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More than Laki. Compound Climate Shocks and Icelandic Volcanism in the Nordic World of the 1780s

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Abstract. The article investigates the 1783–1784 Laki flood lava eruption as a case of regionally differentiated volcanic climate impacts and compound climate–society shocks in the Nordic countries. Drawing on recent advances in paleoclimate reanalysis (ModE-RA), early instrumental weather observations, dendroclimatology, and local environmental histories, it reconstructs seasonal and spatial patterns of climate anomalies and their societal repercussions from Iceland to Finland. A model–data comparison reveals marked regionality: while ModE-RA indicates pronounced post-eruption cooling from 1784 to 1786, instrumental and proxy evidence show strong sub-regional contrasts, including a preceding unrelated severe spring–summer drought in southern Scandinavia and notable discrepancies between ensemble simulations and observed autumn 1783 and winter 1783/84 temperature patterns. The study conceptualizes the Laki crisis as a compound event in the Nordic countries, in which volcanic cooling interacted with antecedent warmth and drought, atmospheric pollution, societal tensions, and institutional vulnerabilities. Pre-eruption drought and grain harvest failures in Denmark and southern and central Sweden,

eruption-related toxic haze and vegetation damage in Iceland, and subsequent cold seasons combined to produce cascading impacts on harvests, food prices, mortality, and social protest, with peak demographic and political effects lagging 2–3 years after the eruption and food crises. By systematically integrating "archives of nature" and "archives of society" across multiple Nordic polities, this study illustrates how an interdisciplinary climate history framework can capture the regional complexity of volcanic forcing and climatic anomalies, clarify tensions between models and observations, and explain divergent societal trajectories under compound climatic stress.

1 Introduction

Large volcanic eruptions of past centuries have recently drawn attention from scholars of climate and society. They provide insights into the causes of past climate variability as well as the workings of the climate system (Robock, 2000; Oppenheimer, 2011; Brönnimann et al., 2019; White et al., 2022). These eruptions can serve as palaeoclimatological experiments, leaving distinct signatures in climate proxies (Sigl et al., 2015; Zhu et al., 2020; Stoffel et al., 2022). Moreover, they provide case studies for climate–society interactions, inviting synchronic comparisons of societal impacts, responses, and resilience across communities (Büntgen et al., 2026). One such event is the Laki flood lava eruption of 1783–1784, also known as the Skaftá Fire (Icelandic: *Skaftáreldar*), which was one of the largest Icelandic eruptions of the past two millennia (Thordarson and Self, 2003; Morison et al., 2024). While its global climatic and societal effects have been previously studied (Zambri et al., 2019 a/b), recent advances in paleoclimatology and historical climatology now enable increasingly high-resolution reconstructions of the eruption's regional climatic, ecological, and societal impacts.

This study undertakes a comparative, regional-scale examination of the Laki flood lava eruption and its effects with a focus on the Nordic countries. This region provides an exceptionally rich body of high-quality data sources, where natural proxies (tree-rings, etc.) and extensive societal records (weather observations, historical records) can be sampled in close proximity to each other. Its diversity of geographical and societal settings allows for comparative approaches that reveal both shared patterns and important internal variability. Following an integrated 'more-than-Laki' perspective, this article addresses climatic and ecological effects alongside societal responses using high-resolution spatial and temporal sources and climate modelling. Through a comparison of physical and written evidence, we examine instrumental observations and diverse proxies that capture the eruption's climate impact as well as current paleoclimate reanalyses (ModE-RA) to understand its impact at regional and local levels. Building on these results, the study provides a new analysis of the eruption's ecological and societal impacts, including the mediating roles of concurrent climate anomalies, political and economic institutions, cultural responses, and historical contingencies. This study addresses ongoing challenges in the study of the Laki fissure eruption including discrepancies between tree ring-based data and instrumental observations in the eruption year, divergences between hemispheric and local climate effects, the interaction of internal climate variability and volcanic forcing. Finally, it explores how a regional approach can help us understand divergent societal responses across the Nordic countries.

2. The Laki Flood Lava Eruption: European and Global Studies

As a major, relatively recent, and well-documented event, the Laki eruption has attracted considerable research. While the eruption was still ongoing, contemporary scholars felt compelled to investigate its causes, effects, and consequences. A local Icelandic priest, Jón Steingrímsson, left a detailed record of the event and its aftermath in his so-called fire treatise (*eldrit*). He described how the "fires were so tremendous that the flames could be seen over the peak[s]" of the mountains, how the plume formed a persistent "black cloud," and how the fallout "gave the grass a hard shell" leaving animals and humans to starve. In Bergen (Norway), observers recorded "a poisoning of the air and withering of the grass." They also documented longer-term climatological effects such as the "sharp frost, so biting and piercingly cold" that followed the eruption "because of the vapours from the fire which were still in the air" (Steingrímsson, 1998).

These observations are consistent with modern reconstructions of the Laki eruption based on sediments, magma, ash, and other proxy data as well as climate model simulations of volcanic climate impacts. These have shown that such major volcanic events can inject large amounts of sulphuric gases such as sulphur dioxide (SO_2) into the atmosphere. These gases form aerosols that affect the Earth's energy balance through their chemical, optical, and radiative properties (Robock, 2000; Timmreck, 2012; Kremser et al., 2016; Zambri et al., 2019a,b; Marshall et al., 2025). Large sulphur-rich eruptions induce surface cooling during the following couple of years, as well as changes in atmospheric circulation, precipitation, and air quality (Witham and Oppenheimer 2004; Iles et al. 2013; Erez and Adam, 2021). Although large tropical eruptions may induce sustained ocean-atmosphere feedbacks that influence global climate for up to decades (Miller et al., 2012; van Dijk et al., 2022), the effects of high-latitude eruptions are confined to the same hemisphere and only for a few years, even when they trigger sea-ice feedbacks (Schneider et al., 2009; Slawinska and Robock, 2018; Toohey et al., 2019; Fuglestvedt et al., 2024; Zhuo et al., 2024).

While the Laki flood lava eruption of 1783–1784 exhibited some atypical elements, it largely conforms to these patterns. It was a basaltic flood lava eruption with explosive phases accompanied by lava fountains and lava flows along the fissure vent. These released large amounts of ash, sulphur, and halogens into the atmosphere over an extended period of eight months (Thordarson and Self, 2003; Thordarson and Larsen, 2007; Zambri et al., 2019a,b; Morison et al., 2024). The southwest segment of the 27 km-long Laki fissure is visible in Figure 1. In total, an estimated 120 Tg SO_2 (6 to 10 times more than the 1991 Pinatubo eruption) were released from 8 June 1783 until 7 February 1784. Of this total, an estimated 94 Tg SO_2 reached the lower stratosphere (at 9–13 km altitude) within the ten explosive phases (Thordarson & Self, 2003). Alongside the c. 939 CE Eldgjá flood lava eruption (also in Iceland), the 1783–1784 Laki flood lava event ranks among the largest known volcanic sulfur emitters during the Common Era (Toohey & Sigl, 2017; Morison et al., 2024; Fuglestvedt et al., 2025). It is identifiable in ice cores across the Arctic region through distinctive anomalies in the concentrations of sulphuric acid, chlorine, and heavy metals, as seen in Figure 2 (Sigl et al., 2013; Gabriel et al., 2024).

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Figure 1: Southwest segment of the Laki fissure in Southern Iceland, showing the series of volcanic craters and vents with their basalt lava deposits from the top of Mt. Laki (photograph, 12 August 2025, Dominik Collet).

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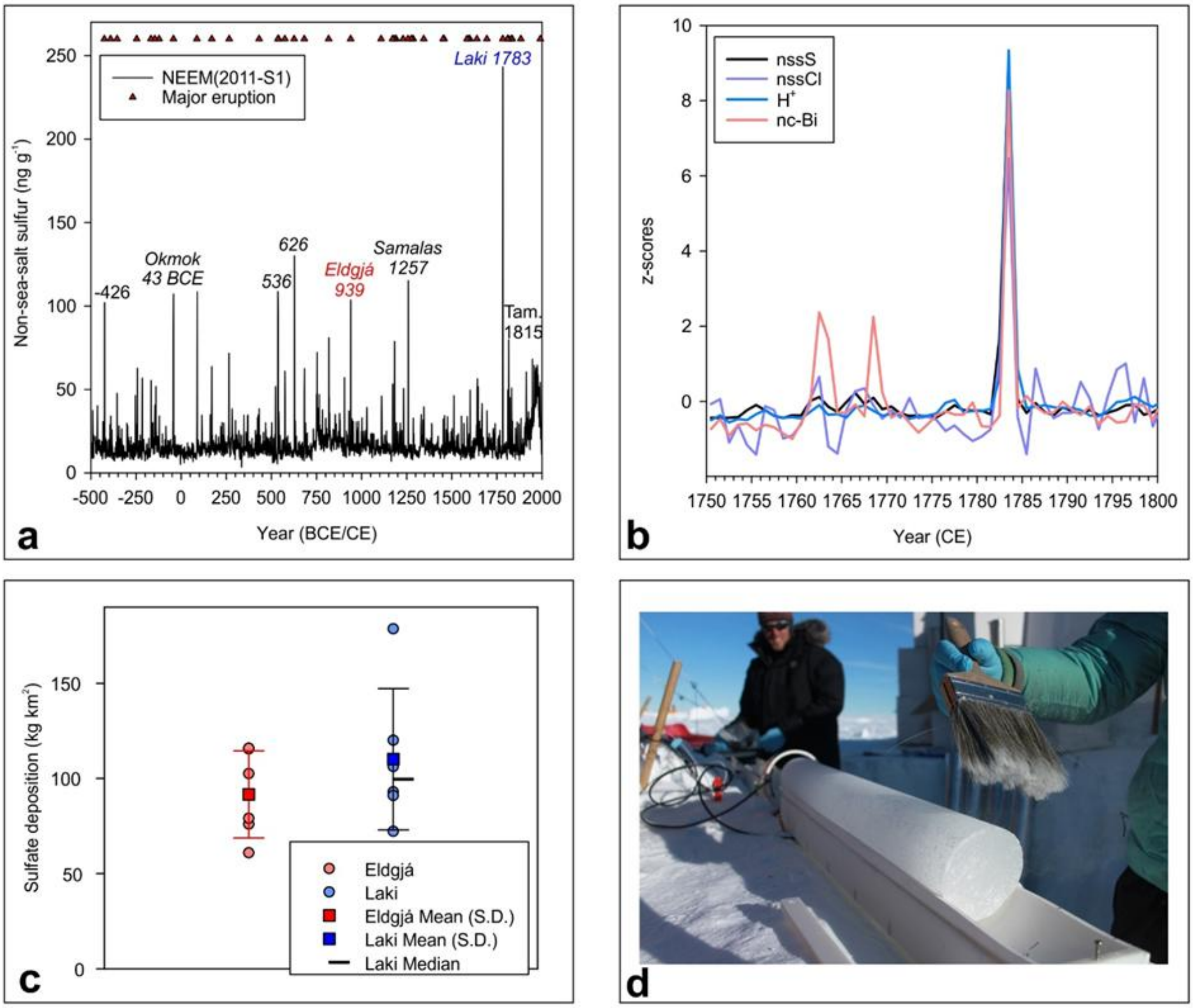

Figure 2: Greenland ice-core records of the 1783 Laki eruption, a: NEEM(2011-S1) annual non-sea-salt sulfur (nssS) concentrations for the past 2,500 years (Sigl et al. 2015), highlighted are all major eruptions (i.e. with stratospheric sulfur injection ≥Pinatubo 1991) (Toohey and Sigl 2017) and selected very large eruptions in 1815 (Tambora), 1257, 939 (Eldgjá, Iceland), 626, 536 CE, 43 BCE and 426 BCE for comparison, b: standardized Greenland composite (N=6) annual concentration records of nssS, non-sea-salt chlorine (nssCl), acidity (H+), and noncrustal bismuth (nc-Bi) between 1750 and 1800 CE (Gabriel et al. 2024), c: ice-core volcanic sulfate deposition in Greenland following the Icelandic flood-lava eruptions of Eldgjá and Laki (Fuglestvedt et al. 2025). Ice-core records from the same six sites (NEEM, NGRIP, Summit, NGT-B19, TUNU and EGRIP) have been stacked to estimate mean sulfate deposition at these sites. Median concentrations are provided for Laki. Adapted from Fuglestvedt et al. (2025); d: electrical conductivity (a proxy for volcanic fallout) is measured in the field on the TUNU2013 ice core (Source: Michael Sigl).

Historical sources and observations add further detail to the physical reconstruction of the Laki eruption and report on the societal consequences in Iceland and throughout Europe. Contemporary documents include: administrative and economic records; personal sources such as weather diaries, letters, and newspaper articles; literature such as songs, sermons, and poems; and a pictorial and epigraphical record focused on the ensuing floods (Brázdil et al., 2010). The eruption is also captured in a unique record of early meteorological observations, some inspired by the eruption's unusual effects. Many measurements relate to the founding of the first global observation network administered by the Societas Meteorologica Palatina (Collet, 2025a). These sources detail unusual warmth and drought in Europe during summer 1783 followed by persistent cooling and heavy precipitation from the winter of 1783 up to 1784–1786 (Kington, 1978, 1988; Thordarson & Self, 2003; Luterbacher et al., 2004). There has been some speculation about the initial hot summer being volcanic in origin, not least due to the visible and persistent presence of volcanic fog or haze. However, the dramatic climatic swings are currently best explained as the progression from unrelated internal climatic variability (initial summer warming) to volcanic forcing (surface cooling) (Zambri et al., 2019b;).

Research on the societal impacts of the eruption has largely concentrated on its immediate effects in Iceland and its repercussions at large scales across Europe and other world regions. In Iceland, lava flows damaged farms and churches near the Laki fissure. Throughout the country, volcanic gases and tephra contaminated water and vegetation, poisoning livestock and people (Thordarson and Self, 1993; Thordarson and Self, 2003; Figure 1). The ensuing "famine of the mist" (*móðuharðindin*) is remembered as one of the deadliest disasters in the island's history (Gunnlaugsson, 1984; Vasey, 1991; Demarée & Ogilvie, 2001; Wieners, 2020; Gunnarsdóttir, 2022; Wieners and Hálfdanarson, 2024). Studies of continental Europe have emphasized negative effects on vegetation and human health, particularly respiratory diseases (Grattan and Pyatt, 1994; Santel, 1997; Durand and Grattan, 1999; Thordarson and Self, 2001; Schmidt et al., 2011; Casey et al., 2019; Kleemann, 2023). Further research has examined the signature ice drifts and floods associated with the extreme winter of 1783/84 (Demarée, 2006; Brázdil et al., 2010; Degroot et al., 2021; Kleemann, 2023; Kleemann and Mseba, 2024). Studies of the eruption's impacts within a national framework include Britain (Michnowicz, 2011; Hellman, 2021), France (Courtillot, 2005; Grattan et al., 2005), the Low Countries (Demarée, 1997), the Czech Lands (Brázdil et al., 2017), Alaska (Jacoby, Workman, and D'Arrigo, 1999), Egypt (Mikhail, 2015), and Germany (Hochadel, 2009; Kleemann, 2022a, 2023). A few studies have followed a comparative approach, examining the eruption's effects across societies and cultures (Oman et al., 2006a/b; Schmidt et al., 2010; Damodaran et al., 2018; Zambri et al., 2019a/b) or its impact on the history of science and ideas (Kleemann, 2023). In the Nordic countries (outside Iceland) studies of the eruption's consequences have investigated single phenomena such as demographic crises (Sogner, 1978; Dybdahl, 2016; Casey et al., 2019) or impacts on agriculture (Gundersen, 2025), and more recently, the interconnected agricultural, economic, and demographic effects of the eruption across southern Sweden (Skoglund & Svensson, 2026). However, a comprehensive assessment integrating climatic, ecological, and historical consequences across a broader Nordic regional scale is still lacking.

3. Sources and Methods

This study combines paleoclimate modeling, instrumental observations, paleoclimate reconstruction, and historical climatology to arrive at a more comprehensive understanding of the Laki fissure eruption and its impacts in the Nordic countries. Integrating "archives of nature" and "archives of society" (Brönnimann et al., 2018; Ebert & Kleemann 2025), it connects physical evidence including multiple proxies from the growth rings of trees with instrumental observations, phenological evidence as well as demographic, administrative, and societal records. While we cover all of the Nordic countries, we focus on Norway and Sweden in particular to highlight their divergent experiences.

