

## Appendix 2a. Radar Wind Profiler Data

### Discussion of Radar Wind Profiler Data

Wind profiler data were collected in two modes at four sites, Big Bend, Eagle Pass, Llano, and Brownsville. (See chapter 2 for a map of these locations and further discussion of the measurements). The 60 m mode gives better vertical resolution but less height coverage while the 100 m mode can extend to higher heights. Generally, the 60 m mode data are used for the lowest 700 mb, with the 100 m data used above that level.

These data were used primarily for three purposes during BRAVO: 1) as input into the MM5 wind fields, 2) as additional input into the ATAD back trajectory model and 3) for evaluation of the EDAS and MM5 wind fields. This appendix is a brief overview of some of these winds and discussion of some of the patterns in wind directions and wind speed with respect to month, hour of day, and site.

Figures 1–4 show directional wind roses for each of the four profiler sites for the 60 m mode for each study month showing how the predominant wind direction changed during the study. At Big Bend, July had the most southerly winds, August the most easterly, and October the most westerly.

Southerly winds predominated at all four sites during July, though at Eagle Pass and Brownsville winds were more southeasterly than southerly. During August, winds at all four sites are more easterly than during July. In September, the wind directions at the four profiler sites are most different from each other, with Eagle Pass experiencing mostly southeasterly winds, Brownsville easterly, Llano southerly, and Big Bend winds from all directions, but with southeasterly and northwesterly being slightly more likely. During October, Big Bend again has winds from all directions, with southerly and northerly being slightly more common than easterly or westerly. Eagle Pass experiences mostly southeasterly and northwesterly winds in October, while Llano winds are from north and south and Brownsville winds are most likely to be easterly.

Another method for discerning some of the patterns in the winds during BRAVO is by boxplots of wind speed and/or direction sorted by various categories. In all of these plots, the heavy center line is the median, the tops and bottoms of the boxes are the 25<sup>th</sup> and 75<sup>th</sup> percentiles and the whiskers extend to the minimums and maximums. Figure 5 shows the vertical wind speed (positive is upward, negative downward) at Big Bend. Patterns for the three remaining sites were similar and are not shown. On average, air is subsiding (sinking) during the afternoon and rising during the rest of the day at all four locations.

Horizontal wind speed did not vary significantly by hour of day, though in general at all sites and during most months, wind speeds tend to be slightly slower during the afternoon than during the remainder of the day. The average differences by hour are small. The only exception to this is wind speeds at Llano tended to be highest on average in the late evening and at minimum around midnight during July and August. Graphs are not shown since the variation by hour was small.

Figures 6–9 show box plots of wind direction by hour. At Big Bend, the predominant daily wind direction pattern varies by month. In July, winds are most commonly southerly during the morning and night-time hours and easterly to southeasterly during the afternoon. In August, winds tend to be easterly throughout the day, being more southeasterly in the morning

and overnight. In September, winds are southerly most of the day, with a wider range of wind directions than during the summer and a greater tendency to be westerly rather than easterly. In October, winds are westerly overnight and during the early morning, moving to more southwesterly during the afternoon.

At Eagle Pass and Brownsville, winds are predominantly south to southeasterly during all months and all hours. Though in October, southwesterly winds are also common and in July, there is a much narrower range of common wind directions than during the later months, with October having the greatest variability. Llano, which is farther north, also has predominantly southerly winds during all months, with wind directions tending to move slightly to the southeast during the afternoon. Like the other three sites, Llano also has more variability in wind direction during October than during summer. However, while winds at Eagle Pass and Brownsville tend to be southwesterly during October, winds at Llano are more likely to be south to southeasterly.

Box plots of wind direction by height and month are shown in Figures 10–13. All four sites have predominantly south to southeasterly winds at the lowest levels and more variability in wind direction with higher heights. At Big Bend, high level winds are southeasterly during July and September, easterly during August, and westerly during October. The pattern at Eagle Pass is similar, except that the highest level winds in September tend to be westerly rather than easterly. At Brownsville, winds are mostly from the south at all heights during July; are southerly at low levels, moving gradually to easterly as the height increases during August, southeasterly at all levels, with more westerlies at the highest heights during September; and easterlies at low levels and southwesterlies at high levels during October.

Wind speeds also tend to vary systematically by wind direction. Box plots illustrating these patterns are shown in Figures 14–17. At Big Bend, on average, the slowest wind speeds are from the east and the west. Highest median wind speeds are for south southeasterly winds, while peak gusts generally occur with winds from the north. The pattern is quite different at Eagle Pass where the pattern varies more with month. In July, highest median wind speeds and peak gusts are for south southeasterly winds, while lowest median wind speeds are generally northwesterly. September and October have similar patterns, except the northerly median wind speeds are higher than during July and peak gusts tend to be either southerly or northerly. Winds from the east and west have the lowest median and lowest maximum wind speeds. In August, there were a few odd observations with very high wind speeds from the southwest and northwest. Except for these values, peak median speeds are usually from the northeast or southeast with highest gusts from the east. At Brownsville, highest median wind speeds occur when winds are from the southeast during July. During all months, lowest median wind speeds are associated with wind from the west through southwest. During August and October median wind speeds for winds from the north are greater than during the other months and are approximately equal to wind speeds for winds from the south. Llano shows similar patterns to Brownsville, though the relative differences between directions tend to be smaller.

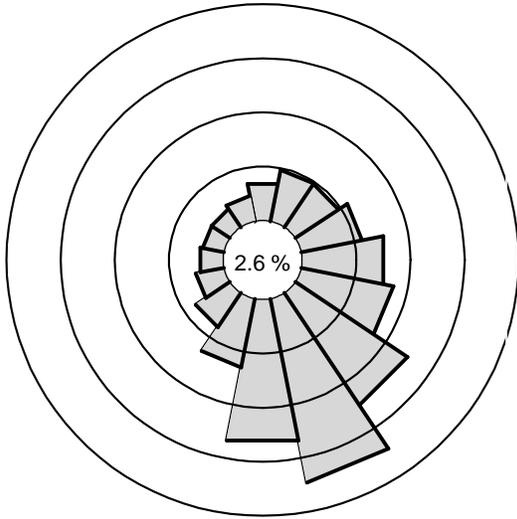
Figures 18–35 show the 100m wind profiler data by hour and height at Big Bend National Park for selected days of interest during the BRAVO study. These days were chosen based on the criteria shown in Table 1.

**Table 1. Dates chosen for display of hourly wind profiler data and reasons for choice.**

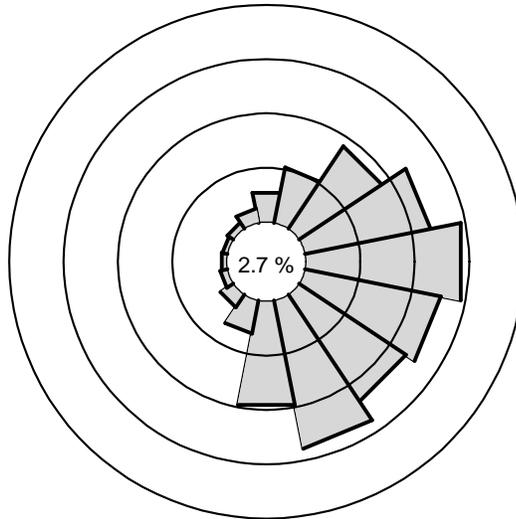
<b>Date</b>	<b>Reason for Choice of Date</b>
Aug. 21, Sept. 1, 14, 15, Oct. 12	High sulfur episodes
July 8, Aug 3, 4, 18	Saharan dust days (based on Si/Ca)
Aug. 15, 17	High soil days
Sept. 5, 6, 7, 8, Oct. 20, 21, 22	Clean days

The vectors on these plots show the horizontal direction from which the wind was blowing, with the horizontal axis being hour of the day and the vertical axis being the height. Arrow lengths are proportional to the wind speed with a 5 m/sec sample shown for comparison on the right side of each graph. As expected, wind speeds are generally slowest near the surface, increasing with height. Morning and night time winds near the surface are usually southerly, while afternoon winds are more likely to be from the east and to have more variability in direction. Higher level winds vary with the synoptic weather patterns and are less influenced by terrain.

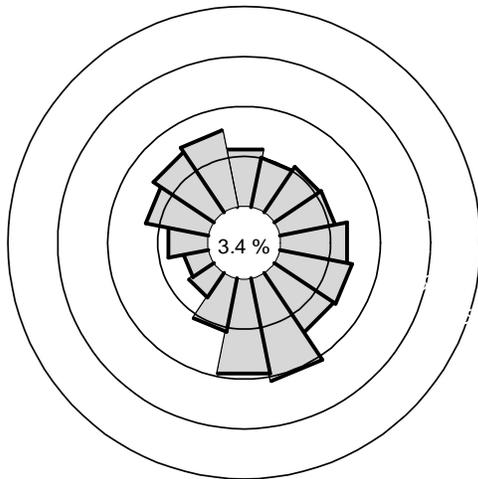
Big Bend Wind Profiler  
July 1999 60m mode



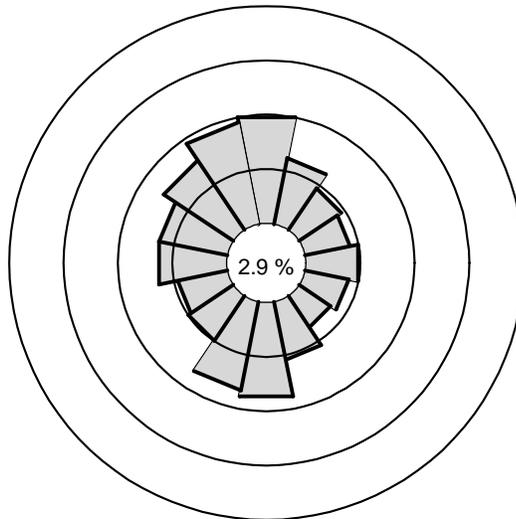
Big Bend Wind Profiler  
August 1999 60m mode



