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COASTAL ZONE WIND ENERGY

Part I: Potential Wind Power Density Fields Based on 3-D Model Simulations
of the Dominant Wind Regimes for Three East and Gulf Coast Areas

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EXECUTIVE SUMMARY

In the first part of the report the results of applying a numerical model of the atmosphere to the problem of locating areas of maximum wind power are presented. Three U.S. coastal regions, of approximately 10^5 km^2 area each, are investigated. For each region the spatial distribution of daily average power density (W m^{-2}) for the lowest 100 m of the atmosphere is given for the three most prevalent weather regimes. These distributions are then combined to form an estimate of the annual average power density for each region. Comparisons with long-term climatological data at stations within each region show good agreement between model estimated and observed wind power density for two of the three regions studied.

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1. OVERVIEW OF NUMERICAL MODEL STUDY

The spatial distributions of wind power within three regions of the U.S. East and Gulf coasts have been studied using the University of Virginia's mesoscale model. Experiments which numerically simulate typical days for the three most prevalent large-scale wind (synoptic) regimes have been combined to provide for each region a distribution of the mean annual wind power density ($W m^{-2}$). All experiments were accomplished on the CRAY-1 computer at the National Center for Atmospheric Research (sponsored by the National Science Foundation).

The locations of the three mesoscale regions singled out for study are indicated in Figure 1. The Chesapeake Bay area was chosen because of the complex coastline configuration and the presence of mean annual winds of at least $4.0 m s^{-1}$. The Apalachee Bay area is representative of a relatively simple coastline having low mean annual wind speeds. The South Texas coastal area was selected because, in comparison to other regions of the East and Gulf coasts, this region has high mean speeds. All three areas have little relief and have low mean elevation.

2. METHODOLOGY AND DETAILS OF THE EXPERIMENTS

The power density distributions reported on here are means for the first 100 m layer of the atmosphere. To determine these layer-means the computed wind power densities ($1/2 \rho u^3$) at 10 m, 30 m, 50 m and 100 m have been combined using weighting factors which represent the percent contribution of each level to the total mass of the layer, specifically 0.20, 0.20, 0.35 and 0.25. Daily averages are the result of equal weighting of the 1440 minute-by-minute values computed. Such daily average, layer-mean power densities are determined for each 10 km x 10 km grid square of each mesoscale area.

The methodology for determining the duration of the four climatological seasons from a wind energy point-of-view (Garstang, et al., 1980) has been employed to specify the percent of the time that each synoptic category prevails. These data are presented in Tables 1-3 for three stations representative of the regions studied. The detailed description of the various synoptic categories is contained in Garstang, et al. (1980).

The underlined entries in Tables 1-3 indicate those specific situations (season and category) for which numerical experiments were performed. The two-letter-one-number code entered beside these underlined percentages identifies the numerical experiment based upon that

Figure 1. Stippled rectangles are the areas where the wind power distributions are investigated using the University of Virginia's mesoscale model:

CB -- Chesapeake Bay Area
 AB -- Apalachee Bay Area
 ST -- South Texas Coastal Area.

Annual average wind speed (m s^{-1}) normalized to 10 m above ground level for 36 coastal locations are included.

Table 1. Occurrence of Each Synoptic Category for Hampton, Virginia;
Chesapeake Bay Area.

Season (Fraction of Year)	Synoptic Category	Percent of Season	Percent of Year	Percent of Total Annual Wind Power*
Spring (0.186)	I	26.3	4.9	4.8
	II	6.8	1.3	1.6
	III	21.4	<u>4.0</u> CB2	6.2
	IV	36.3	<u>6.8</u>	4.9
	V	6.8	1.3	1.0
	X	2.4	0.5	---
Summer (0.216)	I	34.4	7.4	9.4
	II	4.5	1.0	1.5
	III	17.0	3.7	3.9
	IV	25.3	<u>5.5</u> CB3	4.2
	V	13.4	<u>2.9</u>	2.6
	X	5.4	1.2	---
Fall (0.197)	I	17.5	3.4	2.6
	II	4.3	0.8	2.2
	III	16.0	3.1	6.2
	IV	38.7	<u>7.6</u> CB3	7.7
	V	12.6	<u>2.5</u>	1.1
	X	10.9	2.1	---
Winter (0.401)	I	14.1	5.6	6.5
	II	8.5	3.4	3.8
	III	22.7	<u>9.1</u> CB2	14.6
	IV	50.5	<u>20.2</u> CB1	14.8
	V	1.2	<u>0.5</u>	0.4
	X	3.0	1.2	---

X : Category undeterminable

* : Excluding undeterminable cases

---: No entry

Table 2. Occurrence of Each Synoptic Category for Miami, Florida;
Apalachee Bay Area.

