Five years of microwave link derived rainfall research in Sweden

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Commercial microwave link networks

SMHI

Sweden

- ~ 20.000 microwave links (PTS)
- Ongoing measurements:
  - ~400 + 500 + 100 MWLs in the Gothenborg, Stockholm & Malmö regions.
  - Temporal resolution at 10 seconds and aggregated to 1 minute.
  - Spatial resolution depends on region, but for these cities currently at 500x500m

Characteristics

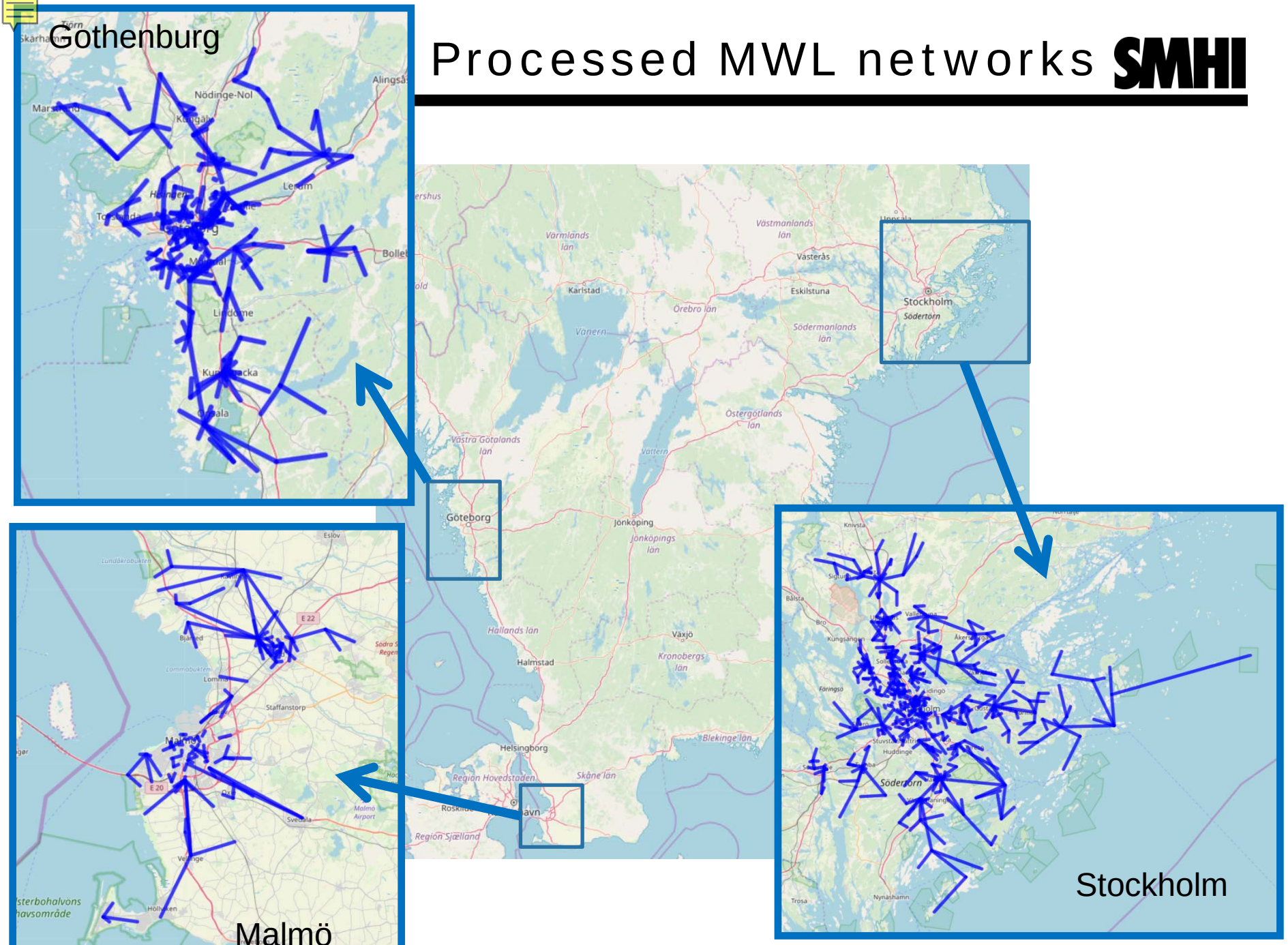
- Good coverage (especially in cities)
- Very high temporal resolution
- Measurements near the ground
- Lower accuracy than rain gauges

