

VARIABILITY OF ENERGY VAPOR AND CO₂ EXCHANGE OVER
TWO MIDWESTERN DECIDUOUS FORESTS

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1. INTRODUCTION

Fluxes of CO₂, H₂O, and energy are measured on 46 m towers at two AmeriFlux sites in Indiana (MMSF) and Michigan (UMBS). Turbulent fluxes are obtained by eddy-covariance, using 3-d sonic anemometers in conjunction with closed-path infrared gas analyzers. The experimental set-up, instrumentation, data processing and analysis are very similar between the two sites (for details, see Schmid *et al.* 2000a,b). However, there are distinct differences in their geographic and climatic setting. Here we compare the seasonal variations of carbon dioxide, energy and vapor fluxes between the two sites for 1999. Differences in net ecosystem exchange of CO₂ are discussed in terms of the energy and water regimes of the two sites. For the MMSF site, the results for 1999 will also be compared to those of 1998. The period from August to the end of November of 1999 was classified as a severe drought in the eastern United States. It is found that this drought had a strong influence on energy partitioning, by reducing evapotranspiration, but did not seriously affect carbon exchange and sequestration.

Morgan Monroe State Forest (MMSF), located in South Central Indiana (39° 19' N 86° 25' W), is an extensive managed secondary successional broadleaf forest (in the maple-beech to oak-hickory transition zone), with a wide variety of tree species present (Grimmond *et al.*, 2000; Schmid *et al.*, 2000a). The mean canopy height of the forest is 26-27 m. Vegetation (leaf and bole) area index (VAI) for 1998 reached a maximum of 4.7 ± 0.5 ; in 1999 the value was slightly higher, 5.1 ± 0.7 .

The other site, at the University of Michigan Biological Station (UMBS, 45°35' N, 84°42' W) lies in the north of Michigan's lower peninsula in a northern hardwood forest dominated by only five species and a mean Canopy height of 22-23 m (Schmid *et al.*, 2000b; Su *et al.*, 2000). The maximum VAI for 1999 at UMBS was 3.9 ± 0.1 m.

2. ENERGY PARTITIONING

Much of the turbulent exchange of heat, vapor and CO₂ is driven or controlled by the vegetative status of the forest at these sites. The partitioning of daytime available energy into sensible heat (H) or latent heat (LE) shows seasonal variations that are closely related

to the phenology of the forests (Figure 1). During winter and early spring before leaf out, about 80% of the available energy is converted to sensible heat. In spring, the daily maxima of H rise with the increasing radiation, but this trend is abruptly reversed within a few days after bud-break. Once the foliage has fully emerged, up to 80% of the available energy is used for evapotranspiration.

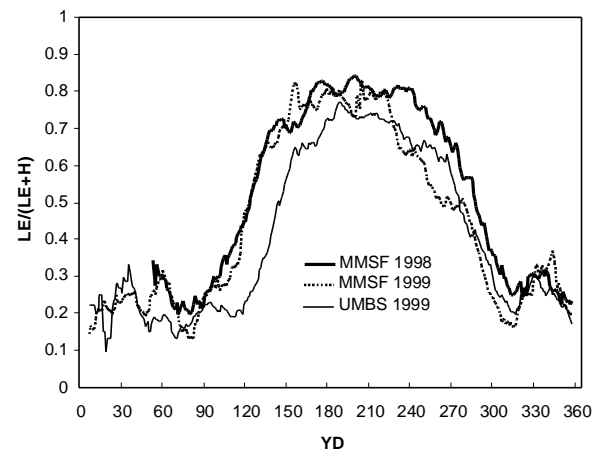


Figure 1: Daytime energy partitioning into latent and sensible heat at MMSF (1998, 1999) and UMBS (1999). The lines are moving averages over 15 days. The drought at MMSF between YD 99/220-270 reduced the evaporative energy use by 25% compared to the previous year.

At MMSF, this transition started in early April in both reported years and was nearly complete by the end of May (YD ~ 90 to 150). At UMBS bud break occurred more than a month later in 1999 (after YD 120), but was also nearly complete by late May. With the lower overall VAI at UMBS, the dominance of latent over sensible heat transfer is not as strong as at MMSF in mid summer. In 1998, LE was dominant until almost the end of October at MMSF, when the foliage started to drop. The region around the MMSF site experienced a severe drought with only traces of precipitation between August and October of 1999. As a result, the ratio of LE/(LE+H) started to drop steeply at the beginning of August (YD 99/213) and went below 0.5 in early October, much earlier than leaf fall for that year. The more northern region of UMBS was not as much affected by this drought. The latent heat fraction starts to drop in early October, synchronous with the phenological fall date. It is interesting that this drought in the lower Midwest did

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not appear to have a detectable effect on carbon sequestration, despite its marked influence on evapotranspiration (see below).

