Kananaskis Valley Winds in Summer

L. B. MacHattie[1]

Department of Forestry and Rural Development, Ottawa, Canada

(Manuscript received 18 August 1967)

ABSTRACT

Anemograph charts from three stations in a north-south valley were analyzed to find the degree to which average diurnal variations were explainable on the basis of valley wind theory and local topography. Prominent diurnal cycles of the cross-valley component were found in the monthly averages at each station. At one station it was a morning-evening slope-wind cycle; at the other two, a day-night cycle up and down a sub-valley. The component along the main valley showed greater complexity, which is partially attributed to gradient wind interference in the afternoon when convective activity is greatest. The diurnal patterns for a group of selected clear days were similar to, but slightly sharper than, those of the monthly average charts.

1. Introduction

Surface wind has a significant effect on the spread of forest fires, pollen, seeds and insects. It directs the advective component of energy in evapotranspiration. It is well known that the local surface wind often differs from the gradient shown on the surface synoptic chart; the precise manner in which topography causes such differences is only partially established.

Geiger (1965) has reviewed the theory of winds in a mountain valley and reproduced Defant's diagram. Davidson and Rao (1958) and Buettner and Thyer (1966) discussed the inaccuracies of this diagram and associated theory in the light of their own and others' observations. Urfer-Henneberger (1964) confirmed that slope winds are a continuing rather than a transient feature, and that they are unsymmetrical and in harmony with the unsymmetrical exposure of the valley sides to insolation.

Most of the above investigations used observations from selected clear days only, in order to study the valley wind system undistorted by synoptic-scale pressure gradients. This paper describes what winds occur (regardless of synoptic situation), then discusses:

a) the reasons for the main features of the observed wind patterns, and
b) the degree to which the monthly patterns reflect those for low-gradient clear days.

2. Area, instruments and method

The surface wind observations were made in the northward draining Kananaskis valley of southwestern Alberta in 1960, as part of a study of the variation with topography of meteorological factors affecting forest flammability. Fig. 1 is a contour map of the area. A description of the Kananaskis valley was given in a previous report (MacHattie, 1966).

The wind data are derived from three anemographs of Meteorological Service of Canada design, type 45 (Department of Transport, 1951). These show a step on the chart for the passage of each mile of wind; the wind direction (to 8 points) is recorded at the time of each step.

TABLE 1. Anemometer locations and exposures.

Station name	Station elevation: Above sea level (ft)	Station elevation: Above valley floor (ft)	Period of record	Anemometer exposure
Headquarters	4560	50	All year	48 ft above ground on grassy knoll south of 40-ft pine stand
Meadow	4730	0	1 July–9 September	33 ft above grassy river flat
Marmot	5680	950	6 July–28 August*	33 ft above ground in a 15-ft pine stand on a flattened ridge.

* Except 11, 12, 15 July and 8, 9, 23 August.

---

[1] On loan from the Meteorological Service of Canada.

