P1.15 DECADAL WIND TRENDS AT THE SAVANNAH RIVER SITE

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1. INTRODUCTION

One possible consequence of global warming is an observed decrease in mean wind speeds over the U.S. within a band between about 30-40 degrees north latitude (Zack, et al. 2005). Recent studies (Pittman, et al. (2004), Galletta, (2005), and Weber, et al. (2005)) at various locations in the eastern U.S. indicate that, indeed, mean surface wind speeds have decreased by 5 to 10% over the last couple of decades.

The Savannah River National Laboratory (SRNL) operates meteorological towers at different locations at the Department of Energy's (DOE) Savannah River Site (SRS), which covers 800 km^2 in southwestern South Carolina. In this paper, we examine the trends in wind speed and vertical and horizontal turbulence intensity over the past 14 years associated with measurements at SRS' eight spatially separated, 61-m towers, and discuss the results.

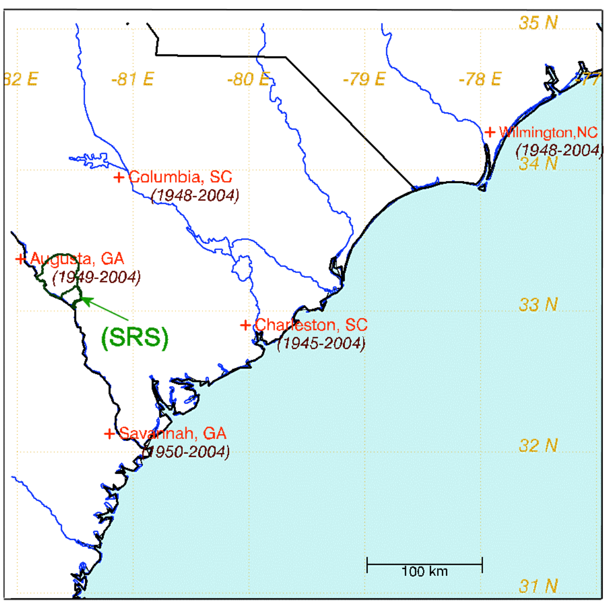

Figure 1: U.S. Southeast Coast with the locations of the SRS and five NWS stations used by Weber, et al. (2005) for a strong winds study.

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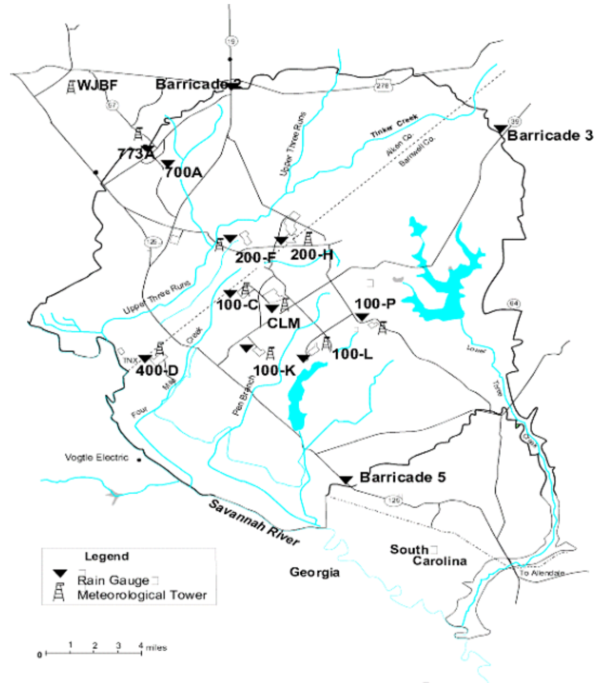

Figure 2. Locations of 61-meter Area Towers at the SRS.

2. METHOD

Figure 1 shows the U.S. Southeast Coast with the location of the SRS and five NWS stations used by Weber, et al. (2005) for a strong winds study. The SRS is ~160 km (100 mi) inland. Three of the NWS stations used in the strong wind study (Wilmington [ILM], Charleston [CHS], and Savannah [SAV]) are within ~16 km (10 mi) of the coast while the remaining two (Columbia [CAE] and Augusta [AGS]) are ~200 km (124 mi) inland.

Figure 2 shows the locations of eight 61-m Area Towers (designated A, C, D, F, H, K, L, and P) within the SRS. Temperature, speed, and the standard deviations of wind direction σ_A and elevation σ_E were extracted from archives of the 61-m Area Towers for the time period 1991 to 2004. Data values collected at 15-minute intervals with questionable quality assurance flags were thrown out during the data selection process. In addition, checks were made to eliminate any wind speed, direction, σ_A and σ_E value less than zero. Finally, temperature values outside the range $-15 \le T < 45$ °C were also excluded during the data selection process.

