MEMOIR

OF

ELIAS LOOMIS.

1811-1889.

BY

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BIOGRAPHICAL MEMOIR OF ELIAS LOOMIS.

ELIAS LOOMIS was born in the little hamlet of Willington, Conn., August 7th, 1811. His father, the Rev. Hubbell Loomis, was pastor in that country parish from 1804 to 1828. He was a man possessed of considerable scholarship, of positive convictions, and of a willingness to follow at all hazards wherever truth and duty, as he conceived them, might lead. He had studied at Union College, in the class of 1799, though apparently he did not finish the college course with his class. He is enrolled with that class in Union College, and he also received, in 1812, the honorary degree of Master of Arts from Yale College. At a later date he went to Illinois, and there was instrumental in founding the institution which afterwards became Shurtleff College.

Although the boy inherited from his father a mathematical taste, yet his love for the languages also was shown at a very early age. At an age at which many bright boys are still struggling with the reading of English, he is reported to have been reading with ease the New Testament in the original Greek. He prepared for college almost entirely under the instruction of his father. He was, for a single winter only, at the Academy at Monson, Mass. Owing in part to feeble health he was more disposed, in those early years, to keep to his books than to roam with other boys over the Willington hills. In his later life he frequently said that in his early days he never had a thought of asking what subjects he was most fond of, but studied what he was told to study.

At the age of fourteen he was examined and was admitted to Yale College, but owing to feeble health he waited another year before actually entering a class. In college he appears to have been about equally proficient in all of the studies, taking a good rank as a scholar, and maintaining it through his college course. President Porter remembers well the retiring demeanor of the young student, and his concise and often monosyllabic expressions, peculiarities which he retained through life. During his Junior and Senior years he roomed with Alfred E. Perkins whose bequest was the first large endowment of the Yale College Library. He graduated in 1830.

A few weeks before graduation he left New Haven and entered a school, Mount Hope Institute, near Baltimore, to teach mathematics, and he remained there for a year and a term. One of his classmates, the late Mr. Cone of Hartford, said that Mr. Loomis had intended to spend his life in teaching, and that it surprised him when he heard that this purpose was abandoned, and that Mr. Loomis had gone, in the autumn of 1831, to the Andover Theological Seminary with the distinct expectation of becoming a preacher. This new purpose was, however, again changed when a year later he was appointed tutor in Yale College. A vacancy in the tutorship occurred in the May following (1833), and while not yet twenty-two years of age he returned to New Haven and entered upon the duties of the office. Here he remained for three years and one term. In the spring of 1836 he received the appointment to the chair of Mathematics and Natural Philosophy in Western Reserve College, at Hudson, Ohio. He was allowed to spend the first year in Europe. He was, therefore, during the larger part of the years 1836–'7 in Paris attending the lectures of Biot, Poisson, Arago, Dulong, Pouillet, and others. He did not visit Germany because of want of money. A long series of letters written by him at this time appeared in the Ohio Observer, and the contrast between England and France as he saw them and the same places as seen by the tourist to-day is decidedly interesting.

He purchased in London and Paris apparatus for his professorship, and the outfit for a small observatory, and in the autumn of 1837 began his labors at Hudson. Here he remained for seven years, maintaining with unflagging perseverance both his work in teaching and his scientific labors. In judging of this work at Hudson we must remember that he was not with perfect surroundings. He was without an assistant and without the counsel and encouragement of associates in his own branches of science. The financial troubles which culminated in this country in 1837 were peculiarly severe upon the young and struggling college. Money was almost unknown in business circles in Ohio, trade being almost entirely in barter. In this way principally was paid so much of the promised salary of $600 per annum as was not in arrears. In one of his letters he congratulates himself that all of his bills that were more than two years old had been paid. In another he says that there was not enough money in the college treasury to take him out of the State. When he left Hudson the college offered to pay at once the arrears of his salary by deeding to him some of its unimproved lands.

In 1844 he was offered, and he accepted, the office of Professor of Mathematics and Natural Philosophy in the University of New York. In this new position he undertook the preparation of a series of text books in the Mathematics, and for some years a large part of the time which he could spare from his regular college work was given to the preparation of these books.

When Professor Henry resigned his professorship at Princeton in order to accept the office of Secretary of the Smithsonian Institute, Professor Loomis was offered the vacant chair. He went to Princeton and remained there during one year, at the end of which he was induced to return again to his old place in the University of New York. Here he continued until 1860, when he was elected to the Professorship in Yale College, made vacant by the death of Professor Olmsted. For the last twenty-nine years of his life he labored for Yale College and for science, passing away on the 15th of August, 1889.

Let us look now in succession at the different lines of his activity during these fifty-six years—four in the tutorship at New Haven and in Europe; seven at Hudson, Ohio; sixteen in New York city and Princeton, and twenty-nine in New Haven.

For the first year on returning from Andover to New Haven he was tutor in Latin, although it seems that he might, had he chosen it, have been tutor of Mathematics. I believe that at the beginning his mind was not yet definitely turned towards the exact sciences. In his childhood he had taken specially to Greek. In college he was equally proficient in all of his studies. He is represented to have led his class at Andover in Hebrew, and now on entering the tutorship he chose to teach the Latin language and literature. During the second year he taught Mathematics, and the third year Natural Philosophy. His later success in scientific work was, I believe, in no small measure due to his earlier broad and thorough study of language.

I have made some inquiry in order to learn what it was that turned his intention and tastes towards science. One of his colleagues in the tutorship, the Rev. Dr. Davenport, says that he recollects very distinctly the first indication to his own mind that Tutor Loomis was turning his thoughts in this direction. The great meteoric shower of 1833 came early in the period of his tutorship, and the views of Professor Twining and Professor Olmsted about the astronomical character and origin of these interesting and mysterious bodies were a common topic of conversation among scientific men in the College, especially wherever Professor Olmsted was present. The tutors were accustomed to meet as a club from time to time in the tutors' rooms in turn, and Dr. Davenport well recollects the occasion when Tutor Loomis brought in a globe and discussed before the club the new theories about these bodies. Up to this time Tutor Loomis had seemed to him to have given his thoughts and study to language rather than to science.

In January, 1834, there were constituted in the Connecticut Academy of Arts and Sciences twelve committees, representing the several departments of knowledge, and Tutor Loomis was put on the Committee on Mathematics and Natural Philosophy. These are the only signs of scientific taste or activity which I have detected earlier than the autumn of 1834, after he had been a year and a term in the tutorship. From this time on to the end of his life he gave his time and energies to several subjects that are enough distinct one from the other to make it convenient to disregard a strictly chronological account of his labors, and consider his work in each subject by itself.

A subject of which he early undertook the investigation was *Terrestrial Magnetism.* We often use the rhetorical phrase "True as the needle to the pole," but, looked at carefully, the magnetic needle is anything but constant in direction; like the weather vane on the steeple, it is ever in motion, swinging back and forth, in motions minute and slow it is true, but still always swinging. It has fitfully irregular motions; it has motions with a daily period; motions with an annual period; and motions whose oscillations require centuries for completion.

The *daily* motions of the magnetic needle were those which Tutor Loomis first studied. At the beginning of the second year of his tutorship he set up by the north window of his room a heavy wooden block, and on it the variation compass that belongs to Yale College. Here for over thirteen months he observed the position of the needle at hourly intervals in the day time, his observations usually being for seventeen successive hours of each day.

The results of these observations, together with a special discussion of the extraordinary cases of disturbance, were published in the American Journal of Science in 1836. No similar observations of the kind made in this country had at that time been published. So far as I am aware, none made before 1834 have since been published, except ten days' observations made by Professor Bache in 1832. In fact, I know of only one or two like series of hourly observations made in Europe earlier than these by Tutor Loomis. He also at this time formed the purpose of collecting all the observations of magnetic declination that had been hitherto made in the United States, and of constructing from them a magnetic chart of the country. He appealed successfully to the Connecticut Academy of Arts and Sciences for its sympathy and aid. The work of collecting facts was so far advanced before leaving New Haven that when he had been a few months professor at Hudson he forwarded to the American Journal of Science a discussion of the observations thus far obtained, and with them a map of the United States, with the lines of equal deviation of the needle drawn upon it. Two years later he published additional observations and a revised edition of this map.

These were the first published magnetic charts of the United States, and though the materials for their construction were not numerous, and in many cases those obtainable were not entirely trustworthy, yet sixteen years later, when a map was made by the United States Coast Survey from later and more numerous data, Professor Bache declared that between his own new map and that of Professor Loomis, when proper allowance had been made for the secular changes, the "*agreement was remarkable.*"

The northern end of a perfectly balanced magnetic needle turns downward, and the angle it makes with the horizon is called the magnetic *dip*. This angle is an important one, and is observed with accuracy only by using an expensive instrument, and taking unusual pains in observing. Hence only a few observations of this element were found by Professor Loomis. From these, however, he ventured to put on his first magnetic map a few lines that exhibited the amount of the *dip*.

While he was in Europe he purchased a first-class dipping needle, for Western Reserve College, and at Hudson and the neighborhood in term time, and at other places in vacation, he made observations with this needle. Some of these observations were made before his second magnetic chart was published, and upon this map were now given tolerably good positions of the lines of equal magnetic dip. But he continued his observations for several years, determining the dip at over seventy stations, spread over thirteen States, each determination being the mean of from 160 to over 4,000 readings. These observations were published in several successive papers in the transactions of the American Philosophical Society at Philadelphia.

Various papers on terrestrial magnetism, in continuation of his earlier investigations, appeared in 1842, in 1844, in 1847, and in 1859, but movements in Germany, England, and Russia had meanwhile been inaugurated which led to the establishment by governments of a score of well equipped magnetic observatories, and this subject passed largely out of private hands.

