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Disaggregating path-averaged rain rate estimates from commercial microwave links with a multiplicative random cascade model

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Commercial microwave links (CMLs) measure total attenuation along their path. Thus when used as opportunistic sensors, they provide path-averaged rainfall estimates. This poses a challenge for rainfall map reconstruction and potentially for rainfall estimation itself, as the conversion of attenuation to rain rate implicitly assumes uniform rainfall along the CML path.

We propose a new algorithm called CLEAR (CML Segments with Equal Amount of Rainfall) for disaggregating path-integrated rain rates along a CML path using a multiplicative cascade model. This model redistributes rain rates by successively dividing the CML into segments with equal rainfall amounts but varying segment lengths. The redistribution is driven by a cascade generator, with variance dependent on the rain rate of the parent segment and its length. Spatial consistency of the disaggregated rain rates across the entire network is ensured by a spatial coherence rule, which determines which segment receives a higher rain rate using information from neighbouring CMLs. The algorithm is tested on CML path-averaged rain rates obtained from 210 virtual rainfall fields, simulated for a real network topology in Prague, CZ, consisting of 67 CMLs. In addition, the performance of the algorithm is demonstrated in a case study where real observations from the same CML network are used.

The CLEAR algorithm is efficient in estimating rainfall maxima and minima along a CML path, achieving RMSE values of 2.8 and 1.3 mm/h, respectively, compared to 4.7 and 3.5 mm/h for the original path-averaged rain rates. It also outperforms the benchmark GMZ algorithm, which has for estimated rain rate maxima and minima along a CML path RMSE values of 6.8 and 1.8 mm/h, respectively. While the results are slightly worse when considering the exact position of the disaggregated rain rates, CLEAR still outperforms GMZ in this aspect. Additionally, due to the stochastic nature of multiplicative cascades, CLEAR is capable of providing uncertainty estimates. The evaluation shows that CLEAR tends to underestimate uncertainty, as reflected in the width of the uncertainty bands. This is partly due to shortcomings in reproducing rainfall intermittency and partly because the ensemble variance is driven by a cascade generator model that does not account for uncertainties in the spatial coherence rule.

Multiplicative cascades used in the CLEAR algorithm have proven to be efficient for 1D disaggregation and are applicable even for sparse CML networks. However, further research is needed to enhance CLEAR's uncertainty estimation and improve the estimation of rainfall intermittency.

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