Exploring the added value of low-cost sensors via citizen observatories for peak rainfall monitoring in cities (Case study: Brussels)

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FloodCitiSense

MISMATCH BETWEEN RAIN GAUGES AND RADAR RAINFALL

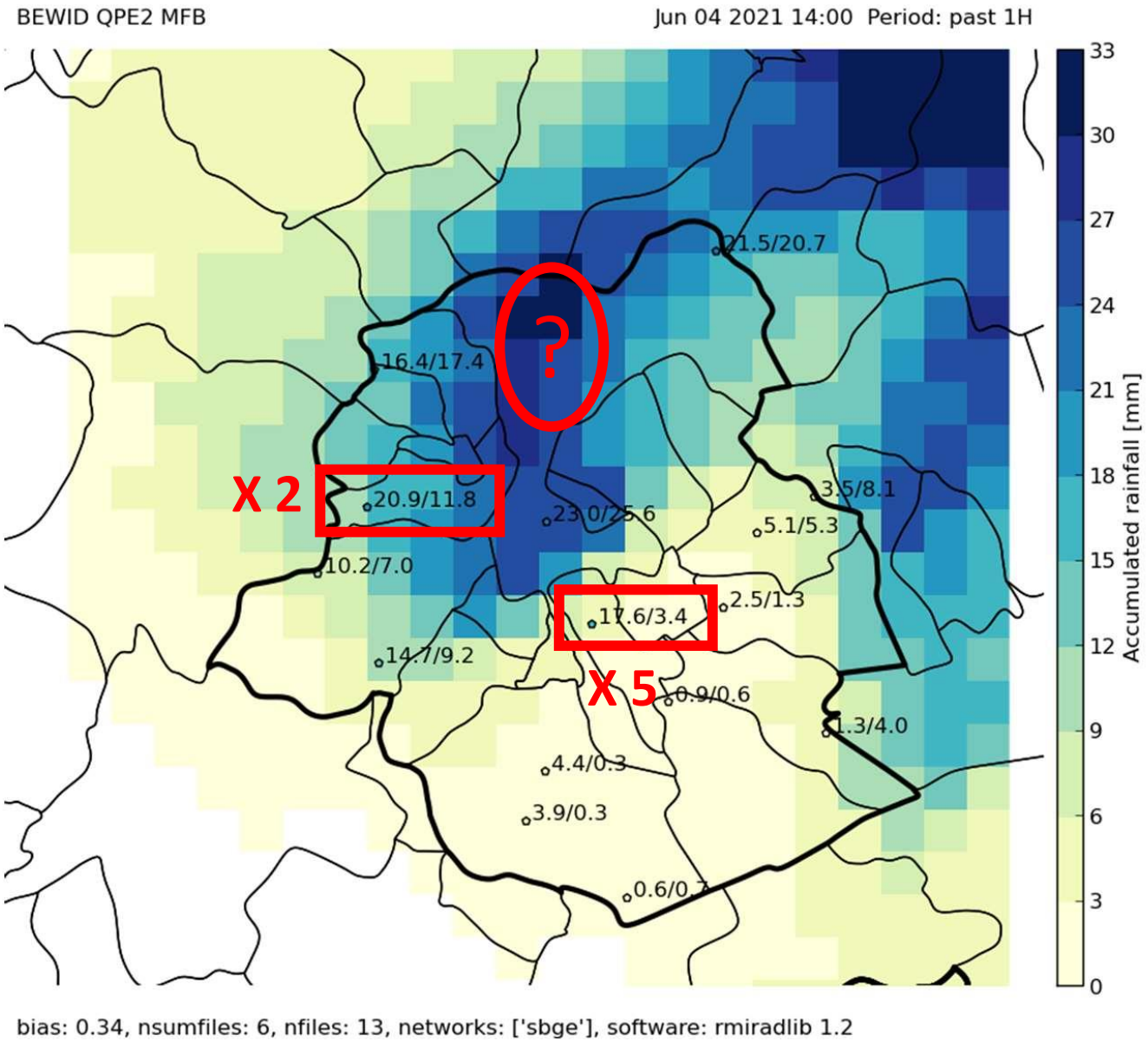
HOURLY RAINFALL ACCUMULATION

- RAIN GAUGE / RADAR

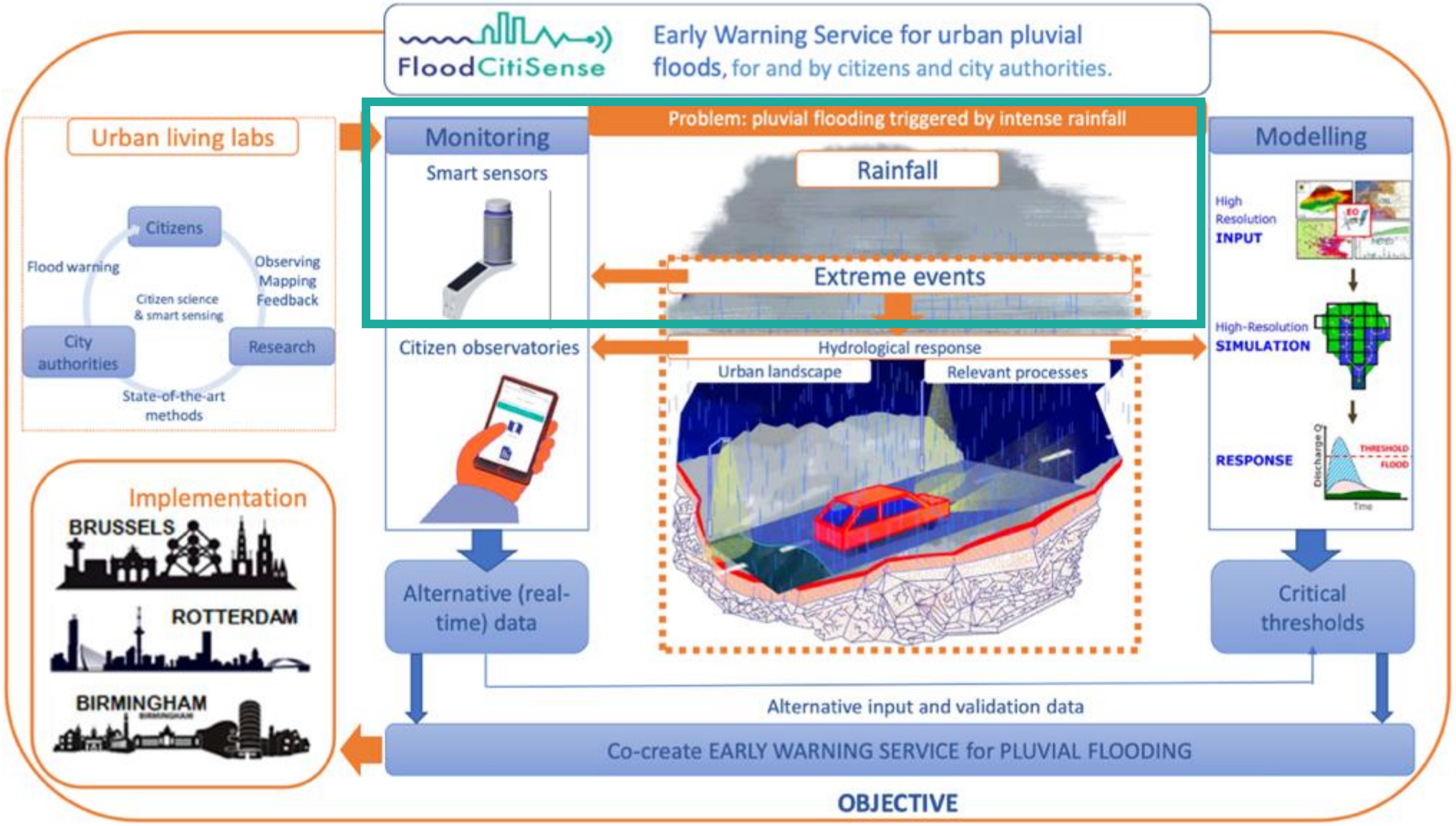
(LOCALIZED) INTENSE RAINFALL TRIGGER PLUVIAL FLOODING

Can low-cost sensors be an added value for localized peak rainfall monitoring?

FloodCitiSense

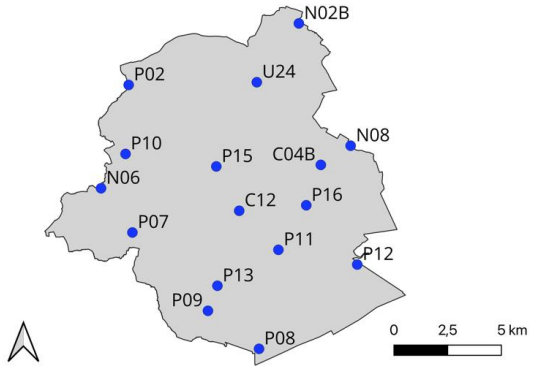


→ VISIT WEB STORY @ FLOODCITISENSE.EU



FLOWBRU
Monitoring Brussels Water by HYDRIA

Flowbru rain gauges network (16)



Measurement technique: High-precision **weighing** gauge sensors, weigh the rain and convert into volume

