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SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR JANUARY, 1916.

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GENERAL PRESSURE DISTRIBUTION OVER THE UNITED STATES AND CANADA, INCLUDING THE SANDWICH AND ALEUTIAN ISLANDS, ALASKA, AND THE WESTERN PORTION OF THE MIDDLE ATLANTIC OCEAN.

The month was remarkable for the persistence of abnormally-high pressure waves over the Aleutian Islands, Alaska, and the middle Atlantic Ocean. There were but two days during the month, the 5th and 19th, when pressure fell below the normal over the Aleutian Islands and Alaska, then only to a very moderate extent, and followed quickly by a rapid rise to much above normal conditions. Over the North Atlantic there were three falls to slightly below normal conditions—on the 3d, 8th, and 17th. At the same time uniformly low pressure prevailed over the South Pacific, as indicated by reports from Honolulu, with a marked fall and severe storms from the 16th to the 18th, inclusive. There were only two days, the 1st and 29th, when the pressure at Honolulu was above the normal, and then only a tenth of an inch or so. There was, however, a marked fall in pressure at Sitka on the 19th and 20th, which did not extend to the northward. In the Pacific States low pressure prevailed throughout the month with a few unimportant exceptions, and on January 27 the barometer at San Francisco read 28.84 inches, the lowest pressure (reduced to sea level) ever recorded at that station. The previous record of low pressure was 29.12 inches on February 21, 1891. To the eastward of the Pacific States there was quite a regular succession of high and low areas, some of them of quite marked character, but as a rule they did not reach the Atlantic States, as the prevailing high pressure over the ocean diverted them after they reached the central portion of the country so that they moved northeastward over the Upper Lake Region and from thence east-northeastward.

The general result of this distribution was a prolonged period of heavy rains and snows in the Pacific States, snows in the plateau region, and rains and snows over the central portion of the country, and quite dry weather in the Atlantic and east Gulf States. Coupled with this there was very cold weather over the Northwest and extreme West and very warm weather over the Atlantic and Southern States. Over the cold districts many of the thermometer readings were the lowest of record, while over the warm districts readings equaling or exceeding previous high records for the month of January were frequent.

STORM WARNINGS.

On the morning of the 2d a western disturbance of quite marked character was central over eastern upper Michigan with a trough extending southeastward into a secondary depression over the District of Columbia, and southwest storm warnings were ordered from Delaware Breakwater to Boston. The storm did not develop

further and only moderately strong winds occurred. During this time pressure was quite high over the Northwestern States, but during the 3d another disturbance from the West moved rapidly eastward, and on the morning of the 4th it was central over northwestern Lake Superior, with strong high pressure to the southeastward. Southwest storm warnings were accordingly ordered at 11 p. m. from Delaware Breakwater to Eastport, Me., and fresh to strong southwesterly gales occurred, following the eastward passage and increasing intensity of the storm. On the morning of the 5th the warnings were extended southward to Washington, N. C., and strong southwest gales also occurred over that section. The warnings were changed to northwest from Delaware Breakwater to Eastport at 11 p. m. of the 5th, and the gale did not subside until after the morning observation of the 6th. On the morning of the 6th the warnings from Baltimore to Washington, N. C., were changed to northwest, but were lowered at 9 p. m., as the winds diminished by afternoon.

By the morning of the 7th a moderate disturbance had developed over western North Carolina and, as pressure was quite high to the northeastward, northeast storm warnings were ordered from Norfolk, Va., to Hatteras, N. C., at 10:30 a. m. Moderate northeast gales occurred during the day and night and until after the morning observation of the following day.

