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PUTTING WIND RESOURCE ATLASES TO USE

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ABSTRACT

An assessment of an area's wind resource and proper site selection are critical to the successful utilization of wind energy. This paper describes how the twelve recently published wind energy resource atlases for the United States and its territories can be used to evaluate various aspects of an area's wind resource. Interpretation of information in the atlas on various geographic scales (regional, state and station) and time scales (annual, seasonal and diurnal) is discussed. In addition to techniques for extracting the magnitude of the wind resource, methods are presented for estimating the seasonal and diurnal variations of the wind resource for an area, the certainty with which the resource has been estimated and the fraction of land area with a given wind resource.

INTRODUCTION

Wind energy resource atlases have been produced for 12 regions of the United States and its territories. The atlases depict various aspects of the wind resource in graphic, tabular and narrative form. Major users of wind energy resource atlases include: local, state and federal agencies involved in energy planning, private power producers, electric utilities and cooperatives, wind turbine manufacturers and distributors, and energy organizations. The atlases are intended to meet the needs of these and a variety of other users. For ease in use and interpretation, the atlases have been structured in a standard format. Moreover, the atlases were produced using comparable data sets, analysis techniques and presentations to ensure the comparability of the wind resource assessments. For convenience, information on the wind resource is summarized at regional, state, and local scales; however, the assessments are not intended to be site specific. Supplemental information, such as the degree of certainty in the resource estimates and the land area represented by the assessment values, is provided to aid in the interpretation of the resource assessments.

The wind energy resource assessments are based primarily on readily available, summarized, near-surface wind data; upper-air data contri-

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buted to the assessments in mountainous areas. The data used in the assessments were obtained from various sources: the National Climatic Center (NCC), the U.S. Forest Service, universities, utilities, and other government and private organizations. The National Climatic Center offered the largest collection of wind data [1]. Screening procedures were applied to identify stations with the most useful data and to eliminate stations that would not significantly contribute information on the resource.

For the purpose of estimating the geographical variation of the wind resource, wind energy flux was chosen over wind speed since the energy flux incorporates in a single number the combined effect of the distribution of wind speeds and the dependence of the energy flux on air density and on the cube of the wind speed. For locations for which the distribution of wind speeds was not available, the energy flux was estimated by assuming the speed distribution followed a Rayleigh distribution [2]. Qualitative indicators of the wind resource aided in estimating the magnitude and extent of the resource in some data-sparse areas. These indicators included the identification of certain combinations of topographical and meteorological features [3], areas containing eolian landforms [4], and areas with flagged trees [5].

The analysis of the wind energy is shown on maps using wind power classes. Each wind power class represents a range of wind energy fluxes (or wind power densities) likely to be encountered. Table 1 gives the wind power classes used in the regional atlases for the 10-m and 50-m reference levels. A 1/7 power law for mean wind speed and 3/7 power law for mean wind energy flux relates the 50-m estimates to the 10-m estimates.

TABLE 1. CLASSES OF WIND POWER DENSITY AT 10 m AND 50 m[(a)]

	10 m (33 ft)		50 m (164 ft)	
Wind Power Class	Wind Power Density, watts/m²	Speed,[(b)] m/s (mph)	Wind Power Density, watts/m²	Speed,[(b)] m/s (mph)
	0	0	0	0
1	100	4.4 (9.8)	200	5.6 (12.5)
2	150	5.1 (11.5)	300	6.4 (14.3)
3	200	5.6 (12.5)	400	7.0 (15.7)
4	250	6.0 (13.4)	500	7.5 (16.8)
5	300	6.4 (14.3)	600	8.0 (17.9)
6	400	7.0 (15.7)	800	8.8 (19.7)
7	1000	9.4 (21.1)	2000	11.9 (26.6)

(a) Vertical extrapolation of wind speed based on the 1/7 power law.
(b) Mean wind speed is based on Rayleigh speed distribution of equivalent mean wind power density. Wind speed is for standard sea-level conditions. To maintain the same power density, speed increases 5%/5000 ft (3%/1000 m) of elevation.

The analyses of the wind energy resource apply to terrain features that are well exposed to the wind, such as plains, tablelands, hilltops, ridge crests and mountain summits. In wooded or urban areas, the assessment values represent large clearings that are relatively free of obstructions to the wind (e.g., grass, no trees or buildings in immediate vicinity). Local terrain features may interact with the windfield to cause the wind energy to vary considerably over short distances, especially in coastal, hilly, and mountainous areas. Thus, there may be local areas of higher or lower wind energy than can be shown on the maps. Maps depicting the degree of certainty of the resource estimates are included and should be used in combination with the resource maps.

