FluxPro: Real Time Monitoring and Simulation System for Eddy Covariance Flux Measurement

Wonsik Kim [1], Hyeong-Ho Seo [2], Daisuke Komori [3], Keisuke Ono [1], Masayoshi Mano [1] and Akira Miyata [1]

1: National Institute for Agro-Environmental Sciences, Tsukuba, Japan; 2: Agricultural Research Center for Climate Change, Jeju, Korea, 3 Institute of Industrial Science, Tokyo, Japan.

INTRODUCTION

To cope with the extreme events against crop cultivation in changing climate, the realtime monitoring of photosynthesis and evapotranspiration and those prompt forecasting are indispensable. So we are constructing ***FluxPro*** to monitor and forecast CO_2 and H_2O fluxes (*Fc* and *lE*) simultaneously. One of the functions of ***FluxPro***, namely monitoring, provides the observed fluxes to surveil the live condition of crop growth and cultural environment using open-path eddy covariance flux measurement system. The other function, forecasting, serves the simulated fluxes to optimally control the cultivation condition of crop growth under any extreme events using data-model synthesis system (DMSS).

MATERIALS & METHODS

- Available site

Site ID: TJK004, PMJ003
Crop type:
Tangerine orchard at Jeju, Korea (33°30'28.47"N 126°40'51.29"E, asl 80m)
Paddy field at Mase, Japan (36° 3'14.03"N 140° 1'36.89"E, asl 10m)

- Eddy covariance flux measurement (EC)

Sonic anemometer: CSAT3, Campbell Scientific and DA-600, Kaijo
Open-path gas analyzer: LI7500 and LI7000, LI-COR

- Data communication

Micrologger: CR3000, Campbell Scientific
Ethernet interface: NL115, Campbell Scientific
Datalogger Support Software: Loggernet, Campbell Scientific

- Monitoring analyzing and forecasting software

FluxPro

- Reference

Flux calculation:
Leuning, R., 2004. Measurements of trace gas fluxes in the atmosphere using eddy covariance: WPL corrections revisited. In X. Lee, W. Massman, and B. Law (Eds.), *Handbook of Micrometeorology* (pp. 119–132). Kluwer Academic Publishers, The Netherlands.
Uncertainty analysis:
Kim, W., D. Komori, and J. Cho, 2011a. Characteristics of fractional uncertainty on eddy covariance measurement. *Journal of Agricultural Meteorology*, in press.
Kim, W., J. Cho, D. Komori, M. Aoki, M. Yokozawa, S. Kanae, T. Oki, 2011b. Tolerance of eddy covariance flux measurement. *Hydrological Research Letters*, in review.
Model simulation: Kim, W., S. Kanae, Y. Agata and T. Oki, 2005. Simulation of potential impacts of land use/cover changes on surface water fluxes in the Chaophraya river basin, Thailand. *Journal of Geophysical Research*, **110**, D08110, doi:10.1029/2004JD004825.

RESULTS

Monitoring

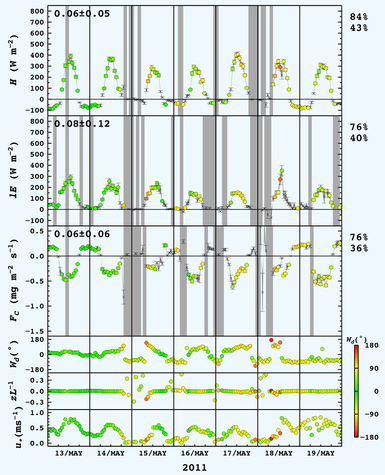


Figure 1. Time series of observed hourly *H*, *lE* and *Fc* showing tolerance *T* (whiskers), and associated micrometeorological parameters. Hourly flux is shown by circles for weekly data within $T\pm\sigma$ (left-upper numeral) or by crosses for weekly data that are not within $T\pm\sigma$ based on Figure 2. Vertical gray regions are the screen for flux from consecutive spikes more then twice in its one-hour turbulence trend.

Analysis

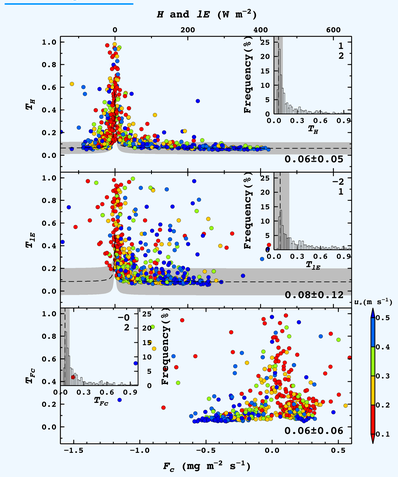


Figure 2. The relationship of tolerance *T* to *H*, *lE* and *Fc*, and the frequency distribution of *T* for those fluxes. Dashed lines show *T* and gray areas indicate the range of the scale parameter σ over the data recording period. The numerals in the bottom-right corner of the main panels represent weekly $T\pm\sigma$, and those in the top-right corner of the inset histograms indicate kurtosis and skewness.