3.1. Early meteorological observations

Several systematic meteorological observations in the Nordic countries cover the period of the Laki eruption and surrounding decades. The Uppsala temperature series began in 1722, with Lund and Stockholm following in 1752 and 1754–1756, respectively (Moberg & Bergström, 1997; Bergström & Moberg, 2002; Skoglund, 2022). For Denmark, Peder Horrebow (1728–1812) started his instrumental observations in 1751 in Copenhagen at Rundetårn (Frich et al., 1996; Cappelen, 2010). Beginning in 1780, Thomas Bugge (1740-1815) expanded with stations across Danish territories, including Iceland and Norway (Ramanujam & Thode Jensen, 2020), and supplementary records from the Faroe Islands between 1781 and 1782 (Svabo, 1959). Instrumental observations in Finland, then a part of the Swedish Kingdom, include: Tornio (Torneå), where measurements began in 1737, marking one of the northernmost early meteorological records in the region (Klingbjer & Moberg, 2003; Luoto et al., 2013); Turku (Åbo) in 1748, an important early urban observation site on the southwest coast (Luoto et al., 2013; Lundstad et al., 2025); and Oulu (Uleåborg) in 1776, located by the Gulf of Bothnia (Klingbjer & Moberg, 2003). Of the Finnish early instrumental data only the Oulu observations are included in the ModE-RA dataset. Norway's early instrumental climate record includes Trondheim, where Johan Daniel Berlin's (1714–1787) systematic observations began in 1762, followed by those of Diderich Christian Fester (1732–1811) until 1802 (Birkeland, 1949). Starting in 1783, as part of the Societas Meteorologica Palatina (SMP) network, Jacob Nicolaj Wilse made thrice-daily measurements of temperature and air pressure in Spydeberg, near Oslo, and these provide one of the earliest series for inland southeastern Norway (Winkler, 2023). These data have been normalized, corrected for instrumental errors and converted into daily means (Pappert et al., 2021). However, there was a growing interest among Norwegian intellectuals and officials for meteorology in the 1780's, and several others conducted measurements and/or visual observations on their own initiative before, during, and after the Laki years. They were recorded at Øvre Eiker, at Østre Toten, Trysil, and Seljord—all sites in southeastern Norway (Wishman, 2007).

3.2. Tree-ring Records

We investigated regional climatic impacts using tree-ring chronologies from present-day Norway, Sweden, and Finland, as detailed in Table S1 in Appendix. The network of tree-ring chronologies extends north of 64°N in Norway and Sweden and north of 66°N in Finland, thus including regions not covered by instrumental observations. Previous studies have demonstrated that, in addition to being sensitive to climatic variations, tree-ring based data also correlates with local harvest data and other important ecosystem parameters (Babst et al., 2014; Huhtamaa et al., 2017; Skoglund, 2022, 2023; Buschwal et al., 2025; Skoglund & Ljungqvist, 2026). Twelve of the chronologies employed in this study are growing season temperature reconstructions based on tree ring width (TRW), maximum latewood density (MXD), and blue intensity (BI) (Esper et al., 2012; Gunnarson et al., 2012; Björklund et al., 2013; McCarroll et al., 2013; Björklund et al., 2014; Helama et al., 2014; Zhang

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et al., 2016; Fuentes et al., 2018; Linderholm & Gunnarson, 2019; Svarva et al., 2026, Khumalo et al., in preparation). Six chronologies are late spring and summer precipitation or drought reconstructions (Helama et al., 2009; Jönsson & Nilsson, 2009; Seftigen et al., 2015; Rocha et al., 2020; Stridbeck et al., 2026). Many of these reconstructions were included in ModE-RA and were included here to assess the spatial variability of ecological responses to the Laki eruption, enabling comparisons along a north–south transect and between coastal and continental environments. All the chronologies were created using detrended and dated tree-ring series, the details of which are found in the corresponding references. The temperature sensitive chronologies were then standardized (z-scored) relative to the 1733–1782 mean and standard deviations. The reference period for precipitation sensitive trees is from 1734 to 1782, since this is the longest common period before the eruption. These chronologies reflect varying seasonal sensitivity of different tree-ring parameters. In general, the MXD (and BI) chronologies in this study are more sensitive to the broader summer season (April–August), while TRW chronologies are more sensitive to a narrow window of July–August.

3.3. Paleoclimate Reanalysis

To further investigate the climatic responses, we utilize Modern Era (ModE) climate reanalysis products: ModE-SIM, ModE-RA, and Mode-RAclim (Valler et al., 2024). These reanalyses are widely used to assess climate variability and its drivers over the past 500 years, including volcanic eruptions (Brönnimann et al., 2024; Brönnimann et al., 2025; Gabriel et al., 2025; Brázdil et al., 2026; He et al., 2026; Skoglund and Ljungqvist, 2026; Warren, 2026). ModE-SIM is an ensemble of global climate simulations driven by external radiative forcings covering the period 1422–2009. It is based on a medium-sized ensemble of simulations with the ECHAM6 atmospheric general circulation model (Hand et al., 2023). It is also the basis for ModE-RA: a three-dimensional reanalysis product with a monthly resolution using an offline data assimilation approach that combines information from early instrumental measurements, paleoclimate proxy data, and historical documentary records with the ModE-SIM ensemble members (Valler et al., 2024). The latest product, ModE-RAclim, emphasizes the instrumental and proxy data and minimizes the influence of climate models on its output. Whereas ModE-Sim and ModE-RA will both include the model response to volcanic forcing, in ModE-RAclim the climatic response will exclusively result from the observations (Warren et al., 2024). In this article we will base our analyses on ModE-RA unless otherwise specified.

3.4. Demographic records

Starting in 1749, the Swedish state used standardized forms distributed to local parish priests to systematically collect statistics of marriages, births, and deaths sorted by gender, age, and marital status (Castenbrandt, 2014). The institution responsible for the collection was named *Tabellverket* (Eng. Tabular Commission). By the 1780s, this collection covered most of Sweden, including present-day Finland, enabling the calculation of crude death rates ‰ (CDR) and excess mortality at national and regional levels (e.g., southern Sweden). In many cases, descriptions of local harvest conditions and grain prices were included in these reports (see Skoglund, 2024). We also considered reports from dioceses in Finland, then part of the Swedish Kingdom.

In Denmark-Norway (then a dual monarchy), parish registers of births, deaths, and marriages together with later compilations in national statistical series enable reconstruction of crude death rates for the 1780s, including regional variations (e.g., the Trondheim, Agder, and Oslofjord districts relative to western and northern Norway) (Drake, 1969; Sogner, 1979). These series may be compared with food price and trade data and with information on causes of death (e.g., smallpox, dysentery, or "strong fevers") where such information is available in order to analyze peaks in mortality in relation to harvest failures and disruption of grain imports (Sogner, 1976; Herstad, 2000; Eitrheim et al., 2022).

For Iceland, serial parish data are fragmentary. Nevertheless, existing reconstructions of population size and mortality—based on parish registers, Danish administrative material, and contemporary narratives—provide estimates of the scale and timing of the population loss during *móðuharðindin* (Gunnarsson, 1984; Vasey, 1991; Wieners, 2020; Gunnarsdóttir, 2022; Wieners, 2024). In all cases, we interpret these quantitative indicators in conjunction with qualitative evidence on famine, migration, and disease to distinguish between direct climatic effects and impacts mediated through food shortages and epidemic outbreaks.

3.5. Narrative and Phenological Records

The visible haze, turbulent weather, and natural hazards that followed the Laki fissure eruption captured the attention of contemporaries, making this event one of the best documented pre-modern climate anomalies in the Nordics (Thordarson & Self, 2003). Many local observers included descriptions of agricultural impacts, phenology, and wind direction as well as the dry fog, unusual odor, and damage to vegetation possibly related to the eruption. These observers included the governor of Iceland Magnus Stephensen (Stephensen, 1785) and priests, such as Johan Nordal Brun in Bergen (Døhl, 1945), Sæmundur Magnússon Hólm in Copenhagen (1783, published in English as Hólm, 1799), and Eric Ångman in Föllinge, Jämtland (Ångman, 1793). Some of these priests mixed diligent naturalist observations with religious interpretations. The impacts of these turbulent years were also reflected in popular culture, such as the broadside ballad (*skillingsvise*) "On God's Great Punishment, which in 1784 affected the whole of Northern Norway, when the Grain Crop […] was Spoiled by the Cold and ruined entirely" (Tiendeboen, 1785). In addition, a variety of farmers kept weather diaries that hold important information (Lundstad, 2004). Together, these sources impart a fine-grained picture of societal perceptions, interpretations, and response to climatic anomalies of the 1780s in the Nordic countries. We have employed them in this study to contextualize and cross-check the harvest and population records and to reconstruct local experiences of famine, disease, and social protest.

4. Results

4.1. Climatic Impacts

To evaluate climatic and ecological impacts of the eruption in the following section we are using instrumental records, tree-ring records, narrative records, and ModE-RA data. Instrumental records and ModE-RA data indicate an unusually warm summer (June–August) throughout Fennoscandia in 1783 (see e.g. **Figure 3**), at a time of dry conditions and harvest failures

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in southern Norway and Sweden. Northern tree-ring maximum latewood density chronologies—a proxy for summer temperatures—show lower density in 1783, which in some studies has been attributed to the adverse effects of the high atmospheric sulphuric aerosol burden on plant growth (Edwards, et al. 2022; Kleemann, 2022b). Reports to *Tabellverket* in parishes in northernmost Sweden describe warm conditions during early summer, but with a sharp cold spell and night frosts beginning in late July (e.g., Nederkalix Church Archives, 1783). ModE-RA—which includes data from instrumental and written observations as well as tree-ring proxies (see **Table S2, S3 Figure S1-S2** in Appendix)—shows warm conditions prevailing over central and southern Scandinavia during summer 1783 and cooling limited to northern latitudes (**Figure 3**) which lack local instrumental data coverage. The winter of 1783–1784 reflects similar regional diversity, with a cooler southern Fennoscandia and slightly warmer winter in the northern regions. This is followed by a drastically cooler spring throughout Fennoscandia and a cool summer of 1784. Temperatures remained below average during most months and seasons through 1786 (**Figure 3**), whereas no clear trend emerges for large-scale precipitation anomalies (**Figure 4**).

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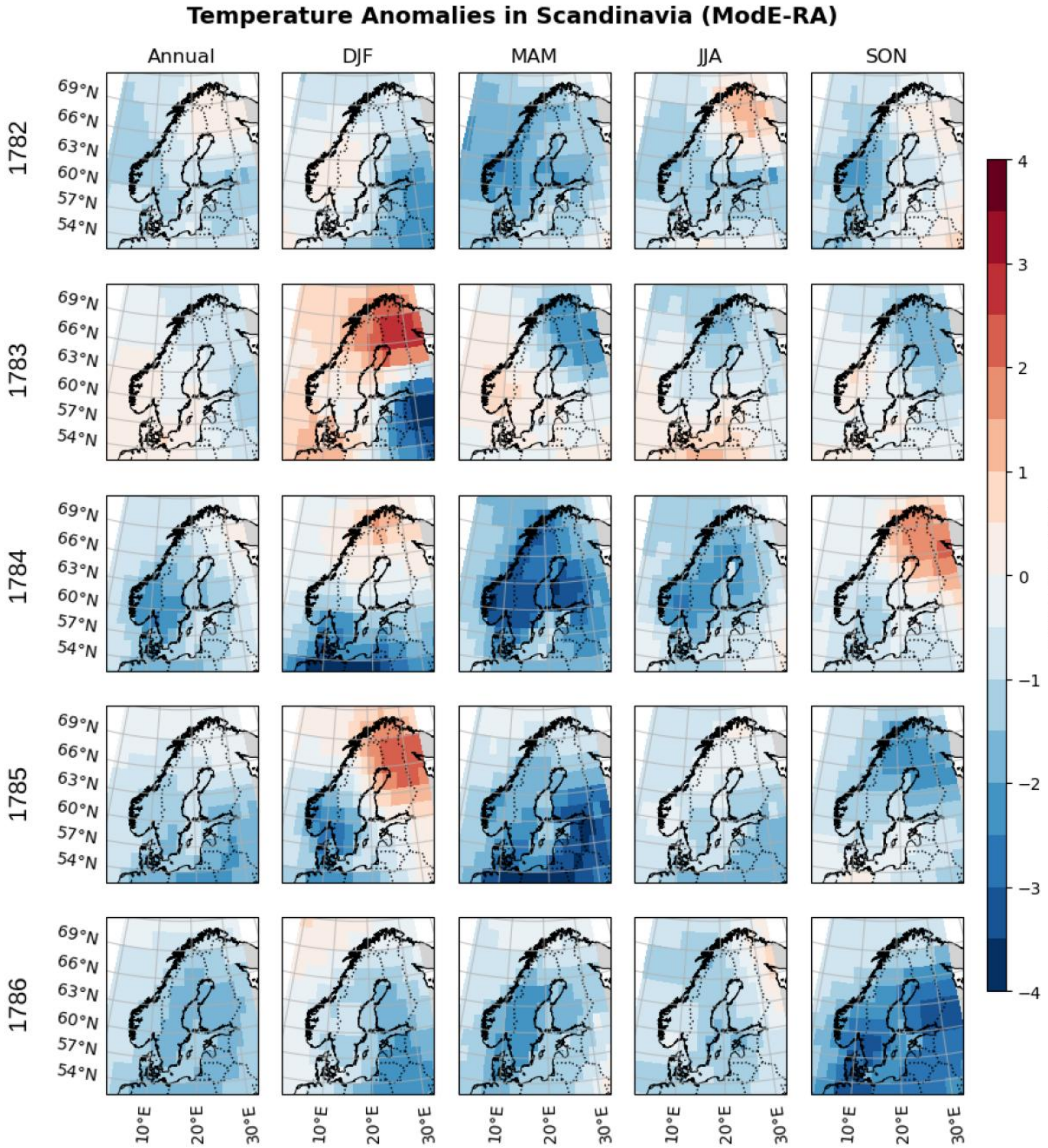

Figure 3: Surface air temperature anomalies (deg C) over Scandinavia for the annual and seasonal (DJF, MAM, JJA, SON) means in 1782–1786 based on ModE-RA paleo-reanalysis data (Valler et al., 2024). Anomalies are calculated with respect to the six-year means (1777–1782) prior to the Laki 1783–1784 eruption.

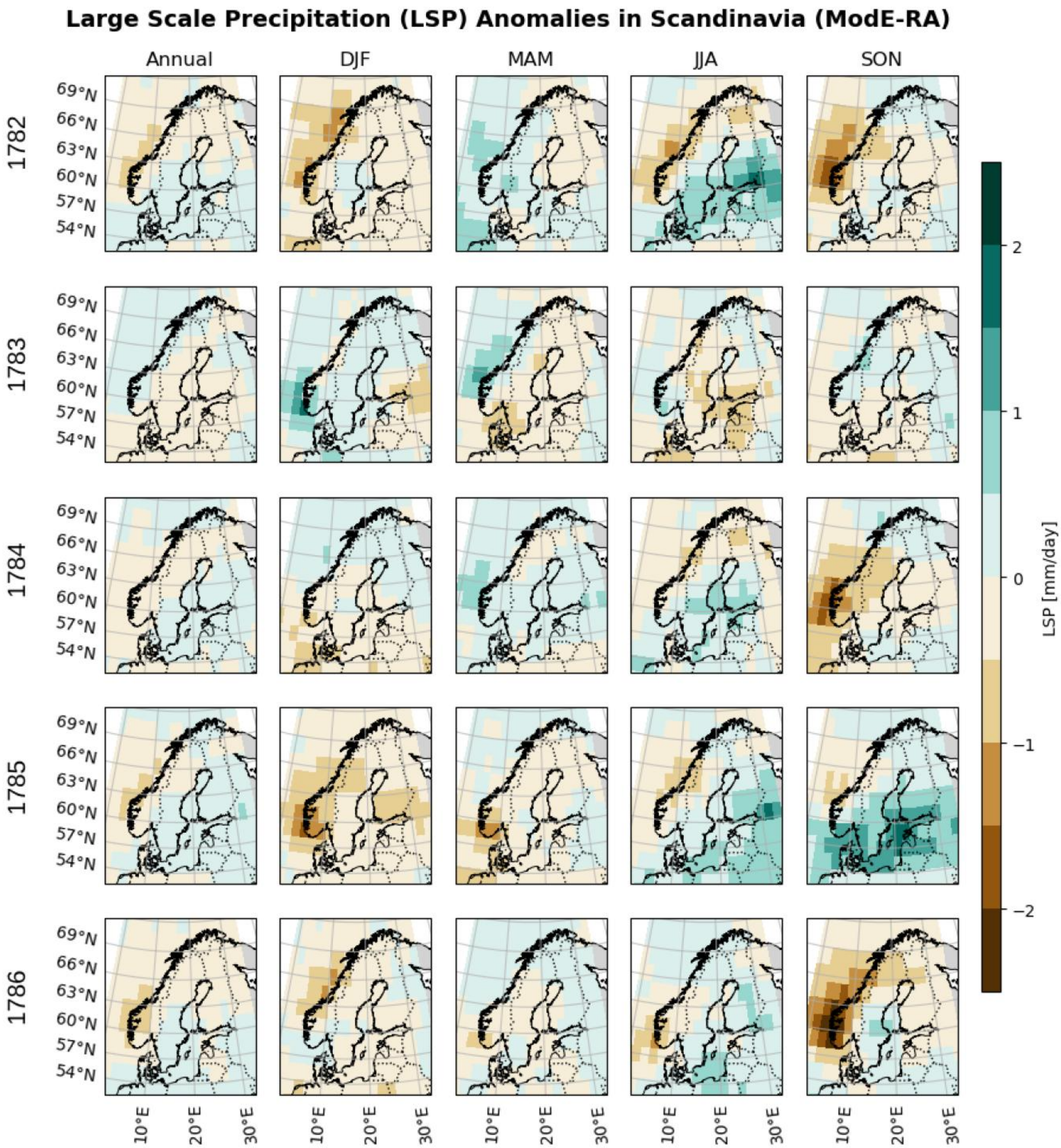

Figure 4: Large-scale precipitation anomalies (mm/day) over Scandinavia for the annual and seasonal (DJF, MAM, JJA, SON) means in 1782–1786 based on ModE-RA paleo-reanalysis data (Valler et al., 2024). Anomalies are calculated with respect to the six-year means (1777–1782) prior to the Laki 1783–1784 eruption.

