Real-time operation of urban drainage models

RainGain workshop on
ON URBAN PLUVIAL FLOOD MODELLING
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Real-time operation of urban drainage models

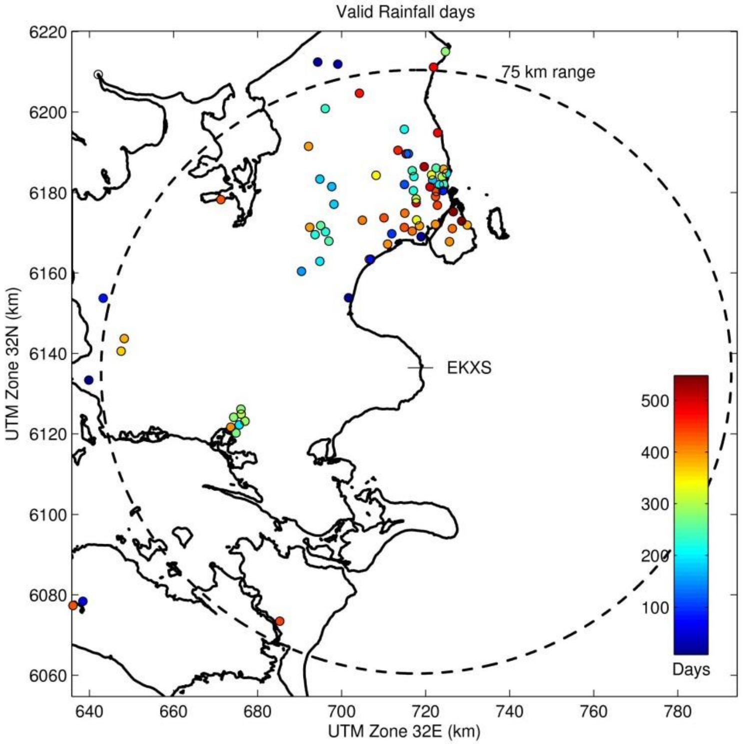
Title in programme: Real-time calibration of urban drainage models

Outline:

- Calibration of radar data
- Real time calibration of radar data
- Radar rainfall Nowcasting
- Real time calibration of drainage models
- Example: Real-time urban flood modelling with nowcasted radar rainfall data

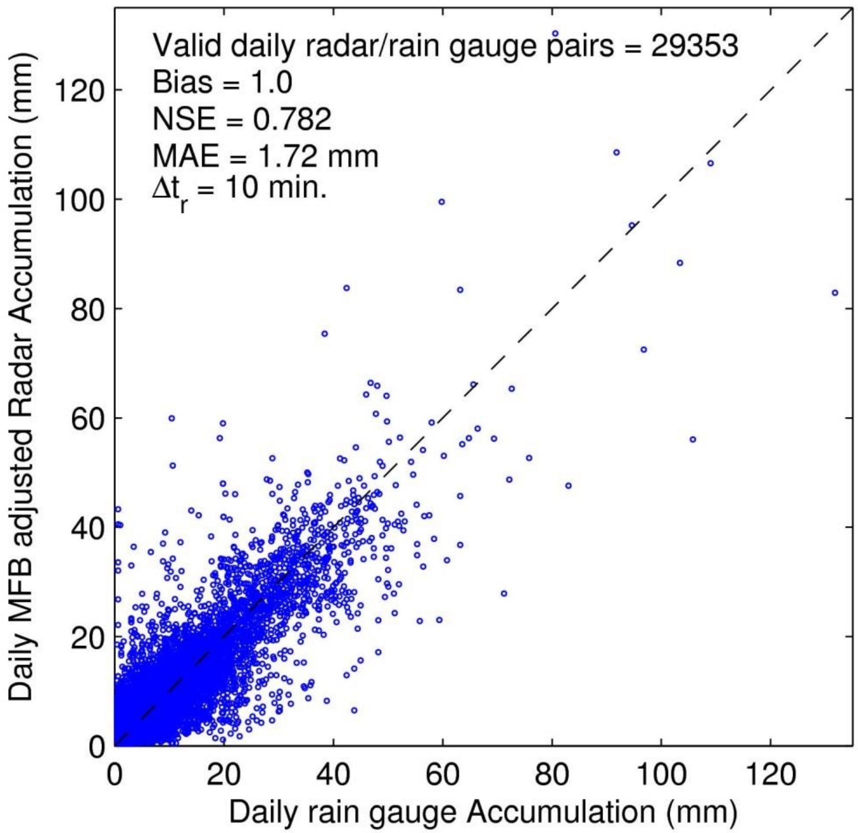
Mean Field Bias adjustment (on historical data)

- 10 years of radar observations (2002-2012) from DMI C-band radar at Stevns (EKXS).
- DMI pseudo-CAPPI product
  resolution: 500 x 500 m^2, 10 min.
- 49-79 rain gauges within the 75 km range
  resolution: 0.2 mm, 1 min.
- Fixed Z-R-relationship
- Posterior Mean field bias adjustment



Thorndahl, S., Nielsen, J.E., Rasmussen M.R. (2014) *Bias adjustment and advection interpolation of long-term high resolution radar rainfall series,* **Journal of Hydrology,** Volume 508, 214-226.

