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Hydrology and Earth System Sciences Discussions

Interactive comment on "Satellite remote sensing of water turbidity in Alqueva reservoir and implications on lake modelling" *by* M. Potes et al.

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Response to referee 2 by Potes et al. "Satellite remote sensing of water turbidity in Alqueva reservoir and implications on lake modelling" submitted to HESS (hess-2011-324)

We thank the referee for the constructive comments and suggestions that in our opinion contributed to clarify and improve the manuscript. Bellow follows a full transcription of the referee comments, as well as our reply.

Parte 1.

General Comments:

The authors present results obtained from applying satellite remote sensing to retrieve information on lake water turbidity (Alqueva Reservoir, Portugal). The Flake model is also used to investigate the importance of the water extinction coefficient (estimated from turbidity) in the evolution of the lake surface water temperature. This reviewer considers this topic is valuable and of interest to the Limnological community and within the scope of the HESS. The manuscript needs significant improvement and many issues need to be addressed as discussed below. The manuscript needs a good English editing for style and clarity. The introduction needs to be more focused (and shorter) on information supporting the main objectives of the manuscript. Overall the underlying analysis appears sound. The presentation of the results is discussed although sometimes purely descriptive and no many sources are cited as evidence of the claims the authors are making.

Reply

The authors agree and the manuscript was carefully checked and English improved. In addition, the introduction was modified and restructured mainly due to the suggestions given by reviewer 1.

The authors mention the need for including 1D lake models into weather prediction and climate models. This argument needs much better evidence and explanation.

Reply

As pointed out, in 2010, by Mironov et al.: "In most numerical weather prediction (NWP) and climate models, the effect of lakes is either entirely ignored or is parameterized very crudely. In coarse resolution models, a large number of small-to-medium size lakes are indistinguishable sub-grid scale features. These lakes become resolved scale features as the horizontal resolution is increased. Then, a physically sound model (parameterization scheme) is required to predict the lake surface temperature and the effect of lakes on the structure and transport properties of the atmospheric boundary layer. Apart from being physically sound, a lake model must meet stringent requirements

of computational economy." Three-dimensional lake models may accurately represent both vertical and horizontal transport of momentum and heat but have high computational costs and so its use in operational NWP will most likely be impossible for some years to come. For NWP and climate applications, one-dimensional lake schemes, and in particular the FLake two-layer bulk model, seems to be a good compromise between a physically based representation of the evolution of the lake thermal structure and the associated computational costs. Very recent papers give more arguments to the importance of the representation of lakes in NWP and climate models and that this can be carried out using 1D models (e.g. Balsamo et al., 2012, Kheyrollah Pour et al., 2012). In the revised text, we added some arguments and explanations and include more references that support the need for including lake schemes in weather prediction and climate models.

Parte 2.

Specific Comments:

Page 11358, lines 17-18. A bit vague sentence. Please re-write it.

Reply

The sentence was rewritten.

Page 11358, lines 21-22.What do the authors mean by “several factors”? Please mention them.

Reply

This was substituted by physical and chemical properties.

Page 11358, line 26. Replace “in the water sample” with “in the water column”.

Reply

Replaced.

Page 11359, line 11. What do the authors mean by “water interaction processes”?

Reply

“Light and water interaction processes” means how solar energy reacts when reaching the water surface. This process is described by Moore (1980): “If the solar energy that reaches a water surface is represented by I0, the interaction is expressed by:

where ISR is the solar flux that is specularly reflected at the water surface (the mirror effect), IA is the flux absorbed by the water and IB is flux backscattered to the water surface and thereby available for remote detection.”

Page 11359, lines 16-17. References should be mentioned in chronological order.

Reply

References were changed accordingly.

Page 11360, lines 1. Replace “at demonstrating” with “to demonstrate”.

Reply

The sentence was removed. A new paragraph stating the objectives was rewritten.

Page 11360, lines 3-4. It is unclear what the authors mean about this paragraph. Also what about “lake schemes”?