Because the wind energy estimate generally applies to well-exposed locations, the fraction of the land area represented by the wind power class depends on the physical characteristics of the land-surface form. For example, on a flat open plain close to 100% of the area will have a similar wind power class, while in hilly and mountainous terrain the wind power class will only apply to that small proportion of the land area that is well exposed. Areal distribution maps show the percentage of land area with or exceeding a given wind power class.

The objectives of this paper are to demonstrate the use of the regional atlases to determine six aspects of the wind resource: 1) the magnitude of the wind resource; 2) the certainty of the resource estimate; 3) the fraction of land area that the resource estimate represents; 4) the seasonal variation of the resource; 5) the diurnal variation of the resource; and 6) the prevailing wind direction(s) of the wind resource. The primary intent of this exercise is to provide the user with a better understanding of how to interpret and use the information in the atlases for estimating various aspects of the wind resource in his geographic area of interest.

Assessment Area Selected

For demonstrating the use of the resource atlases, an area roughly 100 miles by 100 miles in size has been selected. The area has a wide diversity of land-surface forms, ranging from open plains to high mountains, and a wide range in wind resource estimates and in degrees of certainty of the estimates. Across the nation, numerous types of areas exist, ranging from flat, smooth plains with a fairly uniform wind resource over a large area to mountainous and coastal regions where the resource can vary dramatically over short distances (1 to 5 km). However, this area was chosen as a prime example to demonstrate the interpretation and use of the resource atlases in a variety of scenarios.

Estimating the Magnitude of Annual Wind Resource

Figure 1 shows the estimated annual average wind resource at exposed locations in the assessment area. The numbers on the figure refer to the wind power classes given in Table 1. The assessment area is

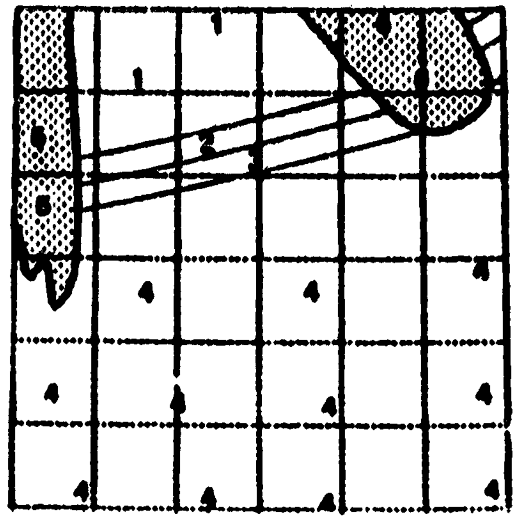
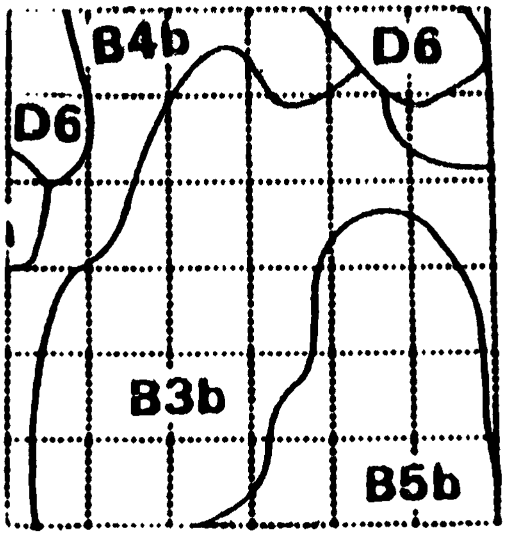


FIGURE 1. ANNUAL AVERAGE WIND RESOURCE. NUMBERS REPRESENT CLASSES OF WIND POWER, WITH "1" THE LOWEST AND "7" THE HIGHEST.

divided into grid cells; each grid cell is 1/4° latitude by 1/3° longitude, which in this case is roughly 17 miles on a side. In the atlases, the grid cells are 1/4° latitude by 1/3° longitude in the conterminous United States, 1/2° latitude by 1° longitude in Alaska, and 1/8° latitude by 1/8° longitude in Hawaii and Puerto Rico. The east-west dimensions of the grid cells vary in size with latitude. The primary purpose of the grids is to aid in locating the area of interest and for ease in switching from one map to another; they are not intended for precise positioning.

A topographic map should be used to determine the relative exposure of the area of interest. Is the area in a lowland or river valley, on a tableland, plateau, or hilltop, or on an open plain with little local relief? A large-scale topographic map, such as a 1:250,000 scale, should be used to determine the relative exposure with respect to major terrain features. In producing the wind resource assessments, sectional aeronautical charts, 1:500,000 scale, were valuable in evaluating general exposure of locations from which data were commonly available. Small-scale topographic maps, such as 15-min maps (1:24,000) can be used to determine local exposure with respect to small-scale features (e.g., bluffs, small hills, etc.).

