DNMI

NORDKLIM – Nordic co-operation within Climate activities

Nordic climate maps

O.E.Tveito, E.J.Førland, H.Alexandersson, A.Drebs,
T.Jónsson, H. Tuomenvirta, E. Vaarby Laursen

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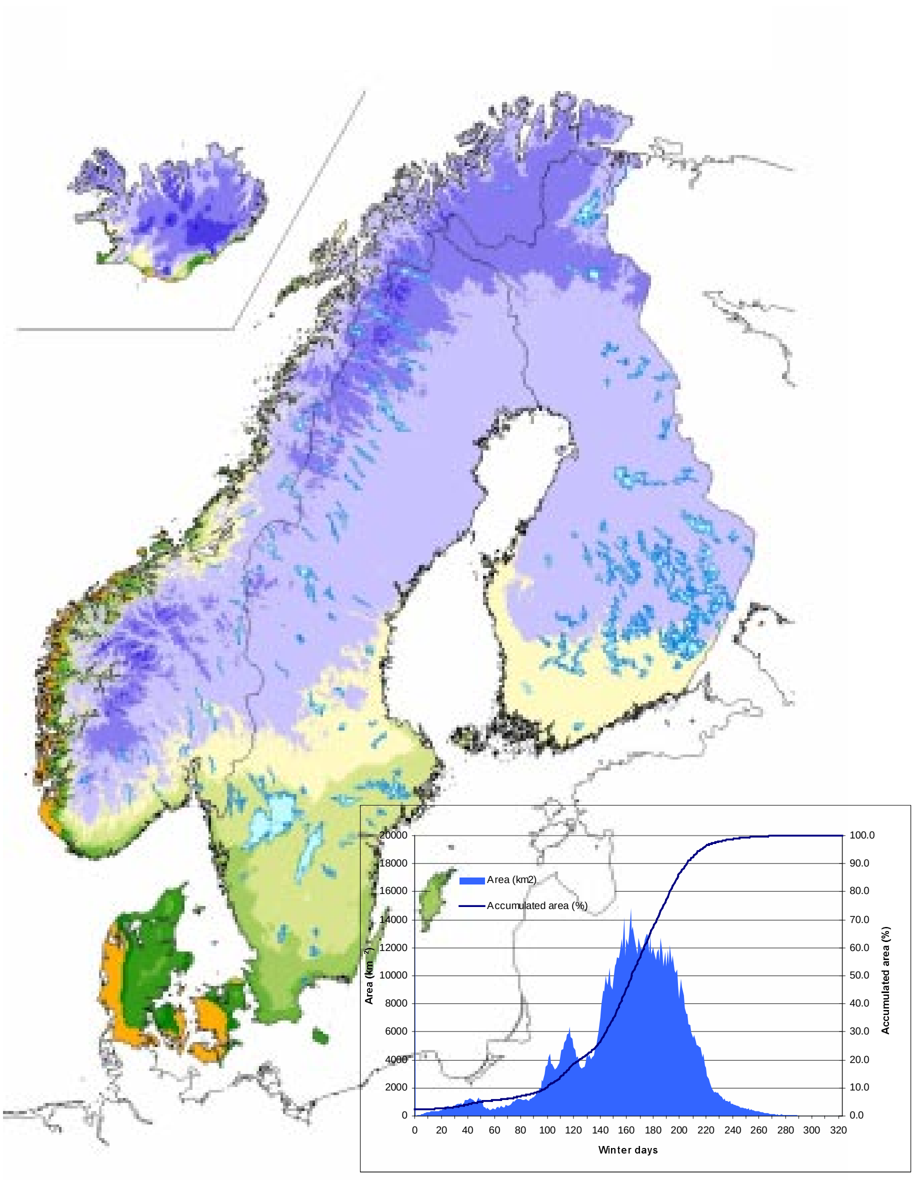

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PROJECT CONTRACTORS:

NORDKLIM/NORDMET on behalf of the National meteorological services in Denmark (DMI), Finland (FMI), Iceland (VI), Norway (DNMI) and Sweden (SMHI)

SUMMARY:

In this report maps of days with precipitation above certain thresholds and maps of temperature seasons are presented. These maps are established by utilizing geographical information systems (GIS), and demonstrate the power of such systems.
The report shows an application calculating daily mean temperatures based on mean monthly temperatures, and how these can be applied in a gridded approach. In this report maps of start, end and length of temperature seasons as well as degree-day sums are established applying this algorithm.
These maps show the potential of gridded climate data sets, and the added value a novel GIS may give such information.

KEYWORDS:

Geographical Information Systems (GIS), Gridded climate data sets, Temperature, Days with precipitation

SIGNATURES:

....	....
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NORDKLIM Activity Manager	Head of the DNMI Climatology Division

Foreword

This report is prepared under task 2 in the Nordic NORDKLIM project: *Nordic Co-Operation Within Climate Activities.* The NORDKLIM project is a part of the formalised collaboration between the NORDic METeorological institutes, NORDMET.

The main objectives of NORDKLIM are:

1) *Strengthening the Nordic climate competence for coping with increased national and international competition*
2) *Improving the cost-efficiency of the Nordic meteorological services (i.e. by i*mproving procedures for standardized quality control & more rational production of standard climate statistics)
3) *Coordinating joint Nordic activities on climate analyses and studies on long-term climate variations*

The NORDKLIM project has two main tasks:

1. **Climate data** (Network design, Quality control, long-term datasets).
2. **Climate Applications** (Time series analysis, use of GIS within climate applications, mesoscale climatological analysis, extreme values and return periods).

A detailed description of the project is given by Førland et al.(1998).

NORDKLIM is coordinated by an Advisory Committee, headed by an Activity Manager. Each of the main tasks is headed by a Task manager.

The Advisory Committee in NORDKLIM is presently consisting of:

Hasse Alexandersson, SMHI
Eirik J. Førland, DNMI (Activity Manager)
Raino Heino, FMI
Trausti Jónsson, VI
Lillian Wester Andersen, DMI

The present task managers are: Task 1: Pauli Rissanen (FMI), Task 2: Ole Einar Tveito (DNMI)

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Contents

1. Introduction

Climate reference values have a wide usage in different levels of society. One important and traditional use is as a reference for estimating design values in engineering (building construction, dam safety). Such design values are usually sime type of extremes. Calculation of the these are however often based on relations including the mean values, especially at locations without measurements. One example where such reference values are important is the energy system, which needs climate information for both energy consumption as well as (hydropower) production. Temperature is in this respect an important variable for the energy demand, while both precipitation and temperature are key factors for hydropower production potential. Both mean values and estimates of extremes are important. Extremes are important in dimensioning the system for extreme floods, extremely low temperatures (high energy consumption). Such systems are based on available information, and the current standards are related to the standard normal period 1961-90. Also in agriculture is temperature an important element. Measures of mean temperatures or temperature seasons are used for planning the most efficient cultivation of different crops.

During the last years focus is given to the problem of climate change. Continuous and fine scale descriptions of climatic reference values are of great importance when discussing regional climatic trends, and their impact on different processes (water balance, agriculture, soilfrost, etc.). Such information may serve a solid platform for describing local impact due climate variability, and is ideal in combination with downscaling of GCM results. Such analysis will show whether the current design values can be used, or if the design calculation has to be adjusted for the expected future climate.

The climate sectors in the Nordic meteorological institutes have a long tradition for cooperation, and this document is the third volume with climate maps describing normal mean values for the period 1961-90. Tveito et al. (1997) present annual and seasonal maps of precipitation, applying ordinary kriging for interpolating point values to continuous precipitation fields. In Tveito et al. (2000), detailed maps of monthly mean values for temperature were estimated applying a residual kriging approach, including topographical information in the interpolation procedure. Both these two works utilize the technology of geographical information systems (GIS).

In this report, two type of maps describing the mean values from the standard normal period 1961-90 are presented:

- Maps of number of days with precipitation above 0.1, 1.0 and 10.0 mm.
- Maps of growing days, degree days etc.

The maps are established by using state-of-the-art geographic information systems (GIS) technology. This report will not focus technical details how GIS-functionality is applied, but the results presented are a documentation of the potential of applying GIS and digital maps in climatological analysis.

2. Number of days with precipitation above certain thresholds.

Maps of precipitation above certain thresholds give an indication of the “wetness” in different areas. Such information is important for e.g. irrigation purposes and urban drainage system design. In this chapter maps of number of days exceeding 0.1, 1.0 and 10.0 mm are presented.

2.1 Data

The data used to present the following maps are based on the national normal datasets from Denmark (Frich & al, 1997), Finland (FMI, 1990), Norway (Førland, 1993), Sweden (Alexandersson et al., 1997) and Iceland. The total station network consists of 788 stations:

- Finland : 94
- Denmark: 212
- Sweden: 79
- Norway: 355
- Iceland: 48

Figure 2.1 shows the location of the station used in the precipitation analyses. The map illustrates the large national differences in number of stations with available information. In Denmark and Norway the station coverage is quite dense, while in Sweden and Finland the density is relatively sparse. In Iceland the coverage is good in coastal areas, while the interior is sparsely covered by observations. The regional differences in station density may influence the spatial analysis.

2.2 Maps

Figure 2.3 shows annual mean of number of days with precipitation $\geq$ 0.1 mm. This threshold is dubious of several reasons. A value of 0.1 mm is reported if the observer measures from one single drop and up to 0.1 mm when emptying the gauge. The station network is a mix between stations observing precipitation amount once a day (precipitation stations), and stations with 2-4 observations a day (synoptic weather stations and climate stations). Because of shorter exposure for evaporation, the frequency of 0.1 mm amounts will usually be larger at stations measuring several times a day, than at the precipitation stations. There are also different evaporation characteristics for the different precipitation gauges used in the Nordic countries (Førland et al., 1996). It is also a fact that the most reliable observers are more likely to notice small precipitation amounts (0.0 and 0.1 mm) than others.

Because of the above-mentioned features, systematic differences between neighbouring stations may give unrealistic local patterns in some areas (e.g. the maximum value in northern Finland is caused by high-quality measurements at the Observatory in Sodankylä). For larger amounts of daily rainfall, the influence of these features will be negligible, and the maps showing exceedance above 1.0 and 10.0 mm will be more robust than the map for $\geq$ 0.1 mm.

