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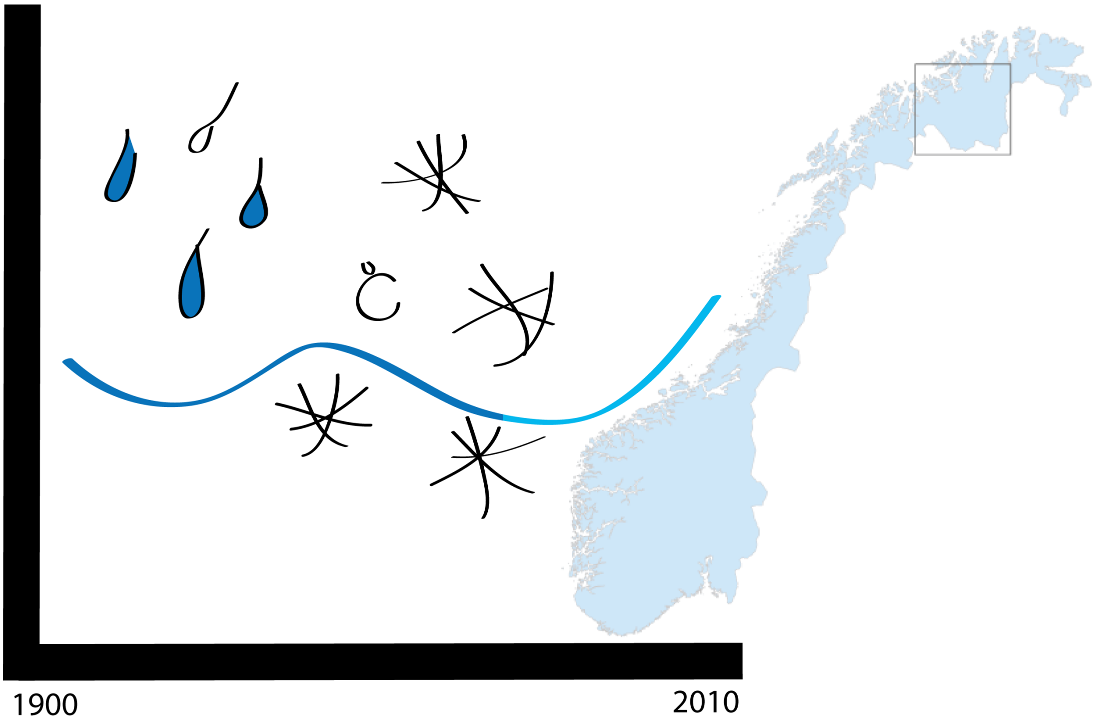
Climate

Long-term climate trends of Finnmarksvidda, Northern-Norway

Dagrun Vikhamar-Schuler, Inger Hanssen-Bauer and Eirik Førland



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Abstract

In this study long-term trends of temperature, precipitation and snow at five stations on Finnmarksvidda (Kautokeino, Karasjok, Sihccajavri, Cuovddatmohkki and Suolovuopmi) and two coastal stations (Tromsø and Nordreisa) were examined. Several climate parameters were chosen for analysis: annual and seasonal temperature, annual and seasonal precipitation sum, maximum snow depth, snow season duration, rain-on-snow events, black frost days and cold periods. Comparison of the meteorological stations shows considerable climatic difference between the continental stations and the coastal stations. For the individual stations there are considerably more differences in decadal variability for precipitation than for temperature, and even more for snow.

Keywords

Snow, temperature, precipitation, Finnmark, Northern Norway

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1 Introduction

This report has been written as part of the IPY project EALAT (http://icr.arcticportal.org/en/ealat), Work Package 1: *Identification of local climate conditions important for reindeer herding and development of basic climate scenarios.* The main goal of the entire EALAT project is to assess the vulnerability of reindeer herding in Finnmark and Yamal (Russia) to effects of climate change. This report contributes to reach the main goal by describing the historical climate in Finnmark the last 100 years, from the coast to the inland areas.

