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Discussions

Interactive comment on "Impact of bushfire and climate variability on streamflow from forested catchments in southeast Australia" *by* Y. Zhou et al.

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We would like to thank the two reviewers' comments and suggestions for the improving the manuscript "hess-2013-102". A major revision has been done, and corresponding responses are provided below. A revised version has been provided in a separate pdf file as well.

Reviewer #1: Overall This is an important and relevant topic that deserves consideration. However, for a paper that focuses on the impact of fire on a forested catchment, there is little consideration of the impact of fire on the hydrological processes that are

affected by fire. For example, it is well documented that depending on the fire severity, there is a change in the infiltration rates of the soil, due to, amongst other factors, burning of the organic matter in the topsoil which may result in a hydrophobicity of the soil. This may then result in an increase in surface overland flow. It is such factors that may describe some of the discrepancies between modelled and observed streamflow. These factors are identified as "climate variability" in this paper which may not necessarily be the case. This has been briefly acknowledged in the conclusion section of the paper (P4418L26 to P4419L1), but not adequately enough. In the methodology, it is stated that " changes of catchment characteristics are primarily due to vegetation changes (deltaQveg)". I do not believe this is the only factor contributing to the change in streamflow. Where assumptions are use, these need to be well backed up. Therefore, I do not think this work should be published until major revision has been done and/or the reason for not including fire induced changes are well justified and backed up by suitable references. If these factors are considered, then the conclusions will be strengthened.

——————— Response: Thanks for the comments/suggestions. We agree with the reviewer's comments, and we have done a major revision, and provide explanations and discussions. (1) The effects of fire on soil properties have been added in the introduction section. Lines 78-90: "A number of studies have found that bushfires impact on streamflow by destroying the vegetation cover and litter layer, and altering the soil properties (e.g. Brown, 1972; Scott, 1993, 1997; Shakesby and Doerr, 2006; Mataix-Solera, et al., 2011; Soulis, et al., 2012). On the one hand, bushfires cause a dramatic change in vegetation cover, and present potential for a distinct temporal change in evapotranspiration (ET) as the early loss of leaf area transitions into regrowth or recovering forest. Secondly, bushfires destroy the organic matter destabilizing the soil structure in top soils (Mataix-Solera, et al., 2002), produce ash (a mixture of black carbon, soot, charred material, charcoal and mineral material) (Moody et al., 2009), and enhance the impacts of water repellency (Debano, 2000). Therefore, soil infiltration capacity can be reduced due to surface pores sealed by fine soil and ash particles and the hydrophobic compounds on the soil surface (Shakesby & Doerr 2006; Sheridan et al. 2007). Cumulatively, these effects increase runoff, and peak flow magnitude (Soulis, et al., 2012)." (2) The methodology (3.1 General Framework) has been revised as follows: Lines 282-313: "Streamflow is controlled not only by climate conditions, but catchment characteristics. It can be assumed that streamflow changes as a result of climate variability and the changes in catchment characteristics, which can be written as: deltaQtot = delta Qcc + deltaQclim (1) where deltaQtot is the total streamflow change in two periods, 1 and 2, estimated as deltaQtot = Q2obs-Q1obs, Q1obs is the mean annual streamflow observed in the period 1 when catchment disturbance is negligible (the baseline) and Q2obs are the mean annual streamflow observed in the period 2 when catchment disturbance is significant; deltaQcc is the change in streamflow caused by the change in catchment characteristics, deltaQclim is the change contributed by climate variability. The three forested catchments selected in this study are not subject to dam regulations or diversions. Therefore, changes of catchment characteristics are primarily due to bushfire caused vegetation cover loss and changes in soil properties (deltaQfire). As a result, deltaQcc is replaced by deltaQfire and Eq. (1) can be rewritten as: deltaQtot = deltaQfire + deltaQclim (2) deltaQtot can be estimated from streamflow data observed from the two periods. deltaQfire can be quantified once dletaQclim is available. Here, the lumped rainfall-runoff models are used to estimate deltaQclim. First, these models are driven by climate inputs and calibrated against observed streamflow data in the period 1. Secondly, the calibrated models are driven by climate inputs in the period 2 to simulate streamflow in that period. Since these calibrated models are only driven by climate variables, rainfall and areal potential evapora-transpiration (APET), the changes in the simulated streamflow from the two periods are solely caused by climate variability. Therefore, the climatic variability impact on streamflow (deltaQclim) can be estimated as: deltaQclim = Q2sim – Q1sim (3) where Q1sim is the mean annual streamflow simulated in the calibration period, Q2sim is the mean annual streamflow simulated in the test period (or post-bushfire period). This approach assumes that there are no noticeable changes in model bias from model calibration

