METEOROLOGY IN AMERICA *

II.—Organisation of the United States Signal Service.

THERE are probably few departments of the Executive of the United States which have been of such essential practical value as the Signal Service; and among those who have been instrumental in establishing it, we cannot avoid mentioning the names of the Hon. Halbert E. Paine of Wisconsin, the Hon. Henry L. Dawes of Massachusetts, and the Hon. William W. Belknap, Secretary of War.

It may be added that, without distinction of party, the whole people of the country, the press, both Houses of Congress, and the President, have earnestly sustained and advanced this important branch of the public service.

The military system is one of the most valuable features in the constitution of this Signal Service for the benefit of Commerce. The advantages of having the whole corps of weather observers in the army are manifest and manifold. Each observer feels the responsibility of a sentinel at his post, which begets in him a sentiment of devotion to duty the strongest of which men are capable, and which has often led the soldier to imitate the example

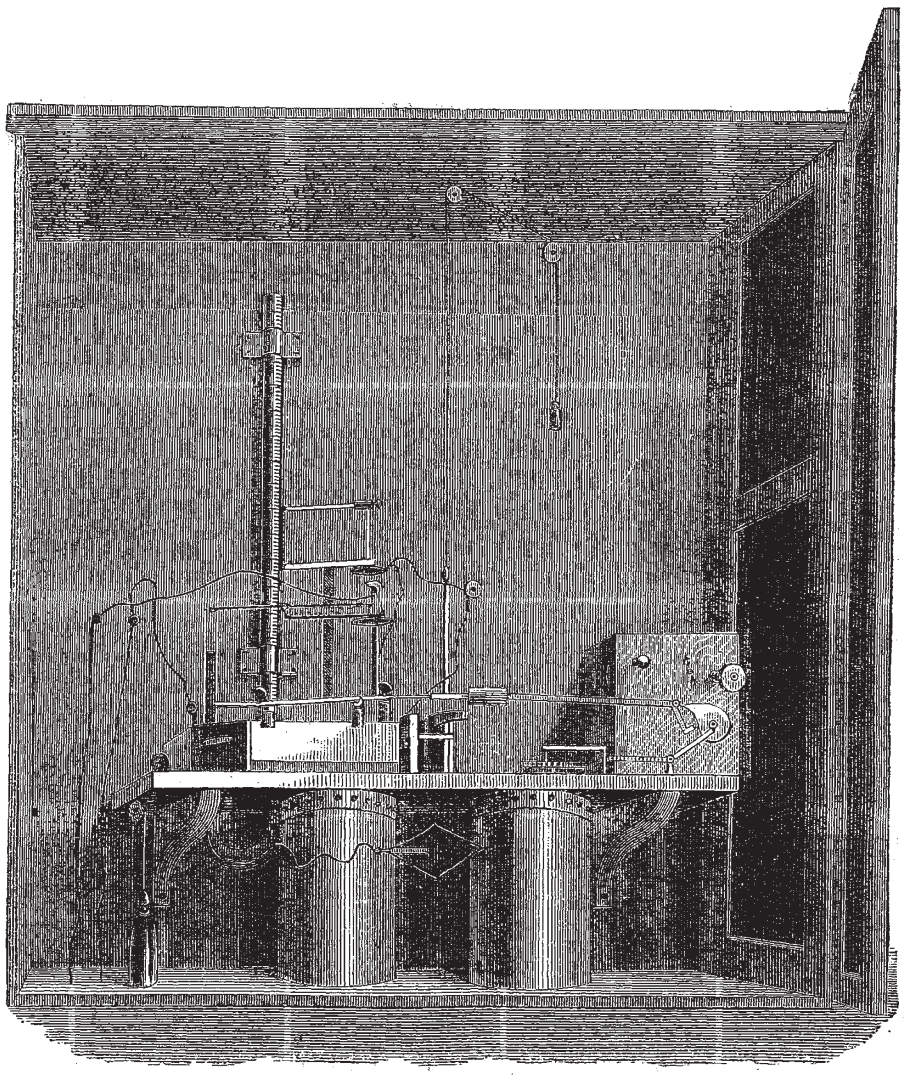

FIG. 4—PROF. HOUGH'S NEW PRINTING BAROMETER

of the Roman guard at Pompeii, who, after nearly eighteen centuries, was taken from its ruins in his martial position, showing that he had not fled before the molten flood from Vesuvius. Experience has proved what the sense of the Government originally suggested, that observations would be most punctually and scrupulously taken at the different stations by men accustomed to the discipline and obedience, even in minutest details, of army subalterns.

