

Was BRAVO Meteorology “Typical”?

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Summary

The Big Bend Regional Aerosol and Visibility Observational (BRAVO) study of 1999 was an intensive, Texas-wide field study designed to explore the causes of visibility impairment at Big Bend National Park. When considering BRAVO Study findings, it is important to understand how the BRAVO period fit into the “big picture.” This task poses the question: were BRAVO conditions “typical”?

This analysis compared historical meteorological data at Big Bend (1994 through 1998) to the BRAVO period in 1999. The TCEQ found that differences between historical and BRAVO period daily relative humidity (RH) three out of the four months were statistically significant; however, the 5-year data set revealed a high degree of variability. Temperature differences during the summer months were also statistically significant, but differences were small (within 2°C). Wind roses showed patterns during BRAVO months were generally similar to those during 1995 through 1998, though some differences were observed. Overall, the BRAVO meteorology examined here can be considered characteristic to the park, and the impact of specific differences will depend upon the application.

Wind roses were generated from EPA’s CASTNET (Clean Air Status and Trends Network) data. Historical temperature and RH data came from transmissometer data files on the IMPROVE (Interagency Monitoring of Protective Visual Environments) network as of August 2001. The 1999 data came from the BRAVO BIBE1 transmissometer data set as of April 6, 2001. All statistical comparison tests were performed at a 0.05 significance level.

Analysis and Results

To investigate if BRAVO weather conditions were characteristic of the park, the TCEQ compared temperature and relative humidity (RH) data from 1994-98 to 1999. Historical data were pulled from the IMPROVE network¹. All daily temperature and RH means were based on days with at least 15 valid hourly measurements at the BIBE1 transmissometer. Because comparisons were between data sets originally intended for light extinction analyses, *only hours with RH below 90 percent* factored into the averages (when examining light extinction, this criterion is intended to prevent fog or rain from being confused with haze events). At Big Bend, this threshold did not affect many days.

High RH values affected approximately 4 percent of hours during July through October at Big Bend in the 5-year period preceding BRAVO (and potentially eliminated 22 out of 615 days from the averages). During BRAVO, only 1 percent of hours were affected (eliminating only two days). The occurrence of fewer hours with RH greater than or equal to 90 percent during BRAVO may have introduced bias into the comparisons, but with less than 5 percent of days affected in either data set, the impact was probably minimal.

This analysis considered the daily average from each time period, grouped by quarter and month.

The summer quarter (defined as July, August, and September) mean daily temperature and RH were not statistically different from earlier years at the 0.05 level. However, monthly comparisons did show some differences.

The 1999 mean daily RH in July, August, and October were statistically different than the previous 5 years at the 0.05 level; however, the standard deviation in the 5-year data set indicated a high degree of variability. These results came from Sheffé’s test, used to compare means from populations of differing sample sizes. The 1999 values were not consistently higher nor lower than the historical period. **Table 1** shows daily mean RH comparisons by month, with the standard deviation in parentheses. Shaded cells indicate which differences were statistically significant.

**Table 1–Daily Average Temperature, RH, and $f(RH)$ at Big Bend
Hours with RH < 90%**

| | July | | August | | September | | October | |
|--------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | '94-'98 | '99 | '94-'98 | '99 | '94-'98 | '99 | '94-'98 | '99 |
| <i>Temperature</i> | 29 °C (2) | 27 °C (2) | 28 °C (2) | 29 °C (2) | 25 °C (3) | 26 °C (3) | 21 °C (4) | 21 °C (4) |
| <i>N_{temp}</i> | 154 | 31 | 148 | 29 | 145 | 30 | 141 | 31 |
| <i>RH</i> | 45% (13) | 54% (10) | 50 % (13) | 40% (10) | 51% (12) | 47% (11) | 45% (15) | 36% (10) |
| <i>N_{RH}</i> | 154 | 31 | 148 | 29 | 145 | 30 | 141 | 31 |
| <i>f(RH)²</i> | 1.2 | 1.5 | 1.3 | 1.1 | 1.4 | 1.3 | 1.3 | 1.1 |

The 1999 daily average temperatures in July and August 1999 were statistically different than previous years at the 0.05 level (but are still within 2° C). The non-parametric Kruskal-Wallis test was used in this case because daily average temperatures were not normally distributed (**Figure 1**). It is not clear if the deviation from normality was the result of problems with IMPROVE data, or if the reason lies in Big Bend’s characteristic swings between cold and mild temperatures during the fall and winter months of the year³ (the BRAVO period showed a similar deviation from normal distribution). **Figures 1 and 2** show the distribution of historical temperature and RH data; data that fall along the quantile-quantile (QQ) reference line have an approximate normal distribution.