Season (Fraction of Year)	Synoptic Category	Percent of Season	Percent of Year	Percent of Total Annual Wind Power*
Spring (0.121)	I	21.3	2.6	2.6
	II	1.1	0.1	0.2
	III	9.2	1.1	1.0
	IV	15.2	1.8	2.7
	V	45.8	5.5	5.6
	X	7.4	0.9	---
Summer (0.345)	I	17.5	6.1	6.2
	II	0.1	0.0	0.0
	III	1.7	0.6	1.0
	IV	0.6	0.2	0.1
	V	66.2	<u>22.9</u> AB1	27.2
	X	13.9	4.8	---
Fall (0.186)	I	24.5	<u>4.6</u> AB2	4.3
	II	2.0	0.4	0.8
	III	8.0	1.5	1.3
	IV	17.0	3.2	5.0
	V	32.5	6.1	7.2
	X	16.0	3.0	---
Winter (0.348)	I	26.2	<u>9.1</u> AB2	9.3
	II	3.3	1.1	1.1
	III	9.5	3.3	3.6
	IV	36.6	<u>12.7</u> AB3	12.5
	V	19.1	6.6	8.3
	X	5.3	1.8	---

X : Category undeterminable

* : Excluding undeterminable cases

---: No entry

Table 3. Occurrence of Each Synoptic Category for Brownsville, Texas;
South Texas Coastal Area.

Season (Fraction of Year)	Synoptic Category	Percent of Season	Percent of Year	Percent of Total Annual Wind Power*
Spring (0.156)	I	24.8	3.9	4.1
	II	1.1	0.2	0.4
	III	4.8	0.8	0.4
	IV	24.8	3.9	2.8
	V	40.4	6.3	7.9
	X	4.1	0.6	---
Summer (0.293)	I	19.1	5.6	5.7
	II	0.0	0.0	0.0
	III	1.4	0.4	0.3
	IV	3.5	1.0	0.7
	V	67.8	19.9 ST2	22.5
	X	8.2	2.4	---
Fall (0.156)	I	18.6	2.9	3.6
	II	0.6	0.1	0.1
	III	7.2	1.1	1.5
	IV	28.3	4.4	4.8
	V	35.5	5.5	5.7
	X	9.8	1.5	---
Winter (0.395)	I	23.0	9.1 ST1	11.3
	II	2.3	0.9	1.0
	III	8.6	3.4	3.1
	IV	56.7	22.4 ST1&3	19.9
	V	6.6	2.6	4.2
	X	2.8	1.1	---

X : Category undeterminable

* : Excluding undeterminable cases

---: No entry

situation. These code names are convenient titles for the various experiments. Table 4 contains the initialization data and parameterization used for each of the nine experiments. The code names appear in the second heading-line of Table 4. Figures 2-4, 6-8 and 10-12 are the daily average distributions of wind power density for the nine experiments.

Figures 2-4, 6-8 and 10-12 are the daily average distributions of wind power density for the nine experiments. Figures 5, 9 and 13 are estimates of the annual distribution of wind power density within each region based upon the three daily results. The weighting factors used to arrive at these estimates are given in Table 5. In essence, the influence of the many season-category combinations with small percent occurrence are represented in the annual average as parts of the three dominant season-categories. To more appropriately represent those small season-category combinations which closely resemble the three major ones, the percentages for the same categories in the two adjacent seasons have been included in the occurrence of each experiment. For example, in the case of experiment AB1, referring to Table 2, $22.9 + 5.5 + 6.1 = 34.5$, the value given in the second number-column of Table 5. These percent occurrences are then normalized to 1.00, $34.5/74.6 = 0.46$.

3. DISCUSSION OF RESULTS

In spite of the complex land-water configuration of the Chesapeake Bay Area, there is a consistent pattern in the power density particularly during the cooler seasons. The results of experiments CB1 and CB2, Figures 2 and 3, both contain primary maxima offshore and secondary maxima over the lower and upper reaches of the Bay itself. The primary minimum occurring over the central Delmarva Peninsula is also a persistent feature of the cooler seasons. A marked decrease in overall wind power accompanies the warmer seasons as CB3, Figure 4, shows. The offshore maximum reoccurs, but now it is exclusively a nighttime feature. Averaged over the year, Figure 5, the various areas of maximum located offshore merge into one large, nearly uniform region of approximately 325 W m^{-2} . The gradient in power density is especially strong in the southern portion of Delaware. Considering only annual average wind potential, there appears to be little advantage in moving offshore more than 20 km.