However, the map in figure 2.3 gives an indication of number of rainy days in the Nordic countries. The whole region gets precipitation at least every third day (Figure 2.2a). Approximately 65% of Fennoscandia experience precipitation every second day. Along the

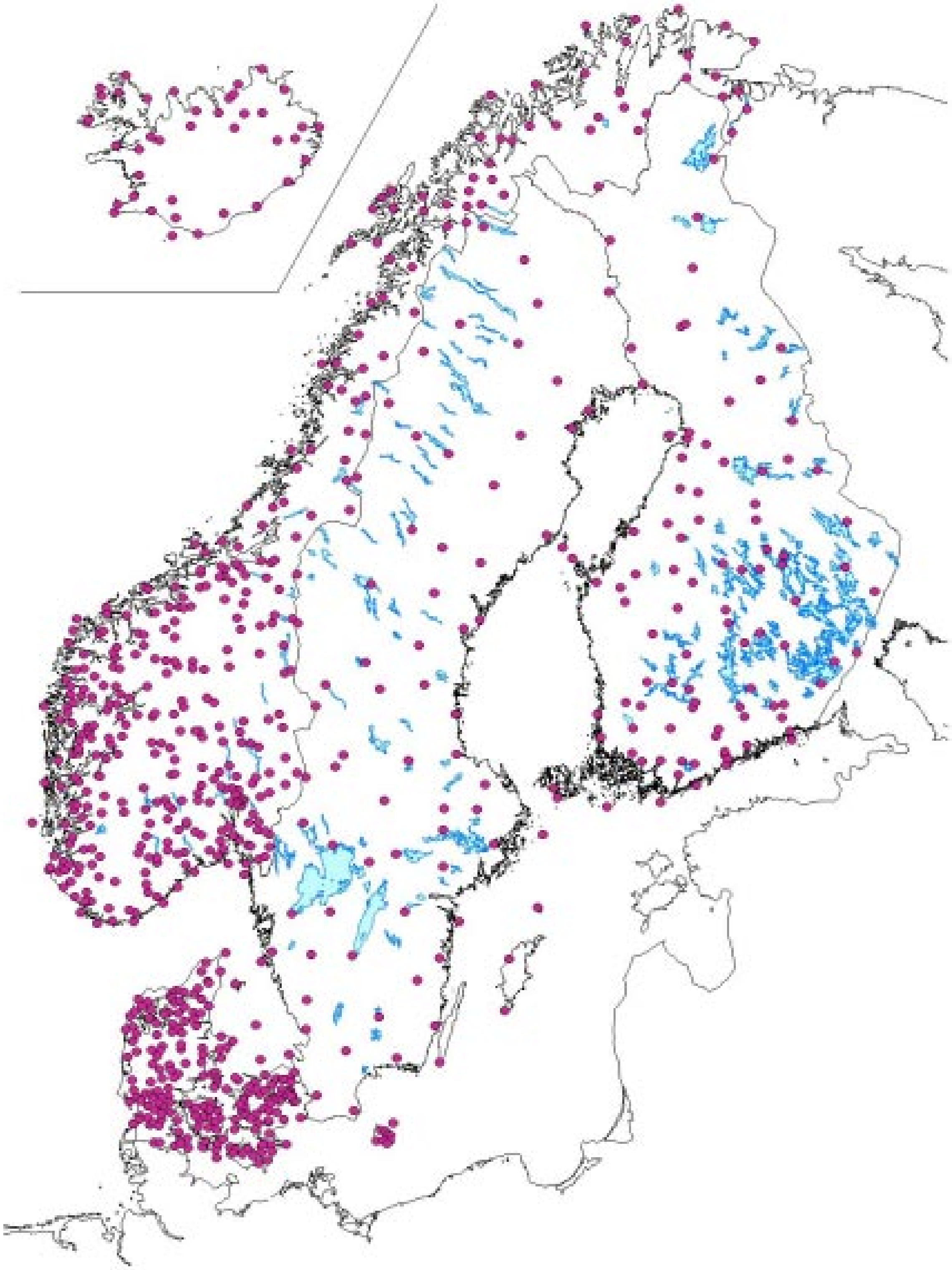

Figure 2.1 Stations used to derive maps for mean annual number of days with precipitation above 0.1, 1.0 and 10.0 mm.

Atlantic coast and at Sodankylä in eastern Finland, number of days with precipitation more the 0.1 mm exceeds 200. In Iceland, the pattern is north-south, with a dry zone in the interior in north-east. There are many days with precipitation along the coast (>175) except at the eastern coast. The Icelandic station network mainly consists of stations along the coast, and is especially lacking stations in the interior in the southern part of the country.

Figure 2.4 shows number of days with precipitation ≥ 1.0 mm and figure 2.5 a similar map for precipitation levels ≥ 10.0 mm. These maps show much more significant patterns of wet and dry areas in Fennoscandia. These patterns show an east-west gradient. The western coast of Norway experiences almost twice as many days with precipitation as the eastern parts. A large area in central southern Norway, located in the "rainshadow", have less than 100 days with precipitation grater than 1.0 mm, while the coastal area just 100 km away has more than 175 days. But there are also coastal areas with few days with precipitation above 1.0 mm. The Baltic coasts in Sweden and Finland have less than 125 days, and there are some spots (Öland, Gotland and some zones in Gulf of Bothnia) that have less than 100 days. Local maximum zones are found also in western Denmark and in Halland in Sweden. In Iceland, the maximum number of days is found at the southern coast, and the minimum zone is in the interior in the north.

The map of days with precipitation more than 10 mm shows an even more distinct east-west pattern. The maximum zone is found in the western part of Norway, between Bergen and Nordfjord, but the entire coastline between Lindesnes and Bodø shows higher values than any other place in Fennoscandia. The eastern parts have very few very wet days. One interesting feature is the "plume" of few wet days through Dalarna in Sweden into northern parts of Hedmark and Oppland in Norway.

Studying the areal frequency distribution of precipitation above different thresholds in Fennoscandia, it is interesting to notice the change in the shape of the distribution. Most of Fennoscandia (>90%) have between 150 and 225 days with precipitation ≥ 0.1mm. The distribution has a central gravity. Comparing this with the histogram of days with precipitation ≥ 1.0 mm, there is shift towards to a more skewe distribution. More than 2/3 of Fennoscandia has between 150 and 175 days with precipitation ≥ 1.0mm. The tendency to a more skew distribution is even more obvious regarding the distribution of days with precipitation ≥ 10.0 mm, for which the shape is similar to the γ-distribution. In more than 50% of Fennoscandia there are less than 100 days with precipitation ≥ 10.0 mm.

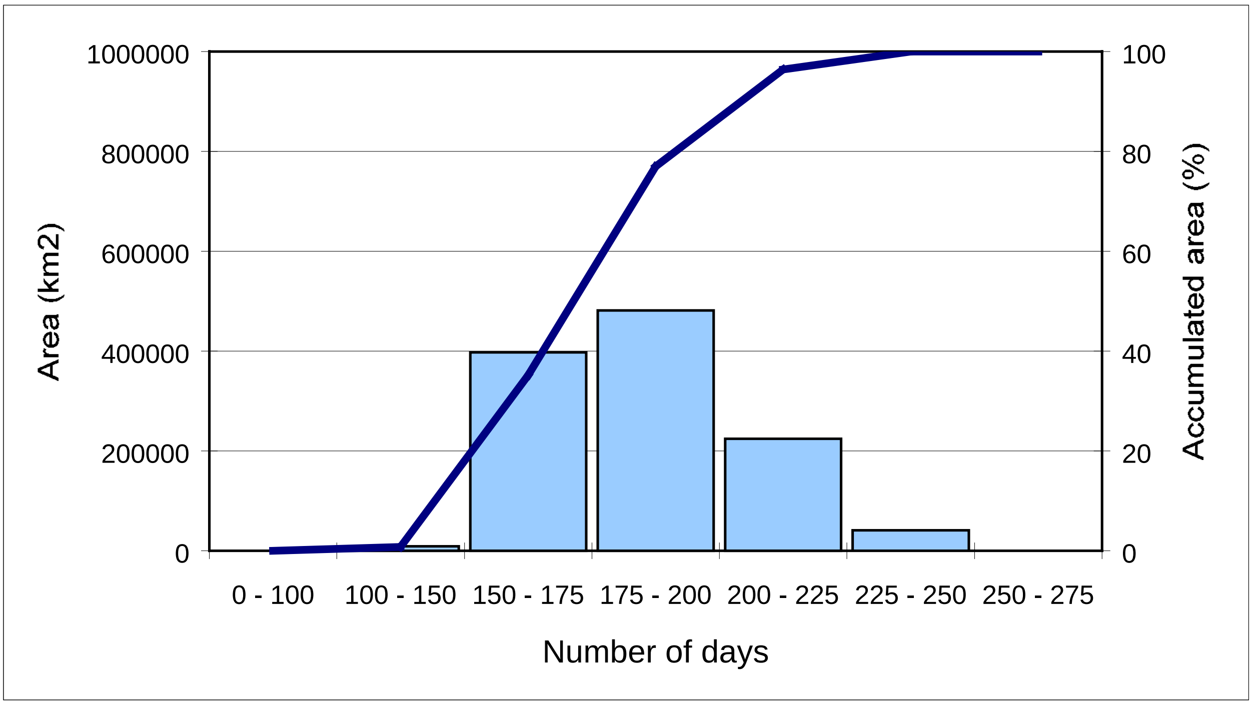

Figure 2.2a Frequencies of days with precipitation ≥ 0.1 mm. The figure shows the area falling into each of the intervals.

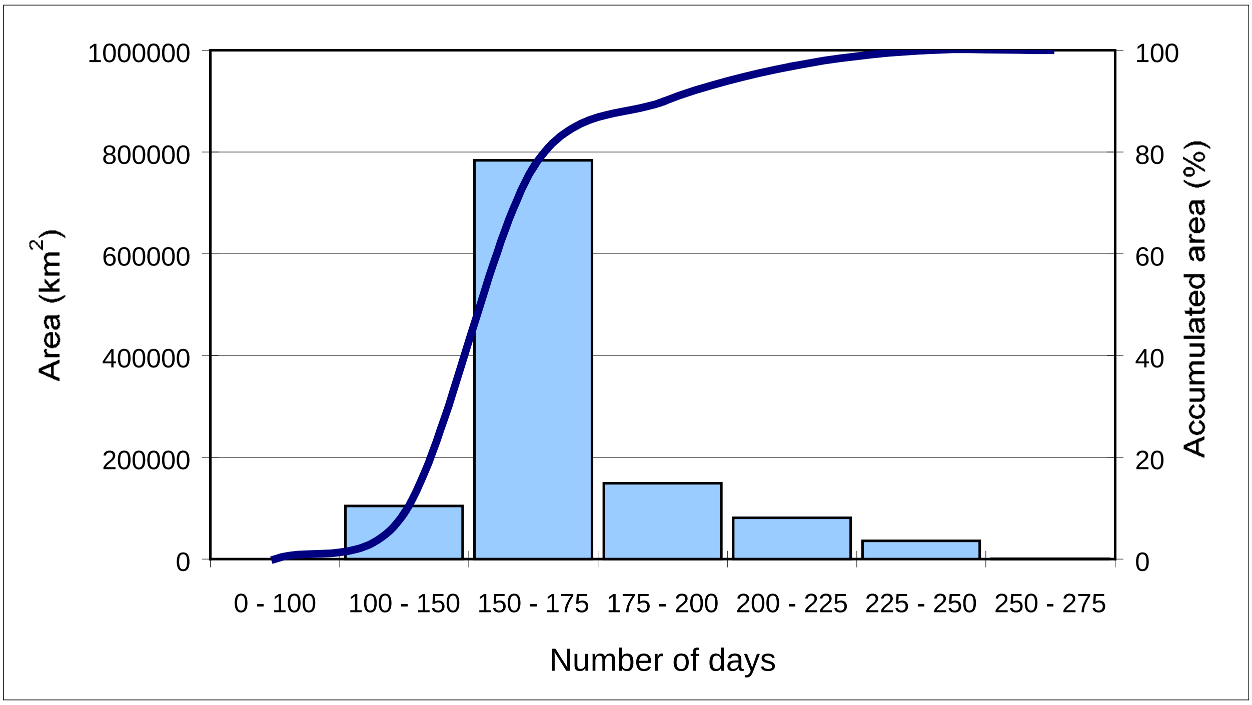

Figure 2.2b Frequencies of days with precipitation ≥ 1.0 mm. The figure shows the area falling into each of the intervals.

