Why We Need to Estimate the Fractional Uncertainty of Eddy Covariance Flux Measurement?

Wonsik Kim (National Institute for Agro-Environmental Sciences, Japan) and Hyeong-Ho Seo (Rural Development Administration, Korea)

NIAES

INTRODUCTION

Fruitful studies on exchanges of energy, water and carbon dioxide between the atmosphere and terrestrial ecosystem has been produced under a global network (http://fluxnet.ornl.gov). The exchange is defined by a flux, and in traditional the flux is estimated with eddy covariance (EC) method as a mean flux F for 30-min or 1-hr, because no techniques have been established for a direct measurement of a momentary flux itself. Therefore, the exchange analysis with F is to paid attention to estimations of spatial or temporal mean, because the exchange estimated by arithmetic mean seems to be inappropriate. Namely, the sample F used in this averaging have nonidentical qualities within one another in accordance with different micrometeorological and ecophysiological snapshots while those are measured by the same instruments for one hour. To overcome this issue, we propose a weighted mean using a fractional uncertainty ε estimated by F and its uncertainty υ, and then present the performance tested with a mean diurnal variation for gap filling and a data assimilation for data correction in EC measurement.

MATERIALS & METHODS

- **Key equations**

1. Fractional uncertainty (Kim *et al.* 2011)

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

2. Uncertainty (Finkelstein and Sims 2001)

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

3. Weighted average (Kim *et al.* 2015)

$$\overline{F} = \frac{\displaystyle\sum_{i=1}^{n} \frac{F_i}{\varepsilon_i^2}}{\displaystyle\sum_{i=1}^{n} \frac{1}{\varepsilon_i^2}}$$

4. Weighted uncertainty (Kim *et al.* 2015)

$$\overline{\upsilon} = \left[\frac{\displaystyle\sum_{i=1}^{n} \frac{(F_i - \overline{F_i})^2}{\varepsilon_i^2}}{\displaystyle\sum_{i=1}^{n} \frac{1}{\varepsilon_i^2}} \right]^{\frac{1}{2}}$$

- **Instrumentation**

1. Sonic anemometer: CSAT3, Campbell Scientific, Utah, USA
2. Open-path gas analyser: LI7500, LI-COR, Nebraska, USA

RESULTS

General Meteorological Information

Figure 1. Hourly trends of air and canopy temperatures (Ta and Tc), relative humidity (RH), wind speed and direction (Ws and Wd), precipitation (P), and vapor pressure (e) at a tangerine orchard in Jeju Korea from 11 to 17 January 2015.

Figure 2. Hourly fluxes of sensible and latent heat, and carbon dioxide (H, lE and Fc) with ±1σ whiskers as an uncertainty υ, and hourly micrometeorological parameters of Wd, ζ and $u*$. Each group of trends is colored according to the scale of ε and Taylor's parameter τ, respectively. Turbulence measurements for these estimation were collected at the same period of Figure 1.

Mean Diurnal Variation for Gap Filling

Figure 3. Hourly mean diurnal variation (MDV) of sensible and latent heat, and carbon dioxide fluxes (H, lE and Fc) with a dataset of the figure 2. Closed circles and light blue regions denote weekly weighted means and those ±1σ as uncertainty υ, and circles and their whiskers denote weekly arithmetic means and those ±1σ as υ, respectively. The vertical bars at the bottom of the subpanels indicate weekly acquisition ratios (AR) of an hourly MDV.

Data Assimilation for Data Correction

Figure 4. Temporal data assimilation of hourly latent heat flux lE (blue) and bulk conductance g (green) using Ensemble Kalman Filter (EKF) considering the uncertainty υ of flux measurements during the same period of previous figures. The Bulk Conductance Model forced by air temperature and humidity is applied in the data assimilation. Closed circles and those whiskers denote the hourly EC measurements and those ±1σ as υ, respectively. Lines and those light coloured regions are assimilated lE and g, and those ±1σ by EKF. Every dataset applied in the data assimilation is come from the dataset used previous figures.

DISCUSSION

- The fractional uncertainties ε of sensible H and latent lE heat, and carbon dioxide Fc fluxes during a target week are 9, 19 and 16%, and those first and third quartiles are 7 and 14, 12 and 32, and 9 and 28%, respectively (Figure 2). This result shows that ε is significantly affected by the scalar measurement such as temperature, mixing ration of H_2O and CO_2, and the ε is correlated with the Taylor's parameter τ rather than the frictional velocity $u*$.

- The hourly mean diurnal variation estimated by the weighted mean is more reasonable and greater than those of the arithmetic mean in accordance with the consideration of data quality using ε (Figure 3). This result shows not only attention against data correction of lE and Fc but also suspicion about underestimation of H and lE measured by eddy covariance (EC) technique.

- The temporal trend of lE presented by data assimilation using Ensemble Kalman Filter (EKF) with lE and its ε measured by EC successfully detects the unreliable lE by EC (Figure 4). This result shows that we can suggest a new method for data gap filling and data correction of EC measurement using just only meteorological data of temperature and humidity.

- More information analysed at various EC measurement sites, and those realtime results are available at http://matthew.niaes.affrc.go.jp/amen/fluxpro/ and an instrumental details refer to Kim *et al.*, (2015)

REFERENCES

- Finkelstein, P., and P. Sims (2001): Sampling error in eddy correlation flux measurements. *Journal of Geophysical Research*, **106**, 3503–3509.
- Kim, W. *et al.* (2011): Characteristics of fractional uncertainty on eddy covariance measurement. *Journal of Agricultural Meteorology*, **67**:163-171.
- Kim, W. *et al.* (2015): *FluxPro* as a realtime monitoring and surveilling system for eddy covariance flux measurement. *Journal of Agricultural Meteorology*, **70**:32-50.

wonsik@affrc.go.jp

REMARKS