Faro Sheep Site Wind Analysis
August 2000 to June 2002

For
Yukon Energy Corporation
Whitehorse, Yukon

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by
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This report summarizes the wind monitoring data from Yukon Energy's Faro Sheep wind monitoring site. The monitoring period begins August 3, 2000 at 1730 and ends July 4, 2002 at 0850.

The first part of this report describes and summarizes the data from August 2000 to June 2002. The data summary ends at June 30, 2002 because there are only 3.5 days of useable data from July 2002. The second part summarizes the data monthly, parameter-by-parameter and is presented in tables and one-page graphs.

Part 1.
Site Description

The Faro Sheep wind monitoring site is located 826 metres above sea level at N62˚12’9.3’’ and W133˚15’45.4’’, which is approximately 97 metres higher than, and 5.9 km to the east of, the Faro airport. The Faro Sheep wind monitoring site consists of two anemometers installed on the same tower: Anemometer “A”, which is installed 30 metres up the tower and Anemometer “B”, which is installed 15 metres up the tower. Both anemometers are un-heated Maxi-40 anemometers. The tower also supports a wind vane ***at 30 meters*** and a temperature sensor ***near ground level***. The data were automatically stored on Nomad data logger cards.

Wind Speed and Direction Summary

Figures 1 through 5 summarize the wind speed from the two anemometers and the wind direction data from the wind vane over the course of the monitoring period.

Figure 1. Monthly Averages for Faro Sheep Site - August 2000 to June 2002

Month	**Anemometer A 30 metre data (m/s)**		**Anemometer B 15 metre data (m/s)**		**Wind Vane**
	Wind Speed	Standard Deviation of Wind Speed	Wind Speed	Standard Deviation of Wind Speed	Wind Direction (degrees)
August 2000	4.03	0.59	3.29	0.64	1.72
September 2000	4.55	0.81	3.83	0.84	188.96
October 2000	4.74	0.79	3.99	0.82	167.37
November 2000	4.01	0.64	3.04	0.62	150.53
December 2000	3.56	0.58	2.14	0.62	145.04
January 2001	6.32	0.86	5.04	0.90	138.09
February 2001	5.53	0.74	4.55	0.77	165.95
March 2001	5.16	0.95	4.22	0.85	179.22
April 2001	4.46	0.87	3.86	0.89	150.74
May 2001	4.09	0.85	3.57	0.85	189.85
June 2001	3.77	0.85	3.24	0.85	190.12
July 2001	3.83	0.78	3.29	0.80	238.89
August 2001	4.40	0.83	3.75	0.84	213.12
September 2001	4.57	0.81	3.80	0.84	164.15
October 2001	4.76	0.74	3.97	0.74	149.77
November 2001	5.78	0.81	4.46	0.82	125.66
December 2001	5.17	0.71	4.06	0.74	138.77
January 2002	4.64	0.58	3.69	0.60	134.65
February 2002	5.86	0.78	4.70	0.80	158.05
March 2002	4.53	0.67	3.77	0.69	196.29
April 2002	4.60	0.80	3.99	0.82	240.14
May 2002	4.30	0.92	3.68	0.91	190.24
June 2002	3.83	0.88	3.31	0.88	219.80
Average*	**4.63**	0.78	**3.79**	0.79*	**166.83**

* Note that the standard deviations are higher for the 15 metre data, indicating a more varied wind speed for the anemometer installed closer to the ground.

