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The MONTHLY WEATHER REVIEW is based on data from about 3500 land stations and many ocean reports from vessels taking the international simultaneous observation at Greenwich noon.

Special acknowledgment is made of the data furnished by the kindness of cooperative observers, and by Prof. R. F. Stupart, Director of the Meteorological Service of the Dominion of Canada; Señor Manuel E. Pastrana, Director of the Central Meteorological and Magnetic Observatory of Mexico; Camilo A. Gonzales, Director-General of Mexican Telegraphs; Capt I. S. Kimball, General Superintendent of the United States Life-Saving Service; Commandant Francisco S. Chaves, Director of the Meteorological Service of the Azores, Ponta Delgada, St. Michaels, Azores; W. N. Shaw, Esq., Secretary, Meteorological Office, London; H. H. Cousins, Chemist, in charge of the Jamaica Weather Office; Señor Anastasio Alfaro, Director of the National Observatory, San José, Costa Rica; Rev. L. Gangoiti, Director of the Meteorological Observatory of Belen College, Havana, Cuba.

As far as practicable the time of the seventy-fifth meridian, which is exactly five hours behind Greenwich time, is used in the text of the MONTHLY WEATHER REVIEW.

Barometric pressures, both at land stations and on ocean vessels, whether station pressures or sea-level pressures, are reduced, or assumed to be reduced, to standard gravity, as well as corrected for all instrumental peculiarities, so that they express pressure in the standard international system of measures, namely, by the height of an equivalent column of mercury at 32° Fahrenheit, under the standard force, i. e., apparent gravity at sea level and latitude 45°.

## SPECIAL ARTICLES, NOTES, AND EXTRACTS.

### PRESENT DAY CLIMATES IN THEIR TIME RELATION.

By FRANK MORRIS BALL, Department of Geology, University of Minnesota. Dated Minneapolis, Minn., April 10, 1906.

It is often asserted by people who have lived in a locality for many years that the climate of their region has undergone marked changes during their residence, the most common statements being that cold weather came earlier in the fall, that greater snowfall was experienced, that the thermometer registered more continuously low temperatures in years past than at present, and that the rainfall is increasing or decreasing in amount. In the light of the modern science of statistics these statements are open to serious question. The human organism is at best an inaccurate register of temperature, and memory is more liable to be impressed with some single manifestation of weather than with the average of weather conditions which go to make up climate. A vivid impression of a day on which the thermometer registered 40° below zero is quite likely to remain in the mind for a long time, but the week of moderately cold weather which followed the cold snap and which, when averaged with the lowest temperature noted, made only average winter weather, is quite likely to be unnoticed, or, if noted at all, soon forgotten.

The introduction of instruments for the measurement of weather conditions, and the registration of all temperature changes according to an absolute instead of a relative standard show conclusively that when a long period of years is considered climatic averages are essentially stable.

The accompanying tables illustrate this stability of climate at places widely separated and subject to the control of different climatic factors.

Tables 1 and 2 show the annual temperatures and rainfall for neighboring localities in Minnesota.

Hann's Handbook of Climatology quotes the computations of Angot on the dates of vintage in France since the fourteenth century. Table 3 shows an oscillation but no permanent change in climatic conditions during this long period.

Tables 4 and 5, given by Russell in his book on meteorology, show temperature averages for St. Petersburg, Russia, and Philadelphia, Pa.

When long periods of years are considered, an oscillation of climate seems to be apparent. Thus for North America an 11-year oscillation has been computed, corresponding to the sun-spot cycle. This variation has not been shown to be persistent or general in occurrence. In Europe a 36-year period of oscillation of both rainfall and temperature is found by Brückner to occur. These variations are always slight, however, and do not as a rule exceed 0.5° to 1° on either side of the established mean.

