ENVR 420 – Problem Set 4
Simon Campbell - 34982165
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Comparing Different Methodologies for Quantifying Evapotranspiration: *A case study for a catchment in Southwestern British Columbia*

1. Introduction

Daily evapotranspiration (ET) in a catchment can be measured using different methods; some of which use diurnal fluctuations in groundwater and streamflow (Gribovszki et.al, 2010), ET based on Potential Evapotranspiration (PET) based on temperature data using R package *EcoHyRology*, and the eddy covariance method. The purpose of this experiment is to compare the different *alternative* methodologies against the *standard* eddy covariance method for measuring daily ET. Differences in daily ET and PET measurements are also considered (briefly).

2. Methods

2.1. Study Site Description

The study site (49°30'N–49°55'N, 124°50'W–125°30'W) is located near the city of Campbell River on Vancouver Island, British Columbia, Canada. The site – referred to as 'Harvested Douglas-fir planted in 2011 (HDF11)' in present day literature – is in a watershed that varies in elevation from 300 – 400 meters and covers an area of ~91 hectares and has been heavily influenced by logging activities (Jollymore et.al, 2012).

2.2 Measurements

Hourly streamflow, groundwater level, and ET data (as well as ancillary precipitation and temperature data) were collected for the use of this study was taken in 2010 from July 14th (00:00:00) to July 28th (23:00:00). A V-Notch weir and water level recorder located at the outlet of the catchment's headwaters was used to continuously measure stream discharge; groundwater level was measured by recording water level in a well; ET was measured using an eddy covariance tower located on site. Data was parsed and processed in Rstudio®, where ET was estimated using the alternative methods described in Gribovszki et al. (2010), as well as the PET estimate using R package *EcoHyRology*. Summaries of the data (Tables 1 and 2) were also assembled in Rstudio®.

2.3 Statistical Analysis

The comparison between the *standard* eddy covariance ET measurement and the different *alternative* ET estimations was done using summary statistics (mean +/- standard deviation of ET values as well as a Welch Two Sample t-test in Rstudio® (Figures 1 and 2).

3. Results and discussion

3.1 Results

Daily *Alternative* ET estimations - Boronina et al. (2005); Schilling (2007); PET using R package *EcoHyRology* - were compiled into a table with the *standard* eddy covariance daily ET measurements (Table 1). The Boronina et al. (2005) and Schilling (2007) methods were calculated based using [Gribovszki et al. (2010) - Equation 2] and [Gribovszki et al. (2010) - Equation 5] respectively; and were able to be used because precipitation did not occur during the time data was collected (Gribovszki et.al, 2010).

All daily ET values were summarized in Table 2 as a mean +/- standard deviation in respect to each method of measurement. We can note from Table 2 that the PET measurement using R package *EcoHyRology* method resulted in the greatest mean value and the least variance. Noting that PET is a maximum representation of ET under certain atmospheric and meteorological conditions (i.e. unlimited water supply), this difference is expected and will therefore not be further considered in this study. However, the differences between PET and ET measurements do imply that the water supply is limited in this catchment at this time (assuming all atmospheric and meteorological parameters used in the R package *EcoHyRology* function are correct).

The Schilling (2007) method resulted in the lowest mean ET estimate with the greatest variance. The mean +/- sd values for the Boronina et al. (2005) and eddy covariance methods lie somewhat in-between the above methods.

A welch two sample t-test comparing the standard eddy covariance daily ET measurement with Boronina et al. (2005); Schilling (2007); PET using R package *EcoHyRology* methods was conducted (Table 2). The resulting P-values over a 95% confidence interval were: p = 3.539e-08; p = 0.00698; p = 2.2e-16 respectively.

ET.bor.mean	ET.bor.sd	ET.sch.mean	ET.sch.sd	ET.ehr.mean	ET.ehr.sd	ET.ec.mean	ET.ec.sd
3.39	0.46	1.71	0.66	6.14	0.16	2.27	0.27

Table 2. Statistical summary of different methods evapotranspiration measurement. Values are represented as a mean and +/- standard deviation in units of mm/day for Boronina et al. (2005), Schilling (2007), PET using R package *EcoHyRology*, and the eddy covariance method displayed frm (left – right).

