Report – Work Package 2

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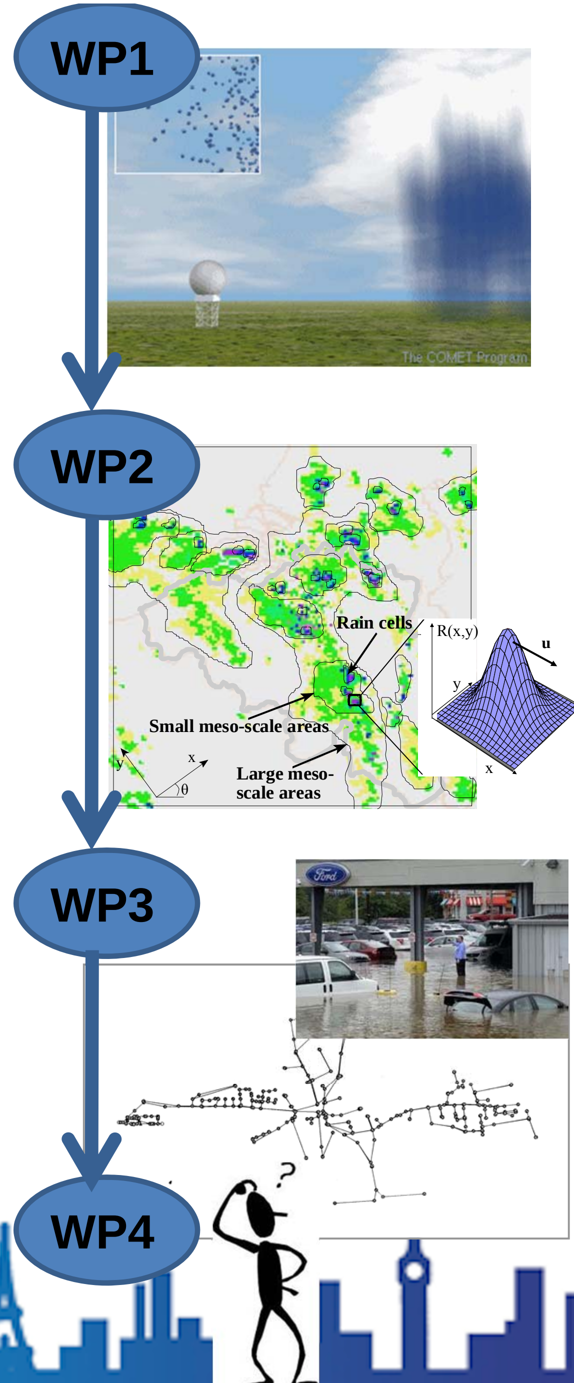
RainGain Project Consortium Meeting, Exeter, 7th October 2014

WP2: Fine-scale rainfall data acquisition and prediction



Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
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INTERREG IVB

WP2: Fine-scale rainfall data acquisition and prediction

General Objective of WP2:

develop and implement a system for estimation and forecasting of fine-scale (100m, minutes) rainfall in support of short term pluvial flood modelling and prediction

WP2 ACTIONS

Action WP2A5: Workshop on radar technology, calibration and rainfall estimation

Action WP2A6: Rainfall estimation in pilot sites

Action WP2A7: Workshop on rainfall forecasting

Action WP2A8: Rainfall forecasting in pilot sites

Action WP2A9: Guidelines and training

Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

REVIEW – WP2 A5

A5: Workshop on radar technology, calibration and rainfall estimation

Output: Report on methods for fine-scale rainfall estimation

International Leuven workshop, 16 April 2012: 35 participants (incl. DHI, INSA Lyon, KNMI, RMI, Aalborg Univ., DTU, Univ. Bradford, Univ. Wageningen, Univ. Liège, Univ. Massachusetts at Amherst, …)

REVIEW – WP2 A5

A5: Workshop on radar technology, calibration and rainfall estimation

Output: Report on methods for fine-scale rainfall estimation

- Workshop: Discussion among the (scientific) project partners and international experts methods and experiences for fine-scale rainfall estimation
- KU Leuven prepared report “Methods and experiences in radar based fine scale rainfall estimation”


RainGain

Review document:

Methods and experiences in radar based fine scale rainfall estimation

- ✓ *Iteration among partners and other experts*
- ✓ *Online now (RainGain website)*
- ✓ *But: Lively document*

REVIEW – WP2 A5

A5: Workshop on radar technology, calibration and rainfall estimation

Output: Report on methods for fine-scale rainfall estimation

report on “Methods and experiences in radar based fine scale rainfall estimation”:

Boxes with illustration of applications by RainGain partners

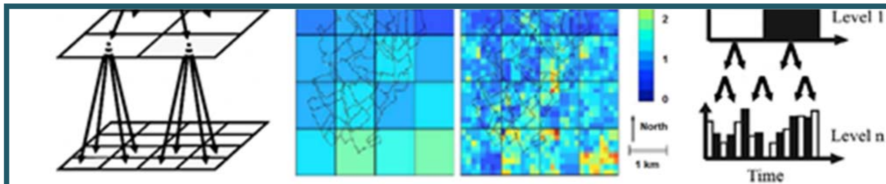


Figure 19: Rainfall downscaling a) downscaling of rainfall fields in space (adapted from Bocchiola, 2007), an example of the spatial downscaling based on real data (adapted from Gires et al., 2012a) and c) downscaling of rainfall series in time (adapted from Lu and Yamamoto, 2008)

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.

- ✓ *Now: Reference document for WP2 activities*
- ✓ *End 2015: Guidelines for “good practise”*

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Fine-scale rainfall estimation: different steps:

- Radar adjustment: Corrections to the raw radar signal (WP1)
- Radar adjustment (WP2):
  - No adjustment
  - Corrections to rain gauge measurements

    OR

  - Radar – rain gauge integration (merging)
- Downscaling (WP2)

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

WP2 “matrix” of methods for:

Estimation of point rainfall measurement errors	Errors in rain gauge measurements	Wind effects
		TBR losses / rain gauge calibration
	Errors in DSD	
Rain gauge interpolation	Thiessen polygon method	
	Isohyetal method	
	Inverse distance weighting	
	Kriging	
Adjustment methods	Adjustment of radar to rain gauge data or disdrometers (or validation of the radar)	Mean field bias correction / single site correction
		Range-dependent adjustment
		Brandes correction
		Quantile mapping (validation and/or adjustment)
		Comparing morphological features (only validation)
	Adjustment of rain gauge to radar data	Kriging with radar-based error correction (KRE)
		Kriging with external drift (KED)
		multiquadric surface fitting technique
		Regression kriging
Integration methods	Co-kriging	
	Kalman filter/Bayesian	
	Local singularity analysis	

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Technical meetings Paris 2013 & Antwerp 2014:

✓ Plans for inter-comparison of methods - applicability and results (quality) - for the pilot cases

		Leuven	London (Cranbrook, Portobello, SW Birmangham)	Paris	Rotterdam
Errors in rain gauge measurement	Wind effects				
	TBR losses / rain gauge calibration				
Errors in DSD					
Thiessen polygon method					
Isohyetal method					
Inverse distance weighting					
Kriging					
Adjustment of radar to rain gauge data or disdrometers (or validation of the radar)	Mean field bias correction / single site correction				
	Range-dependent adjustment				
	Brandes correction				
	Quantile mapping (validation and/or adjustment)				
	Comparing morphological features (only validation)				
Adjustment of rain gauge to radar	Kriging with radar-based error correction (KRE)				
	Kriging with external drift (KED)				
	multiquadric surface fitting technique				
	Regression kriging				
Co-kriging					
Kalman filter/Bayesian					
Local singularity analysis					

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Technical meetings Paris 2013 & Antwerp 2014:

✓ Application/testing of statistical/stochastic downscaling methods:

		Leuven	London (Cranbrook, Portobello, SW Birmangham)	Paris	Rotterd
Disaggregation methods	Based on point process theory				
	Cascade or multifractal methods				
	Weather typing				
	Empirical transfer functions / Generalized linear models				
	Empirical transfer functions / Quantile mapping				
	Neural network models				
Statistical methods to relate coarse-scale rainfall statistics to fine-scale rainfall statistics	Weather typing				
	Empirical transfer functions / Generalized linear models				
	Empirical transfer functions / Quantile mapping				
	Neural network models				
	Markov chain based disaggregation method				
	Scaling relations				
	Areal correction factors				

✓ Universal multifractal method (ParisTech): comparison with Local singularity analysis (ICL/KU Leuven) agreed

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

- Algorithms shared for:
  - Radar adjustment to rain gauges (MFB, Range-dependent, Brandes, quantile mapping; static-dynamic adjustment)
  - Rain gauge interpolation adjustment to radar (kriging: KRE, KED)
  - Radar – rain gauge merging (co-kriging, Kalman filter, + local singularity analysis)
  - Universal multifractal method: *workshop 27 June 2014 at Paris*