We present historical climate data from Finnmarksvidda (five selected meteorological stations) and from two coastal meteorological stations. Long-term trends of temperature, precipitation and snow are studied. Additionally, some meteorological parameters (indices) have been computed that are sensitive to the reindeers access to food through the snow (the sami word "guohtun"). The climate conditions affect the reindeer herding in many ways, but we have chosen to limit our study to indices affecting the food access through the snow. Examples of such indices are rain-on-snow events followed by freezing temperatures possibly creating hard ice layers. Ice layers are negative for the reindeer since they prevent the animals to reach the food below the snow. On the other hand, loose snow structures (depth hoar crystals) increase the accessibility of food below the snow pack. Depth hoar forms preferentially in cold, continental type climate. Therefore, we also examined a cold period indice based on degree days for temperatures below -15 °C.

2 Dataset and analysis

This section gives an overview of the meteorological dataset used in the analysis in this report. Furthermore, it contains a description of how the various climate parameters were computed.

2.1 Meteorological stations at Finnmarksvidda

In this report we have analysed data from seven weather stations (Figure 1). These stations are spatially distributed over the Finnmarksvidda study area (continental climate), except for the Tromsø and Nordreisa stations which are located close to the coast (marine climate). Meta data for each station is given in Tables 1 and 2. The observation period for each station varies widely. It is also important to notice that although observations have been carried out, not all data are available in digital formats. Some of the data are only available in analogue archives. There are a few gaps in the time-series, specifically during the period of the second world war (1940-1945).

Inhomogeneities of the measurement series may be caused by relocation of the meteorological stations or by environmental changes (e.g. new houses, trees). Four of the stations (Nordreisa, Kautokeino, Karasjok and Suolovuopmi) have been moved during the observation period (see Table 1). In this analysis we have merged these series. No corrections for possible homogeneity errors have been made (Nordli, 1997). Temperature data from Karasjok have previously been studied and found to be of high quality (pers. comm. Øyvind Nordli, met.no). The Kautokeino station, however, has been moved from the valley bottom to the valley side, and the winter temperature is probably higher than at the former location (see the graph of the Kautokeino winter temperature after 1970 in Figure 12). This is in accordance with the estimated 1961-1990 climatology for the two localities, as the difference between the mean monthly temperatures at these stations is 0.2°C or less in the period May through November, while the former site systematically is 0.2 to 0.5°C colder for December and January through April (Aune, 1993). Inhomogeneity studies of temperature, snow or precipitation from the Suolovuopmi and Nordreisa stations have not yet been carried out.

An overview of the mean monthly temperature and precipitation for the normal period 1961-1990 for all stations are presented in the Figure 2. The average summer temperatures are rather similar at all stations (+12-13°C in July), while in winter, the inland stations are typically about 10°C colder than the coastal station Tromsø. Also for precipitation, the maximum differences between inland and coast are found during winter. In July, all stations show average precipitation sums between 60 and 80 mm. At the inland station, this represents the annual maximum, while minimum precipitation is measured in winter and early spring. Along the coast, on the other hand, the precipitation is typically increasing from the summer values to a maximum in the autumn, while the minimum is found during spring. On an annual basis, and especially during winter, inland Finnmark is of the coldest and also driest areas in the Nordic countries (Tveito et al., 1997, 2000).

As indices for snow conditions, we have studied the observations of *snow depth* and *snow cover*. *Snow depth* is measured as the total depth of both the old and new snow on the ground. *Snow cover* is the areal extent of snow-covered ground. The snow cover observation is a subjective measure (see Table 3.)