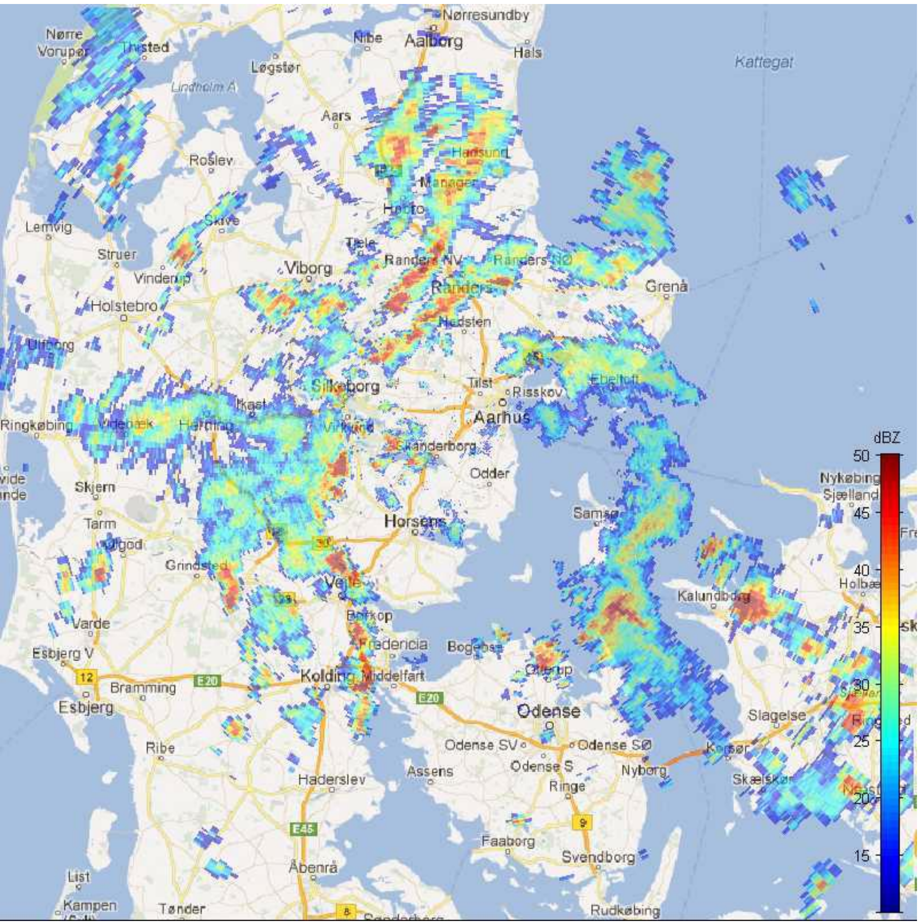
Daily Mean Field bias adjustment



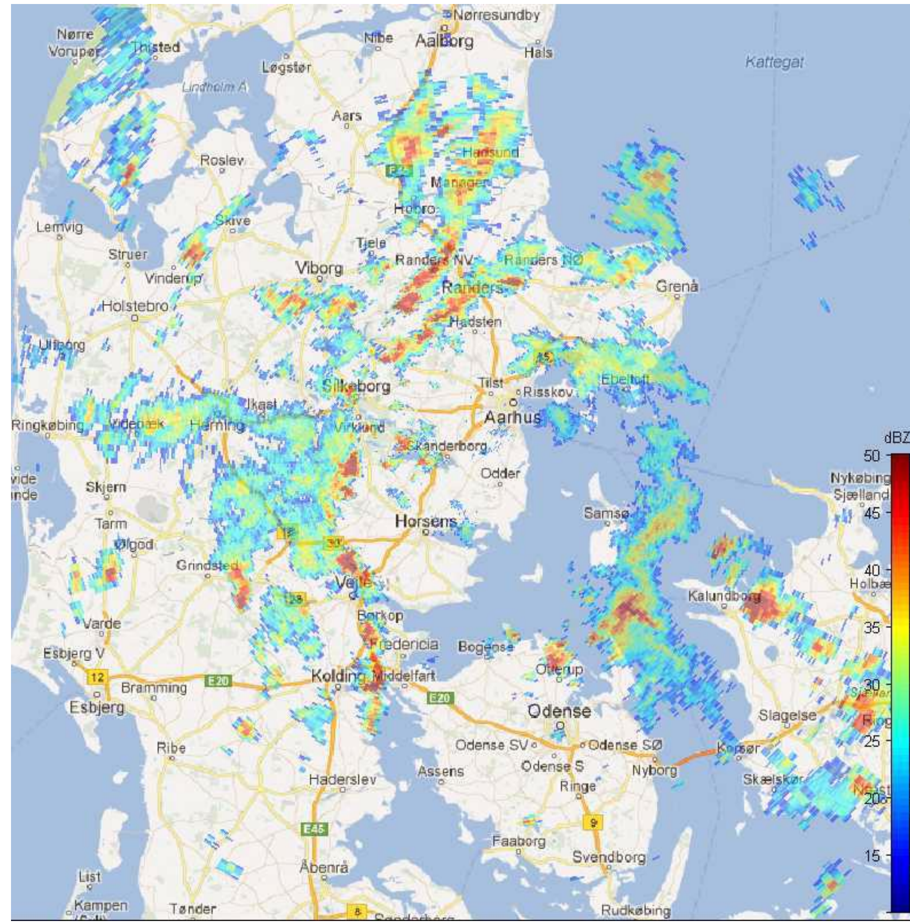
- **MFB = G/R**
- Larger mean field biases during summer time (convective events).
- Larger bias variability during summer periods indicating large shifts in biases from day to day.

Advection interpolation

Nielsen, J.E., Thorndahl, S., Rasmussen, M.R., (2014) *A numerical method to generate high temporal resolution precipitation time series by combining weather radar measurements with a nowcast model*, **Atmospheric Research** 138,

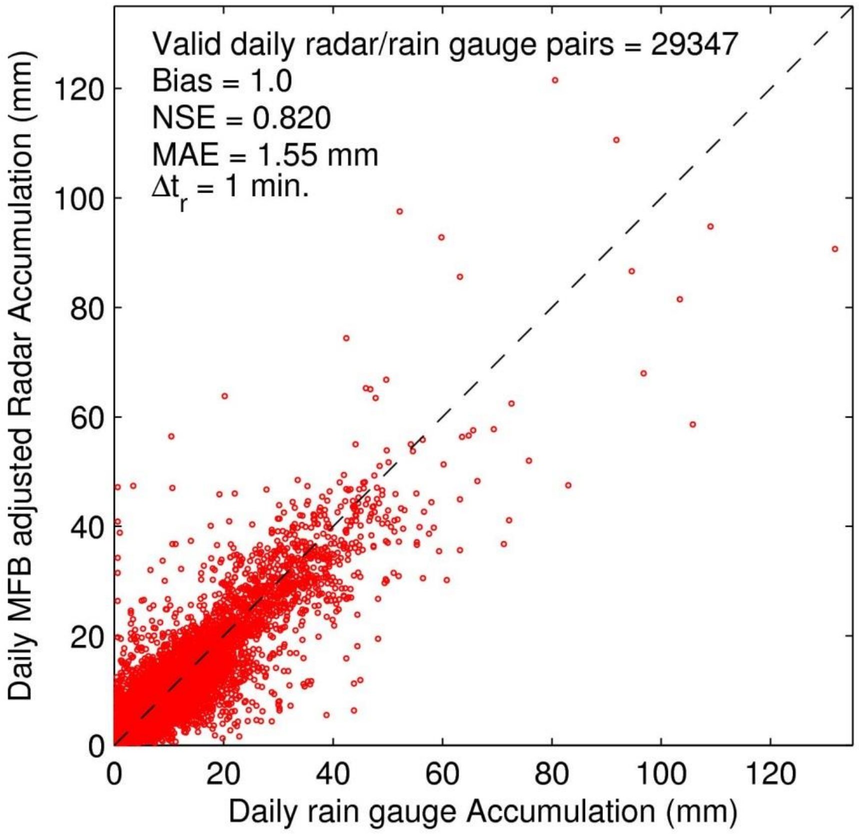


No interpolation Δt=10 min



Advection interpolation Δt=1 min

Advection interpolation



- Reduction of uncertainty (higher NSE and lower MAE) implementing advection interpolation.
- The improvement is even more significant on smaller time scales, e.g. hourly.

