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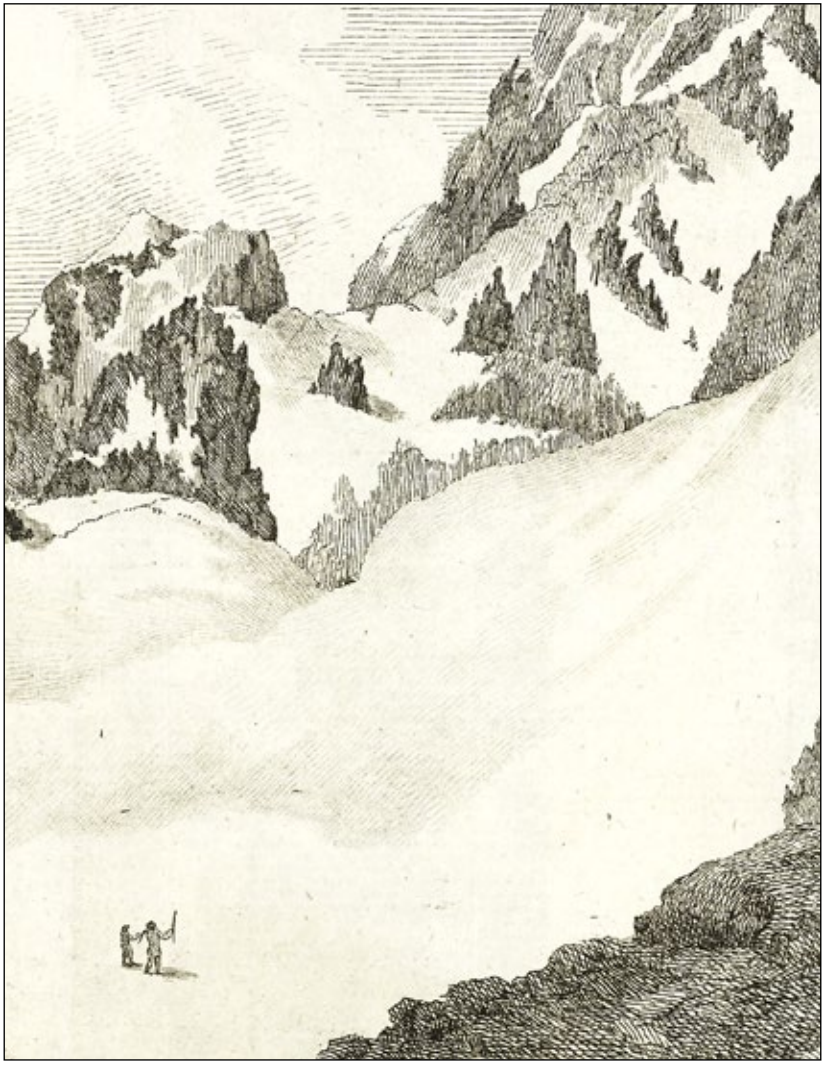
Under the skies of Mont Blanc



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Conception and text: Stéphane Fischer, Musée d'histoire des sciences

Translation: Liz Hopkins

Layout: Corinne Charvet, Muséum d'histoire naturelle

Proofreading: John Hollier, Muséum d'histoire naturelle

Photography: Gilles Hernot, Musée d'histoire des sciences; Philippe Wagneur, Muséum d'histoire naturelle

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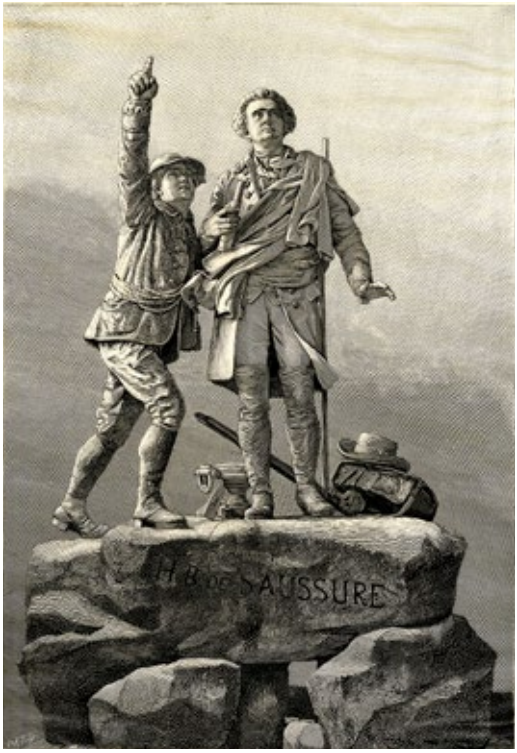
Cover: Horace-Bénédict de Saussure and his son Nicolas-Théodore carrying out scientific experiments during their stay on the Col du Géant.
Horace-Bénédict de Saussure, Voyages dans les Alpes*, Genève, Neuchâtel, 1779-1796*
Bibliothèque de Genève

Saussure's stay on the Col du Géant in July 1788: a fifteen-day scientific expedition in the high mountains

In 1787, the Genevan naturalist Horace-Benedict de Saussure (1740-1799) became one of the first people to climb Mont Blanc (4806 m). He is considered to be a founding father of modern mountaineering. A statue erected in Chamonix in 1887, marking the 100th anniversary of his famous ascent, shows Saussure with his guide who is pointing to the summits. Of course, the expedition to Mont Blanc provided excellent publicity for the Chamonix valley.



Statue of H.-B. de Saussure and his guide Jacques Balmat at Chamonix, erected in 1887 to mark 100 years since their victorious ascent of Mont Blanc
CIG/Bibliothèque de Genève

We tend to forget that for Saussure, Mont Blanc was simply one step in a 20-year quest to better understand the nature of the European mountains and their surroundings, and to try to find a geological explanation for the origins of the Earth.

A year after his ascent of Mont Blanc, Saussure continued his research in the Alpine massif with another exploit: the establishment of a very high altitude atmospheric and meteorological observatory. Saussure's son, Nicolas-Théodore (1767-1845) and a number of porter-guides, camped for two weeks on the summit of the Col du Géant at 3300 m above Chamonix. They undertook a sustained programme of atmospheric and meteorological observations.

