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Erosive wind energy distributions and climatic factors for the West

Leon Lyles

ABSTRACT: Erosive wind energy (EWE) distributions were determined for the 7 western states and Alaska. Wind erosion equation climatic factors (C) were determined for the 10 Great Plains States, the 7 western states, and Alaska. Both EWE and C should be useful in improving design and evaluation of wind erosion control systems and data quality from future national erosion inventories.

CONSERVATIONISTS presently use a wind erosion equation (*8*) to design erosion control systems and to estimate soil loss by wind. Recently, Bondy and associates (*1*) outlined a procedure for computing soil erosion by periods using erosive wind energy distributions. They presented erosive wind energy distributions only for the 10 Great Plains States. Consequently, additional data are needed, especially for the other western states where wind erosion is a serious problem.

Annual climatic factors (C), one of the independent variables in the wind erosion equation, were published in 1962 (*2*). However, only general ranges of values were given. Subsequent maps were prepared for some states (areas), generally by request of the Soil Conservation Service (SCS), and may be found in various SCS Technical Guides or Notes (for example, *4*). Updated maps are needed using more recent climatological data and containing more locations.

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Method of evaluation

Erosive wind energy distribution. I determined erosive wind energy distributions for specific sites in the states west of the Great Plains using methods described previously (*1*). Erosive wind energy is defined by months as the sum of the cube of windspeeds between 8 and 20 meters per second (18-45 miles/hour) in 1-meter-per-second (2.2-mile/hour) increments. I included only locations with 5 years or more of wind data.

Annual climatic factors. The local wind erosion climatic factor (C) is used to characterize the erosive potential of climate (windspeed and surface soil moisture) at a particular location relative to Garden City, Kansas, which has an annual C value of 100 percent based on long-term climatic

Table 1. Percentage of the average annual erosive wind energy that normally occurs by the indicated dates. Computed for the locations shown in figure 1 (except Alaska).

