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GLOBAL WARMING – THE HISTORICAL PHOTOGRAPHIC EVIDENCE

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Abstract

The photographic record of the Alps stretches from the 1840s to the present day and therefore provides visual evidence and significant insight into the devastating impact of global warming on alpine glaciers. In this study, we match photographs from around 1860, 1910 and today, from the same viewpoint, to provide a visual narrative of change in the glaciers of Chamonix Mont-Blanc.

During a cooler period in the 16th-19th centuries, now known as the "Little Ice Age", glaciers descended into alpine valleys and destroyed villages. The most recent maximum of alpine glaciers was attained in the 1820s. They remained fairly close to this maximum until the late 1860s, allowing early photographers to capture them in all their glory. Since then, glaciers have been in general retreat, with shrinkage accelerating on the back of global warming caused by human activity. The speed of change is alarming and is a concern not merely for skiers and alpinists.

Keywords: Climate Change, Global Warming, Little Ice Age, Glaciers, Photography, Stereoscopy

The History of Alpine Glaciation

The extent of alpine glaciation follows a cyclical pattern driven annually by the simple equation of growth through the addition of winter snow and shrinkage from summer melting. If it is cold and wet for several years, the glacier will grow; warm and dry and it will recede. Scientists observe that major glaciation is a natural cyclical phenomenon, with a periodicity of around 100,000 years, caused primarily by oscillations in the Earth's orbit around the Sun. The last major glacial maximum in the northern hemisphere was reached some 25,000 years ago, during the Wűrm period. The Arctic polar ice cap extended south, covering North America as far south as New York, while in Europe, Scandinavia and Scotland were completely covered in ice. A secondary ice cap formed over the Alps. Valleys were filled with ice up to 2,500m deep and glaciers extended onto the surrounding plains, covering what is now Lake Geneva and almost reaching Lyon. After a significant retreat back into the mountains, a secondary maximum was reached around 12,000 years ago during the Younger Dryas period. The glaciers extended back down into alpine valleys, reaching what is now the centre of the town of Chamonix.

A warmer climate then caused the glaciers to retreat. The tree line became higher than today, as evidenced by large tree roots, dating from around 6,000 years ago, being discovered throughout the Alps at altitudes above the level at which such a size of tree currently grows. In the mid-13th century, a short cooler period allowed the glaciers to grow and forced the Vikings to abandon settlements in Greenland. A further cool period during the 16th-19th centuries is now known as the 'Little Ice Age'. Glaciers descended into alpine valleys and destroyed villages. Rivers, such as the Thames in London, froze over in the winter. Scientists currently estimate that global cooling of less than one degree generated these effects, which may have been triggered by volcanic activity releasing particulates into the atmosphere, which reduced the solar flux reaching ground level.

Glaciation in Chamonix

During the Little Ice Age, five major glaciers descended to the Chamonix valley floor: le Tour, Argentière, les Bois (*Mer de Glace*), les Bossons and Taconnaz. In the early 1600s, the hamlet of les Rousier was destroyed by the advance of the Argentière glacier, while the Glacier des Bois destroyed the hamlets of Bonnenuict and Châtelard, and by 1644 was at the doorstep of the village of les Bois. The villagers summoned the local Bishop to bless the village and exorcise the glacier. He must have been well connected; the glacier halted its advance and the village was spared.

The Glacier des Bois is the original name for the glacier popularly known as the *Mer de Glace*. Its length of 12km ranks it the largest glacier in France and third or fourth in Europe. In 1741, British adventurers Windham and Pocock climbed to a viewpoint at Montenvers (see Figures 12-14) and described the awesome scene as like a sea frozen solid during a violent storm. Their description of a 'sea of ice' or '*mer de glace*' remains the name of the glacier to this day and the glacier rapidly became a popular tourist attraction.

During the 17th and 18th centuries, the Glacier des Bois remained fairly static in length, with several maxima. The final

1822 maximum was reached following the enormous volcanic eruption of Mount Tambora in Indonesia in 1815, the largest volcanic event in recorded history, which negatively impacted global weather. After a minor retreat, a secondary maximum was reached in around 1852. This period roughly coincides with the arrival of photographers in the Chamonix valley.

The first stereo-photographers were active in 1856. The most renowned of them, Claude-Marie Ferrier, descended to the surface of the *Mer de Glace* to take a view looking back up at Montenvers (Figure 1[1]), where the original hotel built in the 1840s can be seen on the skyline. At the edge of the glacier, the light grey band of rock indicates glacial retreat from the recent maximum in 1822. Using the height of the men and the two-storey hotel as reference, the reduction in depth would appear to be around 10m over the intervening 34 years.

