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Prediction of plant-, soil- and air-temperature on a microscale in the desert

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PREDICTION OF PLANT-, SOIL- AND AIR-TEMPERATURE ON A MICROSCALE IN THE DESERT

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ABSTRACT

A micrometerological station was set up in Curlew Valley. It consists of radiation sensors, air- and soil-temperature profiles, and surface temperature. After eliminating instrumental difficulties, two selected days of measurements were acquired. A scheme was developed to determine the daily variation of the heat exchange by using selected hours of recordings distributed over the day, taking one reading every second. The heat exchange under dry desert conditions for special cases is derived from these data, and temperature predictions can be developed. The bulk of the data will be taken with the improved equipment during the 1973 growing season.

INTRODUCTION

During 1972, measurements to determine the heat exchange at dry conditions in a sagebrush desert were carried out. These investigations followed a study during the previous year, which was directed towards the knowledge of the impact of radiative exchanges on the surface temperature (Dirmhirn, 1972). While these investigations were carried out mostly with mobile equipment, to concentrate on the horizontal and vertical radiation and temperature distribution around and in vegetation, this year's study involved equipment to record the heat exchange parameters. The goal during the 1972 study was to develop a feasible recording method to determine the components of the heat exchange; radiative exchange, heat exchange with the ground and with the air, all measured under "dry" desert conditions. The study is closely linked to that projected for 1973, in which an extension to "wet" conditions will be tried -- in other words, a determination of the entire heat exchange throughout the year, but with concentration on typical conditions.

Due to difficulties encountered in using the new equipment under desert conditions most of the measurements, also those for "dry" desert, will be taken during the 1973 period.

OBJECTIVES

1. To determine the radiative heat exchange above, around and in desert vegetation, and its impact on plant and soil surface temperature (1971).
2. To extend the study of the radiative measurement to develop a predictive model of soil- plant- and air-temperature in the desert (1972 and 1973).

METHODS

The goal in this study is to determine the heat exchange over desert ground, given by

$$R_n = G + H + LE$$

where:

- R_n net radiation flux
- G heat flux into the ground
- H sensible heat flux in the air
- LE latent heat flux in the air

The environmental parameters measured are:

- incoming solar and scattered radiation
- net radiation
- a vertical temperature profile in the soil
- surface temperature
- a temperature profile in 6 heights above the surface
- a wind profile in 4 heights above the surface

Net radiation is measured, together with shortwave incoming (solar and scattered) radiation, with the intent to develop a relation between the two values for the area in question. Since the measurements of net radiation afford much attention, a relation with the easy-to-record solar and scattered radiation will provide a means to avoid net radiation measurements in the future and to conclude the latter from the former.

Surface temperature as well as the temperature profile in the ground is recorded by means of thermocouples. A reference junction was established in 125 cm depth; temperatures are further measured in 2 cm depths. The junctions are of normal 1 mm diameter gauge thermowire, except for the surface junction which was built from 0.1 mm Cu/0.12 mm Constantan wire to reduce the size. Thus the thermojunction could be placed on the soil surface, covered only by some dust.

The thermocouples for the temperature measurements in the air were also built from the thin wire. Tests and experiences during last year's study suggest a still finer wire for the measurement of air temperature. The thermometers were hence rebuilt by using 0.03 mm diameter Cu and Constantan wire. The heat dissipation from these thermocouples under natural environment is large enough that no over-heating by radiative processes can occur.

The thermometers are placed in the following heights:

5 cm (open spot)	1m
	2m
5 cm (in shade of plant)	4m
20 cm	8m

A triangular television mast is used to carry the thermometers.

Anemometers of the hot wire type are mounted in 4 heights on the mast: 1m, 2m, 4m, and 8m. Commercial hot wire anemometers (Hastings) were used during this year's study, but in-house built hot junction thermoelectric anemometers are being developed and will be used in the 1973 study to measure the vertical wind component (w).