The analysis shows that class 4 wind power is estimated for exposed areas over most of the region in Figure 1, with areas of class 1, 5, and 6 wind power in the northern portion. What exposed features do the map values represent? Figure 2 is a land-surface form map, which shows the general character of the terrain [6]. Table 2 gives the exposed feature represented by the map value for a variety of land-surface forms. As shown in Figure 2, the region of interest is primarily composed of plains with hills, high hills, and low mountains, and two areas of high mountains. The class 5 and 6 areas on the wind resource map in Figure 1 are shaded, which means that the estimates are for exposed ridge crests and mountain summits. Referring back to the



B3b - Plains with Hills

B4b - Plains with High Hills

B5b - Plains with Low Mountains

D6 - High Mountains

FIGURE 2. LAND-SURFACE FORM

TABLE 2. LAND-SURFACE FORM TERRAIN FEATURES REPRESENTATIVE OF EXPOSED LOCATIONS

Land-Surface Form	Exposed Feature (Map Value)	Percentage Area[a]
Plains: A1; B1,2	Plains	93
Plains With Hills: A, B3a,b	Open Plains	79
Plains With Mountains: B4-6a,b	Plains (not shaded)[b]	67
	Ridge Crests and Mountain Summits (shaded)	10
Tablelands: B3-6c,d	Tablelands, uplands	80
Open Hills: C2-4	Hilltops and Uplands	27
Open Mountains: C5-6	Broad Valleys (not shaded)	80
	Ridge Crests and Mountain Summits (shaded)	12
Hills: D3-4	Hilltops and Uplands	9
Mountains: D5-6	Ridge Crests and Mountain Summits (shaded)	3

(a) Percentage represents an average over the land-surface forms found in the region.
(b) Shaded areas on the wind maps, emphasize that map values are estimates for ridge crests and mountain summit locations.

land-surface form map, we find that these class 5 and 6 areas are generally high mountains with vertical relief of 900 to 1500 m (3000 to 5000 ft). Valleys and canyons in these areas will generally have considerably lower wind resource, e.g., only class 1 or 2 power.

Over the remainder of the wind resource map, the class 1 through 4 estimates mostly represent exposed plains (see Figure 2 and Table 2). Hills and low mountains are scattered throughout portions of the plains, as indicated by the land-surface form map. However, these smaller-scale terrain features are not shown on the wind resource map. Hilltops and ridge crests within the plains area may have at least one or two classes higher wind power than that of the plains. Conversely, locations that are in small depressions or are shielded by local terrain features (e.g., hills, mesas, low mountains) will have lower wind power than that indicated by the map values.

As an example of how local terrain effects the wind resource, consider stations A and B in Figure 3. These are two stations with long-term (5 yr or more) digitized hourly or 3-hourly wind data. Both are located in plains areas that are estimated to have the same wind resource (class 4). Table 3 lists the 10-m annual average wind speed and power computed from the hourly data for the two stations. Station A has considerably higher wind power than Station B. Station A has about the same wind resource (class 4-5) as that indicated by the wind resource map, whereas Station B has a lower wind resource (class 2-3). Why is one station represented by the wind power class given in Figure 1 and not the other station, even though both stations are supposedly in the plains? Consulting the station descriptions given in the wind energy resource atlas and identifying the station locations on topographic maps, one finds that Station A is better exposed to the prevailing strong winds than Station B. Station A is located on a plateau that is well-exposed to the wind. Station B, however, is located in a shallow basin with hills and ridges 10 to 15 km away in nearly all directions. Westerly winds (which are the prevailing strong winds in that region) at Station B appear to be diminished by hills and ridges which are about 300 to 400 m (1000 to 1200 ft) higher than the station. Thus, Station A appears representative of the wind resource at well-exposed sites in the open plains, whereas Station B is not so well exposed. Nevertheless, the wind resource information for Station B was still used in qualitatively estimating the wind resource at exposed areas near Station B, assuming that a well-exposed site should have about 1 to 2 classes greater wind power than Station B. Of course, the certainty of the resource at exposed areas is greater near Station A than near Station B. The following section discusses how to use and interpret the certainty rating maps.

Certainty Rating of the Wind Resource

The degree of certainty with which the wind power class at exposed sites can be specified depends on three factors: 1) the abundance and quality of wind data; 2) the complexity of the terrain; and 3) the geographical variability of the resource.

