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FORECASTING RADIATION FOG AT ELKINS, W. VA.

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ABSTRACT

Charts based on variables selected from data available on the preceding evening are developed for forecasting radiation fog at Elkins, W. Va., for autumn and winter months. The variables found useful in forecasting this fog include gradient wind velocity, surface temperature, and dew point depression. One of the interesting findings is that on relatively clear nights easterly gradient winds are more favorable for the formation of radiation fog than are westerly gradient winds. This and other physical aspects of the formation of the fog are discussed.

INTRODUCTION

PROBLEM

One of the problems which occurs almost daily in forecasting for Elkins, W. Va. is that of determining whether or not radiation fog will form during the following night. Elkins is situated in the Tygart River Valley in the Allegheny Mountains with most of the higher ridges to the east of the station (fig. 1). The river flows in a south to north direction just west of the station and considerably higher ground immediately surrounds the station on all other sides. Since it is so protected from the wind, rapid cooling occurs after sunset on relatively clear nights and in many cases this process leads to the formation of fog. This investigation was undertaken in an effort to develop aids in forecasting this phenomenon largely through a quantitative test and analysis of some of the forecasting principles and rules already in use by forecasters. These rules emphasize the importance of variations of gradient wind speed and direction. In the course of the investigation additional factors were introduced in order that a more complete forecasting system could be developed for use subsequent to the determination of the information yielded by the gradient wind. These variables were then combined statistically into a set of charts by means of a graphical correlation procedure.

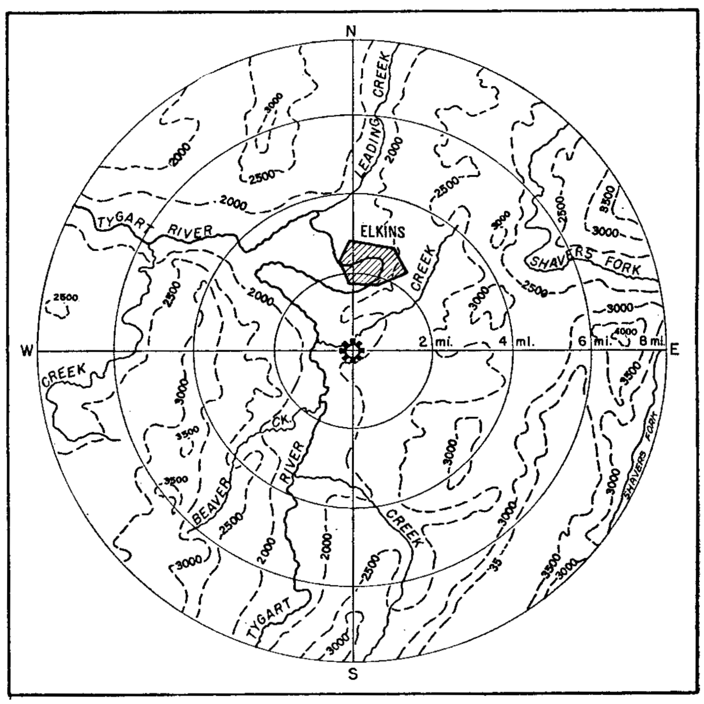

FIGURE 1.—Topographical map of the Elkins, W. Va., area.

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DATA

The month of August was initially selected for study since it is the month with the greatest frequency of radiation fog at Elkins (see table 1). August data for the years 1942 through 1949 were analyzed with those for 1943 and 1949 being withheld for testing purposes. Data for nights during which the sky was cloudy (high overcast, or low broken or overcast) or precipitation occurred, or during which there was a frontal passage were not included in the study. The weather elements used were gradient wind direction and speed, as approximated from the 1930 EST surface map by means of a geostrophic wind scale applied to the sea-level isobars, and temperature and dew point at sunset as interpolated from the hourly observations. Data were tabulated from the hourly observations as to whether the visibility lowered to less than one mile in fog as well as the earliest time this occurred.

