Wind Erosion Prediction System: Weather Generator Submodel

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Introduction

Soil erosion is affected by many climatic factors. Figure 1 illustrates some of these climatic variables, which are used to drive temporal changes in hydrology, soil erodibility, crop growth, and residue decomposition in the Wind Erosion Prediction System (WEPS). This photograph, shows precipitation falling as rain, which affects soil conditions, plant growth, and residue decomposition. Solar radiation, as illustrated by sunshine, not only impacts plant growth but also affects drying of the soil surface. The photograph also indicated the presence of wind, with magnitude and direction components, which affects hydrologic processes and plant growth, as well as well as erosion.

Figure 1. Photograph illustrating some of the weather variables modeled by the WEPS weather generator.

WEPS Weather Requirements

WEPS requires weather inputs on a daily basis and wind speeds on a subdaily basis. Historical records could provide such inputs but are not readily available in sufficiently long periods. Another requirement of WEPS is that the data used be compact relative to the size of the model. However, keeping historical data for the entire U.S. would be prohibitive in terms of data storage for WEPS. Since statistical weather summaries are available for most of the U.S., we concluded that simulated weather would meet these requirements. Our objective was to develop a compact weather database and generator which would simulate the weather inputs required by WEPS.

Weather Simulation for WEPS

The weather generator of WEPS consists of the programs WINDGEN and CLIGEN and is capable of simulating the needed weather variables on a daily basis as well as wind speed on a subdaily basis. The WINDGEN program provides wind speed and direction for WEPS (Skidmore and Tatarko, 1990; Wagner et al., 1992). It was developed specifically for use with WEPS and stochastically simulates wind direction and maximum and minimum wind speeds on a daily basis. In addition, WINDGEN provides the hour at which the maximum wind speed occurs for each day based on historical records. Subdaily wind speeds are generated from within WEPS by the subroutine 'calcwu'.

CLIGEN is the weather generator developed for the Water Erosion Prediction Project (WEPP) family of erosion models (Nicks et al., 1987). It is used with WEPS to generate an average annual air temperature as well as daily precipitation, maximum and minimum temperatures, solar radiation, and dew point temperature. Average daily air temperature and elevation for the site are used to calculate average daily air density within WEPS. CLIGEN will not be described in this document. However, those interested in CLIGEN and how it simulates these variables should consult the WEPP documentation (Nicks and Lane, 1989).

Wind Simulation

Prediction of wind speed and direction, like most meteorological variables, is extremely difficult. Even with advanced technology, such as sophisticated numerical models and super computers, using climatological means is only as accurate as predicting meteorological variables a few days in advance (Tribbia and Anthes, 1987). Therefore for WEPS, we resort to historical statistical information about most meteorological variables and use stochastic techniques to determine the likelihood of various levels of those variables.

Various models have been used to describe wind speed distribution. A glance at frequency versus wind speed, shows that the distribution is not described best by the familiar normal distribution. Distributions that have been used to describe wind speed include the one -parameter Rayleigh (Hennessey, 1977; Corotis et al., 1978); the two-parameter gamma (Nicks and Lane, 1989); and the two-parameter Weibull (Takle and Brown, 1978; Corotis et al., 1978). The Weibull is undoubtedly the most widely used model of common wind behavior representing wind speed distributions.

WEPS Database

One important requirement of a wind simulator for wind erosion modeling it have a compact database. Although the creation of our compact database is described elsewhere (Skidmore and Tatarko, 1990, 1991), we give some of the details here. We used historical monthly summaries of wind speed and wind direction contained in the extensive Wind Energy Resource Information System (WERIS) database at the National Climatic Data Center, Asheville, North Carolina (NCC TD 9793). The WERIS database is described further in Appendix C of Elliot et al. (1986). Data were extracted from WERIS tables and, in some cases, analyzed further to create a database suitable for our needs. We used data from WERIS Table 12 A-L, joint wind speed/direction frequency by month (e.g., Table 1), to calculate scale and shape parameters of the Weibull distribution function for each of the 16 cardinal wind directions by month.

Table 1. Monthly joint wind speed/direction frequency values for March, Lubbock, Texas.