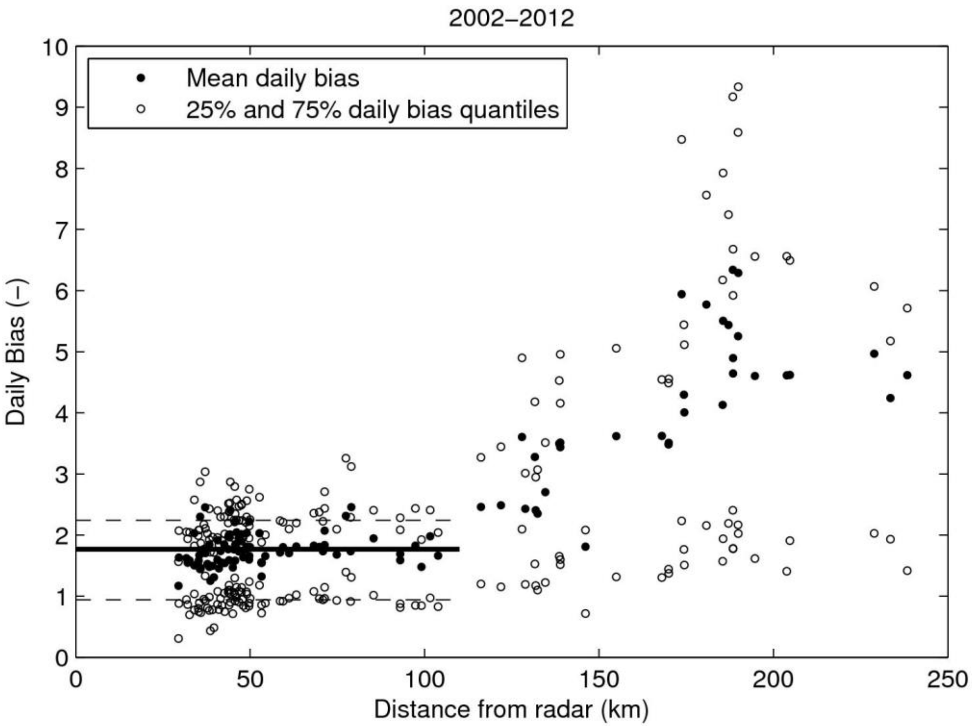
Why Mean Field Bias Adjustment?

- Single radar adjustment

- Homogeneous terrain topology thus limited orographic rainfall effects in Denmark

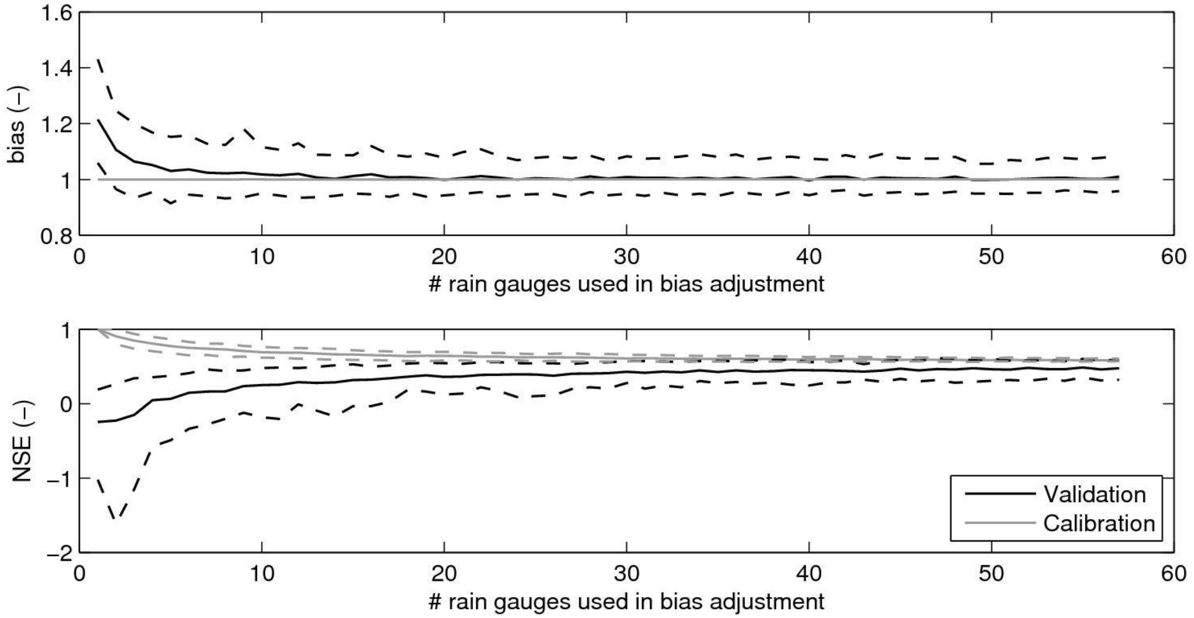
- Limited bias variability within the 75 km range of the radar

- Bias adjustment is crucial!