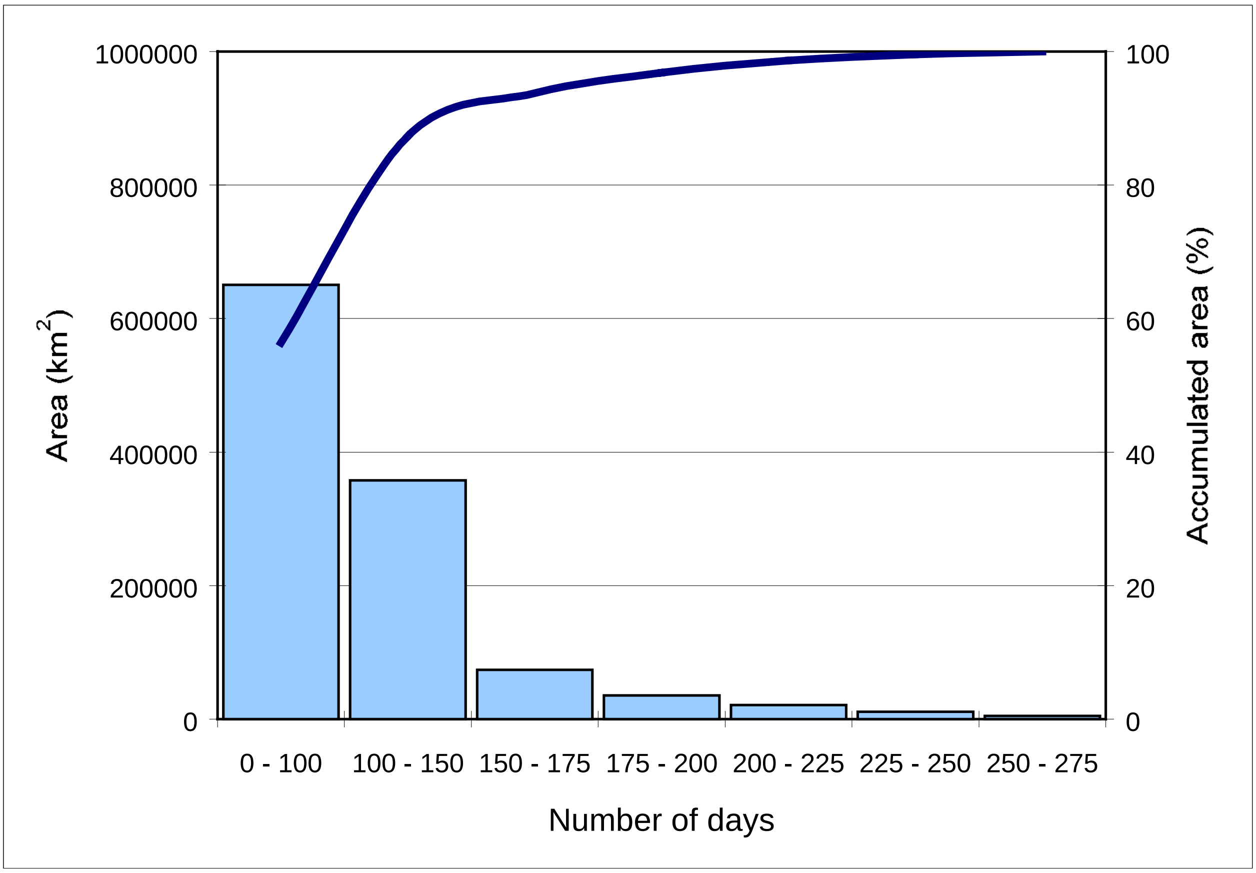

Figure 2.2c Frequencies of days with precipitation ≥ 10.0 mm. The figure shows the area falling into each of the intervals.

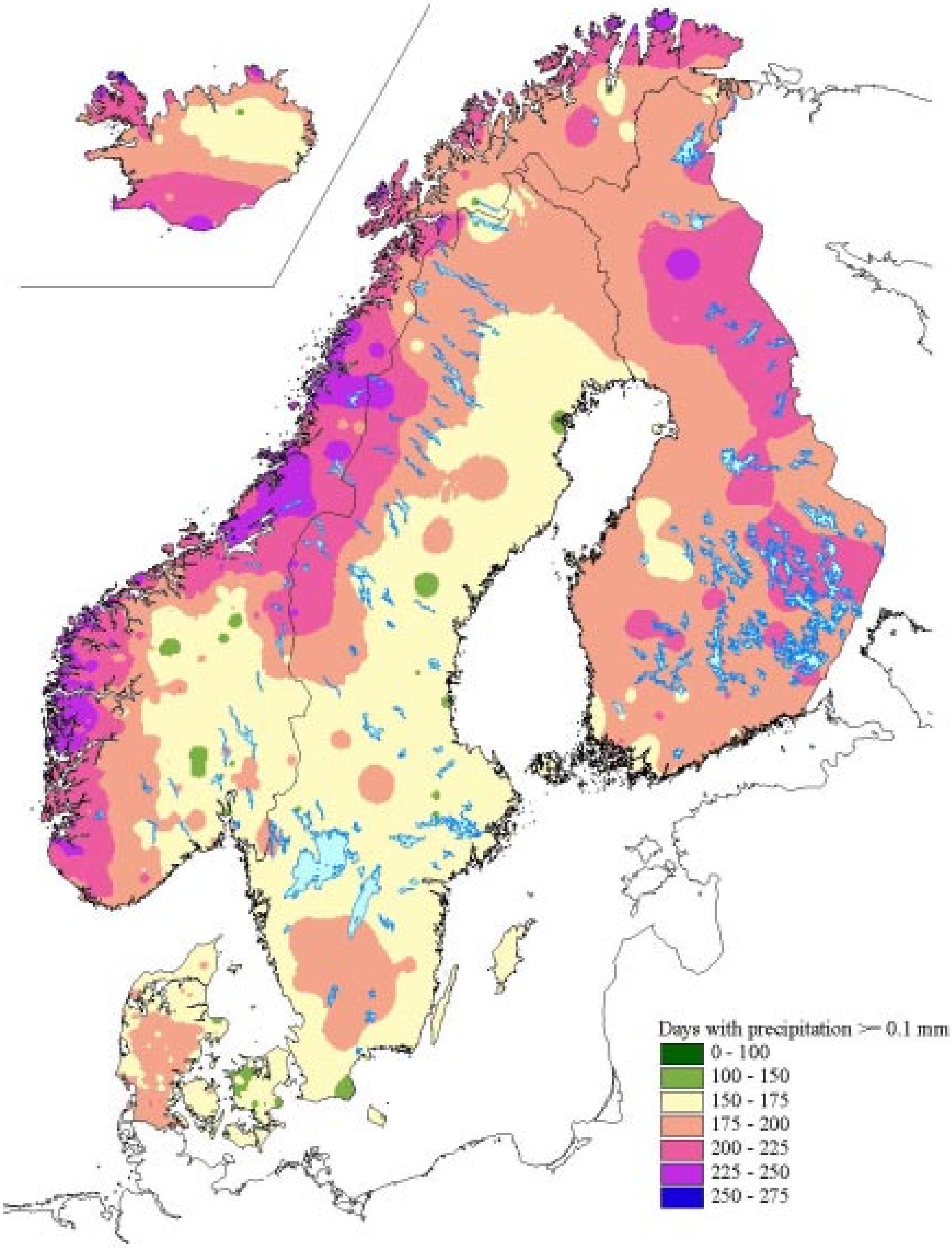

Figure 2.3 Mean annual number of days with precipitation ≥ 0.1 mm for the normal period 1961-90.

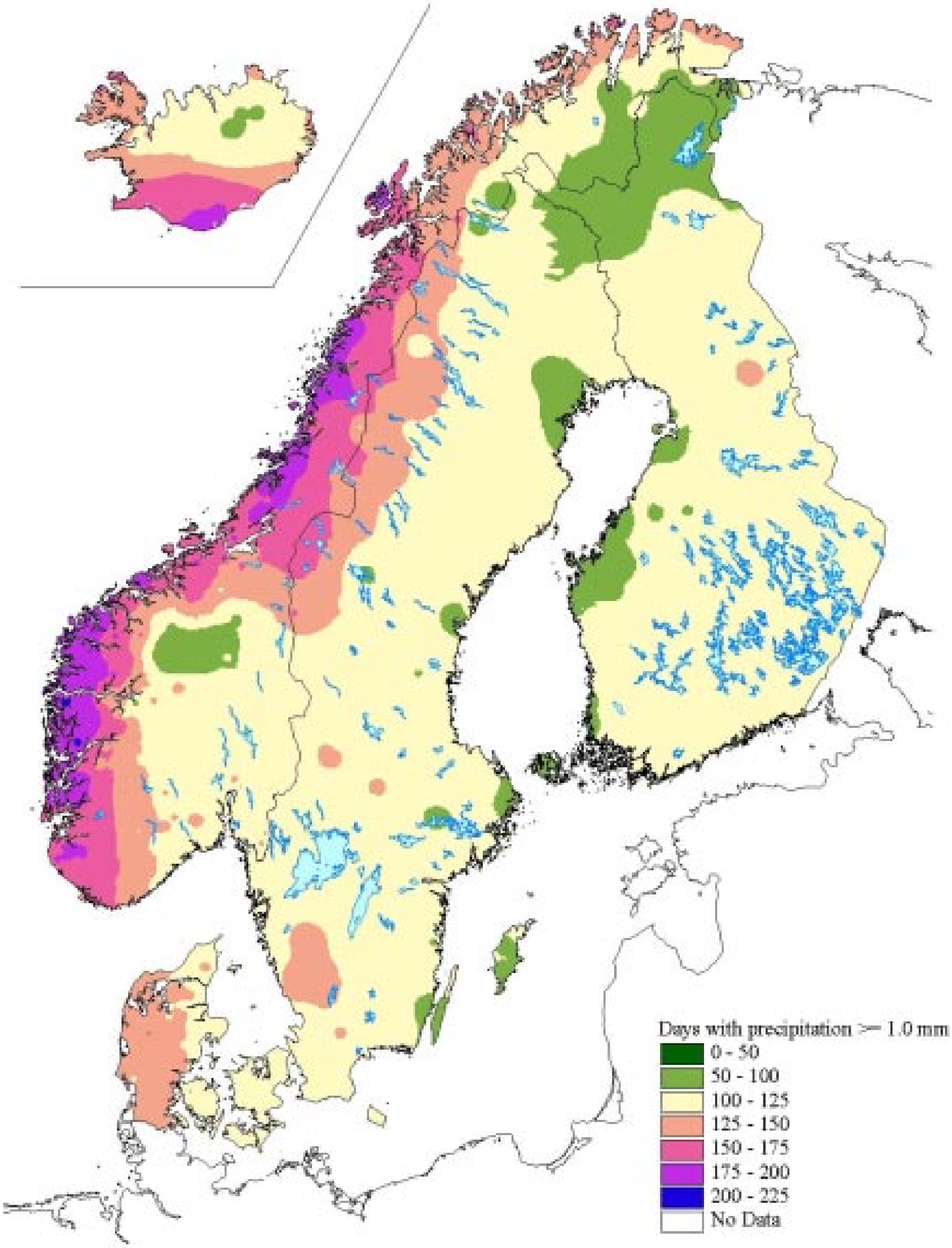

Figure 2.4 Mean annual number of days with precipitation ≥ 1.0 mm for the normal period 1961-90.

