NASA Contractor Report CR-207904

# WSR-88D Cell Trends Final Report

Prepared By:
Applied Meteorology Unit

Prepared for:
NASA, Kennedy Space Center
Under Contract NAS10-96108

NASA
National Aeronautics and
Space Administration

Office of Management

Scientific and Technical
Information Program

1998

**Attributes and Acknowledgments:**

NASA/KSC POC:
Dr. Frank Merceret

**Applied Meteorology Unit (AMU)**

Mark M. Wheeler, author

# Table of Contents

# Table of Contents
**(continued)**

# List of Illustrations

# List of Tables

# Executive Summary

The purpose of this report is to document the Applied Meteorology Unit's (AMU) evaluation of the Cell Trends display as a tool for radar operators to use in their evaluation of storm cell strength. The objective of the evaluation is to assess the utility of the WSR-88D graphical Cell Trends display for local radar cell interpretation in support of the 45th Weather Squadron (45 WS), Spaceflight Meteorology Group (SMG), and National Weather Service (NWS) Melbourne (MLB) operational requirements.

The evaluation guidelines, along with the selected case days, were determined by consensus among the 45 WS, SMG, NWS MLB, and AMU. Four case days for a total of 52 cells were selected for evaluation: 29 March and 23 April 1997 (cold season cases) and 11 July 1995 and 13 August 1996 (warm season cases). The WSR-88D (Level II) base data from the NWS MLB was used along with WATADS (WSR-88D Algorithm Testing and Display) Build 9.0 from the National Severe Storm Laboratory (NSSL) as the analysis tool. WATADS allows for the replay of historical data and has all the algorithms used in the WSR-88D Build 9.0 operational system so it closely matches the WSR-88D Principal User Processor (PUP) product output.

The analysis procedure was to identify each cell and track the maximum reflectivity, height of maximum reflectivity, storm top, storm base, hail and severe hail probability, cell-based Vertically Integrated Liquid (VIL) and core aspect ratio using WATADS cell trends information. One problem noted in the analysis phase was that the Storm Cell Identification and Tracking (SCIT) algorithm had a difficult time tracking the small cells associated with the Florida weather regimes. The analysis indicated numerous occasions when a cell track would end or an existing cell would be given a new ID in the middle of its life cycle.

Analysis of the four case days has shown that most cells associated with significant weather do show a trend in certain cell attributes (a signature). Hail was classified as an event if there was observed or reported .50 inch or greater in the vicinity of a cell. Wind cases were classified as an event if there was reported wind damage or if a microburst signature (gust GT 35 kt) was observed on CCAS wind tower network. Cells that exhibit a rapid increase or decrease in their height of maximum reflectivity and cell-based VIL over the same time period can be associated with significant weather. Those cells that do not show these changes are typically not associated with significant weather events. Other Cell Trends attributes did not show any useful signatures. As an example, the Hail Probability 100% threshold was indicated on 90% (47/52) of all storms.

This investigation has found that most cells, which produce large hail or damaging microburst events, have discernable Cell Trends signatures. Forecasters should monitor the PUP's Cell Trends display for cells that show rapid (1 scan) changes in both the height of maximum reflectivity and cell-based VIL. For microburst development, there is generally

- A 8000 ft or greater decrease in the height of maximum reflectivity (initially at 18000 ft or greater) **and**
- A decrease in cell-based VIL by 10 kg/m$^2$ or greater prior to the wind event.

For the hail events there is generally a rapid (1 volume scan)

- Increase in the height of maximum reflectivity by 8000 ft or greater to 18000 ft or greater **and**
- The cell-based VIL increased by 10 kg/m$^2$ or greater prior to the hail events.

It is important to note that this is a very limited data set (four case days). Fifty-two (52) storm cells were analyzed during those four days. The above mentioned trends increase in the two cell attributes for hail events (reported ½ inch or greater) and decrease in the two cell attributes for wind events (observed or

reported wind damage) were noted in most of the cells. Lead times ranged from 5 to 20 minutes. The probability of detection was 88% for both event types. The False Alarm Rate (FAR) was 36% for hail events and a respectable 25% for microburst events. In addition the Heidke Skill Score (HSS) is 0.65 for hail events and 0.67 for microburst events. For a random forecast, the HSS is 0 and for a perfect forecast, the score is 1.

Radar operators need to monitor storm cells and watch for trends that change quickly. Any quick change in a cell's structure is usually a precursor that a cell characteristic has changed or is changing. These changes can be associated with the development or decay of a severe storm. Using the WSR-88D PUP Cell Trends display can help the forecaster in highlighting trends in a cell's attributes of: maximum reflectivity, height of maximum reflectivity, storm top, storm base, hail and severe hail probability, and cell-based VIL. The AMU found that two of the important attributes to monitor are height of the maximum reflectivity and cell-based VIL. By monitoring these two attributes a forecaster can have a better advantage for determining if a storm cell is becoming severe and may produce a microburst or large hail.

# 1.0 Introduction

## 1.1 Applied Meteorology Unit Tasking

Under the Instrumentation and Measurement Systems Evaluation Task (003), Subtask 4, the Applied Meteorology Unit (AMU) evaluated the use of Cell Trends as a tool for operators to use in their evaluation of storm cell strength. The goal of the AMU's analysis was to determine if there were any thresholds or signatures in the Weather Surveillance Radar 1988 Doppler (WSR-88D) NEXRAD Cell Trends display that would help forecast storm intensity. Consensus between the 45th Weather Squadron (45 WS), Spaceflight Meteorology Group (SMG), and the National Weather Service Melbourne (NWS MLB) determined the evaluation methodology and the case day selections. Four cases were selected for evaluation, two (29 March 1997 and 23 April 1997) cold season cases and two (11 July 1995 and 13 August 1996) warm season cases.

## 1.2 Purpose and Organization of the Report

This report documents the results of the AMU's evaluation of the WSR-88D Cell Trend attributes. Section 2 describes the WSR-88D Build 9.0 Cell Trends display, Section 3 details the data collection and analysis process, Section 4 describes the results of the analysis, and a summary and list of recommendations are included in Section 5.

# 2.0 WSR-88D Cell Trends Background

WSR-88D Build 9.0 added several new capabilities, products, and algorithms to the WSR-88D Principal User Processor (PUP) display. The AMU was tasked to analyze one of the new displays, the Cell Trends display. Cell Trends is a user selectable product that the radar operator is able to choose from the graphics tablet. It uses the new Storm Cell Identification and Tracking (SCIT) algorithm which is used to identify, track, and forecast the movement of storm cells.

## 2.1 Cell Trends Display

Cell Trends is a PUP graphical display that provides users with a volume scan history (up to 10 previous scans) of important parameters for any user-selected algorithm-identified storm cell. Cell Trends is not a product, but is a display which is derived "in real-time" from information that is stored in the Storm Structure (SS) alphanumeric product. As a display an operator must wait for the SS product to arrive in their PUP database prior to displaying Cell Trends on a selected cell. The SS data is derived from the Build 9.0 SCIT algorithm. The Cell Trends display can assist forecasters by illustrating a history of important radar-derived parameters. In particular, the display can help in the assessment of a particular storm's potential severity. A large amount of information about an individual cell is displayed in a single easy-to-interpret display (OSF 1996).

The PUP Cell Trends display consists of four graphical illustrations of the history of the following parameters:

- Upper Left: Cell Top, Cell Base, Height of Centroid, and Height of Maximum Reflectivity
- Upper Right: Probability of Hail (POH), Probability of Severe Hail (POSH)
- Lower Left: Cell-based VIL
- Lower Right: Maximum Reflectivity

The right side of the display (the Status and Annotations area) provides the Cell ID; the AZRAN (AZmiuth and RANge), a small graphical plot of cell location in relation to the Radar Data Acquisition (RDA), and a list of volume scan times included in the trend data. Times listed in gray mean the cell did not exist at that time (Figure 1).

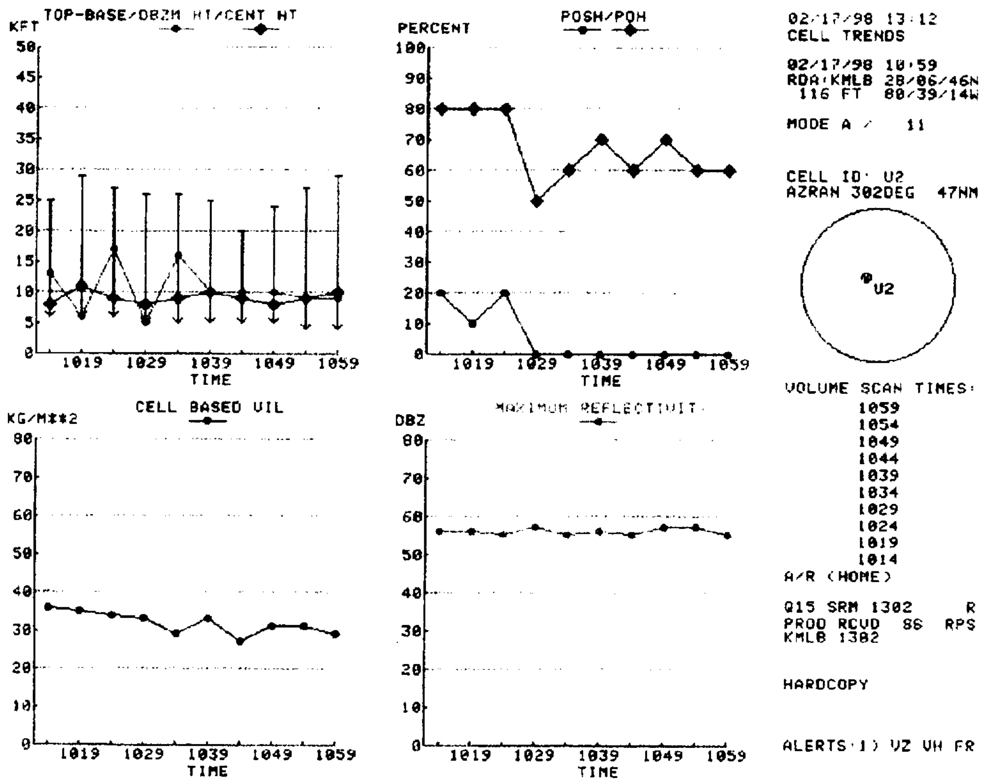



Figure 1. Example of the four-panel WSR-88D PUP Cell Trends Display.

Cell Top/Base are used in reference to the height (in 1000s feet, Kft) of the highest/lowest cell components detected. Cell bases or tops which are found on the lowest or highest elevation slices are indicated on the height line with a "v" or "^", respectively. Centroid Height is the height in Kft of the 3-dimensionial center of mass of the cell. Height of Maximum Reflectivity is the height of the beam centerpoint in Kft of the component which has the highest reflectivity for the cell. Cell-based VIL is the integrated water computed from the maximum reflectivity of all cell components. Probability of Hail is defined as the probability of hail of any size, and Probability of Severe Hail is defined as the probability of hail greater than or equal to 3/4 inch. Maximum reflectivity is measured from zero to 80 dBZ.

### 2.2 Cell-based VIL Display

One of the essential components of the Cell Trends display is the Cell-based VIL. It is calculated for each cell by vertically integrating the maximum reflectivity values of the storm cell centroids at each elevation angle (Figure 2). This is a different calculation than the gridded VIL product, which integrates the values above a fixed surface point.

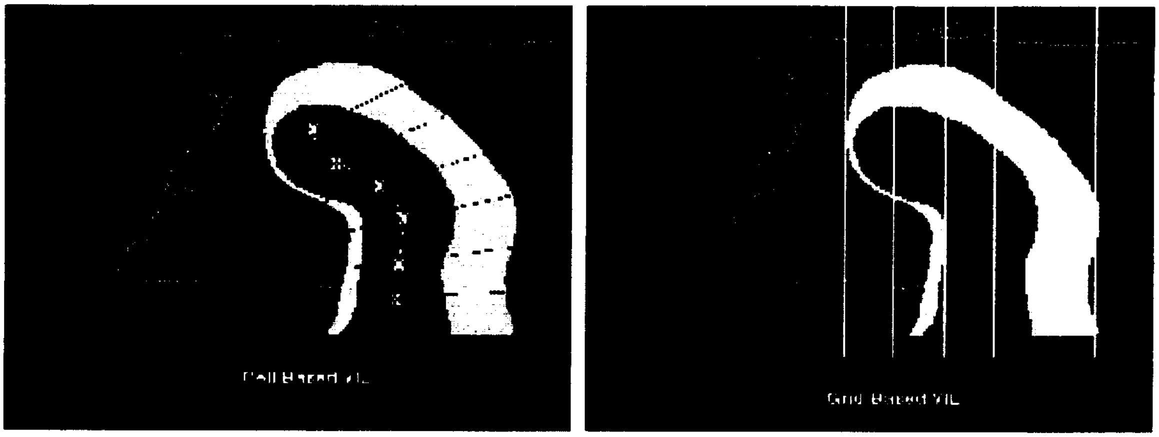


Figure 2. Comparison of cell-based VIL (left) to gridded - based VIL (right).

Although the new SCIT algorithm has demonstrated improvement in the identification of cells in close proximity to the radar, errors may still occur in the cell attributes if a cell is too close to the radar and/or if its reflectivity core is not in the lowest elevation angle. The Storm Cell Centroids subfunction compares the proximity of the center of each cell with those in adjacent elevation scans and vertically correlates each component. If at least two components are vertically correlated, a cell is identified and the cell-based VIL attributes are calculated (Johnson 1998).

Prior to the release of Build 9.0, a single-reflectivity threshold of 30 dBZ was used to identify storms. Therefore, large areas of reflectivity greater than 30 dBZ (i.e., squall lines, Mesoscale Convective Complexes, tropical storms rain bands) were identified as one storm. This resulted in poor storm tracking and forecast performance. The new SCIT algorithm in Build 9.0 uses seven thresholds (30, 35, 40, 45, 50, 55, and 60 dBZ) and shows an improvement in the identification, tracking, and forecast movement of individual cells in lines or clusters.

The accuracy of cell-based VIL, Cell Top and Base, Height of Maximum Reflectivity, etc. can be adversely affected depending on the scan strategy. Large errors can occur in attributes of cells close to the RDA, especially in Volume Coverage Pattern (VCP) 21, where there are large gaps between the beams at higher elevation angles, and in cells within the cone of silence. These gaps are significant between the radar and the CCAS area (Taylor 1994). The limitations on these attributes should be considered anytime the operator uses the PUP Cell Trends display.

### 2.3 Cell Trends Request

The Cell Trends display is generated at the PUP and it uses data from the SS product stored in the PUP database. Since Cell Trends is not a product, the alphanumeric keyboard cannot be used to display Cell Trends. Radar operators who anticipate frequently using the Cell Trends display should add the SS alphanumeric product to the current Routine Product Set (RPS). One-time requests can also be made for the SS. Once the SS product is received at the PUP (toward the end of the scan as it is a derived product), the Cell Trends display can be used. However, for remote users this may not be very timely. The SS product can be archived. Cell Trends information can be displayed later by retrieving the SS product from the archive.

