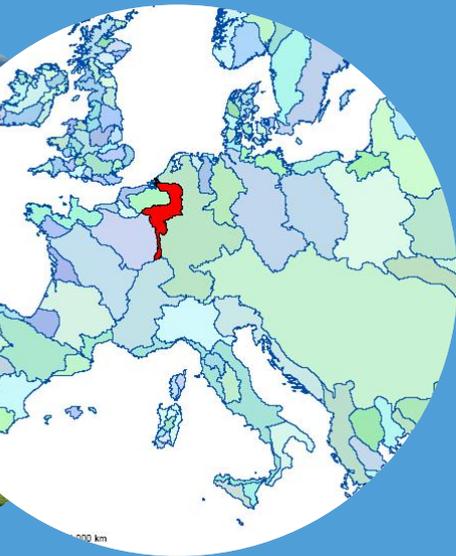
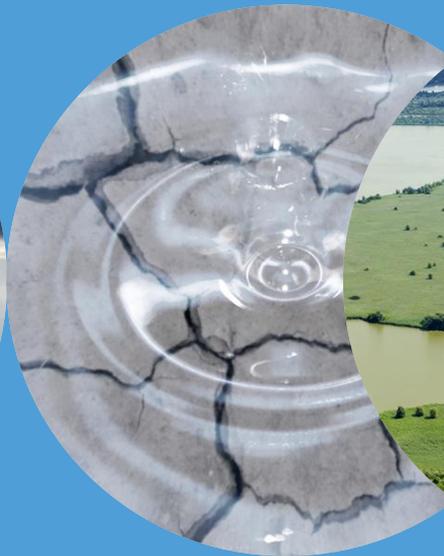


Remote sensing of rainfall: A challenge for meteorology and hydrology

Remko Uijlenhoet

Hydrology and Quantitative Water Management group



Motivation for remote sensing of rainfall



(Victoria Roberts, 2000)

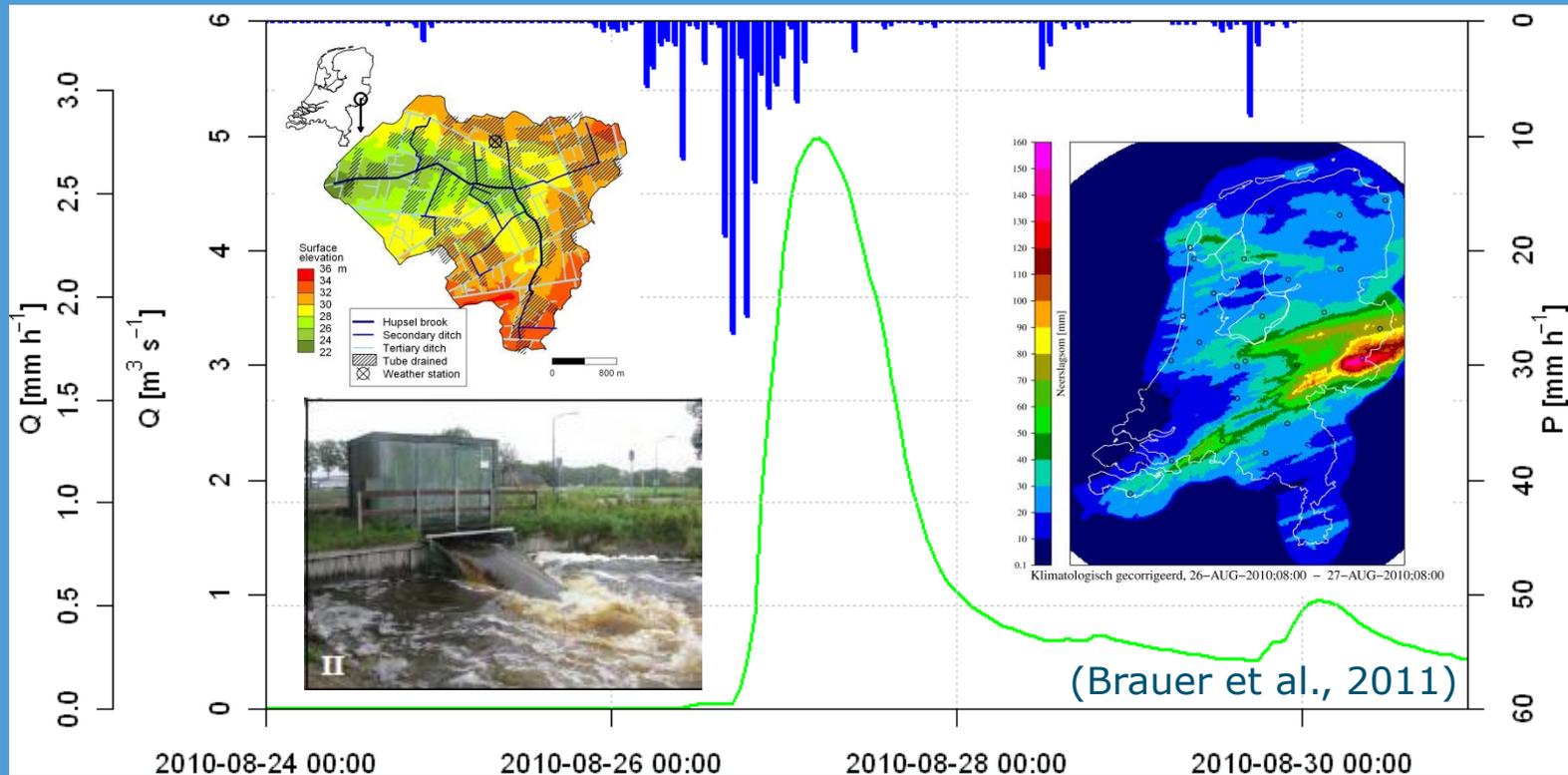


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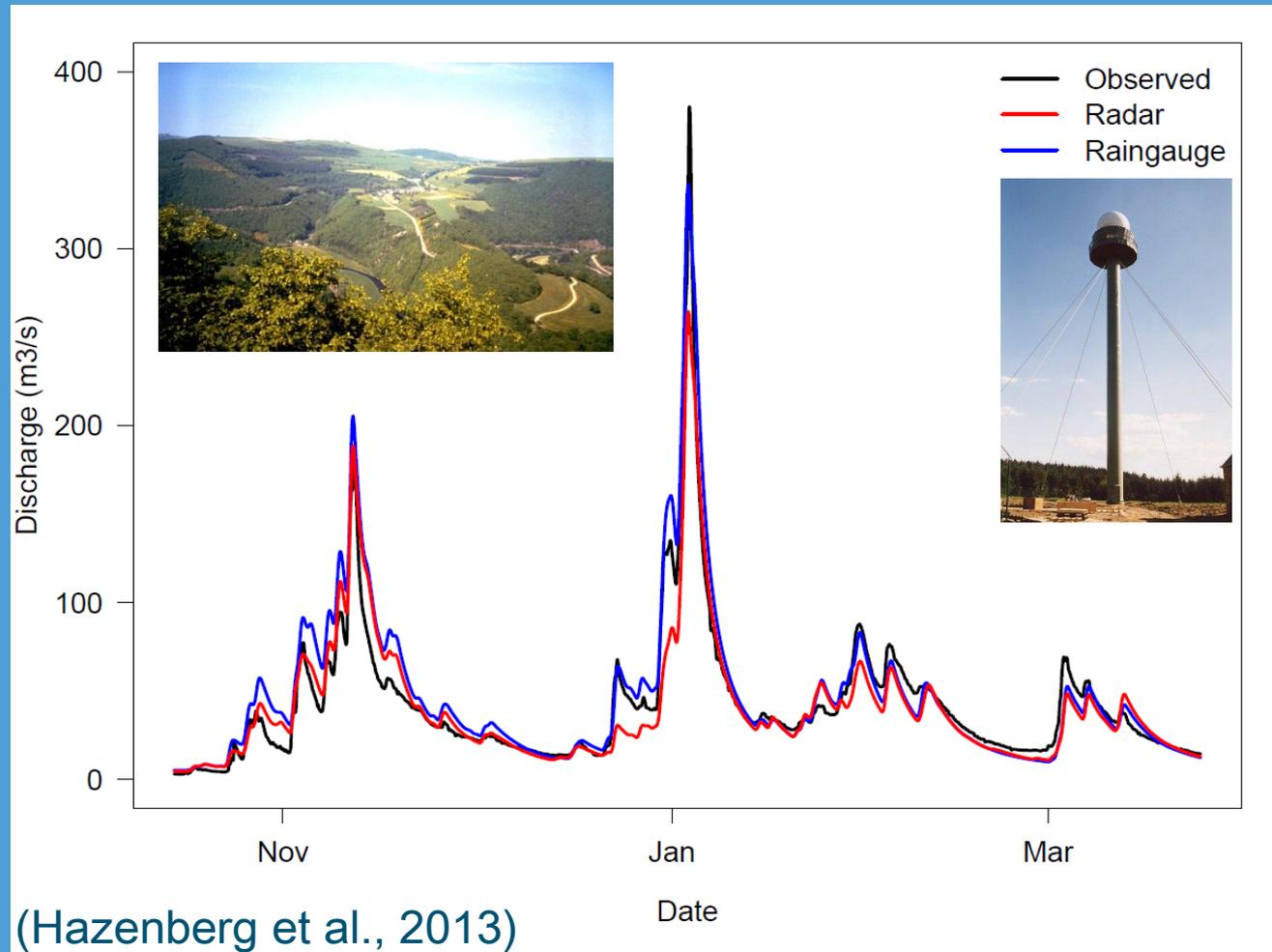
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Hydrological process understanding



- 6.5 km² Hupsel Brook catchment, 26 August 2010: almost 160 mm of rain in 24h!

Catchment rainfall-runoff modeling

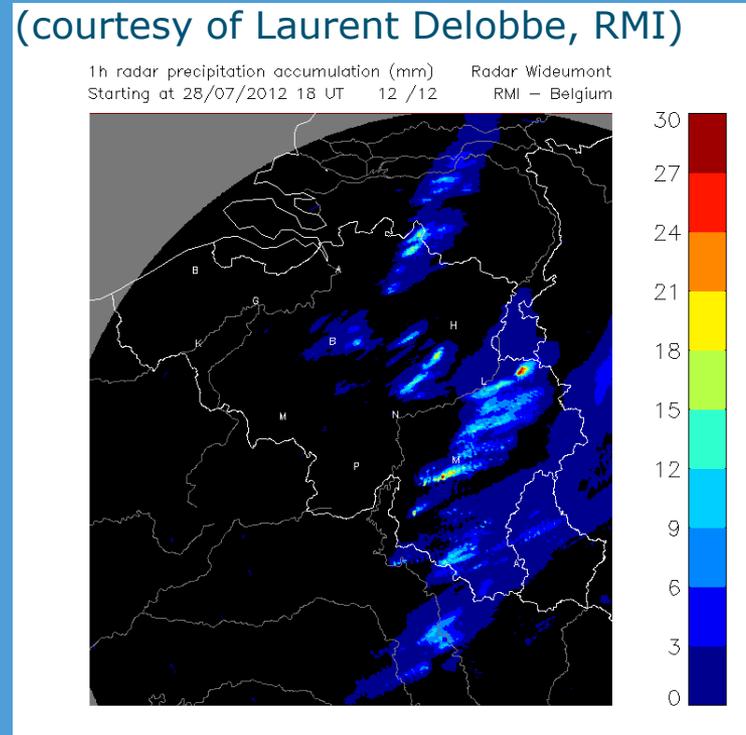


- 1600 km² Ourthe catchment (tributary of Meuse)



Flood forecasting / early warning

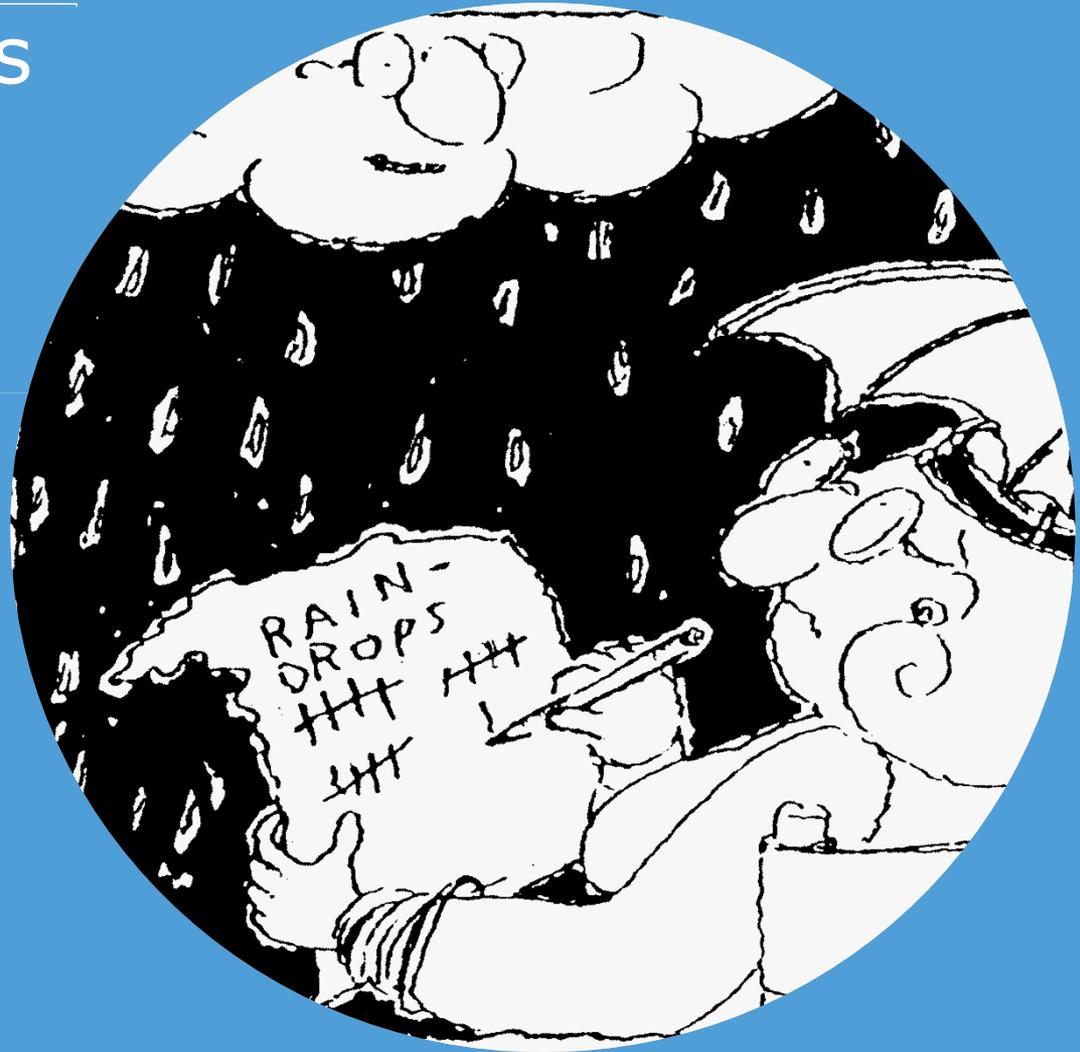
- 28–29 July 2012, Gulp (tributary to Geul) catchment



