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PNNL NEXRAD Wind Retrieval System Users Guide

RK Newsom

October 2010

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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

S.1 The PNNL Nexrad Wind Retrieval System (PNWRS)

Pacific Northwest National Laboratory's (PNNL's) Next-Generation Radar (NEXRAD) Wind Retrieval System (PNWRS) was developed to enable real-time retrieval of spatially resolved wind fields from level ii NEXRAD data. Horizontal velocity fields are retrieved from radial velocity measurements using an algorithm developed at the National Oceanic and Atmospheric Administration's National Severe Storms Laboratory (NSSL) (Xu and Gong 2003, Xu et al. 2006). This algorithm compared favorably to winds measured by wind profiling radars and to an alternate retrieval algorithm (Fast et al. 2008). The retrieval technique, which is referred to as 2DVar, is based on statistical interpolation and can be regarded as an extension of the traditional velocity azimuth display (VAD) technique (Browning and Wexler 1968). In addition to its ability to process wind fields in real-time, the PNWRS can be used to process level II NEXRAD data obtained from the National Oceanic and Atmospheric Administration/National Climatic Data Center (NCDC) archive. This document describes how to install and run the PNWRS and associated software components.

The PNWRS was developed on an x86_64 Linux workstation running Red Hat®[1] Linux®[2] 5. Software components that should be installed on the host machine include the following:

- PNWRS
- IDL 6.2 or higher
- netCDF libraries
- Unidata Local Data Manager (LDM)
- Intel®[3] Fortran Compiler.

LDM is only required in order to process a real-time data-feed. The PNWRS can be used to process archived data without LDM. Also, if the PNWRS is installed on an x86_64 Linux workstation, compilation of the Fortran executables may not be necessary, since the executables are already included in the distribution. In that case, the Intel Fortran Compiler is not be needed.

A number of routines are written in IDL®.[4] The IDL routines are used for ingesting and decoding data, generating image files, and processing hourly averaged wind fields. Thus, the PNWRS will not run without an IDL license (or run-time license).

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[3] Intel is a registered trademark of Intel Corp. in the United States and/or other countries.
[4] IDL is a registered trademark of Research Systems Inc.

Acronyms and Abbreviations

FSL	Forecast Systems Laboratory
LDM	Local Data Manager
NEXRAD	Next-Generation Radar
NCDC	National Climatic Data Center
NSSL	National Severe Storms Laboratory
PNNL	Pacific Northwest National Laboratory
PNWRS	PNNL NEXRAD Wind Retrieval System
UTC	coordinated universal time
UTM	Universal Transverse Mercator
VAD	velocity azimuth display
WSR-88D	weather surveillance radar (1988D)

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1.0 Basic Installation

The basic installation described in this section is sufficient to allow "offline" processing of archived level II weather surveillance radar (1988D), or WSR-88D, data files. This basic capability requires installation of the PNWRS and the netCDF librararies. The distribution comes with the following two compressed files:

- PNWRS_1.0.tar.gz—PNNL's Wind Retrieval System, software, and data
- netcdf-3.6.2.tar.gz—Unidata's netCDF libraries.

1.1 PNWRS Installation

Copy the PNWRS_1.0.tar.gz file to an appropriate directory on the host machine. In the following examples, it is assumed that the PNWRS is installed in the user's home directory ($HOME), but the PNWRS can be installed in any directory. The only requirement is that the internal structure not be altered.

Decompress and unpack the files using the following commands:

gunzip PNWRS_1.0.tar.gz

tar –xvf PNWRS_VER.tar

This will create the directory structure shown in Figure 1.1.

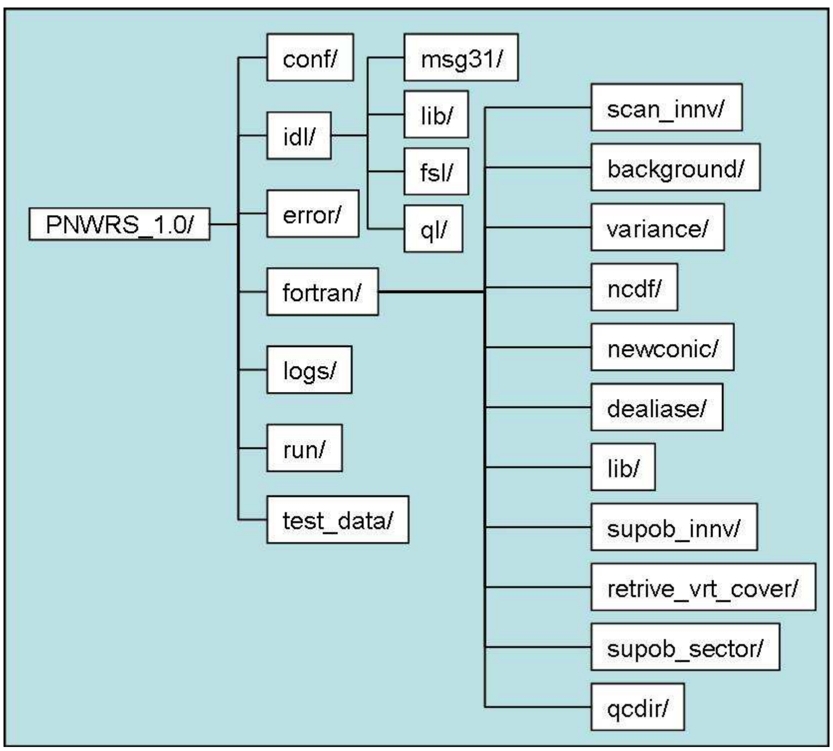

Figure 1.1. PNWRS Directory Structure

The function of each primary directory is briefly described. The conf/ directory contains configuration files that define the Universal Transverse Mercator (UTM) coordinates of virtual sounding sites, as explained in more detail in Section 3.1. The idl/ directory contains an IDL source code for decoding the Level II data format (see ICD), generating quick-look image files and computing hourly averaged data products. The fortran/ directory contains the source code that comprises the core 2DVar algorithm. The run/ directory is the main repository for all the compiled executables and scripts that coordinate various functions within the PNWRS. The logs/ directory contains log files that are generated during execution of the PNWRS. Lastly, the test_data/ directory contains sample data.

