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9.4 ACHIEVING HIGHER INTEGRITY IN NEXRAD PRODUCTS THROUGH MULTI-SENSOR INTEGRATION * †

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1. INTRODUCTION

The initial operational concept for the NEXRAD focused on support for the operational forecaster based on longstanding practice in use of weather radars by the National Weather Service (NWS) and Air Force as well as difficulties in developing reliable, fully automated phenomena detection algorithms [Crum, 1998]. By contrast, achieving high integrity in the narrow band products provided by NEXRAD to external users has received much less attention in the NEXRAD product development process thus far.

However, other government weather information systems [especially the FAA's Integrated Terminal Weather System (ITWS) and the Weather and Radar Processor (WARP)] and non-meteorologist external users of the NEXRAD products through the NEXRAD Information Distribution System (NIDS) vendors need very high integrity NEXRAD products. In the NWS context, the direct utilization of NEXRAD products into numerical weather prediction models will also create much more stringent requirements for integrity of the NEXRAD base data.

Achieving very high integrity through automated analysis of only the data from a single NEXRAD is very difficult. In this paper, we consider the use of a much wider range of contextual information to create high integrity external user products. For instance, with the NEXRAD Open RPG and connectivity to AWIPS and ITWS, a system architecture will exist that will facilitate the implementation of NEXRAD product quality control algorithms that utilize information from other sensors.

In the following sections, we present some examples of how information from various other sources might be used to improve the quality of the data from a NEXRAD. We first show an example of how data from adjacent NEXRADs can be used to help edit out the anomalous propagation (AP) ground clutter which currently is corrupting a number of the NEXRAD reflectivity products intended for air traffic controller use. In cases where the NEXRAD is near a major metropolitan area, data from the FAA's TDWR can be used to improve the integrity of the NEXRAD reflectivity products used for hydrology.

Similarly, gridded wind fields estimated from multiple Doppler analyses, aircraft reports, and numerical models can be used to help address difficult challenges in Doppler ambiguity resolution for a single NEXRAD radar. The paper concludes with suggestions for near term demonstration and evaluation of multi sensor approaches to achieving high integrity in the NEXRAD products.

2. EDITING ANOMALOUS PROPAGATION (AP) GROUND CLUTTER FROM COMPOSITE REFLECTIVITY PRODUCTS

The NEXRAD composite reflectivity and surface reflectivity products are probably the most widely used product by non-meteorologists. However, these products are frequently contaminated by ground clutter, especially ground clutter due to anomalous propagation (AP). Our studies of Memphis and Ft. Worth NEXRAD data have shown that AP is quite common during nocturnal inversions and when cold outflows from thunderstorms pass near the NEXRAD [Isaminger, 1997]. Additionally, comparison

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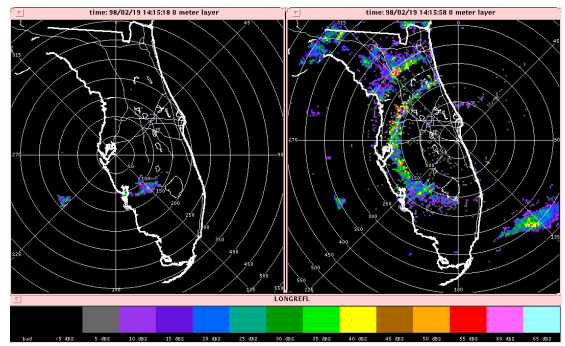
of NIDS vendor "quality controlled" national radar mosaics with the rapid update national mosaics that do not have the same degree of quality control indicate that the NIDS vendors also have identified many regions of AP in the products being provided today from operational NEXRADs.

