

Estimation of the Design Wind Speeds for the Kingdom of Saudi Arabia Based on Short-term Records

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Abstract. The methods of order statistics and that of moments are examined for estimation of the extreme wind speeds from short-term records of the largest monthly winds taken at the six stations in the Kingdom of Saudi Arabia. Basic design wind speeds derived from the largest annual winds taken at the twenty stations of the long-term record, from an earlier study, are employed as the bench mark speeds to assess the reliability of the analyses based on the largest monthly records in the Kingdom. It was found that the method of moments is an appropriate procedure for dealing with short term monthly records and that, in general, it underestimates the design speeds. However, association of probability of 10% of being exceeded with the design speeds so estimated circumvents the situation. A simple procedure for effecting this modification of the design speed is also proposed. The estimated design speeds at the six short-term stations enhance the previous work.

Introduction

The theory of extreme values has been successfully used in civil engineering applicaitons. Floods, winds, earthquakes and floor loadings are all variables whose largest value in a sequence may be critical to a civil engineering system. Wind speeds with various mean recurrence intervals can generally be estimated by extreme value analysis of the largest yearly winds. In this method yearly winds are assumed to be independent, stationary and well presented by Type I or II distribution function. The

method gives reliable values of design wind speed for long term mean recurrence interval when based on wind records of at least 15 years. For short-term records (*e.g.* 3 to 5 years), it is well established in literature that the basic design wind speed can be estimated from monthly winds [1;2].

In order to enhance the previous work [3], which presented design speeds based upon analysis of the largest annual wind (LAW) speed data taken at twenty stations of the long-term (LT) record in the Kingdom, this study employs the largest monthly wind (LMW) speed data taken at the remaining six stations of the short-term (ST) record.

Among the various statistical estimation methods, the distribution parameters of the extreme value probability functions can be determined by the method of order statistics (MOS) and the method of moments (MOM). The main effort of this paper is focussed on assessing suitability of these methods in evaluation of design winds from LMW speeds at ST-stations in the Kingdom of Saudi Arabia (KSA). This is necessary in view of the fact that the method proposed in refs. [1 and 2] for dealing with the ST-record assumes that LMW speeds are independent, stationary and that they follow type I distribution.

The wind data details, and a concise development of the probability distribution functions and that of MOS and MOM for determination of their distribution parameters are presented in what follows. The wind speeds of 50-year mean recurrence interval obtained from MOS applied to LAW speeds taken at LT-stations [3] are employed as the bench mark speeds for assessment of the results from analyses performed on LAW- and LMW-speeds at LT-stations. The study also determines the distribution that best fits the LMW-speeds, evaluates the reliability of design speeds from LMW-records and proposes the possible post-analysis treatment required to enhance the confidence level of such an analysis.

Wind Speed Data

The data comprising the largest annual and monthly wind speeds available with the Meteorological and Environmental Protection Agency (MEPA) include records varying over periods of three to twenty seven years measured at twenty six stations well distributed over the Kingdom. A profile of the wind monitoring stations in the Kingdom, the anemometer heights and the duration of continuous record at the stations are listed in Table 1, and their location map produced in Fig. 1. Twenty of the stations have records over a continuous duration of fifteen or more years which is desirable for the annual extreme value analysis while six stations have records of less than fifteen years.

Table 1. Profile of wind monitoring stations in the Kingdom [4]

Record type	Station code	Station name	Anemometer height (m)	Years of continuous record
Long-term	BA	Badanah	6	15
	BI	Bisha	6	9
	DH	Dhahran	10	24
	GS	Gassim	7	21
	GZ	Gizan	8	24
	HL	Hail	8	25
	JD	Jeddah	10	22
	JF	Jouf	7	15
	KM	Kh-Mushait	9	21
	MD	Madinah	10	27
	NJ	Najran	8	15
	QS	Qaisuma	8	18
	RF	Riyadh	10	23
	RF	Rafah	12	15
	SU	Sulayel	10	18
	TB	Tabuk	9	27
	TF	Taif	8	25
TR	Turaif	8	15	
WJ	Wajeh	10	24	
YB	Yanbu	10	22	
Short-term	AB	Abha	10	4
	BH	Baha	10	4
	GT	Gurayat	10	3
	MK	Makkah	10	8
	RK	Riyadh (KKIA)	10	3
	SH	Sharurah	10	3