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4.1.1. Instrumental records

With few exceptions, instrumental meteorological observations constitute the most reliable source of information for assessing past climates. In this study, these observations usually confirm—but occasionally qualify—large patterns in temperature and precipitation indicated in paleoclimate proxies and climate reanalyses. They also highlight the high-resolution variability of temperatures and precipitation. While many of these observations are included in reconstructions such as ModE-RA, their precision is often obscured by ensemble means. Uppsala and Lund have precipitation records going back to 1723 and 1747, respectively. In Uppsala the April–June season of 1783 is the single driest such season of the entire station precipitation dataset. That year, just 1 mm of precipitation was recorded in April, 13 mm of precipitation in May, and 6 mm precipitation in June. The three-month average was thus less than 7 mm precipitation per month. This is more extreme than even the exceptional 2018 drought (when, however, evapotranspiration was higher due to higher temperatures in May and July). The observational precipitation record from Lund indicates that May–July precipitation was the 2nd lowest ever measured, second only again to 2018. Furthermore, 1783 was the warmest summer ever recorded in Copenhagen up until 2018, with especially warm temperatures in June and July. In Lund, the summer (JJA) was the 11th warmest (7th warmest MJJ) during the period 1752–1911 (Skoglund, 2022; Skoglund & Svensson, 2026). The Stockholm and Uppsala instrumental records indicate above-average temperatures in the summer of 1783, although not as extreme as in Copenhagen or Lund.

The detailed Societatis Meteorologicae Palatinae (SMP) measurements from Spydeberg offer day-to-day insights into weather in Norway around the time of the Laki eruption. The summer temperature in 1783 was about 0.5℃ above the 1961–1990 average (SMP, 1783–1794; Pappert et al., 2021; Gundersen, 2025), making it the warmest of the five years observed at these stations. However, temperatures dropped towards the end of the year and remained unusually cold until early April 1784. The following year, 1784, became the coldest of the five, and temperatures remained low throughout 1785 and into early 1786 before returning to normal that spring. The month of March 1784 was particularly cold throughout large parts of Fennoscandia, with the Trondheim instrumental record showing a mean temperature of -8.6 °C (6.8 °C below the 1761–1790 mean), Uppsala -10.5 °C (7.4 °C below the mean), Stockholm -8.3 °C (5.9 °C below the mean), Lund -4.2 °C (3.9 °C below the mean), and Copenhagen -2.2 °C, (4.5 °C below the mean, based on shorter and more discontinuous record).

4.1.2. Tree-ring data

Trees are influenced by parameters other than climate, making extremes less pronounced than in instrumental climate records. At the same time, tree rings provide an important proxy for assessing the ecological consequences of climatic anomalies (Babst et al., 2014). The TRW chronologies contain more autocorrelation than the MXD and BI records (Ljungqvist et al., 2020). For this reason, we analyze TRW responses separately from MXD and BI. Overall, the tree-ring temperature reconstructions reveal a summer cooling anomaly following the eruption, but the magnitude is not spatially uniform or synchronous. Differences are more latitudinally dependent rather than reflecting a difference between coastal and inland regions. The strongest response was found in the region 59–63°N in 1784 and lasted until 1786, which is consistent with meteorological observations from

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these latitudes (see section 3.1.1. and 4.1.1.). Further north, the response is smaller in duration and magnitude, likely reflecting regional climate differences and local site conditions.

Regarding the reconstructions of temperature from maximum latewood density and blue intensity there is a strong coherence between all the reconstructions, regardless of geographical location, in the decade before the eruption. Following the eruption, visual coherence between temperature-sensitive MXD and BI chronologies create three different groupings (Appendix Figure S4). The first group is the northernmost chronologies in Norway, Sweden, and Finland (Forfjorddalen and N-Scan: 68.4–68.8 °N; 15.8–25 °E), in which the response in 1783 is of a greater magnitude than in 1784. The chronologies in group 1 show a deviation greater than two standard deviations from the 1773–1782 mean during the eruption year (Figure 5). The 1783 ring in these chronologies ranks as the 1st (Forfjorddalen) and 3rd (N-Scan) least dense ring between 1750 and 1800. The northernmost chronologies also appear to have a short-lived response to the eruption, remaining more than one standard deviation from the mean in 1783 and 1784 with only a short period of reduced growth indices. Density values increase rapidly in the three summers after the eruption year at Forfjorddalen and N-Scan.

The second grouping of visually coherent chronologies come from sites in Sweden located 65.3–66.6 °N and 15.5–18.2 °E (Tjeggelväs, Arjeplog, Ammarnäs, and Kittelfjäll). In this group, the response is less extreme in 1783 and in 1784 compared to groups 1 and 3, respectively. These sites show varying degrees of an increase in density in the 1783 ring relative to the previous year. The Kittelfjäll and Arjeplog chronologies most strongly reflect this trend, while the Tjeggelväs and Ammarnäs 1783 rings are only slightly denser than their previous year. In the Ammarnäs chronology, the 1784 ring is the 4th least dense ring between 1750 and 1800. The 1784 ring in the other chronologies rank between 10th and 17th.

The third group are from sites in Norway, Sweden, and Finland location between 59.3–63.1 °N and 7.1–29.3 °E (Agder, Sogndal, Jämtland, Rogen, and the Finnish Lakeland), where the chronologies show a deviation from the 1773–1782 mean of more than two standard deviations in 1784. In this group, the Sogndal and Rogen chronologies reflect an increase in density from 1782 to the 1783 ring, although this increase is not consistent throughout the group. The response from this group is the largest in magnitude and longest in duration compared to the two northernmost groups. MXD and BI values of the 1784 ring in the Jämtland and Sogndal chronologies rank as the 2nd and 7th (respectively) least dense rings in the entire chronology.

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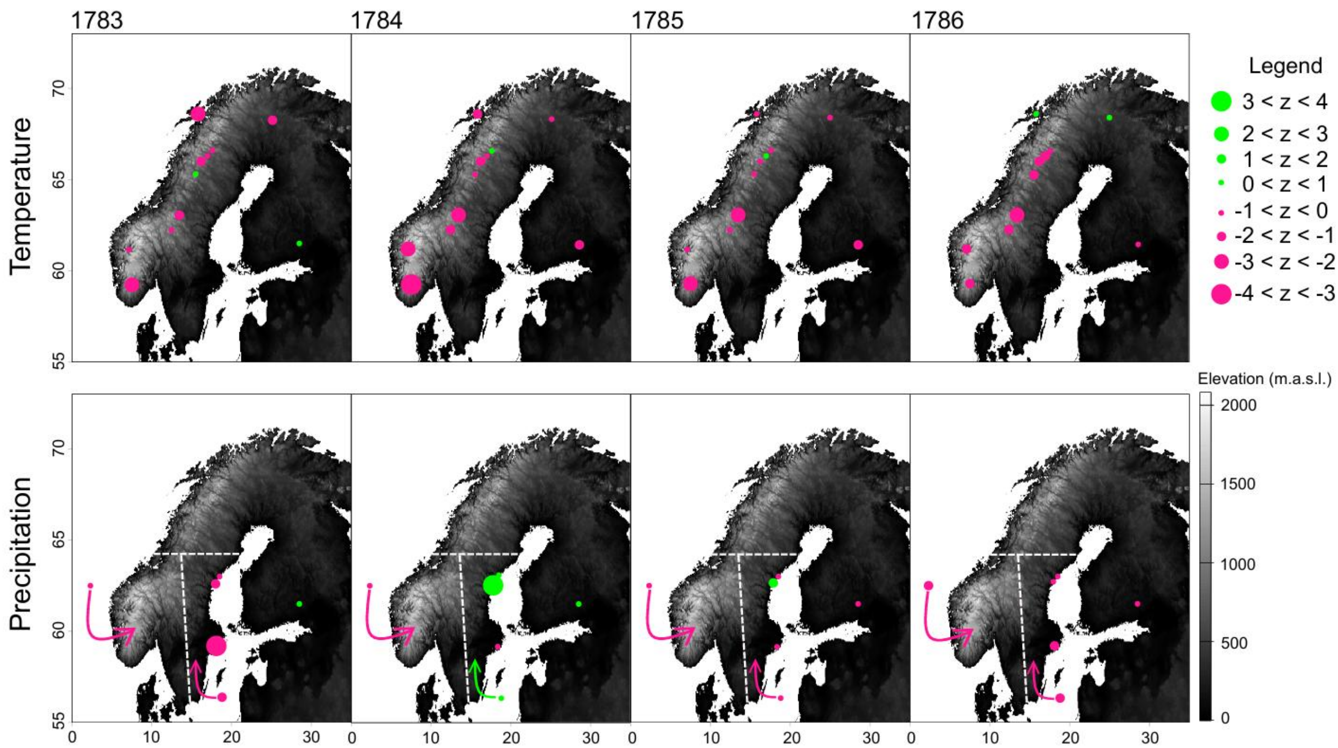

Figure 5: Temperature and precipitation reconstructions derived from tree ring records between 55–75 °N; 0–35°E (Outlined and referenced in Appendix S1; white dashed lines outline reconstruction regions with arrows pointing to the region).

When reconstructing temperature from tree-ring width, the chronologies from Torneträsk (68.4 °N; 19.1 °E), Jämtland (63.1 °N; 13.4 °E), Rogen (62.3 °N; 12.4 °E) in Sweden, and Sogndal (61.2 °N; 7.1 °E) in Norway show an overall decreasing trend from 1780, with a brief increase in the 1785 ring (most pronounced in Torneträsk). Jämtland and Sogndal show decreased growth in the 1784 ring (compared to the 1783 ring) not reflected in the Rogen and Torneträsk chronologies. TRW begins to increase back to mean values from 1786 onwards.

When considering tree-ring derived hydroclimate reconstructions, these are less common than tree-ring based temperature reconstructions in regions where temperature is the main limiting factor for tree growth. This results in lower spatial resolution of precipitation and moisture reconstructions in the northern regions. Overall, the tree-ring based precipitation and drought reconstructions do not indicate a spatially coherent hydroclimate pattern. While several site-specific shifts between dry and wet conditions are observed during 1783–1785, the timing, magnitude, and direction of these anomalies vary among regions and thus are not easily divided into geographic groupings. In this study, we focus on May–June precipitation reconstructions from TRW in southeast Finland (61–62°N, 28–29°E; Helama et al., 2009), east-central Sweden (~63°N; Jönsson & Nilsson, 2009) and the east coast of Sweden (63.0°N, 18.5°E; Stridbeck et al., 2026), and MXD from the Stockholm archipelago in Sweden (~59.2°N, 18.1°E; Rocha et al., 2020) and field reconstructions of Standardised Precipitation Evapotranspiration Index

(SPEI) (Seftigen et al., 2015). Jönsson & Nilsson (2009) and Stridbeck et al. (2026) show strong visual cohesion from 1780 to 1786; however, the amplitude of the year-to-year change is much larger in Jönsson & Nilsson (2009) than the reconstructed values from Stridbeck et al. (2026). In the first reconstruction, May–June precipitation is two standard deviations below, and in the second reconstruction it is one standard deviation below the 1734–1782 average. Precipitation then increases to a positive anomaly in 1784, with the May–June precipitation reconstructed by Jönsson & Nilsson (2009) being over three standard deviations above the mean. Nevertheless, cell wall thickness and BI measurements from the island of Gotland (Sweden, 57.8–57.9 °N; 18.3–18.9 °E) indicate a transition from lower precipitation to increased precipitation in 1785 (Seftigen et al., 2025). In contrast, the southeast Finland precipitation reconstruction (Helama et al., 2009) shows slightly (within one standard deviation) positive May–June precipitation anomalies 1783 and 1784 and slightly negative anomalies in 1785 and 1786.
Reconstructed precipitation near Stockholm (Rocha et al., 2020; 58.8–59.7 °N; 17.6–18.6 °E) indicates precipitation in 1783 more than three standard deviations below the 1734–1782 mean values. This is not reflected in the field reconstructions of SPEI in Sweden (and Norway) by Seftigen et al. (2015), which indicate an SPEI value within one standard deviation from the mean (Sweden z-score = -1.0). The field reconstruction of SPEI across much of Sweden (Seftigen et al., 2015) spatially covers the regions reconstructed by Jönsson & Nilsson (2009), Rocha et al. (2020), and Stridbeck et al. (2026).

4.1.3. ModE-RA Paleo-Reanalysis

For the period 1783–1786, ModE-RA incorporates numerous instrumental records (N=23), tree-ring proxy records (N=56), and documentary records such as river and sea ice break-up dates (N=14) (**see Appendix, Table S2, Figure S1**). In this region, proxies for the summer season are more abundant than those for winter, and north of 66°N there are no proxies for the winter season at all. The majority of assimilated observations are proxies for temperatures; information on precipitation is limited to instrumental records and precipitation-sensitive tree-ring series across southern Scandinavia. **Figure 3** displays seasonal and annual temperature anomalies in ModE-RA expressed as anomalies relative to the mean of the 6-year period 1777 to 1782 prior to the Laki 1783–1784 eruption. Low temperatures persist throughout most of Fennoscandia in the years 1784 to 1786, especially during spring (March to May) of 1784 and 1785. The winter 1784/1785 is slightly warmer over Finland compared to the reference period, which is best explained by three subsequent cold winters in 1780–1782 in the Oulu instrumental record. Consequently, we discuss monthly and seasonal temperature anomalies with respect to the reference period 1751 to 1780.
For the purposes of analyzing temperature variations, we here define the Fennoscandia region as 54–70°N and 0–30°E (see **Figure S2, Appendix**), which encompasses larger areas towards the north and east and includes maritime regions such as the Baltic Sea. For this region, ModE-RA relies heavily on documentary data and paleoclimate proxy data, particularly tree ring-based summer temperatures. Additional instrumental records provide data from the edges of this region (Oulu, St. Petersburg, Vilnius, Gdansk) and complement temperature records located across south-central Scandinavia (Trondheim, Spydeberg, Uppsala, Stockholm, Copenhagen, Lund). The central estimate of annual temperature anomalies relative to the reference period 1751–1780 for the wider Fennoscandia region are -1.1°C (1784), -1.0°C (1785) and -1.2°C (1786). These are the three coldest years between 1750 and 1800. Below-average seasonal temperature anomalies are recorded across all four seasons from fall

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1783 until fall 1786, except for fall 1784. These anomalies are especially pronounced during the spring seasons. The spring (March–May) of 1784 (temperature anomaly of –2.1°C) was the coldest spring during 1750–1800, and the spring of 1785 (-1.9°C) was the second coldest. Mean summer (June–August) temperature anomalies of -1°C were recorded between 1784 and 1787 with minimum values of -1.2°C during the summer of 1784.

The temperature anomalies are most pronounced in south-central Scandinavia (defined as 55–65°N, 5–19°E, see **Figure S2, Appendix**), probably because this region has the highest density of high-resolution instrumental records. Nevertheless, a similar pattern can be found in tree-ring records extending north of the instrumental observations. The central estimates of annual temperature anomalies relative to the reference period 1751–1780 are -1.6°C (1784), -1.1°C (1785), and -1.3°C (1786). The years 1784, 1785, and 1786 rank respectively as the 3rd, 20th, and 13th coldest years in the period 1750–2000. By comparison, 1816 (following the 1815 Tambora eruption) ranks only 18th, with an annual anomaly of -1.1°C. The mean cooling of -1.3°C in south-central Scandinavia averaged over three years 1784–1786 has no parallel in the period since 1750. Below-average seasonal temperature anomalies are recorded across all four seasons from winter 1783–1784 until autumn 1786, especially during the spring seasons. The spring (March–May) temperature anomaly in 1784 of -2.5°C ranks 4th since 1750; those of 1785 and 1786 also rank among the 20 coldest. Mean summer (June–August) temperature anomalies of -1°C are recorded between 1784 and 1787, including a -1.6°C anomaly in 1784. On a monthly basis, 31 of the 36 months following winter 1783–1784 had temperatures below the reference period. Anomalous (bottom 5%) cold months occurred in March 1784 (-5.4°C), November 1786 (-4.2°C), March 1786 (-4.1°C), July 1786 (-2.2°C), and September 1785 (-1.4°C). Note that a shorter reference period (1777–1782, as used in **Figure 3**) is for all seasons within ±0.2°C of the reference period 1751–1780.