The Saussures and their guides climbing to the Col du Géant in July 1788
L'Evêque Henri, Genève, vers 1790
CIG/Bibliothèque de Genève

"I thought it would be interesting to try to fill this lacune in our information about the atmosphere by staying on a high summit for long enough to observe daily readings of the barometer, thermometer, hygrometer, etc., and to closely monitor the occurrence and origin of various weather events such as rainfall, winds and storms", Saussure explained in his account of the stay on the Col du Géant. He had been frustrated by the lack of time spent on the summit of Mont Blanc and the altitude sickness which prevented him from carrying out certain measurements, so he planned to repeat his high-mountain experiments in more favourable conditions.

Fall into a crevasse

The site on the Col du Géant was recommended by his friend Charles-François Exchaquet (1746-1792), an engineer from the Canton of Vaud with detailed knowledge of the Mont Blanc region. The Col was on a new Alpine route which linked Chamonix with Courmayeur during the summer. A year after his victorious ascent of Mont Blanc, Saussure and his son returned to Chamonix in June 1788 to prepare their new expedition. He readied his equipment and recruited guides, sending some of them to build a stone cabin at the Col which would serve as his field laboratory. The start of the expedition was scheduled for 1 July 1788. They camped the first night at Tacul. During the second day, a guide, who was carrying Saussure's mattress, fell into a crevasse. Fortunately, his fall was halted 10 m down by a block of snow. His colleagues managed to bring him to the surface safe and sound.

Saussure could not hide his disappointment when he reached the site: the cabin he had ordered was too small. It was impossible to stand upright inside it, the stone walls had gaps which allowed snow drifts to form inside. The tents were raised on a flat rocky site surrounded by glaciers and bordered by steep rock faces that Saussure described as precipices. Philosophically he opined that "for a dwelling for several days, this site did not offer an agreeable prospect but, as a viewing point, the situation was magnificent".

The porters returned to Chamonix the same day with the exception of Saussure's domestic servants and four guides who were to assist the two Geneva men with their measurements. They were also responsible for food supplies and for coal from Courmayer.

The first day was spent installing and then operating the equipment. On unpacking his two barometers, Saussure saw that the taps, which were supposed to have blocked the mercury in the bulb during transport, had leaked. The cork joint had contracted in the dry air. He was able to repair one of them by wrapping it in a damp cloth so that the cork expanded again.

The magnetometer and the declinometer were installed on stone pedestals while his son traced a meridian on a plateau to act as a reference for the declinometer.

Using the electrometer
Horace-Bénédict de Saussure, Voyages dans les Alpes, *Genève, Neuchâtel, 1796-1803*
Library of the Musée d'histoire des sciences

The camp in a storm

During the second night, the camp was struck by a very violent storm. Taking refuge in their stone cabin, Saussure was nevertheless buffeted by the wind rushing through the cracks in the walls. Through his mattress he felt the mountain shake. Early in the morning, paralysed with cold, he took refuge in a tent. The guides were forced to hold onto the tent pegs to prevent the tents from flying away. The storm and hailstones returned with renewed ferocity. Lightening struck close to the tent, "The air was so charged with electricity that the moment I poked just the tip of my electrometer out of the tent, the balls separated as far as the wires would allow, and on nearly every thunder strike the electricity changed from positive to negative", Saussure wrote.

After this Dantesque night, relatively good weather conditions prevailed apart from a cold wind which rose in the evenings and caused the group much suffering. Nevertheless, the two scientists began an uninterrupted series of measurements taken every two hours until the end of their stay. The son rose at 4 o'clock in the morning to begin taking measurements. Saussure took over at 7 o'clock. They continued the measurements and experiments until midnight.

They were so busy that they did not notice the time passing until the last evening on the 16th July during which Saussure allowed himself time for contemplation. The cold wind that had blown over the camp almost continuously finally stopped. "It seemed as though those high summits did not want us to leave them without regrets" Saussure wrote, adding poetically, "The air around us had the purity and limpidity that Homer attributed to the air of Olympus".

The camp on the Col du Géant
Voyages dans les Alpes, *Genève, Neuchâtel, 1796-1803*
Library of the Musée d'histoire des sciences

The night that followed was even more beautiful, "The moon spilled rivers of silver light over the vast expanse of snow and rock which surrounded the cabin… What a moment for meditation! How many sorrows and how much suffering is compensated for by such moments! The soul rises up, the spirit seems to expand, and in the midst of this majestic silence we hear the voice of Nature and become privy to its most secret operations".

The following day the camp was dismantled. Saussure and the guides returned to Courmayeur. As he descended into the plain, Saussure suffered from the heat and… Hunger! The expedition had run out of food. The provisions had disappeared. Saussure suspected that the guides had stolen them not just for profit but to force the Swiss to go back down to the valley; "They were exceedingly bored on the Col du Géant and the pleasure we took in the last evening and certain regrets expressed by my son, made them fear that we would prolong our stay".

After a day resting at Courmayeur, the Saussures returned to Chamonix via the Col Ferret and Martigny. After carrying out some comparative experiments, they returned to Geneva at the end of July 1788.