Closely connected with terrestrial magnetism, and to be considered with it, is the *Aurora Borealis.* In the week that covered the end of August and the beginning of September, 1859, there occurred an exceedingly brilliant display of the Northern Lights. Believing that an exhaustive discussion of a single aurora promised to do more for the promotion of science than an imperfect study of an indefinite number of them, Professor Loomis undertook at once to collect and to collate accounts of this display. A large number of such accounts were secured from North America, from Europe, from Asia, and from places in the Southern Hemisphere; especially all the reports from the Smithsonian observers and correspondents, were placed in his hands by the Secretary, Professor Henry.

These observations and the discussions of them were given to the public during the following two years, in a series of nine papers in the American Journal of Science.

Few, if any, displays on record were as remarkable as was this one for brilliancy or for geographical extent. Certainly about no aurora have there been collected so many facts. The display continued for a week. The luminous region entirely encircled the North Pole of the earth. It extended on this continent on the 2d of September as far south as Cuba, and to an unknown distance to the north. In altitude the bases of the columns of light were about fifty miles above the earth's surface, and the streamers shot up at times to a height of five hundred miles. Thus over a broad belt on both continents this large region above the lower atmosphere was filled with masses of luminous material. A display similar to this, and possibly of equal brilliancy, was at the same time witnessed in the Southern Hemisphere.

The nine papers were mainly devoted to the statements of observers. Professor Loomis, however, went on to collect facts about other auroras, and to make inductions from the whole of the material thus brought together. He showed that there was good reason for believing that not only was this display represented by a corresponding one in the Southern Hemisphere, but that all remarkable displays in either hemisphere are accompanied by corresponding ones in the other.

He showed also that all the principal phenomena of electricity were developed during the auroral display of 1859; that light was developed in passing from one conductor to another, that heat in poor conductors, that the peculiar electric shock to the animal system, the excitement of magnetism in irons, the deflection of the magnetic needle, the decomposition of chemical solutions, each and all were produced during the auroral storm, and evidently by its agency. There were also in America effects upon the telegraph that were entirely consistent with the assumption previously made by Walker for England, that currents of electricity moved from northeast to southwest across the country. From the observations of the motion of auroral beams, he showed that they also moved from north-northeast to south-southwest, there being thus a general correspondence in motion between the electrical currents and the motion of the beams.

When there is a special magnetic disturbance at any place, there is usually a similar one at all other neighboring places. But these disturbances do not occur at the several places at the same instant of time. Professor Loomis showed that in the United States they take place in succession as we go from northeast to southwest, the velocity of the wave of disturbance being over one hundred miles per minute. The waves of magnetic irregularities were thus connected with the electrical current and with the drifting motions of the streamers in the auroral display.

As incident to this discussion, he collected all available observations of auroras, and he deduced from them the annual number of auroras visible at each place of observation. These numbers, when written upon a chart of the Northern Hemisphere, showed that auroras were by no means equally distributed over the earth's surface. It was found that the region in which they occurred most frequently was a belt or zone of moderate breadth and of oval form, enclosing the North Pole of the earth, and also the North Magnetic Pole. It was therefore much farther south in the Western Hemisphere than in the Eastern. Along the central line of this belt there are more than eighty auroras annually, but on going either north or south from the central line of that belt the number diminishes.

In 1870 Professor Loomis published a paper of importance relating to terrestrial magnetism, in which he showed its connection and that of the aurora with spots on the sun. That the spots on the sun had periods of maxima and minima development had long been known. Lamont had noticed a periodicity in the magnetic diurnal variations. Sabine and Wolf and Gauthier had noticed that the two periodicities were allied. The connection of the period of solar spots with conjunction and opposition of certain planets had been shown by De La Rue and Stewart. Professor Loomis undertook an exhaustive examination of the facts that tended to confirm or refute the propositions that had been advanced. He confirmed and added to the conclusions of Messrs. De La Rue and Stewart. He also brought together such facts as were relevant to the question, and he showed that the regular diurnal variation of the magnetic needle was entirely independent of the solar spots, but that those disturbances that were excessive in amount were almost exactly proportional to the spotted surface of the sun. He also showed that great disturbances of the earth's magnetism are accompanied by unusual disturbances on the sun's surface on the very day of the storm.

Various forms of periodicity in the aurora have frequently been suggested. Professor Loomis, from all available accounts of the aurora, was able to show that while in the center of the zone of greatest auroral frequency auroras might be visible nearly every night, and hence that periodicity could not easily be shown by means of numbers of auroras recorded in such places, yet that such periodicity was distinctly traceable at places where the average number seen was about twenty or twenty-five a year. The times of maxima and minima of the solar spots were seen to correspond in a remarkable manner with the maxima and minima in the frequency of auroral displays in these middle latitudes. Also, from the daily observations made by Messrs. Herrick and Bradley at New Haven during seventeen years, he concluded that auroral displays in the middle latitudes of America are generally accompanied by an unusual disturbance of the sun's surface on the very day of the aurora. The magnetism of the earth, the Aurora Borealis, and the spots on the sun have thus all three a causal connection, and apparently that connection is closely related to the conjunctions and oppositions of certain planets.

Shortly after the publication of this memoir, Professor Lovering published his extensive catalogue of auroras. A further discussion of the periodicity of the auroras was undertaken by Professor Loomis and published in 1873. In this he made use of all the auroras recorded in Professor Lovering's catalogue. They confirmed his previous conclusions, only slight modifications being required by the new facts presented, and by their more systematic collation.

In these papers, as in most of his papers upon other subjects, Professor Loomis was ever intent upon answering the questions: What are the laws of nature? What do the phenomena teach us? To establish laws which had been already formulated by others, but which still needed confirmation, was to him equally important with the formulation and proof of laws entirely new.

Let us now turn to another important line of Professor Loomis's work—*Astronomy*. As I have said, he was early interested in the shooting stars. In October, 1834, he read a paper before the Connecticut Academy of Arts and Sciences upon this subject, probably in substance that which was shortly afterward published in the American Journal of Science. The published paper is principally a restatement of the observations made in Germany in 1823 by Brandes in concert with his pupils for determining the paths of the stars through the atmosphere, together with methods of computation. From the results of Brandes's observations, however, he deduces an argument for the cosmic character of the shooting stars. One month after reading this paper to the Connecticut Academy he engaged in similar concerted observations with Professor Twining, who was then residing near West Point, N. Y. These were only moderately successful, but they were the first observations of the kind undertaken in America.

During the senior year of his college course there arrived at New Haven the five-inch telescope, given to the college by Mr. Sheldon Clark, constructed by Dolland. This instrument was much larger than any telescope then in the country. It was temporarily placed in the tower of one of the college buildings, where it was mounted on castors and wheeled to the windows for use. This temporary abode it occupied, however, for over thirty years. In spite of its miserable location it was, in the decade following its installment, a power in the development of the study of astronomy in Yale College. The lives and works of Barnard, and Loomis, and Mason, and Herrick, and Lyman, and Chauvenet, and Hubbard, and of other graduates of the college prove this. What rich returns for Mr. Sheldon Clark's twelve-hundred-dollar investment!

In 1835 the return of Halley's comet had been predicted, and its appearance was eagerly expected by astronomers and the public: Professor Olmsted and Tutor Loomis first in this country caught sight of the stranger, and throughout its course they noted its physical appearances. With such means as he had at command, Mr. Loomis observed the body's place, and computed from his observations the orbit.

The latitude and longitude of an observatory are constants to be early determined. These were measured by President Day for Yale College in 1811. In the summer of 1835 Tutor Loomis, with such instruments as the college possessed—a sextant and a small portable transit—made numerous observations of Polaris for latitude, and several moon culminations for longitude. From these he computed the latitude and longitude of the Observatory tower. The longitude from Greenwich, though obtained from a small number of observations, differs less than two seconds of time from our best determinations to-day.

While in Europe in 1836–'37 Professor Loomis, as I have said, bought for Western Reserve College the instruments for an observatory. These were a four-inch equatorial, a transit instrument, and an astronomical clock. On his return he erected, in 1837, a small observatory at Hudson, and in September, 1838, began to use the instruments. He had no assistant, and by day had a full allotment of college work. Two hundred and sixty moon culminations and sixteen occultations observed for longitude, sixty-nine culminations of Polaris for latitude, along with observations on five comets, sufficiently extended for a computation of their orbits; these attested his activity outside of his required duties. Some years later, when the corresponding European observations were made public, he prepared an elaborate discussion of these longitude observations, and published it in *Gould's Astronomical Journal.* A sixth comet was observed by him at Hudson in 1850.

It may not seem a very large output of work in six years' time to have determined the location of the Observatory, and to have observed five comets. But we must recollect that the telegraph had not then been invented, that the exact determination of the longitude of a single point in the western country had a higher value then than it can have now, and that it could be obtained only by slow and tedious methods. These were, moreover, days of small things in astronomy in this country. At Yale College there was a telescope but not an observatory. At Williamstown an observatory had been constructed, but it was used for instruction, not for original work. At Washington Lieutenant Gilliss, and at Dorchester Mr. Bond, were commissioned by the Government in 1838 to observe moon culminations in correspondence with the observers in the Wilkes exploring expedition for determining their longitude. These two prospective sets of observations, both of them under Government auspices and pay, were the only signs of systematic astronomical activity in the United States outside of Hudson, when in 1838 Professor Loomis began his observing there. In his Inaugural Address he asks: "Where now is our American Observatory? Where throughout this rich and powerful nation do you find a single spot where astronomical observations are regularly and systematically made? There is no such spot." Even when he left Hudson in 1844 the situation was not largely changed. Mr. Bond had removed his instruments and work to Cambridge. The High School Observatory at Philadelphia had been erected and Messrs. Walker and Kendall were using its instruments. Professor Bartlett had built the observatory at West Point, and had begun to observe there. Lieutenant Gilliss, after years of excellent work in the little establishment on Capitol Hill, had just finished the present Naval Observatory building at Washington; Professor Mitchel had begun to build the Cincinnati Observatory, and the Georgetown Observatory building had been erected. Professor Loomis's work at Hudson should be measured by what others were doing at the time, rather than by the larger performance of to-day.

