Areal rainfall estimation using moving cars as rain gauges - modeling study and laboratory experiment

Ehsan Rabiei, Uwe Haberlandt, Monika Sester and Daniel Fitzner

Motivation and Aims

- High variability of precipitation in space and time
- Increase in short-term intensities
- Sources → conventional rain gauges (accurate but low density)
  → weather radar (large space-time variable bias)
- New potential → moving cars, raincars

Modeling study – Methods and Data

1) Study area, the Harz Mountains in Northern Germany. Four mesoscale catchments of different sizes are selected for areal rainfall estimation.

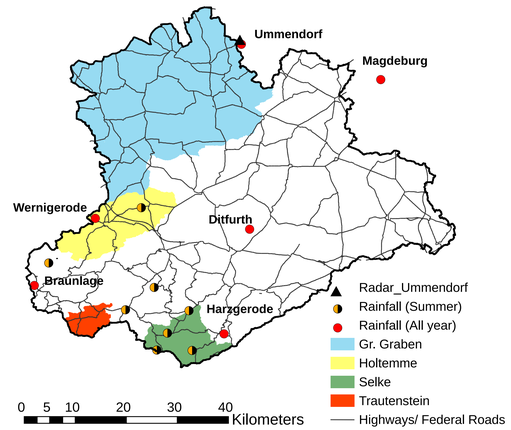

Fig. 1: Study region showing the selected four catchments for the estimation of areal rainfall, the stationary rain gauges network and the location of highways and freeways used for the simulation of the car network. The all year station network represents a typical recording rain gauge network density in Germany. In addition, a weather radar station is covering the whole area within its observation range.

2) A simple traffic model, assumed average speed of the cars on major roads is 80 km/h. Here, only one type of road, major roads, are used neglecting all smaller roads.

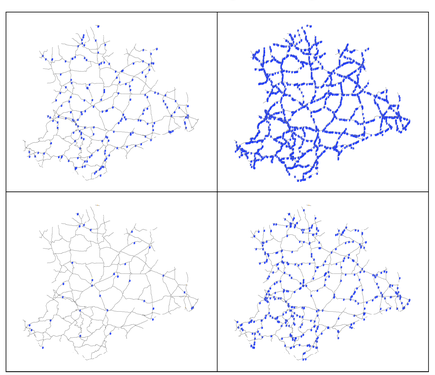

Fig. 2: Example for car distributions considering traffic with a sensor equipment rate of 1% on the road network of the study area, the 3300 km² Bode catchment in Northern Germany, during day (upper row) and night (lower row). On the left is the situation at one particular sampling time (5 min time step), on the right is the information of an accumulated sampling result of one hour.

3) Rainfall observation by cars, the crucial task is to find a relationship between either wiper speed (W) or signals from optical sensors and rainfall intensity (R). Possible ways to establish W-R relationships are:

a) assuming error free W-R relationships → Ordinary Kriging

b) assuming uncertainty in W-R relationships → Indicator Kriging

c) estimating W-R relationship from laboratory experiments.

d) estimating W-R relationships from field experiments

4) Areal rainfall assessment,

- radar as the reference (true)
- ordinary kriging for interpolation of the point rainfall time series from the gauge networks
- indicator kriging for interpolation of the "raincars"

less accurate measurements (old fashion cars) → cars_IK4

rather precise measurements (modern cars) → cars_IK10

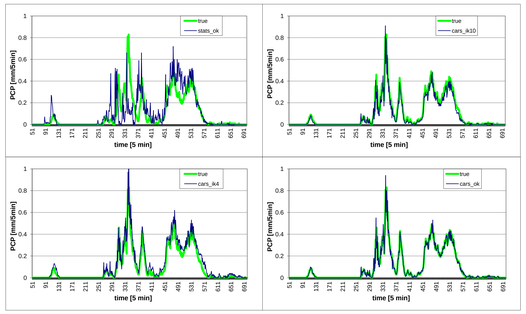

Fig. 3: Areal rainfall time series for the Gr. Graben catchment (as an example) estimated from the stationary gauge network using ordinary kriging (stats_OK) and estimated from the car network with 4% sensor equipment rate using indicator kriging with 4 rainfall classes (cars_IK4), using IK with 10 rainfall classes (cars_IK10) and using OK without rainfall classification (cars_OK). Reference areal rainfall is from radar data (true).

