Employing the WSR-88D for Waterspout Forecasting

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1. Introduction

Waterspouts and weak coastal tornadoes or "landspouts" (hereafter referred to collectively as "spouts") account for much of Florida's severe weather during the "wet season" (Schmocker et al. 1990). The Melbourne NEXRAD Weather Service Office (NWSO) County Warning Area (CWA) includes 160 miles of coastline along the east central Florida peninsula. Within this area, spouts are most frequent from June through September (Fig. 1).

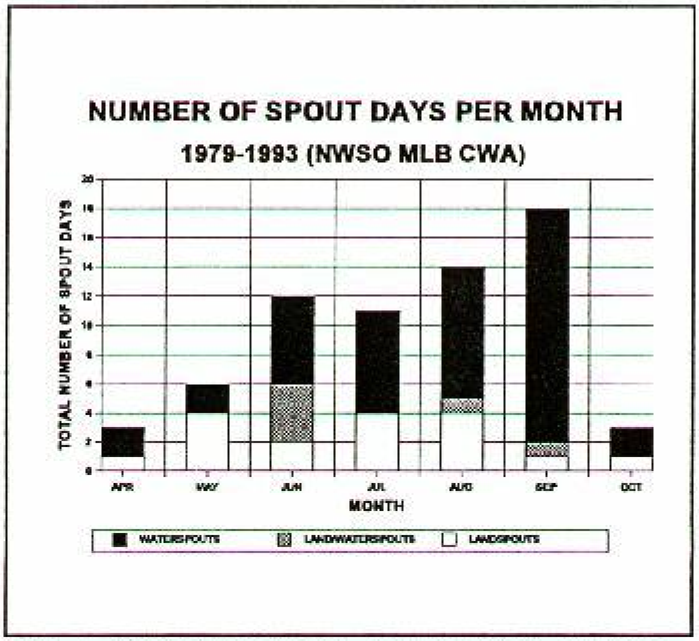


Fig. 1: Depiction of the total number of days per month with reported spouts in NWSO MLB coastal CWA between 1979 and 1993. The land/waterspout category contains cases where landspouts moved offshore or waterspouts moved onshore.

In the past, warnings were issued for spouts only after reports of visual sightings were received. This delay was likely due to the seemingly benign atmospheric conditions in which spouts develop, combined with a lack of pronounced severe weather signatures on conventional radars. However, recent research utilizing the NWSO MLB WSR-88D may now help forecasters warn for spouts prior to receiving visual reports. A preliminary forecast strategy was developed based on post analyses of archived WSR-88D products and regional upper-air data from reported spout days (Choy and Spratt 1994). This strategy has proved useful by providing additional lead time for spout events.

This paper will identify specific atmospheric conditions which have been observed to precede spout generations along the east central Florida coast. A unique WSR-88D Routine Product Set (RPS) list will be shown which can be implemented once these conditions become satisfied. Finally, case studies of two recent events will be illustrated to help familiarize WSR-88D users with the environmental conditions and radar signatures often evident prior to and during spout events.

2. Data Selection

Griffiths (1992) defined the maritime coastal environment as the area extending from about 20 miles inland from the coastline to approximately 50 miles offshore. Consistent with this definition, the MLB CWA coastal counties and their adjacent offshore waters were identified as the study domain. To restrict the investigation to pure "spout" events, days with other types of severe weather reports (wind/hail) and those with nearby tropical cyclones were removed. While this criteria eliminated all dry season and several wet season tornado events, all waterspout cases were retained.

For each day between 1979 and 1992 with at least one spout report, upper-air data from Tampa Bay (TBW) and West Palm Beach (PBI) were examined. Additionally, Cape Canaveral (XMR) soundings and WSR-88D products for nearly all spout events reported to NWSO MLB during 1993 were added to the previous data base.

3. Tornado/Waterspout Classifications

The authors have stratified waterspouts and tornadoes into four categories based upon formation processes. The categories are summarized below.

Type A) is characterized from a non-precipitating cumulus cloud (exclusively F0 on the Fujita scale, Fujita 1981).

Type B) features formation associated with a relatively isolated precipitating cell, or within a cell located along a persistent boundary (up to F1).

Type C) results from a precipitating cell developing near intersecting or colliding boundaries (up to F2).

Type D) usually forms within a severe thunderstorm containing a mesocyclone (up to F5).

Since category B and C spouts most often affect east central Florida, conditions which have proven useful in determining their formation potential will be addressed in the remainder of this paper.

