SECTION II.—GENERAL METEOROLOGY.

SOLAR DISTURBANCES AND TERRESTRIAL WEATHER.

By ELLSWORTH HUNTINGTON, Research Associate in Geography.

[Dated: Yale University, New Haven, Conn., Mar. 7, 1918.]

(*Continued from* this REVIEW, April, 1918, p. 177.)

III. FACULÆ AND THE SOLAR CONSTANT COMPARED WITH BAROMETRIC GRADIENTS.

NOTE.—The third and final section of this paper will appear in the next (June) number of the REVIEW.

—EDITOR.

PREDICTING MINIMUM TEMPERATURES IN GRAND VALLEY, COLO.

By ESEK S. NICHOLS, Meteorologist.

[Weather Bureau office, Grand Junction, Colo., April 18, 1918.]

The devising of methods of predicting minimum temperature, particularly in spring, has been the object of several unpublished studies undertaken by the writer since his assignment to the Grand Junction station in the spring of 1911. These investigations, based on local records, have been of much importance locally, because of the use of temperature forecasts in connection with orchard heating in the Grand Valley, in the midst of which Grand Junction is located.

Previous studies by the writer.—The first of these special studies, made in 1911, considered the minimum temperature as a possible function of the dewpoint that had been recorded at the preceding evening observation; but the conclusion was reached that "there is no useful relation between the two meteorological elements considered. This agrees with the results obtained by Cox[1] in the cranberry marshes of Wisconsin. * * * the dewpoint itself is no indication whatever of the ensuing minimum temperature."

The most important of the special studies was the investigation of the relation between the daily maximum temperature and the ensuing minimum temperature. The individual cases were classified according to evening dewpoint and state of weather and wind in the morning. It was found that, for the month of April, at Grand Junction

$$y=\frac{5}{8}x+z$$

where y is the minimum temperature, x is the maximum temperature, and z is a variable whose value depends on the "class" to which the case belongs. The effect of atmospheric moisture in retarding nocturnal cooling is shown by the following equations, which were obtained for cases classified according to evening dewpoints.

Evening dewpoint.	*Equation.*
20° F. or lower.	$y=\frac{5}{8}x-3$.
21° to 30°.	$y=\frac{5}{8}x-1$.
31° to 40°.	$y=\frac{5}{8}x+1\frac{1}{2}$.
Over 40°.	$y=\frac{5}{8}x+2$.

The effects of state of sky, precipitation, and wind were shown in a similar manner by equations. All equations were plotted on cross-section paper, and have been used with much success in predicting minimum temperature during frost seasons.

Previous method of forecasting for Grand Junction district.—Having determined the probable minimum temperature at Grand Junction, there remains the problem of predicting the temperatures in the orchard districts of the vicinity, where several fruit-district stations have been maintained since 1913. A brief description of the topography of the fruit district, accompanied by an outline map, is contained in my article, "A temperature inversion in the Grand River Valley, Colo."[2] It was at once found:

1. That the relation between the temperature at any one station and that at Grand Junction is variable.
2. That the relations between the temperatures at the different stations on a given date are variable also. These variations accompany different types of pressure distribution and variations in cloudiness, humidity, wind direction and velocity, etc., which must be known or predicted before the temperature forecasts can be made with accuracy.

Hence the method that has been used in forecasting for the fruit district consists of three principal steps:

(*a*) Study of the weather maps and local reports to determine the probable state of the sky, pressure distribution, wind, etc., over the district the following morning.

(*b*) Computation of the probable minimum temperature at Grand Junction, using results obtained under (*a*) and the equations described above.

(*c*) Estimation of the probable minimum temperatures at the substations, using the results obtained under (*a*) and (*b*), and considering topography and individual peculiarities of each substation.

Development of Smith hygrometric formula.—While this method has been very successful, especially in predicting for Grand Junction, it is complicated and requires that the forecaster shall have had long experience in the locality. As substation records for a four-year period have now accumulated, it was intended for the sake of convenience and greater accuracy to compute substation formulæ similar to those used for Grand Junction; but a test of the hygrometric formula developed by Smith shows that it is both accurate and convenient.[3]

In considering the use of the hygrometric formula in predicting minimum temperatures for the Grand Valley stations, it occurred to the writer that the hygrometric conditions observed at Grand Junction must be representative of, or at least related to, those that exist in other parts of the valley. Therefore, it appeared probable that the readings taken at Grand Junction at the regular evening observation (5:40 p. m., local standard time) might be used in computing constants for predicting minimum temperatures at the substations. This

[1] Cox, H. J. Frost and temperature conditions in the cranberry marshes of Wisconsin. (Weather Bureau, Bulletin T.) Page 84.

[2] MONTHLY WEATHER REVIEW, November, 1915, 43: 562–563.

[3] Smith, J. Warren, "Predicting minimum temperatures." MONTHLY WEATHER REVIEW, August, 1917, 45:402–407.

work has been successfully completed for the months of March and April, using available records made during the years 1914 to 1917, inclusive.

The first step was the classification of the individual nights according to months, state of sky and wind velocity at Grand Junction in the morning, and pressure distribution. Then correlation coefficients and hygrometric constants were computed, in accordance with the method described in detail by Smith, for each substation for March and April separately, and for each of the following five classes of nights, as far as records were available:

Classification of nights in the Grand River Valley.

Class I. Sky clear; wind velocity less than 10 miles per hour; and with high-pressure area centered over or immediately west or northwest of the district.

Class II. Sky clear; wind less than 10 miles per hour; and with high-pressure area centered immediately east or northeast of the district, i. e., east of the Continental Divide.

Class III. Sky clear; wind velocity 10 miles per hour or more.

Class IV. Sky partly cloudy; wind velocity less than 10 miles per hour.

Class V. Sky partly cloudy; wind velocity 10 miles per hour or more.

Nights during which appreciable precipitation occurred at Grand Junction were omitted. The number of cases falling under Class V during March was insufficient to warrant computations. Hence, nine sets of coefficients and constants have been computed for each station (with exception of cases where records are broken badly). The results for the Grand Valley stations are so promising that I have computed similar factors for the station at Delta, Colo., which is situated entirely outside of the Grand Valley southeast of Grand Junction, at a distance of about 35 miles in a direct line.

The accompanying tables for March and for April give the numerical results obtained. The headings of the columns correspond with those used by J. Warren Smith in his article referred to above; that is, n is the number of cases used, r is the coefficient of correlation, E is the probable error, and a and b are constants of the hygrometric formula,

$$y = a + bR$$

where R is the evening relative humidity and y is the departure of the morning minimum temperature from the evening dewpoint. For convenience the equations have been plotted on cross-section paper, y as ordinates, R as abscissæ (in actual work a very large scale should be used for clearness and accuracy), so that, in making an evening forecast of minimum temperatures it is now necessary merely to determine, by consulting the daily weather map, the class in which the coming night will fall, and then to take from the appropriate graphs the departures of minimum temperatures from the Grand Junction dewpoint. (See figs. 1 to 9.)

It is regretted that observations for the upper Palisade district are badly broken, so that computations for that part of the valley can not yet be made; the Palisade station is located about 1 1/2 mile west of the town of Palisade, and not in the warmest part of the district.

The high value obtained for the correlation coefficient in almost all cases indicates that increased accuracy in forecasting may be expected as a result of the use of the new formula. However, it should not be expected that successes will be as great in actual work as might appear probable from application of the formula to past records, from which the class in which the night belongs can be determined accurately. The forecaster must determine in advance in which of the five classes the night will fall, if any; and it has been found, in the limited use so far made of the formula that greater inaccuracy is likely to result from incorrect classification than from inaccuracy of the formula when correctly applied.

CONCLUSIONS.

We may conclude, from the above study that—

1. The hygrometric formula of J. Warren Smith is applicable, not only to the prediction of minimum temperature at the station where the hygrometric observations are taken, but to the use of such observations in predicting temperatures at stations many miles away.
2. The formula may be used, not only during clear weather, but also for cases when the sky is partly cloudy.
3. The constants of the formula are, in general, different for the several stations, for the several months, and for differences in certain of the meteorological elements.
4. The forecasting of minimum temperatures will not become simply a mechanical routine, because of the skill necessary in placing the coming night in its proper class.

Finally, the writer believes that the applicability of the formula may be extended still further by using hygrometric observations taken before evening, say at noon, and computing a new series of constants. It is planned to undertake this work when opportunity offers.