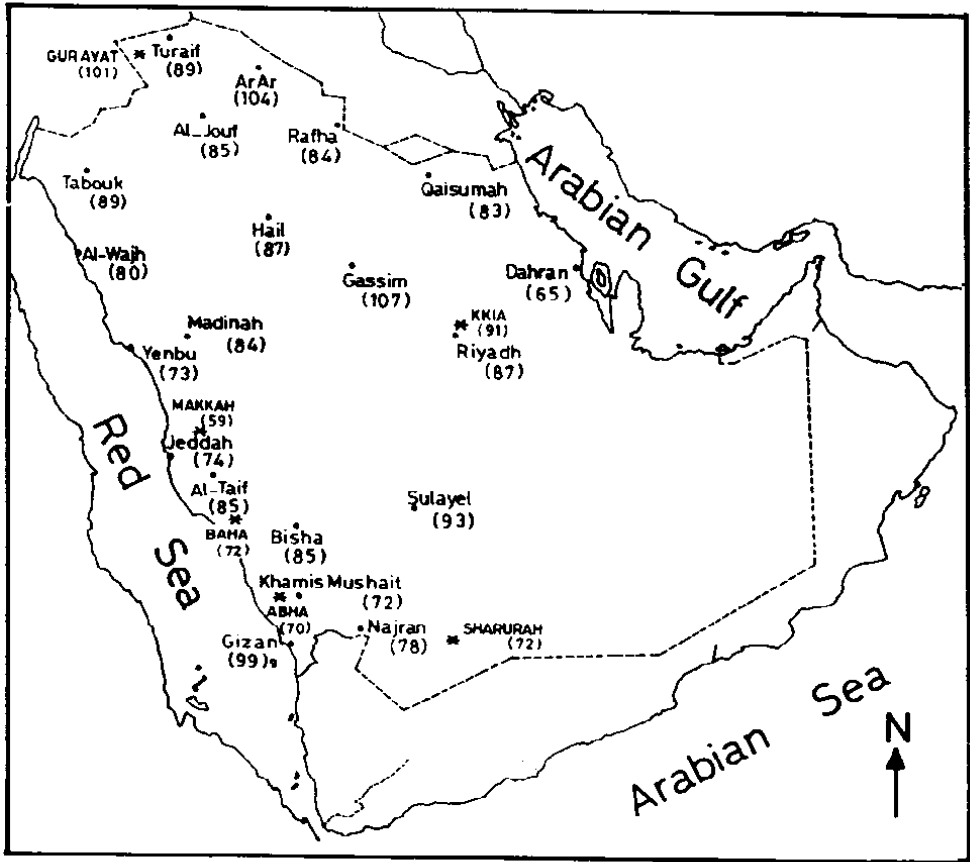


Fig. 1. Location map of wind stations

- Long term wind record
- ☆ Short term wind record

Note: Values in between parentheses indicate basic design wind speeds in mph [4].

In an earlier study [3], the LAW speeds were utilized to estimate design wind speed according to ASCE code [4] procedure at the LT-stations where the records exceed 15 year duration. A sample size of 15 or more is considered to be sufficient to develop representative probabilistic models for the variability in LAW speeds.

Basic Design Wind Speed

Basic design wind (BDW) speed is defined as the wind speed at the standard height of 10 meters above ground in open country and associated with an annual probability of 0.02 of being exceeded, i.e. having 50 year mean recurrence interval. ASCE [4] employs fastest mile wind (FMW) speed as the BDW speed. FMW speed is the maximum annual wind speed at which a one mile long column of wind passes by an anemometer. The BDW speeds, v_{50} , of twenty LT-stations, obtained by extreme value analysis are produced in Table 2, along with the distribution type and their parameters.

Table 2. Extreme value models and BDW speeds (MPH) derived from LAW speeds taken at the LT-Stations in the Kingdom of Saudi Arabia [4].

Station	Type (1)	$u(\omega)$ (2)	$\alpha(\gamma)$ (2)	v_{50} (3)
Badana	I	59.54	11.37	103.9
Bisha	I	51.16	8.73	85.2
Dhahran	I	45.95	4.90	65.1
Gassim	I	63.19	11.59	107.2
Gizan	I	53.48	11.59	98.6
Hail	II	53.52	7.99	87.2
Jeddah	I	48.59	6.44	73.7
Jouf	I	56.88	7.09	84.5
Khamis-Mushait	I	42.05	7.58	71.6
Madinah	I	45.34	9.87	83.8
Najran	II	47.94	8.03	77.9
Qaisumah	I	57.46	6.66	83.4
Riyadh	II	51.98	7.57	87.0
Rafah	I	55.26	7.27	83.6
Sulayel	II	51.22	6.55	92.9
Tabuk	II	54.54	8.05	88.5
Taif	I	51.36	8.68	85.2
Turaif	I	56.53	8.19	88.8
Wajh	I	47.17	8.21	79.7
Yanbu	I	46.58	6.68	72.6

(1) Extreme value distribution type.

(2) In case of the Type II distribution, the values listed belong to the parameters within the parentheses in the column heading.

(3) Basic design wind speed for 50 year mean recurrence interval derived by MOS from the largest annual winds of L-records.

Reliability and Homogeneity of Data

In order for the wind speed data to provide useful information it must be **reliable** and form a **homogeneous** set.

Measured data are considered reliable if the recording instruments are adequately calibrated and are not exposed to local effects due to proximity of obstructions. However, if at any time in future the calibration is found to be inadequate, it is possible to evaluate the corrections and adjust the data.

