Wind Energy Resource Atlas: Volume 6 - The Southeast Region

Prepared for Pacific Northwest Laboratory
Under Agreement B-87925-A-L

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
Under Contract DE-AC06-76RLO 1830

Printed in the United States of America
Available from
National Technical Information Service
United States Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151

Price: Printed Copy \$_____ *: Microfiche \$3.00

*Pages	NTIS
	Selling Price
001-025	\$4.00
026-050	\$4.50
051-075	\$5.25
076-100	\$6.00
101-125	\$6.50
126-150	\$7.25
151-175	\$8.00
176-200	\$9.00
201-225	\$9.25
226-250	\$9.50
251-275	\$10.75
276-300	\$11.00

3 3679 00054 4488

PNL-3195 WERA-6
UC-60

WIND ENERGY RESOURCE ATLAS:
Volume 6 - The Southeast Region

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January 1981

Prepared for
Pacific Northwest Laboratory
Under Subcontract B-87925-A-L

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PREFACE

For the purpose of assessing the national wind resource, the United States and its possessions have been divided into twelve regions. For each region, wind resource assessments are presented in the form of an atlas. The atlases depict in graphic, tabular and narrative form the wind resource on a regional and state level. The information presented in the atlases will help guide homeowners, utilities and industry in decisions concerning the use of the wind as a source of energy.

This atlas of the wind energy resource is composed of introductory and background information, a regional summary of the wind resource, and assessments of the wind resource in each state of the region. Chapter 1 provides background on how the wind resource is assessed and on how the results of the assessment should be interpreted. A description of the wind resource on a regional scale is then given in Chapter 2. The results of the wind energy assessments for each state are assembled in this chapter into an overview and summary of the various features of the regional wind energy resource. Chapter 3 provides an introduction and outline to the descriptions of the wind resource given for each state. Assessments for individual states are presented as separate chapters beginning with Chapter 4. The state wind energy resources are described in greater detail than is the regional wind energy resource, and features of selected stations are discussed. This preface outlines the use and interpretation of the information found in the state chapters.

Much of the information in the state chapters is given in graphic or tabular form. As is discussed in Section 3.1, the sequence of maps, tables, and graphs is the same in each state chapter. References to these figures and tables are made here with an asterisk (*) in place of the chapter number (e.g., Figure *.1, Table *.2). Similar maps and tables are found in Chapter 2 on the regional wind resource. References to the regional maps and tables are made in brackets, [].

Figure *.1 shows the major geographical (mountains, rivers) and cultural (cities, towns) features in the state [Figure 2.1]. This map can be used to orient the reader to the state. Figure *.2 portrays the topography of the state in shaded relief [Figure 2.2]. The shaded relief allows the reader to visualize the character of the terrain surrounding locations of special interest. Superimposed on these state maps (but not the regional maps) is a grid of dashed lines one-third degree (20') longitude by one-quarter degree (15') latitude. This grid is repeated on nearly all subsequent maps to give the reader an adequate frame of reference for locating the same feature on different maps.

Figure *.3 is a map of the land-surface form [Figure 2.3]. The information presented in Sections 1.6 and 1.8 indicates how the land-surface form is used to designate the terrain features considered to have a typical good exposure to the wind. Awareness of what constitutes well-exposed terrain features is crucial to the proper interpretation of the maps of wind power density.

Figures *.4 and *.5 identify and locate wind data sites relevant to the assessment. All locations in each state for which the National Climatic Center (NCC) has wind data in its archives are shown and named in Figure *.4. However, this assessment is based on a subset of NCC data augmented by data from other sources (see Sections 1.1 and 1.2). Figure *.5 shows the location

of all wind data sites used in the assessment. Sections 1.3 through 1.5 briefly describe the methods used to analyze the wind data and evaluate the wind power.

The wind energy resource for a state is illustrated using several maps. The wind power maps represent a careful synthesis of quantitative wind data guided by state-of-the-art concepts on air flow near the earth's surface. Section 1.6 describes how the analysis of the wind data is transformed into the map of annual average wind power density found in Figure *6 [Figure 2.4]. This map gives the annual average wind power density at typically exposed sites. A discussion of the classes of wind power density in Section 1.7 gives the relationship between mean wind power density (watts/m^2) and mean wind speed (m/s or mph).

A certainty rating is used to provide a measure of the ability to objectively evaluate the wind resource in a grid cell. The certainty ratings are given in the maps of Figure *7. The degree of certainty with which the wind power can be estimated depends on the quality and quantity of wind data, the complexity of the terrain and concern over the variability of the wind resource over short distances. How these factors are combined to assign a certainty rating is discussed in Section 1.9.

The terrain feature with typical good exposure to the wind in a particular land-surface form provides a convenient and essential reference point on which to base the analyses of the wind resource shown in Figure *6. However, a substantial portion of the terrain may have poorer than typical exposure to the wind and will have a lower wind resource than shown on the wind power maps. The maps of Figure *8 provide an estimate of the percentage of area in each grid cell that may experience at least each of four different wind power classes. Section 1.10 discusses the assumptions underlying the evaluation of the areal distribution of the wind resource. The area of the state estimated to experience a particular wind power class is given in Table *1 [Table 2.2]. This table summarizes the contribution made by each grid cell to the areal distribution of wind power for the state.

The annual average wind power density compresses into a single statistic time-varying trends on several time scales, e.g., annual, seasonal, monthly, and daily. In this atlas, the seasonal evolution of the geographical distribution of wind power is shown at the state level. The maps of Figure *9 give the average wind power density for winter, spring, summer, and autumn. The interpretation of the seasonal average wind power maps is identical to that for the annual average wind power map. [For the region, Figure 2.5 shows only the season of maximum power.]

Additional information on the time variation and other characteristics of the wind resource in each state is presented for selected locations for which the National Climatic Center placed 1-hourly or 3-hourly time-series data on magnetic tape. Descriptions of the characteristics of the wind resource presented for these stations are given in Section 3.2. The urge to consider information pertaining to one of these sites as representative of some other location must be tempered with the realization that wind characteristics are extremely site-dependent. The degree of correspondence between the wind characteristics at one site and those at another site depends on the similarity between the topographical setting of the sites, the weather patterns that affect the sites and the obstructions to the wind in the vicinity of the sites.

Table *.2 identifies the stations, and gives their locations (see also Figures *.4 and *.5) and annual average wind speed and power density. Figure *.10 shows how the yearly mean speed and power varied during the period of record. The monthly mean wind speed and power over the course of a year are shown in Figure *.11. The hourly mean wind speed over the course of a day is shown in Figure *.12 with a separate curve for each season. Figures *.11 and *.12 indicate the time of year and time of day, respectively, the wind resource is available. Figure *.10, on the other hand, indicates the year-to-year variability that might be expected in the yearly mean resource.

The frequency of occurrence of winds from a particular direction and of winds with a particular speed is shown in Figures *.13 and *.14, respectively. The information on wind direction may be important in assessing the availability of the wind resource relative to surrounding terrain or nearby obstructions. However, it is also important to realize that the wind direction statistics are highly dependent on the location of the instrument site relative to obstructions and major terrain features, e.g., valleys, ridges, and mountain ranges.

Figures *.15 and *.16 portray speed and power frequency statistics in the form of speed and power exceedance curves, respectively. The fraction of the total period of record the speed equals or exceeds a given value is shown in Figure *.15. The power exceedance curve in Figure *.16 gives the fraction of the period of record for which the power exceeds a given value.

As has been shown in the preceding discussion, the order of presentation of the wind resource in this atlas proceeds from a regional perspective in Chapter 2, to a state perspective in the first part of each state chapter, to individual station descriptions in the last part of the state chapters. Attention given to Chapter 1 and Chapter 3 will make it possible for the reader to properly interpret the wind resource presentations.

ACKNOWLEDGMENTS

We wish to acknowledge all those persons who have assisted in the assimilation of the data used in the wind resource assessment for the Southeast, as well as those who have assisted in the construction of this atlas. In particular, we wish to thank Yolanda Goodge, and Howard Edwards for their efforts in assembling the digitized, summarized, and unsummarized data at the National Climatic Center. We also wish to thank the numerous private utilities who contributed data. Mr. Ben Fliegner at GEOMET is to be given particular recognition for his contribution to the computer mapping routines which expedited the graphics effort. Sincere appreciation also should be extended to Ms. Mona Spitzer who typed this document, to Mrs. Elizabeth Owzarski who edited the document, and to Mr. Jack Ricketts at GEOMET and Mr. Greg Azure at PNL who drafted the maps. Finally, special acknowledgment is due to L. Divone and G. Tennyson of DOE, for their support and encouragement as well as their understanding of the many technical aspects and associated difficulties in producing this atlas.

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CHAPTER 1: REGIONAL WIND ENERGY RESOURCE ASSESSMENT

Rapid development of wind as a source of commercial electric power is the principal goal of the Federal Wind Energy Program. Utility planning, wind turbine manufacturing and marketing of wind energy conversion systems all depend on detailed wind resource assessments. This atlas of the Southeast's wind resource, a product of the Wind Characteristics Program Element of the Federal Wind Energy Program, represents a major source of information for meeting these various needs.

This wind energy resource atlas is one of twelve such regional atlases that will be assembled. The other atlases will describe the potential wind resource in eleven other regions of the United States (see Figure 1.1). The spatial and temporal resolution of the wind resource in these regional assessments will be depicted in considerably greater detail than that in existing national assessments (Reed 1975, Coty 1976, Garate 1977, Elliott 1977). To produce the Southeast atlas in a timely fashion, only existing relevant data were used. The other atlases will use comparable data sets, analysis techniques and

presentations to ensure the comparability of the wind resource assessments.

The Southeast atlas assimilates six collections of wind resource data: one for the region and one for each of the five states that compose the Southeast region (Alabama, Florida, Georgia, Mississippi, and South Carolina). At the state level, features of the climate, topography and wind resource are discussed in greater detail than is provided in the regional discussion, and the data locations on which the assessment is based are mapped. Variations, over several time scales, in the wind resource at selected stations in each state are shown on graphs of monthly average and interannual wind speed and power, and hourly average wind speed for each season. Other graphs present speed, direction and duration frequencies of the wind at these locations.

The methods used to identify, screen, evaluate, and analyze the various types of data, and to produce the wind energy resource maps and graphs will only be described briefly. [For more detail

FIGURE 1.1. Geographic Divisions for Regional Wind Energy Assessments

see Zabransky et al. (1980).] However, this discussion will provide the reader with useful background information for interpreting the wind energy resource maps for the Southeast.

1.1 IDENTIFICATION OF WIND DATA SOURCES

The surface wind data on which this atlas has been based were obtained from several sources: the National Climatic Center (NCC), the U.S. Forest Service, university research projects, and nuclear and fossil-fuel power plants and their proposed sites. The National Climatic Center offers the largest collection of wind data. Surveys and indices of wind data archived at the NCC (Changery 1975, 1978; Changery et al. 1977) are extremely helpful in locating available wind data. The Index of Original Surface Weather Records, published for each individual state by the NCC, provides additional information about stations at which wind data have been taken.

The wind data available from the NCC may be in one or more of three formats: summarized, digitized, and unsummarized. Initially, all wind data are in the unsummarized format consisting of the original station weather records. For many stations, the collection of individual observations has been condensed into wind summaries. Changery et al. (1977) present examples of the various summary formats used and indices of the stations for which wind summaries are available. For still fewer stations (primarily airport stations) the NCC has put the original one- or three-hourly weather observations on magnetic tape to create a digitized time series of weather (and wind) observations. [TDF-14 (NCC 1975) describes the data on these tapes.] Table 1.1 indicates the number of stations with wind data in these various formats in the Southeast.

Conventional NCC surface weather data in coastal areas were supplemented by monthly mean wind speeds or frequency distributions found in the Climatic Study of the Near Coastal Zone (Naval Weather Surface Detachment 1976), the Summary of Synoptic Meteorological Observations: North American Coastal Marine Areas - Revised (U.S. Naval Oceanography Command 1975), and the Environmental Guide for the U.S. Gulf Coast (NCC 1972). These reports provided wind data from 25 spatially averaged one-degree latitude by one-degree longitude or larger squares along the east and gulf coasts. Wind summaries at the 150-m (492-ft) and 300-m (984-ft) levels above the surface and

500-m (1640-ft) or 1000-m (3280-ft) above sea level (Winds Aloft Summaries, NCC 1970) for 4 sites in the Southeast supplemented the upper-air wind climatology compiled by Crutcher (1959) for the northern hemisphere.

In contrast to the NCC data, which are primarily from inhabited areas, U.S. Forest Service data in the National Fire Weather Data Library (Furman and Brink 1975) are from remote sites in mountainous and forested areas under the jurisdiction of the Federal government (i.e., national forests, national parks). Eighty-five stations with wind data are reported in the National Fire Weather Data Library for the Southeast (Marlatt et al. 1979). However, only one afternoon observation, at about 2 p.m., is digitized per day during the local fire weather season. None of the fire weather data appeared to be useful in assessing the wind resource in the Southeast.

Wind data from 19 nuclear or fossil-fuel power plants or potential plant sites (Verholek 1977) were examined. Several other wind data sets collected by university research projects have also been identified.

1.2 WIND DATA SCREENING

Table 1.1 indicates the quantity of wind data available in the Southeast. However, not all of these data need to, or should, be used in a wind resource assessment. Screening procedures were developed to identify stations with the most useful data and to eliminate stations that would not significantly contribute information on the distribution of the wind resource.

TABLE 1.1. Stations with Wind Data in the Northeast and Peripheral Area Screened in Assessment

Source and Type	Screened	Retained
National Climatic Center		
Digitized	128	125
Summarized	80	38
Unsummarized	177	5
National Fire Weather Data Library	85	0
Nuclear & Fossil-Fuel Power Plant	19	17
University Research	6	0

Wind data in summarized or digitized format were chosen over unsummarized data. When stations had both summarized and digitized data, the digitized data were used for selected stations to prepare a

more extensive characterization of the wind resource. Unsummarized data were used only when no summarized or digitized data were available.

In areas with a high density of stations with wind summaries, those stations appearing to have the best exposure to the wind, greatest number of daily observations, longest period of record, and longest period of unchanged anemometer height and location were usually selected over other nearby stations. When more than one type of summary (see Changery et al. 1977) was available for a given station, the summary covering the longest period of record with constant anemometer height and location, with the greatest number of wind speed and direction classes, and with the highest frequency of daily observations, was chosen.

1.3 TIME SCALES IN REGIONAL ASSESSMENTS

Several time scales are encountered in the following discussions of the wind resource: annual, seasonal, monthly and diurnal. Annual mean values are generally based on an average of the one- or three-hourly observations of wind speed or power in the period of record; however, a complete calendar year's data (covering January 1 to December 31) is used for calculating individual yearly means. At stations with less than 24 hourly observations or 8 three-hourly observations per day, the values are only representative of the times of day for which the data were taken.

The four seasons are defined as:

- winter - December, January and February
- spring - March, April and May
- summer - June, July and August
- autumn - September, October and November.

The phrase "seasonal trends" refers to the change in monthly mean values over the course of the four seasons.

Monthly mean values are based on as many hours of data as are available for that month in each year of the period of record.

The daily or diurnal cycles of variation in the hourly mean wind power or speed are referenced to local standard time on a 24-hour clock. Midnight is both 00 and 24.

1.4 EVALUATION OF WIND DATA

For the purpose of mapping the geographical variation of the wind resource, wind power density was chosen over wind speed

since the power density incorporates in a single number the combined effect of the distribution of wind speeds and the dependence of the power density on air density and on the cube of the wind speed. Quantitative wind data in three formats were evaluated for mean wind power density: digitized, summarized, and unsummarized. The average wind power density $\bar{P}$ (watts/m²) in a vertical plane perpendicular to the wind direction for stations with one- or three-hourly digitized data was calculated from:

$$\bar{P} = \frac{1}{2n} \sum_{i=1}^n \rho_i V_i^3 \quad (1)$$

where

n = the number of observations in the averaging period

ρ_i = the density (in kg/m³) computed from the station pressure and temperature

V_i = the wind speed (in m/s) at the i th observation time.

For stations with wind summaries, $\bar{P}$ was calculated from:

$$\bar{P} = \frac{1}{2} \bar{\rho} \sum_{j=1}^c f_j V_j^3 \quad (2)$$

where

$\bar{\rho}$ = the mean air density

c = the number of wind speed classes

f_j = frequency of occurrence of winds in the j th class

V_j = the median wind speed of the j th class.

In those cases for which unsummarized wind data were assessed, seasonal and annual wind speed frequency distributions were constructed manually from the original surface weather records by scanning one year's data and entering every fourth hour into the distribution. The wind power density $\bar{P}$ was then computed by Equation (2).

For stations for which only mean wind speeds were available, the wind power density was estimated by assuming the speed frequency distribution followed a Rayleigh distribution (Hennessy 1977, Justus 1978):

$$f(v) = 2v \left(\frac{\Gamma(1.5)}{\bar{V}} \right)^2 \exp \left[- \left(\frac{v \Gamma(1.5)}{\bar{V}} \right)^2 \right] dv \quad (3)$$

where

$f(v)$ = frequency of occurrence of winds of speed v

$\bar{V}$ = the mean wind speed

Γ = the gamma function

v, dv = the speed at which the frequency is estimated and the increment of speed used in the calculation, respectively.

The wind power density was then computed using Equation (2).

