INTRODUCTION

To understand how terrestrial ecosystems respond to global climate change, researchers have globally measured the energy, water, and carbon dioxide flux densities \( F \) globally over various types of vegetation by the eddy covariance (EC) method. However, the process of \( F \) calculation and the method of quality control and quality assurance (QCQA) are complex and site specific. Moreover, instantly maintaining remote EC flux measurement sites against instrumentation problems and administrative difficulties is laborious. To overcome these issues, particularly those of real-time \( F \) monitoring and prompt site management, \( \text{FluxPro} \) was created.

\( \text{FluxPro} \) consists of three functional systems: 1) a gathering system that transports EC measurements from various sites to the \( \text{FluxPro} \) management server; 2) a cooking system that computes \( F \) and its fractional sampling uncertainty \( \epsilon \) together with micrometeorological variables \( \phi \); and 3) a serving system that presents the results of the gathering and cooking systems as charts to be distributed over the internet in real-time. Consequently, \( \text{FluxPro} \) could become an appropriate system for real-time multi-site management, since it not only automatically monitors \( F \) with \( \phi \) and \( \epsilon \), but also continuously surveils EC sites, including copious information and an email alert system.

RESULTS

The Uniform Resource Locator of \( \text{FluxPro} \)

http://matthew.niaes.afrc.go.jp/amen/

Weekly Mean Diurnal Variation

![Weekly mean diurnal variation of sensible heat flux \( H \) and carbon dioxide flux \( F_c \) at paddy fields in Asia (April 26 - May 2, 2014). The error bar denotes the uncertainty value propagated from the hourly sampling uncertainty. Each p:\#007, p:\#003 and \( \Phi \) is the site identification of paddy field at Ratchaburi in Thailand, at Mase in Japan, and at Nukhapsin in Bangladesh, respectively.](image)

### Table 1.

<table>
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<tr>
<th>Parameters</th>
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<tr>
<td>( \epsilon )</td>
<td>Yes</td>
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<td>0.020</td>
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- Sensible heat flux
- Carbon dioxide flux

Figure 1. Weekly mean diurnal variations of sensible heat flux \( H \) and carbon dioxide flux \( F_c \) of paddy fields in Asia (April 26 - May 2, 2014). The error bars denote the uncertainty value propagated from the hourly sampling uncertainty. Each p:\#007, p:\#003 and \( \Phi \) is the site identification of paddy field at Ratchaburi in Thailand, at Mase in Japan, and at Nukhapsin in Bangladesh, respectively.

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Figure 2. Relationship between the fractional sampling uncertainty \( \epsilon \) and the atmospheric stability \( \Phi \). The intercept of the dashed line in \( H(0.02) \pm 0.02 \Phi (0.02) \) for \( \Phi = \pm 2 \) is 0.078 with 0.97% confidence.

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### Figures

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DISCUSSION

- Investigators interested in measurements at each individual site can access the information provided by \( \text{FluxPro} \), not only for his or her own site but also for sites managed by others participating in \( \text{FluxPro} \). Visitors can also scrutinize the \( \text{FluxPro} \) measurements to enhance understanding in their own fields. Specifically, an investigator managing his own site can view \( \text{FluxPro} \)-generated charts online and can receive automatic email alerts, circumventing the need to undertake troublesome instrumental or administrative procedures to manage and maintain his own remote site. Moreover, any investigator or visitor can download \( \text{FluxPro} \) measurements of special interest, and use them in their own scientific quests while investing minimal effort in site management, measurement inspection, and chart presentation. Charts comparing measurements at different sites are also available for comparative purposes (Figure 1).

- Knowing the uncertainty can be equally or perhaps more important than knowing the value itself. For this reason, \( \text{FluxPro} \) provides both the values and uncertainties of hourly \( F \) estimates. The \( F \) are then averaged or integrated over weekly, monthly and yearly timeframes by propagating the hourly uncertainties, as described in section Key Equations. The resulting \( \epsilon \) value is about 10%–30% (minimum about 5%–7%) over the entire set for investigative sites in \( \text{FluxPro} \). The information could be easily compared with \( F \) estimated by numerical models or satellite analysis based on statistical significance.

- Comparing \( \epsilon \) and \( \phi \), we observe that \( \epsilon \) might prove more useful than \( \phi \) because it contains information of statistical uncertainty in the EC measurements. As shown in Figure 2 and Table 1, the minimum uncertainty in the EC measurements is approximately \( \Phi \) under near neutral conditions, and the intercept of \( \epsilon \) is \( 0.078 \) when \( \Phi = \pm 2 \). This result suggests that every EC measurement includes at least 7% sampling uncertainty. Moreover, it suggests that the uncertainty is a function of \( \Phi \).

REFERENCES


MATERIALS & METHODS

- Registered Site
  - 1. ctk004: Corn field at Keshi, Japan
  - 2. cxt002: Cassava field at Tak, Thailand
  - 3. cxt007: Cassava field at Tak, Thailand
  - 4. ddlk030: Deciduous forest at Dangwallyong, Korea
  - 5. dmy020: Deciduous forest at Monri, Japan
  - 6. dmy040: Deciduous forest at Phangy, Thailand
  - 7. dtn100: Diverse land surface Tak, Thailand
  - 8. dtn030: Diverse land surface Tak, Thailand
  - 9. ght003: Grassland at Hidaka, Japan
  - 10. mmk030: Mixed forest at Monri, Japan
  - 11. pmk003: Paddy field at Mymensingh, Bangladesh
  - 12. pmk006: Paddy field at Mase, Japan
  - 13. prt007: Paddy at Ratchaburi, Thailand
  - 14. pmt007: Paddy at Sukhothai, Thailand
  - 15. spk007: Sugarcane at Phitsanulok, Thailand
  - 16. stt007: Sugarcane at Takka, Thailand
  - 17. tsr004: Tangerine orchard at Jaya, Korea

- Instrumentation
  - Sonic anemometer: CSAT3, Campbell Scientific, Utah, USA; DA-600, Kestrel Corporation, Tokyo, Japan; R-S3-50, Gill Instruments, Hampshire, UK
  - Open-path gas analyzer: EC165 Campbell Scientific, LP590, LI-COR, Nebraska, USA
  - Key Equations
  - Relative sampling uncertainty: Finkelstein and Sims (2001), Wonsik et al. (2011)
  - Weighted average for mean diurnal variation of one month: Falge et al. (2001), Kim et al. (2014)