Measured data form a homogeneous set when they are obtained under identical conditions of **averaging time** and **height above ground**.

Averaging Time

The measured annual and monthly wind speeds at all the stations are averaged over ten-minute duration. The ten-minute speed in knots is converted to ten-minute speed in miles per hour. The averaging time for conversion of this speed to FMW is obtained by an iterative procedure, which is used to drive the required fastest mile [5].

Anemometer Height above Ground

Height of 10 m above ground is considered to be the standard instrument height. Wind data measured at any other height are adjusted to the standard height by power law. The values of exponent in the power law for different "exposures" are available in literature [5]. Specifically for meteorological stations, which are invariably located in open country, the exponent is one-seventh.

Probability Functions of the Largest Values

In the case of well behaved climates (i.e. ones in which infrequent strong winds are not expected to occur) it is reasonable to assume that each of the data in a series of the LAW-speeds contributes to the probabilistic behavior of the extreme winds. Generally two types of extreme values distributions are used in literature for modeling the behaviour of extreme wind speeds [6-8]. The Type I (Gumbel) extreme-value probability distribution function, $F_{Iv}(v)$, which provides the probability of not exceeding the wind speed v is defined as,

$$F_{Iv}(v) = \exp \left[- \exp \left(- \frac{v - u}{\alpha} \right) \right], \quad (1)$$

where, α and u are the scale and location parameters, respectively, and are estimated from the observed data at each station. The parameter u is also called as the characteristic largest value.

The Type II (Frechet) extreme-value distribution function, $F_{IIv}(v)$, is,

$$F_{IIv}(v) = \exp \left[- \left(\frac{v}{\omega} \right)^\gamma \right], \quad (2)$$

where the parameters ω and γ are estimated from the observed data at each station. The parameter, γ , is known as the tail length (shape) parameter and ω as the largest characteristic value [9].

Estimation of the Distribution Parameters

There are two methods that are generally employed to estimate the distribution parameters of Eqs. 1 and 2, whichever is applicable to a given set of data. These methods are, the method of order statistics (MOS) and method of moments (MOM). A brief description of these two methods is presented herein.

Method of Order Statistics

The method of order statistics was developed by Lieblein [10] in which the values of cumulative distribution function (CDF), $F_v(v)$, corresponding to a series of LAW-speeds can be estimated as follows,

$$\hat{F}_v(v) = \frac{m(v)}{n+1} \quad (3)$$

where, n is the number of years of record and $m(v)$ is rank of the event, v , in the ascending order of the magnitudes.

The inverse of CDF known as the percentage point function (PPF), $v(F)$, gives the value of wind speed v at a selected value of CDF. For Type I distribution the PPF is linearly related to an intermediate variate $y(F)$, as,

$$v(F) = u + \alpha y(F) \quad (4)$$

where,

$$y(F) = -\ln(-\ln F) \quad (5)$$

In MOS, the determination of distribution parameters is based on least squares fitting of a straight line to the data on probability paper. In case V has Type II distribution function, then the parameter $Z = \ln V$ can be shown to have Type I distribution with $u = \ln \omega$ and $\alpha = 1/\gamma$. This relationship enables use of Type I probability paper for Type II distribution also.

Step-wise procedure of analysis was presented in [3] where the method was used to select an appropriate distribution (i.e. Type I or Type II) function from LAW-record at each LT-stations. The BDW speeds were then estimated by extrapolating the corresponding distribution functions to 50 years mean recurrence interval.

Methods of Moments

In the method of moments (MOM), the distribution parameters are obtained by replacing the expectation and the standard deviation of wind speed records by the corresponding statistics of the sample. In the case of the Type I distribution, it can be shown that using the principles of expectations of the continuous random variable, V (LAW-speed), the mean value, \bar{V} , and standard deviation, $s(V)$, of the LAW-speed, respectively, are [8;11],

$$\bar{V} = u + 0.5772 \alpha \quad (6)$$

$$s(v) = \frac{\pi}{\sqrt{6}} \alpha \quad (7)$$

so that, $\alpha = (\sqrt{6}/\pi)s(v)$ and $u = \bar{V} - 0.5772 \alpha$.

Employing α and u values from Eqs. 6 and 7, and the fact that $y(F)$ at mean recurrence interval, \bar{N} , is approximately equal to $\ln(\bar{N})$, Eq. 4 yields,

$$v'_{\bar{N}} = \bar{V} - 0.45 s(v) + 0.78 s(v) \ln(\bar{N}) \quad (8)$$

where, $v'_{\bar{N}}$ is the estimated extreme wind in mean recurrence interval of \bar{N} years.