1.4.1 Vertical Adjustment

The anemometer height above the surface rarely was at either the 10-m (33-ft) or 50-m (164-ft) reference levels chosen for the presentation of the wind resource. A power law was used to adjust the long-term mean wind speed or power density to the reference level:

$$\frac{\bar{V}_r}{\bar{V}_a} = \left(\frac{Z_r}{Z_a} \right)^\alpha \quad \text{or} \quad \frac{\bar{P}_r}{\bar{P}_a} = \left(\frac{Z_r}{Z_a} \right)^{3\alpha} \quad (4)$$

where

$\bar{V}_{a,r}$ and $\bar{P}_{a,r}$ = the mean wind speed or wind power density at heights $Z_{a,r}$ (the anemometer and reference level, respectively)

α = the power law exponent.

An examination of long-term mean wind speeds at airport locations at which the anemometer height was changed and at tower sites with multiple levels of anemometry indicates an $\alpha \sim 1/7$ to be widely applicable to low surface roughness and well-exposed

sites from which conventional NCC data are available (Elliott 1979b).

A few sites having well-exposed anemometers were located in towns or were surrounded by wooded areas having surface roughness greater than at airport locations. The adjustment of wind data of stations having this characteristic, to the 10-m (33-ft) and 50-m (164-ft) reference levels, was accomplished using the following relationship discussed by Elliott and Barchet (1980):

$$\frac{\bar{V}_r}{\bar{V}_a} = \left(\frac{\beta_r}{\beta_a} \right) \quad \text{or} \quad \frac{\bar{P}_r}{\bar{P}_a} = \left(\frac{\beta_r}{\beta_a} \right)^3 \quad (5)$$

where $\bar{V}_{a,r}$ and $\bar{P}_{a,r}$ are the same as in Equation (4) and the $\beta_{a,r}$ values are adjustment factors determined from a comparison of log-law wind speeds using appropriate roughness values for various surface environments.

1.4.2 Estimates for Mountainous Areas

The quantitative estimation of wind power over mountains made use of Winds Aloft Summaries (NCC 1970) for 4 rawinsonde stations. Monthly and annual wind speed frequency distributions for 150 m (492 ft) and 300 m (984 ft) above the surface as well as for 500 m (1640 ft) or 1000 m (3280 ft) above sea level were used to estimate wind power values for the mean ridge crest or mountain summit elevations in each one-fourth degree latitude by one-third degree longitude grid square. Horizontal interpolation between rawinsonde stations as well as vertical extrapolation to ridge elevation using a power law were employed. This procedure provided an estimate of the free air wind power at the terrain elevation. Since earlier studies (Wahl 1966) have indicated that there is a strong correlation between mountaintop and free-air wind speeds, the wind power at the 10-m (33-ft) and 50-m (164-ft) reference heights was taken to be one-third and two-thirds of the free-air value, respectively, to account for the frictional slowing of the wind near the surface.

These estimates are considered lower limits for exposed ridge crests and mountain summits. Local terrain features in these mountain regions can enhance the power considerably. Wherever possible, the mountaintop estimates were compared with surface data from ridge crests and mountain summits.

1.5 QUALITATIVE WIND INDICATORS

Although more than 185 stations provided the wind resource assessment in the Southeast with quantitative data, these stations were not uniformly distributed. The station location figures for each state show that most NCC stations are located in populated areas and along transportation corridors. Large areas in the Southeast are devoid of any form of quantitative wind data suitable for this assessment, such as south-central Florida, east-central Georgia, northern Mississippi, and western Alabama. Furthermore, in areas of complex terrain, most observation sites are confined to valley locations. To evaluate the distribution of the wind resource in data-sparse areas, two qualitative indicators of the wind speed or power were employed in the assessment.

The most widely used technique depended on certain combinations of topographical and meteorological features (Elliott 1979a) that were associated with high or low wind speeds. Those features indicative of high mean wind speeds are:

- gaps, passes, and gorges in areas of frequent strong pressure gradients
- long valleys extending down from mountain ranges
- high-elevation plains and plateaus
- plains and valleys with persistent strong downslope winds associated with strong pressure gradients
- exposed ridges and mountain summits in areas of strong upper-air winds
- exposed coastal sites in areas of
 - 1) strong upper-air winds, or
 - 2) strong thermal/pressure gradients.

Features that signal rather low mean wind speeds are:

- valleys perpendicular to the prevailing winds aloft
- sheltered basins
- short and/or narrow valleys and canyons
- areas of high surface roughness, e.g., forested hilly terrain.

Areas in which the appropriate features occur were determined by examining

topographic contour and shaded relief maps and synoptic and climatological maps of sea-level pressure patterns and air flow.

A second qualitative indicator is wind-deformed vegetation. This indicator was not used in the Southeast. The only areas where wind-deformed trees have the potential to exist in the Southeast are in the highest elevations of western South Carolina and along the southeastern Florida coast. However, the Florida coast is well covered with quantitative data and the upper-air winds over the extreme southern Appalachians are generally low, thereby making the study of these indicators of only marginal usefulness.

1.6 WIND POWER MAPS

The production of mean wind power density maps, such as those presented for each state, depended on the coherent synthesis of several pieces of information. The goal of the synthesis process was to present wind power density values representative of sites well exposed to the prevailing strong winds. Hilltops, ridge crests, mountain summits, large clearings and other locations free of local obstructions to the wind are expected to have good exposure to the wind (see Table 1.2). In contrast, locations in narrow valleys and canyons, downwind of hills and obstructions, or in forested or urban areas are likely to have poor exposure. The wind power density shown on the maps in this atlas will not be representative of poorly exposed locations. Estimates for ridge crests and summits (the shaded areas on the maps) are lower limits to the wind power expected at exposed sites. In such areas, local terrain features can enhance the wind power considerably (e.g., by a factor of 2 or 3). By specifying the type of wind exposure to which the map values of wind power pertain, we avoid the ambiguity that typical-location or average-for-the-terrain values might introduce. In this atlas, the terms wind energy, wind power and wind power density are used synonymously.

To represent the wind resource at well-exposed sites, it was necessary to become extremely familiar with the land-surface form and topography in the vicinity of every data site. Maps were prepared showing the location of stations, the mean wind speed and mean wind power at the reference level, the character of anemometer exposure, and the land-surface form for each state. On these maps, areas with the appropriate combinations of topographical and meteorological features were identified. A great deal of attention was given to the orientation of topographic features with the

prevailing wind directions. Only after all this information was assembled were the maps analyzed.

1.7 WIND POWER DENSITY CLASSES

The analysis of wind power maps departs from conventional isopleth analyses by showing the boundaries of wind power density classes. Each wind power class represents the range of wind power densities likely to be encountered at exposed sites within an area designated as having that wind power class. Table 1.3 gives the power density limits for the wind power classes used in the atlas for the 10-m (33-ft) and 50-m (164-ft) reference levels. The definitions of the wind power density classes are repeated with the annual wind power map for the region and for each state as a convenience for the reader.

Wind power density is proportional to the third moment of the wind speed distribution and to air density; therefore, a unique correspondence between power density and mean wind speed (the first moment of the speed distribution) does not exist. However, by specifying a Rayleigh wind speed distribution and a standard sea level air density (1.22 kg/m^3) a mean wind speed can be determined for each wind power class limit. The decrease of air density with elevation requires the mean Rayleigh speed to increase by about 3 percent/1000 m elevation (1 percent/1000 ft) to maintain the same power density. If the wind speed distribution is more sharply peaked than the Rayleigh distribution, the equivalent mean speed will be slightly higher than the value in Table 1.3. Conversely, a broader distribution of wind speeds will slightly reduce the equivalent mean speed.

1.8 CLASSES OF LAND-SURFACE FORM

The physical characteristics of the land-surface form affect the number of wind turbines that can be sited in exposed places. For example, over 90 percent of the land area in a flat plain may be favorably exposed to the wind; whereas in mountainous terrain only the ridge crests and passes, which may be only a small percentage (< 5 percent) of the land area, may represent exposed sites. The map of classes of land-surface form by Hammond (1964) provided information on the distribution of plains, tablelands, hills and mountains in the Southeast. Several characteristics are coded on this map:

- percentage of land area occupied by surfaces of gentle inclination (less than 8 percent slope)

- local relief, the maximum difference in elevation within a unit square six miles across
- percentage of gently inclined surfaces that lie in the lower half of the local relief
- land area covered by sand, ice, and standing water
- pattern of major crests, peaks, and escarpments.

The first three characteristics are used in the classification scheme (see Table 1.4); the latter two have been omitted from the maps presented here. A three-character code, for example B3a, designates each class of land-surface form. In this example the "B" indicates that 50 to 80 percent of the area is occupied by gentle slopes; the "3" that the maximum local difference in elevation is 100 to 500 m (300 to 500 ft); and the "a" that more than 75 percent of the gently sloping land is in the lowland. In areas of very little gentle slope (D) or very low relief and great smoothness (A1), the third designator is omitted.

For each land-surface form, the percentage of land area that is representative of well exposed, moderately exposed, and poorly exposed sites has been estimated. These percentages were determined subjectively as a function of the slope, local relief, and profile type. Table 1.2 gives the average percentage of land area that is designated as exposed terrain for the different classes of land-surface form. For simplicity, the percentages shown for each class of land-surface form have been averaged over the range of categories in local relief and profile type found in the Southeast. For example, the 37 percent for open hills is an average for C2-4. The average percentage of land area that is designated as exposed terrain ranges from 95 percent in smooth plains to 3 percent in mountainous areas where the exposed areas are usually the ridge crests and mountain summits.

1.9 CERTAINTY RATING

The analyses of wind power density at exposed sites shown on the wind power maps depends on the subjective integration of several factors: quantitative wind data, qualitative indicators of wind speed or power, the characteristics of exposed sites in various terrain and familiarity with the meteorology, climatology and topography of the region. As a result, the degree of

certainty with which the wind power class can be specified depends on

- the abundance and quality of wind data
- the complexity of the terrain
- the geographical variability of the resource.

A certainty rating from 1 (low) to 4 (high), of the wind energy resource estimate has been made for each cell of a one-quarter degree latitude by one-third degree longitude grid on a state-by-state basis by considering the influence of the above three factors on the certainty of the estimate of the wind power class for each cell. The definitions for the certainty ratings are adopted from those used by Voelker et al. (1979) in a resource assessment of U.S. Forest Service tracts. The certainty ratings for the wind resource assessment are defined as follows:

Rating	Definition
1	The lowest degree of certainty. A combination of the following conditions exists: <ol style="list-style-type: none"> 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: <ol style="list-style-type: none"> 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 the 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: <ol style="list-style-type: none"> 1) There are limited wind data in the vicinity of the cell, but

Rating	Definition
	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.

The assignment of a certainty rating requires subjective evaluation of the interaction of the factors involved.

1.10 AREAL DISTRIBUTION OF THE WIND RESOURCE

As noted above, the wind power density class values shown on the maps apply only to sites well exposed to the wind. Therefore, the map area designated as having a particular wind power class does not indicate the true land area experiencing this wind power. Instead, there is a complicated and difficult-to-quantify relationship among the class of land-surface form, the land-surface area and the map value of wind power density. For each land-surface form, the fraction of land area that would be favorably exposed to the winds, i.e., have the wind power density indicated on the map, was estimated. (See Table 1.2 for averages in various land-surface forms.) Furthermore, to be able to establish a wind power density for the remaining area, it was also necessary to specify a factor by which the wind power shown on the map is reduced in the less exposed areas. As an additional complication, some land-surface forms, such as isolated hills and ridges that rise above a nearly flat landscape, may even experience a higher power density than the map indicates.

To accommodate these various situations, the land area represented by a given land-surface form was divided into four exposure categories: 1) better exposure than typical for the terrain, 2) exposure typical for that land-surface form, 3) partially sheltered exposure, and 4) very sheltered

exposure. The partitioning of the land-surface forms into the four categories was based on the parameters used to classify the land-surface forms and on the experience of the authors and their co-workers with the terrain represented by the land-surface forms.

In order to adjust the wind power density from the map value to the various exposure categories, the power density was scaled to be 1) greater than, 2) equal to, 3) slightly less than, and 4) much less than the map value power density. The factor by which the map value was adjusted to represent the wind power density in each category was determined by the magnitude of elevation relief given by the middle character of the land-surface form code. (The minimum power density allowed for a category was the median value of wind power density class 1.) The scaling factors for the wind power density were based on a conservative application of a power-law type vertical adjustment with the height change specified by the terrain relief code.

In each cell of a grid one-third degree longitude by one-quarter degree latitude, the land-surface form was specified and the wind power class associated with a typically exposed site in the land-surface form was determined. By partitioning the area of the cell into the four exposure categories, and by scaling the wind power class to each category, the contribution of that cell to the areal distribution was determined.

A cell-by-cell 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.

A summary table of the areal distribution that combines the contributions by each cell is provided for the region and for each state. For each power class, the sum of the area contributed by each exposure category is determined for each state and the region. Summing the area associated with each power class in each cell gives the area of the state or region over which the power class exceeds a given value. The table gives the estimated land area (km^2) and the percentage of land area associated with each power class.

Both of these presentations of the areal distribution of the wind resource are highly dependent on the estimates used to partition the land area into the four exposure categories and on the scaling of the power density for each category of exposure. Therefore, 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 cell-by-cell appraisal of the wind resource are far beyond the scope of this regional wind resource assessment. However, as wind information becomes available through new measurement programs or through the discovery and processing of existing data sets, the evaluation of the areal distribution of the wind resource can be improved on a cell-by-cell basis.

TABLE 1.2. Land-Surface Form Terrain Features Representative of Exposed Locations

Land-Surface Form	Exposed Feature (Map Value)	Percentage Area(a)
Plains: A,B1,2	Plains	95
Plains with Hills: A, B3.4a,b	Open Plains (not shaded)(b) Hilltops (shaded)	80
Tablelands: B3-6c,d	Tablelands, Uplands	80
Open Hills: C2-4	Hilltops and Uplands	37
Open Mountains: C5-6	Broad Valleys (not shaded) Ridge Crests and Mountain Summits (shaded)	10
Mountains: D5-6	Ridge Crests and Mountain Summits (shaded)	3

(a)Percentage represents an average over the land-surface forms found in the Southeast region.

(b)Shaded areas on the wind maps emphasize that map values are estimated for ridge crests and mountain summit locations.

TABLE 1.3. Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, ^(b) m/s (mph)	Wind Power Density, watts/m ²	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.

TABLE 1.4. Scheme of Classification

Slope (1st item)

- A >80% of area gently sloping
- B 50 to 80% of area gently sloping
- C 20 to 50% of area gently sloping
- D <20% of area gently sloping

Local Relief (2nd item)

- 1 0 to 30 m (0 to 100 ft)
- 2 30 to 90 m (100 to 300 ft)
- 3 90 to 150 m (300 to 500 ft)
- 4 150 to 300 m (500 to 1000 ft)
- 5 300 to 900 m (1000 to 3000 ft)
- 6 900 to 1500 m (3000 to 5000 ft)

Profile Type (3rd item)

- a >75% of gentle slope is in lowland
- b 50 to 75% of gentle slope is in lowland
- c 50 to 75% of gentle slope is on upland
- d >75% of gentle slope is on upland

CHAPTER 2: REGIONAL FEATURES

In this chapter, the geography, climate, annual average wind power and seasonal variations in the wind power are described for the Southeast region. Assessments of the wind resource for each state of the Southeast were performed using the methods described in Chapter 1. These assessments were then combined to depict the wind energy potential for the region. Major areas in the Southeast that are estimated to have the greatest wind resource are also described in this chapter.

2.1 GEOGRAPHY AND TOPOGRAPHY

The Southeast region, consisting of Alabama, Florida, Georgia, Mississippi, and South Carolina, covers 641,841 km² (247,816 mi²). The region's total population in 1977 of 22,455,000 (see Table 2.1) represents approximately one-tenth of the nation's population. Nearly three-quarters of the people in the Southeast live on the East Coast from South Carolina to Florida. The population density of Alabama and Mississippi combined is about one-half the density in the other three states. The major cities, rivers, mountain ranges and parks are shown in Figure 2.1.

TABLE 2.1. Land Area and Population of the Southeast

State	Area km ²	Area (mi ²)	Population in 1977	Population per km ²	Population (mi ²)
Alabama	133,667	(51,609)	3,690,000	28	(71)
Florida	151,670	(58,560)	8,452,000	56	(144)
Georgia	152,488	(58,876)	5,048,000	33	(86)
Mississippi	123,584	(47,716)	2,389,000	19	(50)
South Carolina	80,432	(31,055)	2,876,000	36	(93)

With the exception of the north-central portion of the Southeast region and a few scattered areas, the topography is relatively low and flat (Figure 2.2). Roughly 41 percent of the topography in the Southeast is irregular plains, 41 percent is flat and smooth plains, and only 18 percent is tableland, hills, and low mountains, which lie in the north-central part of the Southeast. The northern half of Alabama,

the northern part of Georgia, and the far northwestern corner of South Carolina have the most complex terrain of the region, with tablelands, hills, and low mountains (Figure 2.3).

2.2 CLIMATE

The Gulf of Mexico and the Atlantic Ocean significantly affect the climate of the Southeast. The Atlantic Ocean and Gulf of Mexico moderate the temperature and are sources of moisture for all the southeastern states. On a smaller scale, inland water bodies and swamps (e.g., Lake Okeechobee in Florida and the Okefenokee Swamp in Georgia) influence local climate in the southeastern states.

