Institute of Hydrology

Overseas Development Report

Natural Environment Research Council

(First draft prior to revision by INPE)

ANGLO-BRAZILIAN AMAZONIAN CLIMATE PROJECT

(proposed September 1990, as "Anglo-Brazilian Amazonian Climate Observation Study" [ABRACOS])

Interim Report No 6
(1 July 1992 - 31 December 1992)

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Contents

1. Summary

1.1 PROGRESS IN THE PERIOD 1 JULY 1992 TO 31 DECEMBER 1992

(a) A major field campaign (Mission 3) has been successfully completed at the new sites in Ji-Parana, Rondonia. Simultaneous measurements of evaporation have been made above forest and cleared grassland, coupled with intensive plant physiological, soil and interception measurements.

(b) Mission 3 also included a successful collaboration with teams measuring Carbon fluxes and boundary layer development.

(c) The routine collection of climate and soil data has continued at the three pairs of sites across Amazonia.

(d) Further plant physiological data have been collected at the Maraba site during Mission 3 and in shorter periods outside the mission.

(e) The training programme has continued with further productive visits to IH by Brazilian scientists.

(f) English language training of Brazilian participants is now underway.

1.2 PROBLEMS

(a) There have been continuing minor problems in keeping the Landrovers roadworthy. The Landrover in Manaus has required an engine replacement.

(b) Lightening strikes on automatic weather stations and other minor instrumental problems have resulted in the loss of some climate data.

1.3 PLANS FOR THE NEXT SIX MONTHS INCLUDE:

(a) Missions 4 and 5: intensive measurements at Ji-Parana

(b) Additional soil moisture measurements at Fazenda Dimona (Manaus)

(c) Further plant physiological measurements in Maraba

(d) A planning and analysis coordination meeting will held at INPE in early February.

2. Scientific Progress

2.1 CLIMATOLOGY AND MICROMETEOROLOGY

Although the last six months have been dominated by the successful operation of the third data mission, all of the continuously monitored automatic weather stations have been maintained in good condition, and in most cases have returned data reliably. Problems encountered during the period have been due to lightening and aging of equipment that has been in continuous use since the beginning of the project.

2.1.1 Automatic Weather Stations (AWSs)

A very effective system for AWS maintenance and communication by the Brazilian scientists located near the field sites is now in place for the three principle locations within Amazonia. Also a system is now in place whereby an experienced scientist or engineer from INPE can visit any site to tackle more complex problems. In this way most faults are remedied within a few weeks of being identified.

Most of the seven AWSs have returned continuous data. The Manaus and Marabá sites have both suffered from lightning strikes, disabling the loggers and creating unavoidable gaps in the data. Some of the data retrieval hardware has failed unexpectedly after two or more years of duty, creating some smaller periods of missing data.

Satellite transmission of data has been held up during the year by unreliable receiving computers. Much of these problems have now been resolved, although not all stations are communicating successfully for a variety of technical reasons. Notwithstanding these problems, the transmitted data are now in use in UK and Brazil for rapid identification of faults and storm observations for the interception experiment.

A substantial AWS database is now accumulating and being distributed to collaborating institutions in Brazil. As a direct result many papers, presentations and reports are beginning to appear (see Section 3).

2.1.2 Micrometeorology

The objective of the micrometeorology studies within the third data mission during the 1992 dry season was to install the instrumentation at the new site in Rondonia and record the surface energy balance before and beyond the first rain of the wet season. Also the measurement systems were kept running for the benefit of additional research initiatives at the forest and pasture sites. These initiatives were:

a) free and tethered balloon measurements of the boundary layer profile over the forest by a Brazilian team co-ordinated by INPE

b) the measurement of carbon dioxide fluxes at the forest and pasture sites by a group from Edinburgh University, operating under the NERC TIGER programme.

Notwithstanding the difficulties of working at a new location with difficult logistical problems, the main objectives of the mission were achieved.

Heat and evaporation fluxes were recorded at the forest and pasture sites for 12 and 8 days respectively before the first rain fell at each site. The end of the dry season at each site was well marked by storms of 28 mm on 20/8/92 and 12 mm on 18-19/8/92 at the forest and pasture sites respectively. Measurements were recorded for a total of 51 days in the pasture until 30/9/92 and for 56 days over the forest until 3/10/92. These forest flux measurements, using the Institute of Hydrology 'Hydra' eddy correlation device, are the first such measurements since the original collaborative initiative in Manaus in 1983.

Preliminary results are shown in Figures 2.1.1 - 2.1.3. Figure 2.1.1 shows the division of energy between heat and evaporation before the first rain fell. The forest and pasture energy balances are clearly different, with much greater evaporation and reduced heating of the air over the forest. In the pasture, as was shown in our previous measurements for pasture near Manaus, the reduced availability of water suppresses evaporation and directs more energy to heating the air. After several storms (Fig. 2.1.2) the differences are considerably reduced, but evaporation is still greater over the forest. The overall trend in this process is shown in Fig. 2.1.3 which shows the variation of the Bowen ratio (the ratio of the energies going to heat and evaporation) against time. The response of the pasture to the end of the dry season is very much more evident than for the forest. It is of particular interest that within these data there is no obvious difference in Bowen ratio for the forest between the dry and wet periods.

Edinburgh University were successful in gaining much valuable Carbon flux data. A meeting was held at Wallingford in November at which preliminary results were compared.

