Answer to comments of Referee #1

We thank the anonymous Referee #1 for his constructive comments on our manuscript and work which enables us to further improve the quality of our manuscript. In this document we repeat the referee's comments (black font) and add our reply to each point (blue font).

Evaluation

This manuscript presents the analysis of the rain rate estimated from operational telecommunication microwave link in Germany. Received Signal Levels (RSL) from 5 links as well as measurements from 6 rain gauges and 1 weather radar are used in the present study. First, a new approach (based on the Fast Fourier Transform - FFT) to estimate dry and rainy occurrences from link measurements is proposed. Then the collected link data are processed (estimation of the attenuation baseline, conversion of attenuation into rain rate) and compared to rain gauge and radar observations. The new spectral approach for the estimation of dry and rainy occurrences is interesting and innovative. It is in my opinion the real contribution of this manuscript, and should hence be the focus of the paper. The possibility to use telecommunication microwave links for rainfall monitoring is not new (and appropriately referenced in the manuscript). The necessary changes and maybe the additional analyses required may be significant (see general and specific comments below). I therefore recommend to send the manuscript back to the authors for major revisions.

We thank the referee for acknowledging the innovative potential of our wet/dry classification method and agree that it is a crucial contribution of this manuscript. We will thus try to add additional explanation and detail to this part (see also answers to comments of referee #2).

In addition we want to note that our work also presents the innovation of using data loggers to record RSL data from commercial microwave links, making a high sampling rate and a small RSL quantization possible. To our knowledge it is also the first exploitation of commercial microwave links in alpine terrain. Furthermore we show results of a continuous analysis of RSL data for rain rate estimation over several months. That is, no dry period, which can accidentally be classified as wet and contribute rain rate where there should not be one, is left out in the analysis.

General comments

1. As mentioned in the evaluation, I think that the main contribution of this manuscript is the new approach based on FFT to identify dry and rainy periods using link measurements only. The subsequent analyses on the quality of the rain rate estimates should, in my opinion, be refocused to serve the evaluation/ validation of the dry/rainy identification method. The current evaluation based on the "final" rain product (the rain rate) has the drawback of mixing all the sources of errors along the processing chain to get the rain rate (e.g., uncertainty in the attenuation baseline, wet-antenna effects, deviations from ITU power law parameters).

The evaluation of the wet/dry classification algorithm is not based on the "final" rain product. We analyze its performance and limitations in section 6.4 and 6.5 showing the detection error rates in figure 5. However, the analysis of the derived rain rates in section 7 is also of importance. It reveals the impact of the misclassifications of wet and dry periods, contributing the points along the x- and y-axes (mentioned on page 579, line 6-7) of the scatter plots in figure 8 and figure 9. We agree that the absolute values of the derived rain rates are subject to uncertainty introduced by wet-antenna effects and deviations from the ITU power law parameters. This is however always the case when exploiting microwave attenuation data as long as the DSD along the link path and the actual wetting of the antenna are not known. Nevertheless the rain rate is the final product. Hence, in our opinion, it is important to show it.

As mentioned above, the novelty is not in the use of link data to obtain the rain rate, so I would recommend to conduct the same analyses using also some “classical" dry/rainy identification methods (some are listed in Section 6.1). The comparison between the obtained rain rates with rain gauge and radar data will then enable the authors to quantify the improvement of the new proposed identification method with respect to existing approaches.

We agree that a comparison of different wet/dry classification methods is an interesting subject. In our opinion it would be beyond the scope of this manuscript, though. Our focus is to introduce the data acquisition method using data loggers at the towers, to describe our test region and to give a detailed description of the spectral wet/dry classification method together with a discussion of its results and limitations.
A comparison of the different wet/dry classification methods will ideally be undertaken exploiting RSL data from different regions (alpine, flatland, arid). Together with short descriptions of each method this will make up for a paper on its own.

2. In the current version of the paper, I miss some information/comments about the transferability of the proposed approach to other regions. Is there any specific requirements to be able to run this FFT method?

The FFT method requires a high sampling rate, like in our case one sample each minute. For slower sampling rates, e.g. 15 minutes (= 1×10^{-3} Hz) like RSL data that some cell phone network operators provide, the frequency range of the calculated spectra won't cover the important range between 1×10^{-4} to 2×10^{-3} Hz, which we found to show the most significant differences between rainy and dry periods.
Furthermore a slower sampling rate would also cause problems choosing an appropriate window length. Our FFT based method dose not work properly with very short window lengths. It needs a certain frequency resolution of the spectra which is determined by the number of points used to calculate the spectra, given by the window length. At a sampling rate of 1×10^{-3} Hz (that is, each 15 minutes) a window that is four hours long (more or less equal to the one used in the manuscript with 256 points sampled every minute) would only contain 16 points. This could be compensated by increasing the window length. But as mentioned in the manuscript (page 756, line 22) long windows have the tendency to falsely detect wet events before and after the actual rain event. We will explain these constraints in the revised manuscript.