The climate of the Southeast is predominantly subtropical. The Southeast is under the influence of maritime tropical air for a large part of the year, which often leads to daytime generation of showers and thunderstorms inland, particularly in spring and summer. During the winter and early spring, however, frequent incursions of modified continental polar air often generate showers and squalls in the coastal areas.

During spring and summer the subtropical Bermuda high affects the circulation pattern in the Southeast region, producing moist, southeasterly trades along the southeast Florida coast and generally moist southerly flow in the Gulf Coast region. From October to March, the Bermuda high contracts and translates south allowing the Southeast region to be more influenced by northerly flow associated with frequent cold-frontal passages. Winters are coldest in the mountain and valley system of the southern Appalachians and mildest in southern Florida. Average daily minimum temperatures range from -1°C (30°F) in northwestern South Carolina and northern Georgia to 18°C (65°F) in Key West, Florida.

Summers are generally coolest at the coastal stations and in the hills of northern Georgia and northwestern South Carolina. Warmest areas are found in central and southern Alabama and along the predominant coastal plains of Georgia. Average daily maximum temperatures are 33°C (92°F) in central and southern Alabama, and 31°C (88°F) at the coastal stations.

Annual precipitation varies from a high of about 203 cm (80 in.) in the mountains of northwestern South Carolina to only

102 cm (40 in.) at Key West, Florida. The high levels of precipitation in northwestern South Carolina are caused by orographic enhancement. Precipitation amounts of 165 cm (65 in.) occur in the Gulf Coast region of Mobile, Alabama, where coastal and tropical storms occur in mid-to-late summer. The Florida peninsula is also frequented by tropical storms. Precipitation from these storms and from regular summer afternoon showers, just inland from the coast, give the southeastern part of Florida annual precipitation amounts of 152-165 cm (60-65 in.). Snowfall is not common in the Southeast, but it can occur as far south as northern Mississippi, Alabama and Georgia in any given year.

The Southeast region is often exposed to tropical storms and hurricanes, which usually occur between June and October. Annual precipitation amounts are greatly enhanced locally during years when hurricane activity is elevated. In the Gulf Coast region the frequency of hurricane landfall in the Mobile-Pascagoula area is once every 4.9 years while in the Panama City area it is once every 3.8 years. Along the coasts of Florida, Georgia and South Carolina the frequency of major destructive hurricanes is greater, roughly once every 2.5 years.

2.3 WIND POWER IN THE SOUTHEAST

The annual average wind power density in the Southeast is shown in Figure 2.4. The analyses of mean wind power generally apply to terrain features that are favorably exposed to the wind, such as mountain summits, ridge crests, hilltops, and uplands (see Section 1.6). However, nearby terrain features may interact with the wind field to cause the wind power at some exposed sites to vary as much as ± 50 to 100 percent from the assessment value. [See Wegley et al. (1980) for information on terrain features that may increase or reduce wind energy.] In forested or wooded areas, the assessment values are representative of large clearings, such as airports, with good exposure to the prevailing strong winds. In mountainous regions, the analyses also reflect major valleys. The percentage of land area that is favorably exposed to the wind strongly depends on the land-surface form (Section 1.8).

Most of the Southeast region has wind power densities in class 1. Highest wind power occurs in the Blue Ridge Mountains of northern Georgia and northwestern South Carolina. In these areas, estimates of annual wind power for ridge crests and mountain summits range up to class 5 in extreme northeastern Georgia. The wind

power on the elevated tablelands and ridges in northeastern Alabama is estimated to be in class 2. Class 2 wind power is also estimated along the immediate Gulf Coast shorelines and bays of Mississippi, Alabama, and Florida, whereas class 3 wind power is estimated for the Atlantic shorelines of South Carolina, Georgia, and Florida. Higher wind power along the Atlantic shoreline is attributed to trade winds along the southeastern Florida peninsula and the stronger westerlies along the South Carolina and Georgia shorelines. Because of the trade winds and the reinforcing effect of the daytime sea breeze, a narrow strip of land experiencing class 2 wind power occurs along the southeastern Florida coastline from approximately Daytona Beach south into the Keys. The strip extends no more than about 5 km (3 mi) inland from the coastline.

Wind power 50-200 km (30-125 mi) offshore in the Gulf of Mexico is estimated to be slightly less than in the open Atlantic, but annual average wind power estimates range from class 5 to class 6. The higher wind powers are estimated for areas 50-200 km (30-125 mi) off the coasts of Georgia, South Carolina, and northeastern Florida where the stronger westerlies have more influence. These estimates were made using data summaries based on space and time integrated wind data. The data summaries covered 60 years of marine observations over 25 spatially average 1 degree latitude by 1 degree longitude or larger areas along the East and Gulf coasts. The shipboard anemometer heights are unknown but were probably taken on masts some 20-25 km (65-80 ft) above the water surface. Moreover, observations are biased toward fair weather situations because shipping lanes avoided storms as much as possible. Hence, these data should be viewed with caution.

2.3.1 Certainty Rating of the Wind Resource

Certainty ratings of the wind power resource were assigned to each grid cell as described in Section 1.9. Maps of the certainty rating are presented for each state, accompanying the description of that state's wind resource.

The geographical distribution of the certainty rating ranges from low (1) to high (4). Much of the Southeast region has been assigned certainty ratings of 3 and 4 because 1) terrain complexity is low except in northeast Alabama, northern Georgia and northwest South Carolina, 2) there is little geographic variability in the wind resource except in the mountains

and along the coasts, and 3) the region is adequately covered by data.

A number of areas have low certainty ratings of 1 and 2 due to lack of data. Such areas include parts of western and east-central Alabama, northern and central Mississippi, east-central Georgia, parts of southern South Carolina, and north-central and south-central Florida.

A certainty rating of 2 has been given to the mountainous terrain in northeastern Alabama, northern Georgia and northwestern South Carolina because of their higher degree of terrain complexity and variability in the wind resource. Much of the higher terrain has mountaintop estimates made from upper-air data; these areas were given a certainty rating of 2 because of the approximations in the technique (see Section 1.4.2). Atlantic and Gulf Coast regions have a large number of category 2 certainty ratings owing to a greater variability of the wind resource and lack of data.

2.3.2 Areal Distribution of the Wind Resource

Through the superposition of a grid one-quarter degree latitude by one-third degree longitude over the region, the areal distribution of wind power can be computed as described in Section 1.10. Of the 806 grid cells that encompass the Southeast region, only 10 (1.2 percent) have exposed areas with class 3 or higher wind power. Since class 3 or higher wind power occurs on well-exposed ridges and hilltops, much less than one percent of the total land area of the region has class 3 or higher wind power.

Table 2.2 summarizes the results of the computation of the areal distribution for the Southeast region. The subjectivity underlying the assignment of exposure partitioning and power scaling warrants reporting the areas and percentages to only two significant digits (see Section 1.10). Thus, individual areas and percentages may not sum to their stated totals.

It is clear from Table 2.2 that the wind power density in the Southeast is essentially confined to the lower three wind power classes. In fact, over 98 percent of the land area is associated with class 1 wind power. The highest wind power densities (class 3 and 4) are only found on the exposed ridge crests and mountain summits of the Blue Ridge Mountains in northern Georgia and northwestern South Carolina and along the exposed Atlantic shoreline (class 3

only) from South Carolina to the Florida Keys.

2.4 SEASONAL VARIATIONS IN THE WIND RESOURCE

During winter (December, January, and February) the upper-air flow is strongest over the Southeast. At this time maximum wind power occurs over the coastal waters and in the northwestern section of the Southeast region. The exposed ridge crests and mountaintops in extreme northeastern Georgia and northwestern South Carolina have the highest wind power densities (class 6 and 7). Estimated shoreline wind power throughout the Southeast is class 3. Wind power 50-200 km (30-125 mi) offshore is estimated to be class 6 and class 7 as a result of stronger northwesterly flow in winter.

In spring (March, April, and May) the upper-air flow begins to weaken over the Southeast, but insolation over land increases rapidly, creating more instability and vertical mixing. At this time, the coastal regions exhibit the greatest thermal contrasts between land and sea. The combined effects of lingering westerlies and regional, thermally induced flow in the coastal areas produce the highest wind powers of the year along the coast. Class 3 wind power is estimated for the southeastern Florida shoreline. Exposed ridge and mountaintop wind powers during the spring in extreme northeast Georgia and northwest South Carolina are class 5 and 6, which indicates a weakening in strength from winter.

During the summer (June, July, and August) wind powers are universally low (class 1) throughout the Southeast, including the ridge crests and mountain summits of the southern Appalachians. Class 2 power exists only offshore and in the Florida Keys.

In the autumn (September, October, and November) upper-air flow gradually increases over the Southeast. Exposed ridge and mountaintops in the southern Appalachians have slightly increased wind power (class 2 and 3), while estimated wind power along the exposed shoreline of southeastern Florida is class 3.

2.5 MAJOR WIND RESOURCE AREAS

Descriptions of major areas in the Southeast with high annual average wind power (class 4 and above) are briefly summarized in this section. For additional details on these areas, refer to the

individual state maps such as Figures 4.1 through 4.6 for Florida.

2.5.1 Mountains of South Carolina and Georgia

The exposed ridge crests and mountain-tops of the southern Appalachians in extreme northwestern South Carolina and northeastern Georgia have annual average wind power densities of class 4 and 5. This area is highly confined and represents an extremely small percentage of exposed land in the Southeast region.

2.5.2 Gulf of Mexico and Atlantic Ocean

The area 50-200 km (30-125 mi) offshore in the Southeast has estimated wind power densities of class 5 and class 6. The higher wind power category (class 6) occurs off the coasts of northeastern Florida, Georgia, and South Carolina where higher latitude westerlies have more influence.

FIGURE 2.1. Geographic Map of the Southeast

FIGURE 2.2. Topographic Map of the Southeast

FIGURE 2.3. Classes of Land-Surface Form in the Southeast

LAND-SURFACE FORM LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50-80% OF AREA GENTLY SLOPING
C	20-50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50-75% OF GENTLE SLOPE IS IN LOWLAND
c	50-75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

FIGURE 2.4. Annual Average Wind Power in the Southeast

Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, (b) m/s (mph)	Wind Power Density, watts/m ²	Speed, (b) m/s (mph)
0	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.

TABLE 2.2. Areal Distribution of Wind Power Classes in the Southeast

Power Class	Land Area (km ²) Equal or Exceeding Power Class					
	Southeast	Alabama	Florida	Georgia	Mississippi	South Carolina
1	632,600	132,100	142,900	153,300	122,600	81,700
2	9,800	2,600	1,000	4,600	0	1,500
3	1,000	0	0	830	0	180
4	300	0	0	460	0	10
5	63	0	0	30	0	0
6	0	0	0	0	0	0
7	0	0	0	0	0	0

Power Class	Percentage Land Area Equal or Exceeding Power Class					
	Southeast	Alabama	Florida	Georgia	Mississippi	South Carolina
1	100.	100.	100.	100.	100.	100.
2	1.5	2.0	0.73	3.0	0.00	1.8
3	0.16	0.00	0.00	0.54	0.00	0.23
4	0.05	0.00	0.00	0.30	0.00	0.01
5	0.01	0.00	0.00	0.02	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00

FIGURE 2.5. Seasonal Maximum Wind Power in the Southeast

CHAPTER 3: STATE FEATURES

The wind resource for each state is described in Chapters 4 through 8. The state descriptions are presented in a consistent format. The text of each description is followed by maps, graphs and tables that identify features of the geography and the wind energy resource and summarize the data collected from the observation stations. The sequence of maps, tables and graphs used to depict these features is presented in Table 3.1. In the state descriptions, these illustrations are presented so that related information is on facing pages and can be viewed simultaneously.

To avoid repetition in the following chapters, the general format and content of the various maps, tables and graphs used to describe the wind resource for each state are summarized here.

3.1 MAPS OF STATE FEATURES

The maps of cultural geography show the locations of major cities, rivers and terrain features for each state. The maps of shaded topographic relief are reproductions of the 1:500,000 scale U.S. Geological Survey maps. The land-surface form maps are reconstructions of portions of the map of classes of land-surface form by Hammond (1964). (This is also available at a scale of 1:17,000,000 on Plate 62 in the National Atlas of the United States.) The use of the land-surface form map was described in Section 1.8.

Two maps are used to show the locations of stations with wind data. The first map gives the locations and names of the NCC stations with wind data in any form. The other map shows the locations of NCC and other data stations that were utilized in this assessment of the wind resource.

The map of annual average wind power is accompanied by maps of the certainty rating of the estimated annual average wind power by grid cell, and maps of the areal distribution of the wind resource by grid cell. The certainty rating, which ranges from 1 (low) to 4 (high), indicates the level of confidence in the estimates of the wind resource in each cell of the grid. The certainty rating is based on the availability of wind data, the complexity of the terrain, and the inherent geographical variability of the wind resource (see Section 1.9). The maps of areal distribution give the percentage of land area in each cell estimated to experience an annual average wind power class equal to or exceeding power classes 2, 3, 4, and 5 (see Section 1.10).

Maps of the average wind power are presented for each season: winter (December, January, February); spring (March, April, May); summer (June, July, August); and autumn (September, October, November). The legend for the power classes is found with the annual average wind power map.

TABLE 3.1. Maps, Tables and Graphs Used to Depict the Wind Resource

Maps	
Left Hand	Right Hand
Cultural Geography	Topographic Shaded Relief
Land-Surface Form	Legend to Land-Surface Form
NCC Station Locations	Location of Stations Used in Wind Assessment
Annual Average Wind Power	Legend to Wind Power Classes and Table on Areal Distribution
Certainty Rating	Legend for Certainty Rating
Areal Distribution (Power Classes 2 & 3)	Areal Distribution (Power Classes 4 & 5)
Seasonal Average Wind Power (Winter, Summer)	Seasonal Average Wind Power (Spring, Autumn)
Graphs	
Summary Table of Selected Stations	Interannual Speed and Power
Monthly Speed and Power	Diurnal Speed
Directional Frequency	Speed Frequency
Speed Duration	Power Duration

3.2 FEATURES OF SELECTED STATIONS

The analysis of the wind resource on a state and regional basis depends on information from individual stations. For those stations with one- or three-hourly data on NCC magnetic tapes, a very detailed presentation of the temporal variation and character of the wind resource can be obtained. Graphs portraying various features of the wind resource have been prepared for selected stations in each state and are presented in the state chapters. For each station presented, a brief description of the station's topographical setting and unique features is given in the text preceding the maps and graphs. The geographical area represented by a station varies, depending on the complexity of the local terrain and variability of the wind resource.

A table listing the stations for which graphs and summaries of the features of the wind resource are presented precedes the series of graphs. Height adjustments were made only to obtain estimates of the average wind speed and power at 10 m (33 ft) and 50 m (164 ft) given in this table. No attempt was made to adjust to a reference height any of the other wind characteristics (e.g., diurnal wind speeds, frequency distributions of wind speed, wind direction, speed and power duration, etc.) presented in the graphs for selected stations. Caution should therefore be used in comparing and interpreting station plots.

In the plots of interannual wind power and speed, the first line of each graph contains the station name and state. The second line contains the WBAN number. In all other plots, the first line on each station graph contains the station identification that corresponds to the name and location listed in the table and the month and year of the selected period of record. Only one period of record with constant anemometer height was plotted for most stations, even though some stations had several periods of record. However, if there was uncertainty as to which period had better anemometer exposure or if two periods with similar exposure indicated substantially different wind characteristics, two periods of record were plotted. Usually, periods when the anemometer was located on a mast directly on the ground were preferred to periods when the anemometer was located on the roof of a building.

The second line of each station graph contains the WBAN number, the anemometer height (Z) in m and location, and the annual average wind speed (V) in m/s and

wind power (P) in watts/m². V and P are adjusted to 10 m for the graphs of interannual and monthly average wind power and speed and are at anemometer height, Z, for all other graphs.

The coded information listed with the anemometer height is one of the following (Changery 1978):

- R - indicates the anemometer was located on the roof of a control tower, operations building, hangar or other similar structure. Normal mast heights were 2 to 4 m (6 to 12 ft) above roof line; however, many inner-city locations used considerably taller masts. The listed height is elevation above ground level, not roof level; the "R" indicates an exposure type.
- G - indicates the anemometer was located on a mast attached directly to the ground. Most anemometers at airport locations changed from a roof to ground exposure by the early 1960s.
- B - indicates a beacon tower exposure. For these locations, neither R nor G was considered satisfactory.
- UNK - indicates that documentation on instrument heights was not available.

If information on exposure was unavailable, no exposure code is given.

On a few station plots, an E follows the annual average wind power. If a pressure or temperature observation is missing, the wind power for that observation is computed using an air density based on station elevation. If the number of missing observations exceeds 25 percent of the total, then an E is used to designate that the wind power is an estimated value.

Up to 18 graphs of the same type may appear on one page to allow for station-to-station comparison. The scale of each set of plots was determined by the maximum range of values found for all stations in the region.

3.2.1 Interannual Wind Power and Speed

The plots of interannual wind speed and power portray the variations of the yearly average over all periods of record. The beginning and ending of each period of record with constant anemometer height and location are designated by a "plus" symbol on the wind power curve and by a "diamond" symbol on the wind speed curve. If the

anemometer height was unknown, a height of 10 m was assumed. Only yearly mean wind speeds based on 12 months' data (January through December) were plotted.

Year-to-year deviations from the long-term annual average may not be a reliable indicator of the deviations at nearby sites or areas (Elliott 1979b).

