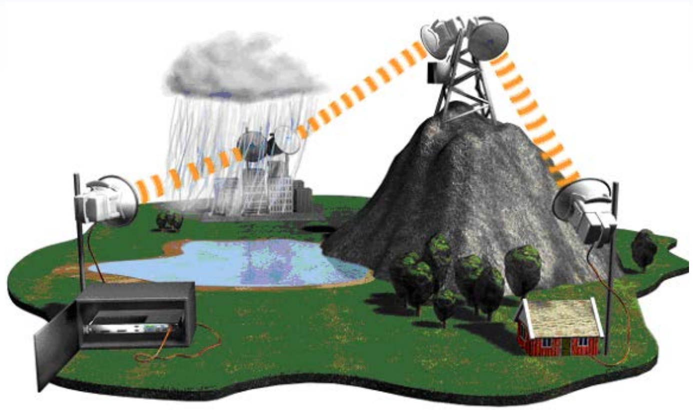
Improving urban drainage modelling with path-average rainfall from telecommunication microwave links



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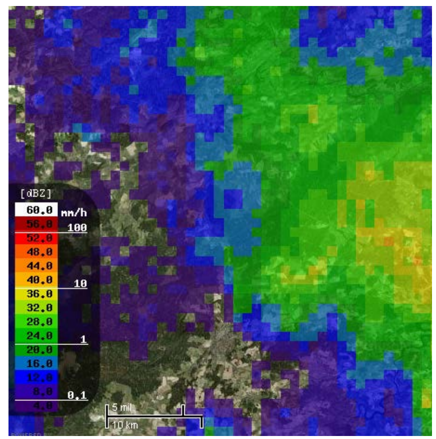
mongabay.com

Rainfall monitoring

Rain gauge

+ direct method
+ time resolution
– point measurement

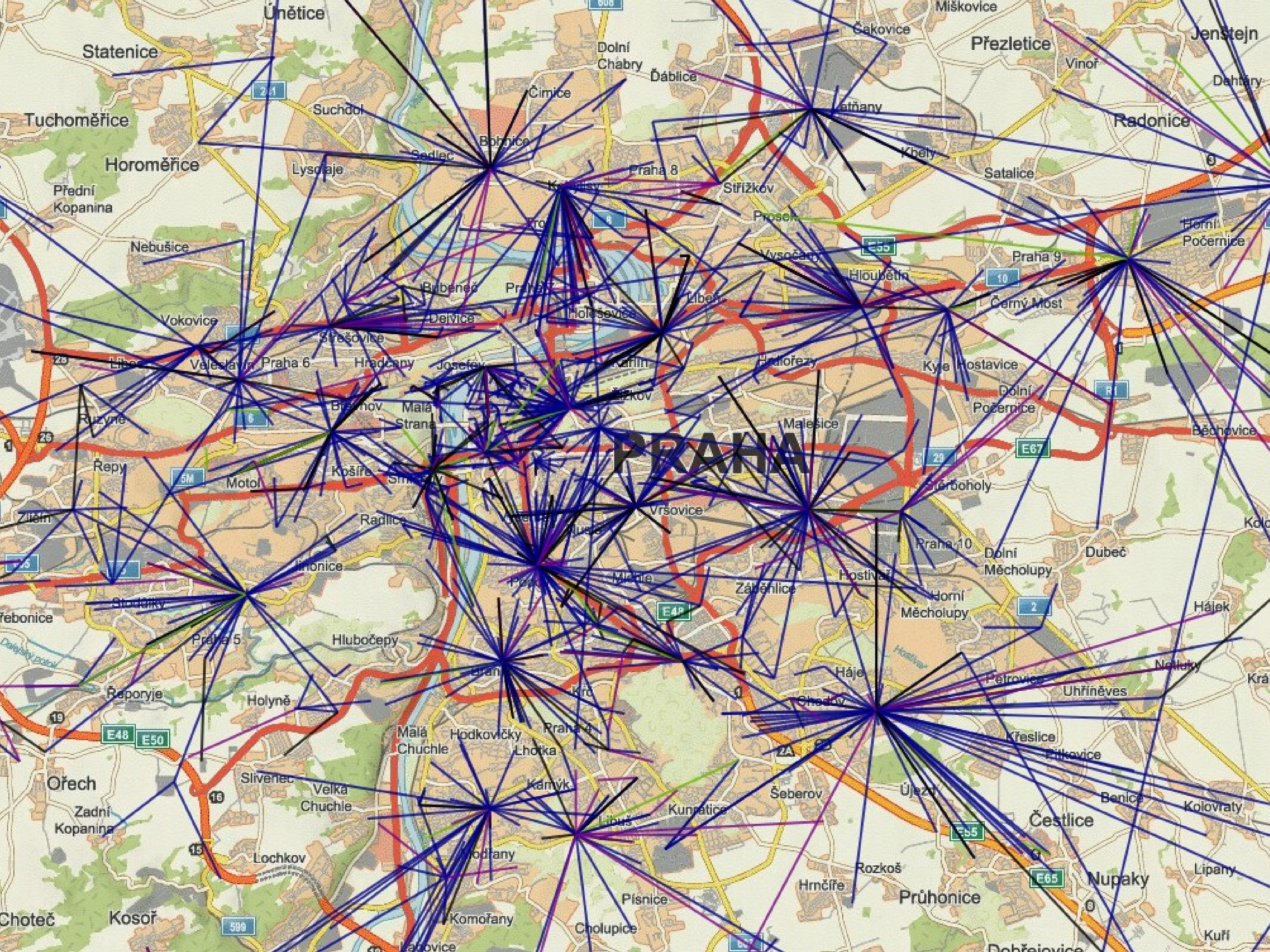
Meteorological radar



+ large area cover
+ spatial information
– indirect method
– low resolution (spatial & time)

