Environment Canada Imaging Cover Page

Report N.:

SKP Box Number: 672572427

CANADA

DEPARTMENT OF TRANSPORT
METEOROLOGICAL BRANCH

AN APPROACH TO FORECASTING LOW SURFACE HUMIDITIES AT NIGHT IN THE ROCKY MOUNTAINS

BY

M.S. WEBB

U.D.C. 551.509.329
551.509.317

CIR. 4377
TEC. 598
FEB. 10/66

CANADA - DEPARTMENT OF TRANSPORT - METEOROLOGICAL BRANCH
315 Bloor Street, West,
Toronto 5, Ontario.

AN APPROACH TO FORECASTING LOW SURFACE HUMIDITIES AT NIGHT IN THE ROCKY MOUNTAINS

by

M. S. Webb

ABSTRACT

Low surface relative humidities at night in the Rocky Mountains can increase significantly the flammability of forested areas. Through examination of the wind and temperature characteristics of the airstream aloft, an approach to forecasting these low humidity occurrences is presented. The extent to which the airstream characteristics favour lee wave formation during these occurrences is discussed.

MÉTHODE DE PRÉVISON DES FAIBLES HUMIDITÉS DE SURFACE, LA NUIT, DANS LES MONTAGNES ROCHEUSES

par

M. S. Webb

RÉSUMÉ

Les faibles humidités relatives de surface, la nuit, dans les montagnes Roucheuses, peuvent augmenter sensiblement l'inflammabilité des régions boisées. Après avoir étudié les caractéristiques du vent et de la température du courant aérien en altitude, l'auteur expose une méthode de prévision de ces cas de faible humidité. Il indique également dans quelle mesure les caractéristiques du courant aérien favorisent alors la formation d'une onde sous le vent.