The number of rain gauges needed to adjust a single radar

- Hourly adjustment of advection interpolated data
- Random selection of 10 validation gauges from a pool of 67 gauges
- Calibration on a random selection of 1 to 57 gauges
- Recommendation: Minimum 10 rain gauges are required for MFB adjustment



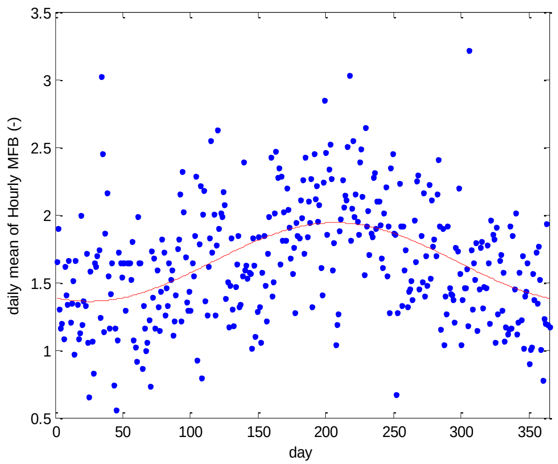
Real-time Continuous Mean Field Bias adjustment

- **Fixed volume** (adjustment based on a mean of the previous x mm rain gauge accumulations)

- **Fixed time** (adjustment based on a period of time, e.g. 24 h)

- Criteria for initializing adjustment:
  - > 1mm in 4 gauges or more
  - Mean of gauge accumulations: > 5 mm (fixed vol)
  - Min and max. MFB factor (based on 10 year dataset)

- If criteria are not kept mean season-depended bias is applied



Thorndahl, S., Nielsen, J.E., Rasmussen, M.R. *Real-time mean field bias adjustment and advection interpolation of high spatiotemporal resolution radar rainfall* (In Prep.)

Real-time Continuous Mean Field Bias adjustment

Problems with real-time mean field bias adjustment

- Different types of rain (stratiform/convective) within an event.
- Adjustment in the beginning of the events.
- Few gauges with observed rainfall (especially a problem during convective events)
- Rapid shifts in MFB (can reduced using a temporal Kalman-filter approach)

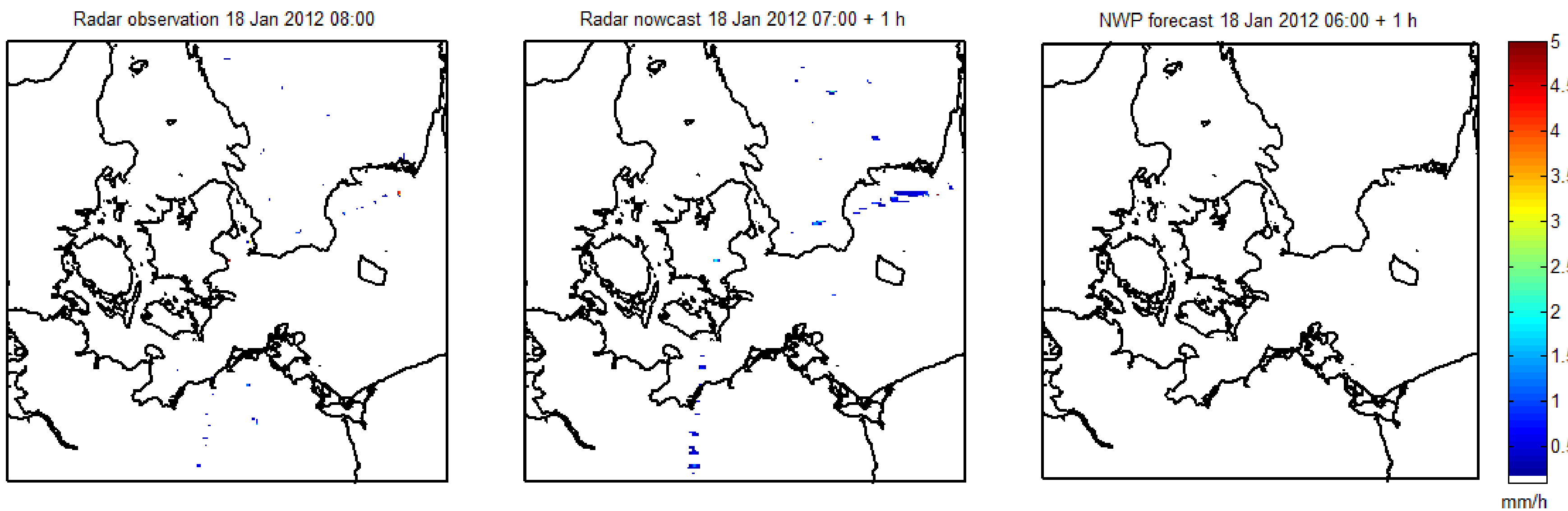
Recommendation:

- Install lots of rain gauges – and not just within the catchment of interest.

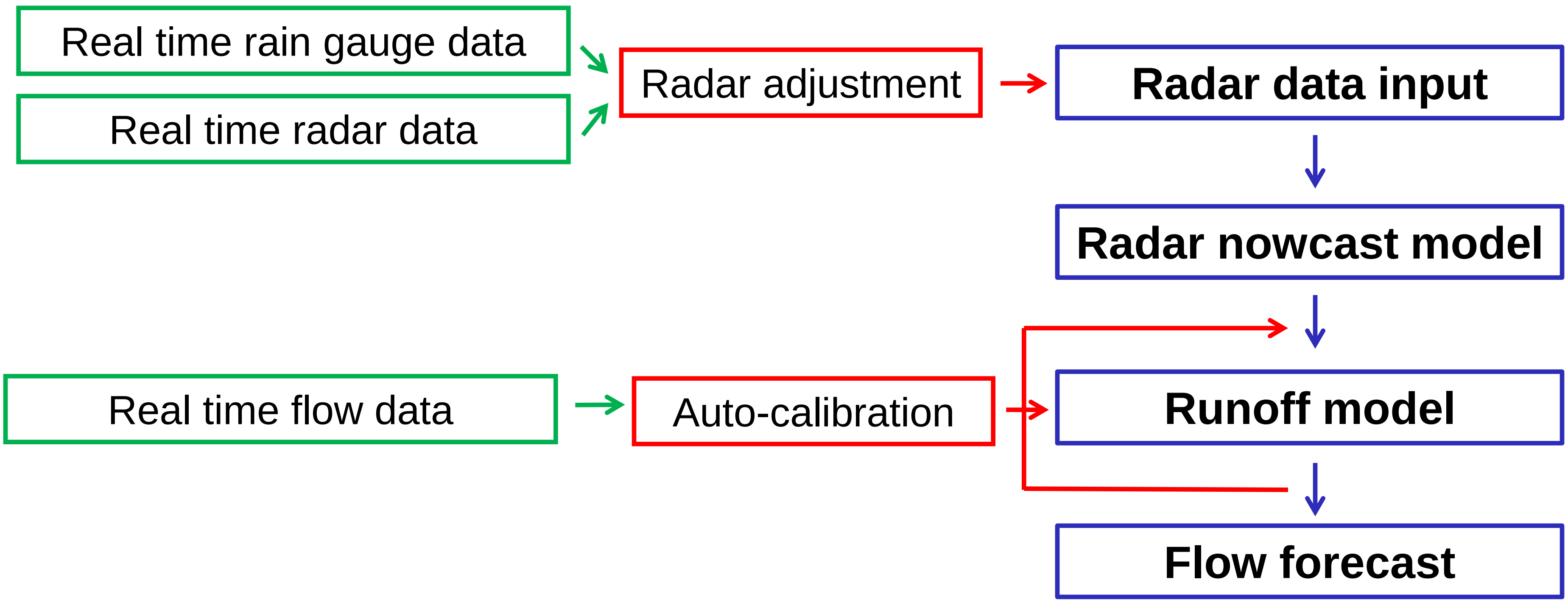
Nowcaster - Radar rainfall extrapolation

