10R.3 The Tornado Outbreak across the North Florida Panhandle in association with Hurricane Ivan

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1. INTRODUCTION

Hurricane Ivan made landfall early on the morning of 16 September 2004, just west of Gulf Shores, Alabama as a category 3 hurricane on the Saffir-Simpson Hurricane Scale. Approximately 117 tornadoes were reported associated with Ivan across the southeast United States. Eight people were killed and 17 were injured by tornadoes (Storm Data 2004; Stewart 2004). The most significant tornadoes occurred as hurricane Ivan approached the Florida Gulf coast on the afternoon and evening of 15 September.

The intense outer rain bands of Ivan produced numerous supercells over portions of the Florida Panhandle, Big Bend, southwest Georgia, and Gulf coastal waters. In turn, these supercells spawned dozens of tornadoes. An elderly man was killed by an F1 tornado, which touched down on Panama City beach and moved across a heavily populated area of Panama City. The tornado was caught on the WJHG-TV tower camera. A short time later, a second F1 tornado touched down in southeast Bay County killing one person when a wood frame house was destroyed. Later that evening, F0, F1 and F2 tornadoes touched down in Franklin, Liberty, Calhoun, and Jackson Counties; all spawned from the same parent supercell. Four people were killed when their mobile homes were destroyed near Blountstown, Florida.

Overall, there were 24 tornadoes reported across the National Weather Service (NWS) Tallahassee forecast area. The office issued 130 tornado warnings from the afternoon of 15 September until just after daybreak on 16 September.

The paper examines the convective cells within the rain bands of hurricane Ivan, which produced these tornadoes across the Florida Panhandle, Big Bend, and southwest Georgia. The structure of the tornadic and non-tornadic supercells is examined for clues on how to better warn for these types of storms. This study will focus on the short-term predictability of these dangerous storms, and will investigate the problem of how to reduce the false alarm rate (FAR), while still maintaining a high probability of detection (POD).

2. OVERVIEW OF THE IVAN TORNADO OUTBREAK

It is widely known that the front-right quadrant of hurricanes can be prolific tornado producers (McCaul 1991), usually within 100 to 400 km of the center of circulation in the hurricane spiral bands. A reflectivity image (Fig. 1) of hurricane Ivan in the late afternoon of 15 September shows a major rain band coming ashore along the Florida panhandle. The telltale signs of supercells lined up along the Florida coastline are clearly evident in the higher reflectivity regions greater than 35 dBZ (yellow and red colors).

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The National Weather Service (NWS) office in Tallahassee issued 130 warnings beginning in the afternoon of 15 September and continuing into the morning of 16 September. Table 1 contains the office warning statistics for the Ivan event. The NWS office only missed 2 tornado events, but also had a high FAR of .846.

Table 1. Hurricane Ivan – Tornado summary statistics, 15-16 September 2004.

Tornado Warnings		**Tornado Events**	
Warnings issued	130	Events	23
Warnings verified	20	Events warned	21
Warnings not verified	110	Events unwarned	2
FAR	.846	Average leadtime	11.2
		% of events w/leadtimes > 0	78.3
		POD	.913
		CSI	.152

Identified mesocyclones and tornado vortex signatures (TVS) from the area WSR-88Ds (Tallahassee (KTLH), Eglin AFB (KEVX), and Ft. Rucker (KEOX)) are displayed in Figure 2. The WSR-88D supports both a Mesocyclone Detection Algorithm (MDA) and Tornado Detection Algorithm (TDA), which provide guidance to the forecaster in making warning decisions. There are more than 50 identified mesocyclones in Figure 2. Also, not all TVSs are plotted, to reduce cluttering of the mesocyclone tracks. However, a sense of the severity is conveyed in the graphic.

Finally, tracks and Fujita scale (F-scale) of verified tornadoes are shown in Figure 3. There were 14 F0, 8 F1, and 2 F2 tornadoes identified. Notice that multiple tornado tracks follow straight lines, most of which were produced by the same parent supercell. The longest multiple tornado track occurred west of Tallahassee, from near the coast to central Jackson County, producing 4 tornadoes, that resulted in 4 deaths, and 8 injuries. Fortunately, much of the time, this tornadic supercell moved across uninhabited and highly rural areas.

In all the following figures, there is no guarantee that the office found and surveyed all the tornadoes that occurred. The Florida Big Bend and Panhandle contain large tracks of forested land, and is extremely rural in many places.

3. HURRICANE IVAN TORNADIC MESOCYCLONES

As stated earlier, the purpose of this study is to examine as many of the observed mesocyclones as possible, and look for clues in the mesocyclone structure, which might help to reduce the FAR, while still maintaining a high POD.

A recent study conducted by the National Severe Storms Laboratory (NSSL), and the Warning Decision Training Branch (WDTB) (Marzban 2001) examined numerous variables from the WSR-88D MDA and the TDA, including additional near storm environment variables. The most important finding was the significance of low-level rotational velocity (Vr). Additionally, Marzban (2001) found that the Heidke Skill Score (HSS) reached a peak at approximately 20 ms^{-1} (40 kts). Recall that Vr is calculated as the absolute value of the maximum outbound velocity in the mesocyclone at a particular elevation angle plus the absolute value of the maximum inbound velocity divided by 2. Incidentally, another local study by Turnage et al. (2000), investigating a strong tornado outbreak in southern Georgia, found approximately the same values of Vr to be an important criteria for tornado formation.

In this section, we will examine 12 of the Ivan tornadoes with respect to Vr. Figure 4 examines the time series of Vr with altitude for the Ivan tornado-producing mesocyclones. Figure 4a documents the Blountstown/ Marianna, FL mesocyclone, which produced 4 tornadoes as the tornadic mesocyclone tracked nearly 75 miles across the Florida Big Bend and Panhandle. Vr is shaded for Vr ≥ 40 kts. Verified tornadoes are indicated across the bottom of the graph along the timeline. Usually, 4 elevation angles describe the analysis of Vr. Unlike many midlatitude mesocyclones, all of the mesocyclones described in this study are nondescending as reported by Trapp et al. (1999). The Blountstown/Marianna mesocyclone (Fig. 4a) is nearly 'textbook' in its appearance with 3 separate episodes of Vr ≥ 40 kts relating to 4 tornadoes.

The Panama City, FL tornado (Fig. 4b) came ashore at St. Andrews State Park, and cut a path through restaurants, stores, and shops as it moved northwestward along Thomas Drive. Seven people were injured at a seafood restaurant that was partially destroyed. One man was killed at a real estate office on Thomas Drive. A spectacular video of the tornado was captured by the WJHG-TV tower camera, which was broadcast live.

The first Vr ≥ 40 kts was recorded offshore (Fig. 4b). The mesocyclone weakened for a time, and intensified again before coming ashore and producing the killer tornado.

The Gulf/Bay, FL County mesocyclone (Fig. 4c) produced 3 tornadoes, one of which killed one person and injured another in Allanton, FL when the F1 tornado destroyed a frame house. This mesocyclone was not as well defined as others in Figure 4.

The Grady County, GA tornado (Fig. 4d) developed very close to the Tallahassee WSR-88D within a region of Vr ≥ 30 kts. The two Early County, GA tornadoes (F0s) (Fig. 4e) developed just outside a region of Vr ≥ 40 kts., but in an area of 35-40 kts Vr. Finally, the Youngstown, FL tornado was reported as the mesocyclone crossed US231 in Bay County, after spending much of its lifecycle over relatively rural Calhoun County.

It appears that Vr ≥ 40 kts is a good indicator of the existence of a possible tornado, but we have seen in Figure 4 that it is not a necessary condition, because one F1 tornado and several F0 tornadoes did occur in much weaker Vr. However, Most of the tornadoes did occur in deep high values of Vr, that is, Vr ≥ 40 kts at higher elevation angles.

In Figure 5, we examine the time series of the same mesocyclones as found in Figure 4 but in a slightly different format called Vr time trends. This is the format the MDA provides to forecasters in AWIPS as guidance in real time. The only drawback is that the altitude of the various elevation angles is not readily known.

4. TORNADIC MESOCYCLONE AND WDSS

Since KEVX and KEOX Archive-II radar data were not available during Hurricane Ivan, the bulk of the Ivan mesocyclone analysis of WSR-88D data have been performed by hand in this report. However, digital Archive-II data were available from KTLH. Using the Warning Decision Support System – Integrated Information (WDSS-II) (Hondl 2002), the Blountstown/Marianna tornadoes were analyzed. Parameters from WDSS are illustrated in Figure 6. The Mesocyclone Strength Index (MSI) and the MSI Rank (Fig. 6a) are very important since they provide an integrated output at all elevation angles. A strong mesocyclone is indicated by MSI values greater than 3600, and by MSI Rank values greater than and equal to 5. Both parameters are contained in the latest MDA and are available in the AWIPS OB4 upgrade. Figure 6b includes various Vr and gate-to-gate velocity parameters. The differences between the hand generated data in Figures 4a/5a and the computer generated data in Figure 6 are minimal.