TABLE 1.—*Average temperature compiled from records kept at Fort Snelling and St. Paul, Minn., since 1822.*

[From C. W. Hall's Geography of Minnesota.]

| Years. | °F. |
|---|---|
| 1822–1824 | 43.33 |
| 1825–1829 | 46.00 |
| 1830–1834 | 46.00 |
| 1835–1839 | 43.60 |
| 1840–1844 | 42.00 |
| 1845–1849 | 43.60 |
| 1850–1854 | 44.40 |
| 1855–1859 | 41.00 |
| 1860–1864 | 42.80 |
| 1865–1869 | 41.80 |
| 1870–1874 | 42.80 |
| 1875–1879 | 42.80 |
| 1880–1884 | 43.40 |
| 1885–1889 | 42.20 |
| 1890–1894 | 43.00 |
| 1895–1899 | 43.00 |
| 1900–1901 | 44.60 |
| 1822–1849 | 44.09 |
| 1850–1877 | 42.60 |
| 1878–1901 | 43.16 |

TABLE 2.—*Annual rainfall at Minneapolis, Minn., since 1866.*

[Compiled by C. W. Hall from the records of William Cheney.]

| Years. | Inches. |
|---|---|
| 1866–1871 | 32.29 |
| 1872–1881 | 27.83 |
| 1882–1891 | 27.09 |
| 1892–1901 | 29.55 |
| Average, 1866–1901 | 28.85 |

The accompanying tables show that no permanent changes of temperature were experienced at the places quoted during the periods of time recorded. It would be beyond the power of actual demonstration to say that the figures prove an absolutely stable climate, but on the other hand no figures exist which prove that climates have changed within the period covered by scientific investigation.

TABLE 3.—*Average of vintage dates at Dijon, France.*

[Compiled by Angot.]

| Period. | Date. |
|---|---|
| 14th century (13 years only) | October 25th. |
| 15th century (60 years only) | October 25th. |
| 16th century | October 28th. |
| 17th century | October 24.5th. |
| 18th century | October 28.8th. |
| 19th century (80 years only) | October 30th. |

TABLE 4.—*Temperature averages at St. Petersburg, Russia, 1743–1875.*

| Years. | °F. |
|---|---|
| 1743–1761 | 39.00 |
| 1762–1779 | 39.60 |
| 1780–1800 | 37.90 |
| 1801–1821 | 37.80 |
| 1822–1836 | 39.20 |
| 1836–1869 | 38.50 |
| 1869–1875 | 37.90 |
| Mean | 38.60 |

TABLE 5.—*Temperature averages at Philadelphia, Pa., 1758–1889.*

| Years. | °F. |
|---|---|
| 1758–1777 | 52.60 |
| 1798–1804 | 54.20 |
| 1829–1838 | 51.50 |
| 1825–1845 | 53.10 |
| 1846–1867 | 54.00 |
| 1871–1889 | 53.10 |

If we stop a moment to reflect that the factors of climate are under the direct control of natural laws, no surprise will be occasioned because of the permanency of climatic averages. That seemingly most wilful and lawless of all elements, the wind, is no less under the direct control of law and responds to it with no less unhesitating obedience than does the earth to the law of gravity in its yearly swing about the sun.

Speaking generally, we may say that any climate is determined by the following factors:

1. Distance from the equator. 2. Elevation above sea level. 3. Distance from large bodies of water. 4. The character and arrangement of surface features. 5. The direction of prevailing winds. 6. When long periods of time are concerned, the distance of the sun from the earth and the attitude of the hemispheres of the earth to the sun during aphelion and perihelion. 7. The relative amount of carbon dioxide present in the atmosphere. Of these elements controlling climates only the 5th is considered variable during periods measurable by man. However, if we classify wind systems and consider the two most important in relation to weather changes, namely, the permanent and cyclonic circulations, we shall see that the permanent winds can not be thought of as variable; a study of cyclonic circulations will bring conviction that these, too, are subject to laws as rigid as the permanent trades and westerlies. The conviction of orderliness of cyclonic movement and the regularity of cyclonic occurrence must stand in place of a demonstration, because of the lack of a clearly stated law of progression of the important wind systems. That they are capable of reduction to formulæ no one doubts, but the efforts of meteorologists in this direction have proved unavailing. As far then as shown by facts which are at hand we must conclude that all climates that have been scientifically observed remain invariable.