The glaciers then went into sharp retreat in the 1870s -80s. There was a stable pause from 1890-1930, followed by further retreat until the 1970s, when increased precipitation provided a little growth. Since then, the retreat has accelerated because of a warmer climate, with the Glacier des Bois (*Mer de Glace*) losing on average 3-5m in depth per year.

A stereoview by Durieux (Figure 2) from *c.*1856 shows the front of the Glacier de Bois to be from 10-20m high. It was recorded in 1820 that this front was advancing at between 1-2m per day! It is not surprising that villagers were terrified, as they witnessed this force of nature moving inexorably towards their chalets, destroying everything in its path. There is therefore a written record of the length of the Glacier des Bois from the end of the 16th century, when it first started to impact the cultivated land and villages at its foot, and this data is presented in Graphic 1. Since 1880, the depth of the ice adjacent to Montenvers has also been recorded, and this is shown on the right axis. It can be seen that since the earliest photos were taken, the glacier has shrunk by 3km from 15km to 12km in length, while the depth of ice at Montenvers has reduced even more drastically from near 250m to under 50m today.

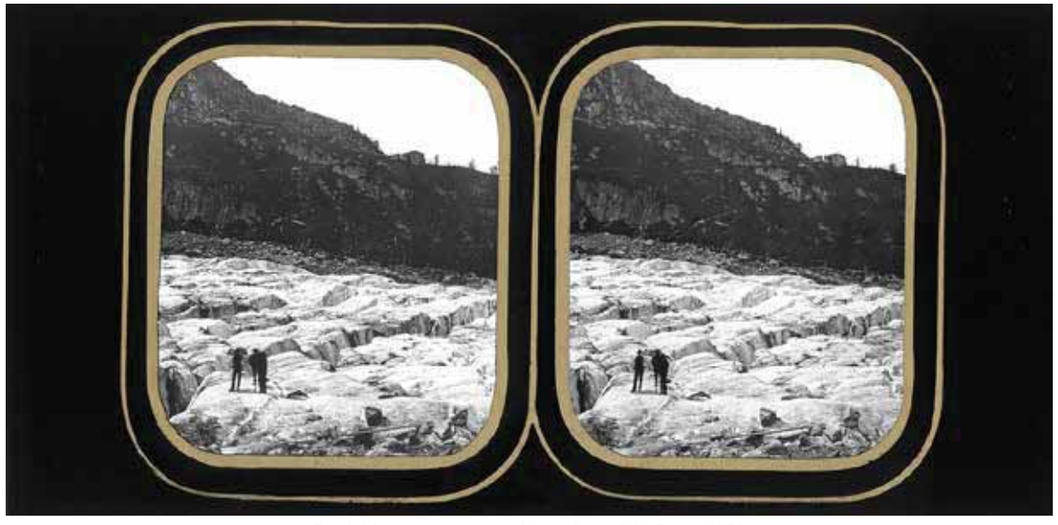


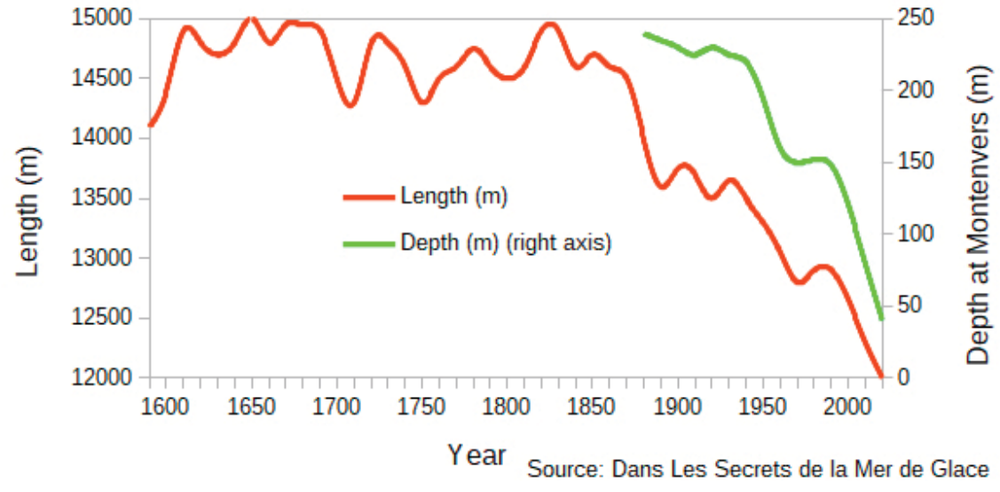
Fig. 1 Montenvers from the *Mer de Glace*, C-M. Ferrier, 1856

1) All images in this paper are from the Peter Blair Collection.

Tourism, Art and Photography

Early travellers viewed the Alps as an inconvenient barrier and a hostile environment, populated by brigands, evil spirits and dragons. The local name for Mont Blanc, the highest mountain in Western Europe, was Mont Maudit or 'Cursed Mountain'.