Figure 2. Faro Sheep Site Wind Speeds
August 2000 to July 2001

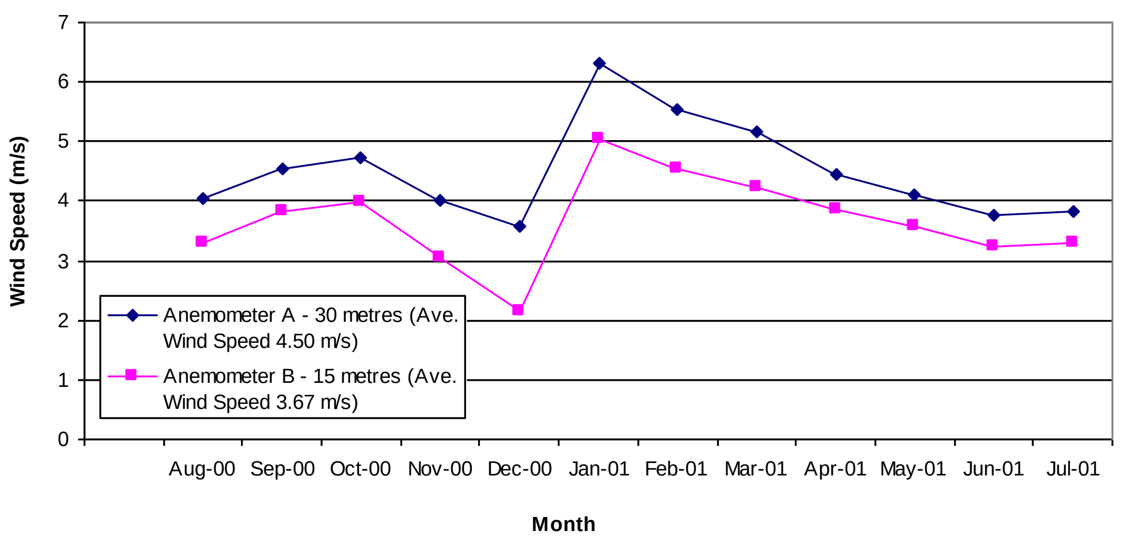