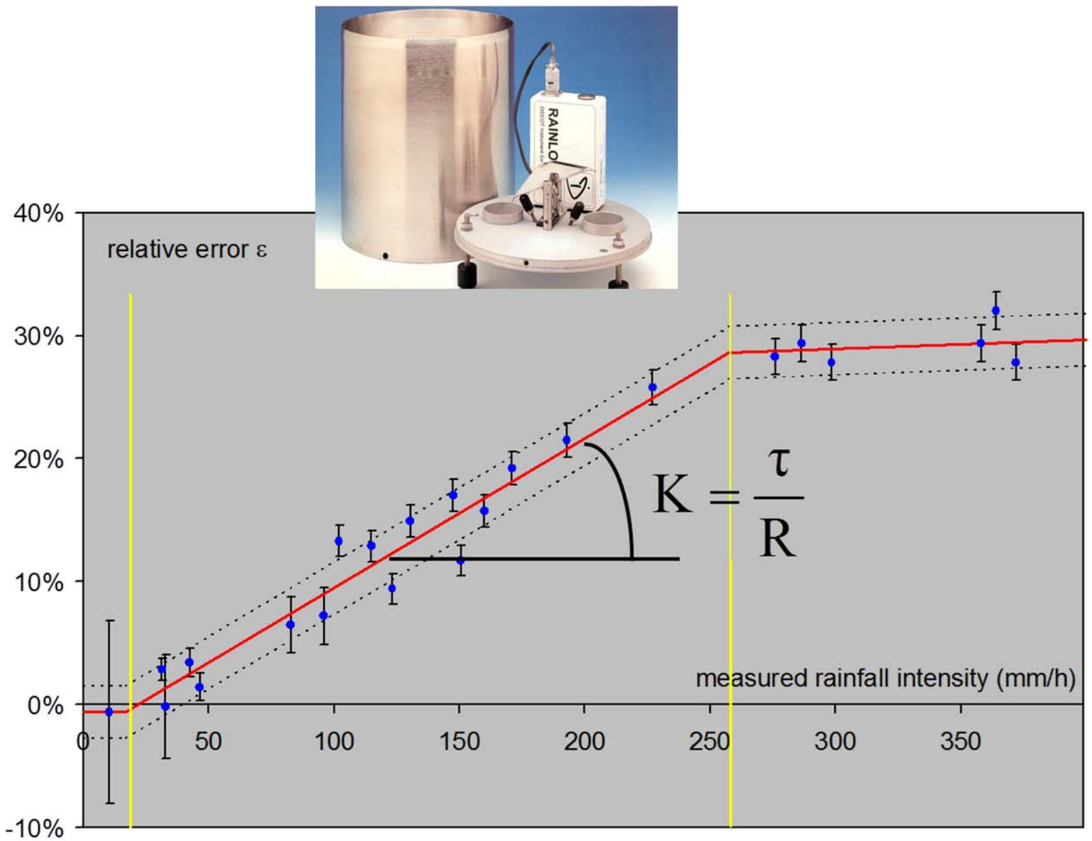
  - Rain gauge error estimation
  - (Radar error estimation; for local ground level rainfall intensities)

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

(Tipping bucket) rain gauge error estimation:



Accuracy tipping-bucket rain gauges:

- resolution R (0.1 mm, 0.2 mm, 0.5 mm)
- uncertainty calibration curve (± 1%)
- influence of wind and local disturbances (± 3 to 5%)

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Intercomparison of methods + analysis of added value of radar data comparison with traditional rainfall estimates (without radar):

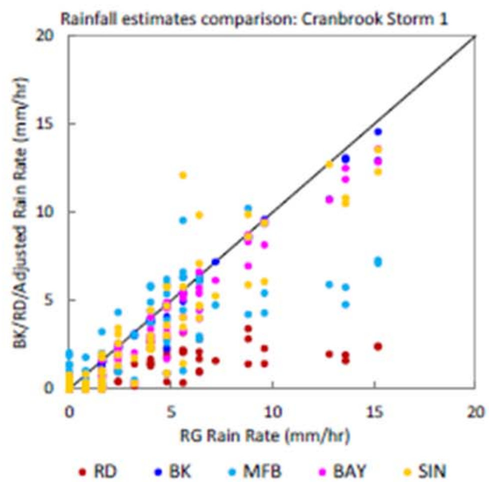
- All adjustment/merging methods proved to improve the applicability of radar rainfall estimates to urban hydrological applications
- They all lead to strongly improved areal average accumulations close to those recorded by rain gauges
- Only the Bayesian methods, especially the singularity-sensitive one, were capable of effectively reproducing high rainfall rates