MWLs

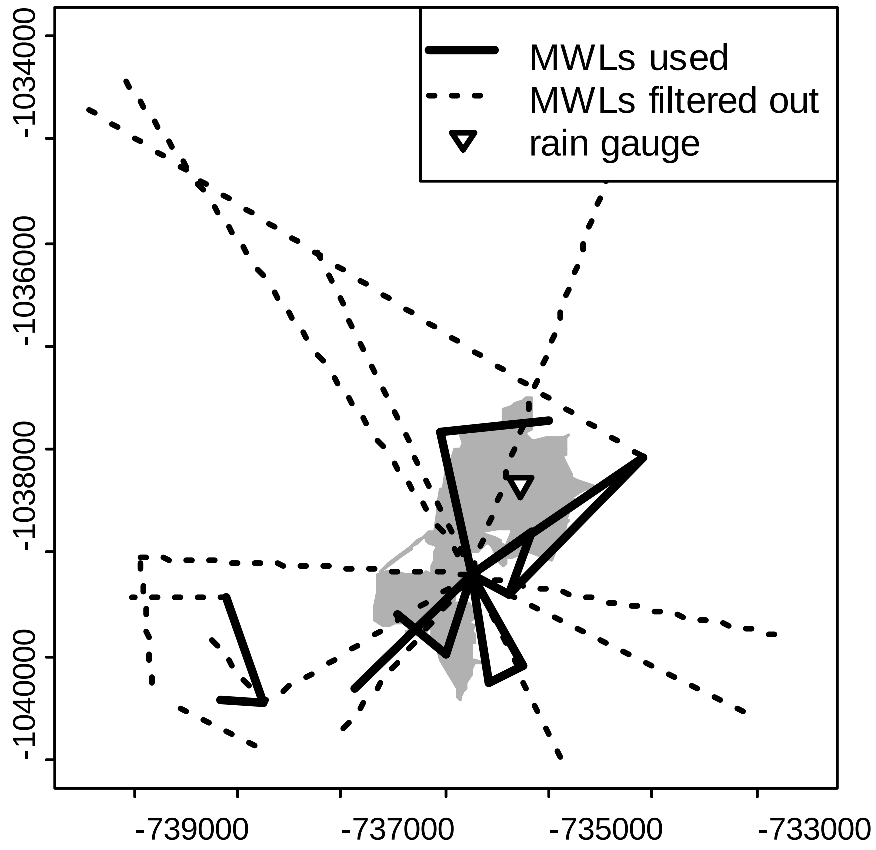
– indirect method
– telecom. device
+ near surface
+ no additional costs
+ path averaged rainfall
+ dense network


Únětice
Statenice
Tuchoměřice
Horoměřice
Přední Kopanina
Nebušice
Suchdol
Lysolaje
Sedlec
Bohnice
Čimice
Dolní Chabry
Ďáblice
Čakovice
Miškovice
Přezletice
Jenštejn
Vinoř
Dehtáry
Letňany
Kbely
Radonice
Satalice
Praha 8
Střížkov
Prosek
Vysočany
Hloubětín
Praha 9
Horní Počernice
Černý Most
Kyje
Hostavice
Dolní Počernice
Běchovice
Bubeneč
Praha 7
Dejvice
Holešovice
Libeň
Vokovice
Střešovice
Veleslavín
Praha 6
Hradčany
Liboc
Josefov
Karlín
Hrdlořezy
Ruzyně
Břevnov
Malá Strana
Žižkov
Malešice
PRAHA
Řepy
Motol
Košíře
Smíchov
Štěrboholy
Zličín
Radlice
Vršovice
Praha 10
Dolní Měcholupy
Dubeč
Jinonice
Nusle
Michle
Záběhlice
Hostivař
Horní Měcholupy
Stodůlky
Třebonice
Praha 5
Hlubočepy
Hájek
Nedluky
Háje
Petrovice
Uhříněves
Řeporyje
Holyně
Braník
Krč
Chodov
Křeslice
Pitkovice
Malá Chuchle
Hodkovičky
Lhotka
Praha 4
Ořech
Zadní Kopanina
Slivenec
Velká Chuchle
Kamýk
Libuš
Kunratice
Šeberov
Újezd
Benice
Kolovraty
Čestlice
Lochkov
Modřany
Rozkoš
Hrnčíře
Průhonice
Nupaky
Lipany
Choteč
Kosoř
Komořany
Písnice
Cholupice
Kuří
E55
E50
E48
E65
E67
E48
10
8
6
5M
2
R1
29
2A
599