Would it be easy to implement your “RSL data logger" to other operational networks? These are important aspects concerning the potential of the proposed approach.

If the links provide an analog voltage output to monitor the RSL an installation of our loggers should be straight forward. Depending on the range of the voltage output an additional small voltage transformator circuit might be necessary. However, to our knowledge not all telecommunication links have an analog voltage monitoring output. It seems more likely to be available at older hardware. That is, the possibility to use our methods would have to be checked with the network providers individually. We will add information on this in the revised manuscript.

3. A maybe less important issue: only the RSL is measured, so the authors implicitly assumed that the transmitted power is constant. From my personal experience, it seems that this is not always true... Could the authors comment on this?

The links that we monitor have a constant transmission power. We will mention this in the revised manuscript.

Specific comments

1. P.742, l.22-23: please provide an order of magnitude of this “desired accuracy".

We will rewrite this sentence.

2. P.745, l.1: this sentence may be confusing: if the DSD does not vary in space and time, the rain rate does not vary either...

We were referring to a change of the “shape” of the DSD rather than its change that results in different rain rates. We will rewrite this part.

3. P.745, l.19: is the term “orography" really appropriate here? Maybe topography is more suited (not sure though...).

We are not sure either. Both terms seem to be used in the scientific literature in this context. According to Wikipedia both “Orography” and “Topography” are fields of science concerned with the shape of the earth’s surface. It seems however that only “Topography” can be used to refer to the surface shape and features themselves. We will thus use “steep topography” in the revised manuscript.

4. P.746, Section 4.1: nothing is said about the transmitted power (see general comment 3), although it must be supposed constant to derive the attenuation affecting a given link.

The links that we monitor have a constant transmission power. We will mention this in the revised manuscript.

5. P.747, Section 4.3: more information about the radar data is necessary: what is the elevation considered?

Elevation angle is 0.5°.

How are filtered the ground clutters (especially in such a mountainous region)?

Data in the southern mountainous part of our test region is not used because the radar beam is completely blocked by the mountains. For the radar data used as comparison for the two links at Mount Hoher Peissenberg there is no ground clutter, because the radar location is about 300 m above the surrounding area towards the east.

What are the coefficients used for the Z-R power law?

We use

$Z = 125*R^{1.4}$

which is the first part of the three part Z-R relation from the RADOLAN project for stratiform rain events. We will elaborate on the radar data in the revised manuscript.

6. P.749, l.18-19: just out of curiosity: is the wet-antenna attenuation always the same in the horizontal and vertical polarizations?

We do not know of any research on this topic. The polarization dependence of the wet antenna attenuation of course depends on the shape of the drops on the antenna radome. Compared to the deformation of falling rain drops resulting in differences of horizontal and vertical diameter of up to a factor of 2 (e.g. H. Pruppacher and K Beard, A wind tunnel investigation of the internal circulation and shape of water drops falling at terminal velocity in air, *Quarterly Journal of the Royal Meteorological Society*, 408, 247-256, 1970), the relevant shape of the drops sticking to the antenna radome will most probably be almost circular. If the drops do not stick to the radome but rather are slowly rolling of, this could be different.

7. P.752, l.8-9: it is not clear to me how these frequency thresholds have been obtained.

The frequency thresholds were chosen by hand to make the algorithm work robustly. Also considering comments by the second referee we will add additional explanation on the choice of these thresholds.

8. P.754, l.22-23: a word must be missing, I do not understand this sentence.

We will rewrite this part.

9. P.755, l.9-11: in Figure 5, the values of σ are (roughly) between 0 and 1.7. Why using 2.5 on P.753-l.23? In addition, I think it should be more clearly indicated what is necessary to estimate σ (types of data, duration, accuracy,...).

The value of 2.5 used as threshold in the example was chosen by visual inspection, so that the detection works best for the examples time series. The values in figure 5 are based on the whole time series from July to October 2010.
As mentioned in the answer to comment 7 of referee #2 we will explain the choice of the parameters for the example in more detail in section 6.3.

10. Section 7 and Figures 8-9: the correlation coefficient only quantifies the degree of linear co-fluctuation between 2 variables. But 2 variables can be perfectly correlated and deviate one from the other by a large bias (e.g., y = 2x). So I would recommend to add a criterion quantifying the possible bias between the rain rate from the different sensors (e.g., ratio of means).

We will add the mean for both measurement types.