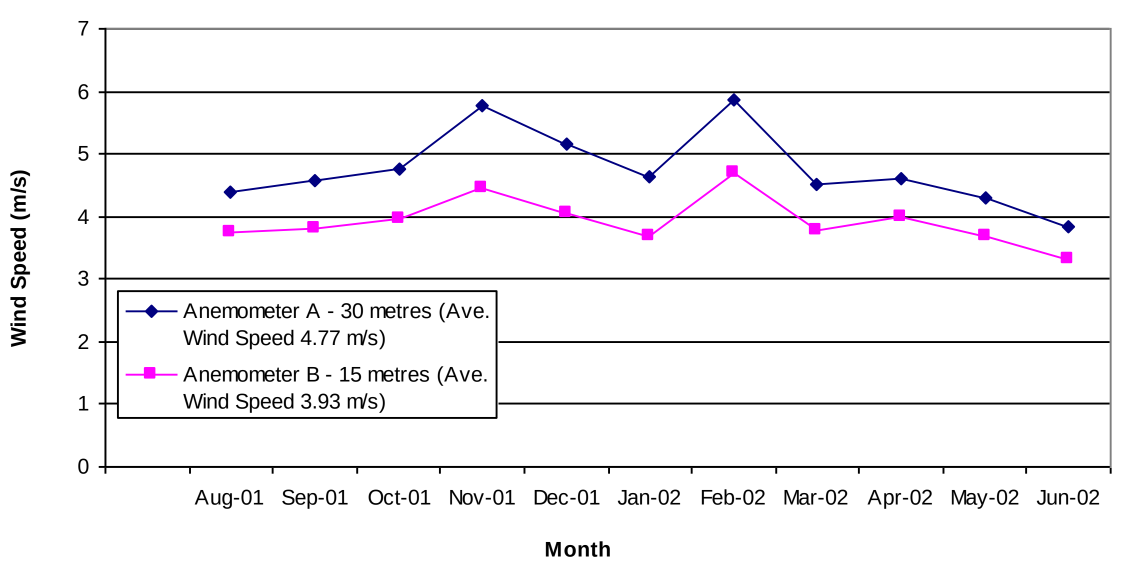
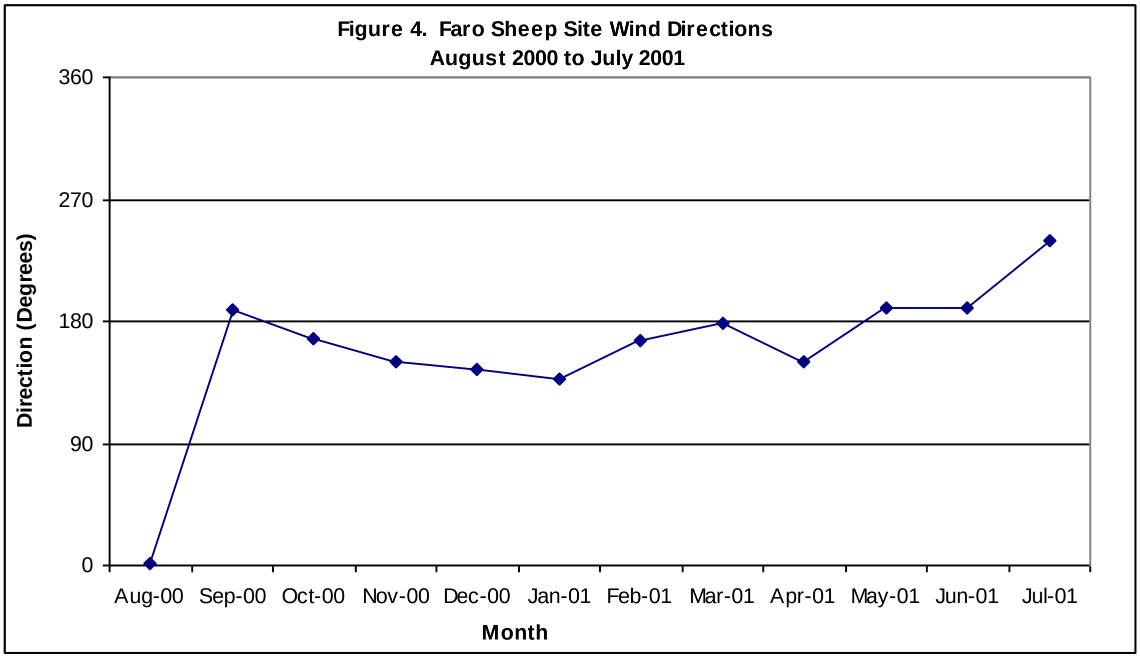
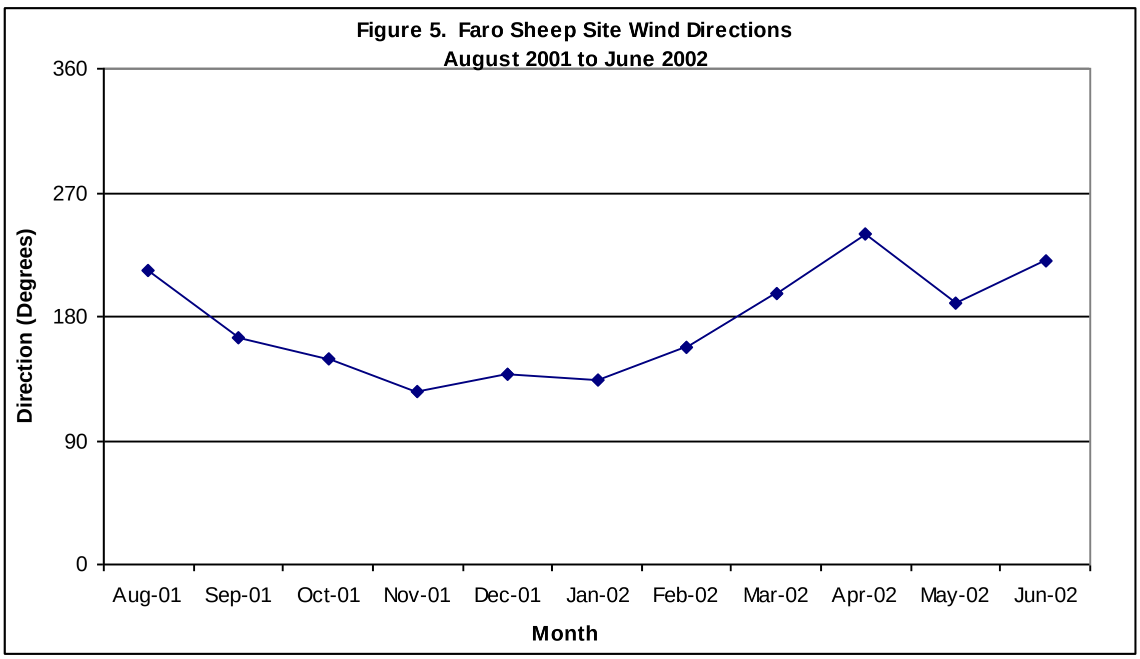


