

## P1.1 THE CURRENT LINUX-INTEL PORTABLE WSR-88D CODE DISTRIBUTION AND A SUMMARY OF HOW IT IS BEING USED IN RESEARCH, DEVELOPMENT, AND OPERATIONS

Thomas J. Ganger\*  
Mitretek Systems, Inc., Falls Church, VA

Michael J. Istok and Warren M. Blanchard  
National Weather Service, Office of Science and Technology, Silver Spring, MD

### 1. INTRODUCTION

The Common Operations and Development Environment (CODE), based upon the Open Radar Product Generator (ORPG) system architecture, is facilitating the development of new algorithms that can be easily integrated into the operational WSR-88D radar. The initial port of the ORPG software to the Linux-Intel platform makes CODE readily available to a larger potential user audience. The current CODE distribution is described including the availability of the Linux port.

The extensive testing, development and analysis capabilities now available by combining CODE with near real-time Level 2 archive data from WSR-88D radars as a data source and TCP/IP for radar product distribution will be described along with examples of how CODE is being used to support research, development, and operations today.

### 2. CODE

The Common Operations and Development Environment (CODE) is sponsored by the National Weather Service (NWS) and the Federal Aviation Administration (FAA) through the NEXRAD Product Improvement (NPI) Program. The objective is to shorten the development, integration and validation cycle for new algorithms and applications on the WSR-88D (Ganger, 2000).

#### 2.1 Overview

ORPG CODE is a WSR-88D algorithm development environment. The CODE package includes several components (Ganger, 2002). The first component is the source code distribution for the ORPG. This includes the complete source code and instructions for the configuration of a workstation for installing, compiling, and running the

ORPG. The ORPG services that are of interest to the algorithm developer are provided by three libraries that are called the "Algorithm API".

The CODE development guide includes an overview of the ORPG software architecture, a guide to the ORPG development environment, and documentation of internal data structures (e.g., base data and final graphic products). The development environment guide provides instructions for using the ORPG makefiles, compiling software, configuring the ORPG in order to add data stores and tasks for new algorithms, the definition and use of algorithm adaptation data, and properly integrating development source code into the ORPG directory structure. The CODE algorithm writing guide includes: documentation of the ORPG Algorithm API, guidance for the proper structure of data driven and event driven algorithms, and sample algorithms demonstrating use of the API. Currently, CODE includes two product analysis tools. One provides a textual output of both the header portions of a graphic product and the data packets, with options to format the data with raw or scaled values. The other tool provides a graphical display of the various data layers within a product.

#### 2.2 Recent Enhancements

##### 2.2.1 Linux Port of the ORPG

The most significant recent change in CODE is support for a Linux-Intel platform in addition to the Solaris-Sparc platform currently used by the operational WSR-88D. ORPG Build 6, released earlier this year, is the first Build to be formally tested on Linux. Though not approved for operational deployment, the Red Hat Linux Intel platform has been tested sufficiently by the Radar Operations Center (ROC) that it can be used for algorithm development with CODE. A CODE distribution using Build 6 was released in August 2004. There are a few known Linux-specific deficiencies that have recently been addressed in ORPG Builds 7 and 8. The target for operational support of the Linux platform is ORPG Build 9. Though formal algorithm development is still primarily accomplished on the operational Solaris platform, during the integration

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\* *Corresponding author address:* Tom Ganger,  
Mitretek Systems, 3150 Fairview Park Drive South,  
Falls Church, Virginia 22042-4519  
e-mail: tganger@mitretek.org

process the ROC tests new algorithm software on Linux in addition to Solaris.

Beginning with CODE Build 6 version 3 (CODE B6 v3), produced in August 2004, both platforms are supported in a single distribution. The system requirements for a Linux based development environment are: a recent Intel PC with a Pentium 3/4 processor, 512 MB of RAM, and a display capability of 1024x768 with 16 bit color (1280x1024 - 24 bit recommended). A CD-ROM drive is required for installation media. Initially Red Hat 9 was the primary operating system supported as this was the development platform used by the ROC. CODE Build 6 version 3 also supports Red Hat Enterprise Workstation 3, which will become the primary operating system as the ROC transitions their development environment.

