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AN IMPROVED PRECIPITATION PROJECTION PROCEDURE FOR THE NEXRAD FLASH-FLOOD POTENTIAL SYSTEM

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1. INTRODUCTION

Accurate precipitation projections are extremely important for flash-flood forecasting. In a previous paper, Walton, et. al (1985) proposed a Flash-Flood Potential (FFP) System for NEXRAD that included a precipitation projection procedure that consisted of basically four phases: 1) estimation of mean storm "dynamics;" 2) estimation of normalized residual and residual persistence; 3) estimation of precipitation initiation times; and 4) projection of precipitation accumulations. The test results from this initial precipitation projection procedure indicated several deficiencies. The projection procedure tended to underestimate areas of heavy precipitation and overestimate areas of light precipitation. Also, because of our simplified mean storm "dynamics" estimation (which applied a single storm velocity and direction to the entire field), areas of anomalous propagation (AP) were being treated as a part of the storm system and moved accordingly. The "projected movement" of the AP was an undesirable attribute of the projection procedure, and along with the over and underestimation of precipitation, led the Hydrologic Research Laboratory to develop another precipitation projection procedure. The "new" precipitation projection procedure is in many ways a simpler procedure and consists of: 1) estimation of the mean, variance, and residual of the precipitation rate; 2) estimation of localized storm velocity; 3) estimation of the residual persistence; and 4) projection of precipitation rates with subsequent conversion to precipitation accumulations. Like the previous precipitation projection procedure, the new procedure is statistically based, fully automated, completely objective, and produces estimates of future precipitation for periods up to an hour in the future. This new precipitation projection procedure will be described in the next section.

2. NEW PRECIPITATION PROJECTION PROCEDURE

At the present time, about half of the National Weather Service's flash-flood warnings have no lead time. The primary purpose of the precipitation projection procedure is to produce short-term forecasts of precipitation accumulations updated at scan rate intervals for up to 1 hour into the future. The projected precipitation is then used within the Flash-Flood Potential System to increase the flash-flood warning lead time. The following subsections will briefly describe each of the components of the new precipitation projection procedure mentioned in the introduction.

2.1 Estimation of the Mean, Variance, and Residual

The precipitation projection procedure uses a spatial moving average for the mean variance and residual of the precipitation rate. The mean is calculated for each box (1/40th Limited Fine Mesh (LFM) Grid) by averaging over a 5 x 5 box (1/40th LFM Grid) region which roughly corresponds to 20 km x 20 km area. The localized spatial moving average of the variance of precipitation rates over this 5 x 5 box (1/40th LFM Grid) region is likewise computed. The variance of observation error is assumed to be proportional to this variance. The residual is defined as the difference between the observed precipitation rate and the mean value of the precipitation rate in an observed scan.

2.2 Estimation of the Localized Storm Velocity

The localized storm velocity and direction are determined by a pattern-matching technique. The technique involves comparing the current precipitation rate field with a previous precipitation rate field at every fifth box (1/40th LFM Grid) for various offsets to determine the minimum sum of absolute differences. The previous precipitation rate field used for this comparison will be either one or two scan intervals ago, selected to achieve a 10-minute time difference as closely as possible. The offsets range from +2 to -2 boxes (1/40th LFM Grid) in the X and Y directions which will account for storm movement in any direction and for storm velocities up to approximately 48 km/hr. The offset with the minimum sum of absolute differences provides the first estimate of the velocity and the direction at every fifth box (1/40th LFM Grid); these first estimates are in turn smoothed by weighted averaging with nearest neighbor first estimate velocities.

Velocities are then interpolated for all the other boxes (1/40th LFM Grid) using an inverse-distance-squared weighted average of the smoothed velocities. Simple persistence is assumed when projecting the storm velocity and direction into the future.

2.3 Estimation of Residual Persistence

The precipitation rates are decomposed into several components. Any rate field is composed of the mean precipitation rate (computed as described above) plus an additive residual. Precipitation rates are presumed to evolve in time in two steps. The first step is a change in the residual component described by a first-order autoregressive random process. The second step is a translation step where the mean and residual are both moved in space according to the localized storm velocity (computed as described above).

The parameters of the residual process are estimated at each scan by translating the residuals of the previous scan according to the localized storm velocity and computing the lag-one autocorrelation of the translated previous residuals with the current residuals.

2.4 Projection of Precipitation Rates with Subsequent Conversion to Precipitation Accumulations

The projected precipitation rate at each box (1/40th LFM Grid) is the mean precipitation rate plus the projected residual. The projected residual is the current residual, times the residual persistence parameter raised to a power equal to the number of time steps into the future. These projected precipitation rates are then moved according to the projected local storm velocity and direction. The projection precipitation accumulations are based on these projected precipitation rates.