1.2 netCDF Installation

Wind field retrievals computed by the PNWRS are stored in netCDF files, which requires the netCDF libraries to be installed on the host machine. For convenience, the PNWRS distribution was shipped with a copy of netcdf-3.6.2.tar.gz, which is the netCDF version used in developing the PNWRS. To install, log in as the root user and copy the netcdf-3.6.2.tar.gz file to /usr/local. Then decompress and unpack this file using the following commands

```
gunzip netcdf-3.6.2.tar.gz

tar –xvf netcdf-3.6.2.tar
```

1.3 Example Test

Once the PNWRS and netCDF libraries have been installed, it is possible to run the PNWRS on archived data. The directory PNWRS_1.0/test_data contains sample level II WSR-88D data that was included to demonstrate how to run the PNWRS.

Typically the PNWRS resides in a user's home directory, and data (raw and processed) are stored elsewhere. Copying the contents of the test_data/ to another location (i.e., a partition with significant storage space available) is recommended since production runs, especially of data ingested and processed in real time, can grow to very large size with time. Data storage requirements depend on the number of radar sites and the length of time that the sites are processed. As an example, we found that approximately 2Tb of storage were required to store both the raw data and the PNWRS output from three radar sites over a period of about 2 years. The following example assumes that the PNWRS was installed in the user's home directory:

```
cp -r $HOME/PNWRS_1.0/test_data/ /data/PNWRS_data
```

The next step is to change directory to $HOME/PNWRS_1.0/run

```
cd $HOME/PNWRS_1.0/run
```

and then edit the $HOME/PNWRS_1.0/run/2dvar_nrl_driver.sh script such that

```
radar=KIWA

year=2010
```

month=02

day=18

homepath=$HOME/PNWRS_1.0

data_home=/data/PNWRS_data/$radar/raw

outpath=/data/PNWRS_data/$radar/2DVar

Save 2dvar_nrl_driver.sh file and then execute the script by typing

./2dvar_nrl_driver.sh

In this example, the 2dvar_nrl_driver.sh script searches the data directory for any level II WSR-88D data files acquired by the KIWA (Phoenix) radar on February 2, 2010. It then processes each file that it finds by calling the 2dvar_msg31.sh script. The 2dvar_msg31.sh script, in turn, calls the various modules associated with the 2DVar algorithm and generates quick look images and netCDF files from the output.

1.4 Input/Output Data Directory Structure

The PNWRS data directory structure is illustrated in Figure 1.2. In this example, it is assumed that the name of the top level directory is PNWRS_data/. "*RRRR*" is the four-character radar designation (e.g., KIWA, KVTX, KSOX, etc.); "*yyyymmdd*" is the year, month, and day; and "*hhmmss*" is the hour, minute, and second. All timestamps are given in coordinated universal time (UTC). This includes timestamps that appear in directory and file names, as well as timestamps inside the files themselves. A brief description of the contents of the various data directories is given below.

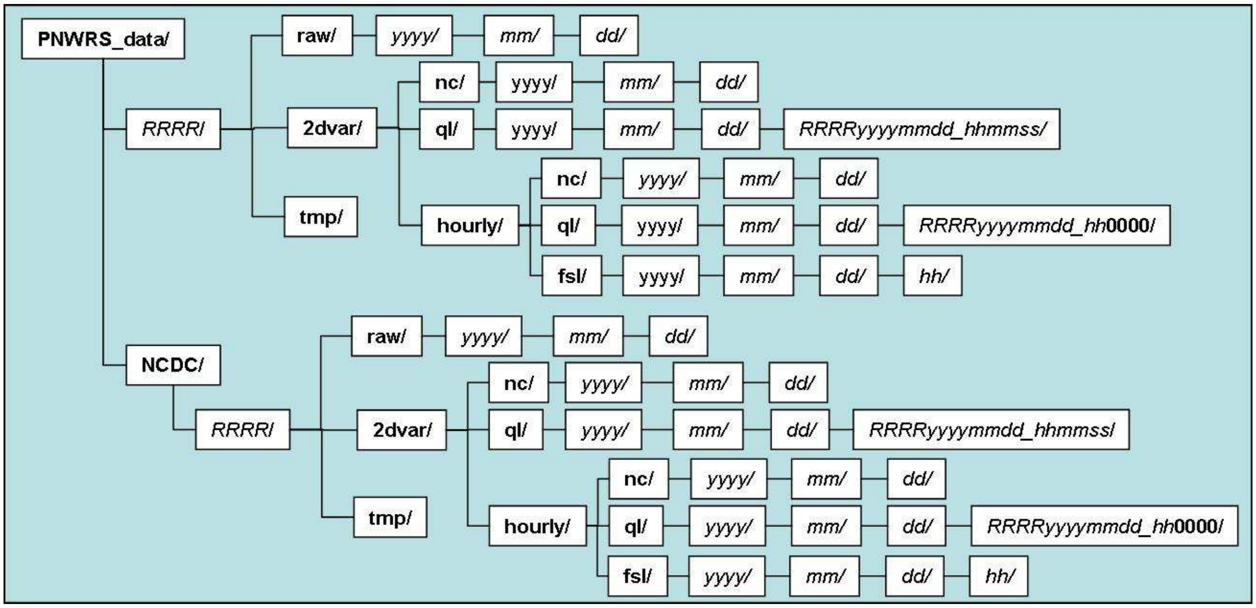

Figure 1.2. The PNWRS Data Directory Structure. In this example, it is assumed that the name of the top level directory is PNWRS_data and that this directory is located in /data. "*RRRR*" is the

four-character radar designation (e.g., KIWA, KVTX, KSOX, etc.); "*yyyymmdd*" is the year, month and day; and "*hhmmss*" is the hour, minute, and second.

