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1. INTRODUCTION

The Radar Operations Center (ROC) is a tri-agency (Department of Commerce, National Weather Service (NWS); Department of Defense, Air Force Weather; and Department of Transportation, Federal Aviation Administration (FAA)) organization whose mission is to provide support for the WSR-88D weather radar system. As technology continues to advance, so has our ability to provide better data quality for operations by incorporating improvements to operational algorithms. In the past, field tests were conducted to determine the viability of new signal processing software algorithms, but with today's ability to record Level 1 data, these algorithms can be thoroughly tested and deployed without requiring a field test. Level 1 data can also be used to determine causes of algorithm failure or discover hardware failures. This paper summarizes the history of data recording, describes the current process of data collection and archiving, describes the application of the data, and provides information on how researchers can retrieve the data from the National Center for Environmental Information (NCEI) for use.

2. HISTORY AND EVOLUTION OF DATA RECORDING

Level 1 data (raw In-phase & Quadrature (I&Q) data or time series data) is critical for algorithm design, development, and evaluation. Originally, the ability to use the data was challenging, due to the limitations of data storage capabilities. As data storage technology has improved, so has our ability to record and use more data.

Original Level 1 data collection only allowed for the capture of a portion of a single cut of a volume due to storage limitations. That coupled with the inability to use data playback for evaluation severely limited the usefulness of the data. As storage capabilities increased, the Ts2File utility software and a control interface were developed. Level 1 recording was then completed with a laptop connected to the radar and the data were recorded to an external large-capacity hard drive. These data were returned to the ROC and archived at the National Severe Storms Laboratory (NSSL). Larger internal storage capacity for the radar allowed for recording up to two volumes of data and then burning the data to a DVD. These DVDs would be returned to the ROC for analysis. (Prather, 2012)

When the Service Life Extension Program (SLEP) reached the signal processor upgrade phase, the computer selected for the RDA introduced an internal hot-swappable hard drive with 2 TB

of storage space. The purpose behind this design was to allow for the replacement of a failed hard drive without needing to replace the entire computer. After deployment was completed, an investigation was made to determine whether Level 1 recording could be performed continuously at operational sites. The Ts2File software is used to create the Level 1 files on the internal drive. To prevent filling the drive, a maintenance script checks the amount of available disk space every 15 minutes, removing the oldest files to maintain free space for operations and continuous recording. Testing demonstrated that Level 1 recording could be performed in the background without any negative impacts on performance. As a safeguard, the operational software also checks hard drive performance and will turn off Level 1 recording if there are indications of a potential problem with the drive while recording is on. Level 1 recording is turned on by default at all sites and can be manually turned off by the forecast office or a technician.

The ROC determined that it would be beneficial for the data to be securely archived in a location that would be available to the general public. NCEI retains and distributes WSR-88D Level 2 and Level 3 data (FMH No. 11, Part A). With the growing size of the local archive and the increased demand for the data, ROC personnel worked with NCEI to create a framework for archiving Level 1 data with corresponding metadata. NCEI developed a web interface where this data can be searched and downloaded. The interface control document (ICD) for the Level 1 data is also available for anyone who wishes to work with the data.

3. CURRENT DATA RETRIEVAL PROCESS FROM TESTBED AND OPERATIONAL SITES

The ROC can collect Level 1 data from the testbed radar configurations whenever the radar is operational and Level 1 recording is active. The testbed radars are connected to the ROC network, and the data are spooled on designated drives. The process clears old data using the same maintenance scripting process as the internal drives on the radar. When data are to be used, collected, and archived, the data are copied from the spool and sent to NCEI using the usual archiving process. This process allows for easier data collection during testing, particularly when there is a need to troubleshoot the radar or unexpected algorithm behavior is observed. It is much easier to collect data from the testbed, and most of the collected data in the NCEI archive is collected from it.

There are three scenarios for requesting data from an operational site: acquiring data to investigate performance anomalies, a determination by software engineers at the ROC that data have characteristics needed for algorithm development and enhancement, and advance planning to acquire particular sets of data for an upcoming event. An operational site may choose not to participate in data collection, and when deciding to pursue data collection, sites that are remote from the nearest weather forecast office are not often chosen because of the

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amount of time and expense it would take for a technician to reach the site and exchange the hard drive.