In the summer of 1844, the year in which Professor Loomis came to New York, a new method in astronomy had its first beginnings. The telegraph line had just been built between Baltimore and Washington, and Captain Wilkes at Baltimore compared his chronometer by telegraph with one at Washington, and so determined the difference of longitude of the two places.

Professor Bache was now Superintendent of the Coast Survey, and he determined at once to use the new method for the purposes of the survey. To Mr. Sears C. Walker was committed the direction of the work; but scarcely less important were the services of Professor Loomis, who for three campaigns had charge of the end of the lines in Jersey City and New York. Their first partially successful efforts were made in 1846, but the practical difficulties were overcome and entire success was obtained by them in 1847 and 1848. In these years the differences of longitude of Washington, Philadelphia, New York, and Cambridge were thus determined with an accuracy far greater than any previous similar determination whatsoever.

The next summer, that of 1849, Professor Loomis assisted in a like work to connect Hudson, Ohio, with the eastern stations. His observations of moon culminations at Hudson were thus available equally with those made at Philadelphia, Washington, Dorchester, and Cambridge for determining the absolute longitudes of Atlantic stations from Greenwich. It was not until 1852 that European astronomers began to use these telegraphic methods in measuring longitudes.

In 1850 Professor Loomis published a volume on the *Recent Progress of Astronomy, especially in the United States.* A first and a second edition were soon exhausted, and in 1856 the volume was entirely rewritten and very much enlarged. Some of the topics in these volumes were the subjects of articles communicated from time to time to the public in this Journal, *Harper's Magazine,* and other periodicals. Another important contribution to astronomy appeared in 1865—that is, his *Introduction to Practical Astronomy.* Eminent astronomers in England and America have expressed in the highest terms their praise of this book. Though it is now thirty-five years since its first appearance, and many treatises on the same subject, some elaborate and some elementary, have since been published, yet for an introduction to practical work I believe that a student will find this volume better than any other for his uses at the beginning of his course.

The increase of our knowledge in astronomy was, from first to last, an object of special interest to Professor Loomis. Before he left New York the income from his text-books enabled him to make to Yale College the generous offer of going to New Haven and working in an observatory at his own charges, provided a suitable observatory should be constructed and equipped for him. Unfortunately, the college was not able, although it was greatly desirous of doing it, to avail itself of his generous offer. Near the same time he joined with public-spirited citizens of New York in an effort to establish an astronomical observatory in or near that city, and for that purpose an act of incorporation was obtained from the New York State Legislature. After going to New Haven he always took the warmest interest in the plans of Mr. Winchester for the establishment of an observatory in connection with Yale University. His counsel and assistance have been instrumental, more than the public could know, in producing and preserving whatever of value has been developed in that observatory.

The science of *Meteorology* has, however, been that in which Professor Loomis has made the most important contributions to human knowledge.

Shortly after his graduation, in 1830, and before he entered upon the tutorship, there appeared the first of a long series of papers by Mr. Redfield, of New York city, upon the theory of storms. In the last year of his tutorship there appeared also the first of a like remarkable series of papers on the same subject by Professor Espy, of Philadelphia. Two rival theories were advocated by these two men, and these theories became the subject of no little discussion in scientific meetings and in scientific journals for a long period of years. Professor Loomis had, from their very inception, taken a warm interest in these discussions and the subject of meteorology, and in particular its central problem, the theory of storms, held in his thought and work the first place from that time to the day of his death.

In his visit to Europe the year before he went to Hudson, he purchased a set of meteorological instruments, and for several years in Hudson he steadily performed the naturally irksome task of making twice each day a complete set of meteorological observations. A few weeks after he entered upon his professorship in Hudson a tornado passed five miles from that place, and he went out immediately to examine the track and learn what facts he could that should bear upon the theory of the tornado. The results were valuable, but he was not altogether satisfied with them. They led him, however, to undertake the discussion of one of the large storms that covered the whole United States.

For this purpose he selected the storm which had occurred near the 20th of December, 1836. Sir John Herschel had recommended hourly observations to be taken by all meteorological observers on four term days in the year—that is, observations for thirty-six successive hours at each equinox and each solstice. This storm fell partly upon one of these term days. Professor Loomis set to work to collect all the meteorological observations made during the week of the storm that he could obtain from all parts of the United States, and from some stations in Canada. The discussion resulting therefrom was read in March, 1840, before the American Philosophical Society at Philadelphia.

Let us for a little while consider the amount of knowledge of the facts about storms in our possession in 1840, the date when this memoir was read and an abstract of it published in Philadelphia. Franklin had noted the motion of storms from southwest to northeast. He said: * "Our northeast storms in North America begin first in point of time in the southwest parts—that is to say, the air in Georgia, the farthest of our colonies to the southwest, begins to move southwesterly before the air of Carolina, which is the next colony northeastward; the air of Carolina has the same motion before the air of Virginia, which lies still more northeastward; and so on northeasterly through Pennsylvania, New York, New England, etc., quite to Newfoundland." Redfield has traced several storms along the West India Islands northwesterly until about in the latitude of 30° their course was turned quite abruptly and they swept off northeasterly along the Atlantic coast toward and even past Newfoundland. Espy found some storms moving easterly or south of east from the Mississippi to the Atlantic.

Brandes had announced as a law that the wind in storms blows inward toward a center; but his law was an induction from a small number of observations. Dove had contended for a whirling motion; Redfield advanced facts to show that the winds blew in circles anticlockwise around a center that advanced in the direction of the prevalent winds, and with him agreed Reid, Piddington, and others. Espy, agreeing with Brandes, claimed that the observations in the various storms showed a centripetal motion of the winds, toward a

* Letter to Alexander Small, May 12, 1760.

center if the region covered by the storm was round, and toward a central line if the storm region was longer in one direction than in another. Espy's conclusions were intimately connected with his theory that in the center of the storm there was an upward motion of the air, and that the condensation of vapor into rain furnished the energy needed for the continuation of the storm. The rival theories of Redfield and Espy were in sharp contest on several points, but the main contention was around this central question: Do the winds blow in circular whirls, or do they blow in toward a center? New York State was collecting observations from its Academies. The American Philosophical Society and the Franklin Institute, aided by an appropriation from the State of Pennsylvania, had united in an effort to learn the facts and the true theory of storms. Under such circumstances the thorough discussion of a single violent storm was likely to add materially to our knowledge. The treatment of this storm by Professor Loomis was probably more complete than that of any previous one, and the methods which he employed were better fitted to elicit the truth than any earlier methods. But the storm was a very large one, extending from the Gulf of Mexico to an unknown distance north, and having its center apparently to the north of all the observers. The results which he was able to secure did not sustain either of the two rival theories, but rather tended to prove some features in each of them. Professor Loomis was not himself satisfied with them, and he therefore waited for another storm that should be better fitted for examination.

In the month of February, 1842, a second tornado passed over northeastern Ohio, and Professor Loomis with one of his colleagues again started out for the examination of the track. The tornado passed over a piece of woods, and hence the positions of the prostrate trees showed clearly the motion of the wind in the passing tornado, and threw much light upon the character of this kind of storm. But the tornado was a single feature of a large storm that covered the whole country, and a second storm of great intensity was also experienced in the same month.

The discussion of these two storms was now undertaken by him. The paper giving the results of that discussion was sent to Professor Bache, and read by him at the centennial meeting of the American Philosophical Society, in May, 1843, and created, as Professor Bache wrote, a great sensation. It was at the time important for the light which it threw upon the rival contending theories of Espy and of Redfield, but it was more important by far by reason of *the new method of investigation* which for the first time was then employed.

In the paper upon the storm of 1836 Professor Loomis had made some advance upon previous methods of representing the facts about storms. But even the method he then used was entirely unfitted to give answers to the questions which meteorologists were asking. Some of those questions were stated in the circulars issued by the joint committee of the American Philosophical Society and the Franklin Institute: What are the phases of the great storms of rain and snow that traverse our continent; what their shape and size; in what direction, and with what velocity do their centers move along the surface of the earth; are they round, or oblong, or irregular in shape; do they move in different directions in different seasons of the year?

The graphic representation by Professor Loomis on the map of the United States of the storm of 1836 had been a series of lines drawn joining the places where at a given hour the barometer was at its lowest point. That line would so far as the barometer was concerned mark for that hour the central line of the storm. The progress of the line from hour to hour on the map showed, though quite imperfectly, how the storm had traveled. Some arrows added showed to the eye also certain facts about the movements of the air.

Professor Espy adopted and thereafter adhered to a modification of this method of representing storm phenomena, and I think meteorologists will agree with me in my opinion that Professor Espy's four Reports from 1842 to 1854, though they contained an immense accumulation of facts, were because of this radical defect of presentation almost useless to meteorological science.