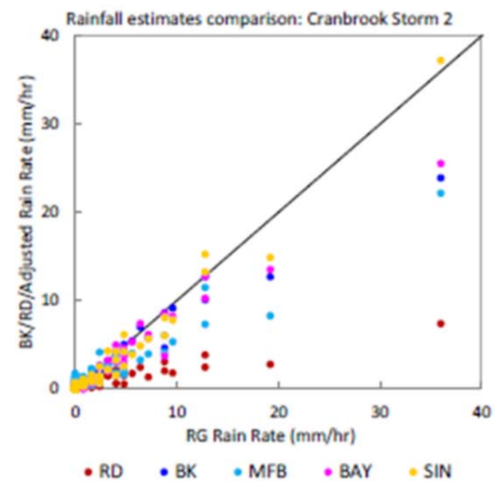
REVIEW – WP2 A6

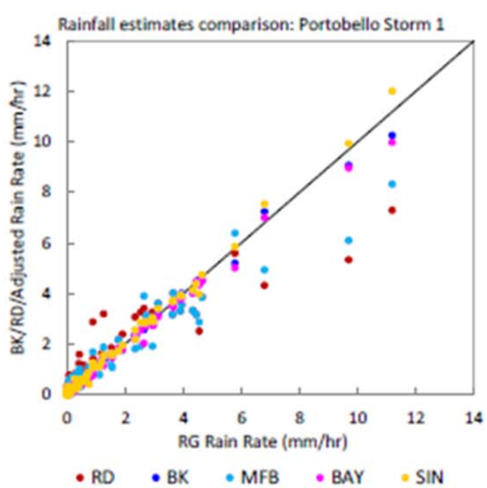
A6: Rainfall estimation in pilot sites

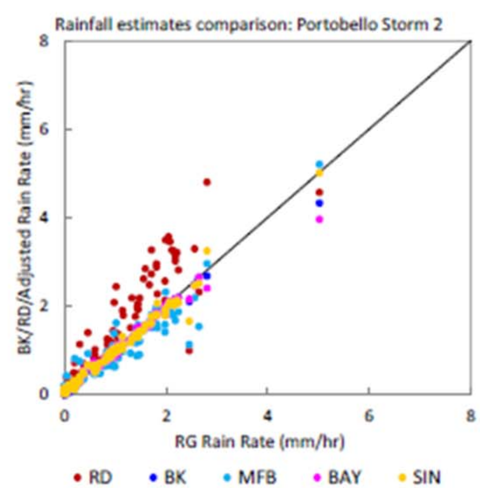
Output: Rainfall estimates for storms in pilot sites

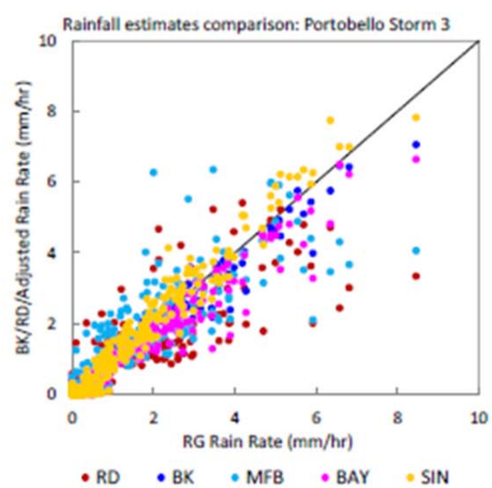
For Cranbrook & Portobello catchments UK and NIMROD C-band radar data:









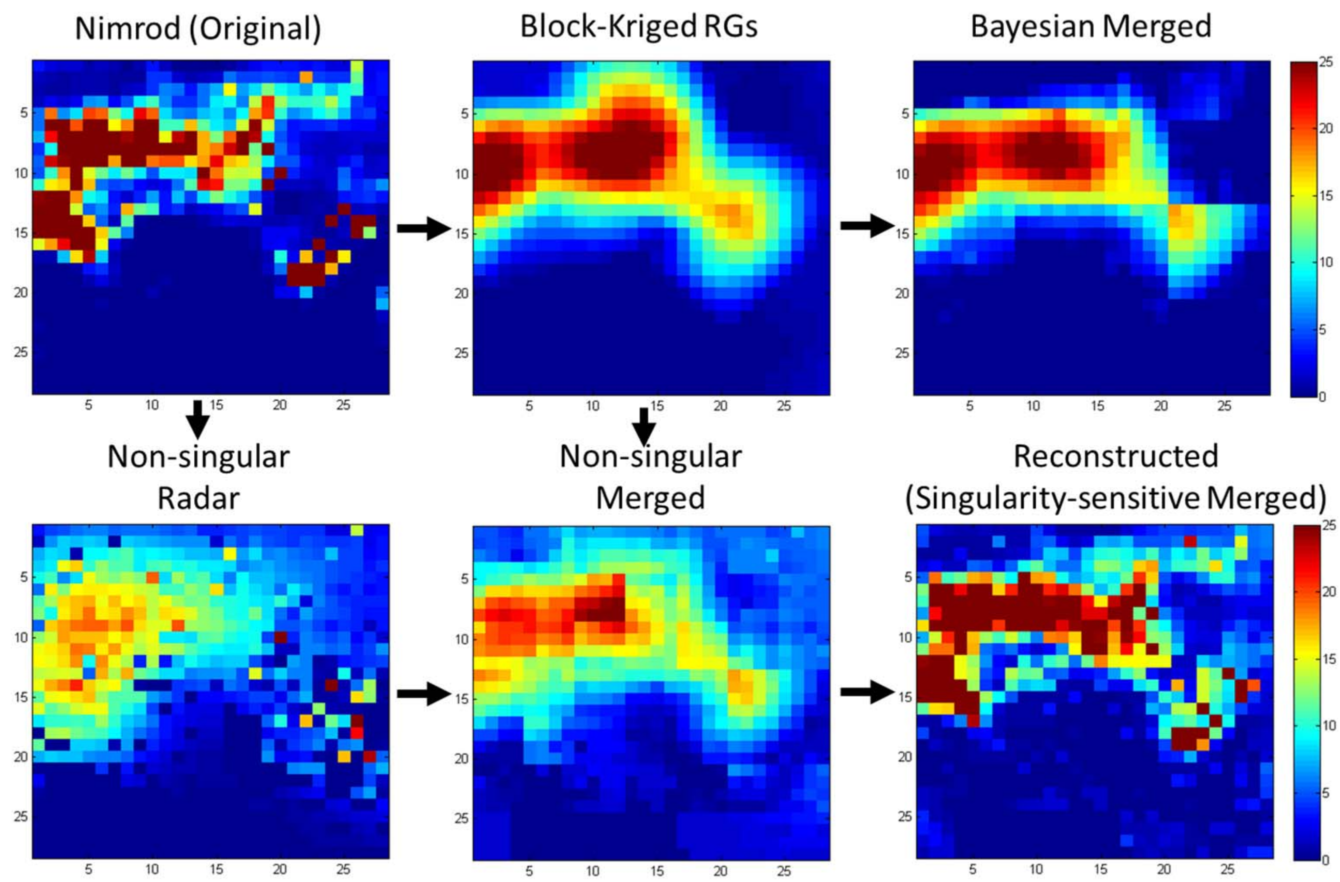


REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

- Merged radar rainfall estimates with local singularity analysis are visually more realistic (preserve spatial structure) and show better temporal continuity: also for nowcasting!