1.4.1 PNWRS_data/RRRR/raw/yyyy/mm/dd

These directories contain level II WSR-88D data that were transmitted in real time via LDM, and they are used as input to the PNWRS. Files in these directories are BZIP2 compressed and the naming convention is given by *RRRRyyyymmdd_hhmmss*.bzip. Each file contains radial velocity, reflectivity, and spectral width data from a single volume scan.

1.4.2 PNWRS_data/RRRR/2dvar/nc/yyyy/mm/dd

These directories contain wind retrievals generated by the PNWRS. The file naming convention is given by RRRRyyyymmdd_hhmmss.nc. Each file in these directories contains the wind field for a given volume scan, such that there is a one-to-one correspondence between the output file name (RRRRyyyymmdd_hhmmss.nc) and the input file name (RRRRyyyymmdd_hhmmss.bzip or RRRRyyyymmdd_hhmmss.gz). Output data are stored as netCDF files. Variable names and attributes in these netCDF files are described in Appendix A.

1.4.3 PNWRS_data/RRRR/2dvar/ql/yyyy/mm/dd/RRRRyyyymmdd_hhmmss

These directories contain "quick look" image files (in PNG format) showing wind retrievals for a given volume scan. These images display the retrieved vector fields on conical scan surfaces at each elevation angle for which successful retrievals were obtained (see Figure 1.3). The naming convention for these files is *RRRRyyyymmdd_hhmmss_eee*.png, where "*eee*" is the elevation angle x 100. Also included are image files showing corresponding VAD results (i.e., profiles of the mean wind speed and direction). The naming convention for these files is given by *RRRRyyyymmdd_hhmmss*_vad.png. There is a one-to-one correspondence between the quick look directory name (*RRRRyyyymmdd_hhmmss*) and the input file name (*RRRRyyyymmdd_hhmmss*.bzip or *RRRRyyyymmdd_hhmmss*.gz).

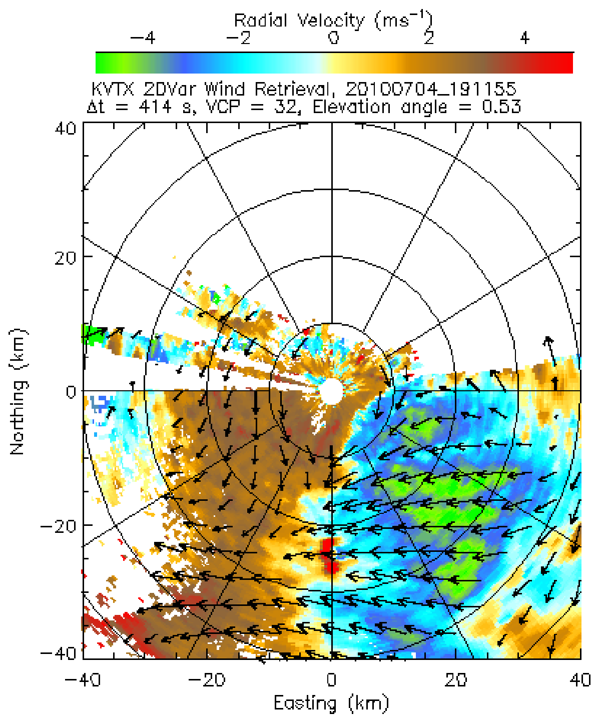

Figure 1.3. Sample Quick Look Image Produced by the PNWRS. This example shows retrieved wind vectors (u and v) on the scan surface at an elevation angle of 0.53°. (Note that for a given elevation angle, the measurements increase with height above the ground as distance from the radar increases.) The colors show the observed radial velocity field, where negative values represent flow toward the radar. These radial velocity data were acquired at about 19:00 UTC on July 4, 2010 by the KVTX (Los Angeles) radar. The easting and northing coordinates are measured relative to the radar location. The data void region in the northern half is caused by terrain blocking.

1.4.4 PNWRS_data/RRRR/2dvar/hourly/nc/yyyy/mm/dd

These directories contain hourly averaged wind fields computed by averaging retrievals from individual volume scans. The file naming convention is *RRRRyyyymmdd_hh0000*.nc, where "*hh*" is the hour at the start of the averaging interval. The format of these files is identical to the single-volume wind retrieval files (i.e., *RRRRyyyymmdd_hhmmss*.nc) as described in Appendix A.

1.4.5 PNWRS_data/RRRR/2dvar/hourly/ql/yyyy/mm/dd/RRRRyyyymmdd_hh0000

These directories contain quick look image files (in PNG format) showing hourly average wind retrievals, as stored in the *RRRRyyyymmdd_hh0000*.nc files. These images display the retrieved vector fields on conical scan surfaces at each elevation angle for which successful retrievals were obtained. The naming convention for these files is given by *RRRRyyyymmdd_hh0000_eee*.png, where "*ee*" is the elevation angle x 100. Also included are image files showing corresponding VAD results (i.e., profiles of the mean wind speed and direction). The naming convention for these files are given by *RRRRyyyymmdd_hh0000*_vad.png. There is a one-to-one correspondence between the image directory name, *RRRRyyyymmdd_hh0000*, and the data file, *RRRRyyyymmdd_hh0000*.nc.

1.4.6 PNWRS_data/RRRR/2dvar/hourly/fsl/yyyy/mm/dd/hh

These directories are used to store ASCII files containing hourly averaged profiles of wind speed and direction. Profiles are stored using the standard Forecast Systems Laboratory (FSL) sounding format (NOAA 2005). The naming convention for the sounding files is given by up*xx*.dat, where "*xx*" is a numerical index that identifies the geographic location or site of the profile. The site index and corresponding UTM coordinates for each profile are prescribed by the user and stored in the *RRRR*_upper_air_stations.dat files found in the PNWRS_1.0/conf/ directory. The *RRRR*_upper_air_stations.dat files are described in more detail in Section 3.1.

