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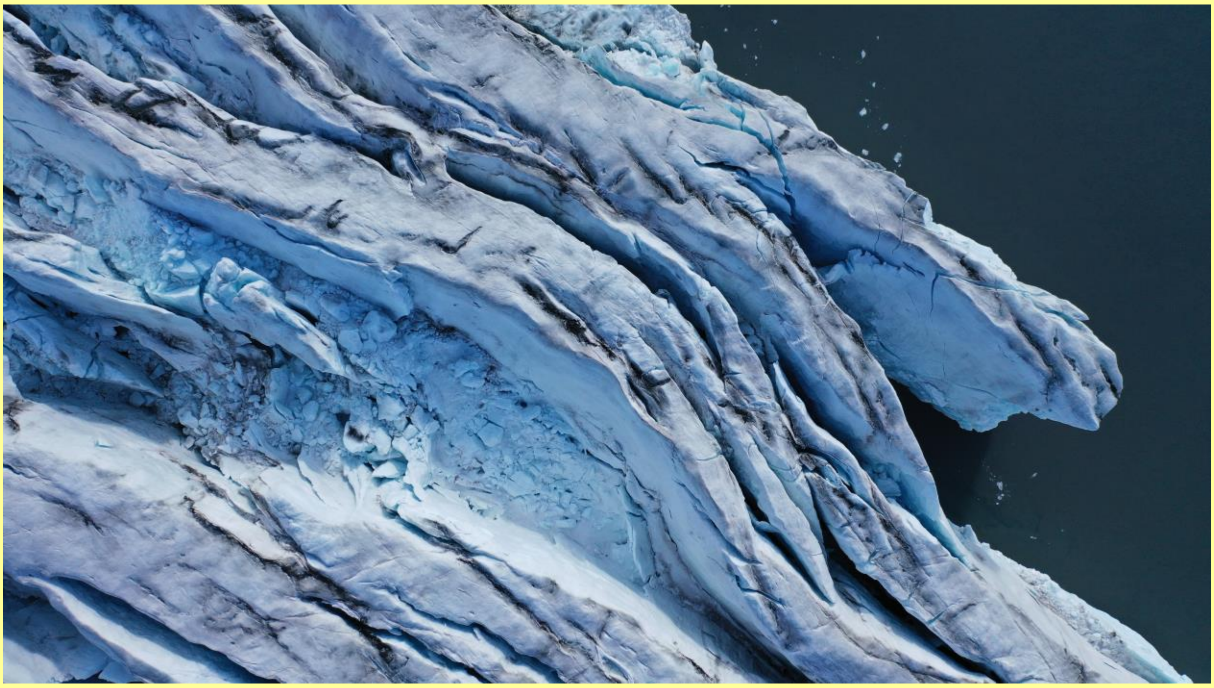

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Air Temperature Conditions in SW Greenland in the Period 1806–1813

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In this paper, we present preliminary research findings on the thermal conditions of south-western Greenland (based on data from Godthåb [now Nuuk]) for the period from 1 November 1806 to 16 August 1813 (Fig. 1). As part of the ongoing NCN research project titled “Reconstructions of climatic and bioclimatic conditions in Greenland and Labrador/Nunatsiavut ca. 1770 to 1939 from Moravian Missionary observations (MORCLIM)”, we discovered a handwritten manuscript (MA/154) in the archives of the Royal Society in London containing previously unknown meteorological measurements from Godthåb for the aforementioned period (Fig. 2). The meteorological observations were carried out by the German mineralogist Dr. Charles Lewis Giesecke (born Johann Georg Metzler [1761–1833]) (Fig. 3), or at least this is what the title page of the manuscript and the Royal Society catalogue describing the source suggests. However, given the numerous biographical accounts of his stay in Greenland (e.g., Monaghan 1993; Jørgensen 1996; Wyse Jackson 1996; Whittaker 2001), there is some doubt as to whether he conducted the meteorological observations alone. During that time, he undertook numerous research expeditions along the south-western coast of Greenland, from Upernavik in the north to Cape Farewell in the south. The purpose of these expeditions was geological research, particularly the collection of minerals. Someone must have been assisting him with the meteorological measurements, given that, over the six-year period (August 1807 – July 1813), there exists an almost complete series of observations taken three times a day (morning, midday, and evening). It is possible that the Moravian missionaries present in the area, who had extensive experience in conducting meteorological observations (Przybylak et al. 2024), were involved. Another possibility is that Giesecke conducted all his geological research during the first year of his stay in Greenland (as he had originally planned), and that, unable to return to Denmark due to the outbreak and continuation of the Napoleonic Wars (Whittaker 2001), he

