A WSR-88D Routine Product Set (RPS) list for waterspouts

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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 MLB) County Warning Area (CWA) includes 160 miles of coastline along the east central Florida peninsula. Within this area spouts are most common between June and September (Fig. 1). During recent years, NWS Modernization and Associated Restructuring (MAR) has lead to an improvement of local spout reporting. Figure 2 illustrates the likely correlation between the spin-up of NWSO MLB and the increase of spout (most notably waterspout) reports.

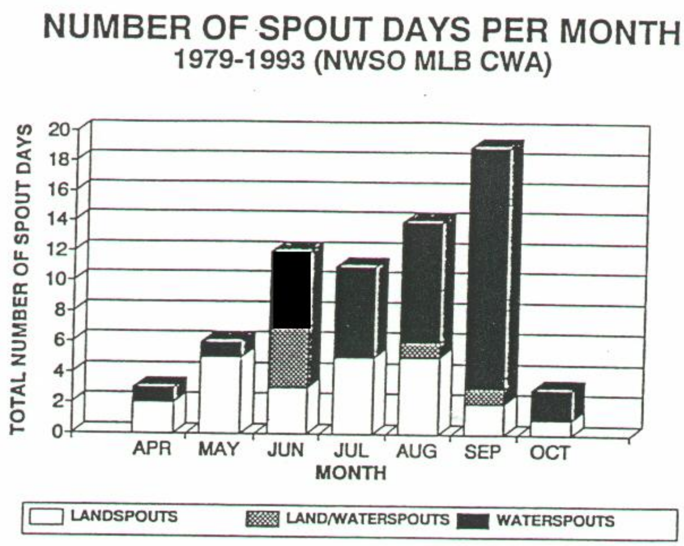

Fig. 1. Depiction of the total number of days per month with reported waterspouts and/or landspouts in the NWSO MLB CWA between 1979 and 1993. The land/waterspouts category contains cases where landspouts moved offshore or waterspouts moved onshore.

This paper will furnish specific atmospheric conditions which have been observed to precede spout generation along the east central Florida coast. Additionally, a WSR-88D Routine Product Set (RPS) list is offered for implementation once these conditions become satisfied. The usefulness of each product on the RPS list will then be highlighted along with helpful hints for WSR-88D based spout detection.

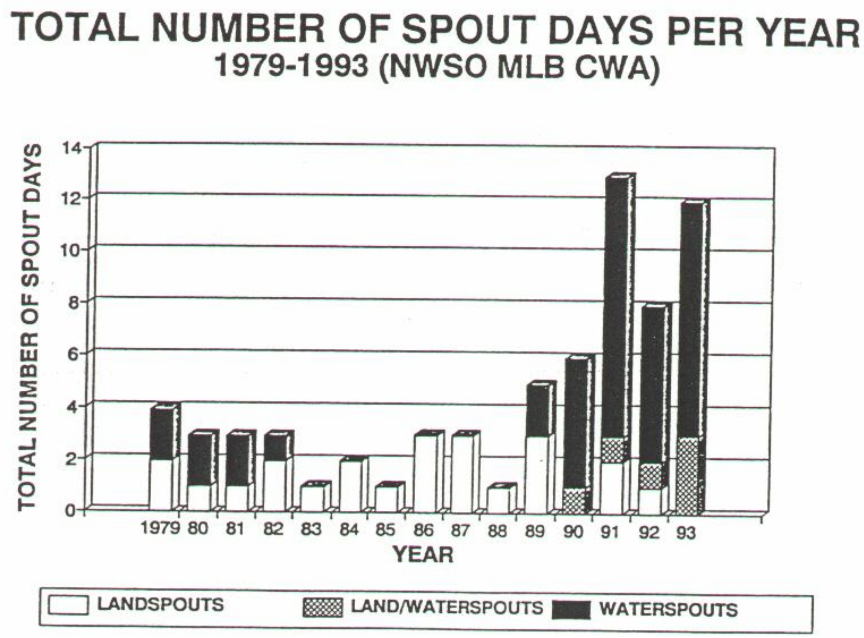

Fig. 2. Illustration of the total number of days per year with reported landspouts and/or waterspouts in the NWSO MLB coastal CWA between 1979 and 1993. Note the increase in waterspout reports beginning during 1990, the first full year of WSO MLB operation.

2. Methodology of 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. Since this inland distance roughly coincided with the width of the east central Florida coastal counties, this region, along with the near-shore coastal waters, were identified as the study domain. In order to restrict the analysis to pure "spout" days as opposed to those with stronger, dynamically driven tornado/tornadic waterspout phenomenon, days with other types of severe weather reports (wind/hail) and/or nearby tropical cyclones were removed. While this criteria eliminated all dry season and several wet season tornado days from the data base, all waterspout days were retained.

