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INTERCOMPARISON OF NEXRAD RAINFALL ESTIMATES AND RAINGAGE MEASUREMENTS FOR GCIP

Remko Uijlenhoet[a,*], James A. Smith[a], Matthias Steiner[a],
Mary Lynn Baeck[a], and Witold F. Krajewski[b]
[a] Princeton University, Princeton, NJ
[b] University of Iowa / IIHR, Iowa City, IA

1. INTRODUCTION

The US National (NEXRAD) Radar Network, covering almost the entire conterminous US, provides a unique tool for hydrometeorological and hydroclimatological research. Composite reflectivity data from the NEXRAD network are being used to compile a 5-year continental-scale database of radar rainfall estimates at a 4 x 4 km spatial resolution and a 1-hour time resolution. To assess the quality of this database, we carry out special projects at different radar sites around the country, where we perform detailed comparisons between the composite reflectivity data, the archived volume-scan reflectivity data and data from dense networks of raingages. Often these are complemented with disdrometer data, lightning data and storm tracking analyses. Here, we report on one such special project, namely for the northern Appalachian region of the northeastern US.

2. RATIONALE

One aspect of rainfall estimation that we focus on in particular is *extreme precipitation*. Improved capability for measuring and predicting extreme precipitation would provide significant economic and societal benefits. The annual average number of deaths directly attributed to heavy rains and floods in the United States is quoted by Dabberdt *et al.* (2000) to be between 100 and 160. On several occasions over the past decade (October 1994, Texas; 5 May 1995, Dallas, Texas), the total property damage caused by flooding associated with extreme rainfall passed the 1 billion dollar mark (Smith *et al.*, 2000a,c; American Meteorological Society, 2000).

Extreme precipitation can be produced in different meteorological environments, such as landfalling tropical cyclones (e.g. Rappaport, 2000), mesoscale convective systems (such as squall lines; e.g. Steiner *et al.*, 1999), supercell thunderstorms (Smith *et al.*, 2000c) and quasi-stationary convective systems over complex terrain (e.g. Smith *et al.*, 1996; Landel *et al.*, 1999; Petersen *et al.*, 1999). Here, we focus in particular on orographic convection.

Often, it is not the extreme precipitation itself, but the associated hydrologic response at the land surface (such as (flash) floods, land slides, debris flow, etc.) that cause the greatest damage (e.g. Smith *et al.*, 2000a,b,c). The impact of extreme precipitation can be particularly severe over urban areas (e.g. Dabberdt *et al.*, 2000; Petersen *et al.*, 1999; Smith *et al.*, 2000b,c).

Two major problems when using single-parameter radar in combination with a standard (fixed) relationship between radar reflectivity (Z) and rain rate (R) are the overestimation of extreme "cold-process" rain (associated with hail contamination; e.g. Smith *et al.*, 2000c) and the underestimation of extreme "warm-process" rain (American Meteorological Society, 2000; Smith *et al.*, 2000c).

3. CASE STUDY

The rugged local topography (Appalachian Mountains, maximum elevations 2000-2500 m) and the intense warm season rainfall in this region (induced by orographic convection) make the Appalachians a challenging site, both from an operational radar perspective and from a hydrometeorological perspective. In fact, some of the largest rainfall accumulations at short time scales have been measured in this region (e.g. the Smethport, PA Storm of 18 July 1942, with a world record rainfall accumulation of over 780 mm in merely 4 hours). Moreover, the availability of rainfall data from a relatively dense raingage network (the IFLOWS network) allows detailed intercomparisons. We present such intercomparisons between the volume scan reflectivity data of the Pittsburgh radar and the corresponding IFLOWS raingage data for the Redbank Creek Storm of 18-19 July 1996. These intercomparisons are supported by analyses of lightning data (providing information about the microphysics of orographic convection) as well as storm tracking analyses (providing information about the dynamics).

The Redbank Creek Storm can be considered a "model" for extreme rain events along the western margin of the central Appalachian region. The flood associated with this storm was the largest in an 80+ year record, exceeding the "hurricane" flood (Agnes - June 1972) and the rain/snowmelt flood (March 1936). Tracking analyses show that the space-time structure of this flood producing storm is characterized by four major convective elements moving in a southeasterly direction across northwestern PA and over the Redbank Creek watershed (41.1°N, 79.1°W, ~1500 km^2). These storms produce intense cloud-to-ground flash rates. They can be considered "large", with rain areas (defined as areas where rain rates are greater than 25 mm h^{-1}) exceeding 400 km^2. The storm elements move with unusually large speeds (exceeding 80 km h^{-1}). The storm is not so much characterized by its large rainfall intensities (remaining less than 200 mm h^{-1}) as by its impressive accumulations (exceeding 200 mm in about 6 hours).

