Final Report for June 1, 1999 to May 31, 2000

Interagency Memorandum of Understanding
Among
The NEXRAD Program,
The WSR-88D Operational Support Facility,
and
The National Weather Service Office of Hydrology

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Executive Summary

This report summarizes the work performed from June 1, 1999 through May 31, 2000 at the National Weather Service (NWS) Hydrologic Research Laboratory and Iowa Institute of Hydraulic Research at the University of Iowa under the Memorandum of Understanding among the NWS Office of Hydrology, the NEXRAD Program, and the WSR-88D Operational Support Facility (OSF).

The major conclusions and recommendations are as follows:

Evaluation of Sterling, Virginia WSR-88D (KLWX) rainfall estimates post-calibration

1) A 3-month comparison analysis of KLWX and IFLOWS rain gauge rainfall after the OSF performed the new enhanced reflectivity calibration procedures indicates a mean storm-total gauge/radar (G/R) ratio of 0.82, or a radar overestimate by 22% on average, for all 25 events analyzed.

2) When these events were segregated into convective- and stratiform-dominated rainfall types, the mean storm-total G/R ratios were 0.58 and 1.10, respectively. Thus for the 11 convective events the radar tended to overestimate by a rather significant 72% on average, while for the 12 stratiform events the radar tended to underestimate by 91% compared to the rain gauges.

3) These results depend on the choice of Z-R relation used in generating the rainfall estimates. The Z-R relation used for each of these cases, as determined by the Sterling Weather Forecast Office, varied depending on the event, but the large majority of events used the convective Z-R relation ($Z=300\ R^{1.4}$) regardless of storm type.

4) Although it is very difficult in this study to separate out rainfall errors due to improper reflectivity calibration verses the use of an inappropriate Z-R relationship for the event, it appears that the enhanced calibration procedures have resulted in reflectivities that may be too large.

Investigation of WSR-88D rainfall estimates for two 1998 heavy precipitation events in south Texas

1) The performance of the WSR-88D PPS algorithm during two extreme rainfall events that occurred in the late summer/early fall of 1998 in South Texas under sustained, markedly tropical environmental conditions was assessed by varying adaptable parameters pertaining to rainfall rate/accumulation and comparing results to gage reports.

2) All simulations from all radars performed with the operationally-sanctioned “default” Z-R relationship (i.e., a = 300; b = 1.4) substantially underestimated rainfall accumulation yielding biases in the range 2.0 - 3.6. Simulations performed with the sanctioned “tropical” relationship (i.e., a = 250; b = 1.2) significantly improved estimates and

reduced statistical measures of error but still underestimated accumulation in all cases, resulting in biases in the range 1.1 - 1.8.

3) Raising the “Hail Cap” threshold alone made little difference in control runs with the Z-R parameters otherwise maintained at their Tropical settings. Some fairly significant increases were observed in the vicinity of precipitation cores in some instances; otherwise, analogous products of the simulations were almost indistinguishable, and few differences were observed in various statistical fields tracked (e.g., Bias; RMS error; etc.).

4) An alternative Z-R relationship (i.e., a = 200; b = 1.2), based upon the Tropical version, would have yielded superior results to the sanctioned Tropical relationship in all cases studied. However, the parameters that would have yielded the best results were somewhat different in each case evaluated, and the number of cases studied was limited. Therefore, it would be difficult to suggest an alternative “Super Tropical” Z-R relationship for possible operational use in events such as those studied here based solely on these results.

Precipitation truncation problem in the WSR-88D PPS algorithm

1) In addition to a previously known minor deficiency in the design of the WSR-88D PPS Rate/Accumulation algorithm that resulted in the truncation of rainfall during very light precipitation rates (e.g., less than ~0.5 mm/hr, or ~21 dBZ) but had little quantitative impact, a second previously unknown problem has been uncovered whereby precipitation amounts may be universally underestimated due to the cumulative effect of slight truncations occurring during the computation of rainfall totals.

2) The impact of this truncation problem or truncation anomaly will vary as a function of the PPS product and the nature and duration of the precipitation event, ranging from minor to quite significant.

3) Quantitatively, the impact for any given product will be directly proportional to the steadiness of precipitation - i.e., the greater the number of volume scans experiencing measurable rainfall at any given grid point, the greater the amount by which rainfall will be underestimated.