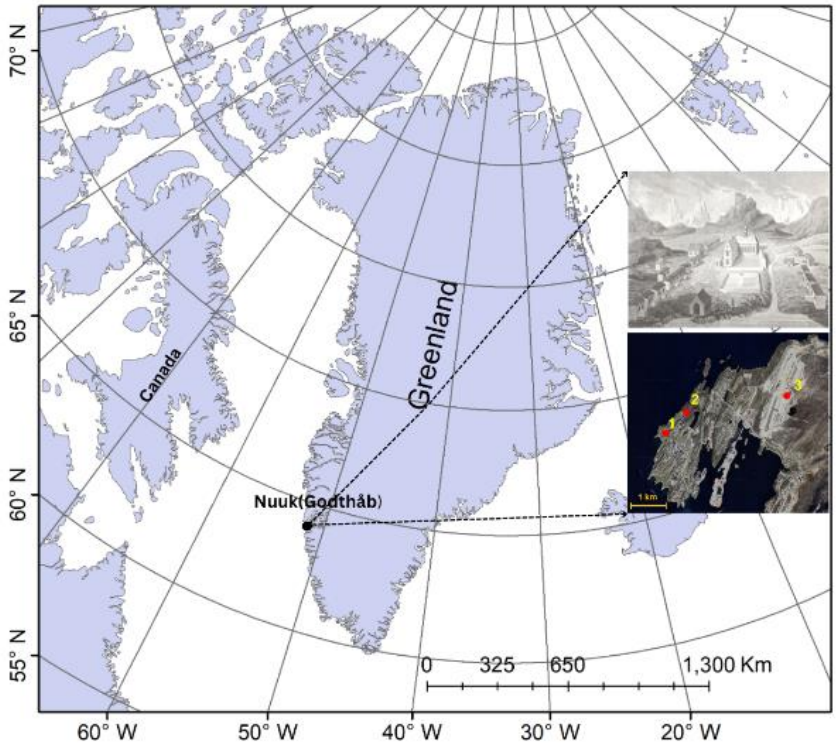

Fig. 1. Study area and location of historical and contemporary sites of meteorological measurements. Explanation: 1 – historical site Godthåb (1806–1813), 2 – 4250 Nuuk (1991–2020), 3 – 4254 Mittarfik Nuuk (2001–2020). Upper photo source: Neu-Herrnhut (Crantz 1820). Map data for location of sites: © Google Earth; images © 2023 Maxar Technologies, © 2023 Airbus, and © 2023 Asiaq.

