Project Report
ATC-317

Description of the Corridor Integrated Weather System (CIWS) Weather Products

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1 August 2005

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LEXINGTON, MASSACHUSETTS

Prepared for the Federal Aviation Administration,
Washington, D.C. 20591

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Springfield, VA 22161

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
ATC-317		

4. Title and Subtitle	5. Report Date
Description of the Corridor Integrated Weather System (CIWS) Weather Products	1 August 2005
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
D. Klingle-Wilson and J. Evans	ATC-317
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
MIT Lincoln Laboratory 244 Wood Street Lexington, MA 02420-9108	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Department of Transportation Federal Aviation Administration 800 Independence Ave., S.W. Washington, DC 20591	Project Report
	14. Sponsoring Agency Code

15. Supplementary Notes

This report is based on studies performed at Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, under Air Force Contract FA8721-05-C-0002.

16. Abstract

Improved handling of severe en route and terminal convective weather has been identified by the FAA in both the Operational Evolution Plan (OEP) (FAA, 2002) and the Flight Plan for 2004–2008 (FAA, 2003) as a major thrust over the coming decade for the National Airspace System (NAS) modernization. Achieving such improved capabilities is particularly important in highly congested corridors where there is both a high density of over flights and major terminals. Delay increases during thunderstorm season have been the principal cause of the dramatic delay growth in the US aviation system. When major terminals also underlie the en route airspace, convective weather has even greater adverse impacts, especially if the convective weather occurs frequently.

In response to the need to enhance both safety and capacity during adverse weather, the FAA is exploring the concept of a Corridor Integrated Weather System (CIWS). CIWS is designed to improve convective weather decision support for congested en route airspace (and the terminals that lie under that airspace) by automatically generating graphical depictions of the current severe weather situation and providing frequently updated forecasts of the future weather locations for forecast times from zero to two hours.

An operational demonstration of the CIWS was conducted during the summer of 2003. This document provides a detailed description of each CIWS weather information product as it was demonstrated in 2003, including a general description of the product, what data sources are used by the product, how the product is generated from the input data, and what caveats in the technical performance apply. A discussion of how the products might be used to enhance safety and support decision-making for traffic management is also included. Detailed information on the operational benefits of the CIWS products demonstrated in 2003 is provided in a companion report (Robinson et al., 2004).

Improvements made to the products for the 2004 and 2005 CIWS operational demonstrations are briefly discussed in the final chapter.

17. Key Words	18. Distribution Statement
	This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	124	

ABSTRACT

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TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

Page

TABLE OF CONTENTS
(Continued)

Page

TABLE OF CONTENTS
(Continued)

Page

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS
(CONTINUED)

Figure No. **Page**

LIST OF ILLUSTRATIONS
(CONTINUED)

Figure No. **Page**

LIST OF ILLUSTRATIONS
(CONTINUED)

Figure No. **Page**

LIST OF TABLES

LIST OF TABLES
(CONTINUED)

1. INTRODUCTION

Improved handling of severe en route and terminal convective weather has been identified by the FAA in both the Operational Evolution Plan (OEP) (FAA, 2002) and the Flight Plan for 2004-2008 (FAA, 2003) as a major thrust over the coming decade for the National Airspace System (NAS) modernization. Achieving such improved capabilities is particularly important in highly congested corridors where there is both a high density of over flights and major terminals.

Delay increases during the months of the year characterized by thunderstorms have been the principal cause of the dramatic delay growth in the US aviation system. Figure 1-1 shows the Air Traffic Operations Network (OPSNET) delay statistics[1] for an eight-year period. Typically, approximately 70% of the OPSNET delays are attributed to weather (e.g., wind, rain, snow/ice, low cloud ceilings, low visibility, tornados, hurricanes or thunderstorms). Weather-related delay is greatest during the summer months when thunderstorms are most frequent. In highly congested airspace, such as shown in Figure 1-2, convective weather presents a particularly difficult challenge because:

- It is not possible to accurately forecast operationally significant convective weather far enough in advance to avoid in-flight adjustments of aircraft routes (National Research Council, 2003) and

- There is often little or no excess capacity available when severe weather occurs. For example, rerouting aircraft around areas of actual or predicted weather can be very difficult when one must be concerned about controller overload in the weather-free sectors.

When major terminals also underlie the en route airspace, convective weather has even greater adverse impacts, especially if the convective weather occurs frequently. In response to the need to enhance both safety and capacity, the FAA is exploring the concept of a Corridor Integrated Weather System (CIWS). CIWS is designed to improve convective weather decision support for congested en route airspace (and the terminals that lie under that airspace) by automatically generating graphical depictions of the current severe weather situation and providing frequently updated forecasts of the future weather locations for forecast times from zero to two hours.

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[1] OPSNET delays are delays of 15 min or more that are reported by the FAA's Air Traffic Operations Network. These delays are attributable to a single FAA facility, which assigns causality to the event.

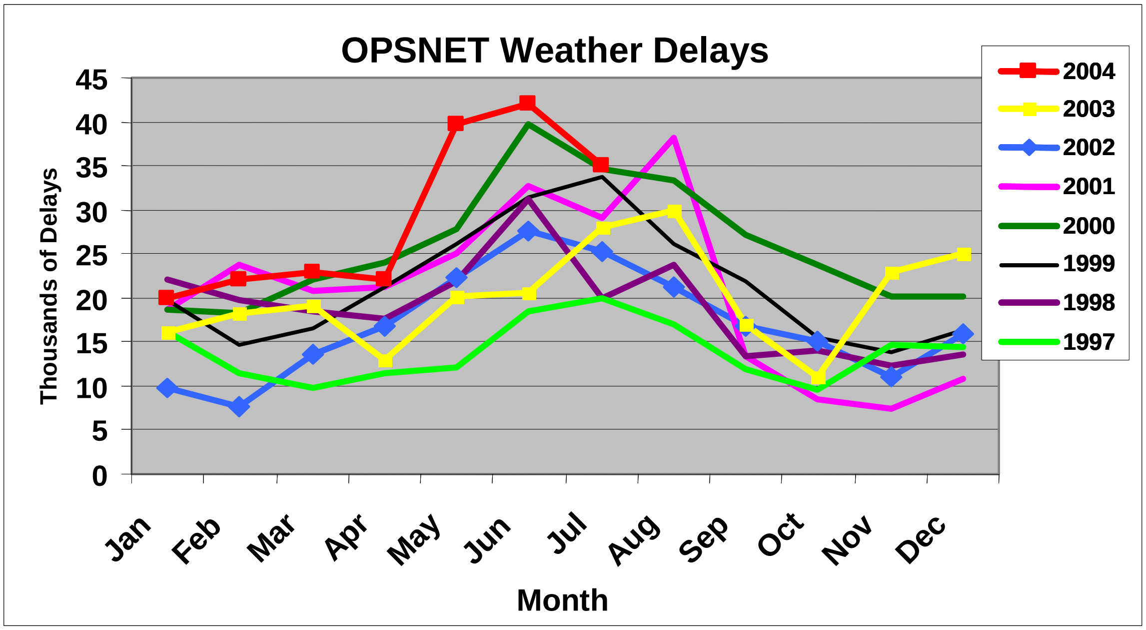

Figure 1-1. U.S. OPSNET delays by month for an eight-year period.

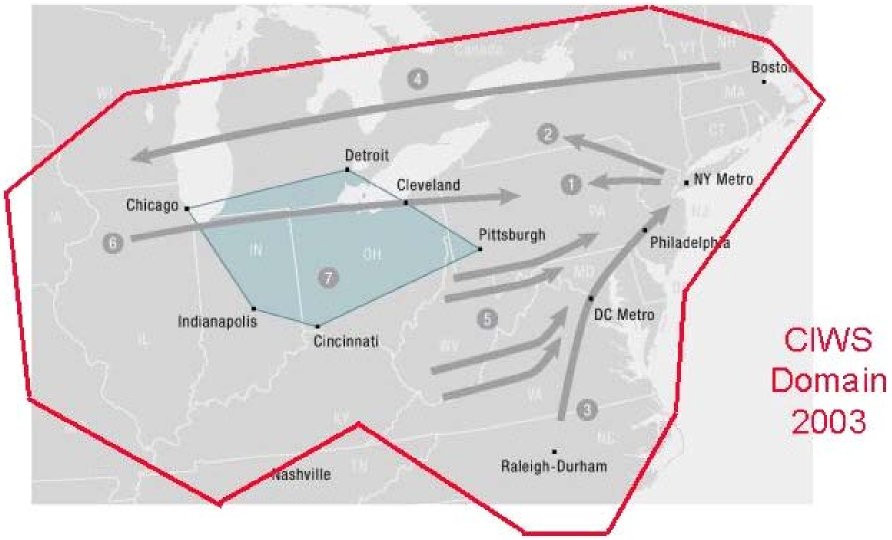

Figure 1-2. Major congestion points in the NAS as identified in the FAA Airport Capacity Enhancement Plan.

CIWS acquires data from FAA terminal weather sensing systems, and National Weather Service sensors and forecast products (Figure 1-3), and automatically generates convective weather products for display on existing systems in both terminal and en route airspace within the CIWS domain. CIWS products are provided to Air Traffic Control (ATC) personnel, airline systems operations centers, and automated air traffic management decision support systems in a form that is directly usable without further meteorological interpretation. Using these products, traffic managers may achieve more efficient tactical use of the airspace, reduce controller workload, and significantly reduce air traffic delay. These tactical traffic flow management products complement the longer-term (two- to six-hour) national forecasts that are needed for flight planning and traffic flow management. The zero- to two-hour tactical forecasts also help bridge the gap between the current weather picture and the strategic plan.

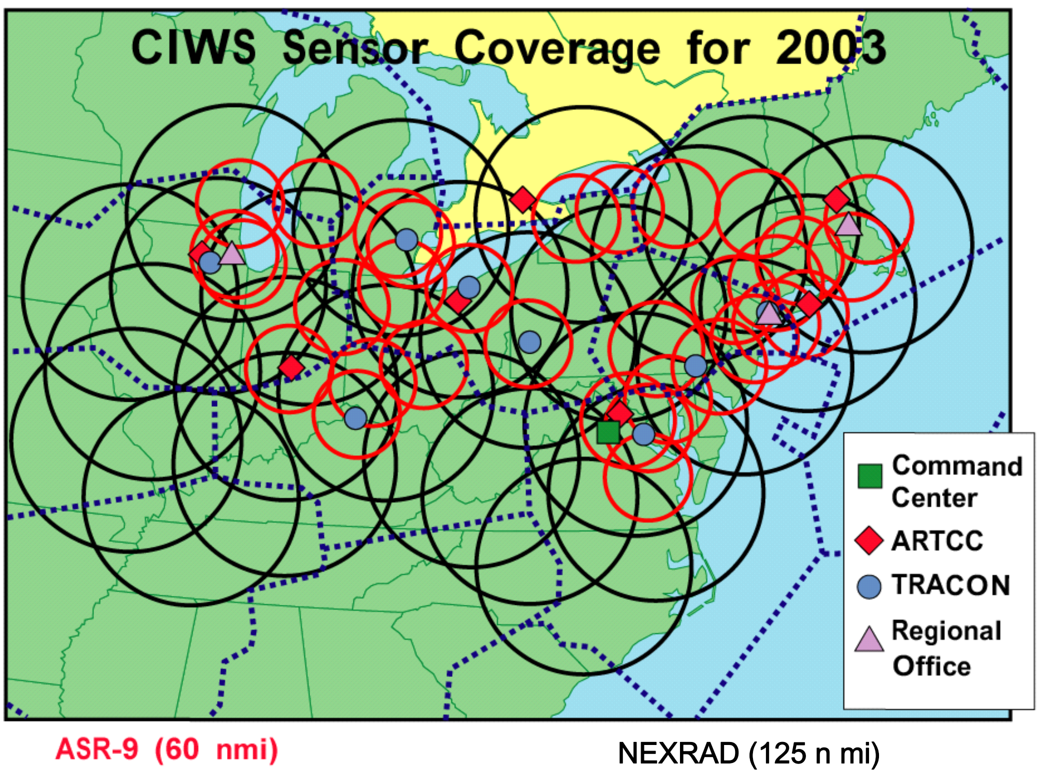

Figure 1-3. Terminal and en route weather sensors used to create CIWS products. The red circles indicate ASR-9 radar coverage, the black circles are NEXRAD radar coverage. Facilities were CIWS situation displays are located are indicated.

Convective storms can be broadly categorized into air mass and line storms. Air mass storms are small scale, seemingly random, disorganized convection. Line storms are collections of cells maintained in a linear pattern or “envelope.” The CIWS precipitation and storm motion products handle both types of storms. Storm tracking and extrapolated position algorithms provide the motions and predicted locations of individual cells.

The CIWS Regional Convective Weather Forecast (RCWF) product provides forecasts for storms out to 120 min in 15-min increments. This is an adapted version of the Integrated Terminal Weather System (ITWS) Terminal Convective Weather Forecast, which has been used operationally since 1998 in the transitional en route airspace around major terminals. This forecast is updated every five minutes and can provide information on rapidly changing weather conditions.

In addition to these primary weather products, the Lightning, Satellite, Forecast Accuracy, and Growth and Decay Trends products assist traffic managers in deciding the best tactical approach to managing airspace impacted by convective weather.

1.1 ABOUT THIS REPORT

This document provides a detailed description of each CIWS weather information product as it was demonstrated during the operational demonstration conducted during the summer of 2003. Within each section the discussion is broken down into subsections including

- a general description of the product,
- what data sources are used by the product,
- how the product is generated from the input data,
- what caveats in the technical performance apply,
- how the product is displayed, and
- how the product might be used to enhance safety and support decision-making for traffic management.

The primary audience for this report is intended to be air traffic managers and airline systems operations center personnel who use CIWS products in operational situations. If a user desires information about a particular product, he/she may reference the chapter describing the product directly. Each chapter is designed to be stand-alone. Cross-referencing to other chapters is minimized such that all material pertinent to a product is presented in the chapter. For example, the Forecast Contours product is generated from the RCWF product. Caveats for the RCWF product also apply to the Forecast Contours product. Rather than refer the user to the RCWF chapter, the pertinent material is simply repeated in the Forecast Contours chapter.

CIWS products are available to users on two platforms: a dedicated Situation Display and a web site. Table 1.1 provides input data sources, update rates, and spatial resolutions for the CIWS product suite. The CIWS Situation Display allows the user to open multiple windows and display different products in those windows. The Situation Display supports four different windows named NEXRAD, ASR, Forecast, and Echo Tops. Different products are displayable in the different windows, as shown in Table 1.2. The CIWS web site also supports four windows: NEXRAD, ASR, Forecast, and Echo Tops. Each window type has a suite of products associated with it and the product suite is different for each window type. The products that are displayable in each web site window are shown in Table 1.3. The Situation Display and web site user interfaces are discussed in Appendix A and Appendix B, respectively.

Table 1.1
CIWS Product Update Rates[1], Data Sources, and Spatial Resolutions.

Product	Data Sources	Product Update Interval (min[3])	Product Spatial Resolution (nmi[3])
VIL[3] Mosaic Precipitation	NEXRAD[3]	2.5	1.0
ASR[3] Mosaic Precipitation	ASR-9[4]	1	0.5
Storm Motion	Precipitation source	1-2.5[5]	---
Storm Extrapolated Position (SEP)	Precipitation source	1-2.5[5]	0.5
Lightning	NLDN[3]	5	0.05
Satellite	GOES[3] East	15	1.0
Echo Tops Mosaic	NEXRAD	5.0	0.5
Echo Tops/Annotation	Echo Tops Mosaic	5.0	0.5
RCWF[3]	NEXRAD	5.0	0.5
Forecast Accuracy	RCWF	5.0	---
Forecast Contours	RCWF	5.0	1.0
Forecast Verification	RCWF	5.0	1.0

1 Unless noted otherwise, update rate is nominal because the actual update is triggered by an external sensor.
2. Performance results from Klingle-Wilson (1995) unless otherwise noted.
3. min minutes
nmi nmi
NEXRAD Next Generation Weather Radar
VIL Vertically Integrated Liquid water
ASR Airport Surveillance Radar
NLDN National Lightning Detection Network
GOES Geostationary Operational Environmental Satellite
RCWF Regional Convective Weather Forecast
4. ASR reflectivity is quality checked against and NEXRAD data.
5. Update interval is a function of the underlying precipitation product.

Table 1.2
Products displayable on the CIWS Situation Display as a function of window type.

	Window Type			
	NEXRAD	**ASR**	**Forecast**	**Echo Tops**
Displayable Products	VIL Mosaic	ASR Mosaic	RCWF	Echo Tops Mosaic
	Storm Motion	Storm Motion	Forecast Accuracy	Echo Tops Annotation
	Echo Tops	Echo Tops	Verification Contours	Growth and Decay Trends
	Lightning	Lightning		Lightning
	Satellite			
	Forecast Contours			
	Growth and Decay Trends			

Table 1.3
Products displayable on the CIWS web site as a function of window type.

	Web site Window Type			
	NEXRAD	**ASR**	**Forecast**	**Echo Tops**
Displayable Products	Satellite	Filtered Storm Motion	Forecast without Verification Contours	Growth and Decay Trends
	Growth and Decay Trends	Lightning	Forecast with 30-minute Verification Contours	Lightning
	30-minute Forecast Contours	Filtered Echo Tops	Forecast with 60-minute Verification Contours	Filtered Echo Tops
	60-minute Forecast Contours		Forecast with 120-minute Verification Contours	
	120-minute Forecast Contours			
	Filtered Storm Motion			
	Lightning			
	Filtered Echo Tops			

Finally, improvements made to the CIWS products for the 2004 operational demonstration are discussed. CIWS coverage was extended in early June 2004 by increasing the number of NEXRAD radars and adding Canadian weather radars. Improvements were made to the RCWF. A Winter Weather Precipitation mode was added in October 2004.

1.2 A WORD ABOUT UNITS

Air Traffic managers typically work in units of nmi for distance, thousands of feet for altitude, and knots (nmi per hour) for speed. Meteorological data and product generation algorithms typically use the metric system (kilometers and meters per second). The intended audience for this report is air traffic users. For this reason, units common to air traffic users are used throughout. Metric units are converted to English units using the following approximations.

Conversion: 1 meter per second (m/s) = 1.94 knots (kn); 1 kilometer (km) = 0.54 nautical miles (nmi), 1 km = 3281 feet.

Approximations

Metric	English
1 km	0.5 nmi
1 km	3300 feet
12 km^2	3 nmi^2
20 km	10 nmi
230 km	125 nmi
300 km	162 nmi
4 km	2 nmi
460 km	248 nmi
60 km	32 nmi
70 km	35 nmi

2. CIWS VIL MOSAIC PRODUCT

The CIWS VIL Mosaic product provides a high-resolution estimate of vertically integrated liquid water (VIL) based on Next Generation Weather Radar (NEXRAD) radar reflectivity data. Because VIL is related to reflectivity, the VIL values are mapped to the corresponding six-level colors used to present weather radar data. Therefore, the VIL map shows the location and intensity of precipitation as indicated by a mosaic of NEXRAD radars. An example of the product is provided in Figure 2-1.[2]

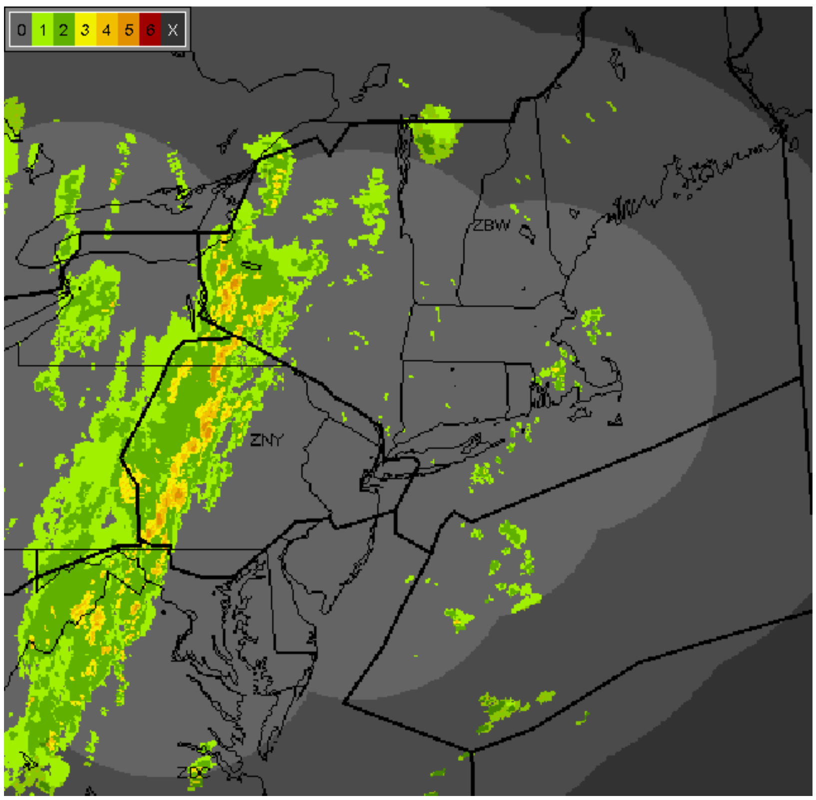

Figure 2-1. Example of CIWS VIL Mosaic Product. The product is a mosaic of VIL computed from individual NEXRAD radars. Cool colors represent lighter precipitation; warm colors represent heavier precipitation.

The CIWS VIL Mosaic product is a mosaic of VIL computed from individual NEXRAD radars. Many of the current en route severe weather information products (e.g., the Weather and Radar Processor [WARP] precipitation products and the ITWS 100 nmi and 200 nmi products) use the NEXRAD base-

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[2] This product is described as it was configured during the 2003 Operational Demonstration. Improvements to the product for the 2004 Operational Demonstration are discussed in Chapter 14.

scan reflectivity or Composite Maximum Reflectivity (CMR) products. The base scan reflectivity product presents the intensity of rain at the altitude of the radar beam, typically the lowest elevation angle. Higher intensity precipitation may exist above the beam. The CMR is the maximum reflectivity at any altitude observed over each grid point location. Under some circumstances the CMR product does not well represent the weather severity (Robinson, 2002). Moreover, winter storms that are benign in terms of turbulence, rain intensity, and hail may have weather levels similar to operationally significant thunderstorms due to a strong returned signal from a narrow altitude range around the freezing/melting level (bright band). The use of CMR also results in false indications of severe weather when Anomalous Propagation (AP) clutter is present.

These false severe weather indications from the CMR-based products can be alleviated by the use of NEXRAD-based VIL precipitation products that depict the integrated amount of water above a grid point. Represented as six-level data, VIL has been found to more closely match the actual storm severity than does the CMR product.

VIL is computed from radar reflectivity returns that may be contaminated by AP ground clutter. Even though the vertical integration minimizes the appearance of AP in the VIL map, it is still desirable to remove as much AP clutter as possible is removed from the data before VIL is computed.

2.1 DATA QUALITY ISSUES

In very simplified terms, radar works by transmitting a pulse of energy and sensing the energy that reflects off targets in the radar beam's path. When the targets are trees and buildings near the radar, the returns are called ground clutter. In the case of thunderstorms, the targets are raindrops. The amount of energy returned from a thunderstorm depends on the amount and size of raindrops in the volume. Thus heavy rain is associated with higher intensity levels.

2.1.1 Anomalous Propagation Clutter Contamination

In the standard atmosphere, a radar beam typically travels in a slightly curved path above the earth's surface (Figure 2-2). Under "anomalous" atmospheric conditions, the path of the beam is more highly curved and may strike the ground even at distances well away from the radar. The returns from the ground are often referred to as "AP clutter."

The atmospheric conditions that cause AP clutter are temperature inversions and moisture gradients. In a standard atmosphere, temperature decreases with height. Occasionally, surface cooling or cooler air near the surface reverses the temperature profile such that temperature increases with height near the ground. In this situation, the radar beam is bent downward and strikes the earth's surface. Although the skies may be cloud-free, this "temperature inversion" causes the ground clutter returns to appear as real weather on the displays. As the inversion strengthens, the AP clutter increases in spatial extent and intensity. An example of AP ground clutter contamination is provided in Figure 2-3.

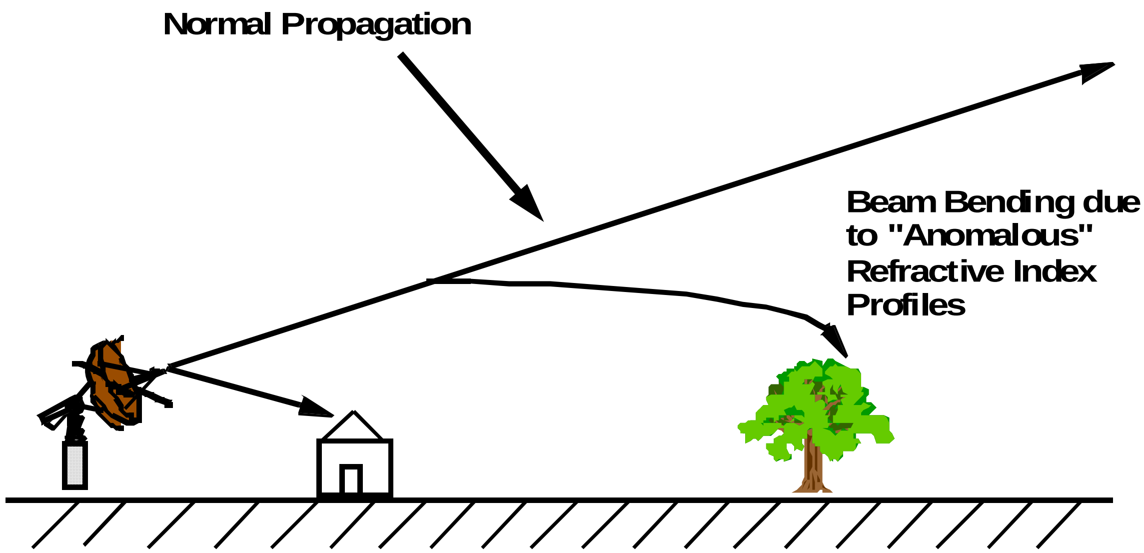

Figure 2-2. Illustration of a radar beam propagating anomalously due to non-standard atmospheric conditions.

