論文の内容の要旨

Abstract of Dissertation

Title: Optimization of Dam Operation using a Distributed Hydrological Model and Weather Forecast (分布型流出モデルと気象予報値を用いたダム操作の最適化)

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Floods and droughts have been affecting human beings since ancient times. In recent decades flood events have occurred at higher frequency and magnitude, particularly in humid regions due mainly to a changing climate and human activities.

Recent extreme flood events have been causing enormous disasters; therefore, the need to reduce them is latent and growing. More than ever the ability to efficiently forecast and manage these events plays a key role in protecting human lives and avoiding other material damages.

An extreme event can be substantially reduced by an optimal dam operation assuming that its capacity is sufficient to attenuate floods and store water for future usage. However, one should take into account that complex river systems need more than one operating reservoir, not only used for flood control purposes, but also for irrigation, water supply, power generation and so on. Then, water release from dams should consider reducing flood damage and storing water at the reservoirs for future water use. In this way, an efficient water resources management can be achieved by an optimal dam operation.

In order to make appropriate dam water release decisions, the potential heavy rainfall needs to be predicted and the river discharge within the whole basin and dams' situation needs to be forecasted. Then, a reference system which is able to take maximum advantage of available forecast information and optimize water release from dams is highly expected by dam operators and community in general. The present study attempts to contribute in this last urgent requirement by coupling a distributed hydrological model to an optimization scheme in order to suggest the dam release schedule.

Conventional dam operation employs lumped models relying partially in the physics with uniform rainfall input and the water release schedule is performed independently for each dam. However, distributed hydrological models can capture rainfall patterns using spatially distributed rainfall. This study couples a physically based distributed hydrological model namely Geo-morphological Based Hydrological Model (GBHM) with embedded dam network operation to the Shuffled Complex Evolution (SCE) optimization algorithm. The optimization variables are the dam water releases. The simulated inflow to dams, updated reservoir status, and river discharge downstream are calculated by the GBHM with embedded dam operation and introduced to the SCE scheme. Normally, manual dam release is performed by dam operators according to expertise to reduce extreme floods downstream. This proposed scheme takes advantage of the SCE in order to evaluate different dam release sets automatically based on stochastic seeding considering the dam constraints and objective function. Therefore, two objective functions are proposed. The first one to minimize the overflow downstream where flood prevention is desired by releasing water before flood develops during heavy rainfall. The second one besides flood reduction also aims future water use by releasing only the amount of water which will be replenished by forecasted flood volume. Moreover, the coupled GBHM-SCE is able to run sequentially using spatial distributed rainfall forecast to optimize dam release while lead-time lasts and define next time step's initial condition using observed data.

The system was applied to the upper Tone river basin which covers 3,300 km^2 targeting the flood 22-24 August 2001 using observed data. First, it was simulated water release of a small dam in a sub-basin of 1200 km^2. It was found that the simulated inflow to dam and over-all river discharge in closer agreement to observed discharge using radar rainfall products rather than point rain gauge data. By using radar rainfall, the operation of the small dam was successfully carried out by setting the release proportional to the water height. Then, in the same sub-basin, the coupled GBHM-SCE with virtual Yamba dam operation, nowadays under construction, was carried out for flood reduction downstream. Next, in the whole upper Tone river basin the coupled GBHM-SCE considered two key dams operation in the objective function for flood reduction downstream. The results showed the feasibility in computation time and efficiency of the objective function to reduce flood downstream when compared simulation using optimized release against using observed release. In addition, the effect of Yamba dam as a case scenario with optimized dam release was simulated at the outlet of the basin.

The application in the whole upper Tone river using 18 hours lead-time rainfall forecast targeted the flood 9-12 July 2002. First, the optimal water release from the two key operating dams was obtained using three different series: 1-6, 7-12 and 13-18 since forecast was issued every 6 hours. The results showed that 1-6 series, opposite to expected, in lower agreement with observed rainfall values than the other two series. Then, three dams participated in the optimization process using the complete 18 hours lead-time with the integrated objective function. This was conceived in order to reduce floods downstream by releasing water as soon as a flood was forecasted downstream; however, the maximum water release was set to be comparable to the total forecasted flood volume downstream. Moreover, it was found that the water level in the reservoirs after the flood event remained close to initial ones suggesting the replenishment of water. Those dams with high initial water level showed the best performance since they were able to release water and store again; on the other hand, the third small dam with low initial water level ended up with higher water level. This process was carried out every 6 hours according to issuing interval forecast. Within this period the optimization procedure was completed providing the dam release schedule and updating initial condition using observed data for the next time step. Then, the forecasted dam release was tested combining with observed rainfall data in order to get the stream flow downstream. The latter was compared against the stream flow obtained using observed release and observed rainfall. In summary, optimized dam release schedules were suggested relying on weather forecast not only reducing flood damage downstream but replenishing water in reservoirs for future water uses such irrigation, power generation, etc. This is an important point in regions affected by typhoons where floods and droughts can be alternated from season to season.

The system has demonstrated high efficiency which can be used as a reference tool in real-time operation. In this way, the present study shows feasibility of taking advantage of forecast information for social benefit considering not only for flood damage reduction, but also for future water use.