ARCTIC
VOL. 35, NO. 4 (DECEMBER 1982) P. 537-541

Cold Air Drainage West of Fort Nelson, British Columbia

STUART A. HARRIS[1]

ABSTRACT. In the early mornings of 7, 22 and 23 January 1982, intense cold air drainage was observed in the valleys on the eastern slopes of the Rocky Mountains west of Fort Nelson, British Columbia. Temperature differences of 31°C were noted, the coldest temperature recorded being -71°C (a new North American record), though even colder temperatures probably occurred at other sites. These were produced by an intense cold arctic high-pressure cell which gave regionally still air and clear skies and permitted marked local cooling during the nights. Similar conditions should be expected elsewhere along the slopes of the Rocky Mountains in northern B.C. and southern Yukon Territory.

RÉSUMÉ. Durant les premières heures matinales des 7, 22 et 23 janvier 1982, un réseau d'air intensément froid fut ressenti dans les vallées du versant est des Rocheuses, à l'ouest de Fort Nelson, en Colombie-Britannique. Une différence de température de 31° C fut enregistrée, la température la plus froide ayant une indication au mercure de -71° C (un nouveau record nord-américain), bien que d'autres sites ont probablement ressenti des températures plus basses encore. Ces températures ont été produites par une haute pression de froid arctique intense qui entraîna un condition atmosphérique calme dans la région ainsi qu'un ciel dégagé, accompagné d'un refroidissement local marqué pendant les nuits. Des conditions semblables existent probablement le long des pentes des Rocheuses dans le nord de la C.-B. et le sud du Yukon.

Traduit pour le journal par Maurice Guibord.

INTRODUCTION

One of the problems of ecological and process studies in mountain regions is the determination of the local climatic regime (Geiger, 1961). Unfortunately, in Canada the existing weather stations are usually located at population centres in locations that are somewhat atypical. Thus the weather stations in Banff, Jasper and Lake Louise townsites are of limited value as a basis for ecological work in the mountains of Banff and Jasper National Parks.

The simple assumption that near-surface air temperature decreases at a steady rate with altitude (see Brown, 1967) does not operate in practice (Harris, 1981). Suggested explanations include inversions (Harris and Brown, 1982), variations in albedo (Harris, 1981), and cold air drainage (Schüepp, 1965), but published studies of the effects of these phenomena in North America are rare.

An extreme case of cold air drainage was encountered during a routine study of ground temperature cables installed along the Alaska Highway near Summit Lake, west of Fort Nelson, British Columbia. The purpose of this paper is to describe the conditions which occur during such events.

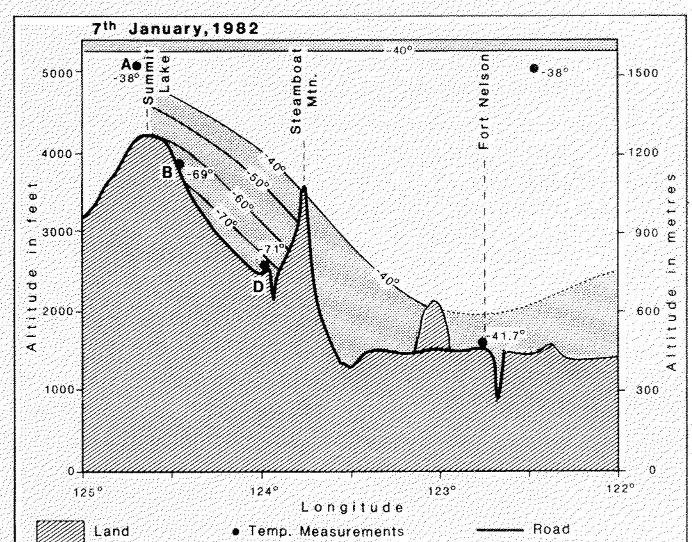

FIG. 1. Interpolated isotherms for the area between Summit Lake and Fort Nelson, along the Alaska Highway, at 1200 h GMT, 7 January 1982. Temperature at Fort Nelson supplied by the Officer-in-Charge, Meteorological Office, Fort Nelson Airport. The 850-mb temperature above Fort Nelson was obtained from the Telex chart, courtesy of the Officer-in-Charge, Meteorological Office, Calgary International Airport.

