THE MICROMETEOROLOGY OF CENTRAL AMAZONIAN RANCHLAND IN THE 1990 DRY SEASON

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ABSTRACT

This paper presents the first comprehensive micrometeorological measurements to be recorded over post-deforestation Amazonian ranchland. The ranch was managed for the production of beef cattle and had been created by felling and burning the original rainforest 12 years previously. The measurements allow derivation of the aerodynamic roughness, and a description of the response of the energy balance and surface conductance to the progressing dry season. Zero plane displacement and roughness length were derived from windspeed profiles as 0,17 ∓ 0,03 m and 0,26 ∓ 0,03 m, respectively, while measurement of energy partition was achieved, with excellent agreement between three independent systems. During the 1990 dry season average evaporation diminished from 3,8 to 2,1 mm d^{-1} as the Bowen ratio increased from 0,43 to 0,67. Values of surface conductance were derived and these compare well with expected trends.

1. INTRODUCTION

The data presented here were collected as part of the ABRACOS project, at a typical central Amazonian cattle ranch created by clearing the original rainforest. The ensuing description could be taken as at least typical of the complex pattern of pasture and secondary regrowth that would remain in Amazonia if deforestation continues unabated.

2. SITE AND INSTRUMENTATION

The site was located on a typical cattle ranch, Fazenda Dimona about 100 km north of Manaus, Amazonas (2° 19'S, 60° 19'W). During the period of data collection the grass height was measured as 28 cm and covered 85% of the ground surface. The pasture extended for at least 2 km in most directions , while the fetch extended not less than 900 m.

Anemometers and aspirated psychrometers were mounted at six levels, logarithmically spaced from 0,5 m to 9,0 m, on a sectional alloy tower. Measurements of net all-wave radiation were made from a height of 9,0 m.

The latent and sensible heat fluxes measurements were made using the Institute of Hydrology eddy correlation device (Hydra), and calculated using the Bowen ratio method from the gradient data provided by both the profile tower and Campbell Scientific (CLS) systems. Hourly rainfall was measured with a 0,2 mm tipping bucket raingauge. A full description of the site and instrumentation is given in Wright et al. (1992).

3. RESULTS

Data were recorded for the 50 day period from 15 September to 3 November 1990. At that time there occurred a series of mostly dry days in which evaporation greatly exceeded rainfall, allowing a substantive soil moisture deficit to develop. This dry period lasted for 20 days following a large storm on 3 October and was only interrupted by a single storm of 5,2 mm on 10 October.

Zero plane displacement, d, and roughness length, z_0, were evaluated using windspeed profile equations for neutral stability and gave values of d= 0,17 m and z_0= 0,026 m.

Figure 1 shows the four components of the energy balance for two periods having contrasting soil moisture status and Table 1 gives the total daily energy for each component with the percentage of available energy, (Rn - G) apportioned to the two outgoing fluxes, H and λE.

Table 1 - Daily totals of energy components for four sample days: net radiation, *Rn*, soil heat flux, *G*, evaporation, *λE*, sensible heat flux, *H*, in *MJ* m^{-2}.

Days	Days since rain	*Rn*	*G*	*λE*	*H*
5 Oct 90	2	14,2	0,3	10,1 (72)	3,8 (28)
6 Oct 90	3	13,9	0,6	9,7 (73)	3,5 (27)
20 Oct 90	17	11,7	0,7	6,1 (55)	5,0 (45)
21 Oct 90	18	9,5	0,4	4,8 (53)	4,3 (47)

Figures in brackets show the evaporation and heat fluxes values as percentages of the total available energy (*Rn - G*)

A continuous record of evaporation has been constructed by combining the results from all available systems in which priority was given to evaporation deduced from the profile tower measurements on the grounds.

Figure 2 shows the latent and sensible heat fluxes and available energy, (Rn - G), for the 35 days for which complete data are available (including rainfall). In the first ten days, evaporation was typically 3,8 mm d^{-1}, (3,3 to 4,1 mm d^{-1}), and consuming on average 70% of the available energy, with a mean Bowen ratio of 0,43. Nineteen days after this storm the evaporation had diminished to 1,7 mm d^{-1}, (52% of the available energy and equivalent to a Bowen ratio of 0,96). For the remainder of the measurement period, during which 6,6 mm of rain fell, evaporation seldom exceeded 3 mm d^{-1}. Mean evaporation through this 12 day period was 2,1 mm d^{-1} with a mean Bowen ratio of 0,67. The concurrent small storms were clearly insufficient to redress the deficit of soil moisture and the available water, see Fig. 2.

