Responses to the comments from the Referee #2

We are very grateful to the Referee for the comments on our manuscript. Those comments are all valuable and very helpful for revising and improving our manuscript. We have substantially revised our manuscript after reading the comments. The Referee's comments are shown in bold and our responses immediately follow.

The Qinghai lake is the largest in land lake in China. It has large volume of biotic resources and tourism resources. Its thermodynamic changes under global warming remains unclear. Su et al. use a one-dimensional lake model to investigate thermodynamic changes of the Qinghai lake in the last three decades. The results show that the Qinghai lake has been warming up in the last three decades and the warming was the strongest in winter. Before getting published, however, this manuscript should be revised in several aspects. Please consider the points listed below and marked out in the manuscript. I strongly recommend language editing by some native English speaker, there are many errors in the grammar and improper expressions.

Comment #1

The authors emphasize the ice cover plays the first role in long-term change of thermodynamics, however, they do not validate the performance of Flake on the ice dynamics. The ice-on and ice-off dates can be obtained from MODIS data. The authors can use the MODIS-derived ice-on and -off dates to validate the performance of the Flake on ice phenology. Here is the data link: http://www.csdata.org/p/214/.

Author's response: Thanks for the referee's suggestion. As referee's suggestion, we use the MODIS-derived ice-on and ice-off dates validate the Flake on ice phenology. We found that the simulated break-up date and freeze-up date are both delayed compared to the observations, but the ice duration is close to the observation. This may be because the ice regime is no only influenced by air temperature, but also by dynamic (wind, currents) and other (inflows, precipitation, etc.) factors, which exceed the ability of FLake to estimate their influence on ice regime. In the revised manuscript, we add the MODIS-derived ice phenology in Fig.7 (in revised manuscript, enclosed), and add the description in section 3.3 Lake ice cover:

"The salinity parameterization for temperature of maximum density and freezing point had a certain effect on the ice phenology simulated by FLake (Fig. 7). The maximum ice thickness was reduced, the freeze-up data was delayed and the break-up data was advanced, leading to a shorter ice duration period compared with default (freshwater) model setting. Nevertheless, the interannual changes between them remained consistent. Compared with satellite observations, the simulated freeze-up and break-up date are later, with some differences in interannual variations but similar range in the ice duration period."

And also added the following in part 4.1:

"Despite a salinity parameterization, the ice phenology modelled by FLake differs significantly from the remote sensing observations. The discrepancy may be related to a number of factors not included in the model. One of them is the effect of salinity on the ice structure, density, and porosity; the others are precipitation, inflows, circulation under ice cover and wind, which is especially important of large-area lakes, like Qinghai Lake (Kirillin et al. 2012). However, the air temperature apparently has the strongest effect on ice regime, especially in long-term changes, which appear to be well-simulated by FLake allowing us to study the effect of air temperature on lake ice regime within the model ability.”

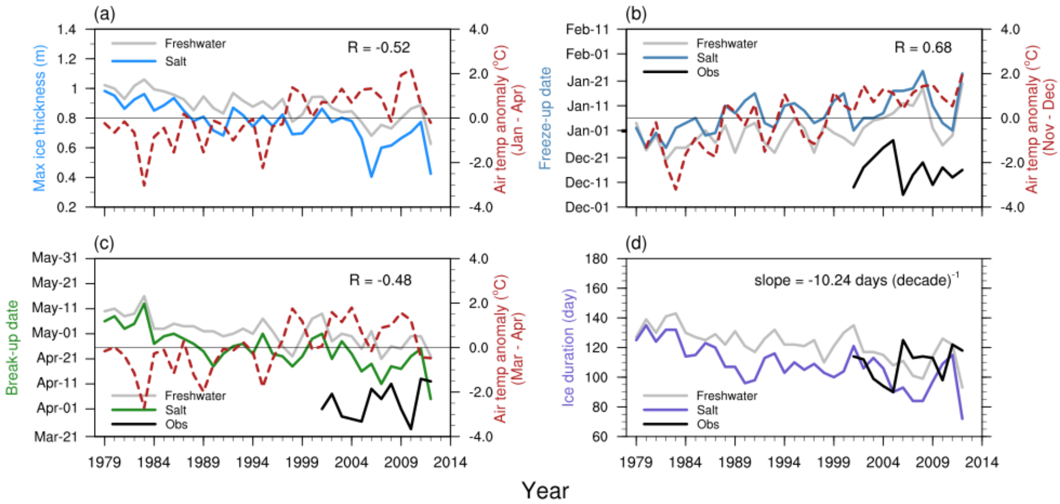

Figure 7: The interannual variations of simulated maximum annual ice thickness (a), break-up date (b), freeze-up date (c) and ice duration period (d) of Qinghai Lake. The coloured (grey) line indicate with (without) salinity parameterization. The red dash line is air temperature anomaly in the specified period and the black line is observed ice phenology derived from satellite.

Comment #2

The author should deemphasize the purpose to validate the performance of FLake on the Tibetan Plateau. Because both Lazhu et al. (2016) and Kirillin et al. (2017) has demonstrated its performance on the Tibetan Plateau. In Lazhu’s study, the Nam Co lake is also a brackish and large lake. They even use observational temperature at different depths to validate its performance. In this respect, their study should be a better case to evaluate the performance of the Flake Model.