They are required to work out no difficult problems in meteorology, but simply to observe and record the indications of their instruments, and to transmit the same without delay or inaccuracy. In doing this work, they have become by tri-daily practice as expert and exact in reading the glasses as any of our veteran scientific men—indeed, as much so as a Fitzroy or a Leverrier could be.

Regarding the Signal Corps scattered through and over all parts of the country, we may compare it to a regiment on drill three times a day, the telegraph instantly revealing to the commanding officer, General Albert J. Myer, at Washington, the slightest failure in any observer.

By this now widely spread and magnificently organised system, the United States army, engaged under the chief

* We are again indebted to *Harper's Weekly* for the continuation of the article by Prof. Maury, and the woodcuts which we reproduce this week.

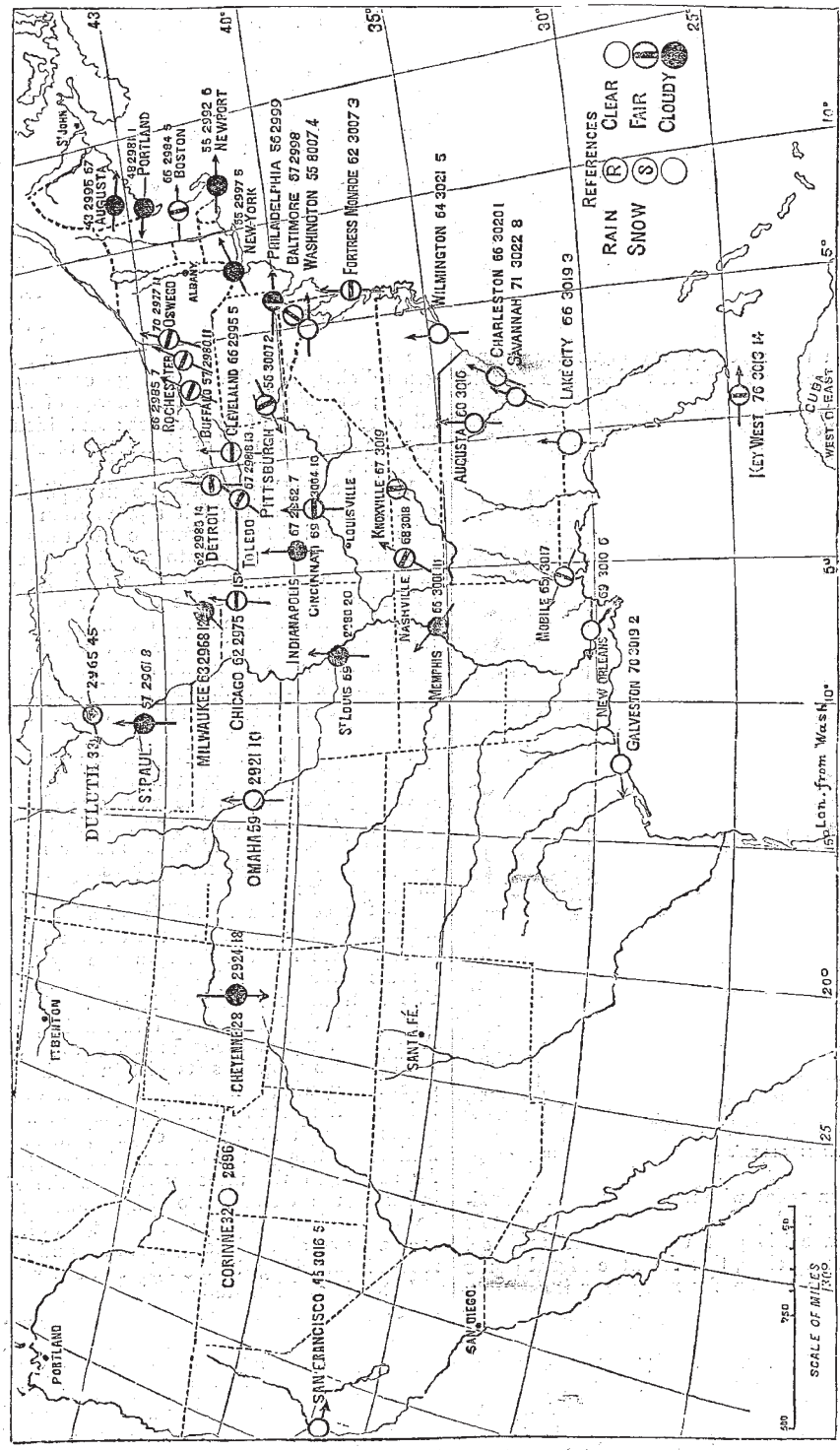

FIG. 5.—WAR DEPARTMENT WEATHER MAP (SIGNAL SERVICE, U.S.A.), SATURDAY, APRIL 8, 1871, 7.35 A.M., WASHINGTON

The Numerals denote: 1st, the State of the Thermometer; 2nd, that of the Barometer; and, 3rd, the Force of the Wind.

signal officer, is in time of peace undergoing a thorough training in the art of telegraphy and signalling, at the same time that it is passing through a most thorough discipline, is being educated to science, and also serving one of the most important ends ever devised for the benefit of commerce.

At Fort Whipple, Virginia, every man is taught to use the telegraph, and to become a skilful operator. He thus has a profession at all times lucrative to himself wherever he may be afterwards thrown. The training, skill, and habits of exactness acquired by the Signal Corps in time of peace will be of the greatest value to the army in time