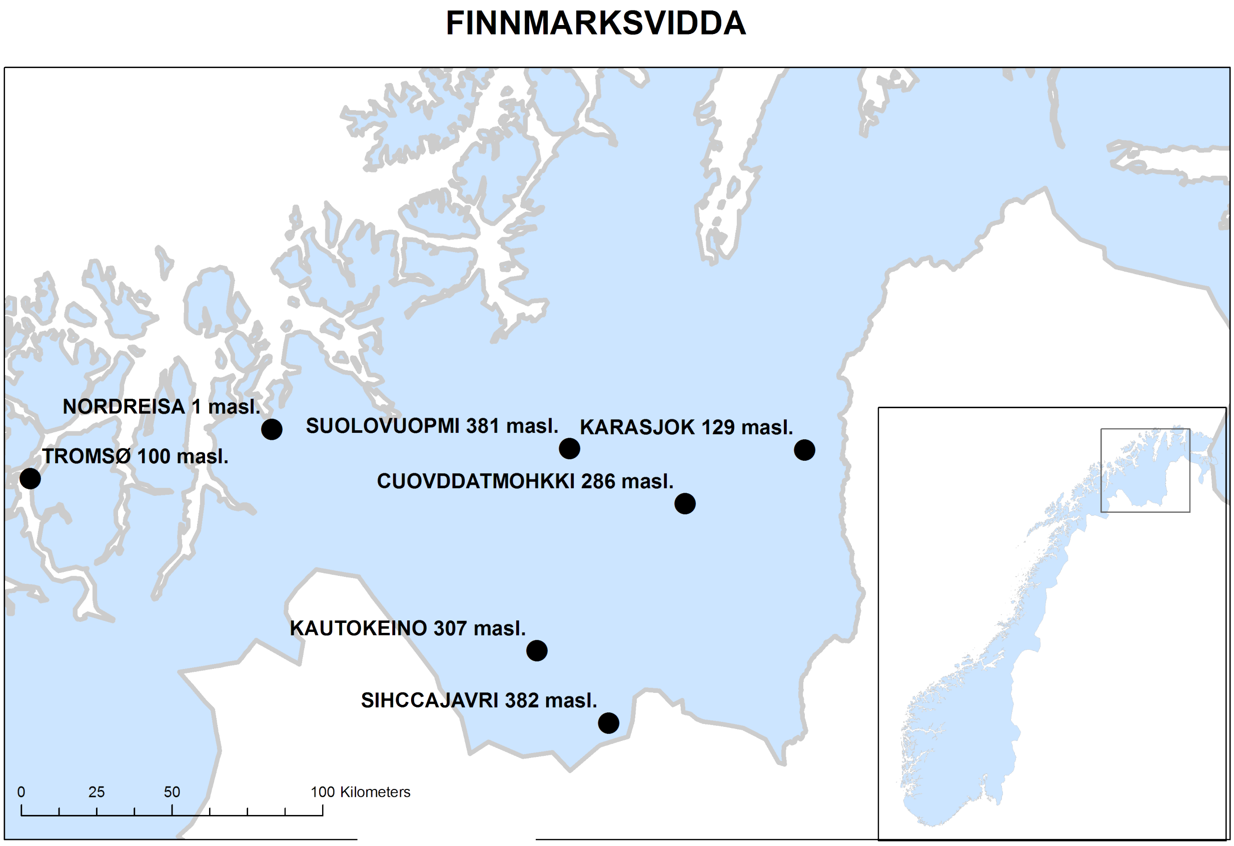

Figure 1: Location of the seven selected meteorological stations located at Finnmarksvidda and on the coast.