During the 18th century, an appreciation of the beauty of nature developed and the Alps became popular for their awesome grandeur and sublime scenery. British adventurers Windham and Pocock are often credited with being the first tourists to enter the Chamonix valley. The account of their visit to the glaciers in 1741 triggered a flood of interest. The Swiss polymath, de Saussure, described the topography and



Graphic 1 Glacier des Bois – Historic Length (m), Year 1590 – 2020 and Depth (m), Year 1880-2020 (Right Axis)

science of the Mont Blanc massif and announced a prize for the first to find a route up Mont Blanc. It was eventually claimed by Jacques Balmat, who made the first ascension with Paccard, the local doctor, in 1786.

Albert Smith turned his 1851 ascension of Mont Blanc into a theatrical extravaganza. It ran for six years in London, playing to over 800,000 people including Queen Victoria. The interest in Western Europe's highest peak became so intense that the phenomena was known as 'Mont Blanc Mania'.

During the 19th century, an increasingly rich and leisured middle class could afford to travel, while the age of steam accelerated and democratised transport. Increasing numbers found their way to the Alps and ensured a ready market for visual representations of alpine scenery, ably provided by a stream of artists versed in the romantic picturesque and the sublime, including J.M.W. Turner.

This pictorial tradition was continued by the early photographers. It is interesting that the very first photographs of Chamonix's glaciers were probably taken by the man who had defined the Victorian aesthetic appreciation of mountain landscape, English art critic, John Ruskin. He took daguerreotypes of the Chamonix valley in 1849 and 1854.

In keeping with the scale of the subject, Friedrich von Martens took large calotypes and panoramas of the Mont Blanc massif in the mid-1850s. Auguste-Rosalie Bisson first visited Chamonix in 1858, and by 1860 had established a studio there; in 1861, he was the first photographer to reach the summit of Mont Blanc. Bisson Frères were renowned for their large format views.

Fig. 2 The Front of Glacier des Bois, Durieux, c.1856

The much smaller stereoscopic format may at first sight be considered an inadequate vehicle with which to capture the sublime. However, the opposite is true. When you look into a stereoscope, your entire field of vision is filled. The immersive three-dimensional effect can be realistically visceral in its portrayal of the scale and immensity of mountains and glaciers, the vertiginous depths of cliffs and crevasses and human insignificance in the vastness of nature. Stereoviews of the Alps became highly popular, both with armchair travellers and as souvenirs, soon capturing well over 90% of the market for topographical photographs. They were affordable, compact and lightweight, yet had the ability, when placed in the stereoscope back home, to transport the tourist back to their favourite viewpoint.

The first stereoscopic views of the glaciers were taken in 1856. Claude-Marie Ferrier had already taken a successful series of Swiss stereoviews in 1855 and in 1856, visited Chamonix Mont-Blanc, managing to climb to the Grands Mulets refuge (3050m) to take what are probably the earliest photographs at high altitude.

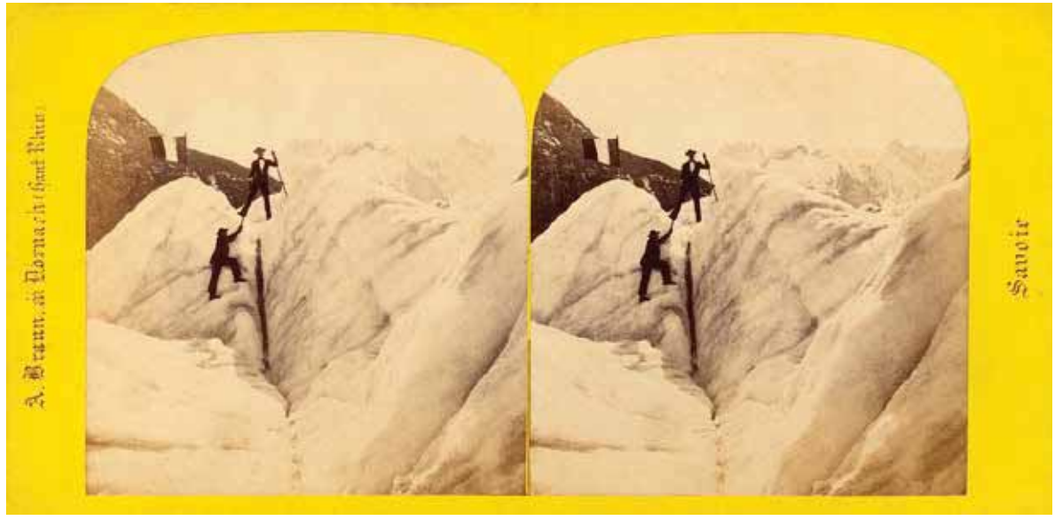


Fig. 3 1035 – Mer de Glace, Flag planted by the Impératrice, Adolphe Braun, 1860

In 1860, Savoie became incorporated into France and soon the dramatic scenery of the Chamonix Mont-Blanc region became the most photographed region in the country outside Paris. Auguste-Rosalie Bisson was the official photographer for the visit of Emperor Napoleon III and Impératrice Eugénie, as they surveyed their new domain. Local photographers Eugène Savioz and Joseph Tairraz were additionally employed by the town to record the Imperial visit. Photographer Adolphe Braun was also present (see Figure 3), on the second of several trips to the Chamonix valley.