Cell Trends can only be displayed using the CELL TRENDS box on the Graphic Tablet, which is located in the OVERLAYS section, colored blue. The operator must first click the puck button within four km (2.2 nm) of an algorithm identified storm in any geographic product, then select the CELL TRENDS box for the Cell Trends to be displayed on either PUP monitor. If two cells are very close, it will display the Cell Trends of the closest cell to where the operator places the cross hairs of the puck.

### 2.4 Cell Trends Limitations

Cell Trends information is dependent on the scanning strategy used to sample the environment. The VCP selected by the operator can have a noticeable impact on the Cell Trends display, especially on trends which use the altitude of a parameter. It is even possible that the display will indicate an increasing or decreasing trend in cell intensity when the cell's intensity is not changing. These false trends may be due to data gaps between beams of different elevation angles. VCP 11, which has fewer gaps between beams, should be used whenever Cell Trends will be used. If the Cell Trends display is needed on particular day, users should coordinate with the RDA operator to reconfigure the radar to use VCP 11. NWS MLB has a local policy to use VCP 11 during convective weather.

Radar users will notice more variability of the Maximum dBZ Height, Centroid Height, and Altitude of Cell Top and Base using VCP 21 as compared to VCP 11, especially for cells within 60 nm. Inaccuracies in cell attributes often occur when cells are in close proximity to the radar. Trends of cell attributes may be misleading anytime cells are within 20 nm of the RDA.

# 3.0 Data Collection and Analysis Procedures

The goal of the AMU's analysis was to determine if there were any thresholds or signatures in the WSR-88D Cell Trends display that would help indicate storm intensity. Each cell's attributes of Maximum Reflectivity, Height of Maximum Reflectivity, Storm Top, Storm Base, Hail Probability, Severe Hail Probability, and Cell-based VIL were recorded during the cell's life cycle. This was accomplished by analyzing each cell's attributes during its life cycle during the four pre-selected case days. The WSR-88D (Level II) base data from the NWS in Melbourne, Florida was used. WATADS (WSR-88D Algorithm Testing and Display) from the National Severe Storm Laboratory (NSSL) was utilized as an analysis tool in this evaluation because of its post-processing capability of Level II data and its superior data analysis and display capabilities and products. In addition, all of the WSR-88D Build 9.0 algorithms are integrated into the software so it closely matches the WSR-88D PUP product output.

The four selected case days were chosen by consensus from the SMG, 45 WS and the NWS MLB organizations. The study days were 11 July 1995, 13 August 1996, 29 March 1997, and 23 April 1997.

The analysis procedure was to identify all cells and track the maximum reflectivity, height of maximum reflectivity, storm top, storm base, hail and severe hail probability, cell-based VIL and core aspect ratio in the Central Florida area (Figure 3) using WATADS Build 9.0 cell trends information. Early in the analysis period (April - May 1997) there were some problems noted in the WATADS software but NSSL issued an updated release. Therefore, all of the previously analyzed data had to be re-analyzed. This was done to make sure the same algorithms were used for each case day. The SCIT algorithm had a difficult time tracking the small cells associated with the Florida weather regimes. The analysis indicated numerous occasions when a cell track would end or an existing cell would be given a new ID in the middle of its life cycle. This created problems tracking cell attributes and analyzing trends of particular cells.

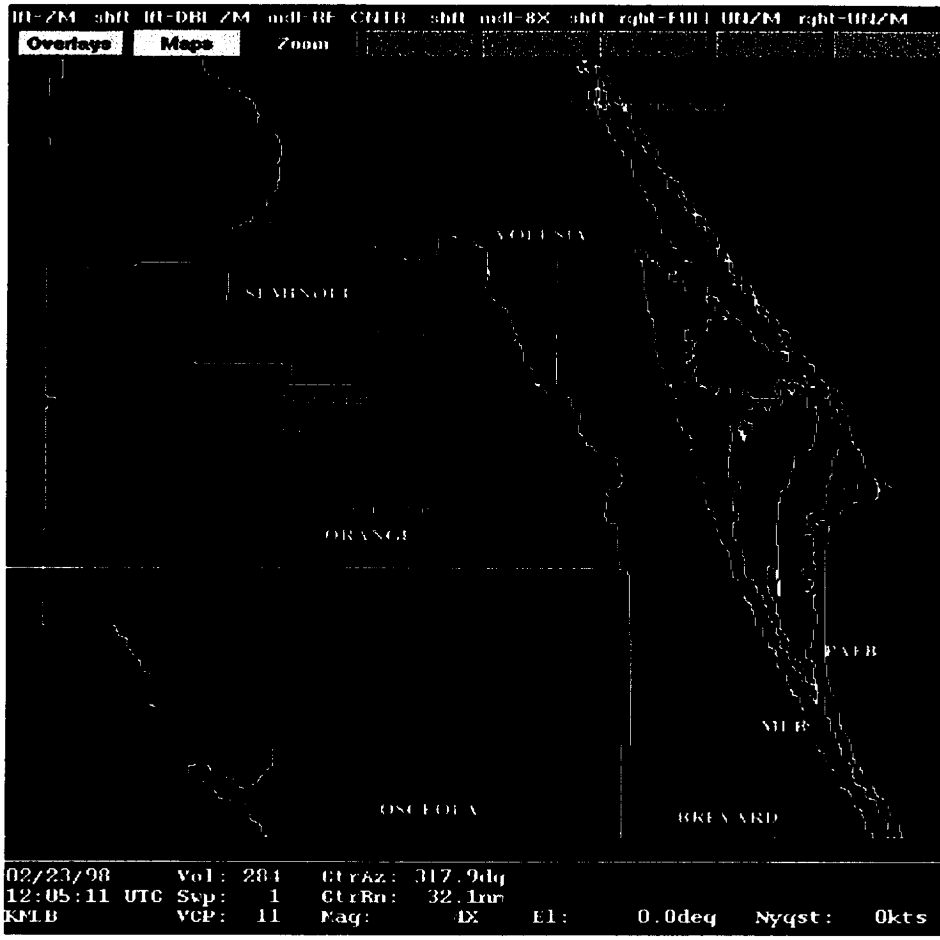



Figure 3. Map of central Florida with counties and essential cities identified.

# 4.0 Individual Case Study Analysis

Four case study days with a total of 52 cells were chosen for analysis. These case study days included two warm season case study days, 11 July 1995 and 13 August 1996, and two cool season case study days, 29 March 1997 and 23 April 1997.

## 4.1 11 July 1995

### 4.1.1 Weather Discussion

The weather pattern on 11 July 1995 was typical for an east-central Florida summer day. High pressure dominated with weak southwesterly flow over the region. This flow pattern is favorable for the development of thunderstorms over the region. Interactions between the east coast sea breeze boundary and horizontal convective rolls (HCRs) would also play a role in the development of thunderstorms. An interesting feature developed by late morning when a wild fire developed in east Orange County. This fire would partially contribute to storm development over the Cape Canaveral Air Station (CCAS) in the afternoon.

By afternoon, the wild fire in east Orange County had produced a smoke plume that drifted to the east-northeast. An outflow boundary from some cells to the southwest collided with this smoke plume and rapid storm development occurred. As the cells developed, their movement was to the east toward CCAS. Another set of cells developed to the north in Volusia County and started propagating to the south along the

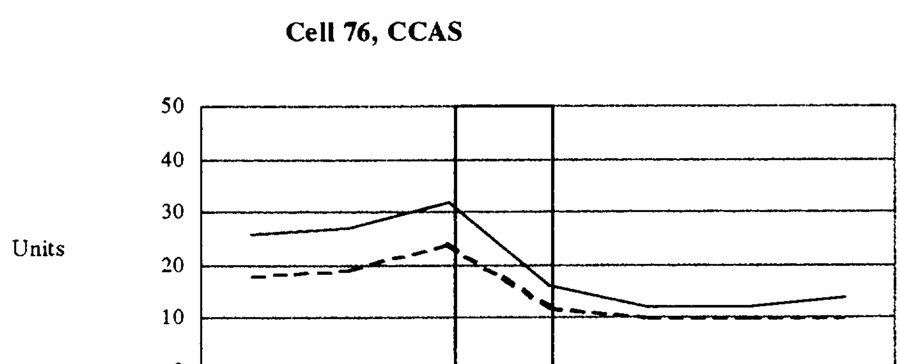
sea breeze boundary. Eventually the two sets of cells would converge over the northern portion of CCAS. As this occurred a short-lived F0 tornado was reported near Complex 40 and a microburst was reported over CCAS. Other significant weather reports included .75" hail in Osceola County, Rockledge, and Palm Bay (Brevard County).

### 4.1.2 Analysis of Data

Nineteen cells were tracked from 1700 to 2000 UTC on 11 July 1995. Cell trends were monitored for each of the 19 cells. Of those 19 cells, eight could be associated with significant weather events. Hail was classified as an event if there was observed or reported .50 inch or greater in the vicinity of a cell. Wind cases were classified as an event if there was reported wind damage or if a microburst signature (gust GT 35 kt) was observed on CCAS wind tower network. There were three reported hail events and five reported wind events. There was no apparent velocity signature (i.e. tornado or MESO) for the F0 tornado over Complex 40. This is typical of short-lived waterspout/landspout 'tornadoes' during Florida's wet season. However, the Cell Trends display for this cell did feature a trend indicative of a possible microburst. During the time period from 1845 - 1850 UTC, Cell 76 (Figure 4) was characterized by

- A 8000 ft or greater decrease in the height of the maximum reflectivity (initially at 18000 ft or greater) and
- A decrease in the cell-based VIL by 10 $kg/m^2$ or greater.

A 53 kt microburst was reported over CCAS at 1900 UTC, 10 minutes after the signature was noted on the Cell Trends display. The same trends were noted in four other cells on 11 July 1995. Microburst wind events (rapid increase/change of 35 kt or greater, noted by a tower or 2 within 4 miles of each other) were noted in the CCAS wind tower network 5 to 20 minutes after the Cell Trend signatures. Though this lead-time is less than 45 WS requirements, it is substantial for warning on convective cells.




| | 1835 | 1840 | 1845 | 1850 | 1855 | 1900 | 1905 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 18 | 19 | 24 | 12 | 10 | 10 | 10 |
| ——— Cell-based VIL (kg/m**2) | 26 | 27 | 32 | 16 | 12 | 12 | 14 |

Time (UTC)

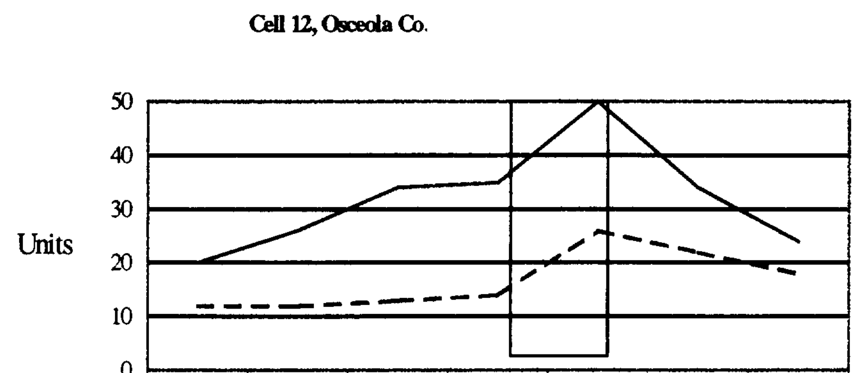
Figure 4. Cell trend information on the height of the maximum reflectivity and cell-based VIL for a storm cell that produced a microburst at 1905 UTC on 11 July 1995. Highlighted are the rapid changes in the cell attributes between 1845 - 1850 UTC.

For the hail events, a Cell Trends signature was observed on two variables: height of the maximum reflectivity and cell-based VIL. The observed signature is characterized by

- The height of the maximum reflectivity increased by 8000 ft or greater to 18000 ft or greater and

- The cell-based VIL increased by 10 kg/m$^2$ or greater prior to the hail events.

Figure 5 depicts the trends for a cell observed in Osceola County on 11 July 1995. A rapid change in both the height of the maximum reflectivity and cell-based VIL can be observed between 1822 and 1827 UTC. Hail was reported near this cell at 1835 UTC.



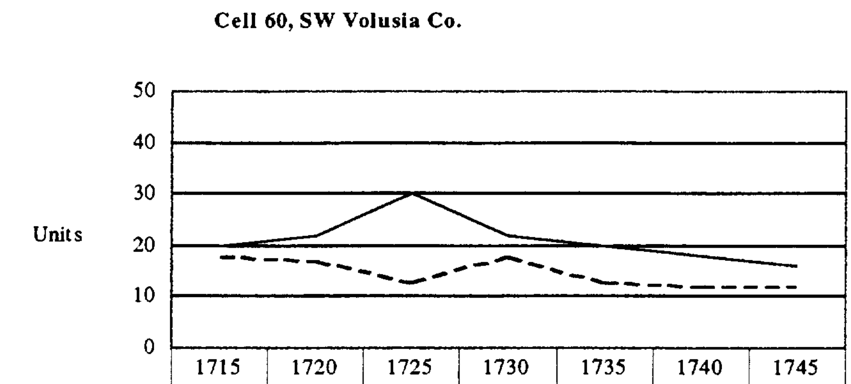

| | 1807 | 1812 | 1817 | 1822 | 1827 | 1832 | 1837 |
|---|---|---|---|---|---|---|---|
| – – – Hgt Max Reflectivity (Kft) | 12 | 12 | 13 | 14 | 26 | 22 | 18 |
| ——— Cell-based VIL (kg/m**2) | 20 | 26 | 34 | 35 | 50 | 34 | 24 |

Time (UTC)

Figure 5. Cell trend information on the height of the maximum reflectivity and cell-based VIL for a storm observed in Osceola County (Deer Park) on 11 July 1995. Hail was reported at 1835 UTC. Highlighted are the rapid changes in the cell attributes between 1822 - 1827 UTC.

Hail was also reported from storm cells in Rockledge and Palm Bay. The aforementioned signature was noted from both cells except the Palm Bay cell. This cell may have been too close to the WSR-88D to detect the hail signature.

Figure 5 displays the trend analysis for a typical non-severe (no observed or reported damage due to wind or hail) storm cell observed on 11 July 1995 in SW Volusia County. None of the above mentioned trends are observed in the height of the maximum reflectivity and cell-based VIL. The cell-based VIL does show some fluctuation but the height of the maximum reflectivity remains fairly flat. This type of pattern (i.e. one cell attribute displayed trend but the other did not) was observed on many of the cells on 11 July 1995.




| Time (UTC) | 1715 | 1720 | 1725 | 1730 | 1735 | 1740 | 1745 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 18 | 17 | 13 | 18 | 13 | 12 | 12 |
| ——— Cell-based VIL (kg/m**2) | 20 | 22 | 30 | 22 | 20 | 18 | 16 |

Figure 6. Height of the maximum reflectivity and cell-based VIL trend information on a typical non-significant cell on 11 July 1995.

On 11 July 1995, 19 storm cells were tracked. Of the 19 cases, four were classified as hail events and five as wind events. Eight of the nine cells showed a detectable trend (See Attachment 1 for all cell attributes). One hail event in Palm Bay did not show this trend. The Palm Bay storm was probably too close to the WSR-88D radar to get a good vertical analyses of the cell. In addition, five storm cells could not be tracked for analysis because their tracks were too short (5 - 10 minutes) or they were not assigned a cell ID by the SCIT algorithm. The Cell Trends hail probability showed very poor results as an indicator with 15 out of 19 storm cells indicating a 100% chance of hail.