TABLE 1.—*Relation between the evening dewpoint and humidity at Grand Junction, Colo., and the following morning's minimum temperatures in the Grand River region in March and April, under different classes of general weather conditions.*

CLASS I.—MORNING CONDITIONS=CLEAR; WIND LESS THAN 10 MIS./HR.; HIGH OVER THE DISTRICT.

Stations.	March.						April.					
	n	r	E	*a*	*b*	−*a*/*b*	u	r	E	*a*	*b*	−*a*/*b*
Grand Junction	17	−0.683	±0.088	24.7	−0.58	43.0	10	−0.887	±0.045	26.6	−0.50	51.2
Ground Exp. (G. J.)	17	−0.690	0.086	16.4	−0.48	34.2	10	−0.881	0.048	21.3	−0.51	41.8
Fruitvale	17	...	...	...	...	...	10	−0.870	0.052	19.7	−0.47	41.9
Palisade	17	−0.711	0.081	18.5	−0.40	46.5	10	−0.858	0.056	22.3	−0.45	49.7
Orchard Mesa	...	...	...	...	...	...	10	−0.876	0.050	22.3	−0.55	40.7
Pomona	17	−0.649	0.095	13.2	−0.43	30.7	10	−0.864	0.054	17.6	−0.46	38.3
Hunter	17	−0.570	0.110	12.2	−0.39	31.5	10	−0.883	0.047	17.6	−0.44	39.9
Fruita	17	−0.642	0.096	13.5	−0.42	31.8	10	−0.847	0.060	17.3	−0.46	37.4
Loma	...	...	...	...	...	...	10	−0.836	0.064	14.1	−0.38	36.9
Delta	...	...	...	...	...	...	10	−0.896	0.042	13.9	−0.38	36.8

CLASS II.—MORNING CONDITIONS=CLEAR; WIND LESS THAN 10 MIS./HR.; HIGH EAST OR NORTHEAST OF DISTRICT (IN APRIL, EAST OF CONTINENTAL DIVIDE).

Stations.	n	r	E	*a*	*b*	−*a*/*b*	u	r	E	*a*	*b*	−*a*/*b*
Grand Junction	11	−0.929	0.029	19.2	−0.32	59.1	12	−0.884	0.042	19.1	−0.29	65.8
Ground Exp. (G. J.)	11	−0.925	0.029	12.4	−0.31	40.0	12	−0.748	0.086	12.7	−0.25	50.9
Fruitvale	...	...	...	...	...	...	12	−0.622	0.119	8.4	−0.18	46.7
Palisade	11	−0.945	0.022	22.6	−0.42	53.9	12	−0.886	0.042	21.4	−0.32	67.3
Orchard Mesa	...	...	...	...	...	...	12	−0.726	0.092	13.3	−0.26	51.2
Pomona	11	−0.968	0.012	12.8	−0.34	37.2	12	−0.780	0.076	10.3	−0.24	42.9
Hunter	11	−0.824	0.065	10.1	−0.25	40.7	12	−0.814	0.066	12.8	−0.29	44.1
Fruita	11	−0.942	0.029	10.6	−0.30	34.8	12	−0.669	0.108	9.6	−0.20	48.0
Loma	...	...	...	...	...	...	12	−0.713	0.096	8.7	−0.21	45.7
Delta	...	...	...	...	...	...	12	−0.845	0.056	11.2	−0.24	46.7

CLASS III.—MORNING CONDITIONS=CLEAR; WIND 10 MIS./HR. OR HIGHER; MISCELLANEOUS PRESSURE CONDITIONS.

Stations.	n	r	E	*a*	*b*	−*a*/*b*	u	r	E	*a*	*b*	−*a*/*b*
Grand Junction	24	−0.874	0.033	26.5	−0.56	47.1	12	−0.887	0.043	32.1	−0.68	47.2
Ground Exp. (G. J.)	24	−0.856	0.037	21.0	−0.51	40.9	12	−0.714	0.100	20.1	−0.38	52.9
Fruitvale	...	...	...	...	...	...	12	−0.652	0.117	20.7	−0.44	47.5
Palisade	24	−0.879	0.031	22.1	−0.50	43.7	12	−0.840	0.060	29.1	−0.70	41.9
Orchard Mesa	...	...	...	...	...	...	12	−0.762	0.085	25.1	−0.54	46.5
Pomona	24	−0.544	0.098	19.2	−0.52	37.2	12	−0.603	0.130	19.0	−0.47	40.4
Hunter	24	−0.704	0.070	17.4	−0.49	35.5	12	−0.784	0.079	22.6	−0.61	37.0
Fruita	24	−0.616	0.080	16.1	−0.48	33.7	12	−0.559	0.140	18.6	−0.47	39.6
Loma	...	...	...	...	...	...	12	−0.765	0.084	19.6	−0.55	35.6
Delta	...	...	...	...	...	...	12	−0.765	0.084	26.3	−0.80	32.9

CLASS IV.—MORNING CONDITIONS=PARTLY CLOUDY; WIND LESS THAN 10 MIS./HR.; MISCELLANEOUS PRESSURE CONDITIONS.

Stations.	n	r	E	*a*	*b*	−*a*/*b*	u	r	E	*a*	*b*	−*a*/*b*
Grand Junction	14	−0.911	0.031	22.0	−0.36	61.0	17	−0.908	0.029	29.3	−0.49	59.8
Ground Exp. (G. J.)	14	−0.862	0.046	16.0	−0.32	50.3	17	−0.861	0.042	23.3	−0.42	55.5
Fruitvale	...	...	...	...	...	...	17	−0.752	0.071	22.5	−0.41	54.9
Palisade	14	−0.794	0.067	21.4	−0.38	55.9	17	−0.862	0.042	22.7	−0.39	58.2
Orchard Mesa	...	...	...	...	...	...	17	−0.839	0.048	23.3	−0.43	54.2
Pomona	14	−0.788	0.068	9.0	−0.26	34.4	17	−0.794	0.060	20.4	−0.41	49.8
Hunter	14	−0.827	0.057	13.5	−0.30	45.2	17	−0.900	0.031	22.2	−0.44	50.5
Fruita	14	−0.696	0.093	12.0	−0.25	47.5	17	−0.928	0.023	21.5	−0.43	50.0
Loma	...	...	...	...	...	...	17	−0.910	0.028	23.1	−0.48	48.0
Delta	...	...	...	...	...	...	17	−0.871	0.040	14.6	−0.47	31.1

CLASS V.—MORNING CONDITIONS=PARTLY CLOUDY; WIND 10 MIS./HR. OR HIGHER; MISCELLANEOUS PRESSURE CONDITIONS.

Stations.	n	r	E	*a*	*b*	−*a*/*b*	u	r	E	*a*	*b*	−*a*/*b*
Grand Junction	...	...	...	...	...	...	17	−0.827	0.062	31.1	−0.50	62.2
Ground Exp. (G. J.)	...	...	...	...	...	...	17	−0.681	0.104	24.1	−0.36	66.9
Fruitvale	...	...	...	...	...	...	17	−0.722	0.093	24.0	−0.39	61.5
Palisade	...	...	...	...	...	...	17	−0.778	0.077	24.5	−0.47	52.1
Orchard Mesa	...	...	...	...	...	...	17	−0.746	0.086	25.8	−0.46	56.1
Pomona	...	...	...	...	...	...	17	−0.593	0.126	18.0	−0.31	58.1
Hunter	...	...	...	...	...	...	17	−0.631	0.117	19.5	−0.36	54.1
Fruita	...	...	...	...	...	...	17	−0.649	0.113	19.8	−0.36	55.0
Loma	...	...	...	...	...	...	17	−0.766	0.081	17.7	−0.35	50.6
Delta	...	...	...	...	...	...	17	−0.628	0.118	17.7	−0.37	47.8

NOTE.—The figures in the columns headed "−*a*/*b*" indicate, for the respective equations, the point where the graph intersects the X axis, i. e., at what relative humidity the temperature will probably be the same as the dewpoint.

