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A Water Balance Model for assessing Hydro Climatic Variability in Tropical Lake Systems: Application to Lake Babati and Lake Emakat, Nothern Tanzania

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A comprehensive understanding of lake hydrology is important to enhance the interpretation of information on past climatic variations retained in tropical lakes as well as to investigate the effect of future climate conditions on lake ecosystems. In this study, a lumped water balance model is developed to describe historical lake water levels and to investigate the impacts of hydro-climatological changes on Lake Emakat and Lake Babati, two closed tropical lakes in Northern Tanzania (East Africa).
The model concept is based on maintaining the water mass balance of the lake system, which is simplified into three main modules: the lake, its catchment area and the connected groundwater reservoir. Water mass exchanges with the atmosphere occur through precipitation, the main input, and evaporation, calculated from meteorological variables using two different energy balance equations. The model also integrates lake and groundwater interaction, by letting the lake water surface balance with the water table in the surrounding groundwater reservoir after every time step. A FORTRAN code is used to solve the water balance equation on a year time step and give the lake volume change resulting from meteorological inputs. The associated lake surface area and lake level are then determined from a depth-volume-area relationship developed from a high resolution bathymetric and topographical maps of the lake and its catchment.
The model parameters were calibrated using available meteorological data and corresponding lake level records. A sensitivity study to assess the relative importance of different hydro–meteorological parameters on the model response indicates that changes in cloud fraction have the largest impact on evaporation, the most important component of the water mass balance. This parameter, therefore, proved to be one of the ultimate control factors of the lakes water balance.
The model application to Lake Emakat suggests that precipitation and cloud fraction changes are the only climate related factors that could justify the large volume change experienced by the Lake during a 200 year period, 10,000 years BP, as estimated by proxy data. On the other hand, the model was applied to establish the necessary ambient condition changes to produce a dry–out and an overflow condition of Lake Babati and to investigate the lake system response to future IPCC climate change projections in the study area. The model shows that a sustained temperature change of less than 3oC or a precipitation change of about 100 mm/year is sufficient to bring the lake from a dry–out to an overflow condition. Simulations of IPCC derived scenarios indicate a clear tendency of the lake to increase its volume and reach the overflow level in relatively short time (approximately 10 years).
Despite the model uncertainties, mainly due to limited data, it provides a means for improved interpretation of proxy data of lake level and past climatic changes retrieved from lake sediments. Furthermore, the model ability to predict the lakes hydrological response to future variations in hydroclimatic conditions and catchment characteristics offers a valuable decision support tool for water resources management