Slenaken flash flood (29 July 2012)



Rainfall properties of importance for remote sensing



(Victoria Roberts, 2000)



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Rainfall microstructure

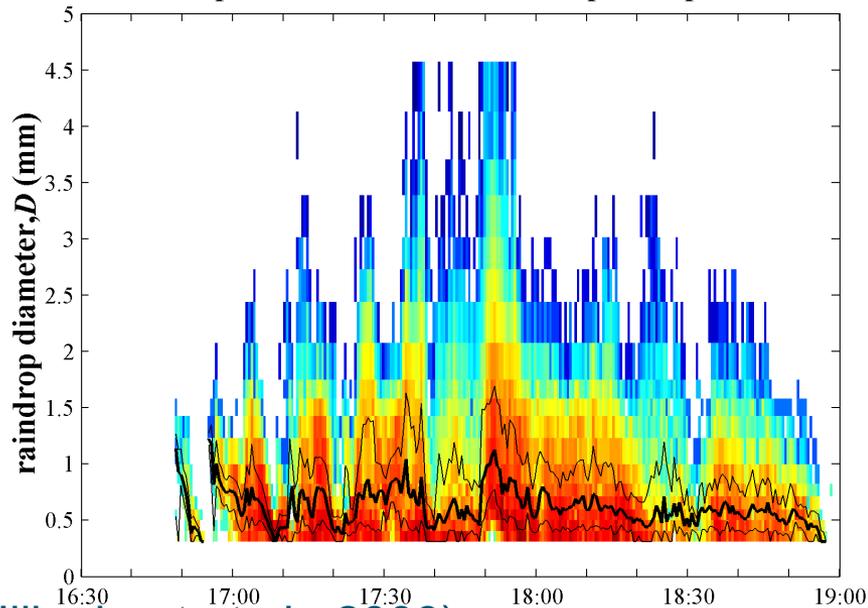


- Measurements of raindrop size distributions at Cabauw Experimental Site for Atmospheric Research (CESAR)

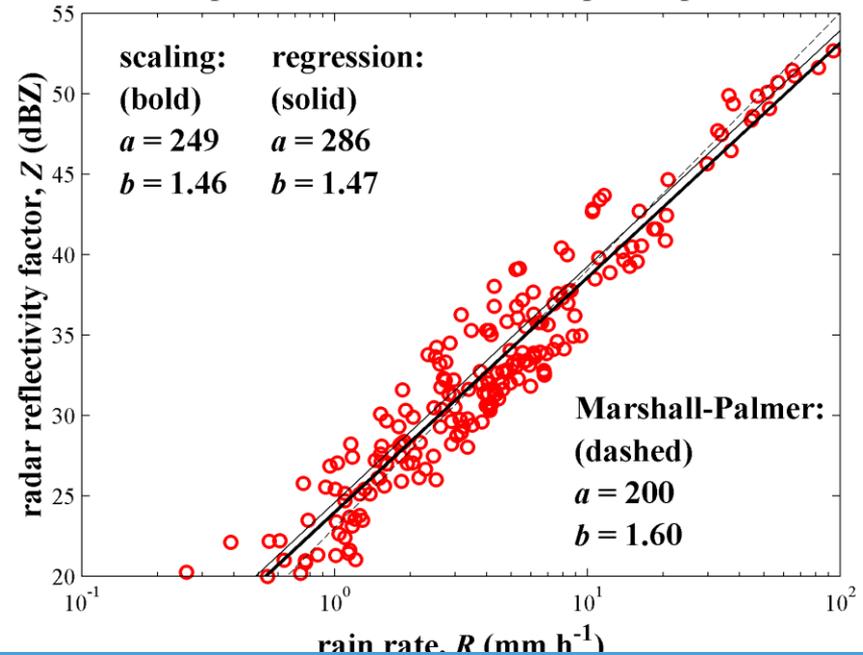


Rainfall retrieval algorithms for ground-based and spaceborne remote sensors

7 September 2002: 258 raindrop size spectra



7 September 2002: 240 raindrop size spectra

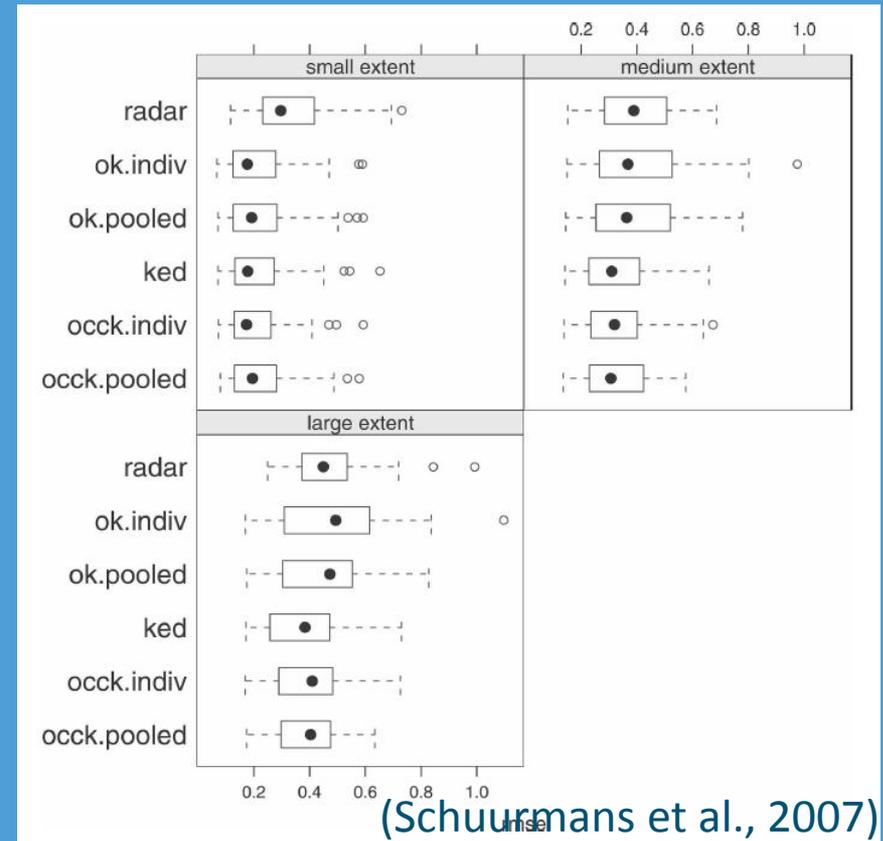
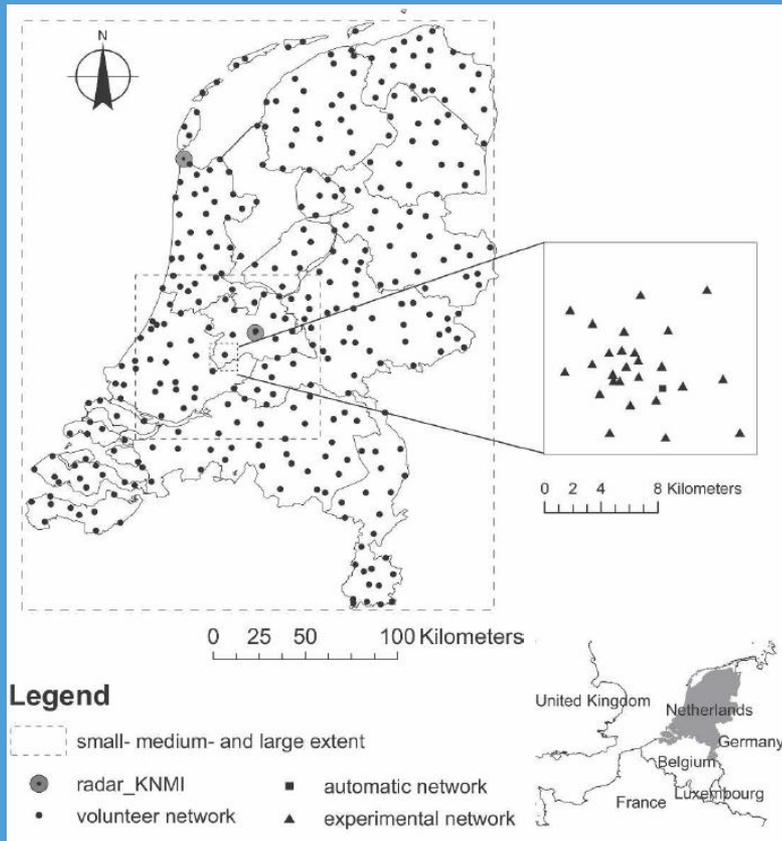


(Uijlenhoet et al., 2003)



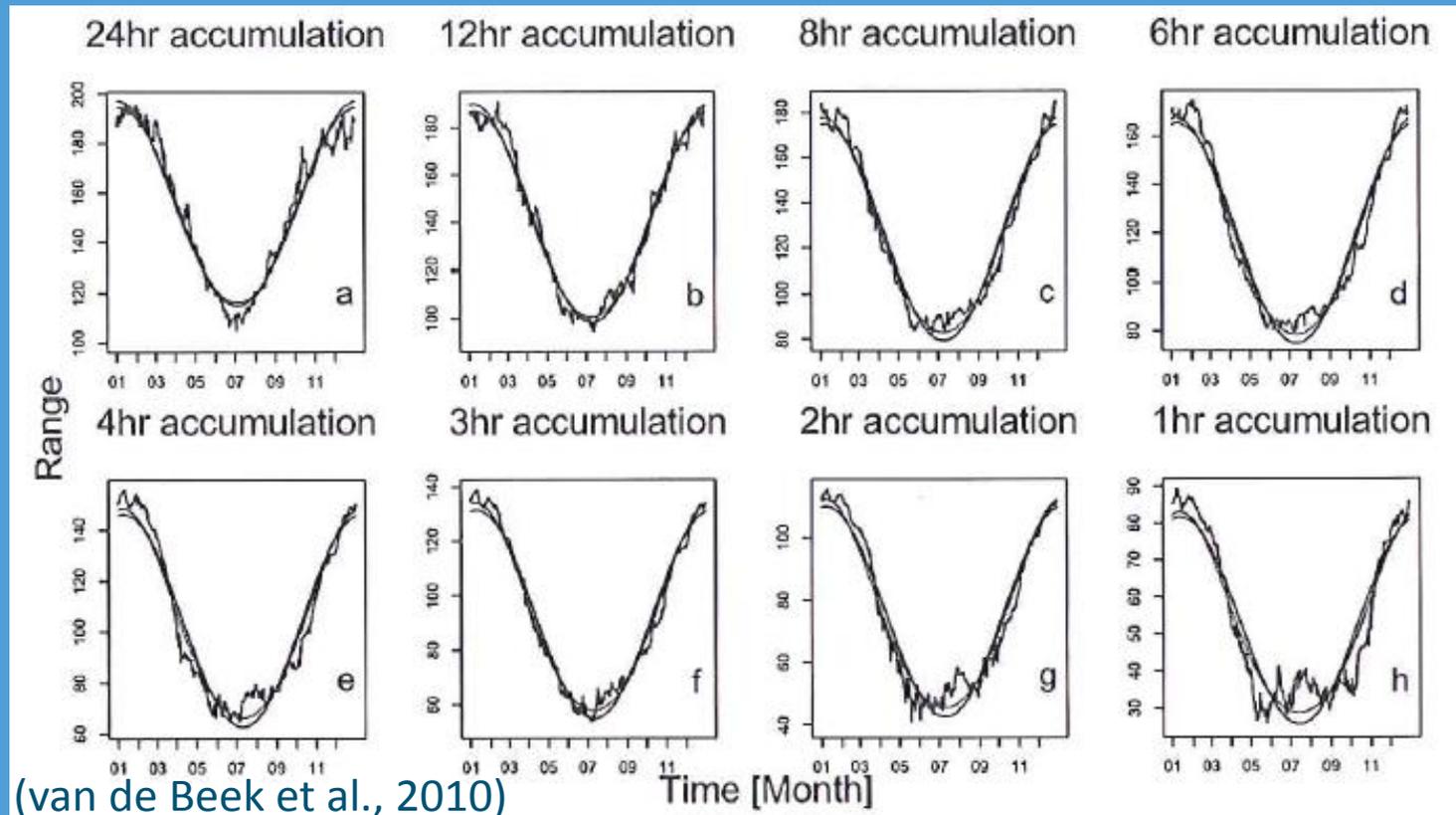
Rainfall macrostructure

- Nested networks; 30 rain gauges within 225 km²



- Small extent: ~200 km²; medium extent: ~10,000 km²; large extent: ~80,000 km²

Parameterization of rainfall decorrelation



(decorrelation distance: $r_{\Delta t} / r_{24} = (\Delta t / 24)^{0.34}$, if Δt in h)

Current research themes and operational challenges



(Victoria Roberts, 2000)