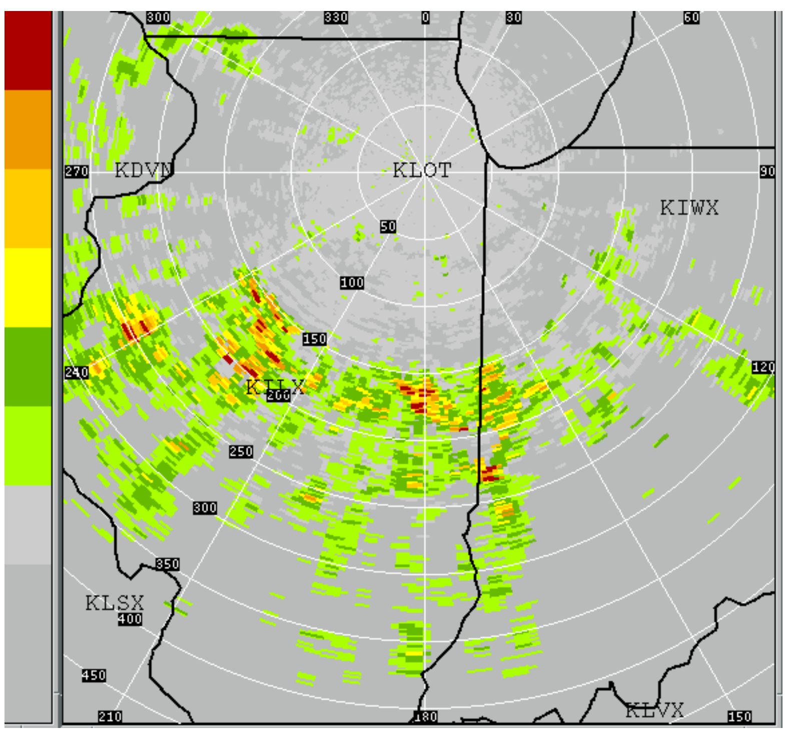

Figure 2-3. Example of AP clutter in weather radar data. Range rings are in kilometers.

AP clutter filtering is performed on the radar base data. AP clutter is characterized by near-zero Doppler velocities and narrow velocity spectrum widths. In contrast to weather, AP clutter appears to "move" very slowly (if at all) and the variance in the velocity estimate is very narrow. Areas containing high reflectivity, near-zero Doppler velocities, and narrow velocity spectrum widths are flagged as AP. These areas are removed from further computations. The NEXRAD computes Doppler velocity data to a distance that is determined by the pulse repetition frequency of the radar, which can vary from scan to scan. Beyond that range, velocity-based filtering cannot be accomplished. The AP clutter breakthrough in Figure 2-3 was not filtered because it was beyond the range of the Doppler velocities.

2.1.2 Bright Band Contamination

Wet ice reflects radar energy very strongly. At the freezing level, where ice and liquid water co-exist to form wet ice, the reflected energy may be equivalent to level three or greater weather. An example of such a "bright band" is provided in Figure 2-4, which is a base reflectivity scan from the WARP. Bright band contamination is reduced by creating a mosaic that incorporates data quality checks. This will be explained further in Section 2.2.

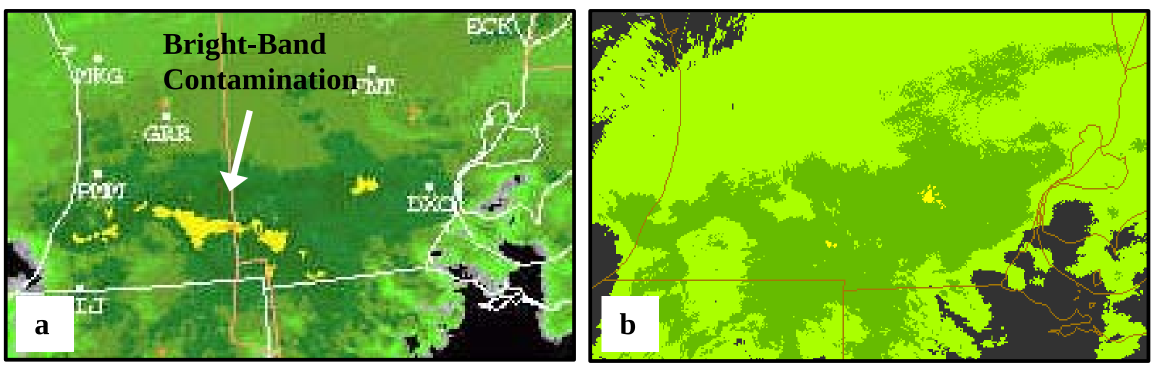

Figure 2-4. Example of how bright band contamination present in (a) the WARP base-scan reflectivity product is reduced in (b) the CIWS VIL Mosaic product.

2.1.3 "Smearing" of weather due to motion

NEXRAD radars scan asynchronously. A storm is generally scanned by different radars at different times. Because storms move, different radars will see the same storm in different locations. A simple mosaic that does not account for the motion of the storms results in spatial "smearing" of the weather. The CIWS VIL Mosaic product compensates for storm motion by advecting the weather forward to a common time prior to generating the mosaic.

2.1.4 Distant weather coverage

The NEXRAD radar can detect precipitation to a range of about 248 nmi. However, at ranges beyond about 125 nmi, the altitude of the lowest-elevation radar beam is such that the low beam may overshoot the storm core. This results in an underestimate of storm intensity. For this reason, the background (all precipitation intensities below level one) is represented by light gray within 125 nmi of any radar while slightly darker versions of all colors are used at ranges beyond 125 nmi. This long-range gray/color shading provides a visual reminder to users that if weather is depicted in these areas, it may actually be of higher intensity than shown. In addition, it is possible that there is weather in this region that is not shown at all in the VIL image.

2.2 PRODUCT GENERATION

After AP-flagging is completed, the liquid water content of a radar sampling volume is computed from radar reflectivity using an empirical relationship. VIL is computed from this liquid water content by summing over the depth of a column. This process is performed for each weather radar.

While the update rate of the VIL from an individual NEXRAD radar may be 4.2 to 11 min (depending upon the scan strategy), the VIL mosaic is generated every 2.5 min. Since input from the individual radars is asynchronous, the latest data scan received from each radar over the past 10 min is incorporated into the mosaic. Using estimates of storm motion (Chapter 4), the weather is advected forward to the current time prior to generating the mosaic. This technique reduces the “smearing” of the weather that results when a mosaic is created without accounting for data latency and storm motion.

In areas of overlapping coverage, multiple estimates of VIL are available. To create the mosaic, a decision must be made about which VIL value most accurately represents the precipitation for the given area. The mosaic is created using a “maximum plausible” rule. The goal of the technique is to select the maximum VIL value for the column while removing VIL values that may be anomalously high due to data artifacts such as AP clutter or bright band contamination. All computed VIL values from radars within 162 nmi of the location are tested. The data are sorted from highest to lowest and the highest value is tested for plausibility. Based on a set of adaptable parameters, including comparison to other VIL values in the area and persistence over time, the maximum plausible VIL value is selected. The persistence check reduces the possibility of erroneously identifying rapidly growing weather as data artifacts and removing real weather from the mosaic. When the mosaic is completed, the VIL values are mapped to six color levels.

2.3 DISPLAY CONCEPT

The CIWS VIL Mosaic product is provided in six-level representation. The levels are color-coded as shown in Figure 2-1; greens represent lighter precipitation, reds represent heavier precipitation. Weather levels below level one are shown as light gray if within 125 nmi of any NEXRAD radar. Slightly darker versions of all colors are used at ranges beyond 125 nmi. The darkest gray level indicates no data regions (areas where there is no coverage by the weather radars). The native resolution of the CIWS VIL Mosaic product is about 0.5 nmi, but the data are displayed with a 1-nmi resolution to reduce bandwidth to the displays in this demonstration system. The mosaic is displayed on a grid that is roughly 1400 nmi east/west by 850 nmi north/south and centered about 85 nmi east of Columbus, OH. The maximum range of the product depends upon the number and location of the NEXRAD radars in the mosaic. The update rate and resolution are provided in Table 2.1.

Table 2.1
CIWS VIL Mosaic Product Update Rates, Data Sources, and Spatial Resolutions.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
VIL Mosaic Precipitation	NEXRAD	2.5	1.0

2.3.1 CIWS Situation Display

CIWS Situation Display (Appendix A) users may choose the weather levels to be displayed by left or right clicking the Precip product status button in the lower left corner of the NEXRAD window. The color of the Precip status button indicates the state and status of the VIL Mosaic product, as shown in Table 2.2.

Table 2.2
Precip Button Color, Product Status, and Product State.

Button Color	Product Status and State
Precip	Unavailable
Precip	Available[1] and displayed in the window
Precip	Available and filtered[2]
1. The product is available as long as at least one radar contributes to the mosaic. 2. The product is not completely displayed.	

There is no white state for the Precip product status button. The coverage pattern indicating the distant radar coverage (inside/outside 125 nmi) is part of the product that may not be "turned off" in the window. For this reason, the product is never completely "Off" even if no weather levels are displayed and thus the Precip button can never be white.

Right clicking the Precip product status button displays the Precip dialog box (Figure 2-5). This example indicates that when the product is not completely displayed (only levels three through six are being displayed); the product status button is yellow. Users may select which levels to display by left clicking the button next to the desired option. The button to the left of the currently displayed levels is highlighted. Left clicking the Precip button toggles the displayed precipitation levels between NONE and the last user selection.

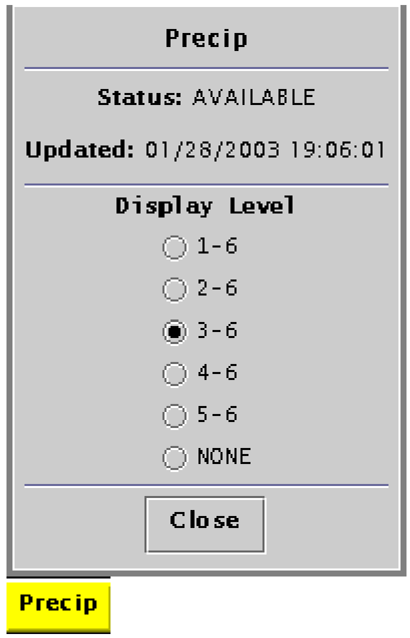

Figure 2-5. Precip product status dialog box and Precip product status button. The yellow button indicates that the VIL mosaic product is filtered because only levels 3 through 6 are displayed.

2.3.2 CIWS Web Site

CIWS web site (Appendix B) users may display the VIL Mosaic product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. An example of the NEXRAD window centered on the Indianapolis Air Route Traffic Control Center (ZID) is provided in Figure 2-6. If the VIL Mosaic product is not displayed in the window, the user may display the product by selecting NEXRAD from the Display drop-down menu (Figure 2-7) and left-clicking Apply.

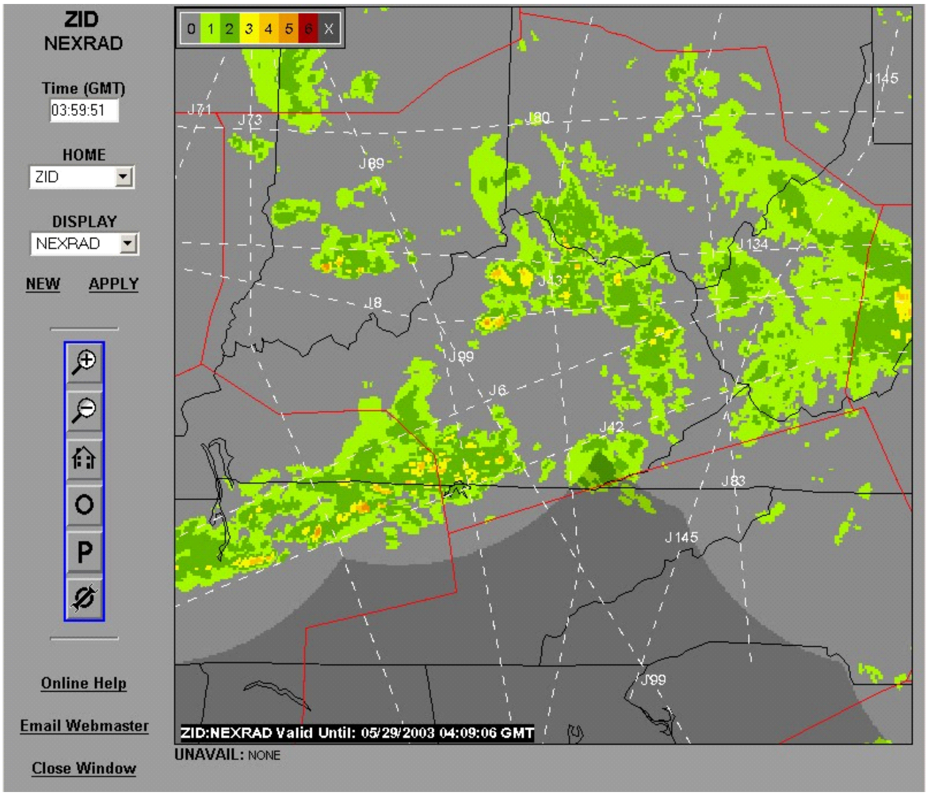

Figure 2-6. Example of the NEXRAD window on the CIWS web site displaying the VIL mosaic product. Window controls are located at the left.

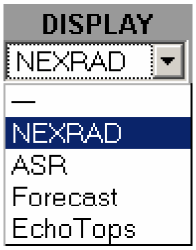

Figure 2-7. Display drop-down menu on the CIWS web site.

2.4 CAVEATS

The VIL Mosaic product updates every 2.5 min while the CIWS ASR Mosaic product (Chapter 3) updates every one minute. Where the products overlap, weather intensity levels between the two products may disagree due to the differences in update rate and sensor characteristics.

An attempt is made to remove AP by examining velocity and by performing data quality checks during the mosaic process. However, AP clutter contamination may still exist in the CIWS VIL Mosaic data. NEXRAD velocity data are only available for a fraction of the 230 nmi range while NEXRAD reflectivity exists out to 230 nmi from the radar. Where velocity data are not available, velocity-based AP editing cannot be accomplished. Thus, AP clutter that exists in these velocity-void areas may contaminate the mosaic. However, the VIL Mosaic product is much less contaminated by unedited AP than are the existing NEXRAD products because the mosaic process rules help eliminate the clutter.

Although the CIWS VIL Mosaic product updates once every 2.5 min, the VIL inputs from the individual radars that comprise the mosaic each update at a rate of 4.2 to 11 min. Storm motion estimates are used to propagate the weather between the individual VIL updates, resulting in an update rate of 2.5 min for the displayed data. Because estimated storm motion does not account for growth and decay of storms or for changes in actual storm motion between updates, the displayed precipitation location and intensity may be different from the actual location and intensity.

2.5 OPERATIONAL USE

The CIWS VIL Mosaic product is a key product for traffic management and situational awareness in the en route airspace. The VIL Mosaic product, when used in conjunction with the other CIWS products such as Echo Tops, Growth and Decay Trends, Storm Motion, and RCWF, provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess the start and end times of weather impacts on en route sectors, jet routes, and terminals throughout the congested airspace corridors.

In operational situations, the CIWS VIL Mosaic product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

The CIWS VIL Mosaic product has been instrumental in facilitating coordination between the ARTCCs and TRACONs. This enhanced coordination has resulted in fewer, shorter ground stops, better management of weather-impacted arrival transition areas, greater departures during adverse weather situations, and optimized runway usage.

3. CIWS ASR MOSAIC PRODUCT

The CIWS ASR Mosaic Product is a representation of the location and intensity of weather from a mosaic of the weather channel data from many ASR-9 radars in the CIWS coverage area. These fan-beam surveillance radars have a maximum range of 60 nmi, and thus do not completely cover the CIWS domain. For this reason, 0.5-nm VIL Mosaic data are used to fill the mosaic image where ASR-9 coverage does not exist. An example of the product is provided in Figure 3-1.

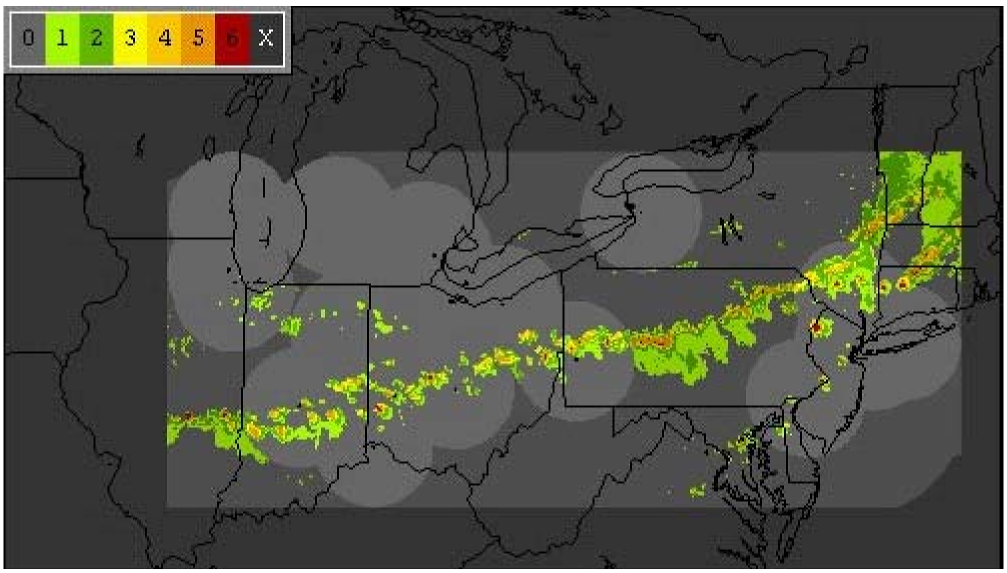

Figure 3-1. Example of the CIWS ASR Mosaic Precipitation Product. The product is a mosaic of precipitation from individual ASR-9 radars. Cool colors represent lighter precipitation; warm colors represent heavier precipitation.

3.1 DATA QUALITY ISSUES

3.1.1 ASR-9 Weather Channel Characteristics

The width of the ASR-9 beam is 1.4 degrees in azimuth and greater than five degrees in elevation (“fan beam”). The radar completes a full 360-degree scan in about five seconds. The primary purpose of this radar is to detect aircraft from the surface to 20,000 ft.

In addition to aircraft detection capabilities, the ASR-9 provides information on the location and intensity of precipitation. The returned signal is passed through a filter that removes ground clutter. The data are smoothed in time over six antenna rotations that results in a 30-sec update rate of the precipitation data. The data are also smoothed in space to a resolution of 0.5 nmi. During this smoothing process, the spatial extent of the highest intensity levels becomes exaggerated. The output is provided in the six-level intensity scale.

3.1.2 Removing AP Clutter from ASR-9 Data

The data from the ASR-9 weather channel are often contaminated by ground clutter due to AP (Section 2.1). AP clutter is removed from the ASR-9 data by comparing the ASR-9 returns to the VIL Mosaic product. Due to the “fan beam” nature of the ASR-9 radar, the weather shown on the display represents a vertical average of the weather over the depth of the beam. Although the ASR-9 radar locates the weather very well, information about the vertical distribution of reflectivity in storms is lost. This vertical information is regained from the NEXRAD radar, which is a pencil-beam radar with a 1-degree beam width.

To remove AP clutter from ASR-9 data, an ASR-9 scan that falls within the NEXRAD volume interval is compared to the VIL data (Klingle-Wilson, et al., 1995). Typically the ASR-9 scan that occurs closest to the middle of the NEXRAD volume scan is used for comparison. Each ASR-9 grid point that contains a valid value is tested against associated values in the pencil-beam data to determine if the ASR-9 value is contaminated by AP clutter. Based on a set of rules, an AP clutter map is built from this comparison. This AP clutter map is used to edit the next-available ASR-9 map received after the pencil-beam data. As further ASR-9 updates become available (at 30-sec intervals), only those grid points that are deemed to have contained AP clutter from the original comparison plus those nearby (e.g., within 1.5 nmi) are removed. A new map is created with each pencil-beam update. AP clutter is removed from the data of each ASR-9 separately.

3.2 PRODUCT GENERATION

A mosaic of all of the edited ASR-9 data is created after AP clutter is removed. In areas of overlapping coverage, the median value of all available values is chosen. If the number of radars contributing to the estimate is even, the higher median value is chosen. Thus, in the case of two radars, the maximum value is used. While the individual ASR-9 radars update every 30 seconds, the update rate of the mosaic is one minute.

The 0.5-nmi resolution VIL Mosaic data are used to fill the space between ASR-9 radars where ASR-9 coverage is not available. Only VIL Mosaic data within 125 nmi of any NEXRAD radar are used. While the resolution of the ASR-9 and VIL Mosaic data are consistent, no effort is made to match or smooth the ASR Mosaic and VIL Mosaic data at the boundaries. The update rate of the VIL Mosaic product is 2.5 min. Thus, while the entire ASR Mosaic product is updated every minute, new data are available for the VIL Mosaic contribution to the mosaic every 2.5 min. Product resolution, data sources, and update are given in Table 3.1.

Table 3.1
CIWS ASR Mosaic Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
ASR Mosaic Precipitation	ASR-9	1	0.5

3.3 DISPLAY CONCEPT

The CIWS ASR Mosaic product is provided in the six-level representation. The levels are color-coded as shown in Figure 3-1. Precipitation intensities below level one are represented by light gray where ASR-9 radars contribute to the mosaic. Slightly darker versions of all colors are used where NEXRAD radars contribute to the mosaic. The dark gray is used to indicate where there is no coverage by the ASR-9 and beyond 125 nmi from the NEXRAD radars.

The resolution of the CIWS ASR Mosaic Precipitation Product is approximately 0.5 nmi. The maximum range of the ASR-9 contribution to the product is dependent upon the coverage of the individual ASR-9 radars that compose the mosaic (approximately 60 nmi). The update rate of the CIWS ASR Mosaic product is one minute.

3.3.1 CIWS Situation Display

CIWS Situation Display (Appendix A) users may choose the weather levels to be displayed by left or right clicking the Precip product status button in the lower left corner of the ASR window. The color of the Precip status button indicates the state and status of the ASR Mosaic product, as shown in Table 3.2.

Table 3.2
Precip Button Color, Product Status, and Product State.

Button Color	Product Status and State
Precip	Unavailable
Precip	Available[1] and displayed in the window
Precip	Available and filtered[2]

1. The product is available as long as at least one radar contributes to the mosaic.
2. The product is not completely displayed.

There is no white state for the Precip product status button. The coverage pattern indicating the current radar coverage is part of the product that may not be "turned off" in the window. For this reason, the product is never completely "Off" even if no weather levels are displayed and thus the Precip button can never be white.

Right clicking the Precip product status button displays the Precip dialog box (Figure 3-2). This example indicates that when the product is not completely displayed (only levels three through six are being displayed); the product status button is yellow. Users may select which levels to display by left clicking the button next to the desired option. The button to the left of the currently displayed levels is highlighted. Left clicking the Precip button toggles the displayed precipitation levels between NONE and the last user selection.

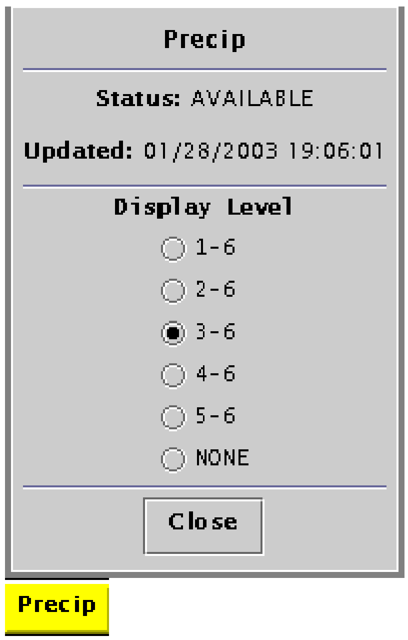

Figure 3-2. Precip product status dialog box and Precip product status button. The yellow button indicates that the VIL mosaic product is filtered because only levels 3 through 6 are displayed.

3.3.2 CIWS Web Site

CIWS web site (Appendix B) users may display the ASR Mosaic product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To display the ASR Mosaic product, the user selects ASR from the Display drop-down menu (Figure 3-3).and then left clicks Apply. An example of the ASR Mosaic product in a web site window is shown in Figure 3-4.

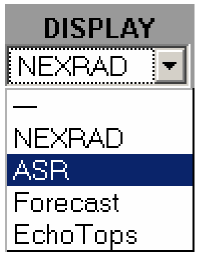

Figure 3-3. Display drop-down menu on the CIWS web site.

