Potential for PMM GV in The Netherlands

using C-band weather radars, rain gauges, commercial microwave links, and personal weather stations

Remko Uijlenhoet
Hydrology and Quantitative Water Management Group

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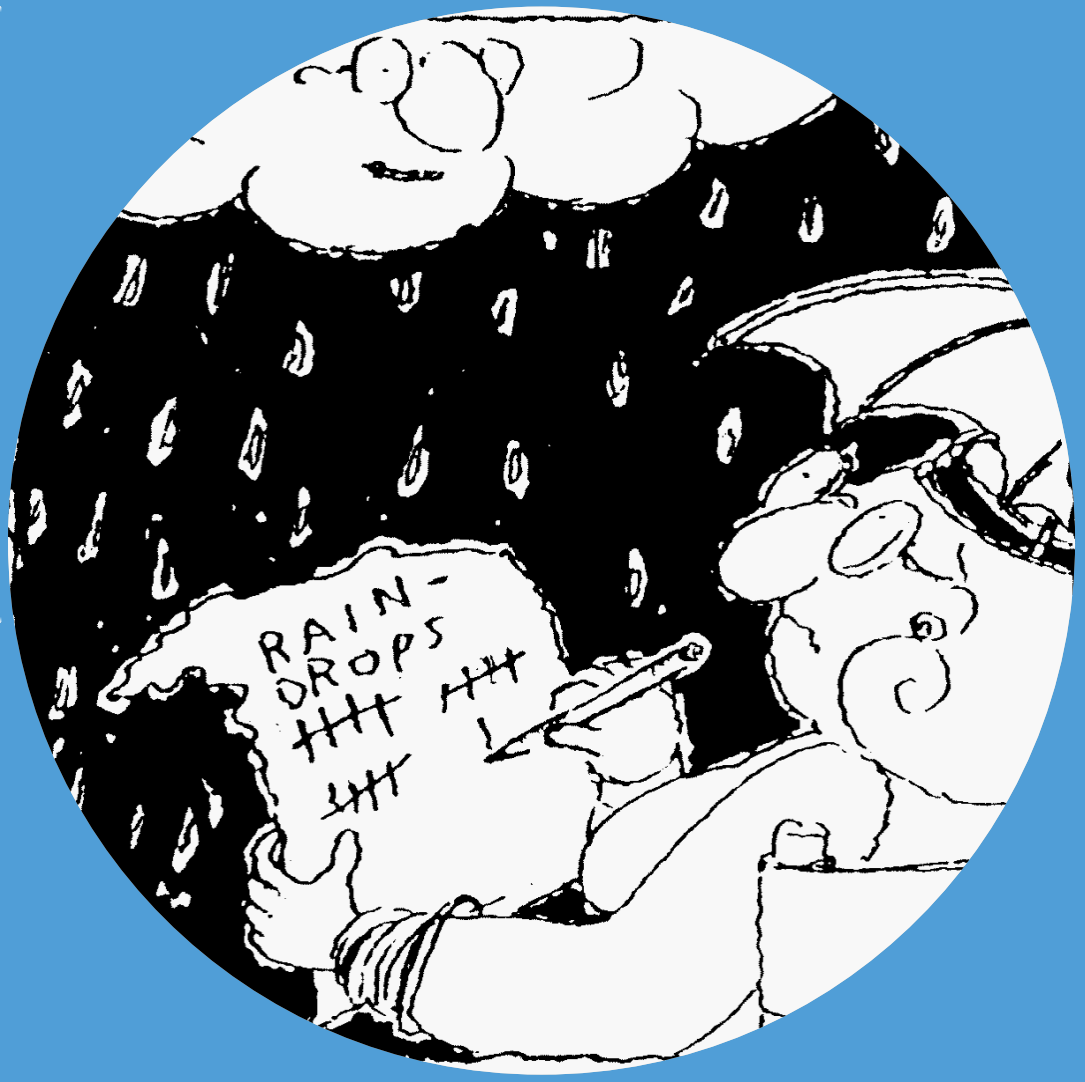
PMM GV in NL: synergy of dedicated and opportunistic sensors



(Victoria Roberts, 2000)

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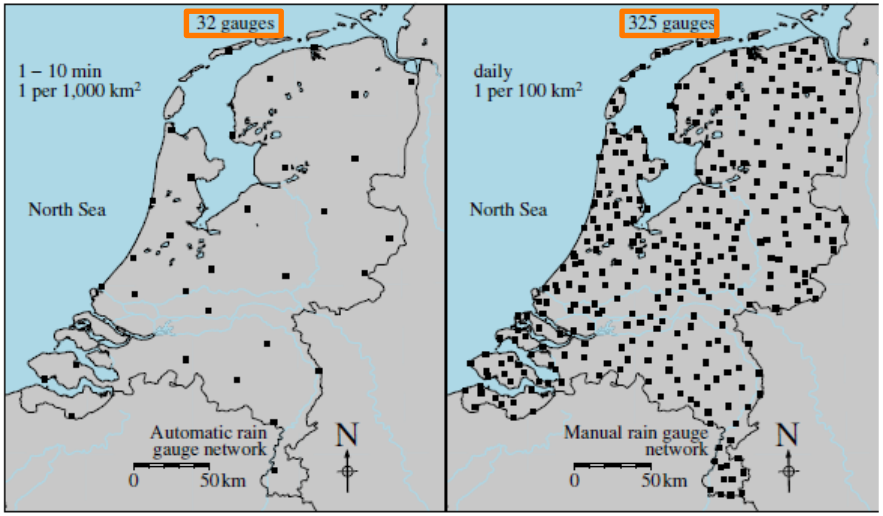
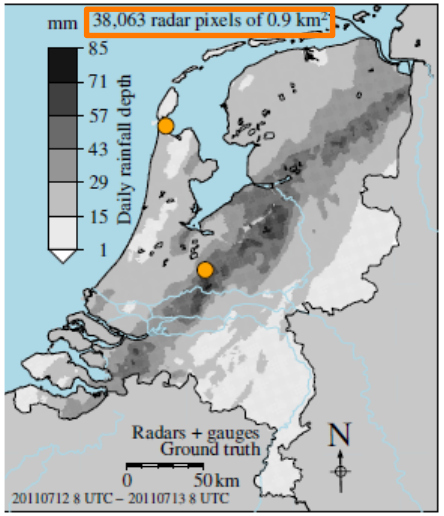
Rainfall observations in The Netherlands



Room for opportunistic sensors



(~1 per 1000 km²)

(~1 per 100 km²)

(~1 per 1 km²)

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Ruisdael Observatory @ Cabauw (NL)

The Dutch, clouds and precipitation ...

- Jacob Ruisdael, *View of Haarlem with Bleaching Grounds* (1665)

Rainfall observations @ Ruisdael

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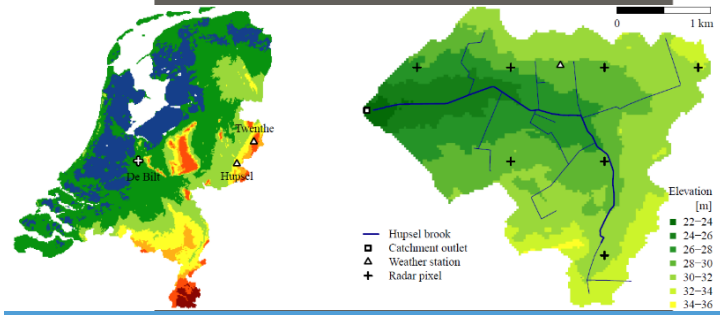
Published September 13, 2018

Special Section: Hydrological Observatories

Core Ideas

- Meteorological and hydrological variables have been measured since 1964.
- Focus was on rainfall–runoff process, land–atmosphere interaction, solute transport.
- Long time series allowed studying effects of land use and water management changes.



The Hupsel Brook Catchment: Insights from Five Decades of Lowland Observations

C.C. Brauer,* Y. van der Velde, A.J. Teuling, and R. Uijlenhoet

The 6.5-km^2 Hupsel Brook catchment has been used as an example rural lowland area to understand rainfall–runoff processes, land–atmosphere interactions, and solute transport and to investigate how they are affected by changes in land use and water management. Meteorological and hydrological variables have been measured nearly continuously since 1964, including the 1976 drought and 2010 flood. In addition, more than 2200 water quality samples have been analyzed since the 1980s, with dedicated field campaigns focused on soil physics, evapotranspiration, and rainfall measurement. Novel insights based on these observations include the conclusion that shallow groundwater tables result in a coupled saturated–unsaturated zone and sustain evaporation in dry periods. Partitioning of rainwater between various flow paths is storage driven and therefore catchment wetness determines, together with groundwater–surface water interaction, the response of runoff to rainfall as well as solute transport.

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Precipitation research community in The Netherlands

PWS – Personal weather stations as opportunistic rainfall sensors

(Victoria Roberts, 2000)

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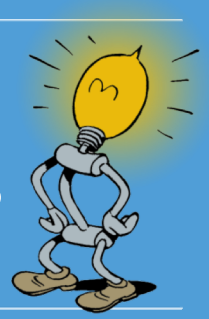
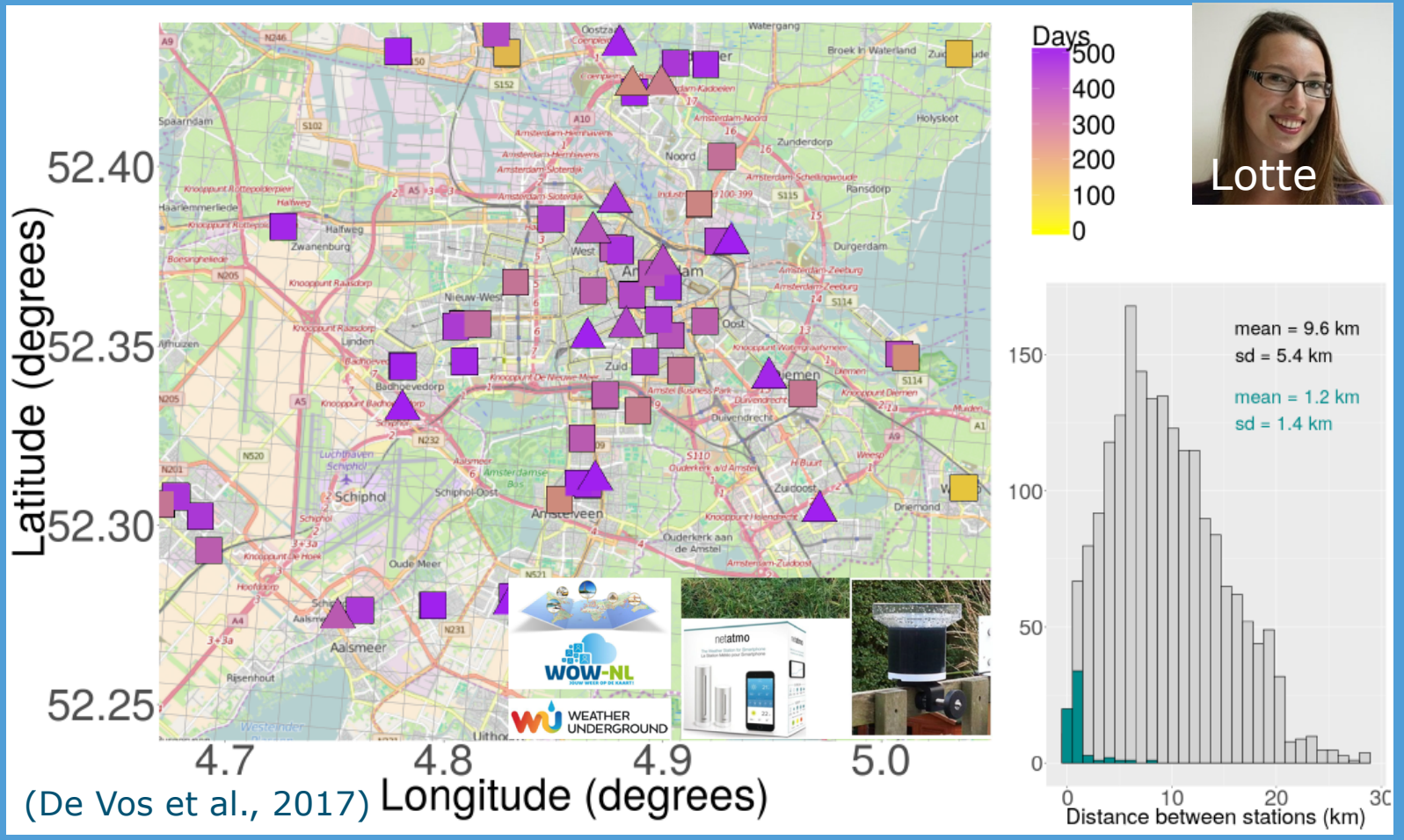
Urban areas: more personal weather stations (PWS) than official rain gauges





(De Vos et al., 2017)

