Relationship between Water Vapor and Carbon Dioxide Exchanges over A Paddy Field

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1. INTRODUCTION

Water vapor (q) and carbon dioxide (c) concentrations in the atmospheric surface layer are now widely measured and collected with application of eddy covariance principle. This high-frequency measurement is used to quantify water vapor exchange (Fq) and carbon dioxide exchange (Fc) in the ecosystem scale. Therefore, understanding of q and c exchanges over agricultural land use. is a key linking a response of plant in canopy scale to climate.

Normally, atmospheric q and c exchanges over agricultural area especially in daytime were dominated by plant processes, such as transpiration and photosynthesis. For q and c exchanges from plant arises from stomatal regulation by closing and opening. During opening of these stomatal apertures on leaf under-surface, q will be released out to the ecosystem, while c is absorbed into the leave (Cowan and Farquhar, 1977). This opposite direction of these gas transfer exhibitions were found when Ohtaki analyzed spectral coherency of turbulence in a wheat field (1985). This reverse transfer direction of q and c results in relation is -1. In 2008, Scanlon and Sahu proposed a q-c correlation approach based on flux variance similarity principle that the relation of stomatal q and c being close to -1. However, in the general ecosystem there are not only stomatal gas exchanges but the other environmental factors, as soil respiration and evaporation, also influence to q and c exchanges. Therefore, the relationship between q and c is reduced and not close to -1 perfectly.

Tolerance of both Fq and Fc were performed on fractional uncertainty ($\emptyset$), describing in Kim *et al.* (2011), to evaluated uncertainty without consideration of flux characteristic and individual site specifications. Therefore, this study applied the fractional uncertainty into the correlation analysis to detect good conditions for analyzing relationship between q and c exchanges coming from plant canopy.

2. STUDY FIELD AND DATA

Eddy covariance data were collected over a rain-fed paddy field located in Sukhothai, Thailand (at 17°03'51"N, 99°42'17"E, 50 m asl.) during 2006 to 2007. The soil of this site was classified as sandy clay. Rice was grown almost same seasonal condition that characterized two seasons within a year. The dry season was almost no rainfall started from November and lasted until the end of April. For the wet season started from May to October. This season rice cultivation usually started when rainwater was available through rainfall during the middle of April to the beginning of May. During this period rice seeds (Pathumthani 80 variety) were sowed and transplanted then. However, water in paddy field became dry since the first week of July along until the end of October. In September during reproduction stage, soil surface was covered again by a short rainfall. Fq, Fc and solar radiation (Rs) were investigated at 7:00 am to 17:00 pm, in which no-rainfall in those period of time, to analyze q and c transfer efficiencies. Flux data was collected in high-frequency (10 Hz) by 3D-sonic anemometer (CSAT3, Campbell Scientific inc.) and infrared gas analyzer (LI7500, LI-COR inc.). Detail of flux monitoring system and correction were described in Kim *et al.* (2015).

3. METHODOLOGY

Data fluctuations generate uncertainty defining as random and illegitimate errors. The random error (δ_r) originate from instrumental uncertainty or statistical fluctuations. For the illegitimate error (δ_i) arise from mistakes or measurement blunders. Tolerances of Fq and Fc are scale parameters performing on fractional uncertainty that defined as

$$\emptyset = \frac{\delta_r + \delta_i}{|F|} \tag{1}$$

where F is flux. This fractional uncertainty analysis has ability to separate δ_r and δ_i from Fq and Fc data by determine baseline of those data. Therefore, the fractional uncertainty is applied into the correlation analysis, in order to remove the fluctuation in Fq and Fc.

This study we separate the fractional uncertainty of both Fq and Fc into following 4 ranges; $0.08 \leq \emptyset_1$, $0.10 \leq \emptyset_2 < 0.08$, $0.15 \leq \emptyset_3 < 0.10$ and $0.20 \leq \emptyset_4 < 0.15$, to filtrate and qualify data series before analyzing gas transfer efficiencies.