5. HURRICANE IVAN NON TORNADIC MESOCYCLONES

In this section, we investigate six of the non tornadic mesocyclones (Figs. 7 and 8). They are presented according to time, not by strength. However, these mesocyclones were selected because they were some of the stronger, longer lived non tornadic mesocyclones that occurred during Ivan landfall. The first mesocyclone to be presented (Figs. 7a and 8a) was a long-lived mesocyclone (70 min) producing Vr in the range of 30 to 39 kts. At 2.5° elevation, there was only one instance of Vr = 30 kts. Most of the tornadic mesocyclones (Figs. 4 and 5) reached values of Vr ≥ 40 kts at higher elevation angles when tornadoes were on the ground. Figures 7b and 8b (Calhoun County, FL) is very similar to Figures 7a/8a with only one instance of Vr reaching a value of 40 kts.

Examining the remainder of the non tornadic mesocyclones in Figures 7 and 8, it is apparent that these mesocyclones are much weaker, both at low levels, and particularly, at higher elevation angles. Figures 7c/8c contain a long lived, relatively vigorous low-level mesocyclone reaching Vr of 61 kts, which came ashore in Franklin County at 2318 UTC as it strengthened. It would be hard for a warning meteorologist not to issue a warning on this storm. However, it did remain relatively weak at higher elevation angles.

6. DISCUSSION AND CONCLUSIONS

Marzban (2001) noted that the NSSL results using Vr were somewhat mixed. The FAR was around 0.75 at Vr = 40 kts, decreasing to 0.60 at even higher values of Vr. The NWS Tallahassee FAR (Table 1) was .846 for this event.

For the most part in this study, tornadoes were associated with fairly deep Vr values normally above 30 kts. It appears for tornado occurrence, large values of Vr must also occur at higher elevation angles. Non tornadic mesocyclones may contain low-level Vr values ≥ 40 kts, but do not normally contain large Vr values at higher elevation angles. All tornadoes reported were associated with nondescending type mesocyclones, which offer few advanced indicators that a tornado will form.

In AWIPS OB4 upgrade, the mesocyclone strength index (MSI) and MSI Rank in the new MDA should offer further improved guidance in making warning decisions.

7. REFERENCES

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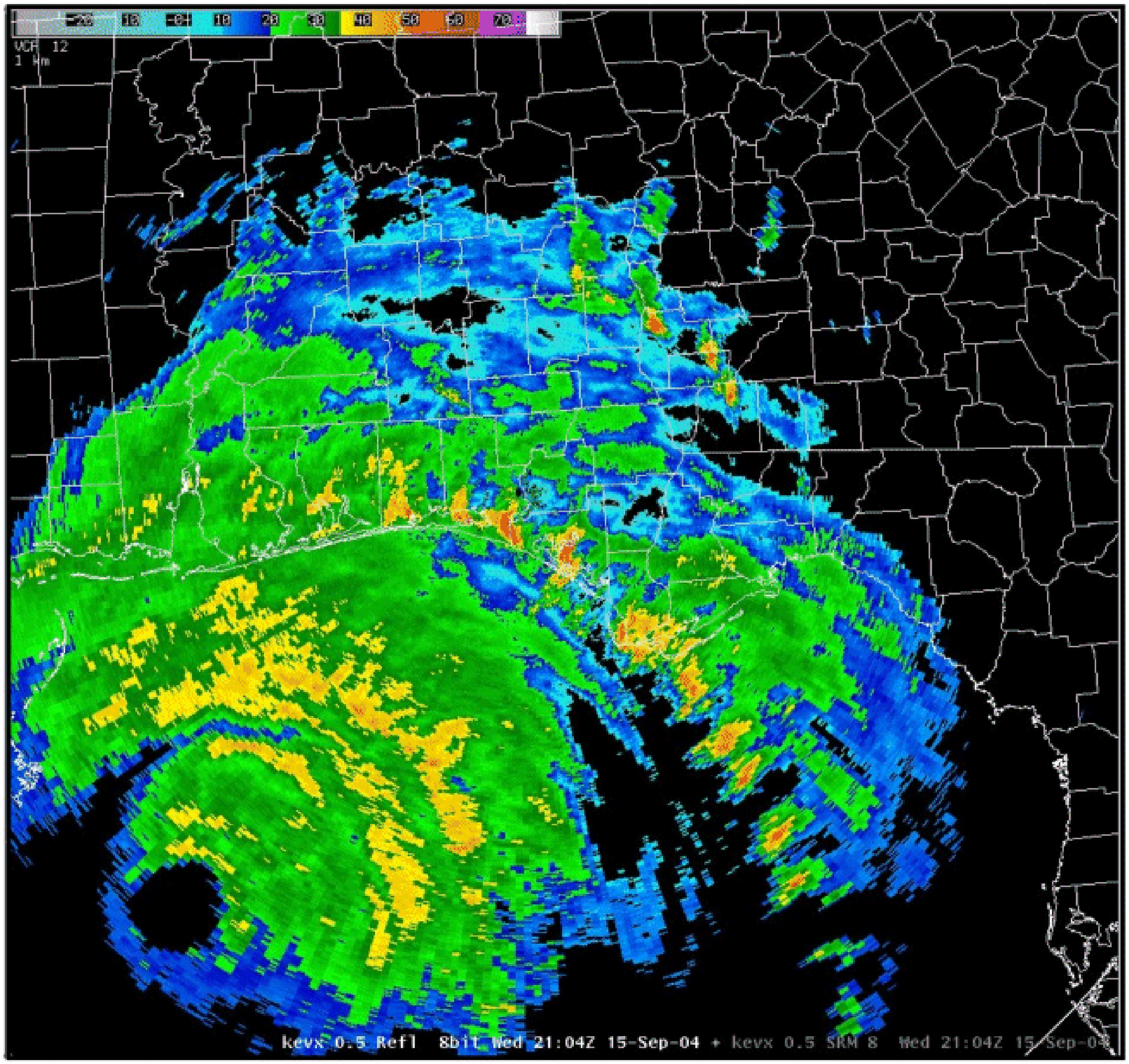


Figure 1. KEVX WSR-88D reflectivity image at 2104 UTC, 15 September 2004.

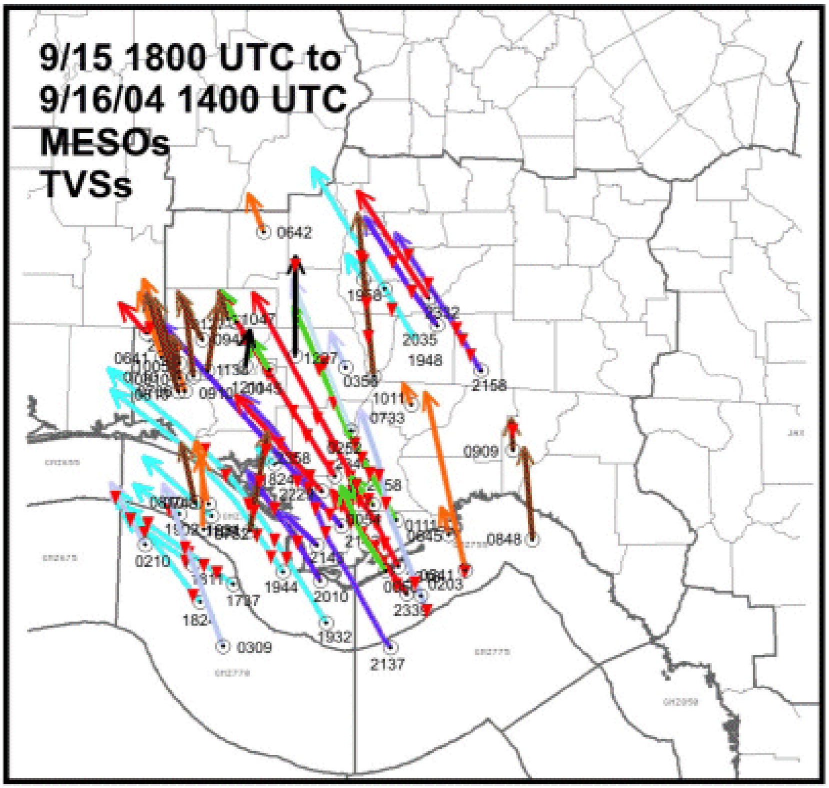


Figure 2. Radar identification of mesocyclone's and TVS's from 3 WSR-88Ds, Tallahassee (KTLH), Eglin AFB (KEVX), and Ft Rucker (KEOX) for the period, 1800 UTC, 15 September to 1400 UTC, 16 September 2004.

