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Surface Heat Budget estimation for Laurance Lake, US

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Abstract

Estimating heat budget factors are important to understand the many physical processes of large lakes and their reaction to the atmosphere. Some of these components are affected by water temperature, while the other depends on atmospheric conditions. This paper estimates the total heat flux for Lawrence lake via a code developed in MATLAB environment. The code can deal with different time resolutions if the lake water surface temperature data were at different time resolutions from the meteorological data. Results showed that solar energy peaks at 842 Watt/m² at 540 Julian day, which is very normal for a sunny summer day, while the longwave radiation has 204 Watt/m² as a min value. The back radiation did not make any reaction for the variation, but it revealed a small gradient. Furthermore, evaporation recorded - 67 Watt/m² as a minimum value at 659 Julian day and 360 Watt/m² as a maximum value at 578.43 Julian day close to the maximum water surface temperature event.

Keywords

Evaporation, heat exchange, heat transfer, heat flux, longwave radiation, lakes and reservoirs, shortwave radiation, solar radiation.

1. Introduction

Lakes have a rapid response to climate changes. Some of the most pervasive and concerning physical effects of climate change on lakes are changes in water heat budgets, evaporation [1,2] and surface water temperature [3]. As climate variations affect water temperature. Water temperature plays a big role in many physical, chemical, and aquatic biological processes. With the increasing water temperatures, the solubility of dissolved oxygen decreases. This leads to reducing the available-oxygen for aquatic fauna and effects on fish [4,5]. In addition, temperature has been changing because of weather, shading of stream bank, discharge of cooling water and others [6]. As a result, surface heat exchange keeps varying surface heat fluxes over time.

Surface heat fluxes calculation techniques have been reported in many references. These fluxes include five components. Some of them depend on water temperature, and others depend on external conditions [7,8]. Monika (2019) worked on problems related to the spread of thermal pollution in rivers and tried to summary it [9]. Edinger's equation was used for calculating the net heat rate, Stephan-law for calculating long wave, and Stefan Boltzmann law for back long radiation. Also, short-wave radiation was determined and then corrected by using Magnusson's equation. Shanahan (1984) described different styles for developing required data [10]. Shanahan took the average reflectance of the water surface to calculate short-wave radiation and adopted the EPA-Model [11]. For evaporation and conduction, Dalton's equation and Bowen's ratio were used [9], or different equations may be applied to be recalibrated for getting the best match with field data [10].



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The purpose of this work is to calculate heat fluxes and perform a comparison between the obtained fluxes and typical values. Several plots were made to show the behaviour of each flux during different periods.

2. Materials and Methods

2.1. Study Area

Laurance Lake is a reservoir at the base of the Mountain Hood in Oregon, drainage into the Middle Fork of the Hood River. The reservoir was constructed in 1968 for irrigation storage, with capacity 3564 acres- feet at full pool [12, 7], see Figure 1.

