The Relationship Between Upper Elevation Weather Data and Snow Accumulations in Nearby Avalanche Starting Zones

by

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We accept this thesis as conforming to the required standard

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ABSTRACT

Snow accumulations during seven time periods were measured on three transects in the Cascade mountains near Hope, British Columbia. Two of the transects were in avalanche starting zones, the third was in an opening in the forest nearby. The measured accumulations were correlated to weather parameters recorded at upper elevation weather stations 4 kilometres away. A single regression model was developed to predict snow accumulation at the starting zone transects. A new parameter, combining the observed average wind vector with each transect aspect, was used to represent the effective loading wind at the starting zones.

Precipitation was by far the best predictor of snow accumulation. The other parameters made little contribution to the model.

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CHAPTER 1 INTRODUCTION

1.0 Introduction

Avalanches disrupt traffic and cause accidents on many mountain highways in British Columbia (Schaerer 1987). The Ministry of Transportation and Highways (MoTH) closes affected sections of these highways when avalanches are expected, but closures are inconvenient and costly to the travelling public and must be minimized. Avalanche experts monitor snow conditions, weather conditions, and avalanche occurrences, to provide accurate avalanche forecasts and ensure that an appropriate balance of public safety and public convenience is maintained. But avalanche forecasts are uncertain (LaChapelle 1980) and unexpected avalanches still occasionally affect open highways, and avalanches which were expected frequently do not occur. The uncertainty associated with avalanche forecasts is partially attributable to imperfect knowledge of snow conditions in avalanche starting zones. Direct observation in starting zones is seldom possible, so snow conditions must be extrapolated from weather data gathered nearby. This thesis examines the link between starting zone snow accumulations and weather data available to an avalanche forecaster.

Deep accumulations of new snow are the most frequent cause of avalanches (McClung and Schaerer 1993). Redistribution by wind can produce particularly deep accumulations in avalanche starting zones (McClung and Schaerer 1993), but the processes that control the distribution of snow in alpine terrain are complex (Kind 1981), so estimates of starting zone accumulations are uncertain. Models of the relationship between weather conditions and snow accumulation have been developed for relatively flat terrain (Fohn 1980) but, although redistribution of snow in avalanche terrain has been examined (see for example

Fohn 1980, Fohn and Meister 1983, Hartman 1984, Schmidt 1986, Meister 1989), no formal models linking weather data to starting zone snow accumulations are available (Marriott and Moore 1984).

Avalanche forecasters gather thousands of weather observations to estimate starting zone snow accumulations, but the volume of data, and the lack of a formal model, make interpretation difficult. This thesis proposes a set of statistics to summarize the primary influences on starting zone snow accumulations, and describes the empirical relationships between these summary statistics and observed accumulations. Two research questions are addressed:

1. How do the weather conditions at two upper elevation weather stations relate to the amount of snow deposited in starting zones four kilometers away?
2. How accurately can snow accumulation in the starting zones be estimated from the weather data?

Answers to these questions will help avalanche forecasters interpret weather data, and suggest a limit to the potential accuracy of avalanche forecasts that are based on weather data alone.

Chapter 1 is a brief introduction. Chapter 2 is an overview of snow distribution, avalanches, and avalanche forecasting. Chapter 3 describes some related research, and identifies the gap in that research addressed by this thesis. Chapter 4 describes the methodology used, and presents the summary data. The relationships between the observed weather and snow accumulations are analyzed in chapter 5. The main findings and limitations of the analysis are discussed in chapter 6. Chapter 7 is a brief conclusion.

CHAPTER 2 AVALANCHES AND SNOW DISTRIBUTION

2.0 Introduction

This chapter describes snow distribution in alpine terrain, the role it plays in avalanche formation, and the consequent need to estimate snow accumulation at specific alpine sites.

2.1 Snow Distribution in Alpine Terrain

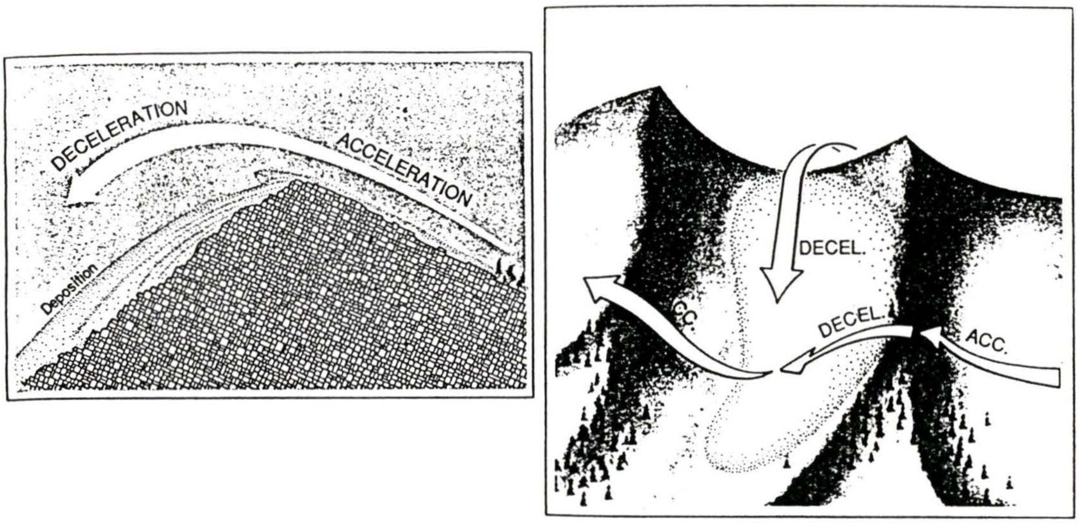
During a storm, lee facing avalanche starting zones can accumulate more than five times as much snow as non-wind-affected areas (McClung and Schaerer 1993). Snow drifting is one of the most important factors in avalanche formation (Kotlyakov and Plam, 1966), but our understanding of the relationship between topography and snow redistribution is incomplete (Berg 1986). The literature addressing the problem of windblown snow in mountainous terrain is sparse (Barry 1992) and no theoretical models are available for predicting the location, size, and depth of drift deposits in avalanche terrain (Kind 1981).

Winds in alpine terrain are extremely variable. Every hill, valley, rock, and tree changes the pattern of air flow so that the detailed wind climate of every landscape is unique (Oke 1987). Even slight variations in synoptic winds can cause marked differences in local wind patterns (Doran and Skyllingstad 1992). When wind encounters a ridge with an upwind or downwind slope greater than 17° the air flow separates from the surface and a low pressure region forms in the lee of the ridge. Eddies form as air is drawn from the flow into the low pressure region and the eddies, seeded into the flow, form a turbulent wake downwind from the ridge (Oke 1987). The complexity of the relationship between terrain and wind makes estimates of winds at specific sites uncertain.

Wind and terrain irregularities combine to cause snow accumulations to vary dramatically in mountainous terrain (Figure 1). Wind accelerates as it approaches, and is constricted by, a ridge and decelerates once past the crest (McClung and Schaerer 1993). If the wind is sufficiently strong during a snow storm, the snow that would otherwise have been deposited on the windward side of the ridge is transported downwind by saltation or turbulent suspension (Radok 1977). Particles transported by saltation bounce along near the surface, while particles in turbulent suspension are carried further aloft and suspended by turbulent air currents. When the air decelerates on the lee of the ridge its capacity to transport snow is diminished and snow settles to the surface. Ridge crests are often bare while the greatest snow accumulations are observed immediately downwind (Fohn 1980).

Snow particles that are already on the surface can be dislodged and transported by wind that is strong enough to overcome the strength of interparticle bonds. The wind speed required to dislodge surface particles - the threshold speed - increases as the bonds develop. The threshold speed is lowest when snow is falling because bonds have not had time to develop and because particle impacts dislodge surface particles much more effectively than wind alone (Schmidt 1980). The threshold speed at the time of deposition is highest in warm temperature, high humidity and strong wind because bond strength increases with temperature, humidity and contact force (Schmidt 1980). Snow particles sublimate as they are transported by the wind (Tabler 1975a), and may disappear completely before they are redeposited if humidity is low and temperature is warm (Pomeroy 1991).

Figure 1 Snow Deposition Patterns in Alpine Terrain

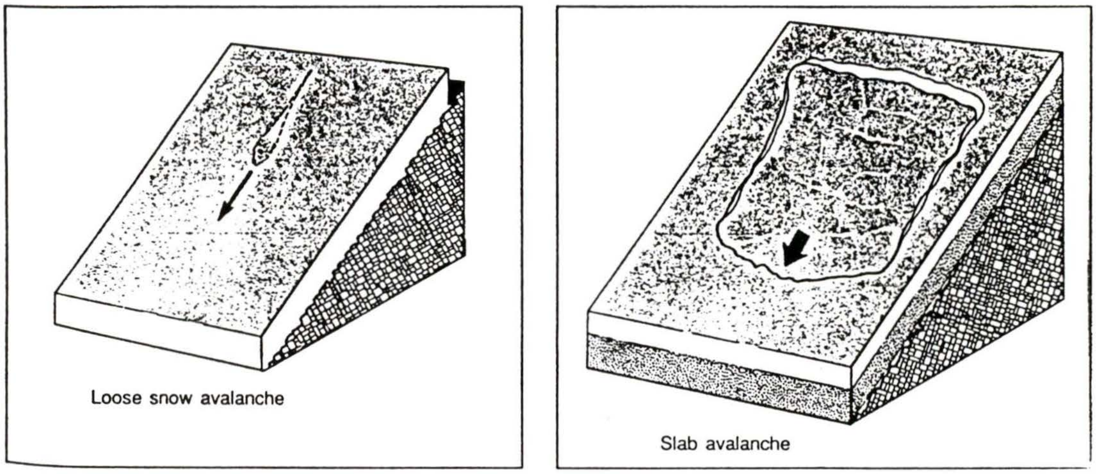


Snow is picked up in acceleration regions and deposited in deceleration regions. This produces lee deposition, cross loading, and deposition in gullies and notches.
From McClung and Schaerer (1993)

2.2 Avalanches

An avalanche is a rapid down-slope movement of a large mass of snow (Schaerer 1981). The snow may begin to move either as loose, individual particles, or as a cohesive slab. A loose-snow avalanche starts at a point near the surface in non-cohesive snow and fans out as it progresses down-slope (Mears 1992) (Figure 2). A slab avalanche occurs when a cohesive surface layer breaks free of the underlying and adjacent snow and begins moving down-slope as a unit. Once in motion, the slab quickly breaks into smaller fragments through friction and collision (Schaerer 1981). Slab avalanches tend to involve much more snow than loose snow avalanches and, as a result, tend to be much more destructive (McClung and Schaerer 1993).

Figure 2 Slab and Loose Snow Avalanches

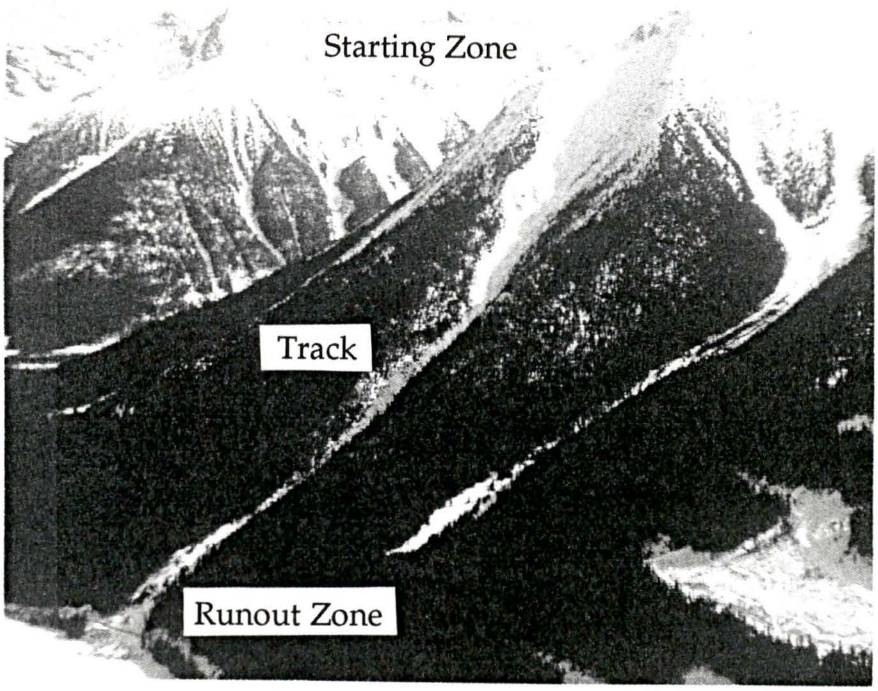


From McClung and Schaerer (1993)

Avalanches recur in the same locations year after year. These locations, or avalanche paths, can be divided into three distinct zones: the starting zone at the top where the snow initially begins to move, the track where the avalanche reaches its maximum speed, and the runout zone at the bottom where it decelerates and stops (Schaerer 1981) (Figure 3). The starting zone must be steep enough to allow an avalanche to start and accelerate but not so steep that snow will not accumulate (McClung and Schaerer 1993). Starting zone inclines typically range from 25° to 50° and most large avalanches begin on slopes between 30° and 40° (Mears 1992). The track incline is usually in the 15° to 30° range, and the runout zone incline is usually less than 15° (Mears 1992).

For a slab avalanche to occur, the starting zone snowpack must have a cohesive slab overlying a weaker layer. The down-slope component of the weight of the slab creates shear stress in the weak layer. Failure begins when the shear stress exceeds the shear strength at one point in the weak layer. This may result from an increase in shear stress, a decrease in shear strength, or a combination of the

Figure 3 Avalanche Path

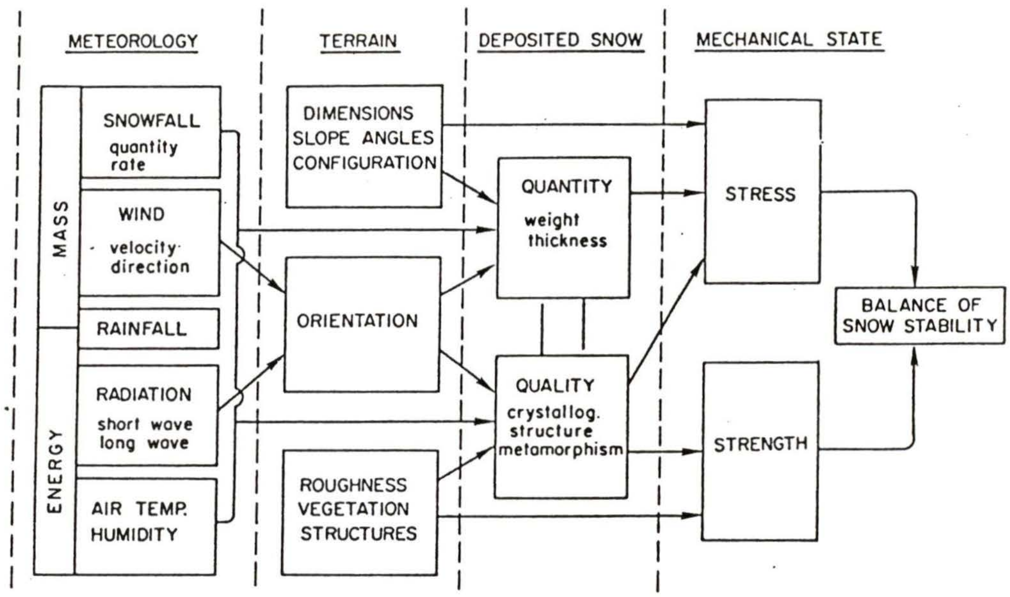


Photograph by author

two (Schaerer 1981). The most common cause of an increase in stress leading to failure is the added weight of accumulating snowfalls or drifting snow (Schaerer 1981, McClung and Schaerer 1993).

Weather and terrain control the quantity and quality of snow deposited in a starting zone. The stress and strength within the starting zone snowpack reflect these interrelated controls. For example, stress increases as snow is deposited by precipitation and wind, but the increased snow depth reduces the temperature gradient within the snowpack and may lead to an increase in the strength of a weak layer (McClung and Schaerer 1993). The complex chain of causation from meteorology to snow stability is illustrated by the Shoda diagram (Figure 4).

Figure 4 Chain of Avalanche Causation



From LaChapelle (1980)

2.3 Avalanche Forecasting

An avalanche forecast is a generalized statement of the future likelihood of avalanching based on the forecaster's estimate of the stress-strength relationship in each avalanche starting zone. Predictions of the start of avalanches are made on an intuitive and empirical basis because the complexity of the stress-strength relationship within an inclined snowpack in an avalanche starting zone makes it impractical to attempt a rigorous, theoretical analysis (Schaerer 1981).

> "There are no instant avalanche forecasts. No fixed formula is available to produce a snow stability rating from arbitrary snow and weather parameters. The forecast is instead integrated through time with evidence accumulated by increments ... This process is intuitively understood and practiced by every successful avalanche forecaster (LaChapelle 1980;76)".

Avalanche forecasters use point measurements of snow and weather parameters to estimate snow and weather conditions throughout entire avalanche areas. Estimates of starting zone snow accumulations are based largely on the forecaster's experience in the area (Marriott and Moore,1984). Where forecasters cannot measure starting zone snow accumulations, estimates are based on an informal model of the controlling processes (Marriott and Moore, 1984).

The forecaster's model of snow redistribution is simple: snow is picked up where the wind is accelerating, transported by a combination of several mechanisms while the wind is sufficiently strong, and deposited where the wind decelerates (McClung and Schaerer 1993). On alpine ridges snow is picked up on the windward side and deposited on the lee side (McClung and Schaerer 1993). Low humidity increases sublimation of blowing snow and reduces accumulation, and very warm temperatures may enhance windward slope "plastering" at the expense of lee slope deposition (Perla and Martinelli 1976). When a deep accumulation of snow forms a heavy cohesive slab, that slab may overload an underlying weak layer, causing it to fail in shear, and start an avalanche. A numerical model that incorporates all these processes could be used to assist forecasters in estimating starting zone accumulations.

CHAPTER 3 RELATED RESEARCH

3.0 Introduction

Most of the research on snow redistribution has focused on either water storage on agricultural land and in watersheds, or drift formation on roads and railways. Snow redistribution in avalanche starting zones is a very different problem because the terrain and resulting wind patterns are much more complex. Fohn (1980), Fohn and Meister (1983), Hartman (1984), Schmidt and Hartman (1986, 1988), and Meister (1989) investigated snow accumulation in avalanche starting zones but did not examine the effect of changing wind directions, or varying starting zone aspects. Estimates of snow accumulation in individual starting zones must take these effects into account, so these gaps in the existing research will have to be filled before a numerical model can be developed to estimate starting zone snow accumulations from weather data.

3.1 Deterministic Models

Many researchers, including Radok (1977), Tabler et al.(1990), and Pomeroy (1991), have investigated snow drifting and the relationship between wind speed and snow drift flux. The drift flux research contributed to the development of several deterministic snow distribution models but none that can be used to predict starting zone snow accumulations.

Tesche (1988) combined deterministic models of cloud physics, mountain winds, and snow drifting processes to predict precipitation accumulations at points on a 2 kilometre square grid in a 70 by 80 kilometre area in California's Sierra Nevada mountains. The model was evaluated with data from a storm on March 30, 1982. The predicted average snow accumulation for the study area was only

6 percent greater than the observed average, but the predicted precipitation at any one point was, on average, 75 percent greater or less than the observed precipitation at that point.

Uematsu et al.(1991) successfully modelled the air flow and consequent snow accumulation patterns associated with an isolated, symmetrical, 16 metre hill. However, the greater complexity of avalanche terrain and the associated turbulent airflow make the application of the model to starting zones a difficult problem.

3.2 Empirical Models

Empirical studies of the relationship between weather and snow accumulation in avalanche terrain have been reported by Fohn (1980), Fohn and Meister (1983), Hartman (1984), Schmidt and Hartman (1986, 1988), and Meister (1989). These studies examined windward and lee slope snow accumulation without defining the wind direction/slope aspect relationship that makes a slope one or the other. This is an important omission since a slope that is directly lee will have a different snow deposition pattern than a slope that is 45° from directly lee and a lee slope one day can become a windward slope the next when the wind direction changes. None of the existing research provides a model to assist avalanche forecasters with their fundamental task: predicting snow accumulations in starting zones with a full range of aspects.

Fohn (1980) conducted a detailed study of snow transport at two similar ridge crests near Davos, Switzerland. The wind profile and drift flux were measured at one site, and the areal snow distribution was measured at the other. The areal snow distribution across the ridge was described by comparing the average snow accumulation on the windward side, the lee side, and at a drift free site. Fohn's data revealed that the snow accumulation on the upper portion of the observed lee slopes was related to the cube of the observed wind speed and that most of the blowing snow processes were limited to within 200 metres of the ridge. In conclusion, Fohn proposed that "aerial mass balance measurements of storm periods...may be used to derive much needed quantitative relationships between crest winds and drift-snow deposition on lee slopes (Fohn 1980;480)". An important limitation of this and several other studies is that the effect that variations in wind direction had on the snow deposition pattern is not discussed and "lee slope" is not defined.

A second study of snow distribution on the ridges near Davos was reported by Fohn and Meister (1983). This study, conducted over four winters, described the overall deposition characteristics on several ridges, and proposed a theoretical approximation of the wind transport processes to explain the observed patterns. Snow water equivalent measurements were taken every 2 to 4 metres along several parallel transects spaced 20 metres apart along each ridge. Each field study resulted in 600 to 1000 data points per ridge, making this the largest study of its kind reported in the literature. The ridges in the study were perpendicular to the prevailing winds. The ratio of water equivalent on the windward side to water equivalent on the leeward side ranged from 1.1 to 2.7, with a mean of 1.63 over the course of the study. The lee and windward slopes combined accumulated the same amount of snow as flat non-wind-affected terrain. The distribution patterns produced by the theoretical models were similar to those observed, but the model's ability to predict the actual quantity of snow deposited was not evaluated. Fohn and Meister recognized that their study was limited to simply shaped ridges that approximated a two dimensional barrier to the prevailing wind and that the process model they proposed could not be expected to apply to more complex terrain shapes. Again, as in Fohn's 1980 study, no accommodation was made for wind direction variability.

Hartman (1984) observed snow accumulation and ablation along several transects at Snowmass, Colorado, to determine the relationships between weather conditions, changes in fetch storage, and changes in starting zone snow accumulation. The transects paralleled the prevailing wind direction and included a single, five location transect in a fetch and several seven location transects in starting zones. Snow depths were recorded after each significant weather event and related to the prevailing weather conditions. Hartman concluded that wind directions of 20° from perpendicular to the ridge caused "accumulation to diminish significantly", that precipitation at the time of transport greatly increased starting zone accumulations, that starting zone snow accumulation was a function of wind speed [increasing to a maximum at 24 m/s (86 km/hr)], and that "the majority of snow deposited in the fetch over the entire winter season either is never transported out of the fetch, sublimates during transport, or is transported beyond starting zones to more dense forest cover of lower elevations (Hartman 1984;197)".

Schmidt and Hartman (1986) described equations to account for fetch storage and sublimation loss, two of the important controls of starting zone accumulation identified by Hartman (1984). The fetch storage equation provides a good estimate of the observed fetch storage but, since the equation requires snow depth in the fetch as an input, it cannot be applied in areas where the fetch is inaccessible. A theoretical sublimation loss equation was proposed to calculate the portion of the drifting snow that sublimates as a function of fetch distance, wind speed, temperature, and humidity. The equation was not tested with empirical data so its accuracy is not known.

Berg (1986) developed a model to calculate snow depth in a depression on a lee slope as a function of wind speed, snowfall rate, and ground topography. Berg found that deposition downwind from the flow separation point was maximized at moderate wind speeds, at higher speeds blow-past predominated, and at lower speeds there was insufficient energy to propel particles far leeward.

Schmidt and Hartman (1988) presented a simple method to identify which paths in the Snowmass ski area were most likely to be loaded by the observed winds. The method required that the wind direction for maximum snow accumulation efficiency be identified, based on experience, for each avalanche path. The difference between the observed wind direction and the maximum snow accumulation direction was used to generate an index of loading efficiency for each path. The index was set at 100 if the observed wind direction was the same as the maximum snow accumulation direction. For each degree of difference between the observed wind direction and the maximum snow accumulation direction the index value was reduced by 5. Thus, if the observed wind direction was 20 degrees from the maximum snow accumulation direction, the loading efficiency index would be 0. The meaning of a loading efficiency index of 0 was not defined but it implies that a lee slope that had an aspect more than 20° off the incident wind angle would receive no wind deposited snow. This relationship is not reported elsewhere in the literature and Schmidt and Hartman did not present data to support their theory.

Schroeter and Whiteley (1987, 1990) developed a model to predict snow accumulations and stream flow in the Grand River basin in Ontario. The Grand River basin is much flatter than avalanche terrain, but the approach applied by Schroeter and Whiteley may be applicable to starting zone snow accumulation modelling. The basin was divided into "zones of uniform meteorology" (ZUM) and each ZUM was subdivided, based on field observations, into "blocks of equivalent accumulation" (BEA) to account for snow accumulation variation. The weather in each ZUM was sampled regularly. When the wind was sufficiently strong, the model redistributed snow from those BEAs with a low capacity to store snow to those with a high capacity to store snow. Wind direction determined which blocks gained or lost snow (Schroeter et al. 1991).

In avalanche terrain, the area represented by a weather station is analogous to a ZUM, and the areas of equivalent aspect near ridges are analogous to BEAs. The amount of snow deposited in a starting zone depends on the amount of snow deposited at a nearby wind-free site (the weather station), the aspect of the starting zone with respect to the wind direction, and the wind speed. Schroeter and Whiteley's empirical model has been useful in the Grand River Basin (Schroeter et al. 1991), and a similar empirical model of starting zone snow accumulation may also prove useful, although field verification in avalanche terrain would be much more difficult.

None of the snow distribution models described have been used for operational avalanche forecasting. The empirical studies of snow distribution in avalanche terrain failed to incorporate the full range of starting zone aspects and wind directions as controls of snow accumulation. Tesche's deterministic model generated estimated snow accumulations on a grid too coarse to predict accumulations in individual starting zones and did not adequately account for the observed snow accumulation variation. Uematsu's model was not extended beyond the simple domain for which it was developed.

Forecasters routinely estimate starting zone snow accumulations from weather data gathered nearby. A numerical model linking the weather data, including all wind directions, to snow accumulations in all starting zones, would be a useful forecasting tool. As a first step toward developing such a model, the next four chapters describe and analyze the relationship between weather data and snow accumulations in two avalanche starting zones.

CHAPTER 4 METHODOLOGY

4.0 Introduction

The empirical relationships between snow accumulations and weather conditions were examined in the Coquihalla avalanche area during February and March 1994. Data were compiled for seven time periods: February 10 - 22, February 22-25, February 25-March 3, March 3-8, March 8-15, March 15-16, and March 16-17. Snow accumulations were measured at the end of each time period along two starting zone transects and one reference transect. Weather conditions were recorded hourly at two nearby upper elevation MoTH weather stations, as part of the Coquihalla highway avalanche safety program.

4.1 Study Site

The study was conducted near the Coquihalla highway, in the Boston Bar Creek valley, approximately 40 km northeast of Hope, British Columbia (Figure 5). Snow data were gathered three kilometres south of the highway, on the ridges west of Needle Peak. Weather data were gathered four kilometres northwest of the snow study sites (Figure 6).

Sixty-nine avalanche paths threaten the 20 kilometre stretch of the Coquihalla highway in the Boston Bar Creek valley. An avalanche hazard management program has been in place since the highway opened in 1986 (B.C. MoTH 1992). Snow stability is monitored throughout each winter and the highway is closed when avalanches are expected. Explosives are used to release avalanches when the highway is closed. The avalanche team gathers weather, snowpack, and avalanche occurrence data to provide the basis for the avalanche forecast. The weather data include manual observations taken twice daily at the summit of the

Figure 5 Location Map

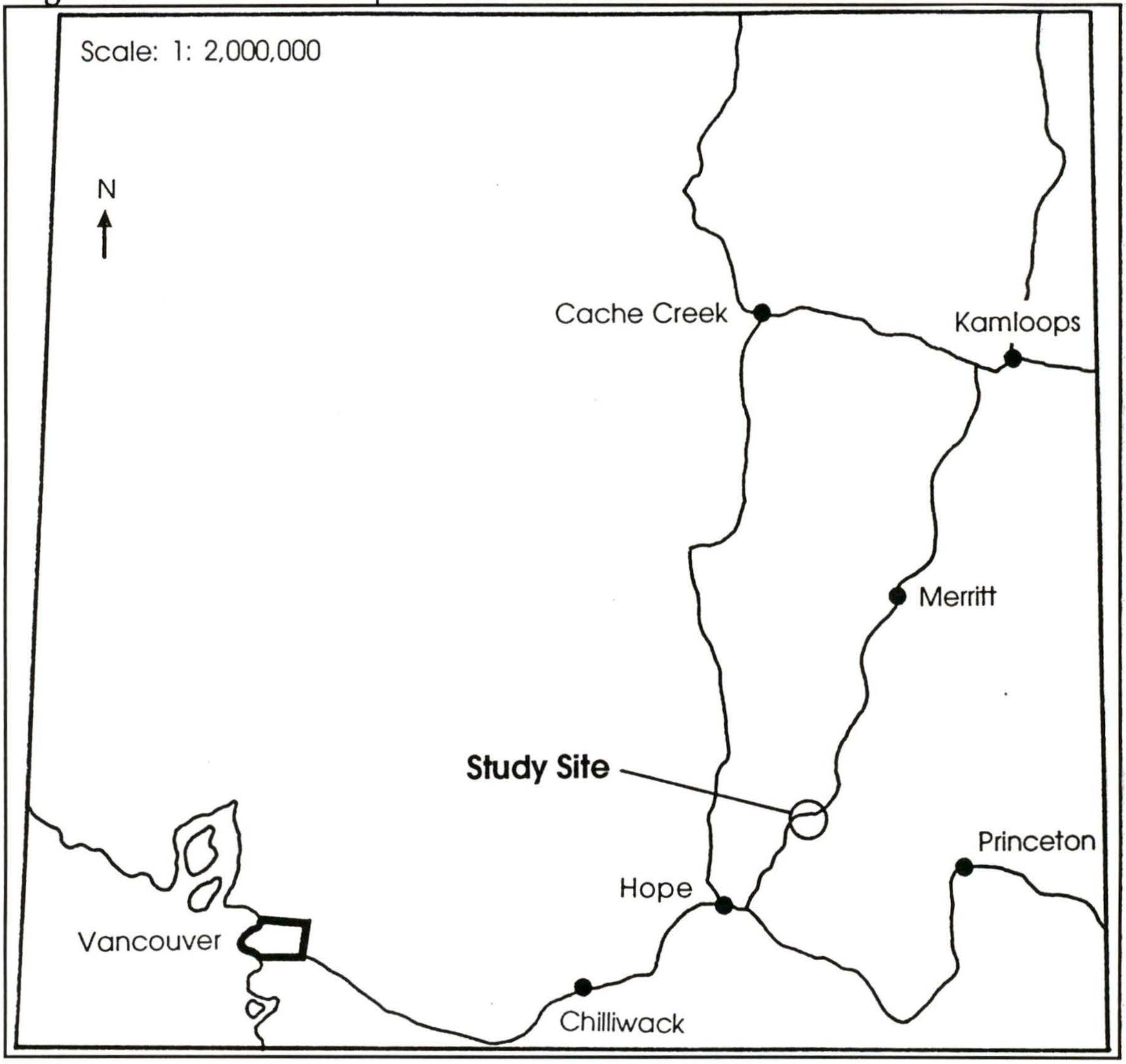
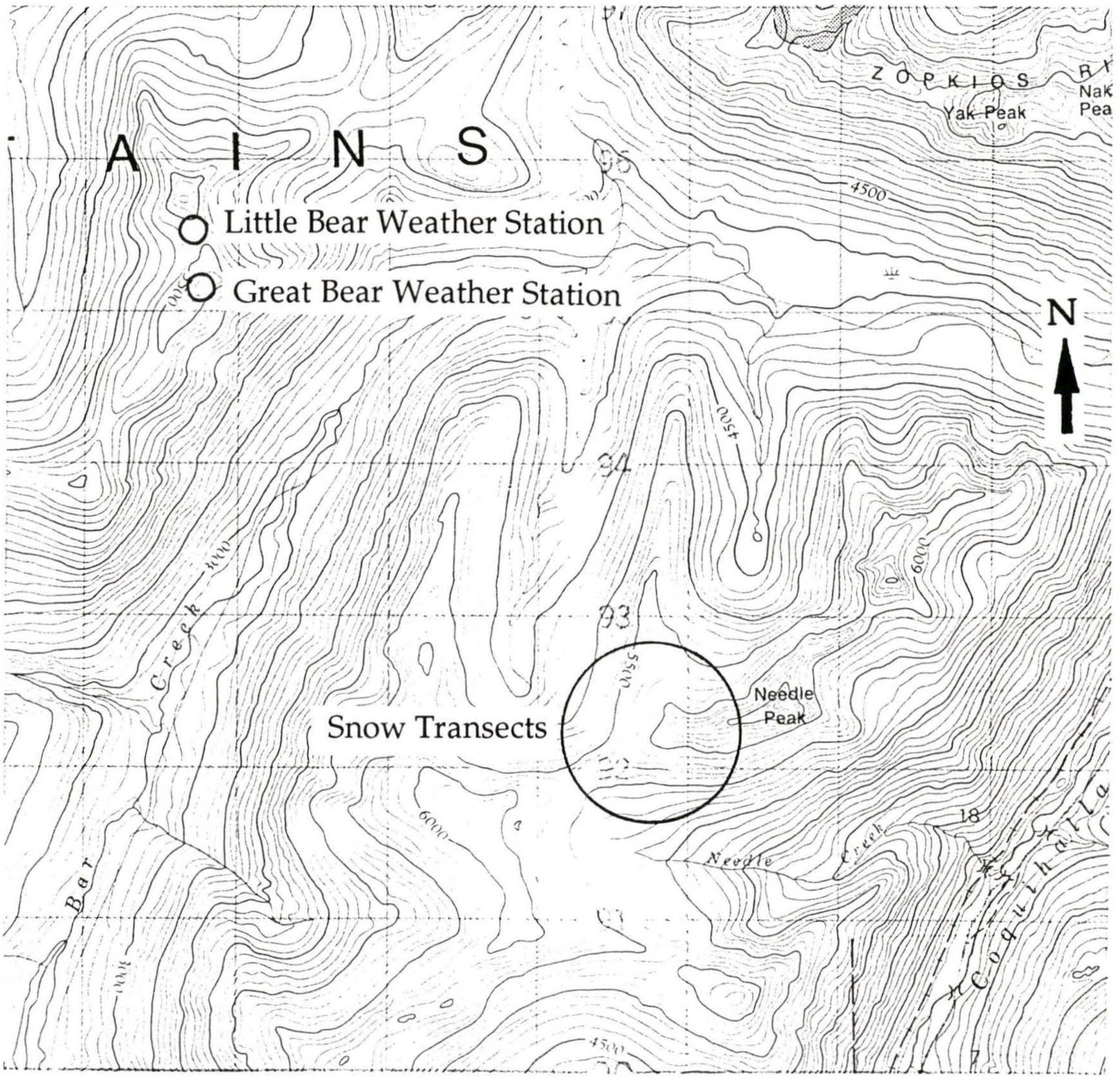


Figure 6 Location of Weather Stations and Snow Transects



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highway, and automatic measurements taken every hour at five upper elevation stations.