period (pre-bushfire) to model test period (post-bushfire) and the calibrated parameter set can be transferred from the calibration period to the test period. Once dletaQclim is quantified, deltaQfire is calculated from Eqs. (2) and (3)." (3) Discussion on bushfire impacts on soil properties has been added into discussion section. Lines 701-716: "Finally, the other fire-related hydrologic processes that should be considered in modelling are changes to soil hydraulic properties and consequent runoff generation. Increases in surface runoff generation after fire have been widely reported in the literature (eg. White and Wells, 1979; Prosser and Williams, 1998; Moody and Martin, 2001; Robichaud, 2000, Johanson et al., 2001; Benavides-Solorio and MacDonald 2001; Onda et al., 2008). Development or enhancement of water repellency (eg.; Shakesby et al., 1993; Robichaud, 2000, Doerr et al., 2000; Martin and Moody, 2001), the effect of ash on infiltration (Campbell et al., 1977, Cerdà and Doerr, 2008; Onda et al., 2008; Woods and Balfour 2010; Ebel et al., 2012) or loss of roughness/detention storage from plant immolation (eg. Lavee et al., 1995 Scott, 1997; Inbar et al., 1998) have been invoked as the agent driving the process change. The implication is water is more efficiently routed to the stream network via infiltration-excess overland flow, and that peak flows in particular may increase markedly (eg. Campbell et al., 1977; Scott, 1993, Moody and Martin, 2001; Moody et al., 2009, Soulis et al, 2012). Some of these runoff generation studies have been at plot or small experimental catchment scales where scale effects may not be captured. " Lines 718-730:"Recent studies into post-fire soil hydraulic responses to fire in similar environments to the wet eucalypt catchments modelled here (Lane et al. 2004; Lane et al. 2006; Sheridan et al. 2007; Nyman et al. 2010) have found that although there is enhancement of water repellency (which is naturally occurring in summer) and generation of surface runoff, this does not translate into broadscale overland flow. The principal reason is the spatial heterogeneity in infiltration properties mainly controlled by macropore distribution and their suction characteristics (Nyman et al., 2010). As the background hydraulic conductivities can be in the order of metres per day, small patches of non-repellent soil can capture any generated flow. Lane et al. (2006) found all flow percentiles increased after fire, but no evidence of altered runoff generation processes. The net result is that it is unlikely these soil factors are important for streamflow analysis on an annual scale in the modelled catchments. However it is emerging that soils in drier eucalypt forests may respond differently (Nyman et al., 2011)." ——————

Specific comments:

P4398L13 – remove the word "model" i.e. . . .simulated runoff, not . . .model simulated runoff.

Response: Revised.

P4398L17 – you mention ET and interception. Interception is an evaporative process and is part of ET (total evaporation). Therefore, remove interception.

Response: Revised.

P4398L20 – change "reasonable" to "reasonably".

Response: Revised.

P4399L3 – remove the word "natural"

Response: Revised.

P4399L5 – change to ". . .the capital of the State of Victoria"

Response: Revised.

P4399L10 - add the word "are" after bushfires.