Figure 3. Faro Sheep Site Wind Speeds
August 2001 to June 2002





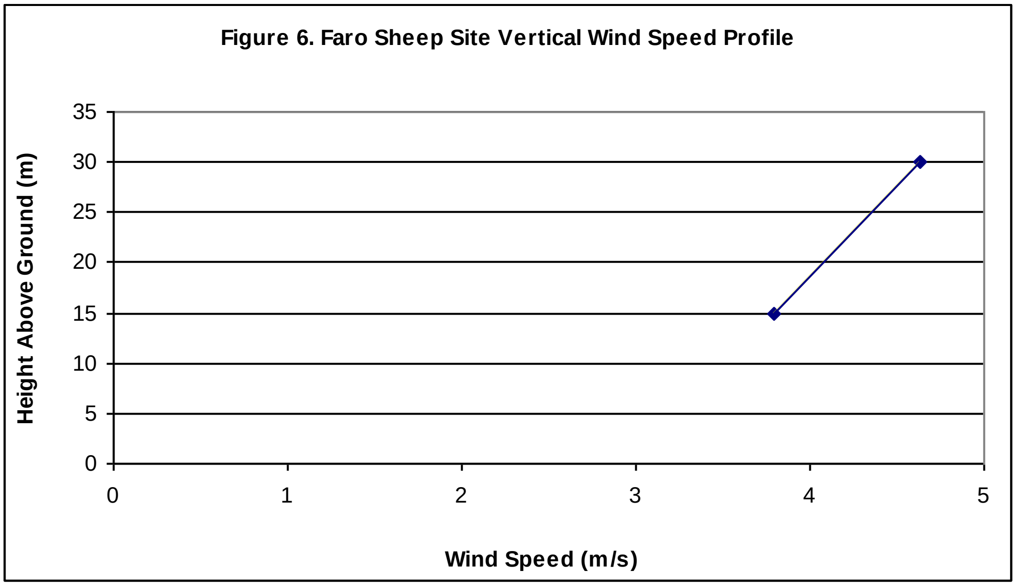


The average wind speed noted in Figure 1 is based on the average wind speed for each month as shown in Figure 1. Throughout the monitoring period the data for several days in several of the months is removed as noted under *Data Quality*, on pages 9 and 10. Therefore, each monthly average is based on the actual number of 10 minute periods for which there is good data, rather than on the total number of 10 minute periods in each month. The annual averages given in Figure 2 of 4.50 m/s at 30 metres and 3.67 m/s at 15 metres are based on the 12 monthly averages from August 2000 to July 2001. The averages given in Figure 3 of 4.77 m/s at 30 metres and 3.93 m/s at 15 metres are not annual averages as they only include the 11 monthly averages from August 2001 to June

2002. ***As per previous notes, an overall annual average based on the data available should be calculated.***

Vertical Projections of Wind Speed

Based on the average wind speeds at 15 and 30 metres, of 3.79 m/s and 4.63 m/s respectively, a linear, vertical profile of the wind speed can be graphed as shown in Figure 6.



