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Midday values of gross CO_2 flux and light use efficiency during satellite overpasses can be used to directly estimate eight-day mean flux

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Abstract

Most satellites provide, at best, a single daily snapshot of vegetation and, at worst, these snapshots may be separated by periods of many days when the ground was obscured by cloud cover. Since vegetation carbon exchange can be very dynamic on diurnal and day-to-day timescales, the limited temporal resolution of satellite data is a potential limitation in the use of these data

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to estimate integrated CO_2 exchange between vegetation and the atmosphere. Our objective in this study was to determine whether consistent relationships exist between midday carbon flux on clear days and daily or 8-day mean values. CO_2 flux data were obtained from eight sites, covering a wide range of vegetation types, which are part of the AmeriFlux system. Midday gross CO_2 exchange was highly correlated with both daily and 8-day mean gross CO_2 exchange and these relationships were consistent across all the vegetation types. In addition, it did not make any difference whether the midday data were derived from the AM or PM satellite overpass times, indicating that midday depression of photosynthesis was not a significant factor in these relationships. Inclusion of cloudy days in the 8-day means also did not affect the relationships relative to single clear days. Although there was a relationship between photosynthetic rates and photosynthetically active radiation (PAR) for half hour data, this relationship tended to saturate at PAR values less than half of full sun and for many of the sites the relationship between daily total photosynthesis and PAR was very weak. Consequently, cloudy conditions had less effect on daily gross CO_2 exchange than would have been expected. Conversely, the saturation of photosynthesis at moderate PAR values resulted in considerable variation in light use efficiency (LUE). LUE was higher for daily and 8-day means than it was at midday on clear days and the correlation between midday and 8-day mean LUE was relatively weak. Although these results suggest that it may not be possible to estimate 8-day mean LUE reliably from satellite data, LUE models may still be useful for estimation of midday values of gross CO_2 exchange which could then be related to longer term means of CO_2 exchange.

Keywords: Carbon uptake; Natural ecosystems; Eddy correlation; PAR; Remote sensing

1. Introduction

Satellite data are increasingly being used to estimate carbon exchange between the vegetation and the atmosphere at regional and global scales (Sellers et al., 1995; Ruimy et al., 1996a; Running et al., 2004). A limitation of satellite data, however, is that they provide only a snapshot in time, generally once a day around midday. In addition, cloud cover results in many missing days of data. Consequently, it is necessary to develop models that predict integrated carbon exchange from these infrequent snapshots. Most such models use satellite data to estimate leaf area index (LAI) and/or the fraction of incident photosynthetically active radiation absorbed by green plants (f_{par}, Myneni et al., 2002) and then estimate carbon exchange from physiological or light use efficiency (LUE, Monteith, 1972) models.

Although LUE is generally estimated either from lookup tables based on vegetation type or from physiological models, recent studies have suggested that it can also be estimated directly from spectral reflectance indices. Of primary interest has been the photochemical reflectance index (PRI, Gamon et al., 1992) that has been shown to correlate with LUE at leaf (Gamon et al., 1992, 1997; Peñuelas et al., 1995, 1998), canopy (Gamon et al., 1992, 2001; Filella et al., 1996; Stylinski et al., 2002; Trotter et al., 2002), stand (Nichol et al., 2000, 2002; Rahman et al., 2001; Strachan et al., 2002) and landscape (Rahman et al., 2004) levels. However, since both LUE and PRI are dynamic (PRI can change rapidly, on the order of 10–30 min, in response to changing environmental conditions, Gamon et al. (1992), estimates of LUE based on a single midday snapshot on clear days may not be representative of the diurnal variation in LUE or of its value on cloudy days. Because of the tendency of photosynthetic processes to saturate at high light intensities, LUE is generally higher at low light intensities. Consequently, LUE is higher early and late in the day, as well as on cloudy days, relative to midday on clear days. LUE may also decline as a result of midday depression of photosynthesis resulting from water limitation or other stresses (Larson et al., 1981; Roessler and Monson, 1985; Hirasawa and Hsiao, 1999; Franco and Lüttge, 2002).

Our objective in this study was to examine the extent to which midday values (corresponding to satellite overpass times) of net and gross carbon uptake, as well as midday LUE, are correlated with daily-integrated values of the same variables. To the extent that such correlations exist, and are consistent across vegetation types, midday values estimated from satellite spectral reflectance data could be used to estimate integrated daily totals without the need of more complex models. We also examined the correlations between midday values and 8-day means that included both clear and cloudy days. The 8-day time-period was chosen since