A COMPARISON OF BEAUFORT, VAISALA AND RADIOSONDE WIND MEASURING SYSTEMS IN THE COURSE OF MIGRATION

BY

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Abstract.
Estimation of wind speed has passed through different measuring systems. One of the initial systems being the Beaufort Scale originally devised by Admiral Beaufort for use at sea but has been modified for use on land as well. The beaufort scale bases the speed of the wind on effects it has on common objects around us.

Vaisala wind measuring system is one of the current systems in use. The system is a remote-indicating wind instrument based on the utilization of a two wire connection between the measurement site and the display site operating to distance of up to 10km.It consists of sensors, control units, display units and recording units designed to perform different functions.

To have an effective socio-economic application of the wind resource it is important to accurately estimate wind speed. In view of this, a comparison of Beaufort, Vaisala and Radiosonde measuring systems with respect to Wind speed measurement has been done and results have revealed that Vaisala is the most reliable system.

INTRODUCTION

Wind is one of the renewable energy resources being pursued to reduce the dependence on fossil-based fuels. However the usefulness of this form of energy is severely restricted by its measurement and variability amongst other concerns. To measure this highly variable resource there is need to have reliable wind measuring systems. Wind has been measured using different systems ranging from Beaufort scale to Vaisala measuring system. This migration has resulted into some benefits being gained by some end-users of these systems. Some of the main applications are in the fields of water pumping and electricity generation. It is critically important that wind measurements by these systems be as accurate estimates as possible to be usefully applied in the designing of wind energy technologies for example. The study therefore attempts to show some systems and their usefulness by comparing the different systems during the course of migration.

METHODS OF COMPARISON

Many methods are presently available through which mean wind speed can be estimated for developmental applications. The three wind measuring systems that are considered in this study are; the **Beaufort scale**, the **Vaisala** and the **Radiosonde**.

Beaufort scale wind measuring system.

FORCE	DESCRIPTION	SPECIFICATION FOR USE ON LAND	KNOTS MEAN LIMITS	
0	CALM	CALM; SMOKE RISES VERTICALLY	0	< 0
1	LIGHT AIR	DIRECTION OF WIND SHOWN BY SMOKE DRIFT, BUT NOT BY WIND VANES	2	1-3
2	LIGHT BREEZE	WIND FELT ON FACE, LEAVES RUSTLE, ORDINARY VANE MOVED BY WIND	5	4-6
3	GENTLE BREEZE	LEAVES AND SMALL TWIGS IN CONSTANT MOTION, WIND EXTENDS LIGHT FLAG	9	7-10
4	MODERATE BREEZE	RAISES DUST AND LOOSE PAPER, SMALL BRANCHES ARE MOVED	13	11-16
5	FRESH BREEZE	SMALL TREES IN LEAF BEGIN TO SWAY; CRESTED WAVELETS FORM ON INLAND WATERS	19	17-21
6	STRONG BREEZE	LARGE BRANCHES IN MOTION; WHISTLING HEARD IN TELEGRAPH WIRES; UMBRELLAS USED WITH DIFFICULTY	24	22-27
7	NEAR GALE	WHOLE TREE IN MOTION; INCONVENIENCE FELT WHEN WALKING AGAINST WIND	30	28-33
8	GALE	BREAKS TWIGS OFF TREES; GENERALLY IMPEDES PROGRESS	37	34-40
9	STRONG GALE	SLIGHT STRUCTURAL DAMAGE OCCURS (CHIMNEY POTS AND SLATES REMOVED)	44	41-47
10	STORM	SELDOM EXPERIENCED INLAND; TREES UPROOTED; CONSIDERABLE STRUCTURAL DAMAGE	52	48-55
11	VIOLENT STORM	VERY RARELY EXPERIENCED; ACCOMPANIED BY WIDESPREAD DAMAGE	60	56-63
12	HURICANE	___	__	>64

Table 1**:** **BEAUFORT SCALE: Specifications and Equivalent Speeds**

Wind force is estimated on a numerical scale ranging from 0 for calm to 12 for hurricane(Table 1).This method is based on the empirical relationship between estimated number and measured wind speed, $U=\sqrt{1.87}\ B$, where

U represents the wind speed and B is the corresponding Beaufort number.

VAISALA WIND MEASURING SYSTEM METHOD

The basic units for Vaisala wind measuring system are: **Sensors**-Anemometer WAA 12,Windvane WAV 12**, Control**-Wind sensor control unit WAT 11, **Display**-Analog wind display unit WAD 11, Analog slave display unit WAD 12,Digital wind display unit WAD 13, Averaging wind display unit WAD 21,**Recording**-Analog wind recorder WAR13. The system is intended for weather stations, Airports and other meteorological, environmental, research and industrial applications.

