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Discussions

Interactive comment on "Temperature and rainfall estimates for past 18 000 years in Owens Valley, California with a coupled catchment–lake model" *by* Z. Yu et al.

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Please refer to the Supplement for all the answers and revised figures.

Response to the Referee comments

RE: hess-2015-167, Temperature and rainfall estimates for past 18,000 years in Owens Valley, California with a coupled catchment-lake model

Referee #1 (F.W. Schwartz):

General Comments: The paper describes an interesting approach to develop a model

based approach to develop snapshots of climate conditions in the Owens valley over the past 18,000 years. It will contribute important new knowledge to the study of the paleolakes and paleoclimates of the American Southwest. There are significant opportunities for improving the paper, which are presented as the following points.

Response-General Comments: We are thankful to the reviewer for the positive and encouraging comments that we believe has helped us to improve the manuscript. Following the reviewer's suggestion, we addressed the following comments in detail as outlined in the responses below.

Comment-1: The paper sets out to test the hypothesis that physically-based lake models offer a more robust way to infer climates and paleosettings. This approach has already been tested in a WRR paper by Matsubara and Howard (2009), which was overlooked in the review of previous work. This study used a similar model-based approach to infer settings of paleolakes in the broader Great Basin area. For my taste, the model is over-referenced in the sense that many papers are referenced but not actually used for much of anything. In addition, the same references are presented over and over again. A rewrite could find ways to make clear larger sections are based on particular works, rather than repeating them over and over.

Response-1: We have carefully reviewed the paper by Matsubara and Howard (2009). We will add it to the review part of previous work in the final completed manuscript. We agree with the reviewer on the "over-referenced" issue and will re-organize the citations in the final revised manuscript.

Comment-2: The review of previous paleoclimate studies beginning at line 19 on 6509 and continuing on to the next page is difficult to follow and needs more careful organization and presentation. A vague reference is made to the North Atlantic region without appropriate context. Similarly, isotope values are provided without much elaboration. The references to Forester, Li et al, etc have no useful information associated with them. I would recommend making this section longer and explaining things in more detail. This rather cursory discussion is not helpful. Another strategy would be to touch a few key points in the text and add a long discussion as “Supporting Information”.

Response-2: We thank the reviewer for the suggestion. In this section, we want to introduce the paleoconditions of the Owens Lake system such as lake area, surface elevation based on various reconstruction studies. Following the reviewer’s suggestions, we will review the paleoconditions of the study region in a chronological order for better organization. We will discuss the changes of lake area and lake surface elevation in detail using the existing literatures in the final revised manuscript.

Comment-3: Section 3 – describing the modeling approach – needs to be improved. A reader cannot look at this section and understand how this modeling was done. The model needs to be described systematically including some of the mathematics. If much of this work is represented by older work, then at least provide some of this material as “Supporting Information”. It is important to emphasize what is new in this study and what has been done previously. I still think the test of sufficiency is the ability to reproduce the model based on descriptions in the paper. At this stage, the descriptions come up short.

Response-3: Following the reviewer’s comments, we will expand this section to describe the modeling approach in detail by providing a conceptual framework of the model and adding the introduction of each module including the snow module, the runoff module, and the lake module in this section. An initial revision is presented as below and will be edited and added to the final revised manuscript:

“. . .. . . In this study, the lake module in the OSHM was modified with the addition of Hostetler’s lake model to replace the empirical equation and used to simulate evaporation over the lake surface. A flow chart including the model components, inputs and relationships of the coupled catchment-lake model is showed in Figure 3. The snow module calculates mean monthly snowfall, snow ablation, and resulting snowpack from temperature, precipitation. Snow accumulation is assumed to be the fraction of pre-

cipitation when the mean monthly temperature is below a critical temperature. The snowmelt is modeled with the index of energy change based on surface temperature. Runoff from snowmelt is dependent upon snow retention and runoff coefficient. Once annual snow accumulation exceeds annual snow ablation a perennial snow pack will form. The perennial snow pack produces glacial ice after the snow pack reaches certain depth. Ice ablation is computed using a degree-day methodology that is similar to the way handled in computing snow ablation. The ice melt is modeled from degree days, degree-day factor and number of days per month. Ice melts only when it is now covered by snow, so ice covered by a perennial snowpack ablates when it moves downslope by the gravity from the zone of accumulation into the zone of ablation. The ice movement is mainly dependent on the terrain slope that can be calculated from the DEM. The runoff model calculates mean annual surface water runoff with the information of rainfall, temperature, snowmelt, and ice melt from the snow model. Interception, Hortonian overland flow, saturated overland flow, potential and actual evapotranspiration, infiltration, soil moisture storage, groundwater recharge and baseflow are implemented in the runoff module. The mean annual runoff matrix, the sum of the mean monthly runoff matrices, is then fed to the lake model to calculate lake extent.