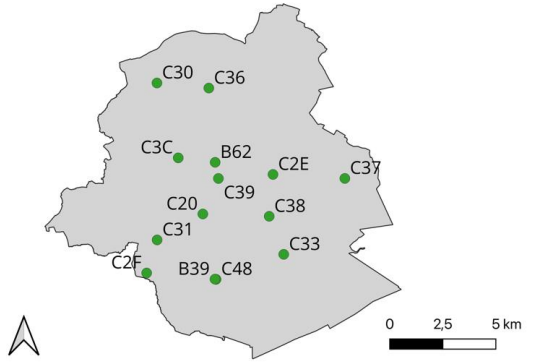
Cost: ± **5000€**

Data: recorded every **5 minutes** and sent in real-time to a central server by **GPRS**

Availability: **100% available**

FloodCitiSense

FloodCitiSense low-cost sensor network (15)



Measurement technique: **Accoustic** sensor (intervalometer) records the **arrival rate of rain drop** and converts into volume

Cost: ± **150 €**

Data: recorded every **5 minutes** and sent in real time via **LoRaWAN – The Things Network** (TTN)

Availabity: **variable**

- battery issue “hibernation effect”
- Connection issues with TTN

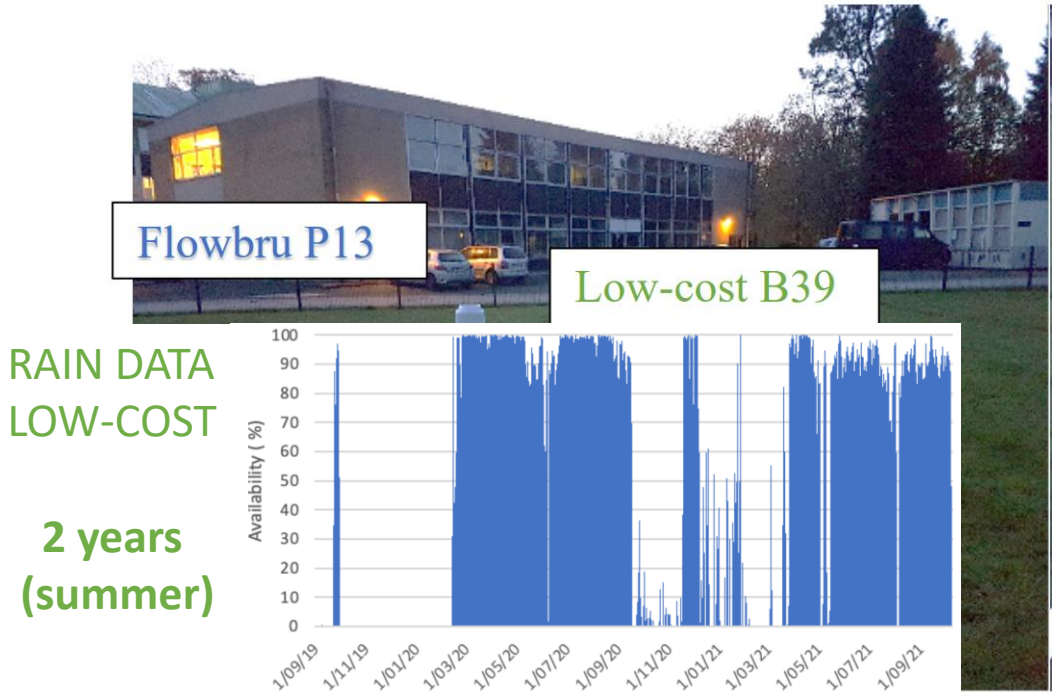
→ Installation own LoRaWAN gateways

RESEARCH (MSc Thesis Julien Lemmens)