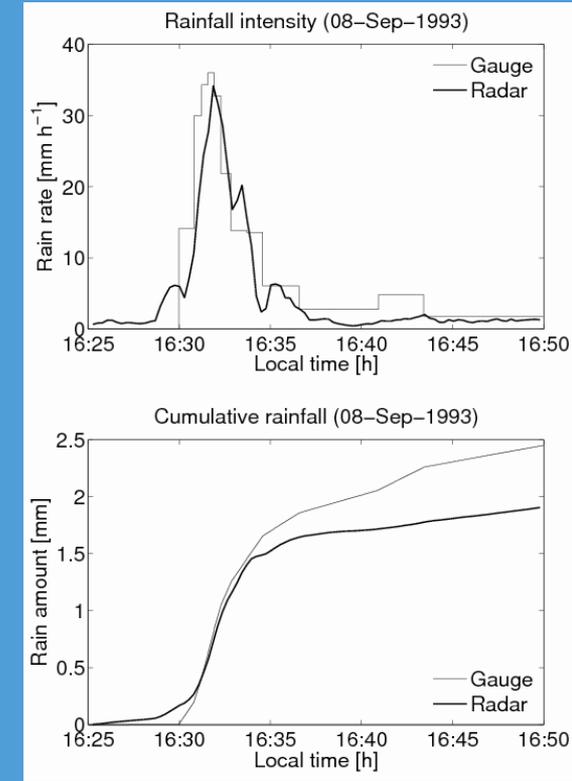
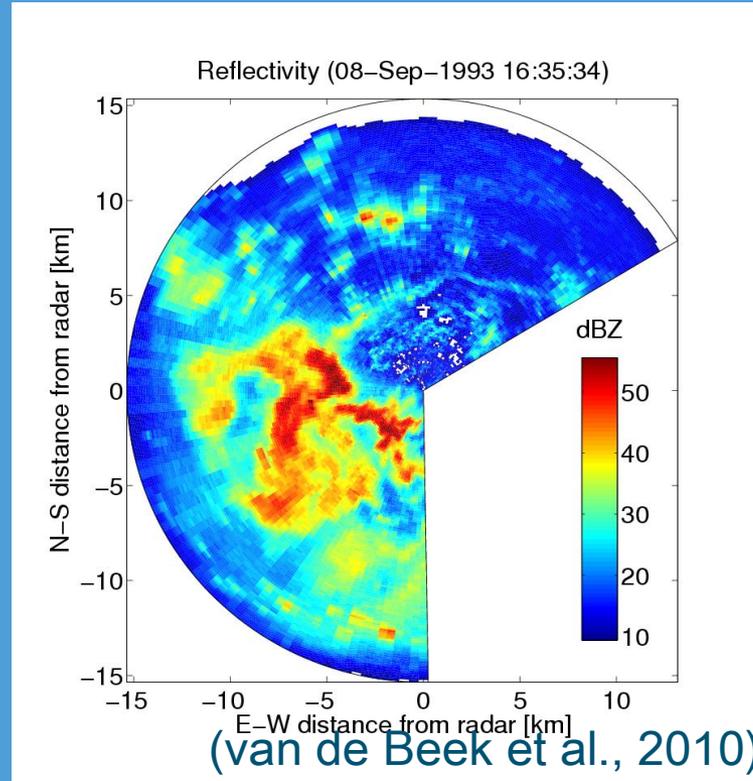


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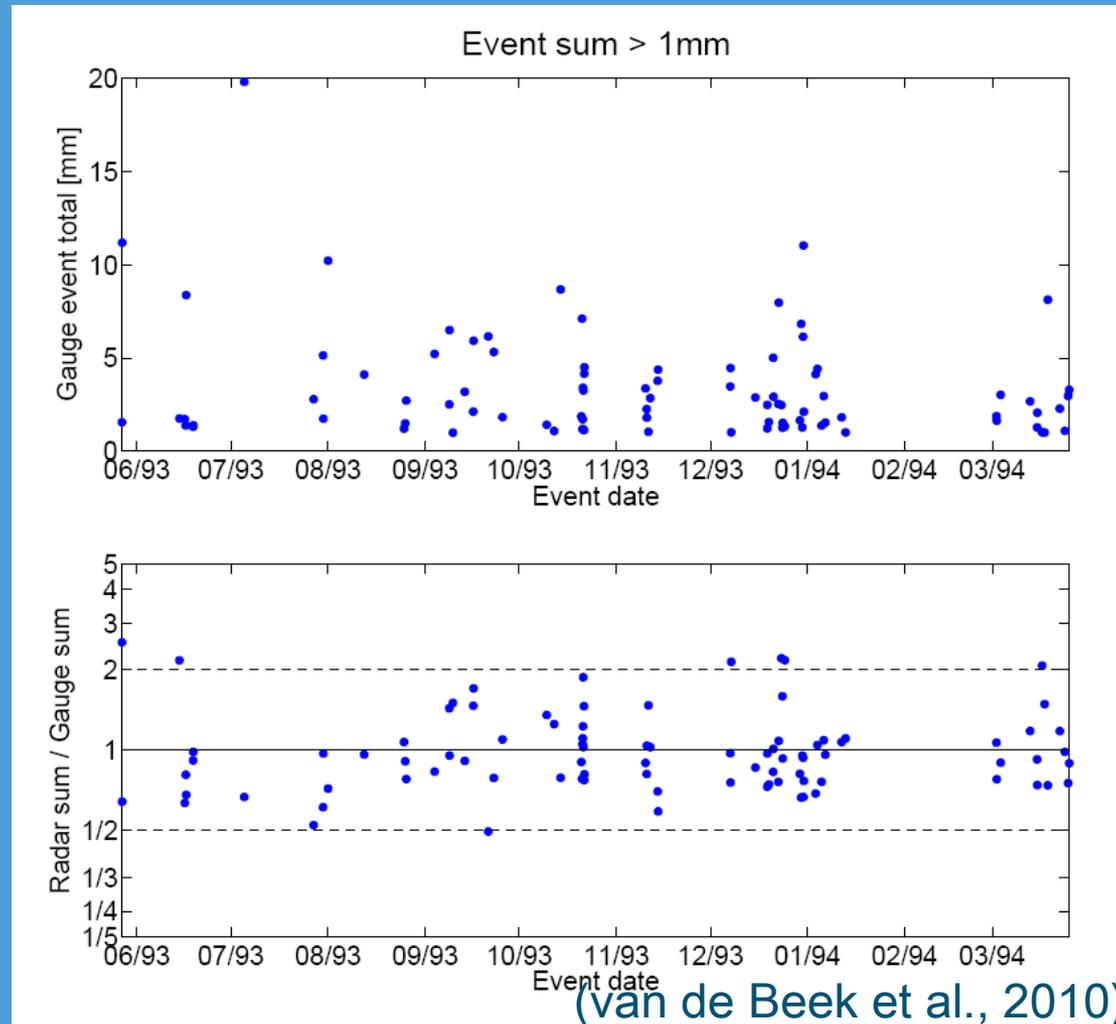
Local high-resolution radar



- IDRA, Cabauw (before: SOLIDAR, Delft)

Long-term radar – rain gauge comparison

- 195 events
(>30 min)



(van de Beek et al., 2010)



Global Precipitation Measurement mission

- ≤ 3 h revisit time for 90% of the globe
- Foot print of ~ 5 km
- Challenge: sampling uncertainties for typical revisit times and foot prints of GPM mission
- Approach: simulation with long-term ground-based radar data set

(NASA,
<http://pmm.nasa.gov/GPM>)

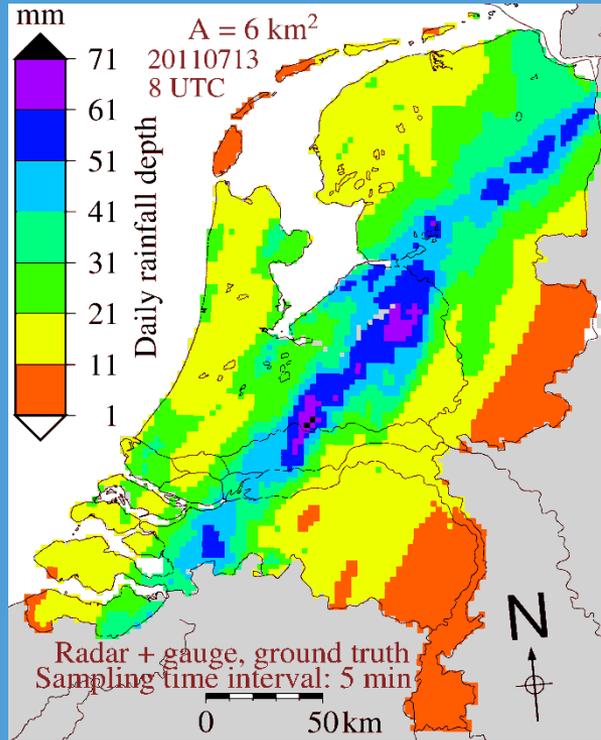


Climatological radar rainfall data set

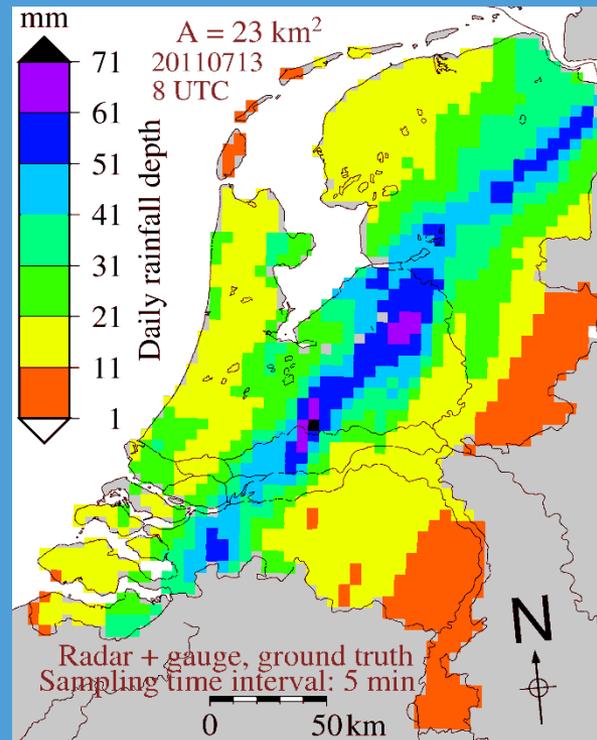
- Based on pseudo CAPPI data from two C-band Doppler weather radars
- High resolution: 7 – 55 dBZ with 0.5 dBZ interval
- Temporal resolution: 5 min
- Spatial resolution: 2.4 km × 2.4 km
- Adjusted using rain gauge data
- Covers land surface of the Netherlands (35 500 km²)
- Period: 1998–2011 (14 years)
- ~85% data availability, i.e. 12 years of data
- Overeem *et al.* 2009 JAMC/WRR; 2010 WRR



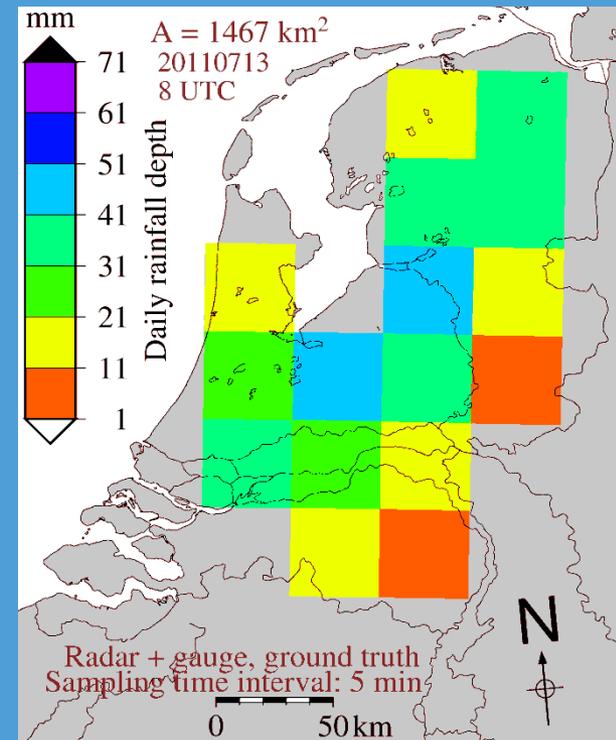
Assume radar data footprint of satellite



Original



2 × 2 pixels

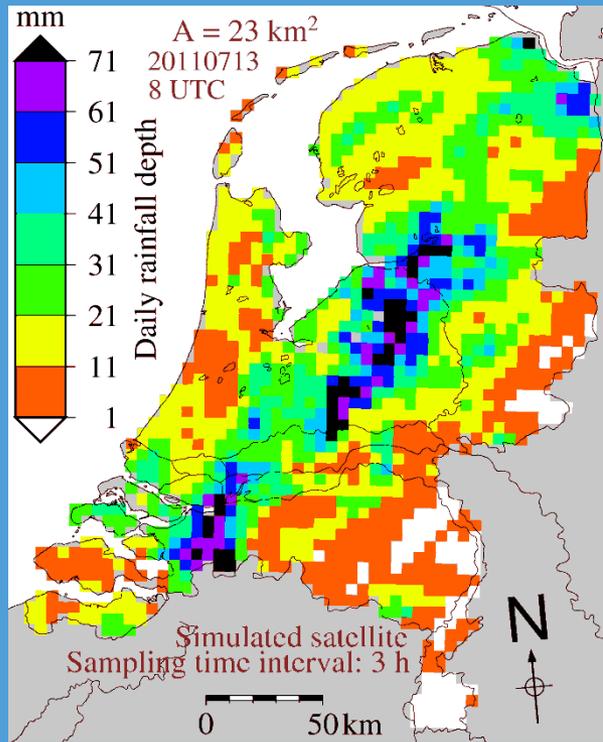


16 × 16 pixels

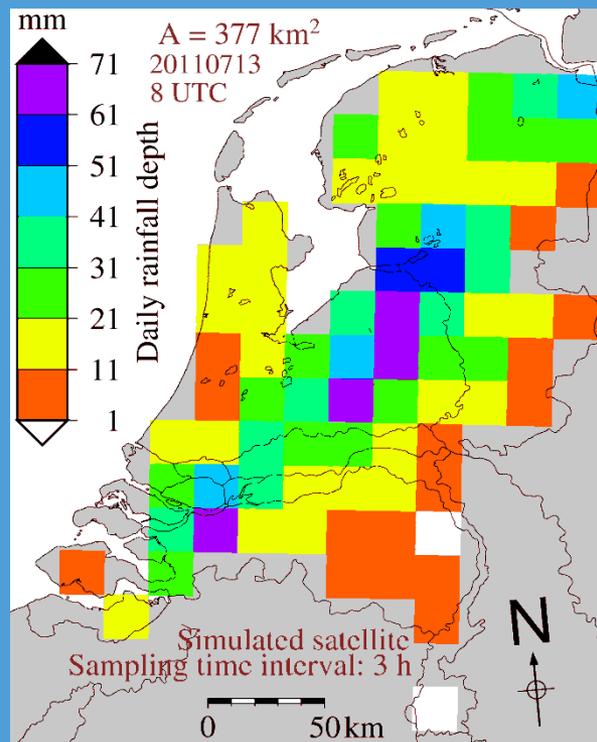
Increasing foot print



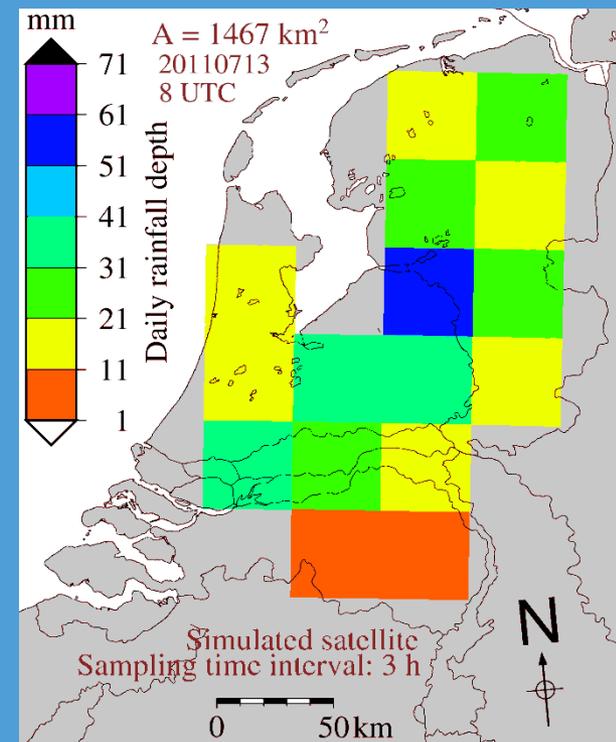
Simulate satellite data, 3 h revisit time