2.1.3 Interception

A new experiment was initiated to measure the water loss from tropical forest by the evaporation of freely available rainwater during and after storms (interception). The procedure is to collect and measure the water that falls to the forest floor during storms and compare this with the rainfall above the forest canopy. Sites were constructed at the Rondonia and Marabá forests. These sites have been recording data since August and October 1992 respectively. The collected water is also being analyzed by Brazilian scientists from CENA for its isotope composition.

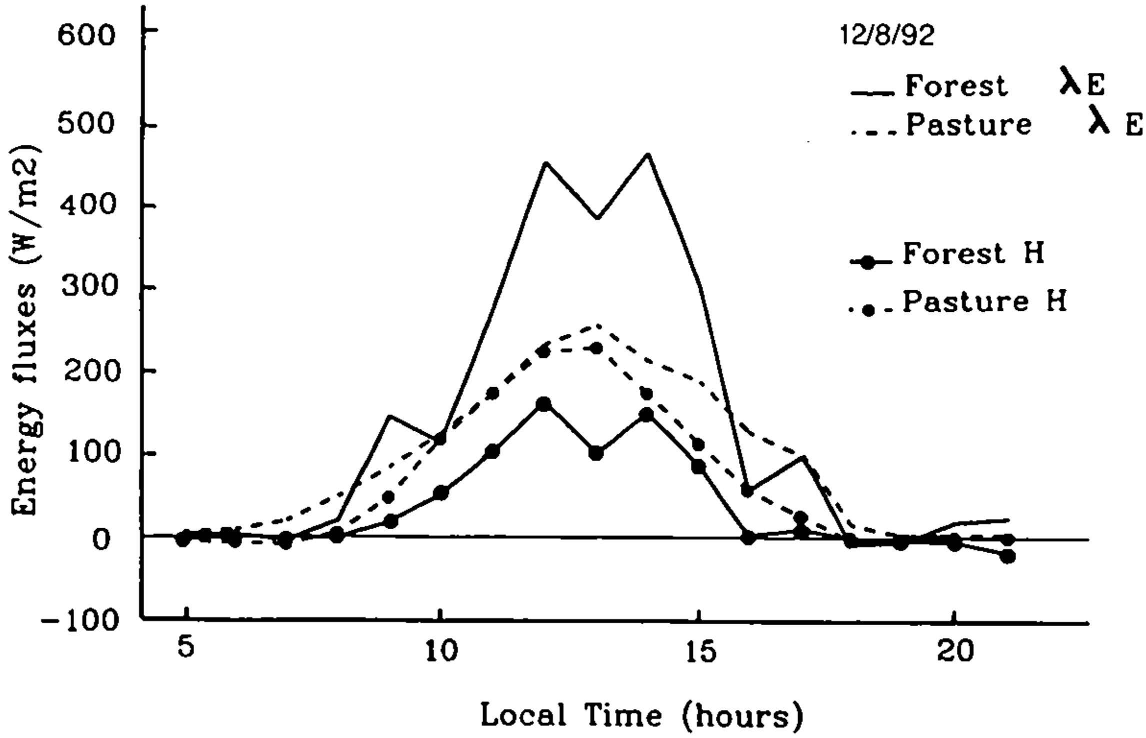


Fig. 2.1.1. Energy balance of Ji-Parana forest and pasture sites at the end of the dry season.

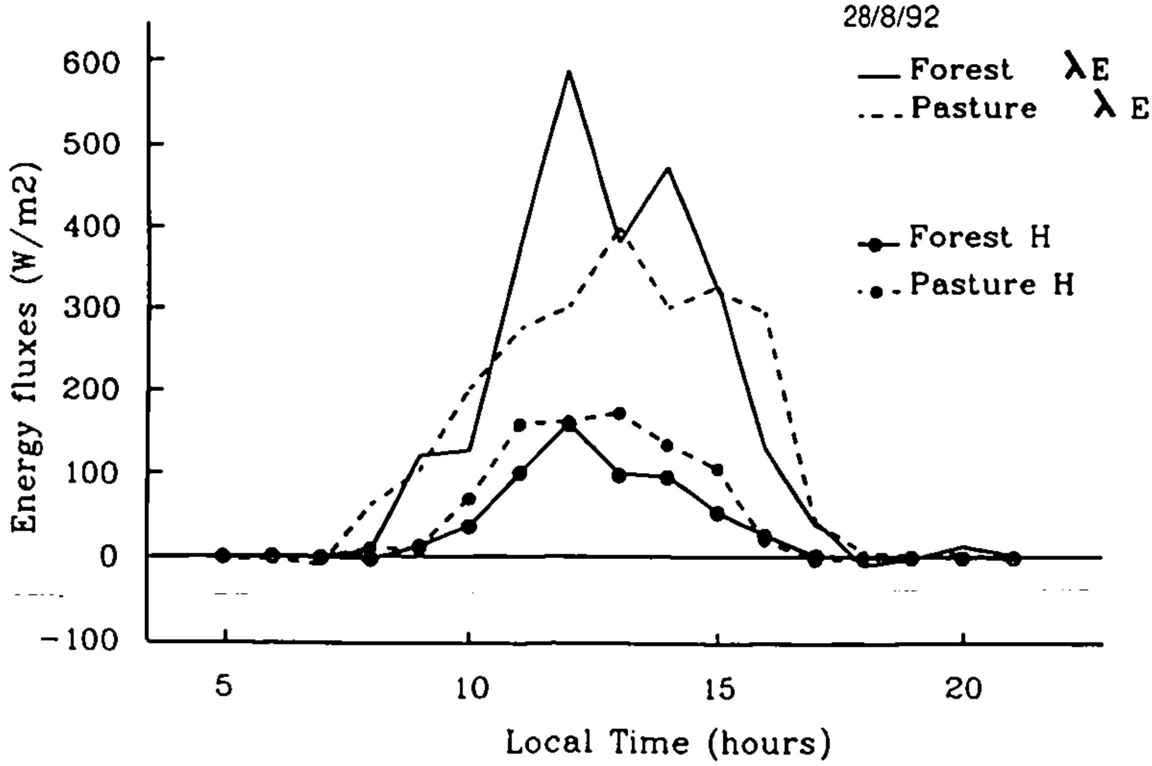


Fig. 2.1.2. Energy balance of Ji-Parana forest and pasture sites after several storms.