No better proof of the relative nature of all human knowledge and the temporary character of all human conclusions can be found than in the above paragraph. The most elementary knowledge of geology and related earth sciences is sufficient to prove that climates have changed many times in the geologic ages through which the earth has passed. All theories accounting for such changes lead irresistibly to the conclusion that climates to-day must be changing, although not in any measurable amount. Within the last three years fresh evidence of undoubted glaciation has been found at the base of rocks of Cambrian age. In Carboniferous time plants requiring an even and uniform climate the year round flourished over most of eastern North America. One of the most remarkable of recent discoveries is the finding of Miocene plant beds in northern Greenland and Spitzbergen. From these places more than 137 species of plants have been described. Oaks, maples, beeches, plane trees, poplars, limes, sequoias, magnolias, pines, firs, spruces, and cypresses, all reaching large tree dimensions, are found in fossil beds within 8° 15′ of the north pole. Of more than twenty species of sequoias which were once scattered over North America from the Pacific to the Atlantic Ocean, only two species are found to-day and they are confined to the Pacific slope. In the stagnant waters of what is now an uninhabitable land water-lilies bloomed and the margins of lakes were thickly clothed with a green mat of sedges and rushes. During the same geologic epoch crocodiles basked in the warm waters of the great interior lakes of France, the hippopotamus wallowed in the mud of the London basin, and lions, tigers, giraffes, tapirs, elephants, and rhinoceroses ranged over the whole of Europe. Instances might be multiplied to prove the existence of a propitious climate over most of the Northern Hemisphere during this same epoch. Reading the record onward through Pliocene or Pleistocene epochs it is noted that the equable climate of the Northern Hemisphere gradually gives way under gradual refrigeration to the climatic conditions of Glacial time. Ages passed and the climate again changed, giving us the present climate, which has been such a spur to the ambition and activity of the northern races. When, therefore, we made the implied statement that climates do not change, we took the little period of recorded history as the measuring stick of an eternity. The fact is that climates do change from age to age, but the rate of change is so slow that the duration of time covered by human occupation has been too short to measure a transition from colder to warmer climatic conditions or vice versa.

Of these past climatic changes, two types may be distinguished—changes that are somewhat local in character, and changes that are more universal and affect the greater part of a hemisphere. It is known that during comparatively late geological time the Gulf of Mexico extended northward as far as Cairo, Ill.; that a vast mediterranean sea covered all the southern part of Russia and extended over western Siberia to the Arctic Ocean; that all the northern portion of the African Sahara Desert was covered with a shallow sea, and that central Asia was sea instead of land. During the progress of time since those conditions obtained, seas then existing were filled and lifted above sea level. There can be no question but that an extension of the Gulf of Mexico northward would affect the climate of all middle North America, or that the great Russian sea would equalize and make humid the regions that are now waste deserts. The land east of the Sahara Desert must have been influenced by a climate entirely different from that of the present, and the lands lying north and south of central Asia must have passed through wonderful climatic changes to reach their present temperatures. These local changes of land and sea areas must have affected the climates of all surrounding lands enormously, and every minor change in coast lines has had its effect on the climate of more restricted areas. Besides these changes of climate, there have occurred those greater variations of temperature and moisture relations noted in the Cretaceous-Miocene and the Miocene-Recent intervals. The character of the Miocene-Recent climatic changes will be brought out later in this paper.

All geologists agree that the climate of the Northern Hemisphere changed from colder to warmer during the Cretaceous-Miocene interval, and that a gradual refrigeration of climate was experienced in passing from the Miocene to the Glacial, and it is just as evident that the glacial cold gave way to the temperate atmospheric conditions of recent time. The fact of the change is evident, but the cause of the change is obscure. In accounting for the thorough glaciation of northern North America and Europe many theories have been advanced.

One of the best known theories is that of Doctor Croll, put forth in his work, "Climate and Time," in 1875. Croll built upon the hypothesis that a Glacial age could be brought about by astronomical causes which would furnish the basis for a series of changes in the influence of climatic factors upon the temperature of the earth's atmosphere. It is very well known that the sun does not stand at the center of the earth's orbit, but at one time of year the earth is some millions of miles nearer the sun than at the opposite period of the annual revolution. Working in conjunction with this change in distance from the sun is what is known as the precession of the equinoxes; that is, the poles of the earth do not point at all times at the same spot in the heavens, but on the contrary each describes a circle which may be likened to that described by the axis of a top when its speed is much reduced. This precessional movement is extremely slow, one revolution, relative to the apsides, being completed in every 21,000 years.

