Air temperatures in Central Amazonia

III. - Vertical Temperature Distribution on a Clearcut Area and in a Secondary Forest near Manaus (Cold Front Conditions July 10 th. 1969)[1]

W. L. F. Brinkmann
M. N. Góes Ribeiro
Instituto Nacional de Pesquisas da Amazônia

Abstract

Air temperatures under cold front conditions were recorded on July 10th 1969 inside and outside a secondary forest at Ducke Forest Reserve. Air temperatures were measured at 2 towers and 8 corresponding levels ranging from 10 cm to 900 cm height. The absolute daily minimum air temperature recorded was 11.0°C, which is exceptionally low for Central Amazonia and 16.0°C below the yearly average air temperature at Manaus measured over a 45-year period of temperature records. The maximum 30-min range of air temperature was observed in the clearing (8.1°C), 7 meters above the ground. The strongest impact of air temperatures in the forest stand was recorded in the canopy area and in the ground stratum due to the formation of cold air cells and cold air sinks. The temperature profiles inside and outside the secondary forest at Ducke Forest Preserve during cold front conditions did not conform with the established temperature patterns in a tropical environment.

Introduction

Cold fronts in Central Amazonia, locally referred to as "friagens", usually occur twice or 3 times a year, normally in the dry season (June to October). Cold fronts are associated with a considerable low in air temperature and strong winds (the complete loss of several huts in Manaus by wind impact was observed in 1969). In a general way, "friagens" are treated by Serra and Ratisbonna (1941), Reinke (1962) and Ratisbonna (1971). Air temperature records near Manaus and at 2 levels in a secondary forest at Ducke Forest Reserve under cold front conditions were analyzed in previous papers (Brinkmann, et. al., 1971, Brinkmann and Góes Ribeiro, 1971a). The marked effect of the "friagens" on the chemical composition of lake waters and the fish population in some flood-plain lakes of Central Amazonia was studied over a period of years since 1968 (Brinkmann and Santos, 1972, Schmidt, 1972). Hardly any investigation was undertaken considering the impact of low air temperature associated with strong winds on the macro and microbial life in the different ecotypes present in Central Amazonia. Although serious harm to the flowering and fructing of several tropical tree species in consequence of temperature lows were reported in the literature, but so far no accurate air temperature data have been collected under cold front conditions in Amazonia.

Material and methods

Two 14-m towers were erected 30 m apart from each on a clearing and in a secondary forest of Ducke Forest Reserve (fig. 1). The site had part of a typical "chapada" of the Tertiary region along the Manaus - Itacoatiara Road (AM-10). The secondary forest is part of a forest regeneration scheme (slash without burn) surveyed by the Forestry Department of INPA. The tower was set up among the dense stand of 10 m to 12 m high Imbaúbas (*Cecropia* spp). The *Cecropia* community and various saplings formed an irregular canopy area in the range of 6 m to 12 m height, with an undulating crown surface and some branched small openings. The forest floor was covered with a thick litter layer, several decomposed tree trunks and a few seedlings and herbs. The clearcut area was part of the weather station at Ducke Forest Preserve, i.e. the tower was erected over a dense shortcut grass cover.

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Shielded NTC-thermistors were used to measure air temperatures at eight levels on each tower (fig. 1, fig. 2). The eight tower levels were :

level	cm above ground
1	10
2	20
3	50
4	100
5	300
6	500
7	700
8	900

The stand was densest above level 5 and was quite open at the levels 2 to 4, while level 1 was at an intermediate position because of the dense litter layer and a few seedlings and herbs. The NTC-thermistors were operated by means of a Wheatstone bridge. The display (ohms) was translated to absolute temperature readings by means of laboratory performed calibration curves. Instantaneous air temperatures were measured on both towers at 30-min intervals. The time interval between reading on and reading off was on the order of 4 minutes.

