and the hot springs, modified the climate at different meridians on the same parallels, caused the tidal wave to diverge, perhaps melted the glacier ice that held the Drift boulders, accounts for the Aurora-borealis and australis, stimulated vegetation, and gave energy to animal life.

A field is thus opened for further investigation, which pertains not to the Geological and Mining Engineer alone, however important to them, but offers labor full of interest for the Astronomer, in defining accurately the modifying periods of greatest heat, light, electricity, magnetism, &c., in connection with the precession of the equinoxes, proximity of the sun, solar spots, form of the earth's orbit, &c.; for the Physicist, in confirming and classifying the observations connected with terrestrial magnetism; for the Physical Geographer, in tracing his orology, courses of rivers, winds, currents, electrical and scismographic phenomena, also the distribution of plants and animals, as well as the distribution of heat and rain, pursuing these researches with hereby increased light and vigor; while to the Naturalist, the Anthropologist and Historian, or Student of the Philosophy of History, there is furnished ample food for reflection.

Finally, above all, these sublime developments should stimulate us all with fresh desire to understand more fully the beautiful and immutable laws by which the Divine Ruler holds the universe in harmonious action, and should cause us to increase our endeavors ever to live in accordance with those divine laws.

SIGNAL SERVICE WEATHER REPORTS.

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The recent instructive articles upon the Signal Service Bureau, in Scribner's and Harper's Magazines and the "American Journal of Science," have by no means exhausted the interest which attaches to the weather bulletins. Without much trespass on the ground which others have so well covered, I will endeavor to present to the readers of the *Journal* some details which I hope will prove acceptable, for a large portion of which I am indebted to the courtesy of Prof. Cleveland Abbe, the accomplished astronomer and meteorologist, to whose skill we owe the successful daily forecasts.

Dr. Franklin's demonstration of the identity of atmospheric and

frictional electricity, and his discovery of the customary travel of storms toward the northeast, the distribution of instruments and instructions to observers by the Franklin Institute, Dr. Emerson's observation that a great rise of the barometer often belies its stereotyped prediction of "Set Fair" by preluding a northeasterly storm, the invaluable generalizations of Redfield and Espy, Ferrell's exhaustive mathematical analysis of "the motions of fluids and solids on the surface of the earth," Blodget's *Climatology of the United States*, Loomis's treatise on Meteorology, Coffin's *Winds of the Northern Hemisphere* and his tabulation of the observations of the indefatigable corps organized by the venerable Secretary of the Smithsonian Institution, Professor Henry's various physical, and especially his electrical, thermal and hyetal researches, Bache's Girard College Observations and Schott's discussion of the magnetic results, are but a portion of the contributions of American students to what might almost be regarded as the American Science of Meteorology.

Foreign meteorologists have not been backward in recognizing and acknowledging their indebtedness to American researches and suggestions, and few of them are so sanguine as to hope for a long maintenance of the accidental precedence, in successful applications of weather telegraphy, which they gained in consequence of the interruption of most branches of scientific labor by our civil war. Our territory, stretching across an entire continent in the normal pathway of storms,—the extensive plains of the Mississippi and Missouri valleys, furnishing peculiar opportunities for the blending of polar and equatorial currents,—our popular government, untrammelled by the exhausting exactions of monarchical power and huge standing armies, and therefore better able to grant the appropriations which are requisite for the support of an efficient corps of observers,—and the happy thought of military organization and responsibility, which Gen. Albert J. Myer, the chief signal officer, has so successfully carried out,—are advantages which may reasonably make us hopeful of tracking the wind, which "bloweth where it listeth," with unprecedented, if not with incredible success.

The hours appointed for the regular observations at each of the fifty-six subordinate stations are 7^h 35^m A. M., 4^h 35^m P. M., and 11^h 35^m P. M., Washington mean time. These hours were fixed upon because there were no others which would divide the day into three so nearly equal portions, and at the same time find the telegraph so free from other business. A system of circuits is specially arranged for

the office: 1, from Washington to New Orleans; 2, from Washington to New York; 3, from Washington to Chicago and San Francisco; 4, from Washington to Lake City; and all the subordinate circuits run into one of these four main stems. The whole line of wires of the Western Union Co., and of the Franklin, in case of the failure of the Western Union, is at the disposal of the Signal Office at the hours above stated. Each observer has an exact minute for starting his observations to Washington, sending them through such cities as desire to receive the report, Key West, for example, sending its despatches through Mobile, New Orleans, etc. These arrangements are made with a view to the greatest possible economy, and the charges are far below the ordinary rates for telegraphing. Montreal and a system of circuits from Canada have lately been added to the list of communicating offices, the legislature of the Dominion having voted the necessary appropriations.

