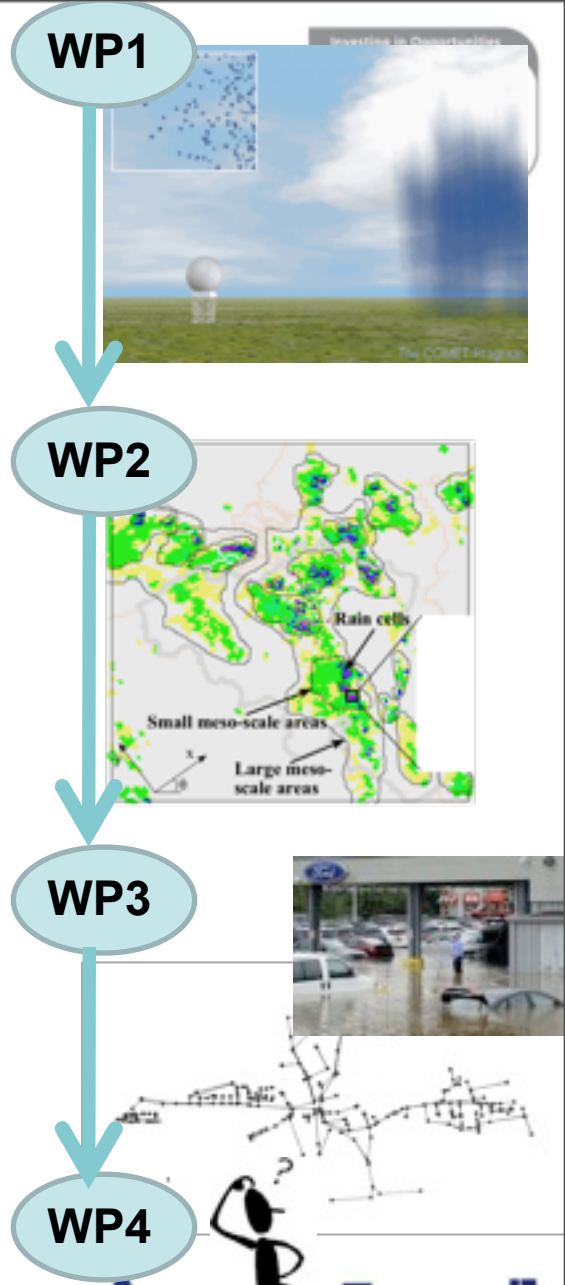
WP2: Fine-scale rainfall data acquisition and prediction:

Objective: develop and implement a system for estimation and forecasting of fine-scale (100m, minutes) rainfall

- Rainfall estimation: combining data from radars (X & C-band) and rain gauges
- Rainfall forecasting: combining with numerical weather prediction

✓implement and test for pilot sites (Leuven, Paris, Rotterdam, London)

✓applicable for urban areas of North-West Europe: guidelines, demonstrations, training, …



WP2: Fine-scale rainfall data acquisition and prediction:

Applications (see WP3, WP4):

•Rainfall estimation: enable city water managers to develop reliable urban water strategies, including plans for urban flood prevention and pollution management

WP2: Fine-scale rainfall data acquisition and prediction:

Applications (see WP3, WP4):

- Rainfall estimation: enable city water managers to develop reliable urban water strategies, including plans for urban flood prevention and pollution management
- Rainfall forecasting: allow local city managers to forecast, warn about and control urban pluvial impacts at street level in real time

WP2: Fine-scale rainfall data acquisition and prediction:

Actions:

WP2	A5 Workshop on radar technology, calibration and rainfall estimation	A6 Rainfall estimation in pilot sites	A7 Workshop on rainfall forecasting	A8 Implementation and testing of rainfall forecasting in pilot sites	A9 Writing guidelines, manuals and training material
	Output: Report on methods for fine-scale rainfall estimation	Output: Rainfall estimates for storms in pilot sites	Output: Report on methods for fine-scale rainfall forecasting	Output: Operational system for rainfall forecasting in pilot sites	Output: Manuals for developed technology + training

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: A5: Leuven workshop on radar technology, calibration and rainfall estimation, 16 April 2012 (M3)

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: A5: Leuven workshop on radar technology, calibration and rainfall estimation, 16 April 2012 (M3)

- ✓ *Attended by 35 international experts (>20 aimed)*
- ✓ *Very interactive and fruitful discussion*
- ✓ *Towards closing the gap between radar meteorologists and urban hydrologists*
- ✓ *Outcome: recommended methods for fine-scale rainfall estimation*

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A5: Leuven workshop on radar technology, calibration and rainfall estimation, 16 April 2012</u> (M3)

- ✓ *Outcome: document: "Methods and experiences in radar based fine scale rainfall estimation"*
- ✓ *Comments by 31 May*

WP2: Fine-scale rainfall data acquisition and prediction:

Content document: "Methods and experiences in radar based fine scale rainfall estimation"

Part 1: Introduction to radar technology for urban hydrologists

Chapter I.	*Introduction to radar technology*
Chapter II.	*Electronic calibration of the weather radar*
Chapter III.	*Different corrections to the raw radar signal: noise cut off, volume correction, attenuation correction, clutter correction*
Chapter IV.	*Influence of the radar scanning strategy on the radar estimates*