Results and discussion

On July 9th, 1969 the cold front reached Central Amazonia (Brinkmann and Góes, 1971) and rushed over the Tertiary region along the Manaus - Itacoatiara Road. Air temperature measurements at Ducke Forest Reserve started at 0030 h on July 10th. The air temperature records on both towers and at all levels were already below the average minimum air temperature (23.0°C) observed at the meteorological station Manaus over a period of 45 years (1910-1955).

The hours from 0000 h to 0700 h were characterized by rapidly oscillating cooling and warming periods in consequence of the heavy impact of cold air on already unstable air masses near the ground. The rapid cooling and warming observed on both towers (fig. 1, fig. 2) prove the micro-cell structure of near-surface air masses as to high turbulent mixing dynamics Rise and fall of air temperatures, however, did not occur coincident in time, magnitude and level on both sites. The maximum 30-min range

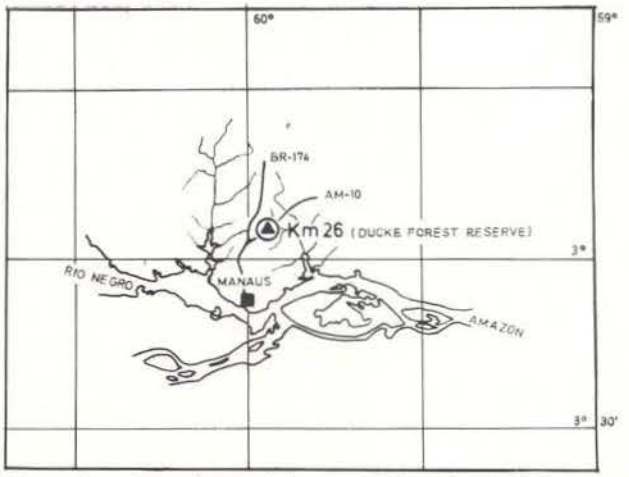

Figure 1 — Experimental site — Ducke Forest Reserve — Central Amazonia.

of air temperatures at all levels reported lows for the secondary forest at levels 1 and 7, but for the clearing at levels 2,6 and 7, while the absolute maximum 30-min range of air temperatures on July 10th. was observed on the clearing at levels 6 and 7 (tab. 1). The daily minima of air temperature in the clearing were observed at levels 4 (0400/0430 h), 7 (0200 h) and 8 (0200/0330 h) very early in the morning, while those at all other levels occured between 0530 h and 0630 h, the normal time of daily temperature inversion. In the forest stand, however, the daily minima of air temperatures occured coincidently at 5 levels.

The remainders were modified by site specific characteristics of the forest structure, which provided temporarily the formation of cold air cells in the canopy area as well as cold air piping through small openings in the canopy surface and cold air sinks. A dizzling rain from 0500 h to 0600 h contributed directly to the decrease of air temperature in the clearing, but operated somewhat delayed in the stand. As a matter of fact, the 7 hours from 0000 h to 0700 h were characterized by a rapid alternation of cooling and warming periods due to turbulent air exchange, a marked modification of normal night-time cooling trends and extremely low air temperatures observed on both towers at all recording levels. The absolute temperature minima on July 10th. were recorded on the clearing at levels 3 (11.0°C) and (11.9°C), while the air temperature in the stand was lowest at levels 1 (13.0°C) and 7 (13.0°C).

