

## WIND ENERGY RESEARCH AND APPLICATION IN MAURITIUS

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### INTRODUCTION

As part of the Government of Mauritius plan to diversify its use of alternative energy sources, the Mauritius Meteorological Office (MMO) initiated a programme to evaluate both the wind and solar energy potential of Mauritius. This paper describes the attempts to assess wind power.

A number of problems were encountered, in particular the use of anemograms which meant that compilation of hourly means was very time consuming. Secondly initial siting of stations in agricultural areas raised doubts as to whether this would provide a comprehensive picture of the windpower potential of Mauritius. Thus following initial work using data collected in 1980, the Government agreed to support a UNDP project to make a proper evaluation to conclude all the windiest sites in Mauritius.

Following a brief explanation of the calculation of wind power, this paper describes the data obtained in 1980 from the original weather stations. Finally the preliminary findings for the comprehensive evaluation now in progress will be presented.

### WIND POWER

The theory behind wind power is simple (Golding 1976). The kinetic energy of the air in motion is expressed by

$$P = \frac{1}{2} MV^2 \quad (1)$$

Where M is the mass and V, the velocity of the air parcel. If D is the density of air passing through a cross-sectional area of A then the mass of that air in unit time is given by

$$M = DAV \quad (2)$$

hence the kinetic energy per unit time is given by

$$P = \frac{1}{2} MV^2 = \frac{1}{2} DAV^3 \quad (3)$$

D can be computed for the standard atmospheric pressure 1000 H<sub>p</sub>, absolute temperature 290°K, using the gas equation in the form

$$D = \frac{P}{RT} = 1.2 \text{ kg per cubic metre} \quad (4)$$

Putnam (1984) suggested 35% as the maximum fraction of power in the wind which could be extracted. Golding (1976) has shown that this efficiency can be increased to 59.3%. With this efficiency, equation (3) becomes

$$P = 0.593 KAV^3 \quad (5)$$

As suggested by Rene (1981), power in the wind can also be expressed by

$$P = \frac{1}{2} - D \frac{C}{j=1} F_j V_j^3 \quad (6)$$

Where C is number of wind speed classes, F<sub>j</sub> the frequency of occurrence of winds in the j<sup>th</sup> class, and V<sub>j</sub> the median wind speed of the j<sup>th</sup> class. The bar in equation (6) indicated average values. With hourly wind speeds available, Rene asserts that the power potential available in the wind is simply expressed by

$$P = 0.955 DV^3 \quad (7)$$

Equation (7) can be used upon the assumption that the frequency distribution is a Rayleigh one.

### ANALYSIS OF 1980 DATA

Raw data from anemograms for seven stations were used to obtain hourly means which can be used to compute simple statistical data required to estimate available wind power and wind speed, treated here simply as a scalar quantity, and the atmospheric pressure.

Raw data from anemograms from seven stations were used to obtain hourly means which are then used to compute simple statistical parameters like correlation coefficients and standard deviations. The seven stations considered are mostly inland the they are all the same standard height of 10 metres above ground level. Medine, Plaisance and Digue Seche are respectively 1, 2 and 3 km from the sea shore. Vacoas is at the site of the Main Meteorological Office, whereas Plaisance is located on the premises of the airport. Table 1 gives the mean monthly wind speeds at each station.

To find the frequency of anticyclones passing near Mauritius in 1980, atmospheric pressure at 1600 hours, local time, of one station, Plaisance was plotted against days of the year. It should be noted that the pressure fluctuation at any point over the island would give the same result since the island is small compared to a synoptic scale of an anticyclone. Changes in atmospheric pressure at any one point would be felt almost anywhere within minutes. The pressure variation, coupled with the variation of the mean 10 minutes wind speed at the same synoptic hour, gives an indication of the meteorological situation.

The criteria for determining the exit of an anticyclone and the entry of another one are:

- (a) a wind speed of less than 2.5 m/sec for two days, and/or
- (b) a fairly steep fall parallel to the low wind.

Daily synoptic charts for this area have been consulted to back up the conclusions reached above. The frequency of anticyclones affecting Mauritius has been found to be 11.4 days. Out of these 3 are lull days on an average. Using the above criteria a back up system must be made ready for 3 out of every 11.4 days (Boodhoo 1984).