William England quit his role as chief photographer for the London Stereoscopic Company in 1863 and undertook his first independent assignment, a stereoscopic tour of Switzerland and Savoie under the special patronage of the Alpine Club. Out of the resulting 130 stereoviews, 21 were of the Chamonix valley. He was repeatedly drawn back to Chamonix Mont-Blanc, photographing the area on at least seven occasions.

Nineteenth century Chamonix was immortalised by an endless stream of other stereo-photographers such as Prot, Plaut, Durieux, Villeneuve, Bertrand, Fourne & Tournier, Grillet, Lamy, Garcin, Julien, Charnaux, Jouvin and Varroquier. The turn of the century brought major publishers like Kilburn, Underwood & Underwood, Stereotravel, Realistic Travels, H.C. White and Keystone. In Chamonix, the first photographers, Savioz and Tairraz, were joined by Michel Couttet, whose son Auguste Couttet later became the outstanding local

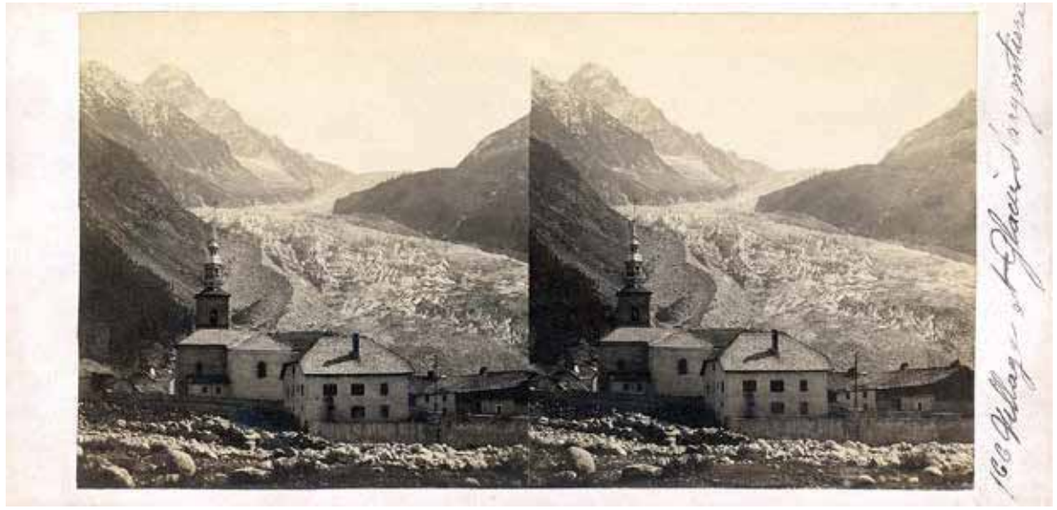


Fig. 4 Village and Glacier of Argentière, Savioz & Tairraz, 1861

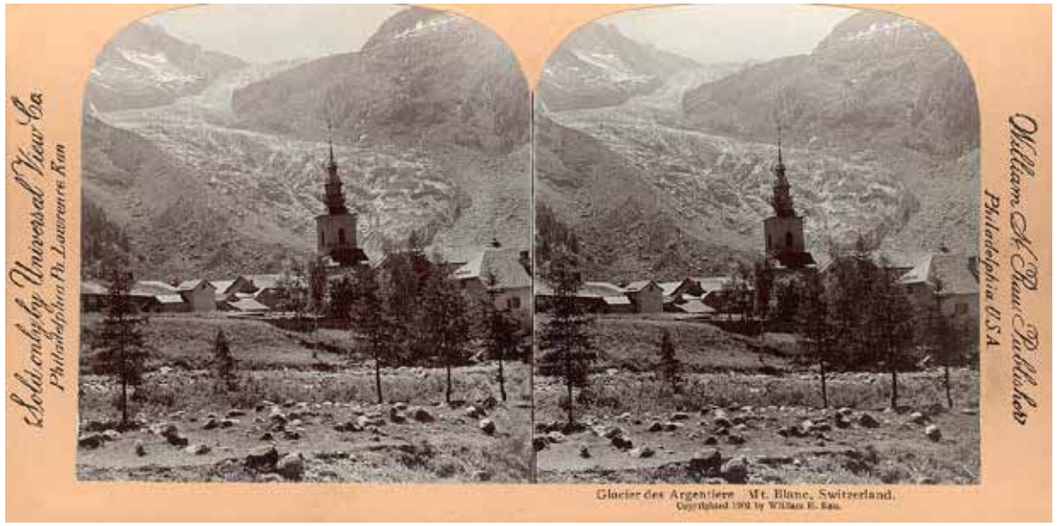


Fig. 5 Village and Glacier of Argentière, Universal View Co., 1902

Fig. 6 Village and Glacier of Argentière, Author, 2015

photographer, winning a medal at the Paris International Exhibition of 1899 and becoming an official photographer for the first Winter Olympics, held in Chamonix in 1924.

The early stereo-photographers would have used the wet collodion technique, which required carrying the darkroom with them. During the 1880s, the availability of pre-prepared dry plate negatives would greatly simplify alpine photography.

The Shrinking Glaciers

The Argentière Glacier dominates the village of Argentière. In the 19th century, the glacier reached the valley floor (1300m) in a broad dramatic sweep, recorded by Tairraz and Savioz in 1861 (see Figure 4). Exposed gravel and rock carried down by the glacier and deposited as it melts back, known as moraine, in front and on each flank of the glacier, indicate the shrinkage from the maximum reached in 1822. By the end of the 19th century (see Figure 5), the glacier was still impressive in extent, but had shrunk in every dimension and even at higher altitude its depth was much diminished. Today, vegetation has reclaimed the area exposed by the glacier, which is now just barely visible from the village, having retreated to an altitude of around 2000m, as shown in the 2015 view by the author (see Figure 6).

The Glacier des Bois has seen an even more dramatic decline. In the mid-19th century, the glacier was visible from Chamonix and reached the valley floor in a broad diagonal, as can be seen in the background of Ferrier & Soulier's view from 1862 (Figure 7).