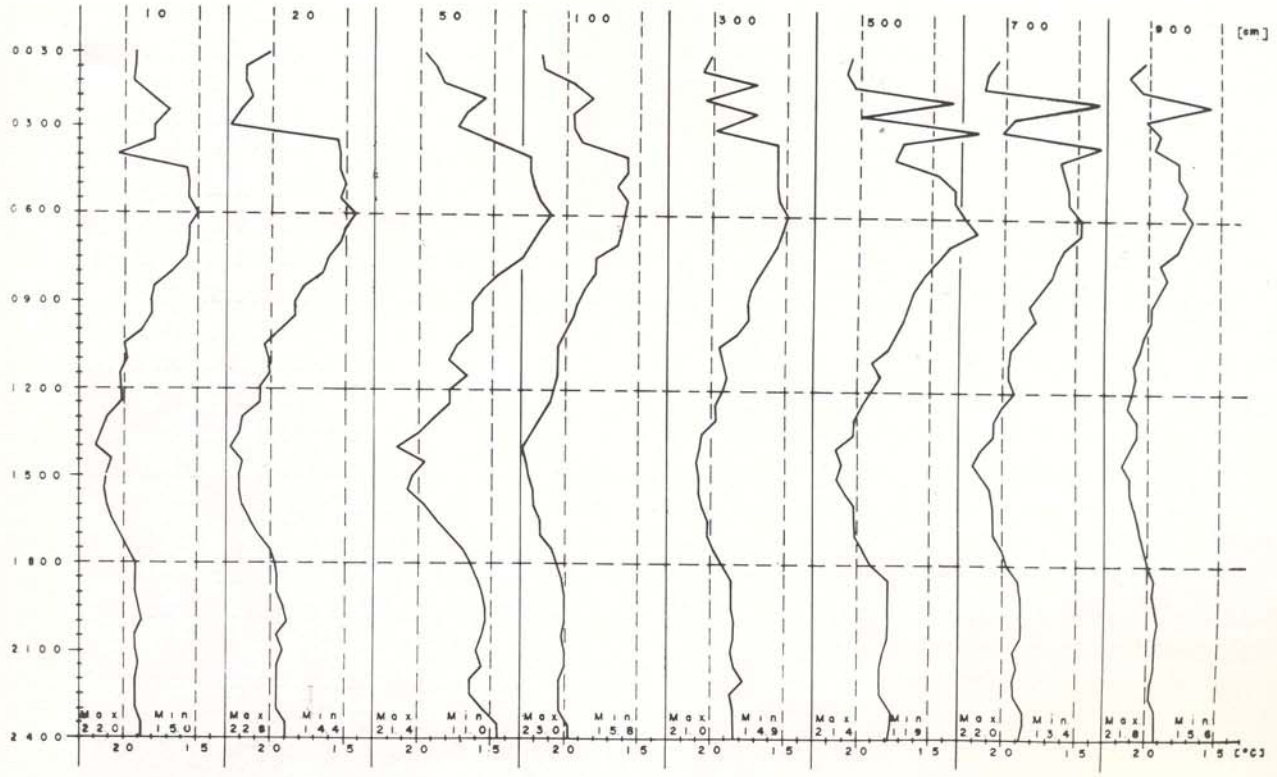

Figure 2 — 30-min records of instantaneous air temperatures at 8 levels outside a secondary forest — cold front conditions July 10th, 1969.