## 4.2 13 August 1996

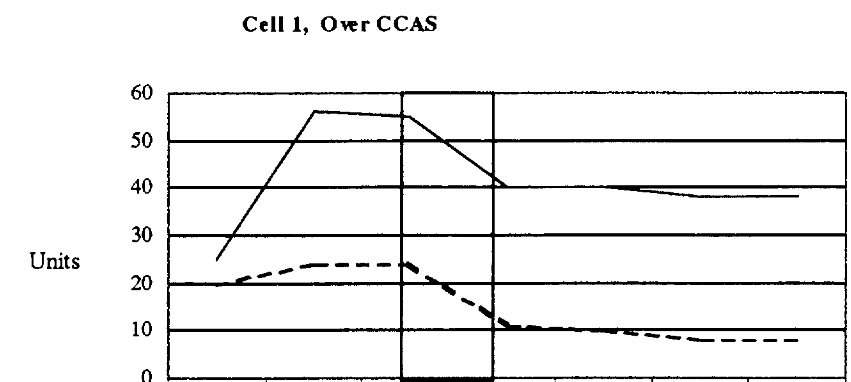
### 4.2.1 Weather Discussion

A weak frontal boundary was located well to the north of central Florida in the south Georgia - north Florida panhandle area during the day. A surface ridge was located in south Florida producing a southwest surface wind flow between 5 - 10 kt over most of south and central Florida. An upper level trough was draped across the southeastern United States with numerical models predicting several shortwaves to move through the mean trough. This resulted in a deep westerly flow through the lower half of the troposphere over the Florida peninsula. With a steady southwest to west low-level flow, the east coast sea breeze (ECSB) developed late in the day and remained near the coast. With the southwesterly mean steering flow (1000 - 700 mb), an increased threat of afternoon thunderstorms was expected near CCAS. Convection would likely increase as the west coast sea breeze (WCSB) moved across the state and as HCRs interacted with the ECSB.

### 4.2.2 Analysis of Data

Throughout the afternoon, 13 storm cells could be tracked and trend information gathered. Of those 13 cells, five were associated with significant weather. There were two F0 tornadoes and the other three produced high wind events. No velocity signatures (MESO or tornado) of the F0 tornadoes were observed in the analysis of the data.

Two microburst events affected the KSC/CCAS area between 2030 - 2115 UTC. Of the two events, one displayed the microburst signature (rapid decrease in the height of the maximum reflectivity and cell-based VIL) prior to the microburst (Figure 7).

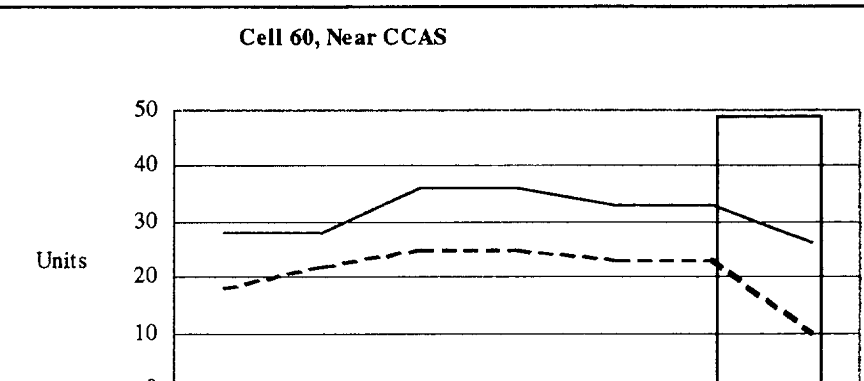



| | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 20 | 24 | 24 | 11 | 10 | 8 | 8 |
| ——— Cell-based VIL (kg/m**2) | 25 | 56 | 55 | 40 | 40 | 38 | 38 |

Time (UTC)

Figure 7. Cell trend information on the height of the maximum reflectivity and cell-based VIL for a storm cell that produced a microburst at 2050 UTC on 13 August 1996. Highlighted are the rapid changes in the cell attributes between 2030 - 2035 UTC.

The cell trend information from the other microburst-producing cell (produced a microburst near the Banana River) was characterized by a decrease in height of the maximum reflectivity of 8000 ft or greater but the cell-based VIL only decreased by 7 kg/m$^2$ prior to the wind event (Figure 7). The wind gust observed with this event was 37 kt where the other event (Cell 1) produced a 46 kt gust.

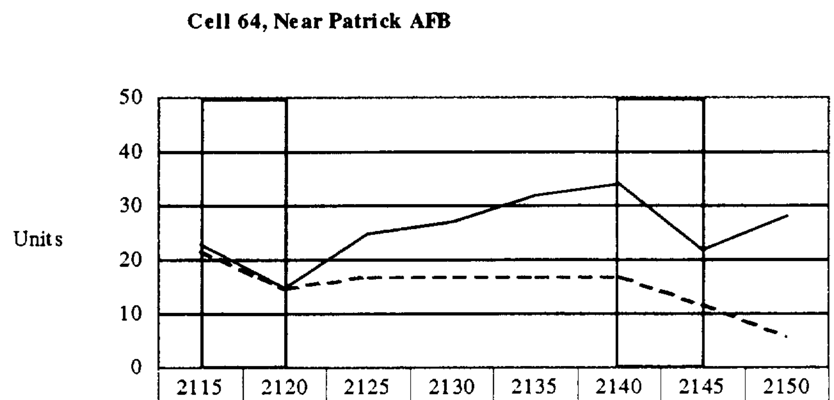



| | 2110 | 2115 | 2120 | 2125 | 2130 | 2135 | 2140 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 18 | 22 | 25 | 25 | 23 | 23 | 10 |
| ——— Cell-based VIL (kg/m**2) | 28 | 28 | 36 | 36 | 33 | 33 | 26 |

Time (UTC)

Figure 8. Cell trend information for the storm cell that produced a microburst over the Banana River west of CCAS at 2200 UTC on 13 August 1996. Cell-based VIL decreased by 7 kg/m$^2$ between 2135 - 2140 UTC. Highlighted are the rapid changes in the cell attributes between 2135 - 2140 UTC.

Another storm cell developed northwest of Patrick Air Force Base (AFB) and propagated southeast along the ECSB. An F0 tornado and a microburst occurred at Patrick AFB between 2130 - 2150 UTC from this cell. The cell associated with this weather event was approximately 19 miles from the MLB WSR-88D. Consequently, the radar did not capture the complete vertical extent of the storm. When this cell first developed northwest of Patrick AFB, it displayed a decrease in the height of maximum reflectivity and cell-based VIL but at a lower magnitude than observed in other detected microburst cells. This may be related to its proximity to the radar (less than 30 miles) and the associated loss of vertical storm coverage. The top of the radar volume scan was at 15 Kft over Patrick AFB and at 20 Kft where the cell first developed. Even with approximately half the storm cell above the top of the radar volume scan, the cell-based VIL increased rapidly and then decreased rapidly between 2115 - 2120 UTC. This was approximately 15 minutes prior to the first reported microburst and the observed F0 tornado. The rapid decrease between 2140 - 2145 UTC is related to another microburst observed at Patrick AFB as the storm cell passed overhead (Figure 9). However, the time series of the height of the maximum reflectivity did not show the same pattern (i.e. rapid decrease in height). It never reached above 17 Kft due to the radar coverage limitation.




| | 2115 | 2120 | 2125 | 2130 | 2135 | 2140 | 2145 | 2150 |
|---|---|---|---|---|---|---|---|---|
| ---- Hgt Max Reflectivity (Kft) | 22 | 15 | 17 | 17 | 17 | 17 | 12 | 6 |
| —— Cell-based VIL (kg/m**2) | 23 | 15 | 25 | 27 | 32 | 34 | 22 | 28 |

Time (UTC)

Figure 9. Trend analysis of a cell that produced a microburst and F0 tornado at PAFB between 2135 - 2145 UTC on 13 August 1996. Highlighted are the rapid changes in the cell attributes between 2115 - 2120 and 2140 - 2145 UTC.

Figure 10 depicts the WSR-88D VCP 11 scan strategy. From the radar out to 10 nm (19 km) very little of an echo structure can be displayed (cone of silence). If a cell forms within this area very little storm structure can be analyzed and an forecaster must rely on other radars, satellite images and/or other data sets to get an understanding of a cells environment. The CCAS/KSC area is outside the cone of silence and most of a cell structure can be analyzed. The top of the scan at Port Canaveral is approximately 41000 ft and extends higher as you go further away from the WSR-88D (Melbourne, FL).

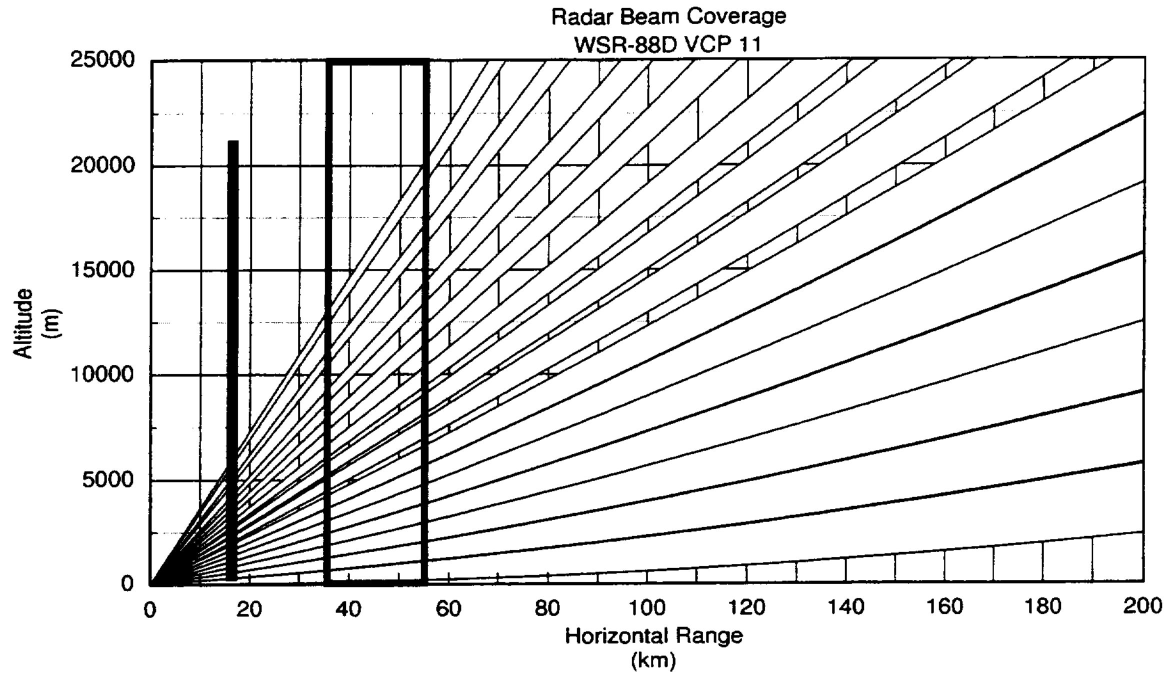



Figure 10. WSR-88D VCP 11 scan strategy showing vertical resolution (The vertical solid bar indicates the location of PAFB and the rectangle highlights the CCAS/KSC area).

A total of eight storm cells were tracked on this day. Of the eight storms, three produced high wind events. Of the three high wind events, one displayed a rapid decrease in the height of maximum reflectivity and cell-based VIL. Another cell that produced a weaker microburst (35 kt) showed the same trends but the magnitude of the decrease in cell-based VIL was only 7 $kg/m^2$. The third cell that affected Patrick AFB was within 30 miles of the radar and consequently, trend data was not available because of limited radar data. Trend information for five cells was not available because of their short life cycles or not being identified by the SCIT algorithm as storm cells. The Cell Trends hail probability showed very poor results as an indicator with six out of seven storm cells indicating a 100% chance of hail.

### 4.3 29 March 1997

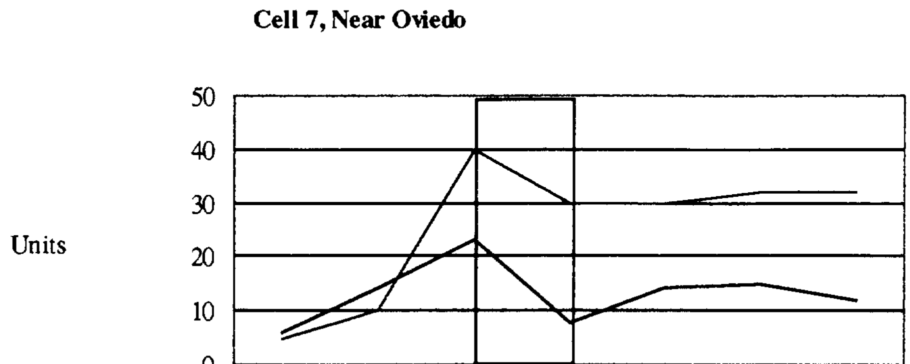
#### 4.3.1 Weather Discussion

The 1200 UTC XMR (CCAS) rawinsonde showed that the atmosphere was conditionally unstable. Tampa's rawinsonde was moist up to 700 mb with a westerly steering flow. The CAPE (Convective Available Potential Energy) was just under 2000 J/kg, the LI (Lifted Index) was -6, and there was a weak disturbance (in the mid-levels) over the Gulf of Mexico that would be over central Florida by afternoon. Afternoon heating and ECSB development would likely trigger thunderstorms just north of central Florida.

#### 4.3.2 Analysis of Data

Of the storms that developed on 29 March 1997, eight storm cells were analyzed using WATADS. Microbursts were the main weather event and three microburst events were identified using the Cell Trends information and reported wind damage or an observed wind gust. One microburst event occurred near Orlando and the other two events occurred in Titusville and over the Kennedy Space Center (KSC).

The first microburst event of the day occurred near Oviedo (Orange County), at approximately 1815 UTC. The radar imagery showed two cells merging just west of the town. Wind damage was reported shortly after these cells merged. The cell attributes of height of maximum reflectivity and cell-based VIL decreased rapidly (1805 - 1810 UTC, Figure 11) prior to the wind event.

