Atmos. Meas. Tech. Discuss., 5, C930–C935, 2012
www.atmos-meas-tech-discuss.net/5/C930/2012/
© Author(s) 2012. This work is distributed under
the Creative Commons Attribute 3.0 License.

Atmospheric Measurement Techniques Discussions

# *Interactive comment on* "Observations of tropical rain with a polarimetric X-band radar: first results from the CHUVA campaign" *by* M. Schneebeli et al.

**M. Schneebeli et al.**

marc.schneebeli@epfl.ch

Received and published: 12 May 2012

General comment:

We acknowledge the fact that the title of the manuscript is not appropriate. Since this study is focusing on radome and rain attenuation correction in tropical rain, the title of the manuscript will be changed accordingly to: "Polarimetric X-band weather radar measurements in the tropics: radome and rain attenuation correction".

The article at hand is not at all a repetition of the recent paper by Schneebeli and Berne, 2012 (SB2012 in the following). While the latter manuscript theoretically develops a new method for processing of polarimetric X-band weather radar data by means of Kalman filtering, the present article applies this method as well as standard attenuation



correction schemes to a data set collected in a tropical region. In contrast to SB2012, the comparison is based on the polarimetric moments (and not just on the rain rate) and the algorithms are applied to the most commonly used X-band weather radar, which appears to strongly suffer from radome attenuation. In most studies, radome attenuation is neglected, hence it is worthwhile to write an article with a focus on this phenomena.

We agree that only one disdrometer is used for the evaluation (which we believe is sufficient for a thorough evaluation of the applied techniques), hence we will not mention the other ground-based in-situ sensors in the abstract anymore.

Reviewer one suggests to make an analysis and comparison on the two different geographical areas and types of rain. This would be however a completely different study and it is certainly not what we aim for in this article. We also do not want to focus on the effect of the different locations on the attenuation correction coefficients: we determine these coefficients during the time of the campaign, hence they are valid for the time of the campaign and we can therefore focus on the performance of the different attenuation correction techniques itself, under the assumption that the coefficients are representative for the period of the comparison.

Specific comments: Page 4, line 18: Will be mentioned. Page 7, lines 10-17: Canting angle was modeled with a standard deviation of 10° (Park et al., 2005) and the drop diameter was limited to values between 0 and 7 mm (i.e. drops with larger diameters are excluded from the analysis). Since we do not know the "best" drop shape model, we use all of the three mentioned drop shape models at the same time, hence we randomly choose one of the three models for every drop detected with the disdrometer. All these clarifications will be mentioned in the revised article. Since no theoretical DSDs are modeled to the data, no specific ranges for the intercept and shape parameters need to be given, since the DSD data is taken directly from the disdrometer. We do not agree that the way we calculate the DSD parameters (without fitting a theoretical DSD) is not desirable for polarimetric algorithms. It all depends on the application. We never state anywhere that we want to have a globally applicable algorithm (which, from our point of view, does not make any sense anyway given the large local as well as global variability of the DSD). We want to have coefficients that are only representative for our very limited observation period and we can obtain such coefficients with our method.

Page 10, Eqs (9)-(16): In the original paper describing this Kalman filter, the equations (9)-(16) are explained in more detail. The reviewer is right that the last term in Eq. 10 can be written differently. The notation in the current version of the article has some ambiguities that are cleared in the original paper SB2012. In the revised version, we will also be clearer on the notation. However, the equation 10 is not generally wrong, as it is detailed out in SB2012. Indeed, there is a typo in Eq (11) and (12) and the reviewer is right that there should be an additional minus sign, which will be corrected in the forthcoming version of the article. Concerning Eqs. (13) and (14), the reviewer is missing the tilde over Kdp, which indicates that Kdp is log transformed.

We strongly disagree with reviewer 1 about his statements of the Kalman filter (KF). KF is not just a mean to reduce measurement noise, it is much more than that. It is an assimilation technique that merges noisy measurements with a dynamic model and a model that links the measurements with the state variables. There are no restrictions how accurate these models must be, it is just important that the model's inaccuracies are properly determined, exhibit a Gaussian behavior and are contained in the associated covariance matrices. The whole story of the determination of the covariance matrices, the validity of the employed empirical models and the whole Kalman filter technique is described in every detail in SB2012, together with a thorough evaluation of the technique. The statement of reviewer 1 that Eqs. (11)-(15) are not accurate enough (which implies that the whole technique cannot be applied) is therefore not justified and also wrong. It is true that Eqs. (14) and (15) imply that Kdp is a function of reflectivity, but as it can be seen in Figure 5-a, these relations exhibit a large scatter, and this error is contained in the associated covariance matrix. The larger the values in this covariance matrix are, the lower is the influence of Eqs (14) and (15) to the final