Terminology

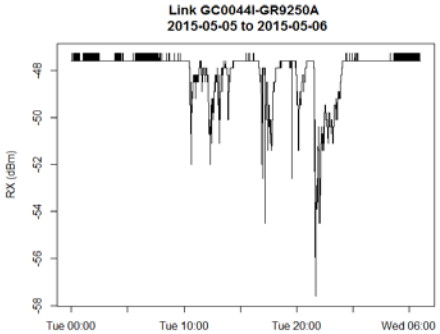
- Node = geographic location of mast with microwave link(s)
- Hop = geographic connection between two nodes
- Link = microwave link along hop
- Sub-link = one signal at link location

Special thanks to Håkan Andersson & Hi3G Sweden AB for providing the microwave link data

Processed MWL networks SMHI



Algorithm to derive rainfall for SMHI operational applications



Signal strenth (*RX,TX*)

Time averaging

Attenuation (A_{ml})

Filter dubious data

Wet/dry classification

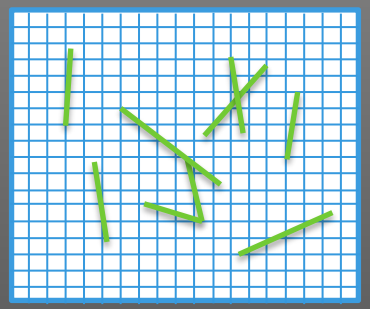
Baseline for wet timesteps

Attenuation → rainfall intensity ITU-R, f(freq, pol, len)

Quality enhancement

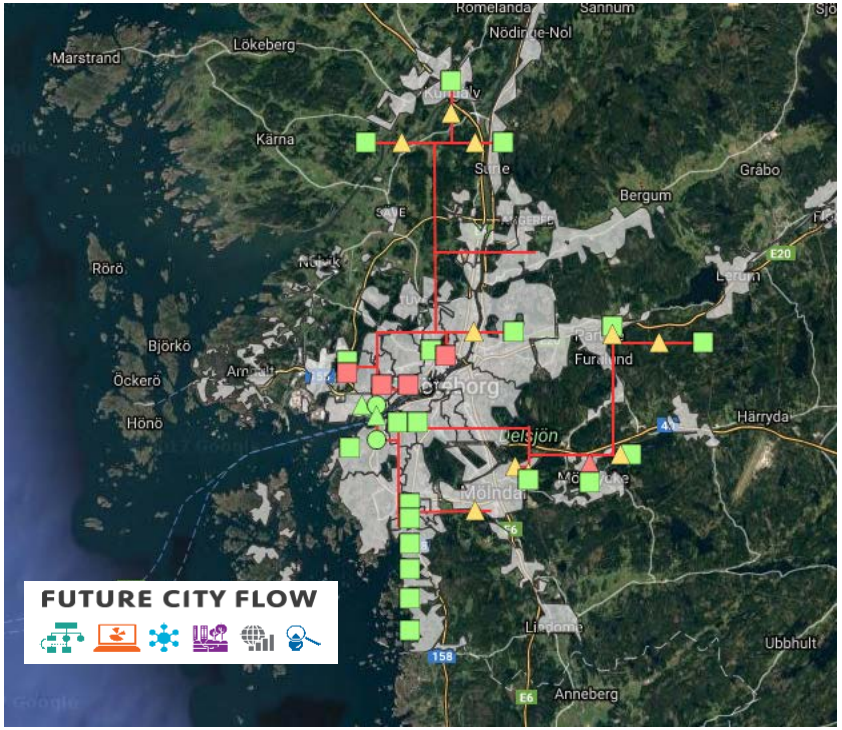
P_m = rainfall intensity, one time series per sub-link

Gridding (IDW)