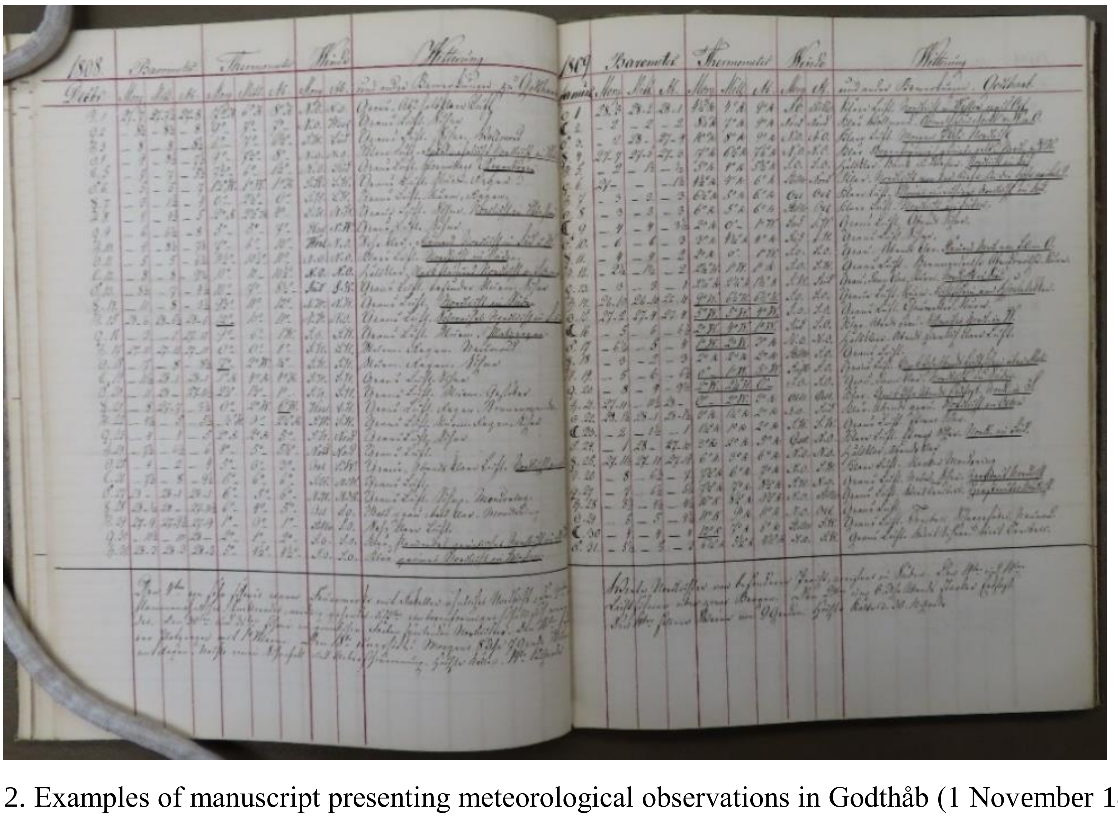

Fig. 2. Examples of manuscript presenting meteorological observations in Godthåb (1 November 1806 – 16 August 1813) (data presented in the manuscript: 1 December 1808 to 31 January 1809). Source: Archives in the Royal Society in London, MA/154.

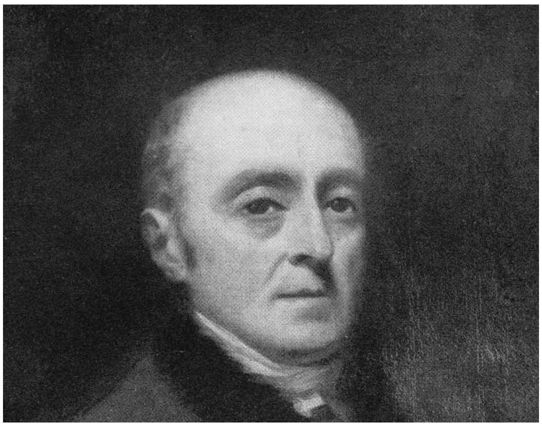

Fig. 3. Portrait of Sir Charles Lewis Giesecke (1761–1833), by the Scottish painter Raeburn (after Whittaker 2001).

decided to begin systematic meteorological observations starting in August 1807. He arrived in Greenland on 31 May 1806, and began meteorological observations only on 1 November 1806, which continued regularly until April 1807. From then until August, the observations were intermittent and irregular. It is therefore likely that he carried out his geological research during the periods of June–October 1806 and then May–July 1807.

As Fig. 2 shows, Giesecke conducted measurements and observations of the following meteorological elements: atmospheric pressure (morning and evening), air temperature (morning, midday, and evening), and wind direction (morning and evening). In addition, in the meteorological register, he briefly described the weather conditions for each day. At the end of each month, he also included a short summary of the weather conditions (at the bottom of the table of meteorological data). Unfortunately, the register does not provide information about the units used for the measurements, nor does it include details about the thermometer's exposure. It is assumed that the thermometer was placed on the north-facing wall outside the building where Giesecke lived. However, in the Arctic, where there is polar day during summer months, such placement does not fully eliminate the influence of solar radiation unless the thermometer is properly shielded.