The system is based on the utilization of a two wire connection between the measurement site and the display site operating to distances of up to 10km.The wind sensor control unit samples the speed and direction sensor's data, converts the values into serial digital format and transmits the data along a serial line. Both the sensors and control unit operate from DC power supply which is supplied by the averaging display unit through the same line.

No supply is needed at the sensor site, and the connection can be made via a standard telephorepair. The sensor control unit operates at –40 to 55 Deg/C temps and is installed to the wind mast near the sensors.

An optional AC powered sensor heating power supply is available for low temperature conditions.

The averaging display unit WAD 21 performs the functions of both the computer and the display device. The instantaneous data transmitted by the wind sensor control unit is received in real time by the display unit (WAD 21) which performs averaging, minimum and maximum calculations and other required data processing and displays the instantaneous and computed values by means of a compact display panel. The display unit is AC powered and feeds the sensors via the two conductor lines. Multiple averaging display unit can be connected to the same current loop line, enabling the information from the same site of sensors to be displayed in several locations.

Only two- conductor cable is still needed and the link operates to the same distances. Also multiple sensor control unit may be connected to the same loop, thus enabling wind information from several locations to be displayed. In that case a switch option is used on the display unit for data source selection. With no need of a sensor control unit the digital display unit WAD 13 is straight connected to the sensor siginal line. It is thus obligated to be installed near the sensor. WAD 13 performs no data processing and shows only instantaneous wind values. Several display units can be connected to display information from a small per of sensors. The display units have to be powered.

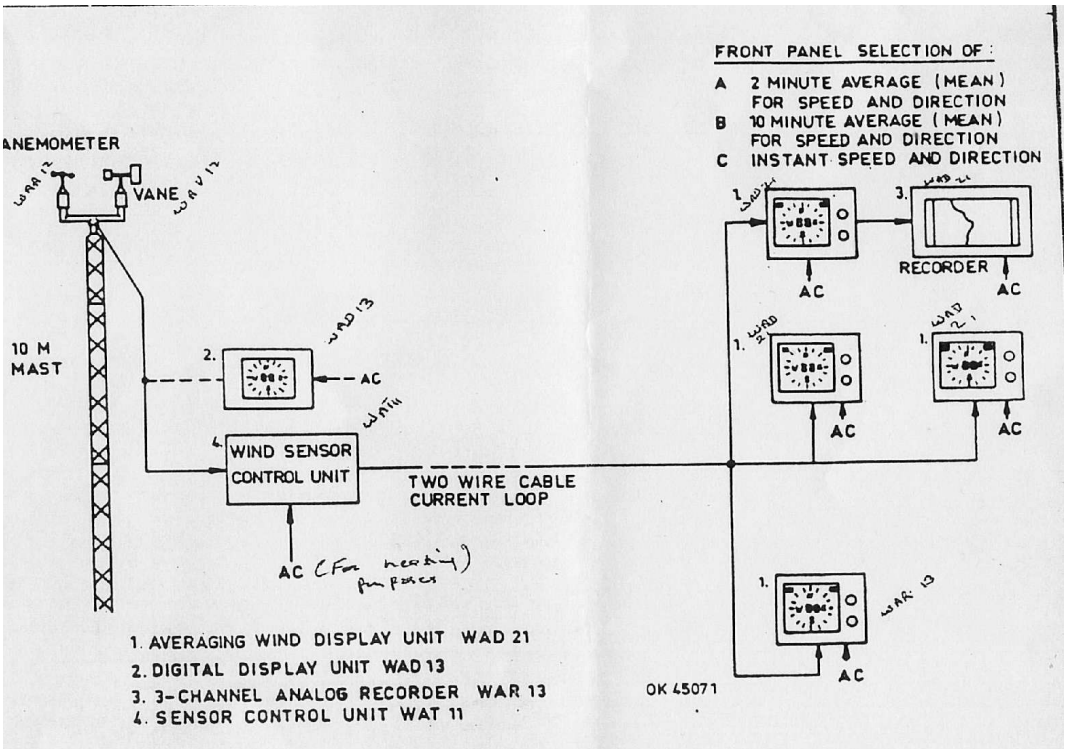

Fig 1: A Configuration scheme of Vaisala system

RADIOSONDE WIND MEASURING METHOD

A small radio transmitter, by means of which observations usually of temperature and wind amongst other parameters are obtained during an ascent. This is done by radar reflections from a sonde (target) carried by the balloon. The major difference between the Radiosonde and the Vaisala system is that the later is a remote instrument while the former is not but has a radio transmitter attached to it.