For each day between 1979 and 1992 with at least one spout report, upper air sounding data from Tampa Bay (TBW) and West Palm Beach (PBI) were examined using output from the SHARP workstation (Hart and Korotky 1991). Additionally, extensive data collection and analyses were performed on nearly all spout events reported to NWSO MLB during 1993 (see Choy and Spratt 1994). This recent undertaking resulted in the addition of Cape Canaveral (XMR) soundings and WSR- 88D products to the previous data base and allowed for development of a preliminary spout forecast strategy.

3. Spout classifications

The authors have stratified waterspouts and tornadoes into four categories based upon maximum observed rotational strengths and formation processes. The categories are summarized below from weakest to strongest rotational potential.

Type A) is characterized by development from a non-precipitating cumulus cloud (exclusively F0 on 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).

Forecasters are very familiar with the dynamic, large shear atmospheric profiles leading to type D events, which in Florida are most common during the dry season. However the rather benign, very moist, weak shear conditions often leading to type A, B, and C events can easily be overlooked. Since category B and C spouts are the most common types to affect east central Florida, conditions which have proven useful in determining their potential will be focussed on in the remainder of this paper.

4. Spout formation and preferred regions

Low level, horizontal vortices are inherent features along shear axes and convergence 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 spout vortex intensifies, 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 (Fig. 3) is quite contrary to the "spin-down" tornado formation associated with storms embedded within high shear environments (Wakimoto and Wilson 1989).

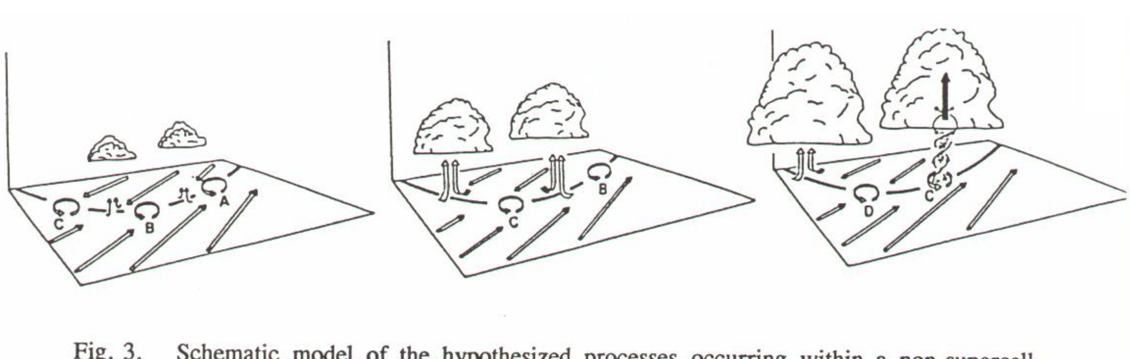

Fig. 3. Schematic model of the hypothesized processes occurring within a non-supercell tornado adapted from Wakimoto and Wilson 1989. The black line is the radar detectable convergence boundary and the letters depict low level vortices.

Unlike large, strong tornadoes, the horizontal width of most spouts often are too narrow to be resolved by WSR-88D velocity products (Wakimoto and Lew 1993). The WSR-88D Spectrum Width (SW) product may be able to partially compensate for this problem. If the spout rotation happens to occur within a single radar sample volume, the WSR-88D will average the inbound and outbound velocities resulting in a low value or perhaps not resolving the velocities at all (Fig.4). However, the SW product would likely indicate a very high value at the location of rotation since it measures the dispersion of velocities within a sample volume.

