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C. FITZHUGH TALMAN, Librarian.

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METHODS AND APPARATUS FOR THE STUDY OF EVAPORATION.

By C. F. MARVIN, Professor of Meteorology. Dated June 21, 1909.

[*Continued from the Monthly Weather Review, April, 1909.*]

II.—INSTRUMENTS.

The instruments described in the following pages were devised to meet the needs of the campaign of work upon the evaporation of water from lakes and reservoirs, which has recently been undertaken by the Weather Bureau.

Although some of the devices were made up fully two years ago, yet they have only recently been employed in actual observations, and the object of the present paper is to bring the new instruments to the attention of those who may wish to use apparatus of this character.

We mentioned in the first section[10] of this paper that our present studies are confined essentially to the phenomena of evaporation from free water surfaces, and the apparatus, therefore, is designed more especially for the measurement of evaporation of water from pans.

GENERAL METHODS OF MEASUREMENT.

No method is known by which we can directly measure the water evaporated from an extended surface of water, soil, ice, snow, etc., as they ordinarily occur in nature. All we can do is to isolate, for example, a pan of this water, soil, snow, or ice and ascertain how much it loses by evaporation from day to day or hour to hour. Two general methods are available, viz:

(1) The weighing method.
(2) The volumetric method.

All existing apparatus for measuring evaporation, with scarcely an exception, belong in one or the other of these classes. If a psychrometer, for example, is regarded as an evaporometer then we need to make a separate class.

The Weighing Method.

The weighing method when available is probably the most exact of any, and perhaps it alone can be employed in the measurement of evaporation from ice, snow, damp soils, growing vegetation, etc. This method, nevertheless, is subject to sharp limitations that often make it wholly unavailable. In many cases it is of great importance that the isolated mass of material be relatively very great as compared with the loss by evaporation in the interval between observations. To weigh the loss under such conditions will generally require costly balances operating under conditions that entail special difficulties, or may be wholly incompatible with the general possibilities of the situation. The weighing method is, therefore, generally unavailable in all extensive field observations.

The Volumetric Method.

The volumetric method resolves itself nearly always simply into the measurement of the depth of water remaining in the evaporating pan or other container. Important errors affect this method and must be carefully accounted for. Among these may be mentioned:

(*a*) The formation of waves and ripples on the water, rendering it difficult to define and measure the mean level of the surface.

(*b*) The wind may drive the water from the lee to the windward side of the pan, causing false readings of changes in level.

(*c*) If not very solidly supported small tiltings and mechanical alterations in the position of a pan may be caused every time an observer approaches it to make a reading. Serious errors may be made in the measurements by such causes.

(*d*) Pans of considerable size floating in the water, and other pans to a lesser degree, may sometimes undergo such mechanical deformations or volumetric alterations as to produce changes in the level of the water-surface that do not correspond to real evaporation.

All possible causes of error such as those we have mentioned must of course be very carefully eliminated. Even in those regions where evaporation is very active it must nevertheless be measured in units of hundredths or even thousandths of inches, and trained scientists are well aware that measurements of this order of exactness cannot be carried forward from day to day except by the aid of apparatus whose essential parts retain the most definite and invariable relations.

Evaporation pans.—Probably the most suitable apparatus for the study of evaporation from an extended water surface consists of a large pan of water provided with means by which the loss of water can be measured or automatically recorded. Experience has shown that the size of the pan and the distance of the water below the rim will make very little difference within reasonable limits of variation. This does not mean that the actual evaporation in a 2-foot pan, 6 inches deep, will be the same as from a 10-foot pan, 6 feet deep, for example. The temperature of the water in the two pans would doubtless prove to be very different; but when this and other differences have been fully taken into account the evaporation will generally be found to be quite the same.

The sheltering effect of the rim of the pan is always important and to minimize this pans of large diameter—4 feet or more—should be used as far as possible. In general the water surface may be kept within 2 inches, or even less, of the rim of the pan. A greater depth may be necessary if water is likely to be splashed out by strong winds. So, likewise, in regions subject to heavy rainfall the height of the rim must be great enough to prevent the overflow of the pan by heavy rains. Circular pans about 4 feet in diameter and 10 inches deep, made of galvanized sheet iron, constitute a good working size.

Rain-sheltered pans.—When rainfall occurs frequently and in considerable amounts it is practically impossible to accurately determine the evaporation if the rain is permitted to fall into the evaporation pan. In the writer's opinion the only plan to follow is to roof over the evaporation pan so that no rain can fall into the apparatus. This roof must not obstruct the perfectly free action of the wind underneath. A pan so exposed will of course show a different march of temperature conditions, but the evaporation equation which will ultimately be developed will take account of this and there are many great advantages in the use of rain-sheltered pans. This plan has been recently put in operation by F. De Willson on the Panama Canal Zone. Evaporation often goes on continuously during showers, as the air is not then necessarily saturated.

Installation of pans.—To avoid and minimize the errors due to change of position and deformation, mentioned above under (*c*) and (*d*), the customary galvanized sheet iron pans must be bedded as perfectly and evenly as possible on rigid supports, and when floated in the water the pans must be trussed and ribbed, or otherwise reenforced, so that deformations do not result from the gentle wave motions of the water.

The still-well.—We now come to the details of the actual measurement of the water that passes out of one of our evaporation pans. These measurements aim to locate accurately the level of the water surface at each observation, so that the lowering of the surface represents the loss of water by evaporation. Any exposed water surface is almost always disturbed by large or small wavelets so that some artifice must be resorted to that will suppress the wave motion and realize the equivalent level the water would assume if stationary. We

[10] Monthly Weather Review, April, 1909, 37:141.