as the precipitation that falls upon their basins, and is their only source of supply.

In 1887 I had occasion to make a table showing the average precipitation upon the basins of Superior, Huron, and Michigan, for a period of about twenty years. This average I found to be 35.65 inches, and the average stage of Lake Michigan during the same period, 1.65 above datum. For the purposes of this article I have done the same thing for a series of eight years, 1888 to 1895, both included. The precipitation during this period averaged 30.44 inches. Lake Michigan fell from +2.64 feet in 1886, the end of a long wet period, to +1.96 in 1887, and to +1.30 in 1888, and finally to —0.5 foot in 1895. Further illustrations upon this point will be found in the following table, which shows the average level of the lake at Chicago for each year. The levels are referred to the adopted datum plane or low water of February and March, 1847.

Chicago datum was established in February or March, 1847, by Edward B. Talcott, chief engineer of the Illinois and Michigan Canal, and Alfred Guthrie (my father), designer and chief engineer of the Canal Pumping Works, which were to supply the summit level (30 miles) with water from the Chicago River (Lake Michigan). It was necessary to place the foundation of these works at a certain point below extreme low water. The unparalleled low stage then prevailing seemed to justify its adoption, and since then it has been the standard.

Many people, especially sailors, believe that the Great Lakes have subterranean sources of supply. This, it seems to me, is disproved by the fact that the lakes are lowest in winter and highest in summer, and always begin to rise as soon as the ice and snow melt in the spring.

Year.	Height.	Remarks.	Year.	Height.	Remarks.
1859	2.98		1879	1.06	Fall in 3 years, 1.50 feet.
1864	1.57	Fall in 5 years, 1.41 feet.	1880	1.26	Lakes continuously high 1880-1886, inclusive. Rainfall 46 inches in 1886.
1865	1.30		1883	2.10	
1866	1.07	Fall in 7 years, 1.91 feet.	1886	2.64	
1867	1.49		1889	0.77	Fall in 3 years, 1.87 feet.
1868	1.01	Fall in 9 years, 1.97 feet.	1890	0.63	
1869	1.13		1891	0.06	
1870	2.09	Rise in 2 years, 1.08 feet.	1892	—0.17	Fall in 6 years, 2.47 feet.
1872	0.81	Fall in 2 years, 1.28 feet.	1895	—0.50	
1876	2.56				

NOTES BY THE EDITOR.

THE CHEMICAL STORM GLASS.

In response to a request from one of our esteemed observers, the Editor would say that the "chemical storm glass," sometimes called "Fitzroy's weather glass," ought not to be considered as in any way a substitute for the mercurial or the aneroid barometer. Meteorologists cannot encourage the application of the word barometer to any instrument except such as measure the pressure or the changes in pressure of the atmosphere. If a hygrometer or a thermometer indicates the approach of a storm, that is no good reason for calling it a barometer.

As a general rule, in our country the temperature rises before a storm and falls afterwards, so also the wind changes, the clouds change, and the humidity rises. If, as an additional help in observing and predicting storms, the observer wishes to know something about the pressure of the air, he must get the genuine barometer and not the chemical storm glass. The substances in these storm glasses are made according to various recipes, some of which are the secrets of the makers (usually camphor and sal ammoniac dissolved in alcohol and water), but in all cases, so far as the Editor knows, the tubes are hermetically sealed and the changes that are apparent in the solution within them are due to the temperature of the solution and to the rate at which this temperature has been changing for a few hours before the observation. There may be cases in which the action of the daylight is appreciable. If any observer has recorded carefully the behavior of his chemical storm glass during a month or year, we shall be glad to have him investigate wherein its indications are better than those of his thermometer.

EVAPORATION.