The inclination of the earth's axis is approximately 23.5°. It is due to this inclination that within each annual cycle the Northern and Southern hemispheres are alternately presented to the sun and thus experience their seasonal changes of temperature. If the North Pole points away from the sun at the time that the earth is at the greatest distance from that luminary, the temperature of the Northern Hemisphere will be greatly reduced. At the present time in the Temperate Zone the greater part of the moisture precipitated is rain, even during the winter; the small portion of moisture which falls as snow disappears within a few weeks at most. But the increased cold which would exist if the North Pole pointed away from the sun at the time of aphelion would result in the precipitation of all the moisture as snow. Not only would the winters be longer, but they would be colder as well. Croll figures that "at present the winters are eight days shorter than the summers, but with the eccentricity at its superior limit and the winter solstice in aphelion the length of the winters would exceed that of the summers by no fewer than 36 days". Lowering the temperature and increasing the number of cold days would tend to increase the amount of snow accumulation during the winter. The result would be that after a period of years with increasing cold the accumulation of snow would be greater than the heat of the short summer could melt. When this condition had been reached, the accumulation of snow would so decrease the summer temperature by radiation and reflection of heat that the air would be cold the year around. The cooling of the atmosphere would result also in the formation of thick banks of fog and clouds, which would shield the earth from the sun's rays and so prevent melting.

The conditions outlined above are insufficient of themselves to bring on a Glacial epoch, but they form the basis of changes upon the earth that appear of sufficient magnitude to cause refrigeration. The chief of these causes is the deflection of ocean currents. It is generally admitted to-day that the chief cause of ocean current movement is the action of the permanent winds on the water surface,[1] and it is evident that any disarrangement of the trades or westerlies would seriously affect the direction and extent of these temperature equalizers, the ocean currents. Croll argues that the reduced temperature of the Northern Hemisphere, occasioned by astronomical causes, would be accompanied by exactly opposite effects in the Southern Hemisphere, where the shortness of the winter and the nearness of the sun in winter would prevent snow accumulation. There would, therefore, be a great difference in temperature between the Northern and Southern hemispheres. This accentuated temperature difference would result in an unusually strong movement of air southward toward the warmer belts, and as a consequence the northern trades would be much stronger than the southern trades, the result being that the belt of equatorial calms would be located at some distance south of the geographical equator. The peculiar wedge-like character of the eastern South American coast would split a surface current impinging upon its angle, or it would deflect southward a current striking south of the angle. It is plain that if the northern were much stronger than the southern trades, the drift of water from the African shore would strike below the point of the wedge and thus flow southward along the Brazilian coast. If none of the waters of the Gulf Stream found their way northward, the amount of heat denied the north Atlantic would be equal to one-fourth the entire amount received upon that area from the sun.[2] "The stoppage of the Gulf Stream," says Croll, "combined with all those causes which we have just been considering, would place Europe under a glacial condition."

A later glacial theory than that advanced by Croll is supported by perhaps the greater number of geologists in the United States to-day. The central idea of this hypothesis is that the chief cause of the refrigeration of climate is to be found in the elevation of large land areas in the high latitudes. The period of geological history just preceding the Glacial epoch is known to have been a time that witnessed the emergence of large land areas over the Northern Hemisphere. It is claimed by the supporters of the elevation hypothesis that the elevation was sufficient to cause the moisture of the air to be precipitated in the form of snow instead of rain. This precipitation was sufficient in amount to prevent its complete melting away during the summer. Glacial conditions once established would be perpetuated through the radiating and reflecting powers of snow and ice acting together with the original cause producing glaciation.

The latest glacial hypothesis is announced by Prof. T. C. Chamberlin, of Chicago, who finds the cause of refrigeration in the depletion of the air of its carbon dioxide. It is well known that the atmosphere would be incapable of holding sufficient heat to support life if it were depleted of its carbon dioxide, its water vapor, and its dust particles. These three components of the air act as conservers of the radiant energy received from the sun by the earth. The slow giving up of the heat derived by the earth from the sun keeps the surface air at a medium temperature. If, however, the above-named three elements were removed from the air,[3] and especially the carbon dioxide, then radiation would keep pace with absorption, thus producing permanent glacial conditions. Doctor Arrhenius, as quoted by Chamberlin, is authority for the statement that a reduction of 45 to 48 per cent of the present amount of carbon dioxide in the air would bring on glacial conditions, and that an increase of 2.5 to 3 times its value would restore the mild temperatures of Tertiary time over the Northern Hemisphere. (Journal of Geology, vol. 5.) The cause of the depletion is ascribed to the enormous degradation of granitic rocks which would occur during the exposure of great land surfaces. The depletion would be furthered by the storing up of carbon dioxide through the agency of plant and animal life. The gradual exhaustion of the carbon dioxide from the air would bring on a period of cold, which would last until the carbon dioxide balance had been restored

[1] We understand this to refer to surface currents, whereas differences of temperature and saltness as affecting density are important in the general conditions.—EDITOR.

