pressure difference; and hence that (provided other conditions be favorable) the moisture on adjacent surfaces may be congealed. In short, under favorable circumstances, the breathing well or blowing cave may become a natural ice machine, clumsy and inefficient, indeed, yet possibly making up in magnitude for its simplicity and the slightness of the pressure differences within its reach. Of course it would seem at first sight that in each passage from low pressure to high and back again, as in the long run, the effects of the natural mechanism would balance, i. e., that the heat given off in inspiration would equal the chill of expiration, so that no refrigeration could ensue; yet when the seasonal ranges of barometer and thermometer are considered, it would seem clear that the heating would tend to culminate in autumn and the chill in spring, in such wise as to sustain the widespread popular opinion on the subject, i. e., that the period of ice melting runs into winter and that of ice forming into late spring and summer.

This is evidently an interesting subject for investigation on the part of the numerous voluntary observers of the Weather Bureau. As Mr. McGee points out, there is a lack of definite information in regard to many features of ice caves. From the fact that ice is occasionally found in July where it is not found in January, the erroneous conclusion has sometimes been reached that there are caves in which ice forms during the summer and melts during the winter. It also appears that measurements of currents flowing into or out of caves are very much to be desired. My own observations[1] indicate that there can be only a slight movement of the air into or out of an ice cave during the summer. A rapid circulation of the air would soon melt the ice, and it is because a circulation can not be maintained that the ice is preserved.

Observations of the temperature of the air in ice caves each month, or, better still, each week, together with measurements to determine whether the ice deposit is increasing or diminishing, would throw much light on the process of ice formation. At the same time it would be a simpler matter to ascertain by means of a light thread held in the hand, or even by observing the movement of the fog from the breath, whether there is any perceptible flow of air into or out of the cave. This latter observation should be made in the passageway leading to the bottom of the cave, where the ice usually forms, as well as near the ice itself. There is danger of mistaking the movement of the air past the mouth of the cave for a movement out of it, and observations at this point should therefore be taken with great caution.

It would also be interesting to notice whether there is any marked increase in the circulation of the air in caves in winter over that in summer.

Already two of our voluntary observers have sent us communications on the subject of ice caves. Mr. A. D. Elmer, Northfield, Mass., writes that there is a cave in the Northfield Mountains in which ice is often found as late as August. He also refers to a very cold stream of water of considerable size in Hilsdale, N. H., over which a thin fog hangs in summer. We should very much like data in regard to the temperature of this stream, and also with respect to the prevalence of fog upon it at different seasons of the year.

Mr. Galloway C. Morris, Caldwell, Warren Co., N.Y., writes of a cave in his vicinity from which ice is often obtained in August. He proposes to make systematic observations in this cave during the coming year.

We can hardly consider an ice cave to be even a crude form of "atmospheric ice machine," as suggested by Mr. McGee. The expansion is not sudden enough nor the range of pressure great enough to produce any appreciable cooling. We must distinguish between the sudden expansion that takes place in the chamber of an air pump and the slow processes of nature.

But let us assume that the present changes continually taking place in nature are accompanied by corresponding changes in temperature at the adiabatic rate. Leaving out of the question the pressure variations due to cyclonic and anticyclonic movements, which, as Mr. McGee has said, must balance each other in the course of the year, we have left differences in the normal pressure from winter to summer, which at sea level amount to only one or two tenths of an inch of mercury. From Professor Bigelow's tables[2] we find that the adiabatic cooling due to a diminution of pressure by 1 inch is only about 5° F., so that the cooling due to expansion from winter to summer mean pressure could hardly amount to more than 1° F. in that part of the cave where the ice is usually found.

Mr. McGee suggests another way in which cooling might be effected. He shows that any marked diminution of the external air pressure must cause a decided flow of air out of the cave; and this outflowing air will expand, especially as it passes through the cave's throat, thereby reducing the temperature at that point. But to make this method effective, it is necessary that the cave be very large and its throat very small; and the ice will be formed, not necessarily at the bottom of the cave, but on the walls at the narrowest part of the outlet, or about the cave's throat. Are there caves in which the ice is formed in this way?—*H. H. K.*

[1] Monthly Weather Review, August, 1901, Vol. XXIX, p. 366.