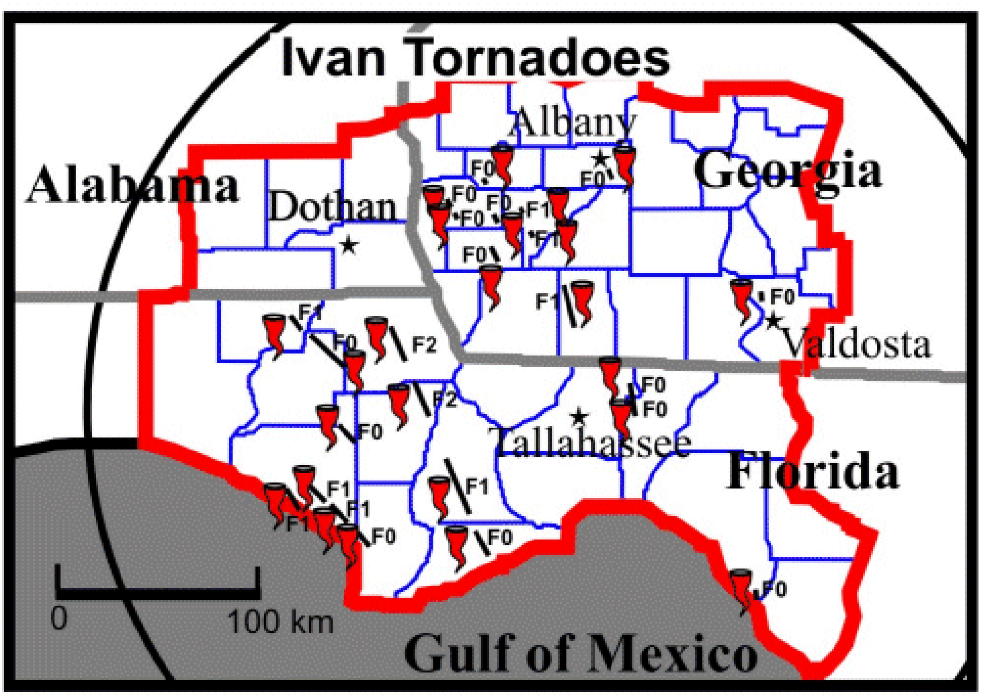


Figure 3. Tornado tracks and F-scale of verified tornado touchdowns during Hurricane Ivan on 15-16 September 2004.

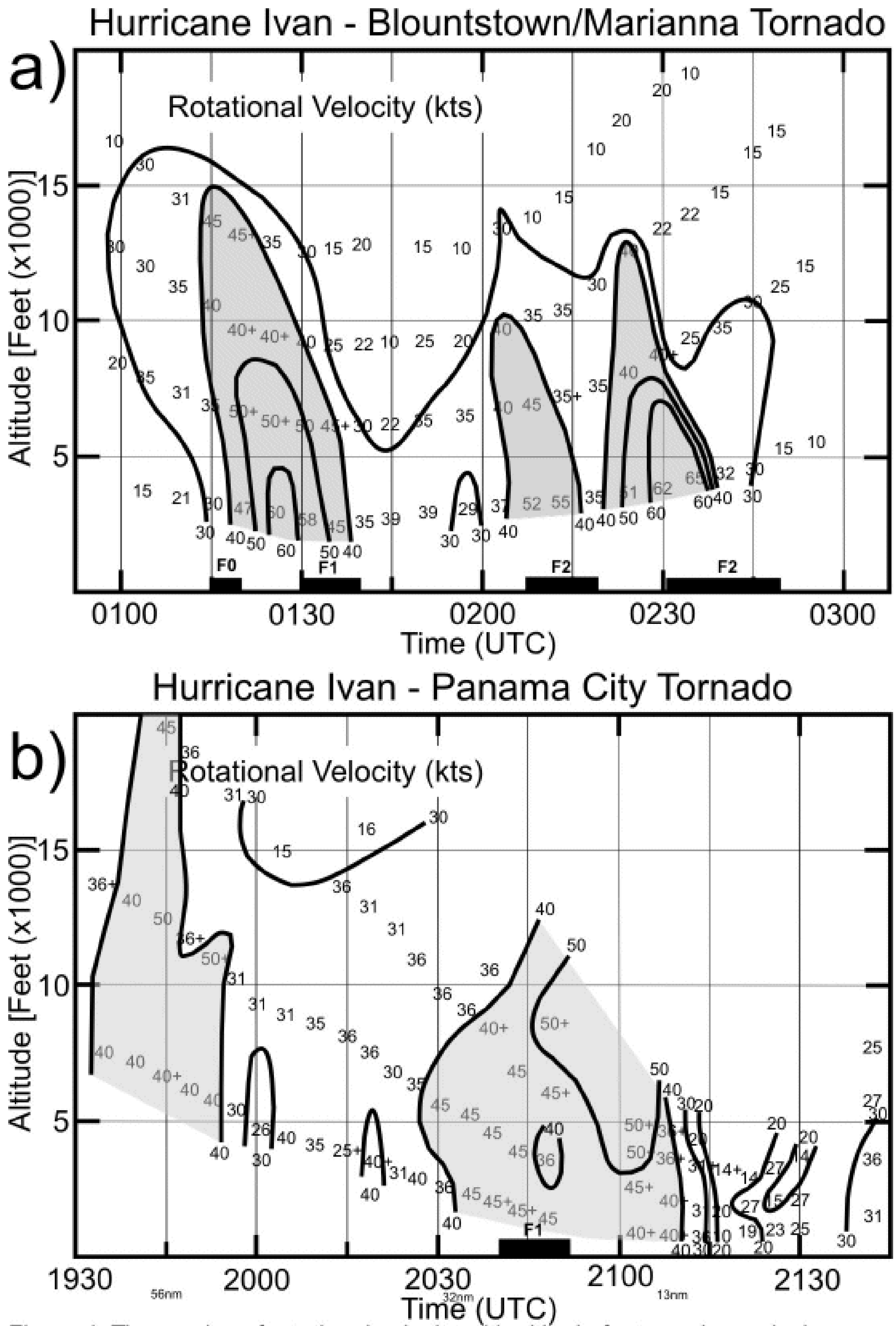


Figure 4. Time series of rotational velocity with altitude for tornado-producing mesocyclones. Times of tornadoes with F-scale are indicated along time line. Rotational velocity greater than 40 kts is shaded. a) Blountstown/ Marianna tornadoes, b) Panama City tornado.

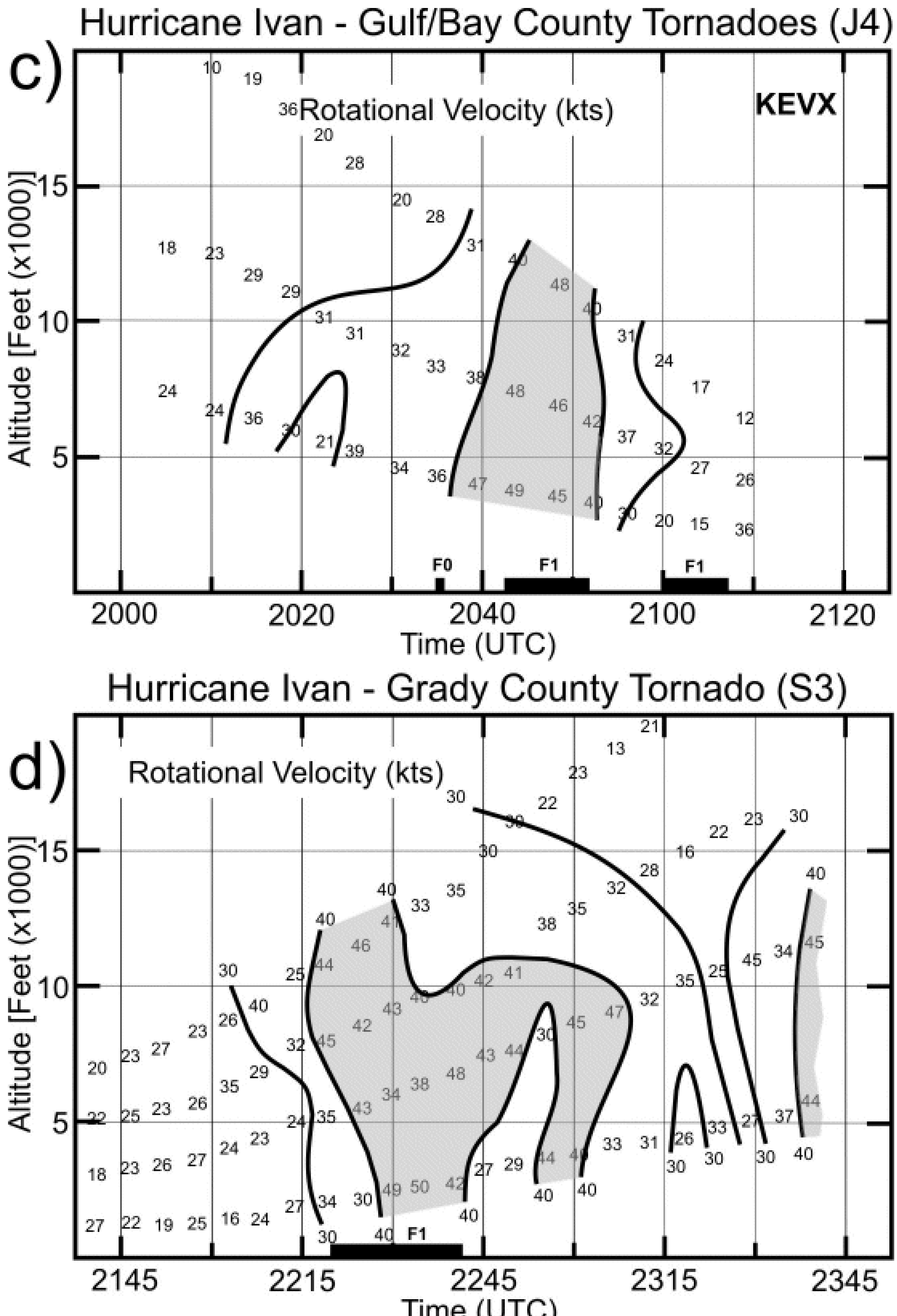


Figure 4, continued. c) Gulf/Bay County tornadoes, d) Grady County tornadoes.

