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A BASIC FINNISH CLIMATE DATA SET 1961-2000 - DESCRIPTION AND ILLUSTRATIONS

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Abstract

Research related to the impact of and adaptation to climate change requires a comprehensive set of climate data. Both scenarios of future climate as well as records of past climate are needed. As a part of the FINADAPT research project, the Finnish Meteorological Institute has produced a set of climate data for the requirements of various research groups. The data set consists of daily mean temperature and daily precipitation data interpolated onto a 10*10 km grid. Interpolation scheme works well with daily temperatures. However spatial variation of daily precipitation is smoothed. This leads to about 17% systematic underestimation in the long-term annual average. In addition to these interpolated data, measurements obtained from five observing stations were also included in the data set. The station data consist of daily precipitation, mean, maximum and minimum temperatures, air humidity, wind speed, snow depth, global radiation, sunshine hours and potential evaporation, as well as growing season temperature and precipitation sum information. The aim of this report is to describe the data set, give some examples of the use of these data and to be literature that can be referred to when the data are used in scientific articles

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TUTKIMUSKÄYTTÖÖN KOOTUN VUOSIEN 1961-2000 PERUSILMASTOAINEISTON KUVAUS

Tiivistelmä

Ilmastonmuutoksen vaikutusten sekä ilmastonmuutoksen sopeutumiseen tähtäävän tutkimuksen pohjaksi tarvitaan kattava aineisto sekä nykyilmastoa että ennakoitua ilmastoa kuvaavia ilmastotietoja. Osana FINADAPT–tutkimushanketta tuotettiin Ilmatieteen laitoksessa havaintoaineistopaketti täyttämään vaikutus- ja sovellutustutkijoiden ilmastotiedon tarpeita. Tämä aineisto koostuu 10 km * 10 km hilaruudukkoon interpoloiduista vuorokauden keskilämpötilan ja vuorokauden sademäärän arvoista. Keskilämpötilan osalta interpolointi-menetelmä toimii hyvin. Sen sijaan käytetty menetelmä tasoittaa vuorokauden sademäärän alueellista jakaumaa. Tämä johtaa systemaattiseen aliarvioon joka pitkän ajan vuosikeskiarvoissa on noin 17 %. Lisäksi viideltä havaintoasemalta toimitettiin joukko ko. asemalla mitattuja ilmastomuuttujia, kuten vuorokauden sademäärä, keskimääräinen, ylin ja alin lämpötila, ilman kosteus ja tuulen nopeus, lumen syvyys, auringon kokonaissäteily ja paistetunnit, potentiaalinen haihdunta ja kasvukauden lämpö- ja sadesummat. Tämän raportin tarkoituksena on kuvata toimitettu aineisto, antaa joitakin esimerkkejä aineiston käyttömahdollisuuksista ja toimia kirjallisuusviitteenä tutkimusraporteissa ja artikkeleissa, joita aineiston pohjalta tehdään.

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CONTENTS

1 INTRODUCTION

Studies related to the effects of climatic variability and changes, as well as investigations into adaptation to these effects, require information about past and present climate. Mean values, variability, and extremes give essential information about the characteristics of climate. The climate data set described in this report can be used, for example, in the development and application of various impact models, as well as a baseline for climate change scenarios.

There have been two major climate and global change research programs In Finland: the Finnish Climate Change Program (SILMU) in 1990-1995 (Roos, 1996), and the Finnish Global Change Programme (FIGARE) in 1999-2002 (Käyhkö and Talve, 2002). In connection with the SILMU programme, a data set consisting of meteorological data interpolated onto a 10*10 km grid was created (Alm et al, 1996). The time series covered the normal period 1961-1990. In the case of the FIGARE programme no special data set describing present day climate was created. However, in both of the above-mentioned programmes, researchers were provided with climate change scenarios aimed at giving the best estimate of future climate in Finland (Carter et al., 1996; Jylhä et al., 2004)

During the 20th century the Finnish climate has warmed by about 0.7 °C (Tuomenvirta, 2004); new scenarios (Jylhä et al., 2004) indicate that a mean annual warming of between 2.4 and 7.4°C in combination with an increase in annual precipitation of 6 to 37% can be expected by the end of this century. Such climate changes as these will have significant impacts in Finland. A research project entitled "Assessing the adaptive capacity of the Finnish environment and society under a changing climate" (FINADAPT) addresses both scientific and policy needs by conducting the first in-depth investigation of the adaptive capacity of the Finnish environment and its society to the potential impacts of climate change. (Carter et al., 2004) A number of multidisciplinary research groups will participate in this program; it was therefore considered appropriate to create a common set of climate data for the use of all these groups. This data set includes daily mean temperature and daily precipitation data interpolated onto a 10*10 km grid. In addition to these interpolated data, values of selected climatological parameters are also provided for five meteorological stations. The aim of this publication is to describe the data set and methods used in the creation, as well as to give a brief overview of the Finnish meteorological observing network.

2 SUMMARY OF METEOROLOGICAL DATA DELIVERED FOR ADAPTION RESEARCH

The Finnish Meteorological Institute (FMI) produces information on the climate of Finland in the form of publications (e.g., Drebs et al., 2002, see also http://www.fmi.fi/kirjasto/ julkaisut.html) and also monthly on the web (http://www.fmi.fi/saa/tilastot.html). Based on the results of a questionnaire to the participants in the FINADAPT project, a data set was prepared to describe the climate of Finland. This data set covers forty years (1961-2000) with a daily time-resolution. It consists of station data as well as gridded data; these are described in section 3.