On the morning of the 9th pressure was very low over the Northwestern States with a strong gradient to the eastward, and at 9 a. m. advisory messages for strong southerly winds were sent to open ports on Lake Michigan, and winds occurred as forecast. This same disturbance continued quite rapidly eastward, and at 11 p. m. of the 9th southwest warnings were again ordered from Hatteras to Eastport. There was also a secondary depression over southeastern Colorado with a strong gradient to the southeastward, and southeast warnings were ordered at the same time on the Gulf coast from Mobile, Ala., to Carrabelle, Fla. Strong winds occurred along the Atlantic coast as forecast, but there were none on the Gulf, as the Colorado disturbance failed to develop, and the warnings were therefore lowered at 10 a. m. of the 10th. At 11 p. m. of the 10th the warnings on the New Jersey coast were changed to northwest, while the southwest warnings on the New England coast were continued, the storm at that time being central over the Province of Ontario. The storm moved more to the northeastward than had been anticipated, and the warnings on the Atlantic coast were lowered at 10:30 a. m. of the 11th. Another disturbance from the North Pacific had been moving southwestward, and by the night of the 11th it had reached north central Texas with a strong and very cold high area to the northward, resulting in very sharp gradients in both pressure and temperature. Advisory warnings were therefore sent to open ports on Lake Michigan for increasing northeast winds with snow. This forecast was fully verified. On the morning of the 12th the disturbance was over southern Illinois with the cold high area still to the northwestward. There was also a secondary disturbance near the mouth of the Rio Grande, and southwest storm warnings were ordered at 12 noon on the Gulf coast from Mobile to Carrabelle. At 6 p. m. southeast storm

warnings were also ordered on the Atlantic coast from Portsmouth, N. H., to Delaware Breakwater, and at Baltimore and Washington. At 4 p. m. the southwest warnings on the Gulf coast were extended to Rockwell, Fla., and at 11 p. m. the southeast ones on the Atlantic coast were extended over the Maine coast and southward to Jacksonville. Again the southern disturbance failed to develop to any great extent and the winds on the Gulf and south Atlantic coasts were no more than fresh, while on the north coast they were fresh to strong. No more warnings were ordered until 11 p. m. of the 16th, when the rapidly rising pressure over the interior of the country, following another western disturbance that was then over the lower St. Lawrence Valley, indicated increasing west to northwest winds on the Atlantic coast, and northwest warnings were therefore ordered at 11 p. m. from Hatteras to Boston. Fresh west to northwest gales occurred on the following day.

On the morning of the 18th a disturbance from the Hudson Bay country was central over western Ontario with increasing intensity, and special observations indicated increasing southerly winds on the north Atlantic coast. Southwest storm warnings were therefore ordered at 3:30 p. m. from Sandy Hook, N. J., to Nantucket, Mass., and moderate southwest to west gales occurred. By the morning of the 19th the storm had passed into the Gulf of St. Lawrence and the warnings were lowered. There was at this time still another disturbance of marked character over western South Dakota with strong pressure gradient to the eastward, and advisory warnings of fresh to strong southerly winds, with snow, were sent to open ports on Lake Michigan. On the evening of the 19th these conditions occurred as forecast. At 4 p. m. of the 20th southwest warnings were ordered from Delaware Breakwater to Eastport, on account of the rapidly decreasing pressure from the western disturbance. Some moderately strong winds occurred on the night of the 20th, but by the morning of the 21st they had diminished greatly and the warnings were accordingly lowered at 9 a. m.

The western storms continued their rapid succession. On the morning of the 22d there was another to the north of Lake Superior, and southwest storm warnings were again ordered from Sandy Hook to Boston, and at 2:30 p. m. extended southward to Atlantic City. At the same time advisory messages for strong northwesterly winds and much lower temperature were sent to open ports on Lake Michigan. All of these conditions occurred as forecast and there were severe southwesterly gales on the north Atlantic coast.

There was no further occasion for warnings until the 28th, when a disturbance from the southwest had reached the Canadian Maritime Provinces by way of the Upper Lakes. Special observations indicated rapidly rising pressure to the westward, and northwest storm warnings were therefore ordered at 1 p. m. from Sandy Hook to Nantucket. Moderate to fresh west to northwest gales occurred and also extended northward along the entire New England coast.

On the morning of the 31st the last disturbance of the month extended from the mouth of the Rio Grande northeastward to Georgian Bay, with the principal center of depression over the latter region. Special observations indicated a further development of this section of the low area and, at 3 p. m., southwest storm warnings were accordingly ordered from Delaware Breakwater to Eastport. There was, however, no further development in the intensity of the storm so that only fresh winds

resulted, and on the morning of February 1 the warnings were ordered down.

