Application of Radar QPE

Jack McKee

December 3, 2014

Topics

- **Context**
- Precipitation Estimation Techniques
- Study Methodology
- Preliminary Results
- Future Work
- Questions

Introduction

- Accurate precipitation data is required for a number of different applications including:
  - Flood forecasting and warning
  - Drought monitoring
  - Meteorological now-casting
  - Post-storm analysis
  - Effect of climate change on precipitation patterns
  - Etc.

Hydrology

- Hydrologists rely on precipitation fields to forecast runoffs

Hydrological modeling

- Hydrological model attempts to model the complex physical characteristics of a basin in order to determine stream flow

"*Rainfall is the main and vital [input] for hydrological modeling and rainfall uncertainty dominates the uncertainty of the model*"

Golding (2009)

Goal

Develop a reliable automated process for obtaining precipitation estimates using state-of-the-art techniques for the acquisition and estimation of spatially distributed rainfall fields

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Precipitation Estimation

Waubuno Stream & Rain Gauge
(UTRCA)

Exeter Radar Station
(Environment Canada)

Rain Gauges - Definition

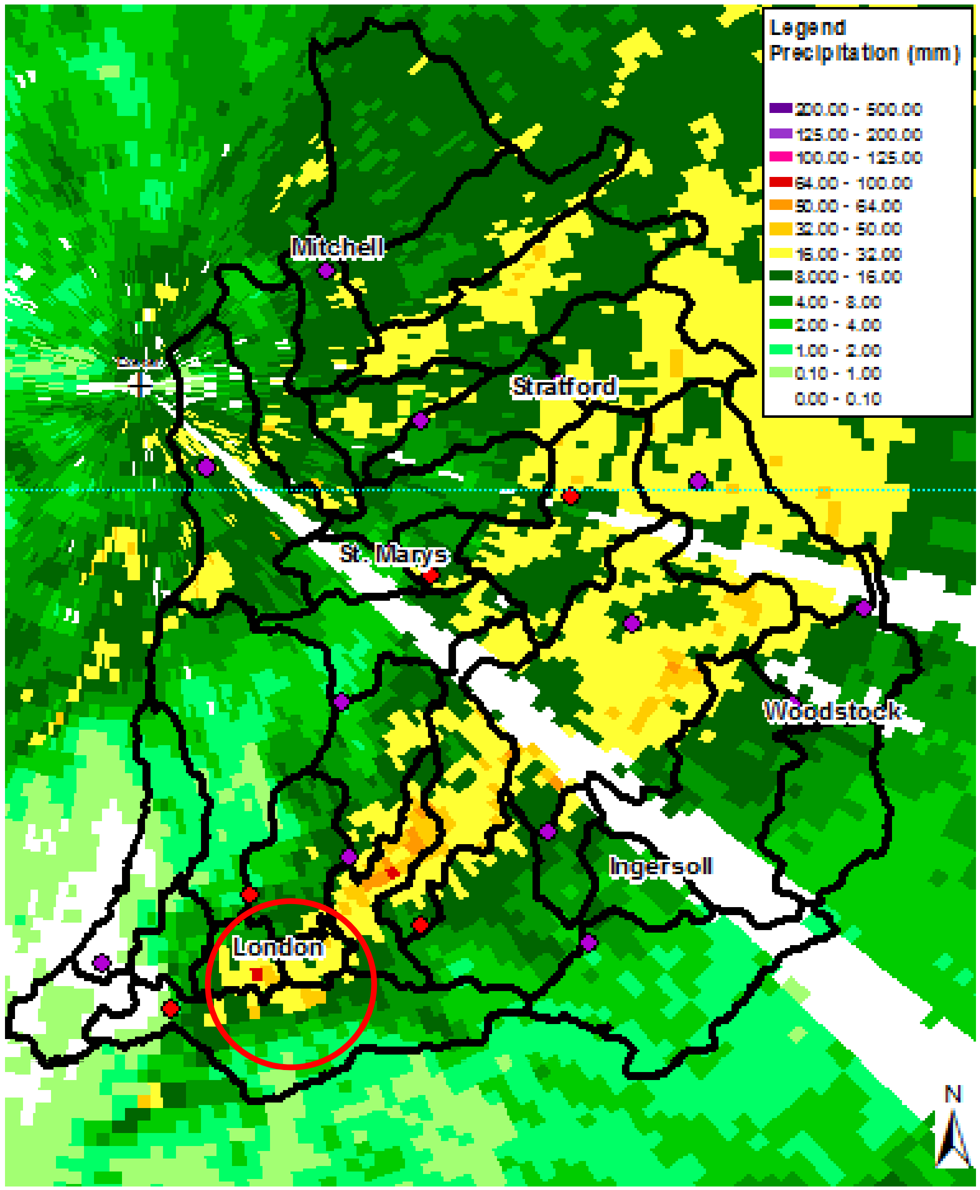
- Most widely used technique for precipitation estimation
- Rain gauges measure the depth of rainfall over a set time for a given location
- Provide accurate point measurements

Rain Gauges - Errors

- Two Critical Sources of Error:
  - inability of point measurements to accurately characterize the spatial distribution of the rainfall field
  - systematic and calibration errors

- Significantly impact the ability to use rain gauge measurement to develop an understanding of the distribution of precipitation