The basic observational data are compiled from five stations that give cross-sections of Finland along south-north (Helsinki-Vantaa, Jyväskylä, Sodankylä) and west-east (Kauhava, Kuopio) axes. A summary of the data is given in Table 1. The observed elements are described in section 2.1 and the derived station data in section 2.2. Station information is given in section 2.3.

2.1 Directly measured elements

Precipitation. In Finland precipitation (mm) is recorded between 6 UTC on the date of the observation and 6 UTC on the following day. Precipitation is collected with a rain gauge whose rim is situated at height of 1.5 m above ground level. Cases of no measured precipitation are coded in the data set with the value -1.

Temperature. The daily mean temperature (°C) is calculated as the mean of the eight daily synoptic measurements. The daily maximum temperature is that measured between 18 UTC on the previous day and at 18 UTC on the date of the observation. The daily minimum temperature is also that recorded between 18 UTC on the previous day and 18 UTC on the date of the observation. Temperatures are measured at a height of 2 metres above ground level in a screen protected from sunlight.

Air humidity. The lowest and highest values of relative humidity (%) are taken from the eight relative humidity observations made at the synoptic hours of 0, 3, 6, 9, 12, 15, 18, and 21 UTC. Relative humidity is measured in the same screen as temperatures are.

Wind. The lowest and highest wind speeds (m s^{-1}) are taken from the eight wind speed observations at the synoptic hours. Each observation is a 10-minute mean wind speed measured with an anemometer (usually of the rotating-cup type). The wind is measured at the following heights above ground level: Helsinki-Vantaa 10 m, Jyväskylä 10 m, Kauhava 16 m, Kuopio 12 m and Sodankylä 22 m.

Snow. The snow depth (cm) is observed at 6 UTC and is measured with a measuring stick placed near the precipitation gauge.

Sunshine hours. The duration of sunshine (h) during the date of observation is measured with a sunshine recorder.

Global radiation. The global solar radiation (kJ m^{-2} during 24 hours) is recorded during the date of observation. It is measured with a pyranometer.

Soil temperature. The soil temperature at a depth of 20 centimetres below the surface is available from two stations: Jyväskylä and Sodankylä. These measurements are made approximately every fifth day.

Table 1. Summary of the data set.

PARAMETER	STATION Helsinki-Vantaa	Jyväskylä	Sodankylä	Kuopio	Kauhava	GRID 10*10 k grid
DAILY DATA						
Precipitation	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000
Mean temperature	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000
Maximum temperature	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Minimum temperature	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Lowest relative humidity	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Highest relative humidity	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Lowest wind speed	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Highest wind speed	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Snow depth	1961-2000	1961-2000	1961-2000	1961-1999	1961-2000	
Sunshine hours	1961-2000	1961-2000	1961-2000	1961-2000		
Global solar radiation	1971-2000	1971-2000	1971-2000			
Potential evaporation	1961-2000	1961-1998	1961-2000	1961-1997	1961-1997	
Soil temperature		1974-2000	1971-2000			
GROWING SEASON						
Start	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
End	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Length	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Temperature sum	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	
Precipitation sum	1961-2000	1961-2000	1961-2000	1961-2000	1961-2000	

Missing data is coded as -99 or -99.0. All times in hours refer to UTC. Finnish Normal time is UTC + 2 hrs while daylight saving time is UTC + 3 hrs.

Observational practices and methods have changed during the forty years covered by the data set. For many elements, round-the-clock observations made by on-site staff have been replaced by those made with automatic equipment. Although the breaks in the temporal homogeneity of the time series have been minimised, it is known that some changes have caused discontinuities. The switch from Wild precipitation gauges to Tretjakov gauges, for example, was accomplished during 1981 and 1982, causing an artificial increase of about 33 mm in the time series of annual mean precipitation over Finland (Tuomenvirta, 2004). Care should be taken in studies of temporal changes.

2.2 Derived elements

2.2.1 Potential evaporation

The calculation of potential evaporation in the current application is made using the so-called Penman-Monteith equation (Eq. 1) (e.g. Monteith, 1981). The unit of E is mm.

$$E = \frac{\Delta * Rn + \rho * c_p * (1 + b * r_a /(\rho * c_p)) * (e_s - e) / r_a}{(\Delta + \gamma * (1 + b * r_a / \rho * c_p)) * L} \qquad (1)$$

L is the latent heat of vaporization ($2.5*10^6$ J kg^{-1}), *Δ* is the slope of the saturated vapour pressure vs. temperature curve (hPa K^{-1}), *Rn* is the net radiation (W m^{-2}), e_s is the saturation vapour pressure (hPa), *e* is the vapour pressure (hPa), ρ is the density of air (1.29 kg m^{-3}), γ is the psychrometer constant (0.66 hPa K^{-1}), r_a is the aerodynamic resistance (sm^{-1}), *b* is the measuring height correction multiplier (Wm^{-2}K^{-1}) and c_p is the specific heat of air (1004 J kg^{-1} K^{-1}). Venäläinen and Heikinheimo (2002) explain how the needed input parameters are obtained from the basic available meteorological information.

2.2.2 Growing seasons

The beginning of the growing season is defined according to the following rules: there is no snow on open places and the daily mean temperature is above +5°C for at least five consecutive days. The growing season is considered to have finished once the daily mean temperature drops permanently below +5°C in the autumn. Both the temperature sum and the precipitation sum during the growing season were calculated using a cut-off limit of 5°C.

2.3 Station descriptions

Table 2 contains basic information on the stations in the data set: coordinates, station height above sea level and height of wind measurement above the ground.

Table 2. Station information.