3. VAPOR FLUXES

The mean daily course of vapor fluxes for May and August is shown in terms of latent heat transfer in Figure 2. In the upper panel (a) the two years of 1998/99 are compared for MMSF. While the fluxes were very similar between the years in May, the 1999 daily maxima in August did not reach the high values of the corresponding curve for 1998. It appears that the ecosystem reacted to water stress just before solar noon and maintained a reduced transpiration regime throughout the afternoon. No sign of water stress is noticeable in the morning hours.

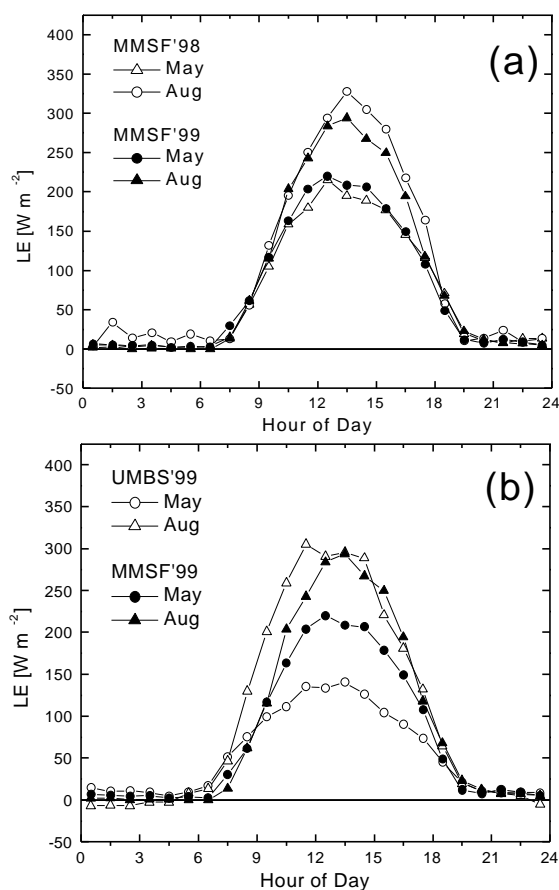


Figure 2: Monthly mean diurnal courses of latent heat fluxes at MMSF (1998, 1999) and UMBS (1999). (a) Spring of 1999 had very similar evaporation to 1998, but in August, the drought of 1999 causes a significant reduction. (b) In May 1999, the vegetation at MMSF is further advanced and transpiration is active; in August, the longer day at the northern UMBS increases daily evaporation over that at MMSF.

Panel (b) of Figure 2 compares latent heat transfer between UMBS and MMSF for May and August. In May,

LE at UMBS is still low. In August, the daily maxima are similar for both sites, but the longer day period at UMBS is expressed by a broader peak in evaporation.

4. CARBON EXCHANGE

The cumulative net ecosystem exchange of carbon (NEE) for the reported periods is shown in Figure 3. Although the drought in late summer of 1999 affected the vapor regime of the forest strongly, no effect on carbon sequestration can be detected. The net uptake rates during the vegetative season are remarkably similar for both years and sites. Differences in net carbon release during winter reflect the colder climate at UMBS and the colder winter of 1999 compared to 1998. The most important control on carbon sequestration appears to be the length of the period over which the forest is a net carbon sink, i.e., the length of the vegetative period.

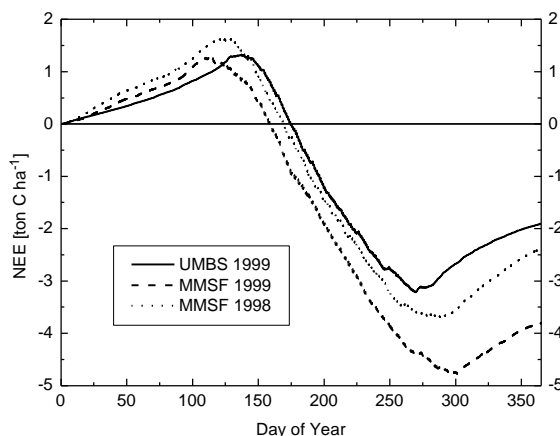


Figure 3: Annual net ecosystem exchange of CO_2 at MMSF (1998, 1999) and UMBS (1999). The annual CO_2 sequestration is strongly related to the length of the growing season.

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