Under the assumption that the random variables \bar{V} and s are, asymptotically normally distributed, it can be shown that for large sample of size n the standard deviation of the estimated wind speed is as follows [11],

$$s[v'_{\bar{N}}] = 0.78 [1.64 + 1.469 (\ln \bar{N} - 0.577) + 1.1(\ln \bar{N} - 0.577)^2]^{1/2} \frac{s}{\sqrt{n}} \quad (9)$$

For $\bar{N}=50$, the Eqs. 8 and 9 become,

$$v'_{50} = \bar{V} + 2.6 s \quad (10)$$

$$s[v'_{50}] = 3.377 \frac{s}{\sqrt{n}} \quad (11)$$

It is shown in [1] and [2], that Eq. 8 can be used to estimate the extreme wind speeds with mean recurrence interval \bar{M} , in months, provided that \bar{V}_m and s_m are defined, respectively, as the sample mean and the sample standard deviation of the LMW speeds. The estimated extreme wind speed with 600 month mean recurrence interval, U_{50m} , and its standard deviation are,

$$v'_{50m} = \bar{V}_m + 4.54 s_m \quad (12)$$

$$S[v'_{50m}] = 5.37 \frac{s_m}{\sqrt{n_m}} \quad (13)$$

Confidence in LMW-analysis

Simiu et al. [2] studied the reliability of estimated wind speeds derived from LMW-data of short records of 3 to 5 years. They employed 67 sets of records from 36 stations. It was found that the differences $U_{50m} - U_{50}$ were less than $\pm s(U_{50m})$ in 66% and less than $\pm 2s(U_{50m})$ in 96% of the cases. They concluded that sample of 36 consecutive largest monthly speeds is usually sufficient to obtain respectable estimates of the extreme wind speed with a mean recurrence interval $N=600$ months (50 years). This finding for the extreme wind speeds in regions with a well-behaved wind climate is also confirmed by additional calculations reported in [1].

Suitability of Analytical Procedures

Several analyses by MOS and MOM which employ LAW- and LMW-speeds at LT-stations are done to assess the extent of their applicability to KSA wind data. Table 3 presents the overall scheme and the parameters involved in these analyses numbered A-1 through A-5. Analysis A-6 is made after critical evaluation of the first five.

Discussion of Results

The results from the analysis listed in Table 3 are discussed below.

Analysis A-1

The analysis employed MOS on LAW speeds taken at LT-stations. The results of this analysis are reproduced from [3] in Table 2. These BWD speeds are considered as the bench mark (BM) speeds.

Results indicated that LAW-speed data were well presented by Type I distribution function at all the LT-stations. However, the Chi-square and Kolmogorov-Smirnov goodness-of-fit tests at 5 percent significance level, indicated that Type II was more appropriate for the data from Hail, Najran, Riyadh, Sulayel and Tabuk stations and as such was adopted at these stations. However, it should be pointed out that the estimated values of BDW speeds using Type II distribution are higher than those calculated by Type I distribution. Also Type II distribution tends to overestimate the values of BDW speeds at recurrence intervals of 100 or more years. The magnitude of error increases with lower values of the tail length parameters, γ , of Type II distribution.

Analysis A-2

The analysis employed MOM on LAW speeds taken at LT-stations and the results are presented in Table 4 and Fig. 2. The purpose is to examine the accuracy of analysis by MOM as it involves assumptions and approximations in its formulation mentioned earlier. It is noted that the deviation of U'_{50} from the bench mark is less than $\pm s(U'_{50})$ at all the stations except Hail, Najran, Riyadh, Sulayal and Tabuk. At these stations the BM speeds of Table 2 were calculated from Type II distribution which normally yields higher values. MOM in general, underestimates the design speeds slightly as shown in Fig. 1. This trend is attributable to approximations inherent in its formulaitons [11].

Table 3. Scheme of analysis of the long and short term winds and their results.

No.	Method	Station	Largest winds			Record length		Table	Result	Comments
			Annual	Monthly	Full	Partial	BDW			
A-1	MOS	LT	X		X		2	u_{50}	Bench mark (BM) speeds	
A-2	MOM	LT	X		X		4	u'_{50}	Compares well with BM except where Type II distribution was used in A-1	
A-3	MOS	LT		X	X		5	v_{50m}	Compares well with BM except at 2 stations	
A-4	MOM	LT		X	X		6	v'_{50m}	Compares well with A-3. Can be confidently employed for LT-stations	
A-5	MOM	LT		X		X	7	v''_{50m}	70% of the results less than BM. Corrective measures indicated	
A-6	MOM	ST		X	X		8	v'_{50m} v^*_{50m}	The estimated speed The proposed speed	

