This document was prepared in conjunction with work accomplished under Contract No. DE-AC09-96SR18500 with the U. S. Department of Energy.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

This report has been reproduced directly from the best available copy.

Available for sale to the public, in paper, from: U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161,
phone: (800) 553-6847,
fax: (703) 605-6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/index.asp

Available electronically at http://www.osti.gov/bridge
Available for a processing fee to U.S. Department of Energy and its contractors, in paper, from: U.S. Department of Energy, Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831-0062,
phone: (865)576-8401,
fax: (865)576-5728
email: reports@adonis.osti.gov

Short Term Climatological Wind Data as a Tool for Wind Forecasting

by

Matthew J. Parker, Allen H. Weber, and Robert L. Buckley
Savannah River Technology Center
Aiken, South Carolina

Corresponding author address:

Matthew J. Parker
Savannah River Technology Center
Westinghouse Savannah River Company
Building 735-7A
Aiken, South Carolina 29808

Phone: 803-725-2805
FAX: 803-725-4233

email: matt.parker@srs.gov

Date Manuscript Received:______

Abstract

Utilizing short-term climatological wind data can enhance wind speed and wind direction forecasts. An analysis of regional or tower-based wind rose summaries can be useful forecast guides especially when synoptic-scale pressure gradients are weak. Predictive data from multiple models can be plotted against short-term climatological wind data to assess deviations from expected norms and differences between forecast models. Site-specific comparisons between predicted data and observed climatological distributions can provide further insights to the forecaster. These methods can be applied to any location where sufficient climatological data (at least two years) is available.

1. Introduction and Background

Over the last half-century, traditional uses of wind data have been to help characterize current meteorological conditions at localities or airports. Today, uses include more specific applications including agricultural, recreational, educational, and transportation interests where onsite measurements are desired. In fact, as sensor technologies improve and production costs decrease, wind measurements will likely become even more common and widespread. Archived wind measurements from any well-maintained station can be used to create short-term climatological records used as input to various atmospheric modeling schemes. In this paper, methods of utilizing short-term climatological data for an additional purpose, as a tool for wind forecasting, are presented.

The Savannah River Technology Center (SRTC) provides comprehensive meteorological support for the US Department of Energy's Savannah River Site (SRS) near Aiken, South Carolina (see Figure 1). The primary source of meteorological data comes from SRTC's network of nine on site 61-m observation towers (Parker and Addis, 1993). In particular, temperature, dew point, wind speed, and wind direction measurements obtained near ground level at the Central Climatology (CC) facility near the geometric center of the SRS are considered to be representative of the general surface meteorological conditions at any given time. Wind measurements are made with Met One Model 1564B cup anemometers and Model 1585 bi-directional wind vanes (bivanes). SRTC also issues daily weather forecasts for outdoor activities, many of which have procedural limitations regarding acceptable wind speeds (eg. cannot exceed 4.5 ms^{-1}) during the course of the work, and these forecasts are validated against the conditions recorded at CC.

Forecasts are usually based on a combination of model data and statistical characterizations (model output statistics (MOS)) derived from model and observed data. However, a forecaster will often consider the tendencies of the local climate, which may lead to further forecast refinements. As a means to improve SRTC's wind speed forecasts, on site and regional short-term climatological wind data sets have been analyzed extensively. For example, during the process of analyzing regional wind data for an SRS dose reconstruction study (Weber, et. al, 2003a), National Weather Service (NWS) observations from the past 50 years were reviewed for several stations in the southeastern United States (Weber, et. al, 2002). In another study, wind data from the CC site from the past 10 years were analyzed (Weber, et.al., 2003b). As a result, tools that allow a forecaster to quickly and objectively compare short-term climatological wind data against forecasted data have been developed, and several examples of such forecast tools are described in this paper.

2. Wind Data

2a. Wind Roses Based on NWS Observations

In Weber (2002), the past 50 years of wind data from selected NWS stations in the southeastern United States were analyzed. The stations included Augusta (AGS), Atlanta

(ATL), Athens (AHN), Columbus (CSG), Macon (MCN), and Savannah (SAV) in Georgia; Charleston (CHS) and Columbia (CAE) in South Carolina; Asheville (AVL), Charlotte (CLT), Raleigh (RDU), and Wilmington (ILM) in North Carolina; and Jacksonville (JAX) in Florida. Figure 2 shows an example of the NWS wind climate data during the afternoon in mid-October. Data are displayed as wind roses, which represent the relative frequencies of wind directions and wind speeds. Longer “petals” indicate higher frequencies of occurrence. Partitions within the petals indicate wind speed “bins” as described in the legend.

During mid October, the Southeastern states shown in Figure 2 are often under the influence of large high-pressure systems over the Appalachian Mountains, which results in a northeasterly wind for the majority of stations. However, the influence of the nearby Appalachian Mountain range is noticeable in the ATL and AHN distributions where wind roses indicate preferential northwest and northeast airflow around the southern extent of the mountains. Airflow channeling of the French Broad River valley, which is oriented from north-northwest to south-southeast, largely influences the wind rose for AVL. Additional examples of these wind roses, sorted by time of day and season, are available at www.srs.gov/weathercenter/winds/S_Ewinds.