A Metrodata Magnetic Tape Recorder was employed as a recording system. This digital recorder is designed for receiving data in time intervals from 1 sec to 1 hr. In our measurements short-term recordings are of importance, as explained in the next section.

RESULTS

During 1972, measurements to determine the heat exchange at dry conditions in a sagebrush desert were initiated. Efforts were focused on getting acquainted with the new recording system under desert conditions and developing appropriate sensors for heat flow measurements above the surface. The results established the possibilities for data collection appropriate to the heat exchange operation, provided a few adaptations of the equipment are performed.

Due to the late delivery of the Metrodata Magnetic Tape Recorder, measurements were not started until July. The process of receiving a computer-compatible tape from the Metrodata Tape recording for use on one of the USU computers was a slow process which took 2-3 weeks each time. Since this conversion is also relatively expensive, and considering our restricted funding, further measurements were postponed until the arrival of the first two days of measurements. Some special features of the recording system could be learned from these first two days of data, the most important being that high air temperatures, as they usually occur under desert conditions during the summer, offset the data record to a degree that reasonable results cannot be expected. Thus, the daytime values during these two sets of measurements were lost.

The nighttime values of the two days of recording, however, showed excellent reliability, so that we could continue measurements after having eliminated the hazards of high temperature errors.

After adaptation of the recording system in the light of the initial experience, three more sets of data were taken in September/October 1972. They proved to be without further errors and will be discussed here.

The scheme to accumulate sufficient data for a number of days throughout the warm season was determined as follows. Since one hour of short-term measurements (one second time interval) for eddy flux correlation computations needs one full tape, careful estimates had to be made for the absolute minimum amount of hours during the day which were necessary to interpolate a daily variation of the atmospheric parameters. We consider the absolute minimum of such hours to be five, distributed over the day as follows (starting time for one hour continuous recording):

1. during the warming period at mid-morning
2. at noon (maximum solar angle)
3. during decreasing solar radiation at mid-afternoon
4. one-half hour after sunset
5. one and one-half hour before sunrise

Thus, the increasing, maximum, and decreasing leg of the course of every atmospheric and ground parameter can be determined. The condition after sunset and throughout the night can be interpolated by using the two hours of measurements during the night (Figure 1).

In Figure 1 the hours of recording are shown for the shortwave solar and scattered radiation flux and for the net radiation flux. Thus a daily variation for the radiative parameters and all others following the course of the radiative flux can be easily interpolated.

This can be done also with the temperature measurements at the different depths and heights above the surface, as shown in Figure 2. Here 5 minute averages for selected temperature measurements are plotted and the daily variation interpolated.

An example for the temperature profile from the soil layers into the air is shown in Figure 3. Values are again 5 minute averages for each middle of hour recording. The active surface zone is apparent in this Figure, where, even as late in the year as October 3, temperatures of more than 40 C are reached during noon, while freezing temperatures occur close to sunrise. The temperature wave is dampened considerably in shallow soil layers, while the air up to 8 m follows the surface temperature wave more readily.

A history of the temperature profile of this type is to be recorded for selected days throughout the 1973 growing season, to provide environmental data for general use in biological studies. However, 1973 data will also be used to determine the heat exchange, including eddy transfer correlations.

A Fourier analysis is presently under way to determine if the time interval of one second is short enough to enter in the equations for the eddy flux method. Figures 4a and 4b show two short-term recordings of the temperature in different levels above the ground during day and night. Further studies are presently underway to determine the size of single eddies under daytime conditions. Frequency response analysis will be employed to analyze the data (Bendat and Piersol, 1971).