Its terminal point, where the river Arveyron surged forth from an ice cavern, was an easy tourist outing from the centre of town. William England's view from 1865 includes a figure to provide a sense of scale (see Figure 8). Intrepid excursionists ventured into the natural ice cavern, which could reach 10m in height. Occasionally it collapsed on top of them! The locals decided to tunnel an artificial grotto into the side of the glacier, for which they charged tourists to visit safely. This grotto existed from 1863 to 1874, by which time the retreat of the glacier made it no longer viable.

One of the most dramatic viewpoints from which to appreciate the Glacier des Bois is Flégère (1877m) on the hillside opposite. In the mid-19th century, the glacier can be seen spilling over the rocky shoulder known as les Mottets and heading down to the valley floor (Figure 9). At the turn of the 19th century, freshly exposed rock at the sides of the glacier indicate some degree of shrinkage; however, the glacier remains an impressive sight (Figure 10). Today, the glacier is no longer visible from the valley floor and no longer exists at the level of les Mottets, leaving behind an empty valley. Even from Flégère, at an altitude of 1877m, the glacier is now just barely visible in the distance (see Figure 11).

Fig. 7 Chamonix and the Glacier des Bois, Ferrier Père et Fils & Soulier, 1862

Fig. 8 330 Source of the Arveyron, Glacier des Bois, William England, 1865

The principal panoramic viewpoint looking down on the glacier is from Montenvers at an altitude of 1913m. It was from here, in 1741, that Windham and Pocock first described the *Mer de Glace* and triggered a flood of tourists. Famous visitors have included Goethe, Victor Hugo, Byron and Mary Shelley, who took inspiration from the scene in writing the novel *Frankenstein*. The first refuge at altitude in the Alps was built here in the 1780s by Charles Blair, to shelter visitors. A small hotel opened in 1840 (see Figure 1), which was replaced in 1880 by a much larger establishment which still operates today. The famous view looking out from Montenvers was beautifully captured by William England on his 1863 tour (see Figure 12). The 1741 description of a 'sea frozen solid in the middle of a violent storm' is still apt, with the tortured surface split by crevasses and pointed seracs.

A cog-railway reached Montenvers in 1909. Many local Chamoniards owned mules, which were rented out to tourists to transport them up the mountain, and therefore, they were initially violently against the train, believing it would reduce their income. The construction work was even sabotaged. But on its completion, the higher number of tourists it could accommodate greatly benefited the local economy. Some of the visitors were immortalised by Auguste Couttet in his view taken in around 1910 (Figure 13). The glacier is only slightly diminished compared with the 1863 view.

