declination, horizontal force and dip have been made as in former years.

The regular determinations of magnetic declination, horizontal force and dip have been made with the new declinometer, the Gibson deflexion instrument, and the Airy dip circle mounted in the new Magnetic Pavilion.

The principal results for the magnetic elements for 1900 are as follow:—

Mean declination	16° 29′·0 West.
Mean horizontal force	4·0014 (in British units). 1·8450 (in Metric units).
Mean dip (with 3-inch needles) ...	67° 8′ 27″.

These results depend on observations made in the new Magnetic Pavilion, and are free from any disturbing effect of iron.

The magnetic disturbances in 1900 have been few in number. There were no days of great magnetic disturbance and eight of lesser disturbance.

The question of the possible effect of disturbances from electric railways on the magnetic work carried on at the Royal Observatory has required very careful consideration in regard to the conditions under which electric traction may be used without injuriously affecting the magnetic registers.

It may be remarked that the French magnetic observatory at St. Maur is in much the same position as Greenwich in respect to electric tramways, and recently M. Moureaux, in charge of that observatory, has found that copper "dampers" (such as have been in use at Greenwich for sixty years, but had not previously been applied to the magnets at St. Maur) reduce the vibratory disturbances from electric tramways to about one-tenth of their amount. This has recently been verified at Greenwich by the converse process of removing the copper "dampers" which are in regular use with the declination and horizontal force magnets, when it was found that the disturbances from existing electric railways were increased to about ten times their amount. It is proposed to apply a "damper" to the vertical force magnet, the need for which has not hitherto been felt, and it is possible that the "dampers" for the other two magnets may be improved by the use of copper of much higher conductivity than was obtainable when they were made sixty years ago.

It is hoped, however, that, in the event of future proposed electric tramways, regulations will be laid down by the Board of Trade to secure adequate protection for the magnetic work at Greenwich, which has now been carried on continuously on the same general system for a period of sixty years, and which could not be transferred to another site.

Meteorological Observations.

The meteorological instruments are all in good order. The registration of atmospheric pressure, temperature of the air, and of evaporation, pressure and velocity of the wind, rainfall, sunshine and atmospheric electricity has been continuously maintained.

The mean temperature for the year 1900 was 50°·5, being 1°·0 above the average for the fifty years 1841–90. During the twelve months ending 1901 April 30, the highest temperature in the shade (recorded on the open stand in the Magnetic Pavilion enclosure) was 94°·0 on July 16. The highest temperature recorded in the Stevenson screen in the enclosure was 91°·8, and in that in the Observatory Grounds 93°·4 on the same day. This is the highest shade temperature recorded in July since 1881. It has been twice exceeded in July in the sixty years 1841–1900, viz., on 1881 July 15, when the temperature reached 97°·1, and on 1868 July 22, when it was 96°·6. A reading of 94°·0 was also recorded on 1876 July 17. The monthly mean temperature for July was 66°·6; it has been exceeded only four times in the preceding sixty years, viz., in 1852, 67°·0; 1859, 68°·9; 1868, 68°·1; and 1876, 66°·7. The month of December was also exceptionally warm, the mean temperature for the month being 45°·7, which is 6°·0 in excess of the fifty years' average. This value has been exceeded three times in the preceding sixty years, viz., in 1852, 47°·6; in 1868, 46°·1; and in 1898, 45°·8. The lowest temperature of the air recorded in the year was 20°·4, on February 14. There were forty-seven days during the winter on which the temperature fell below 32°, a number slightly below the average.

The mean daily horizontal movement of the air in the twelve months ending 1901 April 30 was 298 miles, which is 17 miles above the average for the preceding thirty-three years. The greatest recorded daily movement was 973 miles on January 27, and the least 72 miles on December 23. The greatest recorded pressure of the wind was 34·4 lbs. on the square foot, and the greatest hourly velocity 54 miles, both on January 27.

The number of hours of bright sunshine recorded during the twelve months ending 1901 April 30, by the Campbell-Stokes instrument, was 1513 out of the 4457 hours during which the sun was above the horizon.

The rainfall for the year ending 1901 April 30 was 20·22 inches, being 4·32 inches less than the average of fifty years. The number of rainy days was 151. The rainfall has been less than the average in each year since 1894.

The remaining portion of the report deals with the work done in the remaining departments—namely, chronometer, time-signal, &c. It may be here remarked that arrangements have been made for a re-determination of the Greenwich-Paris longitude in conjunction with observers from the Paris Observatory, two of the four portable transit instruments used in former longitude work being available for the French observers, and the other two for the English.

It has been arranged with M. Lœwy that the first part of the longitude observations shall be made in October next, and the second part in the spring of 1902.