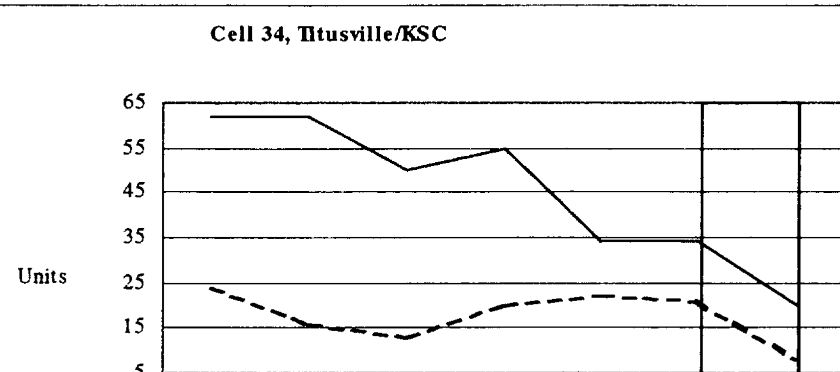



| | 1755 | 1800 | 1805 | 1810 | 1815 | 1820 | 1825 |
|---|---|---|---|---|---|---|---|
| —— Hgt Max Reflectivity (Kft) | 6 | 14 | 23 | 8 | 14 | 15 | 12 |
| —— Cell-based VIL (kg/m**2) | 5 | 10 | 40 | 30 | 30 | 32 | 32 |

Time (UTC)

Figure 11. Cell attributes of height of the maximum reflectivity and cell-based VIL for a cell that produced a microburst near Oviedo at 1815 UTC on 29 March 1997. Highlighted are the rapid changes in the cell attributes between 1805 - 1810 UTC.

As this line of cells continued to develop and move to the east, a new cell developed to the west of Titusville and moved over KSC by 1900 UTC. Both Titusville and KSC reported strong winds with KSC observing winds greater than 58 kt. As it approached Titusville, the storm cell displayed a rapid change in its cell-based VIL and the height of maximum reflectivity. The height of maximum reflectivity decreased rapidly, as did the cell-based VIL, 10 minutes prior to the Titusville event and 20 minutes prior to the KSC event (Figure 12).

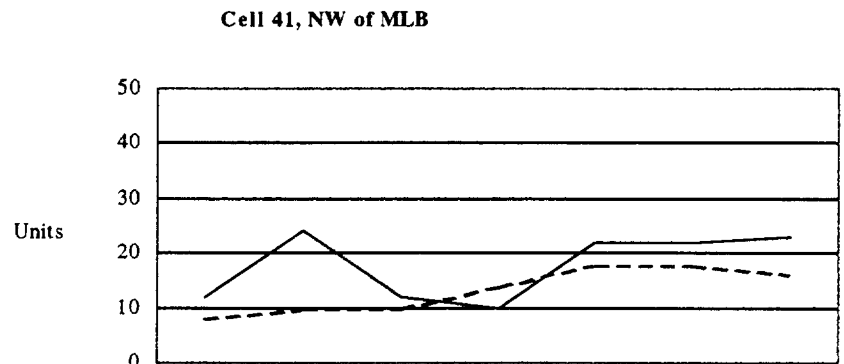



| | 1910 | 1915 | 1920 | 1925 | 1930 | 1935 | 1940 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 24 | 16 | 13 | 20 | 22 | 21 | 8 |
| ——— Cell-based VIL (kg/m**2) | 62 | 62 | 50 | 55 | 34 | 34 | 20 |

Time (UTC)

Figure 12. Time series of cell attributes of height of maximum reflectivity and cell-based VIL for a storm cell that produced a microburst at Titusville and KSC on 29 March 1997. Highlighted are the rapid changes in the cell attributes between 1935 - 1940 UTC.

Many storm cells did not produce any significant weather on this day. An analysis of the five non-significant cells that were identified by WATADS indicated no dual pattern as noted earlier. In Figure 13 the trends of cell-based VIL and height of maximum reflectivity are displayed for a cell that developed northwest of Melbourne. Though there are significant changes in the cell attributes, no dual pattern of a rapid decrease or increase are noted. The changes in the two cell attributes are slightly offset in time.




| | 1845 | 1850 | 1855 | 1900 | 1905 | 1910 | 1915 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 8 | 10 | 10 | 14 | 18 | 18 | 16 |
| ——— Cell-based VIL (kg/m**2) | 12 | 24 | 12 | 10 | 22 | 22 | 23 |

Time (UTC)

Figure 13. Cell attributes of height of maximum reflectivity and cell-based VIL for a non-significant storm cell on 29 March 1997.

On this day, there were seven cells that WATADS was not able to identify because of lost cell identification (i.e. no trend information or no cell ID) or too short of a track, limited to one or two scans. The Cell Trends hail probability showed poor results as an indicator with four out of nine storm cells indicating a 100% chance of hail.

## 4.4 23 April 1997

### 4.4.1 Weather Discussion

On 23 April 1997, a slow moving cold front was located over the western Florida panhandle. There was a diverging dual jet structure aloft, with one branch going to the northeast and the other branch going to the east. This diverging jet pattern caused divergence aloft. Dewpoint temperatures in central Florida were in the upper 60's to lower 70's. Severe weather had already been reported with this cold front as it moved through Alabama and Georgia.

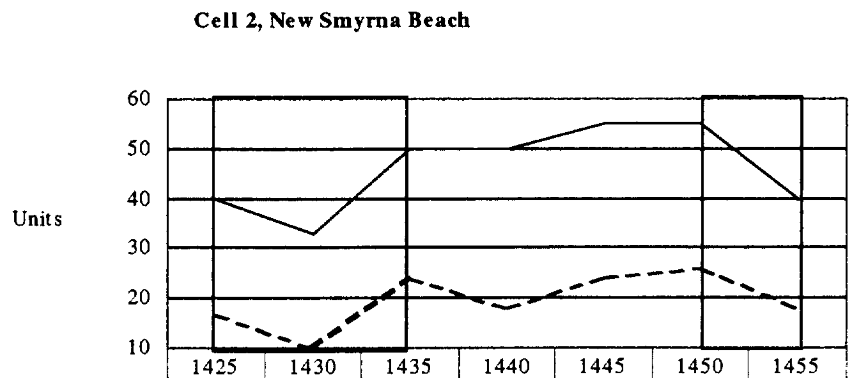
### 4.4.2 Analysis of Data

A total of 26 cells were tracked and analyzed on this day. Of those cells, seven were associated with significant weather; four microburst and three hail events were observed with WATADS. Several cells in the Cocoa to Melbourne Beach area that produced significant weather events were not accompanied by cell trend information since the WSR-88D SCIT algorithm did not identify these storm cells.

The first storm cell for the day occurred in Seminole County and the last cells occurred in both Osceola and Brevard Counties. All cells were associated with a line of developing storms that was moving to the southeast while the individual cells moved along the line to the northeast. Of the four case days, this day had the most trackable and greatest variety of storms.

The trends associated with these cells had the same variation of cell attributes that was discussed earlier. Three of the four wind events met the change in height of the maximum reflectivity and change in cell-based VIL signature requirements.

Figure 14 displays the trends of a cell that moved through the New Smyrna Beach (Volusia County) area between 1415 and 1500 UTC. Between 1425 - 1435 UTC the cell displayed a trend where there is a signature for a possible microburst (1425 - 1430 UTC) and hail (1430 - 1435 UTC), and another microburst (1450 - 1455 UTC). The cell was west of New Smyrna Beach at 1430 UTC and there were no reported weather events. As the storm cell moved over the city at 1450 UTC an F0 tornado was reported. No identifiable velocity signature (i.e. MESO or tornado) was noted in the radar data for the F0 tornado.

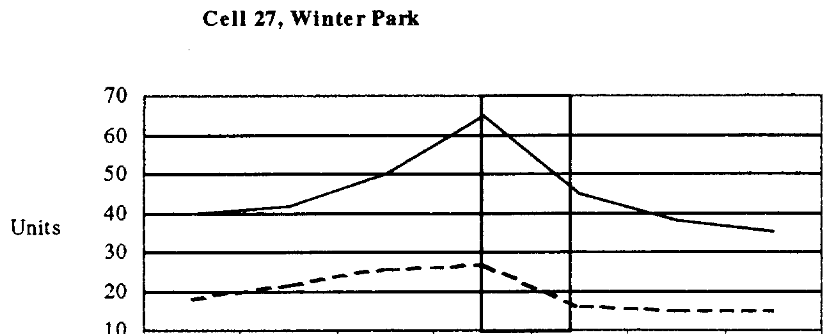



| | 1425 | 1430 | 1435 | 1440 | 1445 | 1450 | 1455 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 17 | 10 | 24 | 18 | 24 | 26 | 18 |
| ——— Cell-based VIL (kg/m**2) | 40 | 33 | 50 | 50 | 55 | 55 | 40 |

Time (UTC)

Figure 14. Time series of cell attributes of height of maximum reflectivity and cell-based VIL for a storm cell that moved through the New Smyrna Beach area between 1445 - 1500 UTC on 23 April 1997. Highlighted are the rapid changes in the cell attributes.

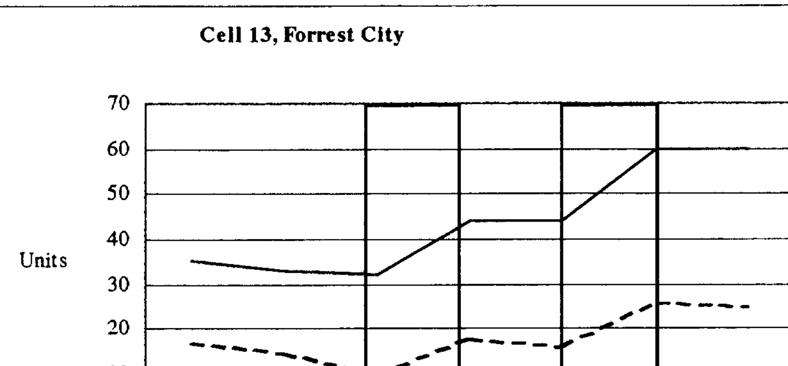
Another storm cell developed and moved through Winter Park (Orange County) between 1515 - 1530 UTC. Wind damage was reported in the area at 1530 UTC. Figure 15 shows the rapid decrease in the height of maximum reflectivity and cell-based VIL between 1510 - 1515 UTC when the storm cell was west of the city.




| Time (UTC) | 1455 | 1500 | 1505 | 1510 | 1515 | 1520 | 1525 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 18 | 22 | 26 | 27 | 16 | 15 | 15 |
| ——— Cell-based VIL (kg/m**2) | 40 | 42 | 50 | 65 | 45 | 38 | 35 |

Figure 15. Time series of cell attributes of height of maximum reflectivity and cell-based VIL for a storm cell that produced a microburst in Winter Park at 1530 UTC on 23 April 1997. Highlighted are the rapid changes in the cell attributes between 1510 - 1515 UTC.

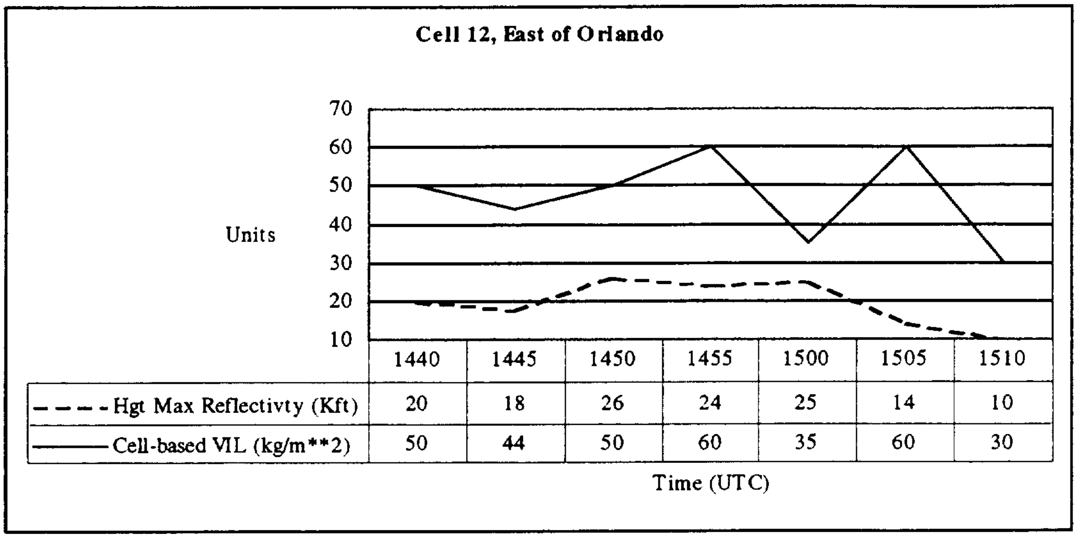
Figure 16 displays the cell attribute trends for a cell that moved through Forrest City (Orange Co.) between 1430 - 1450 UTC. Hail was reported near this cell at 1450 UTC. This cell displayed several impulses as it gained strength prior to 1450 UTC. Between 1430 and 1435 UTC, a rapid increase in both attributes is noted. Though there was no reported hail at this time, the storm cell may have been over an unpopulated area. Another rapid increase can be observed between 1440 - 1445 UTC, five minutes before the reported hail event occurred.




| Time (UTC) | 1420 | 1425 | 1430 | 1435 | 1440 | 1445 | 1450 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivity (Kft) | 17 | 15 | 10 | 18 | 16 | 26 | 25 |
| ——— Cell-based VIL (kg/m**2) | 35 | 33 | 32 | 44 | 44 | 60 | 60 |

Figure 16. Time series of cell attributes of height of maximum reflectivity and cell-based VIL for a storm cell that produced hail in Forrest City at 1450 UTC on 23 April 1997. Highlighted are the rapid changes in the cell attributes between 1430 - 1435 and 1440 - 1445 UTC.

Figure 17 displays the cell attribute trends for one of the non-significant storm cells. Though there are some rapid changes in both cell trend attributes, neither shows the concurrent increase or decrease pattern as noted in the earlier cells.




| | 1440 | 1445 | 1450 | 1455 | 1500 | 1505 | 1510 |
|---|---|---|---|---|---|---|---|
| - - - - Hgt Max Reflectivty (Kft) | 20 | 18 | 26 | 24 | 25 | 14 | 10 |
| ——— Cell-based VIL (kg/m**2) | 50 | 44 | 50 | 60 | 35 | 60 | 30 |

Figure 17. Time series of cell attributes of height of the maximum reflectivity and cell-based VIL for a non-severe storm on 23 April 1997.

There were nine cells that WATADS did not identify as storm cells due to the SCIT algorithm deficiencies or their proximity to the WSR-88D radar. Several of these cells in Brevard County had hail or high wind events reported in their vicinity.

### 4.5 Case Study Summary

Analysis of the Cell Trends attributes of individual storm cells on these four case study days shows that the PUP's Cell Trends display of cell-based VIL **and** Height of Maximum Reflectivity can be used jointly to identify cells that may produce hail and microbursts. For microburst realization, there is a rapid (1 volume scan)

- 8000 ft or greater decrease in the height of maximum reflectivity (initially at 18000 ft or greater) **and**
- A decrease in cell-based VIL by 10 $kg/m^2$ or greater prior to the wind event.

For the hail events there is a rapid (1 volume scan)

- 8000 ft or greater increase in the height of maximum reflectivity (to 18000 ft or greater) **and**
- A increase in cell-based VIL by 10 $kg/m^2$ or greater prior to the hail events.

This investigation has noted that most cells which produce hail or microburst events have discernable Cell Trends signatures. Forecasters should monitor the PUP's Cell Trends display for cells that show changes in the height of maximum reflectivity and cell-based VIL. Other Cell Trends attributes did not show any useful signatures. As an example, the Hail Probability 100% threshold was monitored on 90% (47/52) of all storms. Another important attribute that has a discernable signature but is not available on the cell trend product at this time is the core aspect ratio (CAR). This storm cell attribute has been identified in earlier reports as a precursor of microbursts (decrease of 200 units or greater in one volume scan). CAR = $^{\text{Storm Depth}}/_{\text{Storm Width}}$, where the storm depth is the distance between the storm top and base and the storm width is the width of the storm component containing the maximum reflectivity the storm (Lambert and Wheeler 1997).

