Long-Term Analysis of Effective Heterogeneity of Latent Heat Flux over Diverse Land Use Area

Wonsik Kim[1] and Daisuke Komori[2]

[1]National Institute for Agro-Environmental Sciences, Tsukuba, Japan [2]Tohoku University, Sendai, Japan

INTRODUCTION

There are various issues associated with EC measurements. Conventional methods substantially satisfy data quality control and quality assurance issues (Aubinet et al., 1999; Papale et al., 2006); however, the methods are premised on homogeneous land cover and therefore cannot satisfactorily estimate ET related to LUCC. Göckede et al. (2008) tried to estimate ET over heterogeneous conditions; however, the analysis did not include estimation uncertainty. In addition, although sensible and latent heat fluxes (H and lE) were simultaneously measured over a homogeneous vegetated surface, the uncertainty would differ between the fluxes (Andreas et al., 1998; Katul et al., 1999). Therefore, analysis of heterogeneity together with uncertainty based on long-term EC measurements in an area with ongoing LUCC would be valuable.

MATERIALS & METHODS

- Experimental Site
  Diverse land-use in Tak, Thailand (DTT)
  16°56.390'N, 99°25.793'E, 117 m asl
  http://matthew.niaes.affrc.go.jp/~wonsik/
  Southeast Asian monsoons region
  Mean annual rainfall: 1230 mm — 80% fell between May and October
- Investigation period
  2003 - 2013
- Instrumentation
  Sonic anemometer: CSAT3, Campbell Scientific
  Open-path gas analyzer: LI7500, LI-COR
  Measurement height: 100 m
- Key Equations

Relative sampling error:

$$\varepsilon = \frac{\sigma}{|F|}$$

$$\sigma^2 = \frac{1}{N}\left[\sum_{p=-m}^{m}\gamma_{ww}(p)\gamma_{\xi\xi}(p) + \sum_{p=-m}^{m}\gamma_{w\xi}(p)\gamma_{\xi w}(p)\right]$$

$$\gamma_{\xi\xi}(h) = \gamma_{\xi\xi}(-h) = \frac{1}{N}\sum_{t=1}^{N-h}(\xi_t - \overline{\xi})(\xi_{t+h} - \overline{\xi})$$

$$\gamma_{w\xi}(h) = \gamma_{\xi w}(-h) = \frac{1}{N}\sum_{t=1}^{N-h}(w_t - \overline{w})(\xi_{t+h} - \overline{\xi})$$

Weighted average for mean diurnal variation of one month:

$$F_w = \frac{\sum \frac{F}{\varepsilon^2}}{\sum \frac{1}{\varepsilon^2}}$$

$$\sigma_w = \frac{\sum \frac{(F - F_w)^2}{\varepsilon^2}}{\sum \frac{1}{\varepsilon^2}}$$