A comparison of the ModE-RA results with the model prior (ModE-Sim) and the assimilated proxy and station data (ModE-RAclim) reveals that the ModE-RA results have been skewed by the interannual temperature variability indicated in the paleoclimate proxies, and therefore the output of the analysis obscures seasonal and local variations revealed by instrumental records. Major differences exist between model-simulated temperatures and observations in specific seasons **(Figure 6)**. For autumn (September–November) 1783, for example, the model prior simulates cooling across Scandinavia, whereas observations show warming over the south-central part of the region. Conversely, for winter 1783–1784 the model mean simulates widespread warming over Scandinavia, peaking in the northern latitudes during December–February. The observations, however, suggest that cooling extended from central Europe all the way to central Scandinavia. Similarly, the pronounced cold spring seasons of 1784 to 1786 seen in the observations are not well reproduced in the ModE-Sim ensemble mean. Disagreements between simulations on the one hand and instrumental data and reconstructions on the other are particularly evident regarding precipitation, such as the severe April–June drought in southern Scandinavia.

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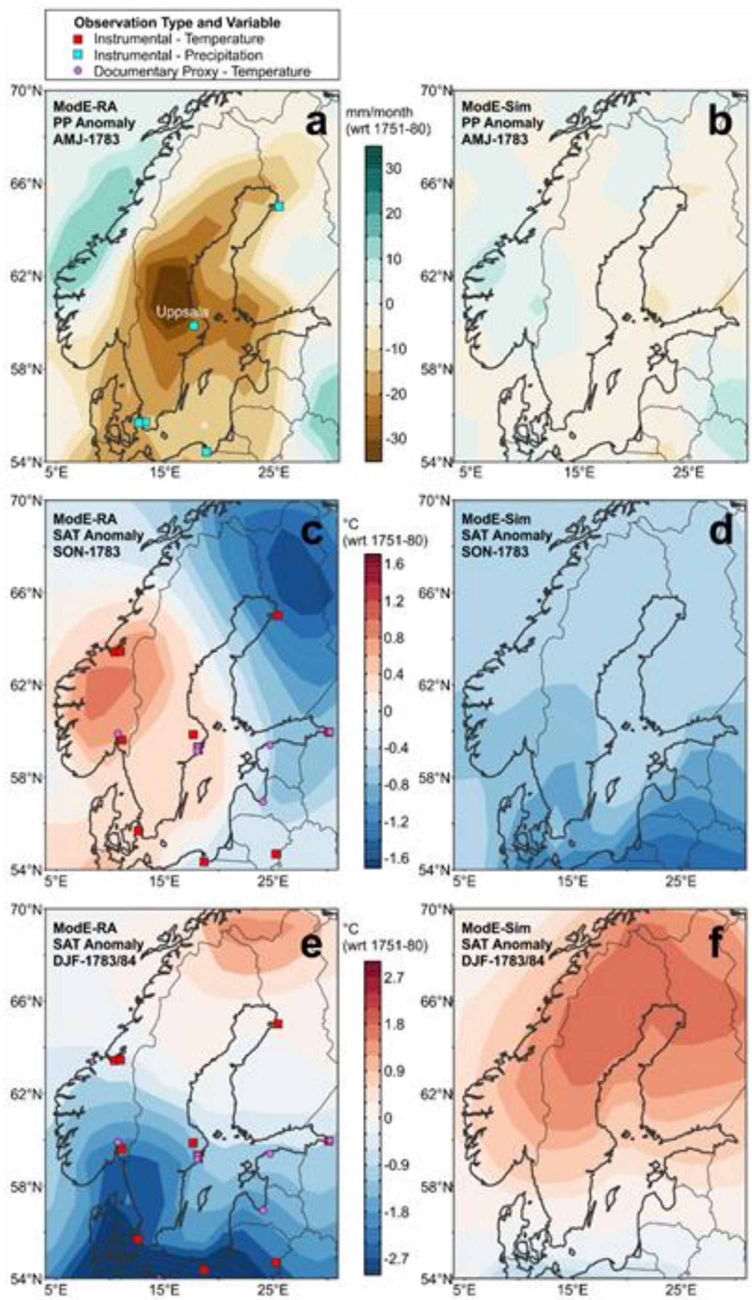

Figure 6: Seasonal climate anomalies relative to the reference period 1751–1780 over Fennoscandia in ModE-RA (Valler et al., 2024) and ModE-Sim (Hand et al., 2023), a: April to June (AMJ) 1783 precipitation anomaly in ModE-RA with sites of instrumental hydroclimate observations indicated (cyan squares; precipitation and number of rain days), b: corresponding AMJ 1783 precipitation anomaly in ModE-Sim, c: September to November (SON) 1783 surface air temperature anomaly in ModE-RA with sites of instrumental temperature observations (red squares) and documentary proxy records (e.g. sea-ice break up dates) indicated (purple circles), d: corresponding SON 1783 temperature anomaly in ModE-Sim, e: December to February (DJF) 1783/84 surface air temperature anomaly in ModE-RA, f: corresponding DJF 1783/84 temperature anomaly in ModE-Sim. All anomalies are calculated for reference period 1751–1780 CE. Maps are created using ClimeApp (Warren et al. 2024).

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4.1.4. Narrative and Phenological Records

Contemporary narrative and phenological records provide additional information on haze and smoke from the eruption as well as evidence of unusual warmth and drought in the summer of 1783 followed by exceptional cold beginning that autumn. Already in 1782 Hans Strøm in Buskerud noted a "miraculous" inversion of weather patterns as the unusual warmth led to better harvests in Mid-Norway than in the South (Wishman, 2007). When the eruption began in 1783 many observers began to note haze and smoke that was sometimes associated with leaf damage. The priest and naturalist Hans Jacob Wille noted that by 24 June 1783 grass and leaves in the Telemark area in eastern Norway "had acquired a yellow-brown color in the outermost tip and then withered. The leaves of summer grain likewise became extremely pale yellow and crumpled" due to the "thick smoke that turned the sunshine red and gave a sulphureous smell" (Wille, 1786). In Bergen, Norway, the priest Johan Nordahl Brun described a similar phenomenon: "We smelled only the smoke, and became ill; like a fog it spread itself, and although its long journey on the wings of the northern winds must have noticeably diminished the poison, it nevertheless fell here upon leaves and herbs, and everything withered" (Nordahl Brun, 1786). In Sweden reports came of an unusually frequent and long-lasting "land-smoke" (*landrök*) and "sun-smoke" (*solrök*), both associated with westerly winds. Some reports, notably from Gothenburg on the west coast of Sweden, associated the sun-smoke with possible harmful effects on people and vegetation. However, most narrative records from Sweden in 1783 focus on the negative effects of the severe summer drought, with the unusual amount of sun-smoke mainly seen as a curiosity (Skoglund & Svensson, 2026). From the province of Jämtland, where harvests usually benefitted from warm summers, there are reports of unusual land- or sun-smoke in 1783 as well as reports lauding the exceptionally good quality of the harvest, with elders comparing the year to the "great white year" (Sw. *det stora hvitåret*) of 1703 when the summer was also exceptionally warm.

By the autumn of 1783, the Norwegian farmer Barthold Henrik Todderud recorded an unusually early and heavy snowfall. On 3 October he wrote: "It snowed heavily and settled on the tilled soil to a depth of two feet." Todderud continued to describe the following months as marked by frequent snowfall and severe cold. Throughout the autumn of 1783 and the winter of 1784, he repeatedly noted both abundant snow and unusually harsh temperatures. On 8 February he wrote: "Much snow fell daily, with strong winds and drifting, which ceased on the 14th of the same month and was followed by intense cold." These conditions persisted well into May. Todderud later reported that the ice on Lake Mjøsa, Norway's largest lake, did not break up until 17 May, an exceptionally late date (Lundstad, 2004). Such prolonged ice cover is extremely rare in this region of inland southern Norway and underscores the severity of the winter and spring following the 1783–1784 period. Similarly, the ice break-up date in 1784 on Lake Mälaren in central-east Sweden, was the second latest in the entire period 1712–1982 (Hildebrandsson, 1915; SMHI 2026).

Other witnesses, such as Hans Strøm, Hans Sommerfeld, and Axel Christian Smith in eastern Norway, also witnessed a warm summer in 1783 that was cut short by sudden frosts starting in the Hedmark region as early as June. They also noted extensive frost damage, untimely snowfall, and delayed plowing and harvesting during the cold anomalies that followed in 1784–1785. For the failed "summer" of 1784 Smith in Trysil reported a period of just 11 weeks without snowcover (Wishman, 2007).

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Their observations are supported by weather notes in local farm diaries, such as the Rolsboka (Årbok, 1946; Nordli et al., 2003), and in private correspondence (f. ex. Suhm, 1798; Øverland 1895). In Hadsel (Vesterålen, Northern Norway) the year 1784 was described simply as a "frost year, from the sea to the mountains, everywhere north of the mountains," a judgment echoed the following year by Nordland Amtmann Joachim de Knagenhielm, who warned that "the whole of Norway north of the mountains has been frozen off" (Brochman, 1936; Støren, 1956). From Jämtland in northern Sweden, there are numerous reports of a cold spring and summer in 1784, leading to a slow development of crops. The heading of grains did not occur until August and was almost immediately followed by the first autumn frosts, which took place as early as August 12. The amount of hay and grain is described as abundant, but with an exceptionally poor quality, since it was harvested while still green, due to the cold growing season. One report from Offerdal parish, close to the mountains, described the harvest failure in 1784 as the worst in more than 40 years (Grinde, 1989).

4.2. Societal impacts and responses

The eruption and its climatic effects had complex social consequences for Nordic societies. These ranged from harvest failures and lost livestock to economic, demographic, and political upheavals. Risks varied both locally and nationally according to geography, trade, and politics. Cultural and policy responses mediated the impacts of disasters, contributing to the heterogeneity of outcomes. Most notable here are divergent political consequences for Sweden and Denmark-Norway as well as the much sharper rise in mortality experienced by Iceland compared to the rest of the Nordics.

4.2.1. Impacts: harvests and livestock

Iceland experienced the most direct negative impacts of the eruption. Lava flows damaged or destroyed farms and churches near the fissure. Tephra and volcanic gases affected most of the country (Thordarson and Self, 1993; Thordarson and Self 2003, Figure 1), poisoning water sources, vegetation, and consequently livestock. Approximately half of Iceland's cattle and horses and the majority of its sheep perished. Prevailing practices of husbandry and hopes for a speedy end to the eruption encouraged farmers to postpone slaughter as long as possible; therefore, many animals became inedible by the time they were finally butchered (Larsen and Thórdarson, 1984; Pétursson et al., 1984; Steingrímsson, 1998). Given Iceland's overwhelming dependence on livestock in the 18th century, the loss of so many sheep and cattle meant a drastic reduction in food supply.

In the other Nordic countries, records indicate significant but localized impacts on harvests and livestock. In *Sweden*, which provides the most detailed records, impacts varied by location and season. Parts of Sweden had already experienced adverse seasons and poor harvests in the years before the eruption. Summer drought provoked harvest losses in central and southern Sweden in 1781; subsequently, a cold summer and severe autumn frosts brought harvest failures to northern Sweden in 1782 (Utterström, 1957). The exceptionally warm and dry late spring and summer of 1783 led to one of the worst harvest failures of the century in central and southern Sweden (roughly 55°N–60°N), where grain yields were more sensitive to drought than low temperatures (Edvinsson et al., 2009; Skoglund, 2022; Ljungqvist et al., 2023; Skoglund & Ljungqvist, 2026). Meanwhile, harvests fared better in northern Sweden in 1783, where grain yields were more sensitive to cold than drought, and where land

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use emphasized the raising of livestock (Skoglund, 2025). The situation reversed again in 1784, when the cold summer brought further harvest failures to northern Sweden (Hellstenius, 1871; Utterström, 1957; Hannerberg 1971; Skoglund 2024). These harvest failures led to shortages of fodder in each of the following years, encouraging farmers in Jämtland and Västernorrland to reduce livestock herds in 1783 and again in 1785 (Skoglund, 2025a). In *Finland*—then part of the kingdom of Sweden—reports sent to the Tabular Commission from the Diocese of Borgå in 1783 describe a succession of poor weather conditions, including excessive rain during the sowing of winter rye, followed by a cold spring, midsummer frosts, and then unusually hot and dry conditions for the rest of the summer, resulting in a poor rye harvest across the Diocese in 1783. According to the report, the harvest of spring crops was adequate except in Karelia, along the border with the Russian Empire. There the spring crop also failed, leading to severe hunger (Tabellverket, 1783).

In *Denmark*, poor harvests in 1781 and 1783 caused by drought preceded the eruption's impacts. Real wage data suggests improved conditions in 1784, but additional poor harvests in 1785 and 1786, in combination with higher food prices, triggered Denmark's last famine in 1786–1787 (Dribe et al., 2017; Sandholt Jensen et al., 2022). In *Norway*, agriculture was limited mainly by the duration of the growing season, which could be cut short by cold or wet weather during spring and summer or early frost in the fall (Sogner, 1976). Post-eruption cooling during 1784–1785 heightened these risks. For instance, from Trøndelag in mid-Norway, a farmer reported in 1784 that cold weather in spring and summer had delayed the sowing and growth of the grain; early frost ruined what little remained, leaving only scant fodder for animals (Leren, 1946). In Voss, a mountainous parish in western Norway, the unusually cold spring and summer delayed the ripening and harvesting of crops; early frost damaged the still unripe grain, and farmers hastily gathered what remained for animal fodder (Kiøbenhavnske Tidender, December 31, 1784). At Trysil, close to the Swedish border in eastern Norway, priest Axel Smith reported that there were only eleven weeks between the last snow in spring and the first snow of autumn in 1784. A study modelling growing degree days in Indre Østfold, southeastern Norway, supports reports of widespread harvest failures in Norway that year (Gundersen, 2025).

4.2.2. Impacts: Trade and economies

By the 1780s, large parts of the Nordic countries depended on imported grain for their subsistence. Some shipments came from within the Nordics and others from outside the region. Thus, food supplies depended upon not only local harvests but also regional agriculture, commerce, and trade policies.

In *Sweden*, northern areas regularly experienced harvest failures and thus relied on exporting minerals, butter, tar, timber, and flax in return for grain (Gadd, 2011; Starlander, 2021; Skoglund, 2025). Moreover, larger cities such as Stockholm and Gothenburg and the mining districts of central Sweden were heavily dependent on grain imports. By the late 18th century, areas of surplus in southern Sweden could cover only about half of the shortfall, necessitating imports of 400,000–450,000 barrels even in a normal year (Åmark, 1915). Therefore, years of poor harvests required additional costly purchases from foreign markets to avoid acute shortages in areas of deficit and price inflation. Already in 1781, timely grain imports to the Swedish realm increased sharply to almost 700,000 barrels of grain, peaking in 1783 and 1784, with over 1,000,000 barrels of grain

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imported in both 1783 and 1784 following the 1783 harvest failures (see **Figure 7**). As a part of the kingdom of Sweden, *Finland* also received a portion of these imports. Nevertheless, some parts of the country faced shortages during the 1780s. In Karelia, for example, grain prices were reported to be the highest in living memory, and very little grain, mostly imported from Russia, remained on the markets (Tabellverket, 1783).

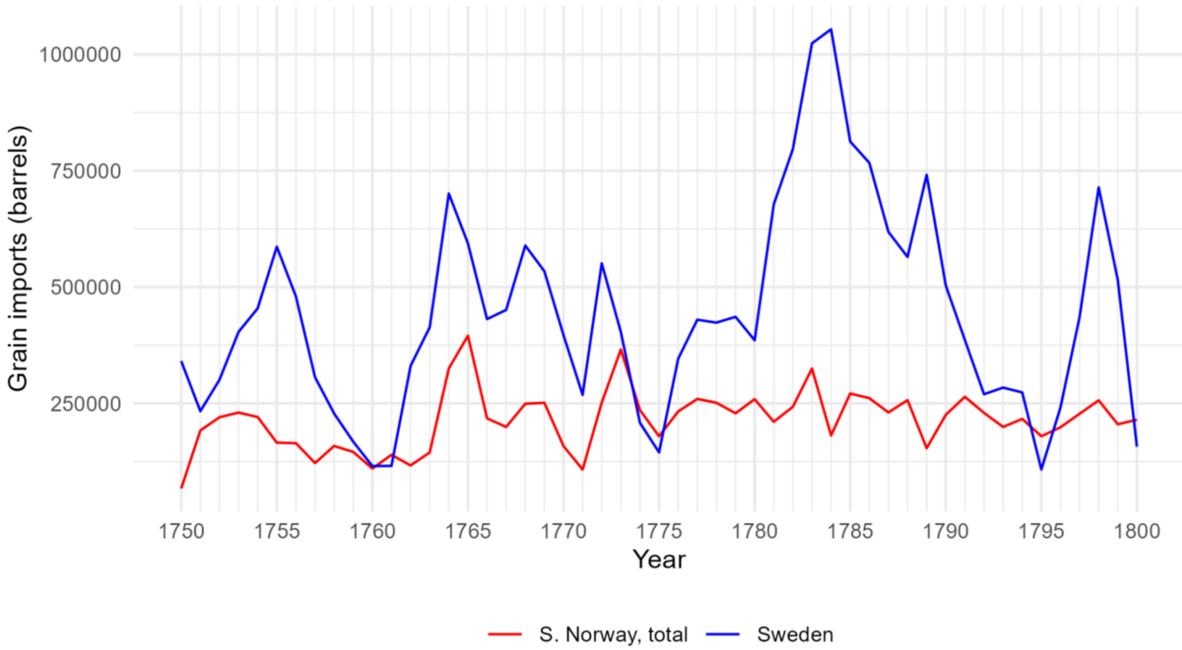

Figure 7: Grain imports to Sweden and southern Norway during 1750–1800, based on import custom records. For Sweden, imports are given in unweighted barrels (146.6 litres) containing threshed grain. Sources: Sweden: Åmark (1915), Southern Norway: Herstad (2000).

