CRH SSD
JUNE 1995

CENTRAL REGION TECHNICAL ATTACHMENT 95-12

A STUDY OF THE ACCURACY OF THE WSR-88D ONE HOUR PRECIPITATION ESTIMATES NEAR THE 124 NAUTICAL MILE BOUNDARY

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1. Introduction

The purpose of this study is to determine the reliability of the one hour precipitation estimates produced by the WSR-88D near the maximum 124 nautical mile (nm) range of the product. This study will prove helpful in determining situations when a flash flood or flood warning should be issued to protect lives and property across Kentucky. Heavy rain occurring over a short period may lead to a flash flood event, especially in the mountainous terrain of eastern Kentucky, while light-to-moderate rain over an extended period could cause a general flooding event.

2. Data Used

The 14 hours of data utilized in this report were gathered from the 1.1 nm resolution one hour precipitation (OHP) display on the KLVX WSR-88D during the 1994 convective season. These data were compared to precipitation amounts recorded by a radio reporting tipping bucket rain gage network called IFLOWS (Integrated Flood Observation and Warning System). The IFLOWS gages used are located across numerous counties in eastern Kentucky. Figure 1 displays the approximate locations of the tipping bucket rain gages and the 124 nm maximum range for the OHP product. A subset of the precipitation categories utilized in the OHP product are indicated below.

OHP CATEGORIES AS DEFINED BY THE WSR-88D

Category	10.00 inches
Category 2	0.01-0.09 inches
Category 3	0.10-0.49 inches
Category 4	0.50-0.99 inches