Wind Speed (m/s)	Wind Direction																	
	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	Calm	Total
Calm	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	1.7	1.7
1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2	.3	.1	.1	.0	.1	.1	.2	.1	.3	.1	.5	.5	.6	.4	.5	.2	.0	4.1
3	.7	.3	.5	.4	.9	.4	.6	.5	.9	.4	1.1	1.1	1.5	.8	.7	.3	.0	11.1
4	1.0	.6	.8	.4	1.1	.9	1.0	.8	1.9	.6	.8	1.2	1.6	1.2	.7	.5	.0	15.1
5	.9	.6	.8	.5	.9	.9	1.0	1.3	2.1	.9	1.2	1.2	1.6	.5	.4	.5	.0	15.4
6	.7	.7	.6	.4	.6	.5	.9	.6	1.6	1.0	1.1	1.2	.7	.6	.3	.5	.0	12.2
7	1.0	.6	.6	.4	.2	.5	.4	.5	1.6	1.0	1.4	.8	.7	.5	.3	.2	.0	10.0
8	1.0	.6	.8	.2	.5	.3	.6	.3	1.4	1.2	1.0	.6	.7	.4	.4	.2	.0	10.1
9	.8	.4	.6	.2	.3	.1	.2	.4	1.0	.8	.7	.6	.6	.4	.2	.3	.0	7.6
10	.3	.4	.2	.2	.1	.0	.1	.2	.8	.4	.2	.3	.4	.3	.1	.1	.0	4.3
11	.3	.4	.1	.1	.0	.0	.1	.1	.5	.2	.3	.3	.5	.1	.1	.1	.0	3.1
12	.2	.1	.0	.0	.0	.0	.0	.1	.0	.1	.1	.2	.4	.1	.1	.0	.0	1.6
13	.2	.1	.0	.0	.0	.0	.0	.0	.0	.8	.2	.1	.3	.2	.1	.1	.0	1.3
14	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1	.2	.1	.1	.0	.0	.7
15	.1	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0	.0	.5
16	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.1	.0	.0	.0	.0	.2
17	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1	.0	.0	.0	.0	.1
18	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1
19	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.1
20	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
21-25	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
26-30	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
31-35	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
36-40	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
41-up	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	7.8	4.8	5.1	2.9	4.9	3.8	5.1	4.9	12.2	6.8	8.9	8.5	9.9	5.7	4.0	3.0	1.7	100.0
Avg	6.9	7.0	6.1	6.0	5.1	5.2	5.5	5.9	6.2	6.7	6.4	6.2	6.4	6.2	5.6	6.3	.0	6.1

The cumulative Weibull distribution function F(u) and the probability density function f(u) are defined by:

$$F(u) = 1 - \exp[-(u/c)^k] \qquad \textbf{[1]}$$

and

$$f(u) = dF(u)/du = (k/c)(u/c)^{k-1} \exp[-(u/c)^k] \qquad \textbf{[2]}$$

where u is wind speed, c is a scale parameter (units of velocity), and k is a shape parameter (dimensionless) (Apt, 1976). Because anemometer heights varied from location to location, all wind speeds (e.g., Column 1, Table 1) were adjusted to a 10 m reference height according to the following:

$$u_2 = u_1(z_2/z_1)^{1/7} \qquad \textbf{[3]}$$

where u1 and u2 are wind speeds at heights z_1 and z_2, respectively (Elliot, 1979).

The calm periods were eliminated, and the frequency of wind in each speed group was normalized to give a total of 1.0 for each of the 16 cardinal directions. Thus,

$$F_1(u) = [(F(u) - F_0)/(1 - F_0)] = 1 - \exp[(u/c)^k] \quad \textbf{[4]}$$

where $F_1(u)$ is the cumulative distribution with the calm periods eliminated, and F_0 is the frequency of the calm periods. The scale and shape parameters were calculated by the method of least squares applied to the cumulative distribution function (Eqn. [4]). Equation [4] was rewritten as:

$$1 - F_1(u) = \exp[-(u/c)^k] \quad \textbf{[5]}$$

Then by taking the logarithm twice, this becomes:

$$\ln[-\ln(1 - F_1(u))] = -k \ln c + k \ln u \quad \textbf{[6]}$$

If we let y = ln[-ln(1 - F_1(u))], a = -k ln c, b = k, and x = ln u, Eqn. [6] may be rewritten as:

$$y = a + bx \quad \textbf{[7]}$$

F_1(u) was calculated from information in tables like Table 1 for each wind speed group to determine y and x in Equation [7]. This gave the information needed to use a standard method of least squares to determine the Weibull scale and shape parameters. To recover the real distribution, we can rewrite Equation [4] as:

$$F_1(u) = F_0 + (1 - F_0)(1 - \exp[-(u/c)^k]) \quad \textbf{[8]}$$

An example of wind speed distributions with various scale and shape parameters is presented in both line and bar graphs in Figure 2. The bar graphs were produced from original data as in Table 1. The wind speed data were corrected to an anemometer height of 10 meters and normalized to 1.0 for total for each cardinal direction before plotting. The line graphs were calculated from Equation [2]; shape and scale parameters were obtained from Tables 4 and 5, respectively, corresponding to the specified month and direction. The shape parameter of Figure 2a is located in Table 4, month 12 and direction 6; likewise the scale parameter of Figure 2a is located in Table 5, month 12 and direction 6.

From WERIS Table 5, we obtained a ratio of maximum/minimum mean hourly wind speed and hour of maximum wind speed by month (e.g., Table 2). Tables 2, 3, 4, and 5 give examples of wind information we compiled into a compact database.