COLD WAVES AND FROSTS.

The great feature of the weather in the United States for the month was the north Pacific disturbance that first appeared on the 5th day of the month. An offshoot from this disturbance moved eastward on the 7th and 8th, but it disappeared north of Lake Superior. Another offshoot on the following day developed more character and moved east-southeastward with increasing intensity, dividing into two sections during the night, one over southeast Minnesota and the other over southeast Colorado. The southern end soon disappeared, but the northern one continued eastward over the usual track, and was followed by a strong high area that first appeared over Alberta on the morning of the 9th. This high area developed rapidly to the southeastward and eastward with below-zero temperatures, and there was every indication that it would extend eastward following the offshoot from the Pacific disturbance, but the main disturbance itself began to move southeastward during the night of the 9th-10th and continued along the western slope of the mountains, reaching central Texas by the night of the 11th. This movement interfered with the eastward progress of the cold wave and high area to the northward, but at the same time the high area continued to increase in magnitude and intensity and the temperatures continued to fall, so that on the morning of the 12th, with the disturbance extending in a narrow trough from east Texas to Lake Michigan, very cold weather prevailed to the westward and northward, with a minimum reading of 58° below zero at Prince Albert, Saskatchewan, and with the line of zero temperature extending to the Kansas-Oklahoma boundary. Below-zero temperatures also prevailed in the Middle Plateau and freezing temperatures in the Pacific States. To the eastward and southward of the disturbance there was an abnormal rise in temperature with a maximum reading of 80° at Meridian, Miss., during the 12th, equaling the January record at that station. On the morning of the 13th the center of the disturbance was over Ontario and the crest of the high area had moved southeastward over the Missouri Valley. The cold wave had continued in the Northwest, had become more intense in the Plains States, and had extended to the Texas coast, where the temperatures were from 4° to 6° below the freezing point. The line of zero temperature had also extended eastward as far as the Illinois-Indiana line and into the northern Upper Lake Region. Snows and rains and severe gales attended the movement, and the usual storm warnings were displayed on the Atlantic and Gulf coasts and cautionary advices were frequently sent to open ports on Lake Michigan. Cold-wave warnings had been ordered on the first appearance of the high area over the Canadian Northwest, and they were gradually extended until between the 10th and 13th they had been ordered for practically the entire country except the Pacific States.

On the morning of the 14th the temperature had fallen decidedly in the Atlantic and east Gulf States, except over central and southern Florida, and low temperatures continued elsewhere, but with a rising tendency west of the Mississippi River. There was at this time another north Pacific disturbance central over northern Nevada and pressure was again rising over the Canadian northwest. The disturbance moved to the southeastward with

decreasing intensity, reaching west Texas by the evening of the 15th. In the meantime another disturbance from the southern Hudson Bay country had moved south-eastward to extreme western Ontario. Both disturbances then continued eastward with rapidly rising pressure following from the Northwest, and, beginning with the 16th, cold-wave warnings were again ordered over the western portion of the Washington forecast district and extended on the night of the 16th throughout the district generally, except the upper Lake region, and cold waves occurred as forecast, the line of freezing temperature extending into northeast Florida on the morning of the 18th.

On the morning of the 17th a marked Pacific disturbance was central off the coast of southern California attended by very heavy rains, while strong high pressure continued to the northeastward. The disturbance moved northeastward to Hudson Bay during the next three days, but a secondary disturbance that developed during the 20th over Colorado moved northeastward to eastern Nebraska by the morning of the 21st, while another disturbance of still more marked character was central north of Montana, with rapidly rising pressure and much lower temperatures closely following. At 8 p. m. of the 21st the Nebraska disturbance was north of Lake Superior, while the Canadian one had passed east of Manitoba with cold weather to the westward, and cold-wave warnings were accordingly ordered for upper Michigan. Early in the afternoon of the 22d cold-wave warnings were also ordered for lower Michigan, but another severe disturbance from the north Pacific intervened and the fall in temperature over upper Michigan, while decided, was not sufficient to justify a cold wave. Over lower Michigan there was practically no fall in temperature. The last-mentioned disturbance moved eastward and, on the morning of the 24th, it extended from eastern Colorado to western Lake Superior in very moderate form, with another very cold high area to the north-westward. Cold-wave warnings were accordingly ordered early in the afternoon for the northern portion of lower Michigan, but again a low pressure area from the West interfered and the warnings were not verified. This low area on the morning of the 26th was central over western Colorado, the general depression extending southeastward into western Texas and thence northeastward into Iowa, while to the northward pressure remained very high, with low temperatures. As pressure continued to rise in the Northwest, cold-wave warnings were ordered on the night of the 26th for the Ohio Valley and lower Michigan, but the low area moved northeastward by way of the upper Mississippi Valley and the upper Lake region, and the fall in temperature, while ranging from 20° to 30°, was not sufficient to justify the hoisting of the cold-wave warnings.