TOPOGRAPHY AND GEOLOGY

Figure 1 shows the topography along the alignment of the Alaska Highway westward from Fort Nelson. The road crosses the foothills east of the northern end of the Rocky Mountains. The outer hills resemble forested mesas and buttes, being composed of horizontally bedded shales and sandstones of Cretaceous age (Taylor and Stott, 1973; Taylor *et al.*, 1968). These form a substantial barrier rising more than 1000 m above mean sea level, aligned in a NNW-SSW direction. Behind them are valley floors more than 300 m lower in elevation and extending back upslope to the drainage divide, which lies between 1295 m on the floor of the pass at Summit Lake and 2820 m along the mountaintop.

Continuous permafrost occurs above 1475 m on the pass, while discontinuous permafrost occurs at lower elevations. Failure of apartment foundations, caused by permafrost, has occurred in Fort Nelson, confirming that some permafrost is present even at the lowest, most easterly locations, as reported by Crampton (1978).

VEGETATION

Tundra occurs above approximately 1475 m but gives way to mixed forest of white spruce, dwarf birch, pine, willow and poplar on the south-facing slopes and black

[1]Department of Geography, The University of Calgary, Calgary, Alberta, Canada T2N 1N4

spruce and willow on the steep north-facing slopes. Pines and poplars are dominant on the alluvial fans. The contrast between the slopes at site C is illustrated in Johnston (1981:Fig. 2.4).

CLIMATE

The study area lies somewhat in the rain shadow of the Rocky Mountains, in a zone where chinooks often occur along the ridge tops and can extend down into the valleys. Mean annual air temperature at Fort Nelson was −1.28°C for the period 1941-1970, and mean annual precipitation was 44.68 cm for the same period (Atmospheric Environment Service, n.d.a.). Higher precipitation occurs along the upper western slopes of the higher NNW-SSE-trending ridges.

METHODS

Information from the 850-mb level (equivalent to about 1524 m elevation) is available from the Class A weather station at Fort Nelson. In December 1981, three weather stations were installed at sites A, B, and D near Summit Lake. Site A was at approximately 1524 m on a north-facing slope, site B at 1170 m on a south-facing slope, and site D at 751 m on the level surface of a low ridge on the valley floor.

At each site, a Lambrecht continuous temperature-recording apparatus was installed in an instrument shelter. The machines were pre-calibrated and the calibration rechecked in the field at temperatures between −30°C and −50°C with an alcohol minimum thermometer. The charts on the recorders are changed once a month, and the results checked with minimum thermometers.

RESULTS

By the end of January, it became apparent that on the coldest days of the winter, there were periodic events when extreme examples of cold temperatures were encountered in the valley bottoms. The three extreme cases were on the nights of 6-7 January, 21-22 January, and 22-23 January 1982 (Table 1). In between these extreme events, there is still a general trend toward lower temperatures in the lower parts of the valley floors, and this shows in the mean air temperatures for January 1982 recorded for the stations (Table 1). The events were occasional, i.e. four occurred in January but not at regular intervals.

TABLE 1. Comparison of minimum air temperatures (°C) for the three weather stations and for Fort Nelson Airport, for the nights of 6-7 January, 21-22 January and 22-23 January 1982

Site	Elevation (m)	Minimum temperature recorded (1982) 6-7 Jan	21-22 Jan	22-23 Jan	Mean January Temperature
A	1540	−38	−35	—	−25.93
B	1170	−69	−60	−41	−26.13
D	751	−71	−61	−63	−34.49
Ft. Nelson Airport	382	−42	−42	−44	−31.60

During the night of 6-7 January the temperature dropped 33°C lower at site D than at site A. The minimum temperature of −71°C at site D is the lowest temperature recorded so far in North America, and it occurred when record low temperatures were not being set elsewhere. Figure 1 shows the apparent temperature regime along this section of the Alaska Highway during the period of lowest recorded temperatures. The data for Fort Nelson Airport and for

