Author reply to anonymous Referee2

We would like to thank Anonymous Referee#2 for the assessment of our paper on flood frequency mapping of a tropical lowland and for his/her comments about the manuscript. Replies to the comments are given below.

Comment: The reviewer raises concerns about the term flood frequency that is used in the article.
Reply: We fully agree that flood frequency is an already established term in hydrology. UNESCO-WMO (1992) defined flood frequency as the number of times above a given discharge or stage that is likely to occur over a given number or years. This term is closely related to flood probability (Leopold et al., 1995), which is defined as the probability of a given stage or discharge being equalled or exceeded in a given year. Therefore, we change the title of our paper into "Flood occurrence mapping..." and we revise the ms accordingly.

Comment: The reviewer suggests to put more emphasis on presenting the interest and the applications of radar techniques in flood mapping and to add references about the state of the art with respect to the methods that can be used for flood mapping.
Reply: We add a paragraph about methods for flood mapping:
The suitability of radar techniques for spatial characterization of floods (e.g. Hess et al., 1990; Oberstadler et al., 1997) draws researchers' interest to explore and apply methods for extracting flood information using satellite radar images. Based on backscattering coefficients of the L-band JERS-1 SAR images, Hess et al. (2003) used a pixel-based classifier to map wetland vegetation and flooding state for the central Amazon basin. They carried out wetland delineation followed by classification of the masked area into 'cover states' that consisted of vegetation cover classes and inundation states for high- and low-water conditions. They obtained cover-state map for the large regions with an accuracy of 78–91% for open water, nonflooded forest, and flooded forest cover-state classes. Lower accuracies were reported for aquatic macrophytes and for flooded woodland. Hostache et al. (2009) proposed a SAR image analysis method

for spatiotemporal characterization of flood events that includes extracting flood extent limit, estimating water level, and constraining water level estimates using hydraulic coherence concepts. The method was applied to an ENVISAT SAR image during the January 2003 flood of the Alzette river. They show that SAR imagery offers the possibilities to obtain distributed remote-sensing-derived water levels over a large area with sufficient accuracy for calibration of a hydraulic model. Matgen et al. (2011) proposed a hybrid approach to automatically extract flood extent from SAR images by estimating the statistical distribution of open water backscatter values from SAR images of floods, radiometric thresholding to extract the core of the water bodies, and region growing to extract all water bodies. Furthermore, they proposed a change detection process using pre- or post-flood SAR reference images to remove over-detection of inundated areas. The methods were evaluated throughout the 2007 flood of the Severn river (using ENVISAT SAR images) and the 1997 flood of the Red river (using RADARSAT-1 images). The study shows that the automated method that includes a change detection procedure yields the same performance as optimized manual approaches.

Comment: The reviewer raises concerns about the methodology part as being not detailed enough with regard to how the threshold values have been defined. He/she suggests to also discuss the sensitivity of the maps to the threshold values.
Reply: We will add a more detailed explanation regarding the methodology in the revised ms. We used the bathymetric track in the Mahakam River for assessing the flood occurrence map. During the field campaign, we carried out an extensive bathymetry survey yielding cross-river depth profiles with an interspacing of about 200 m. We also carried out a stream reconnaissance, which has provided a qualitative confirmation of the results presented. Since the river width is about 300 m and the pixel size is 75 m continuous river bank lines should occur in the flood occurrence map, along the boundaries of river areas with maximum flood counts. This is indeed the case. Figure 1 shows flood occurrence maps obtained using different threshold values, illustrating that the threshold we chose results in a good correspondence between the the river banks lines from bathymetry mapping and those apparent in the flood occurrence map.

Reply to additional comments:

1. We color stretch legends on figure 2.

2. p 11525 l 13: We will replace polarity by polarization.

3. p 11526, l 5-11: We will discuss how we choose the threshold values and what the proposed value means. We move the threshold numerical values, which were previously put in the results and discussion section, to the methodology section. We use the mean backscatter in the floodplain for flooded vegetation detection, as it is generally accepted in the SAR literature that flooded vegetation results in enhanced backscatter returns. Also it was confirmed from our field observations that the floodplain area producing bright returns was indeed flooded, as we will show in the ms.

We remove areas with elevations higher than 24 m asl because our field surveys only covered the middle Mahakam area up to a location upstream of the city of Melak, with an elevation of about 24 m asl. Hope et al. (2005) stated that the middle Mahakam wetland area, also called the Kutai lowland, has an elevation range between sea level and about 24 m asl. The Kutai wetland, including the floodplain lakes, is believed to control the River Mahakam water level and discharges downstream (Hidayat et al., 2011). We intend to use the inundation extent and flooding occurrence information presented in the present paper to study the hydrological functioning of the area.

4. p 11526, l 19-21: We applied Lee filter using a 3x3 pixel window. Lee filtering categorizes data based on statistics calculated within the individual filter window. Being a standard deviation based filter, the Lee filter preserves image sharpness and detail, while suppressing noise. The pixel being filtered is replaced by a value calculated using the surrounding pixels. The approach for pixel value replacement is explained in the ms. Temporal filtering indeed may reduce the speckle even further, but the disadvantage is that temporal variation under certain

conditions can affect the filtered backscatter values corresponding to dates when no noise is present. Although speckle is reduced, the temporal response might locally be degraded and, therefore, this type of filtering may corrupt the flood extent mapping.