4.2 Weather Data

The weather data for this study were collected at the Great Bear and Little Bear remote automatic weather stations. These stations use data loggers to gather measurements from an array of sensors. The data are transmitted hourly by radio to a base station computer at the Coquihalla Summit avalanche office and forwarded by phone to a database in Victoria.

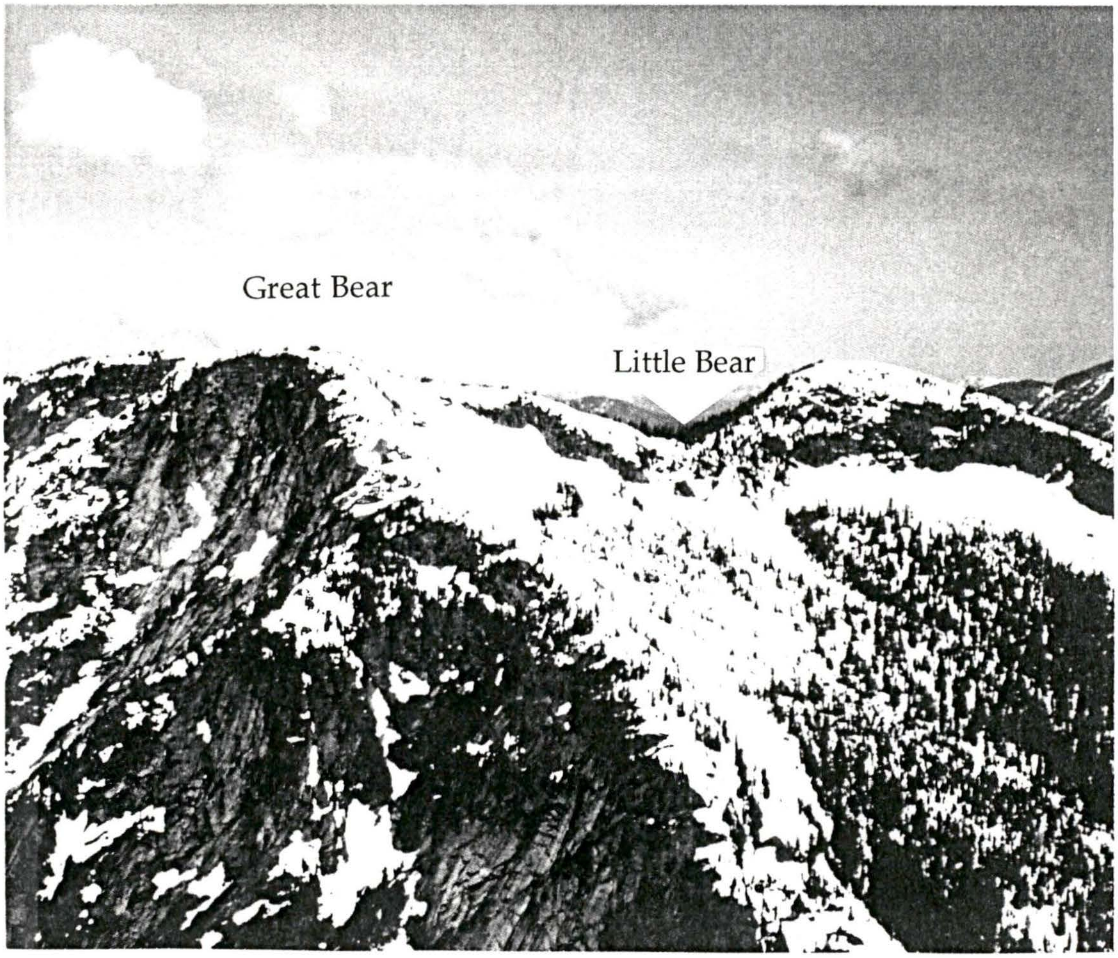
The Great Bear weather station is on the summit of a 1730 m mountain (Figures 7 and 8). Data recorded at Great Bear includes wind speed, wind direction, temperature, and humidity. The hourly temperature and humidity measurements are instantaneous readings. The hourly wind speed and direction measurements are average vector values, calculated from 30 instantaneous speed and direction measurements taken at two minute intervals throughout the hour, using Campbell Scientific's wind vector algorithm (see Appendix 3). The wind sensors are automatically sprayed with alcohol to prevent rime accumulation and consequent inaccurate readings.

The Little Bear weather station is in an opening in the forest, 400 m north of Great Bear, at 1650 m elevation (Figures 8 and 9). Precipitation is measured hourly in a "standpipe" precipitation guage; a 38 cm diameter, 1 m high, plastic pipe that is mounted on top of a tower. The pipe is partially filled with antifreeze, which is periodically stirred by a pump, to ensure that all the snow falling into the guage dissolves in the antifreeze solution (Campbell 1988). The weight of the solution is measured with a pressure transducer, and translated

Figure 7 Great Bear Weather Station

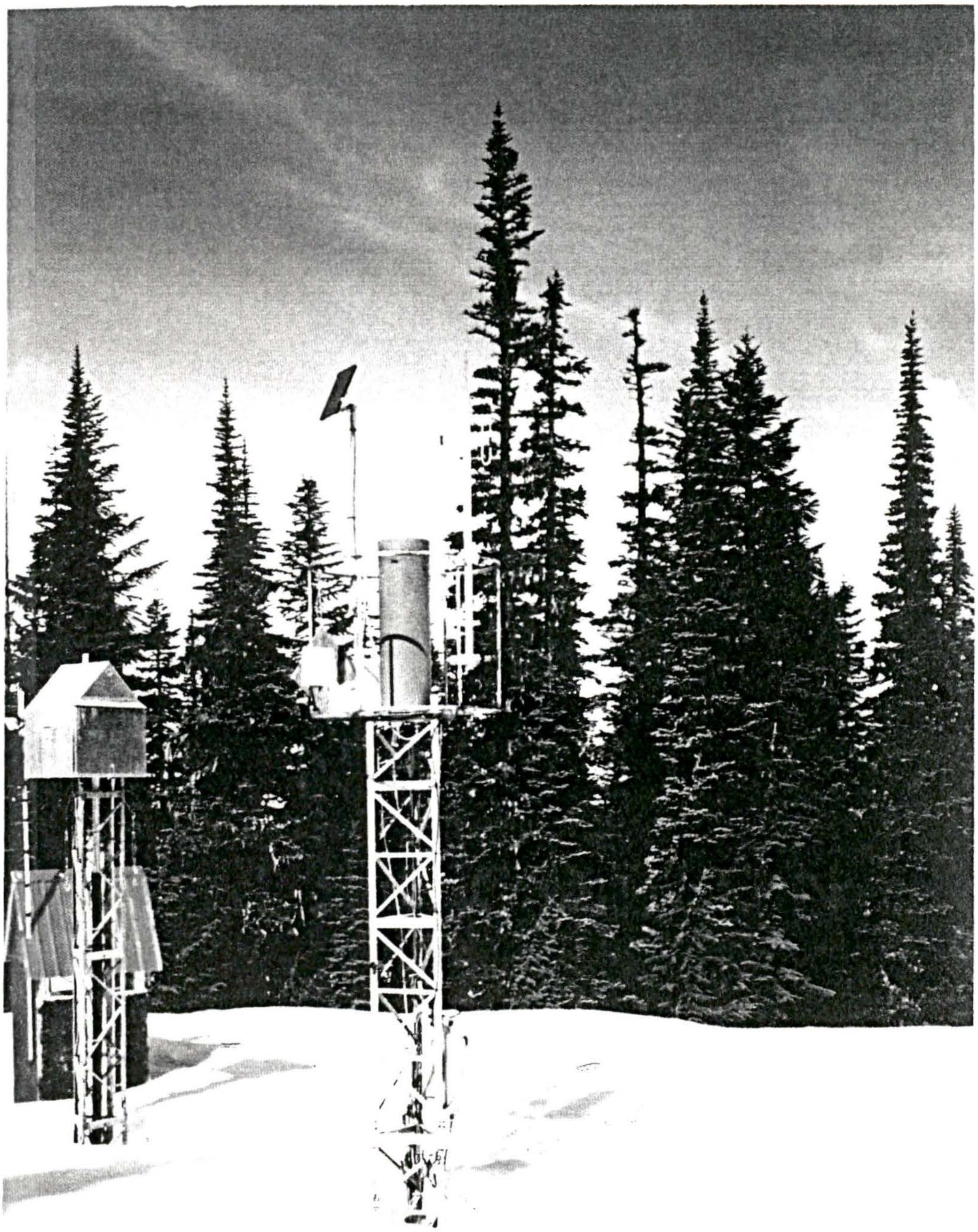
Photograph by author

Figure 8 Great Bear and Little Bear Weather Stations



Photograph by author

Figure 9 Little Bear Weather Station



Photograph by author

into millimeters of precipitation by the data logger. The sheltered location minimizes the effect of the wind on the precipitation catch, and the large diameter of the pipe minimizes capping. The guage was designed specifically for avalanche weather conditions (Campbell 1988) and the readings agree closely with readings at a Ministry of Environment snow course at the same site (Golley 1994).

4.2.1 Precipitation, Temperature and Humidity

Precipitation, temperature and *humidity* summary statistics were calculated for each snow accumulation period. Italics are used to distinguish the statistics from the measured properties.

The *precipitation* for an accumulation period is the sum of the positive hourly precipitation readings that are neither preceded nor followed by a negative reading. A positive reading preceded or followed by a negative reading is assumed to be a fluctuation caused by something other than precipitation. For March 16-17 for example (Table 1), there were 11 hours when precipitation was recorded, and *precipitation* was 15 mm. Hourly precipitation measurements may differ from actual precipitation because of missed catch (blowover) and guage capping (Marriott and Moore 1984), but, since actual precipitation is unknown, the magnitude of the errors are unknown.

The *temperature* and *humidity* for each accumulation period are the arithmetic means of the temperatures and relative humidities recorded during the hours that precipitation was recorded. Temperatures and humidities during hours without precipitation are excluded because they are assumed to have had relatively little influence on snow accumulation since little snow accumulates,

Table 1

Weather Data for March 16 - March 17

Date	Time	Ppt. guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when Ppt (%)	Temp (°C)	Temp when ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	when ppt y (km/h)
16-Mar-94	15:00	530	0	0	0	90	0	-4.5	0	253	38	-36.34	-11.11	0.00	0.00
16-Mar-94	16:00	531	1	1	1	90	90	-4.8	-4.8	240	29	-25.11	-14.50	-25.11	-14.50
16-Mar-94	17:00	531	0	0	0	91	0	-4.9	0	234	23	-18.61	-13.52	0.00	0.00
16-Mar-94	18:00	532	1	1	1	91	91	-4.8	-4.8	231	17	-13.21	-10.70	-13.21	-10.70
16-Mar-94	19:00	532	0	0	0	92	0	-4.9	0	187	15	-1.83	-14.89	0.00	0.00
16-Mar-94	20:00	532	0	0	0	92	0	-5	0	205	10	-4.23	-9.06	0.00	0.00
16-Mar-94	21:00	534	2	2	1	92	92	-5.1	-5.1	198	10	-3.09	-9.51	-3.09	-9.51
16-Mar-94	22:00	536	2	2	1	92	92	-5.1	-5.1	197	9	-2.63	-8.61	-2.63	-8.61
16-Mar-94	23:00	538	2	2	1	92	92	-5.4	-5.4	203	15	-5.86	-13.81	-5.86	-13.81
17-Mar-94	00:00	538	0	0	0	92	0	-6.6	0	234	34	-27.51	-19.98	0.00	0.00
17-Mar-94	01:00	538	0	0	0	92	0	-6.9	0	236	30	-24.87	-16.78	0.00	0.00
17-Mar-94	02:00	540	2	2	1	92	92	-6.8	-6.8	233	29	-23.16	-17.45	-23.16	-17.45
17-Mar-94	03:00	540	0	0	0	92	0	-6.7	0	238	27	-22.90	-14.31	0.00	0.00
17-Mar-94	04:00	541	1	1	1	92	92	-6.6	-6.6	249	24	-22.41	-8.60	-22.41	-8.60
17-Mar-94	05:00	542	1	1	1	92	92	-6.5	-6.5	252	29	-27.58	-8.96	-27.58	-8.96
17-Mar-94	06:00	542	0	0	0	92	0	-6.7	0	236	25	-20.73	-13.98	0.00	0.00
17-Mar-94	07:00	543	1	1	1	92	92	-6.8	-6.8	231	23	-17.87	-14.47	-17.87	-14.47
17-Mar-94	08:00	544	1	1	1	92	92	-6.8	-6.8	241	29	-25.36	-14.06	-25.36	-14.06

Table 1 continued

Date	*Time*	*Ppt. guage total (mm)*	*Ppt. change (mm)*	*Hrly ppt. filtered for noise (mm)*	*Ppt. this hour (1=Yes)*	*RH (%)*	*RH when Ppt (%)*	*Temp (°C)*	*Temp when ppt (°C)*	*Wind Dir (°)*	*Wind Speed (km/h)*	*Wind Vector Coordinates* *x (km/h)*	*y (km/h)*	*when ppt x (km/h)*	*when ppt y (km/h)*
17-Mar-94	09:00	544	0	0	0	92	0	-6.3	0	249	31	-28.94	-11.11	0.00	0.00
17-Mar-94	10:00	544	0	0	0	92	0	-6.3	0	220	26	-16.71	-19.92	0.00	0.00
17-Mar-94	11:00	544	0	0	0	91	0	-5.9	0	226	23	-16.54	-15.98	0.00	0.00
17-Mar-94	12:00	545	1	1	1	91	91	-4	-4	217	18	-10.83	-14.38	-10.83	-14.38
17-Mar-94	13:00	545	0	0	0	91	0	-4.5	0	230	15	-11.49	-9.64	0.00	0.00
Total				**15**	11										
Average for hrs with ppt:							**91.6**		**-5.7**					-16.1	-12.3

Average Wind Speed:	20.2
Average Wind Direction:	232.7

Loading Winds

transect	*aspect*	*incident angle*	*speed*	*loading wind*
A	210	157.3	20.2	**-18.7**
B	76	23.3	20.2	**18.6**

even on lee slopes, when it is not snowing. For March 16-17 the *temperature* was -5.7°C and the *humidity* was 91.6% (Table 1).

4.2.2 Loading Wind

The new parameter - *loading wind* - is proposed to account for the combined effect of wind speed, wind direction, and starting zone aspect on starting zone snow accumulation. The *loading wind* for each starting zone is the vector component of the observed average wind that parallels the down-slope direction of that starting zone. *Loading wind* is an extremely simplified representation of the real effective loading wind at a starting zone but there are no alternative methods described in the literature. No empirical studies to date have adequately accounted for these important influences on snow distribution and no published work uses a parameter similar to *loading wind.*

Wind and aspect act together to cause snow accumulation to differ from the general snow accumulation: windward starting zones receive less snow than average while lee starting zones receive more (Fohn 1980). Strong winds have a more pronounced effect on snow distribution than light winds (Berg 1986). The loading effect of wind is negative (scouring) on windward slopes, positive (depositing) on lee slopes (McClung and Schaerer, 1993) and ranges from negative to positive as some unknown function of wind direction relative to the starting zone aspect.

*Loading wind*s were calculated by first calculating the average wind at Great Bear weather station during each accumulation period, then calculating the vector components of the average wind that paralleled the down-slope directions of transects A and B.

Average winds were calculated by extending the hourly wind algorithm used by the Great Bear data logger (see Appendix 3). Where the hourly wind algorithm calculated the average of 30 instantaneous speed and direction measurements taken during the hour, the accumulation period *loading wind* algorithm calculates the average of the hourly winds recorded during hours when precipitation was recorded. Hourly winds when no precipitation was recorded are excluded because snow accumulation is assumed to be negligible between storms.

Loading wind calculations follow five steps:

1. Calculating x and y coordinates to represent the hourly wind vectors: Hourly wind speed (km/hr) and wind direction (azimuth), are measured separately, but are represented as a single vector from a point (x,y) to the origin (0,0). The formulae for calculating the x and y coordinates of an hourly wind vector are:

   $$x = \text{wind speed} \times \sin(\text{wind direction})$$
   $$y = \text{wind speed} \times \cos(\text{wind direction})$$

   For example, if the hourly wind speed were from 60° at 10 km/hr (Figure 10): $x = 10 \times \sin(60) = 8.6$

   $$y = 10 \times \cos(60) = 5.0$$

2. Calculating the average wind vector for the accumulation period: The average wind vector is represented by its coordinates, X and Y, where:

   $$X = \frac{\Sigma x \text{ (when ppt recorded)}}{\text{number of hours when ppt recorded}}$$
   $$Y = \frac{\Sigma y \text{ (when ppt recorded)}}{\text{number of hours when ppt recorded}}$$

   For example, if the x and y coordinates of two hourly winds are (8.6 , 5) and (-8.6 , 5) then the x and y coordinates (X,Y) of the average of the two are (Figure 11): $X = \frac{-8.6 + 8.6}{2} = 0$

   $$Y = \frac{5 + 5}{2} = 5$$

Figure 10 Wind Vector Coordinates

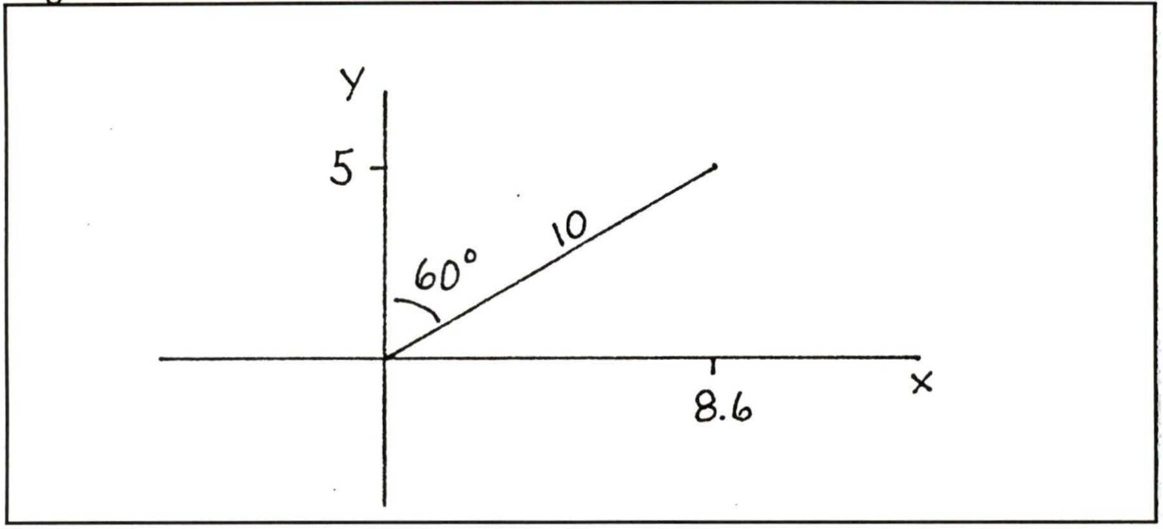
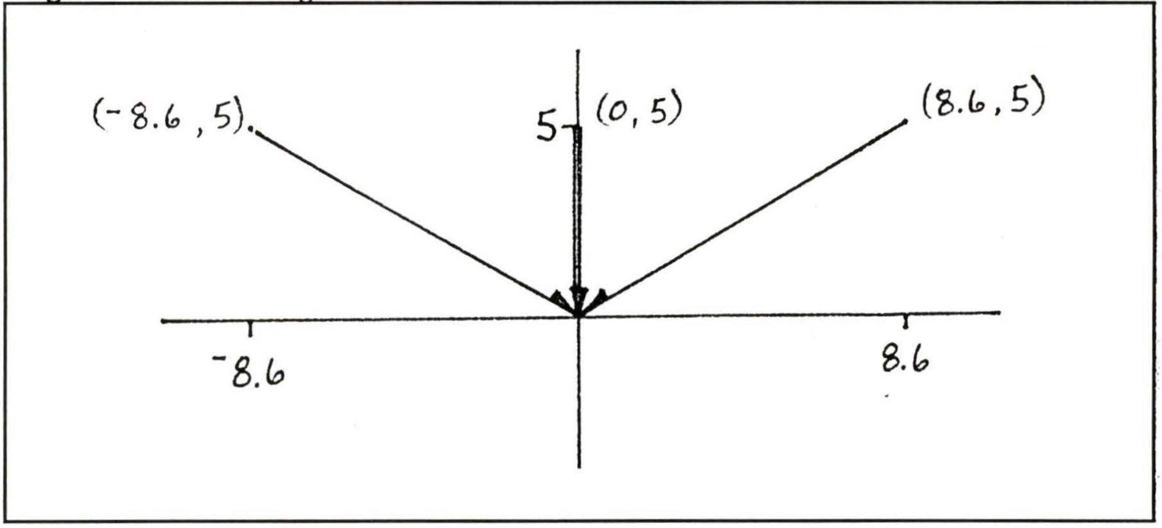


Figure 11 Average Wind Vector Coordinates



3. Calculating the average wind speed and average wind direction:
   The formula for average wind speed (S) is:

   $$S = \sqrt{X^2 + Y^2}$$

   So, continuing with the example, $S = \sqrt{0^2 + 5^2} = \sqrt{25} = 5$

   The formula for average wind direction (D) is:

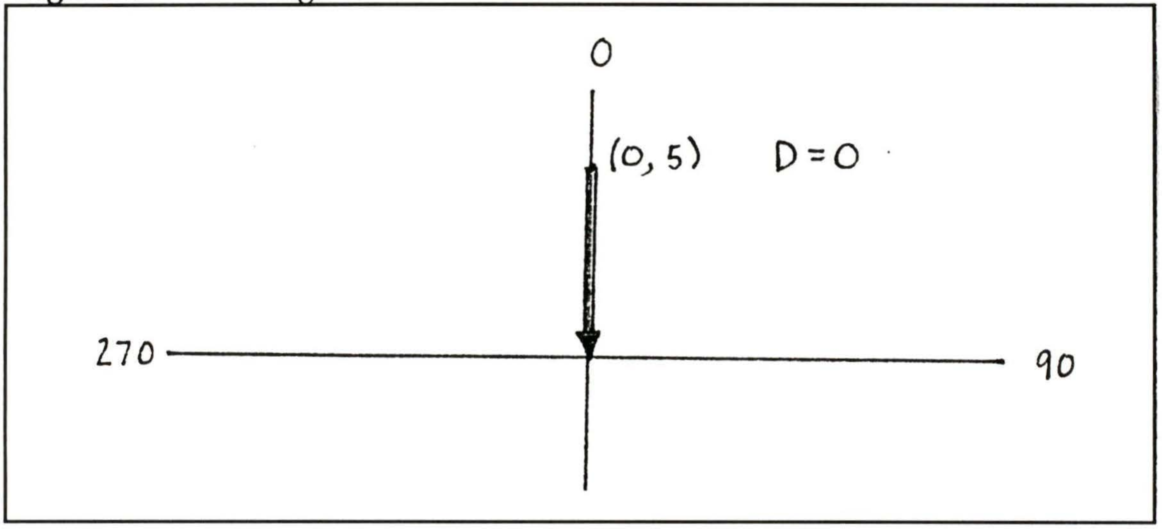
   $$D = 90 - \text{atan2}(X,Y) \times 180/PI \quad \text{if } (\text{atan2}(X,Y) \leq 90)$$

   $$D = 450 - \text{atan2}(X,Y) \times 180/PI \quad \text{if } (\text{atan2}(X,Y) > 90)$$

   This follows the procedure for calculating azimuth from rectangular coordinates described by Robinson and Sale (1953). "Atan2" is a Microsoft

Excel function that returns the angle from the x axis to a line containing the origin (0,0) and a point (X,Y). The angle is measured counter clockwise, so, for example, atan2 (8.6 , 5) returns 30, and atan2 (-8.6, 5) returns 150. For X=0 and Y=5, atan2(0 , 5) = 90, and D = 90 - 90 = 0 (Figure 12).

Figure 12 Average Wind Direction



4. Calculating average wind speed and direction:
   The angle formed by the average wind direction and transect aspect is the incident wind angle (A). The algorithm for calculating A is:

$$A = 180 - (|\text{aspect} - D|) \quad \text{if } (-180) \leq (\text{aspect} - D) \leq 180$$

$$A = 180 - (-1 \times ((\text{aspect} - D) - 360)) \quad \text{if } (\text{aspect} - D) > 180$$

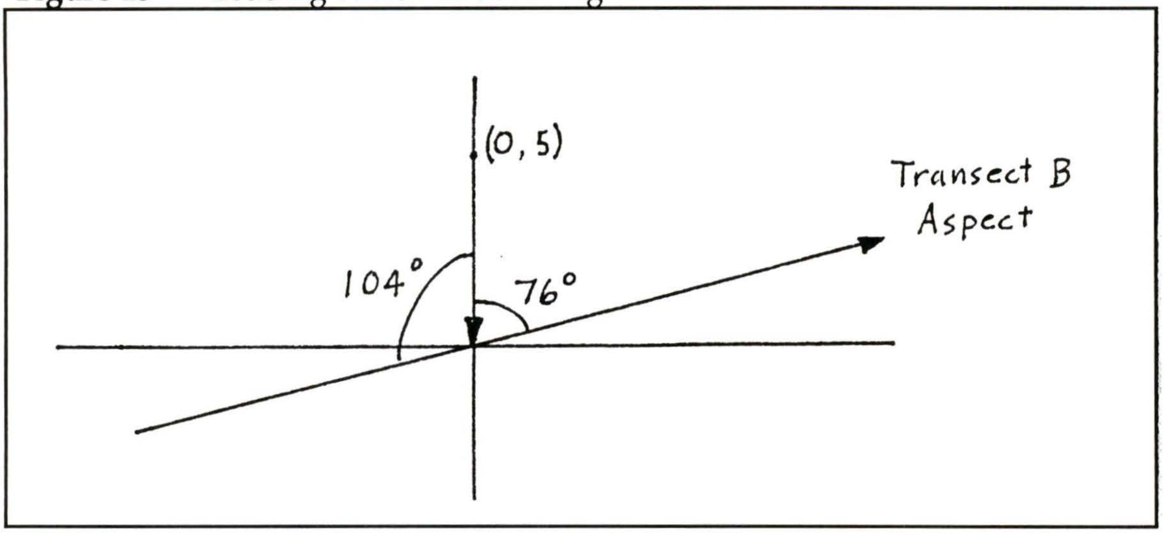
$$A = 180 - ((\text{aspect} - D) + 360) \quad \text{if } (\text{aspect} - D) < -180$$

The aspect of transect B is 76°, so with the wind coming straight out of the north (D = 0), the incident angle at transect B is (Figure 13):

$$A = 180 - |76 - 0|$$

$$A = 104$$

Figure 13 Loading Wind Incident Angle



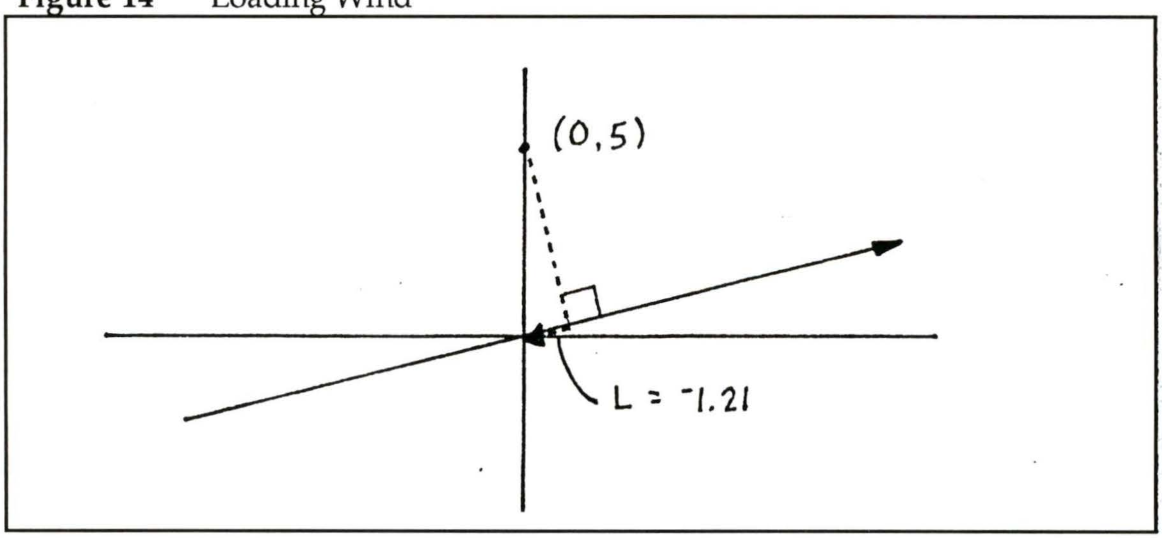
5. Calculating *loading wind* for each transect:
   Loading wind (L) is calculated from the incident angle (A) and average wind speed (S) (Figure 14):

   L = cos A x S

   So, when the average wind speed (S) = 5 and the incident angle (A) = 104:

   L = cos 104 x 5 = -1.21

Figure 14 Loading Wind



The *loading winds* for March 16 and 17, and the inputs used to calculate them, are shown in Table 1. The X and Y coordinates of the average wind vector were -16.1 and -12.3. These coordinates represented a 20.2 km/hr wind from 232.7°. The incident angles were: 157.3° for transect A, and 23.3° for transect B. *Loading wind* was -18.7 at transect A, and 18.6 at transect B. See Appendix 1 for the average winds and *loading winds* for all accumulation periods.

