Interrelationships among wind direction, atmospheric moisture content and stability with the spatial distribution of rainfall and the occurrence of severe weather in Pinellas County, FL

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1. Introduction

To improve the prediction of local mesoscale phenomena, the interrelationships among wind direction, atmospheric moisture content and stability with the spatial distribution of rainfall and the occurrence of severe weather in Pinellas County (Fig. 1) in west central Florida was examined. This peninsular county has some unique topographic features and sea breeze patterns that create warm season forecast challenges.

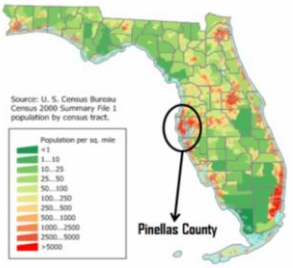

Figure 1. Study area location

2. Methodology

The 1200 UTC radiosonde soundings taken at Ruskin, Florida during June-August, 1995-2009 were used to first identify the predominant wind directions over the county. The dominant wind direction was determined by averaging wind direction from the surface up to 700 hPa. Days with nearby tropical cyclones were not used. The sounding data were then used to further classify days by moisture content using total precipitable water (PW) and thermodynamic stability using Convective Available Potential Energy (CAPE). Composite precipitation maps were then produced. The most significant severe weather cases were examined in Gr2Analyst to determine the influence of sea breeze and outflow boundary interactions, and also the development and vertical extent of the convection, leading to rainfall and severe weather over the county.

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3. Rainfall

The precipitation data used in ArcGIS, obtained from the NWS Southeast River Forecast Center, is derived using a multisensor approach including hourly precipitation estimates from WSR-88D radar that are compared to ground rainfall gauge reports. A bias (correction factor) is calculated and applied to the radar field then combined with gauge fields into a quality controlled multisensor field.

Daily rainfall amounts were also collected from station gauges around Pinellas County to compare to the data gathered from the NWS Southeast River Forecast Center. Figure 2 shows that the daily gauge only rainfall totals by wind direction were higher with a southerly component. The totals were highest around 110 degrees and 240 degrees and no precipitation occurred on days with dominant northwest flow.

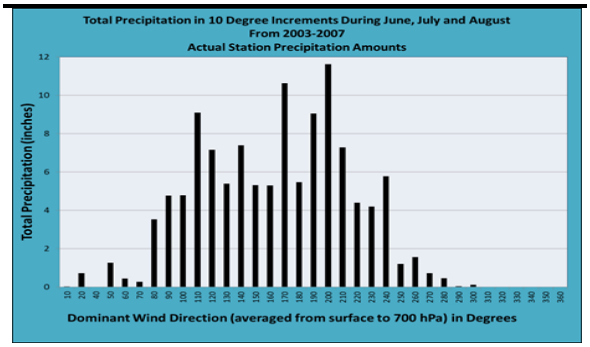

Figure 2. Daily gauge only rainfall amounts totalled by wind direction.

The daily multisensor rainfall amounts were totalled and composited according to the dominant wind direction in 60 degree groups representing northeast through northwest directions. These rainfall composites by wind show where the prevalent rainfall occurs in relation to the dominant wind flow. The multisensor composites (Figs. 3a-f) show the sensitivity of the rainfall distribution to wind direction. For the northeast sector (a. 1-60°),