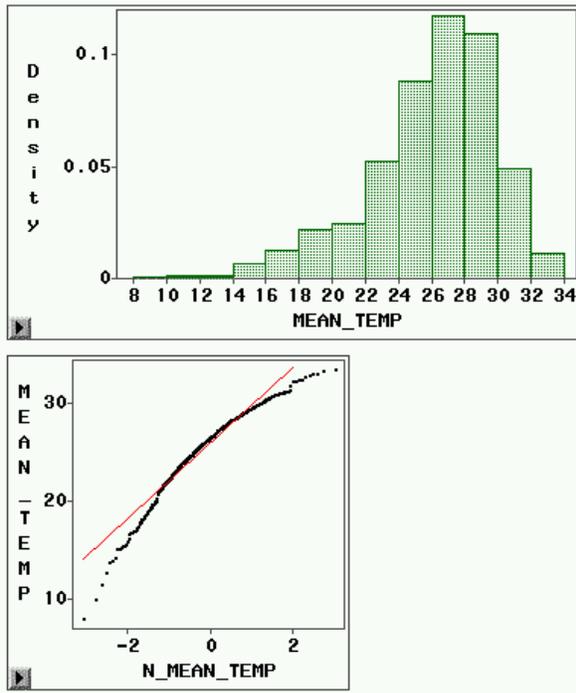


Figure 1 – Daily Average Temperature Distribution and QQ-plot for Big Bend (BIBE1 monitor) for July-Oct. 1994-98

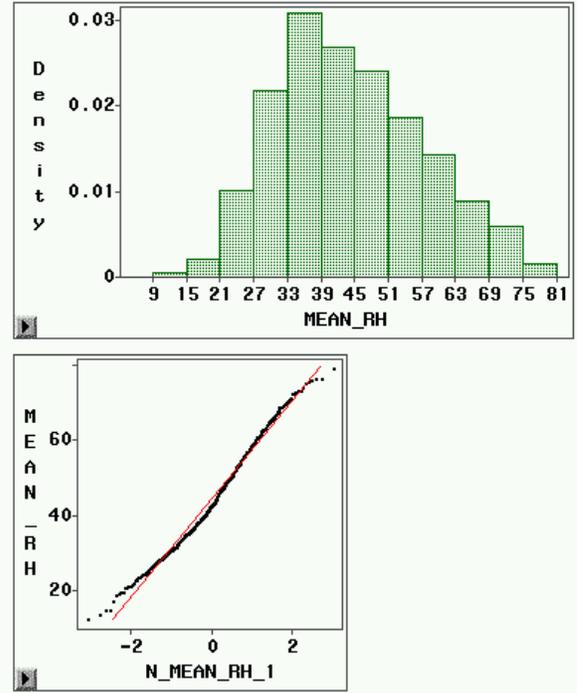


Figure 2 – Daily Average RH Distribution and QQ-plot for Big Bend (BIBE1 monitor) for July-Oct. 1994-98

The TCEQ also examined wind data from 1995 through 1999, available through EPA’s CASTNET website.⁴ Wind roses (again grouped by month) illustrate distributions from 1995-98 versus 1999 (**Figures 3 through 10**). There are some differences, such as a stronger SE component in July 1999 and a varying NW component in October 1999 (less frequent NW winds, but higher speeds from the NNW than the historical period). However, the similarities demonstrate that wind patterns at Big Bend during the BRAVO Study were generally characteristic to the park.

