Temporal interpolation of radar rainfall fields:

Meeting the stringent requirements of urban hydrological applications

Li-Pen Wang, Susana Ochoa-Rodriguez, Christian Onof and Patrick Willems

HS7.8: Precipitation and urban hydrology

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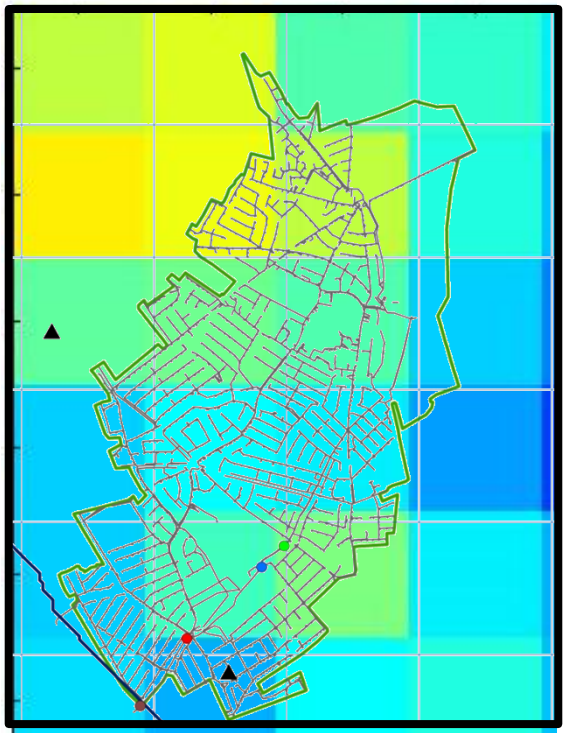
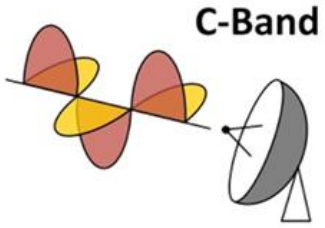
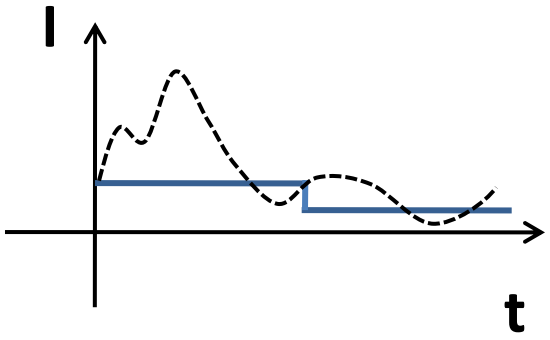
Urban hydrological applications require rainfall estimates of highest accuracy and resolution

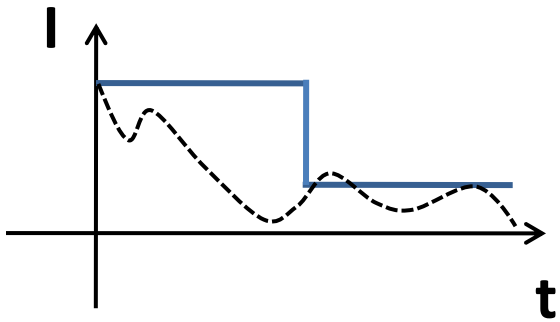
- Radar rainfall estimates provide better description of the spatial-temporal variability of storm (as compared to point rain gauge data)
- Insufficient **accuracy**
- Spatial and **temporal** resolutions may still be insufficient for urban hydrology





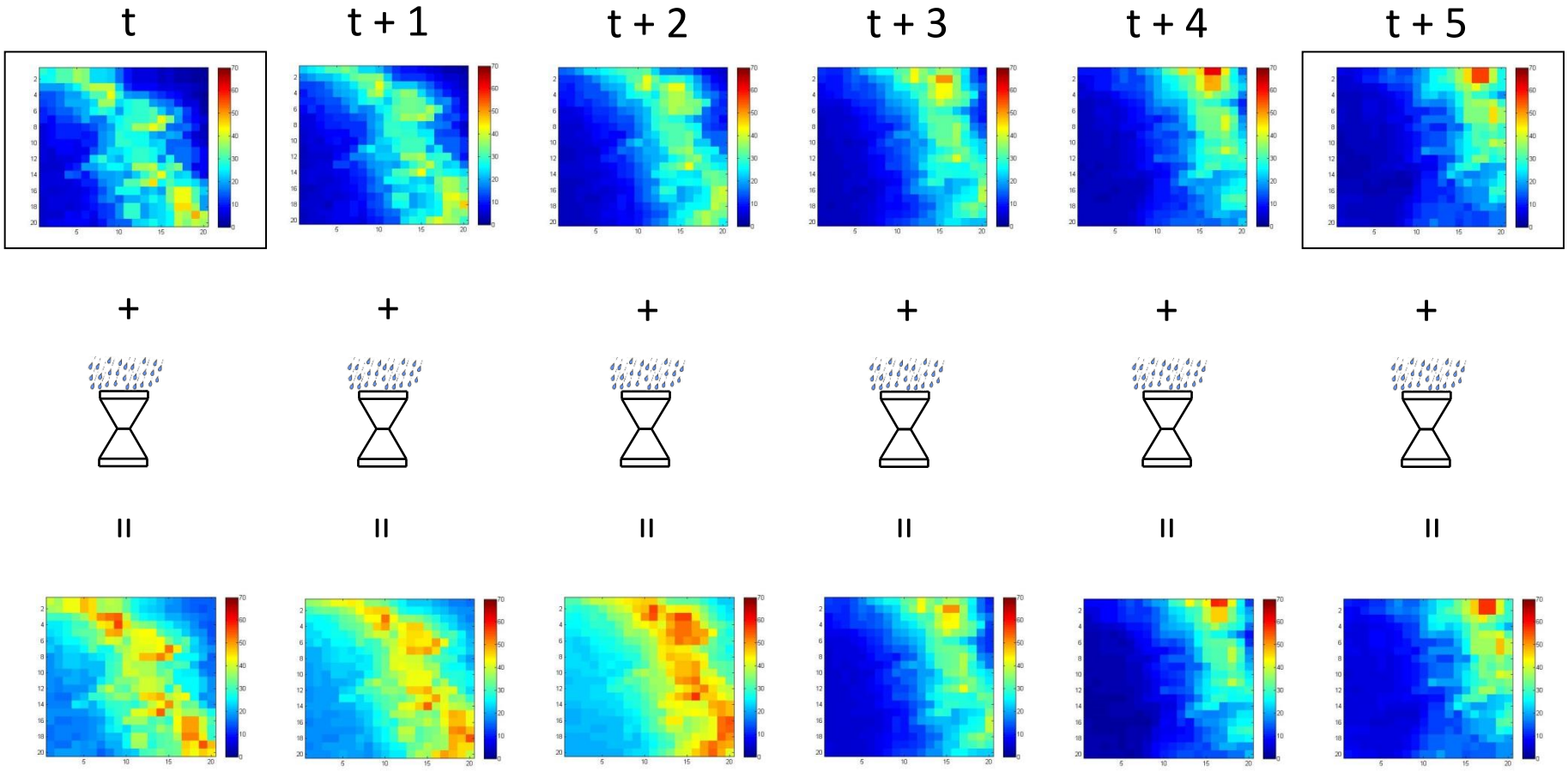
National meteorological services normally provide instantaneous radar images in 5-10 min time interval