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[*] *Corresponding author address*: Dr. Remko Uijlenhoet, Department of Civil and Environmental Engineering, Princeton University, Princeton, New Jersey 08544; phone: (609)258-5429; email: ruijlenh@princeton.edu

An analysis of raingage measurements from a station in the Redbank Creek watershed shows that the yearly distributions of the number of rainfall events with accumulations exceeding 25 and 50 mm exhibit sharp peaks around the 18th of July. Analyses of WSR-88D composite reflectivity data reveal that the Redbank Creek Storm was embedded in a series of extreme rain events that occurred between 16 and 20 July 1996 (like in 1942 and 1889) with similar phase speeds and spatial extents (from Iowa to eastern Canada). Continental scale storm systems are characteristic of the precipitation climatology for the US east of the Rocky Mountains in July.

Three characteristic spatial scales of meteorological controls of extreme floods in the Central Appalachians can be distinguished. At scales exceeding 10,000 km^2, a combination of rain and snowmelt is the main flood-producing factor (e.g. the 19 March 1936 flood). At scales between 1,000 and 10,000 km^2, tropical storms are the main controls (e.g. the Hurricane Agnes Flood of 23 June 1972). Finally, at scales smaller than 1,000 km^2, orographic thunderstorms are the main flood producing factors (with the Smethport storm as the ultimate example). Our analysis of the Redbank Creek storm provides a "model" for the latter type.

4. RESULTS OF INTERCOMPARISONS

We have selected 97 IFLOWS raingages under the Pittsburgh radar umbrella for which the total rainfall accumulation during the Redbank Creek Storm exceeded 25 mm. The rainfall traces from those gages were compared with the corresponding base-scan Level II reflectivity data for the Pittsburgh radar, converted to rain rates using the standard NEXRAD *Z-R* relationship ($Z = 300R^{1.4}$) and accumulated over 15 minutes.

Figure 1 shows scatterplots of 15-minute rainfall rates and total event rainfall accumulations for all 97 gage-radar pairs. The straight lines indicate 1:1 correspondence and the crosses indicate "suspect" gage or radar traces. The overall correspondence seems satisfactory, although the radar-derived rainfall accumulations seem to underestimate the gage-derived accumulations slightly. This observation seems to be confirmed by Figs. 2 and 3, which provide a more detailed look at the time traces of the rain rates and rainfall accumulations for 4 gage locations just west of the Redbank Creek watershed.

Figure 4 shows, for the same gage locations, the "striking" correspondence between the gage-derived 15-minute rain rates and the total number of cloud-to-ground lightning strikes over the same time intervals in 10 km (radius) circles surrounding each of the gages.

5. SUMMARY

We have presented a case study of gage-radar intercomparison for the Redbank Creek, PA storm of 18-19 July 1996. This storm can be considered a "model" for extreme rain events along the western margin of the central Appalachian region, a region that is known for its record rainfall accumulations at short time scales. After quality control of both the gage and the radar data, the correspondence between the two seems to be satisfactory, albeit that the Pittsburgh radar seems to underestimate the IFLOWS gages slightly. The correspondence between gage-derived rainfall rates and cloud-to-ground lightning rates is "striking". This points to the potential of lightning as an additional source of information in quantitative estimation and forecasting of (orographic) convective rainfall (e.g. Tapia *et al.*, 1998).

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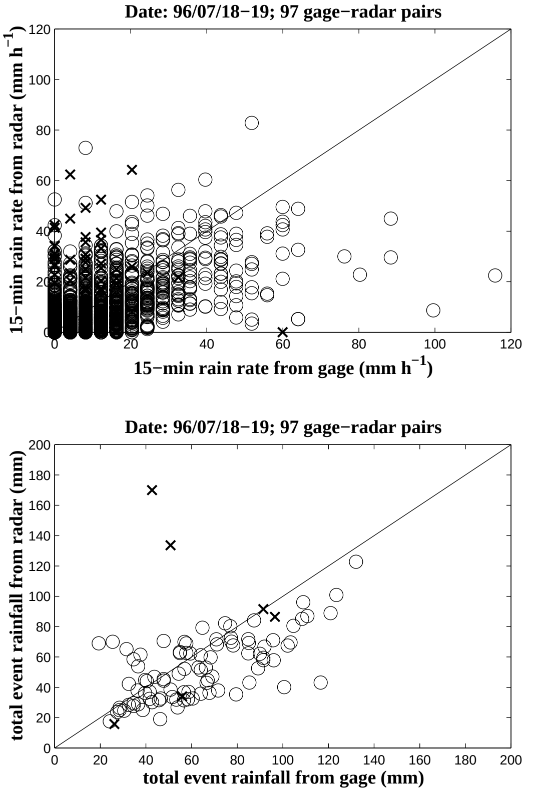

Figure 1. Scatterplots of 15-minute rain rates and event totals for 97 locations.