Big Bend Wind Profiler  
September 1999 60m mode

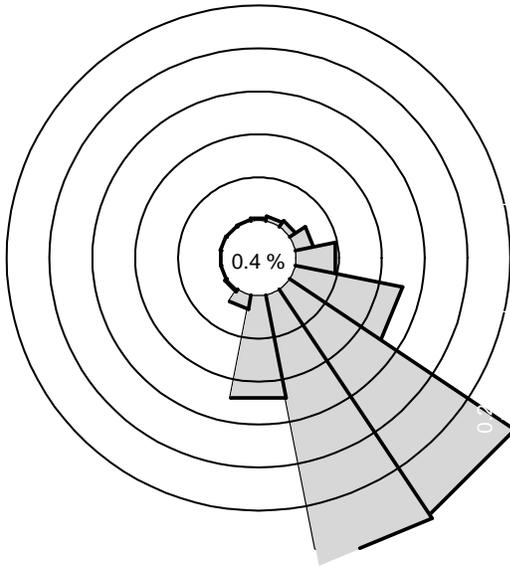


Big Bend Wind Profiler  
October 1999 60m mode

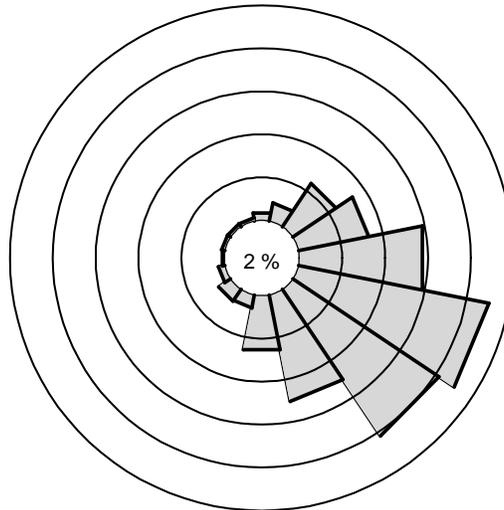


**Figure 1. Wind roses of wind directions from the 60 m mode wind profiler at Big Bend National Park. Each graph is created from 20,000 to 30,000 observations. The percentage in the center is the percent of winds with speeds below 1 m/sec. Winds were measured at heights of 1189 to 3335 m msl. The surface at the profiler site was 1037 m msl. Rings are drawn in increments of 5%.**

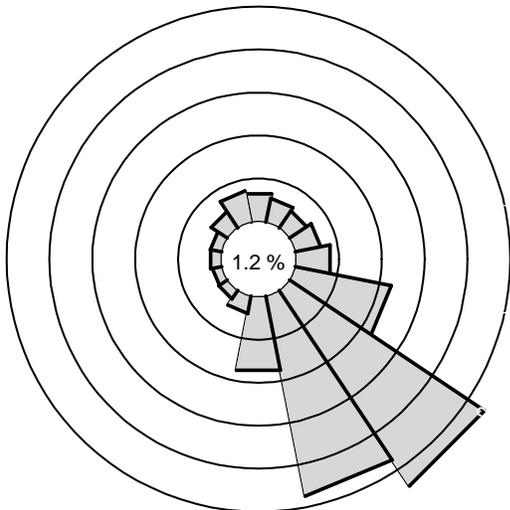
Eagle Pass Wind Profiler  
July 1999 60m mode



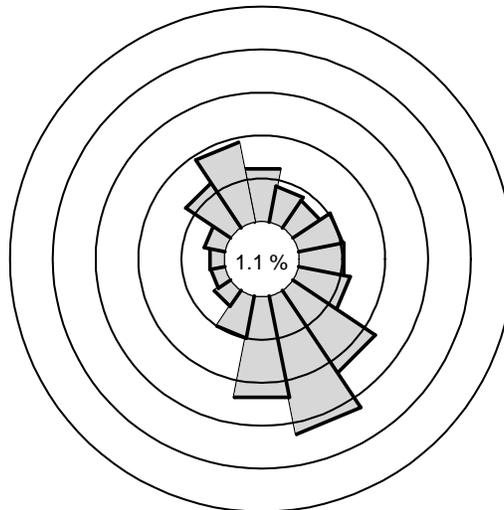
Eagle Pass Wind Profiler  
August 1999 60m mode



Eagle Pass Wind Profiler  
September 1999 60m mode

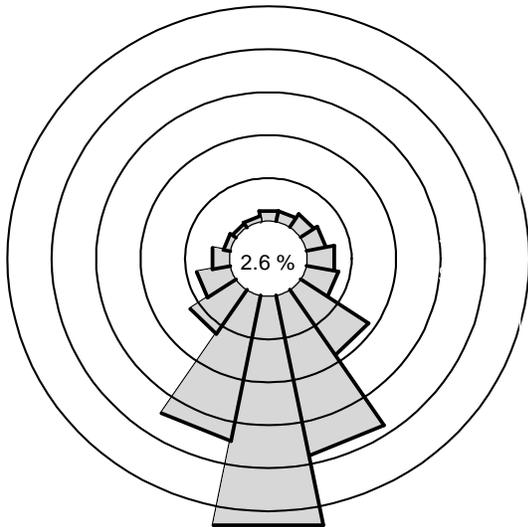


Eagle Pass Wind Profiler  
October 1999 60m mode

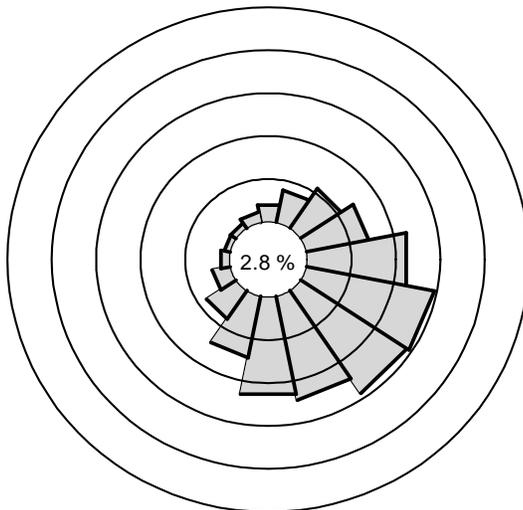


**Figure 2. Wind roses of wind directions from the 60 m mode wind profiler at Eagle Pass. Each graph is created from 20,000 to 30,000 observations. The percentage in the center is the percent of winds with speeds below 1 m/sec. Winds were measured at heights of 361 to 2507 m msl. The surface at the profiler site was approximately 300 m. msl. Rings are drawn in increments of 5%.**

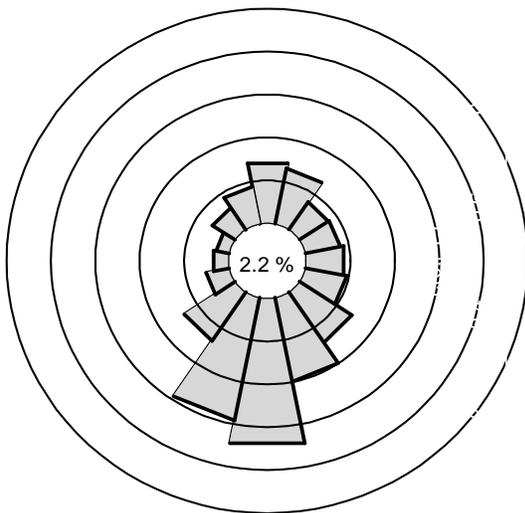
Llano Wind Profiler  
July 1999 60m mode



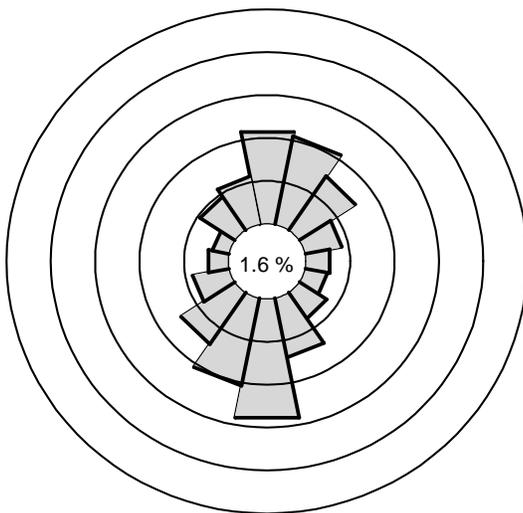
Llano Wind Profiler  
August 1999 60m mode



Llano Wind Profiler  
September 1999 60m mode

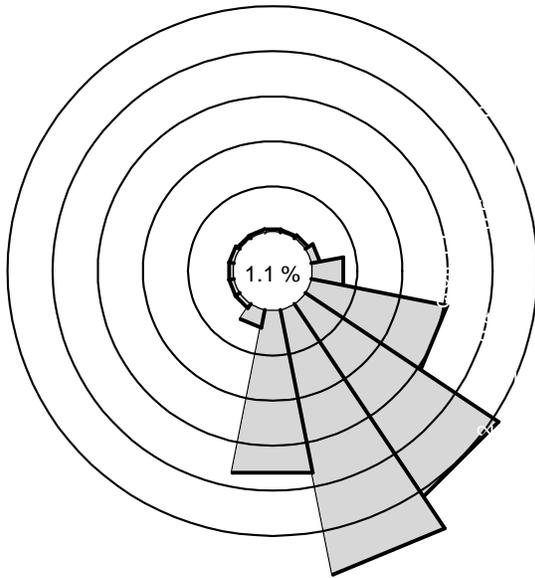


Llano Wind Profiler  
October 1999 60m mode

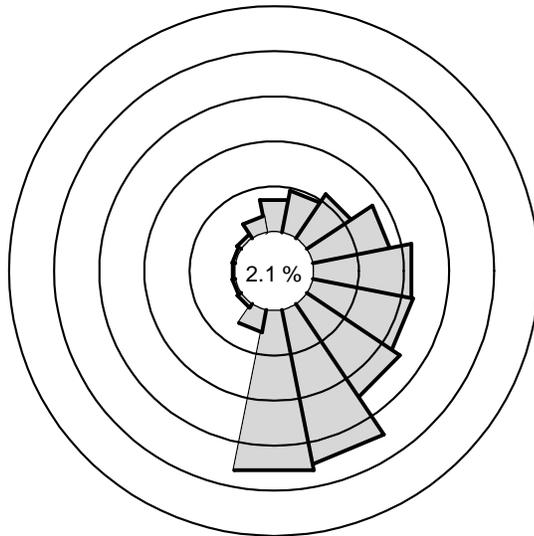


**Figure 3. Wind roses of wind directions from the 60 m mode wind profiler at Eagle Pass. Each graph is created from 20,000 to 30,000 observations. The percentage in the center is the percent of winds with speeds below 1 m/sec. Winds were measured at heights of 479–2513 m msl. The surface at the profiler site was approximately 370 m. msl. Rings are drawn in increments of 5%.**

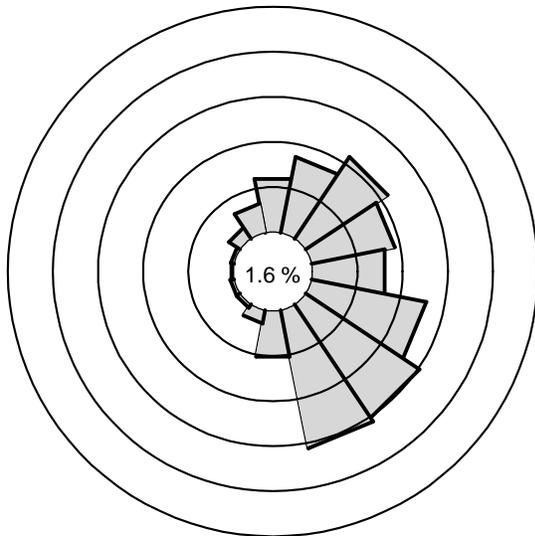
Brownsville Wind Profiler  
July 1999 60m mode