METHODOLOGY

Advection-based temporal interpolation
+
Gauge-based radar data adjustment



Advection-based temporal interpolation:

Multi-scale variational optical flow technique

1. Grey Value Constancy (E_1):

$$I(x, y, t) = I(x + u, y + v, t + \Delta T)$$

2. Gradient Constancy Assumption (E_2):

$$\nabla I(x, y, t) = \nabla I(x + u, y + v, t + \Delta T)$$

3. Smoothness (E_3):

$$\nabla^2 u = \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \quad \text{and} \quad \nabla^2 v = \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}$$

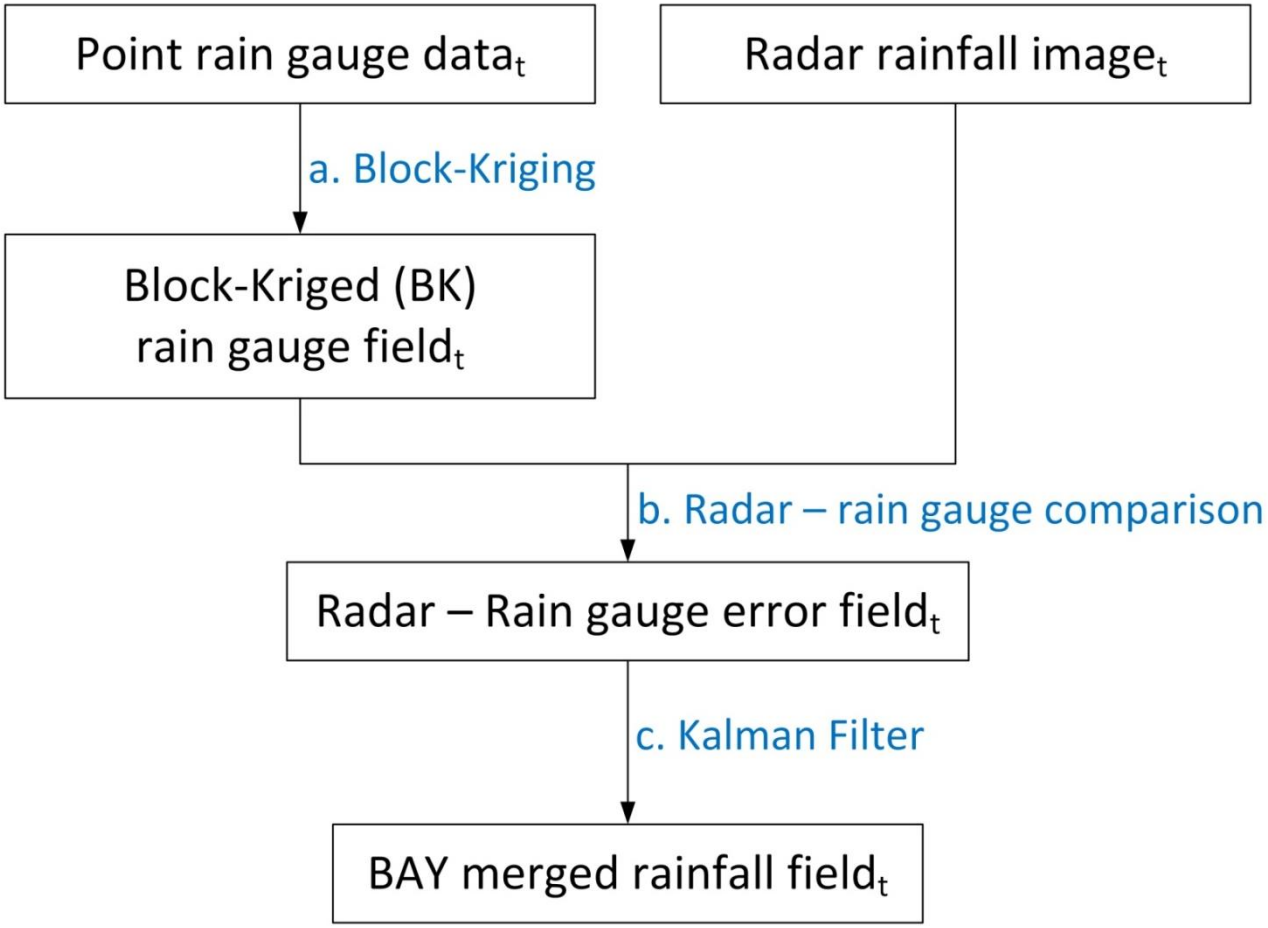
Overall penalty functional:

$$E = E_1 + \gamma \cdot E_2 + \alpha \cdot E_3$$

Brox et al. (2004)