3.2.2 Monthly Average Wind Power and Speed

Graphs of the monthly average wind power and speed portray the monthly and seasonal trends of the wind. Stations with less than 5 years of observations may not show reliable seasonal trends. Also, stations in complex terrain may not represent the seasonal trends in nearby areas because of the influence of nearby terrain. Most of the station curves are within the 0 to 400 watts/m² range with the exception of some coastal stations.

3.2.3 Diurnal Wind Speed by Season

The diurnal variation in wind speed according to seasons is plotted on graphs containing four curves, one for each season. Local standard time (LST) is used with hour 24 as midnight and hour 1 as the beginning hour. For National Weather Service and Federal Aviation Administration stations, the diurnal curves are usually based on 24 observations daily for periods ending before 1965, and on 8 observations daily for periods ending after 1964. For Air Force stations the diurnal curves are usually based on 24 observations daily regardless of the period. The diurnal curves for Navy stations are based on 24 observations daily for periods ending before March 1972 and on 8 observations daily for periods ending after February 1972.

3.2.4 Directional Frequency and Average Speed

Graphs of the annual average frequency of occurrence show the percentage of time that the observed wind direction was from each of 16-point compass sectors and the average wind speed of all observations in each sector. Some stations show a definite bias toward 8-point compass observations. The coincidence of peaks in the two curves

indicates that the highest wind speeds occur from the prevailing directions. Caution should be 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.

3.2.5 Annual Average Wind Speed Frequency

Graphs of the annual average frequency of observed wind speeds are shown in 1 m/s intervals about each whole m/s wind speed. Along with the observed distribution, a Rayleigh wind speed distribution based on the annual mean speed is shown. Some of the stations show pronounced peaks in the observed distribution; these peaks reflect observer bias toward certain wind speeds, such as 2, 5, and 8 m/s (5, 10 and 15 knots). This bias occurs more frequently in records from before 1960. Because many of the wind instruments used had a threshold velocity of about 1.5 m/s (3 knots), the frequency of observations in the 1 m/s class is often lower than the frequency of the calm and 2 m/s classes.

3.2.6 Annual Average Wind Speed and Power Duration

The percentage of time that a given wind speed or power is exceeded is shown in two sets of graphs. Abrupt changes in the slope of the duration curves for speed and power usually correspond to peaks in the speed frequency distribution caused by observer bias and instrument threshold velocity. Points are plotted at 1 m/s intervals for the speed duration curves. Points are plotted at 1 m/s intervals for the speed duration curves. Points are plotted every 50 watts/m² up to 500 watts/m² and every 100 watts/m² up to 1,000 watts/m² in the power duration curves.

ALABAMA

CHAPTER 4: ALABAMA

Alabama covers an area of 133,667 km² (51,609 mi²) and had a population of 3,690,000 in 1977. In 1970, about 58 percent of the people lived in urban areas. Birmingham and Mobile are the two largest cities (Figure 4.1)

The terrain complexity generally increases moving south to north across Alabama, with irregular plains in the south and open hills in the north (Figure 4.2). Local relief ranges from 0 to 30 m (0 to 100 ft) in southern Alabama, to 305 to 915 m (1,000 to 3,000 ft) in northern Alabama (Figure 4.3). The ridges and peaks of the southern Appalachian Mountains in northeastern Alabama are the most prominent topographic features in the State.

Digitized and summarized wind data are fairly abundant in the eastern half of the state, but sparse in the western half (Figures 4.4 and 4.5). About a third of the stations had relatively short (3-5 years) data records. Interpolated upper-air data were used to supplement the ground station data in northeastern Alabama.

4.1 ANNUAL AVERAGE WIND POWER

The analyses of mean wind power generally apply to terrain features that are favorably exposed to the wind, such as mountain summits, ridge crests, hilltops, and uplands (see Section 1.6). However, nearby terrain features may interact with the wind field to cause the wind power at some exposed sites to vary as much as ± 50 to 100 percent from the assessment value. [See Wegley et al. (1980) for information on terrain features that may increase or reduce wind energy.] In forested or wooded areas, the assessment values are representative of large clearings, such as airports, with good exposure to the prevailing strong winds. In mountainous regions, the analyses also reflect major valleys. The percentage of land area that is favorably exposed to the wind strongly depends on the land-surface form (Section 1.8).

The annual average wind power density in Alabama (Figure 4.6) is almost exclusively class 1. The only exception occurs in northeastern Alabama where the Appalachian foothills begin. In this region, exposed ridge and mountaintop estimates show class 2 wind power density. Class 2 wind power is estimated along the exposed Gulf Coast shoreline of Alabama and in Mobile Bay. Estimated wind power densities 50 to 200 km (30-125 mi) offshore in the Gulf of Mexico are in class 5.

4.1.1 Certainty Rating of the Wind Resource

A few areas in the central and western portions of the state were given a certainty rating of 2 because of data sparseness and moderate terrain complexity. No year-round data were available from exposed sites in mountainous terrain, consequently ridge crest wind power estimates in northeastern Alabama were given a certainty rating of 2 (Figure 4.7). The remainder of Alabama was given certainty ratings of 3 and 4 because either adequate data were available or lack of terrain complexity ensured limited geographic variability of the wind resource.

4.1.2 Areal Distribution

The areal distribution of wind power in Alabama is illustrated in Figure 4.8 and Table 4.1. The numbers identify the percentage of area in each cell of the grid in which the annual average wind power equals or exceeds some threshold value. In cells that have been designated as having class 2 power, this estimate applies only to the exposed ridge crests. Therefore, only 2 percent of the total land area of Alabama has class 2 power. Ninety-eight percent of the land area has class 1 wind power.

4.2 SEASONAL WIND POWER

Wind power maps for each season are shown in Figure 4.9. The season of maximum wind power is predominantly winter, however, spring is the maximum wind power season for a few stations along the Gulf Coast.

4.2.1 Winter

Wind power is highest during the winter over most of Alabama. Ridge top estimates in northeastern Alabama are class 2, 3, and 4 while the remainder of the state, with the exception of the Gulf Coast and the northwestern portion, is characterized by class 1 wind power. Class 2 wind power occurs in the vicinity of exposed land areas along the Gulf Coast in winter, particularly around Mobile Bay. Class 2 wind power also extends into the northwestern portion of Alabama during winter. Along the exposed shoreline of the Gulf Coast, class 3 wind power is estimated, while much higher wind power (class 6) is estimated for the area 50-200 km (30-125 mi) offshore in the Gulf of Mexico.

4.2.2 Spring

The exposed ridge crests of northeastern Alabama are estimated to have class 2 and 3

wind power in spring. Wind power in the remainder of the state falls in the class 1 category. Along the exposed Gulf Coast and in the far northwestern section of the state, class 2 wind power occurs. The immediate exposed shoreline has class 3 wind power estimates, while 50 to 200 km offshore, the open water is characterized by class 4 wind power.

4.2.3 Summer

In summer, the entire state has class 1 wind power, including the exposed ridge crests in northeast Alabama. The wind power along the immediate shoreline and in Mobile Bay is estimated as class 2.

4.2.4 Autumn

Exposed ridge crests in northeastern Alabama and the exposed Gulf Coast shoreline have estimated class 2 wind power. Over the open water of the Gulf of Mexico (50 to 200 km offshore), wind power is estimated to be class 5. The remainder of the state is characterized by class 1 wind power.

4.3 FEATURES OF SELECTED STATIONS

Table 4.2 gives the location and annual wind speed and power density of 12 stations in Alabama. Graphs of other features of the wind resource at these stations are shown in Figures 4.10 through 4.16.

Anniston/Calhoun County Airport is located in a valley oriented northeast-southwest at the southern end of the Appalachian Mountains. This location is representative of the low-lying areas within the valley-ridge system in that prevailing wind directions at Anniston are consistent with the valley orientation. Birmingham Municipal Airport is also located in a valley at the southern end of the Appalachian Mountains, but its location is in an area where the valley widens and where the mountains, to the east, become lower and oriented more north-south; prevailing winds are more northerly or easterly.

Dothan Airport, Evergreen Airport, and Cairns/Ft. Rucker Field are representative of the lowland plains that compose a large physiographic segment of the Southeast. Dothan and Ft. Rucker lie 35 and 55 km (22 and 34 mi), respectively, due west of the Chattahoochee River in the southeast corner of the state while Evergreen is located 52 km (33 mi) east of the Alabama River in the south-central part of the state. All three areas are surrounded by gently-rolling irregular hills.

Huntsville/Madison County Airport and Muscle Shoals Airports are situated adjacent to the Tennessee River valley. Huntsville Airport is 10 km (6 mi) north of and 66 m (200 ft) above the river and 20 km (13 mi) southwest of Huntsville. Muscle Shoals Airport is located 5 km south of and 15 m (50 ft) above Wheeler Lake Reservoir, opposite the city of Florence. The prevailing wind direction at Muscle Shoals conforms to the general valley orientation in this region. This prevailing direction is not seen at Huntsville Airport because it is considerably more removed from the valley.

Mobile/Bates Field and Brookley AFB/ Mobile represent the near coastal area, however neither station has direct shoreline exposure. Bates Field is situated 20 km (13 mi) west of Mobile Bay and over 66 m (200 feet) above sea level. Brookley AFB lies on the west shore of Mobile Bay on the southeast periphery of Mobile. Both stations experience prevailing onshore Gulf air flow during the summer months.

Montgomery/Donnelly Field and Selma/Craig AFB are located in the central section of the state along the Alabama River. Craig AFB is 5 km (3 mi) southeast of Selma and 3 km (2 mi) south of the Alabama River. Donnelly Field is situated 12 km (8 mi) southeast of the Alabama River and 12 km (8 mi) southwest of Montgomery. Both sites are surrounded by gently rolling hills.

Tuscaloosa Municipal Airport is situated 1 km (0.6 mi) northwest of the Black Warrior River and 5 km (3 mi) west of the city. Nearby, the airport is surrounded by gently rolling hills but within 25 km (16 mi), to the north and east, hills become more numerous.

4.3.1 Interannual Wind Power and Speed

An insufficient length of digitized record to assess interannual trends or variability exists at two stations (Dothan and Evergreen) as can be seen in Figure 4.10. Large interannual variability during periods of constant anemometer height exists at Birmingham, Mobile, Mobile/Brookley, Montgomery, and Selma. At these stations, the highest annual average wind power exceeds twice the lowest annual average wind power. Substantial variability also exists at Muscle Shoals. A long-term downward trend in wind speed and power is evident at Mobile for the period 1963 through 1978. Interpretation of such trends must be done with caution because, over a period of time, equipment wear and increased friction can result in lower recorded wind speeds

and powers. Degradation of exposure from growth of surrounding vegetation could also cause such a trend.

4.3.2 Monthly Average Wind Power and Speed

The largest monthly variations in wind power occur at Huntsville and Muscle Shoals, both in northern Alabama, and at Mobile on the Gulf Coast (Figure 4.11). At all three stations, the March maximum of wind power is over five times the August minimum. Overall, the month of maximum wind power ranges from January to March; however, wind power peaks occur most frequently in March.

4.3.3 Diurnal Wind Speed by Season

All 12 stations show quite similar diurnal patterns for wind speed (Figure 4.12). The typical pattern shows a daytime rise in wind speed, with a peak wind speed in early to mid-afternoon (1300 to 1500 LST) and a relatively uniform minimum mean speed from 1900 to 0500 LST. There is some tendency for the peak to occur later in the day during spring and summer (1400 or 1500 LST) than during the autumn (1300 LST) because of extended daytime heating in summer.

4.3.4 Directional Frequency and Average Speed

Prevailing surface wind directions in Alabama are highly variable from station to station. North, south, and east appear to be the most frequently occurring wind directions (Figure 4.13).

The average wind speed is highest for prevailing northerly and southerly flow at Mobile and Brookley AFB near the coast. Inland stations most frequently exhibit strongest winds from the west or northwest.

Anniston, Dothan and Muscle Shoals all have highly irregular wind direction frequency

patterns; Dothan also has an irregular wind speed pattern. These irregular patterns are the result of observer bias toward the eight-point compass sectors north, northeast, east, southeast, south, southwest, west, and northwest. Despite the irregular patterns, the prevailing winds at Anniston generally conform to the northeast-southwest valley orientation and at Muscle Shoals to the northwest-southeast orientation of the Tennessee River valley.

4.3.5 Annual Average Wind Speed Frequency

Observer biases are apparent from the peaks at 2, 5 and 7 m/s (5, 10 and 15 mph) in the wind speed frequency distributions (Figure 4.14) for Anniston, Dothan, Evergreen, Muscle Shoals and Tuscaloosa. These stations have periods of record in the late 1940s and early to mid-1950s. Stations with more recent records show little evidence of this bias.

The best agreement between the actual frequency distribution and the Rayleigh distribution was evidenced at Huntsville, Mobile, and Montgomery, and generally at other stations with the more recent records. The poorest comparison occurred at Selma which experienced a very high frequency of calms (>30 percent). This large percentage of reported calm winds may be the result of anemometry having threshold velocities greater than 1 m/s; few, if any, cases of 1 m/s winds are recorded.

4.3.6 Annual Average Wind Speed and Power Duration

The percent of time that a given wind speed or power is exceeded is shown in Figures 4.15 and 4.16. Abrupt changes in the slope of the duration curves correspond to peaks in the speed frequency distribution caused by observer bias and instrument threshold velocity.

FIGURE 4.1. Geographic Map of Alabama

FIGURE 4.2. Topographic Map of Alabama

FIGURE 4.3. Land-Surface Form Map for Alabama

LAND-SURFACE FORM LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50-80% OF AREA GENTLY SLOPING
C	20-50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50-75% OF GENTLE SLOPE IS IN LOWLAND
c	50-75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

FIGURE 4.4. NCC Station Locations in Alabama

FIGURE 4.5. Location of Stations Used in Alabama Resource Assessment

FIGURE 4.6. Alabama Annual Average Wind Power

Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, ^(b) m/s (mph)	Wind Power Density, watts/m ²	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.

TABLE 4.1. Areal Distribution (km²) of Wind Power Classes in Alabama

Power Class	Land Area	% Land Area	Cumulative Land Area	% Cumulative Land Area
1	129,500	98.	132,100	100.
2	2,600	2.0	2,600	2.0
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	0	0.00	0	0.00

FIGURE 4.7. Certainty Rating of Alabama Wind Resource

CERTAINTY RATING LEGEND

Rating	Definition
1	<p>The lowest degree of certainty. A combination of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A low-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A high-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>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.</p>

FIGURE 4.8. Areal Distribution of Wind Resource in Alabama (Power Classes 2 and 3); Percent of Land Area with or Exceeding Power Class Shown

FIGURE 4.8 (Continued). Areal Distribution of Wind Resource in Alabama (Power Classes 4 and 5); Percent of Land Area with or Exceeding Power Class Shown

WINTER

SUMMER

FIGURE 4.9. Seasonal Average Wind Power in Alabama (Winter, Summer)

SPRING

AUTUMN

FIGURE 4.9 (Continued). Seasonal Average Wind Power in Alabama (Spring, Autumn)

TABLE 4.2. Alabama Stations With Graphs of the Wind Characteristics

Station	Station Name ^(a)	Latitude, Degrees North	Longitude, Degrees West	Elevation of Station, m	Period of Record, Month/Year	Annual Average Wind Speed m/s				Annual Average Wind Power, watts/m ²		
						Anemometer Height	At Anemometer Height, m	At 10 m	At 50 m	At Anemometer Height, m	At 10 m	At 50 m
Anniston AL	Anniston/Calhoun County Airport	33.58	85.85	184	01/48-04/55	10.4	2.8	2.8	3.5	46	45	90
Birmingham AL	Birmingham Municipal Airport	33.57	86.75	192	06/63-12/78	6.7	2.9	3.1	3.9	42	50	99
Dothan AL	Dothan Airport	31.23	85.43	98	11/50-12/54	9.8	3.4	3.4	4.3	56	57	113
Evergreen AL	Evergreen Airport	31.42	87.03	78	12/49-12/54	8.8	2.4	2.5	3.1	31	33	65
Cairns AL	Ft. Rucker Fld.	31.27	85.72	90	06/56-12/70	4.0	2.3	2.6	3.3	25	37	74
Huntsville AL	Huntsville/Madison County Airport	34.65	86.77	192	10/67-12/78	7.6	3.6	3.7	4.7	66	74	148
Mobile AL	Bates Field	30.68	88.25	68	03/62-12/78	6.7	3.8	4.0	5.0	66	78	156
Mobile AL	Brookley AFB	30.63	88.07	8	04/59-08/66	4.0	2.9	3.3	4.2	39	58	116
Montgomery AL	Dannelly Fld.	32.40	86.23	66	10/58-12/78	7.0	3.0	3.2	4.0	43	50	100
Muscle Shoals AL	Muscle Shoals Airport	34.75	87.62	171	12/48-12/54	14.3	3.4	3.3	4.1	66	57	113
Selma AL	Craig AFB	32.35	86.98	50	03/54-03/60	15.2	2.7	2.6	3.2	41	34	68
Tuscaloosa AL	Tuscaloosa Municipal Airport	33.23	87.62	56	01/49-12/54	21.6	2.8	2.5	3.1	46	33	66

(a) AFB - Air Force Base
FLD - Field

FIGURE 4.10. Interannual Wind Power and Speed for Alabama

FIGURE 4.11. Monthly Average Wind Power and Speed for Alabama

FIGURE 4.12. Diurnal Wind Speed by Season for Alabama

— PERCENT FREQUENCY LEFT ORDINATE - PERCENT
 - - - WIND SPEED RIGHT ORDINATE - M/S
 PNL-3195 WERA-6
 ABSCISSA - WIND DIRECTION

FIGURE 4.13. Directional Frequency and Average Wind Speed for Alabama

— ACTUAL DISTRIBUTION ORDINATE - PERCENT
 - - - RAYLEIGH DISTRIBUTION ABSCISSA - M/S
 PNL-3195 WERA-6

FIGURE 4.14. Annual Average Wind Speed Frequency for Alabama

ORDINATE - PERCENT
ABSCISSA - M/S
PNL-3195 WERA-6

FIGURE 4.15. Annual Average Wind Speed Duration for Alabama

ORDINATE - PERCENT
ABSCISSA - WATTS/M²
PNL-3195 WERA-6

FIGURE 4.16. Annual Average Wind Power Duration for Alabama

FLORIDA

CHAPTER 5: FLORIDA

Florida covers an area of 151,670 km² (58,560 mi²) and had a population of 8,452,000 in 1977. In 1970, about 81 percent of the people lived in urban areas. Jacksonville and Miami are the two largest cities (Figure 5.1).