Conclusion

There were some differences between historical (1994-98) and BRAVO period temperature and RH monthly averages. However, historically RH has had a high degree of variability. When statistically significant, temperatures differences were small (within 2°C). Wind roses showed patterns during BRAVO months were generally similar to those during 1995 through 1998. Overall, meteorological conditions during the Study seemed fairly typical of the park. The degree to which the differences identified in this analysis play a role in interpreting BRAVO Study findings will depend on the particular application.

Disclaimer

The results, findings, and conclusions expressed in this paper are solely those of the authors and are not necessarily endorsed by the management, sponsors, or collaborators of the BRAVO

Study. A comprehensive final report for the BRAVO Study is anticipated in 2003.

Endnotes

1. “IMPROVE: Interagency Monitoring of Protected Visual Environments.” Program website. <<http://vista.cira.colostate.edu/improve/>> (17 Oct. 2001).
2. Relative humidity adjustment factor used to account for growth of hygroscopic species. Used to calculate light extinction from aerosol data. Estimated average $f(\text{RH})$ from daily average RH, using RH vs. $f(\text{RH})$ Table 4-2 in U.S. EPA’s *Draft Guidance for Demonstrating Attainment of Air Quality Goals for PM_{2.5} and Regional Haze* (January 2001).
3. “Big Bend National Park—Frequently Asked Questions.” National Park Service (NPS) website. <<http://www.nps.gov/bibe/faq.htm>> (24 Oct. 2001).
4. “CASTNET (Clean Air Status and Trends Network): Hourly Meteorological Data.” EPA website. <<http://www.epa.gov/castnet/metdata.html>> (25 Oct. 2001).

