Shemya Island Extreme Wind Analysis

This letter report documents an analysis of extreme wind probability calculated from Automated Surface Observing System (ASOS) data collected from Eareckson Air Force Base on Shemya Island. Although data back to 1943 is archived at NCDC, twenty years of data – from 1990 to 2009 (the most recent year available) – was purchased from the National Climatic Data Center (NCDC). With this data, IEC 61400-1 extreme wind probability classification was calculated as Class I by 2nd and 3rd edition criteria in most data views although that is a borderline (with Class II) consideration by 3rd edition criteria in some views. In one data view analysis, the classification is Class II by 3rd edition criteria. Note, however, that ASOS data is quite dissimilar to meteorological tower data for wind energy analysis (see below) and hence one must use considerable caution when using it in this capacity.

Given the highly robust nature of the winds on Shemya Island and the particular limitations of ASOS data, a met tower instrumented for wind power analysis with a data collection period of one year is strongly recommended. A met tower would shed light on the extreme wind question by providing more accurate wind speed data and with standard deviation not available with ASOS, turbulence intensity could be calculated.

IEC 61400-1 Criteria

IEC wind turbine classification by extreme wind is shown in the table below for both 2nd and 3rd editions. Note that v_{ref} refers to the 10-minute mean wind speed at hub height with a 50 year return period, v_{G50} refers to the 3-second gust wind speed with a 50 year return period and v_{G1} refers to the 3-second gust wind speed with a 1 year return period.

IEC Wind Turbine Classes

WT Classes	I	II	III	IV	S
v_{ref} (m/s)	50.0	42.5	37.5	30.0	designer specified
v_{ave} (m/s)	10.0	8.5	7.5	6.0	
v_{G50} (m/s)	70.0	59.5	52.5	42.0	
v_{G1} (m/s)	52.5	44.6	39.4	31.5	

Grey highlight denotes IEC 61400-1 2nd ed. criteria not included in 3rd ed.

ASOS Data Collection

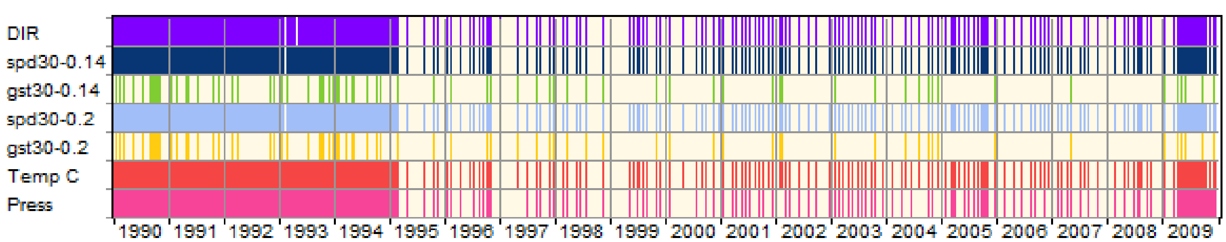
For ASOS, wind speed and direction are sampled once per second and an average is computed every five seconds. The five second data are rounded to the nearest degree and knot. A running two-minute average is computed from the five-second data. The two-minute average is stored each minute. This running two-minute average is reported at the observation time which normally is once per hour. This compares to NRG Symphonie met tower data logger where data is sampled every two seconds and then averaged and logged every ten minutes.

The principal difference then is that with ASOS data the reported hourly data is not actually a one-hour average, but rather a two-minute average reported every hour. Compared to a true one hour average, this can bias high or low depending on whether or not wind speeds were increasing or decreasing during the hour. If wind speeds are constant during the hour, then there is no bias. This is complicated a bit however by frequent sub-hour reporting in the ASOS data. For purposes of analysis, these sub-hour data, where encountered, were averaged to one hour, but these one hour data averages actually represent ten-minute averages (see Extreme Wind Probability below)

Clearly a sampling approach to data analysis is not as comprehensive as full coverage, but over a long period of time the samples well represent the population, so the error decreases. Be aware then that the extreme wind probabilities estimated in this letter report are based on a sampling approach, and not a full coverage approach to data collection. But, with twenty years of hourly data analyzed, it likely well represents the wind regime of Shemya.

