EDGE™

(Enterprise Doppler Graphics Environment)

DATA ANALYSIS AND DISPLAY SYSTEM

1. Introduction

The EDGE™ (Enterprise Doppler Graphic Environment), radar management and data display software system, developed by Enterprise Electronics Corporation, manages the operation of a wide variety of meteorological radar system configurations and models. EDGE™ controls and monitors the transmitter/receiver and antenna, acquires and processes intensity, velocity, and spectral-width data, generates products, and provides display and archival functions.

2. Functions and Features

2.1 Standard Functions

The EDGE™ data system is designed to perform all operational tasks related to a meteorological radar system and provides the following functions and features in an easy to use graphical interface:

- Radar transmitter/receiver control
- Radar antenna control
- Radar signal-processor control
- Radar control and product scheduling functions
- Radar data ingest functions
- Radar product generation
- Raw data and product archiving and retrieval
- Flexible product display
- Data communications capability
- Diagnostic and maintenance functions

Ease of use, flexibility and practical functionality were primary criteria in the design of EDGE™. These requirements were achieved through the following design criteria:

- The system is designed for the DEC UNIX operating system on the new DEC ALPHA systems, with easy portability to a wide variety of computing platforms
- Modular programming to facilitate future expansion of capabilities
- Open-systems software tools are used to facilitate software maintenance and inter-operation with other computing systems

- The system provides the required functionality to compete in the international marketplace as the bench mark of price and performance for weather radar control and data analysis systems
- Distributed computing capabilities
- The system is easy to operate yet capable of sophisticated operations in terms of both system control meteorological data gathering and analysis
- Sophisticated network capability is an integral part of the system

3. Hardware Architecture

The elements required to form a complete weather data analysis system from a hardware point of view are a radar system, a Radar Signal Processor and a display and control workstation.

3.1 Radar System Elements

The following subsystems make up the complete radar system:

- Radar transmitter-receiver unit
- Antenna control unit, with serial control and serial angle ports
- BITE (Built in Test Equipment) subsystem, with TSG (Test Signal Generator)

3.2 Radar Signal Processor

The radar signal processor contains the following subsystems:

- A/D conversion unit, with 12-bit resolution
- DSP signal processing unit, with 825 MOPs of power
- Preprocessor unit, based upon a Motorola microprocessor
- Interface unit containing at least one of the following ports:
  - an Ethernet 10 MBS port
  - a parallel DMA interface unit
  - high speed serial I/O ports

3.3 EDGE™ Data Analysis and Display Platforms

The ALPHA series of 64 bit workstations and servers from Compaq is the standard operation platform for EDGE™. The operating system of choice is the Compaq Tru64 UNIX, the industry standard operating system for scientific workstations. The EDGE™ data system has the flexibility to operate on other open architecture platforms, as well, and has been ported to the popular LINUX operating system.

3.3.1 Main Computer

The main EDGE™ computer is required for primary systems operations and data processing for local use and distribution to the network when applicable. The recommended main computer is either the Compaq Alpha workstation or server series for UNIX or a high end Pentium workstation for LINUX. The minimum configuration for the main computer includes the following:

- 64 Bit, Alpha CPU(32 bit Pentium for LINUX Version)
- 500 MHz CPU speed
- 512 RAM
- 9.0 GB hard disk space
- Keyboard and Mouse
- High resolution 21” color monitor, (1600 x 1200)
- 3-D, 24 bit high resolution graphics accelerator
- 8 Gbyte, 4 MM DAT tape archive device
- 600 Mbyte CD-ROM RW drive
- 2 Serial Ports
- 1 enhanced Parallel Port
- 1 SCSI - 2 Port
- Ethernet port
- IDL License

3.3.2 Archival System

Data archival and retrieval is an important factor in overall system performance. The EDGE™ data system supports a wide variety of archival devices including floppy disks, hard disks, tape devices and optical devices. Each individual EDGE™ user node or workstation is provided with a CD-ROM drive, hard disk, and either a tape drive or a Read-Write CD drive for local short-term storage.

Long-term storage is also provided on common devices that can be accessed by any user on the network. The following storage devices are supported for long-term storage of archival data:

- Optical Library Jukebox System
- 4mm DAT Tape Auto Loader
- DLT Tape Systems
- Storage Works Solutions

3.3.3 Hard Copy Units Supported

The EDGE™ data system individual workstations/nodes are supplied with the latest version of the HP Inkjet color printer with a parallel interface for local printing tasks. EDGE also supports an HP Color Laser Printer that can be made available to all network nodes through a terminal server attached to the network.

3.3.4 Interactive Network Workstations

The EDGE™ data system supports remote EDGE™ workstations attached to the primary network. These remote units have local storage and I/O devices. Interactive remote stations can access and assume control of all system functions with the proper access codes or passwords.

3.3.5 Non-Interactive Remote Units

Non-interactive (passive) remote units can be included in the system configuration. A remote terminal can be located anywhere on the network and used to monitor and store system products.

The standard remote unit is the EEC PC-based EDGE™ data display system connected to the network through a terminal server and a serial line either directly or over a dial-up or leased telephone line. The EDGE™ PC can receive and display data products but has no system control functions.

3.4 Network Hardware

The EDGE™ data system, in most configurations, is distributed over an Ethernet Local Area Network(LAN) or a Wide Area Network(WAN) with distinct Local Area Network(LAN) segments joined together. The primary segment is usually located at the radar operations site with the major secondary LAN segment located at the radar transmitter building. Additional LAN segments can be located virtually anywhere through standard communications links.

Any network topography will require some amount of network control and monitoring hardware. In most EDGE™ configurations a complete network solution is available from EEC. Obtaining the entire data processing solution from a single vendor has many advantages in practical applications.

Some of the devices typically used in networks are listed below. Each topography is different so any given device may or may not be used, depending on local requirements and the mission.

- Managed and unmanaged MultiSwitch Hubs - Large Network traffic control and routing is usually implemented through a series of hubs located at the sites involved. The EDGE supports the intelligent, modular hubs that can replace dedicated devices in the network backbone. Intelligent hubs provide the flexibility to respond to moves, adds, and changes.
- FDDI Network and Fiber Optic Components - The bandwidth requirements, based on the huge amounts of data moving over the networks, often dictate that the entire WAN is centered around a fiber solution to take advantage of the 100mbps transfer rates and increased transfer distances. Single Mode Fiber can support nodes several kilometers apart.
- Routers and Bridges - Whether using fiber or copper wire, most networks require bridging and routing devices to control and regulate network traffic. Routers are used to route EDGE™ products and regulate network traffic, through modems and leased or dial-up lines, to remote LAN segments supporting EDGE™ Remote Displays, Interactive Workstations, and analysis terminals. This link is intended to serve as the primary connection between two sites and should be the fastest available at the time of installation. Digital phone circuits such as ISDN, T1/E1 links, fiber optic links and satellite links can all be used.
- Multiprotocol Communications Server for the Network - Most network environments require a communications server to distribute low speed data to client users. The terminal server can be used as the network server for all serial communications to the system output devices such as printers and, through modems, to the remote Interactive Display Units and EDGE™ Remote Displays.

4. Software Architecture

4.1 Software Development Environment

The EDGE™ Data system was developed by EEC exclusively for complete weather radar control and versatile data analysis. The end result is a system that is, at the same time, both easy to use and capable of generating a complete range of weather analysis products.

The EDGE™ Data system was written for and operates under the Compaq Tru64 UNIX (Formerly DEC UNIX) environment for the Alpha workstations and servers. EDGE has also been ported to the LINUX operating system.

5. EDGE™ Data System Operational Overview

The EDGE™ data system is a comprehensive radar control and data analysis system designed to be the primary operating system for a wide variety of EEC radar systems and user missions. The elements of the typical EEC radar system which form the background for EDGE™ operations are:

- The radar transmitter/receiver/antenna
- The radar control and signal processor unit
- The radar Built In Test Equipment unit (BITE)
- The EDGE™ processing computer or computers

The task of interfacing to the radar system elements and generating the radar and archival products is divided into three separate operational software processing modules, which may execute on the same or on different computers in various distributed computing configurations. These modules are:

- Radar Executive (REX)
- Product Generation Processor (PGP)
- Interactive Workstation Processor (IWP)

5.1 Radar Executive (REX)

The Radar Executive (REX) is the core of the EDGE™ software system, performing the majority of the data gathering, radar control functions and system interface functions. All other software modules of whatever type must connect through the REX to obtain data from or affect the operation of the radar system. The REX consists of three major subsets of tasks that can roughly be divided into Command Processing, Data Acquisition Processing and Scheduler Processing. These semi-modular functions are essential to the operation of the radar system and are configured for specific radar systems. Therefore, each EDGE™ data system requires at least one workstation dedicated to REX operations and functions which include system operations scheduling. Other functions, such as product generation and display functions may also reside on the REX workstation but can be distributed to external processors. Each radar system must have at least one Product Generation Processor Module and one Interactive Workstation Processor Module attached to the system by some means for complete and proper operation.

a. The Data Acquisition Processing

The task of interfacing to the Radar Control Unit, the Radar Signal Processor, and the radar BITE subsystem, in real time, is accomplished by the Data Acquisition Processor subset of the REX. The REX data acquisition processor uses a discrete set of commands which cause various actions, including data ingest and system configuration commands. The result of the data acquisition process is radar data and system status.

As Scheduler tasks are activated, the radar, antenna, and signal processor are set by the REX to the parameters required by the task. Data is acquired by the data acquisition process at the specified intervals and sent out to the IWP for storage.

b. Command Processing

The Central Command Processing section of REX sends commands to, and receives status and data from, the Data Acquisition Processor. In turn the REX-CP is responsible for executing commands which may come from the scheduler or interactive user workstations.

The REX-CP manages radar and antenna operation and volume-data ingest, maintains communications with the scheduler, and communicates with the Product Generation Processor. Through parameters entered by the user, the REX-CP initiates special products and features such as windshear detection and warning. Upon detection of the proper criteria, the REX-CP also initiates the broadcast of severe conditions warnings in both audible and visual formats.

5.2 The Product Generation Processor

The Product Generation Processor (PGP) receives commands from the REX-CP and executes these commands via product generators to produce and distribute the full range of products from either currently accumulated or archived volume data.

A complete set of standard products and any optional products installed are available to the user.

EDGE™ STANDARD PRODUCTS And FEATURES	
Product Abbreviation	**Product Name**
PPI	Planned Position Indicator
CAPPI	Constant Altitude Planned Position Indicator
RHI	Range Height Indicator
BASE	Low Altitude Reflectivity Product
HMAXZ	Height of Maximum Z Product
LRA	Layer Reflectivity Average Product
CMAX	Column Maximum Product with Horizontal Max Projection
VIL	Vertically Integrated Liquid Product
ETOPS	Echo Tops Product Standard and 3-D
ACM	Accumulated Rainfall Product
XSEC	Arbitrary Vertical Cross Section Product
VAD	Velocity Azimuth Display
SURV	Real-time Surveillance Displays – PPI, RHI, Sector Scan, Hybrid Scan & "A" Scope

EDGE™ OPTIONAL PRODUCTS AND FEATURES	
Forecasting And Analysis Options	
MVVP/ TVAD	Boundary Layer Winds product –
BRIGHT	Bright Band detection
VECTOR	Storm Motion
TRACK	Storm Tracking with Strike Warning
ALERT	Severe Weather Warnings with text outputs
HAILP	Hail Probability
CLUTTER	Clutter Map – (3-D Static Map)

Hydrological Products and Features	
GAGE	Rain Gauge
SUBC	Subcatchment
FLOOD	Flash Flood Alert (Requires SUBC Product)

Windshear Detection Products and Features	
SHEAR	Shear Processing License Includes:
	Horizontal Shear (Radial)

	Combined Shear(Radial & Azmuthals)
	Velocity Vertical Section
	Shear CAPPI
CMM	Combined Moments Map
GUST	Gust Front Detection, Microburst Detection, Mesocyclone, Algorithm (Requires Shear License)

Dual Polarization Products and Features	
ZDR	PPI/RHI/CAPPI Products
HMC	Hydrometeor Classification
HAIL	Hail Signal Product

The standard products and any optional products installed can be generated on either a scheduled or an interactive basis by the operator workstations. In both cases the product parameters are set by the users in task control structures formatted as radar signal processor configuration files.

5.3 The Interactive Workstation Processor

The Interactive Workstation Processor (IWP) interprets and executes commands entered by the user through keyboard or mouse action. Commands involving display functions or image-processing functions are executed directly by the IWP. Commands involving radar management or product generation are forwarded to the Central Command Processor for execution.

Products generated by the EDGE™ data system may be displayed in a single or a dual display window. The data scales, color tables, overlays/underlays, filtering, zoom factor, and pan position are all under the control of the user through a mouse-driven series of pull-down menus. Movie loops (image animation) may be created either interactively or automatically.

Image displays are presented in 32-level color maps. The display colors are fully editable with the system mouse. Colors may be interactively mixed or interpolated through a smoothing scale. Thirty two levels are also available for both the overlay and underlay planes. Overlay and underlay images are read as standard BMP format files allowing output from Geographical Information Systems or other drawing packages to be used. Product images may be smoothed using graphic filters to enhance features.

Up to 96 product displays may be animated in time. The user has full control over the number of images animated, the time period covered, the direction (forward-forward or forward-reverse), and speed.

Real time images may be viewed at any local IWP. Up to two real-time displays may be viewed at once. Most of the display enhancements and features are also available for the real-time images.

5.4 Archiving

Products and raw-data sets marked for archiving are buffered on the local disks of the REX platform and then archived to local tape. A public index of archived volumes and products is maintained and represented on the main menu as small visual copies of the actual image. These are called piclets in all EDGE™ documentation and are often called thumbnails in general software documents. Archived volumes and products can be restored to the data system on demand. Products and data can also be routed to a shared network archive device.

Products may also be archived locally on Interactive Workstation Processors.

5.5 System Initialization

Upon initialization the EDGE™ data system loads default information from a disk file. The default parameters are defined by the user in the tools menu. The following default items are under the control of the operator:

- Radar site parameters (site name, x-y location, height)
- Radar default technical parameters (transmitter power, wave guide losses, operating frequency, radome losses, calibration coupler loss, receiver noise level, allowable pulse widths, PRF limits by pulse width)
- Time zone
- Color tables for intensity, velocity, and spectral width
- Display parameters (data scales, range scales, overlays)
- Standard task control structures
- Desired product set consisting of any or all installed products
- Last defined warning thresholds
- Last defined warning areas
- Last defined archiving parameters

Any optional products, features or parameters will be loaded at initialization if resident in the system.

6. The Radar Executive (REX) Data Acquisition Process

6.1 Radar Control

The following radar functions are controlled by the REX Data Acquisition Process:

- Transmitter on-off
- Radiate on-off
- Servo on-off
- Pulse-width selection
- PRF selection
- Warnings if a problem occurs with the control function
- Test signal generator control for maintenance and system alignment/calibration

6.2 Antenna Control

The following antenna-control functions are controlled through the REX Data Acquisition Process:

- Azimuth scan rate
- Azimuth position
- Azimuth scan direction (clockwise, counter-clockwise)
- Elevation scan rate

- Elevation position
- Elevation sequence

The control algorithms for antenna rotation-rate selection will provide an optimal rotation speed for the currently defined task based on the system mode of operation and the processing required for valid data. The automatic rotation speed can be over-ridden by a user-specified speed.

6.3 Signal Processor Control

The current requirements for signal processor operation are stored in the REX processor control structure by the scheduler when the current operation is scheduled. When a change in the processor control structure is required, a new set of parameters must be downloaded to the signal processor by the REX. In the absence of any change in the processor control structures the processor responds to repeated process-and-dump commands from the host.

The following signal-processor control functions are controlled through the Data Acquisition Processor:

- PRF (single and dual-PRF modes)
- Gate size in meters (62.5/125/250/500/1000/2000). The 62.5 meter gate size is only implemented on systems with a pulse width under 0.5 µsec.
- Number of azimuth samples (4-255)
- Angle synchronization enable-disable, and angle increment
- Thresholds (all Signal Processor thresholds supported)
- Number of range bins
- Velocity unfolding 1:1, 3:2, and 4:3
- Clutter filter on-off and filter selection

6.4 BITE Control

The radar BITE (Built-In Test Equipment) unit is controlled and monitored by the REX. Status and faults are reported through the status system. Faults may be masked by the user.