The results are displayed in the form of a wind energy map in Figure 1. Contrary to expectations and assumptions long established at the Meteorological Office of Mauritius, very promising results have been found along the North East coast of

Mauritius, whereas formerly it was taken for granted that the wind speed was greatest over the high grounds and to the south east. This finding has been confirmed by the more extensive survey described below.

### **UNDP WIND ENERGY EVALUATION**

As mentioned in the introduction, the positioning of weather stations used in the 1980 survey did not cover all the potentially important areas of the island. The UNDP financed programme, implemented by the Meteorological Service is being conducted to look more comprehensively at the feasibility of utilising wind resources to supplement existing electrical generation and as far as possible to meet future increased electric power needs in Mauritius.

Ten sites (Figure 2) were selected where anemometers were erected. These were mostly along the south, south east and north eastern coasts and a few over the Central Plateau. These sites had been shortlisted from more than 30 sites chosen according to meteorological characteristics. At one location, Bigara, four sensors were installed along a 200 metre tower at the 10, 30, 72 and 122 metre levels. The aim here was to find the wind profile inland as any generator installed would most certainly be above the standard 10-metre level at which anemometers are generally installed.

The instruments in the field consist of a cup anemometer and wind vane combination manufactured by Weather Measure Corporation (Model W200 SP). The anemometers were brought to Mauritius already calibrated by the contractor, the Battelle Memorial Institute in Washington State, USA. Each anemometer was connected to a data field unit (the Wind Prospector's Instrument, abbreviated WPI) which performs field processing of the data and stores the results (Figure 3).

The data are collected from the sites each month although the storage capacity of the WPI is about 40 days. The data extracted from the WPI is stored on an audiocassette tape. Processing is greatly simplified since the WPI does a considerable amount of processing. The instrument acquires wind speed and direction data once every 1.5 seconds. These data are averaged over a 6 min interval, then processed by the WPI to yield the following wind statistics:

- (a) Wind speed frequency histogram.
- (b) Joint distribution of wind speed versus wind direction.
- (c) Joint distribution of wind speed versus time of day.
- (d) Joint distribution of wind direction versus time of day.
- (e) Turbulence intensity frequency histogram (using standard deviations based on the 1.5 second sampling).

The WPI also records the peak gust speed (between data extractions).

For final analysis audiocassettes are read through a demodulator into the graphics terminal of a Hewlett-Packard both at Battelle and at the Meteorological Office.

## RESULTS AND CONCLUSIONS

Table 2 gives some of the main characteristics over the period August 1983 - June 1984. Figure 2 presents the same results in the form of an energy map. Coastal areas are by far the windiest places of Mauritius with the southern, eastern and even north eastern coasts receiving the most wind energy flux. As mentioned earlier, this is contrary to what has been assumed at the Mauritius Meteorological Office. Formerly it was taken for granted that the south east coast which falls directly under the prevailing south east trade winds and the high grounds are the windiest. However, the trade winds striking the island which acts as an obstacle, are deflected sideways thus depriving the higher central areas of the island of most of its winds (Figure 4).

The wind profile at Bigara shows that friction greatly reduces the wind close to the ground. However, above 30 metres wind speed becomes more or less constant (Figure 5) at nearly twice the speed measured at the 10 metre level. Since wind energy is directly proportional to the cube of the speed, the wind power will be many times higher at 30 than 10 metres level. At the 10 metre level the windiest sites are along the coasts where the investigation is being carried on. But the results at Bigara are important because most generators are located around the 30 metre level. Bigara could also be the best candidate site as it carries the least percentage of calm periods (between 3 and 4% of the time).

Although the survey demonstrates considerable potential for a wind energy exploitation programme in Mauritius, a number of points need to be borne in mind.

- a. The investment cost is extremely high and any generator should repay the investment in not less than 20 years. This applies particularly to a case like Mauritius where 99% of the land is electrified.
- b. It must be made certain that the very high winds and gusts experienced during tropical cyclones will not damage the generators. So far very few, if any, generators even at the famous test centre in Colorado, USA have been exposed to and resisted gusts of the order of 81 m/sec as experienced during cyclones in Mauritius.

If wind generators are installed, these should be limited to medium capacity and used for subsidiary purposes, eg pumping water or catering for the needs of small enterprises. However if a suitable cyclone-proof (or nearly so) system becomes available, wind energy could be used to supply between 5% and 10% of the total energy needs (which amounts to around 100 Mega Watts at present) of Mauritius.