4.3 Snow Data

Snow accumulations were observed along three transects, A, B, and C, within a one square kilometre area, four kilometres southeast of Great Bear weather station (Figure 15). Transects A and B provided a measure of wind-affected snow accumulations in avalanche starting zones. Transect C provided a measure of snow accumulation at a sheltered site nearby.

Transects A and B were on steep open slopes that appeared to be starting zones for infrequent avalanches, though neither slope avalanched during the study. The transects were 200 metres long running straight down the fall line from the ridge crests to ensure that the effects of blowing snow processes caused by the ridges were adequately represented (Fohn (1980) observed that these processes were largely contained within 200 metres of ridge crestlines). Each transect had seven snow measurement stations. The stations were 25 metres apart for the first 100 metres from the ridge, where the greatest snow accumulation irregularity was expected (Fohn and Meister 1983), and 50 metres apart for the second 100 metres. Transect A (Figure 16 and 18) had an aspect of 210°, measured by compass, a maximum elevation of 1790 metres, measured by altimeter, and a maximum incline between stations of 33°, measured by clinometer. Transect B (Figure 17 and 19) had an aspect of 76°, a maximum

Figure 15 Map of Snow Transects

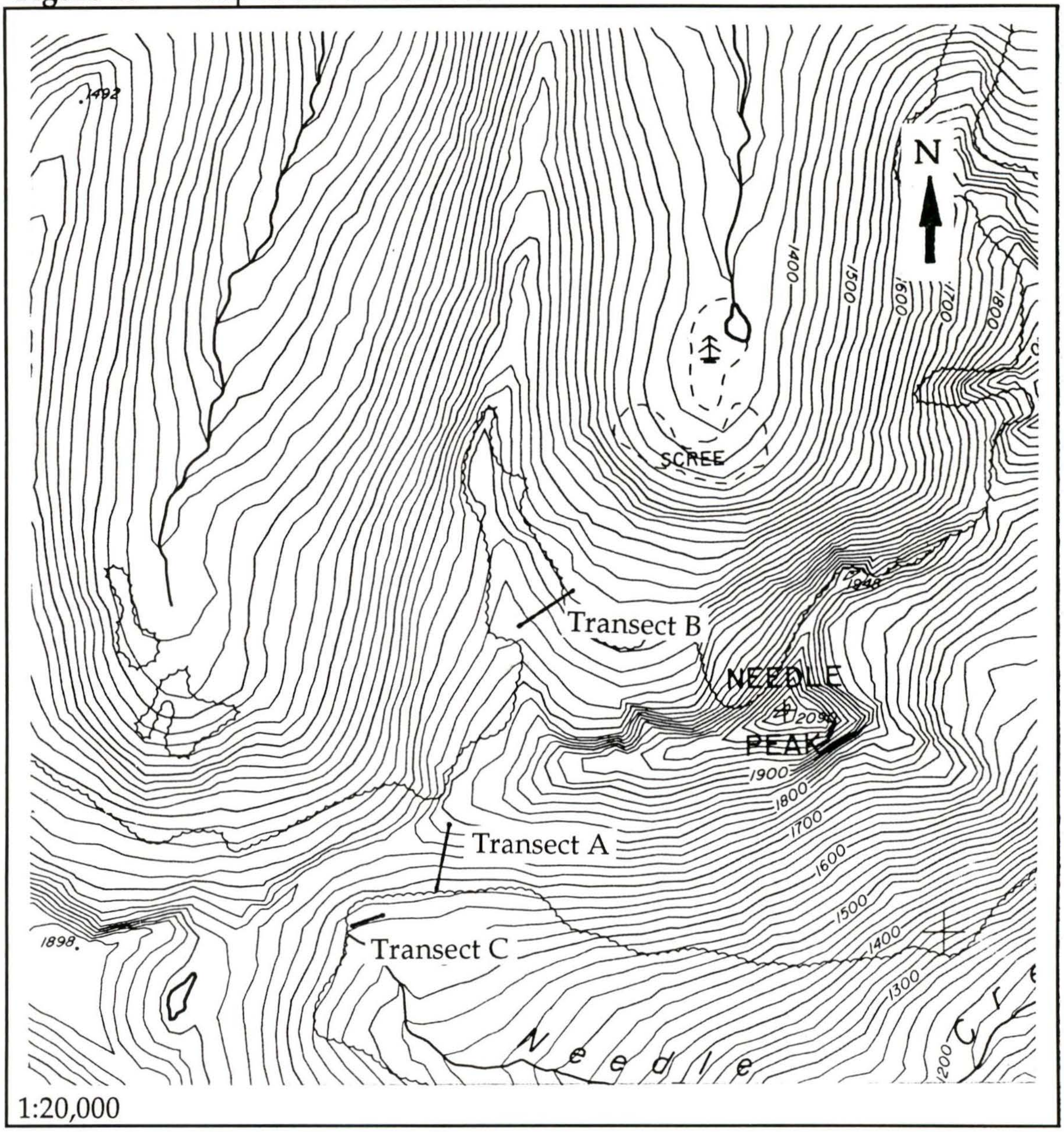


Figure 16 Photograph of Transects A and C

Photograph by author

Figure 17 Photograph of Transect B

Photograph by author

Figure 18 Profile of Transect A

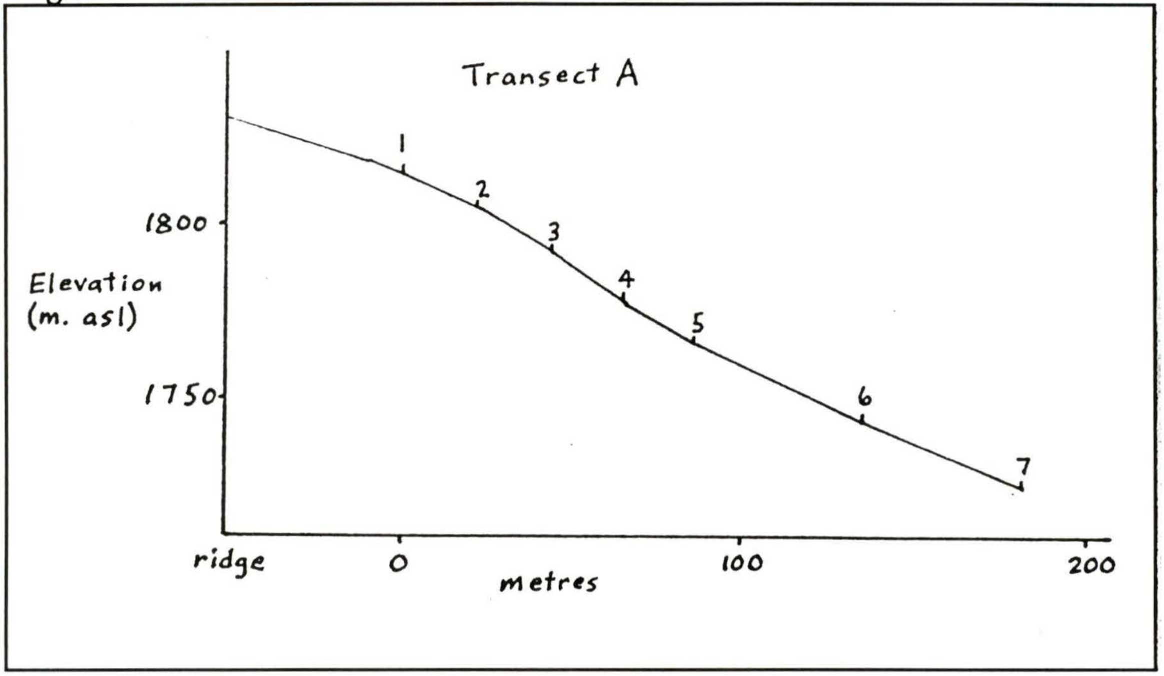
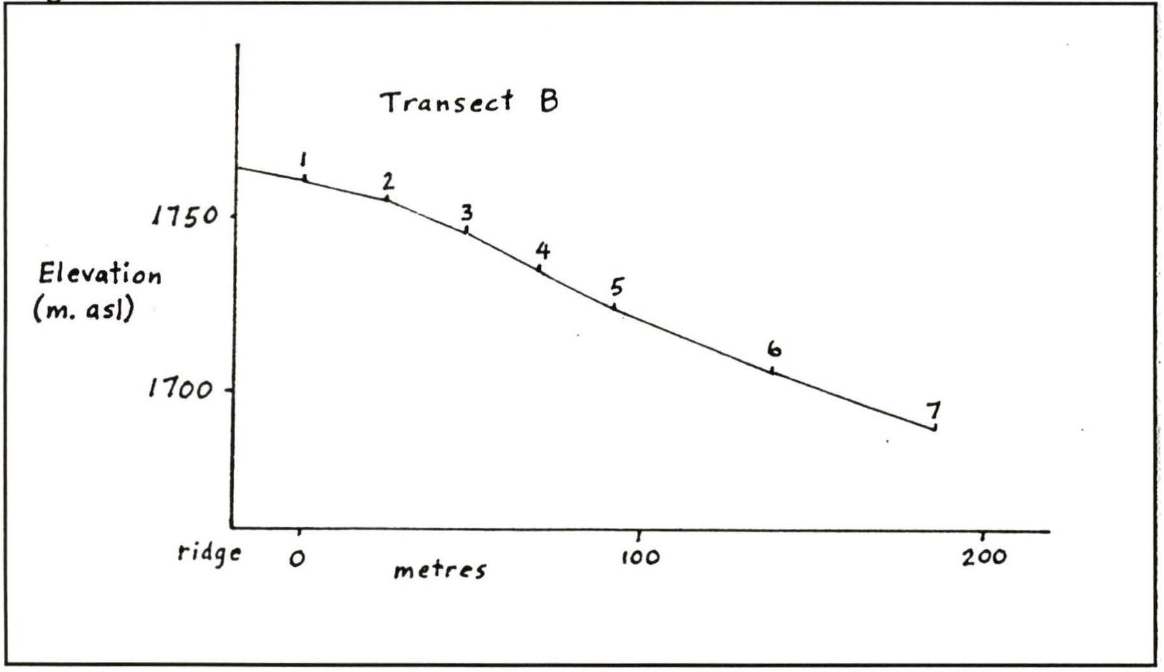


Figure 19 Profile of Transect B



elevation of 1750 metres, and a maximum incline between stations of 26°. Transect C (Figure 16) had three stations spaced roughly 50 metres apart in scattered trees on gently sloping ground at 1660 m elevation, 200 metres southwest of transect A and 1000 metres southwest of transect B. The transects were accessed by ski from the highway. Return trips took from five to eight hours, depending on snow conditions. Seven sets of readings were gathered from transects A and C and five from transect B. Transect B was the second east-facing transect chosen. The first east-facing transect, 1000 metres southwest of transect C, was buried in wind-deposited snow and avalanche debris between February 10 and February 22. The avalanche hazard made access to the transect unsafe on February 22, so a safer site, transect B, was chosen.

4.3.1 Snow Measurement Methods

There are a wide range of methods available for measuring snowfall (Goodison et al. 1981). In Canada, the standard tools for measuring snow for avalanche forecasting are the snow board and the precipitation guage (National Research Council of Canada and Canadian Avalanche Association 1989). A snow board is a 40 cm by 40 cm plywood square placed on the snow surface and marked with a stake so it can be found after it is buried by subsequent snowfalls. The depth of the snow on the board is measured with a ruler. After the measurement is recorded, the board is cleared and replaced on the snow surface.

For this study, snow was measured on snowboards marked with bamboo wands (Figure 20). The depth of the snow on each board was measured at the end of each accumulation period. The weights of samples of the snow on boards three and five in transects A and B, and on board two in transect C, were measured with a spring scale. The measured depths and weights were used to calculate the water equivalent of the snow.

Figure 20 Measuring Depth of Snow on a Snowboard

J.Filippone photograph

4.3.2 Snow Accumulations

The water equivalent of the snow on each board was calculated following the procedure described by the National Research Council of Canada and the Canadian Avalanche Association (1989). The weighted average water equivalents of the snow on each transect were calculated for each accumulation period and included in the analysis as *snow accumulation.*

There were four steps involved in calculating the *snow accumulation* on transects A and B:

1. Calculating the specific gravity of the snow on boards 3 and 5.
2. Calculating the weighted average of the two specific gravities.
3. Calculating the water equivalent of the snow on each board in the transect by multiplying the depth of snow on the board by the weighted average specific gravity of the snow on boards 3 and 5.
4. Calculating the average of the water equivalents on all the boards in the transect.

Calculations were the same for transect C except that step 2 was unnecessary because specific gravity was measured on a single board - board 2.

For example, on March 17, 10 cm of snow had accumulated on board 5 of transect A (Table 2). The sampling tube with a cross sectional area of 28 cm^2 was inserted vertically into the snow to extract a 280 cm^3 (10 cm x 28 cm^2) snow sample. The sample weighed 45 g so the specific gravity was 0.161 (45 g/280 g) and the water equivalent of the 10 cm of snow was 16.1 mm (0.161 x 10 cm x 10 mm/cm). The weighted average specific gravity of the snow on boards 3 and 5 was (0.142 x 5 cm + 0.161 x 10 cm)/(5 cm + 10 cm) = 0.155 . This average specific gravity was used to convert the measured snow depths on all the boards into their water equivalents. For example, the 20 cm of snow on board 7 had a water equivalent of 31.0 mm (20 cm x 0.155 x 10 mm/cm). Finally, the average of the seven water equivalents was calculated. The average water equivalent of the snow accumulated on transect A on March 16 and 17 was (0.0 + 4.6 + 7.7 + 12.4 + 15.5 + 34.0 + 31.0)/ 7) = 15.0 mm.

When the snow on the board was homogeneous, as it was for the March 16-17, single samples were used to calculate the water equivalent on boards 3 and 5. When the snow was layered, the water equivalent of each layer was calculated

Table 2

Snow Data: Transect A, March 16 - 17

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	average s.g.	est board water eq. (mm)
1	0										0.0
2	3										4.6
3	5		5	5	20	0.14	7.1	7.1	0.14		7.7
4	8									0.155	12.4
5	10		10	10	45	0.16	16.1	16.1	0.16		15.5
6	22										34.0
7	20										31.0
						Average Snow Accumulation (mm water):					15.0

Table 3

Snow Data: Transect A, February 10 - 22

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	average s.g.	est board water eq. (mm)
1	22										35.5
2	64										103.2
3	36	15 - 36	21	17.9	35	0.07	14.7				58.1
		0 - 15	15	17.9	100	0.20	29.9	44.6	0.12		
4	49										79.0
5	84	63 - 84	21	17.9	30	0.06	12.6			0.161	135.5
		47 - 63	16	17.9	90	0.18	28.7				
		39 - 47	8	17.9	140	0.28	22.3				
		9 - 39	30	17.9	105	0.21	62.8				
		0 - 9	9	17.9	125	0.25	22.4	148.9	0.18		
6	90										145.2
7	99										159.7
						Average Snow Accumulation (mm water):					102.3

separately and summed to determine the total water equivalent and average specific gravity of the snow on the board. For example, from February 10 to 22, board 5 of transect A accumulated 84 cm of snow (Table 3). The 84 cm was divided into five distinct layers. The top layer was 21 cm deep and a 501 cm^3 (17.9 cm x 28 cm^2) sample taken from the layer weighed 30 g. The specific gravity of the layer was 0.06 (30 g /501 g) and it had a water equivalent of 12.6 mm (0.06 x 21 cm x 10 mm/cm). The water equivalent of all of the layers combined was 148.9 mm, and the weighted average specific gravity of all the snow on the board was 148.9 mm/(84 cm x 10 mm/cm) = 0.18.

4.3.3 Relative Snow Accumulation

The quantity of snow that accumulated on each transect is represented by the statistic *snow accumulation*: the mean water equivalent of the snow on all the boards in that transect. The *snow accumulation* on a transect reflects both the amount of precipitation that fell during the accumulation period and the effect of the weather conditions, particularly the wind, during that period. The statistic, *relative snow accumulation,* was calculated to permit comparison of snow distribution patterns between accumulation periods with different *precipitation*. The *relative snow accumulation* at each transect is the *snow accumulation* at that transect expressed as a multiple of the *precipitation* recorded at Little Bear weather station. For example if the *snow accumulation* was 20 mm, and the *precipitation* was 10 mm, the *relative snow accumulation* at the transect would be 2.0.

4.4 Summary Statistics

The summary statistics used in the analysis are presented in Table 4. These statistics replace thousands of individual observations, and embody many simplifying assumptions.

Table 4

Summary Data

Accumulation Period	Weather			Loading Wind		Snow Accumulation			Relative Accumulation		
	Ppt (mm)	Temp (°C)	RH (%)	Wind A (km/h)	Wind B (km/h)	A (mm water)	B (mm water)	C (mm water)	A/Ppt	B/Ppt	C/Ppt
Feb 10 - 22	152	-5.3	90.4	-13.98		102.3		159.2	0.7		1.0
Feb 22 - 25	46	-8.5	89	-9.62		51.3		58.9	1.1		1.3
Feb 25 - Mar 3	71	-0.6	88.4	-17.01	15.86	26.9	71.4	46.7	0.4	1.0	0.7
Mar 3 - 8	43	-2.1	78.1	-10.03	10.82	52.5	77.8	45.1	1.2	1.8	1.0
Mar 8 - 15	24	1.4	72.5	-5.61	7.75	1.3	16.6	8.9	0.1	0.7	0.4
Mar 15 - 16	6	-3.4	91.8	-17.2	16.89	8.7	20.7	8.8	1.5	3.5	1.5
Mar 16 - 17	15	-5.7	91.6	-18.68	18.59	15	28.6	26.2	1.0	1.9	1.7

CHAPTER 5 ANALYSIS

5.0 Introduction

In this chapter a series of statistical tests are used to examine how weather conditions affected snow accumulations at the three transects during the study period. There are no studies described in the literature that provide a standard methodology for measuring the correlations between weather data and starting zone snow accumulations, despite the fact that these correlations are a basic assumption in avalanche forecasting (National Research Council and Canadian Avalanche Association 1989).

5.1 Precipitation and Snow Accumulation

Precipitation is the primary control of snow accumulation and, in most areas, the most significant avalanche forecasting consideration (National Research Council and Canadian Avalanche Association, 1989). In this first section of the analysis correlation and regression analysis are used to examine the relationship between *precipitation* recorded at the Little Bear weather station and *snow accumulation* measured at the three transects.

5.1.1 Spearman's Correlation Analysis of Precipitation vs Snow Accumulation

Snow accumulations at transects A, B and C are graphed against *precipitation* in Figures 21, 22 and 23. The scattergrams suggest that the expected positive correlations were observed, but the strength of the correlations varied between transects.

The correlations are tested with Spearman's Rank Correlation at significance level 0.10. Spearman's correlation coefficient (r_s) is a measure of the monotone

Figure 21 Snow Accumulation at Transect A vs Precipitation

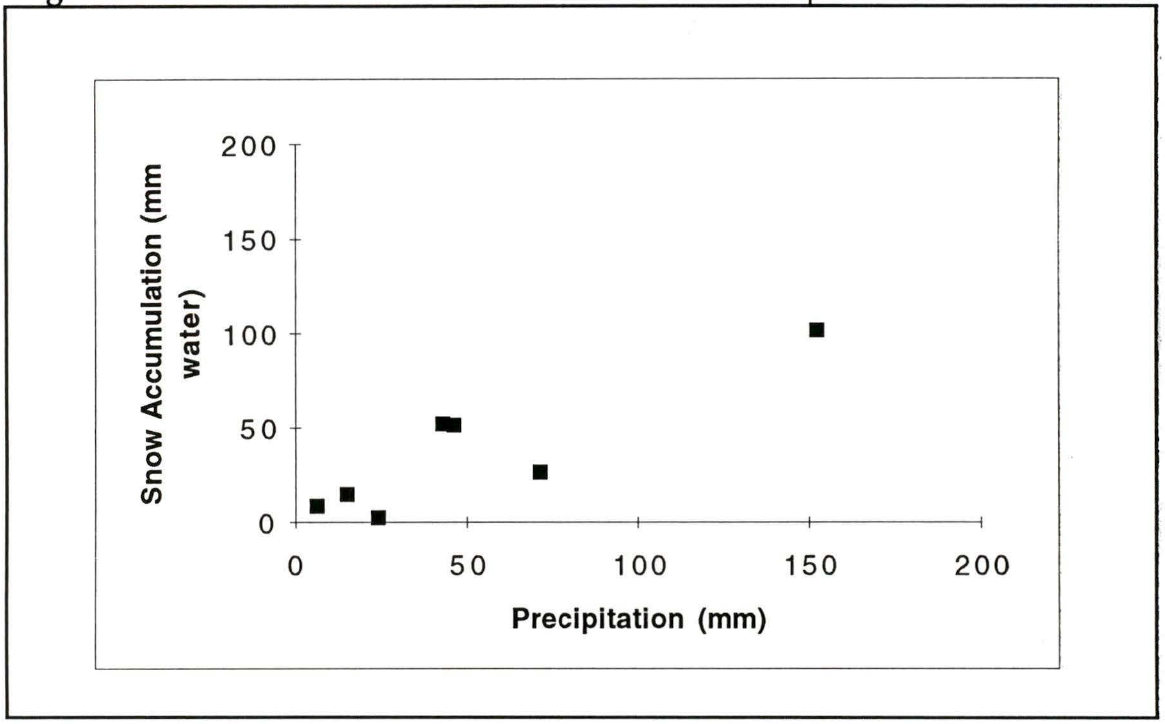


Figure 22 Snow Accumulation at Transect B vs Precipitation

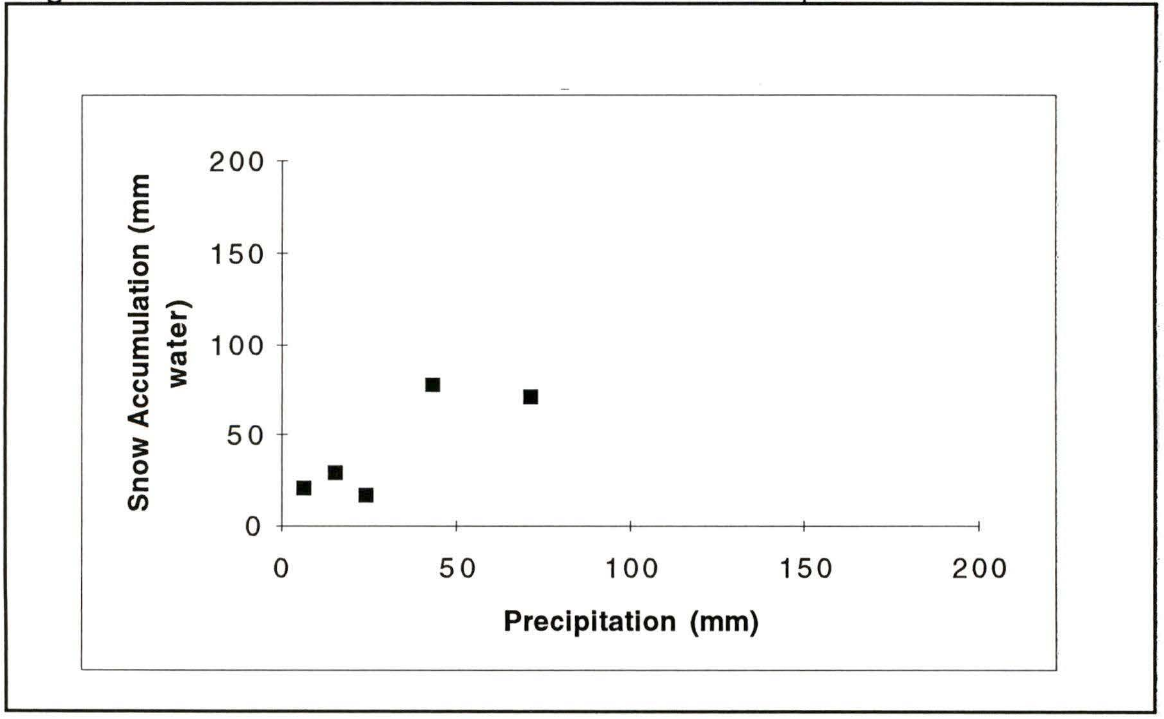
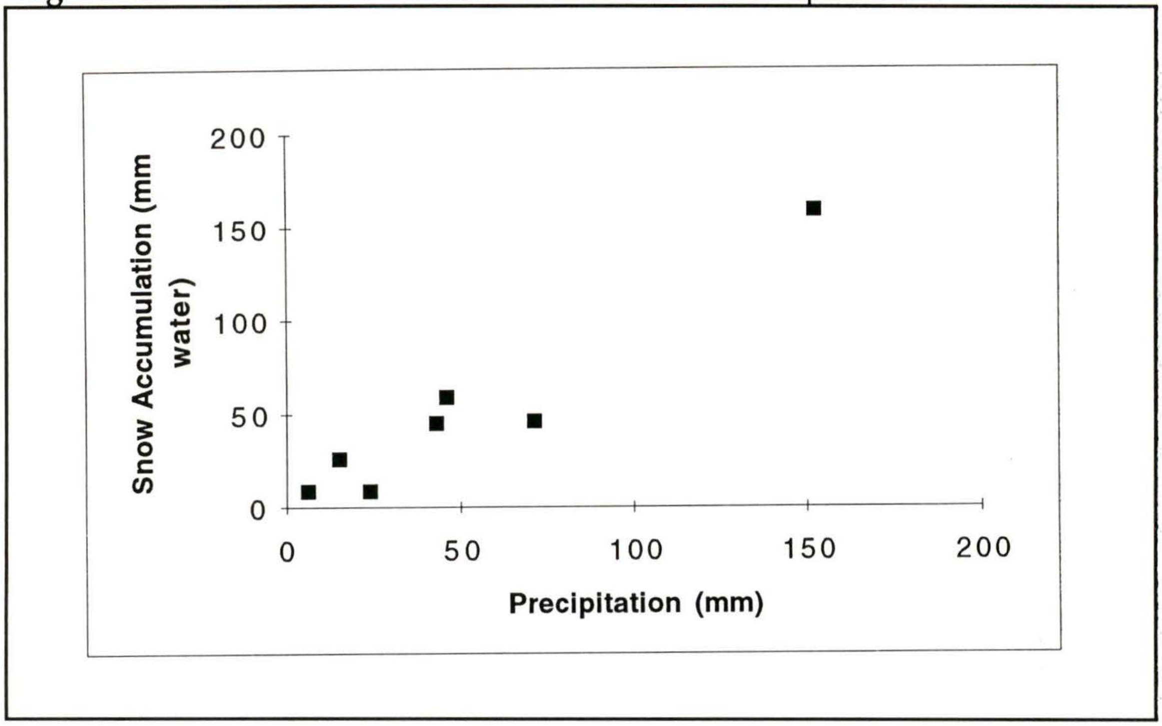


Figure 23 Snow Accumulation at Transect C vs Precipitation



association between variables, ranging from 1.0, indicating a perfect positive correlation, to -1.0, indicating a perfect negative correlation. The null hypothesis for each transect is: *snow accumulation* is not positively correlated to *precipitation*.

r_s is calculated with the formula:

$$r_s = 1 - \left(\frac{6\,\Sigma\, d^2}{N^3 - N}\right)$$

d = difference in the *precipitation* and *snow accumulation* ranks.

N = number of observations.

The probabilities (p) of $r_s \geq$ observed r_s, under independence, are tabulated in Kendall and Gibbons (1990).

The results of the correlation calculations are presented in Table 5. *Snow accumulations* on transect C ($r_s = 0.93$, $p = 0.003$), and A ($r_s = 0.75$, $p = 0.033$) are

Table 5

**Spearman's Correlation:
Snow Accumulation vs Precipitation**

Transect A

	Precipitation		Snow Accumulation				
date	*mm*	*rank*	*mm*	*rank*	*d2*	*rs*	*p*
22-Feb	152	1	102.3	1	0	0.75	0.033
25-Feb	46	3	51.3	3	0		
3-Mar	71	2	26.9	4	4		
8-Mar	43	4	52.5	2	4		
15-Mar	24	5	1.3	7	4		
16-Mar	6	7	8.7	6	1		
17-Mar	15	6	15	5	1		

Transect B

	Precipitation		Snow Accumulation				
date	*mm*	*rank*	*mm*	*rank*	*d2*	*rs*	*p*
3-Mar	71	1	71.4	2	1	0.60	0.175
8-Mar	43	2	77.8	1	1		
15-Mar	24	3	16.6	5	4		
16-Mar	6	5	20.7	4	1		
17-Mar	15	4	28.6	3	1		

Transect C

	Precipitation		Snow Accumulation				
date	*mm*	*rank*	*mm*	*rank*	*d2*	*rs*	*p*
22-Feb	152	1	159.2	1	0	0.93	0.003
25-Feb	46	3	58.9	2	1		
3-Mar	71	2	46.7	3	1		
8-Mar	43	4	45.1	4	0		
15-Mar	24	5	8.9	6	1		
16-Mar	6	7	8.8	7	0		
17-Mar	15	6	26.2	5	1		

significantly positively correlated to *precipitation* at Little Bear. *Snow accumulation* on transect B ($r_s = 0.60$, $p = 0.175$) appeared to be positively correlated to *precipitation* but the correlation is not significant.

Transect C was in a relatively sheltered location, but both A and B were above treeline, and therefore more exposed to wind. The strong positive correlation between *precipitation* and *snow accumulation* at C confirms that when it snowed at Little Bear it snowed about the same amount at a sheltered site in the vicinity of the three transects. The weaker correlation at A, and the lack of significant correlation at B, suggest that the wind affected snow accumulations at these transects.

5.1.2. Regression Analysis of Snow Accumulation on Precipitation

Regression models are frequently used to establish the association between snow accumulations at different locations within a climatic region (McKay and Gray 1981). In this section, regression analysis provides two useful measures of the relationship between *snow accumulation* and *precipitation* at each transect. The first, the Coefficient of Determination (r^2), is the portion of the observed period to period variation in *snow accumulation* at a transect that is explained by differences in *precipitation*. The second, the slope of the line of best fit, defines the typical ratio of *snow accumulation* to *precipitation* at each transect.

The calculated r^2 and slope values are estimates of the true values for all accumulation periods. The estimates are not very precise because the samples are small, but they provide a good basis for comparison between transects. The regression of *snow accumulation* on *precipitation* is based on the following assumptions: the data are measured at a ratio scale; the data are measured without error; the relationship between *snow accumulation* and *precipitation* is linear; residuals are pairwise uncorrelated; and, the conditional distribution of *snow accumulation* residuals for each precipitation value has a mean of 0, a constant variance, and is normally distributed (Norcliffe 1977). The scattergrams (Figures 21, 22, 23) do not suggest any serious violations of these assumptions, and there is no reason to suspect that they are unreasonable.

The results of the regression analyses are presented in Tables 6, 7, 8 and Figure 24. The y intercepts are fixed at 0 to reflect the assumption that no snow accumulated at the transects when no precipitation was recorded at the weather station. As a result, the calculated r^2 values are ratios of explained snow accumulation variation from 0, to total observed snow accumulation variation from 0, rather than from the mean snow accumulation. For transect A, $r^2 = 0.90$ and slope = 0.68; for transect B, $r^2 = 0.90$ and slope = 1.21; and for transect C, $r^2 = 0.97$ and slope = 1.00.

The high r^2 values indicate that *precipitation* explained most of the *snow accumulation* variation at all three transects. The fact that the r^2 values were smaller for the wind-affected transects, A and B, than for the sheltered transect, C, suggests that wind is an important influence on *snow accumulation.*

The slopes of all three regression lines are consistent with expectations. Transect C, located in a sheltered clearing, tended to accumulate the same amount of snow as Little Bear (slope = 1.0). Transect B, a lee site, and therefore subject to wind deposition (*loading wind* always positive, Table 4), tended to receive 1.21 times as much snow as Little Bear. Transect A, a windward site, and therefore

Table 6

Regression: Snow Accumulation at A on Precipitation

Regression Statistics

R Square*	0.90
Adjusted R Square	0.88
Standard Error	16.68
Observations	7

Analysis of Variance

	df	*SS*	*Mean Sq*	*F*	*Signif. F*
Regression	1	15209.19	15209.19	54.64	0.0003
Residual	6	1670.03	278.34		
Total	7	16879.22			

	Coeff.	*Std Error*	*t*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
Ppt	0.68	0.09	7.39	0.0003	0.45	0.90

* the intercept is fixed at 0 so R Square = the sum of the squared fitted snow accumulations divided by the sum of the squared observed snow accumulations.