“Exploring the added value of low-cost sensors for peak rainfall monitoring in cities (Case study: Brussels)”

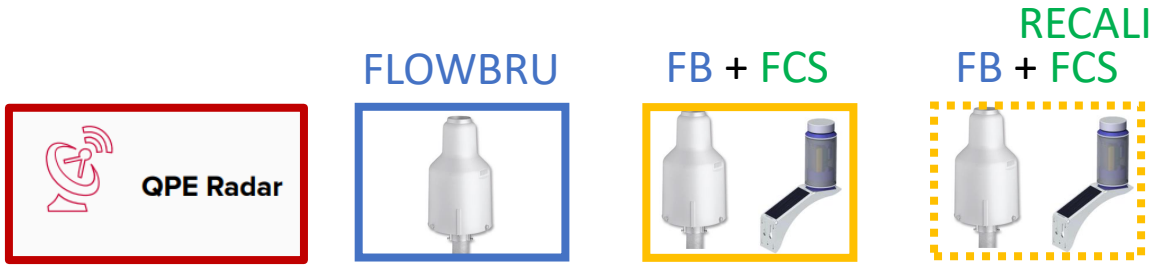
LOCAL COMPARATIVE ANALYSIS

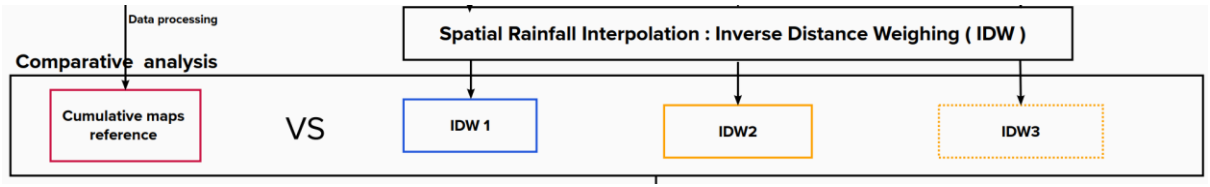
1. **Performance** of **low-cost** during peak rainfall?
2. Does **recalibration** lead to improved results?



SPATIAL DISTRIBUTION ANALYSIS

3. Does low-cost data enhance **rainfall distribution** estimation during heavy precipitation events?
4. Is dynamic multiplier recalibration transferable to other low-cost sensors?