Location and Number	Feb. 1	Mar. 1	Apr. 1	May 1	June 1	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Dec. 1	Jan. 1
Alaska												
1 Anchorage	9.9	28.4	41.7	52.5	59.8	64.2	66.1	68.7	73.8	79.6	93.1	100
2 Aniak	13.0	26.1	41.6	52.1	59.9	63.1	64.6	67.8	73.3	80.9	90.2	100
3 Barrow	9.5	17.3	23.2	29.6	36.1	40.4	45.2	54.2	63.9	77.0	91.5	100
4 Bethel	14.4	28.8	41.3	49.3	53.7	56.5	59.8	65.1	70.5	77.4	87.3	100
5 Bettles	5.1	11.3	25.8	36.2	49.3	64.0	68.4	72.9	82.6	86.6	91.7	100
6 Big Delta	18.2	33.2	43.0	47.7	52.2	53.3	54.0	56.1	61.6	70.7	85.6	100
7 Fairbanks	2.1	7.0	16.8	32.6	55.5	73.6	82.1	88.7	91.1	96.5	97.8	100
8 Galena	12.7	25.7	36.5	46.6	50.8	55.8	60.2	66.5	72.8	79.7	90.6	100
9 Gulkana	1.7	14.5	23.3	34.4	46.8	55.6	62.2	72.8	83.1	90.7	95.7	100
10 Kenai	15.8	33.0	45.1	50.4	53.9	56.8	59.3	63.1	66.9	77.5	88.5	100
11 Kotzebue	13.6	24.8	33.8	42.7	46.7	51.4	57.0	63.7	70.1	78.0	90.1	100
12 Manley Hot Springs	6.1	10.6	17.6	36.8	49.0	61.3	64.3	66.5	71.0	90.2	95.5	100
13 McGrath	7.4	18.6	31.6	41.7	52.5	58.0	61.7	75.2	81.9	89.8	91.1	100
14 Nome	11.0	26.5	36.7	47.0	52.1	55.0	57.7	62.7	69.7	78.3	89.8	100
15 Northway	10.8	24.1	37.3	51.4	58.2	65.4	68.9	72.8	76.3	81.2	90.3	100
16 Tanana	2.0	17.9	33.8	47.5	53.3	57.1	61.0	61.0	66.8	76.4	84.1	100
17 Unalakleet	17.1	32.7	44.8	50.9	53.3	54.9	57.3	60.9	65.9	73.3	87.6	100
Arizona												
1 Ashfork	7.4	15.3	27.4	45.1	56.4	65.8	70.6	74.2	79.8	87.9	95.0	100
2 Chandler	6.1	14.2	24.6	35.3	44.4	52.5	65.3	73.4	81.3	89.1	95.2	100
3 Douglas	8.9	18.2	38.4	55.6	70.7	77.6	80.5	81.8	83.3	87.8	93.7	100
4 Flagstaff	8.2	16.7	30.2	42.9	56.6	68.6	70.8	72.2	77.9	84.1	92.3	100
5 Ft. Huachuca	8.1	19.4	38.7	61.9	76.4	85.0	88.1	89.5	90.7	91.7	94.5	100
6 Kingman	7.2	17.1	29.3	45.2	55.5	66.1	72.4	76.6	81.2	89.0	95.0	100
7 Phoenix	2.3	7.3	17.1	35.4	51.7	63.9	78.8	88.5	92.9	95.4	98.0	100
8 Prescott	3.5	13.3	29.0	49.9	66.1	80.9	86.4	89.5	93.0	95.4	98.5	100
9 Tucson	8.5	16.2	28.8	42.4	51.9	64.1	72.7	76.1	81.3	86.1	92.1	100
10 Winslow	7.7	15.3	36.2	51.5	65.5	76.5	82.2	86.5	89.0	92.1	94.9	100
11 Yuma	6.2	15.8	26.7	40.0	49.4	57.4	72.3	82.0	84.3	96.8	93.9	100
California												
1 Bakersfield	2.9	7.6	17.8	33.9	58.0	78.0	84.6	90.9	94.2	95.5	97.1	100
2 Beale	18.7	31.1	42.9	51.3	57.0	62.3	63.5	65.0	68.8	76.0	83.9	100
3 Bishop	4.2	13.1	30.9	45.9	58.5	65.8	70.6	75.6	81.1	88.9	95.0	100
4 China Lake	5.9	14.3	27.5	41.3	54.3	65.3	72.0	78.9	84.7	90.7	95.5	100
5 Daggett	3.2	11.8	27.8	42.7	62.6	72.9	79.4	84.4	89.6	94.0	98.1	100
6 El Centro	5.4	13.8	27.9	45.0	64.9	79.9	83.0	85.6	88.9	92.7	97.0	100
7 Eureka	9.1	20.6	35.3	49.2	65.8	75.8	79.7	81.8	84.3	88.3	93.3	100
8 Fairfield	2.5	6.4	11.1	17.7	28.5	44.4	63.8	79.7	90.3	95.6	98.2	100
9 Fresno	3.7	9.4	25.0	41.8	64.9	86.4	91.4	93.1	94.2	96.6	98.0	100
10 Imperial Beach	9.9	22.5	36.6	50.3	61.2	68.8	74.4	78.5	82.2	85.7	93.5	100