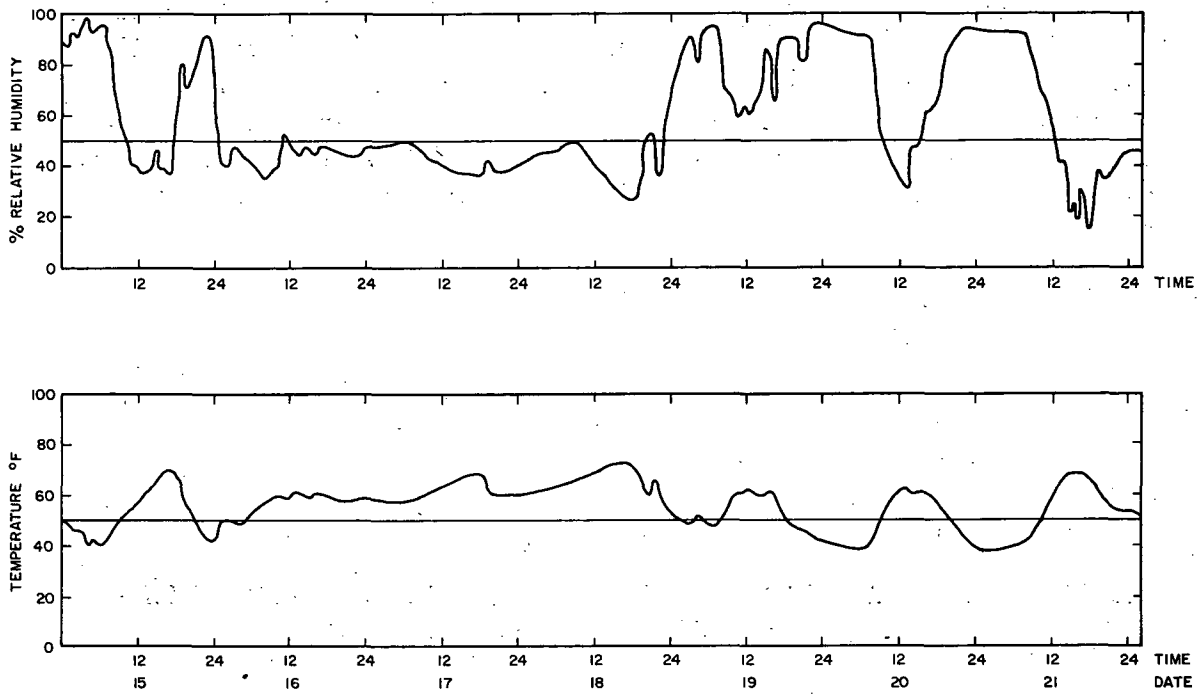

Figure 1
Hygrothermograph Trace From Kananaskis Valley for August, 1960

AN APPROACH TO FORECASTING LOW SURFACE HUMIDITIES AT NIGHT IN THE ROCKY MOUNTAINS

by

M. S. Webb

(Manuscript Received May 17, 1965, Revised Form November 24, 1965)

Introduction

In mountainous areas the diurnal pattern of relative humidity near the surface of the ground is occasionally disrupted when the humidity remains notably lower than normal for all or part of the night (Figure 1). These periods of low humidity are of great importance in forest fire control because they cause a continuing decrease in moisture content and a corresponding increase in the flammability of potential wood fuels, (MacHattie 1966), Wright and Beall 1945, Byram 1959). If these occurrences could be predicted, forest fire control would benefit greatly through the more efficient and effective use of available men and equipment.

As an airstream passes over a mountain range, subsidence often occurs to the lee. In this descending current, the temperature will rise due to adiabatic heating, and, provided the air is unsaturated, the relative humidity will decrease. The presence of such a current could be reflected in surface temperature and humidity graphs, with the effects being more pronounced at night.

This paper examines the relationship between low humidity occurrences at night in a mountainous area and the characteristics of the airstream aloft.

Data Sources

From June 21 to September 8, 1960, twenty hygrothermograph stations were in operation in the Kananaskis Valley area of Southwestern Alberta to record characteristic relative humidities in forested mountain areas (MacHattie 1966). Each hygrothermograph was carefully installed in a Stevenson screen $4\frac{1}{2}$ feet above the ground. The relative humidity recordings obtained from these stations are used in this paper.

The Kananaskis Valley is located in the Rocky Mountains at approximately 51 N 115W, and runs in a north-south line (Figure 2). The Kananaskis Range forms the western side of the valley. This

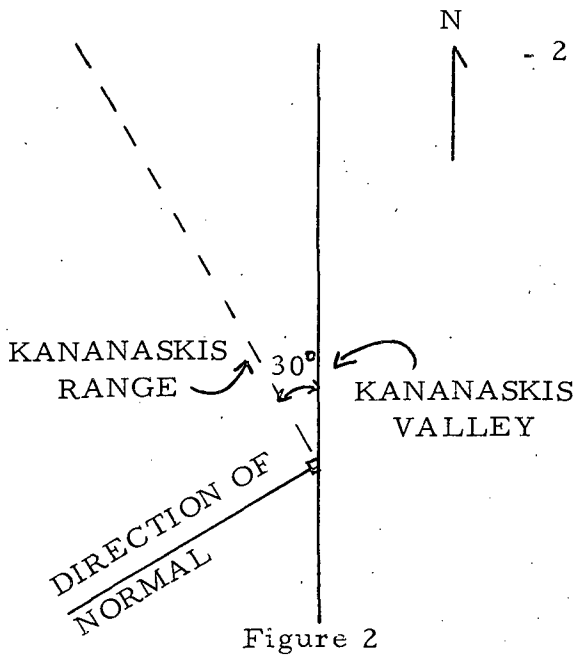

Figure 2
Schematic Sketch of Kananaskis Area

range with an elevation from 4000 to 6000 feet above the valley floor presents a continuous and unbroken barrier to westerly winds. The valley floor averages about 4600 feet above sea level. A complex network of similarly orientated ranges extends westward to the Pacific Coast. All the hygrothermograph stations were located east of the Kananaskis Range.