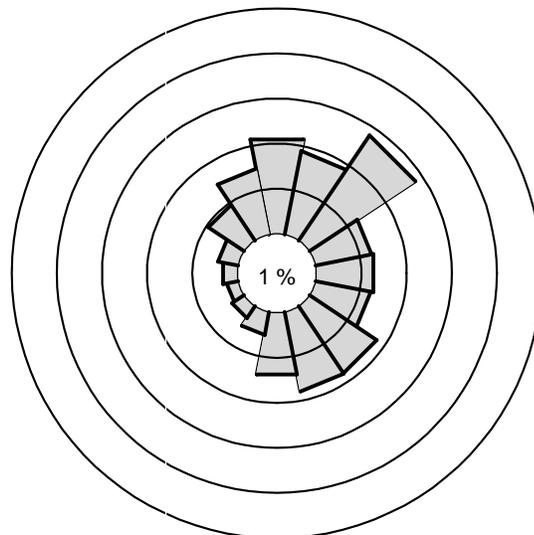
Brownsville Wind Profiler  
August 1999 60m mode



Brownsville Wind Profiler  
September 1999 60m mode



Brownsville Wind Profiler  
October 1999 60m mode



**Figure 4. Wind roses of wind directions from the 60 m mode wind profiler at Brownsville. Each graph is created from 20,000 to 30,000 observations. The percentage in the center is the percent of winds with speeds below 1 m/sec. Winds were measured at heights of 115–3865 m msl. The surface at the profiler site was approximately 6 m. msl. Rings are drawn in increments of 5%.**

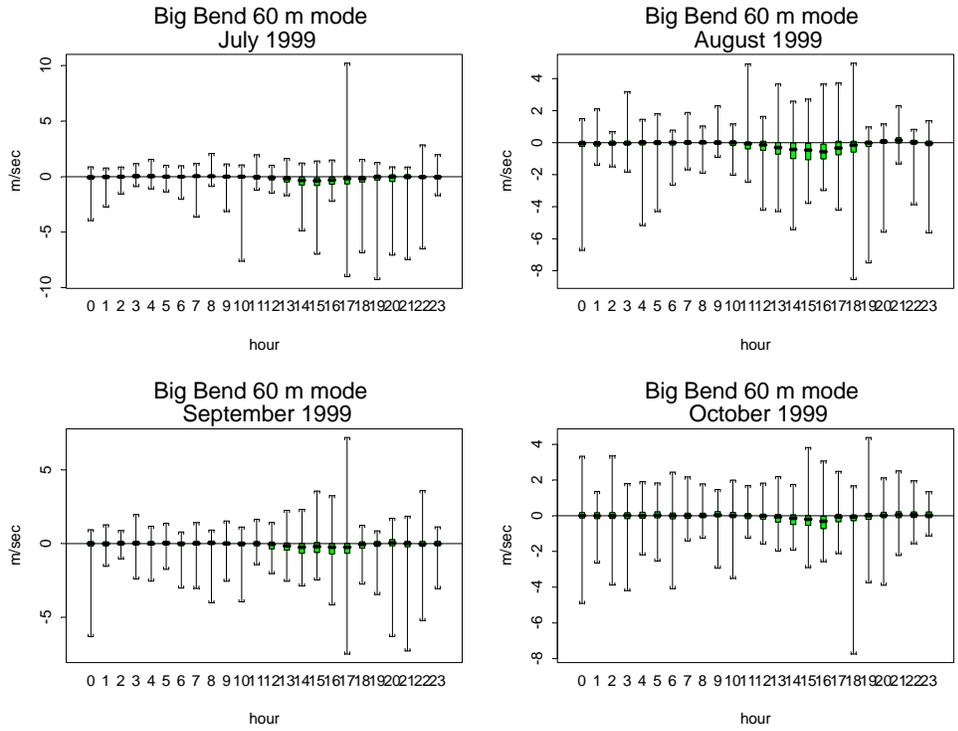


Figure 5. Vertical wind speeds (m/sec) by hour and month at Big Bend.

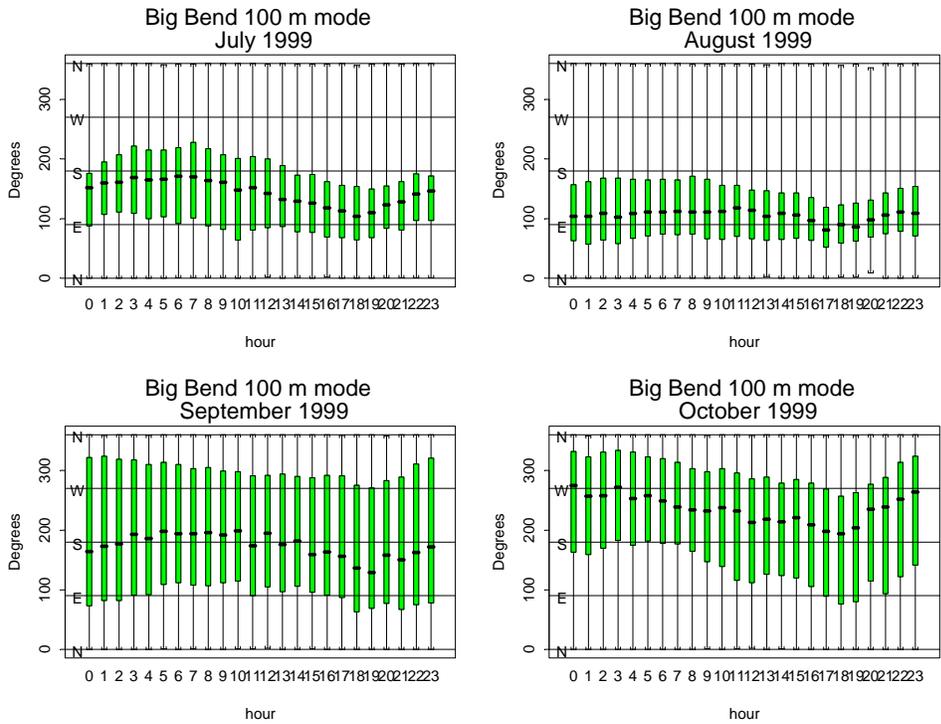
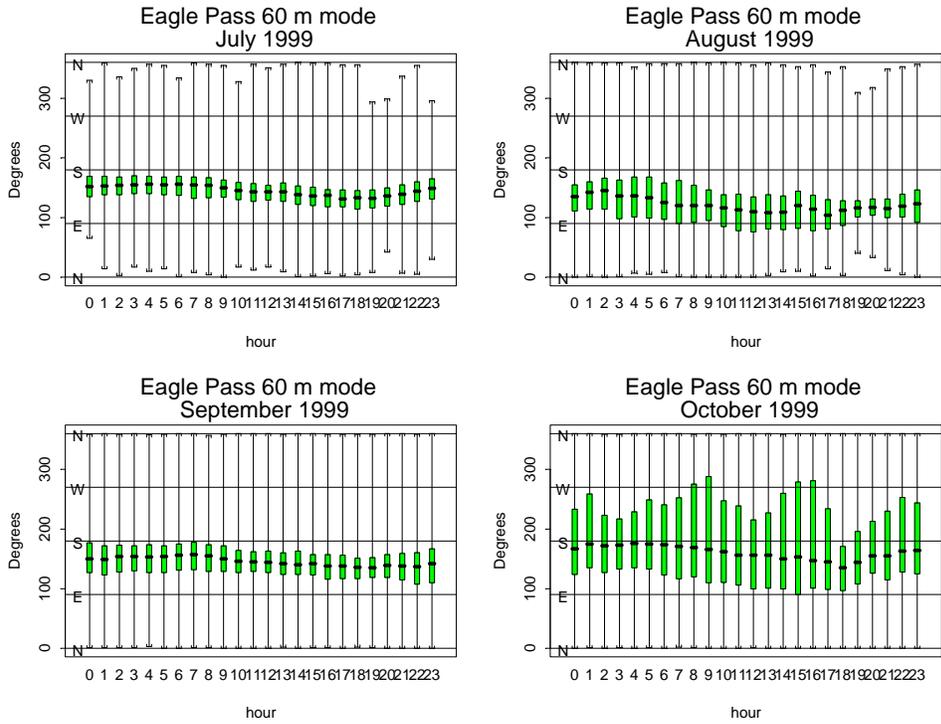
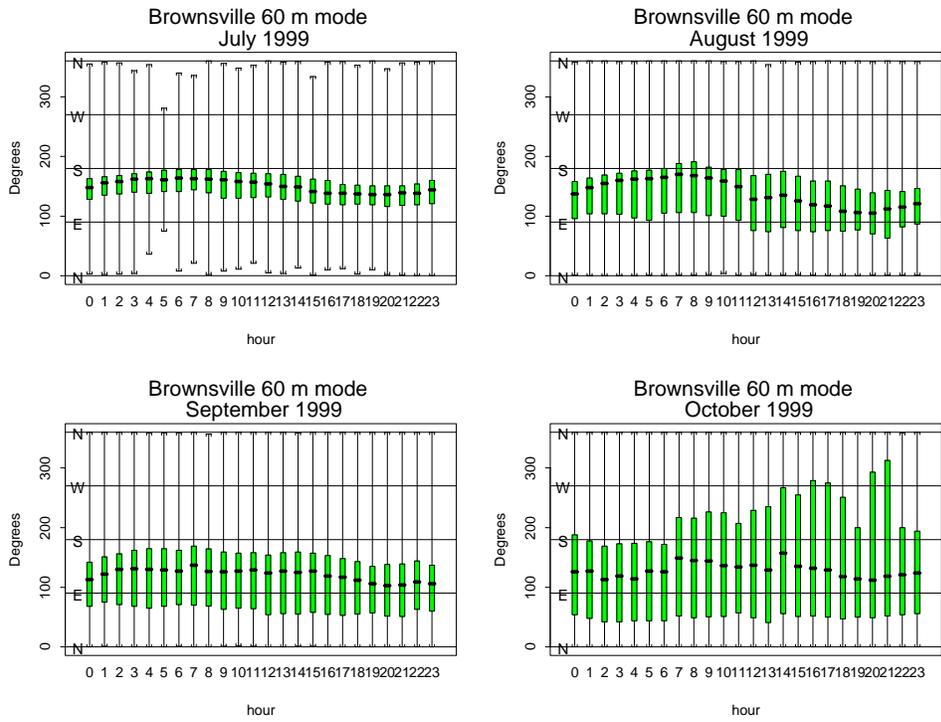


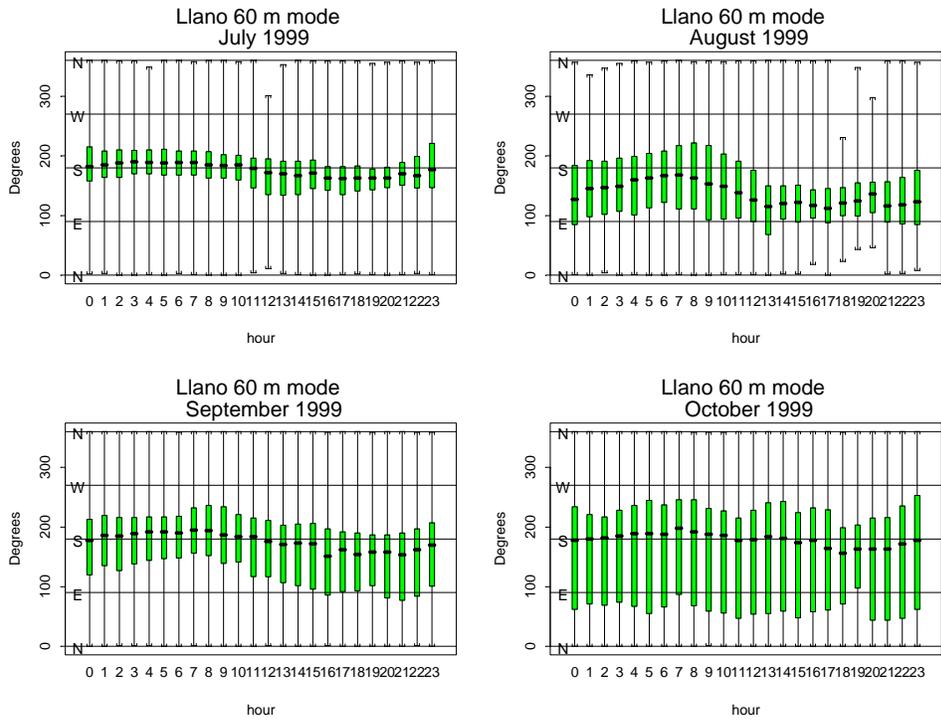
Figure 6. Wind direction by hour of day and month at Big Bend.



