Analysis of Evapotranspiration (ET) Calculation Algorithm at Pine Tree Forest in Idaho

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Abstract

This study attempted to evaluate evapotranspiration (ET) estimation algorithm at a lodgepole pine tree open forest in eastern Idaho, United States. The coordinate location of study area (Latitude is 44.5o N; Longitude is 111.4o W) and the Elevation is 1950 meter. By performing eddy covariance method for the data collected under 10:30 am in local solar time, clear-sky condition and 16-day period. Furthermore, the accuracy of ET model was evaluated by using sensible flux dataset measured by scintillometer. This experiment considers scintillometer-measured sensible flux data to evaluate the accuracy of ET model. In scintillometer, evapotranspiration computed using radiation measurement data. There were two sets of sensible and latent heat flux data. One was measured on the south tower, and the other was measured on the north tower. The dataset from the south tower was much more reliable in term of data availability. This study used sensible heat and latent heat flux data from the south tower. The dataset from north tower were used only as supplementary dataset when the dataset from south tower were not available. This study concluded that scintillometer was be able to provide ground truth ET dataset to improve the accuracy of ET estimation algorithm and it suggests that to obtain the accuracy measurement of ET estimation actual, a simple linear adjustment should be applied in the ET algorithm model.

Keywords:
Evapotranspiration, Eddy covariance method, Scintillometer, Accuracy, Algorithm, Linear adjustment.

1. Introduction

Understanding evapotranspiration (ET) availability with reasonable accuracy will make it useful for planning and managing the availability of water for human life. Miscalculation in ET estimation and accuracy will affect seriously to decision-making. ET from the land's surface is among the potential targets for estimation and observation. This study was conducted to provide a reasonably accurate ET estimation. The eddy covariance method provides measurements of sensible heat and latent heat fluxes over an area and has been widely used in micrometeorology for over 30 y (Burba & Anderson, 2010). Some of the flux measurement dataset, measured globally by several researchers, has been available to the public; it is similar to AsiaFlux and AmeriFlux. Comparing the ET estimation results to latent heat flux measurements using the eddy covariance system has been the most popular method. Nevertheless, the contribution of recent studies regarding ET estimation and its accuracy using the eddy covariance method has still not achieved the expected results; there are difficulties in terms of accuracy to obtain an appropriate result. The energy imbalance problem and reductions in the accuracy of ground-measurement data have prevented an evaluation of the quantitative accuracy of ET estimation.

This study focused on evaluating the accuracy ET estimation algorithm. Two methods were used to assess the accuracy of the algorithm model; first, eddy covariance method and the second, scintillometer data measurement. The eddy covariance system has underestimated ET, it is because of an energy closure problem. There are some uncertainties and it fails to capture a portion of the energy flux. Scintillometer dataset measurement also has underestimates ET. This study proposed that ET estimation algorithm needs a simple linear adjustment to address the ET measured using a scintillometer. Only by applying scintillometer data, particularly for a derivation in the ground-measured ET flux, the estimation error of the ET model was be able to quantify. To obtain the accuracy measurement of the actual ET estimation, a simple linear adjustment suggested to be applied in the ET algorithm model.

2. Research Methodology

A daily dataset was subsequently generated using the average data set for 30 min. In the daily dataset, the minimum and maximum heat flux, and sensible and latent heat, were restricted to zero and net radiation. In addition, the monthly average calculation was used for records lacking information for longer than 3 h. Some steps were conducted as the follwing:

Stage 1: Calculation of energy balance closure

It is necessary to know the validity or lack of confidence of the estimation data before comparing with other data. Theoretically, "H + LE" must be adapted to "Rn – G." However, the eddy covariance system "H+LE" is typically lower than "Rn - G," in which Rn is investigated by radiation observations and G is evaluated by soil heat flux plates (e.g., Wilson et al., 2002). This energy imbalance is a sign of the inability to capture part of the energy flux via the eddy covariance system. This issue is termed the "energy balance closure problem." This issue is controversial, and the correction techniques extensively differ by study, including no correction (Matsumoto, 2016). In this study, the energy balance closure issue of the EPSCoR dataset was checked by comparing "H+LE" defined by eddy covariance and "Rn-G" defined by radiation and soil flux observations.