2 × 2 pixels



8 × 8 pixels

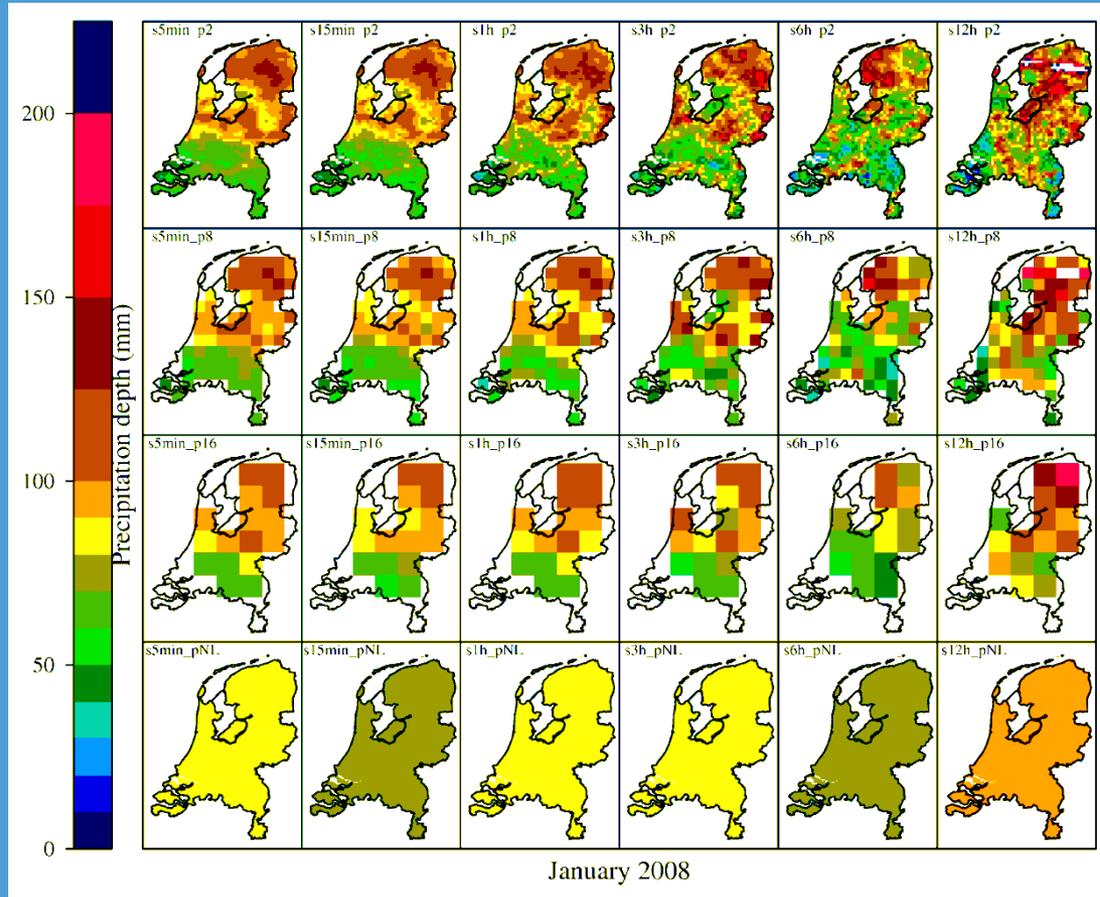


16 × 16 pixels

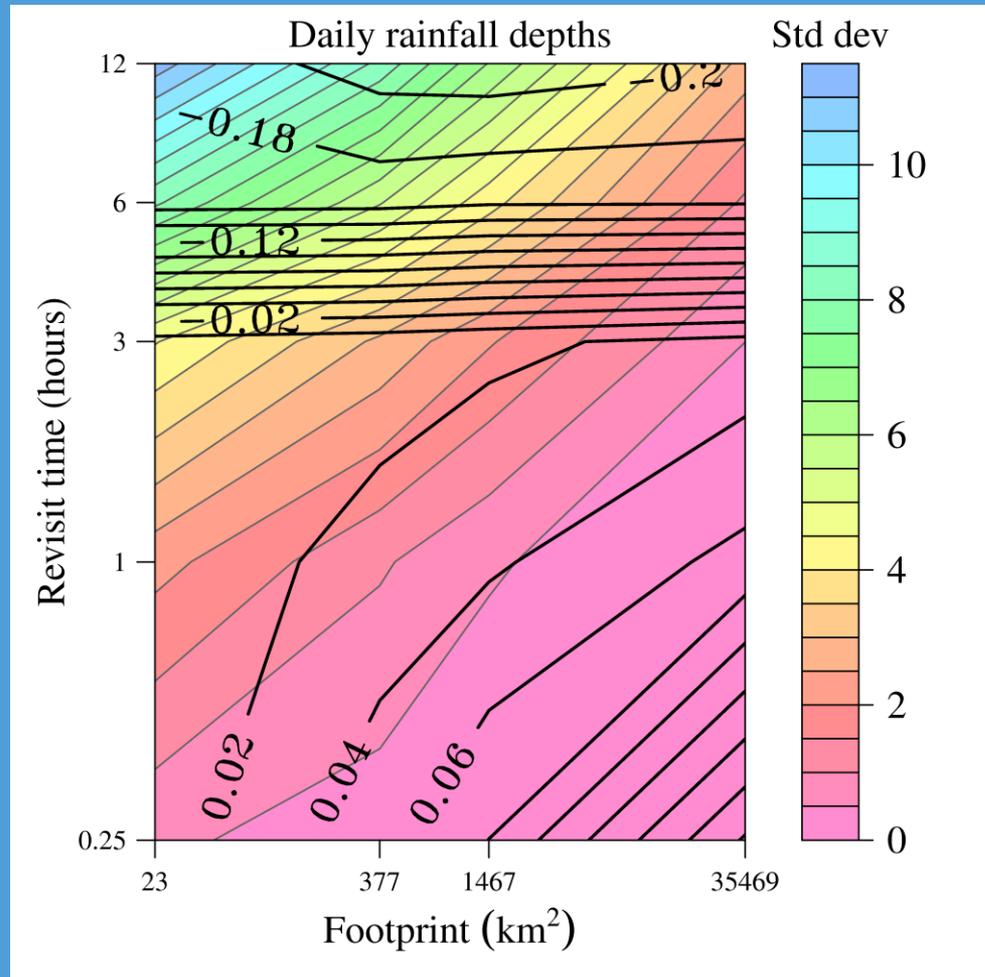
Increasing foot print



Monthly rainfall depth January 2008



Std dev and bias of daily rainfall depths



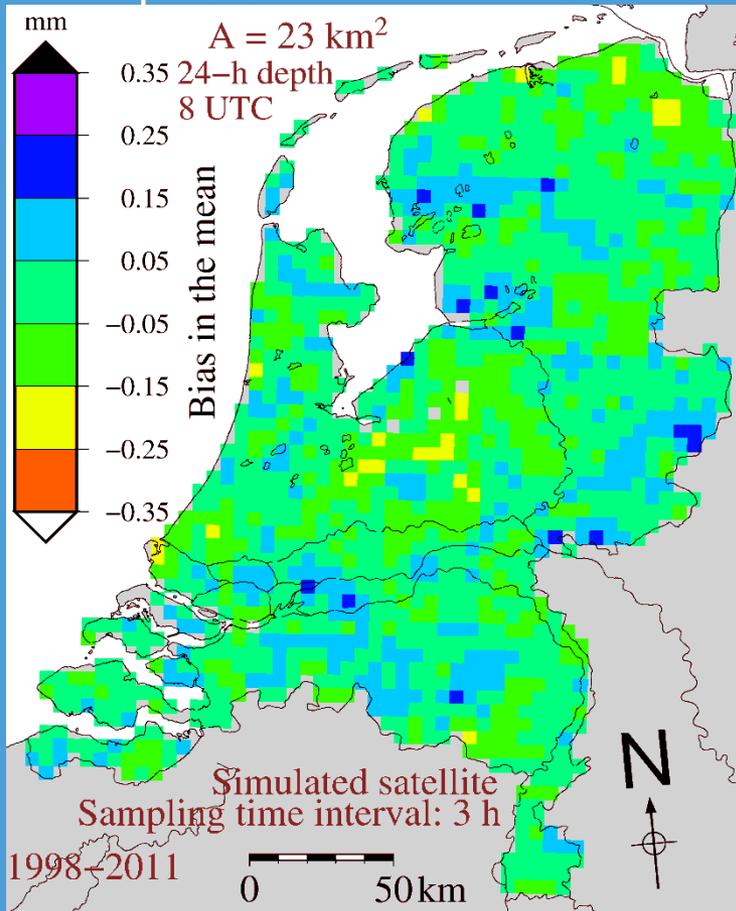
1998 – 2011

Residuals from each pixel and each day used to calculate bias (black line) and res. std. dev.

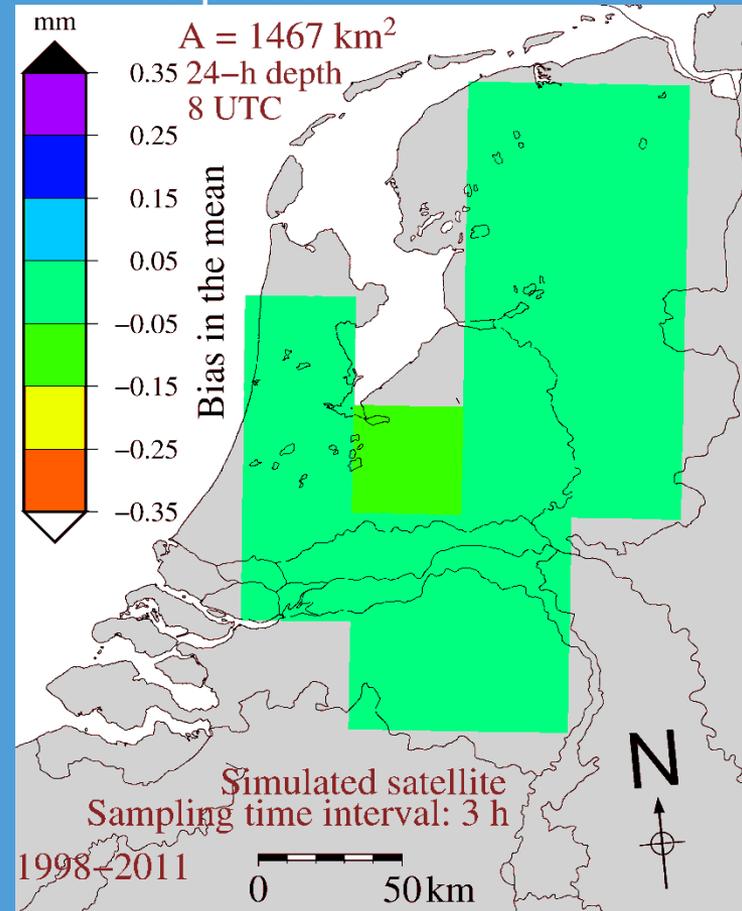


Bias in 24 h rainfall depth; 1998–2011

2 × 2 pixels



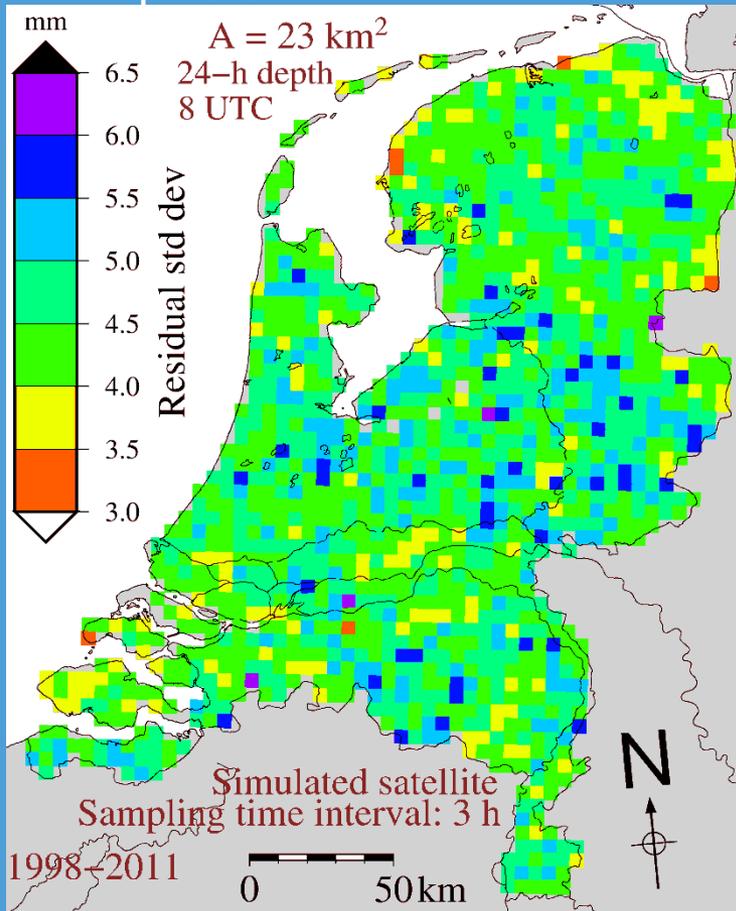
16 × 16 pixels



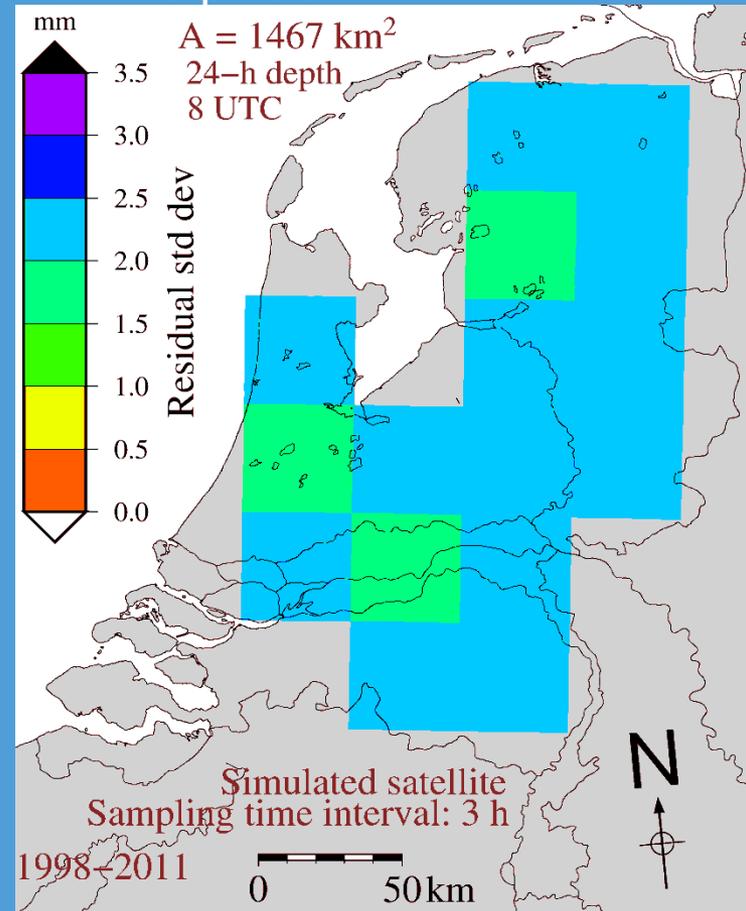
Small bias for revisit time of 3 h, $A = 23 \text{ km}^2$