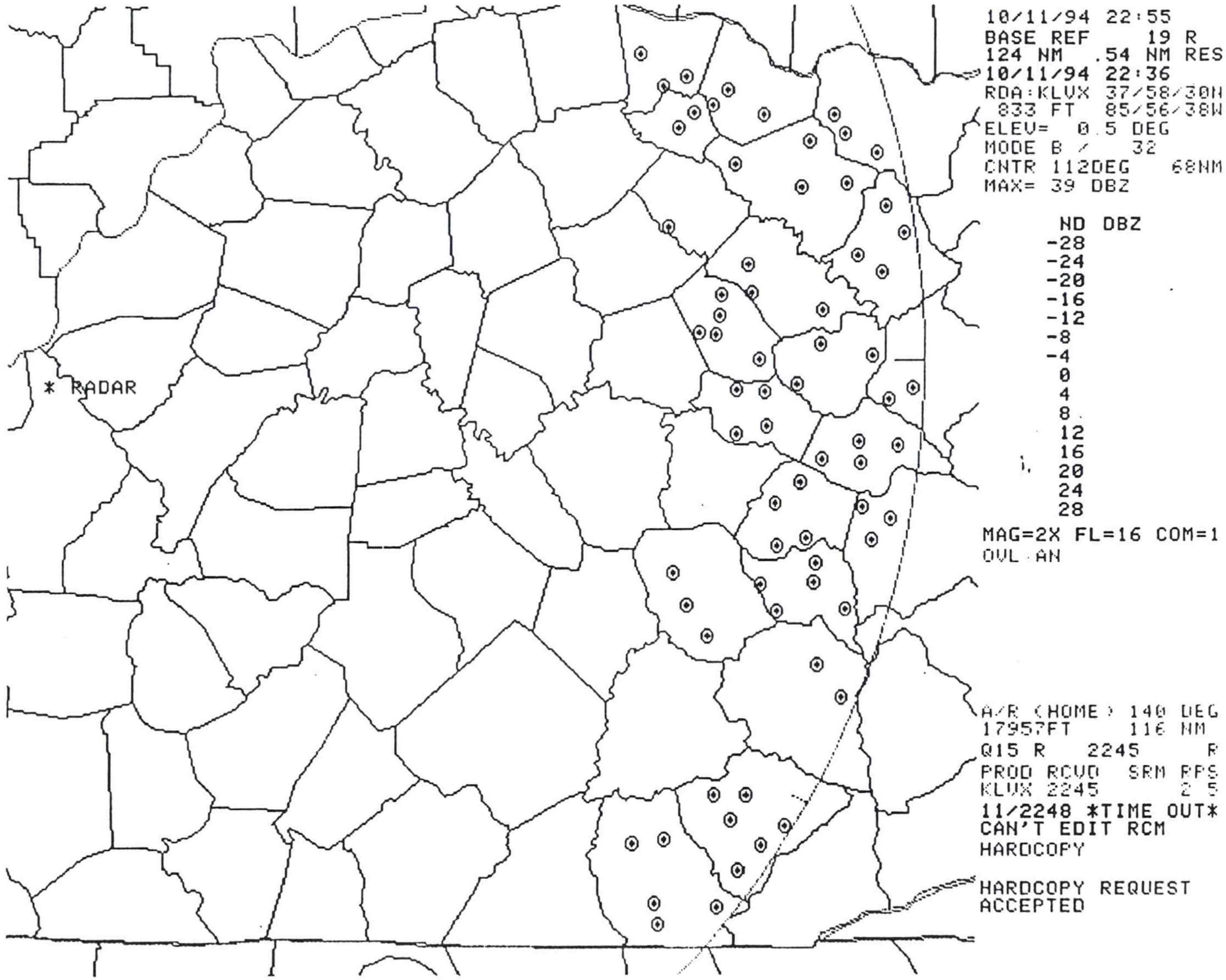

Figure 1. The circles represent the approximate location of the IFLOWS gages in eastern Kentucky, the curved line is the 124 nm range marker, and the asterisk represents the location of the KLVX WSR-88D radar.

3. Synoptic Situation

Widespread showers and thunderstorms containing light-to-moderate precipitation with embedded areas of heavy rain were present during the 14 hours of concern within this study. The 14 hours were collected from four different synoptic events. A few locations received high amounts of rain, but none presented a flash flood danger. All of the precipitation events were in advance of an approaching cold front and were convective in nature, which could cause errors in the precipitation estimate scheme employed by the WSR-88D. These possible errors will be touched upon later in this paper.

4. Results

Figure 2 displays the method in which the WSR-88D OHP estimates were compared to the IFLOWS rain gage amounts. This was achieved by annotating the IFLOWS rainfall amounts onto the OHP display for the corresponding hour. When comparing the gage amounts to the OHP product, the range of the OHP product was used (e.g., 0.01-0.09 inches for Category 2). If the amount recorded by the gage was not within the correct radar category range, an error occurred. When comparing the radar estimated ranges with IFLOWS gage amounts, all radar pixels immediately surrounding (within 2 nm) the rain gage were used to determine whether an error in precipitation estimation occurred due to possible spatial errors and below beam effects in the WSR-88D.

Results indicated that differences between radar estimated ranges and gage rainfall amounts were predominately within one category. For example, if 0.36 inches (Category 3) of rain was recorded by a tipping bucket and the WSR-88D OHP displayed a Category 2 amount (0.01-0.09), an underestimation of one category would have occurred. Conversely, a display of Category 4 (0.50-0.99) by the WSR-88D would be an overestimation of one category in this example. There were 68 errors in the 323 reports from the 14 hours of IFLOWS/radar comparisons. The error varied by one category in 66 of these reports and by two categories in two reports. With the breakdown of precipitation categories by the WSR-88D, an error of one category would likely be negligible in the lower categories (i.e., lighter precipitation amounts Categories 1 and 2), but more significant in the higher categories where a greater amount of rainfall is involved. Therefore, all errors except for the two mentioned above (two category errors) were classified as negligible (most errors occurred with Categories 1 and 2).