Rain Gauges - Errors



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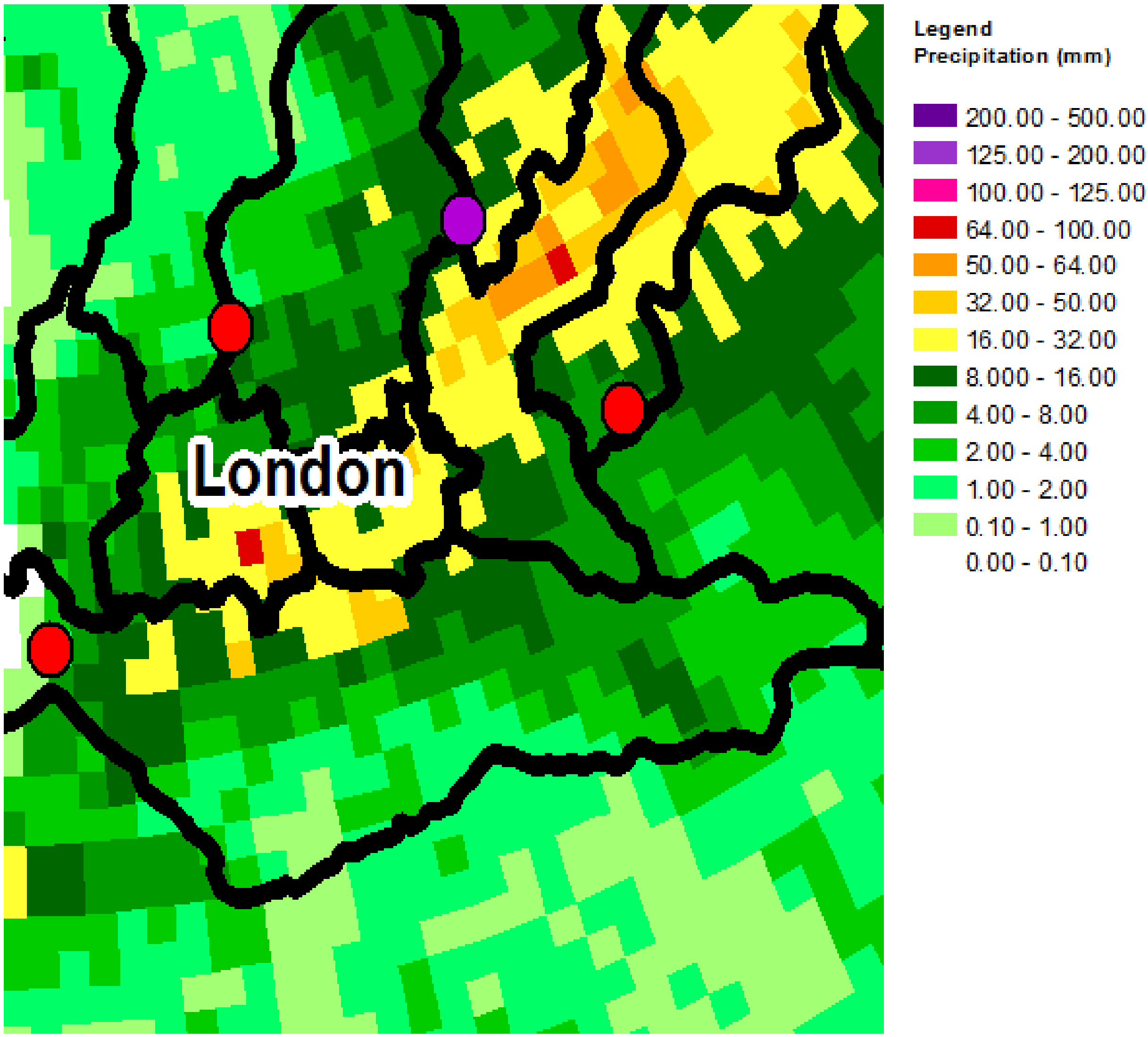
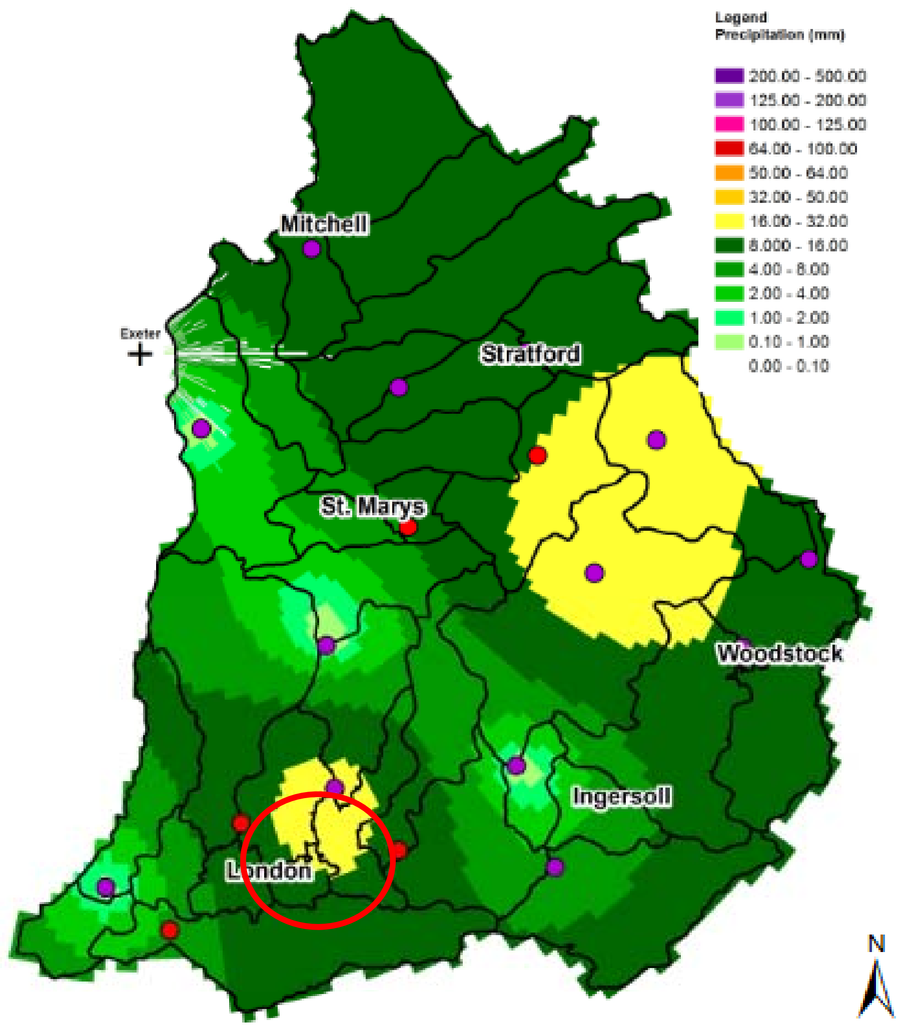
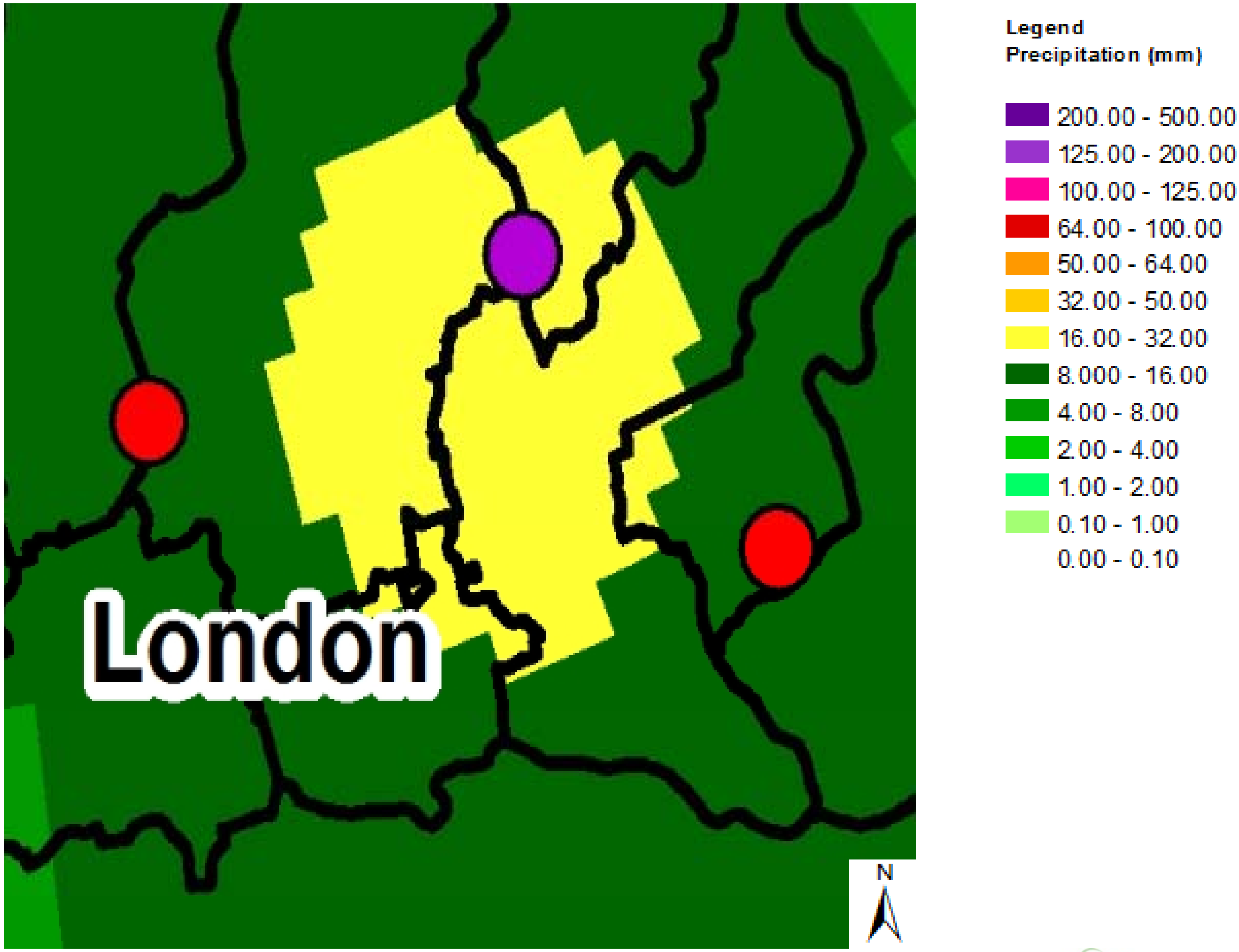
Rain Gauges - Errors