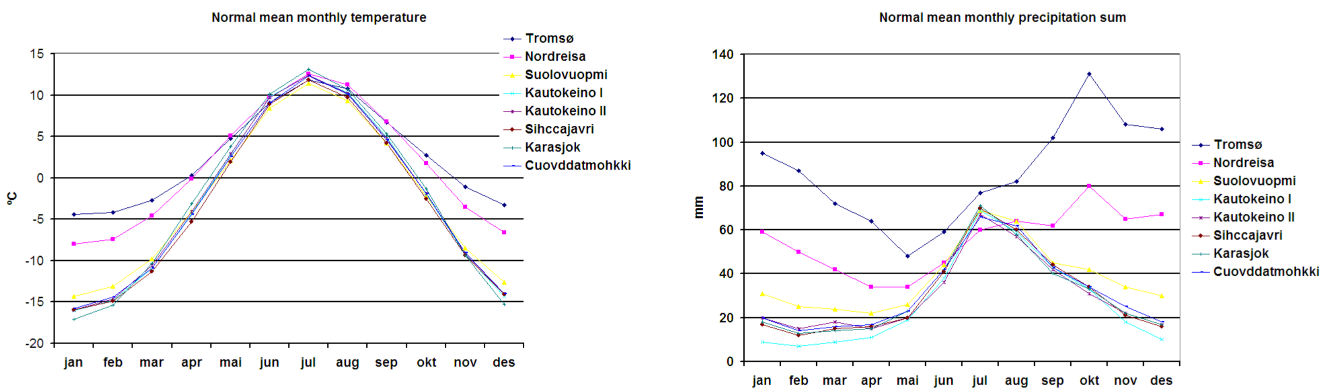

Figure 2: Mean monthly temperature and precipitation for the normal period 1961-1990.

Station number (met.no)	**Station name**	**Elevation m a.s.l.**	**Observation period**
90450	Tromsø	100	1920-
91750	Nordreisa	1	1896-1992
91760	Nordreisa Øyang	5	1992-2006
93300	Suolovuopmi	377	1906-2003
93301	Suolovuopmi-Lulit	381	2004-
93700	Kautokeino	307	1889-1970
			1996-
93710	Kautokeino II	330	1970-1996
93900	Sihccajavri	382	1912-
97250	Karasjok	129	1875-2004
97251	Karasjok-Markannjarga	131	2004
97350	Cuovddatmohkki	286	1955-

Table 1: *Meta data for the meteorological stations.*

Station number	**Station name**	**Precipitation**	**Temperature**	**Snow**
90450	Tromsø	1931-	1931-	1931-
91750	Nordreisa	1896-1992	1959-1992	1896-1992
91760	Nordreisa Øyang	1992-2006	1992-2006	1992-2006
93300	Suolovuopmi	1906-2003	1962-2003	1906-2003
93301	Suolovuopmi-Lulit	2004-	2004-	2004-
93700	Kautokeino	1954-1970	1954-1970	1954-1970
		1996-	1996-	1996-
93710	Kautokeino II	1970-1996	1970-1996	1970-1996
93900	Sihccajavri	1954-	1954-	1954-
97250	Karasjok	1875-2004	1875-2004	1905-2004
97251	Karasjok-Markannjarga	2004-	2004-	2004-
97350	Cuovddatmohkki	1966-	1966-	1966-

Table 2: *Periods when data are available in digital format, specified for each station.*

Snow cover code	Description
0	No snow
1	Minor parts of the ground covered with snow
2	Equal areas with and without snow
3	Major parts of the ground covered with snow
4	Ground fully covered by snow

Table 3: *Snow cover codes observed at the met.no precipitation stations.*

2.2 Time-series analysis

In this Section we describe how the different climate parameters were computed. Trends in the dataset are studied by applying a 10 year gauss filter and linear trend analysis. Results from the analysis are presented in Chapter 3.

2.2.1 Mean temperature

The mean annual temperature is computed from the mean monthly temperatures of a calendar year. Decadal-scale variability is illustrated in the figures by computing the deviation from the mean temperature during the normal period (1961-1990) (example in Figures 2).

Seasonal mean temperature has also been computed according to standard season definitions. Autumn consists of the months September, October and November. Winter consists of the months December, January and February, spring consists of the months March, April and May, while summer consists of the months June, July and August.

2.2.2 Annual precipitation sum

The annual precipitation sum is the sum of monthly precipitation during a calendar year. Decadal-scale variability is studied by computing the deviation from the mean annual precipitation sum during the normal period (1961-1990) (example in Figure 2).

To examine seasonal variations, this parameter has also been computed for autumn, winter, spring and summer.

2.2.3 Maximum snow depth

Maximum snow depth (cm) was computed for every winter season from *daily* snow observations. A winter season is defined to follow the hydrological year (from 1 September to 31 August).

2.2.4 Snow season duration

We here define the snow season duration as the period during a hydrological year with permanent snow cover. For this purpose we first had to compute the start and the end of this season (Dyrrdal and Vikhamar-Schuler, 2009). The snow season start is here defined as the first day in autumn with 10 consecutive days with snow cover code equal to 4 (see Table 3). The end of the snow season is defined as the first day in spring after the last period of 5 consecutive days with snow cover code equal or greater than 2. Furthermore, the snow season duration was computed as the number of days between the first and the last day. These days constitute the period of the hydrological year with permanent snow cover, and thereby excludes short periods with snow fall followed by melt episodes.