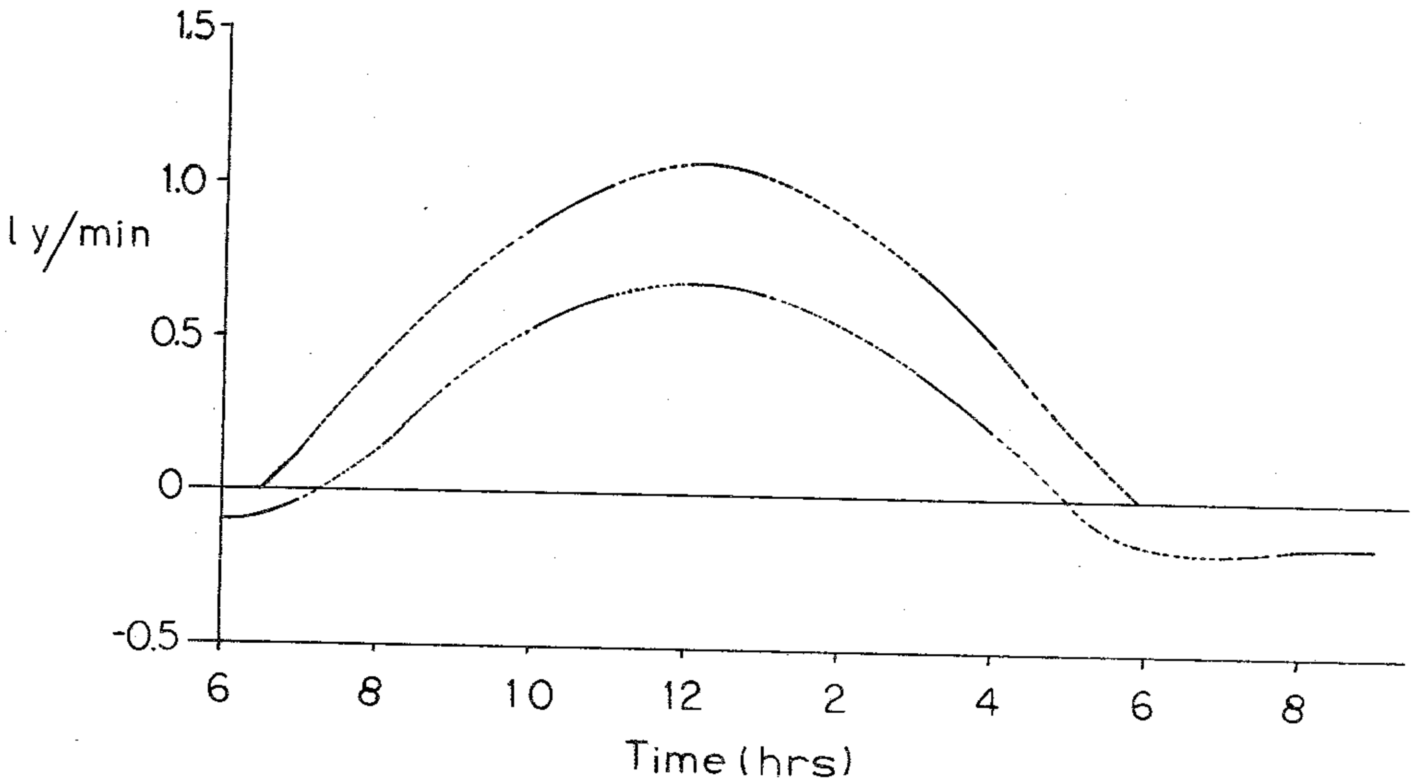

Figure 1. Hours chosen to construct daily variation.