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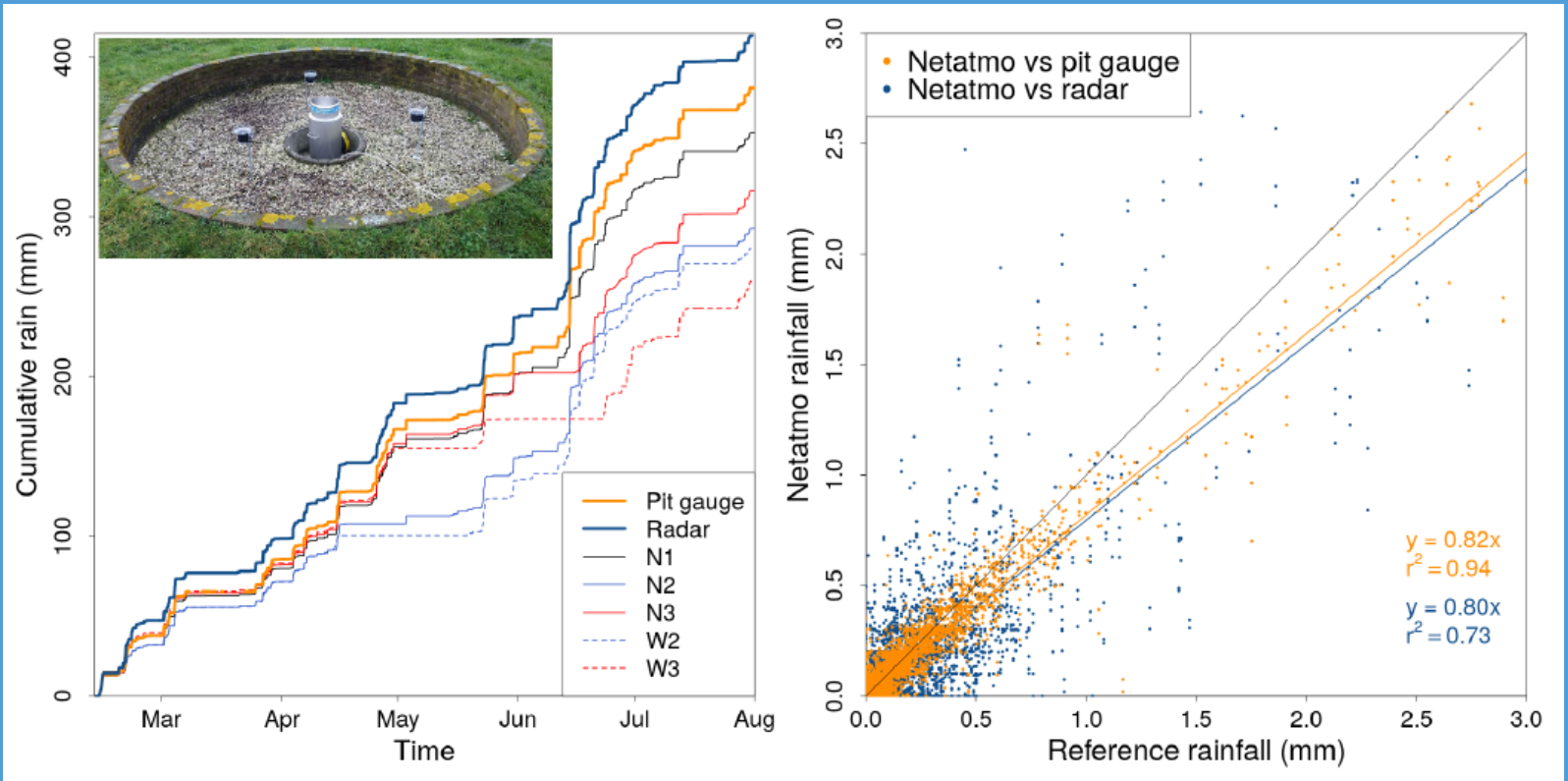
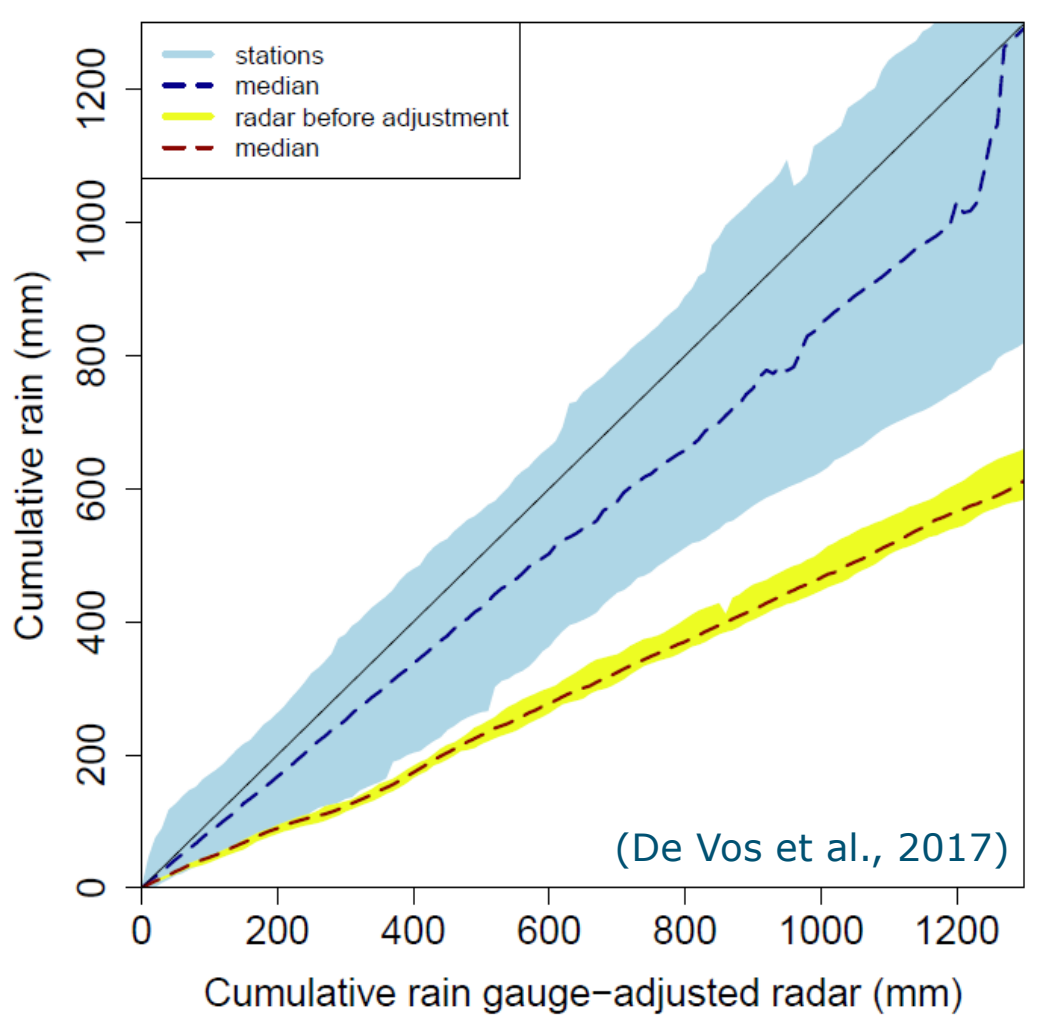
Netatmo tipping bucket rain gauge

Validation of Netatmo stations at Cabauw



(De Vos et al., 2017)

Double mass plots (PWS versus radar)



The advent of opportunistic sensing of our environment

(Victoria Roberts, 2000)

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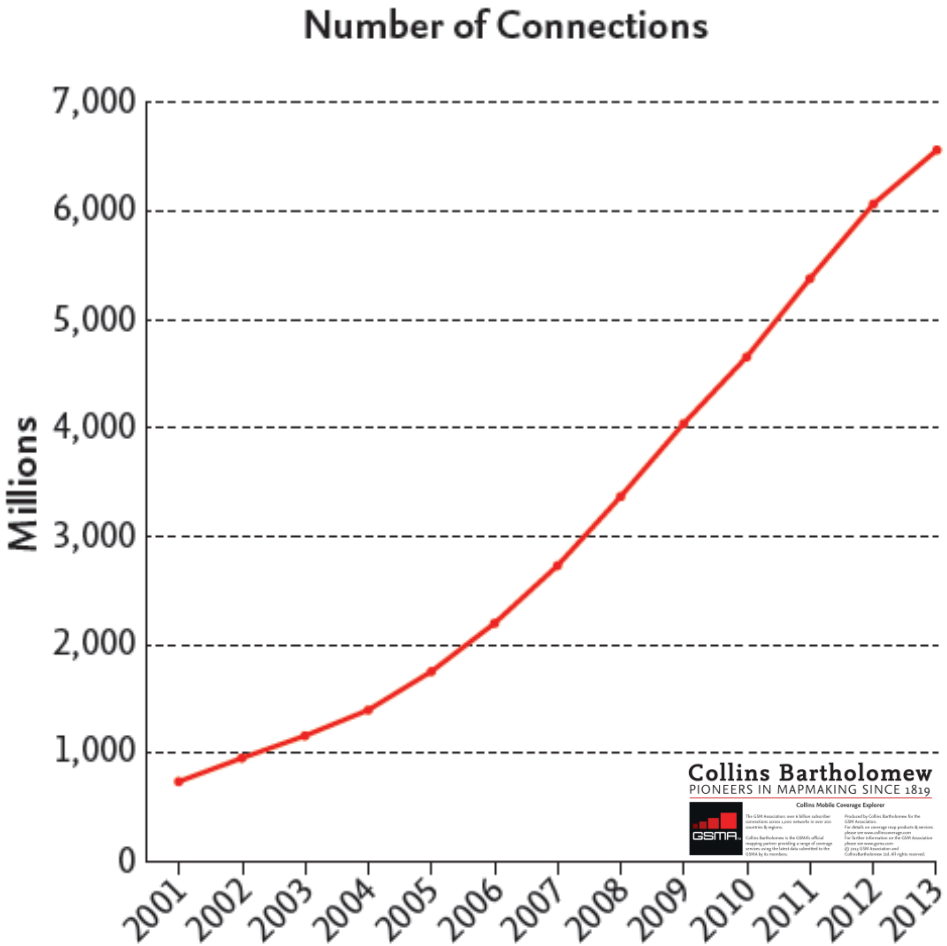
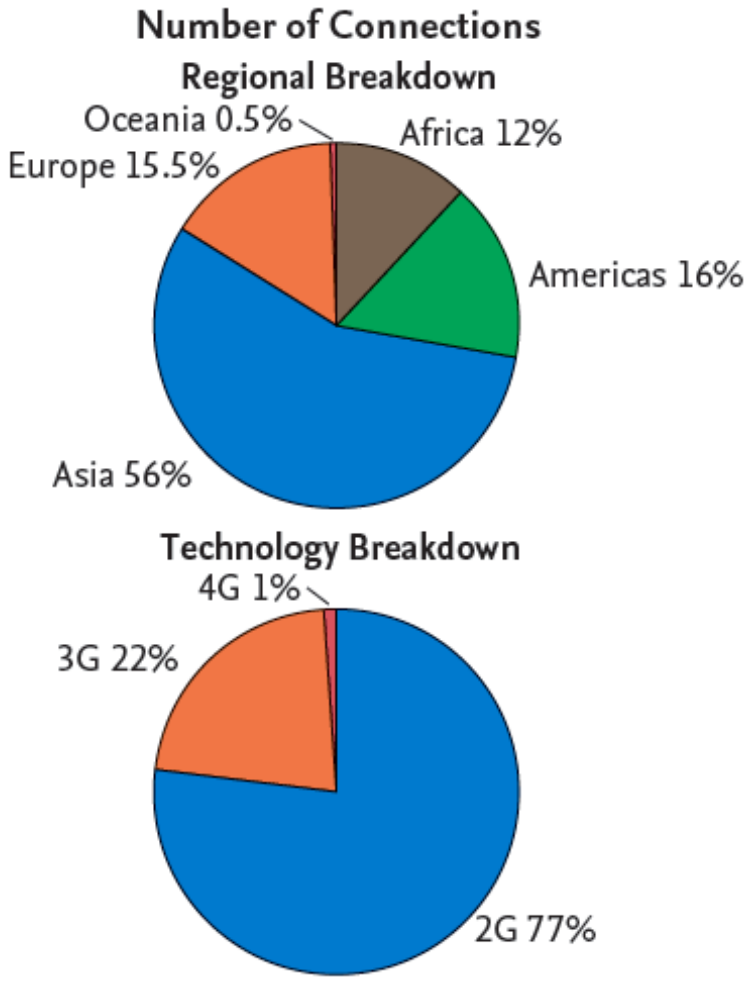
Rapid growth cellular telecommunication





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(identim / Shutterstock)

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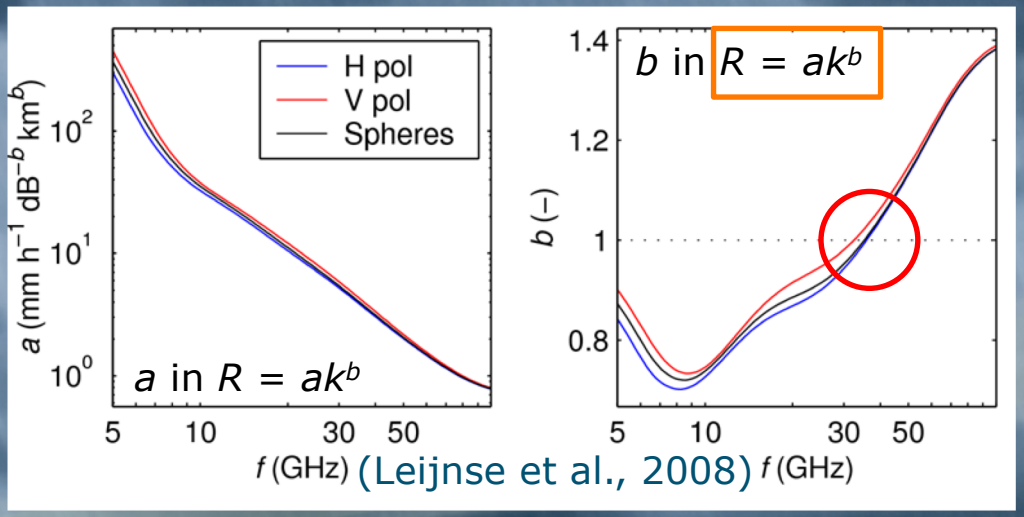
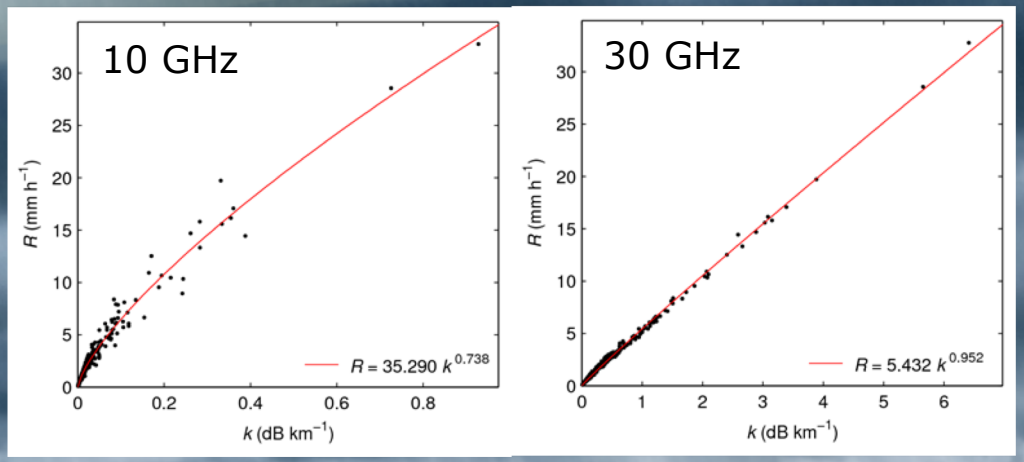
(power-law relations between rain rate R and extinction k)

