Air temperatures in Central Amazonia

I - The daily record of air temperatures in a secondary forest near Manaus under cold front conditions (July 4 th, to July 13 th, 1969)[1]

W. L. F. Brinkmann, *
J. A. Weinman **
M. N. Góes Ribeiro *

ABSTRACT

A "friagem" is a cold front which moves northward from southern Brazil to the Caribbean coast of South America. A set of composite satellite pictures (2) of the American sector of the southern hemisphere as well as the recorded of daily temperatures in a secondary forest near Manaus are presented. The low temperatures and strong winds associated with this phenomenon have a profound effect on the environment of Amazonia.

INTRODUCTION

Cold fronts over central Amazonia, locally known as "friagens", are refered to in Serra, A.B. and Ratisbonna, L.R. (1941), Reinke, R. (1962), Brinkmann, W. L. F. and M. N. Góes Riberio (1971) and Ratisbonna, L. R. (1971). The cold fronts mostly appear over central Amazon during the dry season (June to October). The air temperatures decrease within hours by 10ºC to 15ºC, are extremely low for the tropics and generally associated with high wind speed. Both events, the low temperatures and high wind velocities have a marked effect on the biosphere in central Amazonia.

MATERIAL AND METHODS

Air temperatures were recorded simultaneously at two different levels (30 cm and 350 cm above ground) by a remote recording two point thermophagh. The instrument was set up in a specially designed instrument shelter at about 50 cm above the ground. The temperature sensors were mercury filled bulbs encased in brass probes with capillary connection to the instrument. The probes are temperature compensated. The thermograph was laboratory calibrated before exposure. The sensors were shielded against direct radiation by standardized aluminum housings. The recording charts were reset every 7 days. Temperature data were recorded (tabulated) at half an hour intervals over the period of measurements (see Table 1; Table 2).

Air temperatures were recorded in a secondary forest at Ducke Forest Reserve, Km 26 of the Manaus - Itacoatiara Road. The secondary forest is part of a natural forest regeneration scheme (slash, but no burn) supported by the forestry department of INPA. The dense stand is dominated by Imbaúbas (*Cecropia* spp). 10 - 12 m high.

1) — Granted by Banco Nacional de Desenvolvimento Econômico under contract INPA/FUNTEC 89/70. This paper was originally published in Vol. 1, Nº 1 of this Revista. Because of omissions of lines and clauses of the text, and also because the tables and illustrations were not included in the publication of the paper, it is now republished in this issue of Revista.

2) — The pictures were produced by N.O.A.A.