Wind speed projections to 40 and 50 metres above ground can be calculated using a logarithmic equation[1] that looks like: ***This calculation should use the annual figure rather than the period figure.***

$$\bar{u} = \frac{u_*}{\kappa} \ln\left(\frac{z}{z_o}\right)$$

where κ is the Von Karman constant and usually has the value of 0.4. The friction velocity u_* and the aerodynamic surface roughness length z_o are calculated from measured wind speed profiles. z is the height to which the wind speed is being projected and $\bar{u}$ is the projected wind speed.

First, the surface roughness length z_o needs to be calculated as follows:

Equation 1: $4.63 = (u_*/0.4)(\ln(30/z_o))$

Equation 2: $3.79 = (u_*/0.4)(\ln(15/z_o))$

Transforming Equation 2 gives Equation 3

Equation 3: $u_* = (3.79)(0.4)/\ln(15/z_o)$

[1] Troen & Lundtang Petersen, *European Wind Atlas*, 1989, p566

Now substitute Equation 3 for u_* in Equation 1 to give Equation 4 (the 0.4 values of κ cancel each other out)

Equation 4: $4.63= ((3.79)(\ln(30/z_o)))/\ln(15/z_o)$

$4.63/3.79= \ln(30/z_o)/\ln(15/z_o)$

$1.22= (\ln 30-\ln z_o)/(\ln 15-\ln z_o)$

$1.22\ln 15-1.22\ln z_o=\ln 30-\ln z_o$

$1.22\ln 15-\ln 30=1.22\ln z_o-\ln z_o$

$-0.096212=0.22\ln z_o$

$-0.44=\ln z_o$

$e^{-0.44}=z_o$

$0.65=z_o$

Calculated roughness length, z_o, is 0.65 m

Next, the friction velocity u_* needs to be calculated:

Using Equation 3 from above

$u_* = (3.79)(0.4)/\ln(15/0.65)$

$u_* = 0.48$ m/s

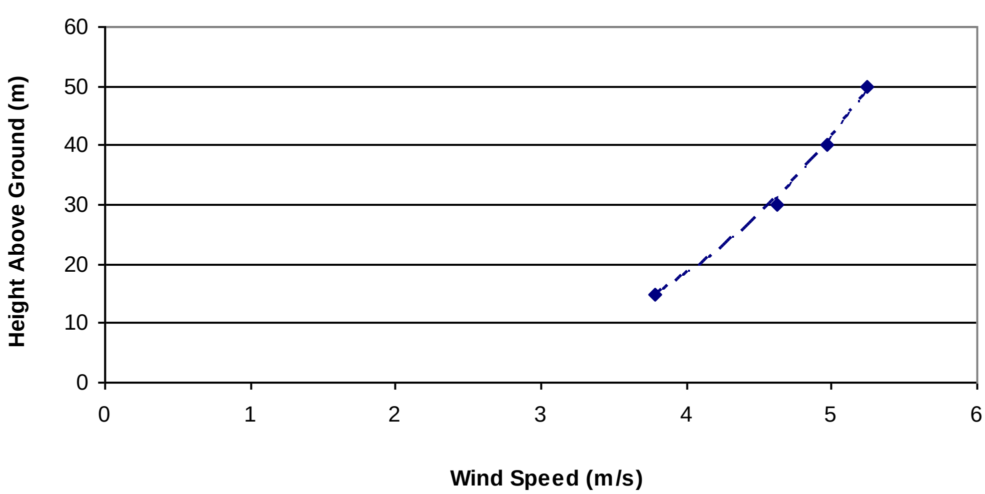
Now the ***annual*** wind speeds at 40 and 50 metres above ground level can be calculated:

Wind Speed at 40 m= (0.48/0.4) (ln (40/0.65))=4.97m/s

Wind Speed at 50 m= (0.48/0.4) (ln (50/0.65))=5.24m/s

Based on the average wind speeds at 15 and 30 metres and the calculated wind speeds at 40 and 50 metres above ground an exponential vertical profile of the ***annual*** wind speed at the Faro Sheep site can be graphed as shown in Figure 7.