4. Spout Formation and Preferred Areas

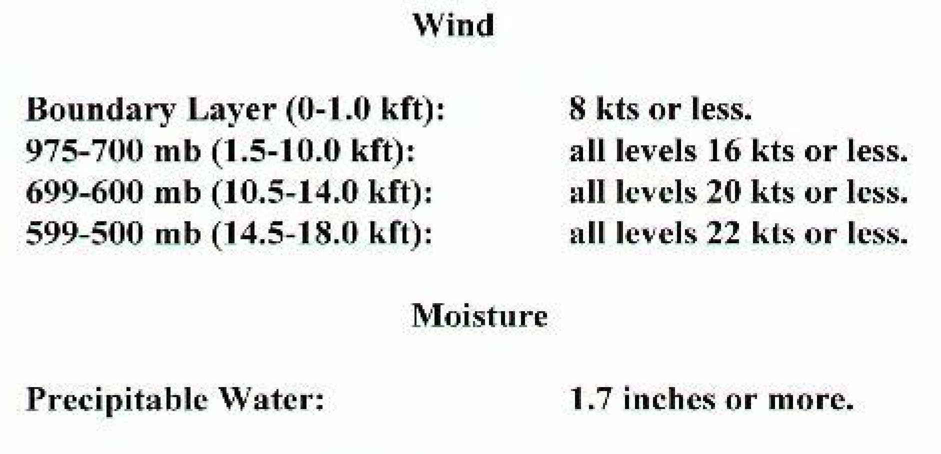
Low level, horizontal vortices are inherent features along shear axes and convergent zones (Wakimoto and Wilson 1989). Within a moist, minimally sheared air mass, the updraft of a developing convective cell can occasionally become vertically collocated with a vortex along a boundary, resulting in upward stretching within the column. As the vortex intensifies a spout results. The ensuing pressure drop often produces a condensation funnel which can be seen extending below the cloud base, sometimes all the way to the surface. This "spin-up" process is quite contrary to the "spin-down" tornado formation associated with storms embedded within high shear environments (Wakimoto and Wilson 1989).

Coastal geographical configurations can lead to areas with local spout maxima. Uniquely shaped and orientated coastal plains combined with numerous intracoastal islands and large, warm shallow lagoons have been shown to produce areas of localized convergence (Zhong and Takle 1993). Such convergence patterns tend to initiate cell growth under certain synoptic regimes and maybe partially responsible for the observed increase in spout occurrence as boundaries develop or propagate through the vicinity. In Florida, the most prolific areas include Tampa Bay, Cape Canaveral, Palm Beach, and the keys. Some other favored regions of localized spout development include New Orleans, Galveston, and Corpus Christi (Golden 1977).

5. Forecast Strategy

A systematic five-step approach to coastal spout forecasting was devised to help increase forecaster awareness of formation potential and to convey this information to the public prior to occurrence.

1) Analyze the latest soundings to determine if the favorable wind and moisture conditions shown in Table 1 are fulfilled.



Wind

Boundary Layer (0-1.0 kft):	**8 kts or less.**
975-700 mb (1.5-10.0 kft):	**all levels 16 kts or less.**
699-600 mb (10.5-14.0 kft):	**all levels 20 kts or less.**
599-500 mb (14.5-18.0 kft):	**all levels 22 kts or less.**

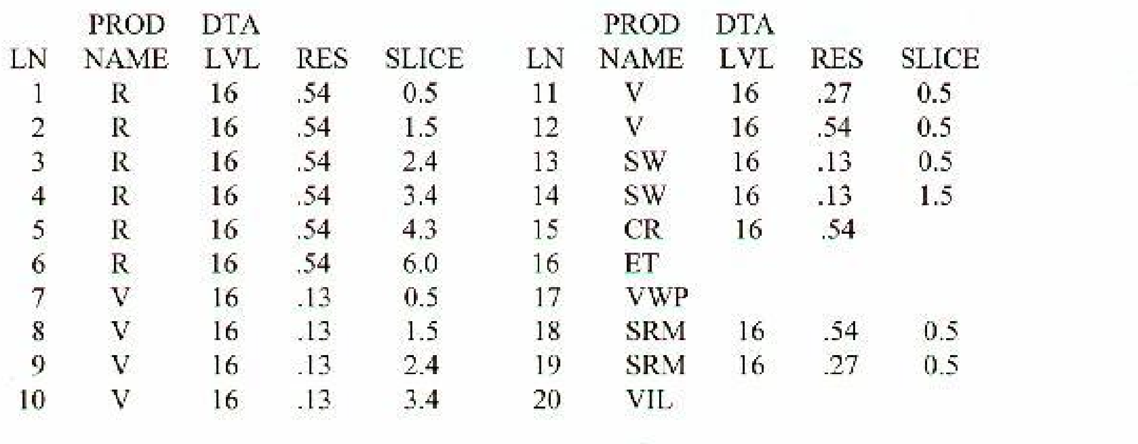
Moisture

Precipitable Water:	**1.7 inches or more.**

Table 1. Conditions favorable for spout formation.