1.4.7 PNWRS_data/RRRR/tmp

These directories are used as temporary working areas by LDM's pqact.conf script. As data packets containing partial volume scans are received, they are accumulated into a single file until an end-of-volume-scan message is received. The tmp directories are used to store the partial volume scan files during this building process.

1.4.8 PNWRS_data/NCDC

As indicated in Figure 1.2, this directory has a structure that is identical to PNWRS_data/. The PNWRS_data/NCDC/RRRR/raw directories are used to store level II WSR-88D data obtained from the National Oceanic and Atmospheric Administration/NCDC archive. The NCDC data files use a different compression method and a slightly different data format than the files transmitted through the real-time data feed by LDM. LDM data can be processed either offline by the user or autonomously in near-real-time, whereas the NCDC data are only processed offline. The main function of the PNWRS_data/NCDC directory is to maintain a clear separation between input data and results obtained from these two different sources (NCDC vs LDM). The NCDC level II data are compressed using GZIP and the naming convention is given by *RRRRyyyymmdd_hhmmss*.gz. Information about how to obtain level II WSR-88D data from NCDC is given below.

1.5 Obtaining Archived Level II WSR-88D Data

Level II WSR-88D data can be obtained from NCDC through http://www.ncdc.noaa.gov/nexradinv/. This site provides a graphical interface for selecting the radar site. Once the site is selected, the user then specifies the time period. Also, be sure to select level II (base data) when making the request. After the request is submitted, the user will be notified via email when the data is ready for FTP. This service is free to universities and government organizations. An annual subscription fee is charged for private-sector users.

2.0 Near-Real-Time Data Processing Using LDM

In addition to offline processing of archived data, the PNWRS can be used to process a real-time feed of level II WSR-88D data. This feature requires the installation of Unidata's LDM software on the host machine and permission to receive data from one of four top-tier distribution sites. This section describes the procedure for setting up the real-time processing feature.

2.1 Obtain Permission to Receive Data

Data from WSR-88D sites are initially transmitted to one of four National Weather Service's regional servers. Using the Unidata LDM software, the data from each of the four National Weather Service's servers are routed to four top-tier sites for distribution to the general user community (Crum et al. 2010). In order to receive data, the user must contact the person responsible for administering data flow at one of the top-tier sites. Once the request is approved, the administrator at the top-tier site will set up their LDM server to "allow" transmission to the user's local machine (IP address). The following is a listing of top-tier sites and contact information:

- University of Maryland
- Education and Research Consortium of the Western Carolinas, Hunter Goosmann, 828-350-2415, hgoosmann@ercwc.org
- Purdue University, Professor Matthew Huber, 765-494-3258, huberm@purdue.edu
- University of Oklahoma, Craig Cochell, 405-325-8689, craigc@ou.edu.

Currently PNNL receives data from the Purdue site.

2.2 Install LDM

The Unidata LDM is a collection of cooperating programs that select, capture, manage, and distribute arbitrary data products. The system is designed for event-driven data distribution and includes network client and server programs and their shared protocols.

The current version of LDM is freely available, and can downloaded from the Unidata website at http://www.unidata.ucar.edu/software/ldm/. This site also provides detailed installation instructions and a wealth of documentation on using and configuring LDM. It is beyond the scope of this document to describe all of the functionality of LDM. The following subsections provide specific instructions on how to configure LDM to receive a live data feed of level II WSR-88D and to enable processing of this data by the PNWRS.

2.3 Configuring LDM

Configuration files for LDM are located in the etc/ directory of the LDM distribution. For reference, sample LDM configuration files are provided with the current PNWRS distribution. It is important to note that a number of parameters in these files are specific to the PNNL host machine and to the data source. These parameters will need to be modified for LDM and the PNWRS to run on a different machine.

Currently PNNL receives level II WSR-88D data from the LDM server at Purdue University (castor.itap.purdue.edu). For instructional purposes, the following examples assume that the upstream LDM server is castor.itap.purdue.edu and that data are being requested for the KPDT (Pendleton, Oregon) radar. To receive data from a different radar, simply replace ‘KPDT’ with the desired four-character radar name. A complete listing of WSR-88D radar names is provided in Appendix A.

2.3.1 Modify the etc/netcheck.conf File

Add the appropriate address for the upstream LDM server. This is the address of a top-tier server and is the server from which the local machine receives its data, e.g.,

upstream:castor.itap.purdue.edu

2.3.2 Modify the etc/ldmd.conf File

Modify the “request” statement to specify the upstream server address and radar name. For example, to receive level II WSR-88D data from the KPDT radar via the Purdue LDM server, the “request” statement would be:

REQUEST NEXRAD2 “L2-BZIP2/(KPDT)” castor.itap.purdue.edu

2.3.3 Modify the etc/ pqact.conf File

The pqact.conf file tells LDM what to do when requested data packets are received. In order for the PNWRS to process the data feed, the following (example) lines must appear in the pqact.conf file:

NEXRAD2 ^L2-BZIP2/(KPDT)/([0-9][0-9][0-9][0-9][0-1][0-9][0-3][0-9])([0-2][0-9][0-5][0-9])([0-9][0-9])

FILE /data/PNWRS_data/\1/tmp/\1\2_\3\4

NEXRAD2 ^L2-BZIP2/(KPDT)/([0-9][0-9][0-9][0-9][0-1][0-9][0-3][0-9])([0-2][0-9][0-5][0-9])([0-9][0-9]).*/E/

EXEC /usr/local/ldm/PNWRS_1.0/run/Process_Radar.sh \1\2_\3\4

Again, the above example assumes that data from the KPDT radar was requested (in the ldmd.conf file), that the top level data directory is /data/PNWRS_data, and that the PNWRS distribution resides in /usr/local/ldm. The user will have to make appropriate changes to these paths to get the PNWRS to run on the local machine.

The first “*NEXRAD2*” statement above tells LDM to append data packets to a file in the /data/PNWRS_data/KPDT/tmp directory. The second “*NEXRAD2*” statement tells LDM to initiate processing by the PNWRS if an end-of-volume-scan signal is received (/E).