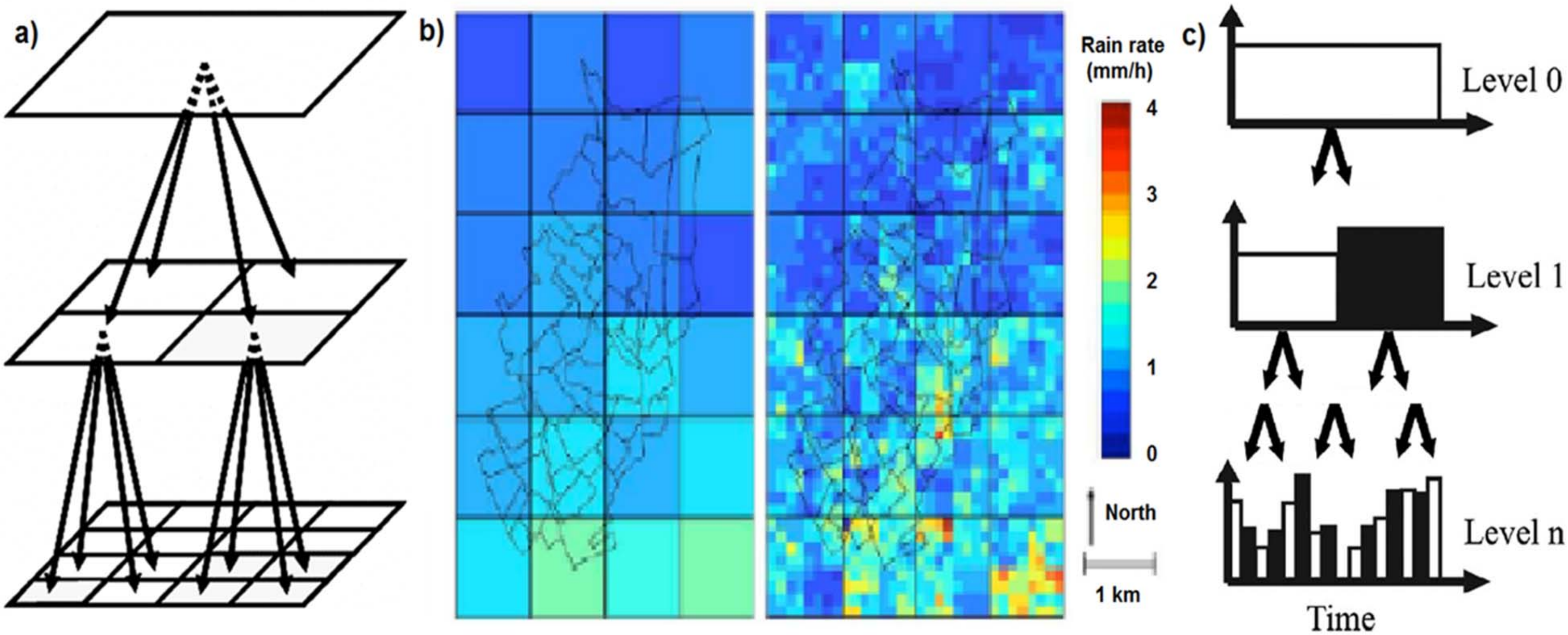


REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

- Stochastic downscaling approach by Universal Multifractal cascade process allow estimation of uncertainty associated with small scale unmeasured rainfall variability (i.e. below the C-band radar resolution)



REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Comparison / experiences with:

- coarser (NWE-scale) C-band / spatially interpolated rain gauges
  - ***Finer scale features are missing***
- fine-scale X-band, city scale: dual pol vs. single pol, Doppler, cheap marine or low cost portable vs. pulse or FMCW radar

  Single pol, low cost X-band (Leuven, London):
  - ***Clutter correction and calibration of Z-R relationship to rain gauges very important for single pol radar + unstable clutter + problems with wet radome (blanking d. heavy rainfall in vicinity radar (desp. shelter)***
  - ***Added value single pol radar compared to rain gauges networks or merged rain gauges – C-band questionable***
- super-resolution polarimetric C-band

  Very promising (MetOffice)

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

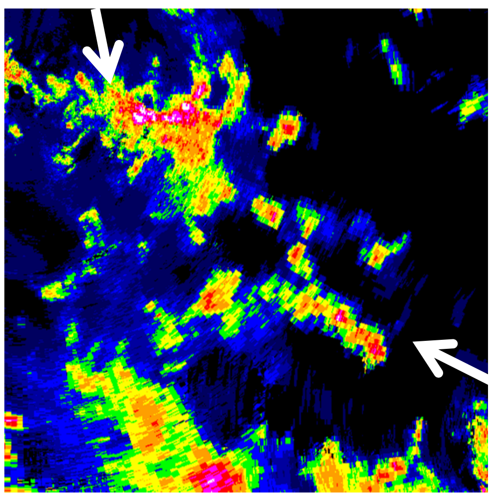
Super resolution rainfall product from Met Office C-band network:

Radars operated with 75 m pulse length (out to 125 km range)

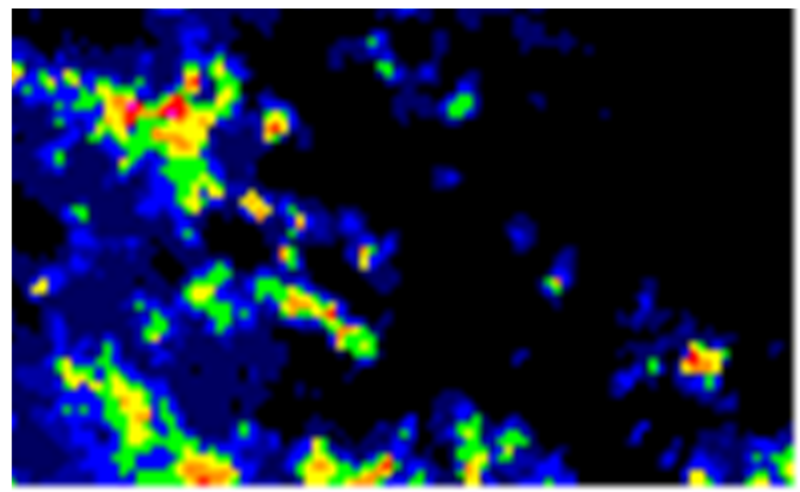
Radars operated with 600 m pulse length (out to 255 km range)

Scans Interleaved: 75 m and 600m scans completed within each 5 minute operational "volume"