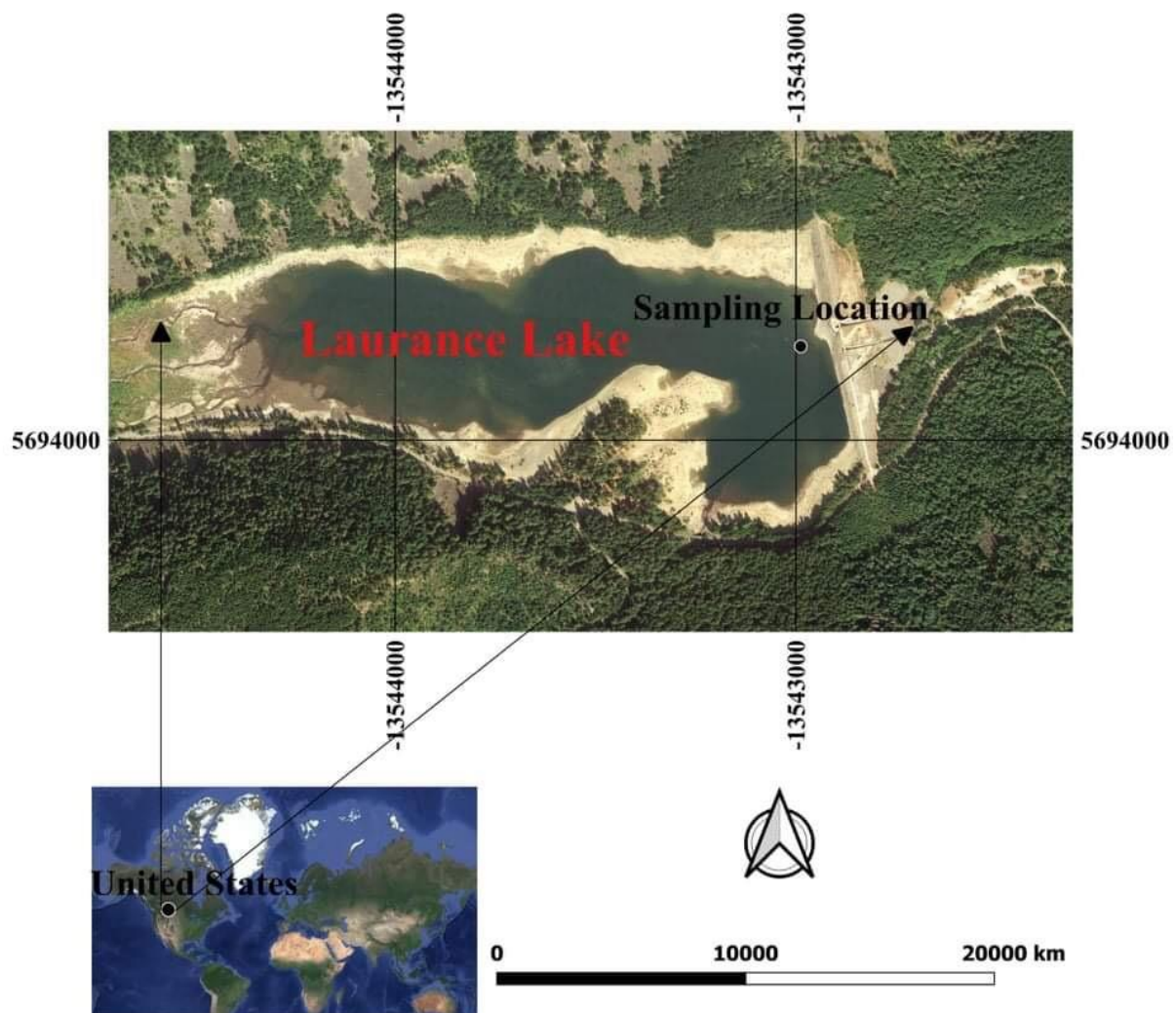


Figure 1. Laurance Lake, Oregon, US.

2.2. Data and coding

The MATLAB code was summarized in a schematic flowchart as shown in Figure 2. The required meteorological input data was measured at the dam (For more details, see [12]) for the period from 480 to 680 Julian day (Jday). In addition, the water surface temperature was demanded by the model.

The available water temperature was in two-time resolution from meteorological data. Therefore, linear interpolation was taken into account to determine water surface temperature at any required time. For atmospheric long radiation calculation, the required data of clouds cover and air temperatures were available. Dew point temperature was also used to determine the saturated vapor pressure. Wind profile was calculated based on the corrected wind speed data, and then it was entered along with saturated vapor pressure and air vapour pressure to get evaporation. Conduction radiation was calculated based on Bowen's ratio, and the calculation of short-wave radiation based on the EPA model [11]. Figure 3 and Table 1 show the total heat flux components, and the typical values, respectively.