Rain Gauges - Errors



Rain Gauges - Errors



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Radar - Definition

- Transmits pulses of microwave to detect precipitation particles in the atmosphere

Radar - Definition

- Actually measures reflectivity not rainfall
- Indirectly measures rainfall intensity

Marshall-Palmer (1948)
Relationship

$$Z = aR^b$$

reflectivity Z (mm^6/m^3)

precipitation rate R (mm/hr)

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Radar - Errors

- Radar suffers from numerous sources of error which influence the accuracy of the depth measurements
- Creutin et al. (2000) characterized three major sources of radar error for QPE:
  - Electronic instability and mis-calibration of the radar system
  - Beam geometry
  - Fluctuation in atmospheric conditions

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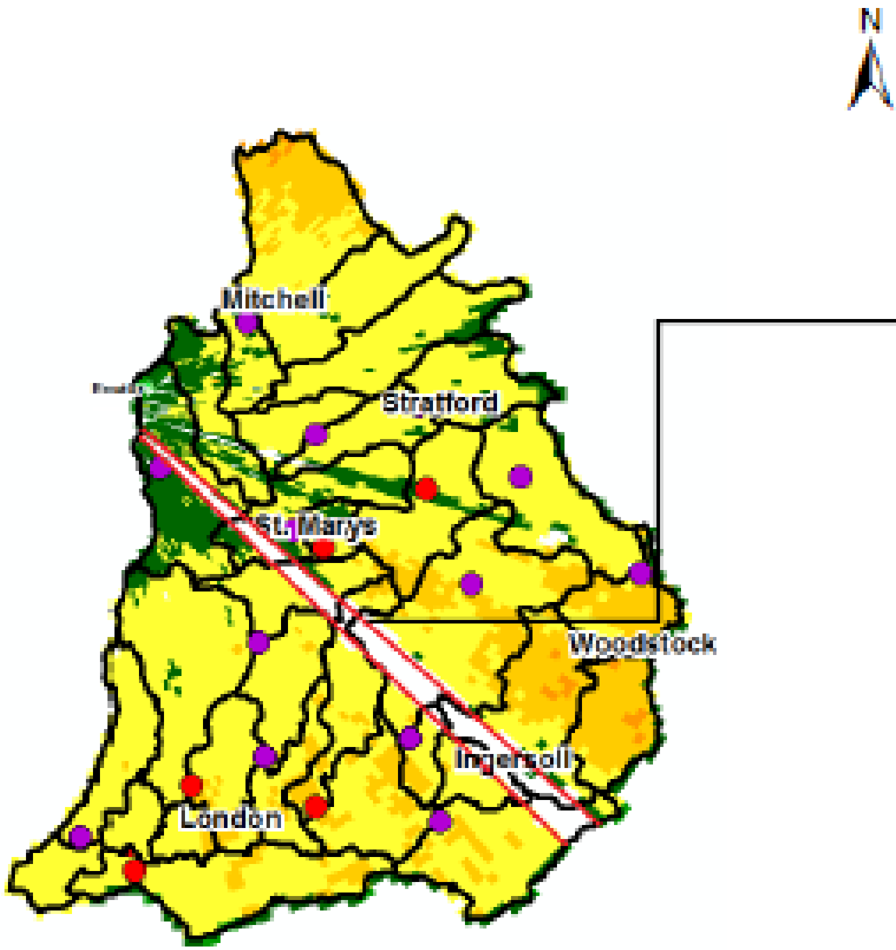
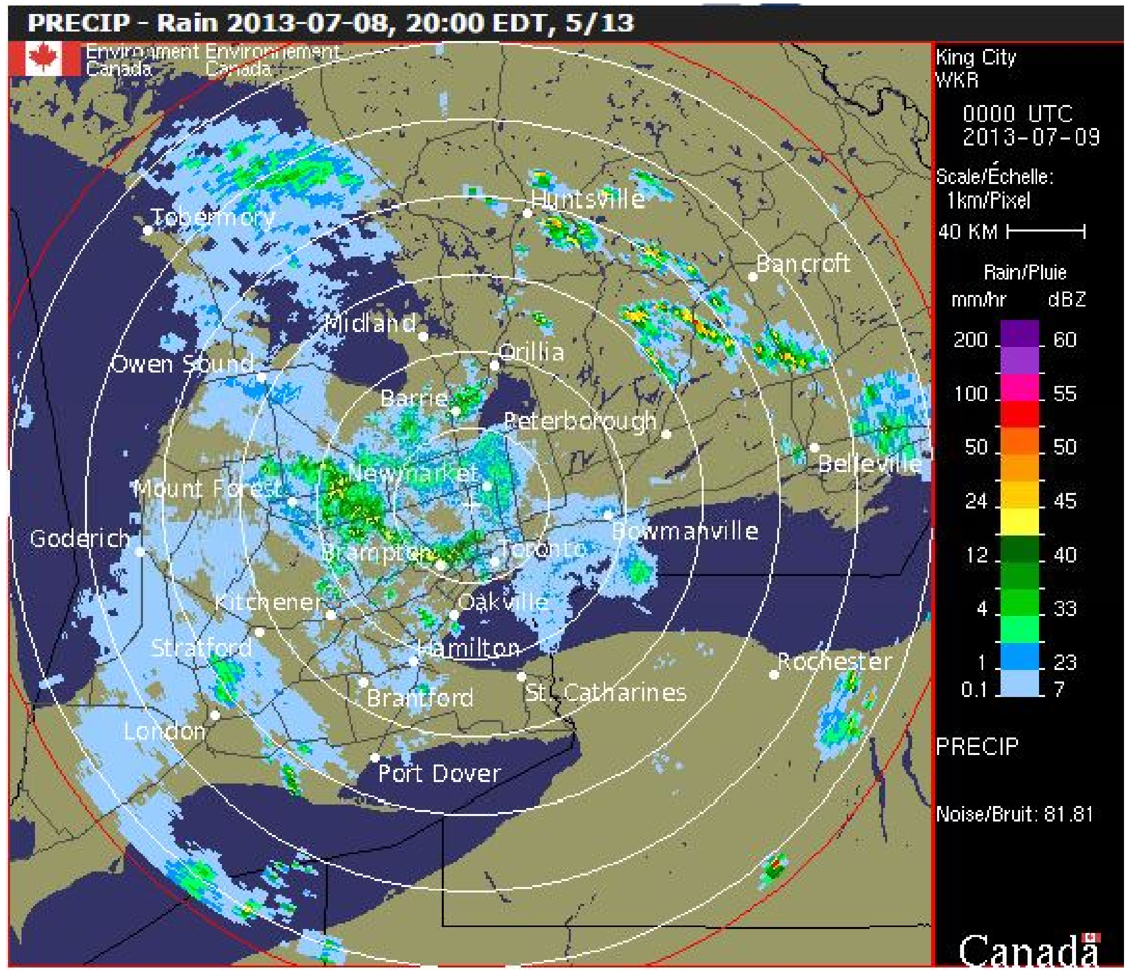
Radar - Errors