Watford



Dartford



100 m gridded product over London product

Equivalent operational 1 km

Raw data gathered from the C-band network operated by the Met Office

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Super resolution rainfall product from Met Office C-band network:

Progress:

- Improvements the quality control of high resolution data
- Antenna pointing correction improvements implemented for operational 100m product
- Full assessment of wind-drift correction methodology

Plans:

- Research into improved convection diagnosis algorithms to improve QPE in embedded convective events is ongoing
- Advected and Merged (with gauges) 100m accumulations (March 2015)

REVIEW – WP2 A6

A6: Rainfall estimation in pilot sites

Output: Rainfall estimates for storms in pilot sites

Still to be further explored:

- How do rainfall data resolution and data reliability interrelate?
- What reliability can be delivered by different configurations of radar and rain gauges in cities?

-> to be done in cooperation with WP3 !!

REVIEW – WP2 A7

A7: Workshop on fine-scale rainfall forecasting

Output: Report on methods for fine-scale rainfall forecasting

International Antwerp workshop, 31 March 2014: 42 participants (incl. FMI, KNMI, RMI, Univ. Bristol, Aalborg Univ., DTU, Univ. Wageningen, …)

REVIEW – WP2 A7

A7: Workshop on fine-scale rainfall forecasting

Output: Report on methods for fine-scale rainfall forecasting

- Workshop: Discussion among the (scientific) project partners and international experts methods and experiences for fine-scale rainfall nowcasting
- Detailed minutes
- Report/guidelines?

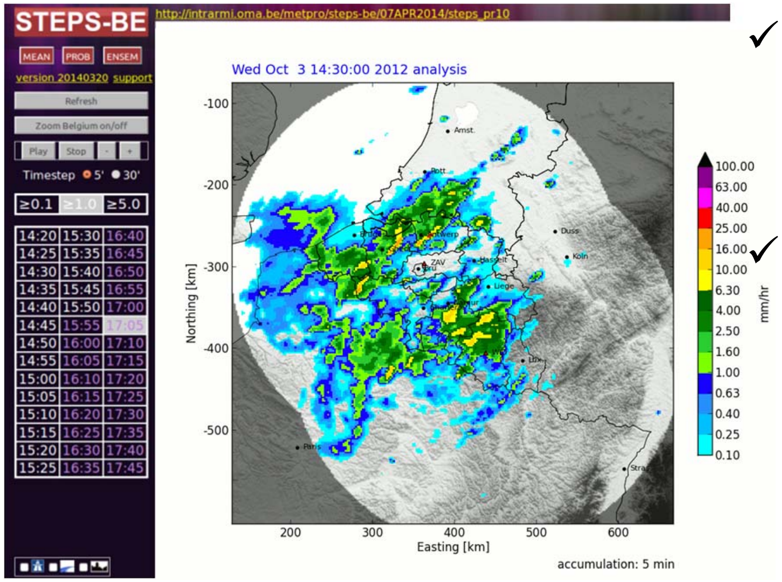
REVIEW – WP2 A8

A8: Fine-scale rainfall forecasting in pilot sites

Output: Rainfall forecasting system for pilot sites

- UK (ICL & Met Office i.c.w. Bristol University):
  - STEPS (Probabilistic fine-scale rainfall nowcasting with the Short-Term Ensemble Prediction System)

- Belgium (KU Leuven i.c.w. RMI, linked to BelSPO PLURISK project):
  - INCA nowcasting model RMI (C-band based): deterministic
  - STEPS (prototype ready) : probabilistic