3.0 Hourly Averaged Wind Fields and FSL Output

When the PNWRS is coupled to LDM to generate near-real-time wind retrievals, the retrieval algorithm is called whenever a complete volume scan is received. The time it takes a radar to complete a single volume scan is generally between 5 and 10 minutes, depending on the particular volume coverage pattern. The PNWRS processes volume scans with negligible latency (it typically takes about 30 seconds on a modern x86_64 Linux workstation). As a result, the PNWRS usually generates about 6 to 12 wind retrieval (netCDF) files per hour.

For many mesoscale modeling applications, hourly averaged upper air soundings are desired. It is also desired to have these soundings provided in a standard sounding data format. Thus, the functionality was added to the PNWRS to generate hourly averaged wind retrievals in standard FSL format (NOAA 2005). Hourly averaged wind fields are computed by averaging wind retrievals produced from individual volume scans. As noted above, there are typically between 6 and 12 volume scans (and wind retrievals) per hour. These hourly averaged data products can be generated from either archived wind retrievals or from retrievals produced in real-time. The process for generating the hourly averaged wind fields is described in the following subsections.

3.1 Virtual Sounding Sites

To generate hourly averaged wind fields, the user must first define the locations at which upper air soundings are desired. This involves creating an ASCII file that contains the UTM coordinates of the virtual sounding stations. These files are stored in the /PNWRS_1.0/conf directory. The file names are given by *RRRR*_upper_air_stations.dat, where "*RRRR*" is the usual four letter radar name (e.g., KIWA, KVTX, KPDT, etc.). A sample listing for the KPDT radar is provided below.

```
11, UTM Zone
Name   ID   Xcoord (km) Ycoord (km) Time Zone elevation(m)
KPDT,  0,    315.7382,   5036.3364, 8, 750.13
KPDT,  1,    323.7382,   5036.3364, 8, 860.14
KPDT,  2,    331.7382,   5036.3364, 8, 816.67
KPDT,  3,    339.7382,   5036.3364, 8, 761.35
KPDT,  4,    347.7382,   5036.3364, 8, 703.36
KPDT,  5,    355.7382,   5036.3364, 8, 574.10
KPDT,  6,    363.7382,   5036.3364, 8, 751.05
KPDT,  7,    371.7382,   5036.3364, 8, 961.02
KPDT,  8,    379.7382,   5036.3364, 8, 837.18
```

The first line in the file specifies the UTM zone (11 in this case). The first and second columns of subsequent lines contain the radar name and the station ID, respectively. The third and forth columns contain the UTM easting and northing coordinates, respectively. The last column is the surface altitude of the site in meters above sea level.

The station ID is used when creating the FSL sounding files. One sounding file is created for each hour and for each virtual sounding station specified in the *RRRR*_upper_air_stations.dat file. The naming convention for the sounding files is up*xx*.dat, where "*xx*" is the site ID. As described in Section 1.4, these FSL sounding files are stored in the

PNWRS_data/*RRRR*/2dvar/hourly/fsl/*yyyy*/*mm*/*dd*/*hh* directory.

Range from radar is an important consideration when constructing the *RRRR*_upper_air_stations.dat files. Generally, the ground range between the virtual sounding site and the radar should not exceed 50 km, although retrievals are possible at ranges up to 100 km under favorable weather conditions. Beyond 50 km, the retrievals become increasingly sparse and less accurate.

3.2 Hourly Averages from Archived Retrievals

The computation of hourly averaged wind fields from archived retrievals is achieved by editing and then running the convert_to_fsl_driver.sh script, found in the PNWRS_1.0/run directory. In order to run this script, it must be properly configured. In general, the following lines will need to be modified by the user:

```
DATA_HOME=/data/PNWRS_data

PNWRS_HOME=$HOME/PNWRS_1.0

IDL=/usr/local/bin/idl

NEXRAD_RADAR_NAME=KIWA

YYYYMMDDHH=2010021819
```

In the above example, the script is configured to compute hourly averages using retrievals from the KIWA radar at 19:00 UTC on February 18, 2010. The above example assumes that the top level data directory is /data/PNWRS_data, that IDL is located in /usr/local/bin/idl, and that the PNWRS distribution is located in the users $HOME directory. If any of these directories are different on the host machine, they will need to be modified accordingly.

3.3 Hourly Averages from Real-Time Retrievals

The computation of hourly averaged wind fields from the real-time data feed is handled as a so-called cron-job. To set up the cron-job the user must edit the crontab file by typing

```
crontab -e
```

and adding the appropriate lines. As an example, the PNNL crontab file contains the following lines:

```
0 * * * * $HOME/PNWRS_1.0/run/convert_to_fsl.sh KPDT

0 * * * * $HOME/PNWRS_1.0/run/convert_to_fsl.sh KVTX

0 * * * * $HOME/PNWRS_1.0/run/convert_to_fsl.sh KSOX
```

These lines tell the crontab to execute the convert_to_fsl.sh script at the beginning of every hour. In this case, the algorithm searches for and then averages all single-volume retrievals that were created during the previous hour.

4.0 Compilation

If the PNWRS is installed on an x86_64 Linux machine running Red Hat Linux 5, recompilation should not be necessary. Nevertheless, this section describes the process in the event that recompilation is necessary. Compilation of the Fortran codes requires that the Intel Fortran Compiler (version 10.1 or higher) be installed on the host machine.

4.1 Fortran

The PNWRS_1.0/run directory is the repository for all executable files used by the PNWRS. The following is a list of all executable files generated from Fortran source files:

background.x

Ncdf.x

newconic.x

QC3d.x

scan_innv.x

supob_innv.x

supob.x

variance.x

vrvt_rt.x

The source files for these executable files are stored in the various subdirectories under the PNWRS_1.0/fortran directory.