2) If conditions are deemed favorable, boundary detection becomes paramount. Use WSR-88D products, along with surface analyses and high resolution visible satellite imagery, to determine if boundaries are present in or near a preferred area.

3) Once a boundary is located, check WSR-88D reflectivity products frequently for convective development in the vicinity. If convective development commences, implement the spout RPS list (Table 2) at the PUP.

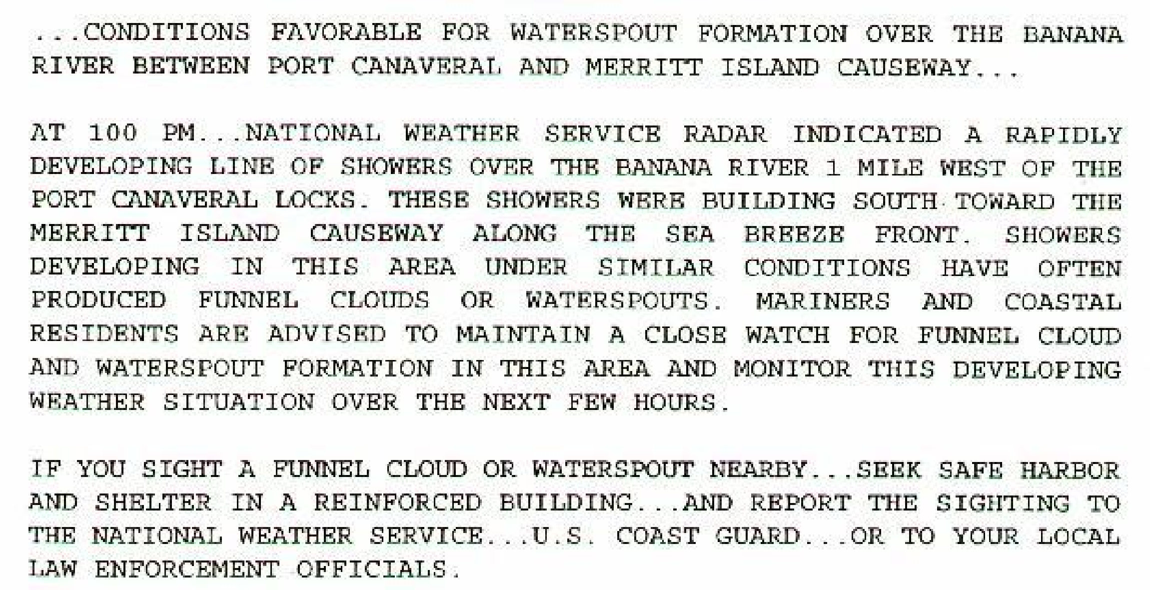


	PROD	DTA				PROD	DTA		
LN	NAME	LVL	RES	SLICE	LN	NAME	LVL	RES	SLICE
1	R	16	.54	0.5	11	V	16	.27	0.5
2	R	16	.54	1.5	12	V	16	.54	0.5
3	R	16	.54	2.4	13	SW	16	.13	0.5
4	R	16	.54	3.4	14	SW	16	.13	1.5
5	R	16	.54	4.3	15	CR	16	.54	
6	R	16	.54	6.0	16	ET			
7	V	16	.13	0.5	17	VWP			
8	V	16	.13	1.5	18	SRM	16	.54	0.5
9	V	16	.13	2.4	19	SRM	16	.27	0.5
10	V	16	.13	3.4	20	VIL			

Table 2. WSR-88D Routine Product Set (RPS) list for waterspouts. See Spratt and Choy, 1994 for a detailed explanation of the usefulness of each product.

4) Use RPS list products to evaluate cell development along boundaries. If rapid cell growth is

observed, issue a Marine Weather Statement (MWS) or an enhanced short-term forecast (NOW) addressing the potential for spout formation. Here's an example of such a statement.



...CONDITIONS FAVORABLE FOR WATERSPOUT FORMATION OVER THE BANANA RIVER BETWEEN PORT CANAVERAL AND MERRITT ISLAND CAUSEWAY...