Figure 3 displays the average error (algebraic sign retained) trends for each of the categories within the 14 hours studied. For the scope of this study, an error will be noted 100 percent of the time for Category 1. The reason is that, only those gages receiving rainfall were studied (i.e., the WSR-88D did not report a value for that particular point). Estimated rainfall amounts in the lower categories (i.e., Categories 1 and 2) were underestimated by the WSR-88D,

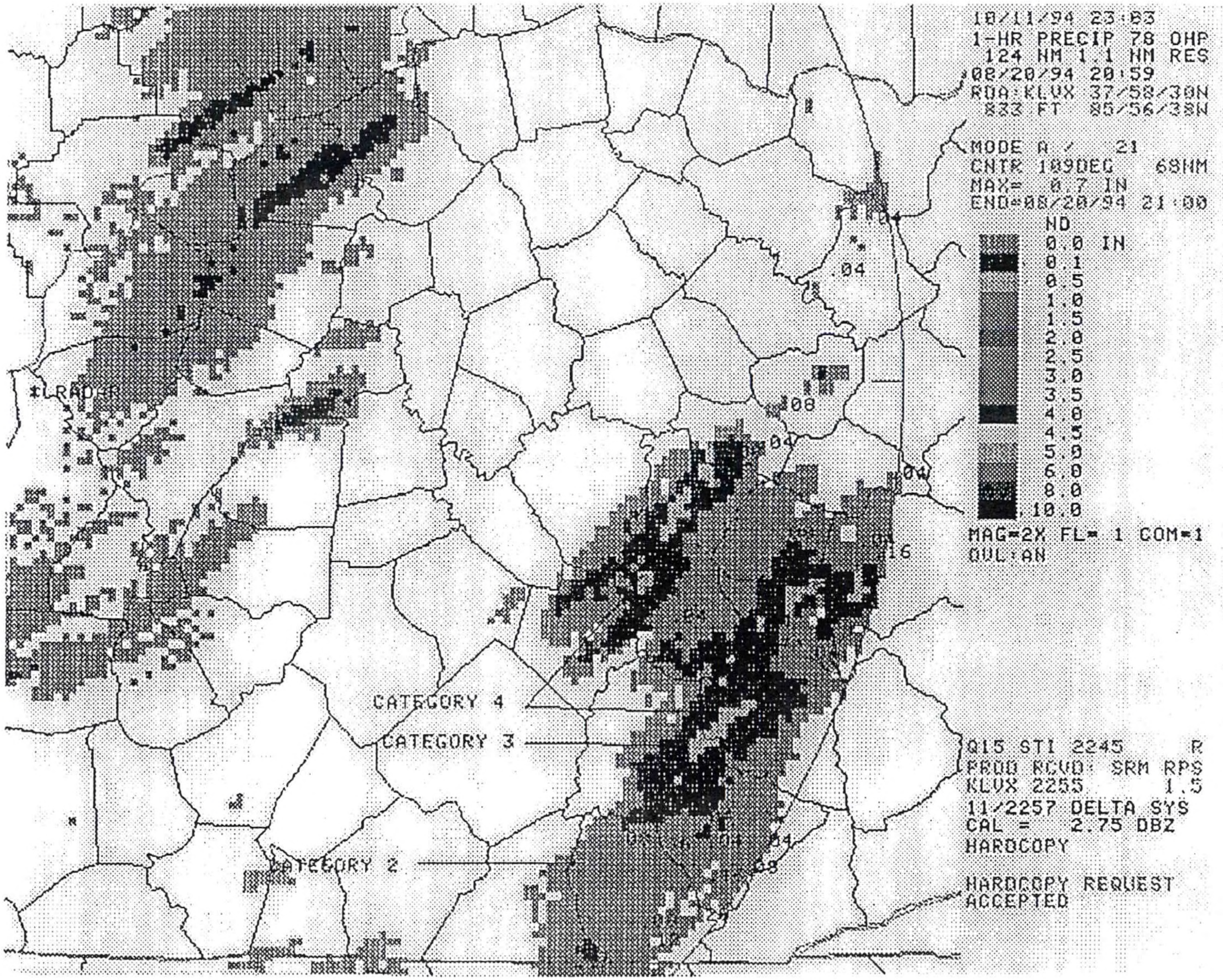

Figure 2. One-hour precipitation display correlated with the same hourly report from the various IFLOWS gages. The decimal points in the rainfall amounts represent the approximate location of the rain gage. The asterisk represents the location of the WSR-88D radar.