The make_2dvar.sh script, which is located in the PNWRS_1.0/run directory, can be used to compile one or more of the Fortran executables. To compile all the executables simply set the following variables to 1:

((lib=1))

((ncdf=1))

((dealiase=1))

((qc=1))

((background=1))

((supob=1))

((scan_innv=1))

((supob_innv=1))

((retrive=1))

((newconic=1))

((variance=1))

To disable compilation of a particular executable, set the corresponding variable to 0. To execute the make_2dvar.sh script, type the following at the Linux command prompt:

./make_2dvar.sh

4.2 IDL

In addition to the Fortran sources, there are a number IDL routines that are used to decode the compressed level II data, to generate quick look image files, and to compute hourly averaged data products. Like Matlab, IDL is a high-level interpretative language. For distributable applications, IDL does not compile source files. Instead, any procedures or functions used by an application must be resolved and contained in a so-called SAVE file. Table 4.1 describes the functionality associated with each of the three IDL .sav files used in the PNWRS. This section describes how to recreate (or compile) these .sav files

Table 4.1. IDL .sav Files Used in the PNWRS and Their Functions

IDL .sav File Name	Function
qc_input_msg31.sav	Reads the compressed LDM or NCDC level II WSR-88D data files and converts to a format readable by the NSSL quality control algorithm QC3d.x
plot2dvarql.sav	Reads a netCDF file generated by the PNWRS and creates quick-look image files of the retrieved wind field
convert_to_fsl.sav	Computes an hourly averaged wind field, generates quick-look image files, stores the results to a netCDF files, and creates sounding files in FSL format

4.2.1 qc_input_msg31.sav

To create the qc_input_msg31.sav file, change directories to PNWRS_1.0/idl/msg31/, and begin an IDL session by typing

idl

Then, at the IDL command prompt type the following:

.r make_qc_input.pro

This will execute the IDL script that creates the qc_input_msg31.sav in the PNWRS_1.0/run directory.

4.2.2 plot2dvarql.sav

To create the plot2dvarql.sav file, change directories to PNWRS_1.0/idl/ql/, and begin an IDL session by typing

idl

Then, at the IDL command prompt type the following:

.r make_ql.pro

This will execute the IDL script that creates the plot2dvarql.sav in the PNWRS_1.0/run directory.

4.2.3 convert_to_fsl.sav

To create the plot2dvarql.sav file, change directories to PNWRS_1.0/idl/fsl/, and begin an IDL session by typing

idl

Then, at the IDL command prompt type the following:

.r make_fsl.pro

This will execute the IDL script that creates the convert_to_fsl.sav in the PNWRS_1.0/run directory.

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Appendix A

Appendix A

A.1 netCDF File Format

The PNWRS stores retrieved wind fields in netCDF files. The retrieved wind components (u and v) are typically defined on a uniform horizontal grid at several scan elevation angles, although the retrieval locations can be irregularly spaced. The dimensions of the retrieved wind components are nel, nx, and ny, where nel is the number of elevation angles, and nx and ny are the horizontal grid dimensions. The coordinates of the horizontal grid are defined by the arrays x (easting) and y (northing) and are measured in kilometers relative to the radar site. Since the winds are defined on the scan surfaces, the vertical coordinates of u and v depend on x and y. Thus, the vertical coordinate z has the same dimensions as u and v (nel, nx, and ny).

The netCDF files also contain the measured radial velocity data from the radar and the VAD wind profiles produced by the PNWRS. Radial velocity data are stored in the ur_raw variable. This variable has dimensions nel, naz, and nr, where naz is the number of azimuth angles and nr is the number of range samples. The elevation angle, azimuth angles, and range values are stored in el_raw, az_raw, and r_raw, respectively.

The following listing summarizes the structure of the PNWRS netCDF files.

```
netcdf KIWA20070312_081850 {

    dimensions:
        nx = 81 ;
        ny = 81 ;
        nel = 3 ;
        nvad = 51 ;
        nr = 400 ;
        naz = 370 ;

    variables:

        float x(nx) ;
            x:units = “km” ;
            x:comment = “x coordinate (relative to radar) of retrieved
            velocity” ;

        float y(ny) ;
            y:units = “km” ;
            y:comment = “y coordinate (relative to radar) of retrieved
            velocity” ;
```

```
float z(nel, ny, nx) ;
    z:units = “m” ;
    z:comment = “Height (relative to radar) of retrieved
    velocity” ;

float u(nel, ny, nx) ;
    u:units = “m/s” ;
    u:comment = “x-component of retrieved velocity” ;

float v(nel, ny, nx) ;
    v:units = “m/s” ;
    v:comment = “y-component of retrieved velocity” ;

float r_raw(nr) ;
    r_raw:units = “km” ;
    r_raw:comment = “range to gate center of raw data” ;

float az_raw(nel, naz) ;
    az_raw:units = “degrees” ;
    az_raw:comment = “Azimuth angle of raw data” ;

float el_raw(nel) ;
    el_raw:units = “degrees” ;
    el_raw:comment = “Elevation angle of raw data” ;

float ur_raw(nel, naz, nr) ;
    ur_raw:units = “m/s” ;
    ur_raw:comment = “raw radar radial velocity” ;

float z_vad(nvad) ;
    z_vad:units = “m” ;
    z_vad:comment = “z coordinate (relative to radar) of
    velocity in VAD profile” ;

float u_vad(nvad) ;
    u_vad:units = “m/s” ;
    u_vad:comment = “x component of velocity in VAD
    profile”;

float v_vad(nvad) ;

    v_vad:units = “m/s” ;

    v_vad:comment = “y component of velocity in VAD
    profile”;

// global attributes:
:TypeName = “2DVar Wind Retrieval” ;
:radar_name = "KIWA" ;
:vcp = 32 ;
:radar_latitude = 33.289 ;
:radar_longitude = -111.67 ;
:radar_altitude = 427. ;
```

```
:start_seconds_since_19700101 = 1173687681 ;
:elapse_seconds = 423 ;
:Missing = 999. ;
}
```

A.2 Radar Sites

A listing of WSR-88D sites are given in Table A.1 below. This information is also contained in the nexrad.information file located in the PNWRS_1.0/run directory.