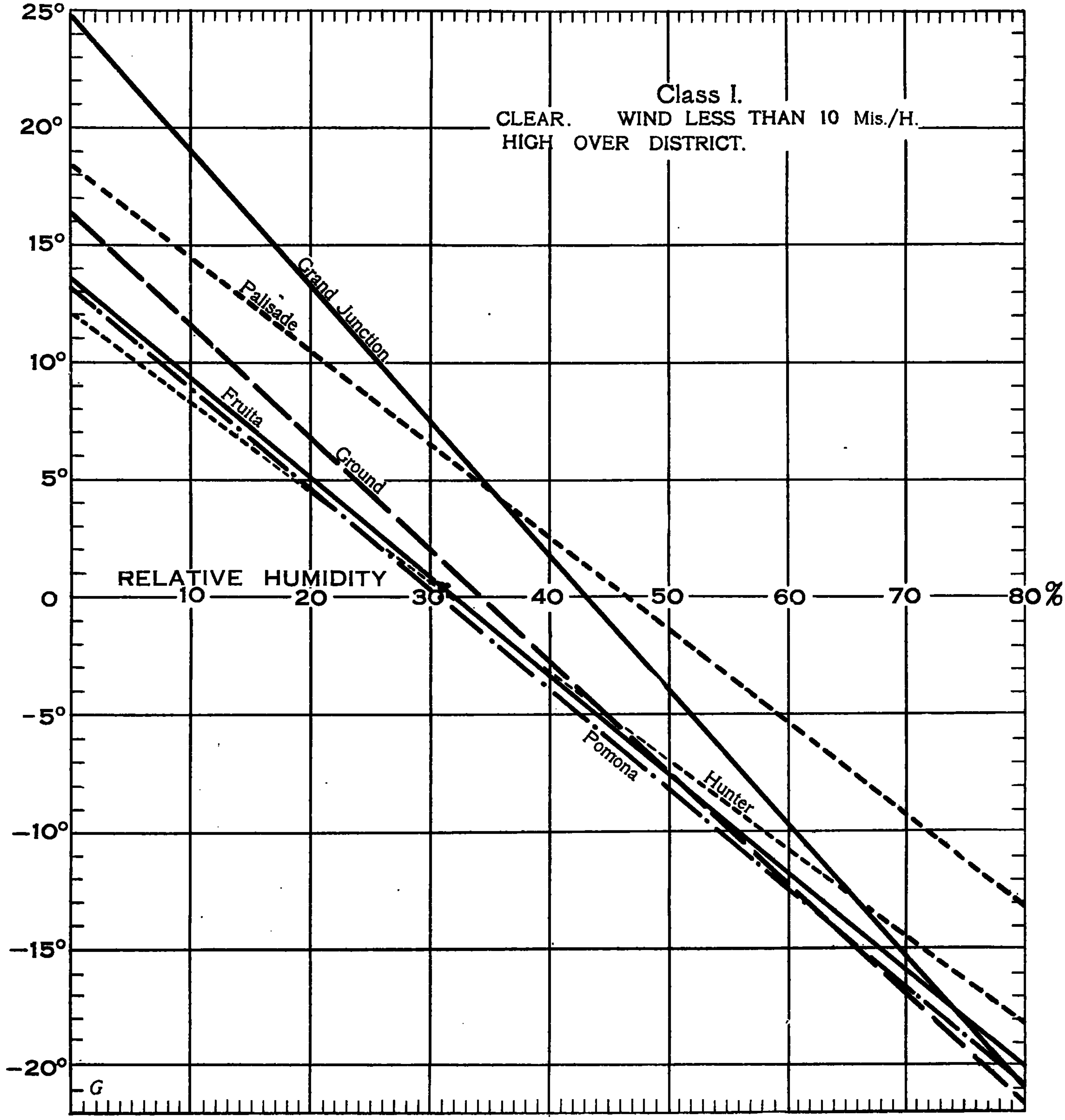

Fig. 1.—Graphs of equations for March for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

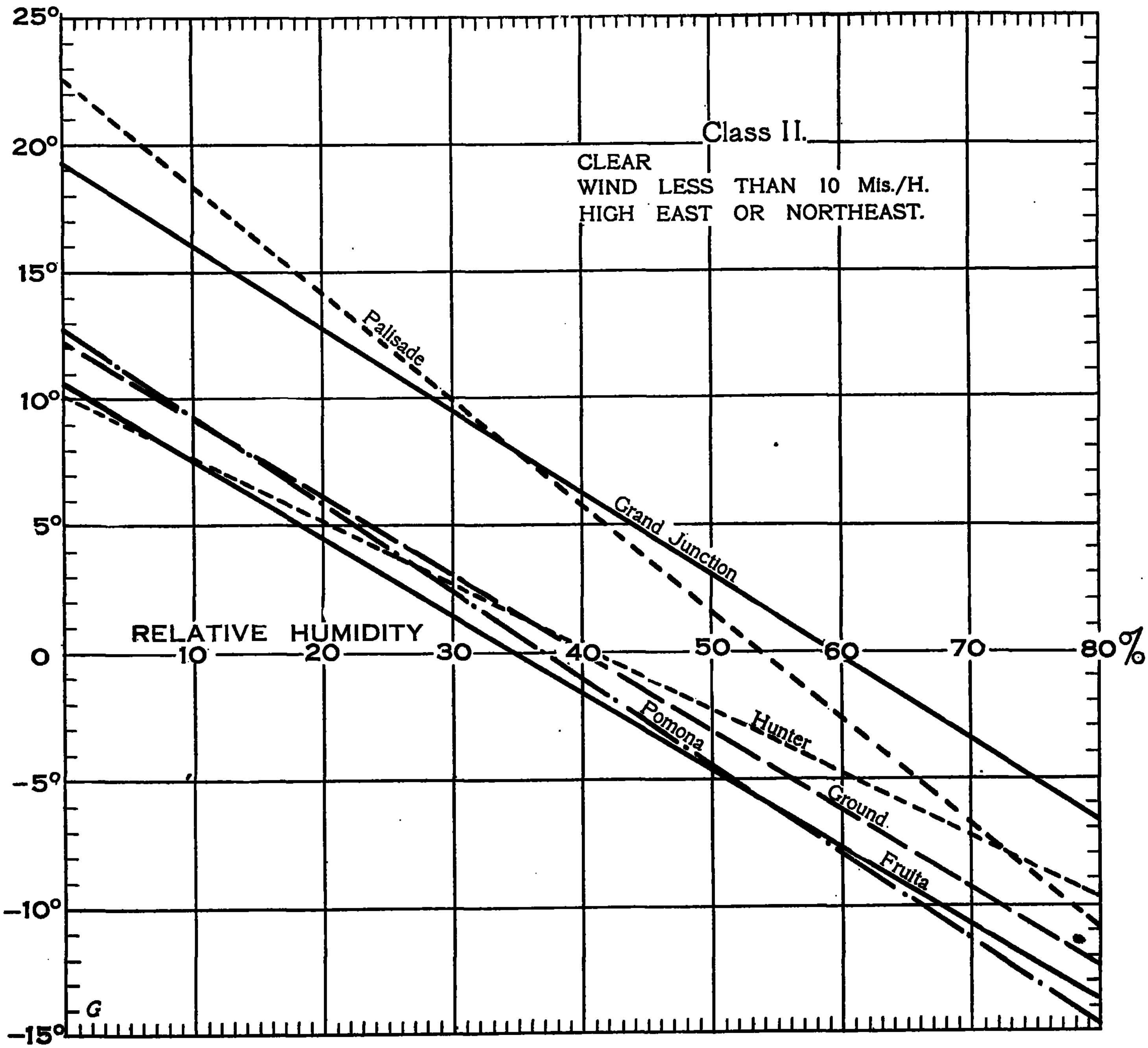

FIG. 2.—Graphs of equations for March for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