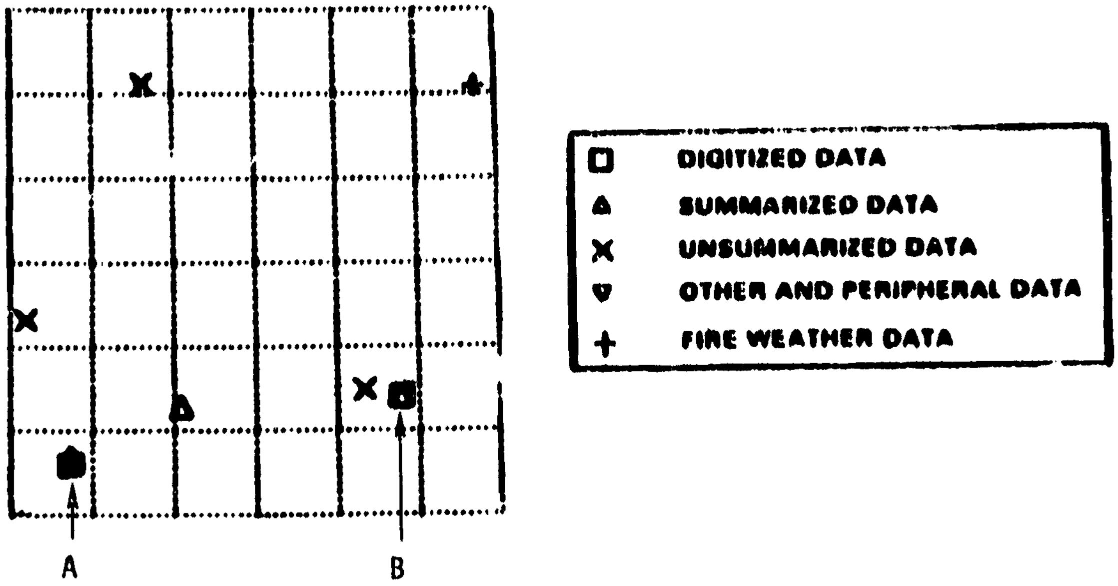


FIGURE 3. STATIONS USED IN ASSESSMENT AREA

TABLE 3. ANNUAL AVERAGE WIND SPEED AND POWER AT TWO STATIONS IN AREA

Station	10 m Speed (m/s)	10 m Power (W/m^2)	Power Class[(a)]
A	6.1	242	4-5
B	5.3	167	2-3

(a) Power class determined from 10 m power $\pm$ 25 W/m^2

In the atlases, a certainty rating from 1 (low) to 4 (high) of wind energy resource estimate is given for each grid cell. Certainty ratings are shown in Figure 4 for the area of interest. The assignment of a certainty rating, as defined in Table 4, requires the subjective evaluation of the factors involved. In Figure 4, the certainty ratings of the resource estimates range from 1 (low) to 4 (high). A certainty of 1 has been assigned to that region where the wind resource estimates change from class 4 to class 1 and no data exists at exposed sites. The only cells with a high certainty of the wind resource estimate are near Station A, where data from this well-exposed site can be confidently applied to estimate the resource in nearby areas because of the low complexity of the terrain and low variability of the resource. Other cells in which stations exist have been assigned a certainty of 2 or 3. Some of the stations may have limited data (e.g., unsummarized, daytime only, short period of record, etc.) which can only be used as an indicator of the wind resource. Other stations, such as Station B, may not be representative of a well-exposed site, but serve as a qualitative indicator for estimating the resource at exposed areas. The

2	3	2	2	2	2
2	1	1	1	1	1
2	1	1	1	1	2
2	2	2	2	2	2
3	3	3	3	3	3
4	4	3	2	2	2

FIGURE 4. CERTAINTY RATING OF RESOURCE. NUMBERS REPRESENT DEGREE OF CERTAINTY OF THE WIND RESOURCE: 1 - LOW; 2 - LOW-INTERMEDIATE; 3 - HIGH-INTERMEDIATE; 4 - HIGH.

TABLE 4. CERTAINTY RATING LEGEND

Rating	Definition
1	The lowest degree of certainty. A combination of the following conditions exists: 1) No data exist in the vicinity of the cell. 2) The terrain is highly complex. 3) Various meteorological and topographical indicators suggest a high level of variability of the resource within the cell.
2	A low intermediate degree of certainty. One of the following conditions exists: 1) Little or no data exist in or near the cell, but the small variability of the resource and the low complexity of the terrain suggest that the wind resource will not differ substantially from the resource in nearby areas with data. 2) Limited data exist in the vicinity of the cell, but the terrain is highly complex or the mesoscale variability of the resource is large.
3	A high intermediate degree of certainty. One of the following conditions exists: 1) There are limited wind data in the vicinity of the cell, but the low complexity of terrain and the small mesoscale variability of the resource indicate little departure from the wind resource in nearby areas with data. 2) Considerable wind data exist but in moderately complex terrain and/or in areas where moderate variability of the resource is likely to occur.
4	The highest degree of certainty. Quantitative data exist at exposed sites in the vicinity of the cell and can be confidently applied to exposed areas in the cell because of the low complexity of terrain and low spatial variability of the resource.

ridge crest and mountain summit resource estimates (the shaded areas in Figure 1) were assigned a certainty rating of 2, because upper air data were used to approximate the resource in these areas.