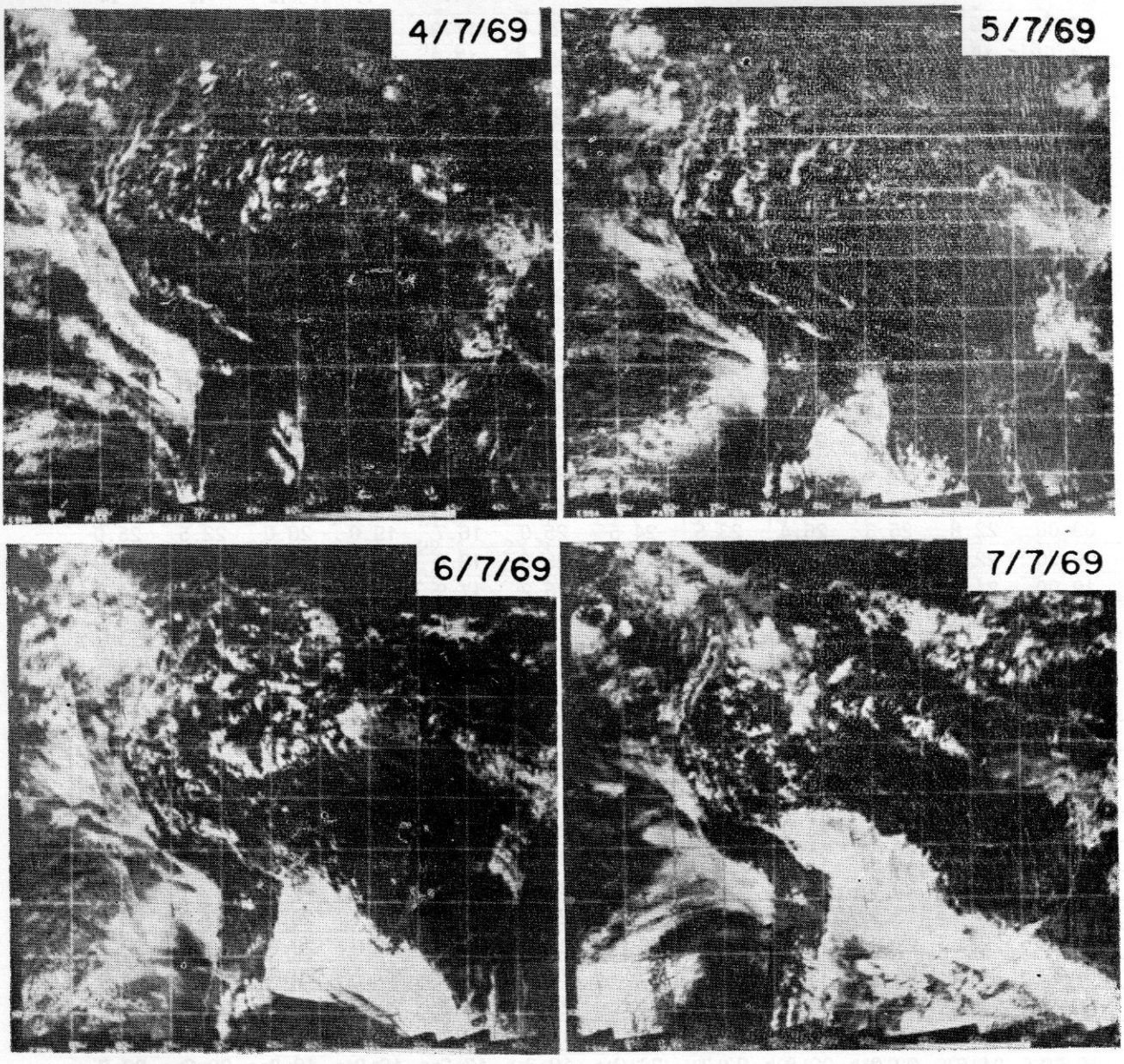
(*) — Instituto Nacional de Pesquisas da Amazônia.
(**) — Department of Meteorology, University of Wisconsin, Madison, Wi, USA.