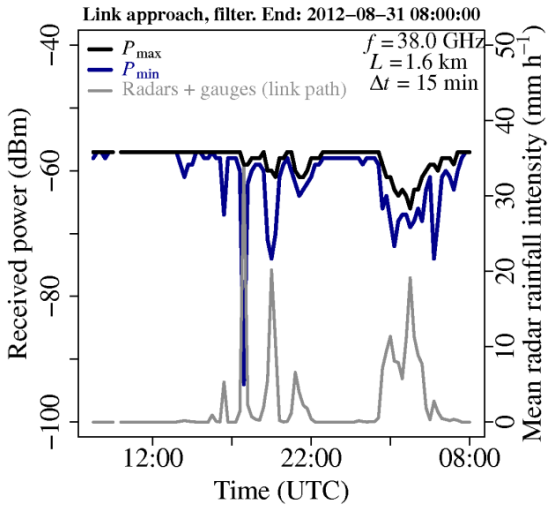


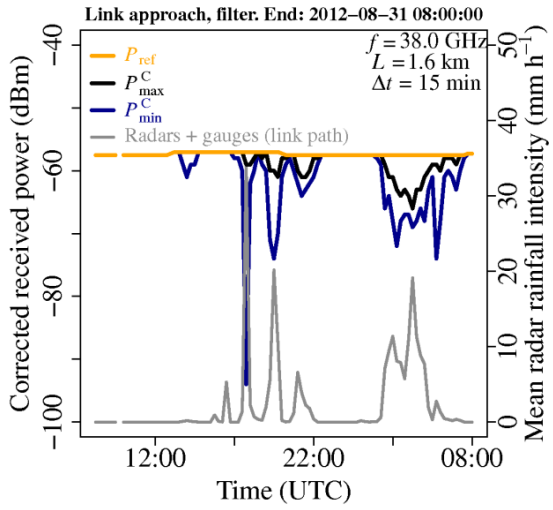
(Leijnse et al., 2008)

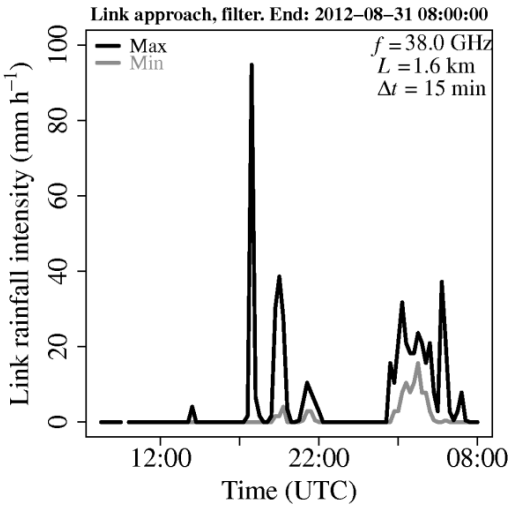


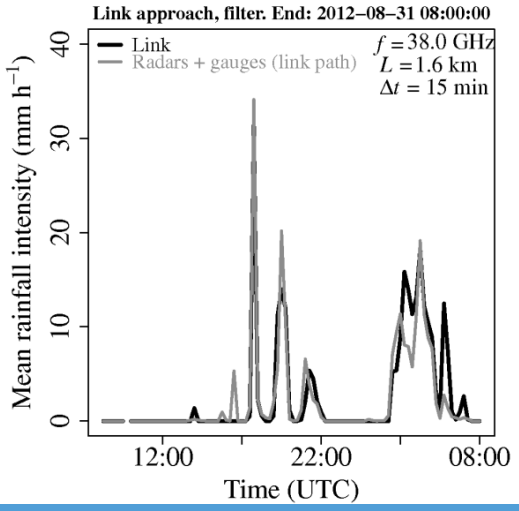
(identim / Shutterstock)

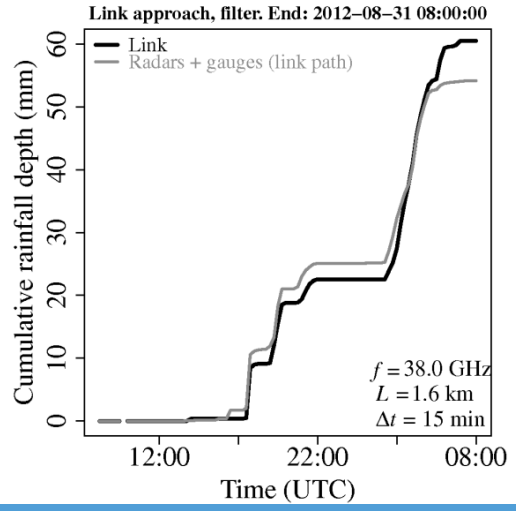
Rainfall retrieval in Amsterdam (08-30-12)

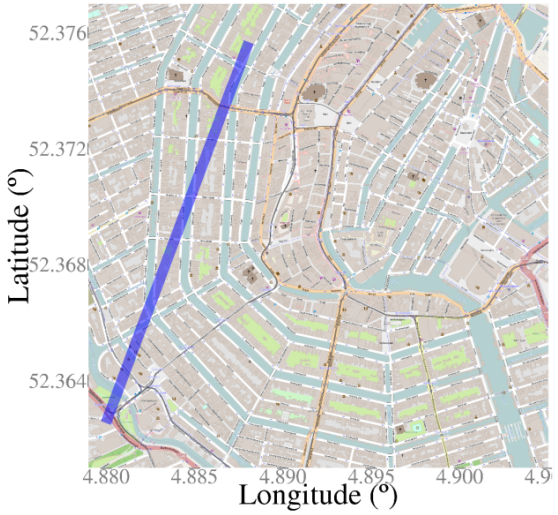












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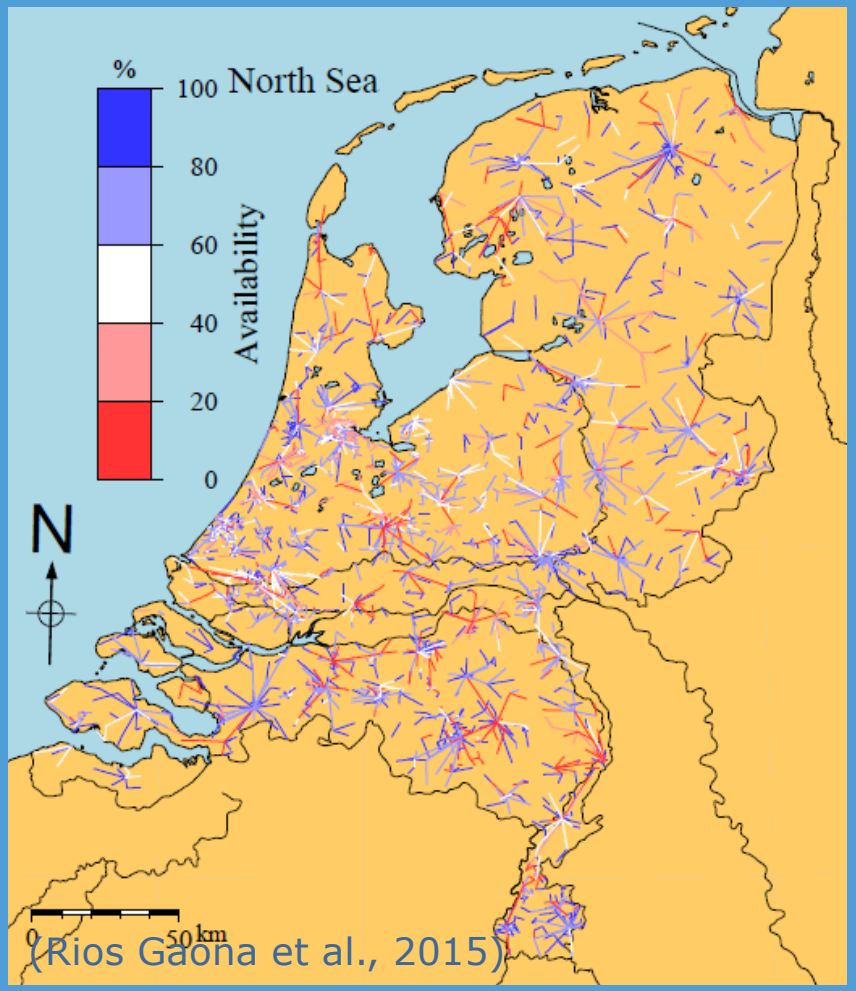
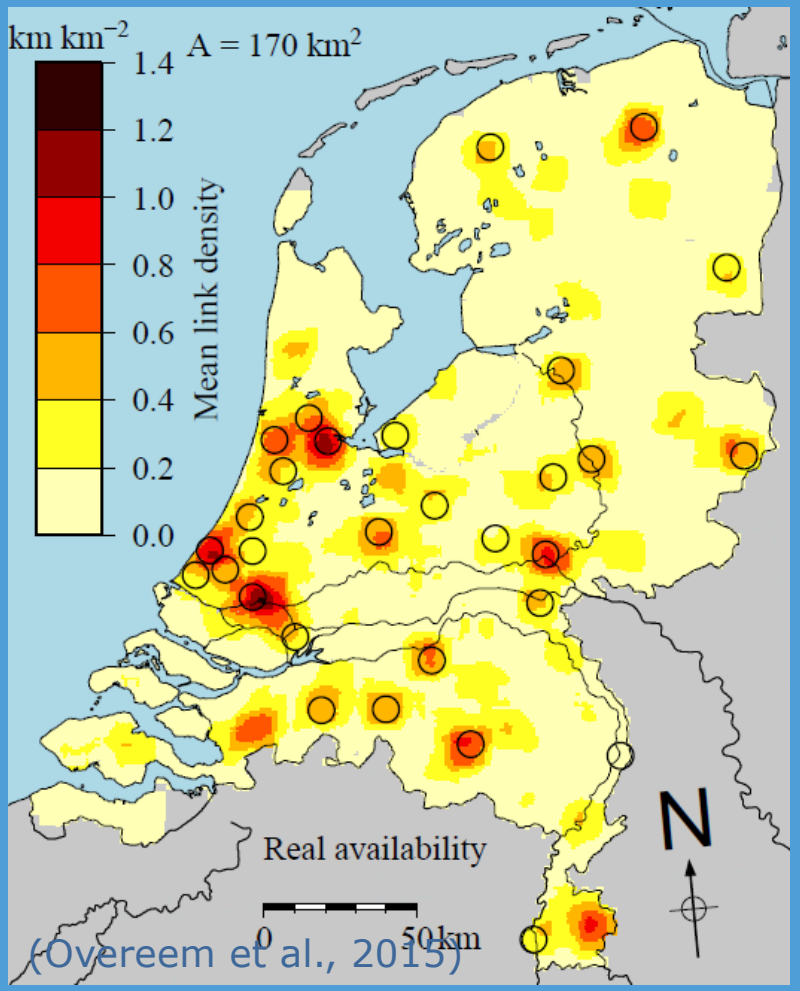
Density and availability of link network

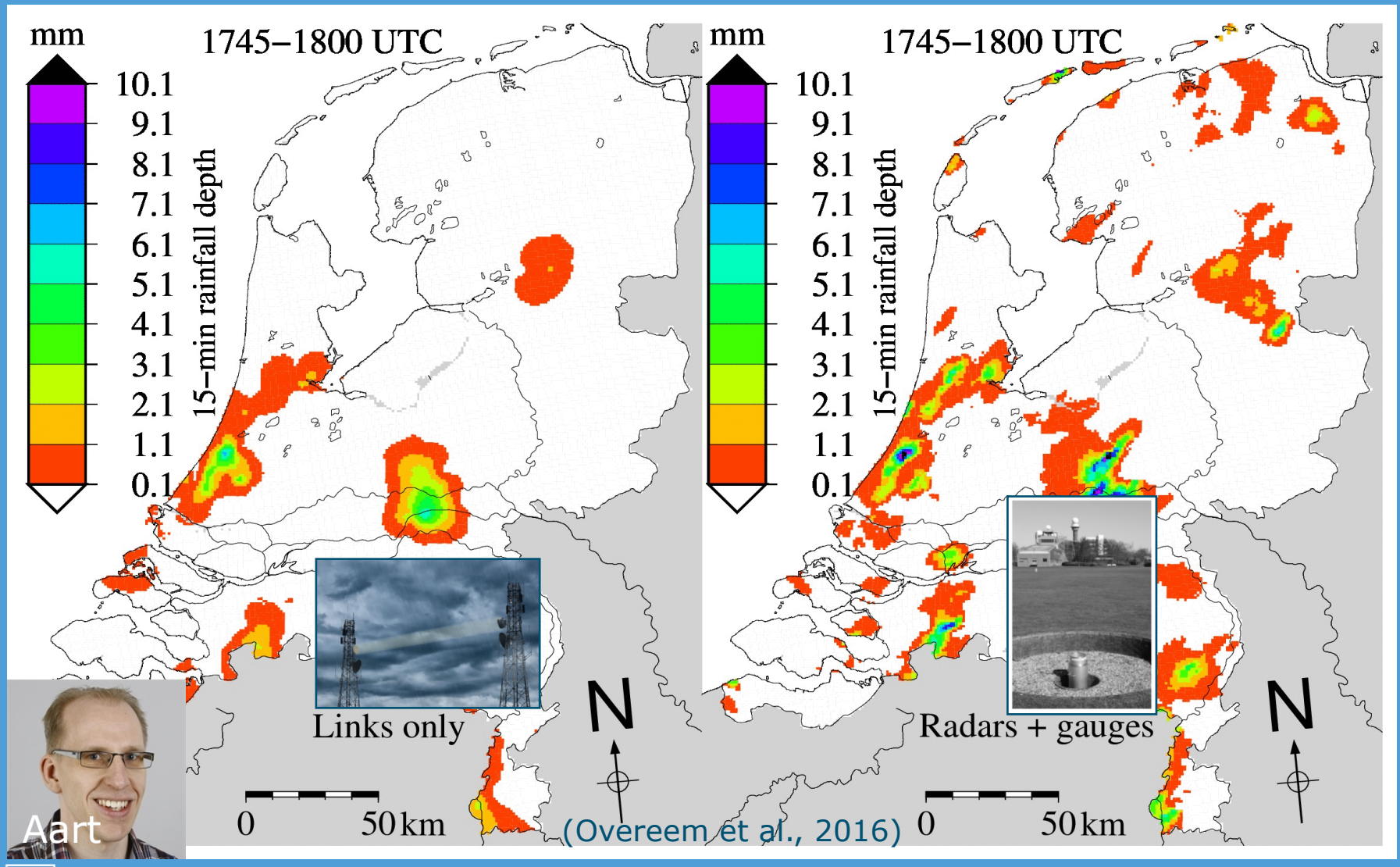


(Rios Gaona et al., 2015)



(Overeem et al., 2015)

Microwave links versus radar + gauges



(Overeem et al., 2016)

Comparison of different rainfall products for The Netherlands

(Victoria Roberts, 2000)

