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A coupled water-energy model reveals key interdependencies between hydro-climatic variability, energy generation, and power distribution in the Greater Mekong Sub-region

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Driven by an unprecedented thirst for energy, several countries in the Greater Mekong Sub-region (GMS) are expanding their hydropower systems by installing dozens of dams, which provide energy supply, storage, and revenue from export of excess energy. The operation of the installed hydropower dams is challenged by multiple factors, including environmental constraints, the capacity of the transmission lines, and water availability, which varies on both intra- and inter-annual scale. To understand and quantify these interdependencies, we developed a spatially-distributed water-energy model of the GMS. Hydrological and hydraulic processes are simulated with the VIC model, which we modified to account for the operation of all main hydropower reservoirs in the region. With this modification, VIC estimates the effect of rainfall variability and reservoir operation on the available hydropower. The latter is the input to a Network-Constrained Unit Commitment model, which schedules the hourly energy production mix to satisfy national demands at a minimum cost—while considering the operational constraints of the power generation and transmission facilities. Simulation results over a 10-year period reveal a strong dependency of the energy production mix on the hydro-climatological conditions. During the monsoon months (June-October), the energy system can almost entirely depend on hydropower production, while during pre-monsoon months, the system relies substantially on fossil fuels, imports, and other renewables. Interestingly, simulation results show that the dispatch of hydropower is constrained by the capacity of the transmission lines, which are severely stressed during the monsoon. This implies that available hydropower may remain unused if transmission capacity is not adequate. These conditions are exacerbated by large-scale climate phenomena, such as the El Niño Southern Oscillation.