In the article, we present the thermal conditions prevailing during that time. The unit used for air temperature measurements (°C) was determined by comparing the recorded values with parallel temperature observations conducted in another location in Godthåb during the years 1811–1812 (Vinther et al. 2006). The exact times of temperature measurements are unknown. Nevertheless, we calculated daily mean temperatures using a weighted average: $(T_{morning} + T_{midday} + 2 \times T_{evening}) / 4$. The obtained results were compared both with earlier temperature observations from the years 1784–1792 (Przybylak et al. 2024) and with later records, including modern observations from the period 1991–2020.

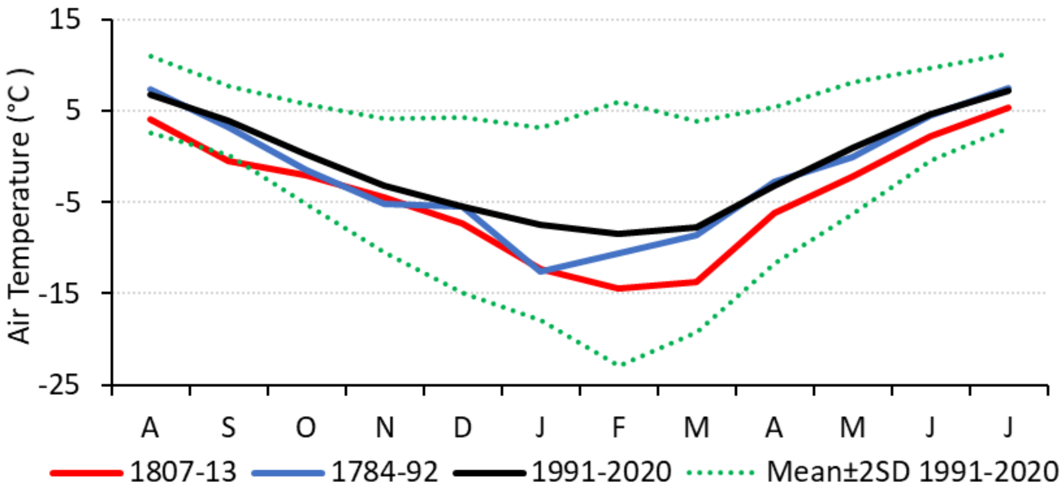

Fig. 4. Annual cycles of air temperature in the historical periods (1784–1792 and 1807–1813) and at present (1991–2020). Data for 1784–1792 taken from Przybylak et al. (2024).

Due to the irregularity of meteorological observations between 1 November 1806 and 31 July 1807, we present here an analysis for the period of regular observations, i.e. August 1807 – July 1813 (6 full years). The average annual temperature reached –4.0 °C, the coldest year was 1811 (–7.3 °C), and the warmest was 1809 (–1.8 °C). In the annual cycle, the coldest temperature occurred in February (–14.4 °C) and the warmest in July (5.3 °C) (Fig. 4). In the daily cycle, the highest average annual temperature was noted at midday (–2.1 °C) and the lowest in the evening (–5.1 °C). For all sub-daily measurement times, the warmest month was July, while the coldest was February (midday and morning) or March (evening). The highest temperature was observed on 16 July 1810 (18.5 °C), while the lowest was on 21–24 February 1812 (–36.5 °C). The temperature in the historical period was on average 3 °C colder than today (1991–2020). In the warmest month (July) in both comparative periods, this difference reached 1.7 °C, whereas in the coldest (February) it was 6.1 °C (Fig. 4). This was the greatest difference of all months.

Acknowledgments. We express our gratitude to the local Inuit communities in the south-western coast of Greenland, who probably cooperated with Sir Charles Lewis Giesecke in their lands in the 19th century, as well as to Narodowe Centrum Nauki (grant no. 2020/39/B/ST10/00653) for the financial support of our work.