AT 100 PM...NATIONAL WEATHER SERVICE RADAR INDICATED A RAPIDLY DEVELOPING LINE OF SHOWERS OVER THE BANANA RIVER 1 MILE WEST OF THE PORT CANAVERAL LOCKS. THESE SHOWERS WERE BUILDING SOUTH TOWARD THE MERRITT ISLAND CAUSEWAY ALONG THE SEA BREEZE FRONT. SHOWERS DEVELOPING IN THIS AREA UNDER SIMILAR CONDITIONS HAVE OFTEN PRODUCED FUNNEL CLOUDS OR WATERSPOUTS. MARINERS AND COASTAL RESIDENTS ARE ADVISED TO MAINTAIN A CLOSE WATCH FOR FUNNEL CLOUD AND WATERSPOUT FORMATION IN THIS AREA AND MONITOR THIS DEVELOPING WEATHER SITUATION OVER THE NEXT FEW HOURS.

IF YOU SIGHT A FUNNEL CLOUD OR WATERSPOUT NEARBY...SEEK SAFE HARBOR AND SHELTER IN A REINFORCED BUILDING...AND REPORT THE SIGHTING TO THE NATIONAL WEATHER SERVICE...U.S. COAST GUARD...OR TO YOUR LOCAL LAW ENFORCEMENT OFFICIALS.

5) If rotation or strong wind fields are seen on high resolution radar products coinciding with a rapidly

developing cell, issue a Special Marine Warning (SMW) or a tornado warning (TOR) if landfall is anticipated.

6. Case Studies

a. Merritt Island Landspout

The synoptic scale pattern of 24 June 1993 was dominated by a light easterly surface flow with the Bermuda High located over the Carolinas. Winds were generally 15 kt (8 m/s) or less from the surface through the 500 millibar (mb) level (Fig. 2). The 2200 UTC 24 June sounding from Cape Canaveral indicated a very deep moist layer with moderate instability (Fig. 3), typical for this time of year.

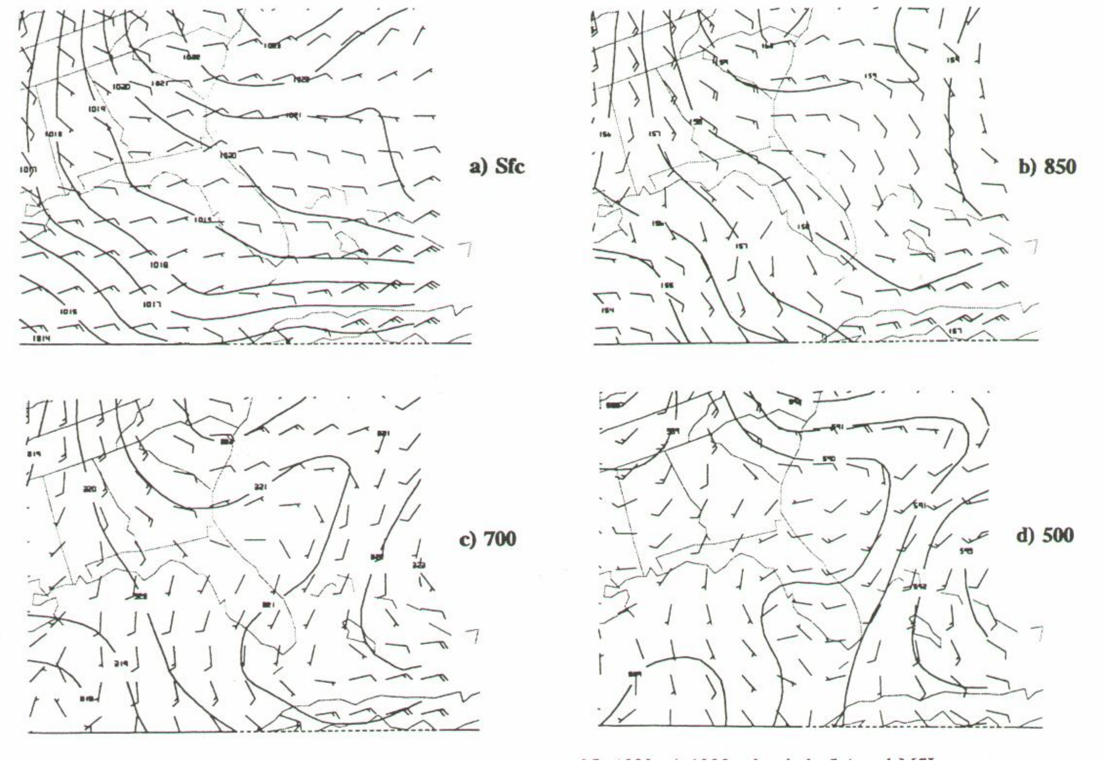


Figure 2. Synoptic scale pattern at Surface, 850, 700 and 500 mbs on 24 June 1993.

