Refining baseline and wet antenna models for improved rainfall estimation from CML data

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Estimating the baseline is key to deriving rainfall from commercial microwave links (CMLs). Different rainfall detection methods result in varying baselines, which affect wet antenna attenuation (WAA) parameters. We investigate how WAA parameters change across methods and explore combining them to improve rainfall estimates. Results show that using radar or combining methods enhances CML rainfall accuracy.

Data

Commercial microwave links (CMLs) within 2 km of a rain gauge, 1 month of data from:

- Sweden (OpenMRG), 129 CMLs
- Italy (OpenRainER), 17 CMLs
- Norway, 59 CMLs
- Germany, 52 CMLs

CML processing models (waa_wet/dry_mask)

waa:

- kt: Pastorek et al. (2022) KR-alt: A_max*(1 - exp(-d*R^Zeta))
- ct: constant WAA

wet/dry: (for estimating the baseline, 5 min average)

- rad: weather radar along CML
- mlp: Øydvin et al. (2024)
- rsd: Graf et al. (2020)
- cnn: Pols et al. (2020)

mask: wet/dry method used to filter rainy steps

Training and testing of models

- 50% train test split
- Train: Bootstrap 3 CML-gauge pairs from each dataset. WAA parameters tuned so that the 12 hours aggregated rainfall sums |CML – gauge| is minimized
- Test: Using median WAA parameters from test, evaluated using 60 minutes CML and gauge sums

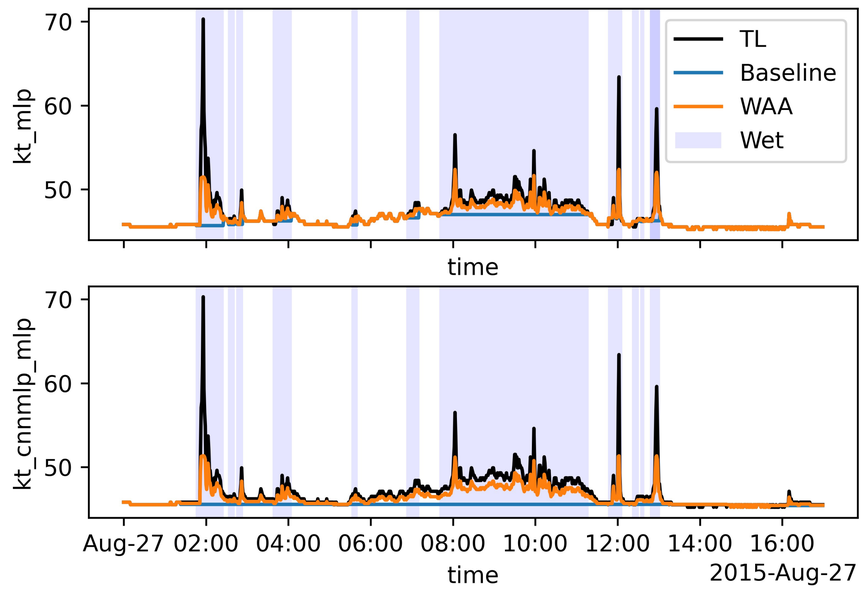

Figure 1: CML time series processing using the kt_mlp and kt_cnnmlp_mlp models.

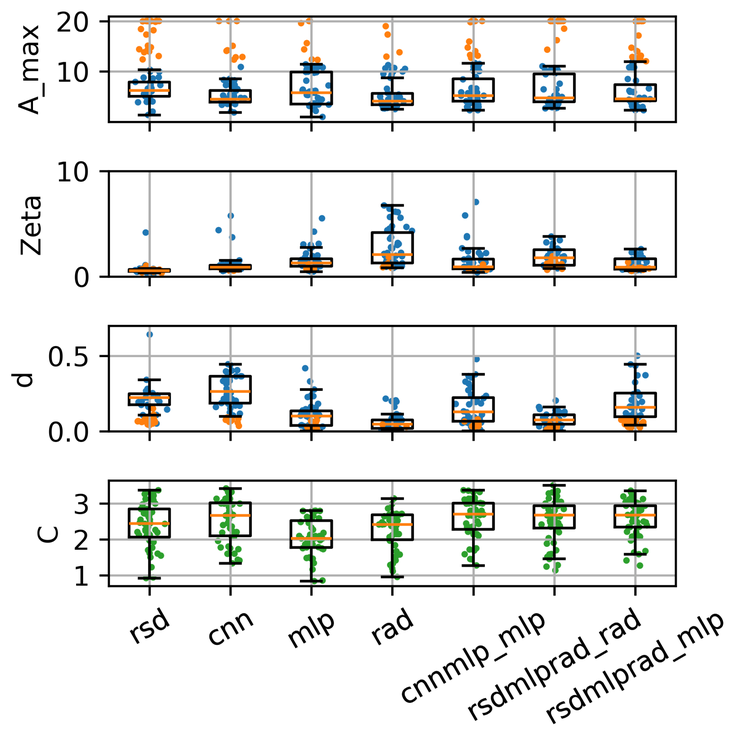

Figure 2: Results from training. Optimal parameters for the kt (A_max, Zeta, d) and ct (C) WAA models.