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Inventory of Meteorological Records in the Labrador/Nunatsiavut and Southwestern Greenland Carried Out by the Moravian Brethren and their Successors Since the 18th Century

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As part of the National Science Centre research project entitled "Reconstructions of Climatic and Bioclimatic Conditions in Greenland and Labrador/Nunatsiavut ca. 1770 to 1939 from Moravian Missionary Observations (MORCLIM)", we visited numerous Moravian Church archives across Europe, including the Moravian Church House in Muswell Hill, London; the Unity Archives – Moravian Archives Herrnhut in Germany; and the Moravian Archives in Bethlehem in USA. Additionally, we consulted and checked several other archives and libraries where we suspected early instrumental meteorological data might be located for stations in southwestern Greenland and Labrador (see Fig. 1). A complete list of the archives and libraries visited is available on the project website: https://morclim.umk.pl/pages/research/.

During this preliminary archival research, we captured thousands of photographs of original handwritten manuscripts containing early instrumental meteorological data and weather notes (see Fig. 2), as well as secondary compilations of meteorological data found in 18th- and 19th-century scientific publications.

Many of these data, pertaining to air temperature, atmospheric pressure, as well as wind speed and direction, have already been transcribed, quality-controlled, and made available in the open data repository of the Centre for Climate Change Research (https://repod.icm.edu.pl/dataverse/ncu-cccr) under an open license, in accordance with the **FAIR** principles. Accordingly, the datasets by Demarée et al. (2023), Singh et al. (2023, 2024), and Chmist et al. (2024) are fully **F**indable, **A**ccessible, **I**nteroperable, and **R**eusable for further research and analysis.

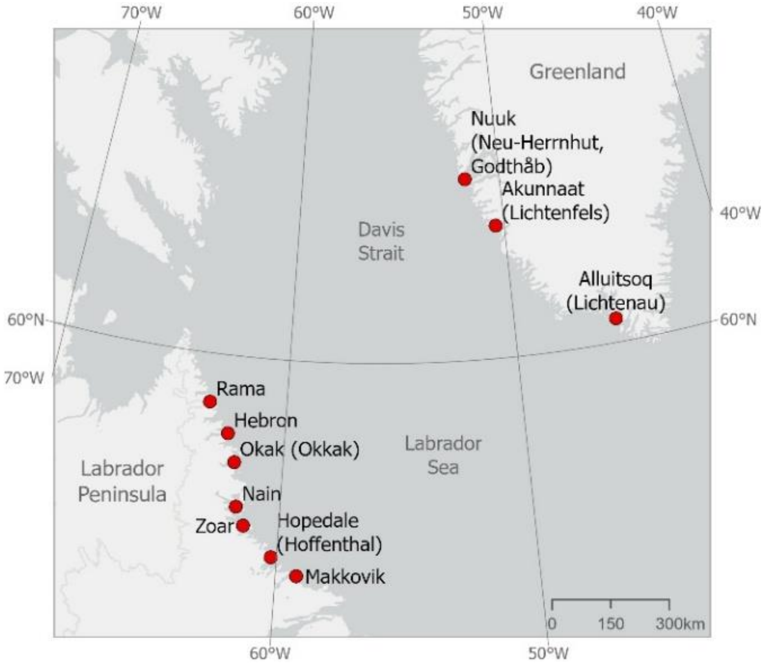

Fig. 1. Location of historical Moravian Brethren missions where meteorological measurements were carried out.

