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Climatological Aspects of Eastern United States Back-Door Cold Frontal Passages[1]

LANCE F. BOSART, VITO PAGNOTTI, AND BERNHARD LETTAU—*Department of Atmospheric Science, State University of New York at Albany, N.Y.*

ABSTRACT—Results of a study on back-door cold fronts for the months April through October of 1964–71 are presented. Results include information on frequency, associated air-mass duration, precipitation, temperature and dew-point temperature changes, sky cover, and rate of frontal movement. Composite 850- and 500-mb height contours are also constructed.

Our findings include: (1) for the sample period, southward penetration of back-door cold fronts is a maximum in June as is frontal frequency, (2) orography plays a prominent role in funneling shallow cold air pools southward east of the Appalachians, (3) more than half of all frontal passages are associated with trace amounts or less of precipitation, (4) heaviest precipitation tends to occur in conjunction with the advancing cold fronts at the more southern and western locations and with the returning warm fronts at northern and eastern locations, (5) temperature changes following frontal passage decrease from north to south and from the coast inland (dew-point temperature changes follow a similar pattern but not so clearly), and (6) cloudiness increases following frontal passage, especially at southern and inland locations.

The composite study reveals a short-wave trough at both the 850- and 500-mb level just east of Hudson Bay preceding the initial movement of back-door cold fronts southward. This short wave intensifies east-southeastward toward the Canadian Maritime Provinces while anticyclogenesis takes place upstream.

1. INTRODUCTION

Several times each year, east–west-oriented cold fronts push south and southwestward along the eastern seaboard of the United States in advance of a polar anticyclone moving across eastern Canada. These features, known locally as back-door cold fronts, are more frequent during the warmer part of the year and, since low-level winds to the rear of these fronts are from the north through east, penetrate considerably further southward to the east than to the west of the Appalachians.

These frontal passages appear to play a prominent role in establishing a relatively sharp climatological gradient at about 41°N. For example, the normal daily maximum temperature in July increases southward locally at the rate of 1°C/1° lat.—a value that exceeds the average value by a factor of five.

From a research point of view, back-door cold fronts offer the opportunity to study boundary-layer processes in association with the pronounced ageostrophic flow under normally stable lapse conditions. Friction and topography are significant influences on the rate of movement and geographical location of such features. Likewise, anticyclogenesis is often associated with such fronts, suggesting that a knowledge of the upper level conditions attending back-door cold fronts is important in describing the phenomenon as well as understanding the relevant dynamics.

Environmental factors are also related to this phenomenon. The passage of a back-door cold front will frequently break an eastern United States heat wave with maximum temperature falls of 20°F and produce a significant reduction in the demand for electric power. Likewise, high air pollution episodes can occur in the vicinity of the frontal boundary under light gradients and stable conditions. Back-door cold fronts also influence the ecological cycle through changes in precipitation, evaporation, and cloudiness patterns. Finally, there is the forecast problem itself. It is our personal experience that back-door cold fronts penetrate farther southward with greater authority and retreat more slowly than forecast.

The purpose of this paper is to examine the back-door cold front as a contributor to the establishment of climatological gradients over the eastern United States. We will investigate (1) the frequency of frontal passage as a function of geographical location in the northeastern United States, (2) air-mass [usually maritime polar (mP)] duration, (3) precipitation, (4) temperature and dew-point temperature changes, (5) sky-cover changes, (6) frontal movement, and (7) mean conditions aloft. The period of study includes the months April through October for the years 1964–71, with specific cases listed in appendix 1. The three approximately northeast–southwest station bands used in this investigation are shown in figure 1. These were selected to represent coastal as well as inland conditions east and west of the Appalachians. Corresponding station call letters are tabulated in appendix 2. The principal data source is *Local Climatological Data* (National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, N.C.), supplemented by surface and upper air North American charts transmitted routinely over facsimile from the National Meteorological Center (NMC).

[1] Contribution No. 115 from the Eastern Deciduous Forest Biome, U.S.-IBP.

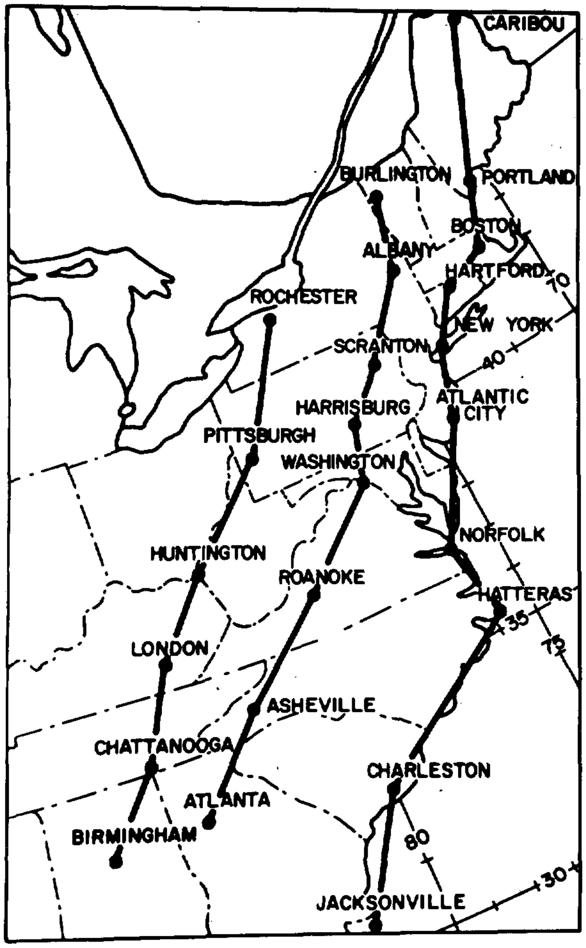

FIGURE 1.—Location of stations used in the climatological computations.

