, this phenomenon could be anticipated from the 500-mb. chart for 1500 GMT, March 27, for the cold advection indicated by the flow from North Dakota southeastward to the South Atlantic States indicated an increase in gradient and a deepening of the trough in the vicinity of the coast. However, here again, although the trend could be predicted, the degree of the development was not foreseen.

The sea level chart for 1830 GMT of the 28th (fig. 11) shows that a Low center had already formed in Virginia. The cyclogenesis continued for the next 24 hours as the center moved southeastward offshore (fig. 12) and then curved northward with continued deepening (fig. 13).

On comparison of the temperature fields at 500 mb. for 1500 GMT on the 28th (fig. 10) and for 0300 GMT on the 29th (fig. 14) it is apparent that the temperature gradient in the southern portion of the trough had almost doubled. The winds and contour gradient had also increased which means that the cyclonic vorticity had increased. This cold advection with its associated increase in temperature and contour gradients continued to move offshore and is indicated on the 500-mb. chart for 0300 GMT on the 30th (fig. 15) by the strong cyclonic circulation between 30° and 35° N. and between 60° and 65° W.

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