Low-lying, flat plains constitute over 90 percent of Florida's land-surface form. Less than 10 percent of the land-surface form is irregular plains occurring in northwest Florida (Figure 5.2). Local relief ranges from 0 to 30 m (0 to 100 ft) for over 90 percent of Florida, to 30 to 90 m (100 to 300 ft) in northwest Florida (Figure 5.3).

Wind data are most common along the eastern coastline of Florida from Jacksonville down to Key West as well as in the western panhandle of the state. There is a general paucity of wind data in the interior of Florida (Figures 5.4 and 5.5).

5.1 ANNUAL AVERAGE WIND POWER

The analyses of mean wind power generally apply to terrain features that are favorably exposed to the wind, such as mountain summits, ridge crests, hilltops, and uplands (see Section 1.6). However, nearby terrain features may interact with the wind field to cause the wind power at some exposed sites to vary as much as + 50 to 100 percent from the assessment value. [See Wegley et al. (1980) for information on terrain features that may increase or reduce wind energy.] In forested or wooded areas, the assessment values are representative of large clearings, such as airports, with good exposure to the prevailing strong winds. In mountainous regions, the analyses also reflect major valleys. The percentage of land area that is favorably exposed to the wind strongly depends on the land-surface form (Section 1.8).

The annual average wind power for Florida (Figure 5.6) shows that almost the entire state is represented by class 1 wind power. The only exceptions are the coastal areas and the Florida Keys. The immediate, exposed Atlantic shoreline of eastern Florida is estimated to have a wind power density of class 3. The southeast trade winds, amplified by a daytime sea breeze, produce a very narrow strip of class 2 wind power over the land within 5 km (3 mi) of the southeastern Florida coastline. Class 2 wind power also occurs along the exposed Gulf Coast shoreline and in the Florida Keys. The areas 50-200 km (30-125 mi)

offshore surrounding Florida are estimated to have class 5 wind power, except for class 6 in waters 50-200 km (30-125 mi) off the northeastern Florida coastline where the westerlies have a stronger influence.

5.1.1 Certainty Rating of the Wind Resource

Certainty ratings for Florida (Figure 5.7) are mostly high (3 and 4) because the topography is not complex and there is little geographic variability of the wind resource. An exception exists in south-central Florida where a certainty rating of 2 occurs because of a scarcity of data in the Everglades. A certainty rating of 2 is similarly given to the area in northern Florida where the panhandle and peninsula join because data are lacking. Some variability in the wind resource occurs along the Atlantic and Gulf coasts of Florida, including the Keys, that has resulted in coastal certainty ratings of 2 and 3. There are a few Gulf Coast locations where data are sparse and the resource is variable that have been given a certainty rating of 1.

5.1.2 Areal Distribution

Figure 5.8 and Table 5.1 show that an extremely high percentage (99 percent) of the land area is characterized by class 1 wind power. Literally, the only class 2 land area exists along a narrow strip of coastline in southeast Florida. The area represented by the number of grid squares in this coastal zone slightly exaggerates the amount of land impacted by class 2 wind power because the higher winds extend no more than 5 km (3 mi) inland.

5.2 SEASONAL WIND POWER

Seasonal wind power maps are shown in Figure 5.9. Spring is the season of maximum wind power on the Florida peninsula and along the northwestern panhandle coast. Further inland on the Florida panhandle and over the surrounding coastal waters, winter is the season of maximum wind power. In summer, wind power is at a minimum throughout the state.

5.2.1 Winter

In winter the Florida peninsula is spared from the strongest influence of the increased upper air flow of the westerlies. The northern panhandle and northcentral areas of the state have class 1 wind power. However, the more exposed coastal and southern peninsula areas of the state show

somewhat higher wind power in class 2. The immediate shoreline along the Gulf and Atlantic Coasts has an estimated wind power in class 3 during winter, whereas several stations in the Florida Keys have measured winds that yield class 3 power. Wind power is much higher 50-200 km (30-125 mi) off the Florida coastline in winter; class 6 occurs in the Gulf of Mexico and classes 6 and 7 exist off the southeastern and north-eastern Florida coastlines, respectively.

5.2.2 Spring

In spring the upper air flow begins to weaken, but insolation over land increases rapidly, creating more instability and vertical mixing. The coastal regions exhibit the greatest thermal contrasts between land and sea at this time of the year. Wind power is generally higher on the Florida peninsula in spring than in winter, yet it is still confined to the same wind power classes as in winter. The exception occurs along a thin coastal strip (less than 5 km (3 mi) wide) in southeastern Florida, where class 3 wind power occurs. This zone, roughly extending south from Daytona Beach, comes under the influence of strengthening trade winds during the spring. A significant sea breeze is also superimposed in daytime. Wind power along the immediate shoreline is correspondingly estimated to be in class 3. Estimated wind power 50-200 km (30-125 mi) offshore in the Gulf of Mexico is class 4, while on the Atlantic side of the peninsula wind power ranges from class 6 to class 5 at corresponding distances off the northeastern and southeastern Florida Coasts, respectively.

5.2.3 Summer

During summer the entire state is estimated to have class 1 wind power. The exposed shoreline and offshore areas in the Gulf of Mexico and Atlantic Ocean are estimated to have class 2 wind power.

5.2.4 Autumn

With the exception of the coastal areas of the state, class 1 wind power is found everywhere in Florida during autumn. The exposed shoreline of the Gulf Coast, the Keys and the exposed shoreline of northeastern Florida exhibit class 2 wind power, while the exposed shoreline of southeastern Florida has higher wind power (class 3) resulting from the trade wind influence. This influence extends up to 5 km (3 mi) inland producing a thin coastal strip of class 2 wind power. Wind powers 50-200 km (30-125 mi) offshore in the Gulf of Mexico and Atlantic Ocean are class 5 and 6, respectively.

5.3 FEATURES OF SELECTED STATIONS

Table 5.2 gives the location and annual wind speed and power density of 17 stations in Florida. Graphs of other features of the wind resource at these stations are shown in Figures 5.10 through 5.16.

Over 90 percent of Florida is a low-lying flat plain with two dominant land-surface forms, sand and standing water. Because of the prevalence of flat terrain, adequately sited anemometry stations can be representative of large areas. There are no anemometry stations in Florida that adequately represent the irregular plains that comprise less than 10 percent of Florida's land area.

Orlando/Herndon Field is representative of the flat plains of east-central Florida. Herndon Field is located within the urban confines of Orlando 75 km (47 mi) west of Cape Kennedy. Avon Park/Avon Park Air Force Base is more centrally located on the peninsula due west of Vero Beach, however, because there are topographic rises within 5 miles to the east and west, the stations exposure cannot be considered typically representative of central Florida.

Cape Kennedy/Cape Kennedy AFB, Cocoa Beach/Patrick AFB, and Daytona Beach/Daytona Regional Airport are all representative of the flat coastal zone of east-central Florida. Both Cape Kennedy AFB and Patrick AFB are located on flat sandy barrier islands. Patrick AFB has an elevation of 3 m (9 ft) with excellent ocean exposure while Cape Kennedy AFB lies 2 km (1.3 mi) west of the ocean. The Daytona Regional Airport lies about 95 km (59 mi) north of Cape Kennedy AFB and is situated 5 km (3 mi) inland on the west side of Daytona Beach.

Ft. Myers/Page Field is located on the southwestern coast of Florida about 3 km (2 mi) east of the Caloosahatchee River and 17 km (11 mi) northeast of the Gulf of Mexico. This station is representative of the flat plains in the southwest coastal region of the state.

Homestead/Homestead AFB, Miami/Miami International Airport, and West Palm Beach/Palm Beach International Airport are all representative of the flat coastal plain of southeast Florida. None of these airports has an ocean exposure. Homestead AFB lies about 10 km (6 mi) west of the Atlantic Ocean. Miami International Airport is located about 13 km (8 mi) west of the Atlantic with an urban setting. Palm Beach International Airport is about 5 km (3 mi) west of the Atlantic and about 60 km (38 mi) east-southeast of Lake Okeechobee. This station also has an urban setting.

Jacksonville/Jacksonville International Airport is representative of the flat plains of northeastern Florida. It lies about 24 km (15 mi) west of the Atlantic Ocean and 15 km (9 mi) north of downtown Jacksonville.

Key West/Key West International Airport is the only true island location having excellent ocean exposure. It lies about 90 km (56 mi) southwest of the Florida mainland. This station is representative of the near-offshore area of southern Florida.

Milton/Whiting Naval Air Station, Panama City/Tyndall Air Force Base, Pensacola/Saufley Field, and Valparaiso/Eglin Field are all representative of the flat coastal plains of the Florida panhandle. None of these stations has direct ocean exposure. Whiting Naval Air Station is located north of the Gulf of Mexico and north of East Bay. To the north are higher, irregular plains, which provide 30 to 90 m (200 to 300 ft) local relief. Tyndall Air Force Base is located about 2 km northeast of the Gulf of Mexico. Higher, irregular plains, 30 to 90 m (100 to 300 ft) in elevation, occur about 25 km (16 mi) north of the station. Sauflay Field is situated about 20 km (13 mi) north of the Gulf, and about 10 km (6 mi) west of downtown Pensacola. There are higher, irregular plains having an elevation of 30 to 90 m (100 to 300 ft) about 20 km (13 mi) north of the station. Eglin Field is located about 4 km (2.5 mi) north of Choctawhatchee Bay, and about 10 km (6 mi) north of the Gulf of Mexico. The bay is protected by a barrier island. Higher, irregular plains occur about 10 km (6 mi) north of the station.

Tallahassee/Tallahassee Municipal Airport is representative of the flat plains of northern Florida. This station is about 40 km (25 mi) north-northwest of Apalachee Bay. Topography becomes higher, 30 to 90 m (100 to 300 ft), and more irregular within 5 km (3 mi) to the east. The airport itself is located in a slight topographical depression.

Tampa/Tampa International Airport is situated in the flat coastal region of southwestern Florida adjacent to, and east of, Old Tampa Bay. The Gulf of Mexico lies about 30 km (19 mi) to the west. The best exposure is southwest of Old Tampa Bay toward the airport. The city of Tampa is east of the airport.

5.3.1 Interannual Wind Power and Speed

Large interannual variability during periods of constant anemometer height

occurred at Avon Park, Cape Kennedy, Homestead, Jacksonville, Milton, Orlando, Panama City, Pensacola, Tampa, and Valparaiso (Figure 5.10). At these stations, the highest annual average wind power exceeded twice the lowest annual average wind power. Substantial variability also exists at Cocoa Beach and Key West. A long-term downward trend in wind speed and power is evident at Cape Kennedy (1964 through 1977), Daytona Beach (1960 through 1978), Homestead (1956 through 1970), and Tampa (1966 through 1978). Interpretation of such trends must be done with caution because, over a period of time, equipment wear and increased friction can result in lower recorded wind speeds and powers. Exposure degradation may also result from vegetative growth over a period of time. Some of the interannual variability may be related to the interannual frequency of tropical storm occurrence on the Florida peninsula.

5.3.2 Monthly Average Wind Power and Speed

The largest monthly variations in wind power occur at three coastal stations: Cocoa Beach and West Palm Beach on the Atlantic coast, and Panama City on the north Gulf coast (Figure 5.11). At each of these stations, the maximum wind power is over three times the minimum. In general, maximum wind power occurs from October through April; peak wind powers occur most frequently in February and March. The lowest monthly values of wind power occur at Avon Park which may have locally poor anemometer or topographic exposure.

5.3.3 Diurnal Wind Speed by Season

With the exception of Key West and Cocoa Beach, the 17 stations all show quite similar diurnal patterns for mean wind speed (Figure 5.12). The typical pattern shows a daytime rise in wind speed with a peak in the early to late afternoon (1300 to 1600 LST) and a relatively uniform minimum wind speed from 2100 to 0600 LST. There is some tendency for the peak to occur later in the day during spring and summer (1400 to 1600 LST) than during the autumn and winter (1300 or 1400 LST) because of stronger heating and extended daylight during spring and summer.

The peak appears to be damped in magnitude at two exposed coastal locations. One such site is Key West, an island station that shows almost no diurnal variation. The other is Cocoa Beach, a coastal station with direct ocean exposure. Here little diurnal variation occurs except in summer when increased surface heating produces

stronger daytime winds. Ocean-dominated stations display little, if any, diurnal variation because daytime thermal contrasts are reduced.

5.3.4 Directional Frequency and Average Speed

Prevailing surface wind directions at Florida stations are east, north and south. Stations along the Atlantic coast (e.g., Cocoa Beach, West Palm Beach, Miami) have a prevailing easterly wind direction. The Gulf Coast stations are more variable, but principal prevailing wind directions are north and south (Figure 5.13). Key West, with the least continental influence, has prevailing southeast winds consistent with the trades.

Along the Atlantic coast highest wind speeds are associated with northeast winds. In the interior of the state and along the Gulf Coast, the highest wind speeds correspond with southerly flow.

5.3.5 Annual Average Wind Speed Frequency

Peaks in the wind speed frequency distributions for Avon Park (2 and 5 m/s) and Homestead (3 and 5 m/s) indicate observer biases to reporting these wind speeds. Instrument

thresholds are apparently greater than 1 m/s for Daytona Beach, Ft. Myers, Jacksonville, Key West, Orlando, Tallahassee, Tampa, and West Palm Beach as few or no cases of 1 m/s winds are recorded. These winds are generally recorded as calm and can falsely bias the record. For example, Jacksonville and Tallahassee report 15 and 20 percent calm conditions, respectively, which are probably unrealistically high.

The actual frequency distribution and the Rayleigh distribution appear to be in best agreement at Daytona Beach, Miami, and West Palm Beach which are all located on the Atlantic coast and have the most recent records. Avon Park and Milton have the poorest agreement with the Rayleigh distribution and also experience a high frequency of calms (≥ 20 percent).

5.3.6 Annual Average Wind Speed and Power Duration

The percent of time that a given wind speed or power is exceeded is shown in Figures 5.15 and 5.16. Abrupt changes in the slope of the duration curves correspond to peaks in the speed frequency distribution caused by observer bias and instrument threshold velocity.

FIGURE 5.1. Geographic Map of Florida

FIGURE 5.2. Topographic Map of Florida

FIGURE 5.3. Land-Surface Form Map for Florida

LAND-SURFACE FORM LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50-80% OF AREA GENTLY SLOPING
C	20-50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50-75% OF GENTLE SLOPE IS IN LOWLAND
c	50-75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

FIGURE 5.4. NCC Station Locations in Florida

FIGURE 5.5. Location of Stations Used in Florida Resource Assessment

FIGURE 5.6. Florida Annual Average Wind Power

Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, ^(b) m/s (mph)	Wind Power Density, watts/m ²	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.

TABLE 5.1. Areal Distribution (km²) of Wind Power Classes in Florida

Power Class	Land Area	% Land Area	Cumulative Land Area	% Cumulative Land Area
1	141,800	99.	142,900	100.
2	1,100	1.0	1,100	1.0
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	0	0.00	0	0.00

FIGURE 5.7. Certainty Rating of Florida Wind Resource

CERTAINTY RATING LEGEND

Rating	Definition
1	<p>The lowest degree of certainty. A combination of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A low-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A high-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>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.</p>

FIGURE 5.8. Areal Distribution of Wind Resource in Florida (Power Classes 2 and 3); Percent of Land Area with or Exceeding Power Class Shown. An asterisk denotes 100%.

