Clouds, sounding ballons and stratosphere; Teisserenc de Bort: a life in Meteorology

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First years

Léon Teisserenc de Bort was born in Paris in 1855. His father was Minister for Agriculture and possessed an important fortune that gave him the possibility to be a patron. Notably he helped buy some meteorological instruments for some local scientific Societies.

There are no sources concerning the youth of Teisserenc de Bort. We only know that he moved towards Meteorology on the advice of his tutor and that he learnt the basic knowledge of this science in a small meteorological station in the south of France. His career started in the mid 70's when he became secretary of the Société Météorologique de France, founded twenty years earlier by Emilien Renou and Charles Sainte-Claire Deville.

Teisserenc de Bort at the BCM: 1878-1892

In 1878, Meteorology in France separated formelly from Astronomy and became independent of the Paris Observatory. On May the 14th 1878, a decree created the Bureau Central Météorologique (BCM) and the physicist Eleuthère Mascart became director.

Léon Teisserenc de Bort joined the BCM immediately after its foundation. Two years later, in 1880, he became director of the service of general meteorology, which involved the organization of observations in the French colonies and on the ships, as well as research on the understanding of the global problems of Earth's physics.

The first result obtained by Léon Teisserenc de Bort was the so-called " Loi des isonomales" that connects the anomalies of the distribution of heat to those of the pressure, so that any excess of heat matches to a lack of pressure and reciprocally. Following previous French works through the 19th Century as well as the studies of the German physicist and meteorologist Hoffmeyer, Teisserenc de Bort demonstrated the fact that the different kinds of weather were directly linked to the position of the areas of high and low pressure. Those positions are of a definite number and oscillate around some average positions determined by the distribution of lands and seas. Teisserenc de Bort named those areas: *center of actions* of the atmosphere.

Here we will focus on the period following his departure from the French meteorological institution, so I refer you to his numerous publications[1] for further details concerning this major meteorological result and other works.

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[1] Notably: in *Comptes rendus de l'Académie des sciences* : "Isobares, vents et isonèphes d'été sur l'Atlantique", CII, 1381, 15 juin 1886; "Cartes magnétiques de l'Algérie, de la Tunisie et du Sahara algérien", CVII, 147, 9 juillet 1888; "Répartition de la pression atmosphérique à la surface du globe", CIX, 878, 2 décembre 1889; *Annales du BCM* : "Etude sur l'hiver de 1879-1880 et recherche sur la position des grands centres d'action de l'atmosphère dans les hivers anormaux, 1883, IV, pp. 17-62; "Etude sur la position des grands centres d'action de l'atmosphère au printemps, 1885, IV, pp. 31-56;

In 1892, Mascart accepted de Bort's request for long-term leave that would allow him to go on with his research on experimental meteorology, which (according Teisserenc de Bort) was incompatible with his daily presence in the office in Paris and, I believe, was also incompatible with the lack of financial and human support of this institution.

Settling down in Trappes

In 1895 the international meteorological board decided to organize, for one year and in different countries, a programme of measurements of the heights and speeds of clouds using photogrammetric methods. Teisserenc de Bort, who did a special study of clouds as a member of the international classification commission[2], took charge of the organization of the French station.

As a large area was required, he bought a 3 hectare – site in the south west of Paris, on the plateau of Trappes (altitude: 170 m) and started the construction of what was about to become the first European station of dynamic Meteorology. Indeed, beyond this cloud study, Teisserenc de Bort intended to realize a sort of meteorological laboratory that could permit a global kind of research, and not only the purely local observations of several elements, as it was done in most meteorological observatories.

The scientific work started in 1896-1897, the international year of the clouds, and, following what had been decided at the Upsala Meteorological Conference, it began with the measurements of heights, speeds and directions of clouds. The measurements were performed by two different ways: first consisted on the determination of the relative speed of the cloud by using a nephoscope-mirror or the so-called " herse-Besson" method, and the second gave the height and the real displacement in space by some successives triangulations based on photogrammetric measurement. Concerning the calculating part, the speed was determined by the difference of positions as they were given by two observations separated by one minute. The method was not new but Teisserenc de Bort obtained better precision in taking the photographs, by solving the problem of the variability of the photographic plate along the optical axis of the theodolite[3].

Atmospheric soudings

Conscious that ordinary observations could only provide information on nearby region (" the deepest layers of our aerial ocean ", as he used to say), Teisserenc de Bort decided to explore the upper atmosphere. First with kites (as M. Lawrence Rotch did in the Blue Hill Observatory) then mainly with sounding balloons. These experimental practices, innovative in the field of Meteorology, went along with the

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"Etude sur la circulation générale de l'atmosphère", 1887, IV, pp. 35-44; "Sur la prévision du temps; conditions actuelles et moyen de l'améliorer", 1888, I, pp. 1-19; "Laws of the distribution of Cloudiness over the surface of the globe", *The American Meteorological journal*, 1890; "Report on the present state of our knowledge respecting the general circulation of the atmosphere", *Congrès de Chicago*, Août 1893

[2] Comité météorologique international; H. Hildebrandsson, A. Riggenbach, L. Teisserenc de Bort: *Atlas international des nuages*, 1896.

[3] "Mesure des hauteurs et des mouvements des nuages par la Photographie à Trappes", *Annales du BCM*, I, 1897, pp. 193-205.

development of a wide range of techniques and knowledge, which soon spread through Europe. The Trappes observatory was visited by several foreign meteorologists, notably Assmann and Berson, who came there in June 1899, to become familiar with the methods , and then organize the Prussian Aeronautische Observatorium.