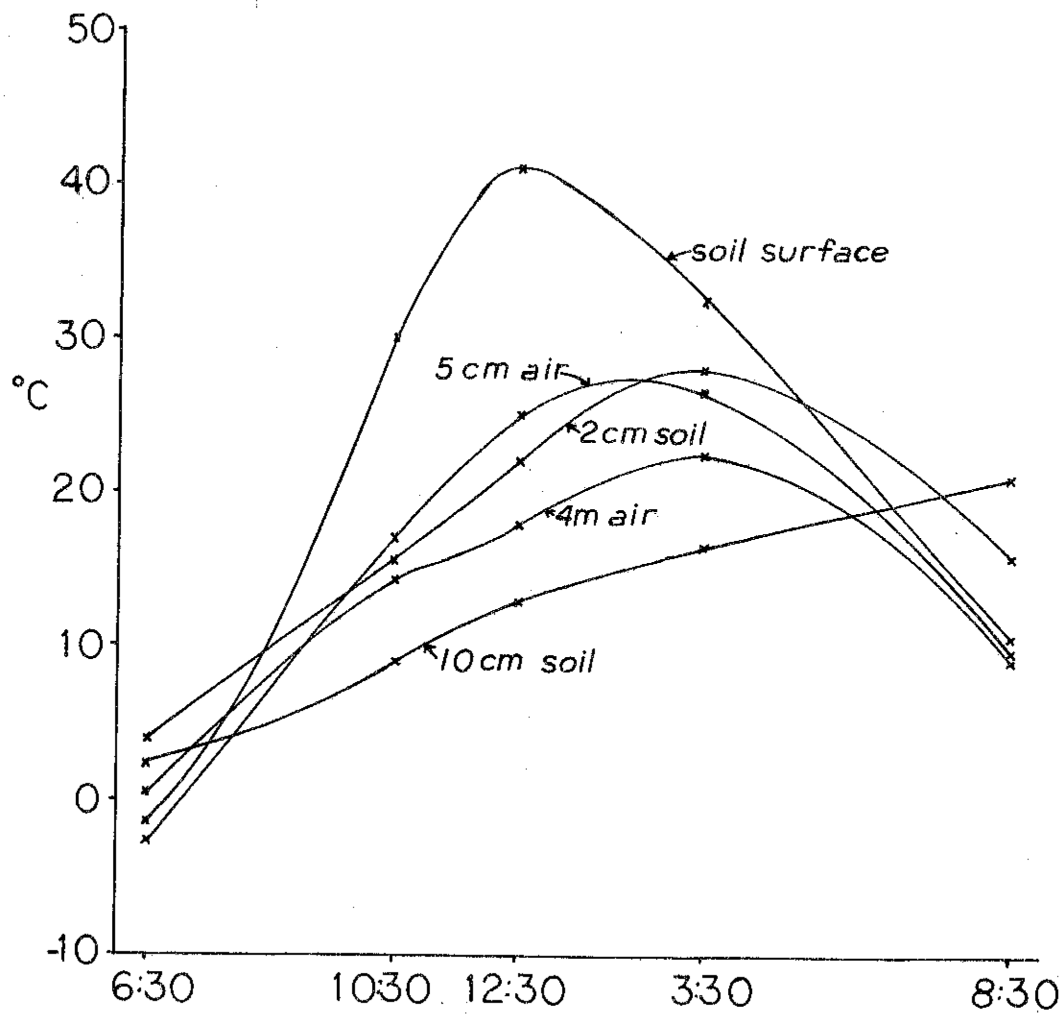

Figure 2. Daily variation of surface, soil and air temperature, October 3, 1972.