state estimate. Finally, it is true that non-linear relations in Eqs. (9) to (16) lead to an extended Kalman filter and the formulation of the extended KF includes the calculation of Jacobians. However, it cannot be avoided to use an extended KF in Eqs (9) to (16), no matter if the original or the log transformed Kdp is used. In addition, Eqs (9) to (16) are analytic expressions and it is therefore very easy (and accurate) to calculate the derivative, hence the inaccuracies that are due to the introduction of an extended KF formulation are very small compared to the other inaccuracies.

Overall, I recommend the lecture of SB2012, where all the above issues are addressed in every detail.

Page 11, lines 12-20: Again, the validity and accuracy of this method was assessed in SB2012 and the reader is referred to this article for any detail regarding the estimation of the calibration offset. In SB2012 an experiment was conducted with stochastically simulated rain fields and it was found that with this method, the bias can be determined with an accuracy of 0.3 dB. It is clear that in reality, this value will be higher, but it is certainly lower than the "couple of dB" suggested by reviewer 1.

Page 11, lines 21-29: HB is defined as Hubbert and Bringi (1995) in the figure caption. I don't see that the estimation of Phidp and deltahv fail in the region of 5 to 10 km. It must be made clear that Kdp is not estimated from Zh, as repeatedly claimed by reviewer 1. Kdp is estimated from a combination of different estimators, each one having a certain estimation error. It is also clear that the estimation of Kdp with the Kalman filter exhibits errors. However, the Hubbert and Bringi method exhibits much larger errors, since a lot of smoothing on the phase is necessary in order to be able to retrieve the derivative. We also do not state anywhere that our method is perfect, but it is a method that underwent thorough peer-review and actually the article at hand is not about the method itself, it is about the the accuracy that can be achieved for the determination of polarimetric observables by employing different methods. From our point of view, Figure 4-d perfectly shows the validity of the KF method: the retrieved Phidp and the retrieved deltahv nicely add up to the measured (and noisy) Psidp. This would not be possible if the KF algorithm was wrongly formulated. Of course there are some inconsistencies: these are due to the noisy Psidp measurements and possible errors in the equations (9) to (16) that are not accounted for in the associated covariance matrices. This is however all explained in SB2012.

Page 12 Eq. (18): We do agree and will clarify this in the revised manuscript.

Page 13, lines 13-15: We do agree and will clarify accordingly.

Page 14, lines 5-6, Fig. 6: We principally do agree that rather the differential phase should be taken as an indicator (or threshold) of differential attenuation than a sum of the reflectivity. Fig. nr. 6 will be therefore changed accordingly. Concerning the noise in Zdr for such low values: we are aware that Zdr is noisy in such low reflectivity conditions, but just the size of the ensemble will compensate for this effect. In addition, the clear peak in the histogram shows that the made assumptions do not hamper the applicability of the proposed method.

Page 15, lines 8-9, Fig. 5: We are aware of the scatter between Zh and Kdp. As mentioned, this scatter is contained in covariance matrix associated to relationships given in Eq. (9) to (16). However, we do not plan to fit a modified gamma-distribution to our DSDs in order to estimate and display the DSD parameters, since this is not necessary for our application. The large scatter between the relations given in the Eqs (9) to (16) is sufficiently characterized with Figure 5.

Page 15, lines 9-16: The two methods are not similar, although they are not completely independent as well. We will therefore explain in more detail the two methods and the differences between them.

Page 15, lines 17-18: We have not investigated this issue so far. We will try to assess this effect with the method detailed out on page 14. Due to the large scatter that is inherent in this method (due to the low Zdr values), it is however not yet clear how accurate Zdr biases can be determined as a function of the rain rate.



Page 19, lines 21-22: We agree and will change the manuscript accordingly.

Page 19, lines 26-28: For the revised manuscript three figures will be made in order to illustrate the different attenuation contributions: the raw Zh, Zh + radome attenuation, Zh+rain attenuation.

Page 21, lines 26 to 28: We agree and change the manuscript accordingly.

Page 21, lines 24 to 25: Similar Kdp ranges (-25 to 10 dB) will be used in the revised manuscript.

Page 21, line 17: Will be changed.

---

Interactive comment on Atmos. Meas. Tech. Discuss., 5, 1717, 2012.