DATA and COMPARISONS

In order to assess the quality, reliability and consistency of Beaufort, Radiosonde and Vaisala methods employed in this study, wind speed values have been compared.

- **Beaufort scale method:** measurements for the month of August were estimated at about 10m height above the ground at Chelstone station in Lusaka as shown in table 2.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
01	07	05	00	00	11	03	07	21	18	04	
02	09	12	00	00	10	01	01	13	11	03	
03	10	17	09	02	10	10	03	10	00	00	
04	06	06	00	02	00	03	05	00	03	00	
05	08	08	00	00	00	06	08	01	08	06	
06	04	05	10	00	01	10	03	05	10	06	
07	01	06	06	03	10	11	00	08	10	06	
08	07	06	13	09	16	10	08	11	03	09	
09	08	10	11	06	09	01	07	10	13	00	
10	05	07	00	00	13	00	00	03	15	00	
11	11	08	12	03	09	08	00	05	03	00	
12	06	07	07	03	00	09	04	04	03	06	
13	04	00	00	07	00	09	09	02	00	03	
14	00	08	00	08	00	13	11	00	00	01	
15	08	06	15	13	03	11	14	00	00	02	
16	12	05	09	11	03	07	17	04	09	00	
17	07	04	04	06	07	08	01	00	11	05	
18	00	08	03	00	10	02	11	00	12	04	
19	03	05	06	00	10	06	08	08	07	04	
20	06	07	07	00	13	09	05	07	11	07	
21	04	04	00	03	12	05	05	00	14	10	
22	15	01	00	14	00	07	00	01	03	07	
23	07	00	00	04	13	02	01	09	04	05	
24	10	02	06	06	16	00	10	09	03	01	
25	08	09	04	08	15	00	13	10	04	05	
26	13	00	06	01	06	10	00	17	01	06	
27	11	04	00	06	06	07	00	18	00	05	
28	05	11	01	00	00	06	08	13	01	11	
29	06	04	07	09	09	03	09	05	03	11	
30	08	06	05	01	10	03	03	07	11	06	
31	04	14	03	11	18	00	00	05	05	01	
August mean windspeed	6.9	6.3	4.6	4.4	7.7	5.8	5.5	6.6	6.3	4.3	

Table 2: The daily August wind-speed estimates.

- **The Vaisala method:** wind speed values for the month of August were estimated at 10m height above the ground at Lusaka International Airport station as shown in table 3 below.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	
01	04	02	03	01	07	05	03	09	09	00	
02	05	05	01	00	05	05	03	03	05	03	
03	06	09	06	05	05	07	03	05	02	02	
04	05	02	02	03	03	03	05	02	05	02	
05	05	02	03	02	03	03	08	04	04	04	
06	05	03	05	01	04	07	03	07	05	04	
07	05	05	04	03	05	09	01	06	06	02	
08	06	06	08	07	07	05	04	06	05	05	
09	09	06	07	05	06	03	03	05	07	02	
10	06	00	01	01	05	03	00	05	07	02	
11	04	06	03	05	05	05	03	00	04	02	
12	00	07	05	05	04	04	05	00	03	03	
13	03	02	02	04	01	05	08	02	02	03	
14	03	06	04	05	03	08	06	00	00	02	
15	05	05	09	07	04	07	09	02	03	04	
16	07	05	05	05	05	07	07	03	03	01	
17	05	06	06	04	04	06	03	00	07	03	
18	03	07	04	03	07	06	06	02	05	02	
19	06	06	05	02	05	06	07	03	05	00	
20	02	02	05	02	07	08	05	03	07	01	
21	05	02	03	05	05	02	05	00	05	06	
22	09	03	01	07	01	03	03	03	04	05	
23	05	00	02	04	07	01	04	05	04	02	
24	05	05	04	06	07	01	08	04	03	02	
25	06	06	04	04	07	03	06	05	04	03	
26	07	03	02	03	04	06	03	05	03	04	
27	07	05	03	02	05	03	01	07	03	02	
28	03	06	06	01	03	04	06	07	01	06	
29	05	05	05	05	03	02	07	05	03	05	
30	08	05	07	03	06	03	05	04	06	03	
31	03	08	05	06	09	04	01	05	05	04	
August mean Wind-speed	5.1	4.6	4.3	3.8	4.9	4.6	4.5	3.8	4.3	2.9	