Gauge-based radar data adjustment:

Bayesian radar-rain gauge data merging

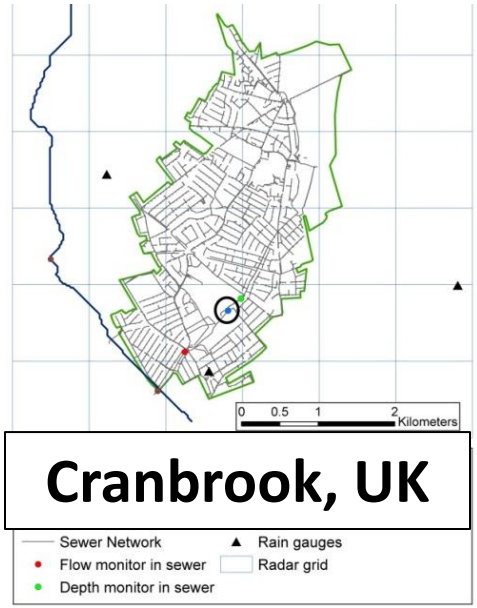


(Todini, 2001; Wang et al., 2013)

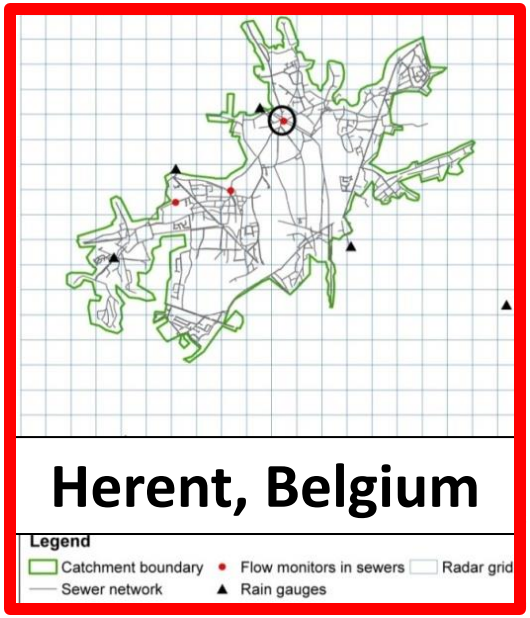
CASE STUDY

Testing methodology

- RG
- RD 5
- RD 10
- BAY 5
- BAY 10
- RD 5-1
- RD 10-1
- BAY 5-1
- BAY 10-1



Cranbrook, UK

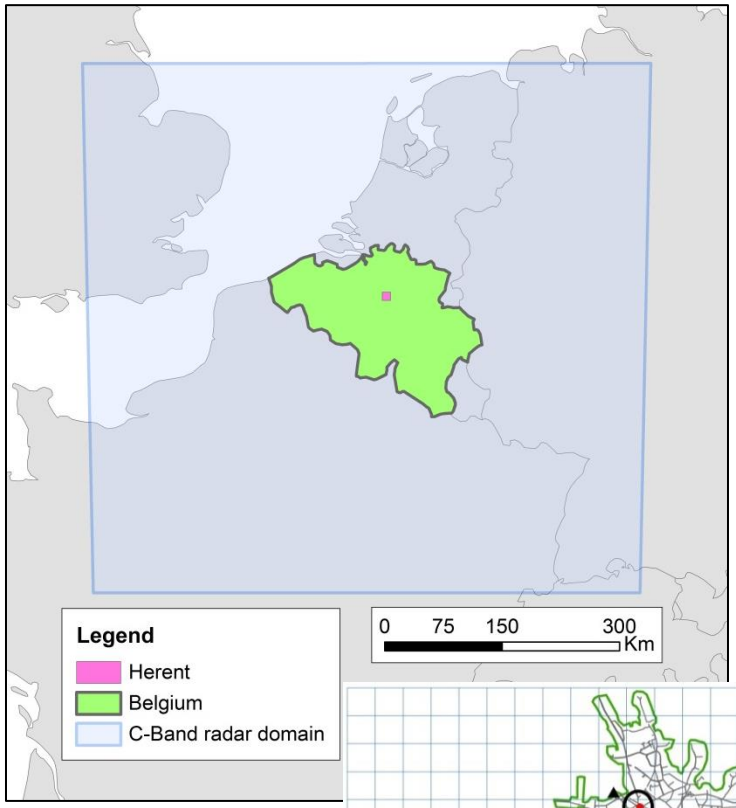


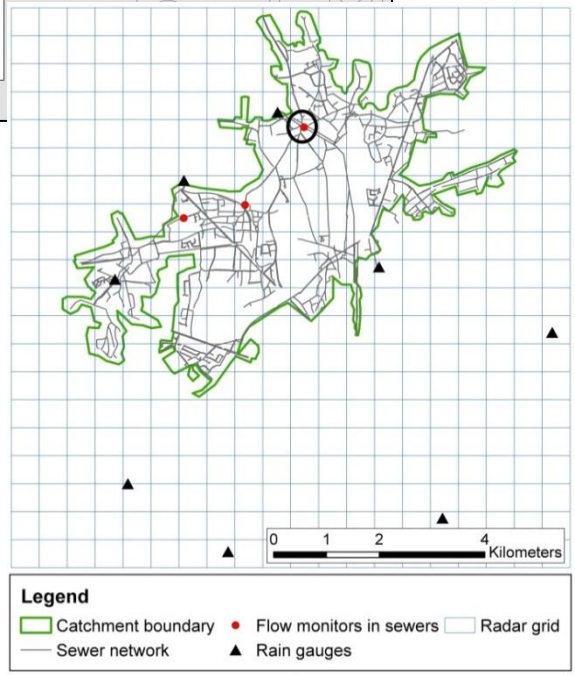
Herent, Belgium

Analysis of hydraulic outputs

Herent, Belgium

- **Radar data – Interpolation domain**
  - ~ 700 X 670 km^2
  - Composite reflectivity from 2 C-band radars (Royal Meteorological Institute of Belgium)
  - 5 min / 529 m
  - Marshall-Palmer Z-R relation
- **Local data - Merging domain:**
  - 10.6 X 10.6 km^2 (Herent)
  - 7-8 rain gauges, 1 min resolution
- **Hydrological/hydraulic testing:**
  - Drainage area = ~25 km^2 (14 % impervious)
  - InfoWorks CS semi-distributed sewer model
  - 3 flow gauges (2 min resolution)