Radar nowcast model based on CO-TREC

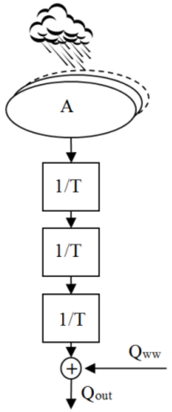
- Single radar
- Correlation based estimation of movement vectors
- Extrapolation of vector field
- Leadtime of 0 to 2 hours
- Simulation every 10 min.



Real-time calibration of urban drainage models



Types of models

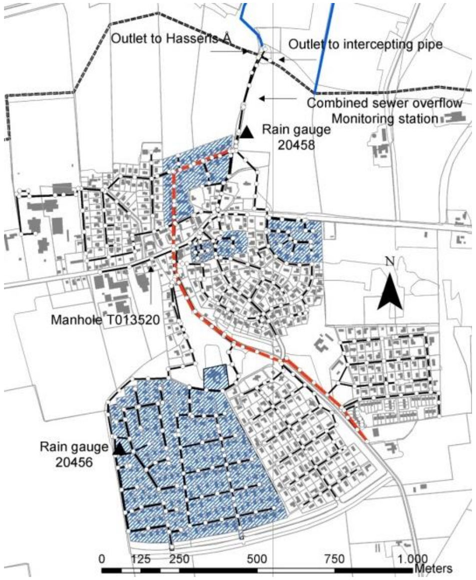


Lumped models

- e.g. time-area, linear reservoir
- Forecast of flow/water level in a single (or few points) of the drainage system e.g. inlet to WWTP
- Short computation time
- Few parameters

Distributed model

- e.g. MOUSE, Mike Urban
- Forecast of flow/water levels everywhere in the drainage system
- Long computation time
- Several parameters
- More difficult to calibrate in real-time (especially if more than one observation)



Auto-calibration of urban drainage models

- The concept is to obtain the best possible model fit of the observed flow at the current time step before initiation of the flow forecast.

Calibration data

- Flow, water level, overflow registration

Optimization method

- Quasi-Newton optimization for non-linear systems

Optimization criteria

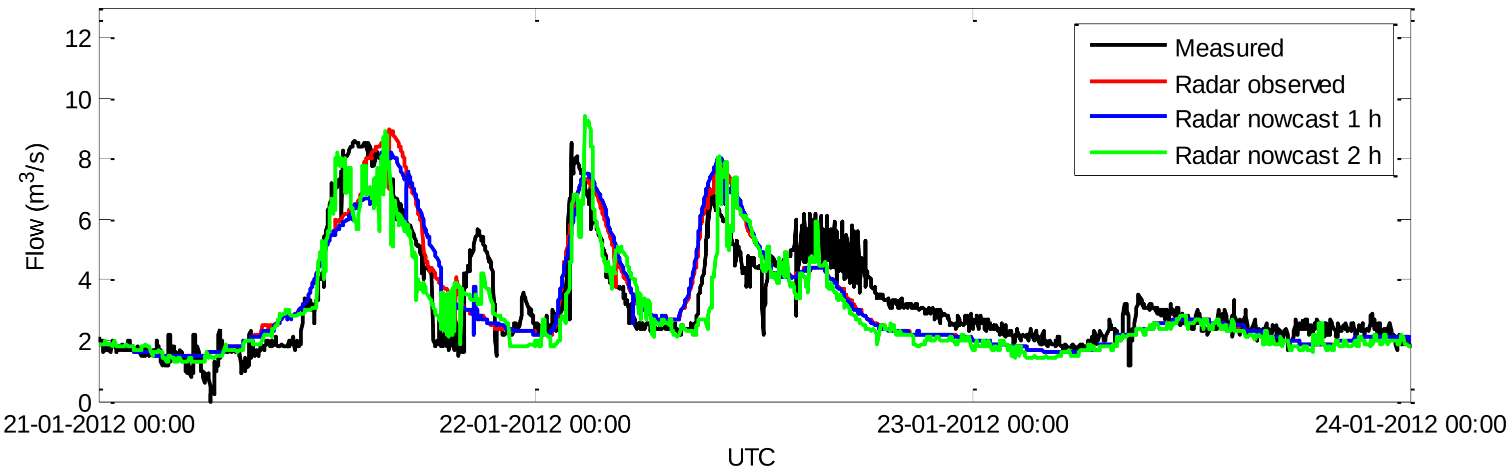
- min(f)

$$f = 1 - \exp\left(\frac{-\frac{1}{N}\sum_{j=1}^{N}\left((M_i - O_i) - \overline{(M_i - O_i)}\right)^2}{\frac{1}{N}\sum_{i=1}^{N}\left(O_i - \overline{O}\right)^2} \right)$$

Few parameters → few iterations → easy optimization
(Keep it simple)

Example – lumped drainage model

Purpose: to forecast inlet flow to Lynetten Waste Water Treatment Plant



System runoff time: 0 – 2 h

- Optimization parameters:
  - Contributing Area (A),
  - Time constant (T),
  - Dry weather flow (Q_{ww})

Thorndahl, S., Poulsen, T. S., Bøvith, T., Borup, M., Ahm, M., Nielsen, J. E., Grum, M., Rasmussen, M. R., Gill, R., Mikkelsen, P. S. (2013) *Comparison of short term rainfall forecasts for model based flow prediction in urban drainage systems.* **Water Science and Technology** 68(2)

