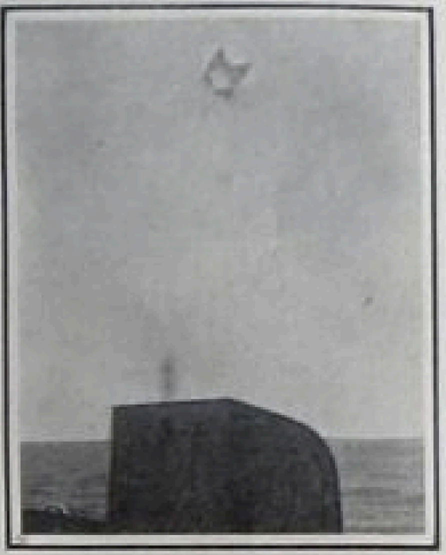
SOUNDING THE OCEAN OF AIR ABOVE US.

ATMOSPHERIC EXPLORATION.



The science of meteorology has so far progressed, that we know with considerable accuracy the nature, composition, and general properties of the lower air. If meteorology is to become anything like an exact science, in other words, if we are to predict the weather not only of to-morrow, but even of next week, with more accuracy than is now possible, we must have at our disposal data which will enable us to determine the condition of the upper layers as well and their effect upon the lower layers. In the interest of that investigation, we find that the modern meteorologist has been conducting for the last two decades investigations that will sooner or later bring together an enormous mass of facts, which the mind of some master meteorologist will some day whip into scientific correlation.

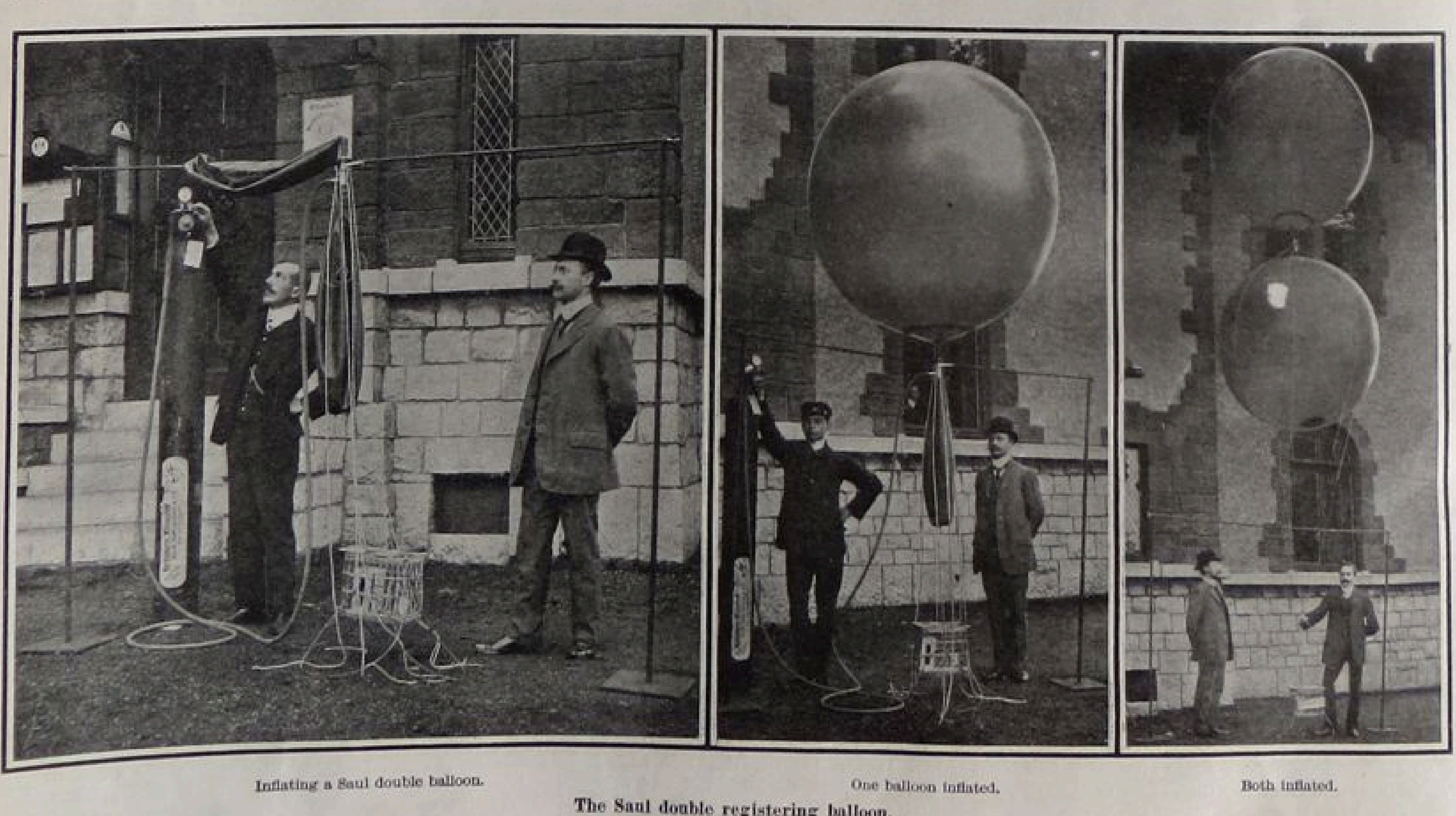
In this effort to discover the physical attributes of the upper layers of the air, barometers, hygrometers, thermometers, and wind gages are employed. The barometer measures the weight of the air; the hygrometer, its moisture; the thermometer, its heat; the wind gage, its velocity. These instruments, all of them well known in meteorological research, have been considerably modified for the study of the upper air, a modification necessary because they must be lifted to great heights by means which make it impossible to employ great weights. Hence it is that they are made of feathery lightness and are ingeniously combined. The combination is usually known as a "meteorograph." Thus the thermometer and barometer are merged into a meteorograph, specifically known as a baromethermograph, a contrivance which is provided with two automatic styles, one of which writes down the pressure of the air and the other its varying temperature. Sometimes the barometer, thermometer, and hygrometer are joined in a single instrument, which notes the humidity as well as the pressure and temperature. The records are made upon clock-driven cylinders covered with lamp black, because no ink has been found which will not freeze in the bitter cold of the upper air. At lower levels special inks and paper can be employed. The construction of these meteorographs has involved not a little ingenuity. Perhaps the men who have contributed most in devising special forms of instruments are Mr. S. P. Fergusson and Mr. H. H. Clayton of the Blue Hill Meteorological Observatory in this country.