Modeling Study – Results

- rain gauge → red line
- car_OK → light dotted
- car_IK10 → medium dotted
- car_IK4 → heavy dotted
- D_{sub}-station → blue triangles
- D_{sub}-car → blue squares

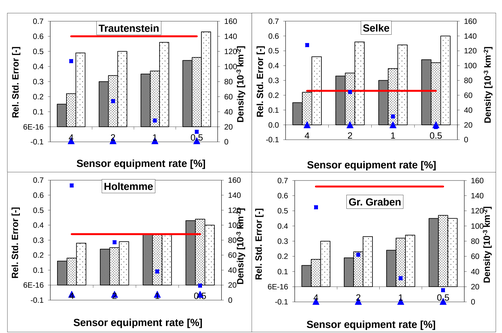

Fig. 4: Performance of areal rainfall estimation from rain gauge network (horizontal red line) and from the 4 car networks with different sensor equipment rates (bars).

Laboratory Experiment – Data

Rainfall by a sprinkler irrigation system, for:

- Stationary cars
- W-R relationship for different rainfall intensities

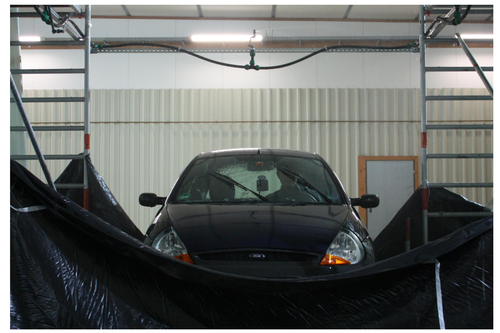

Fig. 5: cars with different wiper systems are being investigated under different rain intensities produced by a sprinkler irrigation system in laboratory. By changing the nozzles and the pressure on the nozzles different intensities are adjusted. The produced rainfalls , measured by conventional rain gauges, is recorded in a PC and analysed against wiper frequencies, afterwards.

Laboratory Experiment – Results

Estimating W-R relationship:

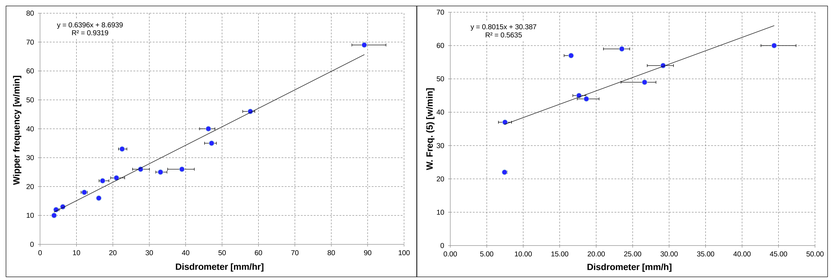

Fig. 6: Example for W-R relationship done in the laboratory. Except for the automatic option, right figure, the wiper is adjusted according to the visibility. The left figure represents the wiping activity when the adjustment is done completely manually.

Outlook

- Simulating car movement in the laboratory
- Field experiments: W-R relationship for moving cars
- Communication between cars-stations, update W-R relationship

Literature

HABERLANDT, U. and Sester, M. (2010): Areal rainfall estimation using moving cars as rain gauges – a modelling study. Hydrol. Earth Syst. Sci., 14, 1139-1151, 2010

DFG Deutsche Forschungsgemeinschaft

EGU General Assembly 2012, Vienna

Institute of Water Resources Management, Hydrology and Agricultural Hydraulic Engineering
Correspondence: rabiei@iww.uni-hannover.de

Leibniz Universität Hannover