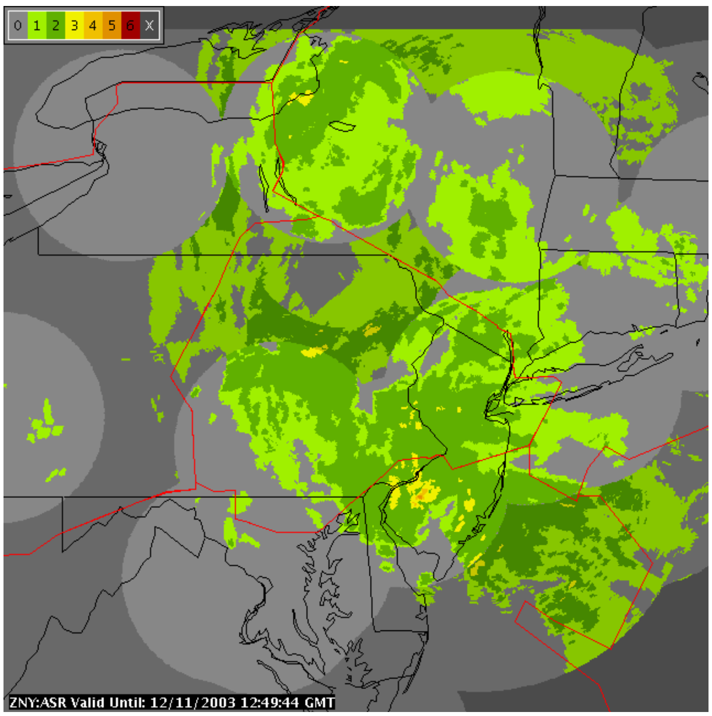

Figure 3-4. Example of the ASR window on the CIWS web site displaying the ASR mosaic product.

3.4 CAVEATS

The CIWS ASR Mosaic product has a 1-min update rate while the VIL Mosaic product is updated every 2.5 min. The weather levels associated with the ASR Mosaic will probably differ from the weather levels in the VIL Mosaic where the products overlap because of the differences in the update rates and sensor/smoothing characteristics.

3.4.1 Underestimation at long ranges

The accuracy of the weather depiction from a single ASR-9 radar is a function of range from the radar. In addition, the weather level that is reported by the ASR-9 weather channel is a vertically averaged estimate of storm intensity. At long ranges, the vertical extent of the beam intercepts more than 30,000 feet of altitude while the storm core may occupy about 9000 feet (Figure 3-5). Thus, the vertical average over the depth of the beam is likely to produce an underestimate of storm intensity. This may not be an operational problem where there is overlapping coverage from other ASR-9 radars in the mosaic.

3.4.2 Underestimation in radar "cone of silence"

For any radar that does not point vertically, there is an area above the radar that is not scanned known as the "cone-of-silence." As illustrated in Figure 3-5, the beam does not intercept the high reflectivity core of storms near the radar, resulting in an underestimation of the intensity of the weather near the radar.

3.4.3 Underestimation due to aggressive ground clutter editing near the radar

The ASR-9 radars may also underestimate precipitation reaching the ground at sites with high-level ground clutter returns near the radar. Typically the radar systems at these sites are tuned to aggressively remove ground clutter near the radar, thus possibly removing precipitation returns. This may not be an operational problem where there is overlapping coverage from other ASR-9 radars in the mosaic.

3.4.4 AP clutter breakthrough near NEXRAD radars

Pencil-beam radars also have a cone-of-silence within which the weather is not completely sensed. Since it is impossible to know the true value of the weather in these regions, ASR-9 returns within a threshold distance of the pencil-beam radars (i.e., 7.5 nmi for the NEXRAD) are not edited unless there is supporting evidence from other pencil-beam radars.

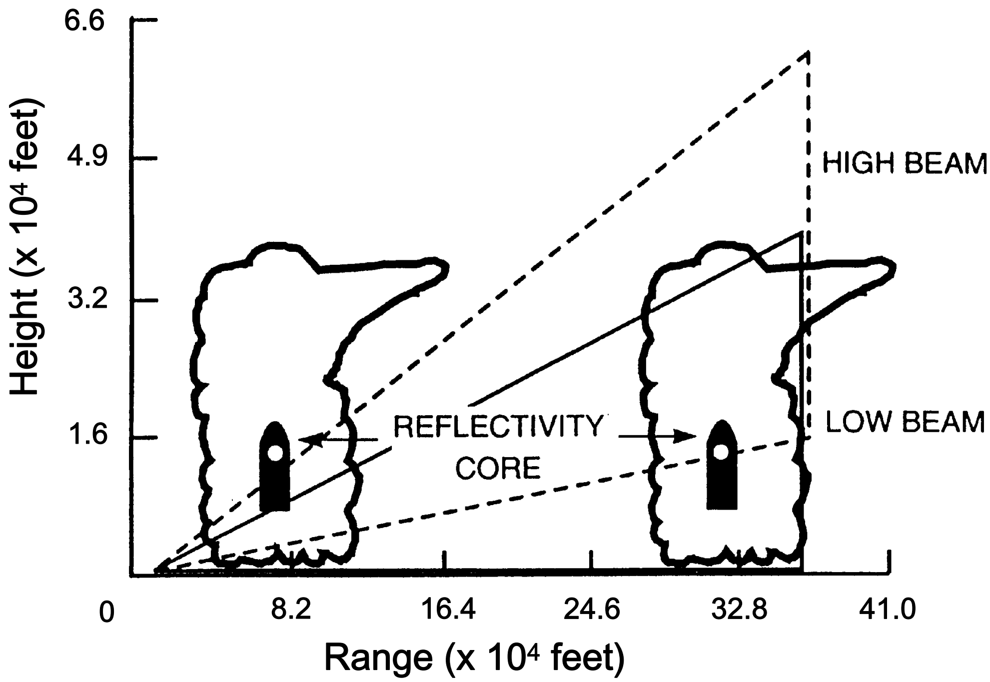

Figure 3-5. Illustration of how the ASR-9 might produce an underestimate of storm intensity. Near the radar in the cone of silence, storms are not completely sensed. At long ranges, averaging over a large vertical depth cause underestimation.

3.4.5 AP clutter breakthrough due to conservative AP editing

The philosophy of the AP-editing technique is to remove as much AP clutter as possible without removing valid weather signals. Thus, the AP-editing approach is conservative. AP clutter may remain in the map so that valid weather returns will not be erroneously removed. This is most likely to occur when there is weather in close proximity to the AP clutter. In addition, if no pencil beam radar data support AP-editing, the ASR-9 data are passed to the mosaic process unedited. In such cases AP clutter may contaminate the mosaic.

3.4.6 AP clutter breakthrough due to growth

AP clutter is identified by comparing the ASR-9 scan that falls within the NEXRAD volume interval to the VIL Mosaic data. AP clutter often grows like weather, increasing in spatial extent and intensity. Only those grid points that have been determined to contain AP clutter in the initial fan beam/pencil-beam comparison are edited. If AP clutter develops in other grid points, it will remain in the CIWS ASR Mosaic product until the next comparison is made. An example of AP clutter breakthrough is shown in Figure 3-6. Points identified as AP in the original comparison are shown in black. The areas of AP breakthrough are shown in six-level colors in the detailed image. These areas will be passed forward and will appear in the ASR Mosaic product.

3.5 OPERATIONAL USE

The ASR Mosaic product is a key product for improved traffic management and situational awareness within its coverage area. When used in conjunction with other CIWS products such as Storm Motion and RCWF, the ASR Mosaic product provides rapid-update information essential to improved air traffic management decisions in situations where storms are growing rapidly. The principal weather data source available in the TRACON is the ASR-9 precipitation product. The ASR Mosaic product facilitates coordination between the ARTCCs and TRACONs. This enhanced coordination has resulted in fewer, shorter ground stops, less air-borne holding, better management of weather-impacted arrival transition areas, greater departures during adverse weather situations, and optimized runway usage.

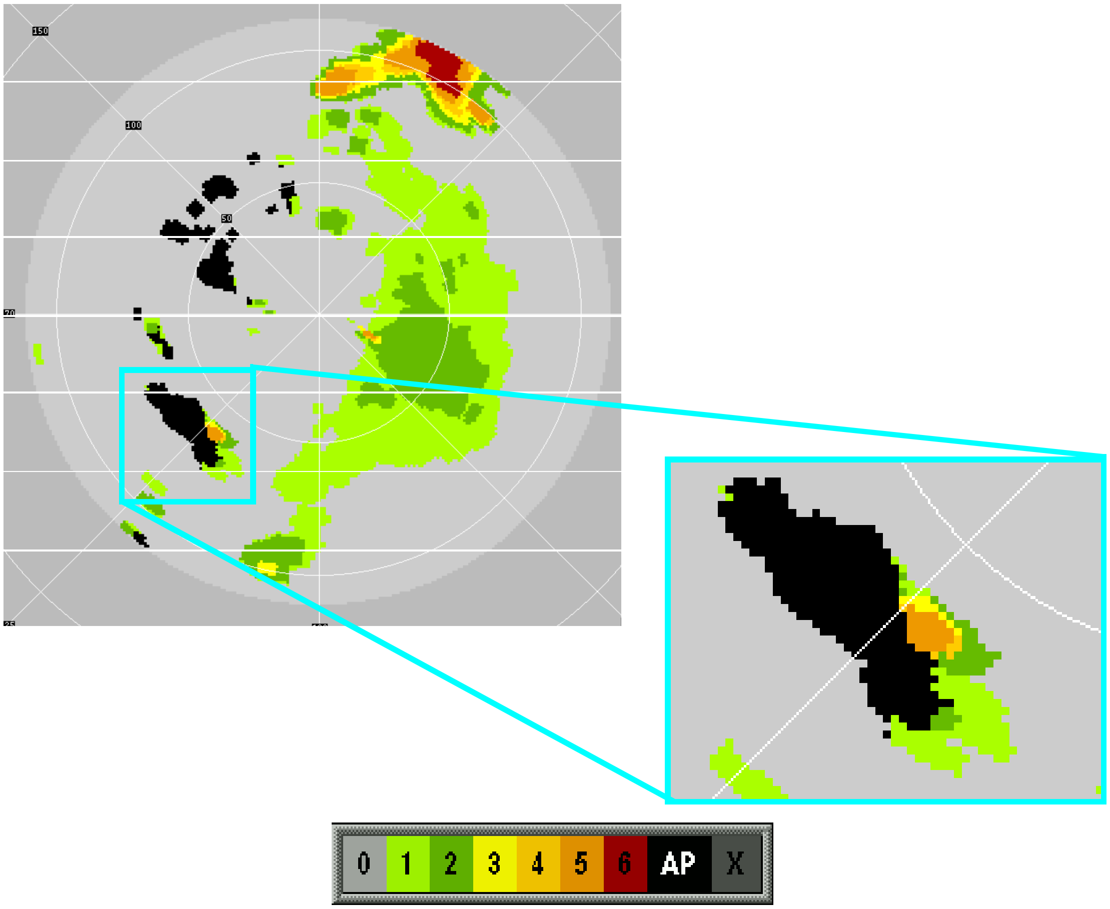

Figure 3-6. Example of AP clutter breakthrough in ASR-9 weather data. Areas identified as AP in AP-edit process are indicated in black. As weather develops, it extends beyond the AP-clutter editing map. These areas or breakthrough are passed forward and appear in the ASR Mosaic product.

4. CIWS STORM MOTION PRODUCT

The CIWS Storm Motion product provides an indication of the motion (speed and direction) of storms as well as 10- and 20-min storm extrapolated positions everywhere in the corridor airspace. The motions of storms are displayed by arrows (indicating direction) and numerals (indicating speed). An example of the product is provided in Figure 4-1. Storm extrapolated positions provide leading-edge contours of cells or cell groups and extrapolates these contours to indicate the likely positions of these cells projected 10 and 20 min into the future.

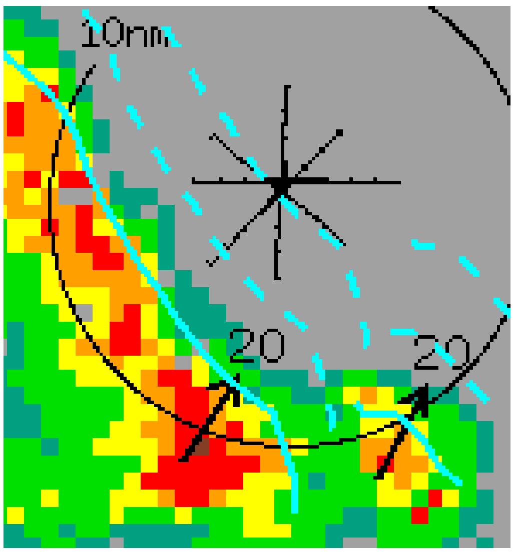

Figure 4-1. Example of the CIWS Storm Motion product. The black arrows and numerals indicate speed and direction. The cyan lines indicate the leading edge, 10-, and 20-minute expect location of the level 3+ weather.

4.1 PRODUCT GENERATION

4.1.1 Storm Motion Estimation

The CIWS Storm Motion product is computed for each precipitation product (i.e., the CIWS VIL Mosaic and CIWS ASR Mosaic products). A cross-correlation pattern matching technique is used to compare two precipitation images that are separated in time (Chornoboy, et al., 1994). It is assumed that differences between the two images result solely from the motion of the weather; storm growth, evolution, and decay are not considered. Briefly, the method divides a radar image into overlapping local regions. The method correlates the weather in each region to find its most likely point of origin in the previous scan. Figure 4-2 illustrates this spatial partitioning and full-grid analysis. The Storm Motion algorithm takes an area (highlighted region in Figure 4-2a) and finds the best match for it in an earlier scan. This procedure is repeated using overlapping regions to construct a grid. For external display, the Storm Motion algorithm interpolates the grid to cells as illustrated in Figure 4-2b.

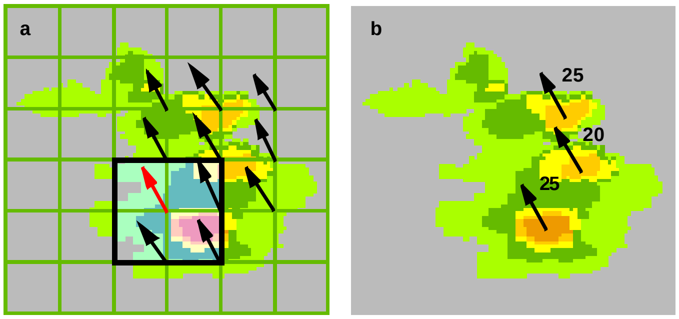

Figure 4-2. Example of the generation of the Storm Motion product. Motion vectors are assigned to storms based on the gridded storm motion values.

The ability of the cross-correlation technique to compute motion is a function of the resolution of the input data and the speed of the weather. For example, the update rate of the ASR Mosaic is one minute, but storms do not move far enough in one minute for the technique to compute an accurate motion. Storm motion estimates are computed from ASR Mosaic product images that are separated in time by about five minutes. The spatial and temporal resolutions of the data limit the accuracy of the motion vectors to ± 2.5 kn.

In convective situations, storm motion is often a composite of actual storm movement and any apparent motion that is due to growth and decay. For example, squall lines are usually observed to move from west to east. However, individual storm cells within the line may move to the northeast, with new cells developing at the southern end of the squall line and old cells dissipating at the northern end. The storm motion vector for this situation might indicate movement to the east-northeast.

4.2 STORM EXTRAPOLATED POSITION

The Storm Extrapolated Position software ingests CIWS precipitation products (i.e., either the CIWS VIL Mosaic or ASR Mosaic products) to identify areas of level three or greater weather and compute storm contours. Closely associated cells are first grouped, filling in and smoothing level three gaps of 2.5 nmi or less. The internal Storm Motion grid is used to determine leading and trailing edges and only the leading edge of each contour is displayed. These contours are extrapolated 10 and 20 min into the future.

The accuracy of the extrapolations is directly dependent upon the accuracy of the Storm Motion algorithm. However, the error associated with extrapolation increases with increasing extrapolation time. In general, the 10-min extrapolations will be about 95% accurate within about one nmi of the actual weather 95% of the time. The accuracy of the 20-min extrapolation depends on the growth and decay characteristics of the storms. For storms whose shapes do not change significantly in 20 min, the 20-min extrapolations are accurate approximately 85% of the time. For all storms (including those that grow and/or decay), the 20-min extrapolations are accurate approximately two-thirds of the time.

4.3 DISPLAY CONCEPT

Storm motion is indicated by constant-length black arrows showing the direction of motion, and accompanying text showing the storm speed in knots. Storm speeds are rounded to the nearest five knots. No motion arrows are plotted for storms with speeds of less than five knots; rather a black, unfilled square is used to indicate that the storms are nearly stationary. The update rate of the products depends on the update rate of the underlying precipitation product, 2.5 min for the VIL Mosaic and one minute for ASR Mosaic (Table 4.1).

Table 4.1
CIWS Storm Motion Product Update Rates, Data Sources, and Spatial Resolutions.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Storm Motion/Storm Extrapolated Position	VIL Mosaic	2.5	0.5
Storm Motion/Storm Extrapolated Position	ASR Mosaic	1	0.5

Storm motion estimates are produced for all level three or greater weather and the vectors are assigned to the highest weather levels contained within the level three regions. The maximum range of the Storm Motion product is defined by the underlying precipitation product. In the NEXRAD window, storm motion arrows are displayed on storms that fall within 125 nmi of any NEXRAD radar. In the ASR window, storm motion estimates are plotted only on the ASR-9 contribution to the mosaic.

As shown in Figure 4-1, three storm extrapolated position contours are displayed for each storm cell and/or storm cell group. The contours correspond to 0-, 10- and 20-min extrapolations. A solid blue line indicates the 0-min (current location) contour of the leading edge of level 3 weather; dashed blue lines indicate the 10- and 20-min extrapolations. In the NEXRAD window, storm extrapolated position lines are displayed on storms that fall within 125 nmi of any NEXRAD radar. In the ASR window, storm extrapolated position lines are plotted only on the ASR-9 contribution to the mosaic.

4.3.1 CIWS Situation Display

CIWS Situation Display (Appendix A) users may choose to display the Storm Motion product by left or right clicking the Stm Mot product status button in the lower left corner of the NEXRAD window and/or ASR window. The color of the Stm Mot status button indicates the state and status of the product (Table 4.2).

Table 4.2
Stm Mot Button Color, Product Status, and Product State.

Button Color	Product Status and State
Stm Mot (red)	Unavailable
Stm Mot (green)	Available and displayed in the window
Stm Mot (yellow)	Available and filtered
Stm Mot	Available but not displayed in the window

Right clicking the Stm Mot product status button displays the Stm Mot dialog box (Figure 4-3). In addition to the status, time-of-last-update information and state button, this dialog box provides a Filter by Zoom option. When a window is zoomed out and many storm cells are present, there may be so many storm motion arrows and extrapolated position lines that the underlying weather image is obscured. In such cases, users may select the Filter by Zoom option to reduce the number of arrows and lines. Figure 4-3 illustrates that when the product is not completely displayed (i.e., when Filter by Zoom is selected), the product status button is yellow. Left clicking the Stm Mot product status button toggles the display of the Storm Motion product between off and the last setting (either Off/On or Off/Filter by Zoom).

4.3.2 CIWS Web Site

The Storm Motion product is displayable in the NEXRAD and ASR windows only. CIWS web site (Appendix B) users may display the Storm Motion product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To toggle the display of the Storm Motion product in either the NEXRAD window or the ASR window, the user selects the P button and clicks on the box adjacent to the "Filtered Stm Mot" option in the Products dialog box (Figure 4-4). A check mark in the box indicates that the product is displayed. If the box is empty, the product is not displayed. When many storm cells are present, there may be so many storm motion arrows and lines that the underlying weather image is obscured. Filtering reduces the number of arrows and lines and is enabled by default on the web site.

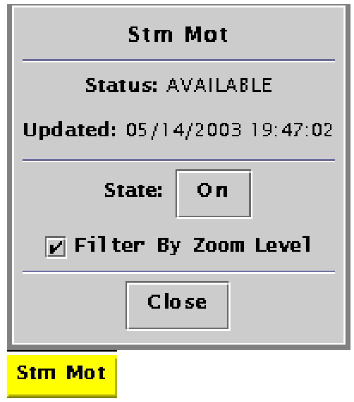

Figure 4-3. Stm Mot product status dialog box and Stm Mot product status button. The yellow button indicates that the Storm Motion product is filtered as a function of window zoom setting.

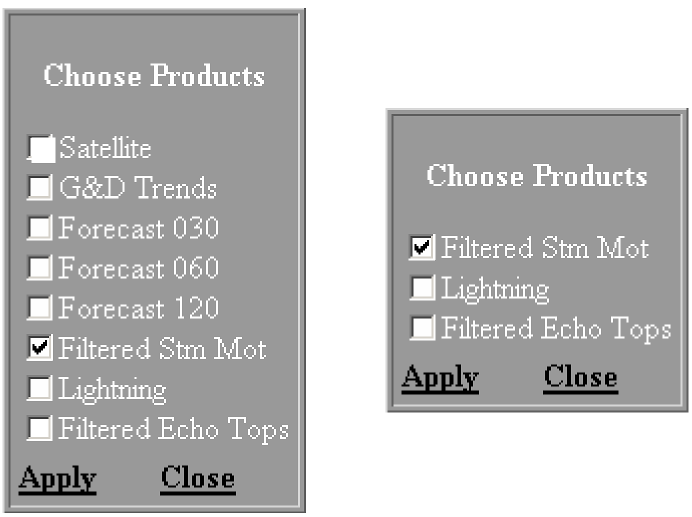

Figure 4-4. Stm Mot product status dialog box and Stm Mot product status button. The yellow button indicates that the Storm Motion product is filtered as a function of window zoom setting.

4.4 CAVEATS

Vectors and/or contours associated with cells along the boundary of the precipitation map may not be reliable. Inaccuracies can result when distant storms first enter into the "field of view" of the precipitation map.

The update rate of the CIWS Storm Motion product is a function of the underlying precipitation product. When the underlying precipitation is the ASR Mosaic product, the update rate is one minute. When the underlying precipitation is the VIL Mosaic, the update rate is 2.5 min. The motion estimates associated with the ASR Mosaic-based Storm Motion product may differ from the VIL Mosaic-based storm motion estimates where the products overlap because of the differences in the update rates and sensor characteristics.

It is important to emphasize that the Storm Motion product does not predict the initiation of new cells. The product is relevant only for cells that exist at the time of the current radar scan. Despite the display of 10- and 20-min extrapolations, the product is not intended as an indicator of cell life span.

The algorithm currently does not take into account any effects due to storm growth and decay. Extrapolations may not be representative of future weather in situations where there are high rates of cell growth and/or decay.

Extrapolated position contours will not be available for storms whose leading edges are too short. In addition, extrapolated positions will not be drawn for storms whose speeds are less than 7.5 kn.

4.5 OPERATIONAL USE

The CIWS Storm Motion product is a key product for traffic management and situational awareness. When used in conjunction with the other CIWS products such as Echo Tops, Growth and Decay Trends, VIL Mosaic, and RCWF, the Storm Motion product provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess start and end times of weather impacts on en route sectors, jet routes, and terminals throughout congested airspace corridors.

In operational situations, the Storm Motion product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

The CIWS Storm Motion product has been instrumental in facilitating coordination between the ARTCCs and TRACONs. This enhanced coordination has resulted in fewer, shorter ground stops, better management of weather-impacted arrival transition areas, greater departures during adverse weather situations, and optimized runway usage.

5. CIWS LIGHTNING PRODUCT

The CIWS Lightning product provides a map of cloud-to-ground lightning strike locations. Lightning strike locations are indicated by white plus signs (+). An example of the product is provided in Figure 5-1.

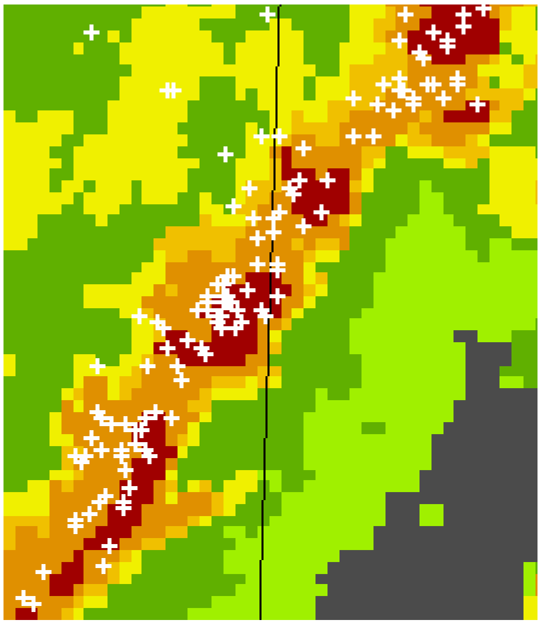

Figure 5-1. Example of the Lightning product displayed in the NEXRAD window. Lightning strike locations are indicated by white plus signs.

5.1 PRODUCT GENERATION

Cloud-to-ground lightning strikes are detected by the National Lightning Detection Network (NLDN) and are plotted in the NEXRAD, ASR, and Echo Tops windows as white plus signs (+). These plus signs indicate the locations of lightning strikes that have occurred over the previous six minutes. Lightning data are available for the entire United States. The grid upon which lightning strikes are plotted is the same size as the grid that contains the VIL Mosaic product. Only the lightning strikes that fall within this grid are plotted.

5.2 DISPLAY CONCEPT

Cloud-to-ground lightning strikes are available for display in the NEXRAD, ASR, and Echo Tops windows. The locations of strikes that have occurred in the past six minutes are indicated by white plus signs (+). The update rate of the product is two minutes (Table 5.1).