Fig. 9 Glacier des Bois viewed from Flégère, European Scenery, c.1865

The author's 2010 view of the train leaving Montenvers station (Figure 14) tells a different story. Instead of resembling a sea of ice, the glacier is covered in gravel and rock at the level of Montenvers and only looks like ice in its upper regions. The surface level is now over 150m lower than it was a century before and the bare walls of its exposed bed are readily visible.

On the right-hand bank of the *Mer de Glace*, opposite Montenvers, another popular vista is from the Chapeau. A small chalet has served snacks and drinks to tourists here since 1855. Back then, tourists used to take a mule up to Montenvers and then cross the glacier on foot, exiting it by the *Mauvais Pas* (the poor path), a narrow cliff path which gave access to the Chapeau chalet. Meanwhile your mule redescended to the valley and was brought up to meet you at the Chapeau, ready for your return to Chamonix. This excursion on the glacier gave rise to some of the most evocative tourist images of the Victorian era. The voluminous crinoline skirts worn by the ladies seem particularly unsuited to scrambling around on the icy surface (see Figure 15).

The view from the Chapeau (1576m) provides a different perspective to that from Montenvers (1913m), which is over 300m higher. Now you are looking out over the surface rather than looking down on the glacier. The standpoint from which Ferrier Père et Fils & Soulier captured the view in 1860 (Figure 16) is below the level of the surface of the glacier, which

Fig. 10 Glacier des Bois viewed from Flégère, Wehrli, c.1910

Fig. 11 Glacier des Bois viewed from Flégère, Author, 2015

Fig. 12 39 Mer de Glace from Montenvers, William England, 1863

cascades down towards the photographer. The Hotel Montenvers can be found on the dark, tree-covered promontory opposite. A 1900 view by Underwood & Underwood (Figure 17) has been taken from just above the chalet. The glacier level has fallen by a few tens of metres, confirmed by freshly exposed rock under Montenvers opposite. The author's view from 2015 (Figure 18) highlights the sorry plight of the retreating glaciers. No discernable glacier remains at the level of the Chapeau. Any ice is completely covered with gravel and rock. As the glacier shrinks it becomes sluggish and any material carried down accumulates on its surface. At this stage in a glacier's evolution, the aptly descriptive technical term is a 'dirty glacier'.

Human Contribution to Global Warming

As we look forward, the continuing relentless shrinking of the glaciers seems inevitable. On top of any natural climate variations, the impact of burning fossil fuels has increased the emission of carbon dioxide. This gas acts to block infra-red radiation from escaping the Earth, creating the 'greenhouse effect', which is contributing to global warming. Other gases, such as methane and water vapour, also contribute to the greenhouse effect; however, carbon dioxide accounts for over 80% of the impact. Figure 2 shows the measured level of carbon dioxide in the atmosphere over the past 1,000 years. Over this period, the average level has been around 280ppm, but over the past century it has increased by 50% to 420ppm. This

Fig. 13 Mer de Glace from Montenvers, Auguste Couttet, c.1910

can be fairly accurately measured by analysing tiny air bubbles trapped in ice cores drilled deep into the polar ice caps. Scientists estimate that carbon dioxide levels are now at their highest level for 10 million years and it could be decades for the full warming impact of the greenhouse effect to reach equilibrium.

The increased level of carbon dioxide and the resultant greenhouse effect has accelerated the natural cyclical recovery from the low temperatures of the Little Ice Age. Global temperatures have increased by over one degree compared with the average of the past century. Scientists have estimated the average temperatures of the past 1,000 years by looking at many different proxy measures including tree ring growth, ice core analysis, pollen analysis, marine sediment analysis, isotope ratio analysis etc. The estimates have been averaged by the 2 Degrees Institute in Graphic 3, which charts the temperature difference for each year compared with the 1,000-year average. The temperatures from around 1850 onwards are actual measured temperatures. Note the cool period during the Little Ice Age and the rapid increase over the past century, mirroring the build-up of carbon dioxide in the atmosphere. The data from Graphic 1. for the length of Glacier des Bois are added on the right-hand axis to show the strong correlation between temperature and length of glacier.