An algorithm has been developed to edit AP based on altitude of the radar beam, the radial velocity, and the spectrum width [Isaminger, 1997] that will be implemented in NEXRAD build 10. This algorithm is quite effective when there is radial velocity data associated with a reflectivity measurement [Isaminger, 1997]. However, because different waveforms are used to estimate the NEXRAD reflectivity data and the velocity/spectrum width data, it is not uncommon to find reflectivity data with no corresponding radial velocity/spectrum width data. These situations where reflectivity data has no corresponding data typically arise when considering reflectivity data at ranges which are greater than the velocity waveform "first trip" (e.g., about 115 km range). At ranges > 115 km, altitude discrimination also tends to have difficulties since the bottom tilt of the radar typically extends above 3 km. Since most of the area covered by a NEXRAD is at relatively longer ranges (e.g., 50 % of the area within a range of 230 km lies outside a range of 160 km), removing AP completely based on data from a single radar is very difficult*.

Since AP is tied to the local atmospheric conditions around a NEXRAD, one can consider using the data from nearby NEXRADs to help identify AP contamination on a radar. Figure 1a shows an example of serious AP on the Melbourne, FL NEXRAD following the passage of a cold front which could not be completely edited by the algorithm which is being implemented in build 10. There is a ring of unedited AP that starts at about 120 km range, with peak composite reflectivities as high as 50 dBz. In Figure 1b, we see the corresponding edited data from the Tampa NEXRAD. There is a small cell within the region of AP from the Melbourne radar that is clearly defined in the Tampa data. Figure 1c shows the GOES infrared image 15 minutes prior to the NEXRAD data. We see that the region of AP on the Melbourne radar was largely clear in the GOES data. By contrast, the cell at sea (135 degrees Azimuth) is seen to have an infrared signature characteristic of convective weather. Satellite images could also clearly be of use in AP recognition, although these must be used with care due to the slower update rate of the satellite images (e.g., the cell to the southeast of Tampa is not obvious in the GOES image).



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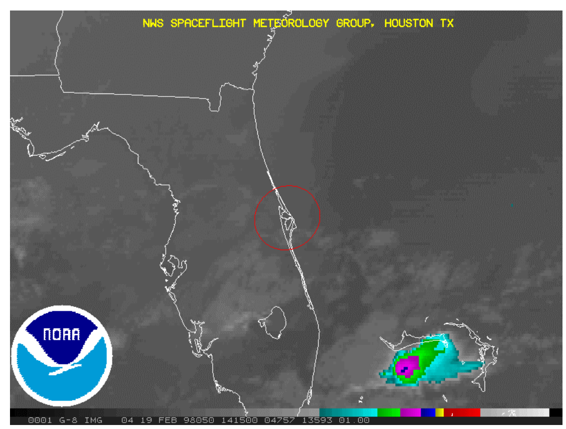

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Figure 1a and 1b show composite reflectivities for the Tampa and Melbourne NEXRADs at 14:11 GMT on 2/19/98, respectively, after application of the AP editing algorithm described in [Isaminger, 1997]. Figure 1c shows the GOES infrared imagery at 13:59 GMT.

We have examined four other cases of AP on the Ft. Worth and Memphis NEXRADs that could not be fully edited with the build 10 algorithm. In all of these cases, the regions of unedited AP for the various NEXRADs did not overlap. We should note that there could be situations (e.g., with rapid growth of a storm) where the different NEXRADs with roughly the

* We have also investigated the use of reflectivity product spatial variability (i.e., "texture") to discriminate between AP and weather. However, texture has increasing difficulties indiscrimination at longer ranges.

same range to a location disagree significantly in composite reflectivity values because the volume scans were accomplished at different times. However, these differences due to differences in volume scan measurement times do not persist with time.

The conclusion we reach is that composite reflectivity data from an adjacent NEXRAD can be very useful for editing AP from composite reflectivity data generated by a single radar which has the build 10 algorithm to remove AP at close ranges.

3. USING TDWR DATA TO IMPROVE THE INTEGRITY OF NEXRAD SNOWFALL RATE DATA

One of the difficult weather sensing challenges for the current NEXRAD network is the measurement of snow, especially snow arising from bodies of water due to the low altitudes of the precipitation [National Research Council, 1995]. Significant problems also arise when there is "bright band" contamination. To illustrate, the NEXRADs that provide coverage for New York City have a surface tilt with a beam extent that extends up to an altitude of approximately 1.6 km.