For the Apalachee Bay Area, summertime conditions, experiment AB1, Figure 6, result in a modest and broad maximum in wind power west of the main Florida Peninsula. The cooler seasons are attended by a band of maxima close to the coastline of the Florida Panhandle if the large-scale (geostrophic) wind flow is essentially out of the south, experiment AB2, Figure 7, and an area of maximum in the middle of the

Table 4. Initialization and Parameterization of the University of Virginia Mesoscale Model for the Coastal Zone Wind Energy Studies, 1978-1980.

Element	Chesapeake Bay Area		
	CB1	CB2	CB3
Data base:			
1) synoptic-scale	13 Jan 74	21 Mar 57	9 Aug 75
2) rawinsonde	Dulles, 1200Z	Washington Nat. 03 and 21Z	Dulles, 1200Z
Mean latitude ($^{\circ}$ N)	38	38	38
Horizontal grid interval (km)	10	10	10
Horizontal grid size (X)x(Y)	30x36	30x36	30x36
Vertical levels	A	A	A
Time step(s)	60	60	60
Land surface:			
1) albedo	0.20	0.20	0.20
2) roughness length (cm)	10	8	10
Integration initialization	sunrise	sunrise	sunrise
Initial planetary boundary layer (m)	900	1350	1500
Initial shelter - height temperature (C)	-1.0	4.2	12.0
Initial surface pressure (mb)	1027.0	1012.0	1013.0
Sea surface temperature (C)	8.0	8.0	22.0
Free atmospheric lapse rate of potential temperature ($K\ km^{-1}$)	3.5	3.7	6.3
Geostrophic wind (meteor. deg/m s^{-1})	310/8	330/10	300/6
Wind shear to 6 km ($m\ s^{-1}\ km^{-1}$):			
1) u-component	+3.4	-0.0	+1.0
2) v-component	-1.2	-1.0	-2.0
Soil characteristics:			
1) density ($g\ cm^{-3}$)	1.45	1.75	1.45
2) specific heat ($cal\ g^{-1}\ K^{-1}$)	0.28	0.33	0.28
3) diffusivity ($cm^2\ s^{-1}$)	0.002	0.004	0.002
4) wetness (%)	5.4	20.0	5.4

Table 4 (cont.)

Element	Apalachee Bay Area		
	AB1	AB2	AB3
Data base:			
1) synoptic-scale	28 Jul 63	21 Nov 62	22 Feb 56
2) rawinsonde	Tampa, 1200Z	Tampa, 1200Z	Tampa, 1500Z
Mean latitude ($^{\circ}$ N)	30	30	30
Horizontal grid interval (km)	10	10	10
Horizontal grid size (X)x(Y)	38x28	38x28	38x28
Vertical levels	A	A	A
Time step(s)	60	60	60
Land surface:			
1) albedo	0.20	0.20	0.20
2) roughness length (cm)	7	7	7
Integration initiation	sunrise	sunrise	sunrise
Initial planetary boundary layer (m)	900	1500	950
Initial shelter-height temperature ($^{\circ}$ C)	21.0	18.8	7.0
Initial surface pressure (mb)	1019.0	1013.4	1024.0
Sea surface temperature ($^{\circ}$ C)	29.0	21.0	20.5
Free atmospheric lapse rate of potential temperature ($K\ km^{-1}$)	4.6	5.0	2.9
Geostrophic wind (meteor. $deg/m\ s^{-1}$)	090/5	190/7	010/6
Wind shear to 6 km ($m\ s^{-1}\ km^{-1}$):			
1) u-component	+1.2	+2.0	+3.8
2) v-component	+0.4	0.0	-1.6
Soil characteristics:			
1) density ($g\ cm^{-3}$)	1.60	1.65	1.65
2) specific heat ($cal\ g^{-1}\ K^{-1}$)	0.25	0.30	0.30
3) diffusivity ($cm^2\ s^{-1}$)	0.003	0.004	0.004
4) wetness (%)	10.0	20.0	20.0

Table 4 (cont.)