By contrast to these changes in evaporation, sensible heat flux shows no apparent response to soil moisture stress or rainfall, partly explained by the increasing cloudiness, evident in the decreasing available energy. Therefore, as the evaporation decreases and the Bowen ratio increases, the sensible heat flux remains relatively constant because of the consistent and coincident reduction in available energy.

Bulk surface conductance, g_s, was calculated from an inverted form of the Penman-Monteith equation, while the aerodynamic conductance, g_a, was calculated for daylight hours where it was allowed for effects of stability and the different source and sink heights of water vapour and momentum (Verma 1989). Figure 3 shows the hourly values of surface conductance for the four sample days considered previously. There is a marked decrease in the conductance during the early hours of each day, almost certainly a result of dew evaporating from the vegetation and soil. The conductance then remains relatively constant, falling only slightly through the day until a further more rapid fall occurs during the last few hours of daylight. There is also a marked reduction in overall conductance after the 20 days of progressive soil moisture depletion.

4. DISCUSSION

Figure 4 shows the measured evaporation compared with estimates of modelled transpiration using a surface conductance model (Dolman et al., 1991) for the nearby (80 km) primary rainforest, previously calibrated at the same forest site. Bastable et al. (1992) showed that the rainfall patterns at the two sites are similar for the period.

Using recent models of forest conductance dependent on available soil moisture (Rowntree, 1991), and assuming pessimistic values of rooting depth (1,5 m), evaporation (4,5 mm d^{-1}) and soil moisture saturation and wilting point volume (0,46 and 0,18), it is easily shown that transpiration is likely to proceed from rainforest unimpeded by soil moisture deficit for twice the period shown here.

Of particular interest is the similarity between the evaporation characteristics at this site in the first ten days after the storm of 3/10/90 (see Fig. 1), and those modelled and measured at the nearby rainforest. The reported measurements of Shuttleworth et al. (1984) of evaporation showed broadly similar seasonal conditions to the data presented here, and representative of the end of the central Amazonian wet season. The mean daily evaporation was 3,5 mm d^{-1}, ranging from 1,75 to 4,23 mm d^{-1}, which compares well with the measured and modelled values shown in Fig. 4.

After normalization to available energy, (Rn - G), the modelled evaporation ratios from the forest, equivalent to $(1+\beta)^{-1}$, are very similar to the ratios for the ranchland grass during this period, see Fig. 5. This suggests that the numerical differences in evaporation during this initial period are mostly attributable to differences in net radiation, and therefore to differences in the albedo and mean surface temperature. Furthermore the similarity in evaporation ratios between sites suggests that the lower combined conductivities associated with the ranchland are compensated forby the higher humidity deficits (Bastable et al. 1992). As well, the effect of soil moisture stress after the wet period in the absence of rainfall shows a rapid divergence in the proportion of energy used for evaporation by forests on the one hand, and pasture land on the other.

Surface conductance calculated from these data represents the whole-canopy value including evaporation from both the vegetation and the soil. The large early morning conductances at this site are probably due to the evaporation of dew (Bastable et al. 1992) and perhaps, to a lesser extent, the contribution of the soil surface which may recover some of its moisture deficit overnight.

5. CONCLUSIONS

The data presented here provide a first description of the energy balance of the pasture land typically introduced with Amazonian forest clearance, and in particular the aerodynamic and surface controls which determine its evaporation rate. On the basis of the data presented, the evaporation rate during the dry season is likely to be significantly different from that of the original forest. The observed evaporation rate after substantial rainfall is comparable to the transpiration rate from virgin forest, however, once the superficially available water has been consumed, evaporation diminishes, and the response to soil moisture deficit is rapid.

The climatic effect of deforestation given by Nobre et al. (1991) predicts increase severity of the dry season, both through increased persistence of the season and reduced rainfall during it. Intuitively, the results given here would indeed increase in severity, since the amount of water vapour returned to the atmosphere is rapidly reduced during these grassland rooting depth.