In the discussion of the storms of 1842, instead of the line of minimum depression of the barometer, Professor Loomis drew on the map a series of lines of equal barometric pressure, or rather of equal deviations from the normal average pressure for each place. A series of maps representing the storm at successive intervals of twelve hours were thus constructed, upon each of which was drawn a line through all places where the barometer stood at its normal or average height. A second line was drawn through all places where the barometer stood $\frac{2}{10}$ of an inch below the normal; and other lines through points where the barometer was $\frac{4}{10}$ below, $\frac{6}{10}$ below, $\frac{8}{10}$ below, etc.; also lines were drawn through those points where the barometer stood $\frac{2}{10}$, $\frac{4}{10}$, $\frac{6}{10}$, etc., above its normal height. The deviations of the barometric pressure from the normal were thus made prominent, and all other phenomena of the storm were regarded as related to those barometric lines. A series of colors represented respectively the places where the sky was clear, where the sky was overcast, and where rain or snow was falling. A series of lines represented the places at which the temperature was at the normal, or was 10 or 20 or 30 degrees above the normal, or below the normal. Arrows of proper direction and length represented the direction and the intensity of the winds at the different stations. These successive maps for the three or four days of the storm furnished to the eye all of its phenomena in a simple and most effective manner.

You have, no doubt, most of you, already recognized in this description the charts, which to-day are so common, issued by the United States Signal Service and by weather service bureaus in other countries. The method seems so natural that it should occur to any person who has the subject of a storm under consideration; but the greatest inventions are ofttimes the simplest, and I am inclined to believe that the introduction of this single method of representing and discussing the phenomena of a storm was the greatest of the services which our colleague rendered to science. This method is at the foundation of what is sometimes called "the new meteorology," and the paper which contains its first presentation stands forth, I am convinced, as the most important paper in the history of that science. I regret that I cannot aid my memory by quoting the exact words, but I remember distinctly what seemed to me an almost despairing expression made many years ago by one who had high responsibility in the matter of meteorological work, as he looked out upon the confused mass of observations already made, and felt unable to say in what direction progress was to be expected. With this I contrast the buoyant expressions of another officer charged with like responsibility, as he showed me, one or two decades later (in 1869), charts constructed like those of Professor Loomis, and said: "I care not for the mass of observations made in the usual form. What I want is the power and the material for making such charts as these." These two expressions of Sir George Airy and of Le Verrier mark the progress and the direction of progress in meteorology developed by Professor Loomis's memoir.

What was his own judgment of the method at the time of its publication, and of its value in meteorology, can be seen from his words at the close of the memoir, which I beg permission to quote.

"It appears to me that if the course of investigations adopted with respect to the two storms of February, 1842, was systematically pursued we should soon have some settled principles in meteorology. If we could be furnished with two meteorological charts of the United States daily for one year—charts showing the state of the barometer, thermometer, winds, sky, etc., for every part of the country—it would settle forever the laws of storms. No false theory could stand against such an array of testimony. Such a set of maps would be worth more than all which has been hitherto done in meteorology. Moreover, the subject would be well nigh exhausted. But one year's observation would be needed; the storms of one year are probably but a repetition of those of the preceding. Instead, then, of the guerilla warfare which has been maintained for centuries with indifferent success, although at the expense of great self-devotion on the part of individual chiefs, is it not time to embark in a general meteorological crusade? A well-arranged system of observations spread over the country would accomplish more in one year than observations at a few insulated posts, however accurate and complete, continued to the end of time. The United States are favorably situated for such an enterprise. Observations spread over a smaller territory would be inadequate, as they would not show the extent of any large storm. If we take a survey of the entire globe we shall search in vain for more than one equal area which could be occupied by the same number of trusty observers. In Europe there is opportunity for a like organization, but with this incumbrance, that it must needs embrace several nations of different languages and governments. The United States, then, afford decidedly the most hopeful field for such an enterprise. Shall we hesitate to embark in it; or shall we grope timidly along as in former years? There are but few questions of science which can be prosecuted in this country to the same advantage as in Europe. Here is one where the advantage is in our favor. Would it not be wise to devote our main strength to the reduction of this fortress? We need observers spread over the entire country at distances from each other of not more than fifty miles. This would require five or six hundred observers for the United States. About half this number of registers are now kept in one shape or another, and the number by suitable efforts might probably be doubled. Supervision is needed to introduce uniformity throughout, and to render some of the registers more complete. Is not such an enterprise worthy of the American Philosophical Society? The general government has for more than twenty years done something, and has lately manifested a disposition to do more for this object. If private zeal could be more generally enlisted, the war might soon be ended, and men would cease to ridicule the idea of our being able to predict an approaching storm."

This plan of a systematic meteorological campaign was cordially seconded by Professors Bache and Peirce. At a somewhat later date the American Academy of Sciences of Boston appointed a committee, of which Professor Loomis was chairman, to urge upon the proper authorities the execution of the plan. The American Philosophical Society of Philadelphia united its voice with that of the Academy. About this time Professor Henry was made Secretary of the Smithsonian Institution. He determined to make American meteorology one of the leading subjects of investigation, to be aided by the Institution. At Professor Henry's request, Professor Loomis prepared a report upon the meteorology of the United States, in which he showed what advantages society might expect from the study of the phenomena of storms; what had been done in this country towards making the necessary observations, and towards deducing from them general laws; and, finally, what encouragement there was to a further prosecution of the same researches. He then presented in detail a practicable plan for securing the hoped-for advantages in their fullest extent.

This plan looked to a unifying of all the work done by existing observers, a systematic supervision, a supplementing of it by new observers at needed points, a securing of the coöperation of the British government and the Hudson's Bay Company in the regions to the north of us, and finally a thorough discussion of the observations collected. A siege of three years was contemplated. In the history of the several steps that finally led to the establishment of the United States Signal Service this report has an important place.

The scheme laid down by Professor Loomis was in part followed out by the Institution. But the fragmentary character of the observations, the want of systematic distribution of the places of the observers, and the imperfections of the barometers made the material collected difficult of discussion. Professor Loomis waited in hopes of some better system.

In 1854 Professor Loomis undertook a rediscussion of the storm of 1836, using the new methods introduced for treating the storms of 1842. A visit to Europe shortly after enabled him to collect a large number of observations upon a storm or series of storms that occurred in Europe about a week later than that American storm. He had long been anxious to connect, if possible, these two storms, as he said, "stepping across the Atlantic." The European and the American storms, however, not only proved to be distinct one from the other, but the discussion showed clearly that many of the laws of American storms were radically different from those of the European storms. The results of the whole discussion were published in 1859 by the Smithsonian Institution.

Upon going to New Haven, in 1860, he commenced the collection of all the meteorological observations that had been made in New Haven and the immediate vicinity, and succeeded in finding sets which, when brought together, made up a nearly continuous record through 86 years. The results of these observations formed the subject of a memoir published by the Connecticut Academy of Arts and Sciences in 1866.

It became part of his duties in college to deliver a course of lectures upon the subject of meteorology. In preparation for these he caused to be printed in very limited numbers the outlines of a treatise upon meteorology, to be used as the basis of his series of lectures. In 1868 he developed this outline into a treatise suited to use in college classes and in private study. This treatise, notwithstanding the rapid advances of the science during more than twenty years, is still indispensable to the student of meteorology.

The better system of observing, for which Professor Loomis had been long waiting, came when the United States Signal Service was established, in 1871. The daily maps of the weather published by the Bureau were constructed essentially after the plan which Professor Loomis had, thirty years before, invented for the treatment of the storms of 1842. As soon as these maps had been published for the two years 1872 and 1873, Professor Loomis commenced in earnest to deduce from them the lessons which they taught us respecting the nature and the phenomena of United States storms. To this investigation he gave nearly all his energies during the remaining fifteen years of his life.

For several years he employed and paid for the services of assistants whose time was given to the preparation of material for use in his studies. The aggregate cost of this assistance was of itself a very large contribution to science. Beginning in April, 1874, he presented regularly at each of eighteen successive meetings of this Academy, in April and in October of each year, a paper entitled "Contributions to Meteorology." These were at first based upon the publications of the Signal Service alone, but as years went by like publications appeared in Europe that were useful for his work. These papers were published in July and January following the Academy meeting, and they regularly formed the first and leading article in eighteen successive volumes of the American Journal of Science. Gradually, one after another of his college duties were committed to others that he might give his whole strength to these investigations.

An attack of malaria now interrupted the regularity of the series. His advancing years and diminishing strength warned him that the end of his investigations could not be far distant. The number of hours in which he could work each day was slowly diminishing. Five more papers followed at somewhat less regular intervals.

In 1884 he began a revision of the whole series of papers. They had been presented without much regard to systematic order in the subjects investigated, and new material had accumulated from time to time, so that a thorough, systematic revision seemed absolutely necessary.

In 1885 he presented to this Academy the first chapter of the revision, in which he discussed the areas of low pressure—their form, their size, their motions, and the phenomena attending them. Two years later, in 1887, the second chapter of the revision was presented, in which he discussed the areas of high pressure, their form, magnitude, direction and velocity of movement, and their relation to areas of low pressure. Gradually his physical strength was failing, though his mind was as bright and clear as ever. To this work, the only work which he was now doing, he was able to give two or three hours a day. Anxiously he husbanded his strength, slowly and painfully preparing the diagrams and the tables for the third chapter upon rain areas, the phenomena of rainfall in its connection with areas of low pressure, and the varied phenomena of unusual rainfall. "I see," he said to a friend, "not the end of this subject, but where I must stop. I hope I shall have strength to finish this work, and then I shall be ready to die."

This third and finishing chapter was finally passed through the printer's hands and some advance copies distributed to correspondents abroad in the summer months of 1889. His work upon the theory of storms he felt was finished. As he paid the bill of the printer, he said to him: "When I return at the close of the vacation I expect to put into your hands for printing a new edition of the *Loomis Genealogy.*" Before the close of the vacation he died.