Hydrological evaluation

- Hydro-dynamic drainage network model calculating inflow to sewage treatment plant (Ryaverken)
- Model calibrated toward gauges
- 9 events simulated using gauge (GAU), microwave links (MWL) and radar (RAD) as precip. input
- Hydrological evaluation (entire catchment area): 4 locations with flow observations
- **Results: MWL best in most cases**



Average for 9 events

	Ryaverket			Dykarledning			Kodammarna			Järnvägsg.		
Source	**RAD**	**MWL**	**GAU**	**RAD**	**MWL**	**GAU**	**RAD**	**MWL**	**GAU**	**RAD**	**MWL**	**GAU**
VE (%)	**17**	**12**	**15**	**14**	**15**	**15**	**23**	**13**	**17**	**17**	**8**	**20**
R^2 (-)	**0.68**	**0.88**	**0.81**	**0.58**	**0.81**	**0.72**	**0.78**	**0.81**	**0.66**	**0.43**	**0.59**	**0.44**

VE= volume error

Water flow direction

2018 Gothenburg

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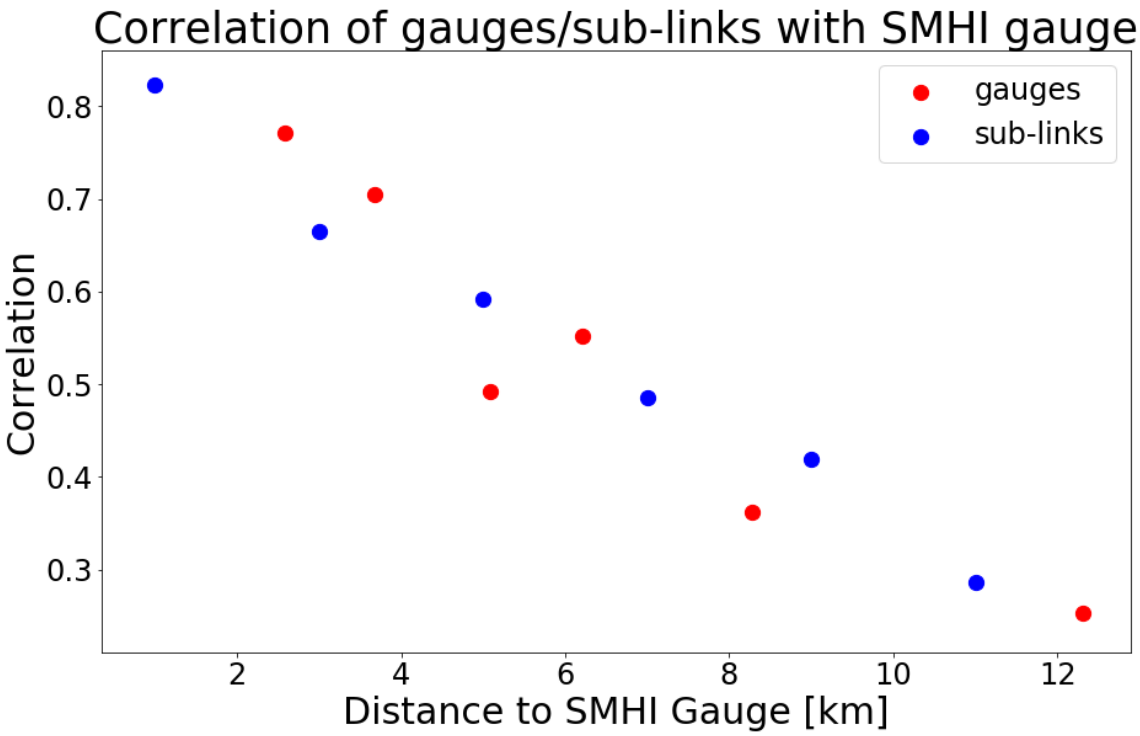
Spatial Correlation



Comparison

- Correlation vs. distance to SMHI's gauge in central Gothenburg @ 15min
- Municipal gauges vs. all MWLs in the region.