Element	South Texas Coastal Area		
	ST1	ST2	ST3
Data base:			
1) synoptic-scale	19 Feb 56	19 Jul 63	16 Mar 56
2) rawinsonde	Lake Charles, 1500Z	Brownsville, 1200Z(20)	Brownsville, 1500Z (winds: Corpus Christi, 1500Z)
Mean latitude (°N)	26	26	26
Horizontal grid interval (km)	10	10	10
Horizontal grid size (X)x(Y)	26x42	26x42	26x42
Vertical levels	A	A	A
Time step(s)	60	60	60
Land surface:			
1) albedo	0.20	0.20	0.20
2) roughness length (cm)	5	5	5
Integration initia- tion	sunrise	sunrise	sunrise
Initial planetary boundary layer (m)	1200	900	1300
Initial shelter - height temperature (C)	20.0	23.5	10.2
Initial surface pressure (mb)	1012.0	1015.0	1027.0
Sea surface temperature (C)	20.5	29.0	21.5
Free atmospheric lapse rate of poten- tial temperature (K km ⁻¹)	2.6	3.8	1.9
Geostrophic wind (Meteor. deg/m s ⁻¹)	240/7	160/5	345/7
Wind shear to 6 km (m s ⁻¹ km ⁻¹):			
1) u-component	+3.0	-1.0	+5.0
2) v-component	+0.0	-0.8	+1.3
Soil characteristics:			
1) density (g cm ⁻³)	1.65	1.60	1.65
2) specific heat (cal g ⁻¹ K ⁻¹)	0.30	0.25	0.30
3) diffusivity (cm ² s ⁻¹)	0.003	0.003	0.003
4) wetness (%)	20.0	20.0	20.0

A: Predictions made at eleven levels for winds (4, 10, 30, 50, 100, 500 m, 1, 2, 3, 4, 6 km), at twelve levels for thermodynamic variables (surface, 7, 20, 40, 75, 300, 750 m, 1.5, 2.5, 3.5, 5, 6 km) and at ten depths in the soil (5 to 50 cm at 5 cm intervals).

Figures 2-5. Chesapeake Bay Area - Power density (W m^{-2}), layer-mean for the first 100 m of the atmosphere. Values are given for each 100 km^2 (10 km north-south x 10 km east-west) determined from meteorological variables predicted by the University of Virginia's mesoscale model. Initial conditions and parameters are given in Table 4. Equally weighted minutely values used to compute the daily averages. Heights above the surface and weightings (in parentheses) used in the determination of the layer-mean: 10 m (0.20), 30 m (0.20), 50 m (0.35) and 100 m (0.25). Centers of relative maximum (X) and minimum (N) are indicated along with solid isolines drawn at 50 W m^{-2} intervals. Numbers in the background are the power density values for each grid square. The land-water boundary is depicted in detail for ease of orientation and location whereas in the computer integrations the character of the surface for each grid-square is represented by its percent of land area. Intersections of 75° , 76° and 77°W with 37° , 38° and 39°N are marked.

Figure 2. Daily average 100 m, layer-mean power density ($W m^{-2}$), experiment CBL.

Figure 3. Daily average, 100 m layer-mean power density (W m^{-2}), experiment CB2.

Figure 4. Daily average, 100 m layer-mean power density (W m^{-2}), experiment CB3.

Figure 5. Annual average, 100 m layer mean power density ($W m^{-2}$). Heavy dots are locations of verification stations.

Figures 6-9. Apalachee Bay, Florida -- Power density (W m^{-2}), layer-mean for the first 100 m of the atmosphere. Values are given for each 100 km^2 (10 km north-south x 10 km east-west) as determined from meteorological variables predicted by the University of Virginia's mesoscale model. Initial conditions and parameters are given in Table 4. Equally weighted minutely values used to compute the daily averages. Heights above the surface and weightings (in parentheses) used in determination of the layer mean: 10 m (0.20), 30 m (0.20), 50 m (0.35) and 100 m (0.25). Centers of relative maximum (X) and minimum (N) are indicated along with solid isolines at 50 W m^{-2} intervals. Numbers in the background are the power density values for each grid square. Land areas are stippled. The land-water boundary is depicted in detail for ease of orientation and location whereas in the computer integrations the character of the surface for each grid-square is represented by its percent of land area. The intersection of 83° , 84° and 85°W with 29° and 30°N are marked.

Figure 6. Daily average, 100 m layer-mean power density ($W m^{-2}$), experiment AB1.

Figure 7. Daily average, 100 m layer-mean power density ($W m^{-2}$), experiment AB2.

Figure 8. Daily average, 100 m layer-mean power density ($W m^{-2}$), experiment AB3.