Figure 3 shows a series of wind roses for mid April for the same region as Figure 2. A common diurnal pattern appears for the coastal stations ILM, CHS, SAV, and JAX. In the pre-sunrise hours (upper left), these stations rarely observe onshore winds from the east. By afternoon (upper right), air flowing onshore becomes more likely, and by early evening (lower left), the sea breeze becomes the dominant wind feature. This continues into the late evening hours (lower right) as well.

This diurnal pattern can aid the forecaster. Easterly winds in the pre-sunrise hours are very unlikely from a climatological standpoint, so a forecast for easterly winds during this time period should only be issued when the necessary (and unusual) synoptic conditions occur. Later in the day towards and during the evening, the forecaster can anticipate the strong likelihood of sea breeze conditions resulting in an onshore airflow. Wind speeds also tend to increase in magnitude over the course of the day from sunrise into late evening.

2b. Wind Rose Data Based on Measurements at the Central Climatology Tower

A sample of wind rose data for the Central Climatology tower (Weber et. al, 2003b) for mid October is portrayed in Figure 4. Wind conditions over time are shown for each monitoring level (4, 18, 36, and 61 m) above ground as the day progresses. For the upper three levels of the tower, northeasterly winds are most likely throughout most of the 24 hour period, which is consistent with the synoptic conditions described in Section 2a. The lowest level (4 m) often observes a northeasterly or northwesterly wind during daylight hours, but a southeasterly wind can also be observed after sunset. This information quickly provides the forecaster with a climatological perspective on the expected wind regime for the CC site during mid October. Such information is particularly useful when synoptic scale pressure gradients are weak and wind fields are much more likely to be influenced by local terrain. Additional examples of these wind roses, sorted by time of year, are available at www.srs.gov/weathercenter/winds/C_C_winds.

3. Forecast Applications

3a. Application of Climatological Wind Data as a Forecasting Tool

In addition to the wind roses, another useful diagram portraying climatological wind data is shown in Figure 5. The frequency of occurrence for each wind speed class is shown as a color-coded backdrop and plotted for a 48 hour period. The data used for this particular plot is representative of a two-week period in mid October for AGS and is valid roughly from October 08-21. Forecasted wind speeds for AGS from several well-known predictive models are plotted onto the climatological (color-coded) background. Summary information on these models is provided in Table I. Time series values from each model can be reviewed quickly against the climatological backdrop to ascertain whether strong deviations from "normal" conditions are expected to occur. For example, the consensus of the models shows lower wind speeds during the 22 UTC (10-21-02) to 02 UTC time period. These speeds (in the 0-2 ms^{-1} range) are consistent with what would be expected as shown by the relatively higher frequencies of occurrence shading (in the 40% to 50% range). Afterward, wind speeds increase to a peak in the 2-4 ms^{-1} range at around 10 UTC. Again, this is consistent with what would be expected based on climatological data in the 45% to greater than 50% frequencies of occurrence. The forecaster can make similar assessments for the entire model forecast period shown. These plots have the added benefit of identifying model outliers, which can then be examined more closely. If the examination of the outlier provides sufficient justification, the forecaster can decide to weight the forecast accordingly.

On this type of plot, large predicted deviations are readily apparent from the expected norms, but actual conditions may be expected to deviate from the expected norms when intense high or low pressure systems move through the affected area. The climatological data are also very useful in coastal or mountainous locations that are dominated by local terrain influences (i.e. valleys, oceans, etc.). Model predictions that deviate from strong local influences should make the forecaster wary that the forecast may require adjustments.

Figure 6 shows an example of wind direction predictions and climatological data. As with the wind speed plot (Figure 5), model data time series are portrayed against a backdrop of climatological wind direction data. Forecasts that diverge strongly from climatology are quickly identified and may be assessed for validity. In this case, the models forecast a shift from northwest (NW) or west (W) winds to northeast (NE) except for the RAMS model, which predicts easterly (E) winds. Therefore, the RAMS results might need to be scrutinized carefully before finalizing the forecast.

In practice, the SRTC forecaster would have similar plots for CAE (plots not shown) since wind characteristics at the SRS are often very similar. This forecaster would also have the plot shown in Figure 4 from Central Climatology. As stated previously, large high-pressure systems often dominate in mid October, and synoptic scale pressure gradients can be relatively small. Therefore, local terrain features will most likely influence the wind speed and direction especially during nighttime hours on clear, calm nights when the atmospheric (nocturnal) boundary layer becomes decoupled from synoptic scale flow.

3b. Comparison of Observed and Modeled Data

In the previous sections, the use of short-term climatological wind data and model forecast data have been discussed. Another useful comparison is between short-term climatological data and distributions of model data for identical periods. As an example, wind data from RAMS interpolated to the CC site were compared with measurements for the 1999-2001 period. Model calculations were made for 26 m and were compared to corresponding interpolated values derived from CC observations at 18 and 36 m. Distributions were generated based on season (i.e. spring represented by March, April, and May; summer represented by June, July, and August, etc.) and a given hour of the day. Figure 7 depicts a comparison of wind roses for early afternoon (18 UTC). During the spring months the most frequently predicted wind direction is WSW, while observed winds are most likely to be westerly. Modeled wind speeds also tend to be higher than observed during the summer months, especially if from the southwest. The observed bimodal distribution during autumn (west and northeast) differs from the predominately northeasterly winds predicted by RAMS. In winter, RAMS predicts more northeasterly winds than are actually observed. Figure 7 helps illustrate the potential for using short-term wind roses as a means for comparing model-predicted distributions with observations from the CC site as a function of season and day. This technique could be applied to any location that has a sufficient observation record (at least 2 years) and corresponding location specific model data.