Table 5.1
CIWS Lightning Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Lightning	NLDN	5	0.05

Lightning strikes are plotted on a grid that is the same size as the grid used for the VIL Mosaic product. This grid is roughly 1400 nmi east/west by 850 nmi north/south and centered about 85 nmi east of Columbus, OH. Any strikes that fall within this grid are plotted in the windows, even if there is no corresponding radar coverage. For example, in the ASR window, the grid containing the ASR Mosaic is just large enough to contain all of the ASR-9 radars in the mosaic. The grid containing the lightning data is significantly larger than the grid containing the ASR Mosaic. As a result, users will see lightning strikes plotted where there is no corresponding radar coverage in that window. In this case, lightning can be used as an indicator of the locations of storms where no radar coverage is available.

5.2.1 CIWS Situation Display

CIWS Situation Display (Appendix A) users may choose to display the Lightning product in the NEXRAD, ASR, and/or Echo Tops windows, by left or right clicking the Lightning product status button. The color of the Lightning status button indicates the state and status of the product (Table 5.2). Left clicking the Lightning product status button toggles the display of the Lightning product between on and off. Right clicking the Lightning product status button displays the Lightning dialog box, which indicates the status and state of the product.

Table 5.2
Lightning Button Color, Product Status, and Product State.

Button Color	Product Status and State
Lightning	Unavailable
Lightning	Available and displayed in the window
Lightning	Available but not displayed in the window

5.2.2 CIWS Web Site

The Lightning product is displayable in the NEXRAD, ASR, and Echo Tops windows. CIWS web site (Appendix B) users may display the Lightning product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To toggle the display of the Lightning product, the user selects the P button and clicks on the box adjacent to the “Lightning” or “Lightning Strikes” option on the Products dialog box (Figure 5-2). A check mark in the box indicates that the product is displayed. If the box is empty, the product is not displayed.

Figure 5-2. Products dialog box for the NEXRAD (left) and ASR (middle) and Echo Tops (right) web site windows. Check marks indicate that the Lightning product is displayed in the associated windows.

5.3 CAVEATS

The CIWS Lightning product acquires data from the NLDN, which detects only cloud-to-ground lightning. Lightning that occurs within and between clouds is not detected and, therefore, not displayed.

5.4 OPERATIONAL USE

The CIWS Lightning product, when used in conjunction with the other CIWS products such as CIWS VIL Mosaic, Echo Tops, Growth and Decay Trends, and RCWF, provides valuable information for assessing route impacts. The presence of lightning in storms often indicates storm severity and helps users identify areas pilots may wish to avoid. This information has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

6. CIWS SATELLITE PRODUCT

The CIWS Satellite product provides satellite images for the CIWS coverage area. Satellite data may be displayed as a background to the VIL Mosaic product. An example of the product is shown in Figure 6-1. During the day, the visible channel of the satellite data is displayed. Infrared satellite data are displayed from when the sun is roughly 30 degrees above the western horizon until the sun is about 30 degrees above the eastern horizon.

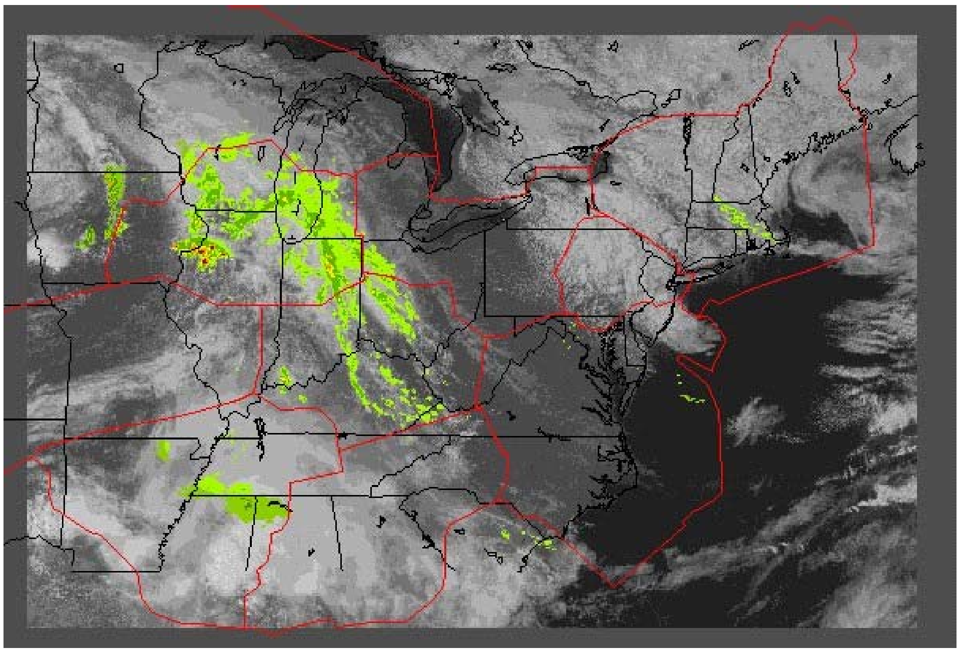

Figure 6-1. Example of satellite data in the NEXRAD window. The satellite data serve as a background to the precipitation.

6.1 PRODUCT GENERATION

Satellite data are acquired from the GOES-East satellite and are plotted in the NEXRAD window. Satellite data are clipped to match the size of the grid that contains the VIL Mosaic product. To reduce bandwidth to the displays in this demonstration system, the resolution of the satellite data is one nmi. The update rate of the satellite data is 15 min (Table 6.1).

Table 6.1
CIWS Satellite Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Satellite	GOES East	15	1.0

6.2 DISPLAY CONCEPT

Satellite data are provided in gray-scale and are displayable only in the NEXRAD window. Satellite data are plotted on a grid that is the same size as the grid used for the VIL Mosaic product. This grid is roughly 1400 nmi east/west by 850 nmi north/south and centered about 85 nmi east of Columbus, OH. All satellite data within this grid are plotted in the window, even if there is no corresponding precipitation coverage. Therefore, users may see areas in the satellite data typically associated with precipitation, but no precipitation returns may be displayed there because radar coverage does not extend to those areas. When satellite data are displayed, the background precipitation coverage pattern is not visible.

6.2.1 CIWS Situation Display

CIWS Situation Display (Appendix A) users may choose to display the Satellite product in the NEXRAD window by left or right clicking the Satellite product status button. The color of the Satellite product status button indicates the state and status of the product (Table 6.2). When the satellite data are displayed in the window, the title bar indicates if the data are visible (Sat: Vis) or infrared (Sat: IR). Left clicking the Satellite product status button toggles the display of the Satellite product between on and off. Right clicking the Satellite product status button displays the Satellite dialog box, which indicates the status and state of the product. Additional information displayed in the dialog box includes the time of the last product update and whether visible or infrared data are currently displayed.

Table 6.2
Satellite Button Color, Product Status, and Product State.

Button Color	Product Status and State
Satellite (red)	Unavailable
Satellite (green)	Available and displayed in the window
Satellite	Available but not displayed in the window

6.2.2 CIWS Web Site

The Satellite product is displayable in the NEXRAD window only. CIWS web site (Appendix B) users may display the Satellite product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To toggle the display of the Satellite product, the user selects the P button and clicks on the box adjacent to the "Satellite" option on the Products dialog box (Figure 6-2). A check mark in the box indicates that the product is displayed. If the box is empty, the product is not displayed.

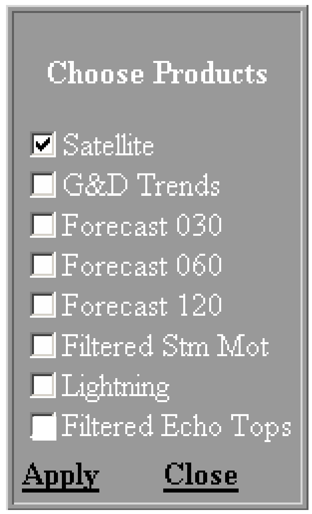

Figure 6-2. Products dialog box for the NEXRAD web site window. The check mark indicates that the Satellite product is displayed.

6.3 CAVEATS

The Satellite product will be unavailable approximately four times per day while the GOES-East satellite executes a full-hemispheric scan.

6.4 OPERATIONAL USE

CIWS Satellite product may be used for situational awareness and as an aid to planning traffic flow. The information contained in the Satellite product can be used to identify areas of developing convection where a radar signal does not yet exist.

7. CIWS ECHO TOPS MOSAIC PRODUCT

The CIWS Echo Tops Mosaic provides estimates of echo top heights in a gridded format. An example of the product is provided in Figure 7-1. Blues and greens represent lower echo top values while yellows and red indicate higher echo tops values.

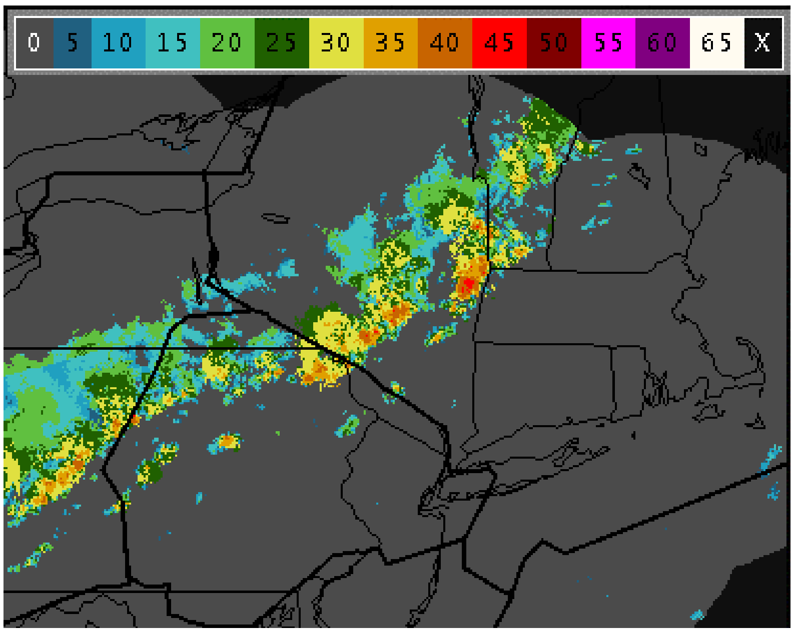

Figure 7-1. An example of the Echo Tops Mosaic. Cooler colors indicate lower echo tops; warmer colors indicate higher echo tops.

7.1 PRODUCT GENERATION

The echo top of a storm is typically defined as the highest altitude at which the weather level associated with the storm drops below level one or the altitude of 18 dBZ (Figure 7-2). CIWS developed a new technique for best estimating the echo tops because the operational NEXRAD product lacked the precision required for air traffic management applications.

The existing Echo Top product generated by the NEXRAD system is defined as the height of uppermost beam that equals or exceeds the chosen reflectivity level. The resulting product has a 2 nmi horizontal resolution and a 5000-foot vertical resolution. This technique leads to “sawtooth” estimates that produce ring patterns in the echo top image (Figure 7-3). In addition, the technique often results in the underestimation of echo tops that can be as large as range/beam spacing. For example, at a range of 32 nmi from the radar, the underestimation can be as much as 3300 feet.

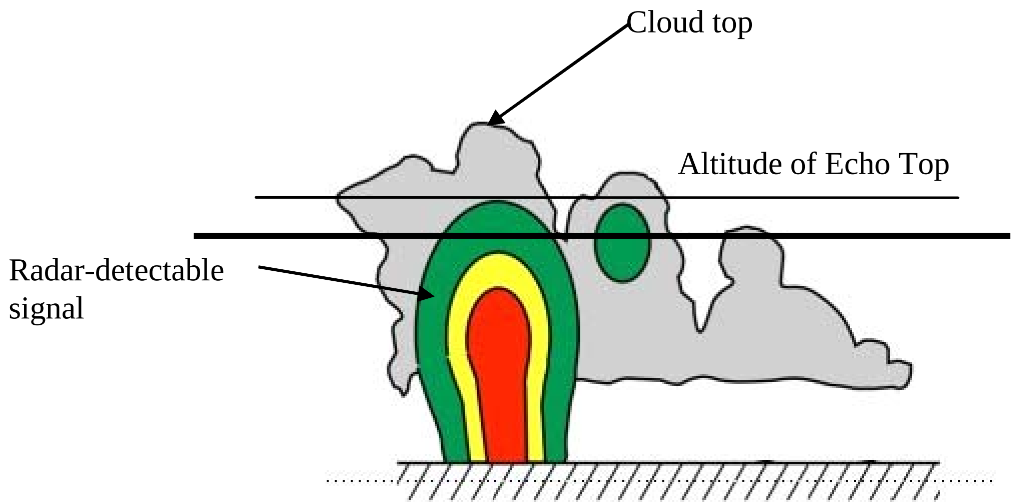

Figure 7-2. Illustration of the echo top associated with a storm cell. The altitude of the echo top is indicated by the horizontal black line.

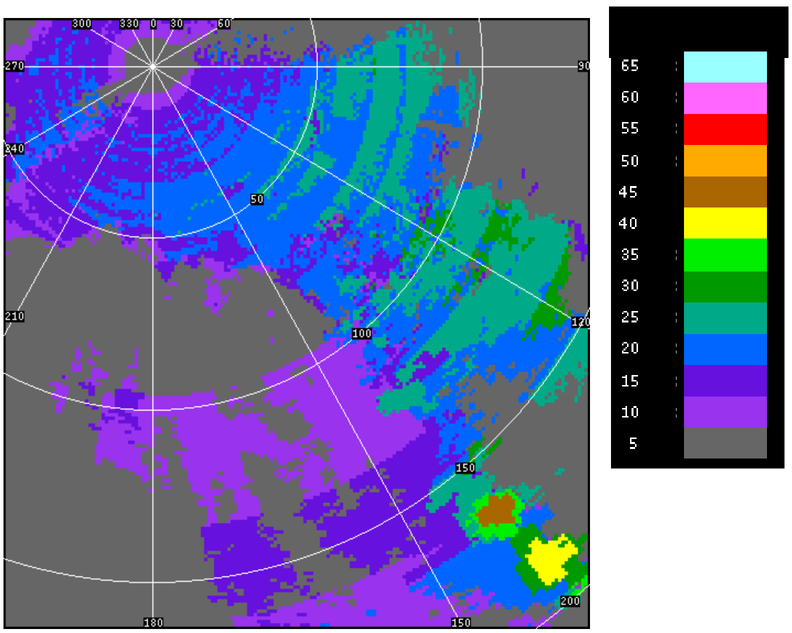

Figure 7-3. Sawtooth/ring pattern associated with the NEXRAD Echo Tops product.

The CIWS Echo Tops Mosaic product is created by ingesting the raw radar data from individual weather radars. Using the assumption that reflectivity changes linearly between radar measurements the radial radar data are interpolated vertically to estimate the height of the 18 dBZ surface to the nearest 1000 feet (Figure 7-4). The grid is searched for the highest altitude in a column at which the radar reflectivity drops to the threshold value (typically 18 dBZ). This process is performed for each individual radar and then the echo tops mosaic is created. In areas of overlapping coverage, the maximum echo top value for a particular grid point is chosen for the mosaic.

In some instances, the highest altitude to which the radar scans is still too low to reach the top of the storm's radar echo. This can happen at ranges close to the radar when the storm occupies the radar's cone-of-silence (Figure 3.5) and at further ranges for very large storms. These storms "top" the radar beam and, as a result, the echo tops are underestimated. Regions of "topped" echoes are give a value equal to the altitude of the nearest surrounding valid estimates.

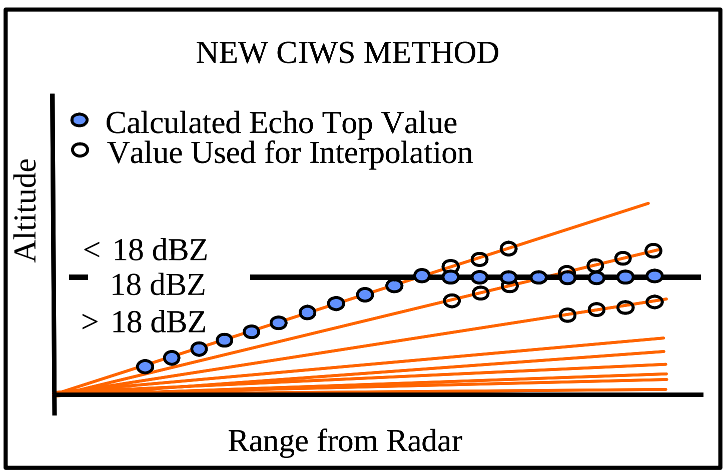

Figure 7-4. Illustration of the technique for computing the CIWS Echo Tops product.

7.2 DISPLAY CONCEPT

The CIWS Echo Tops Mosaic provides estimates of echo top heights in a gridded format. An example of the product is provided in Figure 7-1. Blues and greens represent lower echo top values while yellows and red indicate higher echo tops values. While the product is computed with a 0.5-nmi horizontal and 1000-foot vertical resolution, the displayed resolution is one nmi in the horizontal and 5000 feet in the vertical because of the bandwidth limitations of the display. The update rate is 2.5 min and the coverage is equal to the 125-nmi NEXRAD coverage (Table 7.1).

Table 7.1
CIWS Echo Tops Mosaic Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Echo Tops Mosaic	NEXRAD	5.0	0.5

7.2.1 CIWS Situation Display

The CIWS Echo Tops Mosaic product is provided in the Echo Tops window only. CIWS Situation Display (Appendix A) users may control the display of the Echo Tops Mosaic via the Echo Tops product status button in the Echo Tops window. The color of the Echo Tops product status button indicates the state and status of the product (Table 7.2).

Table 7.2
Echo Tops Button Color, Product Status, and Product State.

Button Color	Product Status and State
Echo Tops (red)	Unavailable
Echo Tops (green)	Available and displayed in the window
Echo Tops (yellow)	Available and filtered
Echo Tops	Available but not displayed in the window

Right clicking the Echo Tops product status button displays the Echo Tops product status dialog box (Figure 7-5). In addition to providing the status and state of the product, the dialog box allows the user to filter the echo tops product. For example, selecting the "30 – 65+ kft" option in the dialog box suppresses the display of echo tops values below 30,000 feet. If any filtering is chosen, the product status button is yellow. Left clicking the Echo Tops product status button toggles the display of the product between off and the last setting in the dialog box.

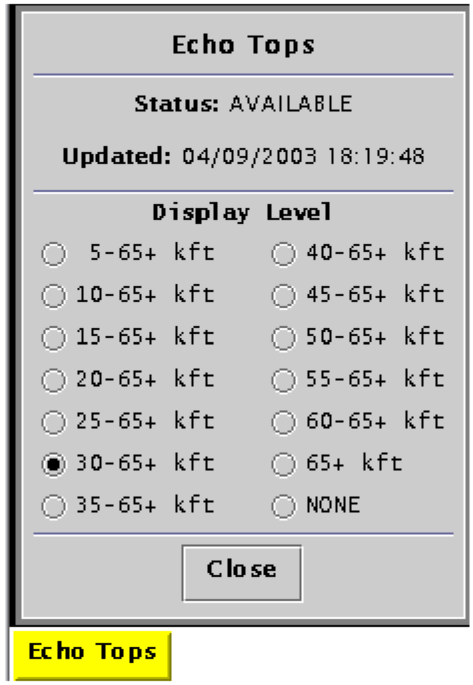

Figure 7-5. Echo Tops product status button and product status dialog box. The yellow button indicates that the product is filtered. In this example, only tops above 30,000 feet are displayed.

7.2.2 CIWS Web Site

The Echo Tops Mosaic product is displayable in the Echo Tops window only. CIWS web site (Appendix B) users may display the Echo Tops product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To display the Echo Tops mosaic, the user selects Echo Tops from the Display drop-down menu (Figure 7-6) and then left clicks Apply.

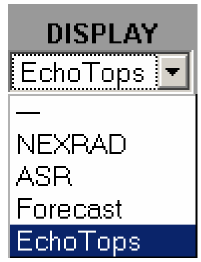

Figure 7-6. Display drop-down menu on the CIWS web site.

7.3 CAVEATS

The Echo Tops product reports the altitude of the echo top as shown in Figure 7-3, which is the top of the storm as detected by the *radar*. Pilots typically report *visible* cloud tops which can be higher than radar echo tops. For this reason, the CIWS Echo Tops product may not agree with pilot reports but CIWS operational experience has shown that disagreement is rare.

7.4 OPERATIONAL USE

The CIWS Echo Tops Mosaic product is a key product for traffic management and situational awareness. When used in conjunction with the other CIWS products such as VIL Mosaic, Growth and Decay Trends, and Storm Motion, the CIWS Echo Tops Mosaic product provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess the start and end times of weather impacts on en route sectors and jet routes throughout congested airspace corridors.

In operational situations, the Echo Tops Mosaic product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

8. CIWS ECHO TOPS/ANNOTATION PRODUCT

The CIWS Echo Tops and Annotation products provide echo tops values in label format. An example of Echo Tops in the NEXRAD window is shown in Figure 8-1.

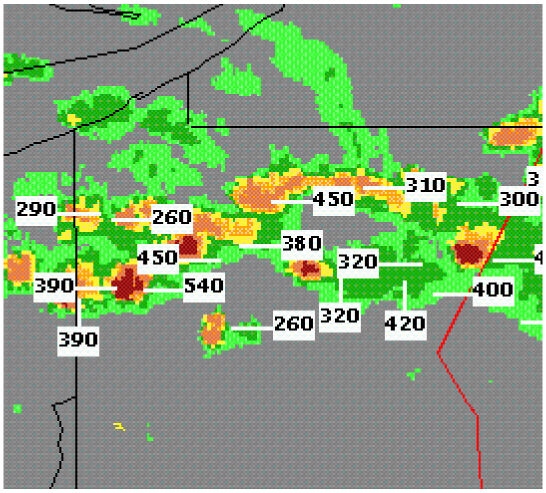

Figure 8-1. Echo Tops product in the NEXRAD window. Labels show echo tops in "flight level" nomenclature (i.e., 450 is 45,000 feet).

8.1 PRODUCT GENERATION

The Echo Tops/Annotation product is computed from the gridded echo top data. The Echo Tops Mosaic is searched for areas of echo tops values whose spatial extent is at least 3 nmi^2 and whose echo tops exceed 20,000 feet. Peak values that meet these criteria are tagged with the echo tops labels. The locations of the peaks are then translated to the NEXRAD, ASR, and Echo Tops windows for display. If the radar is topped by large distant storms or storms within the radar cone-of-silence, the storm echo top is underestimated. In these cases, a plus sign (+) is placed after the echo top estimate. For example, 540+ indicates that the echo top is at least 54,000 ft and may be higher. The resolution of the product is 1000 feet and the update rate is 2.5 min (Table 8.1).

Table 8.1
CIWS Echo Tops/Annotation Product Update Rate and Data Source.

Product	Data Sources	Product Update Interval (min)
Echo Tops/Annotation	Echo Tops Mosaic	5.0

8.2 DISPLAY CONCEPT

The Echo Tops/Annotation product is provided in “flight level” nomenclature. For example, an echo top of 54,000 feet is shown as 540. The labels consist of black text in a white box with a white line pointing to the location of the echo top value. A plus sign (+) following the number indicates the minimum altitude of the echo top and that the actual altitude may be higher.

8.2.1 CIWS Situation Display

This product is available on the CIWS Situation Display (Appendix A) in the NEXRAD and the ASR windows as Echo Tops, and in the Echo Tops window as Annotation. Display of the Echo Tops labels in the NEXRAD and ASR windows is controlled by the Echo Tops product status button and by the Annotation product status button in the Echo Tops window. Users may choose to display the Echo Tops/Annotation product by left or right clicking the Echo Tops and/or Annotation product status buttons. The color of the product status button indicates the state and status of the product (Table 8.2).

Table 8.2
Echo Tops/Annotation Button Color, Product Status, and Product State.

Button Color	Product Status and State
Echo Tops	Unavailable
Echo Tops	Available and displayed in the window
Echo Tops	Available and filtered
Echo Tops	Available but not displayed in the window

Right clicking the Echo Tops and/or Annotation product status buttons displays the corresponding dialog boxes as shown in Figure 8-2. This dialog box allows the user to select the position of the labels relative to the weather, to filter by zoom, and/or to filter by altitude. There are three options for label position: Surround, Left only, and Right only. If Surround is selected, the labels are positions around the weather as shown in Figure 8-3. The “Left only” and “Right only” options cause the labels to be plotted to the left or right of the weather, respectively (Figure 8-3). Label position does not affect the color of the product status button.

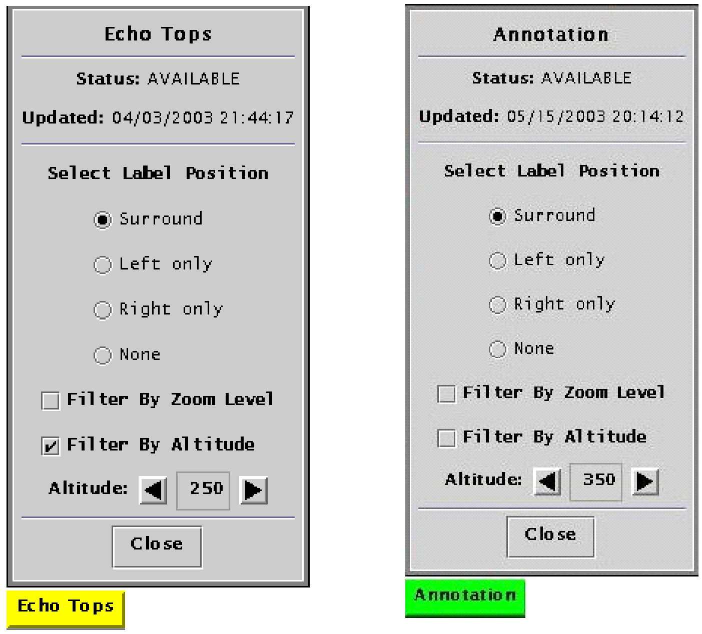

Figure 8-2. Echo Tops and Annotation product status buttons and dialog boxes. The yellow echo tops button indicates that the product is filtered. In this example, the product is filtered by altitude. The green Annotation button shows that the product is completely displayed.