The regular dispatch from each station consists of four lines of cipher, with five figures in each line. These figures are appropriated as follows:

Line 1.—Height of barometer, 3 figures; number of station, 2 figures.

Line 2.—Height of thermometer, 2 figures; relative humidity, 2 figures; direction of wind, 1 figure.

Line 3.—Velocity of wind, 2 figures; date, 2 figures; state of weather, 1 figure.

Line 4.—Upper clouds, 1 figure; lower clouds, 1 figure; rain fall, 3 figures.

The economy and simplicity of this arrangement may be readily shown by a single example:

0	1	2	5	6
6	2	7	7	8
0	2	1	4	1
2	0	0	0	0

The "Key" furnishes the following interpretation: "Barometer, 30.12 inches; Station, 56 = Montreal; Thermometer, 62°; Relative Humidity, 77 per cent.; Wind, 8 = N. W.; Velocity of wind, 2 miles per hour; Date, August 14; Weather, 1 = Fair; Sky, 2 eighths covered with cirrus clouds; Lower clouds, 0; No rain since last report."

The messages are sent in unbroken succession from the consecutive stations, the operator noting upon each sheet of figures the time when it was received. The division of the columns into four-line groups is made in the office, and the items are transferred, 1, to the manifold bulletin; 2, to the bed-plate for printing the daily maps; 3, to the map for official study, on which the isobaric lines (lines of equal barometric pressure) are drawn, and any notes or remarks are written which may facilitate forecasts.

In addition to the observations for telegraphic transmission, others are taken at the customary local hours, 7 A. M., and 2 and 9 P. M. These are entered on "Form 4" of the printed blanks, under the following heads: "Date of observation; Time of observation; Height of barometer; Height of attached thermometer; Height of exposed thermometer; Reduced barometer; Hygrometer (open air), Dry bulb, Wet bulb; Relative humidity; Direction of wind; Velocity of wind in miles per hour; Daily velocity of wind; Pressure of wind, lbs. per square foot; Amount of cloud; Direction in which upper clouds move; Rain (or snow) commenced (Time); Rain (or snow) ended (Time); Amount of rain or melted snow; Remarks." The sheets containing these entries are forwarded weekly, by mail, to Washington, together with copies of the daily telegrams as checks on the telegraphic reports.

When the returns from about half the stations have been received Prof. Abbe and his assistants commence a detailed synopsis, noting especially the changes in the barometer and thermometer, whether stationary, rising or falling, the direction of the wind, state of the weather and moisture of the atmosphere. From this synopsis the estimate of probabilities is made and a decision is formed as to the proper signals to be displayed, on the lake shores and the Atlantic and Gulf coasts, for the benefit of commerce. Press reports are also prepared, dated 10 A. M., 7 P. M. and 1 A. M., which are at once given to the agents of the Associated Press, and telegraphed by them to all their correspondents. The Bureau forwards the reports, at its own expense, to a few points which are not reached by the Associated Press.

In making the estimates it is necessary to bear continually in mind the general principles of pneumatics and hydrodynamics, and especially the laws developed in Ferrel's treatise, to which I have already referred. The following rule is of great service: "Stand with your left hand toward the place where the barometrical reading is lowest,

and your right hand toward that where it is highest, and you will have your back to the direction of the wind which will blow during the day." This is generally known as Buys Ballot's law, having been empirically deduced by Prof. Buys Ballot, of Utrecht, apparently without knowing that he had been anticipated by the purely theoretical reasoning of Ferrel. Capt Toynbee, of the British Meteorological Office, proposes to substitute for the places of highest and lowest barometer those where there has been the greatest rise and fall during the previous day, in order to judge of the direction toward which the wind is tending, and his modification often furnishes results of considerable value.

Since storms are the culminations of atmospheric disturbance, it is natural to look for them where such disturbance is greatest, either on the borders of the greatest barometric elevation, or at the centres of greatest depression. In estimating differences of pressure, and consequent wind producing force, "barometric gradients" are used which are customarily expressed in hundredths of an inch of mercury per fifty geographical miles. For example, if the barometer at Philadelphia stands at 30, while the one at Fortress Monroe stands at 29.50 inches, the distance being about 200, or 4×50 geographical miles, the gradient is $50 \div 4$, or 12.5. The best meteorological manuals give a variety of empirical rules, which have been deduced by Prof. Dove and others, for interpreting the indications of the barometer under various conditions of temperature, moisture, wind and season, which add greatly to its value as a guide for forecasts.