Table 4. BDW speed (MPH) from LAW-record at LT-stations by method of moments

Station	\bar{V}	s	v'_{50}	$s(v'_{50})$	$u'_{50} - u_{50}$
					$s(v'_{50})$
Badana	65.5	12.5	98.2	9.68	-0.59
Bisha	55.6	9.6	80.7	7.25	-0.62
Dhahran	48.6	5.7	63.2	3.78	-0.50
Gassim	69.2	12.9	103.0	9.08	-0.46
Gizan	59.6	12.9	93.3	9.29	-0.57
Hail	57.8	8.7	80.5	5.76	-1.16
Jeddah	52.0	7.2	70.7	5.58	-0.54
Jouf	60.6	8.1	81.6	6.28	-0.46
Kh-Mushait	46.1	8.7	68.8	6.13	-0.46
Madinah	50.6	11.3	79.9	7.48	-0.52
Najran	51.5	7.3	70.6	6.37	-1.15
Qaisumah	60.9	7.7	80.9	5.97	-0.42
Riyadh	56.4	9.4	80.8	6.23	-1.00
Rafaha	59.0	8.0	79.7	6.37	-0.61
Sulayel	56.3	9.9	81.9	7.48	-1.47
Tabuk	58.8	8.7	81.5	5.76	-1.22
Taif	56.0	9.9	81.6	6.56	-0.55
Turaif	60.8	9.0	84.2	7.37	-0.63
Wajh	52.0	9.3	76.4	6.16	-0.54
Yanbu	50.1	7.7	70.1	5.42	-0.46

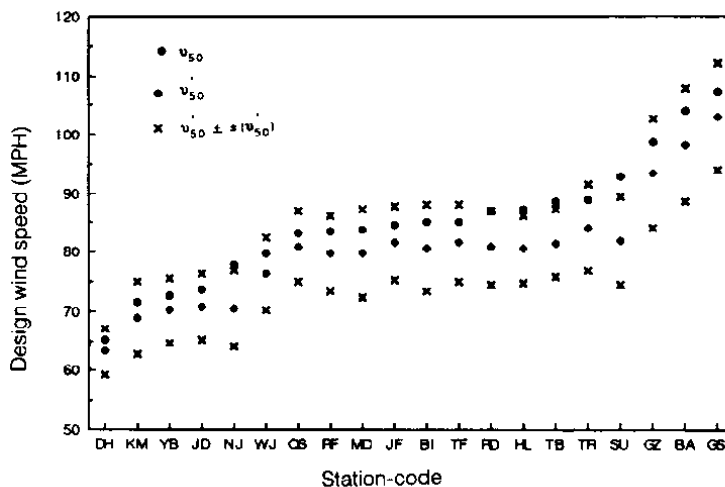


Fig. 2. Comparison of BDW from MOM Analysis of LAW-Speeds with the BM-Speeds.
Note: Refer Table 1 for the station identified by the code.

Analysis A-3

This analysis employed MOS on LMW speeds taken at LT-stations and the results are presented in Table 5 and Fig. 3. The purpose here was to check the suitability of Type I distribution for LMW speeds and compare the design speeds obtained from largest monthly record, U_{50m} , with those from largest annual record, U_{50} . In general, the analysis indicates that Type I distribution best fits the LMW-speeds. The errors in U_{50m} are within $\pm 10\%$ of the BM speeds at all the stations excepting at Al-Jouf and Dhahran. However, this analysis overestimates the design speeds at eight stations with Dhahran and Al-Jouf being 19.3% and 16.4% higher than the BM, respectively as shown in Fig. 3. This trend is attributable to lower values of LMW speeds which control the slope of the regression line as is indicated by the regression of Al-Jouf data shown in Fig. 4. The analysis also reveals that the LMW-speeds at Madina and Gizan stations may as well fit Type II distribution. This distribution yields a design speed of 103.4 MPH at Madina, which is 22% higher than the BM speed. This reinforces the basic assumption that Type I is the most suited distribution for estimation of design speeds from LMW record.

Table 5. Type I Extreme Value Models and BDW Speeds (MPH) Derived from LMW-Speeds Taken at the LT-Stations.

Station	u	α	U_{50m}	Error%(1)
Badana	37.74	9.27	97.1	-6.7
Bisha	31.80	8.27	84.7	-0.6
Dhahran	33.60	6.89	77.6	19.3
Gassim	33.82	11.52	107.5	0.4
Gizan	31.62	9.49	92.3	-6.8
Hail	33.15	8.64	88.4	-1.4
Jeddah	30.82	6.68	73.5	-0.2
Jouf	35.40	9.85	98.4	16.4
Kh-Mushait	30.54	6.44	71.7	0.2
Madinah	29.50	7.45	77.1	-8.0
Najran	30.25	8.08	81.6	5.0
Qaisumah	39.60	8.03	91.0	8.5
Riyadh	32.83	7.85	83.0	-4.6
Rafaha	36.17	8.30	89.2	6.7
Sulayel	33.48	8.27	86.4	-7.0
Tabuk	34.70	8.62	89.9	1.6
Taif	34.14	7.66	83.1	-2.5
Turaif	39.39	9.03	97.1	9.3
Wajh	31.89	6.95	76.3	-4.3
Yanbu	34.48	5.67	70.7	-2.6

(1) Referred to BM speed of Table 2.