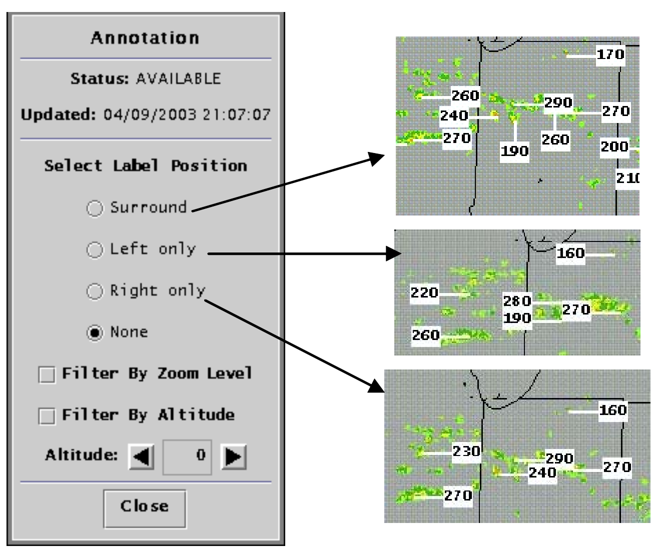

Figure 8-3. Examples of Surround, Left only, and Right only label positions.

When a window is zoomed out and many storm cells are present, there may be so many echo tops labels that the underlying weather image is obscured. In such cases, users may select the Filter by Zoom option to reduce the number of labels. When Filter by Zoom is enabled, enough labels are removed from the window so that all remaining higher-value labels are visible.

Users may also choose to suppress the display of echo tops labels below a specified value by selecting the Filter By Altitude option. The Altitude selection interface is used to specify the altitude below which no labels are to be displayed. When either the Filter By Zoom or the Filter By Altitude option is selected, the product status button is yellow. Left clicking the Echo Tops and/or Annotation product status buttons toggles the display of the product between NONE and the last filter setting.

8.2.2 CIWS Web Site

The Echo Tops product is displayable in the NEXRAD, ASR, and Echo Tops windows. CIWS web site (Appendix B) users may display the Echo Tops product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To toggle the display of the Echo Tops product, the user selects the P button and clicks on the box adjacent to the "Filtered Echo Tops" option on the Products dialog box (Figures 8-4). A check mark in the box indicates that the product is displayed. If the box is empty, the product is not displayed. When many storm cells are present, abundant echo top labeling may obscure the underlying weather image. Echo top label filtering alleviates this problem. The filtering option is provided by default on the web site.

8.3 CAVEATS

Echo top peaks are not necessarily co-located with peak weather levels. For this reason, the echo tops labels will not necessarily point to peaks in the VIL Mosaic or ASR Mosaic when plotted in the associated windows. Care should be taken when using the product with zoom-based filtering enabled. It is possible that not all operationally significant echo top values are displayed.

Figure 8-4. Products dialog box for the NEXRAD (left) and ASR (middle) and Echo Tops (right) web site windows. Check marks indicate that the Filtered Echo Tops product is displayed in the associated windows.

8.4 OPERATIONAL USE

The CIWS Echo Tops/Annotation product is a key product for traffic management and situational awareness. When used in conjunction with the other CIWS products such as VIL Mosaic, Growth and Decay Trends, and Storm Motion, the CIWS Echo Tops Mosaic product provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess the start and end times of weather impacts on en route sectors and jet routes throughout congested airspace corridors.

In operational situations, the Echo Tops/Annotation product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

9. CIWS RCWF PRODUCT

The automated convective weather forecast product technology used in the CIWS features:

- Scale separation technology and classification of precipitation by type to optimize performance on a regional basis,
- Storm growth and decay trends explicitly determined,
- Use of satellite and numerical model data in conjunction with radar data,
- Explicit consideration of small scale forcing (e.g. storm initiation, growth, and dissipation) during the 0 - 60 min forecast range and larger scale forcing (e.g. fronts, large scale stability) for the 60 - 120 min forecast range, and
- Real time metrics for the forecast accuracy that assist the user in estimating the forecast utility as a function of forecast time and location within the CIWS domain.

The CIWS RCWF product provides two-hour forecasts (in 15-min increments) of low, moderate, and high probabilities of level three and greater weather (Boldi, et al., 2002). The product self-scores so that an estimate of its performance over time is always available as a Forecast Accuracy Score (Chapter 10). An example of the Forecast product is provided in Figure 9-1. The forecast image shows the 60-min forecast of high probability of level 3 and greater weather (solid yellow), moderate probability of level 3 and greater weather (light gray), and low probability of level 3 and greater weather (medium gray).

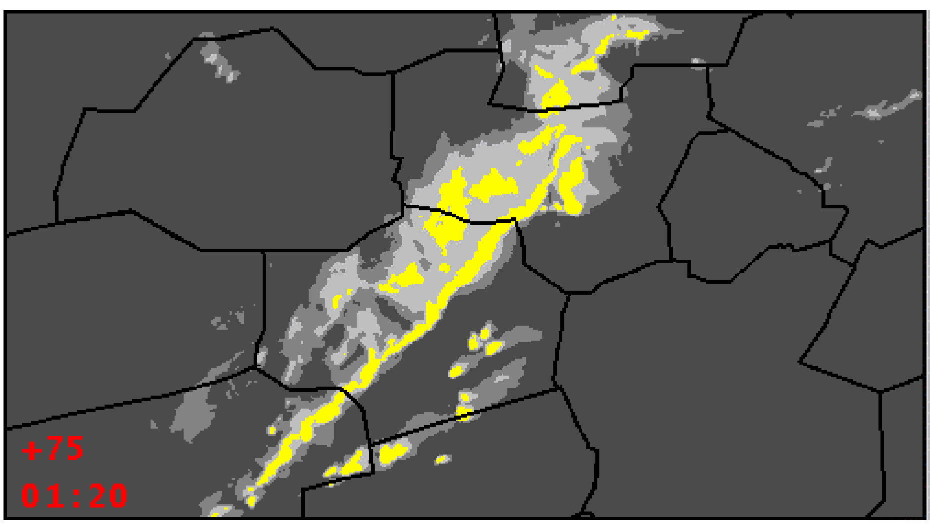

Figure 9-1. Example of the RCWF product. The 60-minute forecast is shows. High probability of level 3 and greater weather is indicated by yellow; moderate probability is lighter gray, and low probability is darker gray.

9.1 PRODUCT GENERATION

9.1.1 Scale Separation

Large-scale organized storms are made up of clusters of single cells which are themselves short-lived. As these multi-cell storms propagate, new storms grow (often along a preferred flank) and old storms decay. The net storm motion is a result of this discrete propagation and is often very different from the individual cell motion. To determine the motion of the long-lived storm elements, the large-scale (envelope) signal must be extracted and tracked. The separation of the large-scale component from the full-scale image is accomplished by filtering techniques.

To illustrate the effect of elliptical filtering, a line storm case study was selected where the envelope motion and cell motion were quite different. Figure 9-2 shows the "full-scale" unfiltered precipitation image, the large-scale (Envelope) image filtered with a large elliptical kernel, and the small-scale (Cell) image filtered with a small circular kernel. from the unfiltered image. The storm motion vectors resulting from correlation tracking within the large- and small-scale images can be quite different. The envelope motion indicates the motion of the forcing underlying the convection, while the cell motion closely follows the steering level winds.

9.1.2 Weather Classification

A weather classification technique is used to identify the various weather types that exhibit these different motions, since the motion used to forecast future storm locations can vary significantly with respect to the type of weather present. The weather classification used in the RCWF currently catalogues the following weather types: line storms; lines; large, small, and embedded cells; and stratiform precipitation.

Classification is first accomplished by removing low-level weather from the precipitation image. Next, a variability image is made to distinguish the non-convective (low variability) from the convective (high variability) regions. The non-convective regions are classified as stratiform. A large filter is applied to the convective regions to extract the line features from the image. The convective regions that are not classified as lines are sorted into three weather types based on their size: small cells, large cells, and embedded cells. Small cells are those cells that range in size from 2 to 10 nmi. Large cells range between 10 and 35 nmi, and embedded cells are those cells greater than 35 nmi. Rule-based algorithms are then used to assign the appropriate motion to the different weather type regions. Regions that have not been assigned a weather classification are assigned a background motion vector, that is, vectors that have been interpolated from the weather-classified vector fields.

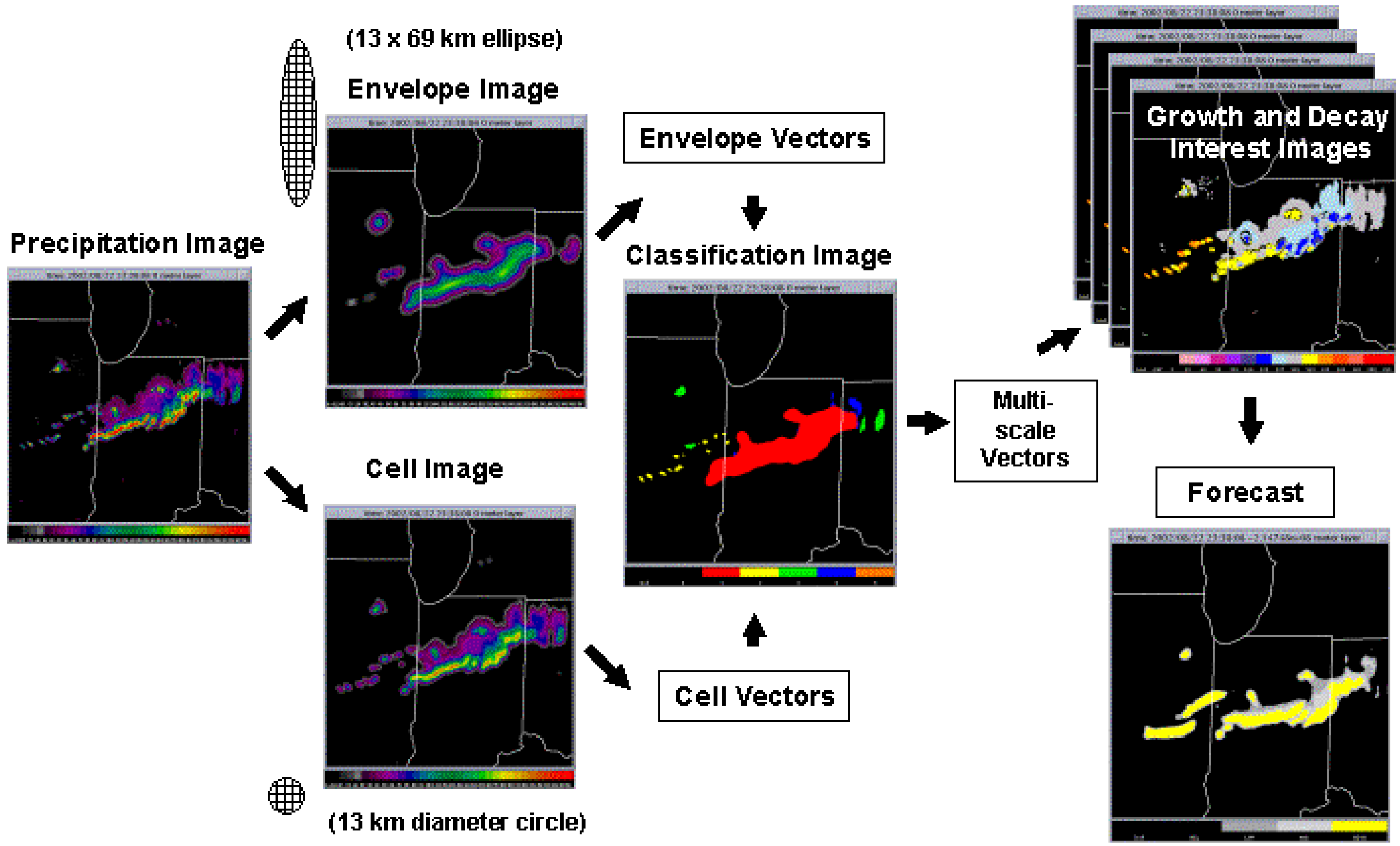

Figure 9-2. Illustration of the RCWF algorithm showing how scale separation, weather classification, and growth and decay trending are used to complete the forecast.

9.1.3 Growth and Decay Interest Images

Not only is accurate tracking of storms essential, measuring the growth and decay trend of these storms is crucial to making an accurate two-hour forecast. To model this growth and decay, a variety of radar-, satellite-, and numerical model-based feature detectors are used to generate interest images. One such feature detector generates an interest image that highlights areas of linearly aligned growing cumulus clouds. This interest image is used to forecast areas for the initial growth along a surface convergence boundary. Interest images for both short- and long-term radar-based growth and decay trends are generated. These interest images and others are combined using a weighted average technique to produce the forecasts. The weight functions form the model for how the storms will evolve over time.

Conceptual and empirical models for storm evolution are used to form the weight functions. The weight functions are based upon the weather type classification and forecast time interval. One basic guideline is that line storms are persistent, long-lived features while air mass cells tend to be much shorter lived. For instance, a small isolated air mass cell that shows slight decay in the trend image will likely produce a 30-min forecast where this cell has diminished in intensity. Furthermore, since it is classified as a small air mass cell it will likely be completely removed beyond the 75-min forecast by the weight functions. Conversely, if an area of precipitation is classified as a line storm and shows decay in the trend image, the forecast will still show some moderate to high probability coverage in the forecast area even at two hours.

9.2 DISPLAY CONCEPT

The RCWF provides real-time probability forecasts of level three and greater weather out to two hours. The product uses a three-level probability map showing regions of low, (medium gray), moderate (light gray), and high (solid yellow) probabilities of level three and greater weather (Figure 9-1). The display animates the forecast from 60 min prior to the current time to 120 min into the future in 15-min increments. The loop is continuous unless interrupted by the user. A loop counter is displayed in the lower right corner of the Forecast window. The top number is the relative forecast time, or the time difference from the current time to the time of the weather shown in the display window. This time is positive for the forecast images and negative for past weather images. Beneath the relative forecast time is the absolute data or forecast time in UTC. The font is white when the images are looping and red when the loop is paused. The update rate of the RCWF is 5 min (Table 9.1).

Table 9.1
CIWS RCWF Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
RCWF	NEXRAD	5.0	0.5

9.2.1 CIWS Situation Display

The RCWF is displayable in the Forecast window only. CIWS Situation Display (Appendix A) users may choose to suppress the display of past weather and/or choose the end time of the forecast loop. These selections are controlled via the Forecast dialog box (Figure 9-3) that is accessed by right clicking the Forecast product status button located at the lower right of the Forecast window.

The Forecast product status button may be used to determine the status and state of the Forecast product (Table 9.2). The Forecast product may not be completely turned off in the Forecast window, so the button color can never be white.

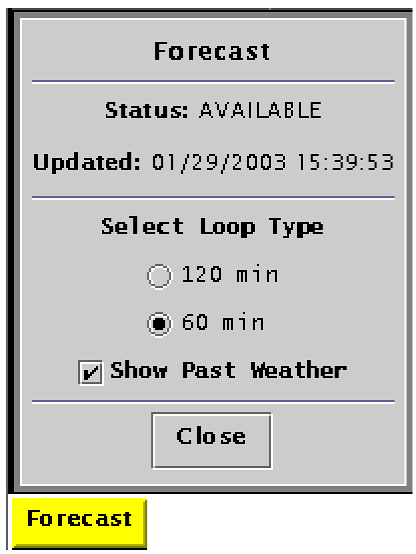

Figure 9-3. Forecast product status dialog box and Forecast button. The yellow Forecast button indicates that the product is filtered. In this case, forecasts beyond 60 minutes are not displayed.

Table 9.2
Forecast Button Color, Product Status, and Product State.

Button Color	Product Status and State
	Unavailable
	Available and displayed in the window
	Available and filtered

Right clicking the Forecast product status button displays the Forecast dialog box. The Forecast dialog box provides product status and time-of-last-update information. In addition, the dialog box provides to the capability to select the end-of-loop time and the option to show past weather. By default, the loop starts at -60 min and moves forward through the 120-min forecast in 15-min increments. Under these conditions, the Forecast button is green. Users may choose whether or not to view past weather in the loop by clicking on the box next to "Show Past Weather" in the Forecast dialog box. If the box contains a check mark, past weather is shown. If the box is empty, past weather is not shown. If past weather is not displayed, the RCWF loop starts at the current time and loops through the 60-min or 120-min forecast (depending upon the loop settings) and the Forecast button is yellow. Users may also select the end-of-loop time by either left clicking the Forecast button or via the Forecast dialog box. In Figure 9–5, the end-of-loop time is selected to be 60 min (as indicated by the highlighted button to the left of this option) and the forecast button is yellow. If the 120-min forecast is displayed, but the past weather is not displayed, the button is yellow also. The button is green if both the 120-min forecast and past weather are displayed.

Left clicking the Forecast button toggles the display of the Forecast product in the window between the 60-min and 120-min forecasts. The display of past weather cannot be affected by left-clicking the Forecast button.

Users may choose to interrupt the forecast loop to examine individual images. This is accomplished via the Loop Controls dialog box. To display the Loop Controls dialog box (Figure 9-4), the user left clicks the View button beneath the window title bar on the Forecast window and selects Loop Controls. To pause the loop, the user left clicks any of the buttons in the dialog box. If the box to the left of the Loop Controls option contains a check mark, the Loop Controls dialog box is currently displayed in the window. If the box is empty, the Loop Controls dialog box is not displayed. To change the loop speed, left click the desired speed. (The current loop speed is indicated by the highlighted button.) To display individual loop images, left click the Stop, Forward Image, Backward Image, Forward to loop end, or Backward to loop end buttons. When the loop is stopped, the text "[PAUSED]" is displayed in the window title bar and the text turns red. To restart the loop, left click Start.

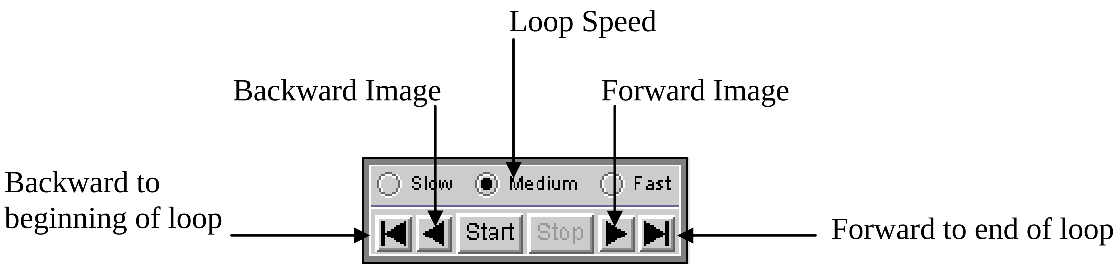

Figure 9-4. Loop Controls dialog box.

9.3 CIWS WEB SITE

The RCWF Forecast product is displayable in the Forecast window. CIWS web site (Appendix B) users may display the RCWF product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To display the Forecast product, the user selects Forecast from the Display drop-down menu (Figure 9-5) and then left clicks Apply.

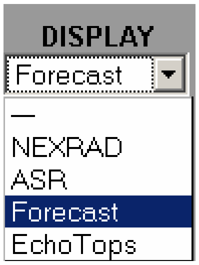

Figure 9-5. Display drop-down menu on the CIWS web site.

9.4 CAVEATS

The CIWS RCWF product produces forecasts for all types of thunderstorms but the accuracy for line storms tends to be better than for air mass storms. Line storms are larger scale, better organized, longer lived, and often have well-defined forcing mechanisms, making forecasts for these types of convective systems more reliable. Research to improve forecasts for air mass thunderstorms is continuing.

The CIWS RCWF accounts for the motion and growth/decay of existing storms. The algorithm does not predict the development of new cells where no convection previously existed. The kind of systematic growth and decay that leads to the storm envelope moving one way while the individual cells move a different way, *is* included in the RCWF.

In future versions of the RCWF algorithm, estimates of convective forcing in the boundary layer, and exploitation of the GOES satellite data and numerical model data will be added to improve the zero to two-hour forecasts.

9.5 OPERATIONAL USE

The CIWS RCWF product is a key product for traffic management and situational awareness in the en route airspace. When used in conjunction with the other CIWS products such as VIL Mosaic, Growth and Decay Trends, and Echo Tops Mosaic, the CIWS RCWF product provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess start and end times of weather impacts on en route sectors, jet routes, and terminals throughout congested airspace corridors.

In operational situations, the RCWF product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

The CIWS RCWF product has been instrumental in facilitating coordination between the ARTCCs and TRACONs. This enhanced coordination has resulted in fewer, shorter ground stops, better management of weather-impacted arrival transition areas, greater departures during adverse weather situations, and optimized runway usage.

10. CIWS FORECAST ACCURACY PRODUCT

The RCWF product self-scores and produces the Forecast Accuracy product. The number reported to the users is a Critical Success Index (CSI) score. The CSI is similar to a Probability of Detection but also includes a penalty for false alarms. The Forecast Accuracy product is a measure of how well the past 30-, 60- or 120-min forecasts performed. It is not a measure of the *current* forecast accuracy. An example of the product is provided in Figure 10-1.

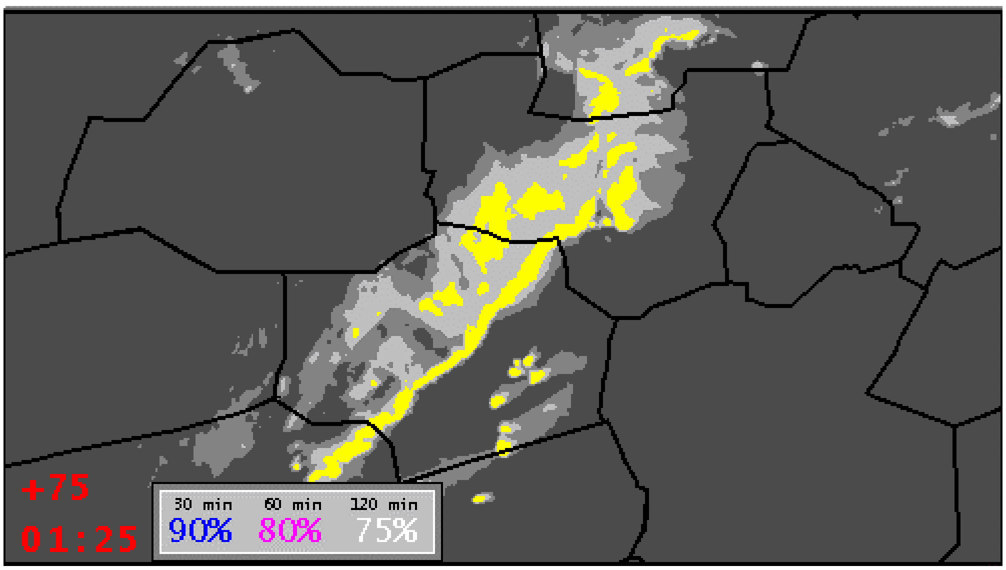

Figure 10-1. Example of the Forecast Accuracy product displayed in the Forecast window. The 30-min score is shown in blue, 60-min in magenta, and 120-min in white.

10.1 PRODUCT GENERATION

Because the weather regime can vary greatly across an area the size of the CIWS domain, a single Forecast Accuracy score for the entire domain is not specific enough to provide insight into the algorithm performance. At the request of the users, Forecast Accuracy scores are generated for square regions centered on each “Home”. The size of these boxes is such that the Forecast Accuracy scores computed within them are operationally meaningful and appropriate to the airspace of interest. For the Situation Display, the box is 280 nmi x 280 nmi, centered on the selected airport. The size of the scoring box on the web site is 370 nmi x 370 nmi centered on the selected ARTCC. The product update rate and resolution are provided in Table 10.1.

Table 10.1
CIWS Forecast Accuracy Product Update Rate and Data Source.

Product	Data Sources	Product Update Interval (min)
Forecast Accuracy	RCWF	5.0

Every forecast of **high** probability of level three and greater (3+) weather is scored against the weather that is present at the forecast validation time. For example, the forecast made one hour ago and valid for the current time is scored against the weather that is present at the current time. Sufficient level 3+ weather must be present to generate a forecast. If, at the validation time, there is insufficient level 3+ weather, the forecast is not scored. Truth is the actual weather that occurred at the forecast validation time. The 30-min and 60-min scores are computed by centering a box that is 5 nmi x by 5 nmi on a pixel and comparing the forecast and truth fields within the box. The 120-min forecast is scored using a 10 nmi x 10 nmi box, recognizing the changing accuracy requirements with forecast lead time. A hit is a high probability forecast confirmed by truth of level 3+. A false alarm is a high probability forecast that corresponds to truth below level 2. Partial credit is given for a high probability forecast confirmed by level 2 weather or a moderate probability forecast confirmed by level 3+ weather. A miss is a forecast of less than moderate probability and truth of level 3+. From these statistics, the Forecast Accuracy product is computed.

Forecast Accuracy scores are provided for the 30-min, 60-min, and 120-min forecasts. This score is a measure of past performance of the RCWF forecast. For example, the 60-min Forecast Accuracy for the current time is a measure of how well the forecast that was made an hour ago compared to the current weather. It is not an estimate of how good the current forecast will be at the validation time. While past performance does not guarantee future performance, past performance is a reasonable estimation for future performance. The Forecast Accuracy scores can increase and decrease throughout a weather event.