The temperature is invariably elevated upon one side of an area of low or high pressure and depressed on the other, and it is generally warmer in advance of any storm centre and colder in the rear. In forming estimates, if due regard is paid to the elevation, latitude and physical surroundings of the station, the thermometric indications of rising and falling temperature are valuable auxiliaries.

The humidity is large in advance of storm centres, and small in their rear. Increasing humidity is, therefore, an intimation of an approaching storm; decreasing humidity, of clearing-up weather. The more moist the air the greater will be the effect of a general diminution of pressure or temperature in inducing rain.

A "backing" wind is a well known sign of unsettled weather; a "veering" wind, or one which shifts with the sun, is an indication of fair weather. Within areas of high pressure the winds blow from the centre; in areas of low pressure, towards the centre; in either

case they are deflected towards the right hand as they move forward. Backing currents, or currents which, in the northern hemisphere, move in a direction opposite to that of the hands of a watch, are called cyclones, or cyclonic; veering currents are termed anticyclones, or anticyclonic. The backing or veering of the currents should not, however, be confounded with the shifting of the wind, which is determined by the directions in which the centre of the area of disturbed pressure lies and is moving. Hurricanes, the Chinese "great-winds" or typhoons, and the most sudden and violent storms, are cyclonic. It is often said that all storms are cyclonic, and even that all winds have a cyclonic origin, both of which statements are incorrect. The prevailing currents in the United States are anti-cyclonic, those in Western Europe cyclonic. Anti-cyclonic storms occur on both continents, but more often in America than in Europe. One of the surest indications of the approach of a storm to our southern and south-eastern coasts is the cyclonism of the winds in that region. Cyclones, in our hemisphere, tend to move northward, anti-cyclones southward.

The clouds, by their forms, changes and motions, indicate the relative temperature, moisture, pressure and direction of upper currents. The dependence of rain upon the meeting and blending of warm and moist with cooler bodies of air, is shown by the prevalence of two layers of cloud in stormy regions, the upper stretching far in advance of the lower, but descending and joining it in the rear of the area over which rain is falling. The "stratus" or "layer" clouds are generally reported in connection with threatening weather at the different stations, and the higher and more fleecy—"cirro-stratus"—usually precede the storm clouds at some distance.

The general movement of the areas of stormy and clear weather, high and low pressure, warm and cold temperature, moist and dry air, is eastward, over the larger portion of our territory, with velocities ranging from one to fifty, and probably averaging less than thirty miles per hour. This movement, which is controlled by the flow of the upper atmosphere, and is most uniform in winter, greatly facilitates predictions of the progress of storms from the Rocky Mountains to the Atlantic seaboard, and a careful observation of the areas of greatest humidity most favorable to rapid condensation will suggest probable sinuosities in their track. The more violent winds generally follow in the rear of the area of lowest pressure, but those

which precede that area may often be more dangerous, on account of the accompanying rain, snow, mist or fog.

As a typical illustration of the ease with which our ordinary winter storms can be traced, Prof. Maury refers to the reports of February last. On Feb. 21st, in the midnight report, the commencement of a storm was announced at San Francisco. Its progress was followed from bulletin to bulletin, until it reached the Atlantic coast. On the 23d, at 4h. 35m. P. M., the announcement was made: "it is probable that the storm predicted for to-day will soon reach Lake Michigan, where clouds and brisk winds now prevail." It made its appearance on the lake on the morning of the 24th, when the office again successfully predicted that it would "move north-eastward, with comparatively little rain or snow except in Canada, and southerly winds with rain from Cape Hatteras to Maine."

One of the most important hydrodynamic principles is the tendency towards equilibrium. The alternations of solar heat and nocturnal radiation, modified by the different capacities of mountains, forests, deserts, lakes and oceans for absorbing and retaining warmth and moisture, are continually disturbing the atmospheric equilibrium, and the problem of the weather-seer is to judge, from the actual conditions at any moment, what must take place to restore the normal condition of a given place or region, for a given day or season. For this purpose, tables and charts, constructed from the averages of long series of observations, such as are given in Coffin's "Winds of the Northern Hemisphere," and in Buchan's article on the mean pressure of the atmosphere (Edinburg Transactions, vol. xxv. Art. xvii), are of great service. Buchan's diagrams of monthly isobaric lines, although based upon comparatively meagre observations, are the best guide yet published to the equilibrating forces which are constantly struggling against the disturbances. The signal office is collecting an immense amount of observations, with the view of preparing similar charts specially fitted for American use, and it is also investigating various laws of local disturbance, which will eventually be published, so as to be practically available.