Figure 9. Annual average, 100 m layer-mean power density ($W m^{-2}$). Heavy dots are locations of verification stations.

Figures 10-13. South Texas Coast Area - Power density (W m^{-2}), layer-mean for the first 100 m of the atmosphere. Values are given for each 100 km^2 (10 km north-south x 10 km east-west) as determined from meteorological variables predicted by the University of Virginia's mesoscale model. Initial conditions and parameters are given in Table 4. Equally weighted minutely values used to compute the daily averages. Heights above the surface and weightings (in parentheses) used in determination of the layer-mean: 10 m (0.20), 30 m (0.20), 50 m (0.35) and 100 m (0.25). Centers of relative maximum (X) and minimum (N) are indicated along with solid isolines drawn at 50 W m^{-2} intervals. Numbers in the background are the power density values for each grid square. Land areas are stippled. The land-water boundary is depicted in detail for ease of orientation and location. In the computer integrations, however, the character of the surface for each grid-square is represented by its percent of land area. The interactions of 97° and 98° W with 25° , 26° , 27° and 28° N are marked.

Figure 10. Daily average, 100 m layer-mean power density ($W m^{-2}$), experiment STL.

Figure 12. Daily average, 100 m layer-mean power density ($W m^{-2}$), experiment ST3.

Figure 13. Annual average, 100 m layer-mean power density ($W m^{-2}$). Heavy dots are locations of verification stations.

Table 5. Weightings used to Determine Annual Average Power Densities.

Numerical Experiment	Occurrence from Tables 1,2&3 (Percent of Year)	Occurrence Including Adjacent Seasons (Percent of Year)	Weighting Fac- tors Normalized to 1.00
CB1	20.2	27.0	0.45
CB2	13.1	19.9	0.33
CB3	<u>7.6</u>	<u>13.1</u>	0.22
	36.9	60.0	
AB1	22.9	34.5	0.46
AB2	13.7	22.4	0.30
AB3	<u>12.7</u>	<u>17.7</u>	0.24
	44.7	74.6	
ST1	24.0*	36.4	0.46
ST2	19.9	31.7	0.41
ST3	<u>7.5</u>	<u>10.2</u>	0.13
	51.4	78.3	

*The sum of the entries ST1 and ST3 from Table 3 is 31.5%, as it is above. However, 2/3 of the situations categorized as "Winter IV" were accompanied by geostrophic winds having a southerly component, the remaining 1/3 had a predominant northerly component. The situations with a southerly component are better represented by ST1; reference Table 4, the geostrophic wind entries. Thus, $9.1 + 2/3 (22.4) = 24.0$.

Apalachee Bay for northerly large-scale flow, experiment AB3, Figure 8. Only during the nighttimes of the warmer seasons is the power density substantial ($> 300 \text{ W m}^{-2}$ at 50 m, refer to Garstang, et al., 1980, Figures 27-30). This warm season nocturnal maximum located west of the peninsula is persistent and is present even in the annual average distribution, Figure 9. The Apalachee Bay experiments appear to confirm the indications of data from coastal stations that, on an annual average, wind power potential is not high.

From the South Texas coastal area experiments, it is seen that warm season conditions, i.e., large-scale winds generally from the south, experiment ST2, Figure 11, result in daily average maxima over portions of the coastline and minima offshore. This condition is particularly prevalent during the summertime afternoons (refer to Garstang, et al., 1980, Figures 32-35). During the colder seasons, when the geostrophic flow has a considerable westerly to northwesterly component, experiments ST1 and ST3, daily average maxima are located offshore as is shown in Figures 10 and 12. These offshore maxima are strongest during the winter-time nights. A simple pattern emerges from the combination, according to the weightings in Table 5, of the three experiments, Figure 13. The annual average wind power maximum occurs approximately 40 km seaward of the southern portion of the barrier island chain. The area of minimum is found inland from Brownsville, over the Rio Grande Valley. The southern half of Padre Island is not far removed from the area of annual maximum.

4. VERIFICATION OF RESULTS

Within the three regions studied, eight coastal stations which were used in the initial phase of the University of Virginia coastal wind energy study (Garstang, et al., 1978) are located. The annual average power density at anemometer height was computed for each station from meteorological data recorded hourly. These single-level power density values along with station names, anemometer heights and years of record are contained in Table 6. As part of the initial wind energy study, the average value of the exponent α to be used in the power-law relationship for the variation of wind speed u with height

$$u(z) \sim z^{\alpha}$$

was determined for various stations at which the anemometer height had been changed during the period of record. These exponent values are also given in Table 6. If no anemometer height change occurred during the period of record, or if the length of record at a height was less than

Table 6. Coastal Stations Used in the Verification of 100 m Layer-Mean Annual Average Power Density.