10.2 DISPLAY CONCEPT

The Forecast Accuracy score is presented in a text box in the lower left corner of the Forecast Window. The 30-min score is in blue; the 60-min score is in magenta (pink), and the 120-min score is in white. (This color code is maintained in both the Forecast Contours and Verification Contours, discussed in the other chapters.) If the forecast is still initializing and not enough time has elapsed to score the forecast, the Forecast Accuracy scores will contain the text “INIT”. If there is not sufficient level 3+ weather to score the forecasts, the Forecast Accuracy scores will contain the text “L3<MIN.” Otherwise, Forecast Accuracy scores are presented as percentages.

The Forecast Accuracy scores displayed in the window are for the box centered on the Home of the window. To change the source of the scores, the window Home must be changed.

10.2.1 CIWS Situation Display

The Forecast Accuracy product is displayable in the Forecast window only. CIWS Situation Display (Appendix A) users may control the display of the Forecast Accuracy product via the Accuracy product status button. Left clicking the Accuracy button toggles the display in the window.

The Accuracy product status button may be used to determine the status and state of the Forecast Accuracy product (Table 10.2).

Table 10.2
Accuracy Button Color, Product Status, and Product State.

Button Color	Product Status and State
Accuracy	Unavailable
Accuracy	Available and displayed in the window
Accuracy	Available but not displayed in the window

Right clicking the Accuracy button displays the Forecast Accuracy dialog box. This dialog box provides status information and an interface to toggle the display of the product in the window.

10.2.2 CIWS Web Site

On the CIWS Web Site (Appendix B), the Forecast Accuracy product is displayed in the lower left corner of the Forecast window. The product is always displayed and users may not remove the product from the window. To display the Forecast window, the user selects Forecast from the Display drop-down menu (Figure10-2) and then left clicks Apply.

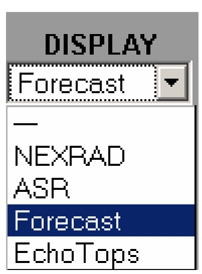

Figure 10-2. Display drop-down menu on the CIWS web site.

10.3 CAVEATS

The Forecast Accuracy score reflects the recent past performance of the CIWS RCWF product.

The RCWF product produces forecasts for all types of thunderstorms but the accuracy for line storms tends to be better than for air mass storms. Line storms are larger scale, better organized, longer lived, and often have well-defined forcing mechanisms, making forecasts for these types of convective systems more reliable. This is reflected somewhat in the Forecast Accuracy scores, but the Verification Contours (Chapter 11) better depict this variable performance. Research to improve forecasts for air mass thunderstorms is continuing.

The CIWS RCWF accounts for the motion and growth/decay of existing storms. The algorithm does not yet predict the development of new cells where there were no cells previously. The kind of systematic growth and decay that leads to the storm envelope moving one way, while the individual cells move a different way, *is* included in the RCWF forecasts.

In future versions of the RCWF algorithm, estimates of convective forcing in the boundary layer, and exploitation of the GOES satellite data and numerical model data will be added to improve the zero to two-hour forecasts.

10.4 OPERATIONAL USE

The Forecast Accuracy scores enable traffic managers to quickly assess the performance of the CIWS RCWF product, thereby instilling a sense of confidence in the forecast products. As a result, air traffic managers can make better user of the CIWS forecast products to manage air traffic flows.

11. CIWS FORECAST VERIFICATION PRODUCT

The CIWS Verification Product provides contours of forecasts on past and current weather images in the Forecast window. It is really a companion to the Forecast Accuracy product (Chapter 10), providing a spatial context to the accuracy numbers. These contours represent the forecasts of high probability of level three or greater weather that were made 30, 60, and 120 min prior to the weather image upon which they are displayed. An example of the product is provided in Figure 11-1.

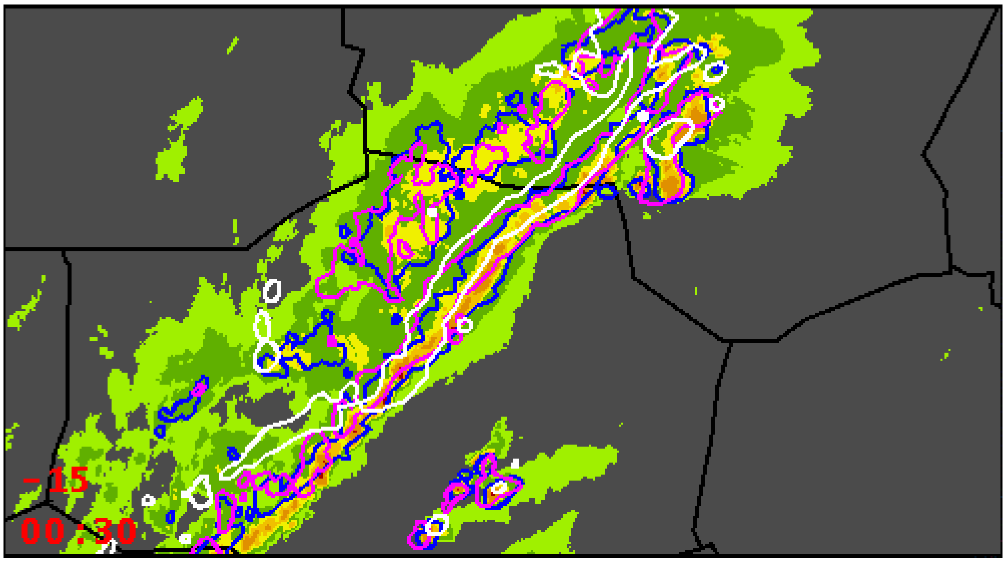

Figure 11-1. Example of the CIWS Forecast Verification Product. The blue contours are the 30-min verification contours, magenta are 60-min, and white are 120-min. Product Generation

The Forecast Verification product uses the forecasts of high probability of level three or greater weather generated by the CIWS RCWF product (Chapter 9). Contours are drawn around areas of high probability (solid yellow in the forecast product) for the 30-, 60-, and 120-min forecasts for each of the past and current weather images in the loop. Forecasts that verified at the time of the loop image are overlaid on the image for comparison. For example, in Figure 11-1, the image time is 00:30 UTC. The blue contours show the forecast of high probability of level 3+ weather that was generated 30 min prior to the image, at 00:00 UTC. The magenta contours are for the forecast made at 23:30 UTC (60 min prior), and the white contours are from the forecast made at 22:30 UTC (120 min prior). Product update rate and spatial resolution are provided in Table 11.1.

Table 11.1

CIWS Verification Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Forecast Verification	RCWF	5.0	1.0

11.1 DISPLAY CONCEPT

Verification contours are displayed in the Forecast window only and only on the past and current weather images. The 30-min verification contours are displayed in blue, the 60-min contours are in magenta (pink), and the 120-min contours are in white. In this way, users may assess the accuracy of past forecasts by visually comparing them to the actual weather that was present at the verification time.

11.1.1 CIWS Situation Display

The Verification Contours product is displayable in the Forecast window only. The CIWS Situation Display (Appendix A) may control the display of the Verification Contours product via the Verification product status button in the Forecast window. The color of the product status button indicates the status and state of the product (Table 11.2).

Table 11.2

Verification Button Color, Product Status, and Product State.

Button Color	Product Status and State
	Unavailable
	Available and displayed in the window
	Available and filtered
	Available but not displayed in the window

Right clicking the Verification button displays the Verification dialog box (Figure 11-2). This dialog box provides status information and time of last update. To toggle the display of the three sets of contours in the window, the user left clicks the check box adjacent to the desired option. If the checkmark is present, the associated contours are displayed in the window. If the check box is empty, the associated contours are not displayed. If one or two sets of contours are not displayed, the product status button is yellow. Left clicking the Verification button toggles the display of the product between off and the last setting.

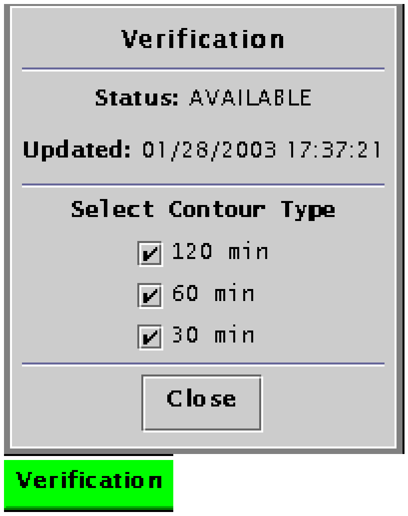

Figure 11-2. Verification dialog box and status button for the Forecast Verification Contours product. The green Verification button and check marks indicate that all (the 120-min, 60-min, and 30-min) of the verification contours are displayed. CIWS Web Site

The Verification Contours product is displayable in the Forecast window. CIWS web site (Appendix B) users may display the Verification Contours product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To display the Forecast product, the user selects Forecast from the Display drop-down menu (Figure 11-3) and then selects Apply. To display the Verification Contours product, the user selects the P button and clicks on the box adjacent to the desired options from the Products dialog box (Figure 11-4). A dot in the white circle indicates that the product is displayed. If the circle is empty, the product is not displayed.

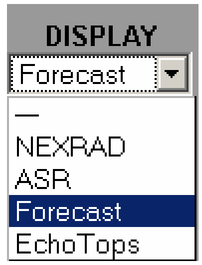

Figure 11-3. Display drop-down menu on the CIWS web site.

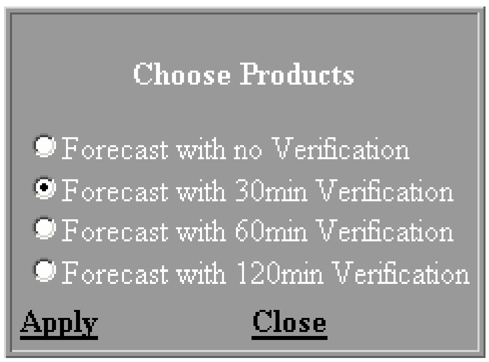

Figure 11-4. Products dialog box from the Forecast web site window. In this example, the 30-min verification contours are displayed in the Forecast window.

11.2 OPERATIONAL USE

The Verification Contours product may be used as an alternative to the Forecast Accuracy scores. This product enables traffic managers to quickly assess the performance of the CIWS RCWF product in a particular region of airspace, thereby instilling a sense of confidence in the forecast products.

In operational situations, CIWS forecast products have proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

12. CIWS FORECAST CONTOURS PRODUCT

The CIWS Forecast Contours Product provides forecast contours in the NEXRAD window. These contours represent the 30-, 60-, and 120-min forecasts of high probability of level three or greater weather. An example of the product is provided in Figure 12-1.

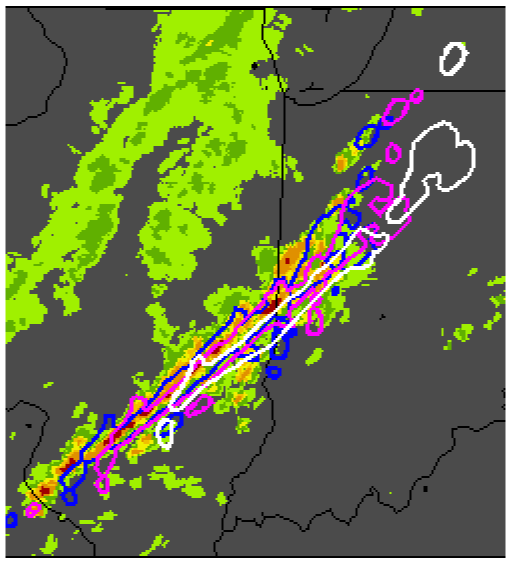

Figure 12-1. Example of the CIWS Forecast Contours Product. The blue contours are the 30-min forecast contours, magenta are 60-min, and white are 120-min.

12.1 PRODUCT GENERATION

The Forecast Contours product uses the forecasts of high probability of level three or greater weather generated by the CIWS RCWF product (Chapter 9). Contours are drawn around areas of high probability (solid yellow in the forecast product) for the 30-, 60-, and 120-min forecasts. Those contour locations are then translated to the NEXRAD window. Product update rate and spatial resolution are provided in Table 12.1.

Table 12.1

CIWS Forecast Contours Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Forecast Contours	RCWF	5.0	1.0

12.2 DISPLAY CONCEPT

Contours of forecasted high probability of level three or greater weather are displayed in the NEXRAD window only. In keeping with the color codes introduced in the Forecast Accuracy product, the contours for the 30-min forecast are displayed in blue, the 60-min contours are in magenta (pink), and the 120-min contours are in white. In this way, users may view the current weather and the forecasts at-a-glance in the NEXRAD window.

12.2.1 CIWS Situation Display

The Forecast Contours product is displayable in the NEXRAD window only. CIWS Situation Display (Appendix A) users may control the display of the Forecast Contours product via the Forecast product status button in the NEXRAD window. The color of the product status button indicated the status and state of the product (Table 12.2).

Table 12.2

Forecast Button Color, Product Status, and Product State.

Button Color	Product Status and State
	Unavailable
	Available and displayed in the window
	Available and filtered
	Available but not displayed in the window

Right clicking the Forecast button displays the Forecast dialog box (Figure 12-2). This dialog box provides status information and time of last update. To toggle the display of the three sets of contours in the window, the user left clicks the check box adjacent to the desired option. If the checkmark is present, the associated contours are displayed in the window. If the check box is empty, the associated contours are not displayed. In the example shown, the 30-min contours are not displayed so the product status button is yellow. Left clicking the Accuracy button toggles the display of the product between off and the last setting.

Figure 12-2 Forecast dialog box for the Forecast Contours product. The yellow Forecast button shows that not all of the contours are displayed. In this example, only the 60-min and 120-min contours are displayed, as indicated by the check marks.

12.2.2 CIWS Web Site

The Forecast Contours product is displayable in the NEXRAD window. CIWS web site (Appendix B) users may display the Forecast Contours product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To display the Forecast Contours product, the user selects the P button and clicks on the box adjacent to the desired options from the Products dialog box (Figure 12-3). A check mark in the box indicates that the product is displayed. If the box is empty, the product is not displayed.

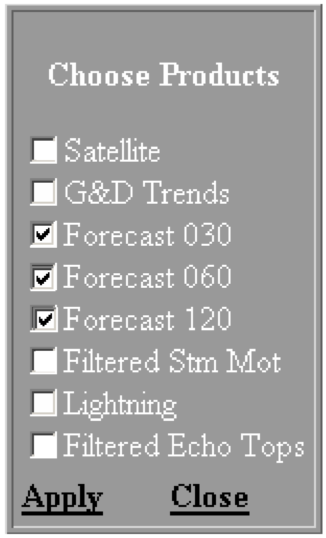

Figure 12-3. Products dialog box for the NEXRAD web site window. The check marks shows that the 30-, 60-, and 120-min forecast contours are displayed.

12.3 CAVEATS

The CIWS Forecast Contours product is a straightforward contouring of the forecast of high probability of level 3+ weather. Therefore, the caveats that apply to the CIWS RCWF product also apply to the Forecast Contours product. Specifically RCWF produces forecasts for all types of thunderstorms but the accuracy for line storms tends to be better than for air mass storms. Line storms are larger scale, better organized, longer lived, and often have well-defined forcing mechanisms, making forecasts of these convective systems more reliable. Research to improve forecasts for air mass thunderstorms is continuing.

The CIWS RCWF accounts for the motion and growth/decay of existing storms. The algorithm does not yet predict the development of new cells where no precipitation previously existed. The kind of systematic growth and decay that leads to the storm envelope moving one way, while the individual cells move a different way, *is* included in the RCWF forecasts.

In future versions of the RCWF algorithm, estimates of convective forcing in the boundary layer, and exploitation of the GOES satellite data and numerical model data will be added to improve the zero to two-hour forecasts.

12.4 OPERATIONAL USE

The CIWS Forecast Contours product may be used as an alternative to the CIWS RCWF loop. The Forecast Contours product is a key product for traffic management and situational awareness in the en route airspace. When used in conjunction with the other CIWS products such as VIL Mosaic, ASR Mosaic, Growth and Decay Trends, and Echo Tops Mosaic, the Forecast Contours product provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess start and end times of weather impacts on en route sectors, jet routes, and terminals throughout congested airspace corridors.

In operational situations, the Forecast Contours product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

The Forecast Contours product has been instrumental in facilitating coordination between the ARTCCs and TRACONs. This enhanced coordination has resulted in fewer, shorter ground stops, better management of weather-impacted arrival transition areas, greater departures during adverse weather situations, and optimized runway usage.

13. CIWS GROWTH AND DECAY TRENDS PRODUCT

The CIWS Growth and Decay Trends Product shows areas where storm growth or decay has been detected over the past 15 to 18 min. The product is not a forecast or estimate of future storm evolution, but rather a reliable diagnosis of recent storm behavior. Growth trend areas are depicted by an orange/black cross-hatched pattern while decay is shown as navy blue regions. An example of the product is provided in Figure 13-1.

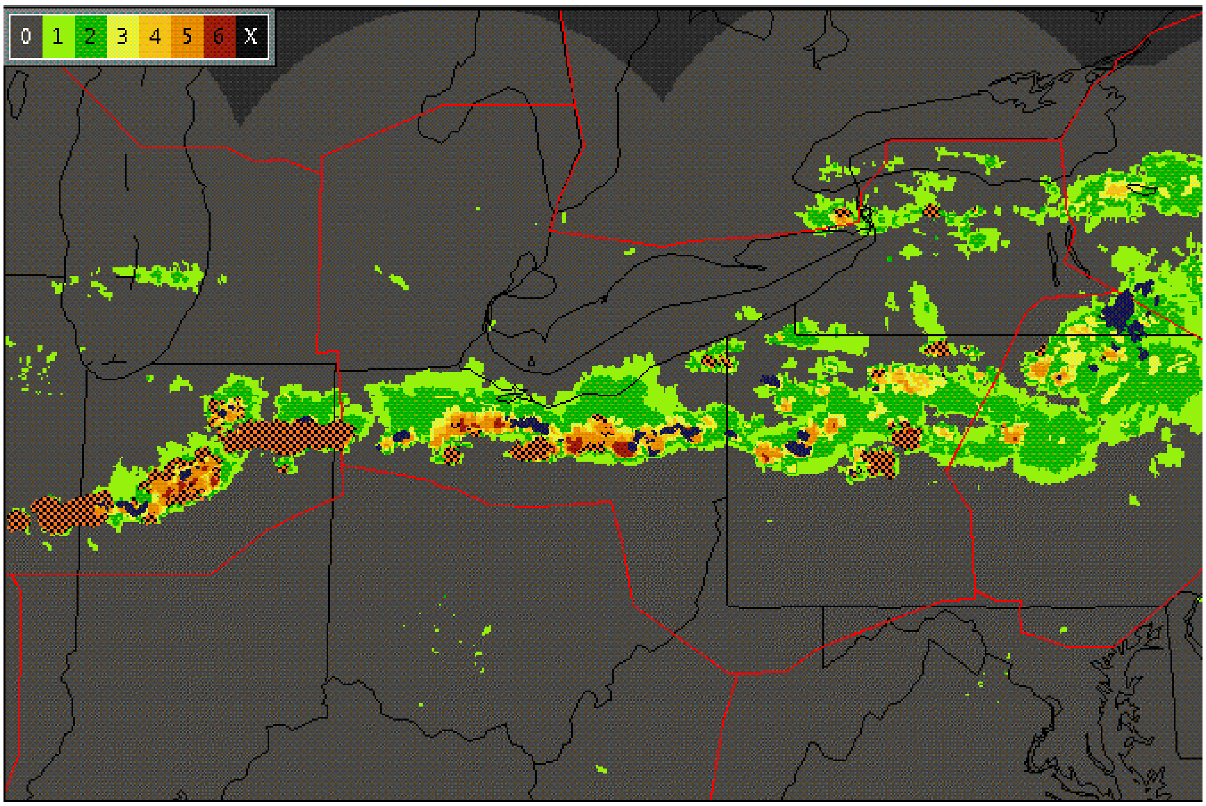

Figure 13-1. Example of the CIWS Growth and Decay Trend Product. This product shows areas where storm growth or decay has been detected over the past 15 to 18 minutes. Growth trend areas are depicted by an orange/black cross-hatched pattern while decay is shown as navy blue regions.

13.1 PRODUCT GENERATION

Growth and decay trend areas are identified during the generation of the CIWS RCWF product. Trends are computed by advecting a prior image to the current time (according to special short-time-scale motion vectors) and differencing the two images. The resulting difference image is typically quite noisy, so a number of them are averaged together to produce the final product. In CIWS, three difference images are averaged. The final product thus represents a *persistent* trend diagnosed over a 15 to 18 min period (depending on the NEXRAD scan strategy in operation). Product update rate and spatial resolution are provided in Table 13.1.

Table 13.1

CIWS Growth and Decay Trends Product Update Rate, Data Source, and Spatial Resolution.

Product	Data Sources	Product Update Interval (min)	Product Spatial Resolution (nmi)
Growth and Decay Trends	RCWF	5.0	1.0

13.2 DISPLAY CONCEPT

Growth and decay trends are displayed in the NEXRAD and Echo Tops windows only. Growth trends are displayed in orange cross-hatch and decay trends are displayed as navy blue.

13.2.1 CIWS Situation Display

The Growth and Decay Trends product is displayable in the NEXRAD, Echo Tops, and ASR windows. CIWS Situation Display (Appendix A) users may control the display of the Growth and Decay Trends product via the G&D Trends product status button. The color of the product status button indicates the status and state of the product (Table 13.2).

Table 13.2

Growth and Decay Trends Button Color, Product Status, and Product State.

Button Color	Product Status and State
G&D Trends	Unavailable
G&D Trends	Available and displayed in the window
G&D Trends	Available but not displayed in the window

Right clicking the G&D Trends button displays the G&D Trends dialog box that shows the status and state of the product. Left clicking the G&D Trends button toggles the display of the product between off and on.

13.2.2 CIWS Web Site

The Growth and Decay Trends product is displayable in the NEXRAD and Echo Tops windows. CIWS web site (Appendix B) users may display the product by logging onto the CIWS web site and selecting the desired region from the CIWS Domain Map. By default, the window that is created contains the VIL Mosaic product centered on the chosen Home. To toggle the display of the G&D Trends product, the user selects the P button and clicks on the box adjacent to the “G&D Trends” option on the Products dialog box (Figure 13-2). A check mark in the box indicates that the product is displayed. If the box is empty, the product is not displayed.

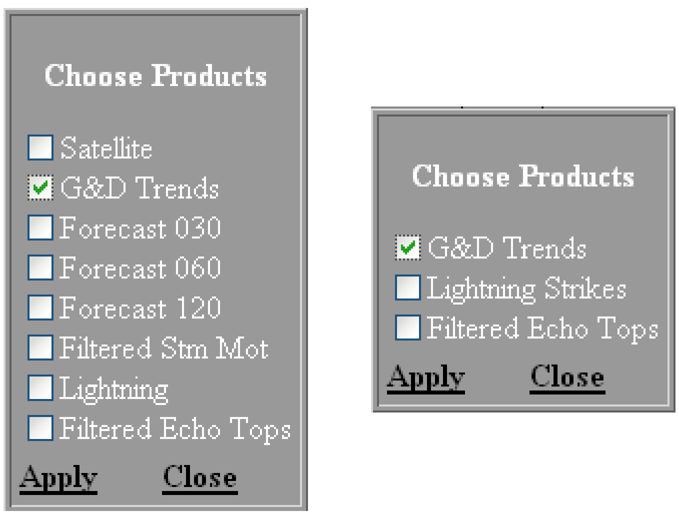

Figure 13-2. Products dialog box for the NEXRAD (left) and Echo Tops (right) web site windows. Check marks show that the Growth and Decay product is displayed in the associated windows.

13.3 CAVEATS

The Growth and Decay Trends product depicts areas where existing convection is, or has been, growing or decaying over the past 12 to 15 min. It does not show areas where convection is expected to develop.

The combination of the update rate and current product generation scheme limits the operational effectiveness of the decay trend in identifying longer term, persistent storm dissipation. Research to improve product performance in this area is on-going.

13.4 OPERATIONAL USE

The CIWS Growth and Decay Trends Product is a key product for traffic management and situational awareness. When used in conjunction with the other CIWS products such as Echo Tops, VIL Mosaic, ASR Mosaic, Storm Motion, and RCWF, the Growth and Decay Trends product provides information essential to improved air traffic management decisions. Using this information, users can more accurately assess the start and end times of weather impacts on en route sectors, jet routes, and terminals throughout congested airspace corridors.

In operational situations, the Growth and Decay Trends product has proven useful for keeping routes open longer, proactively closing routes, and/or reopening closed routes earlier; proactively and efficiently rerouting aircraft and avoiding unnecessary reroutes; directing traffic through gaps in the weather; reducing miles-in-trail restrictions; directing pathfinders; and allowing high-altitude traffic the opportunity to fly over the weather.

The CIWS Growth and Decay Trends product has been instrumental in facilitating coordination between the ARTCCs and TRACONs. This enhanced coordination between the ARTCCs and TRACONs has resulted in fewer, shorter ground stops, better management of weather-impacted arrival transition areas, greater departures during adverse weather situations, and optimized runway usage.

14. IMPROVEMENTS TO PRODUCTS FOR 2004 OPERATIONAL DEMONSTRATION

Following the 2003 Operational Demonstration, enhancements were made to the coverage the CIWS product suite.