Res std dev 24 h rainfall depth; 1998–2011

2 × 2 pixels

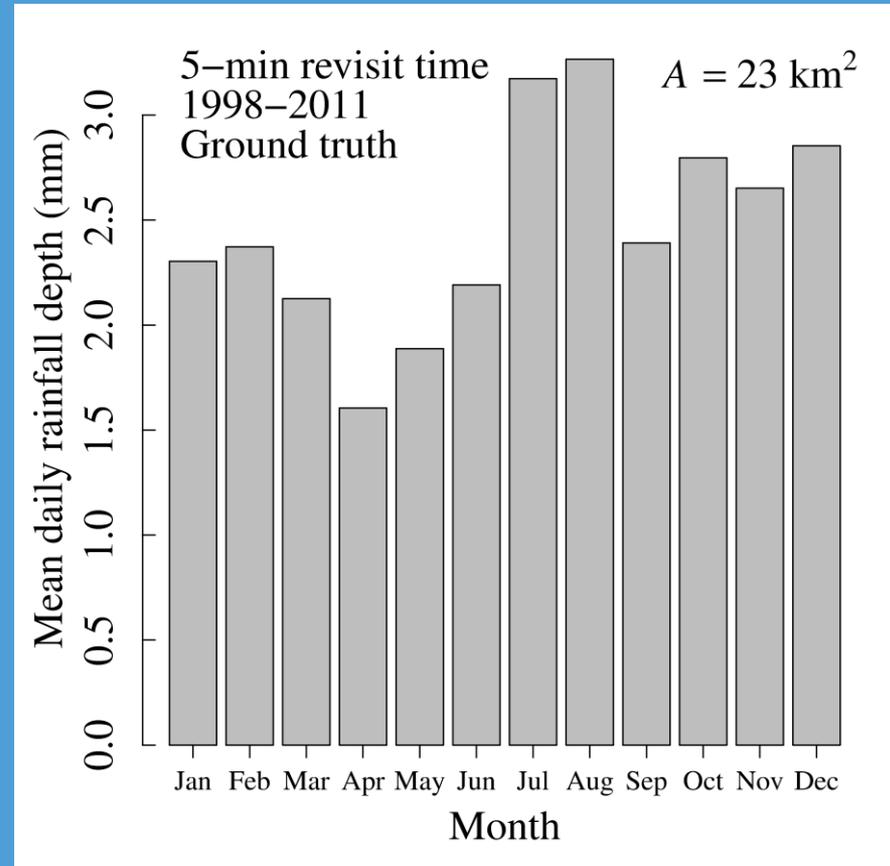
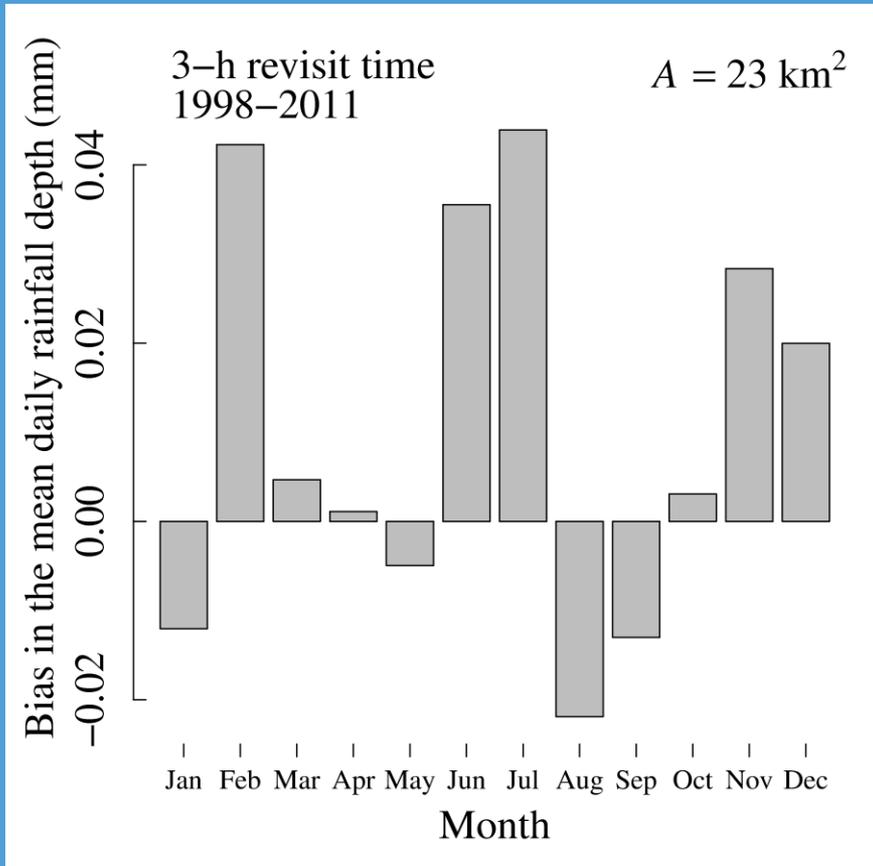


16 × 16 pixels



Large res std dev for revisit time of 3 h, $A = 23 \text{ km}^2$

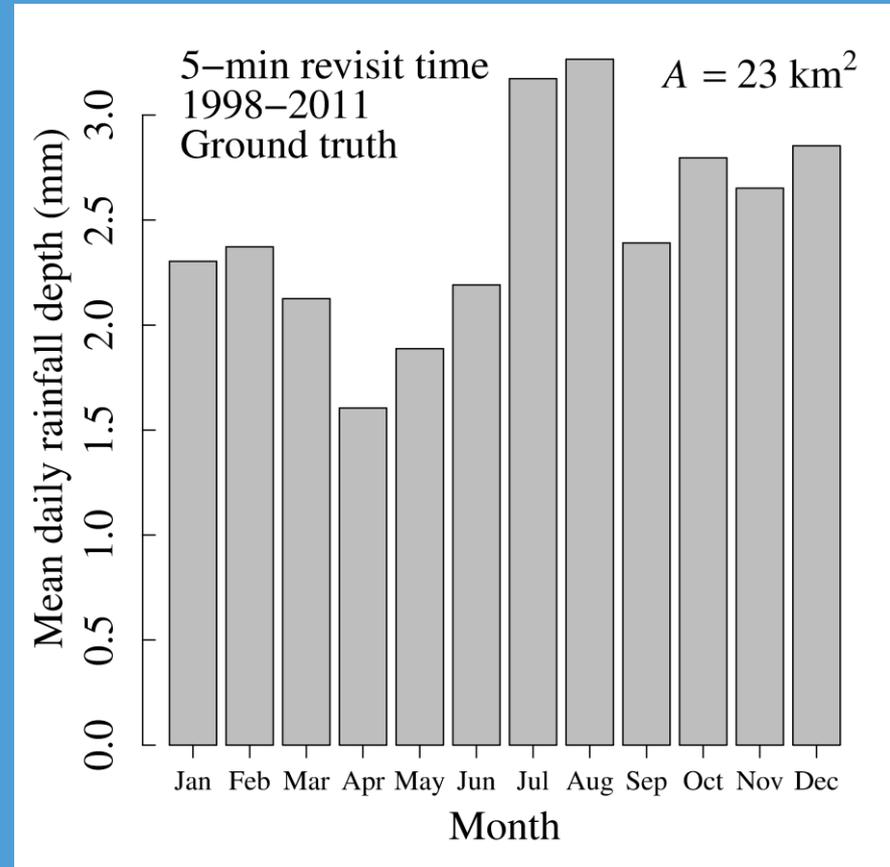
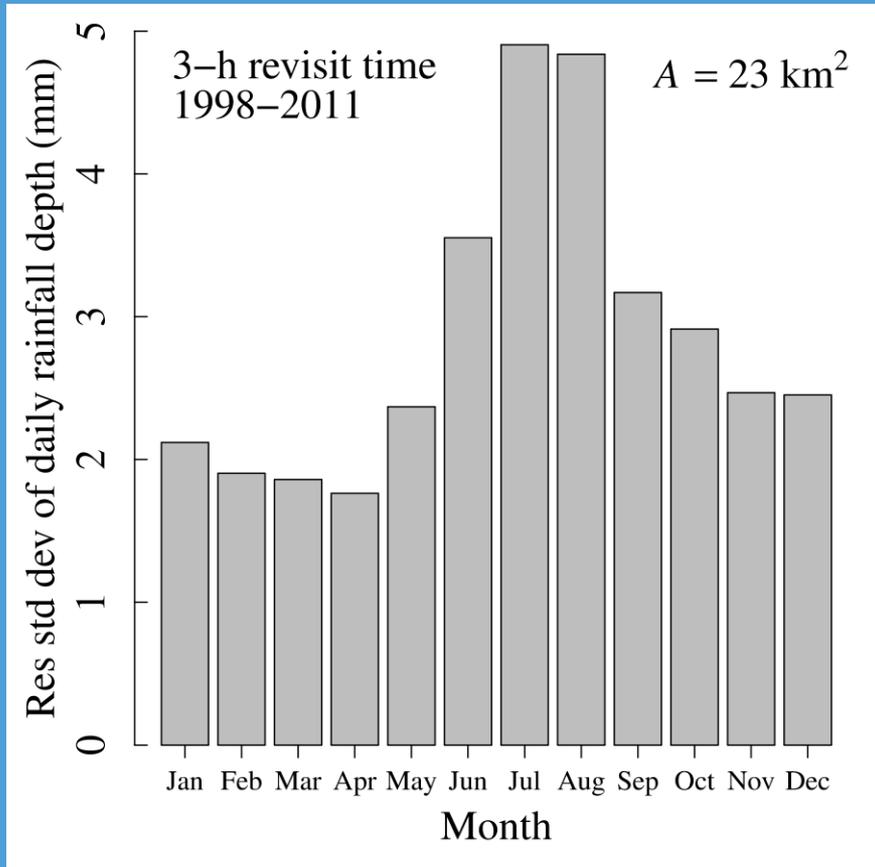
Seasonality in sampling uncertainty?



Mean monthly value of daily spatially averaged bias
(not significant for bias in the mean)



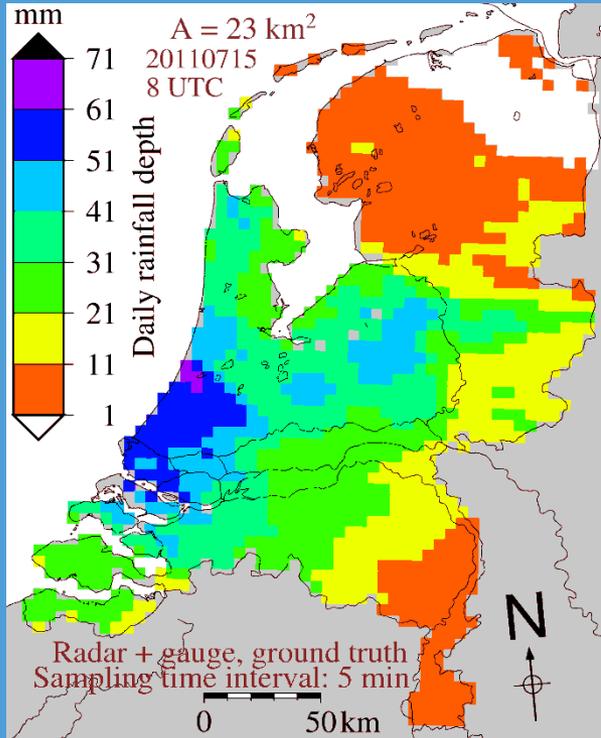
Seasonality in sampling uncertainty?



