Appendix 4a. Comparison of MM5, EDAS, and FNL Winds to Radar Wind Profiler Winds

Introduction

MM5, EDAS, and FNL wind fields were used for several source and receptor models applied for the study. REMSAD and CMAQ used MM5 fields. The receptor models used either MM5 or a combination of EDAS (July-September) and FNL (October). For some receptor models, both MM5 and the EDAS/FNL combination were used, with somewhat differing attribution results. It is of interest to evaluate the accuracy of the wind fields used to help reconcile the results.

Methodology

Wind data from the radar wind profilers were compared to wind data for the MM5, EDAS, and FNL output four times per day, at 6:00 am, noon, 6:00 pm, and midnight Central Standard Time. The radar wind profiler data is available for 60 meter thick layers up until about 2000-2500 m AGL, then every 100 m up to about 3500-4000 m AGL. The models have varying layer thicknesses, typically closer near the ground, and then telescoping upward. A simple approach was used to obtain "paired" data for the models and radar wind profilers. We selected the single radar wind profile level closest to the model layer height for comparison.

Several measures were used to compare model and radar wind profiler (RWP) winds, including:

- Average model wind and average RWP wind speed
- Magnitude of vector difference between modeled and RWP winds.
- Average difference in wind direction (degrees)
- Average absolute value of wind direction difference
- Percent of periods where model and RWP wind directions were within 20 degrees and 30 degrees
- Percent of wind directions from 8 general directions (N, NE, E, SE, S, SW, W, NW) of model and RWP by layers- 0-500 m, 500-1500 m, >1500

The typical number of model/observation comparisons by layer for each observation time is shown below:

Level/Model	MM5	EDAS	FNL
0-500 m	4	2-3	1
500-1500 m	5	4	1
1500-3800 m	5	4	1

The FNL fields have few vertical levels within the lower troposphere.

Because the EDAS fields were not available for October 1999, the summary of MM5 fields was done for the July- September and October periods separately. This facilitates the comparison of the EDAS and MM5 performance measures for the same temporal periods. The performance of the MM5 fields can be compared to that of the FNL fields for the month of October.

Results

Some summary statistics for the MM5, EDAS, and FNL comparison to the radar wind profilers for the period July-September 1999 are shown in Table 1.

Table 1. Comparison of MM5, EDAS, and FNL winds to radar wind profiler winds for July-September. Data is averaged over all vertical levels and over all observation times. The column variables are described under the first 5 items in the bulleted list shown earlier.

MM5, EDAS, and FNL evaluation for July-September								
Location	**Model**	**ModelWS**	**rwp ws**	**Diff WS**	**M- rwp wd**	**abs value**	**20 deg?**	**30 deg?**
Big Bend	MM5	5.53	5.57	4.18	-3.19	38.54	0.37	0.52
Big Bend	EDAS	5.32	5.70	4.44	-6.97	43.20	0.33	0.47
Big Bend	FNL	6.05	5.69	5.66	-6.33	52.12	0.25	0.37
Llano	MM5	6.16	5.87	3.77	-6.17	31.19	0.52	0.67
Llano	EDAS	5.86	5.96	3.40	-3.19	31.04	0.53	0.67
Llano	FNL	5.55	6.22	6.53	-4.38	43.99	0.34	0.49
Brownsville	MM5	7.16	7.04	2.92	-3.62	20.24	0.67	0.81
Brownsville	EDAS	6.84	7.11	2.77	-2.80	20.58	0.67	0.79
Brownsville	FNL	6.73	7.19	4.53	-4.58	32.20	0.45	0.60
Eagle Pass	MM5	6.75	7.63	4.00	-3.37	26.29	0.56	0.71
Eagle Pass	EDAS	6.87	7.83	3.80	0.93	24.04	0.60	0.76
Eagle Pass	FNL	6.47	7.97	5.28	4.09	34.08	0.44	0.61

For both MM5 and EDAS, the model average wind speeds were quite close to the RWP average wind speed, although there was a slight under-prediction of wind speed by both models at Eagle Pass. The FNL showed somewhat larger differences compared to the RWP. The average vector differences in model and RWP wind speeds were the least at Brownsville for all 3 models. A slight counterclockwise bias of a few degrees in wind direction was noted at all sites for both models (except EDAS and FNL at Eagle Pass). The average absolute value of wind direction differences ranged from about 20 degrees for EDAS and MM5 at Brownsville to about 40 degrees for the models at Big Bend. For the FNL, differences were larger, averaging about 30 degrees at Brownville and 50 degrees at Big Bend. It will be shown that much of the difference at Big Bend is at the lower levels, likely due to channeling of flow by local terrain features. The fraction of model wind directions within ± 20 degrees ranged from one-quarter at Big Bend for

FNL to two-thirds at Brownsville for EDAS and MM5. The fraction of model winds within ± 30 degrees ranged from about three-eighths for FNL at Big Bend to about four-fifths at Brownsville for EDAS and MM5.