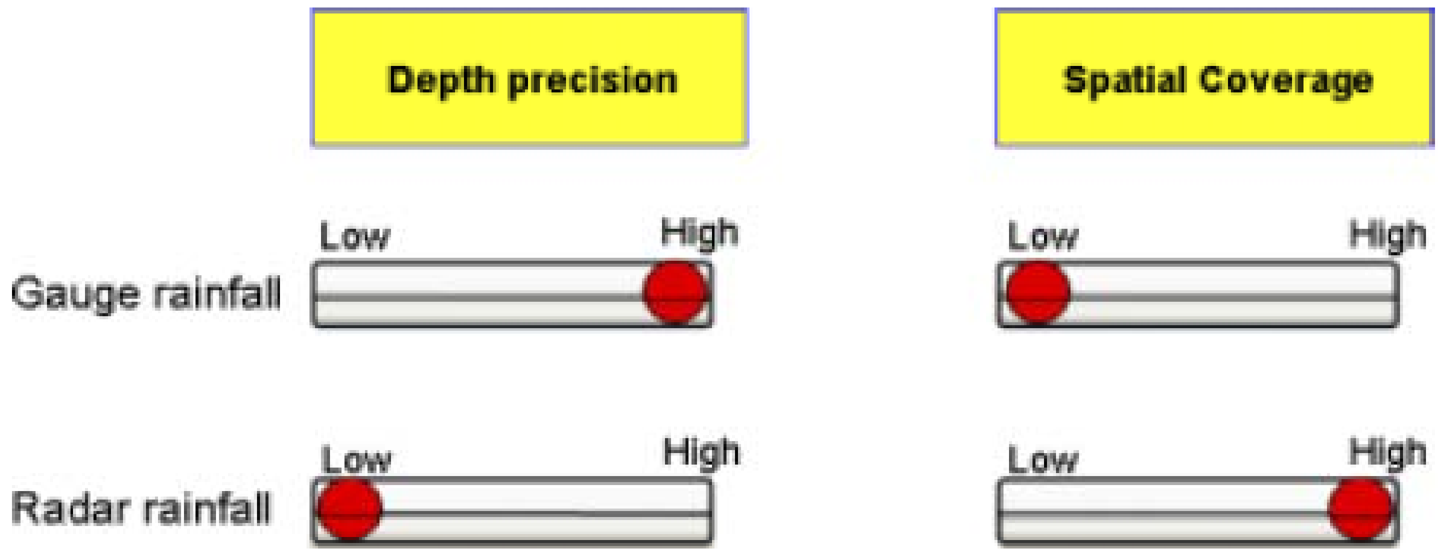
Shadow Zone due to woodlot in close proximity to radar station (Radar image taken from 31 July 2013 event)

Radar - Errors

- Radome wetting caused underestimation of rainfall accumulation of 100 mm (Boodoo et al. 2014)



Comparison



Kim et al. 2008 modified from Robbins et al. 2004

Merging Methods

- Developed to take advantage of each individual instruments strength while minimizing their respective weaknesses

"The combined use of radar and rain gauges to measure rainfall is superior to the use of either separately"

Wilson (1970, p. 495)

Assumptions

1. Gauge measurements are accurate for the gauges location
2. Radar successfully measures relative spatial and temporal variability's of precipitation
3. Gauge and radar measurements are valid for the same location in time and space
4. Relationships based on comparisons between gauges and radar(s) are valid for other locations in space and time

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Objectives

- Study broken down into two parts:
  1. Compare the accuracy of gauge-radar merging schemes in the UTRb;
  2. Assess the impact on accuracy of predicted flows in the Thames River and its tributaries

- Implement the “best” estimation technique in a near-real time automated process

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Objectives

- Study broken down into two parts:
  1. **Compare the accuracy of gauge-radar merging schemes in the UTRb;**
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Study Methodology

- Rainfall estimations are compared against an independent verification network assumed to represent the “true” rainfall field
- Previous study has shown several factors to have an influence on the overall accuracy including:
  - Rain gauge density
  - Temporal resolution of correction
  - Storm type

MFB

- Mean Field Bias (MFB) correction
- Changes the multiplicative a factor in the Z-R relationship
- Correction is applied evenly to entire spatial domain

$$Z = aR^b$$

$$C = \frac{\sum_{i=1}^{N} G_i}{\sum_{i=1}^{N} R_i}$$

BSA

- Brandes Spatial Adjustment (BSA)
- Assumes radar bias is spatially dependent due to atmospheric and conditions
- Uses Barnes objective analysis (Barnes, 1964) to distributed correction factors

$$WT_i = \exp\left(\frac{-d^2}{EP}\right) \qquad F_1 = \frac{\sum_{i=1}^{N} WT_i * G_i}{\sum_{i=1}^{N} WT_i}$$

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LB

- Local Bias (LB) correction with ordinary kriging
- Adopts the geostatistical method of kriging to distributed correction factors
- The regionalized variable is the correction factor at the gauge location which describes radar bias at discrete locations across the radar field

CM

- Conditional Merging (CM) also known as kriging with radar based error
- Assumes radar observation produces a true field of unknown values, while the rain gauges produce an unknown field of true values

$$\varepsilon_R(s_i) = R(s_i) - R_K(s_i). \qquad Corr.Precip(s_i) = G_K(s_i) + \varepsilon_R(s_i).$$