hour/day	4	5	6	7	8	9	10	11	12	13	14
00.30	18.7	19.5	21.0	21.2	20.0	20.4	17.4	16.3	16.4	17.2	18.1
01.00	18.7	19.3	20.9	21.0	19.8	20.3	17.2	16.2	16.3	17.2	17.9
01.30	18.6	19.0	20.7	20.8	19.7	20.0	17.0	16.1	16.2	17.1	17.7
02.00	18.6	18.9	20.5	20.6	19.5	19.9	16.8	16.1	16.1	17.1	17.6
02.30	18.6	18.8	20.3	20.5	19.4	19.7	16.7	16.1	16.1	17.1	17.5
03.00	18.5	18.7	20.3	20.4	19.2	19.6	16.5	16.1	16.0	17.1	17.4
03.30	18.5	18.5	20.1	20.2	19.0	19.5	16.3	16.0	15.8	17.0	17.2
04.00	18.5	18.3	20.0	20.0	18.8	19.3	16.1	16.0	15.7	17.0	17.1
04.30	18.5	18.2	19.8	19.9	18.7	19.2	16.0	16.0	15.5	17.0	17.0
05.00	18.5	18.2	19.5	19.7	18.5	19.0	15.8	16.0	15.5	17.0	16.9
05.30	18.4	18.1	19.3	19.5	18.3	19.0	15.6	16.0	15.4	17.0	16.9
06.00	18.3	18.0	19.2	19.5	18.2	19.0	15.5	15.9	15.3	17.0	16.9
06.30	18.3	18.0	19.2	19.4	18.2	19.0	15.3	15.9	15.4	17.0	18.0
07.00	18.5	18.9	19.4	19.4	19.0	21.0	15.1	16.0	16.5	17.5	20.0
07.30	19.5	19.9	21.0	19.5	20.5	22.5	15.0	16.3	17.5	18.0	21.5
08.00	22.0	22.5	23.5	20.5	21.0	24.4	15.1	16.5	17.7	19.0	23.6
08.30	22.2	24.8	25.2	21.5	22.5	26.1	15.2	16.7	17.7	21.4	23.6
09.00	22.0	26.4	26.9	22.1	23.9	26.0	15.3	17.0	17.6	21.3	23.5
09.30	21.8	26.2	26.7	22.1	23.9	25.8	16.0	17.4	19.0	21.2	23.4
10.00	21.6	25.8	26.5	22.5	24.0	25.6	16.3	17.5	19.4	21.3	23.2
10.30	21.5	25.7	26.3	22.7	24.4	25.5	16.5	17.6	19.4	21.3	23.0
11.00	21.3	25.5	26.0	23.5	24.7	25.3	17.0	17.8	19.4	21.5	23.0
11.30	21.3	25.3	26.0	24.0	24.7	25.0	17.1	17.9	19.3	21.6	23.1
12.00	21.4	25.2	25.9	24.5	24.6	24.7	17.0	18.0	19.2	21.5	23.5
12.30	21.7	25.2	25.7	24.3	24.5	24.5	17.4	18.5	19.0	21.5	23.6
13.00	22.0	25.2	25.5	24.0	24.5	24.3	17.7	18.7	18.9	21.5	23.7
13.30	22.3	25.0	25.4	23.8	24.4	24.1	18.6	19.1	19.0	21.6	23.9
14.00	22.5	24.8	25.1	23.5	24.0	24.0	18.6	19.3	19.2	21.6	23.9
14.30	23.0	24.6	25.0	23.4	24.3	23.8	18.5	19.3	19.4	21.6	23.9
15.00	23.0	24.5	24.9	23.3	24.3	23.5	18.4	19.3	19.3	21.5	24.1
15.30	22.9	24.2	24.6	23.2	24.2	21.5	18.3	19.2	19.1	21.4	24.0
16.00	22.7	24.0	24.4	23.0	24.0	21.3	18.1	19.1	19.0	21.3	23.9
16.30	22.6	23.9	24.3	22.9	23.5	21.1	18.0	19.0	18.9	21.3	23.8
17.00	22.5	23.7	24.0	22.6	23.3	20.2	17.8	18.9	18.7	21.0	23.5
17.30	22.3	23.5	23.9	22.4	23.0	20.0	17.6	18.7	18.5	20.8	23.3
18.00	22.0	23.2	23.5	22.2	22.7	19.7	17.5	18.5	18.3	20.5	23.0
18.30	21.8	23.1	23.4	22.0	22.5	19.5	16.5	18.2	18.2	20.4	22.8
19.00	21.6	23.0	23.2	21.8	22.4	19.3	16.5	18.0	18.0	20.2	22.5
19.30	21.5	22.7	23.0	21.5	22.1	19.1	16.5	17.8	17.8	20.0	22.3
20.00	21.2	22.5	22.8	21.4	22.0	19.0	16.5	17.7	17.7	19.8	22.1
20.30	21.0	22.3	22.6	21.3	21.9	18.9	26.5	17.6	17.6	19.7	22.0
21.00	20.8	22.1	22.5	21.0	21.6	18.7	16.5	17.4	17.5	19.5	21.7
21.30	20.7	21.9	22.3	20.8	21.4	18.5	16.5	17.2	17.3	19.3	21.5
22.00	20.5	21.7	22.0	20.6	21.3	18.3	16.5	17.0	17.2	19.0	21.3
22.30	20.3	21.6	21.9	20.5	20.9	18.1	16.5	16.9	17.2	18.8	21.1
23.00	20.1	21.5	21.7	20.4	20.8	17.9	16.5	16.7	17.2	18.5	20.9
23.30	19.8	21.3	21.5	20.2	20.7	17.7	16.4	16.6	17.2	18.3	20.7
24.00	19.6	21.0	21.3	20.0	20.5	17.5	16.3	16.5	17.2	18.2	20.5