of war. The telegraph is capable of indefinite utilisation. General Von Moltke, it is well known, conducted the late operations of the German army on the battle-fields of France sitting in the rear with his map before him, and his telegraphic operator at his side, keeping him in communication with all parts of the field. It has been frequently said by distinguished military men that the telegraph will be one of the most effective weapons in any war that may now occur. How necessary for the Government to keep up the efficiency of such a corps as that of which we have spoken!

As the organisation under General Myer now exists, the President and Secretary of War have a responsible military man at every important post in the country. If a warlike expedition appears on any part of our coast, causing a panic or stampede, there may be a thousand wild rumours of frightened message-senders. The Government, however, is in the receipt every eight hours (and can be in the receipt every hour if it wishes) of a reliable

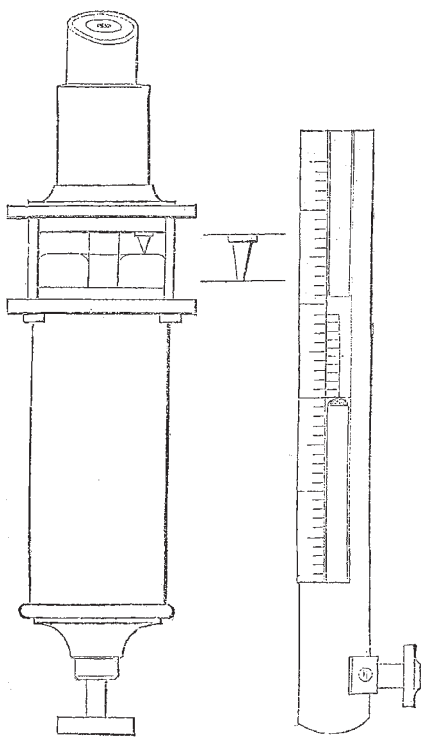

FIG. 6.—SECTION OF GREEN'S STANDARD BAROMETER

message from its own agent, who reports on his responsibility what he saw and knows to be true; and this observer will not leave his post until ordered to do so. As a mere Government police, therefore, the Signal Corps would be worth to the nation far more than it can ever cost, even if its operations should be more widely extended, as will speedily be done.

Each sergeant is sent to the Signal Service school for instruction at Fort Whipple, Virginia, where he is immediately supplied with Loomis's "Text-book of Meteorology," Buchan's "Hand-book of Meteorology," Pope's "Practical Telegraphy," and the "Manual of Signals for the United States Army," together with all the instruments necessary for practical instruction. The books he must thoroughly master. He is required to cite once daily didactically, and to practise a certain time with the instruments. He is required to remain under tuition until considered by the instructor competent to take charge of a station and perform the necessary duties, when he is ordered before a board, consisting of three army officers, for examination, when, if considered incompetent, he is returned to Fort Whipple for further instruction and practice.