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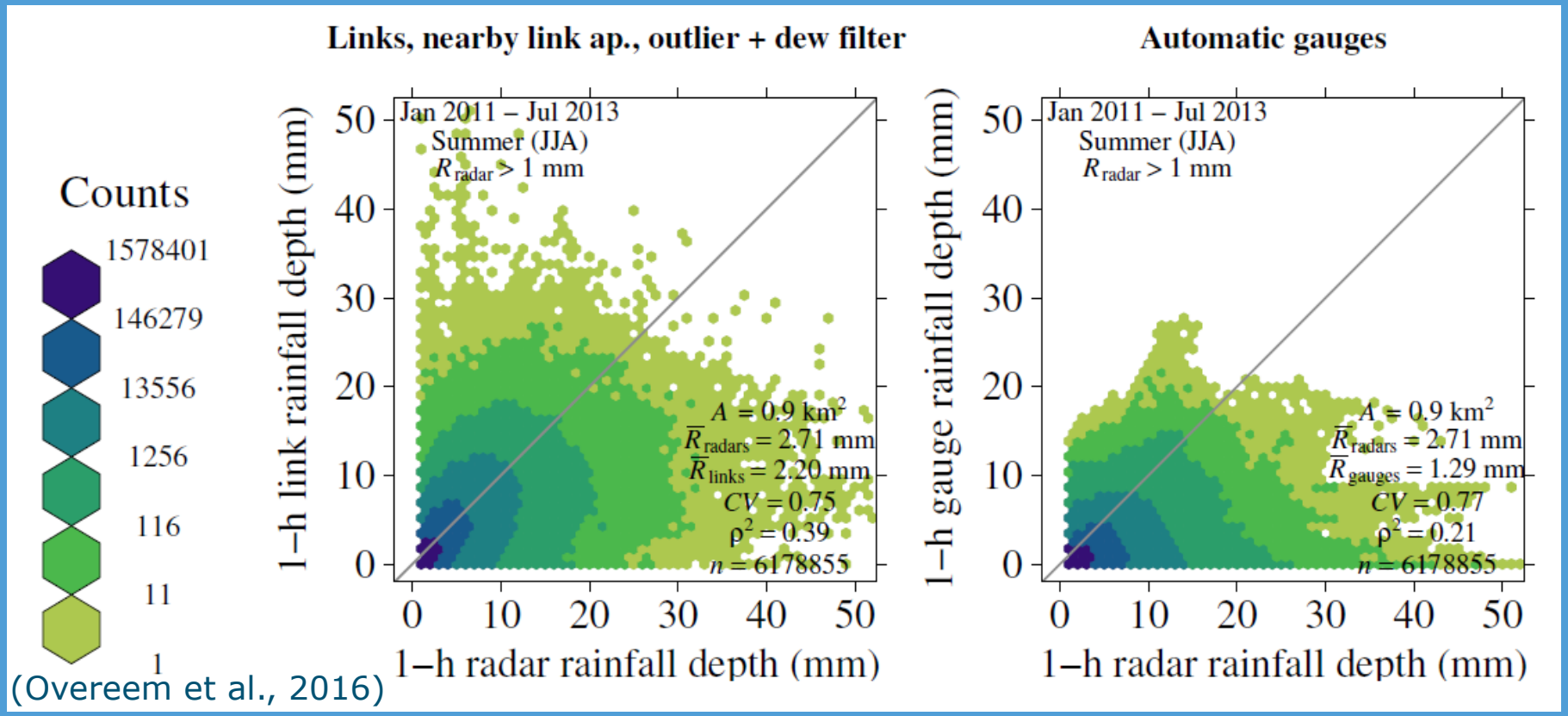
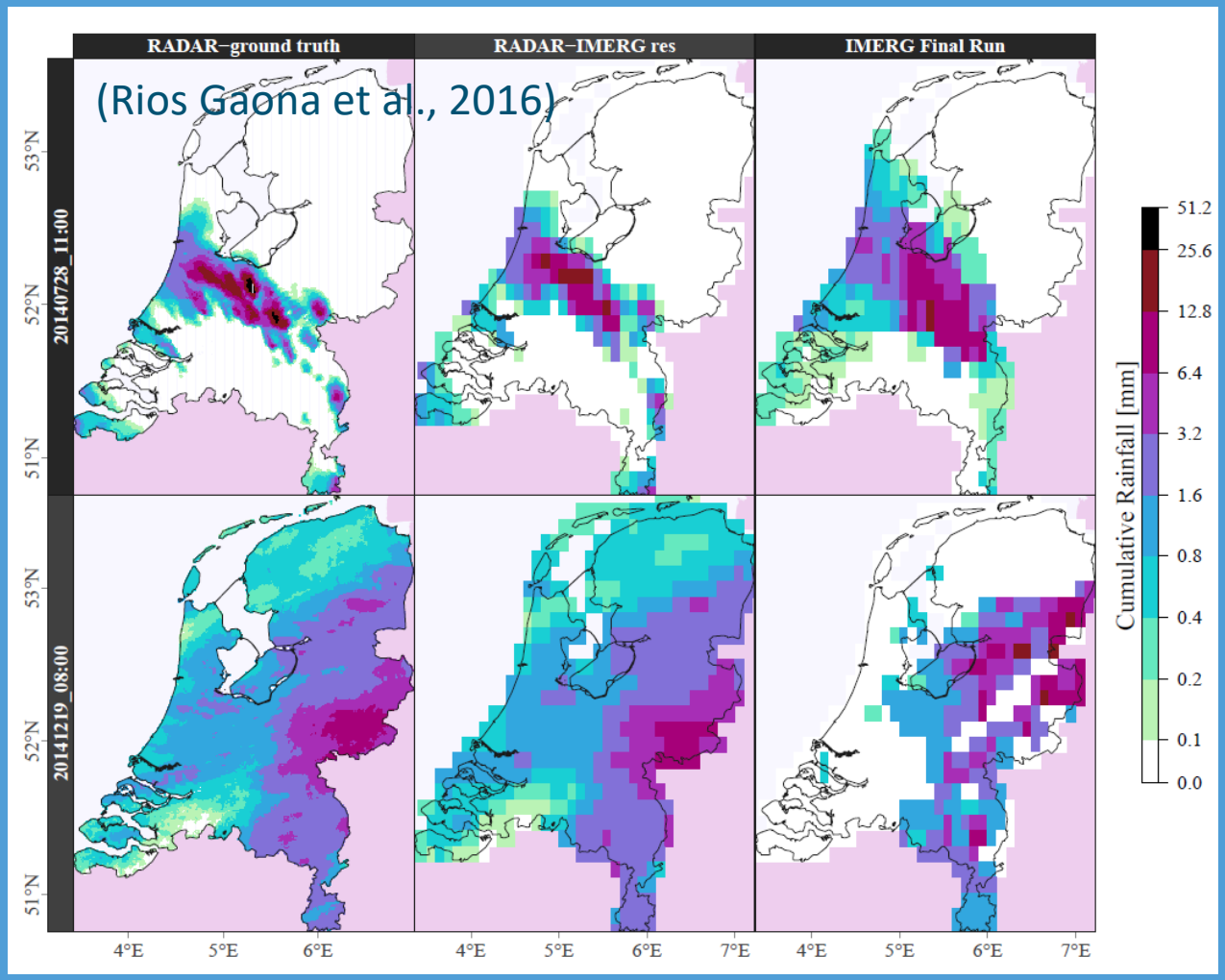
Links and gauges vs. weather radar

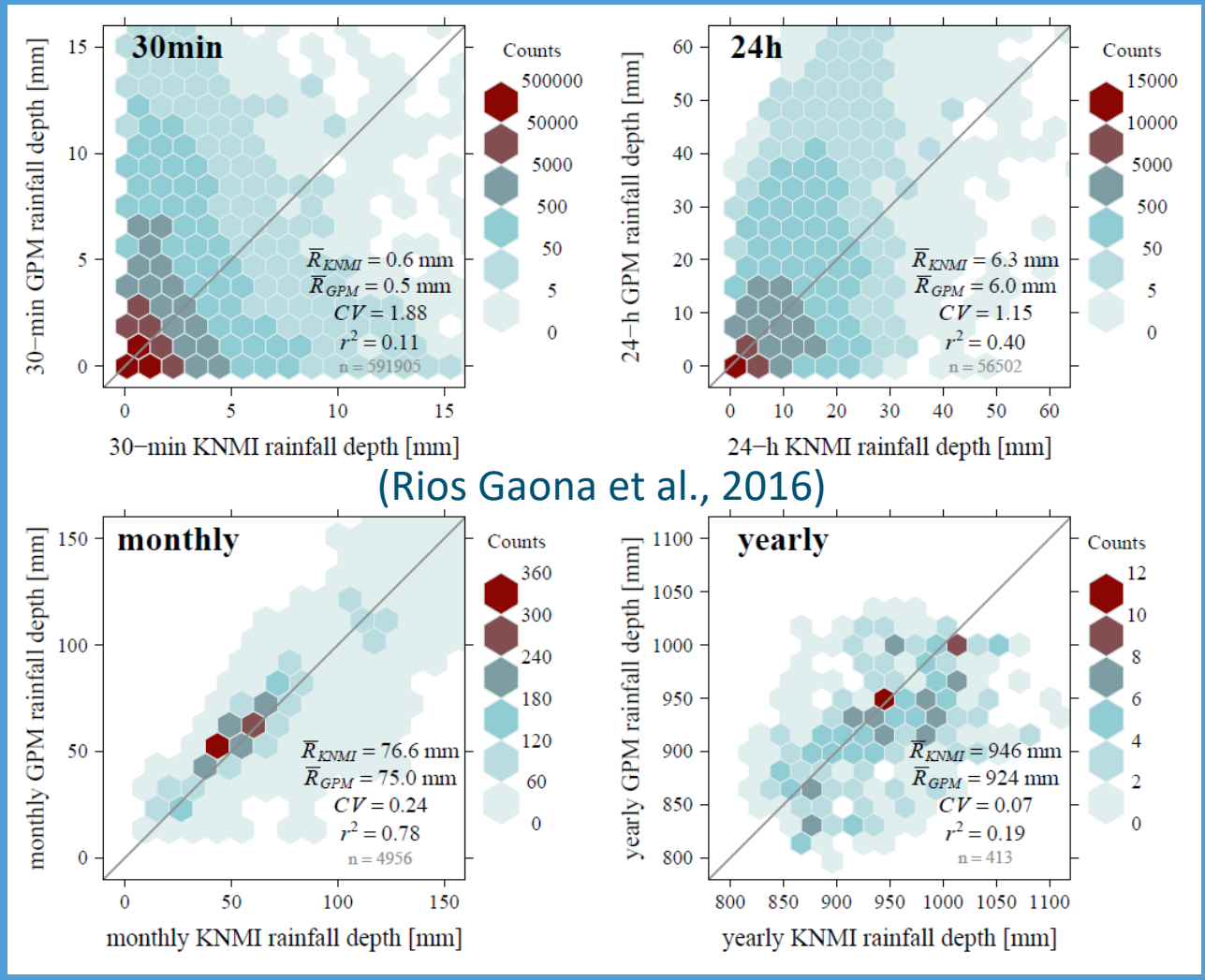


(Overeem et al., 2016)

