Gauge-Radar Precipitation Merging Methods for Reliable Flood Forecasting

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Introduction

- Engineers and hydrologists use hydrologic models for planning, flood forecasting and warning, and water budget modeling
- These models are based on the relationship between rainfall and runoff and serve to define fluvial responses including: a) flooding (Fig. 1); b) drying up of stream flows (Fig. 2); and c) an increase or decrease in the sediment transport capacity of the stream


Figure 1


Figure 2

- Confidence in hydrological models is dependent on the accuracy and reliability of precipitation inputs[1]
- Rain gauges and weather radar are the most widely used instruments for the collection of near real-time rainfall estimations
- Both instruments suffer from well-known errors
- Numerous techniques have been proposed to merge rain gauge and radar measurement techniques at high spatial and temporal resolutions in order to minimize errors and take advantage of the strengths of each instrument[2]

Research Objective

- Assess the accuracy of gauge-radar merging methods on estimated rainfall accumulations and on predicted flows using Environment Canada's radar network

Study Site

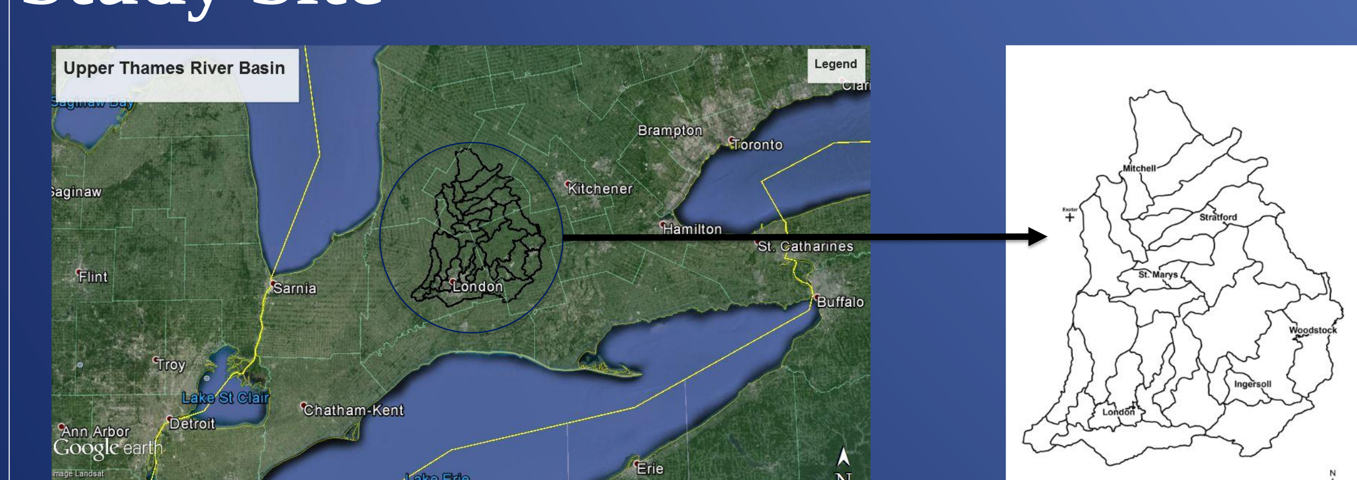

Figure 3

- Upper Thames River basin (UTRb) located in Southwestern Ontario has an area of 3421 km^2 (Fig. 3)
- Basin receives an annual average of 955 mm of precipitation with approximately 40% being carried downstream by the Thames River[4]

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Methodology

- Merging methods include:
  - Mean field bias correction (MFB)
  - Brandes spatial adjustment (BSA)
  - Local bias correction with ordinary kriging (LB)
  - Conditional merging (CM)
- Generated rainfall field accuracy is tested against an independent verification gauge network
- The independent verification network is assumed to represent the true rainfall field
- Adjustment of radar data is done at hourly and event based temporal resolution
- Merging methods are tested against raw radar data alone and kriged (ordinary kriging) rainfall field based on rain gauges alone


Figure 4: Waubuno Stream & Rain Gauge (UTRCA)


Figure 5: Exeter Radar Station (Environment Canada)