Another issue is the nature of the data collected by ASOS. This data is logged to the nearest knot (nautical mile per hour), so at most two significant figures in the reported measurement. Further, a number of recordings in the data set appear to be inaccurate. In September 2005, a 67 m/s average (converted from knots) was recorded during a particular hour with a missing gust speed. This appears to have been a data recording error of some sort and was deleted from analysis. But, in 1990, a very high and by all appearances accurate wind speed and gust were recorded which will influence the Gumbel distribution calculation of extreme wind probability if included.

A further problem is data coverage. Data was requested from NCDC as far back as January, 1990, but at that time ASOS did not exist, so data was measured by a predecessor system. In examining received data, it appears that the transition to ASOS occurred in early 1995 (see below). The reported data through the transition period appears normal, but data coverage after introduction of ASOS is suddenly much sparser, with long periods of missing data. This continued until 2009 when data coverage improved, but not to the extent recorded by the previous weather system.



Extreme Wind Probability

Extreme wind probability for IEC classification is calculated with a best-fit Gumbel distribution using yearly maximum 10-minute average and 2-second gust data. This requires a number of years of data; seven preferably. With the Shemya ASOS and pre-ASOS data, a sufficient number of years (20) of data is present, but in two-minute sampling averages as discussed above. The two minute data was translated to ten-minute data by a logarithmic function to statistically translate time periods of data. Data was converted from knots to meters per second and then translated from the 10 meter recording height to a 30 meter turbine hub height with two power exponent (α) values of 0.14 and 0.20. An α of 0.14 was chosen as this is a likely shear value on flat, featureless Shemya Island. The second α of 0.20 was chosen as it is the default shear value referenced in IEC 61400-1.

Several calculations of extreme wind probabilities are presented below, including 30 meter at α values of 0.14 and 0.20, α of 0.14 with some data filtered, ASOS-only (1995 to 2009) data, and pre-ASOS-only data by both standard and modified Gumbel analysis.

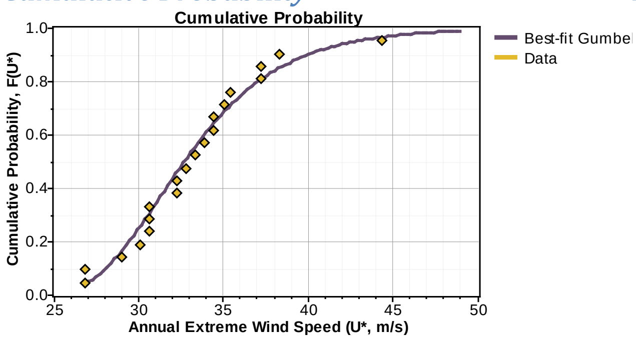
1990 to 2009 Data, α = 0.14

With all data from 1990 to 2009, a power law exponent of 0.14, and only filtering the extremely high 2005 data point, a Gumbel distribution predicts a 10-minute mean wind speed with a 50 year return of 46.3 m/s.

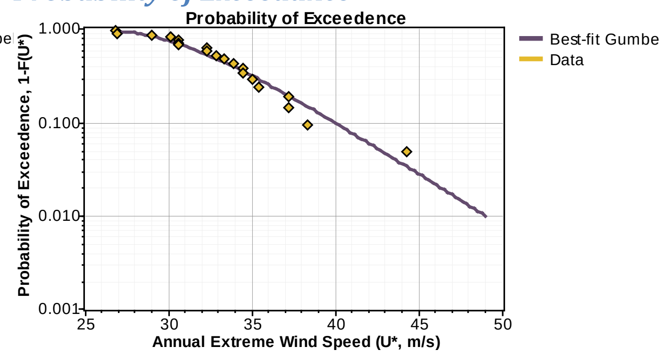
Return Period

Return Period (yr)	Extreme Wind Speed (m/s) 10-min means	Gusts
20	42.7	54.2
25	43.6	55.5
50	46.3	59.2
100	49.0	62.8