4. Conclusions

Short-term climatological data can be used as part of the procedure for forecasting wind speed and direction. Wind roses and time series plots of frequency of occurrence can be combined with predicted model data to assist the forecaster. Wind roses that depict observed and modeled data for a corresponding site-specific location are also useful to determine model accuracy over periods of two years or more. Similar methods could be employed at any location where sufficient historical wind observations are available.

5. Acknowledgements

Funding for this work was supported by the U. S. Department of Energy under Contract DE-AC09-96SR18500.

6. References

Buckley R. L., 1998: Numerical Weather Forecasting at the Savannah River Site. *Transactions of the American Nuclear Society*, **79**, 47-48.

Parker, M. J. and R. P. Addis, 1993: Meteorological Monitoring Program at the Savannah River Site. WSRC-TR-93-0106. Westinghouse Savannah River Company, Aiken, South Carolina.

Weber, A. H., R. L. Buckley, M. J. Parker, R. Harvey, and D. M. Hamby, 2003a: The Creation of an Historical Meteorological Database for Environmental Dose Assessment. ***Environmental Monitoring and Assessment***, 83: 255-281. Kluwer Academic Publishers, Dordrecht, the Netherlands.

Weber, A. H., R. L. Buckley, and R. J. Kurzeja, 2003b: Wind Climate Analyses for SRTC's Central Climatology Site (U). WSRC-TR-2003-00141. Westinghouse Savannah River Company, Aiken, South Carolina.

Weber, A. H., R. L. Buckley, M. J. Parker, and C. H. Hunter, 2002: Wind Climate Analyses for National Weather Service Stations in the Southeast (U). NTIS-DE2003-80793. National Technical Information Service, Springfield, Virginia.

List of Figures

Figure 1: Map of the Savannah River Site and environs. NWS sites at Augusta, GA (AGS), Columbia, SC (CAE), and CC are also depicted. Contours represent mean elevation above sea level in 25-m increments. Urban areas are lightly shaded.

Figure 2: Regional wind roses for the afternoon time frame in mid-October. Data are taken from a roughly 50-year period (1950-2000). Time shown in local standard time (LST = UTC + 4 hours).

Figure 3: Regional wind roses over the course of a day in mid-April. Data are taken from a roughly 50-year period (1950-2000). Note the development of a sea breeze at the coastal sites of ILM, CHS, SAV, and JAX.

Figure 4: Diurnal wind roses for the four levels (4, 18, 36, and 61 m) of CC for mid-October. Data are taken from a 10-year period (1991-2000).

Figure 5. Example of modeled wind speed forecast time series plotted against a backdrop of climatological frequency.

Figure 6. Example of modeled wind direction forecast time series plotted against a backdrop of climatological frequency.

Figure 7. Comparison of RAMS (Mod) and observed (Obs) data for the CC site. Time shown is 18 UTC for each season.

List of Tables

Table I. General model information

Table I. General Model Information

Code	Name	Web Site
RAMS*	Regional Atmospheric Modeling System	www.rams.atmos.colostate.edu
ETA	NWS mesoscale model	www.emc.ncep.noaa.gov
RUC	Rapid Update Cycle	www.fsl.noaa.gov
MESO	Meso-Eta mesoscale model	www.emc.ncep.noaa.gov
AVN	Aviation/Global Forecast System	www.emc.ncep.noaa.gov
MM5	Penn State/NCAR mesoscale model	www.mmm.ucar.edu/mm5/mm5-home.html

*Note that RAMS simulations are generated by SRTC for site-specific applications using NWS models for initialization and boundary conditions (Buckley, 1998).