Station Name (Municipality)	Latitude	Longitude	Altitude	Height of wind measurements
Helsinki-Vantaa airport (Vantaa)	60º19'34.4"	24º57'44.2"	53 m	10 m
Jyväskylä airport (Jyväskylän maalaiskunta)	62º24'7.6"	25º40'42.9"	139 m	10 m
Kuopio airport (Siilinjärvi)	63º01'	27º48'58.0"	94 m	12 m
Kauhava airport	63º06'	23º02'	42 m	16 m
Sodankylä observatory	67º22'4.5"	26º37'58.0"	179 m	22 m

Sodankylä observatory

The station is located on the banks of the River Kitinen (175 m asl). To the east there are wide-spread aapa mires, while in other directions are widespread forest on moraine soil and some hills (230 to 250 m asl). The small community of Sodankylä lies about 5 km to the north. The soil temperature measurement site is surrounded by a sparse pine stand. At the site itself, the vegetation is lichen and heather. At a depth of 20 cm the soil near the soil temperature probes consists of 73% gravel and 27% sand with some humus (Heikinheimo and Fougstedt 1992).

Kuopio airport

The station is located at the tip of a peninsula beside Lake Juurusvesi (82 m asl) in the lake district of Eastern Finland. Within a circle of 10 km around the station, the area consists of 35 to 40% of water bodies. The land area consists of moraine covered by spruce and mixed forest with several bedrock and drumlin, hills. The city of Kuopio (about 85 000 inhabitants) is located 10 km to the south-west.

Kauhava airport

The station is located in the Kauhava river valley, dominated by large clay fields at a height of 40 to 45 m asl. The river valley is surrounded by partly-forested moraine and sand land with bedrock hills to about 60 to 80 m asl. The community of Kauhava lies to the south, about 1-2 km from the station.

Jyväskylä airport

The station is located on the glacifluvial delta plain of the Central Finnish terminal moraine (140 m asl). The ground is mostly dry woodland. 1 km to the east there is a north-south valley (100 to 120 m asl) with widespread agricultural activities. Elsewhere is forest (140 to 180 m asl) and moraine with hills up to 240 m asl. 2 km to the west of the station lies Lake Luonetjärvi (134 m asl, about 5 km²).

Helsinki-Vantaa airport

The station is located on a crest (40 to 70 m asl) of bedrock moraine and heathland with isolated bogs. The highest bedrock hills reach to about 80 m asl. In the surrounding 2 to 4 km there are extensive agricultural activities on clay plains (20 to 30 m asl.). There are city-like settlements at a distance of 2 to 5 km, while 13 km to the south is the city centre of Helsinki (about 550 000 inhabitants). The station lies about 17 km north of the coastline of the Gulf of Finland.

3 GRIDDED DATA

The largest part of the data set consists of daily mean temperature and daily precipitation totals in Finland interpolated onto a 10*10 km grid. A data set of monthly temperature, precipitation and global radiation have already been created but so far no interpolated daily data sets have been available.

3.1 Description of grid

The grid used in the data set is based on the Finnish National Coordinate system known as YKJ. The projection is the so-called Gauss-Kruger with a central-meridian at 27°N. The westernmost coordinate of the area we have used is 3075000 and the easternmost 3735000. The most southern and the most northern grid squares have coordinates 6635000 and 7785000, respectively. Only those grid squares that are located inside or on the Finnish borders are used in the interpolation (Figure 1).

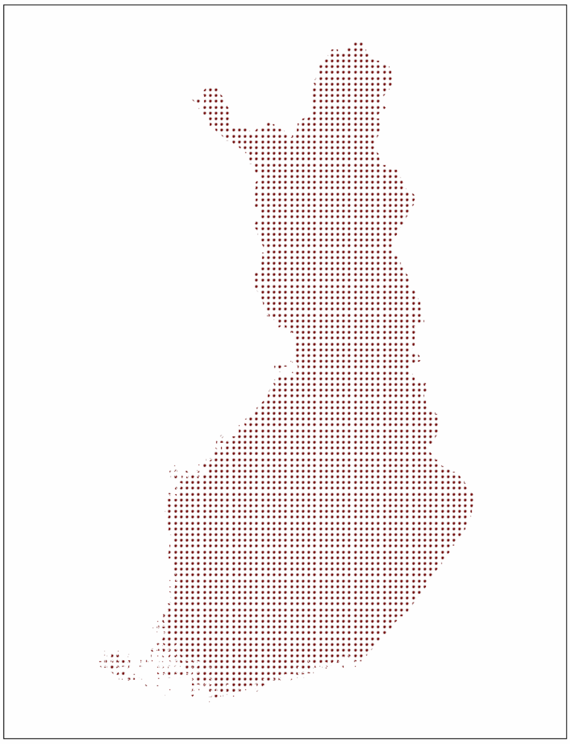
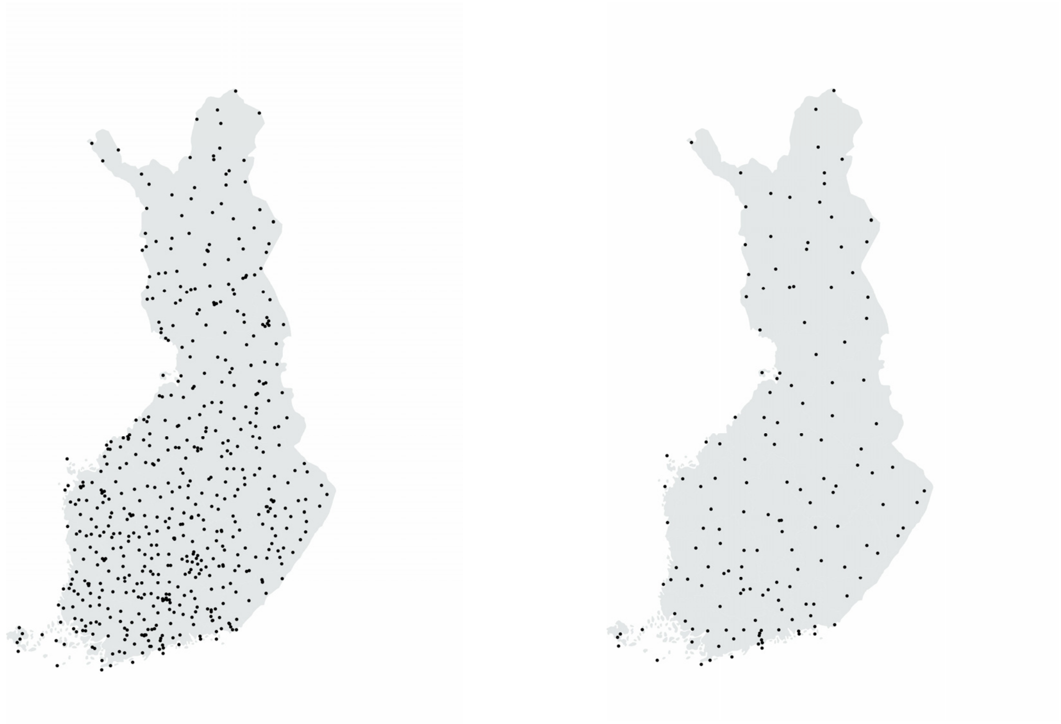