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        Welch Two Sample t-test

data:  ET.summary$ET.eddycov and ET.summary$ET.boronina
t = -8.12, df = 22.801, p-value = 3.539e-08
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -1.4045075 -0.8339592
sample estimates:
mean of x mean of y
 2.266667  3.385900


        Welch Two Sample t-test

data:  ET.summary$ET.eddycov and ET.summary$ET.schilling
t = 3.0314, df = 18.62, p-value = 0.00698
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 0.1730074 0.9482459
sample estimates:
mean of x mean of y
 2.266667  1.706040


        Welch Two Sample t-test

data:  ET.summary$ET.eddycov and ET.summary$ET.ehr
t = -47.467, df = 22.564, p-value < 2.2e-16
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -4.042319 -3.704348
sample estimates:
mean of x mean of y
 2.266667  6.140000
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Figure 1. Welch two sample t-test for alternative ET estimation methods; Boronina et al. (2005) [top], Schilling (2007) [middle] and PET using R package *EcoHyRology* [bottom] compared to the eddy covariance method.

Julian Day	ET.boronina	ET.schilling	ET.ehr	ET.eddycov
195	3.44	1.89	6.10	2.07
196	3.51	1.87	6.20	2.21
197	2.95	2.85	5.90	2.47
198	3.38	2.77	6.00	2.04
199	3.60	2.74	5.90	2.59
200	3.79	0.95	6.00	2.20
201	3.83	1.10	6.30	2.01
202	3.12	1.43	6.40	2.51
203	3.63	2.20	6.20	2.74
204	3.11	1.69	6.00	1.93
205	2.53	1.39	6.10	2.52
206	3.15	0.97	6.30	2.55
207	3.41	1.17	6.30	2.03
208	2.90	1.38	6.30	2.23
209	4.44	1.17	6.10	1.90

Table 1. Daily ET values for different methods of ET measurement. Values are expressed in units of mm/day for Boronina et al. (2005), Schilling (2007), PET using R package *EcoHyRology*, and the eddy covariance method displayed from (left – right).

3.2 Discussion

The resulting daily ET values for different methods of ET measurement (Table 1) show that the Schilling (2007) method most accurately estimated ET, based on the closeness of values to the *standard* eddy covariance ET measurement; noting that the p-value is ~ 3 orders of magnitude less than the other comparisons, as well as visual comparison in Tables 1 and 2. T-test results (Figure 1) showed the greatest p-value being associated with the Schilling (2007) and standard methods; meaning that the differences between (standardized) mean daily ET values was the smallest. If the null hypothesis H0 states that there is no difference between the standard and alternative methods (see .Rmd file), we must then reject H0 based the insufficient evidence to prove H0. If we are to treat the standard method as representative of the true daily ET value, then we can conclude that the Schilling (2007) method is the best estimate.

Schilling (2007) and Schilling and Kiniry (2007) the groundwater level fluctuates in a diurnal pattern, where a nighttime increase is associated with groundwater inflow to the observed region and a daytime decrease is associated with losses by evapotranspiration (Gribovszki et. al, 2010). Our results indicate that groundwater driven evapotranspiration may be taking place in the study catchment.

However, we should note that there are possible inconsistencies with the data. The eddy covariance ET method is a direct measurement the ecosystem scale; meaning it is representative of the entire catchment. The Boronina et al. (2005) and Schilling (2007) methods are estimating ET based on proxy data of diurnal fluctuation in streamflow and groundwater respectively (Gribovszki et. al, 2010), which were measured at a single location according Jollymore et.al, (2012). It may not be accurate to compare a measurement that are representative of a reach-scale, with measurements that are representative of an ecosystem scale. The validity of the eddy covariance method relies on proper calibration, which is a major assumption in this study.

On another note, proxy data does not offer the same degree of accuracy associated with a direct measurement; the Boronina et al. (2005) and Schilling (2007) methods are simplifications of ET. Therefore, we should acknowledge that evapotranspiration may be driven by groundwater fluctuations only at the reach-scale.

Conclusion

This study was an attempt to compare the different *alternative* methodologies against the *standard* eddy covariance method for measuring ET. Our results indicate that evapotranspiration may be driven by groundwater fluctuations only at the reach-scale, as the Schilling (2007) method appears to be the best estimate of ET in comparison to a direct measurement; under the assumption that these methods are representative of ET on the same spatial scale.

References

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