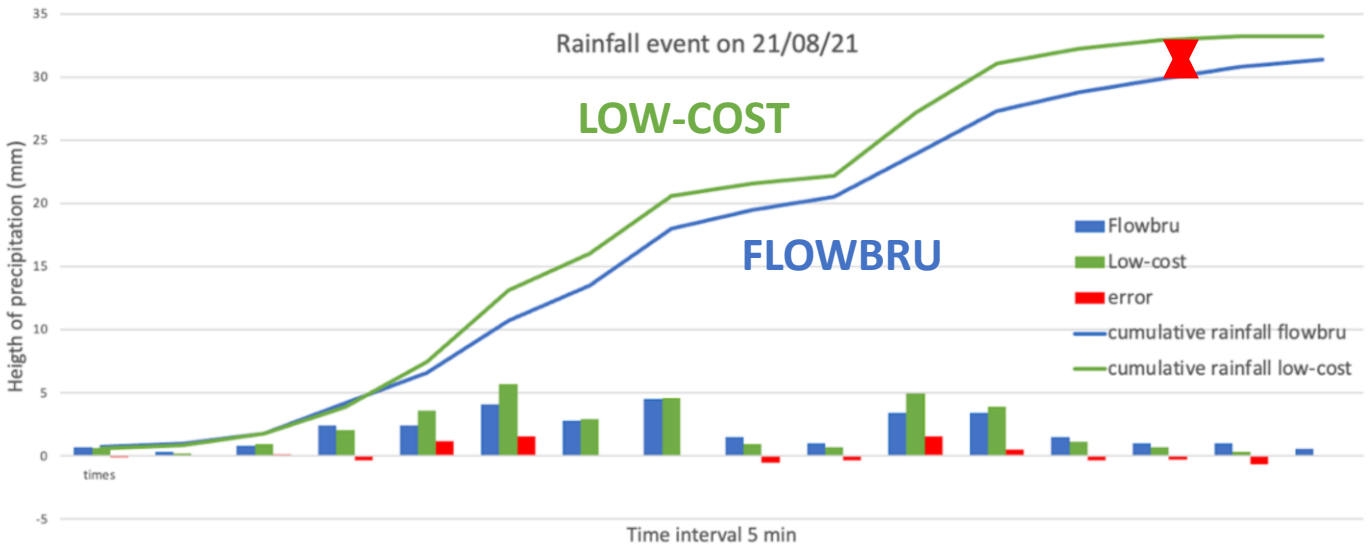


LOCAL STUDY - RESULTS

1. What is the performance of a LCS during peak rainfall events? (7 events with RP > 2 yrs)

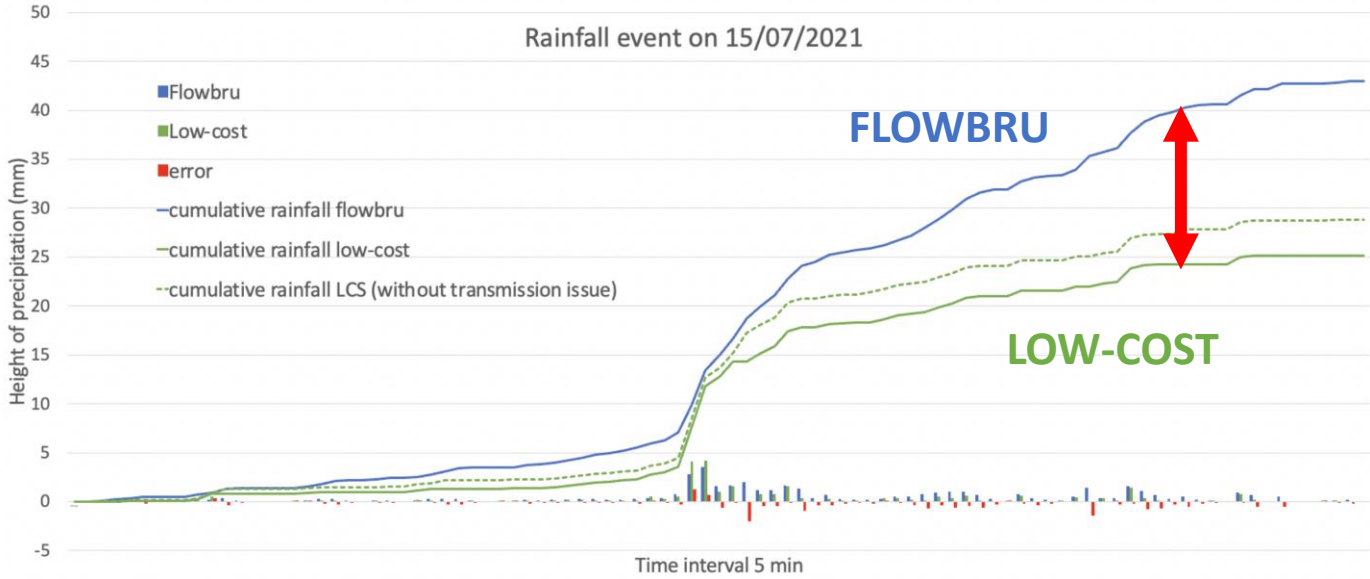
- Short and high-intensity rainfall

→ good accuracy



- Long and moderate-intensity rainfall

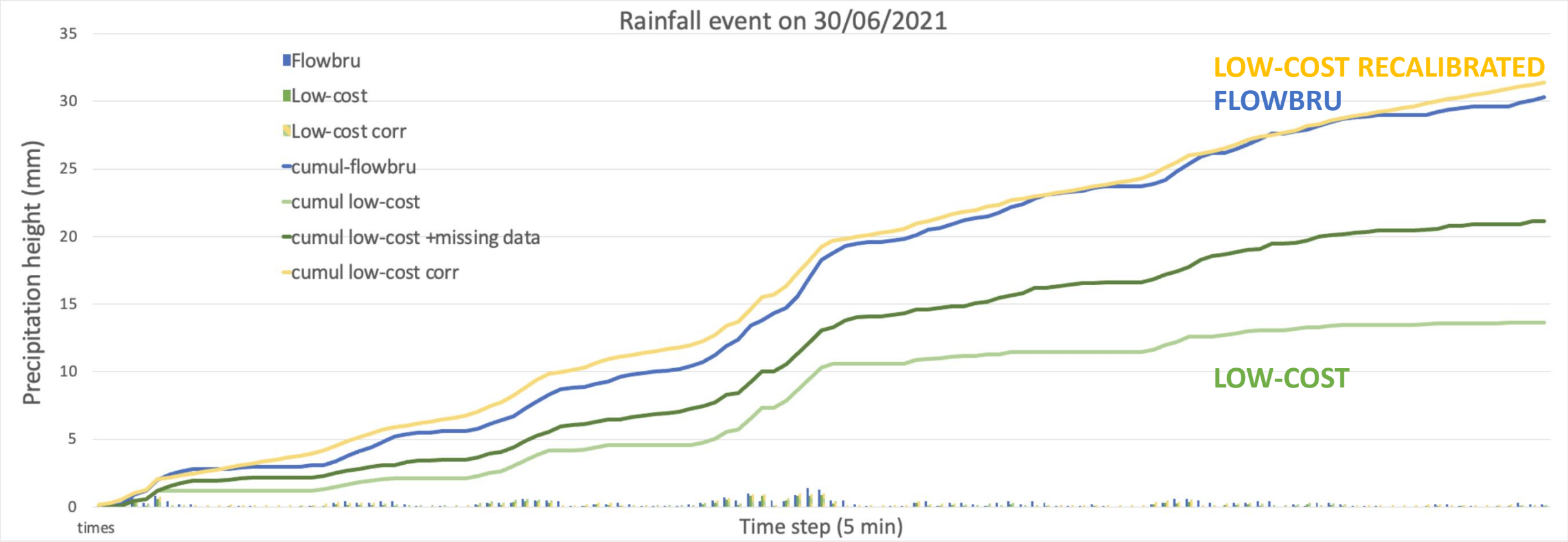
→ clear underestimation



Shortcomings : missing data low intensity & LoRaWAN (4,4% rain)

LOCAL STUDY - RESULTS

2. Does recalibration via the use of a dynamic multiplier improve low-cost monitoring results? (based on 251 data pairs – testing 3 different multipliers)