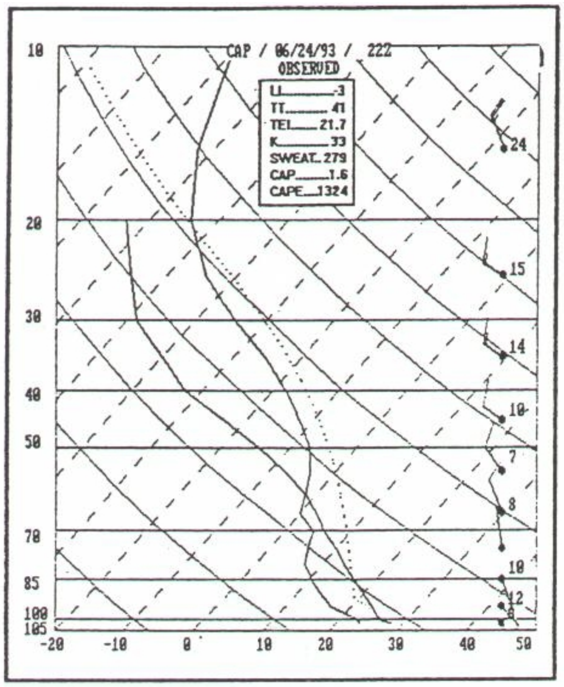


Figure 3. Cape Canaveral Sounding at 2200 UTC June 24, 1993.

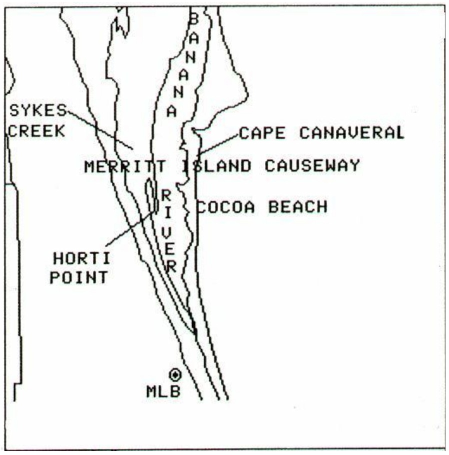


Figure 4. Merritt Island map

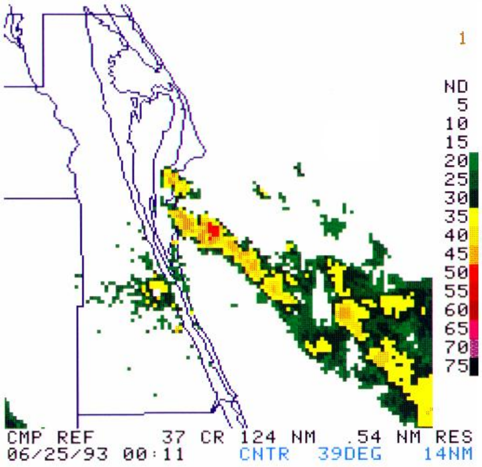


Figure 5. Comp. Ref. 0011 UTC.

Melbourne's WSR-88D indicated numerous thunderstorms offshore over the Atlantic well east of Cape Canaveral throughout the late afternoon. These storms appear to have initiated a convergence line which later extended from dissipating storms northwestward toward the coast. By early evening, showers began to build along the line toward shore with the Composite Reflectivity (CR) product indicating a narrow band of moderate reflectivity (45-49 dBZ) extending from offshore to the southern edge of Cocoa Beach ((Fig. 4) and (Fig. 5)).