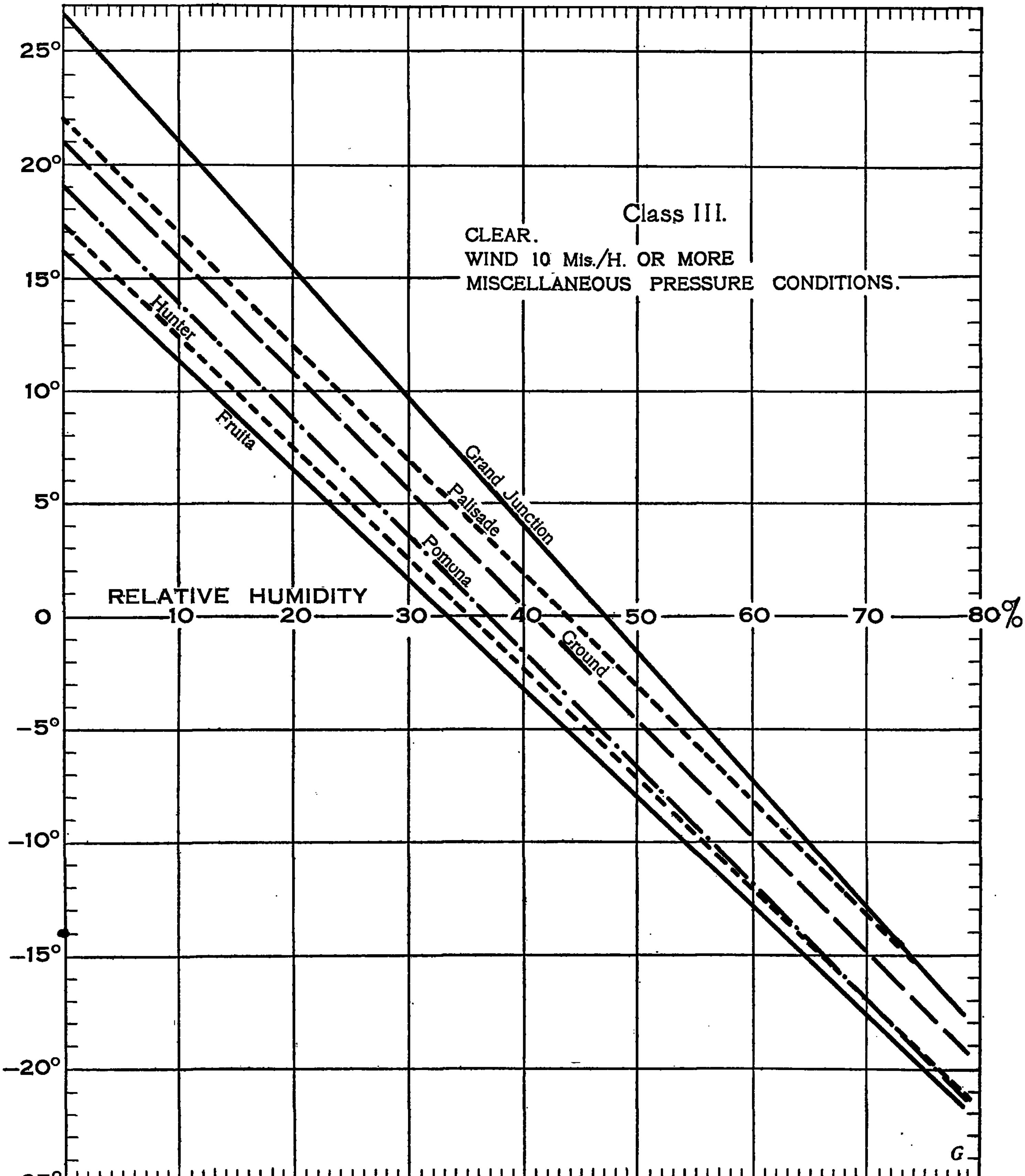

FIG. 3.—Graphs of equations for March for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

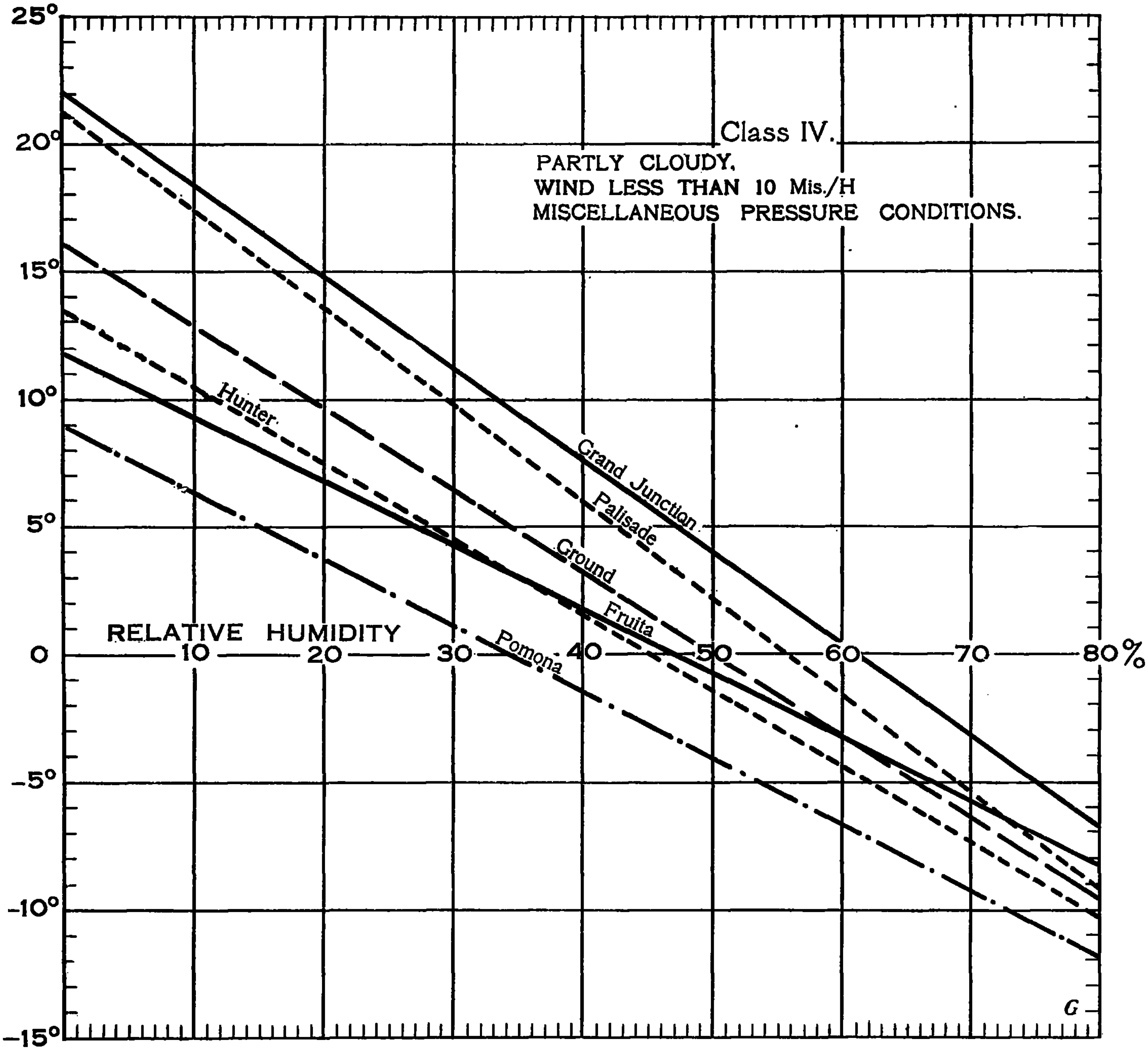

FIG. 4.—Graphs of equations for March for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