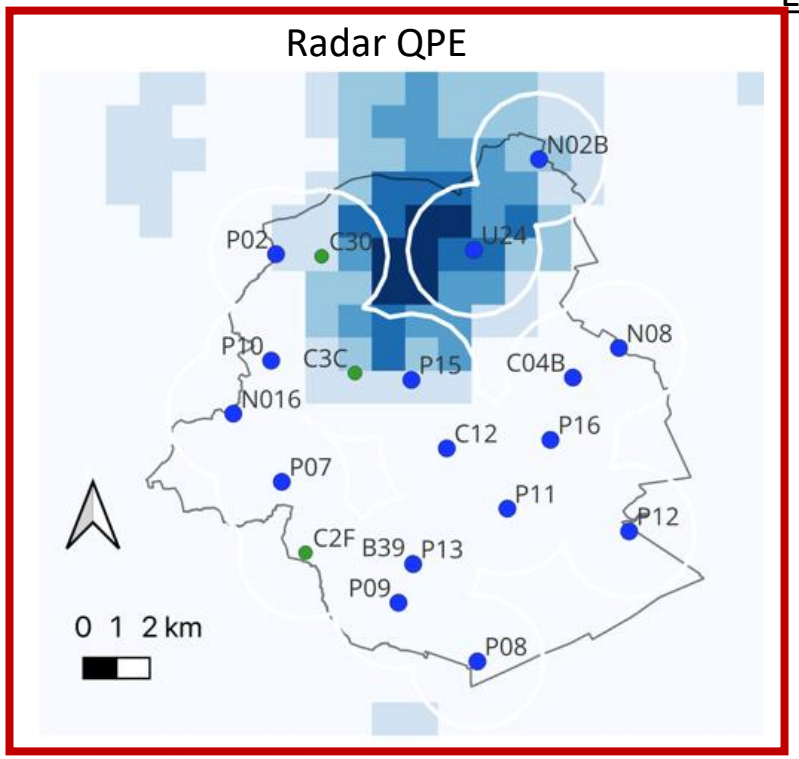


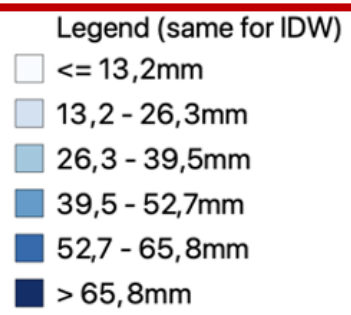
- Long and moderate-intensity rainfall → clear yes Multiplier-Polynomial
- Short and high-intensity rainfall → not significant Multiplier-average