Table 1 lists the total number of storm cells investigated along with the total number of severe weather events on each case day. Several cells which had severe wind or hail events associated with them could not be classified because the SCIT algorithm in WATADS did not identify and track the storm or the lifecycle of the storm was too short (i.e. 5 minutes, one volume scan).

To be verified as an event there had to be a report (i.e. NWS Storm Data or observation) of hail (.50 inch or greater) or wind damage. In addition, the KSC/CCAS wind tower network data was used for the verification of microburst events in the CCAS/KSC area (gust GT 35 kt).

Table 1. Severe Weather Events

| Date | Wind Events | Hail Events | Cells with No ID | Total Cells Analyzed |
|---|---|---|---|---|
| 7/11/95 | 5/0 | 3/1 | 5 | 19 |
| 8/13/96 | 2/2 | 0/0 | 5 | 7 |
| 3/29/97 | 3/0 | 0/0 | 7 | 8 |
| 4/23/97 | 5/0 | 4/0 | 9 | 18 |
| Note: Ratio - cases that met criteria / cases that did not | | | | |

Results for the verification of the Cell Trends hail and microburst signatures are listed in Table 3. Table 2 is an example of the four-cell contingency table used. It is important to note that this a very limited data set (four case days). Fifty-two storm cells were analyzed during those four days. The statistics show a better trend in forecasting wind events than hail. However, only 12 hail events were noted versus 22 microburst events. In addition, all of the non-verified hail and microburst cell signatures were over low-populated areas of central Florida. The probability of detection was 88% for both severe weather categories. The False Alarm Rate (FAR) was 36% for hail events and a respectable 25% for microburst events. In addition the Heidke Skill Score (HSS) is 0.65 for hail events and 0.67 for microburst events. The HSS ranges from 0 to 1. A score of 0 indicates no forecast skill (a random forecast) and a score of 1.0 corresponds to a perfect forecast skill

Table 2. Example of four-cell contingency table used for verification and definitions of verification scores.

| | | Observed Event | |
|---|---|---|---|
| | | Yes | No |
| Forecast Event | Yes | a | b |
| | No | c | d |

N = a + b + c + d

False Alarm Rate (FAR) = b / (a + b )

Probability Of Detection (POD) = a / ( a + c )

Critical Success Index (CSI) = a / ( a + b + c )

Heidke Skill Score (HSS) = [ ( a + d ) - E ] /( N - E )

E = [ ( a + c ) ( a + b ) + ( b + d ) ( c + d ) ] / N

Table 3. Cell Trends Attributes Statistics

| | | | | | | |
|---|---|---|---|---|---|---|
| Hail Signature | | | | | | |
| | | Observed | | FAR | = | 0.36 |
| | | Yes | No | POD | = | 0.88 |
| Forecast | Yes | 7 | 4 | CSI | = | 0.58 |
| Hail | No | 1 | 25 | HSS | = | 0.65 |
| Microburst Signature | | | | | | |
| | | Observed | | FAR | = | 0.25 |
| | | Yes | No | POD | = | 0.88 |
| Forecast | Yes | 15 | 5 | CSI | = | 0.68 |
| Microburst | No | 2 | 25 | HSS | = | 0.69 |

# 5.0 Summary and Recommendations

As part of the Instrumentation and Measurement Systems Evaluation Task (003), subtask 4, the AMU was tasked to evaluate the use of Cell Trends as a tool for operators to use in their evaluation of storm cell strength.

Analysis of the four case days has shown that most cells associated with significant weather do show a trend in certain cell attributes (a signature). Cells that exhibit a rapid increase or decrease in their height of maximum reflectivity and cell-based VIL over the same time period can be associated with significant weather. Those cells that do not show these changes are typically not associated with significant weather events. Other Cell Trends attributes did not show any useful signatures. As an example, the Hail Probability 100% threshold was indicated on 90% (47/52) of all storms.

The height of maximum reflectivity and cell-based VIL are two of the eight cell attributes that can be monitored by using the WSR-88D PUP Build 9.0 Cell Trends display.

One limitation of the WSR-88D SCIT algorithm which has been identified by this analysis is that it is not fine tuned for the central Florida weather environment. The cells that typically develop in Florida are small and at times their reflectivity core is above the .5 elevation scan. The SCIT algorithm loses track of these cells quickly making it very difficult to monitor trends of cells for any length of time. One set of radar algorithms for all radars may not be appropriate. Different areas of the country if not individual radar sites may need to be able to fine-tune all the parameters of the different WSR-88D algorithms according the meteorological situation.

Radar operators need to monitor storm cells and watch for trends that change quickly (1 scan). Any quick change in a cell's structure is usually a precursor that a cell characteristic has changed or is changing. These changes can be associated with the development or decay of a severe storm. Using the WSR-88D PUP Cell Trends display can help the forecaster in highlighting trends in a cell's attributes of: the maximum reflectivity, height of maximum reflectivity, storm top, storm base, hail and severe hail probability, and cell-based VIL. By monitoring these attributes a forecaster can get a sense of development or decay of a storm cell.

The AMU found that two of the important attributes to monitor are height of the maximum reflectivity and cell-based VIL. By monitoring these two cell attributes a forecaster can have advance warning that a storm cell may become severe and produce a microburst or hail. Lead times ranged from 5 to 20 minutes. A forecasters needs to be aware that any quick change (1 scan) in a cell's attributes can be a signal that a cell characteristics are changing and the cell maybe becoming severe. The WSR-88D Cell Trends display allows that forecaster to monitor these cell attributes by selecting a cell through the use of the graphic tablet.

One method to observe a storm on the WSR-88D PUP is to monitor the composite reflectivity product with storm track information overlaid. A forecaster can then use the puck and select a storm of interest (usually highly reflective) and display that cell's trend information. If a storm cell trend information matches the precursor information as described in this report a warning may be needed for that cell. During this analysis period the average time period of tracking a cell was 20 minutes with the longest being 1.3 hours.

# 6.0 References

Johnson, J. T., 1998: Warning Decision Support System: The Next Generation. Preprints. *14th International Conference on Interactive Information and Processing Systems,* Phoenix, AZ, Amer. Meteor. Soc.

Lambert, W. C. and M. Wheeler, 1997: Final Report on the AMU NEXRAD Exploitation Task, *NASA Contractor Report*, 45 pp.

OSF System Support Branch, 1996: WSR-88D Next Generation Weather Radar Operator Handbook Principal User Processor, Volume I, Graphic Tablet, 1-163.

Taylor, G. T., 1994: *Report on the Comparison of the Scan Strategies Employed by the Patrick Air Force Base WSR-74C / McGill Radar and the NWS Melbourne WSR-88D Radar*, NASA Contractor Report 196291, 30 pp.

Tables 4 – 7 list all the cell attributes that were analyzed during this study. Highlighted in bold with the letters W (wind) and H (hail) are the verified wind and hail events. Highlighted in bold (no letter W or H) are the wind and hail signatures with no observed verification (false alarms). ID = storm identification number by WATADS, AzRng = Azimuth/Range of cell, MR = Maximum Reflectivity, HMR = Height of Maximum Reflectivity, ST = Storm Top, SB = Storm Base, SVIL = Storm VIL, CAR = Core Aspect Ratio.

Table 4. Cell Attribute Data for 11 July 1995 (H - hail W - wind)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1840 | 30 | | 57 | 6 | 40 | 5 | 60 | 600 |
| 1845 | 30 | | 57 | 8 | 40 | 5 | 60 | 610 |
| 1850 | 30 | | 57 | 14 | 40 | 5 | 60 | 660 |
| 1855 | 30 | | 57 | 14 | 30 | 5 | 55 | 600 |
| 1900 | 30 | | 57 | 14 | 18 | 5 | 55 | 480 |
| 1905 | 30 | | 57 | 14 | 18 | 5 | 55 | 560 |
| 1910 | 30 | | 57 | 8 | 24 | 5 | 55 | 660 |
| 1915 | 30 | | 57 | 10 | 24 | 5 | 55 | 660 |
| 1920 | 30 | | 56 | 14 | 30 | 5 | 40 | 640 |
| 1925 | 30 | 351/37 | 56 | 14 | 30 | 5 | 44 | 640 |
| 1930 | 30 | | 56 | 14 | 30 | 5 | 44 | 610 |
| 1935 | 30 | | 55 | 12 | 28 | 5 | 30 | 470 |
| 1940 | 30 | | 55 | 12 | 20 | 4 | 30 | 380 |
| 1945 | 30 | | 53 | 10 | 20 | 2 | 22 | 280 |
| 1910 | 64 | 327 | 55 | 16 | 40 | 5 | 50 | 400 |
| 1915 | 64 | | 55 | 16 | 40 | 5 | 50 | 460 |
| 1920 | 64 | | 55 | 16 | 42 | 5 | 52 | 600 |
| 1925 | 64 | | 55 | 12 | 42 | 5 | 48 | 550 |
| 1930 | 64 | | 55 | 10 | 38 | 5 | 38 | 460 |
| 1935 | 64 | | 55 | 10 | 38 | 5 | 36 | 380 |
| 1940 | 64 | | 55 | 8 | 30 | 5 | 24 | 380 |
| 1900 | 100 | | 60 | 18 | 30 | 5 | 30 | 250 |
| 1905 | 100 | | 65 | 20 | 38 | 5 | 60 | 500 |
| 1910 | 100 | | 65 | 20 | 38 | 5 | 60 | 500 |
| 1915 | 100 | | 63 | 18 | 38 | 5 | 60 | 420 |
| 1920 | 100 | | 65 | 18 | 38 | 5 | 60 | 400 |
| 1925 | 100 | | 65 | 22 | 32 | 5 | 58 | 380 |
| 1930 | 100 | | 65 | 22 | 32 | 5 | 58 | 380 |
| **1935** | **100** | | **67** | **24** | **28** | **5** | **55** | **360 W** |
| **1940** | **100** | **255/9** | **68** | **12** | **25** | **5** | **44** | **280 W** |
| 1700 | 70 | | 55 | 22 | 42 | 4 | 36 | 600 |
| 1705 | 70 | | 55 | **22** | **42** | **5** | **36** | **540 W** |
| 1710 | 70 | | 52 | **14** | **38** | **4** | **20** | **280 W** |
| 1715 | 70 | | 50 | 10 | 30 | 4 | 10 | 200 |
| 1720 | 70 | 295/31 | 45 | 10 | 18 | 4 | 5 | 100 |
| 1725 | ` | | 45 | 10 | 18 | 6 | 5 | 100 |

| Table 4. Cell Attribute Data for 11 July 1995 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 1730 | 70 | | 50 | 17 | 22 | 6 | 16 | 100 |
| 1735 | 70 | | 51 | 17 | 22 | 6 | 16 | 100 |
| 1740 | 70 | 332/54 | 53 | 14 | 25 | 6 | 22 | 260 |
| 1745 | 70 | | 53 | 14 | 25 | 6 | 22 | 2 |
| 1750 | 70 | | 50 | 14 | 22 | 6 | 16 | 160 |
| 1800 | 3 | | 54 | 18 | 26 | 10 | 20 | 400 |
| 1810 | 3 | | 55 | 18 | 30 | 10 | 24 | 420 |
| 1820 | 3 | | 53 | 12 | 20 | 10 | 18 | 300 |
| 1825 | 3 | 322/31 | 50 | 16 | 20 | 10 | 20 | 300 |
| 1835 | 3 | | 50 | 18 | 20 | 10 | 26 | 500 |
| 1840 | 3 | | 50 | 19 | 20 | 10 | 27 | 500 |
| **1845** | **3** | | **54** | **24** | **30** | **10** | **32** | **620 W** |
| **1850** | **3** | | **54** | **12** | **30** | **10** | **16** | **400 W** |
| 1855 | 3 | | 50 | 10 | 20 | 10 | 12 | 300 |
| 1900 | 3 | | 50 | 10 | 20 | 10 | 12 | 340 |
| 1905 | 3 | 346/40 | 45 | 10 | 20 | 10 | 14 | 600 |
| 1910 | 3 | | 40 | 8 | 20 | 5 | 12 | 440 |
| 1915 | 3 | | 40 | 8 | 20 | 5 | 12 | 440 |
| 1920 | 3 | | 45 | 14 | 30 | 5 | 22 | 580 |
| 1925 | 3 | | 45 | 14 | 30 | 5 | 22 | 580 |
| 1930 | 3 | | 52 | 18 | 24 | 8 | 18 | 400 |
| 1935 | 3 | | 52 | 18 | 24 | 8 | 18 | 400 |
| 1940 | 3 | | 45 | 11 | 22 | 5 | 18 | 220 |
| 1945 | 3 | 5/37 | 30 | 13 | 24 | 8 | 16 | 440 |
| 1920 | 53 | | 45 | 18 | 30 | 5 | 10 | 440 |
| 1925 | 53 | | 45 | 18 | 30 | 5 | 10 | 440 |
| 1930 | 53 | | 50 | 18 | 30 | 5 | 20 | 400 |
| 1935 | 53 | | 50 | 18 | 30 | 5 | 20 | 460 |
| 1940 | 53 | | 55 | 18 | 30 | 5 | 40 | 400 |
| 1945 | 53 | | 55 | 18 | 30 | 5 | 40 | 360 |
| 1950 | 53 | | 57 | 18 | 30 | 5 | 44 | 250 |
| 1955 | 53 | | 57 | 18 | 30 | 5 | 44 | 360 |
| 2000 | 53 | | 60 | 18 | 44 | 5 | 38 | 460 |
| 2005 | 53 | 328/40 | 50 | 18 | 30 | 5 | 20 | 280 |
| 1935 | 68 | | 55 | 16 | 20 | 2 | 20 | 320 |
| 1940 | 68 | | 55 | 11 | 20 | 2 | 22 | 320 |
| 1945 | 68 | | 55 | 11 | 20 | 2 | 22 | 320 |
| 1950 | 68 | | 56 | 16 | 30 | 2 | 24 | 300 |
| 2000 | 68 | | 55 | 14 | 20 | 2 | 24 | 280 |
| 2005 | 68 | | 55 | 14 | 20 | 2 | 24 | 280 |
| 2010 | 68 | | 60 | 18 | 22 | 2 | 24 | 180 |