11 Lemoore	9.2	22.0	37.7	51.0	61.5	71.5	73.8	75.1	77.4	86.3	91.8	100
12 Livermoore	7.1	14.3	22.1	30.6	42.6	56.7	70.1	80.7	87.8	93.0	96.2	100
13 Long Beach	5.6	19.9	40.2	59.2	69.4	73.5	76.3	80.3	84.8	89.2	95.7	100
14 Merced	13.2	29.3	45.5	58.3	65.1	72.6	74.1	75.3	77.3	83.1	90.0	100
15 Montague	11.7	24.6	39.4	53.0	61.8	65.9	69.6	72.5	76.1	83.1	92.5	100
16 Monterey	8.1	17.6	32.8	49.2	64.7	73.5	76.9	81.0	83.2	86.5	90.0	100
17 Needles	9.5	22.0	34.2	45.3	54.9	63.0	66.8	71.2	74.6	81.1	89.8	100
18 Oakland	6.9	19.6	30.9	44.0	58.8	70.2	75.4	80.1	85.2	91.1	95.2	100
19 Oceanside	17.1	32.7	45.5	52.8	57.7	61.3	63.7	66.2	71.0	75.8	85.8	100
20 Oxnard	14.5	27.5	38.5	47.9	56.5	58.9	59.4	60.0	61.3	65.9	76.8	100
21 Palmdale	5.4	12.2	25.7	39.2	52.5	65.3	74.1	80.7	85.2	89.0	94.0	100
22 Paso Robles	3.4	6.9	12.5	21.5	34.9	53.6	70.9	82.7	89.9	94.2	97.5	100
23 Redding	7.6	18.5	31.0	40.3	51.1	62.0	68.0	72.6	78.7	84.7	92.4	100
24 Riverside	7.4	17.0	24.7	33.5	42.9	52.5	63.9	74.9	82.6	88.0	93.5	100
25 Sacramento	16.9	32.9	44.9	51.6	58.1	64.9	66.8	68.6	70.9	78.1	87.5	100
26 San Francisco	3.4	9.1	18.1	29.8	44.4	59.4	70.9	80.9	88.3	94.6	97.3	100
27 San Rafael	13.4	25.0	36.3	46.4	54.3	62.0	66.0	70.5	74.3	80.7	87.3	100
28 Sunnyvale	8.6	17.4	25.9	35.6	46.3	60.3	69.0	76.8	82.4	87.7	92.0	100
29 Thermal	1.2	4.7	11.8	25.8	45.0	59.5	70.4	79.6	89.7	95.4	98.9	100
30 Vandenberg	6.3	13.5	29.8	46.7	68.4	76.5	78.1	79.7	83.6	89.0	94.9	100
31 Williams	19.3	39.7	61.1	66.2	72.3	77.8	80.5	82.2	84.8	89.4	94.4	100
Idaho												
1 Boise	13.5	26.7	42.7	56.2	64.3	69.0	71.3	72.9	75.1	80.0	88.0	100
2 Burley	12.5	22.5	39.3	52.3	62.3	68.4	71.7	73.8	77.1	82.4	89.4	100
3 Idaho Falls	10.2	18.1	34.2	48.9	59.8	69.2	71.6	74.1	80.9	88.9	96.4	100
4 King Hill	8.4	16.8	31.7	45.7	58.8	66.9	72.9	75.3	82.0	87.6	93.6	100
5 Mountain Home	7.8	18.9	31.8	46.7	57.6	66.1	71.7	75.8	80.5	87.6	93.4	100
6 Pocatello	13.3	26.5	38.9	51.1	59.4	67.0	70.9	74.0	77.8	81.7	89.7	100
7 Twin Falls	11.2	23.2	39.3	55.4	63.9	70.0	72.0	73.6	76.2	81.4	88.7	100
8 Strevell	23.3	44.6	51.8	58.3	64.0	69.0	72.9	76.4	80.3	84.2	91.5	100
Nevada												
1 Beowawe	5.6	17.4	31.9	45.0	56.8	66.1	74.1	80.9	86.5	92.2	95.5	100
2 Buffalo Valley	9.3	24.8	37.4	47.6	57.8	67.5	74.1	78.7	82.7	88.4	94.4	100
3 Elko	6.5	14.1	25.3	35.2	46.4	57.6	67.6	75.2	82.8	90.4	94.7	100
4 Fallon	11.1	22.2	40.9	58.6	69.7	77.1	78.8	80.1	82.3	87.3	91.6	100
5 Las Vegas	6.8	15.5	29.2	42.8	54.6	66.1	71.9	77.8	82.6	88.4	94.6	100
6 Lovelock	13.2	19.7	34.6	46.3	56.5	69.3	77.7	83.7	87.6	93.4	96.5	100
7 Reno	9.0	18.3	32.3	45.6	56.5	65.1	71.3	77.1	81.4	87.7	92.8	100
8 Tonopah	5.3	15.9	31.7	47.4	60.6	69.5	74.0	78.0	82.7	88.5	94.4	100
9 Ventosa	12.5	27.5	44.0	60.6	75.5	79.6	83.3	86.6	90.0	93.0	96.3	100
10 Winnemucca	6.7	15.9	30.3	44.6	56.4	65.8	73.1	79.7	84.8	93.0	95.9	100