Table 1.—*Percentage of nights visibility at Elkins lowers to less than 1 mile due to radiation fog.*

Month	Number of years	Percentage of relatively clear nights	Percentage of all nights
July	2	50	26
August	5	76	38
September	4	59	32
November	5	18	7
December	5	14	4
January	6	29	6
February	3	10	2

THE FORECASTING CHARTS

CONSTRUCTION

As the first step in the development of the forecasting procedure the cases on which the study is based were plotted on a polar graph. This showed immediately that the material could be readily stratified into two parts since the cases with gradient winds from north through south via west showed a much lower percentage frequency of fog* cases than those with gradient winds from north-northeast through south-southeast via east. A third group was made up of cases when a ridge of high pressure was centered over Elkins and gradient wind was not measurable. Within these first two groups the gradient wind speed and difference between the temperature and dew point at sunset were examined for their joint effect on the reduction of visibility to less than one mile in radiation fog the following night as well as on the earliest time this occurred (cf. [1], [2]).

Figure 2 with these independent variables as coordinates was constructed for westerly gradient winds by the following procedure. If fog reduced the visibility to less than 1 mile, the time was entered corresponding to that particular gradient wind speed and dew point depression. If the visibility was not reduced to less than 1 mile during the night, "N" was entered on the chart. For the construction of frequency and time isopleths the data were arbitrarily divided into small groups of about five readings per group. This arbitrary division is shown in figure 2 by the light solid lines. The percentage frequency and time of occurrence were then found for each group and placed on the charts near the location that would seem to best represent the average location of the readings. Time and frequency isopleths were then drawn for these values and are shown in figure 2 as dark solid lines.

Since Taylor [1] presumably found that temperature was also a variable to be considered in the construction of fog prediction diagrams, figure 3, with this as a variable together with the difference between the temperature and

*The word "fog" henceforth in this paper means visibility restricted to less than 1 mile in radiation fog.

