Country-wide rainfall maps from a commercial cellular telephone network

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A84 EGU2012-5937

1. Introduction

Networks of microwave links are used in mobile telecommunication for wireless transmission and reception of information. The principle of rainfall estimation using microwave links is that electromagnetic signals transmitted from one mobile telecommunication antenna to another are attenuated by rainfall (Figure 1). This causes a decrease in the received power at one end of a link. Figure 2 shows the minimum received power (blue) over a 24-hour period for a single link and the corresponding mean radar rainfall intensity (red), which can be seen to be negatively correlated. The received powers are a by-product of the communication between mobile telephones. From the received power the path-integrated attenuation can be calculated, from which the path-average rainfall intensity can be derived, as has been shown by Messer *et al.* (2006) and Leijnse *et al.* (2007) for commercial microwave link data. In this study data from a commercial cellular telephone network, which were kindly provided by T-Mobile NL, are used to obtain country-wide rainfall maps for the Netherlands.

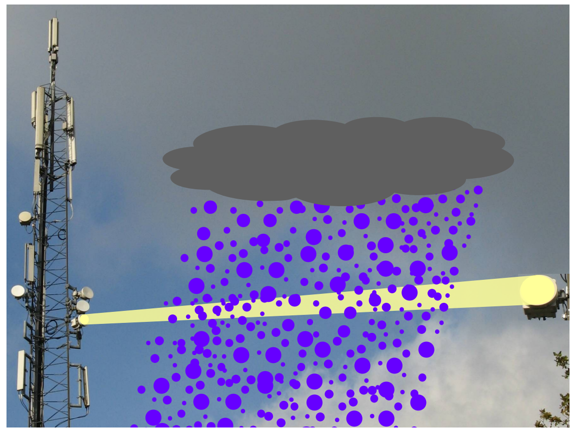

Figure 1: *A commercial microwave link.*

2. Data and methodology

Minimum and maximum received powers with a temporal resolution of 15 min are obtained from on average 1445 commercial microwave links for 22 days in June, August and September 2011. For each link, gauge-adjusted path-averaged radar rainfall intensities are derived. It is important to correct for link signal fluctuations not related to rainfall, which is achieved by combining the received powers from links within 15 km. If the mutual decrease in the minimum received power is large enough, a 15-min interval is classified as a wet spell. This results in a corrected received power, which removes the signal fluctuation at 4 UTC (Figure 2).

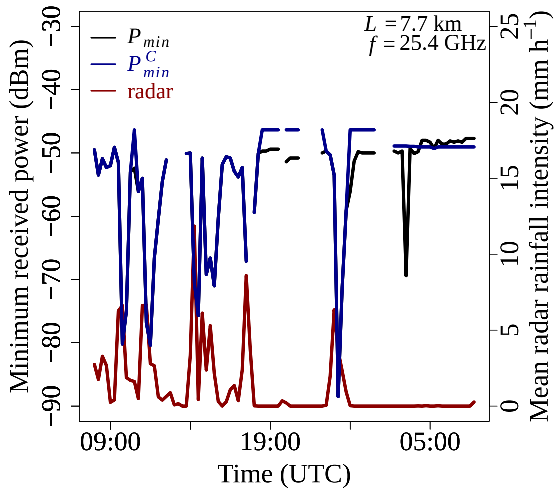

Figure 2: *Minimum received power (black), corrected power (blue) and mean radar rainfall intensity (red) for a day in July 2009 (Overeem et al., 2011).*

Now, from the received power at one end of a microwave link, the path-averaged rainfall intensity can be calculated:

$$\langle R \rangle = \alpha \cdot a \left(\frac{P_{ref} - P^C_{min} - A_a}{L}\right)^b + (1-\alpha) \cdot a \left(\frac{P_{ref} - P^C_{max} - A_a}{L}\right)^b \qquad (1)$$

with $\langle R \rangle$ the path-averaged mean 15-min rainfall intensity (mm h^{-1}), P the received power (dBm), P_{ref} the reference level (dBm), L the link length (km), a and b coefficients, α determines the contribution of P_{min} and P_{max}, and A_a is a correction for wet antennas and remaining errors. Optimal values of α and A_a are found by calibration with daily radar rainfall data from 11 days. Before calibration a filter is applied to remove outliers.

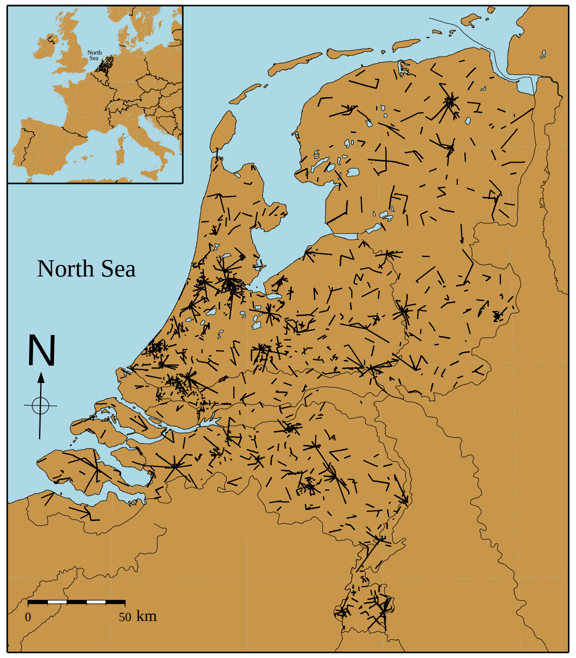

Figure 3: *Part of the microwave link network of one provider.*

3. Validation

From $\langle R \rangle$ daily rainfall depths are calculated for 11 days for on average 1423 links. Figure 4 shows that the path-averaged link-based daily rainfall depths correspond quite well with the radar-based ones for this validation data set. Subsequently, the daily rainfall depths are interpolated using ordinary kriging to obtain rainfall maps. For most of the 11 days rainfall patterns show a strong correspondence with those based on gauge-adjusted radar data, see Figures 5 and 6 for an example.