Example – Fully distributed drainage model

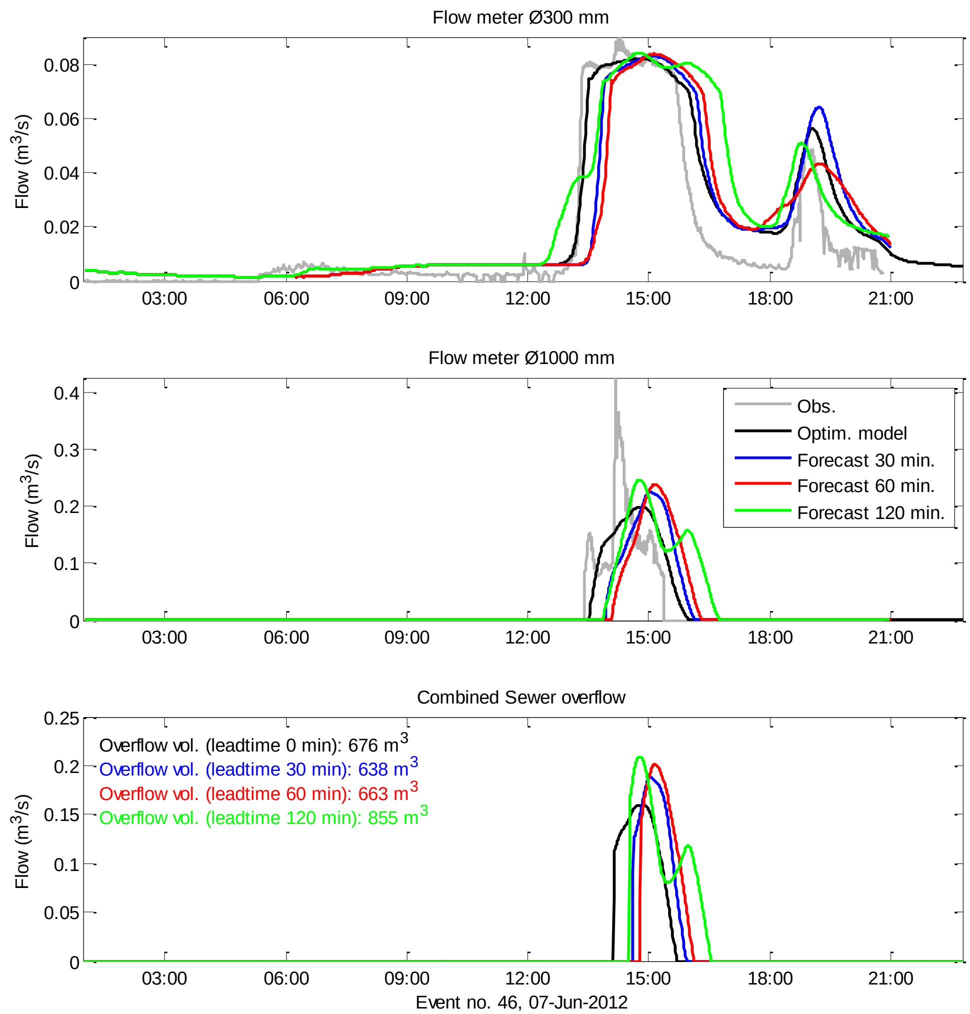
Combined sewer system of Frejlev

Purpose: to forecast system capacity and combined sewer overflow

System runoff time: 0 – 30 min

- Optimization parameters:
  - Contributing Area (A),
  - Surface conc. time (t_c),
  - Dry weather flow (Q_{ww})

Thorndahl, S., Rasmussen, M. R. (2013). *Short-Term Forecasting of Urban Storm Water Runoff in Real-Time using Extrapolated Radar Rainfall Data.* **Journal of Hydroinformatics** 15 (3)



Real-time urban flood modelling with nowcasted radar rainfall data

- System is currently running in real time (but unfortunately no flooding has occurred since we started ☺)

- Presentation of a historical event: **6 Aug 2012**

- Case: Center of Aalborg

Real-time urban flood modelling with nowcasted radar rainfall data

Setup – Flood model:

- Digital elevation model:
  Horisontal resolution: 1.6 m
  Vertical resolution: 0.01 m

- Model: Mike Urban (drainage system) + Mike 21 (2D flood), DHI

- Manholes: 600

- Area: 4.2 km^2

- Flood model resolution: 1.6 x 1.6 m^2

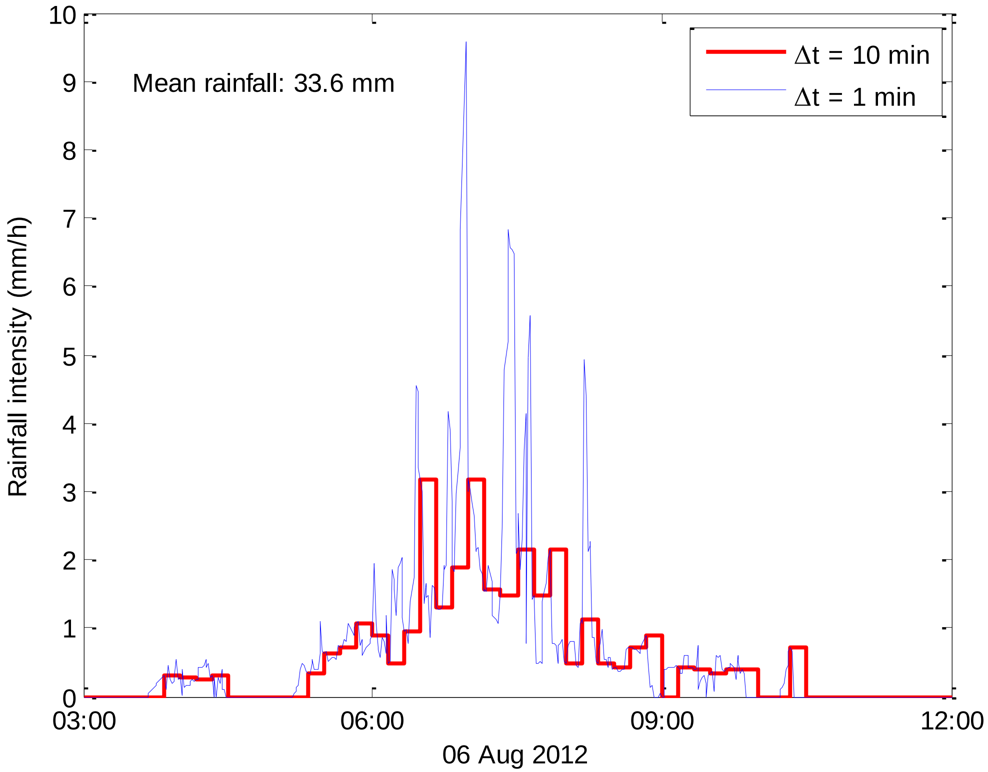
- Number of grid cells: 1500 x 1100

-Computation time: ~0.2-0.3 x real-time (on a standard desktop pc)

