Geophysical Research Abstracts
Vol. 17, EGU2015-10286, 2015
EGU General Assembly 2015

Developing a CFD-based Approach to Estimate Evaporation from Water Surfaces in (Semi-) Arid Regions

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In arid and semi-arid regions where evaporation highly exceeds rainfall, approximately one half of the stored water in shallow lakes may be lost due to evaporation. Precisely estimating this for very shallow lakes is however a daunting tasks due to the complexity of lake thermodynamics and the interactions between the water surface and air. Evaporation in water is largely uncoupled from land based evapotranspiration and most methods used are case-specific equations which are usually not applicable for other lakes. In this study a Computational Fluid Dynamics(CFD) Evaporation Model is established to adequately quantify the evaporation losses by simulating the air flow and heat transfer in the atmospheric boundary layer. Consideration of the air flow and heat transfer is required to simulate the fetch effect. This model will help to understand the complexities involved in open water evaporation and consequently will lead to more accurate estimates and better strategies for managing and controlling the evaporative loss of fresh water in arid and semi-arid regions.
The proposed approach is used to drive a convective mass-transfer coefficient (wind function) required for estimating evaporation of water bodies with the mass-transfer method. The model was applied for a small shallow (with a surface area of 45 hectares and 3m deep on the average) artificial lake in Ghana called Binaba. The heat and mass transfer coefficient over the water surface and their distributions were extracted from the CFD analysis. The results showed that the CFD-derived wind functions were very similar to those empirically derived from the measurements over the lake using Eddy Covariance(EC) System. The evaporation rates calculated with the synthetic wind functions were in good agreement with hourly and daily evaporation measurements for the lake. The established CFD-model is generalizable and cost effective, since it needs low input data. Besides, the model is able to provide additional parameters such as the spatial distribution of the evaporation rate over the water surface. The application of CFD to estimate water bodies evaporation looks very promising.