2.5 Projected Error Variance

The procedure estimates not only the projected precipitation accumulations as described above, but also the error variance of the projected accumulations. The error variance is composed of two parts which are presumed to be independent. The first part is simply the effect of observational error in the current scan as it affects the projected rate scans. The second part is due to the growing uncertainty in projection of the residuals. The error variance of the projected residuals can be derived from the properties of the lag-one autoregressive process used to model the residuals, accounting for the fact that these errors in the residuals are themselves correlated in time so that the error variance in the accumulations is not simply a sum of the error variances in the individual projected residuals as rates. Error in estimation of the mean is also included in a statistical sense, but not in the sense of any unaccounted for dynamics in the precipitation process itself. Errors due to the estimation and variability of the localized storm velocities are not explicitly accounted for.

The computation of the error variance of projected accumulations allows error bounds to be computed. Likewise, they allow an estimate of the probability of exceedance of any particular precipitation threshold.

3. PRELIMINARY RESULTS

A 5-1/4 hour case acquired as part of the Prototype Regional Observing and Forecasting Service's (PROFS) summer 1983 forecasting exercise from the National Center for Atmospheric Research (NCAR) CP2 radar was used to test the precipitation project procedure. The CP2 radar has technical characteristics similar to NEXRAD. The data produced by the NCAR CP2 radar are very similar to the proposed NEXRAD data characteristics with one major exception, clutter suppression. Clutter suppression was not applied to the NCAR CP2 data. In areas affected by ground clutter, NEXRAD will apply clutter suppression to the data. It is hoped that the clutter suppression will increase the accuracy of NEXRAD projected precipitation estimates in clutter areas. NCAR CP2 data were collected from 1813Z to 2326Z, July 23, 1983. PROFS extracted the reflectivity data for the four low tilts from the field tapes, converted the data into Universal Tape Format (UTF), and sent them to the Radar Hydrology Group (RHG) of the Hydrologic Research Laboratory in December 1983. In addition to the radar data, verification data collected by their chase teams and other observers were acquired from PROFS, and independent data were obtained from the National Climatic Data Center's Hourly Precipitation Data for Colorado.

An example of the projected precipitation output by the NEXRAD FFP system can be found in figure 1. This graphical product will be displayed at the NEXRAD PUP on a 4 km x 4 km grid out to 230 km and have up to 16 color levels. It will provide the projected precipitation for up to 1 hour into the future and be updated every scan (approximately every 6 minutes). Difference fields, calculated by subtracting the 1-hour projected precipitation from the 1-hour observed precipitation obtained from the NEXRAD Precipitation Processing System (PPS), show that from 72 to 86 percent of differences were within ±3 millimeters and 91 to 97 percent of differences were within ±10 millimeters (figure 2). For flash flooding, areas of intense precipitation are of extreme importance to the forecaster. To test the ability of the precipitation projection procedure to predict these areas, difference fields were calculated for boxes (1/40th LFM Grid) where the precipitation from the FFP or the PPS was greater than 12.7 mm/hr. For observed or projected areas with rainfall intensities greater than 12.7 mm/hr, only 7 to 32 percent of differences were within ±10 millimeters. For half-hour projections of precipitation, the percentage of differences within ±10 millimeters ranged from 20 to 48 percent for the same rainfall intensity. The above results were obtained from twenty scans representative of the 5-1/4 hour data set.

