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Hydrology and Earth System Sciences Discussions

Interactive comment on "Areal rainfall estimation using moving cars as rain gauges – a modelling study" *by* U. Haberlandt and M. Sester

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GENERAL REMARKS (BOTH REFEREES)

We are very grateful to the referees for their comments and suggestions on our manuscript. The main critique of both referees is that we have not provided experimental results for the link between windscreen wiper frequency and rainfall intensity. We agree fully with the referees that this would be mandatory for an objective validation of the feasibility to measure rainfall this way. We even think that extensive experimental work in the field and in the laboratory and several more theoretical studies are required before this idea may be used or may be rejected in practise. However, this cannot be achieved with this first and only paper on this issue. Practical experiments are far beyond the scope of this study. The main purpose of our paper was to present this new idea and show initial modelling results which should encourage further research and facilitate subsequent practical experiments. In the following we will respond to the specific comments of the referees. We are confident to be able to provide a revised version which will answer all specific comments. We still believe that the paper after such a revision is interesting enough to be presented to a broader scientific community on the HESS platform. We would like to ask the editor for a statement if such a proposed revision without carrying out new research based on practical experiments is sufficient for the publication of our paper in HESS.

SPECIFIC COMMENTS OF REFEREE #1:

1. An assessment of the interpolation uncertainty could be made by cross validations considering different network densities. For that real rainfall networks with observed rainfall or synthetic networks with radar data input could be used. Using measurements of nearby rainfall stations for the calibration of wiper frequency – rainfall intensity relationships for passing cars is exactly what is suggested with on-line calibration in option c).

2. There are several studies available which recommend merging methods using both point rainfall observation and weather radar data to improve rainfall estimation for hydrological simulations (e.g. Goudenhoofdt and Delobbe, 2009). The authors think, that those methods could be applied to evaluate if combined rainfall information provides better reference rainfall data for calibration than the single information from conventional rain gauges alone.

3. Weather radar rainfall is used here only for relative comparisons of the performance between different point station networks and car networks. The word "truth" means here "reference". This modelling study requires having available space-time high resolution rainfall fields as reference for comparisons of interpolated fields from the point and car networks. Instead also stochastically generated rain fields could have been

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employed for this purpose (see e.g. Seo et al., 1990). However, the authors have preferred to use radar data, since those data are probably closer to reality regarding space-time dynamics than pure stochastic data, and it avoids the additional introduction of a stochastic weather generator.

4. For this study the cars are simply generated with uniform density on all roads. This is motivated by the fact, that only one type of road, namely major roads, are used neglecting all smaller roads, and it simplifies this initial analysis. This procedure will certainly to be refined in subsequent studies to consider the spatial variability in traffic density. If other roads were also included it would increase the spatial traffic variability but it would also further increase the potential of the car network for improved rainfall estimation (see section 4.1).

5. Yes. Rainfall from that raster cell in which the gauge is located or which the car is just crossing at the observation time interval is taken as observed point value.

6. The values in Table 2 are the result of empirical counting of discrete car positions in the whole area within a time interval of one hour for three time phases of the day (day, evening, night). Given car velocity, traffic density, road length, observation time interval and sensor equipment rate those figures can also be calculated analytically. The values in the second column are computed by normalizing the first values by the whole area, resulting in an average car position density per hour and km2. Note that the figures in Table 2 are in fact the number of car locations (and not the number of cars) counted within one hour for a discrete observation time interval of 5 minutes. The difference is visualized in Fig. 4, where on the left panels the real number of cars is shown and on the right panels the integration of car positions used for observations over one hour.

7. Cars can only travel on roads. So the car precipitation network is restricted to roadways. Considering the preferred location of road lines e.g. in valleys and the relation of rainfall to elevation (i.e. on average higher rainfall for higher locations) the

car network forced on roads might e.g. underestimate precipitation. For that reason one additional computer experiment is carried out generating cars anywhere within the catchment area ignoring roadways.

8. To answer questions regarding point measurement errors using cars as rain gauges practical experiments have to be carried out. This study answers questions regarding interpolation uncertainty given different network densities (how many cars are needed) and regarding the required discretisation of the rainfall sensors in cars (3 cases: continuous, 10 classes, 4 classes). The discretisation can be seen as assumed observation uncertainty, as more coarse the classification as more uncertain the observation. However, for each case it is only assumed here (and not proven) rainfall can be observed with this discretisation accuracy. The real accuracy of the rainfall measurement using wiper frequencies will most certainly depend on the factors mentioned by the referee. The quantification of those errors, however, is subject to further research which includes extensive practical experiments.

SPECIFIC COMMENTS OF REFEREE #2:

1. See our response to the general comments and to the comment 8 of referee #1. The indicator kriging approach using 10 classes or 4 classes for wiper frequencies allows considering different uncertainties in rainfall observation by cars. Still, it assumes a correct definition of the class intervals which might add uncertainty after practical testing.

2. See above. Spatial variation of uncertainty is partly addressed by analysing 4 different subcatchments with different topography, precipitation characteristics, network density, etc. There are certainly many more factors which may be evaluated regarding uncertainty which requires several future studies. This additional information can be included taking available land use data into account, e.g. driving under trees, in dense city area, etc.

3. See our response to comment 3 of referee #1.

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CITED REFERENCES:

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