FOR EACH CATEGORY

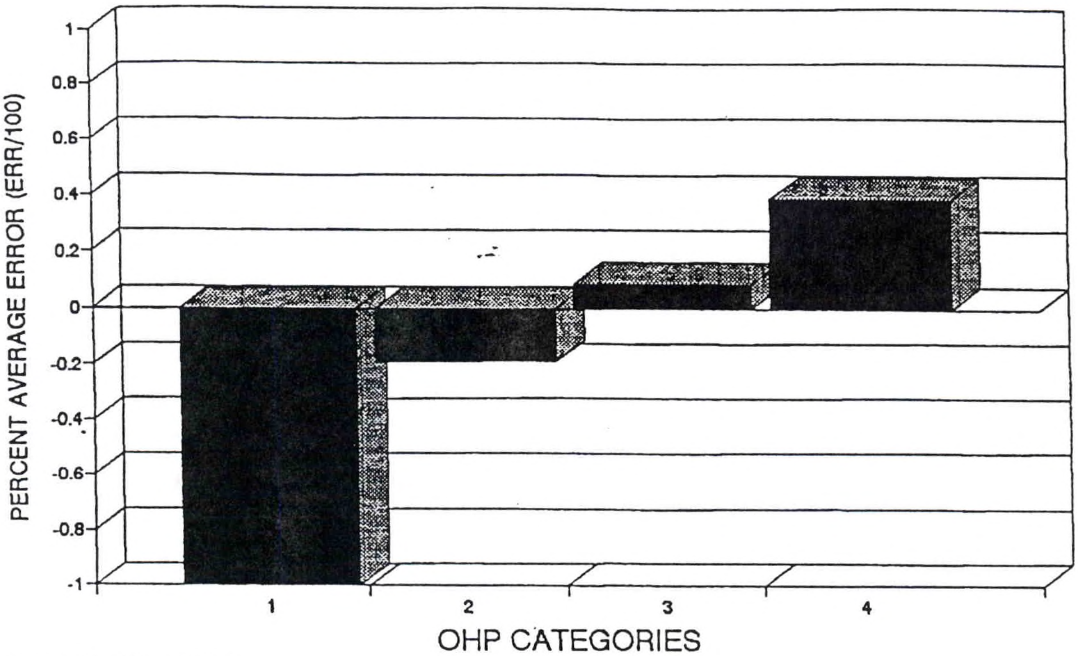

Figure 3. A representation of the radar overestimate (positive values) and underestimate (negative values) for each of the four categories involved within this study. A value of -0.25 represents an underestimation by the WSR-88D 25 percent of the time, while a value of 0.25 represents an overestimation by the WSR-88D 25 percent of the time.

while the amounts in the higher categories (i.e., Categories 3 and 4) were overestimated by the WSR-88D OHP algorithm. This could potentially hide a location of flash flooding for underestimated radar amounts or could give a false pretense of flooding for overestimated rainfall. These error values were determined by summing the errors within each category over the 14 hours and dividing by the total number of IFLOWS reports for each respective category. This then leads to Figure 4 which shows the absolute errors (algebraic sign omitted) by precipitation category. When the WSR-88D indicated no rainfall (Category 1) but corresponding IFLOWS gages revealed that light rain fell, an error of 100 percent was noted. The OHP Category 2 (0.01-0.09) exhibited a 19 percent error versus gage observations (i.e., 19 percent of the time the gages reported Category 2 rainfall, while the radar indicated a different category amount). OHP Category 3 (0.10-0.49) exhibited a 12 percent error, while OHP Category 4 (0.50-0.99) was in error 37 percent of the time. The smaller error values from radar Categories 2 and 3 are more representative than those in Categories 1 and 4 since the majority of observed precipitation amounts during the 14 one-hour periods fell within Categories 2 and 3. The errors calculated for Figure 4 were achieved similarly to those in Figure 3, the only difference being that absolute errors were used.