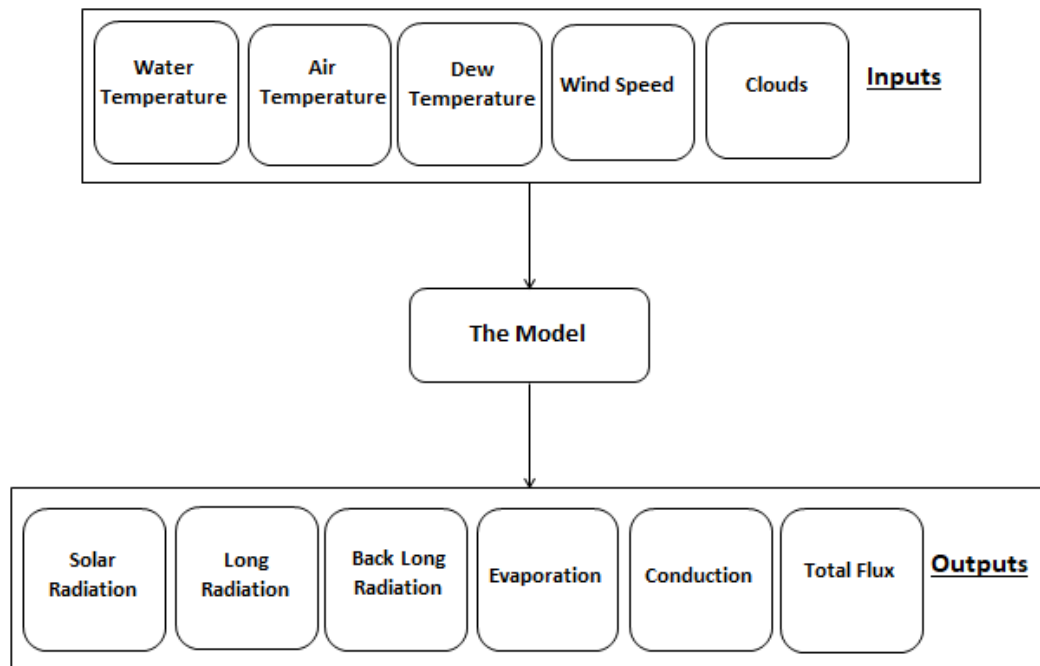


Figure 2 MATLAB code summarization.

Finally, the Laurance Lake heat fluxes (Watt/m²) were obtained using the term by term method [7] as follows:

$$H_n = H_{sn} + H_{an} - H_{Br} - H_e - H_c$$

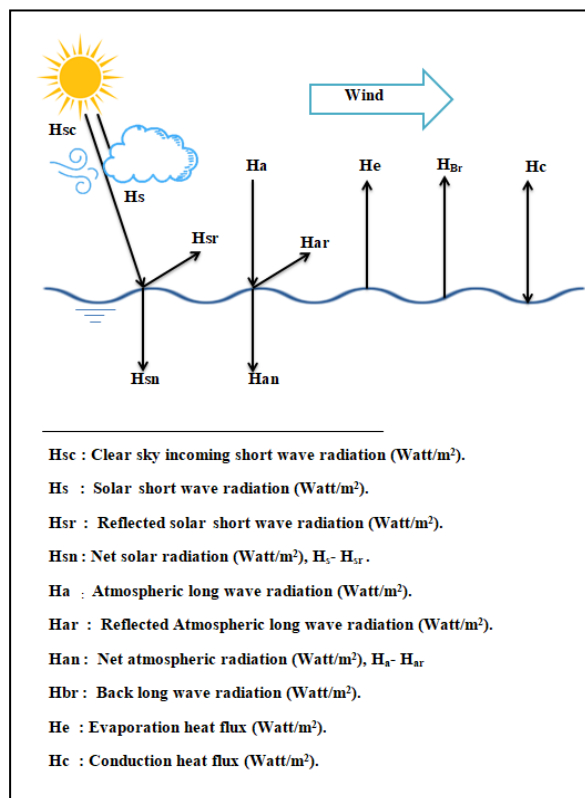


Figure 3 Surface heat flux components.

Table 1. Approximate values of the heat flux components (Watt/m^2) [9, 7]:

Fluxes	Range
	(50 – 350)
Solar radiation	For a sunny day, (800 – 1000)
	For a very cloudy day, (100 – 300)
Atmospheric radiation	(200 – 400)
Back radiation	(30 – 450)
	(250 – 500)
Evaporation	(300 – 500)
	(0 – 35)
Conduction	(-70 – 200)

Solar short wave radiation comes from the sun, and atmospheric radiation is produced from the atmosphere [13]. The value of short-wave radiation depends on various factors such as solar altitude, scattering and absorption, reflection and shading [14]. There are several models for calculating shortwave radiation. In this paper, the EPA model was adopted. This model was used in the water quality model CE-QUAL- W2 [8]. For more details about the heat budget determination approach, see [7].