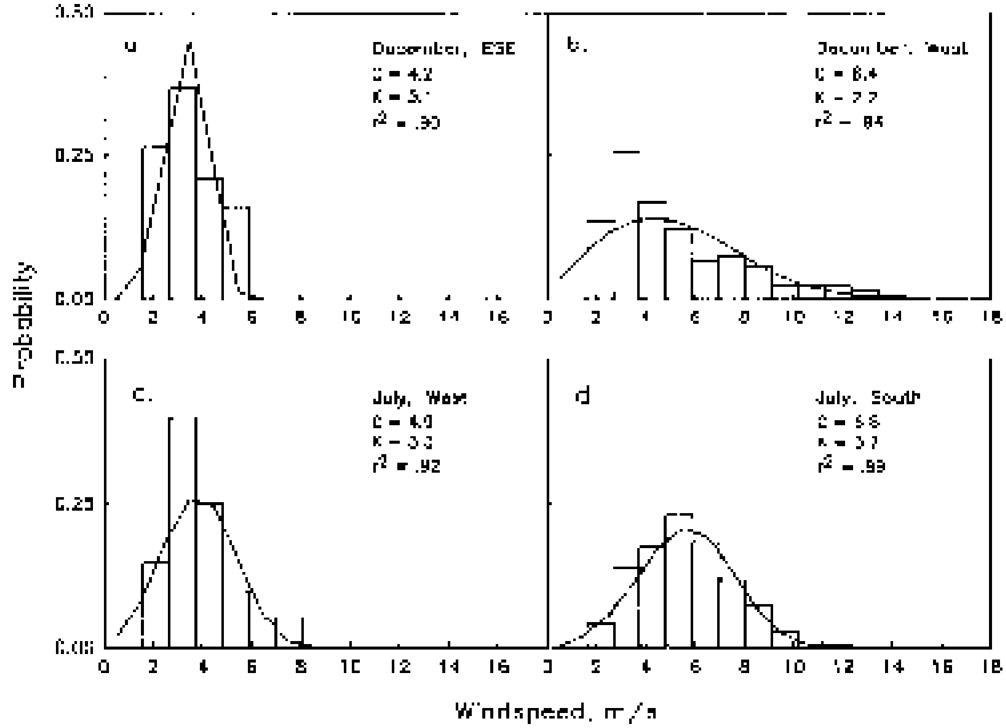

Figure 2. Wind speed distributions from summarized data (bar graphs) compared to Weibull calculated distributions (line graphs) for various combinations of months and wind directions, Lubbock, Texas.

Table 3. Wind direction distribution by month in percent for Lubbock, Texas.

Wind Direction	Month 1	2	3	4	5	6	7	8	9	10	11	12
1	8.2	9.7	7.8	5.5	5.3	3.1	2.3	2.9	5.9	6.3	8.8	9.0
2	5.0	4.9	4.8	3.6	3.7	2.2	1.5	2.6	4.8	5.0	4.4	4.8
3	5.0	5.9	5.1	4.1	4.1	3.2	3.9	4.2	6.3	5.3	4.8	4.7
4	3.8	4.2	2.9	4.5	4.8	4.1	3.8	4.7	4.9	4.1	3.1	3.1
5	4.0	4.3	4.9	5.3	5.9	5.0	5.9	6.7	6.3	4.3	4.4	2.2
6	3.1	3.8	3.8	4.7	6.6	6.1	5.7	6.3	5.7	3.0	3.2	1.9
7	3.3	3.8	5.1	6.5	10.5	10.4	10.0	9.7	7.5	4.2	3.4	2.1
8	2.9	3.3	4.9	4.9	8.3	9.5	11.6	14.9	13.6	9.0	5.4	3.7
9	9.8	8.7	12.2	16.4	16.4	26.8	27.4	24.1	18.6	19.7	11.7	9.4
10	6.0	5.7	6.8	6.5	6.9	9.2	8.8	7.2	7.9	9.6	7.5	7.4
11	9.6	8.5	8.9	7.7	7.3	5.9	5.9	5.1	6.2	8.2	9.9	10.1
12	9.6	9.3	8.5	7.9	4.7	3.4	2.4	2.8	3.5	6.0	9.0	9.8
13	12.3	10.8	9.9	6.7	5.1	3.3	2.0	1.7	3.5	6.1	9.0	11.8
14	6.3	6.2	5.7	4.6	3.0	1.5	1.0	1.1	1.7	3.2	5.1	7.7
15	4.7	4.9	4.0	3.4	2.6	1.6	0.8	1.1	2.0	3.0	4.3	5.3
16	3.8	3.4	3.0	3.0	1.8	1.1	0.6	1.1	2.1	2.9	3.0	4.0
17	2.7	2.7	1.7	1.4	1.8	1.5	3.1	5.0	4.0	3.6	4.8	4.3

Directions are clockwise with 1 = north and Month 1 = January. Direction 17 represents calm periods.

Table 2. Ratio of maximum to minimum hourly wind speed (max/min) and hour of maximum wind speed.