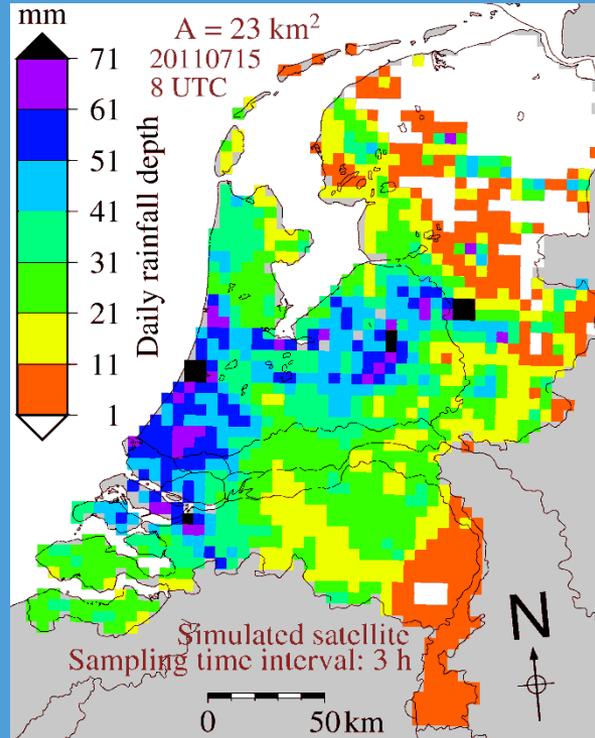
Mean monthly value of daily spatially averaged res std dev
Res std dev relatively large for Jun – Aug (NH summer)



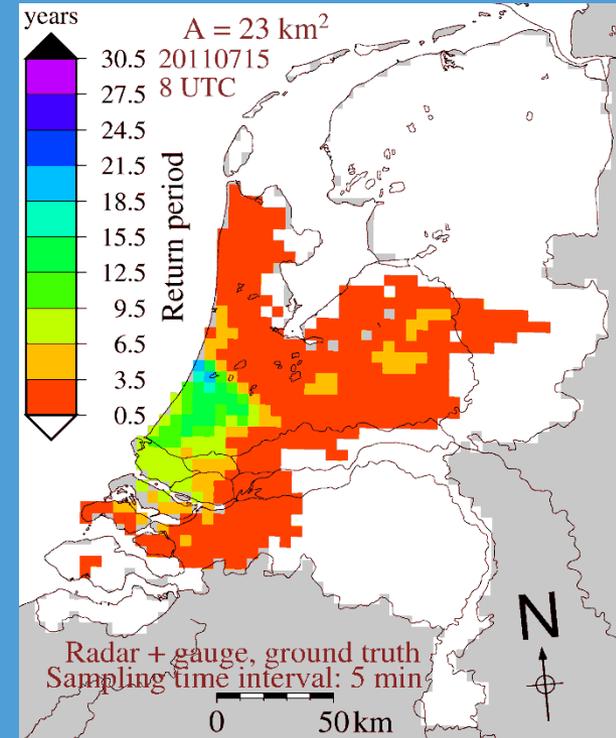
Case study: Extreme daily rainfall



Ground truth

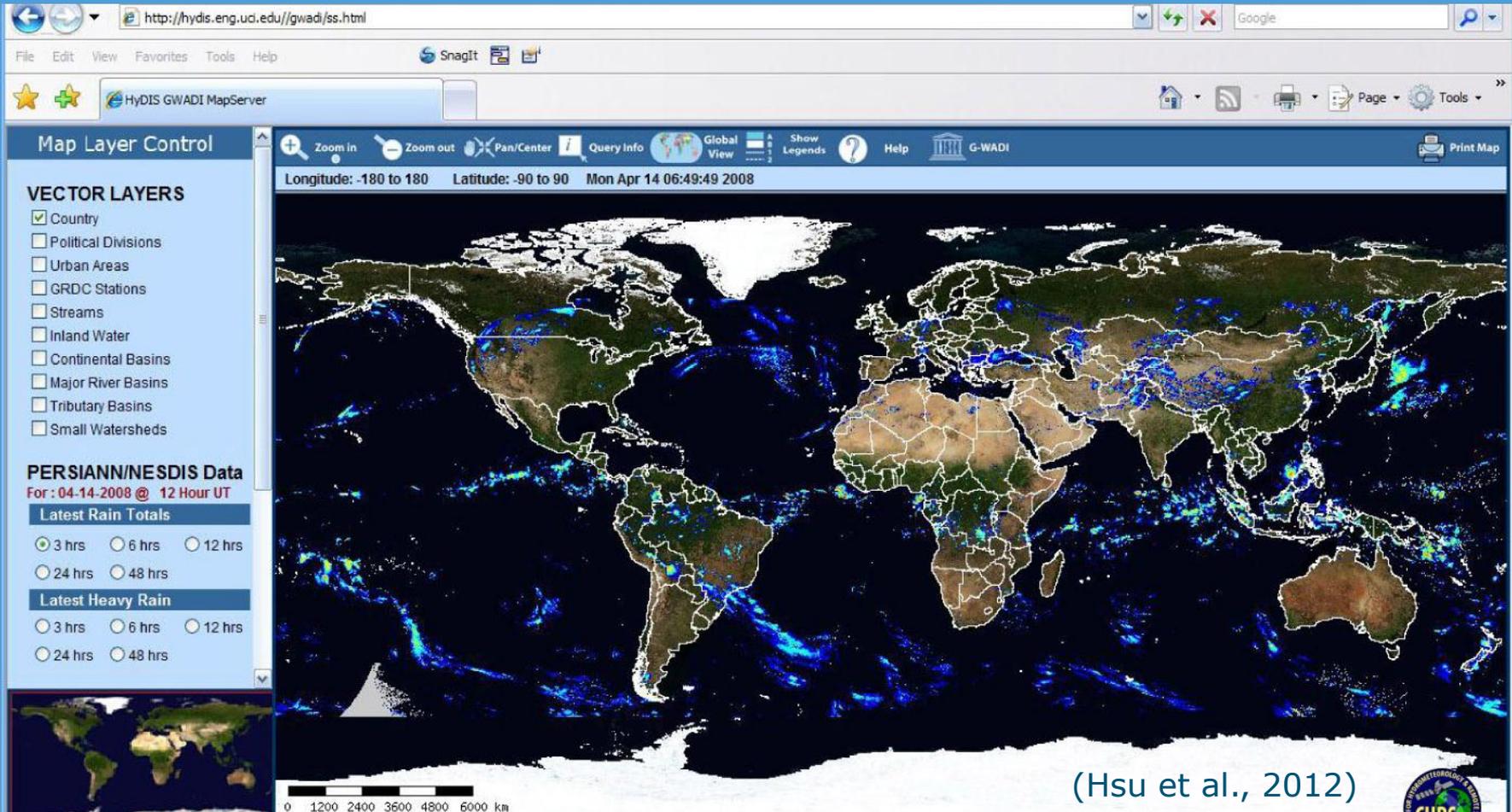


Simulated satellite
Revisit time of 3 h

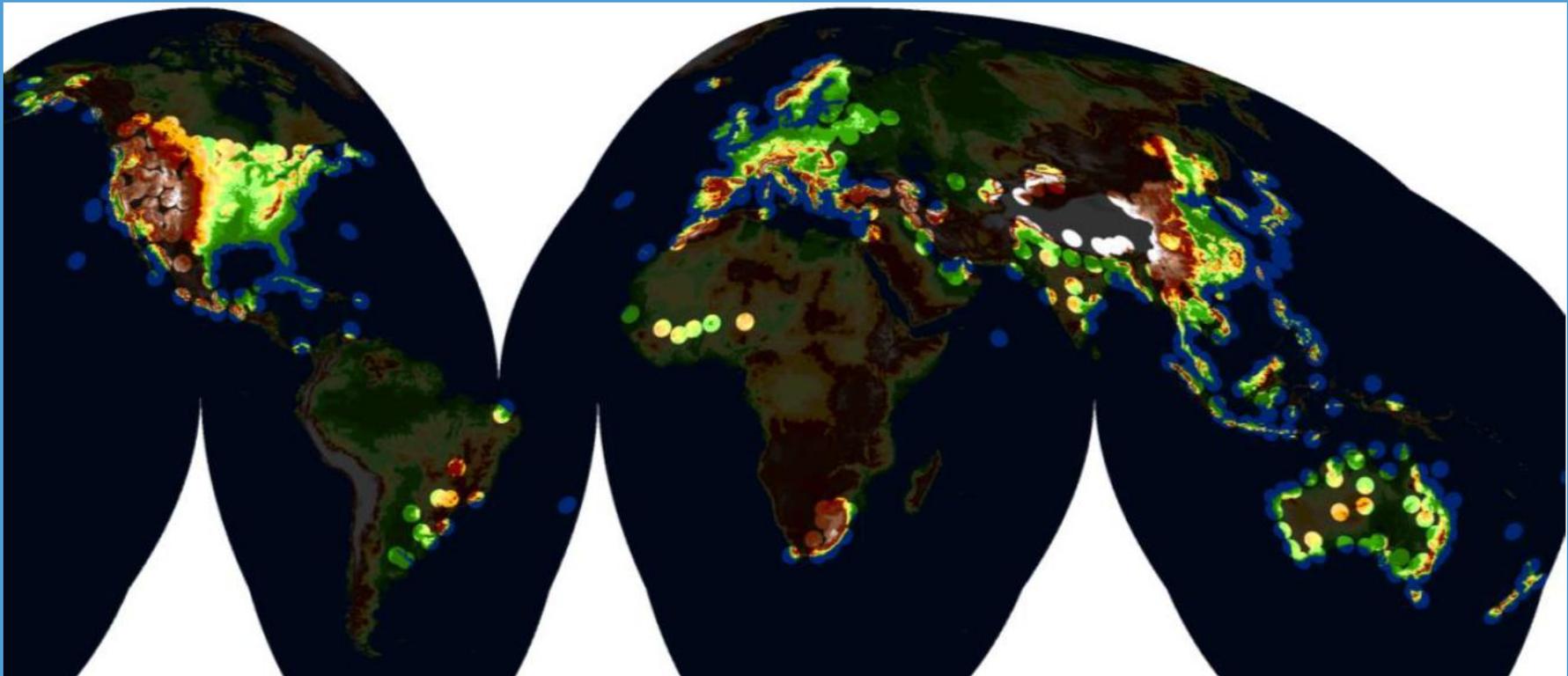


Return period
Overeem *et al.*, 2010 WRR

Satellites need ground truthing



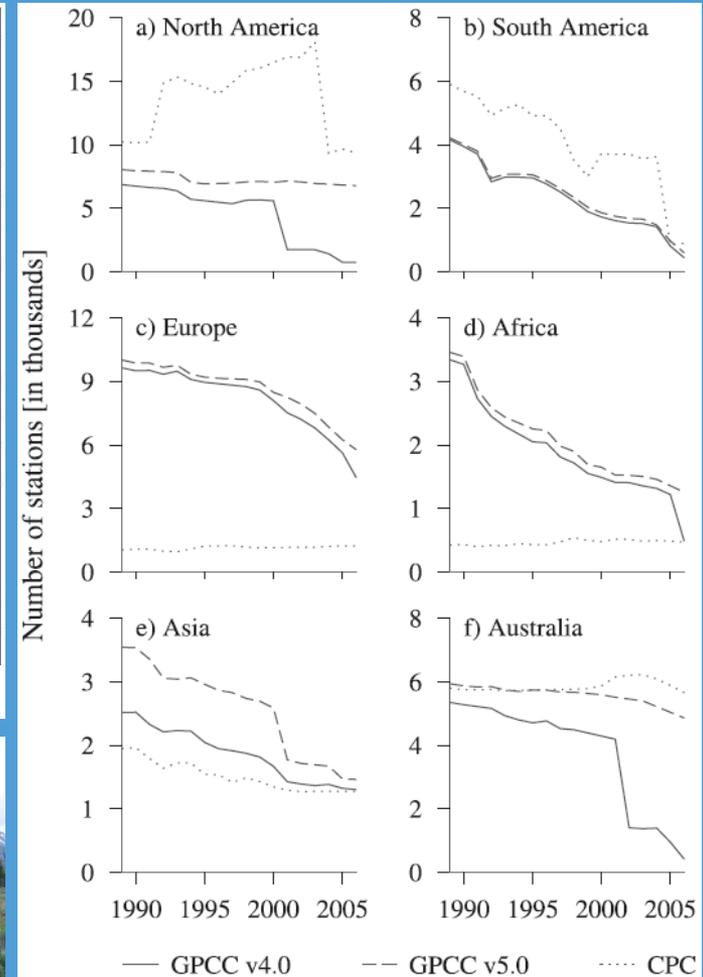
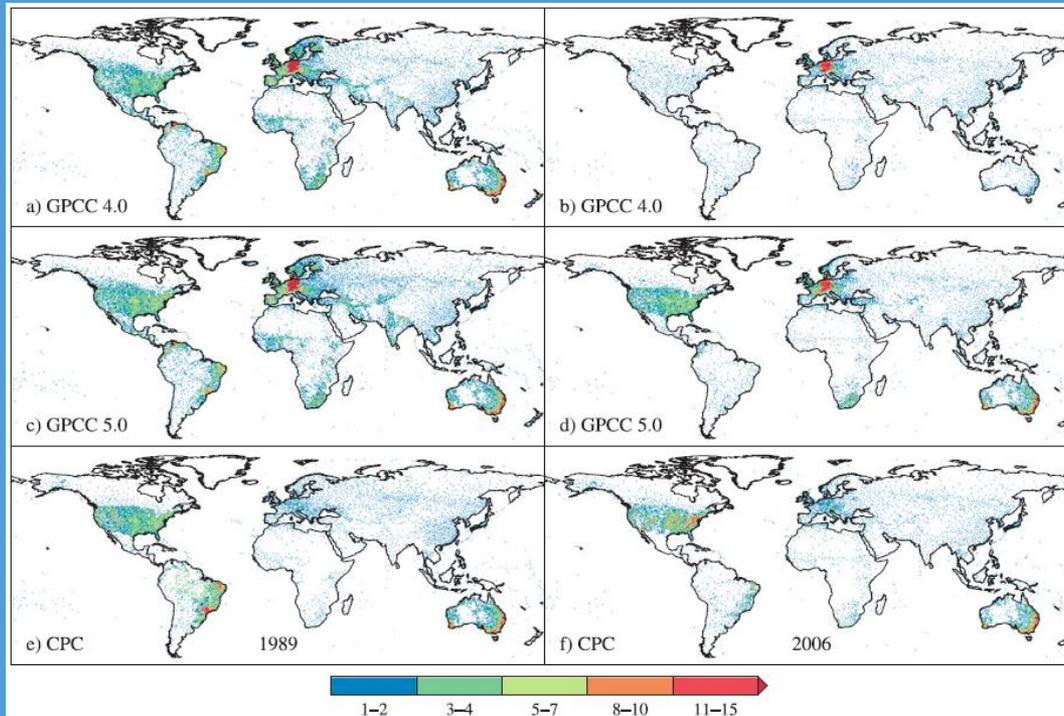
Global weather radar coverage incomplete



(Heistermann et al., 2012)