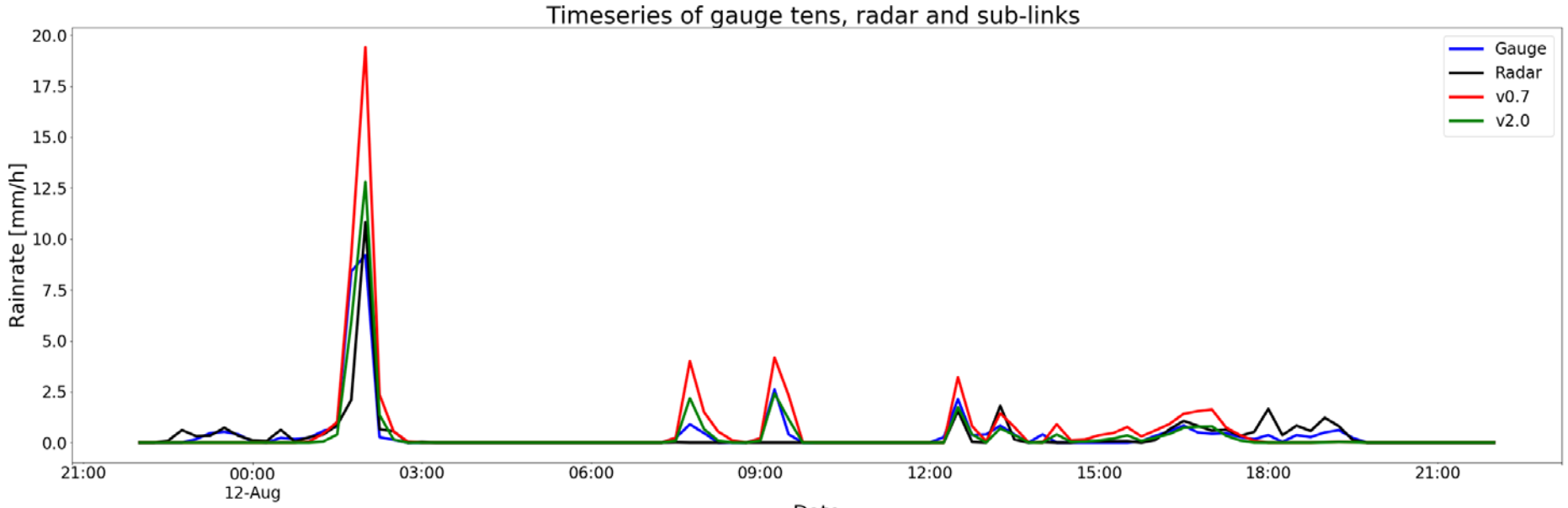
Results

- Correlation decline due to natural spatial variability of rainfall
- **MWLs similar to gauges** → likely capture spatial relationships equally well (or better if gauges are lacking)

2019 Stockholm - Validation

- Time period analysed was 2018-07-28 to 2018-10-31
- 6 gauges
- 1071 sub-links converted to map
- 12 radars (+ more in neighbouring countries) merged to a map
- Accumulated to 15 minute data