Each state chapter in the resource atlases contains a description of the certainty rating maps and usually includes interpretations on the certainty rating assigned. Because the certainty rating required the subjective evaluation of the interaction of the factors involved, there may be some variation among the different regional atlases in the evaluation of the various factors and in the certainty ratings assigned. For these reasons, certainty ratings may not always match along state or regional borders.

The wind resource maps should always be used in combination with the certainty rating maps. In areas of high certainty, one should not imply that the resource is known and that no further information or data is required. The assessments are not site specific. Moreover, assumptions on the representativeness and exposure of a station's data may, in some cases, bias the estimates. Influences of local obstructions, such as trees, buildings, and terrain, are usually unknown. In some cases, apparently well-exposed stations with long-term data (e.g., 10 to 30 yr) have been found to show questionable trends, such as increasing or decreasing mean wind speeds over a long period of time. This is not to say that measurements at the prospective site are always needed to improve the certainty of the resource. What's important is to understand the particular set(s) of data and information that were used in estimating the resource in the area of interest and to understand the meteorology of the area. Over regions of extreme variability in the resource, an almost infinite number of measurement stations may be needed to fully characterize the resource over the area; whereas over flat regions of uniform resource, few, if any, additional measurement stations may be needed, provided the data used are actually representative in the first place.

Estimating the Areal Distribution of the Resource

Because the wind power class values shown on the maps apply only to areas well exposed to the wind, the map area does not indicate the true land area experiencing this power. The fraction of the land area represented by the wind power class depends on the physical characteristics of the land-surface form. For example, on a flat open plain close to 100% of the area will have a similar wind power class, while in hilly and mountainous areas the wind power class will only apply to a small proportion of the area that is well exposed. For each land-surface form, the fraction of land area that would be representative of exposed locations has been estimated (see Table 2 for averages in various land-surface forms). Furthermore, to be able to establish a wind power class for the remaining area, it was also necessary to determine a factor by which the wind power was reduced in the less exposed areas or increased in better exposed areas (e.g., isolated hills and ridges that rise above a plain may experience a higher wind power class than the map indicates). To adjust the wind energy flux from the map value to the various exposure categories, the energy flux was scaled to be 1) greater than, 2) equal to, 3) slightly less than, and 4) much less than the map value. Greater detail on these scaling and partitioning procedures are given in the wind energy resource atlases.

In the regional atlases, a representation of the areal distribution is given in a map that indicates the percentage land area in a cell over which the wind power class equals or exceeds a threshold value. Four maps are shown in the chapters on the state wind resources for threshold values of classes 2, 3, 4, and 5. These maps refer only to the annual average resource.

For the area of interest, Figure 5 shows the estimated percent land area in each cell with or exceeding power class 4. Over much of the B3b area (plains with hills - see Figure 2), 80% of the land area is estimated to have wind power class 4 or higher. However, only 2% of the land area is estimated to have class 4 or higher power in the mountainous regions indicating class 5 and 6 wind resource in Figure 1. If a cell contained two or more land-surface forms, then the land-surface form which occupied most of the cell to which the map value pertained was generally chosen. The areal distribution derived from the wind power and land-surface form maps must be considered only an approximation. The quantity and quality of wind data and topographic information required to make a highly accurate appraisal of the areal distribution of the wind resource are far beyond the scope of these assessments.

CLASS 4

2	0	0	0	2	2
2	0	0	5	5	65
10	68	80	80	80	80
68	80	80	80	65	65
68	80	80	80	65	65
68	80	80	80	65	65

FIGURE 5. AREAL DISTRIBUTION OF RESOURCE. NUMBERS REPRESENT PERCENT LAND AREA WITH OR EXCEEDING WIND POWER CLASS 4.

Estimating the Seasonal Variation of the Resource

In each state chapter of the regional atlases, maps of the average wind power class are presented for each season: winter (December, January, February); spring (March, April, May); summer (June, July, August); and autumn (September, October, November). For the area of interest, the four seasonal maps are shown in Figure 6. On these maps, the northern basin shows little seasonal variation (class 1 and 2 throughout the year), whereas the wind resource over most of the plains varies from class 6 in winter to only class 2 in summer. This exemplifies the fact that seasonal variation can vary over short distances. Local variations in the wind resource (of a scale too small to be shown on these maps) are often greater in winter than other seasons, as a result of more stable atmospheric conditions. Moreover, the 1/7 power law (3/7 for energy flux) may not be as applicable to vertically adjusting the seasonal average wind resource estimates as it is to the annual average resource. However, the 1/7 power law was used nationwide for the adjusting seasonal average resource estimates because of the lack of sufficient information on the geographical and seasonal variation of the wind profile with height at exposed sites. Thus, the certainty ratings of the seasonal average resource estimates (which have not been determined in these regional assessments) are expected to be lower, in general, than the certainty ratings of the annual average wind resource. Moreover, the distribution of the certainty ratings may change seasonally as the distribution of the wind resource estimates change, e.g., as the spatial variability of the resource over an area increases, the certainty of the resource in that area usually decreases.

