Response to Reviewer #5.

Anonymous Referee #5

Received and published: 10 May 2013

The authors investigated different implementations of generic reservoir operation rules to be used in in earth system models. In particular, the combination of storage and releases targets for multi-purpose reservoirs was studied in terms of usage priorities, withdrawals versus consumption demand, and natural versus regulated mean flow for calibrating the operating rules. The different operating rules were tested for the Columbia River Regulation System. Overall, the paper is well written but in some areas lengthy, which is supported by very long and complex sentences. Some aspects are subject for revision before accepted for publication.

We wish to thank the reviewer 5 for his/her comments and constructive criticism which have led to an improved manuscript. Below are answers in line with the comments.

1. The authors should explicitly explain the hydrological modeling, i.e. VIC was used for simulating river discharges for the whole Columbia River Basin, MOSART was applied to the subbasin. Which one?

A schematic presenting the modeling framework has been added.

2. Were all 125 reservoirs taken into consideration?

Figure 1 has been revised in order to clarify that all 125 reservoirs were simulated.

3. I assume water withdrawals were not available in a gridded format and for that reason being estimated. Please explain.

Water withdrawals and consumptive uses were originally available by county on an annual time scale. Consumptive uses were temporally downscaled and spatially disaggregated by sector by Brown et al. 2013. Given our online simulation, we focused on consumptive use for the extraction and we estimated the withdrawals at finer spatio-temporal scales based on the downscaled consumptive uses. This has been clarified in the text and the schematics.

4. Equation 4: regional water withdrawals and consumption. What is meant by regional?

Regional has been replaced by Pacific Northwest in the text, equation and schematic. See comment above as well.

5. The acronyms given in the text and also in the figures should be the same.

Acronyms were checked throughout the text.

6. Sensitivity analysis: How sensitive are storage releases with regards to water withdrawals versus water consumption and natural flow versus regulated flow? I think this is finally not well elaborated. How big is the impact of cascaded river discharges released from multiple reservoirs?

The reservoir releases are more affected by the change in the mean annual flow coming from the natural or impounded flow estimates rather than by change in demand in this case study. In particular for small reservoirs the demand anomaly is used while the scaling anomaly is identical whether we use withdrawals or consumptive use in our representation (equation). Figure 8 illustrates the sensitivity of the flow, storage and water supply deficit to change in the operating rules at The Dalles, Grand Coulee and American Falls. The larger the reservoir capacity the more the storage is impacted by upstream cascaded regulation. However (impounded) releases are not necessarily impacted. The smaller the reservoir capacity, the less the storage is impacted. Releases seem not that impacted either. The sensitivity analysis on the regulated flow for example does not show significant changes. The reservoir storage acts as a buffer and shows the most sensitivity. Changes in water supply is a consequence – minimum flow is released but the supply will be curtailed. We clarify this point in the text.

A figure is also added to give an example of the sensitivity of the monthly pre-releases for Grand Coulee for the different operating rules to illustrate how the predictors affect the releases. They differ from the flow out of Grand Coulee because in reality the reservoir spills in the Spring resulting in higher and smoother flows during snowmelt. Ensuring that the reservoir spills in the combined operating rules is a compromise to make sure that the reservoir fills as much as it can before the irrigation season. This point is also added in the text to illustrate the figure.

7. Different existing operating rules are compared. What is the overall improvement?

A table has been added to clarify the set of newly developed operating rules. The regulated flow and storage have been improved. We also clarified the best implementation of the system in order to bring consistency between modelers leveraging from the Hanasaki model.

The results section has been re-organized so as to answer explicitly and directly the scientific questions, i.e. sensitivity and improvement.

In detail:

P 3504, l 14 and P 3524, l 11: Reference Doell and Lehner (2009) is not existent. P 3505, l 27: Please correct Doel et al. by Doell et al.

Added.

P 3508, l 14: Multiple locations: How many were considered?

Three. This has been clarified.

P 3510, l 5: Reference Selley et al. 1998. Please add to the reference list or check spelling (Solley et al. 1999?).

Typo corrected.

P 3510, l 13: "Total monthly consumptive demand. . ." Although reservoirs are prioritized for irrigation, total consumptive demand was used. Why?

See comment above. Added schematics and associated text clarify it.

P 3510, 17-20: Here is some more explanation needed as measured datasets for water withdrawals and water consumption are available.

In the context of an ESM, expected water demand will be consumptive irrigation demand. We simply adjust this consumptive demand as to derive a withdrawal demand which is based on observed regional ratios between consumption and withdrawals. This corresponds to information readily available to ESMs and follows Biemans et al. 2011 set up. Her irrigation demand was actually coming from a physically based crop model which explains that only the consumptive demand was available and she use regionally varying delivery efficiency factors. This point is clarified in the text.

On another note, the operating rules only are based on the withdrawals in this non-fully coupled system. They could be fine tuned for monthly varying adjustments which should increase the monthly variability in the release. This should actually increase the benefit of using withdrawals for the set up of the calibration rules.

P 3512, l 17: "(i) it includes the demand that can be self-met with local water,. . ." Does this mean that the total demand in a subbasin was assigned to the reservoir?

This has been removed.

P 3514, l 2-3: please convert Mgal in cubic meters.

Units have been converted to millions cubic meters (MCM).

P 3514, l 4: "As USGS observed demand. . ." I assume both water withdrawals and consumption have been observed beyond 1999.

Actually, only withdrawals are reported in the USGS publications after 1995.

P 3514, l 10-11: Maintaining 10% of river discharge as environmental flow is often used. Any evidence or reference?

We agree. We tracked it but did not find any specific reference.

P 3505, l 13-19: These sentences should be written more "realistically", as e.g. figure 4 shows a decline in performance. An "accurate" representation is important but probably not feasible at the large scale.

P 3516, l 1-3: acronyms differ from those in Figure 3 .

We revised the acronyms to be uniform.

P 3518, l 13-15: I think that's far too optimistic, in particular the timing is not well represented. The authors should try to explain the reasons for the decline in performance (from The Dalles to American Falls).

We revised the section.

P 3518, l 18-19: At the first glance, this statement is not correct. Simulated regulated flow mostly overestimates observed regulated flow. On average, underestimation is apparent between mid June and October.

We revised the section.

P 3519, l 23-25: How did you calculate the demand not met? Using water withdrawals? If so, then sectoral differentiation would be important (not total water withdrawals as calculated from water consumption with a fixed share). Demand curve did not change much between 1990 and 1997. Why could the demand peaks be met in 1990 or 1994 but not in other years (Figure 6)? Reduction in precipitation?

The unmet demand is computed for each subbasin as the difference between the consumptive demand and the supply. The deficit is then aggregated to the basin scale. In a fully coupled implementation, when withdrawals are to be used for the "demand" and the "extraction", the authors agree that demand sectors will be of importance in terms of priorities. The distribution to activity sectors is the subject of on-going effort.