When a site reports a data quality issue to the ROC WSR-88D Hotline, a Hotline representative may contact a site technician to request that the data be sent to the ROC for analysis, particularly when the cause of the data quality issue is indeterminate. The data can be used to isolate the underlying cause of the issue, which may be hardware or software related. If the anomaly is determined to be from a hardware issue, steps are taken to work with the site technicians to correct or repair it. If the cause is a shortcoming or failure of a signal processing algorithm, the Level 1 data are used along with data playback processes to determine the cause of the failure and to release an update to the algorithm in a future software release.

When there is a need or interest in acquiring the data, the ROC Hotline discusses it with the site's radar operators and, if they agree to send the data, the Level 1 recording process is halted to preserve the data for collection. The ROC sends a replacement hot-swappable hard drive to the site. The site technician will then take the radar offline and exchange the drive. The process takes about 5-10 minutes to execute, resulting in minimal radar downtime. The radar is then restored to operation and the hard drive containing the data is shipped back to the ROC. Once the drive is received at the ROC, the available Level 1 data times are retrieved from the disk and a block of data is selected for archiving. That data is then compressed and prepared for electronic transfer to NCEI.

Level 1 data sets have been archived at NCEI and available to the public since 2020. Prior to archiving, the selected Level 1 data are compressed and combined into hourly archive files. A summary file with a short narrative about the weather or atmospheric conditions that were captured in the data set is generated, along with a metadata file which is used to catalog the data set in the NCEI database. This metadata includes the radar site, date and time range, VCP(s) utilized, and keywords (e.g., tornado, gust front, wind farm, etc.) for more efficient searching. Files are transmitted to NCEI over a secure connection, where each individual file is verified as complete before being archived. Once data are archived at NCEI they become available to the general public for download through a web interface.

The data selection criteria for determining collection depends upon the situation. Some collections are for addressing performance issues in response to Hotline requests, but most are ROC requests made after events of significance or interest. Priority is given to selecting data sets that differ from cases that are already contained in the database, such as weather types, performance anomalies, or scanning strategies. The ROC has also requested assistance from sites in advance of predicted weather events, such as hurricanes or blizzards, so that the data can be collected. Three recent planned collections were: Hurricane Ian in September 2022, from both KBYX (Key West, FL) and KTBW (Tampa Bay, FL); the lake effect snow storm in November 2022 from KBUF (Buffalo, NY); and tornadic thunderstorms in central Iowa on March 31, 2023 from KDVN (Quad Cities, IA) and KDMX (Des Moines, IA). All of these data sets are available for download at NCEI. Because Level 1 data files are large in size, reviewing corresponding Level 2 data to determine the usefulness of a data set is recommended.

4. AVAILABILITY AND USE

With the establishment of the archive at NCEI, the data are more easily accessible to the research community. It is our hope that with the increased availability of the data that these data will be more widely used for the development of new algorithms and signal processing techniques. The ROC has used the data for troubleshooting, algorithm development, radar performance evaluation, and scanning strategy development. By using data playback techniques, many cases can be processed and the performance of new algorithms evaluated without requiring operational time on a radar system. Using data playback substantially decreases the amount of time it takes to release new signal processing methods to operations. Techniques for which NEXRAD Level 1 data have been used thus far are radial based noise estimation (Ivic, 2014), bias reduction (Ivic, 2019), azimuthal sampling (Nai, 2020), Clutter Mitigation and Detection (Ellis, 2022), wind turbine clutter detection (Dixon, 2023), and others.

Currently, the link for the NCEI Level 1 data search engine can be found at <https://www.ncei.noaa.gov/access/search/data-search/nexrad-level-1-event-data>. The page has an interactive search to allow users to find desired events or features in the data. Some examples of options are: clutter, hurricane, quasilinear convective system (QLCS), tornado, wind farm, and blizzard. Searches can also be performed by radar ICAO, date, state, and VCP. Metadata and file descriptions can be found at <https://www.ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.ncdc:C01597>.

5. CONCLUSION

Level 1 data are a valuable resource for algorithm development and performance analysis on I&Q signals. Through collaborative efforts of the WSR-88D community and technological advancements, Level 1 data can now be obtained much more efficiently and effectively than in the past. The advancement of data storage capacity has significantly impacted our ability to use Level 1 data, and their availability through the NCEI archive will allow more researchers to utilize real-time data to develop more effective algorithms for the improvement of radar data quality. In turn, this will have substantial benefits to and increase accuracy of forecasting and benefit the public by protecting lives and property.

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