2. PREVIOUS RESEARCH

Previous research on this subject has been limited, perhaps because of the lack of synoptic excitement usually associated with the passage of back-door cold fronts and the accompanying anticyclogenesis. Wexler (1951), however, did recommend further study of this phenomenon with attention being devoted to the role of anticyclogenesis in the warm air above the frontal surface. Carr (1951) noted the eastward movement of a cold "V-shaped" trough at the 500-mb level over the adjacent Atlantic Ocean shortly before surface frontal passage. Winds aloft were usually northerly or northeasterly in back-door situations.

Hovey et al. (1967) conducted a study of New England back-door cold fronts for the period 1958–66 for all months of the year. Only those fronts that moved south of Portland, Maine, and had a westerly component to their movement were considered. They found a maximum frequency in September, when eight of the total 39 cases occurred, while May and June together yielded 13 for a secondary maximum period. They noted stalling of fronts between Portland, Maine, and Boston, Mass., in only three cases, indicating that the climatological gradient lay generally south of Boston. Winds at the 500-mb level were generally northwesterly with a High centered over the lower Ohio Valley with ridging extending northward toward Hudson Bay. The maximum duration of maritime polar (mP) air associated with back-door cold fronts was 5 days, the average being about 2 days. The average rate of frontal movement was 3° lat./12 hr, with a maximum of 5° lat./12 hr. An increase in cloudiness and relative humidity, with a resulting greater decrease in maximum temperature as compared to minimum temperature, was generally noted following frontal passage. Precipitation was seldom noted with the frontal passage; however, drizzle was often reported in the mP air behind the front.

3. CASE SELECTION CRITERIA

The cases selected for this study were limited to those in which an approximately east–west-oriented cold front was first observed north of latitude 45°N and whose lifetime exceeded 24 hr. These fronts were analyzed through the following categorization and averaging techniques, some of which were necessitated by the format of the available data.

Air-Mass Duration

The duration of mP air associated with back-door fronts was estimated to the nearest half-day. It was defined as beginning with the time of cold frontal passage at each station, and ending either at the time of the return warm frontal passage or when a significant dew-point temperature rise (arbitrarily taken to be 10°F) occurred at the station. Surface wind direction changes were used in the interpretation of weak cases.

Occasionally, it was difficult to establish the time of termination of the mP regime. For these cases, the duration was defined as extending from the time of back-door cold frontal passage to the time of passage of another frontal system; that is, until a definite change of air mass had occurred.

From the air-mass duration recorded for each station for each frontal case according to these general criteria, a monthly percentage frequency was calculated for each of the months April through October over the period of study. A total percentage frequency was also calculated.

Precipitation Totals

Two slightly differing techniques were employed in the precipitation study. Hourly precipitation amounts at each station were normally totaled in three categories: (1) cold frontal precipitation—from 12 hr before cold frontal passage to 24 hr after cold frontal passage; (2) warm frontal precipitation—24 hr before warm frontal passage to time of frontal passage; and (3) total frontal precipitation—from 12 hr before cold frontal passage through the time of warm frontal passage. The time period chosen for recording cold frontal precipitation was noncentered, since it is questionable whether precipitation occurring 12 hr or more ahead of frontal passage is associated with the front. Recording of precipitation for the warm frontal case was terminated at the nearest hour following passage. Total