Station Name	Anemometer* Height (m)	Years of Data	Single-Level	Exponent (α)	100 m Layer-Mean Annual Average Power	
			Annual Average Power Density (Wm^{-2})		Density (Wm^{-2}):	From Data
CHESAPEAKE BAY AREA						
Dover (AFB), DE	<u>4.6</u>	1957-64	85	0.124**	196	203
Wallops Island						
(X-85), VA	<u>10.0</u>	1967-76	99	0.209**	250	254
Hampton (Langley	<u>29.3</u>	1955-59	160			
AFB), VA	<u>4.0</u>	1960-64	57	0.209	210	223
Virginia Beach	<u>12.8</u>	1955-59	122			
(Oceana NAS), VA	<u>4.0</u>	1960-64	73	0.240	313	274
APALACHEE BAY AREA						
Tampa (McDill AFB),	<u>22.9</u>	1955-57	66			
FL	<u>4.0</u>	1958-64	47	0.061	73	67
Panama City (Tyndall						
AFB), FL	<u>3.0</u>	1958-64	51	0.066	86	88
SOUTH TEXAS COAST AREA						
Corpus Christi (NAS),	<u>19.2</u>	1955-60	259			
TX	<u>6.7</u>	1961-64	160	0.213	455	151
Brownsville (Int.						
Airport), TX	<u>17.1</u>	1955-60	191	0.213**	362	141

*Underlined heights used as basis for computing layer-mean values.

**Exponent not determinable for this station; value of nearest station used. (In the case of Dover, DE, Atlantic City, NJ was used.)

two years, the exponent for the closest station having a usable anemometer height change is entered.

Using these exponents and the fact that

$$P(z) \sim u^3 \sim z^{3\alpha}$$

P being wind power density, average annual values for 10, 30, 50 and 100 m above the surface were computed. These were then combined using the same weighting factors as were applied to the computer generated values, specifically 0.20, 0.20, 0.35 and 0.25. The resulting 100 m layer-mean annual average power density values are listed in Table 6. The heavy dots on Figures 5, 9 and 13 are the station locations. The power density value (background numbers) closest in distance to each dot is given in the last column of Table 6.

The agreement found in the Chesapeake Bay and Apalachee Bay areas is good. The very slight overestimate of the power density in the Chesapeake Bay area is attributable to the better representation of the windier months, experiments CB1 and CB2, than the less windy warm months, CB3. (The large exponent for Virginia Beach station may result from a significant change in location of the anemometer at the time of its height change. The "from data" value in Table 6 may therefore be artificially high.)

In the South Texas area agreement is not good and the following reasons for the underestimate close to the coastline are given.

- 1) Situations having large-scale flow essentially from the south are less than adequately represented by the single summertime experiment ST2. Such situations, as Figure 11 indicates, are particularly rich in wind energy close to the coastline.
- 2) Effects on the atmospheric boundary layer caused by surface differences in albedo, roughness, etc. on a scale smaller than the resolution used in the experiments may be active particularly during situations of large-scale flow parallel to a coastline. In the vicinity of a sharp (in the cross-wind direction) but extended (along-wind) change in surface characteristics, these effects can result in localized wind maxima caused by the maintenance of strong thermodynamic gradients which in the numerical experiments are too effectively diffused.
- 3) The exponent determined from the Corpus Christi wind data may be too large for the Brownsville case, especially since the Port Arthur, Texas value is 0.174 and the Florida Peninsula values are much less.

Considering that the annual estimates contained in Figures 5, 9 and 13 were obtained from the combination of only three season-category representations, the agreement shown in Table 6 demonstrates the usefulness of a wind power assessment technology which uses a first-principles numerical model. Even in the case of the South Texas coastal area, where the verifications show large underestimates at the coastline, the overall pattern of wind power density is probably correct since it is not greatly affected by the shortcomings listed above. For the Chesapeake Bay area the essentials of the predicted wintertime pattern were found to be present during the field program carried out in a 3600 sq km area in the vicinity of Wallops Island, Virginia (see Gartang, Pielke and Snow 1980). Such verifications by short term measurements within a sub-area or by comparison with longer term station data, as in Table 6, increase credibility in the numerical predictions for the rest of the mesoscale area modeled and for other seasons.

5. REFERENCES

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