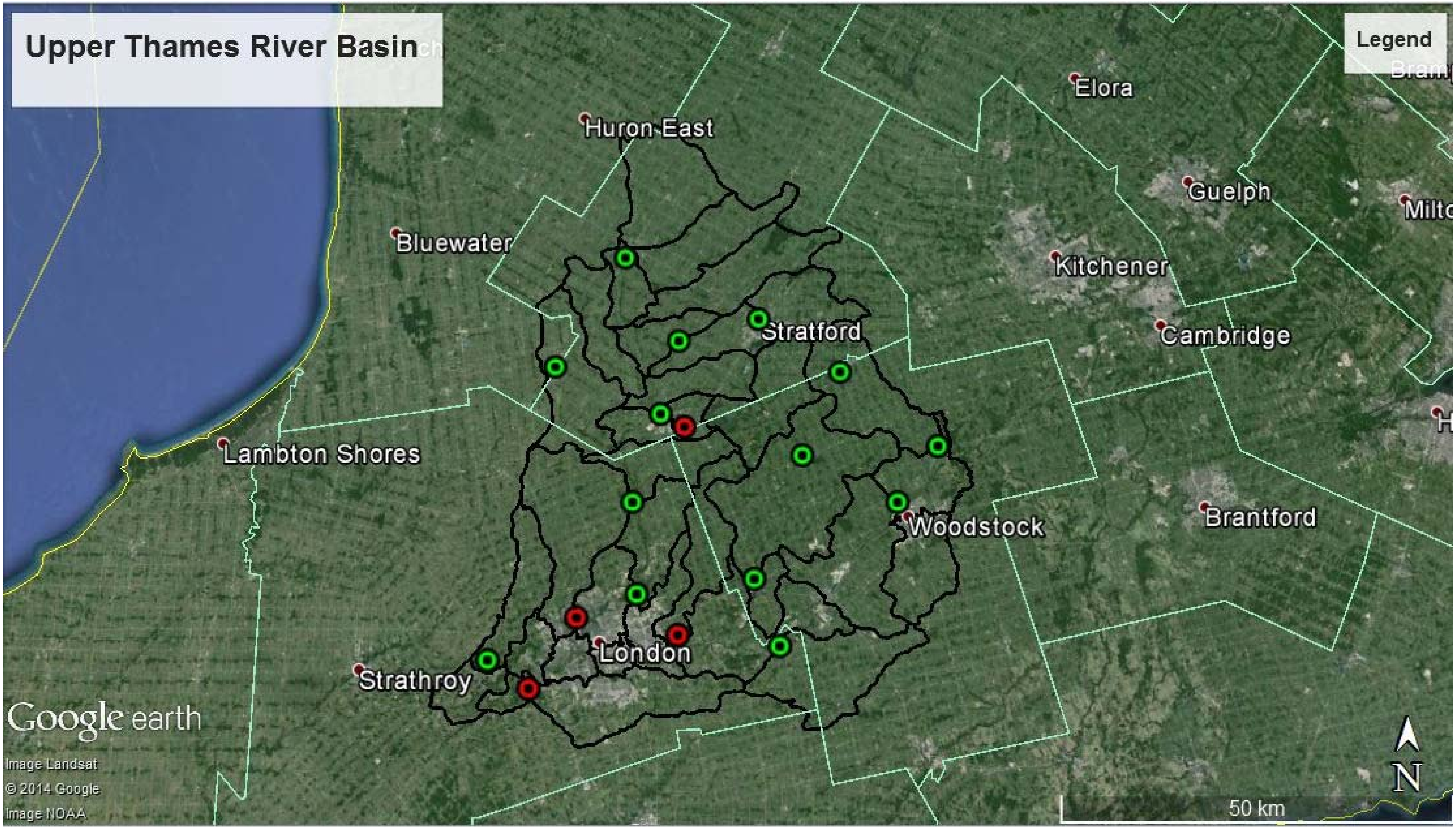
Study Area

- Upper Thames River Basin (UTRb)
- 3421 km^2
- Delineated into 34 sub-basins

Data Description – Rain Gauges

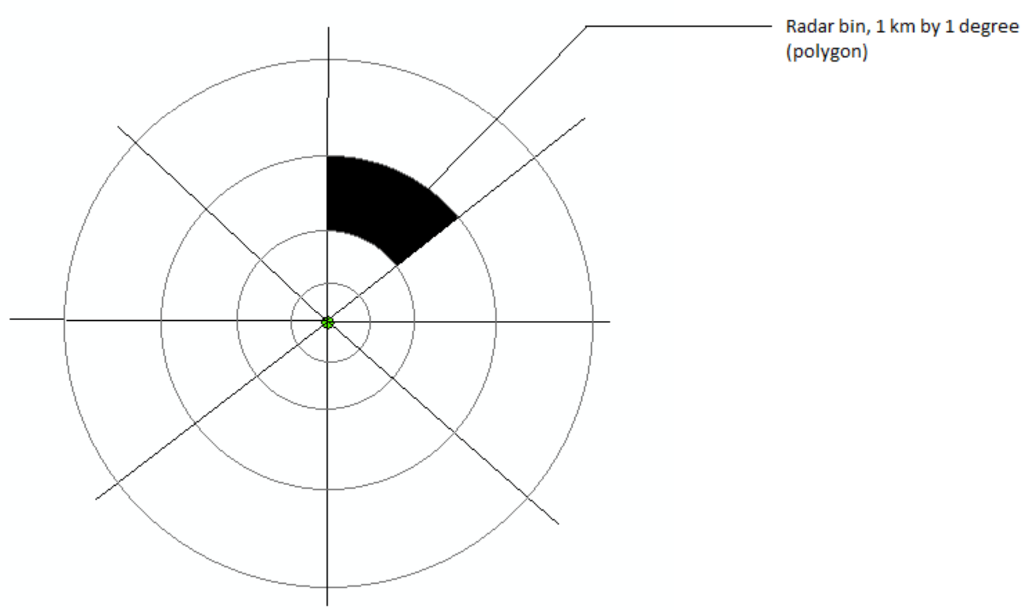
- Upper Thames River Conservation Authority operates 20 tipping bucket rain gauges
- Record on an hourly time interval
- 14 gauges selected for correction
- 4 gauges selected as an independent verification network
- 2 were located in the shadow zone