3. Results and Discussion

The data covered the period from 480 to 680 Julian day. Solar energy becomes maximum in summer days [15]. It recorded 842 Watts/m^2 as a maximum value at 540 Julian day and of 606 Watt/m^2 as a minimum value. For a summer sunny day, this is typical. Atmospheric radiation recorded 204.1 watts/m^2 as the min value. These high values is returning to air temperature interacting with the high strength of short-wave radiation during summer days (Figure 4 and 5). While Conduction heat flux curve simulates the water temperature curve, back long radiation goes down to its minimum value of 340 Watts/m^2 at 487 Julian day (Figure 6) when the water surface temperature has the minimum value.

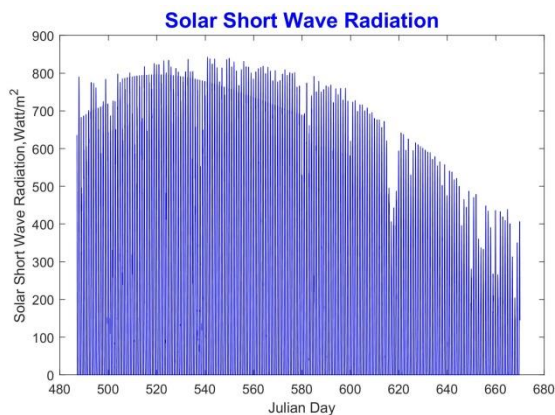


Figure 4. Solar radiation.

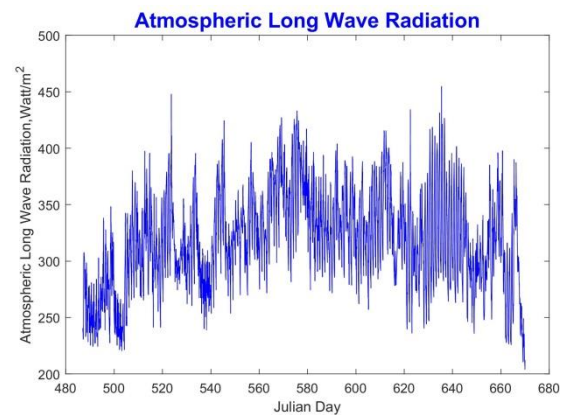


Figure 5. Atmospheric radiation.

Evaporation has a value of -67 Watt/m^2 as a minimum value at 659 Julian day and a maximum value of 360 Watt/m^2 at 578.43 Julian day when the maximum water surface temperature was at 576 Julian day. Conduction and evaporation are in inverse proportion by a ratio called Bowen's ratio. Figure 7 and 8 clearly illustrate this relationship.

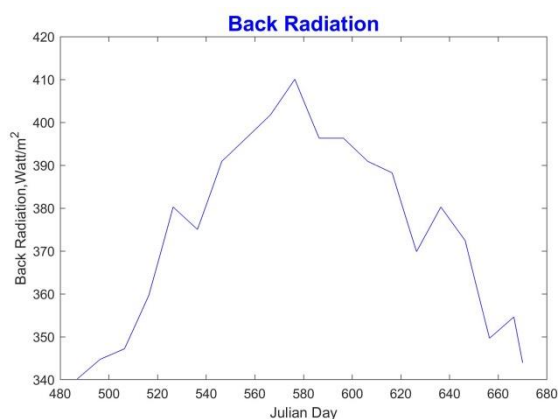


Figure 6. Back radiation.

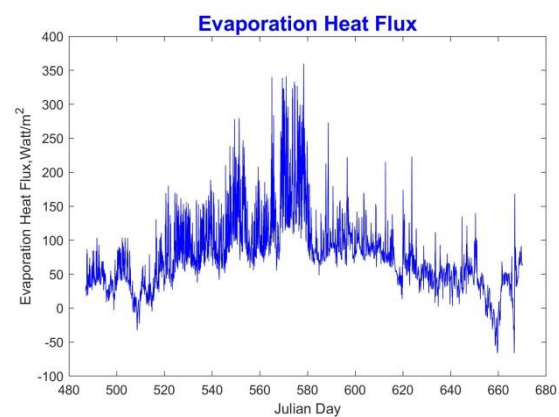


Figure 7. Evaporation radiation.