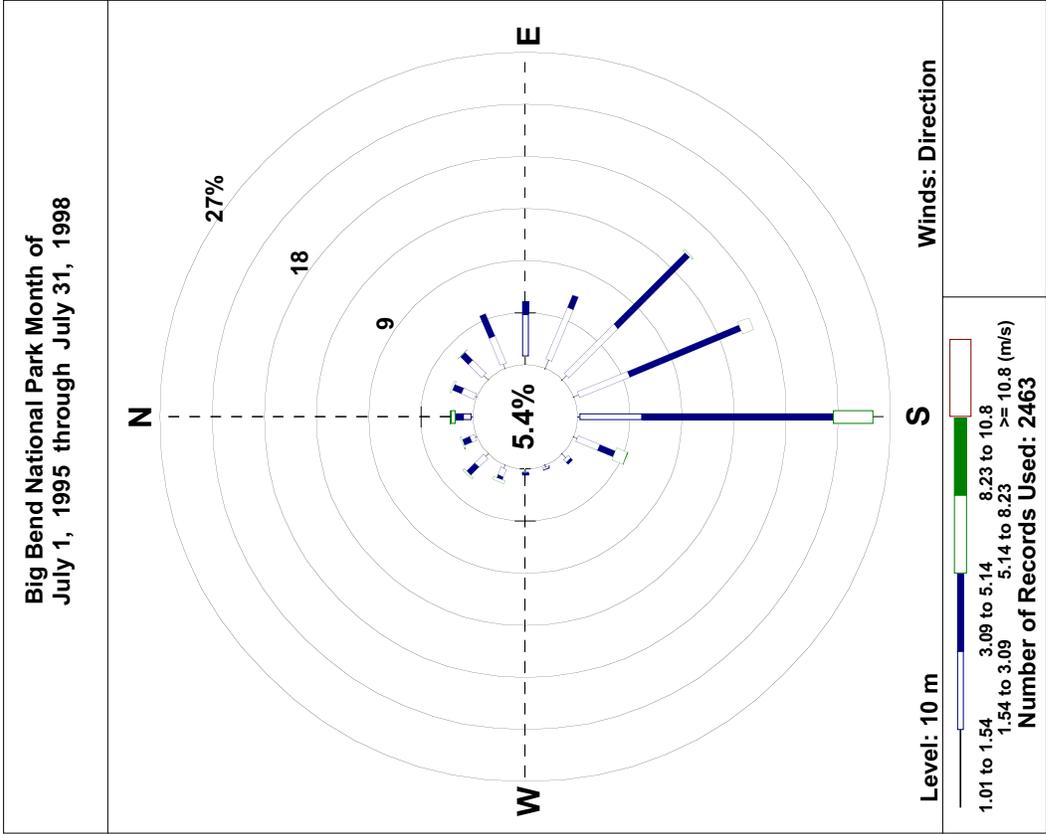


Figure 3
Month of July Wind Rose, '95-'98

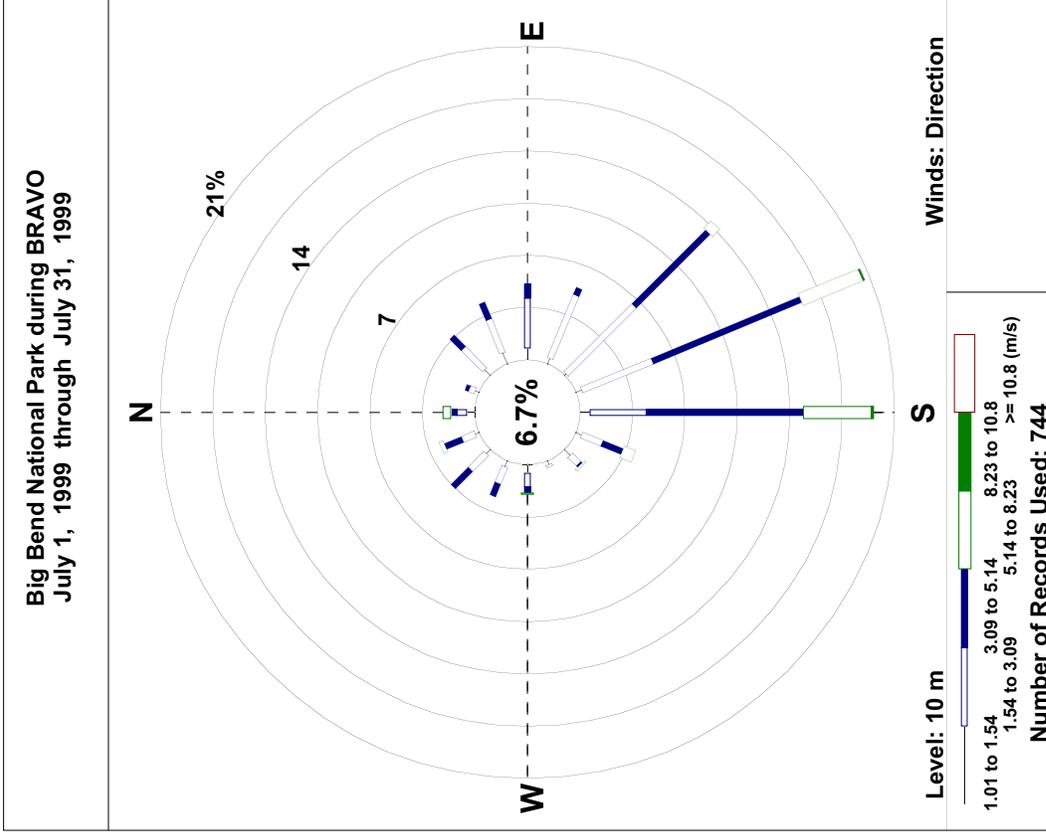


Figure 4