If, after a rigid examination, he is found capable, he is assigned to a station, and the necessary stationery and instruments furnished him (the latter consisting of the barometer, thermometer, hygrometer, anemoscope, anemometer, and rain-gauge), and instructions to make three observations daily, viz., at the time corresponding with 7.35 A.M., 4.35 P.M., and 11.35 P.M. Washington time, so that every observer at each station should be reading his instruments at the same moment, and in the following order, viz., 1st, barometer; 2nd, thermometer; 3rd, hygrometer; 4th, anemoscope; 5th, anemometer; and 6th, rain-gauge.

In addition to the duties discharged by the officers of the Examining Board, Colonel Mallery, A.S.O., has the general charge of the very large correspondence of the office; Captain Howgate has charge of the statistics and all observations of the service; and Lieutenant Capron has the difficult post of instructor of sergeants at Fort Whipple.

Where a single person has been required to do the work of a station, receiving full reports from all stations, the labour occupied twenty hours out of the twenty-four. But the rule now adopted is to provide each station with two men—one a sergeant in charge and the other a private soldier as assistant. The observer stationed on Mount Washington has been alone on the mountain most of the time, and always responsible for the work.

In addition to a number of officers who form the Board of Examination, General Myer is also ably assisted by Major L. B. Norton, the property and disbursing officer of the Signal Service.

Prof. Cleveland Abbé, long known as an officer of the Cincinnati Observatory, and as an eminent meteorologist, is employed chiefly in the work of making out the daily synopsis of the weather, and deducing therefrom the weather "probabilities," which are given to the public by telegram through all newspapers desirous of furnishing them to their readers.

To the conspicuous ability of all of these officers is attributable the success of the enterprise.

The ordinary barometer in use by Signal Office observers is that of Mr. James Green (the well-known scientific instrument maker of New York)—an instrument adopted by the Smithsonian Institution, and also by the American navy, as the most perfect to be obtained.

This barometer has its cistern furnished with a small glass index, which shows when the mercury is at the right height in the cistern. This is adjustable by a screw which works through the bottom of the instrument against the flexible bottom of the cistern. The instrument is ready for use when the mercury touches the little V-shaped index in the cistern. So simple and complete is this barometer that any one can use it, and it ought to be in the hands of all business gentlemen, and all who are interested in watching the mutations of the weather.

Latitude and longitude on the earth's surface mark very conspicuous differences in the mean barometrie pressure, as will be seen by a study of the Isobarometric Chart for the United States, which we gave last week.

The barometer has a slight fluctuation also under several influences. It rises when the moon is on the meridian in some places. It has a diurnal oscillation, amounting on the equator to more than one-tenth of an inch, but in the latitude of New York to only 0·05 inch, the greatest height being about ten A.M., and the least about four P.M. The nocturnal variations are much less. In the latitude of Philadelphia and New York the north-east wind causes another variation of one-fourth of an inch, due to the meeting of two atmospheric waves giving a still higher wave, and hence a higher barometer. There

is also the variation due to the height of the observer's station above the sea. This is, of course, of the first importance. The other fluctuations are comparatively unimportant, and do not blind an observer to those ominous fluctuations which precede the storm, the tornado, and the hurricane. The oscillations which indicate a storm are very marked. The tornado which recently ravaged St. Louis was preceded by a gradual fall of the mercury in the barometer, for thirty hours previous, of an entire inch. At Boston, within thirty-seven years, the barometer has ranged from 31·125 inches to 28·47 inches, the difference being 2·655 inches. At London it has ranged through more than 3·5 inches; but in the tropics not so much.

During the passage of a cyclone the mercury oscillates rapidly. The most noticeable fall occurs from four to six hours before the passage of the storm centre. This fall is often over an inch, and sometimes two inches.

Great changes are usually shown by falls of barometer exceeding half an inch, and by differences of temperature exceeding fifteen degrees. If the fall equals one-tenth of an inch an hour we may look out for a heavy storm. The more sudden the change the greater the danger. But it is too often forgotten that the fall of the mercury is a forewarning of what will occur in a day or two, rather than in a few hours.

