INTRODUCTION

Under the scientific issues of global climate change, monitoring CO₂ flux (F) including sensible and latent heat flux (H and E) has been carried out using eddy covariance (EC) technique, and accumulating those data are available to investigate the issues over the worldwide. However, it is difficult to make up the data to explore ecosystem inter-comparison, model development, and model-data synthesis, because uncertainty and/or heterogeneity informations are lacked in EC measurements.

Here, we demonstrate that fractional uncertainty (Φ) of EC measurement by Wonsik’s method (Kim et al., 2009) typifies stability, uniformity, and randomness. 2) possesses baseline (Φ_b), Slope heterogeneity scale parameter (η). These characteristics suggest that Φ could be a general information not only to process data quality control of EC measurement but also to analyze uncertainty with heterogeneity for data inter-comparison, model development, and model-data synthesis.

RESULTS

Figure 1. Temporal monthly means of fractional uncertainty (Φ) measured at DTT13 over tropical deciduous forest (DTT13) from January 2005 to December 2007. Red, blue, and green symbols denote fractional uncertainties of sensible and latent heat, and CO₂ fluxes (Φ_{s,h} and Φ_{e,c}), respectively. The solid represents standard deviation of Φ by least median of squares method. The open circle denotes Φ with lower limits near Glycine.

Figure 2. Variability of fractional uncertainty (Φ) according to flux measurement height (z) over all vegetation types of the tables of experimental sites. The values of symbols are the same as figure 1 and the open circles denote Φ at heterogeneous sites (DTT11 and DTT13).

Figure 3. Fractional uncertainty of sensible heat flux (Φ_h) by averaging timescale (τ) at various measurement sites (DTT11: open bright ; DTT13: open dark ; PST: closed bright and CTT: closed dark) for approximately 24 hours of data during the same season. We calculated the standard deviation of Φ and dashed line and grey region describe Φ_{s,h} and its mean ± twice of standard deviation, respectively. The red curve represents temporal scale at PST (30 minutes) and 30 µs, and it is characterized that Φ of unit τ for heterogeneous land surfaces has a bias toward larger values than Φ of defined at homogeneous sites. Therefore, we suggest the use of a heterogeneity scale parameter defined as η-1/ω, where η is the random fractional uncertainty interpolated by the theoretical function with measured Φ with τ-0.5 hour to minimize instability effect on ω.

Figure 4. Uncertainty (η), R-bitgamy (τ), and heterogeneity (η) based on fractional uncertainty (Φ) of 1 hour averaging timescale (τ) according to fluxes and sites. Colors and site ID are the same as in figure 1 and tables of experimental sites, respectively. The solid curve shows the curve values calculated with those propagation formulas of one independent conditions using estimated Φ standard deviations.

DISCUSSION

• Our results confirm the suggestion by Kim et al. (2008, 2009a, 2009b) that estimated Φ with least median of squares method to filter outliers contaminated by illegitimate error has stability over a homogeneous land cover.
• Estimated Φ over a heterogeneous land surface is greater than those of homogeneous, and it is characterized that Φ is also uniformity year round regardless of the kind of fluxes.
• The Φ_{s,h}, Φ_{e,c}, and Φ_{B} at each site were nearly same, but larger Φ was estimated at heterogeneous sites (DTT11 and DTT13: open symbols in Figure 2). Therefore, it is possible that Φ typifies heterogeneity of land surface.

Our investigation so far suggests that Φ has uniformity over a homogeneous land surface, and minimum Φ over a heterogeneous surface, consequently, we can define a constant Φ at a unit averaging timescale (i.e. 1 hour) without concern for the spatiotemporal scale, and provide the quantity to 0.98 ± 0.03 based on CTT and SPT data.
• The Φ of unit τ for heterogeneous land surfaces has a bias toward larger values than Φ of defined at homogeneous sites. Therefore, we suggest the use of a heterogeneity scale parameter defined as η-1/ω, where η is the random fractional uncertainty interpolated by the theoretical function with measured Φ with τ-0.5 hour to minimize instability effect on ω.
• The values of η for DTT11 and DTT13 in complex landscapes were respectively 0.65 and 0.70, and those for PST and CTT in a uniform landscape were 0.5 except 0.3 except 0.5x0.25 for PST in spite of the visual homogeneity.

CONCLUSIONS

• We found that the data sets with both uncertainty and heterogeneity informations can be easily generated by the same criteria regardless of inherent site properties. Therefore, we suggest that not only Φ but also η should be used with EC flux data for site inter-comparison and model validation.
• Additionally, the informations of Φ and η of EC measurement could be directly applicable to model development and model-data synthesis.

REFERENCES


MATERIALS & METHODS

• Experimental sites (Kim et al., 2003, 2008, 2009)

<table>
<thead>
<tr>
<th>SiteID</th>
<th>Location</th>
<th>Mea. &amp; Canopy</th>
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<th>Target Data</th>
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</tr>
</tbody>
</table>

• Expected value

\[ \Phi = E(\Phi) = \text{Minimize median} \]

Expected value of fractional uncertainty, \( E(\Phi) \)

• Uncertainty

\[ \Phi = \rho \tau^{-1} \]

Fractional uncertainty. Φ: Scale of Φ. ρ: Flux averaging timescale. τ

• Heterogeneity

\[ \eta = 1 - \frac{\omega}{\rho} \]

Heterogeneity scale parameter. η: Scale of \( \eta \) for \( \rho = 0.05 \)