The Lake module computes basin geometry from the DEM of the model domain. The module first calculates the drainage direction at each point. The grid point drains to the lower than all eight neighbors. An individual drainage basin is defined as the set of all points that drain to the same terminal. Closed basins are identified by number. The basins that include exterior to the model domain are removed from consideration with all assigned the same number. Drainage divides are those pairs of adjacent grid cells that lie on the border between the two basins. The outlets for each drainage divide represent the lowest point along each divide and the controlling elevation for each outlet is the higher of the two paired elevations. Each basin has a set of outlets that are sorted in ascending order so that the lowest or active outlet can be figured out easily. The runoff from the Runoff module is summed for each set of points comprising a basin to calculate annual stream inflow to each basin. Lake water is assumed to exit a basin through either overflow through the active outlets or evaporation from the lake water surface or both with ignoring groundwater contribution to the lake water. The overflow is triggered when the lake water surface elevation is greater than the elevation of the active outlets. The lake water evaporation is a function of climate and water mass geometry. Orndorff (1994) computed the evaporation with a regression equation of maximum temperature and pan coefficient that was used approximately to represent the effect of lake water geometry on the evaporation. Hostetler and Bartlein (1990) developed a physically based eddy diffusion model to simulate lake evaporation based on a vapor pressure deficit between a lake surface and the overlying atmosphere and available energy. The air at the interface between the air and the lake water surface is always at saturation and the saturation vapor pressure at the interface is a function of the lake surface temperature. Accurate calculation of lake surface temperature is prerequisite to accurate estimates of evaporation. The lake surface temperature was estimated with a surface energy model. In this study, the physically based eddy diffusion model was used to replace the empirical regression equation of the lake module developed by Orndorff (1994)."

Comment-4: It is not clear why the section on calibration comes before the section on input parameters. The paper needs to explain what the "calibration" means in the context of the overall study and specifically what parameters were available to be calibrated. So little is written about the parameters that this section on calibration is vague. The system that exists at the present time is really different than those in the past. I would be concerned about what parameters actually would be the same and considered calibrated. The goodness of fit criterion needs to be explained more clearly.

Response-4: We will move the section on input parameters before the section on calibration. The parameters in the original manuscript include both input variables such as precipitation, temperature, solar radiation, cloud cover, wind speed, atmospheric pressure, and DEM and constant parameters such as constant temperature for the justification of the portion of snowfall and rainfall, degree day factor for snowmelt, con-

stant fraction for interception, and etc. We didn't introduce these constant parameters as they are introduced in detail by Orndorff (1994). We will classify the concept of input variables and constant parameters in the final revised version. The "calibration" in the original manuscript actually contains two parts: (1) calibration of parameters in three modules (snow module, runoff module, and lake module) during the modern time with precipitation and temperature from observed data; (2) the inverse modeling of input variables (precipitation and temperature) during past periods. In the calibration during the current time, we will calibrate the constant parameters for three modules discussed above so that the simulated lake area can best match the observed lake area. Then these calibrated parameters will remain unchanged for the inverse modeling during past periods. We will also classify the difference of these two steps in the final revised manuscript to make the calibration section clear.

Comment-5: The paper needs to describe the inverse process in detail for the various time snapshots. Clearly a trial and error process was used. How many trials were involved, what parameter(s) formed the basis for goodness of fit and how well was that parameter fitted. The paper must convince the reader that the inversions were done properly and a very good fit was achieved. Were temperatures and rainfall correlated in the inversion process? Did many combinations giver a very good fit? In other words, how unique was the inverse.