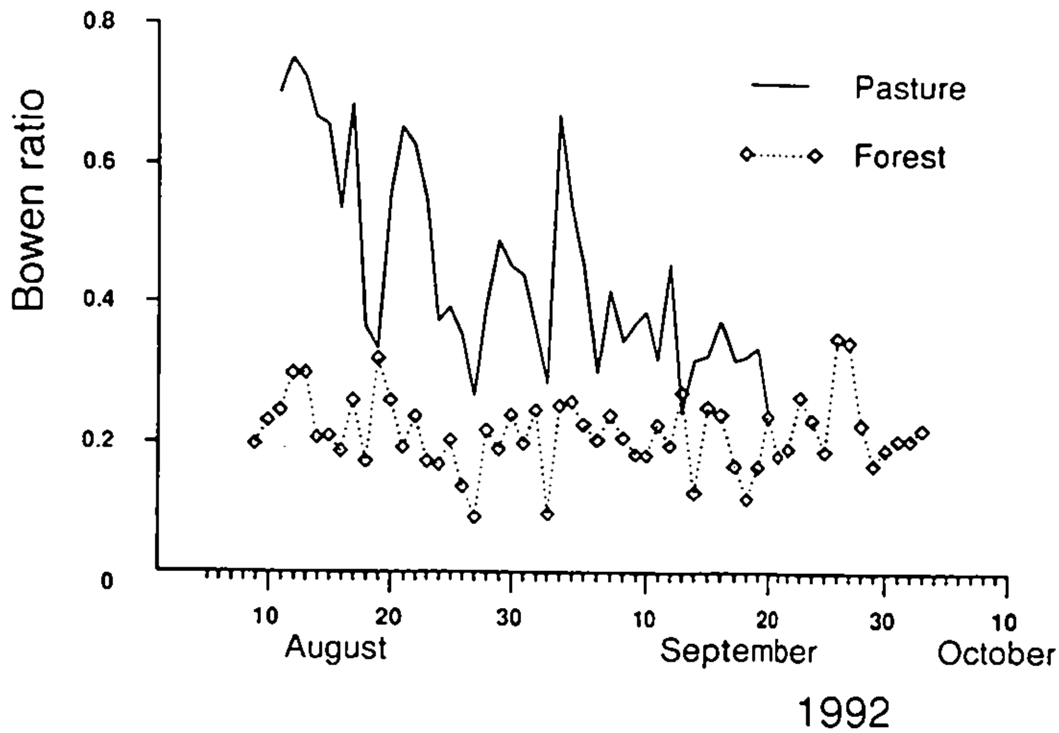


Fig. 2.1.3. Variation of the ratio of sensible heat to evaporation (the Bowen ratio) for grass (solid line) and forest (broken line) at the Ji-Parana sites.

2.2 PLANT PHYSIOLOGY

2.2.1 Ji-Parana Site

A similar set of plant physiological studies as for the previous experiments in Manaus were set up and carried out at the Ji-Parana sites for Mission 3. All work was successfully carried out, although a few constraints were apparent due to the more complex logistics of these sites. Vegetation cover, leaf area index and biomass were measured in the clearing, while gas exchange and plant water relations were measured in both virgin forest and a nearby clearing over an 8-week period in August and September 1992. Data analyses carried out so far are given below.

Percent vegetation cover

Ten transects were assessed for their vegetation cover in the fetch area of the clearing micrometeorological tower. Each transect was 30 m long, and they were spaced 10 m apart. The results are as follows:

Component	Percentage cover
Brachiaria brizantha	78.3
Dry, flat grass & other spp.	12.7
Bare soil	8.5
Dead tree	0.6

Leaf Area Index (L^*) and Biomass of the dominant vegetation in Fazenda Nossa Senhora Apareceda, Rondonia.

The major grass species at this site has been identified as *Brachiaria brizantha* (A. Rich) Stapf. Twelve 0.5 m^2 quadrates of the grass were cut and measured for their area and biomass at the beginning of Mission 3 (10/08/92) and then the same again at the end (21/09/92). There was no significant difference between the measurements taken at the beginning and the end of the mission. Pooling all the area measurements gives L^* of 1.37 +/- 0.11 (mean +/- S.E.), a stem area index of 0.24 +/- 0.12 and a total plant area index of 1.61 +/- 0.13. These values compare well with the L^* obtained in Missions 1 and 2 at Fazenda Dimona (central Amazon, ODA report no.4). While leaf and stem biomass were quite similar to those measured on the grasses at Fazenda Dimona, the amount of dead biomass was approximately double that found in Fazenda Dimona.

Also present at Fazenda Nossa Senhora are a scattered population of palms, mainly "Babacu", the L^* contributed by these palms was estimated to be 0.05 only 4 per cent of the leaf area contributed by the grasses.

