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Discussions

Interactive comment on "Real-time reservoir flood control operation enhanced by data assimilation" *by* Jingwen Zhang et al.

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This manuscript presents a method called ROMEDA which integrates simulation, optimization and data assimilation to operate a reservoir in real-time. The main contribution is the development of a human-machine interactive method for real-time reservoir operation. Actually, especially for a complex operational problem, an operator uses a decision support system as a tool to find the possible optimal solutions and chooses a solution based on his/her experience for the actual implementation. Thus, it is not a novel concept in the field of the decision support systems. The specific comments are as follows:

Reply: Thanks for your comments. First, please allow us to clarify the purpose of our

work. We aim at a real-time human-machine interactive method for reservoir operation during a flooding event, using data assimilation of real-time observations to reduce the uncertainty from the simulation model. This method is new (according to our knowledge) by directly linking the reservoir operator with a traditional real-time reservoir operation model (integrated optimization and simulation). The computer model runs by rolling time windows. For one time window, it assimilates the observation of water levels and adopt the actual release the operator makes (which can be the same or different from the model recommended optimal value) at the end of the time period, and then moves to next and generates recommended release again. Meanwhile, the operator checks the recommended release from the model during each time window and decides to take it or do it differently based on their own justification. Thus regarding the novelty, we would argue that this study proposes an online (or real-time) human-machine interactive method for reservoir operation.

Simulation model

As the Saint-Venant equations are used to simulate the stream flow along a long channel (658 km), it is required to explain how to consider the inflow into each cross-section from a large catchment (5600 sq-km). Instead, inflow hydrographs at the reservoir are shown in Figure 7 and 8.

Reply: Thanks. The reservoir authority provides the inflow data for the on-channel reservoir, including the streamflow from an upstream section (section 1) and lateral flow (q in Eq 1) within one segment (i.e., at 489 km away from dam) These two sources are inputs to the Saint-Venant equations (Eq 1 and 2) simulating the on-channel reservoir. The inflow hydrographs in Figure 7 and 8 are the sum of two sources of inflow to reflect the magnitude and variation of the inflow. More explanation will be added in the manuscript.

Reservoir routing or flood routing is usually used in the reservoir operation study. This study uses unsteady flow routing for a long and narrow reservoir. The reason to use unsteady flow routing is described in Line 308-311. As the reservoir releases are controlled for two objectives (one control point), the simulation model could be simplified by using a mass balance equation and the area-capacity curve.

Reply: It is not appropriate to treat the surface of the on-channel reservoir with a significant slope as a flat surface during the flooding season. Thus, it is not appropriate to simulate the reservoir flood routing by a static storage-stage relationship assuming a flat surface. Besides, we use the stage (water level)-capacity curve rather than the area-capacity curve in reservoir simulation. This is because the stage (water level)-capacity curve is usually determined under a flat surface condition, without considering the dynamic reservoir storage (i.e. the spatial variability of water level for the on-channel reservoir). Thus, the 1-D unsteady flow routing model is used to simulate the flood routing in the on-channel reservoir to calculate the dynamic reservoir storage.

Optimization model

As two objectives are considered, there may be more than a single optimal solution and how to choose a solution in PADDS should be explained.

Reply: Thanks. Flood control and hydropower generation both are considered as objectives in the multi-objective optimization model, and PADDS is the algorithm used to solve the multi-objective problem Since flood control is the primary objective during the flooding season, the solution in favor of flood control in the Pareto frontier is selected. More explanation will be added in the manuscript.

ROMEDA

In general, an optimization-simulation approach is used to operate a reservoir or a reservoir system and the operators choose a solution based on their experiences when there exists a number of possible optimal solutions. ROMEDA highlights the effectiveness of the human-machine interactive method for real-time reservoir operation. It is demonstrated with a way that the operator accepts or rejects the model result according to the storage threshold. This demonstration is very sample and does not present a human-machine interaction practically.

