EGU24-12006, updated on 15 Sep 2024
https://doi.org/10.5194/egusphere-egu24-12006
EGU General Assembly 2024

Integrated water balance reveals that Lake Titicaca is driven by extreme climate variability

Nilo Lima[1], Denis Ruelland[2], Marisa Escobar[3], Antoine Rabatel[1], Waldo Lavado[4], and Thomas Condom[1]

[1]Institut Geosciences Environnement, University of Grenoble Alpes, 38000 Grenoble Cedex 5, FRANCE (nilobcred@hotmail.com)
[2]CNRS, HydroSciences Laboratory, University of Montpellier, 34093 Montpellier Cedex 5, FRANCE
[3]Independent researcher, California, UNITED STATES
[4]Servicio Nacional de Meteorología e Hidrología (SENAMHI), 15072 Lima, PERU

For decision making, it is crucial to provide an estimate of the main water balance fluxes to help understand trends and drivers of lake fluctuation in the past and in the future. However, the quantification of fluxes is a complicated task due to the scarcity of hydro-climatic data in space and over time, which hampers addressing all the local and regional hydrological processes at play, notably in the face of multi-decadal climatic and anthropogenic changes. These challenges are addressed at the scale of the Lake Titicaca hydro-system (57000 km^2). Lake Titicaca (8400 km^2) is located at 3812 m a.s.l. in the Altiplano of South America. Lake water levels measured since the beginning of the last century show extreme fluctuations within a range of approximately 6 m. This study presents an approach to disentangle the climatic and anthropogenic drivers of past fluctuation of Lake Titicaca. For this, we implemented a conceptual integrated modeling chain that represents the following components: (i) production and routing processes based on a precipitation-runoff model including snow and glacier as well as net water consumption from irrigation in order to estimate lake inflows; and (ii) lake basic functioning according to inflows, direct precipitation and evaporation, bathymetry and outflows. The modeling chain was implemented in the Water Evaluation and Planning System (WEAP) platform at a daily time step over a 30-year period (1985–2015) and was driven by climate inputs derived from ground station data and ERA5 reanalysis. Model calibration and evaluation was based on geodetic mass balance, catchment streamflow, and lake water levels. The results indicate that the estimated annual water balance in the upstream catchments shows that the climate regime is mainly dominated by rainfall since snowfall only represents 1% of total precipitation (716 mm). Ice melt also accounts for 1% of total precipitation. The simulated actual evapotranspiration represents on average 565 mm year^{-1}, of which 3% correspond to net irrigation consumption. Runoff is approximately 173 mm year^{-1}. By scaling this runoff to the lake area, upstream inflow represents 53% of the total inflows into the lake (1818 mm year^{-1}), the remaining 47% corresponding to direct precipitation over the lake. Evaporation losses from the lake are estimated to mean annual value of 1718 mm and downstream outflows 142 mm. Then, the Lake Titicaca is primarily driven by interannual variations in precipitation. The evaporation rate can exacerbate conditions in dry years. The integrated

modeling chain will later be used to assess how water levels could be altered by climate change and management options such as water withdrawals and lake releases.