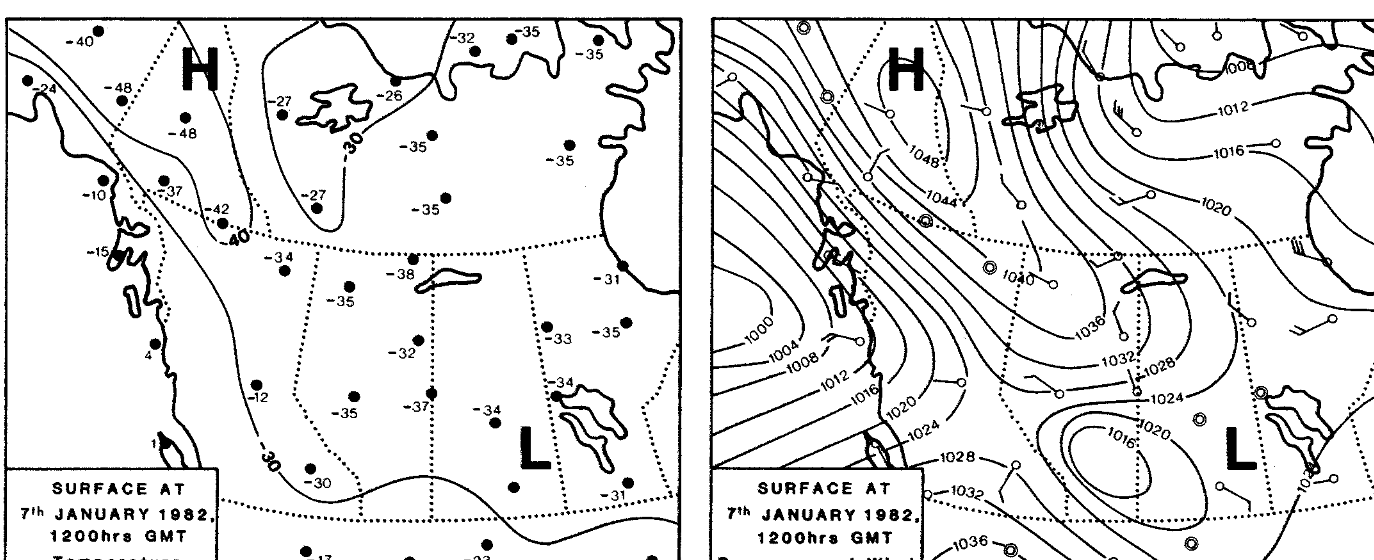

FIG. 2. Surface temperature and pressure in northwestern Canada at 1200 h GMT, 7 January 1982. Based on the Telex charts of the Atomosphereic Environment Service, courtesy of the Officer-in-Charge, Meteorological Office, Calgary International Airport.

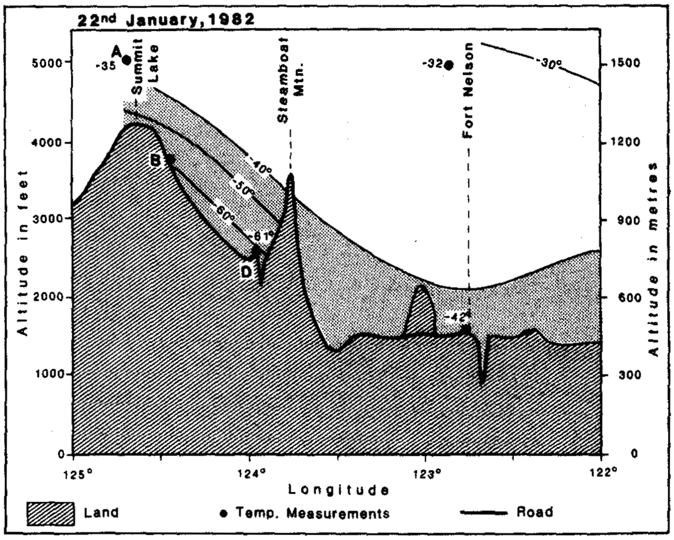

FIG. 3. Interpolated isotherms for the area between Summit Lake and Fort Nelson, along the Alaska Highway, at 1200 h GMT, 22 January 1982. Temperature at Fort Nelson supplied by the Officer-in-Charge, Meteorological Office, Fort Nelson Airport. The 850-mb temperature above Fort Nelson was obtained from the Telex chart, courtesy of the Officer-in-Charge, Meteorological Office, Calgary, International Airport.

the 850-mb level are based on the measurements made at the Class A station. Figure 2 shows the surface conditions in northwestern Canada at the time. An intensely cold arctic high-pressure air mass had moved into southern Yukon and northern Alberta, and calm conditions prevailed, permitting localized temperature differentiation in the valleys to become extreme. In fact, in Figure 1, Fort Nelson is the warmest low-elevation area, lying between the cold air mass on the plains and the zone of cold air at the foot of the mountains.