Simulation

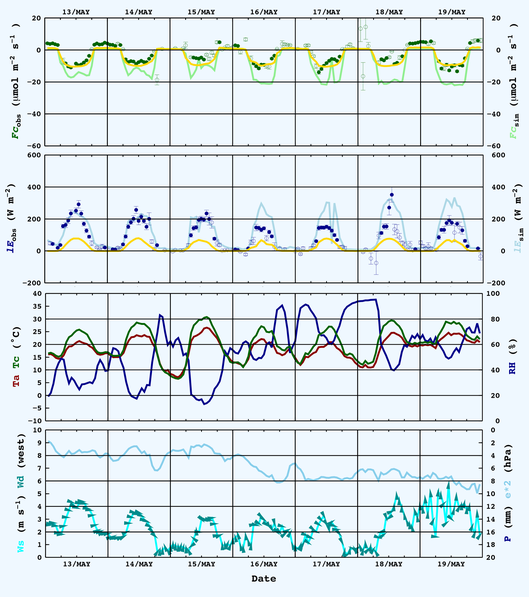


Figure 3. Time series of measured and simulated hourly *Fc* and *lE*, and observed meteorological variables. In upper two flux panels, light-green (*Fc*) and light blue (*lE*) lines present the simulation results by SiB2 with inherent parameter set, and gold lines are the result of a developing model whose parameters are optimized by Markov Chain Monte Carlo technique using flux data.

Forecasting

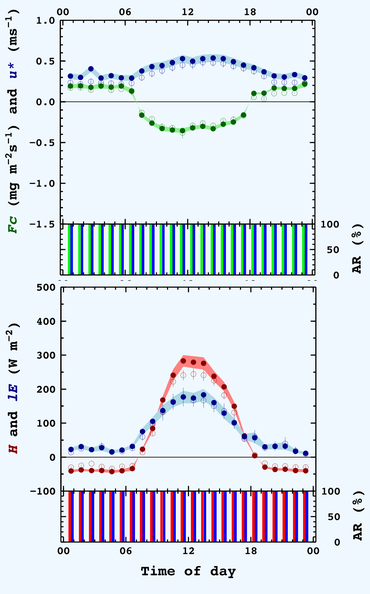
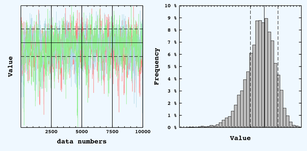


Figure 4. Weekly mean diurnal variations of *Fc*, *u**, *H* and *lE* based on observational data. Shaded areas indicate the range of flux uncertainty. In this analysis, the mean *Fc* and *lE* are 1.04±0.14 mm day^{-1} and -1.30±0.04 g m^{-2} day^{-1}, respectively.

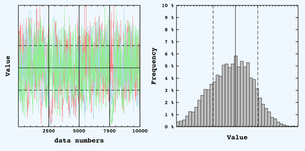
DISCUSSION

- Realtime monitoring subsystem of ***FluxPro*** is successfully constructed at http://kings.niaes2.affrc.go.jp/ for tangerine orchard at Jeju, Korea and paddy field at Mase, Japan as a pilot research. Consequently it is possible to do the online surveillance of *Fc* and *lE* in considering tolerance of EC (Figure 1). This live presentation is useful to inspect photosynthetic activity and soil moisture condition at cultivated field based on hourly time scale.
- As a convenient solution for realtime monitoring by EC system, Kim *et al.* (2011a and 2011b) method is applied to produce the data quality control, and then reasonable EC measurements are filtered among the robust EC measurements in real time base (Figure 2).
- In order to develop the realtime forecasting subsystem of ***FluxPro***, SiB2 with inherent parameter set, and a newly developing model whose parameters are optimized by Markov Chain Monte Carlo (MCMC) technique using EC measurements are investigated over the online base to check the availability over various environmental conditions.
- As examples of parameter optimization within the developing model, the following figures show 3-sample paths and posterior distributions of parameters provided by the Metropolis–Hastings algorithm. The two trend panels indicate three latest-trend after burn-in of 90,000.

Estimated photosynthetic capacity
-0.37±0.05 mg m^{-2} s^{-1}



Estimated aerodynamic resistance
98±47 s m^{-1}



- The *Fc* and *lE* simulated by SiB2 is tendency toward overestimation, therefore some parameters tuning is required for more reliable simulation. Meanwhile, those by the developing model including data assimilation skill are reasonable in common sense, however we may obtain more precious simulation results according to the considering EC measurement uncertainty to statistical inference, and the additional parameterizing for special meteorological events i.e. after rain, high windspeed et cetera.

REMARKS

- Additional testing over the various crop types and elaborate investigating for model parameter estimations are required for ***FluxPro*** to cope with extreme weather events for crop cultivation on a field level using EC and DMSS.

wonsik@affrc.go.jp