TABLE I — Daily record of air temperatures in a secondary forest (Ducke Forest Reserve) under cold front conditions (30 cm above ground).

hour/day	4	5	6	7	8	9	10	11	12	13	14
00.30	19.9	19.4	20.4	20.1	20.7	20.5	17.2	17.4	17.4	18.4	18.8
01.00	19.9	19.3	20.3	20.1	20.6	20.4	17.2	17.4	17.4	18.4	18.8
01.30	19.8	19.3	20.3	20.1	20.5	20.4	17.0	17.5	17.4	18.4	18.8
02.00	19.8	19.2	20.2	20.1	20 2	20.5	16.8	17.5	17.3	18.4	18.6
02.30	19.6	19.1	20.2	20.1	20.0	20.3	16.7	17.4	17.1	18.4	18.5
03.00	19.5	19.0	20.1	20.0	19.7	20.3	16.6	17.3	17.0	18.3	18.5
03.30	19.5	19.0	20.0	20.0	19.6	20.4	15.8	17.1	16.8	18.2	18.4
04.00	19.5	19.0	19.9	20.0	19.5	20.2	15.6	17.0	16.6	18.2	18.1
04.30	19.5	19.1	19.9	20.0	19.3	19.9	15.5	17.0	16.5	18.2	18.0
05.00	19.5	19.2	19.9	20.0	19.1	20.2	15.4	17.0	16.5	18.2	18.0
05.30	19.5	19.2	19.8	20.0	19.0	20.3	15.1	17.0	16.4	18.2	18.0
06.00	19.4	19.0	19.9	19.9	19 1	20.3	15.0	17.0	16.5	18.3	18.4
06.30	19.4	19.3	20.0	20.5	20.0	20.3	15.2	17.3	17.0	18.5	18.5
07.00	20.5	20.5	21.0	20.8	21.0	21.5	15.6	17.6	18.0	19.1	20.0
07.30	21.3	22.0	23.5	22.0	22.0	22.5	16.0	18.2	19.0	19.5	21.5
08.00	22.5	23.8	25.0	22.3	22.5	23.5	16.5	18.5	19.2	20.5	23.0
08.30	22.8	24.8	25.9	23.2	23.0	24.5	16.9	18.5	19.0	22.0	24.5
09.00	22.8	25.3	26.4	23.5	24 5	25.0	16.7	19.0	20.0	22.5	25.0
09.30	22.3	25.9	26.8	25.0	25.5	25.3	18.0	19.0	21.0	23.2	25.0
10.00	21.5	26.6	27.2	25.5	26.5	26.2	17.9	19.4	21.5	23.0	24.9
10.30	20.5	27.0	27.2	26.0	27.2	26.0	18.5	19.4	21.3	23.6	25.0
11.00	22.5	27.3	27.3	26.5	27.4	25.5	18.7	19.4	21.2	23.1	25.5
11.30	23.5	27.3	27.8	26.5	27.0	24.5	18.3	19.5	21.0	24.0	25.0
12.00	24.3	28.4	27.8	26.5	27.2	25.5	19.0	20.9	20.7	23.0	26.1
12.30	27.5	29.0	25.0	26.0	26.6	25.0	19.3	20.9	20.2	23.6	25.7
13.00	26.0	28.0	26.5	23.5	28.5	21.5	19.5	21.1	20.7	23.5	26.6
13.30	26.2	24.0	27.7	25.1	26.6	22.0	20.0	21.3	20.8	23.6	27.0
14.00	26.5	23.5	22.0	25.0	26.5	22.5	20.2	21.0	21.4	23.5	26.3
14.30	26.7	23.3	22.0	25.1	27.4	23.0	20.0	21.1	21.0	23.7	26.4
15.00	26.5	23.0	24.2	25.4	27.2	23.0	19.9	21.0	20.7	23.4	26.7
15.30	25.4	23.3	24.2	25.3	26.8	22.5	19.6	21.1	20.3	23.2	26.5
16.00	25.2	23.5	24.0	25.0	26.0	20.5	19.4	21.0	20.5	22.8	26.4
16.30	24.5	23.5	23.8	24.0	25.3	20.4	18.9	20.7	20.4	22.5	25.5
17.00	24.0	23.3	23.4	23 5	24.3	20.3	18.5	20.5	20.0	22.0	24.5
17.30	22.4	22.5	23.0	23.0	23 8	19.5	18.1	19.5	19.5	21.5	23.5
18.00	21.6	22.0	22.8	22.7	23.0	19.3	17.9	19.0	19.0	20.9	22.7
18.30	21.5	21.7	22.5	22.4	22.5	19.2	17.7	18.5	18.6	20.5	22.5
19.00	21.5	21.5	22.4	22.0	22.3	19.2	17.6	18.0	18.7	20.1	22.2
19.30	21.0	21.3	22.2	21.9	22.2	19.1	17.6	17.9	18.8	20.0	22.0
20.00	20.9	21.0	21.5	21.7	22.0	19.0	17.7	17.9	18.8	19.7	21.8
20.30	20.7	20.9	20.8	21.6	22.0	18.9	17.7	17.8	18.6	19.5	21.5
21.00	20.5	20.9	20.7	21.5	21.7	18.7	17.8	17.7	18.3	19.3	21.3
21.30	20.4	20.9	20.6	21.3	21.6	18.4	17.9	17.6	18.3	19.1	21.1
22.00	20.1	20.8	20.5	21.2	21.5	18.0	17.6	17.5	18.3	19.0	21.2
22.30	20.0	20.7	20.4	21.1	21.2	17.9	17.6	17.5	18.4	19.0	21.3
23.00	19.8	20.7	20.3	21.0	21.0	17.4	17.5	17.5	18.4	18.9	21.0
23.30	19.5	20.6	20.2	20.9	20.8	17.2	17.5	17.5	18.4	18.8	20.8
24.00	19.4	20.5	20.0	20.8	20 7	17.1	17.5	17.4	18.4	18.7	20.6