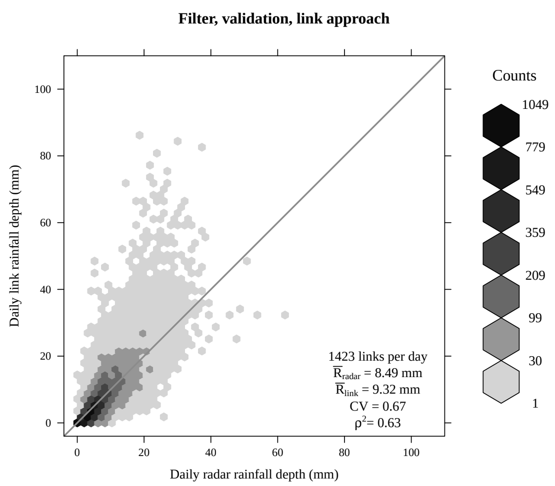

Figure 4: *Validation of link-based daily rainfall depths against path-averaged radar daily rainfall depths.*

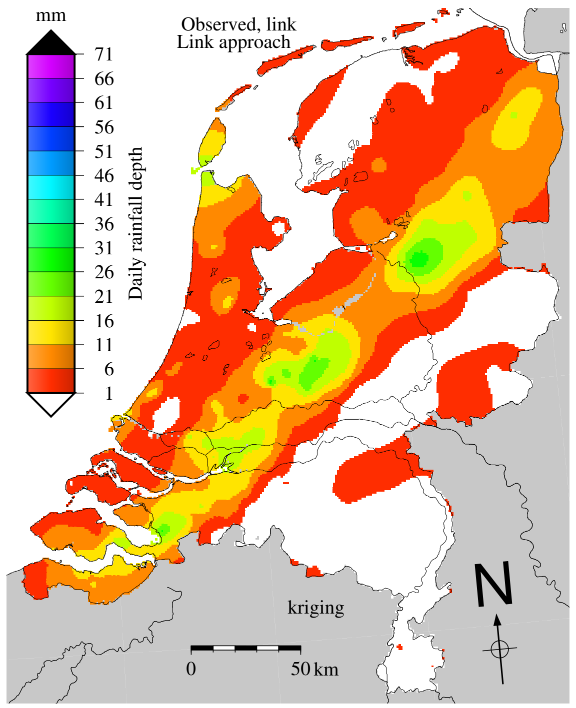

Figure 5: *Interpolated daily rainfall depth, solely based on commercial microwave link data for September 11, 2011.*

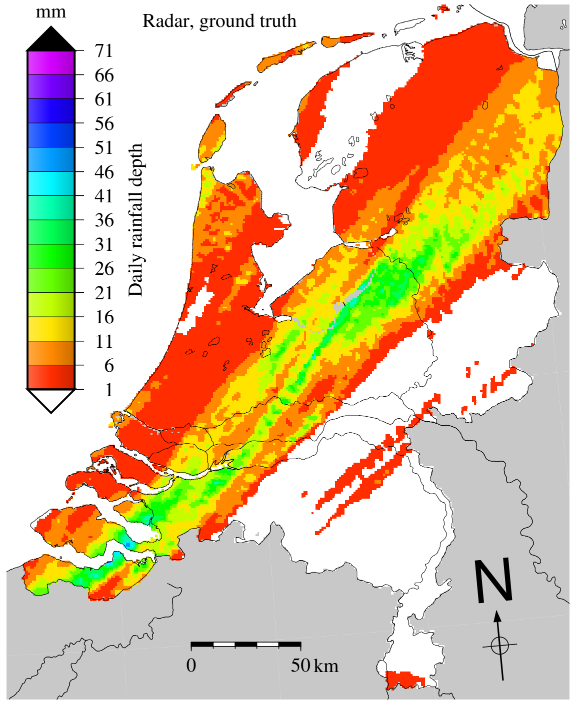

Figure 6: *Gauge-adjusted daily radar rainfall depth for September 11, 2011.*

4. Conclusion

Rainfall was estimated using a network of commercial microwave links covering the Netherlands. A validation shows that the quality of link-based daily rainfall depths is already quite good. This holds a promise for measuring rainfall in areas where few or no radars or rain gauges are available.

References

Leijnse, H., R. Uijlenhoet, and J.N.M. Stricker, 2007: Rainfall measurement using radio links from cellular communication networks. *Water Resources Research*, 43, W03201.

Messer, H.A., A. Zinevich, and P. Alpert, 2006. Environmental monitoring by wireless communication networks, *Science*, 312, 713.

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