	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
max/min	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.5	1.6	1.6	1.5
hour max	15	12	15	15	18	18	18	15	15	15	12	15

Values from WERIS Table 5 for Lubbock, TX (Skidmore and Tatarko, 1991) where Month 1 = January.

Table 4. Weibull shape parameters by month and direction for Lubbock, Texas.

Wind Direction	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	2.5	2.5	2.7	2.6	2.8	2.3	2.2	2.6	2.3	2.5	2.7	2.7
2	2.8	2.4	3.2	2.9	2.8	2.7	3.2	2.3	3.1	2.8	2.7	2.6
3	2.8	3.1	3.3	2.8	2.7	2.9	2.8	3.3	3.2	3.3	3.0	3.2
4	3.9	3.4	3.0	3.5	3.0	2.6	2.8	2.9	3.2	3.1	2.7	3.2
5	3.1	3.2	3.3	2.9	3.0	3.4	3.1	3.2	3.3	3.0	3.6	2.8
6	3.4	3.6	3.9	3.3	3.6	4.4	3.7	3.9	3.3	3.5	3.6	5.1
7	3.7	3.3	3.3	3.3	3.4	3.6	3.5	3.5	3.9	4.1	3.6	5.4
8	3.2	4.1	3.3	3.5	3.3	3.5	3.8	3.7	3.5	2.9	3.0	4.5
9	2.9	3.2	3.6	3.3	3.3	3.7	3.7	3.7	3.4	3.3	3.3	3.2
10	3.1	3.5	3.7	3.7	3.2	3.5	3.9	3.6	4.0	3.2	3.5	3.2
11	3.4	3.2	2.7	3.2	3.2	3.0	3.5	3.0	3.4	3.0	3.2	3.2
12	2.5	2.6	2.5	2.4	2.5	2.9	3.4	3.6	3.0	2.7	2.6	2.6
13	2.1	2.4	2.2	2.5	2.6	2.2	3.3	3.1	3.0	2.4	2.2	2.2
14	2.1	2.2	2.3	2.5	2.4	3.6	4.1	3.5	2.6	2.4	1.8	2.0
15	2.4	2.6	2.2	2.5	2.5	3.1	3.3	2.9	2.9	2.0	2.2	2.3
16	2.2	2.6	2.7	2.3	2.8	3.3	2.6	3.5	2.5	2.1	2.4	2.4
17	2.6	2.6	2.7	2.9	3.0	3.1	3.3	3.2	3.0	2.7	2.6	2.6

The directions are clockwise starting with 1=north. Direction 17 is for total wind.

Table 5. Weibull scale parameters by month and direction in m/s for Lubbock, Texas.

Wind Direction	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	8.0	8.2	8.8	8.3	8.0	7.6	5.8	5.0	6.4	7.5	7.5	7.9
2	8.2	9.2	9.0	8.6	8.3	7.6	6.0	5.7	7.3	7.5	6.7	8.1
3	6.6	7.8	8.0	8.3	7.9	7.2	5.8	5.8	5.9	7.0	6.5	6.8
4	6.5	6.5	7.8	6.9	7.3	6.3	5.9	5.2	5.3	6.2	5.7	6.3
5	6.0	6.3	6.7	6.4	6.6	6.3	5.2	4.8	4.6	5.2	5.0	5.0
6	5.3	6.4	6.8	7.1	7.1	6.2	5.3	5.0	5.2	5.1	5.1	4.2
7	5.5	6.4	7.2	7.2	7.4	6.8	6.0	5.5	5.5	5.3	4.8	5.2
8	5.9	6.1	7.5	8.5	8.0	7.5	6.3	5.8	5.9	6.2	5.8	5.2
9	6.2	7.0	7.9	8.5	8.1	8.0	6.8	6.5	6.5	6.6	6.2	6.5
10	7.2	7.2	8.7	8.5	8.1	7.7	6.9	6.5	6.9	6.9	6.9	7.4
11	7.3	7.6	8.2	8.4	7.6	6.9	6.1	5.9	6.1	6.2	6.5	6.9
12	6.5	7.0	8.0	8.6	7.8	7.0	5.4	5.0	5.2	5.9	6.4	6.0
13	6.7	6.8	8.3	8.8	7.2	6.4	4.9	4.4	5.3	5.1	6.3	6.4
14	7.1	7.2	7.8	8.1	7.0	5.6	4.3	4.2	4.6	5.1	6.0	6.9
15	6.1	6.1	7.2	7.2	7.1	5.3	4.6	4.5	4.4	4.9	6.4	6.5
16	7.1	7.7	7.7	8.3	6.6	5.7	4.8	3.9	4.9	6.4	7.1	7.2
17	6.8	7.3	8.1	8.2	7.7	7.3	6.3	5.8	5.9	6.3	6.4	6.7

Directions are clockwise starting with 1=north. Direction 17 is for total wind.