Data Description – Rain Gauges

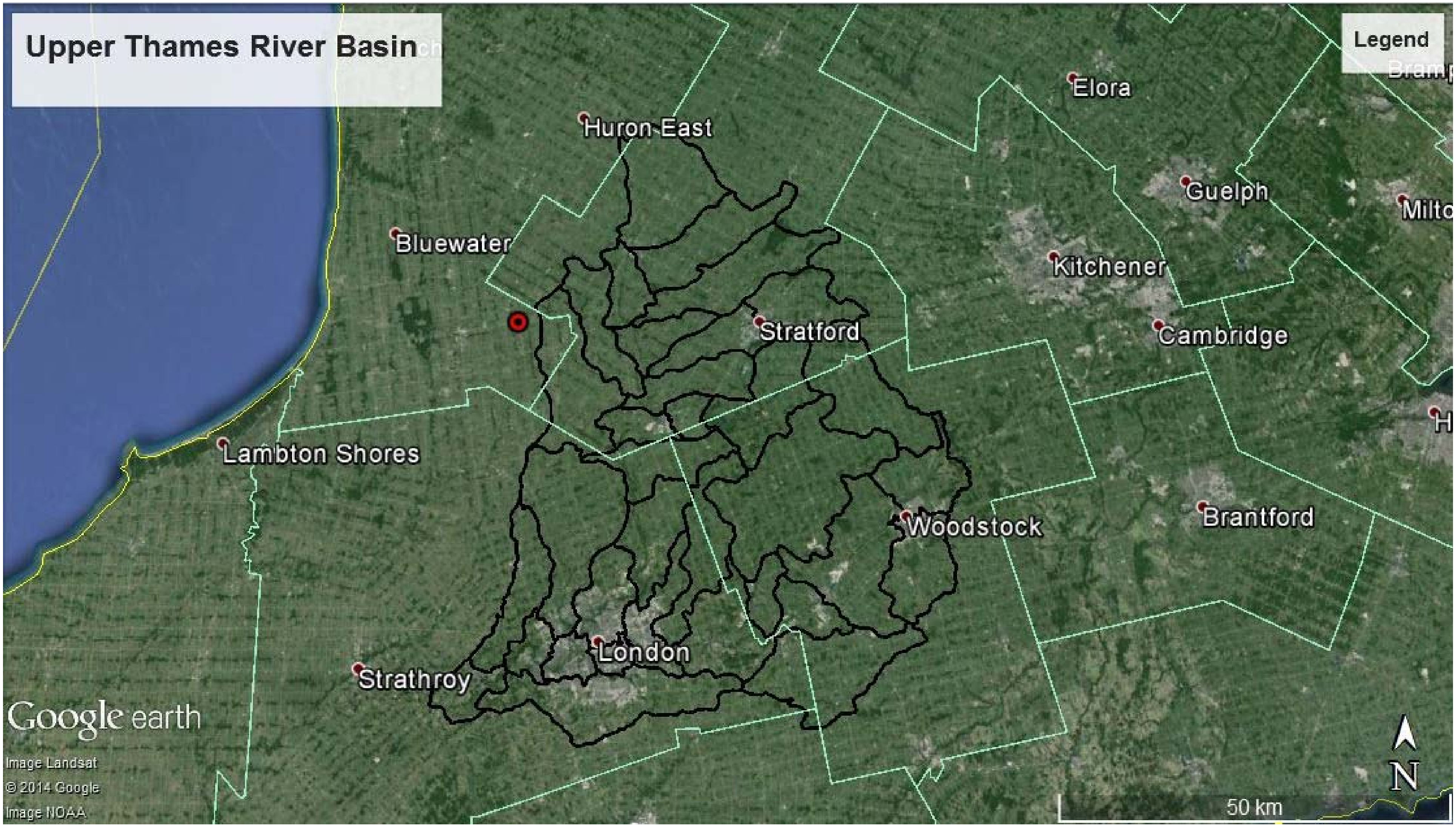


Data Description - Radar

- Radar provided by Environment Canada's meteorological research center
- Corrected QPE is only provided up to a range of 120 km



Data Description - Radar



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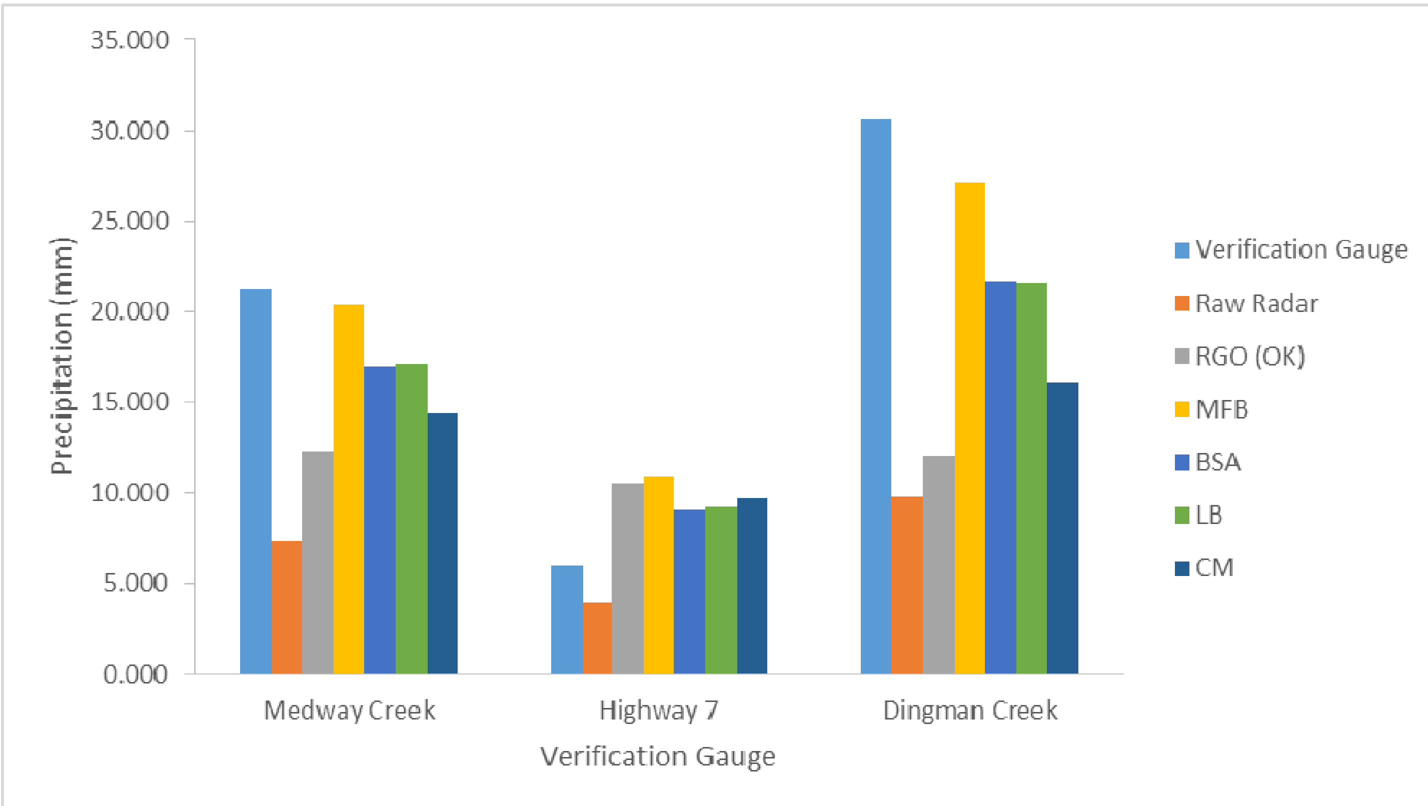
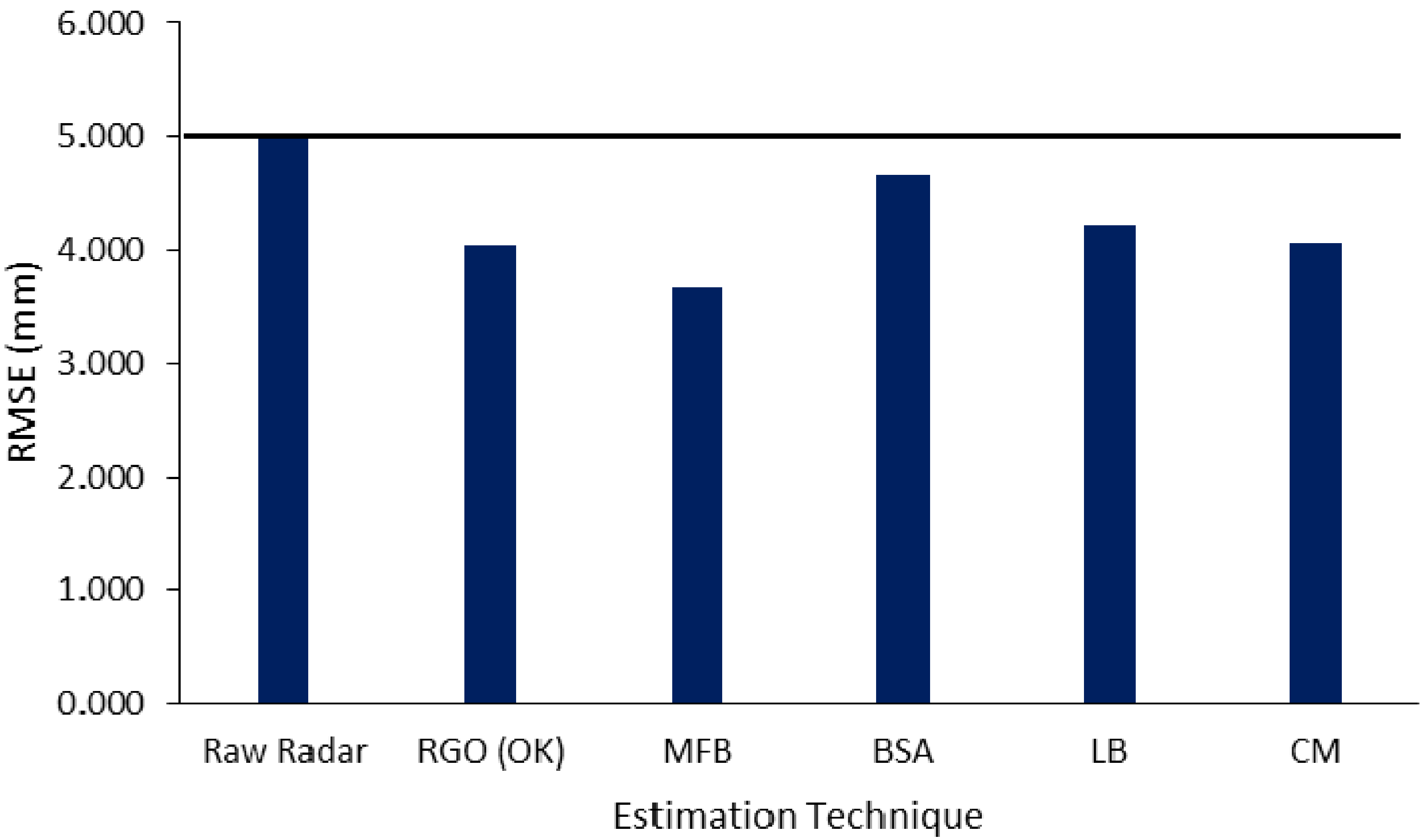
Variability