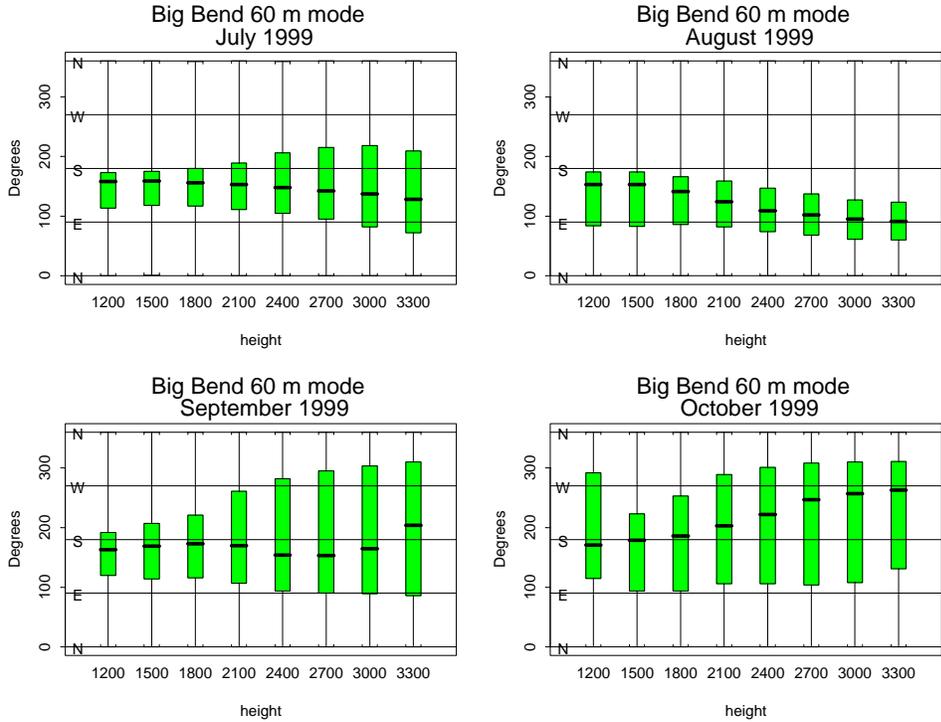
**Figure 7. Wind direction by hour of day and month at Eagle Pass.**



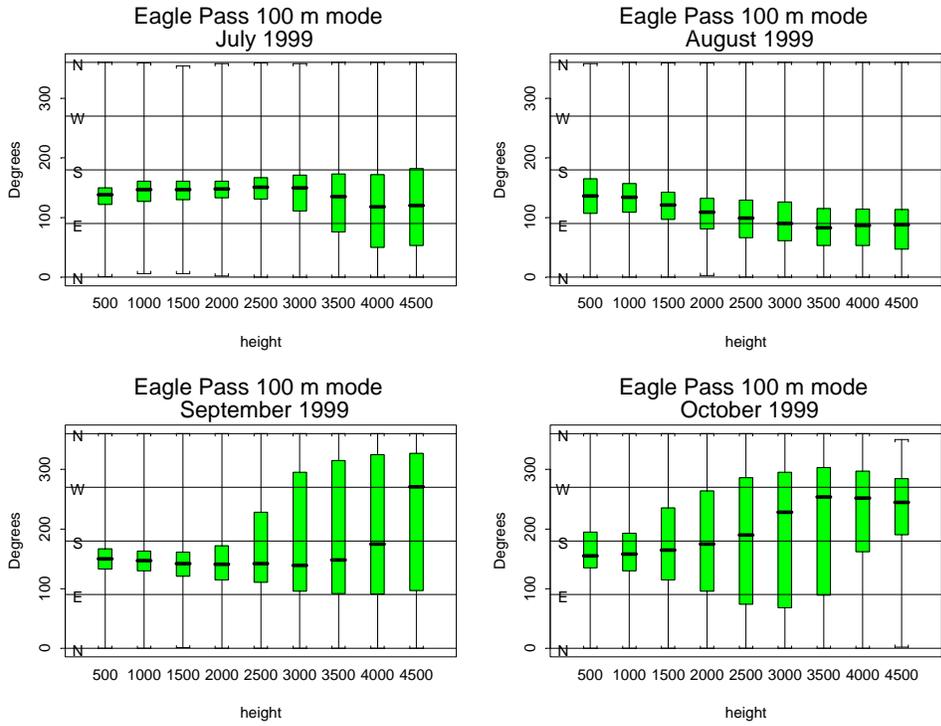
**Figure 8. Wind direction by hour of day and month at Brownsville.**



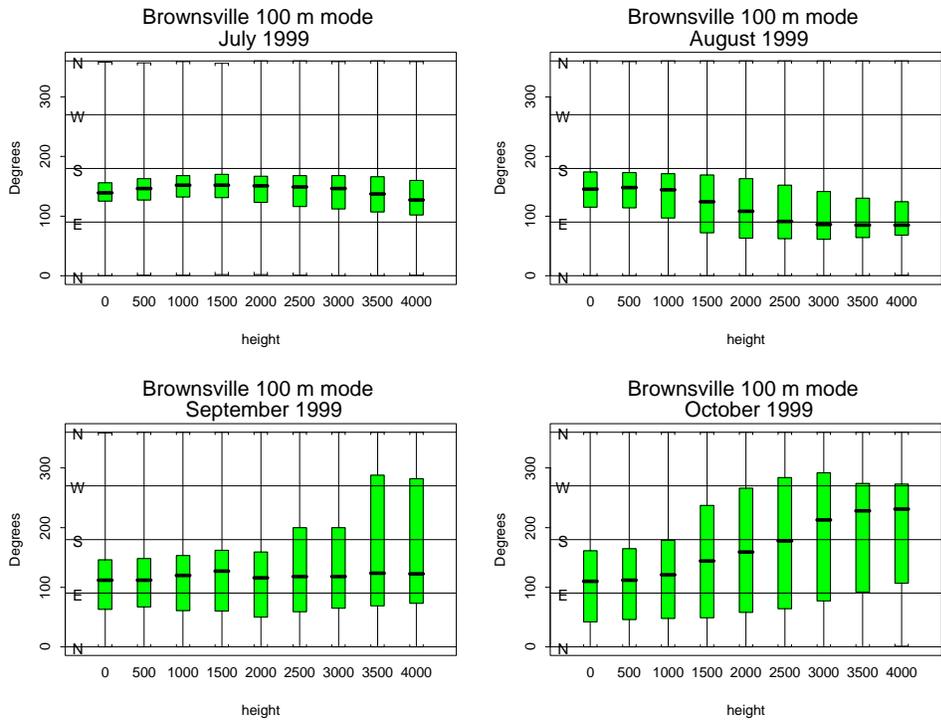
**Figure 9. Wind direction by hour of day and month at Llano.**



**Figure 10. Wind direction by height at Big Bend.**



**Figure 11. Wind direction by height at Eagle Pass.**



**Figure 12. Wind direction by height at Brownsville.**

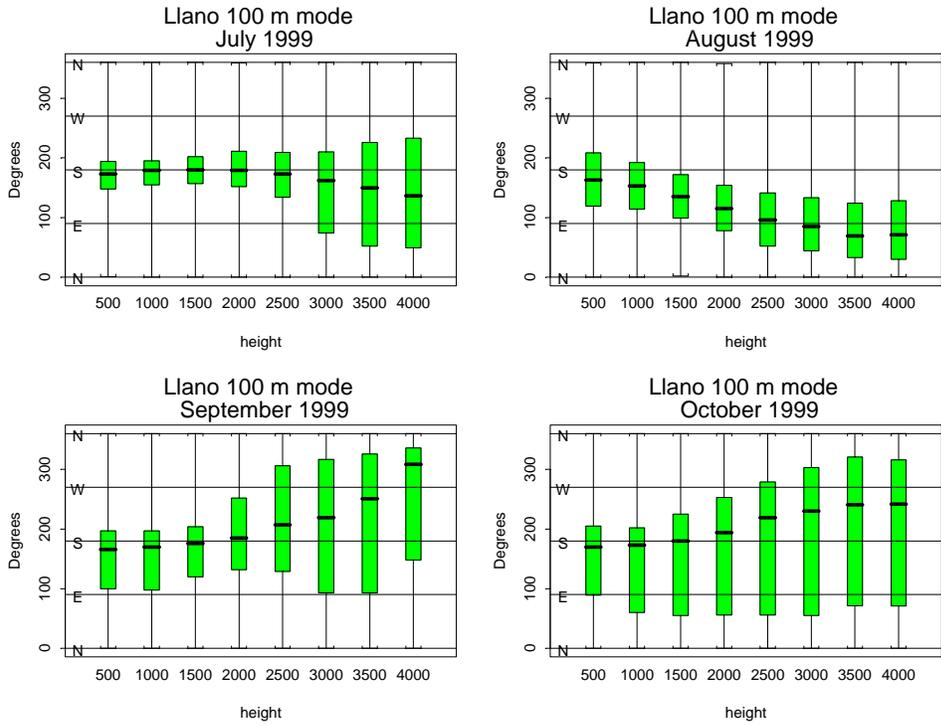


Figure 13. Wind direction by height at Llano.