Weibull shape and scale parameters (Tables 4 and 5) were used to calculate wind speed distributions illustrated in Figure 3. This figure is intended to give a visual overview of wind speed distributions at a location. Each of the eight "curves" in the figure is at a 45 degree interval and is oriented in the direction of the wind that it represents. For example, comparing curves for wind speed distributions from the west and south to their parallel wind speed scales shows that the westerly winds have a greater probability of high speeds than southerly but that southerly winds have a greater probability at medium speeds.

Wind direction distribution for each location was summarized by month from the "TOTAL" row near the bottom of Table 1 for each location.

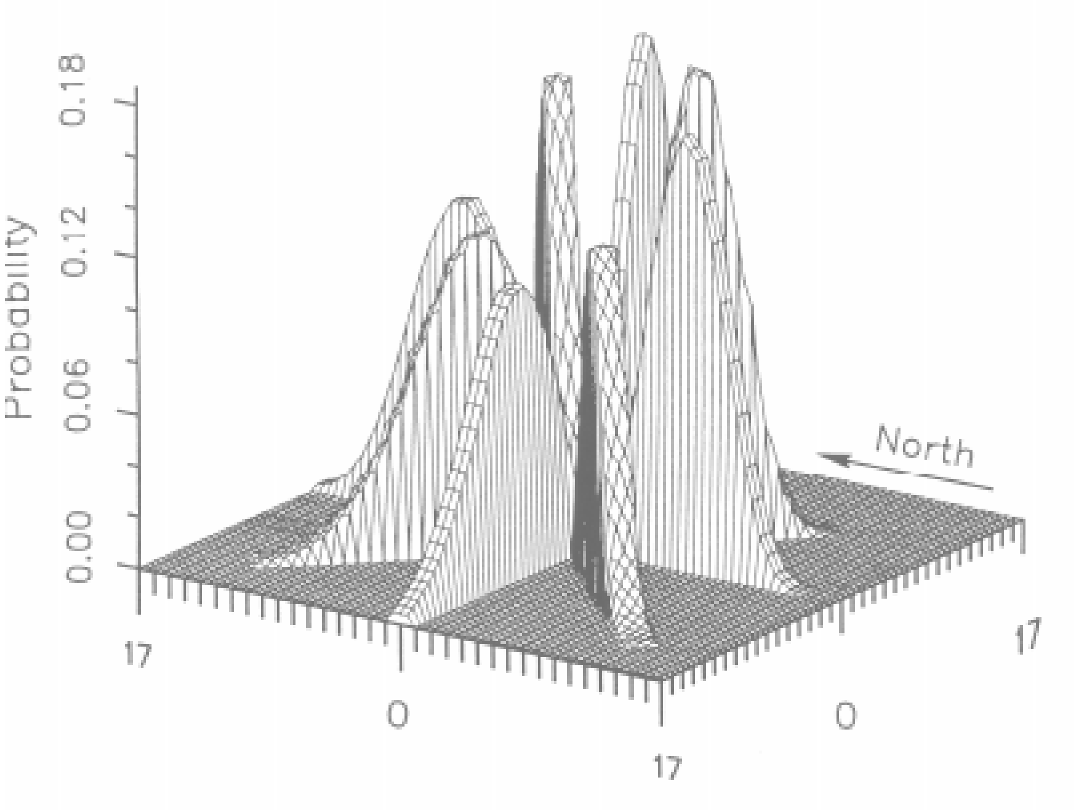

Figure 3. Wind speed probability distribution by direction for March at Lubbock, Texas.

Other pertinent data, obtained from the Wind Energy Resource Atlas of the United States (Elliot et al., 1986), included latitude, longitude, city, state, location name, Weather Bureau Army Navy (WBAN) number, agency responsible for the weather station, period of record, anemometer height and location, and number of observations per 24-hour period.

We eliminated WERIS sites from our database if they represented fewer than 5 years of data, the anemometer height was not known, or fewer than 8 observations were taken per day. Where more than one satisfactory observation period/site remained in a metropolis, we picked the site with the best combination of the following: (1) maximum number of observations per day, (2) longest period of record, (3) 1 hourly versus 3 hourly observations, and (4) best location of anemometer (ground mast > beacon tower > roof top > unknown location). The WINDGEN database currently consists of statistical parameters for 672 locations in the United States (see Figure 4).