These three chapters of his revised edition of *Contributions to Meteorology* constitute the full and ripe fruitage of his work in his favorite science. They will for a long time to come be the basis of facts by which writers in theoretical meteorology must test their formulas. They cover all the important points taken up in the twenty-three earlier memoirs, with one important exception, the relation of mountain observations to those made on the plains below. The laws connecting these two are not yet clearly indicated; much remains to be learned about them, and they are of the utmost importance in theoretical meteorology. He felt most deeply the backward steps taken by the United States Signal Service when mountain observations and the publication of the *International Bulletin* were discontinued. "The National Academy of Sciences," he said, "ought at once to take up the subject and use all its influence to secure the restoration of these two services."

Professor Loomis at various times studied certain other questions in physics and astronomy that were more or less allied with the subjects to which he gave the principal part of his time, and he published the results of his studies. He made a series of experiments on currents of electricity generated by a plate of zinc buried in the earth. He examined the electrical phenomena in certain houses in New York; the curious phenomena of optical moving figures; the vibrations sent out from waterfalls as the water flows over certain dams; the orbits of the satellites of Uranus; the temperature of the planets; the variations of light of the stars η Argus and Algol; and the comet of 1861.

The subject of family *Genealogy* has a peculiar fascination for many minds. It would be an interesting study by a collection of facts to determine practically what are the elements in a man's character which lead him to engage in this peculiar study. Certain it is that men of most diverse disposition are led into it. I should not have thought it likely that Professor Loomis would have taken up the subject very seriously. Others have expressed to me the same thought, and he himself says that he did not think it strange that others should be surprised at his devoting so much time to this subject, for he was surprised at it himself. He became interested in the subject early in life, and that interest remained unbroken to his last days. For near forty years before his first publication he collected from time to time materials for a list of the descendants of his ancestor, Joseph Loomis, who came from Braintree, England, in the year 1638, and settled in Windsor, Connecticut, in 1639. In each of his four visits to Europe he extended his inquiries to his ancestor's earlier history in England. The materials thus collected were put in type in 1870. He published a list containing 4,340 descendants of Joseph Loomis bearing the Loomis name. He regarded it as entirely provisional, printed to help himself in making further researches, and to excite interest in others of the name, who would thus be led to give additional information, or correction of errors.

Finding that to a limited extent only could he hope by correspondence to gain the information desired, he now undertook in his vacations to canvass the country by personal visits. He collected lists of names from every available source—from catalogues of every description, from city directories, county directories, county maps, and county tax-lists—and he compiled from these sources lists of all the Loomis names he could find. Arranging these names by counties, he undertook to visit each family personally. In this way he made a pretty thorough canvass of every part of New England and New York State, of nearly every part of New Jersey and Pennsylvania, of the northern part of Ohio, and of some of the western cities.

After five years of these researches he published the second edition of the *Loomis Genealogy*, in which were given 8,686 names of persons that bore the Loomis name, descendants of Joseph Loomis in the male branches.

Five years later, in 1880, Professor Loomis printed in two additional volumes a provisional list of 19,000 descendants of Joseph Loomis in the female branches. Large as was this list, he did not regard it as more than a first outline of a census of the descendants of the original emigrant, and he hoped in the near future to publish an additional volume. For this he has left in manuscript many corrections and large additions that will be of use to the future Loomis Genealogist.

Am I tarrying too long upon the vacation work of Professor Loomis? If so, I plead as a partial excuse that among these direct descendants of Joseph Loomis there were enrolled more than 200 graduates of Yale College, and nearly 100 more of its graduates have married members of this numerous family.

Professor Loomis was doubtless more widely known as the author of mathematical text-books than as a worker in new fields in science. Shortly after coming to New York he prepared a text-book in algebra. The market was ready for a good book of this kind, and the work prepared for it was a good one. It was followed the next year by a geometry. This was an attempt, and if judged by its reception and sale it was a successful attempt, to combine in a school-book the rigid demonstrations of Euclid with the courses of thought in Legendre and in modern science. The task is one of peculiar difficulty, as the existence and activities of the English Society for the Improvement of Geometric Teaching now for near twenty years illustrate. Other books followed the Geometry from year to year, the whole forming a connected series from Arithmetic upward, so that the list of his works finally numbered near twenty volumes. His experience in teaching, his rare skill in language, his clear conception of what was important, and his unwearied painstaking, combined to produce text-books which met the wants of teachers. About 600,000 volumes have been sold, benefiting the schools and colleges and bringing to the author a liberal and well-merited pecuniary return.

We ought not on this academic occasion to omit to speak of the teacher. College graduates who have been under his instruction will probably retain a more positive impression of the personal traits and the character of Professor Loomis than of most of their other teachers. His crisp sentences, lucid thought, exactness of language, and steadiness of requirement more than made up for any apparent coldness and real reserve. These characteristics of his riper years were peculiar to him from the beginning of his life as a teacher. During his tutorship he was thought to be strict as a disciplinarian, and this may have unfavorably affected his influence with some members of the class of 1837, in Yale College, of which he was tutor. It was not so with all of them. One of the members of that class, Chief Justice Waite, as he came to Commencement a few years since, occupying at the time the highest office which a lawyer in the line of his profession can in this country secure, said: "If I have been successful in life, I owe that success to the influence of Tutor Loomis more than to any other cause whatever."

There was in Professor Loomis so much of reserve that to many persons he seemed cold and without interest in the lives of others. But this was mainly due to appearances only. The tear would at times come unbidden to his eye. His correspondence with his classmates in the years immediately following graduation shows warm interest in all that concerned them. From Hudson he wrote often to Mr. Herrick, and complained much of isolation, but more especially of isolation from scientific companions and books.

In 1840 he married Miss Julia E. Upson, of Talmadge, Ohio, a lady about whom those who knew her have spoken to me only in terms of praise, and for whose memory Professor Loomis cherished a tender reverence. She died in 1854, leaving two sons. From this time Professor Loomis lived in apartments, surrounded by his books and devoted to his studies. His sons after passing their school and college days went to their own fields of work. During many years of his New Haven life he was unable to receive visitors in the evening. He made very few new friends, and one after another of his old ones passed away. To his work he was able to give undivided his time and his strength. His mind did not seem to require the excitement of social intercourse for its full and healthful activity. Isolated though he was, there was in him no trace whatever of selfish or morbid feeling. In council his advice was always marked by his clear judgment of what was important, and at the same time what was practicable. Whatever he himself had the right to decide was promptly decided by a yes or a no, and few persons cared to question the finality of his decision. But when his colleagues, or others, had the right to decide he accepted their decision without questioning or subsequent murmur. Upon being told that his letters to Mr. Herrick had come to the College Library, and that he could, if he chose, examine them and see whether there were among them any which he would prefer not to leave in this *quasi* public place, he promptly replied: "No; I never wrote a letter which I should be ashamed to see published."

After coming to New York he had a generous income from his books, besides his salary as professor. The amount he saved from his income was carefully and prudently invested, and before his death the savings with their accumulations were a large estate; how large only he and his banker knew.

To establish an Astronomical Observatory had been through life a cherished object. He entered into and aided heartily the plans of Mr. Winchester, both before and after Mr. Winchester asked his Trustees to transfer his magnificent endowment to Yale University. Professor Loomis looked forward to a large institution in the future on the observatory site. To endow this public service, after making liberal provision for his two sons, he bequeathed his estate. The income from more than $300,000 will eventually be available to continue the work of his life. With clear judgment of what was most important, he limited the use of that income to the payment of salaries of persons whose time should be exclusively devoted to the making of observations for the promotion of the science of astronomy, or to the reduction of astronomical observations, and to defraying the expenses of publication. He knew that if he provided observers, other benefactors would furnish buildings and instruments and the costs of supervision and maintenance.

One of his college classmates told me that Mr. Loomis left college with the definitely expressed purpose that the world should be better for his living in it. The central proposition in his Inaugural Address at Hudson, in 1838, was: "That it is essential to the best interests of society that there should be a certain class of men devoted exclusively to the cultivation of abstract science, without any regard to its practical applications; and consequently that such men, instead of being a dead weight upon society, are to be ranked among the greatest benefactors of their race." He chose this cultivation of science for his principal work for man, and he kept steadily through his whole life to the chosen work. Verily the world is better for the life and work of ELIAS LOOMIS.

PUBLICATIONS OF ELIAS LOOMIS.

1. On shooting stars. *Am. Jour.* (1), vol. 28, pp. 95–104. April, 1835.

2. Halley's comet (Olmsted and Loomis). *New Haven Daily Herald*, September 1, September 4, September 28, and December 31, 1835.

3. Halley's comet (Olmsted and Loomis). *Am. Jour.* (1), vol. 29, pp. 155–156. October, 1835.

4. Observations on the comet of Halley, made at Yale College. *Am. Jour.* (1), vol. 30, pp. 209–221. July, 1836.

5. Observations on the variation of the magnetic needle, made at Yale College in 1834 and 1835. *Am. Jour.* (1), vol. 30, pp. 221–233. July, 1836. (*Sturgeon's Ann. Electr.*, vol. 2, pp. 270–282.)

6. Letters from Europe. (Thirty-six letters.) *Ohio Observer* (1837).

7. Meteoric shower of November 13. *Cleveland Observer*, November, 1837.

8. Hourly meteorological observations for the December solstice of 1837, made at Western Reserve College. *Cleveland Observer*, December 23, 1837.

9. Hourly meteorological observations for the vernal equinox of 1838, made at Western Reserve College. *Cleveland Observer*, March, 1838.

10. Observations on a hurricane which passed over Stow, in Ohio, October 20, 1837. *Am. Jour.* (1), vol. 33, pp. 368–376. January, 1838.

11. Splendid meteor (May 18, 1838). *Cleveland Observer*, May 22, 1838.

12. Hourly meteorological observations for the summer solstice of 1838, made at Western Reserve College. *Cleveland Observer*, June, 1838.

13. On the variation and dip of the magnetic needle in different parts of the United States. *Am. Jour.* (1), vol. 34, pp. 290–309. (With a map.) July, 1838.