The eclipse of May 28, 1900, was observed by the Astronomer Royal with Mr. Dyson and Mr. Davidson in Portugal, while this year Mr. Dyson, with the assistance of Mr. Atkinson, went to Sumatra, and Mr. Maunder to Mauritius, for the recent eclipse of May 18.

In his general remarks the Astronomer Royal points out the great pressure of work that has fallen on all members of the staff during the past year. Two eclipse expeditions have been prepared and sent out, the revision of Groombridge's Catalogue for 1810, in connection with the Greenwich Second Ten-Year Catalogue (1890), the transfer of books and records to the New Observatory, and the rearrangement of the library and record rooms, all have added considerably to the ordinary work of the Observatory. Finally, he points out that within the last five months one-third of the whole staff of computers have left the Observatory for other posts and have had to be replaced by boys new to their work. Such an extensive change in the temporary staff has, to a certain extent, disorganised the work and has thrown a great strain on the assistants, who are charged with carrying it on under such difficult conditions. Considering the training and experience required in the varied work which, at Greenwich, has to be done by computers, a greater degree of permanence in the staff appears to be necessary for the continued efficiency of the Observatory.

THE MECHANICAL FORCES OF NATURE AND THEIR EXPLOITATION.

THE question of the probable end of the world's coal supply, in the not far distant future, is one which has in recent years been the cause of much discussion. In connection with this subject a pamphlet published by the Urania Gesellschaft of Berlin, on "Die mechanischen Naturkräfte und deren Verwertung," by F. Reuleaux, is of interest. In a clear and popular manner the author traces and explains the gradual utilisation by mankind of the various natural forces, from the ancient Assyrian water wheel to the installations of Niagara, and the Parsons steam turbine. It has been calculated that the supply of coal in England can only last at the most 200 years more; and though the coal-fields of the other European countries have not been used to the extent that the English ones have, still their eventual exhaustion can already be anticipated. The total consumption is now about 600 million tons per year, or, measured as a volume, about 500 million cubic yards. Assuming a yearly increase of 5 per cent. (it is at the present moment greater than this) this would mean that during the present century 6½ billion cubic yards of coal will be taken from the earth's coal mines. A cube of this volume would have a side over ten miles long.

It may be urged that this is not a matter of immediate importance; still, in considering the future industrial state of the world one must admit that great changes must take place, and that countries which have been indebted for their growth to their natural resources of power in the form of coal must give way to those countries where power is supplied in another form. On examining the natural sources of power, one sees that really the only other available source of power besides coal, which, it may be said, can be regarded as the accumulated energy of the sun, stored up through countless ages, is water power. This, unlike coal, is a source of energy which is always with us. The sun piles the waters of the ocean upon the mountain side, and following the force of gravity it flows down again in a never ending cycle, watering, fertilising and, under the careful direction of mankind, rendering the land fruitful and inhabitable and providing for the wants of the human race a source of power immeasurably greater than any power to be derived from the combustion of coal, and what is more, a source of power which will never cease, or be exhausted, while the world lasts. To form a computation of the total energy of the atmospheric depositions is very difficult. It has been calculated to reach the value of 100,000 million horse-power. The realisation of the one-thousandth part of this would be enough to replace the whole of the coal consumption for an incalculable time to come.

An example of how a water power can be used to its fullest extent is furnished by the Upper Hartz. There nearly every drop of water available is utilised, and, although boasting no streams of any size, the respectable total of 3300 horse-power is generated and used in the mining operations carried on there. It is, however, with the advent of electricity that the full realisation of water power has become possible. By means of the facilities offered us by this agent we arrive back at the original motive power of mankind, and will be enabled to tap energies incalculable in comparison with our present ones. This greatest and farthest-reaching application of electricity is but now in its infancy. In 1891, only ten years ago, the first long distance power transmission plant was erected at Lauffen on the Neckar. The power, amounting to 100 horse-power, was transmitted to the electro-technical exhibition at Frankfort on the Maine, a distance of 110 miles, at a voltage of 8000 volts, using a three-phase current. In the short space of time since then immense progress has been made. Now whole towns and large tracts of country are supplied with power and light from distant waterfalls, and new industries have sprung into existence which were formerly impossible. The future developments of this branch of science will be as great, comparatively, as the mighty forces of nature they are designed to employ, and in endeavouring to imagine them the scientific mind merges into the poetic, with which it is, after all, very closely related.