The fault monitoring equipment, including the BITE, is primarily a continuously operating subsystem which monitors vital system parameters and alerts the operator when any monitored parameter has faulted. The fault alert can be in the form of a visual indicator as well as a digitized audio output. All fault alarms and indications are added to a log file for reference and may also be directed to a hard copy device. Although the emphasis for the fault monitoring equipment is hardware fault monitoring it should be noted that software faults may also be directed to a log file for further analysis. The fault monitoring equipment consists of several subsystems each having dedicated functions.

The BITE system has the capability to produce automated measurements and monitoring of system parameters, as well as easy expansion.

6.5 Data Acquisition And Buffering

The primary function of the REX Data Acquisition Process is to acquire intensity, velocity, and spectral-width data from the radar signal processor. In normal operation the signal processor produces an output data set of the type requested in the processor control structure every N pulses. The REX responds to interrupts from the

Signal Processor as each data set is completed by reading back the data set and then initiating another process command.

The acquired data is stored in an adjustable buffer (the ray buffer). As requests for data come from the Central Command Processor, data is supplied from the ray buffer. Buffering has the effect of relieving the real-time pressure on the REX, allowing real-time processing to be implemented in UNIX.

While the REX Data Acquisition Process is designed to process up to four data moments (intensity, uncorrected intensity, velocity, and spectral width), the data structures allow the future, easy addition of up to four additional moments, such as differential reflectivity, to the data stream.

As an optional add-on capability, the REX Data Acquisition Process supports the generation and use of spatially oriented clutter maps, unique to EDGE™, to help ensure a clean, clutter free display in all dimensions. Clutter maps are collected on a clear day and used to remove fixed echoes from subsequent intensity products. Several maps may be combined to minimize contamination by weather. Fixed echoes removed are optionally replaced by interpolation from nearby echoes.

The REX also causes the automatic collection of a noise sample through the Signal Processor. Whenever a predetermined length of time has passed since the last noise sample, a new noise sample will be taken at the beginning of the next scan sequence. A noise sample can also be commanded directly by the user.

6.6 The REX Command Processing Function

The REX also contains a central command processor section, for discussion purposes called the REX-CP, which provides the primary control functions for the system, manages data volumes, and ensures proper archiving. The REX-CP is tightly interfaced to the scheduler, which must reside on the same computer as the REX-CP, and the Product Generation Processor. All REX-CP commands may be logged to a command file along with a time/date stamp.

6.6.1 Interface To Networks

The REX-CP acts as a centralized communications hub between the users (operating Interactive Workstation Processors), the data acquisition process, and the product generation (occurring at the Product Generation Processor).

6.7 Scheduler

The data system scheduler is the causative agent for all data-acquisition actions in the data system, as well as for many product generation and archiving operations.

The scheduler has a command channel to the REX-CP, through which it forwards commands stored in the current schedule. The schedule is a data structure containing commands and execution times (either absolute or relative times), along with repetition intervals and repetition counts. When the criteria required for a command to become executable are fulfilled, the command is sent to the Central Command Processor for execution.

The functions of the scheduler are:

- **Radar operations -** The scheduler implements the radar parameters requested by the operator, as defined in the control structure currently activated by the scheduler. All radar control parameters and operational features can be implemented through the control structures.
- **Antenna operations -** The scheduler implements the antenna scan parameters requested by the operator, as defined in the control structure currently activated by the scheduler. All antenna control operations can be implemented through the control structures.

- **Signal processor operations -** The scheduler implements the signal processor parameters requested by the operator, as defined in the control structure currently activated by the scheduler.
- **Product generation -** The scheduler queues all requested products upon completion of the volume scan or sweep required by the products requested. The responsibility for completing the products is passed to the Product Generation Processor.
- **Archiving -** The scheduler queues all requested archiving activities upon completion of the current sweep. The responsibility for completing the archiving activities on data volumes and products is passed back to the REX-CP for execution.

6.7.1 Scheduler Operations

The scheduler acts upon a list of one or more task control structures, entered by the operator. Each task control structure contains the following information defining the operations required by the task:

- The radar control parameters
- The antenna control parameters
- The signal-processor control parameters
- Any product generation definitions required, with priorities
- Any archiving operations required, with priorities
- The priority of the scan task relative to other tasks
- The time for execution of the task (once, immediate, repetitive)

A set of default tasks are included to aid either as examples or used in the predefined form.

The scheduler regularly scans the current list of task control structures, to qualify the structures as either ready or not ready for execution. A task control structure is defined as ready for execution if the time for that task has arrived, and there is sufficient time to complete the task before the next scheduled execution time for that task.

Of those tasks ready for execution the task with the highest priority is executed. Note that this implies that tasks with lower priority will be interrupted by higher-priority tasks, prior to their completion. However, tasks will not be interrupted except after the completion of a sweep, unless the sweep requires more than 30 seconds to complete.

6.7.2 User Manipulation Of Tasks

The interactive user (executing on an Interactive Workstation Processor) creates task control structures by editing in the data system menus. Tasks can be edited, deleted, saved, retrieved, and modified. A typical system will have a variety of task control structures saved under meaningful names ("15_minute_scan"), which suffice for normal operations. Special tasks will be created as the need arises.

The user schedules a task by selecting the filename of the task, assigning a priority, and defining the time-of-execution of the task. The time of execution may be defined in the following flexible ways:

- Immediate (run now, if the priority allows)
- As soon as possible (run whenever the priority allows, without regard to the time of execution)
- Run once at time "t" (run at a specific time, if the priority allows)
- Run at time t + n*dt (run at a specific time, and thereafter at intervals of dt, if the priority allows)

- The operator can also abort tasks (kill them for the current or next execution, but leave them in the scheduler queue) or remove them from the scheduler queue entirely

6.7.3 Status System

The REX data acquisition process and Product Generation Processor report their status to the Central Command Processor. The REX-CP maintains these status items as well as internal status parameters as a global group of status parameters accessible to all processes. These global status parameters include:

- The current status of the radar and antenna systems
- The current status of the radar signal processor
- Currently scheduled operations (antenna control sequence, radar parameters, signal processor parameters, algorithm parameters, products to be generated)
- Current list of standard scheduled products generated by the data system, and their status (latest issue, oldest issue)
- Current list of requested products and status (pending, generating, generated, aborted)
- Current index of archived data and products available on line
- Status displays of these parameters may be called up on the operator workstation

Status information is acquired by the following processes. Note that in each case the module determines whether the status information indicates a significant system fault if a significant system fault is detected an error message is transmitted.

- Radar management modules
- Antenna control modules
- Signal-processor control modules
- Pre-processor control modules
- DMA communications module
- Ethernet communications module
- Disk archiving module
- Tape archiving module
- Printer control module
- Archive management modules
- Product generation modules
- Display management modules
- System control modules (logins, network control)

6.7.4 Volume Management

In response to scan commands, the REX-CP will ingest data and create data structures called volumes. The latest and current volumes (as well as other previous or archive volumes, depending upon the amount of memory available) are stored in active memory, from where they are available for product generation and they may be written to disk.

Volumes have a well-defined standard structure. Most products are generated from volumes.

6.7.5 Volume Archiving

The Central Command Processor supports archiving and retrieval of raw data volumes as well as products, in both compressed and uncompressed format. Archiving can be scheduled along with the other data acquisition and product generation parameters, or archiving can be initiated after the fact for a given data volume or product.

- **Disk archiving -** Archiving of volumes and products to archive media takes place through an intermediate disk archive. It is possible to move disk-archived data to/from tape, and the disk archive can serve as an intermediary archive to allow tapes to be changed without losing data. When the disk archive nears full capacity a garbage collector can be enabled to remove the oldest archive data so that new data can be archived. The user can also delete archive volumes and products from the system disk, if he has the proper password privileges. All archived data is stamped with the time of the data acquisition, product generation, and archival. Restored data may be placed in a separate temporary directory structure to separate it from the operational data.
- **Tape archiving -** Tape archive and retrieval is supported under the control of the user interface. Indices of archived data will be maintained on the system disk, to facilitate searches for data volumes without reading archive tapes.
- **Archive retrieval -** The user interface will support archive data retrieval from tape to disk for further processing, product generation, and display. At any time the user interface will provide a list of current volume and product data on line, and the indices of archived data maintained on the system disk will facilitate searching for data volumes stored on tape. All or part of a tape volume may be read back into the data system, at which point the contents of the newly retrieved data will appear in the user interface indices.

6.7.6 Real-Time Display Broadcast

The REX-CP is responsible for broadcasting real-time data to user workstations. As ray data is ingested the data is copied, converted to standardized display levels, compressed, and transmitted by Ethernet broadcast. Any interested workstation on the network may receive and display this data.

Another feature is the realtime surveillance mode which allows the operator interaction from the controlling workstation. In this mode the operator has complete control of radar and the Radar Signal Processor.

6.7.7 Interface to Product Generation Processor

The Product Generation Processor receives commands from the Central Command Processor. These commands cause products to be generated from volume data, with product parameters as defined by the command string. The Central Command Processor also furnishes the Product Generation Processor with volume data and volume indices.

7. The Product Generation Processor

The Product Generation Processor (PGP) is responsible for the creation and distribution of products. The PGP receives and executes commands from the REX-CP. These commands may originate either directly from a user or from the scheduler.

Products may be created from the current volume (the volume currently building in memory), the latest complete volume (currently in memory or virtual memory), or an archive volume from disk. The location of the volume for which product generation is requested is inferred by the Product Generation Processor from the Volume Index maintained by the REX-CP. Each product generation command will contain a set of parameter definitions for the product to be generated.

Products may be stored to a local directory, an archive, a global directory, or to any combination of the storage options.

The user may request product generation in two ways: through the scheduler or through immediate requests.

Products generated by the scheduler are specified in the scheduler structure, along with the scan pattern required and other radar parameters. Products specified in this manner are generated as soon as the raw data required for the product is available, according to a priority sequence established by the operator.

Products generated through an immediate request may be generated from current data or archive data. The user specifies the product parameters and data volume.

EDGE™ presents a healthy mix of radar meteorological products which provide complete analysis tools to the user. EDGE™ products are created from volume scans consisting of multiple 360° azimuth scans. The elevations used in the volumes and the azimuthal resolution may vary as the operator wishes. EDGE™ volume scans are stored in the original resolution and the complete resolution is used in the product generation. Most EDGE™ products are created from a unit, called a cell, which is one degree in azimuth in width, one range bin of the original scan resolution in length; the length has been mapped along the surface. For this reason, products are resolved to this resolution prior to Cartesian conversion; but, this process is done using logic which allows the original resolution to fully contribute to the results. In many cases, the volume data located above these cells are processed; in column maximum, the greatest value above the cell is selected; in layer average, the average of the values in a layer above the cell is processed; in VIL, the liquid water above the cell is processed; and so on.

Any combination of EDGE™ products may be generated from a single volume scan either at data acquisition time, or later from archived volumes. The generation of products from archived volumes allows for products which may become of some significance to the user, yet were not envisioned at acquisition time, to be generated when required. The EDGE™ product generator has the capability, within the limits of processor availability and sensibility, to generate many products from a single volume scan. Since EDGE™ is a distributed system, products may be generated locally without impacting the resources of the data acquisition computer.

Products and Displays Available:

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Hydrological Products and Features	
GAGE	Rain Gauge
SUBC	Subcatchment
FLOOD	Flash Flood Alert (Requires SUBC Product)

Windshear Detection Products and Features	
SHEAR	Shear Processing License Includes:
	Horizontal Shear (Radial)
	Combined Shear(Radial & Azmuthals)
	Velocity Vertical Section
	Shear CAPPI
CMM	Combined Moments Map
GUST	Gust Front Detection, Microburst Detection, Mesocyclone, Algorithm (Requires Shear License)

Dual Polarization Products and Features	
ZDR	PPI/RHI/CAPPI Products
HMC	Hydrometeor Classification
HAIL	Hail Signal Product

7.1 Moments

The word ‘moment’ has grown in radar data system terminology to mean more than a significant instance and come to indicate any measured or derived data quantity. Current signal processors available for EDGE™ provide the essential radar moments of corrected intensity, uncorrected intensity, radial velocity, and spectral width. Differential reflectivity is available as an option. From these and other date sources within the system, EDGE™ produces a number of derived quantities including liquid water, accumulation, rain rate, height, and shear.

7.1.1 The Uncorrected Intensity Moment

This moment is indicated by the symbol ‘U’ and is the integrated logarithmic channel intensities with range normalization (20 log (range)) added and offset by the radar constant and presented as dBZ. Any EDGE™ intensity product may be constructed from this moment at the operator’s discretion. Although this moment will contain all the clutter present in the original acquisition, it is useful in observing some phenomena which may be lessened or destroyed by the clutter correction process.

When used in intensity products which produce rainrate, the total rainrate moment is derived using the Marshall-Palmer Z-R relation. This moment is designated as ‘T’ in EDGE™. In other derived moments, such as liquid water and accumulation, no special designation is used, and are therefore indistinguishable from moments derived from the corrected intensity.

7.1.2 The Corrected Intensity Moment

The symbol ‘Z’ is commonly used to specify this moment. One may also find references to this moment by the symbol ‘CZ’. It is the uncorrected intensity moment which has been processed by the signal processor and EDGE™. The result is presented in dBZ. In the ESP-7, the statistical clutter filter may be selected instead of Doppler filtering and atmospheric attenuation correction applied as well.

In EDGE™, this moment may be further corrected using a clutter map, occultation correction, rainfall attenuation, and bright-band correction. In an EDGE™-ESP-7 system, all of these corrections may be applied upon each other; although, the resulting data quality may be suspect. These corrections are always applied to the corrected intensity moment and replace this moment in the volume. The uncorrected intensity moment is always left untouched. When used in intensity products which produce rainrate, the corrected rain rate moment is derived using the Marshall-Palmer Z-R relation. This moment is designated as ‘R’.

7.1.3 The Radial Velocity Moment

The radial velocity is calculated in the signal processor using the pulse-pair algorithm and is presented in fractions of the Nyquist interval, which is resolved to meters per second towards or away from the radar. This moment is referred to as ‘V’.

EDGE™ acquires radial velocity measurements for all scans. Early in EDGE™ development, it was decided that this moment, as well as spectral width, is always of some significance and that the additional complications of excluding it were not worth the confusion. Therefore, the distinction between so-called ‘Doppler’ and ‘intensity’ scans does not apply to EDGE™ processing. If not used in the product mix selected at volume generation time, this moment is archived on disk for later study. If never used, it has no effect on the processing. Radial velocity measurements may be corrected for clutter in the signal processor, but the original uncorrected velocity is not available. Radial velocities may be further corrected in EDGE™ using de-aliasing techniques.

7.1.4 The Spectral Width Moment

Spectral width, referred to as ‘W’, is a measure of the standard deviation of the time-series frequency values derived from the linear receiver. This moment is presented as fractions of the Nyquist interval and is resolved to meters per second.

This moment is often presented directly as a measurement of turbulence. This practice is somewhat imprecise since no clear consensus of how to measure turbulence has been presented by the radar community. Until this research is complete, EDGE™ will present all products derived from this moment as width in meters per second. There are no moments derived from this quantity.

7.1.5 The Differential Reflectivity Moment

Differential reflectivity is a measurement of the difference in two intensity values gathered in separate polarization orientations of the transmitted energy. The implementation of this moment will require a dual polarization antenna system. The moment is designated by EDGE™ as ‘D’ and is used in hydrometeor classification with the resulting moment designated as precipitation type or ‘H’.

7.2 Data Corrections

The corrected intensity moment may be further processed by EDGE™ to enhance data quality and the radial velocity measurement may be de-aliased for storm motion. These corrections, in general, are done post-process and are at the user's discretion. All of these corrections are implemented in a way to minimize computer resource usage.

7.2.1 Bright Band Correction

Using research from the British Met Office, reflectivity measurements are corrected for the bias introduced from super-reflective water-coated ice in the melting layer. This correction is applied in real-time as the data is collected. This correction is separate from the bright-band detection algorithm which is run post-process. The notion that "if bright-band is detected, it can be corrected" turns out to be a wild generalization. The fact that the data has been bright-band corrected is noted in the volume scan information header and presented in the annotation of all products derived from this data.

7.2.2 Beam Blockage Correction

Corrected intensity values may be further corrected for attenuation due to partial beam blockage caused by an obstruction or the horizon. A high resolution table of the range and elevation of obstructions by azimuth is acquired at the site and entered into EDGE™. When a volume is corrected, each ray of data is examined. If the beam was partially blocked by the obstruction, an attenuation factor is applied to subsequent out-range measurements. This attenuation factor is a function of the amount of blockage and is user-controlled with a default supplied.