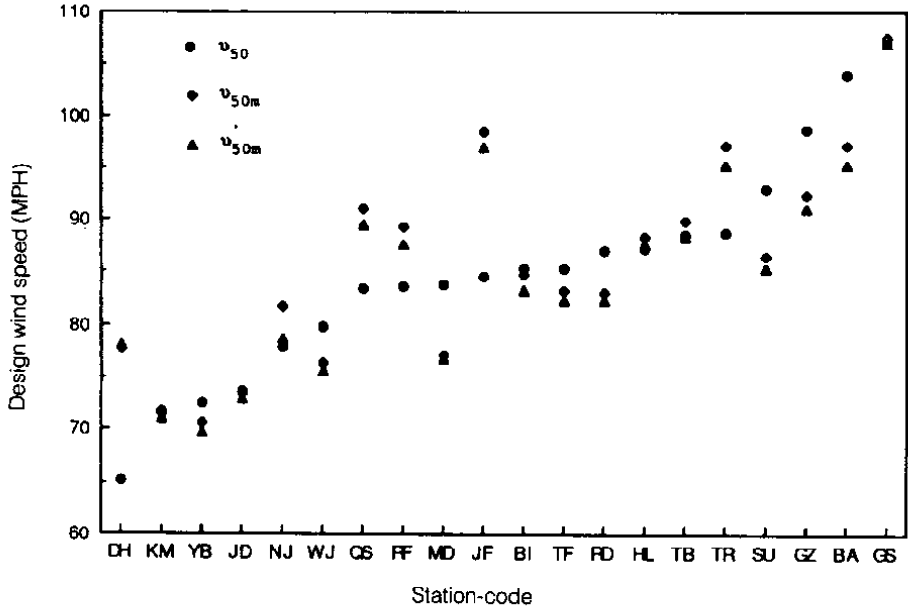


Fig. 3. Comparison of BDW from MOS and MOM analysis of LAW-speeds at LT-stations with the BM-speeds.

Note: Refer Table 1 for the station identified by the code.

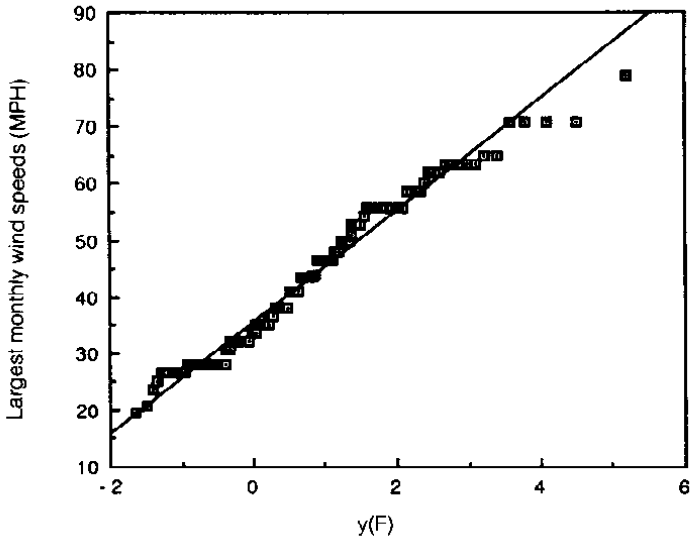


Fig. 4. Regression curve for MOS-analysis of LMW-speeds at Al-Jouf station.

Analysis A-4

This analysis employed MOM on LMW speeds taken at LT-stations and the results are presented in Table 6 and Fig. 3. Design speeds from this analysis are close to those from A-3. MOM, therefore, can be confidently applied to long-term LMW-speeds.

Analysis A-5

This analysis employs MOM on randomly chosen three-year subsets of LMW speeds taken at LT-stations to evaluate BDW, U''_{50m} which are presented in Table 7 and Fig. 5. The purpose here is to calibrate these speeds with the results from A-4. Sixty per cent of the design speeds are within $\pm s(U''_{50m})$ and 90% within $\pm 2s(U''_{50m})$. However, 70% of the design speeds, U''_{50m} , are less than the corresponding bench mark speeds as shown in Fig. 5. This indicates that there is a high probability of underestimating design speeds from the Saudi Arabian short-term LMW-data. A modification to analysis by MOM, therefore, is desirable to furnish a simple and practical procedure for estimating design speeds from these records.