Response-5: We thank the reviewer for pointing out the inadequate description for the inverse modeling. Ideally, the inverse modeling should be conducted for six input variables including precipitation, temperature, solar radiation, cloud cover, wind speed and atmospheric pressure. However, solar radiation, cloud cover, wind speed, and atmospheric pressure is less sensitive to the simulation of lake water surface elevation. As a result, we used the constant solar radiation, cloud cover, wind speed, and atmospheric pressure obtained from current observed data for the simulation during past periods. That means only precipitation and temperature will be adjusted during the inverse modeling processes. The precipitation and temperature combinations for inverse modeling were created within the range shown in Table 1. Precipitation was prepared using the interval of one percent of modern precipitation, temperature was prepared using the interval of 0.1 degree. For example, Mifflin and Wheat (1979) suggested a decrease of 3 degrees of annual average temperature and an increase of 68% annual average precipitation in Late Wisconsin compared to those in the modern time. We will create 30*68 combinations of precipitation and temperature for the inverse modeling. 30 is the temperature combination with interval of 0.1 degree ranging from (0.1 to 3). 68 is the precipitation combination with interval of 1% increase of modern precipitation ranging from (1% to 68%). The combination which generates the best match with the lake surface elevation or lake surface area determined from the geological evidence will be selected as the unique climate scenario for a certain time snapshot. We will include the detailed procedures in the final revised manuscript.

Comment-6: Several different aspects of the overall presentation of the study results need to be improved. First, the organization should be more conventional. The methods should be contained in a single section. As is, the methods are sprinkled through several sections. The writing and grammar need improvement by a native English speaker. Many sections are basically Chinese-English.

The figures need improvements as well. Figure 1 has overly small fonts. Figure 2 is a cluttered mess with some lines undefined and missing units (e.g., per mil). Figure 7 has 6 small maps which are difficult to see and compare. I would suggest a 2-D schematic map providing the sequence of lakes in proper elevation context (like a computer program flow chart) with a 2-D basin shape with elevations.

It is not clear with Figure 8 that the simulated temperatures and the estimated temperatures actually fit that well. Additional discussion is required.

Response-6: In the revised manuscript, we combined the Section 3 Description of Model and Modeling Strategies, the Section 4 Calibration of Catchment-Lake Model, and the Section 5 Input Parameters into the Method Section. Also, additional editing

has been applied to the revised manuscript. All re-organizations and edits will be included in the final revised manuscript

We also revised the figures as suggested. The fonts in Figure 1 were enlarged. Figure 2 was revised by showing the legend and units. For Figure 7, we didn't understand the suggestions by the reviewer very well. We want to illustrate the changes of simulated lake extents during different periods. As a result, we simplified the factors in the map which only include lake extents (Deep Blue), stream network (Light blue), and hillshade (Gray). For Figure 8, the temperature and precipitation estimated from pollen is a time series while the simulated data is one year average temperature and precipitation at specific time snapshots (modern time, 3ka B.P., and etc.). We cannot direct compare them rather than looking at the trends. The temperature from both pollen and our modeling indicate a decreasing trend during the selected period while the precipitation from both pollen and our modeling indicate an increasing trend. We will add the discussion of Figure 8 and revised Figures shown as below in the revised manuscript.

Referee #2:

General Comments: The authors combined numerical modeling and proxy data to quantify the paleoclimate information including precipitation and temperature in the Owens Valley. I think this paper provides valuable information for exploring the climate change in the western U.S. and it has potential implications for water resource assessment in California over a long period. I recommend the publication of this article after addressing the following specific comments.

Response-General Comments: We are thankful to the reviewer for the positive and encouraging comments that we believe has helped us to improve the manuscript. Following the reviewer's suggestion, we reviewed more literature and addressed other comments in detail as outlined in the responses below.

Specific Comments:

1. It seems that authors may not be aware of some recently publications studying similar questions and reporting similar results. Please refer to the following papers for introducing or discussing their findings: Munroe and Laabs,2011; Munroe and Laabs, 2013; Broecker and Putnam, 2012; Goebel et al., 2011 (the complete reference is listed in the following). There may be more, so I encourage the authors to make a more thorough literature review.

Response-1: We thank the reviewer for referring us to other relevant publications. We feel the review of these publications set the background for our manuscript better and enriched the introduction and the manuscript on the overall. We will include these studies in the introduction part in the final revised version.

2. Equation (2) on page 6510, and Equation (4) on page 6511. Check these two equations, where the water balance may not be satisfied. The net change in volume of the lake is missing in these two equations.