Hourly averages were determined from scalar averages of 15-minute archived data of wind, temperature, σ_A and σ_E. In the case of σ_A this is not strictly valid, since one must account for the changes in the mean wind direction from one 15-minute period to the next. However, we decided to ignore the contributions from wind direction changes in this paper and save a more exact analysis for a later presentation.

3. RESULTS AND DISCUSSION

a. NWS Stations

Weber, et al. (2005) showed a decreasing trend for the NWS stations' mean wind speed for the period 1951-2003 (NCDC, 2005) of about 5% per decade (0.5% per year). The individual NWS stations' (AGS, CAE, CHS, ILM, AND SAV) annually averaged wind speeds are shown in Figure 3 with an overall trend line determined by linear least squares regression. Since the coastal stations (CHS, ILM, and SAV), seem to strongly influence the period 1950-65, it was decided to group the wind data for the stations into coastal (CHS, ILM, and SAV) and inland (AGS and CAE) groups. These results are shown in Figures 4 and 5 along with the trend lines for each group.

The slope of the linear regression trend line shows that the interior stations' wind speed indeed is not decreasing at the same rate as the coastal stations, but the rate is still a fairly consistent downward trend of 0.008 m/s per year. While seemingly quite small, in terms of the overall mean speed of around 3.5 m/sec, this is a decrease of about 0.23% per year; and when only the past 14 years for inland stations are considered the decrease is 0.023 m/s per year or 0.885% per year, a significantly larger amount. Given the relatively small magnitude of an average wind speed on the order of 3.5 m/s (in this case), a decreasing trend would be expected to be rather slight since the annual mean wind speed would not be expected to approach zero.

b. SRS Area Towers

The SRS Area towers' 15-minute-averaged measurements were broken up by daytime and nighttime, based on time of year and latitude of SRS. Results for annual means are presented for both daytime and nighttime for 4 variables: wind speed (m/s), σ_A (degrees), σ_E (degrees), and temperature (ºC). Figures 6 to 9 show the time series of the annual means and linear least squares regression lines for the 14-yr period.

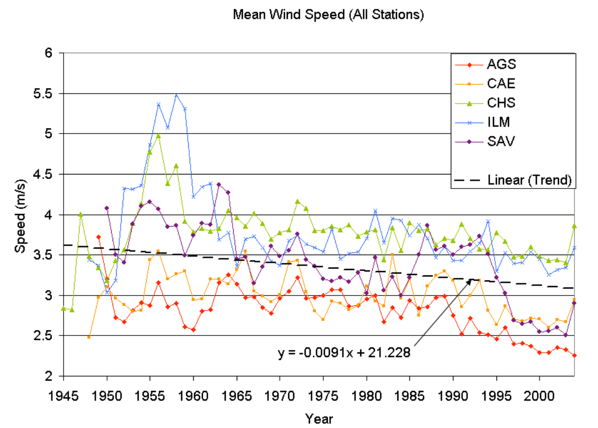

Figure 3: Time series of annual averages of all five stations' (CHS, ILM, AGS, CAE, and CAE) and slope of trend line for pooled wind speeds.

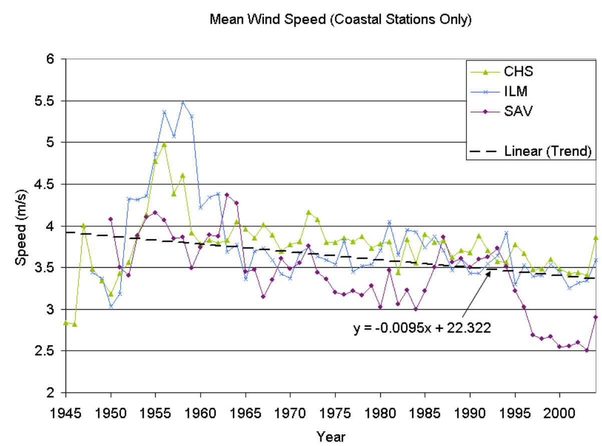

Figure 4: Time series of annual averages and slope of trend line of the coastal stations' (CHS, ILM, SAV) pooled wind speeds.

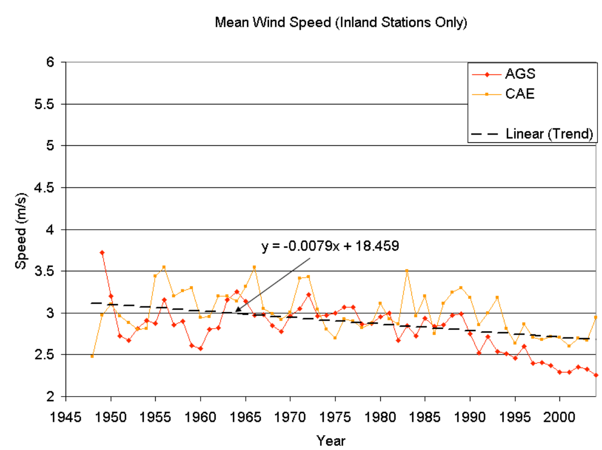

Figure 5: Time series of annual averages and slope of trend line of the inland stations' (AGS and CAE) pooled wind speeds.