Table 7

Regression: Snow Accumulation at B on Precipitation

Regression Statistics	
R Square*	0.90
Adjusted R Square	0.87
Standard Error	18.16
Observations	5

Analysis of Variance

	df	*SS*	*Mean Sq*	*F*	*Signif. F*
Regression	1	11353.62	11353.62	34.43	0.004
Residual	4	1319.19	329.80		
Total	5	3419.21			

	Coeff.	*Std Error*	*t*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
Ppt	1.21	0.21	5.87	0.004	0.64	1.79

* the intercept is fixed at 0 so R Square = the sum of the squared fitted snow accumulations divided by the sum of the squared observed snow accumulations.

Table 8

Regression: Snow Accumulation at C on Precipitation

Regression Statistics

R Square*	0.97
Adjusted R Square	0.96
Standard Error	13.99
Observations	7

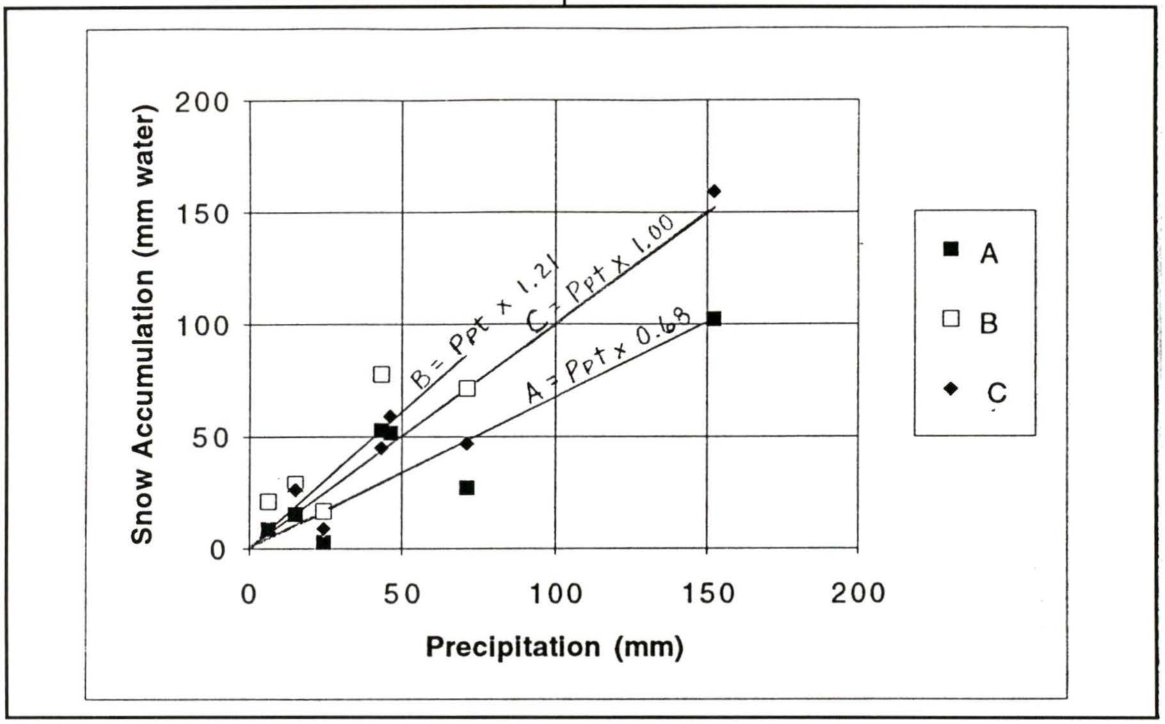
Analysis of Variance

	df	*SS*	*Mean Sq*	*F*	*Signif. F*
Regression	1	32697.87	32697.87	1167.12	0.0001
Residual	6	1173.97	195.66		
Total	7	33871.84			

	Coeff.	*Std Error*	*t*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	0	#N/A	#N/A	#N/A	#N/A	#N/A
Ppt	1.00	0.08	12.93	0.0001	0.81	1.18

* the intercept is fixed at 0 so R Square = the sum of the squared fitted snow accumulations divided by the sum of the squared observed snow accumulations.

Figure 24 Linear Regression Lines of Best Fit for Snow Accumulation at Each Transect on Precipitation



subject to wind scouring (*loading wind* always negative), tended to receive only 0.68 times as much.

5.2 Loading Wind and Snow Accumulation

In this section the relationship between *loading wind* and *snow accumulation* is investigated. Two hypotheses are proposed:

1. In a single accumulation period, transects with greater *loading wind* have greater *snow accumulations.*
2. At a single transect, the accumulation periods with greater *loading winds* have greater *snow accumulations.*

These hypotheses are tested with Friedman's Test for a Randomized Block Experiment and Spearman's Rank Correlation.

5.2.1 Friedman's Test of Loading Wind vs Snow Accumulation

A scattergram of *snow accumulation* vs *loading wind* for all transects and time periods is shown in Figure 25. The data points for each period are connected. The generally positive slopes of the connecting lines suggests that, in a single accumulation period, transects with greater *loading wind* have greater *snow accumulations*. This hypothesis is tested with Friedman's Test for a Randomized Block Experiment, as described by Devore (1987). The null hypothesis is: *snow accumulation* does not depend on *loading wind.*

The significance level for this test is 0.05 because more data are included than in the tests for individual transects. Friedman's coefficient, Fr, has an approximately χ^2 distribution with I -1 degrees of freedom, where I is the number of *snow accumulation* ranks (Devore 1987), so a calculated Fr greater than $\chi^2_{.05, I-1}$ would mean that the P-value, the probability associated with the hypothesis that *snow accumulation* does not depend on *loading wind,* is less than 0.05.

Fr is calculated with the formula:

$$Fr = \frac{12}{IJ(I+1)} \Sigma R_i^2 - 3J(I+1)$$

where I = number of *loading wind* ranks = 3

J = number of accumulation periods = 5

R_i = the sum of the *snow accumulation* ranks associated with each *loading wind* rank (Table 9)

$$\Sigma R_i^2 = 25 + 121 + 196 = 342$$

$$Fr = \frac{12}{(3)(5)(3+1)} (342) - (3)(5)(3+1) = 8.4$$

$\chi^2_{.05,2} = 5.99$ (Devore 1987)

8.4 > 5.99, therefore the null hypothesis can be rejected.

Figure 25 Snow Accumulation vs Loading Wind

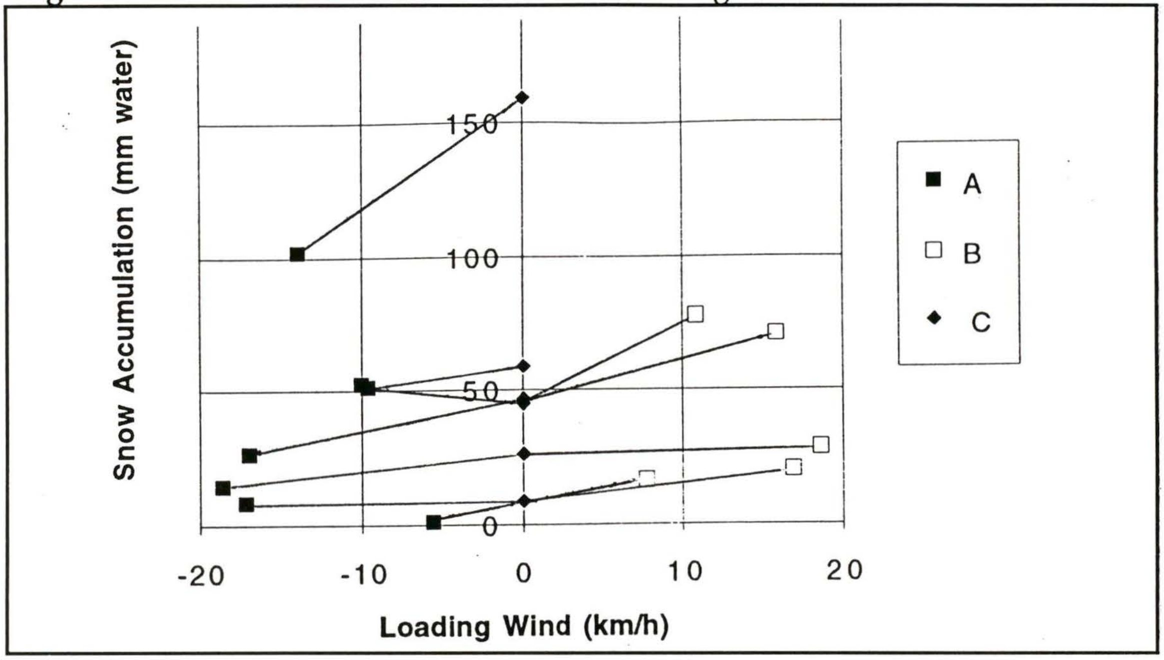


Table 9 **Friedman's Test: Snow Accumulation vs Loading Wind**

	Loading Wind (rank)			*Snow Accumulation (rank)*		
	A	B	C	A	B	C
Mar 3	-17.0 (3)	15.9 (1)	0 (2)	26.9 (3)	71.4 (1)	46.7 (2)
Mar 8	-10 (3)	10.8 (1)	0 (2)	52.5 (2)	77.8 (1)	45.1(3)
Mar 15	-5.6 (3)	7.8 (1)	0 (2)	1.3 (3)	16.6 (1)	8.9 (2)
Mar 16	-17.2 (3)	16.9 (1)	0 (2)	8.7 (3)	20.7 (1)	8.8 (2)
Mar 17	-18.7 (3)	18.6 (1)	0 (2)	15.0 (3)	28.6 (1)	26.2 (2)

	Snow Accumulation Rank						
Loading Wind Rank	*Mar 3*	*Mar 8*	*Mar 15*	*Mar 16*	*Mar 17*	R_i	R_i^2
1	1	1	1	1	1	5	25
2	2	3	2	2	2	11	121
3	3	2	3	3	3	14	196

The data provide strong evidence that *snow accumulation* in a single accumulation period depends on *loading wind*. The transect with the greatest *loading wind* almost always receives the most snow. However, these results must be interpreted with caution because, coincidentally, transect B always had a greater *loading wind* than transect A, and, as a result, a Friedman's test of any fixed transect attribute would have produced the same results as the test of *loading wind*.

5.2.2 Spearman's Correlation Analysis of Relative Snow Accumulation vs Loading Wind

In this section the correlations between snow accumulations and *loading winds* at individual wind-affected transects are examined. Snow accumulations are expressed as *relative snow accumulations* (the ratio of *snow accumulation* to *precipitation*) to allow the wind effect in periods with different *precipitation* to be compared. For each of sites A and B, the null hypotheses is: *relative snow accumulation* is not positively correlated to *loading wind*. The hypotheses are tested at significance level 0.10 using the exact Spearman's probabilities as tabulated by Kendall and Gibbons (1990).

A scattergram of *relative snow accumulation* vs *loading wind* is shown in Figure 26. The correlations, as summarized in Table 10, indicate that at transect B, the lee transect, *relative snow accumulation* is significantly positively correlated to *loading wind* ($r_s = 0.80$, $p = 0.067$), but at transect A, the windward transect, *relative snow accumulation* and *loading wind* are not significantly positively correlated ($r_s = -0.32$, $p > 0.5$).

Table 10

Spearman's Correlation:
Relative Snow Accumulation vs Loading Wind

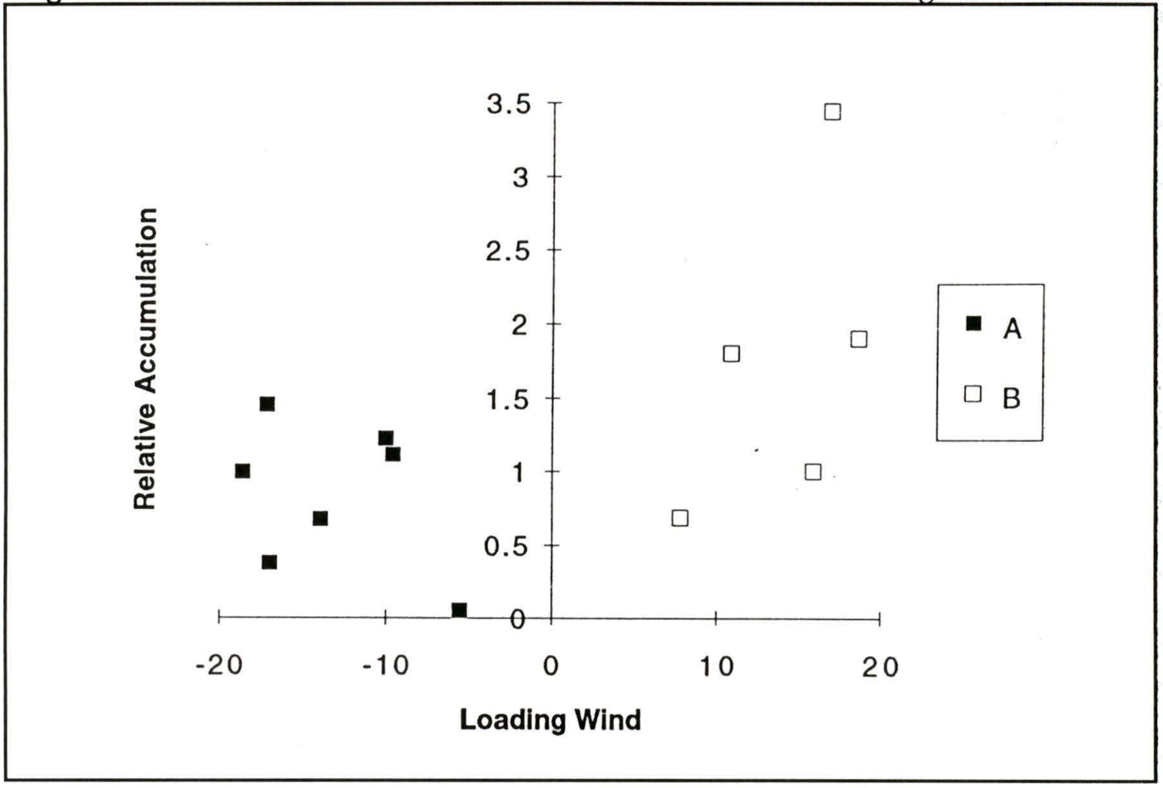
Transect A

	Loading Wind		*Relative Accumulation*				
date	*km/h*	*rank*	*snow/ppt*	*rank*	*d2*	*rs*	*p*
22-Feb	-13.98	4	0.67	5	1	-0.32	>.5
25-Feb	-9.62	2	1.12	3	1		
3-Mar	-17.01	5	0.38	6	1		
8-Mar	-10.03	3	1.22	2	1		
15-Mar	-5.61	1	0.05	7	36		
16-Mar	-17.2	6	1.45	1	25		
17-Mar	-18.68	7	1.00	4	9		

Transect B

	Loading Wind		*Relative Accumulation*				
date	*km/h*	*rank*	*snow/ppt*	*rank*	*d2*	*rs*	*p*
3-Mar	15.86	3	1.01	4	1	0.8	0.07
8-Mar	10.82	4	1.81	3	1		
15-Mar	7.75	5	0.69	5	0		
16-Mar	16.89	2	3.45	1	1		
17-Mar	18.59	1	1.91	2	1		

Figure 26 Relative Snow Accumulation at A and B vs Loading Wind



5.3 Predicting Snow Accumulations with a Multiple Regression Model

In this section, a multiple linear regression model is developed to predict *snow accumulation* at transects A and B from *precipitation* and *loading wind*. This model is analogous to the informal model that forecasters use to estimate starting zone accumulations from weather data, and is proposed to provide insight into the uncertainty associated with those estimates. The regression statistics are presented in Table 11.

The model has three important peculiarities that limit the inferences it can support: 1. It attempts to explain *snow accumulation* over both time and space, but while *loading wind* varies between both time periods and locations, *precipitation* varies between time periods only. As a result, single *precipitation* values enter the

Table 11

Regression:
Snow Accumulation on Precipitation and Loading Wind

Transect	*Date*	*Precipitation*	*Loading Wind*	*Snow Accumulation*
A	22-Feb	152	-13.98	102.3
	25-Feb	46	-9.62	51.3
	3-Mar	71	-17.01	26.9
	8-Mar	43	-10.03	52.5
	15-Mar	24	-5.61	1.3
	16-Mar	6	-17.2	8.7
	17-Mar	15	-18.68	15
B	3-Mar	71	15.86	71.4
	8-Mar	43	10.82	77.8
	15-Mar	24	7.75	16.6
	16-Mar	6	16.89	20.7
	17-Mar	15	18.59	28.6

Regression Statistics	
Multiple R	0.86
R Square	0.74
Adjusted R Square	0.68
Standard Error	17.76
Observations	12

Analysis of Variance

	df	*SS*	*Mean Sq*	*F*	*Signif. F*
Regression	2	8061.63	4030.82	12.78	0.002
Residual	9	2838.43	315.38		
Total	11	10900.06			

	Coeff.	*Std Error*	*t*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	11.61	7.64	1.52	0.1630	-5.67	28.88
Precipitation	0.68	0.13	5.02	0.0007	0.37	0.98
Loading Wind	0.68	0.38	1.80	0.1055	-0.17	1.53

model twice, once as a predictor of *snow accumulation* on transect A and once as a predictor of *snow accumulation* on transect B, but can make no contribution to explaining the difference in *snow accumulations* at the two sites. 2. There is a gap in the observed *loading winds* between -5.6 and +7.5 (see Table 11). The gap results in the data being divided into two distinct clusters (see Figure 26) and, consequently, the linearity of the relationship between *loading wind* and *snow accumulation* is overstated, and the probability that there is in fact no relationship between *loading wind* and *snow accumulation* (after the effect of *precipitation* is eliminated) may be greater than that calculated (t=1.80, P=.1055, Table 11) 3. The scattergram of *relative snow accumulation* vs *loading wind* (Figure 26) does not suggest a linear relationship, and since the the linearity of the relationship is an important assumption of the linear regression model (Norcliffe 1977), the contribution of *loading wind* to explaining the variation in *snow accumulation* may be exaggerated.

The multiple linear regression model that provides the best estimates of *snow accumulation* is:

$$\textit{snow accumulation} = 11.61 + 0.68 \times \textit{precipitation} + 0.68 \times \textit{loading wind}$$

This model explains 74% of the total variance in *snow accumulation* ($r^2 = 0.74$), and the standard error of estimate (root mean square error) is 17.76 mm. For comparison, using *precipitation* as the only predictor, r^2 is 0.65 and the standard error of estimate is 19.65 mm (Table 12).

The predicted *snow accumulations* and their associated errors are presented in Table 13. The average errors are expressed both in millimetres and as a percentage of the average *snow accumulation* at each transect. At transect A the average error of the multiple regression model was 35% of the average *snow*

Table 12

Regression:
Snow Accumulation at A and B on Precipitation

Regression Statistics

Multiple R	0.80
R Square	0.65
Adjusted R Square	0.61
Standard Error	19.65
Observations	12

Analysis of Variance

	df	*SS*	*Mean Sq*	*F*	*Signif. F*
Regression	1	7040.43	7040.43	18.24	0.002
Residual	10	3859.64	385.96		
Total	11	10900.06			

	Coeff.	*Std Error*	*t*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	12.89	8.41	1.53	0.16	-5.86	31.63
Precipitation	0.62	0.14	4.27	0.002	0.30	0.94

Table 13

Snow Accumulation Prediction Errors

Transect	*Date*	***Snow Accumulations***				***Errors (Absolute Value)***		
		Observed	*Predicted by*			*Predicted by*		
			Ppt	*Regression Models*		*Ppt*	*Regression Models*	
				Wind and Ppt	*Ppt*		*Wind and Ppt*	*Ppt*
A	22-Feb	102.3	152	104.9	106.7	49.7	2.6	4.4
	25-Feb	51.3	46	36.2	41.3	5.3	15.1	10.0
	3-Mar	26.9	71	48.1	56.7	44.1	21.2	29.8
	8-Mar	52.5	43	33.9	39.4	9.5	18.6	13.1
	15-Mar	1.3	24	24.0	27.7	22.7	22.7	26.4
	16-Mar	8.7	6	4.0	16.6	2.7	4.7	7.9
	17-Mar	15	15	9.1	22.1	0	5.9	7.1
	Average	36.9				19.1	13.0	14.1
					%	**52**	**35**	**38**
B	3-Mar	71.4	71	70.3	56.7	0.4	1.1	14.7
	8-Mar	77.8	43	48.0	39.4	34.8	29.8	38.4
	15-Mar	16.6	24	33.1	27.7	7.4	16.5	11.1
	16-Mar	20.7	6	27.1	16.6	14.7	6.4	4.1
	17-Mar	28.6	15	34.3	22.1	13.6	5.7	6.5
	Average	43.0				14.2	11.9	14.9
					%	**33**	**28**	**35**

Note: The regression models were developed with data from the two transects combined. The errors presented here are the errors associated with using the models to predict snow accumulation at each transect.

Figure 27 Snow Accumulations at Transect A, Predicted and Observed

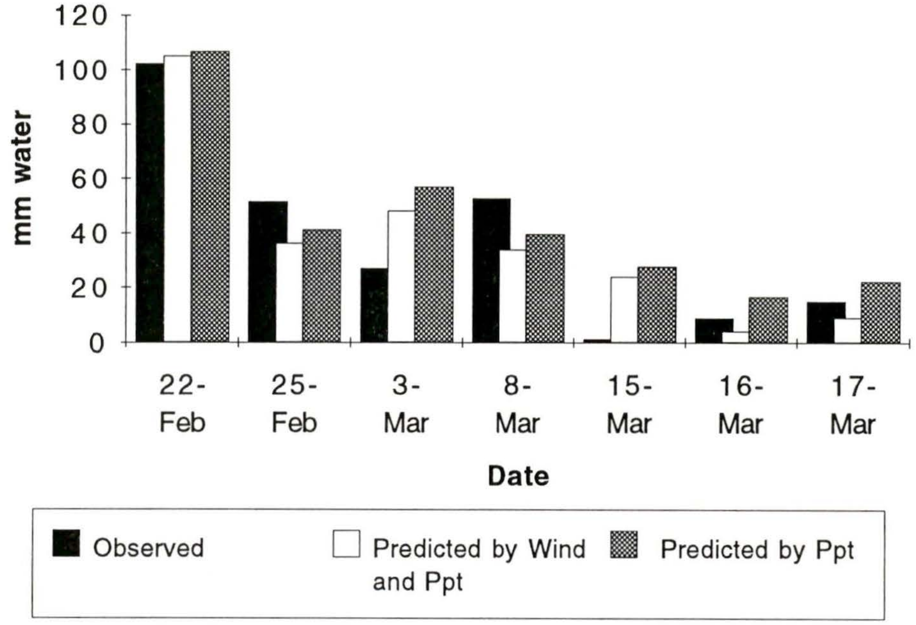
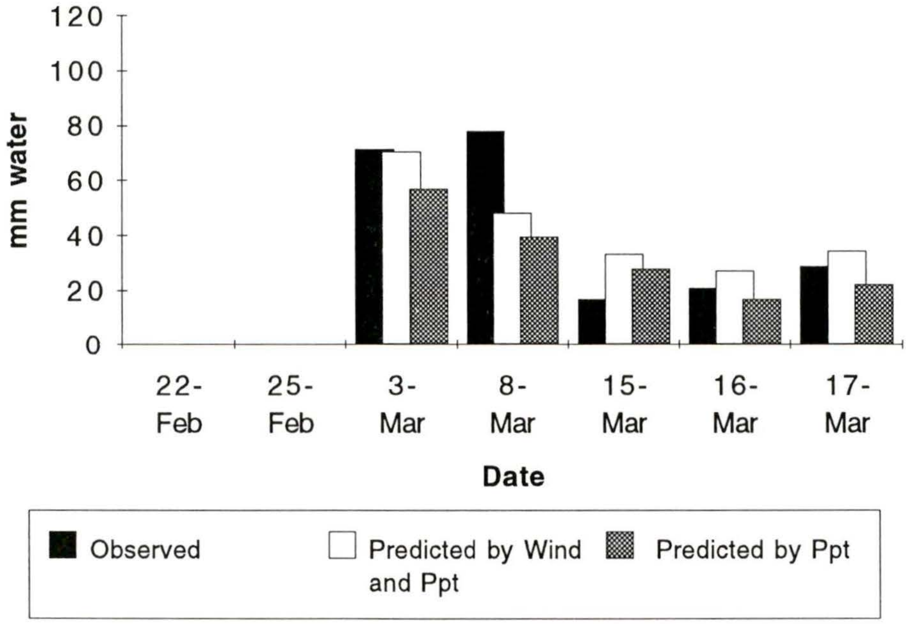


Figure 28 Snow Accumulations at Transect B, Predicted and Observed



accumulation. At transect B the average error was 28% of the average *snow accumulation*. The predicted and observed *snow accumulations* are compared in Figure 27 and 28.

The multiple regression model is the best predictor of *snow accumulations* at both transects, but, despite the exaggerated explanatory power of *loading wind*, it provides only a modest improvement over the regression model using *precipitation* as the sole predictor. The multiple regression model explains 9% more of the variance in the observed *snow accumulation* than the simple regression model, but 26% of the variation remains unexplained. This unexplained variation in *snow accumulation* accounts for some of the uncertainty associated with avalanche forecasts.

5.4 The Effect of Humidity and Temperature on Snow Accumulation

In this section regression analysis and Spearman's correlation analysis are used to determine if the unexplained variation in *snow accumulation* is related to *temperature* or *humidity*. It is generally accepted that a combination of low humidity and warm temperature increases sublimation of wind transported snow and reduces the quantity of snow deposited (Perla and Martinelli 1976, Pomeroy 1991). Temperature further reduces lee accumulation by promoting windward slope plastering at the expense of lee accumulation (Perla and Martinelli 1976). If temperature and humidity influenced snow deposition in this way during the study, then *snow accumulations* on transect B, the lee transect, would have been higher than average when *humidity* was high and *temperature* low, and lower than average when *humidity* was low and *temperature* high.

Temperatures and *humidities* were regressed on *precipitation* and *loading wind* to define average values. Parameter estimates are presented in Table 14. The regression equations are:

Temperature = 3.08 + 0.04 x *precipitation* - 0.45 x *loading wind*

Humidity = 57.98 + 1.9 x *loading wind.*

Temperatures and *humidities* greater than the those calculated by the regression equations (positive residuals) were greater than average. *Temperatures* and *humidities* less than those calculated by the regression equations (negative residuals) were less than average.

The regression equation, *snow accumulation = 5.84 + 0.96* x *precipitation + 0.48* x *loading wind* (Table 14) defines the average *snow accumulation* at transect B as a function of *loading wind* and *precipitation. Snow accumulations* that were greater than calculated with the regression equation were greater than average. *Snow accumulations* that were less than calculated with the regression equation were less than average. If, as expected, low humidity resulted in low lee slope accumulations, *humidity* residuals would have been positively correlated to *snow accumulation* residuals. If warm temperatures resulted in reduced lee slope accumulations, *temperature* residuals would have been negatively correlated to the *snow accumulation* residuals.

The correlations between the *temperature* and *humidity* residuals and the *snow accumulation* residuals at transect B are tested with Spearman's Rank Correlation at significance level 0.10. Two null hypotheses are proposed:

1. *Snow accumulation* is not negatively correlated to *temperature;* and
2. *Snow accumulation* is not positively correlated to *humidity.*

Table 14

Regressions:
Snow Accumulation at B, Temperature and Humidity on Precipitation and Loading Wind

Date	*Snow*		*Temperature*		*Humidity*	
3-Mar	71.4		-0.6		88.4	
8-Mar	77.8		-2.1		78.1	
15-Mar	16.6		1.4		72.5	
16-Mar	20.7		-3.4		91.8	
17-Mar	28.6		-5.7		91.6	
Regression Statistics						
R Square	0.70		0.76		0.98	
Standard Error	22.48		1.86		1.18	
Prob > F	0.30		0.24		0.02	
Parameter Estimates						
Intercept	5.84		3.08		57.98	
Precipitation	0.96		0.04		0.00	
Loading Wind	0.48		-0.45		1.90	
Residual, Rank						
3-Mar	-10.06	4	0.919	2	0.46	2
8-Mar	25.57	1	-1.848	5	-0.33	4
15-Mar	-15.95	5	0.949	1	-0.15	3
16-Mar	0.99	2	0.918	3	1.71	1
17-Mar	-0.55	3	-0.938	4	-1.70	5

The results of the correlation analysis are presented in Table 15. For *temperature* residuals vs *snow accumulation* residuals $r_s = -0.90$, $p = 0.04$. The null hypothesis can be rejected, the data provide evidence that *snow accumulations* are significantly negatively correlated to *temperature.* For *humidity* residuals vs *snow accumulation* residuals $r_s = -0.10$, $p > 0.5$. In this case the null hypothesis can not be rejected, the data do not provide evidence that *humidity* and *snow accumulations* are positively correlated.

Table 15

Spearman's Correlation:
Snow Accumulation Residuals vs Temperature and Humidity Residuals

Snow Accumulation Residuals vs Temperature Residuals

Date	*Temp*	*rank*	*Snow*	*rank*	*d2*	*rs*	*p*
3-Mar	0.919	2	-10.1	4	4	-0.90	0.04
8-Mar	-1.848	5	25.6	1	16		
15-Mar	0.949	1	-16.0	5	16		
16-Mar	0.918	3	1.0	2	1		
17-Mar	-0.938	4	-0.5	3	1		

Snow Accumulation Residuals vs Humidity Residuals

Date	*Humidity*	*rank*	*Snow*	*rank*	*d2*	*rs*	*p*
3-Mar	0.46	2	-10.1	4	4	-0.10	>.5
8-Mar	-0.33	4	25.6	1	9		
15-Mar	-0.15	3	-16.0	5	4		
16-Mar	1.71	1	1.0	2	1		
17-Mar	-1.70	5	-0.5	3	4		

CHAPTER 6 DISCUSSION

6.0 Summary of Study Findings

In chapter 4, statistics summarizing precipitation, wind, temperature and humidity were calculated, as noted in 4.2.1, italics are used to distinguish these statistics from the properties of the same name. In chapter 5 the relationships between these summary statistics and the observed snow accumulations were analyzed. In this chapter the results of the analysis are summarized and several of its important limitations are discussed.

The analysis confirmed that *precipitation* is by far the best predictor of starting zone *snow accumulations*. The correlation between *precipitation* at the weather station and *snow accumulation* was strongest for the sheltered transect, but the correlation was significant for the windward transect as well. *Snow accumulations* at the sheltered transect tended to be the same as at the Little Bear weather station. This suggests that the non-wind-affected *snow accumulations* in the immediate area of the three transects was roughly the same as precipitation measured at Little Bear.

The wind redistributed snow during the study period. The redistribution resulted in a *snow accumulation* surplus where *loading winds* were positive, and a *snow accumulation* deficit where *loading winds* were negative. There was a significant positive correlation between *loading wind* and *snow accumulation* at the lee transect, there was no significant correlation at the windward transect (Table 10). The correlation between *loading wind* and *snow accumulation* in the presence of *precipitation* was not significant at $\alpha < 0.10$. (Table 11, $P = 0.1055$).

These results suggest that *loading wind* would be valuable for identifying which of several starting zones receives more snow during an accumulation period, and would therefore be most prone to avalanching. This would be a particular advantage to regional avalanche forecasters who must keep track of several avalanche areas without the benefit of day to day field observations.

Temperature was negatively correlated to lee slope *snow accumulations* during the study. This is consistent with expectations, but the result should be interpreted with caution because of the the small sample size (n = 5).

Humidity did not affect lee slope *snow accumulation* during the study. However, the narrow range of observed humidities (73% to 92%) was probably not adequate to test the expected relationship to snow accumulation.

The regression model provided an indication of level of accuracy with which starting zone snow accumulation, and therefore snowpack stress, can be estimated from weather data. While there is a great deal of uncertainty associated with the coefficient of determination, it is clear that no model can explain all of the observed variability in snow accumulation. The uncertainty associated with the model's estimates translates into uncertainty associated with avalanche forecasts. These results serve as a reminder that, while deterministic models can contribute to an avalanche forecast, the forecast must be developed with inductive reasoning, involving a diverse range of information, to reduce the uncertainty (LaChapelle 1980).

6.1 Limitations of the Study

The main limitations of this study are a consequence of the sampling design. Only two starting zones were sampled, one seven times and the other five. These data do not adequately represent all starting zone aspects or all weather conditions, so inferences drawn from the analysis cannot be generalized. Unfortunately, no comparison between *snow accumulations* predicted by the regression model and predictions based on the conventional intuitive model is possible because the intuitive model is not defined quantitatively in the literature.