Fig. 14 Mer de Glace from Montenvers, Author, 2010

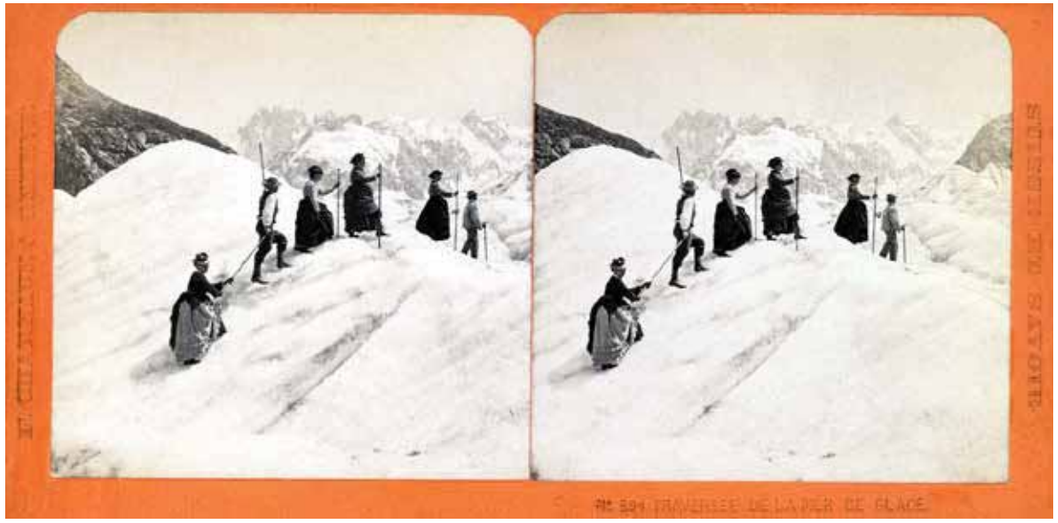
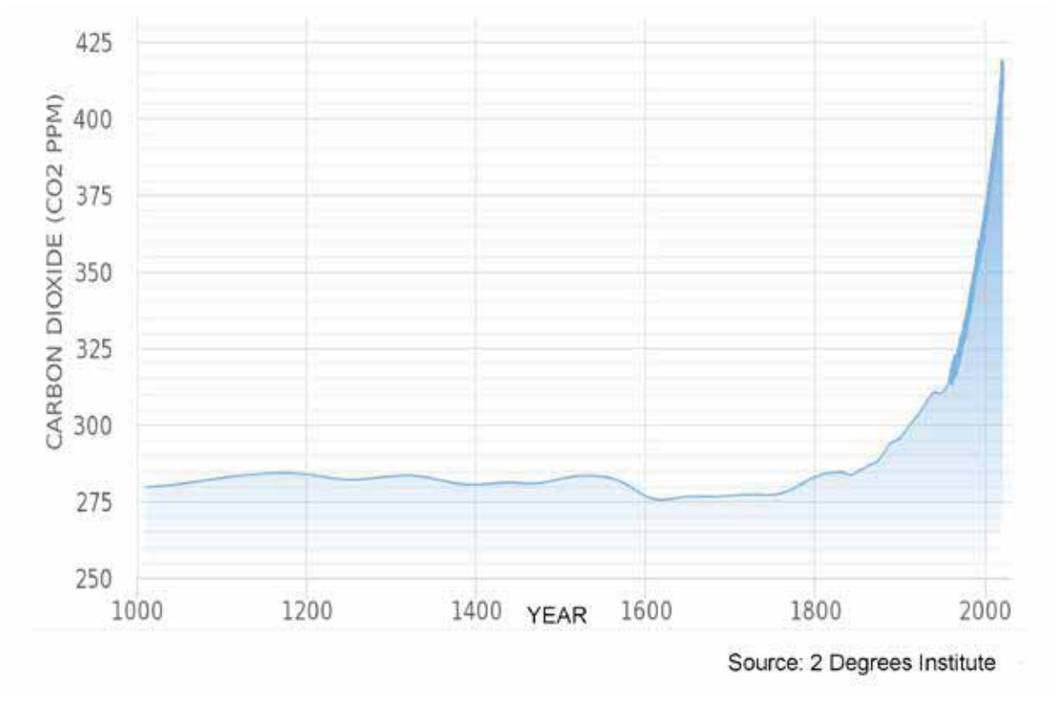


Fig. 15 Tourists on the Mer de Glace, Charnaux, c.1870

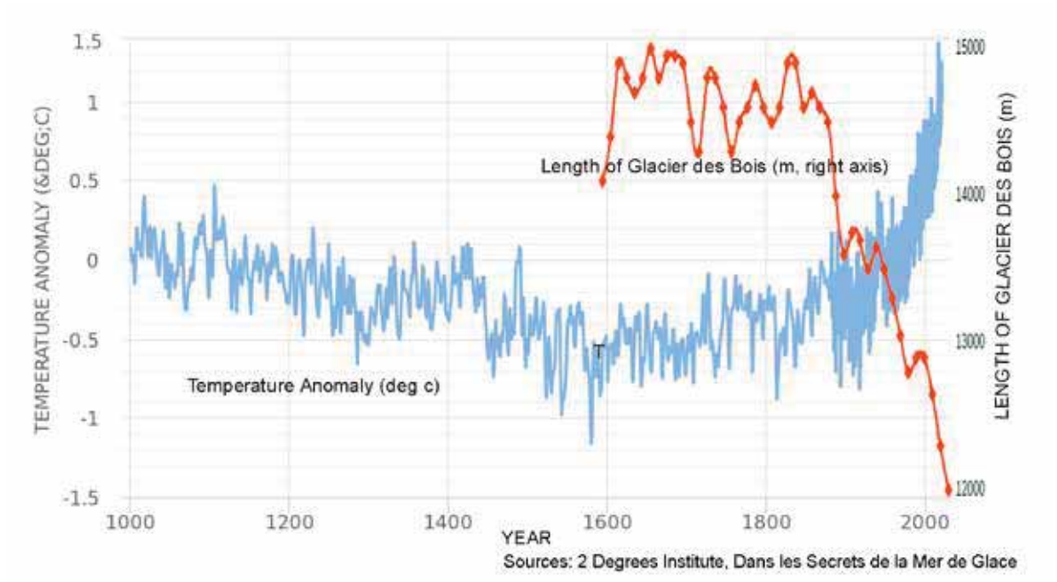
Fig. 16 Mer de Glace from the Chapeau, Ferrier Père et Fils & Soulier, 1861