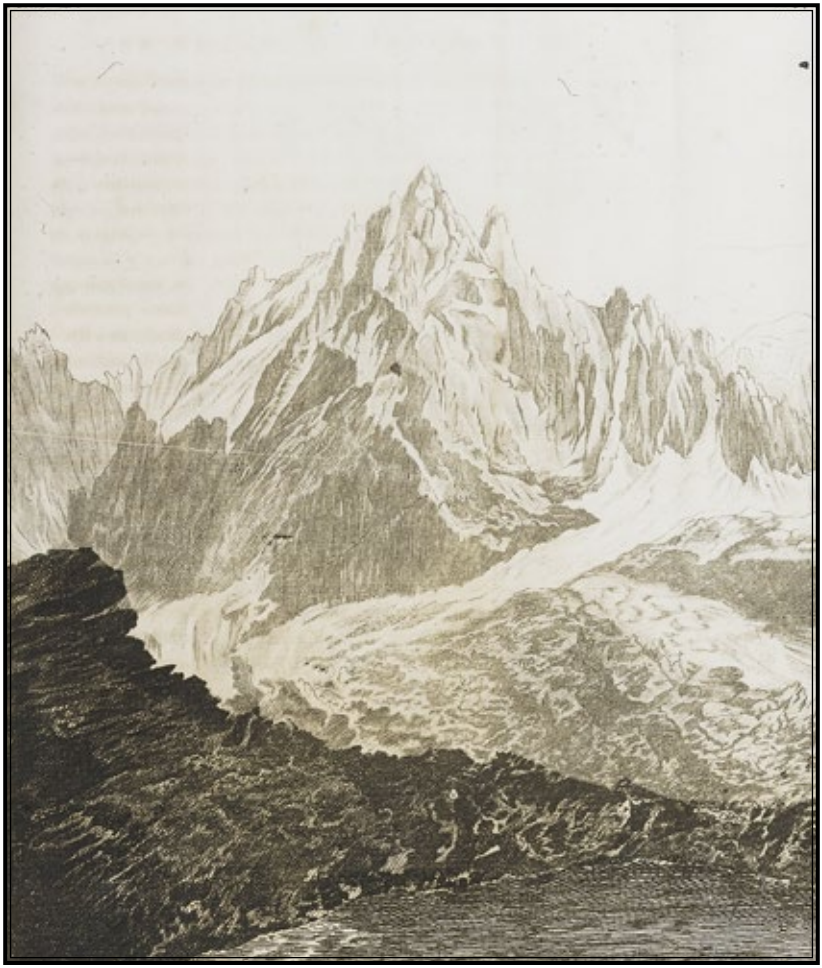
Mountains: Saussure's natural laboratory

Saussure always looked at the Alps from a geologist's perspective. He looked for granite massifs and the faults and folds which could give information about the Earth's history. High mountains are the ideal place as they "bring to the light of day a large expanse of natural sections, where we observe with the greatest clarity and can comprehend at a glance, the order, the situation, the direction, the thickness and even the nature of the strata of which they are composed", Saussure explained in the preface to *Voyages dans les Alpes*.

His quest to find the origins of the Earth did not prevent Saussure from approaching the Alps from a multidisciplinary perspective. He was a geologist but also a geographer, botanist, meteorologist, chemist and physicist. He made the Alpine massif a true natural laboratory for measurements and experiments. He invented instruments specially adapted to his needs; hygrometer, cyanometer, electrometer, magnetometer etc.

As part of his atmospheric and meteorological research, he became one of the first scientists to carry out comparative measures at different altitudes: Mediterranean, Geneva (360 m), Chamonix (1300 m), Col du Géant (3300 m) and Mont Blanc (4807 m).

This comparative methodology and multidisciplinary approach were taken up by the famous explorer Alexander Von Humboldt (1769-1859) during his expedition to South America and the Andes at the very beginning of the 19th century. In fact, Saussure's cyanometer and hygrometer were in the baggage of the German geographer and naturalist.

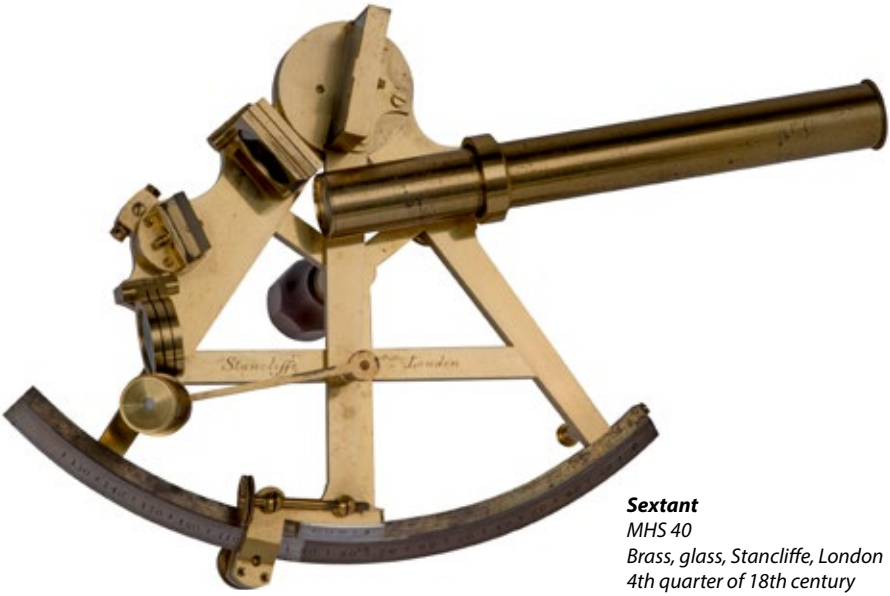


L'aiguille du Midi
Horace-Benedict de Saussure, Bourrit, Voyages dans les Alpes*, t. 2, Fauche, Neuchâtel, 1803, Library of the Musée d'histoire des sciences*

Some examples of Saussure's measurements and observations on the Col du Géant.

Altitude and position

Saussure describes how his son twice measured the meridian altitude (altitude of an astronomical object as it crosses the meridian) in order to determine the latitude without, however, identifying the instrument he used. Nicolas-Théodore Saussure certainly used a sextant – a reflecting instrument fashionable at the time – and a mirror to serve as an artificial horizon. Longitude measures were more complicated. The watch (set to Geneva time?) they had planned to use had stopped working so the Saussures were forced to determine their position by triangulation from reference objects (the summit of Mont Blanc, the Priory of Chamonix, the aiguille du Géant and the village of Courmayeur).



Sextant
MHS 40
Brass, glass, Stancliffe, London
4th quarter of 18th century

Altitude was initially calculated by triangulation by measuring the height of the aiguille du Midi, visible from both the Col du Géant and Chamonix (the latter measurements were taken on their return). The resulting height was 1763 toises above the Mediterranean, that is, 3437.85 m. This figure became the reference for barometric height measurements calculated according to the Trembley formula (3406 m) and that of De Luc (3350 m).