Cumulative Probability



Probability of Exceedance



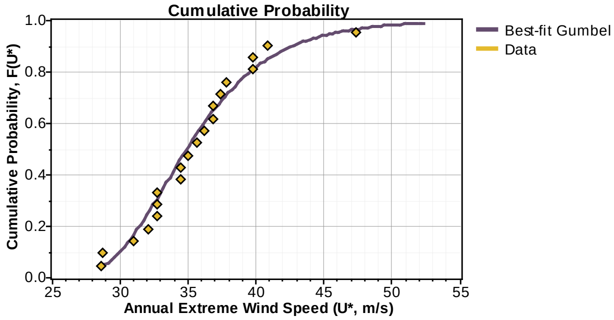
1990 to 2009 Data, α = 0.20

With all data from 1990 to 2009, a power law exponent of 0.14, and only filtering the extremely high 2005 wind speed, a Gumbel distribution predicts a 10-minute mean wind speed with a 50 year return of 49.3 m/s.

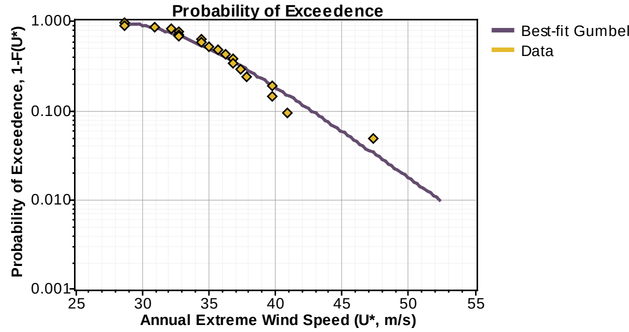
Return Period

Return Period (yr)	Extreme Wind Speed (m/s)	
	10-min means	Gusts
20	45.6	57.9
25	46.6	59.2
50	49.5	63.2
100	52.3	67.1

Cumulative Probability



Probability of Exceedance



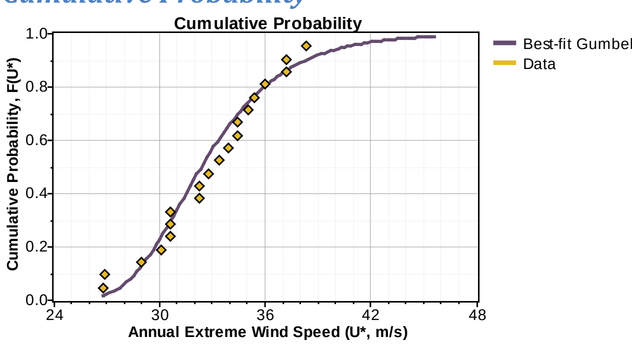
1990 to 2009 Data, α = 0.14, high 1990 data point filtered

With all data from 1990 to 2009, a power law exponent of 0.14, filtering the abnormally high 1990 wind speed and the extremely high 2005 wind speed, a Gumbel distribution predicts a 10-minute mean wind speed with a 50 year return of 43.5 m/s.

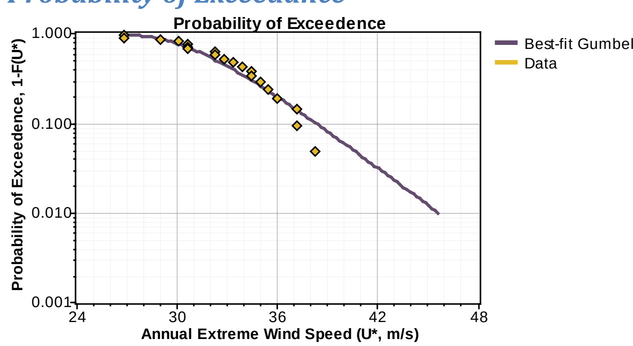
Return Period

Return Period (yr)	Extreme Wind Speed (m/s)	
	10-min means	Gusts
20	40.5	54.2
25	41.3	55.5
50	43.5	59.2
100	45.6	62.8