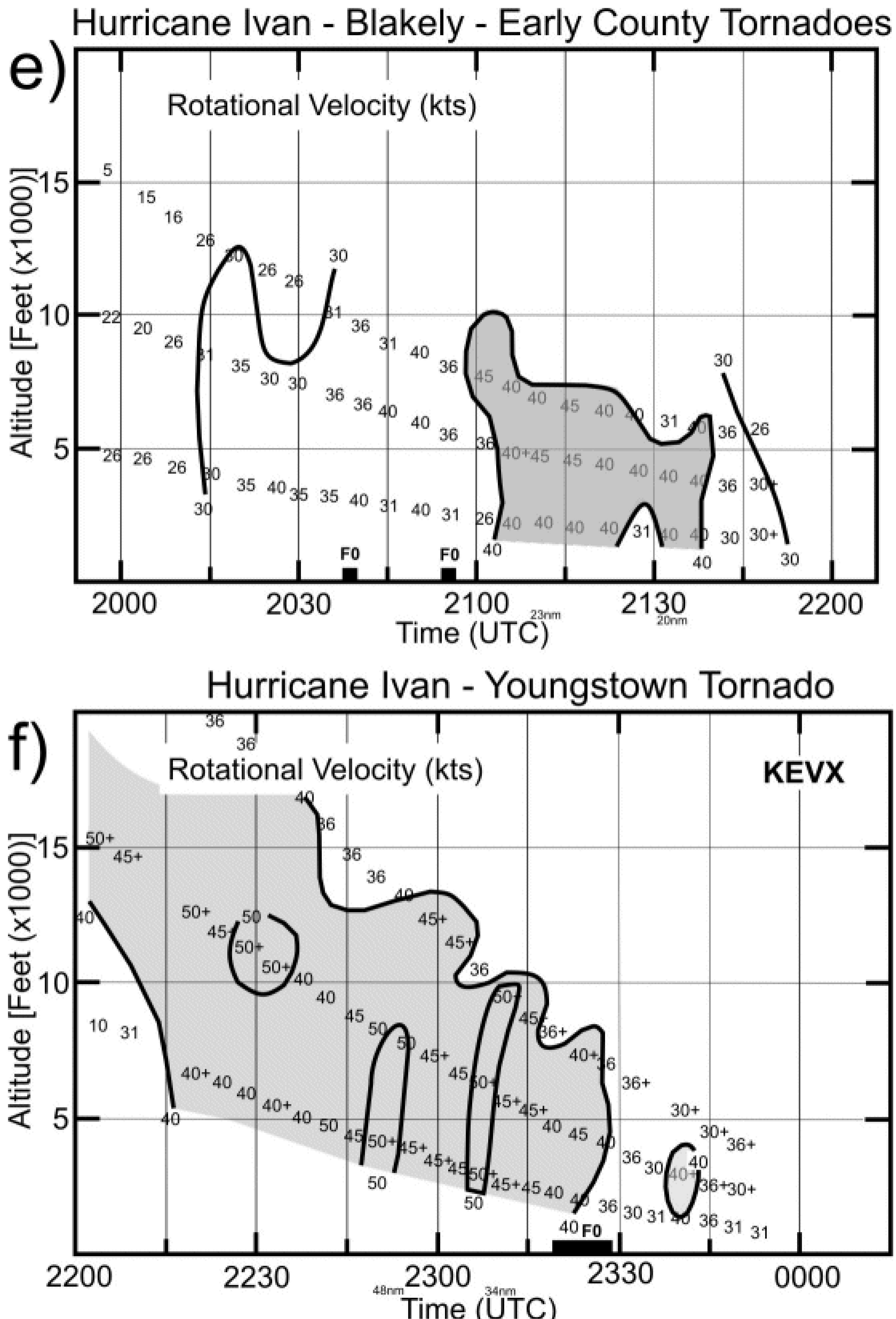


Figure 4, continued. e) Blakely - Early County tornadoes, and f) Youngstown tornado.

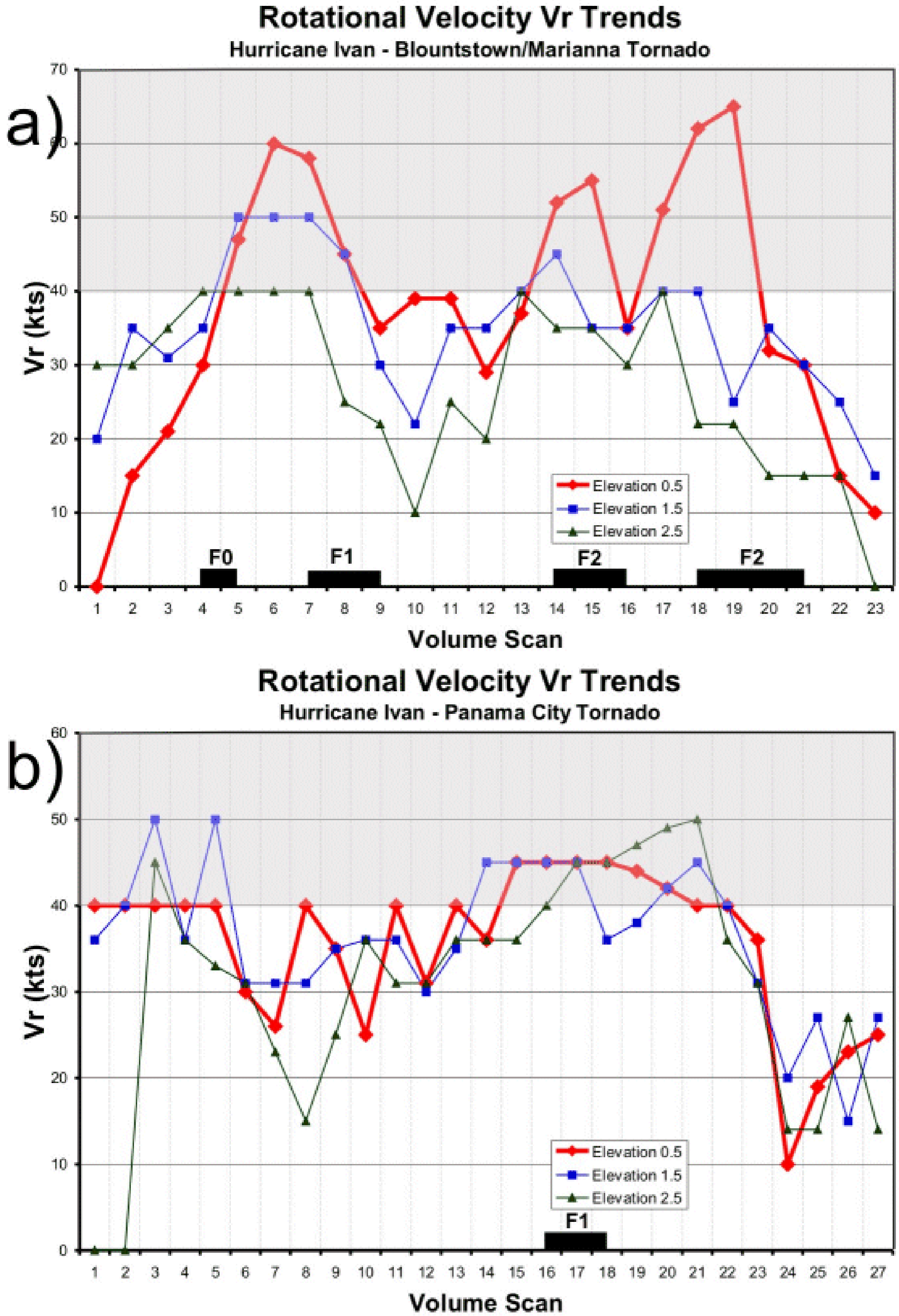


Figure 5. Rotational velocity time trends with elevation 0.5 deg (red), elevation 1.5 deg (blue), and elevation 2.5 deg (green). Times of tornadoes with F-scale are indicated along abscissa. Rotational velocity greater than 40 kts is shaded. a) Blountstown/Marianna tornadoes, b) Panama City tornado.