Denmark produced a surplus of grain that traditionally covered deficits in *Iceland* and *Norway*, which exported timber, minerals, or cod fish in return (Herstad, 2000). These relationships were codified in a total Danish trade monopoly with Iceland (from 1602) as well as a Danish grain monopoly covering the south-eastern parts of Norway (from 1735) in which Danish traders enjoyed exclusive rights to sell Danish grain in Danish ships. The grain monopoly could provide a steady stream of provisions into Norway during normal years, but in times of crisis it often became a source of vulnerability, especially when harvests failed in both countries. Poor harvests in Denmark in 1781–1783 severely strained the Danish grain supply. Imports from Denmark to southern Norway began to fall in 1781, and grain prices rose steeply from 1782 onwards (Herstad, 2000; Eitrheim et al., 2022). Disruptions to the timber trade during the American Revolution (1775–1783) compounded the distress, particularly in regions of southern Norway reliant on timber exports (Sogner, 1976). Imports of Danish grain to Norway decreased dramatically in 1784, due to the drought-induced Danish harvest failure of 1783, coinciding with Norway's harvest failures of 1784 due to cold conditions and leading to a subsistence crisis in the spring of 1785 (see Figure 7; Herstad, 2000) .

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4.2.3. Impacts: Disease and mortality

In *Iceland*, the agricultural devastation rapidly translated into a demographic catastrophe. The massive loss of livestock was followed by acute food shortages, malnutrition, and increased susceptibility to disease. By 1785, approximately one-fifth of the Icelandic population had died. Icelanders remember the eruption by its aftermath as *móðuharðindin* ("the famine of the mist"), one of the deadliest disasters in the island's history (Gunnarsson, 1984; Vasey, 1991; Wieners, 2020; Gunnarsdóttir 2022).

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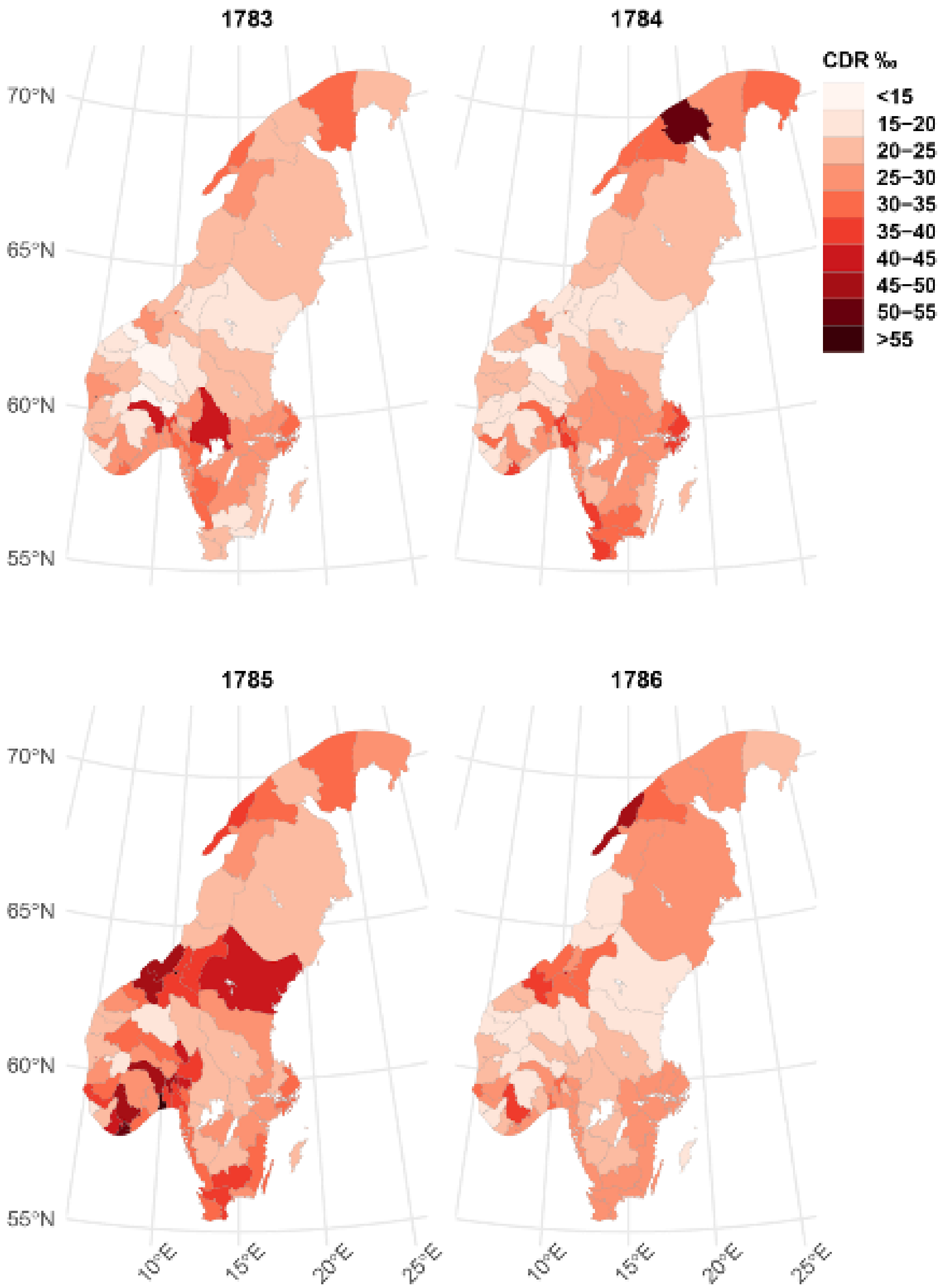

Figure 8: Regional crude mortality rates ‰ (number of deaths per 1,000 people per year) in Norwegian Deaneries (*Prosti*) and Swedish (present-day borders) counties (*län*) for the years 1783–1786 (based on Demografiska databasen: Centre for Demographic and Ageing Research (CEDAR), SHiPS [data set], http://ships.ddb.umu.se/, 2026 and own research).

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Other Nordic countries also experienced elevated mortality. Death rates peaked in 1785–1786 in Sweden and Norway, driven by harvest failures and regional disease transmission (**Figure 8**). These patterns highlight the impact of famine-related infectious diseases as a cause of death (Ljungqvist et al., 2024). In *Sweden*, the impacts stopped short of a demographic catastrophe, but some areas were strongly affected by hunger, cold, and disease. Intense cold during the winters and springs of 1783–1784, 1784–1785, and to a lesser extent 1785–1786 would have elevated mortality both alone and in synergy with malnutrition. Previous studies have shown that in most of Sweden from the 18th to the early 20th centuries cold winters and springs increased mortality, especially among infants and children (Eckstein et al., 1984; Bengtsson & Broström, 2010; Rocklöv et al., 2014; Åström et al., 2016). In particular, February–April mean temperatures are negatively correlated with parish-level all-cause mortality across Sweden during the period 1749–1859 (Chen et al., 2025).

In southern Sweden, where shortages were most severe, an epidemic of smallpox elevated child mortality (Skoglund & Svensson, 2026). Sweden's southernmost counties—the worst affected by the spring and summer drought of 1783—also had the area's highest mortality. Parts of northern Sweden were affected as well. Västernorrland county, which suffered harvest failures in 1782 and again in 1784 and which neighboured the hard-hit Norwegian province of Trøndelag, witnessed exceptional mortality during the post-eruption years.

Denmark experienced increased mortality on a national level, especially in the mid-1780s. The crude death rate (CDR) reached 31.0 per 1,000 inhabitants in 1786, and deaths continued to exceed births in 1787. In *Norway*, disease followed in the wake of prolonged scarcity and famine. Parish records show a clear spike in disease-related deaths beginning before the eruption in 1782 and culminating in the famine year of 1785, when Norway's CDR reached 33.6 per 1,000 (**Figure 8**). The main killers were smallpox, dysentery, and "strong fevers" (a term often associated with typhoid fever and typhus). Excess mortality rose in all four main regions of Norway, although with considerable variation. The worst-hit areas were Trondheim, Agder, and districts around the Oslofjord, including Larvik. Western and northern Norway and some more remote inland regions fared better. Among the towns, Trondheim, Kristiansand, and Larvik were particularly hard hit, with mortality close to 60 per 1,000 inhabitants, while Stavanger and Bergen saw much smaller increases.

In *Sweden* and *Finland*, by contrast, the combination of prior drought, high grain prices, and localized harvest failures produced hardship but not demographic catastrophe, probably thanks largely to mitigation measures described below. Nonetheless, the realms were not unscathed. In southern Sweden, where shortages were most severe, contemporary reports mention beggar children perishing in snowdrifts as well as a harsh smallpox epidemic that elevated child mortality (Skoglund & Svensson, 2026). In eastern Finland, people resorted to emergency foods such as bark bread and to begging across parish boundaries. Others sought grain across the eastern border with Russia (Tabellverket, 1783). Excess mortality during 1784–1786 exceeded that of the famine of 1772–1773 both in Sweden's southernmost counties, which had been most severely impacted by the summer drought, and in Västernorrland county in northern Sweden, which suffered harvest failures in 1782 and 1784 and which neighbored Trøndelag, one of Norway's worst-hit provinces (Skoglund & Svensson, 2026). These regional differences likely reflect variations in the spread of epidemic disease and differences in social structure and relief capacity. The Laki-related years thus appear less as an unprecedented shock and more as a crisis that mapped onto and intensified pre-existing climatic and social vulnerabilities.

4.2.4. Impacts: Politics

The compound crises of the 1780s also exposed and sharpened underlying economic and political tensions. However, whereas *Sweden* and *Finland* largely contained the political fallout, Denmark-Norway experienced serious conflicts over grain, credit, and monopoly privileges, which fed into a broader protest movement.

In the Kingdom of Sweden, the ruling monarch Gustav III had previously used the1772–1773 famine to justify his 1772 *coup d'etat* and the kingdom's return to royal absolutism (Hallenberg et al., 2025). The king's political position as well as Sweden's tradition of royal paternalism supported a policy of extensive market interventions and costly grain imports to cover shortages during the 1780s. A proactive royal grain commission (1783–1790) organized relief, especially in south-western and south-eastern districts (Utterström, 1957; Palm, 1997; Skoglund & Svensson, 2026). Import taxes across the kingdom (including Finland) were reduced to four *skillings* (Eng. shillings) in August 1783 and removed altogether in November (Kovero, 1945). In both 1783 and 1784, imports reached record levels of slightly above 1,000,000 barrels of grain each year—figures unsurpassed until the late 19th century and possibly the greatest per capita inflow ever imported to Sweden (Åmark 1915; SCB, 1972).

This readiness to intervene was mirrored by parts of the bourgeoisie, who arranged private charity collections, such as that organized by the newspaper *Nytt och Gammalt* in Lund (1784; Palm, 1997). Provincial and parish grain banks in Sweden also lent out grain and distributed aid relief (Berg, 2007). These actions lessened the political impact of the 1780s economic and agricultural crisis in the short term. The monarch's carefully staged benevolence was so successful that his local regents were sometimes commemorated with local memorials (**Fig. 9**). As a result, it was only in 1786 that Gustav III faced increasing opposition, and he may have launched Sweden's war against Russia in 1788 in part to reduce domestic political pressure (Artéus, 1992).

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Figure 9: Memorial inscribed on the Dalman Tower in the city wall of Visby (Gotland), Sweden, reading in English translation: "This granary shall preserve a thankful memory to the Vice County Governor, Major and Knight, Sir Lars Reinhold Dalman's worthy patronage and aid for the distressed inhabitants of Gotland in the year of 1784 when a severe grain shortage put pressure on the realm." Photo: Fredrik Charpentier Ljungqvist, May 25, 2025.

In contrast, the Danish kingdom faced a major popular uprising in southern Norway. Denmark was usually a grain exporter. Now that it struggled to supply itself, relief for Norway fell short. Danish authorities initially sought grain from the Baltic region to cover the growing deficit. However, their efforts had to compete with Swedish buyers, who had entered the market earlier in response to the drought of 1783. Denmark managed to import approximately 130,000 barrels from late 1783 through mid-1784—a considerable amount, considering Denmark was usually a grain exporting region, but far less than Sweden. Of

this total, royal granaries in Norway received only about 10,000 barrels (Johansen, 1969). Danish authorities had already suspended import restrictions on southern Norway back in 1782, when it became clear that Danish grain alone would not suffice in the bad years preceding the volcanic shocks. Yearly records from three monopoly-affected ports show foreign supplies increasing fivefold after the suspension (Herstad, 2000). Kristiania (today's Oslo) outpaced the other ports, receiving earlier and larger relief. Governor Albrecht Philip Levetzau's coordination, drawing on military granaries and emergency purchases, earned the admiration of his contemporaries, who praised him in biblical terms as "a true Joseph" (Sogner, 1976). However, while suspension of import restrictions likely shortened the ensuing crisis, it offered only local relief and could not compensate for the long-term dependency created by the Danish monopoly and the near collapse of Danish imports by 1784.
Elsewhere, the few granaries established during the preceding 1770s crisis largely stood empty, having already distributed their meagre stocks in the bad years prior to the eruption (Hansen, 2015). Frustration over stalling public relief further escalated as private industrial enterprises with access to credit remained ostentatiously well stocked. At the Froland ironworks in southern Norway, owner Hans Smith boasted of ordering grain from Danzig in 1784 to keep his business running. However, locals protested that he cornered local markets for private gain and accused him of exploiting their desperation and binding them more tightly with debt (Løyland, 2018).
By 1786, anger over grain policies and other grievances against officials, privileged traders, and speculators coalesced in the Lofthus uprising (No. *Lofthusopprøret* or *Lofthusreisinga*). The movement began in Agder, one of the regions hit hardest by the crisis. The Lofthus rebels expressly drew on the harvest failures to galvanize opposition and promote their campaign. Local farmers marched on Kristiansand, demanding tax reductions and an end to trade privileges and official abuses (Fiskaa, 2012; Løyland, 2018). The revolt only ebbed away after its name-giving leader Christian Lofthus was arrested in 1787.
While the aftermath of the Laki eruption provided legitimacy and a trigger for the uprising, the movement was also fueled by long-standing economic tensions and fused with wider political debates. In the early 1770s, a series of climate-driven harvest failures had coincided with a string of liberal reforms, press freedom, and deregulation in Denmark-Norway. During this experiment, Norwegian intellectual circles began an intense discussion on grain policy, known as the Philopatreias debate (Håland, 2022). The discussion also broadened into larger political demands among patriotic Norwegians for an independent bank and a separate university for the Norwegian part of the realm (Herstad, 2000). The reforms and the debate were cut short when their architect, Johan Christian Struensee, fell from grace and was executed in the political realignment of 1772. However, in the years following the Laki eruption, a similar political conjuncture revived this "hidden transcript" (Dørum, 2021). Just as in 1772, food shortages and high prices in 1784 coincided with a palace coup. It brought to power the sixteen-year-old Crown Prince Frederik, displacing the conservative Guldberg regime and opening the way for reformers in government (Damsholt et al., 2019; Kofoed & Jensen, 2022). The Lofthus rebels quickly adopted the physiocratic free-trade sentiments from the earlier Philopatreias debate, confidently identifying Norwegian peasants as "the most useful and productive class" (Fiskaa, 2013). The failing harvests lent credence to their demands and reignited widespread fears of escalating peasant debt, famine, and economic dependency. The unusual unrest in Norway prompted the establishment in Copenhagen of a special committee to investigate and redress grievances. It sat alongside a similar commission on the

devastation in Iceland, with several members serving on both bodies. In 1788, reports from both commissions contributed to a striking shift in the king's council's position on grain controls: the monopoly on grain trade that had underpinned Danish Norwegian economic relations since 1735 was unceremoniously abandoned (Herstad, 2000). Although this reversal neither ended the subsistence crises nor transformed trade practices during the 1780s, the confluence of natural and societal turbulence helped seed ideas of self-governance that from now on shaped Norway's path towards constitutional self-governance in 1814 (Pedersen, 2012; Dørum & Sandvik, 2012; Pedersen & Munch-Møller, 2012; Glenthøj & Ottosen, 2014).