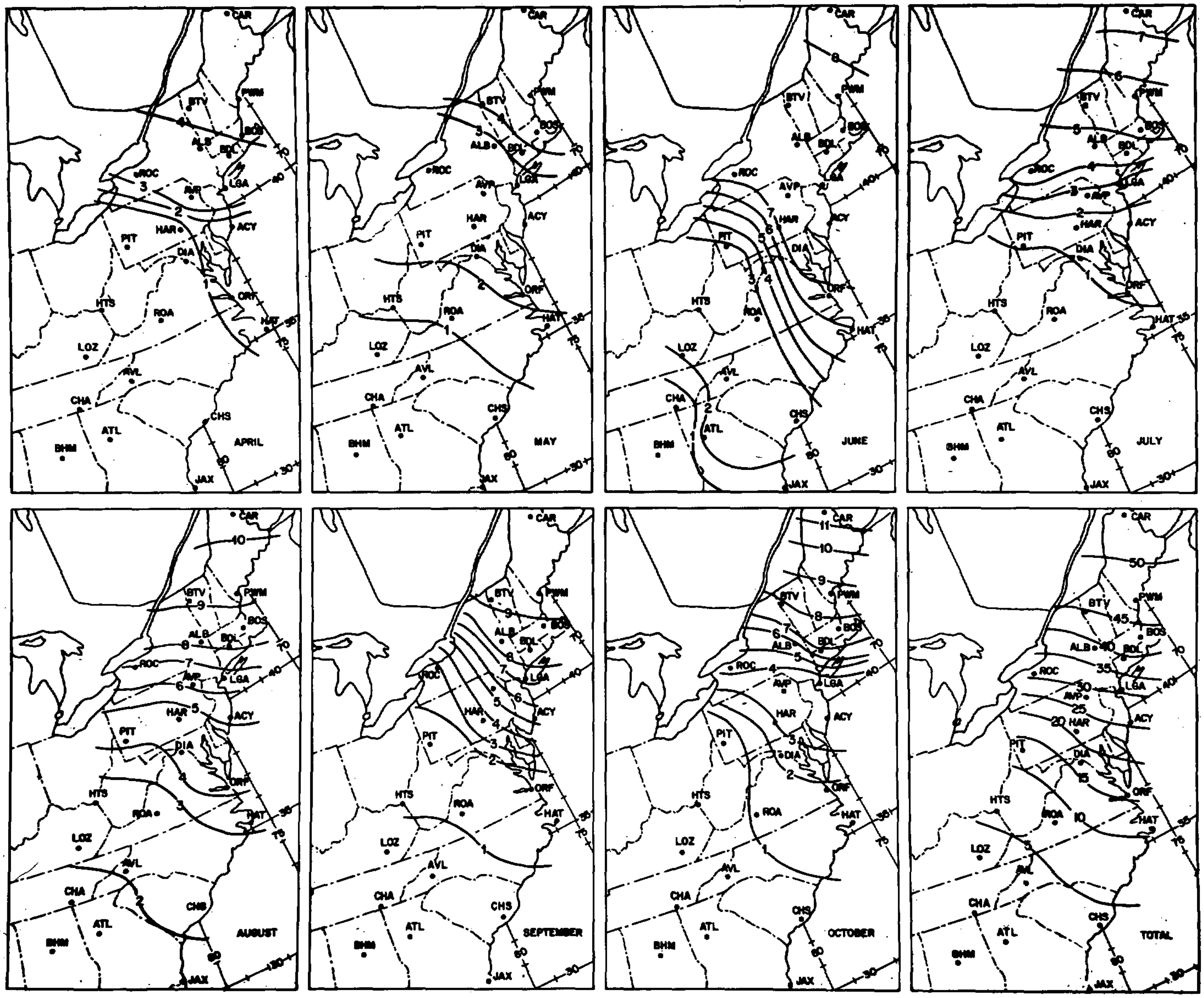

FIGURE 2.—Number of occurrences of back-door cold frontal passages by month for April through October of 1964–71 and the cumulative 7-mo total.

frontal precipitation is defined so that all precipitation due to overrunning associated with the frontal episode is recorded.

In the overlap cases; that is, when there were 2 days or less between cold and warm frontal passages, the rainfall occurring during the first half of the intervening time period was considered cold frontal; that occurring in the second half was considered warm frontal precipitation.

Parameter Changes

Averages of temperature and dew-point temperature available at 3-hr intervals were computed for 24 hr before and 24 hr after the time of cold frontal passage. The data for the time of frontal passage were included in the computation of both 24-hr averages; that is, the time periods were centered on cold frontal passage. The changes were computed as the following 24-hr average minus the previous 24-hr average. Similarly, an average sky cover (tenths) and the change in average sky cover was computed for 24-hr periods on either side of the frontal passage. Additionally, a mean change in the average sky cover between the periods was computed for each station. The sky-cover data making up the 24-hr periods also had a sampling interval of 3 hr.

Rate of Frontal Movement

A simple latitudinal shift of the most rapidly moving portion of the front within the station network was computed to determine the rate of movement of the fronts. A displacement was noted for 6-hr periods (0000–0600 GMT, 0600–1200 GMT, etc). An average over all cases and for all time periods was calculated.

Mean Contour Maps

Two additional frontal criteria were developed to construct mean contour maps: (1) a high-pressure area behind

TABLE 1.—*Back-door cold frontal precipitation*

Station	Number of cases	Average precipitation per case	Maximum precipitation	Percentage of cases with a trace or less
CAR	53	0.07	1.53	55
PWM	46	.07	0.89	65
BOS	43	.05	0.74	79
BDL	40	.05	0.74	75
LGA	30	.06	0.72	70
ACY	24	.09	1.27	71
ORF	16	.05	0.69	88
HAT	13	.11	1.04	69
CHS	4	.03	0.07	50
JAX	2	.83	1.56	0
BTV	46	.10	0.88	59
ALB	38	.06	1.27	66
AVP	29	.05	0.36	59
HAR	21	.18	1.22	57
DIA	17	.20	1.85	59
ROA	7	.37	2.02	57
AVL	4	.11	0.43	75
ATL	3	.51	1.54	67
ROC	30	.05	0.24	67
PIT	12	.21	0.87	50
HTS	6	.25	1.03	33
CHA	1	.06	–	–
BHM	1	0	–	–