14.1 EXPANDED COVERAGE (JUNE 2004)

When severe thunderstorms occur in the Midwest, major delays are experienced by US air carrier passenger flights because the major east-west jet routes through the upper Midwest are blocked by the weather. In such situations, through a cooperative agreement between the FAA, US air carriers, and NavCanada, the US air carriers may use the Canadian "play book" routes that pass north of Toronto, Canada.

One of the significant problems in using these Canadian routes for US flights has been our lack of high quality information on convective weather in this region of Canada which lies outside the coverage of the US network of NEXRAD weather radars. Through a joint initiative of the FAA and NavCanada, a major new weather decision support capability for ATC facilities in both countries started operation in June 2004. NavCanada is providing real time information from five Canadian weather radars operated by the Meteorological Service of Canada to CIWS. Eight more US radars were also added at the same time (Figure 14.1).

14.2 IMPROVEMENTS TO CIWS PRODUCTS (JUNE 2004)

Several modifications were made to the CIWS RCWF product. These include changes to the tracking technique, weather classification scheme, trending, and forecast appearance. The strategy for quality control of motion vectors was improved to provide better tracking of storms on a local scale, including storms exhibiting rotation.

The Echo Tops Mosaic and Growth and Decay Trending products are now used to further classify weather sub-types (i.e., growing line regions, etc.). NWS numerical model data is used to mitigate the Growth and Decay boundary false alarms. Users may also note a change in the appearance of the Forecast product. Regions of low and moderate probability may appear more extensive (Figure 14.2). In response to feedback from CIWS users desiring an optional forecast for tactical routing decisions, the CIWS Forecast product is now a "radar map" forecast providing a deterministic forecast of what the radar will show in advance. Low, moderate, and high color levels now refer to low, moderate, and high precipitation levels.

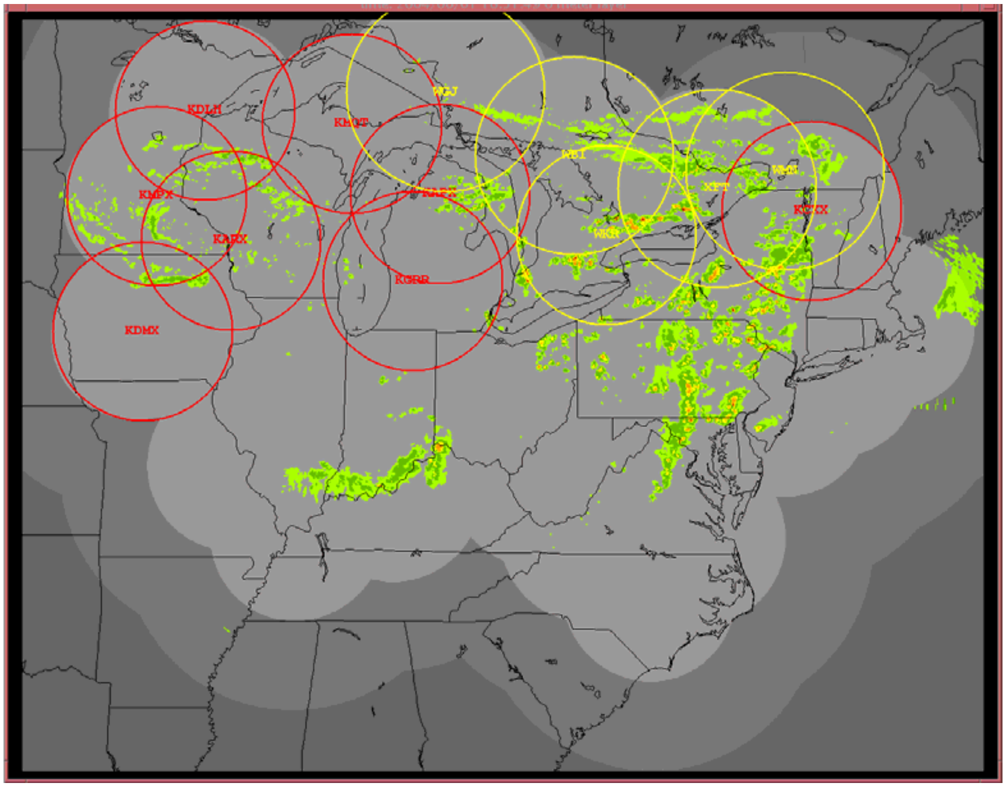

Figure 14.1. Illustration of enhanced CIWS coverage with the addition of five (5) Canadian radars (yellow circles) and eight (8) US radars (red circles) to the pre-existing domain. The Canadian McGill radar data (WMN) is included, but was not available for this example.

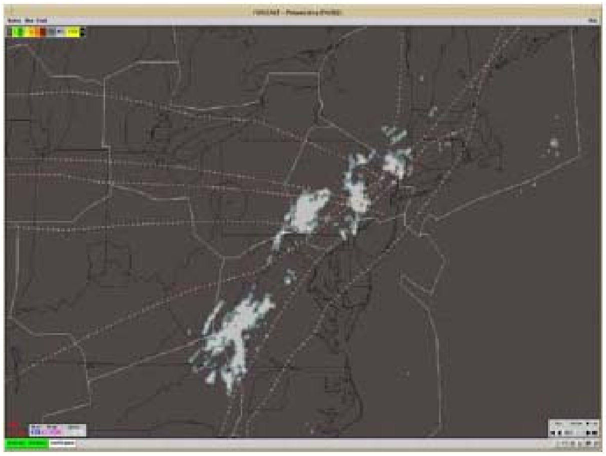 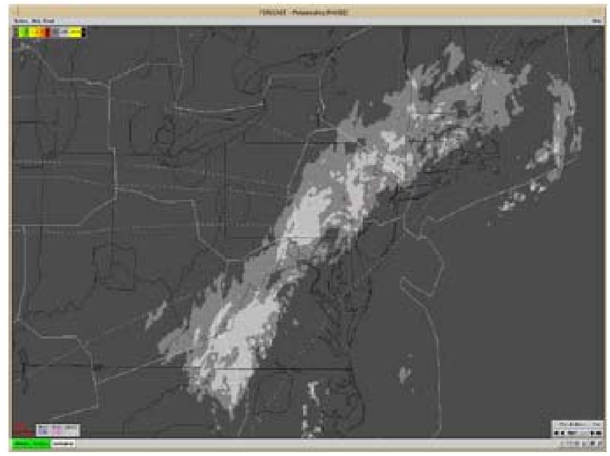

Figure 14.2. Comparison of the 60-min forecast as generated by the 2003 CIWS RCWF algorithm (left) and the forecast product after the 2004 upgrade (right). The 2004 algorithm forecasts the radar map rather than the probability of certain levels of precipitation.

14.3 WINTER MODE RCWF (FALL 2004)

A Winter mode forecast product, developed and tested at the New York ITWS site, has shown promise for reducing delays during winter snow events. Radars are capable of detecting much more than six intensity levels. However, the radar data are quantized for display into the standard six-level representation and it is this quantization that obscures the fine detail available in the radar data. Snow and light rain typically fall into the Level 1 category. The Standard Forecast, which forecasts level 3 and greater weather, is not designed to forecast level 1 events. To better capture these lower intensity events (snow storms, hurricane remnants, and stratiform rain), the CIWS RCWF operates in two modes: Standard and Winter. In modes, the forecast product loops from -60 min through +120 min and the coverage pattern indicating the distant radar coverage (inside/outside 125 nmi) has been added.

In Standard mode, precipitation levels 1-6 are shown in past and current weather images (Figure 14.3). Standard mode forecasts are displayed in three levels: low (dark gray), moderate (light gray), and high (yellow) to represent the level 3+ weather forecast. The color bars show the colors associated with the six levels and the three forecasts.

In Winter mode past and current weather images, levels 2-6 are displayed the same as in Standard mode. However, the floor of the Level 1 precipitation category is lowered from 18 dBZ to 15 dBZ. Level 1 is then subdivided into levels 1a, 1b, and 1c, represented by three shades of green. Direct comparison of the past and current weather images in the Winter and Standard mode (Figure 14.3) reveals very slight differences in the coverage of the level 1 weather (due to the lowering of the floor) and greater detail within the level 1 weather. In Figure 14.3, the VIL Mosaic images serves as a surrogate for the "current" weather image in the Standard mode loop.

Winter mode also provides three forecast levels corresponding to forecasts of level 1c+ weather: low (dark gray), moderate (light gray) and the high (green) (Figure 14.4). The color bars show the shades of green used to represent levels 1a, 1b, 1c, and the forecast for level 1c+.

The Forecast Accuracy product provides a measure of how well the past 30-, 60- or 120-min forecasts performed. When displayed in Standard mode, the scores pertain to the forecast of level 3+ weather. When displayed in Winter mode, the scores pertain to the forecasts of level 1c+ weather. Forecast Accuracy scores in Winter mode are typically much higher than Standard mode scores because there are many more pixels to score, especially in weak precipitation.

Verification contours are outlines of high forecasts displayed on the past and current weather images. For the Standard forecast, this is the past high forecasts of Level 3+ weather; for the Winter Forecast, this corresponds to the past high forecasts of Level 1c+ weather.

To toggle the display of the Winter mode forecast, the user left clicks the View button on the Forecast window. The View menu (Figure 14.5) contains a Winter Mode option. If a check appears in the box, the Winter mode is displayed in the Forecast window. If the box is blank, the Standard mode is displayed. Users may toggle the mode at any time during the loop. Left clicking the box toggles the display of the check mark.

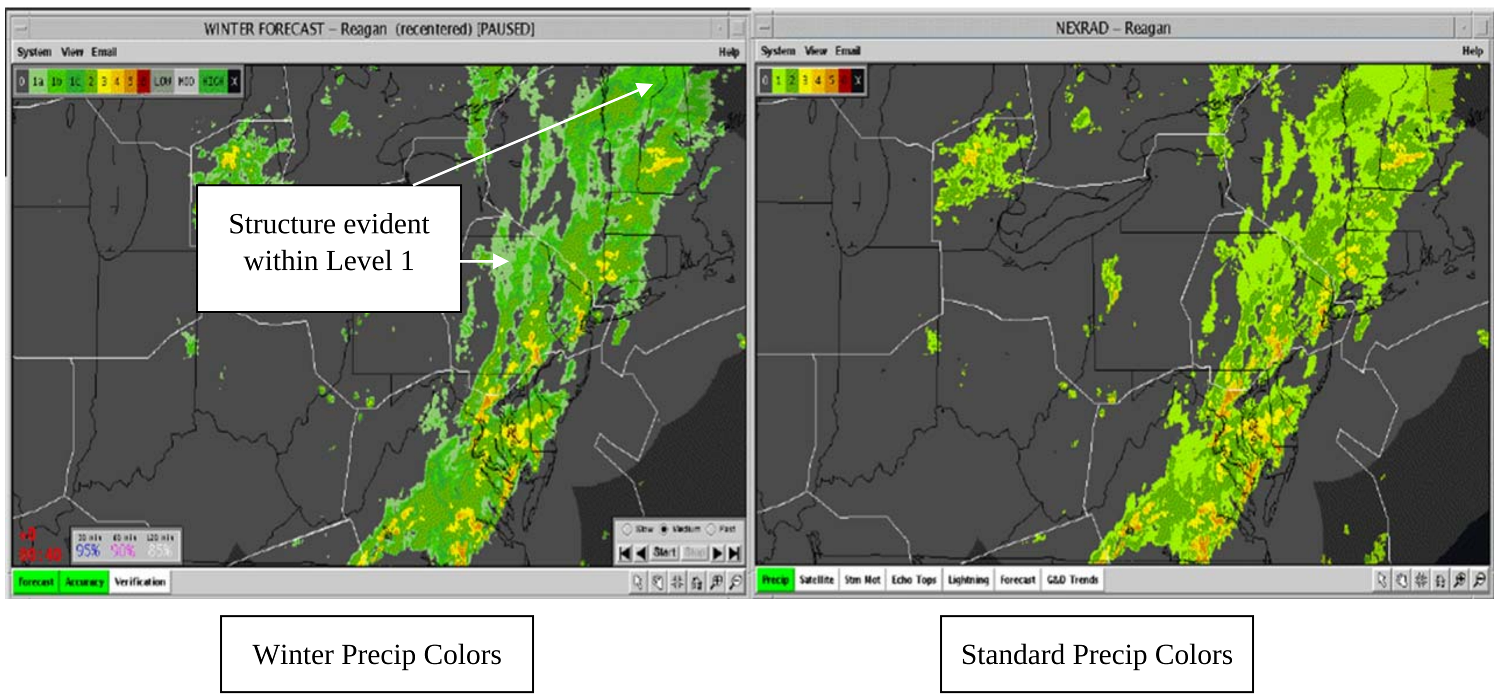

Figure 14.3. Comparison of the current weather image in the Winter mode forecast loop (left) and the corresponding VIL Mosaic image serving as a surrogate for the Standard mode forecast loop (right). This example illustrates the increase in detail in the lighter precipitation levels available in Winter mode.

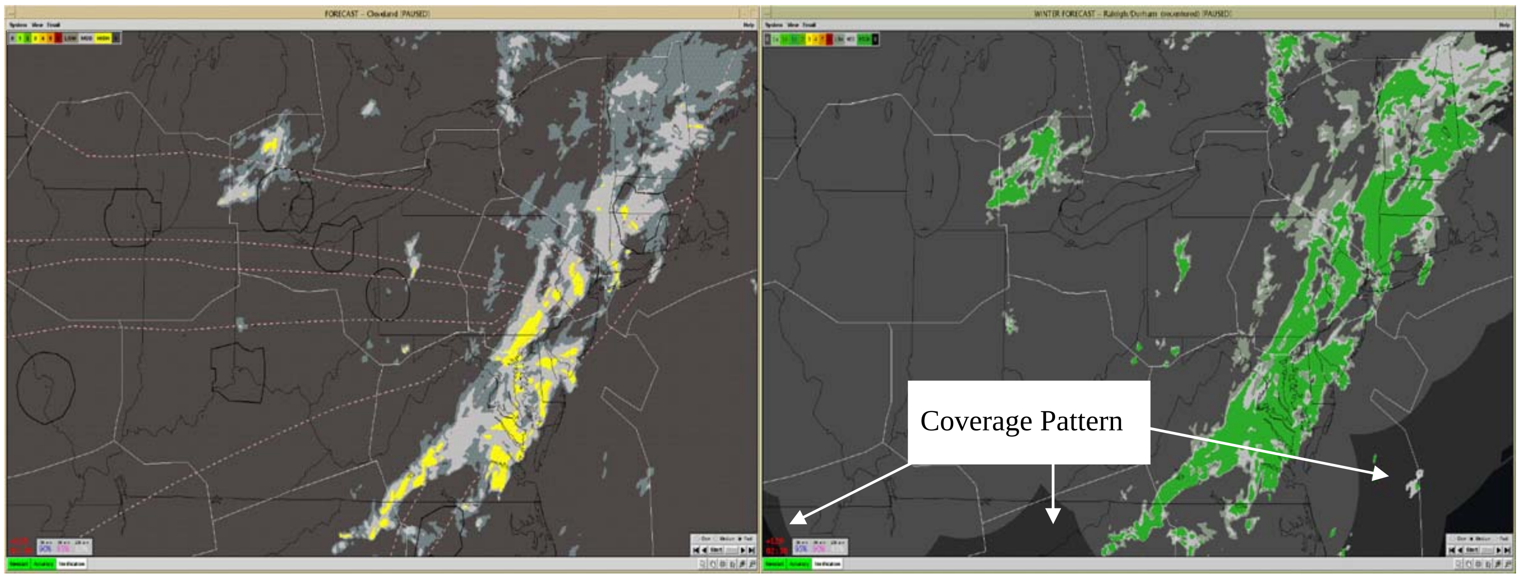

Figure 14.4. Comparison of Standard mode forecast (left) and Winter mode forecast (right). Standard mode provides forecasts of level 1 (darker gray), level 2 (lighter gray), and level 3+ (yellow). Winter mode provides forecasts of level 1a (darker gray), level 1b (lighter gray), and level 1c+ (green).

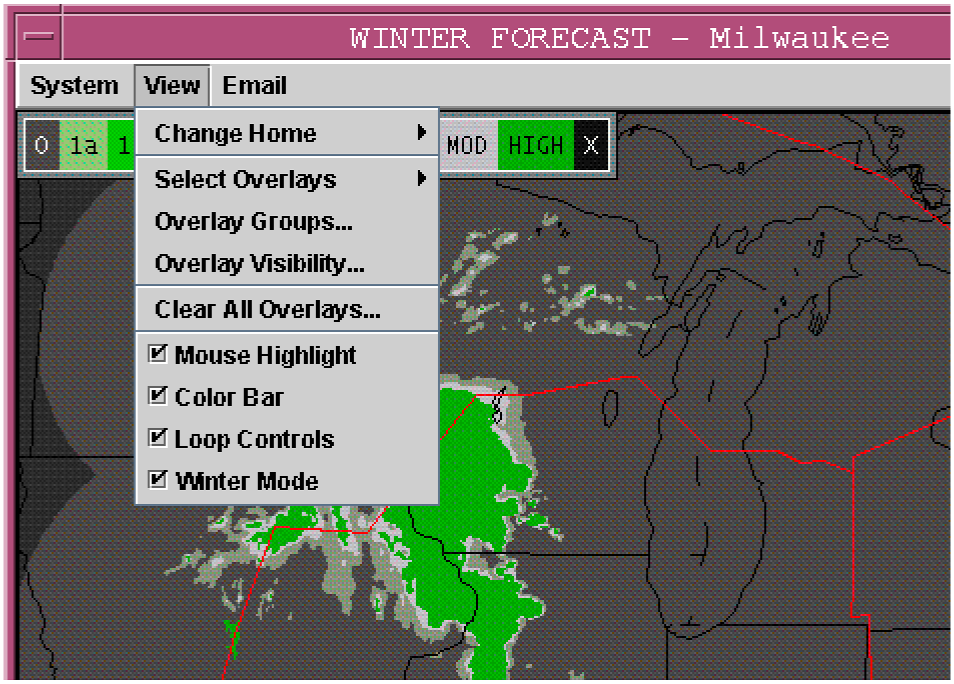

Figure 14.5. View menu containing the Winter Mode option. The check mark indicates that Winter mode is selected.

14.4 INDICATION OF "TOPPED" ECHO TOPS

Echo tops are estimated by determining the altitude above which the intensity of the radar echo drops below level 1 (18 dBZ). In some cases, the highest altitude to which the radar scans is still too low to reach the top of the storm's radar echo. This can happen at ranges close to the radar when the storm occupies the radar's cone-of-silence (Figure 3.5) and at further ranges for very large storms. These storms "top" the radar beam and, as a result, the echo tops are underestimated.

The Echo Tops/Annotation Product (Chapter 8) indicates that the radar beam has been topped by displaying a plus sign (+) after the echo tops estimate. For example, a value of 540+ indicates that the storm is at least 54,000 ft high and is probably higher.

Prior to October 2004, there was no indication in the Echo Tops Mosaic product (Chapter 7) that storms were topped. Topped regions were assigned the echo top value of the surrounding valid estimates. With the Fall upgrade, regions of topped echo tops are displayed as black regions in the Echo Top Mosaic. Figure 14.6 provides an example of topped echo tops for large, distant storms and in the cone-of-silence. Prior to the upgrade, topped regions were assigned the nearest valid echo top value (a and c). After the upgrade, topped regions are indicated by black (b and d).

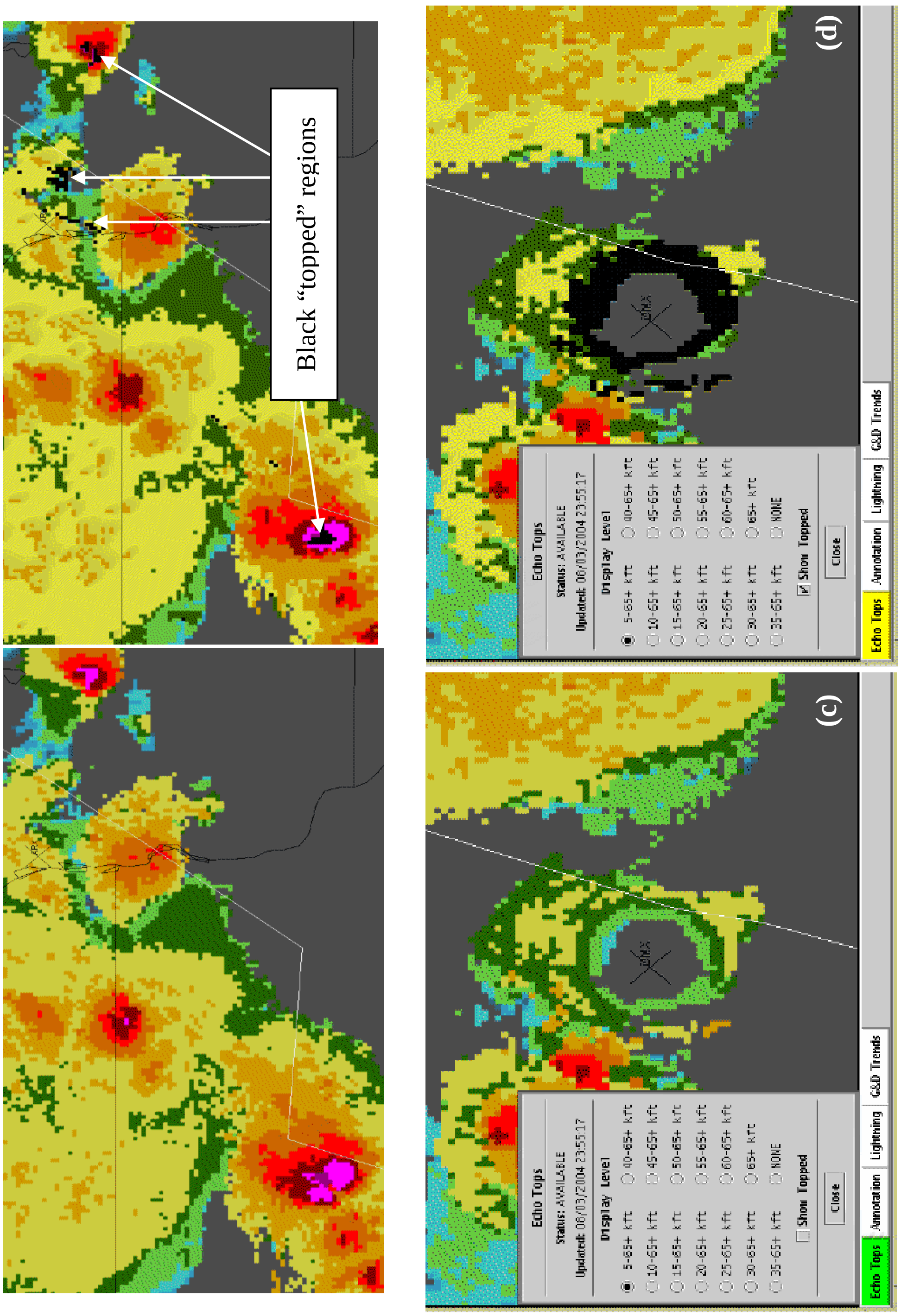

Figure 14.6. Examples of “topped” echo tops from large distant storms before (a) and after (b) and cone-of-silence issues before (c) and after (d) the October 2004 upgrades.

Display of the Topped Echo Tops feature is user-selectable. To toggle the display of topped regions, users right click the Echo Tops product status button in the Echo Tops window. The Echo Tops dialog box (Figure 14.6) is displayed. The box associated with the "Show Topped" option indicates the display status. A check mark indicates that topped regions are displayed; a blank box means topped regions are not displayed. Left-clicking the box toggles the display status.

14.5 EXPANDED RADAR COVERAGE

In Fall 2004, CIWS radar coverage was extended to the southwest by the addition of the Memphis radar. Figure 14.7 shows the new coverage pattern. The addition of this radar provides coverage to the Memphis area users.

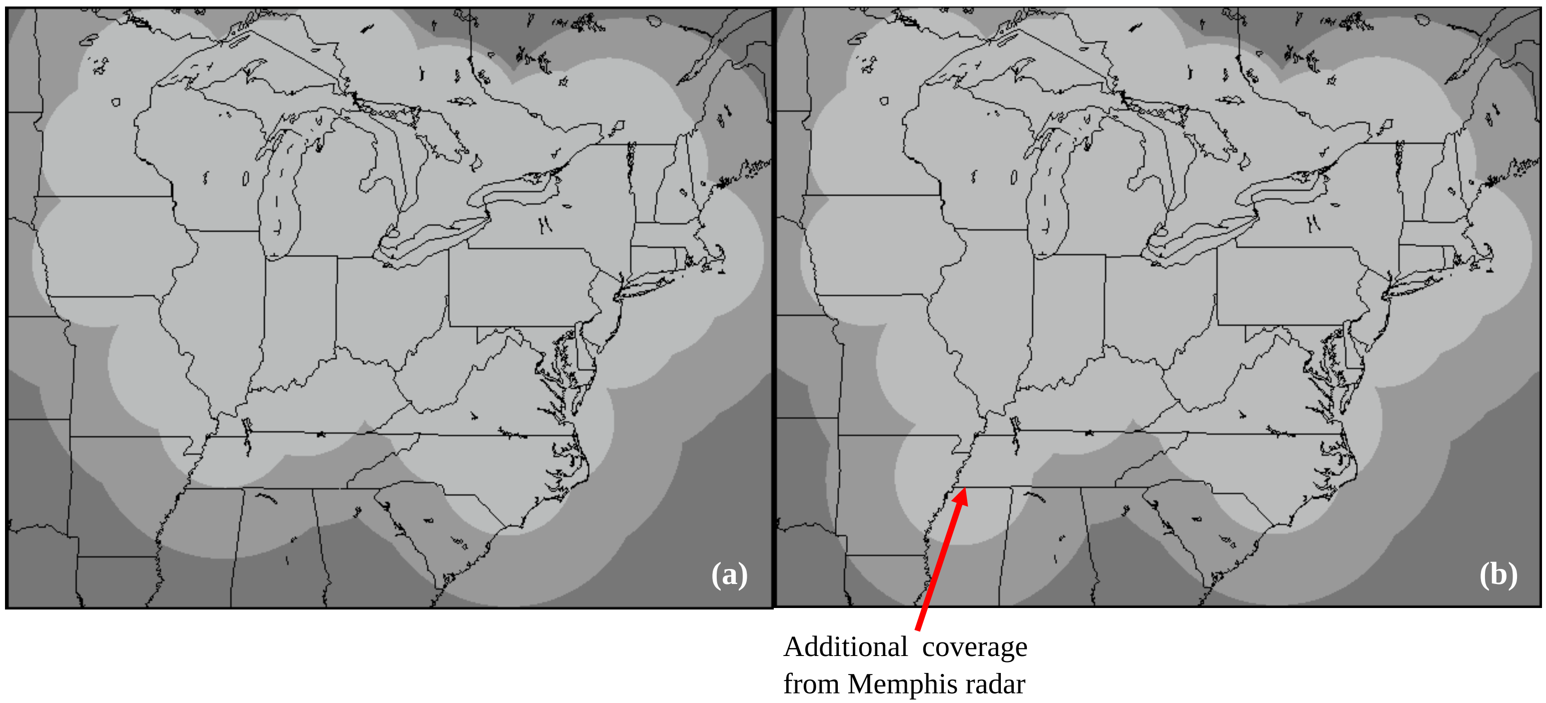

Figure 14.7. CIWS coverage (a) before and (b) after the October 2004 upgrade.

