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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Rainfall estimation using moving cars as rain gauges – laboratory experiments" *by* E. Rabiei et al.

Anonymous Referee #1

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This paper is a follow-up study of Haberlandt and Sester (2010) where the authors show the potential of cars to measure rainfall by obtaining information on wiper frequency of windshield wipers. In that study radar rainfall depths are assigned to the simulated moving cars, which are subsequently employed to estimate areal rainfall. That simulation study was useful, but few is known about the relation between wiper frequency / optical sensor readings and rainfall intensity. Hence, it is valuable to estimate these relationships from laboratory experiments. In my opinion, this paper is a good attempt to give a first estimate of these relationships, which can be helpful for an operational application in the future. The paper is well-written. I believe that this paper is suitable for publication if the remarks below are largely taken into account. For some remarks it is sufficient if a clarification is given in the reply.

P 4208, L 19: Not only wiper speed, but also signal length is used. Furthermore, wiper activity is also controlled manually by a driver and registered. Please mention these different settings.

P 4208, L 25 - 26: The authors could briefly touch upon the relevance of accurate spatial precipitation assessment, such as operational usefulness for water management. Authors could also be more specific and mention the definition of short (e.g., < 1 hours) or, for example, the requirements in terms of spatial resolution.

P 4209, L 4: "but these are poor in density". This is often the case, but some areas or countries may have a relatively high density of recording gauges. The statement could therefore be slightly weakened, e.g., "but these are often poor in density".

P 4209: The authors consider radar data, but not merging of radar and rain gauge data, which is a common approach and will often give better results. This can give useful rainfall estimates, although particularly for real-time applications, the number of automatic rain gauges is often quite low, so that there is room for improvement. The quality of radar data depends on the applied corrections. New operational ground-based weather radars are often of the dual-polarization type, which gives more opportunities for physical corrections. It is recommended to extend the introduction a bit to describe the different (potential) observational systems in more detail.

P 4209, L5: Although the (potential) usefulness of radar data for quantitative precipitation estimation is increasing, I would not call it a new source of rainfall information. Development started some 70 years ago and several meteorological institutes have been operating weather radars for decades.

P 4209, L6: "has a large space-time variable bias in rainfall estimation". This will often be the case, but certainly not always, depending on, for instance, the weather type. In addition, gauge-adjusted radar data can have a considerably smaller space-time variable bias, depending on the adjustment method and the number of available recording rain gauges.

P 4209, L8: Although microwave links are not used to operationally measure rainfall, it may be worth describing the measurement technique shortly, and/or refer to some papers, e.g., Messer et al. (2006), Leijnse et al. (2007). They were the first to show that microwave links from cellular communication networks can be used to retrieve rainfall. Other references which could be added are, e.g., Zinevich et al. (2009) or Overeem et al. (2013).

P 4209, L14: "They use" instead of "They used".

P 4209, L 21: "show" instead of "have shown".

P 4209, L 26: For clarity it could be added that wiper speed is controlled manually by a driver or automatically by optical sensors.

P 4210, L 20: A number of times "homogenous" is used, but this should be "homogeneous".

P 4210: A bit more information could be given about the quality of tipping bucket rain gauges to measure rainfall in the laboratory. Some references could be added, e.g., WMO or related scientific papers, which may be available.

P 4213: "RainCars" in Section heading should be replaced by "cars".

P 4213, L 13: "by applying different sensitivities". Will the possible sensitivity settings also differ between car models? And what can be concluded from applying different sensitivity settings for the investigated car?

P 4213, L 17: "depending on the car type". I expect aerodynamics to influence the impact of raindrops on windshield / sensor (e.g., the shape and size of the hood).

P 4213, L 18-20: What would be the effect of a wiper passing the optical sensor? Could the wiper, which is wet, cause some water droplets to move from the wiper to the optical sensor? (e.g., when the wiper reaches its lowest position for which there is a large change in velocity)

P 4214, L 7-8: How do drops on the surface allow some beams to escape? Could this be clarified?

P 4219, L 8: How the prediction limits have been calculated and shouldn't these be called confidence limits?

P 4219, L 9: The number of points in Figure 5 seems to be 16 (left) or 9 (right), which is substantially lower than the 32 from Table 3 (particularly for the automatically adjusted wiper activities). This seems to be a serious limitation of the automatic system, which could be stated (more clearly) in the conclusions. In addition, there also seems to be a reduction in the number of classes for the manually adjusted wiper frequency, or am I mistaking?

P 4219, L 12: I believe "w" = wipes has not been defined yet.

P 4219, L 22: "on the windshield" instead of "on windshield".

P 4219, L 26-28: Could the authors clarify this?

P 4220: In Figure 6, rainfall intensities are plotted against rainfall intensities or signal lengths and not against wiper frequency. Hence, W-R relationships are not considered.

P 4220, L21: "likely comparable data processing". Is it meant that a similar linear relationship is used by the manufacturer to convert optical sensor signal to wiper frequency?

P 4222, L 5: Rain type in terms of rainfall velocity?

P 4222, L22: Do the authors have an explanation for the (linear) relationship between W and R?

P 4222: The authors could clearly state the limitation to reproduce smaller rainfall intensities. A rainfall intensity of 9 mm/h is already quite large. Are sufficient wiper frequencies left for this and higher intensities? In addition, it could be mentioned that the results for the manual driver are to some extent subjective and can depend on the

person. Did the same driver control the wiper frequency for every experiment?

P 4223, L 19: Replace "Assuming," by "Assuming".

P 4224: One may wonder whether the nozzles are able to realistically produce rain. For instance, "rain" starts at 3 meters height in the laboratory, whereas in reality rain travels usually at least hundreds of meters in the vertical, which influences the drop size distribution (e.g., through break up due to collisions). Hence, it is, as the authors already recommend, important to perform a field study. Ideally, such a field study would involve several cars which are used to make a local areal rainfall estimate. In addition, the authors may clearly mention whether an operational application would be feasible, in terms of logging car sensors, expenses, and sending sensor data to a central database. An ultimate goal would be to make real-time rainfall maps based on car sensor data or to adjust radar data employing car sensor data.

Figure 6: Some statistics could be added to plot b), e.g., mean intensities for tipping bucket and Hydroneon, coefficient of variation.

Figure 7: The experiment does not use a car, which may influence the results. This could be stated more explicitly in the paper. Black line concerns mean experimental results. It is not entirely clear to me why the black lines in a) and b) differ (how they have been constructed). Therefore, the methodology with respect to Figure 7 could be described more clearly, I find it a bit difficult to understand.

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, doi:10.5194/hess-14-1139-2010

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

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munication networks. Science 312, 713

Overeem, A., Leijnse, H., Uijlenhoet, R., 2013. Country-wide rainfall maps from cellular communication networks, Proceedings of the National Academy of Sciences, 110, 2741-2745, doi:10.1073/pnas.1217961110

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