Fig. 1. The grid squares used for interpolated data.

3.2 Meteorological station network

The number of stations making measurements has varied during the 40-year period. Since 1966 the number of daily precipitation measurements available in FMI's climatological database has exceeded 400, whereas during the first few years there are only 100-200 stations available in the database. The interpolation program used in the current study cannot handle situations in which several stations are located near each other inside same grid square, and measure very different values. This situation happens from time to time in the case of rain showers during summer. In order to be able to make the calculation automatic, the procedure excludes cases in which the distance between the stations was less than seven kilometres. As a result of this limitation, we lose, in the case of the densest network, roughly 5-10% of the stations.

As an example, on 1st of February 1985 there were originally 565 precipitation stations, of which only 474 were used for the interpolation (Figure 2 a). The number of daily temperature measurement stations has been between 100-200 (Figure 2 b).



a) b)

Fig. 2. a) The daily precipitation measurement stations on 1st of February 1985 and b) The daily temperature measurement stations.

3.3 The spatial interpolation method

The spatial interpolation method currently used at the Finnish Meteorological Institute is known as kriging. This method is based on the theory presented by Ripley (1981) and programmed by Henttonen (1991) for climatological applications in forestry (see also Venäläinen and Heikinheimo, 1997; Venäläinen and Heikinheimo, 2002; Vajda and Venäläinen, 2003).

The interpolated values of daily maximum, daily minimum and daily precipitation sum as obtained using the kriging interpolation method were compared (Kuittinen et al., 1999) with results obtained using the interpolation method used in the crop growth monitoring system of the Joint Research Centre. According to that comparison, the results obtained using kriging were better, especially in the case of daily minimum temperature and precipitation. Vajda and Venäläinen (2003), using this same method, interpolated a number of climatological parameters onto a 1 km * 1 km grid in Northern Finland. They discovered that the error, e.g., in the case of average summer daily mean temperature, varied between -0.6 and +0.6 °C with an RMS error of 0.3 °C. Thus, we may assume that the mean temperature values can be interpolated reasonably well.

The precipitation is more problematic due to large spatial variation especially in the case of rain showers and in these cases the interpolated value may differ remarkably from the measured one. Large spatial variation of precipitation seems to create also systematic differences between measured and interpolated values. The method tends to cut the peak values away and when the measured values were compared with the interpolated values it was found that the interpolated values were systematically lower than the measured values in the cases when the measured precipitation values were above 10 mm/day. If daily precipitation was less than 5 mm then there was no systematic difference between the interpolated and measured values. The data used in this comparison consisted of measurements made at about 70 stations in 1.1.2000-31.12.2000. The spatial variation of monthly precipitation sum values is smaller than that of the daily values. Earlier we have interpolated monthly precipitation sum values using the same method and same grid. When we calculated mean annual precipitation sum for each grid square based on 1.1.1991-31.12.2000 data it was found that the values were on average 17% higher if the monthly data was used as input in the interpolation. In this sense it is good to remember that if long term mean values are calculated based on interpolated daily precipitation data they tend to be systematically smaller compared with the case when monthly or annual data is used as input in the interpolation.

4 A FEW ILLUSTRATIONS BASED ON THE DATA

The spatial features of the mean temperature over Finland can be seen in Fig 3: the coldest places in Lapland have a below-zero mean annual temperature, while in south-western Finland the mean annual temperature is around +5 °C. When we compare the 1961-2000 period with the decades 1961-1970, 1971-1980, 1981-1990 and 1991-2000 (Figure 4 and Table 2) we can see that 1961-1970 was a cold decade, while 1991-2000 was a warm decade. The difference between these two ten-year periods is roughly one degree. The year-to-year variation of annual mean temperature calculated as the mean of all grid square values is from -0.4 to 3.8 °C. The coldest year was 1985 and the warmest 1989. Figure 5 also shows the time series of seasonal (3-month) temperatures.