7.2.3 Rainfall Attenuation

Intensity values may be enhanced by correction of attenuation due to energy loss in rainfall. A user-controlled factor (K) in units of dB attenuation-per-kilometer is entered by supplying the factor (A) and coefficient (B) of the equation $K=AZ^B$, where Z is reflectivity (mm^6/m^3). Typically, A equals 0.000069 and B equals 0.67 for a radar operating in the 5.5 GHz frequency range. The attenuation factor is accumulated and applied throughout the range. Better results are achieved if the data is clutter-map corrected prior to attenuation processing since cluttered values can cause great inaccuracies out-range.

7.2.4 EDGE Velocity De-aliasing Algorithm

EDGE includes a velocity dealiasing algorithm that is used when Dealiased Velocity is selected for PPI products and in the GUST product as part of the microburst, gust front and mesocyclone algorithms.

A single complete tilt is passed to the dealiaser. The workspace is initialized and the dealiasing occurs in two passes through the dealiasing algorithm. Each pass is performed as follows:

The tilt is processed one ray at a time until all available rays have been processed.

Steps:

1. Load proceeding adjacent ray, previously dealiased. This is set to raw velocities for first ray on first pass.
2. Load ray to be dealiased. This is raw velocities on first pass and "dealiased" velocities on subsequent passes.
    a. Remove Noise i.e. High Spectral Width, Speckles, and Small Holes
    b. Initialize ray working space

3. Ray is processed one gate at a time.
   a. Each gate is compared with previous gate to check for folding. First valid velocity in ray is assumed to be unfolded.
   b. If it cannot be determined whether the gate is folded or unfolded, the velocity may be declared invalid and removed.
4. The ray is then checked for errors using both radial and azimuthal gate-to-gate checks. If inconsistencies are detected all or part of the ray may be declared invalid and removed.
5. The final ray after processing is smoothed.
6. The "dealiased" ray is stored.
7. The workspace is set up for the next pass.

7.2.5 Range Correction

All mapped EDGE™ products are corrected for range as a function of elevation. That is, the data elements are presented at the range locations in the finished product which the element is above on the surface. Stated another way, range in EDGE™ products is range along the earth's surface, not radar slant range. Whenever more than one range bin maps into a single surface location, logic is used to select which bin will be represented. The interpretation logic is dependent on the product generated. For example, in a column maximum product, the greatest value would be mapped.

7.2.6 Smoothing

All mapped EDGE™ products may be smoothed in either range or azimuth or both. At present, simple *boxcar* smoothing of user-defined width is implemented. Other, more sophisticated methods are planned.

7.3 Derived Moments

EDGE™ processes the data acquired from the signal processor using standard techniques to produce several additional data quantities. In all cases, constants used in these calculations are user-defined and supplied with common defaults. Generally, these derived moments are presented in products for a more detailed analysis of the weather.

One will often want to use these products not as a single isolated information source, but as one source of information in combination with several other products. For example, suppose one wants to survey a region of active thunderstorms and pick out which are currently most dangerous and which are most likely to develop into dangerous storms. Starting with the CMAX product all the storms containing reflectivities at any altitude exceeding some threshold value, say 50 dBZ, could be quickly located. An inspection of the ETOP product would then show which of these had especially high tops indicating they contained strong active updrafts. HMAXZ could be used to separate young developing storms (high max z) from old decaying storms (low max z). Finally the currently most severe could be pin-pointed with the VIL product. A storm with high VIL value, max z above base level and a high echo top could be marked as being possibly very dangerous.

7.3.1 Total Rain Rate

All EDGE™ intensity products are available in the native units of dBZ. Uncorrected reflectivity data are useful in observing phenomena which may be compromised by the various data corrections and are also interesting for comparison to the corrected data. When converted to rain rate, uncorrected intensity values represent total measured reflectivity which, under certain conditions, may be a better indication of the weather than corrected values. EDGE™ allows any reflectivity product to be presented as rain rate in either mm/hr or in/hr. This conversion is done using the Marshall-Palmer relation $Z=AR^B$, where Z is linear reflectivity in mm^6/m^3 and R is rain rate in mm/hr. The default for quantity 'A' is 200.0 and quantity 'B', 1.6. In EDGE™ the total rain rate moment is referred to as 'T'.

7.3.2 Rain Rate

Corrected intensity is also available as rain rate, designated as 'R'. The same relation is used in the conversion as is used for total rain rate. Corrected rain rate represents the best estimate of rainfall with any corrections applied. Noteworthy is the fact that if all corrections are turned off in both EDGE™ and in the signal processor, Z would equal U and therefore, R would equal T.

7.3.3 Liquid Water

Either corrected or uncorrected reflectivity may be used to calculate liquid water content. This value is integrated to form the vertically integrated liquid product which is an important indication of severe weather and storm potential. The conversion is done using the formula $W=AZ^B$; A and B are user supplied constants (defaults of $3.34X10^{-5}$ and 0.0067), Z is reflectivity and W is liquid water in kilograms. When integrated in height, the resulting units for the VIL product is kg/m^2. This moment is designated as L.

7.3.4 Height

The antenna height, range, bin spacing, and elevation of the radar measurement are used to calculate the height above mean sea level. Standard refraction of the radar beam is considered as well as earth curvature in the equation:

$$\mathbf{H = (r^2 + R'^2 + 2\, r\, R' \sin(\phi))^{1/2} + R' + H_0}$$

Where ϕ is the elevation angle, H_0 is the antenna height, r is the range, R' is 4/3 earth's radius and the result, H, is the height of the bin. A very accurate indication of the starting and ending elevation at which each ray was gathered is stored in the ray. Depending upon the product being generated, the center of these elevations or the highest elevation is used in the height calculation. The calculation is done in meters and the resolution is preserved until the display phase.

This moment is designated as 'H' and is available in the Echo Tops product in resolution of 100 meters. Height may be presented as kilometers, miles, or thousands of feet (kft).

7.3.5 Radial Shear

The difference in velocity measurements in the radial (range) direction is radial shear. This moment is referred to as 'S' in EDGE™. The resulting differences are smoothed and are available as either a PPI or CAPPI product.

7.3.6 Azimuthal Shear

The difference in velocity measurements in the azimuth direction is called azimuthal shear. These quantities are referred to as 'A' in EDGE™. The resulting differences are smoothed and presented as either a PPI or CAPPI product.

7.3.7 Combined Shear

The mean difference between radial and azimuthal shear is referred to as combined shear and is referred to as 'C' in EDGE™. The smoothed result is available as either a PPI or CAPPI image.

7.3.8 Hydrometeor Classification

The differential reflectivity moment is used to derive the type of hydrometeor in the airspace and is referred to as 'H'. This classification is presented as either a PPI or CAPPI product.

7.3.9 Accumulation

Rain rate is integrated in time to form rain depth or accumulation and the moment is designated as 'P'. The accumulation moment is presented in millimeters or inches and is integrated in periods of one, three or 24 hours. A user-specified time period may also be used.. The conversion from intensity to rain rate may be done using corrected or uncorrected data. A special Z-R relation is used to prevent impact on the normal rain rate products. Rain gauge results from several locations throughout the coverage area may be entered and a correction factor applied to the accumulations.

8. EDGE Standard Products

8.1 PPI Product

The PPI product is a 'plan' view of a single elevation sweep of 360° of azimuth. The standard PPI product may be produced using the following moments:

Moment	Description	Units
Z	Corrected Intensity	dBZ
U	Uncorrected Intensity	dBZ
R	Rainrate	mm/hr, in/hr
T	Total rainrate	mm/hr, in/hr
V	Radial Velocity	m/s, kn, km/hr, mi/hr
W	Spectral Width	m/s, kn, km/hr, mi/hr
S	Radial shear	m/s/km, kn/km, mi/hr/mi
A	Azimuthal shear	m/s/km, kn/km, mi/hr/mi
C	Combined shear	m/s/km, kn/km, mi/hr/mi

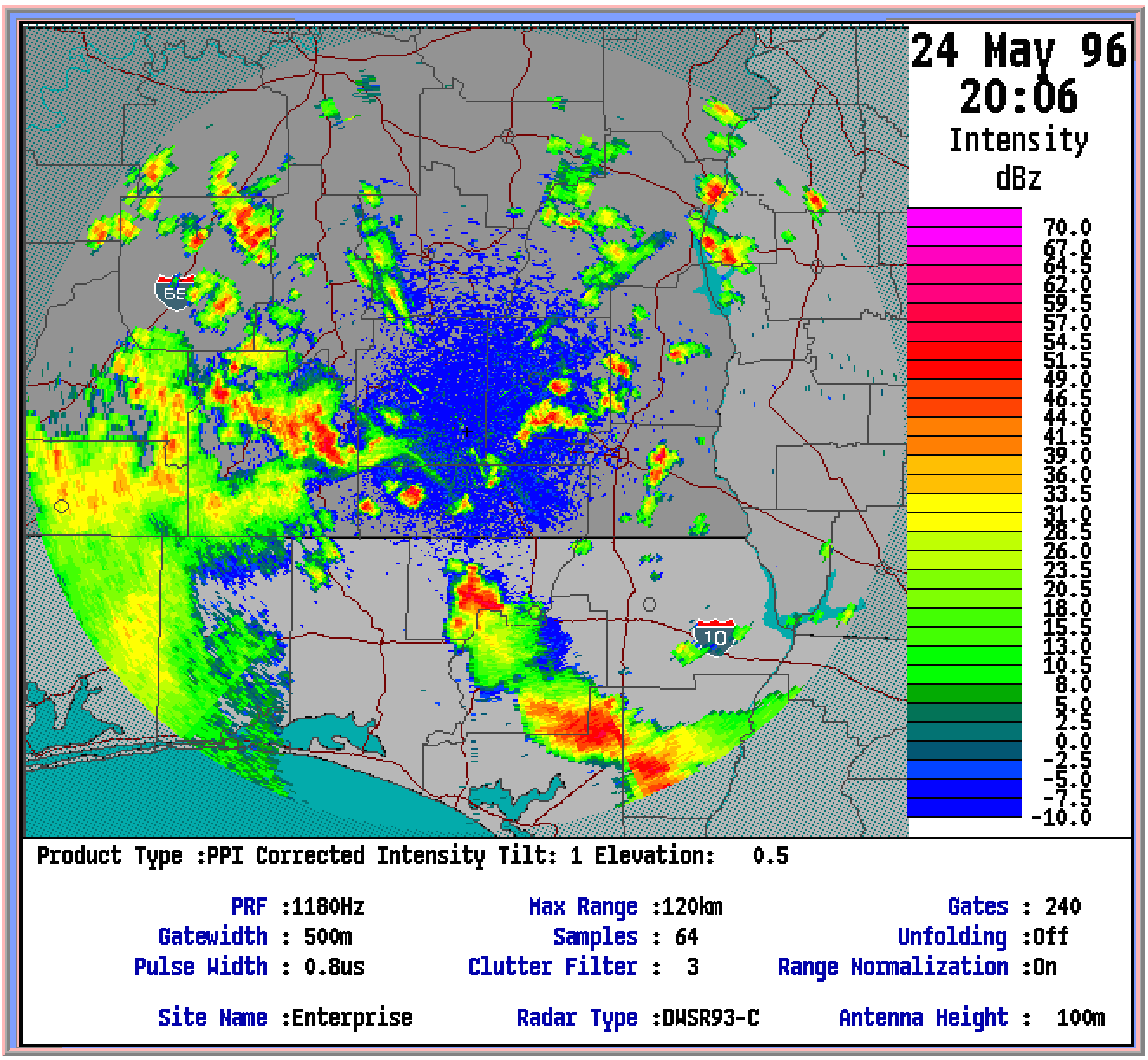
Table 8.1, PPI Product Moments

PPI Product Configuration

Several options are available when generating a PPI product. The elevation of the PPI is selected from those in the volume scan. The maximum range of the product may be selected up to the range of the volume scan. The moment to use in the product may be selected from the list in the table above. Optional boxcar smoothing may be applied to the product.

Option	Selection
Elevation	From elevations in the volume scan
Maximum Range	in meters up to the maximum range of the volume
Moment	Z, U, R, T, V, W, S, A, C
Smoothing	Smoothing width: 2-10 pixels

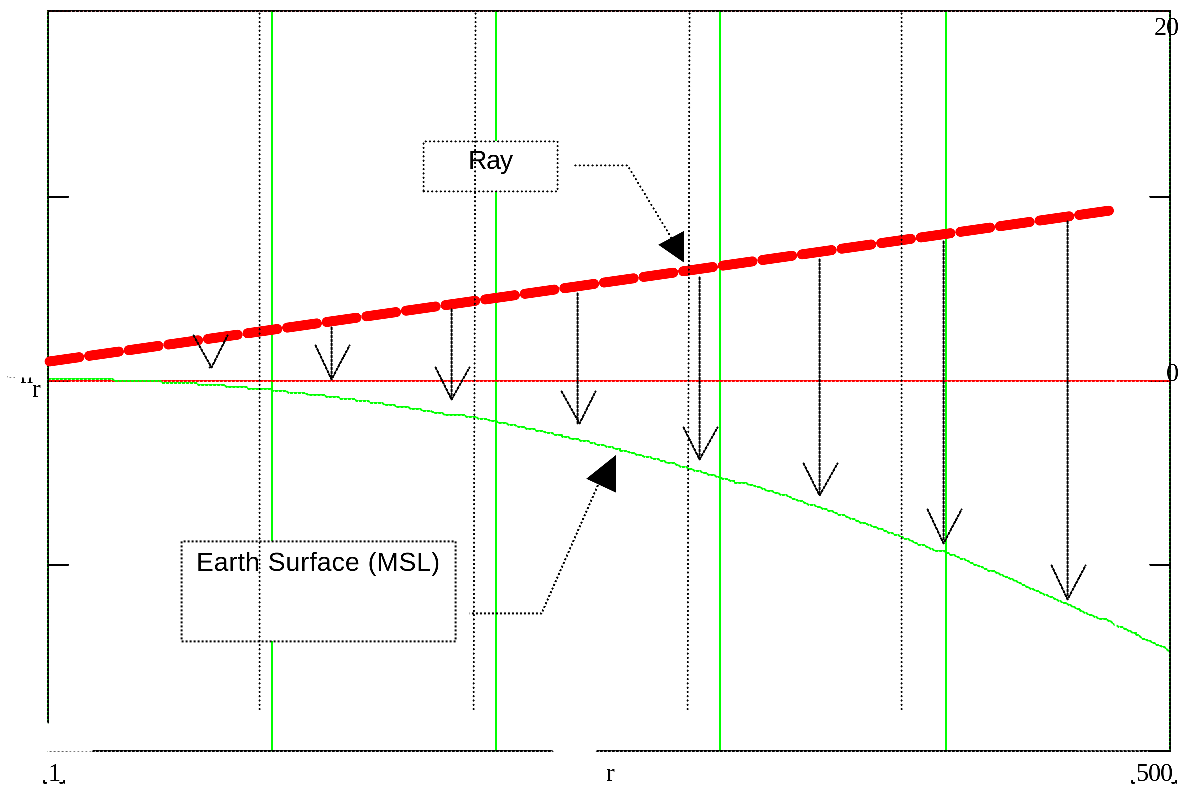
Table 8.2, PPI Product Options



PPI Product Example

PPI Product Technical Description

The PPI Product is generated as a polar product preserving the original gate size and number of gates. The product is generated in one-degree azimuthal resolution. The elevation of the product is specified by the user as well as the moment. The elevation is acquired from the stored volume scan. Each ray at that elevation is copied into the PPI product. If the rays are separated by more than one degree, then the ray is duplicated to fill the intervening space. If more than one ray falls within one degree, the maximum value is selected. Optional smoothing may be applied in both range and azimuth. The PPI product is corrected for slant-range, standard refraction, and earth curvature while being converted to a standard Cartesian projection.



PPI Product Generation

The PPI Product (PPI)

This is one of the original radar products since it is the 'natural' product of a radar in a horizontal scan mode. The PPI has been around the longest and is the product with which people are most familiar. In that respect it is widely used to obtain a quick overview of the present weather situation and to identify regions of particular interest for more in-depth study.

8.2 CAPPI Product

The CAPPI ("constant-altitude PPI") product is a horizontal cross section at a user-specified altitude produced from the raw data volume through interpolation. Data from all elevations and all azimuths of the volume scan are used to estimate the precipitation intensity, velocity, or spectral width in a horizontal plane. The CAPPI product is available at any height from 100 meters up to 30 kilometers.

The CAPPI product algorithm consists of interpolating the raw data from the volume structure on a ray-by-ray basis. There are three possible types of interpolation, depending upon whether the point of interpolation lies within the scan volume, above the highest sweep of the scan volume, or below the lowest sweep of the scan volume:

Where the point of interpolation lies within the data volume (that is, not above the highest elevation scan nor below the lowest elevation scan) each output point in the polar output data set is interpolated between the pair of elevation rays encompassing the observation point.

