Changes in Flood Dynamics in the Lower Mekong River Basin Due to Upstream Flow Regulation

Yadu Pokhrel\textsuperscript{1}, Sanghoon Shin\textsuperscript{1}, Dai Yamazaki\textsuperscript{2}, Zihan Lin\textsuperscript{1}, and Jiaguo Qi\textsuperscript{1}

\textsuperscript{1}Michigan State University
\textsuperscript{2}The University of Tokyo

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Abstract

The Mekong river is one of the most complex river systems in the world that is shared by six nations in Southeast Asia. The river still remains relatively undammed (most existing dams are in the tributaries and are small), and its hydrology today is dominated by large natural flow variations that support the highly productive agricultural and riverine ecological systems; however, this is changing due to the alterations in land use and construction of new dams both in the tributaries the mainstream. Understanding the changes in surface water dynamics is therefore crucial to provide realistic future predictions of changes in downstream floodplain and riverine ecology due to the construction of dams in the upstream. While the existing dams have caused little impact on mainstream flows, those under construction and planned are likely to cause severe and potentially permanent damage to downstream hydro-agro-ecological systems, and adversely impact the livelihood of millions. Here, using hydrodynamic model simulations (CaMa-Flood), we show that the effects of flow regulation on downstream river-floodplain dynamics are relatively predictable along the mainstream Mekong, but flow regulations could potentially disrupt the flood dynamics in the Tonle Sap River (TSR) and small distributaries in the Mekong Delta. Results suggest that TSR flow reversal could cease if the Mekong flood pulse is dampened by 50\% and delayed by one-month. While flood occurrence in the vicinity of the Tonle Sap Lake and middle reach of the delta could increase due to enhanced low flow, it could decrease by up to five months in other areas due to dampened high flow, particularly during dry years. Further, areas flooded for less than five months and over six months are likely to be impacted significantly by flow regulations, but those flooded for 5-6 months could be impacted the least.
1. Introduction

The Mekong river has been relatively unaltered by humans compared to other river basins of comparable size, but it is now undergoing unprecedented changes due to the construction of large-scale hydropower dams across the basin; a series of dams have already been built in recent years and 16 in the mainstream and over 100 in the tributaries are planned to be completed by 2030 (Fig. 1).

In this study, we address the following two questions:
1. What is the role of seasonal flood pulse and TSR flow reversal in modulating the TWS variations in the MRB?
2. What are the potential impacts of changes in flood pulse due to upstream flow regulation on river-lake flood inundation dynamics in the LMRB?

The modeling framework used comprises of a global hydrological model (HiGW-MAT) and a river-floodplain routing model (CaMa-Flood). GRACE data are also used.

2. Models: HiGW-MAT1 (1°) and CaMa-Flood2 (10km)

Fig. 2: A schematic depiction of various hydrological processes (soil moisture movement, crop, and groundwater dynamics) simulated by HiGW-MAT model (a) and the schematic of the treatment of river-floodplain geometry in CaMa-Flood model.

3. Results

Fig. 3: (a, b) Comparison of simulated flood occurrence (number of months) with satellite-based data; (c-g) simulated and observed water levels.

Fig. 4: Comparison of simulated terrestrial water storage (TWS) variations with GRACE-based TWS, and role of river-floodplain storage on TWS dynamics over the entire MRB (top) and only for the lower portion of the basin shown in Fig. 3 (bottom).

Fig. 5: Effects of potential flow regulation by different degree at the dam location shown in Fig. 6 on streamflow dynamics at selected locations in the LMRB.

Fig. 6: (A) Changes in flood occurrence during an average year; (B) changes in flooded areas under different degrees of flow regulation and altered peak timing (one month early and delayed); (C) same as in (A) but for dry and wet years.

4. Summary and Conclusions

- River-floodplain water storage explains ~26% of the total terrestrial water storage dynamics in the MRB and ~49% in the LMRB (Fig. 4).
- Reduction in the peak of flood pulse by more than 20% near Stung Treng gauging station could cause a significant alteration in the water balance of the TSL, potentially ceasing the flow reversal in the TSR. If the flood peak at the same location is dampened by 50% and delayed by one-month.
- During average and wet years, flood occurrence could increase at the outer fringe of the TSL and post-flooding agricultural regions in the middle reach of the Delta; during dry years flood occurrence could reduce by up to 5 months around the outer edge of the flooded areas in the TSL.
- While areas flooded for less than five months and over six months are likely to be impacted significantly by flow regulations, areas flooded for 5-6 months could be impacted the least.

References:

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