The FNL performed worse than EDAS and MM5 for all criteria except average wind direction difference (bias), where it was about the same. Some of this difference may be due to the use of a single radar wind profiler level to compare with the comparatively very coarse FNL vertical layers. Perhaps averaging the RWP data within each FNL layer would give better results.

Comparing Tables 1 and 2, it can be seen that MM5 performance for October was much worse than for the July to September period, while the FNL performance was slightly poorer for October than for July-September. The magnitude of the MM5 vector wind speed errors increased from 50-100% during October compared to July-September. Bias in wind directions increased substantially to (16-23 degrees counter-clockwise). The average absolute value of the wind direction difference increased substantially and the fraction of winds within ± 20 degrees and ± 30 degrees decreased substantially.

Even though the FNL performance degraded during October, the FNL performed about as well as MM5 for October. Wind speed differences were somewhat higher for FNL than MM5, but wind direction bias was less for FNL compared to MM5. Fraction of wind directions within 20 and 30 degrees was very similar for the models, with a slight edge to MM5.

Table 2. MM5 and FNL performance for July-September compared to October.

MM5 and FNL evaluation for October								
		ModelWS	**rwp WS**	**Diff WS**	**M- rwp wd**	**abs value**	**20 deg?**	**30 deg?**
Big Bend	MM5	5.20	6.15	6.18	-21.30	58.92	0.22	0.31
Big Bend	FNL	6.12	6.67	7.05	-12.00	64.31	0.22	0.32
Llano	MM5	6.07	7.00	6.14	-16.31	49.60	0.33	0.45
Llano	FNL	6.46	7.73	6.22	2.22	50.40	0.36	0.46
Brownsville	MM5	6.77	6.47	5.76	-16.51	44.58	0.35	0.47
Brownsville	FNL	6.59	6.68	6.16	6.99	50.53	0.31	0.43
Eagle Pass	MM5	6.12	7.60	6.45	-22.86	46.34	0.34	0.46
Eagle Pass	FNL	6.86	8.28	7.01	4.55	52.01	0.33	0.42

Comparison of model and RWP wind roses

In this section we compare the percent of wind directions from 8 general directions (N, NE, E, SE, S, SW, W, NW) of model and RWP by layers- 0-500 m, 500-1500 m, and >1500 m. The comparisons are done for the period July-September 1999 because we have MM5 and EDAS winds for these periods (no EDAS for October).

Llano

The comparison of frequency of MM5 and EDAS winds to radar wind profiler winds at Llano are compared in Figure 1. In the lowest 500 m, the wind direction frequency compared well to the radar wind profiler for both models. For the layer 500 m to 1500 m, the EDAS frequency was quite similar to the RWP frequency, while the MM5 showed more E and SE winds and fewer S and SW winds than did the RWP. For the 1500- 4000 m layer, both models showed substantial differences from the RWP, in particular with more easterly winds and fewer northerly winds.

Big Bend National Park

The comparison of frequency of MM5 and EDAS winds to radar wind profiler winds at Big Bend National Park are compared in Figure 2. The RWP winds at the lowest level are mainly from the south, while the models show winds predominantly from the SE and E. The low level winds at Big Bend are most likely due to channeling by local terrain; the model winds would not be expected to resolve this channeling. At the 500 m – 1500 m level, there is better agreement between the models and the RWP as the RWP winds shift more toward the southeast and east. The best agreement is for the layer above 1500 m, although both models are a bit low on northerly winds (especially MM5) and high for easterly and southeasterly winds.

Eagle Pass

Figure 3 compares Eagle Pass MM5 and EDAS winds to RWP winds for July-September. The models and RWP show that southeasterly winds dominate, particularly at the lowest level where 60% of observations show southeasterly winds. EDAS somewhat over-predicts the frequency of SE wind at 0-500 m, while MM5 has somewhat greater frequency of easterly winds at the expense of southerly winds observed. At 500-1500 m, the frequency distributions of both models match well with observations.

Brownsville

Brownsville model and observed wind are shown in Figure 4. The MM5 distribution very closely matches the observed distribution at the 0-500 and 500-1500 m levels. EDAS matches observations well over the 500-1500 m layer, but underestimates SE and NE winds and overestimates southerly winds in the 0-500 m layer. Both models show some discrepancy from observations above 1500 m.

Vertically Averaged MM5 and EDAS comparisons

Figure 5 shows the average MM5, EDAS, and RWP wind direction frequency distributions averaged over all vertical levels at Llano, Big Bend, Eagle Pass and Brownsville.