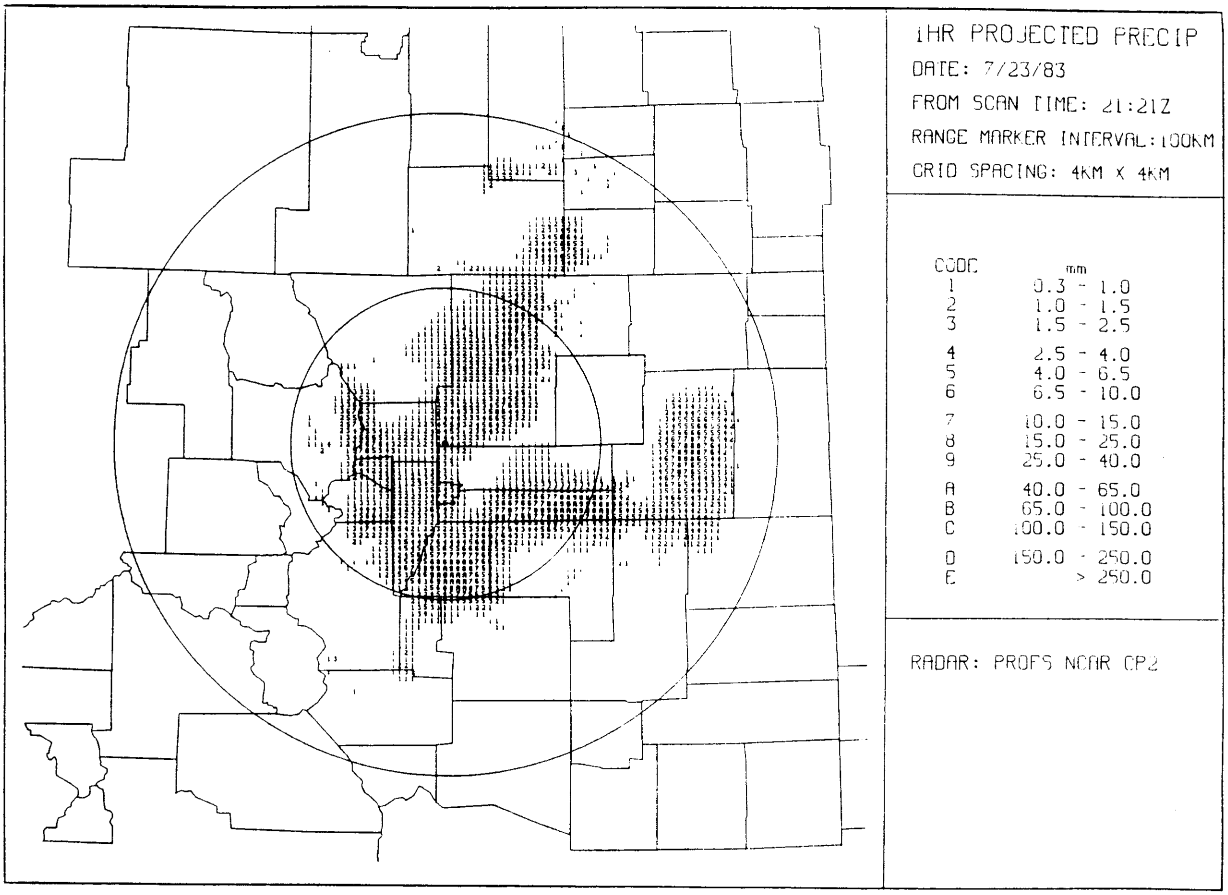

Fig. 1. One-hour projected precipitation from NEXRAD FFP system.

	Difference Interval (mm) \ SCAN TIME(Z)	19:11	19:16	19:21	19:26	19:41	19:46	19:51	20:16	20:21	20:26	20:31	20:41	20:46	20:51	21:21	21:26	21:31	22:11	22:21	22:26
overestimation ↑	> 80	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0
	70 → 80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	60 → 70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	50 → 60	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	40 → 50	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
	30 → 40	0	0	1	1	0	1	0	1	1	0	0	1	1	1	0	0	0	0	0	0
	20 → 30	2	1	1	1	1	1	0	1	1	1	1	2	2	2	1	1	1	1	0	0
	10 → 20	3	3	2	2	2	2	1	2	2	3	3	4	3	4	3	3	4	1	1	1
	3 → 10	9	9	10	9	6	5	4	6	7	8	10	10	10	10	7	6	9	5	5	4
	3 → -3	86	87	85	84	85	82	82	81	80	80	79	79	80	77	77	72	79	77	75	77
↓ underestimation	-3 → -10	0	0	1	3	5	8	11	7	6	5	3	3	2	4	9	13	5	11	11	12
	-10 → -20	0	0	0	0	0	1	2	2	2	2	1	0	1	0	2	2	1	3	5	3
	-20 → -30	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	2	2
	-30 → -40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1
	-40 → -50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-50 → -60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-60 → -70	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	-70 → -80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	< -80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Fig. 2. Percentage of boxes (1/40th LFM Grid) within the various difference (PPS-FFP) intervals for 20 selected scan times.

4. CONCLUSION

Overall, the new precipitation projection procedure performed well. Storm structure was maintained and areas of known AP were not moved along with the rest of the storm system. However, preliminary test results still indicate underestimation of high precipitation rates and overestimation of low precipitation rates; but to a much lesser extent than the previous precipitation projection procedure. Some of the over and underestimation of precipitation rates by the projected precipitation procedure resulted from errors in estimating the localized storm speed and direction. This was evidenced by areas of over and underestimation being adjacent to one another. We believe that when averaged over an area or watershed, the over and underestimation will tend to cancel out and provide a better estimate. Tests are underway to verify this hypothesis.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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