Gas Exchange of Fazenda vegetation

Leaf conductance measurements commenced in early August when the grass had been subject to at least 2 months without rain. The average of 3 days measurements at this time gave a maximum stomatal conductance of 211 mmol $m^{-2}s^{-1}$ (i.e 5 mm s^{-1}) for leaves in full sunlight. For shaded leaves the conductance was halved (123 mmol m^{-2} s^{-1}). After 18 August rain occurred at least once a week, and with more water available conductances reached as high as 490 mmol m^{-2} s^{-1} (13 mm s^{-1}), but did not attain the high conductances shown by *Brachiaria decumbens* in Fazenda Dimona in 1991 (ODA Interim report 4 Fig 3.4.1). Leaf conductance of Babacu palm measured at the same time as the grass showed conductances of approximately half the grass values, and together with the fact that the LAI of the palms is small, implies that the contribution of the palms to the total vegetation water use of the Fazenda is marginal compared with the grasses. These data along with the estimates of LAI will now be combined with the weather station measurements of wind speed, temperature and specific humidity deficit to calculate total vegetation conductance using the CLATTER model developed by Dr J. Roberts.

Comparison of forest structure and micrometeorology at three ABRACOS sites

Figure 2.2.2 compares the structure of the three ABRACOS forest sites and their corresponding diurnal rhythm of temperature, wind speed (u) and specific humidity deficit (SHD) within and above the forest canopy. The data shown are from three days where weather conditions were stable (i.e. no rainstorms and few clouds) and therefore comparable. The markedly different structure of the Reserva Vale (RV) forest compared with the other two sites (Reserva Ducke, RD, & Reserva Jaru, RJ) is mirrored in its micrometeorological profile. Wind, temperature and SHD within the forests were more closely coupled with the weather station sensors at this site than at the other two sites. In RD, wind speeds within the canopy are decoupled from the wind above the canopy during the night, and were fairly decoupled during the day-light hours. Air temperatures at RV were almost uniform during the day, but reached over 2°C difference between the AWS station and within the forest canopy during the night. RD and RJ showed differences of approximately 2.5°C between 25m and ground level during the day. Temperatures were more uniform during the night at these sites except for the temperature at the AWS station at RJ which fell 3°C below that within the forest at this time. Specific humidity deficit at RV followed a similar pattern at the different heights in the canopy, with only about 3 g kg^{-1} difference between top and bottom. RJ varied as much as 6 g kg^{-1} between 25m and the ground level. At RD, the SHD at the floor of the forest was strongly decoupled from that of the rest of the forest.

2.2.2 Maraba site

Plant physiological studies were made in two measurement periods, the first one in September and October 1992 coincided with the mission at Ji-Parana and an additional short period of measurements was made in December 1992. In these periods studies were made of leaf gas exchange in both the forest and clearing areas. There were very clear differences in stomatal conductance with moderately high values being maintained in the forest even at the end of the dry season, while in the clearing low conductances were observed throughout September and October and were still persisting in December, although the wet season had begun. Leaf water potential values from the forest in September and October 1992 were higher than in August 1991 and were a consequence of both a lower evaporative demand and a higher soil water status.

In September measurements of within-canopy microclimate at the forest site were initiated and measurements were made for four weeks. Further measurements were made for a shorter period in December. The measurement system consists of six levels of measurement of temperature, specific humidity deficit, windspeed and net radiation with the automatic weather station providing an uppermost level for this profile. An example of some of these data is shown along with comparable data from the other ABRACOS sites in Figure 2.2.2. The major role envisaged for the within-canopy microclimate data from all three ABRACOS forest sites is as inputs to a multi-layer canopy transpiration model (CLATTER) developed during the Institute of Hydrology's first project in Brazil.

An on-going study at the forest site which was initiated in late August 1991 is the determination of the foliage area which falls as litter and is collected in litter traps on the forest floor. The data from this study, combined with information on the life span of leaves, can provide estimates of the total leaf area index (L^*) in the forest. Assuming in the first instance that the leaf life span is 12 months L^* is estimated as 5.74 which is the cumulative L^* of litter collected between 26 August 1991 and 24

August 1992. Information on L* and its vertical distribution is also an important input to the CLATTER model. At present information is not available on the vertical distribution but it is possible that some destructive sampling to estimate this can be conducted in the Maraba region.

In contrast to the forest, L* in the clearing at Maraba was very low in the dry season. The mean from twelve samples taken in September 1992 was 0.49 +/- 0.43. While there is substantial variation it might be concluded that at the end of the dry season at Maraba L* was lower than has been observed so far at either of the other two ABRACOS clearing sites during the dry season (see Section 2.2.1, this report and ABRACOS Project Report No. 4).

2.3 Soil moisture

Data collection is proceeding well at all sites. There were some problems at the Ji-Parana site but these have been solved.

2.3.1 Reserva Jaru Forest, Ji-Parana

The seasonal cycle of soil water storage at this site has a much greater magnitude than at the Fazenda Dimona forest site near Manaus. The maximum seasonal storage change in the 3.6 m depth of profile measured was almost 700 mm, compared to less than 200 mm near Manaus. This large change is not entirely due to losses by evaporation during the longer dry season at this site. The data indicate that a water table rises to within 1.2 m of the surface and some of the large decrease in storage can be attributed to the fall in the water table as the groundwater slowly drains to the river. Hydrologically, this site behaves very differently from the Manaus site.