A variation of an inch is certain to be followed by a tornado or violent cyclone. In the tropics "the glass" has been known to show a fall of more than an inch and a half in one hour!

The following guides in predicting weather changes are selected from the "Barometer Manual" of the London Board of Trade, and are suggestive:

I. If the mercury standing at thirty inches rise gradually while the thermometer falls, and dampness becomes less, N.W., N., or N.E. wind; less wind or less snow and rain may be expected.

II. If a fall take place with a rising thermometer and increasing dampness, wind and rain may be expected from S.E., S., or S.W.; a fall in winter with a low thermometer foretells snow.

III. An impending N. wind before which the barometer often rises may be accompanied with rain, hail, or snow, and so forms an apparent exception to the above rules, for the barometer always rises with a north wind.

IV. The barometer being at 29½ inches, a rise foretells less wind or a change of it northward, or less wet. But if at 29 inches a fast first rise precedes strong winds or squalls from N.W., N., or N.E., after which a gradual rise with falling thermometer, a S. or S.W. wind will follow, especially if the rise of the thermometer has been sudden.

V. A rapid barometric rise indicates unsettled, and a rapid fall stormy weather with rain or snow; while a steady barometer, with dryness, indicates continued fine weather.

VI. The greatest barometric depressions indicate gales from S.E., S., or S.W.; the greatest elevations foretell wind from N.W., N., or N.E., or calm weather.

VII. A sudden fall of the barometer, with a westerly wind, is sometimes followed with a violent storm from the N.W., N., or N.E.

VIII. If the wind veer to the S. during a gale from the E. to S.E., the barometer will continue to fall until the wind is near a marked change, when a lull may occur. The gale may afterward be renewed, perhaps suddenly and violently; and if the wind then veer to the N.W., N., or N.E., the barometer will rise and the thermometer fall.

IX. The maximum height of the barometer occurs during a north-east wind, and the minimum during one from the south-west; hence these points may be considered the poles of the wind. The range between these two heights depends on the direction of the wind, which causes, on an average, a change of half an inch; on the moisture of the air, which produces in extreme cases a change of half an inch; and on the strength of the wind, which may influence the barometer to the extent of two inches. These causes, separately or conjointly with the temperature, produce either steady or rapid barometric variations, according to their force.

PRESENT OPERATION OF THE SERVICE

Although the Signal Service is yet in its infancy, and must be patiently nursed and cherished by the people for some years before it can expect to do and discharge its full mission, under General Myer's indefatigable care and skilful management it has already achieved much good, and more than compensated the public for the expense of its establishment. Since it was instituted last summer, "the chief signal officer has," to quote the words of the *New York World*, "thoroughly organised and equipped a system which now embraces in its scientific grasp every part of the land from Sandy Hook to the Golden Gate of California, and from Key West to the Dominion of Canada."

Three times every day synchronous observations are taken and reports made from the stations—one at eight A.M., one at four P.M., and the third at midnight. These observations are made by instruments, all of which are perfectly adjusted to a standard at Washington. They are also all taken at the same moment exactly, these observations and reports being also timed by the standard of Washington time. The reports from the stations are transmitted in full by telegraph. By a combination of telegraphic circuits, the reports of observations made at different points synchronously are rapidly transmitted to the different cities at which they are to be published. They are, however, all sent of course to the central office in Washington. These reports are limited to a fixed number of words, and the time of their transmission is also a fixed number of seconds. These reports are not telegraphed in figures, but in words fully spelled out. There are now about forty-five stations for which provision has been made, and which are in running order. These have been chosen or located at points from which reports of observations will be most useful as indicating the general barometric pressure, or the approach and force of storms, and from which storm warnings, as the atmospheric indications arise, may be forwarded with greatest despatch to imperilled ports.

These stations are occupied by expert observers furnished with the best attainable instruments, which are every day becoming more perfect, and to which other instruments are being added.

The reports of observers are as yet limited to a simple statement of the readings of all their instruments, and of any meteorological facts existing at the station when their tri-daily report is telegraphed to the central office in Washington.