Table continued on next page

Table 1. Percentage of the average annual erosive wind energy that normally occurs by the indicated dates. Computed for the locations shown in figure 1 (except Alaska).

Location and Number	*Feb. 1*	*Mar. 1*	*Apr. 1*	*May 1*	*June 1*	*July 1*	*Aug. 1*	*Sept. 1*	*Oct. 1*	*Nov. 1*	*Dec. 1*	*Jan. 1*
Oregon												
1 Astoria	16.6	29.6	40.0	48.6	53.3	57.5	61.4	65.4	68.9	74.8	87.0	100
2 Baker	11.3	33.0	44.3	66.0	77.4	77.4	77.4	77.4	77.4	88.7	88.7	100
3 Burns	13.7	24.1	40.6	53.8	56.1	61.5	63.8	64.9	68.3	75.8	89.1	100
4 Cascade Locks	11.4	24.8	30.8	36.6	43.1	49.3	56.3	62.5	68.8	77.5	88.6	100
5 Eugene	9.6	20.5	33.7	43.3	49.7	55.2	62.9	68.8	77.1	82.2	91.2	100
6 Klamath Falls	13.4	24.5	38.7	50.8	58.0	62.1	64.7	67.5	70.8	78.0	88.0	100
7 LaGrande	18.4	34.0	44.3	51.8	56.3	58.7	60.5	62.4	65.3	70.2	82.2	100
8 Ontario	3.6	8.7	16.2	44.4	57.2	65.5	74.7	84.8	89.9	95.0	97.9	100
9 Pendleton Field	4.4	15.6	29.1	42.6	53.7	66.4	73.2	79.0	84.5	87.1	92.2	100
10 Portland	23.0	39.0	50.8	55.7	57.3	58.3	59.3	60.0	61.4	65.5	78.4	100
11 Redmond	13.4	30.6	44.4	55.4	62.5	66.2	68.2	70.2	75.2	79.6	90.4	100
12 Roseburg	0	0.1	99.7	99.7	99.7	99.8	99.8	99.9	99.9	99.9	100.0	100
13 Salem	23.1	40.4	50.6	55.7	57.9	58.8	60.5	61.3	63.0	66.7	80.3	100
14 Sexton Summit	13.1	24.1	33.3	40.2	44.9	49.9	55.3	61.1	70.6	74.9	87.6	100
15 Siskiyou Summit	6.4	15.5	22.7	27.4	38.4	52.3	69.4	79.4	86.7	89.8	95.3	100
Utah												
1 Bryce Canyon	9.1	17.1	32.6	44.4	59.9	74.5	77.6	81.5	86.3	90.2	95.4	100
2 Hanksville	6.1	11.7	29.7	42.8	57.9	75.0	77.5	81.0	86.3	92.0	96.9	100
3 Locomotive Springs	3.6	8.0	24.8	40.1	58.3	67.4	75.3	83.5	89.7	93.7	97.4	100
4 Milford	3.7	14.6	24.6	37.8	52.2	63.0	72.7	76.2	82.9	90.0	97.1	100
5 Ogden	7.7	15.8	24.9	33.5	42.7	51.0	59.4	68.5	77.3	86.1	92.9	100
6 Salt Lake City	8.8	19.4	32.7	43.2	53.0	63.6	69.5	81.4	85.5	88.8	93.5	100
7 St. George	3.3	10.3	28.0	40.6	54.1	69.8	77.2	87.1	90.3	92.2	97.0	100
8 Tooele	6.6	15.2	28.0	42.1	54.0	64.5	70.5	78.3	84.5	90.2	95.0	100
9 Wendover	8.7	18.1	33.7	50.5	60.7	69.5	74.0	79.1	82.7	87.4	94.3	100
Washington												
1 Bellingham	16.8	37.7	50.6	56.8	58.8	60.6	61.8	62.9	63.5	70.7	83.9	100
2 Chehalis	18.0	30.7	41.7	47.8	52.8	55.6	58.7	61.8	64.9	71.0	82.0	100
3 Everett	17.8	32.9	45.8	53.9	56.9	59.5	61.6	62.8	67.0	72.2	84.5	100
4 Hoquiam	21.5	35.8	47.6	55.0	62.0	63.6	66.1	68.3	70.8	79.2	87.5	100
5 Moses Lake	9.7	18.2	33.7	47.9	56.7	65.8	70.1	72.9	79.4	86.1	92.7	100
6 Seattle	20.3	36.4	49.6	56.5	57.8	58.4	58.6	58.9	60.6	67.8	79.9	100
7 Spokane	12.8	28.6	41.7	53.6	59.5	63.9	66.2	68.3	71.6	76.9	87.3	100
8 Tacoma	16.6	30.7	45.2	55.5	60.5	62.6	63.8	65.0	68.3	75.5	87.7	100
9 Walla Walla	14.0	28.9	45.5	56.5	61.5	64.8	66.7	68.6	70.8	73.4	86.0	100
10 Yakima	8.0	14.4	36.1	65.7	80.2	88.2	90.2	91.3	92.9	95.6	97.8	100