Table 4. Cell Attribute Data for 11 July 1995 (continued)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 2015 | 68 | 157/7 | 60 | 19 | 25 | 2 | 24 | 200 |
| 2020 | 68 | | 60 | 19 | 25 | 2 | 24 | 200 |
| 2025 | 58 | 125/7 | 60 | 10 | 18 | 2 | 20 | 200 |
| 1805 | 46 | 246/32 | 55 | 18 | 32 | 16 | 30 | 600 |
| 1810 | 46 | | 55 | 18 | 32 | 16 | 30 | 540 |
| 1815 | 46 | | 55 | 18 | 32 | 16 | 40 | 500 |
| 1820 | 46 | | 55 | 18 | 32 | 16 | 40 | 500 |
| 1825 | 46 | | 56 | 18 | 32 | 16 | 30 | 400 |
| 1830 | 46 | | 45 | 18 | 32 | 16 | 18 | 500 |
| 1935 | 14 | 237/4 | 62 | 18 | 20 | 4 | 24 | 0 |
| 1940 | 14 | | 60 | 18 | 20 | 4 | 24 | 0 |
| 1945 | 14 | | 65 | 16 | 18 | 2 | 20 | 0 |
| 1950 | 14 | | 66 | 16 | 18 | 4 | 20 | 50 |
| 1955 | 14 | | 66 | 16 | 18 | 4 | 20 | 50 |
| 2000 | 14 | | 55 | 4 | 6 | 2 | 4 | 10 |
| 1807 | 12 | | 55 | 12 | 24 | 4 | 20 | 400 |
| 1812 | 12 | | 55 | 12 | 24 | 4 | 26 | 460 |
| 1817 | 12 | | 55 | 13 | 34 | 4 | 34 | 500 |
| **1822** | **12** | | **55** | **14** | **36** | **4** | **35** | **500 H** |
| **1827** | **12** | | **55** | **26** | **42** | **4** | **50** | **220 H** |
| 1832 | 12 | | 55 | 22 | 40 | 4 | 34 | 290 |
| 1837 | 12 | | 55 | 18 | 35 | 10 | 24 | 500 |
| 1842 | 12 | | 55 | 16 | 32 | 4 | 30 | 340 |
| 1847 | 12 | | 55 | 16 | 30 | 4 | 30 | 200 |
| 1852 | 12 | 269/32 | 55 | 10 | 28 | 4 | 30 | 240 |
| 1742 | 38 | 327/32 | 55 | 10 | 28 | 4 | 20 | 200 |
| 1747 | 38 | | 50 | 20 | 28 | 4 | 20 | 200 |
| 1752 | 38 | | 47 | 20 | 24 | 8 | 55 | 400 |
| 1757 | 38 | | 50 | 20 | 24 | 5 | 55 | 440 |
| 1802 | 38 | | 55 | 12 | 38 | 6 | 50 | 640 |
| 1807 | 38 | | 55 | 12 | 38 | 6 | 50 | 600 |
| 1812 | 38 | | 55 | 12 | 45 | 6 | 44 | 500 |
| 1817 | 38 | | 55 | 12 | 45 | 6 | 44 | 500 |
| 1822 | 38 | | 55 | 12 | 45 | 6 | 22 | 540 |
| 1827 | 38 | 329/28 | 46 | 20 | 38 | 6 | 22 | 370 |
| 1832 | 38 | | 55 | 20 | 40 | 6 | 20 | 360 |
| 1837 | 38 | | 55 | 22 | 40 | 6 | 24 | 380 |
| 1842 | 38 | | 60 | 22 | 40 | 6 | 32 | 600 |
| 1847 | 38 | | 55 | 22 | 40 | 6 | 32 | 480 |
| 1852 | 38 | | 50 | 20 | 40 | 6 | 30 | 360 |
| 1857 | 38 | | 55 | 24 | 45 | 6 | 30 | 620 |

| Table 4. Cell Attribute Data for 11 July 1995 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 1902 | 38 | | 55 | 17 | 35 | 6 | 20 | 500 |
| 1907 | 38 | | 55 | 16 | 15 | 6 | 10 | 380 |
| 1912 | 38 | | 55 | 16 | 15 | 6 | 10 | 360 |
| 1917 | 79 | | 55 | 18 | 20 | 6 | 22 | 200 |
| **1907** | **79** | **345/18** | **60** | **15** | **30** | **2** | **38** | **320 H** |
| **1912** | **79** | | **62** | **26** | **30** | **2** | **50** | **500 H** |
| 1917 | 79 | | 63 | **18** | **30** | **8** | **40** | **200** |
| 1922 | 79 | | 63 | 18 | 30 | 6 | 42 | 300 |
| 1927 | 79 | | 61 | 16 | 20 | 2 | 38 | 260 |
| 1932 | 79 | | 61 | 16 | 20 | 2 | 38 | 250 |
| 1937 | 79 | | 65 | 14 | 18 | 2 | 32 | 200 |
| 1942 | 79 | 360/9 | 55 | 2 | 16 | 0 | 8 | 150 |
| 1932 | 59 | 246/6 | 63 | 17 | 20 | 4 | 22 | 260 |
| 1937 | 59 | | 63 | 17 | 20 | 4 | 22 | 240 |
| 1942 | 59 | | 63 | 16 | 20 | 10 | 24 | 240 |
| 1947 | 59 | | 63 | 16 | 20 | 10 | 24 | 150 |
| 1952 | 59 | | 66 | 16 | 20 | 4 | 22 | 150 |
| 1957 | 59 | | 66 | 16 | 20 | 4 | 22 | 150 |
| 2002 | 59 | | 55 | **4** | **10** | **0** | **8** | **0** |
| 1900 | 59 | | 60 | **20** | **36** | **8** | **60** | **260** |
| 1905 | 59 | | 60 | 20 | 36 | 5 | 60 | 400 |
| 1910 | 59 | | 65 | 24 | 40 | 2 | 60 | 400 |
| 1915 | 59 | | 60 | 22 | 38 | 2 | 60 | 500 |
| 1920 | 59 | | 60 | 22 | 38 | 2 | 60 | 540 |
| 1925 | 59 | | 64 | 23 | 30 | 2 | 60 | 370 |
| 1930 | 59 | 259/13 | 65 | 12 | 28 | 2 | 57 | 300 |
| 1715 | 60 | 326/56 | 55 | 18 | 22 | 12 | 20 | 200 |
| 1720 | 60 | | 60 | 17 | 22 | 8 | 22 | 120 |
| 1725 | 60 | | 55 | 13 | 22 | 5 | 30 | 300 |
| 1730 | 60 | | 53 | 18 | 20 | 5 | 22 | 240 |
| 1735 | 60 | | 50 | 13 | 20 | 5 | 20 | 240 |
| 1740 | 60 | | 50 | 12 | 20 | 5 | 18 | 220 |
| 1745 | 60 | | 50 | 12 | 18 | 5 | 16 | 220 |
| 1750 | 60 | | 49 | 12 | 16 | 5 | 14 | 220 |
| 1755 | 60 | | 48 | 10 | 16 | 5 | 10 | 200 |
| 1800 | 71 | | 54 | 18 | 30 | 5 | 20 | 400 |
| 1805 | 71 | | 55 | 18 | 30 | 5 | 22 | 500 |
| 1810 | 71 | | 55 | 18 | 30 | 5 | 22 | 460 |
| 1815 | 71 | | 55 | 18 | 30 | 5 | 20 | 400 |
| 1820 | 71 | | 55 | 18 | 30 | 5 | 20 | 400 |
| 1825 | 71 | | 58 | 18 | 20 | 5 | 12 | 520 |

| Table 4. Cell Attribute Data for 11 July 1995 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 1830 | 71 | 344/48 | 52 | 18 | 20 | 5 | 14 | 300 |
| 1835 | 71 | | 52 | 18 | 20 | 5 | 14 | 300 |
| 1840 | 71 | | 59 | 18 | 32 | 5 | 30 | 600 |
| 1845 | 71 | | 59 | 18 | 32 | 5 | 30 | 600 |
| 1850 | 71 | | 54 | 18 | 30 | 5 | 24 | 480 |
| 1855 | 71 | | 54 | 14 | 30 | 5 | 24 | 400 |
| 1900 | 71 | | 52 | 12 | 32 | 5 | 10 | 380 |
| 1905 | 71 | 346/40 | 56 | 12 | 32 | 5 | 10 | 420 |
| 1910 | 71 | | 60 | 14 | 44 | 5 | 44 | 440 |
| **1915** | **71** | | **48** | **27** | **42** | **5** | **50** | **500 W** |
| **1920** | **71** | | **45** | **10** | **40** | **5** | **38** | **380 W** |
| 1925 | 71 | | 45 | 10 | 40 | 5 | 38 | 380 |
| 1930 | 71 | | 45 | 10 | 38 | 5 | 32 | 300 |
| 1935 | 71 | | 42 | 10 | 38 | 5 | 32 | 300 |
| 1940 | 71 | | 42 | 10 | 38 | 5 | 32 | 300 |
| 1945 | 71 | 355/33 | 53 | 8 | 38 | 5 | 22 | 300 |
| 1950 | 71 | | 53 | 8 | 30 | 5 | 20 | 240 |
| 1955 | 71 | | 53 | 8 | 30 | 5 | 20 | 240 |
| 2000 | 71 | 359/29 | 53 | 8 | 20 | 5 | 10 | 240 |
| 1830 | 8 | 340/21 | 55 | 18 | 40 | 10 | 20 | 240 |
| 1835 | 8 | | 55 | 18 | 40 | 5 | 20 | 240 |
| 1840 | 8 | | 57 | 20 | 44 | 5 | 40 | 560 |
| 1845 | 8 | | 57 | 20 | 44 | 5 | 40 | 540 |
| 1850 | 8 | | 57 | 14 | 40 | 5 | 40 | 380 |
| 1855 | 8 | | 57 | 14 | 40 | 5 | 40 | 380 |
| **1900** | **8** | | **55** | **14** | **40** | **10** | **25** | **580 H** |
| **1905** | **8** | | **60** | **24** | **37** | **5** | **45** | **380 H** |
| 1910 | 8 | | 60 | 24 | 37 | | | 380 |
| 1915 | 8 | | 60 | 18 | 35 | 5 | 45 | 240 |
| 1920 | 8 | | 60 | 18 | 35 | 5 | 45 | 200 |
| 1925 | 8 | | 60 | 17 | 28 | 5 | 40 | 200 |
| 1815 | 59 | 270/36 | 57 | **14** | **30** | **5** | **20** | **200** |
| 1820 | 59 | | 55 | **27** | **40** | **5** | **40** | **390** |
| 1825 | 59 | | 55 | 20 | 40 | 5 | 40 | 380 |
| 1830 | 59 | | 55 | 18 | 42 | 5 | 44 | 500 |
| 1835 | 59 | | 55 | 18 | 40 | 12 | 40 | 340 |
| 1840 | 59 | | 55 | 18 | 32 | 14 | 22 | 200 |
| 1845 | 59 | | 55 | 18 | 32 | 5 | 20 | 200 |
| 1850 | 59 | | 55 | 12 | 30 | 5 | 20 | 280 |
| 1855 | 59 | | 51 | 6 | 24 | 5 | 10 | 180 |
| 1825 | 8 | 349/11 | 49 | 14 | 20 | 5 | 20 | 300 |

| Table 4. Cell Attribute Data for 11 July 1995 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 1830 | 8 | | 50 | 14 | 20 | 5 | 20 | 300 |
| 1835 | 8 | | 56 | 18 | 34 | 12 | 30 | 220 |
| 1840 | 8 | | 55 | 18 | 42 | 5 | 42 | 60 |
| 1845 | 8 | | 55 | 18 | 42 | 5 | 38 | 60 |
| 1850 | 8 | | 55 | 12 | 20 | 5 | 20 | 60 |
| 1917 | 36 | 5/23 | 40 | 10 | 20 | 5 | 16 | 200 |
| 1922 | 36 | | 40 | 10 | 20 | 5 | 16 | 200 |
| 1927 | 36 | | 42 | 12 | 22 | 5 | 20 | 100 |
| 1932 | 36 | | 55 | 18 | 30 | 12 | 32 | 320 |
| 1937 | 36 | | 55 | 18 | 30 | 10 | 36 | 360 |
| 1942 | 36 | | 55 | 18 | 42 | 5 | 42 | 360 |
| **1947** | **36** | | **55** | **20** | **30** | **5** | **35** | **450 W** |
| **1952** | **36** | | **55** | **12** | **28** | **5** | **23** | **230 W** |
| 1957 | 36 | | 40 | 12 | 26 | 5 | 20 | 200 |
| 2002 | 36 | | 36 | 8 | 20 | 5 | 10 | 100 |

Table 5. Cell Attribute Data for 13 August 1996 (H - hail W - wind)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1930 | 5 | 321 | 57 | 6 | 40 | 5 | 38 | 520 |
| 1935 | 5 | | 56 | 14 | 40 | 5 | 36 | 340 |
| 1940 | 5 | | 55 | 14 | 18 | 5 | 30 | 240 |
| 1945 | 5 | 321/30 | 55 | 8 | 24 | 5 | 28 | 180 |
| 1950 | 5 | | 55 | 14 | 30 | 5 | 28 | 220 |
| 1955 | 5 | | 55 | 14 | 30 | 5 | 30 | 220 |
| 2000 | 5 | | 57 | 10 | 20 | 2 | 30 | 220 |
| 1932 | 34 | 313 | 58 | 12 | 18 | 5 | 36 | 150 |
| 1937 | 34 | | 55 | 19 | 30 | 5 | 30 | 200 |
| 1942 | 34 | | 55 | 18 | 37 | 5 | 32 | 300 |
| 1947 | 34 | | 55 | 18 | 40 | 5 | 40 | 400 |
| 1952 | 34 | 313/26 | 57 | 18 | 18 | 5 | 27 | 220 |
| 2020 | 1 | 348/22 | 62 | 20 | 30 | 2 | 25 | 220 |
| 2025 | 1 | | 66 | 24 | 40 | 2 | 56 | 220 |
| **2030** | **1** | | **65** | **24** | **40** | **2** | **55** | **560 W** |
| **2035** | **1** | | **50** | **11** | **45** | **2** | **40** | **340 W** |
| 2040 | 1 | | 50 | 10 | 45 | 2 | 40 | 380 |
| 2045 | 1 | | 50 | 8 | 40 | 2 | 38 | 200 |
| 2050 | 1 | | 52 | 8 | 38 | 2 | 38 | 180 |
| 2055 | 1 | | 55 | 8 | 36 | 2 | 30 | 200 |
| 2100 | 1 | | 55 | 10 | 30 | 2 | 22 | 380 |
| 2105 | 1 | | 55 | 8 | 30 | 2 | 22 | 200 |
| 2110 | 1 | | 55 | 8 | 30 | 2 | 22 | 200 |
| 2115 | 1 | 13/28 | 53 | 8 | 27 | 2 | 15 | 200 |
| 2120 | 1 | 15/29 | 50 | 5 | 22 | 2 | 10 | 170 |
| 2105 | 64 | | 55 | 24 | 20 | 2 | 27 | 200 |
| 2110 | 64 | | 60 | 20 | 20 | 2 | 23 | 360 |
| **2115** | **64** | | **62** | **23** | **20** | **2** | **23** | **420 W** |
| **2120** | **64** | | **65** | **15** | **20** | **2** | **15** | **200 W** |
| 2125 | 64 | 326/7 | 65 | 17 | 20 | 2 | 25 | 240 |
| 2130 | 64 | | 67 | 17 | 20 | 2 | 27 | 260 |
| 2135 | 64 | | 67 | 17 | 20 | 2 | 32 | 240 |
| **2140** | **64** | | **60** | **17** | **24** | **2** | **34** | **420 W** |
| **2145** | **64** | | **60** | **12** | **24** | **2** | **22** | **200 W** |
| 2150 | 64 | | 55 | 6 | 24 | 2 | 28 | 300 |
| 2155 | 64 | | 55 | 6 | 24 | 2 | 28 | 200 |
| 2200 | 64 | | 55 | 6 | 24 | 2 | 22 | 200 |
| 2022 | 3 | | 47 | 6 | 18 | 5 | 10 | 240 |
| 2027 | 3 | | 50 | 5 | 18 | 5 | 14 | 300 |
| 2032 | 3 | | 55 | 5 | 24 | 5 | 20 | 340 |
| 2037 | 3 | | 55 | 18 | 34 | 5 | 20 | 600 |