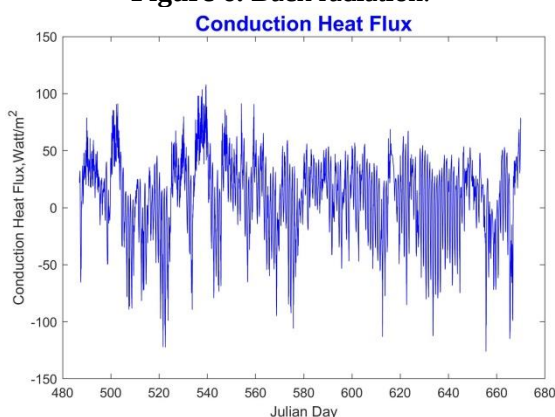


Figure 8. Conduction radiation.

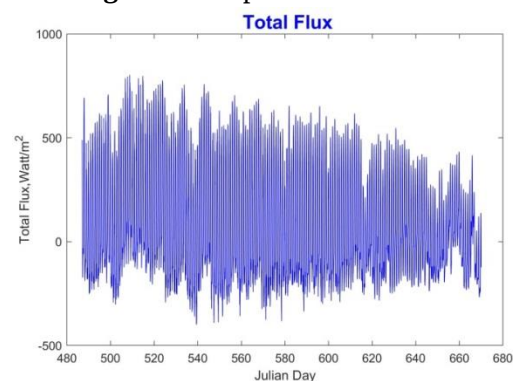


Figure 9. Total flux.

Figure 10 shows the fluxes during the period (500- 530) Julian day, where the variation of the fluxes become more obvious. The fluctuation of short-wave radiation is due to the natural phenomenon of sunrise and sunset. When short-wave radiation recorded the maximum value during day hours (particularly in summer days), an expectable increase in air temperature and water temperature. As a

result, the related heat fluxes for each temperature will experience an increase too. The increases vary differently based on the heat fluxes dynamics. Initially, the solar flux transmitted from the sun, and it takes the highest amount in the daytime and literally in the middle of the day with a maximum value of 833 Watt/m^2 . Atmospheric radiation appears rather calm with fluctuations at the start and end of the day. These fluctuations are getting between (447 to 220) Watt/m^2 with a mean value of 319 Watt/m^2 . Fluxes in Figure 10 present a clear inverse relationship between conduction and evaporation. In contrast, the back radiation seems unaffected by any variable other than water temperature. It looks like that the flux takes the shape of a straight line, but in fact, it is presenting by a weak gradient of 34.65. The total flux nearly copies the solar radiation shape, showing the role of solar radiation.