Reply: Thanks. Indeed some studies (Hejazi Cai., 2011; Hejazi et al., 2008; Castelletti et al., 2010) couple a “mentor model” (describing reservoir operators’ experiences made via machine learning methods such as ANN) with a numerical simulation/optimization model to explore better reservoir operation plans. However, this is not what we want to do in this paper. However, we have to admit that in the demonstration of the ROMEDA method, we assume some simple (but reasonable) rules for the interaction between operators and the model, i.e., reservoir operators do not follow the model suggested reservoir releases but take some actions based on their own consideration and experiences, when the storage is below the maximum storage required for leaving space for coming storms. This is one of the possible ways of the operators and the model interact. As reservoir operators’ considerations vary by person and by reservoir and involve multiple factors, such as policies and regulations, how to set more realistic rules for an operator to follow or not follow the modeled recommended releases is worthy of additional research, which is beyond the scope of this study, i.e., demonstrating that the proposed ROMEDA works.

References:

Hejazi, Mohamad I., and Ximing Cai. "Building more realistic reservoir optimization models using data mining–A case study of Shelbyville Reservoir." Advances in water resources 34.6 (2011): 701-717.

Hejazi, Mohamad I., Ximing Cai, and Benjamin L. Ruddell. "The role of hydrologic information in reservoir operation–learning from historical releases." Advances in water resources 31.12 (2008): 1636-1650.

Castelletti, A., et al. "TreeâĂŘbased reinforcement learning for optimal water reservoir operation." Water Resources Research 46.9 (2010).

Case study

It is very strange for me to see a bed-profile of a natural river behind a reservoir. The river bed levels are up and down in many places and the bed level is very close to -50 m between section 10 and 11 (Figure 6). Therefore, a brief explanation is required to understand the bed-profile of this river. The unit of the longitudinal distance (km) should be mentioned in Figure 6. In addition, the area-capacity curve should be provided to show how the water stores in on-channel reservoir.

Reply: The case reservoir in this paper is an on-channel reservoir with a long bed-profile. A brief explanation will be added to understand the bed-profile of the on-channel reservoir. The longitudinal distance (km) is added in Figure 6. As explained above, we use the stage (water level)-capacity curve rather than the area-capacity curve in the reservoir simulation.

Figure 6 Longitudinal profile of the on-channel reservoir (see below)

I have no major issues with the results, discussions and conclusions. However, the most important problem is that ROMEDA does not involve a novel formulation for real-time operation of a reservoir. It will be more interesting to the readers if the authors emphasize on how the decision-maker's experience or behavior can be effectively integrated into a decision-support system to solve a real-time control problem.

Reply: Thanks. As stated above, the construction of a human's mental model to mimic the reservoir operators' behaviors/experiences/considerations is not the purpose of this paper. However, this is not what we want to do in this paper. As stated above, reservoir operators directly interact with the model (coupled simulation and optimization) and thus there is no need to use a computer-based mentor model to mimic the operators' behaviors. By the way, such models are usually limited in its effectiveness. ROMEDA is new (according to our knowledge) by directly linking the reservoir operator with a traditional real-time reservoir operation model (integrated optimization and simulation). In other words, ROMEDA proposes "online" interactions between model and user while

such interactions with existing DSSs are usually "off-line."

Therefore, I suggest that a major revision is required to improve the methodology and to investigate the new experiment for further consideration.

Reply: Thanks for your valuable comments. We hope our reply can clarify the confusing part of the manuscript.

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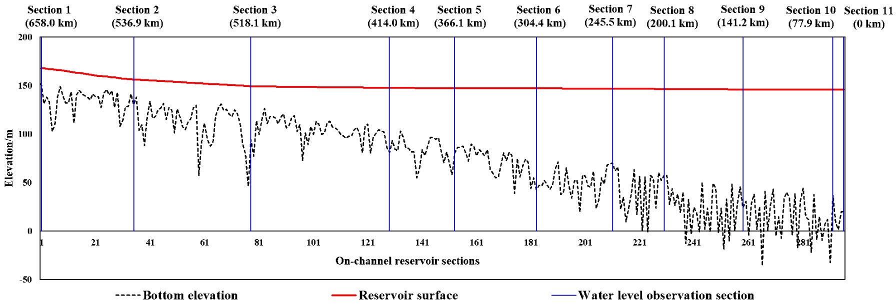
Section 1
(658.0 km)
Section 2
(536.9 km)
Section 3
(518.1 km)
Section 4
(414.0 km)
Section 5
(366.1 km)
Section 6
(304.4 km)
Section 7
(245.5 km)
Section 8
(200.1 km)
Section 9
(141.2 km)
Section 10
(77.9 km)
Section 11
(0 km)
Elevation/m
On-channel reservoir sections
Bottom elevation
Reservoir surface
Water level observation section

Fig. 1.