Fifty years ago, the experiment was made of intrusting instruments of precision to venturesome balloonists. Because a human being cannot live in the thin air of great altitudes, these experiments sometimes proved fatal. Hence it is that the meteorologist has adopted, in a measure, the methods of the marine biologist. In other words, he sounds the ocean of air at the bottom of which we live.

His sounding methods are dependent upon the employment of kites and free unmanned balloons. By their means it has become possible to elevate the delicate instruments which automatically record the physical condition of the upper air, and to bring to the earth an accurate account of atmospheric happenings many miles above the earth's surface. The men to whom most of the credit for this new means of i vestigation is due are Prof. A. Lawrence Rotch of the Blue Hill Meteorological Observatory, in this country; Dr. Richard Assmann, of Germany, and Teisserenc de Bort, of France.

The exploration of the upper air by kites has been carried to the greatest perfection by Prof. Rotch. It may safely be said that his study of the lower four miles of air is the most complete that has yet been made. The kites employed by him—and, for that matter, by almost every meteorologist—are of the open box type invented by Mr. Lawrence Hargrave. The kites often measure 9 feet in length. Such is the pull exerted by them, that it is impossible to employ muscular power to control them. For that reason, they are hauled in by engine-driven winches. Devices are employed which register the pull of the kite and the length of the line in use. Often it happens that as much as ten miles of line may be paid out. In spite of the great lifting capacity of such a kite, it could not attain any considerable height if it were held by hemp alone. A cord or rope would necessarily be so heavy and thick, that a kite would be severely taxed in pulling it up. Hence it is common to employ fine music wire, which is both strong and light. The elevation attained by a kite is determined in fair weather by means of theodolites. At night and in hazy weather the meteorograph readings themselves must be depended upon.

Four miles may be considered the maximum height that a kite is capable of attaining. To sound the reaches of air above that level, the free or unmanned balloon is employed, of which the most skillful use has been made by Teisserenc de Bort and by Dr. Richard Assmann. These free balloons are filled with pure hydrogen gas, which expands with increasing elevation. Since the degree of inflation obviously depends upon the height to be attained, considerable care must be taken not to fill the gas bag entirely. If the balloon is to reach a point where the air is one-half as dense as at the level of the sea, the gas bag is filled about one-half. If a height is to be attained at which the air density is one-fourth that at the level of the sea, the bag is filled about one-fourth. It is very evident that for the attainment of very great heights, the balloon's capacity must be great and the construction exceedingly light. This explains why instruments of feathery lightness must be employed. Originally, fairly large paper balloons were employed for the purpose, by Teisserenc de Bort, but the India-rubber balloons of Assmann have now taken their place. These India-rubber balloons vary in diameter from three to five feet. They have reached considerable heights. At the maximum elevation of the balloon, the expansion of the hydrogen gas eventually bursts the bag. In order that the instruments may not be dropped precipitously to the ground, they are checked in their descent by a parachute. Instead of a parachute, a slightly inflated auxiliary balloon may be employed, which does not explode, and which has sufficient buoyancy to prevent a too rapid fall of the instrument. Recently, S. Saul, of Aachen, Germany, has advocated the use of two balloons connected by an aluminium pipe provided with a valve. The weight of this pipe is much less than the netting generally applied to the balloon to carry the basket containing the recording instruments, and is certainly much lighter than a para-