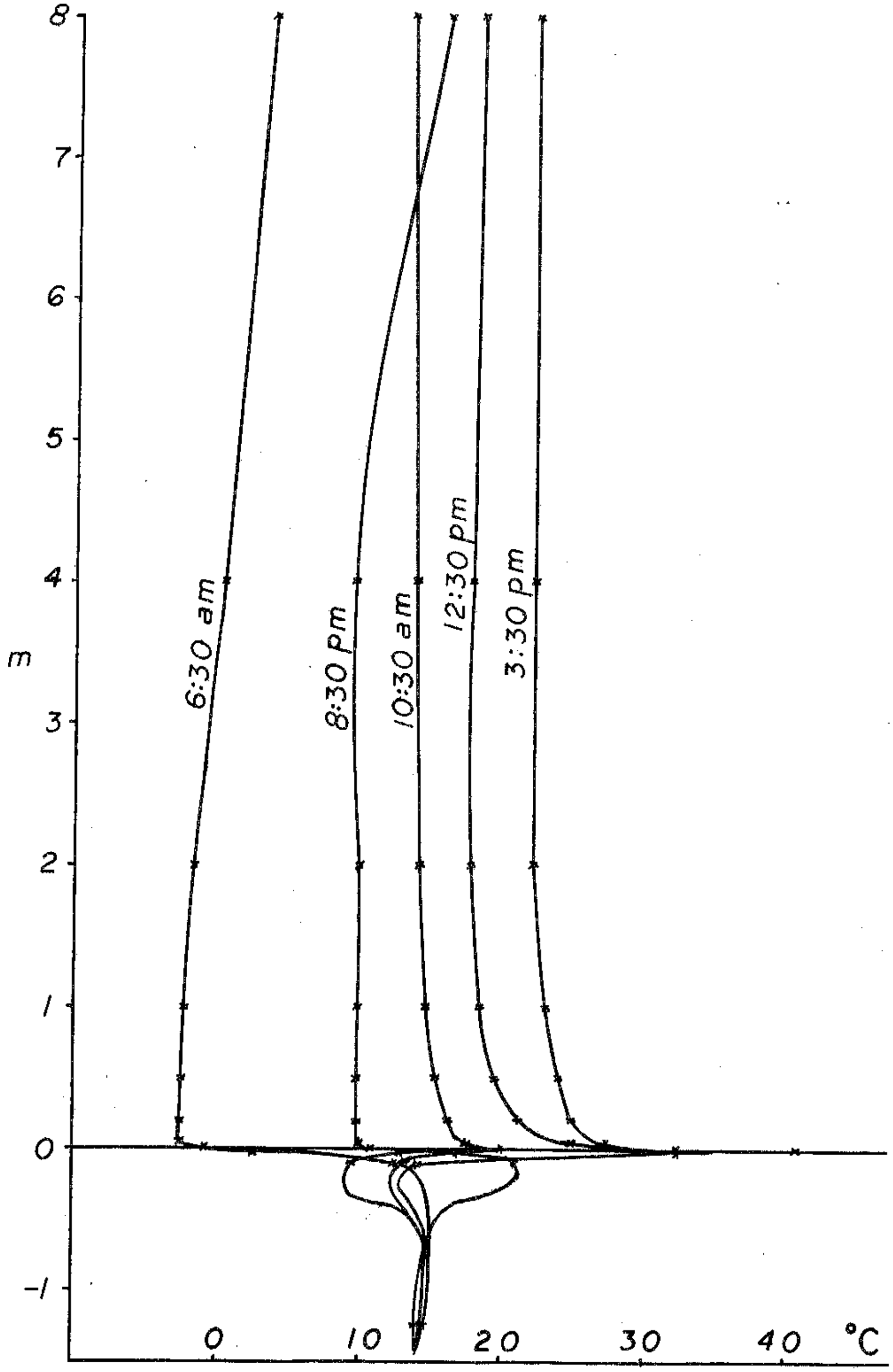

Figure 3. Profiles of soil and air temperature, October 3, 1972.