6. REFERENCES

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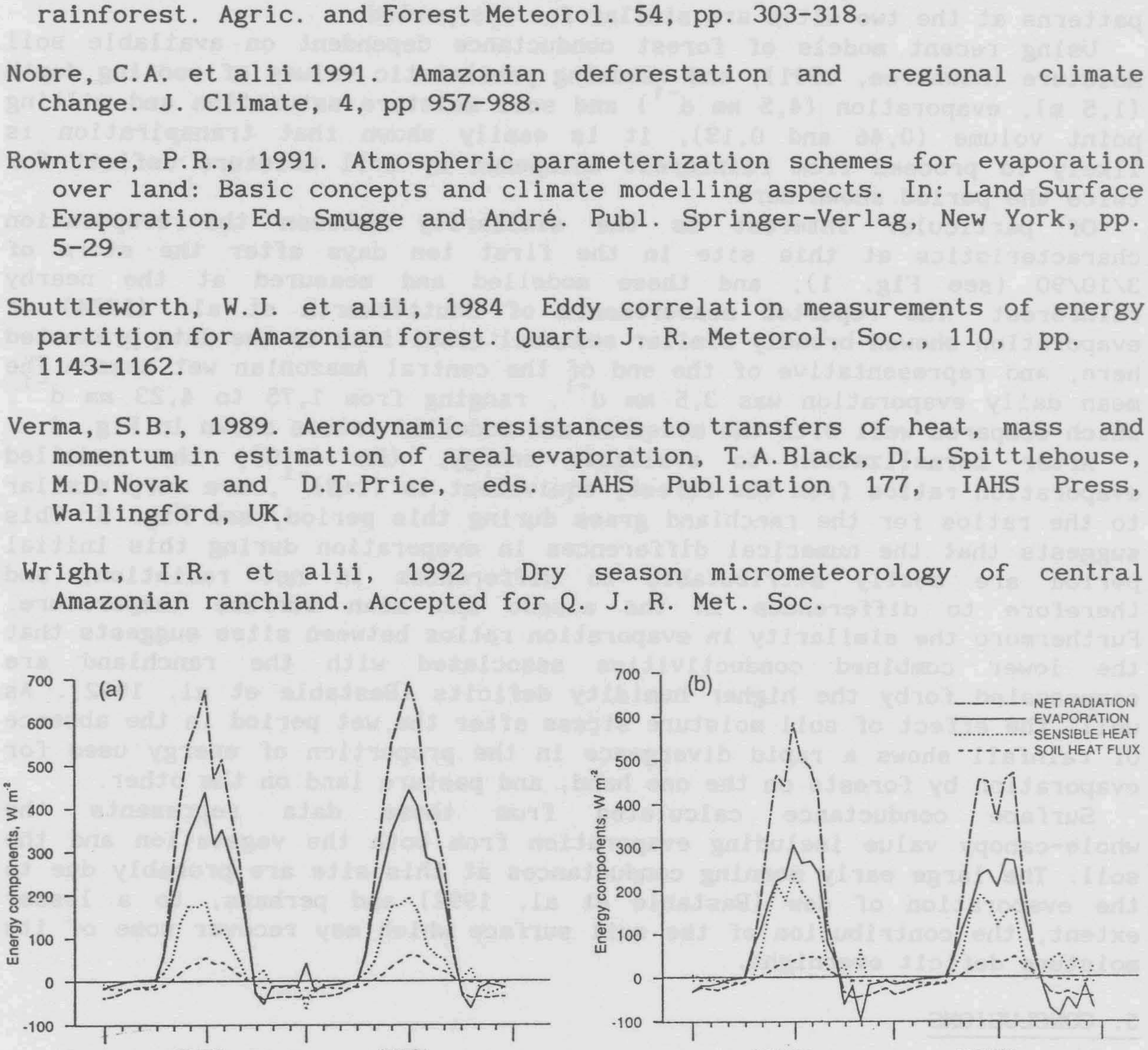

Fig. 1. Surface energy components for periods representing (a) low and (b) substantial soil moisture stress ($W.m^{-2}$).

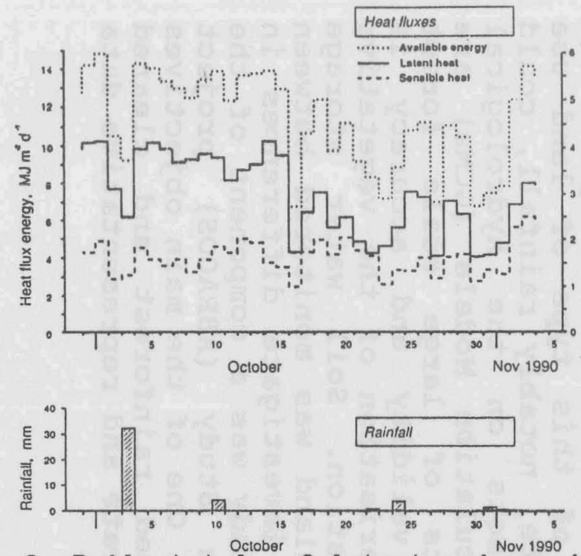

Fig. 2. Daily totals of latent and sensible heat flux, available energy and rainfall for the period of complete data recovery ($W.m^{-2}$).