October comparisons for MM5

Because the October statistics showed poorer performance for MM5 compared to the July-September period, it is worth looking at October in some detail. Figure 6 compares MM5 wind direction frequency distribution to RWP distribution for October. Averaged over all levels, the MM5 frequency distribution is close to the observations. For each layer, particularly the 0-500 m layer, differences are more pronounced. Comparison of the 0-500 m level performance for July – September (Figure 4) to that for October illustrate why the performance statistics were so much worse for October at Brownsville.

Figure 7 compares MM5 to RWP wind direction frequencies for the 500 - 1500 m levels at Eagle Pass for July to September and October. Much better agreement can be noted for the July-September period than for the October period.

Summary

MM5 and EDAS performance was similar for the July to September period for which both models were available. MM5 performed similar to or slightly better than FNL for October, with the exception of a pronounced counter-clockwise bias for MM5 winds in October. The MM5 performance was much worse for October than for the July-September period.

A clear preference for the MM5 or EDAS/FNL combination of wind fields has not been established by this analysis.

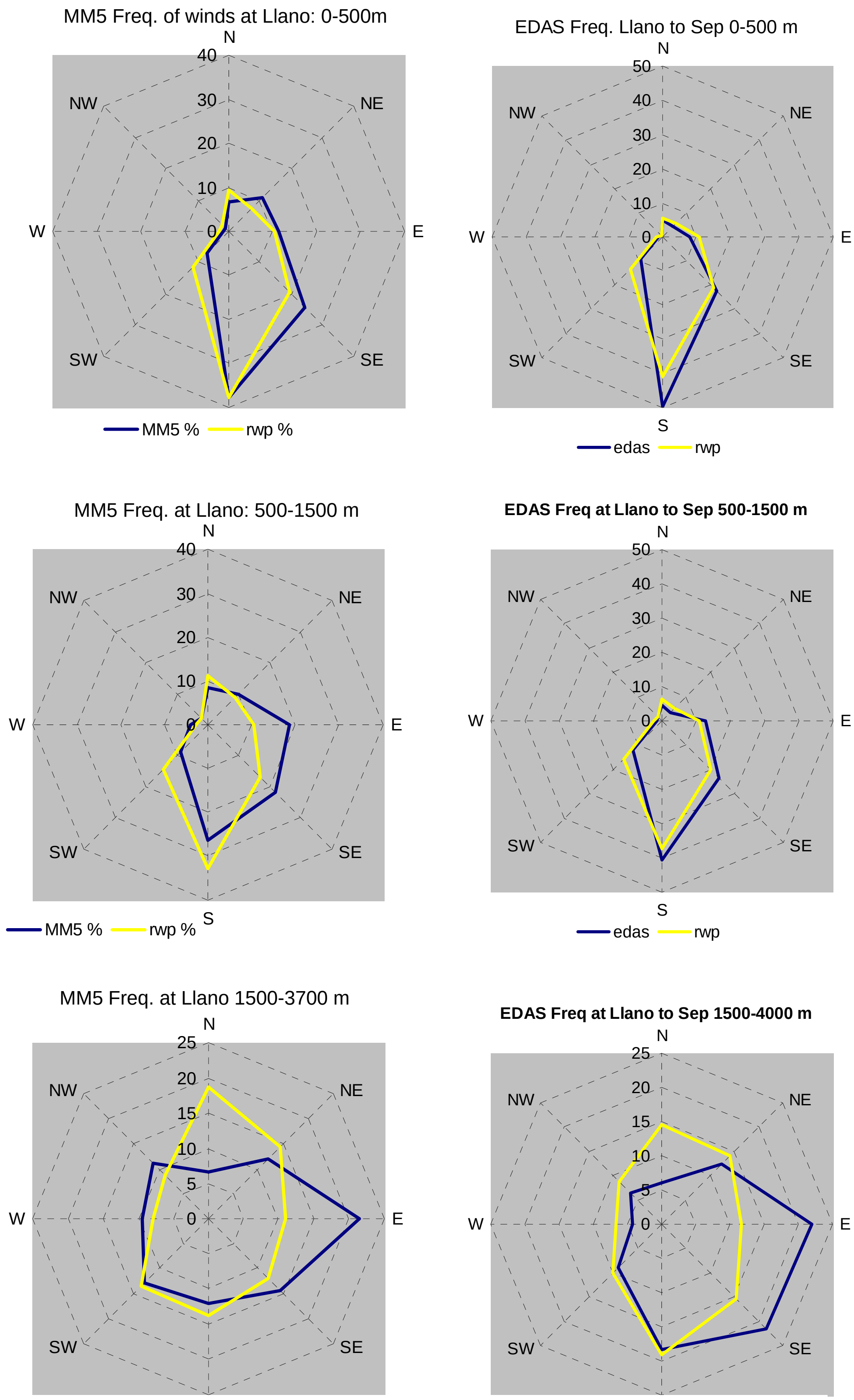

Figure 1. Comparison of MM5 and EDAS wind direction frequency to radar wind profiler winds by level at Llano.