In the case where the interpolation point is above the highest ray of the data set, the value of the data measured at the highest ray, immediately below the point of observation, is used, provided that the difference in height between the point of observation and the measurement used is less than 500 meters.

In the case where the interpolation point is below the lowest ray of the data set, the value of the data measured at the lowest ray, immediately above the point of observation, is used, provided that the difference in height between the point of observation and the measurement used is less than 500 meters.

The calculation of the height of the observations for the CAPPI product takes into account the curvature of the earth and atmospheric refraction, according to the following equation:

$$\mathbf{H = (r^2 + R'^2 + 2\, r\, R' \sin(\phi))^{1/2} + R' + H_0}$$

where h is the height of the observation, r is the range to the gate in question, ϕ is the elevation angle, R is the effective earth radius, and H is the altitude of the radar. The effective earth radius (such as 4/3 earth radius) may be specified by the customer.

In the case where there are no values above the height (in the cone of silence), the user may have the echoes from the lower elevations filled in, effectively creating a so-called 'ZPPI' or elect to leave this part of the product blank. This blank area will appear as grayed-out in the product.

Various structures are added to the product structure to record the system parameters prevailing during the data acquisition (radar and signal processor parameters, time, radar site name, etc.).
The resulting product may contain the following moments:

Moment	Description	Units
Z	Corrected Intensity	dBZ
U	Uncorrected Intensity	dBZ
R	Rainrate	mm/hr, in/hr
T	Total rainrate	mm/hr, in/hr
W	Spectral Width	m/s, kn, km/hr, mi/hr
S	radial shear	m/s/km, kn/km, mi/hr/mi
A	Azimuthal shear	m/s/km, kn/km, mi/hr/mi
C	combined shear	m/s/km, kn/km, mi/hr/mi

8.3 RHI Product

The RHI ("Range-Height Indicator") product is a polar-format display of a single elevation sweep at one azimuth from an RHI data volume. The data is presented with full resolution, in polar format. No interpolation, thresholding, or other data manipulation is performed, so that the raw data may be observed in its most fundamental state. The product is available for intensity, velocity, or spectral width.

The RHI product algorithm consists of copying the data from the (RHI) volume structure directly into the product structure. Various annotations are added to the product structure to record the system parameters prevailing during the data acquisition (radar and signal processor parameters, time, radar site name, etc.).

8.4 Low Altitude Reflectivity Product (BASE)

Traditionally many radar systems have relied upon the Pseudo-CAPPI product as a measure of low level precipitation for use in precipitation subcatchment accumulation as well as composite systems. The Pseudo-CAPPI derives data from several (usually four) antenna sweeps or PPIs. Data from the sweep at the lowest elevation is used for the outer ranges of the product. As range decreases, data from higher elevation scans are used. This selection typically follows some user-designated criteria. The consequence of this procedure is to minimize the effect of clutter contamination and attenuation due to low level beam blockage near the radar in the lower elevations.

The EDGE™ Base product achieves the goal using a much more sophisticated and reliable algorithm. Several PPI scans are still used to create the product; but, they are converted to rectangular coordinates and placed into a three dimensional cube with the same resolution as the original gate spacing. The Base Section algorithm then examines each vertical column of reflectivity values separately. The lowest level, clutter free intensity data in each column is used to create the product. In this manner, high quality, close range data in the lower elevations that may be unaffected by clutter and not attenuated by beam blockage will be used as the precipitation estimate. In the same light, out range data in the higher elevation, that may, for whatever reason, not be represented in the lower elevations would have been lost in the Pseudo-CAPPI, will be present in the Base product.

The base product is a good indication of rainfall which is impacting the surface. The maximum height for which to search for returns is user-defined with a default of 30 km. The range is corrected and resolution resolved to one degree with the maximum return selected for the product. The following moments are available in a base product:

Moment	Description	Units
Z	Corrected Intensity	dBZ
U	Uncorrected Intensity	dBZ
R	Rainrate	mm/hr, in/hr
T	Total rainrate	mm/hr, in/hr

BASE Product Moments

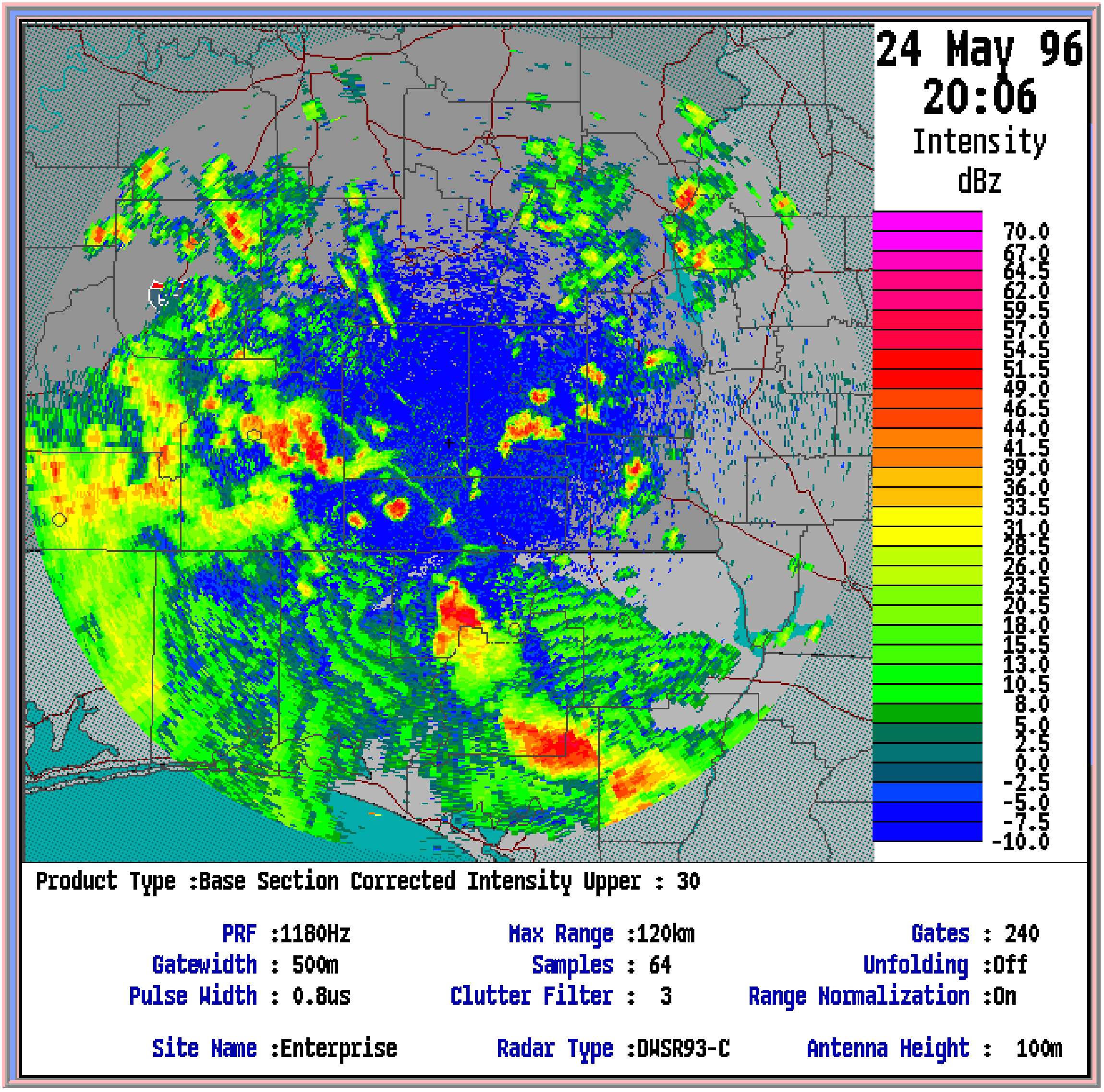
The BASE Product Options

The BASE product allows several options. The range of the product may be specified up to the maximum range of the volume scan. The moment used in the product may be selected from the above table. Optional smoothing may be applied.

The BASE product allows the user to specify the upper altitude for the product to search in the volume for echoes.

Option	Selection
Elevation	From elevations in the volume scan
Maximum Range	in meters up to the maximum range of the volume
Moment	Z, U, R, T, V, W, S, A, C
Smoothing	Smoothing width: 2-10 pixels
Upper limit	Highest search altitude to search

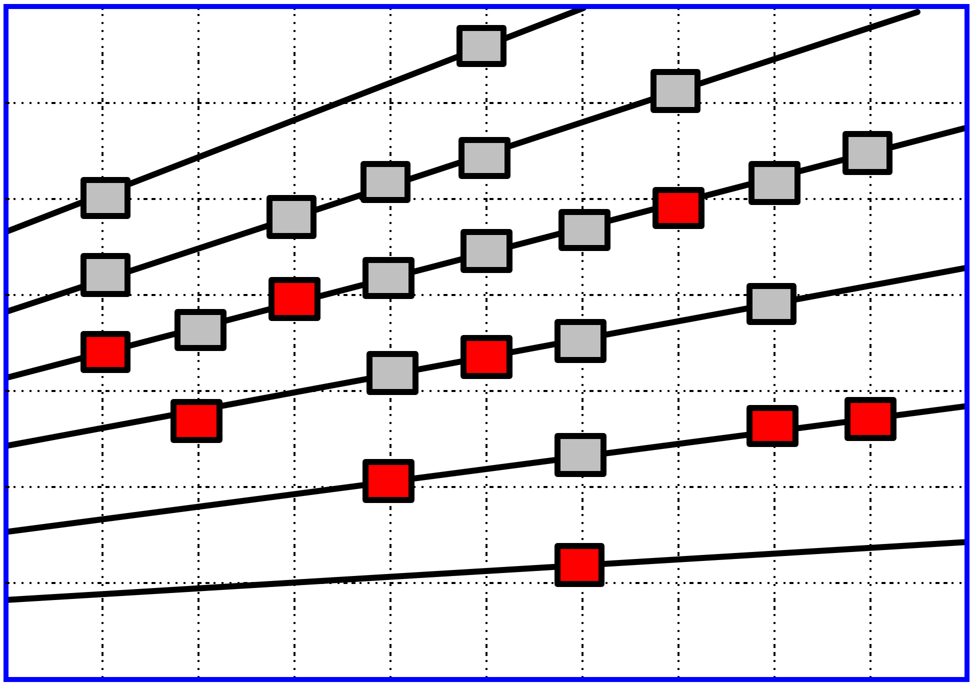
BASE Product Options



BASE Section Example

The Base Section Product Technical Description

The Base Section product is generated as a polar product with the original gate size and number. The product is generated at one degree azimuthal resolution. The user specifies the moment to use in the product. The height of each cell in the volume is calculated. The moment of the cell closest to the earth's surface is selected for the product. The base section product is corrected for slant-range, standard refraction, and earth curvature while being converted to a standard Cartesian projection.



BASE Section Echo Selection

This figure illustrates a cross section enlargement of a volume scan. The small rectangles represent echoes along each ray. The BASE algorithm selects the lowest in height echo in each vertical column for the base section product. The darker colored echoes would be selected in this case.

The Base Product (BASE)
This shows the intensity of precipitation at cloud base and thus gives some indication of the development of a storm regardless if the precipitation is reaching the surface yet.

8.5 The Height of Maximum Z Product (HMAXZ)

The HMAXZ product is a presentation of the altitude above Mean Sea Level(MSL) of the maximum reflectivity in each cell. The results are available in the H moment as either kilometers, kilofeet, or miles. The product may be constructed from either corrected or uncorrected intensities.

Moment	Description	Units
H	Height	km, kft, mi

Table 8.3, HMAXZ Product Moment

8.5.1 The HMAXZ Product Options

The HMAXZ product allows several options. The range of the product may be specified up to the maximum range of the volume scan. The moment, either Z or U, used to construct the product may be selected. Optional smoothing may be applied.

Option	Selection
Maximum Range	in meters up to the maximum range of the volume
Moment to use in construction	Z, U
Smoothing	Smoothing width: 2-10 pixels

Table 8.4, HMAXZ Product Options

8.5.2 The HMAXZ Product Technical Description

The HMAXZ product is generated as a polar product with the original gate size and number. The product is generated at one degree azimuthal resolution. The value and height of the maximum echo at each cell in the volume is determined. The radar antenna height is added and the resolution is fixed at 100 meters. The product is then projected into a standard Cartesian projection.

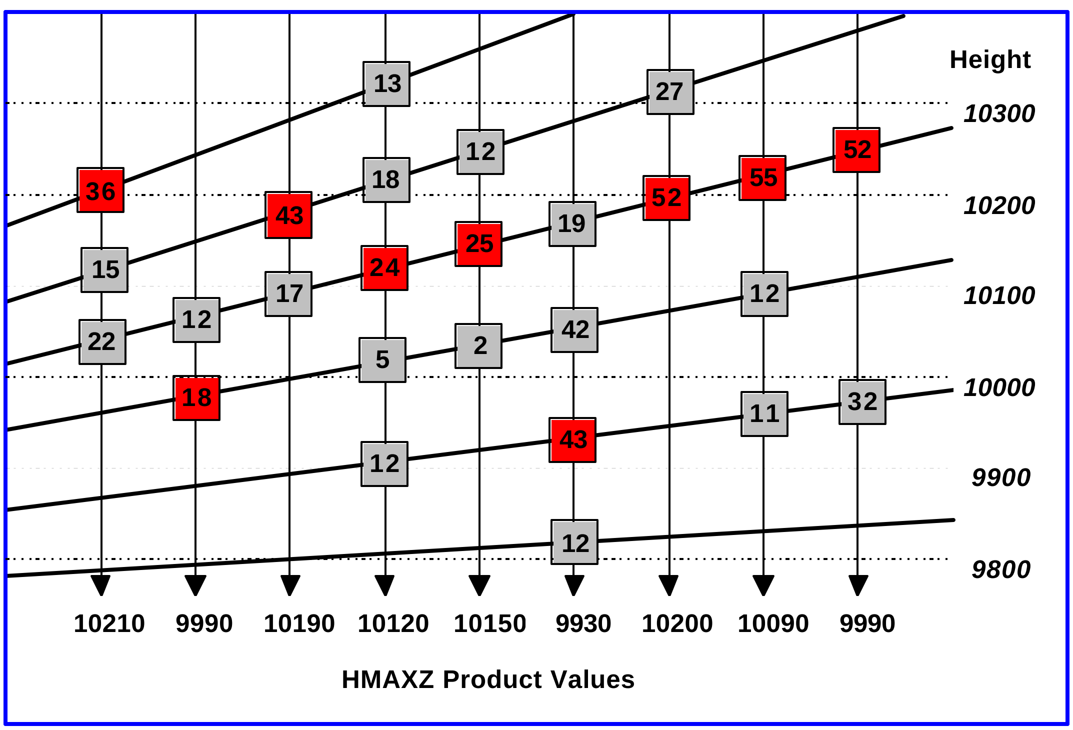


Figure 8.1, HMAXZ product description

The HMAXZ algorithm selects the echo greatest in intensity in each column as illustrated by the darker echoes in the figure. The selection may be made from either the corrected or uncorrected intensity values. The height of the selected echo is placed in the product.

The Height of Maximum Z Product (HMAXZ)

The HMAXZ product can be used to evaluate the development stages of a thunderstorm by showing whether the maximum intensity is at relatively high, medium or low levels. It can also be used to locate the freezing level in stratiform precipitation where the maximum reflectivity coincides with the melting layer 'bright band'.

8.6 The Layer Reflectivity Average Product (LRA)

The LRA product is the average reflectivity between two user-defined horizontal planes parallel to the earth’s surface. The reflectivity may be averaged from the corrected or uncorrected values. The averaging is done in linear power. The product may be presented in any of these moments:

Moment	Description	Units
Z	Corrected Intensity	dBZ
U	Uncorrected Intensity	dBZ
R	Rainrate	mm/hr, in/hr
T	Total rainrate	mm/hr, in/hr

8.6.1 The LRA Product Technical Description

The LRA product is generated as a polar product with the original gate size and number. The product is generated at one degree azimuthal resolution. The upper and lower limit of the layer to be examined is supplied by the user. The volume is examined and the height of each cell is calculated. If the cell lies within the defined layer, the linear power of the echo is added to the result and a normalization constant for that cell is incremented. After the entire volume has been processed, the result is normalized using the resulting values producing average reflectivity for that layer. The product is then projected into a standard Cartesian projection.