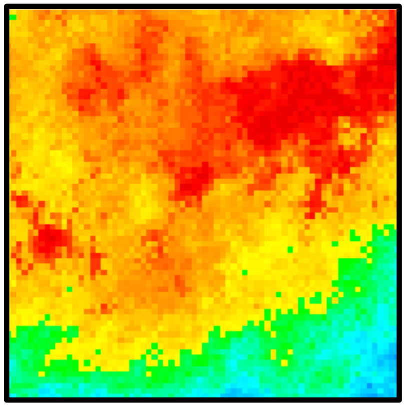
Case study in Prague

Case study area:

- 2.33 km^2
- impervious area of 64 %
- separate drainage system
- 29 MWLs (15 used)
- 1 rain gauge



Case study in Prague

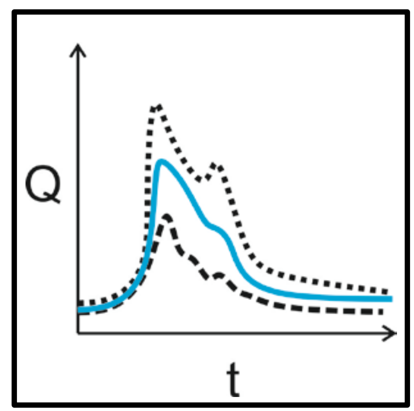


75 virtual rainfall events

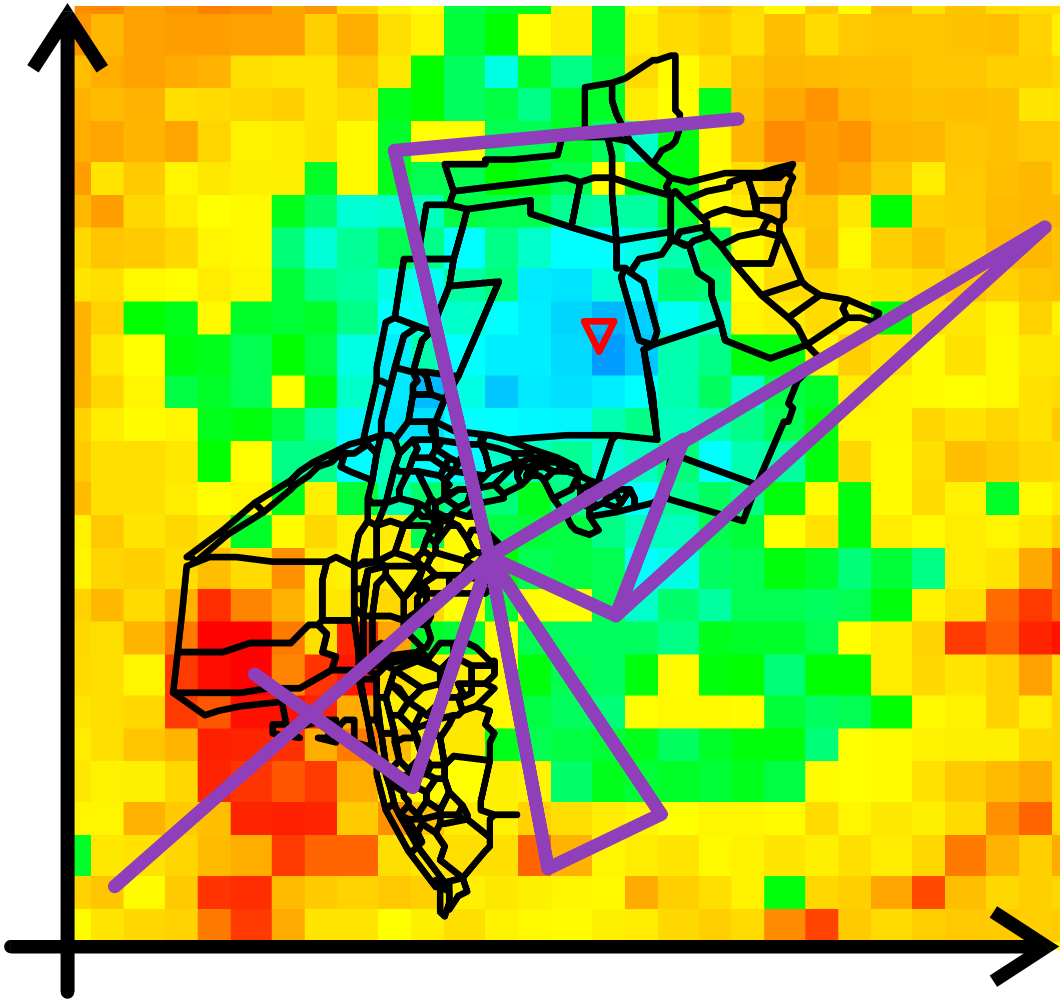
size:	7 x 7 km^2
spatial. res:	100 x 100 m^2
time step:	5 min
duration:	50 min