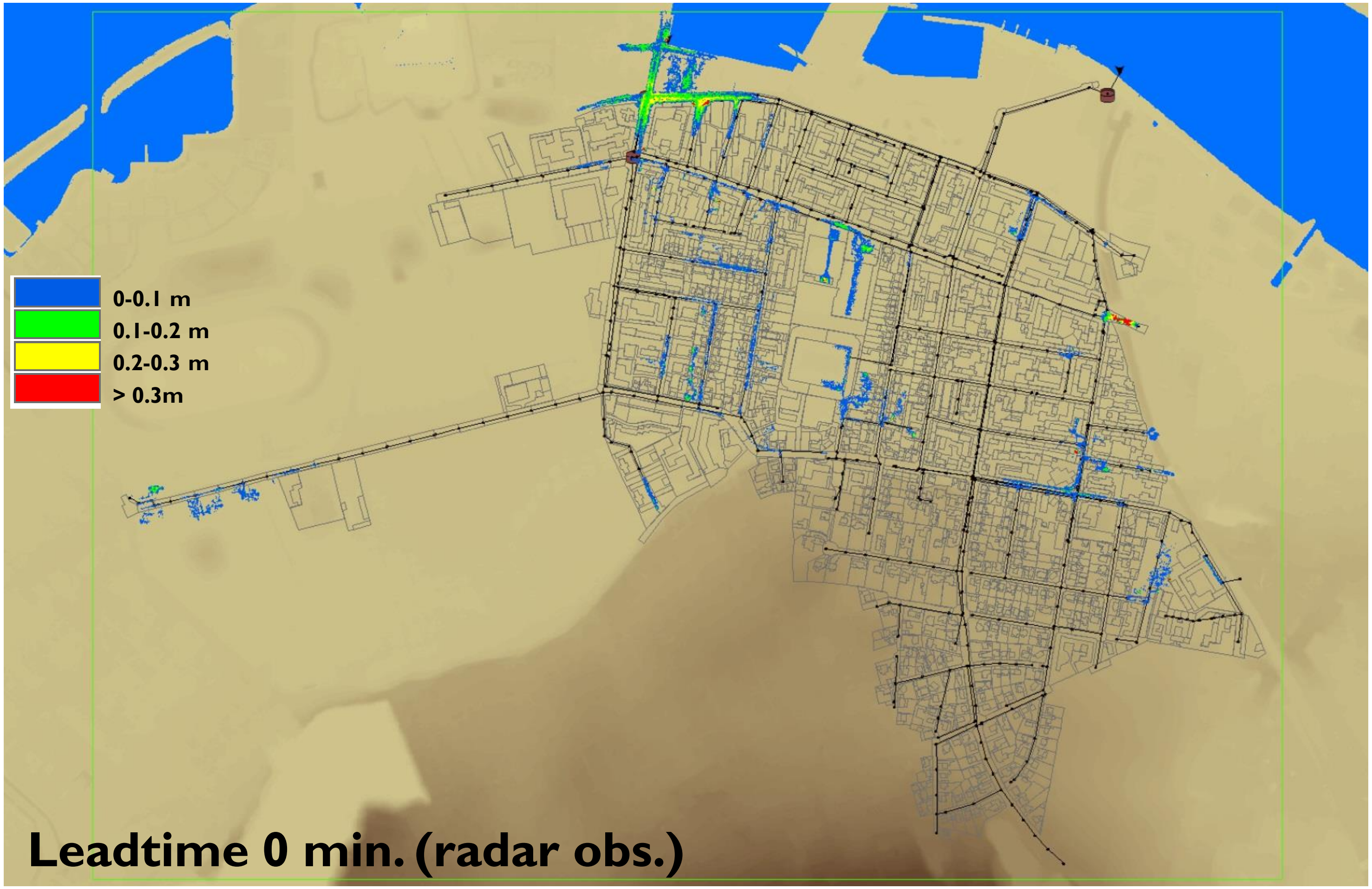
Real-time urban flood modelling with nowcasted radar rainfall data

Setup – radar rainfall input:

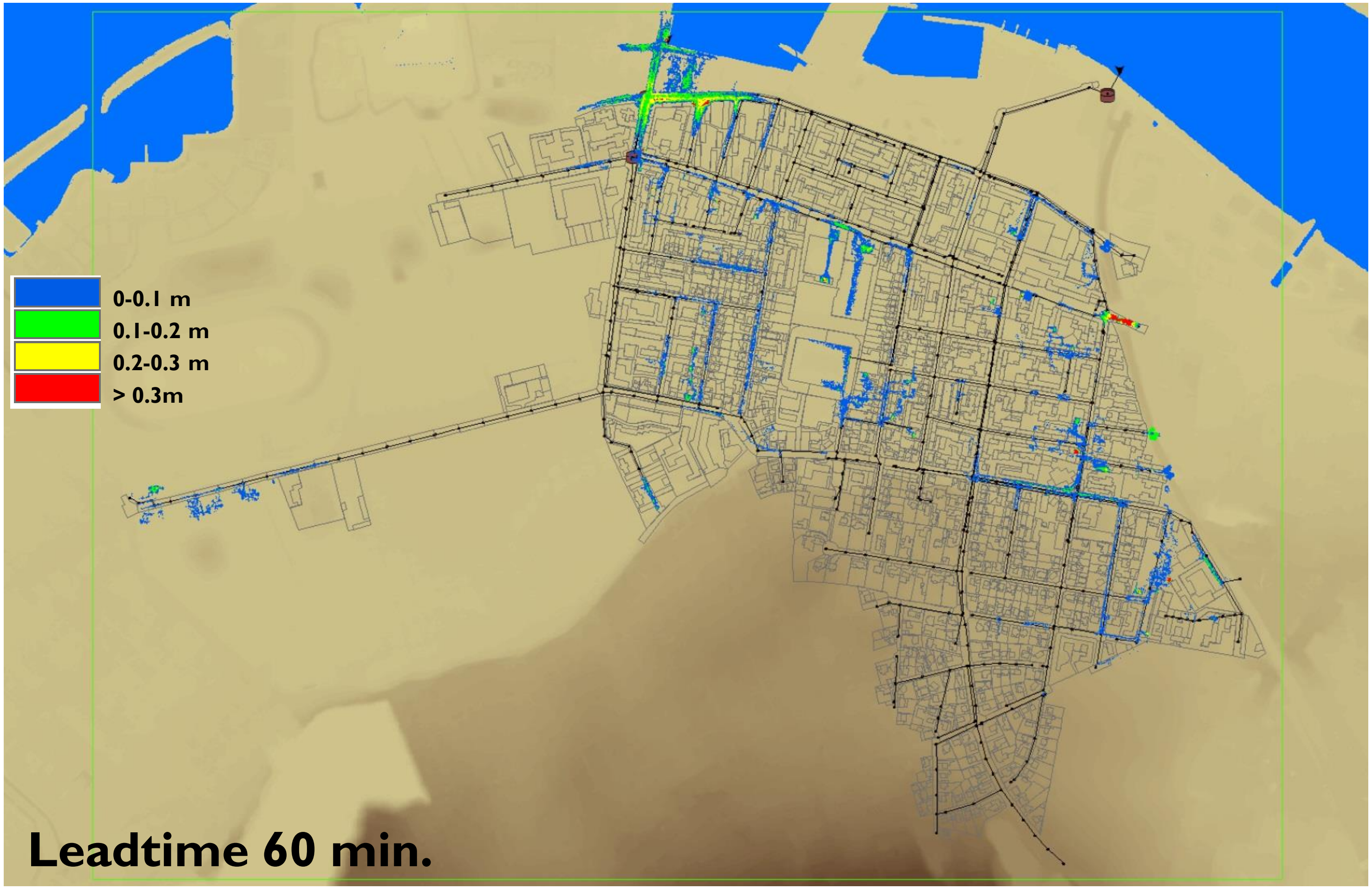
- Adjusted in "real-time" with 9 rain gauges (fixed time: 24 h)
- Advection interpolation is applied
- Nowcast with leadtimes: 30, 60, 90 and 120 min



No real-time calibration of the model


0-0.1 m
0.1-0.2 m
0.2-0.3 m
> 0.3m
Leadtime 0 min. (radar obs.)


0-0.1 m
0.1-0.2 m
0.2-0.3 m
> 0.3m
Leadtime 30 min.

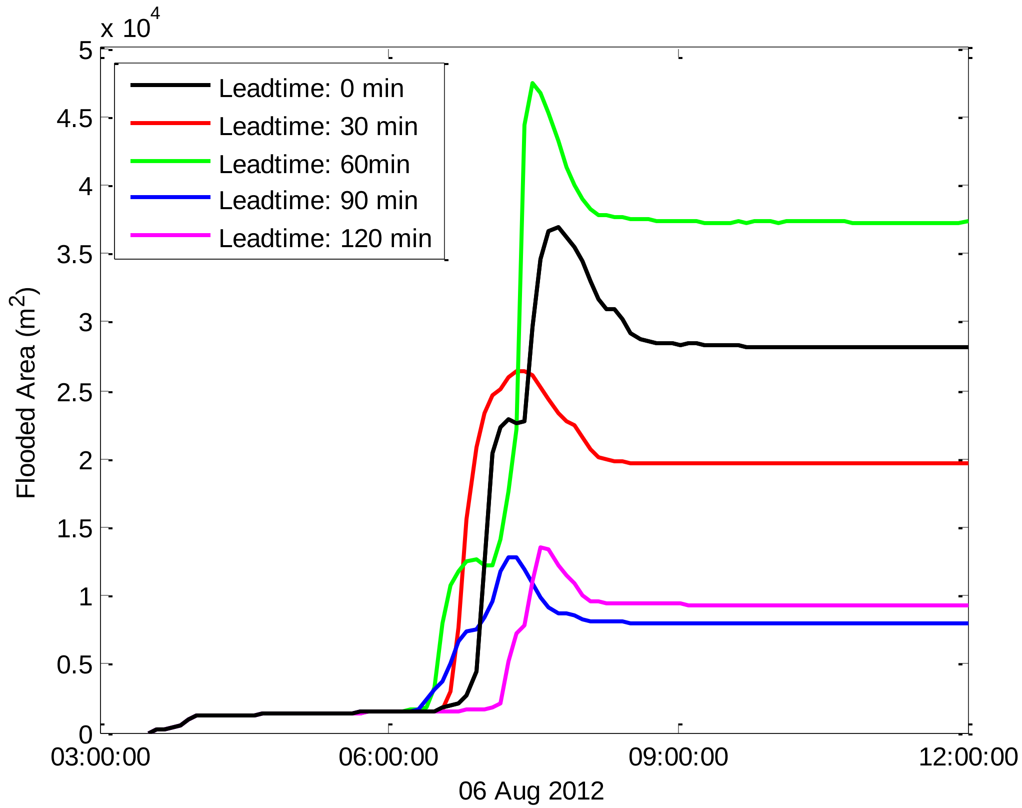

0-0.1 m
0.1-0.2 m
0.2-0.3 m
> 0.3m
Leadtime 60 min.


0-0.1 m
0.1-0.2 m
0.2-0.3 m
> 0.3m
Leadtime 90 min.


0-0.1 m
0.1-0.2 m
0.2-0.3 m
> 0.3m
Leadtime 120 min.

Real-time urban flood modelling with nowcasted radar rainfall data

- Some divergence between flood levels for different leadtimes
- Timing seems to be okay
- Convective thunderstorm (usually difficult to extrapolate from radar data)
- Flood occur within 30-45 min from it starts to rain!
- **Can we calibrate these types of events?**



My personal recommendations for forecasting urban pluvial floods

- Calibrate/validate drainage/flood model on historical data (if possible)
- Calibrate radar in real-time with rain gauges (if possible)
- It might not be worth trying to calibrate the drainage/flood model in real-time.
- Use both radar nowcasts and NWP forecasts (if possible).
- Cross your fingers that your model can predict the next flood!

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