Stage 2: Evaluation of ET estimation

The ET estimation algorithm was used to estimate ET. While the algorithm was created for satellite surface temperature observations, the ground measured surface temperature is a substitute for satellite measurements to assess the algorithm's performance. Therefore, Ts(act) is the actual surface temperature calculated by simulated surface longwave radiation. Surface emissivity was considered to be 0.98 for surface computations, which represented the average emissivity value of the team Pinon-Juniper published by Arp and Phinney (1979). To render the implementation comparable to the satellite implementation, only data gathered prior to 10:30 am were calculated on the local solar time, under a clear-sky condition, and as suggested by Tasumi et al. (2016b).

3. Discussion

3.1. Analyzed data

To completely comprehend the outcomes of the flux assessment, it is important to know the information in the field. The average annual temperature from March 2011 to February 2012 was 1.9°C. The dry season extends from mid-July to September. Soil water content was well correlated to rainfall, except during winter (when the soil froze) and in the phase after soil-water reached field capacity (approximately 26%). Figure 3.1 shows a comparison between air and surface temperature. In the case of surface temperature, as a part of the four-way measurement of the radiometer assuming surface emissivity as 0.98 is measured. Both temperatures were appropriately compared, and a positive linear correlation between the two was confirmed.

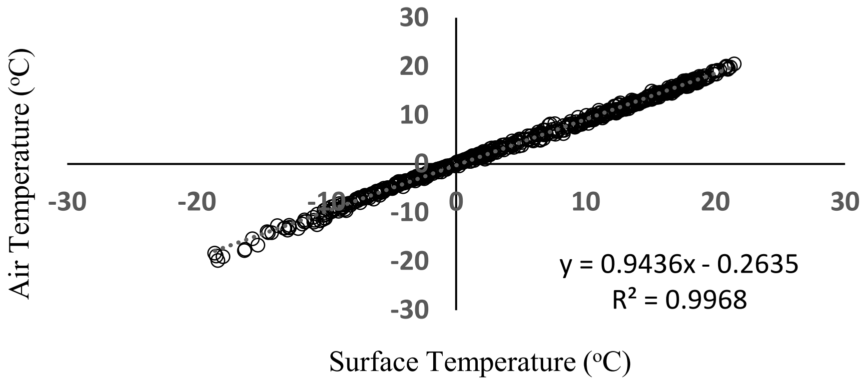

Figure 3.1. Comparison between daily surface and air temperatures during the analytical period

3.2. Energy balance measurement results

To evaluate daily energy balance closure, the energy available calculated using radiation and soil heat measurements (Rn - G) and using eddy covariance flux measurements (H + LE) was compared (Fig. 3.2.). Latent heat of fusion, which typically occurs in snow-covered locations, is lacking from the observational data as a disadvantage of measurements. The evaluation was also conducted only from June to September to prevent the potential effect of ice and to more carefully assess energy balance closure.

The gradient of the linear regression lines was, however, 0.80–0.88 in both cases and the intercept was very small, indicating that the eddy covariance method captured only approximately 80–88% of the available energy, nearly 12 to 20% of the energy was lost; the amount of missing energy agrees with the average amount reported by Wilson et al. (2002).