APPENDIX A: CIWS SITUATION DISPLAY OVERVIEW

The CIWS Situation Display allows the user to open multiple windows and display different products in those windows. The Situation Display supports four different windows named NEXRAD, ASR, Forecast, and Echo Tops. Different products are displayable in the different windows, as shown in Table A.1. Figure A.1 shows an example of the four windows.

Each window contains a title bar that identifies the window type (NEXRAD, ASR, Forecast, or Echo Tops) and the Home of the window. The window Home is the defined reference point for the window. By default, the window is centered on its Home, but users may re-center the window without redefining the Home. The title bar also contains buttons that control standard window functions, such as displaying the window menu, iconifying, or maximizing/restoring the window size and location.

Buttons are located beneath the title bar. When a button is selected, a menu is displayed. Menus are single-selection interfaces that remain open on the display until a selection is made or until the cursor is moved off the menu and the selection button is clicked. Menu options include single selection checkboxes that complete an action, walking menus that are identified by arrows, and options that result in the display of dialog boxes. Dialog boxes are multiple selection interfaces that are displayed by selecting a menu option containing three dots (…) or by right-clicking the Product Status buttons. Dialog boxes are closed by left-clicking the Close button or close automatically 30 seconds after the last selection in the dialog box.

Each window contains a System button that is located in the top left corner of the window. This button displays a drop-down menu that is used to create new windows, manage window configurations, manage overlay groups, and customize overlay colors for all windows. Actions taken under this button affect all windows.

To the right of the System button is the View button. This button is used to change the Home of the window, control the display of overlays, toggle Mouse Highlighting, and/or display the color bar in the window to which the button is attached. In addition, the View button is used to display loop controls (Forecast window only).

The Email button allows users to send e-mail messages to the CIWS group. Questions concerning CIWS, its display and/or products, benefits information, etc. are sent to ciws-mail@ll.mit.edu for action.

The Help button located at the top right corner of any window provides on-line help. Topics include the Situation Display Graphical User Interface (GUI), CIWS products, and contact information.

Table A.1.

Products displayable in the CIWS Situation Display windows.

	Window Type			
	NEXRAD	**ASR**	**Forecast**	**Echo Tops**
Displayable Products	VIL Mosaic	ASR Mosaic	RCWF	Echo Tops Mosaic
	Storm Motion	Storm Motion	Forecast Accuracy	Echo Tops Annotation
	Echo Tops	Echo Tops	Verification Contours	Growth and Decay Trends
	Lightning	Lightning		Lightning
	Satellite			
	Forecast Contours			
	Growth and Decay Trends			

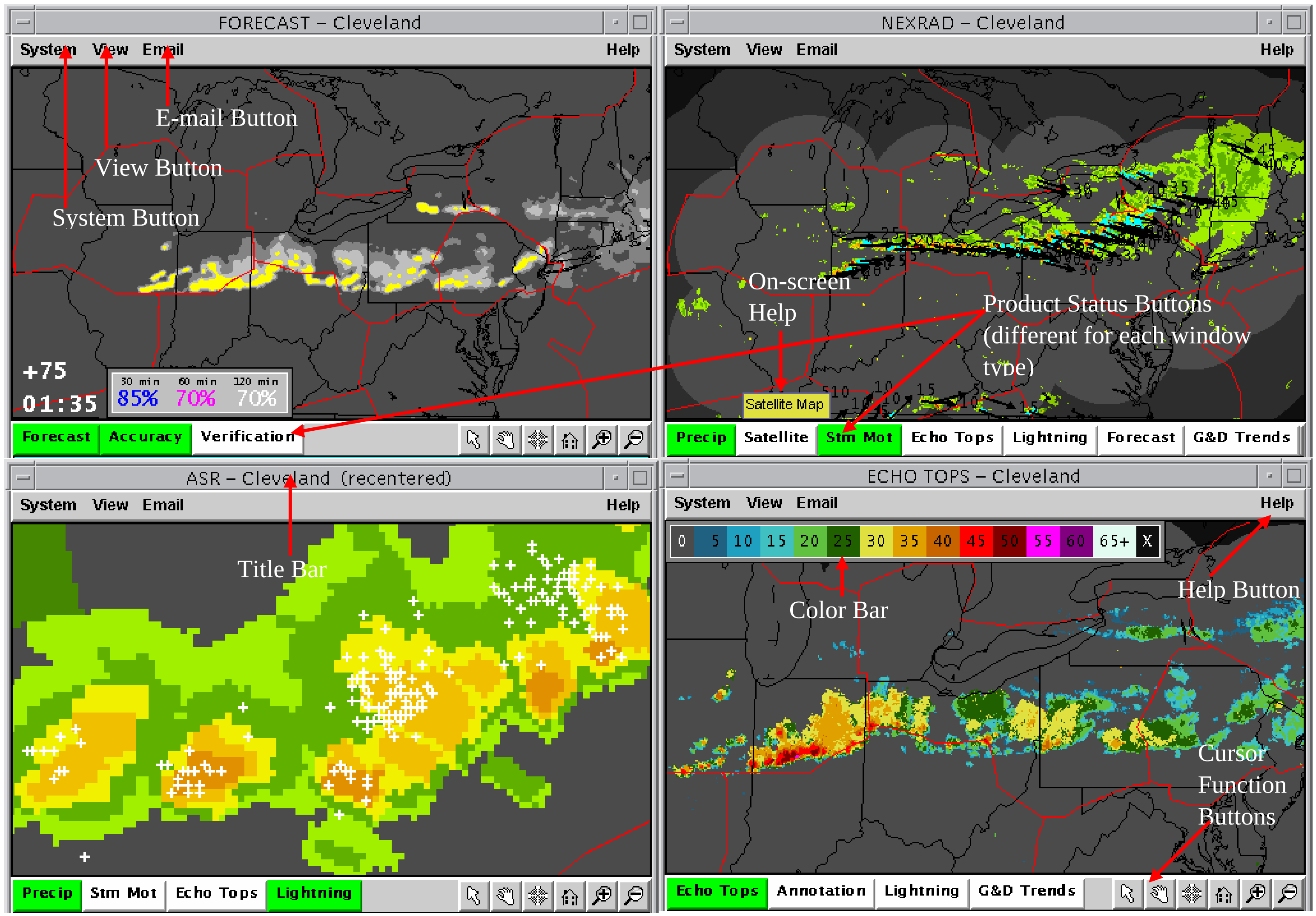

Figure A.1. Example of the CIWS Situation Display showing the four available window types and features.

The Cursor Function buttons at the lower right corner of each window control the cursor functions for the window. These buttons are used to pan, re-center, return to Home, zoom in and zoom out.

In the lower left corner of each window, and stretching across the lower border, are Product Status buttons that control the display of products in the window and provide product status information. There is one product status button for each product that is displayable in the window. Because each window type has its own product suite, the list of product status buttons for each window type is different.

APPENDIX B: CIWS WEB SITE OVERVIEW

CIWS products are available to users through the internet via a web site supported by MIT Lincoln Laboratory. The CIWS website has been developed to provide CIWS data to users who do not have access to a directly connected Situation Display. However, any user who has been assigned a user name and password may access the web site. The web site shows the CIWS product data as images and text.

The products can be viewed using any browser. Much of the functionality of the Situation Display is supported on the web site. Access to the web site is restricted to manage server load. Users are assigned a user name, or account, and a password. Multiple workstations may be logged onto the web site simultaneously.

The CIWS web site address is www.wx.ll.mit.edu/ciws. At this address, the welcome page (Figure B.1) is displayed. The top section of the page is the entry area. The bottom section lists a) system requirements, b) upgrade notifications, and c) display information.

1. To enter the CIWS web site, the user left-clicks the CIWS Domain Map link on the welcome page. The login page (Figure B.2) is displayed.

2. The user types the account (user name) and password information on the login page where prompted.

3. The user left-clicks OK. The CIWS domain map appears (Figure B.3).

The CIWS domain is divided into eight regions: ZBW, ZNY, ZDC_N (ZDC North), CYZ, ZOB, ZID, ZAU, and ZME_ZKC. On the map, these designations are links that, when selected, open a product window that is zoomed-in and centered on the selected region. An example of a ZID window is provided in Figure B.4. In addition, beneath each region link is a link designated “Domain.” Selecting these links opens a window that displays the full CIWS domain centered on the associated region. For example, a window created by clicking the Domain link beneath ZOB is shown in Figure B.5. This window displays the full CIWS domain centered on ZOB.

When a link is selected from the Domain map, the window that opens contains the CIWS VIL product. There are four window types available on the web site: NEXRAD, ASR, Forecast, and Echo Tops. Each window type has a suite of products associated with it and the product suite is different for each window type. The products that are displayable in each window are shown in Table B.1.

Figure B.1. CIWS web site welcome page.

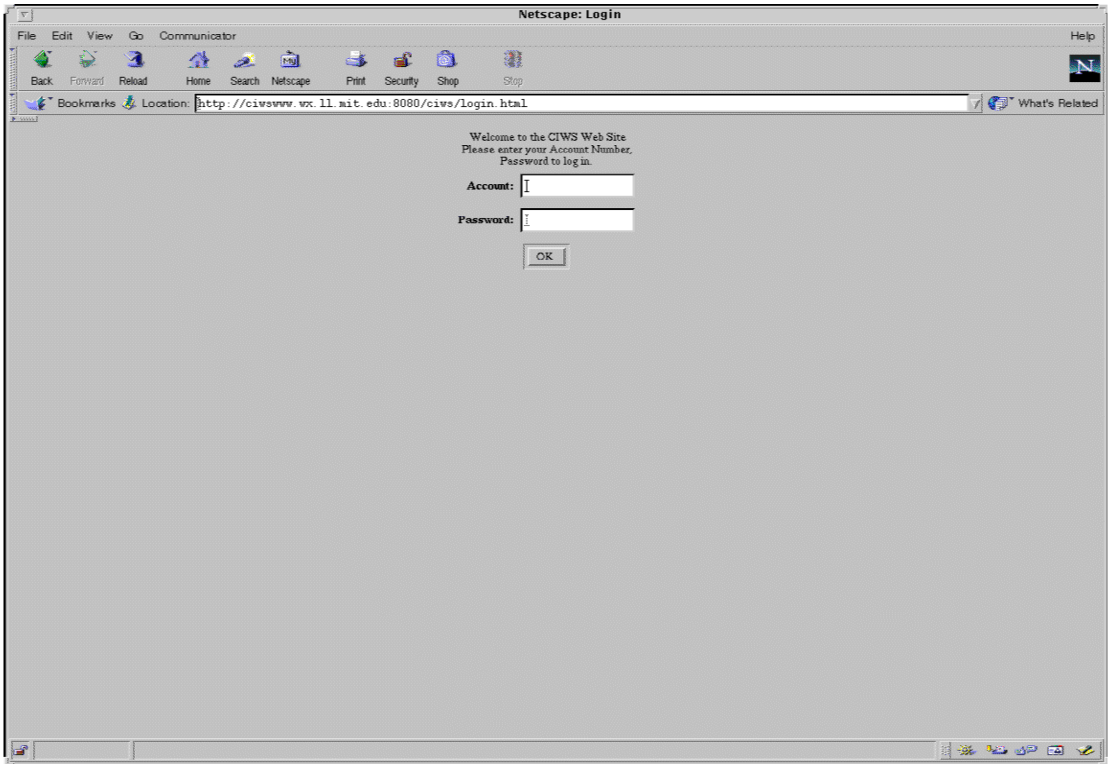

Figure B.2. CIWS web site login page.

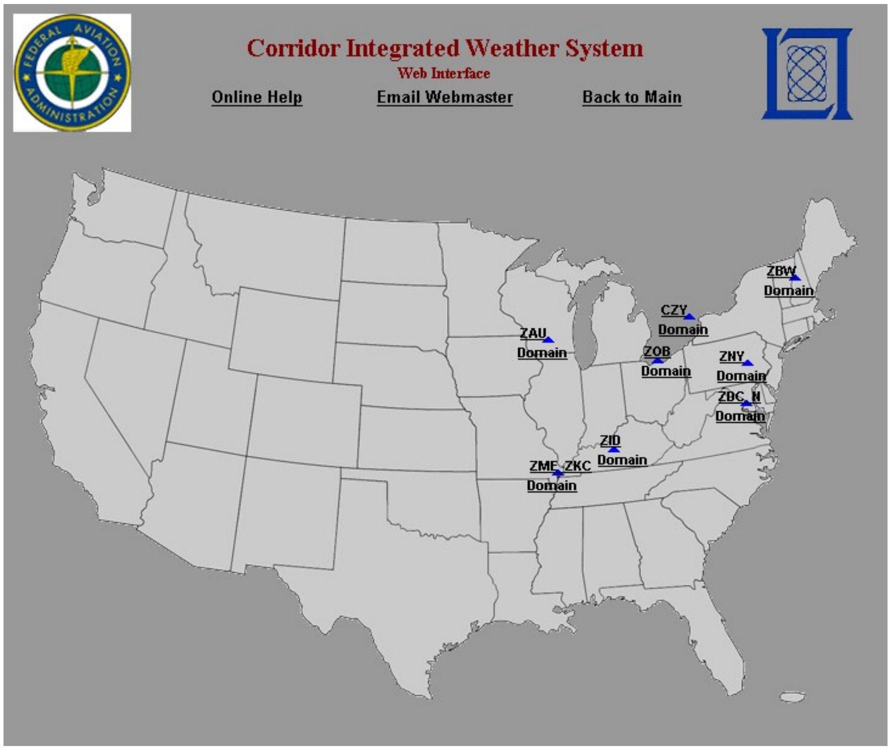

Figure B.3. CIWS Domain Map Page.

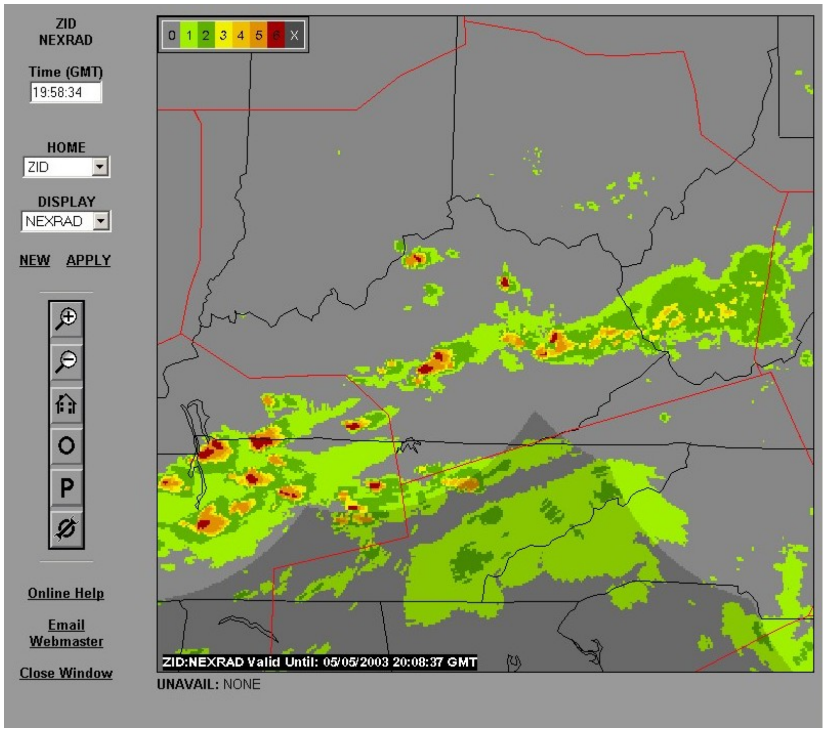

Figure B.4. Example of the ZID window that results from selecting ZID from the CIWS domain map.

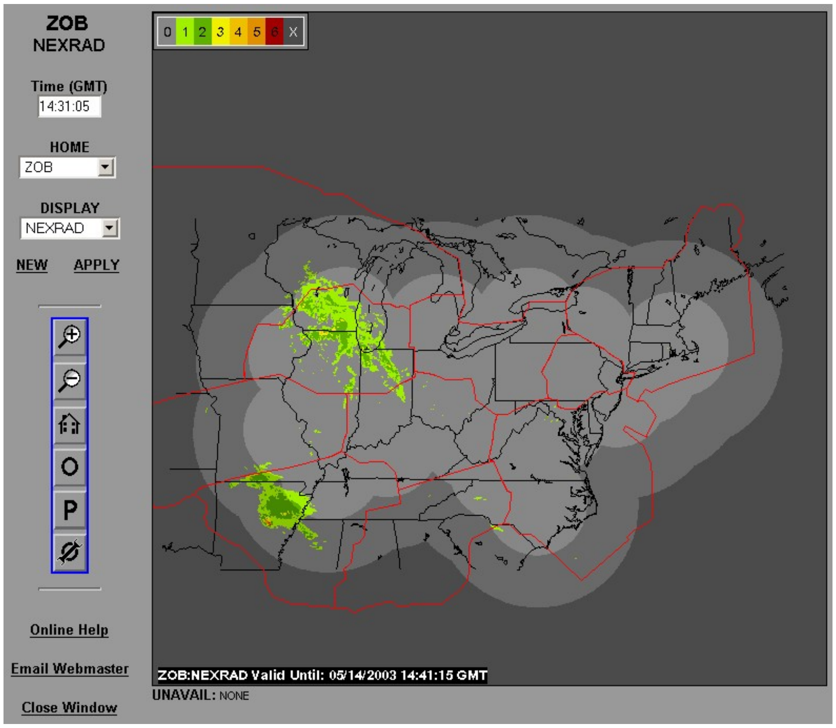

Figure B.5. Example of the ZOB window that results from selecting ZOB Domain link from the CIWS domain map.

Table B.1.
Products available for display as a function of window type.

	Web site Window Type			
	NEXRAD	**ASR**	**Forecast**	**Echo Tops**
Displayable Products	Satellite	Filtered Storm Motion	Forecast without Verification Contours	Growth and Decay Trends
	Growth and Decay Trends	Lightning	Forecast with 30-minute Verification Contours	Lightning
	30-minute Forecast Contours	Filtered Echo Tops	Forecast with 60-minute Verification Contours	Filtered Echo Tops
	60-minute Forecast Contours		Forecast with 120-minute Verification Contours	
	120-minute Forecast Contours			
	Filtered Storm Motion			
	Lightning			
	Filtered Echo Tops			

All windows share some basic characteristics and features. Windows differ by the product suites and color bars. The left side of any window (Figure B.6) provides window information and selection menus. Windows update automatically. Left-clicking in a window re-centers the window on the click-location.

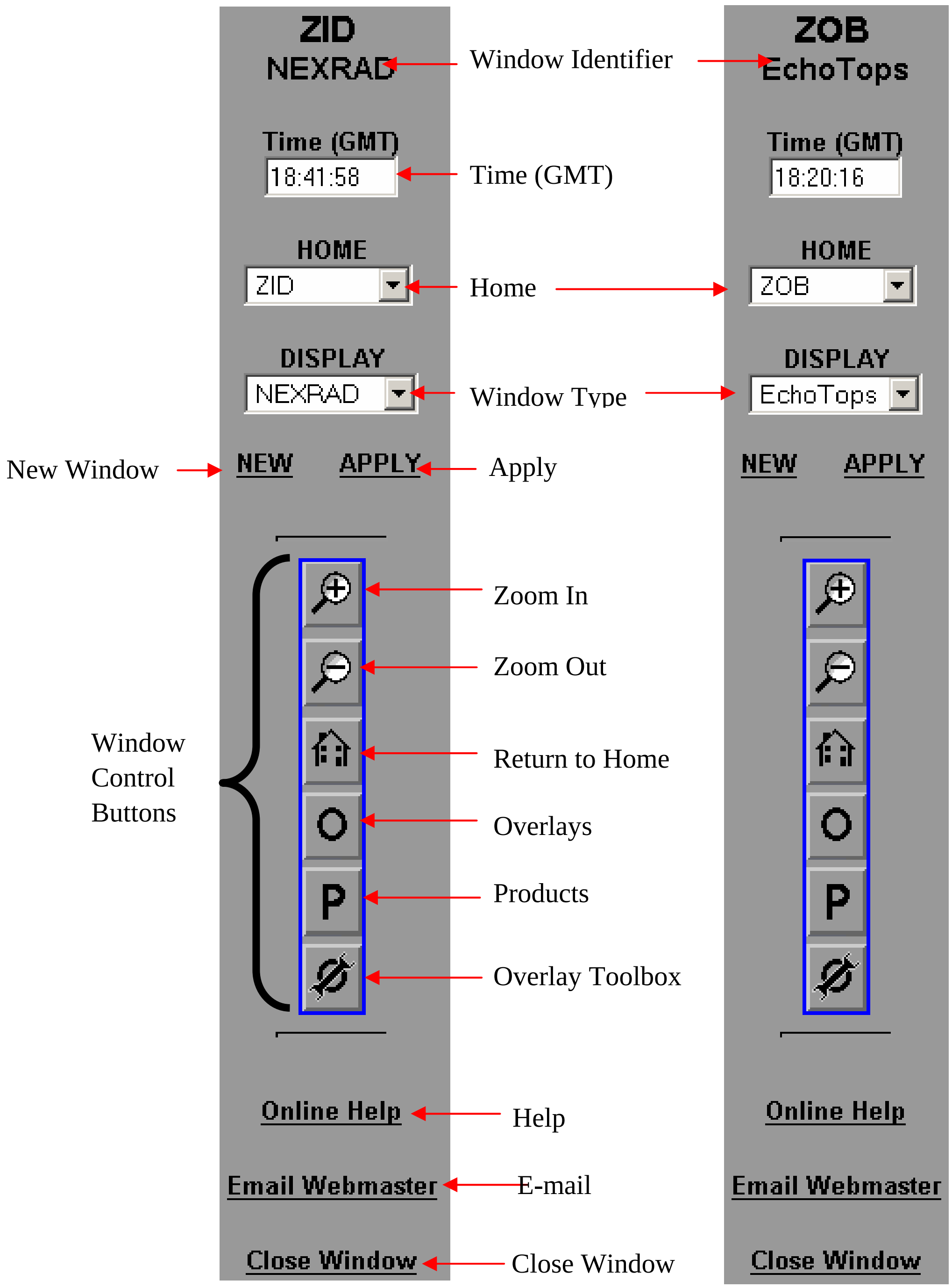

Figure B.6. Left hand side of web site weather window.

GLOSSARY

ACE	Airport Capacity Enhancement
AP	Anomalous Propagation
ARTCC	Air Route Traffic Control Center
ASR-9	Airport Surveillance Radar – Model 9
ATC	Air Traffic Control
CIWS	Corridor Integrated Weather System
CMR	Composite Maximum Reflectivity
CSI	Critical Success Index
dBZ	Units of radar reflectivity
FAA	Federal Aviation Administration
GOES	Geostationary Operational Environmental Satellite
GUI	Graphical User Interface
ITWS	Integrated Terminal Weather System
kft	Altitude in thousands of feet
km	kilometers
kn	knots
m/s	meters per second
min	Minutes
NAS	National Airspace System
NEXRAD	Next Generation Weather Radar
NLDN	National Lightning Detection Network
nmi	Nautical miles
OEP	Operational Evaluation Plan
OPSNET	Air Traffic Operations Network
RCWF	Regional Convective Weather Forecast
TRACON	Terminal Radar Approach Control
UTC	Universal Coordinated Time
VIL	Vertically Integrated Liquid Water
WARP	Weather and Radar Processor
ZAU	Chicago Air Route Traffic Control Center
ZBW	Boston Air Route Traffic Control Center

ZDC	Washington DC Air Route Traffic Control Center
ZID	Indianapolis Air Route Traffic Control Center
ZKC	Kansas City Air Route Traffic Control Center
ZME	Memphis Air Route Traffic Control Center
ZNY	New York Air Route Traffic Control Center
ZOB	Cleveland Air Route Traffic Control Center

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