Example of timeseries at Tensta on 12 August 2018



15min resolution

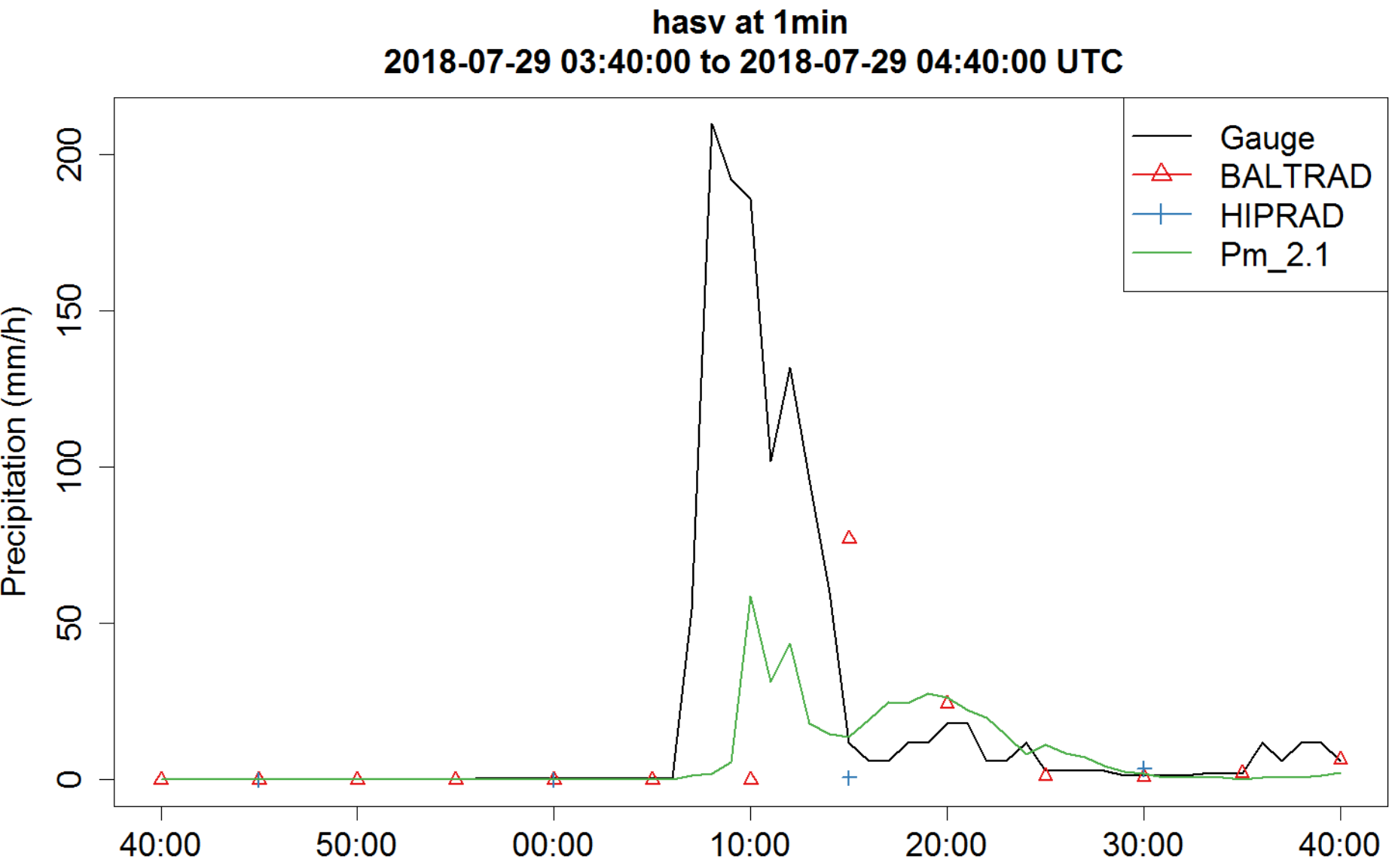
Peak performance?

The 29th July event

- Intense rainfall during the night: 15-min accumulation >10-year return period at Hässelby
- Consequences: flooding, blocked roads, flooded railway stations, canceled flights at Arlanda, problems at hospitals etc.

Source: https://www.expressen.se/tv/vader/kaos-i-extremregnet--oversvamningar-och-installda-flyg/, 2018-07-29