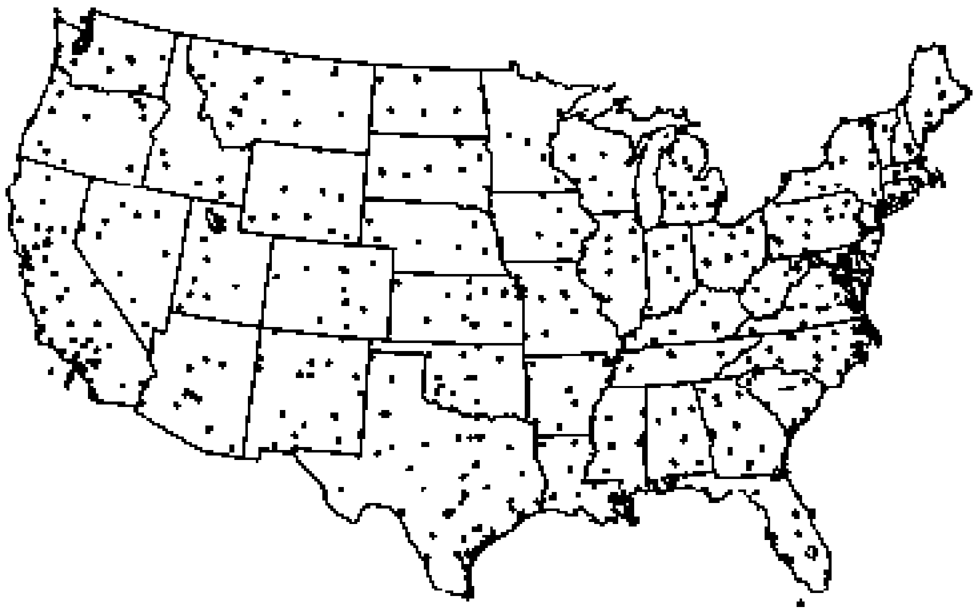

Figure 4. Locations in the conterminous United States that are contained in the WEPS wind database.

The following few paragraphs outline procedures to access the WEPS weather database and how it is used to simulate wind direction and wind speed.

Determination of Wind Direction

Read the wind direction distribution array for the specified month (Table 3). Calculate the cumulative wind direction distribution so that it ranges from 0.0 to 1.0 (Figure 5). Draw a random number, RN, where 0.0 < RN < 1.0, and compare it with the cumulative wind direction distribution. If the random number is equal to or less than the probability of the wind being from the north (i.e., direction = 1, Table 3), then the simulated wind direction is north. If the random number is greater than the cumulative probability of the wind being from the north and equal to or less than the probability of the wind being from the north northeast, then the simulated wind direction is north northeast, and so on. If the random number is greater than the cumulative probability of the wind being from all of the 16 cardinal directions, then the simulated wind is calm.

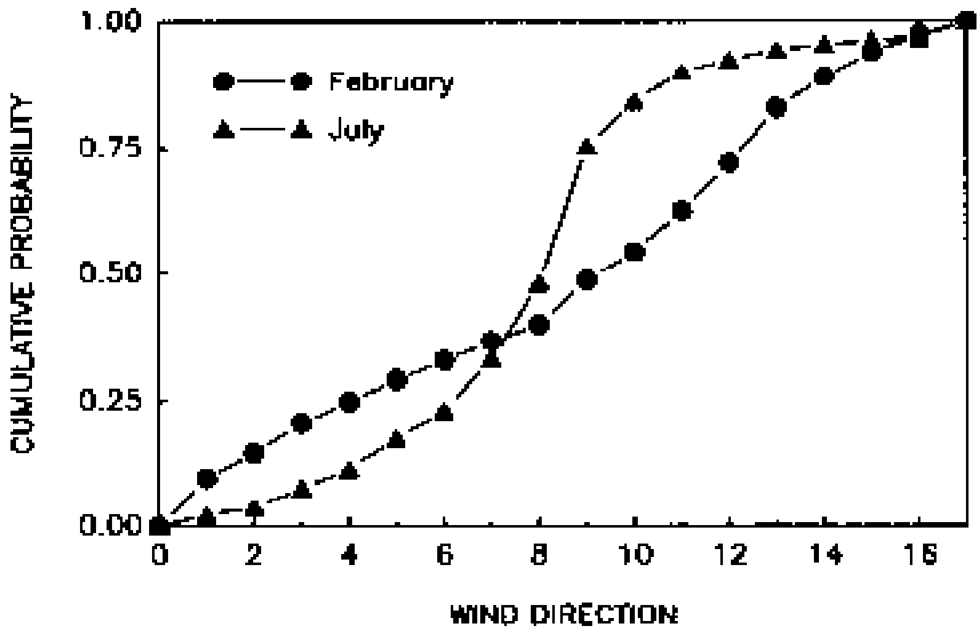

Figure 5. Cumulative probability distributions of wind direction in February and July for Lubbock, Texas.

Determination of Wind Speed
Once wind direction is simulated, access the database to determine the Weibull shape, k (Table 4), and scale, c (Table 5), parameters for that direction, and the month under consideration in preparation for the next step.

Rearrange Equation [8] to make wind speed, u, the dependent variable:

$$u = c\{-\ln[1-(F(u)-F_0)/(1-F_0)]\}^{1/k} \qquad \textbf{[9]}$$

Draw a random number, 0.0 < RN < 1.0, assign its value to F(u), and subtract from it the frequency of calm periods, F_0. If F(u) < F_0, then u is calm. In the rare case that F(u) = 1.0, the argument of ln in Equation [9] is zero and does not compute. Therefore, if F(u) > 0.999, let F(u) = 0.999. Otherwise, calculate u from Equation [9] for F_0 < F(u) < 0.999 to determine a period of simulated wind speed. If the period is 1 day, then u represents simulated daily mean wind speed.