5. Discussion

5.1. The Laki Eruption and Climate in the Nordic Countries

5.1.1. Model–Data Comparison

We observed the most significant model–data difference concerning the unusual warmth and drought during the summer of 1783. General circulation model (GCM) simulated climate responses over Fennoscandia are generally characterized by an eruption-induced radiative surface cooling that develops in summer 1783 and persists for 2–3 years (e.g. Oman et al., 2006; Zambri et al., 2019b). While climate models predict surface cooling, early instrumental data (e.g. from Lund, Stockholm and Uppsala) and historical documentary records show the summer of 1783 was anomalously warm in parts of Europe, including southern Scandinavia. The summer warmth is attributed to a persistent atmospheric blocking over Northern Europe with a high-pressure system preventing cold polar air from moving southwards (Thordarson & Self, 2003; Zambri et al., 2019b). Prior to this western and northern European summer heatwave, southern Scandinavia had also experienced a major drought, including record-low precipitation in Lund and only 40 mm of precipitation in Uppsala between April and June (**Fig. 6**) (Skoglund, 2024).

The radiative response following the summer of 1783 led to multi-year temperature anomalies captured in model simulations, reanalysis products, and instrumental measurements **(Figs. 3–5, 8, Figs. S2,3)**. Whereas our data sources show severe cold anomalies on daily, monthly and interannual timescales, differences exist in their severity, spatial distribution, and persistence. Heterogeneity is even more pronounced when considering hydroclimate.

Comparison of ModE-RA, ModE-SIM, and ModE-RAclim demonstrates that ModE-RA very closely reproduces the observations of instrumental and proxy data across all four seasons **(Fig. S3)** with both ModE-RA and ModE-RAclim showing much higher year-to-year variability than resolved by the ensemble mean of ModE-Sim. Major spatial differences between 'observations' and simulations exist for many seasons (examples in **Fig. 5**) for the variables precipitation and temperature with the simulations typically showing more uniform anomalies of lower strength compared to the ModE-RA and also when directly compared to the instrumental records.

Whereas the severity of the volcanic cooling is not exceptional in a long-term context, the duration and persistence of the cooling are anomalous since 1750 CE. Negative temperature anomalies were most pronounced during the spring and summer (including growing season) of 1784 and 1785 following the eruption. ModE-RA and instrumental series indicate that by 1786,

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regional temperatures began returning to pre-eruption baselines, though some secondary feedback effects on sea ice and reduced ocean heat transport may have lingered even longer as indicated by sea-ice observations in the Baltic Sea and climate model simulations.

5.1.2. Signals of the Laki Eruption in Tree-Ring Data

The interaction between climate conditions and tree ring response appears to be regional. The decade before the eruption, 1772–1782 is characterised by synchrony across all temperature-sensitive chronologies. This changed after 1783 and the tree ring response became regionally distinguishable. Temperature-sensitive chronologies, especially in the northern part of Fennoscandia, reflect lower density in 1783, likely because of high atmospheric sulphuric aerosol (e.g. Edwards et al., 2022). Reports from Norrbotten, northernmost Sweden, describe how the first half of the summer was warm, followed by a sharp turn to colder temperatures and early frosts by July, leading to very poor harvests in 1783 (Hellstenius, 1871; Nederkalix Church Archives, 1783). The response in tree rings has previously been investigated by Edwards et al. (2022) using wood anatomy measurements. These measurements indicated that growth in the first half of the 1783 ring was consistent with a warmer than average temperature; however, this was abruptly interrupted in the second half of the year, resulting in thinner cell walls and less density in the ring overall .

Swedish tree ring-based temperature reconstructions between 65.3–66.6° N reflect an increase in density in 1783 at some sites, particularly Arjeplog and Kittelfjäll. The 1784 ring in these trees is only slightly less dense. Swedish and Norwegian temperature reconstructions between 59.3–63.1° N record a slight increase in density for the 1783 ring followed by a more drastic decrease in density in 1784, more consistent with instrumental records from the same region and model simulations noting 1784 as the coldest year. Moisture reconstructions based on tree rings in Sweden and Finland do not show any regionally uniform response to the eruption. The anomalies do not indicate any particular consistent trend (drying or wetting). In Sweden, tree-ring records indicate predominantly dry conditions during the 1780s, with 1783 standing out as an exceptionally dry year (4th percentile in a 996-year record and 2.5th percentile in a 285-year record) (Seftigen et al., 2017; Rocha et al., 2020).

While historical records make note of leaf damage during the eruption summer (1783), possibly related to acidic fallout, there is no conclusive evidence from the tree ring chronologies that this affected the trees in these chronologies. Harvest records across Scandinavia show little evidence of acid damage in 1783. Areas where harvests were usually good in years of warm summers, such as Trøndelag (Norway; 63°N) or Jämtland (Sweden; 63°N), experienced harvests of excellent quality, despite reports of unusual amounts of sun- or land-smoke, whereas areas where warm and dry summers were usually detrimental for harvests, such as southern Sweden, reported poor harvests. In other words, fluctuations in temperature and precipitation adequately explain harvest outcomes in 1783, with no clear anomalies that could be associated with damage from acid (Skoglund & Svensson, 2026). For tree growth, defoliation events have a strong negative correlation to growth and can impact growth for two to four years after defoliation occurs (Sangüesa-Barreda et al., 2014; Javoy et al., 2025). A defoliation event following the eruption would have had a drastic effect on tree growth, disproportionate to temperature alone. Since conifers require sustained minimum temperatures of at least 5°C (Rossi et al., 2008; Li et al., 2021), the reduced temperatures in spring–summer 1784 would have already delayed the trees' growing season.

5.2. Analyzing Climate–Society Interactions

Experiences of the Laki fissure eruption and its climatic effects in the Nordic region offers a focused comparative study of impacts in similarly situated countries, illustrating both divergences and similarities. As discussed in section 4.2, climate variability and weather had heterogeneous local and national impacts on harvests, food supplies, economies, populations, and politics. These societal impacts varied according to local environmental factors, background circumstances, and community and political responses. At the same time, our findings emphasize patterns in the underlying dynamics of climate–society interactions.

As with current global warming, disasters of the 1780s did not follow directly from climate variability but from intersections of meteorological hazards, exposure, and vulnerability. Hazards associated with post-eruption cooling—i.e., cold wet summers and early frosts—particularly affected harvests at the northern margins of agriculture. Yet, crucially, the unusual warmth preceding the eruption had already affected grain production in drought-sensitive regions of southern Sweden and Denmark, and the resulting grain shortages affected vulnerable populations across the Nordic countries. The findings in section 4.2 demonstrate that these vulnerabilities were related not only to environmental and economic conditions but also to commercial and political arrangements, particularly Denmark's trade monopolies. Moreover, this study highlights the societal impacts of compound events, defined as "the combination of multiple drivers and/or hazards that contributes to societal and/or environmental risks" (Duvat, 2026). In particular, Iceland's "famine of the mist" involved a combination of damage from the eruption, poisoning of vegetation, consequent loss of livestock, pre-existing vulnerabilities in agricultural arrangements, slow information flows, and economic dependence, in addition to climatic factors.

Exceptional cold could potentially produce direct, substantial societal impacts. For example, early frosts and failed harvests could swiftly increase poverty and hunger among the most marginal communities in Finland (Huhtamaa et al., 2022). Nevertheless, the most widespread and substantial consequences were often indirect, delayed, and displaced. Death rates peaked 2–3 years after the eruption and not only in locations of adverse weather or harvest failures. Significant political consequences, including the Lofthus uprising and abolition of Danish monopolies in Norway, followed another 2–3 years later. Disruptions to trade and prices spread effects throughout the kingdoms of Sweden and Denmark-Norway. These patterns highlight the role of "cascading impacts," which "occur when an extreme hazard generates a sequence of secondary effects in natural and human systems that result in physical, natural, social, or economic disruption, whereby the resulting impact is significantly larger than the initial impact" (Duvat, 2026). In particular, the situation in the Nordic countries during the 1780s reveals interactions among harvest failures, human and animal health, population displacement, infectious diseases, and economic and political instability. **Figure 10** illustrates these climate–society dynamics, including potential for feedback mechanisms among different levels of societal impacts (biophysical, economic, population, political).

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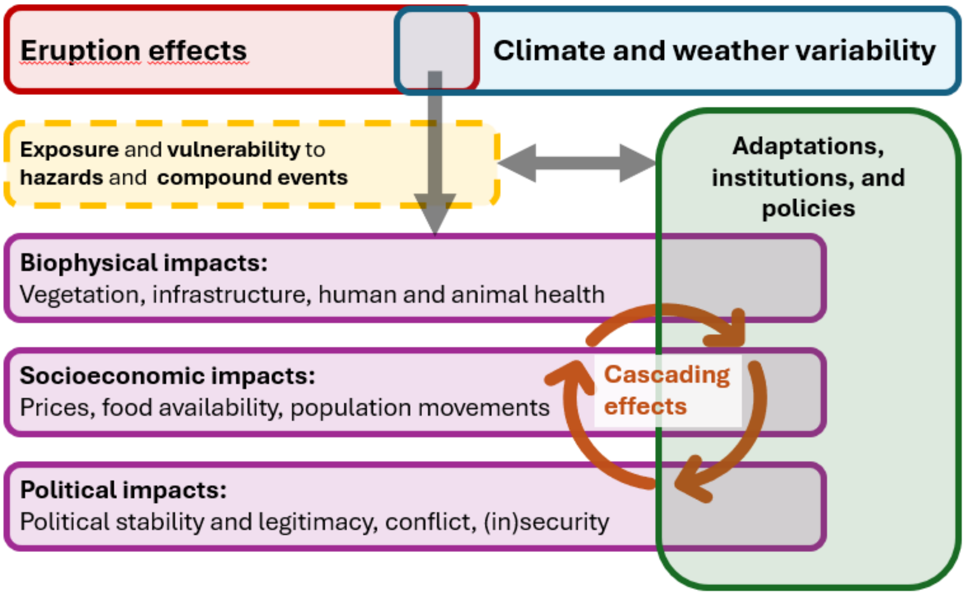

Figure 10: A schema of climate–society interactions. During the 1780s, the Nordic countries faced repeated extremes of temperature and precipitation due to a combination of climate and weather variability and effects of the Laki fissure eruption. These extremes affected societies mainly through exposure and vulnerability to meteorological hazards. Although the most direct impacts were biophysical, including loss of crops and livestock, compound events raised risks of cascading effects on socioeconomic and political conditions as well. Feedback loops among different types of impacts could result in sustained and widespread consequences, including elevated mortality from the spread of famine-related diseases among impoverished or displaced populations. At the same time, disaster risk encouraged responses meant to reduce exposure and vulnerability and to counteract cascading effects. Cultural adaptations, resilient institutions, and timely and effective policies could determine whether disasters spiraled into economic, demographic, or political crises. (Figure based on Collet et al., 2025b.)

This study finds that the eruption's cascading effects were mediated by bottom-up and top-down responses. Cultural adaptations, effective institutions, and timely political decision-making could limit disaster risk and prevent impacts on agriculture from escalating into famine, population displacement and disease, or economic and political disruption. In particular, timely Swedish grain imports may have averted further famine and political turmoil like that seen in Denmark-Norway. Although harvest was badly affected in some regions of Finland, for example, the situation did not escalate into a demographic crisis. Nevertheless, this study highlights significant limits on human agency and societal resilience during pre-industrial subsistence crises. Traditional household responses to hunger could be maladaptive when, for example, migration in search of relief spread diseases such as typhoid. Measures such as local charity, distribution from granaries, and even grain imports could reduce but not eliminate famine. Economic development, science and technologies, and the expanding powers of the state all helped in the long term to mitigate the worst effects of climate variability. Nevertheless, some towns and rural parishes of Norway and Sweden faced even higher mortality during the 1780s than in the region's previous subsistence crisis during the early 1770s (Dribe et al., 2017).

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In Nordic history the overall extent of the 1780s crisis was less severe for its populations than that of the 1770s and less politically transformative as the post-Napoleonic upheavals. However, in Norway it reminded the people of the manifest shortcomings of their economic arrangements with Denmark in times of crisis. The concurrence of climatic shocks, political turbulence, and social unrest eventually resulted in the abandonment of the contested Danish grain monopoly. While the effects of this political reversal were more symbolic than practical, they provided an important rallying point for the emerging Norwegian patriotism and helped to mobilize support on the path towards the declaration of independence in 1814 (Dørum & Sandvik, 2012).

6. Conclusion

The Laki flood lava eruption of 1783–1784 appears in this study not as a single, homogeneous climatic shock, but as the trigger for a suite of regionally differentiated and seasonally varying anomalies across the Nordic countries. Drawing on ModE-RA paleo-reanalysis and related products (Valler et al., 2024; Warren et al., 2024) alongside instrumental and proxy evidence, we find that warm and dry late spring and summer conditions in 1783 in central and southern Fennoscandia contrasted with late summer cooling at higher latitudes, and that the subsequent springs and summers of 1784–1786 were extremely cold compared with the preceding decades. These results underline the importance of regionality: a major high-latitude eruption interacting with natural variation produced distinct climatic regimes within the Nordic region that cannot be reduced to a single, uniform "Laki signal" (Edwards et al., 2022).

Tree ring networks and tree ring-derived reconstructions deepen this picture of regional complexity. Maximum latewood density chronologies in the northernmost regions and precipitation-sensitive chronologies in central and southern Fennoscandia record sharp but short-lived reductions in 1783, while more southerly temperature-sensitive chronologies show their strongest negative anomalies in 1784, with notable contrasts in the rank and duration of impacts across sites. Together, instrumental observations, proxies and simulations demonstrate that the climatic aftermath of Laki was structured by latitude, exposure, and internal variability, and was not uniform across Fennoscandia.

Combinations of pre-eruption drought, the eruption's environmental effects, and post-eruption cooling created compound events whose direct impacts were followed by cascading effects. Hazards associated with post-eruption cooling—cold, wet summers and early frosts—interacted with antecedent warmth and moisture deficits, especially in drought-sensitive main agriculture regions in Denmark and southern Sweden, where grain shortfalls pre-dated the eruption. Elsewhere in the Nordic region, harvest failures, livestock losses, and constrained grain markets contributed to rising prices, episodic famines, and disease, with mortality peaks in 1785–1786 and pronounced regional variation.

These conclusions depend on an explicitly interdisciplinary approach that integrates "archives of nature" and "archives of society". ModE-Sim, ModE-RA, and ModE-RAclim link the external forcing of the eruption to spatially explicit fields of temperature and precipitation (Hand et al., 2023; Valler et al., 2024; Warren et al., 2024), while tree-ring and documentary proxies help identify ecological impacts and climatic fluctuations at regional to local scales. Early instrumental observations together with harvest and mortality data, allow us to follow how climatic anomalies translated into biophysical, economic,

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demographic, and political impacts. Narrative sources—from Icelandic fire treatises and sermons to petitions, songs, and pamphlets—illuminate how contemporaries interpreted these shocks and mobilized around them. In Denmark–Norway, for example, cumulative grievances over grain policy, scarcity, and official abuses fed into the Lofthus uprising and ultimately into the abolition of the Danish grain monopolies.

By foregrounding regionality, compound events, and interdisciplinarity, this study moves beyond portrayals of Laki as a monolithic "European" or "global" disaster (Oppenheimer, 2011; Schmidt et al., 2011; Zambri et al., 2019a, 2019b). Instead, it shows how a single volcanic eruption generated a spectrum of climatic anomalies and crisis trajectories within the Nordic macro-region, depending on the interplay of atmospheric circulation, ecological limits, market structures, and political governance. These findings have implications both for the interpretation of past volcanic episodes and for present-day risk assessment. They suggest that future high-latitude eruptions are unlikely to produce uniform outcomes but will operate through interacting climatic and institutional pathways whose consequences can only be understood through sustained collaboration between the natural sciences and the humanities.

Appendix A

Table A1: Locations and references of tree-ring chronologies compared in Fig. 5, arranged in alphabetical order.