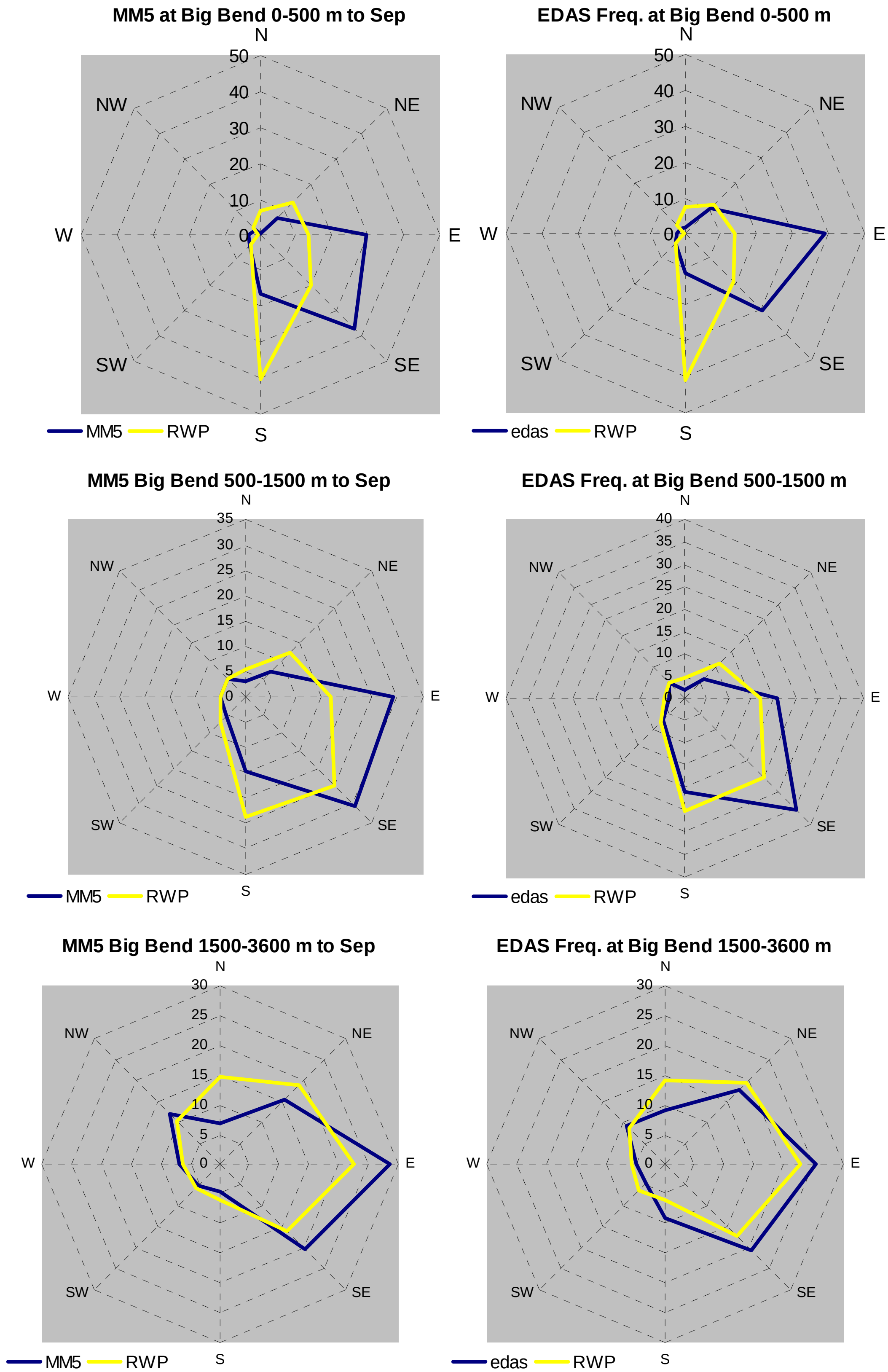

Figure 2. Comparison of MM5 and EDAS wind direction frequency to radar wind profiler winds by level at Big Bend.