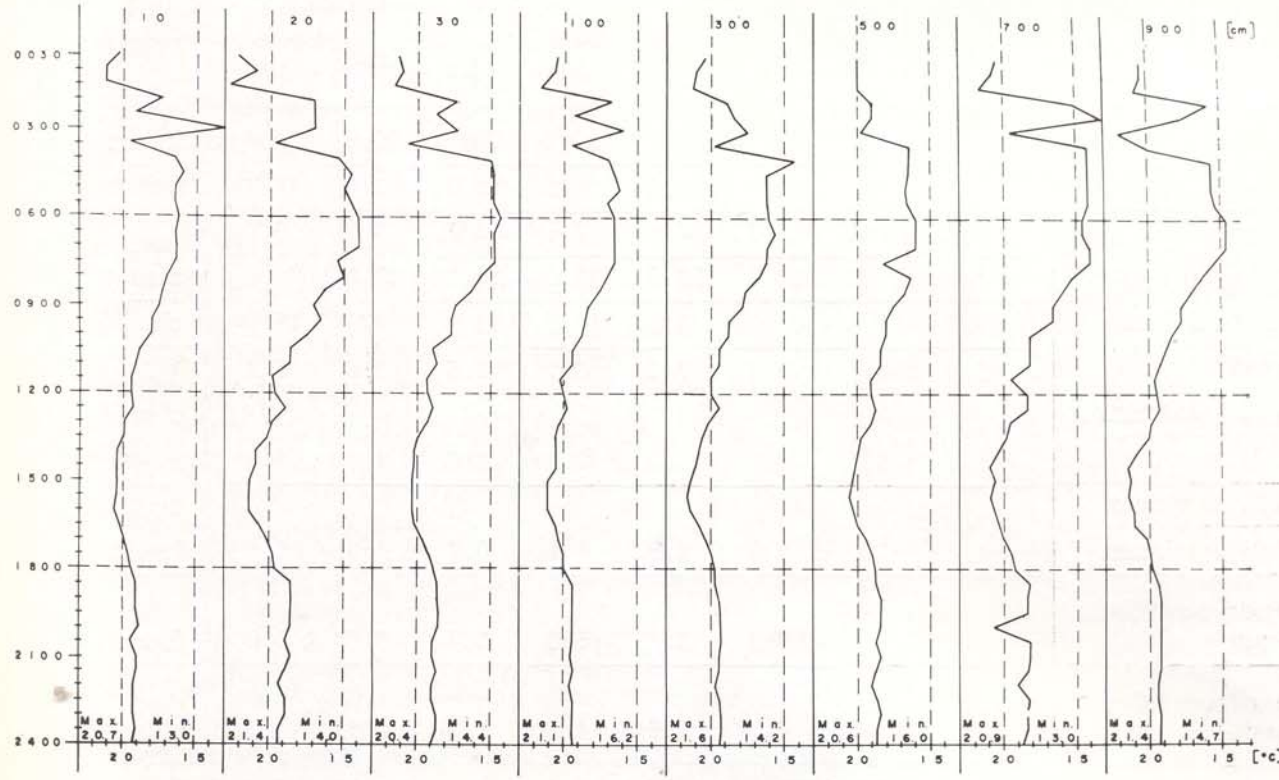

Figure 3 — 30-min records of instantaneous air temperatures at 8 levels inside a secondary forest — cold front conditions July 10th, 1969.

Shortly after sunrise rapidly rising air temperatures were recorded at all levels on the clearing, while night-day temperature inversion in the stand delayed up to 2 hours due to the canopy strata playing an important role as an interceptor of solar radiation. But evidently, cold air cells stored in the stand, played also an important part.

The 2 hours from 1400 h to 1600 h contained the daily maxima of air temperature at all levels. These maxima were below the average yearly air temperature in Manaus (26.2°C) observed over a 45- year period of measurements. Evidently, maximum air temperature at all levels on both towers were below the average minimum air temperature of July (23.0°C), recorded at the climatological station Manaus. The daily energy input by solar radiation at the experimental site was not able to heat up the near-surface cold air sinks to a normal air temperature standard. The period from 1600 h to 1830 h reflected the rapid fall in temperature at all levels to a very stable and uniform rate of air temperatures (18.0°C to 21.0°C), which characterized the 6 hours from 1800 h to 2400 h at all levels inside and outside the forest except for level 3 in the clearing.

As a matter of fact, radiational cooling after sunset was covert by stabilized cold air sinks near the ground. The cellular air mass structure near the ground, observed during the 7 hours from 0000 h to 0700 h in the early morning had vanished completely and was replaced by a more or less homogenous cold air layer. The ratio daily maximum air temperature open/ stand was positive at all levels, which stood for a less pronounced warming in the stand during daytime as followed from radiation interception in the canopy strata and cold air sinks. The ratio daily minimum air temperature open/ stand was as well positive for all levels except for levels 3 and 6, where extremely low air temperatures were recorded on the clearing, due to turbulent cold air transport and additionally radiational night-time cooling, which was strongest about 50 cm above the ground. During the night, however, the canopy surface of the stand normally becomes the primary radiating surface of a forest. But referring to cold front conditions, the night-time cooling was more pronounced due to cold air cells stored in the canopy area and cold air sinks, effective in accordance with the forest structure. As a matter of fact, the typical day and night