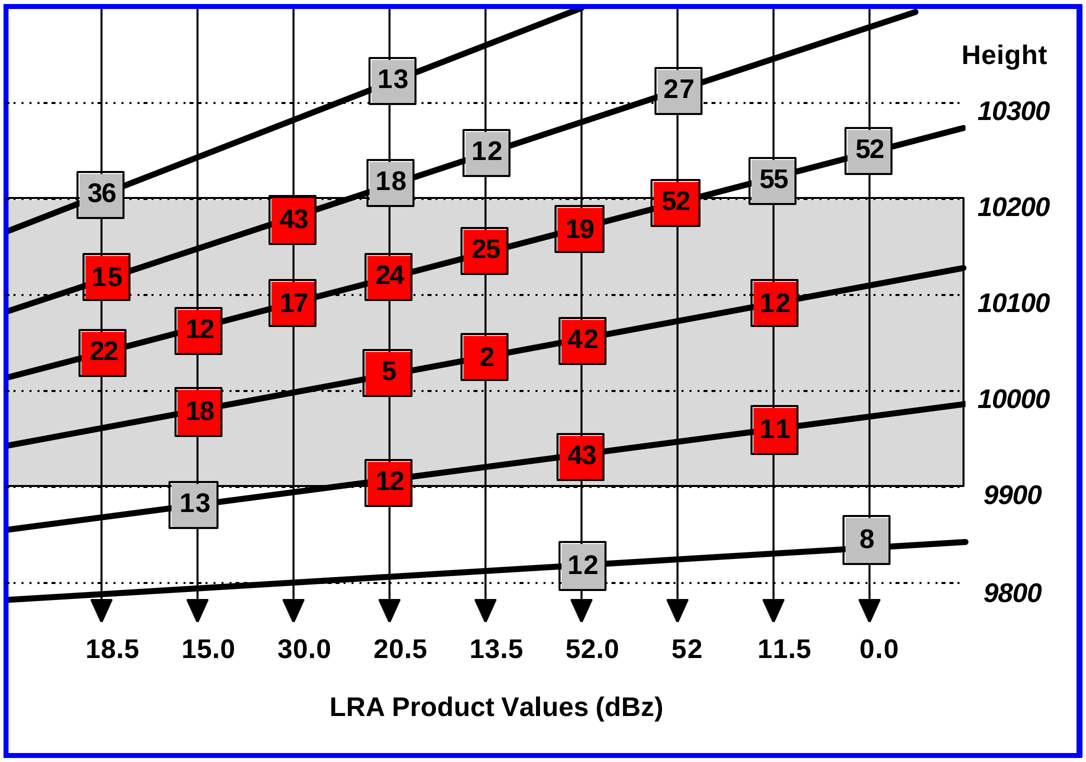


Figure 8.2, LRA Description (upper=10200, lower=9900)

In the illustration, the darker echoes are selected for the product because they fall within the specified layer. The average of these values is used in the product. The averaging is done in linear power.

The Layer Reflectivity Average Product (LRA)

In a sense this is simply an improved version of the CAPPI which can be used for meaningful horizontal comparison of precipitation regions. It is sometimes more useful than the CAPPI since information is given about a layer whose thickness is specified by the user, rather than only about a very thin layer at a single altitude.

8.7 Column-Maximum Product (CMAX)

The CMAX product is an indication of the maximum reflectivity in each cell. A minimum and maximum height may be user-defined and defaults to zero and 30 kilometers. This allows for generation of layer maximum products by setting these values to the limits of the desired layer. The CMAX product is available in the following moments:

Moment	Description	Units
Z	Corrected Intensity	dBZ
U	Uncorrected Intensity	dBZ
R	Rainrate	mm/hr, in/hr
T	Total rainrate	mm/hr, in/hr

CMAX Moments

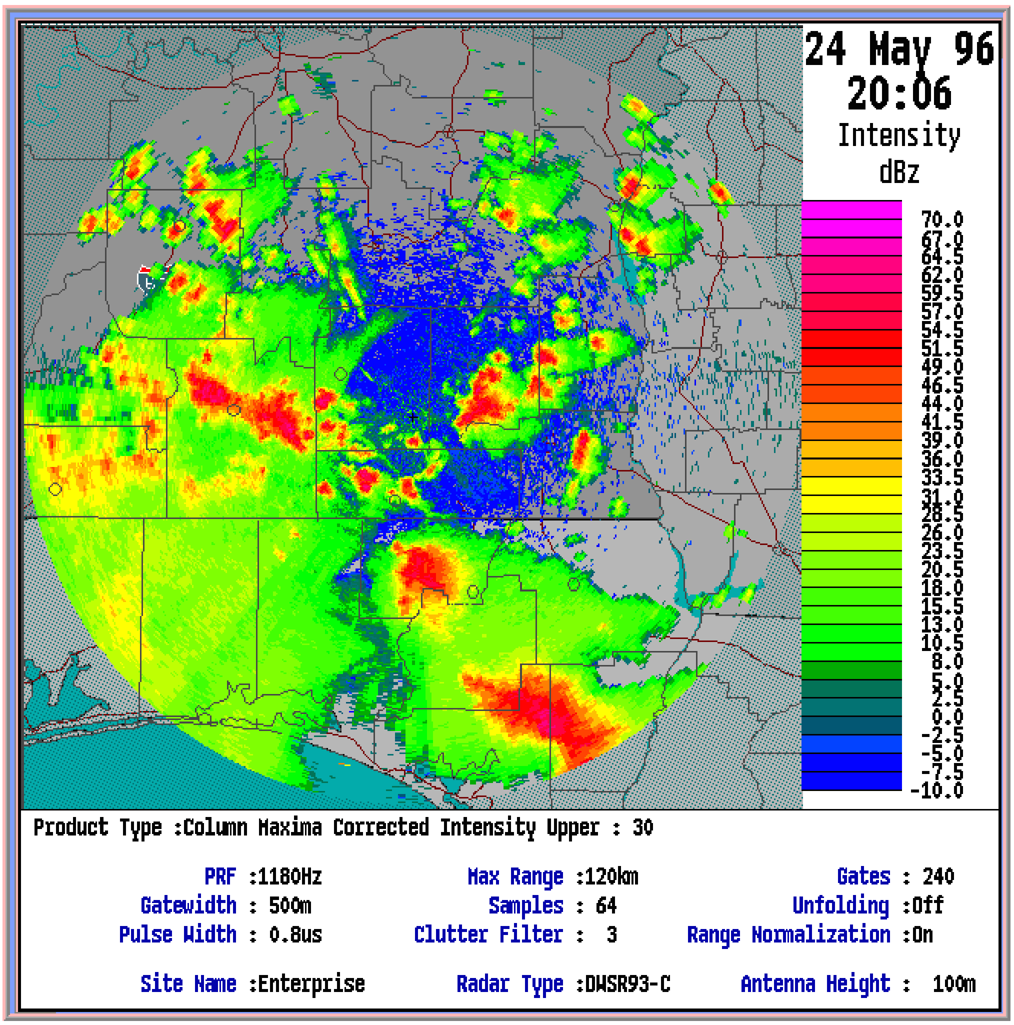
The CMAX Product Options

The CMAX product allows several options. The range of the product may be specified up to the maximum range of the volume scan. The moment used in the product may be selected from the above table. Optional smoothing may be applied.

The CMAX product allows the user to specify the upper and lower altitude for the product to search in the volume for echoes.

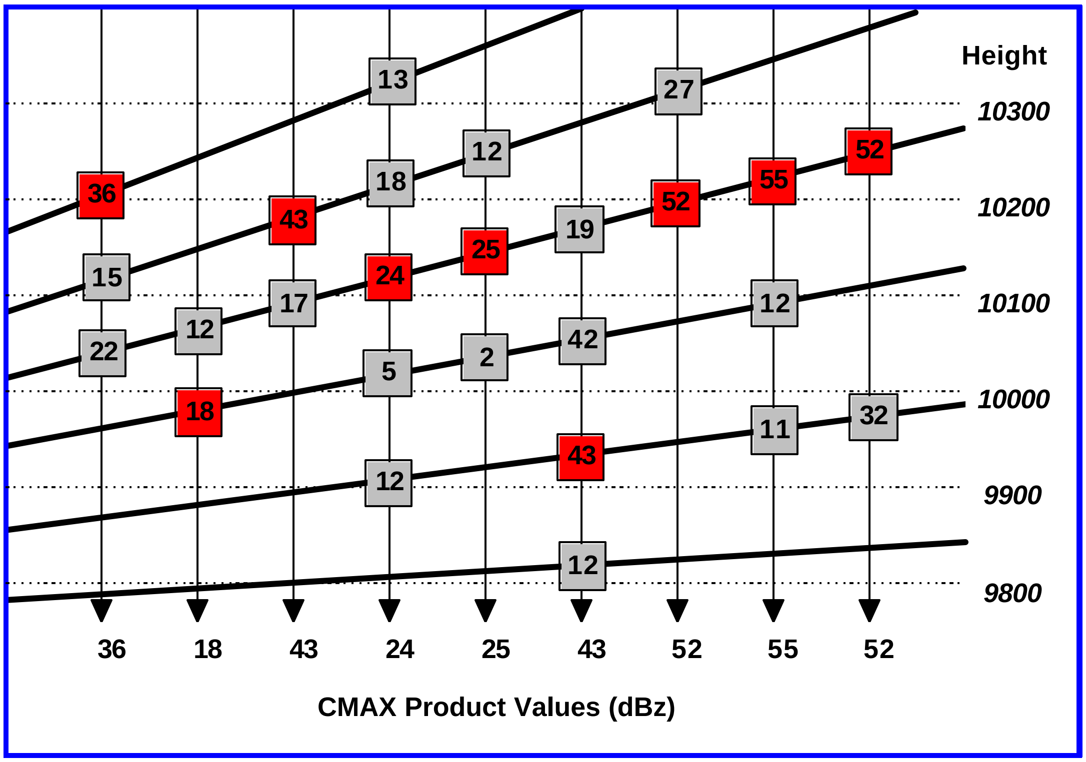
Option	Selection
Maximum Range	In meters up to the maximum range of the volume
Moment	Z, U, R, T, V, W, S, A, C
Smoothing	Smoothing width: 2-10 pixels
Upper limit	Highest search altitude
Lower limit	Lowest search altitude

CMAX Product Options



CMAX Product Example

The CMAX Product Technical Description
The CMAX product is generated as a polar product with the original gate size and number. The product is generated at one degree azimuthal resolution. The upper and lower limit of the layer to be examined is supplied by the user.



CMAX Product Description

The maximum value at each column is selected for the product value.

The Column Maximum Product (CMAX)
This is useful for a quick surveillance of regions of convective precipitation to locate both mature and newly developing thunderstorms, since storms that have only a small region of high intensity precipitation will show up the same as storms that have high intensity precipitation through a great depth. Side panels may also be displayed showing vertical distribution of maximum reflectivity for each horizontal row and column.

8.8 Vertically-Integrated Liquid Product (VIL)

The VIL product integrates the liquid water (W) moment in vertical space at each cell producing total liquid content per square meter. An upper and lower altitude above MSL may be user-defined allowing the VIL to be calculated for a particular layer of the atmosphere.

The VIL product may be constructed from either the corrected or uncorrected intensities. The results are presented as kilograms per square meter.

Moment	Description	Units
VIL	Vertically Integrated Liquid	kg/m^2

VIL Product Moment

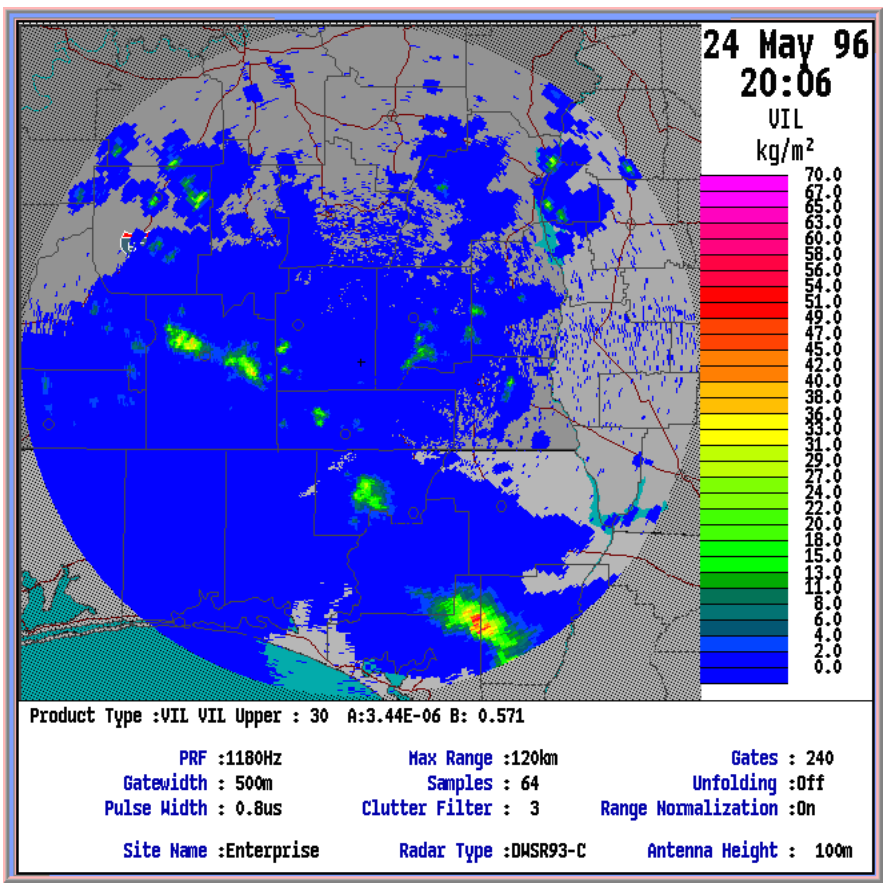
The VIL Product Options

The VIL product allows several options. The range of the product may be specified up to the maximum range of the volume scan. The moment used in the product may be selected from the above table. Optional smoothing may be applied. Either corrected to uncorrected intensity values may be used to construct the product.

The VIL product allows the user to specify the upper altitude for the product to search in the volume for echoes.

Option	Selection
Maximum Range	in meters up to the maximum range of the volume
Smoothing	Smoothing width: 2-10 pixels
Upper limit	Highest search altitude to search
Moment used	Z, U

Table 8.5, BASE Product Options



VIL Product Example

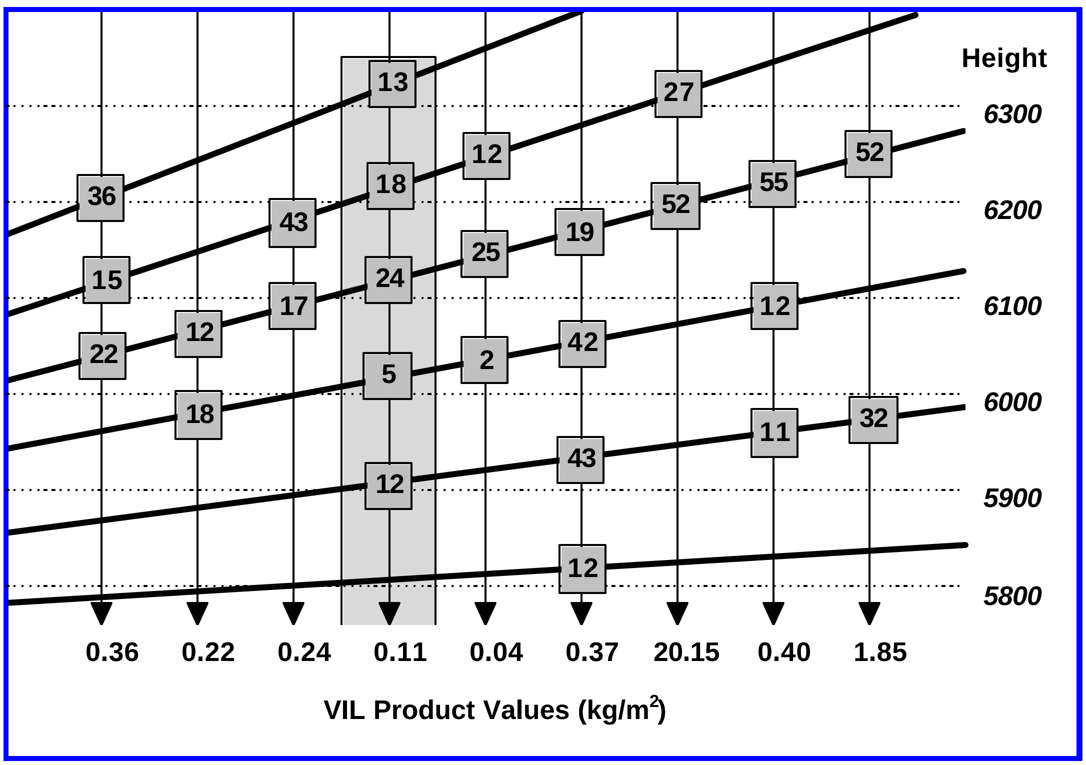
VIL Product Description

The VIL product uses the formula:

$$M = 3.44\text{X}10^{-6} \int_{\text{bottom}}^{\text{top}} Z^{4/7}\, dh$$

Where M is vertically integrated liquid in kg/m^3, Z is reflectivity in mm^6/m^3, and h is height. This was presented by D.R. Green and R.A. Clark, 1972 in "***Vertically integrated liquid water… Monthly Weather Review, Vol 100, No. 7***".