Effective heterogeneity

$$\eta = 1 - \frac{\omega}{\varepsilon}$$

RESULTS

Annual and Interannual Effective Heterogeneity Trends

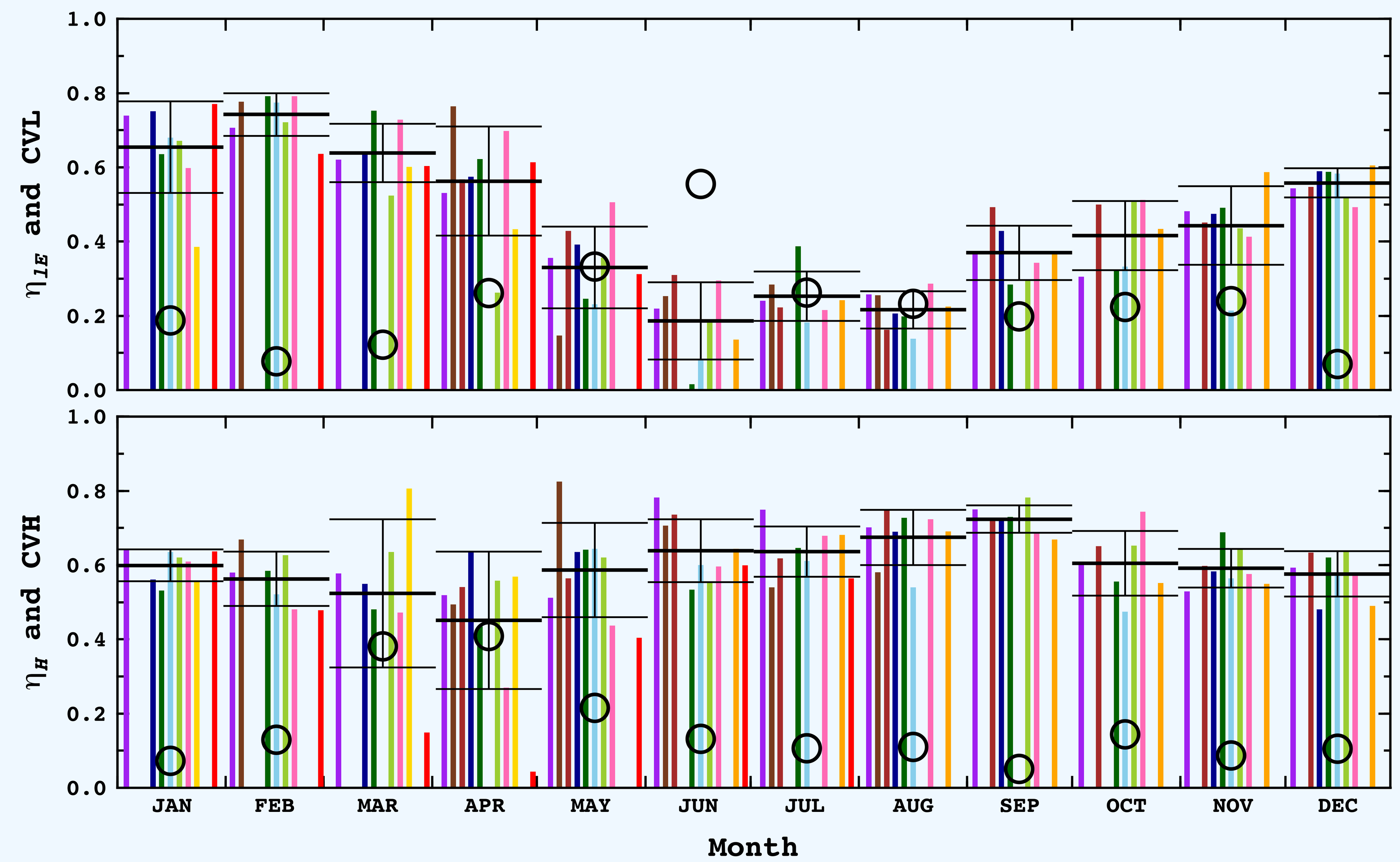

Figure 1. Annual and interannual effective heterogeneity of latent heat flux(η_{lE}: top panel) and of sensible heat flux (η_H: bottom panel) for 11 years (2003 : purple–2013 : red). The hovering horizontal bar and the open circle in each panel denote the monthly mean and the coefficient of variation (CV), respectively. Tails represent the standard deviation for a month.