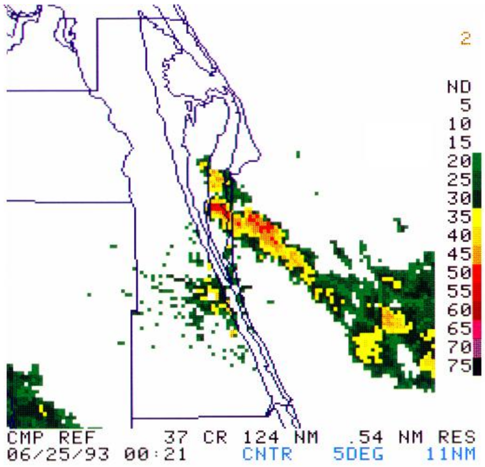


Figure 6. Comp. Ref. 0021UTC

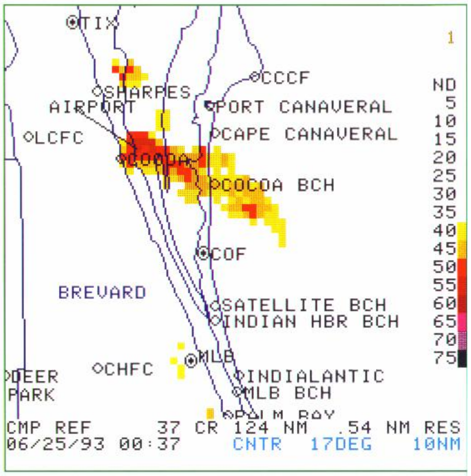


Figure 7. Comp. Ref. 0037 UTC

At 0021 UTC, a stronger echo (50-54 dBZ) covered a small area just south of Merritt Island Causeway on the east bank of the Banana River (Fig. 6). By 0031 UTC, this echo had shifted west over the central portion of the river, and by the next volume scan (0037 UTC), the northern two-thirds of Horti Point was covered by a 50-54 dBZ echo (Fig. 7). The first public report of a tornado was received around 0035 UTC. At that time the CR radar product indicated a small area of 55-59 dBZ just west of Sykes Creek. The WSR-88D Echo Top (ET) and Vertically Integrated Liquid (VIL) products likewise indicated rapid cell intensification up until the time of the event. Both the base Velocity (V) product at 1.5 deg elevation and the Storm Relative Motion (SRM) product at 0.5 deg revealed evidence of weak rotation for a few volume scans near the estimated time of the observed tornado. The indication was however, revealed by only a few pixels within a region of random inbound/outbound scatter. A post storm ground survey revealed that several light aircraft, a few trees, and weak structures were damaged along a short path on Merritt Island.

b. Cape Canaveral Waterspout

During 22 October 93, a weak front was positioned over north Florida with prefrontal conditions dominating central Florida and the adjacent coastal waters (Fig. 8). The Cape Canaveral sounding indicated the local air mass to be extremely moist and unstable at 1500 UTC (Fig. 9).