Subdaily wind speeds in WEPS will be calculated whenever the maximum wind speed for the day exceeds a set erosion threshold (i.e., default is 8 m/s). To compute subdaily wind speeds, consider a diurnal variation. We present an example of hourly wind speeds, but shorter or longer periods are permitted in WEPS.

Read from the wind database the ratio of maximum to minimum mean hourly wind speed and the hour of maximum wind speed for the location and month under consideration. Calculate the maximum and minimum wind speeds for the day based on the representative wind speed as calculated above and given the ratio of maximum to minimum wind speed:

$$urep = (umax + umin) / 2 \qquad \textbf{[10]}$$

and

$$uratio = umax / umin \qquad \textbf{[11]}$$

where *urep* is the daily mean representative wind speed as calculated from Equation [9], *uratio* is the ratio of daily maximum, *umax*, to daily minimum, *umin*, wind speed. Solving Equations [10] and [11]) for *umax* and *umin* gives:

$$umax = 2 \; uratio \; urep / (1 + uratio) \qquad \textbf{[12]}$$

and

$$umin = umax / uratio \qquad \textbf{[13]}$$

Therefore, wind speed for any hour of the day u(I) can be simulated from:

$$u(I) = urep + 0.5(umax - umin) \; \cos[2\pi(24 - hrmax + I) / 24] \qquad \textbf{[14]}$$

where *hrmax* is the hour of the day when wind speed is maximum; *I* is the index for hour of day, and the other variables are as previously defined.

Comparison of WEPS Simulated Wind to Measured Wind

Measured and simulated, average, hourly, annual, wind speeds for Lubbock, Texas were compared. The average annual wind speed at 3-h intervals was obtained from Table 06 of the WERIS database (Elliot et al., 1986) and adjusted to a 10 m height. Annual umax, umin, and hrmax, obtained from the same source, were 6.55, 4.19 m/s, and 15 h, respectively. These values were used in Equation [14] to simulate hourly wind speed, which is compared to measured wind speed in Figure 6. This procedure forces agreement between simulated and observed values for daily maximum and minimum speeds and ensures that the times of simulated and observed maximum speeds agree with the frequency of reported observations of wind speed.

The form of wind speed variation is not purely sinusoidal, which causes a discrepancy between simulated and observed times of minimum wind speed. If we were interested primarily in low wind speeds, we could easily force the agreement at low wind speeds by modifying Equation [14]. However, for wind erosion simulation, we are interested primarily in the higher wind speeds, and Equation [14] appears to fit the higher observed wind speeds quite well.

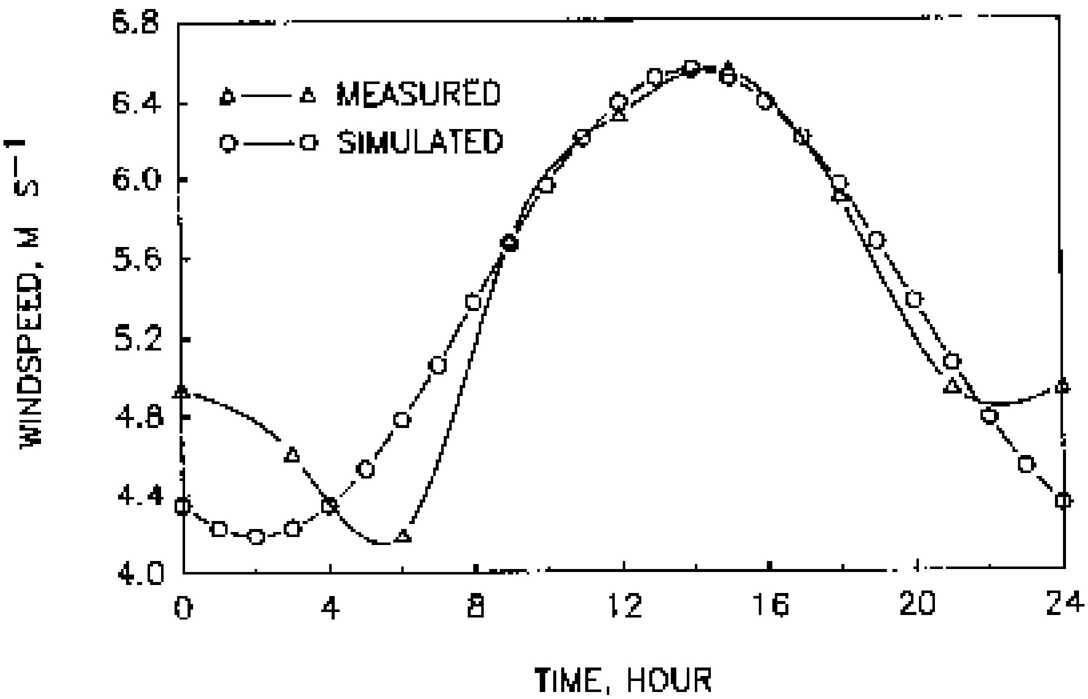

Figure 6. Measured and simulated average hourly annual wind speeds for Lubbock, Texas.