THE COLOUR AND POLARISATION OF BLUE SKY LIGHT.[1]

THE theory of the colour of the sky has been of slow growth. One of the first explanations that we find in scientific literature—almost barbarous in its crudity and unsupported by fact or theory—is the speculation of Leonardo da Vinci that the blue of the sky is due to the mixing of the white sunlight, reflected from the upper layers of the air, with the intense blackness of space. This corresponds to the speculative stage of science, the age of the philosophers. In the next step analogy comes into play; this is a most valuable and effective tool for the man of science endowed with a vivid scientific imagination and with a keen, clear insight into nature, but for others a most dangerous weapon. In this case it is wielded by no less an intellect than that of Sir Isaac Newton. In his optical investigations, about 1675, he had been led to a study of the colours produced when light is reflected from thin films of transparent substances; these he found to depend upon the thickness of the film. When it is very thin it appears black; as the thickness gradually increases it becomes blue, then white, yellow, red, &c. This blue which first appears, and which may be seen surrounding the black spot on soap bubbles, Newton termed the "blue of the first order," and he thought it was of the same tint as the blue of the sky. Analogy now steps in and suggests that the colour of the sky is due to the reflection of sunlight from transparent bodies of such a size that the reflected light is the blue of the first order. This was Newton's belief, and he thought that the reflecting particles were small drops of water.

This is the first theory worthy of serious consideration, and was for a time generally accepted as correct. But no theory based on pure analogy can be regarded as final; it must first be subjected to the most severe analytical and experimental criticism of which we are capable. If it stands the test, well and good; if not, it must be rejected. In 1847 Clausius subjected Newton's theory to a strict mathematical analysis, and proved that, if the blue of the sky is the blue of the first order, resulting from the reflection of light from transparent bodies, these bodies must be in the form of thin plates or thin-walled, hollow spheres. They cannot be solid drops or spheres, for then astronomical objects would never be sharply defined; a star would appear as large as the sun, and the sun immensely larger; all celestial objects would appear as large discs of light, brightest at the centre and fading out gradually toward the edges. For this reason Clausius, believing the blue to be that of the first order, held the opinion that the reflecting bodies were hollow spheres, or vesicles of water. The belief in the existence of so-called "vesicular vapour" did not originate with Clausius, but was a relic which had persisted from the speculative age to this time in spite of its *a priori* improbability, and the natural opposition so caused. As the theory of vesicular vapour has now been completely discarded we need say no more about it; the real value of the work of Clausius lies in the proof that the light from the sky cannot be due to the regular reflection of sunlight from small drops of water.

The experimental test was applied by Brücke, who pointed out that the blue of the sky is radically different from the blue of the first order. Thus, the era of analogy began to give way to that of experimentation and analysis, which must go hand in hand.

Brücke (1853) proved that the light scattered from a turbid medium is blue, and Tyndall (1869) performed his beautiful experiments on this subject, in which he showed that when the particles causing the turbidity are exceedingly fine (too small to be seen with a microscope) the scattered light is not only a magnificent blue but is polarised in the plane of scattering, the amount of polarisation is a maximum at an angle of 90° with the incident light, and the definition of objects seen through it is unimpaired by the turbidity. Here, for the first time, all the essential features of sky light were reproduced in the physical laboratory. This experiment of Tyndall's was at once recognised as giving the key to the problem. Lord Rayleigh (1871–1899) undertook the analytical treatment of the subject and proved that when white light is transmitted through a cloud of particles, small in comparison with the cube of the shortest wave-length present in the incident light, the light scattered laterally is polarised in the plane of scattering, the maximum of polarisation is at 90° to the incident light, and the intensities of the components of the scattered light vary inversely as the fourth powers of their wave-lengths; no account is taken of the light which has undergone more than a single scattering. All these facts have been shown to agree with the phenomena observed in the laboratory when light is passed through turbid media. Recently (1899) Lord Rayleigh has shown that in this way about one-third of the total intensity of the light from the sky may be accounted for by the scattering produced by the molecules of oxygen and nitrogen in the air, entirely independent of the presence of dust, aqueous vapour, or other foreign matter.

We cannot do better than to stop here for a few moments to consider Lord Rayleigh's physical explanation of the scattering produced by small particles. On this theory, light is propagated as transverse vibrations of the atoms or corpuscles of a medium that acts like an elastic solid; it is something like the waves that go along a rope when one end is shaken, only in the case of light we are dealing with no rope but with an infinite medium. When we speak of a beam of light being polarised we mean that all the vibrations in this beam take place in the same plane, and the plane of polarisation may be defined as the plane passing through the direction of propagation of the light but perpendicularly to the direction of the vibrations, and therefore perpendicular to the plane of vibration. Now, imagine a beam of parallel light advancing through a homogeneous medium, say the free ether, in a vertical direction; there will be no light propagated except in this direction; there will be no scattered light. If, however, there exist in it particles optically denser than the ether, but small as compared with the wave-length of light, then light will be scattered laterally by these. Indeed, the effect of these particles is to locally increase the effective inertia of the ether, whereas the rigidity remains unaltered; therefore, when a wave advancing through the medium reaches one of these particles, the displacement of the medium at this point is less than it would be were the particle absent. If we should apply to each

[1] Abridged from an article by Dr. N. E. Dorsey, in the U.S. *Monthly Weather Review*, September 1900.