[2] Croll, Climate and Time, Chapter 2.

[3] Of course this implies that vapor and water, lakes and oceans, flora and fauna are removed, but the argument of the rest of this paragraph implies that water and vapor still remain.—EDITOR.

through the reduced rate of denudation of granitic rocks brought about by restricted land areas, and the feeding back into the atmosphere of enough carbon dioxide to stop the rapid radiation of heat from the surface.

Whatever the cause of glaciation, be it cosmical or terrestrial, or any combination of the two, it is almost certain that the cold came on slowly, and, after the several Glacial and inter-Glacial advances and retreats had succeeded one another, it passed slowly away. The coming of the cold was deliberate enough to allow of changes in animal structure, as evidenced by the woolly rhinoceros and the mammoth. These animals, up to this time devoid of hair, took on a fine woolly coat as a protection against the cold. Plants migrated southward as the cold increased from year to year, and a great many species placed themselves beyond the reach of the ice. The last retreat of the ice front and the coming of warmer weather allowed these species to gradually take possession of the ground from which they were driven, until at present plants bloom in the most northern regions uncovered by the ice in summer.

Most explanations of the cause of glaciation agree that during the period of northern cold the southern lands experienced a mild and even tropical temperature. The wind systems, under this arrangement, would necessarily be different from the wind systems of to-day. First, the exchange of air between the Arctic and Torrid zones would be accomplished by stronger currents than at present, because of the then greater differences in temperature between Arctic and Tropical regions. Second, the exchange of air between the relatively warmer sea and the great ice fields would be continuous throughout the whole period of cold. At present the temperate land areas are relatively warmer than the ocean only in the summer season, and air currents at this time flow from the sea toward the land. In the Glacial age this tendency would be reversed, and the air would flow from land to sea through the whole period of cold. The direction of winds would be subject to the same laws as at present. In Glacial time there was then the same system of trade and antitrade winds as at present, except that these winds were in all probability stronger and extended much farther beyond the geographical equator than they do to-day. There was no doubt a permanent system of westerly winds, but it must have extended over a zone of land and water much nearer the equator than the westerlies of to-day. If our present cyclonic systems existed, and there seems to be no reason why they should not have existed, they too must have formed and traveled eastward in a belt below the Ohio River. The chief wind systems of the glaciated area would be the transfer of air from Tropic to Arctic regions and from ice field to sea. The low temperature necessary for refrigeration would condense to snow all moisture brought from the moist warm regions by the return air currents, so that, whereas most of our moisture is now received in the form of rain, the moisture of Glacial time would be precipitated entirely as snow within the area of glaciation.

If we would grasp the relation of our own climates and see where they stand in the grand oscillations of temperatures in the past, we must picture the slow passing away of glacial conditions, which is not completed even to-day. We are now experiencing a phase of climatic oscillation which had its beginning thousands of years ago. The different published opinions as to the length of time since the retreat of the last ice sheet from our continent would justify an approximate estimate of 10,000 years. Whatever the causes producing glacial conditions may be, these are evidently brought about by the operation of forces acting through immense stretches of time, and the effects of such glaciation pass away as slowly. The conditions of the past 10,000 years, or more, during which the ice has melted away from the land between the Ohio River and the Arctic Circle, have not yet carried the Northern Hemisphere beyond glacial conditions. We are still living in the Glacial epoch. Greenland, a country of approximately 512,000 square miles, has an ice cap of 320,000 square miles area and a thickness of not less than 2000 feet. From the high mountains of Europe and Asia and from the middle and northern Rockies of North America long tongues of ice still force their way down through the valleys, and throughout the whole North Temperate Zone snow lies upon the ground for several months each year. The larger part of the great plains of Canada and Siberia, similar to the Mississippi Valley and the fertile stretches of northern Europe in all other respects except those depending directly upon climate, still lie barren and all but useless because of the forbidding cold. Should Miocene climate return to the earth these magnificent reaches of land would be capable of supporting more population than the earth now possesses. We are moving away from extreme glacial conditions at the present time, but we have not yet passed beyond the general conditions of that period of cold. Whether we are approaching conditions when Greenland will again be the home of palms and corals no man can say.