14. On the latitude and longitude of Yale College Observatory. *Am. Jour.* (1), vol. 34, pp. 309–313. July, 1838.

15. Meteors of August 9. *Cleveland Observer*, August 11, 1838.

16. An inaugural address, delivered August 21, 1838. 8vo, pp. 38. New York, 1838.

17. Hourly meteorological observations for the autumnal equinox of 1838, made at Western Reserve College. *Cleveland Observer*, September, 1838.

(Professor Loomis also observed on the term days in December, 1838, and in March and June, 1839.)

18. On the meteor of May 18, 1838, and on shooting stars in general. *Am. Jour.* (1), vol. 3, pp. 223-232. January, 1839.

19. Meteorological table and register. *Am. Jour.* (1), vol. 36, pp. 165-173. April, 1839.

20. Observations to determine the magnetic dip at various places in Ohio and Michigan. In a letter to Sears C. Walker, Esq. Read June, 1839. *Am. Phil. Soc. Trans.*, vol. 7, pp. 1-6. (*Am. Phil. Soc. Proc.*, vol. 1, p. 116; *Am. Jour.* (1), vol. 38, p. 397.)

21. Astronomical observations made at Hudson Observatory, latitude 41° 14′ 37″ north and longitude 5^h 25^m 42^s west, with some account of the building and instruments. (Latitude of observatory; moon culminations; occultations.) *Am. Phil. Soc. Trans.*, vol. 7, pp. 43-51. Read October, 1839. (*Am. Phil. Soc. Proc.*, vol. 1, pp. 129-130.)

22. Additional observations of the magnetic dip in the United States. *Am. Phil. Soc. Trans.*, vol. 7, pp. 101-111. Read October, 1839. (*Am. Phil. Soc. Proc.*, vol. 1, pp. 144-145.)

23. On the storm which was experienced throughout the United States about the 20th of December, 1836. *Am. Phil. Soc. Trans.*, vol. 7, pp. 125-163. (With three plates.) Read March, 1840. (*Am. Phil. Soc. Proc.*, vol. 1, pp. 195-198; *Am. Jour.* (1), vol. 40, pp. 34-37.)

24. Meteorological sketches. (Eight papers.) *Ohio Observer*, 1840.

25. On the variation and dip of the magnetic needle in the United States *Am. Jour.* (1), vol. 39, pp. 41-50. (With a map.) July, 1840.

26. Observations to determine the magnetic intensity at various places in the United States, with some additional observations of the magnetic dip. *Am. Phil. Soc. Trans.*, vol. 8, pp. 61-72. Read November, 1840. (*Am. Phil. Soc. Proc.*, vol. 2, pp. 308-310.)

27. On the magnetic dip in the United States. *Am. Jour.* (1), vol. 40, pp. 85-92. (*Sturgeon's Ann. Electr.*, vol. 7, pp. 156-162.) January, 1841.

28. Meteorological observations made at Hudson, Ohio, latitude 41° 14′ 40″ north, longitude 5^h 25^m 47.5^s west, during the years 1838, 1839, and 1840. (Barometer; thermometer and hygrometer; winds; rain.) *Am. Jour.* (1), vol. 41, pp. 310-330. October, 1841.

29. Astronomical observations made at Hudson Observatory, latitude 41° 14′ 40″ north and longitude 5^h 25^m 45^s west. (Latitude of observatory; moon culminations; occultations; comet 1840, II; orbit of comet.) *Am. Phil. Soc. Trans.*, vol. 8, pp. 141-154. Read April, 1841.

30. On the dip and variation of the magnetic needle in the United States. *Am. Jour.* (1), vol. 43, pp. 93-116. April, 1842.

31. Encke's comet. *Ohio Observer*, April, 1842.

32. On a tornado which passed over Mayfield, Ohio, February 4, 1842, with some notices of other tornadoes. *Am. Jour.* (1), vol. 43, pp. 278–300. (With a map.) April, 1842.

33. Supplementary observations on the storm which was experienced throughout the United States about the 20th of December, 1836. *Am. Phil. Soc. Trans.*, vol. 8, pp. 305–306. Read May, 1842.

34. Observations on the magnetic dip in the United States. *Am. Phil. Soc. Trans.*, vol. 8, pp. 285–304. Read May, 1842. (*Am. Phil. Soc. Proc.*, vol. 2, pp. 176–178.)

35. Icebergs in the Atlantic. *Ohio Observer*, July, 1842.

36. The comet. (Five papers, with orbit.) *Ohio Observer*, March, 1843.

37. On two storms which were experienced throughout the United States in the month of February, 1842. *Am. Phil. Soc. Trans.*, vol. 9, pp. 161–184. (With 13 maps.) Read May, 1843. (*Am. Phil. Soc. Proc.*, vol. 3, pp. 50–56.)

38. On vibrating dams. *Am. Jour.* (1), vol. 45, pp. 363–377. (Cuyahoga Falls; East Windsor; Springfield; Northampton; Gardiner; Hartford.) October, 1843.

39. Meteorological journal kept at Western Reserve College. (Forty-seven papers.) March, 1840, to January, 1844. *Ohio Observer.*

40. Modern astronomy. *New Englander*, vol. 2, pp. 3–18. January, 1844.

41. Comparison of Gauss's theory of terrestrial magnetism with observation. *Am. Jour.* (1), vol. 47, pp. 278–281. October, 1844.

42. Astronomical observations made at Hudson Observatory, latitude 41° 14′ 42.6″ north and longitude 5^h 25^m 39.5^s west. Third series. *Am. Phil. Soc. Trans.*, vol. 10, pp. 1–15. Read November, 1844. (*Astron. Nachr.*, vol. 22, pp. 203–210, No. 517, October, 1844. *Roy. Astr. Soc.*, *Month Notices*, December, 1844.) (Latitude of observatory; moon culminations; occultations; longitude of observatory; Encke's comet; comet of 1843; Mauvais's comet; Faye's comet.)

43. Meteorological observations made at Hudson, Ohio, latitude 41° 14′ 42″ north, longitude 5^h 25^m 40^s west, during the years 1841, 1842, 1843, and 1844, with a summary for seven years. (Barometer; thermometer and hygrometer; winds; clouds; rain.) *Am. Jour.* (1), vol. 49, pp. 266–283. October, 1845. (*Astr. Nachr.*, vol. 22, pp. 203–210.)

44. Physical constitution of the moon. *Sidereal Messenger*, vol. 1, pp. 20–22. September, 1846. (*Am. Jour.* (2), vol. 2, pp. 432–433.)

45. A treatise on algebra. 12mo, pp. 346. New York, 1846.

46. On Biela's comet. *Am. Jour.* (2), vol. 2, pp. 435–438. November, 1846.

47. The planet Neptune. *Am. Review*, vol. 6, pp. 145–155. August, 1847.

48. On the determination of differences of longitude made in the United States by means of the electric telegraph, and on projected observations for investigating the laws of the great North American storms. (Letter to Lieutenant Colonel Sabine.) *Phil. Mag.*, 3d series, vol 31, pp. 338–340. August, 1847.

49. Notice of some recent additions to our knowledge of the magnetism of the United States and its vicinity. *Am. Jour.* (2), vol. 4, pp. 192–198. September, 1847.

50. Elements of geometry and conic sections. 8vo, pp. 222. New York, 1847.

51. Notice of a water-spout. *Am. Jour.* (2), vol. 4, pp. 362–364. November, 1847.

52. Report on the meteorology of the United States, submitted to the Secretary of the Smithsonian Institution. *Sen. Doc.* No. 23, 30th Congress, first session, pp. 193–207. Ordered printed January, 1848.

53. Historical notice of the discovery of the planet Neptune. *Am. Jour.* (2), vol. 5, pp. 187–205. March, 1848.

54. Note respecting Halley's comet. *Am. Jour.* (2), vol. 5, pp. 370–372. May, 1848.

55. The relations of Neptune to Uranus. *Am. Jour.* (2), vol. 5, pp. 435–437. May, 1848.

56. Elements of plane and spherical trigonometry, with their applications to mensuration, surveying, and navigation. 8vo, pp. vi, 148. New York, 1848.

57. Tables of logarithms of numbers and of lines and tangents for every ten seconds of the quadrant, with other useful tables. 8vo, pp. xvi, 150. New York, 1848.

58. On the determination of the difference of longitude by means of the magnetic telegraph. *Roy. Soc. Proc.*, vol. 5, pp. 787–789. 1849.

59. Experiments on the electricity of a plate of zinc buried in the earth. *Am. Jour.* (2), vol. 9, pp. 1–11. January, 1850. (*Am. Assoc. Proc.*, pp. 196–200, 1849. *Bibl. Univ.*, *Archives*, vol. 13, pp. 265–281.)

60. On the longitude of Hudson (Ohio) Observatory. *Astron. Jour.*, Nos. 8 and 9. May, 1850.

61. On the proper height of lightning rods. *Am. Jour.* (2), vol. 10, pp. 320–321. (Read August, 1850.) (*Am. Assoc. Proc.*, pp. 38–43. 1850.)

62. On the electrical phenomena of certain houses. *Am. Jour.* (2), vol. 10, pp. 321–323. (Read August, 1850.) (*Am. Assoc. Proc.*, pp. 12–15, 1850. *Edin. New Phil. Jour.*, vol. 50, pp. 225–227.)

63. On optical moving figures. *Am. Assoc. Proc.*, pp. 293–295. 1850.

64. The recent progress of astronomy, especially in the United States. 8vo, pp. 257. New York, 1850.

65. Elements of analytical geometry and of the differential and integral calculus. 8vo, pp. 278. New York, 1851.

66. On Kirkwood's law of the rotation of the primary planets. *Am. Jour.* (2), vol. 11, pp. 217–223. March, 1851.

67. Observations on the first comet of 1850, made at Hudson, Ohio. *Gould's Astr. Jour.*, vol. 1, pp. 179–180. March, 1851.