Location	Country	Coordinates	Proxy	Sensitivity	Reference paper
Agder	Norway	59.3°N; 7.5°E	BI	July-August Temperature	*Khumalo et al. in preparation*
Ammarnäs	Sweden	66°N; 16.2°E	MXD	April-August Temperature	Björklund et al. (2013)
Arjeplog	Sweden	66.3°N; 182°E	BI, MXD	April-August Temperature	Björklund et al. (2014)
Central-Southern Norway	Norway	55-65°N; 4.5-14°E	TRW, MXD	June-August Standardized Precipitation Evapotranspiration Index (SPEI)	Seftigen et al. (2015)
Central-Southern Sweden	Sweden	55-65°N; 14-20°E	TRW, MXD	June-August Standardized Precipitation Evapotranspiration Index (SPEI)	Seftigen et al. (2015)

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Forfjorddalen	Norway	68.8°N; 15.8°E	MXD	June-August Temperature	McCarroll et al. (2013)
Jämtland	Sweden	63.1°N; 13.4°E	TRW, BI	April-September Temperature	Linderholm & Gunnarson (2019)
Kittelfjäll	Sweden	65.3°N; 15.5°E	MXD	April-August Temperature	Björklund et al. (2013)
Northern Scandinavia	Norway, Sweden, Finland	68.4°N; 25°E	MXD	June-August Temperature	Esper et al. (2012)
Rogen	Sweden	62.3°N; 12.4°E	TRW, BI	June-August Temperature	Fuentes et al. (2018)
Skuleskogen	Sweden	63.0°N; 18.5°E	BI	May-June Precipitation	Stridbeck et al. (2026)
Smitingen & Vårdkasen	Sweden	62.6°N; 18.0°E	TRW	May-June Precipitation	Jönsson & Nilsson (2009)
Sogndal	Norway	61.2°N; 7.1°E	MXD	April-September Temperature	Svarva et al. (2026)
South east Finland	Finland	61-62°N; 28-29°E	TRW	May-June Precipitation, May-September Temperature	Helama et al. (2009)
South east Finland	Finland	61-62°N; 28-29°E	MXD	May-June Precipitation, May-September Temperature	Helama et al. (2014)
Stockholm	Sweden	58.8-59.7°N; 17.6-18.6°E	MXD	May-July Precipitation	Rocha et al. (2020)
Tjeggelväs	Sweden	66.6°N; 17.6°E	MXD	April-August Temperature	Gunnarson et al. (2012)

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Table S2: Metadata for ModE-RA observations in Oct 1782–Mar 1783 for the region 54–70°N and 0–31°E, sorted by latitudes (Valler et al. 2024).

°E	°N	Variable	Type	Name
25.52	65.05	no_of_rainy_days	instrumental	Uleoborg
25.43	65.05	temperature	instrumental	Uleoborg
25.40	64.99	temperature	instrumental	OULUNSALO_PELLONPAA
12.90	63.50	temperature	instrumental	Trondheim/Vaernes
10.90	63.50	pressure	instrumental	TRONDHEIM
10.45	63.41	temperature	instrumental	TRONDHEIMVOLL
30.30	59.97	historical_proxy	documentary	Newa_fall_correctedfreezing_date
30.30	59.97	historical_proxy	documentary	Newa_springthawing_date
30.30	59.97	temperature	instrumental	St Petersburg
30.27	59.93	pressure	instrumental	St. Petersburg
17.60	59.90	precipitation	instrumental	UPPSALA AIRPORT
17.60	59.90	pressure	instrumental	UPPSALA
10.70	59.90	historical_proxy	documentary	Randsfjorden_springthawing_date
17.64	59.86	temperature	instrumental	Uppsala
11.08	59.62	pressure	instrumental	Spydeberg
11.08	59.62	temperature	instrumental	Spydeberg
24.75	59.50	historical_proxy	documentary	BalticSeaIceMaximum_Extent_AnnualSeaIceExtent
24.80	59.42	historical_proxy	documentary	Tallinn_springthawing_date
24.75	59.40	historical_proxy	documentary	Tallin_ice_break_upice_break_up
18.05	59.35	sea_level_pressure	instrumental	Stockholm
18.05	59.35	temperature	instrumental	Stockholm

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18.06	59.34	pressure	instrumental	Stockholm
18.05	59.33	historical_proxy	documentary	Mlaren_springthawing_date
18.00	59.15	historical_proxy	documentary	City_of_Stockholm_export_tax_1st_Departurefirst_ship_departure
18.00	59.15	historical_proxy	documentary	City_of_Stockholm_import_tax_1st_Arrivalfirst_ship_arrival
18.00	59.15	historical_proxy	documentary	Stockholm_official_statistics_from_the_harbour_master_of_Stockholm_when_the_sailing_season_started.start_sailing_season
18.00	59.15	historical_proxy	documentary	Stockholm_sea_passport_insurance_document_for_shipsship_insurance
24.05	56.97	historical_proxy	documentary	Western_Dvina_springthawing_date
24.10	56.95	historical_proxy	documentary	Daugava_River_Rigaice_break_up_series
13.20	55.70	precipitation	instrumental	LUND
12.50	55.70	temperature	instrumental	Koebenhavn
12.57	55.68	no_of_rainy_days	instrumental	Copenhagen
13.10	55.40	pressure	instrumental	LUND
25.10	54.63	temperature	instrumental	VILNIUS
18.67	54.35	precipitation	instrumental	Gdansk
18.67	54.35	temperature	instrumental	Gdansk
14.50	54.00	historical_proxy	documentary	Western_Baltic_Ice_severity_indexsea_ice_severity

Table A2: Metadata for ModE-RA observations in April–September 1783 for the region 54–70°N and 0–31°E, sorted by latitudes (Valler et al. 2024).

°E	°N	Variable	Type	Name
18.73	69.53	natural_proxy	tree_proxy	B14_europe_norw008.rwl
25.63	69.42	natural_proxy	tree_proxy	B14_europe_norw007.rwl

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28.13	69.32	natural_proxy	tree_proxy	B14_europe_finl061.rwl
17.22	69.08	natural_proxy	tree_proxy	B14_europe_norw009.rwl
28.48	68.92	natural_proxy	tree_proxy	B14_europe_finl047.rwl
26.88	68.87	natural_proxy	tree_proxy	B14_europe_finl062.rwl
27.25	68.83	natural_proxy	tree_proxy	B14_europe_finl021.rwl
15.73	68.80	natural_proxy	tree_proxy	B14_europe_norw010.rwl
15.73	68.73	natural_proxy	tree_proxy	P2k_Arc-McCarrol.Forfjordalen.2013_bsummer
25.87	68.67	natural_proxy	tree_proxy	B14_europe_finl060.rwl
27.33	68.49	natural_proxy	tree_proxy	P2k_Arc-McCarroll.Laanila.2013_bsummer
16.03	68.48	natural_proxy	tree_proxy	B14_europe_norw001.rwl
15.43	68.47	natural_proxy	tree_proxy	NTREND_FORF
28.07	68.45	natural_proxy	tree_proxy	B14_europe_finl059.rwl
19.60	68.26	natural_proxy	tree_proxy	P2k_Arc-Tornetrask.Melvin.2013_bsummer
19.67	68.23	natural_proxy	tree_proxy	B14_europe_swed019w.rwl
27.45	68.13	natural_proxy	tree_proxy	B14_europe_finl058.rwl
27.20	68.07	natural_proxy	tree_proxy	B14_europe_finl045.rwl
25.00	68.00	natural_proxy	tree_proxy	P2k_Eur-NScan.Esper.2012_bsummer
15.73	67.62	natural_proxy	tree_proxy	B14_europe_norw012.rwl
15.33	67.60	natural_proxy	tree_proxy	B14_europe_norw011.rwl
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20.37	66.85	natural_proxy	tree_proxy	B14_europe_swed002.rwl
17.60	66.60	natural_proxy	tree_proxy	P2k_Arc-Tjeggelvas.Bjorkelund.2013_bsummer
18.20	66.30	natural_proxy	tree_proxy	P2k_Arc-Arjeplog.Bjorklund.2014_bsummer
30.80	66.27	natural_proxy	tree_proxy	B14_asia_russ016.rwl
17.98	66.07	natural_proxy	tree_proxy	B14_europe_swed017.rwl

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17.09	65.95	natural_proxy	tree_proxy	NTREND_TAA (Tjeggelvas, Arjeplog, Ammarnäs composite)
16.10	65.90	natural_proxy	tree_proxy	P2k_Arc-Armarnaes.Bjorkelund.2013_bsummer
24.15	65.83	historical_proxy	documentary	Tornio_springthawing_date
15.50	65.20	natural_proxy	tree_proxy	P2k_Arc-Kittelfjall.Bjorkelund.2013_bsummer
25.52	65.05	no_of_rainy_days	instrumental	Uleoborg
25.43	65.05	temperature	instrumental	Uleoborg
25.40	64.99	temperature	instrumental	OULUNSALO_PELLONPAA
13.97	64.45	natural_proxy	tree_proxy	B14_europe_swed327.rwl
10.90	63.50	pressure	instrumental	TRONDHEIM
12.90	63.50	temperature	instrumental	Trondheim/Vaernes
10.45	63.41	temperature	instrumental	TRONDHEIMVOLL
13.25	63.30	natural_proxy	tree_proxy	NTREND_JAEM
13.34	63.25	natural_proxy	tree_proxy	P2k_Arc-Zhang.Jamtland.2016_bsummer
13.33	63.12	natural_proxy	tree_proxy	B14_europe_swed326.rwl
22.33	63.00	historical_proxy	documentary	Kyrnjoki_Seinjokiice_break_up_series
14.80	62.82	natural_proxy	tree_proxy	B14_europe_swed008.rwl
7.50	62.50	natural_proxy	tree_proxy	schweingruber_mxdabd_grid41
12.50	62.50	natural_proxy	tree_proxy	schweingruber_mxdabd_grid42
22.50	62.50	natural_proxy	tree_proxy	schweingruber_mxdabd_grid44
27.50	62.50	natural_proxy	tree_proxy	schweingruber_mxdabd_grid45
18.48	62.33	natural_proxy	tree_proxy	B14_europe_swed324.rwl
28.19	62.19	natural_proxy	tree_proxy	NTREND_SFIN
28.33	62.00	natural_proxy	tree_proxy	P2k_Eur-FinnishLakes.Helama.2014_bsummer
8.47	61.72	natural_proxy	tree_proxy	B14_europe_norw015.rwl
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30.90	61.37	natural_proxy	tree_proxy	B14_asia_russ081w.rwl
22.28	60.45	historical_proxy	documentary	Aura_River_Turkuice_break_up_series
25.68	60.38	historical_proxy	documentary	Porvoonjoki_Porvooice_break_up_series
29.58	60.27	natural_proxy	tree_proxy	B14_asia_russ115w.rwl

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24.90	60.19	historical_proxy	documentary	Finland_Pheno_IndexPhenoIndex
16.08	60.13	natural_proxy	tree_proxy	B14_europe_swed323.rwl
30.30	59.97	historical_proxy	documentary	Newa_spring-2thawing_date
30.30	59.97	temperature	instrumental	St Petersburg
30.27	59.93	pressure	instrumental	St. Petersburg
10.70	59.90	historical_proxy	documentary	Randsfjorden_spring-2thawing_date
17.60	59.90	precipitation	instrumental	UPPSALA AIRPORT
17.60	59.90	pressure	instrumental	UPPSALA
17.64	59.86	temperature	instrumental	Uppsala
9.48	59.70	natural_proxy	tree_proxy	B14_europe_norw014.rwl
11.08	59.62	pressure	instrumental	Spydeberg
11.08	59.62	temperature	instrumental	Spydeberg
24.80	59.42	historical_proxy	documentary	Tallinn_spring-2thawing_date
18.05	59.35	sea_level_pressure	instrumental	stockholm
18.05	59.35	temperature	instrumental	Stockholm
18.06	59.34	pressure	instrumental	Stockholm
18.05	59.33	historical_proxy	documentary	Mlaren_spring-2thawing_date
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18.70	59.20	natural_proxy	tree_proxy	B14_europe_swed302.rwl
18.27	59.18	natural_proxy	tree_proxy	B14_europe_swed328.rwl
12.50	57.50	natural_proxy	tree_proxy	schweingruber_mxdabd_grid67
24.05	56.97	historical_proxy	documentary	Western_Dvina_spring-2thawing_date
13.20	55.70	precipitation	instrumental	LUND
12.54	55.69	temperature	instrumental	Koebenhavn
12.57	55.68	no_of_rainy_days	instrumental	Copenhagen
13.10	55.40	pressure	instrumental	LUND
25.10	54.63	temperature	instrumental	VILNIUS
18.67	54.35	precipitation	instrumental	Gdansk
18.67	54.35	temperature	instrumental	Gdansk

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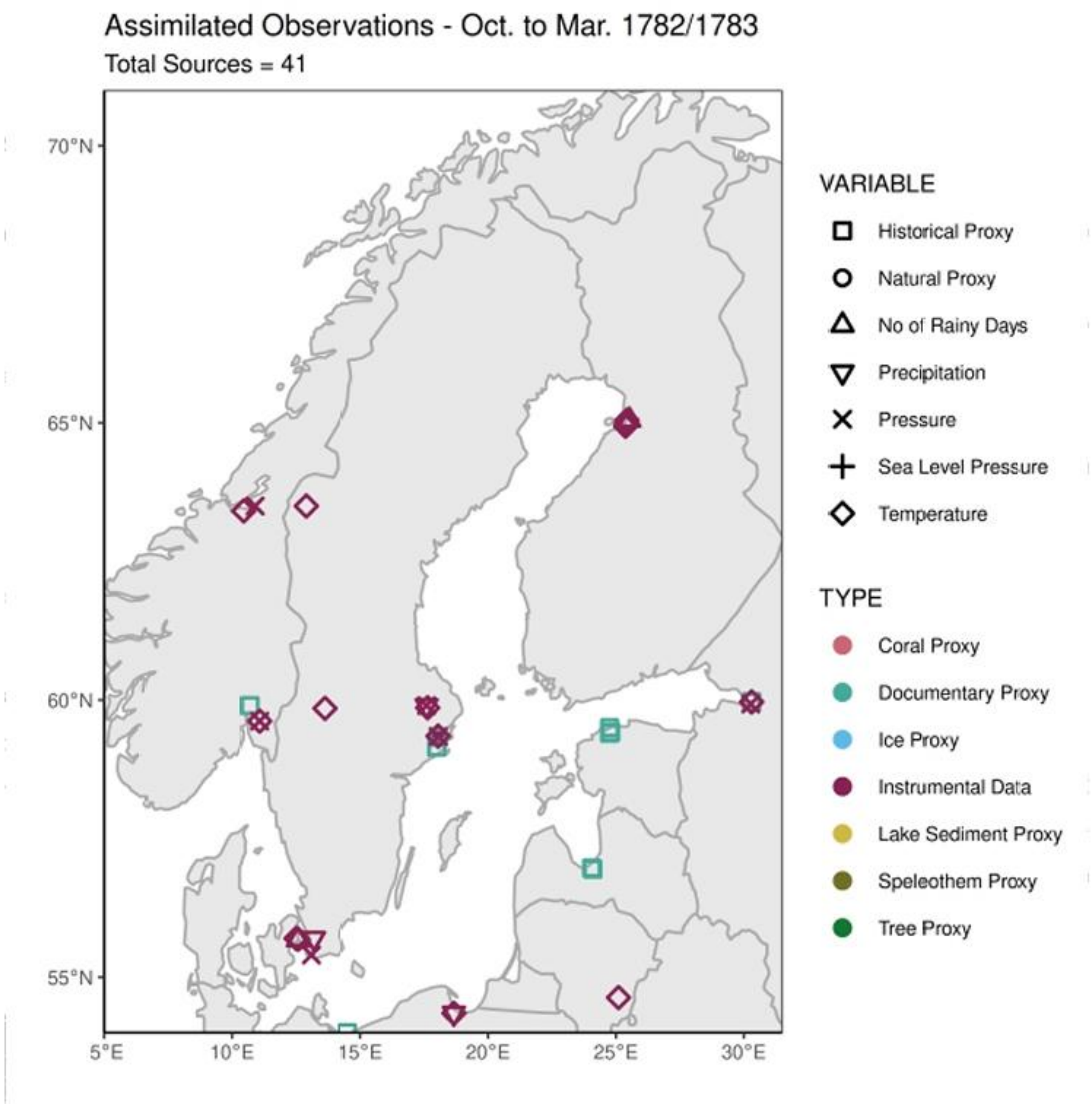