Viewed in their broader connections our present climates, at least of the Northern Hemisphere, are but stages in the grand oscillation of temperature between the tropical heat of a Miocene epoch and the arctic cold of a Glacial, on the one hand, and the temperate heat of a recent and possibly the tropical heat of some future epoch yet unnamed, on the other.

The winds, which are warmed by the mild Pacific Ocean and sweep across the western slopes of California and Oregon, owe their existence to the fact that the axis of the earth is inclined a few degrees to the plane of revolution; that the earth is a spinning ball, and that land and water areas under the sun's rays are unequally heated in like periods of time. The high plains of America and Asia, as well as those of Africa, owe their aridity to their position in latitude and to the protecting mountain walls thrown around them. Lower the American cordilleras 3000 feet and the arid regions west of the Mississippi River will cover themselves with forests of magnificent extent, the angular Bad Lands will take on the rounded forms of an Appalachia, and the sand-choked rivers of the West will be lined with happy, industrious cities from the one hundredth meridian to the Pacific Ocean.

Speaking broadly, we may look upon the present climates of the globe as depending upon certain arrangements of climatic units. If any one of these units should change, the whole climatic scheme of our present epoch would be disarranged. If, for example, the inclination of the earth's axis were to change so much that it became perpendicular to the plane of the orbit of the earth, the seasons would cease to change and the most delightful and helpful of our temperature variations would not exist. There would then be but one season, and that would last always. Each parallel of latitude would have its own peculiar temperature and moisture conditions, which would remain invariable from year to year. The nights and days would not vary their length a second from century to century. If the general temperature average of the earth were to decrease, the temperate regions could become almost arctic. In fact any change in the surface of a land area, or in the position and movement of the earth in space, or in the composition of the atmosphere, would destroy the delicate balance of the agents of climatic control now existing, and the result would be a revolution in the affairs of men, whose civilization has been built up in accordance with the present arrangement of winds and rainfall. Civilization has grown up in certain parts of the earth, and not in other parts, because of certain advantages that these more favored spots possessed over their less fortunate neighbors. No large cities exist upon Hudson Bay, and none can ever exist there under present climatic conditions. The heavy rainfall of the Amazon basin and the consequent swollen character of the rivers prevents the extension of transportation lines in that region; the dryness of the Gobi Plateau has prevented China from expanding westward. What a nation shall raise depends upon the climate of the region in which that nation happens to be situated, and what is produced influences the laws, habits, and customs of the whole people. North America owes more to its variety of climate than to its variety of soil. A temperate climate, with its recurring periods of heat and cold, is responsible for our being the busy, bustling nation that we are.

## RELATIONS BETWEEN VELOCITIES OF PROGRESSION OF LOWS AND THE AREAS OF RISING AND FALLING PRESSURE ACCOMPANYING THEM.

By STANISLAV HANZLIK, Ph. D. (Prague). Dated Washington, D. C., February 24, 1906.

Before entering on this subject, which is a further contribution to the answer of question No. 2, as stated in the introduction to my paper in the MONTHLY WEATHER REVIEW, August, 1904, Vol. XXXII, pp. 358–363, I wish to quote some lines from Professor Ekholm's paper in the Meteorologische Zeitschrift for August, 1904, to which I partially owe the impulse that started this study. Ekholm in his paper entitled "Weather Charts of Pressure Oscillations (Wetterkarten der Luftdruckschwankungen)" presents a suggestion how to better the present status of weather forecasting in Europe. In his introduction he quotes a proposition once made by the English meteorologist, Clement Ley, that thousands of weather charts should be systematically arranged in the form of a weather dictionary and made accessible to the public by publication. The forecast would then be given by predicting the appearance of a chart having a specific number in this dictionary. Ekholm says, "I do not know at present any better method than this one, and have for more than ten years been occupied with the construction of a weather dictionary".

In the next paragraph Ekholm turns to weather forecasting, to the methods of to-day and to the faults of the methods. After that he takes up the main subject of his paper, namely, the charts of pressure changes, and tries to show from a mathematical point of view the importance of such charts for a deeper understanding of the weather and improvement in weather forecasting. The interval between two successive charts should be so short that we may clearly see how the conditions shown by one chart developed from those of the preceding. In this way we learn the nature of the interpolation of the weather function and a proper understanding of this allows us to take the next step, i. e., the extrapolation from the last chart, or in other words the forecasting of the weather. This latter can be done only by means of empirical methods, on account of the incompleteness of our observations and the imperfections of theoretical hydrodynamics.