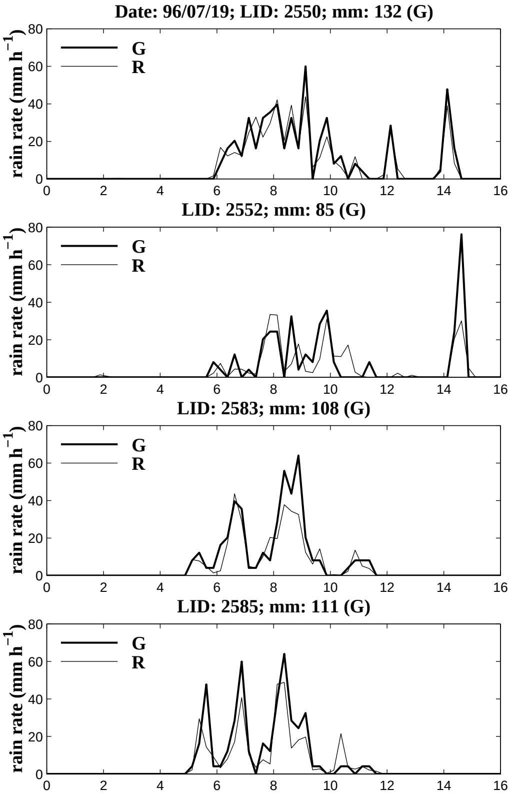

Figure 2. Time series of raingage (G) and radar-derived (R) 15-minute rain rates.

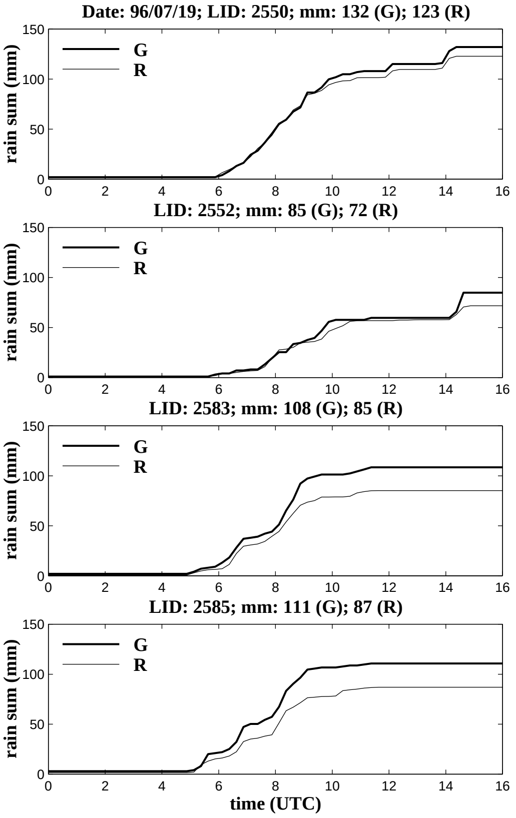

Figure 3. Time series of raingage (G) and radar-derived (R) rainfall accumulations.

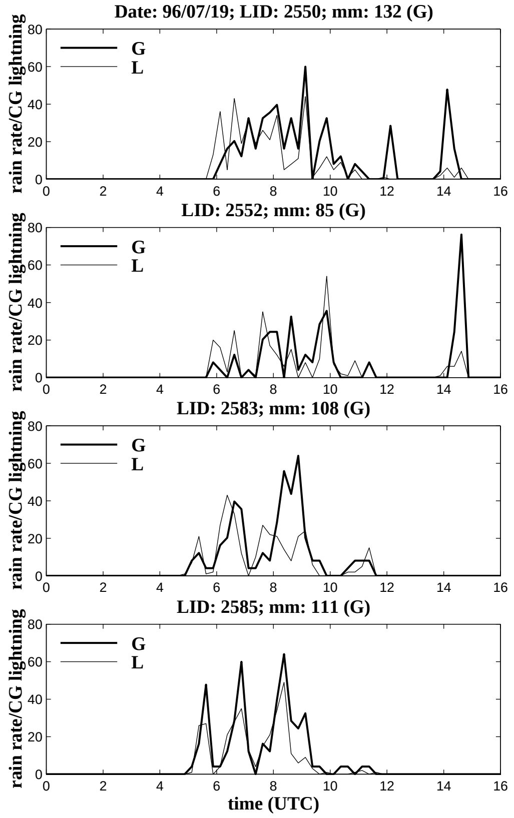

Figure 4. Time series of raingage rates (G) and cloud-to-ground lightning rates (L).