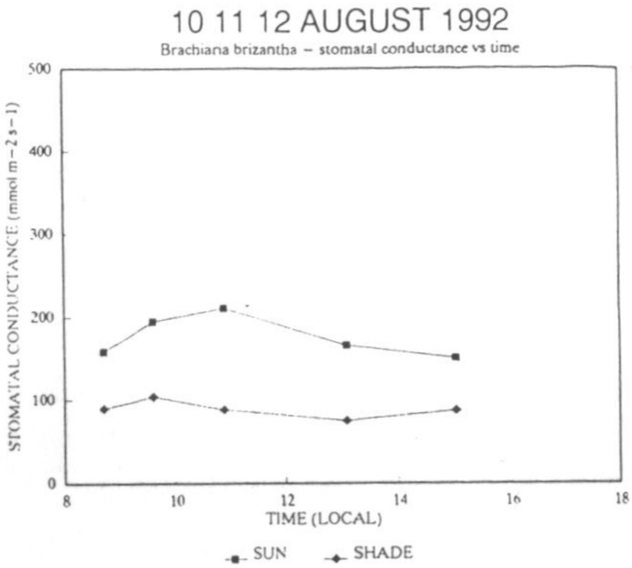
2.3.2 Fazenda Dimona Forest water levels

Four water level sensors and a data logger were installed at the foot of the slope in the forest in October 1992. The sensors are located in tubes along a transect along which the depth to the water table decreases from about 4 m bgl to 1.7 m bgl. Since the start of the wet season, several recharge events have been observed. In the major events, the water table rises first and fastest where the water table is nearest to the surface. This rise reverses the normal gradient towards the valley floor, causing a slower and slightly delayed increase in level at the tubes where the water table is deeper. It was observed from earlier weekly monitoring in the 1990 - 91 wet season that the gradient towards the valley increases significantly later in the wet season. This appears to be the result of deep drainage/recharge beginning to occur through the full depth of the unsaturated zone beneath the plateau areas.

The water level sensors will provide more detailed data on these processes and improve the understanding of the hydrological behaviour of the study area.

Fig. 2.2.1. Stomatal conductance of *Brachiaria brizantha* in Fazenda Nossa Senhora (NS) on three days during ABRACOS mission 3. Each point represents 5 plots sampled, each plot consisting of 3 mature leaves.

A



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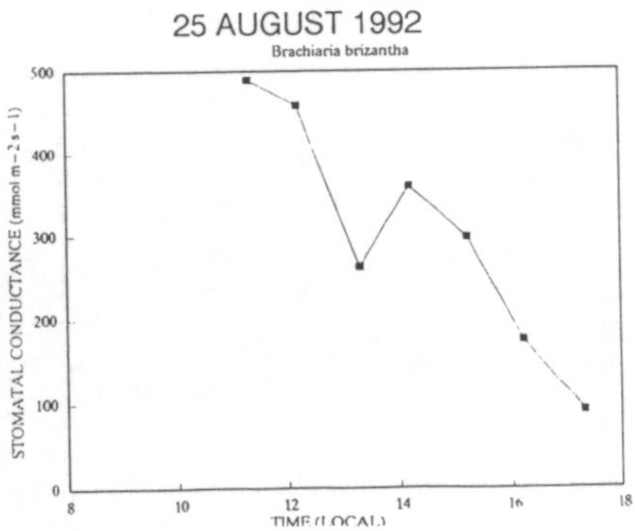