Ekholm explains the construction of pressure change charts as follows: Let us enter on our synoptic charts, for each station, the change of pressure from one reading to the next, and draw the lines of equal change; then we find, in general, closed curves of the same form as the cyclones and anticyclones. In one area the pressure has risen; he calls this the area of rise (Steigungsgebiet), with a place of greatest rise (Steigungscentrum), and similarly elsewhere an area of fall with a center of greatest fall.

According to Ekholm probably the first[1] who made use of these pressure change charts for weather forecasting in Europe was Brounow, who in 1878 published a paper entitled: *The pressure change charts and the method of determining the direction of motion of a barometric minimum in the immediate future*[2], wherein he shows that in certain cases the track of the low for the next day can be determined by means of the areas of fall and rise, but though he excludes all complicated cases the accordance with observations is not quite satisfactory. This subject was later investigated by Sresnewsky in his paper: *Large oscillations of the air pressure in the year 1887.*[3]

The results of the investigation on the relation of areas of falling and rising pressure to the lows are given by Sresnewsky in the following sentences:

(1) The center of the cyclone is always to the left of the point of most rapid fall of pressure. (2) This is explained as due to the great eccentricity of the outer isobars of the cyclone and also due to the difference of barometric gradients on both sides of cyclones. (3) The area of most rapid decrease in the southeast quadrant of the cyclone coincides with the area of strongest storms, and moves nearly parallel to the center of the cyclone. (4) There are cases when the area of fall moves apparently independently of the cyclone while the latter remains nearly stationary in the extreme north of Europe.

These are the most important points in Sresnewsky's investigation that concern the relations of cyclones to the areas of fall and rise. These atmospheric waves are, in Ekholm's opinion, very important phenomena. When there are strong storms in Swedish waters the areas of fall and rise follow similar tracks parallel to each other, while the cyclone keeps somewhat to the left of the track of the area of fall. When the cyclone reaches the land the intensity of the storm diminishes, the velocity of motion of the storm decreases, and the areas of fall and rise, with some delay, move in a southern or southwestern direction as if there were no apparent connection between them and the cyclonic area. The continued study of these areas of change in their relation to the cyclones led Ekholm to believe that for the weather and wind these are of greater importance than the cyclones themselves. "It seems to me highly probable", says Ekholm, "that these oscillations are caused by the cyclones and anticyclones of higher levels, which sometimes, but not always, cause a corresponding cyclone or anticyclone on the surface of the earth". Worthy of mention is the cyclonic character of the area of fall, namely the overcast sky and the occurrence of rain. Ekholm closes his paper with some remarks on the charts of change for other meteorological elements.

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While in Harvard University preparing my paper published in the MONTHLY WEATHER REVIEW (August 1904, page 358,) I tried to draw the pressure change charts for the study of different velocities of lows. I temporarily abandoned this work on account of the great labor, but when I obtained access to the pressure change charts in the central office in Washington I took the study up again with much greater interest, after I had read and thoroughly studied the above-mentioned papers of Ekholm and Sresnewsky.

For the investigation of the relations between the lows and the areas of rise and fall, I used a scheme which may be explained as follows:

I considered lows for three successive weather maps at intervals of twelve hours, for instance, 8 a. m., 8 p. m., and the next following 8 a. m.; or 8 p. m. and the next following 8 a. m. and 8 p. m. The length of the track between the three readings was measured and the lows were grouped in two classes: those with "increasing" and those with "decreasing" velocity—according to whether the length of the track in the second half, between the second and third observation,

[1] The charts of changes of temperature and pressure for each eight hours and twenty-four hours began to be constructed and used by the Weather Bureau (Signal Service) in 1872; the corresponding charts for twelve and twenty-four hours still continue. Many studies of these charts were made in the United States before or Brounow's paper of 1878.—EDITOR.

[2] P. Brounow. "Von den Aenderungskarten und die Methode, etc." Anhang zu dem Bulletin für das Jahr 1879. Central Physical Observatory, St. Petersburg, Dec. 18, 1878. (Lithograph, with 5 charts.)

[3] Ueber starke Schwankungen des Luftdruckes im Jahre 1887. Bull. Soc. Imp. Nat. Moscou, 1895, No. 3.