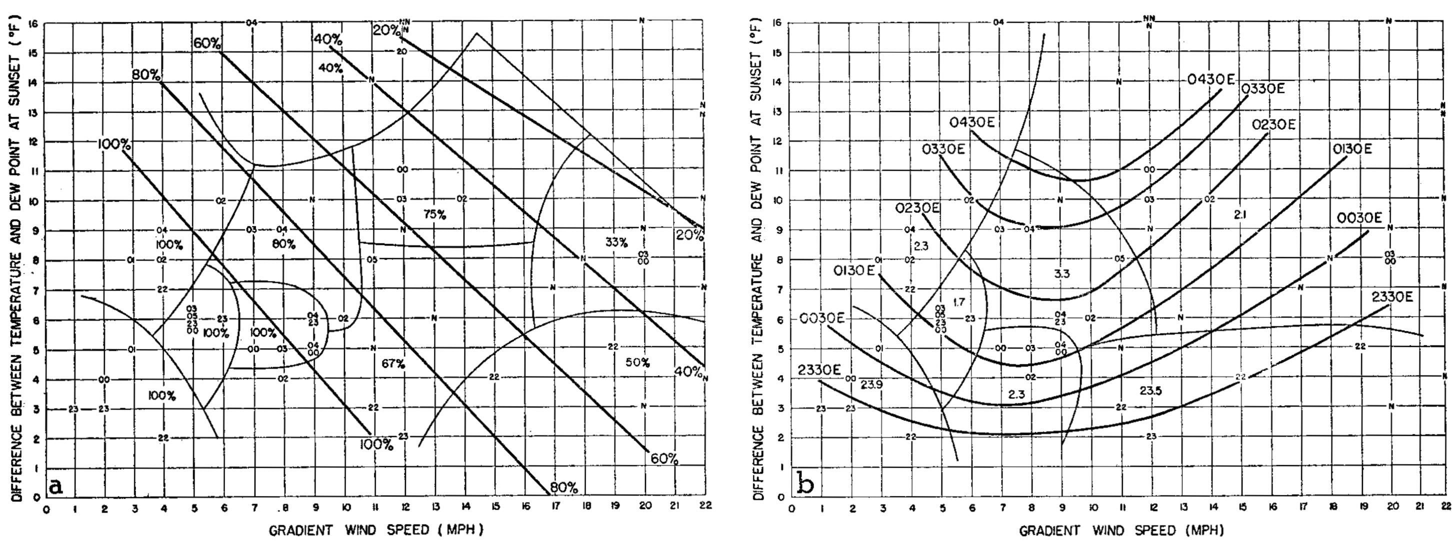

Figure 2.—Charts for August cases with gradient wind directions from north through south via west, showing (a) isopleths of probability and (b) isopleths of time that the visibility at Elkins will lower to less than 1 mile due to radiation fog. See text for explanation of plotted data and construction of charts.

dew point at sunset was constructed. The time isopleths were drawn by using the same method of groupings as was done in figure 2b.

Now in order that the relationship suggested by figure 2b could be combined with the relationship suggested by figure 3, figure 4 was constructed using a technique suggested by Brier [3]. The times of occurrences for all the cases with westerly gradient winds were estimated. For each case there were two estimated times of formation, one from figure 2b and one from figure 3. Then with these sets of readings as coordinates, the corresponding actual time of formation was plotted on figure 4 and the time isopleths drawn. However, it was found that the linear correlation coefficient relating predictions obtainable from the latter chart was no higher than could be obtained from figures 2b and 3 taken separately. This result was found also for the charts for easterly gradient cases.

A similarly constructed set of charts with the same variables as those used in figures 2–4 was prepared for cases with easterly gradient winds. These diagrams are shown in figures 5–7.

Figure 8 is made up from cases when a ridge of high pressure was centered over Elkins and no gradient wind was measurable. These cases showed 100 percent chance of occurrence, so this figure merely suggests a time of occurrence.

Charts for September and winter months (November through February) were made following the same procedure as that used for August. The winter months were grouped together because there seemed to be little advantage to be gained from the use of the individual charts for each month; in fact the advantage of having more data to use in the preparation of the charts probably made them more accurate as the percentage of nights with fog was much lower than for August and September. No work was done on the month of October. Only the charts for August are shown in this paper but the others are similar in appearance to those for August.

TESTS

After noting that figures 4 and 7 added little to the correlations, a test was made of figures 2, 5, and 8 for August 1943 and 1949, comparing their forecasts with the official airway forecasts on clear nights when no clouds were fore-

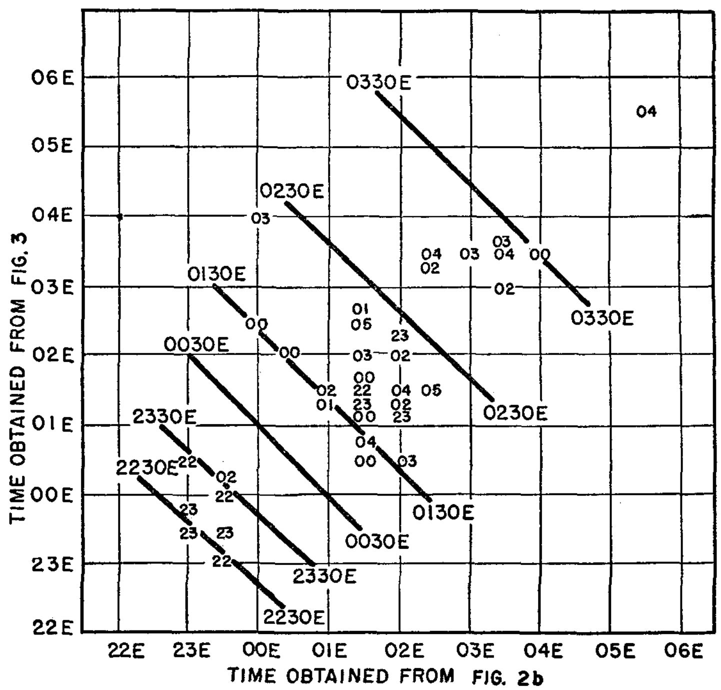

FIGURE 4.—Chart for August cases with gradient wind directions from north through south via west, showing isopleths of time that visibility at Elkins will lower to less than 1 mile due to radiation fog. Time in this chart is given as a function of the times from figures 2b and 3.