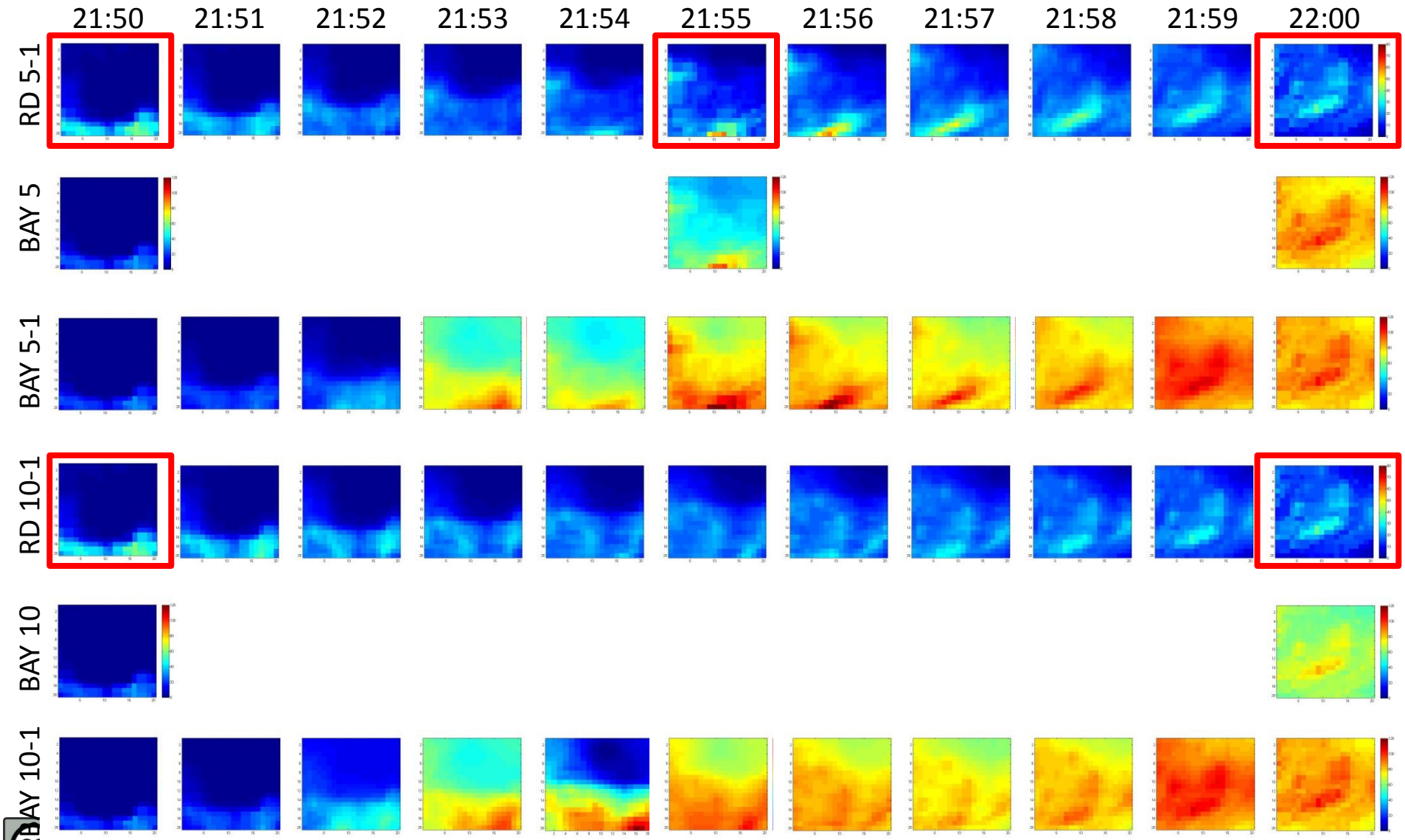


Selected storm events during 2012-2013

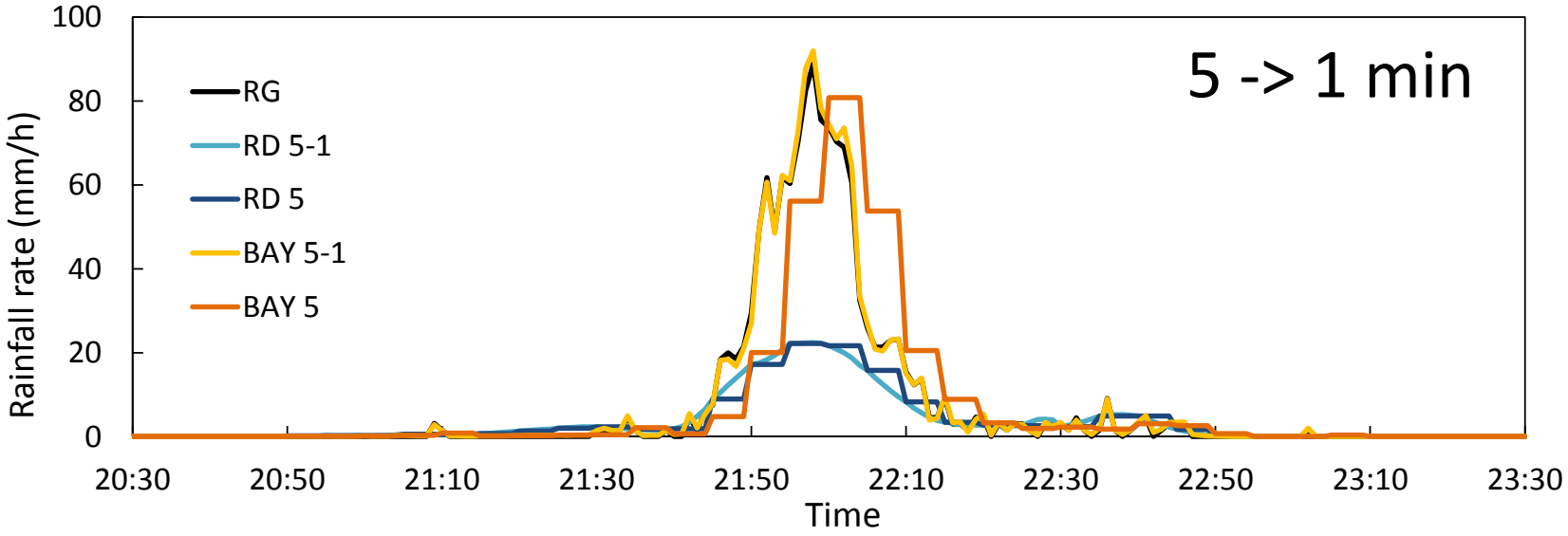
ID	Date	Duration (h)	RG #	RG Total (mm)	RG Peak (mm/h) 1/5 min	RD Total (mm)	RD Peak (mm/h) 5 min
HER-S01	23rd Sep 2012	1.8	8	9.99	25.94/20.40	20	41.89
HER-S02	08th May 2013	4	7	9.22	32.48/28.97	7.97	18.16
HER-S03	27th Jul 2013	5	8	21.39	86.11/78.94	10.06	16.2
HER-S04	27th Jul 2013	3	8	21.73	88.85/78.11	10.75	22.23