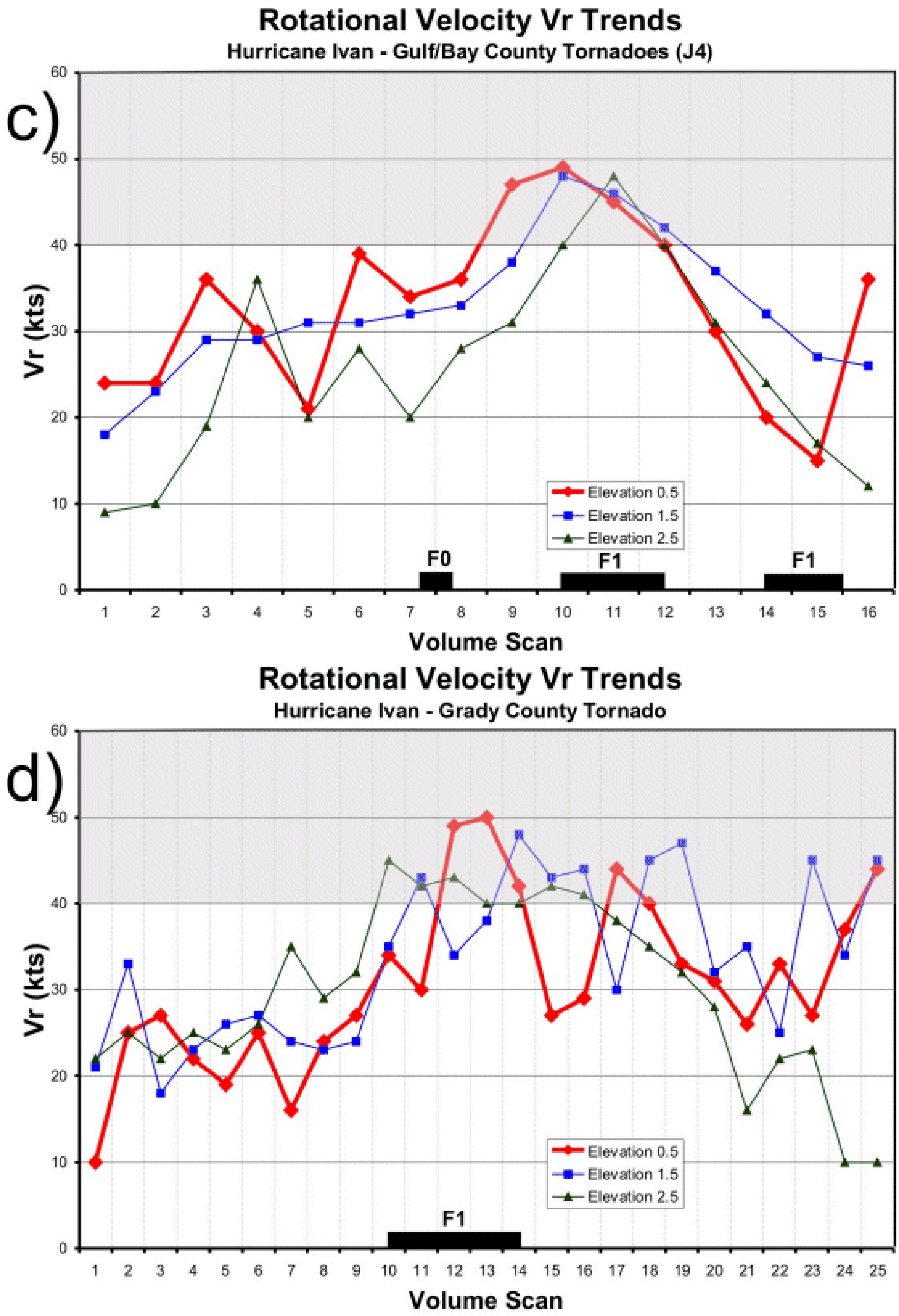
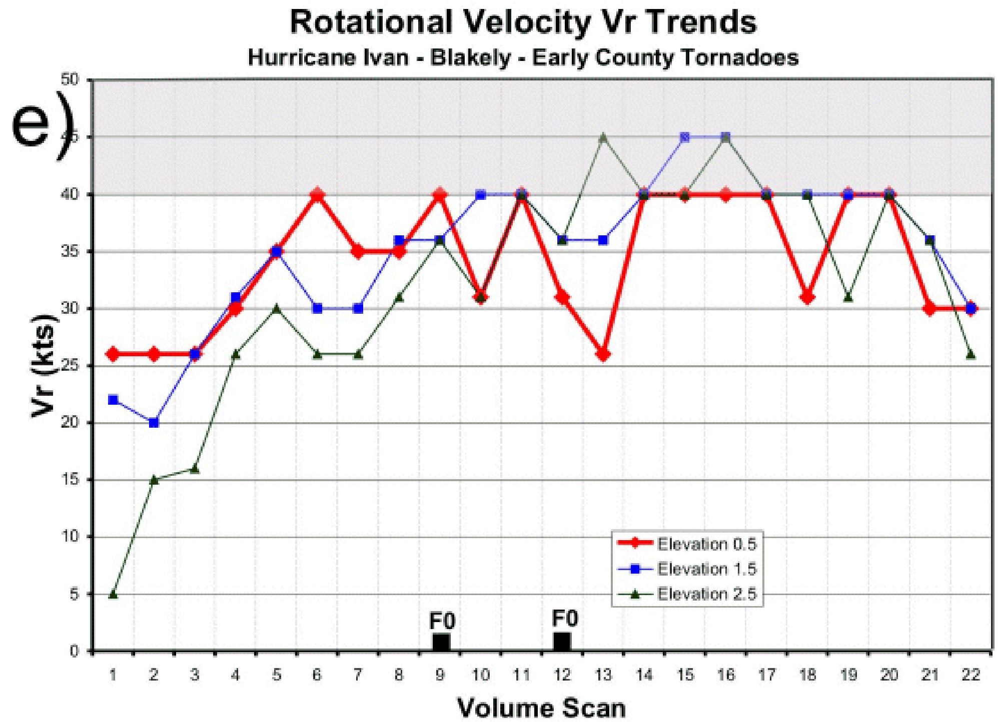


Figure 5, continued. c) Gulf/Bay County tornadoes, d) Grady County tornadoes.



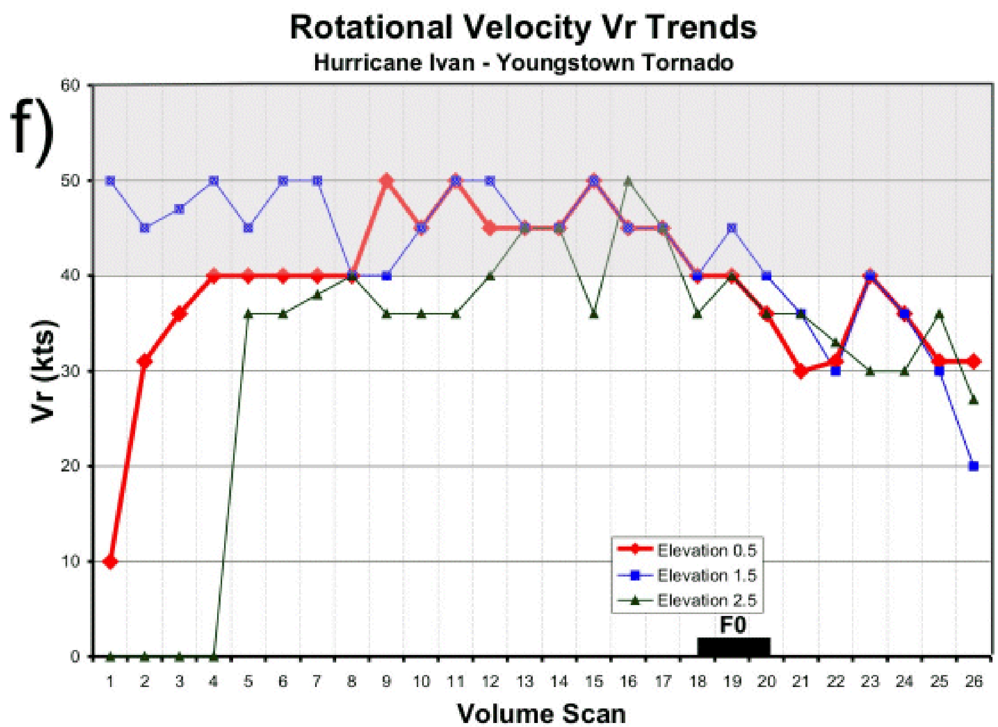


Figure 5, continued. e) Blakely - Early County tornadoes, and f) Youngstown tornado.