Because an Intel PC is Little Endian architecture, the ORPG services must handle byte-swapping correctly to place the distributed products into network byte order (Big Endian format). To simplify this, the Algorithm API and other ORPG services were enhanced in Build 6 and existing algorithms were modified to use the new API services. The CODE guide covers these new services and also provides additional guidance on writing final product data fields (e.g., 4-byte integers, 2-byte integers, and single byte fields) in a manner that will be executed correctly on both platforms. The sample algorithms supplied with CODE were modified to compile and work correctly on Linux.

Finally, the CODE data display and analysis tools CODEview Text (CVT) and CODEview Graphics (CVG) have been modified to correctly handle the byte-swapping requirements of the Linux platform.

With the Linux port, a CODE development environment can now be obtained for the cost of an Intel PC and a Red Hat operating system.

### 2.2.2 ORPG Adaptation Data Infrastructure

The adaptation data infrastructure for the ORPG was replaced in Build 6. This was a complete make-over with an entirely different concept and design. Adaptation data are now stored in a central ORPG hierarchical database and are defined in special configuration files using a Data Element Attribute (DEA) syntax, Figure 1. New algorithm API services are used to read data from the database. The DEA scheme is easier to maintain and facilitates sharing of adaptation data between algorithms. The CODE B6 v3 distribution provided initial guidance in the definition and use of this data.

```
alg_name    value = Vil/Echo Tops

beam_width  value = 1.00;
            name = Beam Width [BW];
            type = double;
            range = [0.50, 2.00];
            accuracy = [0.01];
            unit = degrees;
            description = Angular width of the radar beam ...

min_refl    value = 18.3;
            name = Min Ref Threshold [MRT];
            type = double;
            range = [-33.0, 95.0];
            accuracy = [0.1];
            unit = dBZ;
            description = Minimum reflectivity used ...

max_vil     value = ;
            name = Max VIL Threshold [MVT];
            type = int;
            range = [1, 200];
            unit = kg/m**2;
            description = Maximum allowable VIL product ...
            default = KDDC KILX KSGF: 100,
                    KCLX KINX KRLX KSRX: 120,
                    KICT: 200, Other_sites: 80;
```

Figure 1 Extract from a DEA File

### 2.2.3 CVG Enhancements

Recently, the CODE distributions have been increasingly used in activities other than algorithm development and implementation. Two of these activities are discussed later in this paper. As a result, CODEview Graphics (CVG) is being used as a product display device in situations requiring long-term monitoring of products produced by a continuously running ORPG. CVG has been extensively enhanced in support of these activities.

The user interface has been reorganized placing all functions involving product display (other than selection of the product) on the individual display screens rather than the main CVG window. This includes functions for zoom, product animation (looping display), and display attributes (range / azimuth grid and background maps). The product database selection dialog has been integrated into the main CVG window reducing screen clutter and making the primary mode of product selection immediately available. All functions involving CVG preferences and actual product selection remain on the main window.

Figure 2 depicts the CVG main window and product database selection dialog. A product information panel has been added to aid in selection of products having multiple versions available as a result of one-time requests. This panel displays the six product-specific parameters contained in the

request message when the product listing is highlighted via a mouse click or up and down arrow keys. The information displayed in the database list has been changed significantly, also to aid product selection. The volume date-time is included, the product code has been added (in addition to the internal product ID), and the 1-3 character short name (mnemonic) has been separated from the

rest of the product description. The list filtering capability has been expanded to provide the ability to filter on volume number and/or one of the following: product ID, short name, product code. The volume number is now the same as displayed by the ORPG rather than an internal sequence number.