WP2: Fine-scale rainfall data acquisition and prediction:

Content document: "Methods and experiences in radar based fine scale rainfall estimation"

Part 2: Methods and experiences in radar based fine scale rainfall estimation

Chapter V.	*Estimation of rainfall rates from radar measurements (single pol, dual pol)*
Chapter VI.	*Combining radar rainfall estimates with other rainfall measurements (merging methods, matching of scales, error estimation)*

WP2: Fine-scale rainfall data acquisition and prediction:

Content document: “Methods and experiences in radar based fine scale rainfall estimation”

Boxes with illustration of applications by RainGain partners

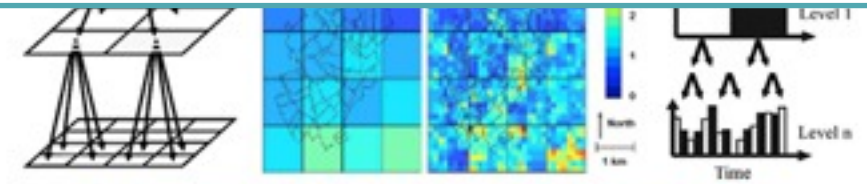


Figure 19: Rainfall downscaling a) downscaling of rainfall fields in space (adapted from Bacchiola, 2007), an example of the spatial downscaling based on real data (adapted from Gires et al., 2012a) and c) downscaling of rainfall series in time (adapted from Lu and Yamamoto, 2008)

For an extensive overview on and review of these techniques, the reader is referred to Lovejoy and Schertzer (2007) or Schertzer and Lovejoy (2011) and the references therein. Applications in our field include e.g. Marsan et al., 1996; Pathirana and Herath, 2002; Biaou et al., 2003; Ferraris et al., 2003; Macor et al., 2007; Royer et al., 2008; De Montera et al., 2009; Gires et al., 2012a and b, among others.

Example from RainGain consortium: Multifractal cascade downscaling methods in practice:

Gires et al. (2012b) investigated the effect of the uncertainty due to the unknown smaller scale variability on a semi-distributed urban rainfall-runoff model. The spatial resolution of the used C-band radar data was 1 km; the temporal resolution was 5 minutes. In order to quantify the effect of the small scale variability, an ensemble set of realistic fine scale rainfall fields was generated based on the universal multifractal cascade approach. These ensembles are then used as input for the urban rainfall runoff model and the in-sewer conduit flows were simulated. The variability among the simulated hydrographs is then estimated to quantify the uncertainty. This approach is applied on the Cranbrook catchment, which is a 900ha urban area situated in the east of London, UK.

They implemented 4 multifractal downscaling methods, 2 spatial downscaling (2D) methods and 2 spatio-temporal downscaling (3D) methods. A schematization of the two approaches is shown in Figure 20. Comparison led to the conclusion that the 2D approach might overestimate the results, whereas the 3D approach gives more realistic results. They concluded that it is strongly recommended to use distributed (radar) rainfall in urban hydrology. Moreover, they encourage the use of X-band radar, which allows measuring rainfall at a higher resolution. The extra added value of radar measurements during summer is also endorsed by their results, especially for intense small scale convective events.

WP2: Fine-scale rainfall data acquisition and prediction:

Content document: "Methods and experiences in radar based fine scale rainfall estimation"

- ✓ *Mid 2013: Reference document for WP2 activities*
- ✓ *Mid 2015: Guidelines for "good practise"*

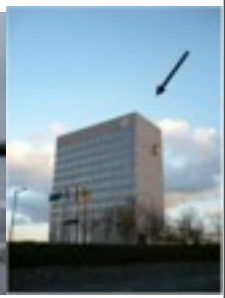
WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

- ✓ Outcomes: fine-scale rainfall estimates for recent storms in pilot sites + comparison with traditional rainfall estimates (without radar)

- ✓ Tasks:
  - ✓ Radar calibration and adjustment based on rain gauge data
  - ✓ Different calibration/adjustment methods
  - ✓ Comparison & integration of fine-scale (X-band, city scale; super- resolution C-band) with rain gauge and coarser (NWE-scale) C-band radar data
  - ✓ Rainfall estimation error/uncertainty analysis
  - ✓ Interfacing with the applications in WP3 & WP4

WP2: Fine-scale rainfall data acquisition and prediction:



Actions: <u>A6: rainfall estimation in pilot sites</u>

- ✓ Leuven (X-band radar DHI):
  - Past and current:
    - Radar adjustment to rain gauges (different periods): empirical transfer functions, identification of dependencies on season, storm type, intensity, wind speed, wind direction, temperature, spatial size, location of storm
    - Testing merging methods (gauges, X-band, C-band): Range-dependent, Mean Field Bias, Brandes, Kriging
    - Checking for missing or erroneous pixels