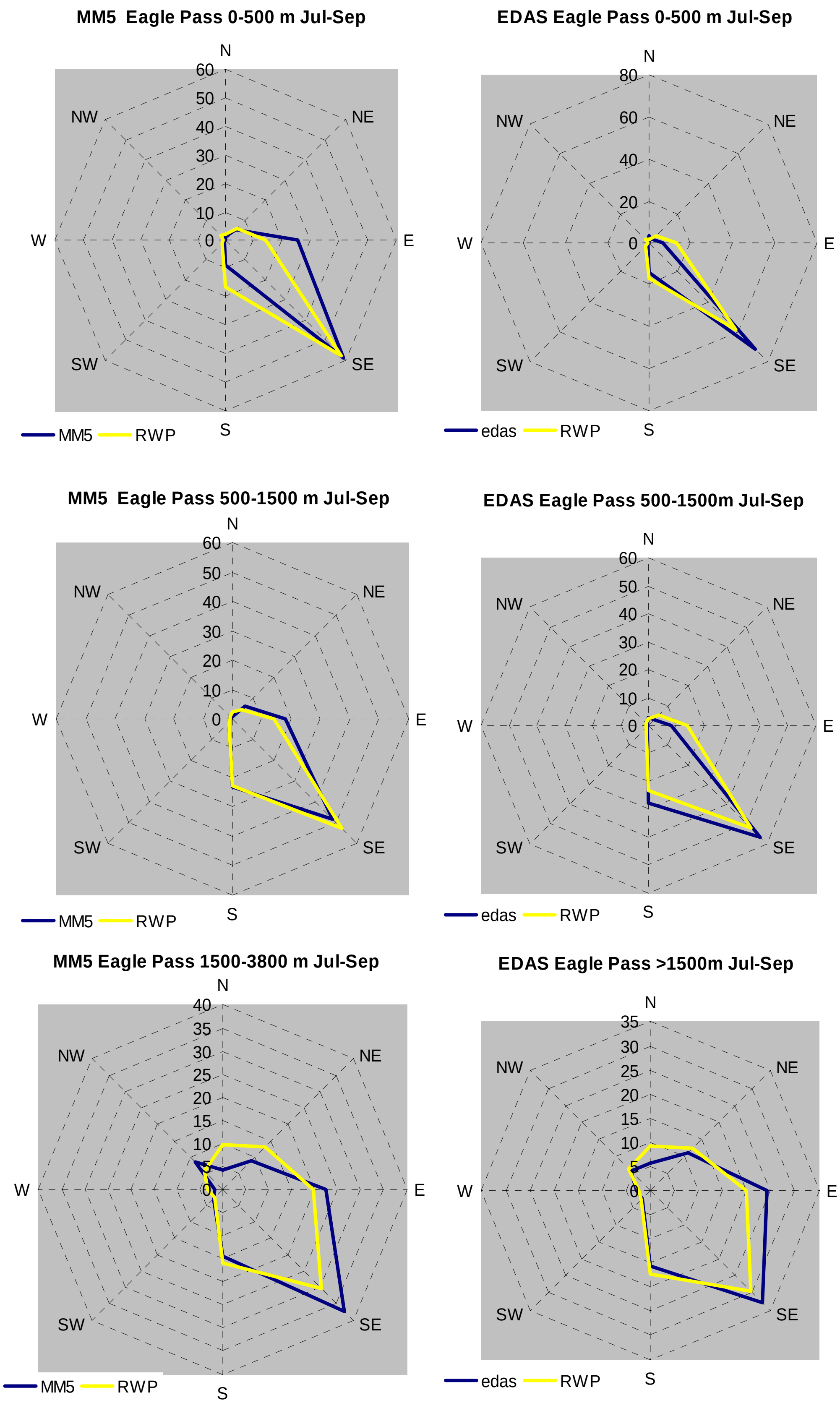

Figure 3. Comparison of MM5 and EDAS wind direction frequency to radar wind profiler winds by level at Eagle Pass.