TABLE II — Daily record of air temperatures in a secondary forest (Ducke Forest Reserve) under cold front conditions (350 cm above ground).



Composite satellite pictures (July 4 th. - July 7 th., 1969).

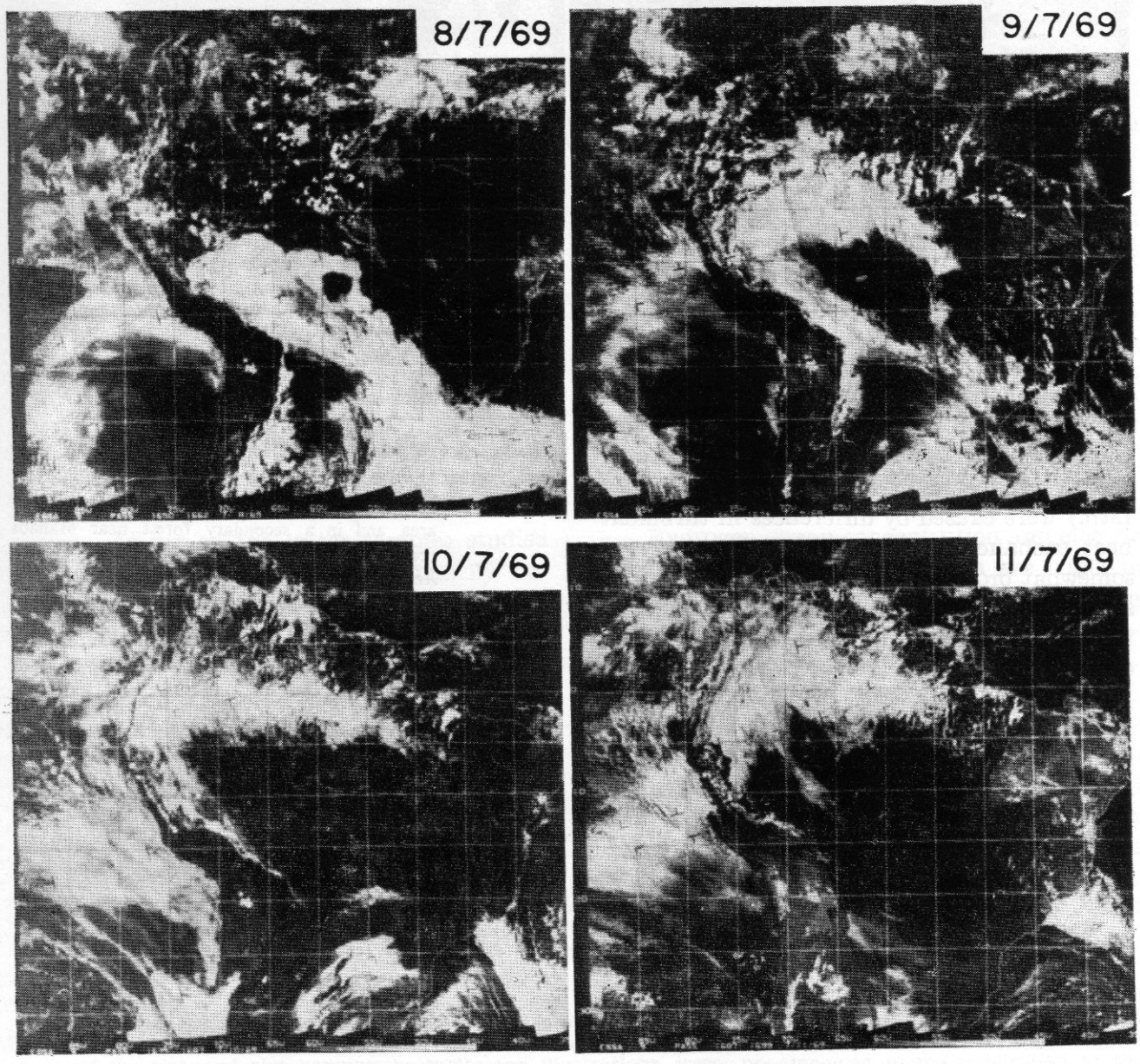
There are no defined canopy strata. The ground is covered with a thick litter layer, several decomposed trunks and a few seedlings and herbs.

Results and discussion

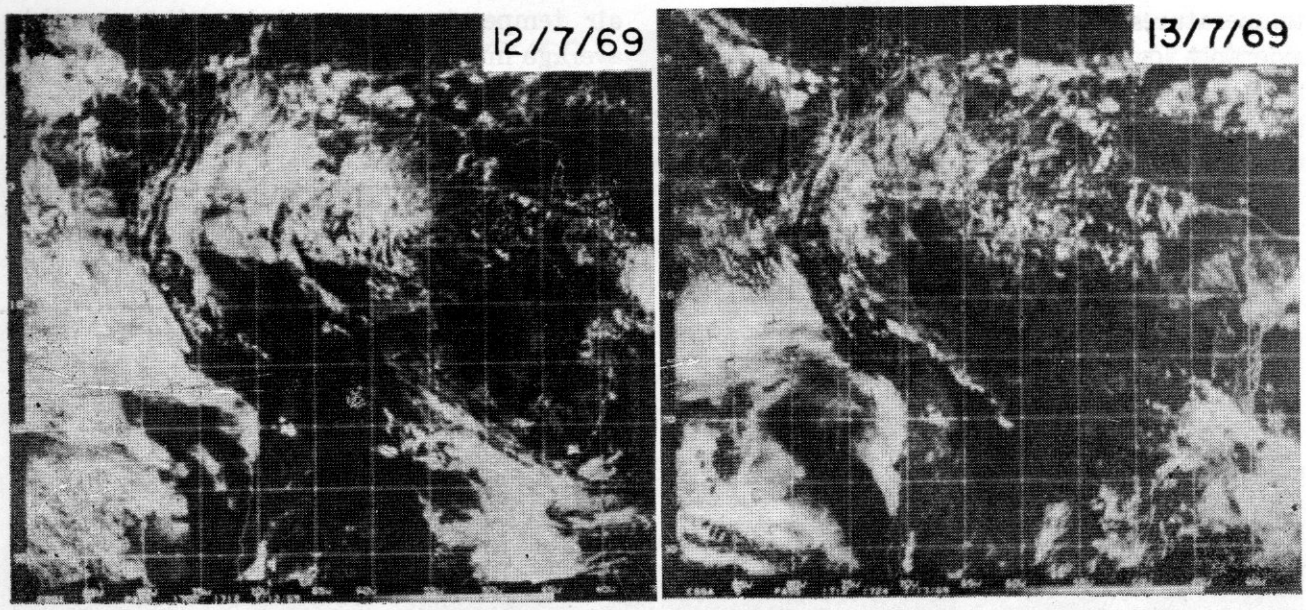
From July 4th, 1969, on, the cold front moved steadily northward (see satelite composite pictures) and reached central Amazonia at July 9th. Air temperatures in the secondary forest recorded a slight decrease at both levels at about 1600 hours (see Table 1, Table 2). Then the center of the cold front rushed in and air temperatures dropped in about 16 hours to the low of 15°C (July 10th, 0600 to 0730 hours). Cold front conditions remained up to July 14th, 1969 (about 0600 hours). At the time of the first strong impact of the cold front, air temperatures were similar at both recording levels, but deviated from one another after several hours. Air