SPATIAL DISTRIBUTION STUDY - RESULTS

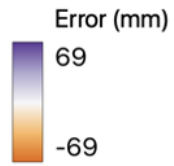
Event 2 of 15/08/20 15h20 ->17h25

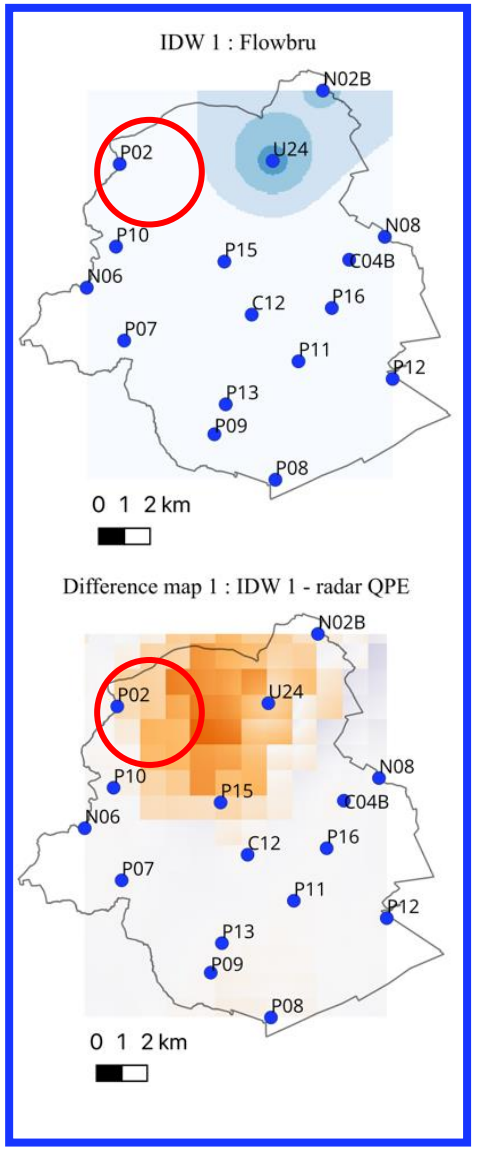
ERROR DECREASES



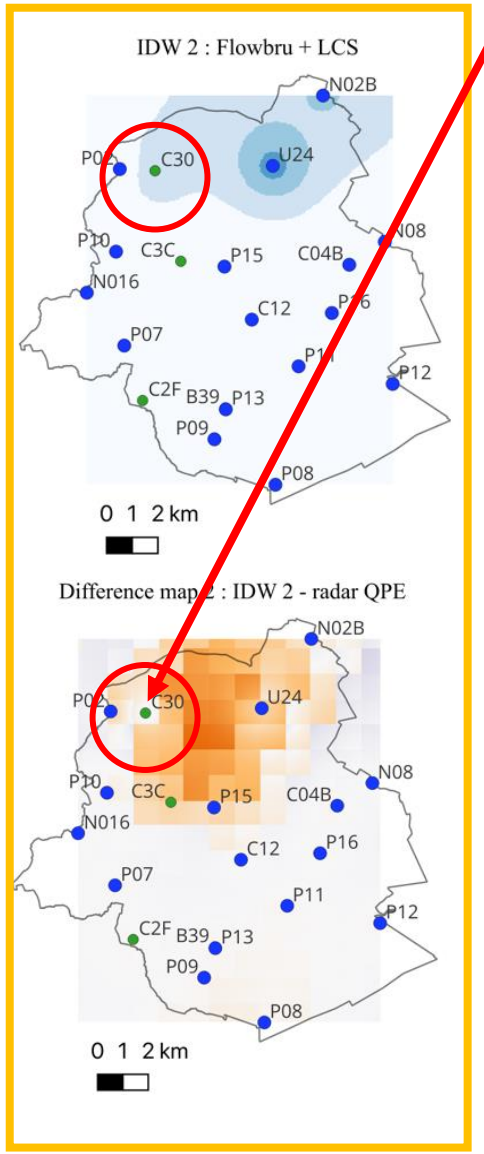


RADAR QPE

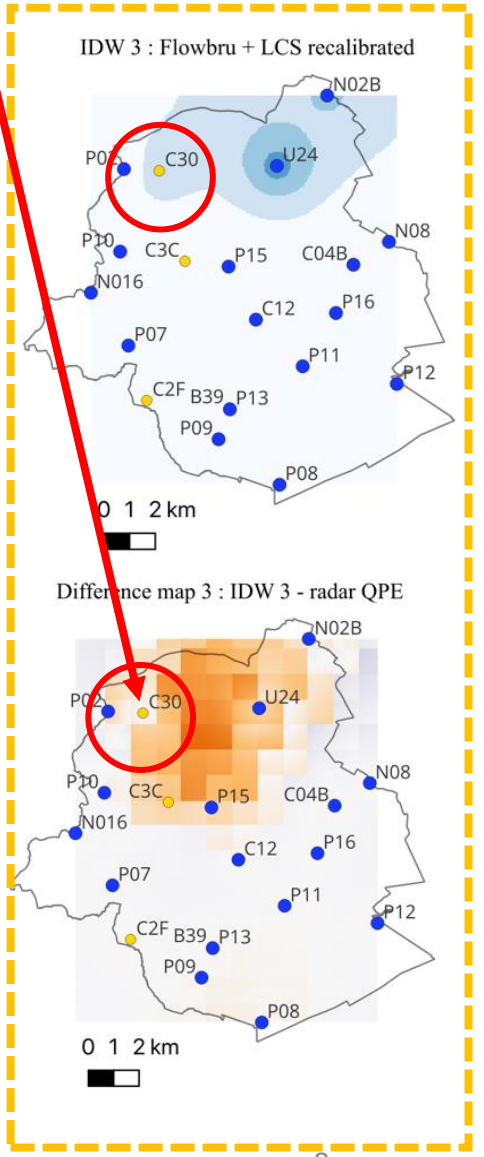




FLOWBRU



FLOWBRU + FCS



FLOWBRU + FCS RECALI

SPATIAL DISTRIBUTION STUDY - RESULTS

Goodness-of-fit statistical analysis

	Rainfall event	Duration (min)	FB RMSE 1 (mm)	FB+LCS RMSE 2 (mm)	Number of LCS	Impact of LCS on FB (RMSE1-RMS2)/RMS1	FB+LCS*M RMSE 3 (mm	Impact recalibrated LCS on FB (RMSE1-RMS3)/RMS1	Type of multiplier	Impact recalibration (RMS2-RMSE3)/RMSE1
1	17/06/20	140	10,17	11,10	5	-9,08%	10,80	-6,15%	M-Poly	2,93%
2	15/08/20	125	15,85	15,16	4	4,37%	15,23	3,88%	M-Average	-0,49%
3	16/08/20	90	4,43	3,72	4	15,90%	3,74	15,42%	M-Average	-0,47%
4	4/06/21	45	11,09	11,45	4	-3,27%	11,09	0,02%	M-Average	3,29%
5	27/06/21	70	3,92	2,79	5	28,84%	2,88	26,48%	M-Average	-2,36%
6	10/07/21	240	3,75	3,05	4	18,72%	3,76	-0,32%	M-Poly	-19,05%
7	15/07/21	850	9,48	8,21	3	13,37%	8,63	8,92%	M-Poly	-4,45%
8	25/07/21	50	4,80	4,87	5	-1,46%	4,83	-0,76%	M-Average	0,70%
9	9/08/21	75	3,18	3,04	4	4,50%	3,05	4,12%	M-Average	-0,38%
10	21/08/21	135	5,07	5,17	4	-1,83%	5,14	-1,40%	M-Poly	0,43%
				Average:	4,2	7,01%		5,02%		-1,98%

3. Does low-cost data enhance rainfall distribution estimation during heavy precipitation events?

Yes -> average error reduction by 7%

Complicated the task → because of the LCS distribution and sample selection of rainfall events

4. Is it feasible to apply the dynamic multiplier technique to other low-cost sensors in order to improve their accuracy?

No, overall the recalibration does not seem to have a positive impact
(limited sample set!)

CONCLUSIONS

Main goal: Exploring the added value of **low-cost sensors (LCS)** for peak rainfall monitoring

Main limitations:
- Amount of LCS available
- Recalibration based on limited rainfall data → desynchronization and missing data
- QPE radar data as reference → may bias the interpretation of results

Main findings:
- LCS **good accuracy** for short and intense rainfall, less for long and medium rainfall
- **Recalibration** can improve the results of LCS, but seems not to be transferable to other sensors
- At the Brussels scale the addition of LCS have a positive impact

Recommandation for operational work:
- Improve the battery and data transmission of LCS → data avaibility
- Improve the sensitivity of LCS for low rainfall → accuracy

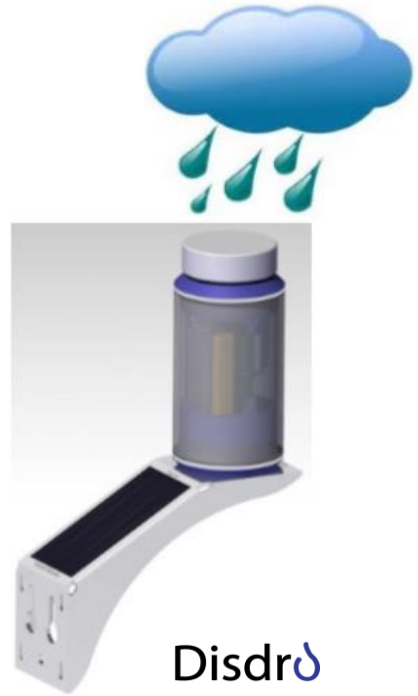
Any question ?

BACKUP SLIDES

Low-cost RAIN sensors

Second generation sensor

- **Acoustic** precipitation gauge
- **Battery** alimented by efficient solar panel
- Data transmission via **LoRa** technology

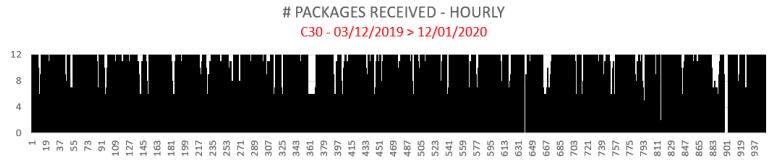


Low-cost rain sensor
Disdrometrics

Sensors components provided by Disdrometrics and assembled during **Citizen Science workshops** in Brussels, Rotterdam and Birmingham (# 50 participants)