The precipitation gauge used in Finland was changed during 1981 and 1982. The so-called wind error is smaller in the case of the newer instrument. A comparison of precipitation amounts prior to the change of instrument with the values measured after the change is therefore not fully valid. According to this study, the annual precipitation sum during the decades 1981-1990 and 1991-2000 was about 60 mm larger than during the decades 1961-1970 and 1971-1980; however, part of the difference is due to the improved measurement equipment (Table 3). If these values based on interpolated daily values are compared with values based on interpolated monthly or interpolated annual values these values are systematically somewhat smaller as explained on page 16.

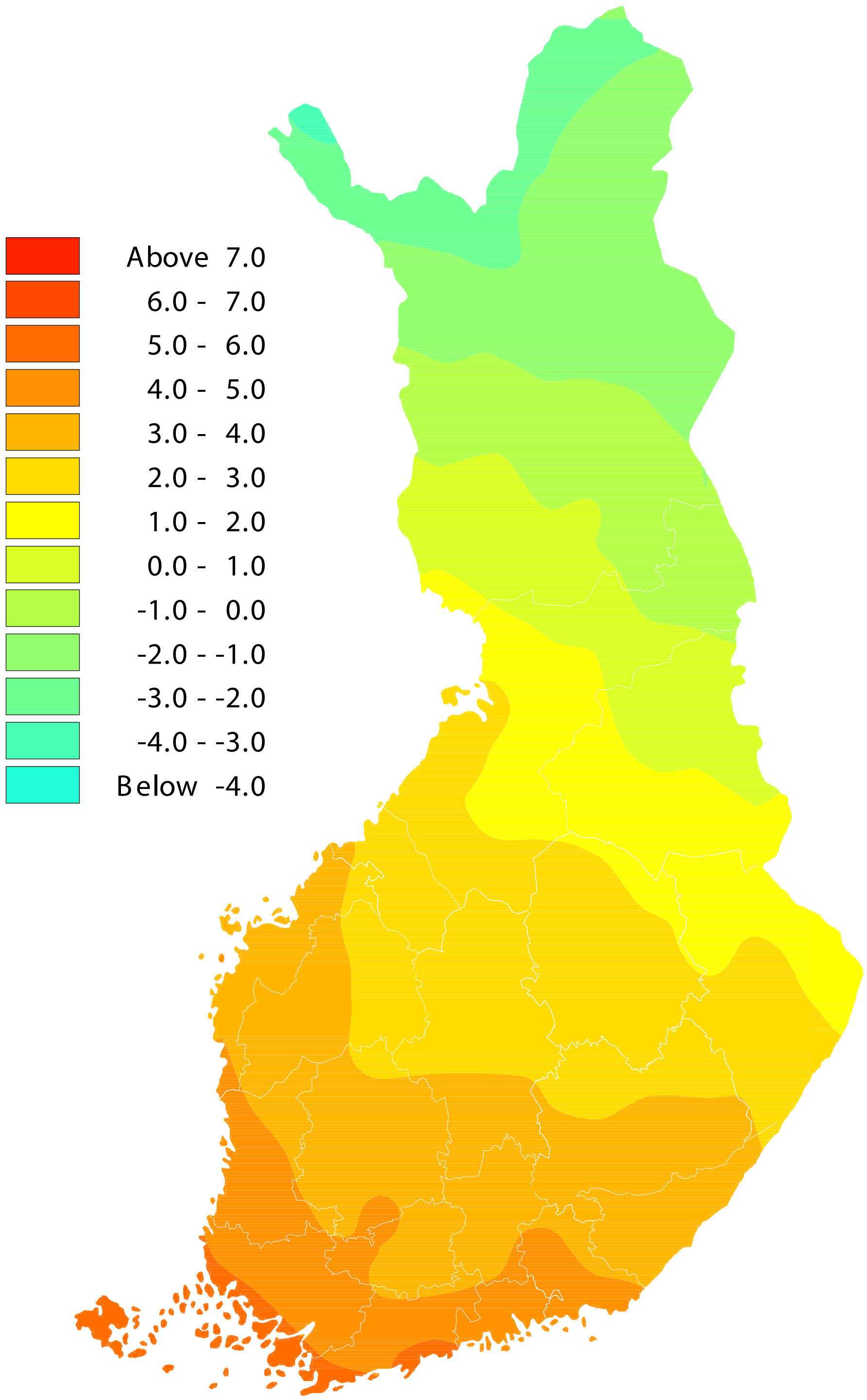


Fig 3. The annual mean temperature in Finland, 1961-2000

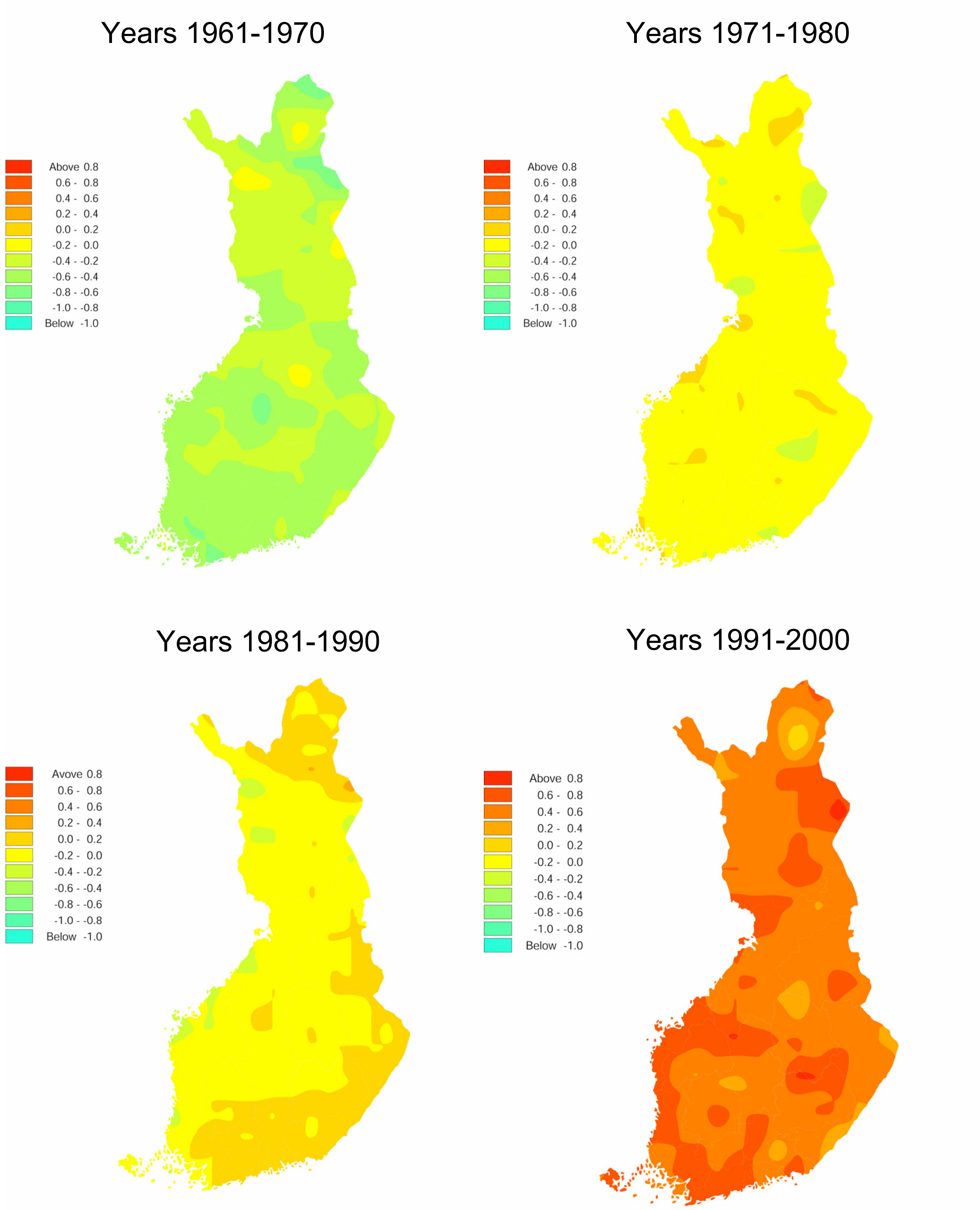


Fig. 4. The deviations between the four ten-year periods and the 1961-2000 annual mean temperature (i.e., temperature of 10-year period – temperature of 1961-2000).

Table 3. Monthly mean temperatures (T) and precipitation amounts (RR) calculated over the whole of Finland for various time periods, between the years 1961 and 2000.

T_month	1961-2000	1961-1990	1971-2000	1961-1970	1971-1980	1981-1990	1991-2000
1	-10.2	-11.0	-9.7	-11.7	-9.6	-11.6	-7.8
2	-10.0	-10.3	-9.5	-11.6	-9.8	-9.4	-9.1
3	-5.4	-5.8	-4.9	-6.8	-5.5	-5.0	-4.3
4	0.2	0.1	0.3	-0.1	-0.2	0.6	0.5
5	6.9	7.1	7.1	6.5	7.0	7.8	6.5
6	12.8	12.8	12.7	12.9	13.0	12.4	12.7
7	15.0	15.0	15.2	14.4	15.4	15.2	15.1
8	13.0	12.9	12.9	13.1	13.0	12.5	13.3
9	7.9	7.8	7.8	8.1	7.5	7.8	8.0
10	2.5	2.5	2.3	3.1	1.1	3.2	2.5