TABLE 3.—*Total frontal precipitation*

Station	Average precipitation	Maximum precipitation	Number of cases with ≤ trace	Percentage of cases with ≤ trace
CAR	0.10	1.53	26	49
PWM	.09	0.89	30	65
BOS	.10	1.45	30	70
BDL	.11	1.84	26	65
LGA	.10	0.72	18	60
ACY	.09	1.27	15	63
ORF	.05	0.69	14	88
HAT	.11	1.04	9	69
CHS	.03	0.07	2	50
JAX	.83	1.56	0	0
BTV	.13	1.14	25	54
ALB	.07	1.27	23	61
AVP	.10	0.70	15	52
HAR	.21	1.22	10	48
DIA	.21	1.85	10	59
ROA	.37	2.02	4	57
AVL	.11	0.43	3	75
ATL	.51	1.54	2	67
ROC	.12	1.56	18	60
PIT	.23	1.10	6	50
HTS	.25	1.03	2	33
CHA	.06	–	–	–
BHM	0	–	–	–

TABLE 2.—*Returning warm frontal precipitation*

Station	Number of cases	Average precipitation per case	Maximum precipitation	Percentage of cases with a trace or less
CAR	16	0.08	0.35	50
PWM	13	.06	0.59	85
BOS	13	.07	1.21	77
BDL	16	.14	1.84	75
LGA	12	.05	0.30	83
ACY	9	.01	0.06	78
ORF	4	0	–	100
HAT	2	0	–	100
CHS	0	–	–	–
JAX	0	–	–	–
BTV	20	.07	0.61	75
ALB	16	.02	0.25	81
AVP	14	.11	0.61	71
HAR	12	.04	0.25	58
DIA	6	.03	0.16	83
ROA	1	0	–	100
AVL	0	–	–	–
ATL	0	–	–	–
ROC	19	.10	1.32	68
PIT	6	.04	0.23	83
HTS	1	0	–	100
CHA	0	–	–	–
BHM	0	–	–	–

the front, with one or more closed isobars and (2) the characteristic back-door tilt (northwest–southeast) of the front east of the Appalachians.

For the construction of the mean upper air maps, the time periods were centered with respect to t_0, where t_0 refers to the 0000 or 1200 GMT nearest the approximate time of back-door cold frontal passage at Portland, which was chosen as the reference station since Hovey et al. (1967) found the climatological gradient to be south of this location. Heights were recorded and averaged for t_0-24 hr, t_0, and t_0+24 hr at the available radiosonde stations for the cases selected. Ten cases with well-defined surface features were selected for use in construction of the mean contour maps using the general criteria described earlier.

4. RESULTS

Frequency of Occurrence

The 53 cases selected for study are listed chronologically in appendix 1. These cases were gleaned from an inspection of NMC surface facsimile maps available at 3-hourly intervals. The dates represent the day (based on GMT) the front passed southward through Caribou, Maine. The annual total varied from a maximum of 11 in 1969 to a minimum of two in 1965. Figure 2 shows the monthly average of back-door cold frontal passages for April through October and the cumulative 7-mo totals in the station network.

A late summer and early fall maximum is noted with an absolute maximum occurring in October. The greatest southward penetration is in June and August. There is a characteristic decrease in frequency from northeast to southwest across the station network, and a well-marked tendency for the fronts to slip down the Atlantic coast east of the Appalachian mountains.