2.2.5 Rain-on-snow events

Rain-on-snow events are typically mild weather events leading to rain falling on an existing snow cover. The consequences of such an event is often extensive snow melt and densification of the snow pack. If the event is followed by a period with very cold weather, strong ice layers can be created in the snow pack. Such ice layers are known to act as a barrier to ungulate grazing, and in severe cases may lead to starvation for reindeer.

In our analysis we define a rain-on-snow event as a day when the precipitation falls as rain (more than one mm) on a snow-covered ground (more than five cm snow depth). If the air temperature is above 1°C the precipitation is assumed to fall as rain.

2.2.6 Black frost days

Black frost days are cold snow-free days, i.e. periods with snow-free ground and air temperatures below zero degrees. We have counted the number of black frost days for each hydrological year (1 September-31 August).

Periods with black frost during autumn is favourable to avoid generation of ice layers between the snow cover and the ground. If the weather is mild and the ground is wet before the first snow fall, ice layers may form. The risk is highest if the mild weather period is followed by cold weather situations (freezing temperatures).

2.2.7 Cold season and degree days

We have studied degree days as a measure of how cold it has been and how long it has been cold. We have counted the number of days with temperatures below -15°C for each hydrological year (1 September-31 August). Additionally, we have computed the cumulated degree days. This is the sum of average daily degrees for days with temperatures below -15°. We computed degree days for hydrological years and not for calendar years. To avoid misinterpretation of trends introduced by missing data, we excluded years with more than 15 days with missing data.

Loose snow structures (depth hoar crystals) are favourable for accessing the food below the snow pack. Depth hoar crystals form preferentially in cold, continental type climate. The higher the temperature gradient between the snow surface and the ground surface is, the more efficient the formation of depth hoar crystals is. This gradient depends on the snow surface temperature, the ground surface temperature and the snow depth. Hence, long periods with cold weather favours the generation of depth hoar crystals, and are therefore favourable for the reindeers access to food through the snow.

2.2.8 Growing season and degree days

Growing degree days are a measurement of the growth and development of plants during the growing season. Development does not occur at this time unless the temperature is above a minimum threshold value (base temperature). The base temperature varies for different organisms, but is often set to +5°. Growing degree days is not of importance for reindeer winter pastures, but is included to show some historical climatic aspects of the summer pastures.

We have counted the number of days with temperatures abowe +5°C for each calendar year (1 January-31 December). Additionally, we have computed the cumulated growing degree days. This is the sum of average daily degrees for days with temperatures abowe +5°C.

3 Results and discussion

This Section contains figures of the climate parameters computed for the stations Tromsø, Nordreisa, Suolovuopmi, Kautokeino, Sihccajavri, Karasjok and Cuovddatmohkki. The climate parameters are:

1. Mean temperature (annual and seasonal values)
2. Mean precipitation sum (annual and seasonal values)
3. Maximum snow depth (annual)
4. Snow season duration (including first and last day of snow season)
5. Rain-on-snow events
6. Black frost (Cold, snow-free periods)
7. Cold season and degree days
8. Growing season and degree days

3.1 Meteorological stations

3.1.1 Tromsø

Results for Tromsø meteorological station are shown in Figures 3- 5. This station is located close to the coast and therefore represents marine climate conditions.

3.1.2 Nordreisa

Results for Nordreisa meteorological station are shown in Figures 6- 8. This station is located close to the coast and therefore represents marine climate conditions.

3.1.3 Suolovuopmi

Results for Suolovuopmi meteorological station are shown in Figures 9- 11.

3.1.4 Kautokeino

Results for Kautokeino meteorological station are shown in Figures 12- 14.

3.1.5 Sihccajavri

Results for Sihccajavri meteorological station are shown in Figures 15- 17.

3.1.6 Karasjok

Results for Karasjok meteorological station are shown in Figures 18- 20.