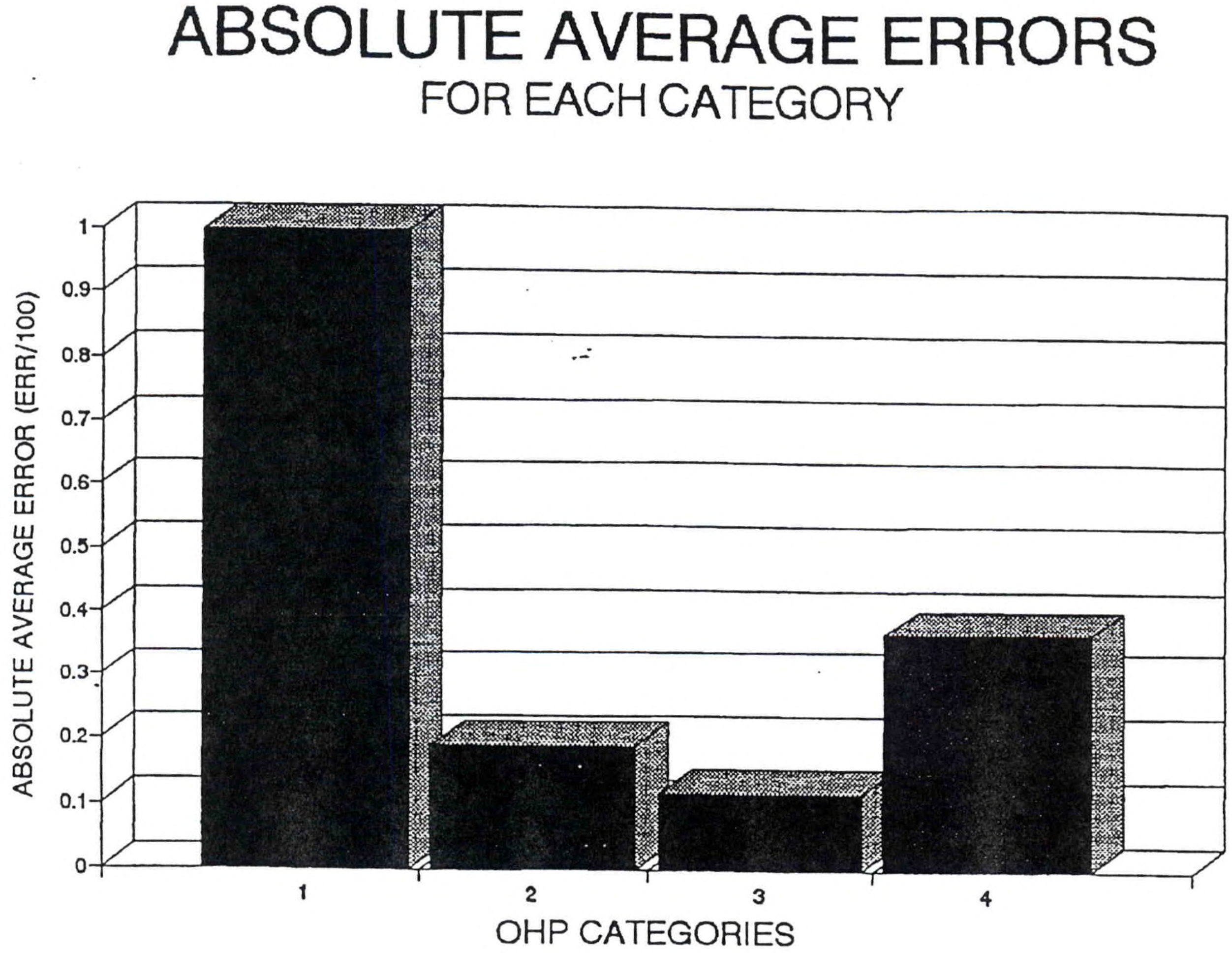

Figure 4. A graphical representation of the percentage of absolute error experienced in each category. For example, a value of 0.5 represents an error by the WSR-88D 50 percent of the time for rainfall amounts within the respective category.