[2] Report of the Chief of the Weather Bureau, 1898–99, Vol. II, pp. 550–553.

THE TEMPERATURE OF WATER IN WELLS.

Mr. R. J. Redding, Voluntary Observer, and Director of the Georgia Experiment Station, has sent us the following communication:

I remember seeing it stated in some publication, many years ago, that there is a close correspondence between the mean annual temperature of the water of ordinary wells and the mean annual temperature of the air above the same location. In connection with the statement it was suggested that a traveler, if supplied with a good thermometer, might approximately ascertain the mean annual temperature of the air of any region by simply finding by actual test the temperature of the wells. I have looked in vain for any amplification of the statement in some encyclopedia or other repository of popular information. In a desultory way I have verified the statement quite a number of times but have kept no record of observations, and can only write from memory: In Ocala, Fla., I found the temperature of the well water (February) to average about 72° F.; in Americus, Ga., 66°; in Ellaville, Ga., 66°; in Macon, Ga., 65°; Experiment, Ga., 62°; Atlanta, Ga., 60°; Dahlonega, Ga., 56°; Minneapolis, Minn., 46°. These are all the observations I can recall, but I have made others. On referring to a standard isothermal chart I found a very close correspondence between the temperature above noted and the mean annual temperatures of the air of the same locality. When I have had opportunity to note temperatures of the water of a given well at all seasons of the year I have observed a variation of as much as 2° between the maximum and the minimum, where the well was not deeper than 25 to 30 feet. This range decreases as the depth increases until, according to my limited observations, when the depth of 50 to 60 feet is reached there is no perceptible variation, the temperature of the water remaining uniform the year round. In shallow wells, say 25 to 30 feet, the water was found to be colder by one or two degrees in June than in December, which suggests that it requires about six months for the extreme temperature of the air above to become manifest at that depth. I have thought that this fact explains and justifies the claim often made by well owners, that their well water is colder in midsummer than in midwinter.

The temperature of water in wells must evidently be intimately connected with the temperature of the ground at different depths. Unfortunately, comparatively little attention has been given to this subject in the United States, although it has been quite thoroughly studied in Europe. Perhaps the best series of observations are those that were made at Munich, Bavaria[1] from 1861–1885, and from which a diagram was constructed showing the mean temperature of the ground at different depths for each month of the year. This diagram has

[1] Die Bodentemperature an der K. Sternwarte bei München. Von Dr. K. Singer. Anhang. Deutsches Meteorologisches Jahrbuch, 1889. Band XI.

been reproduced in Prof. Wm. M. Davis' Elementary Meteorology, p. 33.

From these observations we learn that while the average annual temperature at Munich for the period 1861–1885 was 6.9° C., the average annual ground temperatures at different depths were as follows.

Depth.	Temperature of ground.
Meters.	° C.
1.29	9.18
2.46	9.16
3.63	9.12
4.80	9.12
5.97	9 06

This indicates a ground temperature nearly 2.3° C. in excess of the air temperature at a depth of 1.3 meters, which is greater than has usually been observed. Thus, Wild[2] concluded after a study of observations at many different places that the annual mean temperature of the ground at a depth of 1 meter exceeds the annual mean of the air temperature by only 1° C., but that this value is by no means constant, but rather has a probable error of 1° C.

In the American Meteorological Journal, Vol. VII, p. 267, Prof. Mark W. Harrington, says: "The temperature of the soil usually increases slowly, and on a simple law as we descend to lower depths." He then gives the following table[3] summarizing the observations made near Edinburgh, and taken from Transactions Royal Society Edinburgh, Vol. VII, p. 204.

Station.	Average annual temperature (from five years' observations).			
	Depth of 3.2 feet.	Depth of 6.4 feet.	Depth of 12.8 feet.	Depth of 25.6 feet.
	°	°	°	°
Observatory	45.49	45.86	46.36	46.87
Experimental Gardens	46.13	46.42	46.76	47.07
Craighleith	45.88	45.92	45.92	46.07

It is therefore safe to say that in general the average annual temperature of the ground a few feet below the surface is slightly warmer than the average annual temperature of the air at the same place, and that it varies but little with distance from the surface. After a certain depth is reached, however, the earth maintains a constant temperature throughout the year, and from this point on there is a marked increase in temperature as we descend. The depth of the upper surface of invariable ground temperatures varies with the geologic formation, as also does the rate of increase of temperature below this level.