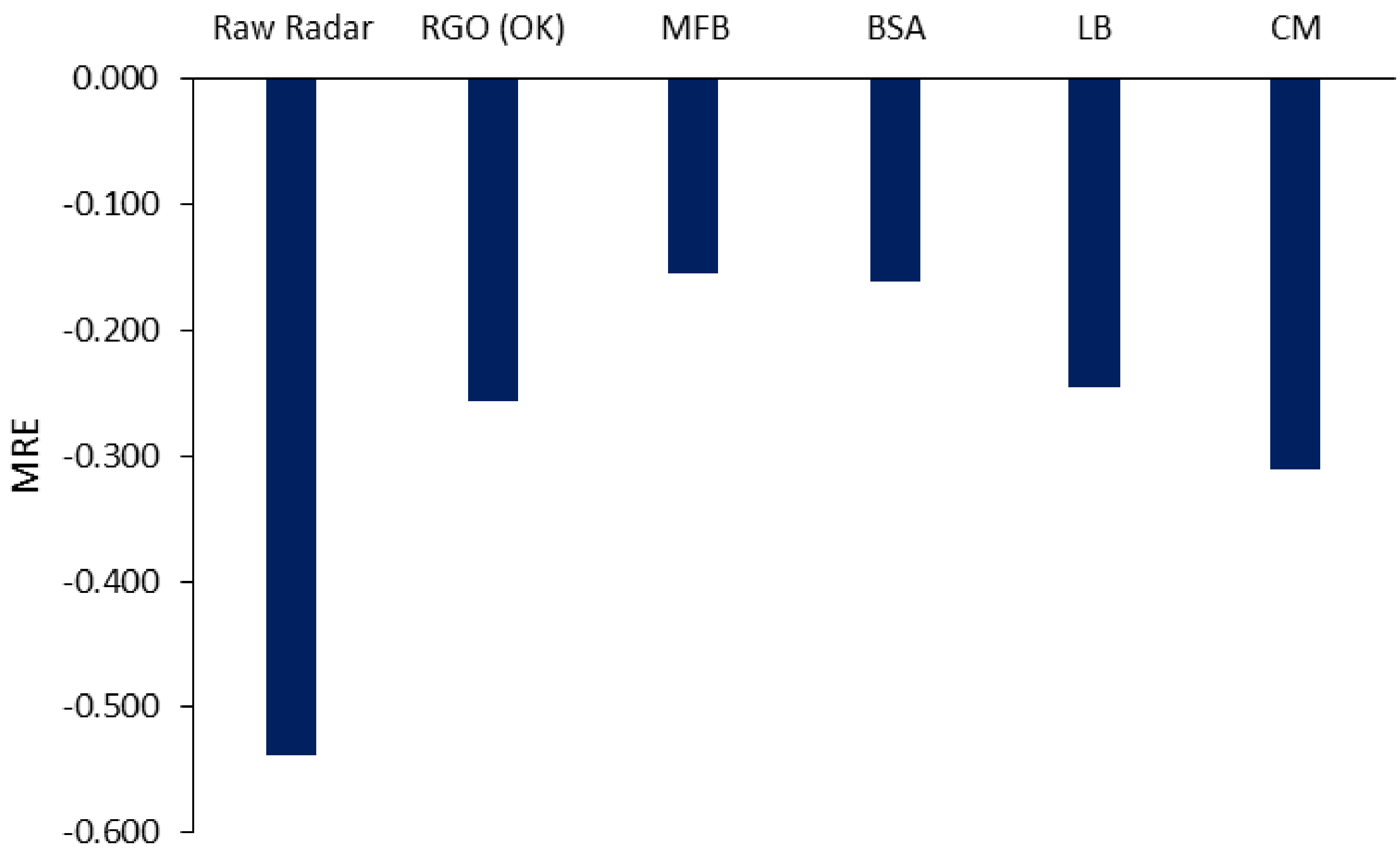
Hourly accumulation for each estimation technique
September 10, 2014, 22:00 (UTC)