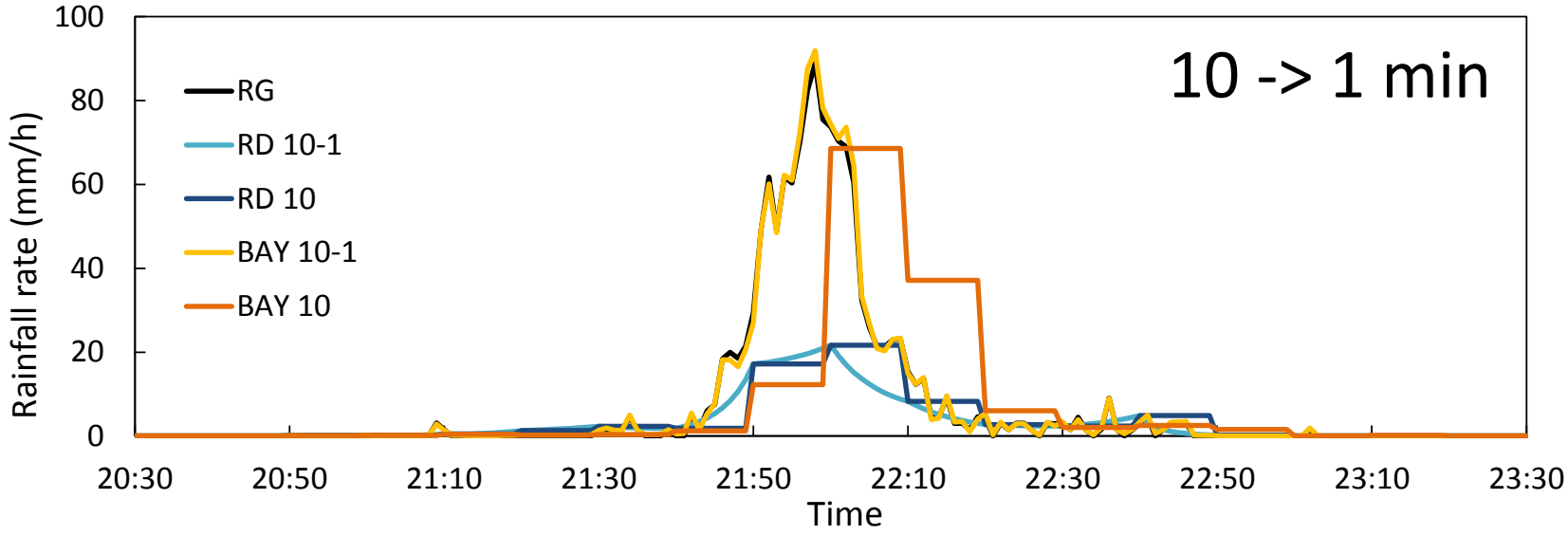
RESULTS & DISCUSSION

Snapshots during storm peak: HER-S04

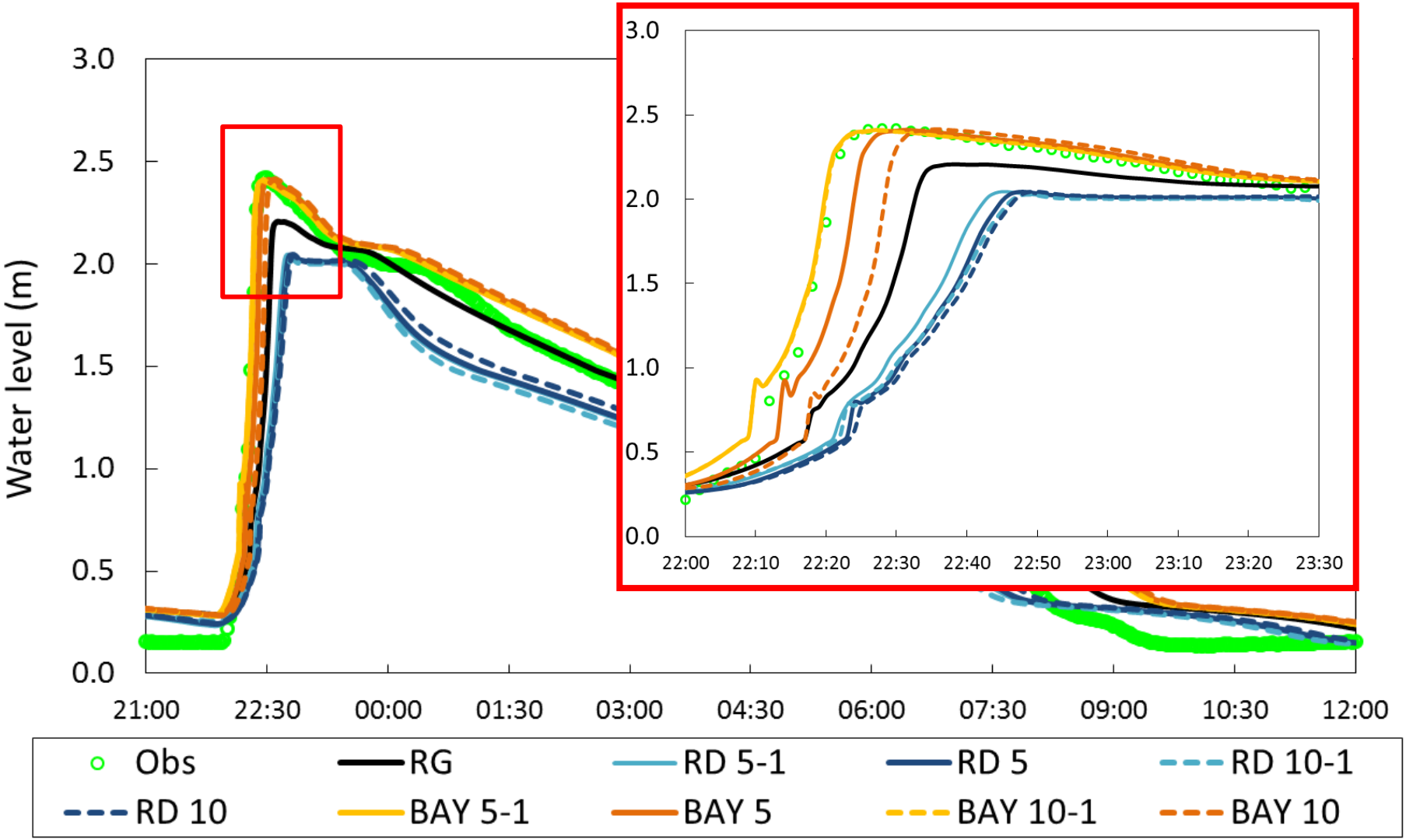


Profiles of areal-average rainfall inputs: HER-S04





Hydrographs of the observed and simulated water level: HER-S04



Hydraulic performance for the selected events

ID	RG	RD 5-1	RD 5	RD 10-1	RD 10	BAY 5-1	BAY 5	BAY 10-1	BAY 10
R^2 - Coefficient of Determination									
HER-S01	0.965	0.930	0.936	0.889	0.879	0.957	0.953	0.962	0.978
HER-S02	0.962	0.903	0.892	0.903	0.892	0.943	0.919	0.941	0.905
HER-S03	0.890	0.724	0.693	0.708	0.636	0.985	0.970	0.984	0.934
HER-S04	0.929	0.888	0.869	0.870	0.856	0.994	0.979	0.994	0.937
β - Regression Coefficient									
HER-S01	1.022	1.045	1.044	1.030	1.036	0.979	0.998	1.075	1.111
HER-S02	0.734	0.520	0.524	0.474	0.571	0.731	0.712	0.692	0.781
HER-S03	0.911	0.655	0.693	0.663	0.617	0.974	0.972	0.972	0.955
HER-S04	0.846	0.786	0.775	0.766	0.775	0.904	0.897	0.903	0.877
RMSE - Root-Mean-Square Error (in m)									
HER-S01	0.144	0.170	0.162	0.199	0.236	0.197	0.162	0.118	0.111
HER-S02	0.304	0.583	0.566	0.643	0.576	0.298	0.332	0.346	0.313
HER-S03	0.230	0.432	0.409	0.418	0.474	0.152	0.171	0.152	0.210
HER-S04	0.184	0.299	0.309	0.330	0.299	0.148	0.165	0.148	0.210

Conclusionss

- A methodology was proposed to generate good quality radar rainfall estimates at high temporal resolution, which meet the requirements of urban hydrological applications.
- The proposed methodology enables best use of the sensor data normally available at urban scales
  - Accuracy and temporal resolution of rain gauges
  - Spatial description of rain fields provided by radars