In a paper on the Geothermal data from deep Artesian Wells in the Dakotas,[4] N. H. Darton of the United States Geological Survey says:

> In many parts of the world it has been found that the rate of increase of temperature averages about 1° for each 50 feet, below the first 40 feet, in which the temperature is usually regarded as that of the mean annual temperature of the region. In the greater part of the artesian basin of the Dakotas the rate of increase is found to be greatly more than this, attaining at Fort Randall a rate of 1° for each 17½ feet. At this well the temperature of the water is 80° F., or possibly slightly more, but the depth from which it is derived is only 576 feet, which indicates the abnormally high rate of increase.

Since the water collected in wells usually percolates very slowly through strata at about the same level as the bottom of the wells, it follows that in general the average annual temperature of the water thus collected is apt to be a little higher than the average annual temperature of the place, and it may be several degrees higher in wells of great depth.

At 30 and 40 feet below the surface the maximum temperature does not occur until January; and conversely the minimum temperature occurs in July. In consequence the maximum and minimum temperature of water in wells of this depth should occur during these same months, as has been noted by Mr. Redding, provided the well is tightly closed at the top, so as to prevent the cold surface air of winter from gravitating into it. This latter source of cooling is really very important, and to it must often be attributed the many notable exceptions to our rule; we have already called attention to one, in the frozen well at Brandon, Vt.[5]—*H. H. K.*

PERIODICITY IN CLIMATE.

We have often had occasion to maintain that no appreciable permanent change in climate has taken place during the past two hundred years, or since records of temperature and of the flora and fauna, the freezing of rivers, the depth of snow and other climatic phenomena have been kept with sufficient accuracy to justify any rational conclusions. On the other hand, there can be no doubt that large fluctuations take place in the character of the seasons and years, and some of these fluctuations have been called "periodic," although they are not confined to periods of any well-defined length, and ought therefore to be designated as systematic rather than periodic. Thus, Brückner found that the fluctuations of a variety of phenomena grouped themselves roughly about an ideal 35-year period, although no one of them was confined strictly to that. The Editor's idea has always been that the presence of continents, oceans, plateaus, and especially the ice and snow of the polar regions, by contrast with the great oceans of the globe, must introduce systematic irregularities into the general circulation of the atmosphere, which reacting on each other, must produce frequent repetitions of warm or cold, wet or dry seasons in specific regions of the earth. Such repetitions will, for a while, recur at nearly the same interval but by and by at another interval, so that no uniform constant period could possibly represent them all. An article in the Boston Transcript, as quoted in the monthly report of the Iowa Climate and Crop Section for February, 1901, states that during the past year the streams of New England, the Middle States, the Northwestern States, and the Pacific coast have been at their lowest ebb in a century, but the streams of Arizona and Texas, which five years ago were apparently about to disappear entirely, have taken on new life and more water is flowing from them at the present time than for many years past. Of course, sometimes streams may be high in the winter and low in the summer, or vice versa, and the outflow of water or the "run off" does not depend altogether on the rainfall, but largely on the topography of the watershed and on the character of the rainfall, whether it comes in many small showers or a few heavy rains; it also depends upon evaporation, which is a function of the sunshine, the wind, the vegetation, and the soil. With regard to the rainfall, the Transcript says that in New England from 1830 to 1850 there was an abnormal deficiency; from 1850 to 1865 it was normal, and since then it has been far above the average. The Ohio and Mississippi valleys have also had their years of dryness and excessive rain. Now, the years of drought or rain are not the same in New England, the Mississippi Valley, New York, Texas, Arizona, California, and Oregon. The regions of excess and deficit move around from place to place over the

[2] H. Wild. Ueber die Bodentemperaturen in St. Petersburg u. Nukuss Rep. of Meteorologie. Band VII. No. 4. St. Petersburg. 1878. P. 88.

[3] Professor Harrington's table is slightly in error in that he failed to reduce the French feet, in which the depths were indicated, to English feet.

[4] Am. Jour. Sci., 1898, vol. 5, p. 162.

[5] See Monthly Weather Review, August, 1901, p. 370.