Each observer at the station writes his report on manifold paper.* One copy he preserves, another he gives to the telegraph operator, who telegraphs the contents to Washington. The preserved copy is a voucher for the report actually sent by the observer; and if the operator is careless and makes a mistake, he cannot lay the blame on the observer, who has a copy of his report, which must be a fac-simile of the one he has handed to the operator. The preserved copy is afterwards forwarded by the observer-sergeant to the office in Washington, where it is filed, and finally bound up in a volume for future reference.

When all the reports from the various stations have been received they are tabulated and handed to the officer (Prof. Abbé) whose duty it is to write out the synopses and deduce the "probabilities," which in a few minutes are to be telegraphed to the press all over the country.

* Thin paper with black carbon paper between the sheets. The pen is a dry *stylus*, and being pressed on the upper sheet, it makes a similar mark on the sheets beneath it.

This is a work of thirty minutes. The bulletin of "probabilities," which at present is all that is undertaken, is made out thrice daily, in the forenoon, afternoon, and after the midnight reports have been received, inspected, and studied out by the accomplished gentleman and able meteorologist who is at the head of this work.

The "probabilities" of the weather for the ensuing day, so soon as written out by the professor, are immediately telegraphed to all newspapers in the country which are willing to publish them for the benefit of their readers.

Copies of the telegrams of "probabilities" are also instantly sent to all boards of trade, chambers of commerce, merchants' exchanges, scientific societies, &c., and to conspicuous places, especially sea-ports, all over the country.

While the professor is preparing his bulletins from the reports just furnished him by telegraph, the sergeants are preparing maps which shall show by arrows and numbers exactly what was the meteorologic condition of the whole country when the last reports were sent in. These maps are printed in quantities, and give all the signal stations. A dozen copies are laid on the table with sheets of carbon paper between them, and arrow stamps strike in them (by the manifold process) the direction of the wind at each station. The other observations as to temperature, barometric pressure, &c., &c., are also in the same way put on them.

These maps are displayed at various conspicuous points in Washington—*e.g.*, at the War Department, Capitol, Observatory, Smithsonian Institution, and office of the chief signal officer. They serve also as perfect records of the weather for the day and hour indicated on them, and are bound up in a book for future use.

Every report and paper that reaches the Signal Office is carefully preserved on file, so that at the end of each year the office possesses a complete history of the meteorology of every day in the year, or nearly 50,000 observations, besides the countless and continuous records from all of its self-registering instruments.

When important storms are moving, observers send extra telegrams, which are despatched, received, acted upon, filed, &c., precisely as are the tri-daily reports. One invaluable feature of the system as now organised by General Myer is that the phenomena of any particular storm are not studied some days or weeks after the occurrence, but while the subject is fresh in mind. To the study of every such storm, and of all the "probabilities" issued from the office, the chief signal officer gives his personal and unremitting attention. As the observations are made at so many stations, and forwarded every eight hours, or oftener, by special telegram from all quarters of the country, the movements and behaviour of every decided storm can be precisely noted; and the terrible meteor can be tracked and "raced down" in a very few hours or minutes. A beautiful instance of this occurred on the 22nd of February last, just after the great storm which had fallen upon San Francisco. While it was still revolving around that city, its probable arrival at Corinne, Utah, was telegraphed there, and also at Cheyenne. Thousands of miles from its roar, the officers at the Signal Office in Washington indicated its track, velocity, and force. In twenty-four hours, as they had forewarned Cheyenne and Omaha, it reached those cities. Chicago was warned twenty hours or more before it came. Its arrival there was with great violence, unroofing houses and causing much destruction. Its course was telegraphed to Cleveland and Buffalo, which, a day afterwards, it duly visited. The president of the Pacific Railroad has not more perfectly under his eye and control the train that left San Francisco to-day than General Myer had the storm just described.