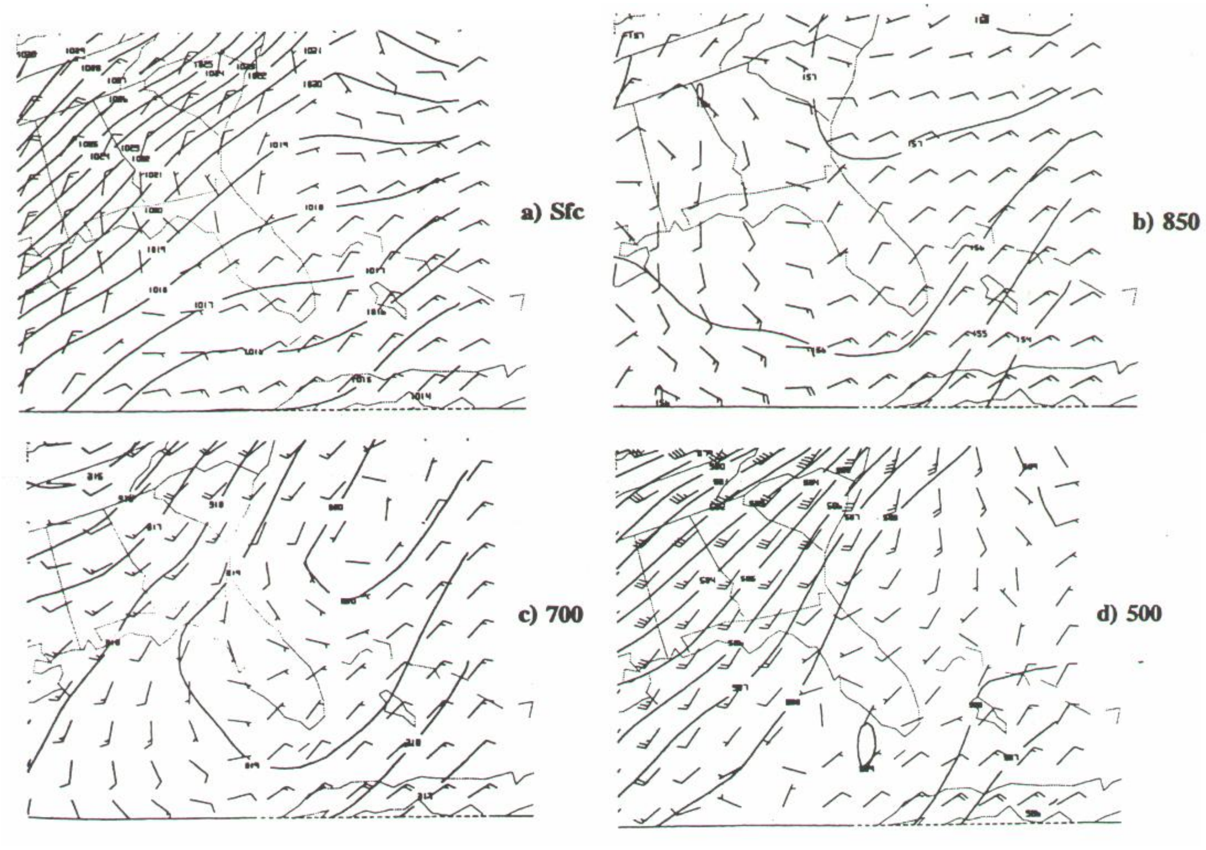


Figure 8. Synoptic scale pattern at Surface, 850, 700 and 500 mbs on 22 October 1993.

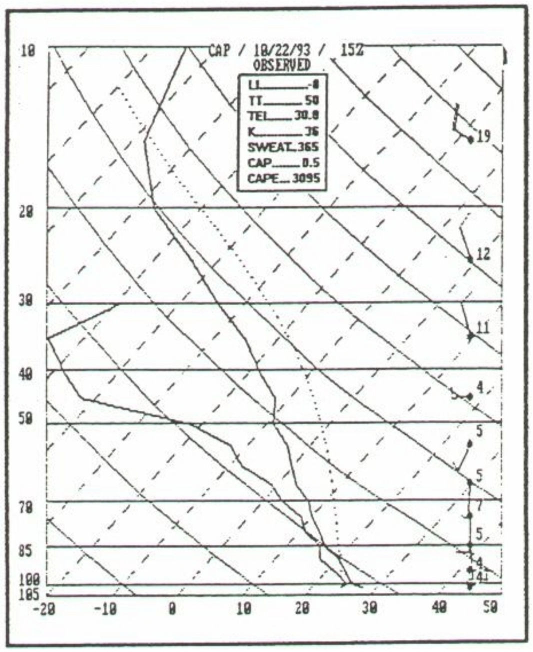


Figure 9. Cape Canaveral Sounding at 1500 UTC October 22, 1993.

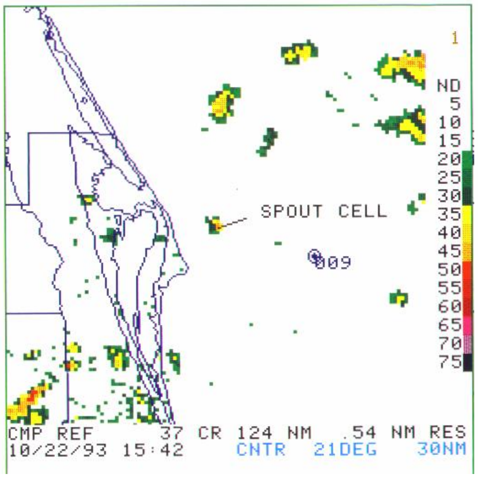


Figure 10. Comp. Ref. 1542 UTC.

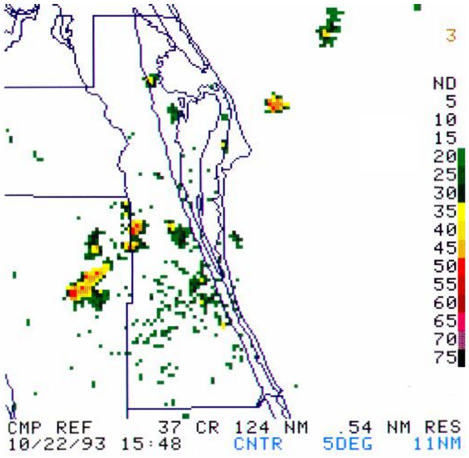


Figure 11. Comp. Ref. 1548 UTC.