FIGURE 5.8 (Continued). Areal Distribution of Wind Resource in Florida (Power Classes 4 and 5); Percent of Land Area with or Exceeding Power Class Shown

WINTER

SUMMER

FIGURE 5.9. Seasonal Average Wind Power in Florida (Winter, Summer)

SPRING

AUTUMN

FIGURE 5.9 (Continued). Seasonal Average Wind Power in Florida (Spring, Autumn)

TABLE 5.2. Florida Stations with Graphs of the Wind Characteristics

Station	Station Name ^(a)	Latitude, Degrees North	Longitude, Degrees West	Elevation of Station, m	Period of Record, Month/Year	Annual Average Wind Speed m/s				Annual Average Wind Power, watts/m ²		
						Anemometer Height	At Anemometer Height, m	At 10 m	At 50 m	At Anemometer Height, m	At 10 m	At 50 m
Avon Park ^(b) FL	Avon Park AFB	27.63	81.33	20	12/64-12/70	4.9	2.2	2.4	3.1	23	31	62
Cape Kennedy FL	Cape Kennedy AFB	28.47	80.55	5	04/63-12/77	10.4	3.4	3.4	4.2	53	52	104
Cocoa Beach FL	Patrick AFB	28.23	80.60	3	05/58-12/70	4.0	4.0	4.5	5.7	76	113	225
Daytona Beach FL	Daytona Regional Airport	29.18	81.05	10	01/65-12/78	7.0	3.8	4.0	5.1	71	83	165
Ft. Myers FL	Page Field	26.65	81.87	5	01/65-12/78	6.1	3.6	3.9	4.9	60	74	148
Homestead FL	Homestead AFB	25.48	80.38	5	01/56-12/70	5.2	3.2	3.5	4.4	55	73	145
Jacksonville FL	Jacksonville Inter- national Airport	30.50	81.70	9	01/71-12/78	6.1	3.2	3.4	4.3	52	64	128
Key West FL	Key West International Airport	24.55	81.75	7	06/64-12/78	7.0	5.0	5.2	6.6	113	132	262
Miami FL	Miami International	25.80	80.27	4	03/60-12/78	7.0	4.2	4.4	5.6	83	95	190
Milton FL	Whiting NAS	30.72	87.02	54	02/69-12/78	4.0	2.3	2.7	3.3	27	40	80
Orlando FL	Herndon Fld.	28.55	81.33	37	01/60-12/74	6.1	3.9	4.2	5.3	68	84	168
Panama City FL	Tyndall AFB	30.07	85.58	7	02/58-06/70	3.0	3.1	3.7	4.6	46	77	153
Pensacola ^(b) FL	Saufley Field	30.48	87.35	28	11/48-08/62	17.7	3.9	3.6	4.5	92	72	144
Tallahassee FL	Tallahassee Municipal Airport	30.38	84.37	18	03/65-12/78	7.6	2.9	3.0	3.7	38	43	85
Tampa FL	Tampa International Airport	27.97	82.53	11	03/65-12/78	6.7	3.7	3.9	4.9	54	64	128
Valparaiso FL	Eglin Field	30.48	86.52	20	09/61-09/67	6.1	3.0	3.3	4.1	44	54	108
West Palm Beach FL	Palm Beach Inter- national Airport	26.68	80.10	67	01/65-12/78	6.7	4.3	4.5	5.7	94	112	222

(a) AFB - Air Force Base
NAS - Naval Air Station

(b) Wind speed and powers at these stations are based on less than 24 hourly observations (usually 12 to 18 daytime observations).

FIGURE 5.10. Interannual Wind Power and Speed for Florida

FIGURE 5.11. Monthly Average Wind Power and Speed for Florida

FIGURE 5.12. Diurnal Wind Speed by Season for Florida

——— PERCENT FREQUENCY LEFT ORDINATE - PERCENT
 - - - - - WIND SPEED RIGHT ORDINATE - M/S
 PNL-3195 WERA-6
 ABSISSA - WIND DIRECTION

FIGURE 5.13. Directional Frequency and Average Wind Speed for Florida

— ACTUAL DISTRIBUTION ORDINATE - PERCENT
 - - - RAYLEIGH DISTRIBUTION ABSCISSA - M/S
 PNL 3195 WERA-6

FIGURE 5.14. Annual Average Wind Speed Frequency for Florida

ORDINATE - PERCENT
ABSCISSA - M/S
PNL-3195 WERA-6

FIGURE 5.15. Annual Average Wind Speed Duration for Florida

ORDINATE - PERCENT
ABSCISSA - WATTS/M²
PNL-3195 WERA-6

FIGURE 5.16. Annual Average Wind Power Duration for Florida

GEORGIA

CHAPTER 6: GEORGIA

Georgia covers an area of 152,488 km² (58,876 mi²) and had a population of 5,048,000 in 1977. In 1970, about 60 percent of the people lived in urban areas. Atlanta and Columbus are the two largest cities (Figure 6.1).

The terrain complexity generally increases moving southeast to northwest across Georgia. The corresponding physiographic regions of the state include the coastal plain in the southeast, the central piedmont area, and the Appalachian foothills and mountains in the northwest (Figure 6.2). Local relief ranges from 0 to 30 m (0 to 100 ft) in southeastern Georgia, to 305 to 915 m (1,000 to 3,000 ft) in northern Georgia (Figure 6.3).

Wind data are distributed relatively evenly throughout Georgia except for the east-central and northern mountainous areas (Figures 6.4 and 6.5). Interpolated upper air data were used to supplement the ground station data in northern Georgia.

6.1 ANNUAL AVERAGE WIND POWER

The analyses of mean wind power generally apply to terrain features that are favorably exposed to the wind, such as mountain summits, ridge crests, hilltops, and uplands (see Section 1.6). However, nearby terrain features may interact with the wind field to cause the wind power at some exposed sites to vary as much as + 50 to 100 percent from the assessment value. [See Wegley et al. (1980) for information on terrain features that may increase or reduce wind energy.] In forested or wooded areas, the assessment values are representative of large clearings, such as airports, with good exposure to the prevailing strong winds. In mountainous regions, the analyses also reflect major valleys. The percentage of land area that is favorably exposed to the wind strongly depends on the land-surface form (Section 1.8).

The annual average wind power map for Georgia (Figure 6.6) shows that wind power is predominantly class 1 over much of the state. Class 2 wind power occurs on exposed isolated peaks such as Lookout Mountain in the northwestern corner of Georgia and in the open high hills of northern Georgia. Exposed ridge and mountaintops in the Blue Ridge Mountains of northern Georgia are estimated to have wind power ranging up to class 5. Class 3 wind power is also estimated along the exposed shoreline of Georgia including some

of the larger bays. Wind power is estimated to be class 6, 50 to 200 km (30-125 mi) offshore.

6.1.1 Certainty Rating of the Wind Resource

Although the wind data density in east-central Georgia is low, the terrain is not complex and the wind resource is expected to have little geographic variability. Hence, a certainty rating of 2 is indicated for this area (Figure 6.7). The complexity of the terrain in the Blue Ridge Mountains of northern Georgia produces a certainty rating of 2 near the border with North Carolina. A certainty rating of 2 can also be found along the Georgia coast and in a small area south of Warner Robins; these areas lack data. The remainder of the state has certainty ratings of 3 and 4.

6.1.2 Areal Distribution of the Wind Resource

Nearly 97 percent of the land area in Georgia is associated with class 1 wind power (Figure 6.8 and Table 6.1). Class 2 wind power is found over only 2.5 percent of the land area and it is associated with the open hills in northern Georgia. The exposed ridge and mountaintops in the Blue Ridge Mountains have wind power ranging from class 3 to class 5, yet represent only 0.5 percent of the land area. The number of grid cells associated with class 2 and 3 wind power suggest 4 percent of the land area is in each of these classes, but only the exposed ridge and mountaintops within these grid cells have the higher wind power. Thus, topographic sheltering effects within the grid squares reduce these percentages.

6.2 Seasonal Wind Power

Seasonal wind power maps are shown on facing pages in Figure 6.9. The northwest half of Georgia has highest wind power in winter, while spring is the season of maximum wind power in the southeastern half of the state.

6.2.1 Winter

In winter much of the state has wind power of class 1. Class 2 wind power is found along the coast, with estimates of class 3 on the immediate shoreline. In the higher elevations of northern Georgia, wind power ranges from class 2 in tablelands to estimates of class 7 in the Blue Ridge Mountains in the extreme northeastern part

of the state where some elevations are over 1,400 m (4,500 ft). Class 4 and 5 wind powers are estimated for the ridges in extreme northwestern Georgia. The wind power is estimated to be class 7 for distances of 50 to 200 km (30-125 mi) offshore.

6.2.2 Spring

Highest wind power on the exposed ridge crests and mountain tops in the Blue Ridge Mountains are in classes 5 and 6. Open high hills in northern Georgia have wind power in classes 2 and 3. The irregular plains and open low hills and valleys of the state have class 1 wind power. Class 2 wind power occurs along the coastal areas while the exposed shoreline of Georgia has estimated class 3 wind power. Offshore, at distances of 50-200 km (30-125 mi), the wind power increases to class 6 over the open water.

6.2.3 Summer

The entire state has low (class 1) wind power in summer, including the exposed ridge crests and mountain tops in the Blue Ridge Mountains. Class 2 wind power is estimated over the coastal waters of Georgia in summer.

6.2.4 Autumn

In autumn, the exposed ridge crests and mountaintops of the Blue Ridge Mountains show a slight increase in wind power to class 2. Similarly, high open hills in northern Georgia also have class 2 wind power. The greatest part of the land area of the state, including the flat coastal plain and the irregular plains and low hills of the piedmont, has class 1 wind power. The exposed Georgia shoreline has wind power in class 2, while the open waters, 50 to 200 km (30-125 mi) offshore have much higher wind power in class 6.

6.3 FEATURES OF SELECTED STATIONS

Table 6.2 gives the location and annual wind speed and power density of 13 stations in Georgia. Graphs of other features of the wind resource at these stations are shown in Figures 6.10 through 6.16.

Albany/Albany Naval Air Station, Alma/Bacon County Airport, and Valdosta/Valdosta Municipal Airport are representative of the flat plains of southern Georgia. Albany Naval Air Station lies about 5 km (3 mi) east of the city of Albany. Bacon County Airport is located 55 km (34 mi) southwest of the Altamaha River, 5 km (3 mi) west of

Alma. Valdosta Municipal Airport is situated about 17 km (11 mi) north of the Georgia-Florida border and 5 km (3 mi) south of Valdosta in smooth flat terrain.

Brunswick/Glynco Naval Air Station and Savannah/Savannah Municipal Airport are both representative of the flat coastal area of southeastern Georgia. Glynco Naval Air Station is located about 17 km (10 mi) west of the Atlantic Ocean and 3 km (2 mi) north of Brunswick. The Savannah Municipal Airport lies about 35 km (22 mi) west of the Atlantic Ocean and 7 km (4 mi) southwest of the Savannah River. Although it is in the coastal zone, it is not exposed as well as Glynco Naval Air Station.

Athens/Athens Municipal Airport, and Atlanta/Hartsfield Airport are representative of the band of irregular plains that have elevations of 30 to 90 m (100 to 300 ft) and stretch southwest to northeast across northern Georgia. These irregular plains account for about 15 percent of Georgia's land area. Athens Municipal Airport is located in northeastern Georgia, about 65 km (41 mi) west of the Savannah River. Hartsfield Airport lies in northwestern Georgia about 90 km (56 mi) west-southwest of Athens on the southern limits of Atlanta.

Augusta/Bush Field is located in the Savannah River valley on the Georgia-South Carolina border about 1 km west of the Savannah River. The station's environment is characteristic of a valley location within irregular plains.

Columbus/Columbus Metropolitan Airport is situated near the Georgia-Alabama border about 5 km (3 mi) east of the Chattahoochee River. The airport is located within the urban confines of Columbus. Irregular plains characterize the surrounding topography.

Macon/Lewis B. Wilson Airport and Warner Robins/Robins AFB are both located in central Georgia. The environmental topography is characterized by irregular plains. The Lewis B. Wilson Airport is 15 km (9 mi) south of Macon and about 4 km (2.5 mi) west of the Ocmulgee River. Open low hills (30 to 90 m local relief) occur within 10 km (6 mi) to the north of the airport. Robins AFB is located 7 km (4 mi) southeast of Lewis B. Wilson Airport adjacent to, and west of, the Ocmulgee River. Open low hills (30 to 90 m local relief) occur within 15 km north of the Air Force Base.

Marietta/Dobbins AFB and Rome/R.B. Russell Field both lie in the tablelands

(90 to 150 m local relief) of northwestern Georgia. Dobbins AFB is about 330 m (1,070 ft) above mean sea level and is the highest of the Georgia wind stations used in this study. The city of Marietta surrounds the Air Force Base. R.B. Russell Field is located 10 km (6 mi) north of Rome in a valley. Open hills lie about 10 km (6 mi) to the northwest which have relief ranging from 90 to 150 m (300 to 500 ft) above local elevation.

6.3.1 Interannual Wind Power and Speed

Large interannual variability during periods of constant anemometer height occurred at Alma, Augusta/Bush, Brunswick, Macon, Marietta/Dobbins, Rome/Russell, and Warner Robins (Figure 6.10). With the exception of Augusta/Bush and Warner Robins, the highest annual average wind power exceeds twice the lowest annual average wind power at these stations. Substantial variability also exists at Albany, Athens, Atlanta, and Savannah. A long-term downward trend in wind speed and power is evident at Albany (1957 through 1966). Interpretation of such a trend must be done with caution because, over a period of time, equipment wear and increased friction can possibly result in lower recorded wind speeds and powers. Exposure degradation may have occurred as a result of vegetation growth. Some of the interannual variability may also be attributable to the influence of occasional hurricane passage as well.

6.3.2 Monthly Average Wind Power and Speed

The largest monthly variations in wind power occur at inland stations: Athens, Atlanta, and Warner Robins (Figure 6.11). At each of these stations, the maximum wind power is over three times the minimum. In general, maximum wind power occurs from January through April; peak wind powers occur most frequently in March. Marietta/Dobbins is the most elevated of all the Georgia stations represented, yet wind speeds and powers seem particularly low. This may be due to poor exposure.

6.3.3 Diurnal Wind Speed by Season

With the exception of Athens and Atlanta, the 13 stations all show quite similar diurnal patterns for wind speed (Figure 6.12). The typical pattern shows a daytime rise in wind speed with a peak wind speed in the early to late afternoon (1300 to 1600 LST) and a relatively uniform minimum mean speed from 2100 to 0600 LST. There is some tendency for the peak to occur later in the day during spring and summer (1400 to 1600 LST) than during the autumn and winter (1300 to

1400 LST) as a consequence of extended daytime heating in summer. The peak appears to be damped in magnitude at Athens and Atlanta while the nighttime wind speeds tend to be higher than at other Georgia stations. These stations (particularly Atlanta) may be better exposed especially in view of the low frequency of calm conditions.

6.3.4 Directional Frequency and Average Speed

Prevailing surface wind directions in Georgia are highly variable from station to station. West and west-northwest are the most frequently occurring prevailing wind directions throughout the 13 stations. The two Atlantic coastal stations, Brunswick and Savannah, have a westerly prevailing wind direction (Figure 6.13).

The average wind speed is highest for northeast winds at Brunswick and for west-northwest winds at Savannah; both are on or near the Atlantic coast. In general, the highest wind speeds most frequently occur with west-northwest winds. However, at Brunswick, the highest winds are from the northeast similar to other coastal stations to the south in Florida where the westerlies are less dominant.

6.3.5 Annual Average Wind Speed Frequency

Observer biases are apparent from the peaks at 2, 3 or 5 m/s (4, 6 and 10 knots) in the wind speed frequency distributions for Alma, Marietta, and Rome. These stations have the earliest periods of record among the selected stations that were used (see Figure 6.14). The stations with more recent records show little evidence of observer bias.

The frequency distribution for Savannah, a near-coastal station, appears to be in the best agreement with the theoretical Rayleigh distribution. Albany, Brunswick, Marietta and Warner exhibit a very high frequency of calms (> 20 percent) and have the poorest agreement with the Rayleigh distribution. Such a high frequency of calms may be caused by high anemometer threshold velocities.

6.3.6 Annual Average Wind Speed and Power Duration

The percent of time that a given wind speed or power is exceeded is shown in Figures 6.15 and 6.16. Abrupt changes in the slope of the duration curves correspond to peaks in the speed frequency distribution caused by observer bias and instrument threshold velocity.

FIGURE 6.1. Geographic Map of Georgia

FIGURE 6.2. Topographic Map of Georgia

FIGURE 6.3. Land-Surface Form Map for Georgia

LAND-SURFACE FORM LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

PLAINS WITH HILLS OR MOUNTAINS

A, B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50-80% OF AREA GENTLY SLOPING
C	20-50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50-75% OF GENTLE SLOPE IS IN LOWLAND
c	50-75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

FIGURE 6.5. Location of Stations Used in Georgia Resource Assessment

FIGURE 6.4. NCC Station Locations in Georgia

FIGURE 6.6. Georgia Annual Average Wind Power

Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, ^(b) m/s (mph)	Wind Power Density, watts/m ²	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.

