

## **Part I: The history of the Mer de Glace AD 1570–2003 according to pictorial and written documents**

### *Summary*

Glacier fluctuations are sensitive indicators of climate variability. Glacier length, though an indirect and delayed signal of climate information, can yet be used for the examination of the glacier-climate relationship. At the end of the 19th century, the first accurate measurements of glacier length fluctuations were carried out. Unfortunately, the preceding time of the Little Ice Age (LIA) is not documented by instrumental data, and interdisciplinary approaches that use both historical and physical methods are needed to reconstruct the behaviour of glaciers back in time.

The Mer de Glace is a valley glacier 12 km long that is situated at the northern exposition of the Mont Blanc (France). Including all tributaries, it covers an area of about 32 km<sup>2</sup> and spans an altitudinal range from 1500 to 4000 m asl. It is the longest and largest glacier of the western Alps. During the LIA, the Mer de Glace nearly continuously reached the bottom of the valley of Chamonix at 1000 m asl. The attractiveness of the landscape and the easy accessibility soon made the glacier a desirable object of study for scientists, artists and tourists, leading to a large number of historical documentary data.

For the Mer de Glace, there exists a glacier length curve for the period from 1590 to 1911, made by Mougin (1912). Further investigations of glacier fluctuations during the late Holocene were made by Wetter (1987). The aim of the present study is to establish a revised and refined glacier length curve for the Mer de Glace, using newly available documentary data.

The analysis and interpretation of historical documents allows the determination of former glacier extents. Documents containing pictorial information on the glacier terminus (drawings, paintings, prints, photographs, and maps) as well as texts (descriptions of the valley, etc.) are used. A rigorous selection of the documentary data (e.g., dating of a painting) is necessary in order to get reliable information, including the comparison of an old picture with today's situation in the field. Excellent examples of glacier representations of the Mer de Glace are given by the drawings of Jean-Antoine Linck (1766–1843) and Samuel Birman (1793–1847), and the maps by James David

Forbes (1809–1868) and Eugène Viollet-le-Duc (1814–1879). Additionally, moraines have been mapped for the determination of former glacier extents.

The analysis of old topographical maps (from 1906, 1939, 1958, and 1967) and a photogrammetric evaluation of recent aerial photographs (from 2001) yield a detailed description of the present state of the glacier. The calculation of digital elevation models (DEMs) allows the quantification of volume changes for the Mer de Glace for the 20th century.

The revised and refined glacier length curve for the Mer de Glace goes as far back as 1570. Not surprisingly, the glacier shows a generally large extent during the LIA. The largest glacier extension, documented by several archive texts and moraines, occurred around 1644. The largest glacier advance in the 19th century culminated in 1821 and is roughly 40 m smaller than the 1644 advance. A second advance in the 19th century occurred in 1852, with the glacier still lying roughly 70 m behind the well-formed 1821 moraines. Other major glacier advances are documented around 1600, 1720, and 1778. Since the 1850s, the glacier has retreated more or less continuously (except for some minor advances, e.g. until 1995) by more than 2 km until the present-day. During the 20th century, the Mer de Glace shows a remarkable ice volume loss which mainly took place in the lower part of the glacier.

The new glacier length curve is in good agreement with the curve made by Mougín (1912). However, significant differences occur around 1850, when the glacier extent seems to have been much more extensive than assumed by Mougín. Furthermore, the new documentary data allows a more detailed description of glacier fluctuations for the 1750–1820 period. The glacier extension around 1644 is roughly 100 m smaller than shown by the Mougín curve.

A comparison of the Mer de Glace length curve with the one of the Unterer Grindelwaldgletscher (Zumbühl, 1980; Zumbühl et al., 1983) yields an astonishing simultaneity between the glaciers, despite the different settings in the western and central Alps. Small differences occur around 1855 (19th century maximum of the Unterer Grindelwaldgletscher) as well as between 1650 and 1750 (generally greater extension of the Mer de Glace with more variability). In order to further confirm the knowledge gained, it would be interesting to consider more Alpine glaciers, and also to extend the comparison by studying LIA glacier fluctuations in other parts of the world.