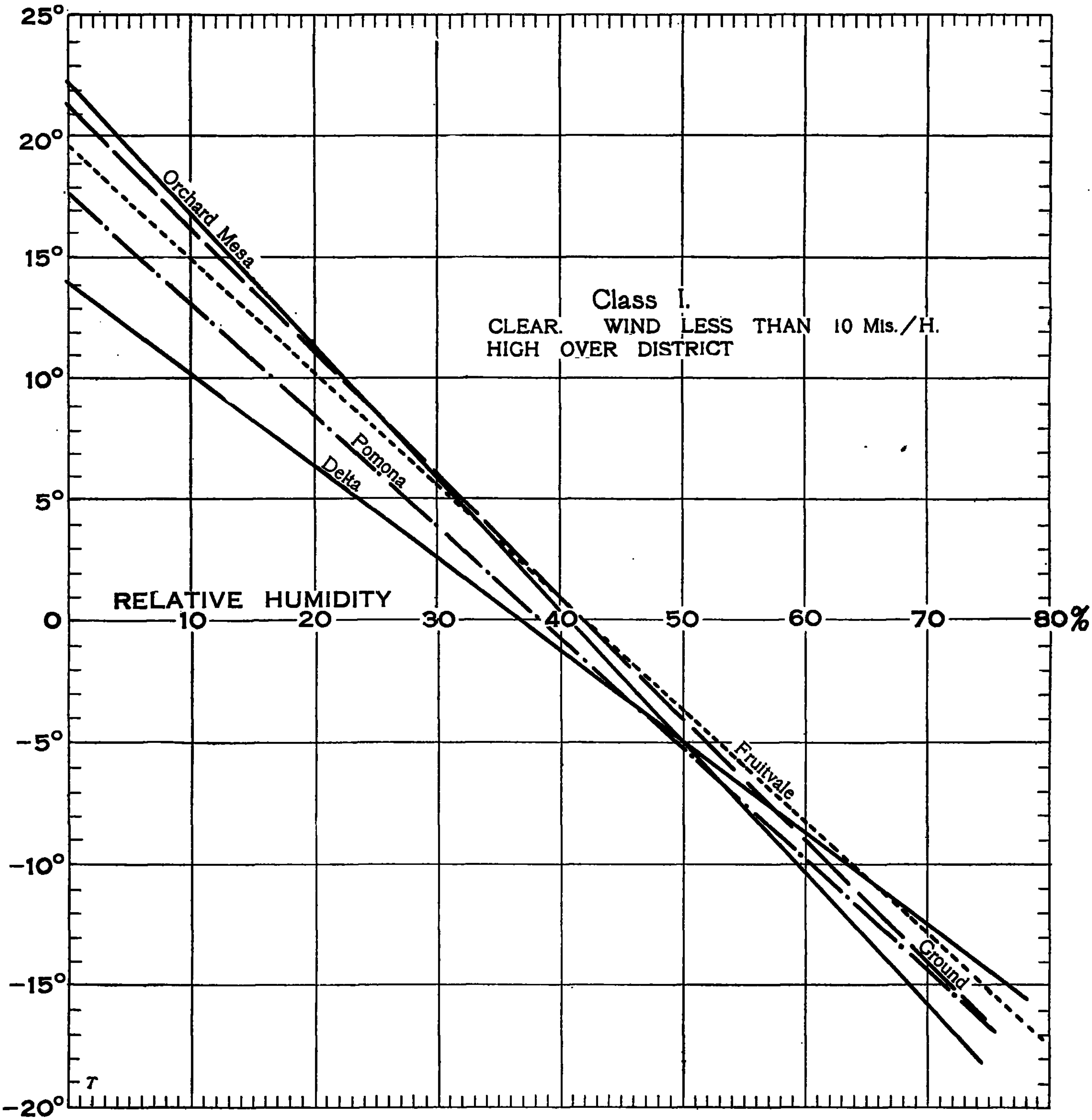

FIG. 5a.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

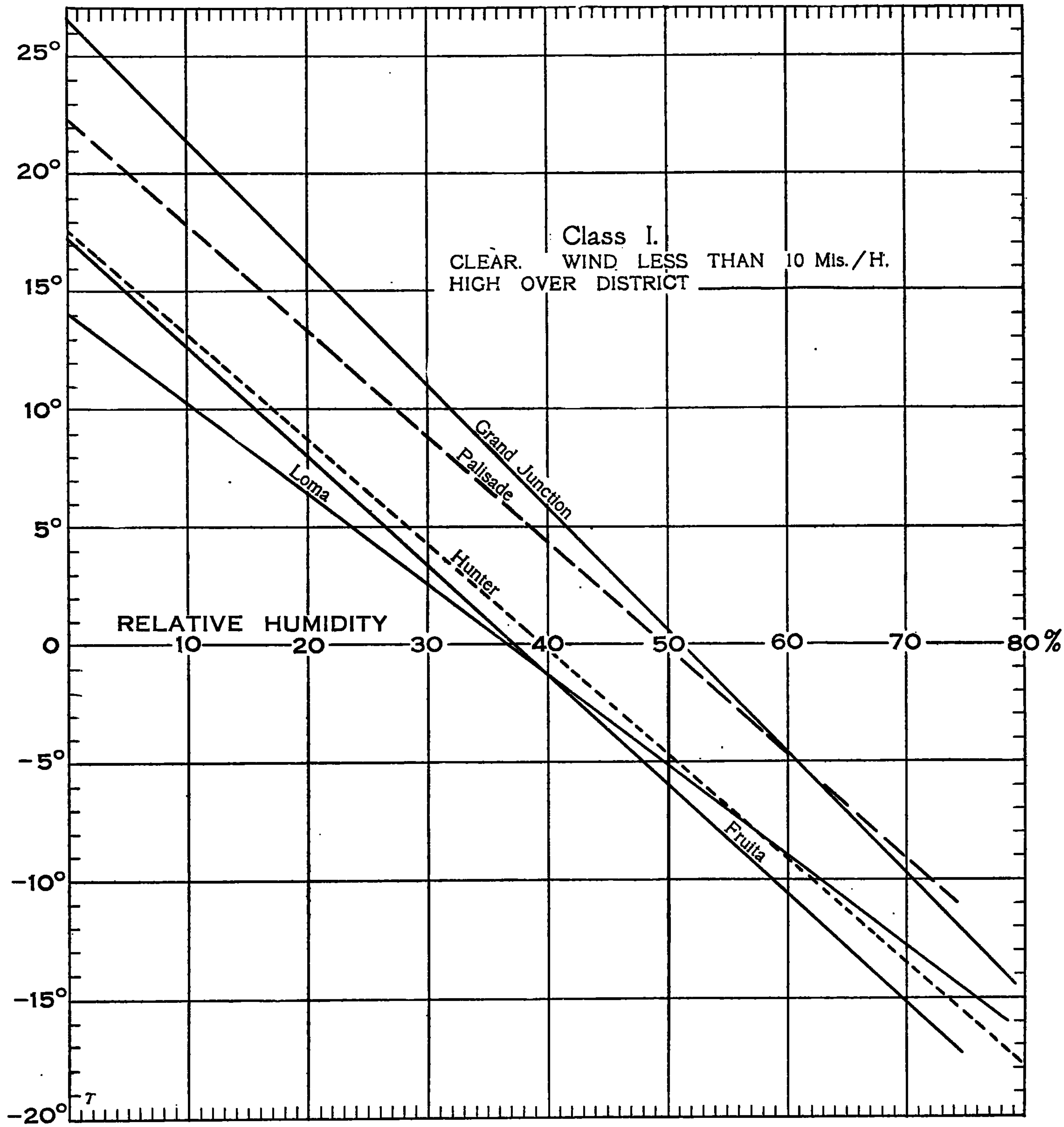

FIG. 5b.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

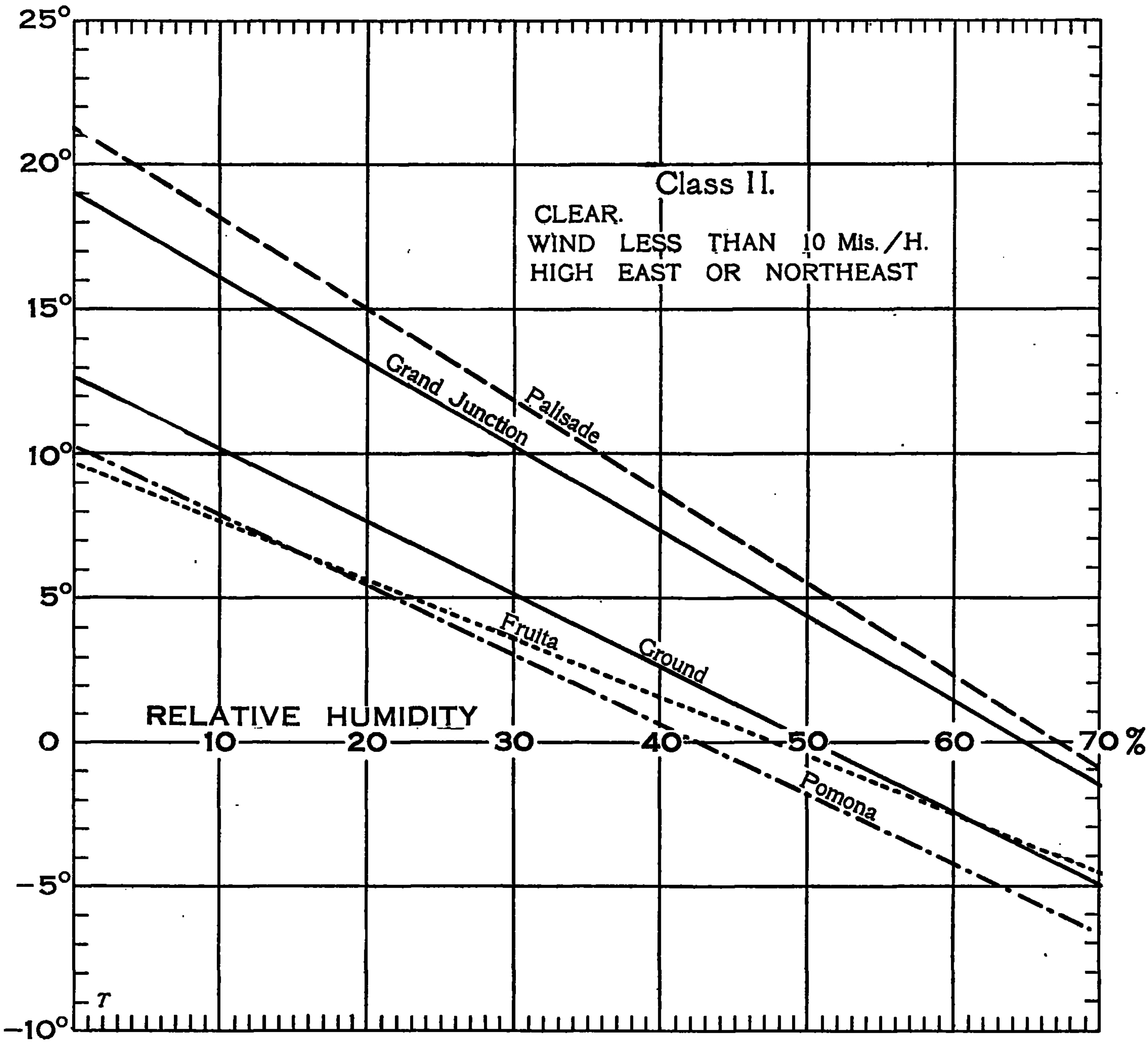