Inflating a Saul double balloon. One balloon inflated. Both inflated.

The Saul double registering balloon.

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chute. The arrangement is such that when the double balloon reaches its maximum height, the one bursts, and the other, not having sufficient buoyancy to carry the whole weight of the apparatus, sinks slowly to the earth. At the same time it serves to attract the attention of the finder, because it floats a few feet above the ground. The balloons can be filled in the open air, even in windy weather, by one man, whereas special care must be taken with the ordinary system.

To every basket in which the instruments of a sounding balloon are contained, a printed notice is attached which offers a reward for their return. A very large number of the instruments which drop to the earth thus find their way back to the observatories.

Sounding balloons reach astonishing elevations, and travel at speeds varying from 40 to 80 miles an hour. Although a large number of *ballons-sondes* were dispatched from St. Louis in 1904-7 under the direction of Prof. Rotch, none had been employed in the eastern States until last year. In May and July, 1908, four *ballons-sondes* were launched from Pittsfield, Mass., with special precautions to limit the time they remained in the air and so prevent them from drifting out to sea with the upper westerly wind. Three of the registering instruments have been returned to the Blue Hill Observatory with good records. The first instrument sent up on May 7th was not found for ten months, and the record is very interesting because it gives complete temperature data from the ground up to 17,700 meters, or 11 miles. This is 650 meters higher than the highest ascension from St. Louis, which, by a coincidence, was also the first one to be made there. On May 7th a general storm prevailed, so that the balloon, traveling from the east, was soon lost in the cloud and its subsequent drift could not be followed, but the resultant course was 59 miles from the southwest, as determined by the place where the instrument fell two hours later. A paper balloon will reach its greatest height in about six hours; a rubber balloon, in three hours.

The air-exploring stations of the entire world have banded themselves into an association for the purpose of carrying on a systematic exploration of the upper air, on agreed dates. Thus we find that each year an "international week" of exploration takes place, in addition to the regular work of each observatory. These international weeks may fall in the spring, sum-

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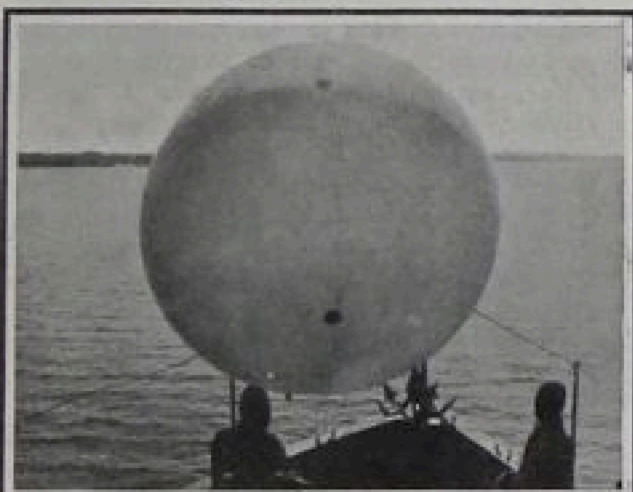
Sending up a pilot balloon.



Preparing for a balloon ascent.

A balloon ascent on Lake Victoria Nyanza.

A kite ascent on Lake Victoria Nyanza.

One of the box kites used.

Controlling a kite with a hand windlass.

Noting the course of pilot balloons with special theodolites. The pilot balloons are liberated to ascertain the direction and velocity of the wind before the liberation of registering balloons.

GERMAN METEOROLOGICAL INVESTIGATIONS IN EAST AFRICA.

Ang. Chemie.