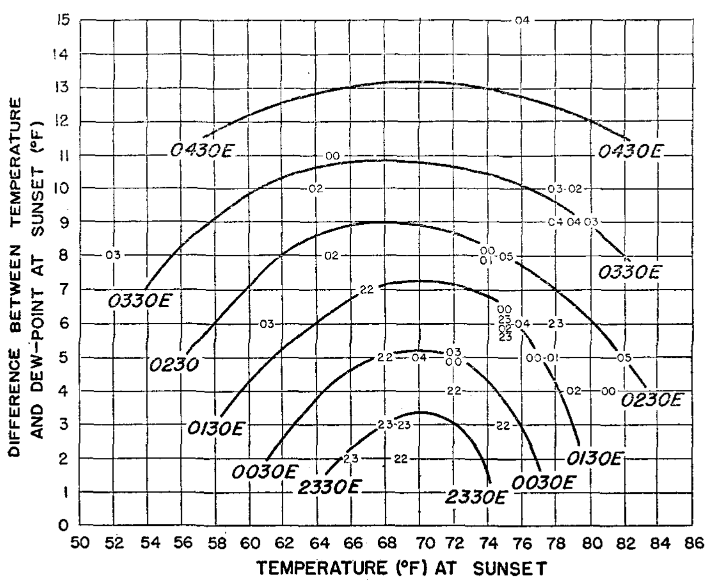

FIGURE 3.—Chart for August cases with gradient wind directions from north through south via west, showing isopleths of time that visibility at Elkins will lower to less than 1 mile due to radiation fog.

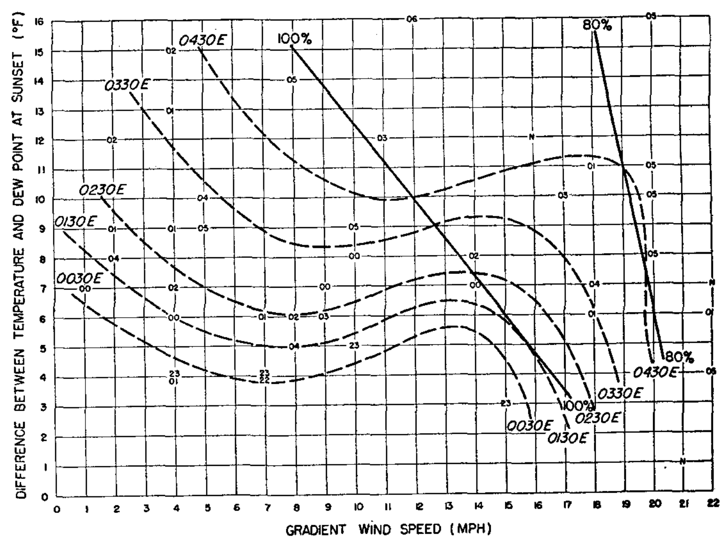

FIGURE 5.—Chart for August cases with gradient wind directions from north-northeast through south-southeast via east, showing isopleths of probability (solid lines) and time (dashed lines) that visibility at Elkins will lower to less than 1 mile due to radiation fog.

cast in the official airway forecast. The results of this test are tabulated in table 2. A separate tabulation was made for each month since the charts were consulted each evening in August 1949 before the official forecast was made. The average error per forecast with regard to time of formation came out to be 1.8 hours for official airway forecast and 1.2 hours for the charts.