4) The impact will be greatest during persistent, light precipitation events and least during heavy events of short duration.

5) The problem is potentially more serious in the hourly-based PPS products (including OHP, THP, USP and DPA), which are determined by adding and subtracting from a running-hourly-total field, than in the Storm Total Precipitation (STP) product, which is determined by addition only.

6) When several of the case studies of the 1998 South Texas extreme tropical rainfall events were rerun with a prototype version of the PPS algorithm that corrects all known

instances of the truncation problem, results were considerably improved. Runs with the operational Tropical Z-R settings yielded biases close to one, reduced RMS errors and improved correlation coefficients.

Seasonal variation in multi-radar coverage for WSR-88D precipitation estimation in a mountainous region

1) Climatological analyses of the frequency of precipitation in the Hourly Digital Precipitation (HDP)/Digital Precipitation Array (DPA) from 14 WSR-88D sites in the Northwest River Forecast Center (NWRFC) service area have been carried out for the period 1996-1999.

2) Effective radar coverage maps for precipitation estimation have been derived from the climatological analyses for both the cool and warm season. These maps will be used by the NWRFC in the new operational rainfall estimation algorithm called RFC-Wide Multisensor Precipitation Estimator (MPE).

3) The results indicate the true range of the radar for precipitation estimation is significantly less than 230 km for many radars in the region and varies greatly with azimuth due to beam blockage of the lower tilts caused by the mountainous terrain.

4) The individual radar coverage maps have been used to create an effective multi-radar mosaic which also shows areas with poor or no radar coverage. The results also show that there exists a large seasonal variability in the effective multi-radar coverage of the WSR-88D network in the NWRFC region, with extremely poor coverage in the cool season.

Convective-stratiform separation

1) Exploratory analyses have been carried out toward development of a real-time convective-stratiform separation algorithm in support of Vertical Profile of Reflectivity (VPR) correction on the WSR-88D.

2) The results indicate that a number of reflectivity-morphological variables offer great potential for this purpose. It is proposed that a prototype algorithm based on discriminatory skills in such variables be developed.

3) Three variables have been identified as particularly skillful in convective-stratiform separation: the maximum apparent rain rate in the vertical, the local spatial correlation coefficient of the maximum apparent rain rate in the vertical, and the local spatial correlation coefficient of the height of the top of the apparent convective core.

4) The initial results, obtained by simple application of the three thresholds, are very encouraging. They suggest that optimal linear estimation based on indicator variable

transformation is well-suited for probabilistic quantification of convective-stratiform separation. It is proposed that such a procedure be prototyped and evaluated.

5) The variables examined and identified as promising in this work need to be further tested against a wide spectrum of precipitation events. Also, the search for other potentially skillful variables needs to continue.

6) Generation of validation data sets remains a critical outstanding issue. Manual mass-generation based on visual examination of volume-scan reflectivity data is not only labor-intensive but will also require a graphical user interface tool. A user operations concept needs to be developed for VPR correction (including convective-stratiform separation) to address such issues.

Large sample evaluation of two methods to correct range dependant error for WSR-88D rainfall estimates

1) Two methods to correct radar rainfall errors due to nonuniform vertical reflectivity profiles (VPR), one used operationally in Switzerland and a newly developed one which generates locally-based VPRs, were evaluated using two years of Tulsa, Oklahoma WSR-88D and rain gauge data.

2) The results confirm that significant improvement in the accuracy of WSR-88D rainfall products may be expected from operational implementation of VPR correction, but to deal with spatial variability in the vertical profile of reflectivity, convective-stratiform separation is needed.

3) Both methods reduced the range dependant bias and RMS errors, but the local correction method produced better results. Improvements are best during the cold season.

4) A climatology of VPR was developed for the Tulsa WSR-88D.

5) Both methods have shortcomings for operational application, including computer processing demands, and more efficient alternatives are being examined and developed.

Evaluation of anomalous propagation echo detection in WSR-88D data: A large sample case study

1) A neural network-based method to detect anomalous propagation echo in WSR-88D data is evaluated and applied to a large amount of radar data over two years at Tulsa, Oklahoma.

2) The procedure is effective in reducing the bias in rainfall estimates. The agreement of long term accumulations between the radar and rain gauge data is remarkable considering that no tuning of the rainfall estimation algorithm was performed.

3) Use of a long-term sample of radar data is necessary to provide meaningful and statistically stable results.