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Impacts of the land-lake breeze of the Volta reservoir on the diurnal cycle of cloudiness and precipitation

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Lake Volta in Ghana is the artificial lake on Earth with the largest surface area (8502 km2). It has been constructed in the early 1960s, with the lake being filled around 1966. Land-lake breezes and their effects on the diurnal cycle of local wind systems, cloudiness, and precipitation have been studied for several tropical lakes, among which studies on the effects of Lake Victoria in East Africa are one of the most perceived ones. To date, no studies on the strengths and effects of the land-lake breeze of the Volta reservoir are known to the authors. Using surface station data, a variety of satellite data on clouds and precipitation, and a convection-resolving regional model, the land-lake breeze and its impacts were studied for Lake Volta between 1998 and 2015.

The observational data sets confirm a significant land-lake circulation. The only manned weather station operated by the Ghana Meteorological Service that is situated at the lake is Kete Krachi. Hourly observations for 2006 and 2014 show on several days a clearing of skies in the afternoon associated with a shift in the surface winds from southwest to southeast, the latter potentially indicating a lake breeze effect. Cloud occurrence frequency derived from the CLARA-A2, MODIS, and CLAAS2 cloud masks and the cloud physical properties from CLAAS2 clearly show the development of clouds at the lake breeze front in the course of the morning and around mid-day. This effect is most pronounced in March when also the difference between the surface temperatures of the lake and the desiccated land surface is strongest. During the peak of the wet season in July, the lake breeze cloudiness is masked by a high background cloudiness and likely also weaker due to the strong southwesterly monsoon flow that tends to weaken the land-lake circulation. However, the precipitation signal was found to be strongest in July, most probably due to the fact that in boreal fall, winter and spring, the lake breeze cloudiness often fails to develop into afternoon showers or thunderstorms, or if, they are short-lived with substantial below-cloud evaporation.

Two cases in 2007 and 2014 were synoptically analyzed with weather charts and modeled using the COSMO model, the current regional operational weather forecasting model of the German Weather Service (DWD). The COSMO experiments with and without the lake were integrated for 48 hours at convection-resolving resolution of 2.8 km. Initial and boundary conditions were taken from ECWMF operational analysis. Model results confirm the development of the daytime lake breeze and suggest that the existence of the lake has substantially changed the local circulation, cloudiness and precipitation regime. Our results imply a significant impact of the artificial lake on the local climate and ecosystems that warrants further study.