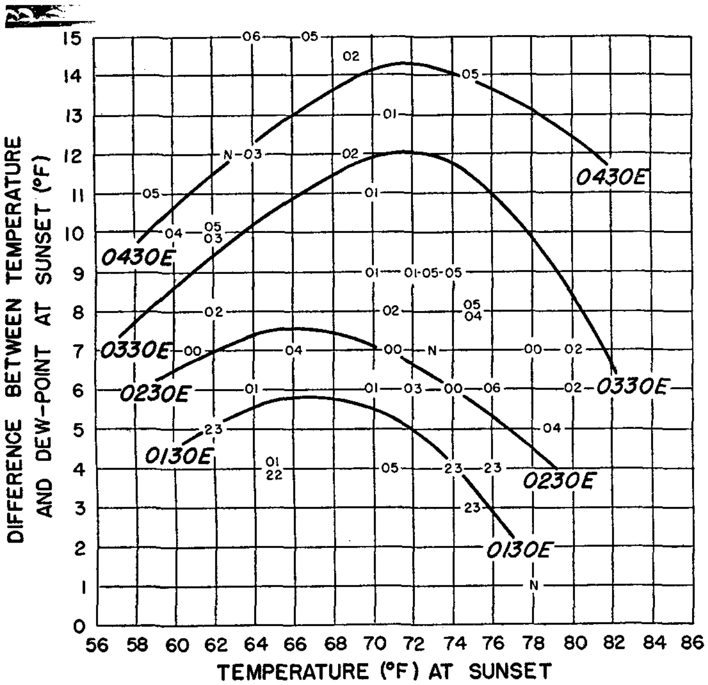

FIGURE 6.—Chart for August cases with gradient wind directions from north-northeast through south-southeast via east, showing isopleths of time that visibility at Elkins will lower to less than 1 mile due to radiation fog.

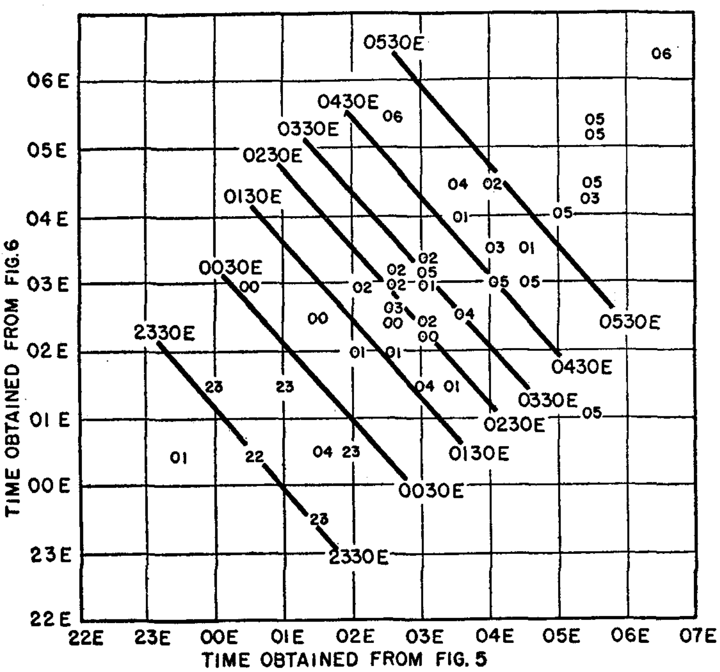

FIGURE 7.—Chart for August cases with gradient wind directions from north-northeast through south-southeast via east, showing isopleths of time that visibility at Elkins will lower to less than 1 mile due to radiation fog. Time in this chart is given as a function of the times from figures 5 and 6.