RMSE



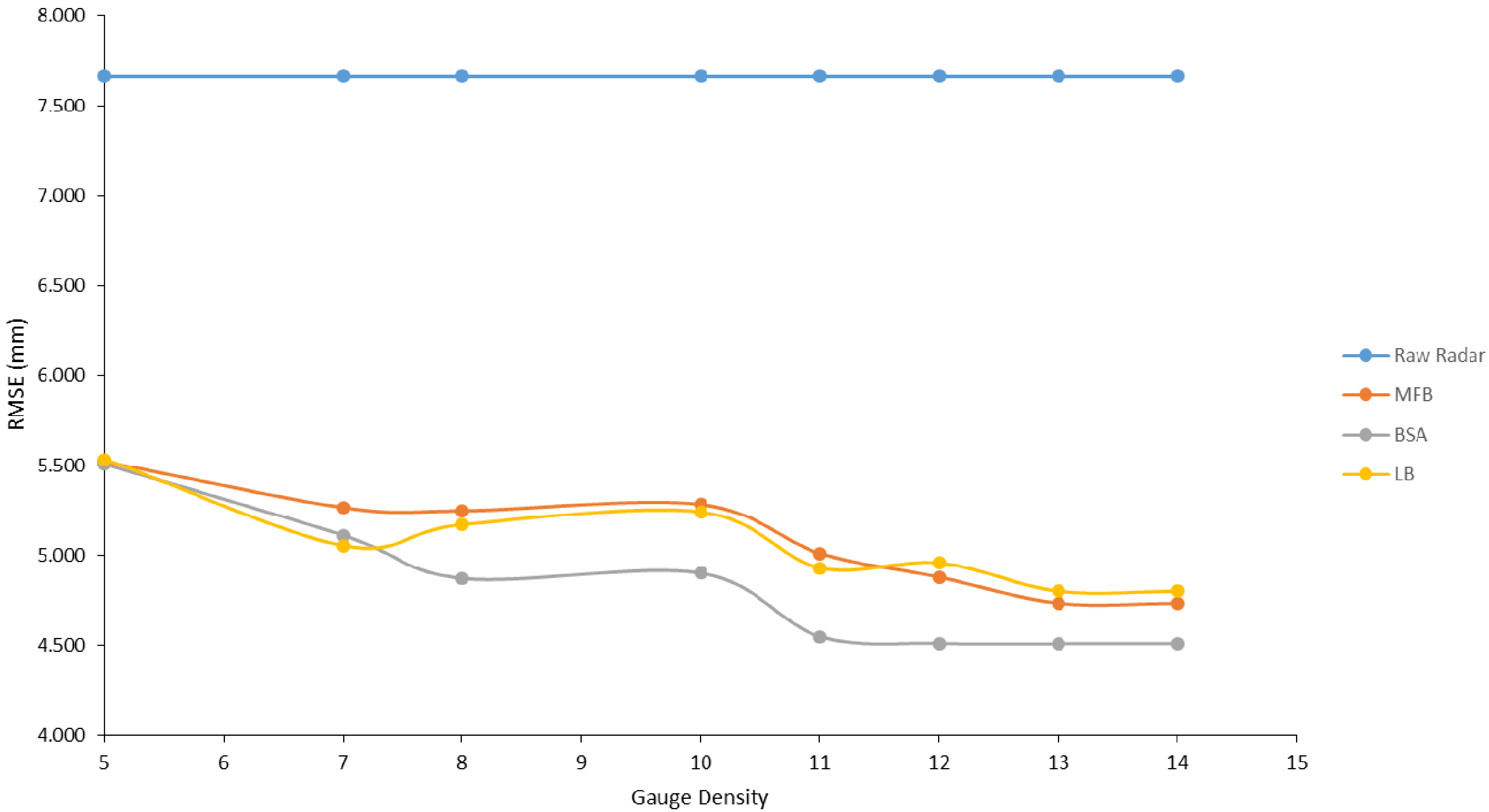
6.000
5.000
4.000
3.000
2.000
1.000
0.000
RMSE (mm)
Raw Radar
RGO (OK)
MFB
BSA
LB
CM
Estimation Technique

MRE

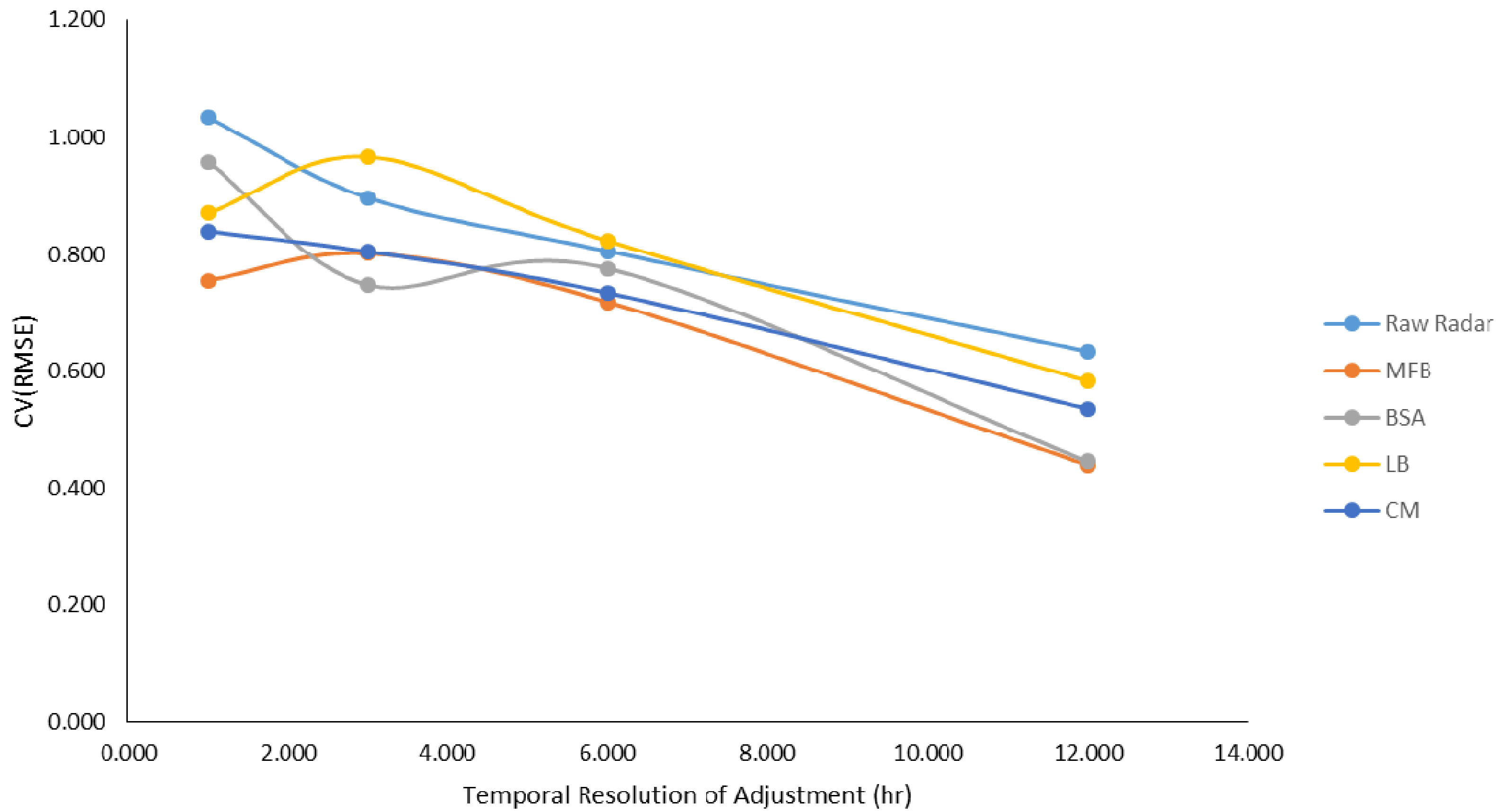


Raw Radar
RGO (OK)
MFB
BSA
LB
CM
0.000
-0.100
-0.200
-0.300
-0.400
-0.500
-0.600
MRE

Gauge Sensitivity



Temporal Sensitivity



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Future Work

- Test the effect of storm type (based on seasonal differences)
- Assess the impact of the merging methods on simulated flows in the UTRb using a semi-distributed hydrological model

Acknowledgements

UPPER THAMES RIVER
CONSERVATION AUTHORITY

Environment Canada

Western Engineering

NSERC
CRSNG

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