FIG. 6a.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

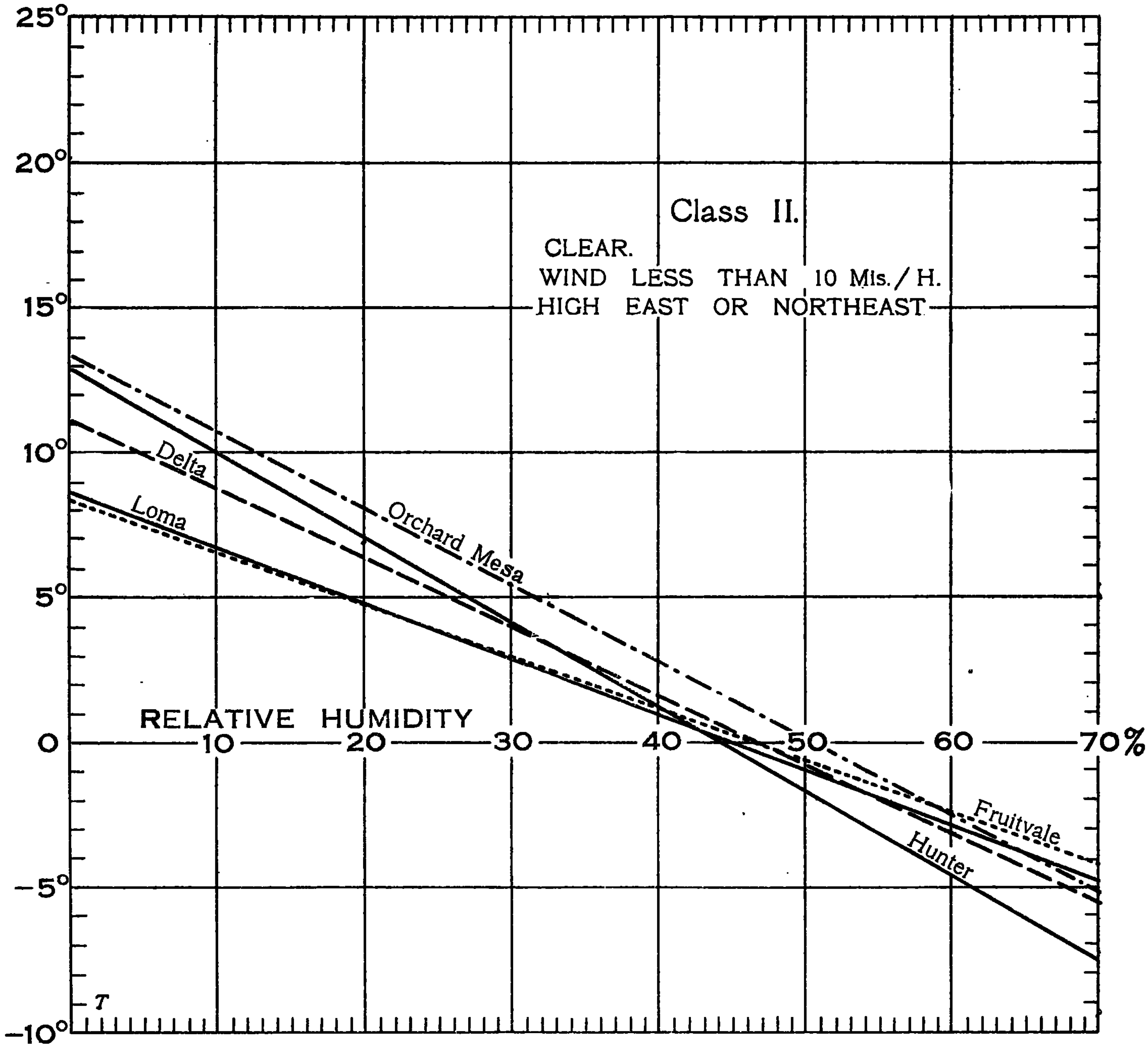

Fig. 6b.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

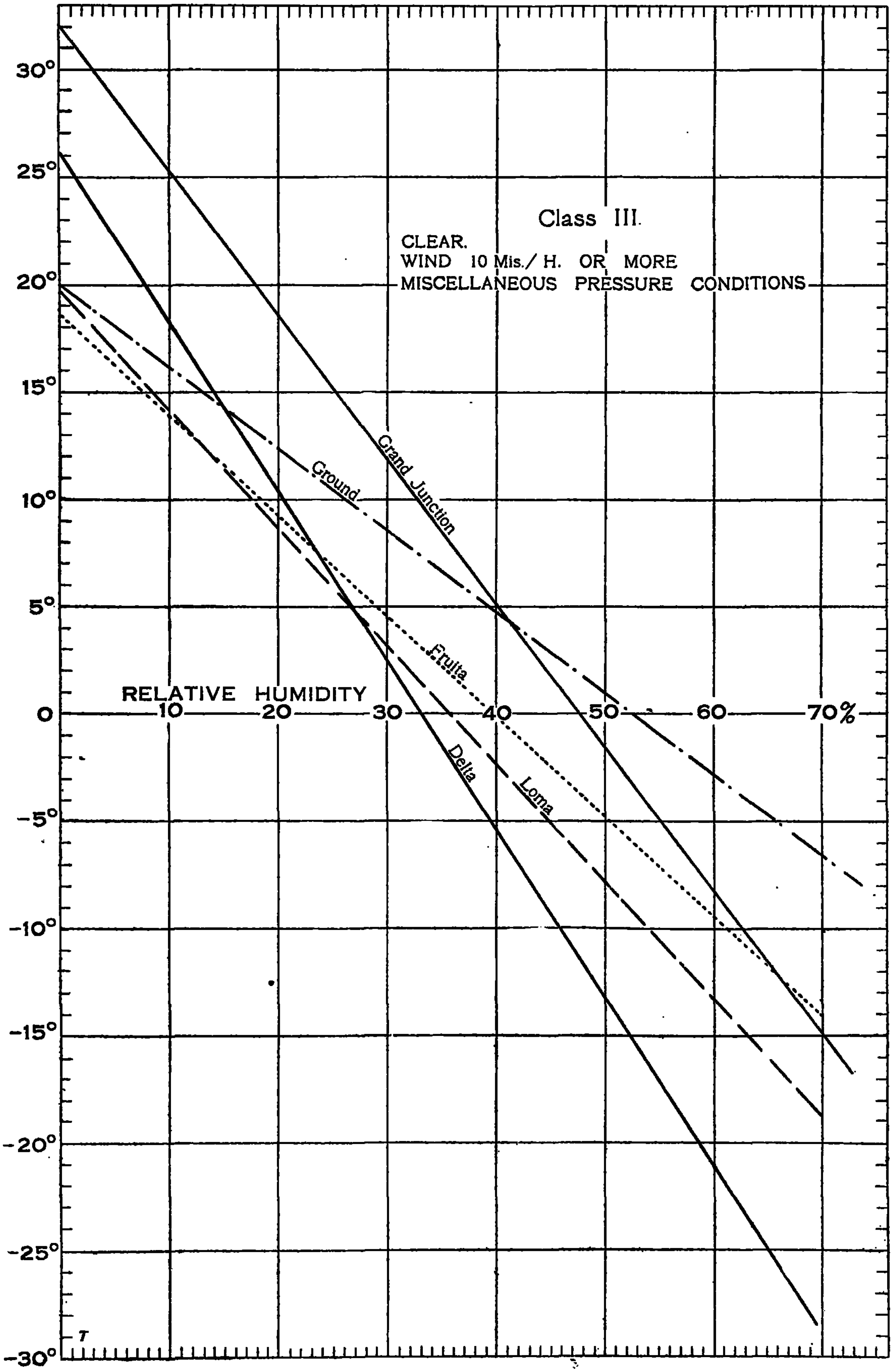

FIG. 7a.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