To evaluate seasonal trends more directly for a particular area or cell, one could plot the wind power class values for each season and connect the points. For adjusting the seasonal estimates to better or less exposed areas than that typically represented by the map value, one should keep in mind that the variations in resource with terrain height and local terrain influences are usually greater during the colder (more stable) months. As an example here, the difference in the wind resource between Station A (well exposed) and Station B (in a shallow basin) is greater in the winter than in the spring. Station A's winter and spring average wind energy fluxes are 366 W/m^2 (class 6) and 244 W/m^2 (class 4-5), respectively, while Station B's are 235 W/m^2 (class 4-5) and 198 W/m^2 (class 3-4), respectively. Thus, the ratio of the winter to spring wind energy flux is 1.50 at Station A and 1.19 at Station B, which indicates that the seasonal trends of the wind resource vary locally as terrain and exposure conditions vary. This effect is highly pronounced between ridge crests and valley bottoms, which may have opposite seasonal trends in wind resource.

In the regional atlases, graphs of monthly average wind power and speed for selected stations with digitized hourly or 3-hourly data are presented. Caution should be used in the interpretation and application of these graphs. Stations with less than 5 yr of observations may not show reliable monthly or seasonal trends. Also, stations in complex terrain may not represent the monthly/seasonal trends in nearby areas.

