Geophysical Research Abstracts
Vol. 16, EGU2014-13057, 2014
EGU General Assembly 2014

Hydrological budget of Lake Chad: assessment of lake-groundwater interaction by coupling Bayesian approach and chemical budget

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Estimation of lake-groundwater interactions is a crucial step to constrain water balance of lacustrine and aquifer systems. Located in the Sahel, the Lake Chad is at the center of an endorheic basin of $2{,}5.10^6$ km^2. One of the most remarkable features of this terminal lake is that, despite the semi-arid context and high evaporation rates of the area, its waters are fresh. It is proposed in the literature that the solutes are evacuated in the underlying quaternary aquifer bearing witness to the importance of surface water and groundwater exchanges for the chemical regulation of the lake. The water balance of this system is still not fully understood. The respective roles of evaporation versus infiltration into the quaternary aquifer are particularly under constrained.

To assess lake-groundwater flows, we used the previous conceptual hydrological model of the lake Chad proposed by Bader et al. (Hydrological Sciences Journal, 2011). This model involves six parameters including infiltration rate. A probabilistic inversion of parameters, based on an exploration of the parameters space through a Metropolis algorithm (a Monte Carlo Markov Chain method), allows the construction of an *a posteriori* Probability Density Function of each parameter yielding to the best fits between observed lake levels and simulated. Then, a chemical budget of a conservative element, such as chloride, is introduced in the water balance model using the optimal parameters resulting from the Bayesian inverse approach.

The model simulates lake level and chloride concentration variations of lake Chad from 1956 up to 2008. Simulated lake levels are in overall agreement with the observations, with a Nash-Sutcliffe efficiency coefficient above 0.94 for all sets of parameters retained. The infiltration value, obtained by such probabilistic inversion approach, accounts for 120 ± 20 mm/yr, representing 5% of the total outputs of the lake. However, simulated chloride concentrations are overestimated in comparison to the scarce measurements available over that period. As an example, the mean chloride concentration measured in the southern pool on a basis of our synthesis of existing chemical data since the 1970's is approximately three time lower than the computed mean concentration. This may be due to either the non-representativeness of our chemical dataset or overestimation of the evaporation rate that is fixed to 2000 mm/yr in our model.

This study tackles the quantification of the lake water flows to the quaternary aquifer system and the associated uncertainties from a probabilistic point of view. This is an essential step to improve predictions of groundwater resources in the Lake Chad Basin under climate change.