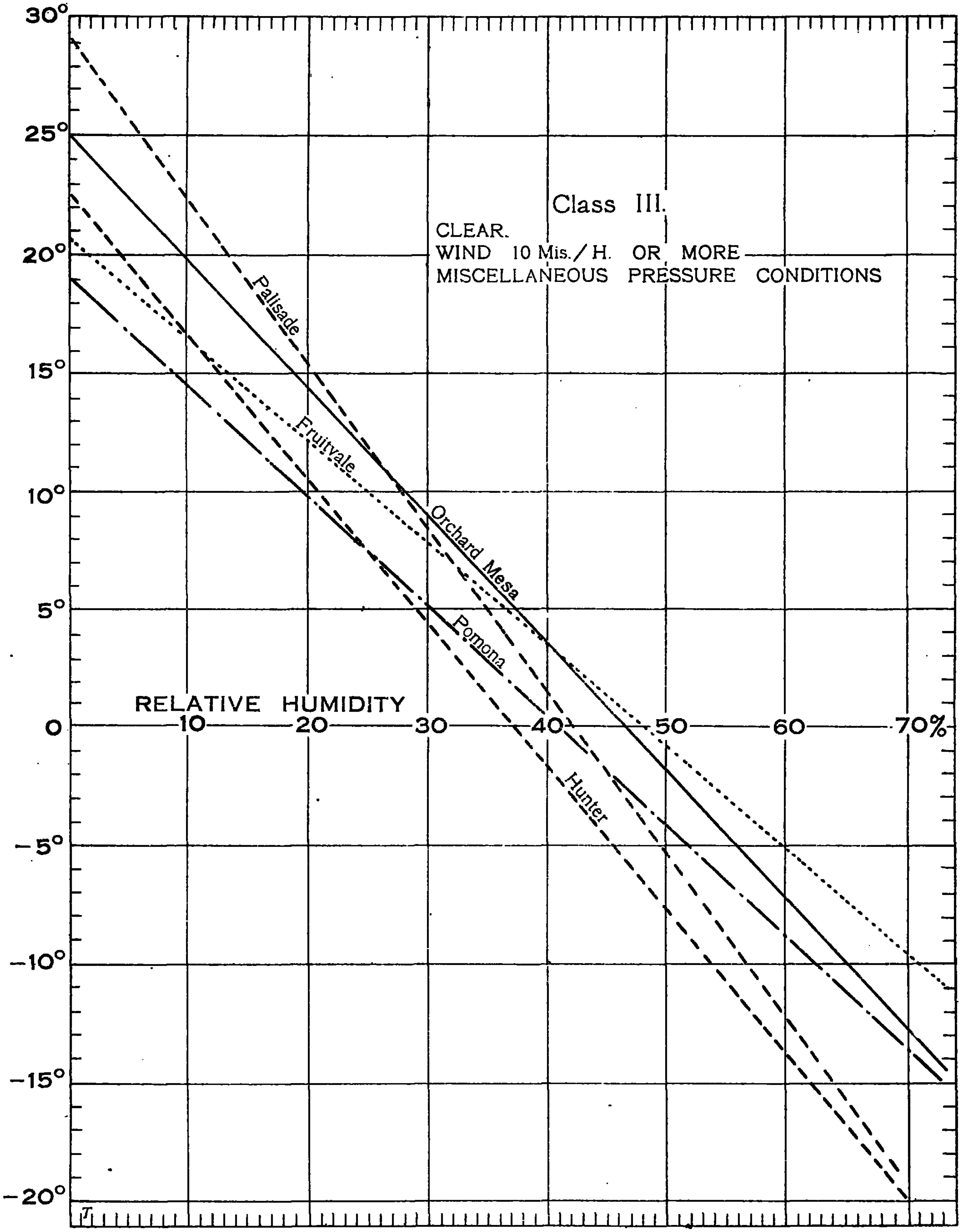

FIG. 7b.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

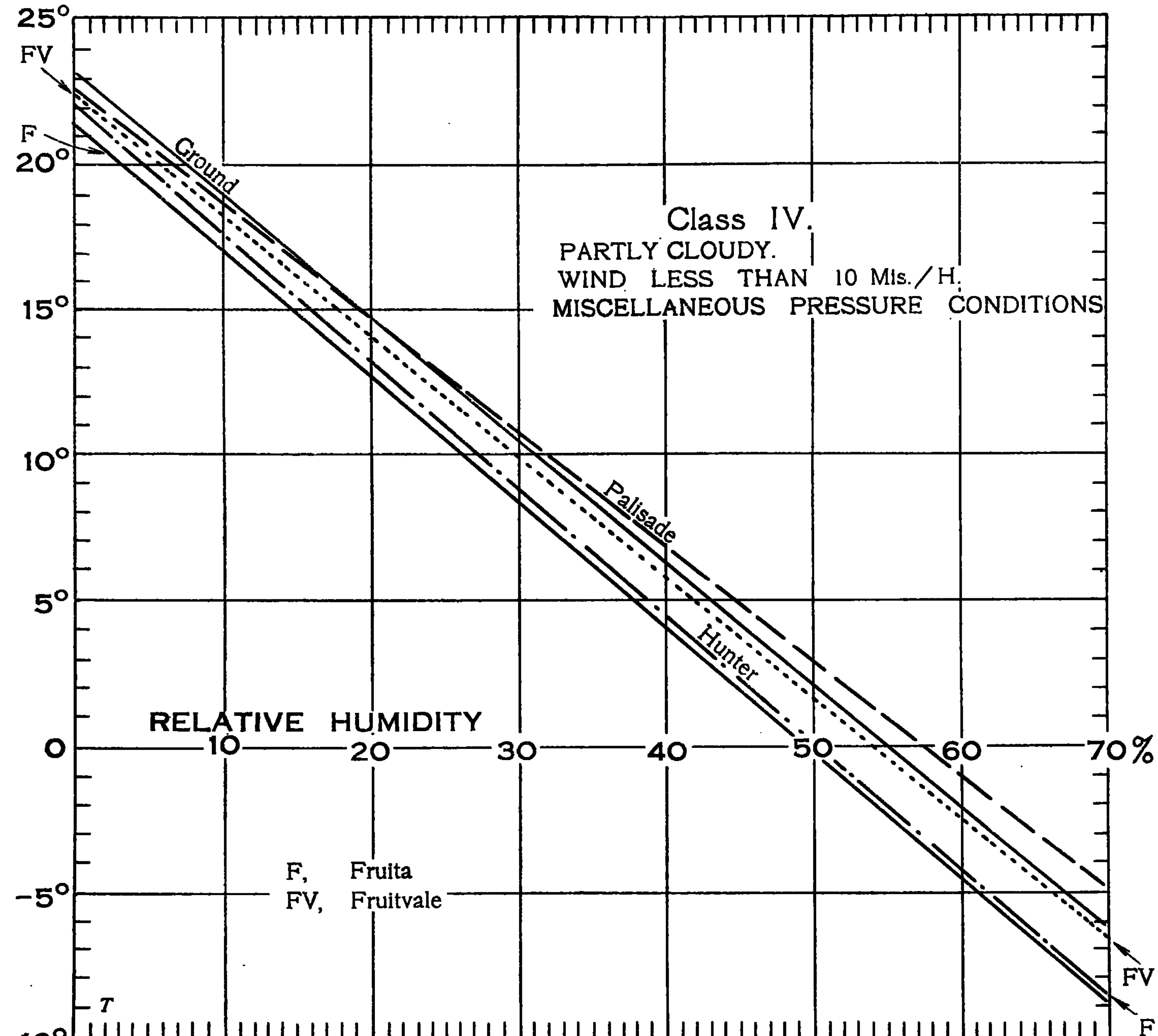

FIG. 8a.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

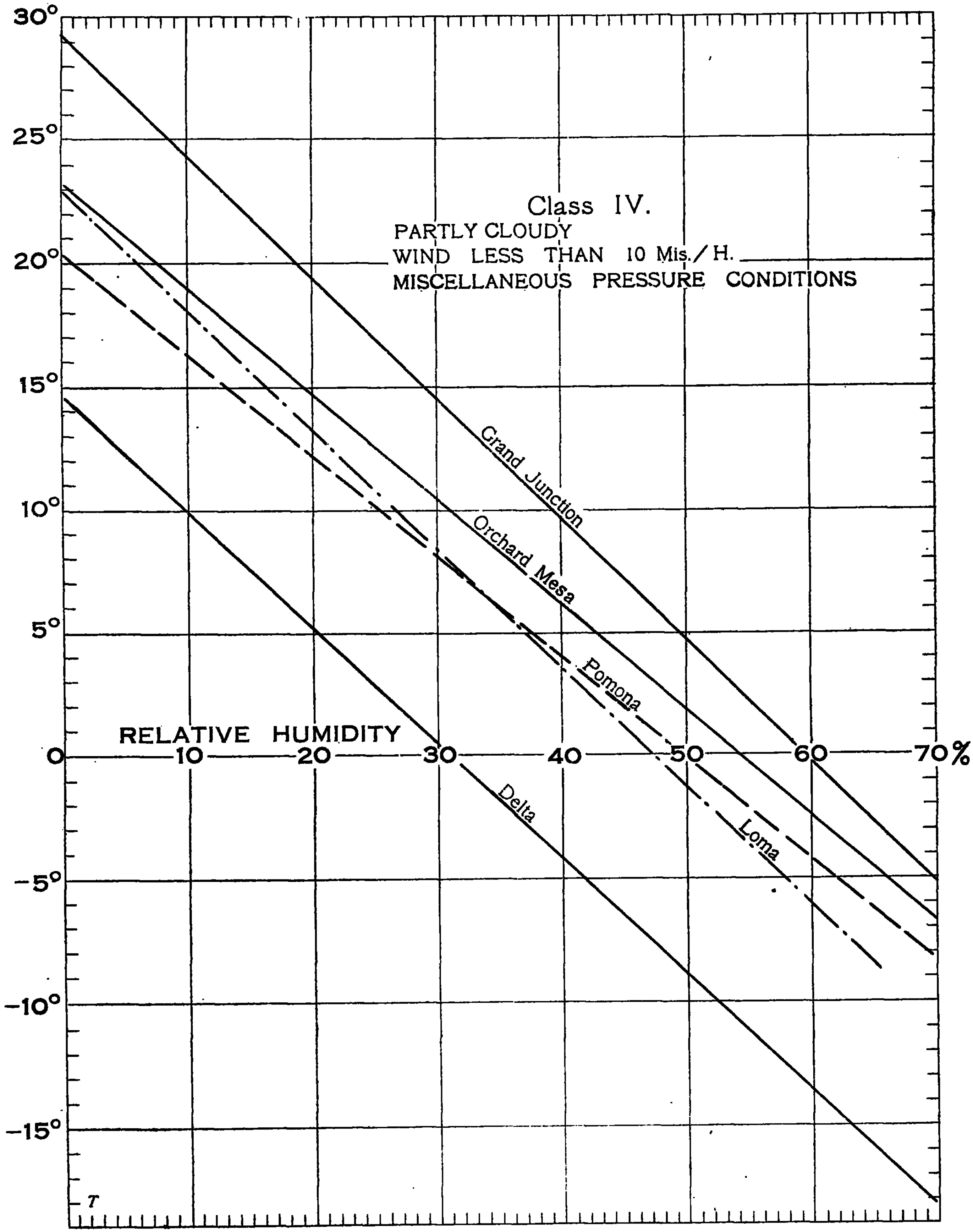