Month of July Wind Rose, BRAVO

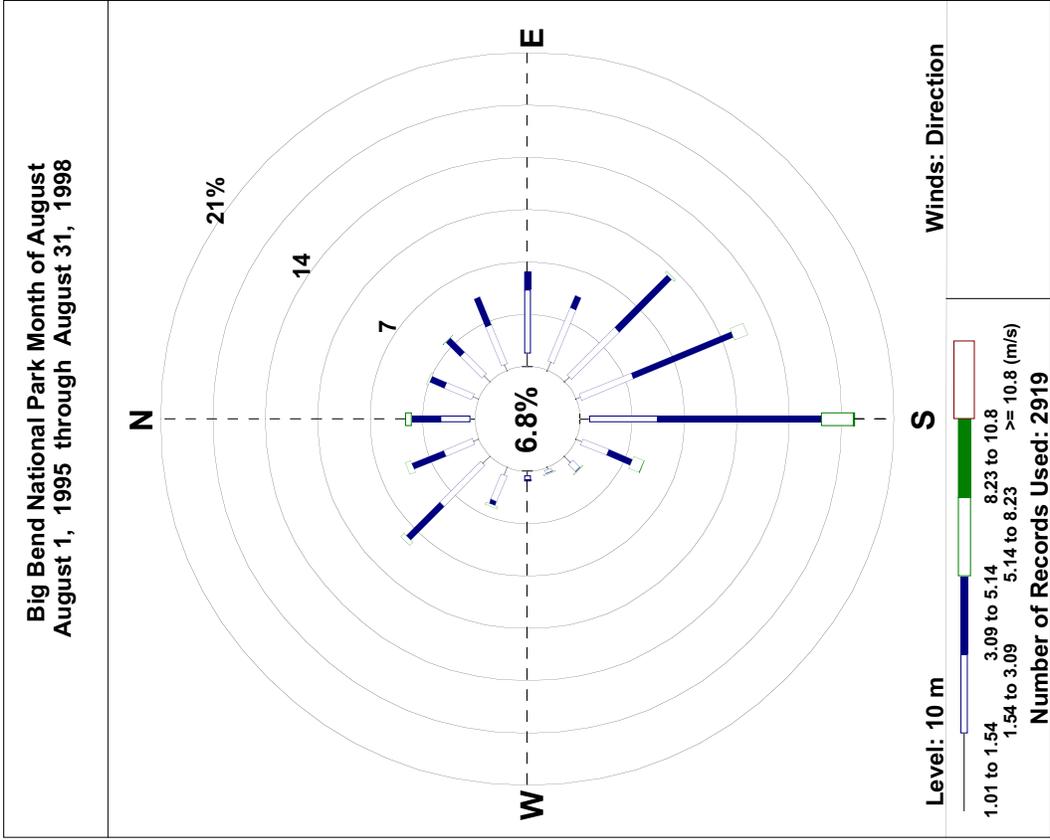


Figure 5
Month of August Wind Rose, '95-'98

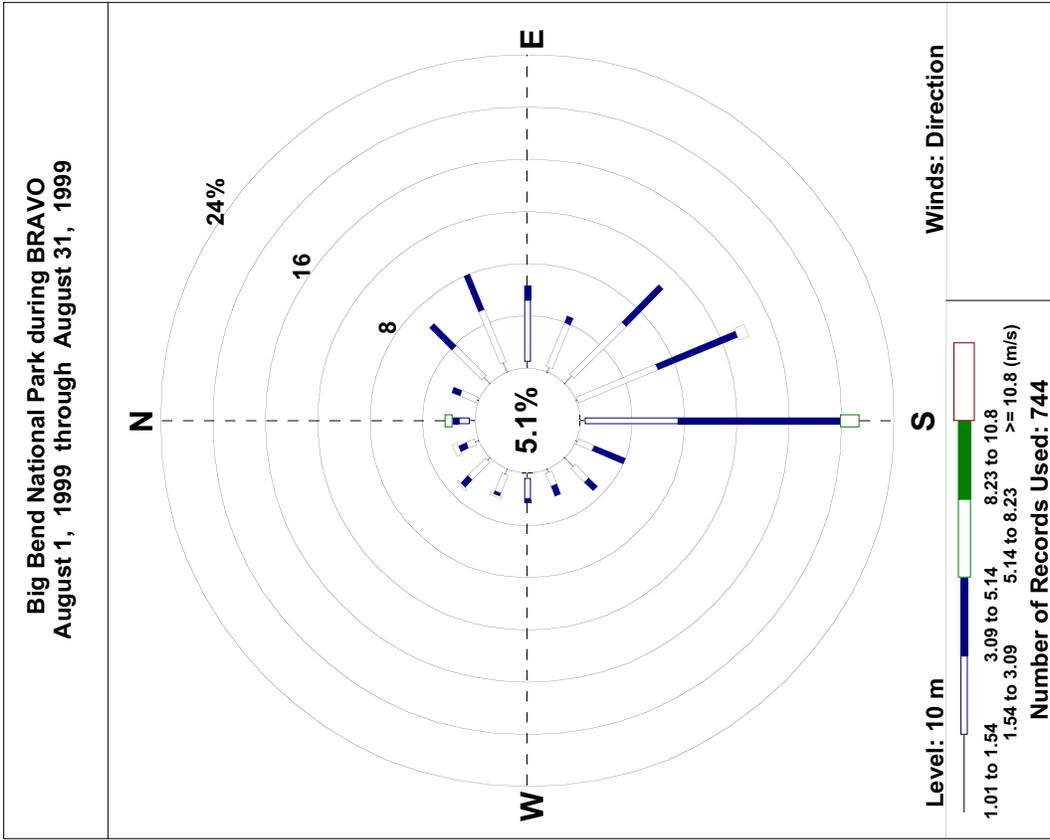