## RODRIGUES

A similar investigation has been conducted of the wind regime over the island of Rodrigues. As a result a small 2.5 Kw generator has been installed at Anse Quitar. The performance of this generator has been very encouraging. The Government of Mauritius is now considering the feasibility of installing four similar generators at Port Sud Est, Anse Ally, Riviere Coco, and Les Graviers. Wind speeds are relatively higher (Table 3) than over Mauritius.

Unlike Mauritius the terrain of Rodrigues is so varied that despite its small size (roughly 109 km<sup>2</sup>) electrification, which is extremely expensive, is confined to

only the main areas. Hence wind may have an important role in supplying energy on this island. The wind pump at Anse Quito was primarily intended to pump water from boreholes to a reservoir for distribution to households. So encouraging are the results that the water storage capacity has been doubled. Even so, there is a surplus of electrical energy which is shortly to be distributed to an agglomeration of about 18 houses in Anse Quito. The total pumping system output from the date of commissioning on 24 May 1983 up to the end of April 1984 was approximately 1.7 million gallons of water pumped over a period of 1788 hours of operation. These figures have more than doubled up to the present.

### CONCLUSION

The survey of Mauritius has shown a major potential for exploiting wind energy at various sites. However, the wind energy programme needs to consider its exploitation in relation to the energy resources and capital investment costs. The case for exploiting wind energy is much clearer for Rodrigues, where electricity generation by other means is less universally available.

This wind energy programme is still in progress and data presented here are only the preliminary findings. However, the changes should be so small as not to substantially affect the conclusions.

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**TABLE 1: Correlation matrix for daily mean speed for 1980**

<b>Stations</b>	<b>Vacoas</b>	<b>Plaisance</b>	<b>FUEL</b>	<b>D Seche</b>	<b>MDA</b>	<b>Medine</b>	
Plaisance	0.79						
FUEL	0.31	0.30					
D Seche	0.29	0.31	0.51				
Mon Desert Alma	0.32	0.33	0.63	0.82			
Medine	0.31	0.18	0.61	0.44	0.52		
Pamplemousse	0.29	0.23	0.66	0.76	0.83	0.67	

**TABLE 2: Standard deviation values**

<b>Station</b>	<b>Vacoas</b>	<b>Plaisance</b>	<b>FUEL</b>	<b>D Seche</b>	<b>MDA</b>	<b>Medine</b>	<b>Pamplemousse</b>
Standard deviation	0.65	0.87	1.82	1.42	1.37	1.23	1.28

**TABLE 3: Mean monthly wind speed at each station using 1980 data**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Vacoas	4.1	3.7	3.8	2.9	3.3	3.7	4.0	4.0	3.9	3.5	3.5	3.2
Plaisance	3.5	3.1	3.1	2.2	2.9	3.8	4.1	4.0	3.8	3.3	3.2	3.0
Pamplemousse	3.9	5.3	4.2	2.6	3.3	2.2	2.8	3.4	3.7	3.1	3.6	3.1
FUEL	3.4	4.2	3.0	2.8	3.4	3.5	4.4	4.2	3.9	4.1	3.2	2.6
D Seche	4.3	4.7	3.6	2.8	3.4	2.9	3.1	4.1	4.7	4.2	4.7	3.9
MDA	6.1	5.0	4.3	2.8	3.9	3.1	4.4	4.9	4.3	2.2	4.6	4.5
Medine	3.9	5.6	4.6	3.2	4.3	3.1	3.3	3.5	3.0	3.0	2.3	1.9