Author's response: Thanks for the Referee’s kind advice. We agree with the reviewer: the studies of Lazhu et al (2016) and Kirillin et al (2017) considered several aspects of the performance of FLake on the Tibetan Plateau lakes. The first study was focused on the evaporation estimations at Nam Co Lake (salinity ~1.78 g l^{-1}), the second one considered thermal regime of freshwater lakes. The present study comprehensively tests the FLake performance on the largest, brackish lake of the Plateau as a “worst-case” test for a 1-D freshwater model. It suggests that the results are extendable on the vast majority of the Tibetan lake system with at least the same or better performance. And in the revised manuscript, the salinity effects on temperature of maximum density and freezing point had been considered based on the comments, and the model performance has been improved. According to the reviewer’s suggestion, we deemphasize the purpose to evaluate Flake but still mentioned one of our study purposes was to evaluate the FLake model in the Tibetan Plateau. The changed content in the revised manuscript in section 4.1 Model performance were as follows:

“Following the study of Lazhu et al. (2016) at Nam Co Lake (salinity ~1.78 g l^{-1}) and Kirillin et al. (2017) at Ngoring Lake (a freshwater lake), the good prediction of the LST over the largest, brackish lake of Tibet Tibetan by the relatively simple, highly parameterized model FLake, verified by satellite and buoy data, is one of the core results of this study.”

Comment #3

Even the Qinghai lake is a brackish lake, but its salinity is not low (~12.5 g/L). I agree with the authors that the salinity would not change the mixing type (dimictic), but salinity produces effects on the dates of spring and autumn overturning, which will change the energy flux. do the authors have any other observation data related the mixing of lake water column? If they have, they should show it or have some description on it.

Author's response (see also the reply to the first comment of Reviewer#1):

Thanks for the referee's good evaluation and kind suggestion. In order to additionally investigate the potential salinity effects, we rerun the FLake model coupled with the salinity effects on temperature of maximum density and freezing point, and found that the salinity had an effect on the dates of spring and autumn overturning. The energy fluxes were also reanalyzed based on the new simulation results that were improved but did not change the main conclusions. More observation data on mixing of lake water column are required for a more thorough analysis of salinity influence on stratification. As described above in response to Referee #1, We added the following text to Section 4.1 "Model performance":

"Salinity can influence the temperature of maximum density (T_m) and the freezing temperature of water (T_f). According to the 12.5g/L salinity of Qinghai Lake, these two parameters equal to 1.28 °C and -0.69 °C instead of the default model configurations of 4 °C and 0 °C respectively. Considerations of the salinity effects leads to a slightly earlier of the spring overturn and a later autumn overturn and consequently to an extension of the lake stratification period. Because the salinity stratification effects cannot be completely included in the model designed for freshwater lakes, the simulated mixing regime may have some differences from the actual situation of Qinghai Lake. The major features of the dimictic seasonal mixing regime, as simulated by the model, may be suggested to be close to the reality."

I have some other comments and suggestions, please find the attached PDF file for details.

Comments in the supplement:

Comment #1

P3 L20: "The lake usually freezes up in December/January and the ice breaks up in early April." Where dose these data come from? Your observation or reference.

Author's response: These data are come from the published paper by Li et al (2016). The reference was already included in the paragraph. We are very sorry for our unclear expression. To clarify the data source, we changed the corresponding part as follows:

"The lake is ice-covered from December/January to early April; the average annual lake water temperature is 5.4 °C, with the maximum monthly temperature of 17.2 °C (August) and the minimum of -2.0 °C (January) (Li et al., 2016)."

Comment #2

P4 L5: Do you have water temperature observations on different depths? If you have, you'd better show it.

Author's response: No, we don't have the observations on different depths so far.

Comment #3

P5 L5: What is the version of the Flake model?

Author's response: We download the official version of FLake from the model's website http://www.flake.igb-berlin.de/index.shtml, and have already described it in section Data availability in the revised manuscript as:

"The lake model FLake is available from the model community site (http://www.flake.igb-berlin.de/index.shtml)."

Comment #4

P5 L12: You do not have to emphasize the computational efficiency to much which has been emphasized in row-5, page-3. Considering the computing ability of current PCs, almost all one-dimensional or two-dimensional models can be well executed.

Author's response: According to the comment, we deleted the sentence below that emphasize the computational efficiency in the revised manuscript:

"This simple two-layer parameterization of the water column provides FLake with computational efficiency, while preserves the essential physics."

Comment #5

P7 L5: what does this mean? do you mean the break-up and freeze-up dates are the most sensitive proxy to all the meteorological parameters, including air temperature, solar radiation, and wind?

Author's response: We removed the sentence below in revised manuscript:

"The variations of break-up and freeze-up dates are sensitive to the meteorological conditions, in the first place, air temperature, solar radiation, and wind."

Comment #6

P7 L16: What is the direction of the energy flux? Outgoing-negative, incoming-positive?