The importance of accurately sensing the rate of snow reaching the ground and predicting the movement of snow bands is much greater for major metropolitan areas than for rural areas. Fortunately, such metropolitan areas typically have additional sensors that could be of assistance to the NEXRAD in coping with difficult situations. Specifically, we suggest the use of the FAA's TDWR data to help identify situations where the NEXRAD is either overshooting the area of significant snow and/or being contaminated by "bright band" returns. In a number of cases (e.g., New York City, Cincinnati, Columbus, and Baltimore) the TDWR is much closer to the city than is the NEXRAD. Additionally, the TDWR has a much narrower beam (0.5 degrees) so that it is measuring much closer to the ground even when at the same range as the NEXRAD.

There are several options for automated use of the TDWR data in this context. One option is to use the TDWR data to set a data quality flag on the NEXRAD product which would indicate a possible problem (e.g., possible overshoot or bright band contamination) at the range and azimuth in question. Another option is simply to provide the TDWR data in addition to the NEXRAD data to external users, which then transfers the responsibility for sorting out the "truth" to each external user. Another option (somewhat in the spirit of the ITWS system) would be to automatically provide a "best" consensus estimate separately from the nominal NEXRAD product.

4. UNFOLDING NEXRAD RADIAL VELOCITY DATA

The quality of the NEXRAD radial velocity data is also very important for external users, especially those seeking to estimate winds and/or drive numerical weather prediction models. One of the significant challenges in Doppler dealiasing is handling cases where a region with valid radial velocity data is surrounded by regions with no valid velocity data (e.g., due to low signal-to-noise ratio (SNR) outside a region of precipitation and/or because of range folded returns). In such cases, the usual approach of range and/or azimuth continuity of radial velocity fields cannot be used to determine whether the radial velocity data has been folded. Use of a uniform wind field model based on data from the single NEXRAD has been very helpful, but clearly requires assuming continuity of winds over fairly long distances in some cases.

These problems of low SNR and/or range folding returns tend to increase with range from the NEXRAD. This suggests considering the use of radial velocity data from an adjacent NEXRAD that may be at closer range and/or do not have range folded returns in the same locations.

Near large metropolitan areas, the ITWS terminal winds product could be a major aid to resolving radial velocity ambiguities since this product uses NEXRAD, TDWR, RUC 2, and MDCRS data to determine its wind estimates [Cole, 1994]. One concern with using integrated data such as the ITWS product to resolve radial velocity ambiguities is the danger that the integrated gridded estimate itself could have been corrupted by a previously undetected velocity fold in the NEXRAD data.

The ITWS terminal winds product generation algorithm does test for outliners before combining the various radial velocity estimates [Cole, 1994] and has had very few erroneous estimates due to radial velocity ambiguities [Cole, personal communication, 1998]. To assist in resolving ambiguities with external data, we recommend that the NEXRAD radial velocity data have a data quality flag set by the unfolding algorithm which would indicate which estimates were viewed as potentially folded due to lack of range and/or azimuth continuity.

5. SUMMARY

In this paper, we have described some examples of multi-sensor approaches that could be used to improve the integrity of the products provided by a single NEXRAD. In one case we have promising but limited experimental results, while the other two examples are at this time somewhat speculative. Our principal objective here is to propose a different way of thinking about NEXRAD product integrity with the hope of inducing a dialog on ways of addressing these and other long standing NEXRAD data integrity issues.

For each of the examples presented here, a system such as ITWS or AWIPS that is integrating the NEXRAD data with data from other sensors could address the NEXRAD quality problems as far as its products were concerned. However, external users without access to all of the integration data sources should be able to rely on the integrity of the NEXRAD products they do receive. We propose that the NEXRAD program consider providing an edited narrow band product data stream for such users which takes advantage of the best product quality control technology.

The approaches presented here need experimental validation. We hope to test all the approaches at the New York ITWS site [Evans, 1999] which has real time access to base data from two NEXRADs, a TDWR, and the ITWS terminal winds product.

6. REFERENCES

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