While the observers now in the field are perfecting themselves in their work, the chief signal officer is training other sergeants at the camp of instruction (Fort Whipple, Virginia), who will go forth hereafter as valued auxiliaries. It has been fully demonstrated by the signal officer that the army of the United States is the best medium through which to conduct most efficiently and economically the operations of the Storm Signal Service. Through the army organisation the vast system of telegraphy for meteorological purposes can be, and is now being, most successfully handled. "Whatever else General Myer has not done," says the *New York World*, "he has demonstrated that there can be, and now is, a perfect network of telegraphic communication extending over the whole country, working in perfect order, by the signal-men, and capable of furnishing almost instantaneous messages from every point to the central office at Washington. Think of a single jump by wire from San Francisco 2,700 miles eastward three times a day! When General Myer undertook to put this system in working order, the telegraph companies said it was impossible—no such thing had ever been heard of in telegraphing. It is now a grand *fait accompli*, as much as the passing of the Suez Canal by ships or the escaping from Paris by balloons." *

At present the signal officer aims only to give a synopsis of each day's weather, and a statement of what weather may be expected or will probably occur. The "probabilities" so far have been most beautifully verified and confirmed.

It is not thought wise to undertake more than can be securely accomplished. The synopses and "probabilities" are all that intelligent shippers and careful seamen require. Shippers will not send their vessels to sea if the weather synopsis indicates threatening or alarming weather.

Travellers can consult the "probabilities" before leaving home; and any severe storm that menaces any city or port is now specially telegraphed thither, and the announcement is made by bulletins posted in the most public places.

By the modest estimate of the signal officers, the following is a table showing percentage of "probabilities" that have been verified:

Fully verified	50 per cent.
Verified in part . . .	25 ,,
Failed	25 ,,

It must, however, be borne in mind that the failures have often been due to lack of information from points where as yet no observer-sergeant is stationed.

FUTURE AIMS

The Signal Service has, up to this time, acted upon the wise maxim of "making haste slowly," and undertaking to do nothing which was not in its power to do safely and securely without risk of failure. It has acted upon the confidence it has in the people that they will patiently await the development of solid science, meantime leaving no stone unturned to hasten forward the observations which may lead to a more exact acquaintance with the habits, movements, and tracks of our American storms. Great progress has in a very short time been made in this knowledge, and every day new light is dawning upon the science of storms.

The instruments of the service have been bought on trial. They are undergoing the most varied experiments. In a short time, it is hoped, they will be greatly improved and perfected, and then the chief signal officer's results will be more satisfactory to himself, and his labours will be greatly facilitated. The celerity with which important results have already been attained by this officer has surprised and startled both himself and the friends of the great movement.

As soon as possible, therefore, the Signal Office will have its signal posts along the lakes and on our Atlantic sea-board, where cautionary signals will be displayed, warning vessels of approaching gales and storms, and

* *New York World*, March 5, 1871.

also a signal for clear weather. These will be displayed by day and by night by a very simple and suitable contrivance now being perfected by General Myer. In New York already arrangements have been made for displaying the signals to shipping in the harbour from a lofty structure on the roof of the Equitable Life Insurance Company's office, the best station that could be chosen. The display of these storm signals proper will place the American Signal Bureau at once in a position to render inestimable service to shipping and all commercial interests.

These signals will at first be neglected by ruder and more unskilful seamen and shippers; but, as in the case of the famous Fitzroy signals on the English coast, every week will add new demonstrations of the value and utility of this system—one of the most splendid gifts bequeathed by modern science to the human race.

The signalling of storms and desolating cyclones to the unsuspecting seaman will, it is believed, mark a new era in our lake and coast navigation, and be the means of annually saving many lives and millions of dollars' worth of our floating property.

The comparison of these signals with the weather following the signals will be then a matter of special attention. Every discrepancy can then be carefully noted and probed, and every day the meteorologists in charge of the "probabilities" will find the means of rectifying any errors they may have fallen into, and daily increasing the accuracy and perfecting the plan of their forecasts.

The storm signals will be displayed at any hour of the day or night when the instrumental indications give notice of bad weather; and experience has already shown that generally at least twenty-four hours' forewarning can be given from the central office in Washington of all important weather phenomena. With the telegraph to premonish, forecasts for two or three days in advance are hazardous and unnecessary. For almost all practical purposes of life a day's notice of atmospheric disturbances is quite sufficient, and more reliable than longer premonitions. It will be a grand triumph for American science when the electric telegraph is so utilised that it will bring all citizens of the United States into electric communication with each other, and the most fearful storm, as well as the sunshine and shower, shall be every day a subject of forewarning or congratulation throughout the land, and even on the lakes and oceans that wash the American coasts.