data (2). Equations for computing the C factors are

$$C = 386 \frac{\bar{u}_z^3}{\left[\sum_{i=1}^{i=12} 10(P\text{-}E)_i\right]^2} \qquad [1]$$

where $\bar{u}_z$ is average annual windspeed in meters per second at a height of 9.1 meters (30 feet), i represents months, and

$$10(P\text{-}E) = 115\left(\frac{P/2.54}{1.8T+22}\right)^{10/9}$$

$$P \geq 1.27 \text{ cm (0.5 in)}; \qquad [2]$$
$$T \geq -1.7°C \text{ (28.4°F)}$$

where P is normal monthly precipitation in centimeters and T is normal monthly temperature in °C. The denominator in equation 1 is called the Thornthwaite precipitation-evaporation index (6). The restriction on precipitation in equation 2 assumes that monthly amounts less than 1.27 centimeters (0.5 inch) do not increase the wind erosion potential. Consequently, if P is less than 1.27 centimeters, use 1.27. Also, the restriction on precipitation prevents C from becoming unreasonably large in desert climates (as P-E index approaches zero, C approaches infinity). Chepil and associates (2) adopted Thornthwaite's restriction on temperature in computing the P-E index, although Thornthwaite's reasoning does not fully apply to wind erosion potential. He was primarily concerned about correlating climate with plant growth. However, at temperatures below freezing, evaporation rates are low and precipitation that occurs is in the solid state. The temperature limit also overcomes the problem of dealing with negative numbers in computing the P-E index.

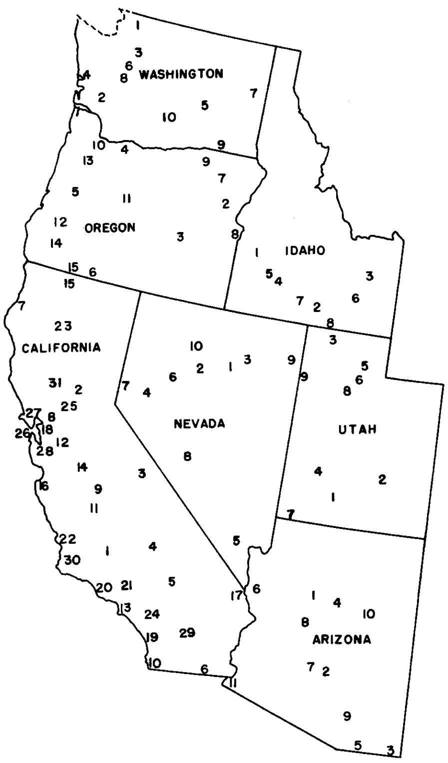

Figure 1. Key map of West for location of applicable erosive wind-energy distribution data from table 1.

I obtained the 1941-1970 monthly normals of temperature and precipitation by state from the National Climatic Center, Asheville, North Carolina. Various wind data sources were used (3, 5, 7). Because the trend for measuring wind is to standardize the height at 10 meters (33 feet), I adjusted the data to that height (if actual heights were known) by using a power law exponent of 1/7 in the equation describing the windspeed profile.[1] However, for several locations the actual height of wind measurements was unknown.

Results and discussion

Table 1 gives erosive wind energy data for the West (including Alaska). These

[1]Elliott, D. L. 1979. "Adjustment and Analysis of Data for Regional Wind Energy Assessments." Paper presented at the Workshop on Wind Climate, Asheville, N.C., November 12-13.

data (except for Alaska) are related to the key map in figure 1. Individual locations show extremes of 40.4 percent (Barrow, Alaska) and 99.8 percent (Roseburg, Oregon) of annual erosive wind energy occurring in the first six months. Of the states evaluated, Arizona shows the most erosive wind energy occurring during the first six months while Alaska shows the least (Table 1).