The absence of *loading winds* near 0 is a particularly important limitation. If the aspect of a site were roughly perpendicular to the wind direction, the *loading wind* would be near 0. With *loading winds* near 0, slight changes in wind direction would cause the site to alternate between lee and windward, with consequent major differences in *snow accumulation.* The absence of small positive or negative *loading winds* from the data caused the *snow accumulation* vs *loading wind* data to group into two separate clusters (Figure 26). The intermediate values, with their expected higher variance, are missing, and the linearity of the relationship between *loading wind* and *snow accumulation* is exaggerated by the multiple regression model. As a result, the true predictive power of *loading wind* is almost certainly less than the 9% reduction in unexplained variance in *snow accumulation* calculated in the regression model.

Another important problem is that the *snow accumulation* values may not be good measures of the true starting zone accumulations. Snow depths along transects A and B varied dramatically at each observation. The average coefficient of variation for each transect was 0.76 (see Appendix 2). This suggests that the snow accumulation values used in the analysis might have been quite different had the transects been moved slightly, and, as a result, the outcome of the analysis might have been different. This sensitivity to the location of the transects could be overcome by using areal samples of starting zones. However, areal samples would have had too many stations to be completed in a single day as required.

The problem of snow depth variability was compounded by problems with the calculations used to determine transect water equivalents. The assumption that because the snow samples were close together they would have similar specific gravities followed from Goodison et al.(1981) and Fohn and Meister (1983) but the data suggest that this did not always hold true for transects A and B. Density samples suggested that the densities varied along the length of transects A and B (see Appendix 2). Consequently, the calculated *snow accumulations* may not be good estimates of the true quantity of water on the boards. Again, more samples would have been better, but were not possible within the time available on each trip.

CHAPTER 7 CONCLUSION

7.0 Conclusion

This study addressed two research questions:

1. How do the weather conditions at two upper elevation weather stations relate to the amount of snow deposited in starting zones four kilometers away?
2. How accurately can snow accumulation in the starting zones be estimated from the weather data?

Of the observed weather parameters; precipitation, wind, temperature, and humidity, only precipitation was closely related to starting zone snow accumulation. Loading wind, a new parameter combining wind speed and direction with starting zone aspect, was weakly related to period to period variation in snow accumulation at individual starting zones, but strongly related to starting zone to starting zone variation during individual time periods. Temperature was negatively related to the variation in snow accumulation in the lee starting zone that was not explained by variations in precipitation and wind, and humidity was not related to the unexplained snow accumulation variation in the lee starting zone.

A multiple linear regression model was developed to predict snow accumulations in two starting zones. At one starting zone, the accumulations predicted by the model were, on average, 35% greater or less than the observed accumulations. At the other starting zone the predictions were 28% greater or less than the observed accumulations. These large errors suggest that snow accumulations in individual starting zones cannot be accurately estimated from weather data. Further, they imply that numerical models will be unable to predict avalanches in individual paths from weather data until more of the snow accumulation variance can be explained.

7.1 Future Research

Future research into the problem of estimating starting zone snow accumulations from weather data would benefit from increasing the number of sampled accumulation periods and starting zones. Remote sensing, using attenuation of background gamma radiation as a measure of snow accumulation (see Offenbacher and Colbeck, 1991), might be a safe and effective alternative to manual observations. The large data set that remote sensing would provide could be used to develop a regression model with well defined prediction intervals to clearly define the potential accuracy of starting zone snow accumulation estimates.

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Appendix 1

Weather Data

Description of Weather Variables

Variable Name	Description
Date	Date of the reading.
Time	Time of the reading.
Ppt guage total	Depth of water in the Little Bear precipitation guage.
Ppt change	Change in the ppt guage total since the last hour.
Hrly ppt filtered for noise	Ppt change unless the ppt change reading for that hour or the hour before or after is negative.
Ppt this hour	Counter of the number of hours with recorded, non-noise, precipitation. 1 if precipitation recorded.
RH	Relative humidity at Great Bear.
RH when Ppt	Relative humidity recorded during hours when precipitation was recorded. If no preciptation was recorded this value is set to 0.
Temp	Temperature at Great Bear.
Temp when Ppt	Temperature recorded during hours when precipitation was recorded. If no preciptation was recorded this value is set to 0.
Wind Dir	Wind direction (azimuth) at Great Bear calculated by the data logger from 30 instantaneous readings taken during the hour.
Wind Speed	Wind speed at Great Bear calculated by the data logger from 30 readings during the hour.
Wind Vector Coordinates	
x	The component of the wind vector that is from the east = wind speed x sin(wind dir)

Wind Speed	Wind Dir	x
10	270	-10.00
10	60	8.66
10	300	-8.66
10	180	0.00

Variable name	Description
y	The component of the wind vector that is from the north = wind speed x cos(wind dir)

Wind Speed	Wind Dir	y
10	270	0.00
10	60	5.00
10	300	5.00
10	180	-10.00

x and y when ppt	The east and north components of the wind vectors calculated as above for hours with precipitation, and set to 0 for hours without precipitation.
Average wind speed	Vector average =((average x)**2 + (average y)**2)**1 /2

Average x	Average y	Average Speed
10	10	14.14
10	5	11.18
-10	0	10.00

Average wind direction	the angle between north and the line joining the origin (0,0) and (x,y)

x	y	Average dir
1	1	45
-1	-1	225
1	0	90
0	1	360

Aspect	Transect aspect
Incident Angle	Angle between the the average wind direction and the transect aspect.

wind direction	aspect	incident angle
270	90	0
360	90	90
45	90	135
90	90	180

Loading Wind	= cos(incident angle) x average wind speed

incident angle	av wind speed	loading wind
0	10	10.00
45	10	7.07
90	10	0.00
180	10	-10.00

Appendix 1

Weather Data for February 10 - February 22

Date	Time	Ppt guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when Ppt (%)	Temp (°C)	Temp when Ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	y (km/h)
10-Feb-94	16:00	211	0	0	0	89	0	-7.5	0	263	9	-8.93	-1.10	0.00	0.00
10-Feb-94	17:00	210	-1	0	0	90	0	-7.7	0	271	16	-16.00	0.28	0.00	0.00
10-Feb-94	18:00	210	0	0	0	90	0	-7.7	0	290	17	-15.97	5.81	0.00	0.00
10-Feb-94	19:00	210	0	0	0	90	0	-8.1	0	262	14	-13.86	-1.95	0.00	0.00
10-Feb-94	20:00	210	0	0	0	90	0	-8.1	0	246	13	-11.88	-5.29	0.00	0.00
10-Feb-94	21:00	210	0	0	0	90	0	-8.1	0	264	10	-9.95	-1.05	0.00	0.00
10-Feb-94	22:00	210	0	0	0	90	0	-8.2	0	255	13	-12.56	-3.36	0.00	0.00
10-Feb-94	23:00	210	0	0	0	90	0	-8.4	0	255	13	-12.56	-3.36	0.00	0.00
11-Feb-94	00:00	209	-1	0	0	90	0	-8.7	0	275	19	-18.93	1.66	0.00	0.00
11-Feb-94	01:00	209	0	0	0	90	0	-8.7	0	272	13	-12.99	0.45	0.00	0.00
11-Feb-94	02:00	209	0	0	0	90	0	-8.7	0	291	16	-14.94	5.73	0.00	0.00
11-Feb-94	03:00	209	0	0	0	90	0	-8.8	0	270	13	-13.00	0.00	0.00	0.00
11-Feb-94	04:00	209	0	0	0	90	0	-8.4	0	284	21	-20.38	5.08	0.00	0.00
11-Feb-94	05:00	209	0	0	0	90	0	-8.5	0	285	15	-14.49	3.88	0.00	0.00
11-Feb-94	06:00	209	0	0	0	90	0	-8.7	0	287	19	-18.17	5.56	0.00	0.00
11-Feb-94	07:00	209	0	0	0	90	0	-8.8	0	283	17	-16.56	3.82	0.00	0.00
11-Feb-94	08:00	209	0	0	0	90	0	-9	0	245	13	-11.78	-5.49	0.00	0.00
11-Feb-94	09:00	209	0	0	0	90	0	-8.9	0	253	13	-12.43	-3.80	0.00	0.00
11-Feb-94	10:00	209	0	0	0	90	0	-8.8	0	247	13	-11.97	-5.08	0.00	0.00
11-Feb-94	11:00	210	1	1	1	90	90	-8.1	-8.1	243	16	-14.26	-7.26	-14.26	-7.26
11-Feb-94	12:00	210	0	0	0	90	0	-7.7	0	247	14	-12.89	-5.47	0.00	0.00
11-Feb-94	13:00	210	0	0	0	90	0	-8	0	250	20	-18.79	-6.84	0.00	0.00
11-Feb-94	14:00	210	0	0	0	90	0	-8.1	0	247	24	-22.09	-9.38	0.00	0.00
11-Feb-94	15:00	210	0	0	0	90	0	-8	0	245	18	-16.31	-7.61	0.00	0.00

11-Feb-94	16:00	210	0	0	0	90	0	-7.9	0	258	19	-18.58	-3.95	0.00	0.00
11-Feb-94	17:00	211	1	1	1	90	90	-7.5	-7.5	270	21	-21.00	0.00	-21.00	0.00
11-Feb-94	18:00	211	0	0	0	90	0	-7.1	0	269	22	-22.00	-0.38	0.00	0.00
11-Feb-94	19:00	212	1	1	1	90	90	-6.8	-6.8	256	22	-21.35	-5.32	-21.35	-5.32
11-Feb-94	20:00	212	0	0	0	90	0	-6.4	0	266	24	-23.94	-1.67	0.00	0.00
11-Feb-94	21:00	213	1	1	1	90	90	-6.4	-6.4	248	28	-25.96	-10.49	-25.96	-10.49
11-Feb-94	22:00	213	0	0	0	90	0	-6	0	249	25	-23.34	-8.96	0.00	0.00
11-Feb-94	23:00	214	1	1	1	90	90	-5.7	-5.7	249	24	-22.41	-8.60	-22.41	-8.60
12-Feb-94	00:00	215	1	1	1	90	90	-5.7	-5.7	247	24	-22.09	-9.38	-22.09	-9.38
12-Feb-94	01:00	216	1	1	1	90	90	-5.8	-5.8	243	20	-17.82	-9.08	-17.82	-9.08
12-Feb-94	02:00	217	1	1	1	90	90	-5.7	-5.7	235	25	-20.48	-14.34	-20.48	-14.34
12-Feb-94	03:00	218	1	1	1	90	90	-5.7	-5.7	236	30	-24.87	-16.78	-24.87	-16.78
12-Feb-94	04:00	218	0	0	0	90	0	-5.8	0	238	23	-19.51	-12.19	0.00	0.00
12-Feb-94	05:00	218	0	0	0	90	0	-5.5	0	235	31	-25.39	-17.78	0.00	0.00
12-Feb-94	06:00	219	1	1	1	90	90	-5.5	-5.5	233	28	-22.36	-16.85	-22.36	-16.85
12-Feb-94	07:00	219	0	0	0	90	0	-5.5	0	244	30	-26.96	-13.15	0.00	0.00
12-Feb-94	08:00	219	0	0	0	91	0	-5.6	0	244	27	-24.27	-11.84	0.00	0.00
12-Feb-94	09:00	219	0	0	0	91	0	-5.6	0	225	23	-16.26	-16.26	0.00	0.00
12-Feb-94	10:00	220	1	1	1	91	91	-5.4	-5.4	242	28	-24.72	-13.15	-24.72	-13.15
12-Feb-94	11:00	220	0	0	0	90	0	-5.2	0	220	20	-12.86	-15.32	0.00	0.00
12-Feb-94	12:00	221	1	1	1	90	90	-4	-4	194	16	-3.87	-15.52	-3.87	-15.52
12-Feb-94	13:00	221	0	0	0	91	0	-4.8	0	200	24	-8.21	-22.55	0.00	0.00
12-Feb-94	14:00	222	1	1	1	91	91	-4.9	-4.9	178	18	0.63	-17.99	0.63	-17.99
12-Feb-94	15:00	222	0	0	0	91	0	-5.1	0	196	16	-4.41	-15.38	0.00	0.00
12-Feb-94	16:00	222	0	0	0	91	0	-5.3	0	185	9	-0.78	-8.97	0.00	0.00
12-Feb-94	17:00	223	1	1	1	91	91	-5.6	-5.6	188	11	-1.53	-10.89	-1.53	-10.89
12-Feb-94	18:00	223	0	0	0	91	0	-5.5	0	163	9	2.63	-8.61	0.00	0.00
12-Feb-94	19:00	224	1	1	1	91	91	-5.5	-5.5	216	13	-7.64	-10.52	-7.64	-10.52
12-Feb-94	20:00	225	1	1	1	91	91	-5.5	-5.5	196	14	-3.86	-13.46	-3.86	-13.46
12-Feb-94	21:00	226	1	1	1	91	91	-5.3	-5.3	195	13	-3.36	-12.56	-3.36	-12.56
12-Feb-94	22:00	227	1	1	1	91	91	-5	-5	198	16	-4.94	-15.22	-4.94	-15.22
12-Feb-94	23:00	230	3	3	1	91	91	-4.7	-4.7	192	18	-3.74	-17.61	-3.74	-17.61
13-Feb-94	00:00	233	3	3	1	91	91	-4.5	-4.5	223	16	-10.91	-11.70	-10.91	-11.70
13-Feb-94	01:00	236	3	3	1	91	91	-4.4	-4.4	177	9	0.47	-8.99	0.47	-8.99
13-Feb-94	02:00	239	3	3	1	91	91	-4.5	-4.5	190	11	-1.91	-10.83	-1.91	-10.83

13-Feb-94	03:00	241	2	2	1	91	91	-4.9	-4.9	230	18	-13.79	-11.57	-13.79	-11.57
13-Feb-94	04:00	244	3	3	1	91	91	-5.1	-5.1	188	18	-2.51	-17.82	-2.51	-17.82
13-Feb-94	05:00	247	3	3	1	91	91	-4.9	-4.9	191	7	-1.34	-6.87	-1.34	-6.87
13-Feb-94	06:00	250	3	3	1	91	91	-4.9	-4.9	196	11	-3.03	-10.57	-3.03	-10.57
13-Feb-94	07:00	252	2	2	1	91	91	-4.9	-4.9	206	9	-3.95	-8.09	-3.95	-8.09
13-Feb-94	08:00	255	3	3	1	91	91	-5.1	-5.1	235	10	-8.19	-5.74	-8.19	-5.74
13-Feb-94	09:00	258	3	3	1	91	91	-5.4	-5.4	246	17	-15.53	-6.91	-15.53	-6.91
13-Feb-94	10:00	260	2	2	1	91	91	-5.6	-5.6	228	16	-11.89	-10.71	-11.89	-10.71
13-Feb-94	11:00	262	2	2	1	91	91	-5.5	-5.5	235	13	-10.65	-7.46	-10.65	-7.46
13-Feb-94	12:00	262	0	0	0	91	0	-5.6	0	238	16	-13.57	-8.48	0.00	0.00
13-Feb-94	13:00	263	1	1	1	91	91	-6.1	-6.1	248	19	-17.62	-7.12	-17.62	-7.12
13-Feb-94	14:00	265	2	2	1	91	91	-5.9	-5.9	241	12	-10.50	-5.82	-10.50	-5.82
13-Feb-94	15:00	266	1	1	1	91	91	-5.8	-5.8	212	10	-5.30	-8.48	-5.30	-8.48
13-Feb-94	16:00	267	1	1	1	91	91	-6.3	-6.3	203	13	-5.08	-11.97	-5.08	-11.97
13-Feb-94	17:00	270	3	3	1	91	91	-6.6	-6.6	217	18	-10.83	-14.38	-10.83	-14.38
13-Feb-94	18:00	270	0	0	0	91	0	-7.4	0	231	39	-30.31	-24.54	0.00	0.00
13-Feb-94	19:00	269	-1	0	0	91	0	-8.7	0	234	47	-38.02	-27.63	0.00	0.00
13-Feb-94	20:00	270	1	0	0	91	0	-8.6	0	238	33	-27.99	-17.49	0.00	0.00
13-Feb-94	21:00	271	1	1	1	91	91	-8.5	-8.5	255	20	-19.32	-5.18	-19.32	-5.18
13-Feb-94	22:00	272	1	1	1	91	91	-8.8	-8.8	246	34	-31.06	-13.83	-31.06	-13.83
13-Feb-94	23:00	273	1	1	1	91	91	-8.7	-8.7	243	21	-18.71	-9.53	-18.71	-9.53
14-Feb-94	00:00	275	2	2	1	91	91	-8.5	-8.5	254	26	-24.99	-7.17	-24.99	-7.17
14-Feb-94	01:00	277	2	2	1	91	91	-8.3	-8.3	248	16	-14.83	-5.99	-14.83	-5.99
14-Feb-94	02:00	278	1	1	1	91	91	-8.2	-8.2	237	23	-19.29	-12.53	-19.29	-12.53
14-Feb-94	03:00	279	1	1	1	91	91	-8.1	-8.1	235	27	-22.12	-15.49	-22.12	-15.49
14-Feb-94	04:00	280	1	1	1	91	91	-7.8	-7.8	240	23	-19.92	-11.50	-19.92	-11.50
14-Feb-94	05:00	280	0	0	0	91	0	-7.9	0	229	29	-21.89	-19.03	0.00	0.00
14-Feb-94	06:00	281	1	1	1	91	91	-7.5	-7.5	236	21	-17.41	-11.74	-17.41	-11.74
14-Feb-94	07:00	281	0	0	0	91	0	-7.3	0	230	28	-21.45	-18.00	0.00	0.00
14-Feb-94	08:00	281	0	0	0	91	0	-7.2	0	219	25	-15.73	-19.43	0.00	0.00
14-Feb-94	09:00	281	0	0	0	91	0	-6.9	0	219	21	-13.22	-16.32	0.00	0.00
14-Feb-94	10:00	282	1	1	1	91	91	-5.5	-5.5	196	24	-6.62	-23.07	-6.62	-23.07
14-Feb-94	11:00	283	1	1	1	91	91	-5.4	-5.4	209	23	-11.15	-20.12	-11.15	-20.12
14-Feb-94	12:00	283	0	0	0	91	0	-4.9	0	204	24	-9.76	-21.93	0.00	0.00
14-Feb-94	13:00	284	1	1	1	91	91	-4.7	-4.7	189	22	-3.44	-21.73	-3.44	-21.73

14-Feb-94	14:00	285	1	1	1	91	91	-4.5	-4.5	201	18	-6.45	-16.80	-6.45	-16.80
14-Feb-94	15:00	285	0	0	0	91	0	-4.7	0	191	20	-3.82	-19.63	0.00	0.00
14-Feb-94	16:00	284	-1	0	0	91	0	-4.9	0	202	29	-10.86	-26.89	0.00	0.00
14-Feb-94	17:00	284	0	0	0	91	0	-5.2	0	197	22	-6.43	-21.04	0.00	0.00
14-Feb-94	18:00	284	0	0	0	91	0	-5.1	0	198	17	-5.25	-16.17	0.00	0.00
14-Feb-94	19:00	285	1	1	1	91	91	-5	-5	194	18	-4.35	-17.47	-4.35	-17.47
14-Feb-94	20:00	286	1	1	1	91	91	-4.8	-4.8	198	17	-5.25	-16.17	-5.25	-16.17
14-Feb-94	21:00	287	1	1	1	91	91	-4.8	-4.8	202	11	-4.12	-10.20	-4.12	-10.20
14-Feb-94	22:00	289	2	2	1	91	91	-4.8	-4.8	199	8	-2.60	-7.56	-2.60	-7.56
14-Feb-94	23:00	290	1	1	1	91	91	-4.7	-4.7	204	18	-7.32	-16.44	-7.32	-16.44
15-Feb-94	00:00	292	2	2	1	91	91	-4.7	-4.7	202	15	-5.62	-13.91	-5.62	-13.91
15-Feb-94	01:00	293	1	1	1	91	91	-4.7	-4.7	198	19	-5.87	-18.07	-5.87	-18.07
15-Feb-94	02:00	295	2	2	1	91	91	-4.7	-4.7	196	10	-2.76	-9.61	-2.76	-9.61
15-Feb-94	03:00	296	1	1	1	91	91	-4.6	-4.6	190	14	-2.43	-13.79	-2.43	-13.79
15-Feb-94	04:00	298	2	2	1	91	91	-4.6	-4.6	192	15	-3.12	-14.67	-3.12	-14.67
15-Feb-94	05:00	299	1	1	1	91	91	-4.4	-4.4	193	18	-4.05	-17.54	-4.05	-17.54
15-Feb-94	06:00	301	2	2	1	91	91	-4.2	-4.2	185	19	-1.66	-18.93	-1.66	-18.93
15-Feb-94	07:00	304	3	3	1	91	91	-4	-4	208	12	-5.63	-10.60	-5.63	-10.60
15-Feb-94	08:00	306	2	2	1	91	91	-3.8	-3.8	213	18	-9.80	-15.10	-9.80	-15.10
15-Feb-94	09:00	309	3	3	1	91	91	-3.4	-3.4	189	16	-2.50	-15.80	-2.50	-15.80
15-Feb-94	10:00	311	2	2	1	91	91	-3.3	-3.3	177	17	0.89	-16.98	0.89	-16.98
15-Feb-94	11:00	313	2	2	1	91	91	-3.3	-3.3	210	20	-10.00	-17.32	-10.00	-17.32
15-Feb-94	12:00	314	1	1	1	91	91	-3.5	-3.5	226	20	-14.39	-13.89	-14.39	-13.89
15-Feb-94	13:00	316	2	2	1	91	91	-3.4	-3.4	243	17	-15.15	-7.72	-15.15	-7.72
15-Feb-94	14:00	316	0	0	0	91	0	-3.7	0	236	22	-18.24	-12.30	0.00	0.00
15-Feb-94	15:00	316	0	0	0	91	0	-4	0	229	18	-13.58	-11.81	0.00	0.00
15-Feb-94	16:00	316	0	0	0	91	0	-4.2	0	210	11	-5.50	-9.53	0.00	0.00
15-Feb-94	17:00	316	0	0	0	91	0	-4.5	0	238	17	-14.42	-9.01	0.00	0.00
15-Feb-94	18:00	316	0	0	0	91	0	-5	0	237	23	-19.29	-12.53	0.00	0.00
15-Feb-94	19:00	315	-1	0	0	91	0	-4.9	0	236	19	-15.75	-10.62	0.00	0.00
15-Feb-94	20:00	315	0	0	0	91	0	-4.8	0	196	8	-2.21	-7.69	0.00	0.00
15-Feb-94	21:00	315	0	0	0	91	0	-4.7	0	196	10	-2.76	-9.61	0.00	0.00
15-Feb-94	22:00	315	0	0	0	91	0	-4.5	0	196	10	-2.76	-9.61	0.00	0.00
15-Feb-94	23:00	316	1	1	1	91	91	-4.3	-4.3	196	13	-3.58	-12.50	-3.58	-12.50
16-Feb-94	00:00	316	0	0	0	91	0	-4.1	0	195	21	-5.44	-20.28	0.00	0.00

16-Feb-94	01:00	316	0	0	0	91	0	-3.7	0	195	19	-4.92	-18.35	0.00	0.00
16-Feb-94	02:00	317	1	1	1	91	91	-3.3	-3.3	195	19	-4.92	-18.35	-4.92	-18.35
16-Feb-94	03:00	317	0	0	0	91	0	-3.4	0	154	25	10.96	-22.47	0.00	0.00
16-Feb-94	04:00	318	1	1	1	91	91	-3.2	-3.2	126	37	29.93	-21.75	29.93	-21.75
16-Feb-94	05:00	319	1	1	1	91	91	-2.8	-2.8	126	35	28.32	-20.57	28.32	-20.57
16-Feb-94	06:00	320	1	1	1	91	91	-2.1	-2.1	133	25	18.28	-17.05	18.28	-17.05
16-Feb-94	07:00	321	1	1	1	91	91	-1.9	-1.9	163	22	6.43	-21.04	6.43	-21.04
16-Feb-94	08:00	322	1	1	1	91	91	-1.8	-1.8	163	22	6.43	-21.04	6.43	-21.04
16-Feb-94	09:00	323	1	1	1	91	91	-1.7	-1.7	165	19	4.92	-18.35	4.92	-18.35
16-Feb-94	10:00	323	0	0	0	91	0	-1.4	0	166	25	6.05	-24.26	0.00	0.00
16-Feb-94	11:00	323	0	0	0	91	0	-1	0	174	20	2.09	-19.89	0.00	0.00
16-Feb-94	12:00	323	0	0	0	90	0	-0.8	0	154	25	10.96	-22.47	0.00	0.00
16-Feb-94	13:00	324	1	1	1	90	90	-0.9	-0.9	187	13	-1.58	-12.90	-1.58	-12.90
16-Feb-94	14:00	324	0	0	0	90	0	-0.9	0	170	21	3.65	-20.68	0.00	0.00
16-Feb-94	15:00	324	0	0	0	90	0	-1	0	157	26	10.16	-23.93	0.00	0.00
16-Feb-94	16:00	324	0	0	0	90	0	-1.1	0	147	24	13.07	-20.13	0.00	0.00
16-Feb-94	17:00	325	1	1	1	90	90	-1.3	-1.3	196	16	-4.41	-15.38	-4.41	-15.38
16-Feb-94	18:00	325	0	0	0	90	0	-1.5	0	200	13	-4.45	-12.22	0.00	0.00
16-Feb-94	19:00	326	1	1	1	91	91	-1.6	-1.6	146	23	12.86	-19.07	12.86	-19.07
16-Feb-94	20:00	326	0	0	0	91	0	-1.6	0	158	26	9.74	-24.11	0.00	0.00
16-Feb-94	21:00	326	0	0	0	90	0	-1.6	0	139	27	17.71	-20.38	0.00	0.00
16-Feb-94	22:00	326	0	0	0	91	0	-1.8	0	144	28	16.46	-22.65	0.00	0.00
16-Feb-94	23:00	326	0	0	0	91	0	-1.9	0	147	33	17.97	-27.68	0.00	0.00
17-Feb-94	00:00	326	0	0	0	91	0	-1.9	0	158	28	10.49	-25.96	0.00	0.00
17-Feb-94	01:00	326	0	0	0	91	0	-1.8	0	147	28	15.25	-23.48	0.00	0.00
17-Feb-94	02:00	327	1	1	1	91	91	-1.8	-1.8	177	19	0.99	-18.97	0.99	-18.97
17-Feb-94	03:00	327	0	0	0	91	0	-1.8	0	163	15	4.39	-14.34	0.00	0.00
17-Feb-94	04:00	328	1	0	0	91	0	-1.8	0	144	29	17.05	-23.46	0.00	0.00
17-Feb-94	05:00	327	-1	0	0	91	0	-1.8	0	132	32	23.78	-21.41	0.00	0.00
17-Feb-94	06:00	327	0	0	0	91	0	-1.8	0	130	29	22.22	-18.64	0.00	0.00
17-Feb-94	07:00	328	1	0	0	91	0	-2	0	110	33	31.01	-11.29	0.00	0.00
17-Feb-94	08:00	327	-1	0	0	91	0	-1.9	0	106	33	31.72	-9.10	0.00	0.00
17-Feb-94	09:00	328	1	0	0	91	0	-1.8	0	115	33	29.91	-13.95	0.00	0.00
17-Feb-94	10:00	328	0	0	0	91	0	-1.4	0	114	26	23.75	-10.58	0.00	0.00
17-Feb-94	11:00	328	0	0	0	91	0	-1.2	0	134	23	16.54	-15.98	0.00	0.00

17-Feb-94	12:00	329	1	1	1	91	91	-0.8	-0.8	152	19	8.92	-16.78	8.92	-16.78
17-Feb-94	13:00	329	0	0	0	90	0	-0.1	0	143	18	10.83	-14.38	0.00	0.00
17-Feb-94	14:00	330	1	1	1	90	90	0	0	150	13	6.50	-11.26	6.50	-11.26
17-Feb-94	15:00	330	0	0	0	89	0	0.1	0	205	6	-2.54	-5.44	0.00	0.00
17-Feb-94	16:00	331	1	1	1	90	90	-0.8	-0.8	273	7	-6.99	0.37	-6.99	0.37
17-Feb-94	17:00	331	0	0	0	90	0	-1.5	0	267	7	-6.99	-0.37	0.00	0.00
17-Feb-94	18:00	331	0	0	0	91	0	-2.4	0	254	8	-7.69	-2.21	0.00	0.00
17-Feb-94	19:00	331	0	0	0	91	0	-3.2	0	252	13	-12.36	-4.02	0.00	0.00
17-Feb-94	20:00	330	-1	0	0	92	0	-3.9	0	251	16	-15.13	-5.21	0.00	0.00
17-Feb-94	21:00	330	0	0	0	92	0	-4.5	0	249	10	-9.34	-3.58	0.00	0.00
17-Feb-94	22:00	330	0	0	0	92	0	-4.9	0	234	14	-11.33	-8.23	0.00	0.00
17-Feb-94	23:00	331	1	1	1	92	92	-5.2	-5.2	233	13	-10.38	-7.82	-10.38	-7.82
18-Feb-94	00:00	331	0	0	0	92	0	-5.5	0	244	14	-12.58	-6.14	0.00	0.00
18-Feb-94	01:00	331	0	0	0	92	0	-5.9	0	277	20	-19.85	2.44	0.00	0.00
18-Feb-94	02:00	331	0	0	0	92	0	-5.9	0	298	18	-15.89	8.45	0.00	0.00
18-Feb-94	03:00	332	1	1	1	92	92	-6.1	-6.1	272	14	-13.99	0.49	-13.99	0.49
18-Feb-94	04:00	332	0	0	0	92	0	-6.8	0	245	19	-17.22	-8.03	0.00	0.00
18-Feb-94	05:00	333	1	0	0	92	0	-7.2	0	249	29	-27.07	-10.39	0.00	0.00
18-Feb-94	06:00	332	-1	0	0	92	0	-7.4	0	244	21	-18.87	-9.21	0.00	0.00
18-Feb-94	07:00	332	0	0	0	92	0	-7.7	0	247	18	-16.57	-7.03	0.00	0.00
18-Feb-94	08:00	333	1	1	1	92	92	-7.8	-7.8	241	20	-17.49	-9.70	-17.49	-9.70
18-Feb-94	09:00	333	0	0	0	92	0	-7.4	0	254	18	-17.30	-4.96	0.00	0.00
18-Feb-94	10:00	334	1	1	1	92	92	-7	-7	249	16	-14.94	-5.73	-14.94	-5.73
18-Feb-94	11:00	334	0	0	0	92	0	-6.4	0	237	16	-13.42	-8.71	0.00	0.00
18-Feb-94	12:00	334	0	0	0	92	0	-6.3	0	251	15	-14.18	-4.88	0.00	0.00
18-Feb-94	13:00	334	0	0	0	91	0	-7.1	0	240	19	-16.45	-9.50	0.00	0.00
18-Feb-94	14:00	334	0	0	0	92	0	-6.9	0	246	19	-17.36	-7.73	0.00	0.00
18-Feb-94	15:00	334	0	0	0	92	0	-7.1	0	242	19	-16.78	-8.92	0.00	0.00
18-Feb-94	16:00	334	0	0	0	92	0	-7.2	0	243	17	-15.15	-7.72	0.00	0.00
18-Feb-94	17:00	334	0	0	0	92	0	-7.5	0	246	17	-15.53	-6.91	0.00	0.00
18-Feb-94	18:00	334	0	0	0	92	0	-7.6	0	235	14	-11.47	-8.03	0.00	0.00
18-Feb-94	19:00	334	0	0	0	92	0	-8	0	227	18	-13.16	-12.28	0.00	0.00
18-Feb-94	20:00	334	0	0	0	92	0	-7.9	0	233	17	-13.58	-10.23	0.00	0.00
18-Feb-94	21:00	334	0	0	0	92	0	-7.9	0	226	16	-11.51	-11.11	0.00	0.00
18-Feb-94	22:00	334	0	0	0	92	0	-8	0	232	13	-10.24	-8.00	0.00	0.00