Transfer efficiencies of q and c calculate from correlation of vertical wind speed and gas concentrations ($\rho_{w\prime,s\prime}$) as equation 2.

$$\rho_{w\prime,s\prime} = \frac{\overline{w's'}}{\sigma_w \sigma_s} \tag{2}$$

when $\overline{w's'}$ is gas flux that calculated by average of multiple results of fluctuations belonging to vertical wind speed (w') and gas concentration (s'). σ_w and σ_s are standard deviations of vertical wind speed and gas concentration, respectively.

4. RESULTS AND DISCUSSION

The correlation coefficients between two scalars of gas concentrations and vertical wind speed over a paddy field were analyzed and performed as atmospheric q and c transfer efficiencies. These transfer efficiencies were calculated in daytime to investigate the gas exchanges, driving by plant transpiration and photosynthesis. However, Fq and Fc in observed condition were contaminated by environmental factors, which induced fluctuation in the data series. To control contaminant in data coming from soil c emission, gas transfer efficiencies were collected over submerged cultivated period.

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Transfer efficiencies of *q* and *c* were illustrated as a function of *Rs*, dividing by $\emptyset_1$, $\emptyset_2$, $\emptyset_3$.and $\emptyset_4$ (Fig.1 (a) and (b), respectively). Most data of both gas transfer efficiencies within $\emptyset_4$ (red circle) appeared in low range of *Rs*. Moreover, constants of the gas transfer efficiencies in this range was lower than those of regression lines.

In $\emptyset_4$ range revealed high fluctuations, therefore the regression lines of transfer efficiencies were analyzed by using data less than 15% of coefficient variation. The constants of *q* transfer efficiency provided similar value (0.38 ± 0.03) with that of *c* (0.39 ± 0.04), showing as regression lines in Fig.1 (a) and (b).

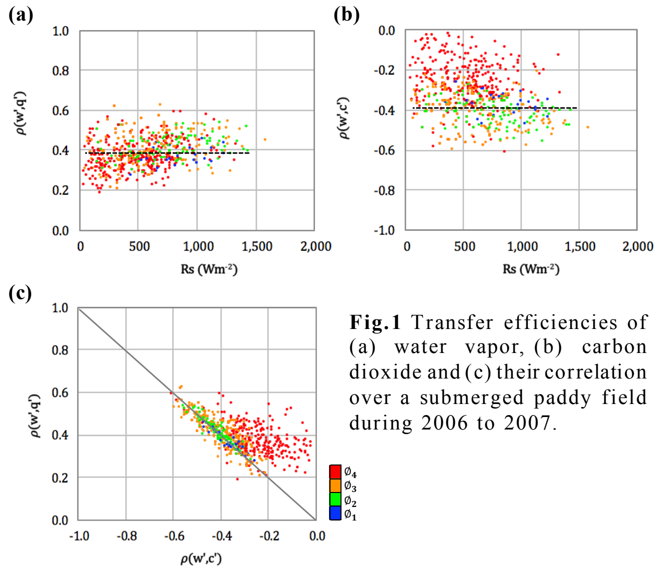

Fig.1 Transfer efficiencies of (a) water vapor, (b) carbon dioxide and (c) their correlation over a submerged paddy field during 2006 to 2007.

According to flux similarity principle, the scalar within a homogenous surface layer are governed by the same properties of turbulence in the same time and measured at the same position should exhibit correlation perfectly that close to -1. In our study, relation of *q* transfer efficiency to that of *c*, within less than 15% of coefficient variation, also revealed good agreement that correlation close to -1 (Fig.1 (c)). This result indicated that the integrated approach between analysis of fractional uncertainty and gas transfer efficiencies could filtrate the uncertainty in observed data.

As the demonstrated results, although the data was collected from submerged paddy, *c* transfer efficiency shown higher sensibility than that of *q*.

5. CONCLUSIONS

1.) Fractional uncertainty method seems to reduce the fluctuation coming from environmental factors.
2.) A good correlation between *q* and *c* in this study could confirm the variance similarity of stomatal flux.
3.) Analysis of fractional uncertainty over a paddy provide good correlation of *q* and *c*, when coefficient variation less than 15%.

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