This makes the assumption of liquid water throughout the volume and a standard drop size distribution. The constants in the equation are furnished with the shown defaults; but they are user-definable.



VIL Product Description

Intensity Values and Height

$dbz_i :=$ $A_i :=$

12	5910
5	6020
24	6120
18	6220
13	6320

$$Z_i := 10^{\frac{dbz_i}{10}}$$

$$w_i := 3.44 \cdot 10^{-6} \cdot (Z_i)^{\frac{4}{7}}$$

Calculate water content

Do the integration

$$V_1 := w_1 \cdot A_1$$

$$V_2 := w_1 \cdot (A_2 - A_1) + \frac{(A_2 - A_1)\cdot(w_2 - w_1)}{2}$$

$$V_3 := w_2 \cdot (A_3 - A_2) + \frac{(A_3 - A_2)\cdot(w_3 - w_2)}{2}$$

$$V_4 := w_3 \cdot (A_4 - A_3) + \frac{(A_4 - A_3)\cdot(w_4 - w_3)}{2}$$

$$V_5 := w_4 \cdot (A_4 - A_3) + \frac{(A_4 - A_3)\cdot(w_4 - w_3)}{2}$$

$$VIL := V_1 + V_2 + V_3 + V_4 + V_5$$

$$VIL = 0.112$$

VIL Product Example Calculation

This figure shows an example of a VIL calculation for the shaded column in the above figure.

The Vertically Integrated Liquid Product (VIL)

A recent study indicated that this was the second most widely used NEXRAD product, and was considered to be better for detecting hailstorms than the hail detection algorithm. In general it can be considered as a means of locating the most active and severe storms in a region since these would be the storms that would be expected to have the greatest reflectivity through the greatest depth.

8.9 Echo-Tops Product (TOPS) Standard and 3-D

The TOPS product is the height of the highest (in altitude) return in the cell. Either corrected or uncorrected reflectivity may be used to generate the product.

Moment	Description	Units
H	Height	m, ft

Table 8.6, TOPS Moment

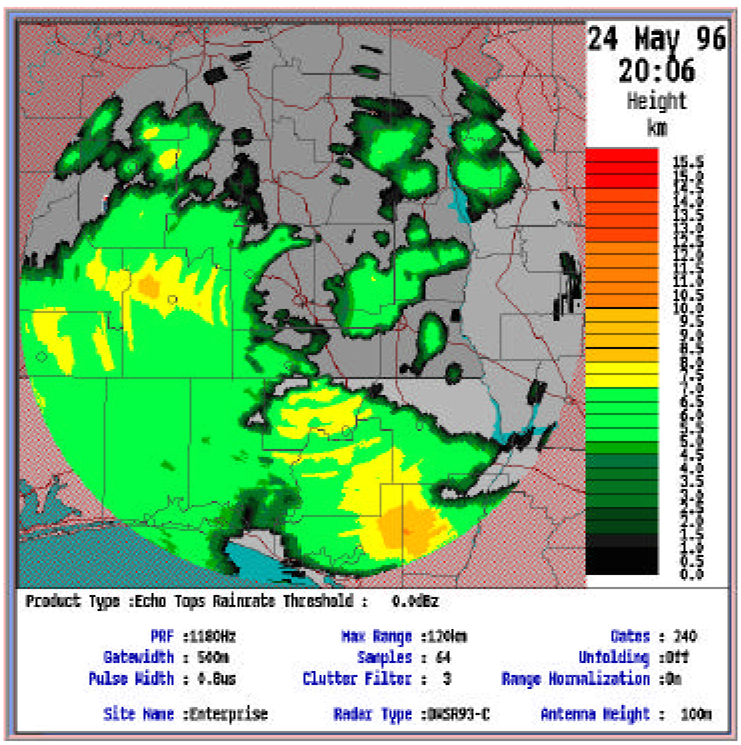
The TOPS Product Options

The TOPS product allows several options. The range of the product may be specified up to the maximum range of the volume scan. The moment used in the product may be selected from the above table. Optional smoothing may be applied.

An intensity value may be entered in dBZ by the user; as the default any echo is considered. This value is used as the minimum intensity value considered for the product

Option	Selection
Maximum Range	in meters up to the maximum range of the volume
Moment	Z, U, R, T, V, W, S, A, C
Smoothing	Smoothing width: 2-10 pixels
Minimum dBz	Lowest intensity to consider
Moment to use	Z, U

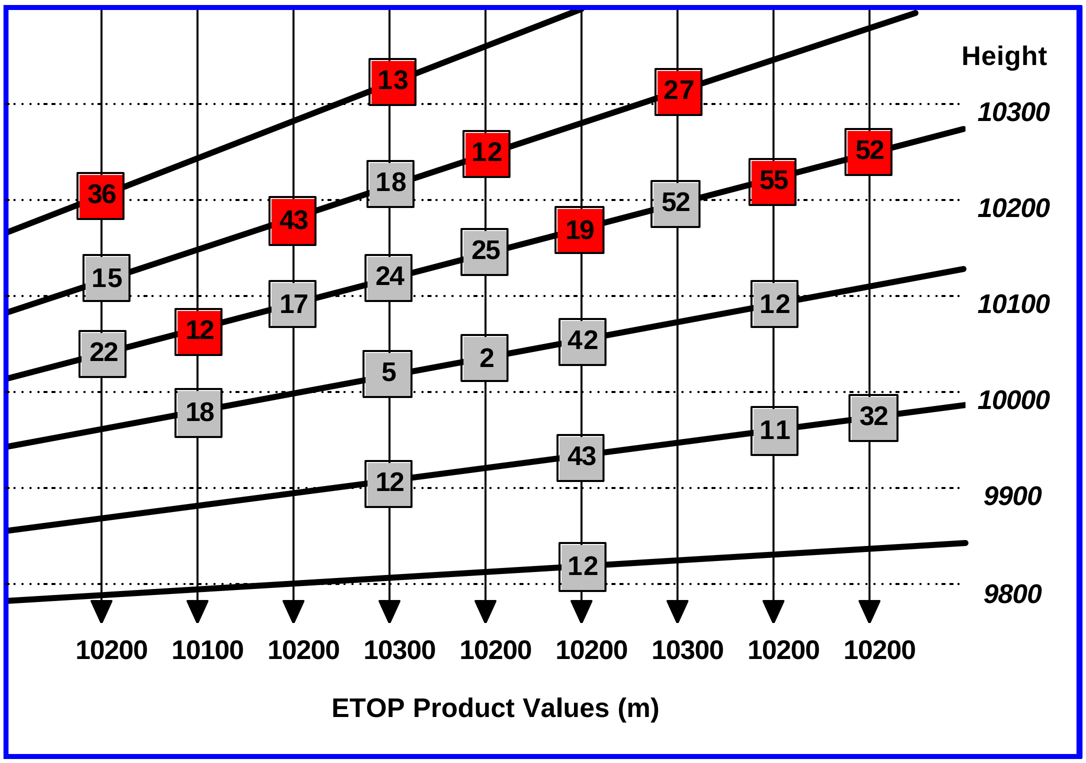
TOPS Product Options



TOPS Product Example

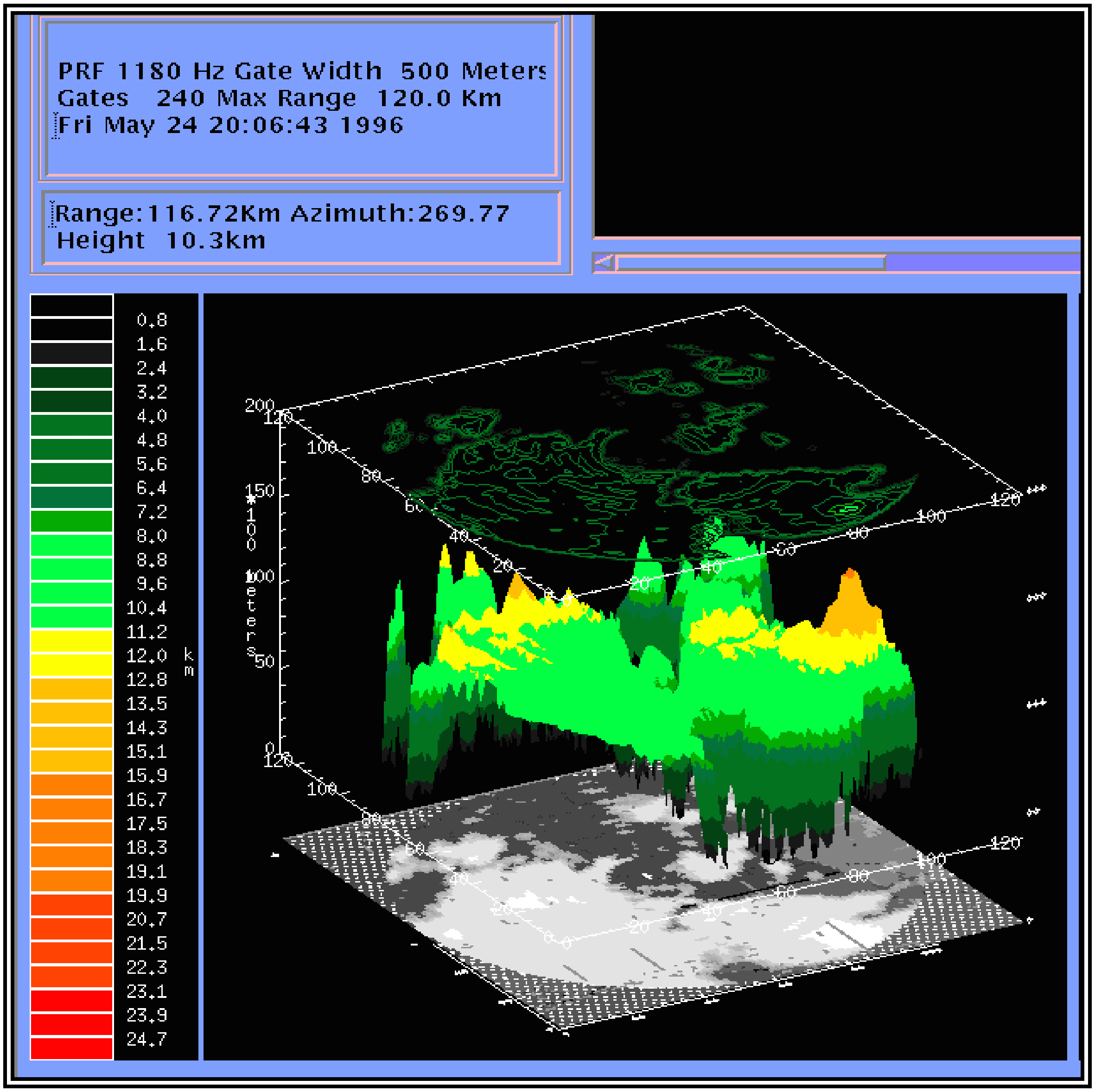
TOPS Product Description

The TOPS algorithm transverses the volume scan calculating the height of the echoes. The highest in altitude echoes with intensities above the threshold are selected. The height of these echoes are placed in the product. The resolution is 100 meters. In resolving the data to standard cell resolution, the highest in altitude echo is selected.



TOPS Product Description

The highest echoes in each column are selected for the TOPS product. The altitude of these echoes are stored in the product. EDGE includes a three dimensional display of echo tops.



TOPS 3D Display

The Echo Tops Product (TOPS)
This can be used to locate areas with strong updrafts which can lift precipitation up to the highest levels. This will show both mature and developing thunderstorms and can be used to determine which frontal bands have the strongest updrafts or locate regions of embedded convection in areas of stratiform precipitation.

8.10 Accumulated Rainfall Product (ACM)

The Accumulated Rainfall Product (ACM)
The ACM product is the depth of water accumulated on the surface in a period of time. ACM products are available for one, three, 24, and user-defined hourly intervals. As volumes are acquired, they may be marked

as accumulation candidates. The data is resolved to 240 kilometer by one square kilometer Cartesian resolution, normalized in time and added to the various accumulation grids. As the various periods are passed in time, ACM products are automatically generated. ACM products may be constructed from either corrected or uncorrected intensities and are converted to rainrate using a separate Z-R relation, allowing for specialized corrections to impact only these products. A series of rain gauge reports may be used as comparisons to the accumulation data (normalized in time) to form correction factors which are used to correct the accumulation data.

Accumulation data is integrated into Cartesian grids which have a resolution of 480 by 480 by one kilometer resolution with the radar site located at the center. The grids are stored on disk in case of power failure. The subcatchment and gauge products are also generated from these grids. Accumulation data is normalized in time using the last integration as the start time and assuming linear change to the current sample. As each integration period is passed in time, the various products are automatically generated. One period may be user defined in one hour resolution. The ending hour of the 24 hour product may be user-defined allowing the *end of the rain day* changes to meet local procedures.

The Accumulated Rainfall Product (ACM)
This product, when the radar has been properly calibrated relative to ground based measurements, can be used for a variety of purposes. Among the most important are stream flow and flood forecasting, and the estimation of soil moisture, agricultural crop health and forest fire potential.

8.11 Arbitrary Vertical Cross-Section Product (XSEC)

The XSEC product is a display product. That is, it is not automatically generated at acquisition time, as the previous products are. Display products are generated at user demand in real-time. The XSEC product is generated as the result of the user indicating a start and end point on any displayed product and requesting the product. The XSEC algorithm transverses the volume data in three dimensions along the defined line generating a vertical cross section of the requested moment. This product is displayed to the user directly after generation. This means that only workstations which have access to the volume data can generate XSEC products. XSEC products may be generated using any of the following moments:

Moment	Description	Units
Z	Corrected Intensity	dBZ
U	Uncorrected Intensity	dBZ
R	Rain rate	mm/hr, in/hr
T	Total rainrate	mm/hr, in/hr
V	Radial Velocity	m/s, kn, km/hr, mi/hr
W	Spectral Width	m/s, kn, km/hr, mi/hr
S	radial shear	m/s/km, kn/km, mi/hr/mi
A	Azimuthal shear	m/s/km, kn/km, mi/hr/mi
C	combined shear	m/s/km, kn/km, mi/hr/mi

Cross Section Product Algorithm
The vertical cross-section is produced as a fixed-format two-dimensional array of interpolated elements. Note that this is in contrast to most of the products, which are typically produced in polar coordinates.

The fixed dimensions of the vertical cross section product are 125-m cells in the vertical, and 384 cells in the horizontal. While the vertical resolution of the product is fixed, the horizontal resolution depends upon the length of the vector drawn by the user. Whatever the length of that vector (provided that it is greater than zero), the horizontal resolution of the product will be that length divided by 384.

The vertical cross section product algorithm consists of interpolating the raw data from the volume structure for each point in the output data set. There are three possible types of interpolation, depending upon whether the point of interpolation lies within the scan volume, above the highest sweep of the scan volume, or below the lowest sweep of the scan volume:

Where the output point lies within the raw data volume, the output data point is interpolated from the measured points at the two azimuths and two elevation angles bracketing the observation point;

Where the output point lies above the raw data volume, the output data point is interpolated from the two measured points at the highest elevation angle bracketing the observation point, provided that the height difference between the point of observation and the measurement points is less than 500 meters;

Where the output point lies below the raw data volume, the output data point is interpolated from the two measured points at the lowest elevation angle bracketing the observation point, provided that the height difference between the point of observation and the measurement points is less than 500 meters;

Various structures are added to the product structure to record the system parameters prevailing during the data acquisition (radar and signal processor parameters, time, radar site name, etc.).

8.12 Velocity Azimuth Display(VAD)

The VAD product is a display product that may be requested from any displayed velocity product and is generated and displayed on demand. This product uses the VVP method to generate a graph of wind speed and direction along with the RMS error of the calculation verses altitude.