IMERG vs. gauge-adjusted weather radar

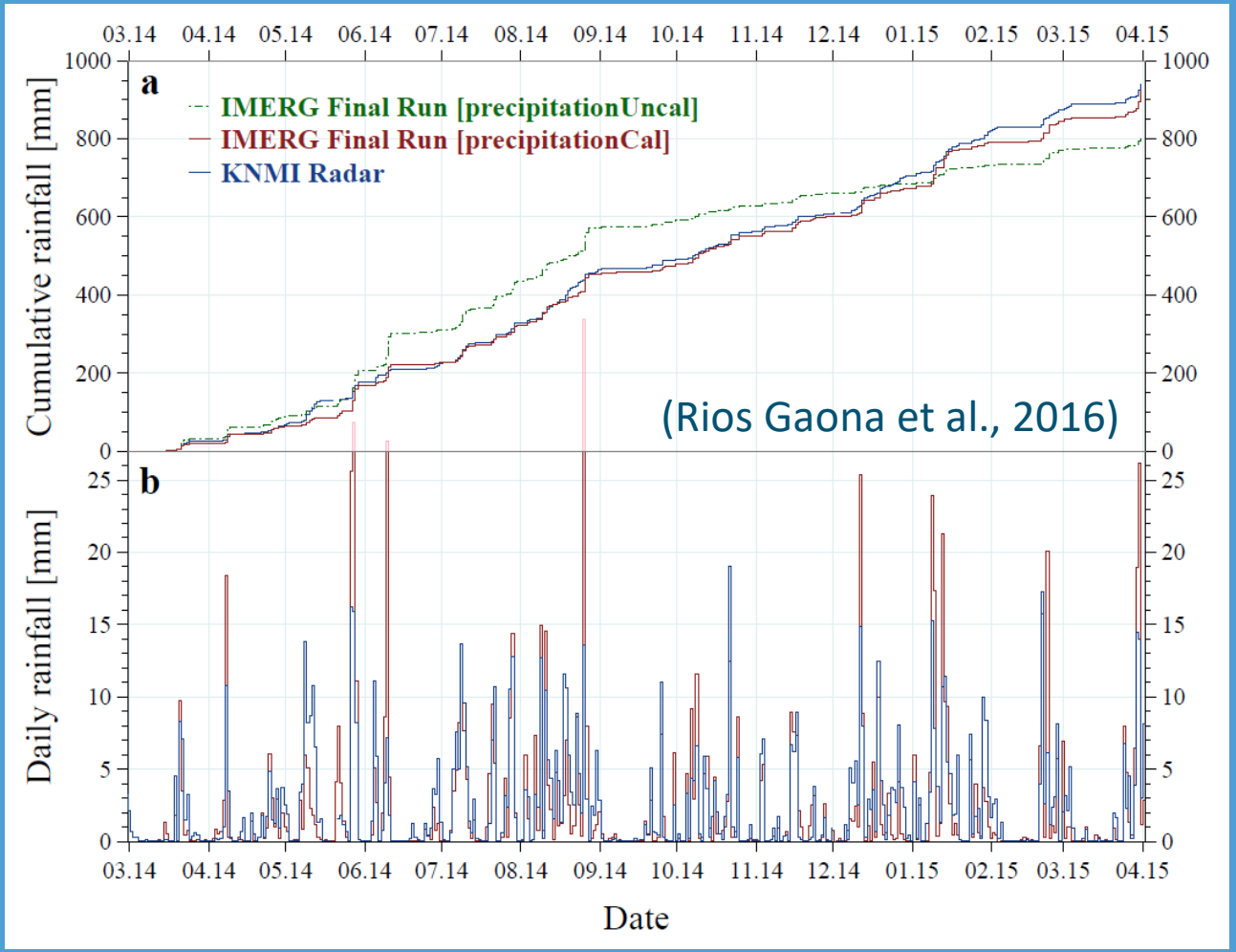


IMERG vs. gauge-adjusted weather radar



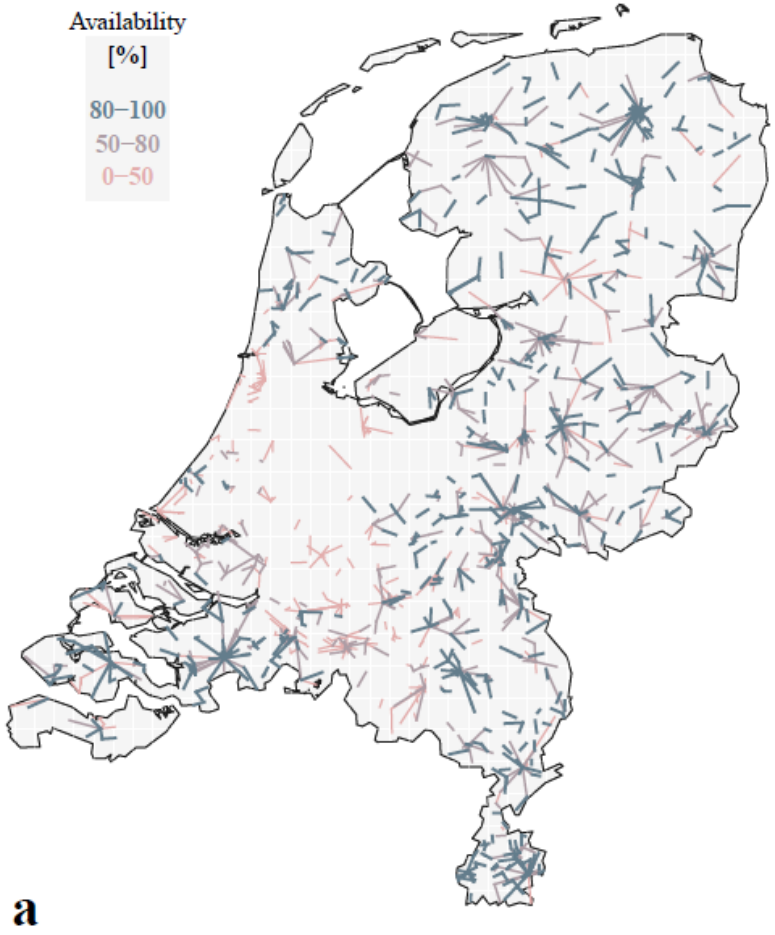
(Rios Gaona et al., 2016)

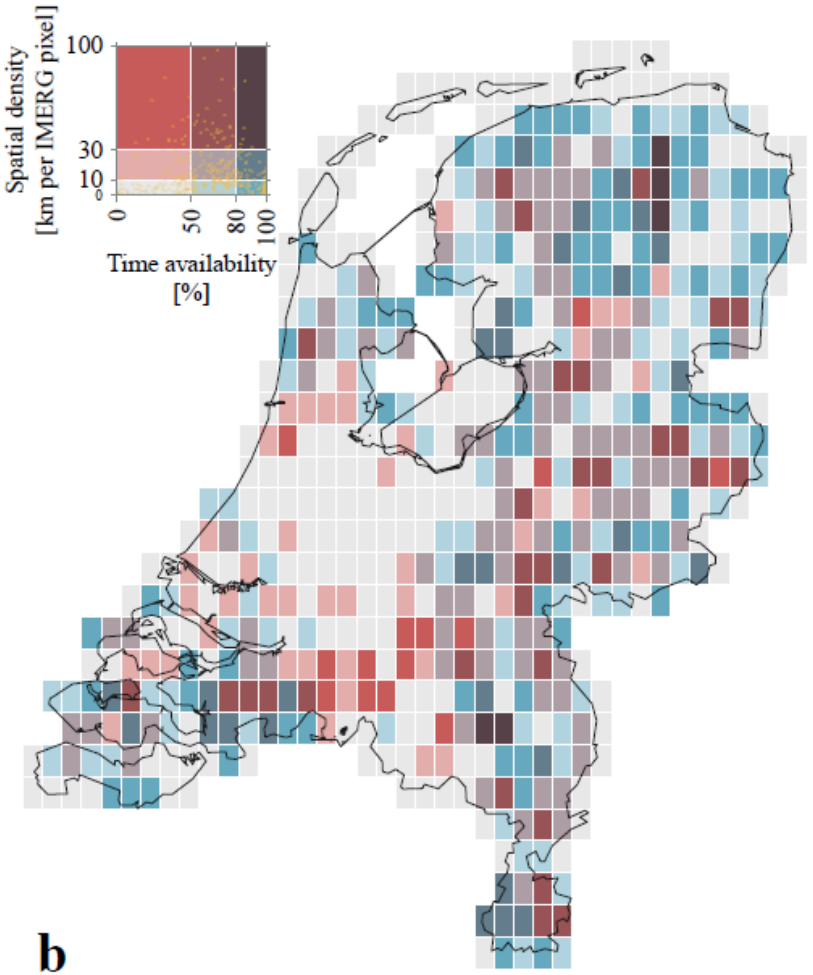
IMERG vs. gauge-adjusted weather radar



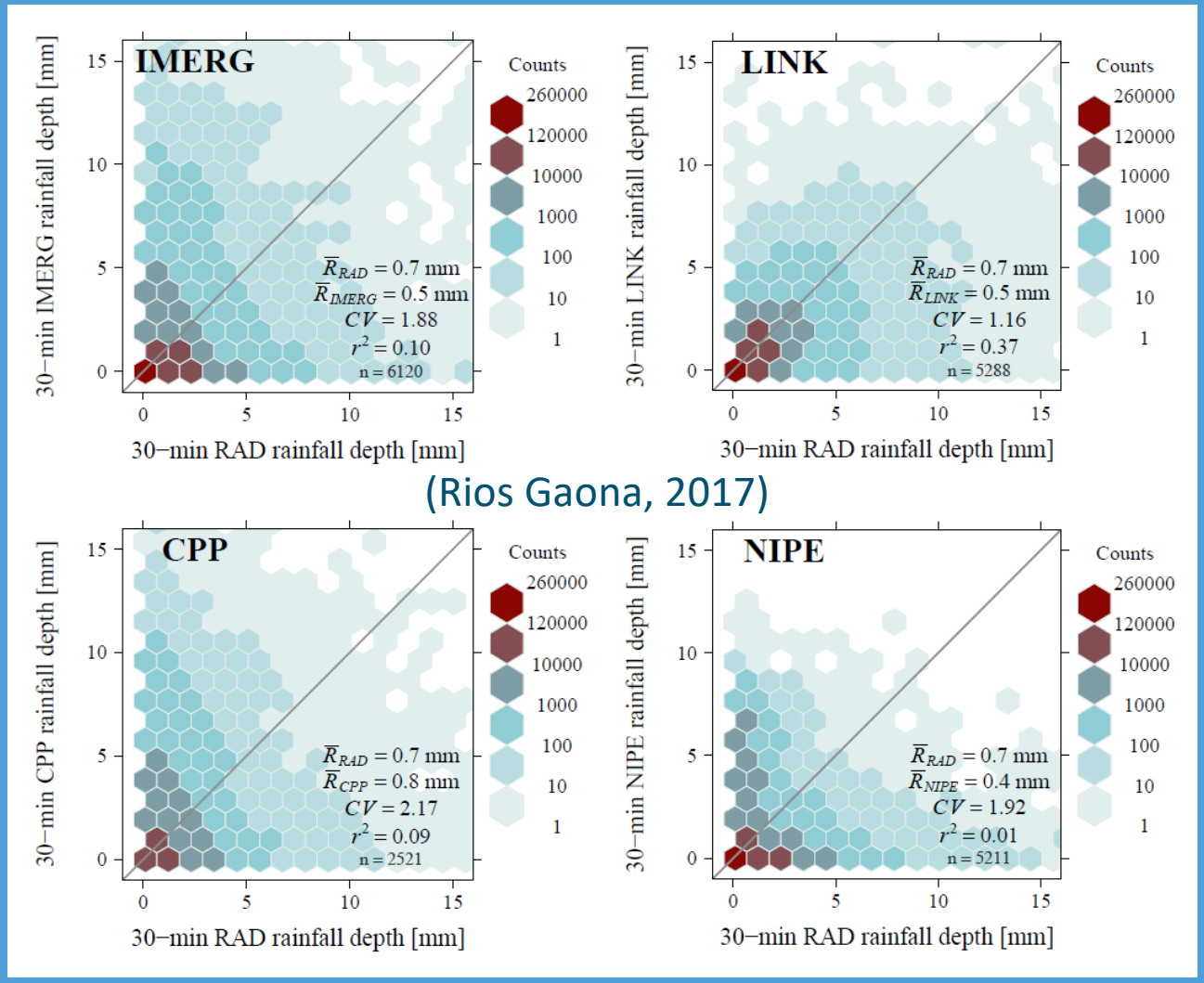
Adding microwave links to the picture

(Rios Gaona, 2017)

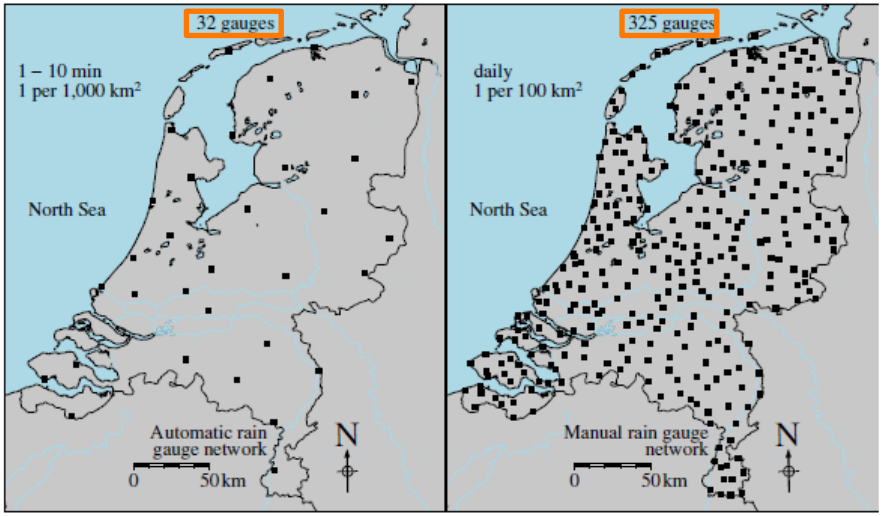




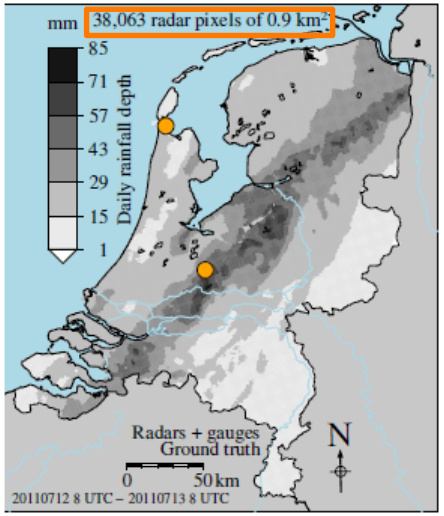
… as well as two MSG IR+VIS products



Rainfall observations in The Netherlands



Room for opportunistic sensors



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Meteorological and hydrological PMM GV

(Victoria Roberts, 2000)

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Wageningen Urban Rainfall Experiment

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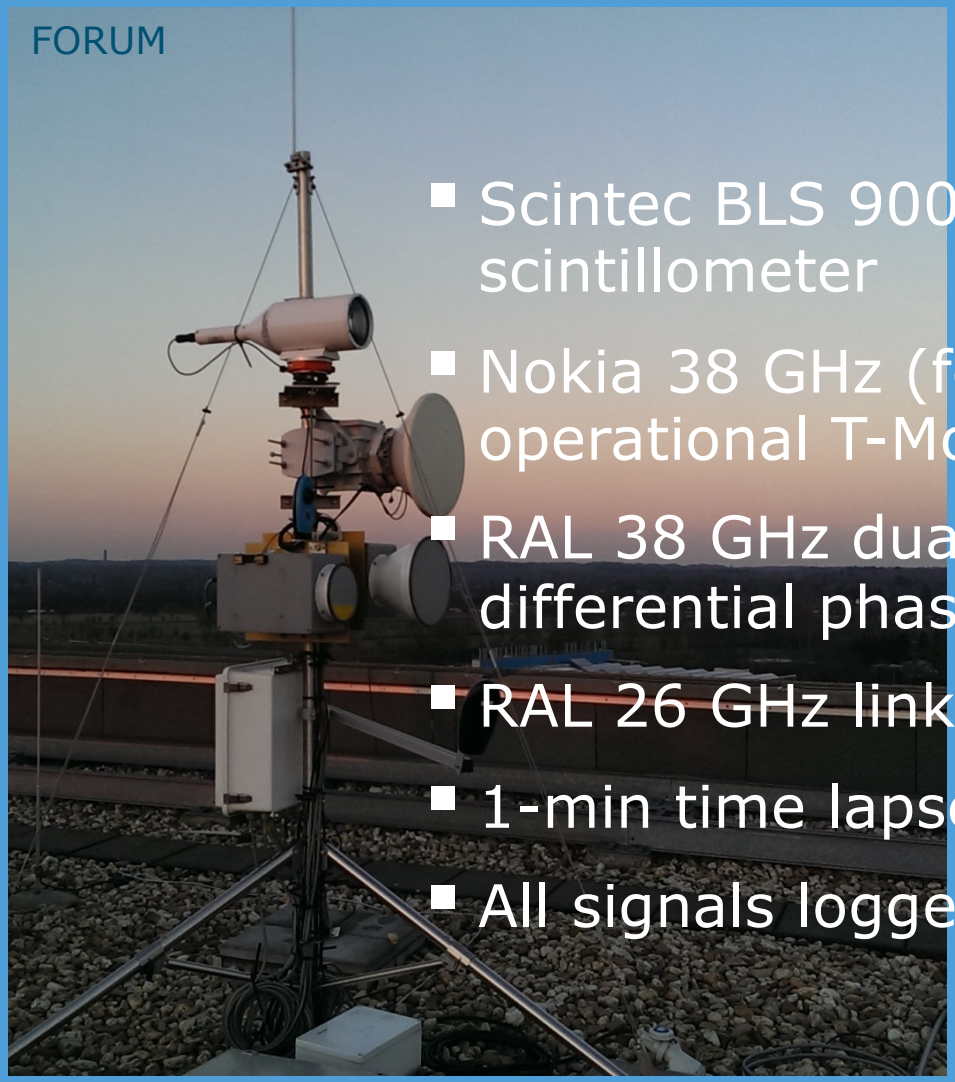
Backbone: 2.2 km multi-frequency link



