Geophysical Research Abstracts
Vol. 18, EGU2016-5352, 2016
EGU General Assembly 2016

Precipitation regimes in the Levant during the Holocene inferred from Dead Sea lake levels and stochastic modeling

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The Dead Sea is a terminal lake of one of the largest watersheds in the Levant (∼43,000 square km), draining sub-humid to hyperarid climate zones. The large size of the watershed and the synchronous regional pattern of annual precipitation are the main reasons that the Dead Sea lake levels are good proxies for the Levant precipitation. Since the mid-1960s intensive water diversions from this watershed caused a dramatic human-induced level drop (currently >1 m/year). Holocene lake levels were used to infer regional precipitation regimes. Previous studies have associated lake level rises and drops with past wet and dry periods in the region, but their quantitative assessment remains a challenge. Moreover, the attributing of lake levels alterations to changes in precipitation regime still misses natural precipitation variability and there is a need to identify and separate their effects. The current study confronts these basic challenges that underlie the transfer of proxy to climatic parameter procedures. It uses here a unique stochastic framework under which we link precipitation regime with the Dead Sea lake levels, considering changes and trends in both mean and variance. Then we infer Levant precipitation regime during the Holocene.

The present mean and variance of annual precipitation and lake levels are represented by (a) Kfar Giladi rain station, determined as the best correlated with natural Dead Sea lake level changes, and, (b) using a water balance model; this allowed simulating mean and variance of annual lake levels. Stochastic simulations included scenarios of changes in precipitation regime considering both constant and trended mean annual precipitation. We assessed probabilities of obtaining specific rises and drops, derived from reconstructed Holocene lake levels, under diverse scenarios. The results suggest that late Holocene precipitation regime could be governed by periods of increasing and decreasing trends of mean annual precipitation in the range of -15 to + 15 mm /decade (these are mean values for tens of decades) with a reference of 83% of the present day mean annual precipitation.

A similar analysis was conducted for the modern lake level measurements. As expected, the steep, human-induced, lake level drop since the 1960s is statistically illegitimate at any simulated precipitation change scenario. A natural lake level drop that preceded the man-made one (1930-1963), can be explained by a sharp decreasing precipitation gradient, steeper than 50 mm/decade for the 33 year interval, suggesting a drying period was governing the region. It is interesting to note that the analysis of precipitation data for the same period also indicates a negative trend, however it is not statistically significant. Our findings pinpoint the difficulty of identifying substantial precipitation trends due to their high natural variability.