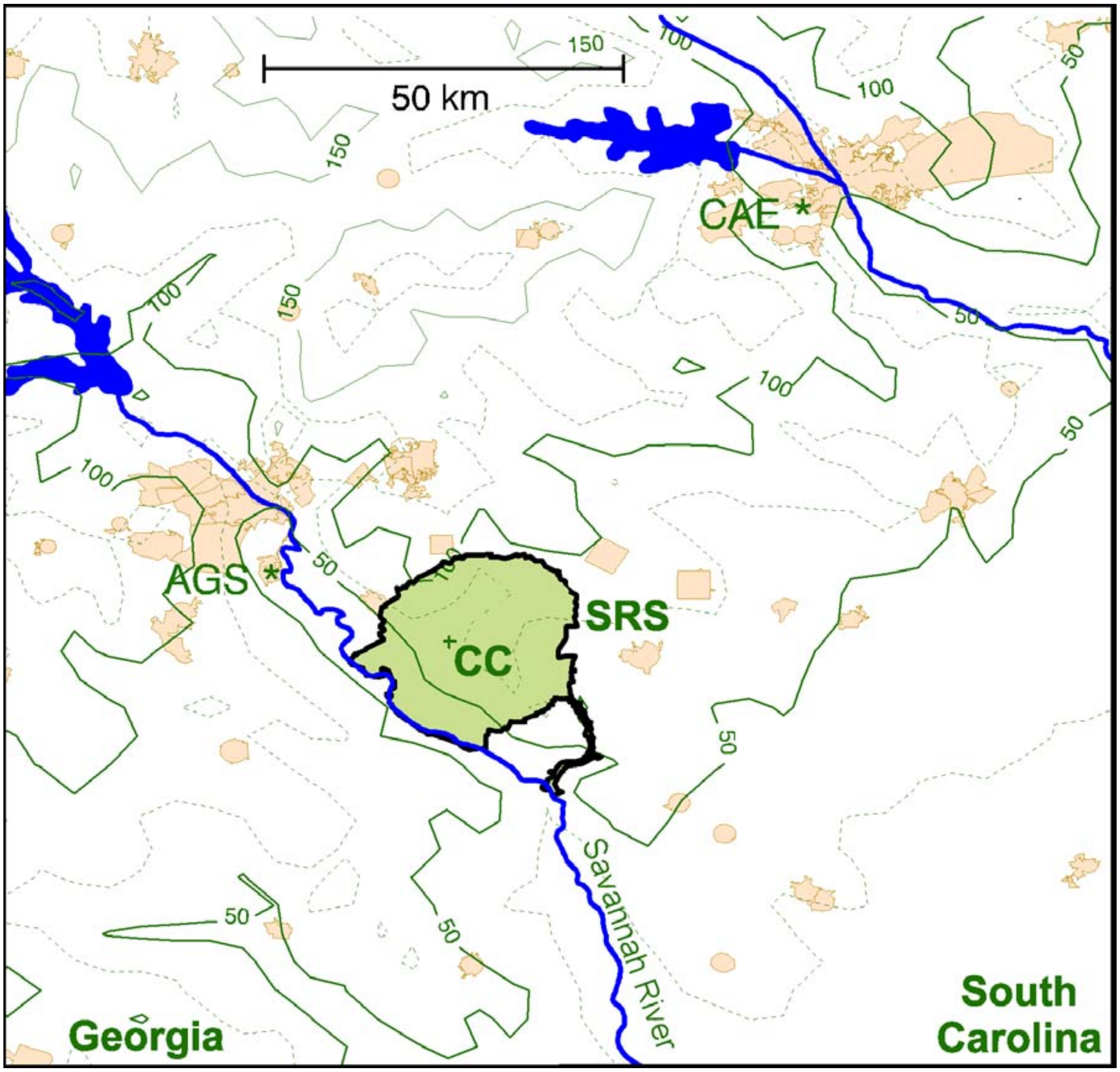

Figure 1: Map of the Savannah River Site and environs. NWS sites at Augusta, GA (AGS), Columbia, SC (CAE), and CC are also depicted. Contours represent mean elevation above sea level in 25-m increments. Urban areas are lightly shaded.