Response: Revised.

P4399L10 – add the word "and" after SE Australia.

Response: Revised.

P4400L14 – change the word "greater" to "more"

Response: Revised.

P4400L14 – change "essentially endorsed" to "agreed with"

Response: Revised.

P4400L24 – add the word "the" before trunk.

Response: Revised.

P4400L26 – add a comma after However.

Response: Revised.

P4401L18 – be consistent with the spelling of "modeling" and "modelling". Both are correct, but choose one spelling and be consistent throughout the document.

Response: Revised. "modelling" is used throughout the manuscript.

P4402L5 – change "usefully" to "successfully"

Response: Revised.

P4402L10 – change "parameter" to "parameters"

Response: Revised.

P4402L14 – add the word "on" before the word streamflow.

Response: Revised.

P4402L21 – this is the first time that you mention the three models that you are using (i.e. AWRA-L, Xinanjiang and GR4J). Therefore, you need to reference the authors/developers of these models here.

Response: Revised as suggested.

P4403L13 – add a reference to the statement "the ash stands were all regrowth originating from the 1939 bushfires (reference)".

Response: Revised. The data set used in this study is from the State Forest Resource Inventory (SFRI).

P4403L17 /18 – reword the sentence "it is assumed. . ..fire-killed ash".

Response: Revised in lines 228-230: "It is assumed that any regeneration area from 1984 was salvage logging if the ashes in this area are not killed by fires."

P4403L24 – change "significant percentages" to "a significant percentage"

Response: Revised.

P4404L2 – remove the word approximately.

Response: Revised.

P4404 – The data used for the calibration and validation of the GR4J model in Table 6 is not discussed in the data section (i.e. section 2.2). Please include this.

Response: The description of the four catchments selected for model validation is added in Section 2.1, see lines 243-248: "The four median-size forested catchments around the three bushfire impacted catchments are selected for model validation. These four catchments are unregulated and they were not affected by the bushfires (Fig.1 (âĚą), catchments (1) – (4) named 405205, 405209, 405227 and 227202). All these four catchments have long term reliable streamflow records spanning from pre-bushfire to post-bushfire period. Therefore, they can be used for investigating the transposability of calibrated model parameters in time." And lines 250-253: "The catchment area for the four catchments varies from 109 to 1080 km2 (Table 1). The four catchments are largely covered by eucalypt forest, with a forest ratio varying from 0.86 to 1.0. Mean elevations for catchments 405205, 405209, 405227, and 227202 are 670.5m, 604.4m, 751.4m, and 155.3m, respectively." The data used for the GR4J model have been added in section 2.2. See lines: "The data for the Latrobe, Yarra and Starvation Creek catchments and the four validation catchments are available for 1966-2007, 1973-2004, 1971-2000 and 1975-2009 respectively. The

daily streamflow data is obtained from the Victorian Water Resources Data Warehouse (http://www.vicwaterdata.net) and checked for data quality to be used for hydrological modeling (Vaze et al., 2010a). The climatic data (daily precipitation, P, areal potential evapotranspiration, APET, maximum temperature, Tmax, minimum temperature, Tmin, actual vapour pressure, e, and solar radiation, Rs) used in this study come from the 'SILO Data Drill' produced by the Queensland Department of Environment and Resource Management (www.derm.qld.gov.au/silo ; Jeffrey et al., 2001)."

P4404L23 – change "are resulted from" to "as a result of"

Response: Revised.

P4405L8/9 – you mention that the changes of catchment characteristics are primarily due to vegetation change. However, as this is a paper about the impact of fire, the impacts thereof on the soil hydrophobicity due to burning of organic matter and the changes this has on the infiltration etc. also play a role in the changes in streamflow. This is not accounted for in this paper and is a major shortcoming of the methodology.