- **Reference RF**
- **Rain gauge RF**
- **MWL RF**

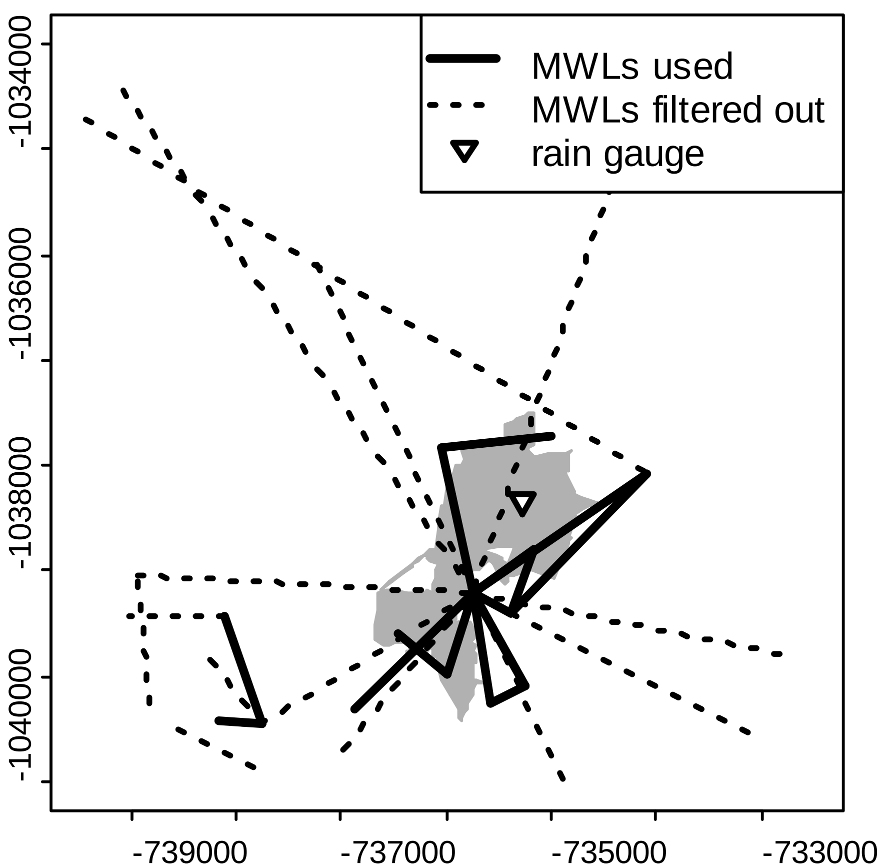
Rainfall-runoff model

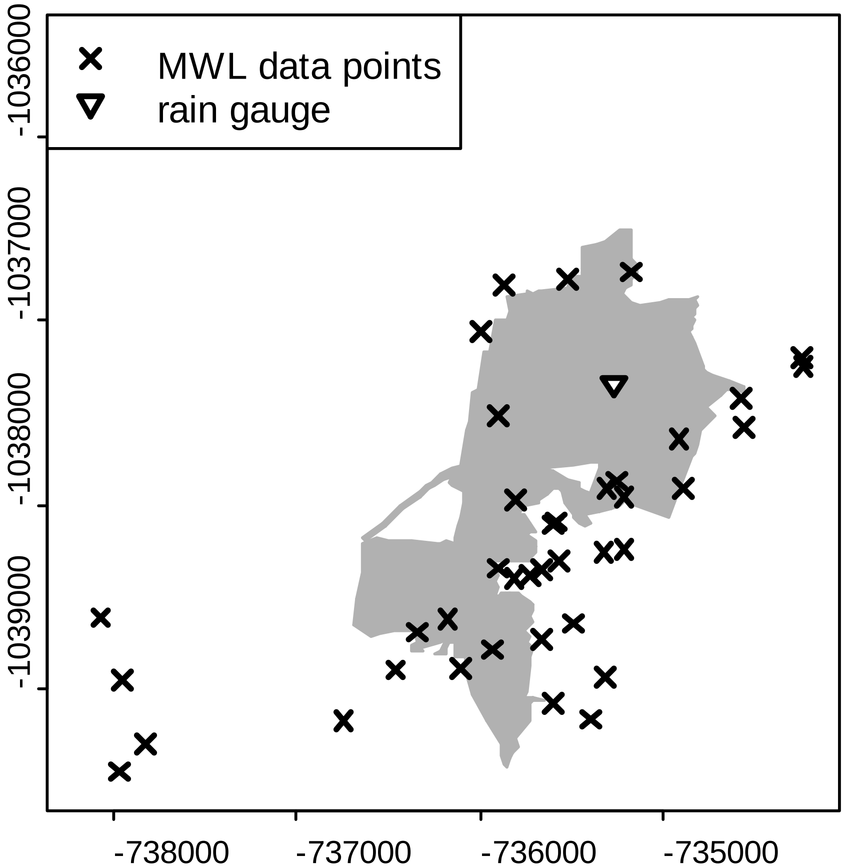


Extracting rainfall series

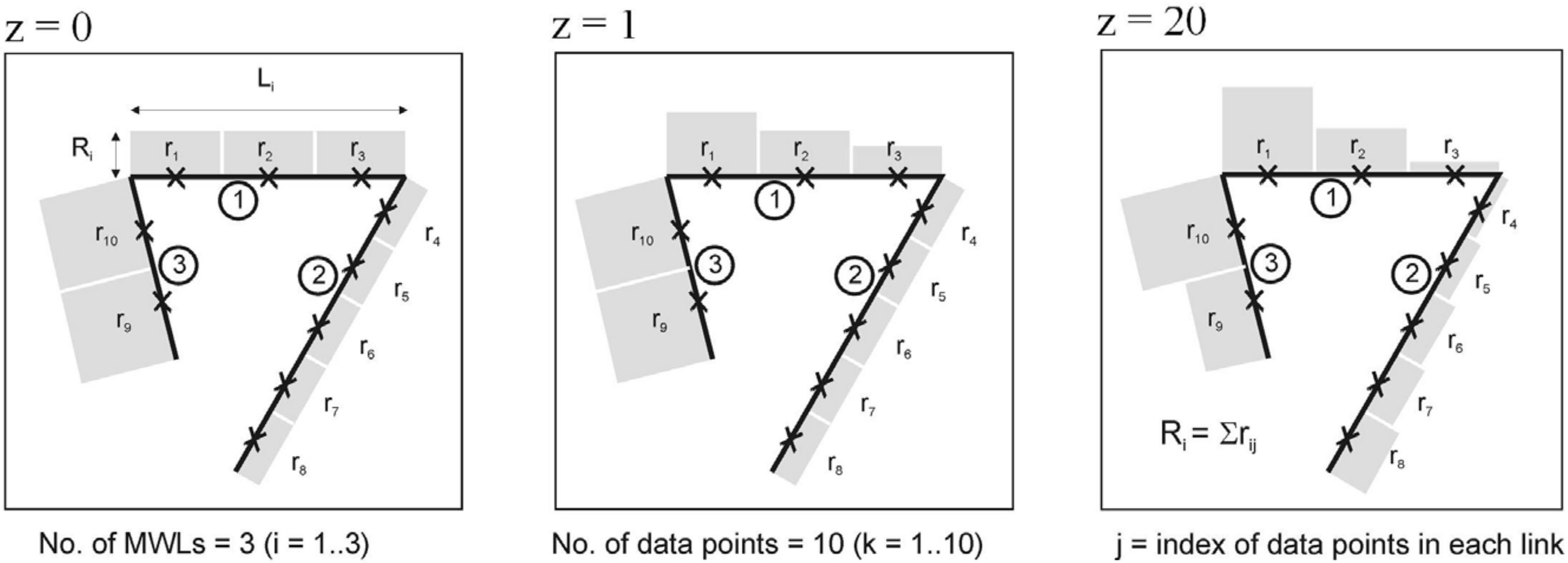


MWL rainfall reconstruction