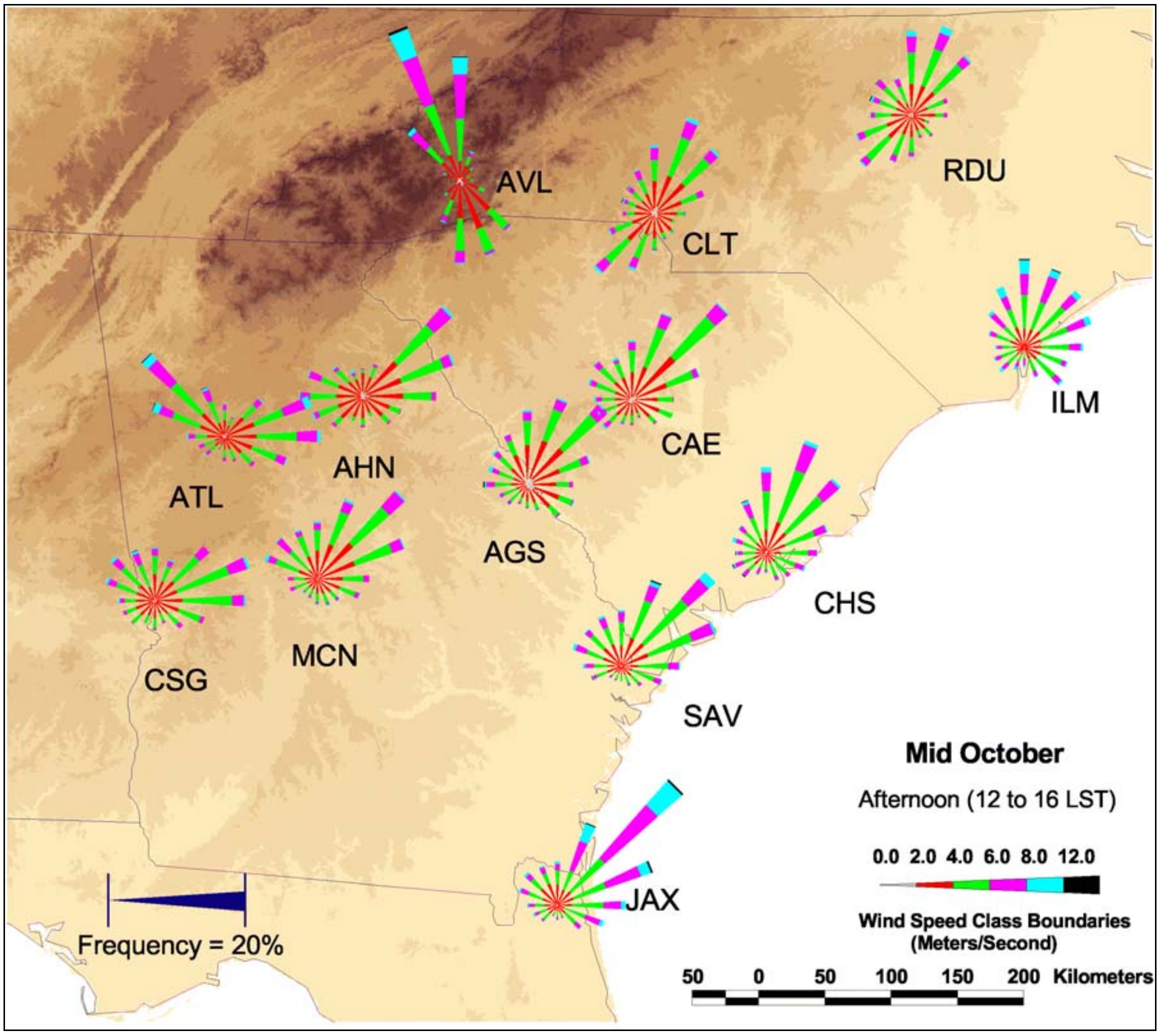

Figure 2: Regional wind roses for the afternoon time frame in mid-October. Data are taken from a roughly 50-year period (1950-2000). Time shown in local standard time (LST = UTC + 4 hours).

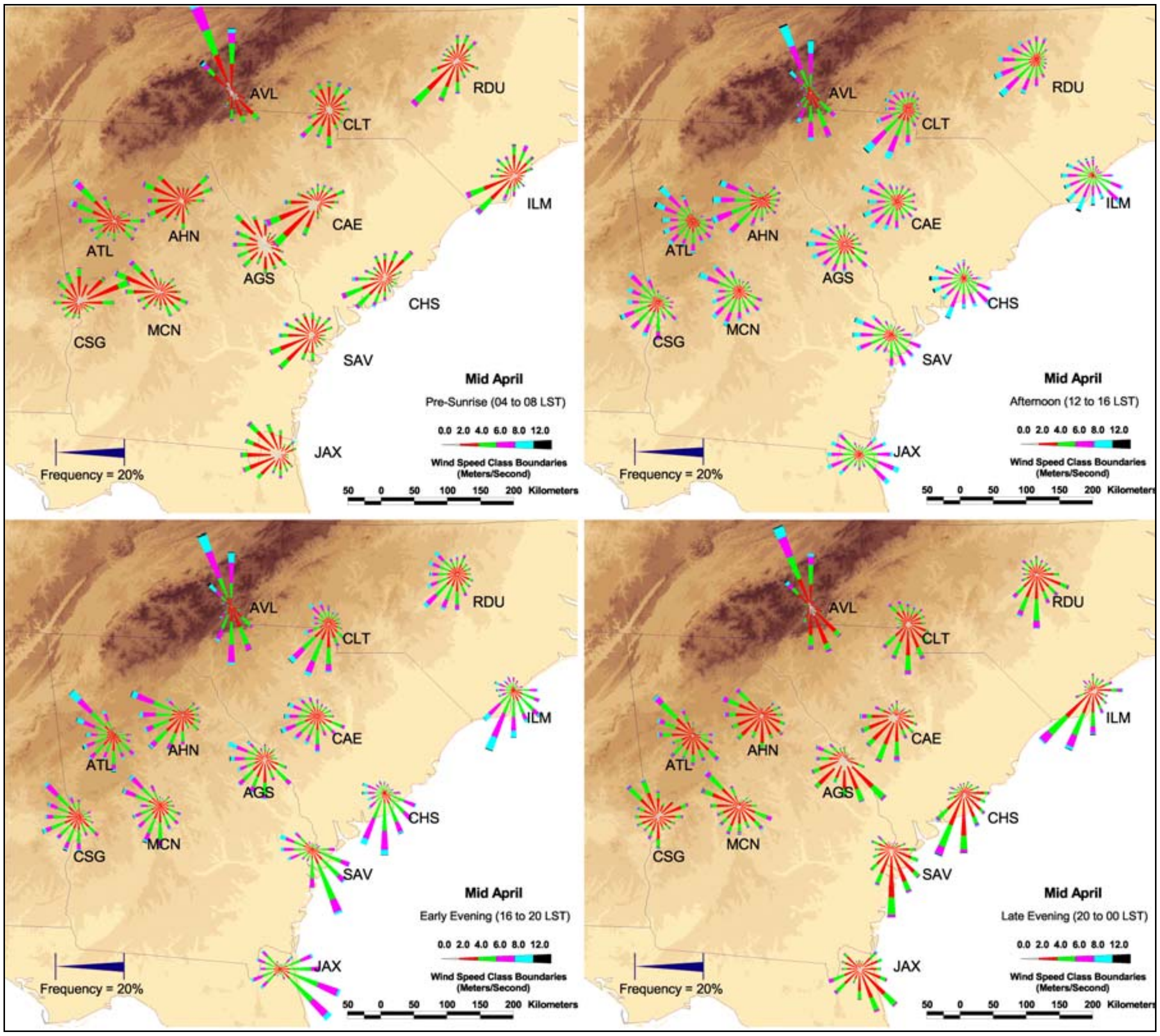

Figure 3: Regional wind roses over the course of a day in mid-April. Data are taken from a roughly 50-year period (1950-2000). Note the development of a sea breeze at the coastal sites of ILM, CHS, SAV, and JAX.