However, the temperature at Havre, Mont., at 8:15 a. m. of the 27th fell to -56.7° F., or lower than any previous January record at that station, and was also the very lowest recorded temperature there for any month of any year. At 7 a. m. the temperature was -55° F. and at 8 a. m. it was -56°. On the night of the 27th cold-wave warnings were ordered for western and northern New York, the upper Ohio Valley, and east Tennessee. This warning was practically verified, and the cold wave extended into New England.

As low pressure still persisted throughout the Central-West and Southwest, with the cold high area to the north-westward, cold-wave warnings were ordered on the night of the 29th for Mississippi and western Tennessee, but the Central-West disturbance moved very slowly and the warnings were ordered down on the following morning.

It will be noted that many of the cold waves forecast failed of verification, and this failure must be attributed solely to the abnormal movement of the western low areas, which was almost uniformly to the north-north-eastward after reaching the southern Plains States. This abnormal movement was, of course, due to the prolonged and unprecedented persistence of the high area over the western Atlantic Ocean, which was maintained with almost undiminished strength throughout practically the entire month, notwithstanding the fact that at different times there were some evidences of its partial dissolution at least.

DISTRICT WARNINGS DURING JANUARY.

Chicago district.—January averaged very cold throughout the Northwest, with frequent temperature changes, and cold-wave warnings for some portion of the district were issued on 20 days during the month. The warnings of the 1st, 3d, 14th, 25th, and 30th were for a small part of the district, covering only one or two States, while those of the 4th, 5th, 9th, 10th, 11th, 12th, 15th, 21st, 22d, 23d, 24th, 26th, 27th, 29th, and 31st covered larger areas. The most important warnings were those of the 4th, covering the pronounced cold wave of the 5th throughout the Northwest, those of the 9th for the cold wave over the northern half of the district, those of the 11th-12th for the severe cold wave of the 13th in the upper Mississippi Valley and western Lake region, and those of the 23d-24th for the cold wave of the 24th-25th in Montana, the Dakotas, and Nebraska.

Heavy-snow warnings were issued for northeast and central Minnesota on the 1st and for northern Wisconsin and northern and eastern Minnesota on the 26th.—*Chas. L. Mitchell, Assistant Forecaster.*

Denver district.—The month was stormy and more than the usual number of special warnings were issued.

Frost warnings of the 11th, 12th, and 31st for southern Arizona were fully verified, while the warnings, generally for local frost, of the 7th, 13th, 19th, and 20th were verified in part. The warning of the 15th was a failure; instead of frost, rain set in.

A cold-wave warning was issued on the morning of the 4th for north-central Colorado and in the evening for eastern Colorado. While sharp falls occurred, temperatures did not reach verifying values. The anticyclone's influence was lessened by a remnant of low pressure left along the foothills of the Continental Divide.

The cold-wave warning on the evening of the 9th, for eastern Colorado and northeastern New Mexico, was fully verified only along the middle eastern border of Colorado. The course of the anticyclone was too far eastward, probably due to increasing domination of the low west of the mountains.

On the morning of 11th cold-wave warnings were issued for Colorado, northern New Mexico, northern Arizona, and southern and eastern Utah. These warnings were fully verified, the cold wave being confined entirely to the areas specified.