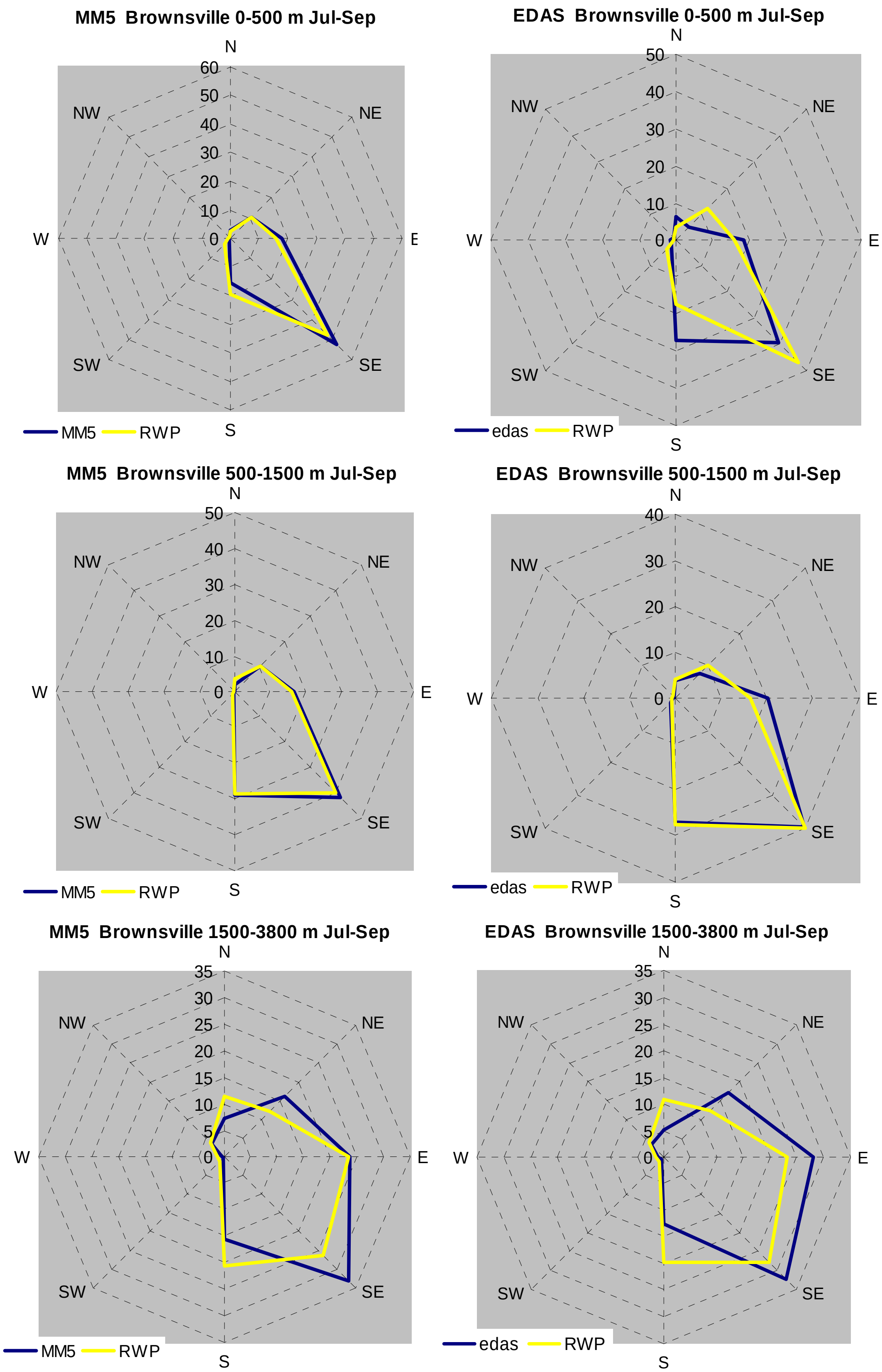

Figure 4. Comparison of MM5 and EDAS wind direction frequency to radar wind profiler winds by level at Brownsville.