Table A.1. WSR-88D Sites

Radar Name	Site Name	North Latitude			West Longitude			Alt (m)
		deg	min	sec	deg	min	sec	
KABR	Aberdeen	45	27	21	98	24	47	416
KABX	Albuquer	35	8	59	106	49	26	1809
KAKQ	Wakefld	36	59	2	77	0	26	59
KAMA	Amarillo	35	14	0	101	42	33	1113
KAMX	Miami	25	36	40	80	24	46	29
KAPX	Alpena	44	54	26	84	43	11	471
KARX	LaCrosse	43	49	22	91	11	28	409
KATX	Seattle	48	11	40	122	29	45	181
KBGM	Binghmtn	42	11	59	75	59	5	514
KBHX	Eureka	40	29	54	124	17	31	762
KBIS	Bismark	46	46	15	100	45	38	530
KBLX	Billings	45	51	14	108	36	24	1112
KBMX	Birmnghm	33	10	20	86	46	11	227
KBOX	Boston	41	57	21	71	8	13	66
KBRO	Brwnsvil	25	54	58	97	25	8	22
KBUF	Buffalo	42	56	56	78	44	12	236
KBYX	KeyWest	24	35	51	81	42	11	23
KCAE	Columbia	33	56	55	81	7	6	100
KCBW	Caribou	46	2	21	67	48	23	262
KCBX	Boise	43	29	26	116	14	8	953
KCCX	StateCol	40	55	23	78	0	13	753
KCLE	Clevelnd	41	24	47	81	51	35	257
KCLX	CharlSC	32	39	20	81	2	32	58
KCRP	CorpusCr	27	47	3	97	30	40	43
KDAX	Sacramen	38	30	4	121	40	40	39
KDDC	DodgeCty	37	45	39	99	58	8	809
KDIX	Philadel	39	56	49	74	24	39	65
KDLH	Duluth	46	50	13	92	12	35	465
KDMX	DesMoine	41	43	52	93	43	22	329

Table A.1. (contd)

Radar Name	Site Name	North Latitude deg	North Latitude min	North Latitude sec	West Longitude deg	West Longitude min	West Longitude sec	Alt (m)
KDTX	Detroit	42	41	59	83	28	18	357
KDVN	Davnport	41	36	42	90	34	51	254
KEAX	KansCity	38	48	37	94	15	52	328
KEMX	Tucson	31	53	37	110	37	49	1616
KENX	AlbanyNY	42	35	11	74	3	50	577
KEPZ	ElPaso	31	52	23	106	41	53	1281
KESX	LasVegas	35	42	4	114	53	29	1503
KEWX	Austin	29	42	14	98	1	42	218
KEYX	Edwards	35	5	52	117	33	39	865
KFCX	Roanoke	37	1	28	80	16	26	899
KFDR	Fredrick	34	21	44	98	58	35	396
KFFC	Atlanta	33	21	46	84	33	57	292
KFSD	SiouxFal	43	35	16	96	43	46	451
KFSX	Flgstaff	34	34	28	111	11	52	2286
KFTG	Denver	39	47	12	104	32	45	1705
KFWS	FtWorth	32	34	23	97	18	11	228
KGGW	Glasgow	48	12	23	106	37	30	713
KGJX	GrndJnxn	39	3	44	108	12	50	3061
KGLD	Goodland	39	22	1	101	42	1	1127
KGRB	GreenBay	44	29	54	88	6	41	237
KGRR	GrndRapd	42	53	38	85	32	41	261
KGSP	Greer	34	53	0	82	13	12	322
KGWX	Columbus	33	53	48	88	19	44	165
KGYX	PrtlndME	43	53	29	70	15	23	140
KHGX	Houston	29	28	19	95	4	45	30
KHNX	Hanford	36	18	51	119	37	56	100
KHTX	Huntsvil	34	55	50	86	5	0	551
KICT	Wichita	37	39	17	97	26	34	421
KICX	CedarCty	37	35	27	112	51	44	3261
KILN	Cincnati	39	25	13	83	49	18	352
KILX	LinclnIL	40	9	2	89	20	13	207
KIND	Indianap	39	42	27	86	16	49	266
KINX	Tulsa	36	10	30	95	33	53	224
KIWA	Phoenix	33	17	21	111	40	12	427
KIWX	FtWayne	41	21	32	85	42	0	293
KJAN	JacksnMS	32	19	4	90	4	48	116
KJAX	Jaxnvill	30	29	5	81	42	7	35
KJKL	JacksnKY	37	35	27	83	18	47	446
KLBB	Lubbock	33	39	15	101	48	51	1013
KLCH	LkCharls	30	7	31	93	12	57	24

Table A.1. (contd)

Radar Name	Site Name	North Latitude			West Longitude			Alt (m)
		deg	min	sec	deg	min	sec	
KLIX	NewOrlns	30	20	12	89	49	32	37
KLNX	N.Platte	41	57	28	100	34	35	930
KLOT	Chicago	41	36	17	88	5	5	227
KLRX	Elko	40	44	23	116	48	10	2086
KLSX	St.Louis	38	41	56	90	40	58	215
KLTX	WilmngOH	33	59	22	78	25	44	39
KLVX	Louisvil	37	58	31	85	56	38	249
KLWX	Sterling	38	58	31	77	28	40	107
KLZK	LitlRock	34	50	11	92	15	44	193
KMAF	Midland	31	56	36	102	11	21	889
KMAX	Medford	42	4	52	122	43	2	2299
KMBX	MinotAFB	48	23	33	100	51	54	465
KMHX	Morehead	34	46	34	76	52	34	39
KMKX	Milwauke	42	58	4	88	33	2	307
KMLB	Melbourn	28	6	48	80	39	15	31
KMOB	Mobile	30	40	46	88	14	23	83
KMPX	Minneapl	44	50	56	93	33	56	318
KMQT	Marquett	46	31	52	87	32	54	460
KMRX	Knoxvill	36	10	7	83	24	6	433
KMSX	Missoula	47	2	28	113	59	10	2404
KMTX	SaltLake	41	15	46	112	26	52	1999
KMUX	SanFran	37	9	19	121	53	54	1077
KMVX	GrndFork	47	31	40	97	19	32	325
KNKX	SanDiego	32	55	8	117	2	31	316
KNQA	Memphis	35	20	41	89	52	24	111
KOAX	Omaha	41	19	13	96	22	0	380
KOHX	Nashvill	36	14	50	86	33	45	201
KOKX	NewYork	40	51	56	72	51	50	56
KOTX	Spokane	47	40	49	117	37	36	742
KPAH	Padukah	37	4	6	88	46	19	149
KPBZ	Pittsbrg	40	31	54	80	13	5	381
KPDT	Pndlton	45	41	26	118	51	10	477
KPUX	Pueblo	38	27	34	104	10	53	1615
KRAX	Raleigh	35	39	56	78	29	23	136
KRGX	Reno	39	45	15	119	27	44	2554
KRIW	Riverton	43	3	58	108	28	38	1712
KRLX	CharlWV	38	18	40	81	43	23	359
KRTX	PrtlndOR	45	42	53	122	57	55	509
KSFX	IdahoFls	43	6	21	112	41	10	1384
KSGF	Sprgfild	37	14	7	93	24	2	414