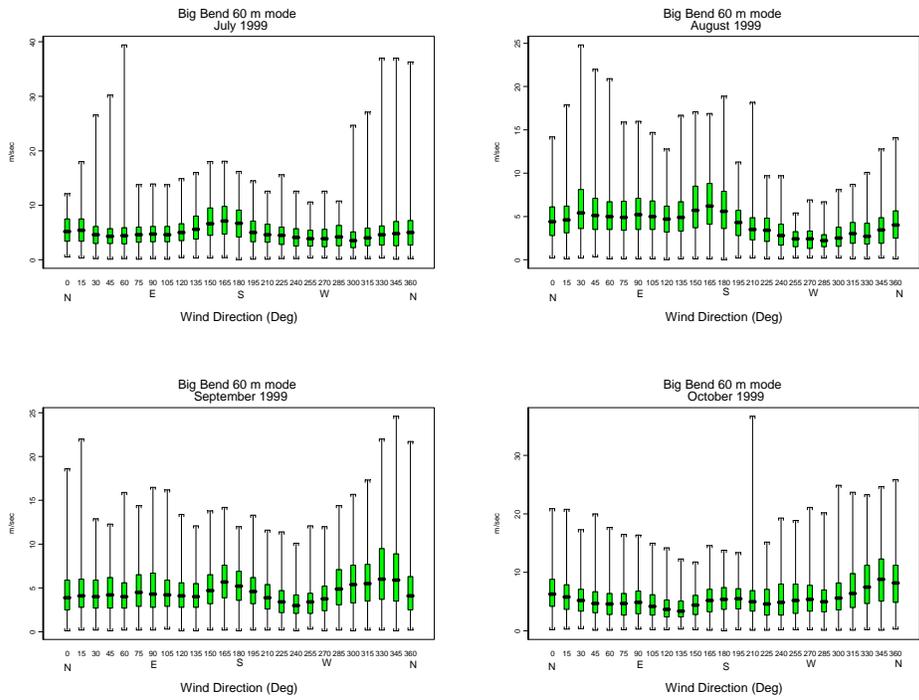
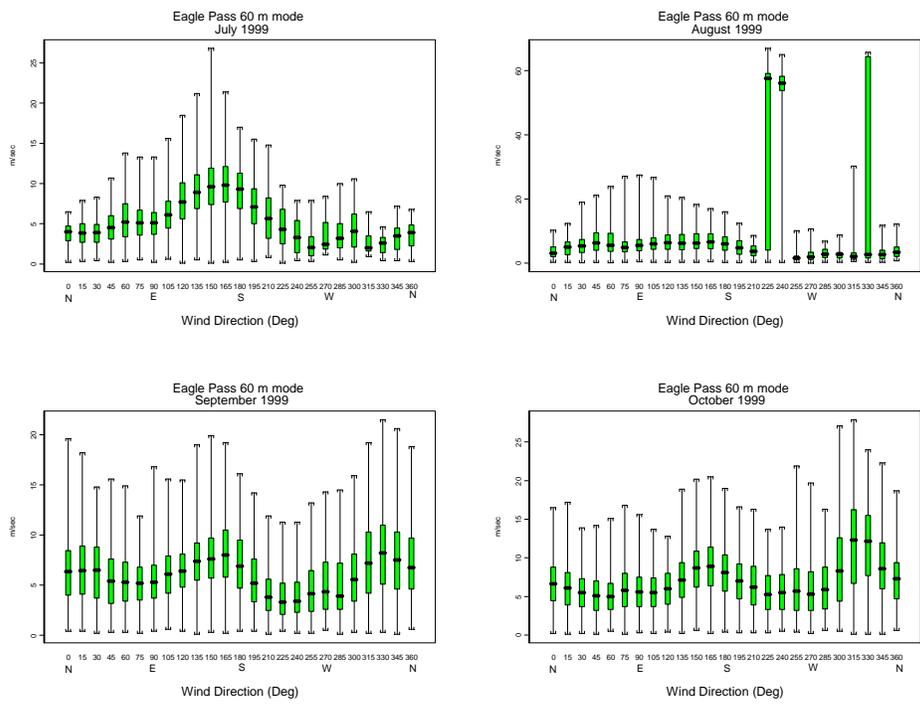
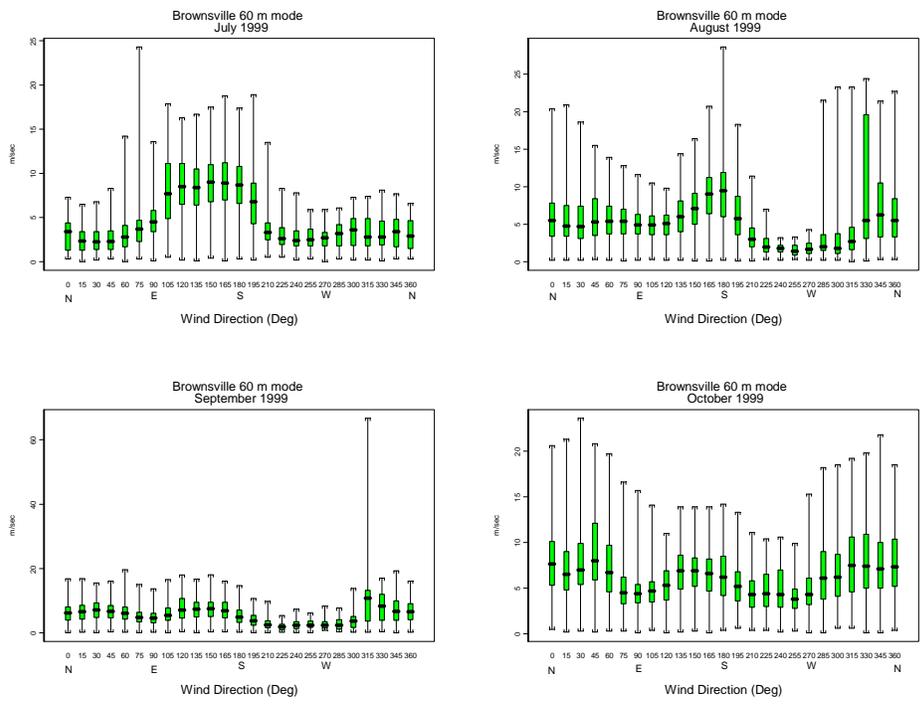


Figure 14. Wind speed by wind direction and month at Big Bend.



**Figure 15. Wind speeds by wind direction and month at Eagle Pass.**



**Figure 16. Wind speeds by wind direction at Brownsville.**

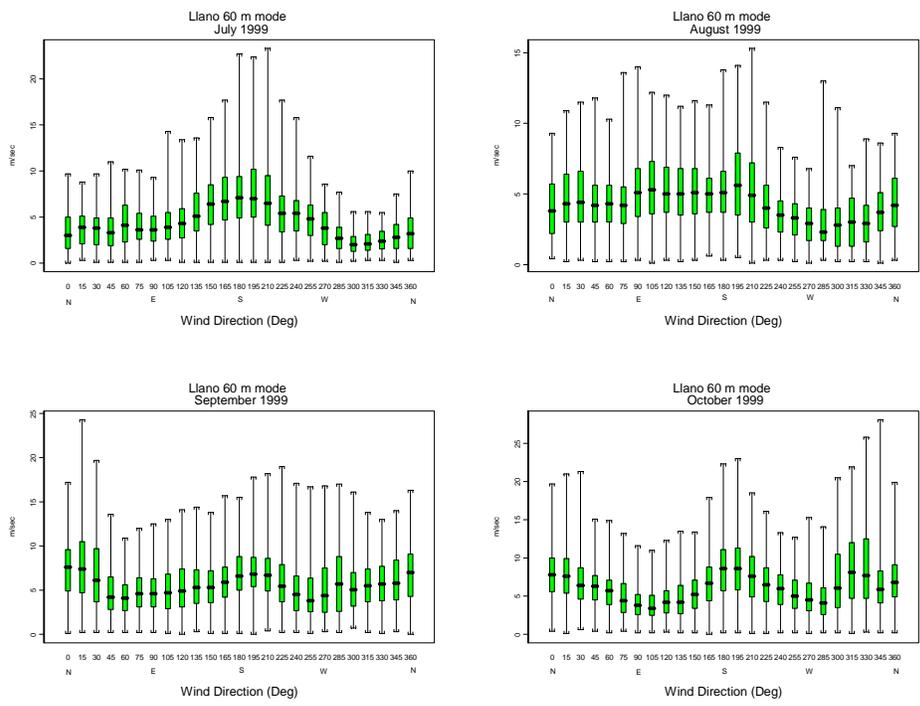


Figure 17. Wind speeds by wind direction and month at Llano.

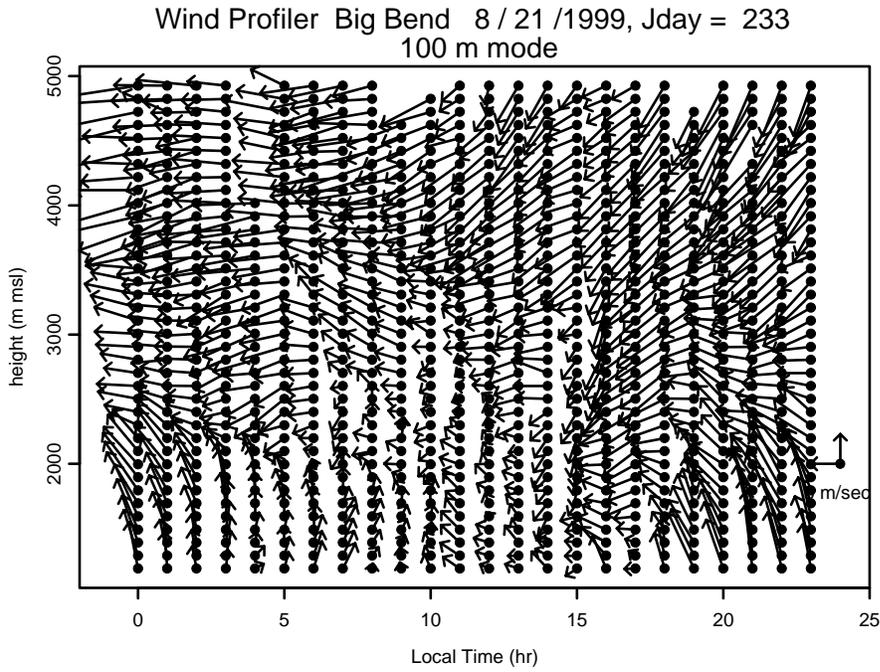


Figure 18. Wind vectors by time and height from 100 m Big Bend Wind Profiler on Aug. 21, 1999 (high sulfur day).