Number of rain gauges rapidly declining

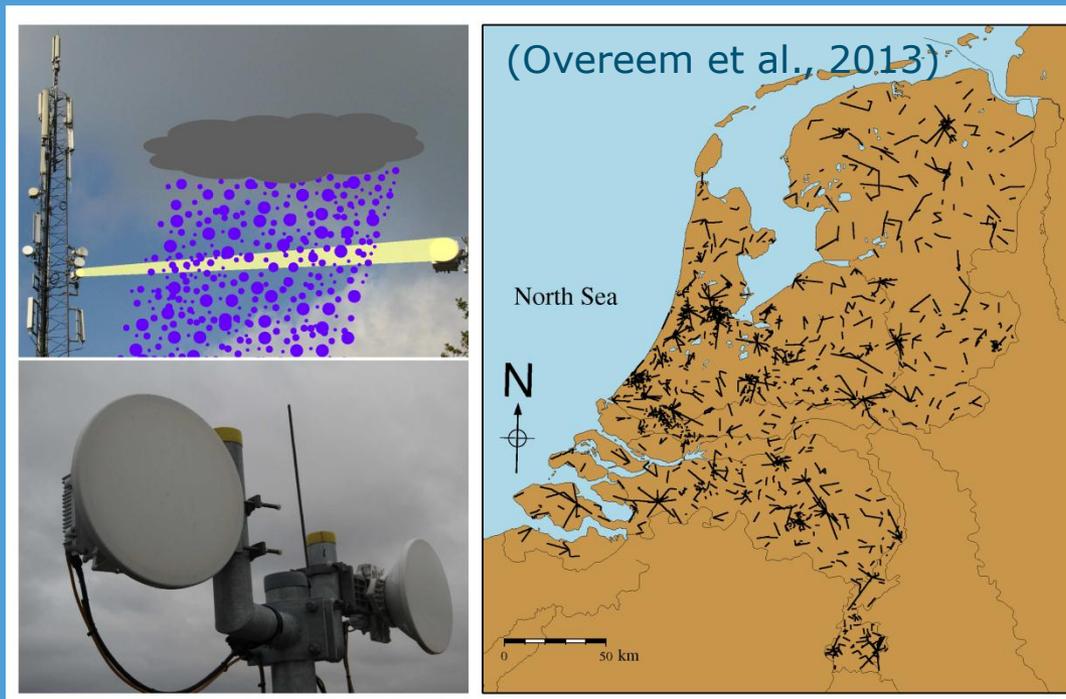


(Lorenz and Kunstmann, 2012; NY Times green blog, 2 July 2012)



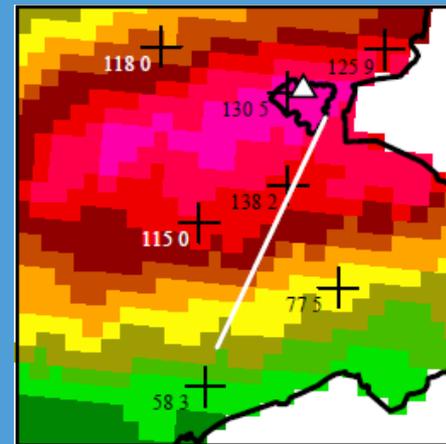
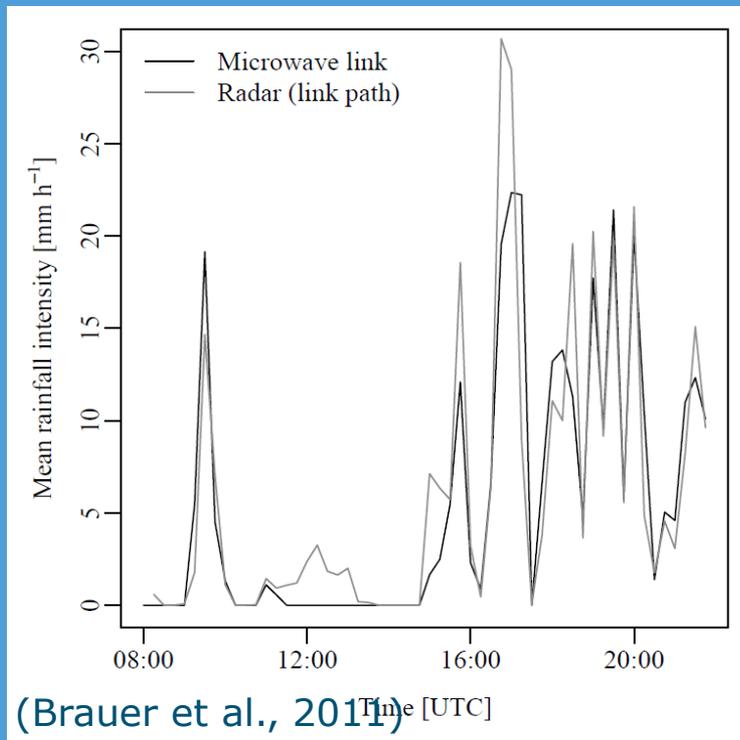
Rainfall measurement using cell phones?!

- Microwave links from cellular telecommunication networks for areal rainfall measurement



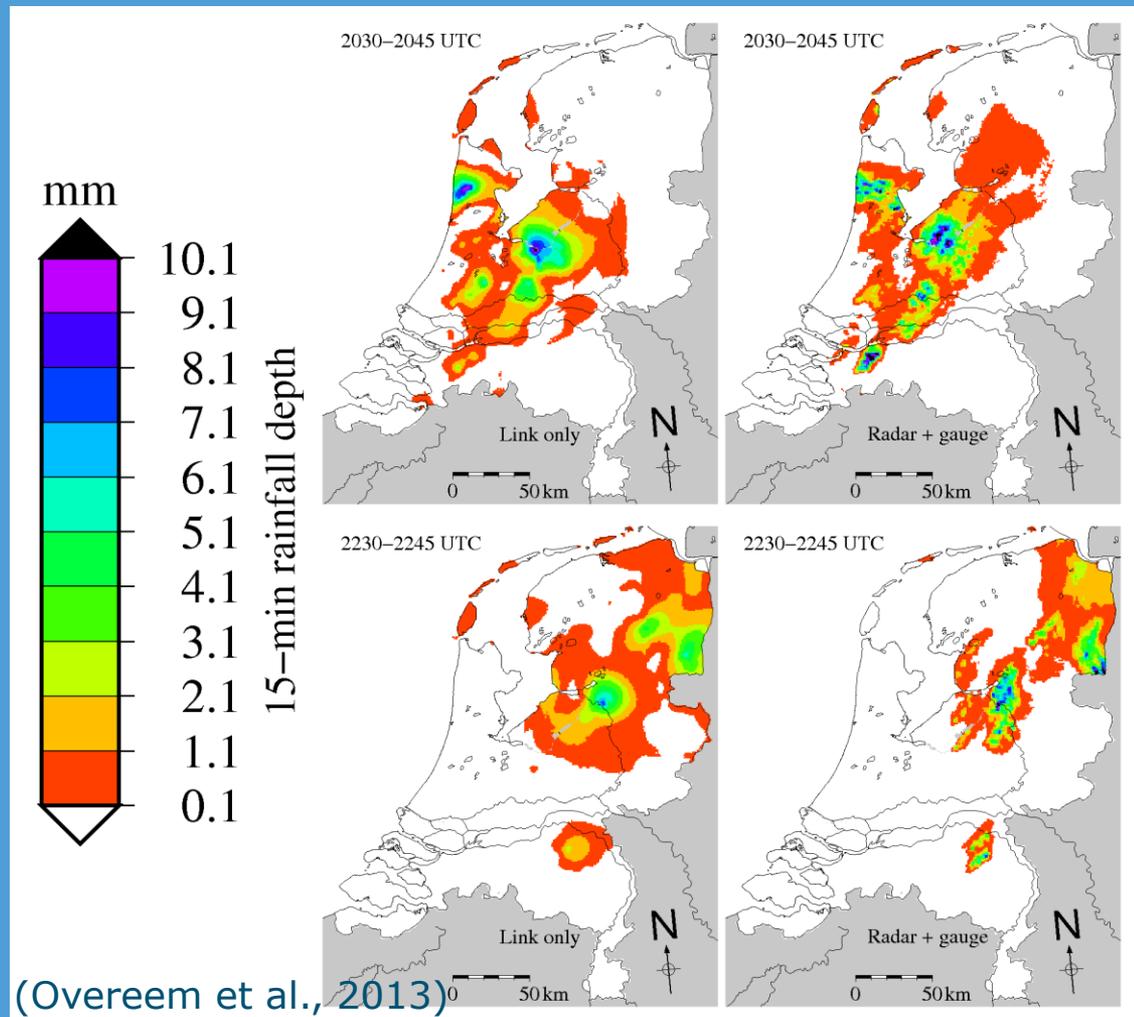
Comparison of microwave links with radar

- Microwave links provide valuable complementary data

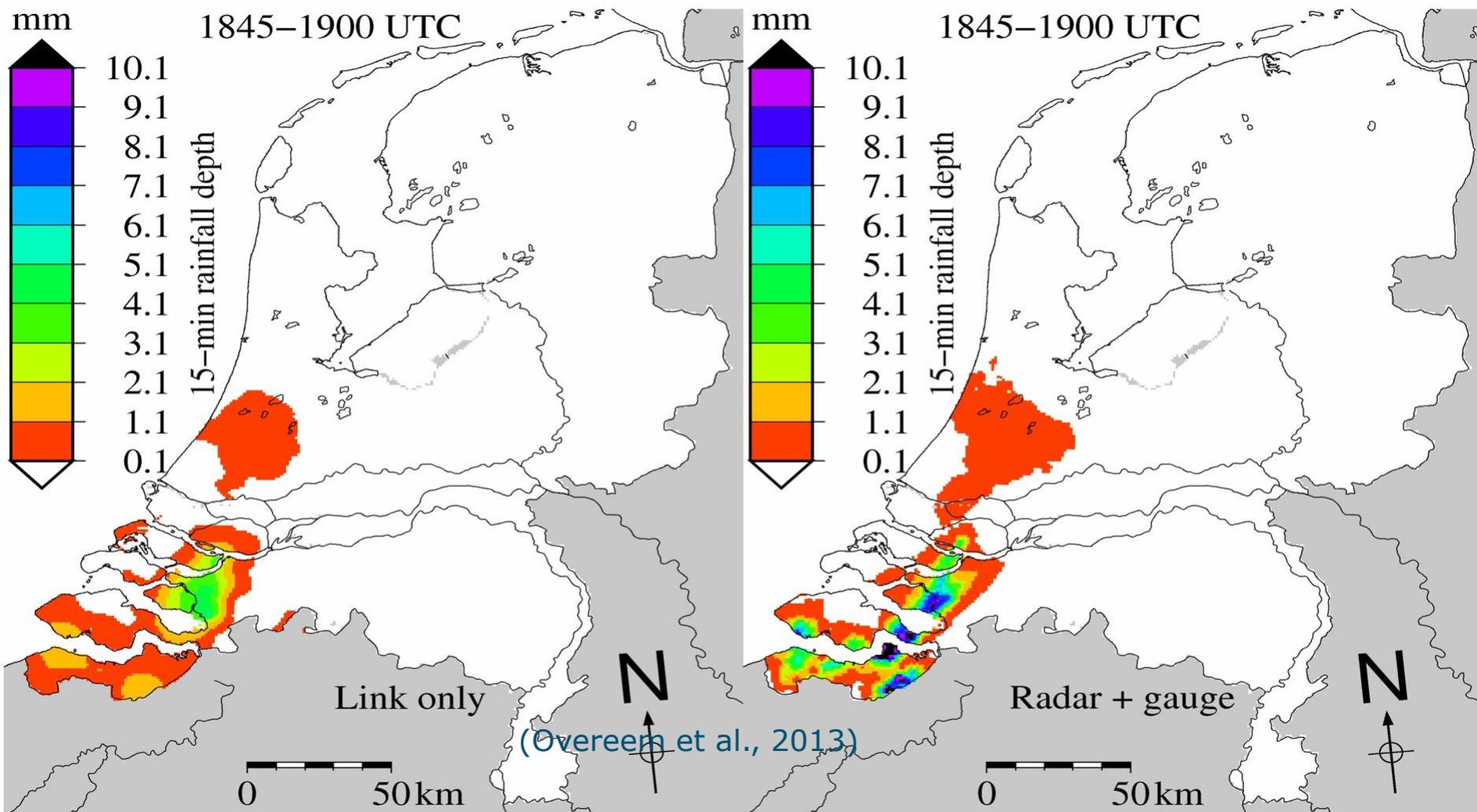


15-min rainfall maps for The Netherlands

- 2,400 microwave links (left) vs. radar + gauges (right)