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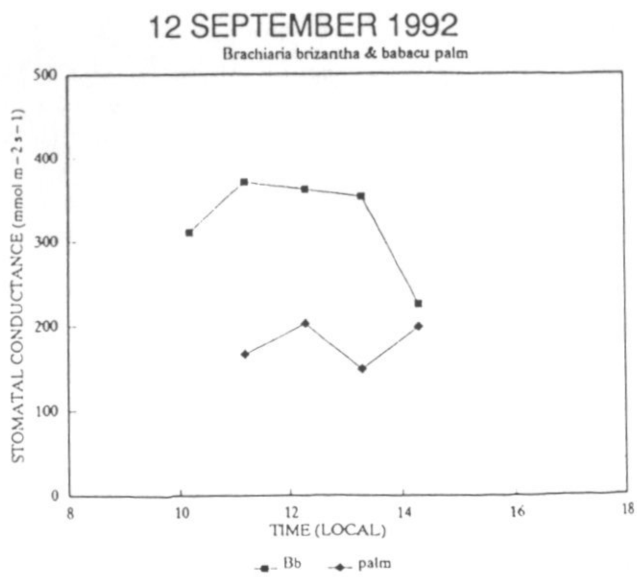
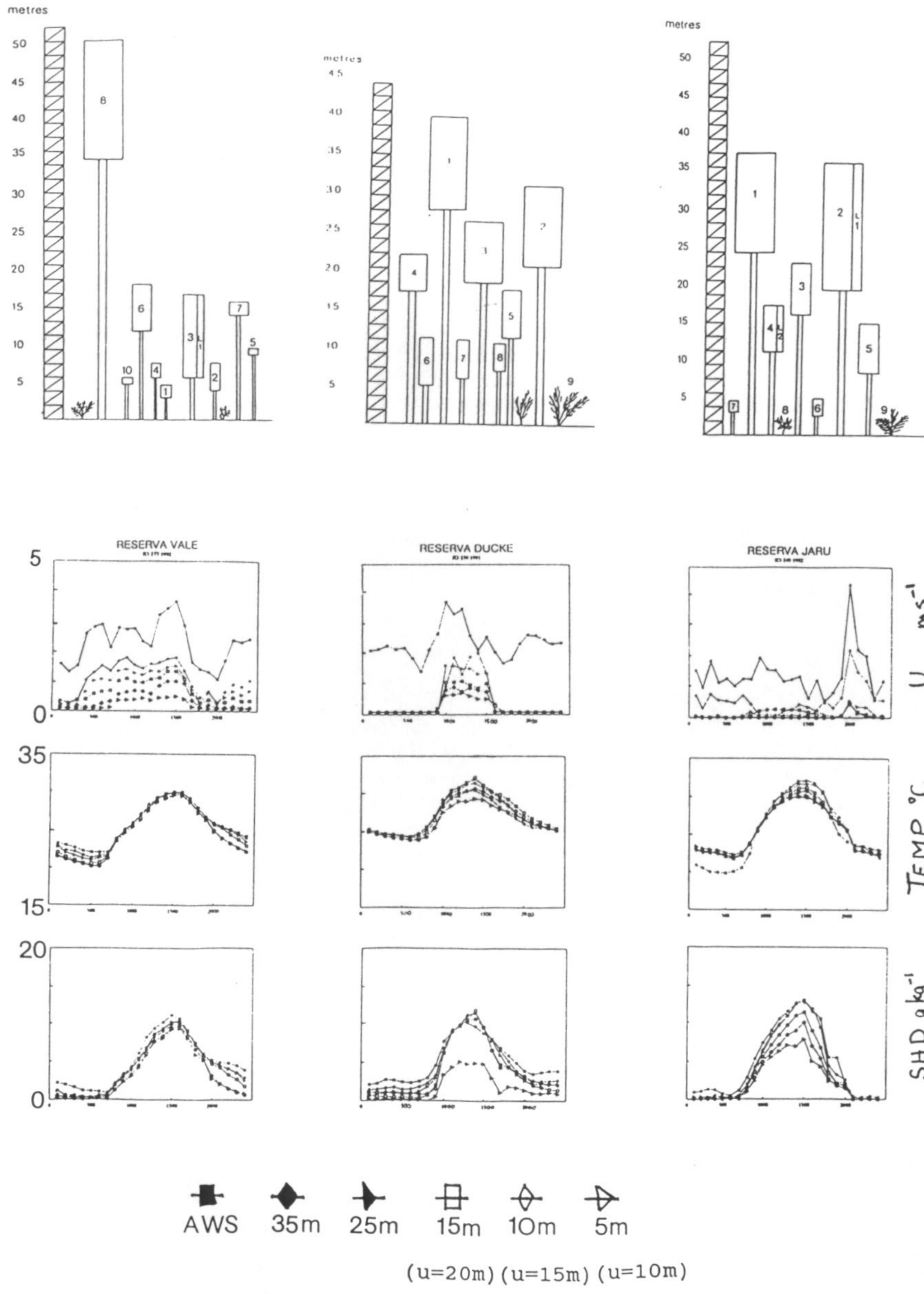


Fig. 2.2.2. Profile of trees immediately surrounding the towers at all three ABRACOS sites and the corresponding tower profiles of wind speed, air temperature and specific humidity deficit (SHD). Each weather station (AWS) is placed at top of the towers



3. Publications

3.1 The paper describing the preliminary analysis of the Mission 1 micrometeorology data has now been published as

Wright, I.R., J.H.C. Gash, H.R. da Rocha, W.J. Shuttleworth, C.A. Nobre, G.T.M. Maitelli, C.A.G.P. Zamparoni and P.R.A. Carvalho. 1992. 'Dry season micrometeorology of central Amazonian ranchland'. Quart. J. R. Met Soc. 118, pp 1083-1099.

3.2 The paper presented by W.J.Shuttleworth at the Oxford Conference on Tropical Forests has now been published as

Shuttleworth, W.J. and Nobre, C.A., 1992. Wise forest management and its linkages to climate change. Proc. Oxford Conference on Tropical Forests, 77-90.

3.3 The paper describing leaf area and aboveground biomass of both rainforest and nearby pasture in the Manaus area:

McWilliam, A.L.C., Roberts, J.M., Cabral. O.M.R., Leitao, M.V.B.R., da Costa, A.C.L., Maitelli, G.T. and Zamparoni, C.A.G.P. 1993. Leaf area index and above-ground biomass of terra firme rainforest and adjacent clearings in Amazonia. Functional Ecology.

has been accepted for publication and is expected to appear early in 1993.

3.4 The paper describing the differences in near surface climate measured between the clearing and forest in Manaus:

Bastable, H.G., W.J. Shuttleworth, R.L.G. Dallarosa, G. Fisch and C.A. Nobre. 1993. 'Observations of climate, albedo and surface radiation over cleared and undisturbed Amazonian Forest'. Int. J. Climatology.

has been accepted for publication and is expected to appear within the first few months of 1993.

3.5 The paper describing an analysis of the effects of burning on grassland albedo:

Fisch G., I. R. Wright and H. G. Bastable. 1993. 'Albedo of tropical grass: A case study of pre and post burning.'. Int. J. Climatology.

has been accepted for publication and is expected to appear within the first few months of 1993.

3.6 Brazilian Meteorological Congress

Martin Hodnett, Anna McWilliam and Ivan Wright attended the Brazilian Meteorological Congress held in Sao Paulo from 28 September to 2 October 1992. Five papers resulting from the project were presented in a session entitled Amazonian Micro-meteorology. A great deal of interest was shown in the work presented and further useful contacts were made with researchers in this field.

4. Training

4.1 SR VINICIUS UBARAMA

Senor Vinicius Ubarama made a short visit to the Institute of Hydrology for three weeks in June 1992, for training in the theory and practice of interception measurements. The objective being to install interception experiments at Ji Paraná and Marabá during the year and have the experiment run from within Brazil. The sites will be operated under the supervision of Senor Ubarama and the analysis will form part of his Post graduate research at INPE.

The two experiments are now in operation.