Fig. 17 Mer de Glace from le Chapeau, Underwood, 1900

Fig. 18 Mer de Glace from le Chapeau, Author, 2015



Graphic 2 Level of carbon dioxide in atmosphere
in parts per million (ppm), Year 1000-2020



Graphic 3 Temperature anomaly compared with 1,000-year average (degrees c), years 1000-2020, length of Glacier des Bois (m), 1590-2020 (right axis)

Conclusion

Climate change has many potential consequences for our environment, but this paper will focus only on those associated with mountain glaciers, the loss of which could have multiple repercussions.

There is a direct economic impact on regions with glaciers. In addition to loss of amenity and a shorter season for skiers, alpinists note impairment of access and increased risk from rockfall. Tourism will be impacted, as a 'dirty glacier' is less attractive than a 'sea of ice'.

As glaciers retreat, they leave behind the gravel and rock entrained on their surface. This deposit is known as moraine. Frequently, lakes form behind moraine barriers. Lakes can also form in pockets trapped underneath melting glaciers. The natural dams holding back the water in each case are unconsolidated and fragile. They can collapse catastrophically with resultant flash floods. In 1892, a pocket of water under the

Fig. 19 Alan Alpenfelt setting up his 'Kaiser Panorama' display, Author, 2019

Tête Rousse Glacier in the Mont Blanc massif burst through and flooded the town of St Gervais, killing over 200 people. Although the glaciers of the Alps are well monitored to avoid the repetition of such a disaster, glaciers in the Himalayas or Andes are not. Further deadly flooding events are likely.

Glaciers act like a sponge, absorbing water during the winter and releasing it during the summer. Major European rivers, like the Rhone and the Rhine, are fed by glacier melt water in the summer. Without glaciers, summer river levels would be reduced and the movement of barge traffic constrained, and this is already being seen in summer months on the important Rhine waterway. Seasonal water shortages will become more common. Many hydro-electric stations depend on glacial melt water and there could also be an impact on nuclear power generation, because in France several nuclear power stations depend on river water cooling.

An increase in temperature of one degree in the course of our lifetime is imperceptible to a human. Therefore, a proxy measure has to be used to illustrate the significance of this change on the environment. The historic photographic record

Fig. 20 Mer de Glace from Montenvers, William England, 1863 and Alan Alpenfelt, 2019

documents the devastating impact of a one-degree change in temperature on alpine glaciers and therefore can be a useful visual tool for demonstrating global warming in action.

Appendix: Alan Alpenfelt's 'Binaural Views of Switzerland'

In 2019, inspired by the stereoviews from William England's tour of Switzerland in 1863, Swiss artist Alan Alpenfelt took the ideas in this article one step further.

Travelling by public transport, Alpenfelt followed in England's footsteps and identified the exact spots from which the historic images had been captured. He audio-visually recorded the scene today and created a multi-media virtual reality installation entitled 'Binaural Views of Switzerland'.

In addition to the modern binaural recording, he recreated an imagined sound-scape for 1863 for each location. The combination of aural and visual prompts provides a highly immersive experience which successfully transports the viewer back into 1863. It is with some shock that we return to the present and are confronted with the changes wrought by development and climate change on the Alps.

Part of the installation involves video clips from several of the locations. Video 1. provides a glimpse of Alpenfelt's portrayal of the *Mer de Glace* from Montenvers. The video camera is located in exactly the same position as William England's camera. Alpenfelt places himself in the foreground, matching the position of one of England's assistants. The modern scene fades to the 1863 scene and then back. The video provides a striking illustration of global warming in

Video 1 *Mer de Glace* from Montenvers, Alan Alpenfelt (2019) and William England (1863)

action; the volume of ice lost over the past 156 years is quite staggering.

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