The quantities of water added to the atmosphere daily by evaporation from the oceans and the continents constitute a fundamental consideration in meteorology; the quantities evaporated from cultivated fields, forests, and other forms of vegetation are equally important in agriculture, but as yet we have confessedly attained to only a very imperfect knowledge of this subject. Meteorologists have generally observed the amount evaporated from a small surface of water exposed either in the open air and sunshine, or else within such a shelter as is used for the open air thermometer; lately a disc of moist paper has been substituted for the surface of water, as in the Piche evaporometer. Agriculturists, on the other hand, have made use of the lysimeter, which consists of a deep metallic box buried in the earth and having its open upper side flush with the surface of the ground. This box is filled with soil in which plants may or may not be growing, according to the object of the investigator. Record is kept of the amount of water or rain that is added to the lysimeter box from day to day, and also of the amount of water that drains from the bottom of the box. The difference between the two is adopted as the natural evaporation from the soil. The soil in the box may be kept very wet, to imitate a morass, or very dry to imitate a desert; the fineness of the soil may vary from coarse gravel to the finest silt.

If we desire the actual amount evaporated into the atmosphere we must do more than record the results of the above forms of apparatus. The evaporating surface of water in the shaded thermometer shelter will indeed give up its moisture in proportion to the temperature of the water and to the velocity and dryness of the wind at its surface, but these three important factors have values so different out of doors from those within the shelter that such records can, at the best, only give us a crude idea of the actual evaporation from surfaces in the open air. A great evaporation within the shelter, caused by a strong, hot dry wind, may be accompanied by but little evaporation from the surrounding country if the latter be a desert of rock and gravel.

On the other hand, by means of the lysimeter, one may indeed determine directly the evaporation from soil of any character exposed to the natural outdoor conditions, but there then remains the difficult task of determining how much soil of each respective kind really occurs in the surrounding territory. In order, therefore, to determine the actual evaporation from land surfaces one must observe a large number of lysimeters and make an extensive minute survey of the country. The calculations incident to this latter method are very laborious.

The ordinary psychrometric observations give the dew-point or quantity of moisture in a small unit volume of air at any moment. If in the course of the day this quantity increases we are not thereby warranted in concluding that the increase is due to a local evaporation, it may have been brought from a distance by the wind, or it may even have come down from the clouds as rain. If observations of dew-point are carefully made on all sides of a large field, over which a gentle wind is blowing and if it should appear that there is a little more moisture in the air on the leeward side than on the windward side one might conclude, provisionally, that this increase represented the quantity of moisture thrown by evaporation into the air as it gently moved over the surface of the field. But even this conclusion must be modified indefinitely by the consideration that in blowing across the field the wind does not move horizontally, but in a series of rolls and whirls by which the lower air in which we are observing becomes mixed with upper air, about whose moisture we know little or nothing.

In the midst of all these uncertainties it seems almost hopeless to attempt anything like an accurate determination of the moisture actually added to the atmosphere by evaporation from any extensive region of land or water; the question is far more complex than the determination of the evaporation from a reservoir of water, which latter problem is often attacked by the hydraulic engineers. Including the earth and its atmosphere in one comprehensive view, we may certainly say that the total annual evaporation from snow and ice, fresh water and salt water, must average the same as the total annual precipitation. We may even make an annual average for each continent, and say that the evaporation from the land plus the water that flows away in the rivers must equal the rainfall, and as the river discharge is frequently well known, we may, by subtraction, infer the evaporation. For the oceanic surface, on the other hand, the evaporation must equal the rainfall plus the river discharge from the continents.

The latest contribution to our knowledge of evaporation from land surfaces is published by Prof. E. Wollny of Munich, at page 486, Vol. XVIII, of his "Forschungen." As the result of three years continuous observation of five lysimeters and a neighboring evaporometer, he concludes:

1. That the quantity of moisture evaporated from the soil into the atmosphere is considerably smaller than that evaporated from a free surface of water.

2. That the evaporation is smallest from naked sand, and largest from naked clay, whereas naked turf and humus or vegetable mould have a medium value.

