Hydrol. Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/hess-2017-415-RC2, 2017
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Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "Evaporation suppression and energy balance of water reservoirs covered with self-assembling floating elements" *by* Milad Aminzadeh et al.

Anonymous Referee #2

Received and published: 4 November 2017

Review of "Evaporation suppression and energy balance of water reservoirs covered with self-assembling floating elements" By Milad Aminzaheh, Peter Lehmann, Dani Or Recommendation: Accept with some revisions General Comment: This is a well-written and presented article. It provides a relatively simple but surprisingly comprehensive theoretical and physical basis of evaporation suppression from simple, shallow reservoirs from which more detailed work can emerge. It does this by comparing models of an uncovered reservoir to ones covered by white and black circular discs. A 1-D, column approach was used. I wondered why triangular covers were not considered as they have the potential of having no gaps between them (or much smaller ones than a disc).

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The paper could be well served by articulating right at the outset the methodology you use. This is how I perceive it (from reading p. 11): 1. Calculation of evaporation reduction due to discs 2. Effect of heat balance of the discs on water column, the primary evaporation reduction element 3. Effect of heat balance of the gaps between discs on water column, including conduction from disc to water. 4. Effect of the increase of gap water surface temperature due to 2 and 3.

Advection of (likely) colder water into the column was brought up in a discussion of managed input vs output for the reservoir but non-advective heat transfer was only considered for the bottom of the column. What about the four sides (can assume a simple soil temperature profile)?

The diffusivity coefficient, D, did not appear to include any internal dynamics such as non-linear and/or breaking waves, which would likely increase it. The authors might consider such inclusion for completeness. Although, I must admit, internal motions in such a shallow reservoir would not be very large or complex. However, I am not aware of any observations of internal motions in shallow reservoirs and there are few for larger, deeper ones (with bottom topography forcing the wave motion). Managed releases would exacerbate wave activity.

It appeared implicitly assumed that the water was not turbid, a rare condition in most reservoirs. A short discussion of the effect of turbidity on the columnar distribution of heat would enhance the work and provide an avenue for further theoretical work.

While the amount of open water subject to heating is small in this study, for completeness at least a nod to the Claeusius-Clapeyron relationship should be noted (and, I guess, dismissed). It had a major impact on the “failure” of monomolecular layer cover evaporation suppression in the famous Lake Hefner (Oklahoma, USA) Evaporation Reduction Experiment in 1967 (Bean and Florey, 1968, Water Resources Res., 4, 206-208; also notes an evaporation reduction of about 60%) because the water warmed up when evaporation was reduced. Wind removed the layer, exposing the warm water,

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which then had higher evaporation due to the warmer water resulting in a net loss.

One must ask, though, if the general design of these small, shallow reservoirs, a given in this work, is a good beginning. So while physical intervention, as discussed here, is important, the general design of a reservoir is equally important.

An important metric, the mean depth, D = V/A, where V is the reservoir volume and A, its surface area was not discussed. An efficient reservoir would be one where V is large and A is small resulting in a large value of D; in other words a cylinder will evaporate less than a bowl of the same volume. In this case 3m < D < 10m was considered. This is very shallow, implying a rapid response of reservoir heat content to varying atmospheric forcing; in other words the surface temperature, the main driver of the evaporative process, responds rapidly to latent and sensible heat transfer as well as the mean temperature of the volume. There is little phase lag between the near surface heat balance and interior heat balance; both will closely follow the daily average air temperature and net radiation input.

In a deeper reservoir, Lake Mead was used where D is 165, there is a considerable phase lag in the diurnal and seasonal variations of surface versus interior temperature. For instance, in summer daytime air temperature will likely exceed the water temperature; a stable situation resulting in reduced evaporation especially in windless conditions. The reverse is true at night, when water temperatures are likely warmer than air temperature. Since during summer mid-latitude daylight hours substantially exceed nighttime hours so the lower evaporation during the day will dominate. In Fall, surface temperature will decrease due to lower insolation amount and duration, but will this will likely be mitigated by heat transfer into the surface layer by relatively warmer water in the interior resulting in relatively warmer surface temperature than air temperature throughout the day resulting in potentially more evaporation in that season (and Winter) compared to summer. The results shown in this article do not support this heuristic argument. However, eddy correlation observations over a period of years over Lake Superior (Blanken, P. et al., 2011, J. Great Lakes Res., 37, 707-716) show

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this nicely.