During the morning hours, showers and thunderstorms were occurring over the Gulf Stream about 50 nm (93 km) east of Daytona Beach and Cape Canaveral. A persistent stationary boundary, indicated by a line of cumulus congestus, was evident in the visible satellite imagery in the lowest elevation R and CR products. This boundary extended from the area of showers and thunderstorms offshore over the Gulf Stream, southwestward to Cape Canaveral. Convective activity also began to develop over the central Florida interior as surface temperatures climbed into the mid 80's over much of the area. By 1542 UTC, showers began to develop inland along the southwestern edge of the boundary and an initial cell formed offshore, just east of Cape Canaveral (Fig. 10). By 1548 UTC, the CR product indicated 15- 54 dBZ reflectivities in this cell (Fig. 11). A SKYWARN observer reported a waterspout offshore just east of

Cape Canaveral commencing around 1552 UTC. The spout was also reported by observers at the Kennedy Space Center (KSC) soon thereafter. The volume scan at 1600 UTC indicated the CR values continued in the 50-54 dBZ range, decreasing to 45-49 dBZ by 1606 UTC ((Fig. 12) and (Fig. 13)). The spout-producing cell maintained its intensity briefly before rapidly dissipating, which was apparent in the tendencies of the ET, VIL, and CR values. Velocity products did not indicate any signs of rotation or enhanced wind fields during the event. This short lived spout did not threaten the coast or cause damage to vessels.

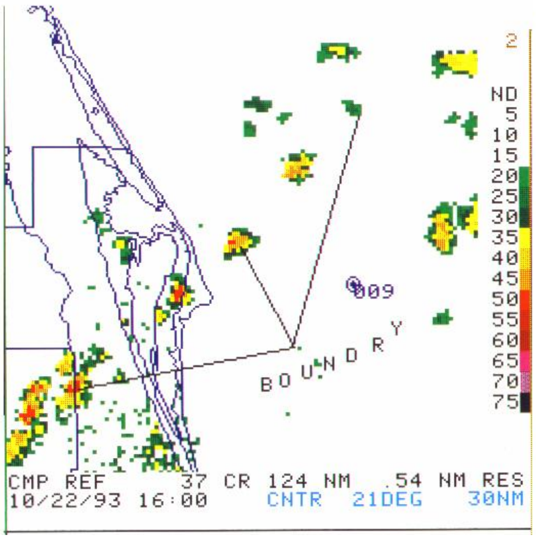


Figure 12. Comp. Ref. 1600 UTC.

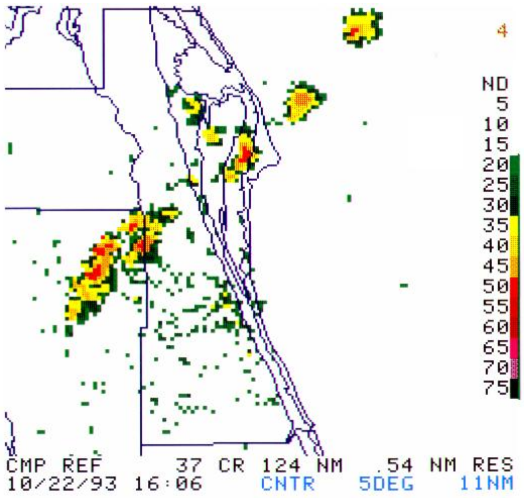


Figure 13. Comp. Ref. 1606 UTC.

7. Conclusions

In the past, waterspouts and weak coastal tornadoes (landspouts) have most often been warned for only after observational reports were received. In order to provide lead time for such events, a preliminary forecast strategy was devised for spouts. The strategy initially determines whether the synoptic and mesoscale surroundings are favorable for spout formation. If specific conditions are fulfilled, a unique RPS list may be initiated at the associated PUP to better evaluate potential spout producing cells. If cells begin to develop rapidly along/near a boundary within a climatologically favored region, an enhanced short-term forecast (NOW) or Marine Weather Statement (MWS) can be issued to possibly forewarn, or at least condition the public to possible occurrence prior to formation. The final step is to issue a Special Marine Warning (SMW) or a tornado warning (TOR) if rotation or strong wind fields are detected by radar coincident with a rapidly developing cell along the boundary, or if an observational report is received. To help demonstrate the utility of the forecast strategy, case studies of two recent spout events were reviewed. Several WSR- 88D Composite Reflectivity (CR) products were also provided which portrayed spout cells rapidly developing along boundaries.

This attempt to improve operational spout forecasting will undoubtedly require local and regional modifications over time. However, it is likely that increased forecaster skill in anticipating spout formation will lead to more timely responses, resulting in an improved service for mariners and coastal residents.

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