While it would be preferable to study the characteristics of the airstream aloft using ascent data from upstream radiosonde stations, it was decided that this method would not be practical as they are between 250 and 550 miles away, i.e. 24 or more hours distant. The approaching airstream could undergo sufficient changes in stability and wind characteristics while crossing this distance, as to render the radiosonde data an unreliable indicator of airstream conditions over the valley. A preliminary analysis of the temperature and wind characteristic of the airstream as provided by these radiosonde ascents, yielded no evidence of any interrelationship with the occurrences of low surface humidities in the Kananaskis Valley. Therefore, it was decided to examine the airstream characteristics over the Kananaskis Valley by interpolation from the 700, 500 and 300 millibar constant pressure charts. These charts were kindly supplied by the Central Analysis Office.

Parameters

For the purposes of this investigation a relative humidity value of 70% or less at night is defined as low. This value, while arbitrary, does represent a level below which the flammability of wood fuels becomes significant (Gisborne 1928). Night is defined as the period from midnight to 6 a.m. local time, since the effects of a subsiding current would be most apparent during this interval. The hygrothermograph recordings showed that the relative humidity for this period would normally be in excess of 90%. A low humidity night is defined as one during which the 20 stations recorded a total of 40 hours or more of low relative humidity during the night period.

By interpolation between the 0000 and 1200 G. M. T. charts, representative values for the geostrophic winds and temperatures were determined for the night period. Winds were measured to the nearest 10 degrees and 5 knots and temperatures to the nearest degree Centigrade. Estimation of change in winds and temperatures with height were based solely on these figures derived from the constant pressure charts. No attempt was made to ascertain any variations between levels.

Results

Occurrences of Low Humidity Nights

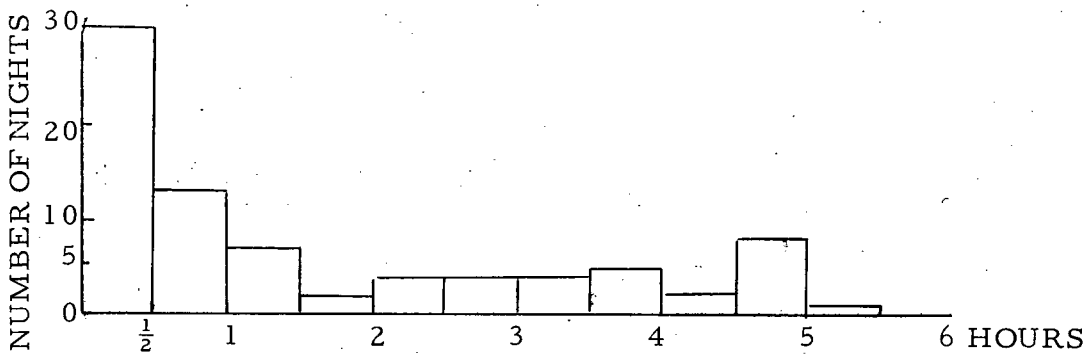

Figure 3
Average Duration in Hours per Night per Station of
Low Relative Humidities for All Stations

The frequency of occurrence by duration of low humidities is shown in Figure 3. Since brief fluctuations in humidity are not uncommon, the initial high incidence of low humidity averages, followed by a rapid decrease in frequency as averages increase, is not surprising. This decrease ends abruptly with a small but marked increase in frequency of nights with low humidities averaging 2 or more hours in duration per station. This suggests that some new factor is influencing the humidities. This increase could be produced by the downward penetration of drier air caused by orographic subsidence.