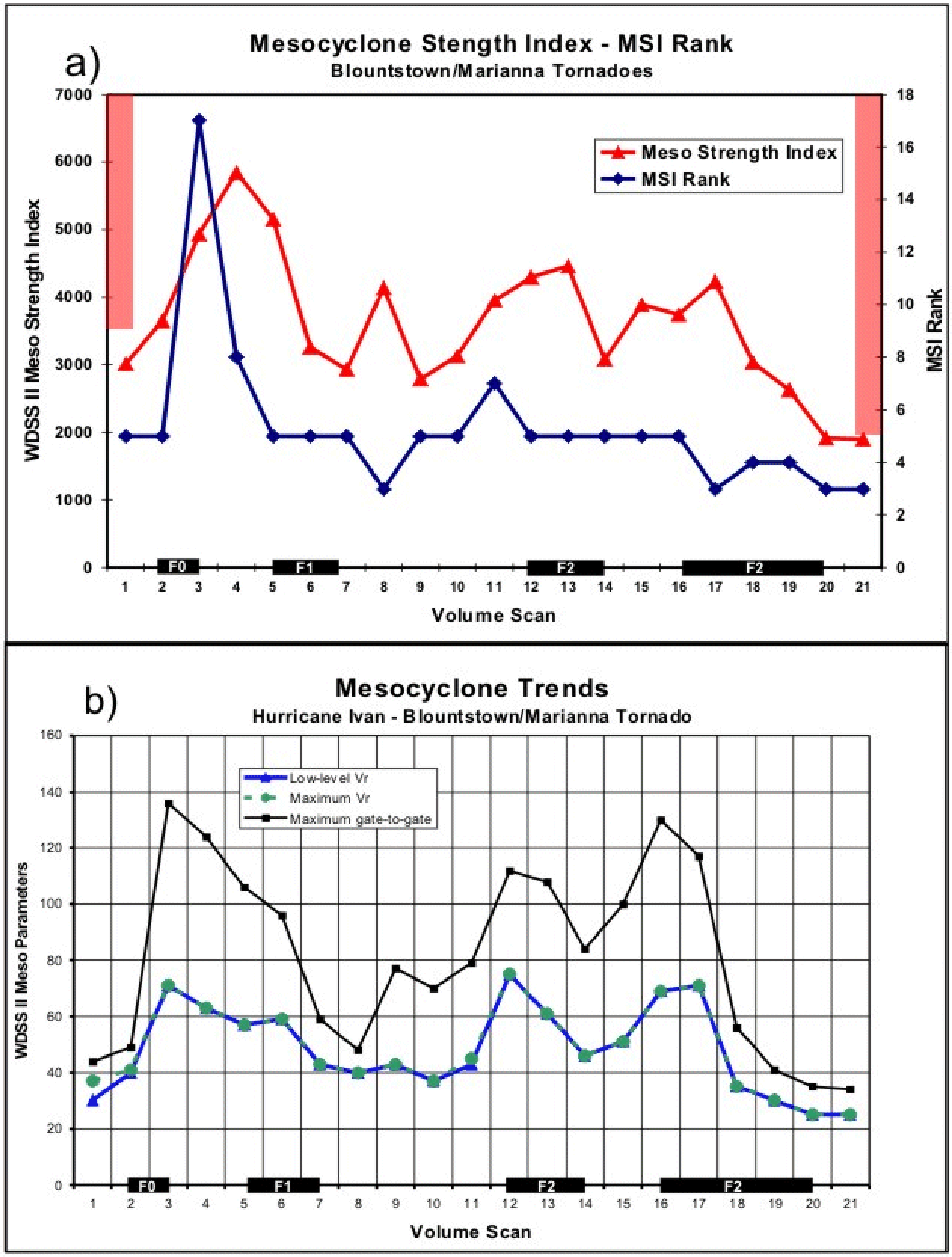


Figure 6. WDSS-II computed time trends for Blountstown/Marianna tornadoes for the for the period, 0110-0256 UTC, 16 September 2004. a) Mesocyclone strength index and Rank, and b) Rotational and gate-to-gate velocity parameters.

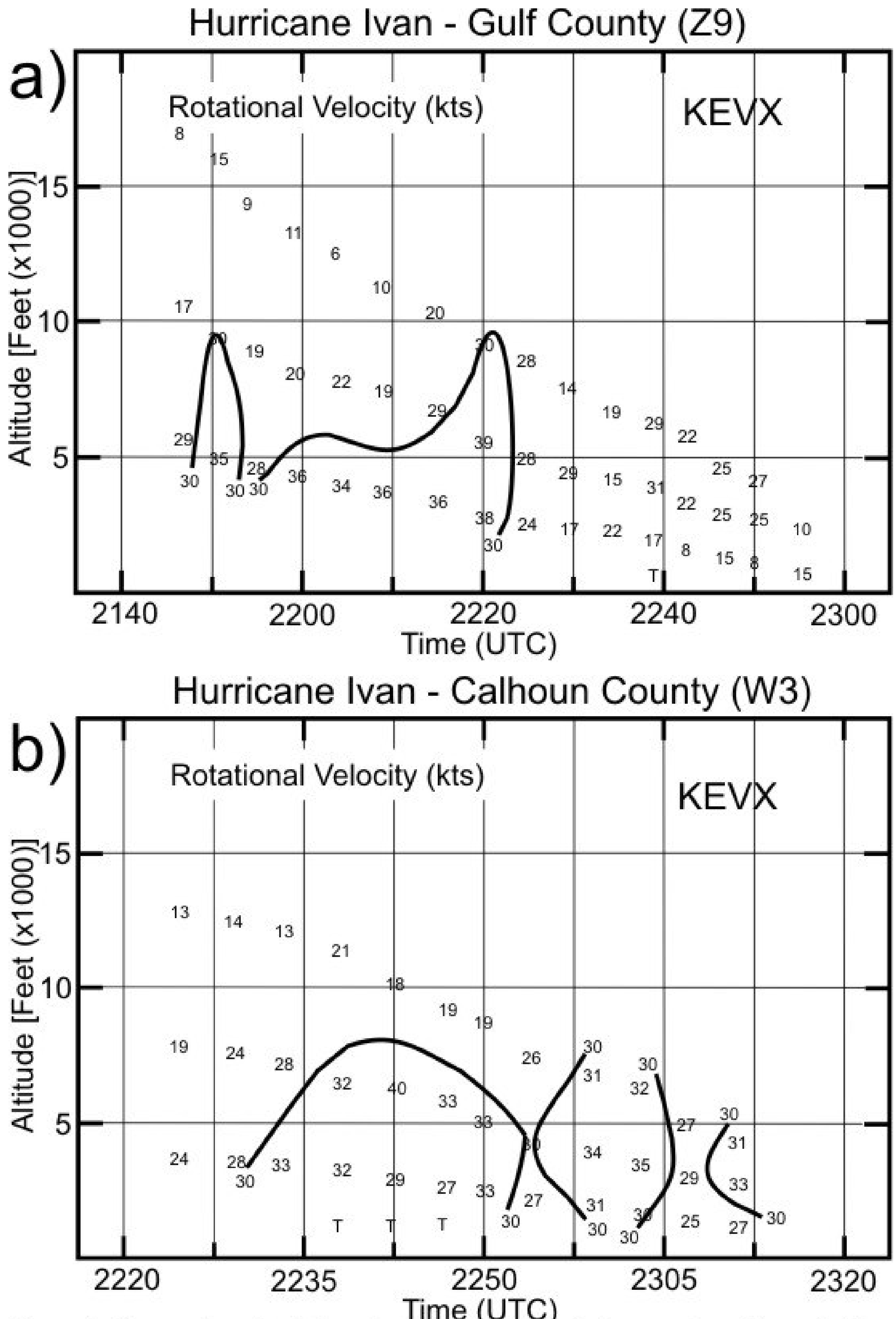


Figure 7. Time series of rotational velocity with altitude for non tornado-producing mesocyclones. Rotational velocity greater than 40 kts is shaded.
a) Gulf County mesocyclone, b) Calhoun County mesocyclone.

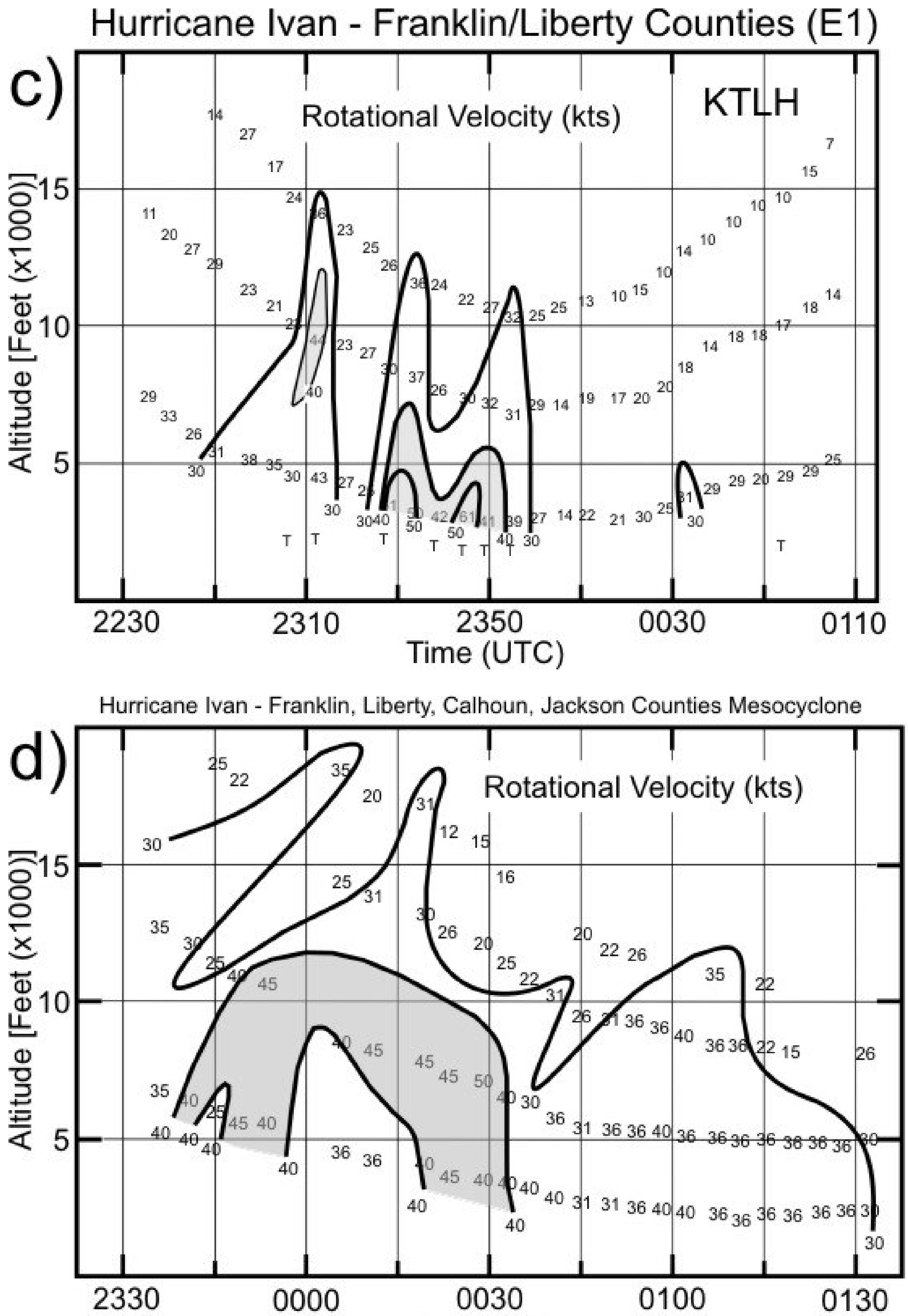


Figure 7, continued. c) Franklin/Liberty County mesocyclone, d) Franklin, Liberty, Calhoun, Jackson Counties longlived mesocyclone.

