Response to Reviewer # 1 Comments (manuscript # hess-2017-415):

"Evaporation suppression and energy balance of water reservoirs covered with self-assembling floating elements"

Milad Aminzadeh, Peter Lehmann, and Dani Or

Dear Editor,

We greatly appreciate the constructive and insightful comments made by reviewer # 1. In the following, we address the main concerns raised by reviewer regarding a) the model validation, b) stress transfer at a covered surface, and c) surface thermal mixing.

Reviewer comment: *First, at best, this investigation is speculative as there is no verification data presented to show whether or not is predictions are robust. At the simplest level, it would be anticipated that if a reservoir was covered in such a way as to prevent the penetration of electromagnetic radiation into its surface by elements of low thermal conductivity, the surface thermal forcing would be reduced. Therefore the outcomes shown in Figure 6 are not surprising. The authors have elected to use meteorological data that does not appear to have been gathered in the vicinity of a reservoir and apply it to a "hypothetical" reservoir. The key question is the degree to which the predictions are reliable and the authors have not addressed this question. As stated on page 11, the authors do have access to a model reservoir that is described in Appendix A. It is difficult to comprehend why they have not verified their model for a system where they were able to make measurements.*

Reply: The reviewer is correct that certain aspects pertaining to covered "reservoir scale" predictions remain tentative and would require confirmation using reservoir scale data (the lack of publically available data from covered reservoirs for model validation was acknowledged on page 12, line 19). However, we have tested key aspects of the model using information from uncovered reservoir response to natural conditions (USGS Lake Mead data – see Figure 4) to establish a reference for evaluating how floating covers would affect the energy balance of a covered reservoir. We also incorporated insights from laboratory experiments using floating covers in a "small basin" from our lab at ETH Zurich. Laboratory evaporation experiments using 1.44 m^2 basin and 0.16 m depth (as depicted in Figure A) were in good agreement with model predictions for evaporation suppression and effects of cover color (as mentioned in page 15, line 3). Clearly, aspects related to vertical temperature profiles and mixing of covered reservoirs under natural atmospheric conditions would not be captured in such a shallow basin in the lab. In summary, the application of sound physical principles for modeling of evaporation suppression, detailed model validation for uncovered reservoir using multi-seasons measured data, and (limited) insights from laboratory experiments for covered and uncovered basins, render the investigation not so "speculative". Hence, the investigation offers quantitative predictions for the effects of covers (that indeed do not contradict intuition, except the “surprising” result that white and black covers were equally effective in suppressing evaporation).

Figure A: The water basin with 1.2×1.2 m^2 surface area and 0.16 m depth in our laboratory; uncovered (left) and covered with black discs (right)

Reviewer comment: *Equation (4) is the conventional expression for stress transfer at an uncovered surface in the absence of wind wave growth. On page 11, line 13 we are told that $u*_a$ has been determined from bluff body theory. There is no discussion of the merits of combining these characterizations when their underlying assumptions are clearly at odds.*

Reply: The derivations are motivated by the paucity of expressions for aerodynamic interactions of airflows with floating elements on water surfaces (in contrast, numerous studies have addressed interactions with wavy or bluff body covered solid surfaces). The situation is even more complicated considering phase change where heat and mass transfers at evaporating water surfaces potentially affect aerodynamic interactions over such partially covered water surfaces.

The eddy thermal diffusivity in the vertical temperature equation (Eq. 1) was based on a relatively simple and physically-based formulation of Henderson-Seller [1985] (Eq. 3) that expresses eddy diffusivity as a function of friction velocity at the water surface. Note that Eq. (4) emerges from equality of shear stresses at an interface. We invoked a well-established theory of drag partitioning over rough surfaces developed by Shao and Yang [2008] and Nepf [2012] that has been recently evaluated by Haghighi and Or [2015] to quantify the friction velocity (u_a^*) of air and define the friction velocity at the water surface (u_s^*) based on Eq. (4). Furthermore, we tested this representation by considering the boundary layer thickness (a function of u_a^* [Haghighi and Or, 2015]) obtained from direct measurements of mass loss from our water basin covered with floating discs and simulations using COMSOL. Details of aerodynamic interactions between airflows and floating cover elements are key to evaluation evaporation suppression and thermal effects in covered reservoirs and deserve specially designed studies (beyond the scope of the present work). Nevertheless, we provide additional details on the friction velocity and boundary layer thickness in Appendix B.

Reviewer comment: *In Figure 2, the authors invoke a conventional approach to the numerical modelling surface mixing of reservoirs which encapsulates unstable convection due to surface cooling. However, such an approach is unreliable in terms of heat fluxes and the authors' own observations with their infrared camera should show. Certainly the longstanding work by Andy Jessup and his collaborators have revealed very different behavior of the surface skin (responsible for radiant heat from the surface) from that of the bulk.*

Reply: We thank the reviewer for raising this point. Equation (1) is a generic differential equation for describing vertical temperature profiles either in a water body or in a solid slab (with $D_w = 0$). What differentiates the solutions for these two cases is vertical mixings in water body triggered by thermal/density instabilities (e.g., a cold layer of water due to evaporative cooling overlying warmer water below). Such mixing processes are triggered at small scales diurnally (due to evaporative cooling at the surface), or seasonally where subsurface heat accumulation raises to the surface and unifies the vertical temperature profile in a reservoir (either Monomictic or Dimictic reservoirs). Note that the simple vertical mixing approach of Dake and Harleman [1969] preserves the energy balance of the reservoir.

We fully agree with the reviewer that surface heat fluxes vary by imposing such mixing scenario. We thus imposed the vertical mixing on the "mean daily" temperature profile providing the initial condition at the beginning of next day. This step prevents transfer of heat towards the bottom of the water body (such as would happen in a solid slab). Consequently, the "instantaneous" values of surface temperature and surface heat fluxes are obtained directly from the temperature equation with surface boundary conditions represented in Eq. (8) or (12), hence unaffected by surface thermal mixing as depicted in Figure 2. This can be seen, for example, by comparing winter surface temperature of uncovered reservoir in Figures 5 and 6b. The good agreement between model predictions of vertical temperature profile in Lake Mead and measurements (Figure 4) further confirms our modeling approach based on Dake and Harleman [1969] without affecting the calculation of surface temperature and thus surface heat fluxes represented in Table 2.

We thank again the reviewer for many helpful comments and hope the Editor finds the clarifications satisfactory.

Sincerely,

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