Available online at www.sciencedirect.com
SCIENCE DIRECT
Agricultural and Forest Meteorology 134 (2005) 135–142
AGRICULTURAL AND FOREST METEOROLOGY
www.elsevier.com/locate/agrformet

Re-calibrating TsuBiMo with eddy-covariance measurements at Takayama

G.A. Alexandrov [a,*], Y. Yamagata [a], N. Saigusa [b], T. Oikawa [c]

[a] NIES, Onogawa 16-2, Tsukuba, Ibaraki 305-8506, Japan
[b] AIST Tsukuba West, Tsukuba, Ibaraki 305-8569, Japan
[c] Tsukuba University, Tsukuba, Ibaraki 305-8572, Japan

Received 31 March 2004; accepted 4 August 2005

Abstract

For applying a model of carbon cycle over geographic grid we have to calibrate it at this scale. A scheme for such calibration was demonstrated earlier and applied to calibrating TsuBiMo with the collection of NPP data selected from Osnabrück database. The scheme includes several steps: (1) reducing the number of undefined model parameters to a single lumped parameter (SLP); (2) finding its value for each database entry; (3) formulating an empirical model linking the SLP and climate; and (4) globalizing the process-based model in hand by assigning SLP values to the nodes of geographical grid proceeding from the global fields of climatic variables. Applying this scheme to calibrate TsuBiMo with the CO_2 fluxes measured at the Takayama site, we derive the empirical model for linking SLP and monthly temperature. We show that the empirical model is suitable for projecting with TsuBiMo inter- and intra-annual changes of GPP and NEP at the Takayama site, which represents the biome of cool-temperate deciduous forests. Finally, we discuss how the empirical model may be adjusted for applying to other biomes.

Keywords: Gross primary production (GPP); Carbon cycle; Net ecosystem production (NEP)

1. Introduction

The Takayama site is a part of the network initiated by International Geosphere–Biosphere Program (IGBP) for coordinating measurements of gas, water and energy exchange between terrestrial ecosystems and the atmosphere. The major purpose of this network (so-called FLUXNET) is to assess net CO_2 uptake of biomes on an annual basis and to quantify year to year differences. Since the measurements cannot adequately characterize all combinations of environmental and climate conditions, the regional and global assessments are presumed to be based on models extrapolating and interpolating measured fluxes in time and space (Valentini et al., 1999).

TsuBiMo (Alexandrov and Oikawa, 2002; Alexandrov et al., 2002) is one of the models that serve the purpose mentioned above. It proceeds from a reference data set (Alexandrov et al., 1999) derived from Osnabrück collection of net primary production (NPP) data and some widely available data sets on climate, solar radiation and a remotely sensed vegetation index. The model attributes the *spatial* gradations in NPP to correspondent gradations in environmental factors averaged over the growing season. Hence, to apply the model for projecting *temporal* changes in NPP, we accept a kind of *ergodic hypothesis*[1] (Karev, 1997; Logofet and Alexandrov, 1984; Southall et al., 2003).

* Corresponding author at: CGER/NIES, Onogawa 16-2, Tsukuba, Ibaraki 305-8506, Japan. Tel.: +81 298 50 2974; fax: +81 298 50 2960.
E-mail address: g.alexandrov@nies.go.jp (G.A. Alexandrov).

[1] Ergodic hypothesis, providing foundation for classical statistical mechanics, was introduced by L. Boltzman in the end of 19th century (Vonplato, 1991). It is also closely related to the probability theory and the theory of dynamical systems.

0168-1923/$ – see front matter
doi:10.1016/j.agrformet.2005.08.012

In reality, the function relating *spatial gradations* in fluxes to environmental factors may differ from the function relating *temporal changes*. The measurements which were carried out at Takayama site by Saigusa et al. (2002) form a collection of data, which is in a statistical sense comparable with the Osnabrück collection, that makes it possible to re-calibrate the model for projecting *temporal* changes in fluxes without taking the ergodic hypothesis, at least in the case of the biome of cool-temperate deciduous forests that the Takayama site represents.