FIG. 8b.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.

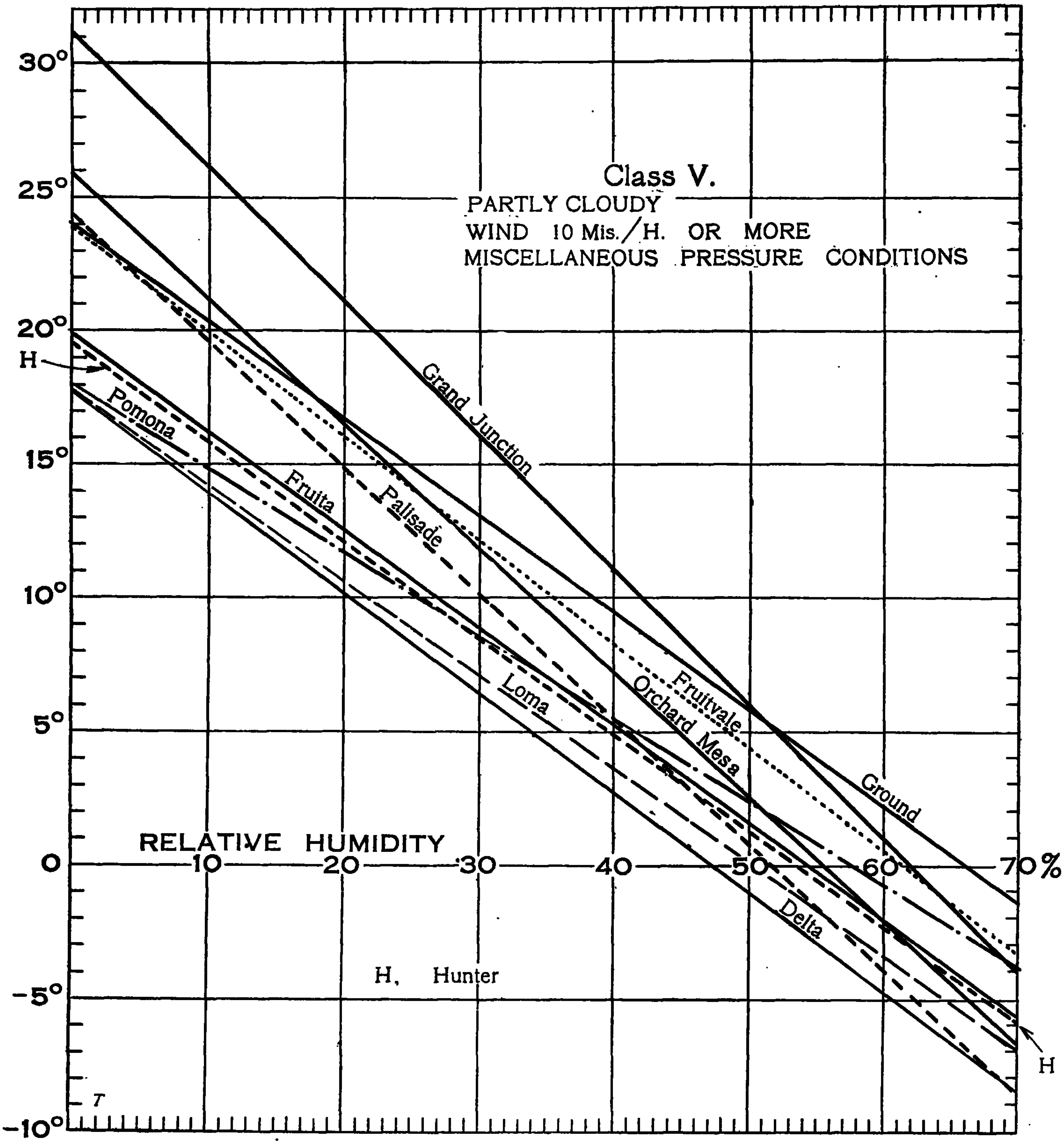

FIG. 9.—Graphs of equations for April for computing the departure of morning minimum temperatures from the evening dewpoint at Grand Junction.