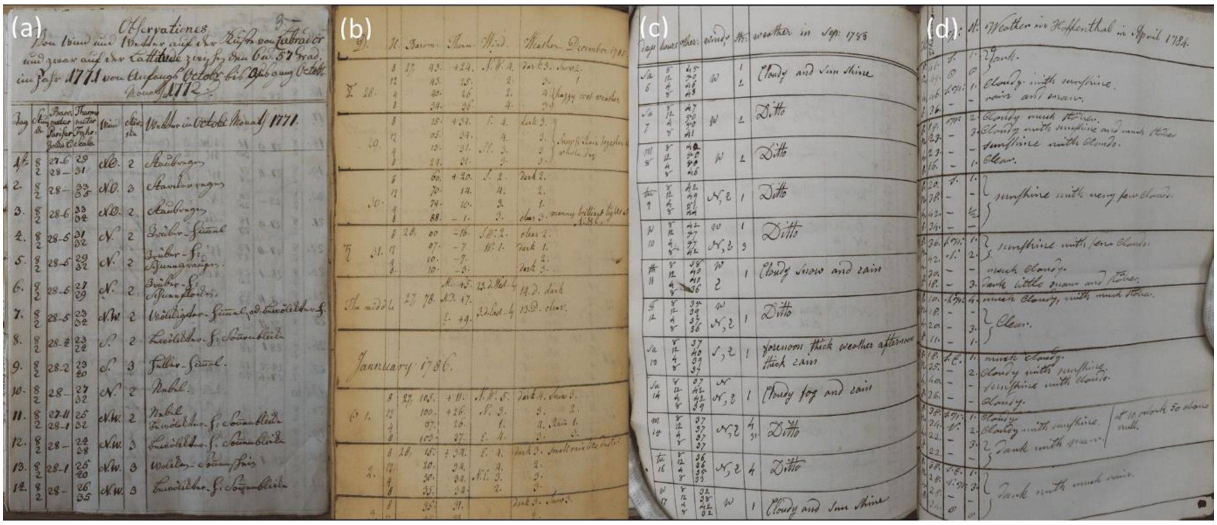

Fig. 2. Examples of manuscripts presenting meteorological observations: (a) Nain (1 October 1771 to 31 July 1786), source: Unitätsarchiv MDF.1817, the Moravian Archives in Herrnhut (Germany), data presented in the manuscript for 1 to 14 January 1771; (b) Nain (22 August 1777 to 31 July 1786), source: R.S.MA 143, The Archives of the Royal Society in London, data presented in the manuscript for 28 December 1785 to 11 January 1786; (c) Okak (1 August 1779 to 31 July 1784), source: R.S.MA 144, The Archives of the Royal Society in London, data presented in the manuscript for 6 to 17 September 1780; (d) Hopedale (1 October 1782 to 16 August 1786), source: R.S.MA 144, The Archives of the Royal Society in London, data presented in the manuscript for 25 March to 8 April 1784 (after Singh et al. 2025).

The oldest meteorological data series for southwestern Greenland and Labrador date back to the 18th century (see Fig. 3). For these series, we have detailed knowledge of their content, temporal coverage, and resolution. After the departure of the Moravian missionaries, meteorological observations in many of the aforementioned locations were continued throughout the 19th and 20th centuries by the national meteorological services of Denmark, Germany, and Canada. The data have been collected; however, they still require thorough cataloguing in terms of their content and potential use in further scientific research.

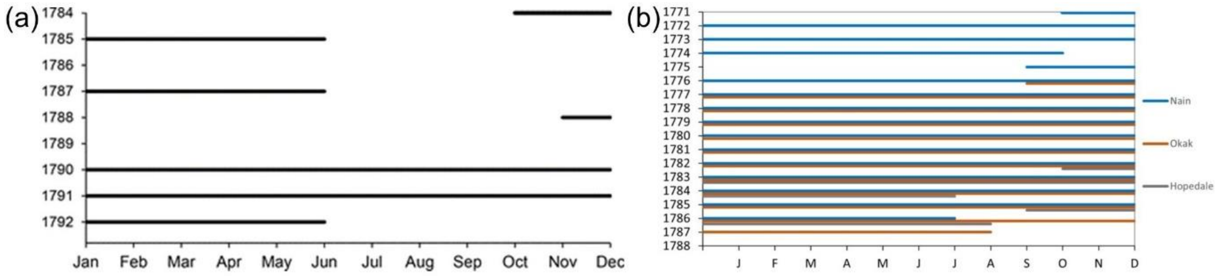

Fig. 3: (a) Coverage of air temperature data in Nuuk (previously Godthaab), 1784–1792 (after Przybylak et al. 2024) and (b) air temperature data availability for Labrador for the late 18th century (after Singh et al. 2025).