Complete circle
MHS 102
Brass, glass, Hurter, London, 2nd half of 18th century

Botany and zoology

Thirty years before, at the beginning of his career, Saussure had discovered the Chamonix valley in his capacity of botanist. He had been sent by the Bernois doctor Albert de Haller (1708-1777) who wanted to carry out an inventory of the Swiss flora. During his stay on the Col du Géant, botany no longer really interested Saussure. He just managed to briefly mention the presence of "very small pretty crimson and white flowers" named *Aretia helvetica L*. (or Swiss Androsace).

Swiss Androsace
Wikipedia

Saussure nevertheless began collecting lichen from the rocks to send to a M. Daval ("an English gentleman living in Orbe and a passionate plant amateur") for examination. M. Daval sent the specimens to a well-known botanist in London who identified two new species.

Saussure's zoological observations were even more patchy. The only animal that seems to have been living continuously on the Col du Géant was an all-black spider. Saussure notes three chamois who passed and three species of bird: a wallcreeper, a snowfinch and Alpine choughs which enlivened their solitude in the wild.

Geology

Examination of the rocks around the Col du Géant did not reveal any surprises. As on Mont Blanc, the rocks are almost entirely of granite, gneiss and schist. Saussure heated the samples he brought down to the plains with a blowlamp to see how they transformed under high temperatures, or he scratched them with a steel point to assess their hardness. He notes the presence of a blue/grey calcareous rock he discovered on his descent from the Col du Géant to Courmayeur which, when dissolved in nitrous acid, produced a "lively effervescence".

Finally, Saussure was duly impressed by the geological spectacle of Mont Blanc seen from the Col du Géant, especially the diverse vertical strata of its main component, granite. "One sees up to the summit the vertical sections of granite which compose this enormous massif… These layers are repeated as far as the southern foot of Mont Blanc, which sits on the Allée blanche; but, as I have observed elsewhere, the layers gradually become less steeply inclined the further they are from the central mass of the mountain. It can be compared to boards stacked against a wall to which we give wider footings the further out they are". Saussure was one of the first to raise the hypothesis of "horizontal folding in the opposite direction" to explain the formation of vertical layers in the Alps.

Sample of Saussure's mineral collection
Musée d'histoire des sciences

Barometric readings

In spite of problems with a barometer, Saussure managed to make 85 measurements during his stay on the high mountain. He used the measurements not only to calculate the altitude of the camp but also to make comparisons with two other measuring stations, Chamonix and Geneva, where two colleagues made similar readings.

Comparing the readings, Saussure observed that at the Col du Géant, the barometer reading was at its lowest in the morning before rising up to 14h, then declining a little until 16h and then climbing again. In Geneva and at Chamonix, the situation was inversed: the barometer reading was at its highest in the morning before declining up to 16h when it was at its lowest, after which it rose again. Saussure explained correctly that daytime heating (caused by the sun) expands the air on the plain (thus a drop in pressure) which rises in altitude, bringing a rise in pressure.

Portable barometer
MHS 967
Wood, glass, brass, Paul, Geneva, 1763

Table des variations moyennes du barometre pendant le jour.

Heures du jour.	VIII. h. m.	X.	XII.	II h. s.	IV.	VI.	VIII.	Moyenne.
Col du Géant.	0,000.	1,609	2,551.	3,473.	2,494	2,772.	4,087.	2,427.
Chamouni.	6,972.	5,607.	3,000.	1,214.	0,000	2,493.	6,586	3,696.
Geneve.	5,343.	4,693.	3,222.	1,308.	0,000.	1,050.	3,736.	2,765.

Comparison of pressure readings
Horace-Benedict de Saussure, Voyages dans les Alpes, *Genève, Neuchâtel, 1796-1803*
Library of the Musée d'histoire des sciences

Thermometers, air temperature and snow

Similar to his series of measurements of pressure, Saussure carried out numerous measurements of air temperature, making comparisons with Chamonix and Geneva. Average temperatures (shade) on the Col du Géant were 4.5°C, at Chamonix 21.61°C and 24.98°C at Geneva.

On the Col du Géant, temperatures were read every two hours with two alcohol thermometers using the Réaumur scale. Results show that the coldest part of the day, in the mountains as well as on the plain, is just before sunrise. Highest temperatures were recorded at about 14h on the Col de Géant and at Geneva, but towards midday at Chamonix. Saussure explained that this was caused by thermal inversion on the flanks of the mountains. The measures of temperature showed that the sun heats less in the mountains than on the plain. This seems obvious today but it wasn't in Saussure's time when knowledge about climatic conditions in the high mountains was rudimentary. The measures also showed a reduction in the daily temperature difference in summer with altitude. The difference between the coldest and warmest moments was 4.2°R (5.32°C) on the Col du Géant, 10.092°R (12.615°C) at Chamonix and 11.023°R (13.794°C) at Geneva. Finally, on the basis of the aforementioned observations and measures, Saussure concluded that, in summer, temperatures in the mountains declined by 1°R (1.25°C) every 100 toises (195 m) of altitude. This is exactly the reference thermal gradient used today which is 0.6°C per 100 m (up to 10,000 m).

Alcohol thermometer
MHS 185
Glass, Paul, Geneva, 4th quarter of 18th century.

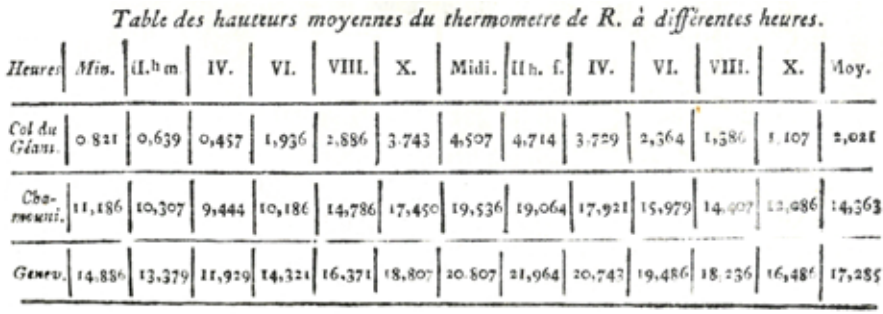


Table des hauteurs moyennes du thermometre de R. à différentes heures.