4.2 SRA GILDA MAITELLI

Senora Gilda Maitelli is a lecturer in climatology at Federal University of Mato Grosso and was a collaborating micrometeorologist during the 1990 field measurement season. Senora Maitelli, who has been specialising in urban climate, came to the Institute of Hydrology for 10 weeks from October 1992 to work on the ABRACOS climate data.

Two years of climate data from the AWS sited in Manaus City were analyzed and compared with the AWS data from the pasture and forest sites. The work is likely to appear as a paper or report later in 1993.

A further important conclusion resulting from Senora Maitelli's visit is identification of future policy for urban studies within ABRACOS. It is clear that data are now required from closer to the city centre and in collaboration with other institutions in Manaus, a more spatially comprehensive study of the Manaus urban climate is being considered.

4.3 FUTURE VISITS

Dra Tatiana Sa of EMBRAPA - CPATU at Belem, Para will spend January and February 1993 at the Institute of Hydrology. Dra Sa has been very closely involved in the plant physiology programme at the forest and clearing sites at Maraba. The purpose of the visit will be to collaborate in a detailed analysis of data from these studies in preparation for publication.

Plans are also being made for Sr Osvaldo Cabral of EMBRAPA, Manaus to come on a training visit later in 1993.

4.4 ENGLISH LANGUAGE TRAINING

Two Brazilian participants in the project have now completed the intensive English language training course run by the British Council in Recife. A further six participants are expected to take the course early in 1993.

5. Vehicles

5.1 BACKGROUND

The project has 4 vehicles, 2 Landrover 127s delivered to Manaus in July 1990 and two Landrover Defender 130s delivered in July 1991, one to Ji-Parana and the other to Maraba. These vehicles are nominally identical, but the two 127s have an older type of turbo diesel engine and are unique in Brazil in this respect. All of the other ODA Landrovers have the modern "TDi" engine.

5.2 GENERAL

Operating conditions are fairly arduous and some of the vehicles have clocked up a large number of kilometres. The Maraba vehicle, for example has covered over 60,000 km in a little over a year. Suspension components need regular replacement and rear shock absorbers, rear pivots and front and rear lower arm bushes seem to have particularly short lives. This adds considerably to the running expenses, particularly as spares have to be shipped from the UK. Three of the vehicles have suffered fatigue cracking of the front axle casing. Two have been replaced and the third was successfully repaired by welding.

Ensuring regular and correct routine and preventative maintenance is a problem, particularly the changing of oil, air and diesel filters. These are especially important when working under arduous conditions. Landrover Brasil are proposing running 2 day basic maintenance and driving skills courses for drivers. This is excellent idea and should reduce repair bills.

5.3 MANAUS LANDROVER 127

This vehicle is out of action with a severely cracked block, bent connecting rod and damaged cylinder head. The engine is of the old type and it appears that the best course of action is to replace it with a modern TDi unit which is available from Landrover with all ancillaries as a retrofit kit. This is a more viable option than an expensive repair of the old unit, which could well still give further trouble. Changing the engine for a TDi unit will leave the project with the one and only vehicle with the old type engine in Brazil (currently in Ji-Parana). To pay for this unforeseen expense it will be necessary to draw on the contingency fund. This is expected to cost approximately £4000.

6. Plans for future fieldwork

6.1 SOIL MEASUREMENTS IN MANAUS

i) Installation of new equipment to measure water potentials in the range from -50 to -3000 kPa (beyond the range of tensiometers). This will be carried out in collaboration with Prof. E Vertamatti of CTA, and the ODA unit of TRL, Crowthorne. Installation will probably be carried out in May, and measurements made through to October. Equipment of this type will also be installed at the Maraba sites.

ii) An experiment will be carried out to measure the unsaturated hydraulic conductivity in situ at several depths at Fazenda Dimona. This work will be carried out in collaboration with Prof. R André of USP, provisionally starting in June.

In addition visits will be made to the sites at Maraba and Ji-Parana to check equipment and data collection procedures.

6.2 JI-PARANA

The major field campaigns for 1993 will again be concentrated at the Ji-Parana sites. Mission 4 originally planned for March 1993 will be delayed to April 1993. This will ensure that the soil profile is fully saturated and will also allow Mission 4 to run into Mission 5. This will remove the need for a substantial amount of work involved in dismantling and re-erecting the equipment. Mission 5 is currently planned to end at the end of June 1993. A planning meeting for Missions 4 and 5 is to be held at INPE in early February 1993.

6.3 MARABA

A parallel mission to the one at Ji-Parana in April to June will also take place during the same period at Maraba. The emphasis of the studies at Maraba will be on plant physiological studies and continues the studies which have been made at approximately three-monthly intervals since August 1991. The objective of these studies is to provide a basic understanding of the physiological mechanisms which control transpiration and also to provide estimates of transpiration for both the forest and clearing by combining data on leaf stomatal conductance (scaled up to a value for canopy conductance by multiplying by leaf area index) with weather variables in a combination formula. These physiological studies comprise leaf gas exchange in the forest and clearing, leaf water relations in the forest and leaf area index and above-ground biomass in the clearing. Within-canopy measurements of temperature, humidity deficit, windspeed and net radiation will also be made and this will extend this type of information to a wider range of seasonal conditions.

7. Modelling studies

7.1 U.K.

The last six months have seen the final stages of individual submodel work by the Institute of Hydrology (IH) and the U.K Met. Office (UKMO), and the beginning of the joint work to operate the IH field data and process models within the UKMO biosphere model. The models and data have been successfully combined to show the feasibility of the next stage of work, which is to calibrate the model and highlight areas for improving the parameterisation.