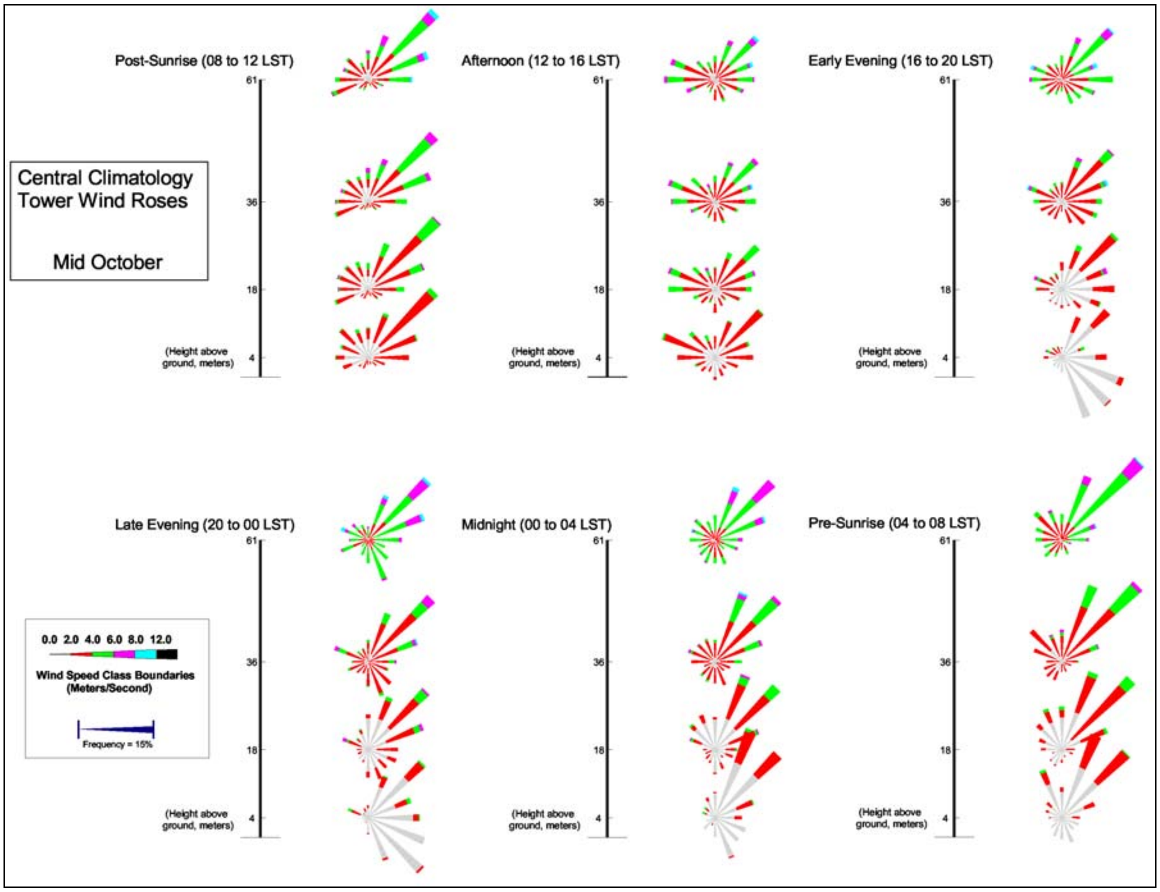

Figure 4: Diurnal wind roses for the four levels (4, 18, 36, and 61 m) of CC for mid-October. Data are taken from a 10-year period (1991-2000).