Reply

The term “parameterization scheme” is commonly used in the NWP and climate modelling community to discriminate a component (module) of a complex modelling system from its host that is referred to as an NWP (climate) model. In this context, a "lake parameterization scheme" or simply a "lake scheme" is a numerical model, which intends to represent the evolution of some properties of the lakes, particularly of its surface temperature. For clarity we will use the expression “lake parameterization schemes” in the revised manuscript.

The introduction of a lake model requires the knowledge of some lake dependent parameters, namely lake depth and water optical properties. A global dataset of lake coverage and lake depth for use in numerical weather prediction and climate modelling was developed by Kourzeneva et al. (2012). Less attention has been devoted to the optical characteristics of the water. It is our aim, with this article to demonstrate the possibilities and potential of using satellite remote sensing data to obtain information on lake water turbidity. The water turbidity is an optical property of water that can be related to the parameters used by the current lake parameterization schemes. We also carried out a sensitivity study in order to highlight the importance of the water optical properties in the evolution of its surface temperature.

Page 11360, lines 14-18. This sentence is very long. Please re-write it.

Reply

The sentence was rewritten.

Page 11360, line 21. Please mention how lakes do affect the structure of the atmospheric boundary layer.

Reply

Atmospheric boundary layer structure is strongly dependent on surface-atmosphere transfer processes. There is a large contrast in surface properties and hence in surface fluxes of heat, moisture and momentum between inland water and land. In particular, the presence of lakes increases the thermal inertia, decreasing the thermal amplitude and the daytime instability of the boundary layer, increases the availability of water for evaporation and reduces the surface friction. At many places in the world lakes are seasonally covered by ice, which induce additional effects on the atmospheric surface layer. As a result, the presence of lakes strongly affects the structure of the atmospheric boundary layer.

It seems to us that a detailed description of the effects of lakes in the atmospheric

boundary layer is beyond the scope of the introduction of this article. Accordingly we think it will be enough to include a reference with a classic review (Zilitinkevich, 1991).

Page 11360, line 23. How do weather forecast models interact with lake models? Please justify the inclusion of 1D lake “schemes” in operational numerical weather prediction models. It is unclear.

Reply

As explained above, lake parameterization schemes are (or will be in a near future) a component of operational NWP models. The interactions between the atmospheric component of such NWP models and the lake parameterization schemes (as with other surface parameterization schemes) are represented by two-way exchanges of heat, moisture and momentum. In the revised text, we added some arguments and explanations and included more references that support the need of including lake schemes in weather prediction and climate models.

Page 11361, line 1. Please clarify “a lake parameterization scheme”.

Reply

It has been addressed above and clarified.

Page 11361, line 8. References should be mentioned in chronological order.

Reply

Changed.

Page 11361, line 9. What do the authors mean by “on the water mass conditions”?

Reply

“Water mass conditions” means the combination of organic and inorganic material present in the water mass. This was now added to the manuscript.

Page 11361, lines 18-24. Please re-write and state clearly the two objectives of the

manuscript.

Reply

Rewritten. We included one more objective (three objectives now) on the manuscript.

Page 11361, line 28. Should be “Section 5”.

Reply

Replaced.

Page 11362, line 1. Add “Study site” to the title. The “s” is missing in “method”.

Reply

Added.

Page 11362, line 8. Mention total phosphorus and chl-a concentrations in the reservoir.

Reply

These values are now included in the manuscript.

Page 11362, line 18. Replace “This selection aims” with “The selection of these sites aims”.

Reply

Replaced.

Page 11362, line 27. Add a reference.

Reply

A reference was added.

Page 11363, lines 4-21. These paragraphs need to be shortened. There is no need to describe things in detail. Cite references instead.

Reply

The paragraphs were shortened.

Page 11364, line 14. Should be “is not”.

Reply

Changed.

Page 11364, lines 17-18. Please explain “The second simulation of the satellite signal in the solar spectrum”.

Reply

Second Simulation of the Satellite Signal in the Solar Spectrum (6S) is the radiative transfer code adopted to perform the atmospheric correction. This has been rephrased.

