Hydrology and Earth System Sciences Discussions

Interactive comment on "

Potential of high-resolution detection and retrieval of precipitation fields from X-band spaceborne Synthetic Aperture Radar over land" *by* F. S. Marzano et al.

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Referee #3

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This paper presents analyses of X-SAR retrievals of rainfall, using both reflectivity and phase measurements. This study is highly relevant because of the need for high resolution rainfall data. In this sense, X-SAR measurements nicely complement the existing TRMM and the planned GPM missions. I do, however, have some comments regarding the manuscript. I feel that the analyses regarding TRMM (both Figure 2 and the analyses regarding the downsampling of X-SAR data) could be removed so that more attention can be given to quantitative analyses of X-SAR rainfall retrievals. Detailed comments are given below. »> We thank the reviewer for the substantial appreciation of the work. Indeed, we have modified the Introduction by better specifying the role of XSAR rainfall estimation within the future international context and by stressing both its potential (i.e., high-spatial resolution access to remote regions, non-instrumented areas, ocean surfaces and mountainous regions) and its limitations (i.e., low temporal resolution or repetition period due to limited swath, typically less than 200 km, and orbit duty cycle, typically less than 20%). We have also better used the figures to support the arguments of the paper. Our detailed replies are found below.

Major comments: I find Section 4 (Spatial variability of rainfall fields observed from space) difficult to understand for several reasons. First of all, it is not clear to me what the authors would like to show in this section. It is clear and somewhat trivial that spatial averaging (with and without a spatial weighting function) will alter the characteristics of a spatially variable field. What is the question they would like to answer, or what is the hypothesis they want to (dis)prove? This should at least be clearly stated in this section as well as in Section 1 (Introduction). »> The goal of the section was to show how not only the mean value, but also the whole statistics of the rain field is changed by the weigthed spatial averaging due to the antenna beamwidth. This is not a new analysis and some results are expected, indeed. However, to the hydrology community it may be important to understand the potential value of the spatial high-resolution of space-based retrievals. The section "Introduction" has been modified to clarify these goals.

Secondly, it is unclear how the downsampling of TSX was exactly done. If it is done through simple averaging in space (as I understand from Fig. 7), then the error bias should not be influenced (which it clearly is on p. 7467). A more detailed explanation should be provided. »> Unfortunately, rain field is an intermittent non-linear field. This means that we have areas with zero values and areas with strong horizontal gradients (as seen from Fig. 7). When performing a convolution with a spatial discrete filter, such as that of the antenna beamwidth, the output field is a field whose statistics is filter-width and sampling-point dependent. These effects should explain the obtained results and have been inserted within the revised text.

Thirdly, it is unclear to me how the histograms of Figs 8 and 9 are constructed. Why are the classes different, and what is meant by "pixels are grouped by a down-sampling factor" (p. 7467, line 26 and p. 7468, lines 22-23)? For this reason I find it very difficult to interpret these figures, and to understand what message the authors want to convey with them. »> We accepted the suggestion of the reviewer to clarify the construction of Fig. 8 and 9 which have been improved as well. We basically carried out a spatial average, by considering the larger sensor-like beamwidth, and a down-sampling by considering contiguous averaged field-of-views (or pixels). This means that spaceborne with a larger antenna beamwidth will have a smaller number of larger pixels within the same observed image (or scene). Note that the so called down-sampling is affected by a bias due to the arbitrary choice of the initial center pixel. We have inserted these comments within the revised text which has been completely rewritten.

The X-SAR retrievals could be analyzed in a more quantitative manner with the data that are available. Adding such analyses to this paper would certainly make it stronger. It would give insight into the quality and possible weak points of the use of X-SAR for rainfall retrieval. The quantitative analyses of the comparison between WR and TerraSAR-X reflectivity-derived rainfall could be elaborated. »> As mentioned in the text, the TSX case study has been already analyzed in a previous paper using different

empirically-based retrieval techniques and characterizing the expected errors. More-over, a sensitivity analysis with respect to the WR-based rain retrieval algorithm has been carried out. We refer to the paper Marzano et al. (2010, IEEE TGRS) for further details.

And why not include a comparison of COSMO SkyMed X-SAR reflectivity-derived rain-fall to WR data similar to the TerraSAR-X analysis? Furthermore, the comparison between WR rainfall estimates and the COSMO SkyMed X-SAR interferograms could be made more quantitative. A simple regression analysis would already add very valu-able information, whereby results could be compared to values previously observed in literature. »> Unfortunately, the CSK data were not properly calibrated to perform a quantitative analysis of the amplitude returns. Moreover, the selected case study was much less intense than that of Hurricane Gustav so that the rain signature on the XSAR image is expected to be less striking (see Marzano et al., 2010). This is the reason why we concentrated on the coherence image analysis as pre and post CSK satellite passages were available. This approach is, indeed, quite novel in the field and we believe might be complementary to the XSAR backscatter signature analysis in case of low-to-moderate rainfall.

If TRMM data are used in this study, and TRMM data are simulated from X-SAR mea-surements, why are the two not compared quantitatively? »> Unfortunately, TRMM data were available only a 1.5 hour before the XSAR passage so that were not con-sidered in the quantitative analysis with TSX and WR. Note the TRMM-like images in Figs. 7 are synthetic fields generated by spatial filtering.

I think it is important to stress the effect of the long revisit time of typical X-SAR satel-lites, and that the potential for shorter revisit times is at the cost of coverage. »> Within the Introduction we have now stressed both XSAR potential (i.e., high-spatial resolution access to remote regions, non-instrumented areas, ocean surfaces and mountainous regions) and XSAR limitations (i.e., low temporal resolution or repetition period due to limited swath, typically less than 200 km, and orbit duty cycle, typically less than 20%).

Was the regression analysis to derive a, b, bv, cv and ce carried out using the Ter-raSARX and WR data from hurricane Gustav? If so, this should be clearly stated in the Section where statistics of the comparisons of the two are discussed. »> Agreed. We have better clarified the origin of the coefficients and the related aspects.

Minor comments: In Section 1 (Introduction), the authors state that they will investigate the effect of nonuniform beam filling. From this I expected that this would be related to the X-SAR retrievals, but in the remainder of the paper this investigation is about the this effect for the TRMM instruments (PR and TMI). »> Agreed. We have better clarified our aims within the Introduction.

The second part of Eq. (1b) is missing a dz. »> Corrected.

Can the values of ae and be (p. 7461, line 7) be related to relations between specific attenuation and rainfall intensity derived from drop size distributions? »> In principle they could if the spatial pattern (along the X-SAR observation geometry) of the particle size distribution is known. This is not our case, unfortunately (a hint might be the use of a polarimetric WR). Anyway, in the Appendix, similarly to Marzano et al. (2010), we have shown how to relate specific attenuaitona dn rain-rate to X-SAR scattering coefficient.

Can the values of a, b, bv and cv (p. 7461, line 24) be related to relations between specific attenuation, radar reflectivity, and rainfall intensity derived from drop size distributions? »> In principle they could if the particle size distribution is known.

Eq. (4) on p. 7462 is incorrect. It should be:

»> Corrected.

On p. 7463, line 20, it should be "Moisseev". »> Corrected.

On p. 7469, line 2, it should be "TSX-TMI". »> Corrected.

On p. 7469, lines 8-9, could you quantify this correlation between the X-SAR temporal

coherence reduction and the WR reflectivity field? »> Values have been quantified and reported.

On p. 7471, there is an error in Eq. (A9). It should be:

»> Corrected.

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