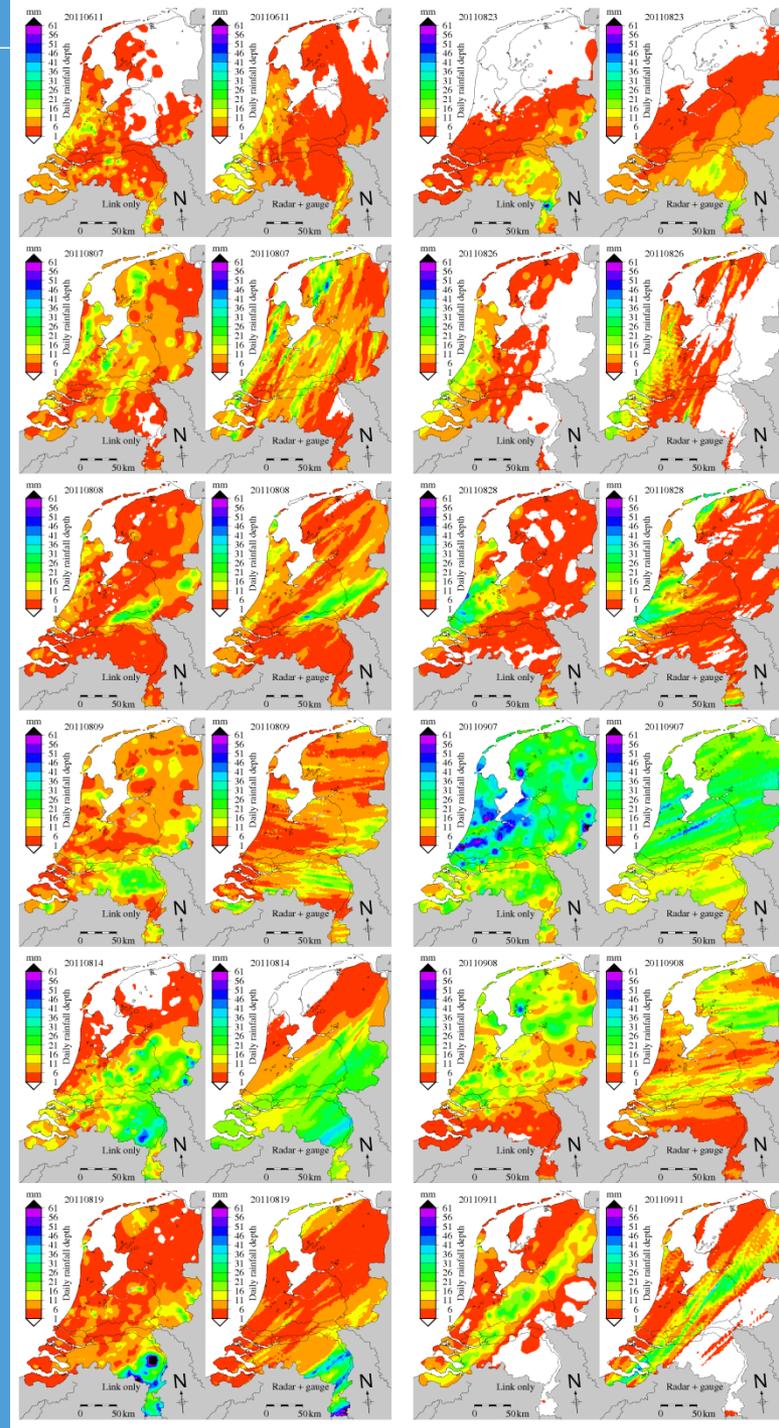


Microwave links versus radar + gauges



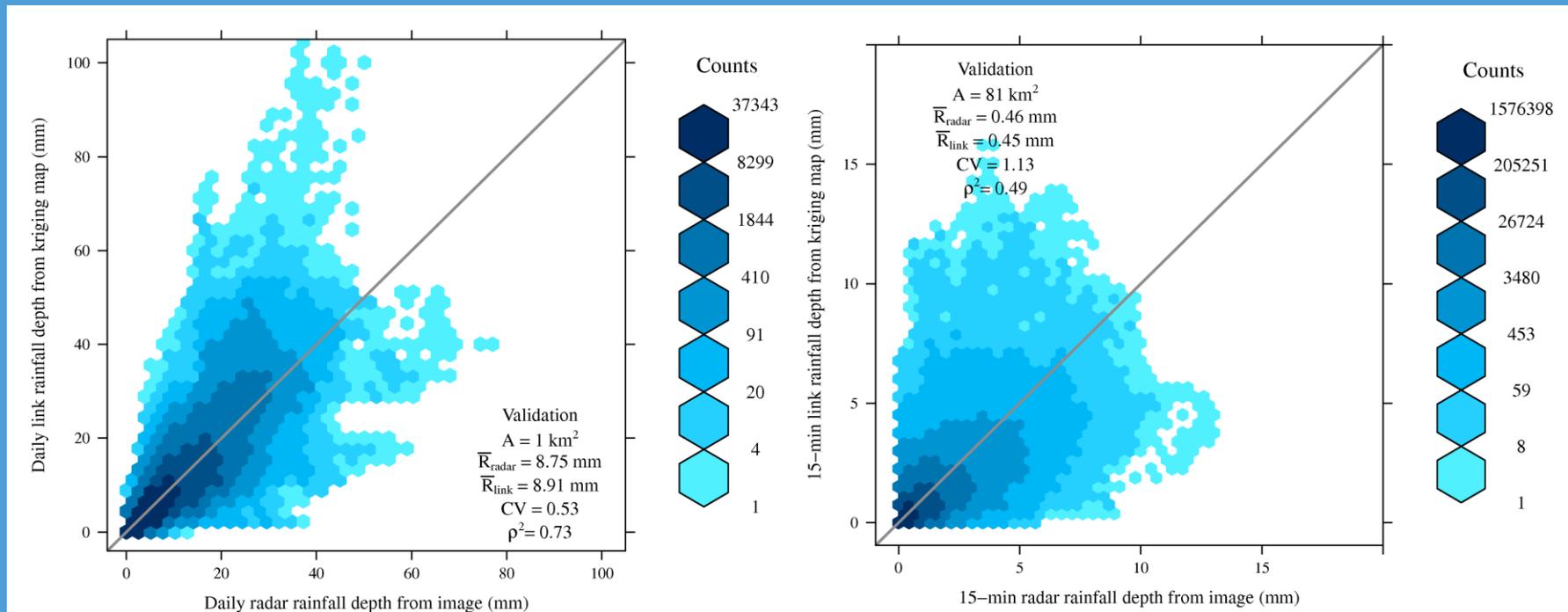
Daily rainfall maps

- 12 days, microwave links (left) vs. radar + gauges (right)



Microwave links vs. radar + gauges

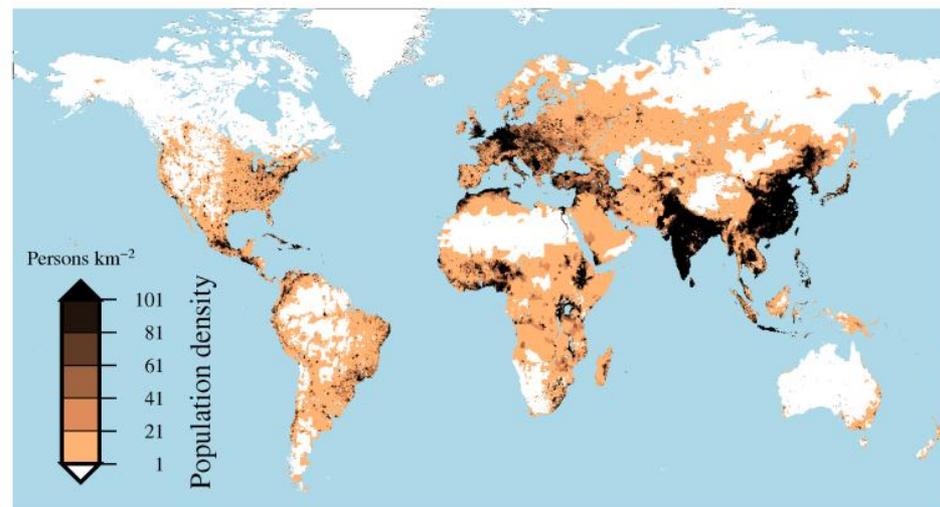
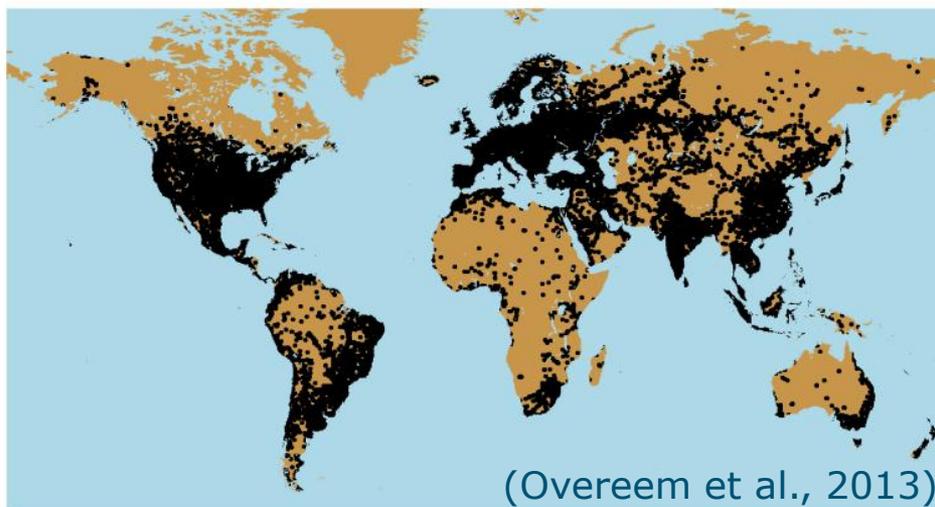
- Daily local (left) and 15-min regional (right) comparison



(Overeem et al., 2013)

Global cell phone and population density

- Potential over poorly gauged regions / continents
- Urban areas poorly gauged, but high cell phone density



Concluding remarks



(Victoria Roberts, 2000)



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Conclusions from IPC11 (1–3 July 2013)

- Maintain / expand ***in situ gauge networks*** for ground validation / retrieval algorithm development for ground-based and spaceborne rainfall remote sensors
- Take full advantage of ***volume-scanning capability*** of current operational weather radars
- Take full advantage of ***existing operational radar networks***
- Compile ***long-term quality-controlled weather radar data sets*** (incl. uncertainty)



Conclusions from IPC11 (1–3 July 2013)

- Investigate potential of **local high-resolution weather radars** for urban applications
- Further upgrade of operational networks to **polarimetric weather radar** for improved precipitation classification and rainfall estimation
- Take full advantage of space / time resolution of upcoming GPM (**Global Precipitation Measurement**) mission
- Extend **rainfall maps from radio links** to other continents



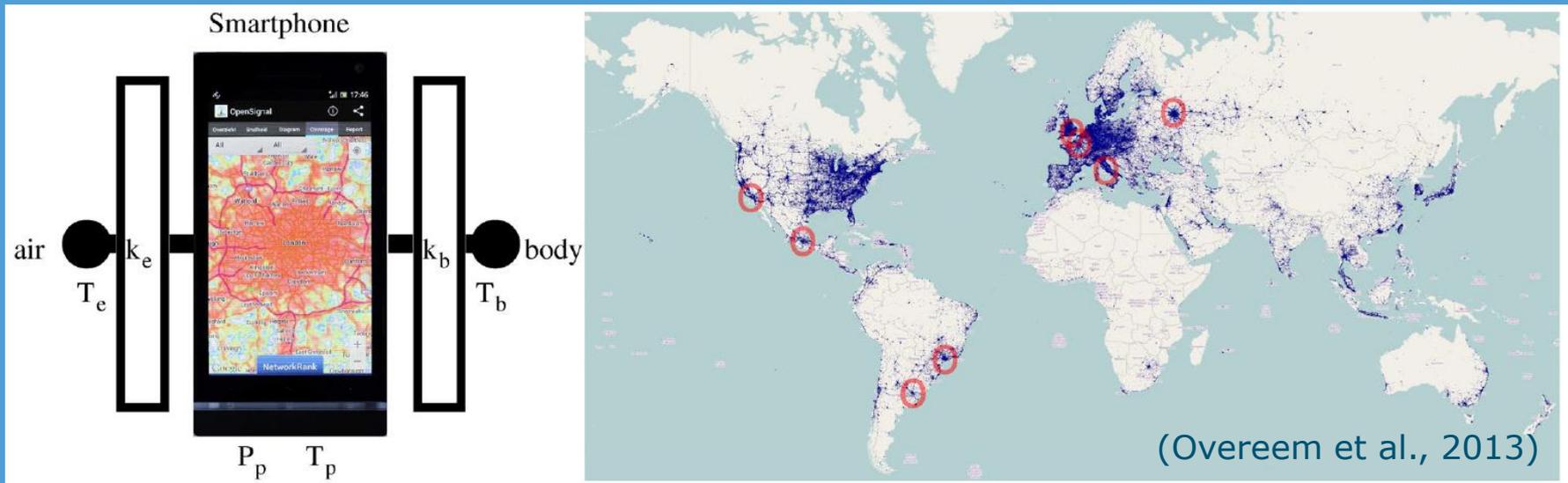
Environmental monitoring using smartphones

GEOPHYSICAL RESEARCH LETTERS, VOL. 40, 4081–4085, doi:10.1002/grl.50786, 2013

Crowdsourcing urban air temperatures from smartphone battery temperatures

A. Overeem,^{1,2} J. C. R. Robinson,³ H. Leijnse,² G. J. Steeneveld,⁴
B. K. P. Horn,⁵ and R. Uijlenhoet¹

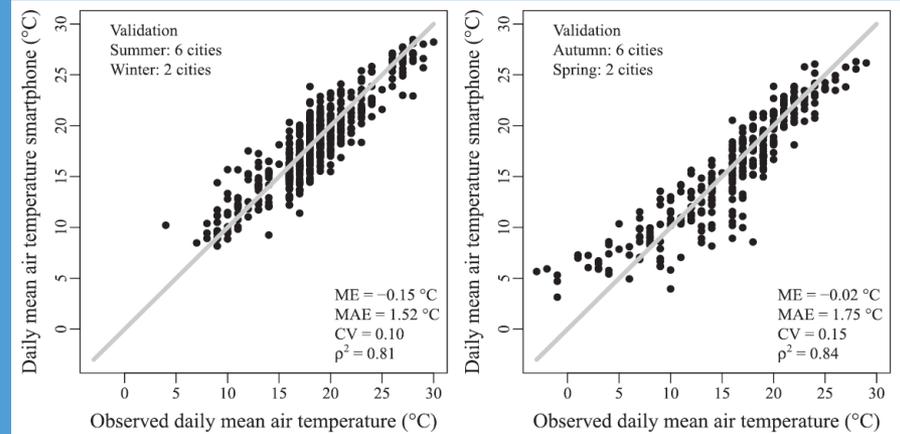
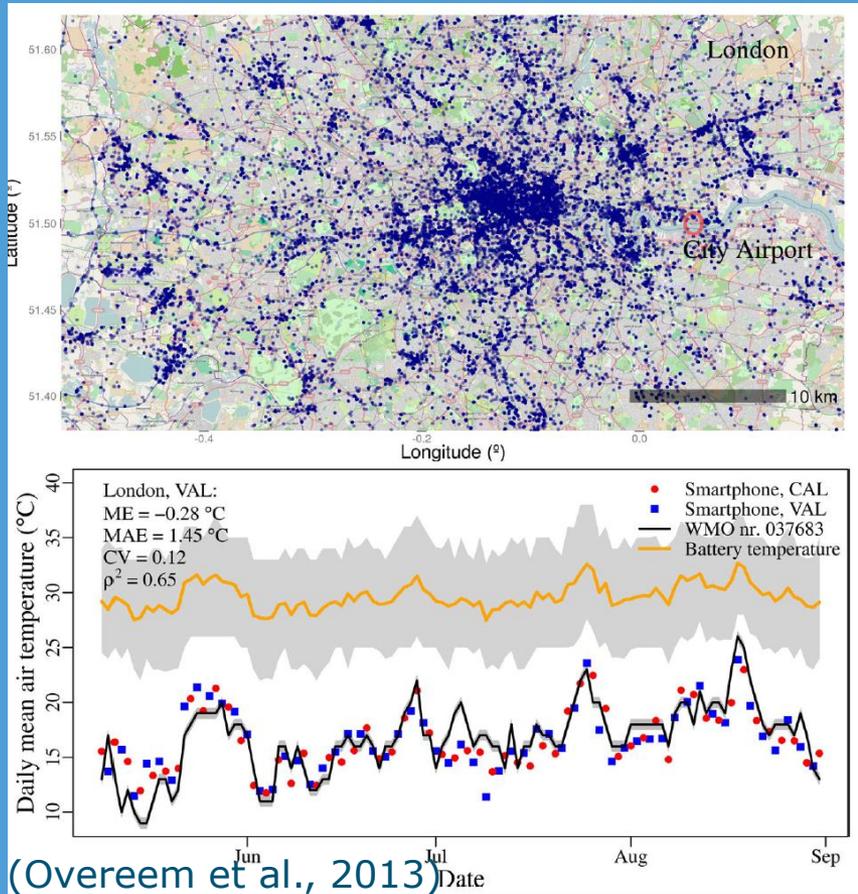
Received 21 June 2013; revised 18 July 2013; accepted 22 July 2013; published 14 August 2013.



(Overeem et al., 2013)



Daily mean urban air temperatures from smartphone battery temperatures



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