Heures	Min.	I.h m	IV.	VI.	VIII.	X.	Midi.	II h. s.	IV.	VI.	VIII.	X.	Moy.
Col du Géant.	0 821	0,639	0,457	1,936	2,886	3,743	4,507	4,714	3,729	2,364	1,386	1,107	2,021
Chamouni.	11,186	10,307	9,444	10,186	14,786	17,450	19,536	19,064	17,921	15,979	14,907	12,986	14,363
Genev.	14,886	13,379	11,929	14,321	16,371	18,807	20,807	21,964	20,747	19,486	18,236	16,486	17,285

Temperature comparison
Horace-Bénédict de Saussure, Voyages dans les Alpes*, Genève, Neuchâtel, 1796-1803*
Library of the Musée d'histoire des sciences

Saussure tested the methodology of air temperature readings at altitude, which is a very important component of the calculation of altitude using pressure. By comparing a number of readings taken in shade and sun, Saussure became convinced that a thermometer exposed to the air heats as a result of direct solar rays rather than air temperature. Temperature readings used to calculate pressure must therefore be taken in the shade.

Saussure took temperature readings of the surrounding snow. Having taken samples at different depths, he was sure that snow only freezes at the surface and that the ice crust goes no deeper than 3 metres. Below this depth, the snow remains soft. This confirmed what he had already proposed, that is, that the base of the snow domes of the high summits is composed of snow and not ice. However, there could be ice on the edges of cliffs and crevasses where air is able to penetrate. "I observed the proof of this on Mont Blanc. The thick snow lying on moderate slopes develops fissures which intersect at right angles, making large rectangular blocs. The blocs are often so regular that they look as if they have been cut out with scissors. The people of Chamonix call them sérés or séracs, after the name of a dense square-shaped cheese which is made there from whey".

Evaporation

In his *Essai sur l'hygrométrie,* a foundational work on the subject published in 1783, Saussure showed in a laboratory that, in rarefied air, water evaporates at a lower temperature than at normal pressure. At the summit of Mont Blanc, he managed to verify experimentally that water boils at 85°C and not 100°C as is the case at sea level.

On the Col du Géant, he carried out new hygrometric experiments, this time to compare evaporation in mountains compare rates of evaporation at altitude and on the plain, under normal atmospheric conditions. Sheltered from the wind in a tent, he stretched a small canvas over a frame which he then attached to the beam of a pair of scales. Having dampened the canvas with a sponge and having noted its initial weight, he weighed the apparatus at regular intervals to record the quantity of water that had evaporated. At the same time, he took readings of the ambient temperature and humidity. He observed that, in the mountains, a small rise in temperature exerts more influence on evaporation than a rise in dryness while the inverse takes place on the plain.

In the framework of these hygrometric measurements, Saussure also did some more interesting experiments. In order to quantify the cooling which results from rapid evaporation, Saussure placed the bulb of a thermometer inside a damp cloth, tied it up with string and swung it round at high speed until the thermometer showed the lowest temperature. Saussure was not able to distinguish whether temperature or dryness in the ambient atmosphere played the most important role in cooling the thermometer.

Hygrometer and air humidity

During his past expeditions Saussure had already carried out detailed studies on the comparative evolution of atmospheric humidity in the mountains and on the plain. He had shown that on the plain, humidity is at its lowest at midday because of the rise in temperature and maximum at altitude because of "the ascension of vapours raised by their own lightness and vertical winds produced by the sun". During his stay at the Col du Géant, he continued hygrometric measurements and observed that during the night during fine weather, humidity in the air is not as high as during the day. "During the night we can see vapours and gases, both humid and dry, condensing and descending as the sun stops lifting them up to the upper air levels. Initially they fall and produce while they do so dew or humidity, then they continue to fall and pile up at the bottom of the valleys, and during this time, the air that we breathe purifies and dries itself more and more, as I have observed in the high mountains".

Considering the total humidity of the air, Saussure confirmed what he had already observed during his ascension of Mont Blanc, that is, that it is far lower in mountains than on the plain.

Hair hygrometer
MHS 153
Brass, Paul, Geneva, 4th quarter of 18th century

Eudiometer and oxygen content

During his stay at high altitude, Nicolas-Théodore de Saussure carried out measurements of "air cleanliness", in other words, of its oxygen content. His experiments were inspired by a method developed by the Scottish chemist Joseph Priestly (1733-1804) in 1772. The approach involved measuring the proportion of oxygen found in the air by mixing a sample of the surrounding air with nitrous air (nitric oxide NO). The mixture of the two gases produced shimmering vapours while the total volume decreased. The greater the oxygen content, the larger the decrease. In carrying out this experiment, Saussure repeated a methodology developed several years earlier while making similar measurements on the summit of the Buet. This time, instead of using very fragile glass laboratory instruments, he used much more basic but more robust equipment. Nitrogenated and ambient air were introduced through a funnel into a small glass phial placed upside down in a bucket filled with water. On contraction of the gas, the water

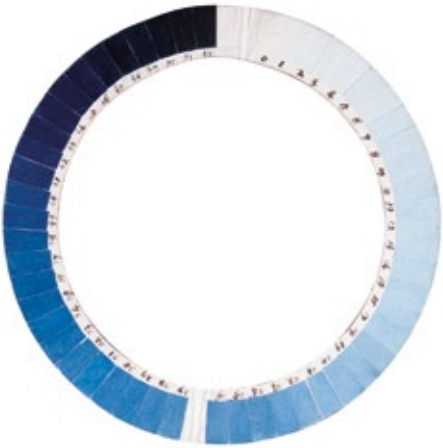
Box of reagents for mountain experiments
MHS 11
Wood, glass, 18th century

flowed up into the glass tube. The weight of the water gave an immediate indication of the volume of oxygen present in the air analysed. The results showed that the air in Geneva and in Chamonix contained more oxygen than that on the Col du Géant.

The Saussures also repeated the experiment, already carried out on the summit of Mont Blanc, which aimed to chemically verify the presence of carbon dioxide in the atmosphere using lime water. The lime water was diluted with distilled water, poured into a recipient and opened to the ambient air. After several hours, the lime water, initially transparent, had a thin skin on the surface indicating the presence of carbonic gas in the atmosphere. Given the absence of vegetation, fire or fermentation at that altitude, Saussure concluded that the gas was not produced at high altitude but came from the valleys and plains.