	(cm) 10	20	50	100	300	500	700	900	site
daily maximum	20.7	21.4	20.4	21.1	21.6	20.6	20.9	21.4	forest
daily minimum	13.0	14.0	14.4	16.2	14.2	16.0	13.0	14.7	forest
range	7.7	7.4	6.0	4.9	7.4	4.6	7.9	6.7	
daily maximum	22.0	22.8	21.4	23.6	21.0	21.4	22.0	21.8	clearing
daily minimum	15.0	14.4	11.0	15.8	14.9	11.9	13.4	15.6	clearing
range	7.0	8.4	10.4	7.8	6.1	9.5	8.6	6.2	
daily maximum / daily maximum	1.1	1.1	1.1	1.1	1.0	1.0	1.1	1.0	clearing / forest
daily minimum / daily minimum	1.2	1.0	0.8	1.0	1.1	0.7	1.0	1.1	clearing / forest
maximum 30-min range	6.5	2.8	5.9	3.4	5.6	3.4	6.5	3.9	forest
maximum 30-min range	4.4	7.0	4.7	2.5	4.1	8.0	8.1	4.8	clearing

Table 1 Observed and computed temperature data at 8 levels inside and outside a secondary forest under cold front conditions on July 10th, 1969.

temperature profiles as reported in literature for tropical forests (Richards, 1952, et. al.) did not conform with those observed under cold front conditions in Central Amazonia. Obviously, the temperature structure inside and outside the forest stand during cold front conditions do not match any established temperature pattern in the Tropics.

Conclusions

Actually, the daily minimum air temperature in Central Amazonia has been recorded at about 0600 h during night-day temperature inversion. The average minimum air temperature record in July was 23.0°C at the climatological station Manaus, based on a 45-year period of measurements. Under cold front conditions, however, the absolute minimum air temperature observed on July 10th, 1969 was 12.0°C lower than the average mentioned above. The range from absolute minimum air temperature observed on July 10th, 1969 was 12.0°C lower than the average mentioned above. The range from absolute minimum air temperature at Ducke Forest Preserve to the yearly average air temperature at Manaus was even more distinctive (16.2°C). About twice or 3 times a year cold front conditions occur in Central Amazonia, i.e. air temperatures decrease for a period of 20 to 30 hours by 6°C to 12°C below the average minimum air temperature observed under normal conditions. Without any doubt, these exceptionally low air temperatures have a marked effect on flora and fauna of the Tertiary uplands along the Manaus-Itacoatiara Road, although accurate data are lacking yet. The authors emphasize a research program dealing with low temperature effects on germination, flowering and fructing of various tropical tree species and crops as well as low air temperature impact on the microbial standing crop executed under controlled field conditions.

Resumo

As temperaturas do ar durante a friagem do dia 10 de julho de 1969, foram registradas em uma clareira e uma capoeira na Reserva Florestal Ducke. As temperaturas foram medidas em duas torres improvisadas em 8 diferentes níveis na amplitude de 10 a 900 cm de altura.

A temperatura mínima absoluta do dia foi de 11.0°C, sendo excepcionalmente baixa para a Amazônia Central e aproximadamente 16.0°C abaixo da temperatura média anual da cidade de Manaus. A amplitude máxima registrada em 30 minutos foi de 8.1°C na clareira a 7 m acima do nível do solo e o mais forte impacto das baixas temperaturas na capoeira foi registrada na área das copas e perto da superfície do solo de acordo com a formação das células e das caidas de ar frio. Os perfís da temperatura na clareira e na capoeira na Reserva Florestal Ducke durante a friagem, não se enquadram com a situação estabelecida para o ambiente tropical.

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