The temperature differential between sites A and D was 26°C on the night of 21-22 January. A second, more localized event occurred at site D the following night (Fig. 3), after only a three-hour interval between approximately 11:00 A.M. and 2:00 P.M. local time. Again the cross-section suggests a shallow, intensely cold zone in the valley floors leading from the mountains. This dissipates rapidly on the plains and is absent at Fort Nelson. The surface weather map (Fig. 4) shows a very intense high-pressure ridge located just east of Fort Nelson, and negligible winds were present in the area despite the relatively steep pressure gradient to the west. The air was cooling *in situ* under a clear sky, although cloud occurred further south.

The occasional intense temperature differentiation could be a result of differential rates of reradiation from the ground surface due to differences in topography, vegetation and albedo, or it could be a result of cold air drainage. Reradiation and consequent temperature differentiation are inevitable during the long, cold, clear nights. Their combined effects can be tested by averaging the diurnal temperature ranges for the weather stations during a period when a ridge of cold air brings cold, clear conditions to the region. Such conditions were present from 27 December 1981 to 6 January 1982. Table 2 shows the average diurnal temperature ranges for 28 December 1981 - 3 January 1982 for sites A, B and D and for Fort Nelson A, together with the diurnal temperature range on 7 January 1982. The average diurnal temperature ranges for the three stations for the seven-day period show differences of only 2.5°C. The extreme values indicate that there are only small differences in reradiation between the sites when the results of reradiation and insolation are integrated in this way.