Table 6. BDW speed (MPH) from LMW-record at LT-Stations by method of moments

Station	\bar{V}_m	S_m	U'_{50m}
Badana	43.0	11.5	95.2
Bisha	36.5	10.3	83.1
Dhahran	37.5	8.6	78.0
Gassim	40.4	14.6	107.0
Gizan	37.0	11.9	91.0
Hail	38.1	10.9	87.6
Jeddah	34.6	8.4	73.0
Jouf	41.0	12.3	96.9
Kh-Mushait	34.2	8.1	71.0
Madinah	33.7	9.5	76.7
Najran	34.6	9.7	78.6
Qaisumah	44.1	10.0	89.5
Riyadh	37.3	9.9	82.2
Rafah	40.9	10.3	87.6
Sulayel	38.2	10.4	85.3
Tabuk	39.6	10.8	88.4
Taif	38.5	9.6	82.2
Turaif	44.5	11.2	95.2
Wajh	35.9	8.7	75.5
Yanbu	37.7	7.1	69.7

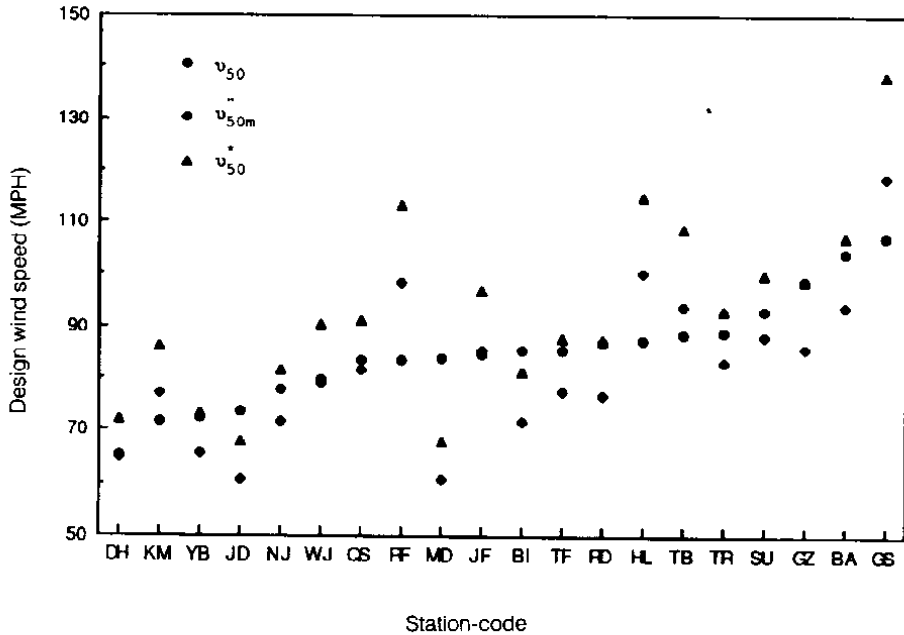


Fig. 5. Comparison of BDW from MOM analysis of 3-years subsets of LAW-speeds at LT-stations with the BM-speeds.

Note: Refer Table 1 for the station identified by the code.

Modification of MOM Results from ST-record

Assigning a probability to wind speed of 90% of not being exceeded, the modified BDW speed, U_{50m}^* , can be calculated at a station under the assumption that the random variable, the MOM design speed from the LMW record taken at ST-stations, U_{50m}'' , is asymptotically normally distributed as,

$$U_{50m}^* = U_{50m}'' + k_z s(U_{50m}'') \quad (14)$$

where, factor $k_z = 1.282$.

The modified design speeds, U_{50m}^* , from the subsets of LT-record are obtained by employing corresponding U_{50m}'' in Eq. (14) and produced in Table 7 and Fig. 5. The modification effectively reduces the trend of underestimating, and in general, it is recommended to employ modified MOM procedure for finding estimated design speed from ST-speeds.

Table 7. BDW speed (MPH) from 3-year subsets of LMW-records at LT-stations by method of moments

Station	Period ⁽¹⁾	\bar{V}_m	S_m	U_{50m}''	$s''(50m)$	$\frac{U_{50}''-U_{50m}''}{s(U_{50m}'')}$	U_{50m}''	$\frac{U_{50}''-U_{50m}''}{s(U_{50m}'')}$
Badana	1980-82	40.9	11.6	93.56	10.38	-0.99	106.9	0.29
Bisha	1981-83	33.0	8.5	71.59	7.60	-1.79	81.3	-0.51
Dhahran	1982-84	36.7	6.2	64.85	5.55	-0.05	72.0	1.24
Gassim	1976-78	39.4	17.4	118.40	15.57	0.72	138.4	2.00
Gizan	1977-79	37.8	10.6	85.92	9.69	-1.28	98.6	0.00
Hail	1973-75	42.9	12.6	100.10	11.28	1.14	114.5	2.43
Jeddah	1970-72	32.1	6.3	60.70	5.64	-2.31	67.9	-1.02
Jouf	1983-85	39.8	10.0	85.20	8.95	0.08	96.7	1.36
Kh-Mushait	1977-79	40.8	8.0	77.12	7.16	0.77	86.3	2.05
Madinah	1985-87	30.5	6.6	60.46	5.91	-3.95	68.0	-2.67
Najran	1978-80	32.8	8.6	71.84	7.70	-0.79	81.7	0.49
Qasumah	1982-84	44.9	8.1	81.67	7.25	-0.24	91.0	1.04
Riyadh	1967-69	35.0	9.2	76.77	8.23	-1.24	87.3	0.04
Rafaha	1981-83	39.4	13.0	98.40	11.64	1.27	113.3	2.55
Sulayel	1984-86	41.3	10.3	88.06	9.22	-0.52	99.9	0.76
Tabuk	1968-70	36.7	12.6	93.90	11.28	0.48	108.4	1.76
Taif	1980-82	36.5	9.0	77.36	8.05	-0.97	87.7	0.31
Turaif	1979-81	44.2	8.6	83.24	7.70	-0.72	93.1	0.56
Wajh	1971-73	33.0	10.1	78.8	9.04	-0.09	90.4	1.18
Yanbu	1984-86	36.1	6.5	65.61	5.82	-1.20	73.1	0.08

(1) Randomly selected 3-year period of LMW-speeds.