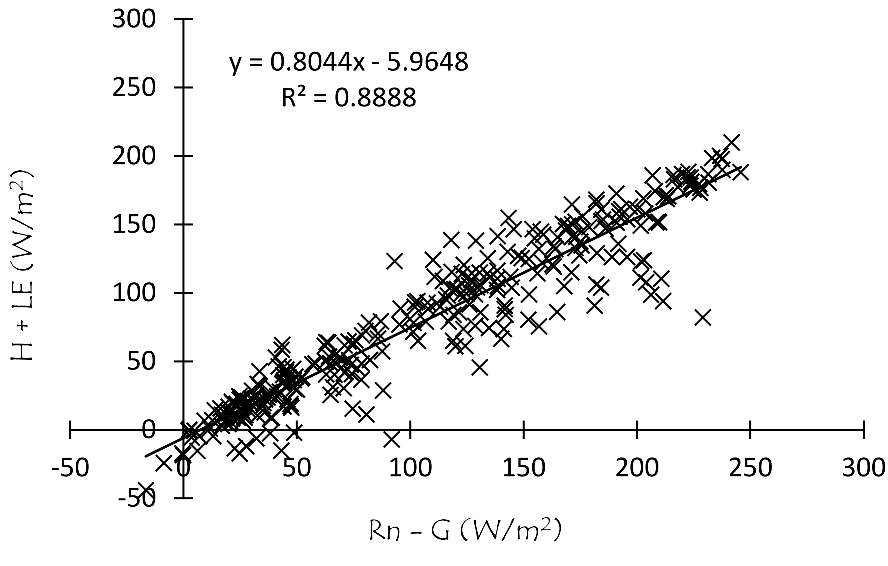

Figure 3.2. Comparison of available energy measured by radiometer and soil heat flux plates (Rn – G) and by the eddy covariance system (H + LE): All periods, including winter.

3.3. Evaluation of ET estimation results

Figure 3.3. shows a monthly projected ET contrast with two ET measurements; ET is evaluated without any an energy balance closure correction (meas1) and the other records as latent heat all missing energy (meas2). Thus,

ET(meas2) is described as ET(meas2) = (Rn – G – H)/L, where "Rn – G" is available energy evaluated by radiometer and soil flux plates, H is evaluated using an eddy covariance method with no energy balance closure adjustment, and L is vaporizing latent heat.
Actual ET is supposed to be between "meas1" (with no energy balance adjustment) and "meas2" (with the maximum energy balance enhancement). During the period October to May, the estimated ET was near "meas2." However, the estimated values for June, July, and August (and September 2012) were considerably overestimated. When the maximum measurement value correction (meas2) was assumed to be the actual ET, the annual prediction inaccuracy was 30%, the majority of which occurred between June and September. The total difference between "meas2" and the predicted value from October to May is 18 mm and corresponds to 5% of the observed ET. If the incorrect numbers (meas1) are considered to be the real ET, the annual estimation inaccuracy is 96%, which is extremely high. During most months except some of the wintertime, major overestimations occurred given this assumption. It was difficult to quantitatively conclude the estimation precision because of the energy balance closure problem in the real ET measurement.

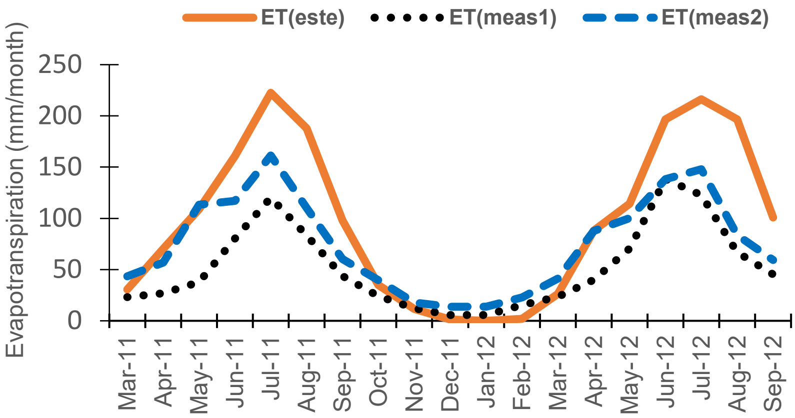

Figure 3.3. Estimated actual ET compared to measured ET without any correction (ET(meas1)) and ET measured by accounting for all missing energy as latent heat (ET(meas2).

4. Conclusion

The uncertainty of ET measured given the issue of energy closure, there is a question regarding the measured energy flux. Aerodynamically, H should be zero if the surface and air temperature differentiation is zero. The air temperature in the study site was consistently similar to the surface temperature, implying that the H in the study area was small. However, H was not small, which is inconsistent. In this study, the estimated ET was compared to two sets of measured ET data from the eddy covariance system; one ET measured without correction for the energy balance closure and another ET measured by taking all missing energy as latent heat to account for the energy balance closure. A simple linear model adjustment considerably enhanced the agreement between the measured ET and model-estimated ET data.

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