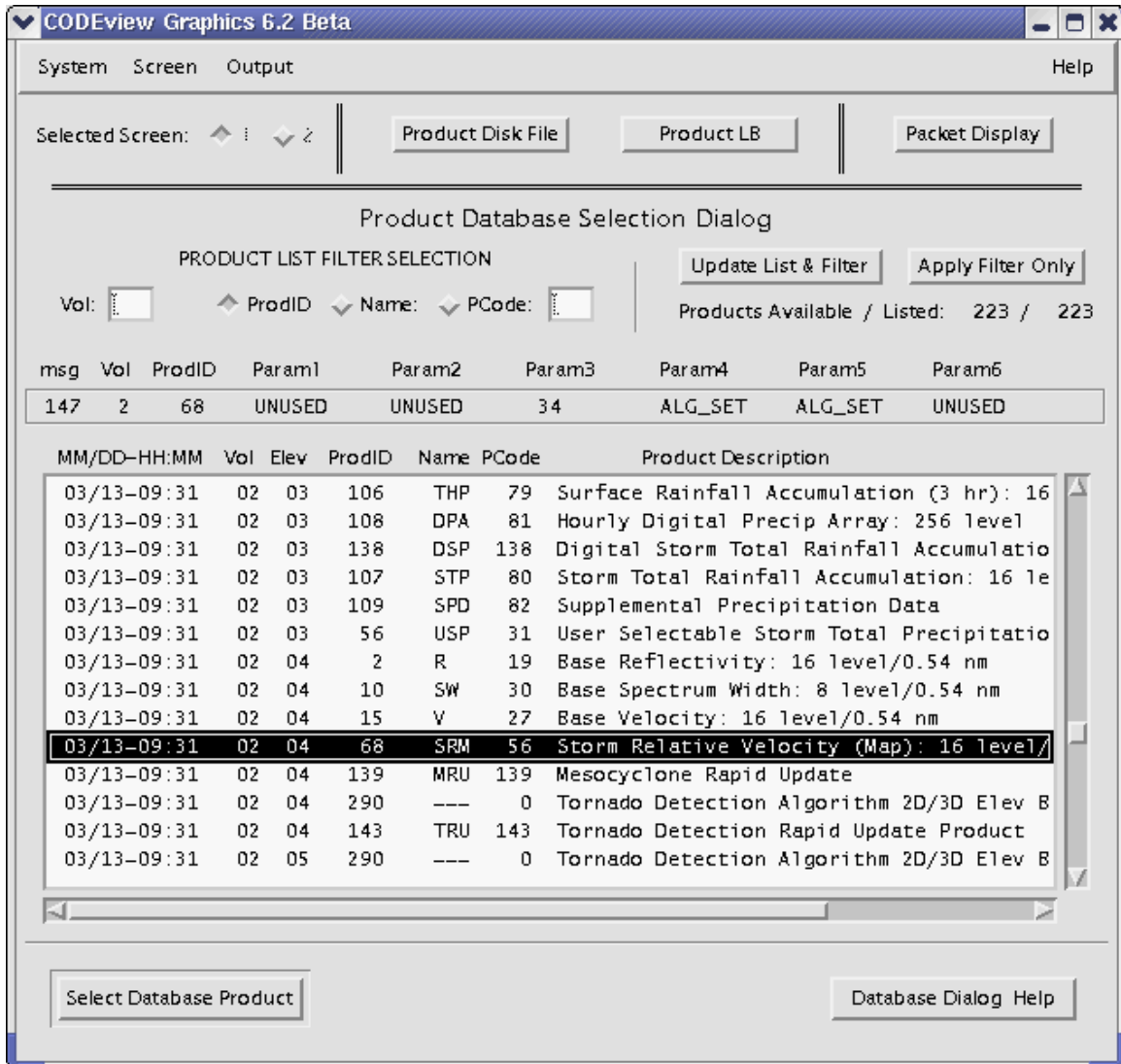


Figure 2 CVG Product Selection Dialog (Main Window)

One result of these modifications has been to cut the number of actions (mouse and keyboard) required to display a product in half.