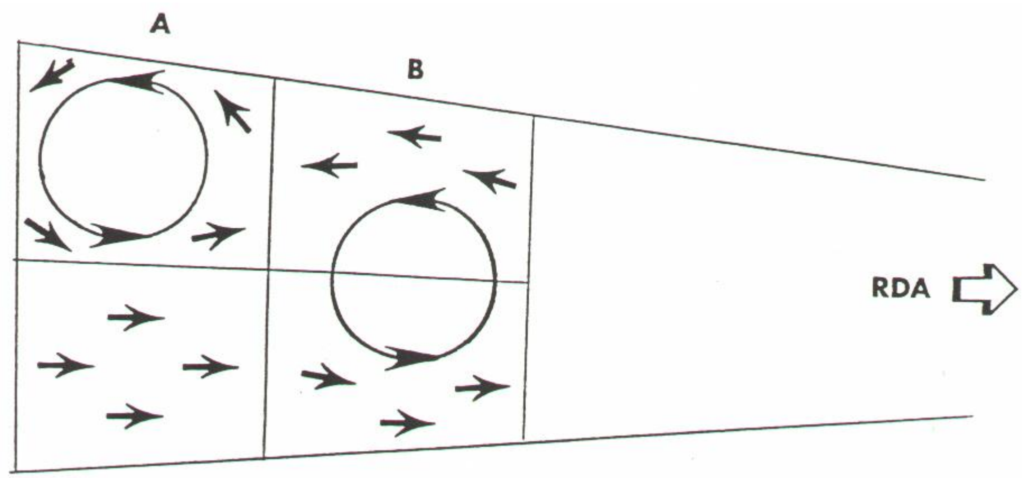

Fig. 4. Four sample volumes are represented as boxes in the diagram. The first sample volume pair, below the letter A, represents a spout circulation contained in a single sample volume. For this worse case scenario, the WSR-88D would average the inbound and outbound velocities and display a resultant very low value. However, the Spectrum Width (SW) product would likely indicate a very high value, since it measures the dispersion of velocities within a sample volume. Sample volume pair B represents the best case scenario of rotational placement with respect to the radar beam as gate to gate shear would be observed in velocity products and very low SW values would be displayed.

Even if the rotation of a particular spout is able to be resolved by radar, other characteristics make realtime detection difficult. Spouts typically occur at very low levels, especially during formation, so any velocity signature would only be apparent within close proximity to the radar site (approximately 30 NM radius) due to beam considerations. Also, the short duration of most events lessen response time for the forecaster and therefore the public. To compensate for these factors, the forecaster needs to initially identify favorable precursor conditions within a preferred area to properly assess the potential for spout formation. Subsequent procedures based on WSR-88D indications can then be used to highlight the cells most likely to produce spouts.

Certain areas seem to exist where local geographic conditions lead to a higher frequency of spouts as compared with adjacent regions. 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 (Zong and Takle 1993). Such local convergence patterns tend to initiate cells under certain synoptic regimes and may be 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 pronounced regions of localized spout development include New Orleans, Galveston, and Corpus Christi (Golden 1977).

5. Determination of favorable synoptic and mesoscale conditions

Morning upper-air sounding data should be examined for all sites in the vicinity (using SHARP workstation alphanumeric statistics) to determine if the following precursor conditions are satisfied:

WIND

Boundary layer (0-1.0 kft): 8 knots or less
975-700 mbs (1.5-10.0 kft): all levels 16 knots or less
699-600 mbs (10.5-14.0 kft): all levels 20 knots or less
599-500 mbs (14.5-18.0 kft): all levels 22 knots or less

MOISTURE

Precipitable Water value: 1.7 inches or more.

Fulfillment of all criteria indicate a potential for spout formation, given that certain mesoscale conditions, addressed below, also become ideal. Marginal agreement with the conditions indicate a moderately favorable environment, while strong winds/large shear and/or deficient moisture signify spouts will be unlikely. In general, the weaker the winds are, and deeper the moisture is, in lower and mid levels, the higher the potential is for spouts.

If any of the area soundings indicate a potential or marginal potential for spouts, attention needs to shift to boundary detection. Satellite loops and detailed surface analyses should be examined for hints of synoptic scale fronts, troughs or wind shift lines. Spouts often form near/along dissipating frontal boundaries which can usually be located only through continuity from previously known positions. In the absence of synoptic boundaries, WSR-88D products and high resolution satellite imagery should be scrutinized for the presence of mesoscale boundaries, often noted as persistent cumulus congestus lines.

Any distinguishable boundaries should be interrogated frequently by radar for convective development in their vicinity. If cells begin to develop along/near the boundary, it is suggested that the current RPS list be replaced with a list similar to the one provided in Table 1. If several boundaries are observed, convective development near the location where the boundaries intersect is especially prone to spout formation. If an area of interest appears to be boundary free, spout development will be less likely. However, proceed to use all available data sources to search for the formation/identification of a boundary.

LN	PROD NAME	DTA LVL	RES	SLICE	LN	PROD NAME	DTA 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	8	.13	0.5
4	R	16	.54	3.4	14	SW	8	.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			0.5
9	V	16	.13	2.4	19	SRM			1.5
10	V	16	.13	3.4	20	VIL			

Table 1. This WSR-88D Routine Product Set (RPS) list should be used when atmospheric conditions are deemed favorable for spouts. The list contains many high resolution, low elevation angle products for analyzing potential spout cells close to the radar site.

Although a large portion of the Florida wet season days will exhibit favorable synoptic scale conditions for spouts, rapid convective development over preferred areas in close proximity to a boundary will occur much less frequently.