**TABLE 4: Wind characteristics over Mauritius, August 1983 - June 1984**

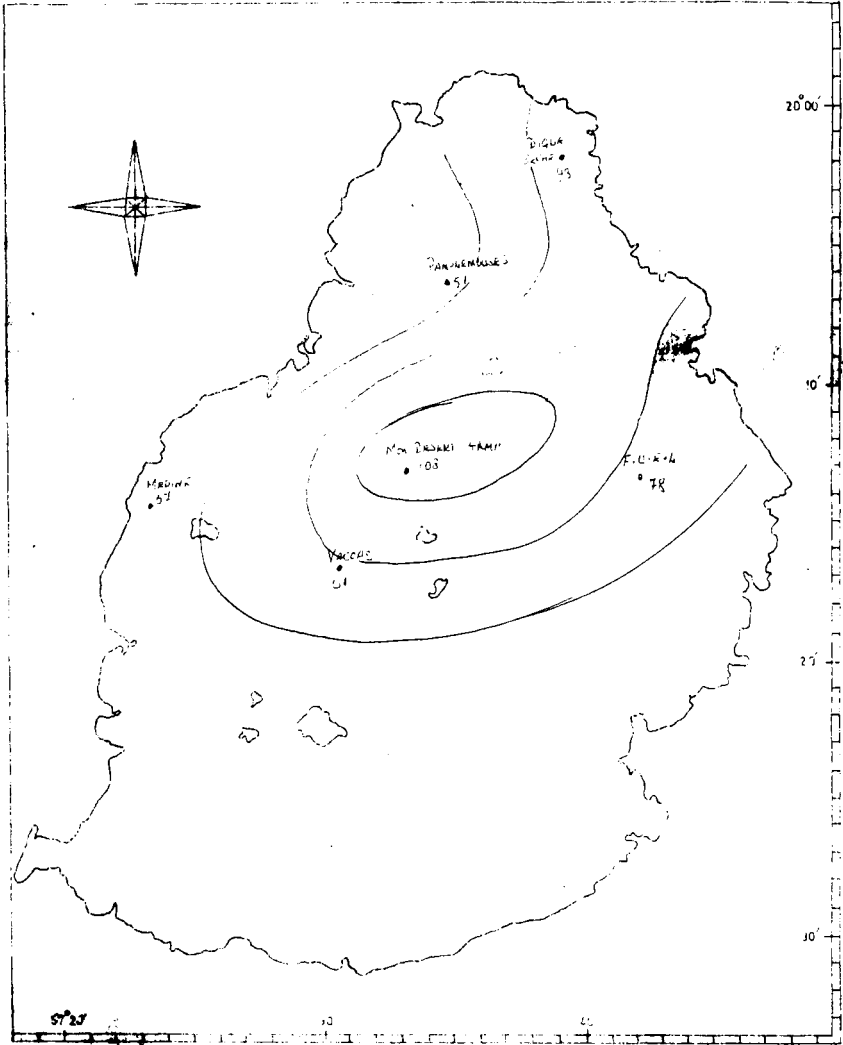
<b>Station</b>	<b>Mean speed (m/s)</b>	<b>Standard deviation</b>	<b>Mean Energy flux (w/m<sup>2</sup>)</b>	<b>Calm (% of time wind speed 2 m/s)</b>
Grand Bassin	5.14	1.96	112.65	6.87
Bois Cheri	3.6	1.68	44.0	19.37
Gris Gris	6.07	2.55	216.77	3.17
St Felix	4.11	2.0	74.53	18.11
B Ombre	5.0	2.62	154.6	22.02
U Park	3.68	1.89	54.7	24.44
G Port	5.38	2.72	199.4	18.70
Palmar	4.66	1.72	82.9	8.9
St Antoine	5.21	2.23	151.82	12.55
MGI	3.95	1.94	72.58	30.23
Bigara* (32 ft)	3.24	1.82	140.24	3.00
Bigara (100 ft)	6.15	2.15	184.42	4.02
Bigara (240 ft)	7.57	2.98	384.35	4.97
Bigara (400 ft)	8.1	3.36	570.66	4.23

\* Four anemometers were installed on a tall tower at Bigara on the 32, 100, 240 and 400 ft levels.

**TABLE 5: Winds over Rodrigues**

<b>Area</b>	<b>Mean wind speed (m/s)</b>
Anse Ally	4.7
Les Gravieres	5.9
Port Sud Est	9.5
Riviere Coco	6.4
Pointe Canon	10.2

