Amazonian surface fluxes and boundary layer development: results from ABRACOS and prospects for LBA.

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Introduction

The Anglo-Brazilian Amazonian Climate Observation Study, ABRACOS, had the objective of improving the representation of Amazonia in Global Circulation Models by collecting field data for calibrating land surface models and for validating the GCM predictions of present climate. Comparative measurements of climate and soil moisture were made at three forest and pasture sites in Amazonia: near Manaus in central Amazonia; near Marabá in south-eastern Amazonia; and near Ji-Paraná in south-western Amazonia (Gash *et al.*, 1996; Gash and Nobre, 1997). These latter two sites are close to the margins of the rainforest zone and have a pronounced dry season. Evaporation and sensible heat flux were measured at the pasture site near Manaus (Wright et al., 1992) and over the pasture and forest sites near Ji-Paraná in Rondônia (Wright *et al.*, 1995; 1996). Carbon dioxide fluxes were also measured at the Ji-Paraná sites (Grace *et al.*, 1995a; 1995b; Grace *et al.*, 1998). Boundary layer development was measured over pasture and forest during the Rondonia Boundary Layer Experiment in Ji-Paraná (Nobre *et al.*, 1996). The data from ABRACOS are freely available (Gash and Nobre, 1997).

Comparison of observed climate with GCM predictions

The climate measured at the three ABRACOS sites was compared with the average climate predicted by the ECMWF, Hadley Centre and LMD GCMs (Culf, *et al.*, 1998). Large differences were found between the model predictions and the measurements: for example, on average the Hadley Centre model over predicted net radiation by 18 per cent and the LMD model by 25 per cent. On the other hand the ECMWF model underpredicted net radiation by 14 per cent. However, these figures hide larger differences which occur between sites and seasons. Much of these differences can be attributed to the models' predictions of cloudiness.

Albedo

Albedo was measured at all the forest sites. The overall mean albedo was 13 per cent, but a seasonal trend was observed with higher albedos being found during the dry season than during the wet season (Culf, *et al.*, 1995; 1996). This seasonal fluctuation amounted to 1 per cent of the incoming solar radiation.

Forest transpiration

The evaporation measurements (Wright et al., 1992, 1995, 1996a) have shown that, in the dry season, the shallower rooting depth of the pasture leads to a reduction in the evaporation in response to the development of a soil moisture deficit. In contrast the deeper rooting depth of the forest allows the evaporation to continue throughout the dry season, with as yet, no reduction in evaporation being observed (Hodnett et al., 1996, Wright et al., 1996a). Figure 1 shows the both the evaporation and the soil moisture content measured in the Reserva Jaru Forest in Rondônia. The measurements were taken in the first part of the dry season and show no reduction in evaporation or rate of depletion of soil moisture as the dry season progresses. Evaporation was not measured during the second half of the dry season, but the soil moisture continued to decline for the whole of the dry season. Although recent results from forest near Manaus do suggest a reduction in peak transpiration rates may occur during the dry season (Mahli *et al.*, 1998). The overall picture is that forest transpiration does not have a major responce to soil moisture deficit. Indeed, it appears that for rainforest to occur there must be

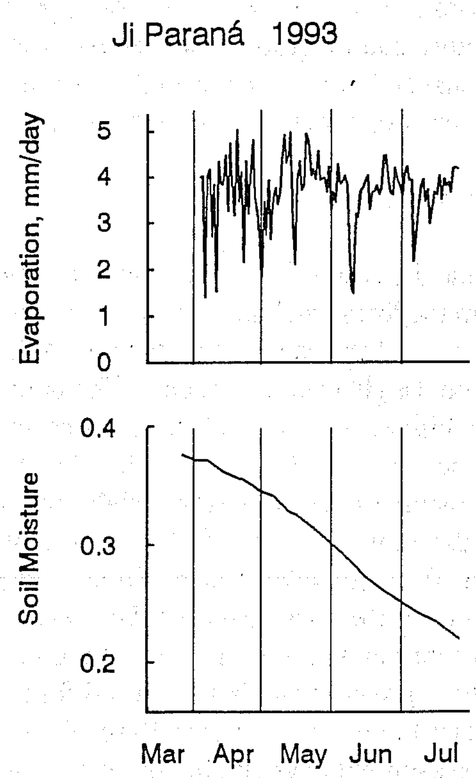

Figure 1:The evaporation from Reserva Jaru Forest during the dry season and the soil moisture (volume fraction) in the top 3.6 m of soil.

a) sufficient water available in the soil to allow the forest to continue transpiring without water stress through the driest dry season

and

b) sufficient rainfall during the wet season to allow transpiration during that season, as well as to rewet the soil profile sufficiently to support transpiration the following dry season.