Open data via our **Web** **and** **Mobile App**

Challenges low-cost sensors

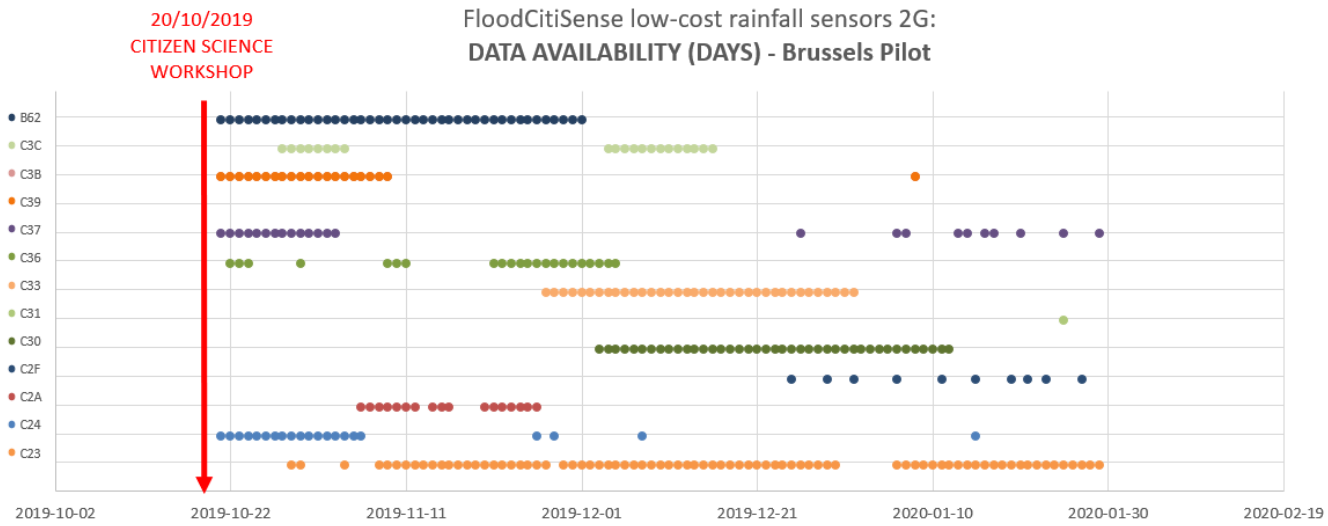


LoRa > using [Global Open LoRaWAN network](#)

- Theoretical ranges of gateway and sensors are much lower in urban context
- Problems: no connection, unstable connection = loss of packages, etc.
- Solution: Extra OWN gateways installed!
- Result > important **data gaps!**

Batteries

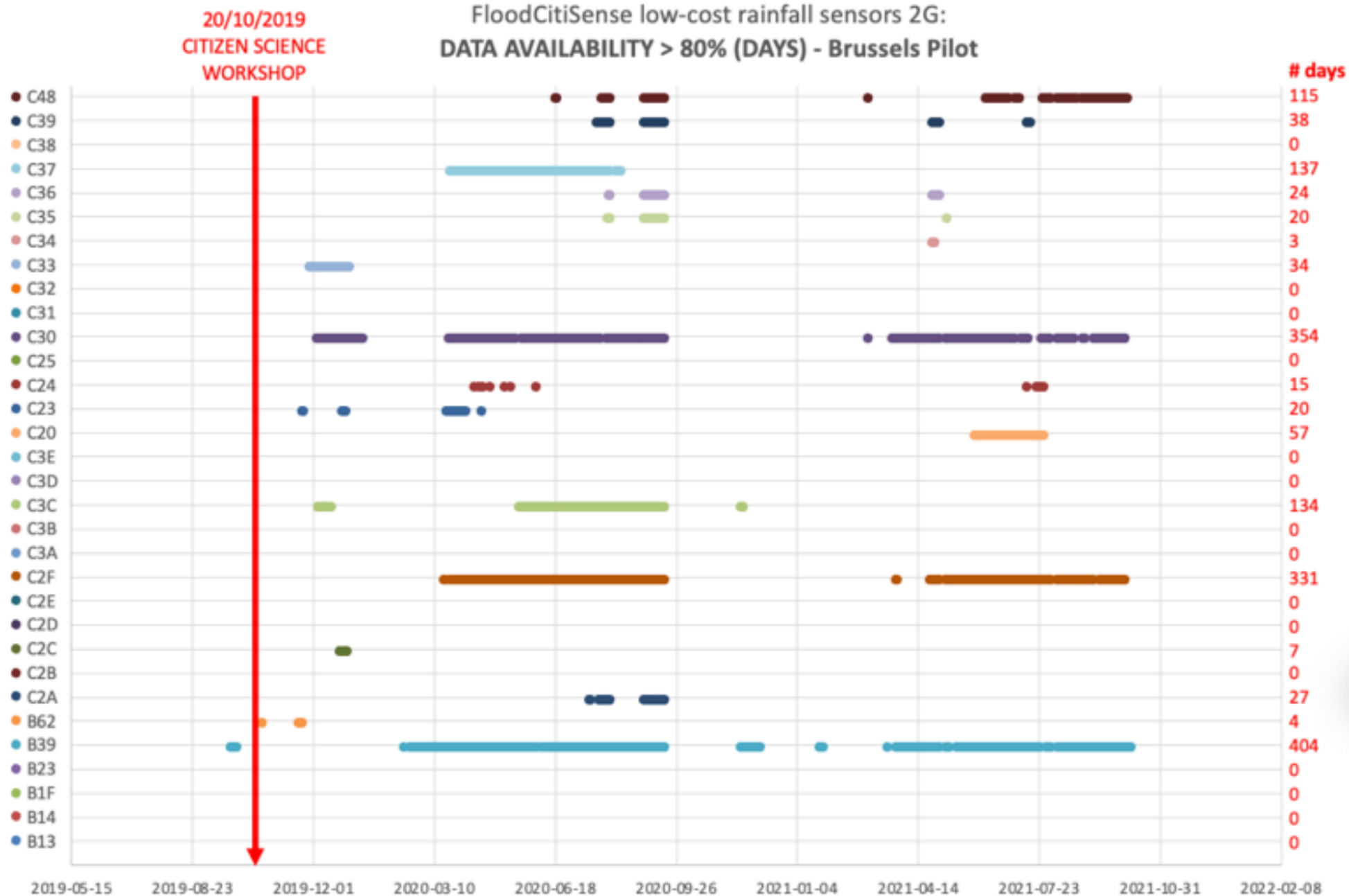
- Major challenge during winter (low sun)
- Many sensors lost connection
- Revival of some sensors (7) in spring ☺



