Author’s response to interactive comments by Referee #1

Post-processing is essential to the automated accumulating precipitation gauges, although it is just a filtering technique. This study proposed an improved post-processing technique to tackle the noise caused by diurnal oscillations and drift from the evaporation of the bucket contents. Comparing with other techniques, the major advantage of the suggested one is its fully automated processing with a 24-hour latency.

Generally, this study is well written and presented. I am happy to see this paper published in the Atmospheric Measurement Techniques. But the following issues should be addressed properly before the paper can be considered for publication.

1. For users, people would like to know what are the performances of the filter for all-weather precipitation. Compared to a much smaller amount of solid precipitation in the cold season, testing the filter might be more important in the warm season. First of all, the drift from evaporation in the warm season can be much more serious in most cold regions, and the evaporation rate can be much larger. Secondly, the noise features can be quite different between warm and cold seasons. Thus, to make the conclusion more solid for both rainfall and solid precipitation, I would like to see the performance for the warm season.

AC: The reviewer makes a good point. It is important that users know the performance of the filter for each season. For this analysis, however, we chose winter for several reasons:

1)The data set that we had available to us was a mainly cold season precipitation data set originating from the WMO-SPICE (or post-SPICE) project. We chose this data set because it had a known quality. This data came with relatively meticulous metadata such as service logs and field notes so that we were confident in our ability to quality control this data to allow for a level playing field for each filter. The quantity and quality of the warm season data from SPICE is reduced and much of this wasn’t readily available at the time that this analysis was undertaken.

2)The signal to noise ratio is always lower in the winter due to lower (generally) precipitation rates. In our opinion, this makes filtering of winter data substantially more difficult than filtering of summer data, where small absolute errors are less likely to be large relative errors.

3)We know that the evaporation signal in the SPICE data is significant during the shoulder seasons (Fig. 5c as an example), perhaps even more significant relative to total precipitation than evaporation during the summer months. We felt that this cold (shoulder) season evaporation would be a considerable challenge to the filters.

To help answer the question about warm season performance, we ran a separate control experiment on the warm season and added 11 available unprocessed warm season time series to the analysis.

The results of the warm season control analysis suggested that in general, the performance of NAF remained consistent, NAF-S improved, O15 became even more unstable, and the performance of NAF-SEG dropped somewhat, apparently because of a lower recovery rate for evaporation (Table 4). However, NAF-SEG continued to outperform NAF and O15 in nearly every metric.

Although we don't have nearly as much summer data as winter data due to the focus of SPICE, we filtered 11 available warm season time series of known data quality for comparison with winter results. All filters showed a slight reduction in performance for the warm season with an increase in RMSD vs. the cold season (Table 5). The biggest increase in RMSD was in the O15 filter (increase of nearly 0.03 mm).

Action: We have clarified our justification in the methods section for focussing on the filtering of cold season data but since we agree that assessing the performance during the warm season is also important, we have added the warm season control exercise and the addition of the 11 warm season time series to the methods sections and summarized the results from these experiments in the appropriate sections, including an update of Tables 2-5 and the addition of Table A2. A substantial addition to the Discussion section was made to discuss the results of both the pre-processed and unprocessed warm-season testing.

2. Compared to the robustness of NAF-S, the validity of NAF-SEG is closely related to the setting of the minimum threshold P* = 0.001 mm. Although the authors assert it is somewhat arbitrary within the tested conditions of solid precipitation measurements, it might be challenging for the noise features in the warm season. Considering the more variability of precipitation and stronger evaporation in the warm season, further exploration in the point is necessary. In addition, there is no validation for the raw precipitation data when using the filters. Therefore, validation using independent measurements from the tipping bucket would be very helpful for the filtered measurements from the accumulating gauges.

AC: Analysis not shown in the manuscript tests the sensitivity of NAF-SEG to P* and found little to no sensitivity (which was actually somewhat surprising), but the reviewer would be correct in assuming that the tests were only performed on winter data. This can be tested relatively easily using the same data used to address comment 1. As for using tipping bucket rain gauge (TBRG) data as a reference (during warm season tests), the authors feel that TBRG data has it's own inherent problems and would be not be conducive for use as a reference or even as an independent validation due to known issues with splash, siphoning delays, unknown maintenance issues, calibration, etc. We think that the greatest potential for future improvements could be the incorporation of present weather detectors or disdrometers into the filtering process for identifying light and false events.

Action: Using the same observed warm season time series data discussed above, the NAF-SEG filter was tested using different P* values ranging from 0.0001 mm to 0.5 mm. This is a very similar test to that run using cold season data. Results were similar to the cold season in that the response in the metrics was subtle up to 0.05, only dropping off substantially at 0.5. This was added to the discussion section. Also, in response to the reviewers question about independent validation, we added a paragraph to the discussion section suggesting that the use of present weather detectors or optical disdrometers could be explored to validate or improve filtering techniques. The use of a TBRG or other precipitation detectors is out of the scope of this current analysis.

3. As we know the performances of the filters are slightly related to the climate of the observed sites. Further discussion of the relationships between the biases for the 44 raw time series would help understand the validity of the filters in different environments.

AC: The reviewer makes a good point. However, it's not the filter that is impacted by climate but rather the behaviour of the precipitation gauge. Although climate is a factor (e.g. wind vibration, temperature signals, evaporation), there are many non-climate related factors that also have a significant impact on gauge performance, such as electrical interference, service interval, or even the actual installation of the gauge and infrastructure. These are very difficult to isolate from the impacts of climate. Examining the impact of these factors, including climate conditions, on the signal behaviour of the gauge was discussed in the SPICE final report and was recommended for further analysis, but understanding these impacts are out of scope for this analysis.

Action: In the discussion section, we suggest that filtering techniques (whether this filter or others) could be improved by better understanding the cause of signal noise and filtering made easier by reducing signal noise during measurement.

Minor comments:

(1) P1-L5: If my understanding is correction, this study is talking about the weight-based precipitation gauge. It is quite confusing when using 'automatic precipitation gauge', 'automated accumulating precipitation gauge' and 'automated accumulating (weighting) precipitation gauge'.

AC: These gauges are in fact accumulating automated weighing precipitation gauges.

Action: We will define this better and make the nomenclature consistent to “automated weighing gauge”

(2) P12-L406: ‘his’ to ‘this’

Action: done