- Scintec BLS 900 NIR scintillometer
- Nokia 38 GHz (former operational T-Mobile link)
- RAL 38 GHz dual-pol differential phase link
- RAL 26 GHz link
- 1-min time lapse cameras
- All signals logged at 20 Hz

(Van Leth, 2015)

Ground truth: 5 Parsivel disdrometers*

*courtesy of A. Berne, EPFL

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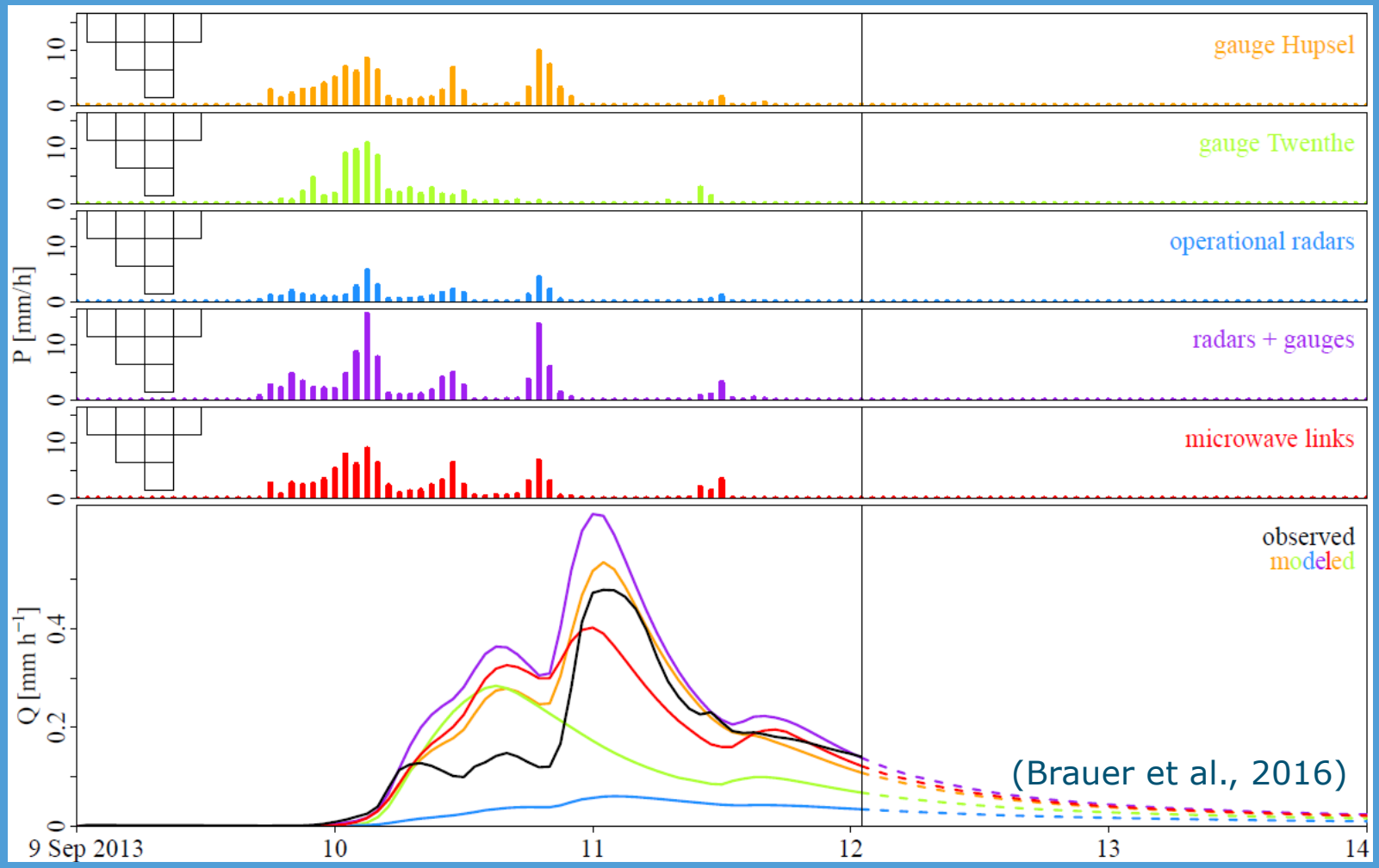
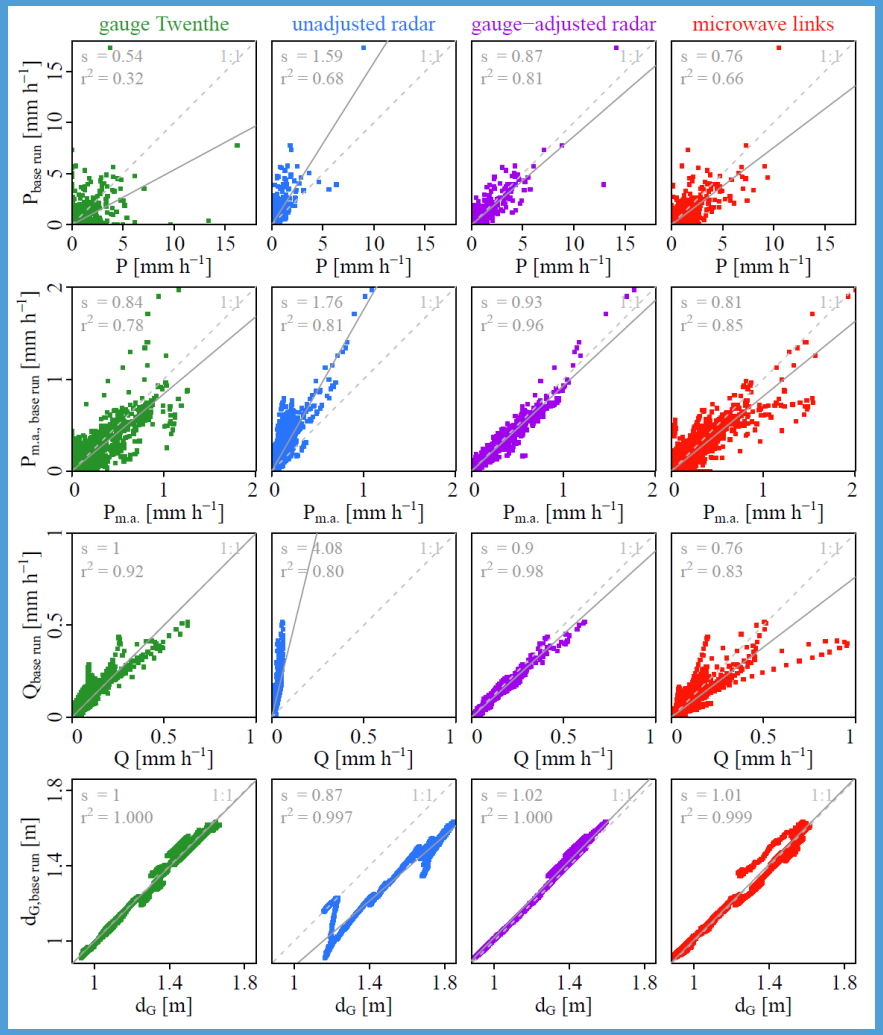
Hydrological impact Hupsel Brook



Propagation of rainfall errors in catchment



(Brauer et al., 2016)

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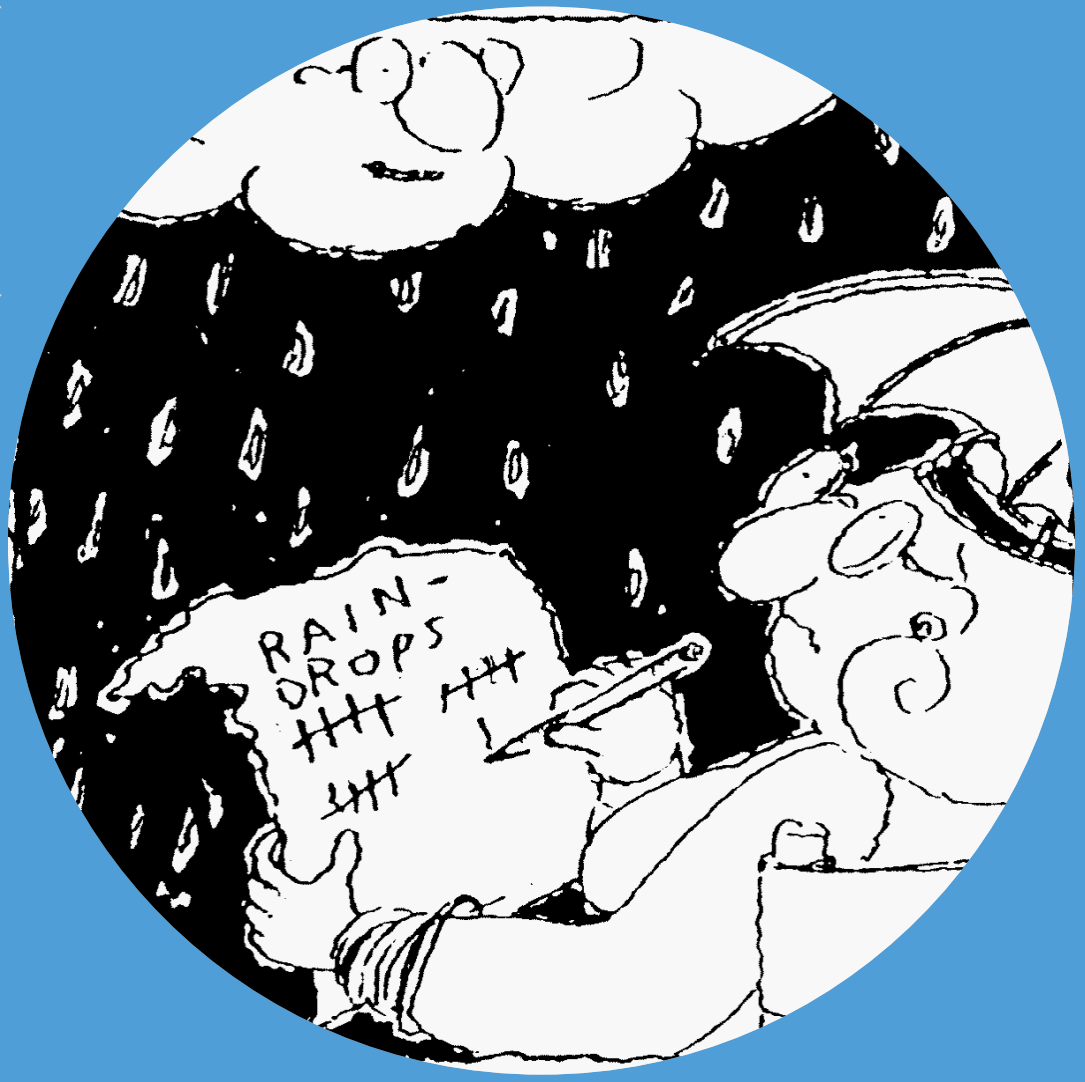
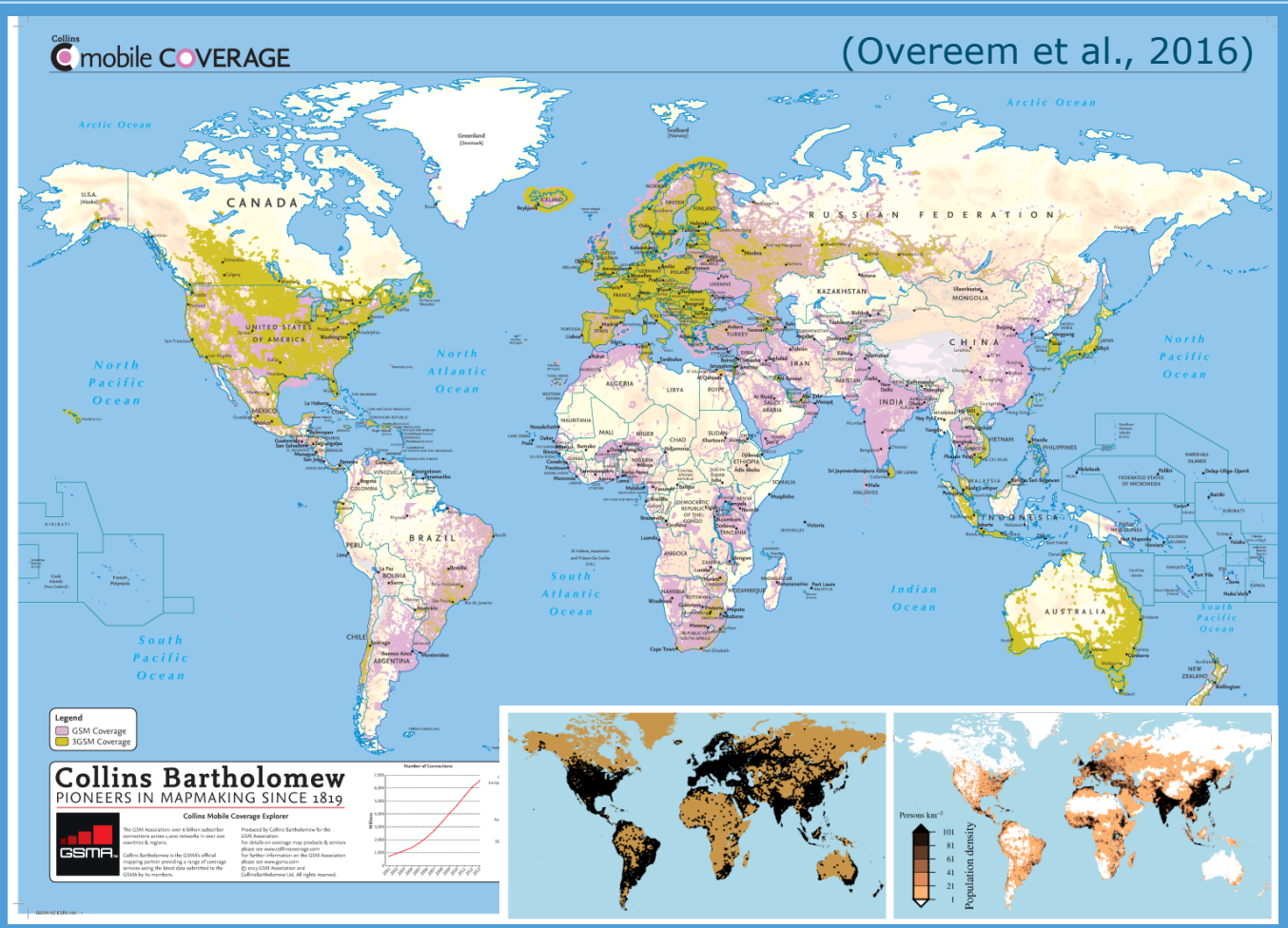
Conclusions and outlook