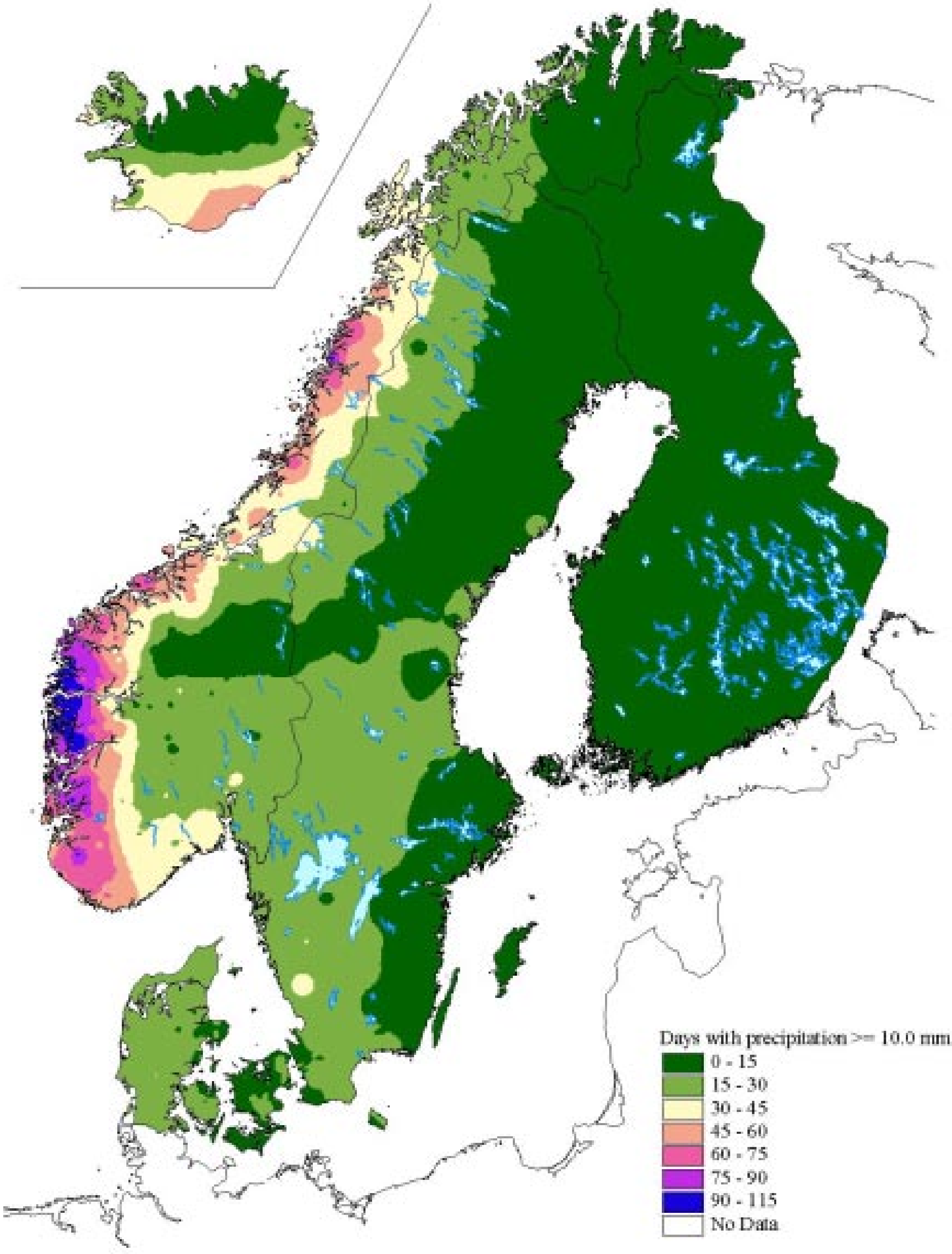

Figure 2.5 Mean annual number of days with precipitation ≥ 10.0 mm for the normal period 1961-90.

3. Maps of temperature derivates

By temperature derivates is meant different climate descriptions derived from air temperature series. Such derivates may be the length of growing or heating seasons, the start/end of these seasons and the thermal sums above/below given temperature thresholds. In this chapter some examples of mapping of temperature derivates are presented.

Map basis

The maps are based on the Nordic normal temperature maps (Tveito et al., 2000). These are grids representing monthly mean temperatures 1961-90. They are established using a detrended kriging approach. 1247 stations point normal values from the Nordic countries have been "normalized" by a climatic trend expression. The trend was defined by linear regression, where three different topographical parameters (altitude, mean altitude in a 20 km radius and minimum altitude within the same radius), longitude and latitude were used to predict monthly mean temperatures. This deterministic trend was removed from the observations, and kriging was used to interpolate a gridded "normalized" temperature field with 5x5 km^2 resolution. The trend expression was then added to the normalized field, applying gridded representations of the predictors on 1x1 km^2 resolutions.

In order to determine temperature seasons and degree-days, daily normal values have to be estimated. These are achieved by interpolating daily values from the monthly normal temperatures applying a cubic spline algorithm (see e.g Press et al. 1992). In the approach applied here, a constraint was added to the spline equation. This constraint ensures that the deviation between the gridded monthly mean temperature and the mean monthly temperature based on the daily (splined) values are within an acceptable tolerance (0.001 °C is used). The amplitude of the spline curve was adjusted by shifting the positions of the monthly mean (default in the middle of the month). This was done iteratively until the tolerance criterion was fulfilled (S.L.Lystad, pers.comm.). This method reproduces the observed daily thirty year means quite well as shown in figure 3.1. Daily normal values were calculated for each grid-cell.

Growing season

In the Nordic countries the growing season is defined as the period when the daily mean temperature is above 5°C. Here three maps are presented: first and last day, and the length of the growing season. Figure 3.2b shows the start of the growing season. Figure 3.2a shows the frequency distribution of the start of the growing season in Fennoscandia. The first day in Fennoscandia with mean daily temperature above 5°C is 3. April. By May 9., the growing season has started in 50% of Fennoscandia. The long tail in the right part of the distribution is interesting, showing that there are areas where the growing season starts late in the summer. Actually 1650 km^2 of Fennoscandia do not reach the 5°C mean daily temperature during a normal summer. These areas are found at high altitudes, and they coincide to a large degree with areas covered by glaciers.

Figure 3.3 shows the last day of the growing season. The corresponding frequency distributions are found in figure 3.3b. The same distribution pattern as for the first day is found, but now the long tail is found in the left side of the distribution. This is confirmed by figure 3.4a that shows the distribution of the length of the growing season. There is a long tail towards short growing season. The spike at zero indicates the area having no growing season in a normal summer, while figure 3.4 shows the length of the season. All three graphs show that the start and end of the growing season is much better defined as the "peak level" in the summer ("end of start" and "beginning of end").

Winter season.

The winter season can be defined as the period when the daily mean temperature is below 0°C. Figure 3.5a shows the length of this season. Figure 3.5b shows the areal frequency distribution, and it is noticed that large parts of Denmark and the west coast of Norway up to Trondheimsfjorden normally do not have winter according to this definition. The tails are quite long, especially towards the left side where maritime effects may play an important role. On the right side, small areas with winter season longer than 300 days occur. The accumulated areas are so small that they are not visible in the graph. These are mountain areas marked with a dark blue color in figure 3.5a.

Degree days.

Degree-days are defined as the degree sum above a defined threshold. Mathematically this can expressed as:

$$T_D = \sum_{i=1}^{365} T_i - \hat{T} \qquad | \qquad T_i \geq \hat{T}\,,$$

where T_i is the daily temperature normal and $\hat{T}$ is the reference temperature. T_D is the number of degree-days.

Figure 3.6 shows the degree-days of the growing season, which is defined of the sum of degree days over 5°C. This map differs from the growing season map (fig 3.4). The growing season map shows the length of the season, or the season when crops ideally are able to grow. The degree-day map gives a measure for the total "energy" available to the crops. This means than even if the growing season is longer e.g. at the western coast of Norway, the total energy in counts of degree-days may be higher in other areas with shorter season. This is also reflected by the frequency curves, as shown in figure 3.6b. This frequency has a much more quadratic shape, with very distinct start and end. This is another indication that even if the season is relatively short, the heating sum can be as high as in areas where the season is longer. At the right side, coastal areas with a high degreesum (Denmark and coastal areas in southern Sweden) make the tail a little longer.

Another degree-day map is shown in figure 3.7. This map shows the degree sum for temperatures below 17°C, which is often used as an indication of energy need for house warming.

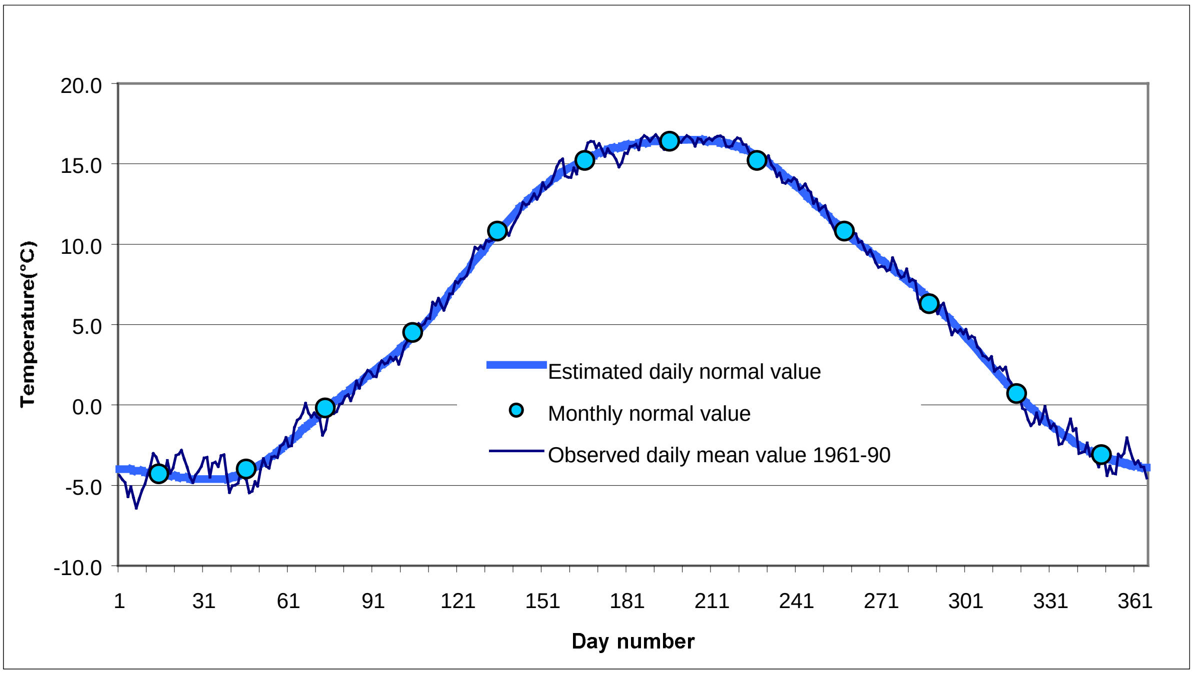

Figure 3.1 Daily normal temperatures 1961-90 for station 18700 Oslo-Blindern, Norway, based on observations and on interpolation of monthly mean temperatures.