Cumulative Probability



Probability of Exceedance



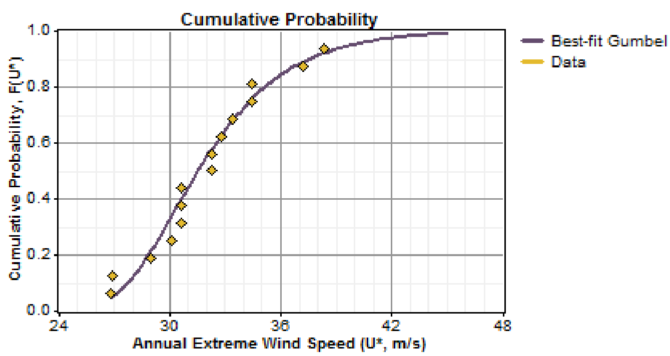
1995 to 2009 Data, α = 0.14

With just ASOS (newest) data from installation in March 1995 to 2009, a power law exponent of 0.14, and only filtering the extremely high 2005 data point, a Gumbel distribution predicts a 10-minute mean wind speed with a 50 year return of 42.8 m/s.

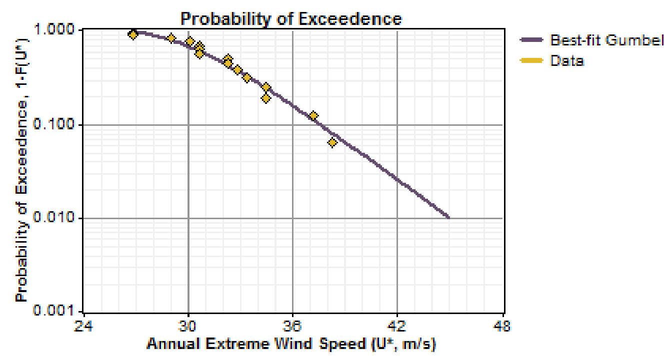
Return Period

Return Period (yr)	Extreme Wind Speed (m/s) 10-min means	Gusts
20	39.8	49.0
25	40.5	49.8
50	42.8	52.6
100	45.0	55.3

Cumulative Probability



Probability of Exceedence



1990 to 1994 Data, α = 0.14

With pre-ASOS (older system) data from January 1990 to December 1994, a power law exponent of 0.14, and no filtering, a Gumbel distribution modified for monthly data input versus yearly data input predicts a 10-minute mean wind speed with a 50 year return of 43.1 m/s.

Return Period

Shemya	RETURN YR	10 min average, m/s	1 sec gust, m/s
30 meter	2	32.7	40.9
	10	37.9	47.5
	15	39.2	49.1
	30	41.5	51.9
	50	43.1	53.9
	100	45.3	56.7

1990 to 1994 Data, α = 0.14

With pre-ASOS (older system) data from January 1990 to December 1994, a power law exponent of 0.14, and no filtering, a normal Gumbel distribution with a limited data set (five years instead of the recommended seven years minimum) input predicts a 10-minute mean wind speed with a 50 year return of 40.3 m/s.

Return Period

Return Period (yr)	Extreme Wind Speed (m/s) 10-min means	Gusts
20	39.0	67.9
25	39.3	69.8
50	40.3	75.7
100	41.3	81.6

Basic Wind Data

Other wind data of relevance are average wind speed, wind direction, temperature and pressure.