TABLE 2.—*Contingency tables comparing official airway forecasts and forecasts from the charts for 1943 and 1949*

Observed	Official airway forecast: Fog	No fog	Totals	Forecast from the charts: Fog	No fog	Totals
1943						
Fog	13	4	17	17	0	17
No fog	1	0	1	1	0	1
Totals	14	4	18	18	0	18
1949						
Fog	11	3	14	14	0	14
No fog	3	1	4	3	1	4
Totals	14	4	18	17	1	18
1943 and 1949						
Fog	24	7	31	31	0	31
No fog	4	1	5	4	1	5
Totals	28	8	36	35	1	36

EXAMPLES

The following two examples outline the use of these charts. Let us start with the following readings—gradient wind velocity west 10 m. p. h. (determined from 1930 EST surface map), temperature at sunset 70° F., dew point depression at sunset 10° F. Figure 2 gives about 65 percent chance of occurrence and a time of formation of about 0400 EST. Now going to Figure 3 we get a time of formation of about 0300 EST. Using these two readings for time on figure 4, we get a final time of occurrence of 0330 EST. For another example consider gradient wind southeast 10 m. p. h., temperature 80° F., dew point depression 12° F. Figure 5 yields 100 percent chance and a time of 0500 EST. Figure 6 suggests a time of 0430 EST. Using these two readings for time on figure 7, we get a final time of occurrence of 0530 EST.

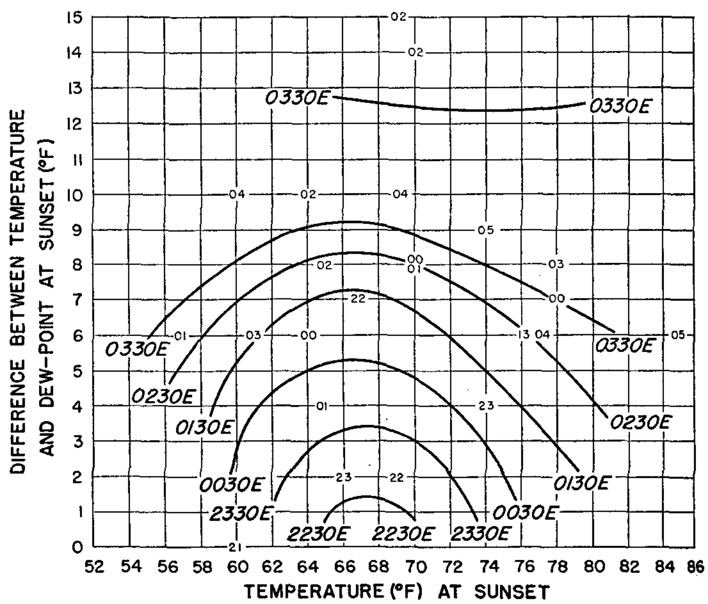

FIGURE 8.—Chart for August cases with Elkins at the center of a High, showing isopleths of time fog will lower to less than 1 mile due to radiation fog.

PHYSICAL ASPECTS OF FOG FORMATION

EFFECTS OF LOCAL TOPOGRAPHY

In the course of developing the forecasting procedure, several physical aspects of fog formation were investigated. An investigation to find a reason for the greater predominance of radiation fog with an easterly flow as compared to a westerly flow was made. The data showed that sunset dew points averaged slightly lower for the easterly cases and the average difference between the temperature and the dew point at sunset was larger for the easterly cases; neither of these findings could be used to explain the greater predominance of radiation fog associated with the easterly gradient winds. It is possible that in the case of Elkins, the greater frequency of fog cases with an easterly flow is due to the fact that Elkins is more sheltered from the wind when it is blowing from an easterly direction than when it is blowing from a westerly direction (fig. 1). Greater cooling of the air near the ground will occur in the former case because there will be less mixing of the air than in the latter case. This point may be examined further by considering figure 9. As shown in the sketch, station "A", located similarly to Elkins relative to the ridge, is situated so that it would be more protected from an easterly wind than station "B" would be. In this case the fall in temperature, due to nocturnal radiation, would be greater at station "A" than at station "B" since at station "B" the easterly surface wind would tend to disturb the air near the surface. In both cases there would be possibility of drainage of cool air down the side of the mountain but since the coolest air would be at the lower points, most of the air coming down the sides of the mountain would flow above the cooler air at the bottom. It is also possible that the relationship lies principally in the greater stability of the air masses present with easterly as compared with westerly winds.