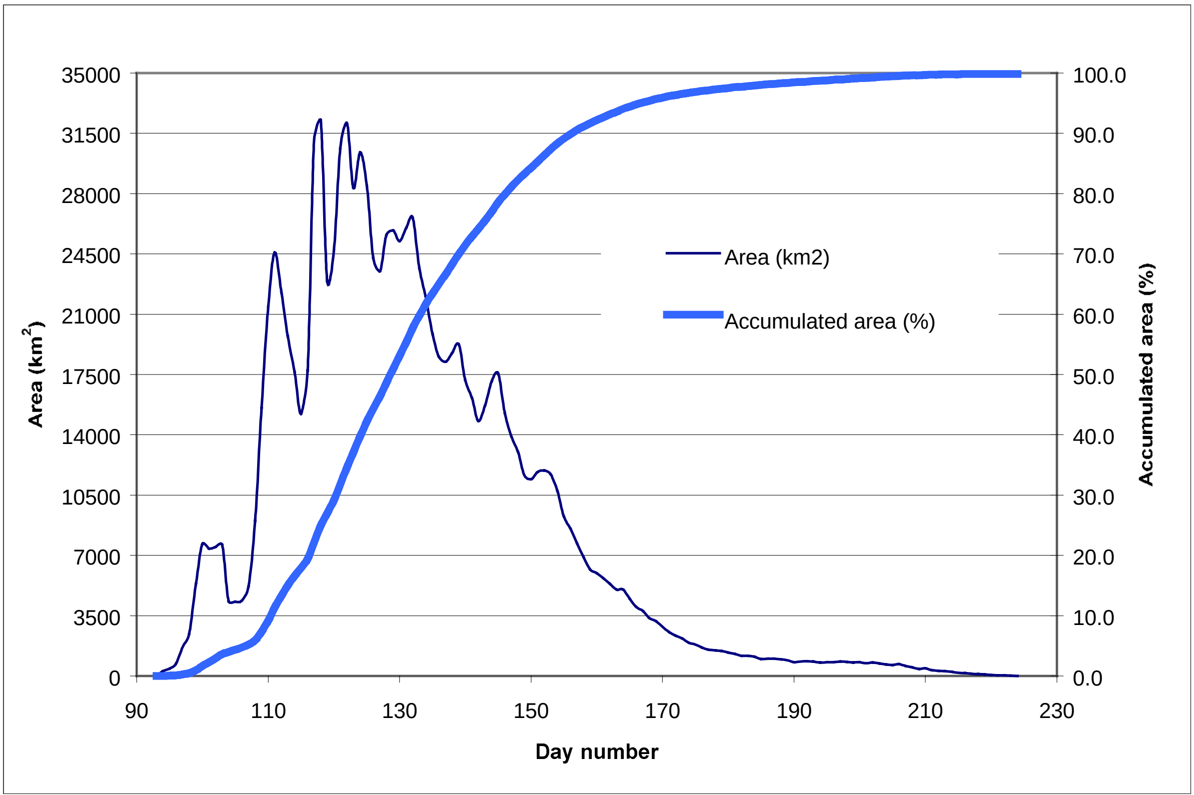

Figure 3.2a. Areal distributions of the start of the growing season.

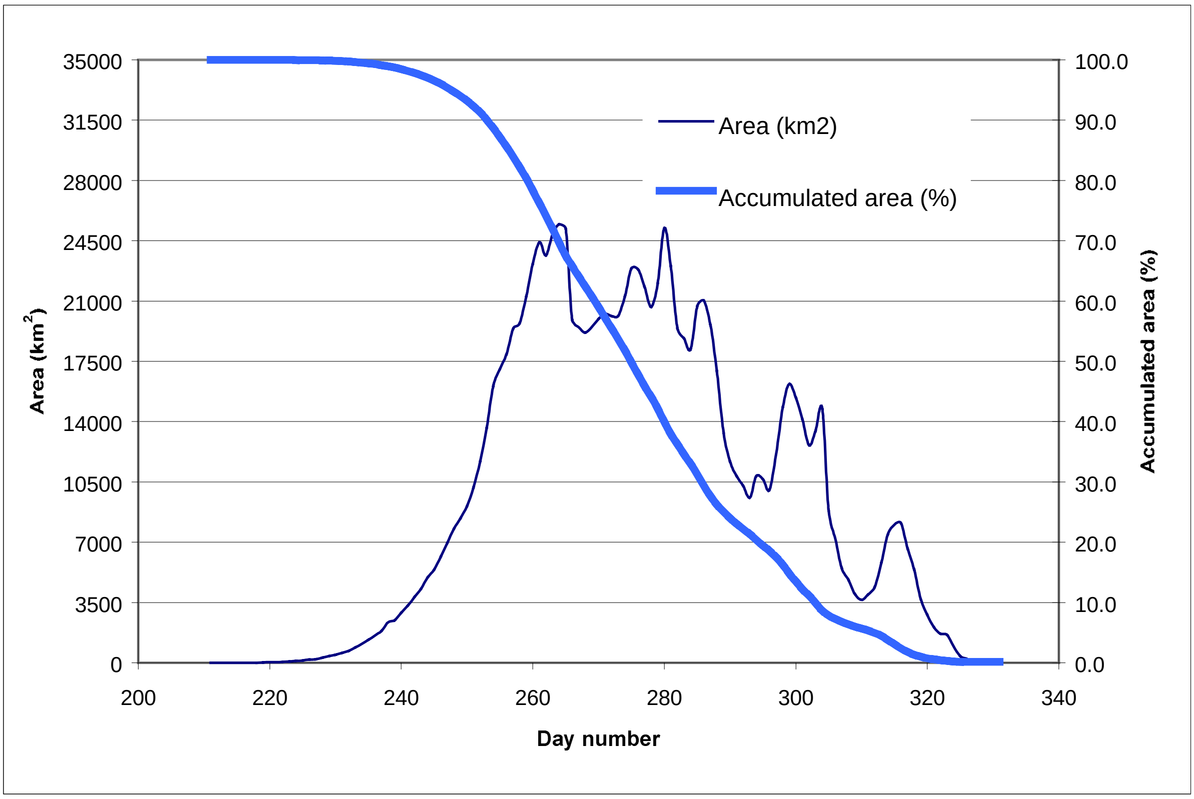

Figure 3.3a Areal distributions of the end of the growing season.

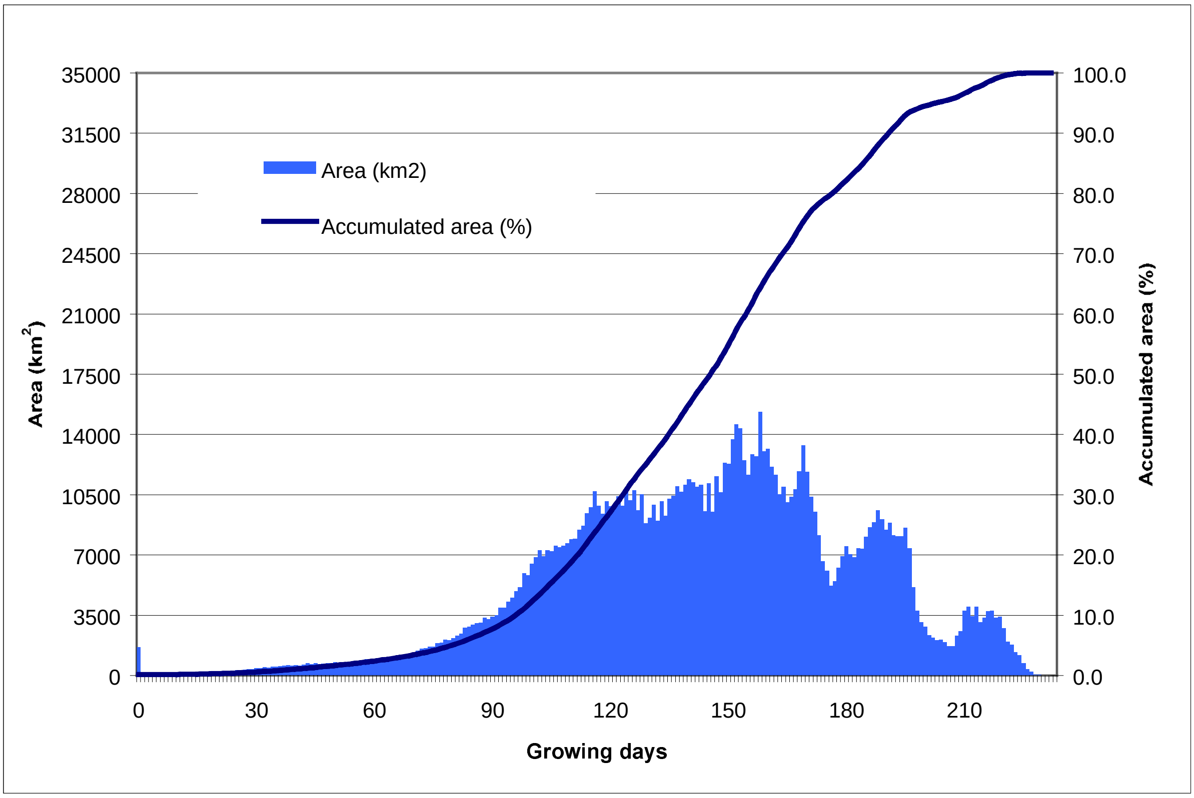

Figure 3.4a. Areal distributions of the length (number of days) of the growing season