There has been a very general impression that it would be much more difficult to anticipate the storms in summer than in winter. There is undoubtedly a greater variety of disturbances during hot weather, and it is impossible to track the commotions which come to us from the Atlantic, for so great a distance as those from the Pacific. But difficulty is always a stimulus to ingenuity, and the degree of

success, which has attended the summer work of the office has been most gratifying.

From the 2d to the 4th of June a storm passed from Key West through the centre of the Gulf of Mexico, the daily bulletins signalling its progress. The cyclonic winds in the Gulf States gave notice of its approach, and the office accordingly issued the warning on the morning of the 2d, "it is probable that the high winds in the Gulf will advance with rain to the coast of Louisiana." A heavy storm swept with great damage over Louisiana and Galveston, from the morning of June 3d, to the evening of June 4th. The approach of a damaging storm, heralded by similar indications, to the coasts of Florida, Georgia and South Carolina, was shown by the bulletin of 1 A. M. on Aug. 16th, and its progress duly reported for the four following days, until it had "moved north eastward, beyond the cognizance of our stations."

One of the most important generalizations which may be regarded as almost conclusively established, is the fact that the summer storms and tornadoes appear simultaneously over well defined regions of falling or low barometer, and never over districts of rising or higher barometer. Several cases have occurred of areas of low barometer advancing from San Francisco with pleasant weather, and producing a storm upon arrival at the lakes.

The disturbances in the upper atmosphere more frequently pervade the whole mass in winter than in summer, producing wide-spread storms. Similar disturbances, when the thin lower stratum of heated air at the earth's surface presents the proper conditions of penetrability, may produce numerous local storm-eddies in summer, in the subjacent area which would have been involved in a general storm if it had been winter. In winter, areas of low barometer stretch out towards the lakes oftener than in any other direction, a fact which is generally attributed to the moisture of the air over the lakes. Prof. Abbe thinks that precipitation, which is oftener shown in the form of cloud than in the form of rain, accounts for the phenomenon more satisfactorily than the mere presence of moisture. The greater persistence of low pressure in the lake region than elsewhere during summer, is perhaps more especially attributable to the solar heat which produces, at that season, a normal region of low barometer in the British Provinces, similar to the one in the interior of Asia. In each of those districts there is normal high barometer during winter.

There are, on the other hand, some districts in which the persistence of high barometer during summer is very striking. They are, perhaps, more frequent in the neighborhood and west of mountain ranges, in Western Pennsylvania for example, as if the air, in its eastward flow, were compressed by the resistance it encountered in traversing the ridge. From the 15th to the 18th of July last, the barometer had been steadily ascending from Western Virginia to Massachusetts. On the 18th, the dense air suddenly poured over the mountains, driving a small but severe storm on to the coasts of New Jersey. This storm was wholly exceptional in the experience of the office, and it therefore came without any official warning.

The haziness of summer and autumn, especially of "Indian summer," have often been attributed to burning prairies, but many have been skeptical as to the possibility of a local fire kindling so "great a matter." During the past few weeks the observers have been able partially to remove this doubt. From the 12th of August, the bulletins, for several days in succession, announced a dense smoke at Detroit, sufficient to impede navigation on Lake Huron. Much of it came from burning woods in upper Michigan, some of it from the woods east of Lake Huron. The smell and haze gradually spread south-eastward as far as Maryland, furnishing indications of the direction of the upper atmospheric currents, and operators at Oswego and other stations eastward or north-eastward, also reported "dense smoke" or haze.

Eager Olivers, "asking for more," already solicit predictions for two or more days in advance. If the forecasts for a single day were infallible, they might be used as the basis for new ones, and so on indefinitely. But if the first forecasts prove true in only three cases out of four, those based upon them would be probably correct in only nine cases out of sixteen, which is little better than a random guess. Still we may hope that the tabulations and discussions in which the office is now engaged, the Smithsonian investigations of annual and secular rainfall which are now in press, and the study of meteorological records by groupings in lunar and planetary periods, will ere long warrant bolder undertakings. Until some safe basis for more extended forecasts has been found and tested, let us be thankfully content with our present daily announcement of "probabilities," which, even if it does not fully satisfy the most sanguine longings, is far beyond anything that could have been reasonably anticipated from so brief and limited experience.