Measuring the blueness of the sky: the cyanometer

For Saussure, the degree of blueness of the sky was an important meteorological indicator which allowed quantification of opaque vapours or exhalations suspended in the air. According to him, air that was entirely transparent and that contained no suspended opaque vapours would be black. However, air is never completely transparent. It contains elements in dissolution which particularly reflect blue light and which are responsible for the blue of the sky. The purer the air, the deeper the mass of air, the darker the blue seems. However, the mixture of opaque gases and exhalations, those which are not dissolved, reflect different colours. It is these colours mixed with the natural blue of the air which produce all the coloured nuances between the darkest blue (pure air) and grey or white (sky loaded with vapours). When the sky appears paler on the horizon than at the zenith, it's because vapours are more abundant there. Saussure's explanation is a little simplistic. But he knew nothing about the way in which molecules and aerosols diffuse light; they were not discovered until the second half of the 19th century.



Circular cyanometer
Paper, cardboard, Saussure, 4th quarter of 18th century
Bibliothèque de Genève

Saussure took a new circular cyanometer of 52 colour tones (from white to black) to the Col du Géant. It was much more efficient than the square model with only 16 shades which he had used on Mont Blanc. He left a similar model each with his colleagues stationed at Chamonix and Geneva so that they could make comparative measurements. According to his new instrument, the blue at the Col du Géant was 37 on his scale, that of Chamonix 27 and at Geneva 26.5. The measurement on Mont Blanc a year earlier was 39.

Observations showed that, early in the morning, the air over the Col du Géant contained as many gases as on the plain. But during the day, the depth of blue easily outstripped the blue of the plain and at Chamonix. Saussure's explanation was that high altitude opaque vapours were evaporated by the sun's rays in the less dense air of the high mountains.

Saussure tried to repeat a measurement of the transparency of air on Mont Blanc but had to renounce it because of altitude sickness. He thought that air transparency is one of the reasons for low temperatures because the sun's rays are not able to warm it. In order to measure air transparency, he used a diaphanometer, a kind of cardboard target which he himself had invented, on which a series of concentric black circles were drawn. The measurement was the distance from which the black circles could no longer be distinguished from each other. Saussure and his son tried to carry out the experiment on a snow field 400 m in length. It was a total failure. The two men sank into the deep snow and were blinded by the reflection of the sun.

Declination compass and magnetic variation

During his stay on the Col du Géant, Saussure investigated magnetism and, in particular, daily variations of the magnetic declination (the angle between magnetic and geographic North), a subject which intrigued many scientists at the time. For these investigations, Saussure took with him a declination compass which he had purchased in England and which he had specially prepared. In order to increase the sensitivity of the instrument, he suspended the magnetic needle rather than leave it lying horizontally.

On their arrival at the Col du Géant, Nicolas-Théodore Saussure plotted a meridian in order to obtain geographic North and set the compass which indicated a magnetic declination of 19°.

Declination compass
MHS 16
Steel, wood, brass, Adams, London, 3rd quarter of 18th century

Magnetometer
MHS 108
Wood, steel, brass, Paul, Geneva, 4th quarter of 18th century

Having installed the compass on a stone support inside a tent, Saussure observed variations in magnetic declination continuously for nine days. He noted that the needle moved towards the west daily until about 14h before gradually returning to the east. Measures taken in Chamonix and Geneva, showed the same pattern. Saussure suggested that the variations could be caused by "the action of a fluid substance, subject to large oscillations. Such a substance, without being the magnetic fluid, did nonetheless have a certain influence and is itself subject to the action heat or light".

Further, Saussure maintained that observations carried out by other scholars had proven that the daily variations had a constant association with either the time of day or with the seasons, a relationship which apparently depended on heat or light, or the "general balance between vapours or exhalations", rather than gravitation. We now know that the daily variations are caused by the sun's electromagnetic waves on the exposed face of the earth. Interactions between the solar wind and upper atmosphere give variations over 24 hours of the magnetic field lying beyond the earth. Saussure unsuccessfully tried to show these magnetic variations with a magnometer of his own design to measure the attractive force of a magnet. However, thanks to this instrument, he did manage to establish that the attractive force of a magnet is reduced in cold conditions and increased in warm conditions.

Physiology and mountain sickness

During his long stay on the mountain Saussure took the opportunity to carry out some physiological experiments to assess the effect of rarefied air on the human body. Using a guide provided by a doctor, he made regular observations of his own body: temperature, pulse, amount of urine excreted, number of inhalations and exhalations.

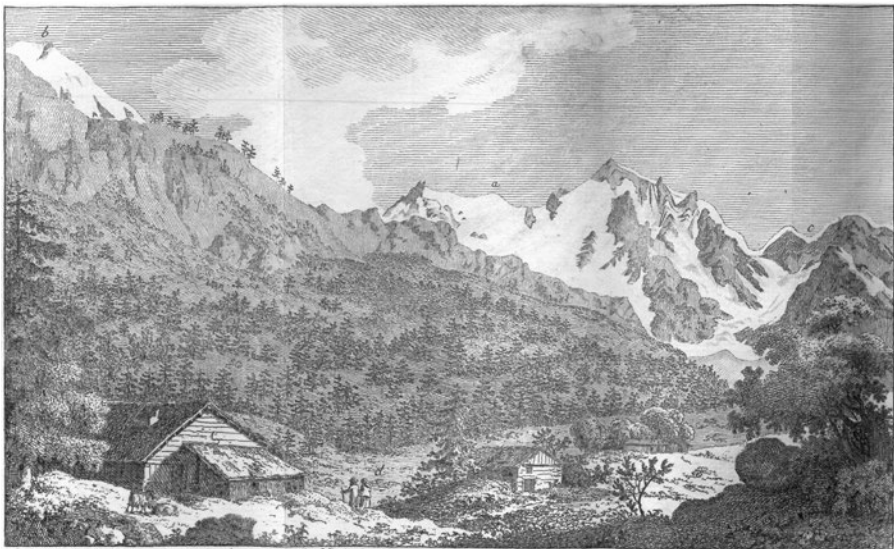
Saussure described in great detail the sensations he felt on arriving at the Col du Géant. Breathlessness, the difficulty of sustaining repeated physical effort. He noted that the altitude made him more irritable, impatient and even subject to temper outbursts. "Hunger seemed to be more insistent; but we were also more easily satisfied and my digestion seemed to be more rapid than on the plain". On the other hand, Saussure emphasised that during their tasks and observations they had a "demonstrably freer mood, were more active and less easily fatigued, I would even say more creative than in the lowland".