Table:1: Results from testing. Root mean squared error (RMSE), Bias, Pearson correlation coefficient (PCC), Matthews correlation coefficient (MCC) evaluated against nearby rain gauges for Norway, Italy, Germany, Sweden and the mean of the four datasets (All)

Metric	Country	kt_rsd	kt_cnn	kt_mlp	kt_rad	kt_cnnmlp_mlp	kt_rsdmlprad_rad	kt_rsdmlprad_mlp	ct_rsd	ct_cnn	ct_mlp	ct_rad	ct_cnnmlp_mlp	ct_rsdmlprad_rad	ct_rsdmlprad_mlp
RMSE	Norway	0.340000	0.360000	0.310000	0.340000	0.320000	0.330000	0.310000	0.360000	0.360000	0.330000	0.360000	0.330000	0.360000	0.320000
	Italy	1.920000	0.810000	0.750000	0.710000	0.750000	0.690000	0.750000	2.050000	0.830000	0.780000	0.740000	0.770000	0.710000	0.770000
	Germany	1.720000	1.900000	1.040000	0.750000	0.940000	0.750000	1.040000	1.890000	1.990000	1.130000	0.790000	1.010000	0.790000	1.090000
	Sweden	0.340000	0.340000	0.360000	0.320000	0.340000	0.300000	0.340000	0.540000	0.500000	0.580000	0.510000	0.480000	0.460000	0.470000
	All	1.080000	0.852500	0.615000	0.530000	0.587500	0.517500	0.610000	1.210000	0.920000	0.705000	0.600000	0.647500	0.580000	0.662500
Bias	Norway	-0.510000	-0.690000	-0.600000	-0.530000	-0.540000	-0.460000	-0.500000	-0.740000	-0.900000	-0.790000	-0.900000	-0.830000	-0.890000	-0.810000
	Italy	0.380000	-0.180000	-0.190000	-0.020000	-0.020000	0.010000	-0.020000	0.300000	-0.350000	-0.160000	-0.230000	-0.250000	-0.210000	-0.240000
	Germany	-0.030000	-0.080000	-0.210000	0.060000	-0.090000	0.020000	-0.020000	-0.170000	-0.320000	-0.300000	-0.370000	-0.420000	-0.400000	-0.340000
	Sweden	-0.130000	-0.150000	-0.280000	-0.080000	0.030000	-0.070000	0.050000	-0.200000	-0.330000	-0.200000	-0.300000	-0.310000	-0.330000	-0.290000
	All	-0.072500	-0.275000	-0.320000	-0.142500	-0.155000	-0.125000	-0.122500	-0.202500	-0.475000	-0.362500	-0.450000	-0.452500	-0.457500	-0.420000
PCC	Norway	0.560000	0.460000	0.630000	0.510000	0.620000	0.550000	0.630000	0.490000	0.440000	0.590000	0.460000	0.590000	0.480000	0.600000
	Italy	0.420000	0.780000	0.820000	0.840000	0.810000	0.850000	0.810000	0.430000	0.770000	0.810000	0.820000	0.810000	0.830000	0.810000
	Germany	0.330000	0.280000	0.460000	0.660000	0.560000	0.650000	0.540000	0.310000	0.260000	0.480000	0.630000	0.510000	0.620000	0.490000
	Sweden	0.870000	0.860000	0.850000	0.880000	0.880000	0.900000	0.880000	0.760000	0.750000	0.720000	0.760000	0.770000	0.790000	0.780000
	All	0.545000	0.595000	0.690000	0.722500	0.717500	0.737500	0.715000	0.497500	0.555000	0.650000	0.667500	0.670000	0.680000	0.670000
MCC	Norway	0.411145	0.330881	0.440577	0.436731	0.436207	0.470887	0.441508	0.292408	0.201823	0.298402	0.229481	0.262427	0.254448	0.288256
	Italy	0.533106	0.630630	0.600098	0.691565	0.616091	0.713109	0.648542	0.563421	0.509543	0.519003	0.535002	0.516300	0.586460	0.552142
	Germany	0.654959	0.691220	0.693038	0.789012	0.696008	0.802215	0.700297	0.550255	0.533153	0.569785	0.565854	0.548093	0.561860	0.557945
	Sweden	0.717952	0.724049	0.719140	0.717613	0.729430	0.735407	0.731703	0.665387	0.647109	0.644428	0.629789	0.641048	0.643121	0.656794
	All	0.579290	0.594195	0.613213	0.658730	0.619434	0.680405	0.630513	0.517868	0.472907	0.507904	0.490031	0.491967	0.511472	0.513784

References:

- Graf, M., Chwala, C., Polz, J., & Kunstmann, H. (2020). Rainfall estimation from a German-wide commercial microwave link network: optimized processing and validation for 1 year of data. Hydrology and Earth System Sciences, 24, 2931–2950
- Pastorek, J., Fencl, M., Rieckermann, J., & Bares, V. (2022). Precipitation Estimates From Commercial Microwave Links: Practical Approaches to Wet-Antenna Correction. IEEE Transactions on Geoscience and Remote Sensing, 60, 1–9
- Polz, J., Chwala, C., Graf, M., & Kunstmann, H. (2020). Rain event detection in commercial microwave link attenuation data using convolutional neural networks. Atmospheric Measurement Techniques, 13, 3835–3853
- Øydvin, E., Graf, M., Chwala, C., Wolff, M. A., Kitterød, N.-O., & Nilsen, V. (2024). Technical note: A simple feedforward artificial neural network for high-temporal-resolution rain event detection using signal attenuation from commercial microwave links. Hydrology and Earth System Sciences, 28, 5163–5171.