Response: Thanks for your insightful comments. The methodology has been revised and the changes in soil properties caused by bushfire have been included in revised version of the study. The revised methodology is provided in the answers of overall comments and the section of "3.1 General Framework" (Lines 282-313) and "4.5 Discussion" (Lines 701-716 and Lines 718-730).

P4405L15 – change "second" to "secondly"

Response: Revised.

P4405L16 to19 – Further to the point made previously (P4405L8/9), it is stated that the models are only driven by climate variables. Therefore, if this is true, then the models do not take physical catchment characteristics into account and cannot account for the changes due to fire.

Response: "3.1 General Framework" (see lines 282-313) has been shown in answers to overall question. First, hydrological models are calibrated against observed streamflow data in pre-bushfire period. It assumed that the catchment characteristics are implicitly accounted for into the model parameters in the calibration process. Secondly, the calibrated models are driven by climate inputs in post-bushfire period to simulate streamflow in post-bushfire period. It means that simulated streamflow includes catchment characteristics under pre-bushfire period conditions, but the climate inputs are of post-bushfire period. Therefore, the changes in the simulated streamflow from the two periods are solely caused by climate variability. And the climatic variability impact on streamflow (deltaQclim) can be estimated as: deltaQclim = Q2sim –Q1sim Once deltaQclim is quantified, the bushfire impact on streamflow is quantified by: dletaQfire = deltaQtot - deltaQclim

P4406 – give the references for the models in each of the model descriptions.

Response: The references are added in the model descriptions. See lines 316: "Three hydrological models, GR4J (Perrin et al., 2003), Xinanjiang (Zhao, 1992) and AWRA-L (Van Dijk, 2010), are used in this study."

P4407L1 change ". . .in the year 1980. . ." to ". . .in 1980. . ."

Response: Revised.

P4407L12 – vegetation not vegetations

Response: Revised.

P4409L15 – insert the word "enough" after the word robust.

Response: Revised.

P4409L23 – add "a" before the word reduction.

Response: Revised.

P4409L24 – you mention interception and evapotranspiration as separate processes.

However, interception is an evaporative process and is part of evapotranspiration. Evapotranspiration means the same as "total evaporation" which includes ET = transpiration + interception + soil evaporation + open water evaporation). I think you mean a reduction in interception and transpiration (as these are both canopy dependent processes).

Response: Thanks for your clear explanation. It is a reduction in interception and transpiration. It has been corrected.

P4410L4 - insert "the" before 1983.

Response: Revised.

P4410L7 – Is the "vegetation cover change" due to different species (pioneer species) being introduced? Please be a bit more specific in describing "vegetation cover change.

Response: Vegetation cover change in the paper means vegetation cover loss caused by bushfire. We have specified in the paper.

P4411L20 - insert "the" before 1983.

Response: Revised.

P4411L25 – insert "to" before the word "vegetation" Response: Revised.

P4411L29 – insert "the" before Xinanjiang model Response: Revised.

P4413L12and13 – change the sentence to "In the first 15yrs after the bushfires, . . ."

Response: Revised in lines 577-579: "In first 15 years after bushfires (1983-1998), bushfire causes substantial increase in streamflow and its impact on streamflow are much larger than that of climate variability."

P4414L12 – change sentence to "All four of these catchments have a long. . ."

Response: Revised in lines 577-579: "The four median-size forested catchments around the three bushfire impacted catchments are selected for model validation. These four catchments are unregulated and they were not affected by the bushfires (Fig.1 (âĚą), catchments (1) – (4) named 405205, 405209, 405227 and 227202). All these four catchments have long term reliable streamflow records spanning from pre-bushfire to post-bushfire period. "

P4414L15 – Why is only the GR4J model used for the parameter transposability experiments. This needs to be fully justified or else do this with all three models.