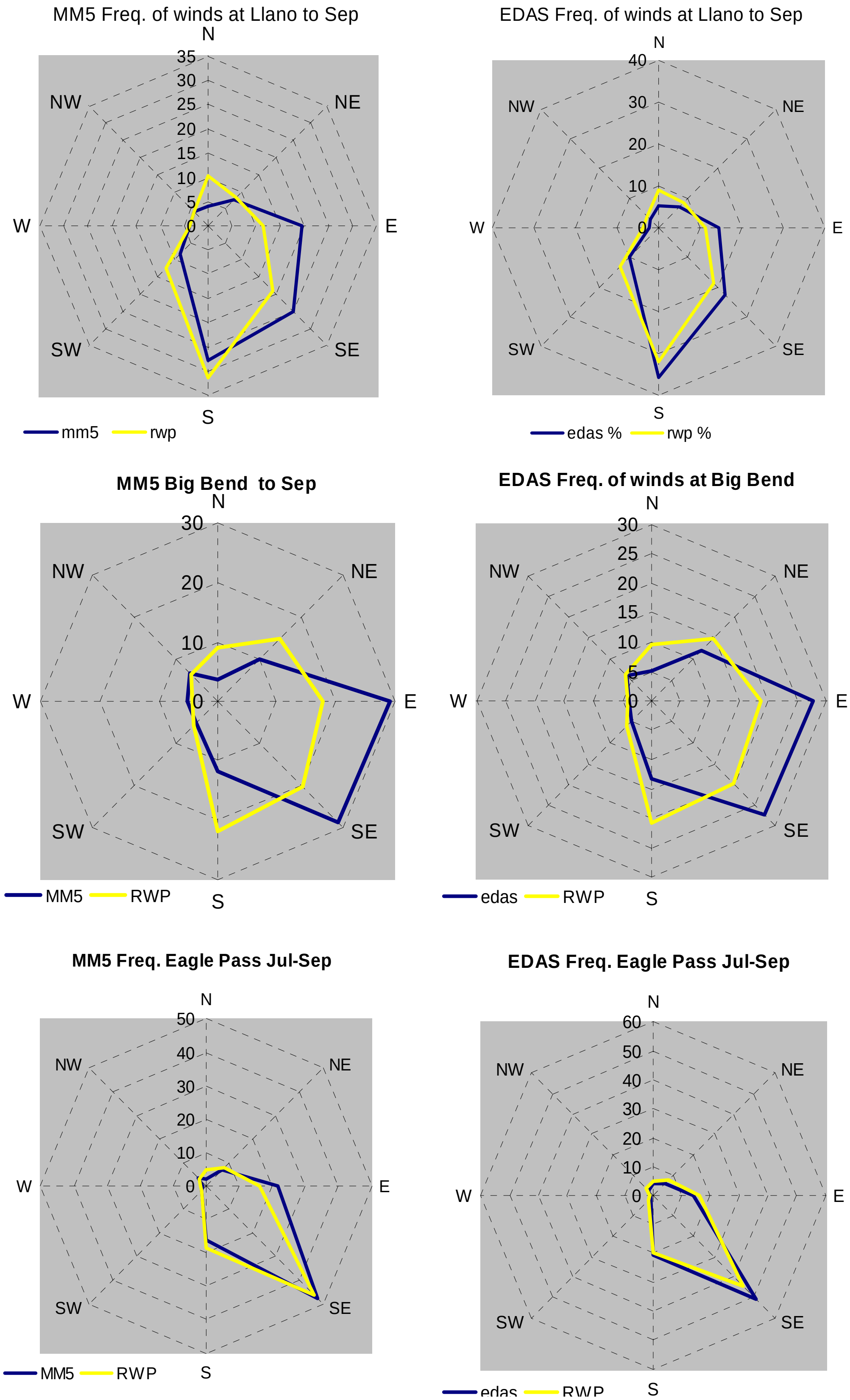

Figure 5. MM5 and EDAS comparisons to RWP, averaged over all vertical levels at Llano, Big Bend and Eagle Pass.

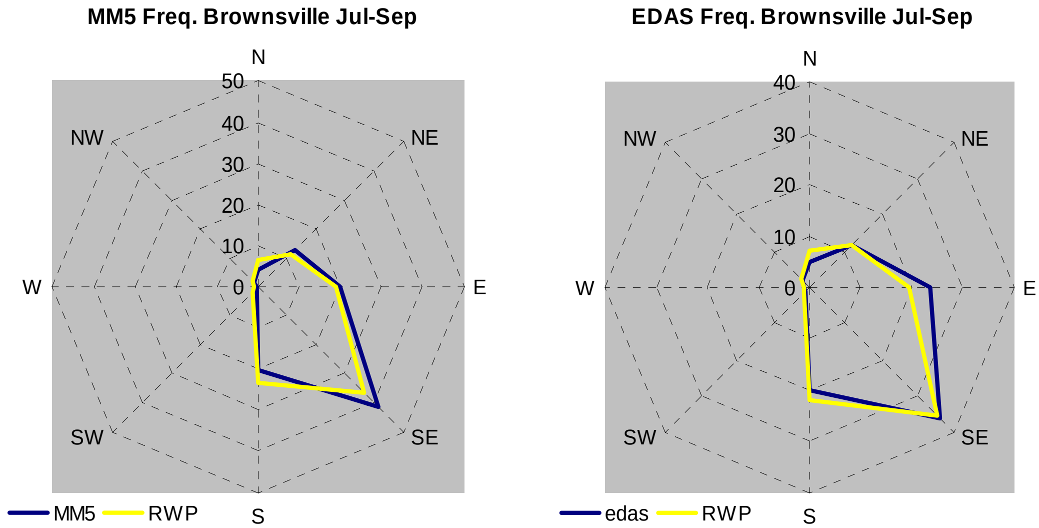

Figure 5 (continued). MM5 and EDAS comparisons to RWP, averaged over all vertical levels at Brownsville.