Figure 7. Calculated Vertical Wind Speed Profile for Faro Sheep Site



Long Term Average Wind Speed

It was hoped that a long term average wind speed could be projected for the Faro Sheep site based on the correlation of its wind speeds to the Faro Airport's wind speeds. However the correlation in wind speeds between the two sites is too weak, with a Pearson's Correlation Coefficient[2] of 0.16 for Anemometer A and 0.25 for Anemometer B. The wind direction data for the two sites has a strong correlation coefficient of 0.93 as does temperature, with a correlation coefficient of 0.99. Each of these correlations is represented graphically in Figures 8 through 10.

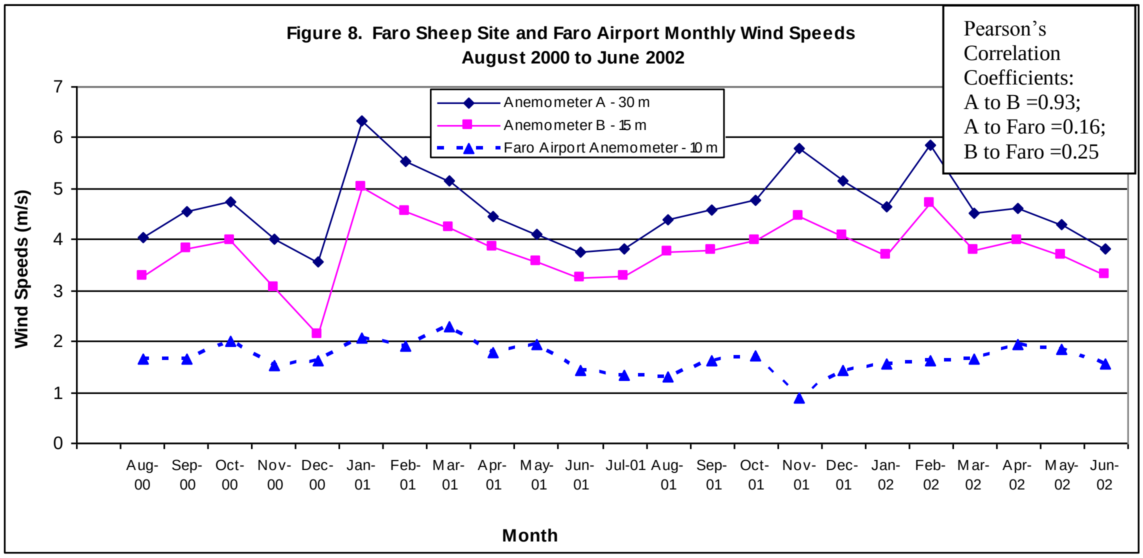


Figure 8. Faro Sheep Site and Faro Airport Monthly Wind Speeds August 2000 to June 2002