Table 3: The daily August wind speed estimates

- **Radiosonde method**:-wind speed values for the month of August were estimated at about 10m height above the ground at Lusaka City Airport station. This data was extracted from Temp messages(TTAA) and translated into monthly wind speed means as shown in table 4 below under **Lusaka city Airport for example.**

	Chelstone station(Beaufort)	**Lusaka International Airport (Vaisala)**	**Lusaka city Airport (Radiosonde)**
1994	**6.9**	**5.1**	**4.9**
1995	**6.3**	**4.6**	**5.1**
1996	**4.6**	**4.3**	**4.1**
1997	**4.4**	**3.8**	**4.6**
1998	**7.7**	**4.9**	**6.7**
1999	**5.8**	**4.6**	**4.9**
2000	**5.5**	**4.5**	**5.0**
2001	**6.6**	**3.8**	**5.2**
2002	**6.3**	**4.3**	**4.8**
2003	**4.3**	**2.9**	**3.3**

Table 4: The August mean wind-speed with respect to Beaufort, Vaisala and Radiosonde systems.

- **Specific wind power (**numerical application).

The monthly average energy input per unit area for a wind pump is determined by the monthly average wind speed and follows from the equation.

Pav,wind = ½ pa Vav^3 in which

Pav,wind = monthly average specific wind power (W/m^2)

ρa = Specific air density (Kg/m^3)

Uav = monthly average wind speed (m/s)

Variable	**Beaufort**	**Vaisala**	**Radiosonde**
ρa (kg/m^3)	1.2	1.2	1.2
Uav(m/s)	5.81	4.28	4.86
P (W/m^2)	**117.6**	**47.0**	**68.9**

Table 5: wind power with respect to Beaufort,Vaisala and Radiosonde systems.

		Mean(Beaufort)	**Mean(Vaisala)**	**Average**	**Diff**	**STD**	
	1994	6.900	5.100	6.000	1.800	1.273	
	1995	6.300	4.600	5.450	1.700	1.202	
	1996	4.600	4.300	4.450	0.300	0.212	
	1997	4.400	3.800	4.100	0.600	0.424	
	1998	7.700	4.900	6.300	2.800	1.980	
	1999	5.800	4.600	5.200	1.200	0.849	
	2000	5.500	4.500	5.000	1.000	0.707	
	2001	6.600	3.800	5.200	2.800	1.980	
	2002	6.300	4.300	5.300	2.000	1.414	
	2003	4.300	2.900	3.600	1.400	0.990	

Table 6: wind speed means, standard deviations, averages and differences with respect to Beaufort and Vaisala wind measuring systems.

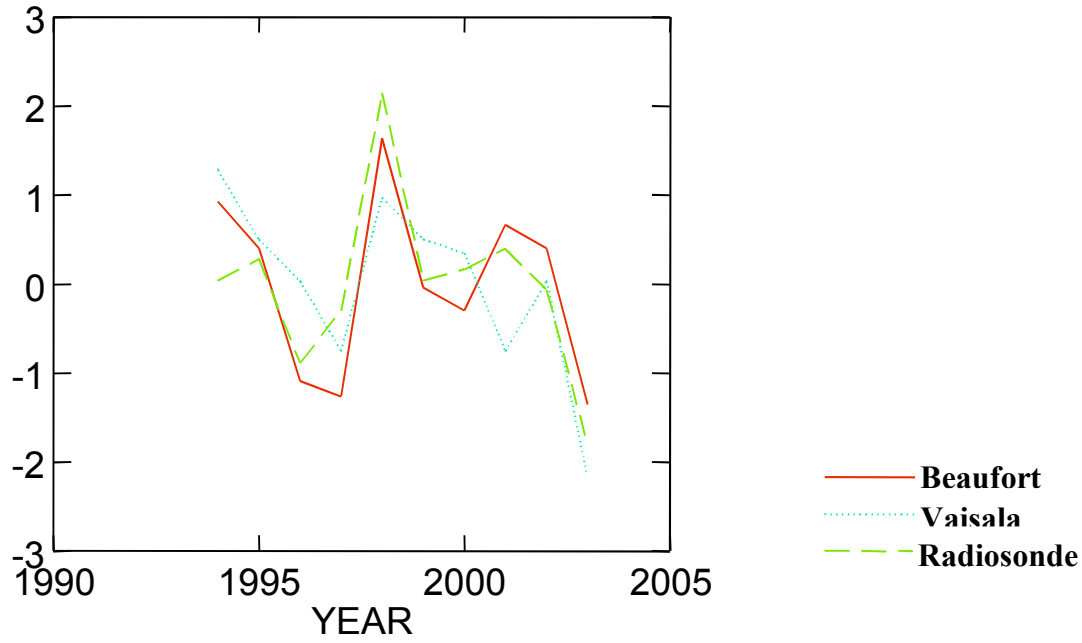

Fig 2: The anomaly pattern for August 1994 to 2003 wind speed estimates.