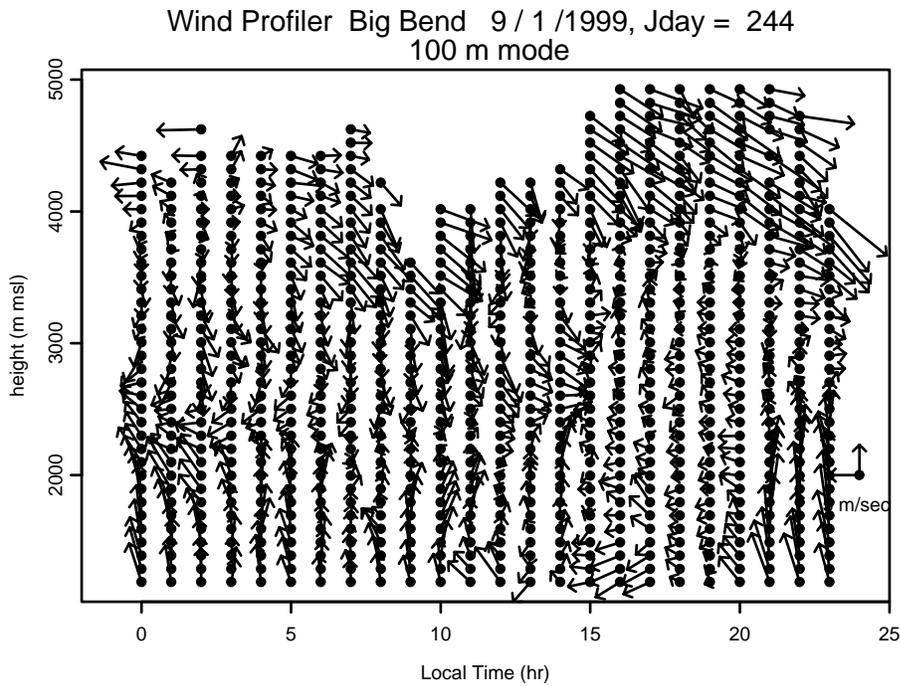


Figure 19. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 1, 1999 (high sulfur day).

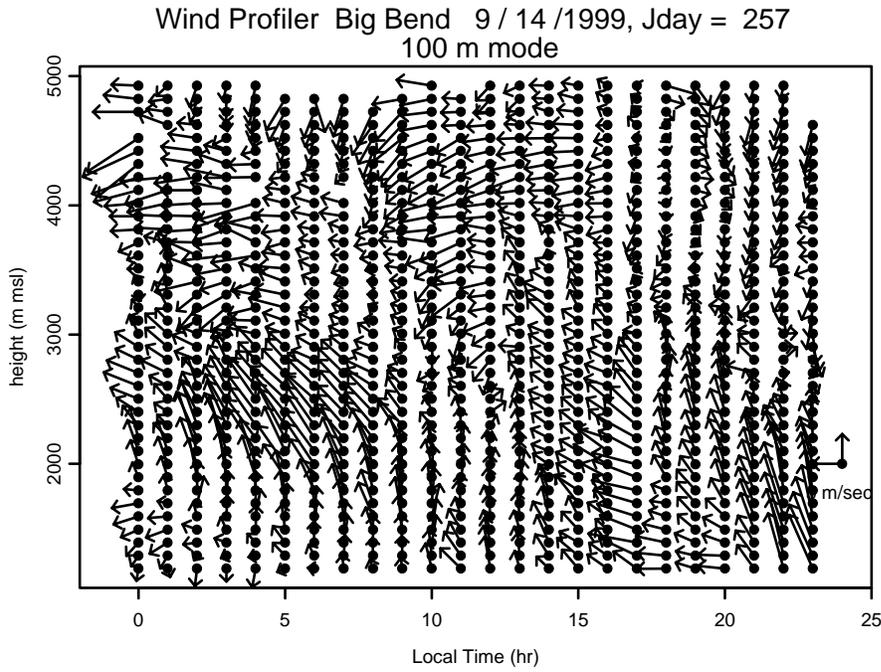


Figure 20. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 14, 1999 (high sulfur day).

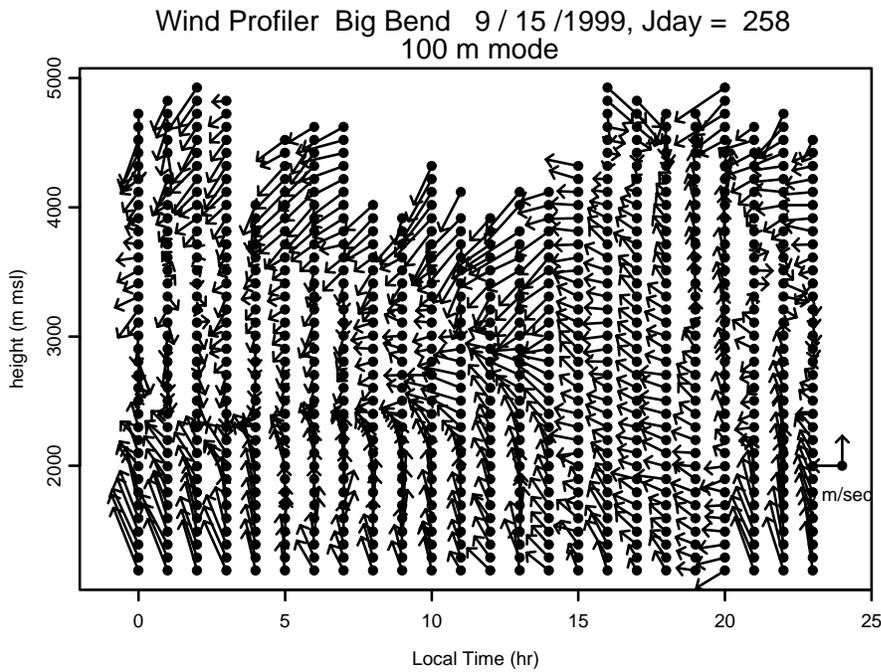


Figure 21. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 15, 1999 (high sulfur day).

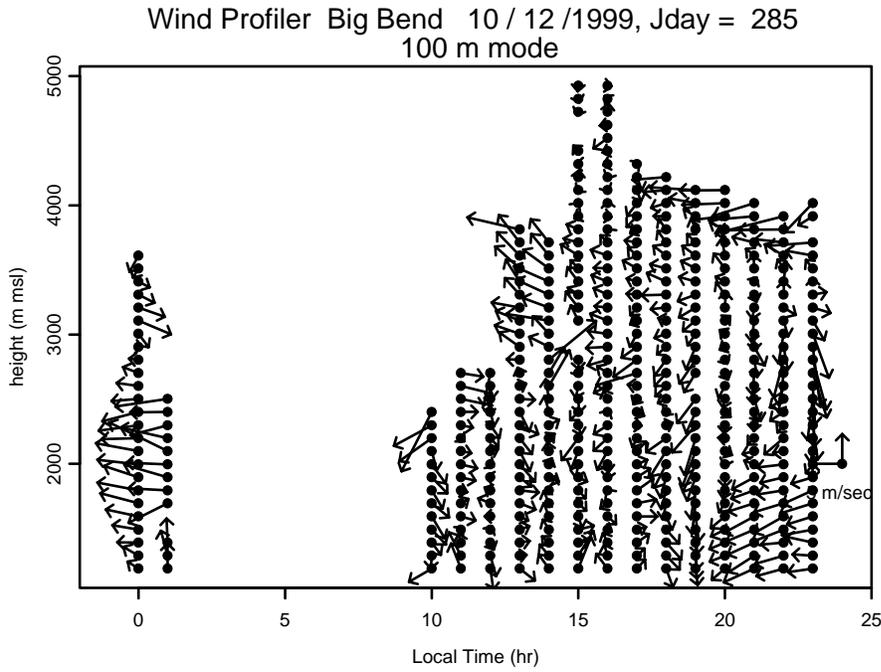


Figure 22. Wind vectors by time and height from 100 m Big Bend wind profiler on Oct. 12, 1999 (high sulfur day).

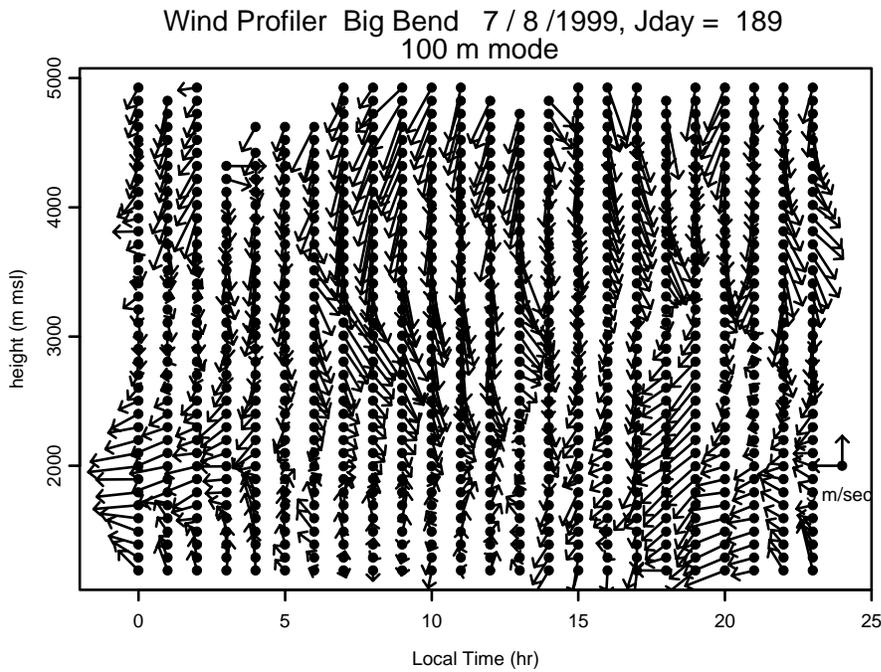


Figure 23. Wind vectors by time and height from 100 m Big Bend wind profiler on July 8, 1999 (Saharan dust day).

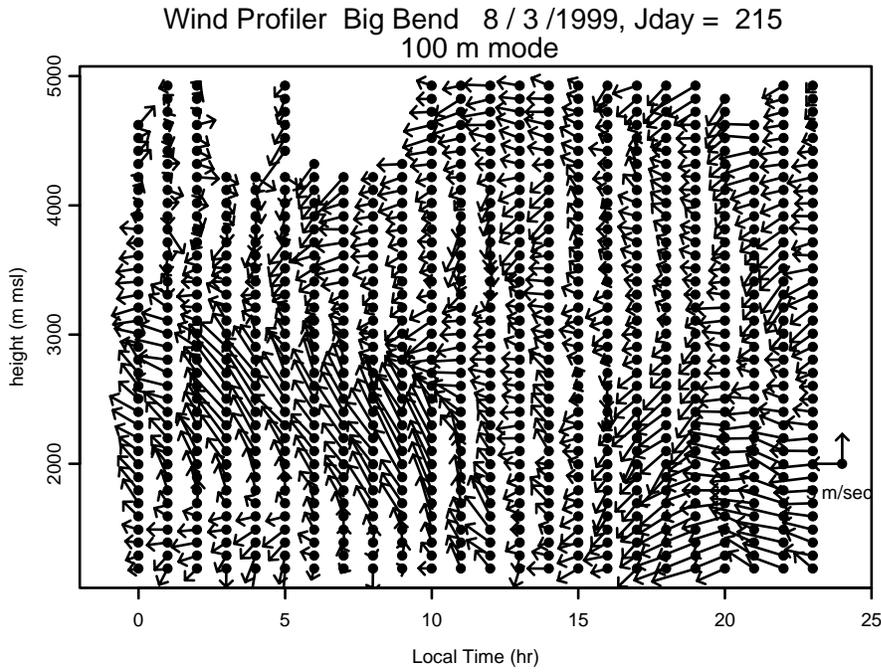


Figure 24. Wind vectors by time and height from 100 m Big Bend wind profiler on August 3, 1999 (Saharan dust day).