EFFECT OF TEMPERATURE

Figures 3, 6, and 8 all show fog to occur the earliest when temperatures at sunset are in the upper sixties. To further investigate this effect a chart (not shown) was plotted showing the difference between temperature and dew point at sunset against dew point at sunset using data for August, September, and the winter months. The greatest percentages of occurrence of fog and the earliest times of formation were found for dew-point temperatures at sunset in the upper fifties and lower sixties.

The probable mechanism of the phenomenon as suggested by Mook [2] in a similar analysis of Taylor's fog predicting diagram for Kew [1] is briefly this: For the same dew point depression at sunset, fog occurs less frequently at higher temperatures because according to Brunt [4], the higher moisture values are associated with a decrease in net outgoing radiation; and at lower temperatures, according to Petterssen [5], the air lacks sufficient moisture to produce fog. Therefore, at some middle

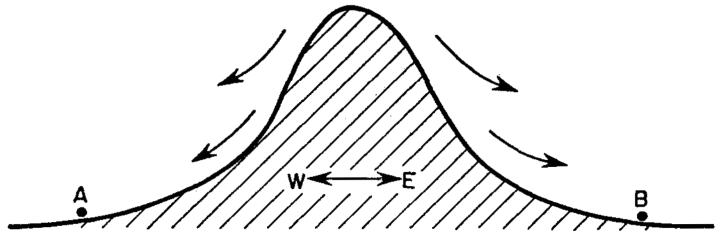

FIGURE 9.—Sketch showing effect of a mountain on nocturnal cooling in valleys on either side.

point, there will be a maximum frequency of fog. However, as might be expected, the most favorable combination of temperature and dew-point depression is slightly different at the two stations, Kew and Elkins, perhaps due to differences in the coefficient of heat conductivity of the soil and other geographical factors.

OTHER ASPECTS OF THE CHARTS

It appears from examination of figures 2b and 5 that the gradient wind speed (within the range of data shown) has less effect on the time of formation of fog at Elkins than does the dew-point depression at sunset. This seems to be particularly true in the case of westerly gradient winds during August. During September and the winter months (November through February), the gradient wind speed seems to have almost no effect on the time of fog formation. Both figures 2a and 5 show that in general the greater the gradient wind speed and the larger the dew point depression at sunset, the less the chance of fog.

One aspect which is not readily explainable is that the time lines on both figures 2b and 5 have dips where the gradient winds are 5 to 10 miles per hour.

CONCLUSIONS

The following conclusions are drawn from this investigation:

1. Visibilities of less than 1 mile at Elkins due to radiation fog are much more common during July, August, and September than during November, December, January, and February.
2. Gradient winds from north-northeast through south-southeast via east are much more favorable for the lowering of the visibility to less than 1 mile due to radiation fog than gradient winds from north through south via west.
3. There is almost no chance of visibility lowering to less than 1 mile due to radiation fog with gradient winds from north through south via west during winter months.
4. There is better than an even chance of the visibility lowering to less than 1 mile due to radiation fog during August and September with gradient winds from north-northeast through south-southeast via east.

5. Chance of visibility lowering to less than 1 mile decreases as gradient wind speed increases.
6. Gradient wind speed has only a small effect on the time the visibility will lower to less than 1 mile during August and September and practically no effect during November, December, January, and February.
7. The smaller the depression of the dew point at sunset, the greater the chance the visibility will lower to less than 1 mile due to radiation fog and the earlier it will occur.
8. During the winter months the lower the temperature at sunset, the less likely the visibility will lower to less than 1 mile due to radiation fog and the earlier it will form. Also it is not likely to form if the temperature at sunset is less than 30° F.
9. When radiation fog at Elkins becomes deep enough to produce a "ceiling", this "ceiling" will be zero more than 90 percent of the time.

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