Nevertheless, the proposed modification overestimates the design speed at some stations as shown in Fig. 5. It is, therefore, proposed that in such a situation a detailed cost and reliability study of the structural system at hand be carried out to justify a lower value of the factor k_z .

Estimation of BDW Speeds from LMW-speeds of ST-Record

The analysis A-6 employs MOM on LMW record taken at the six ST-stations in KSA and the results are presented in Table 8. Both the design speeds, U''_{50m} and U^*_{50m} are listed in the table. The U^*_{50m} values may confidently be employed as the design speed at these stations.

Table 8. BDW speed (MPH) from LAW-record at LT-stations by method of moments

Station	\bar{V}	s_m	U''_{50m}	$s(U''_{50m})$	U^*_{50m}
Abha	36.9	6.0	64.1	4.65	70.0
Baha	34.2	6.8	65.1	5.27	71.8
Gurayat	43.3	10.1	89.3	9.04	100.9
Makkah	24.4	6.7	54.7	3.67	59.4
Riyadh (KKIA)	40.0	9.0	80.8	8.06	91.1
Shururah	28.7	7.6	63.0	6.80	71.7

Summary and Conclusion

The study investigated the question whether design wind speeds can be estimated confidently from short terms of three to eight years available in the Kingdom. The study referred to basic design wind speeds from an earlier study of long-term records as the bench mark speeds, employed the methods of order statistics and moments on the largest annual and monthly speeds of the long-term records to assess the results derived from the largest monthly records.

The methods of order statistics indicated that the largest monthly speeds are well modeled by type I distribution function. However, this function highly overestimated the design speeds at five out of twenty long-term stations as compared to the bench mark speeds. Type II distribution function was also found to overestimate the design speeds from the largest monthly records at all the stations.

The method of moments using the largest monthly winds provides a good estimate of the design speeds when continuous monthly records of fifteen or more years are employed.

The design speeds from method of moments derived from randomly selected three-year subsets of the largest monthly speeds taken at the long-term stations, were underestimated at 70% of the stations. Therefore, in order to rectify this situation, it is proposed to modify the design speeds from short-term records to reflect a desired probability of not being exceeded. This approach is employed to estimate the design speeds for probability of 90% of not being exceeded at the six stations of short-term records in the Kingdom.

The proposed modification, however, tends to overestimate the actual values at some stations and as such cannot be employed as a blanket procedure. Therefore, a detailed cost and reliability analysis of the structural system needs to be conducted at the design stage. Lower values of modification factor can be evaluated to attain minimum total cost of the structural system.

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تقدير سرعات الرياح لأغراض التصميم في المملكة العربية السعودية اعتماداً على بيانات قياسات قصيرة المدى

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ملخص البحث. تشمل هذه الورقة دراسة السرعات القصوى للرياح اعتماداً على بيانات قياسات قصيرة المدى عند ست محطات رصد في المملكة العربية السعودية وذلك باستخدام طريقة الترتيب الإحصائي وكذلك طريقة العزوم. ولتقدير موثوقية طرق التحليل الإحصائي باستخدام أعلى قيم لسرعات الرياح الشهرية في المملكة اعتبرت قيم السرعات التصميمية للرياح المحسوبة من السرعات السنوية القصوى عند عشرين محطة ذات قياسات طويلة المدى والتي تم حسابها في دراسة سابقة هي القيم المرجعية. وقد تم استخدام القياسات الشهرية لسرعات الرياح عند تلك المحطات لهذا الغرض.

وقد لوحظ تميز طريقة العزوم بإمكانية حساب معيار التفاوت القياسي للسرعات التصميمية. كما وجد أنه من الممكن الاعتماد على طريقة العزوم لحساب سرعات الرياح لأغراض التصميم على الرغم من أنها بشكل عام تعطي قيماً لسرعات الرياح أقل من السرعات المرجعية. لذا فقد تم اقتراح طريقة لزيادة تلك القيم بحيث ألا تقل عن القيم المرجعية باحتمالية ١٠٪، وعلى هذا الأساس فقد تم حساب السرعات التصميمية للرياح عند ست محطات رصد أخرى بالمملكة (والتي ليس لها قيم مرجعية) وبذلك تضاف نتائجها إلى النتائج التي تم نشرها سابقاً.