7.2 U.S.A.

Dr H. Bastable of the Institute of Hydrology visited the climate modelling group (COLA) at the University of Maryland for three months. During this visit the ABRACOS pasture data were used to calibrate the COLA simplified biosphere model (SiB). Very encouraging results were obtained in predicting evaporation, heat flux and soil thermal performance under most conditions. The model performed less well during the 1990 dry period. This model will in due course be the basis of the model in the new Brazilian climate centre.

7.3 FRANCE

Problems with the convection code in the French GCM, resulted in errors in the predicted rainfall over Amazonia. This has delayed implementation of the programme to calibrate the French GCM with the Fazenda Dimona data. This is now scheduled to take place in the first half of 1993.

8. Staff changes

8.1 Dr W.J.Shuttleworth left the Institute of Hydrology at the end of 1992 to take up a post at the University of Arizona. Dr J.H.C.Gash has taken over his duties as UK coordinator of the project.

8.2 Dr A.D.Culf has taken over the responsibilities of project climatologist, replacing Dr H.G.Bastable.

8.3 Mr I.R.Wright has been promoted from HSO to SSO, with effect from 1 October 1992. He will continue to work on the project.

9. Future work

9.1 OPERATION OF THE NETWORK OF CLIMATE AND SOIL STATIONS

Current plans are that there will be no financial support available from the project for continuation of data collection from the network of climate and soil stations after the end of calendar year 1993. However it is recognised that these stations are now providing valuable long term record of data and it would be highly desirable to continue taking data from these stations for a much longer period than the present project allows. Not only would a longer run of data be of much greater value from the hydrological or climatological time scale, but the stations are also likely to play an important role in current plans for a major international experiment planned to study the large scale energy, water and carbon balance of the Amazon basin in 1996/97.

At present it is not clear where funds might be found to allow data collection to continue, but it is a matter of high priority that they should be found.

9.2 A SECOND PHASE TO THE PROJECT

Discussions between Brazilian and British scientists have been taking place on a possible second phase to the project. The Brazilian scientific community is anxious to extend the work to include measurements in the cerrado and caatinga savanna areas to the south of the rainforest, and to include measurements of the comparative hydrology of rainforest and clearings.

10. Financial overview

10.1 The overall project budget substantially remains as it was in Interim Reort No. 6 (June 1992).

10.2 It is expected that there will be some carry over from 1992/93 to 1993/94, particularly with respect to the costs of operating Mission 4 which is now scheduled for April 1993 and will therefore fall into next financial year. This is included in the Rolling Project Budget.

10.3 *Rolling project budget (in £K)*

		Year 1 89/90	Year 2 90/91	Year 3 91/92	Year 4 92/93	Year 5 93/94	Year 6 94/95	Totals
1.	CAPITAL COSTS							
1.1	<u>Hardware associated with Phase 2</u>							
1.1.1	Micrometeorological Equipment	0.5	43.2	10.4	26.0	21.0	-	101.1
1.1.2	Plant Physiological Equipment	-	71.8	10.7	-	-	-	82.5
1.1.3	Soil Moisture Equipment	1.3	13.4	-	-	-	-	14.7
1.2	<u>Hardware associated with Phase 3</u>							
1.2.1	Climatological Equipment and	-	77.5	42.3	8.5	3.1	-	131.4
	Receiving Stations		38.7	1.3	2.0	3.0	-	45.0
1.2.2	Soil Moisture Equipment	-						
1.3	<u>Transport and Site Facilities</u>							
1.3.1	Forest Towers	-	62.7	5.7	-	1.6	-	70.0
1.3.2.A	Transport Facilities (Op. and Maint.)	-	6.4	8.2	11.0	10.4	-	36.0
1.3.2.B	Transport Facilities (Purchase)	-	88.0	-	-	-	-	88.0
1.3.3	Site Facilities	-	4.1	21.3	4.1	2.0	-	31.5
1.4	<u>UK-based Hardware and Facilities</u>							
1.4.1	Computers	-	24.0	0.3	-	-	-	24.3
TOTAL CAPITAL		1.8	429.8	100.2	61.3	31.4	-	624.5

		Year 1 89/90	Year 2 90/91	Year 3 91/92	Year 4 92/93	Year 5 93/94	Year 6 94/95	Totals
2.	RECURRENT COSTS (Other than vehicle support)							
2.1	Sundry Scientific Supplies	-	24.6	15.9	26.0	25.5	16.5	108.5
2.2	Freight Charges	-	27.8	25.1	10.0	9.9	-	72.8
2.3	Counterpart Travel Costs (Scientific)	-	21.1	25.0	34.0	18.4	-	98.5
2.4.A	Counterpart Travel (Project Management)	0.2	4.6	5.4	5.4	5.4	23.5	44.5
B	Short-term training in UK	-	-	6.3	17.0	24.5	24.2	72.0
C	English Language Training	-	-	-	13.0	12.5	8.5	34.0
2.5	Institute of Hydrology Travel Costs	-	71.0	80.2	68.6	86.4	30.8	337.0
2.6	Institute of Hydrology Consultant	0.5	9.3	8.7	8.5	8.4	5.5	40.9
2.7	Institute of Hydrology Staff Costs	34.4	233.1	260.9	266.6	280.0	218.3	1293.3
TOTAL RECURRENT		35.1	391.5	427.5	465.0	457.6	324.8	2101.5
TOTAL PER YEAR		36.9	821.3	527.7	526.3	489.0	324.8	2726.0
Currently approved financial limit for project (including contingency)								2906.0

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