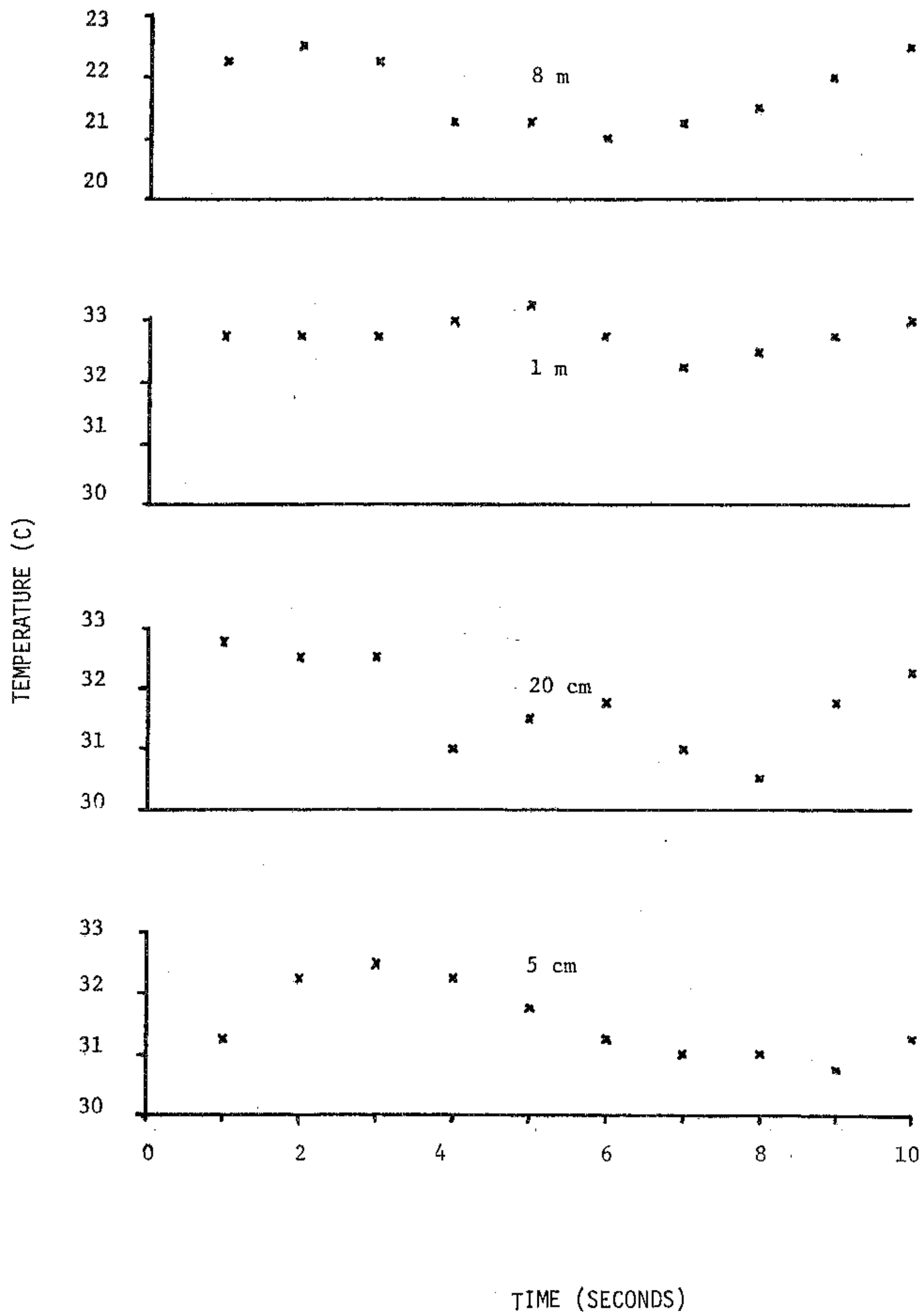

Figure 4a. Short term variation of air temperature in different levels at midday.

