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Distributed TOPMODEL approach for rainfall-runoff routing modeling in large-scale basins

Roberto Valmir Da Silva[1*], Yosuke Yamashiki[2], Kaoru Takara[2]

[1]Grad. Sch. Eng., Kyoto Univ., [2]DPRI, Kyoto Univ.

Rivers are an important component in water cycle, they link the returned water from the land to the oceans. In this sense, global scale hydrological modeling is a fundamental issue in order to determine the water quantity and quality inputs into the oceans. Generalized Circulation Models (GCMs), representing physical processes in the atmosphere, ocean, cryosphere and land surface, are the most advanced tools currently available for simulating the global climate system. GCM have improved with computers and increase knowledge about climate. That is why, in the past decade, GCM modeling using large-scale runoff routing models (RRMs) has received special attention. RRMs are based on grid-cells that represent reservoirs and they rout the flow to the outlet using a linear function. The use of RRMs have basically three purposes: (1) to study the freshwater flux into the oceans, which may affect ocean convection, ocean salinity and ice formation, (2) to evaluate the GCMs performance and (3) to study the impact of climate change on water resources. RRMs are based on grid-cells that represent reservoirs and they route the flow to the outlet using a linear function. TOPMODEL is a hydrological model based on variable source area assumption. Its main parameter is the topography index derived from a digital elevation model. This study has the objective to apply a modified GIS-based TOPMODEL approach as a RRM and to carry out stream discharges simulation and predictions using a climate projection. Three large-scale basins were selected, the Amazon basin (7.05 million km2), the Yangtze basin (1.72 million km2) and the Brahmaputra basin (1.73 million km2). The global topographic data was extracted using ETOPO5 data, from the National Geophysical Data Center (NGDC), National Environmental Satellite (NOAA). Basins boundaries and stream networks were acquired from Global Runoff Data Center (GRDC) and Global Drainage Basin Database (GDBD), respectively. The climate observed daily data were obtained from the Intergovernmental Panel on Climate Change (IPCC). For daily data model calibration, time series for the Amazon data encompass the period from 1990 to 1995. For the Yangtze basin the period of data used corresponds to the 2004 year and for Brahmaputra basin from 1990 to 1991. The Penman method was used to estimate evapotranspiration. For discharge predictions the climate projection data (MRI AR4, A1B scenario, 20 km mesh resolution) was obtained from KAKUSHIN program which has the objective to establish a probabilistic global warming projection by using both GCM and an earth system model with intermediate complexity (EMIC), combined with advanced statistical techniques. The original TOPMODEL approach was utilized in a cell-to-cell framework, therefore, changing the local deficit distribution based on the topographic index to a more realistic approach. Thus, the spatial distributed rainfall data from GCMs could be used. Two types of flow routing were implemented, (1) velocities as a function of cumulative area and discharge and (2) a simplified Muskingun-Cunge method. Monte Carlo simulations were used to find the best set of parameters according to the Nash-Sutcliffe coefficient. The simulations using the new TOPMODEL approach were compared to the original one. The results show that the modified TOPMODEL approach produced better results than the original TOPMODEL approach. Also, the modified approach is a feasible model to carry out discharge predictions using climate scenarios.

Keywords: Distributed model, TOPMODEL, GCM, RRM