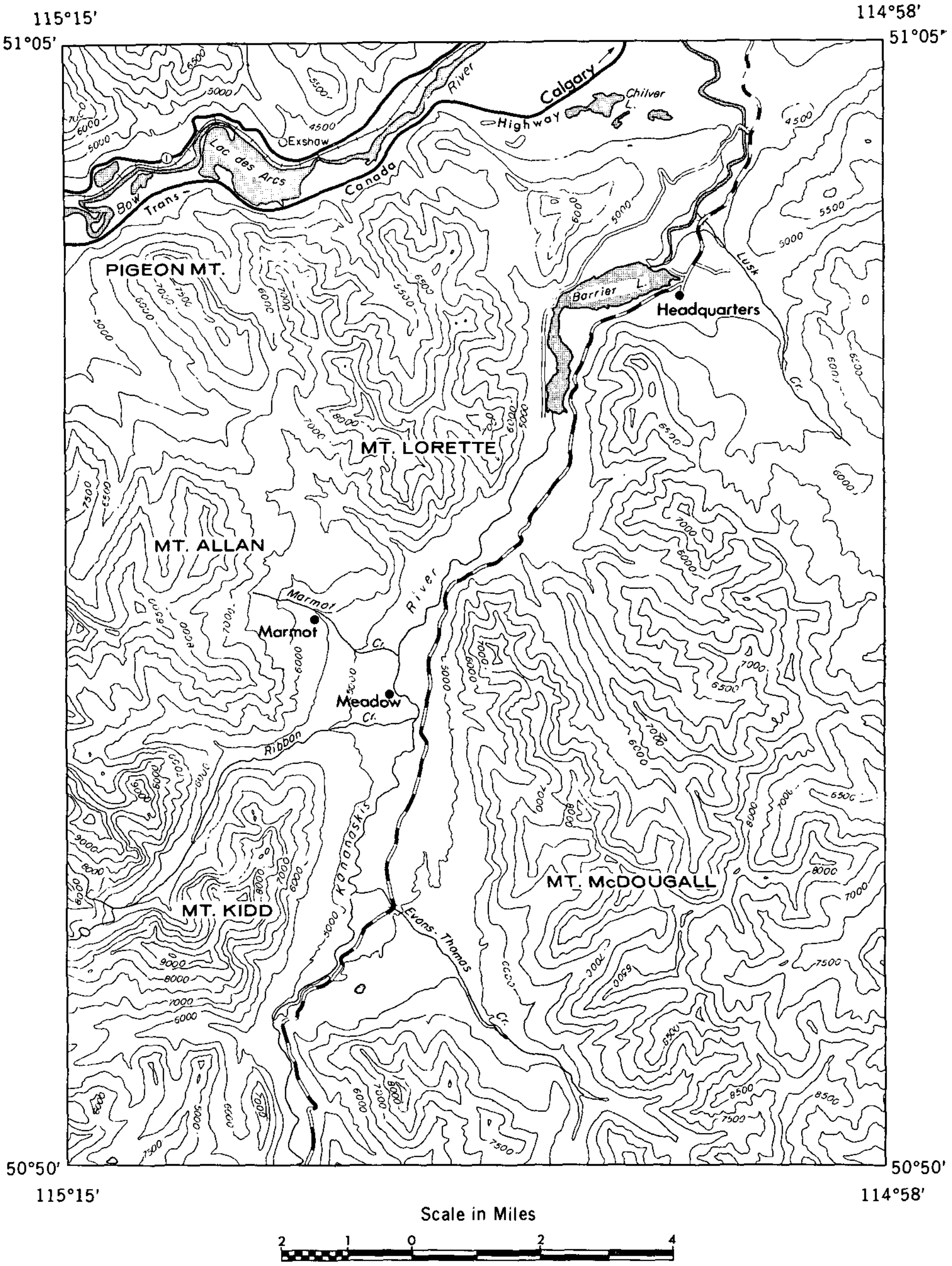

Fig. 1. Contour chart showing the three anemometer sites in the lower Kananaskis valley. The contour interval is 500 ft.

The anemometers were exposed at the locations marked in Fig. 1 and described in Table 1. The exposures were not ideal, but their limitations are not thought to compromise the conclusions drawn below.

Hourly abstracts of average speed and direction were made from the anemograph charts. The hourly values were then resolved into components along and across the valley direction. The valley direction was taken as north-south at Meadow and Marmot, northeast-southwest at Headquarters.

To represent the diurnal wind pattern during low gradient clear weather, 13 days were found for which:

a) the geostrophic wind (on both 700-mb and sea-level synoptic charts) was generally less than 15 mph, and
b) daily sunshine was 9 hr or more.

Thermograph charts were also examined to make sure the temperature pattern was not abnormal. The days which met these criteria were 3–6 and 14–18 July and