Kites and balloons

Human ascensions in hot-air balloons incontestably provide the safest way to get much atmospheric information ; nevertheless they are expensive, highly dependent on the weather and, above all, they are soon limited by the fact that no human being can rise beyond 10000 meters high without danger. To go further, we must substitute instruments for persons, and two means were used to carry these in the atmosphere.

The first one requires kites : always linked to the ground, they can transmit information concerning a phenomena in real time. But the handling is delicate and it is difficult to go over 2500 meters high. With a rotating place of control, a very flexible winding drum, a cable of an increasing section (to get more altitude for a given lenght of cable) and with several kites, Teisserenc de Bort reached the height of 5000 meters[4]. Nevertheless the need for a favourable wind, the imperfections of kites or steel cables (whose frequent breaking had serious consequences for aerial electrical lines) led to the kites being replaced by sounding balloons.

Sounding balloons have a spherical shape and are made of rubber or paper. They are from 3 to 8 m in diameter for paper-balloons (ie: 14 to 270 m^3), or from 0,4 to 2m for rubber ones. The size depends on the weight of the instruments that will be taken up. Considering the fact that the weight was the critical parameter, the first task of Teisserenc de Bort and his collaborator was to devise special instruments, lighter than those traditionally used. The margin of tolerance being small for a simple tool, it seems that they mainly tried to devise multi-purpose instruments[5].

The balloons are filled up with hydrogen (a small factory – part of the meteorological station – provides it at will) to get a higher ratio between the lifting power and volume. The speed is about 4 to 8 meters per second.

The major problem with the balloons is that it is impossible to inflate and release them in the open-air, as soon as it is windy. What is more, if the inflation is performed in an ordinary hangar, the balloon gets torn as soon as it passes the entrance. It is essential (at least if the balloon is more than 2m in diameter) to be able to free the balloon from its ropes before the wind acts upon it. Teisserenc de Bort decided to build a vast hangar over a rotating platform, so that the opening could be orientated in any direction. When filled up in a quiet atmosphere, the balloon is then taken out of the hangar and released. Protected by the hangar for a while, the action of the wind becomes important only when the instruments suspended under the balloon are at some distance over the ground.

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[4] “Sur les ascensions dans l’atmosphère d’enregistreurs météorologiques portés par des cerfs-volants.“ *CRAS*, CXXIX, p. 131, 10 juillet 1899.

[5] “Instruments enregistreurs employés à Trappes“, 1904, *Conférence météorologique de Saint-Pétersbourg*

The instruments are protected against the cold by felt or cork coverings. The basket that contains them is enclosed in a paper bag with a silvered outside that reflected sunlight and prevented the instruments from a kind of sunburn that would pervert the measurements. (When the cloudy weather precluded a visual following of the balloon, the release was performed at night). Most of the time the basket contained an instrument whose elasticity has been tested to support the decrease of pressure without disturbing the registering process, and that works as a thermometer, a barometer and an hygrometer. Each inscription is traced by a metallic point over an aluminium sheet coated with lampblack. This procedure is preferable to the use of a paper sheet which would be damaged by dampness and cold.

During the ascent, the fall of pressure induces an increase in the volume of the balloon and often its blow-out, at least for rubber-balloons. To keep the instruments for being destroyed, one placed a kind of coat around the balloon that works as a parachute after the blow-out, or added a second balloon which doesn't blow and then slackens the speed of the fall. The paper-balloons, which are cheaper, do not explode. They fall normally and are immediately torn after landing, so the instruments couldn't be dragged. The basket contained a letter for the person who finds the balloon. It gives instructions to bag the instruments and send the whole to the Observatory, for a reward. The percentage of loss did not exceed 3%; and that concerned balloons that fell over a forest or out to sea. A clockwork mechanism associated with a valve which provoked the tearing of the balloon, was devised and used in some cases, in order to circumscribe the area of the fall.

Results

The soundings, whose main components have just been described, had as a major consequence, the discovery of a layer of about several thousands meters depth, where the temperature stops its decrease[6]. As there are no vertical motions of the air in this layer, Teisserenc de Bort named it *The stratosphere* and, as an opposition, he named the inferior layer *The troposphere*. With several sounding campaigns around Paris or in others areas (Siberia, Danmark, Atlantic ocean or Mediterranean sea) as part of international scientific expeditions, Teisserenc de Bort was able to determine the structure of the stratosphere all over the globe.

Conclusion

I've oppered here a brief insight into the life and works of Léon Teisserenc de Bort, who set his country on the path of dynamic Meteorology[7], spending time and fortune on that enterprise, who was both an amateur and a well-known scientist and whose example, associated with others of different kinds, illustrates the incredible diversity of lives, careers and fields of interest that were part of Meteorology around 1900.

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[6] "Sur les caractères de la température dans l'atmosphère libre au-dessus de 10 kilomètres", 1904, *Conférence météorologique de Saint-Pétersbourg* ; Jean Mascart: "L'étude de la haute atmosphère et les travaux de Léon Teisserenc de Bort", *La Nature*, 1913, pp. 296-300.

[7] *Les bases de la météorologie dynamique* (en collaboration avec H. Hildebrandsson), Gauthier-Villars, Paris, 1906