MWL rainfall reconstruction



Rainfall approximation at j_{th} data point:

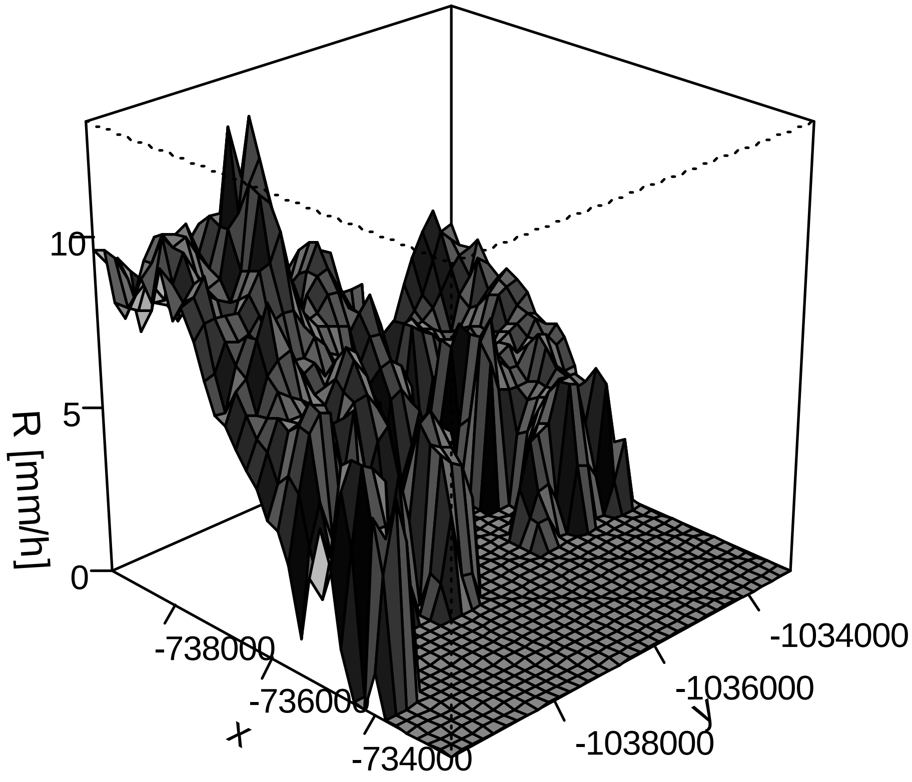
$$\theta_j = \frac{\sum_{k \notin MWLi} (r_k * l_k^{\,2})}{\sum_{k \notin MWLi} l_k^{\,2}} \quad \textbf{(1);}$$

Adjusting rainfall distribution along i_{th} link:

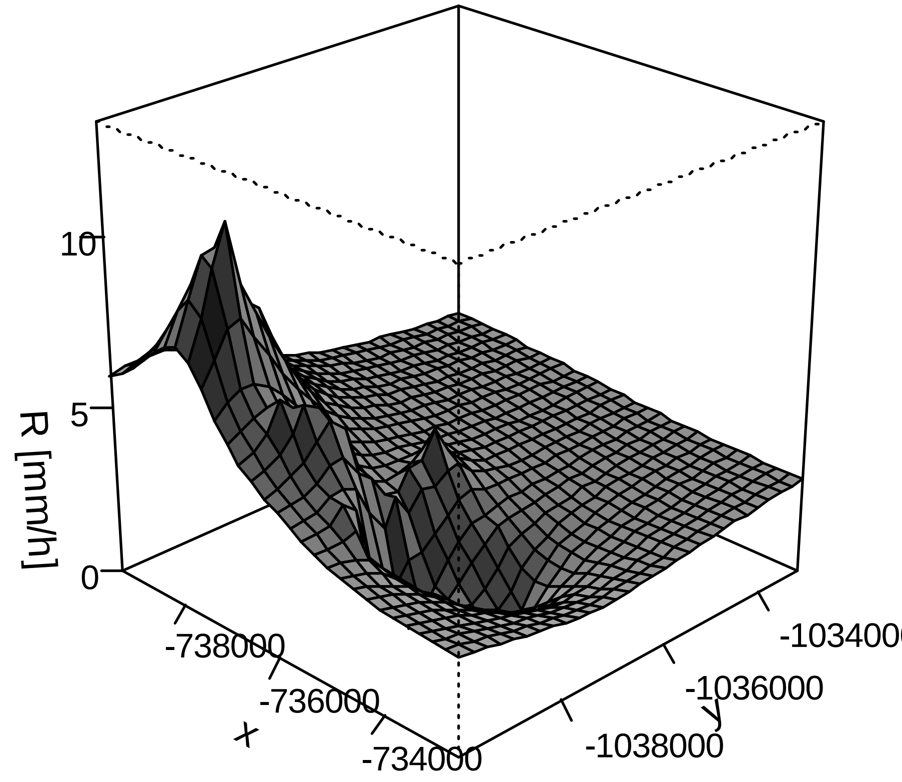
$$\frac{\sum_{j \in MWLi} r_j}{L_i} = R_i \quad \textbf{(2);}$$

$$F = \sum_{j \in MWLi} (r_j - \theta_j)^2 \quad \textbf{(3)}$$

MWL rainfall reconstruction



Original rainfall



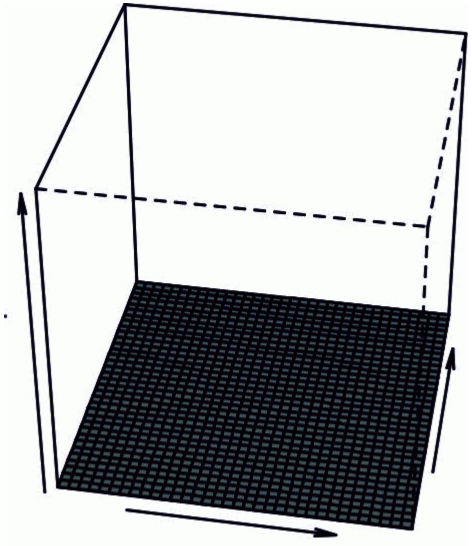
Reconstructed rainfall

Results - Rainfall

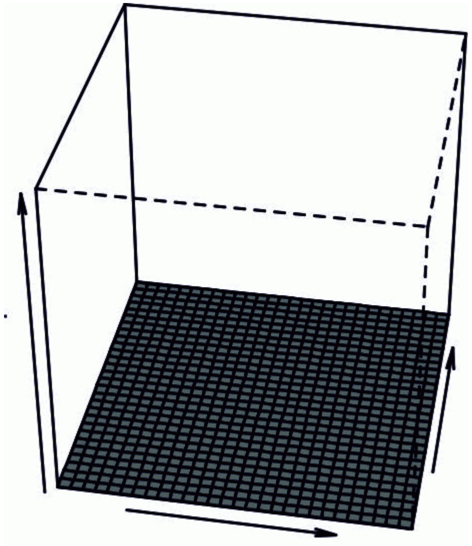
	RV mean rel. error	Rmax mean rel. error
RG	-9 % (32 %)	48 % (25 %)
MWL	6 % (38 %)	-31 % (17 %)

- RG underestimtes total rainfall volumes
- RG overestimates rainfall peaks
- MWL overestimates total rainfall volumes
- MWL underestimtes rainfall peaks