Figure 6
Month of August Wind Rose, BRAVO

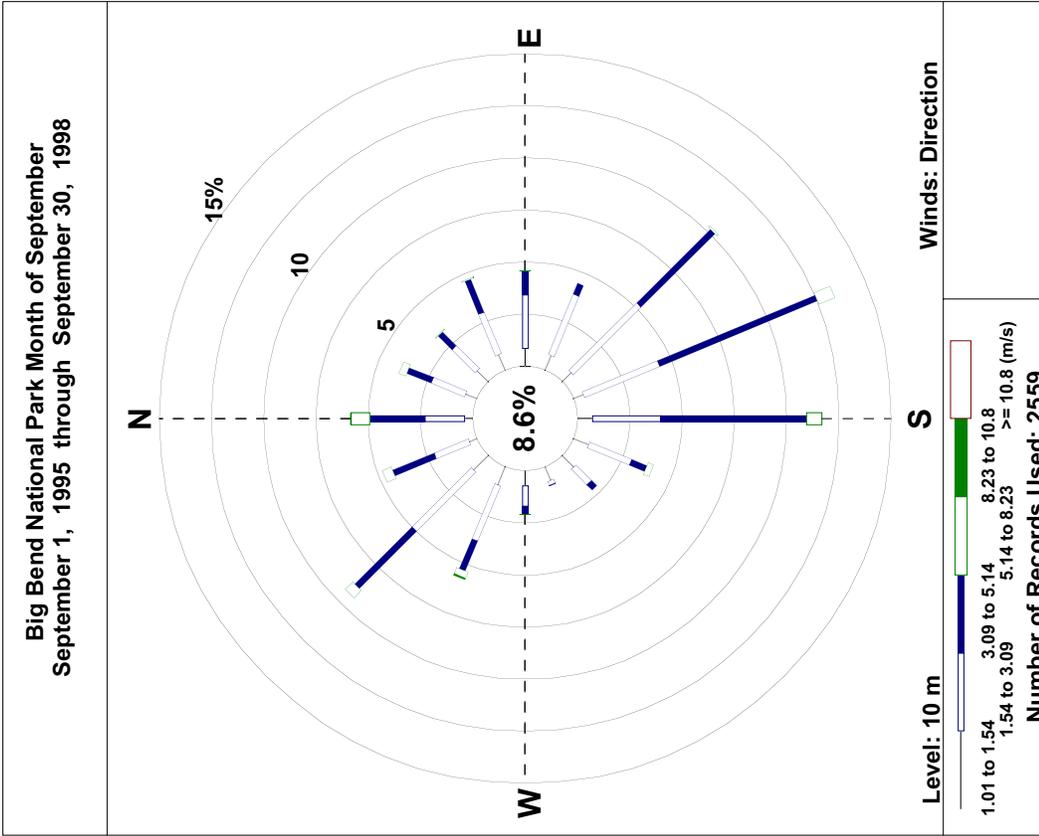


Figure 7
Month of September Wind Rose, '95-'98

