P1.18 THE DEVELOPMENT OF A NEW VALIDATION TECHNIQUE FOR TROPICAL CYCLONE RAINFALL

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1. INTRODUCTION

One of the most significant impacts of tropical cyclones is the copious amount of rainfall they often produce. Drowning from inland flooding in landfalling tropical cyclones is the leading cause of death from storms affecting the United States in the past 30 years. For this reason, the Tropical Prediction Center has stated that one of its highest priorities is to improve quantitative precipitation forecasting (QPF) for tropical cyclones. Dynamical numerical models provide one way of forecasting rainfall from tropical cyclones. While such models enable the depiction of the temporal and spatial evolution of tropical cyclones and their associated rain fields, they often exhibit errors related to inadequate initial conditions and model physics. Knowledge of these errors can aid the forecaster in interpreting numerical guidance of rainfall and adjusting their forecasts accordingly.

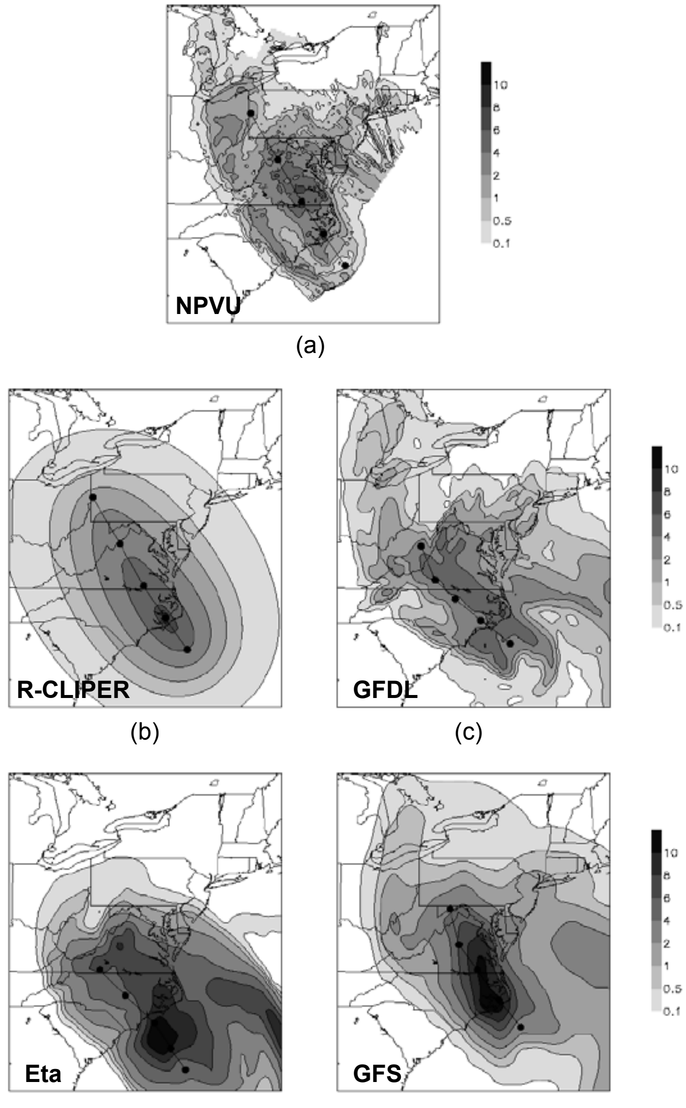
An accurate diagnosis of rainfall forecast errors requires a validation scheme that accurately measures the performance of the forecast system. However, no standard technique has been developed to validate rainfall forecasts from tropical cyclones. Conventional measures of precipitation forecast skill, such as skill score, are difficult to interpret in the context of tropical cyclones due to the strong dependence of rain location and magnitude on the forecasted track of the storm and differences in the spatial and temporal sampling areas of rain gauge data compared to model output. Therefore, a key task in improving rainfall forecasts is to develop validation schemes for tropical cyclone rainfall that provide a baseline measure of forecast skill independent of track error and sampling issues. In this presentation a new technique will be presented that addresses these issues.

2. METHODOLOGY

For this presentation the rainfall validation technique is illustrated by comparing forecasts from operational numerical models (GFDL, GFS, and Eta forecasting models) and the Rainfall Climatology and Persistence model (R-CLIPER) with gridded rainfall data from the National Precipitation Validation Unit (NPVU). The NPVU is a 4-km dataset consisting of radar-derived rain rates corrected by raingage amounts where available. The resolutions of the GFDL, GFS, Eta, and R-CLIPER models are 1/6 degree, 1/2 degree, 12 km, and 1/6 degree, respectively. Hourly rainfall fields are available for the R-CLIPER and NPVU, while 3-hourly or 6-hourly accumulated rainfall is available from the GFDL, GFS, and Eta models.

3. RESULTS

The validation technique presented here was developed and tested for Hurricane Isabel (2003). Figure 1 shows 24-hr accumulated rainfall fields for the NPVU dataset and the R-CLIPER, GFDL, Eta, and GFS models. For the time period shown here (12 UTC 18 to 12 UTC 19 September),



(a)

(b) (c)

(d) (e)

Figure 1. Plot of 24-hr accumulated rainfall (in) from 12 UTC 18 to 12 UTC 19 September 2003 for Hurricane Isabel for (a) NPVU data; (b) R-CLIPER; (c) GFDL; (d) Eta; and (e) GFS models. Dynamical forecast models (c, d, and e) were initialized at 12 UTC 17 September. Dark solid line denotes best track or forecast position, with position of storm every 6 h denoted.