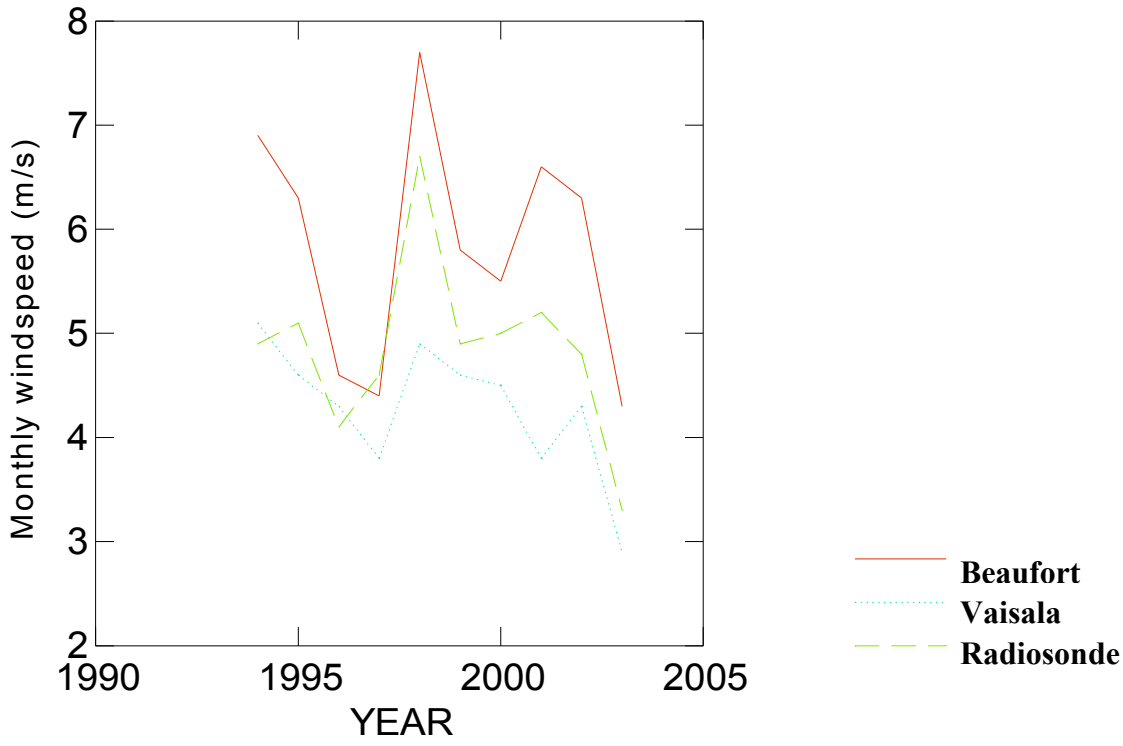

Fig 3: The 12utc August mean wind speed estimates from 1994 to 2003.

When comparing the August (monthly) wind speed values from the Beaufort, Radiosonde and Vaisala systems-the maximum difference found actually amounts to 2.8m/s in 1998 and 2001 with Beaufort system reading higher. The minimum difference being 0.3m/s with Vaisala system having a lower reading. Also comparison results given in table 6 show that the Beaufort and Vaisala systems are consistent and in agreement in 1996 and 1997.The agreement is only and in general at about 4m/s.The highest standard deviation of 1.98 occurred in 1998 and 2001 while the lowest standard deviation of 0.2 occurred in 1996 .The Beaufort system values are offset by several meters per second.

The monthly wind speed values from the Beaufort, Radiosonde and Vaisala systems when applied in the formulae for specific wind power-show that the Beaufort system reads higher than the other two systems in most cases (refer to table 5)

DISCUSSION AND CONCLUSION

The variations by Beaufort system are large and abrupt while those variations from the Vaisala system are smooth and consistent/gradual. Respective variations or discrepancies might be due to differences in location, technology and parallax error but some unexplained variations such as those anomalies depicted by Radiosonde system in fig 2 remain not yet understood and need further investigations. The need for accurate measurement of wind speed is highlighted in the results for specific wind power for use in water pumping and electricity generation (for example). Which value should we use needs further investigation.

From the analysis and assessments done the results show that Vaisala wind measuring system is the most suitable system/method.

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