Last, I recall talking with a farmer who was the leader of a ditch company that managed a small reservoir as assumed here. He was very interested in estimating evaporation and, of course, suppressing it with some sort of cover as described here. I asked him if he had planted a wind break on the windward side. He was stunned and said he had not thought of it. So I said: "But you thought of it for your fields and that isn't open water. Furthermore, it would be a good use of otherwise "lost" leakage to ground water." So while I understand this windbreak approach and the consideration of internal boundary layers formed by changes in surface friction is not conducive to such a study as outlined here, I feel a theoretical approach to these aspects of real world reservoirs would be worthwhile in the search for low-impact geoengineering of simple reservoirs. This group obviously have the tools and expertise.

Specific Comments using page, line, equation, figure and table numbers

p. 2, l. 15: I believe the recent use of black balls in a Los Angeles reservoir was not aimed at evaporation reduction but the reduction of toxic algae blooms. I think Israeli engineers have used white ping-pong like balls to reduce evaporation in test reservoirs (don't have a reference).

p. 7, eq. 6a: Please check for references for some of these empirical relationships. Some equations are referenced, some not.

p. 7, eq. 6b: some readers will not recognize the Brundt-Viasala relationship, which carries some restrictive assumptions with it. Interestingly on a windless or low wind day, this might be more likely during the day and convective mixing, as noted in this work, which is more likely at night when surface temperature might be lower than temperatures below.

p. 7, l. 12-13: Do you have a reference for the assumption?

p. 8, eq. 8: explain why you use C for vapor concentration instead of the more recog-

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nizable q, specific humidity.

p. 8, l. 15, Fig. 2: is this the heavy dashed line in the Figure? It needs to be explained.

p. 10, l. 13-14: jargon alert! “three-dimensional vapor shells” Show or explain further. Also what is meant by “lateral spacing”? Perhaps you can show these in Fig. 3b.

p. 12, l. 12: Consider “Given the simplifying assumptions, the model overestimates. . ..”.

P. 13, Fig. 5: Comment on the slow uptake of heat in Spring (cold water/warm air) vs rapid decrease in Fall (warm water/cold air) to add confidence in the model. You might find observational evidence to back up a heuristic argument: surface layer more stable in Spring, more convective in Fall.

p. 13, l. 18-19 “..demonstrate . . . a much colder reservoir.” This is an impressive modeling result and should be tested by a field experiment. Is one being considered?

p. 17, Section 3.3, Ecological considerations: Reservoirs, even small, simple ones as assumed here, while not likely used for recreation, can be important to migratory birds and other wildlife as well as aquatic life in the reservoir (which often provide food for wildlife visiting the reservoir, extending the ecological boundary). Discs, as described here, will inhibit access for wildlife. That should at least be mentioned along with the impossibility of modeling it. Although, for any future work, you might consider entraining a wildlife expert who might.

p. 18, Section 3.4, Costs and water savings: A nice summary. Have an economist vet it, if you haven’t. I especially liked the last sentence. You might mention water scarcity as a conflict enhancer as described recently by Tom Friedman, a well-known columnist for the New York Times. So efficient storage of water becomes political.

p. 22, l. 10-18: You should mention an important effect of the discs I did not see in the paper but suggested in this discussion; the appearance of waves, breaking waves, and spray as wind increases (threshold $\sim$ 6 mps). This radically changes the situation in open, uncovered water and greatly increases the evaporation; modeling this effect

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is still elusive though a check of hurricane boundary layer modeling may provide some insights.

P. 23, Eq. B3: Is this correct? Should it be λ = D/H to be dimensionless as described later in the Appendix?

p. 24, l. 13-15: 3 to 10 m is not enough depth variation. Note that Rn, H, and E are essentially constant and heat storage decreased by 27% for the 10m depth. Can you show the “index” Ta – Tw for the two depths? I predict they will be nearly the same.

Figure 1: I’d replace that with a Google Earth picture of the Front Range (eastward) of Colorado which is dotted with small reservoirs to show how ubiquitous they are. Using the area tool on the USGS National Map Viewer you could show that the combined area of these “small” reservoirs approximate that of major reservoirs in the Colorado River Basin system.

Figure 2: Those two hatched areas do not look equal to me. Explain the dashed line.

Figure 3: What is the red triangle on the far left side? You’ve labeled the down arrows to the far left and right, what is the label for the one between them? What does the expression below fc represent?

Figure 4: “assumed”? Be honest, wasn’t it “tuned”? Were “η” and “β” observed?

Figure 7: I think 7c is a result of the shallowness of the reservoirs you are modeling. They are like an evaporation pan which has a similar trace with respect to season. Deeper reservoirs show a maximum in Fall/Winter and a minimum in Summer for good reasons. Dew forms on the surface of Lake Superior in summer!! I’ve witnessed explosive evaporation events associated with reservoir overturning in mid-winter with air temperature of -12C.

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