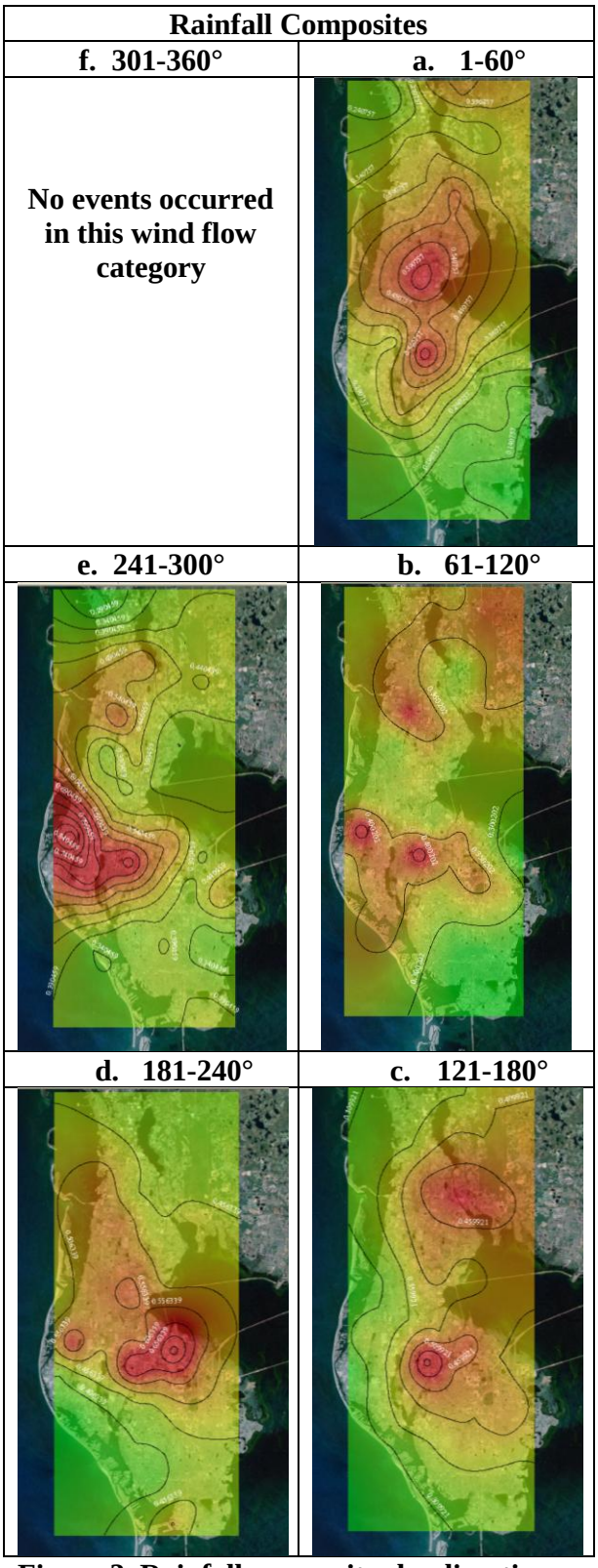

Figure 3. Rainfall composites by direction.

the rainfall was primarily over the central part of the county with two maxima. In the east sector (b. 61-120°), the most significant rainfall maximum was over the central area with a secondary maximum over the north. In the southeast sector (c. 121-180°), the most significant rainfall maximum was central with a secondary maximum over the north. In the southwest sector (d. 181-240°), the maximum was over the central peninsula with a much weaker secondary maximum over the south. In the west sector (e. 241-300°), the rainfall was predominantly over the west central part of the peninsula. These multisensory composites sorted by wind direction in ArcGIS show that precipitation is greatest when there is a westerly component. The most amount of rain occured in the 241-300° category in ArcGIS composites, but ANOVA tests reveal that both the sum and the average amount of precipitation that occurs in the 181-240 ° category is the greatest. Therefore, it was determined that the most rain occurs with a westerly wind flow.

The box and whisker plot of the precipitation averages by wind direction (Fig. 3) shows the median and range of precipitation for each wind direction category.

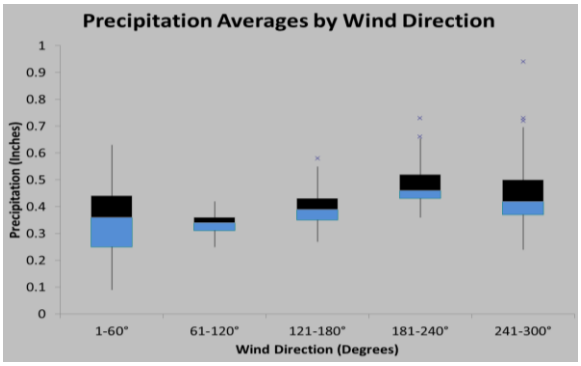

Figure 4. Box and whisker plot of precipitation averages by wind direction.

The minimum amount of precipitation for each of the categories steadily increases, with the exception of the lower threshold of the 241-300° category. This means that with a more westerly component, higher precipitation amounts should be expected. The 0-60°

category has the highest range of precipitation of 0.54 inches, disregarding outliers. The range drops dramatically in the 61-120° category to 0.17 inches, but steadily rises again through the 240-300° category to 0.46 inches. The first outlier appears in the 121-180° category, and steadily increase to three total outliers in the 241-300° category, meaning there is more of a chance of a higher out-of-the-norm precipitation event with a more westerly wind flow. The median amount of rainfall is the highest at 181-240° at 0.52", decreases a small amount in the 241-300° category (0.5"), 0-60° category (0.44"), and 61-120° category (0.36"), but increases again in the 121-180° category (0.43"). This is generally consistent with a westerly component bringing more precipitation.