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mer, autumn, or winter. Kites and balloons have been sent up from almost every quarter of the earth. Perhaps the most recent of these investigations in an out-of-the-way quarter of the globe is the meteorological expedition to East Africa undertaken by the Royal Prussian Meteorological Observatory. The expedition was conducted by Prof. Berson and Prof. Elias. The chief object was to determine the origin of monsoons, an object which was not altogether attained, but on which much light was thrown. An ultimate aim was the prognosis of the rainy season in East Africa and India. On the coast and from a specially chartered steamer on the lake, *ballons-sondes*, pilot balloons, and kites were sent up. The observations over the equator, in the center of the continent, showed very low temperatures at great heights, as did the expedition of Teisserenc de Bort and Rotch on the equatorial Atlantic, but with the difference that over the African continent there was a trace of the permanent inversion layer. The vertical changes were as follows: adiabatic decrease of temperature to 13,000 meters, between 13,000 and 15,000 meters a small inversion, and above 17,000 meters isothermal conditions. Above the southeast monsoon the wind was south-southwest, and three times a westerly wind was observed between 15,000 and 18,000 meters, above the great equatorial current from the east which is supposed to prevail at all heights.

It was feared that a very large per cent

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of the balloons which fell on land would be lost, because of the nature of the country and the sparseness of the population, but on the contrary an astonishing proportion of them was recovered, owing to the keenness of vision of the natives, to whom a small reward was offered for every one returned.

What has been the result of this international aerial sounding? It has been discovered that all over the earth the air is stratified in three more or less distinct layers. The lowermost of these, the layer in which we live and which extends upward for two miles from the surface of the earth (at which height the freezing point is encountered) is a region of turmoil—warm to-day and cold to-morrow. This is the stratum of capricious winds, cyclones and anti-cyclones, of cool descending currents and warm ascending currents. All our weather forecasting is at present based on what can be learned from the general circulation of the air in this lowermost layer.

Above this first layer, which extends upward for perhaps two miles, begins the second layer, which is about six miles thick, and is less turbulent than the first. In it the air grows steadily colder and drier with increasing height. Temperatures as low as 167 deg. below the Fahrenheit freezing point have been recorded here. Whatever thermal irregularities there may be are caused by temperature changes on the surface of the earth and by the reflection of solar heat from clouds. The wind blows always in the same easterly direction; and the greater the height, the more ferocious is the blast.

The last of all the layers thus discovered lies above this. Originally revealed by Teisserenc de Bort and Dr Richard Assmann almost simultaneously, it was first known as the "isothermal stratum," because its temperature seemed to be stationary. Later, when it was found that the temperature, instead of remaining fixed, gradually increased, it was rechristened the "permanent inversion layer." The height of the inversion layer has not as yet been determined. It must not be supposed that, because its temperature rises, it is much warmer than in the second layer. As a matter of fact, its temperature must be placed somewhere between 122 deg. and 140 deg. below the Fahrenheit freezing point. This permanent inversion layer is puzzling in the extreme. In passing from the second to the permanent inversion layer, the wind is stilled to a breeze, the velocity decreasing from 25 to 80 per cent. The air blows no longer in a steadily easterly direction, but almost as capriciously as it does at the surface of the earth. Dryness, excessive dryness, is another characteristic of the permanent inversion layer. In summer time, the permanent inversion layer begins at a height of about 7½ miles above the earth; the higher it lies, the colder it is; the lower it lies, the warmer it is. There is no bodily shifting up and down of warm and cold masses of air, so that a current ascending from the lower level spreads out when it encounters the permanent inversion layer, just as hot air which strikes the ceiling of a room.

Up to about 10 kilometers the decrease of temperature is almost adiabatic, then in the next 5 kilometers there is usually a rise in temperature of 8 deg. to 10 deg. C., with isothermal conditions up to at least 26 kilometers. The lower zone Teisserenc de Bort calls the "troposphere," and the upper one the "stratosphere." The former is a region of violent atmospheric disturbances, for it has been shown that cyclones do not extend above the cirrus clouds, though anti-cyclones persist to greater heights, and therefore the stratosphere is lowest in the cyclone and highest in the anti-cyclone, and its level sinks from the equator to the poles. The stratosphere is a region of interlaced currents and small vertical movements.

Up to the height of the permanent inversion layer, the temperature falls at an average of one degree C. per 100

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meters (one degree F. per 182 feet). Because of the constant upheavals to which the air is subject in its lower levels, this average rate of temperature reduction as we ascend is not always observed. Sometimes it even happens that for a short distance the thermometer rises instead of falls, but ultimately the temperature drops at a uniform rate until it reaches a point lower than that recorded by any North Pole explorer.

The three layers of air which have been discovered by kites and balloons intermingle but slightly; one floats upon the other as oil floats upon water. Of the great ocean of air at the bottom of which we move and live, three-fourths lies below the permanent inversion layer. All our storms, our clouds or dust are phenomena of the lower two layers.