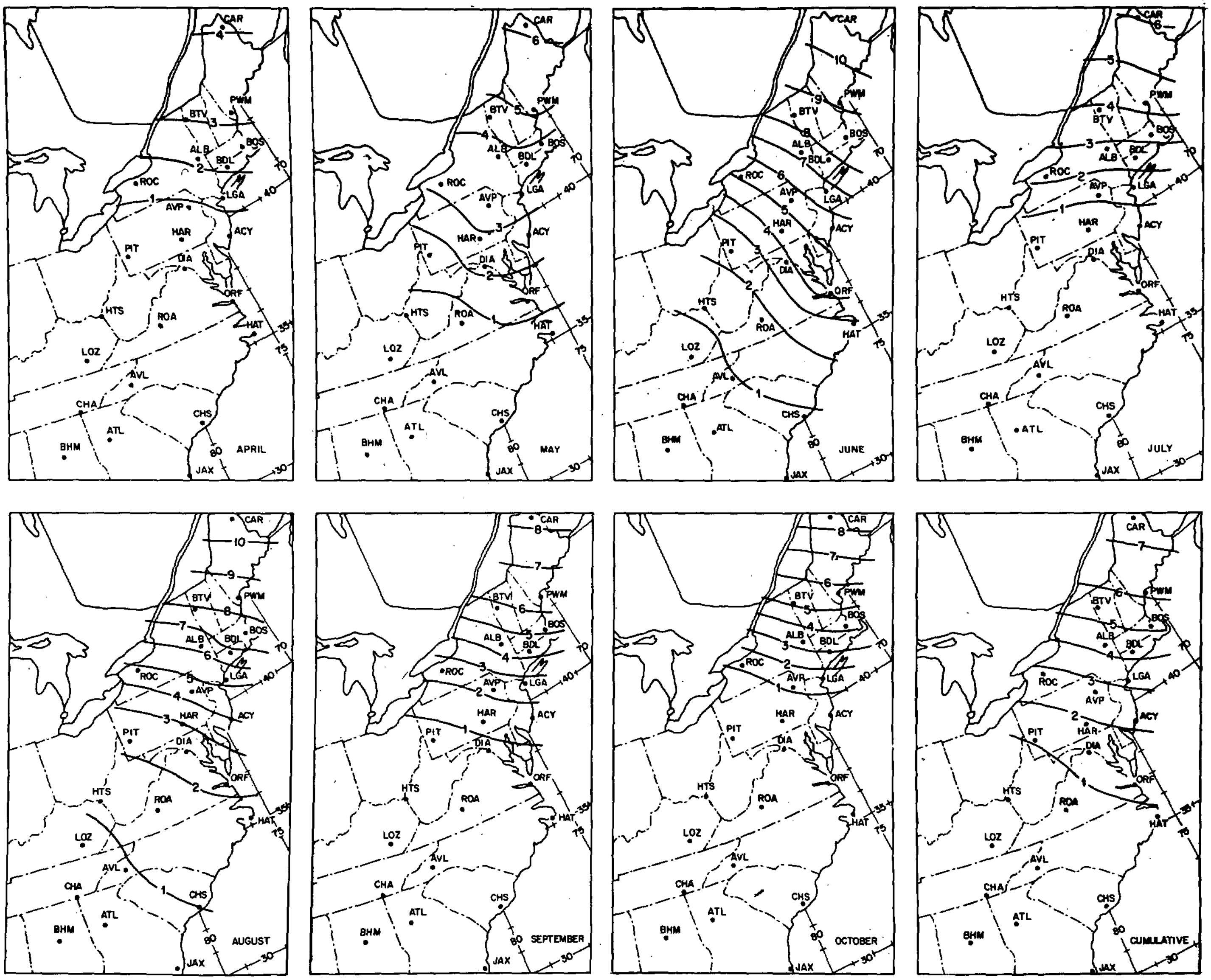

FIGURE 3.—Percentage frequency of air-mass duration associated with back-door cold frontal passages by month for April through October of 1964–71 and the cumulative 7-mo total.

Air-Mass Duration

Air-mass duration associated with back-door cold fronts varied from half a day at extreme southern and southwestern stations to a maximum of 6 days at Caribou, Maine, for individual cases, with the average duration ranging from ½ to 3 days from southwest to northeast. The percentage frequency of air-mass duration associated with the back-door cold fronts by month and the cumulative 7-mo total is shown in figure 3. Maritime-polar air-mass influence is greatest in June and August with the influence decreasing from northeast to southwest. Persistence east of the mountains is especially evident.

Precipitation

The precipitation results are shown in tables 1–3. For each station, table 1 presents the number of cases, the average amount per frontal passage, the maximum amount observed over all cases, and the percentage of cases with a trace or less. Table 2 is similarly constructed for retreating back-door fronts acting as warm fronts, with the number of occurrences given in the first column. Total frontally associated precipitation results are given in table 3.

In general, approximately half of the cold frontal passages were associated with trace amounts (or less) of precipitation. Inland locations in mountainous areas appear to have the highest likelihood of measurable rain. Coastal locations from Hatteras (HAT), N.C., to Boston (BOS), Mass. are the driest areas. Quite often, surface winds in these areas are from the west through northwest prior to the arrival of a back-door front with a resulting weak downslope component and attendant dryness. Some of the hottest weather of the summer is likely under these conditions at coastal locations as sea-breeze regimes are inhibited.

Maximum single-case rainfalls appear to be higher at inland southwestern locations despite fewer cases. This is

TABLE 4.—*Average temperature and dew-point temperature changes accompanying back-door cold frontal passages*

Station	Number of cases	Temperature			Dew-point temperature		
		Average change	Maximum decrease	Maximum increase	Average change	Maximum decrease	Maximum increase
PWM	39	−4	−25	6	−6	−19	6
BOS	36	−7	−19	4	−4	−18	9
BDL	34	−4	−13	4	−3	−18	5
LGA	26	−5	−11	0	−1	−10	10
ACY	16	−5	−14	2	−2	−10	6
ORF	14	−2	−7	3	0	−7	4
HAT	11	0	−4	5	0	−7	4
CHS	2	−3	−4	-	−2	−3	-
JAX	1	−5	-	-	−2	-	-
BTV	39	−4	−14	7	−3	−15	6
ALB	33	−3	−12	6	−2	−12	7
AVP	25	−2	−10	6	−1	−13	7
HAR	18	−4	−9	3	−1	−12	8
DIA	14	−3	−11	6	−1	−14	9
ROA	5	−2	−7	1	0	−6	4
AVL	2	−4	−5	-	−1	−2	1
ATL	1	0	-	-	−3	-	-
ROC	25	−3	−11	7	−2	−14	7
PIT	10	−3	−10	5	−1	−10	5
HTS	4	0	−1	3	0	−3	2

probably associated with weak surface convergence, strong low-level heating, and greater instability in such locations coupled with a tendency for a slowing down of the southward push of the frontal system. Returning warm front precipitation is not as frequent nor as heavy and is concentrated in northeastern regions where cold air is deep enough for overrunning effects to be significant. An exception is Rochester, N.Y., with a relatively higher frequency of measurable rain and a higher maximum rainfall total for warm frontal passages, which may be related to an observed tendency for active thunderstorms to break out across north-central Pennsylvania into western and central New York ahead of a warm front. This activity usually dies out toward the Hudson Valley. Evidently, weak orographic lifting helps to trigger some convective instability in such situations.