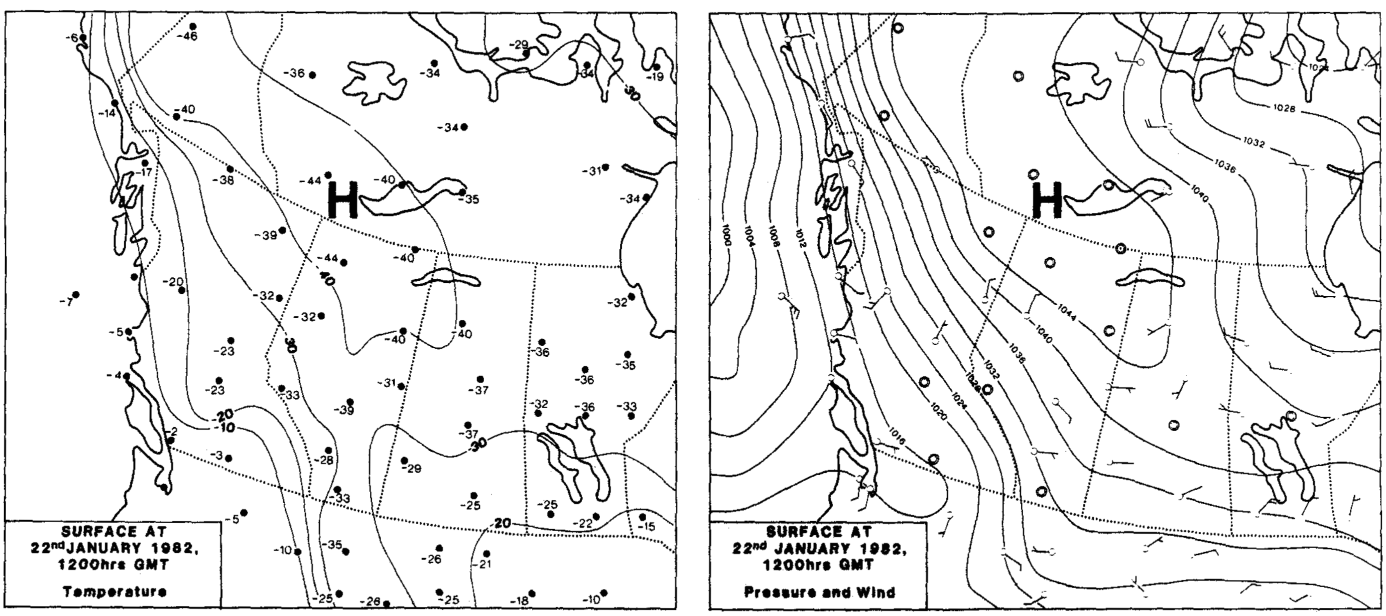

FIG. 4. Surface temperature and pressure in northwestern Canada at 1200 h GMT, 22 January 1982. Based on the Telex charts of the Atmospheric Environment Service, courtesy of the Officer-in-Charge, Meteorological Office, Calgary International Airport.

Clearly these effects are minor compared with the temperature differentiation on 7 January.

The data in Table 2 also demonstrate the fact that there was a weak temperature inversion in the area during the period when cold arctic high pressure was occupying the region. However, the differences in mean air temperature between the stations were again minor.

TABLE 2. Diurnal cooling and temperature differentiation between 28 December 1982 and 3 January 1982, compared with intense overnight temperature differentiation on 7 January 1982, for weather stations and Fort Nelson A

Site:	A	B	D	Fort Nelson A*
Mean daily temperatures 28 Dec 1981 - 3 Jan 1982 (°C)	−28.5	−34.6	−37.4	−37.1
Mean diurnal cooling, 28 Dec 1981 - 3 Jan 1982 (°C)	4.2	5.9	6.7	6.7
Overnight cooling 7 Jan 1982 (°C)	5	32	36	14
Vegetation	Tundra	Mixed deciduous-coniferous forest	Open, stunted black spruce and willow	Grassland
Topography	Crest of bench, north-facing slope of pass	South-facing valley side in narrow valley	Flat terrace in open valley	Flat surface at north end of runway

*Data supplied by Officer-in-Charge, Fort Nelson Meteorological Station

The actual trace of the air-temperature record at site D (Fig. 5) shows clearly the difference between the period of reradiation (27 December 1981 - 4 January 1982) and the cold air drainage on 7 January 1982. On 7 January there were two sudden incursions of much colder air into the zone around the station. During the first one, the temperature dropped 20°C in less than an hour. It was these changes that caused the extreme temperatures. The incursions ceased abruptly when the sun rose, but the exact manner of the disappearance of the cold air cannot be proved. It probably drained downslope and was not replenished. Cold air drainage appears to be the only reasonable explanation for these abrupt large temperature changes in the valleys.

DISCUSSION AND CONCLUSIONS

The cross-sections, data, and temperature charts suggest that the low surface temperatures are the result of local cold air drainage downslope from the Rocky Mountains. The apparent synoptic weather condition for these events is the presence of the cold arctic high-pressure zone extending from southern Yukon to northern Alberta, resulting in clear skies and still conditions. The main common factor is negligible regional wind, permitting modification of the still air in the deeper valleys. The cold air drainage occurs on the slope of the mountains and links up with the outer margin of the main zone of cooling Continental air of the southern Mackenzie Valley. Fort Nelson lies between the two zones of cold winter air.

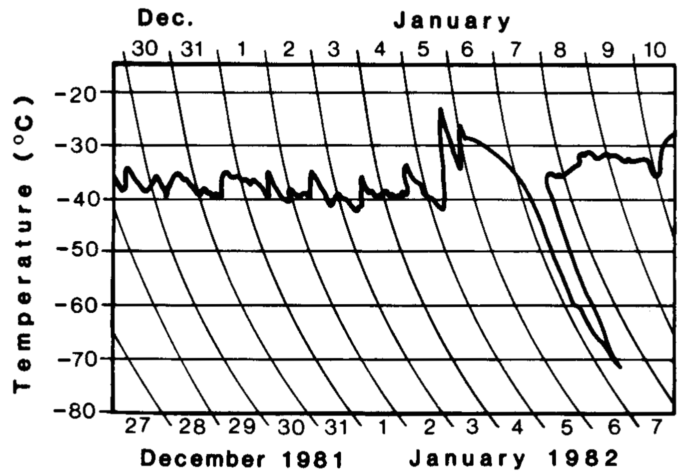

FIG. 5. Air temperature at site B between 29 December 1981 and 10 January 1982.