TABLE 6.1. Areal Distribution (km²) of Wind Power Classes in Georgia

Power Class	Land Area	% Land Area	Cumulative Land Area	% Cumulative Land Area
1	148,700	97.	153,300	100.
2	3,800	2.5	4,600	3.0
3	380	0.24	800	0.54
4	420	0.28	450	0.30
5	30	0.02	30	0.02
6	0	0.00	0	0.00
7	0	0.00	0	0.00

FIGURE 6.7. Certainty Rating of Georgia Wind Resource

CERTAINTY RATING LEGEND

Rating	Definition
1	<p>The lowest degree of certainty. A combination of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A low-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A high-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>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.</p>

FIGURE 6.8. Areal Distribution of Wind Resource in Georgia (Power Classes 2 and 3); Percent of Land Area with or Exceeding Power Class Shown

FIGURE 6.8 (Continued). Areal Distribution of Wind Resource in Georgia (Power Classes 4 and 5); Percent of Land Area with or Exceeding Power Class Shown

WINTER

SUMMER

FIGURE 6.9. Seasonal Average Wind Power in Georgia (Winter, Summer)

SPRING

AUTUMN

FIGURE 6.9 (Continued). Seasonal Average Wind Power in Georgia (Spring, Autumn)

TABLE 6.2. Georgia Stations with Graphs of the Wind Characteristics

Station	Station Name ^(a)	Latitude, Degrees North	Longitude, Degrees West	Elevation of Station, m	Period of Record, Month/Year	Annual Average Wind Speed m/s				Annual Average Wind Power, watts/m ²		
						Anemometer Height	At Anemometer Height, m	At 10 m	At 50 m	At Anemometer Height, m	At 10 m	At 50 m
Albany GA	Albany NAS	31.58	84.12	63	05/68-04/74	4.0	2.1	2.3	3.0	20	30	59
Alma GA	Bacon County Airport	31.53	82.52	61	01/49-12/58	7.0	2.8	2.9	3.7	39	45	91
Athens GA	Athens Municipal Airport	33.95	83.32	247	09/59-12/78	6.1	3.2	3.4	4.3	41	51	101
Atlanta GA	Hartsfield Airport	33.65	84.42	311	12/61-12/78	6.1	3.7	4.0	5.0	56	69	138
Augusta GA	Bush Field	33.37	81.97	45	03/63-12/78	6.1	3.0	3.2	4.1	41	51	101
Brunswick GA	Glynco NAS	31.15	81.38	7	12/58-02/72	4.6	2.5	2.8	3.5	29	41	81
Columbus GA	Columbus Metropolitan Airport	32.52	84.93	123	07/64-12/78	6.1	2.9	3.2	4.0	37	46	91
Macon GA	Lewis B. Wilson Airport	32.70	83.65	110	08/62-12/78	7.0	3.2	3.4	4.3	48	56	111
Marietta GA	Dobbins AFB	33.92	84.52	330	05/56-04/62	22.9	2.8	2.5	3.2	57	40	80
Rome ^(b) GA	R.B. Russel Field	34.35	85.17	195	01/52-09/63	15.5	3.0	2.8	3.5	48	40	79
Savannah GA	Savannah Municipal Airport	32.13	81.20	16	08/64-12/78	6.1	3.4	3.6	4.5	49	61	121
Valdosta GA	Valdosta Municipal Airport	30.78	83.28	66	01/72-12/76	6.1	3.0	3.2	4.0	37	46	91
Warner Robins GA	Robins AFB	32.63	83.60	92	05/56-12/70	4.0	2.2	2.5	3.1	28	42	83

(a) AFB - Air Force Base
NAS - Naval Air Station

(b) Wind speeds and powers are based on less than 24 hourly observations per day for most of the period.

FIGURE 6.10. Interannual Wind Power and Speed for Georgia

FIGURE 6.11. Monthly Average Wind Power and Speed for Georgia

FIGURE 6.12. Diurnal Wind Speed by Season for Georgia

— PERCENT FREQUENCY LEFT ORDINATE - PERCENT
 - - - WIND SPEED RIGHT ORDINATE - M/S
 PNL-3195 WERA-6
 ABSCISSA - WIND DIRECTION

FIGURE 6.13. Directional Frequency and Average Wind Speed for Georgia

— ACTUAL DISTRIBUTION ORDINATE - PERCENT
 - - - RAYLEIGH DISTRIBUTION ABSCISSA - M/S
 PNL-3195 WERA-6

FIGURE 6.14. Annual Average Wind Speed Frequency for Georgia

ORDINATE - PERCENT
ABSCISSA - M/S
PNL 3195 WERA-6

FIGURE 6.15. Annual Average Wind Speed Duration for Georgia

ORDINATE - PERCENT
ABSCISSA - WATTS/M²
PNL-3195 WERA-6

FIGURE 6.16. Annual Average Wind Power Duration for Georgia

MISSISSIPPI

CHAPTER 7: MISSISSIPPI

Mississippi covers an area of 123,584 km² (47,716 mi²) and had a population of 2,389,000 in 1977. In 1970, 45 percent of the people lived in urban areas. Jackson and Biloxi are the two largest cities (Figure 7.1).

Irregular plains are the dominant land-surface form in Mississippi. In the western part of the state, the Mississippi River valley is characterized by a broad region of flat plains in the northwest which gradually tapers to a narrow strip in the southwest part of the state. Flat plains are also found along a narrow Gulf coast strip. Otherwise, irregular plains dominate most of the state with the exception of stretches of open hills in the northeast and east-central regions (Figure 7.2). Local relief ranges from 0 to 30 m (0 to 100 ft) in southern and northwestern Mississippi to 90 to 150 m (300 to 500 ft) in the northeast (Figure 7.3).

Wind data are distributed relatively evenly throughout Mississippi except for the northern part of the state (Figures 7.4 and 7.5).

7.1 ANNUAL AVERAGE WIND POWER

The analyses of mean wind power generally apply to terrain features that are favorably exposed to the wind, such as mountain summits, ridge crests, hilltops, and uplands (see Section 1.6). However, nearby terrain features may interact with the wind field to cause the wind power at some exposed sites to vary as much as + 50 to 100 percent from the assessment value. [See Wegley et al. (1980) for information on terrain features that may increase or reduce wind energy.] In forested or wooded areas, the assessment values are representative of large clearings, such as airports, with good exposure to the prevailing strong winds. In mountainous regions, the analyses also reflect major valleys. The percentage of land area that is favorably exposed to the wind strongly depends on the land-surface form (Section 1.8).

The annual average wind power map for Mississippi (Figure 7.6) shows class 1 power for the entire state. The exposed Gulf Coast shoreline experiences class 2 wind power. Wind power increases to class 5, 50 to 200 km (30-125 mi) offshore in the Gulf of Mexico.

7.1.1 Certainty Rating of the Wind Resource

Certainty ratings of the wind power for Mississippi are presented in Figure 7.7. The wind data density in Mississippi is relatively low. Certainty ratings of 2 are common throughout northern Mississippi due to lack of data. Similarly, a certainty rating of 2 occurs in central Mississippi. Several areas in southern Mississippi also have certainty ratings of 2, including the Gulf Coast. Certainty ratings of 3 and 4 mostly occur in east-central and parts of west-central Mississippi where data are available. It should be noted, however, that despite the sparsity of data, the terrain lacks complexity and the wind resource is expected to have little variation over most of the state.

7.1.2 Areal Distribution of the Wind Resource

Figure 7.8 and Table 7.1 show that all the land area of Mississippi is associated with class 1 wind power from the Mississippi River valley in the west to the irregular plains and low hills in the eastern part of the state.

7.2 SEASONAL WIND POWER

Wind power maps for each season are shown on facing pages in Figure 7.9. Winter is the season of maximum wind power in Mississippi except along the Gulf Coast where there is a spring maximum. Summer is the season of minimum wind power across the entire state.

7.2.1 Winter

Class 2 wind power occurs in northern Mississippi and in the land areas along the Gulf Coast and wind power in class 3 is estimated along the exposed Mississippi shoreline. The remainder of the state has class 1 wind power. Wind power 50-200 km (30-125 mi) offshore increases to class 6.

7.2.2 Spring

Spring wind power in Mississippi shows a similar distribution as in winter, namely class 2 in extreme northern Mississippi and along the Gulf Coast, class 3 along the exposed shoreline and class 1 over the remainder of the state. The wind power values in class 1, which cover most of the

state in spring, are lower than in winter. The class 4 wind powers 50-200 km (30-125 mi) offshore in the Gulf are also lower than in winter.

7.2.3 Summer

Wind power is very low throughout Mississippi in summer and is restricted to class 1. Offshore, in the Gulf of Mexico, wind power is class 2.

7.2.4 Autumn

In autumn, as in summer, wind power throughout Mississippi falls into class 1. Class 2 wind power occurs along the exposed Gulf shoreline, and 50-200 km (30-125 mi) offshore, wind power increases to class 5 over open water.

7.3 FEATURES OF SELECTED STATIONS

Table 7.2 gives the location and annual wind speed and power density of seven stations in Mississippi. Graphs of other features of the wind resource at these stations are shown in Figures 7.10 through 7.16.

Biloxi/Kessler AFB lies along the Gulf coast on the north side of a peninsula. The site is not directly exposed to onshore air-flow because it is surrounded by the city of Biloxi to the south. To the north, the air base is bordered by a protected bay. The station experiences prevailing southerly flow from the Gulf in summer and northerly offshore flow in winter.

Jackson/Thompson Field lies on lowland plains characterized by gently rolling topography. Thompson Field is 10 km (6 mi) east of Jackson and 10 km (6 mi) south of Ross Barnett Reservoir. The site is located in terrain that is representative of a large part of the state.

Columbus AFB is located 15 km (10 mi) north of downtown Columbus. It is situated in a lowland and appears to be somewhat shielded by nearby hills that rise 20-25 m (65-80 ft) above local terrain within 5 km (3 mi) to the east and northwest of the airport.

Greenville is situated on the Mississippi flood plain 13 km (8 mi) east of the Mississippi River. No significant topographical variation exists in the region to influence wind flow. During the summary period, 1954-1960, the station was located at an air force base about 4 km (6 mi) NNE of Greenville.

Greenwood is located on the eastern edge of the broad Mississippi Valley along the Yazoo River. A bench having a topographic rise of over 70 m (200 ft) occurs about 15 km (10 mi) east of Greenwood. The station was located at an airport one mile south of town during the summary period. Greenwood had wind powers that were nearly twice those at other stations in Mississippi. The anemometer was located on a rooftop at the airport during the summary period and may have been influenced by local accelerations around the building.

McComb is located in southeast Mississippi 25 km (17 mi) north of the Louisiana border on the lowland plain in gently rolling terrain. The station was located at McComb Airport which was sited in town during the summary period.

Meridian/Key Field is situated 5 km (3 mi) southwest of downtown Meridian in the east-central part of the state. Meridian Airport is in a lowland. A terrain rise of over 60 m (200 ft) occurs about 3 km (2 mi) east and 5 km (3 mi) west of the airport. Perhaps this partially accounts for the low annual wind speed (2.8 m/s) and high frequency of calms (almost 25 percent).

Topographic influence on wind characteristics is likely to be limited throughout most of Mississippi owing to the lack of major terrain variations.

7.3.1 Interannual Wind Power and Speed

Large interannual variability during periods of constant anemometer height occurred at Biloxi, Jackson, and Meridian (Figure 7.10). The highest annual average wind power exceeded twice the lowest annual average wind power at Biloxi and Jackson. Substantial variability also exists at Columbus and Greenwood. A long-term downward trend in wind speed and power is evident at Jackson (1964 through 1978). Interpretation of such trends must be done with caution because, over a period of time, equipment wear and increased friction can result in lower recorded wind speeds and powers. Exposure degradation from surrounding vegetative growth may also create such a trend.

7.3.2 Monthly Average Wind Power and Speed

The largest monthly variations in wind power occur at inland stations: Columbus, Greenwood, and Jackson (Figure 7.11). At each of these stations, the maximum wind power is over three times the minimum. In

general, maximum wind power occurs from January to April; peak wind power occurs most frequently in March.

7.3.3 Diurnal Wind Speed by Season

All 7 stations show quite similar diurnal patterns for wind speed (Figure 7.12). The typical pattern shows a daytime rise in wind speed, with a peak wind speed in the early to late afternoon (1200 to 1600 LST) and a relatively uniform, minimum mean speed from 2000 to 0600 LST. There is some tendency for the peak to occur later in the day during spring and summer (1400 to 1600 LST) than during the autumn and winter (1200 to 1400 LST) as a result of extended daytime heating in summer.

7.3.4 Directional Frequency and Average Speed

North and south are the most frequently occurring prevailing wind directions throughout the 7 stations in Mississippi (Figure 7.13).

Highest average wind speed is associated with east-southeast and southwest winds along the Gulf coast at Biloxi. In general, the highest wind speeds occur most frequently with north-northwest winds.

Greenville has a highly irregular wind direction frequency pattern, perhaps caused by observer bias. The higher wind speeds at Greenwood may have been related to local accelerations associated with rooftop exposure.

7.3.5 Annual Average Wind Speed Frequency

Observer biases are apparent from the peaks at 2 and 5 m/s (5 and 10 knots) in the wind speed frequency distribution for McComb (see Figure 7.14). The stations with more recent records along with Greenwood's 1949 to 1954 record show little evidence of this observer bias.

Both Columbus and Meridian show calm conditions in over 20 percent of their observations and also display the poorest comparison with the Rayleigh distribution. The lack of any reported 1 m/s winds at Meridian and Greenville may be an indication of instrumentation with threshold velocities greater than 1 m/s. Winds that are in this range (< 2 m/s) are generally recorded as calm and can falsely bias the record. Greenwood, on the other hand, shows only about 5 percent calm wind observations and the best agreement with the Rayleigh distribution.

7.3.6 Annual Average Wind Speed and Power Duration

The percent of time that a given wind speed or power is exceeded is shown in Figures 7.15 and 7.16. Abrupt changes in the slope of the duration curves correspond to peaks in the speed frequency distribution caused by observer bias and instrument threshold velocity.

FIGURE 7.1. Geographic Map of Mississippi

FIGURE 7.2. Topographic Map of Mississippi

FIGURE 7.3. Land-Surface Form Map for Mississippi

LAND-SURFACE FORM LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50-80% OF AREA GENTLY SLOPING
C	20-50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50-75% OF GENTLE SLOPE IS IN LOWLAND
c	50-75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

FIGURE 7.4. NCC Station Locations in Mississippi

FIGURE 7.5. Location of Stations Used in Mississippi Resource Assessment

FIGURE 7.6. Mississippi Annual Average Wind Power

Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, ^(b) m/s (mph)	Wind Power Density, watts/m ²	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.

TABLE 7.1. Areal Distribution (km²) of Wind Power Classes in Mississippi

Power Class	Land Area	% Land Area	Cumulative Land Area	% Cumulative Land Area
1	122,550	100.	122,550	100.
2	0	0.00	0	0.00
3	0	0.00	0	0.00
4	0	0.00	0	0.00
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	0	0.00	0	0.00

FIGURE 7.7. Certainty Rating of Mississippi Wind Resource

CERTAINTY RATING LEGEND

Rating	Definition
1	<p>The lowest degree of certainty. A combination of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A low-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A high-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>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.</p>

FIGURE 7.8. Areal Distribution of Wind Resource in Mississippi (Power Classes 2 and 3); Percent of Land Area with or Exceeding Power Class Shown

FIGURE 7.8 (Continued). Areal Distribution of Wind Resource in Mississippi (Power Classes 4 and 5); Percent of Land Area with or Exceeding Power Class Shown

FIGURE 7.9. Seasonal Average Wind Power in Mississippi (Winter, Summer)

FIGURE 7.9 (Continued). Seasonal Average Wind Power in Mississippi (Spring, Autumn)

TABLE 7.2. Mississippi Stations with Graphs of the Wind Characteristics

Station	Station Name ^(a)	Latitude, Degrees North	Longitude, Degrees West	Elevation of Station, m	Period of Record, Month/Year	Annual Average Wind Speed m/s				Annual Average Wind Power, watts/m ²		
						Anemometer Height	At Anemometer Height, m	At 10 m	At 50 m	At Anemometer Height, m	At 10 m	At 50 m
Biloxi MS	Biloxi Airport ^(b)	30.40	88.92	8	05/64-12/70	4.0	3.1	3.5	4.4	47	70	139
Columbus MS	Columbus AFB	33.63	88.45	68	05/64-12/70	4.0	2.2	2.5	3.1	29	43	86
Greenville MS	Greenville AFB	33.48	90.98	42	04/53-12/60	9.4	3.0	3.0	3.8	50	51	102
Greenwood MS	Greenwood Airport	33.52	90.20	40	01/49-12/54	13.4	4.5	4.3	5.5	125	110	220
Jackson MS	A.C. Thompson Field	32.32	90.08	110	07/63-12/78	6.1	3.3	3.6	4.5	54	67	133
McComb MS	McComb Airport	31.25	90.47	141	12/48-12/54	8.8	3.0	3.1	3.9	42	44	88
Meridian MS	Key Field	32.33	88.75	90	01/65-12/78	6.1	2.6	2.8	3.5	34	42	84

(a) AFB - Air Force Base

(b) Less than 24 observations per day except from January 1964 - August 1965.

FIGURE 7.10. Interannual Wind Power and Speed for Mississippi

FIGURE 7.11. Monthly Average Wind Power and Speed for Mississippi

FIGURE 7.12. Diurnal Wind Speed by Season for Mississippi

— PERCENT FREQUENCY LEFT ORDINATE — PERCENT
 - - - WIND SPEED RIGHT ORDINATE — M/S
 PNL-3195 WERA-6
 ABSCISSA — WIND DIRECTION

FIGURE 7.13. Directional Frequency and Average Wind Speed for Mississippi

— ACTUAL DISTRIBUTION ORDINATE - PERCENT
 - - - RAYLEIGH DISTRIBUTION ABSCISSA - M/S
 PNL-3195 WERA-6

FIGURE 7.14. Annual Average Wind Speed Frequency for Mississippi

ORDINATE - PERCENT

ABSCISSA - M/S

PNL 3195 WERA-6

FIGURE 7.15. Annual Average Wind Speed Duration for Mississippi

ORDINATE - PERCENT
 ABSCISSA - WATTS/M²
 PNL 3195 WERA-6

FIGURE 7.16. Annual Average Wind Power Duration for Mississippi

SOUTH CAROLINA

CHAPTER 8: SOUTH CAROLINA

South Carolina covers an area of 80,432 km² (31,055 mi²) and had a population of 2,876,000 in 1977. In 1970, 48 percent of the people lived in urban areas. Columbia and Charleston are the two largest cities (Figure 8.1).