Parameter Changes

Table 4 presents the results for differences in average temperature and dew-point temperature for 24 hr before frontal passage to 24 hr after frontal passage. The number of cases does not correspond to table 1 because hourly or 3-hourly observations were unavailable from *Local Climatological Data* (e.g., Caribou) or selected monthly observations were missing. Also given in table 4 is the average change (always negative; day after minus day before), the maximum negative change, and the maximum positive change for temperature and dew-point temperature. As would be expected, the average temperature drop decreases from north to south and from the coast inland.

Average dew-point temperature changes are less clear, although there is a tendency for a decrease from north to south. Decreases are noted in northern regions where the cold air is deeper, but the magnitude of the change is reduced by maritime influences.

Note that in some cases the temperature and dew-point temperature increased following frontal passage.

TABLE 5.—*Average sky cover and sky-cover changes*

Station	Number of cases	Sky cover		Average change in cover
		Previous 24 hr	Following 24 hr	
PWM	39	5	5	0
BOS	36	5	6	+1
BDL	34	5	6	+1
LGA	26	4	6	+2
ACY	16	5	8	+3
ORF	14	4	6	+2
HAT	11	7	6	−1
BTV	39	6	5	−1
ALB	33	5	6	+1
AVP	25	4	6	+2
HAR	18	5	8	+3
DIA	15	4	7	+3
ROC	25	4	6	+2
PIT	10	6	7	+1
HTS	4	5	5	0
CHS	2	2	5	+3
ROA	5	3	6	+3
AVL	2	4	6	+2
JAX	1	6	9	+3
ATL	1	6	6	0

Average temperature increases are synoptically associated with short-lived cold fronts that return as warm fronts briefly after passage. Average dew-point increases may be associated either with the latter or with a particularly moist maritime air mass replacing a relatively warm dry air mass.

Sky-cover results are presented in table 5. The number of cases is followed by an average sky cover for the previous 24 hr, an average cover for the following 24 hr, and the average change in sky cover. Sky-cover values are reported to the nearest tenth. An increase in cloudiness following frontal passage is noted at almost all stations. Largest changes are observed in the Middle Atlantic States where back-door cold fronts tend to stagnate. Farther north, deeper into the cold air, the cloud cover increases are reduced (no change at Portland, Oreg.) and may even be negative (Burlington, Vt.).

Rate of Frontal Movement

The average rate of movement for all cases was 1.3° lat./6 hr. By time periods, the averages were 1.4° lat./6 hr from 0000 to 0600 GMT, and 1.2° lat./6 hr for the other three standard intervals.

Mean Upper Contours

Ten cases in italics in appendix 1 were chosen on the basis of their similarity for use in the computation of the mean contours. The mean southernmost extent of these fronts was approximately 38°N and the southernmost coastal passage varied from Windsor Locks, Conn. (BDL) to Hatteras, N.C. (HAT). Figure 4 gives the mean 850- and 500-mb contour maps for t_0- 24 hr, t_0, and t_0+ 24 hr.