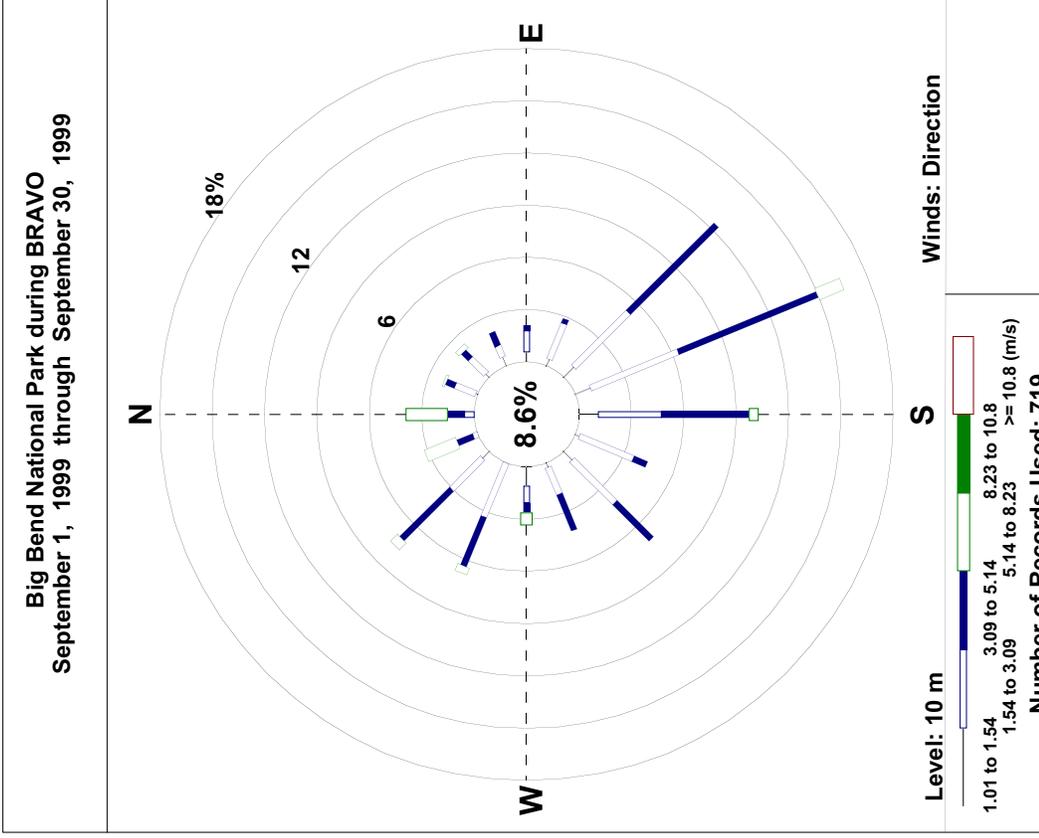


Figure 8
Month of September Wind Rose, BRAVO

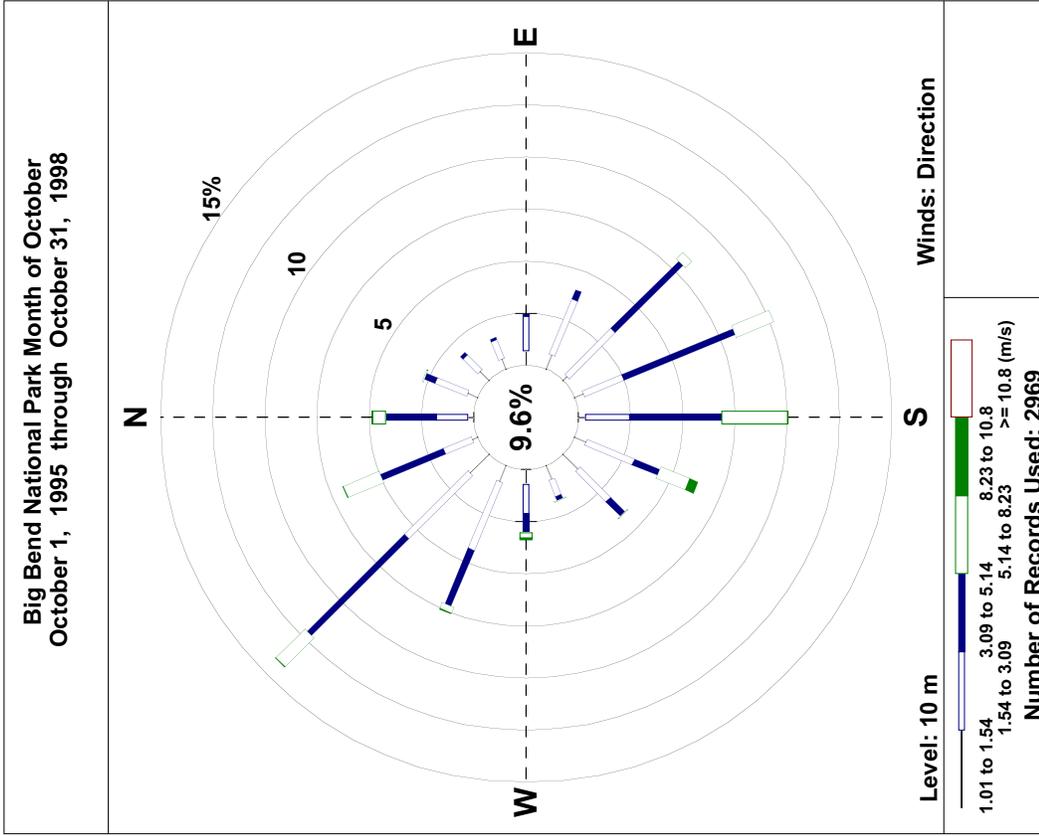