3. That the evaporation is increased to a considerable extent by covering the ground with living plants.

As the result of a minute analysis of the complex relations between the evaporation and the meteorological elements, on the one hand, and the physical features of the soil on the other, Dr. Wollny further concludes as follows:

4. Evaporation is a process that depends both upon the meteorological conditions and on the quantity of moisture contained by the substratum of soil.

5. Among the external circumstances temperature is of the greatest importance, inasmuch as, in general, evaporation increases and diminishes with it, but this effect is modified according as the remaining factors come into play, and in proportion to the quantity of water supplied by the substratum.

6. The influence of higher temperature is diminished, more or less, by higher relative humidity, greater cloudiness, feebler motion of the wind, and a diminished quantity of moisture within the soil, whereas its influence increases under opposite conditions. On the other hand, low temperatures can bring about greater effects than high temperatures if the air is dry, or the cloudiness small, or the wind very strong, or if a greater quantity of water is present within the evaporating substance.

7. For the evaporation of a free surface of water, or for earth that is completely saturated with water, the important elements are, first the temperature, next the relative humidity of the air, and then the cloudiness, direction and velocity of the wind; whereas, for the ordinary moist earth, no matter whether the surface is naked or covered with living plants, it is the quantity of rain upon which the soil depends for its moisture that is the important additional consideration. The effects of the external elements on evaporation become less important, as explained in paragraph 5, in proportion as the precipitation is less and as the soil is more completely dried out by the previous favorable weather, and *vice versa*. For these reasons the rate of evaporation from a free surface of water not infrequently differs largely from that from the respective kinds of soil.

8. Free surfaces of water, and soils that are continuously saturated, evaporate into the atmosphere on the average more water under otherwise similar circumstances than soils whether naked or covered with plants and whether watered artificially or naturally. Only at special times, viz, when the influence of the factors that favor evaporation is most intense, when the plants are in the most active period of growth, and when the soil contains a large percentage of water can the land that is covered with plants show a larger evaporating power than the free water surface.

9. When a soil that is not irrigated is covered with plants it evaporates a far greater quantity of moisture than when the surface is bare. In the former case the evaporation can not exceed the quantity received by the soil from the atmosphere before or during the period of growth. Swampy lands and those that are well irrigated, as also free surfaces of water, can, under circumstances favorable to evaporation, sometimes give to the atmosphere a greater quantity of water than corresponds to the precipitation that occurs during the same time.

10. The evaporating power of the soil is, in itself, dependent upon its own physical properties; the less its permeability for water, or the larger its capacity for water and the easier it is able to restore by capillarity the moisture that has been lost, by so much the more intensive is the evaporation. For this reason the quantity evaporated increases with the percentage of clay and humus in the soil, whereas it diminishes in proportion as the soil is richer in sandy and coarse-grained materials.

11. Soil that is covered with plants loses by evaporation so much more water in proportion as the plants are better developed, or stand thicker together, or have a longer period of vegetation, and *vice versa*.

In conclusion, Wollny repeats that the use of apparatus giving the total evaporation from free water surfaces does not respond to the needs of the agriculturist [and we may add of the meteorologist] but that instruments must be used for measuring the evaporation from masses of earth that are wet with rainfall only and free from stagnant wet soils. Lysimeters are recommended having a section of one-tenth of a square meter and a depth of soil one-half of a meter and set out in the open air sunk flush with the surface of the ground and arranged so as to be easily weighed at any moment and so that the drainage water can easily be measured.

[NOTE.—The above results of Wollny's laborious observations confirm us in the general conclusion that the quantity of water actually evaporated from a large surface of land, such as a definite watershed maintaining a single river, can only be determined by the following considerations: The quantity of water contained in the soil at the end of any given period in excess of what it contained at the beginning, plus the water that is carried off by drainage and river flow, plus whatever is evaporated into the atmosphere either directly or through the crops and forests, must equal the rain and irrigation water added to the soil during that time. As the soil content of water, the riverflow and drainage, and the rainfall can be severally determined by direct observation far better than the evaporation, the latter is to be determined by taking the difference between the rainfall and all other sources of loss or consumption.]