Figures 6 to 9 show decreasing speeds for both daytime and nighttime, fairly constant σ_A, increasing σ_E, and increasing temperature for the period 1991-2004. Trends and means for the 14-year period are summarized in Table 1.

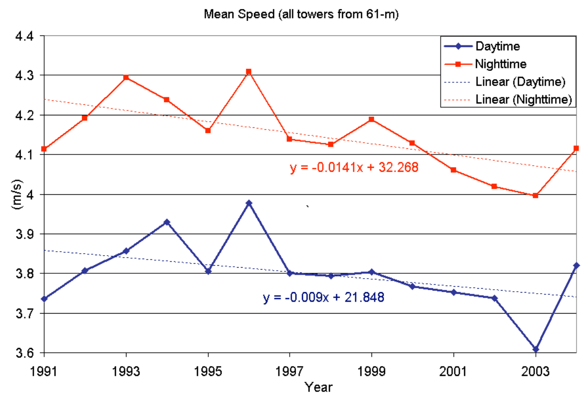

Figure 6: Time series of annual averages and slope of trend line of SRS' 61-m daytime and nighttime wind speed from the Area Towers.

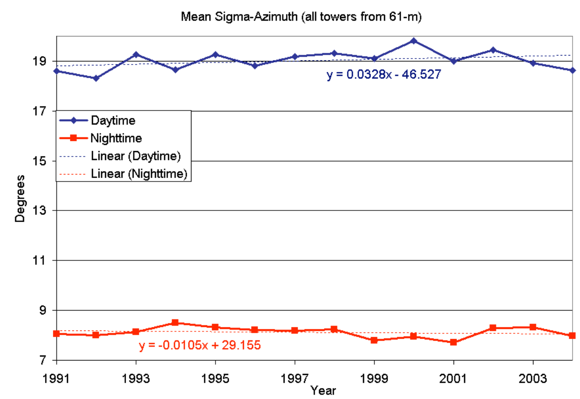

Figure 7: Time series of annual averages and slope of trend line of SRS' 61-m σ_A from the Area Towers.

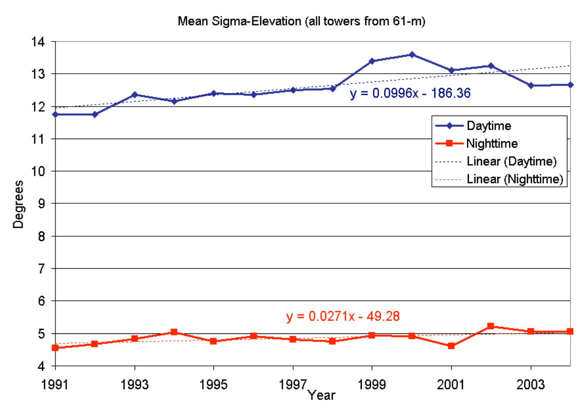

Figure 8: Time series of annual averages and slope of trend line of SRS' 61-m daytime and nighttime σ_E from the Area Towers.

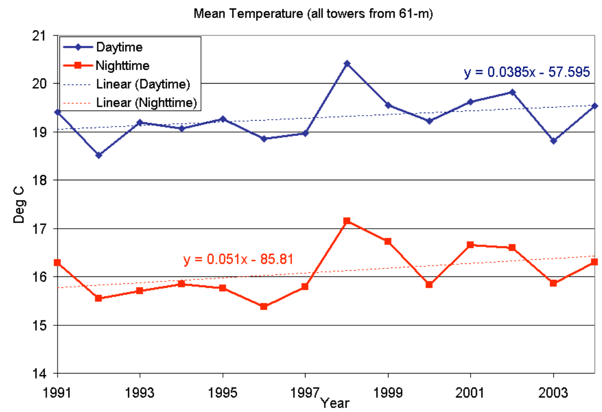

Figure 9: Time series of annual averages and slope of trend line of SRS' 61-m daytime and nighttime temperature from the Area Towers.

Trends in Table 1 show a statistically significant decline in wind speed, and increases in both turbulence intensities, with the exception of σ_A during the night. The temperature is also seen to increase. The increase in σ_E is greater than the increase in σ_A. As one would expect, mean values for the turbulent quantities are higher during the daytime than during nocturnal periods. Note also that higher wind speeds occur at night, as one should expect of values taken from the 61-m level above ground at this location.