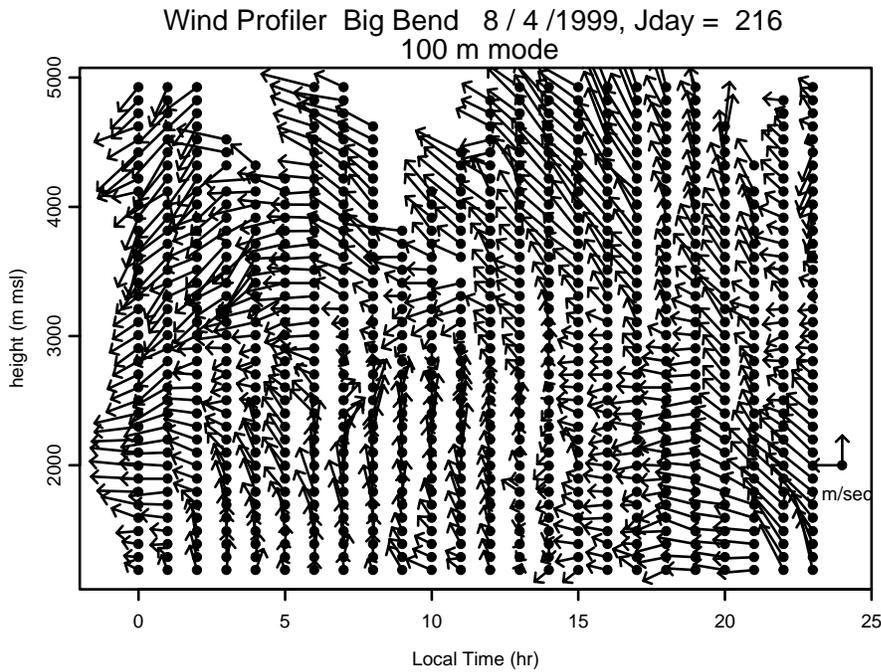
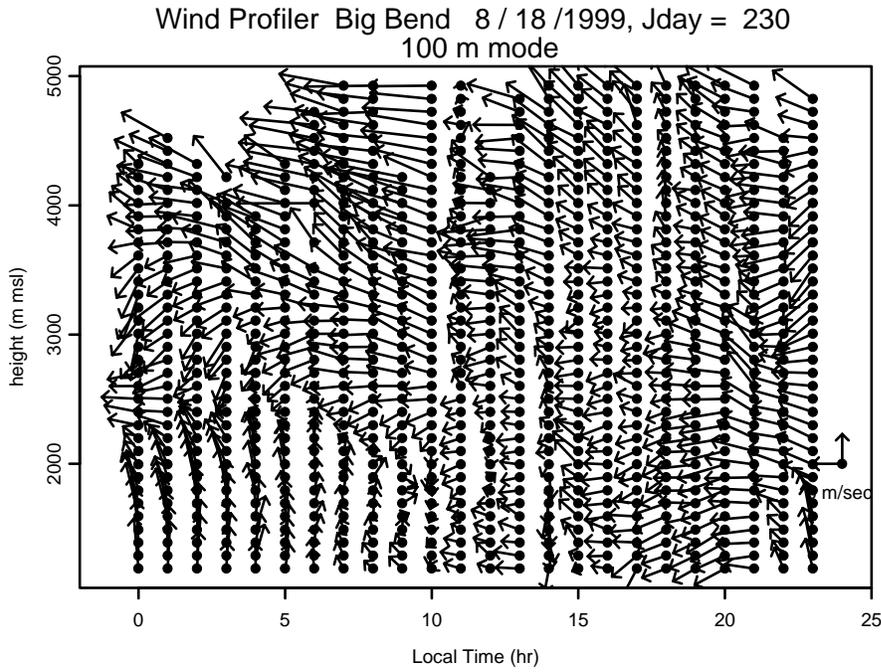
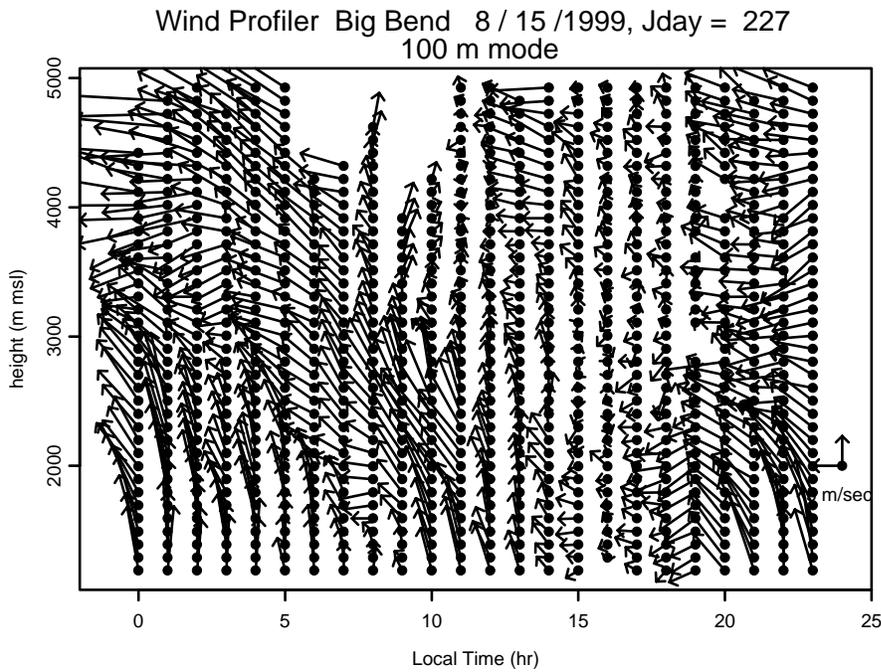


Figure 25. Wind vectors by time and height from 100 m Big Bend wind profiler on August 4, 1999 (Saharan dust day).



**Figure 26.** Wind vectors by time and height from 100 m Big Bend wind profiler on Aug. 18, 1999 (Saharan dust day).



**Figure 27.** Wind vectors by time and height from 100 m Big Bend wind profiler on August 15, 1999 (high fine soil day).

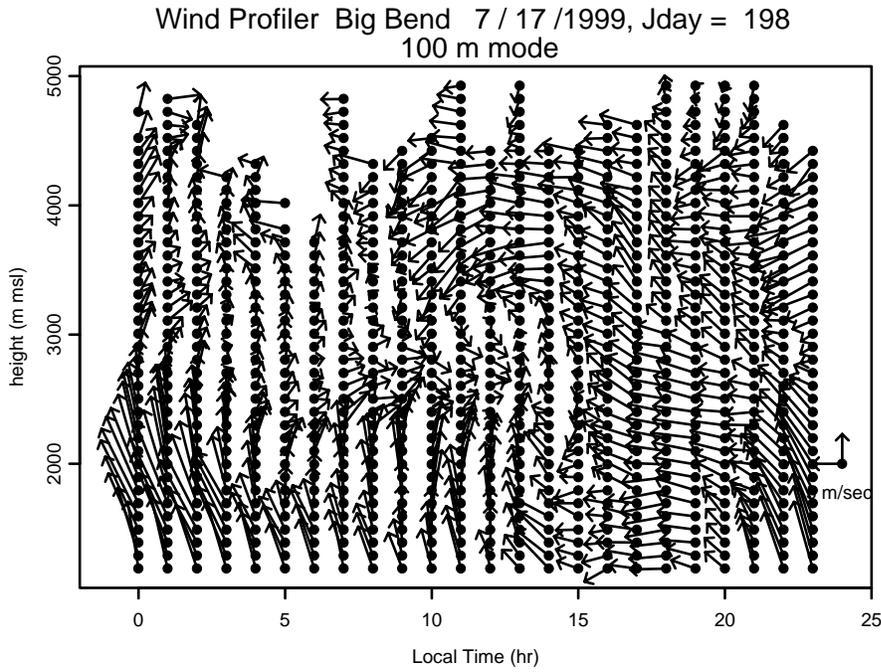


Figure 28. Wind vectors by time and height from 100 m Big Bend wind profiler on July 17, 1999 (High fine soil day).

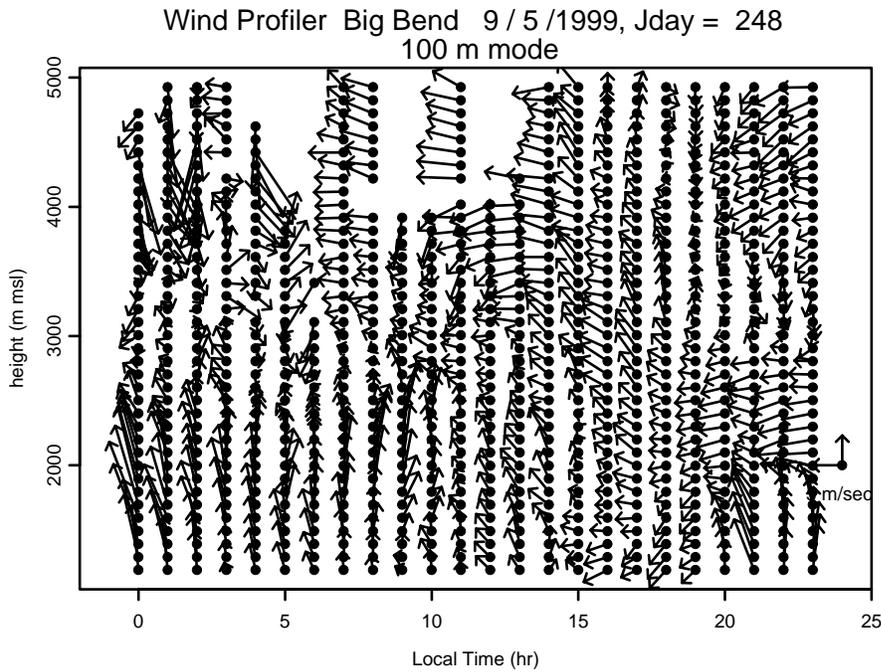


Figure 29. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 5, 1999 (clean day).