The Col du Théodule

After the camp on the Col du Géant, Saussure made two more expeditions to the Alps, accompanied each time by his elder son. The first was during the summer of 1789 around Monte Rosa, a mountain Saussure had seen only from a distance and which he wished to get to know better. For nearly three weeks, the Saussures, accompanied by their Chamonix guides and mules carrying their baggage and scientific equipment, travelled around the Monte Rosa massif which lies on the border between the canton of Valais, the Col du Simplon, the heights of the Anzasca valley in Piedmont, Breuil, Zermatt and, finally, Visp. During the Italian section of their expedition, they took the time to visit several gold and copper mines.

As he had already shown during earlier trips, Saussure was interested in the people who lived in the remote valleys where German, French and Italian were the languages spoken. He was impressed by the physical strength of the women who, replacing their men who were employed in the valleys, worked the fields. The expedition stayed for 11 days at an inn at Macugnaga, at the bottom of the Anzasca valley on the southern slopes of Monte Rosa. Saussure was astonished to see that Monte Rosa is almost entirely composed of horizontal rock strata and not vertical, as is the case for Mont Blanc. He used his stay to measure the height of the mountain or, rather, the altitude of the highest summits, by trigonometry and barometry. He found that the Dufour summit lay at 4738 m (against 4634 m current measurement) and that the Nordend was 4676.1 m (4612 m current). Nicolas-Théodore measured air density by weighing at different altitudes, a glass ball filled with air. The results showed that the observed variations are proportional to the atmospheric pressure shown by the barometer.

Travelling from valley to valley, Saussure and his team reached the Val d'Aoste, then followed the Valtournenche valley as far as Breuil before climbing to the Col du Théodule at over 3300 m then on to Zermatt and Visp. During the climb to the col, the mules sank into the soft snow, forcing the guides to carry their loads instead. When they arrived at the col, where there is a military fortification, Saussure enjoyed a magnificent view of the surrounding mountains especially the Matterhorn "which rises



The Monte Rosa massif seen from near Macugnaga (Italian Piedmont)
Horace-Bénédict de Saussure, Voyages dans les Alpes*, Genève, Neuchâtel, 1796-1803*
Library of the Musée d'histoire des sciences

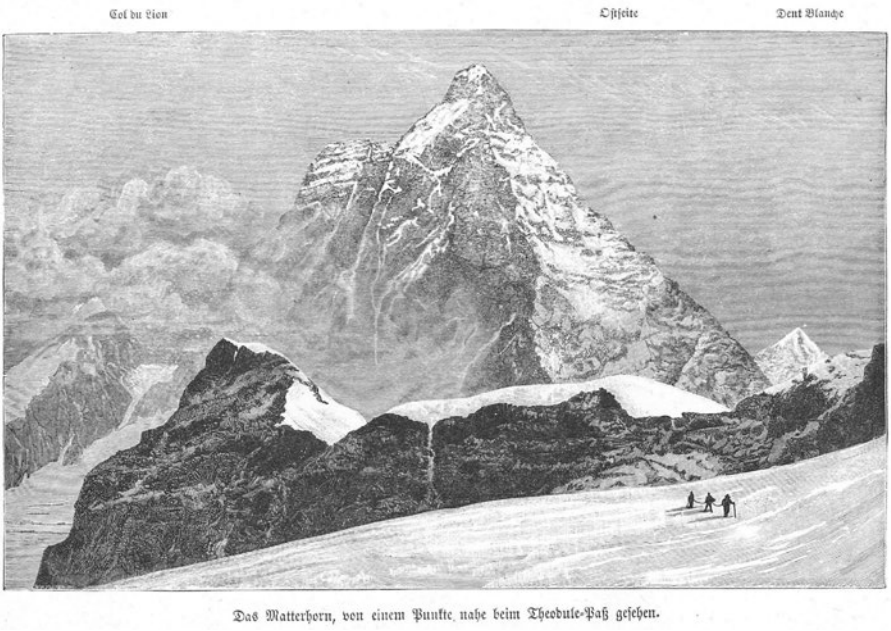
to an enormous height in the form of a triangular obelisk of solid rock which seems to have been cut out with scissors". He admitted that "if I had known about this post, so easily accessible compared to the Col du Géant, much more remote from inhabited areas and only 27 toises lower, I would definitely have chosen it for my meteorological observations and we would have suffered less".

Fascinated by the Matterhorn, Saussure returned to the Col du Théodule in August 1794 on what would be his last Alpine expedition. Still accompanied by his son and by a small team of porter-guides, he went to the Val d'Aoste via the Col du Bonhomme and the Col du Petit-Saint-Bernard. From there he went to Breuil, then the Col de Théodule where he stayed for three days in a tent.

One of his first tasks was to measure the altitude of the Matterhorn. This was done from two separate points whose distance from each other was measured by a survey chain. The readings were made using a sextant and a

mirror which served as an artificial horizon. The height of the two reference points was set by the barometer. Saussure obtained a reading of 4505 m altitude for the Matterhorn (4478 m in reality).

During their three-day stay on the Col du Théodule, the Saussures made their usual meteorological measurements: the blueness of the sky, atmospheric electricity, temperature, pressure, etc. In addition to air temperature, Saussure measured the temperature of the ground using a new instrument which he had designed himself: a thermometer enclosed in a wooden cylinder about 15 cm in diameter. The cylinder was inserted into a hole dug in the ground.