The controls on the CVG graphic display screen, Figure 3, now include all functions to manipulate the display once the product has been selected. The full description of the product being displayed is provided just above the

graphic display panel. The new TAB button provides a capability to display the Tabular Alpha-numeric Block (TAB) portion of the currently displayed graphic product without having to return to the product layer/packet selection dialog.

Another significant enhancement to CVG is improvement in the performance of updating the database product list when being used with a

running ORPG having a full product database.

Other improvements in product display have also been accomplished including changes to the time-series animation (looping display) of products.

## 2.2.4 Other CODE Enhancements

ORPG Builds 5 and 6 included new API helper functions to provide standard date & time conversions, geographical transformations, and data encoding and decoding.

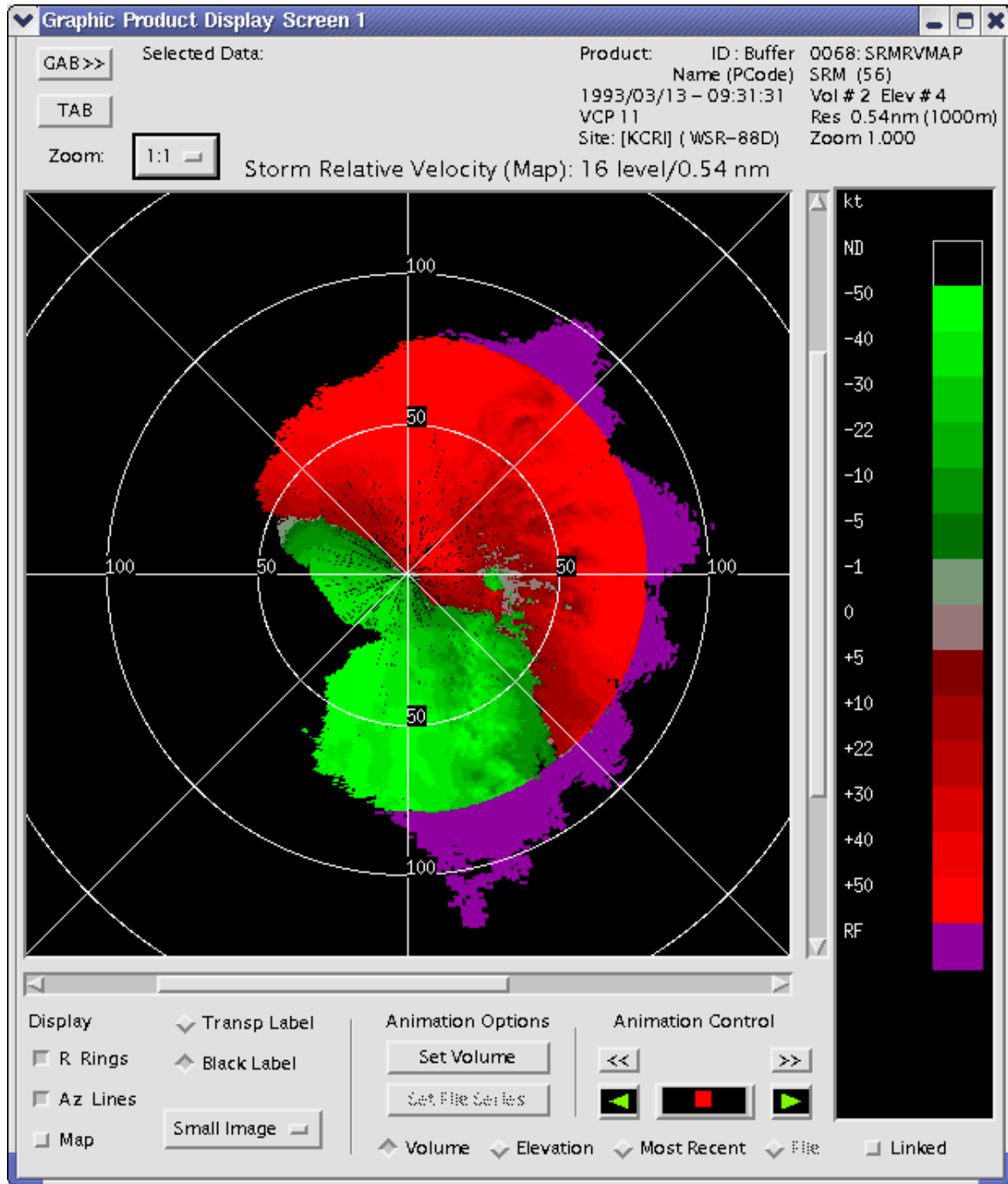


Figure 3 CVG Graphic Display Screen

### 3.0 Sources of Base Data

Without a direct connection to a radar, the typical source of input data is WSR-88D Level II data obtained in one of three ways. The compressed volume data files are input into the CODE ORPG using tools supplied with the ORPG distribution.

#### 3.1 CODE Distribution

CODE distributions include 15 Level II data sets in the form of compressed volume files. These datasets range from several volumes to over 4 hours of data. Most of the data were obtained from archive Level II sources and converted to volume files. A few of the data sets were derived directly from artificially created test data used during the development of the WSR-88D. The data include samples using the various volume scanning strategies and include various forms of precipitation (summer and winter storms, hurricanes, tornadoes, etc.). Data also include cases containing anomalous propagation, switches between radar velocity modes, and spot blanking. A few of the datasets correspond to data used in formal testing by the ROC.

#### 3.2 NCDC Data Archive

The National Climatic Data Center (NCDC) collects Level II data from over 150 NEXRAD sites and makes the data available at no cost to the user via the NCDC radar resources web page (<http://wrf.ncdc.noaa.gov/oa/radar/radarresources.html>). The downloaded archive expands into compressed volume files that can be ingested directly into a CODE ORPG. Del Greco, 2003, provides an overview of the base data archive services provided by the NCDC.