(Victoria Roberts, 2000)

Potential complementary source of information over poorly gauged regions



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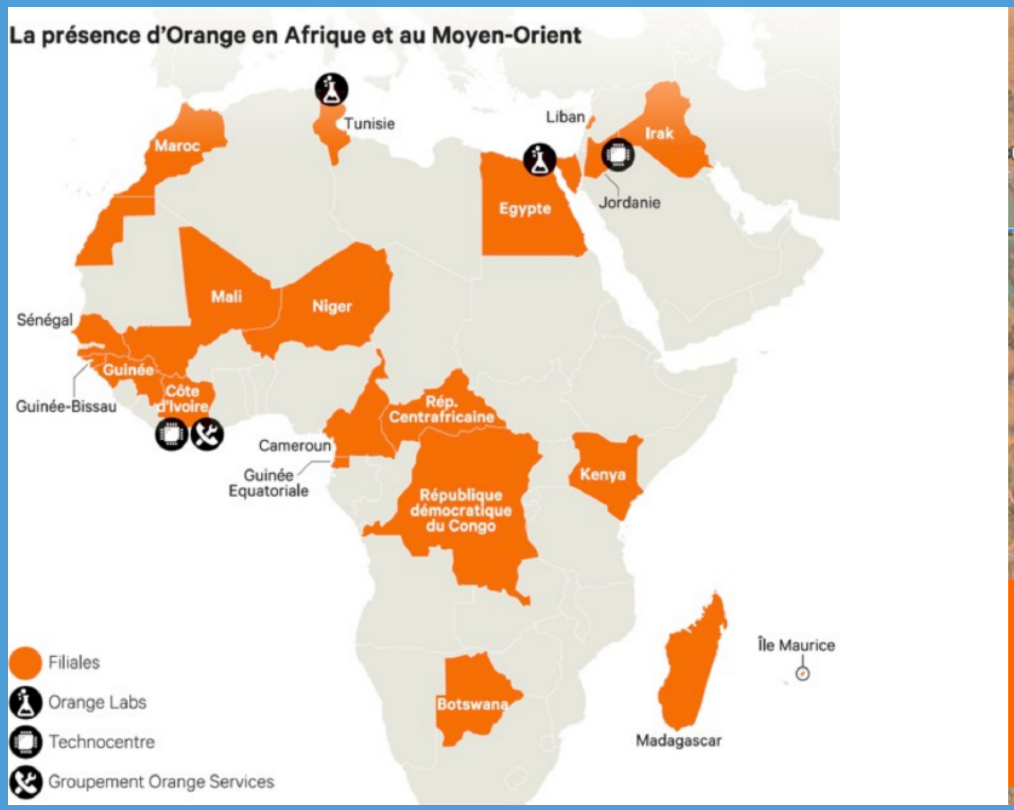
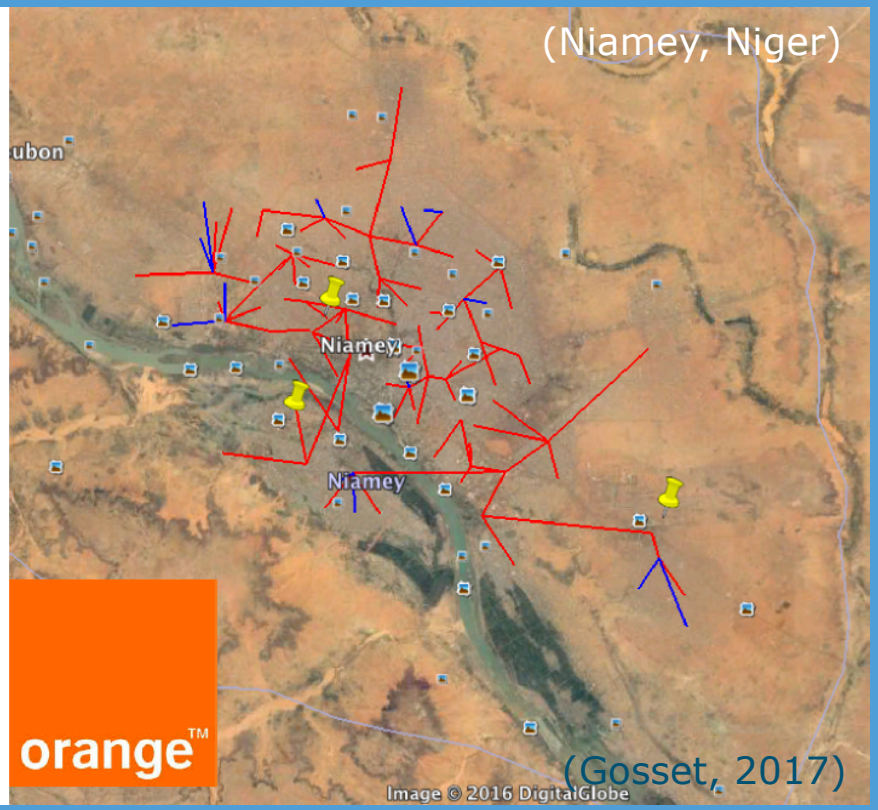
Crucial: agreement with telecom company to get access to received signal level data





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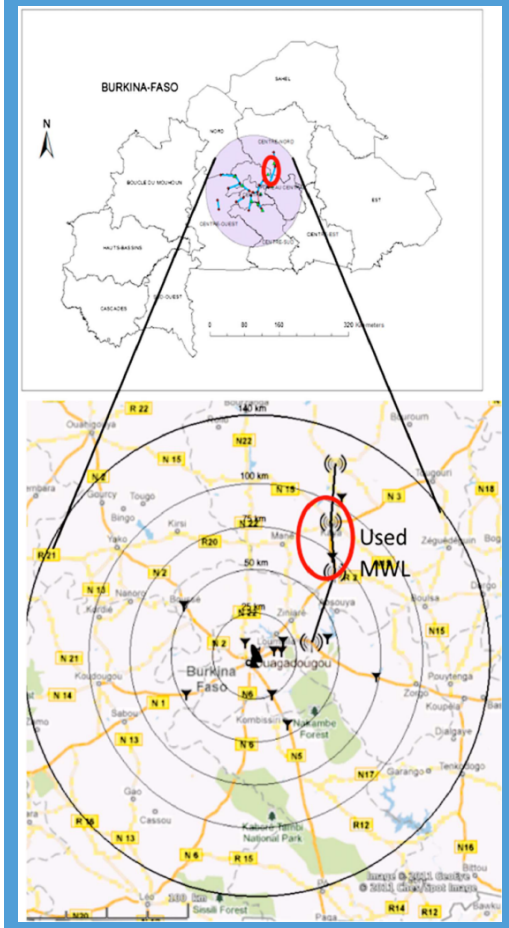
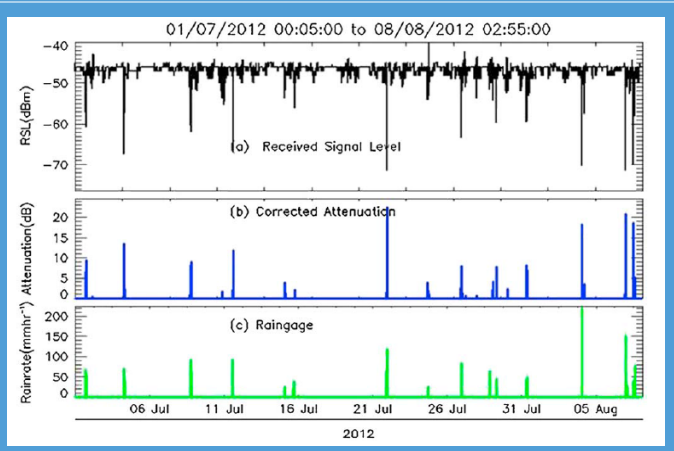
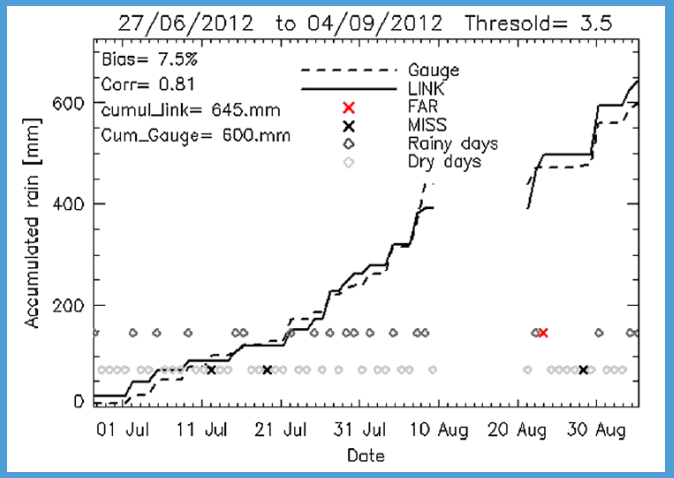
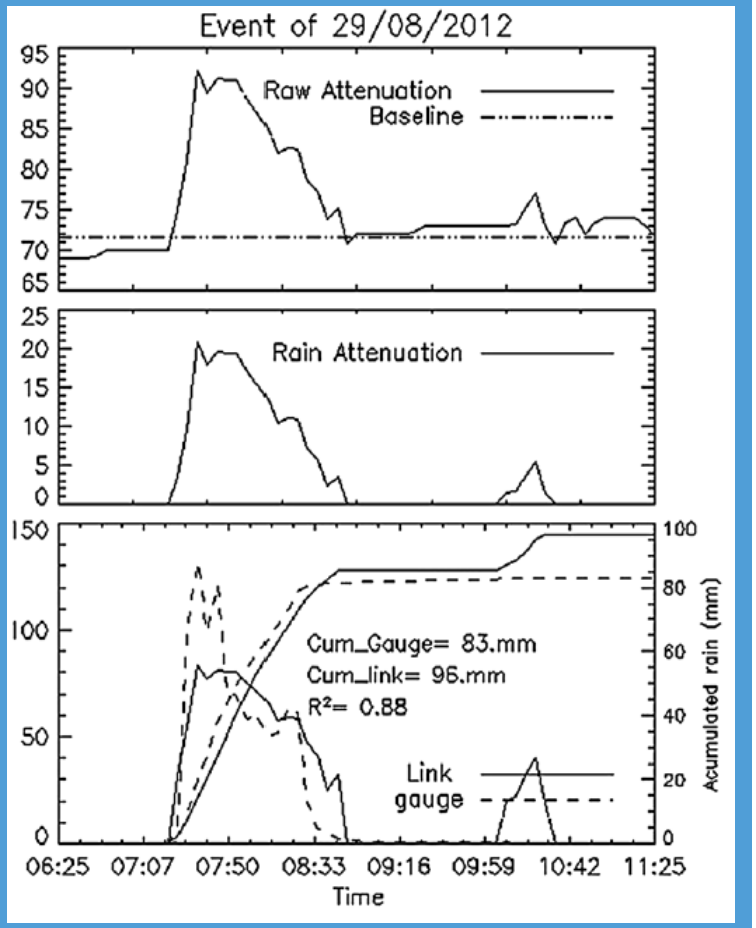
First measurements on African continent