Where these conditions do not apply and the rainfall is too low, or the soil is either too shallow or its water holding capacity too low, forest becomes susceptible to fire and gives way to savanna vegetation. Application of a simple evaporation model to the 27 year rainfall record from Manaus (Hodnett *et al.*, 1996) predicted a soil moisture deficit of 341 mm would have occurred in the driest year. The water holding capacity of the soil near Manaus is low and this deficit would require roots down to a depth of 11 m. This prediction is supported by observations of roots at these depths (Nepstad *et al.*, 1994).

Carbon dioxide

Carbon dioxide fluxes measured during a campaign at the Ji-Paraná site showed the forest to be a systematic sink of carbon (Grace *et al.*, 1995a; 1995b). However model predictions used to extrapolate this result to longer time scales show great sensitivity to temperature and radiation. There is also some doubt about measurements made during low windspeed conditions at night. Further measurements have been at a site in the Manaus region, which also show the forest to be a sink of CO_2 (Mahli *et al.*, 1998)

The atmospheric boundary layer

During the dry season in Ji-Paraná the sensible heat flux from the pasture is greater than that from the forest, and measurements during the Rondonia Boundary Layer Experiment (Nobre *et al.*, 1996) showed that the atmospheric boundary layer grew more rapidly and to a greater height over the pasture. The boundary layer was found to grow some 700 to 1000 m higher over the deforested area than over the forest, with particularly rapid growth between 08:00 and 11:00 hrs. Fisch *et al.* (1996) modelled the boundary layer growth using a one-dimensional slab model but failed to reproduce the rapid growth during the morning. Fisch (1996) postulated that organized meso-scale circulations resulting from juxtaposition of forest and pasture may perhaps lead to more rapid breakdown of the nocturnal boundary layer. Alternatively, over the deforested land the strips of forest and pasture may combine to produce a surface with a high area average roughness - greater than that specified for the simple pasture used in the modeling.
The greater boundary layer growth results in greater cloudiness over the pasture during the dry season with systematically less solar radiation being observed at the surface in the pasture than above the forest (Culf *et al.*, 1996).

LBA

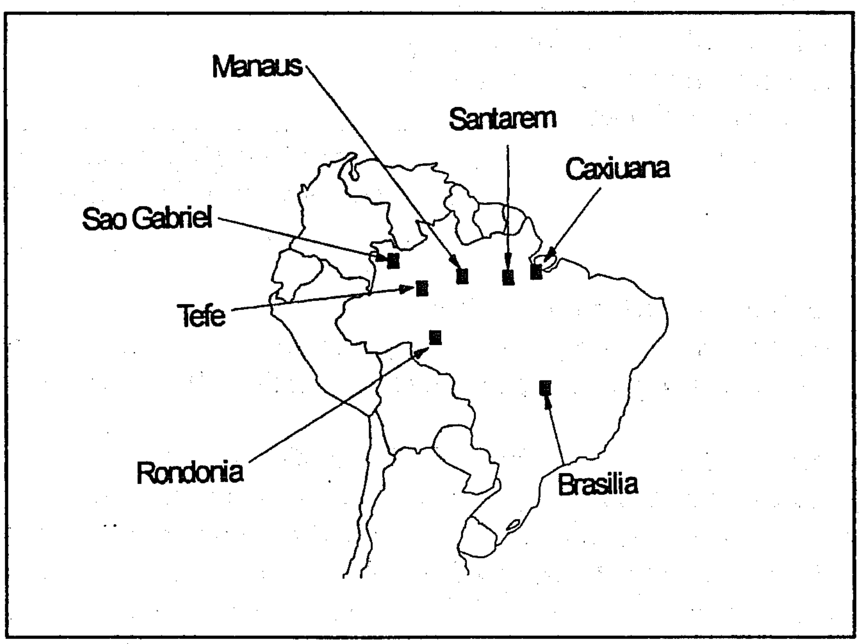

Figure 2: The planned location of LBA sites.

The Large-Scale Biosphere-Atmosphere Experiment in Amazonia - LBA - is an international experiment led by Brazil. LBA questions how Amazonia functions as a regional entity and how this behaviour may change in the future (for further details see Nobre *et al.*, 1996). The physical climate and hydrology components of LBA will collect and model data across a range of space and time scales. Surface fluxes of evaporation and carbon dioxide will be measured at some eight or nine sites, with emphasis on continuous measurements for periods of at least two years. The sites, shown in Figure 2, will range from the dry cerrado vegetation found near Brasília, on the edge of the Amazon Basin, to the very wet climate of the north-west of Amazonia, where there is high rainfall and relatively little seasonal variation. Two atmospheric meso-scale campaigns are planned for the region around Ji-Paraná: a wet season campaign planned for January to March 1999, and a dry season campaign planned for July and August 2000. The wet season campaign will take place in parallel with a TRMM (tropical rainfall) satellite validation mission (LBA-TRMM) and will include rainfall radar and high flying aircraft, as well radiosonde ascents from multiple sites.

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