5. p 11527, l 3-16: We will explain why the pixel backscatter values and the water depth can be correlated. The water depth can induce backscatter change at our diver location especially because of the vegetation succession related to flooding/inundation dynamics in the study area. This is reflected by high correlations for water level gauges located in the lakes and floodplain areas with seasonal cycle shrub-type vegetation and low correlations for the water level gauges located in the peat forest.

6. p 11528, l 15: We clarify this issue in the revised manuscript, we change the sentence into: “Figure 8 shows the flood frequency map of the MMA from nine filtered PALSAR images using backscatter statistics from the permanently inundated main river and lakes by taking the minimum backscatter response as the lower threshold, and mean plus one standard deviation as the upper threshold.” We move the threshold numerical values to the methodology section, as suggested.

7. p 11530, l 4: For clarity, we change the sentence into: “The occurrence of flooding under vegetation was obtained by evaluating pixels in the filtered images against the lower and the upper threshold values taken from the mean and maximum of backscatter values of the regularly inundated floodplain upstream of the MMA.” As suggested by the reviewer, we move the threshold numerical values to the methodology section.

8. Figure 5. The values shown in the figure are mean values, we will add this to the figure caption.

9. Figure 6. We will render this figure lighter, and include marks at locations discussed in the ms.

Reference

Hess, L. L., Melack, J. M., Novo, M., E. M. L., Barbosa, C. C. F., and Gastila, M.: Dual-season mapping of wetland inundation and vegetation for the central Amazon basin, Remote Sens. Env., 87, 404–428, 10.1016/j.rse.2003.04.001, 2003.

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Hope, G., Chokkalingam, U., and Anwar, S.: The stratigraphy and fire history of the Kutai Peatlands, Kalimantan, Indonesia, Quaternary Res., 64, 407–417, 2005.

Hostache, R., Matgen, P., Schumann, G., Puech, C., Hoffmann, L., Pfister, L.: Water level estimation and reduction of hydraulic model calibration uncertainties using satellite SAR images of floods. IEEE T. Geosci. Remote 47 (2), 431441, 2009.

Leopold, L.B., Wolman, M.G., Miller J.P.: Fluvial processes in geomorphology. Dover Publ. Inc., New York, 1995.

Matgen, P., Hostache, R., Schumann, G., Pfister, L., Hoffmann, L., Savenije, H.: Towards an automated SAR-based flood monitoring system: lessons learned from two case studies. Phys. Chem. Earth 36 (7-8), 241252, 2011.

Oberstadler, R., Honsch, H., and Huth, D.: Asessment of the mapping capabilities of ERS-1 SAR data for flood mappig: a case study in Germany, Hydrol. Proc., 11, 1415–1425, 1997.

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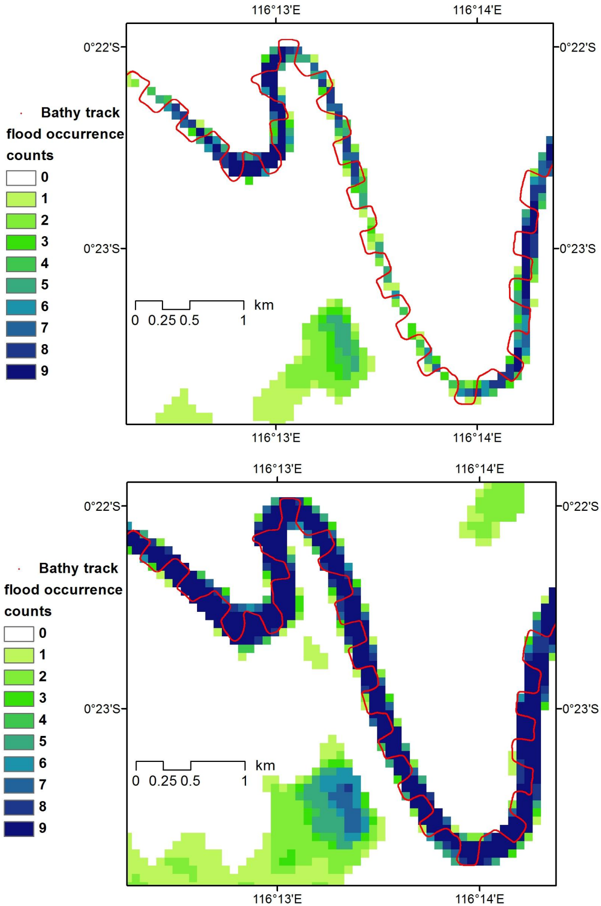

Fig. 1. Bathymetry measurement tracks in the Mahakam River plotted on open water flood occurrence map using the upper threshold value of -14.9 dB (top) and -11.2 dB (bottom).
figure