Mean Wind Speed, 30 meters, data converted to 10-min., 0.14 α, 1990-2009 data

Month	Data Recovery Rate (%)	Ten minute average Mean (m/s)	Median (m/s)	Max (m/s)	1 sec Gust Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)
Jan	50.0	11.39	10.94	37.21	49.25	5.90	2.01	12.83
Feb	51.2	11.37	10.80	37.21	43.23	5.84	2.02	12.81
Mar	49.1	11.12	10.81	32.33	43.31	5.19	2.25	12.53
Apr	50.4	10.10	9.85	30.64	36.66	4.82	2.20	11.39
May	54.2	9.20	8.90	34.47	36.12	4.17	2.33	10.37
Jun	53.9	7.73	7.66	22.44	27.00	3.53	2.33	8.73
Jul	51.8	7.28	7.11	35.43	43.20	3.73	2.01	8.19
Aug	53.4	7.72	7.66	30.10	37.76	3.89	2.05	8.69
Sep	51.1	9.01	8.76	28.56	36.12	4.50	2.08	10.16
Oct	50.8	10.48	9.85	33.38	42.14	5.16	2.12	11.81
Nov	51.1	12.12	11.49	44.32	58.00	5.86	2.19	13.70
Dec	50.7	11.61	11.13	38.31	46.40	5.74	2.13	13.12
All data	51.5	9.89	9.30	44.32	58.00	5.18	1.99	11.15
MMM		9.92						

Mean Wind Speed, 30 meters, data converted to 10-min., 0.20 α, 1990-2009 data

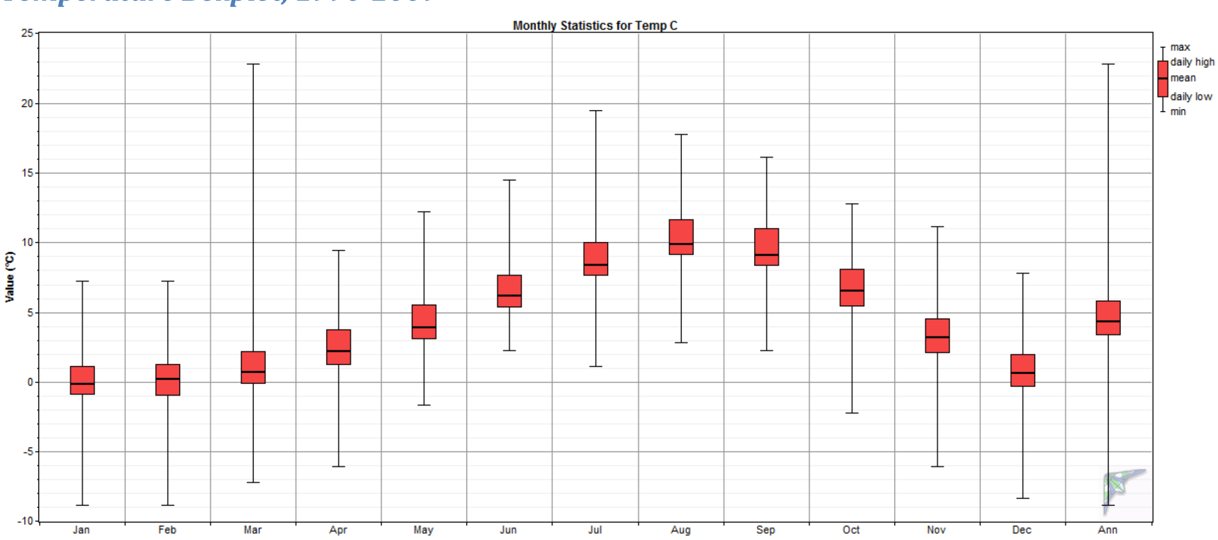
Month	Data Recovery Rate (%)	Ten minute average Mean (m/s)	Median (m/s)	Max (m/s)	1 sec Gust Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)
Jan	50.0	12.16	11.69	39.75	52.60	6.31	2.00	13.70
Feb	51.2	12.14	11.53	39.75	46.18	6.24	2.02	13.68
Mar	49.1	11.88	11.54	34.53	46.26	5.54	2.25	13.39
Apr	50.4	10.79	10.52	32.73	39.16	5.15	2.20	12.16
May	54.2	9.83	9.51	36.82	38.58	4.45	2.33	11.07
Jun	53.9	8.26	8.18	23.96	28.84	3.77	2.33	9.32