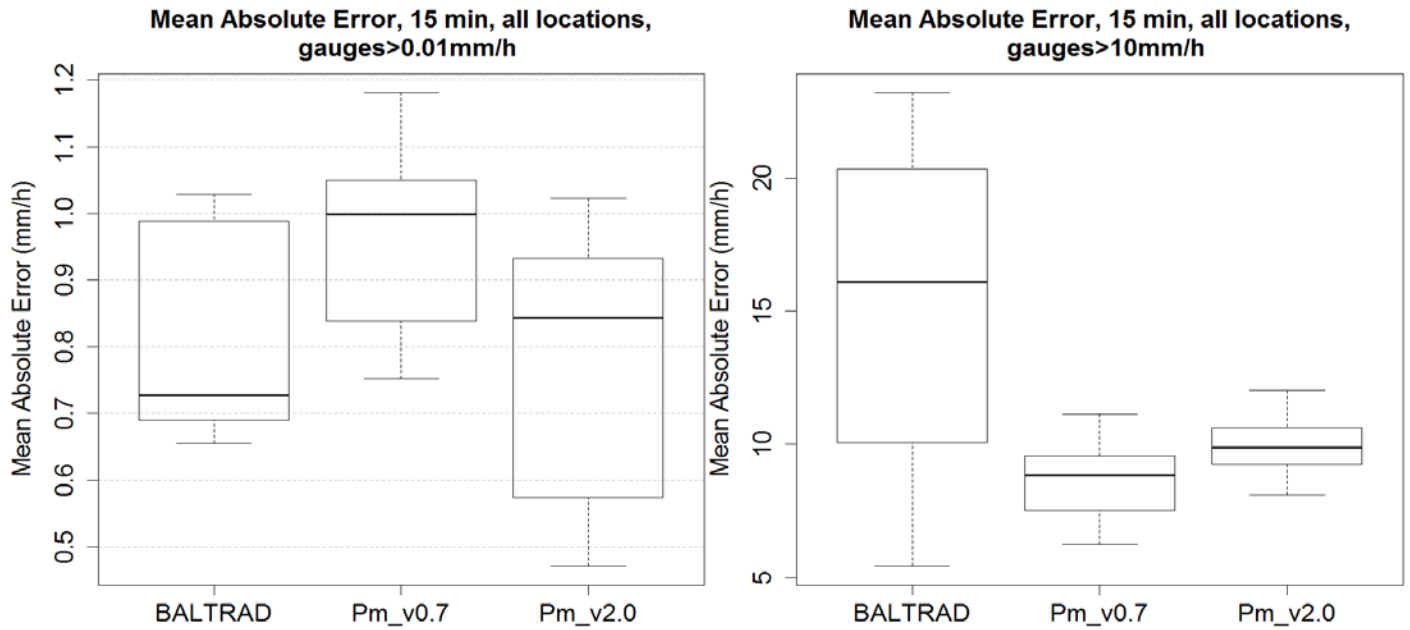
The 29th July event



Summary of statistics

Gauges >0.01 mm/h

	Baltrad	V0.7	V2.0
Bias	-23	26	-15
Correlation	0.53	0.71	0.72
MAE	0.73	1.0	0.84
RMSE	2.2	1.8	1.7



What is the optimal map resolution?