Table A.1. (contd)

Radar Name	Site Name	North Latitude			West Longitude			Alt (m)
		deg	min	sec	deg	min	sec	
KSHV	Shrvport	32	27	3	93	50	29	113
KSJT	SanAnglo	31	22	17	100	29	33	606
KSOX	SantaAna	33	49	4	117	38	9	938
KSRX	FtSmith	35	17	26	94	21	42	215
KTBW	Tampa	27	42	20	82	24	6	32
KTFX	GreatFal	47	27	35	111	23	7	1147
KTLH	Talhasee	30	23	51	84	19	44	49
KTLX	OklaCity	35	19	59	97	16	40	384
KTWX	Topeka	38	59	49	96	13	57	427
KUDX	RapidCty	44	7	30	102	49	47	949
KUEX	GrandIsl	40	19	15	98	26	31	622
KVNX	VanceAFB	36	44	27	98	7	40	379
KVTX	LosAngls	34	24	42	119	10	46	851
KYUX	Yuma	32	29	43	114	39	24	67

A.3 Flow Diagram

Figure A.1 illustrates the various operations and the flow of data associated with the real-time wind retrieval system, as implemented on the PNNL Linux computer. Packets of WSR-88D level II data containing partial volume scan data are transmitted by the Purdue LDM server and received by PNNL LDM server. These data records are accumulated in the local LDM product queue (pq) buffer until an end-of-volume message is received. At this point, processing by the PNWRS is initiated.

The crontab on the local machine is configured to run a script at the top of each hour. The script calls routines that compute an average wind retrieval (over the previous hour) and creates FSL formatted sounding files from these results.

The processes described above run continuously for indefinite periods. It is important that the clock on the local computer be maintained accurate to within approximately 30 seconds of true UTC time.

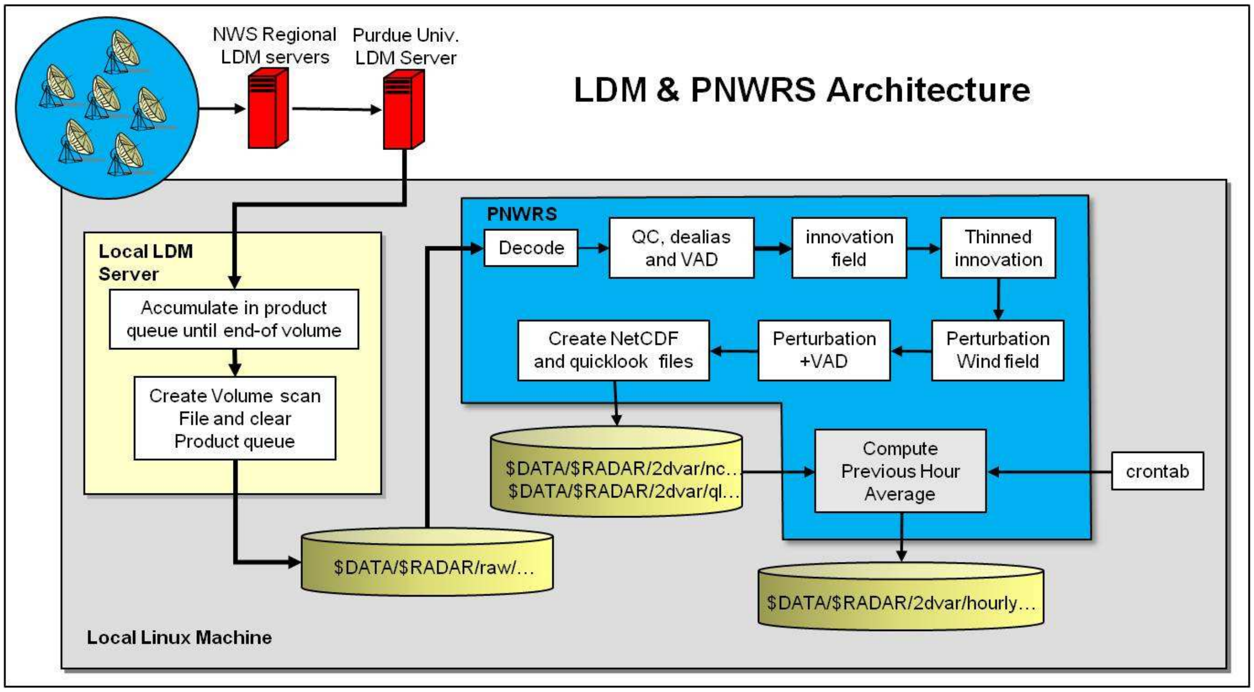

Figure A.1. Flow Diagram Showing the NEXRAD Data Distribution Architecture, the LDM Ingest, and the PNWRS

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