11	-3.4	-3.5	-3.6	-2.8	-3.8	-3.7	-3.2
12	-7.9	-8.4	-7.7	-8.6	-7.7	-9.0	-6.3
Annual average	1.8	1.6	1.9	1.4	1.7	1.7	2.3

RR_month	1961-2000	1961-1990	1971-2000	1961-1970	1971-1980	1981-1990	1991-2000
1	29	27	31	22	24	35	33
2	22	20	24	18	19	23	30
3	25	22	26	20	19	28	31
4	25	24	25	24	25	24	26
5	30	30	30	30	26	34	30
6	48	45	51	40	42	53	57
7	62	61	63	59	59	66	65
8	67	68	66	68	64	74	61
9	52	54	51	55	57	50	45
10	49	46	48	50	41	49	56
11	43	41	44	38	44	42	46
12	34	32	36	28	31	37	39
Annual sum	486	470	495	452	451	515	519

In the original dataset as delivered there are erroneous values in case of Sodankylä; April 16.-28. 1986 data and these should not be used for analyses. In southern Finland *t*he average daily potential evaporation is in southern Finland a little above 4 mm/day during mid-summer days, whereas in northern Finland it is slightly below 4 mm/day (Figure 6). The period of high evaporation is nearly two months longer at Jokioinen than at Sodankylä. This increases considerably the risk of the soil drying out. The average length of the growing season in southern Finland is around 180 days but only about 130 days in northern Finland (Figure 7). During the period 1961-2000, the shortest growing season at Helsinki-Vantaa was about the same as the longest season at Sodankylä. The correlation between the growing season's temperature sum and its length is low in southern Finland (~0.2), increasing northwards and reaching a value of 0.31 at Sodankylä. Figure 8 illustrates the use of municipality borders in presenting growing-season precipitation data. The average precipitation sum for the growing season varies between 200 mm in the north and 400 mm in the south.