In this article, we present a detailed inventory of all archival materials collected to date containing early instrumental meteorological data for the coasts of Labrador and SW Greenland from the 18th to the beginning of the 20th century. This includes an in-depth analysis of their temporal coverage and observational gaps, the meteorological variables measured, and their resolution, as well as key metadata such as measurement methodologies, instruments used, observers, and other relevant contextual information.

Acknowledgments. We express our gratitude to the local Inuit communities of Nunatsiavut and the southwestern coast of Greenland, who welcomed the Moravian missionaries to their lands in the 18th and 19th centuries, as well as to the National Science Centre (grant no. 2020/39/B/ST10/00653) for financially supporting our research.

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Comparison of Contemporary Bioclimatic Conditions in SW Greenland Against Conditions in the Second Half of the 18th Century

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The specificity of Greenland's geographical environment and lighting conditions (polar day and night) causes the climate system in this region to differ significantly from other areas on Earth. Polar regions experience conditions that are very harsh for human life.

The paper estimates the bioclimatic conditions in the region of the modern-day capital of Greenland (i.e., Nuuk, formerly known as Godthåb or Neu-Herrnhut) in the second half of the 18th century. Nuuk is located in the SW coastal part of Greenland. Climate conditions at that time have already been analysed in a paper by Przybylak et al. (2024).

The present analysis was based on air temperature and wind speed data from sites of meteorological observations in this area, namely Neu-Herrnhut (1 September 1767 – 22 July 1768) and Godthåb (January 1790 – June 1792). The first series is the oldest available long-term series of instrumental measurements in the Arctic. Data for the year 1767/68 were obtained from the Moravian Archives in Herrnhut (Fig. 1). Thanks to this, it was possible to present the first bioclimatic conditions for humans in this region of the Arctic. The second series of meteorological measurements covers the period from January 1784 to July 1792, but, for the first years, wind speed measurements are either lacking or of low quality. Therefore, based on available data from this period, it is possible to calculate biometeorological indices only for the period 1790–1792. Data from this period were found in The Royal Library in Copenhagen in the manuscript *Astronomiske og Meteorologisk Iagttagelser, Anstillede i Godthaab i Grønland 1782–1792* (Fig. 1).

In the study, two biometeorological indices: Wind Chill Temperature (WCT) and Predicted Clothing Insulation (Iclp) have been used (Błażejczyk and Kunert 2011). These indices were computed using the BioKlima 2.6 software program (BioKlima 2024). Wind Chill Temperature (in °C) was used to examine apparent cold and to assess the risk of frostbite to the human body in Nuuk. The risk of frostbite according to WCT is as follows: low risk (0 to –9 °C), moderate risk (–10 to –27 °C), high risk (–28 to –39 °C), very high risk (–40 to –47 °C), severe risk (–48 to –54 °C) and extreme risk (–55 °C and colder) (WCT 2013). The predicted thermal insulation of clothing allows for the determination of the thermal insulation needed in given meteorological conditions to maintain the thermal balance of the body (Błażejczyk and Kunert 2011). Iclp was calculated assuming a metabolism of 135 W m^{-2} for a person moving outdoors at 4 km h^{-1}. With reference to the value of the Iclp index (in clo), the thermal environment assessment scale proposed by Krawczyk (2000) may be used: ≤ 0.30 very warm, 0.31–0.80 warm, 0.81–1.20 neutral, 1.21–2.00 cool, 2.01–3.00 cold, 3.01–4.00 very cold, > 4.00 arctic. Calculations of bioclimatic conditions were made for the hours 2–3 pm LT. The results from the historical period from the second half of the 18th century were compared with those for the contemporary period (1991–2000).

