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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Modelling overbank flood recharge at a continental scale" *by* R. Doble et al.

R. Doble et al.

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We thank the anonymous reviewer for their constructive comments on the manuscript. Reviewer comments are in quotes, with our response following the comment.

"The authors performed a study on introduction of an overbank flood recharge scheme to the Australian Water Resources Assessment (AWRA) model, with an attempt to improve the modeling of groundwater recharge. Modeling results were compared with independently observed bore hydrograph responses and point-scale recharge modeling. This study could be an incremental, though not earth-shattering, contribution to the modeling of overbank flood recharge as claimed by the authors that the simulated overbank flood recharge, despite underestimated, accounted for 4-15% of the total recharge at the basins during the study period from Nov 2010 through Mar 2011. In general, this manuscript is written very well. I recommend it be considered for pub-

lication in the journal of Hydrology and Earth System Science after the issues raised below are fully considered and the manuscript is revised accordingly.

(1) The overbank flood recharge may have been underestimated in the Lachlan, Daly, Logan, and Campaspe watersheds. The underestimation is likely because MODIS data you used were not able to detect open water bodies and consequently inundated areas due to cloudiness or that Terra and Aqua satellites were not synchronized with the occurrence of flooding. To further examine this issue, this review suggests that the authors show maps of water bodies detected by MOD09 products to look at how large the influence of clouds could be, and try to quantify uncertainties associated with open water detection using MODIS. Use of Satellite Aperture Rader (SAR) could be a promising alternative to detecting flooding areas. The authors are encouraged to look at these papers (Dellepiane and Angiati 2012; Hostache et al. 2009; Martinis et al. 2011) and discuss this issue in your manuscript."

Overbank flood recharge was underestimated in most of the catchments, but in particular, the Lachlan, Daly, Logan and Campaspe. In some cases this may have been due to the cloud cover and null data due to satellite synchronisation. In the Lachlan catchment, cloud cover and areas of no satellite signal were found to obstruct mapping of open water bodies early in the flood period (1st to 9th December) and this may have led to the flood peak being missed (Figure 1). There are, however, very few open water bodies observed in the period immediately following the flood (11th – 31st December), and very little change in these water bodies in time. This suggests that even with perfect satellite coverage and absence of clouds, detection of open water bodies is likely to have been underestimated.

Insert figure here.

Figure 1 Open water likelihood (OWL) in the Lachlan catchment during flooding in December 2010. Flooded areas detected by MODIS data are indicated in dark blue. Cloud coverage and no data signal are indicated in white. Null data due to no satel-

lite signal (indicated by straight line boundaries between data and no data) is present on the 9th and 16th December. Although there was a large interruption of the data set just prior to and during the start of the flooding (1st to 9th December), very few areas of standing water were observed immediately after the rainfall event (post 11th December).

Cloud cover is recognised as being a major issue with MODIS9 data (Long and Singh 2010). Originally the research looked at using passive microwave data for filling in data gaps caused by cloud cover, but the resolution was found to be too coarse (10km). Research into an improved passive microwave water map is currently being undertaken, but it is not yet at a stage that could be used for this project.

In this case the most appropriate method for dealing with lack of flood data associated with cloud coverage or where satellites were not synchronised was thought to be to replace the missing data with the most recent data that was unaffected by cloud or flight path. This description is included in the methodology (12580, lines 12 – 14), but could be added to in the discussion if required.

Another remote sensing method that may be appropriate for the detection of open water under cloudy conditions is the use of synthetic aperture radar (SAR), although some effort is required in the extremely precise calibration (Dellepiane and Angiati 2012; Hostache et al. 2009; Martinis et al. 2011).

"(2) The authors claimed that the simulated overbank flooding recharge contributed to a "significant" part to the total groundwater recharge, with a lion's share of 15% for riparian recharge and 4% for the Loddon catchment. I do not think this is a significant contribution of the total recharge; it could be within the uncertainties of the total groundwater recharge from the AWRA model. In other words, the motivation of this study should be expressed in a more convinced way."

We understand the reviewer's concern with the term 'significant' contribution to recharge. Perhaps a better description is 'not insignificant'. Although the overbank

flood recharge volume was less than diffuse rainfall recharge and river loss to groundwater over time, it is likely to be of a high enough volume to warrant further investigation in highly allocated groundwater systems. We are happy for this to be reworded as 'not insignificant' or 'of high enough proportion of the total groundwater recharge to warrant further investigation in highly allocated groundwater systems.'

"(3) Calibration of the AWRA model is not clear to this reviewer. What parameters need to be calibrated prior to your modeling effort? How long is the warm-up period? What uncertainties are involved in the forcing data? How do you validate model output (surface flow and drainage) in addition to looking at the groundwater recharge term?"

The model was been calibrated against 300 catchments, validated against another 300 catchments and benchmarked independently against recharge, soil moisture, LAI and ET data sets across the continent. The model was calibrated for 19 parameters with a warm-up period of one year. Investigation into the propagation of uncertainties in the forcing data is currently underway, but rigorous quality control of input data has been undertaken. The calibration process is discussed in further detail in Viney et al. (2013).

"Minor issues: Page 12574 Line 24: OFR is an important, but often overlooked, requirement"

We agree that the word and be changed to but.

"Page 12575 Line 3: Please consider citing the papers (Reager and Famiglietti 2013; Singh and Woolhiser 2002)"

We agree that adding the references Reager and Famiglietti, 2013 and Singh and Woolhiser 2002 to the citations at the end of the first sentence in line 4 would assist the reader in understanding this topic more fully.

