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Discussions

# *Interactive comment on* "Trends and abrupt changes in 104-years of ice cover and water temperature in a dimictic lake in response to air temperature, wind speed, and water clarity drivers" *by* M. R. Magee et al.

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The authors would like to thank Dr. Homa Kheyrollah Pour for providing the valuable comments to further improve the quality of the manuscript. We address the comments and detailed these changes in the point-by-point response below.

This manuscript presents a study to demonstrate a long-term change in ice cover and thermal structure of Lake Mendota using a 1-D hydrodynamic-ice model. I have enjoyed reviewing this manuscript and I do believe that it is suitable for publication in a special issue of Hydrological Processes, in terms of its overall content. In general, the



authors have made sound intellectual arguments and use an appropriate methodological approach, based on knowledge obtained from previous research studies. In addition, they provide a reasonable interpretation of the results obtained from this study. We thank the reviewer for the compliments.

General comments: The author used daily meteorological data to run the DYRESM-WQ-I model, however is mentioned that the model has 1-hr time step at page 6 line 5!

Yes, this is correct. We used a daily timestep for meteorological and inflow/outflow inputs based on the availability of data to complete the study (subdaily data availability was not consistently available for the 100+ year time period). Model output was also at daily intervals. However, the model itself performs calculations at a 1 hour timestep both for the hydrodynamic and ice cover components of the model. This 1 hour timestep was chosen to ensure that change in ice depth is relatively small because the time step is small.

The author used the rain fall and snow fall observations from weather station. Snow accumulation regimes differ significantly not only between but also within the various locations over a lake. Snow depth can be very thin and dense to non-existent on some lakes or lake sections due to the wind. This difficulty in accurately measuring snowfall has to be considered specially when running 1-D models. This can be done by looking at any available in-situ snow observations over lake and calculating the percentage of snow in comparison with the station data. And also it is not clear how the snow density is defined. Are there any in-situ observations available for snow density?

We thank the reviewer for this valuable suggestion. We acknowledge that the snow depth is variable both between the meteorological station and the lake and across the lake itself. In-situ snow observations over the lake are generally limited to one location once per year for only a limited subset of the 104 year model period. During the winter 2009-2010, when ice and snow measurements were taken multiple times, snow depth matches well with errors of <1 cm to 7 cm during the year (see Figure 3a). As we only have 49 snow measurements for 104 years of simulation data, adjusting snow amounts by first comparing in-situ observations to station data may not be appropriate. However, we will definitely use this approach to improve model ability during shorter-term studies in the future. Snow density is predicted according to Equation 11 in Rogers et al (1995 - see manuscript reference list). s=n + (m - n){1 - [exp(-kd)]}). k = -ln[(m- l)/(m - n)], n is the density of fresh snow, l the density 24 h after falling, m the maximum density, and d the number of days since the last snowfall. To our knowledge there are no in-situ measurements of snow density for Lake Mendota.

Some specific questions/comments I have about this manuscript are as follows:

Page 2/lines 24-25: “Air temperature, wind speed, and water clarity are important factors driving these lake ecosystem properties”, reference is missing.

The line has been updated as follows to add references: "Air temperature (Findlay et al., 2001; Lynch et al., 2015), wind speed (Brown et al., 1993; Lynch et al., 2015), and water clarity (Arhonditsis et al., 2004b; Lathrop et al., 1996)."

Page 2/lines 27-29: “The long-term response of lake ice and water temperature to changing air temperature and wind speed is integral to assessment of the potential impacts of climate change on water quality and ecology of lakes.” It is not clear if the author is talking about the role of lake ice on climate or the response of the lakes on climate. Please be more specific.

We thank the reviewer for pointing out this unclear sentence. The authors are discussing the response of lake ice and water temperature to changes in climate and the corresponding impact of lake ice and water temperature changes on lake ecology. The sentence has been edited for clarity as follows: "The response of lake ice and water temperature to long-term changes in air temperature and wind speed is integral to assess potential impacts of climate change on lake ecology."



Page 8, 3.2 meteorological variables: the location where the meteorological data are collected is not clear and how far it is in comparison with the simulation points.