| Table 5. Cell Attribute Data for 13 August 1996 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 2042 | 3 | | 55 | 16 | 34 | 5 | 22 | 410 |
| 2047 | 3 | | 53 | 12 | 28 | 5 | 20 | 380 |
| 2052 | 3 | | 55 | 12 | 28 | 5 | 20 | 380 |
| 2057 | 3 | | 55 | 12 | 27 | 5 | 15 | 380 |
| 2102 | 3 | 322/31 | 50 | 10 | 10 | 5 | 10 | 280 |
| 2040 | 60 | | 62 | 12 | 24 | 5 | 30 | 280 |
| 2045 | 60 | | 62 | 14 | 26 | 5 | 34 | 240 |
| 2055 | 60 | | 57 | 12 | 30 | 5 | 30 | 200 |
| 2100 | 60 | | 57 | 12 | 30 | 5 | 30 | 250 |
| 2105 | 60 | | 57 | 18 | 24 | 10 | 28 | 400 |
| 2110 | 60 | | 60 | 18 | 24 | 8 | 28 | 250 |
| 2115 | 60 | 320/26 | 65 | 22 | 22 | 5 | 28 | 200 |
| 2120 | 60 | | 65 | 25 | 24 | 5 | 36 | 160 |
| 2125 | 60 | | 65 | 25 | 24 | 5 | 36 | 180 |
| 2130 | 60 | | 63 | 23 | 24 | 5 | 33 | 100 |
| **2135** | **60** | | **60** | **23** | **24** | **5** | **35** | **260 W** |
| **2140** | **60** | **5/37** | **58** | **10** | **24** | **5** | **24** | **80 W** |
| 2022 | 3 | 322/31 | 56 | 18 | 27 | 5 | 36 | 200 |
| 2027 | 3 | | 57 | 20 | 30 | 5 | 40 | 300 |
| 2032 | 3 | | 57 | 24 | 36 | 12 | 40 | 400 |
| 2037 | 3 | | 63 | 24 | 44 | 5 | 60 | 620 |
| 2042 | 3 | | 65 | 24 | 44 | 5 | 60 | 560 |
| 2047 | 3 | | 60 | 22 | 44 | 5 | 53 | 370 |
| 2052 | 3 | | 60 | 22 | 44 | 5 | 54 | 300 |
| 2057 | 3 | | 58 | 22 | 40 | 5 | 50 | 360 |
| 2102 | 3 | | 60 | **20** | **40** | **5** | **50** | **390** |
| 2107 | 3 | | 63 | **12** | **38** | **5** | **40** | **180** |

Table 6. Cell Attribute Data for 29 March 1997 (H - hail W - wind)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1755 | 7 | 304/65 | 44 | 6 | 40 | 5 | 5 | 200 |
| 1800 | 7 | | 48 | **13** | **40** | **5** | **10** | **200** |
| **1805** | **7** | | **55** | **24** | **18** | **5** | **40** | **370 W** |
| **1810** | **7** | | **55** | **8** | **24** | **5** | **30** | **110 W** |
| 1815 | 7 | | 52 | 14 | 30 | 5 | 30 | 320 |
| 1820 | 7 | | 55 | 15 | 30 | 5 | 32 | 440 |
| 1825 | 7 | | 54 | 12 | 24 | 5 | 32 | 320 |
| 1830 | 7 | | 55 | 10 | 20 | 2 | 30 | 200 |
| 1817 | 1 | 312/53 | 58 | 7 | 32 | 5 | 30 | 400 |
| 1822 | 1 | | 58 | 13 | 38 | 5 | 30 | 400 |
| 1827 | 1 | | 58 | 13 | 40 | 5 | 28 | 400 |
| 1832 | 1 | | 58 | 12 | 40 | 5 | 26 | 320 |
| 1837 | 1 | | 35 | 15 | 28 | 5 | 36 | 220 |
| 1842 | 1 | | 52 | 12 | 28 | 5 | 20 | 300 |
| 1757 | 2 | | 54 | 10 | 30 | 5 | 20 | 300 |
| 1802 | 2 | | 56 | 6 | 30 | 5 | 24 | 200 |
| 1807 | 2 | | 57 | 10 | 34 | 5 | 30 | 400 |
| 1812 | 2 | | 57 | 14 | 34 | 5 | 40 | 400 |
| 1817 | 2 | | 62 | 12 | 30 | 5 | 34 | 420 |
| 1822 | 2 | | 60 | 12 | 30 | 5 | 34 | 400 |
| 1827 | 2 | | 57 | 12 | 28 | 5 | 30 | 350 |
| 1832 | 2 | 313/48 | 57 | 6 | 24 | 5 | 28 | 240 |
| 1837 | 2 | | 57 | 10 | 26 | 5 | 30 | 240 |
| 1842 | 2 | | 58 | 14 | 30 | 5 | 35 | 300 |
| **1847** | **2** | | **58** | **21** | **40** | **5** | **44** | **420 W** |
| **1852** | **2** | | **58** | **8** | **42** | **5** | **22** | **200 W** |
| 1857 | 2 | 321/41 | 57 | 10 | 42 | 5 | 20 | 220 |
| 1835 | 34 | | 54 | **11** | **24** | **5** | **20** | **220** |
| 1840 | 34 | | 54 | **20** | **30** | **5** | **30** | **360** |
| 1845 | 34 | | 56 | 24 | 34 | 10 | 32 | 410 |
| 1850 | 34 | | 56 | 22 | 40 | 5 | 40 | 460 |
| 1855 | 34 | | 57 | 18 | 42 | 5 | 44 | 440 |
| 1900 | 34 | | 57 | 18 | 44 | 5 | 48 | 440 |
| 1905 | 34 | | 60 | 20 | 44 | 5 | 55 | 440 |
| 1910 | 34 | 334/32 | 67 | 24 | 44 | 5 | 62 | 480 |
| 1915 | 34 | | 65 | 16 | 38 | 5 | 62 | 420 |
| 1920 | 34 | | 65 | 13 | 36 | 5 | 50 | 380 |
| 1925 | 34 | | 65 | 20 | 40 | 5 | 55 | 480 |
| 1930 | 34 | 360/26 | 62 | 22 | 37 | 5 | 34 | 290 |
| **1935** | **34** | | **62** | **21** | **20** | **5** | **34** | **290 W** |
| **1940** | **34** | **332/31** | **58** | **8** | **10** | **5** | **20** | **80 W** |

| Table 6. Cell Attribute Data for 29 March 1997 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 1932 | 31 | | 42 | 10 | 10 | 2 | 6 | 0 |
| 1937 | 31 | | 40 | 11 | 11 | 2 | 6 | 0 |
| 1942 | 31 | | 44 | 11 | 18 | 2 | 6 | 0 |
| 1947 | 31 | | 44 | 12 | 22 | 2 | 8 | 0 |
| 1952 | 31 | | 48 | 12 | 25 | 10 | 8 | 0 |
| 1957 | 31 | | 53 | 12 | 26 | 10 | 6 | 0 |
| 2002 | 31 | | 55 | 12 | 20 | 8 | 6 | 0 |
| 2007 | 31 | | 55 | 8 | 8 | 2 | 7 | 0 |
| 2012 | 31 | | 55 | 8 | 8 | 2 | 7 | 0 |
| 2017 | 31 | 245/14 | 54 | 6 | 6 | 2 | 3 | 0 |
| 1817 | 41 | 5/37 | 44 | 10 | 18 | 5 | 10 | 100 |
| 1822 | 41 | | 45 | 10 | 20 | 5 | 10 | 100 |
| 1827 | 41 | | 50 | 10 | 20 | 5 | 10 | 200 |
| 1832 | 41 | | 52 | 10 | 22 | 5 | 10 | 200 |
| 1837 | 41 | | 48 | 6 | 22 | 5 | 10 | 240 |
| 1842 | 41 | | 45 | 10 | 20 | 5 | 10 | 240 |
| 1847 | 41 | | 50 | 15 | 22 | 5 | 20 | 240 |
| 1852 | 41 | | 55 | 22 | 26 | 5 | 20 | 260 |
| 1857 | 41 | | 50 | 22 | 22 | 10 | 10 | 200 |
| 1902 | 41 | 306/30 | 50 | 22 | 22 | 18 | 10 | 100 |
| 1817 | 73 | 277/41 | 45 | 10 | 18 | 5 | 10 | 100 |
| 1822 | 73 | | 45 | 10 | 20 | 5 | 10 | 100 |
| 1827 | 73 | | 45 | 10 | 22 | 5 | 10 | 200 |
| 1832 | 73 | | 48 | 8 | 22 | 5 | 12 | 100 |
| 1837 | 73 | | 45 | 8 | 22 | 5 | 12 | 200 |
| 1842 | 73 | | 45 | 10 | 18 | 5 | 12 | 200 |
| 1847 | 73 | | 50 | 12 | 22 | 5 | 15 | 300 |
| 1852 | 73 | | 55 | 22 | 28 | 5 | 20 | 360 |
| 1857 | 73 | | 53 | 22 | 26 | 12 | 17 | 200 |
| 1902 | 73 | | 50 | 22 | 24 | 18 | 15 | 100 |
| 1840 | 41 | 307/5 | 45 | 8 | 22 | 5 | 10 | 220 |
| 1845 | 41 | | 50 | 8 | 22 | 5 | 12 | 240 |
| 1850 | 41 | | 55 | 10 | 22 | 5 | 24 | 240 |
| 1855 | 41 | | 55 | 10 | 20 | 5 | 12 | 200 |
| 1900 | 41 | | 55 | 14 | 18 | 5 | 10 | 100 |
| 1905 | 41 | | 55 | 18 | 20 | 5 | 22 | 100 |
| 1910 | 41 | | 50 | 18 | 24 | 5 | 22 | 240 |
| 1915 | 41 | | 57 | 16 | 26 | 5 | 23 | 240 |
| 1920 | 41 | | 55 | 10 | 24 | 5 | 20 | 220 |
| 1925 | 41 | | 48 | 14 | 24 | 8 | 12 | 200 |
| 1930 | 41 | | 46 | 14 | 24 | 12 | 10 | 110 |

Table 7. Cell Attribute Data for 23 April 1997 (H – hail W - wind)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1430 | 40 | | 52 | 6 | 40 | 5 | 18 | 100 |
| 1435 | 40 | | 52 | 14 | 40 | 5 | 18 | 100 |
| 1440 | 40 | | 58 | 14 | 36 | 5 | 18 | 100 |
| 1445 | 40 | | 60 | 14 | 18 | 5 | 34 | 200 |
| 1450 | 40 | | 60 | 8 | 24 | 5 | 50 | 400 |
| 1455 | 40 | | 60 | 12 | 26 | 5 | 53 | 420 |
| 1500 | 40 | | 64 | 14 | 30 | 5 | 60 | 450 |
| 1505 | 40 | | 65 | 14 | 30 | 5 | 64 | 300 |
| 1510 | 40 | | 60 | 14 | 26 | 5 | 40 | 300 |
| 1515 | 40 | 306/39 | 55 | 10 | 20 | 5 | 28 | 300 |
| 1430 | 24 | | 57 | 23 | 42 | 5 | 50 | 300 |
| 1435 | 24 | | 57 | 23 | 42 | 5 | 52 | 500 |
| 1440 | 24 | | 60 | 25 | 42 | 5 | 52 | 520 |
| 1445 | 24 | | 59 | 25 | 42 | 5 | 50 | 500 |
| 1450 | 24 | | 59 | 28 | 44 | 10 | 40 | 360 |
| 1455 | 24 | | 60 | 26 | 42 | 10 | 40 | 240 |
| 1500 | 24 | | 60 | 18 | 44 | 5 | 38 | 100 |
| 1445 | 36 | 284/52 | 60 | 10 | 30 | 5 | 32 | 100 |
| 1450 | 36 | | 60 | 10 | 30 | 5 | 32 | 140 |
| 1455 | 36 | | 59 | **10** | **32** | **5** | **36** | **200** |
| 1500 | 36 | | 60 | **22** | **42** | **5** | **50** | **400** |
| 1505 | 36 | | 65 | **25** | **44** | **5** | **64** | **500** |
| 1515 | 36 | | 65 | **14** | **40** | **5** | **40** | **240** |
| 1520 | 36 | | 60 | 14 | 38 | 5 | 35 | 260 |
| 1525 | 36 | | 57 | 14 | 38 | 5 | 30 | 460 |
| 1530 | 36 | | 55 | 14 | 36 | 5 | 30 | 420 |
| 1535 | 36 | | 50 | 14 | 30 | 5 | 30 | 420 |
| 1540 | 36 | | 50 | 12 | 30 | 10 | 25 | 400 |
| 1545 | 36 | | 29 | 10 | 25 | 10 | 18 | 220 |
| 1545 | 19 | 326/27 | 57 | 18 | 34 | 5 | 28 | 200 |
| 1550 | 19 | | 56 | 22 | 34 | 10 | 32 | 220 |
| 1555 | 19 | | 60 | 17 | 32 | 5 | 40 | 400 |
| 1600 | 19 | | 60 | 17 | 18 | 5 | 26 | 300 |
| 1605 | 19 | | 64 | 18 | 38 | 5 | 40 | 200 |
| 1610 | 19 | | 64 | 18 | 40 | 5 | 40 | 200 |
| 1615 | 19 | | 60 | 12 | 40 | 5 | 34 | 100 |
| 1425 | 3 | 306/52 | 58 | 18 | 32 | 5 | 44 | 400 |
| 1430 | 3 | | 58 | 22 | 44 | 5 | 50 | 440 |
| 1435 | 3 | | 58 | 21 | 42 | 5 | 55 | 520 |
| 1440 | 3 | | 58 | **17** | **40** | **10** | **40** | **330** |
| 1445 | 3 | 322/31 | 62 | **25** | **40** | **5** | **52** | **440** |
| 1500 | 7 | | 60 | 24 | 42 | 5 | 50 | 500 |