"Page 12577 Lines 3-5: Please indicate clearly the temporal scale of your simulations for the study period, hourly? daily? Or others?"

Change the sentence to 'Recharge from flooding was modelled at a daily time step

for seven different catchments for the test period of 1 November 2010 until 31 March 2011.'

"Page 12579 Lines 21-24: Can you provide the name of the MODIS reflectance product? MOD09? Further, one of the fundamental questions of the use of MOD09 to determine the extent of open water bodies is that during flooding periods, multispectral remote sensing is extremely susceptible to image quality that is greatly influenced by clouds. Please refer to the paper (Long and Singh 2010). I am wondering how you dealt with this issue, and indeed suspect the usefulness of MODIS data to provide open water extent due to the limits of temporal resolution in the context of flooding and recharge simulations and cloud impacts. At least, the authors should comment on it."

MOD09GA and MYD09GA reflectance products were used for the study. Comments on the problems associated with cloud cover have been discussed above.

"Pages 12580 Lines 1-7: If I understand correctly, here you are trying to construct the relationship between open water extent and the elevation inundated, and then subtract elevation without inundation to derive the flood depth. If so, please make it clearer."

This should be reworded to "The average open water elevation was calculated by constructing a histogram of the one second DEM within each cell, and selecting the elevation associated with the OWL percentile. This cell elevation is then subtracted from this value to give a depth of flooding (Ticehurst et al., 2009)."

"Page 12581 Lines 7: from areas that are climatically distinct"

Agreed, this should be changed from were to are.

"I suggest that the authors include areas of the seven study basins in your Table 2."

We have added a column in Table 2 to include the area of the catchments.

"Page 12591 Line 17: There were no available flood inundation mapping and soil properties"

Agreed, this sentence should be changed for clarity.

"Section 5.3 is concerned with the motivation of this study. It should be put earlier in the discussion section, instead of in the last part."

We agree that section 5.3 should precede section 5.1. We will change this in the revised copy of the paper.

References

Dellepiane, S.G., & Angiati, E. (2012). A New Method for Cross-Normalization and Multitemporal Visualization of SAR Images for the Detection of Flooded Areas. IEEE Transactions on Geoscience and Remote Sensing, 50, 2765-2779 Hostache, R., Matgen, P., Schumann, G., Puech, C., Hoffmann, L., & Pfister, L. (2009). Water Level Estimation and Reduction of Hydraulic Model Calibration Uncertainties Using Satellite SAR Images of Floods. IEEE Transactions on Geoscience and Remote Sensing, 47, 431-441 Long, D., & Singh, V.P. (2010). Integration of the GG model with SEBAL to produce time series of evapotranspiration of high spatial resolution at watershed scales. Journal of Geophysical Research-Atmospheres, 115 Martinis, S., Twele, A., & Voigt, S. (2011). Unsupervised Extraction of Flood-Induced Backscatter Changes in SAR Data Using Markov Image Modeling on Irregular Graphs. IEEE Transactions on Geoscience and Remote Sensing, 49, 251-263 Reager, J.T., & Famiglietti, J.S. (2013). Characteristic mega-basin water storage behavior using GRACE. Water Resources Research, 49, 3314-3329 Singh, V.P., & Woolhiser, D.A. (2002). Mathematical modeling of watershed hydrology. Journal of Hydrologic Engineering, 7, 270-292 Viney NR, Vaze J, Wang B, Zhang Y, Yang A, Vleeshouwer J, Ramchurn A and Frost A (2013) Comparison of prediction performance of AWRA-L with other models. CSIRO Water for a Healthy Country Flagship, Australia.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 12573, 2013.

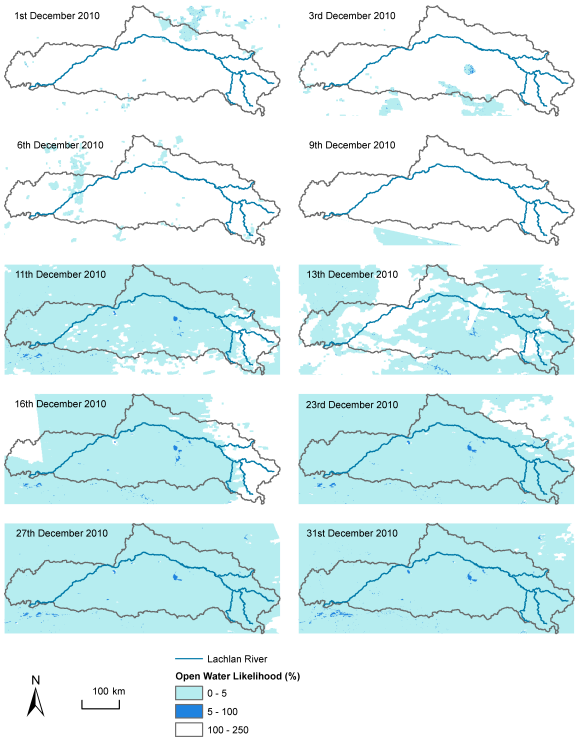
1st December 2010
3rd December 2010
6th December 2010
9th December 2010
11th December 2010
13th December 2010
16th December 2010
23rd December 2010
27th December 2010
31st December 2010
N
100 km
Lachlan River
Open Water Likelihood (%)
0 - 5
5 - 100
100 - 250

Fig. 1.