Radar Data

- Radar data provided by Environment Canada's Meteorological Research Division for the Exeter radar station
- Radar has a range of 120 km
- Radar have a spatial bin resolution of 1 km and an azimuthal resolution of 1 degree and a temporal resolution of 1 hour

Gauge Data

- Gauge provided by the Upper Thames River Conservation Authority
- Study uses data from 17 tipping bucket rain gauges
- Figure 6 displays the locations of the Exeter radar station, both network of correction gauges and the network of verification gauges

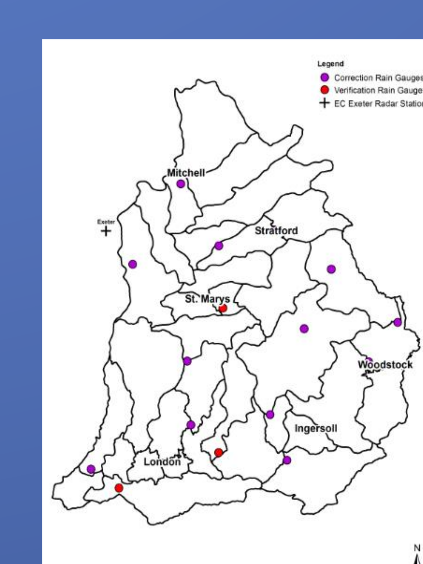
Figure 6

Event Selection

- Due to data constraints with the radar, events were only selected from the summer of 2013 and 2014

References

[1]McMillan, H., B. Jackson, M. Clark, D. Kavetski, and R. Woods. 2011. "Rainfall uncertainty in hydrological modeling: an evaluation of multiplicative error models." *Journal of Hydrology* 400(1-2): 83-94. DOI: 10.1016/j.jhydrol.2011.01.026.

[2]Goudenhoofdt, E. and L. Delobbe. 2009. "Evaluation of radar-gauge merging methods for quantitative precipitation estimates." *Hydrol. and Earth Syst. Sci.* 13: 195-203. doi:10.5194/hess-13-195-2009.

[3]Wilson, J. W. 1970. "Integration of radar and rain gauge data for improved rainfall measurement." *J. of Appl. Meteor.* 9(3): 489-497. doi:org/10.1175/1520-0450(1970)009<0489:IORARD>2.0.CO;2.

[4]Wilcox, I, C Quinlan, C Rogers, M Troughton, I McCallum, Quenneville A, E Heagy, and D Dool. 1998. *The Thames River Watershed: Background study for nomination under the Canadian heritage rivers system.* London: Upper Thames River Conservation Authority.

Results

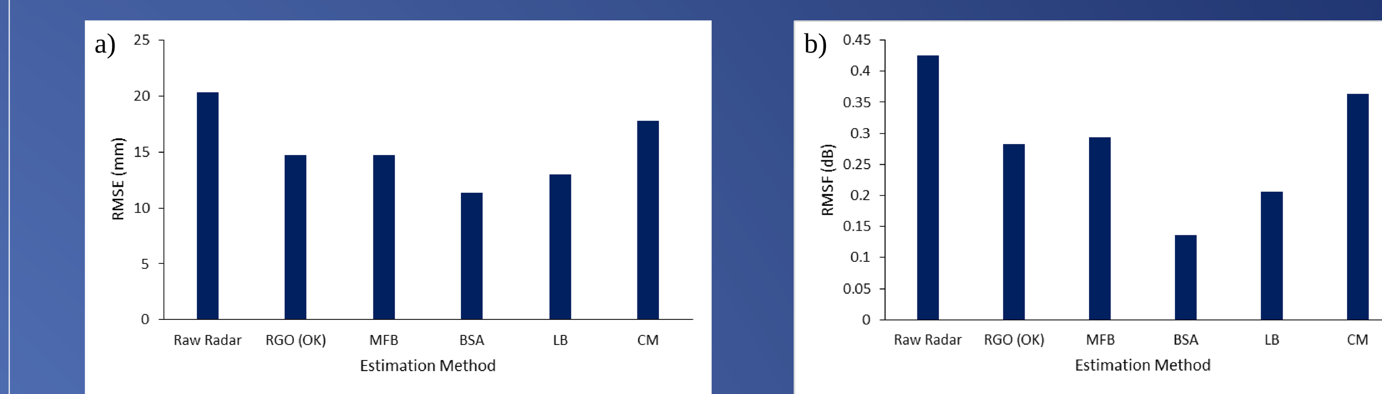

Figure 7

- Figure 7 a) and b) displays the root mean square error (RMSE) and root mean square function (RMSF) respectively for rainfall accumulation error generated during event based correction