18-Feb-94	23:00	334	0	0	0	92	0	-7.9	0	227	10	-7.31	-6.82	0.00	0.00
19-Feb-94	00:00	334	0	0	0	92	0	-8	0	199	11	-3.58	-10.40	0.00	0.00
19-Feb-94	01:00	335	1	1	1	92	92	-8	-8	204	15	-6.10	-13.70	-6.10	-13.70
19-Feb-94	02:00	335	0	0	0	92	0	-8	0	233	8	-6.39	-4.81	0.00	0.00
19-Feb-94	03:00	336	1	1	1	92	92	-8	-8	202	12	-4.50	-11.13	-4.50	-11.13
19-Feb-94	04:00	337	1	1	1	92	92	-8	-8	197	12	-3.51	-11.48	-3.51	-11.48
19-Feb-94	05:00	338	1	1	1	92	92	-8	-8	201	7	-2.51	-6.54	-2.51	-6.54
19-Feb-94	06:00	338	0	0	0	92	0	-8.1	0	233	6	-4.79	-3.61	0.00	0.00
19-Feb-94	07:00	338	0	0	0	92	0	-8.5	0	250	8	-7.52	-2.74	0.00	0.00
19-Feb-94	08:00	338	0	0	0	92	0	-8.5	0	243	9	-8.02	-4.09	0.00	0.00
19-Feb-94	09:00	339	1	1	1	92	92	-7.9	-7.9	253	6	-5.74	-1.75	-5.74	-1.75
19-Feb-94	10:00	339	0	0	0	91	0	-6.6	0	211	3	-1.55	-2.57	0.00	0.00
19-Feb-94	11:00	340	1	1	1	91	91	-5.3	-5.3	250	4	-3.76	-1.37	-3.76	-1.37
19-Feb-94	12:00	340	0	0	0	91	0	-5.3	0	254	6	-5.77	-1.65	0.00	0.00
19-Feb-94	13:00	341	1	1	1	90	90	-4.7	-4.7	254	8	-7.69	-2.21	-7.69	-2.21
19-Feb-94	14:00	341	0	0	0	90	0	-4.6	0	256	7	-6.79	-1.69	0.00	0.00
19-Feb-94	15:00	340	-1	0	0	90	0	-5.4	0	242	8	-7.06	-3.76	0.00	0.00
19-Feb-94	16:00	340	0	0	0	90	0	-5.7	0	248	4	-3.71	-1.50	0.00	0.00
19-Feb-94	17:00	339	-1	0	0	90	0	-7.2	0	237	7	-5.87	-3.81	0.00	0.00
19-Feb-94	18:00	339	0	0	0	91	0	-7.6	0	200	4	-1.37	-3.76	0.00	0.00
19-Feb-94	19:00	338	-1	0	0	91	0	-8.1	0	200	17	-5.81	-15.97	0.00	0.00
19-Feb-94	20:00	338	0	0	0	91	0	-8.8	0	189	15	-2.35	-14.82	0.00	0.00
19-Feb-94	21:00	338	0	0	0	91	0	-9.1	0	187	18	-2.19	-17.87	0.00	0.00
19-Feb-94	22:00	338	0	0	0	91	0	-9.1	0	193	13	-2.92	-12.67	0.00	0.00
19-Feb-94	23:00	338	0	0	0	91	0	-9.5	0	181	10	-0.17	-10.00	0.00	0.00
20-Feb-94	00:00	338	0	0	0	91	0	-9.6	0	163	9	2.63	-8.61	0.00	0.00
20-Feb-94	01:00	338	0	0	0	91	0	-9.4	0	116	11	9.89	-4.82	0.00	0.00
20-Feb-94	02:00	337	-1	0	0	91	0	-9.3	0	117	17	15.15	-7.72	0.00	0.00
20-Feb-94	03:00	338	1	0	0	90	0	-8.8	0	110	15	14.10	-5.13	0.00	0.00
20-Feb-94	04:00	338	0	0	0	90	0	-8.5	0	117	21	18.71	-9.53	0.00	0.00
20-Feb-94	05:00	338	0	0	0	90	0	-8.7	0	111	29	27.07	-10.39	0.00	0.00
20-Feb-94	06:00	338	0	0	0	91	0	-8.6	0	118	33	29.14	-15.49	0.00	0.00
20-Feb-94	07:00	338	0	0	0	91	0	-7.9	0	132	34	25.27	-22.75	0.00	0.00
20-Feb-94	08:00	338	0	0	0	90	0	-7.6	0	136	32	22.23	-23.02	0.00	0.00
20-Feb-94	09:00	339	1	1	1	90	90	-7.2	-7.2	124	35	29.02	-19.57	29.02	-19.57

20-Feb-94	10:00	340	1	1	1	88	88	-4.7	-4.7	143	28	16.85	-22.36	16.85	-22.36
20-Feb-94	11:00	340	0	0	0	86	0	-4.5	0	160	23	7.87	-21.61	0.00	0.00
20-Feb-94	12:00	341	1	1	1	83	83	-2.8	-2.8	196	14	-3.86	-13.46	-3.86	-13.46
20-Feb-94	13:00	341	0	0	0	82	0	-3.1	0	190	17	-2.95	-16.74	0.00	0.00
20-Feb-94	14:00	341	0	0	0	82	0	-2.7	0	208	8	-3.76	-7.06	0.00	0.00
20-Feb-94	15:00	341	0	0	0	84	0	-3.6	0	186	7	-0.73	-6.96	0.00	0.00
20-Feb-94	16:00	340	-1	0	0	87	0	-4	0	193	6	-1.35	-5.85	0.00	0.00
20-Feb-94	17:00	340	0	0	0	88	0	-5	0	194	11	-2.66	-10.67	0.00	0.00
20-Feb-94	18:00	340	0	0	0	89	0	-5.8	0	177	14	0.73	-13.98	0.00	0.00
20-Feb-94	19:00	340	0	0	0	89	0	-6.2	0	151	25	12.12	-21.87	0.00	0.00
20-Feb-94	20:00	340	0	0	0	88	0	-6.7	0	179	25	0.44	-25.00	0.00	0.00
20-Feb-94	21:00	340	0	0	0	88	0	-6.4	0	163	27	7.89	-25.82	0.00	0.00
20-Feb-94	22:00	340	0	0	0	88	0	-6.9	0	178	22	0.77	-21.99	0.00	0.00
20-Feb-94	23:00	340	0	0	0	88	0	-7.3	0	192	24	-4.99	-23.48	0.00	0.00
21-Feb-94	00:00	339	-1	0	0	88	0	-7	0	161	25	8.14	-23.64	0.00	0.00
21-Feb-94	01:00	340	1	0	0	88	0	-7.1	0	197	19	-5.56	-18.17	0.00	0.00
21-Feb-94	02:00	339	-1	0	0	88	0	-7.3	0	170	13	2.26	-12.80	0.00	0.00
21-Feb-94	03:00	339	0	0	0	87	0	-7.2	0	168	21	4.37	-20.54	0.00	0.00
21-Feb-94	04:00	339	0	0	0	88	0	-7.3	0	146	22	12.30	-18.24	0.00	0.00
21-Feb-94	05:00	340	1	0	0	88	0	-7.2	0	142	29	17.85	-22.85	0.00	0.00
21-Feb-94	06:00	339	-1	0	0	88	0	-7.5	0	151	25	12.12	-21.87	0.00	0.00
21-Feb-94	07:00	339	0	0	0	88	0	-7.6	0	164	21	5.79	-20.19	0.00	0.00
21-Feb-94	08:00	339	0	0	0	87	0	-5.8	0	155	27	11.41	-24.47	0.00	0.00
21-Feb-94	09:00	339	0	0	0	85	0	-5.6	0	154	30	13.15	-26.96	0.00	0.00
21-Feb-94	10:00	340	1	1	1	84	84	-5.3	-5.3	140	28	18.00	-21.45	18.00	-21.45
21-Feb-94	11:00	341	1	1	1	84	84	-4.1	-4.1	179	14	0.24	-14.00	0.24	-14.00
21-Feb-94	12:00	341	0	0	0	86	0	-4.4	0	212	5	-2.65	-4.24	0.00	0.00
21-Feb-94	13:00	342	1	1	1	87	87	-5.1	-5.1	268	11	-10.99	-0.38	-10.99	-0.38
21-Feb-94	14:00	343	1	1	1	87	87	-5	-5	275	4	-3.98	0.35	-3.98	0.35
21-Feb-94	15:00	344	1	1	1	88	88	-6	-6	280	12	-11.82	2.08	-11.82	2.08
21-Feb-94	16:00	344	0	0	0	88	0	-7	0	291	14	-13.07	5.02	0.00	0.00
21-Feb-94	17:00	344	0	0	0	89	0	-7.4	0	257	11	-10.72	-2.47	0.00	0.00
21-Feb-94	18:00	343	-1	0	0	90	0	-7.8	0	264	14	-13.92	-1.46	0.00	0.00
21-Feb-94	19:00	343	0	0	0	90	0	-8.1	0	252	11	-10.46	-3.40	0.00	0.00
21-Feb-94	20:00	344	1	1	1	90	90	-8	-8	248	12	-11.13	-4.50	-11.13	-4.50

21-Feb-94	21:00	344	0	0	0	90	0	-8.1	0	241	14	-12.24	-6.79	0.00	0.00
21-Feb-94	22:00	344	0	0	0	90	0	-8.3	0	231	21	-16.32	-13.22	0.00	0.00
21-Feb-94	23:00	344	0	0	0	90	0	-8.4	0	228	22	-16.35	-14.72	0.00	0.00
22-Feb-94	00:00	345	1	1	1	90	90	-8.4	-8.4	240	18	-15.59	-9.00	-15.59	-9.00
22-Feb-94	01:00	345	0	0	0	90	0	-8.7	0	247	14	-12.89	-5.47	0.00	0.00
22-Feb-94	02:00	345	0	0	0	90	0	-8.7	0	274	16	-15.96	1.12	0.00	0.00
22-Feb-94	03:00	345	0	0	0	90	0	-8.6	0	262	17	-16.83	-2.37	0.00	0.00
22-Feb-94	04:00	346	1	1	1	90	90	-8.5	-8.5	252	16	-15.22	-4.94	-15.22	-4.94
22-Feb-94	05:00	347	1	1	1	90	90	-8.3	-8.3	233	13	-10.38	-7.82	-10.38	-7.82
22-Feb-94	06:00	347	0	0	0	90	0	-8.2	0	237	17	-14.26	-9.26	0.00	0.00
22-Feb-94	07:00	348	1	1	1	90	90	-8.2	-8.2	237	23	-19.29	-12.53	-19.29	-12.53
22-Feb-94	08:00	349	1	1	1	90	90	-8.1	-8.1	242	28	-24.72	-13.15	-24.72	-13.15
22-Feb-94	09:00	350	1	1	1	90	90	-7.9	-7.9	223	24	-16.37	-17.55	-16.37	-17.55
22-Feb-94	10:00	350	0	0	0	90	0	-7.6	0	241	23	-20.12	-11.15	0.00	0.00
22-Feb-94	11:00	351	1	1	1	88	88	-6.2	-6.2	240	12	-10.39	-6.00	-10.39	-6.00
22-Feb-94	12:00	352	1	1	1	87	87	-4.3	-4.3	217	11	-6.62	-8.78	-6.62	-8.78
22-Feb-94	13:00	353	1	1	1	87	87	-5.1	-5.1	204	16	-6.51	-14.62	-6.51	-14.62
22-Feb-94	14:00	353	0	0	0	88	0	-6.3	0	203	14	-5.47	-12.89	0.00	0.00
Total:				**152**	112										
Average for hrs with ppt:							**90.4**		**-5.3**					-7.24	-11.96

Average Wind Speed: 13.98
Average Wind Direction: 211.17

Loading Winds

transect	aspect	incident angle	speed	loading wind
A	210	178.83	13.98	**-13.98**

Weather Data for February 22 - February 25

Date	Time	Ppt. guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when Ppt (%)	Temp (°C)	Temp when Ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	when ppt y (km/h)
22-Feb-94	15:00	355	2	2	1	89	89	-6	-6	198	20	-6.18	-19.02	-6.18	-19.02
22-Feb-94	16:00	357	2	2	1	89	89	-6.2	-6.2	196	19	-5.24	-18.26	-5.24	-18.26
22-Feb-94	17:00	358	1	1	1	90	90	-5.7	-5.7	236	25	-20.73	-13.98	-20.73	-13.98
22-Feb-94	18:00	359	1	1	1	90	90	-5.5	-5.5	245	32	-29.00	-13.52	-29.00	-13.52
22-Feb-94	19:00	359	0	0	0	90	0	-6	0	230	30	-22.98	-19.28	0.00	0.00
22-Feb-94	20:00	360	1	1	1	90	90	-6.1	-6.1	242	35	-30.90	-16.43	-30.90	-16.43
22-Feb-94	21:00	361	1	1	1	91	91	-6.3	-6.3	228	36	-26.75	-24.09	-26.75	-24.09
22-Feb-94	22:00	362	1	1	1	91	91	-6.6	-6.6	236	34	-28.19	-19.01	-28.19	-19.01
22-Feb-94	23:00	364	2	2	1	91	91	-6.6	-6.6	257	28	-27.28	-6.30	-27.28	-6.30
23-Feb-94	00:00	366	2	2	1	91	91	-6.7	-6.7	244	26	-23.37	-11.40	-23.37	-11.40
23-Feb-94	01:00	367	1	1	1	91	91	-6.6	-6.6	258	29	-28.37	-6.03	-28.37	-6.03
23-Feb-94	02:00	369	2	2	1	91	91	-6.7	-6.7	260	31	-30.53	-5.38	-30.53	-5.38
23-Feb-94	03:00	372	3	3	1	91	91	-6.6	-6.6	257	27	-26.31	-6.07	-26.31	-6.07
23-Feb-94	04:00	375	3	3	1	91	91	-6.9	-6.9	254	29	-27.88	-7.99	-27.88	-7.99
23-Feb-94	05:00	378	3	3	1	91	91	-7.4	-7.4	263	23	-22.83	-2.80	-22.83	-2.80
23-Feb-94	06:00	379	1	1	1	91	91	-8	-8	284	28	-27.17	6.77	-27.17	6.77
23-Feb-94	07:00	381	2	2	1	91	91	-8.3	-8.3	294	24	-21.93	9.76	-21.93	9.76
23-Feb-94	08:00	383	2	2	1	91	91	-8.5	-8.5	248	26	-24.11	-9.74	-24.11	-9.74
23-Feb-94	09:00	384	1	1	1	91	91	-8.9	-8.9	281	19	-18.65	3.63	-18.65	3.63
23-Feb-94	10:00	386	2	2	1	90	90	-9.5	-9.5	272	23	-22.99	0.80	-22.99	0.80
23-Feb-94	11:00	386	0	0	0	90	0	-9.9	0	274	21	-20.95	1.46	0.00	0.00
23-Feb-94	12:00	386	0	0	0	90	0	-10.4	0	246	19	-17.36	-7.73	0.00	0.00
23-Feb-94	13:00	386	0	0	0	90	0	-10.3	0	261	18	-17.78	-2.82	0.00	0.00
23-Feb-94	14:00	387	1	1	1	90	90	-10.3	-10.3	279	22	-21.73	3.44	-21.73	3.44
23-Feb-94	15:00	387	0	0	0	89	0	-10.5	0	288	16	-15.22	4.94	0.00	0.00
23-Feb-94	16:00	387	0	0	0	89	0	-10.9	0	277	12	-11.91	1.46	0.00	0.00
23-Feb-94	17:00	387	0	0	0	89	0	-11.6	0	259	12	-11.78	-2.29	0.00	0.00

23-Feb-94	18:00	387	0	0	0	89	0	-12.1	0	248	14	-12.98	-5.24	0.00	0.00
23-Feb-94	19:00	387	0	0	0	89	0	-12.4	0	241	11	-9.62	-5.33	0.00	0.00
23-Feb-94	20:00	386	-1	0	0	88	0	-13.7	0	234	4	-3.24	-2.35	0.00	0.00
23-Feb-94	21:00	386	0	0	0	88	0	-14.8	0	47	6	4.39	4.09	0.00	0.00
23-Feb-94	22:00	385	-1	0	0	-99	0	-99	0	1	67	1.17	66.99	0.00	0.00
23-Feb-94	23:00	386	1	0	0	-99	0	-99	0	1	67	1.17	66.99	0.00	0.00
24-Feb-94	00:00	385	-1	0	0	-99	0	-99	0	0	67	0.00	67.00	0.00	0.00
24-Feb-94	01:00	385	0	0	0	-99	0	-99	0	0	67	0.00	67.00	0.00	0.00
24-Feb-94	02:00	385	0	0	0	-99	0	-99	0	0	67	0.00	67.00	0.00	0.00
24-Feb-94	03:00	384	-1	0	0	-99	0	-99	0	360	67	0.00	67.00	0.00	0.00
24-Feb-94	04:00	384	0	0	0	-99	0	-99	0	360	67	0.00	67.00	0.00	0.00
24-Feb-94	05:00	384	0	0	0	-99	0	-99	0	360	67	0.00	67.00	0.00	0.00
24-Feb-94	06:00	384	0	0	0	-99	0	-99	0	360	67	0.00	67.00	0.00	0.00
24-Feb-94	07:00	384	0	0	0	-99	0	-99	0	360	67	0.00	67.00	0.00	0.00
24-Feb-94	08:00	382	-2	0	0	-99	0	-99	0	359	67	-1.17	66.99	0.00	0.00
24-Feb-94	09:00	383	1	0	0	-99	0	-99	0	359	67	-1.17	66.99	0.00	0.00
24-Feb-94	10:00	383	0	0	0	83	0	-19.3	0	92	20	19.99	-0.70	0.00	0.00
24-Feb-94	11:00	383	0	0	0	83	0	-17.8	0	96	23	22.87	-2.40	0.00	0.00
24-Feb-94	12:00	385	2	2	1	80	80	-17.7	-17.7	88	26	25.98	0.91	25.98	0.91
24-Feb-94	13:00	385	0	0	0	78	0	-16.3	0	87	20	19.97	1.05	0.00	0.00
24-Feb-94	14:00	385	0	0	0	78	0	-16.8	0	95	24	23.91	-2.09	0.00	0.00
24-Feb-94	15:00	385	0	0	0	78	0	-16.5	0	92	24	23.99	-0.84	0.00	0.00
24-Feb-94	16:00	384	-1	0	0	79	0	-16.9	0	97	27	26.80	-3.29	0.00	0.00
24-Feb-94	17:00	384	0	0	0	79	0	-18.6	0	101	35	34.36	-6.68	0.00	0.00
24-Feb-94	18:00	384	0	0	0	79	0	-19.1	0	98	39	38.62	-5.43	0.00	0.00
24-Feb-94	19:00	384	0	0	0	80	0	-18.9	0	93	41	40.94	-2.15	0.00	0.00
24-Feb-94	20:00	386	2	0	0	80	0	-18.3	0	96	47	46.74	-4.91	0.00	0.00
24-Feb-94	21:00	385	-1	0	0	82	0	-17.8	0	93	39	38.95	-2.04	0.00	0.00
24-Feb-94	22:00	385	0	0	0	82	0	-17.5	0	89	34	33.99	0.59	0.00	0.00
24-Feb-94	23:00	386	1	1	1	84	84	-16.9	-16.9	71	23	21.75	7.49	21.75	7.49
25-Feb-94	00:00	386	0	0	0	84	0	-16.9	0	74	27	25.95	7.44	0.00	0.00
25-Feb-94	01:00	385	-1	0	0	85	0	-16.7	0	77	29	28.26	6.52	0.00	0.00
25-Feb-94	02:00	387	2	0	0	85	0	-15.5	0	76	22	21.35	5.32	0.00	0.00
25-Feb-94	03:00	388	1	1	1	85	85	-15.4	-15.4	73	20	19.13	5.85	19.13	5.85
25-Feb-94	04:00	389	1	1	1	86	86	-14.2	-14.2	71	14	13.24	4.56	13.24	4.56

25-Feb-94	05:00	390	1	1	1	87	87	-13.7	-13.7	78	9	8.80	1.87	8.80	1.87
25-Feb-94	06:00	390	0	0	0	87	0	-12.9	0	73	10	9.56	2.92	0.00	0.00
25-Feb-94	07:00	391	1	1	1	87	87	-12.7	-12.7	81	10	9.88	1.56	9.88	1.56
25-Feb-94	08:00	391	0	0	0	87	0	-13	0	100	14	13.79	-2.43	0.00	0.00
25-Feb-94	09:00	392	1	1	1	88	88	-12	-12	92	15	14.99	-0.52	14.99	-0.52
25-Feb-94	10:00	393	1	1	1	89	89	-8.9	-8.9	69	11	10.27	3.94	10.27	3.94
25-Feb-94	11:00	394	1	1	1	90	90	-5.7	-5.7	114	6	5.48	-2.44	5.48	-2.44
25-Feb-94	12:00	395	1	1	1	88	88	-2.1	-2.1	160	7	2.39	-6.58	2.39	-6.58
25-Feb-94	13:00	396	1	1	1	84	84	-1.8	-1.8	172	11	1.53	-10.89	1.53	-10.89
Total:				**46**	31										
Average for hrs with ppt:							**89.0**		**-8.5**					-10.86	-4.84

Average Wind Speed: 11.89
Average Wind Direction: 246.00

Loading Winds

transect	aspect	incident angle	speed	loading wind
A	210	144.00	11.89	**-9.62**

Weather Data for February 25 - March 3

Date	Time	Ppt guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when Ppt (%)	Temp (°C)	Temp when Ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	when ppt y (km/h)
25-Feb-94	14:00	396	0	0	0	85	0	-2.4	0	183	8	-0.42	-7.99	0.00	0.00
25-Feb-94	15:00	396	0	0	0	85	0	-2.3	0	190	12	-2.08	-11.82	0.00	0.00
25-Feb-94	16:00	397	1	1	1	87	87	-3.4	-3.4	202	15	-5.62	-13.91	-5.62	-13.91
25-Feb-94	17:00	397	0	0	0	89	0	-3.7	0	206	18	-7.89	-16.18	0.00	0.00
25-Feb-94	18:00	398	1	1	1	90	90	-3.8	-3.8	214	20	-11.18	-16.58	-11.18	-16.58
25-Feb-94	19:00	398	0	0	0	90	0	-3.1	0	216	22	-12.93	-17.80	0.00	0.00
25-Feb-94	20:00	399	1	1	1	90	90	-2.8	-2.8	243	20	-17.82	-9.08	-17.82	-9.08
25-Feb-94	21:00	400	1	1	1	91	91	-2.8	-2.8	263	20	-19.85	-2.44	-19.85	-2.44
25-Feb-94	22:00	401	1	1	1	90	90	-2.6	-2.6	250	18	-16.91	-6.16	-16.91	-6.16
25-Feb-94	23:00	402	1	1	1	91	91	-2.9	-2.9	253	16	-15.30	-4.68	-15.30	-4.68
26-Feb-94	00:00	403	1	1	1	91	91	-3.1	-3.1	245	18	-16.31	-7.61	-16.31	-7.61
26-Feb-94	01:00	404	1	1	1	91	91	-3	-3	254	13	-12.50	-3.58	-12.50	-3.58
26-Feb-94	02:00	404	0	0	0	91	0	-2.9	0	221	14	-9.18	-10.57	0.00	0.00
26-Feb-94	03:00	404	0	0	0	91	0	-3	0	236	13	-10.78	-7.27	0.00	0.00
26-Feb-94	04:00	404	0	0	0	91	0	-3.1	0	234	11	-8.90	-6.47	0.00	0.00
26-Feb-94	05:00	404	0	0	0	91	0	-3.2	0	252	5	-4.76	-1.55	0.00	0.00
26-Feb-94	06:00	404	0	0	0	91	0	-3.6	0	244	9	-8.09	-3.95	0.00	0.00
26-Feb-94	07:00	404	0	0	0	91	0	-3.7	0	222	13	-8.70	-9.66	0.00	0.00
26-Feb-94	08:00	404	0	0	0	91	0	-3.2	0	217	13	-7.82	-10.38	0.00	0.00
26-Feb-94	09:00	405	1	1	1	90	90	-2.3	-2.3	208	14	-6.57	-12.36	-6.57	-12.36
26-Feb-94	10:00	406	1	1	1	85	85	-0.2	-0.2	193	15	-3.37	-14.62	-3.37	-14.62
26-Feb-94	11:00	406	0	0	0	80	0	0	0	184	8	-0.56	-7.98	0.00	0.00
26-Feb-94	12:00	407	1	1	1	85	85	-0.4	-0.4	157	13	5.08	-11.97	5.08	-11.97
26-Feb-94	13:00	407	0	0	0	86	0	0.3	0	169	12	2.29	-11.78	0.00	0.00
26-Feb-94	14:00	408	1	1	1	86	86	0	0	198	14	-4.33	-13.31	-4.33	-13.31
26-Feb-94	15:00	409	1	1	1	86	86	-0.2	-0.2	257	5	-4.87	-1.12	-4.87	-1.12

26-Feb-94	16:00	410	1	1	1	87	87	-1.1	-1.1	285	10	-9.66	2.59	-9.66	2.59
26-Feb-94	17:00	410	0	0	0	88	0	-1.9	0	281	11	-10.80	2.10	0.00	0.00
26-Feb-94	18:00	410	0	0	0	90	0	-2.2	0	279	8	-7.90	1.25	0.00	0.00
26-Feb-94	19:00	410	0	0	0	90	0	-2.2	0	262	5	-4.95	-0.70	0.00	0.00
26-Feb-94	20:00	410	0	0	0	90	0	-2.3	0	250	7	-6.58	-2.39	0.00	0.00
26-Feb-94	21:00	410	0	0	0	90	0	-2.4	0	230	4	-3.06	-2.57	0.00	0.00
26-Feb-94	22:00	411	1	1	1	91	91	-2.4	-2.4	207	12	-5.45	-10.69	-5.45	-10.69
26-Feb-94	23:00	411	0	0	0	91	0	-2.5	0	201	12	-4.30	-11.20	0.00	0.00
27-Feb-94	00:00	411	0	0	0	91	0	-2.6	0	219	10	-6.29	-7.77	0.00	0.00
27-Feb-94	01:00	411	0	0	0	91	0	-2.7	0	207	14	-6.36	-12.47	0.00	0.00
27-Feb-94	02:00	412	1	1	1	91	91	-2.7	-2.7	222	14	-9.37	-10.40	-9.37	-10.40
27-Feb-94	03:00	412	0	0	0	91	0	-2.7	0	230	10	-7.66	-6.43	0.00	0.00
27-Feb-94	04:00	412	0	0	0	91	0	-2.8	0	217	10	-6.02	-7.99	0.00	0.00
27-Feb-94	05:00	413	1	1	1	91	91	-3	-3	245	8	-7.25	-3.38	-7.25	-3.38
27-Feb-94	06:00	413	0	0	0	91	0	-3.2	0	256	14	-13.58	-3.39	0.00	0.00
27-Feb-94	07:00	413	0	0	0	91	0	-3.3	0	253	10	-9.56	-2.92	0.00	0.00
27-Feb-94	08:00	413	0	0	0	91	0	-3	0	251	9	-8.51	-2.93	0.00	0.00
27-Feb-94	09:00	414	1	1	1	91	91	-2.2	-2.2	249	9	-8.40	-3.23	-8.40	-3.23
27-Feb-94	10:00	415	1	1	1	91	91	-2	-2	247	12	-11.05	-4.69	-11.05	-4.69
27-Feb-94	11:00	416	1	1	1	92	92	-1.9	-1.9	238	12	-10.18	-6.36	-10.18	-6.36
27-Feb-94	12:00	416	0	0	0	91	0	-1.6	0	243	12	-10.69	-5.45	0.00	0.00
27-Feb-94	13:00	417	1	1	1	90	90	-1.2	-1.2	239	11	-9.43	-5.67	-9.43	-5.67
27-Feb-94	14:00	417	0	0	0	89	0	-1.6	0	233	11	-8.78	-6.62	0.00	0.00
27-Feb-94	15:00	418	1	1	1	89	89	-1.6	-1.6	231	11	-8.55	-6.92	-8.55	-6.92
27-Feb-94	16:00	418	0	0	0	90	0	-2.1	0	234	14	-11.33	-8.23	0.00	0.00
27-Feb-94	17:00	418	0	0	0	91	0	-2.3	0	223	10	-6.82	-7.31	0.00	0.00
27-Feb-94	18:00	418	0	0	0	91	0	-2.4	0	216	12	-7.05	-9.71	0.00	0.00
27-Feb-94	19:00	418	0	0	0	91	0	-2.4	0	211	15	-7.73	-12.86	0.00	0.00
27-Feb-94	20:00	418	0	0	0	91	0	-2.4	0	217	13	-7.82	-10.38	0.00	0.00
27-Feb-94	21:00	418	0	0	0	91	0	-2.4	0	234	9	-7.28	-5.29	0.00	0.00
27-Feb-94	22:00	418	0	0	0	91	0	-2.2	0	233	12	-9.58	-7.22	0.00	0.00
27-Feb-94	23:00	419	1	1	1	91	91	-1.9	-1.9	220	14	-9.00	-10.72	-9.00	-10.72
28-Feb-94	00:00	419	0	0	0	91	0	-1.6	0	214	16	-8.95	-13.26	0.00	0.00
28-Feb-94	01:00	420	1	1	1	90	90	-1.5	-1.5	218	16	-9.85	-12.61	-9.85	-12.61
28-Feb-94	02:00	421	1	1	1	90	90	-1.1	-1.1	228	15	-11.15	-10.04	-11.15	-10.04

28-Feb-94	03:00	422	1	1	1	90	90	-0.6	-0.6	220	19	-12.21	-14.55	-12.21	-14.55
28-Feb-94	04:00	423	1	1	1	89	89	-0.2	-0.2	236	17	-14.09	-9.51	-14.09	-9.51
28-Feb-94	05:00	424	1	1	1	89	89	0.3	0.3	235	25	-20.48	-14.34	-20.48	-14.34
28-Feb-94	06:00	425	1	0	0	89	0	0.6	0	252	41	-38.99	-12.67	0.00	0.00
28-Feb-94	07:00	424	-1	0	0	88	0	0.4	0	243	48	-42.77	-21.79	0.00	0.00
28-Feb-94	08:00	426	2	0	0	88	0	0.5	0	241	40	-34.98	-19.39	0.00	0.00
28-Feb-94	09:00	428	2	2	1	88	88	0.5	0.5	255	39	-37.67	-10.09	-37.67	-10.09
28-Feb-94	10:00	430	2	2	1	88	88	0.5	0.5	245	27	-24.47	-11.41	-24.47	-11.41
28-Feb-94	11:00	432	2	2	1	89	89	0.3	0.3	243	30	-26.73	-13.62	-26.73	-13.62
28-Feb-94	12:00	434	2	2	1	89	89	0.1	0.1	245	30	-27.19	-12.68	-27.19	-12.68
28-Feb-94	13:00	437	3	3	1	89	89	0	0	244	32	-28.76	-14.03	-28.76	-14.03
28-Feb-94	14:00	439	2	2	1	89	89	0	0	244	23	-20.67	-10.08	-20.67	-10.08
28-Feb-94	15:00	441	2	2	1	89	89	0.2	0.2	244	20	-17.98	-8.77	-17.98	-8.77
28-Feb-94	16:00	442	1	1	1	89	89	0	0	244	18	-16.18	-7.89	-16.18	-7.89
28-Feb-94	17:00	443	1	1	1	90	90	-0.1	-0.1	244	16	-14.38	-7.01	-14.38	-7.01
28-Feb-94	18:00	443	0	0	0	89	0	0.1	0	244	25	-22.47	-10.96	0.00	0.00
28-Feb-94	19:00	443	0	0	0	89	0	0.4	0	244	24	-21.57	-10.52	0.00	0.00
28-Feb-94	20:00	444	1	1	1	89	89	0.5	0.5	228	18	-13.38	-12.04	-13.38	-12.04
28-Feb-94	21:00	444	0	0	0	88	0	0.4	0	215	21	-12.05	-17.20	0.00	0.00
28-Feb-94	22:00	445	1	1	1	88	88	0.6	0.6	226	23	-16.54	-15.98	-16.54	-15.98
28-Feb-94	23:00	445	0	0	0	88	0	0.9	0	227	21	-15.36	-14.32	0.00	0.00
01-Mar-94	00:00	446	1	1	1	87	87	0.9	0.9	204	24	-9.76	-21.93	-9.76	-21.93
01-Mar-94	01:00	446	0	0	0	87	0	1.2	0	201	30	-10.75	-28.01	0.00	0.00
01-Mar-94	02:00	446	0	0	0	86	0	1.7	0	214	29	-16.22	-24.04	0.00	0.00
01-Mar-94	03:00	447	1	1	1	86	86	1.4	1.4	200	27	-9.23	-25.37	-9.23	-25.37
01-Mar-94	04:00	447	0	0	0	86	0	1.2	0	201	24	-8.60	-22.41	0.00	0.00
01-Mar-94	05:00	448	1	1	1	85	85	1.1	1.1	223	33	-22.51	-24.13	-22.51	-24.13
01-Mar-94	06:00	448	0	0	0	85	0	1.1	0	193	27	-6.07	-26.31	0.00	0.00
01-Mar-94	07:00	450	2	2	1	85	85	1.2	1.2	197	35	-10.23	-33.47	-10.23	-33.47
01-Mar-94	08:00	451	1	1	1	84	84	1.5	1.5	191	26	-4.96	-25.52	-4.96	-25.52
01-Mar-94	09:00	451	0	0	0	84	0	1.9	0	194	49	-11.85	-47.54	0.00	0.00
01-Mar-94	10:00	452	1	1	1	85	85	1.5	1.5	229	38	-28.68	-24.93	-28.68	-24.93
01-Mar-94	11:00	454	2	2	1	85	85	1.4	1.4	248	28	-25.96	-10.49	-25.96	-10.49
01-Mar-94	12:00	454	0	0	0	85	0	1.7	0	209	26	-12.61	-22.74	0.00	0.00
01-Mar-94	13:00	454	0	0	0	85	0	2.1	0	242	25	-22.07	-11.74	0.00	0.00