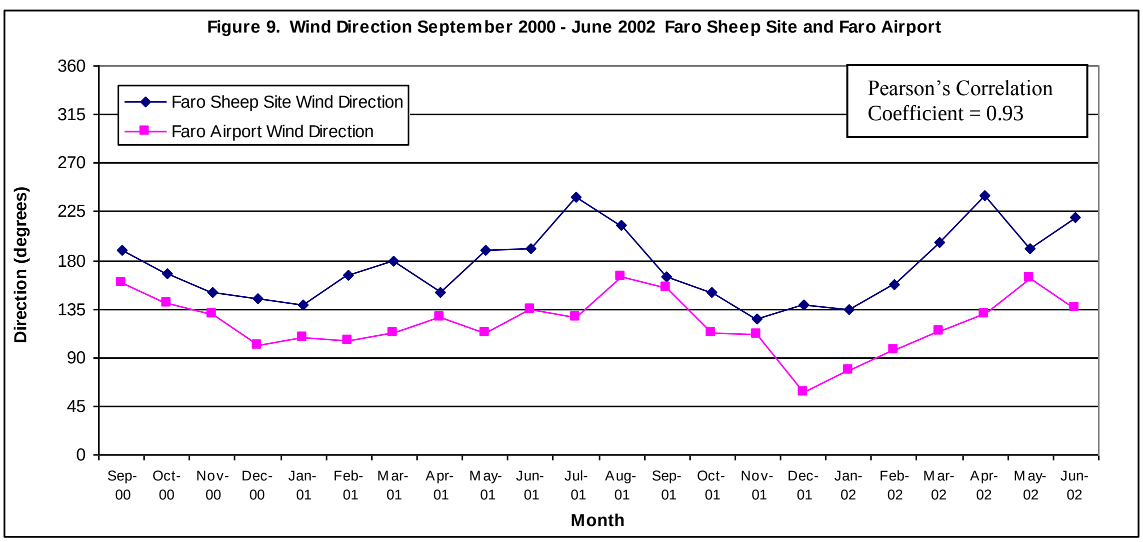


Figure 9. Wind Direction September 2000 - June 2002 Faro Sheep Site and Faro Airport

[2] The Pearson correlation coefficient, r, is a dimensionless index that ranges from –1.0 to +1.0, inclusive and reflects the extent of a linear relationship between two data sets. A value of -1 indicates a perfect negative association and a value of +1 indicates a perfect positive correlation. A value of 0 indicates that the two variables are statistically independent.

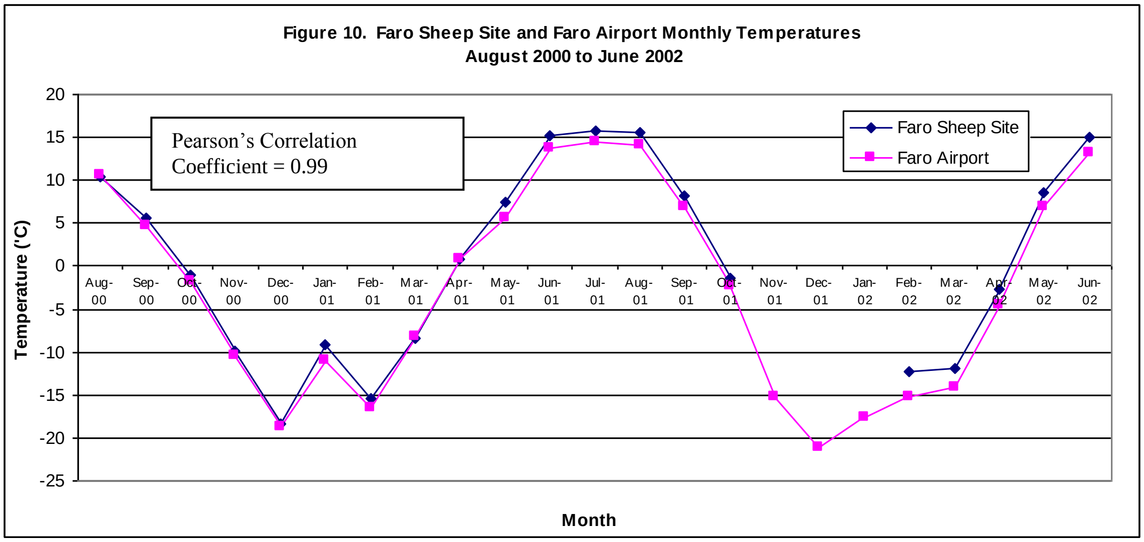


Figure 10. Faro Sheep Site and Faro Airport Monthly Temperatures August 2000 to June 2002

Figure 11 shows the monthly average wind speeds and the long term average wind speed at the Faro Airport, just as a reference, but, ***in the author's opinion,*** should not be used to predict a long term average ***annual*** wind speed at the Faro Sheep site. The Faro Airport Monthly Wind Speed data show that the Faro Sheep site monitoring period occurred during a time when the ***monitoring period*** average wind speed at the Faro Airport was 1.67 m/s. This is 0.13 m/s or 7.2% less than the long term average ***annual*** (LTA) wind speed of 1.80 m/s.