OPENING OF THE MONT CENIS TUNNEL

THE project of constructing a tunnel under the Alps —one of the favourite designs of that ardent patriot and eminent statesman, the late Count Cavour—has now been accomplished, thanks to the skill of the Italian engineers. The scientific requirements and methods adopted are well stated in a recent article in the *Daily News*, to which we are indebted for the following interesting particulars:—

The tunnel was commenced on the 15th of August, 1857. The two points at which it was determined to begin the boring were two wretched little Alpine villages, Bardonnecchia and Fourneaux, the former on the Italian, the latter on the French side of Mont Fréjus, the tunnel being nearly pierced under the above-named mountain, and not, as common report would have it, beneath Mont Cenis. These two villages were of the smallest size and most miserable character, and offered no accommodation whatever to the many hundred workmen employed on either side the mountain. Bardonnecchia, on the Piedmontese side, is a village which, in 1857, when the works commenced, contained about 1,000 souls. The houses in it were really little better than huts, being mostly occupied by shepherds, who were absent with their flocks on the mountains during the summer months. At Fourneaux things were even worse, there being an ordinary population of only 400 inhabitants.

The first problem to be solved, says Mr. Fras. Kossuth, one of the Royal Commissioners of Italian Railways, in his able report on the Mont Cenis Tunnel, was threefold. (1) To fix across the mountain several points which would all be contained in the vertical plane drawn through the axis of the tunnel. (2) To obtain the exact length between the openings. (3) To know the precise difference of level between the two extremities of the tunnel, so as to obtain the proper gradients. In order to execute this programme, a series of observations was established on all the favourable points, and an elaborate trigonometrical survey of the district was commenced. By the end of the season little could be done in the way of surveying; in the winter of the year 1858 all the surveys relating to the alignment and to the length of the tunnel were completed, and all was ready to compile the longitudinal section along the axis of the tunnel. The whole system consisted of twenty-eight triangles, and eighty-six was the number of measured angles. All of these were repeated never less than ten times, the greater part twenty, and the most important as many as sixty times. To give the reader an idea of the extraordinary care and accuracy with which the surveying operations were carried out, it may be mentioned that Signor Mondino repeated his experiments for obtaining the level of the tunnel, or rather of the signals over the mountain in 1857 and 1858, and the difference in the two surveys (over more than 13,000 yards), was only 3·93 inches. Even this was reduced afterwards by Signor Termine to 1·57 inch. The preliminary measurements gave a distance of 13,861·5 yards between the two temporary openings. We say temporary openings, because, although the tunnel is itself constructed in a perfectly straight line from Fourneaux to Bardonnecchia, passengers will not pass through the original straight tunnel, but will be conveyed through a branch one which joins the main line a short distance from Fourneaux. The nature of the ground was such as to necessitate the definite and permanent tunnel being taken through the mountain in a curve; but even the unprofessional reader will see that a straight line was indispensable, in order to secure not only accuracy of direction, but also a through draught of air through the whole length of the tunnel. A most important consideration this latter, as one of the main objections brought against the scheme was the supposed difficulty there would be in keeping the tunnel thoroughly well ventilated. It was also much easier to transmit the necessary motive power along a straight line than on a curve. The tunnel, although its axis was straight, was not constructed on a dead level. The gradients were: From the Bardonnecchia (Italian) end, 4,408·50 feet above the level of the sea, 1 in 2,000 (·0002 per metre) for a distance of 20,997·33 feet. From the Fourneaux entrance (French side), 3 945 feet above the sea, the rising gradient was 1 in 43 4782 (·023 per metre) for 20,587 feet.

The absolute figures are as follows:

Total length of the tunnel, 13,364·86 yards.	
Elevation above the sea-level of the Bardonnecchia entrance	4,381·25
Rise of gradient of 1 in 2,000 for 20,048 feet . .	10·024
Summit level from Bardonnecchia	4,391·274
Elevation above sea-level at Fourneaux entrance .	3,946·50
Rise of gradient of 1 in 45,045 for 200,045·10 feet.	445·00
Summit level from Fourneaux .	4,391·50

This shows a very slight difference from the calculations of the summit level as reckoned at Bardonnecchia, and gives a mean level for the highest point of 4,391·386 feet. The greatest height of the mass of the Alps over the tunnel is 5,307 feet.