Future work

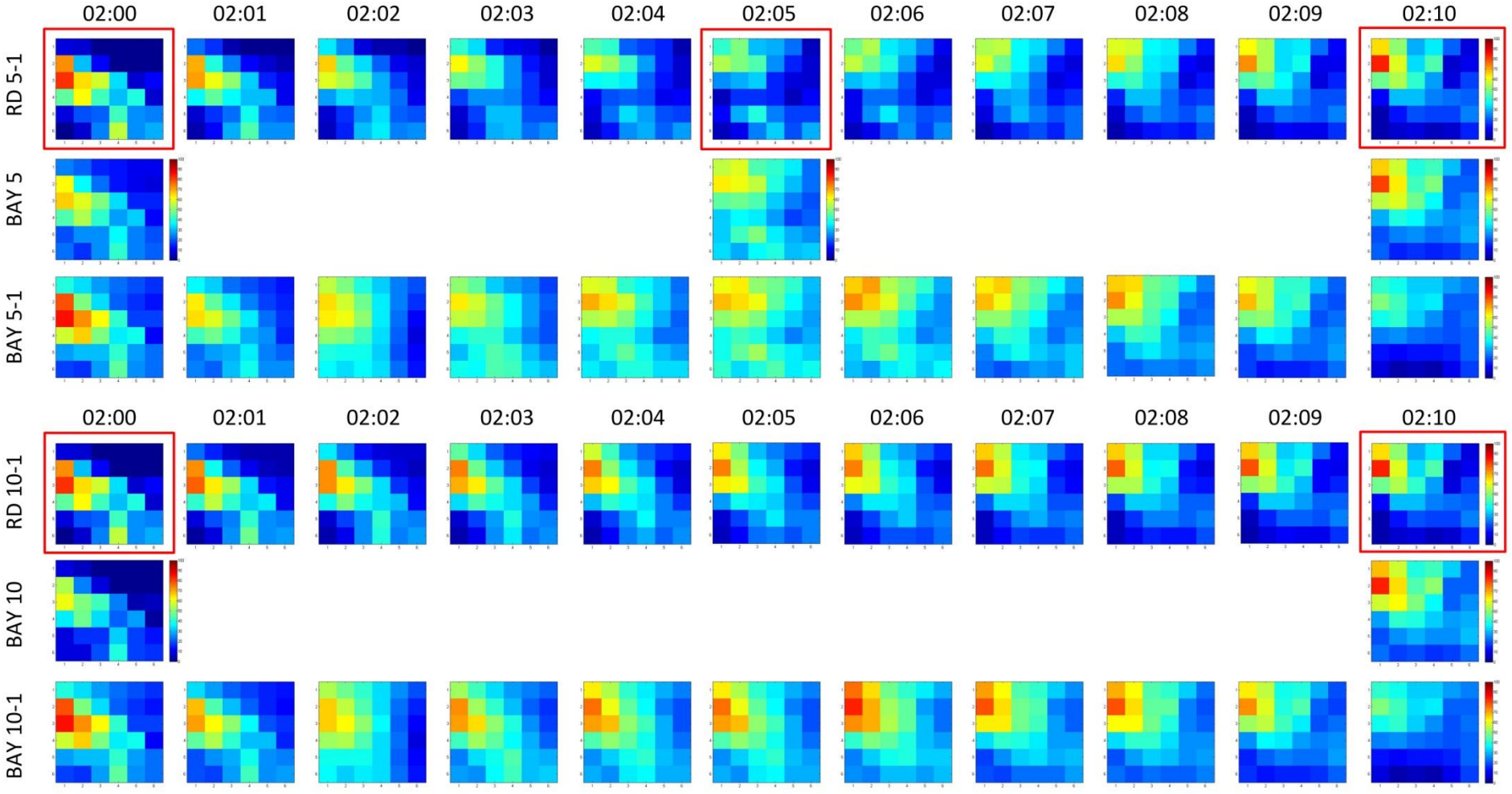
- Account for sampling error coming from high temporal resolution rain gauge data
- Account for temporal correlation of radar-rain gauge biases
- Stochastic implementation of temporal interpolation to describe errors arising from insufficient temporal resolution of radar rainfall estimatess

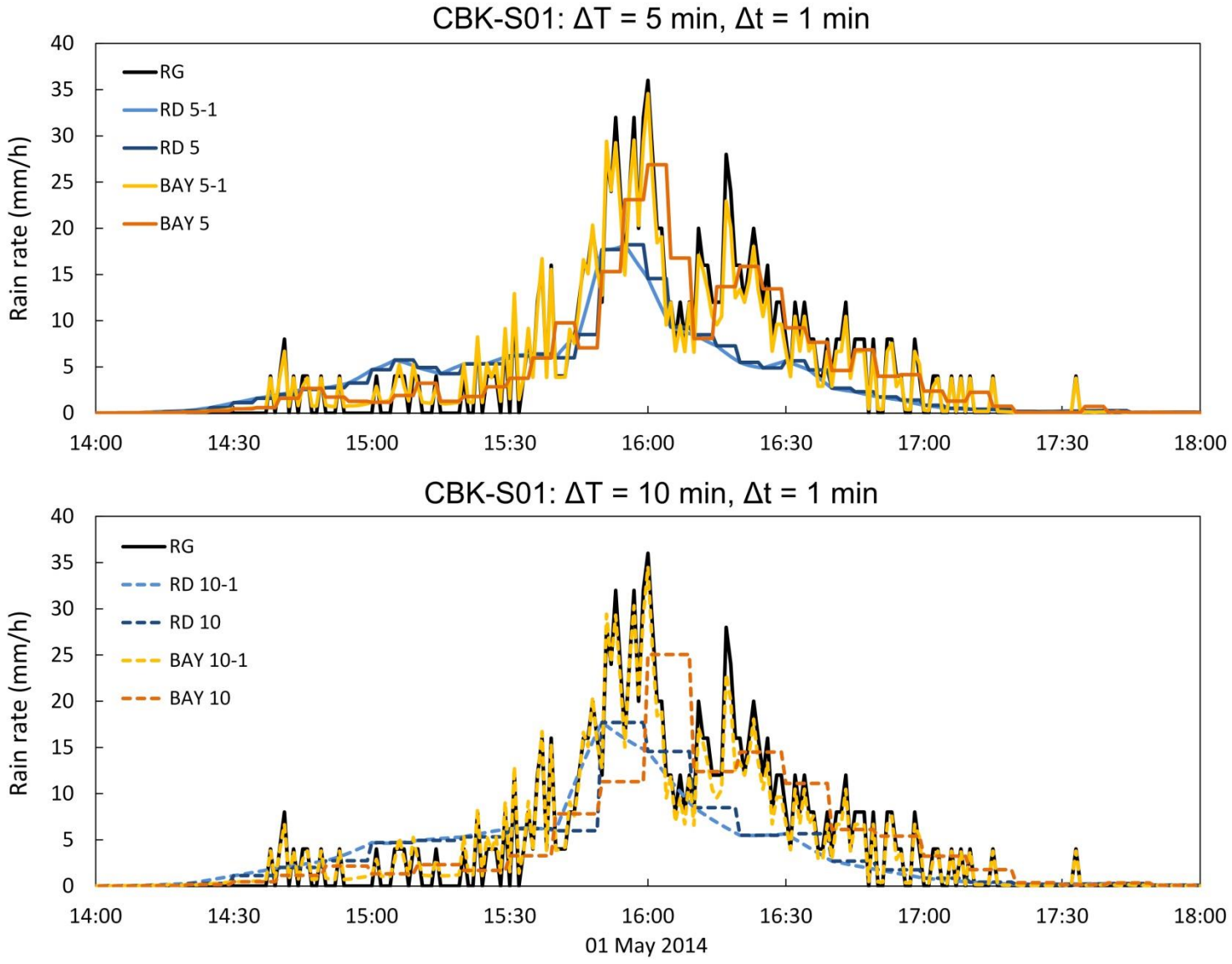
Investing in Opportunities
This project has received European Regional Development Funding through INTERREG IV B.
INTERREG IVB