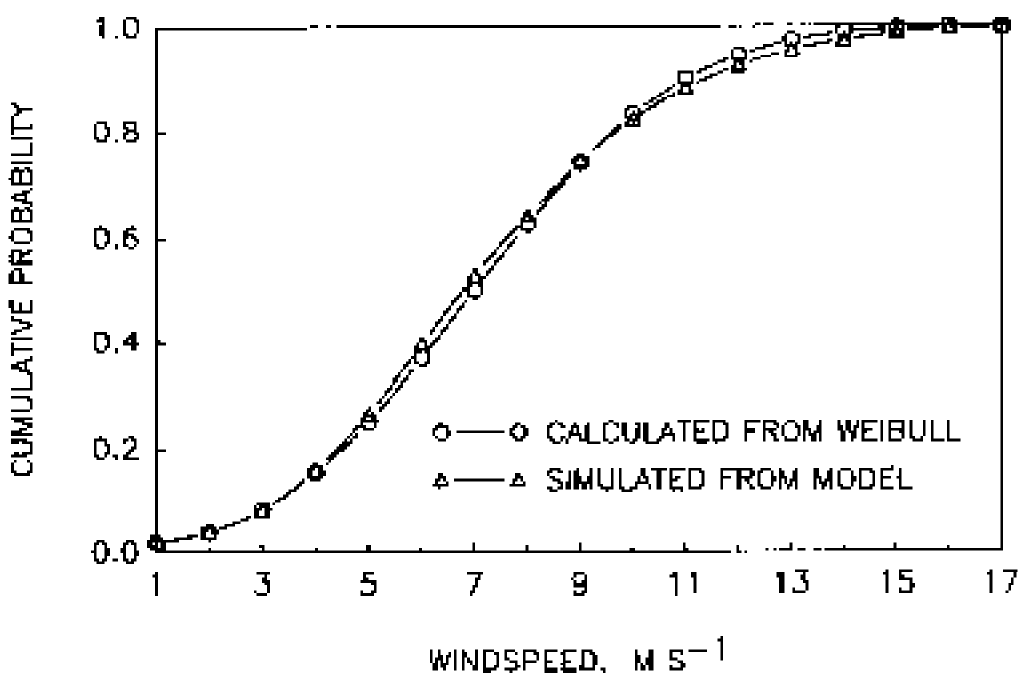

Figure 7. Simulated hourly wind speed compared to speeds calculated from Weibull distribution for March at Lubbock, Texas. Scale and shape parameters were 8.1 ms^{-1} and 2.7, respectively; percent calm, max/min ratio, and hour of maximum wind speed were 1.7, 1.6, and 15, respectively.

Because superimposing diurnal variation on a daily mean wind speed, drawn from a location wind speed distribution, could introduce an error in the overall distribution, we compared cumulative distributions calculated from Weibull to simulated distributions.

Wind speeds were calculated from Equation [14] for I = 1 to 24, 1000 times, thus simulating wind speed at 1-hour intervals for 1000 days. This simulated distribution of 24,000 wind speeds was compared to the distribution defined by Equation [8]. The overall agreement appears excellent (Fig. 7).

How Can We Improve the Simulation of Wind?

Although wind simulation for WEPS appears reasonable, we are continuing to improve our ability to simulate the wind. Several areas are recognized where wind simulation can be improved further.

The first is development of an equation to better fit wind speed distributions. The Weibull distribution fits reasonably well but occasionally is slightly off at the upper tail of the distribution, which represent speeds that can affect wind erosion.

Mountainous areas often affect wind speed distributions in apparently unpredictable ways (e.g., they do not fit the Weibull). More work should be done to improve the simulation of orographic effects on wind speed and direction patterns.

Wind speed and direction often are correlated with other climatic variables such as precipitation associated with storm fronts. Evidence also indicates that drought years are windier than normal years (Holliday, 1987; Stetler and Gaylord, 1996). A better understanding of these correlations will allow the development of conditional probabilities for wind event simulations that more accurately reflect reality.

Using longer periods of historical records could allow for more accurate wind distributions. The WEPS wind data base currently does not include locations with fewer than 5 years of wind data, but most of the records include fewer than 10 years. Because this database uses data published in 1967 (WERIS), many more years of data are available. If longer periods were used, drought years also could be isolated to better simulate years of below-normal precipitation.

Finally, a detailed study of historic, subdaily, wind speed distributions over time might reveal a better fit to these distributions than obtained with Equation [14].

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