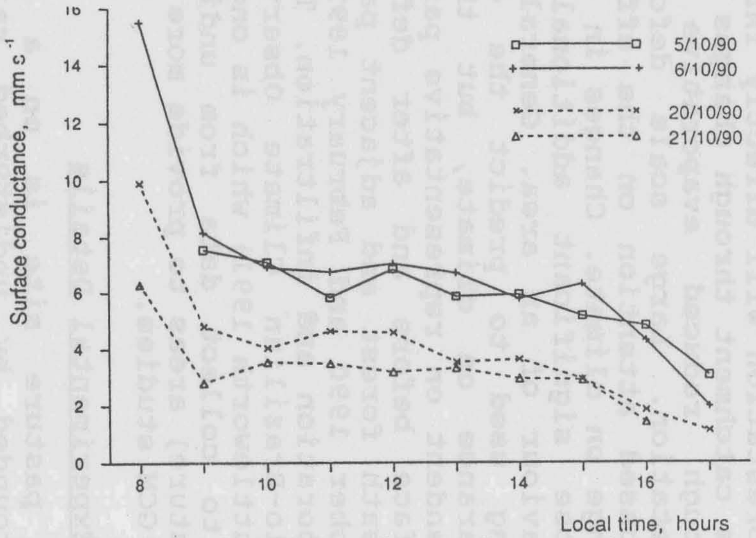

Fig. 3. Calculated hourly surface conductances for four days having contrasting soil moisture stress ($mm.s^{-1}$).

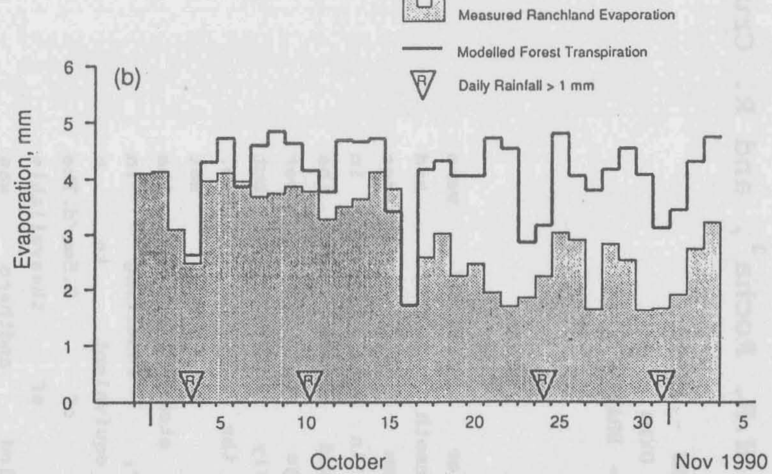

Fig. 4. Measured ranchland evaporation compared with modelled evaporation from the nearby undisturbed forest ($W.m^{-2}$).

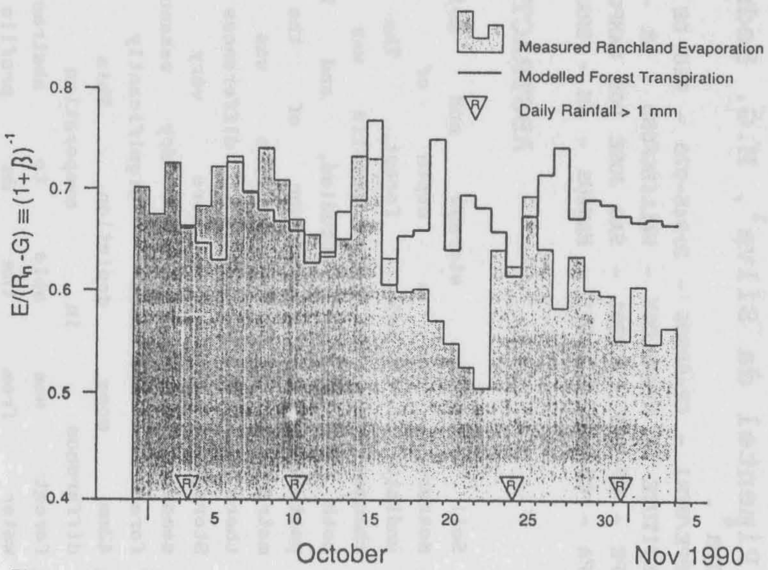

Fig. 5. Evaporation as ratio upon net radiation for pastureland and forest sites.