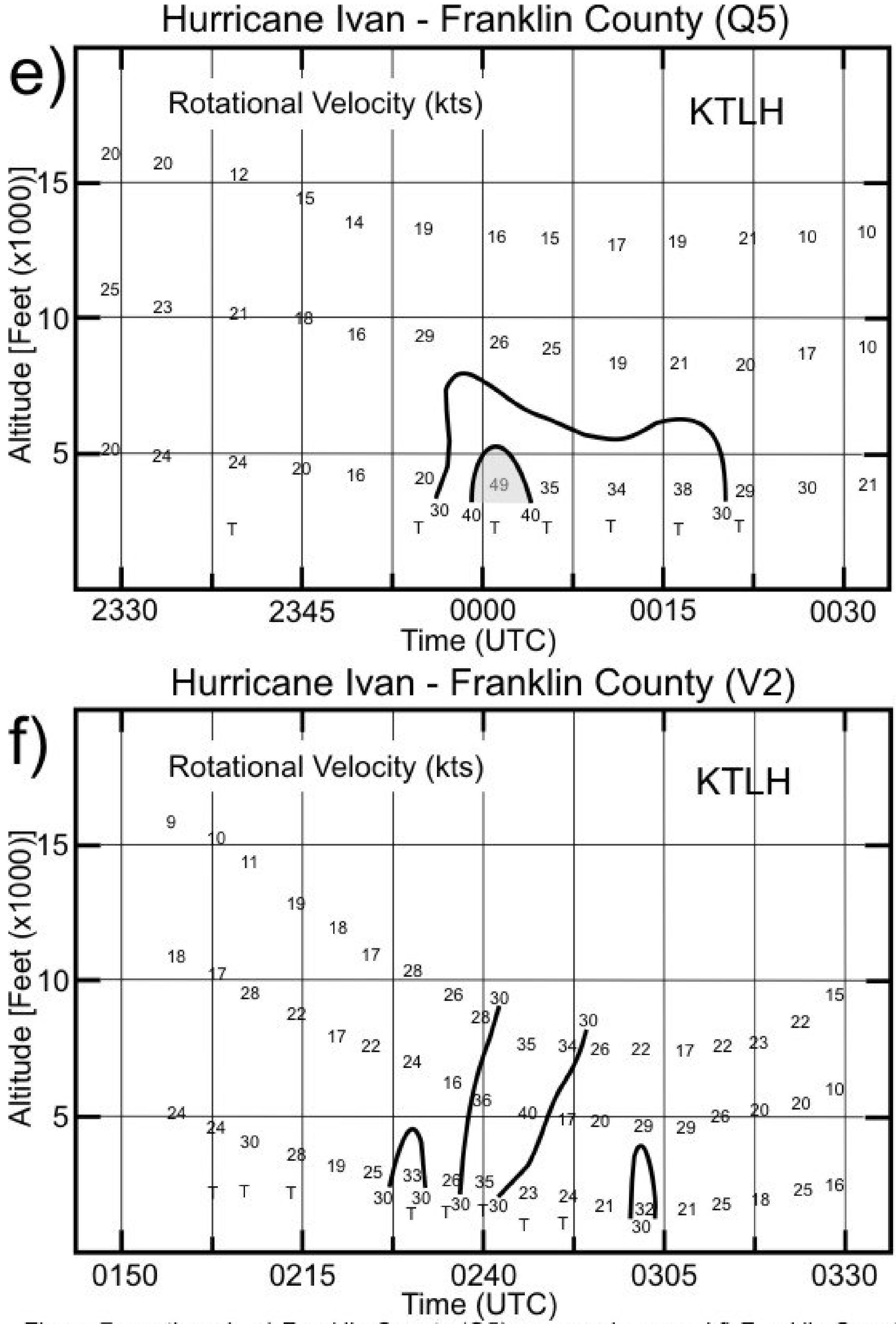


Figure 7, continued. e) Franklin County (Q5) mesocyclone, and f) Franklin County (V2) mesocyclone.

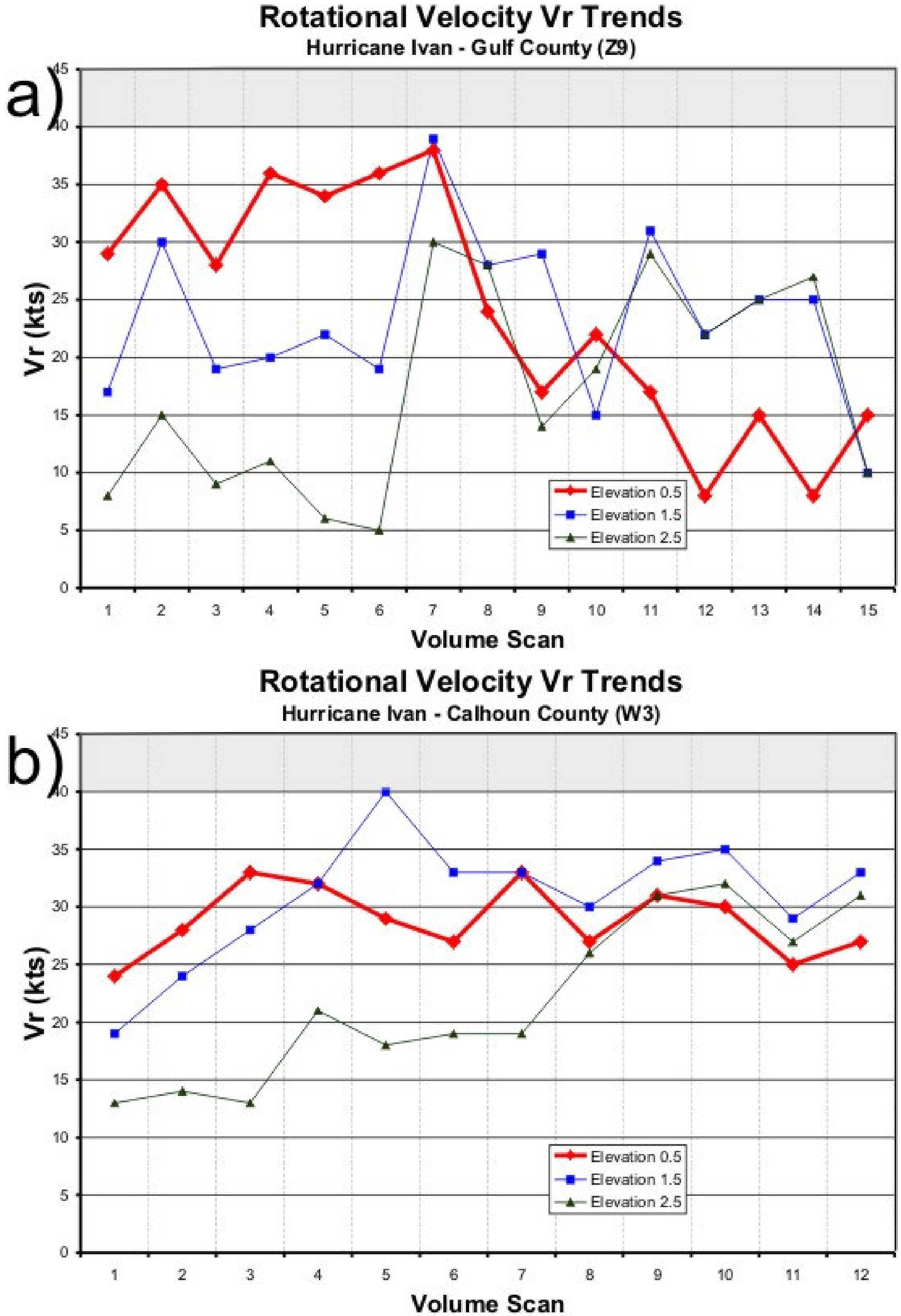
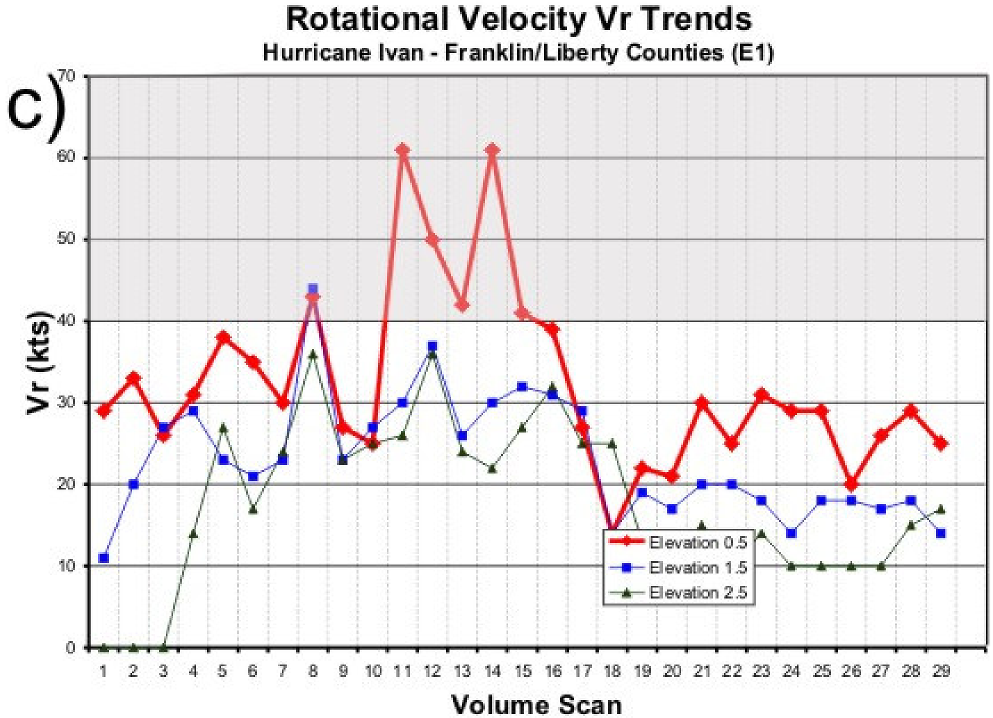