The VAD, sometimes called Velocity Volume Processing or VVP, provides an estimate of the vertical profile of wind speed and direction above the radar site. It is computed from a single sweep at a fixed elevation angle, under the assumption that the wind speed and direction are constant at each height above the radar.

VAD Product Algorithm

The VAD velocity-estimation algorithm analyzes a series of velocity measurements made at all available azimuths and at a single range gate to estimate the horizontal wind components at the height represented by that range gate and that elevation angle. The process is repeated for all available range gates, and a profile of wind direction and velocity is obtained.

The algorithm operates under the assumption that the wind velocity at the height of the range gate in question is uniform in x and y (and thus varies only with height). Under this assumption the velocity component seen by the radar (the “radial” velocity component) will be a simple sinusoid in azimuth, with a peak magnitude equal to the horizontal wind velocity times the cosine of the beam elevation angle, and with a phase dependent upon the wind direction (the phase is such that the maximum incoming velocity is seen when the beam is in the direction of the incoming wind).

In mathematical terms the velocity estimation is achieved through a fit of the measured radial velocities to a simple sinusoid. The fit is done in a least-squares sense, since it is not to be expected that the measurements will have the form of a perfect sinusoidal function of azimuth: there will be errors in the velocity measurement, and the horizontal wind velocity vector will not be perfectly uniform at all the measurement points.

In the VAD algorithm the trigonometric moments of the measured radial velocities are computed and normalized. Next the first three Fourier coefficients are extracted from the moments, and are converted into velocity and direction by an arctangent and a square root. Finally, the RMS fit between the measurements and the sinusoid representing the velocity and direction obtained from the Fourier fit is computed for use as a quality factor.

8.13 Real-time Surveillance Display

The EDGE™ data system provides a real-time surveillance scan based on the display of raw data as it is received from the system signal processor. Any of the available moments can be displayed; reflectivity, corrected reflectivity, velocity, or spectral width. This feature is useful to immediately assess the effects of changes to the radar parameters and provides a quick look at the real-time weather situation around the radar site.

8.14 "A" Scope Display

The EDGE™data system provides a special A-scope display for maintenance and adjustment purposes. The display shows up to four windows of range vs data for the four available monents.

8.15 Sector Scan Display

The Sector-scan Display displays the real-time weather in a user selected and defined sector. The sector may be centered at any selected bearing and can have the following widths; from 22°, 45°, 90° or 180°.

9. EDGE Optional Products and Features

9.1 Boundary Layer Winds Product

The Boundary Layer Winds Product (MVVP) is a combination of two algorithms presented as a Dual Display:

Display 1	MVVP - Modified Volume Velocity Processing
Display 2	TVAD - Tangential Velocity Assumed Display

MVVP:
Purpose: Analysis of mean wind and horizontal divergence in boundary layer. Works in 30 to 60 km range with clear air retums as well as when precipitation is present. Useful for locating preferred regions for thunderstorm development, cold fronts, or major convergence boundaries.

Technique: Divides data from two lowest tilts of a volume into 36 overlapping volumes for which a linear wind analysis is performed giving a mean wind direction, speed and divergence for each. Wind barbs indicating speed and direction are plotted at the center of each volume and contours are drown for the divergence filed.

TVAD:
Purpose: From MVVP display smaller regions can be selected for viewing the local wind variations due to cold fronts, gust fronts, thunderstorms and microburst.

Technique: Estimates of mean tangential wind components are obtained from the MVVP analysis and combined with smoothed radial velocity measurements to produce local estimates of wind speed and direction which are plotted on the screen.

9.2 The Composite Contribution Product (COMP)

The COMP product is a fixed resolution product which is output as both a Cartesian display product and a polar product meant for transmission to the EEC Weather Analysis Radar Network(WARN™) system or other composite network systems. The resolution of the product is selected as either one or two kilometers per bin. There is always 240 kilometers of range stored in the product. If the volume from which this product is generated has less resolution than the output product, the missing data is interpolated. If the range is less than the composite product range, the missing range bins are marked as no-data. The Cartesian product is meant for local quality control of the product.

The COMP product may be created from either corrected or uncorrected intensities. The product itself may be constructed as either a column maximum or base product.

9.3 The Bright Band Detection (BB)

When Bright Band Detection option is turned on, each volume file is automatically (processed scanned) at acquisition time and a vertical intensity profile is constructed. This profile is then examined for the characteristic increase in intensity caused by the “bright band effect” (melting of snow crystals). If a bright band is found the altitude is determined and stored in the volume file header record. Any product produced from that volume will display the altitude of the detected bright band.

9.4 The Storm Motion (VECTOR)

This product is designed to produce short term forecasts of precipitation associated with storms covering large areas and moving as a uniform whole. Examples are frontal rain bands, and hurricane rain bands. The EDGE STORM product uses 2-D pattern recognition to detect similar patterns in successive PPI or CAPPI maps of intensity or precipitation rate. These maps may be separated in time up to an hour apart. A correlation coefficient is calculated between the current map and its immediate predecessor for a variety of offsets in the x and y direction until a maximum value for the correlation coefficient is found. The offset is then used as a motion vector for the entire precipitation field.

9.5 Storm-Tracking with Strike Warnings (**TRACK)**

Track is a product that identifies and tracks storm cells. These cells are defined as three-dimensional contiguous regions of space where the radar reflectivity exceeds a user specified threshold value. Through the use of several factors involving primarily location and size, cells are matched, if possible, from one volume scan to the next and a history file is created where the locations, sizes, and a variety of other statistics are kept for all detected storm cells. The present and past locations are shown on the product image for each active cell, which are overlaid on a column maximage.

Algorithm Description

For input the algorithm requires a volume file with multiple PPI scans at different elevation angles. The initial part of the algorithm processes the scans from the volume file one at a time to produce the a working database.

Each scan is converted into a Cartesian coordinate grid and then sent to a routine that searches through the grid row by row looking for 'runs' where the data values exceed the threshold value. If the 'run' is at least 4 pixels long, a description of the 'run' is stored in a linked list of special data structures called segments.

When all rows of the scan have been searched, and all segments identified and stored in the list, the algorithm continues by sorting the list of segments into groups of adjacent segments creating a new linked list of special data structures called areas.

After all scans have been processed and linked list containing the areas from all levels has been completed, the algorithm continues by assembling the areas into cells by grouping all vertically adjacent areas together. These groups are stored in a linked list of cells.

Next the cells are classified by computing volumes, reflectivity weighted cell centroids, echo tops, echo bases, depth, mean and maximum dBZ, and many other statistics. If the volume of a cell exceeds the minimum volume, a value set by the user, then it is classed as a storm and retained in the list otherwise it is discarded. If a storm meets the criteria for being classed as a severe storm, a warning is issued. A severe storm is defined as one with maximum reflectivity exceeding a user set Maximum dBZ value, default is 55 dBZ.

This concludes the identification section of the algorithm, after which the linked list of storms is passed on to the tracking section of the algorithm. If a storm history file giving a description of storms from previous volume scans exists it is read into memory to create a linked list of old storms, otherwise the new storm list is simply saved to create a history file and no matching is possible. The time of the last observation is compared to the present time, if the difference exceeds reset_time all the old data is discarded, otherwise, if the difference exceeds the user specified value of max_match_time no matching is attempted but the old data is retained, otherwise, a table is constructed containing the 'cost' required to match a storm from the old storm list with each storm in the new storm list.

The 'cost' of a match is determined by a computation that takes into account, the distance between storms (i.e. the required velocity of motion), the area of overlap of the two storms if any, difference in volume, the difference in storm depth, and the time elapsed between the two descriptions. If the necessary velocity of motion exceeds the user specified value, max_speed, then the cost is set at a very high value.

If the cost exceeds the MAX_COST macro value the match is removed from further consideration. The possible matches are then sorted in order of cost. Storm matches are assigned starting with the lowest cost value and proceeding upwards. If one of the storms involved in a potential match is found to have already been matched previously the new match is simply skipped. At present no attempt is made to address the issue of merging or splitting storms. If a match is accepted the storm structure is transferred from the new storm list into its appropriate location in the old storm list.

For each new match, a mean velocity and direction of motion is calculated for the storm. If only two positions are available the direction and speed is found from the difference in the two positions. If more positions are available the motion is estimated by making a least squares best fit matching for a straight line describing position with time which is then used to obtain the mean velocity and direction of motion.

Storms which have been observed within a period of time less than the max_match_time are labeled active, while storms that have not been detected again with in that period of time are labeled inactive and are no longer displayed on the product image, but the data is retained in the history files. Both the updated old storm list and the remaining unmatched new storms are then saved in the updated history files. The history is saved in two file formats, a binary file, storms.hist, used by the stormtrack section, and a text file, hist.txt, which can be printed out for the user to read. Both files can be found in the /edge/data/gust directory.

The column max algorithm is called to create a base image and then, for each active storm an ellipse or series of ellipses is drawn centered on the storm centroid. Each ellipse is drawn with an area equal to the

> mean area at all levels of the storm and with an orientation and shape approximating the distribution of the segments in the storm projected on to a horizontal plane.

9.6 ALERT Product Description

The ALERT product is a user programmable warning generator that has three major parts; the Alert Product Generator, the Alert Product Configuration Files menu, and the separately programmed Products Configuration file. ALERT is product oriented and requires choosing existing EDGE products as the input to the algorithm. The user can choose information from up to 5 products from a list of 8 products to use in defining areas for which an alert warning should be issued. For each product a threshold value is specified. Areas then can be obtained from the product that are either less than, equal to or greater than the threshold. The areas from each product can be combined using AND or OR operations to produce the final areas. The selected areas are sized to eliminate those less than the minimum size. For each of the remaining areas, maximum, minimum and mean values are determined. A warning message is generated for each area that meets the user defined criteria.

A special configuration file must be created for each type of warning desired. Whenever a particular alert is required, EDGE/REX calls the alert product generator and provides the configuration file for the specified alert. The alert product generator searches the existing products in the product directory for those needed to make the alert product. If all the right types of products that have been created within the required time period no product will be generated. Hence the ALERT product configuration file is central to generating alert products. EDGE must also be programmed separately to generate the products required by the ALERT Product Generator.

9.6.1 Alert Product Configuration Files

The product configuration files are ASCII script files that contain the rules used by the alert product generator to create ALERT product. Each specific user defined alert product requires a dedicated configuration file. Valid files are found in /edge/data/alert and have the .ale suffix.

An example script is shown below

```
#############################################
#Comments are lines starting with #
Desc Alert File 1.0
#Special Instructions come first that apply to all products
RANGE        240
AREA         60
TIME         20
#Next list the specific products to be used
CMAX  Z      10     GT     35.0   AND
ETOPS Z      20     GT     6.0    AND
LRA   Z      7.0    4.0    GT     30.0   THEN
#The warning message follows THEN
Warning! Potential Lightning Areas:
Area no. %I
Lat: %N   Long: %W
Size: %A sq km
Maximum Z %X1 dbZ
Max Echo Tops: %X2 m.
Mean Z between 4 and 7 km is %V3 dBZ
#end of file
################################################
```

The rules for the configuration script files are as follows:

1. Comment lines have # as the first character in the line and are ignored. Blank lines are also ignored. These two line types may be placed anywhere in the file.

2. First meaningful line of file contains
desc Alert File <version no.>

3. Optional lines of special instructions precede the product list. These are values to be applied to all the component products. Only three are currently in use.
AREA <lower_limit (km^2)>
RANGE <distance (km)>
TIME <time_interval (min)>
Where AREA is the minimum size area necessary to produce an alert message.
RANGE is the maximum range of the alert product in km which may differ from some or all of the component products.
TIME is the time interval in minutes prior to current time. Component products must have been generated within this interval in order to be used in creating the alert product.
If no AREA or TIME or RANGE values are specified, default values of 50 km^2, 60 minutes and 60 km, respectively will be used.

4. Component product lines contain

<product> [option1, [option2, [option3]]] <relational_operator> <threshold> <logical_operator>
The last component product in the series must have THEN as its logical operator. This serves to indicate that the message follows

5. The message is the final part of the file and may consist of an indefinite number of lines.

6. The message syntax is given below. A separate message will be generated for each alert area found within a given product.

9.6.2 Area Description Symbols Symbol Substitute

%W	Latitude value
%N	Longitude value
%I	Area ID Number
%A	Area Size (sq km)

Component Product References - Each product symbol is followed by an integer indicating the particular product in the order in which it is listed in the Alert definition file.

Symbol	Substitute
%X	Maximum Value
%V	Mean Value
%M	Minimum Value

See script at beginning of section for example of references to product values.

Table of Optional Arguments for Products used in Alert

Product	**Options**		
PPI	moment	tilt	
CAPPI	moment	altitude	
ETOPS	moment	min_dbz	
BASE	moment	min_dbz	
VIL			
CMAX	moment	min_dbz	
HMAX			
LRA	moment	upper	lower
HDR	upper	lower	
PCP	period		

Moments supported for each product

PPI – U,Z,V,W,DV,D,SHR,C,H,R,T
CAPPI – U,Z,V,W,DV,D,SHR,C,H,R,T
ETOPS – U,Z
BASE – U,Z,D,H,R,T
CMAX – U,Z,D,R,T
LRA – U,Z,D,R,T

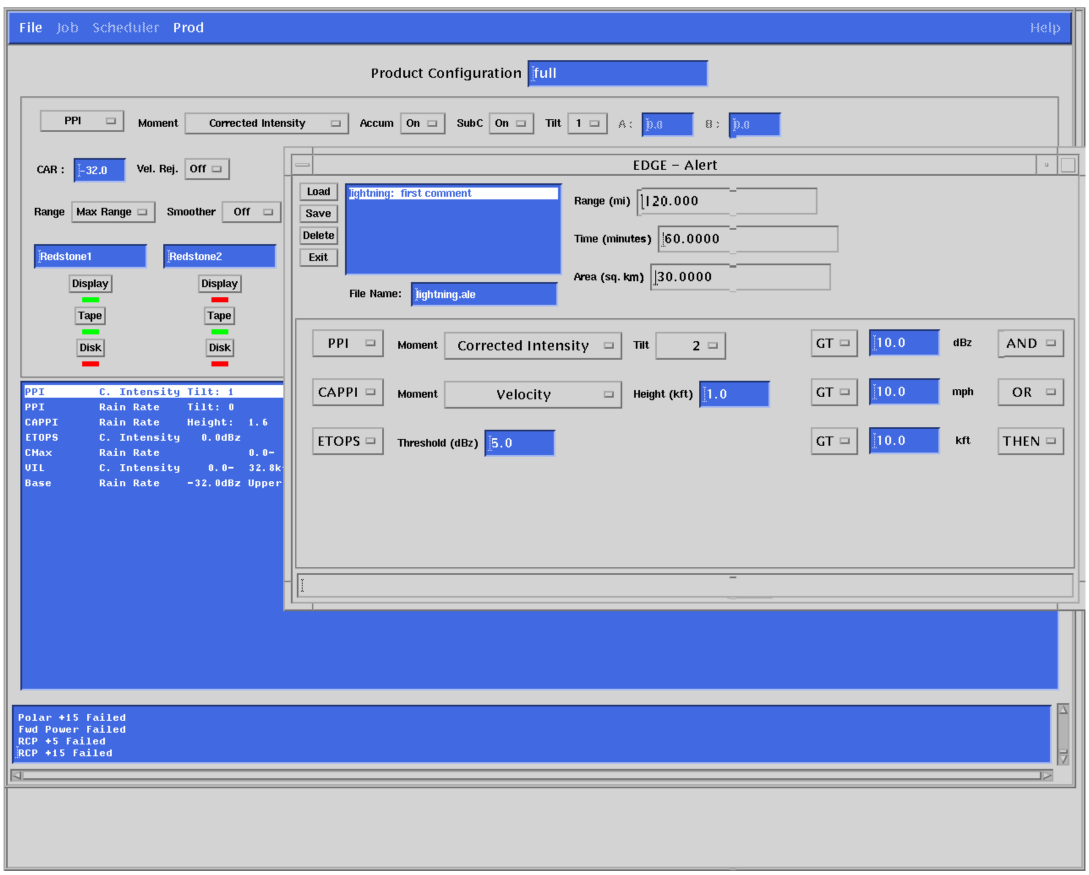
Units used in file are:

U,Z – dBZ
W,V,DV – m/s
HDR,ZDR,D – dB
S,C – m/s/km
R – mm/hr
T – mm

H – number corresponding to precipitation type
VIL – kg/m^2
ETOPS,HMAX – m
Altitude, upper, lower – km

<u>Valid Relational Operators are:</u>
GT – Greater Than
GE – Greater than or Equal to
LT – Less Than
LE – Less than or Equal to
EQ – EQual to
NE – Not Equal to

<u>Valid Logical Operators are:</u>
OR
AND



ALERT MENU

9.7 Hail Probability (HAIL)

Based on hail forecasting algorithm developed by the National Weather Service, and uses the VIL measurements as determined by the radar. The user needs to input local atmospheric sounding data as well (melting level, 500 mb Zonal wind speed, 5fc to 500 mb mean relative humidity). The probability of hail being present at any location is displayed as a color map.