The cold-wave warning of the 15th for the vicinity of Denver, southeastern Colorado, and northeastern New Mexico was fully verified in southeastern Colorado and in northeastern New Mexico, except in the mountains near Santa Fe. For Denver the warning gave only 12 hours' notice.

On the 21st a cold-wave warning was issued for north-central Arizona. This warning was fully verified.

A warning on the 24th for eastern Colorado was fully verified only in extreme northeastern Colorado. The course of the anticyclone was too far eastward.

Warnings were issued on the 26th for western Colorado, northwestern New Mexico, northern Arizona, and southern Utah. These places were visited by a cold wave 24 hours after the expiration of the regulation period. Falling pressure in the west and the southeastward movement of high pressure on the eastern slope delayed the occurrence of the cold west of the mountains.

Warnings issued on the 27th for eastern New Mexico and the 31st for southeastern New Mexico were not verified. The course of the anticyclone was deflected too far eastward.—*Fred. H. Brandenburg, District Forecaster.*

New Orleans district.—Cold-wave warnings were issued on the night of the 10th for Oklahoma and the Texas Panhandle; they were extended on the 11th and 12th over the interior of Texas, Arkansas, and Louisiana to the Gulf coast. An unusually severe cold wave prevailed, with temperatures below zero, over the northwestern portion of the district, 10° F. to 16° F. over the interior of Texas and Louisiana, with freezing on the Gulf coast. The temperature was 22° to 28° in the sugar and trucking region.

Warnings were ordered on the 15th for a cold wave for the northern portion of west Texas, Oklahoma, and the northwest portion of east Texas, and they were extended on the 16th to the Gulf coast. A decided fall in temperature occurred throughout the district, giving temperatures of 18° to 14° over the northern portion of the district, 16° to 24° over the interior, and freezing to the Gulf coast.

On account of an area of high pressure and cold weather, which persisted over the northern Rocky Mountain region from the 24th to the 26th, cold-wave warnings were ordered over Oklahoma and the northwestern portion of Texas on the afternoon of the 24th, and repeated on the 25th and 26th. The high pressure and cold wave remained stationary until the night of the 26th, when a cold wave visited the northwestern portion of the district. The warnings were extended during the 26th and 27th over Arkansas, northern Louisiana, and to the Texas coast. The movement of the cold wave southeastward was retarded, and while a decided fall in temperature occurred over the district, the required minimum temperatures were recorded at only a few stations.

Cold-wave warnings were issued for Arkansas, northern Louisiana, and the interior of eastern Texas on the afternoon of the 29th, but the high pressure area off the south Atlantic coast persisted and the warning failed of verification.

Cold-wave warnings for southern Texas were issued on the morning of the 31st and for southern Louisiana on the night of the 31st. They were justified by resulting conditions.

Storm warnings were ordered for portions of the west Gulf coast on the 11th, 12th, 16th, 20th, and 27th, and verifying winds occurred at some stations, except in the case of the warning issued on the 27th.—*I. M. Cline, District Forecaster.*

Portland, Oreg., district.—A number of storm warnings were issued during the month. All were justified and nearly all verified. Wind velocities of 60 miles an hour were recorded on several days at Tatoosh Island; but the most severe storm of the month was on the 22d, when a current velocity of 94 miles an hour from the south was recorded at North Head, Wash.

A cold-wave warning for southern Idaho was issued on the 15th and was verified by a 20-degree fall in temperature at Pocatello, viz, from 20°F. to 0°F. in 12 hours. There was only a 10-degree fall at Boise.—*T. F. Drake, Local Forecaster.*

San Francisco district.—January, 1916, was unusually stormy on the California coast and many storm warnings were issued. Some of the warnings were not verified by wind velocities from coast stations, but the masters of vessels arriving in port generally agreed that the warnings were justified by outside conditions.

Warnings of floods were issued to southern California points on the 18th and 27th, and were amply justified.

On the afternoon of the 27th, a severe storm passed inland just south of San Francisco, causing the lowest barometer readings on record at many stations. The minimum sea-level pressure at this station was 28.84 inches. Shortly after the passage of the center the wind at Point Reyes Light registered an extreme velocity of 102 miles an hour from the northwest.—*Geo. H. Willson, District Forecaster.*