4. Severe Weather

Severe weather events were obtained from NWS Storm Data (2010). The events examined were hail, wind, tornadoes, and flooding. Days with no data were not included in the total and duplicate reports on the same day were not counted more than once. The shading represents the top three categories: red, orange, and yellow. Most of the severe weather occurred with an easterly component, from 61-180°.

a. Hail

Only hail 1 inch (25 mm) and greater was included in the compilation. The east and southeast wind regimes are those that produced severe hail over Pinellas County. The average dominant wind was 110° at 1.9 ms^{-1}.

Direction (Degrees)	Number of days	Percent of reports
1-60	0	0.00
61-120	7	58.33
121-180	5	41.67
181-240	0	0.00
241-300	0	0.00
301-360	0	0.00

Table 1a. Wind direction, number of days and percent of reports for hail.

	Direction	Speed	CAPE	PW	SWEAT
AVG	110	1.9	1216	45	155.471
MAX	153	3.2	1903	54	191.19
MIN	61	0.97	100	39	98.4

Table 1b. Average, max, and min wind direction speed (ms^{-1}), CAPE (Jkg^{-1}) precipitable water (mm), and SWEAT index for days with hail reports.

b. Tornado

The east, southeast, and west wind regimes are those that are more likely to produce tornadoes over Pinellas County. The average dominant wind was 169° at 2.4 ms^{-1}.

Direction (Degrees)	Number of days	Percent of reports
1-60	0	0.00
61-120	4	30.77
121-180	5	38.46
181-240	1	7.69
241-300	3	23.08
301-360	0	0.00

Table 2a. Wind direction, number of days and percent of reports for tornadoes.

	Direction	Speed	CAPE	PW	SWEAT
AVE	169	2.4	1191	51	187
MAX	287	3.6	2786	62	253
MIN	88	1.2	36	40	134

Table 2b. Average, max, and min wind direction speed (ms^{-1}), CAPE (Jkg^{-1}) precipitable water (mm), and SWEAT index for days with tornado reports.

c. Thunderstorm Wind

The east through southwest wind regimes are those that are more likely to produce severe thunderstorm winds over Pinellas County. The average dominant wind was 149° at 2.0 ms^{-1}.

Direction (Degrees)	Number of Days	Percent of reports
1-60	*0*	0.00
61-120	*7*	41.18
121-180	*6*	35.29
181-240	*3*	17.65
241-300	*0*	0.00
301-360	*1*	5.88

Table 3a. Wind direction, number of days and percent of reports for severe thunderstorm wind.

	Direction	Speed	CAPE	PW	SWEAT
AVE	149	2.0	1298	46	183
MAX	319	5.4	4941	57	293
MIN	88	0.77	38	36	128

Table 3b. Average, max, and min wind direction speed (ms^{-1}), CAPE (Jkg^{-1}) precipitable water (mm), and SWEAT index for days with severe thunderstorm wind reports.

d. Flood

The flood events were associated with northeast to southwest winds more associated with a southerly component. No events were associated with northerly winds. The average dominant wind was 164° at 2.78 ms^{-1}.

Direction (Degrees)	Number of days	Percent of reports
1-60	0	0.00
61-120	4	20.00
121-180	9	45.00
181-240	6	30.00
241-300	2	10.00
301-360	0	0.00

Table 4a. Wind direction, number of days and percent of reports for flooding.

	Direction	Speed	CAPE	PW	SWEAT
AVE	164	2.8	1437	51	198
MAX	258	6.2	3571	64	367
MIN	95	0.72	3	37	54

Table 4b. Average, max, and min wind direction speed (ms^{-1}), CAPE (Jkg^{-1}) precipitable water (mm), and SWEAT index for days with flood reports.

5. Conclusion

The primary influence of rainfall distribution was wind direction, with more rain falling over the peninsula on days with southerly wind component (90° through 270°). Moisture and stability had secondary effects on the location and amount of precipitation in the county. When looking at the spatial patterns of precipitation, more precipitation occurs in the center of the peninsula than near the coasts, with exception of days with wind in the 181-300° category. There were nearly twice as many days with an easterly flow (averaged from the surface to 700 hPa) than with a westerly flow from 2003-2007 during the months of June, July and August.

The identification of such high impact events (tornadoes, downbursts, hail, and waterspouts) are of particular interest for providing awareness to forecasters of the possibility of severe weather. The likelihood of severe weather was also related to wind direction, with more events occurring during easterly flow than westerly. Most severe weather occurred in the 61-180° category. It should be noted that no severe weather reports occurred on days with a 0-60° wind flow category.

This study provides a solid foundation for precipitation, wind flow and severe weather occurrences for Pinellas County, Florida. By examining precipitation and severe weather patterns associated with coastal wind regimes, this study has a wide application for operational meteorologists in coastal areas throughout the world.

6. Acknowledgements

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7. References (Available by request)