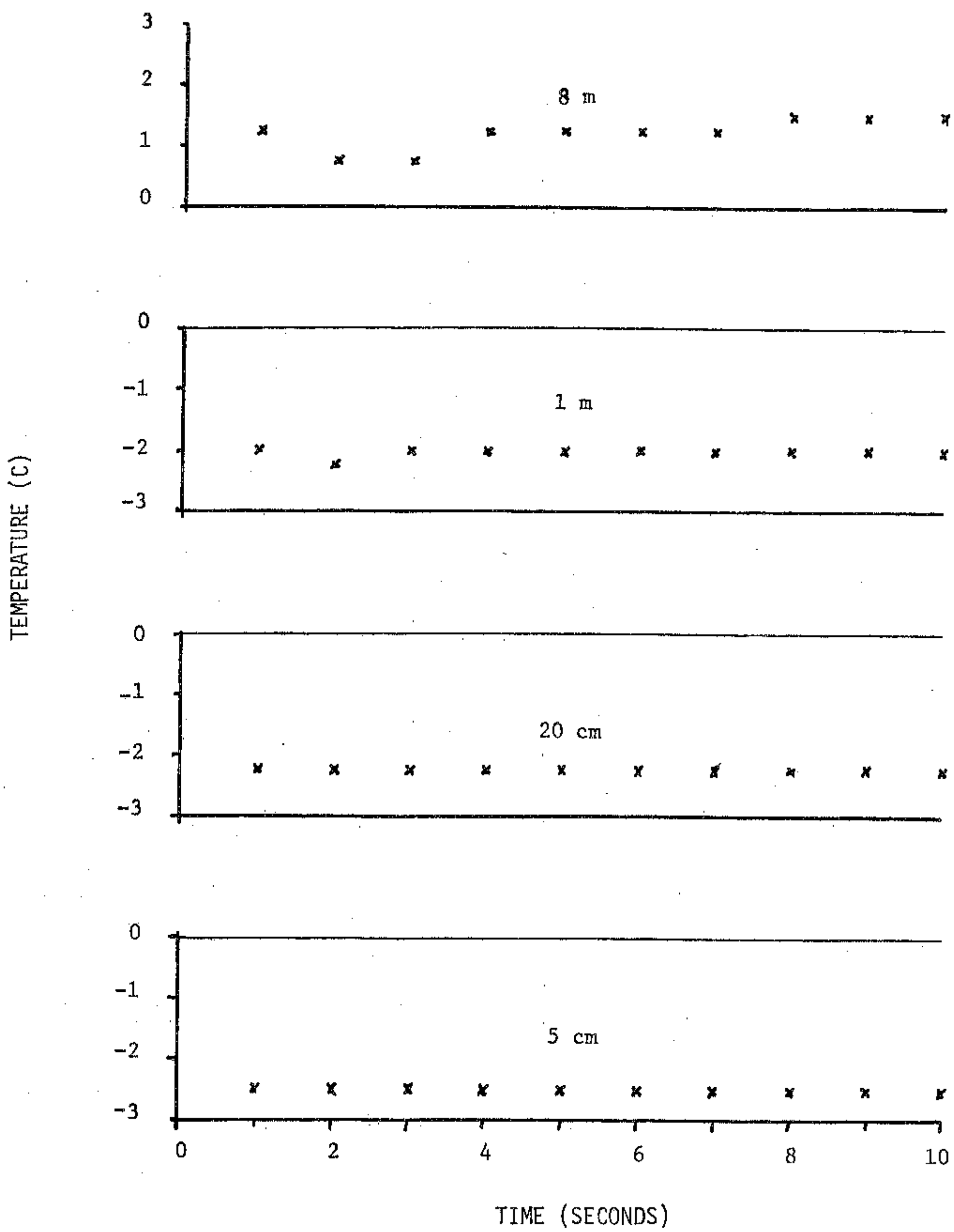

Figure 4b. Short term variation of air temperature in different levels at night.

DISCUSSION

The three days of recordings after adaptation of the equipment proved its capability of providing the data necessary for a broad history of the heat exchange during selected days, as well as for an intensive study of the individual parameters of the heat exchange. After eliminating the errors during this year's study, the main bulk of the data will be collected during the 1973 growing season.

EXPECTATIONS

With a series of selected days measured during 1973, an annual course of the heat exchange under desert conditions will be developed.

Models for the radiative exchange are presently being developed. An available soil model will be used, developed by Hanks, Austin, and Ondrechen (1971). The eddy flux will be measured, using the new sensors, and the heat exchange equation determined for dry and wet conditions.

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