Figure 8. Rotational velocity time trends for non tornado-producing mesocyclones with elevation 0.5 deg (red), elevation 1.5 deg (blue), and elevation 2.5 deg (green). Rotational velocity greater than 40 kts is shaded. a) Gulf County mesocyclone, b) Calhoun County mesocyclone.



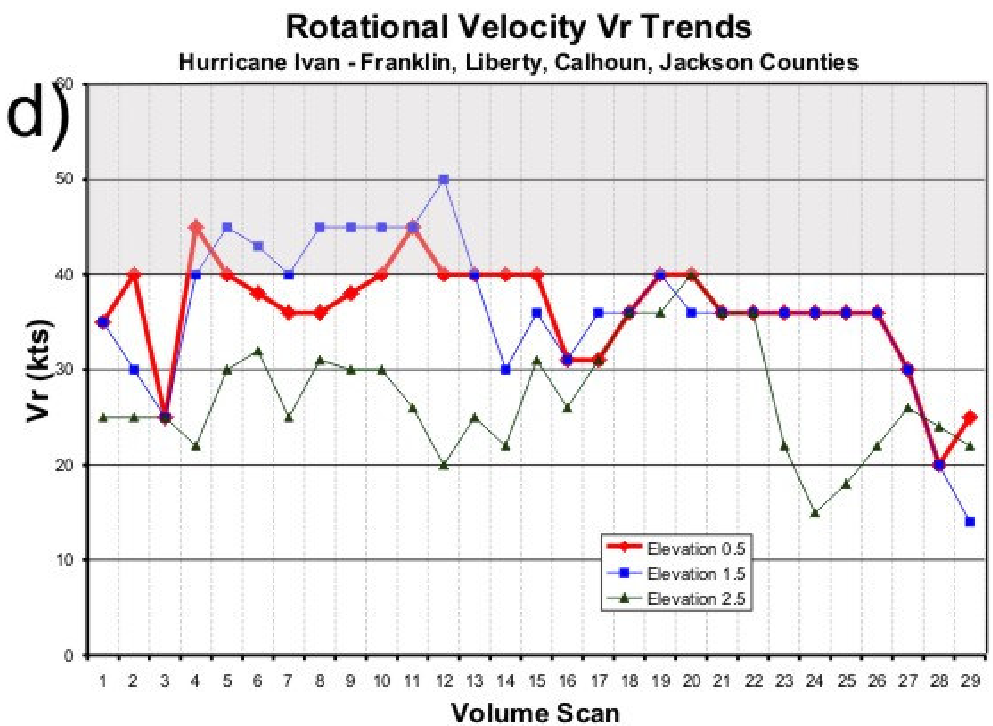
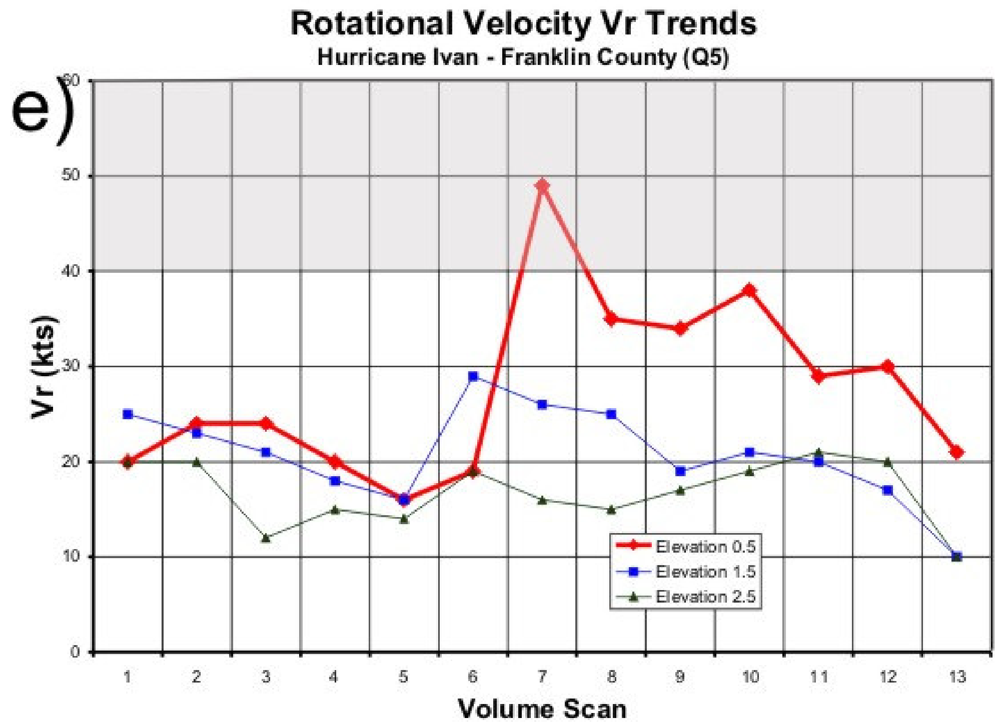


Figure 8, continued. c) Franklin/Liberty County mesocyclone, d) Franklin, Liberty, Calhoun, Jackson Counties longlived mesocyclone.



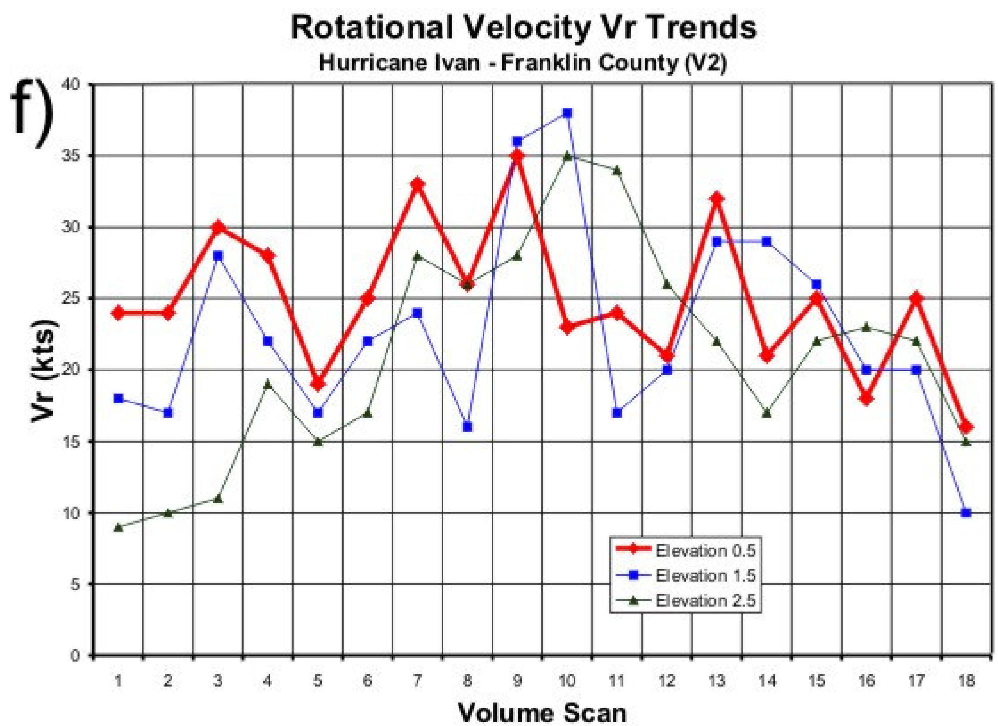


Figure 8, continued. e) Franklin County (Q5) mesocyclone, and f) Franklin County (V2) mesocyclone.