01-Mar-94	14:00	454	0	0	0	85	0	2.2	0	243	29	-25.84	-13.17	0.00	0.00
01-Mar-94	15:00	454	0	0	0	85	0	2.3	0	250	29	-27.25	-9.92	0.00	0.00
01-Mar-94	16:00	454	0	0	0	85	0	2.3	0	240	22	-19.05	-11.00	0.00	0.00
01-Mar-94	17:00	454	0	0	0	85	0	1.8	0	221	13	-8.53	-9.81	0.00	0.00
01-Mar-94	18:00	454	0	0	0	85	0	1.6	0	191	16	-3.05	-15.71	0.00	0.00
01-Mar-94	19:00	455	1	1	1	85	85	1.2	1.2	195	13	-3.36	-12.56	-3.36	-12.56
01-Mar-94	20:00	456	1	1	1	84	84	1.2	1.2	187	14	-1.71	-13.90	-1.71	-13.90
01-Mar-94	21:00	457	1	1	1	84	84	0.9	0.9	183	12	-0.63	-11.98	-0.63	-11.98
01-Mar-94	22:00	458	1	1	1	84	84	0.8	0.8	200	14	-4.79	-13.16	-4.79	-13.16
01-Mar-94	23:00	458	0	0	0	84	0	0.7	0	184	18	-1.26	-17.96	0.00	0.00
02-Mar-94	00:00	458	0	0	0	84	0	1	0	205	25	-10.57	-22.66	0.00	0.00
02-Mar-94	01:00	456	-2	0	0	84	0	1.2	0	198	44	-13.60	-41.85	0.00	0.00
02-Mar-94	02:00	458	2	0	0	88	0	1.2	0	190	35	-6.08	-34.47	0.00	0.00
02-Mar-94	03:00	458	0	0	0	89	0	0.9	0	196	48	-13.23	-46.14	0.00	0.00
02-Mar-94	04:00	459	1	1	1	87	87	1	1	200	37	-12.65	-34.77	-12.65	-34.77
02-Mar-94	05:00	459	0	0	0	80	0	2.1	0	192	27	-5.61	-26.41	0.00	0.00
02-Mar-94	06:00	459	0	0	0	86	0	1.2	0	212	29	-15.37	-24.59	0.00	0.00
02-Mar-94	07:00	464	5	0	0	89	0	1.2	0	179	20	0.35	-20.00	0.00	0.00
02-Mar-94	08:00	461	-3	0	0	89	0	1.1	0	192	25	-5.20	-24.45	0.00	0.00
02-Mar-94	09:00	463	2	0	0	89	0	1.1	0	178	22	0.77	-21.99	0.00	0.00
02-Mar-94	10:00	463	0	0	0	89	0	1.4	0	179	18	0.31	-18.00	0.00	0.00
02-Mar-94	11:00	465	2	2	1	89	89	1.1	1.1	187	10	-1.22	-9.93	-1.22	-9.93
02-Mar-94	12:00	467	2	2	1	89	89	0.7	0.7	212	23	-12.19	-19.51	-12.19	-19.51
02-Mar-94	13:00	467	0	0	0	89	0	1.3	0	223	34	-23.19	-24.87	0.00	0.00
02-Mar-94	14:00	467	0	0	0	91	0	1.3	0	230	34	-26.05	-21.85	0.00	0.00
02-Mar-94	15:00	469	2	2	1	91	91	0.7	0.7	235	31	-25.39	-17.78	-25.39	-17.78
02-Mar-94	16:00	473	4	4	1	91	91	-0.3	-0.3	279	33	-32.59	5.16	-32.59	5.16
02-Mar-94	17:00	473	0	0	0	91	0	-0.7	0	277	25	-24.81	3.05	0.00	0.00
02-Mar-94	18:00	473	0	0	0	91	0	-1.3	0	257	30	-29.23	-6.75	0.00	0.00
02-Mar-94	19:00	473	0	0	0	91	0	-1.8	0	235	16	-13.11	-9.18	0.00	0.00
02-Mar-94	20:00	473	0	0	0	91	0	-2	0	244	18	-16.18	-7.89	0.00	0.00
02-Mar-94	21:00	473	0	0	0	91	0	-2.3	0	251	20	-18.91	-6.51	0.00	0.00
02-Mar-94	22:00	473	0	0	0	91	0	-2.5	0	274	10	-9.98	0.70	0.00	0.00
02-Mar-94	23:00	473	0	0	0	90	0	-2.4	0	270	14	-14.00	0.00	0.00	0.00
03-Mar-94	00:00	473	0	0	0	70	0	-2	0	254	16	-15.38	-4.41	0.00	0.00

03-Mar-94	01:00	473	0	0	0	68	0	-1.9	0	246	19	-17.36	-7.73	0.00	0.00
03-Mar-94	02:00	473	0	0	0	70	0	-1.8	0	275	13	-12.95	1.13	0.00	0.00
03-Mar-94	03:00	473	0	0	0	69	0	-1.8	0	255	6	-5.80	-1.55	0.00	0.00
03-Mar-94	04:00	473	0	0	0	71	0	-1.7	0	262	11	-10.89	-1.53	0.00	0.00
03-Mar-94	05:00	473	0	0	0	77	0	-2.3	0	253	13	-12.43	-3.80	0.00	0.00
03-Mar-94	06:00	473	0	0	0	89	0	-3	0	200	15	-5.13	-14.10	0.00	0.00
03-Mar-94	07:00	473	0	0	0	90	0	-3.2	0	177	15	0.79	-14.98	0.00	0.00
03-Mar-94	08:00	473	0	0	0	84	0	-1.5	0	155	9	3.80	-8.16	0.00	0.00
03-Mar-94	09:00	473	0	0	0	84	0	-1.7	0	254	4	-3.85	-1.10	0.00	0.00
Total				**71**	55										
Average for hrs with ppt:						**88.4**		**-0.6**						-13.37	-11.92

Average Wind Speed: 17.92
Average Wind Direction: 228.28

Loading Winds

Transect	aspect	incident angle	speed	loading wind
A	210	161.72	17.92	**-17.01**
B	76	27.72	17.92	**15.86**

Weather Data for March 3 - March 8

Date	Time	Ppt guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH	RH when Ppt	Temp (°C)	Temp when Ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	when ppt y (km/h)
03-Mar-94	10:00	474	0	0	0	86	0	-0.6	0	218	8	-4.93	-6.30	0.00	0.00
03-Mar-94	11:00	474	0	0	0	85	0	0.1	0	189	3	-0.47	-2.96	0.00	0.00
03-Mar-94	12:00	475	1	1	1	82	82	1.1	1.1	189	3	-0.47	-2.96	-0.47	-2.96
03-Mar-94	13:00	475	0	0	0	85	0	0.2	0	100	9	8.86	-1.56	0.00	0.00
03-Mar-94	14:00	477	2	2	1	87	87	-0.5	-0.5	107	5	4.78	-1.46	4.78	-1.46
03-Mar-94	15:00	478	1	1	1	88	88	-0.7	-0.7	282	10	-9.78	2.08	-9.78	2.08
03-Mar-94	16:00	480	2	2	1	89	89	-0.5	-0.5	256	8	-7.76	-1.94	-7.76	-1.94
03-Mar-94	17:00	482	2	2	1	90	90	-0.5	-0.5	257	18	-17.54	-4.05	-17.54	-4.05
03-Mar-94	18:00	483	1	1	1	90	90	-0.5	-0.5	274	26	-25.94	1.81	-25.94	1.81
03-Mar-94	19:00	483	0	0	0	90	0	-0.5	0	260	20	-19.70	-3.47	0.00	0.00
03-Mar-94	20:00	483	0	0	0	90	0	-0.5	0	222	17	-11.38	-12.63	0.00	0.00
03-Mar-94	21:00	486	3	3	1	90	90	-1	-1	264	14	-13.92	-1.46	-13.92	-1.46
03-Mar-94	22:00	487	1	1	1	90	90	-0.8	-0.8	207	8	-3.63	-7.13	-3.63	-7.13
03-Mar-94	23:00	487	0	0	0	90	0	-0.7	0	209	14	-6.79	-12.24	0.00	0.00
04-Mar-94	00:00	487	0	0	0	90	0	-1.2	0	190	16	-2.78	-15.76	0.00	0.00
04-Mar-94	01:00	487	0	0	0	90	0	-1.4	0	188	21	-2.92	-20.80	0.00	0.00
04-Mar-94	02:00	489	2	2	1	90	90	-1.5	-1.5	201	9	-3.23	-8.40	-3.23	-8.40
04-Mar-94	03:00	492	3	3	1	90	90	-1.9	-1.9	180	11	0.00	-11.00	0.00	-11.00
04-Mar-94	04:00	494	2	2	1	90	90	-2.1	-2.1	187	10	-1.22	-9.93	-1.22	-9.93
04-Mar-94	05:00	498	4	4	1	91	91	-2.5	-2.5	273	17	-16.98	0.89	-16.98	0.89
04-Mar-94	06:00	501	3	3	1	91	91	-2.8	-2.8	232	15	-11.82	-9.23	-11.82	-9.23
04-Mar-94	07:00	502	1	1	1	92	92	-3.2	-3.2	249	19	-17.74	-6.81	-17.74	-6.81
04-Mar-94	08:00	503	1	1	1	92	92	-4.1	-4.1	237	26	-21.81	-14.16	-21.81	-14.16
04-Mar-94	09:00	503	0	0	0	92	0	-4.4	0	243	27	-24.06	-12.26	0.00	0.00
04-Mar-94	10:00	503	0	0	0	92	0	-4.7	0	226	31	-22.30	-21.53	0.00	0.00
04-Mar-94	11:00	503	0	0	0	92	0	-4.5	0	234	28	-22.65	-16.46	0.00	0.00

04-Mar-94	12:00	504	1	1	1	91	91	-4.7	-4.7	246	34	-31.06	-13.83	-31.06	-13.83
04-Mar-94	13:00	506	2	2	1	91	91	-4.1	-4.1	247	29	-26.69	-11.33	-26.69	-11.33
04-Mar-94	14:00	506	0	0	0	90	0	-4.3	0	241	30	-26.24	-14.54	0.00	0.00
04-Mar-94	15:00	506	0	0	0	89	0	-4.7	0	252	34	-32.34	-10.51	0.00	0.00
04-Mar-94	16:00	508	2	2	1	91	91	-4.7	-4.7	247	24	-22.09	-9.38	-22.09	-9.38
04-Mar-94	17:00	509	1	1	1	91	91	-5.2	-5.2	250	27	-25.37	-9.23	-25.37	-9.23
04-Mar-94	18:00	509	0	0	0	91	0	-5.3	0	259	25	-24.54	-4.77	0.00	0.00
04-Mar-94	19:00	510	1	1	1	91	91	-5.6	-5.6	245	24	-21.75	-10.14	-21.75	-10.14
04-Mar-94	20:00	510	0	0	0	91	0	-5.8	0	249	22	-20.54	-7.88	0.00	0.00
04-Mar-94	21:00	511	1	1	1	91	91	-6.2	-6.2	259	20	-19.63	-3.82	-19.63	-3.82
04-Mar-94	22:00	511	0	0	0	91	0	-6.5	0	259	22	-21.60	-4.20	0.00	0.00
04-Mar-94	23:00	511	0	0	0	91	0	-6.5	0	255	19	-18.35	-4.92	0.00	0.00
05-Mar-94	00:00	511	0	0	0	90	0	-6.8	0	267	19	-18.97	-0.99	0.00	0.00
05-Mar-94	01:00	511	0	0	0	91	0	-6.9	0	249	15	-14.00	-5.38	0.00	0.00
05-Mar-94	02:00	511	0	0	0	91	0	-7.2	0	261	16	-15.80	-2.50	0.00	0.00
05-Mar-94	03:00	511	0	0	0	91	0	-7.2	0	267	6	-5.99	-0.31	0.00	0.00
05-Mar-94	04:00	511	0	0	0	91	0	-7.2	0	273	2	-2.00	0.10	0.00	0.00
05-Mar-94	05:00	511	0	0	0	91	0	-7.3	0	277	0	0.00	0.00	0.00	0.00
05-Mar-94	06:00	511	0	0	0	91	0	-8.3	0	42	9	6.02	6.69	0.00	0.00
05-Mar-94	07:00	511	0	0	0	89	0	-9.5	0	38	17	10.47	13.40	0.00	0.00
05-Mar-94	08:00	511	0	0	0	72	0	-9.9	0	38	18	11.08	14.18	0.00	0.00
05-Mar-94	09:00	510	-1	0	0	45	0	-9.4	0	39	34	21.40	26.42	0.00	0.00
05-Mar-94	10:00	511	1	0	0	48	0	-6.7	0	58	16	13.57	8.48	0.00	0.00
05-Mar-94	11:00	511	0	0	0	48	0	-5.8	0	101	14	13.74	-2.67	0.00	0.00
05-Mar-94	12:00	512	1	1	1	49	49	-5.4	-5.4	154	19	8.33	-17.08	8.33	-17.08
05-Mar-94	13:00	513	1	1	1	47	47	-3.8	-3.8	152	15	7.04	-13.24	7.04	-13.24
05-Mar-94	14:00	513	0	0	0	40	0	-1.5	0	170	4	0.69	-3.94	0.00	0.00
05-Mar-94	15:00	513	0	0	0	36	0	-1.1	0	157	2	0.78	-1.84	0.00	0.00
05-Mar-94	16:00	512	-1	0	0	38	0	-2.9	0	157	5	1.95	-4.60	0.00	0.00
05-Mar-94	17:00	512	0	0	0	36	0	-3.9	0	125	3	2.46	-1.72	0.00	0.00
05-Mar-94	18:00	511	-1	0	0	42	0	-8	0	333	3	-1.36	2.67	0.00	0.00
05-Mar-94	19:00	511	0	0	0	47	0	-8.7	0	317	7	-4.77	5.12	0.00	0.00
05-Mar-94	20:00	511	0	0	0	47	0	-9.1	0	297	7	-6.24	3.18	0.00	0.00
05-Mar-94	21:00	510	-1	0	0	47	0	-9.2	0	259	3	-2.94	-0.57	0.00	0.00
05-Mar-94	22:00	510	0	0	0	48	0	-9.8	0	292	6	-5.56	2.25	0.00	0.00

05-Mar-94	23:00	510	0	0	0	49	0	-10.2	0	295	0	0.00	0.00	0.00	0.00
06-Mar-94	00:00	510	0	0	0	46	0	-9.5	0	295	7	-6.34	2.96	0.00	0.00
06-Mar-94	01:00	510	0	0	0	47	0	-9.7	0	295	6	-5.44	2.54	0.00	0.00
06-Mar-94	02:00	510	0	0	0	48	0	-10.3	0	295	2	-1.81	0.85	0.00	0.00
06-Mar-94	03:00	510	0	0	0	46	0	-9.3	0	295	3	-2.72	1.27	0.00	0.00
06-Mar-94	04:00	510	0	0	0	45	0	-9.6	0	297	2	-1.78	0.91	0.00	0.00
06-Mar-94	05:00	510	0	0	0	40	0	-9.9	0	319	0	0.00	0.00	0.00	0.00
06-Mar-94	06:00	510	0	0	0	35	0	-8.6	0	77	9	8.77	2.02	0.00	0.00
06-Mar-94	07:00	510	0	0	0	35	0	-8.2	0	77	13	12.67	2.92	0.00	0.00
06-Mar-94	08:00	510	0	0	0	38	0	-6.9	0	100	15	14.77	-2.60	0.00	0.00
06-Mar-94	09:00	510	0	0	0	42	0	-5.6	0	117	18	16.04	-8.17	0.00	0.00
06-Mar-94	10:00	510	0	0	0	42	0	-4.7	0	135	17	12.02	-12.02	0.00	0.00
06-Mar-94	11:00	512	2	0	0	45	0	-4.3	0	135	23	16.26	-16.26	0.00	0.00
06-Mar-94	12:00	511	-1	0	0	46	0	-3.8	0	137	21	14.32	-15.36	0.00	0.00
06-Mar-94	13:00	512	1	0	0	36	0	-0.3	0	142	7	4.31	-5.52	0.00	0.00
06-Mar-94	14:00	512	0	0	0	36	0	0.4	0	106	2	1.92	-0.55	0.00	0.00
06-Mar-94	15:00	513	1	0	0	35	0	0.6	0	121	2	1.71	-1.03	0.00	0.00
06-Mar-94	16:00	512	-1	0	0	35	0	-1.3	0	144	7	4.11	-5.66	0.00	0.00
06-Mar-94	17:00	511	-1	0	0	34	0	-4.6	0	67	13	11.97	5.08	0.00	0.00
06-Mar-94	18:00	511	0	0	0	36	0	-6.2	0	63	12	10.69	5.45	0.00	0.00
06-Mar-94	19:00	511	0	0	0	38	0	-6.8	0	81	14	13.83	2.19	0.00	0.00
06-Mar-94	20:00	511	0	0	0	39	0	-7.1	0	88	21	20.99	0.73	0.00	0.00
06-Mar-94	21:00	510	-1	0	0	37	0	-7	0	86	27	26.93	1.88	0.00	0.00
06-Mar-94	22:00	510	0	0	0	35	0	-7	0	85	30	29.89	2.61	0.00	0.00
06-Mar-94	23:00	510	0	0	0	34	0	-7.1	0	87	30	29.96	1.57	0.00	0.00
07-Mar-94	00:00	509	-1	0	0	33	0	-6.9	0	86	28	27.93	1.95	0.00	0.00
07-Mar-94	01:00	510	1	0	0	34	0	-7.2	0	93	27	26.96	-1.41	0.00	0.00
07-Mar-94	02:00	510	0	0	0	34	0	-7.4	0	88	19	18.99	0.66	0.00	0.00
07-Mar-94	03:00	510	0	0	0	35	0	-7.5	0	106	25	24.03	-6.89	0.00	0.00
07-Mar-94	04:00	510	0	0	0	34	0	-7.3	0	107	26	24.86	-7.60	0.00	0.00
07-Mar-94	05:00	509	-1	0	0	33	0	-6.9	0	109	32	30.26	-10.42	0.00	0.00
07-Mar-94	06:00	510	1	0	0	33	0	-6.8	0	104	33	32.02	-7.98	0.00	0.00
07-Mar-94	07:00	510	0	0	0	32	0	-6.7	0	100	30	29.54	-5.21	0.00	0.00
07-Mar-94	08:00	510	0	0	0	31	0	-6.1	0	88	21	20.99	0.73	0.00	0.00
07-Mar-94	09:00	510	0	0	0	30	0	-4.5	0	88	16	15.99	0.56	0.00	0.00

07-Mar-94	10:00	511	1	1	1	29	29	-4.5	-4.5	84	12	11.93	1.25	11.93	1.25
07-Mar-94	11:00	511	0	0	0	32	0	-2.4	0	82	4	3.96	0.56	0.00	0.00
07-Mar-94	12:00	512	1	1	1	30	30	0.7	0.7	110	3	2.82	-1.03	2.82	-1.03
07-Mar-94	13:00	512	0	0	0	31	0	1.2	0	200	1	-0.34	-0.94	0.00	0.00
07-Mar-94	14:00	512	0	0	0	28	0	3	0	217	2	-1.20	-1.60	0.00	0.00
07-Mar-94	15:00	512	0	0	0	28	0	3.1	0	242	1	-0.88	-0.47	0.00	0.00
07-Mar-94	16:00	512	0	0	0	28	0	1.8	0	309	2	-1.55	1.26	0.00	0.00
07-Mar-94	17:00	512	0	0	0	30	0	-0.6	0	301	2	-1.71	1.03	0.00	0.00
07-Mar-94	18:00	511	-1	0	0	37	0	-4.1	0	318	2	-1.34	1.49	0.00	0.00
07-Mar-94	19:00	511	0	0	0	40	0	-4.8	0	144	0	0.00	0.00	0.00	0.00
07-Mar-94	20:00	511	0	0	0	40	0	-4.3	0	53	3	2.40	1.81	0.00	0.00
07-Mar-94	21:00	510	-1	0	0	41	0	-4.3	0	64	7	6.29	3.07	0.00	0.00
07-Mar-94	22:00	510	0	0	0	41	0	-4.7	0	67	2	1.84	0.78	0.00	0.00
07-Mar-94	23:00	510	0	0	0	41	0	-4.9	0	79	2	1.96	0.38	0.00	0.00
08-Mar-94	00:00	510	0	0	0	41	0	-5.2	0	88	2	2.00	0.07	0.00	0.00
08-Mar-94	01:00	510	0	0	0	41	0	-5.1	0	72	3	2.85	0.93	0.00	0.00
08-Mar-94	02:00	510	0	0	0	41	0	-3.9	0	84	6	5.97	0.63	0.00	0.00
08-Mar-94	03:00	510	0	0	0	41	0	-4.3	0	102	13	12.72	-2.70	0.00	0.00
08-Mar-94	04:00	510	0	0	0	41	0	-4.1	0	112	15	13.91	-5.62	0.00	0.00
08-Mar-94	05:00	510	0	0	0	38	0	-3.7	0	100	18	17.73	-3.13	0.00	0.00
08-Mar-94	06:00	510	0	0	0	37	0	-3.9	0	97	14	13.90	-1.71	0.00	0.00
08-Mar-94	07:00	510	0	0	0	36	0	-3	0	37	1	0.60	0.80	0.00	0.00
08-Mar-94	08:00	510	0	0	0	35	0	-0.8	0	57	2	1.68	1.09	0.00	0.00
08-Mar-94	09:00	510	0	0	0	33	0	0.6	0	102	9	8.80	-1.87	0.00	0.00
08-Mar-94	10:00	511	1	1	1	33	33	2.3	2.3	106	5	4.81	-1.38	4.81	-1.38
08-Mar-94	11:00	511	0	0	0	32	0	3.1	0	107	0	0.00	0.00	0.00	0.00
08-Mar-94	12:00	512	1	1	1	33	33	4.9	4.9	287	2	-1.91	0.58	-1.91	0.58
08-Mar-94	13:00	514	2	0	0	31	0	7.7	0	183	1	-0.05	-1.00	0.00	0.00

08-Mar-94	14:00	513	-1	0	0	32	0	6.9	0	200	4	-1.37	-3.76	0.00	0.00
08-Mar-94	15:00	513	0	0	0	30	0	7.4	0	204	3	-1.22	-2.74	0.00	0.00
08-Mar-94	16:00	512	-1	0	0	30	0	6.7	0	234	0	0.00	0.00	0.00	0.00
Total:				**43**	27		2109		-57.8					-260.63	-162.37
Average for hrs with ppt:							**78.1**		**-2.1**					-9.65	-6.01

Average Wind Speed: 11.37
Average Wind Direction: 238.08

Loading Winds

transect	aspect	incident angle	speed	loading wind
A	210	151.92	11.37	**-10.03**
B	76	17.92	11.37	**10.82**

Weather Data for March 8 - March 15

Date	Time	Ppt guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when ppt (%)	Temp (°C)	Temp when ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt. x (km/h)	y (km/h)
08-Mar-94	17:00	512	0	0	0	30	0	4.3	0	225	0	0.00	0.00	0.00	0.00
08-Mar-94	18:00	512	0	0	0	36	0	0.5	0	246	0	0.00	0.00	0.00	0.00
08-Mar-94	19:00	511	-1	0	0	36	0	-0.1	0	176	6	0.42	-5.99	0.00	0.00
08-Mar-94	20:00	511	0	0	0	35	0	-0.6	0	156	2	0.81	-1.83	0.00	0.00
08-Mar-94	21:00	511	0	0	0	36	0	0.1	0	246	3	-2.74	-1.22	0.00	0.00
08-Mar-94	22:00	511	0	0	0	37	0	0.8	0	210	7	-3.50	-6.06	0.00	0.00
08-Mar-94	23:00	511	0	0	0	38	0	1	0	233	7	-5.59	-4.21	0.00	0.00
09-Mar-94	00:00	510	-1	0	0	38	0	0.6	0	229	11	-8.30	-7.22	0.00	0.00
09-Mar-94	01:00	510	0	0	0	41	0	0.3	0	262	10	-9.90	-1.39	0.00	0.00
09-Mar-94	02:00	510	0	0	0	42	0	0.5	0	238	10	-8.48	-5.30	0.00	0.00
09-Mar-94	03:00	510	0	0	0	42	0	0.4	0	213	9	-4.90	-7.55	0.00	0.00
09-Mar-94	04:00	511	1	1	1	43	43	0.5	0.5	226	6	-4.32	-4.17	-4.32	-4.17
09-Mar-94	05:00	511	0	0	0	37	0	0.8	0	235	8	-6.55	-4.59	0.00	0.00
09-Mar-94	06:00	510	-1	0	0	36	0	0.7	0	264	8	-7.96	-0.84	0.00	0.00
09-Mar-94	07:00	511	1	0	0	35	0	1.2	0	279	4	-3.95	0.63	0.00	0.00
09-Mar-94	08:00	511	0	0	0	34	0	2.1	0	231	6	-4.66	-3.78	0.00	0.00
09-Mar-94	09:00	511	0	0	0	32	0	3.1	0	251	2	-1.89	-0.65	0.00	0.00
09-Mar-94	10:00	512	1	1	1	32	32	4.3	4.3	282	2	-1.96	0.42	-1.96	0.42
09-Mar-94	11:00	513	1	1	1	30	30	7.1	7.1	297	2	-1.78	0.91	-1.78	0.91
09-Mar-94	12:00	513	0	0	0	29	0	7	0	305	2	-1.64	1.15	0.00	0.00
09-Mar-94	13:00	514	1	1	1	31	31	6.8	6.8	222	2	-1.34	-1.49	-1.34	-1.49
09-Mar-94	14:00	514	0	0	0	31	0	8.5	0	258	3	-2.93	-0.62	0.00	0.00
09-Mar-94	15:00	514	0	0	0	32	0	8.4	0	297	1	-0.89	0.45	0.00	0.00
09-Mar-94	16:00	513	-1	0	0	33	0	6.7	0	310	1	-0.77	0.64	0.00	0.00
09-Mar-94	17:00	513	0	0	0	42	0	3.3	0	310	3	-2.30	1.93	0.00	0.00
09-Mar-94	18:00	512	-1	0	0	44	0	1.7	0	296	1	-0.90	0.44	0.00	0.00

09-Mar-94	19:00	511	-1	0	0	48	0	0.2	0	283	0	0.00	0.00	0.00	0.00
09-Mar-94	20:00	511	0	0	0	49	0	0.8	0	229	1	-0.75	-0.66	0.00	0.00
09-Mar-94	21:00	511	0	0	0	50	0	0.3	0	270	1	-1.00	0.00	0.00	0.00
09-Mar-94	22:00	510	-1	0	0	54	0	-0.6	0	300	2	-1.73	1.00	0.00	0.00
09-Mar-94	23:00	510	0	0	0	55	0	-0.3	0	225	5	-3.54	-3.54	0.00	0.00
10-Mar-94	00:00	510	0	0	0	68	0	-1.4	0	252	12	-11.41	-3.71	0.00	0.00
10-Mar-94	01:00	510	0	0	0	88	0	-2.7	0	205	8	-3.38	-7.25	0.00	0.00
10-Mar-94	02:00	511	1	1	1	90	90	-2.7	-2.7	208	3	-1.41	-2.65	-1.41	-2.65
10-Mar-94	03:00	511	0	0	0	91	0	-2.3	0	210	11	-5.50	-9.53	0.00	0.00
10-Mar-94	04:00	512	1	1	1	91	91	-2.5	-2.5	210	12	-6.00	-10.39	-6.00	-10.39
10-Mar-94	05:00	512	0	0	0	91	0	-2.3	0	245	8	-7.25	-3.38	0.00	0.00
10-Mar-94	06:00	512	0	0	0	91	0	-2.4	0	263	10	-9.93	-1.22	0.00	0.00
10-Mar-94	07:00	512	0	0	0	91	0	-2.8	0	262	19	-18.82	-2.64	0.00	0.00
10-Mar-94	08:00	512	0	0	0	91	0	-2.9	0	261	20	-19.75	-3.13	0.00	0.00
10-Mar-94	09:00	512	0	0	0	91	0	-2.7	0	265	16	-15.94	-1.39	0.00	0.00
10-Mar-94	10:00	513	1	1	1	92	92	-2.7	-2.7	250	14	-13.16	-4.79	-13.16	-4.79
10-Mar-94	11:00	513	0	0	0	92	0	-2.6	0	239	14	-12.00	-7.21	0.00	0.00
10-Mar-94	12:00	513	0	0	0	91	0	-2	0	255	10	-9.66	-2.59	0.00	0.00
10-Mar-94	13:00	514	1	1	1	90	90	-1.6	-1.6	262	15	-14.85	-2.09	-14.85	-2.09
10-Mar-94	14:00	514	0	0	0	89	0	-1.3	0	253	10	-9.56	-2.92	0.00	0.00
10-Mar-94	15:00	515	1	0	0	90	0	-2.4	0	244	9	-8.09	-3.95	0.00	0.00
10-Mar-94	16:00	514	-1	0	0	91	0	-3.1	0	241	15	-13.12	-7.27	0.00	0.00
10-Mar-94	17:00	515	1	0	0	91	0	-3.1	0	230	13	-9.96	-8.36	0.00	0.00
10-Mar-94	18:00	514	-1	0	0	91	0	-3.3	0	247	11	-10.13	-4.30	0.00	0.00
10-Mar-94	19:00	515	1	0	0	92	0	-3.4	0	262	12	-11.88	-1.67	0.00	0.00
10-Mar-94	20:00	515	0	0	0	92	0	-3.4	0	275	13	-12.95	1.13	0.00	0.00
10-Mar-94	21:00	515	0	0	0	92	0	-3.4	0	273	9	-8.99	0.47	0.00	0.00
10-Mar-94	22:00	515	0	0	0	92	0	-3.5	0	286	9	-8.65	2.48	0.00	0.00
10-Mar-94	23:00	515	0	0	0	92	0	-3.6	0	295	7	-6.34	2.96	0.00	0.00
11-Mar-94	00:00	514	-1	0	0	92	0	-3.7	0	274	2	-2.00	0.14	0.00	0.00
11-Mar-94	01:00	514	0	0	0	92	0	-3.7	0	294	8	-7.31	3.25	0.00	0.00
11-Mar-94	02:00	514	0	0	0	92	0	-3.7	0	277	3	-2.98	0.37	0.00	0.00
11-Mar-94	03:00	514	0	0	0	92	0	-3.7	0	274	2	-2.00	0.14	0.00	0.00
11-Mar-94	04:00	514	0	0	0	92	0	-3.8	0	282	3	-2.93	0.62	0.00	0.00
11-Mar-94	05:00	514	0	0	0	92	0	-3.9	0	283	2	-1.95	0.45	0.00	0.00