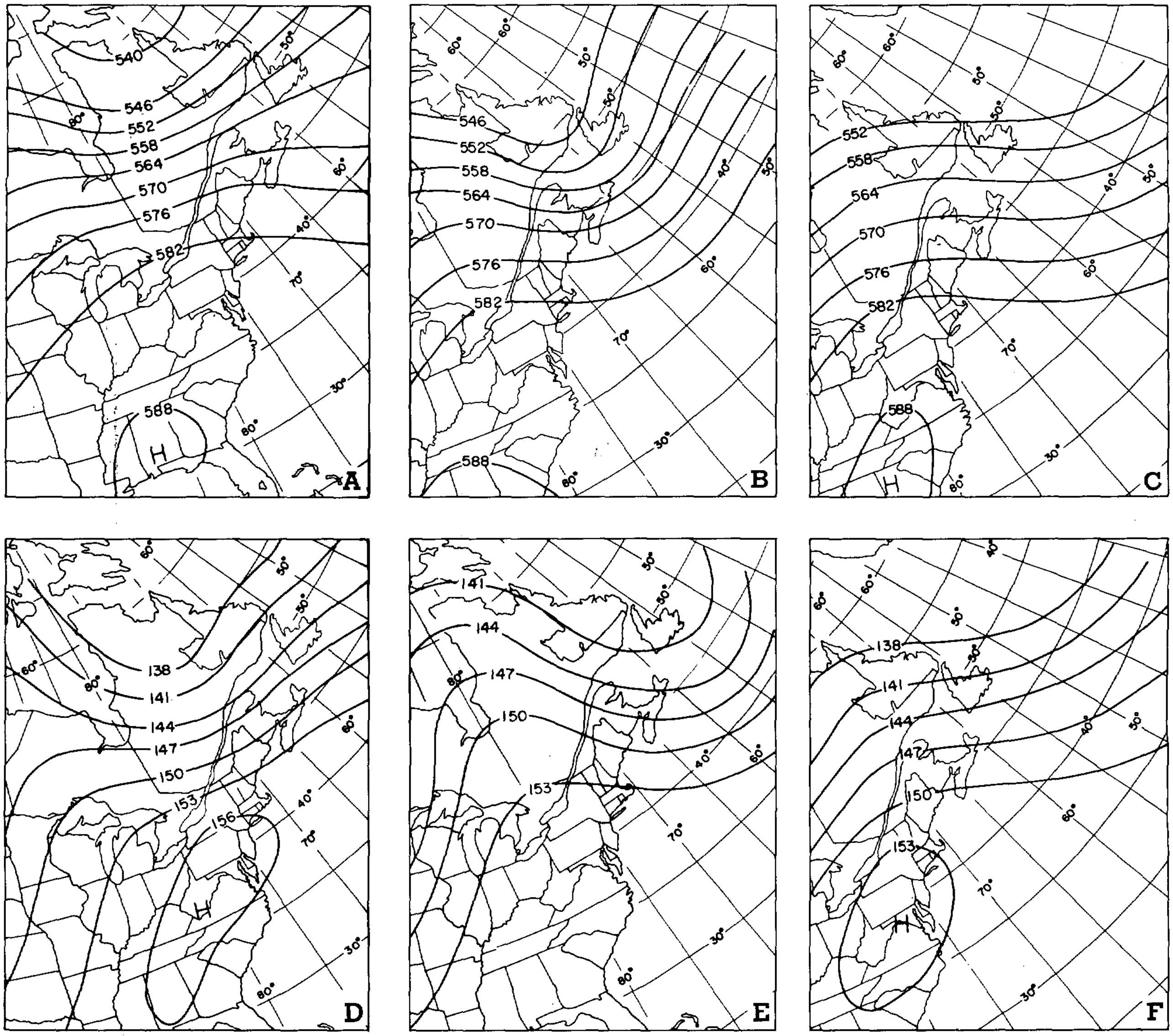

FIGURE 4.—Mean 500-mb contours (m) at (A) t_0-24 hr, (B) t_0, and (C) t_0+24 hr and mean 850-mb contours (dam with leading 1 omitted) at (D) t_0-24 hr, (E) t_0, and (F) t_0+24 hr. Here, t_0 refers to the time of back-door cold frontal passage at Portland, Maine.

A mean ridge is apparent over the eastern United States throughout the 48-hr period. To the north of the ridge, a short wave, initially east of Hudson Bay, digs southeastward across Canadian Maritime Provinces into the Atlantic. A clockwise circulation of air around the building high pressure to the rear of the short wave forces cooler air southward along the Atlantic coast in the classic back-door pattern.

5. DISCUSSION

Any interpretation of the previous results must be balanced by a consideration of the representativeness of the data sample and the somewhat subjective analysis techniques. For example, the study on the rate of frontal movement involved variability in judgment when measuring the latitudinal shift and also in determining the most mobile portion of the front. The average rate for all cases is consistent with the results of Hovey et al. (1967), although the slight preference for more rapid movement between 0000 and 0600 GMT is probably spurious. We thought that there might be a preference for more rapid movement from 1800 to 0000 GMT based on daytime differential heating of land and sea, which would enhance the onshore flow component; however, our results are inconclusive with regard to this speculation. Perhaps a Laplacian of diabatic cooling due to radiation, occurring behind the fronts, leads to low-level negative relative vorticity generation. This, in turn, would enhance low-level anticyclogenesis and a corresponding southward push.

Individuality of frontal characteristics is obscured by the compositing technique, but the characteristic features should stand out for a large-enough data sample, and we are encouraged that our results appear to be synoptically reasonable. The deletion of those fronts that did not fit the general criteria does render this study somewhat incomplete, although the inclusion of more questionable cases might strengthen our results. For example, east–west fronts, which form a few degrees south of 45°N and are considered back-door cold fronts by some meteorologists, often produce copious rainfall in their southward movement. Likewise, north–south-oriented fronts, which on occasion develop into typical east–west back-door cold fronts over the southeastern United States, were not included in this investigation.

Since our investigation only covered 8 yr, it is possible that anomalous flow patterns, which might be favorable or unfavorable to the generation of back-door fronts, existed during that period. We tabulated the monthly 700-mb height anomalies from data presented in the *Monthly Weather Review*. Eight-year average 700-mb height anomaly composites were prepared for April through October.[2]

Height anomalies (not shown) were generally under 2 dam. June, and to some extent August and September, were characterized by a weak anomalous 700-mb northwesterly flow over New England and eastward. July, on the other hand, exhibited a weak anomalous southwesterly flow across New England. Near-normal flow patterns were noted in the remaining months. These results are consistent with our earlier findings on the monthly frequencies of back-door cold fronts.

6. CONCLUSIONS AND COMMENTARY

In summary we note the following:

1. Southward penetration of back-door cold fronts along the Atlantic coast is a maximum in June when the thermal contrast between cold ocean and warm land is a maximum. Frontal frequency is also a maximum at this time. The gradient of back-door cold frontal frequencies and air-mass duration is most nearly east–west in June. Thus, the orographic effect, though quite prominent throughout, is most marked in June and generally the weakest during the summer months when the gradient is more north–south.

2. In the years studied (1964–71), back-door cold fronts were less frequent in the early spring (April and May) than at any other time, April–October, possibly due to the relatively strong winterlike flow patterns observed in the East late in the season during that period. This strong upper level flow pattern, with a mean trough near the east coast, has been a persistent feature in the majority of recent springs. Two examples of this pattern can be found in the mean 700-mb contours for April 1971 and May 1971 presented by Green (1971) and Stark (1971), respectively.