The total absolute error (including over- and underestimates) over the 14-hour study was 21 percent (0.211) (Figure 5). This error was determined by summing the number of absolute errors in each of the 14 periods and dividing by the total number of reports received from the IFLOWS gages. There was a total of 323 IFLOWS reports in this study. Of those reports, the corresponding WSR-88D estimated category range was in error 68 times.

5. Problems

There are several factors to consider when approaching this study. The first deals with the reporting of rainfall by the tipping bucket network (IFLOWS). The tipping buckets used were those that register rainfall in groups of four-hundredths (0.04) of an inch, which is an improvement in accuracy over the one-

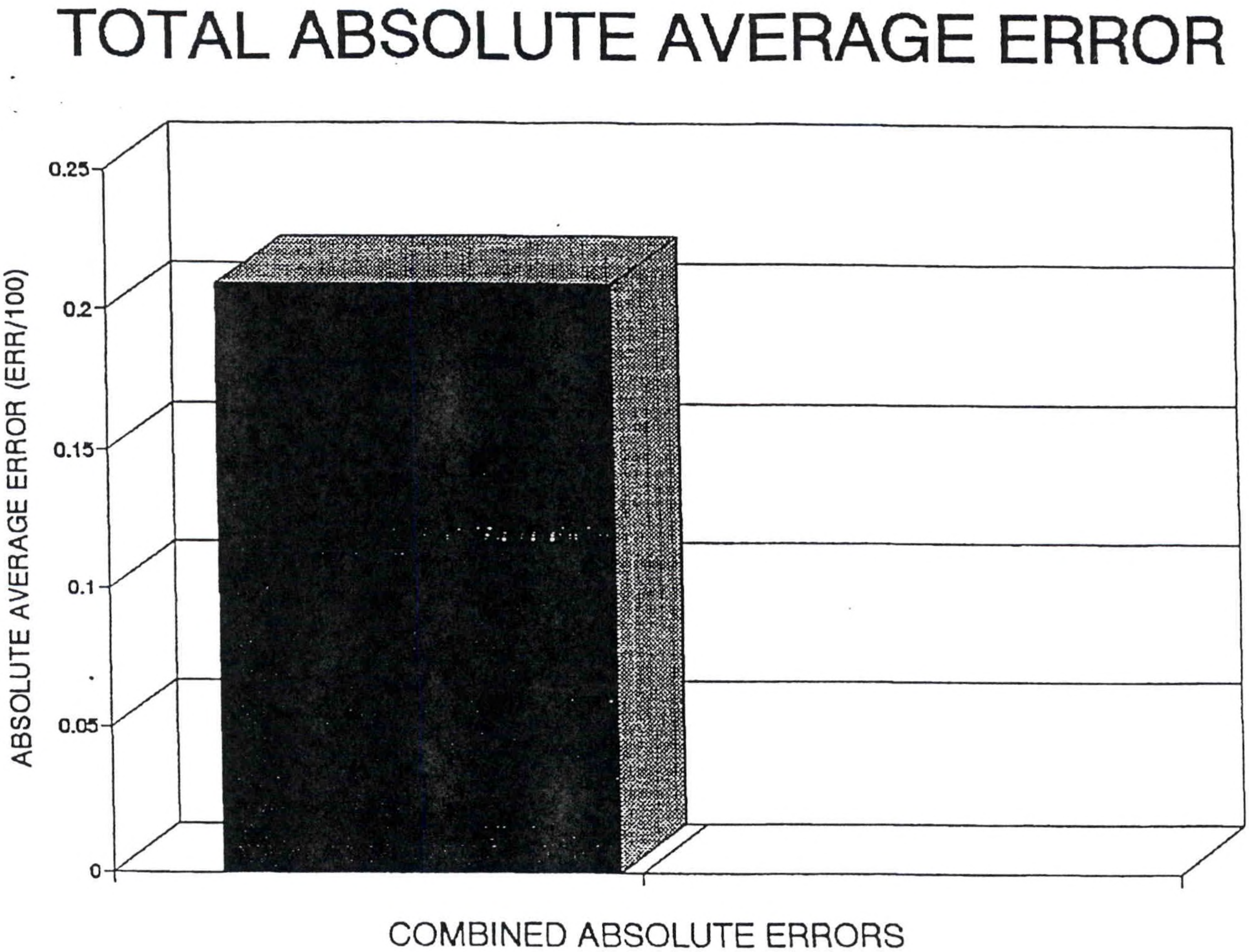

Figure 5. The absolute error of all reports (21 percent), or a representation of the accuracy (79 percent) of the OHP product by the WSR-88D.

hundredth (0.01) tipping bucket rain gage. This could affect the results in this study when an amount of rain less than four-hundredths would not tip the bucket but remain in place until the next event. This problem could be the main factor for radar estimate versus gage observation errors when precipitation amounts were near the cutoff to the next category. For example, if the radar estimated Category 4 rainfall (0.50-0.99) and the IFLOWS gage reported 0.48 inches (Category 3), but 0.03 inches did not tip, then an error of one category (Category 4 estimated versus Category 3 observed) would be noted when in reality, no category error occurred. In addition, in this same example, the Category 4 estimate could be as high as 0.99, but still be recorded as only a one category error compared to the 0.48 inch observed amount.

As cited by the Operational Support Facility (1993), there are several other possible sources of error in WSR-88D rainfall estimates as indicated below.

1) Hail contamination and bright banding (rain mixed with wet snow) which leads to radar overestimates because of the higher backscattering from hail and mixed precipitation.