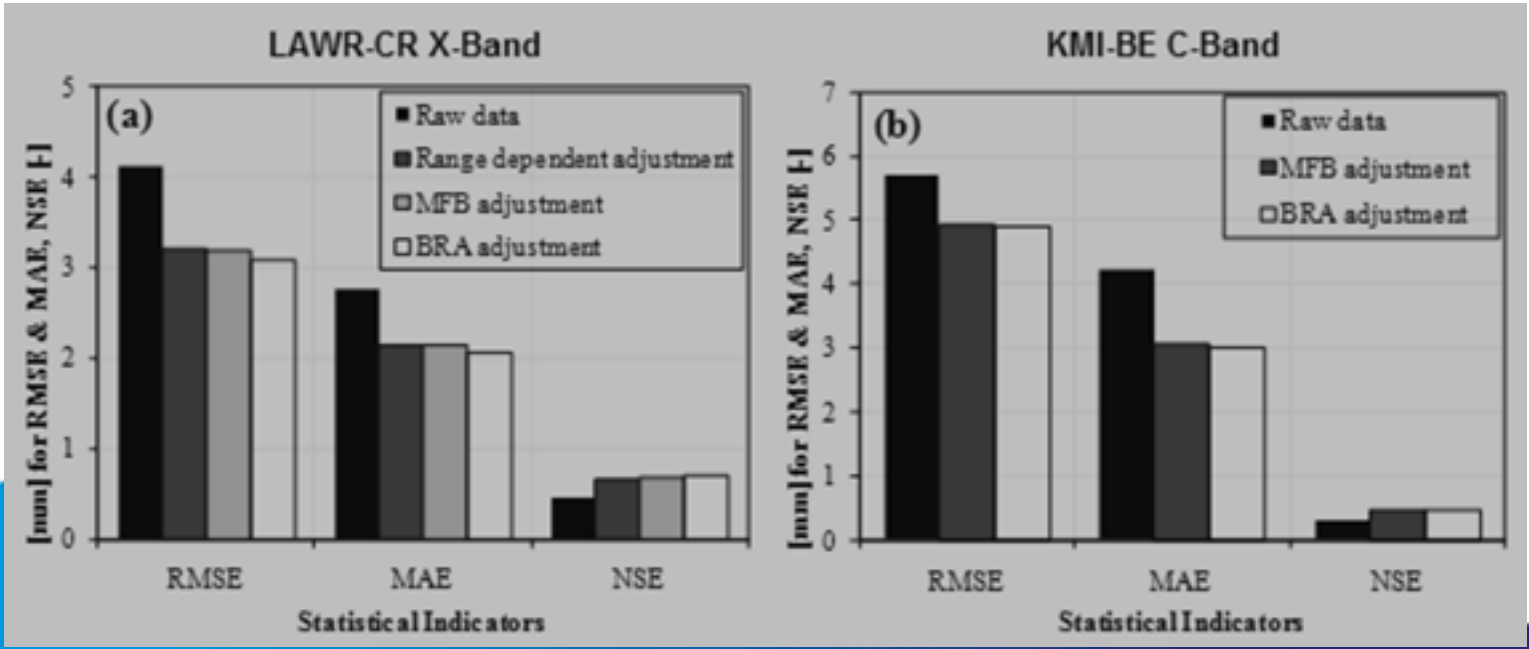
WP2: Fine-scale rainfall data acquisition and prediction:

Actions: A6: rainfall estimation in pilot sites

✓ Leuven (X-band radar DHI):

Comparison merging methods:

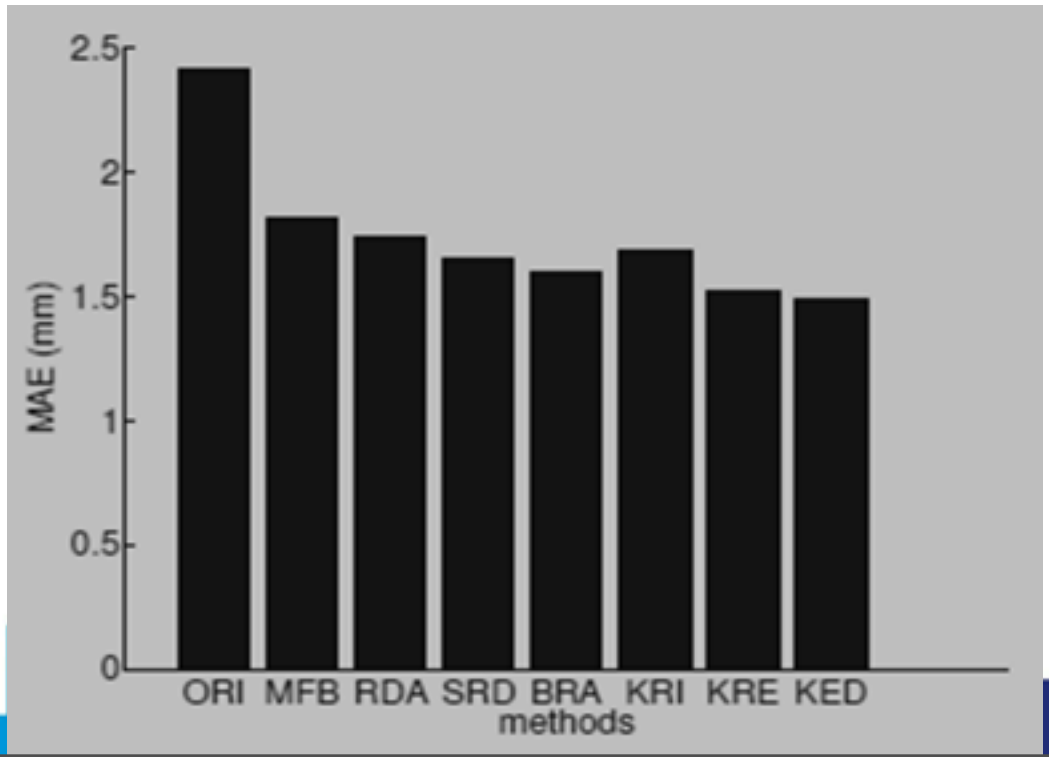
Statistical indicators	Summer period		Winter period	
	LAWR-CR X-band	RMI BE C-band	LAWR-CR X-band	RMI BE C-band
RMSE [mm]	3.09	4.91	3.40	3.76
MAE [mm]	2.06	3.02	2.42	4.38
NSE [-]	0.70	0.48	0.55	0.66



WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

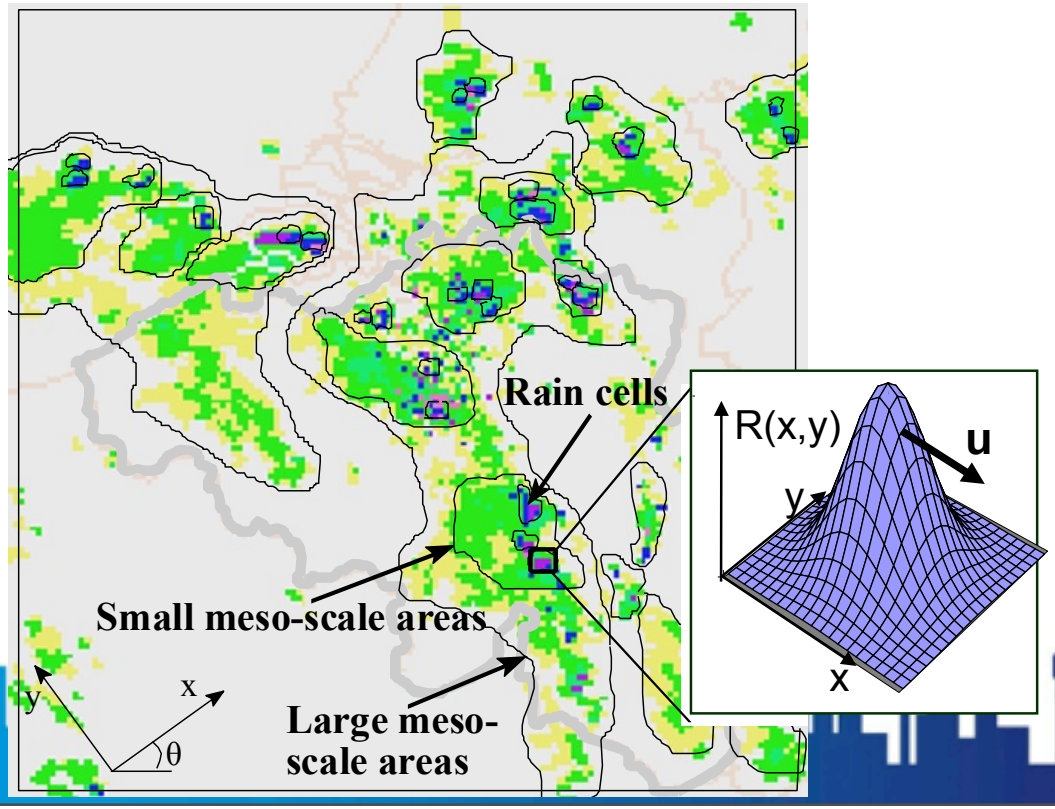
- ✓ Leuven (X-band radar DHI):
  - Comparison merging methods:



WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

- ✓ Leuven (X-band radar DHI & C-band KMI):
  - Calibration conceptual rain storm model:



WP2: Fine-scale rainfall data acquisition and prediction:

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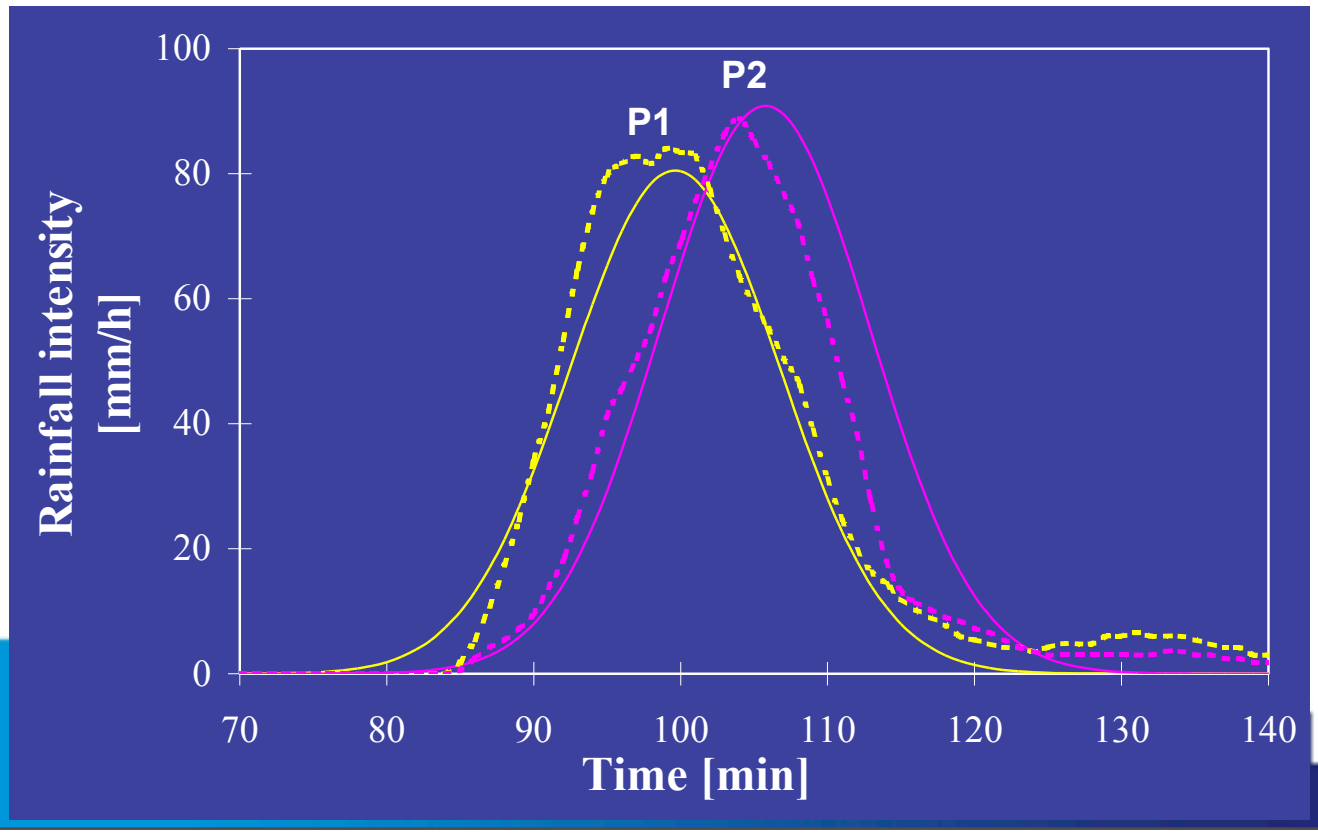

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

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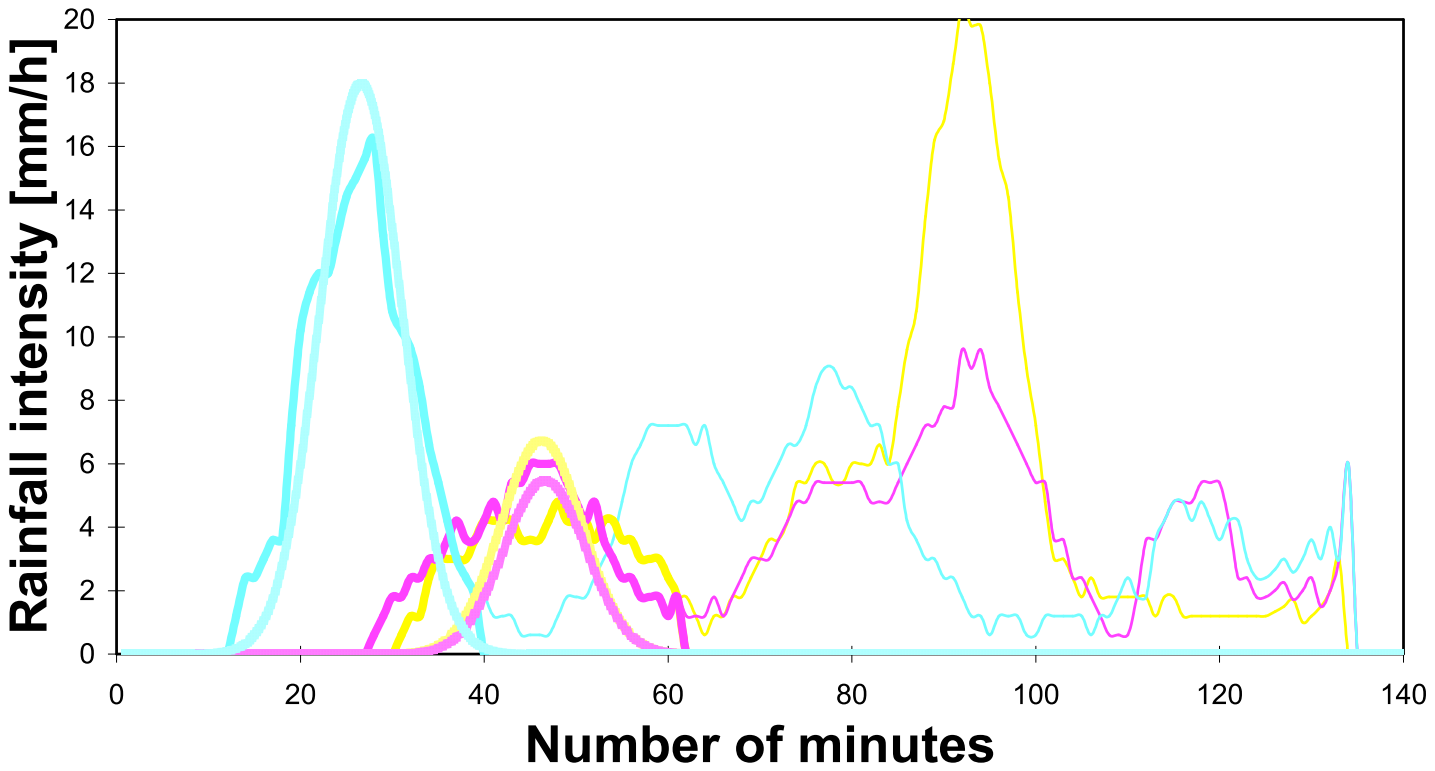