11-Mar-94	06:00	513	-1	0	0	92	0	-4.4	0	191	2	-0.38	-1.96	0.00	0.00
11-Mar-94	07:00	513	0	0	0	92	0	-4	0	191	2	-0.38	-1.96	0.00	0.00
11-Mar-94	08:00	513	0	0	0	91	0	-0.7	0	193	0	0.00	0.00	0.00	0.00
11-Mar-94	09:00	514	1	1	1	87	87	1.6	1.6	14	0	0.00	0.00	0.00	0.00
11-Mar-94	10:00	514	0	0	0	79	0	0.3	0	257	0	0.00	0.00	0.00	0.00
11-Mar-94	11:00	514	0	0	0	76	0	3.4	0	195	1	-0.26	-0.97	0.00	0.00
11-Mar-94	12:00	515	1	1	1	75	75	4.1	4.1	218	1	-0.62	-0.79	-0.62	-0.79
11-Mar-94	13:00	515	0	0	0	80	0	0.5	0	256	3	-2.91	-0.73	0.00	0.00
11-Mar-94	14:00	515	0	0	0	81	0	0.6	0	250	2	-1.88	-0.68	0.00	0.00
11-Mar-94	15:00	515	0	0	0	79	0	2	0	254	3	-2.88	-0.83	0.00	0.00
11-Mar-94	16:00	515	0	0	0	82	0	-0.3	0	254	3	-2.88	-0.83	0.00	0.00
11-Mar-94	17:00	515	0	0	0	87	0	-1.5	0	237	2	-1.68	-1.09	0.00	0.00
11-Mar-94	18:00	514	-1	0	0	90	0	-2.1	0	207	6	-2.72	-5.35	0.00	0.00
11-Mar-94	19:00	514	0	0	0	91	0	-2.4	0	192	11	-2.29	-10.76	0.00	0.00
11-Mar-94	20:00	513	-1	0	0	87	0	-2.3	0	221	11	-7.22	-8.30	0.00	0.00
11-Mar-94	21:00	513	0	0	0	82	0	-2.3	0	232	16	-12.61	-9.85	0.00	0.00
11-Mar-94	22:00	513	0	0	0	73	0	-1.5	0	242	17	-15.01	-7.98	0.00	0.00
11-Mar-94	23:00	513	0	0	0	50	0	-0.6	0	255	24	-23.18	-6.21	0.00	0.00
12-Mar-94	00:00	513	0	0	0	44	0	-0.4	0	260	24	-23.64	-4.17	0.00	0.00
12-Mar-94	01:00	513	0	0	0	45	0	-0.1	0	265	25	-24.90	-2.18	0.00	0.00
12-Mar-94	02:00	513	0	0	0	44	0	0.1	0	265	25	-24.90	-2.18	0.00	0.00
12-Mar-94	03:00	513	0	0	0	44	0	0.3	0	257	18	-17.54	-4.05	0.00	0.00
12-Mar-94	04:00	513	0	0	0	44	0	0.2	0	253	21	-20.08	-6.14	0.00	0.00
12-Mar-94	05:00	513	0	0	0	46	0	0.1	0	260	21	-20.68	-3.65	0.00	0.00
12-Mar-94	06:00	513	0	0	0	44	0	0.4	0	278	18	-17.82	2.51	0.00	0.00
12-Mar-94	07:00	513	0	0	0	45	0	0.2	0	252	11	-10.46	-3.40	0.00	0.00
12-Mar-94	08:00	513	0	0	0	42	0	2.1	0	235	13	-10.65	-7.46	0.00	0.00
12-Mar-94	09:00	514	1	1	1	39	39	4.1	4.1	253	9	-8.61	-2.63	-8.61	-2.63
12-Mar-94	10:00	514	0	0	0	36	0	4.2	0	237	7	-5.87	-3.81	0.00	0.00
12-Mar-94	11:00	515	1	1	1	28	28	5	5	243	13	-11.58	-5.90	-11.58	-5.90
12-Mar-94	12:00	515	0	0	0	25	0	5.8	0	255	15	-14.49	-3.88	0.00	0.00
12-Mar-94	13:00	516	1	0	0	27	0	5.1	0	269	16	-16.00	-0.28	0.00	0.00
12-Mar-94	14:00	515	-1	0	0	27	0	5.2	0	253	17	-16.26	-4.97	0.00	0.00
12-Mar-94	15:00	515	0	0	0	28	0	5.1	0	264	21	-20.88	-2.20	0.00	0.00
12-Mar-94	16:00	515	0	0	0	29	0	4.4	0	277	20	-19.85	2.44	0.00	0.00

12-Mar-94	17:00	514	-1	0	0	39	0	2.5	0	257	17	-16.56	-3.82	0.00	0.00
12-Mar-94	18:00	514	0	0	0	52	0	0.7	0	185	19	-1.66	-18.93	0.00	0.00
12-Mar-94	19:00	514	0	0	0	50	0	3.4	0	210	24	-12.00	-20.78	0.00	0.00
12-Mar-94	20:00	514	0	0	0	52	0	4.2	0	230	27	-20.68	-17.36	0.00	0.00
12-Mar-94	21:00	514	0	0	0	59	0	4.4	0	241	22	-19.24	-10.67	0.00	0.00
12-Mar-94	22:00	514	0	0	0	66	0	4.1	0	234	21	-16.99	-12.34	0.00	0.00
12-Mar-94	23:00	514	0	0	0	63	0	3.4	0	238	21	-17.81	-11.13	0.00	0.00
13-Mar-94	00:00	514	0	0	0	51	0	3.5	0	246	31	-28.32	-12.61	0.00	0.00
13-Mar-94	01:00	514	0	0	0	45	0	4	0	259	27	-26.50	-5.15	0.00	0.00
13-Mar-94	02:00	514	0	0	0	47	0	3.9	0	243	26	-23.17	-11.80	0.00	0.00
13-Mar-94	03:00	513	-1	0	0	49	0	3.7	0	244	27	-24.27	-11.84	0.00	0.00
13-Mar-94	04:00	514	1	0	0	56	0	2.8	0	224	22	-15.28	-15.83	0.00	0.00
13-Mar-94	05:00	514	0	0	0	70	0	1.4	0	227	21	-15.36	-14.32	0.00	0.00
13-Mar-94	06:00	514	0	0	0	84	0	0.3	0	229	20	-15.09	-13.12	0.00	0.00
13-Mar-94	07:00	514	0	0	0	87	0	0.8	0	228	16	-11.89	-10.71	0.00	0.00
13-Mar-94	08:00	514	0	0	0	83	0	1.3	0	240	21	-18.19	-10.50	0.00	0.00
13-Mar-94	09:00	515	1	0	0	73	0	2.3	0	250	24	-22.55	-8.21	0.00	0.00
13-Mar-94	10:00	514	-1	0	0	66	0	3	0	234	25	-20.23	-14.69	0.00	0.00
13-Mar-94	11:00	516	2	0	0	61	0	4.1	0	240	27	-23.38	-13.50	0.00	0.00
13-Mar-94	12:00	515	-1	0	0	58	0	3.7	0	243	23	-20.49	-10.44	0.00	0.00
13-Mar-94	13:00	515	0	0	0	62	0	2.8	0	254	28	-26.92	-7.72	0.00	0.00
13-Mar-94	14:00	515	0	0	0	63	0	2.9	0	258	32	-31.30	-6.65	0.00	0.00
13-Mar-94	15:00	515	0	0	0	63	0	2.5	0	236	33	-27.36	-18.45	0.00	0.00
13-Mar-94	16:00	517	2	0	0	65	0	1.9	0	241	30	-26.24	-14.54	0.00	0.00
13-Mar-94	17:00	512	-5	0	0	69	0	1	0	244	31	-27.86	-13.59	0.00	0.00
13-Mar-94	18:00	514	2	0	0	83	0	0	0	247	29	-26.69	-11.33	0.00	0.00
13-Mar-94	19:00	516	2	2	1	90	90	-0.6	-0.6	273	22	-21.97	1.15	-21.97	1.15
13-Mar-94	20:00	517	1	1	1	91	91	-0.4	-0.4	270	21	-21.00	0.00	-21.00	0.00
13-Mar-94	21:00	519	2	2	1	91	91	-0.4	-0.4	271	19	-19.00	0.33	-19.00	0.33
13-Mar-94	22:00	520	1	1	1	91	91	-0.6	-0.6	268	13	-12.99	-0.45	-12.99	-0.45
13-Mar-94	23:00	521	1	1	1	90	90	-0.7	-0.7	270	15	-15.00	0.00	-15.00	0.00
14-Mar-94	00:00	522	1	1	1	90	90	-0.9	-0.9	294	14	-12.79	5.69	-12.79	5.69
14-Mar-94	01:00	522	0	0	0	90	0	-0.9	0	275	6	-5.98	0.52	0.00	0.00
14-Mar-94	02:00	523	1	1	1	90	90	-1	-1	291	6	-5.60	2.15	-5.60	2.15
14-Mar-94	03:00	523	0	0	0	90	0	-1.1	0	251	6	-5.67	-1.95	0.00	0.00

14-Mar-94	04:00	523	0	0	0	90	0	-1.1	0	276	6	-5.97	0.63	0.00	0.00
14-Mar-94	05:00	523	0	0	0	90	0	-1.4	0	298	10	-8.83	4.69	0.00	0.00
14-Mar-94	06:00	523	0	0	0	90	0	-1.7	0	304	5	-4.15	2.80	0.00	0.00
14-Mar-94	07:00	523	0	0	0	90	0	-2	0	278	0	0.00	0.00	0.00	0.00
14-Mar-94	08:00	523	0	0	0	90	0	-0.7	0	278	0	0.00	0.00	0.00	0.00
14-Mar-94	09:00	524	1	0	0	89	0	2.3	0	5	0	0.00	0.00	0.00	0.00
14-Mar-94	10:00	523	-1	0	0	90	0	0.7	0	98	4	3.96	-0.56	0.00	0.00
14-Mar-94	11:00	524	1	0	0	88	0	1.7	0	116	14	12.58	-6.14	0.00	0.00
14-Mar-94	12:00	525	1	1	1	85	85	3.3	3.3	137	15	10.23	-10.97	10.23	-10.97
14-Mar-94	13:00	526	1	1	1	80	80	4.3	4.3	134	10	7.19	-6.95	7.19	-6.95
14-Mar-94	14:00	526	0	0	0	72	0	6.2	0	163	5	1.46	-4.78	0.00	0.00
14-Mar-94	15:00	526	0	0	0	69	0	5.7	0	168	8	1.66	-7.83	0.00	0.00
14-Mar-94	16:00	526	0	0	0	69	0	5.8	0	168	3	0.62	-2.93	0.00	0.00
14-Mar-94	17:00	526	0	0	0	72	0	4.1	0	148	5	2.65	-4.24	0.00	0.00
14-Mar-94	18:00	524	-2	0	0	82	0	1.8	0	99	17	16.79	-2.66	0.00	0.00
14-Mar-94	19:00	524	0	0	0	87	0	1.2	0	98	32	31.69	-4.45	0.00	0.00
14-Mar-94	20:00	524	0	0	0	86	0	1.3	0	98	31	30.70	-4.31	0.00	0.00
14-Mar-94	21:00	523	-1	0	0	85	0	1.1	0	97	39	38.71	-4.75	0.00	0.00
14-Mar-94	22:00	525	2	0	0	85	0	1	0	100	36	35.45	-6.25	0.00	0.00
14-Mar-94	23:00	523	-2	0	0	81	0	1.8	0	100	23	22.65	-3.99	0.00	0.00
15-Mar-94	00:00	525	2	0	0	74	0	2.4	0	119	20	17.49	-9.70	0.00	0.00
15-Mar-94	01:00	525	0	0	0	70	0	2.6	0	136	15	10.42	-10.79	0.00	0.00
15-Mar-94	02:00	525	0	0	0	67	0	2.7	0	150	18	9.00	-15.59	0.00	0.00
15-Mar-94	03:00	525	0	0	0	67	0	2.3	0	189	23	-3.60	-22.72	0.00	0.00
15-Mar-94	04:00	525	0	0	0	66	0	2.4	0	204	22	-8.95	-20.10	0.00	0.00
15-Mar-94	05:00	524	-1	0	0	68	0	1.7	0	251	14	-13.24	-4.56	0.00	0.00
15-Mar-94	06:00	524	0	0	0	72	0	0.6	0	268	14	-13.99	-0.49	0.00	0.00
15-Mar-94	07:00	524	0	0	0	70	0	0.8	0	272	16	-15.99	0.56	0.00	0.00
15-Mar-94	08:00	524	0	0	0	68	0	2.8	0	244	10	-8.99	-4.38	0.00	0.00
15-Mar-94	09:00	525	1	1	1	69	69	3	3	235	9	-7.37	-5.16	-7.37	-5.16
15-Mar-94	10:00	525	0	0	0	75	0	1.2	0	247	10	-9.21	-3.91	0.00	0.00
15-Mar-94	11:00	525	0	0	0	77	0	0.6	0	254	10	-9.61	-2.76	0.00	0.00

15-Mar-94	12:00	525	0	0	0	77	0	1.2	0	236	6	-4.97	-3.36	0.00	0.00
15-Mar-94	13:00	525	0	0	0	80	0	0.6	0	244	6	-5.39	-2.63	0.00	0.00
15-Mar-94	14:00	525	0	0	0	81	0	0.2	0	251	14	-13.24	-4.56	0.00	0.00
15-Mar-94	15:00	526	1	0	0	80	0	0.9	0	243	12	-10.69	-5.45	0.00	0.00
Total:				**24**	22										
Average for hrs with ppt:							**72.5**		**1.4**					-7.45	-2.17

Average WInd Speed: 7.76
Average Wind Direction: 253.75

Loading Winds

transect	aspect	incident angle	speed	loading wind
A	210	136.25	7.76	**-5.61**
B	76	2.25	7.76	**7.75**

Weather Data for March 15 - March 16

Date	Time	Ppt. guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when Ppt (%)	Temp (°C)	Temp when ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	when ppt y (km/h)
15-Mar-94	16:00	525	0	0	0	81	0	-0.2	0	224	14	-9.73	-10.07	0.00	0.00
15-Mar-94	17:00	525	0	0	0	82	0	-0.7	0	222	13	-8.70	-9.66	0.00	0.00
15-Mar-94	18:00	524	-1	0	0	88	0	-1.5	0	217	11	-6.62	-8.78	0.00	0.00
15-Mar-94	19:00	524	0	0	0	91	0	-1.7	0	202	14	-5.24	-12.98	0.00	0.00
15-Mar-94	20:00	524	0	0	0	91	0	-1.8	0	190	13	-2.26	-12.80	0.00	0.00
15-Mar-94	21:00	524	0	0	0	91	0	-1.8	0	208	18	-8.45	-15.89	0.00	0.00
15-Mar-94	22:00	524	0	0	0	91	0	-1.8	0	200	18	-6.16	-16.91	0.00	0.00
15-Mar-94	23:00	525	1	1	1	91	91	-1.7	-1.7	208	17	-7.98	-15.01	-7.98	-15.01
16-Mar-94	00:00	525	0	0	0	91	0	-2	0	242	16	-14.13	-7.51	0.00	0.00
16-Mar-94	01:00	526	1	0	0	91	0	-2.1	0	228	16	-11.89	-10.71	0.00	0.00
16-Mar-94	02:00	525	-1	0	0	92	0	-2.9	0	223	19	-12.96	-13.90	0.00	0.00
16-Mar-94	03:00	525	0	0	0	92	0	-2.9	0	232	15	-11.82	-9.23	0.00	0.00
16-Mar-94	04:00	525	0	0	0	92	0	-2.9	0	202	16	-5.99	-14.83	0.00	0.00
16-Mar-94	05:00	525	0	0	0	92	0	-3.3	0	186	16	-1.67	-15.91	0.00	0.00
16-Mar-94	06:00	525	0	0	0	92	0	-3.7	0	208	14	-6.57	-12.36	0.00	0.00
16-Mar-94	07:00	526	1	1	1	92	92	-3.3	-3.3	207	14	-6.36	-12.47	-6.36	-12.47
16-Mar-94	08:00	528	2	2	1	93	93	-3.9	-3.9	231	15	-11.66	-9.44	-11.66	-9.44
16-Mar-94	09:00	528	0	0	0	93	0	-3.8	0	239	19	-16.29	-9.79	0.00	0.00
16-Mar-94	10:00	529	1	1	1	93	93	-3.8	-3.8	247	23	-21.17	-8.99	-21.17	-8.99

16-Mar-94	11:00	529	0	0	0	93	0	-4.2	0	248	26	-24.11	-9.74	0.00	0.00
16-Mar-94	12:00	529	0	0	0	92	0	-4.6	0	220	21	-13.50	-16.09	0.00	0.00
16-Mar-94	13:00	530	1	1	1	90	90	-4.5	-4.5	246	28	-25.58	-11.39	-25.58	-11.39
16-Mar-94	14:00	530	0	0	0	90	0	-4.6	0	231	29	-22.54	-18.25	0.00	0.00
Total:				**6**	5										
Average for hrs with ppt:							**91.8**		**-3.4**					-14.55	-11.46

Average Wind Speed: 18.52
Average Wind Direction: 231.77

Loading Winds

transect	aspect	incident angle	speed	loading wind
A	210	158.23	18.52	**-17.20**
B	76	24.23	18.52	**16.89**

Weather Data for March 16 - March 17

Date	Time	Ppt. guage total (mm)	Ppt. change (mm)	Hrly ppt. filtered for noise (mm)	Ppt. this hour (1=Yes)	RH (%)	RH when Ppt (%)	Temp (°C)	Temp when ppt (°C)	Wind Dir (°)	Wind Speed (km/h)	Wind Vector Coordinates x (km/h)	y (km/h)	when ppt x (km/h)	y (km/h)
16-Mar-94	15:00	530	0	0	0	90	0	-4.5	0	253	38	-36.34	-11.11	0.00	0.00
16-Mar-94	16:00	531	1	1	1	90	90	-4.8	-4.8	240	29	-25.11	-14.50	-25.11	-14.50
16-Mar-94	17:00	531	0	0	0	91	0	-4.9	0	234	23	-18.61	-13.52	0.00	0.00
16-Mar-94	18:00	532	1	1	1	91	91	-4.8	-4.8	231	17	-13.21	-10.70	-13.21	-10.70
16-Mar-94	19:00	532	0	0	0	92	0	-4.9	0	187	15	-1.83	-14.89	0.00	0.00
16-Mar-94	20:00	532	0	0	0	92	0	-5	0	205	10	-4.23	-9.06	0.00	0.00
16-Mar-94	21:00	534	2	2	1	92	92	-5.1	-5.1	198	10	-3.09	-9.51	-3.09	-9.51
16-Mar-94	22:00	536	2	2	1	92	92	-5.1	-5.1	197	9	-2.63	-8.61	-2.63	-8.61
16-Mar-94	23:00	538	2	2	1	92	92	-5.4	-5.4	203	15	-5.86	-13.81	-5.86	-13.81
17-Mar-94	00:00	538	0	0	0	92	0	-6.6	0	234	34	-27.51	-19.98	0.00	0.00
17-Mar-94	01:00	538	0	0	0	92	0	-6.9	0	236	30	-24.87	-16.78	0.00	0.00
17-Mar-94	02:00	540	2	2	1	92	92	-6.8	-6.8	233	29	-23.16	-17.45	-23.16	-17.45
17-Mar-94	03:00	540	0	0	0	92	0	-6.7	0	238	27	-22.90	-14.31	0.00	0.00
17-Mar-94	04:00	541	1	1	1	92	92	-6.6	-6.6	249	24	-22.41	-8.60	-22.41	-8.60
17-Mar-94	05:00	542	1	1	1	92	92	-6.5	-6.5	252	29	-27.58	-8.96	-27.58	-8.96
17-Mar-94	06:00	542	0	0	0	92	0	-6.7	0	236	25	-20.73	-13.98	0.00	0.00
17-Mar-94	07:00	543	1	1	1	92	92	-6.8	-6.8	231	23	-17.87	-14.47	-17.87	-14.47
17-Mar-94	08:00	544	1	1	1	92	92	-6.8	-6.8	241	29	-25.36	-14.06	-25.36	-14.06
17-Mar-94	09:00	544	0	0	0	92	0	-6.3	0	249	31	-28.94	-11.11	0.00	0.00

17-Mar-94	10:00	544	0	0	0	92	0	-6.3	0	220	26	-16.71	-19.92	0.00	0.00
17-Mar-94	11:00	544	0	0	0	91	0	-5.9	0	226	23	-16.54	-15.98	0.00	0.00
17-Mar-94	12:00	545	1	1	1	91	91	-4	-4	217	18	-10.83	-14.38	-10.83	-14.38
17-Mar-94	13:00	545	0	0	0	91	0	-4.5	0	230	15	-11.49	-9.64	0.00	0.00
Total				**15**	11		1008		-62.7					-177.13	-135.05
Average for hrs with ppt:							**91.6**		**-5.7**					-16.10	-12.28

Average Wind Speed: 20.25
Average Wind Direction: 232.68

Loading Winds

transect	aspect	incident angle	speed	loading wind
A	210	157.32	20.25	**-18.68**
B	76	23.32	20.25	**18.59**

Appendix 2

Snow Data

Description of Snow Variables

Snow Variable	Description
board	The number of the board. For transects A and B board 1 is closest to the ridge.
snow depth	The depth of snow on the board measured vertically with a ruler.
layer	The heights above the board that bound a distinct layer in the snowpack. Blank if the accumulated snow is not layered.
layer height	The height of the layer that was sampled for weight. Layer height is the same as snow depth if the accumulated snow is not layered.
sample depth	The depth of the sample of snow that was weighed. The samples were taken by inserting an aluminum tube into the layer either horizontally or vertically. The cross sectional area of the tube was 28 cm^2. The volume of the sample was (28 x (sample depth))cm^3.
sample weight	The weight of the snow sample in grams.
layer specific gravity	The sample weight divided by the weight of an equal volume of water. (1 cm^3 of water weighs 1 g).
layer water equivalent	Layer specific gravity times layer depth (in mm).
total water on board	The sum of the water equivalents of each layer.
weighted board specific gravity	Total water on board divided by snow depth in mm.
weighted transect specific gravity	The weighted average of the calculated specific gravities. $= \frac{\Sigma(\text{weighted board specific gravity x snow depth})}{\Sigma \text{snow depth}}$
weighted water on board	Snow depth times weighted transect specfic gravity.
average	The average water equivalent of the snow on the transect = The mean weighted water on board.

Snow Measurements

Snow measurements were taken on February 22 and 25, and March 8, 16, and 17. On February 22 and 25, and March 17 the total snow on the boards was used to calculate the *snow accumulations*. On both March 8 and March 16 there were two distinct layers of snow on the boards that were each used to calculate *snow accumulations* associated with known time periods. In both cases the boundary between the layers was clearly associated with recorded weather conditions. The time the boundaries formed, determined from the weather records, was the end of one accumulation period and the beginning of the next. The snow below the boundary having been deposited between the time the board was last cleared and the time the boundary formed, and the snow above the boundary having been deposited since the boundary formed. On March 8, a crust was observed that would have been formed on March 3 by warm (+2.3°C) temperatures on March 2 and below freezing temperatures on March 3. On March 16, a crust was observed that would have been formed on March 15 boundary by warm temperatures (+6.2°C) on March 14 and below freezing temperatures on March 15 (see Appendix 1 for detailed weather data).

February 10 - 22

Transect A

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	22										35.5
2	64										103.2
3	36	15 - 36	21	17.9	35	0.07	14.7				58.1
		0 - 15	15	17.9	100	0.20	29.9	44.6	0.12		
4	49										79.0
5	84	63 - 84	21	17.9	30	0.06	12.6			0.16	135.5
		47 - 63	16	17.9	90	0.18	28.7				
		39 - 47	8	17.9	140	0.28	22.3				
		9 - 39	30	17.9	105	0.21	62.8				
		0 - 9	9	17.9	125	0.25	22.4	148.9	0.18		
6	90										145.2
7	99										159.7

Average Snow Accumulation (mm water): 102.3

Transect C

1	82										138.40
2	98	65 - 98	33	17.9	40	0.08	26.3				
		47 - 65	18	17.9	100	0.20	35.9				
		0 - 47	47	17.9	110	0.22	103.2	165.4	0.17	0.17	165.40
3	103										173.84

Average Snow Accumulation (mm water): 159.2

February 22 - 25

Transect A

board	*snow depth (cm)*	*layer (cm)*	*layer depth (cm)*	*sample depth (cm)*	*sample weight (g)*	*layer specific gravity*	*layer water equiv (mm)*	*board water equiv (mm)*	*board s.g.*	*transect s.g.*	*est board water eq. (mm)*
1	45										67.9
2	41										61.9
3	29	18 - 29	11	17.9	50	0.10	11.0				43.8
		0 - 18	18	17.9	110	0.22	39.5	50.5	0.17		
4	8									0.15	12.1
5	27	14 - 27	13	17.9	45	0.09	11.7				40.7
		0 - 14	14	17.9	80	0.16	22.3	34.0	0.13		
6	46										69.4
7	42										63.4

Average Snow Accumulation (mm water): 51.3

Transect C

1	27										42.2
2	43	32 - 43	11	14	35	0.09	9.8				
		0 - 32	32	17.9	90	0.18	57.5	67.3	0.16	0.16	67.3
3	43										67.3

Average Snow Accumulation (mm water): 58.9

February 25 - March 3 (March 8 below crust)

Transect A

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	5										17.7
2	5										17.7
3	15		15	17.9	180	0.36	53.9	53.9	0.36		53.2
4	0									0.35	0.0
5	11		11	17.9	175	0.35	38.4	38.4	0.35		39.0
6	11										39.0
7	6										21.3

Average Snow Accumulation (mm water): 26.9

Transect B

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	0										0.0
2	5										24.0
3	26		26	17.9	255	0.51	132.3	132.3	0.51		125.0
4	35									0.48	168.2
5	8		8	17.9	195	0.39	31.1	31.1	0.39		38.4
6	19										91.3
7	11										52.9

Average Snow Accumulation (mm water): 71.4

Transect C

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	11										39.5
2	14		14	17.9	180	0.36	50.3	50.3	0.36	0.36	50.3
3	14										50.3

Average Snow Accumulation (mm water): 46.7

March 3-8 (March 8 above crust)

Transect A

board	*snow depth (cm)*	*layer (cm)*	*layer depth (cm)*	*sample depth (cm)*	*sample weight (g)*	*layer specific gravity*	*layer water equiv (mm)*	*board water equiv (mm)*	*board s.g.*	*transect s.g.*	*est board water eq. (mm)*
1	28										83.0
2	19										56.3
3	13		13	17.9	160	0.32	41.5	41.5	0.32		38.5
4	11									0.30	32.6
5	11		11	17.9	135	0.27	29.6	29.6	0.27		32.6
6	15										44.5
7	27										80.0

Average Snow Accumulation (mm water): 52.5

Transect B

1	0										0.0
2	16										47.4
3	40		40	17.9	160	0.32	127.7	127.7	0.32		118.4
4	49									0.30	145.0
5	20		20	17.9	125	0.25	49.9	49.9	0.25		59.2
6	41										121.3
7	18										53.3

Average Snow Accumulation (mm water): 77.8

Transect C

1	16										36.7
2	23		23	17.9	115	0.23	52.8	52.8	0.23	0.23	52.8
3	20										45.9

Average Snow Accumulation (mm water): 45.1

March 8 - 15 (March 16 below crust)

Transect A

board	*snow depth (cm)*	*layer (cm)*	*layer depth (cm)*	*sample depth (cm)*	*sample weight (g)*	*layer specific gravity*	*layer water equiv (mm)*	*board water equiv (mm)*	*board s.g.*	*transect s.g.*	*est board water eq. (mm)*
1	1					0.45(e)		4.5 (e)			4.5
2	1					0.45(e)		4.5 (e)			4.5
3	0							0.0			0.0
4	0							0.0			0.0
5	0							0.0			0.0
6	0							0.0			0.0
7	0							0.0			0.0

(e): estimated (= Transect C s.g.)

Average Snow Accumulation (mm water): 1.3

Transect B

board	*snow depth (cm)*	*layer (cm)*	*layer depth (cm)*	*sample depth (cm)*	*sample weight (g)*	*layer specific gravity*	*layer water equiv (mm)*	*board water equiv (mm)*	*board s.g.*	*transect s.g.*	*est board water eq. (mm)*
1	4										12.2
2	4										12.2
3	11		11	17.9	160	0.32	35.1	35.1	0.32		33.6
4	7									0.31	21.4
5	4		4	4	30	0.27	10.7	10.7	0.27		12.2
6	4										12.2
7	4										12.2

Average Snow Accumulation (mm water): 16.6

Transect C

board	*snow depth (cm)*	*layer (cm)*	*layer depth (cm)*	*sample depth (cm)*	*sample weight (g)*	*layer specific gravity*	*layer water equiv (mm)*	*board water equiv (mm)*	*board s.g.*	*transect s.g.*	*est board water eq. (mm)*
1	2										8.9
2	2		2	2	25	0.45	8.9	8.9	0.45	0.45	8.9
3	2										8.9

Average Snow Accumulation (mm water): 8.9

March 15 - 16 (March 16 above crust)

Transect A

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	1										1.2
2	6										7.4
3	4		4	4	15	0.13	5.4	5.4	0.13		4.9
4	0									0.12	0.0
5	9		9	9	30	0.12	10.7	10.7	0.12		11.1
6	14										17.3
7	15										18.5

Average Snow Accumulation (mm water): 8.7

Transect B

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	0										0.0
2	0										0.0
3	20		20	17.9	105	0.21	41.9	41.9	0.21		37.7
4	24									0.19	45.3
5	6		6	6	20	0.12	7.1	7.1	0.12		11.3
6	16										30.2
7	11										20.7

Average Snow Accumulation (mm water): 20.7

Transect C

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	10										10.2
2	7		7	7	20	0.10	7.1	7.1	0.10	0.10	7.1
3	9										9.2

Average Snow Accumulation (mm water): 8.8

March 16 - 17

Transect A

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	0										0.0
2	3										4.6
3	5		5	5	20	0.14	7.1	7.1	0.14		7.7
4	8									0.15	12.4
5	10		10	10	45	0.16	16.1	16.1	0.16		15.5
6	22										34.0
7	20										31.0

Average Snow Accumulation (mm water): 15.0

Transect B

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	0										0.0
2	0										0.0
3	16		16	16	80	0.18	28.6	28.6	0.18		29.7
4	40									0.19	74.2
5	10		10	10	55	0.20	19.6	19.6	0.20		18.5
6	25										46.4
7	17										31.5

Average Snow Accumulation (mm water): 28.6

Transect C

board	snow depth (cm)	layer (cm)	layer depth (cm)	sample depth (cm)	sample weight (g)	layer specific gravity	layer water equiv (mm)	board water equiv (mm)	board s.g.	transect s.g.	est board water eq. (mm)
1	13										23.2
2	11		11	11	55	0.18	19.6	19.6	0.18	0.18	19.6
3	20										35.7

Average Snow Accumulation (mm water): 26.2

Appendix 3

Wind Vector Calculations

Wind Vector Calculations

The Campbell Scientific data logger calculates the hourly wind vector for time T from samples taken at interval t. The number of samples in time T = T/t = N. At Great Bear T = 60 minutes and t = 2 minutes, so N = 60 /2 = 30.

Each wind sample is represented by its east and north components, x and y.

$x = \sin(\text{azimuth}) \times \text{speed}$ $\qquad$ $y = \cos(\text{azimuth}) \times \text{speed}$

for example: for a 20 km/h wind from the northeast, x = 14.1, y = 14.1

The hourly vector is represented by its magnitude (S) and azimuth (D).

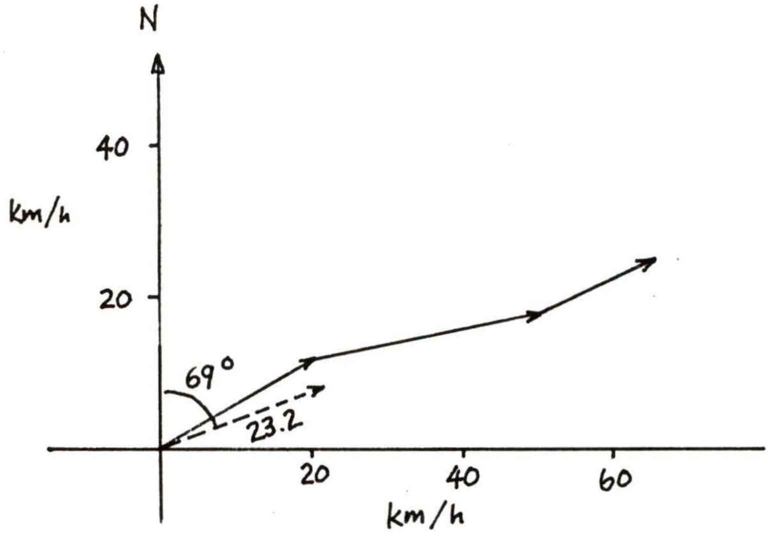
$S = (X^2 + Y^2)^{1/2}$ $\qquad$ $D = \arctan(X/Y)$

$$\text{where } X = \sum_{i=1}^{N} x_i / N \quad \text{and } Y = \sum_{i=1}^{N} y_i / N$$

For example, if three samples were taken in an hour, with east and north components (20, 12), (30, 6) and (15, 7), then:

X = (20 + 30 + 15) /3 = 21.66
Y = (12 + 6 + 7) /3 = 8.33

$S = (21.66^2 + 8.33^2)^{1/2} = 23.2$ km/h
D = arctan (21.66/8.33) = 69°



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Title of Thesis:

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