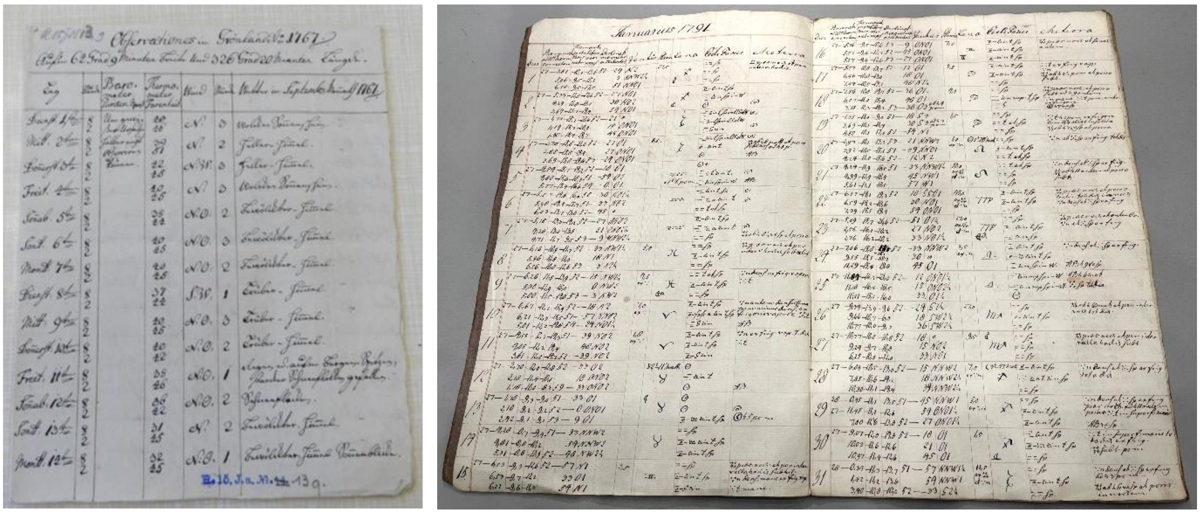

Fig. 1. Examples of manuscripts presenting meteorological observations: (photo on the left) for Neu-Herrnhut (1 September 1767 to 22 July 1768), source – MH R.15 J.a.13.9; and (photo from the right) for Godthåb (1782–1792), source – *Astronomiske og Meteorologisk Iagttagelser, Anstillede i Godthaab i Grønland 1782–1792* (Det Kgl. Bibliotek in Copenhagen; data presented in the manuscript: January 1791).

In the contemporary period, the mean monthly WCT values ranged from –11.4 ÷ –10.5 °C (moderate risk frostbite) in January–March, to 7.9÷8.8 °C (low risk frostbite) in July–August. The average historical monthly values of the WCT are in most cases between extreme values from the contemporary period. In the years 1789–1790 and 1790–1791, there was a higher risk of frostbite than the average from the contemporary period, whereas in 1767–1768 and 1791–1792 the risk of frostbite was lower. In the analysed historical period, the lowest winter values of WCT fell below –30 °C. As a result of low air temperature and high wind speed, the risk of frostbite was very high, i.e. exposed skin could freeze in 10 to 30 minutes.

In the years 1991–2020 in Nuuk, clothing with high thermal insulation properties was necessary for humans to achieve thermal comfort in motion (at metabolism = 135 W m^{-2}). In the annual course, the average monthly Iclp values ranged from 1.3 clo in July and August to 2.4 clo in February. On the other hand, a person who is motionless, i.e. standing (at metabolism = 70 W m^{-2}), needs about 5 clo on average in the winter months. Analysing the historical period in the second half of the 18th century in the years 1789–1792, a person living here required very similar thermal insulation of clothing as today. The only difference noted was that the weather in period 1767/1768 required, for a person in motion, about 0.3 clo less clothing than in the contemporary period.

Acknowledgments. We express our gratitude to the local Inuit communities in Nuuk, who welcomed Moravian missionaries to their lands in the 18th century, and to the National Science Centre (grant no. 2020/39/B/ST10/00653) for financial support of our research.

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