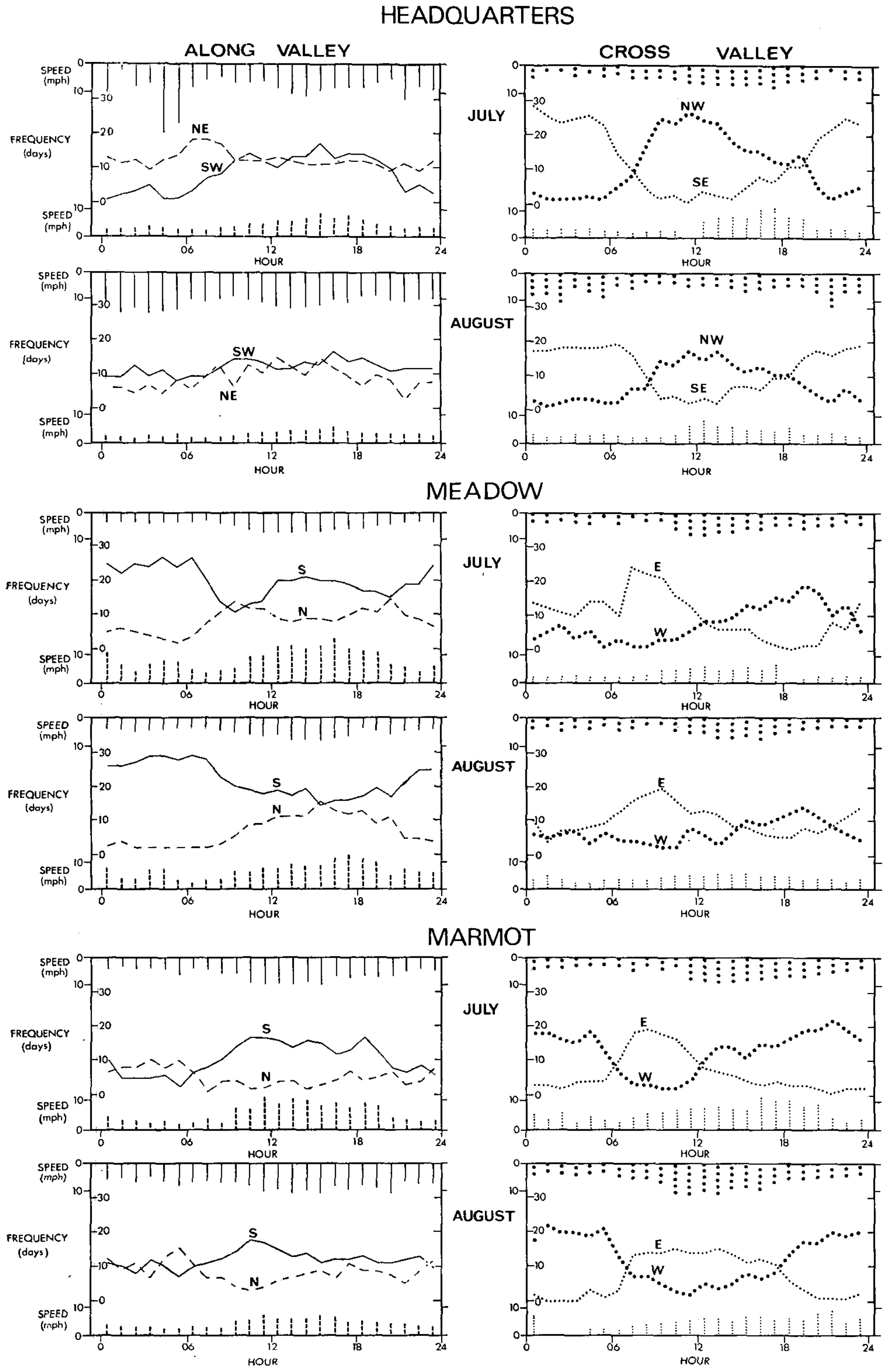

Fig. 2. Hourly frequencies of wind components and their average speeds for along-valley (left column) and cross-valley components (right column). Data for 31 days per month are used except at Marmot.