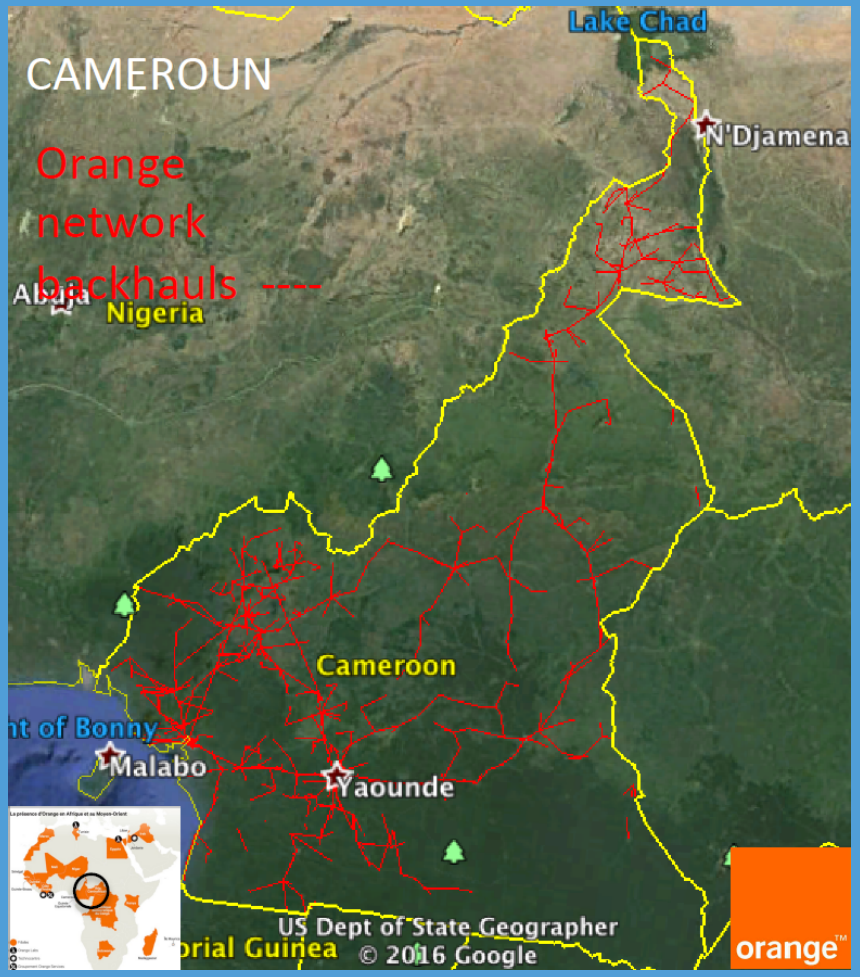


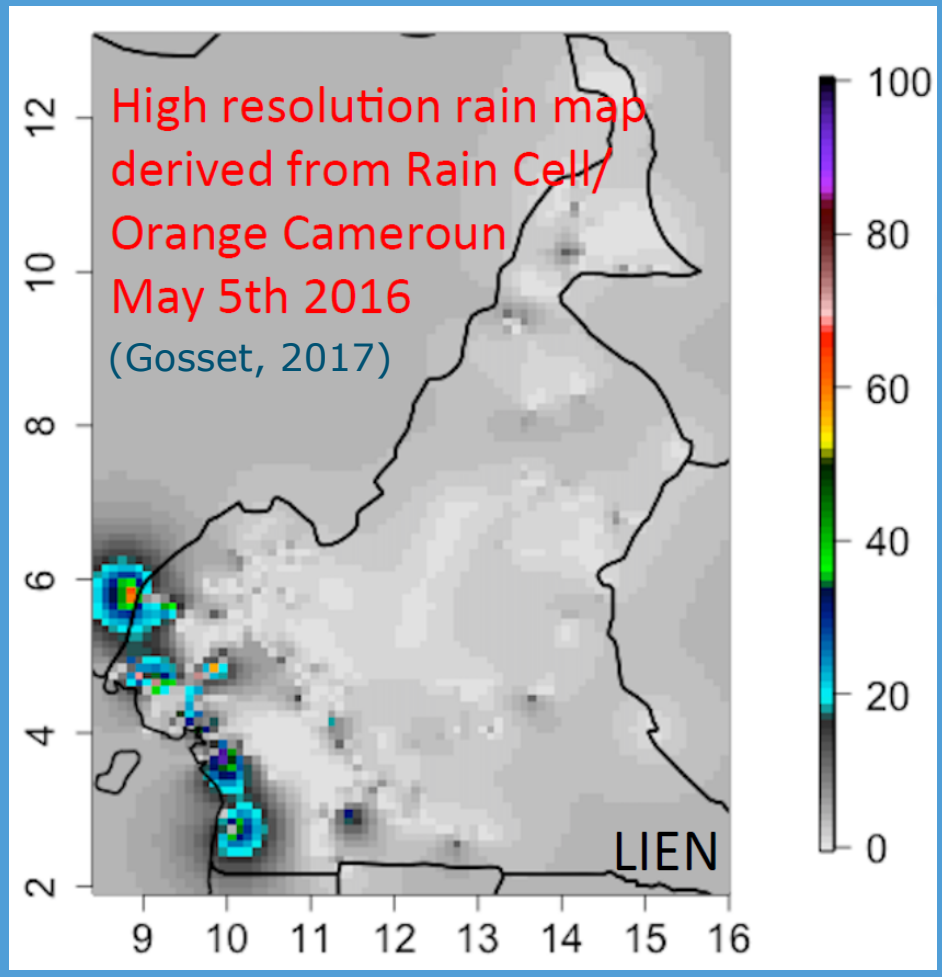




- Doumounia et al. (2014, GRL)

Country-wide rainfall map for Cameroon





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Raincell Africa Training School

(Gosset et al., 2016)

- Ouagadougou, Burkina Faso, 30 March – 2 April 2015

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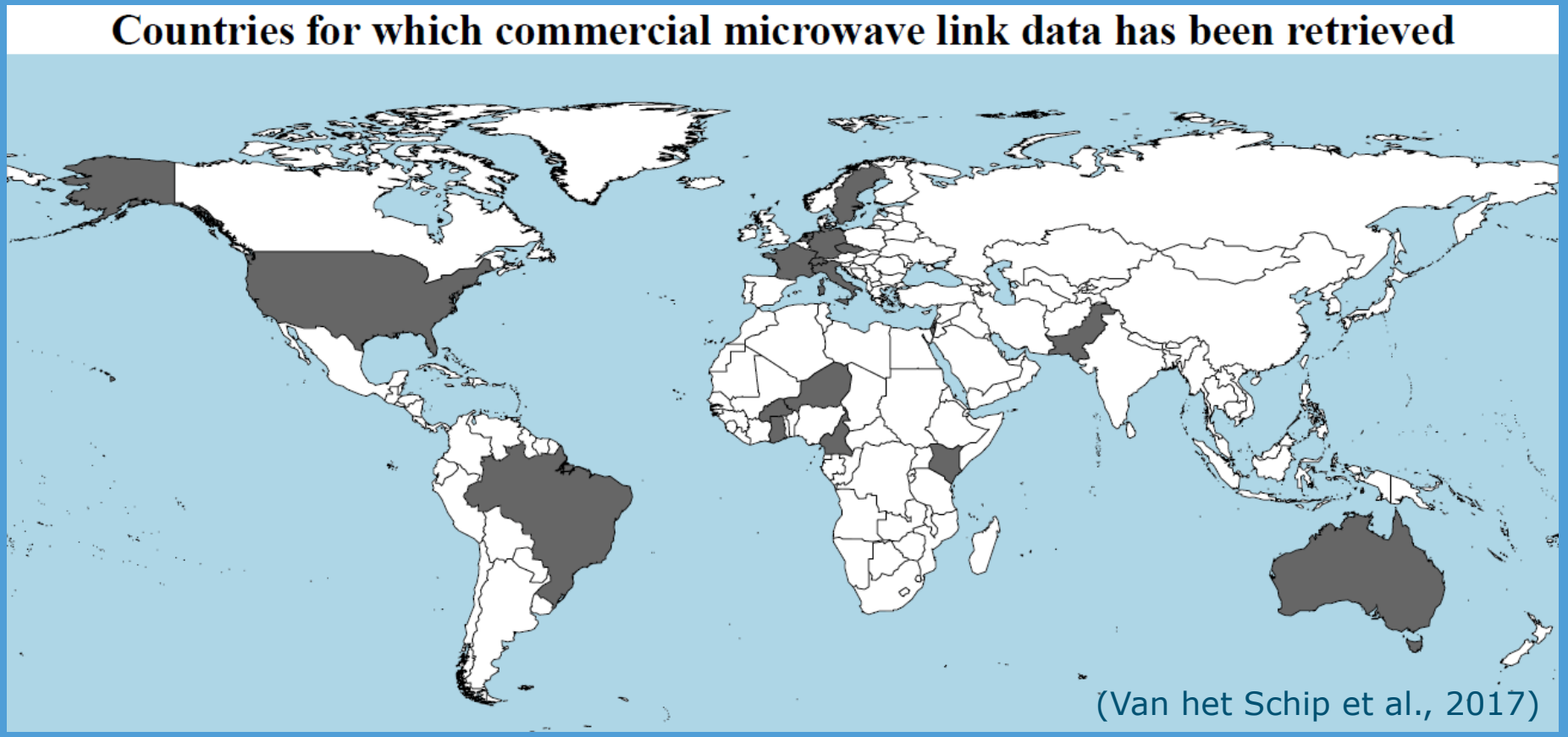
India can likely be added to this map



Semi-operational applications

- https://www.climacell.co/
- https://www.smhi.se/en/services/professional-services/micro-weather-live-data/

ATMOSPHERIC SCIENCE

Rain forecasts go mobile

Analysis of wireless communications data could give accurate weather at street level.

BY JEFF TOLLEFSON

Meteorologists have long struggled to forecast storms and flooding at the level of streets and neighbourhoods, but they may soon make headway thanks to the spread of mobile-phone networks.

The strategy relies on the physics of how water scatters and absorbs microwaves. In 2006, researchers demonstrated that they could estimate how much precipitation was falling in an area by comparing changes in the signal strength between communication towers[1]. But mobile-phone companies were reluctant to give researchers access to their signal data, and the field progressed slowly. That is changing now, enabling experiments across Europe and Africa.

The technology could lead to more-precise flood warnings — and more-accurate storm predictions if the new data are integrated into modern weather-forecasting models. Proponents also hope to use this approach to expand weather services in developing countries.

The newest entry into this field is ClimaCell, a start-up company in Boston, Massachusetts, that launched on 2 April. The 12-person firm says that it can integrate data from microwave signals and other weather observations to create more-accurate short-term forecasts. It notes it can provide high-resolution, street-level weather forecasts three hours ahead, and will aim to provide a six-hour forecast within six months. The company has yet to make information on its system public or publish it in peer-reviewed journals.

ClimaCell will start in the United States and other developed countries, but plans to move into developing countries, including India, later this year. "The signals are everywhere, so basically we want to cover the world," says Shimon Elkabetz, ClimaCell's chief executive and co-founder.

But the fledgling company faces competition from researchers in Europe and Israel who have tested systems at multiple scales, including countries and cities, over the past several years. The scientists recently formed a consortium to advance the technology using open-source software. Coordinated by Aart Overeem, a hydrometeorologist at the Royal Netherlands Meteorological Institute in De Bilt, the group is seeking nearly €5 million (US$5.3 million) from the European Commission to create a prototype rainfall-monitoring system that could eventually be set up across Europe and Africa.

"There is a lot of evidence that this technology works, but we still need to test it in more regions with large data sets and different networks," Overeem says. Although ClimaCell has made bold claims about its programme, Overeem says he cannot properly review the

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Some relevant reports

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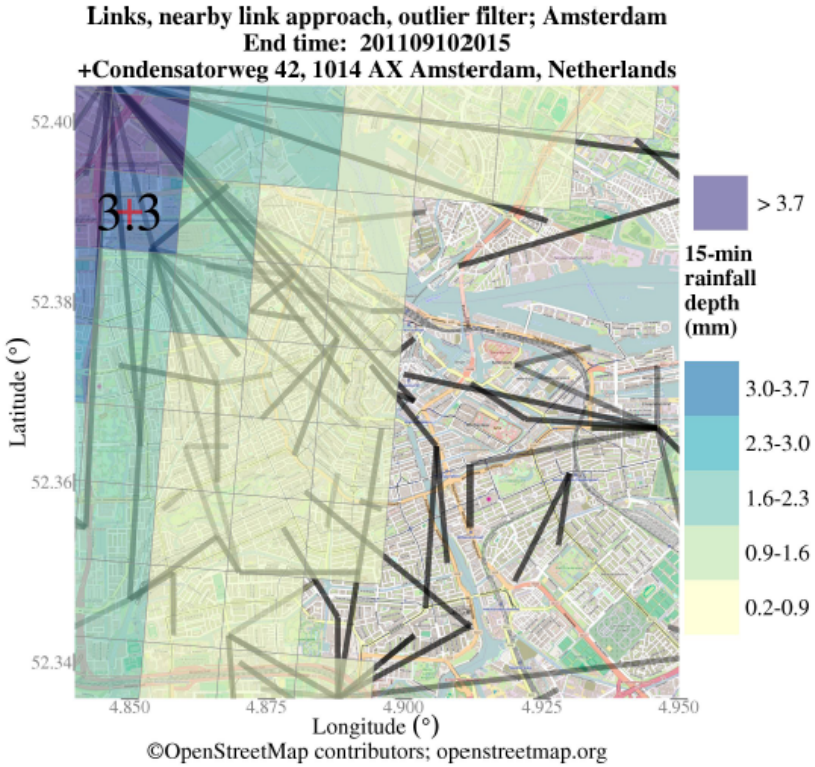
Applicability - R package "RAINLINK"



(Overeem *et al.*, 2016a)

- Rainfall retrieval algorithm
- Rainfall interpolation & visualisation
- A sample link data set
- Code freely available

- https://github.com/overeem11/RAINLINK

Remko.Uijlenhoet
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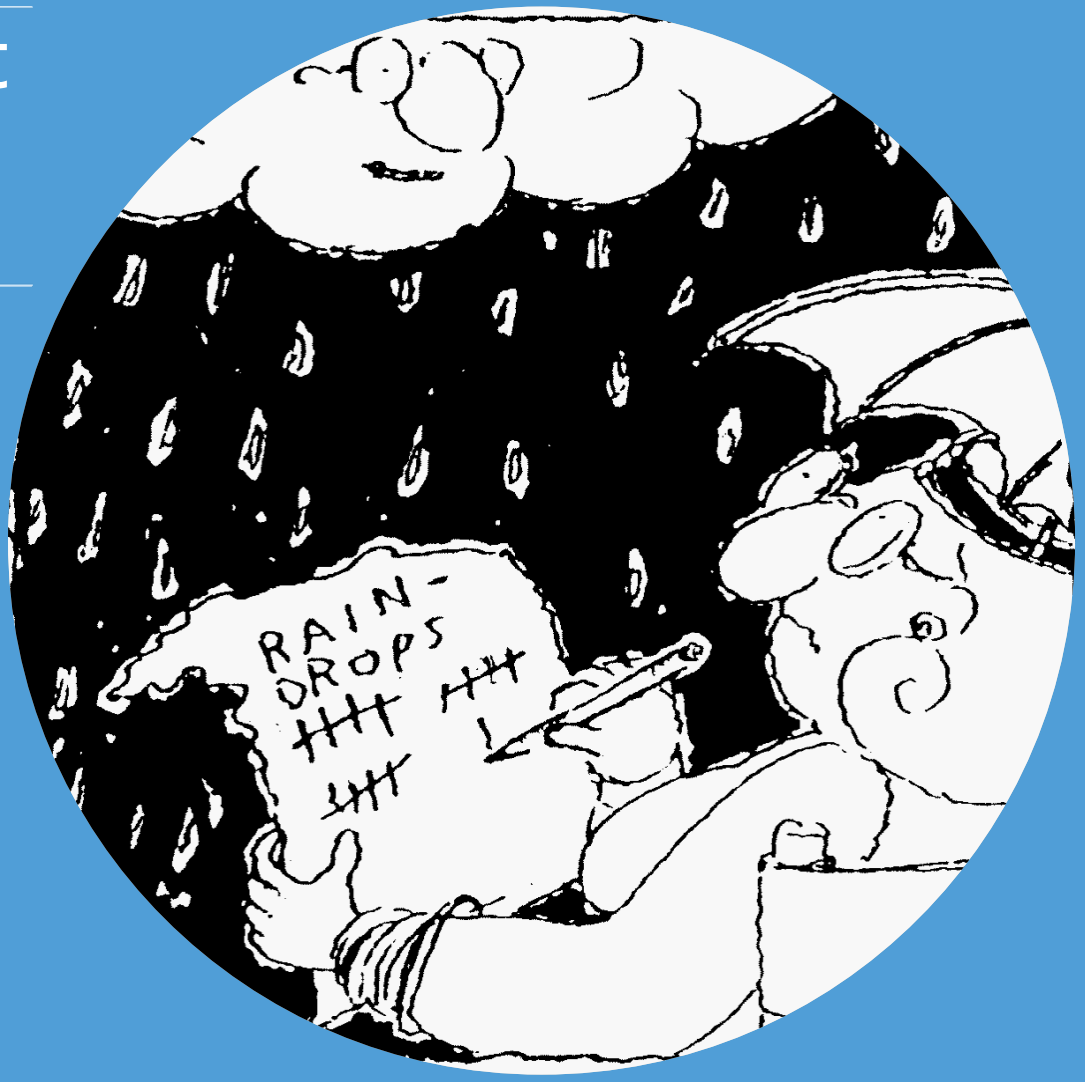

(Victoria Roberts, 2000)

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