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Source: *The Geographical Journal*, Vol. 34, No. 3 (Sep., 1909), pp. 298-300

Published by: geographicalj

Stable URL: <http://www.jstor.org/stable/1777146>

Accessed: 27-06-2016 04:16 UTC

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THE OBSERVATION OF AIR TEMPERATURE IN THE TROPICS.

By G. T. McCaw, M.A., F.R.A.S.

DURING the last few years the question of the accurate determination of the temperature of the air in tropical countries has been forced upon me by a consideration of the methods commonly seen in use in different parts of Africa. My investigations have led to the conviction that in very many cases the problem of the proper protection of thermometers is very imperfectly understood. In the present short paper, I propose to discuss the methods in vogue and the precautions to be adopted.

It is obvious that four conditions must be assured: (1) the instrument must be shielded from the direct rays of the sun, and (2) from the radiation of heat from the ground or adjacent objects; (3) it must be uninfluenced by radiation or convection of heat from any part of the structure erected to carry the thermometer; (4) the bulb must be freely exposed to the circulation of air.

One sometimes sees the instrument hung well in the shelter of the verandah of a house. It may happen that this is satisfactory, or nearly so, but such cases are rare; more often the situation is nearly as bad as it can be; often, again, one may expect very good readings at some hours, and very incorrect measures at others. If the verandah faces east or west, or even in any direction not almost north and south, the readings, especially during the forenoon or afternoon, are certain to be too high in hot weather. The sun beats in on the floor of the stoep and against the wall of the house, and one has often only to stand in such a position to realize that the

radiation from the floor and wall (especially the latter) renders the air actually hotter than it feels in the open sun. Moreover, the roof of the verandah is in general constructed without ventilation, so that the hot air is imprisoned just under the roof, in the very spot where the thermometer is placed.

In this connection it may be mentioned that, to ensure the greatest coolness both in the house and on the stoep, the roof of the verandah should be built double, as shown in the sketch. This method is now being adopted in the Sudan, and greatly conduces to comfort.

Again, it is useless to hang a thermometer in a tent pitched in the open sun, even when the tent is double-roofed, and is opened up on all sides.

Every traveller soon discovers that the canvas holds and transmits a considerable amount of heat, so that on a hot day one cannot stand up in a tent without feeling the oppression of the warm air which is confined under the apex and comes off the canvas.

A fortiori, it is worse than useless to endeavour to get air temperature by fixing the thermometer under a strip of canvas on a light bamboo or wooden framework

placed in the open. Not only does the sun beat through the canvas, while the canvas itself is a very fair conductor and has considerable capacity for heat, but also the instrument is exposed to the full radiation from the ground. If such an arrangement be employed, it could only be serviceable when the whole is protected by a large wide-spreading tree or similar covering, affording dense shade; but even then the instrument is probably exposed to the direct or indirect rays of the sun in the early morning or late evening. A much better arrangement is a large box, with cover and bottom removed in whole or in part, hung from the tree with its longer sides vertical, and oriented east and west, so as to shut out the direct rays when the sun is low. In this box the thermometer should be suspended freely, and not affixed to the sides.

A pent-house should not be used without closing in the sides facing east and west. If the roof be designed so that its slopes are east and west, and the sides under the eaves be thatched or boarded down to the ground, so that the direct sunlight will not strike the floor, a very fairly satisfactory building for meteorological purposes may thus be obtained. The sides facing north and south are then quite open, and every breeze has free access.

In the tropics, however, there seems no building in general so admirably adapted to the purpose as a properly constructed grass hut. The roof and walls must be *thickly* covered with grass, the framework substantial, and the hut must have high windows or doors fully opened to north and south. In such a hut the instruments are completely shielded from the sun's rays, and there is a large air space with free circulation of air. One precaution is necessary: care must be taken that the instruments may not be broken or records upset in high winds. The objections to the hut are that it requires constant repair, if not annual renewal, and that it is difficult to preclude the possibility of entrance of troublesome visitors. Hence, in many cases the Stevenson screen is preferred.