Author's response: For radiation flux and net energy flux, downward is positive and upward is negative. For SH, LH and lake surface released heat flux, upward is positive and downward is negative.

Comment #7

P8 L2: I am confused by the logic of this part. based on the first sentence, I thought that the authors wanted to discuss how the lake-air temperature difference determined the energy flux. but after reading the following two paragraphs, I realized that the authors discussed how the different fractions of the energy flux contributed to the lake-air temperature difference.

Author's response: The first two sentences of this paragraph are contradictory, we deleted the first sentence:

"The lake-air temperature difference is one of the important factors determining the surface heat exchange."

Comment #8

P11: I was confused by this paragraph. as the Figure 6 shows, not only air temperature and wind speed, but also long-wave radiation and short-wave radiation have obvious correlation

with water temperature. Long-wave radiations even have the highest correlation coefficient. Why the author only claims changes in windspeed and air temperature drive the lake warming? Furthermore, the net long-wave radiation has a trend of -1.86 W/m^2/decade, the net short-wave radiation has a trend of 2.35 W/m^2/decade based on the Figure 8. These trends are much larger the trends of sensible heat flux and latent heat flux which are functions of lake-air temperature difference and wind speed. Please consider the roles of short- and long-radiation in lake warming, and add corresponding stuff in your conclusion.

Author's response: The air temperature and longwave radiation are obviously correlated, because the downward longwave radiation is function of the air temperature in the fourth degree (affected by emissivity properties of the atmosphere). Hence, the air temperature is the major factor here. The shortwave radiation is negatively and insignificantly ($R<0.3$) correlated with the water temperature, and do not contribute to the water temperature increase (although can explain the slower increase of the water temperature compared with the air temperature [see Kirillin et al. 2017]). Hence, air temperature remains to be the major factor affecting the long-term trend in water temperatures. But according to the comment, we also add the description of the downward longwave radiation effect in warming the lake in section 4.2 of the revised manuscript as follows:

"As expected, the correlation analysis shows that the changes in LST were closely related to air temperatures, downward long-wave radiation and wind speed (Fig. 6). The increase of the air temperature and downward long-wave radiation plays a key role in lake surface temperature warming, and the decrease in wind speed also promoted the warming of the lake surface temperature. The shortwave radiation is negatively and insignificantly ($R<0.3$) correlated with the water temperature, and do not contribute to the water temperature increase (although can explain the slower increase of the water temperature compared with the air temperature [see Kirillin et al. 2017]). The decrease in ice cover duration increases in turn the annual amount of short-wave radiation penetrating to the water column, accelerating the warming."

Comment #9

P12: For low-altitude lakes in the mid-latitudes? you'd better list at least one reference paper here.

Author's response: According to the comment, we add several references in the revised manuscript and reorganized the language in section 4.3 as follows:

"For low-altitude temperate and boreal lakes, the air temperatures are typically higher than LST after the ice-off and remain higher until temperature equilibrate around mid-summer. In the subsequent period down to ice-on, the LST is typically higher than the air temperature. Hence, the atmospheric boundary layer is generally stable throughout much of the summer season over low-altitude lakes (Rouse et al., 2003; Nordbo et al., 2011; Momii and Ito, 2008; Gianniou and Antonopoulos, 2007; Scott and Huff, 1996)."

Comment #10

P26 Fig. 7: Do you have observational data of ice thickness? ~1.1 m is very thick for lake ice. The thickest ice on the Namco lake is 70 cm based on the observation (Qu et al., 2012, Chinese with English abstract, Lake Ice and Its Effect Factors in the Nam Co Basin, Tibetan Plateau) where is 1500 m higher than the Qinghai lake.

Author's response: We do not have observational data of ice thickness. The simulated maximum ice thickness of ~1.1 m was the situation in 1980s, in the later 2000s, the thickness of the lake ice had dropped significantly to about 0.7 m, same with Namco in this period according to Qu et al (2012). And after considering the salinity effect, the simulated maximum ice thickness further reduced (Fig. 7 in revised manuscript, enclosed). In addition, the Namco Lake (33 m for average depth) is deeper than Qinghai Lake (21 m for average depth), which also may result in different lake ice thicknesses.

Comment #11

P12: Do not understand what the blue bars and red bars represent respectively in Figure 9a

Author's response: According to the comment, we add the explanation to the legend of figure 9 as follows:

"Figure 9: Climatological mean seasonal variations (5-day moving average, lines) in simulated LST and air temperature (a) with their difference (b), downward shortwave radiation(c), downward longwave radiation(d), net shortwave radiation (e) and net longwave radiation (f). The bars indicate monthly averaged mean annual variation trend (red for positive and blue for negative except in (a) that for air temperature and LST respectively) from 1979 to 2012. Solid points at end of the bars mean pass significance test of $p<0.01$ and hollow points mean $p<0.05$. The grey areas indicate the freeze-up and break-up date variation range of the lake."

Response to other comments in supplement:

We tried our best to improve the manuscript and made some changes in the manuscript. These changes will not influence the content and framework of the paper. Many errors in grammar and expression have been revised but not list here. The manuscript will be further revised by the English editorial company.

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