The terrain complexity generally increases moving from the coastal plains in the south-east to the Appalachian foothills and mountains in the northwest (Figure 8.2). Local relief ranges from 0 to 30 m (0 to 100 ft) in the southeast to 305 to 915 m (1000 to 3000 ft) in the northwest (Figure 8.3).

Except for the northwest and the Atlantic coastal area, wind data are sparse in South Carolina. Interpolated upper-air wind data were used to supplement the ground station data in the higher elevations of western and northwestern South Carolina (Figures 8.4 and 8.5).

8.1 ANNUAL AVERAGE WIND POWER

The analyses of mean wind power generally apply to terrain features that are favorably exposed to the wind, such as mountain summits, ridge crests, hilltops, and uplands (see Section 1.6). However, nearby terrain features may interact with the wind field to cause the wind power at some exposed sites to vary as much as ± 50 to 100 percent from the assessment value. [See Wegley et al. (1980) for information on terrain features that may increase or reduce wind energy.] In forested or wooded areas, the assessment values are representative of large clearings, such as airports, with good exposure to the prevailing strong winds. In mountainous regions, the analyses also reflect major valleys. The percentage of land area that is favorably exposed to the wind strongly depends on the land-surface form (Section 1.8).

The annual average wind power map for South Carolina (Figure 8.6) shows a small area of class 3 and 4 wind power in the extreme northwest corner of the state, in the exposed ridge crests and mountaintops of the Blue Ridge Mountains. The class 2 wind power is characteristic of the high Appalachian foothills in northwestern South Carolina. The remainder of the state, consisting of low hills and irregular and smooth plains, has class 1 wind power. The exposed South Carolina shoreline has class 3 wind power. Over open water, 50-200 km (30-125 mi) offshore, wind power increases to class 6.

8.1.1 Certainty Rating of the Wind Resource

Certainty ratings for the wind power estimates in South Carolina are provided in Figure 8.7. A certainty rating of 2 is given for the complex terrain in northwestern South Carolina near the North Carolina border. Certainty ratings of 1 and 2 occur along the South Carolina coast where data are sparse. Data are also lacking in south-central South Carolina where the certainty rating is 2. The balance of the state has certainty ratings of 3 and 4.

8.1.2 Areal Distribution of the Wind Resource

Figure 8.8 and Table 8.1 show the areal distribution of wind power in South Carolina. As in the other states of the Southeast region, the greatest part of the land area (98 percent) in South Carolina is associated with class 1 wind power. The land having class 1 wind power is predominantly composed of smooth coastal plains and irregular plains and low hills of the piedmont. Less than 2 percent of the land area has class 2 wind power; this is found in the high Appalachian foothills in northwestern South Carolina. Very small percentages of the land area (much less than 1 percent) are associated with the exposed ridge crests and mountaintops in northwest South Carolina, which have class 3 and 4 wind power.

8.2 SEASONAL WIND POWER

Wind power maps for each season are shown on facing pages in Figure 8.9. Spring is the season of maximum wind power in all of South Carolina except on the exposed ridge crests and mountaintops in the northwestern part of the state where winter is the season of maximum wind power. Summer is the season of minimum wind power throughout the State.

8.2.1 Winter

During the winter the exposed ridge crests and mountaintops in northwestern South Carolina have the highest wind powers (class 5 and 6) of any land area in the Southeast. The high open Appalachian foothills of northwestern South Carolina have class 3 wind power; wind power estimates along the exposed South Carolina shoreline are also class 3. Class 7 wind power is estimated for areas 50-200 km (30-125 mi) offshore in the open Atlantic waters. A thin strip of coastal land less than 5 km (3 mi) wide has wind power in class 2.

The remaining and largest portion of the state has class 1 wind power in winter.

8.2.2 Spring

The distribution of wind power in spring is similar to the winter pattern except for the northwest mountain ridges and the offshore areas. Exposed ridges and mountain tops in the Blue Ridge Mountains have class 4 and 5 wind power, while the wind power in the high foothills has dropped to class 2. The wind power estimation 50-200 km (30-125 mi) off the coast of South Carolina decreases to class 6 in spring. The exposed shoreline, coastal strip and remainder of the state show no change from their respective class 3, 2, and 1 winter wind powers.

8.2.3 Summer

Summer wind power in South Carolina is low. Class 1 prevails throughout the state including the high exposed elevations in the Blue Ridge Mountains. Offshore wind power is class 2.

8.2.4 Autumn

Wind power begins to increase again in autumn. The exposed ridges and mountain tops in the Blue Ridge Mountains have class 2 and 3 wind power. The high Appalachian foothills in the northwestern part of the state have class 2 wind power as does the exposed South Carolina shoreline. Most of the state, as in other seasons, has class 1 wind power from the coastal plain to the piedmont.

8.3 FEATURES OF SELECTED STATIONS

Table 8.2 gives the location and annual wind speed and power density of ten stations in South Carolina. Graphs of other features of the wind resource at these stations are shown in Figures 8.10 through 8.16.

Three stations are located along the coastal region of the state; however, none of the three sites has direct shoreline exposure. Myrtle Beach AFB lies within 2 km (1.3 mi) of the coastline on the west side of U.S. Highway 17, 10 km (6 mi) south of Myrtle Beach. Charleston International Airport is located 25 km (17 mi) northwest of the Atlantic coastline on the northwest end of Charleston. Beaufort Air Station, on Port Royal Island, is 60 km (40 mi) northeast of Savannah and 25 km (17 mi) northwest of the Atlantic coastline. Even though the Beaufort site is not directly on the coastline, it appears to have a higher degree of coastal exposure than Charleston

because of the water bodies surrounding Port Royal Island even though the wind speed and power at the Beaufort station are less than at the Charleston Airport. The coastal stations have predominantly northerly flow during winter and southerly, onshore, flow in summer.

Florence City Airport and Sumter/Shaw AFB lie on the coastal plains. Florence City Airport is situated 20 km (12 mi) west of the Great Pee Dee River and 5 km (3 mi) east of Florence in northeast South Carolina. Shaw AFB lies 13 km (8 mi) northwest of Sumter and 15 km (10 mi) east of the Wateree River. Both stations are surrounded by relatively smooth terrain providing good topographical exposure for anemometry.

Two stations border the coastal plain and the piedmont region of the State. Eastover/McIntire Air National Guard Base is situated 15 km (10 mi) west of the Wateree River and 20 km (12 mi) southeast of Columbia in the central part of the State. Columbia Metropolitan Airport is located on the southwest periphery of Columbia, South Carolina. Both airfields are surrounded by gently rolling terrain.

Three stations are situated high on the piedmont plain near the foothills of the Appalachian Mountains. Anderson County Airport is located 5 km (3 mi) southwest of Anderson and 8 km (5 mi) east of the Hartwell Reservoir. The Greenville-Spartanburg Jet Airport is located 15 km (9 mi) northeast of Greenville and 3 km (2 mi) south of Greer, South Carolina. Spartanburg Memorial Airport is situated 40 km east-northeast of Greenville on the southern edge of Spartanburg. The prevailing wind directions at these sites are northeast and southwest, which is consistent with the orientation of the Appalachian foothills.

8.3.1 Interannual Wind Power and Speed

Large interannual variability during periods of constant anemometer height occurred at Beaufort, Charleston, Florence, Spartanburg, and Sumter (Figure 8.10). The highest annual average wind power exceeds twice the lowest annual average wind power at Charleston only. Substantial variability also exists at Anderson, Greenville, and Columbia.

8.3.2 Monthly Average Wind Power and Speed

The largest monthly variations in wind power occur at Charleston and Florence (Figure 8.11). At each of these stations, the maximum wind power is over three times the minimum. In general, the highest wind

power occurs from February to April; peak wind power occurs most frequently in February.

8.3.3 Diurnal Wind Speed by Season

All 10 stations show quite similar diurnal patterns for wind speed (Figure 8.12). The typical pattern shows a daytime rise in wind speed, with a peak wind speed in the early to late afternoon (1300 to 1600 LST) and a relatively uniform minimum mean wind speed from 2000 to 0600 LST. There is some tendency for the peak to occur later in the day during spring and summer (1400 to 1600 LST) than during the autumn and winter (1300 or 1400 LST) as a consequence of extended daytime heating in summer.

8.3.4 Directional Frequency and Average Speed

Prevailing surface winds throughout South Carolina are variable from station to station (Figure 8.13). Nevertheless, northeast and west are the most frequently occurring prevailing wind directions. The three coastal stations have northerly and southerly winds most frequently, but the average wind speed is highest at the coastal stations for westerly or southerly wind directions. In general, the highest

wind speeds are most frequently associated with winds from the west-southwest and west. In particular, Anderson has highly irregular wind direction frequency and wind speed patterns, perhaps caused by observer bias.

8.3.5 Annual Average Wind Speed Frequency

Observer biases are apparent from the peaks at 2 and 5 m/s in the wind speed frequency distributions for Anderson and Eastover (see Figure 8.14). Charleston and Spartanburg appear to have the best agreement between the actual wind speed distribution and the Rayleigh distribution. Eastover, Beaufort, Myrtle Beach and Sumter have the poorest agreement with the Rayleigh distribution. Each of these four stations reports a high frequency of calms (15 to 25 percent).

8.3.6 Annual Average Wind Speed and Power Duration

The percent of time that a given wind speed or power is exceeded is shown in Figures 8.15 and 8.16. Abrupt changes in the slope of the duration curves correspond to peaks in the speed frequency distribution caused by observer bias and instrument threshold velocity.

FIGURE 8.1. Geographic Map of South Carolina

FIGURE 8.2. Topographic Map of South Carolina

FIGURE 8.3. Land-Surface Form Map for South Carolina

LAND-SURFACE FORM LEGEND

PLAINS

A1	FLAT PLAINS
A2	SMOOTH PLAINS
B1	IRREGULAR PLAINS, SLIGHT RELIEF
B2	IRREGULAR PLAINS

TABLELANDS

B3c,d	TABLELANDS, MODERATE RELIEF
B4c,d	TABLELANDS, CONSIDERABLE RELIEF
B5c,d	TABLELANDS, HIGH RELIEF
B6c,d	TABLELANDS, VERY HIGH RELIEF

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	PLAINS WITH HILLS
B4,a,b	PLAINS WITH HIGH HILLS
B5a,b	PLAINS WITH LOW MOUNTAINS
B6a,b	PLAINS WITH HIGH MOUNTAINS

OPEN HILLS AND MOUNTAINS

C2	OPEN LOW HILLS
C3	OPEN HILLS
C4	OPEN HIGH HILLS
C5	OPEN LOW MOUNTAINS
C6	OPEN HIGH MOUNTAINS

HILLS AND MOUNTAINS

D3	HILLS
D4	HIGH HILLS
D5	LOW MOUNTAINS
D6	HIGH MOUNTAINS

SCHEME OF CLASSIFICATION

SLOPE (1st LETTER)

A	>80% OF AREA GENTLY SLOPING
B	50-80% OF AREA GENTLY SLOPING
C	20-50% OF AREA GENTLY SLOPING
D	<20% OF AREA GENTLY SLOPING

LOCAL RELIEF (2nd LETTER)

1	0 TO 30m (1 TO 100 ft)
2	30 TO 90m (100 TO 300 ft)
3	90 TO 150m (300 TO 500 ft)
4	150 TO 300m (500 TO 1000 ft)
5	300 TO 900m (1000 TO 3000 ft)
6	900 TO 1500m (3000 TO 5000 ft)

PROFILE TYPE (3rd LETTER)

a	>75% OF GENTLE SLOPE IS IN LOWLAND
b	50-75% OF GENTLE SLOPE IS IN LOWLAND
c	50-75% OF GENTLE SLOPE IS ON UPLAND
d	>75% OF GENTLE SLOPE IS ON UPLAND

FIGURE 8.5. Location of Stations Used in South Carolina Resource Assessment

FIGURE 8.4. NCC Station Locations in South Carolina

FIGURE 8.6. South Carolina Annual Average Wind Power

Classes of Wind Power Density at 10 m and 50 m^(a)

Wind Power Class	10 m (33 ft)		50 m (164 ft)	
	Wind Power Density, watts/m ²	Speed, ^(b) m/s (mph)	Wind Power Density, watts/m ²	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.

TABLE 8.1. Areal Distribution (km²) of Wind Power Classes in South Carolina

Power Class	Land Area	% Land Area	Cumulative Land Area	% Cumulative Land Area
1	80,300	98.	81,750	100.
2	1,300	1.6	1,460	1.8
3	180	0.22	190	0.23
4	10	0.01	10	0.01
5	0	0.00	0	0.00
6	0	0.00	0	0.00
7	0	0.00	0	0.00

FIGURE 8.7. Certainty Rating of South Carolina Wind Resource

CERTAINTY RATING LEGEND

Rating	Definition
1	<p>The lowest degree of certainty. A combination of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A low-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>A high-intermediate degree of certainty. One of the following conditions exists:</p> <ol style="list-style-type: none"> 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	<p>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.</p>

FIGURE 8.8. Area Distribution of Wind Resource in South Carolina (Power Classes 2 and 3); Percent of Land Area with or Exceeding Power Class Shown

Class 4

Class 5

FIGURE 8.8 (Continued). Areal Distribution of Wind Resource in South Carolina (Power Classes 4 and 5); Percent of Land Area with or Exceeding Power Class Shown

WINTER

SUMMER

FIGURE 8.9. Seasonal Average Wind Power in South Carolina (Winter, Summer)

SPRING

AUTUMN

FIGURE 8.9 (Continued). Seasonal Average Wind Power in South Carolina (Spring, Autumn)

TABLE 8.2. South Carolina Stations with Graphs of the Wind Characteristics

Station	Station Name ^(a)	Latitude, Degrees North	Longitude, Degrees West	Elevation of Station, m	Period of Record, Month/Year	Annual Average Wind Speed m/s				Annual Average Wind Power, watts/m ²		
						Anemometer Height	At Anemometer Height, m	At 10 m	At 50 m	At Anemometer Height, m	At 10 m	At 50 m
Anderson SC	Anderson County Airport	34.50	82.72	233	01/49-12/58	9.1	3.4	3.4	4.3	60	68	120
Beaufort SC	Marine Corps Air Station	32.47	80.72	15	01/60-02/72	3.7	2.4	2.8	3.5	28	43	86
Charleston SC	Charleston Inter- national Airport	32.90	80.05	18	10/58-12/78	6.1	3.8	4.1	5.2	67	83	165
Columbia SC	Columbia Airport	33.95	81.12	75	01/67 12/78	6.1	3.0	3.2	4.0	39	48	96
Eastover SC	McEntire Air National Guard Base	33.92	80.80	90	05/64-12/70	3.7	2.3	2.7	3.4	27	42	83
Florence SC	City-County Airport	34.18	79.72	46	03/62-12/64	11.9	3.8	3.7	4.7	61	57	113
Greenville SC	Greenville-Spartanburg Jet Age Airport	34.90	82.22	289	10/62-12/78	7.0	3.0	3.2	4.0	39	45	91
Myrtle Beach SC	Myrtle Beach AFB	33.68	78.93	8	05/59-11/68	3.0	2.8	3.3	4.1	37	62	123
Spartanburg SC	Downtown Memorial Airport	34.92	81.95	248	09/54-10/62	14.9	3.5	3.4	4.2	71	60	119
Sumter SC	Shaw AFB	33.97	80.48	74	04/64-12/70	4.0	2.4	2.8	3.5	30	45	89

(a) AFB - Air Force Base

FIGURE 8.10. Interannual Wind Power and Speed for South Carolina

FIGURE 8.11. Monthly Average Wind Power and Speed for South Carolina

FIGURE 8.12. Diurnal Wind Speed by Season for South Carolina

— PERCENT FREQUENCY LEFT ORDINATE - PERCENT
 - - - WIND SPEED RIGHT ORDINATE - M/S
 PNL-3195 WERA-6
 ABSCISSA - WIND DIRECTION

FIGURE 8.13. Directional Frequency and Average Wind Speed for South Carolina

— ACTUAL DISTRIBUTION ORDINATE - PERCENT
 - - - RAYLEIGH DISTRIBUTION ABSCISSA - M/S
 PNL-3195 WERA-6

FIGURE 8.14. Annual Average Wind Speed Frequency for South Carolina

ORDINATE - PERCENT
ABSCISSA - M/S
PNL 3195 WERA-6

ANDERSON SC 01/49-12/58
93846 Z= 9.1 R. V= 3.4, P= 58

BEAUFORT SC 01/60-02/72
93831 Z= 3.7 G. V= 2.8, P= 38

CHARLESTON SC 10/58-12/78
13880 Z= 6.1 G. V= 3.8, P= 67

COLUMBIA SC 01/67-12/78
13883 Z= 6.1 G. V= 3.0, P= 39

EASTOVER SC 03/64-12/70
3858 Z= 3.7 G. V= 2.3, P= 27E

FLORENCE SC 03/62-12/64
13744 Z= 6.4 G. V= 3.7, P= 58

GREENVILLE SC 10/62-12/78
3870 Z= 7.0 G. V= 3.0, P= 39

MYRTLE BEACH SC 05/59-11/68
13717 Z= 3.0 G. V= 2.8, P= 37E

SPARTANBURG SC 09/54-10/62
93804 Z=14.9 R. V= 3.5, P= 71E

SUMTER SC 04/64-12/70
13849 Z= 4.0 G. V= 2.4, P= 30E

FIGURE 8.15. Annual Average Wind Speed Duration for South Carolina

ORDINATE - PERCENT
 ABSCISSA - WATTS/M²
 PNL-3195 WERA-6

FIGURE 8.16. Annual Average Wind Power Duration for South Carolina

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