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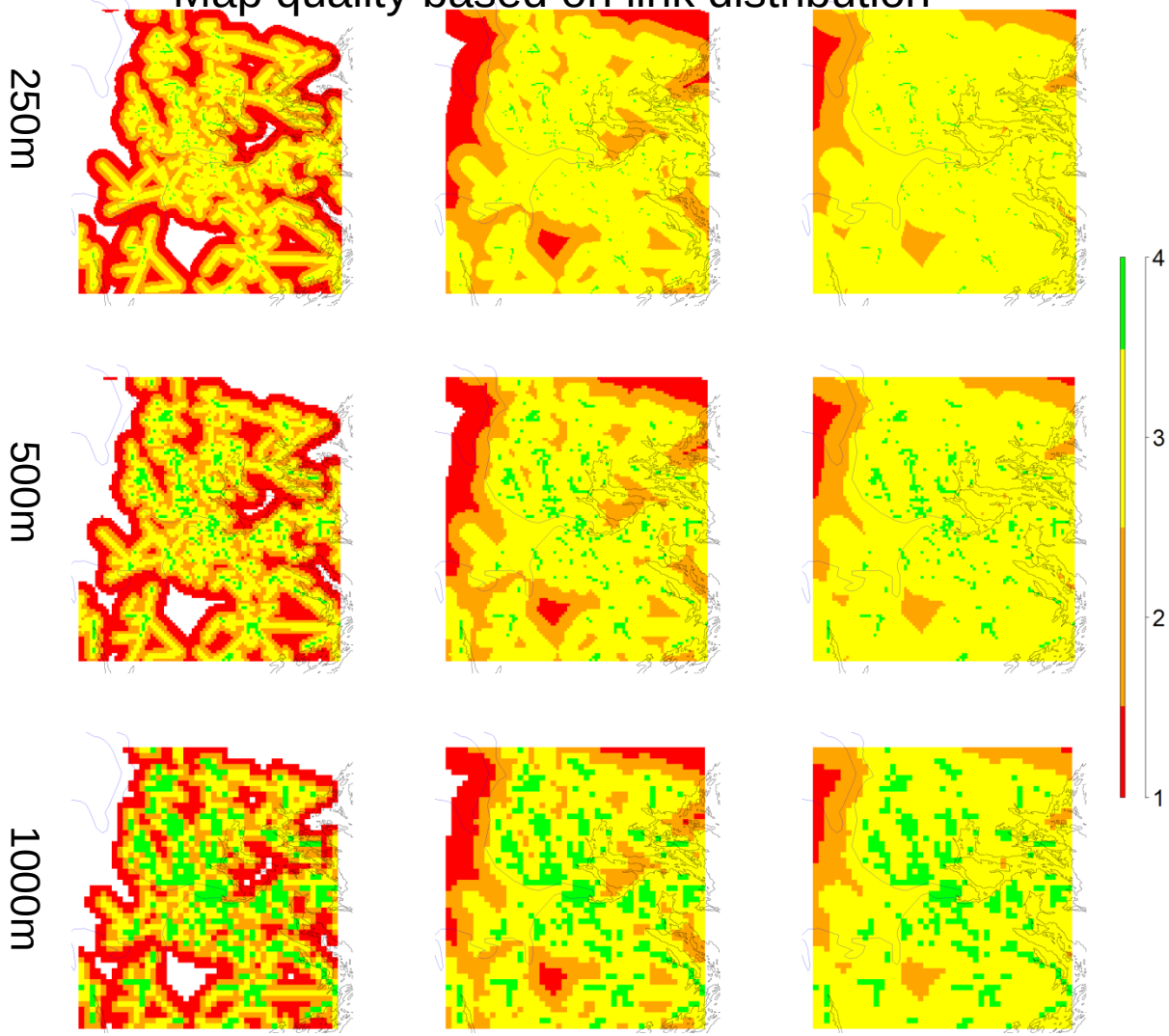
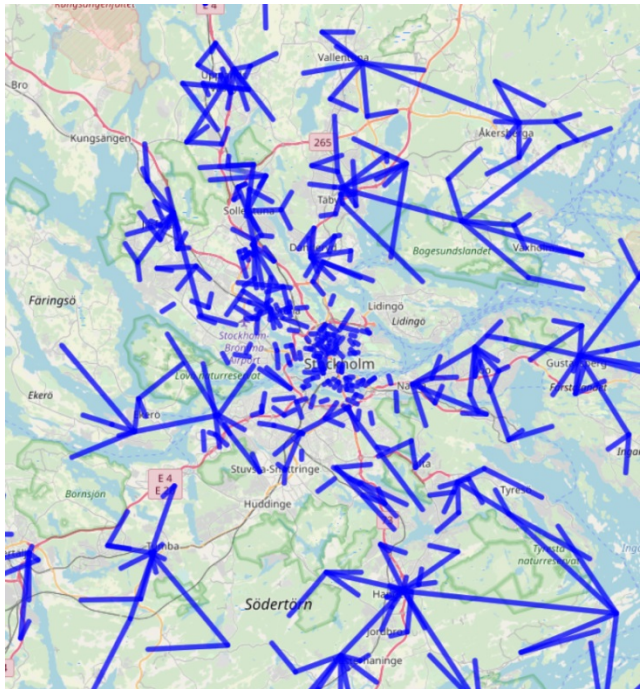
Map quality based on link distribution