✓ *There is a characteristic scale below which rainfall is unpredictable*

✓ *Observation uncertainty contributes to half of the nowcasting error at +0-1h*

REVIEW – WP2 A9

A9: Guidelines and training material

Output: Guidelines, manuals and training

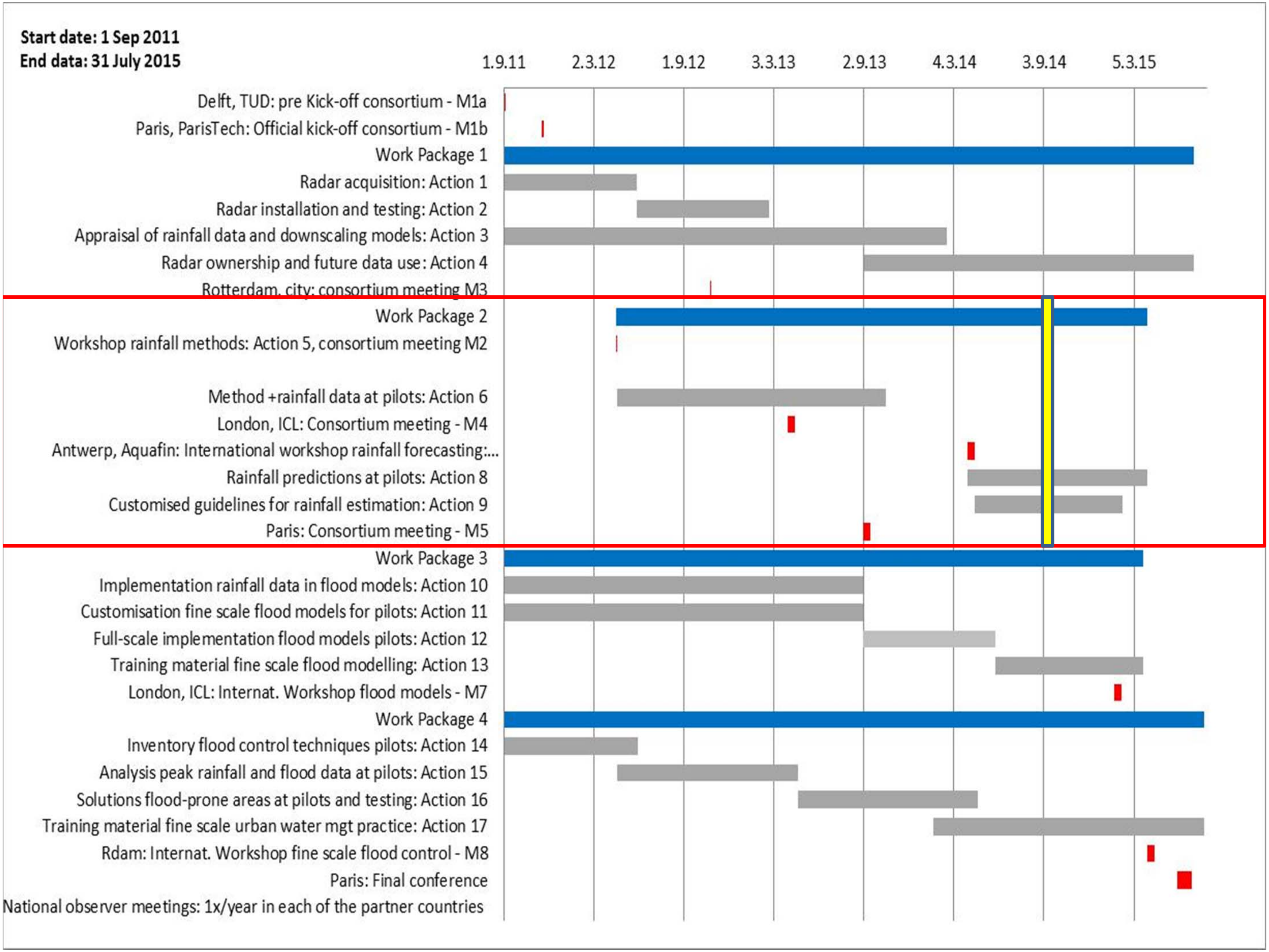
- Guidelines for "good practise"
- "Toolkit" (?) of adjustment – merging - downscaling methods + Training material + Experiences from pilot cases


RainGain

Review document:

Investing in Opportunities

Methods and experiences in radar based fine scale rainfall estimation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End data: 31 July 2015
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5.3.15
Delft, TUD: pre Kick-off consortium - M1a
Paris, ParisTech: Official kick-off consortium - M1b
Work Package 1
Radar acquisition: Action 1
Radar installation and testing: Action 2
Appraisal of rainfall data and downscaling models: Action 3
Radar ownership and future data use: Action 4
Rotterdam, city: consortium meeting M3
Work Package 2
Workshop rainfall methods: Action 5, consortium meeting M2
Method +rainfall data at pilots: Action 6
London, ICL: Consortium meeting - M4
Antwerp, Aquafin: International workshop rainfall forecasting:...
Rainfall predictions at pilots: Action 8
Customised guidelines for rainfall estimation: Action 9
Paris: Consortium meeting - M5
Work Package 3
Implementation rainfall data in flood models: Action 10
Customisation fine scale flood models for pilots: Action 11
Full-scale implementation flood models pilots: Action 12
Training material fine scale flood modelling: Action 13
London, ICL: Internat. Workshop flood models - M7
Work Package 4
Inventory flood control techniques pilots: Action 14
Analysis peak rainfall and flood data at pilots: Action 15
Solutions flood-prone areas at pilots and testing: Action 16
Training material fine scale urban water mgt practice: Action 17
Rdam: Internat. Workshop fine scale flood control - M8
Paris: Final conference
National observer meetings: 1x/year in each of the partner countries