Data in table 1 would be used according to the equation:

$$(E)_p = (EWE)_p\,(E)_a \qquad [3]$$

where $(E)_p$ is the estimated erosion during a given period, $(EWE)_p$ is the proportion of erosive wind energy occurring during the period at a particular location, and $(E)_a$ is the estimated annual erosion obtained from solving the wind erosion equation using period input data for all factors except the climatic factor. For example, assume the location is Big Delta, Alaska, and the period is January through March. Then $(EWE)_p$ equals 0.43 (Table 1), that is, 43 percent of the erosive wind energy occurs during that period.

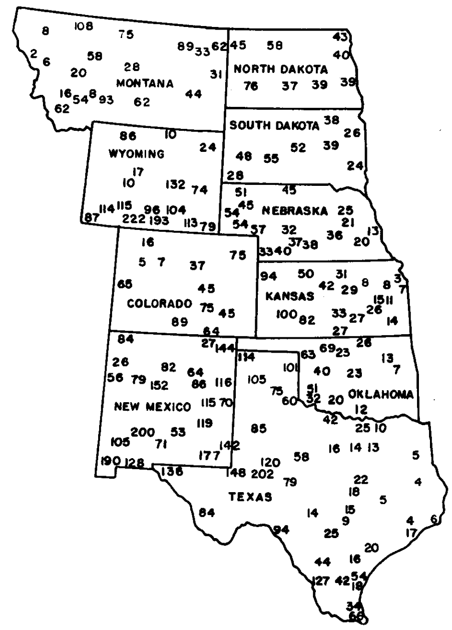

Figure 2. Annual climatic factor (C) in percent for the Great Plains.

Figures 2 and 3 show all the C-factor data (Alaska C-factors are given in table 2). I made no attempt to draw isolines on the maps. Knowledge of terrain features and local climate would be needed to make judgments about how far the point data can be extended areawise.

To illustrate how the monthly precipitation limit of 1.27 centimeters (0.5 inch) influences C-factors in dry climates, I chose Daggett, El Centro, and Thermal, California, and calculated the following C-factors using actual monthly precipitation normals: 2,222, 2,856, and 2,446, respectively. Those values correspond to 975, 445, and 483 using the 1.27 centimeters (0.5 inch) limit (Figure 3). The lower values appear more reasonable for those locations.

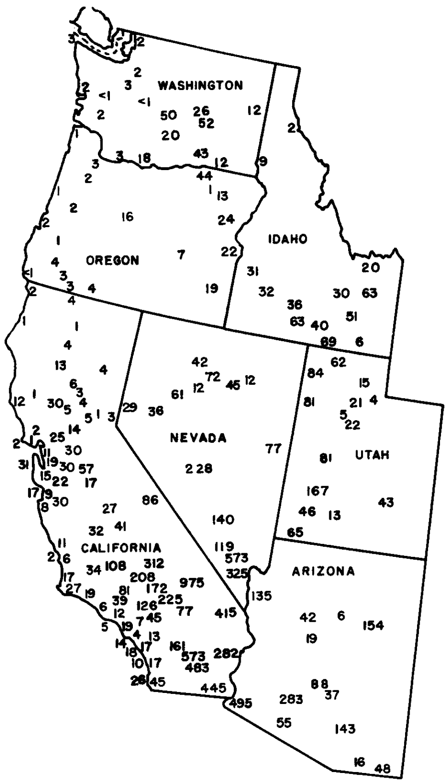

Figure 3. Annual climatic factor (C) in percent for the West.

Both erosive wind energy and C factors should be useful in improving design and evaluation of wind erosion control systems. These data should also be useful in future national erosion inventories and as input to a wind erosion component of an erosion-productivity model now under development by the Agricultural Research Service.

Table 2. Annual C factors for Alaska.

Location	*C-factor (%)*
Anchorage	9
Aniak	4
Annette	1
Barrow	89
Barter Island	84
Bethel	42
Bettles	6
Big Delta	32
Cold Bay	16
Cordova	<1
Elmdorf	2*
Fairbanks	14
Galena	4
Gulkana	11
Homer	2
Juneau	1
Kenai	5
King Salmon	15
Kodiak	1
Kotzebue	87
McGrath	2
Minchumina	4
Nenana	9
Nome	17
Northway	3
Petersburg	<1
St. Paul Island	20*
Shemya	40
Sitka	<1
Summit	7
Talkeetna	1
Tanana	5
Unalakleet	40
Yukutat	<1

*Less than 5 years of wind data.

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