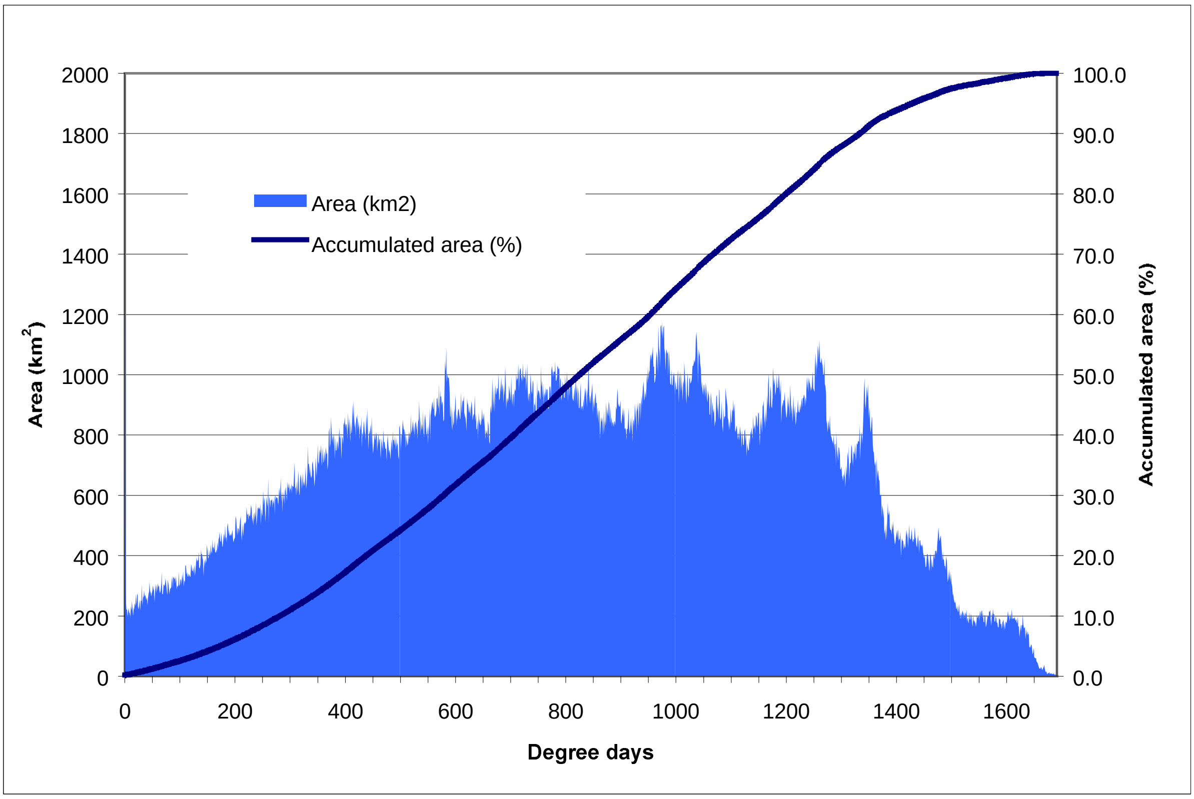

Figure 3.5a. Areal distributions of the degree-days of the growing season

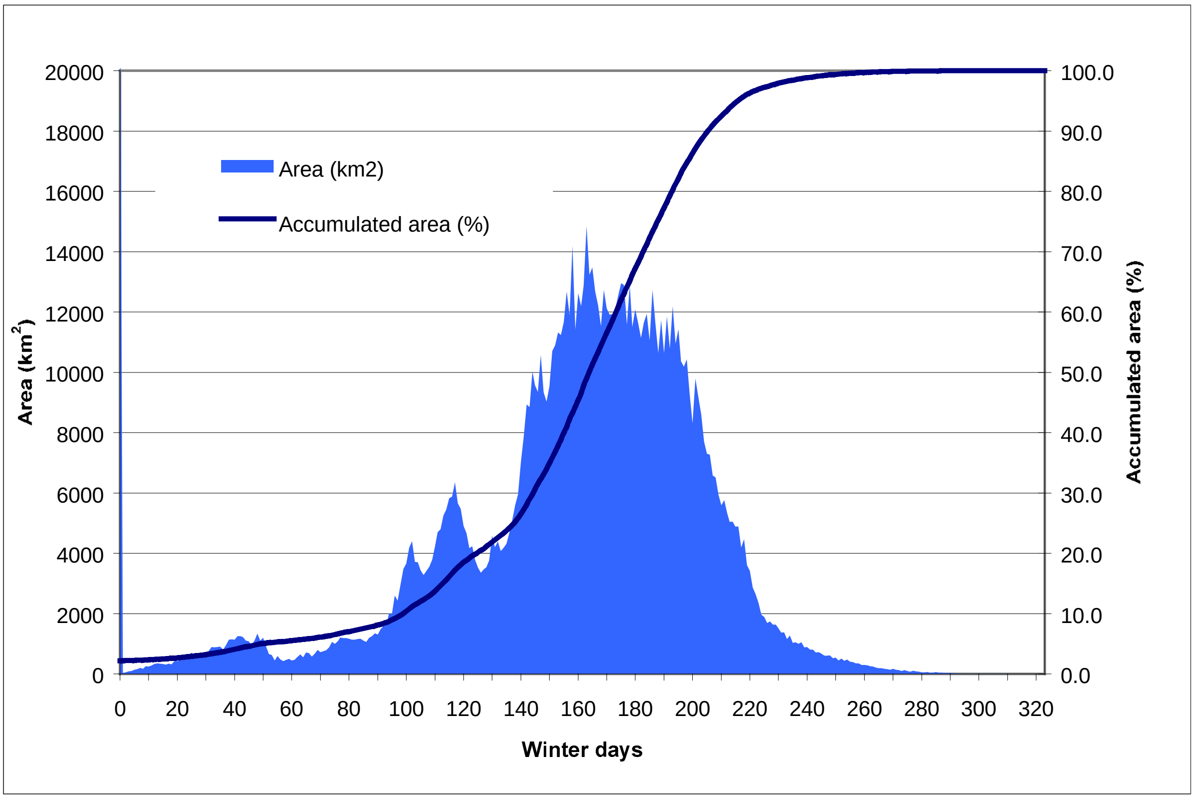

Figure 3.6a. Areal distributions of the length (number of days) of the winter season

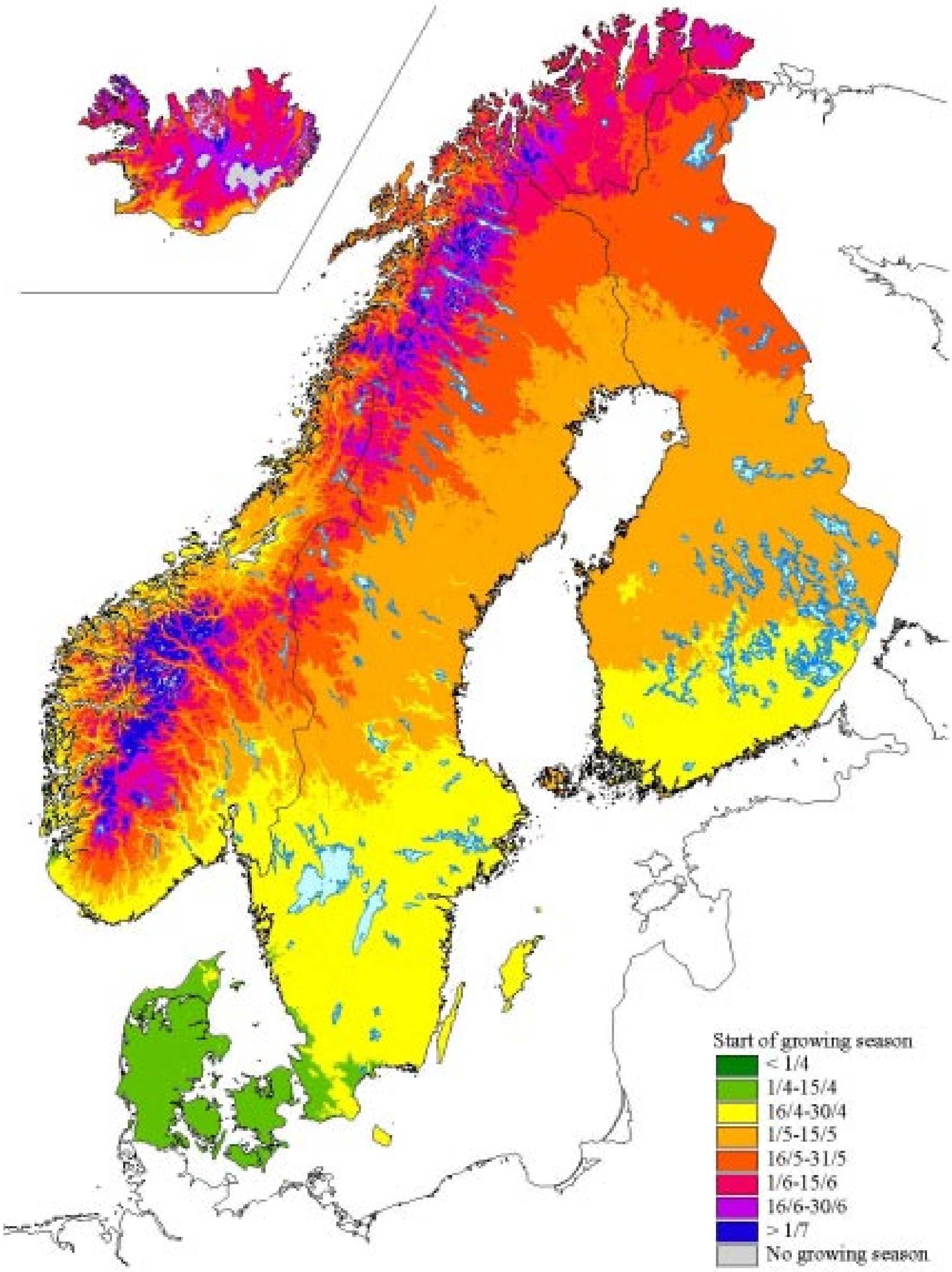

Figure 3.2 Mean start date for the growing season 1961-90 (Daily mean temperature above 5°C).