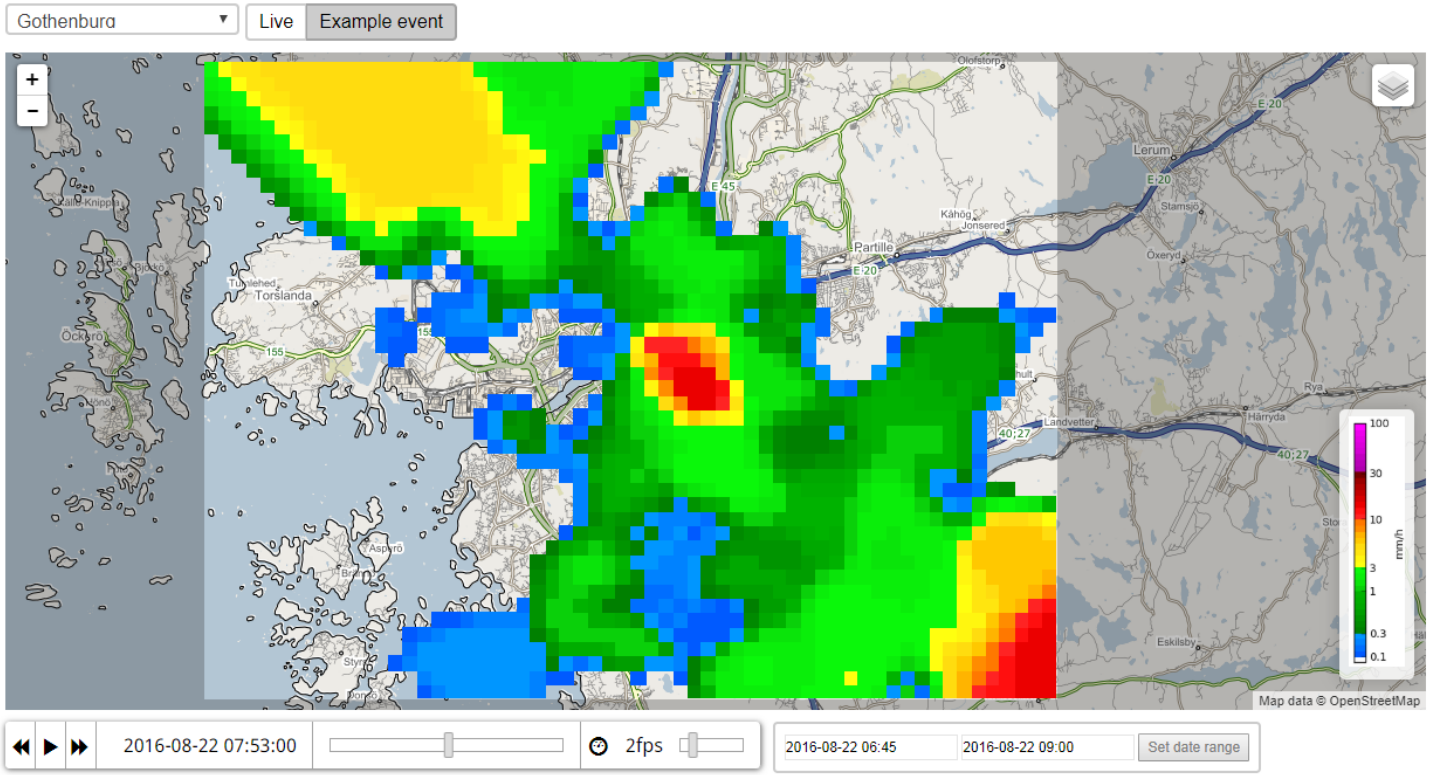
Final results can be found in:

Van de Beek et al., 2020: **Optimal grid resolution for precipitation maps from commercial microwave link networks**, in revision: Adv. In Sci. Res., Special Issue: 19th EMS Annual Meeting: European Conference for Applied Meteorology and Climatology 2019



Live rainfall maps online

- https://www.smhi.se/memo
- Gothenburg since May 2016
- Stockholm since May 2019
- Resolution: 1-min & 500x500m
- Low level of missing data, but network changes must be managed
- It is a demo: some non-rain signal effects present, edge effects etc.



Conclusions

CML Algorithm

- 2.1 is generally better than previous versions

Overall performance

- Wet/dry classification: 80% hit rate for >0mm/h
- Correlations: Very good, similar to nearby gauges, better than BALTRAD & HIPRAD v2.0
- Precip. volumes: improves significantly with v. 2.1. Still over/under-predictions remain in some places. Gauge-adjusted BALTRAD & HIPRAD better than links → potentially apply similiar gauge adjustment algorithms?

Peak performance

- Decent temporal dynamics during 29th July 2018 event, better than BALTRAD & HIPRAD
- High intensities typically underestimated by both links & radar. Links typically have lower average error (MAE) than radar @1min &15min. Note partly this is expected due to the larger sampling volume.
- 40% hit rate for >10mm/h. (60% >4mm/h)
- 0% false alarm for >10mm/h