#### 3.3 LDM Data

The NWS has implemented the electronic collection and dissemination of WSR-88D Level II base data in near real time, using the Abilene Network/Internet 2, see: (<http://abilene.internet2.edu>) and the Unidata Local Data Manager (LDM) see: [my.unidata.ucar.edu/content/software/idd/iddgeneral.html](http://my.unidata.ucar.edu/content/software/idd/iddgeneral.html) (Crum et al, 2005). This distribution allows access to base data from any of 124 operational radars in near real-time ([http://www.roc.noaa.gov/NWS\\_Level\\_2](http://www.roc.noaa.gov/NWS_Level_2)), via a cooperative hierarchical distribution network of universities and research laboratories. An LDM configured processor, "LDM System", with connectivity to a Level II distribution LDM server, may be configured to receive and archive the base data from one or more radars for later playback into the CODE ORPG.

Several organizations have set up "LDM Systems" that receive LDM data and feed the data into an ORPG for real time processing. The Level II base data is distributed in a compressed (BZIP2) form of sequential messages each consisting of multiple radials (up to 100) from the radar. On receipt, the messages may be uncompressed, reconstituting the original radial data, then fed into a CODE ORPG just as if it were directly from a radar RDA. This technique can provide a continuous live base data input stream from an operational radar into a CODE ORPG algorithm development system.

CODE does not include any guidance for setting up an LDM System and ingesting data into the ORPG. The process is rather involved and more than one method has been developed to input the collected data into an ORPG for real-time processing. It is expected that tools to accomplish this will be developed and made available for general use.

#### 4.0 Product Data Collection

The ORPG stores generated products in an internal product database. One option for capturing product output for later study is to rename and save this database file after the ORPG has been shut-down. The CODE display and analysis utilities CVT and CVG can access this saved database file as well as the active database of an ORPG. Saving product test cases in WSR-88D product database files is convenient but has limitations. If the data were run for several hours the file is extremely large and (unless the ORPG and database configuration have been changed) contains many products not of interest to the current activity. In addition, if a collection of products over several hours or days are being captured, the database has a limited size and older product messages are expired to make room for more recent products.

