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Discussions

Interactive comment on "Exploring the use of a superconducting gravimeter to evaluate radar estimates of heavy rainfall" *by* Laurent Delobbe et al.

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In this paper rainfall estimates from a weather radar and an underground gravimeter are compared. A straightforward method of estimating rainfall from the gravimeter is presented. Gravity measurements are first corrected for tidal effects and atmospheric loading, and are then converted to rain accumulations by applying a moving average, and a linear relation between gravity and accumulated water. Results that are presented show that the gravimeter indeed has a strong precipitation signal. It is also shown that the gravimeter data can help in the case of hail, where radars typically overestimate precipitation rates. The paper is well-written and very interesting for readers

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Discussion paper

of HESS. As far as I know, this is the first time that rainfall estimates from an underground gravimeter are reported, and hence the paper is very novel. The paper could benefit from adding known information about uncertainties in gravimeter data in order to facilitate comparison of the two. I have a few further suggestions for minor changes to the paper, after which I think the paper is ready for publication. Specific remarks are given below.

Specific remarks

1. In Figs 2, 4, and 6-9, please add error margins to the gravimeter data so that it is immediately apparent what the expected uncertainty of these measurements are.
2. On p.6, line 23, it is stated that the 5-minute gravity change is averaged over 5-minute intervals in order to remove high-frequency gravity fluctuations due to other sources. It would be very interesting to know how this 5-minute time scale is related to the time scales of hydrological processes that would affect the gravity measurements through the redistribution of water. Please add a statement on the typical timescales of these processes. This can then be related to the 5-minute scale of averaging, but also to the typical time scales of individual rainfall events.
3. In Fig.2, it is clear that there are high-frequency fluctuations present in the gravimeter data. I would recommend discussing these fluctuations, and potential ways to remove them. For example, would it be possible to average gravity differences over longer time intervals (say, 15 or 30 minutes) to remove most of these fluctuations? It would be interesting to see the effect of different averaging time scales on this apparent noise. Please consider adding a sensitivity analysis to the scale of averaging.

4. On p.10, lines 5-6, it is concluded that a rainfall signal can be detected when radar reflectivity exceeds 40 dBZ. However, this conclusion is based on comparison of the 5-minute signals. I think that it is very well possible to detect rainfall signals even if reflectivity values are lower than this if the rainfall is averaged over sufficiently long time periods. This is for example demonstrated in Fig.2, between 1:00 and 6:00 UTC, where the radar only exceeds 20 dBZ most of the time, and 30 dBZ on just a few occasions. Yet the total accumulation by the gravimeter nicely follows that of the radar. So I think that this conclusion is too hard on the method that is presented. Please rephrase this conclusion to reflect this.

5. On p.10, lines 14-15, it is concluded that a 48-dBZ hail cap works better than a 55-dBZ hail cap. This 48-dBZ hail cap corresponds to 36 mm h^{-1} (for M-P) or 34 mm h^{-1} (for RADOLAN). These thresholds seem rather low, and could result in missing significant rainfall. My guess is that this optimal threshold is partially a result of compensation for error sources other than hail. Please comment about this in the paper.

6. In order to make the paper more concise, I suggest removing Figs 6 and 9. The points in Fig.6 are already given in Fig.7, and there is only a minor difference between Figs 7 and 9. Furthermore, results from Fig.9 are also summarized in Table 1.

Minor remarks

1. On p.1, the title does not include the fact that the gravimeter is underground, but this is an essential element of the paper (it probably would no work so well if the gravimeter was at the surface). Please modify the title to reflect this. Suggestion: replace “superconducting” by “underground”

2. On p.2, line 12, consider replacing “puntual” by “point-scale”.

3. On p.2, line 23, consider mentioning that this is mostly the case for C- and X-band radars (not so much for S-band radars).

4. On p.2, line 25, consider referring to Fabry et al. (1994; https://doi.org/10.1016/0022-1694(94)90138-4)

5. On p.2, line 33, consider adding a remark that the radar sampling area is at least 1 million times as large as a gauge sampling area.

6. On p.5, lines 3 and 4, there’s a typo in the units (should be “nm/s^2/hPa”; this occurs twice: on lines 3 and 4). Consider using using notations for units such as “nm s^{-2} hPa^{-1}” instead of using the “/” character throughout the paper to increase readability.

7. On p.5, lines 3-5, it is mentioned here that the values of the coefficients vary with with time as well as the frequency of pressure fluctuations. In the conclusion that is drawn that there is a 15% uncertainty in the gravimeter data is based on the differences between the minimum and maximum values of these coefficients. It is hence implicitly assumed that the time variations of these values is much less than the variation with frequency (or cpd). Is this correct? If so, please add a statement that the time variation is much smaller than the variation with cpd.

8. On p.5, line 8, what are “tares”? I assume this refers to the “gap, steps, or spikes” from the previous sentence. Consider removing this word such that it reads “These are essentially...”.

9. On p.5, line 17, it is unclear to me what “precision” means in this context. Is this the noise expressed in the power spectral density of the gravity signal? Or is it something else (such as mentioned in the abstract on p.1, line 15). Please briefly mention in the paper what is meant by the precision here.

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10. On p.5, line 32, consider removing the word “large”.
11. On p.8, line 23, the mean bias is defined as the ratio of the radar sum and the gravimeter sum. I generally interpret “bias” to mean the systematic error, that becomes negative in case of underestimation (and I think more readers would, too). I therefore recommend expressing the bias as the sum of differences divided by the sum of the reference (i.e., the radar). In practice, this means subtracting 1 from the original numbers. But, in my view, it does give more clarity.
12. On p.8, line 30, consider removing the word “falls”.
13. On p.10, line 32, consider removing the word “falls”.
14. On p.11, line 8, consider removing the word “fall”.

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