Table 7. Cell Attribute Data for 23 April 1997 (continued)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1505 | 7 | | 60 | 24 | 44 | 5 | 24 | 220 |
| 1510 | 7 | | 60 | 22 | 44 | 5 | 38 | 400 |
| 1515 | 7 | | 60 | 12 | 42 | 5 | 50 | 600 |
| 1520 | 7 | | 60 | 20 | 40 | 5 | 30 | 420 |
| 1525 | 7 | | 60 | 20 | 40 | 5 | 40 | 340 |
| 1530 | 7 | | 63 | 14 | 40 | 5 | 60 | 400 |
| 1535 | 7 | | 62 | 14 | 40 | 5 | 55 | 440 |
| 1540 | 7 | | 62 | 14 | 38 | 5 | 55 | 440 |
| 1545 | 7 | | 60 | 6 | 38 | 5 | 52 | 480 |
| 1550 | 7 | 5/37 | 60 | 22 | 36 | 5 | 54 | 290 |
| 1430 | 27 | | 55 | 10 | 24 | 5 | 20 | 200 |
| 1435 | 27 | | 52 | 5 | 24 | 5 | 18 | 240 |
| 1440 | 27 | | 55 | 14 | 30 | 5 | 30 | 300 |
| 1445 | 27 | | 57 | 14 | 34 | 5 | 34 | 300 |
| 1450 | 27 | 328/33 | 57 | 10 | 34 | 5 | 34 | 400 |
| 1455 | 27 | | 57 | 18 | 42 | 5 | 40 | 420 |
| 1500 | 27 | | 60 | 22 | 42 | 5 | 42 | 450 |
| 1505 | 27 | | 60 | 26 | 44 | 5 | 50 | 480 |
| **1510** | **27** | | **64** | **27** | **44** | **5** | **65** | **540 W** |
| **1515** | **27** | | **60** | **16** | **40** | **5** | **45** | **300 W** |
| 1520 | 27 | | 60 | 15 | 40 | 5 | 38 | 300 |
| 1525 | 27 | | 57 | 15 | 38 | 5 | 35 | 240 |
| 1425 | 2 | | 50 | 17 | 34 | 5 | 40 | 260 |
| **1430** | **2** | | **57** | **12** | **40** | **5** | **33** | **180 H** |
| **1435** | **2** | **314/45** | **57** | **24** | **44** | **5** | **50** | **440 H** |
| 1440 | 2 | | 57 | 18 | 44 | 10 | 50 | 300 |
| 1445 | 2 | | 62 | 24 | 42 | 5 | 55 | 520 |
| **1450** | **2** | | **60** | **26** | **44** | **5** | **55** | **500 W** |
| **1455** | **2** | | **58** | **18** | **44** | **18** | **40** | **200 W** |
| 1500 | 2 | | 60 | 18 | 44 | 5 | 30 | 400 |
| 1505 | 2 | | 60 | 20 | 44 | 5 | 35 | 400 |
| 1510 | 2 | | 60 | 18 | 40 | 5 | 35 | 300 |
| 1515 | 2 | | 60 | **16** | **40** | **5** | **40** | **280** |
| 1520 | 2 | | 64 | **24** | **44** | **5** | **60** | **400** |
| 1525 | 2 | | 64 | 20 | 44 | 5 | 60 | 400 |
| 1530 | 2 | | 60 | 12 | 44 | 5 | 60 | 410 |
| 1535 | 2 | | 60 | 12 | 40 | 5 | 60 | 430 |
| 1540 | 2 | 351/34 | 60 | 12 | 44 | 5 | 60 | 440 |
| 1545 | 2 | | 57 | 6 | 40 | 5 | 60 | 500 |
| 1550 | 2 | | 55 | 20 | 38 | 5 | 62 | 330 |
| 1435 | 22 | 300/44 | 57 | 20 | 42 | 5 | 50 | 220 |
| 1440 | 22 | | 58 | 20 | 41 | 7 | 52 | 260 |

| Table 7. Cell Attribute Data for 23 April 1997 (continued) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
| 1445 | 22 | | 62 | 20 | 41 | 7 | 50 | 300 |
| 1450 | 22 | | 60 | 24 | 43 | 5 | 57 | 330 |
| 1455 | 22 | | 57 | 26 | 41 | 14 | 35 | 400 |
| 1500 | 22 | | 60 | 22 | 41 | 8 | 30 | 400 |
| 1509 | 22 | | 60 | 12 | 41 | 5 | 55 | 370 |
| 1515 | 22 | | 62 | 20 | 38 | 5 | 38 | 330 |
| 1520 | 22 | 325/35 | 65 | 14 | 38 | 5 | 62 | 200 |
| 1507 | 20 | 306/39 | 57 | 12 | 42 | 5 | 60 | 260 |
| 1512 | 20 | | 58 | 20 | 40 | 5 | 50 | 460 |
| 1517 | 20 | | 58 | 20 | 40 | 5 | 45 | 400 |
| 1522 | 20 | | 62 | 14 | 41 | 5 | 30 | 220 |
| 1527 | 20 | | 60 | 12 | 40 | 5 | 15 | 200 |
| 1440 | 50 | 348/51 | 53 | 14 | 18 | 12 | 20 | 180 |
| 1445 | 50 | | 55 | 18 | 32 | 8 | 38 | 240 |
| 1450 | 50 | | 56 | 18 | 36 | 18 | 32 | 200 |
| 1455 | 50 | | 57 | 12 | 22 | 8 | 26 | 140 |
| 1500 | 50 | | 57 | 8 | 38 | 8 | 40 | 300 |
| 1505 | 50 | | 54 | 8 | 36 | 5 | 20 | 200 |
| 1510 | 50 | | 50 | 8 | 30 | 5 | 17 | 50 |
| 1515 | 50 | | 45 | 8 | 25 | 5 | 12 | 30 |
| 1520 | 39 | | 64 | 20 | 40 | 5 | 55 | 180 |
| 1525 | 39 | | 60 | 12 | 38 | 5 | 60 | 400 |
| 1530 | 39 | | 60 | 13 | 40 | 5 | 60 | 410 |
| 1535 | 39 | | 60 | 13 | 40 | 5 | 60 | 410 |
| 1540 | 39 | | 58 | 10 | 38 | 5 | 60 | 400 |
| 1545 | 39 | | 60 | 12 | 38 | 5 | 55 | 420 |
| 1550 | 39 | | 60 | **6** | **37** | **5** | **50** | **240** |
| 1555 | 39 | 318/24 | 60 | **22** | **34** | **5** | **62** | **390** |
| 1600 | 39 | | 60 | 18 | 18 | 5 | 38 | 200 |
| 1427 | 12 | 304/53 | 58 | 18 | 32 | 5 | 42 | 400 |
| 1432 | 12 | | 58 | 22 | 42 | 5 | 46 | 440 |
| 1437 | 12 | | 58 | 22 | 42 | 5 | 54 | 500 |
| 1442 | 12 | | 59 | 20 | 41 | 8 | 50 | 480 |
| 1447 | 12 | | 60 | 18 | 40 | 12 | 44 | 300 |
| 1452 | 12 | | 62 | 26 | 40 | 5 | 50 | 420 |
| 1457 | 12 | | 60 | 24 | 40 | 5 | 60 | 520 |
| 1502 | 12 | | 60 | 25 | 42 | 18 | 35 | 200 |
| 1507 | 12 | | 60 | **20** | **42** | **5** | **60** | **600** |
| 1512 | 12 | | 60 | **10** | **40** | **5** | **30** | **200** |
| 1517 | 12 | | 64 | 15 | 40 | 5 | 35 | 300 |
| 1522 | 12 | | 64 | 20 | 40 | 5 | 60 | 400 |
| 1527 | 12 | | 62 | 14 | 40 | 5 | 55 | 400 |

Table 7. Cell Attribute Data for 23 April 1997 (continued)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1532 | 12 | | 62 | 12 | 40 | 5 | 58 | 420 |
| 1537 | 12 | | 60 | 10 | 40 | 5 | 60 | 460 |
| 1542 | 12 | | 60 | 14 | 42 | 5 | 58 | 420 |
| 1547 | 12 | | 60 | 15 | 40 | 5 | 60 | 300 |
| 1552 | 12 | | 60 | 24 | 37 | 5 | 58 | 200 |
| 1557 | 12 | | 58 | 19 | 22 | 5 | 40 | 200 |
| 1447 | 27 | 304/42 | 55 | 18 | 40 | 5 | 40 | 200 |
| **1452** | **27** | | **62** | **24** | **42** | **5** | **62** | **420 W** |
| **1457** | **27** | | **60** | **12** | **42** | **16** | **30** | **300 W** |
| 1502 | 27 | | 64 | 22 | 40 | 5 | 30 | 360 |
| 1507 | 27 | | 62 | 21 | 38 | 5 | 30 | 350 |
| 1512 | 27 | | 64 | 14 | 38 | 5 | 30 | 420 |
| 1517 | 27 | 322/28 | 65 | 19 | 40 | 5 | 64 | 320 |
| 1420 | 13 | 335/71 | 55 | 17 | 30 | 6 | 35 | 200 |
| 1425 | 13 | | 55 | 15 | 40 | 6 | 33 | 200 |
| **1430** | **13** | | **60** | **10** | **40** | **6** | **32** | **200 H** |
| **1435** | **13** | | **60** | **18** | **50** | **20** | **44** | **400 H** |
| **1440** | **13** | | **60** | **16** | **44** | **20** | **44** | **380 H** |
| **1445** | **13** | | **62** | **26** | **44** | **20** | **60** | **200 H** |
| 1450 | 13 | | 63 | 25 | 47 | 6 | 60 | 400 |
| 1455 | 13 | 346/66 | 55 | 24 | 47 | 6 | 60 | 260 |
| 1422 | 6 | 307/65 | 55 | 24 | 30 | 6 | 20 | 100 |
| 1427 | 6 | | 57 | 6 | 36 | 6 | 40 | 400 |
| 1432 | 6 | | 57 | 20 | 38 | 8 | 38 | 120 |
| 1437 | 6 | | 57 | 20 | 40 | 18 | 30 | 160 |
| **1442** | **6** | | **57** | **20** | **42** | **18** | **34** | **340 W** |
| **1447** | **6** | **318/61** | **57** | **10** | **44** | **6** | **22** | **130 W** |
| 1422 | 7 | 298/57 | 55 | 12 | 30 | 6 | 52 | 280 |
| 1427 | 7 | | 57 | 18 | 36 | 6 | 58 | 400 |
| 1432 | 7 | | 57 | 20 | 38 | 6 | 58 | 440 |
| 1437 | 7 | | 57 | 22 | 42 | 6 | 58 | 480 |
| **1442** | **7** | | **57** | **24** | **44** | **6** | **60** | **540 W** |
| **1447** | **7** | **315/54** | **60** | **12** | **40** | **12** | **48** | **280 W** |
| 1452 | 7 | | 62 | 22 | 40 | 6 | 57 | 500 |
| 1457 | 7 | | 57 | 26 | 40 | 16 | 59 | 360 |
| 1427 | 47 | 299/62 | 55 | 14 | 30 | 5 | 29 | 300 |
| **1432** | **47** | | **55** | **14** | **32** | **5** | **31** | **220 H** |
| **1437** | **47** | | **62** | **27** | **40** | **5** | **47** | **520 H** |
| 1442 | 47 | | 55 | 23 | 28 | 5 | 39 | 280 |
| 1447 | 47 | 317/56 | 55 | 12 | 38 | 5 | 27 | 440 |
| 1452 | 47 | | 55 | 12 | 35 | 5 | 27 | 400 |
| 1457 | 47 | | 60 | 10 | 30 | 5 | 30 | 300 |

Table 7. Cell Attribute Data for 23 April 1997 (continued)

| Time | ID | AzRng | MR | HMR | ST | SB | SVIL | CAR |
|---|---|---|---|---|---|---|---|---|
| 1427 | 17 | 320/72 | 60 | 10 | 30 | 5 | 30 | 300 |
| 1432 | 17 | | 57 | 12 | 50 | 5 | 40 | 180 |
| 1437 | 17 | | 62 | 30 | 44 | 22 | 40 | 200 |
| 1442 | 17 | | 62 | 22 | 46 | 5 | 40 | 430 |
| 1447 | 17 | 339/63 | 62 | 22 | 46 | 5 | 12 | 250 |
| 1552 | 17 | 344/59 | 64 | 28 | 50 | 5 | 65 | 440 |

| **REPORT DOCUMENTATION PAGE** | Form Approved OMB No. 0704-0188 |
|---|---|



| 1. AGENCY USE ONLY (Leave Blank) | 2. REPORT DATE | 3. REPORT TYPE AND DATES COVERED |
|---|---|---|
| | April 1998 | Contractor Report |

| | |
|---|---|
| 4. TITLE AND SUBTITLE<br>WSR-88D Cell Trends Final Report | 5. FUNDING NUMBERS<br>C-NAS10-96018 |
| 6. AUTHOR(S)<br>Mark M. Wheeler | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>ENSCO, Inc., 1980 N Atlantic Ave STE 230 Cocoa Beach, FL 32931 | 8. PERFORMING ORGANIZATION REPORT NUMBER<br>98-001 |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)<br>NASA, John F. Kennedy Space Center, Code AA-C-1, Kennedy Space Center, FL 32899 | 10. SPONSORING/MONITORING AGENCY REPORT NUMBER<br>207904 |
| 11. SUPPLEMENTARY NOTES<br>Subject Cat.: #47 (Weather Forecasting) | |
| 12A. DISTRIBUTION/AVAILABILITY STATEMENT<br>Unclassified - Unlimited | 12B. DISTRIBUTION CODE |

13. ABSTRACT (Maximum 200 Words)

This report documents the Applied Meteorology Unit's evaluation of the Cell Trends display as a tool for radar operators to use in their evaluation of storm cell strength. The objective of the evaluation is to assess the utility of the WSR-88D graphical Cell Trends display for local radar cell interpretation in support of the 45th Weather Squadron (45WS), Spaceflight Meteorology Group (SMG), and National Weather Service (NWS) Melbourne (MLB) operational requirements. The analysis procedure was to identify each cell and track the maximum reflectivity, height of maximum reflectivity, storm top, storm base, hail and severe hail probability, cell-based Vertically Integrated Liquid (VIL) and core aspect ratio using WATADS Build 9.0 cell trends information. One problem noted in the analysis phase was that the Storm Cell Identification and Tracking (SCIT) algorithm had a difficult time tracking the small cells associated with the Florida weather regimes. The analysis indicated numerous occasions when a cell track would end or an existing cell would be give a new ID in the middle of its life cycle.

This investigation has found that most cells, which produce hail or microburst events, have discernable Cell Trends signatures. Forecasters should monitor the PUP's Cell Trends display for cells that show rapid (1scan) changes in both the heights of maximum reflectivity and cell-based VIL.

It is important to note that this a very limited data set (four case days). Fifty-two storm cells were analyzed during those four days. The above mentioned trends, increase in the two cell attributes for hail events and decrease in the two cell attributes for wind events were noted in most of the cells. The probability of detection was 88% for both events. The False Alarm Rate (FAR) was a 36% for hail events and a respectable 25% for microburst events. In addition the Heidke Skill Score (HSS) is 0.65 for hail events and 0.67 for microburst events. For random forecast the HSS is 0 and that a perfect score is 1.

| | |
|---|---|
| 14. SUBJECT TERMS<br>Doppler, Radar, Cell Trends, NEXRAD,WSR-88D | 15. NUMBER OF PAGES 35 |
| | 16. PRICE CODE |

| 17. SECURITY CLASSIFICATION OF REPORT | 18. SECURITY CLASSIFICATION OF THIS PAGE | 19. SECURITY CLASSIFICATION OF ABSTRACT | 20. LIMITATION OF ABSTRACT |
|---|---|---|---|
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | NONE |