Annual and Interannual Evapotranspiration Trend

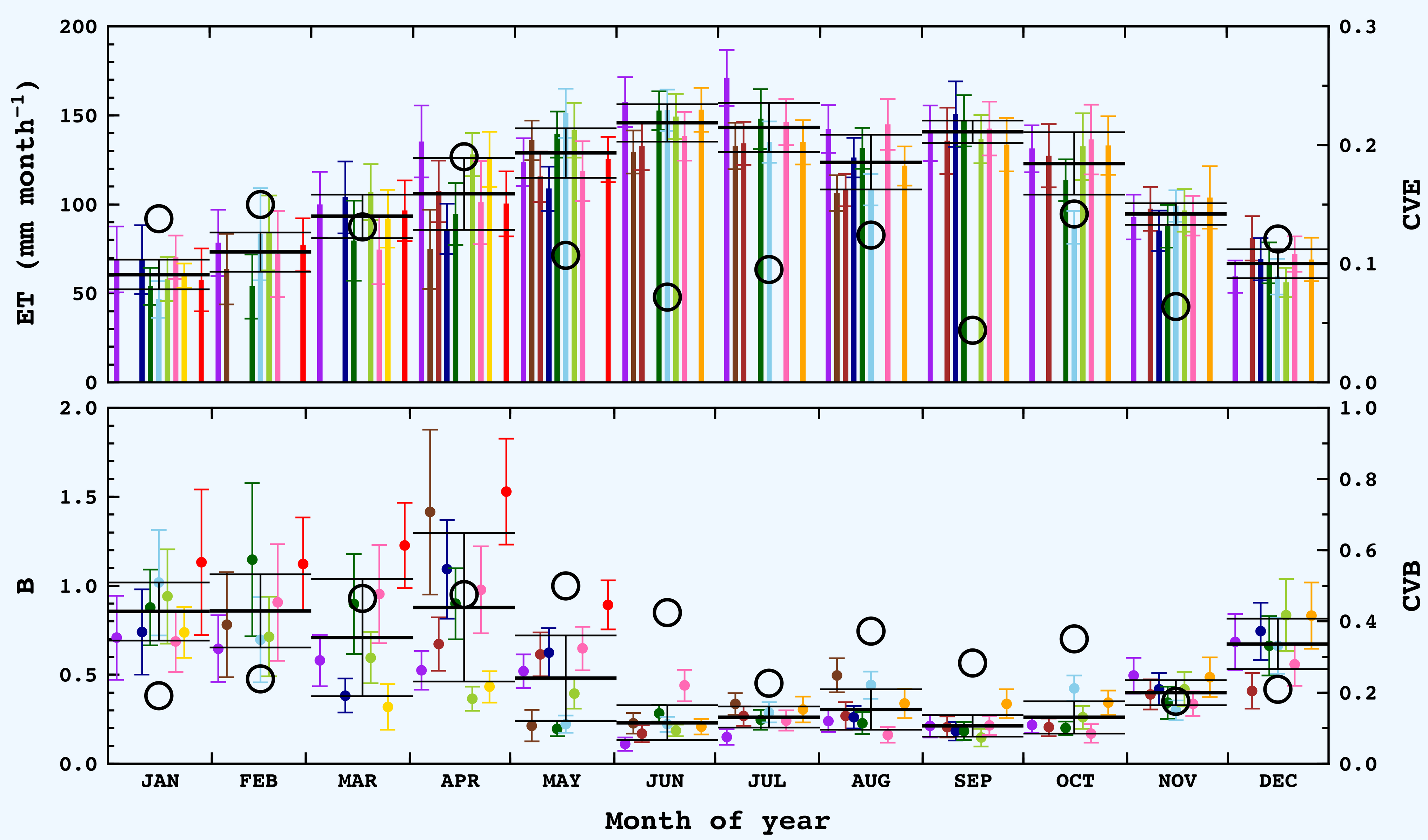

Figure 2. Annual and interannual evapotranspiration (ET: top panel) and Bowen ratio (bottom panel) for 11 years (2003 : purple–2013 : red). The hovering horizontal bar and the open circle in each panel denote the monthly mean and the coefficient of variation (CV), respectively. Tails represent the standard deviation for a month. ET averages and error bars in each month of each year denote the integrated daily mean variation in ET estimated by the hourly latent heat flux lE using the eddy covariance method, and the propagated uncertainty originating from the hourly uncertainty of lE, respectively.

DISCUSSION

- The effective heterogeneities of latent heat flux (η_{lE}) and of sensible heat flux (η_H) seasonally decrease from 0.74±0.06 (February) to 0.19±0.10 (June) and from 0.72±0.04 (September) to 0.45±0.10 (April), respectively (Figure 1). These results indicate that η has a different seasonal pattern: the source area of lE in the wet season is less heterogeneous than the dry season according to the land surface moisture content, and almost reaches saturation under frequent rainfall conditions; the source area of H in the dry season is less heterogeneous than in the wet season according to surface temperature, and reaches nearly the same temperature under peak dry season conditions. Therefore, it is possible to discern η values which are sensitive to each land surface source condition for a given H and lE, and each surface temperature and soil surface wetness condition displays independent seasonality against the landscape heterogeneity. Consequently, we suggest that η might be useful parameter for understanding the effect of land surface heterogeneity on H and lE.
- The interannual variation in seasonality of η_{lE} (CVL) and η_H (CVH), the monthly coefficient of variation (CV) for η was highest in June (0.56) and April (0.42) at maximum lE (365±28MJm^{-2} = E: 146±11mm) and (213±78 MJm^{-2}), respectively (Figure 1 and 2). The largest CV values indicate the month in which the highest interannual variation in η occurred due to the significant differences in temperature or land surface moisture which are controlled by natural meteorological events and LUCC resulting from human activities. Meanwhile, if the CV was primarily controlled only by LUC, the CV would be unchanged based on identical land use within a single year because agricultural management is maintained on an annual or multi-annual basis. Even though the foot print areas differ between the dry and wet seasons, the CV is nearly the same each season. Considering the seasonality of η together with the relationship between P and ET, η might more effectively represent the response of land surface to meteorological events than LUC in this region. Interestingly, the sum of CVL and CVH can explain a significant proportion of the variation in CVB (r=0.82, p<0.001). The result suggests that the interannual variation in land surface conditions can be explained by η_{lE} and η_H instead of B. Thus, η can be used as a scale parameter to define land surface heterogeneity effecting lE and H.

REFERENCES

- Kim, W., D. Komori, J. Cho, S. Kanae, T. Oki (2014): Long-term analysis of evapotranspiration over a diverse land use area in northern Thailand. *Hydrological Research Letters*, 8:45-50.
- Kim, W., D. Komori, and J. Cho (2011): Characteristics of fractional uncertainty on eddy covariance measurement. *Journal of Agricultural Meteorology*, 67:163-171.