68. On the apparent motion of figures of certain colors. *Am. Assoc. Proc.*, pp. 78–81. 1851.

69. On the distribution of rain for the month of September. *Am. Assoc. Proc.*, pp. 145–149, 1851. (*Annual Sci. Disc.*, pp. 389–391, 1852.)

70. The elements of algebra, designed for beginners. 12mo, pp. 260. New York, 1851.

71. On the satellites of Uranus. *Am. Jour.* (2), vol. 14, pp. 405–410. November, 1852.

72. Notice of the hail-storm which passed over New York city on the 1st of July, 1853. *Am. Assoc. Proc.*, pp. 59–79, 1853. (*Am. Jour.* (2), vol. 17, pp. 35–55. *Annals of Science*, vol. 1, pp. 209–215.)

73. Does the moon exert a sensible influence upon the clouds? *Am. Assoc. Proc.*, pp. 80–83, 1853.

74. On the measurement of heights by the barometer. *Am. Assoc. Proc.*, pp. 169–171. 1853.

75. Comparison of the British Association Catalogue of Stars with the Greenwich Twelve-year Catalogue. *Gould's Astron. Jour.*, vol. 3, pp. 177–182. May, 1854.

76. On the resistance experienced by bodies falling through the atmosphere. *Am. Jour.* (2), vol. 17, pp. 67–70. July, 1854.

77. On the satellites of Uranus. *Am. Assoc. Proc.*, pp. 52–55. 1854.

78. The zone of small planets between Mars and Jupiter. (Lecture.) *Smithsonian Report*, pp. 137–146, 1854. (*Harper's New Month. Mag.*, vol. 10, pp. 343–353. February, 1855.)

79. An introduction to practical astronomy, with a collection of astronomical tables. 8vo, pp. 497. New York, 1855.

80. On the temperature of the planets, and on some of the conclusions resulting from this temperature. *Am. Assoc. Proc.*, pp. 74–80. 1855.

81. On the storm which was experienced throughout the United States about the 20th of December, 1836. *Am. Assoc. Proc.*, pp. 176–183. 1855.

82. Astronomical observations in the United States. *Harper's New Month. Mag.*, vol. 13, pp. 25–52. June, 1856.

83. A treatise on arithmetic, theoretical and practical. 12mo, pp. 352. New York, 1856.

84. The recent progress in astronomy, especially in the United States Third edition; mostly rewritten and much enlarged. 8vo, pp. 396. New York, 1856.

85. On the relative accuracy of the different methods of determining geographical longitude. *Brit. Assoc. Rep.*, 1857 (2), pp. 25, 26. August, 1857.

86. On certain electrical phenomena in the United States. *Brit. Assoc. Rep.*, 1857, pp. 32–35; August, 1857. (*Pogg. Annalen*, vol. 100, pp. 599–606. 1857.)

87. Elements of natural philosophy, designed for academies and high schools, with three hundred and sixty illustrations. 12mo, pp. 344. New York, 1858.

88. On the electrical phenomena observed in certain houses in New York. *Am. Assoc. Proc.*, pp. 33–38, 1858. (*Am. Jour.* (2), vol. 26, pp. 58–62.)

89. On the variation of the magnetic needle at Hudson, Ohio. *Am. Jour.* (2), vol. 28, pp. 167–169. March, 1859.

90. Observations of the magnetic dip in the United States. *Am. Phil. Soc. Trans.*, vol. 11, pp. 181–186. Read August, 1859.

91. On certain storms in Europe and America, December, 1836, *Smith. Cont.* (accepted for publication August, 1859), vol. 11, pp. 26, and 13 colored charts.

92. The great auroral exhibition of August 28 to September, 1859. *Am. Jour.* (2), vol. 28, pp. 385–408. November, 1859.

93. On the European storm of December 25, 1836. *Am. Assoc. Proc.*, pp. 281–283. 1859.

94. Notices of the meteor of November 15, 1859. *Am. Jour.* (2), vol. 29, pp. 137–138, 298–300, and 447. January, March, and May, 1860.

95. The great auroral exhibition of August 28 to September 4, 1859—2d article. *Am. Jour.* (2), vol. 29, pp. 92–97. January, 1860.

96. The great auroral exhibition of August 28 to September 4, 1859—3d article. *Am. Jour.* (2), vol. 29, pp. 249–266. February, 1860.

97. The great auroral exhibition of August 28 to September 4, 1859—4th article. *Am. Jour.* (2), vol. 29, pp. 386–399. May, 1860.

98. The great auroral exhibition of August 28 to September 4, 1859, and the geographical distribution of auroras and thunder storms—5th article. *Am. Jour.* (2), vol. 30, pp. 79–100. July, 1860.

99. The great auroral exhibition of August 28 to September 4, 1859—6th article. (Selected from the Smithsonian papers.) *Am. Jour.* (2), vol. 30, pp. 339–361. November, 1860.

100. The great auroral exhibition of August 28 to September 4, 1859—7th article. *Am. Jour.* (2), vol. 32, pp. 71–84. May, 1861.

101. The great comet of 1861. *Am. Jour.* (2), vol. 32, pp. 252–256. September, 1861.

102. On the great auroral exhibition of August 28 to September 4, 1859, and auroras generally—8th article. *Am. Jour.* (2), vol. 32, pp. 318–335. September, 1861.

103. On electrical currents circulating near the earth's surface and their connection with the phenomena of the aurora polaris—9th article. *Am. Jour.* (2), vol. 34. pp. 34–45. July, 1862. (On the action of electrical currents and the motion of auroral beams.)

104. Remarks upon the article of Prof. J. D. Everett. (On reducing observations of temperature.) *Am. Jour.* (2), vol. 35, pp. 31–34. January 1863.

105. The elements of arithmetic, designed for children. 16mo, pp. 166. New York, 1863.

106. On vibrating water-falls. *Am. Jour.* (2), vol. 36, pp. 352–365. November, 1863. (South Natick; Holyoke; Lawrence.)

107. A treatise on astronomy. 8vo, pp. 338. New York, 1865.

108. The aurora borealis or polar light, its phenomena and laws. *Smithson. Rep.*, pp. 208–248, 1865. (*Archives Sci. Phys. Nat.*, vol. 31, pp. 273–285, 1868.) Rewritten and published with illustrations in *Harper's New Month. Mag.*, vol. 39, pp. 1–21. June, 1869.

109. On the physical condition of the sun's surface and the motion of the solar spots. *Am. Assoc. Proc.*, pp. 1–5. 1866.

110. On the period of Algol. *Am. Assoc. Proc.*, pp. 5–7. 1866.

111. Notices of auroras extracted from the meteorological journal of Rev. Ezra Stiles, S. T. D., formerly president of Yale College, to which are added notices of a few other auroras recorded by other observers at New Haven, Conn. *Trans. Conn. Acad.*, vol. 1, pp. 155–172.

112. On the mean temperature and on the fluctuations of temperature at New Haven, Conn., latitude 41° 18′ north, longitude 72° 55′ west of Greenwich (E. Loomis and H. A. Newton). *Trans. Conn. Acad.*, vol. 1, pp. 194–246. (Three plates.)

113. A treatise on meteorology, with a collection of meteorological tables. 8vo, pp. 305. New York, 1868.

114. Shooting stars, detonating meteors, and aerolites. *Harper's New Month. Mag.*, vol. 37, pp. 34–50. June, 1868.

115. A treatise on algebra, revised edition. 8vo, pp. 384. New York, 1868.

116. Influence of the moon upon the weather. *Am. Assoc. Proc.*, pp. 118–122. 1868.

117. On the period of η Argus. *Roy. Ast. Soc., Month. Not.*, vol. 29, pp. 298-299. April, 1869.

118. Remarkable meteor of May 20, 1869. *Am. Jour.* (2), vol. 48, pp. 145–146. July, 1869.

119. Meteorology and astronomy, for academies and high schools. 12mo. New York, 1869.

120. Elements of astronomy, designed for academies and high schools. 12mo, pp. 254. New York, 1869.

121. The descendants of Joseph Loomis, who came from Braintree, England, in the year 1638 and settled in Windsor, Conn., in 1639. 8vo, pp. 292. New Haven, 1870.

122. Recent auroral displays in the United States. *Am. Jour.* (2), vol. 50, pp. 146, 147. July, 1870.

123 Comparison of the mean daily range of the magnetic declination, with the number of auroras observed each year, and the extent of the black spots on the surface of the sun. *Am. Jour.* (2), vol. 50, pp. 153–171. September, 1870. (*Archives Sci. Phys. Nat.*, vol. 40, pp. 352–358.)

124. Recent auroral displays in the United States. *Am. Jour.* (3), vol. 1, p. 309. April, 1871.

125. Recent auroral displays in the United States. *Am. Jour.* (3), vol. 3, p. 389. May, 1872.

126. The elements of analytical geometry, revised edition. 8vo, pp. 261, New York, 1872.

127. Instances of remarkably low temperature observed at New Haven, Conn. *Am. Jour.* (3), vol. 5, pp. 238–239. April, 1873.

128. Comparison of the mean daily range of the magnetic declination and the number of auroras observed each year, with the extent of the black spots on the surface of the sun. *Am. Jour.* (3), vol. 5, pp. 243-260. April, 1873. (*Palermo, Mem. Spettr. Ital.*, vol. 2, pp. 123–124.)