Absolute values of rainfall intensities

- Comparison with high-accuracy Flowbru sensors shows considerable differences in measured rainfall
- Working on recalibration of conversion rate (*Disdrometrics*)

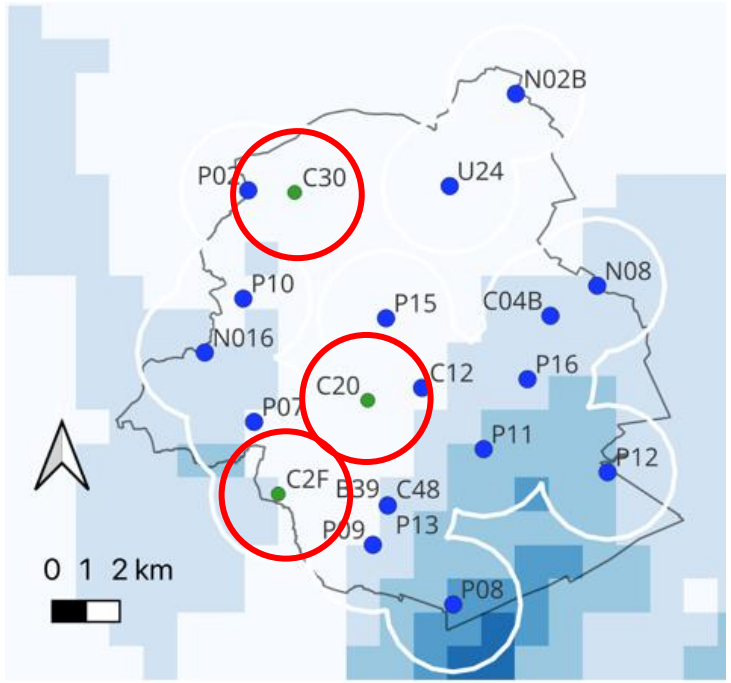
Table 4.2 : Data availability of all LCS



5.2 SPATIAL DISTRIBUTION STUDY - RESULTS

Event 5 of 27/06/21 19h20 ->20h50

Radar QPE



Legend (same for IDW)

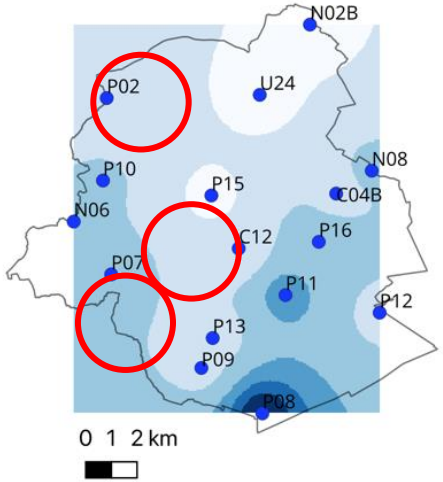
- <= 4,25 mm
- 4,25 - 8,50 mm
- 8,50 - 12,75 mm
- 12,75 - 17,00 mm
- 17,00 - 21,25 mm
- > 21,25 mm

Error (mm)

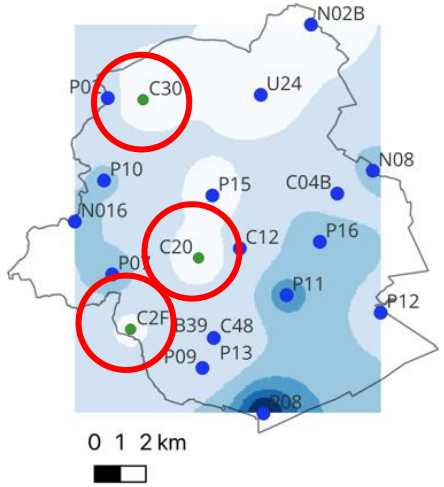
14

-14

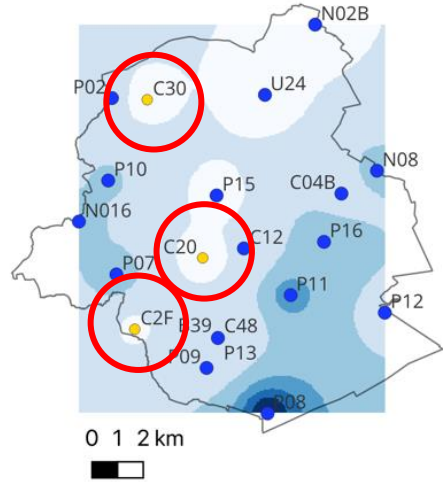
IDW 1 : Flowbru



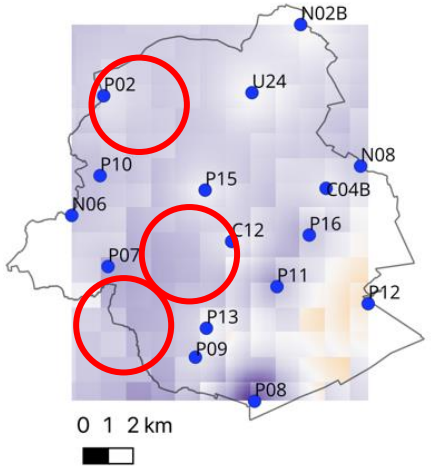
IDW 2 : Flowbru + LCS



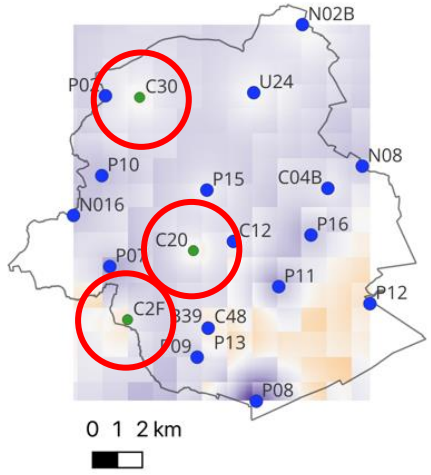
IDW 3 : Flowbru + LCS recalibrated



Difference map 1 : IDW 1 - radar QPE



Difference map 2 : IDW 2 - radar QPE



Difference map 3 : IDW 3 - radar QPE