The Matterhorn seen from the Col du Théodule
Berg und Gletscherfahrten in den Alpen in den Jahren 1860 bis 1869
Edward Whymper, Friederch Steger, Braunschweig, 1872
Viatimages / Médiathèque Valais

As a true naturalist, Saussure also treated himself to "a rich and charming collection of rare plants". During an expedition to the Breithorn, he became fascinated by the small black, hairy insects covered in pointed scales and equipped with long curved antennae which appeared to live contentedly on the snow plaques found at that altitude. In addition these insects – springtails – performed leaps in the snow when one was trying to catch them as if they had a spring beneath their abdomen.

The rest of the stay was mainly concerned with geology and taking mineral samples. Faced with the tormented rock forms of the entwined geological strata and the difficulty of finding a coherent explanation for their emergence from the depths of the primaeval ocean, Saussure seemed rather dejected: "These periodical upheavals have, perhaps, astronomical origins. It would be interesting to determine their ages. In fact, neither storms, nor tides can disturb ocean depths enough to produce such effects. But what could, at least as probable conjectures, penetrate this night of time. Present on this planet since yesterday, and for only one day, we hope for knowledge that we shall probably never attain …". An admission of helplessness with regard to a theory of the earth that he would never achieve?

Further reading

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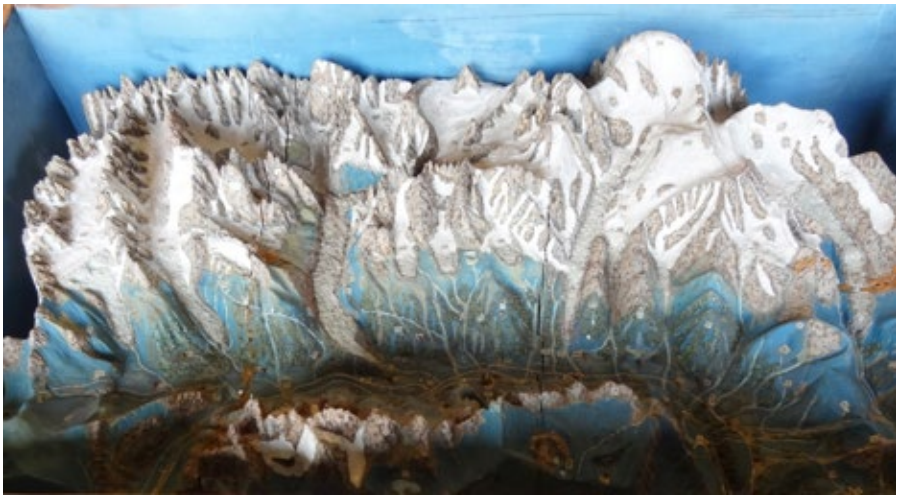
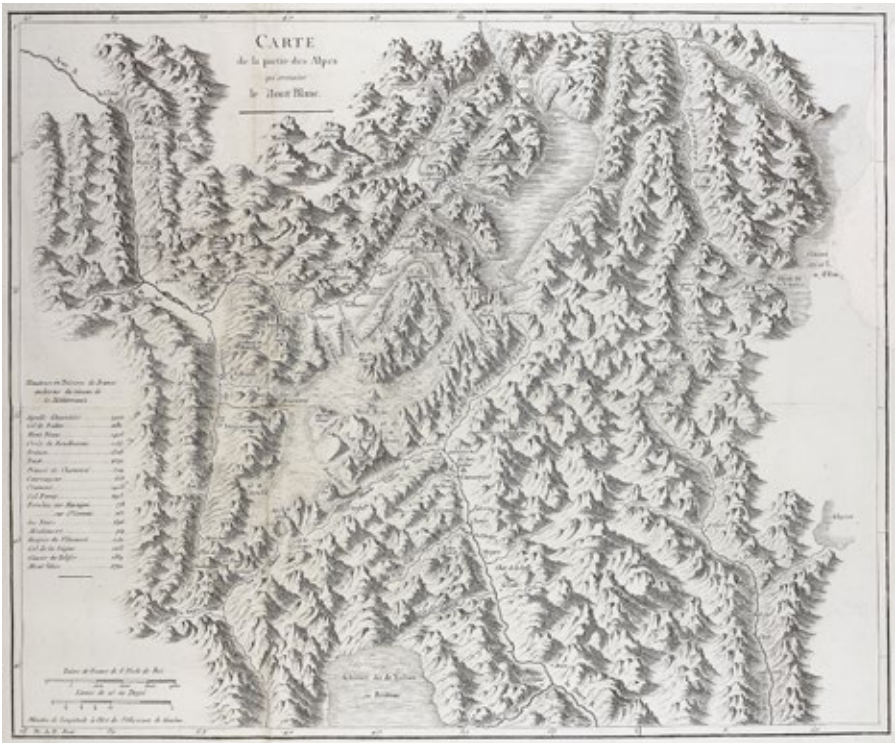
Saussure, his son and guides descend the Tacul glacier. The tent and cabin of the camp at the Col du Géant can be seen in the background.
L'Evèque Henri, Genève, 1790
CIG/Bibliothèque de Genève



Relief of the Mont Blanc massif
Wood, around 1788
Collection of the Geneva section of the Club Alpin Suisse

Following Saussure's Alpine expeditions, especially his ascent of Mont Blanc in 1787, the Vaudois engineer Charles-François Excheaquet started a business in 1788 selling three-dimensional wooden reliefs of the Mont Blanc massif.

View of the Chamonix valley and the Mont Blanc massif
Water-coloured engraving of Mont Blanc published by Chrétien de Méchel at Basle in 1790. The engraving followed the relief by Charles-François Exchaquet, a Vaudois engineer
CIG/Bibliothèque de Genève



Map of the Mont Blanc massif
H.-B. de Saussure, Voyages dans les Alpes, *Geneva, Neuchâtel, 1796-1803*
Library of the Musée d'histoire des sciences

Produced by the Geneva physicist Marc-Auguste Pictet who accompanied H.-B. de Saussure on an expedition around Mont Blanc in 1778.

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GENÈVE

Villa Bartholoni
Parc de la Perle du Lac
Rue de Lausanne 128
1202 Genève
Tél : + 41 22 418 50 60
Open every day from 10am to 5pm except Tuesday
www.museum-geneve.ch
mhs@ville-ge.ch

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