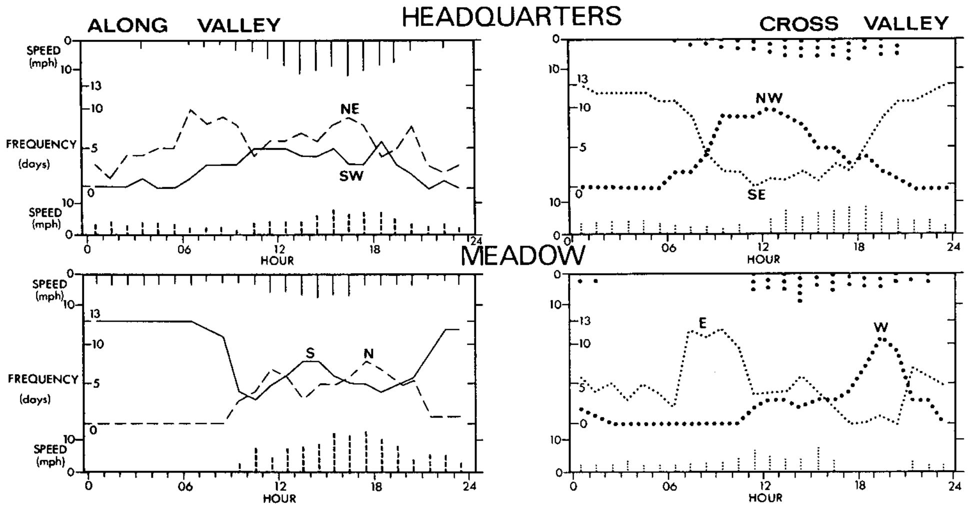

Fig. 3. Hourly wind components for 13 selected clear days, displayed as in Fig. 2.

8–11 August, inclusive. Average hourly components were computed for this 13-day period at Meadow and Headquarters, but not at Marmot because it was inoperative on 6 of the 13 days.

3. Results

Monthly average wind components are shown in in Fig. 2.

Meadow has a consistent down-valley wind at night. The up-valley wind increases in the daytime to maxima in both speed and frequency, but only briefly does it reach the frequency of the down-valley daytime wind. The cross-valley components show east to be dominant in the morning and west in the late afternoon; in each case the wind blows toward the more intensely insolated slope.

In contrast to Meadow, the graphs for Headquarters (Fig. 2) do not show an appreciable oscillation up and down the Kananaskis valley. They do show a distinct cross-valley diurnal cycle. Because this cycle is inverse in direction to what insolation effects in the Kananaskis valley proper would give, and because it is a day-night rather than a morning-afternoon cycle, we conclude that it must be the Lusk Creek sub-valley which is the controlling influence at the Headquarters site. The northwest-southeast components thus show diurnal winds up and down the Lusk Creek sub-valley.

At Marmot the pronounced diurnal variation in east-west components is apparently an oscillation up and down the Marmot Creek sub-valley. A reason is suggested below for the early switchover from east to west in July.

Fig. 3 presents data for the selected clear days. Its main features are similar to Fig. 2. This indicates that the local temperature and pressure differences which stem from radiational variations within the valley are a dominant influence on the average summer day, as well as on those clear days especially selected to maximize such effects.

There are some differences, however, between the clear-day and the monthly graphs. The frequency of up-valley winds in the daytime is greater in Fig. 3 than in Fig. 2 at both Headquarters and Meadow, especially in the late afternoon. Apart from a down-valley intrusion 1300–1500 (discussed below), the clear-day hodograph for Meadow would show a counterclockwise circuit of wind direction; neglecting Coriolis acceleration, this is what elementary theory would predict for a northward draining valley.

4. Gradient wind influence

There are several features in Figs. 2 and 3 which appear to derive from gradient wind influence. Consider the north-south components at Meadow in July. The frequency of up-valley winds rises rapidly for 3 hr after sunrise, but then decreases to a minimum in mid-afternoon. It is suggested that increasing convection during the morning resulted in increasing amounts of gradient wind momentum being brought down into the valley. By noon, this was usually sufficient to reverse the up-valley wind. When convection decreased again in late afternoon and the coupling between surface and gradient wind level disintegrated, the frequency of up-valley winds increased briefly until sunset initiated the return of nocturnal down-valley winds.

A similar pattern is evident in the graph for selected clear days. Because the gradient winds were weaker on these days (than on the monthly averages), the period of gradient wind dominance was briefer.