2) Partial beam filling causes an underestimate at long ranges due to expanded areal coverage.

3) Below beam effects:

    a) A strong horizontal wind can cause an overestimate if the wind displaces precipitation away from the area below the sample volume, and an underestimate if the rain is blowing into the sample.

    b) Evaporation below the beam causes an overestimate because the radar assumes all rain makes it to the surface.

    c) Coalescence causes an underestimate if the beam overshoots the storm core.

4) An improper Z-R relationship (variations in drop size distribution).

5) The storm cells speed of movement.

6) Radar beam blockage.

6. Conclusion

The total error was 21 percent in this study, i.e., the KLVX WSR-88D OHP estimate was correct (within the appropriate category) 79 percent of the time. When an error was reported in this study, it was mainly within one category, which generally would be negligible in the lower categories but could be of more concern in higher categories. Thus, knowing the possible errors previously mentioned, the forecaster could use the rainfall data provided by the WSR-88D with confidence for light or moderate intensity precipitation events, but use more awareness as the intensity of the rainfall increases. However, in an area of heavy convective rain where no hail is present and flash flooding is possible, the reliability of the information provided by the WSR-88D should still be respectable. The error results in this study are very preliminary and based only on a limited data set. Therefore, more hours of data are needed for better evaluation of convective regimes, stratiform regimes, and rainfall amounts over one inch.

7. Acknowledgements

The author would like to thank the following individuals for their contributions of time and advice: Theodore W. Funk, SOO/WSFO Louisville, KY; Mike Callahan, SH/WSFO Louisville, KY; Michael Murphy, SH/WSFO Nashville, TN; and William Wilson, MET/WSFO Louisville, KY.

8. References

Operations Training Branch/Operational Support Facility, 1993: Precipitation algorithms and products. WSR-88D Operations Course Student Training Guide, Topic 8, Lesson 5.