**FIGURE 1: Location of anemometers for the Meteorological Service  
Isochrone of wind power ( $W/m^2$ ) for 1980**



**FIGURE 2: Location of new sites  
Isochrone of wind power ( $W/m^2$ ) based on UNDP financed programme**

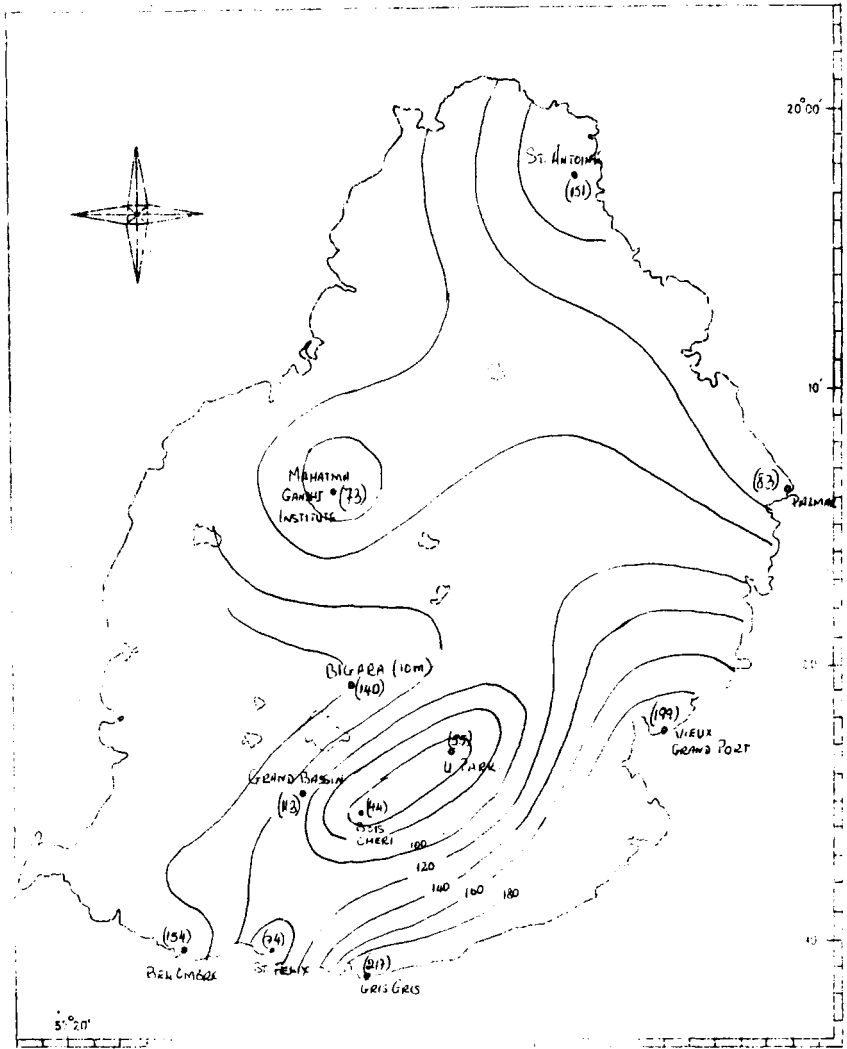