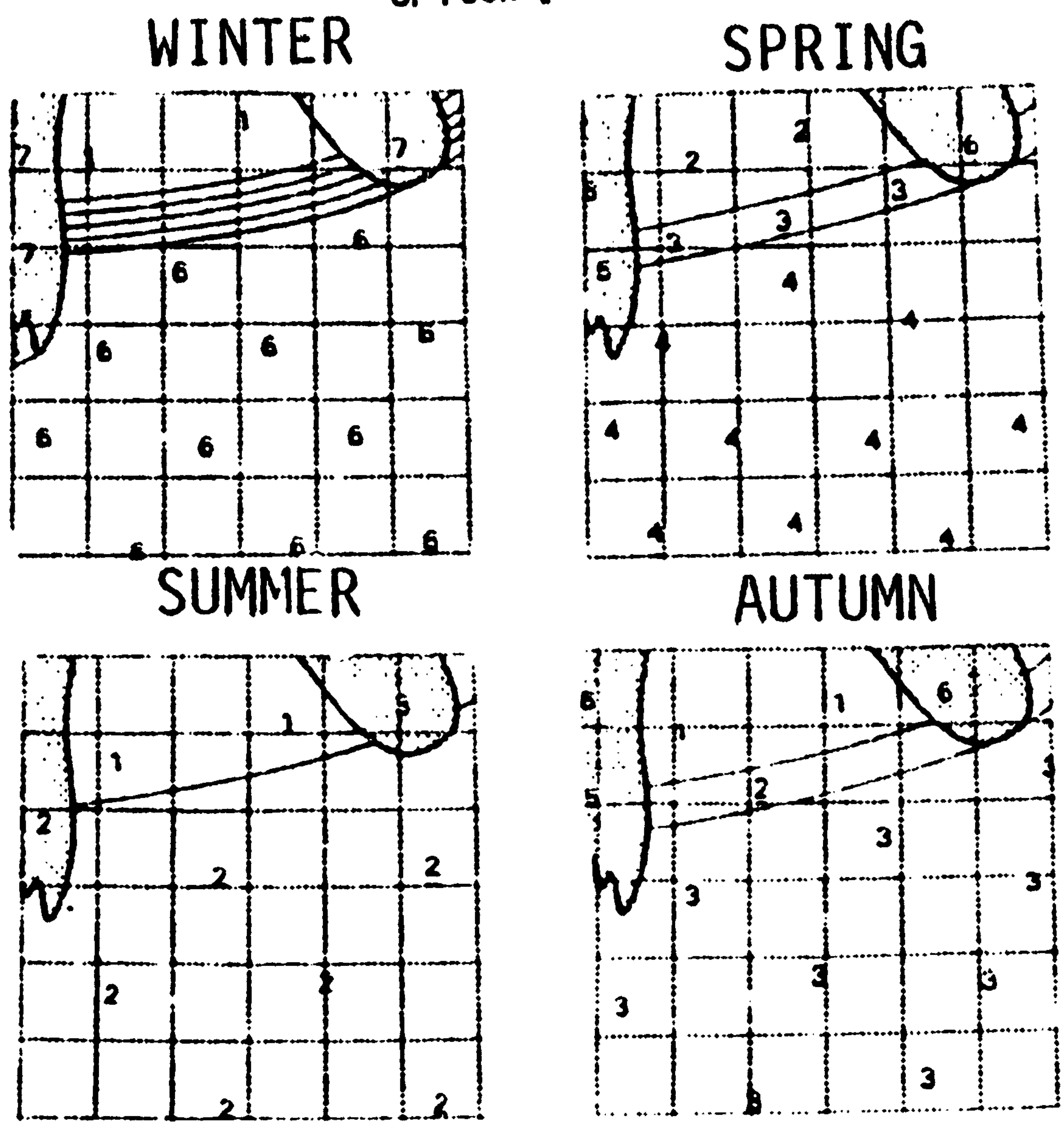


FIGURE 6. SEASONAL AVERAGE WIND RESOURCE

Estimating the Diurnal Variation of the Resource

The diurnal variation of the wind resource at a site typically changes with season and height above ground. Influences of terrain and water bodies cause the diurnal winds to vary locally. Examples of this are drainage winds and sea breezes. Although no maps of the diurnal wind resource are presented in the regional atlases, graphs of the diurnal variation of wind speeds by season are shown for selected stations in each state chapter. Again, caution should be used in applying these diurnal characteristics to nearby areas, especially in hilly, mountainous, and coastal areas. Maximum wind speeds on ridge crests and mountain summits are frequently at night, whereas valley, basins, and open plains typically have afternoon maximum winds.

Figure 7 shows the diurnal variation of wind speeds at Stations A and B. No attempt was made to adjust these data to 10 m or 50 m because of uncertainties in the height variations of the mean wind throughout the day in each season. Typically, the wind shear is considerably greater during night and early morning hours than during the afternoon and early evening hours. At Station A, the diurnal variation is largest in the summer and the smallest in the winter. Since Station A is in a well-exposed location on an open plain, nearby areas with similar exposure can be expected to have similar diurnal variations. At Station B, which is in a shallow basin surrounded by hills and ridges, afternoon mean wind speeds in the spring exceed those in the winter. The diurnal variation of wind speed at exposed hilltops and ridge crests near Station B may be considerably different than that at Station B. These examples demonstrate the importance of knowing a station's exposure (with respect to local terrain, water bodies, etc.) and the meteorology of the area before attempting to apply the diurnal characteristics to nearby areas.

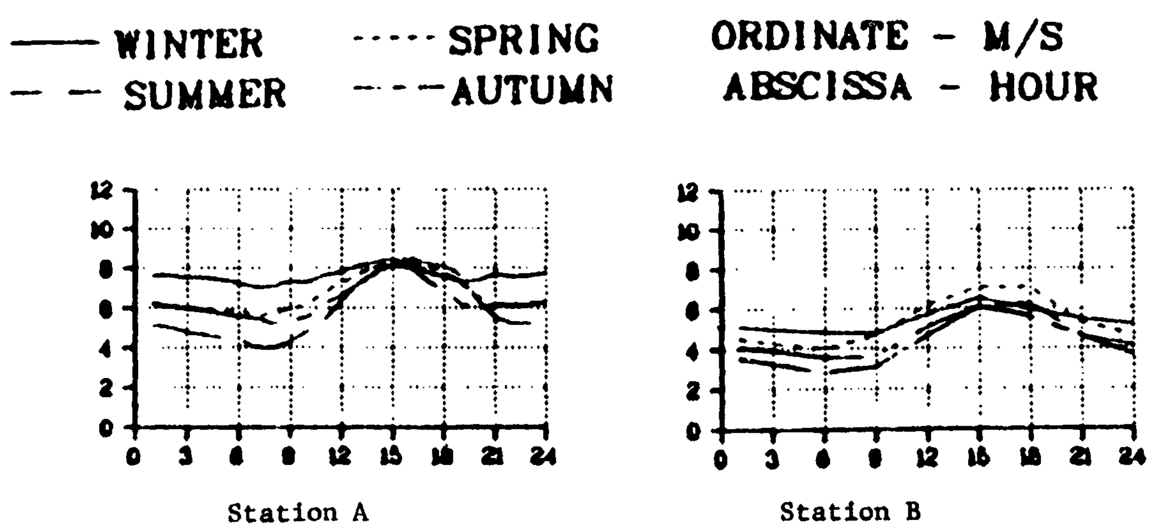


FIGURE 7. DIURNAL VARIATION OF WIND SPEEDS BY SEASON AT TWO STATIONS IN AREA

Estimating the Prevailing Wind Directions of the Resource

In siting wind turbines, a very important consideration is the prevailing direction(s) of the strong power-producing winds. The prevailing or most frequent wind direction may not be the direction with the highest percentage of wind energy. Thus, standard wind roses which only show the frequency of wind direction are not very useful. In the regional atlases, graphs for selected stations show the percentage of time that the observed wind direction was from each of 16-point compass sectors and the average speed of all observations in each sector. The coincidence of peaks in the two curves indicates that the highest wind speeds occur from the prevailing directions. Again, caution should be

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used in applying these data to other sites, because nearby terrain and obstructions strongly influence the wind directions. Some of the directional data presented may not be reliable or representative because of the anemometer location.