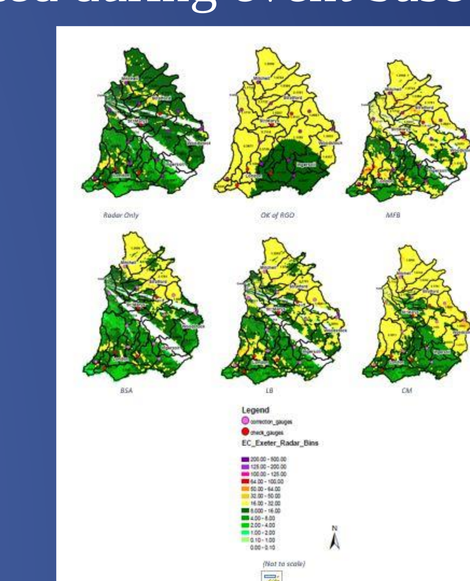
Figure 8

- Figure 8 displays an example of the differences in the spatial distribution of the rainfall fields generated by each merging technique (event based correction for 20 May 2014 event)

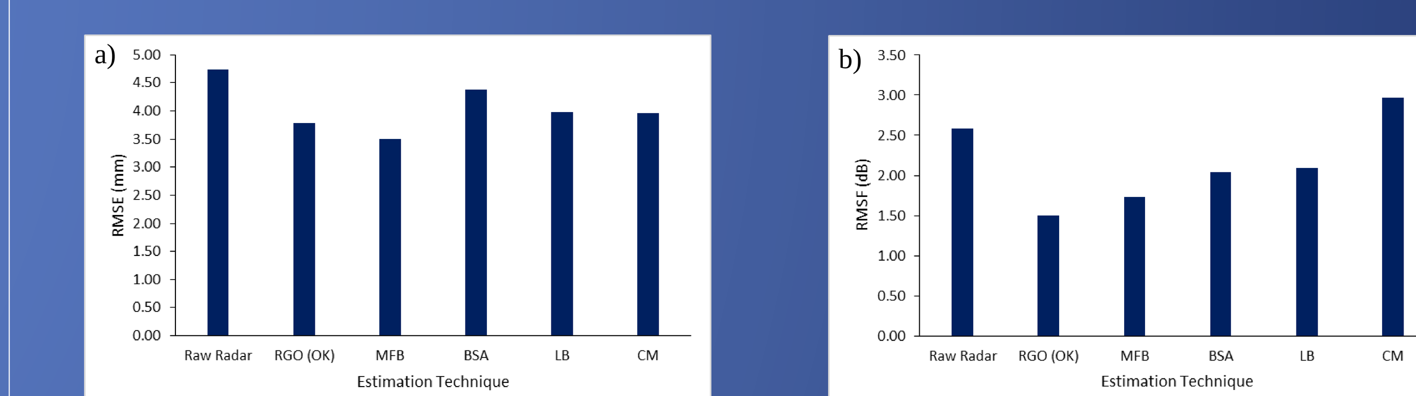

Figure 9

- Figure 9 a) and b) displays the RMSE and RMSF respectively for rainfall accumulation error generated during hourly based correction

Conclusions & Future Work

- Local bias correction methods, BSA and LB, proved superior for event based corrections
- MFB correction provided the greatest reduction in error for the hourly based correction
- Event based accumulations generated significantly smaller relative error as compared to hourly accumulations
- Future work will test the sensitivity of gauge-radar merging methods on gauge density, temporal resolution of correction and storm type.
- Future work will assess of the impact of gauge-radar merging methods on accuracy in modeled flows

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