All data except for solar radiation is obtained from the weather station of the National Climate Data Center (NCDC, NOASS) locate in Madison (MSN) Dane County Regional Airport (Truax Field), which is approximately 4.5 km east of the simulation location. Solar radiation data are obtained from the St. Charles, Illinois weather station, approximately 150 km southeast of Lake Mendota. Section 3.2 has been updated to clarify where the meteorological data were obtained and how far those locations are from the study site, Lake Mendota. Additions are provided in the following.

"Meteorological data for the Madison area have been continuously recorded since 1869, however, the station and techniques have changed several times. Robertson (1989) constructed a continuous, homogeneous daily meteorological dataset from 1884 to 1988 by adjusting for changes in site location and observation time, and resultant changes in the surface roughness (e.g. height of surrounding trees and buildings). These data were appended with data from the most recent weather station of the National Climate Data Center (NCDC, NOAA) located in Madison (MSN) Dane County Regional Airport (Truax Field), approximately 4.5 km east from the simulation location, the same site as that used in 1988. All data except solar radiation can be obtained for Madison (MSN) from http://www.ncdc.noaa.gov/, except solar radiation which can be obtained from http://www.sws.uiuc.edu/warm/weather/ (approximately 150 km southeast of Lake Mendota). Since Robertson (1989) adjusted all historical data to that collected in 1988, no adjustments are applied to the recent data except for wind. In 1996, a discontinuity in the wind record was caused by change in observational techniques and sensor locations (McKee et al., 2000). To address the non-climatic changes in wind speed, data from MSN are carefully compared with those collected from the tower of the Atmospheric and Oceanic Science Building at the University of Wisconsin-Madison (http://ginsea.aos.wisc.edu/labs/mendota/index.htm), approximately 4 km south of simulation location. Hourly data from both sites (UMSN,hourly and UAOS,hourly) during

2003–2010 were used to form a 4×12 (four components of wind direction × 12 months) matrix (K4,12) of wind correction factors, yielding UAOS,daily= Ki,j×UMSN,daily. A comparison of results indicated that the MSN weather station measured a higher magnitude in winds out of the east by 5% and lower magnitude in winds out of the west and south by 30% and 10%, respectively. The adjusted wind data (=Ki,j×UMSN,daily) are used in the model simulation. Overall the adjusted wind data show a decline in mean wind velocities of 16% from 1988−93 to 1994−2014) compared to 7% at a nearby weather station with no known observational changes (St. Charles, Illinois; 150 km southeast of Lake Mendota)."

Page 12/lines 22-26: “Other models including LIMNOS (Vavrus et al. 1996) on Lake Mendota, Wisconsin; MLI (Rogers et al. 1995) on Harmon Lake, British Columbia; and CLIMo (Duguay et al. 2003) on lakes in Barrow, Alaska; Poker Flat, Alaska; and Churchill, Manitoba produced similar errors to Lake Mendota between modeled and observed ice thickness and snow cover”. This comparison should be more specific and the authors have to give a range of error.

To address comment, we have revised the writing as follows (see Page 13/line 20-30): "In comparison, similar discrepancies between modelled and observed ice thickness and snow cover were produced from other models including LIMNOS (Vavrus et al., 1996) on Lake Mendota, Wisconsin with discrepancies of 4−9 cm for ice cover; MLI (Rogers et al., 1995) on Harmon Lake, British Columbia, which had up to 6 cm error for ice cover and 4 cm error for snow cover; and CLIMo (Duguay et al., 2003) on lakes in Barrow, Alaska (differences of 5−6 cm for ice thickness); Poker Flat, Alaska (mean absolute error of 2 cm for ice cover and underestimation of snow - ice thickness of 7 cm); and Churchill, Manitoba (Ice thickness observations were within model values for the snow-free and 100% snow covered scenarios). Duguay et al. (2003) found that variability in snow density and snow accumulation play a significant role in ice thickness, which may account for discrepancies between simulated and observed ice cover thicknesses in our study



Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/hess-2015-488/hess-2015-488-AC5-supplement.pdf

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