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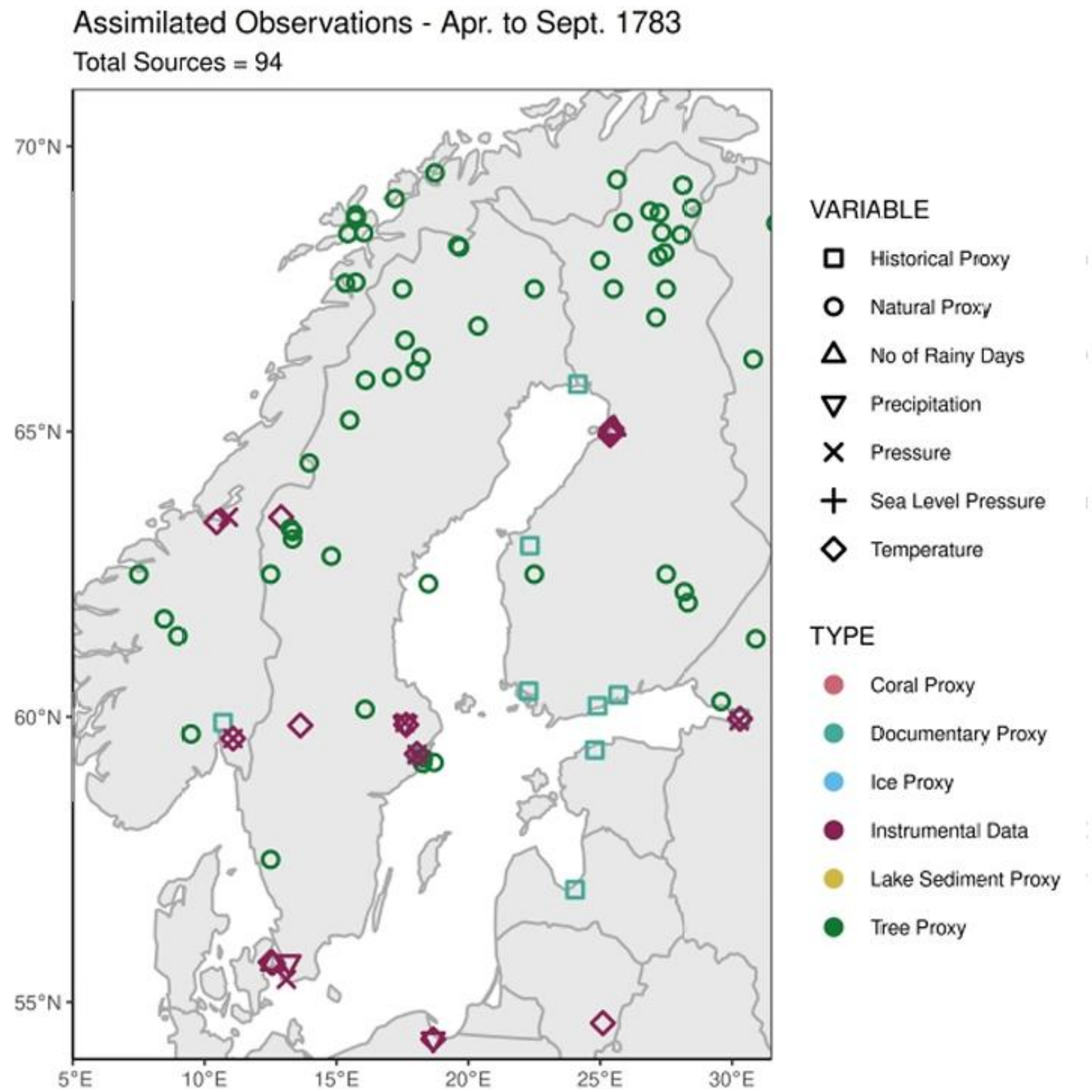

Figure A1: Observations used in ModE-RA during winter (left) and summer (right) season for the year 1783 (Valler et al., 2024; Warren et al., 2024). Note that some markers do not reflect the accurate geographical position. For example, the Trondheim instrumental temperature record is shown as located in Åre, central-western Sweden, and the Uppsala instrumental temperature record is shown as located in Värmland, western Sweden.

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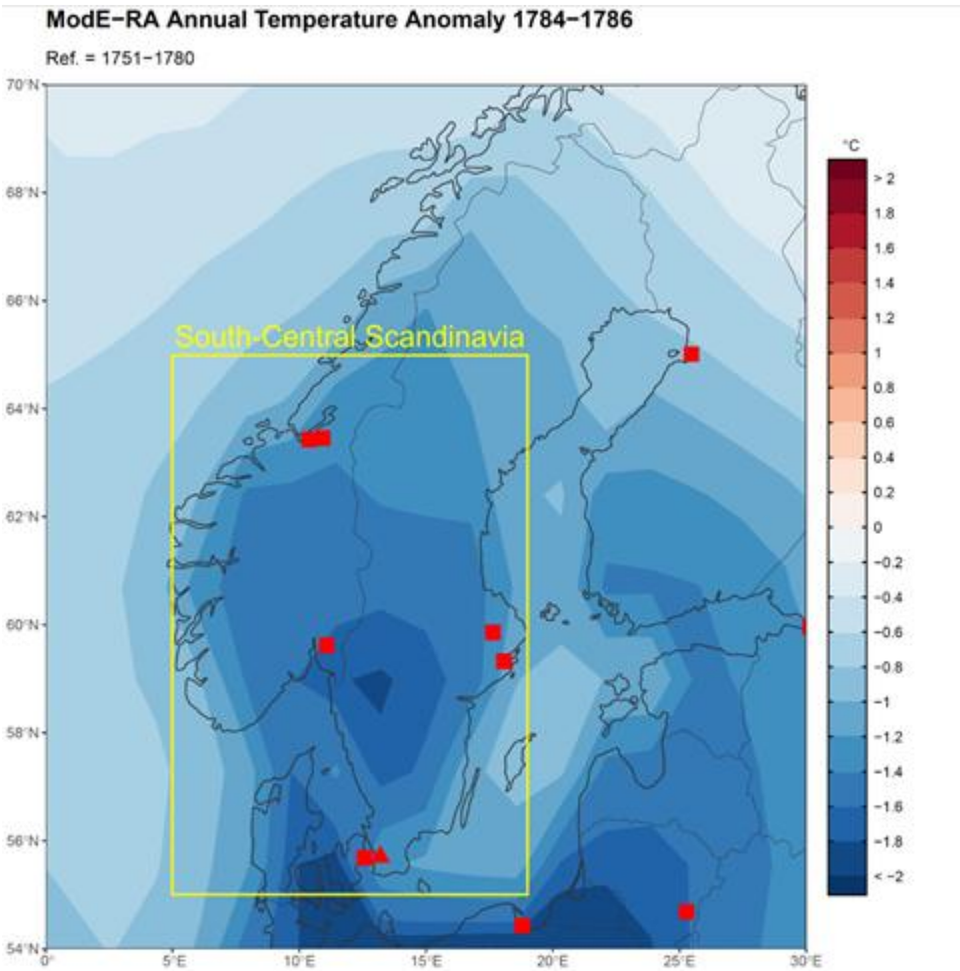

Figure A2: ModE-RA annual average temperature anomaly in Fennoscandia between 1784 to 1786 with respect to 1751–1780 (Valler et al., 2024; Warren et al., 2024).

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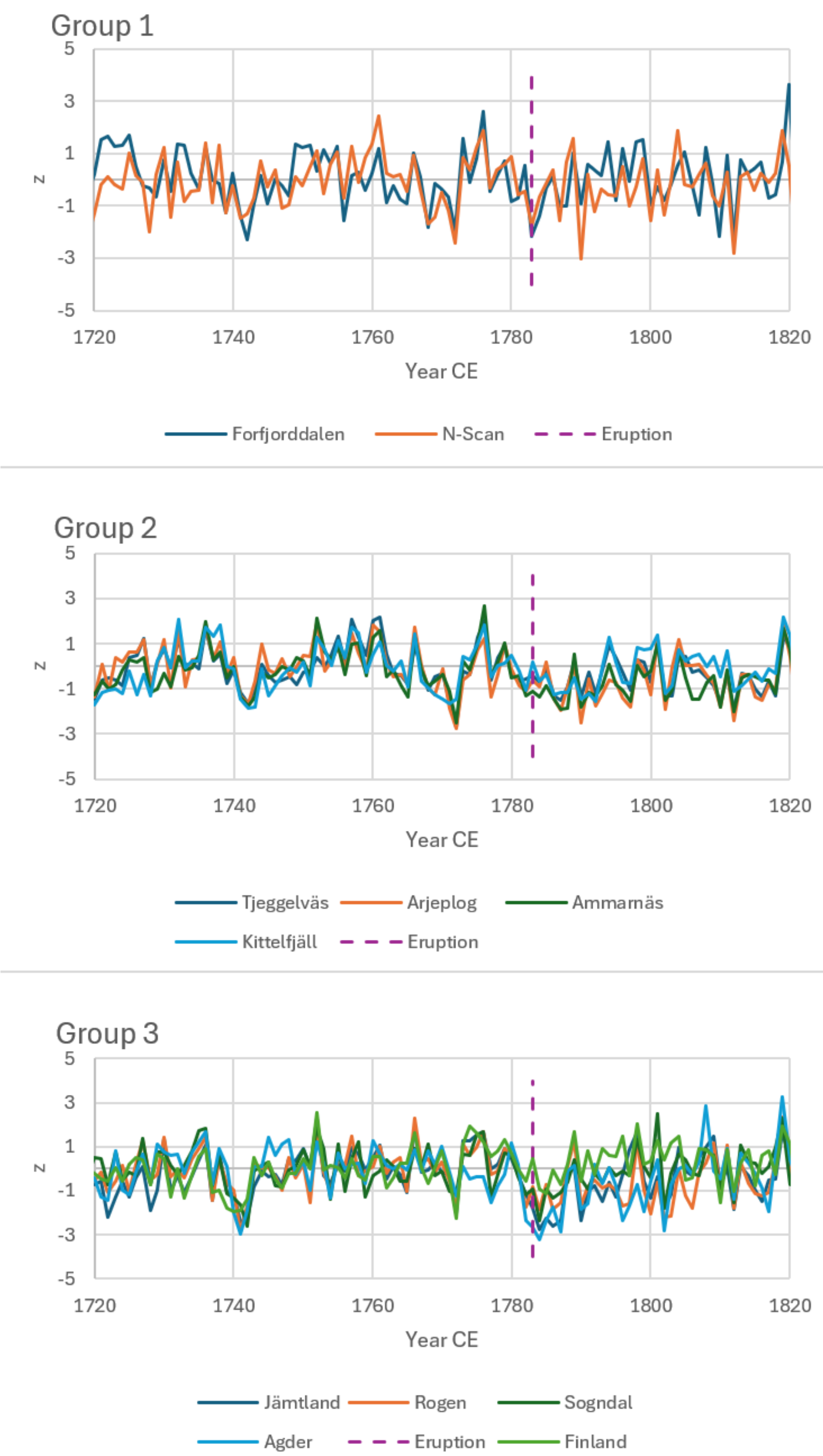

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Figure A3: Tree-ring density chronologies standardized (w.r.t. 1733–1782) over the period 1720–1820 separated by regional responses to the eruption: A) Group 1 including Forfjorddalen (MXD; McCarroll et al., 2013) and N-Scan (MXD; Esper et al., 2012). B) Group 2 in Sweden including Kittelfjäll (MXD; Björklund et al., 2013), Ammarnäs (MXD; Björklund et al., 2013), Tjeggelväs (MXD, Björklund et al., 2013) and Arjeplog (ΔBI; Björklund et al., 2014). C) Group C including Jämtland (MXD; Björklund et al., 2014), Rogen (adjusted ΔBI; Fuentes et al., 2018), Sogndal (MXD; Svarva et al., 2026), Finland Lakelands (Helama et al., 2014) and Agder (Khumalo et al., *in preparation*). The purple dashed line indicates 1783.

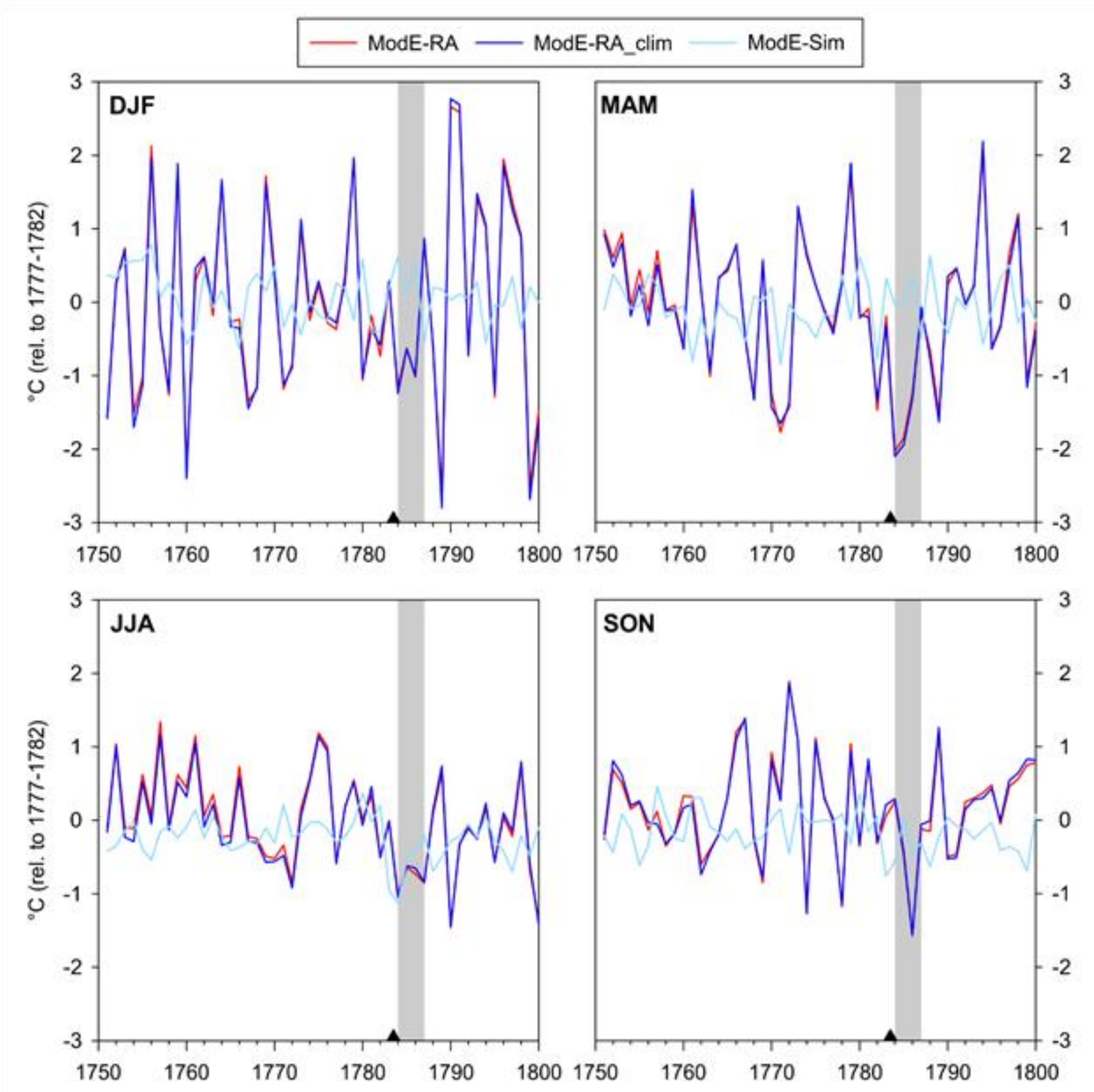

Figure A4: Time-series of ModE-RA, ModE-RA_clim and ModE-Sim seasonal temperature anomalies across Fennoscandia (0–30°E, 54–70°N) between 1751 and 1800 relative to 1777–1782 (Valler et al., 2024; Warren et al., 2024; Hand et al. 2023). Black

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triangle marks the start of the Laki eruption in June 1783–February 1784; grey shading marks the years 1784 to 1786.

Code and data availability

The complete instrumental series, tree-ring chronologies, documentary records are available together with full metadata contained in the ModE-RA palaeoclimate reanalysis database used in the study are publicly accessible via its web-portal: https://mode-ra.unibe.ch/climeapp/. The early instrumental monthly meteorological dataset (HCLIM) is provided by the PANGAEA data centre and can be accessed directly via its DOI https://doi.org/10.1594/PANGAEA.940724. Historical documentary sources (e.g., parish registers, trade-tax records and contemporary narratives) were obtained from national libraries and archives. The Swedish county-level mortality data can be accessed through the open-data SHiPS platform (https://doi.org/10.17197/U23003, Demografiska databasen, 2023) at Demografiska databasen, the Centre for Demographic and Ageing Research (CEDAR), Umeå University, Sweden, https://doi.org/10.17197/U23003. Any other third-party material is listed in the manuscript with full source information.

Author contributions

Dominik Collet, Sam White, Wendy Khumalo: conceptualization (lead), supervision (lead), writing – original draft (lead), writing – review and editing (lead), methodology (equal), visualization (equal), formal analysis and validation (equal). Ingar Mørkestøl Gundersen: conceptualization (lead), writing – original draft (lead), writing – review and editing (lead), methodology (equal), visualization (equal), formal analysis and validation (equal): Heli Huhtamaa, Kirstin Krüger, Hans W. Linderholm, Fredrik Charpentier Ljungqvist, Michael Sigl, Martin K. Skoglund, Ingar Stene, Helene Løvstrand Svarva: writing – original draft (lead), writing – review and editing (lead), methodology (equal), visualization (equal), formal analysis and validation (equal). Dann Grotum, Katrin Kleemann, Elin Lundstad: writing – original draft (equal), investigation (equal), validation (equal).

Competing interests

One of the (co-)authors is a member of the editorial board of Climate of the Past

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