Though CVT can extract products from the database, this is not convenient for capturing a large set of products. There is a utility included with the ORPG called the Narrowband TCP test tool or 'NBTCP'. NBTCP connects to the ORPG TCP/IP communications manager and was originally used as a TCP/IP interface test utility.

NBTCP communicates with the ORPG and requests products using standard request messages. The requested products are saved in a specified directory in the form of single-product binary files. NBTCP can run on the same platform as the CODE ORPG or on a separate workstation on the TCP/IP network. Each file is automatically named in a manner to facilitate identification and contains the volume date-time, the product code, and short

name. CVT and CVG can load and display these product files in addition to reading products from the ORPG database.

## 5.0 Other Uses of CODE

For several years CODE has been used as the primary algorithm development and implementation environment for new science intended for integration into the WSR-88D radar. A recent summary of this work was provided in Istok, 2003. CODE is also proving useful for other analysis activities involving the processing of radar data.

### 5.1 Improvement of Satellite Sea Surface Measurements

Many satellite sensors, which have a mission to observe the ocean surface, are adversely affected by rain events. Amelioration of these problems is difficult because accurate, high resolution rain measurements have not been generally and easily available to research scientists who are seeking to understand and reduce this problem. The development of the new LINUX version of the ORPG WSR-88D CODE provides research scientists with the capability to collect simultaneous, collocated rain measurements from the Level II NEXRAD data archives through the NCDC HDSS on-line access system.

A research project focused on improving the ability of the NASA SeaWinds and QuickSCAT satellites, which employ microwave radars to measure global ocean surface winds during rain events, is benefiting from Linux CODE. This project is directed by Dr. David Weissman of Hofstra University, in collaboration with Mr. Jeffrey Tongue of the NYC office of the NWS. The level II data provides a volumetric description of the precipitation through which the satellite beam must pass. The units of the NEXRAD radar reflectivity are very similar to that which is needed to model the dominant processes that affect the satellite scatterometer radar. Good progress is being made to provide corrections to the satellite observations, using data from several coastal NEXRAD radar sites.

### 5.2 FAA Weather Systems Upgrade

The Weather Sensing Group at MIT/LL has expanded its use of the ORPG CODE clone system beyond the algorithm development process into the area of FAA Weather systems upgrade support.

The FAA's Corridor Integrated Weather System (CIWS) is a demonstration project providing en route weather impact products to ATC controllers in

an area encompassing the Northeast and Midwest United States. The ORPG CODE clones are being used to help assess the benefit CIWS' products bring to the FAA and airlines. CIWS is a real-time system and does not have an established or intended playback functionality for post-analysis purposes. CIWS ingests NEXRAD Archive II data to yield the equivalent of the NEXRAD High Resolution Vertically Integrated Liquid (HRVIL) and High Resolution Enhanced Echo Tops (HREET) products.

For the primary benefits analysis, the OPRG CODE clones are used to recreate the HRVIL and HREET from the NEXRADs within the CIWS area for post analysis of specific weather and/or delay events.

A secondary benefits analysis similarly uses the ORPG CODE clones for generation of HRVIL and HREET products. For this analysis, the products from multiple NEXRADs are put together to create a CIWS-like domain mosaic for an area outside the current CIWS domain. This is used to establish what, if any, benefit would have been realized for a weather or delay event had the demonstration CIWS domain covered this area.

## 6.0 Summary

CODE, with the inherent layered service architecture of the ORPG, has been instrumental in supporting algorithm development for the NEXRAD WSR-88D. The availability of CODE for other uses has been limited by the expense of the original platform and other system requirements. This has changed with the Linux port and the improved availability of Level II data.

Having the data processing capability of the WSR-88D RPG available on a desktop workstation along with a source of radar base data (in the form of special test cases, historical data of interest, or near-real time data) provides a very flexible radar analysis and development environment.

A recent edition of CODE is available for download at the public NWS ftp site:

[ftp://ftp.nws.noaa.gov/software/88D\\_CODE/](ftp://ftp.nws.noaa.gov/software/88D_CODE/)

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