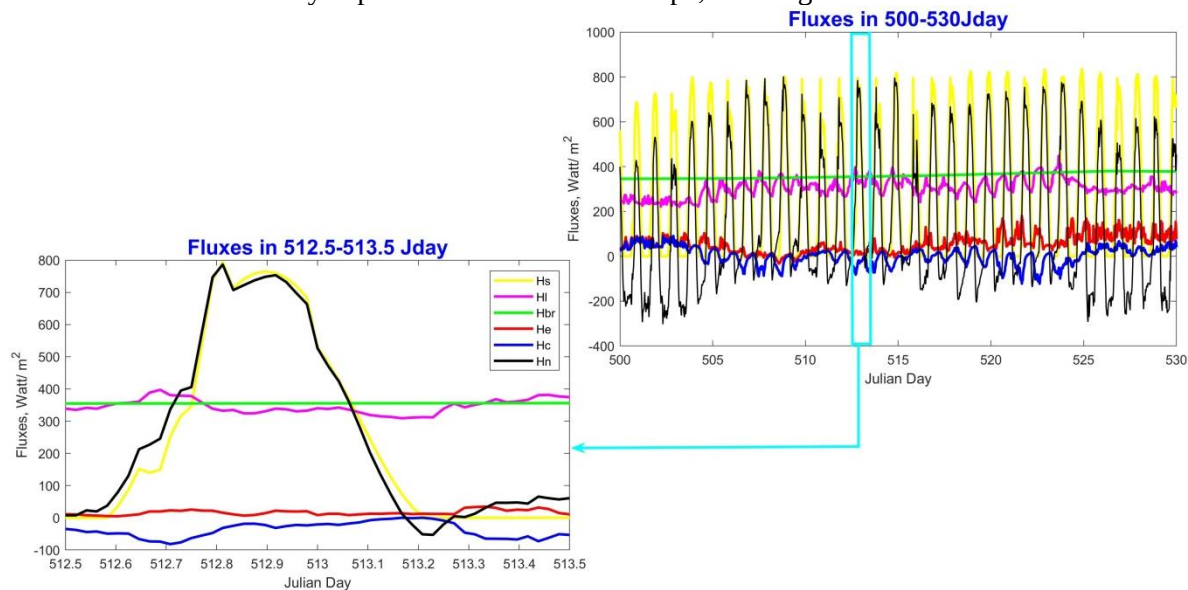


Figure 10. Fluxes during the period (500- 530) Julian day.

4. Conclusions.

In this paper, a development for a MATLAB model was made to calculate surface heat exchange Water-bodies. To calculate solar and atmospheric radiation, conduction, evaporation, long-wave back radiation and total net heat flux, the data from Laurance Lake, US was used. During the period of the study, the fluxes Results were highlighted for daily and seasonal. This was obvious in summer, where the total heat flux has positive values and negative during winter. Each flux has its role to play in the total heat flux, but solar radiation has the dominator role. After the important role of solar radiation, the influence of longwave back radiation comes.

References

- [1] Rodell M, Famiglietti J S, Wiese D N, Reager J T, Beaudoin H K and Landerer F W 1240 and Lo, M.-H.: Emerging trends in global freshwater availability *Nature* **557**
- [2] evaporation accelerated by changes in surface energy allocation in a warmer climate *Nat. Geosci.* **11** 410–414
- [3] Lenters J D, McIntyre P B and Kraemer B M 2015 Rapid and highly variable warming of lake surface waters around the globe *Geophys. Res. Lett.* **42** 10–773
- [4] Wanders N, van Vliet M T H, Wada Y, Bierkens M F P and van Beek L P H 2019 High-resolution global water temperature modeling *Water Resour. Res.* **55** 2760– 2778
- [5] Bhateria R and Jain D 2016 Water quality assessment of lake water: a review. *Sustain Water Resour Manag* **2**: 161–173
- [6] Spellman F R and Drinan J E , “Drinking water regulations,” in *The drinking water handbook, second edition*, 2nd ed., CRC Press, 2012, pp. 27–58.
- [7] Al-Zubaidi H A M 2018 3D Hydrodynamic, Temperature, and Water Quality Numerical Model

- for Surface Waterbodies: Development, Verification, and Field Case Studies
- [8] Cole T M and Wells S A, “CE-QUAL-W2: A two-dimensional, laterally averaged, hydrodynamic and water quality model, version 3.5,” 2006. [Online]. Available: https://pdxscholar.library.pdx.edu/cengin_fac/157/.
 - [9] Kalinowska M B 2019 Effect of water–air heat transfer on the spread of thermal pollution in rivers *Acta Geophys.* **67** 597–619
 - [10] Shanahan P, “Water temperature modeling: a practical guide.,” in *Environmental Protection Agency*, 1984, vol. U.S. EPA R, no. 1, pp. 1–25.
 - [11] Annear R L and Wells S A 2007 A comparison of five models for estimating clear-sky solar radiation *Water Resour. Res.* **43**
 - [12] Berger C, Wells S A and Annear R L 2005 Laurance Lake Temperature Model
 - [13] Grossnickle S C 2000 *Ecophysiology of northern spruce species: the performance of planted seedlings* (NRC Research Press)
 - [14] Chapra S C 2008 *Surface water-quality modeling* (Waveland press)
 - [15] Lofgren B M and Zhu Y 2000 Surface energy fluxes on the Great Lakes based on satellite-observed surface temperatures 1992 to 1995 *J. Great Lakes Res.* **26** 305–314