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the observed rain maximum stretches through central Virginia, along and just to the right of the storm track. Values of 24-hr rain never reach 8 inches anywhere in the domain. There is significant structure in the rainfall field, corresponding both to storm features such as rainbands and topographic effects (e.g., the maximum in western Virginia and the minimum in western Pennsylvania).

The forecast models all produce rain fields that correspond to the observations in varying degrees. The R-CLIPER, which is based on the observed track, produces rainfall amounts that are consistent with the observed amounts. However, since the R-CLIPER assumes a circularly symmetric rain field around the storm at any given time, there is very little structure to the rain field. The GFDL produces rain amounts and structures comparable to the observations, such as bands of heavy rain roughly 150 km on each side of the storm track and a rainfall minimum in western Pennsylvania. The Eta and GFS models also show structure to the rainfall fields (the GFS less so since it is a coarser resolution). Both of those models produce significantly higher rainfall amounts near the location of landfall compared to the observations.

While the comparisons above qualitatively show the performance of the models compared to the observations, they do not provide a quantitative comparison of the model performances across the entire spectrum of rainfall amounts. Figure 2 shows a new way of evaluating rainfall forecasts that can address such issues as track error and sampling area differences. Figure 2a shows the cumulative distribution function (CDF) of rainfall for each model and the observations for the domain shown in Fig. 1. The CDF shown here counts the number of points falling within the threshold indicated. From Fig. 2a it can be seen that the GFDL and GFS models produce about the same distribution of rainfall as was observed except for the higher rain amounts (> 1 inch), where the GFS model produces more heavy rain than was observed. The R-CLIPER produces more light rain than was observed. For example, about 40% of the raining area in the NPVU data is receiving rain amounts up to 0.5 inches, while about 60% is receiving that much rain in the R-CLIPER. The distribution of rain in the Eta model is highly skewed toward the heavy rain amounts. Less than 30% of the rain is 1 inch or less in the Eta, compared to 60% in the observations. Nearly 100% of the rain in the observations is less than 4 inches, while only about 65% of the grid points in the Eta model are producing rain up to this amount.

A comparison of the CDFs is also shown using the probability matching method (PMM; Fig. 2b). The PMM finds the set of pairs of observed and forecast CDFs at which the cumulative probabilities of the two are equal. From this comparison can be seen the tendency to underpredict rain from the R-CLIPER for this case at all rainfall values. The GFDL model also slightly underpredicts rain between 0.5 and 1 inch thresholds. The GFS has a slight high bias at all rainfall values above 0.2 inches. The most significant bias of all is the Eta, which produces 3-4 times more rain than is observed for the 40-80% CDF range. Some of this bias may simply be related to the fact that the storm moved more slowly in the Eta model just prior to landfall (Fig. 1), but further inland the rain amounts appear higher than the observations even when the simulated storm has a translational speed comparable to the actual storm.

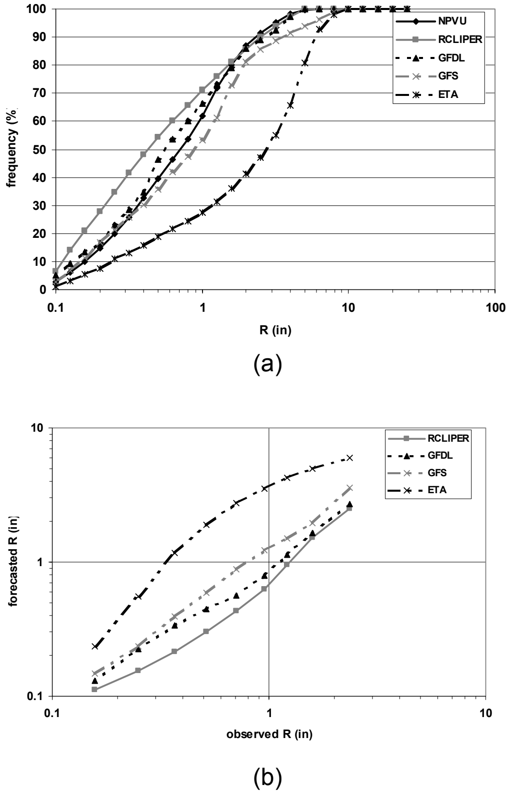

Figure 2. (a) Cumulative probability distributions of observed and forecast 24-h rainfall (inches) for Hurricane Isabel (2003). (b) Probability-matched 24-h rain estimates from observations and forecasts. Each point represents the probability-matched value at 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, and 90% from left to right, respectively.

4. FUTURE WORK

Future work will involve continuing to refine this technique to better account for track error and sampling size differences. The distributions shown in Fig. 2 can be normalized for sampling area and model resolution, and the rain fields should be considered only over land to account for sampling deficiencies offshore. As more storms are evaluated using this technique, comparisons can be stratified by such variables as storm translational speed to minimize that factor as a source of variability in the comparisons. Areally-averaged rainfall can be computed to cover the entire storm or target subregions of the storm to identify differences in the development of asymmetries in the rainfall fields from the different models.

The evaluation techniques introduced here will yield a more comprehensive evaluation of the rain forecasts that covers the entire distribution of rainfall, rather than just focusing on peak rain amounts, and they will allow for a more reliable assessment of the models that may identify biases that can be incorporated into each of the models.