Of the sixty reported spout days across east central Florida between 1979 and 1993, forty-nine (82 percent) satisfied all of the wind and moisture criteria stated above. Hagemeyer and Schmocker (1991), using different criteria than the present study, investigated 11 recent tornadoes (one of which was included in this study) which occurred across east central Florida during the wet season. They found that the average shear between the maximum upper-tropospheric wind (350-200 mb) and the 850 mb wind was significantly larger for tornadoes producing F1 damage than for those resulting in F0 damage (22 knots versus 52 knots). The same relationship was evident in our data base, with waterspout events occurring during much weaker shear than F0-F1 spouts (10 knots versus 18 knots). These findings imply that while weak spouts are most likely during days with light winds throughout much of the troposphere, stronger spouts may be possible with even a modest increase in deep layer shear.

6. WSR-88D spout RPS list and detection tips

A 20 product RPS list (Table 1) has been developed to aid in the interrogation of potential spout producing cells and/or help to validate spout observational reports. Each product was carefully selected with emphasis of the lower elevation angles where the greatest chance of spout detection exists. Evaluation of these high resolution products, along with the techniques described below, should provide the best possible means for identification of potential spout producing cells.

Reflectivity (R): Six base R products and one Composite Reflectivity (CR) product have been listed. The 0.5 and 1.5 deg elevation angle R products, and the CR product are extremely useful in the detection of low level boundaries (sea breeze fronts, outflow boundaries, etc.). When using these products in conjunction with the "combine up" function and filtering the lowest 1 or 2 R levels, boundaries become enhanced and more easily recognizable. These R products can be combined with higher elevation products to ascertain the developmental stage of showers and thunderstorms. It is suggested that the radar operator also create Reflectivity Cross Sections (RCS) to examine vertical development. Production of a CR time lapse will help to highlight propagation and movement of convective cells and boundaries.

Velocity (V): Several base V products have been chosen in an attempt to detect rotation within developing cells along boundaries. Although detection of a distinct rotational velocity signature is unlikely in most instances, such a signature can occasionally be seen. Another use for V products involves tracking enhanced wind fields associated with a cell once an observed spout is reported. Velocity Cross Sections (VCS) should also be requested to further interrogate suspect cells. Since spouts are relatively low level phenomenon with small rotational scales, the highest resolution and lowest elevation products (0.13 NM and 0.27 NM; 0.5 and 1.5 deg) perform best to detect enhanced wind fields and/or rotation. Of course, the closer the spout is to the WSR-88D, the better the chance is for detecting any type of V signature.

Spectrum Width (SW): SW has frequently been an under utilized product at most WSR-88 sites, however, it appears to be helpful as a spout indicator. The scale of rotation in a spout, or spout cell, is often much smaller than the detectable resolution of the radar. If rotation is contained within a single sample volume, the inbound and outbound velocities will cancel or be unresolvable. When this occurs, a high SW value would be expected in that pixel location.

Echo Top (ET): The ET product is extremely useful in determining storms which are increasing rapidly in vertical development. By having an ET time lapse, the radar operator can track developing storms and assess the spout potential. A rapid increasing trend over spout prone areas, rather than the value itself seems useful in highlighting cells with high spout potential.

VAD Wind Profile (VWP): The VWP is very useful in detecting changes in wind direction and speed in the lower levels. Continuing weak wind fields well after the latest sounding or detection of a local boundary passage can be confirmed by VWP's.

Storm Relative velocity Map (SRM): SRM products for the lowest two elevation angles were chosen to again attempt to detect rotation. Due to the weak wind fields in the lower and mid levels which are conducive to spout formation, storm motion will be relatively slow. It is vital to note that potential spout cells often move in various directions relative to the WSR-88D default storm motion due to their limited vertical extent. When using SRM products, be sure to input individual storm motions for cells of interest if they differ from the default value.

Vertically Integrated Liquid (VIL): It has been noticed that spouts frequently develop as VIL values are increasing. This upward trend corresponds well with ET, R, CR and RCS product indications. The VIL product should be inserted in the third time lapse to help recognize cells which pose an increased threat of spout production.

7. Conclusion

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 WSR-88D to better evaluate potential spout producing cells. If cells begin to develop rapidly along/near a boundary within a predetermined preferred region, a Special Weather Statement (SPS) or Marine Weather Statement (MWS) can be issued to apprise the public of an increasing potential for spouts.

This first WSR-88D based attempt to improve operational spout forecasting will undoubtedly require local and regional modifications over time. However, it is surmised that increased forecaster awareness of the spout issue will lead to more timely responses, resulting in improved services for the public's welfare.

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