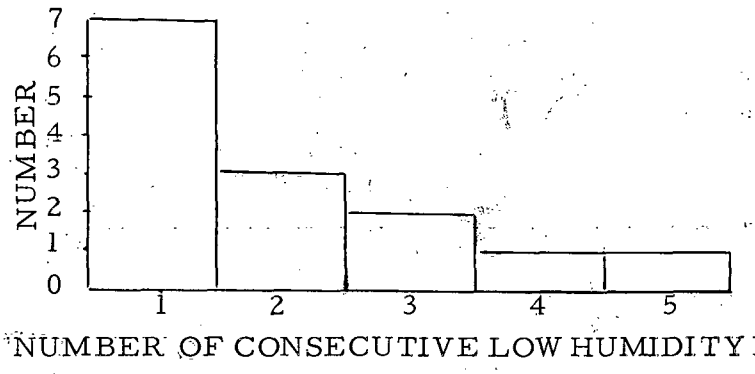

Figure 4
Frequency of Consecutive Low Humidity Nights

Readings on 28 nights showed an average of 2 hours or more of low humidities per station. Figure 4 shows the frequency of consecutive low humidity nights. On two separate occasions, four or more consecutive low humidity nights were recorded.

Airstream Characteristics

Wind direction

Figure 5 shows the frequency by direction of the 700 millibar wind. It can be seen from this histogram that all low humidity nights occurred with a 700 millibar wind direction between 200 and 320 degrees.

Stability and wind speed characteristics

Table 1
Stability and Wind Speed Categories

700-500 MB Temp Difference in °C	Total Number of Nights	Low Humidity Nights		Non-Low Humidity Nights			
		Total	Criteria Satisfied (a) + (b)	Total	Criteria Satisfied (a)	(b)	(a) + (b)
≤16	30	19	17	11	3	7	0
>16	50	9	8	41	34	37	30
TOTALS	80	28		52			

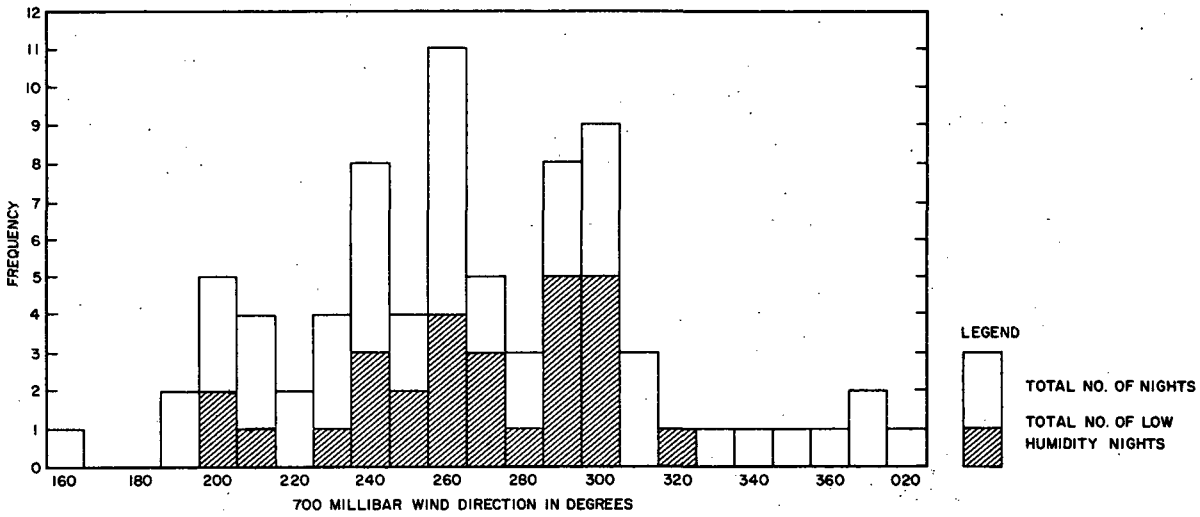

Figure 5
Frequency by Direction of 700 Millibar Wind for
80 Nights Direction Variable on 3 Nights

Criterion (a) 700 millibar wind direction between 200 and 320 degrees.

Criterion (b) i. Wind speed constant or increasing with altitude; and

ii. wind direction not varying with altitude by more than 30 degrees from the 700 millibar direction.

An examination of the airstream characteristics (Table 1) during the 28 low humidity nights showed that 19 had a temperature difference of $\leqq 16^{\circ}C$ between the 500 and 700 millibar levels and winds either constant or increasing by about 15 to 20 knots between the 700 and 300 millibar levels. Seven of the remaining low humidity nights had strongly increasing wind speeds with height. On these latter 7 nights, winds of 20 to 30 knots at the 700 millibar level increased to 60 knots or more at the 300 millibar level. The remaining 2 low humidity nights had only lightly increasing winds with height and a temperature difference $> 16^{\circ}C$.