9.8 Beam Blockage Correction

Corrected intensity values may be further corrected for attenuation due to partial beam blockage caused by an obstruction or the horizon. A high resolution table of the range and elevation of obstructions by azimuth is acquired at the site and entered into EDGE™. When a volume is corrected, each ray of data is examined. If the beam was partially blocked by the obstruction, an attenuation factor is applied to subsequent out-range measurements. This attenuation factor is a function of the amount of blockage and is user-controlled with a default supplied.

9.9 Clutter Map Correction

The EDGE™ implementation of the classical clutter map is superior to any other commercial implementation. A volume scan for which clutter map correction is desired is executed on a clear day and the resulting uncorrected intensity values are stored as a clutter map volume. Subsequent executions of this volume scan will produce volume scan data. This data is compared to the stored clutter map and the corrected intensity moment altered in clutter indicated areas.

Since an entire volume is stored as a clutter map, the exact geometry of the scan is reproduced in the comparison. This is as opposed to systems which use a generalized clutter map at some fixed scan pattern and then resolve the new data to a 'closest fit' before correction. When the correction is done in EDGE™, each elevation scan in the clutter volume is resolved to one-degree azimuthal resolution and was gathered at the precise elevation as the data to be corrected. Since clutter power may vary greatly as a function of antenna position, the correction is much improved.

Intensity measurements found to be cluttered in this process may be corrected in a variety of ways. The method used is under user control at acquisition time. The cluttered intensity value may be removed altogether and replaced by a no-data indication, which appears in the products as a grayed-out area. The value may be interpolated from neighboring non-cluttered measurements. This interpolation is done using linear reflectivity (that is, $10^{dBZ/10}$) and is always in range. Alternatively, the value may have the clutter measurement subtracted, this also in linear.

10. Hydrological Products and Features

10.1 The Gauge Product (GAGE)

An optional add-on to the Accumulated Rainfall and Subcatchments Products is the Gauge Product, designed to assimilate rain gauge data into the EDGE™ accumulation products. Up to 40 rain gauge locations, stated in range and azimuth from the radar, may be entered into a table in EDGE™. At any time, a report may be generated showing the last complete accumulated rainfall from the accumulation grids at each of these locations. If the rain gauge entry system is in use, the actual gauge reports from these locations are also printed along with the difference between the actual and accumulated measurements.

10.2 Subcatchment Product (SUBC)

The Rainfall subcatchment product is an area integration of the Accumulated Rainfall product, used to estimate the volume of precipitation falling in a prescribed geographic area (such as a watershed). Up to 40 geographical areas may be defined in the 480 by 480 kilometer area centered on the radar.

The precipitation subcatchment product is updated each time the 1-hour precipitation-accumulation product is completed. The subcatchment areas are defined by vector coordinates relative to the radar site. EDGE™ can generate the subcatchment definition file from a standard projection map of the area. At each rainfall accumulation period, a report is generated showing each subcatchment area and the average accumulated rainfall in this area. This information comes directly from the accumulation grids, therefore, whichever moment is used to generate the accumulated rainfall product will be used for the subcatchment moment.

10.3 Flash Flood Alert (FLOOD)

User customized warning product based on data output from the rainfall accumulation and subcatchment accumulation products. User may define thresholds of a accumulation in an area and cause warning to be issued when thresholds are exceeded.

10.4 Data Output to Flood Models

Customized data output to flood modeling programs, based on rainfall accumulation and subcatchment accumulation.

11. Windshear Detection Products and Features (Optional)

11.1 Base Shear Package

11.1.1 Radial and Combined Wind Shear Products

A variety of wind shear products are available as extra moments on the standard products or as stand alone products. The radial wind shear product (extra moment available on PPI/RHI/CAPPI) produces an estimate of the radial wind shear at each ray. The azimuthal wind shear product produces an estimate of the wind shear on successive azimuth radials. Combined or tangential shear, is estimated from the sum of the radial and azimuthal shear calculations. Related shear products include microburst detection and gust front detection.

Radial shear is estimated directly from velocity differences from one range cell to the next, while azimuthal shear is estimated from velocity differences from one azimuth to the next. The two components are normalized for the spatial separations of the measurements, in units of m/s/km. The two components of shear are added on an RMS basis, and the result is expressed as the square root of the sum of the squares.

The shear product algorithms were developed and thoroughly tested in the NEXRAD and TDWR programs. The shear products used in EDGE™ are direct developments of these proven algorithms.

The radial shear product is produced from a single azimuth scan, using the measured velocities as qualified using the SQI threshold. The product is a two-dimensional color image, with the color representing the levels of shear to be expected at each point in the scan.

The combined shear product consists of an RMS-summation of the radial and azimuthal components of the horizontal velocity shear. The radial shear (shear from gate to gate in range) and the tangential or azimuthal shear (shear from azimuth to azimuth, as corrected for the changing azimuthal separations of range gates as the range increases) are computed separately, and the square root of the sum of their squares is computed. Where the radar signal strength is insufficient to produce a valid velocity the product data is marked as missing.

The units of the shear product are meters/second per meter, or 1/second. These units may also be expressed in units of knots per nautical mile, m/s per km, and so on, as required by the user. The shear expresses the change of velocity to be expected after traveling a certain distance.

The horizontal shear product may be thresholded to produce text warnings of hazardous shear regions, indicating the horizontal position and magnitude of shear hazards.

11.1.2 Additional Shear Products

Several additional shear products are available as extra cost options to the basic EDGE program. As selection of these are described below:

1. **Combined moments map**
   The combined moment display allows the user to visualize three aspects of the radar data simultaneously, through a vector display. The display consists of an array of small vectors, representing the three moments at each point in the horizontal plane. Three aspects of the vectors - vector length, vector rotation angle, and the width of the arrow head on the vector - to represent the signal intensity, velocity, and spectral width.

3. **Altitude shear map (AMS)**
   This product is implemented as an additional moment to the CAPPI and is created from volume velocity data, through differentiation of the velocity values at the user-specified altitude level. This differentiation may be taken along the radial or azimuthal direction, to produce the radial or azimuthal component of wind shear. The wind shear is a signed quantity, normalized for the spatial difference used in the differentiation process (to create a shear value in units of 1/seconds). The product represents the radial or azimuthal wind shear along a horizontal cut through the storm.

4. **Vertical section shear map (VSS)**
   This product is implemented as an additional moment to the cross section (XSEC) product and is created from volume velocity data, through differentiation of the velocity values above the user-specified surface vector. This differentiation may be taken along the radial or azimuthal direction, to produce the radial or azimuthal component of wind shear. The wind shear is a signed quantity, normalized for the spatial difference used in the differentiation process (to create a shear value in units of 1/seconds). The product represents the radial or azimuthal wind shear along a vertical cut through the storm, above a vector drawn on a PPI or CAPPI by the user using the mouse. The vertical cut can be above any vector, and it is not restricted to vectors passing through the radar site (as RHI displays are).

11.2 Special Shear Products/Features

11.2.1 Ribbon Display Output

A special data format can be provided to drive ribbon displays for products which produce warnings.

11.2.2 Gust Front Detection, Microburst Detection, Mesocyclone, Algorithm (GUST)

This product contains 4 separate pattern recognition algorithms that are run at the same time and the results are all depicted on one product. Two algorithms are used to detect gust fronts and the other two algorithms are used for microburst and mesocyclone detection.

Gust Front Detection:

1. The two lowest level tilts (one must be less than 1.0° in elevation and the other less than 1.25°) are searched for regions where radial velocity is decreasing (converging) in excess of a threshold value. These regions are matched to a number of pattern definition criteria to determine if they represent a gust front.

2. The radial velocity data allows only the detection of gust fronts where they are not aligned with the radar beam. For radically aligned gust fronts, the intensity values from the lowest tilt are searched azimuthally to detect "thin lines" due to accumulation of moisture, haze and insects along convergence boundaries. A pattern recognition technique is employed to "recognize" the "thin lines".

Microburst Detection:
The radial velocity measurements on the lowest tilt which must be at an elevation angle of less than 1°, are searched for regions of increasing radial velocity (divergence). These regions are matched to pattern definition criteria to determine if a microburst is present.

Mesocyclone Detection:
All tilts in a volume are searched for regions of azimuthal shear (rotation). These regions are tested against pattern definition criteria to determine if a mesocyclone is present.

12. Dual Polarization Products and Features

12.1 PPI/RHI/CAPPI Products

When dual polarization is installed the PPI/RHI/CAPPI products may be produced using the differential reflectivity moment.

12.2 Hydrometeor Classification

Differential reflectivity is a measurement of the difference in two intensity values gathered in separate polarization orientations of the transmitted energy. The implementation of this moment will require a dual polarization antenna system. The moment is designated by EDGE™ as 'D' and is used in hydrometeor classification with the resulting moment designated as precipitation type or 'H'.

Hydrometeor Classification
The differential reflectivity moment is used to derive the type of hydrometeor in the airspace and is referred to as 'H'. This classification is presented as either a PPI or CAPPI product.

12.3 Hail Signal Product

The hail signal, Hdr, is computed from the horizontally polarized reflectivity and the differential reflectivity. Positive values indicate the likely presence of hail. The larger the hail signal values the larger the size of the hail stones that would be expected.

13. The Interactive Workstation Processor

The Interactive Workstation Processor is a user-interface and graphics-display tool which provides the link between the radar product user and the data system. The IWP provides real-time and product graphic displays, image manipulation capabilities for these displays, and a mouse/keyboard menu capability for entering requests to the Central Command Processor and (indirectly) to the Product Generation Processor, scheduler, and hence to the radar itself.

The data system features a mouse-driven display capability, described in the following subsections.

13.1 User Interaction

The primary data display consists of an image area, a color-table area, an ancillary data area, and a menu key area. The user interacts with the display by clicking with the mouse on the menu key area. Specialized pull down menus appear for the following major functions:

- Task configuration (radar, antenna, signal processor, products)
- Task scheduling (execution time, priority)
- Display configuration (color table, data scale, overlays)
- Product configuration
- Archive (reading, writing, device selection)
- Tools (site configuration, default configuration, maintenance functions)
- Other display functions (pan, zoom, etc.) may be invoked by keystrokes or special icon buttons
- Surveillance mode for realtime setup and display

13.2 Display Parameters

The following display parameters are under the control of the operator:

- Display maximum range (in km or miles or nautical miles for horizontal units, in km or kft for height units)
- Display offset (pan) and zoom
- Overlays (geographic, political, range rings, azimuth rays)
- Color table (color editing, color contrast, table selection from file)
- Display scale (units, lowest unit, highest unit)
- Ancillary data (date, time, moment, radar name, elevation angle, etc.)

13.3 Image Manipulation

The user can invoke the following image manipulation features:

- Image zoom (1-16 X)
- Image pan using mouse
- Dual or single image mode
- Movie loop setup and run
- Parameter readout by mouse click (the user can interrogate the display to retrieve data values)

Color image overlays and underlays will be provided for all displays. Thirty-two underlay colors, thirty-two overlay colors, and thirty-two product display colors are available. The color of each level and the values represented by each level may be specified.

User-generated overlay annotation is provided.

In addition to the products generated after a data volume has been acquired, the user may display the raw intensity, velocity, or spectral-width measurements in real time as they are acquired by the data system.

Two complete real-time displays are available in PPI or RHI format, according to the current data acquisition mode. The real-time data is received over an Ethernet broadcast directly from the Data Acquisition Processor.

The IWP supports local archiving of display products when installed on a stand alone workstation.

The Surveillance Scan allows the user to interact directly with the radar system. A real-time display presents the data to the user as it is collected in the selected scan strategy (RHI, PPI, POINT, or SECTOR). Complete control of the signal processor is allowed on the same screen. Sector scans and RHI scans may be executed by selecting an area of interest on the PPI screen. In POINT mode, an ‘A’-Scope style display is presented.

14. Diagnostics

The most useful diagnostics for normal data system operations are the status screens described above. These screens indicate the presence of most types of system faults, by indicating the failure of the system to provide one or more types of services.

By studying the types of services interrupted, and checking the completion status of the various modules involved in the creation of those services, it is usually possible to identify the location of the system fault to a narrow range of modules. The most useful diagnostic strategy at that point then becomes a search for whatever system resources are blocking the completion of the required activities.

The following subsections describe additional diagnostic utilities which may be helpful in analyzing system faults. Note that most of these diagnostics were developed to provide testing capabilities required during the software development process. They are provided with the data system software because of their continuing utility.

14.1 General System Check

The EDGE™ data system has an overall system check function, which tests the functionality of the major system software and hardware elements to the maximum extent practical.

The tests provided include the following:

- Radar test through radar BITE
- Antenna test through control tests
- Host processor test through check of process status
- Automatic system calibration utilizing the built-in EEC TSG with controller

These tests are performed during the system initialization process before the data system is fully operational. The tests may also be run at any time through the intervention of the operator (though data acquisition must be disabled for the tests).

14.2 Product Generation Tests

The product generation algorithms on the data system are likely to be updated from time to time, and these algorithms require detailed testing for verification of proper operation.

This testing is best accomplished by operating the algorithm on a test input data set with known mathematical properties. The output data set can then be predicted and compared with the actual output.

Product generation diagnostics are easily performed using the synthetic data sets generated by the utilities described in the preceding section. Logical switches present in the radar data ingest routines are set to force the synthetic data to be used in place of the normal real-time data, and the product outputs are checked through data dumps or displays.

14.3 Radar System Diagnostics

The operator can invoke (if the operator has the required password privileges) several radar system diagnostics tests:

14.3.1 Range And Trigger Utility

This test is used for the adjustment of the range-to-gate-zero and for verification of the data and display range scales.

14.3.2 A-Scope Data Display

The data system provides a special A-scope display for maintenance and adjustment purposes. The display shows up to three windows of range, time, or frequency vs. a variable. The following displays are available in this format:

- Intensity
- Velocity
- Spectral width

14.3.3 Automatic Z Calibration

This utility is implemented as part of the Signal Processor command set.

The hardware required for this function includes the following:

- A BITE controllable signal generator with 1-dB intensity steps and a frequency centered at the radar-transmitter frequency
- A waveguide or other switch to insert the signal generator output into the main wave guide run to the receiver, or into a calibrated directional coupler
- A calibrated directional coupler in the main signal line

The calibration routine operates with the transmitter disabled. The signal generator is connected to the receiver (ahead of the LNA and any STC devices) through the calibrated directional coupler, and stepped through the entire dynamic range of the system in 1-dB steps. The signal is integrated at each setting for a sufficiently long time to reduce the statistical uncertainty in the system response to less than 0.1 dB. The system noise level is subtracted from all measurements. A conversion table is created from the resulting measurements; this table converts all 4096 possible steps of the A/D measurement to relative linear signal power. The slope is downloaded to the signal processor to convert A/D units to signal power, to eliminate any non-linearity in the receiver Log-Z channel.

A simple plot of log-receiver response is created by this utility, and the results of the calibration are stored on the system disk.

An absolute power measurement acquired at approximately mid-scale on the log-Z response is used, together with user-input system constants (antenna gain, transmitter power, wave guide losses, radome losses, etc.), to calibrate the response of the radar in absolute terms.

14.3.4 Manual Z Calibration

A manual calibration option is provided for the data system. The system noise level is measured, and the system response to two or more signal levels is acquired with the help of the radar technician. From the system noise level and the system response the utility computes the most likely A/D-to-power response curve of the log-Z receiver. This 4096-point slope is downloaded to the signal processor to convert A/D units to signal power on the log-Z channel.

A simple plot of log-receiver response is created by this utility, and the results of the calibration are stored on the system disk.

14.3.5 Antenna Diagnostics

This algorithm provides the following functions for measurement of antenna performance and adjustment of servo parameters:

- Graphic displays of position and velocity vs. time
- Step and ramp movements for antenna servo adjustment
- Manual antenna positioning capability (pointing mode, with cursor increments in azimuth and elevation)

14.3.6 BITE Diagnostics

The BITE diagnostic exercises those functions of the radar system BITE which can be tested cooperatively. The purpose of the diagnostic is to verify the control functions implemented through the BITE as well as to verify the read-back functions implemented through the BITE.