The above explanation assumes that the gradient wind effect includes a significant south component. Fig. 4 shows the frequencies of gradient wind directions at the 700-mb level, which is at the height of the higher mountain peaks in this area in summer. The directions were taken from twice daily maps prepared by the Central Analysis Office in Montreal. For most days the gradient direction lay in the 190°–310° sector. Some backing of the actual 700-mb wind from the direction of the map contours would be expected due to friction over the mountains. (Pilot balloon observations made mainly at sunrise on 15 days, 5 July–2 September 1956 from a 6000-ft MSL bluff 2 mi north of Meadow station showed an average backing of 20°, i.e., a 20° difference between the 700-mb gradient direction and the observed wind at 10,000 ft.) The difference in direction between the map gradient and the actual wind at 700 mb would be expected to vary diurnally, reaching a maximum at the time convection exerted the greatest retardation on the 700-mb wind speed. It is concluded that the gradient wind momentum brought down into the valley as a consequence of convection was from the southwest direction, on the average.

The difference between July and August north-south graphs for Meadow is attributed to less intense convection in August than July, due both to lower solar elevation and to fewer hours of sunshine; only 191 hr of bright sunshine were recorded in August, compared to 313 hr in July.

Similarly, the west component of the gradient wind (coupled with greater convective activity in July) is thought to explain the switchover from east to west being earlier in the afternoon in July, than in August, at both Meadow and Marmot sites.

5. Conclusions

In the north-south Kananaskis valley, surface wind components across the direction of the main valley show a more pronounced diurnal cycle than components along the valley, both on selected clear days (with low synoptic pressure gradient) and on monthly averages.

It appears that the effects of sub-valleys (and the slope effect in the main valley) on surface wind are less susceptible to overriding by synoptic-scale influences than the flow along the main valley.

Though mountain and valley winds arise from radiational influences on mountain slopes, it is possible for these local wind patterns to be less apparent on clear days in high summer than on days when incoming radiation is somewhat less intense. This is because convective activity and, hence, the coupling of surface wind with the synoptic gradient wind tend to be stronger on days of more intense radiation.

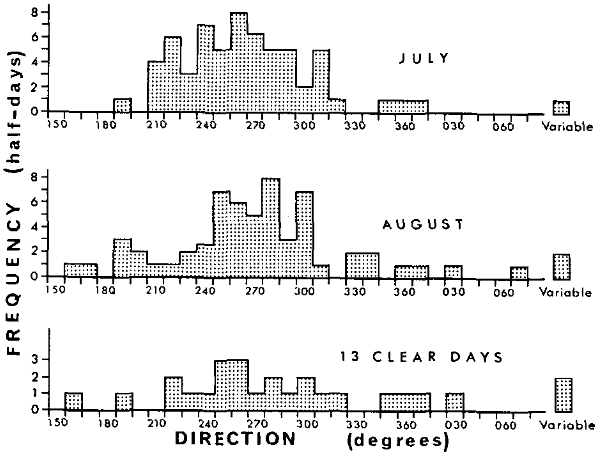

FIG. 4. Histogram of 700-mb contour directions over the Kananaskis valley measured from twice-daily charts (0000 and 1200 GMT).

Daytime up-valley winds will naturally suffer more gradient wind interference than nocturnal down-valley winds.

REFERENCES

Buettner, Konrad J. K., and Norman Thyer, 1966: Valley winds in the Mount Rainier area. *Arch. Meteor. Geophys. Bioklim.*, 14, 125–147.

Davidson, Ben, and P. Krishna Rao, 1958: Preliminary report on valley wind studies in Vermont, 1957. New York University College of Engineering, Res. Paper, 54 pp.

Department of Transport, 1951: Wind equipment M.S.C. pattern. Meteorological Branch Circular 2039, 34 pp.

Geiger, Rudolf, 1965: *Climate Near the Ground.* Cambridge, Harvard University Press, 611 pp.

MacHattie, L. B., 1966: Relative humidity in Rocky Mountain forests of southern Alberta in summer. Canada, Department of Forestry Information Rept. FF-X-1, 54 pp.

Urfer-Henneberger, Charlotte, 1964: Wind- und Temperaturverhältnisse an ungestörten Schönwettertagen in Dischmatal bei Davos. *Schweiz. Amstalt Forst. Vers. Mitt.*, **40**, 389–441.