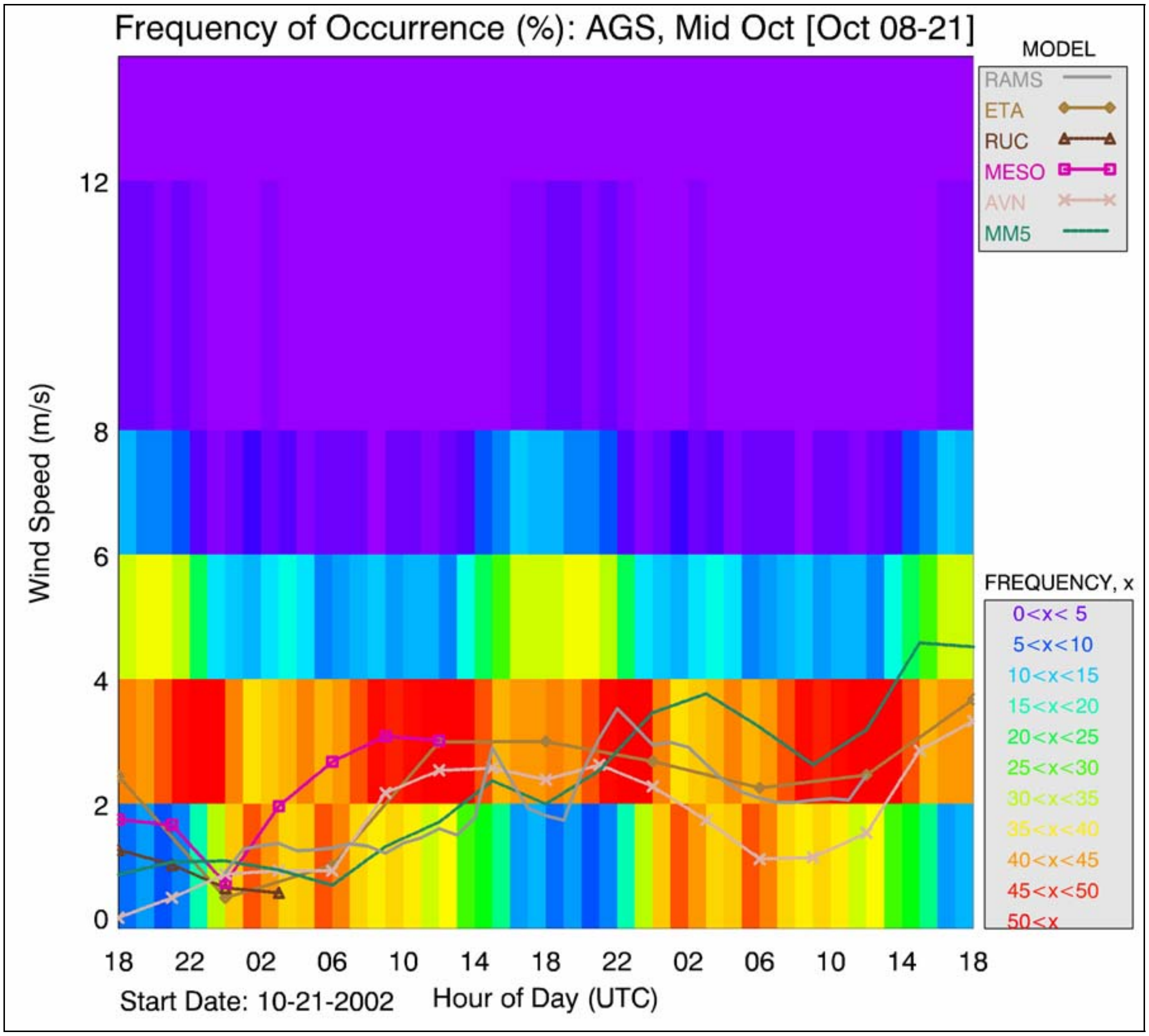

Figure 5. Example of modeled wind speed forecast time series plotted against a backdrop of climatological frequency.