3. The heaviest precipitation occurs inland (upslope) on the average. Coastal stations are under the stabilizing influence of onshore flow from a cold water source. Precipitation also occurs more often and is heavier at the more southern and western stations. The lighter precipitation at the northeastern stations might be explained by greater subsidence to the north and east, to the rear of the intensifying short-wave trough aloft. However, heavier precipitation would be expected to the southwest and west, where overrunning in the southwesterly flow aloft west of the middle and upper level ridge takes place, simultaneously with the southwestward movement of residual cold air in the lower levels. Also, frontal movement toward the southern and western stations is slower. The latter enhances the likelihood of more precipitation at these stations on the basis of a longer duration for rainfall.

4. There is a slight preference for heavier precipitation with the warm front than with the cold front at northern and eastern stations. Presumably, this is an effect of greater warm advection and consequent upward motion where the cold air depth is greater. Caution must be exercised in accepting this conclusion, however, because of the small sample size.

5. The greatest temperature and dew-point temperature differences occur at the northeastern stations, where frontal passage is better defined.

6. It is cloudier after frontal passage, especially at the southern and western stations, probably due to the overall shallowness and stagnation of the frontal zone accompanied by less subsidence aloft.

7. There is a slight preference for more rapid movement of back-door cold fronts in the time period between 0000 and 0600 GMT though, as previously mentioned, both the significance and validity of this observation are questionable.

8. At t_0-24 hr, the characteristic short wave on the mean middle and upper level contour maps is located east of Hudson Bay to the north of the mean ridge. It is seen to move in an easterly to southeasterly direction from its initial position at t_0-24 hr and to sharpen at t_0. The existence of the short wave is remarkable, since the 10 cases used in construction of the mean upper level charts were chosen by examination of the surface charts only. The deepening of the short-wave trough seems instrumental in the early development and movement of the back-door cold front.

9. As it moves eastward, the characteristic short wave is followed by anticyclogenesis aloft. But, during this time, the surface front may still be moving southward. Thus, the usual slight surface anticyclogenesis in the cold air, which contributes to the continuing motion of the front southward, may have its main origin in the warm advection aloft into the deepening ridge above the front, rather than in the accumulation of cold air in the lower levels. Wexler (1951) suggested that such a process might be important in connection with back-door cold fronts.

In conclusion, the back-door cold front has both a definite impact on the climatological features and resulting ecology of a region, and is a nontrivial forecasting problem requiring some further theoretical treatment (e.g., a determination of the relative importance of low-level and middle tropospheric parameters to ascertain whether the anticyclogenesis aloft is the ultimate cause of the additional southward movement of back-door cold fronts).

[2] *Monthly Weather Review*, Vols. 92–99, Nos. 7–12, July–Dec. 1964–1971, and Vols. 93–100, Nos. 1, Jan. 1965–1972.

APPENDIX 1: BACK-DOOR FRONT CASES

1	Apr. 27, 1964	28	Aug. 20, 1968
2	June 7, 1964	29	Oct. 13, 1968
3	June 27, 1964	30	Oct. 19, 1968
4	July 17, 1964	31	Apr. 8, 1969
5	July 19, 1964	32	Apr. 26, 1969
6	Aug. 2, 1964	33	May 3, 1969
7	Oct. 13, 1964	34	Aug. 14, 1969
8	Oct. 27, 1964	35	Aug. 25, 1969
9	May 26, 1965	36	*Aug. 29, 1969*
10	June 7, 1965	37	Sept. 4, 1969
11	*June 24, 1966*	38	Sept. 6, 1969
12	July 4, 1966	39	Sept. 13, 1969
13	Aug. 28, 1966	40	Oct. 19, 1969
14	Aug. 30, 1966	41	Oct. 26, 1969
15	Sept. 3, 1966	42	*Apr. 27, 1970*
16	Sept. 11, 1966	43	May 22, 1970
17	Sept. 18, 1966	44	June 11, 1970
18	May 17, 1967	45	July 29, 1970
19	*June 10, 1967*	46	*June 4, 1971*
20	July 10, 1967	47	June 28, 1971
21	Sept. 6, 1967	48	Aug. 18, 1971
22	*Sept. 19, 1967*	49	*Sept. 5, 1971*
23	Oct. 4, 1967	50	*Oct. 2, 1971*
24	July 12, 1968	51	*Oct. 19, 1971*
25	July 16, 1968	52	Oct. 21, 1971
26	Aug. 4, 1968	53	*Oct. 30, 1971*
27	Aug. 7, 1968		

APPENDIX 2: STATION INDEX

ROC	Rochester, N.Y.
PIT	Pittsburgh, Pa.
HTS	Huntington, W. Va.
LOZ	London, Ky.
CHA	Chattanooga, Tenn.
BHM	Birmingham, Ala.
BTV	Burlington, Vt.
ALB	Albany, N.Y.
AVP	Scranton, Pa.
HAR	Harrisburg, Pa.
DIA	Dulles International Airport, Sterling, Va.
ROA	Roanoke, Va.
AVL	Ashville, N.C.
ATL	Atlanta, Ga.
CAR	Caribou, Maine
PWM	Portland, Maine
BOS	Boston, Mass.
BDL	Bradley Field, Winson Locks, Conn.
LGA	LaGuardia Field, New York City, N.Y.
ACY	Atlantic City, N.J.
ORF	Norfolk, Va.
HAT	Hatteras, N.C.
CHS	Charleston, S.C.
JAX	Jacksonville, Fla.

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