Response-2: These two equations are valid under closed lake basin. Strictly all of lakes in Owens River Valley System are not completely closed basin lake because they do have outlet that can discharge water to down gradient lake if the elevation is above the elevation of the outlet. However, the model is not implemented as the closed basin lake instead of implementing with surface water routing based on the land surface elevation, so the net change in the volume of the lake is considered in the model. The two equations here are only applied to the closed basin lake and that was true for the lakes in the most time of the simulated time period.

3. For the inverse modeling, there should be more than one combination (precipitation and temperature in this paper) that can give a good fit. What constrain conditions did the author apply to select the best combination?

Response-3: The constrain conditions in this model are: 1) the lake outlet elevation based on the paleoshoreline; 2) The temperature and precipitation ranges from the paleoclimate studies. The precipitation and temperature combinations for inverse model-

ing were created within the range shown in Table 1. Precipitation was prepared using the interval of one percent of modern precipitation, temperature was prepared using the interval of 0.1 degree. For example, Mifflin and Wheat (1979) suggested a decrease of 3 degrees of annual average temperature and an increase of 68% annual average precipitation in Late Wisconsin compared to those in the modern time. We will create 30*68 combinations of precipitation and temperature for the inverse modeling. 30 is the temperature combination with interval of 0.1 degree ranging from (0.1 to 3). 68 is the precipitation combination with interval of 1% increase of modern precipitation ranging from (1% to 68%). The combination which generates the best match with the lake surface elevation or lake surface area determined from the geological evidence will be selected as the unique climate scenario for a certain time snapshot.

4. One purpose of looking back is to better predict the future. The authors should provide an assessment of the broader implication of their findings for the study region, for example, by briefly discussing how to connect the paleoclimate information with future climate change.

Response-4: The proposed model was able to approximated reproduce the extent and paleo lakes based on the simple additive change/multiplicative change for temperature/precipitation of the modern time. This model can also be used for the future prediction of the lake system with current GCM outputs. In this way, we can look into the future whether we will encounter the same magnitude drought/flood periods that we have tasted before or even more severe conditions. This assessment of the broader implication will be added in the conclusion section of the final revised manuscript.

5. Line 19, page 6514: “A number of input parameters are required ……” Please be more specific on the number of parameters. Also please expand the introduction of parameters; for example, which parameters are more sensitive to the model result?

Response-5: Seven input parameters are required for the coupled catchment-lake model which include precipitation, temperature, solar radiation, cloud cover, wind speed, atmospheric pressure and DEM. However, solar radiation, cloud cover, wind speed, and atmospheric pressure is less sensitive to the simulation of lake water surface elevation compared to precipitation and temperature. Tectonic changes can be neglected during the studied temporal scale which mean DEM stay the same during all the simulations. As a result, precipitation and temperature are the only two input parameters considered in the inverse modeling. We will include this discussion in the final revised manuscript.

6. Figure 3, page 6534: The simulated runoff in the Mono Lake drainage basin should be long-term average of the monthly runoff. In which period was the long-term average calculated? The authors need to clearly state the calibration period.

Response-6: The period is 1971 to 2000 that correspond the PRISM 30 years normal for the 1971 to 2000. This statement will be added in the final revised manuscript.

7. Figure 5, page 6536: The three figures are not readable. Please use different line patterns, colors, and larger labels for better illustration.

Response-7: Figure 5 was revised as suggested below:

8. Figure 8, page 6539: It seems that the simulation did not match the estimated temperature based on pollen. What can be inferred from this figure? The authors need to discuss more about the comparison.

Response-8: This comment was also pointed out by the first referee. For Figure 8, the temperature and precipitation estimated from pollen is a time series while the simulated data is one year average temperature and precipitation at specific time snapshots (modern time, 3ka B.P., and etc.). We cannot direct compare them rather than looking at the trends. The temperature from both pollen and our modeling indicate a decreasing trend during the selected period while the precipitation from both pollen and our modeling indicate an increasing trend. This discussion will be added in the final revised manuscript.

Typing Errors:

1. Page 6512 Line 24: “Monon” should be “Mono”.

2. Missing units for the Y Axis in Figure 2.

Response-Typing Errors: We thank the reviewer for pointing out the typing errors. We have corrected them in the final revised manuscript.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/12/C3984/2015/hessd-12-C3984-2015-supplement.pdf

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 6505, 2015.