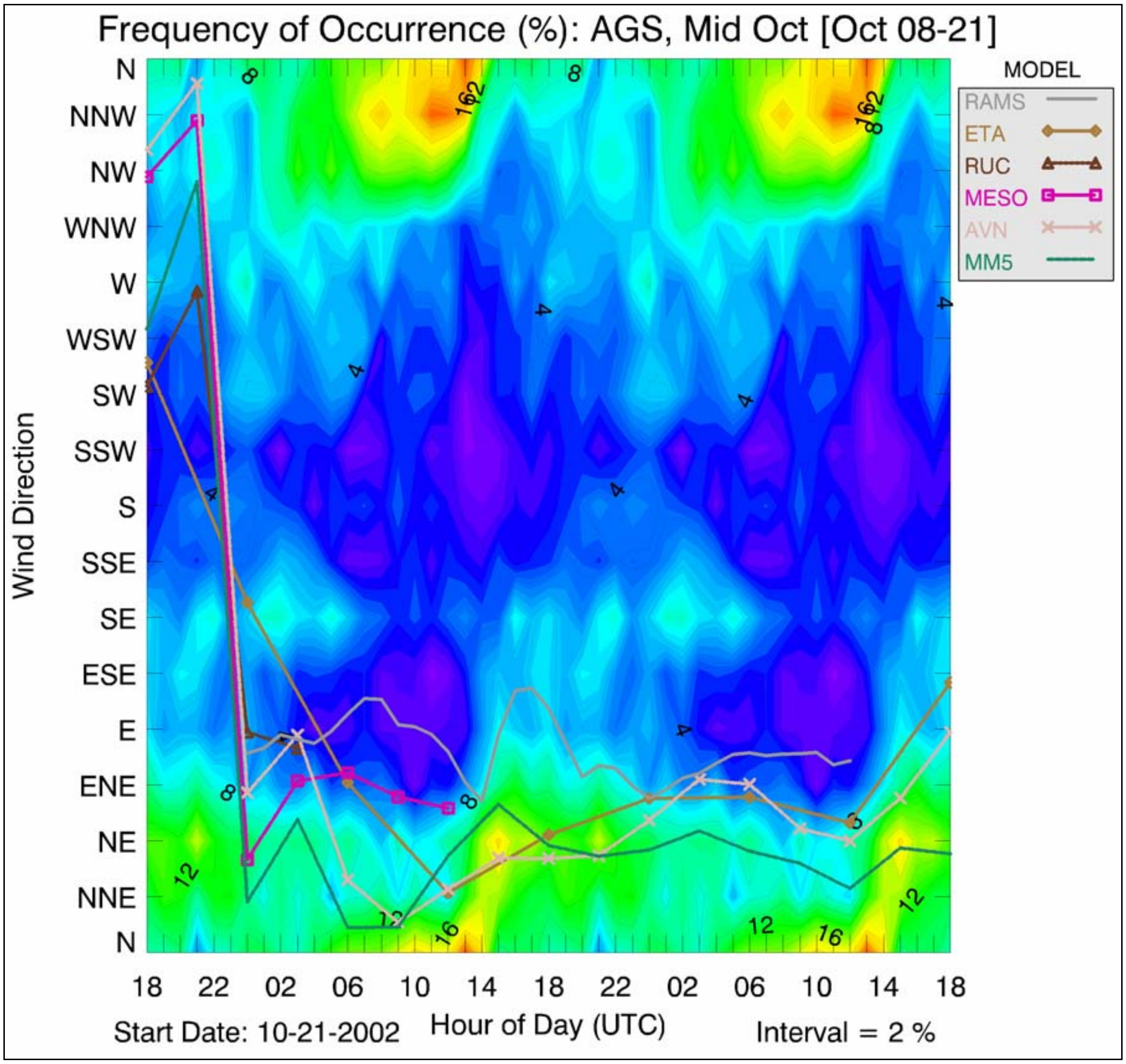

Figure 6. Example of modeled wind direction forecast time series plotted against a backdrop of climatological frequency.

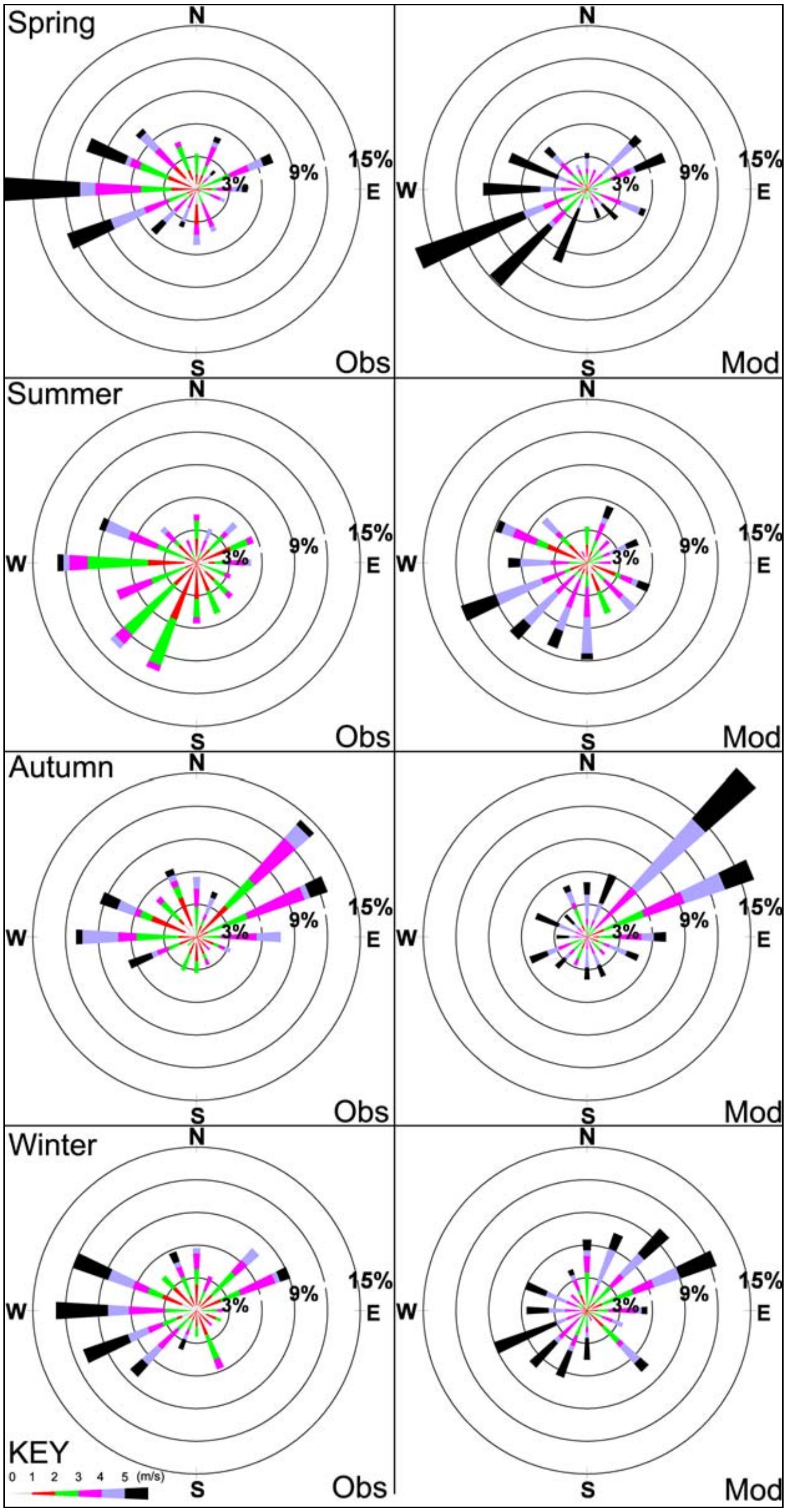

Figure 7. Comparison of RAMS (Mod) and observed (Obs) data for the CC site. Time shown is 18 UTC for each season.