Page 11365, lines 1-5. Please indicate where the measurements were taken, i.e. at Mourao and Montante?

Reply

This was clarified in the revised manuscript.

Page 11365, lines 7-8. The authors are just repeating the Figure 2 caption.

Reply

Changed.

Page 11365, lines 16-20. The authors are just repeating the Figure 3 caption.

Reply

As suggested by the reviewer 1, Figure 3 was substituted by the graphs added to Figure 2, showing the spectral behaviour of the comparison. The text of the manuscript was modified accordingly.

Page 11366, line 9. The authors mention 89 data points, what is the spatio/temporal distribution of these measurements? Please clarify.

Reply

Measurements were taken at six sites during the three campaigns (Mourão site on 27 July 2010, Mourão and Montante sites on 25 August 2010 and three distinct places near Mourão site on 24 February 2011). MERIS level 1 has 15 spectral bands which would supply a total of 90 points. MERIS N1+6S present 89 points because the atmospheric correction failed for one of the data points. This is now clarified in the manuscript.

Page 11366, line 9. Replace “To sum up” with “In summary”.

Reply

Replaced.

Page 11366, line 26. The word “retrieved”, do the authors mean “measured”?

Reply

The word “retrieved” means “obtained through”. The sentence was rewritten.

Page 11367, line 1. Explain “limnological data”.

Reply

“Limnological data” means in this case water turbidity. The sentence was rewritten.

Page 11367, line 8. References should be mentioned in chronological order.

Reply

Changed.

Page 11367, line 12. Indicate location of the turbidity measurements.

Reply

The locations (Mourão and Montante) were added.

Page 11367, line 22. Where the highest turbidity (60 NTU) was measured within the reservoir? Have the authors done a determination of the particle size?

Reply

The highest turbidity measured was in Mourão site. This information was added to the manuscript. The determination of the particle size was not done.

Page 11367, line 28. References should be mentioned in chronological order.

Reply

Changed.

Page 11368, line 21. What does the shape factor CT mean? Page 11369, line 5. Explain “the same concept of self-similarity”.

Reply

The authors agree that the model has to be better explained. Hence, in the revised manuscript we added the following paragraph in page 11368, line 18: This concept, based on empirical evidence with some theoretical support, assumes that the dimensionless temperature Φ profile in the thermocline can be fairly accurately parameterized through a universal function of dimensionless depth: ;

where z is the depth, TS is the mixed-layer surface temperature, TBOT the temperature at the lake bottom, h the thickness of the mixed-layer and D the total lake depth. (D - h) is the thermocline depth. Several polynomial approximations for Φ may be found in the literature (see Mironov, 2008). In FLake, a 4th order polynomial is assumed for Φ and its shape is completely defined by its integral between ζ=0 and ζ=1, which is the shape factor, CT. The dimensionless shape factor varies between a minimum value,

0.5, corresponding to a mixed layer stationary state or retreat , and a maximum value, 0.8, the maximum allowed curvature in the mixed layer deepening process.

Page 11369, lines 19-22. It would be nice to have some measurements to validate the algorithm!

Reply

It is our intention to validate the algorithm in the near future. At the moment there were no more measurements available.

Page 11370, line 2. Should be “In order to investigate the importance ...”

Reply

Changed.

Page 11370, line 5. Remove “off-line”.

Reply

The term “off-line” was be replaced by “Stand-alone“

Page 11370, line 8. Replace “are” with “were”.

Reply

Replaced.

Page 11370, line 9. Replace “water thermal profile” with “water column was thermally stratified”.

Reply

Replaced.

Page 11370, line 10. Is wind direction not required?

Reply

No, the wind direction is not required in the present version of FLake. The formulations of the fluxes do not depend on the wind direction. The unique parameter that would depend on the wind direction is the fetch. In fact, it will be possible to define different fetch values depending on wind directions, but actually only one fetch value for each grid point is considered, thus not depending on wind direction.

Page 11370, line 22. Replace “tackled” with “taken”.