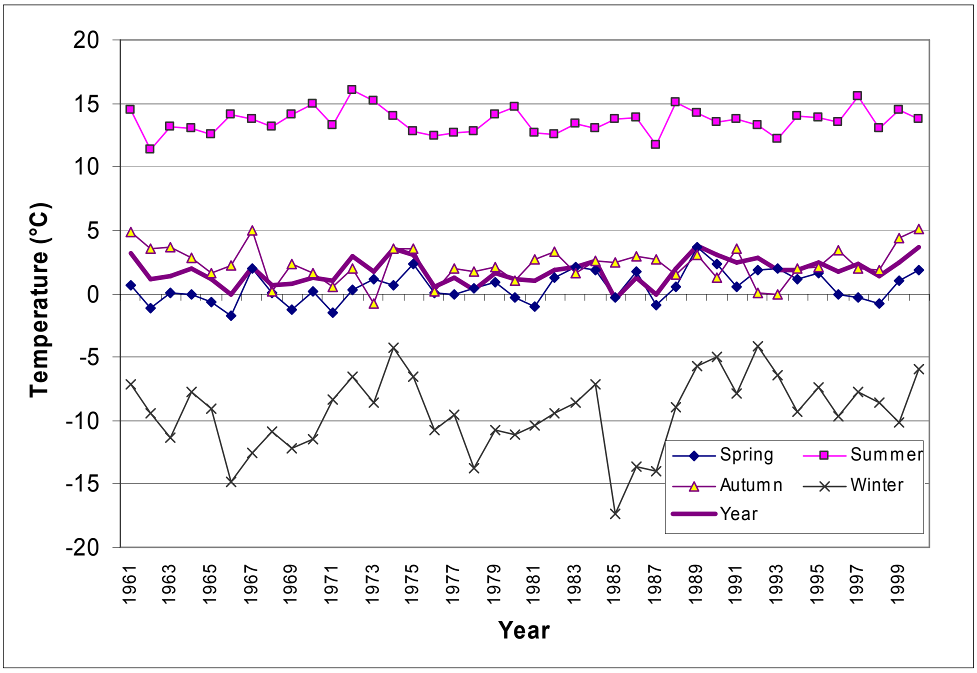


Fig. 5. The annual and seasonal mean temperatures in Finland during the period 1961-2000 calculated as the mean of grid square values.

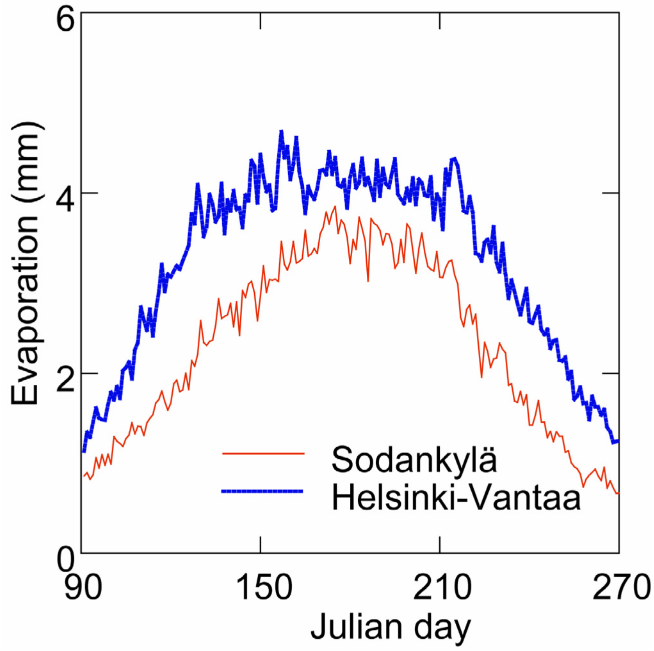


Fig. 6. Average daily potential evaporation (mm) at Helsinki-Vantaa and Sodankylä during the period 1961-2000.