temperatures 30 cm above ground were considerably lower than those at 350 cm above the forest floor. From July 10th. - July 13th. the air temperature at this particular level was well below the monthly average minimum temperature (23°C), measured at the meteorological station of the city of Manaus over a period of 55 years (1910 - 1965). Air temperatures stayed below the absolute minimum temperature of the month (20.0°C) between July 10th. — July 12th. 350 cm above ground, air temperatures were below the monthly average minimum temperature (23°C) between July 10th. and July 12th., i.e. at this particular level the effect of the cold front slightly faded (see Table 2).

With regard to "normal" temperature conditions, the air in the stand was heated up quickly in the early morning and showed the daily maximum temperatures between 0900 and 1200 hours at both recording levels (see Table 1; Table 2 — July 5th. - July 9th.).



Composite satellite pictures (July 8 th. - July 11 th., 1969).



Composite satellite pictures (July 12 th and July 13 th. 1969).

The strong impact of inflowing cold air masses and the reduced radiation input during the "friagem" (heavy overcast) caused a shift of the daily maximum to the early afternoon (July 10th. and 11th.). With respect to daily minimum temperatures (between 0600 and 0700 hours) no shift was observed either under normal or under cold front conditions. The lower temperatures at the 30 cm recording level (July 10th. - July 13th.) were caused by differences in turbulent heat exchance. While the 350 cm level was somewhat protected by the canopies of various saplings, the 30 cm level was partially exposed to cold air sinks, reinforced by light winds outside the stand.

Resumo

No período de 3 a 14 de julho de 1969 a temperatura do ar foi medida em duas altitudes em uma capoeira da Reserva Florestal Ducke, Estrada Manaus - Itacoatiara (Km — 26). Do dia 10 até o dia 13 a temperatura foi influenciada por uma onda fria (friagem) caida no local e cujo desenvolvimento foi observado por satélite (fotografado). No início da friagem, a temperatura baixou nos dois níveis até 15°C voltando após algumas horas a apresentar variações devido ao movimento turbulento das camadas de ar.

Bibliography cited

Brinkmann, W. L. F. & Góes Ribeiro, M. N.

1971 — Air temperatures in central Amazonia. III. Vertical temperature distribution on a clearcut area and in a secondary forest near Manaus (cold front conditions July 10th, 1969). *Acta Amazônica*, vol. 2 (1) [in press].

Ratisbonna, L. R.

1971 — *Climate of Central and South America : Brazil, World Survey of Climatology*. Elsevier Publishing Co. [in press].

Reinke, R.

1962 — *Das Klima Amazoniens*. Inaugural — Dissertation. Tübingen, 101 pp.

Serra, B. A. & Ratisbonna, L. R.

1941 — *As ondas de frio da bacia Amazônica*. Rio de Janeiro, Min. da Agric., Serviço de Meteorol., 21 pp.