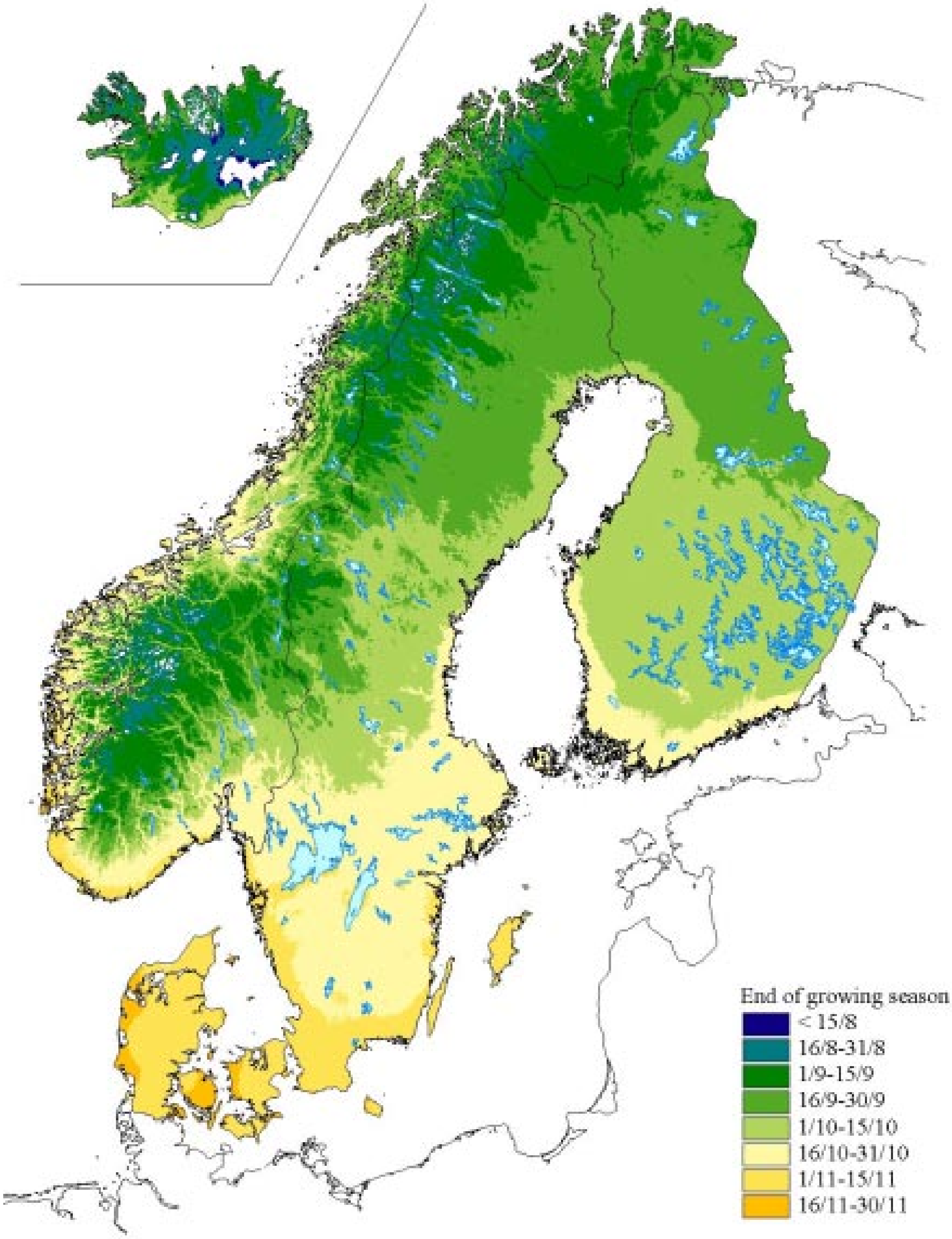

Figure 3.3 Mean end date for the growing season 1961-90 (Daily mean temperature above 5°C).

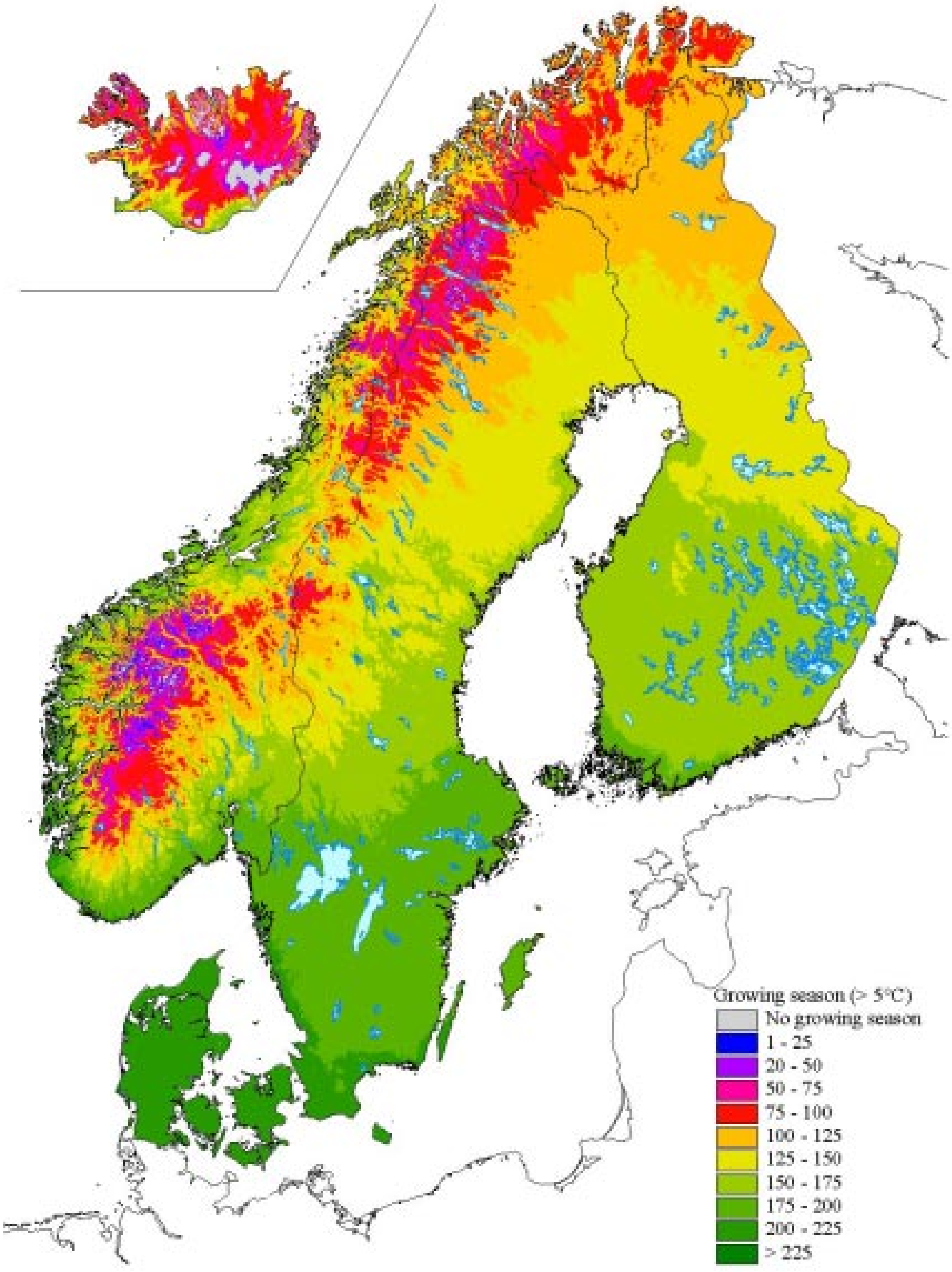

Figure 3.4 Mean length of the growing season 1961-90 (Daily mean temperature above 5°C).

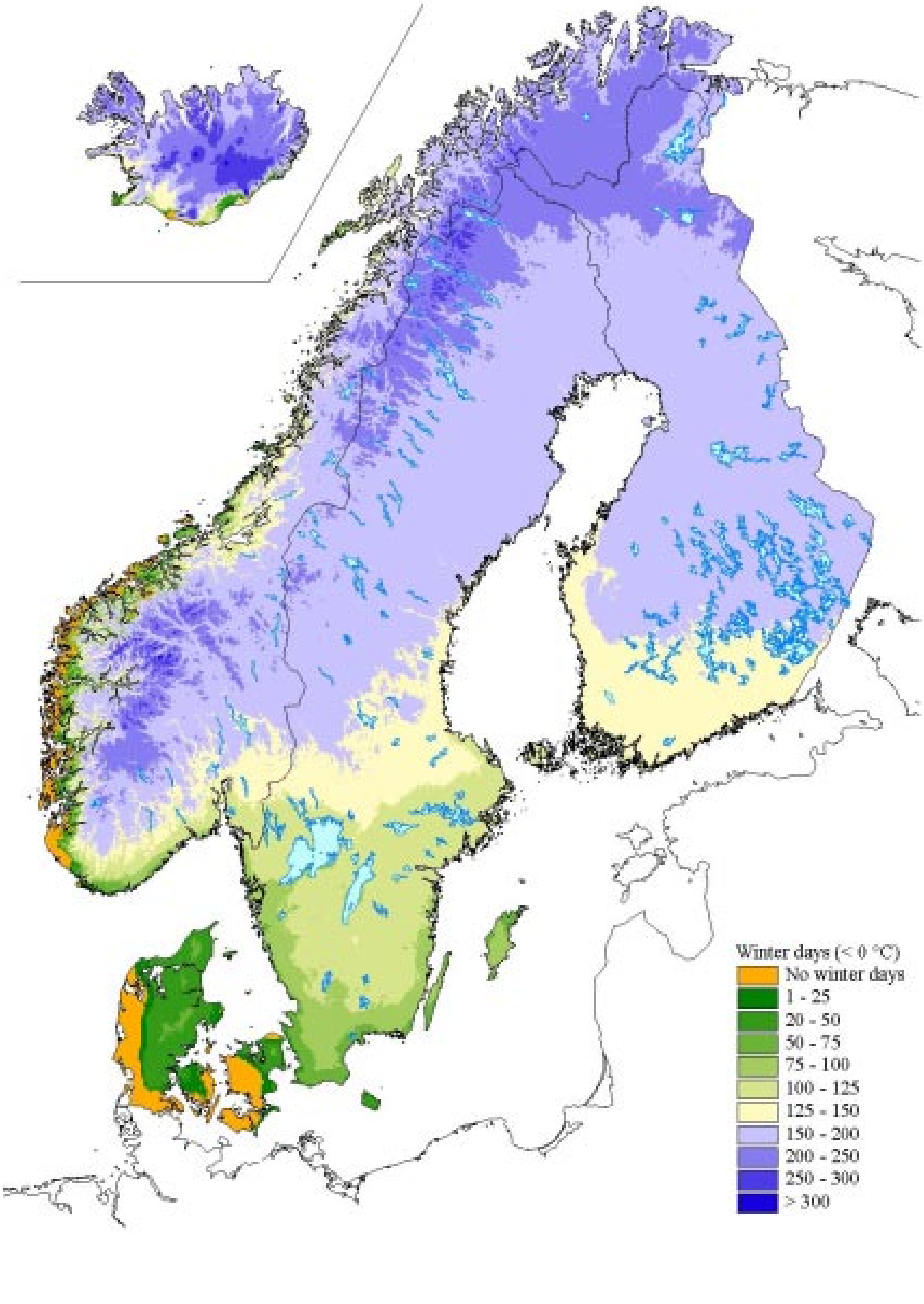

Figure 3.5 Mean length of the winter season 1961-90 (Daily mean temperature below 0°C).