Consider now the 52 non-low humidity nights. There were 11 with a temperature difference $\leqq 16^{\circ}C$. While 7 of these nights satisfied criterion (b), not one of the 7 fulfilled criterion (a). This leaves 41 nights with a temperature difference $> 16^{\circ}C$. None of these had strongly increasing winds comparable to the 7 low humidity nights.

Suggested Explanation

Since low humidity nights occur with the more stable lapse rate between the 700 and 500 millibar levels, the low night humidities are unlikely to be caused by turbulent mixing alone. Subsidence penetrating to near the ground within the valley could account for it, but some mechanism would be required to induce this subsidence against a stable lapse rate. Lee waves are a possibility.

It is well known that waves often form in an airstream to the lee of a mountain range. These waves, referred to as lee waves, are not unlike the ripples which form in a shallow stream as the water flows over a submerged obstacle.

Scorer (1949, 1958) has shown that in order for waves to form to the lee of a mountain range, the airstream must have a suitable combination of decreasing stability and increasing winds with height. He found that a decrease in a parameter l^2 was mandatory. (also see Booker 1963)

where $l^2 = \frac{\beta}{U^2}$

g - acceleration of gravity

β - stability

U - wind speed

The greater the decrease of l^2 with height, the greater the likelihood that waves exist in the airstream.

Since the wind speed usually increases with height, l^2 will usually decrease in value with height. Wave formation will only be likely when the decrease in l^2 with height is more substantial than usual (Corby 1957). A 700 - 500 millibar temperature difference of $\leq$ 16°C combined with nondecreasing winds with height and/or strongly increasing winds with height could result in a substantial decrease in this value and, hence, a good probability of wave formation. Thus, from Table 1, it is apparent that 26 out of 28 low humidity nights took place under conditions that appeared favourable to lee wave formation.

The direction of the 700 millibar wind on low humidity nights is not incompatible with this explanation (see figure 5). The friction which occurs as the airstream crosses the mountains will cause a breakdown in the geostrophic balance with the result that the winds will back. In the present instance, this means that the winds will have a more southerly direction; 20 to 30 degrees would not be unreasonable. Hence, the 23 low humidity nights with an apparent geostrophic wind direction at 700 millibars between 240 and 300 degrees would actually be centred closely about the direction (240 degrees) which is perpendicular to the axis of the Kananaskis Range.

Summary

This paper has reported on occurrences of low night relative humidity as shown by hygrographs operated for an 80 day period in summer in a mountainous area. Twenty-eight nights showed a station average of 2 hours or more of humidities below 70% between midnight and 6 a.m. It was found possible to distinguish these 28 low humidity nights from the remaining nights on the basis of the following airstream criteria.

(a) 700 millibar wind direction between 200 and 320 degrees.

(b) i. Temperature difference between 700 and 500 millibars of $\leq 16^{\circ}$ C and winds which do not decrease with height or

ii. winds increasing with height from 20 or 30 knots at the 700 millibar level to 60 knots or more at the 300 millibar level.

The following table shows the number of nights for which these criteria were satisfied.

Criterion Satisfied	Low Humidity Nights (total of 28 nights)	Non-Low Humidity Nights (total of 52 nights)
(a)	28	41
(a) and (b)	25	3

When judging the success of these results as a forecasting tool, it must be remembered that these criteria were chosen specifically to fit the data. They suggest that occurrences of low humidities can be attributed to subsidence of orographic origin -- possibly lee waves. The next step is to apply these criteria to independent data in order to determine their applicability and validity. In the meantime, they are presented as an approach to forecasting low humidity nights.

APPROVED,

J. R. H. Noble,
Director,
Meteorological Branch.

References

(1) Booker, D. R., 1963: Modification of Convective Storms by Lee Waves, Meteorological Monographs, American Meteorological Society, Vol. 5, No. 27, pp 11.