Reply

Replaced.

Page 11370, line 23. The word “tunning” does not sound right.

Reply

Tuning a model is a common practice in meteorological and climate modelling. Hourdin et al. (2012), for example, insist “in the importance of free model parameters tuning, an often hidden but fundamental aspect of climate modelling. Tuning is needed because the models, and in particular the parameterizations of physical processes, are only approximate representations of reality”. (in Hourdin et al., 2012, the word “tuning” is used 62 times)

Page 11371, line 1. Please express the water temperature in degrees Celsius.

Reply

The temperatures are now expressed in degrees Celsius.

Page 11371, line 1. How does D=23 m compare with the average depth of the reservoir? What about h? How many simulations were performed in order to find out these values? This reviewer is concerned about this procedure.

Reply

In the tuning process, 3 parameters were considered free (fixed depth, D, initial values

for h and CT). The model ran for an ensemble of realistic values of these variables: D between 10 and 50 m, with a step of 1 m; h between 1 and 20 m, step 1m; CT between 0.50 and 0.80 (all range), step 0.01. It means that about 24000 simulations were performed for the 61 days period. The configuration, which minimized the root mean square error between modelled and observed hourly mean surface temperature were chosen. This information was now added to the revised manuscript.

The average depth of the reservoir is 16.6 m, but in the place where atmospheric data are collected the depth is of about 35 m. As it is a recent man made reservoir, the bottom slopes are high, especially in the centreline of the river valley. As pointed out in the manuscript, the water temperature measurements are only available at 3 levels (surface, middle and bottom), which are not sufficient to adjust a FLake initial profile that is characterized by four variable. Moreover, the depth of the middle level is not known. Thus, we have no direct estimate for the initial value of h to compare with the model tuning result.

Page 11371, line 3. Replace “Model runs ...” with “Each simulation was performed for 61 days using a time step of 30 min”.

Reply

Replaced.

Page 11371, line 11. Should be “in” after the comma.

Reply

Replaced.

Page 11372, lines 1-5. The simulated water temperatures in both cases show a more sudden daily change compared to the measured one. Please explain why.

Reply

In both cases, but more clearly in the Mo61, the simulated surface (mixed layer) water

temperatures show some events of sudden daily changes, not visible in the measured one. These events are initiated with a sharp fall in the surface layer temperature, due, in the simulations, to the rapid increase of the mixed layer depth, h, which passes (in Mo61) from values less than 2 m to values greater than 8 m (not shown). Thus the decrease in simulated temperature is due to the fact that the mixture brings deeper (colder) water to the surface. In turn, h increases due to the occurrence of high speed wind events (greater than 10 ms-1). In reality, this fact was not observed in the studied period. The difference between model and observations may be due to errors in wind measurements, or, more probably, to horizontal mixtures not expected to be represented in 1-D models, which bring water from areas where the lake depth is lower than h and therefore do not cool. Another explanation may be an incorrect representation of the evolution of h in windy conditions and when the water lake is very stratified. This possibility needs further investigations. This explanation is added to the revised manuscript.

Page 11372, line 6. What about the errors associated with the forcing data? Is the model scheme free of numerical diffusion error? Please clarify.

Reply

The model (FLake) is based on the integral approach, i.e. it is methodologically similar to mixed-layer type models, it does not solve the diffusion equations. It solves a set of (4) ordinary differential equations (in time) for the time dependent parameters that define the temperature profile (mixed-layer temperature, mixed-layer depth, bottom temperature and shape factor). So the term "numerical diffusion" in strict sense is not applicable. The time integration scheme is a very simple Euler scheme. But most processes in lakes are relatively slow, so that with small time step it does not cause numerical stability problems.

As to the forcing, it is of course an issue. If Flake is forced by wrong atmospheric input, surface fluxes will be wrong as well and one cannot expect a good performance. The

owner of the dataset used to force our simulations did not report any specific error or warning in this period. In the reply to the previous question, we increase the discussion of the results with comments about errors associated with forcing.

References

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