Response: All the three models are used for the parameter transposability modelling experiments. The results from the three models are similar, and Table 6 shows the model calibration and validation results for the GR4J model. See lines 438-440: "The three models are used for the parameter transposability modelling experiments. The results from the three models are similar, and Table 6 shows the model calibration and validation results for the GR4J model. "

P4414L18 to P4415L23 – this section is under the "discussion" heading, but is really a description of the results in Table 6. It would fit better under the "results and discussion" heading.

Response: Revised. We have added a section of "4.2 Model cross-validation". The description of the results has been moved to section 4.2.

P4415L24 – Change sentence to "A caveat to this is that..."

Response: Revised in lines 631-633: "However, we cannot be sure how much canopy area was affected due to lack of detailed information about the fire intensities for the 1983 bushfire."

P4418L5 – change the word "sketchy" to "limited"

Response: Revised.

P4418L19 – once again, there is a separation of interception and evapotranspiration.

See earlier comments.

Response: Corrected. The sentence is revised in 763-765: "We hypothesise the flow increases were mainly caused by the loss of leaf area and tree morality because of the bushfires and associated reductions in interception, actual transpiration and soil infiltration rates."

Fig 1. Please add what the Roman numerals i, ii, iii and 1v represent in the figure caption.

Response: Revised as "Fig.1. Location for the three study catchments and four validation catchments (I and II), bushfire extent (III) and logging extent (IV) for the three study catchments"

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C2518/2013/hessd-10-C2518-2013-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 4397, 2013.

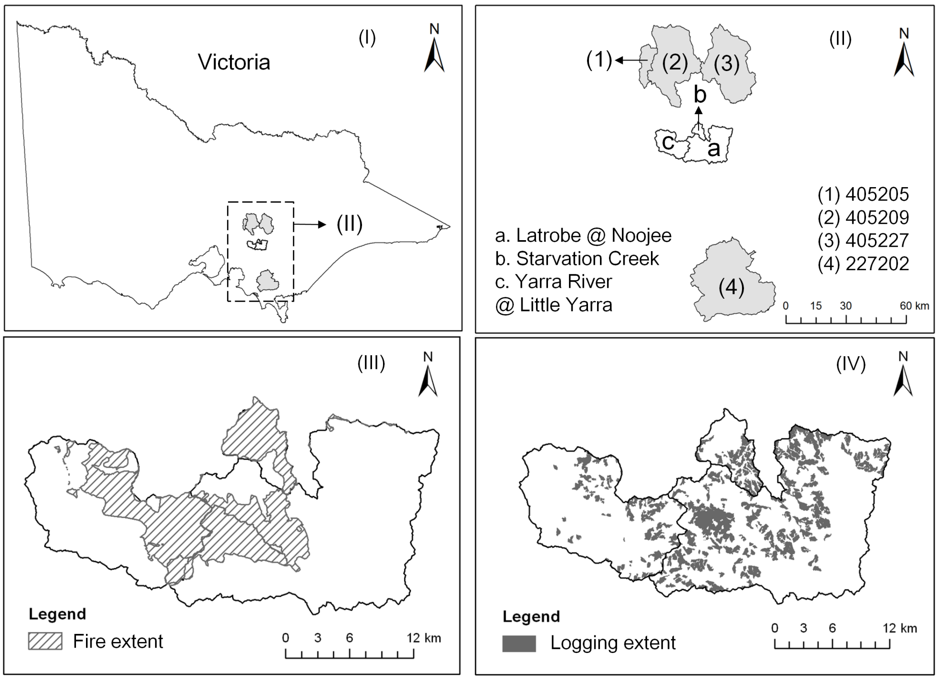
(I)
N
Victoria
(II)
(II)
N
(1)
(2)
(3)
b
c
a
(1) 405205
(2) 405209
(3) 405227
(4) 227202
a. Latrobe @ Noojee
b. Starvation Creek
c. Yarra River
@ Little Yarra
(4)
0 15 30 60 km
(III)
N
Legend
Fire extent
0 3 6 12 km
(IV)
N
Legend
Logging extent
0 3 6 12 km

Fig. 1.