Figure 9
Month of October Wind Rose, '95-'98

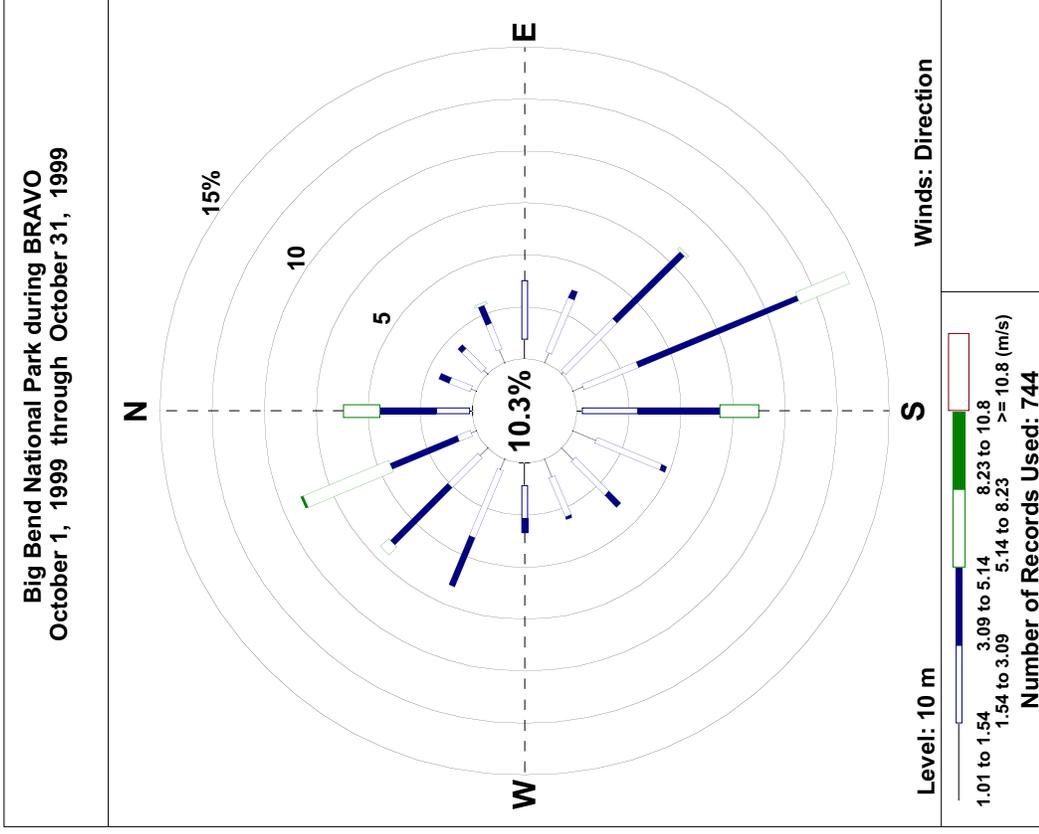


Figure 10
Month of October Wind Rose, BRAVO