(2) Byram, G. M., 1959: In Forest Fire Control and Use by K. P. Davis, McGraw-Hill, New York, pp 584.

(3) Corby, G. A., 1957: Air Flow Over Mountains, Meteorological Reports #18, H. M. S. O., London, pp 53.

(4) Gisborne, H. T., 1928: Measuring Forest Fire Danger in Northern Idaho, Misc. Publication #29, U. S. Dept. of Agriculture, pp 64.

(5) MacHattie, L. B., 1966: Relative Humidity in Rocky Mountain Forests of Southern Alberta in Summer. (Manuscript for publication).

(6) Scorer, R. S., 1949: Theory of Waves in the Lee of Mountains, Quarterly Journal of Royal Meteorology Society, Volume 75, No. 323, pp 41-56.

(7) Scorer, R. S., 1958: Natural Aerodynamics, Pergamon Press, London, pp 312.

(8) Wallington, C. E., 1961: Meteorology for Glider Pilots, John Murray, London, pp 284.

(9) Wright, J. G. and H. W. Beall, 1945: The Application of Meteorology to Forest Fire Protection, Technical Communication #4, Imperial Forestry Bureau, pp 23.

CIR-4377 UDC: 551.509.329
TEC-598 551.509.317
10 Feb. 66.

CANADA

Department of Transport - Meteorological Branch
315 Bloor St., W., - Toronto 5, Ontario

An Approach to Forecasting Low Surface Humidities at Night in the Rocky Mountains

by M. S. Webb

7 pps. 5 figs. 1 table. 9 refs.

Subject reference: 1. Forecasting Humidity.
2. Kannanaskis Valley.
3. Upper air data applied to forecasting

CIR-4377 UDC: 551.509.329
TEC-598 551.509.317
10 Feb. 66.

CANADA

Department of Transport - Meteorological Branch
315 Bloor St., W., - Toronto 5, Ontario

An Approach to Forecasting Low Surface Humidities at Night in the Rocky Mountains

by M. S. Webb

7 pps. 5 figs. 1 table. 9 refs.

Subject reference: 1. Forecasting Humidity.
2. Kannanaskis Valley.
3. Upper air data applied to forecasting

CIR-4377 UDC: 551.509.329
TEC-598 551.509.317
10 Feb. 66.

CANADA

Department of Transport - Meteorological Branch
315 Bloor St., W., - Toronto 5, Ontario

An Approach to Forecasting Low Surface Humidities at Night in the Rocky Mountains

by M. S. Webb

7 pps. 5 figs. 1 table. 9 refs.

Subject reference: 1. Forecasting Humidity.
2. Kannanaskis Valley.
3. Upper air data applied to forecasting

ABSTRACT: Low surface relative humidities at night in the Rocky Mountains can increase significantly the flammability of forested areas. Through examination of the wind and temperature characteristics of the airstream aloft, an approach to forecasting these low humidity occurrences is presented. The extent to which the airstream characteristics favour lee wave formation during these occurrences is discussed.

ABSTRACT: Low surface relative humidities at night in the Rocky Mountains can increase significantly the flammability of forested areas. Through examination of the wind and temperature characteristics of the airstream aloft, an approach to forecasting these low humidity occurrences is presented. The extent to which the airstream characteristics favour lee wave formation during these occurrences is discussed.

ABSTRACT: Low surface relative humidities at night in the Rocky Mountains can increase significantly the flammability of forested areas. Through examination of the wind and temperature characteristics of the airstream aloft, an approach to forecasting these low humidity occurrences is presented. The extent to which the airstream characteristics favour lee wave formation during these occurrences is discussed.

ABSTRACT: Low surface relative humidities at night in the Rocky Mountains can increase significantly the flammability of forested areas. Through examination of the wind and temperature characteristics of the airstream aloft, an approach to forecasting these low humidity occurrences is presented. The extent to which the airstream characteristics favour lee wave formation during these occurrences is discussed.