The Stevenson screen, as commonly constructed in the homeland, is not suitable for countries where there is a high continuous temperature throughout the day. On hot days, when the air is stagnant, or even when the breeze is very gentle or fitful, such a structure becomes a reservoir of heat. If the dimensions of the chamber are greatly enlarged, so as to be about a cubic metre in volume, and if the roof is made double, and the apertures between the lateral ventilators increased in proportion, the objections to the screen will disappear, and the arrangement will probably be the best possible for all stations where it is proposed to keep continuous records. The base of the compartment should not be left open, as is sometimes done, since the instruments are then exposed (except near midday) to the radiation from the soil. Again, other things being equal, the apparatus should be raised above the ground as high as conveniently possible. It will probably be advantageous to orient the structure, so that the doors may face north and south; where no intruders are feared, one or both of these doors, according to the position of the sun, can be left open, thereby increasing the chance of freer movement of the air around the bulbs.

For the traveller in a tropical land where there is no natural shade, it is probable that Regnault's principle of the sling-thermometer can be applied with success; it will assuredly give more accurate determinations of the true air temperature, especially during the hotter hours, than can be obtained with ill-designed portable screens of canvas or wood. A thermometer for this purpose should be enclosed in a stout, solid wooden case, closed at both ends, the bulb being exposed in a hole about $\frac{3}{4}$ inch in diameter drilled transversely through the case, to permit the free play of air around the bulb. As in all good thermometers, the bulb ought to be elongated, not spherical. The instrument is suspended by a strong cord tied to a ring at the top of

the case. It should be swung in a horizontal plane as high above the ground as practicable, without climbing eminences higher than ant-heaps. Naturally, the reading will be made immediately on the instrument being brought to rest. Some care must be exercised in doing this, as a chuck upwards will cause the mercury to rise in the tube.

In hot countries like the Sahara, where the radiation from the soil is very great, the air may be superheated by the radiation to relatively considerable heights. According to Prof. W. E. Thrift, in such regions the variation of temperature with height would perhaps be considerable, particularly so near the ground. The main effect would probably arise from convection currents, though these might tend towards equalization, but it is not quite obvious whether their effect would be *relatively* greater in hot than in cold countries.

Experiments are wanting to show the results of variation of height. It is advisable, then, that a certain height above the soil, say 6 feet, should be adopted by all observers with a view to uniformity.

A recent experiment* by Prof. R. W. Wood has a very direct bearing on the subject here considered. He finds that the heat in greenhouses is not, as commonly supposed, caused by a lengthening of the heat-waves which impedes their return passage through the glass, but is essentially due to the imprisonment of the mass of heated air. It will thus be seen how important it becomes to construct a chamber which will not in the least interfere with free circulation, for in the normal state in the open the air is in constant motion, and that motion is nowhere greater than in the tropics.

It is hoped that the considerations above advanced may lead to unification of method with a concomitant increase of accuracy, and that these notes may be especially of assistance to those observers who have little leisure for study in the press of administrative duty.

THE SYSTEMATIC DESCRIPTION OF LAND FORMS.†

By Prof. W. M. DAVIS, Harvard University.

ONE of the most serious tasks of the geographer is the preparation of accurate and intelligible descriptions of the forms of the lands. The earlier method employed in such descriptions was essentially empirical, in that it made no attempt at explanation; its terms, including such words as hill, valley, mountain, plain, river, lake, gave no indication of origin for the features that they named. But in association with these terms were certain others, such as delta, dune, volcano, lava-flow, sea-cliff, which always gave a suggestion of origin. The introduction of terms of the second class was a natural result of the increase of geological knowledge, whereby the existing features of the Earth's surface are more and more clearly seen to result from the action of ordinary processes through long periods of time.

To-day a belief in the reasonable production of land-forms has become so general, that the question may fairly be asked, whether it is not now possible to develop a method of thorough-going explanatory description, which shall treat all land-forms in view of their origin. I have been experimenting on the development

* *Phil. Mag.*, February, 1909.

† Research Department, March 18, 1909.