Figure 11. Faro Airport Average Monthly Wind Speeds (m/s)

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	LTA
January	2.30	1.93	1.24	0.53	1.35	1.43	1.87	1.40	2.06	1.55	1.57
February	2.36	1.22	1.97	2.28	1.79	1.82	1.62	1.40	1.90	1.63	1.80
March	2.17	2.40	2.56	2.11	2.13	1.98	1.16	2.39	2.28	1.65	2.08
April	1.76	1.96	2.11	2.27	2.06	2.02	2.16	2.07	1.77	1.93	2.01
May	1.93	2.15	2.20	2.24	2.20	2.42	1.85	1.96	1.95	1.83	2.07
June	1.74	2.14	1.78	1.90	1.98	1.88	1.52	1.78	1.42	1.57	1.77
July	1.72	1.60	1.82	1.66	1.37	2.00	1.91	1.40	1.33	1.59	1.64
August	1.80	1.58	1.65	1.39	1.61	2.15	1.10	1.64	1.32	1.39	1.56
September	2.22	2.07	1.77	1.97	1.56	1.84	1.77	1.67	1.63	1.03	1.75
October	1.98	2.24	1.97	1.64	1.95	2.00	2.35	2.02	1.71	2.19	2.01
November	2.15	2.25	1.54	1.35	2.10	1.43	1.73	1.52	0.91	1.93	1.69
December	1.72	2.25	1.84	1.53	2.34	1.38	1.93	1.62	1.43	0.99	1.70
Annual Ave.	1.99	1.98	1.87	1.74	1.87	1.86	1.75	1.74	1.64	1.61	1.80

Data Quality

The data run from August 3, 2000 at 1730 to July 4, 2002 at 0850. However, within this time period there are gaps and irregularities in the data which are listed below in chronological order.

- The wind speed data for August 2000 are unusually steady at 0 degrees.
- There are no temperature data until August 31, 2000 at 1410.

- The direction data remain steady at 292 degrees from September 29, 2000 at 0110 until the end of the month.

- After March 25, 2001 at 1900 data readings at 40 and 50 minutes past the hour become unusual:
    - wind speeds and standard deviations of wind speeds are 1 to 2 orders of magnitude higher than normal and
    - all temperature readings are in the thousands of degrees.

  The unusual data have been removed. In total, approximately 5.4% of the March and 33% of the April data are removed.

- There is a gap in the data of approximately 9 days from April 29, 2001 to May 8, 2001. After this time the temperature, wind speed and standard deviation of the wind speed data return to normal.

- Between November 10, 2001 at 0150 and January 6, 2002 at 0210 all temperature readings are in the range of 50 to 150˚C and data readings on the hour and at 10 minutes past the hour are also unusual:
    - direction data are at either 0 or 1 degree;
    - wind speed data average approximately 90 m/s; and
    - standard deviations of the wind speed data average approximately 130 m/s.

  The Faro Airport temperatures are substituted for this period and the unusual data removed. In all, approximately 33% of the data from November 10, 2001 to January 6, 2002 are removed

- There is a gap in the data of approximately one month from January 6, 2002 at 0210 to February 7, 2002 at 1800. After this time the temperature, direction, wind speed and standard deviation of the wind speed data return to normal.

- Beginning at July 3, 2002 at 0900 the data become unusual:
    - wind speeds remain constant at 0.5 m/s;
    - the standard deviations of the wind speeds remain constant at 0 m/s;
    - the directions remain constant at 1 degree; and
    - the temperatures remain constant at -54˚C.

  This data is deleted, giving only 3 days and 9 hours worth of data for July 2002.

- Since there is so little data for July 2002, this month is not included in the annual summary.