In addition, means and trends were determined for each variable and time of day by *season* (MAM, JJA, SON, DJF denote spring, summer, autumn, and winter, respectively). Results are shown in Table 2.

The results by season indicate declines in speed at all times of the year. The mean wind speeds are highest in the spring, and lowest in the summer. The largest declines have also occurred during the spring months, as well as during the autumn nocturnal period.

The trends of σ_A are increasing during daytime in the winter, as well as at all times in the spring and summer; declines of σ_A are experienced during the winter nocturnal period and autumn daytime period, and are relatively unchanged during the nocturnal autumn period. The biggest increasing trend of σ_A is during the daytime in the summer. This would seem to indicate a relationship to increasing convective activity. The highest mean values of σ_A are found during the summer, both for day and night periods, while the lowest daytime values are observed in winter, and the lowest nighttime values are observed in autumn.

The trends for σ_E are increasing at all times except during the winter at night. As for the yearly trends, the seasonal trends of σ_E tend to be slightly higher than for σ_A with the biggest increases occurring during the day in the winter and summer months. The maximum mean of σ_E during the daytime is observed in summer, while at night it is observed in the winter. On the other hand, the minimum of σ_E in the day is observed in winter, and in autumn at night.

Temperature trends indicate an increase in all seasons except during the winter. In particular, the rates of temperature increase in spring, summer, and autumn are seen to be larger at night. Overall, temperatures have increased the most during autumn nighttime.

	Day		Night	
	Total Mean	Slope (per yr)	Total Mean	Slope (per yr)
Speed (mps)	3.78	-9.00E-03	4.11	-1.41E-02
σ_A (deg)	18.61	3.28E-02	8.02	-1.05E-02
σ_E (deg)	12.21	9.96E-02	4.81	2.71E-02
Temperature (ºC)	19.48	3.85E-02	16.29	5.10E-02

Table 1: Least-square linear regression line slopes and mean values by variable and time of day for the 14-years of measurements on SRS' 61-m towers.

		Day		Night	
Variable	Season	Mean	Slope (per yr)	Mean	Slope (per yr)
Speed (mps)	Winter	4.11	-7.40E-03	4.36	-3.90E-03
	Spring	4.21	-1.58E-02	4.39	-1.85E-02
	Summer	3.34	-8.60E-03	3.59	-1.13E-02
	Autumn	3.62	-3.00E-03	4.09	-2.29E-02
σ_A (deg)	Winter	17.60	5.90E-02	9.04	-8.18E-02
	Spring	19.02	1.67E-02	8.77	9.70E-03
	Summer	20.19	8.14E-02	9.38	5.11E-02
	Autumn	18.88	-3.44E-02	8.09	-3.00E-04
σ_E (deg)	Winter	11.80	1.15E-01	5.71	-1.23E-02
	Spring	12.64	9.76E-02	5.57	4.49E-02
	Summer	13.25	1.11E-01	5.29	5.22E-02
	Autumn	12.49	7.24E-02	4.92	3.49E-02
Temperature (ºC)	Winter	9.81	-6.54E-02	8.71	-4.82E-02
	Spring	18.96	9.10E-02	16.73	9.53E-02
	Summer	26.46	2.28E-02	24.18	4.29E-02
	Autumn	19.56	8.52E-02	17.50	1.11E-01

Table 2: As in Table 1, but broken up into seasonal slopes and means where Winter, Spring, Summer, and Autumn denote the months of DJF, MAM, JJA, SON, respectively.

DISCUSSION/CONCLUSIONS

Both the NWS data and the SRNL data show clearly that the mean annual wind speed is decreasing in this area of the Southeast. We can make a comparison between the rates of decrease of mean speed of the ~60 years of NWS data taken at ~10 m and the 14 years of SRNL data taken at 61 m. The rate of ~0.885% per year for the NWS stations is about three times the rate of ~0.3% per year for the SRNL Area towers. We do not consider this difference to be significant after taking into account the differences in data collection methods, geographical locations, and heights of measurement between the two data sets.

The daytime and nighttime temperatures are increasing at a rate of ~0.04 and ~0.05 ºC respectively, per year. The standard deviations of wind direction angle σ_A for daytime and nighttime from the Area towers are increasing at a rate of ~0.03 and ~0.01 degrees per year, respectively. The standard deviations of wind elevation angle σ_E for daytime from the Area towers are increasing at a rate of ~0.03 degrees per year. Nighttime values have decreased by ~0.10 degrees per year.

The increases in the rate of σ_A and σ_E for daytime and nighttime suggest that convective activity is increasing due to an increase in the mean temperatures for daytime and generally for nighttime. The daytime rate is increasing more rapidly than the nighttime rate.

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