Below we briefly describe the model and explain in detail the method of calibration, then report the results of calibration and illustrate the achieved goodness-of-fit, and finally discuss the domain of the re-calibrated model and how it may be applied for predicting annual NEP along regional and global geographical grids.

2. Method

2.1. Reference data set

We compiled the reference data set, covering the period of three years (1999–2001), by using measured daily values of net ecosystem exchange (NEE), air temperature, PAR above canopy, and fraction of absorbed PAR (FPAR) measured as the ratio of PAR below the tree canopy to that above the tree canopy. The reference data set consists of 1069 records representing a simple 28-term moving average values of daily net ecosystem production (P_e, in $\mathrm{gC\,m^{-2}\,day^{-1}}$), air temperature ($T_d$), day time average PAR flux density above canopy (Q_{PAR}, in $(\mu\mathrm{mol\ PP})\ \mathrm{m^{-2}\,s^{-1}}$), the fraction of PAR absorbed by leaves (f_{PAR}), and day length (D).

The day length was calculated from the day number (Iqbal, 1983):

$$D = \frac{2}{15}\cos^{-1}[-\tan[\phi]\tan[\delta]], \tag{1}$$

where ϕ is latitude, and δ is solar declination

$$\begin{aligned}\delta = {} & 0.006918 - 0.399912\cos[\Gamma] + 0.070257\sin[\Gamma] \\ & - 0.006758\cos[2\Gamma] + 0.000907\sin[2\Gamma] \\ & - 0.002697\cos[3\Gamma] + 0.00148\sin[3\Gamma]\end{aligned} \tag{2}$$

and Γ is day angle

$$\Gamma = 2\pi\frac{\mathrm{DOY} - 1}{365} \tag{3}$$

where DOY stands for ‘day of the year’.

The measured FPAR relates to a tree crown (including non-photosynthetic organs like branches), whereas f_{PAR} relates to the total leaf area of the site, including the understorey formed by dwarf bamboo. Since dwarf bamboo is an evergreen plant, we assume that f_{PAR} is always higher than 0.6, and that

$$f_{PAR} = \begin{cases} \mathrm{FPAR}, & \text{when FPAR} > 0.7 \\ 0.6 + 0.1\left(1 - \cos^{1/4}\left[\pi\dfrac{\mathrm{DOY} - \dfrac{\mathrm{DOY}_1 + \mathrm{DOY}_2}{2}}{\mathrm{DOY}_2 - \mathrm{DOY}_1}\right]\right), & \text{when FPAR} \le 0.7 \end{cases} \tag{4}$$

where DOY_1 is the day (in autumn) when FPAR becomes as low as 0.7 and DOY_2 is the day (in spring) when FPAR becomes as high as 0.7 (Fig. 1). It is worth mentioning, that this formula is not applicable when the understorey is covered by snow.

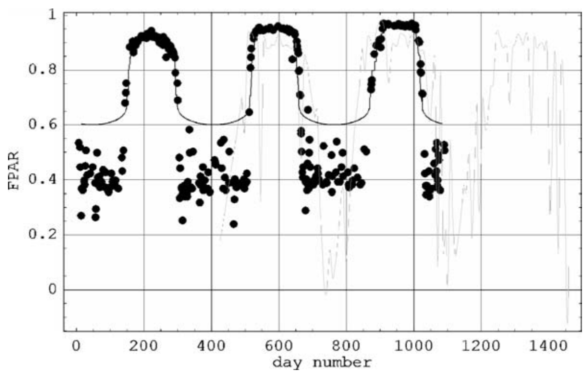

Fig. 1. Fraction of absorbed PAR (FPAR): dots denote the values of FPAR measured in situ which relates to a tree crown (including non-photosynthetic organs like branches), black line shows the course of f_{PAR}, and gray line shows the course of MODIS-FPAR, day number starts from January 1, 1999.