The intensity of the cooling in the valleys far exceeds that recorded in Europe (e.g. Schüepp, 1965 at Davos, Switzerland) and appears to be greater than that so far reported at Verkhoyansk. The Alaska Highway data were obtained during the first month of study, and further investigation will likely reveal more striking results. It should also be noted that these measurements were not made in what might be expected to be the coldest part of the landscape. The actual minimum air temperature is lower than the previous record for North America, which was −81°F or −62°C at Snag Airport (Atmospheric Environment Service, n.d.b.:3). Undoubtedly other valleys at the foot of the mountains in southern Yukon and northern B.C. experience similar conditions.

The section of the Alaska Highway just west of Fort Nelson has a particularly high rate of vehicle failure in winter, according to local residents. This has been attributed to the steepness of the grades in the area, but our data indicate that the exceptionally cold temperatures may be partly responsible. The periodic cold temperatures have additional importance since this is the easiest east-west route through the northern Rocky Mountains in northeastern B.C. and will be seriously considered as a route for the proposed natural-gas pipeline.

During preliminary drilling for the pipeline route, a large number of holes penetrated ground ice along the river valley immediately east of Steamboat Moutain (J. Elwood and D. Fisher, pers. comm.), though little ground ice was encountered in drillholes south of Fort Nelson. Large quantities of ground ice are found in the same area where the cold air west of Steamboat Mountain escapes eastwards through the Muskwa River gap and dissipates on the lowlands. Thus cold air drainage probably has considerable influence on the distribution of icy permafrost in the river valleys along this section of the Cordillera.

ACKNOWLEDGEMENTS

The field work was carried out to augment the Summit Lake permafrost study done for the Terrain Sciences Division, Geological Survey of Canada.

REFERENCES

ATMOSPHERIC ENVIRONMENT SERVICE. N.d.a. Temperature and precipitation 1941-1970. Means for the period 1941 to 1970 and extremes up to 1970. British Columbia. Downsview, Ontario: Environment Canada. 93 p.

———. N.d.b. Temperature and precipitation 1941-1970. Means for the period 1941 to 1970 and extremes up to 1970. The North Y.T. and N.W.T. Downsview, Ontario: Environment Canada. 24 p.

BROWN, R.J.E. 1967. Permafrost in Canada. Geological Survey of Canada Map 1246a. Division of Building Research, National Research Council of Canada. Publication NRC 9769.

CRAMPTON, C.G. 1978. The distribution and thickness of icy permafrost in northeast British Columbia. Canadian Journal of Earth Sciences 15:655-659.

GEIGER, R. 1961. Das Klima der badennahen Luftschicht. Brunswick, Germany: Friedrich Vieweg & Sohn. 5th ed.

HARRIS, S.A. 1981. Climatic relationships of permafrost zones in areas of low winter snow cover. Arctic 34:64-70.

——— and BROWN, R.J.E. Permafrost distribution along the Rocky Mountains in Alberta. THe Roger J.E. Brown Memorial Volume. Proceedings of the 4th Canadian Permafrost Conference, Calgary, Alberta. Ottawa: National Research Council. 59-67

JOHNSTON, G.H. (ed.). 1981. Permafrost Engineering Design and Construction. Toronto: John Wiley and Sons. 540 p.

SCHÜEPP, W. 1945. Unterschungen über den winterlichen Kaltluftsee in Davos. Verhandlungen der Schweizerischen Naturforschenden Gesellschaft. 127-128.

TAYLOR, C.G. and STOTT, D.F. 1973. Tuchodi Lakes Map-Area, British Columbia. Ottawa: Geological Survey of Canada. Memoir 373. 37 p.

——— and BAMBER, E.W. 1968. Geology, Fort Nelson. Map 3-1968, Sheet 94J. Preliminary Series. Ottawa: Geological Survey of Canada.