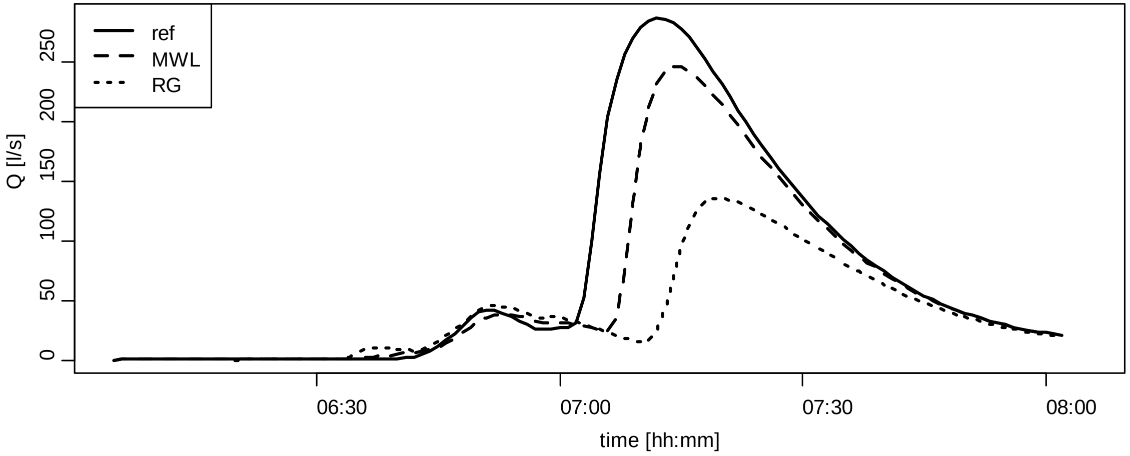
Results - Event no. 26



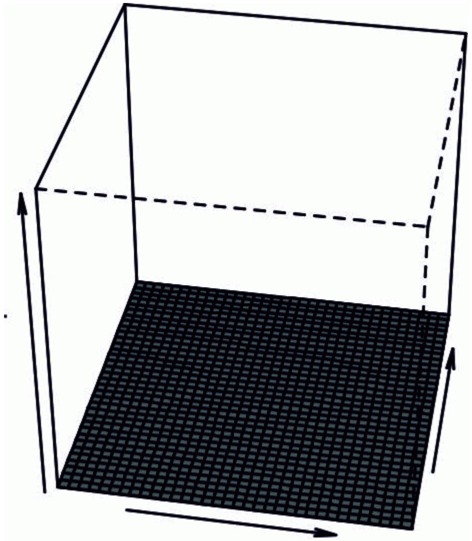
Reference rainfall



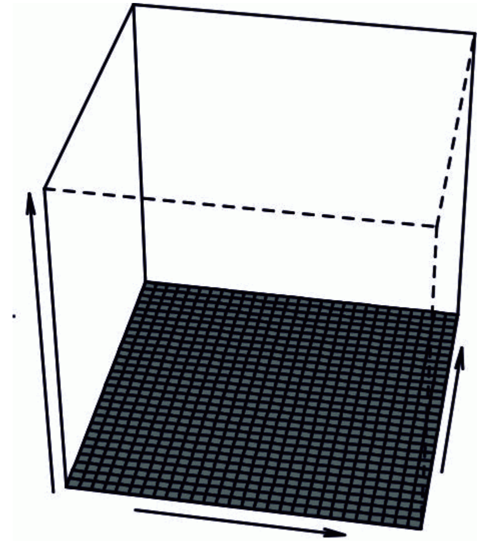
Reconstructed rainfall



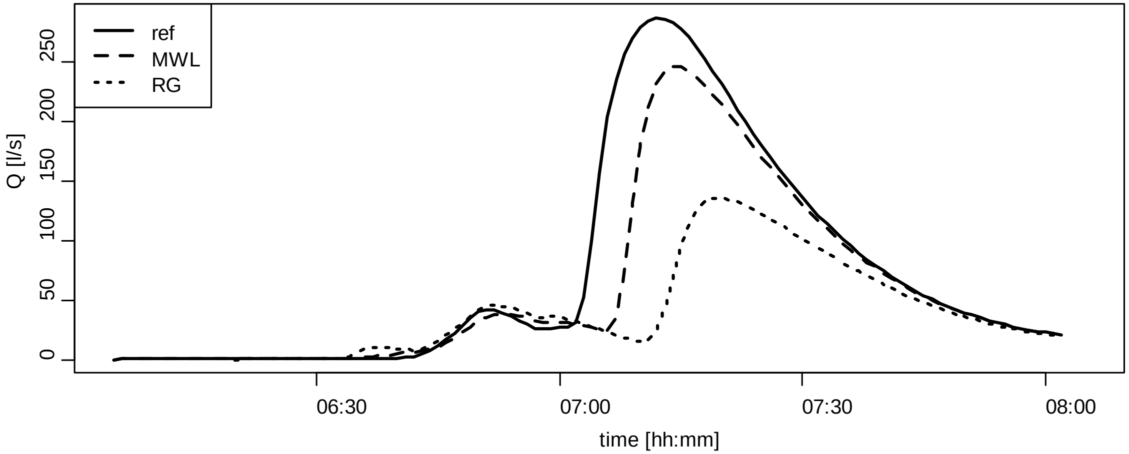
Results - Event no. 26



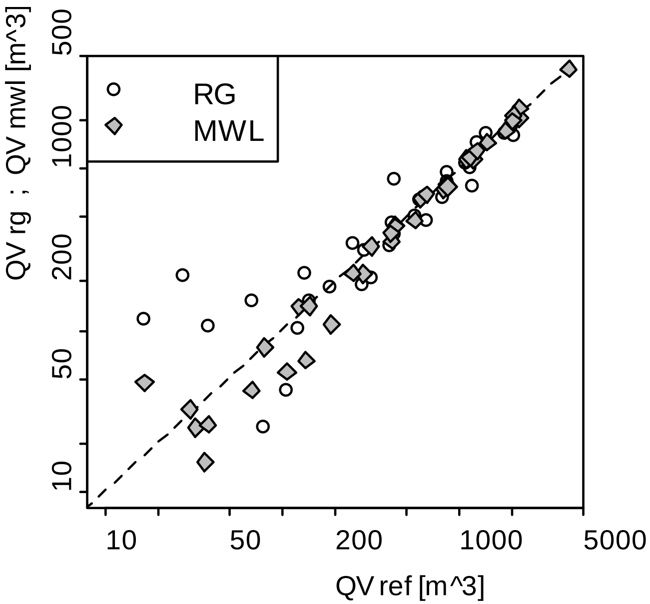
Reference rainfall

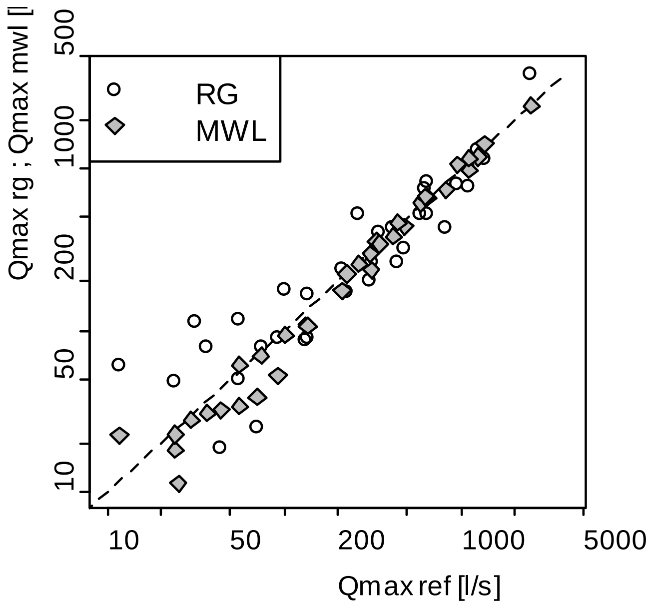


Reconstructed rainfall



Results - Runoff





	QV mean rel. error	Qmax mean rel. error
RG	25 % (115 %)	16 % (85 %)
MWL	-2 % (38 %)	-6 % (23 %)

Discussion of results

- **Averaging of rainfall peaks by MWLs affects pipe flow prediction less then potential missing of peaks by RG**
- *Runoff hydrograph is smoothed by time-area method and by wave routing*

- **The uncertainty in the RG measurement is enhanced by the coarse temporal sampling**
- *The monitoring techniques which reflect the spatial variability do not require such a high sampling frequency*

Discussion of method

- **MWL rainfall estimates from real power level measurements contain additional uncertainties.**
- *the uncertainties could be minimized:*
  - *I. by combining the MWL information with rain gauge and weather radar information*
  - *II. by implementing a more sophisticated reconstruction algorithm taking advantage of the spatio-temporal correlation of different observations.*

Conclusion

- MWL rainfall reconstruction underestimates rainfall peak intensities, but very well reproduces areal averaged rainfall intensities
- The averaging of rainfall peaks over a larger area from MWL observations does not influence the runoff dynamics as significantly as missed rainfall peaks by RGs
- **MWLs can reduce input uncertainties in rainfall-runoff modelling and improve discharge predictions**