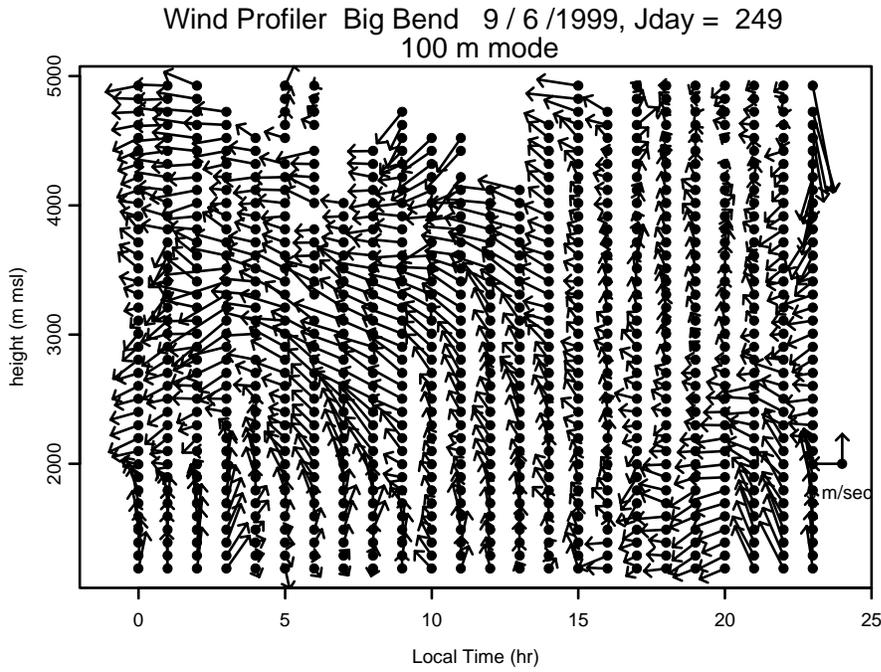


Figure 30. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 6, 1999 (clean day).

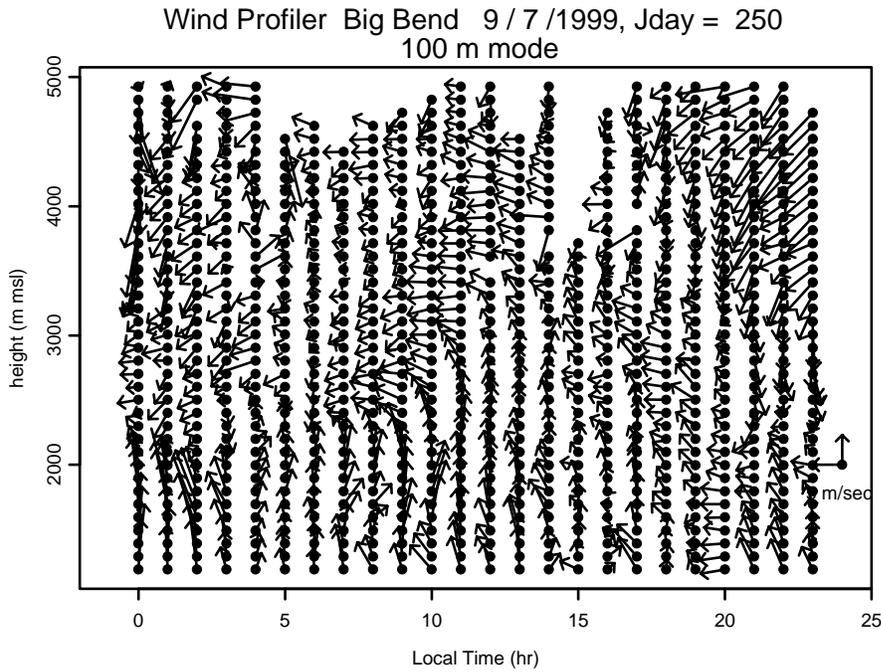


Figure 31. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 7, 1999 (clean day).

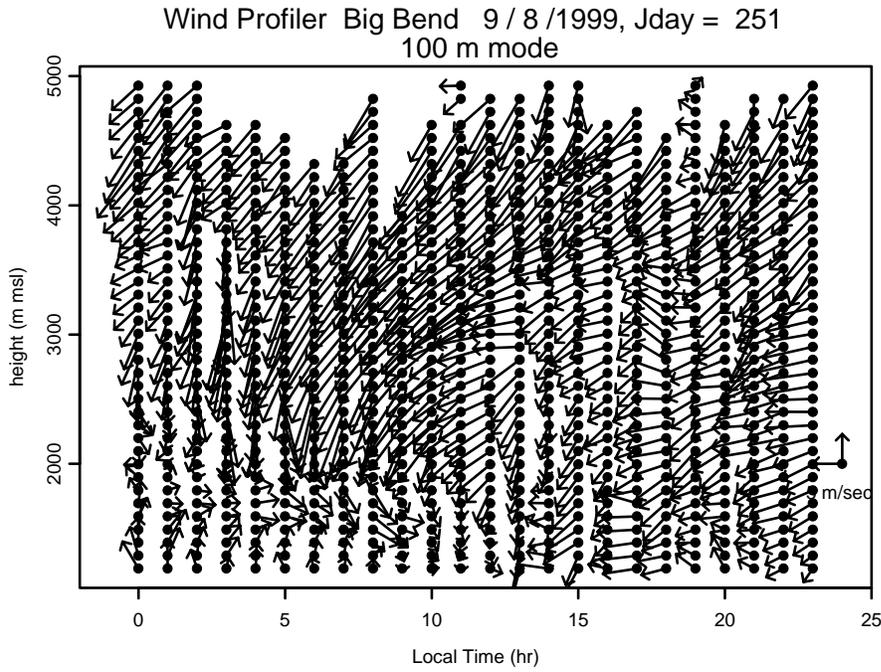


Figure 32. Wind vectors by time and height from 100 m Big Bend wind profiler on Sept. 8, 1999 (clean day).

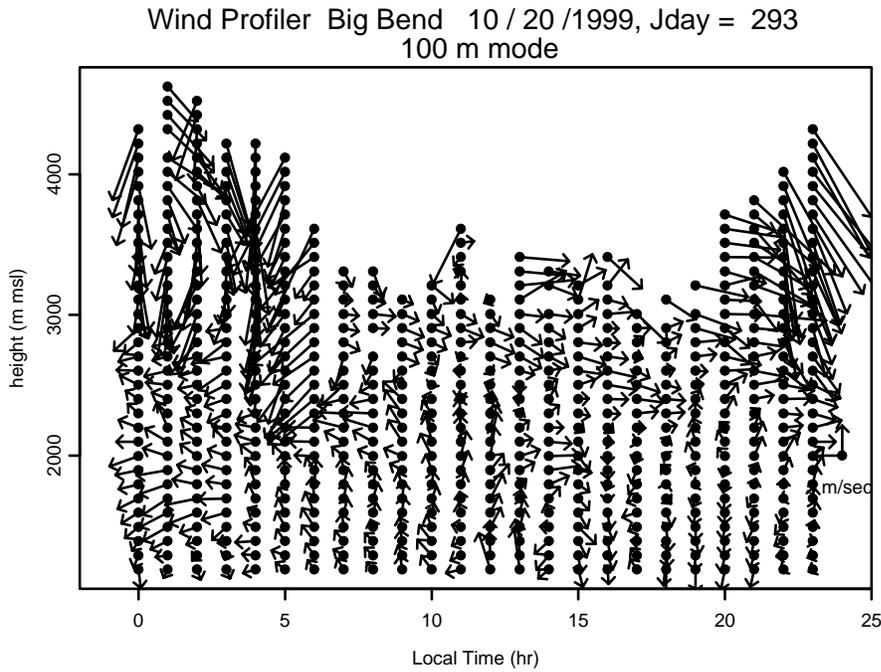


Figure 33. Wind vectors by time and height from 100 m Big Bend wind profiler on Oct. 20, 1999 (clean day).

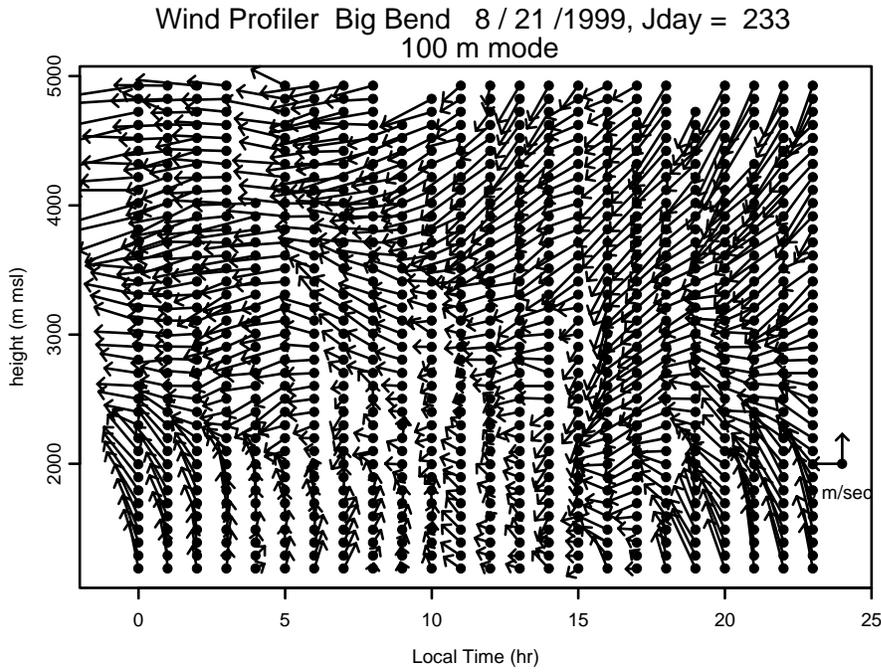


Figure 34. Wind vectors by time and height from 100 m Big Bend wind profiler on Oct. 21, 1999 (clean day).

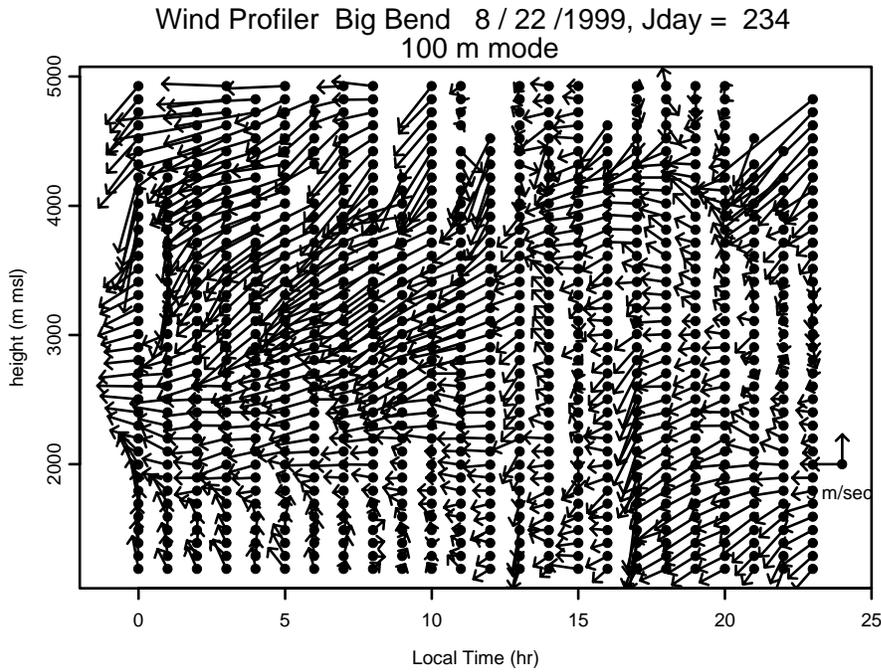


Figure 35. Wind vectors by time and height from 100 m Big Bend wind profiler on Oct. 22, 1999 (clean day).