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

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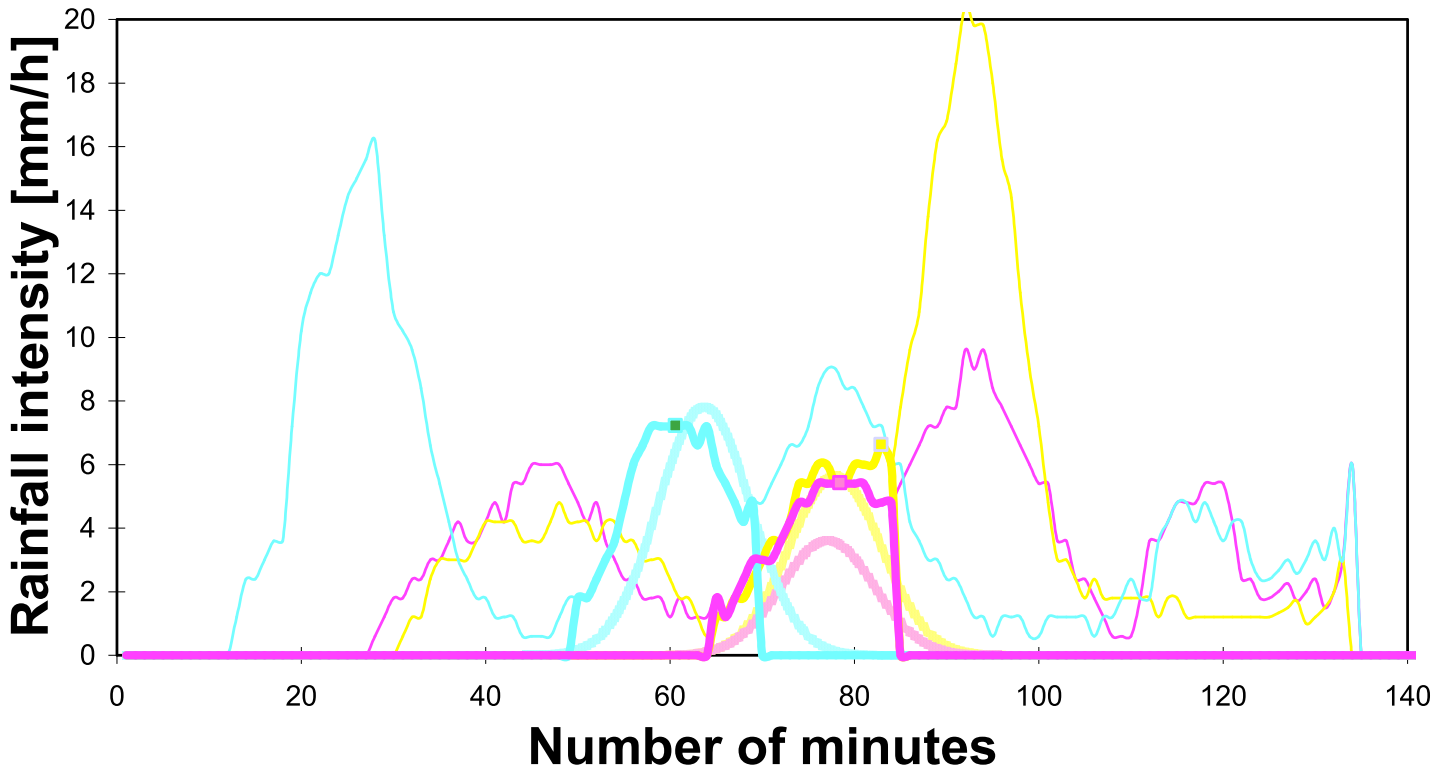
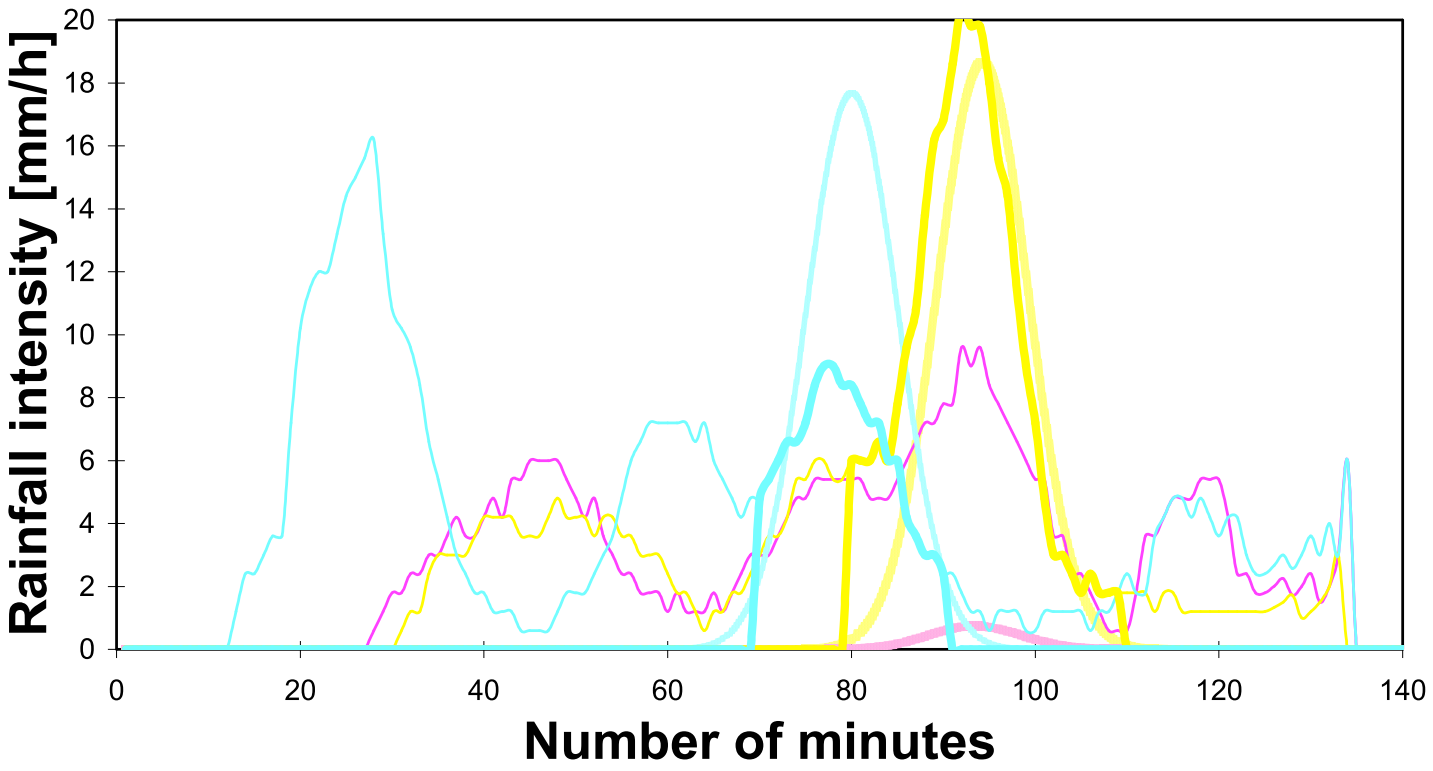


WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

- ✓ Leuven (X-band radar DHI & C-band KMI):
  - Calibration conceptual rain storm model:



WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

✓ Leuven (X-band radar DHI):

- Future:
  - Other merging methods: Kalman filter, quantile mapping, weather typing, scaling relations
  - Conceptual rain storm model: filling-up missing sector direction airport

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

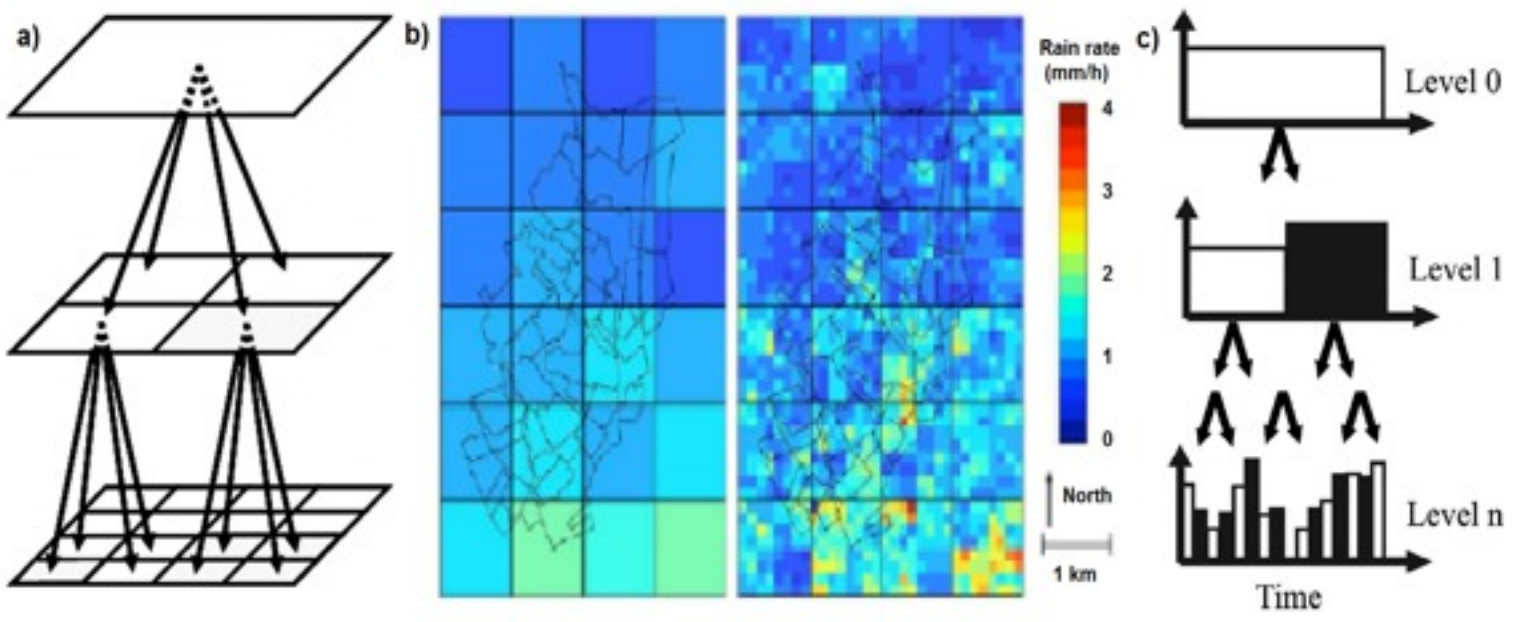
- ✓ London ("super resolution" C-band Met Office + soon: X-band Rainscanner Selex):
  - Radar adjustment to rain gauges & Testing merging methods (gauges, C-band): Mean Field Bias, KED

- ✓ The Netherlands: experiences with Cabauw Experimental Site for Atmospheric Research (CESAR)
  - Comparison C-band, X-band & rain gauges data

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A6: rainfall estimation in pilot sites</u>

- ✓ Paris:
  - A.Gires: multifractal based downscaling method (incl. uncertainty bands on downscaling result, highest correlation between coarse and fine scale rainfall)



WP2: Fine-scale rainfall data acquisition and prediction:

Actions: A6: rainfall estimation in pilot sites

Timing:

- ✓ Leuven & London: by spring 2014
- ✓ Rotterdam & Paris: by autumn 2014 (first results)
  summer 2015 (final results)

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: A6: rainfall estimation in pilot sites

Added value trans-national cooperation:

- ✓ Exchange of knowledge and experience with different types of radar technologies and fine-scale rainfall estimation methods
- ✓ Inter-comparison of methods
- ✓ Inter-comparison of radars: cost-benefit evaluation
- ✓ Harmonization of approaches and set up of guidelines for end user good practices, of benefit for regional development

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A7: Workshop on rainfall forecasting (M6)</u>

- ✓ Outcome: recommended methods for fine-scale rainfall forecasting

- ✓ Spring 2014, Antwerp
- ✓ Active role for radar meteorologists (MetOffice, KMI, Meteo France, KNMI)
- ✓ Linked to PLURISK project for Belgian Science Policy office (multidisciplinary risk analysis for risks induced by extreme rainfall over urban areas)

WP2: Fine-scale rainfall data acquisition and prediction:

Actions: <u>A8: implementation for pilot sites</u>

- ✓ Outcomes: operational system for fine-scale rainfall forecasting in pilot sites + results for min. 10 extreme storms

✓Timing:

Leuven & London: by summer 2015

WP2: Fine-scale rainfall data acquisition and prediction:

Actions A7 & A8: Rainfall forecasting (short-term forecasting = nowcasting)

Subtopics addressed:

- Combination of (fine and coarse scale) radar data with Numerical Weather Prediction (provided by national meteo services)
- Use of lightning detection data
- Advective-statistical forecast model
- Spatial and temporal downscaling
- Error/uncertainty estimation in function of forecast lead time / probabilistic forecasts
- Interfacing with the applications in WP3 & WP4

WP2: Fine-scale rainfall data acquisition and prediction:

Action A8: Rainfall forecasting (short-term forecasting = nowcasting)

London (ICL & Met Office i.c.w. Bristol University):

- STEPS nowcasting model (some tests already ongoing)

Leuven (KU Leuven & Aquafin i.c.w. KMI):

- KMI nowcasting model (some tests already ongoing)

WP2: Fine-scale rainfall data acquisition and prediction:

Action A9: Guidelines

- ✓ Outcome: reference and user's manuals on developed technologies for rainfall estimation and forecasting
- ✓ Training and dissemination during National Observer Meetings