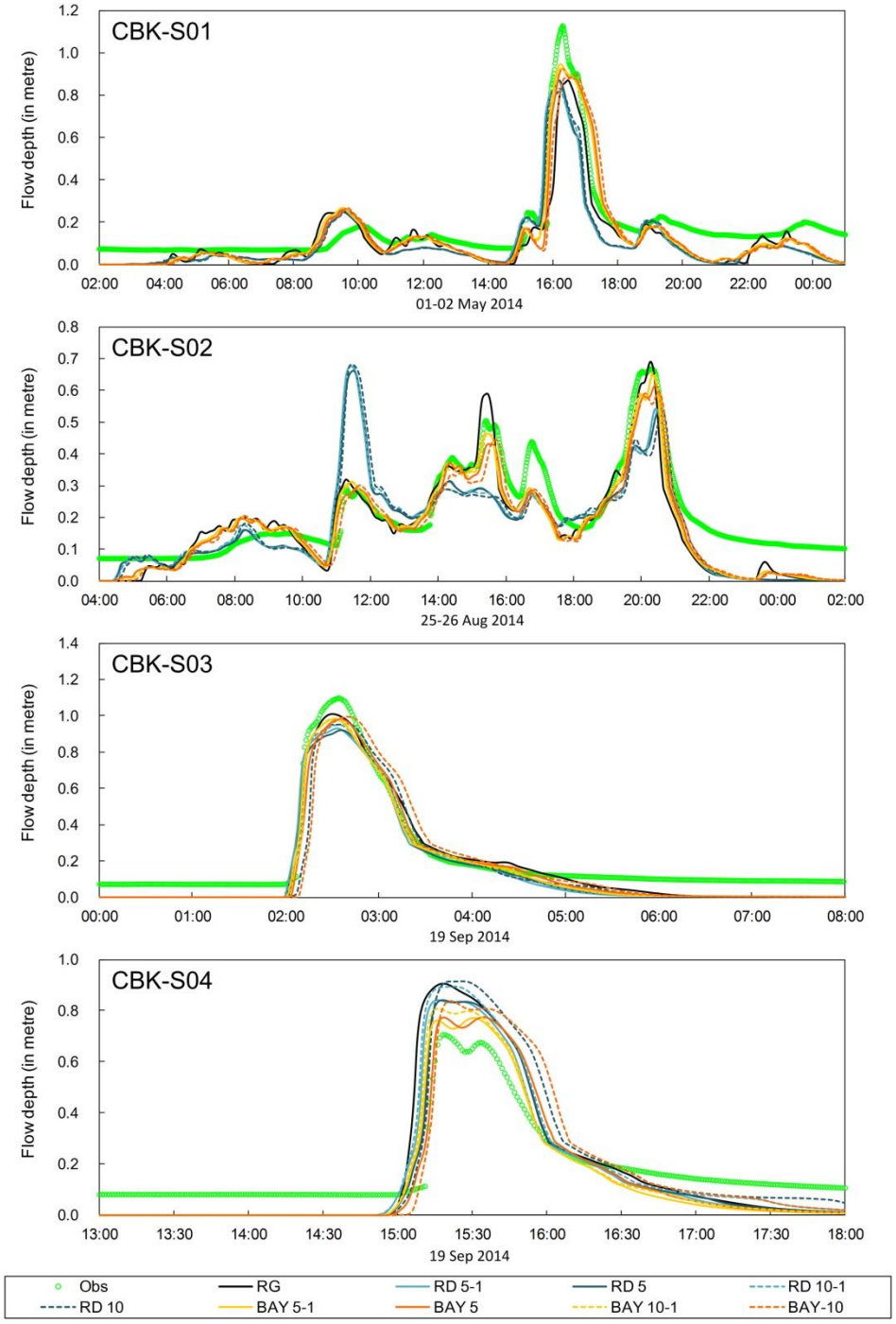
QUESTIONS?

Thank You!

Li-Pen Wang
Lipen.Wang@bwk.kuleuven.be


02:00
02:01
02:02
02:03
02:04
02:05
02:06
02:07
02:08
02:09
02:10
RD 5-1
BAY 5
BAY 5-1
02:00
02:01
02:02
02:03
02:04
02:05
02:06
02:07
02:08
02:09
02:10
RD 10-1
BAY 10
BAY 10-1


CBK-S01: ΔT = 5 min, Δt = 1 min
Rain rate (mm/h)
RG
RD 5-1
RD 5
BAY 5-1
BAY 5
0
5
10
15
20
25
30
35
40
14:00
14:30
15:00
15:30
16:00
16:30
17:00
17:30
18:00
CBK-S01: ΔT = 10 min, Δt = 1 min
Rain rate (mm/h)
RG
RD 10-1
RD 10
BAY 10-1
BAY 10
01 May 2014


CBK-S01
Flow depth (in metre)
01-02 May 2014
CBK-S02
Flow depth (in metre)
25-26 Aug 2014
CBK-S03
Flow depth (in metre)
19 Sep 2014
CBK-S04
Flow depth (in metre)
19 Sep 2014
Obs
RG
RD 5-1
RD 5
RD 10-1
RD 10
BAY 5-1
BAY 5
BAY 10-1
BAY-10