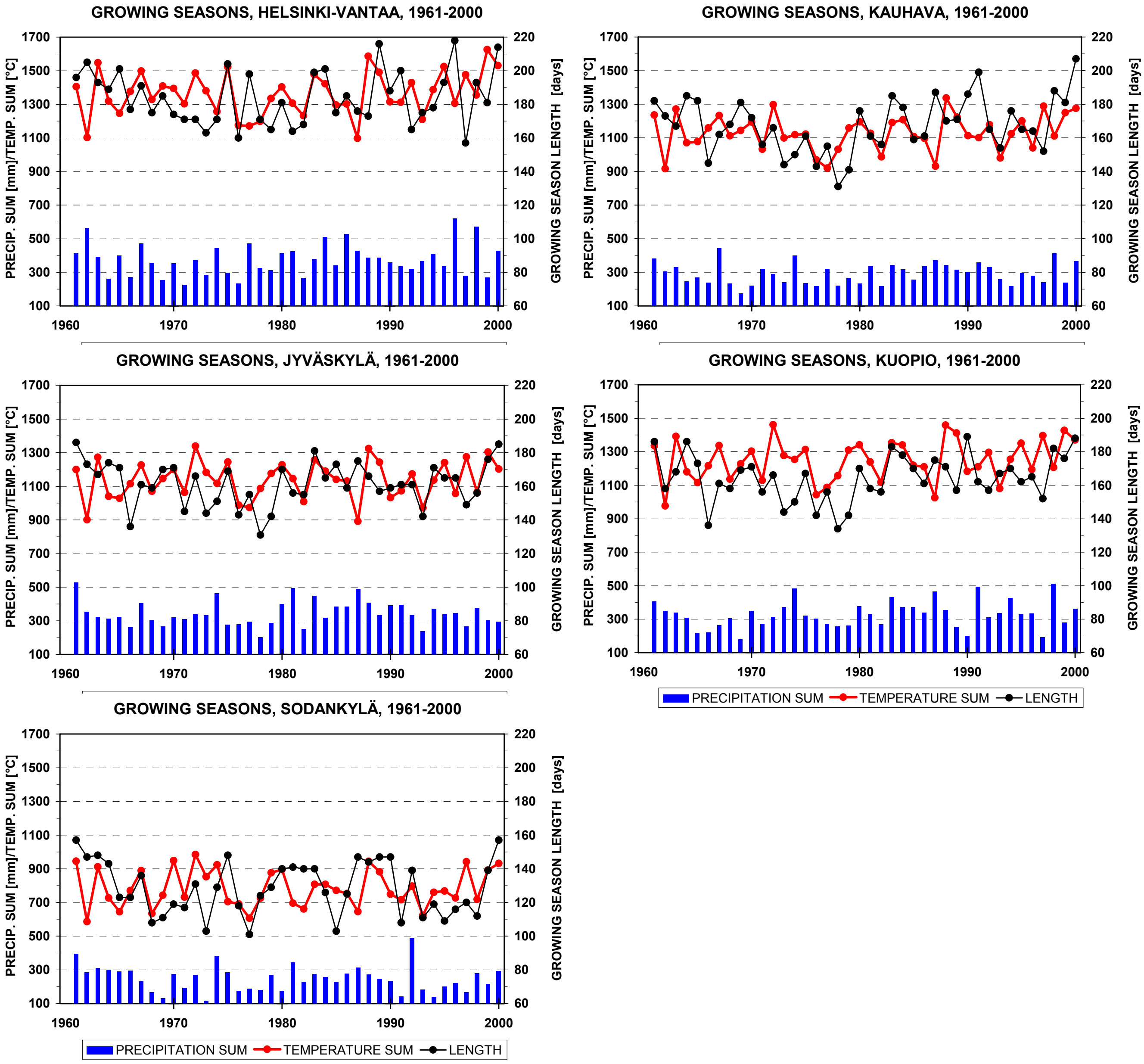


Fig. 7. Growing season temperature sum, precipitation sum, and length at five stations (Helsinki-Vantaa, Jyväskylä, Sodankylä, Kauhava, Kuopio), 1961-2000.

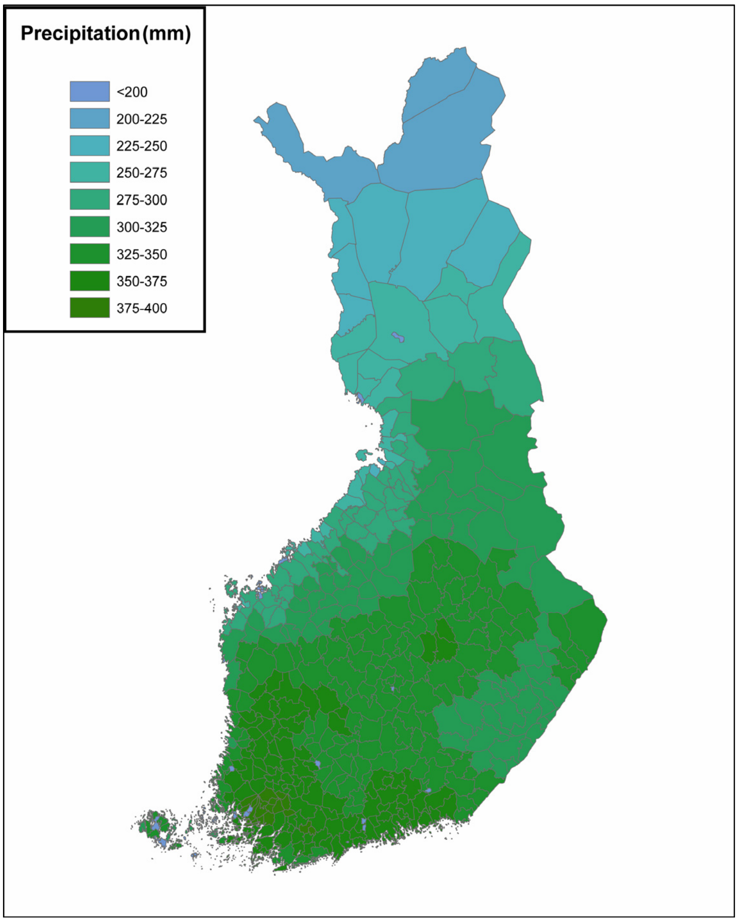


Fig. 8. The average 1971-2000 precipitation sum for the growing season for Finnish municipalities.

5 CONCLUSIONS

Gridded meteorological data makes new ways of analyses possible: the calculation of averages over certain areas, municipalities (Figure 8), watersheds or the whole country, for example, becomes relatively simple. It is hoped that these new opportunities will further research on climate change impact and adaptation, in which analyses of the complex interaction between the biosphere and atmosphere are needed at spatial scales ranging from local to national.

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