Jul	51.8	7.78	7.60	37.85	46.15	3.98	2.01	8.75
Aug	53.4	8.25	8.18	32.15	40.33	4.16	2.05	9.28
Sep	51.1	9.63	9.35	30.51	38.58	4.81	2.08	10.85
Oct	50.8	11.19	10.52	35.65	45.01	5.51	2.12	12.62
Nov	51.1	12.95	12.27	47.34	61.96	6.26	2.18	14.62
Dec	50.7	12.40	11.89	40.92	49.57	6.13	2.13	14.01
All data	51.5	10.56	9.94	47.34	61.96	5.53	1.99	11.91
MMM		10.59						

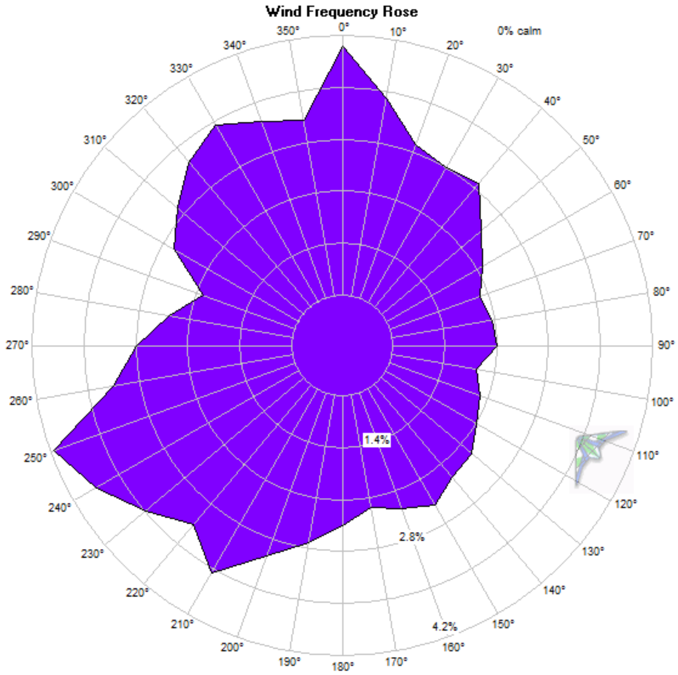
Wind Speed, 30 meters, data converted to 10-min., 0.14 α, 1990-1995 data

Month	Data Recovery Rate (%)	Ten minute average Mean (m/s)	Median (m/s)	Max (m/s)	1 sec Gust Max (m/s)	Std. Dev. (m/s)	Weibull k	Weibull c (m/s)
Jan	99.1	11.05	10.40	35.0	49.2	6.05	1.89	12.44
Feb	99.5	11.31	10.82	37.2	43.2	6.13	1.87	12.68
Mar	99.7	11.18	10.94	32.3	43.3	5.32	2.19	12.59
Apr	99.3	9.23	8.76	26.3	35.5	4.66	2.04	10.38
May	99.6	8.91	8.76	28.5	34.5	4.24	2.16	10.01
Jun	99.8	7.57	7.63	22.4	27.0	3.77	2.09	8.53
Jul	100.0	7.43	7.22	35.4	43.2	3.87	1.97	8.35
Aug	100.0	8.22	8.21	30.1	37.8	4.39	1.90	9.22
Sep	100.0	8.50	7.99	26.8	36.1	4.55	1.90	9.54
Oct	100.0	10.28	9.85	32.3	42.1	5.31	1.98	11.55
Nov	99.9	12.09	11.56	36.0	58.0	5.67	2.25	13.64
Dec	100.0	11.52	11.22	33.9	39.4	5.65	2.14	12.99
All data	99.7	9.81	9.30	37.2	58.0	5.30	1.90	11.02
MMM		9.77						

Temperature Boxplot, 1990-2009



Wind Frequency Rose,1990-2009



Air Density Boxplot (in kg/m³), 1990-2009