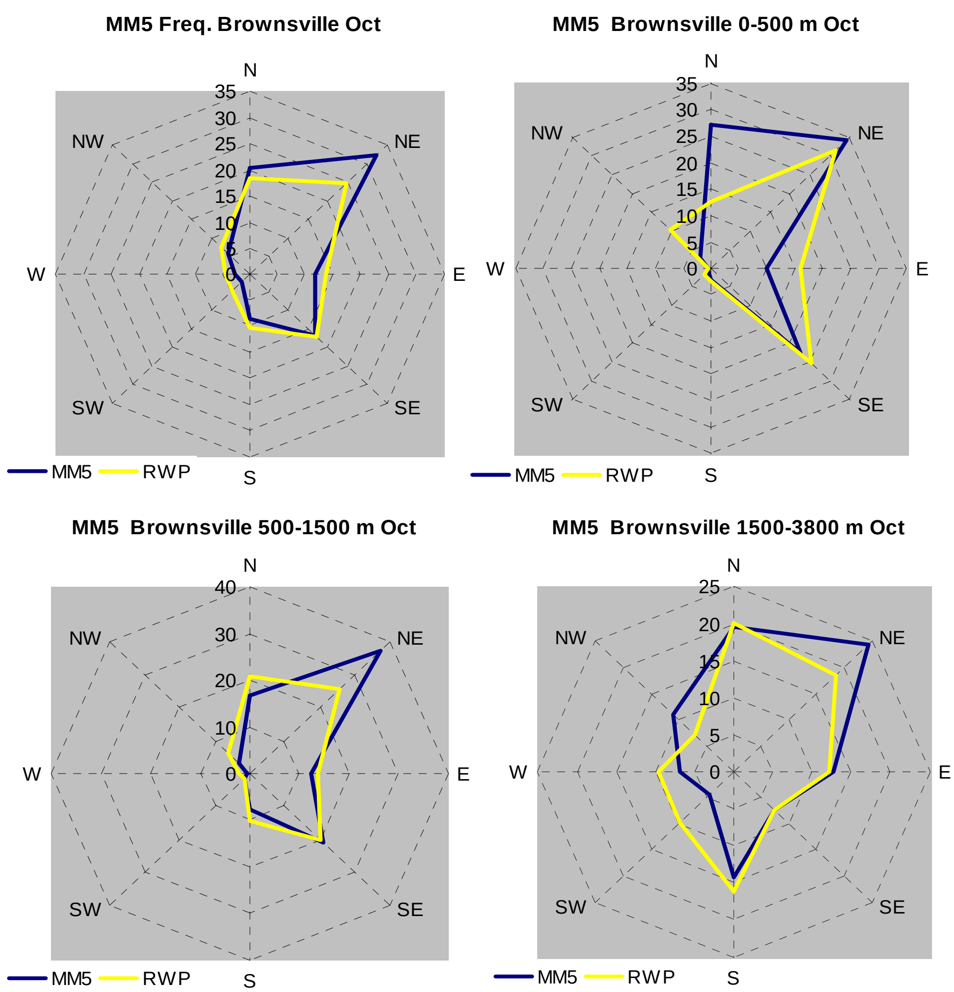

Figure 6. Comparison of MM5 to RWP at Brownsville, October 1999. First panel is average over all levels.

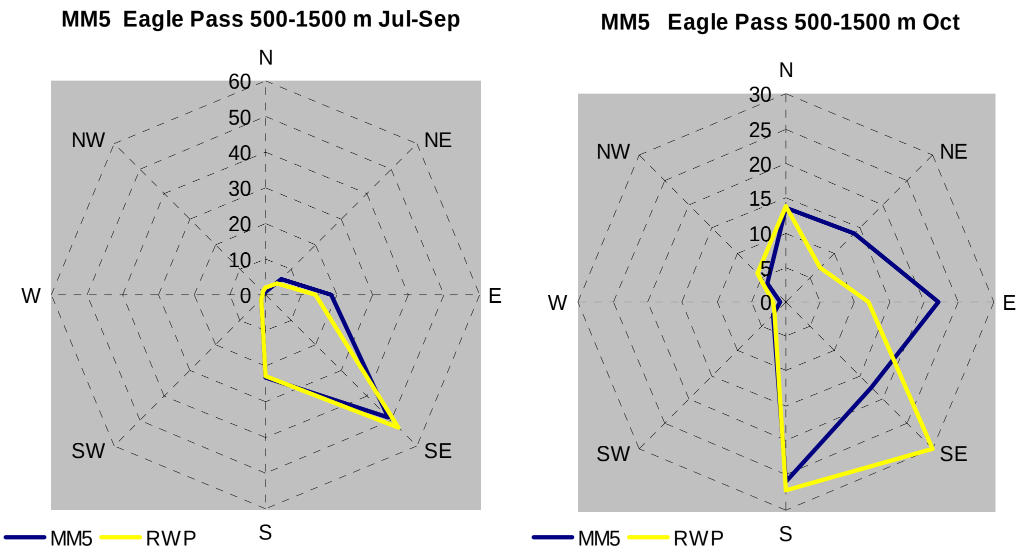

Figure 7. Comparison of MM5 and RWP frequency distributions for the 500–1500 m levels at Eagle Pass during July–September and October.