Figure 8 shows the directional frequency and average speed for Stations A and B. At Station A, the most frequent prevailing strong winds are from the west-southwest and west. Because Station A is a well-exposed site on an open plain with no apparent terrain obstructions nearby, the directional data should be applicable to nearby areas with similar exposure. At Station B, the prevailing strong winds are also from the west-southwest; although moderately strong winds from the east-northeast occur, they are much less frequent than those from the west-southwest. Because of Station B's location, there may be some local terrain influences on the wind direction. However, these are not readily apparent from the graphs and topographic maps of Station B.

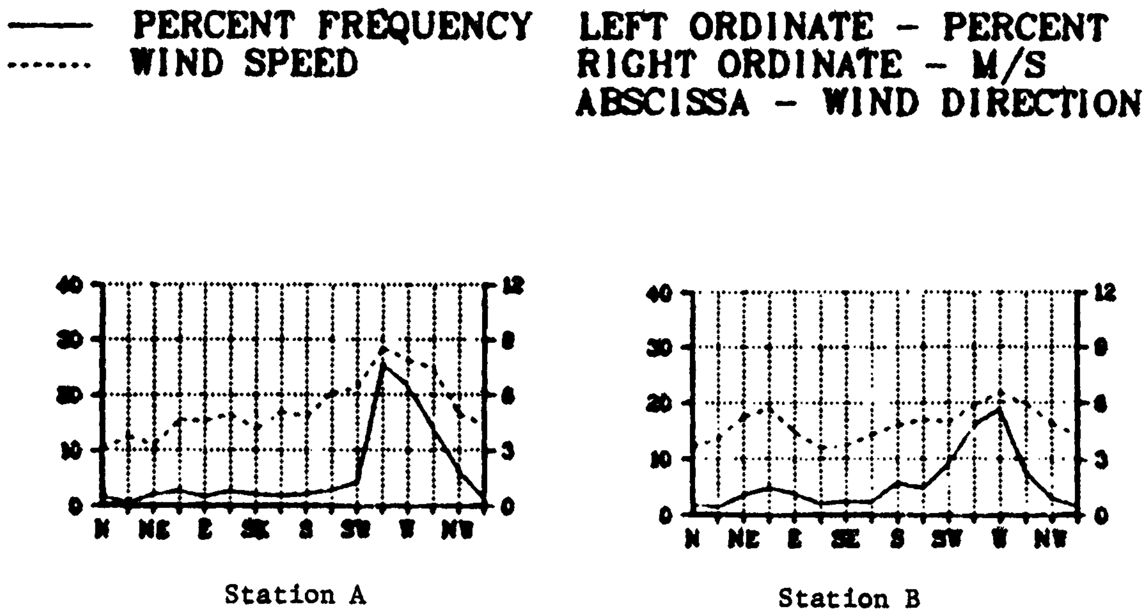

FIGURE 8. DIRECTIONAL FREQUENCY AND AVERAGE SPEED AT TWO STATIONS IN AREA

Considering the directional frequency and speed data from both Station's A and B and other stations in the region, it appears that the areas with the highest wind energy potential are those well exposed to westerly winds. Ridges that are perpendicular to these westerly winds may have considerably higher wind energy flux than exposed flat areas.

CONCLUSION

Described above are some of the ways in which information in the regional wind energy resource atlases can be put to use to evaluate various aspects of an area's wind resource. One key point which we have tried to emphasize in this paper is the importance of properly interpreting the wind resource maps and other information in the atlases. The wind resource maps alone are not adequate for an evaluation of an area's wind resource. The user should be aware of those areas where the resource estimates serve as only rough indicators (low certainty ratings). Additionally, the user should be aware that the map assessment values only refer to the fraction of land area in each land-surface form that is considered to be well exposed to the wind. We recommend that these various components of the resource assessment be considered together for a more thorough investigation of an area's wind resource. Use of grid cells on most of the maps in the atlas should make it easy for the user to locate his area and transfer the information conveniently from one map to the other. Any comments or suggestions on the information given in the wind resource atlases and the presentation of this information would be kindly appreciated by the author.

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