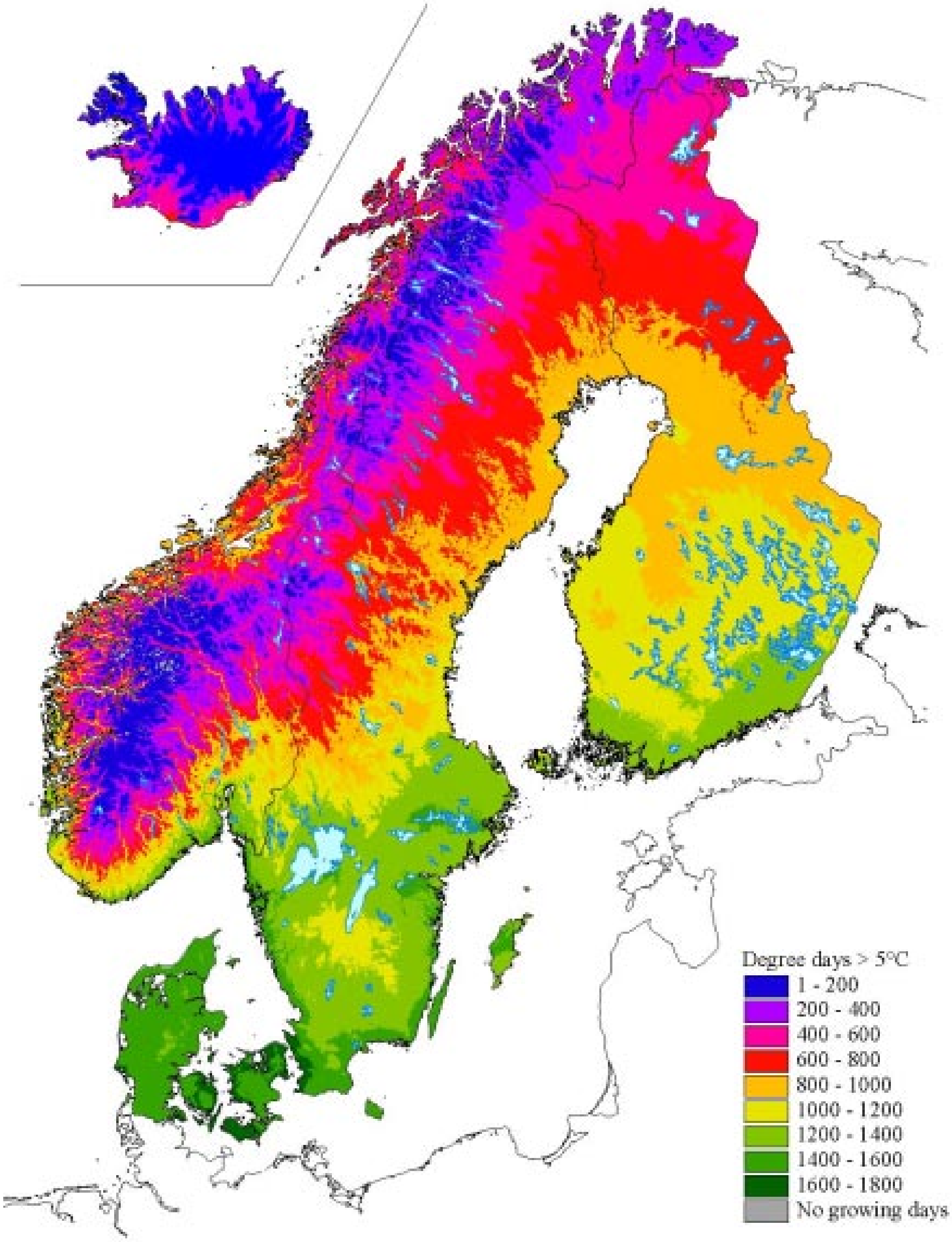

Figure 3.6 Mean degree-days in the growing season 1961-90 (Daily mean temperature above 5°C).

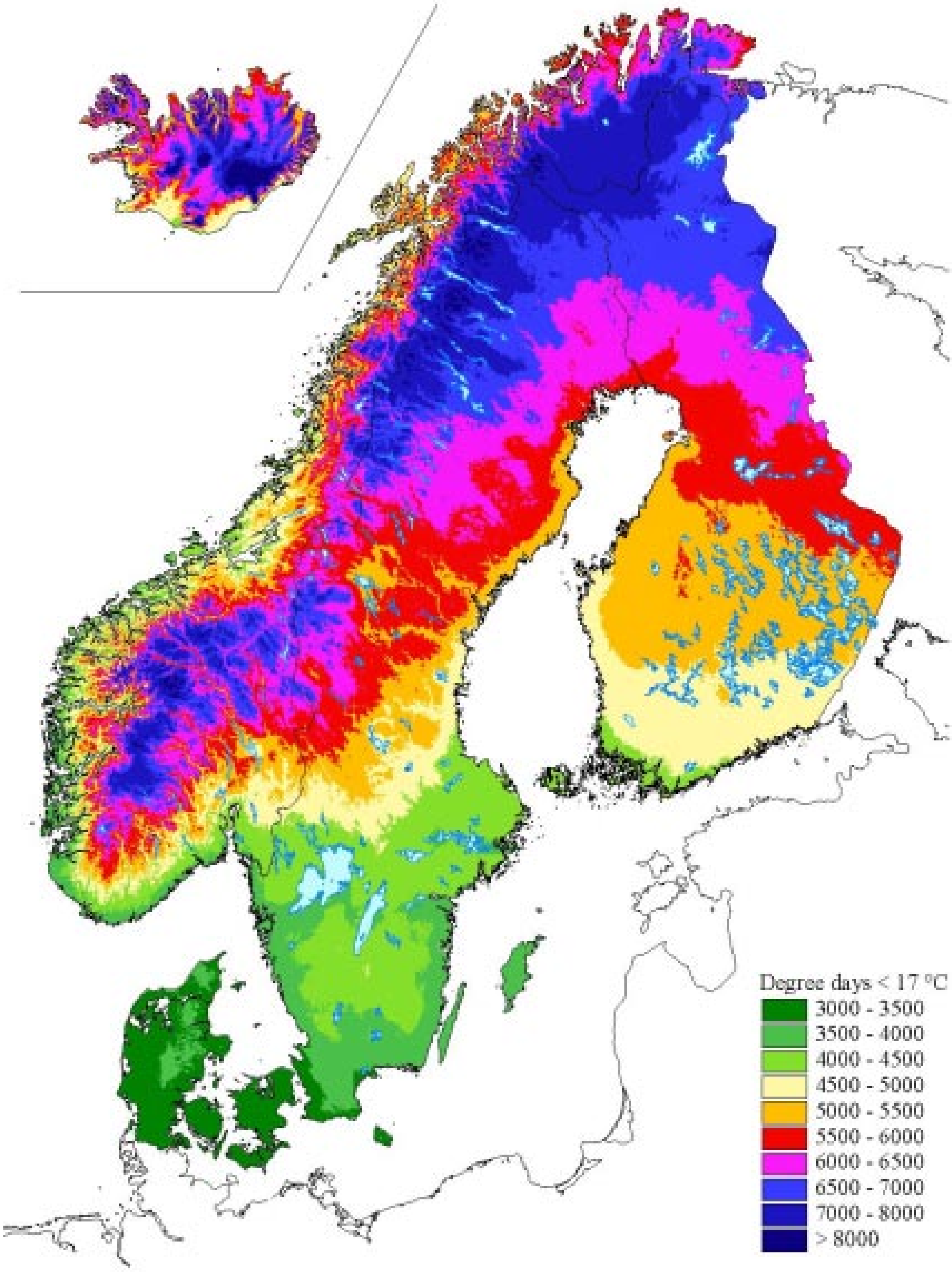

Figure 3.7 Mean degree-days in the heating season 1961-90 (Daily mean temperature below 17°C).

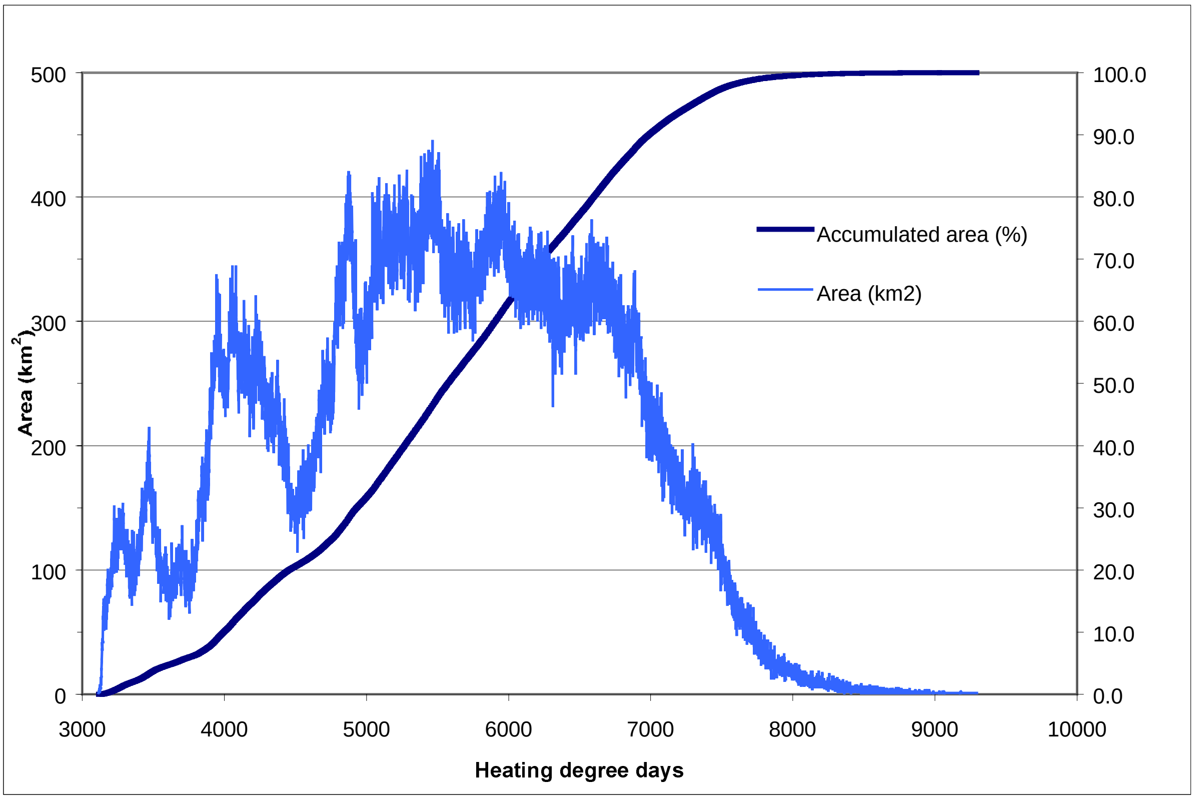

Figure 3.7a. Areal distributions of the degree-day sum in the heating season

4. Summary and conclusions

In this report maps of days with precipitation above certain thresholds and maps of temperature seasons are presented. These maps are established by utilizing geographical information systems (GIS), and demonstrate the power of such systems.

The maps of precipitation above certain thresholds show interesting features about the Nordic precipitation climate. The east-west gradient is enhanced when increasing the precipitation threshold. The areal frequency distribution also becomes more skew when the threshold increases.

The temperature maps are based on daily mean temperatures calculated from monthly mean grid temperatures from the Nordic temperature maps (Tveito et al., 2000) by a spline algorithm. Several maps showing start, end and length of temperature seasons, as well as degree-day maps are presented. These maps show the potential of gridded climate data sets, and the frequency distributions shown also documents the possibilities and added value a novel GIS may give such information.

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