FIGURE 3: The system - its parts

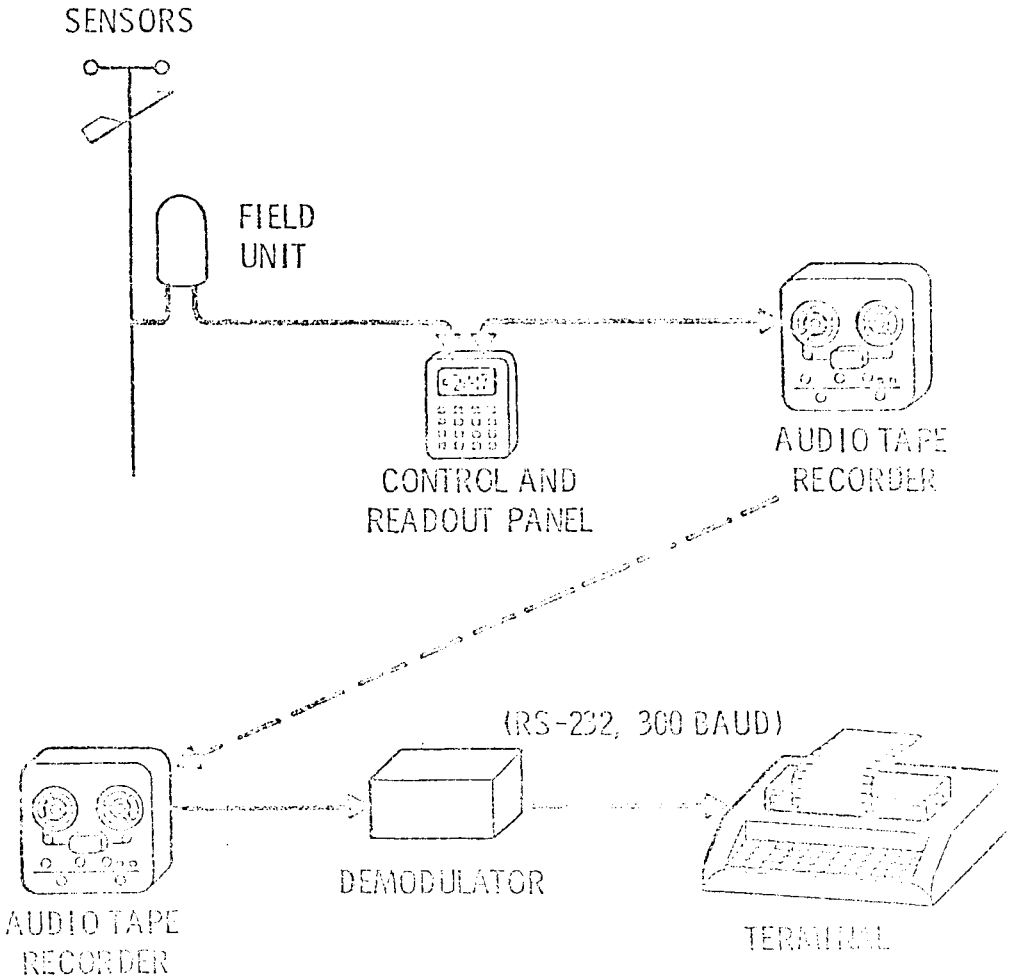


FIGURE 4: Relief map of Mauritius in feet & metres

Shaded areas show high wind energy potential.  
Arrows show probable deflection of wind.

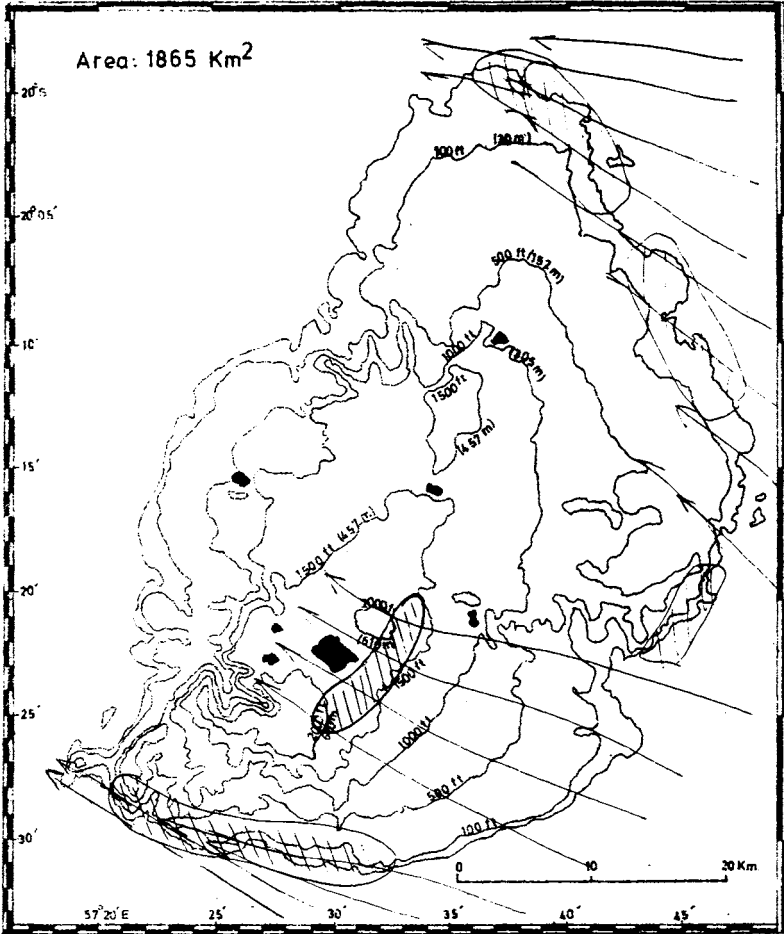


FIGURE 5: Wind profile of Bigara