- Further research is needed to investigate influence of MWL estimation uncertainties on runoff predictions

Research outlook

- Numerical experiment including effects of uncertainties in both MWL and RG measurements

- From 2013 experimetns with real data from Prague MWL network, rain gauges and drainage system

Acknowledgment

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Sweco Hydroprojekt a. s.

Conclusion

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Rainfall fields

- Rainfall fields:

10 m/s to the North-East intermittency of 55 %, 7.7 m/s to the South-East and intermittency of 50 %, 5.5 m/s to the North East and intermittency of 70 %. The duration of each event is 50 minutes.

(To eliminate the influence of positioning of the rainfall field over the study area, the relative position of the catchment to the rainfall fields was repeatedly changed to cover 25 different locations uniformly distributed over the field.)

Current state of knowledge

Messer et. al., 2006:
„cellular rainfall measurements have features in between those of gauges and of radar"

Rieckermann et. al., 2009:
„Continuous measurements from 23 microwave links were evaluated against reference data from 13 rain gauges... ...We can demonstrate that 50 % of the predictions are within an error of 1.2mm/h (RMSE)"

Our study investigates:
"Potential of MWLs to capture rainfall spatial dynamics and thus reduce input uncertainties in rainfall-runoff modelling and improve discharge predictions."

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- MWL overestimates total rainfall volumes
- MWL underestimtes rainfall peaks

threshold $Q_{max\ ref}$ > 10 l/s and $Q_{max\ est}$ > 5 l/s: Exceeded by 33 events