129. Results derived from an examination of the United States weather maps for 1872 and 1873. (With two plates.) *Am. Jour.* (3), vol. 8, pp. 1–15. Read in N. A. S. April, 1874. (Influence of rainfall upon the course of storms; influence of the wind's velocity upon the progress of storms; relation between the velocity of the wind and the velocity of a storm's progress; to determine whether a storm is increasing or diminishing in intensity; form of the isobaric curves; classification of storms; where do the storms which seem to come from the far West originate?)

130. Elements of the differential and integral calculus, revised edition. 8vo, pp. 309. New York, 1874.

131. Results derived from an examination of the United States weather maps for 1872 and 1873. *Am. Jour.* (3), vol. 9, pp. 1–14. (With plate.) Read in N. A. S. November, 1874. (Direction and velocity of the wind within areas of maximum pressure; consequences of the outward flow of air from an area of high barometer; monthly minima of temperature; long-continued periods of cold weather; storm of January 6–8, 1874; connection between the velocity of the wind and the distance between the isobars in the neighborhood of a storm center.)

132. Results derived from an examination of the United States weather maps for 1872, 1873, and 1874—3d paper. (With plate.) *Am. Jour.* (3), vol. 10, pp. 1–14. Read in N. A. S. April, 1875. (Directions of storm paths; diurnal inequality in the progress of storms; influence of rainfall upon the course of storms; influence of a neighboring area of high barometer upon the progress of a storm; form of the isobaric curves; great and sudden changes of temperature; storm of January 15, 1875, at Denver, Colo.)

133. The descendants of Joseph Loomis, who came from Braintree, England, in the year 1638 and settled in Windsor, Conn., in 1639, second edition, revised and enlarged. 8vo, pp. 611. New Haven, 1875.

134. Key to treatise on algebra. 12mo, pp. 219. New York, 1875.

135. Contributions to meteorology, being results derived from an examination of the United States weather maps and from other sources—4th paper. (With plate.) *Am. Jour.* (3), vol. 11, pp. 1–17. Read in N. A. S. November, 1875. (Movement of areas of high barometer; monthly minima of temperature; influence of winds on the temperature, moisture, and pressure of the atmosphere; diurnal inequality in the rainfall; comparison of storm paths in America and Europe; oscillations of the barometer in different latitudes; storms traced across the Atlantic Ocean; velocity of ocean storms; storms of January 29 to February 8, 1870, on the Atlantic Ocean; application of Ferrel's formula; stationary storms.)

136. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—5th paper. (With two plates.) *Am. Jour.* (3), vol. 12, pp. 1–16. Read in N. A. S. April, 1876. (Low temperature of December, 1872; form of areas of maximum and minimum pressure; relation of rainfall to variations of barometric pressure; stationary storms near the coast of Newfoundland; course and velocity of storms in tropical regions.)

137. Elements of geometry, conic sections, and plane trigonometry. Revised edition, with appendix. 8vo, pp. 443. New York, 1876.

138. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—sixth paper. (With three plates.) *Am. Jour.* (3), vol. 13, pp. 1–19. Read in N. A. S. October, 1876. (Period of unusual heat in June, 1873; rain areas, their form, movements, distribution, &c.; rainfall of two inches at stations south of latitude 36°; rainfall of two inches at stations north of latitude 36°.)

139. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—7th paper. (With three plates.) *Am. Jour.* (3), vol. 14, pp. 1–21. Read in N. A. S. April, 1877. (Rain areas, their form, dimensions, movements, distribution, &c.; areas of low pressure without rain.)

140. Key to elements of algebra. New York, 1877.

141. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—8th paper. (With two plates.) *Am. Jour.* (3), vol. 15, pp. 1–21. Read in N. A. S. October, 1877. (The origin and development of storms; violent winds; barometric gradient.)

142. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—9th paper. (With three plates.) *Am. Jour.* (3), vol. 16, pp. 1–21. Read in N. A. S. April, 1878. (Low barometer at Portland, Oregon; low barometer at San Francisco; areas of high barometer; temperature of Iceland and Vienna compared.)

(The above nine papers were translated by M. H. Brocard into French, and were published as No. 50 (2) of *Moigno's Actualitès Scientifique*, Paris, 1880, with the title *Memoires de Mětěorologie Dynamique.*)

143. A collection of algebraic problems and examples for the use of colleges and high schools in examinations and class instruction. 8vo, pp. 258. New York, 1878.

144. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—10th paper. (With two plates.) *Am. Jour.* (3), vol. 17, pp. 1–25. Read in N. A. S. November, 1878. (Storms of the Atlantic Ocean; fluctuations of the barometer on Mt. Washington and Pike's Peak; high winds on Mt. Washington; high winds on Pike's Peak.)

145. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and other sources—11th paper. (With two plates.) *Am. Jour.* (3), vol. 18, pp. 1–16. Read in N. A. S. April, 1879. (The winds on Mt. Washington compared with the winds near the level of the sea; abnormal storm paths.)

146. Anthony D. Stanley, professor of mathematics. In *Yale College, a sketch of its history, &c.*, vol. 1, pp. 254–256. 1879.

147. Connecticut Academy of Arts and Sciences. *Ibid.*, pp. 329–337.

148. Contributions to meteorology, being the results derived from an examination of the observations of the United States Signal Service and from other sources—12th paper. (With three plates.) *Am. Jour.* (3), vol. 19, pp. 89–109. Read in N. A. S. October, 1879. (Mean pressure of the atmosphere over the United States at different seasons of the year; comparison of barometric minima in Europe and America; barometric minima advancing with unusual velocity.)

149. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—13th paper. (With two plates.) *Am. Jour.* (3), vol. 20, pp. 1–21. Read in N. A. S. April, 1880. (Great and sudden changes of temperature; barometric minima across the Rocky Mountains; mean monthly range of the barometer.)

150. The descendants (by the female branches) of Joseph Loomis, who came from Braintree, England, in the year 1638 and settled in Windsor, Conn., in 1639. 2 vols., 8vo, pp. 1132. New Haven, 1880.

151. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—14th paper. (With three plates.) *Am. Jour.* (3), vol. 21, pp. 1–20. Read in N. A. S. November, 1880. (Course and velocity of storm centers in tropical regions; American storms advancing in a southeasterly direction; American storms advancing northerly and easterly; course of hurricanes originating near the Bay of Bengal, China Sea, &c.; rainfall in tropical cyclones; storms in the middle latitudes advancing in a westerly direction; storms advancing westerly over Europe and the Atlantic Ocean.)

152. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—15th paper. (With one plate.) *Am. Jour.* (3), vol. 22, pp. 1–18. Read in N. A. S. April, 1881. (Reduction to sea level of barometric observations made at elevated stations; height of the Signal Service stations.)

153. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—16th paper. (With a map.) *Am. Jour.* (3), vol. 23, pp. 1–25. Read in N. A. S. November, 1881. (Mean annual rainfall for different countries of the globe; cases of excessive rainfall; cases of deficient rainfall.)

154. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—17th paper. (With three plates.) *Am. Jour.* (3), vol. 24, pp. 1–22. Read in N. A. S. April, 1882. (Relation of rain areas to areas of low pressure.)

155. Contributions to meteorology—18th paper. (With a map.) *Am. Jour.* (3), vol. 25, pp. 1–18. Read in N. A. S. November, 1882. (Mean annual rainfall for different countries of the globe; relation of rain areas to areas of low pressure.)

156. Contributions to meteorology—19th paper. (With three plates.) *Am. Jour.* (3), vol. 26, pp. 442–461. Read in N. A. S. April, 1883. (The barometric gradient in great storms.)

157. Contributions to meteorology—20th paper. (With two plates.) *Am. Jour.* (3), vol. 28, pp. 1–17 and 81–93. Read in N. A. S. April, 1884. (Reduction of barometric observations to sea level.)

158. Letter addressed to the Chief of the Bureau of Statistics in regard to the principal sources of the rainfall of different sections of the United States. *Report on the internal commerce of the United States.* Submitted May, 1885. Appendix No. 6, p. 208. Washington, February, 1885.

159. Contributions to meteorology—21st paper. (With a plate.) *Am. Jour.* (3), vol. 30, pp. 1–16. Read in N. A. S. April, 1885. (Direction and velocity of movement of areas of low pressure.)

160. Contributions to meteorology. *Nat. Acad. Sci. Mem.*, vol. 3, part 2, pp. 1–66. (Areas of low pressure, their form, magnitude, direction, and velocity of movement; also published as *Contributions to meteorology, revised edition.* 4to, pp. 1–67, plates 1–66. New Haven, 1885.)

161. Contributions to meteorology—22d paper. (With a plate.) *Am. Jour.* (3), vol. 33, pp. 247–262. April, 1887. (Areas of high pressure, their magnitude, and direction of movement; relation of areas of high pressure to areas of low pressure.)

162. Contributions to meteorology. *Nat. Acad. Sci. Mem.*, vol. 4, part 2, pp, 1-77 (with 16 plates). (Areas of high pressure, their form, magnitude, direction, and velocity of movement; relation of areas of high pressure to areas of low pressure;) also published as *Contributions to meteorology, chapter II, revised edition.* 4to, pp. 67–142, plates 17–32. New Haven, 1887.

163. Contributions to meteorology—23d paper. *Am. Jour.* (3), vol. 37, pp. 243–256. Read in N. A. S. November, 1888. (Relation of rain areas to areas of high and low pressure.)

164. Contributions to meteorology. *Nat. Acad. Sci. Mem.*, vol. 5, part 1. (Mean annual rainfall for different countries of the globe; conditions favorable to rainfall; conditions unfavorable to rainfall; examination of individual cases of rainfall in the United States, in Europe, over the Atlantic Ocean; areas of low pressure without rain;) also published as *Contributions to meteorology, chapter III, revised edition.* 4to, pp. 143–232, plates 33–51. New Haven, 1889.