3.1.7 Cuovddatmohkki

Results for Cuovddatmohkki meteorological station are shown in Figures 21- 23.

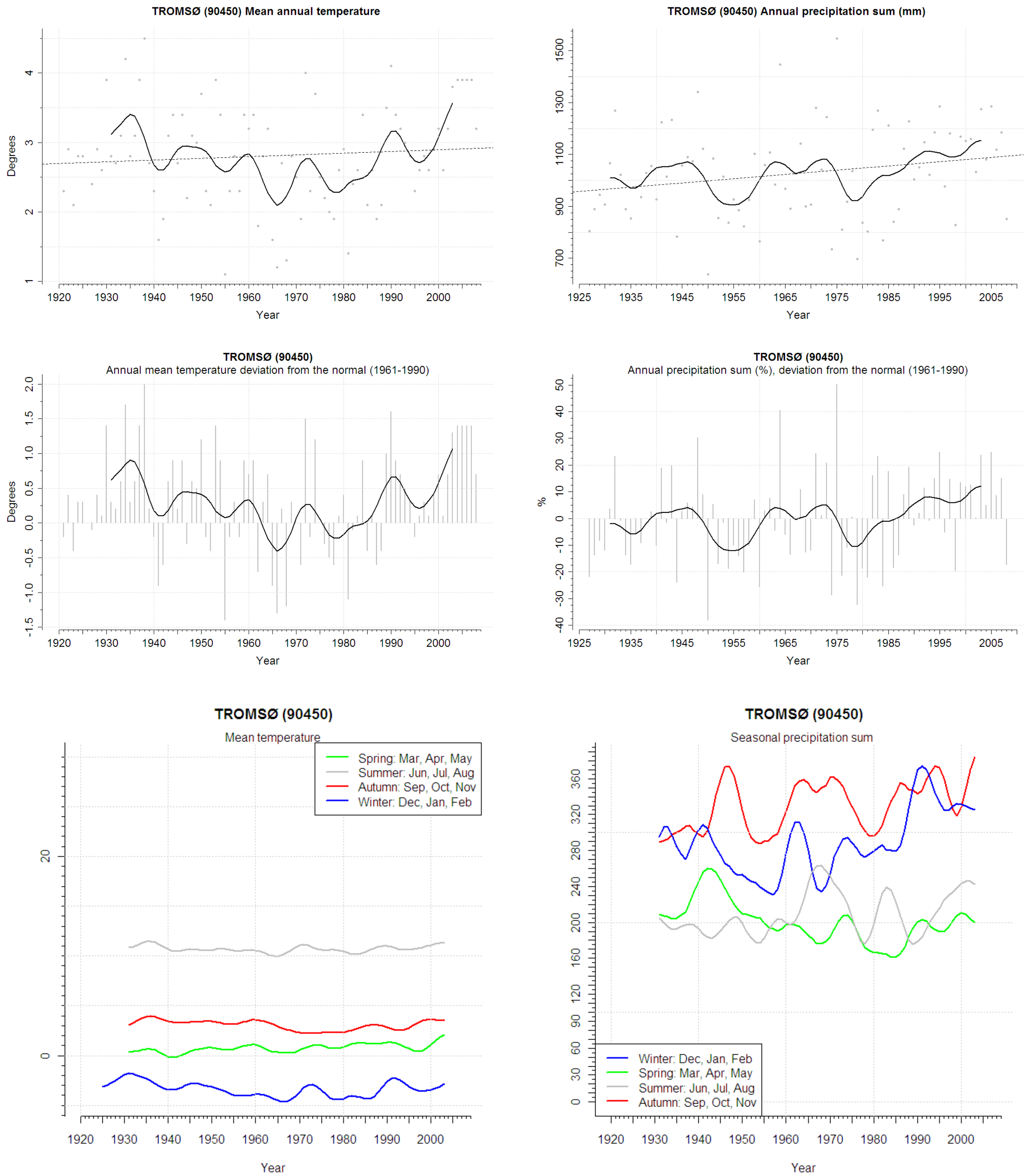

Figure 3: *Tromsø meteorological station: Temperature and precipitation.*

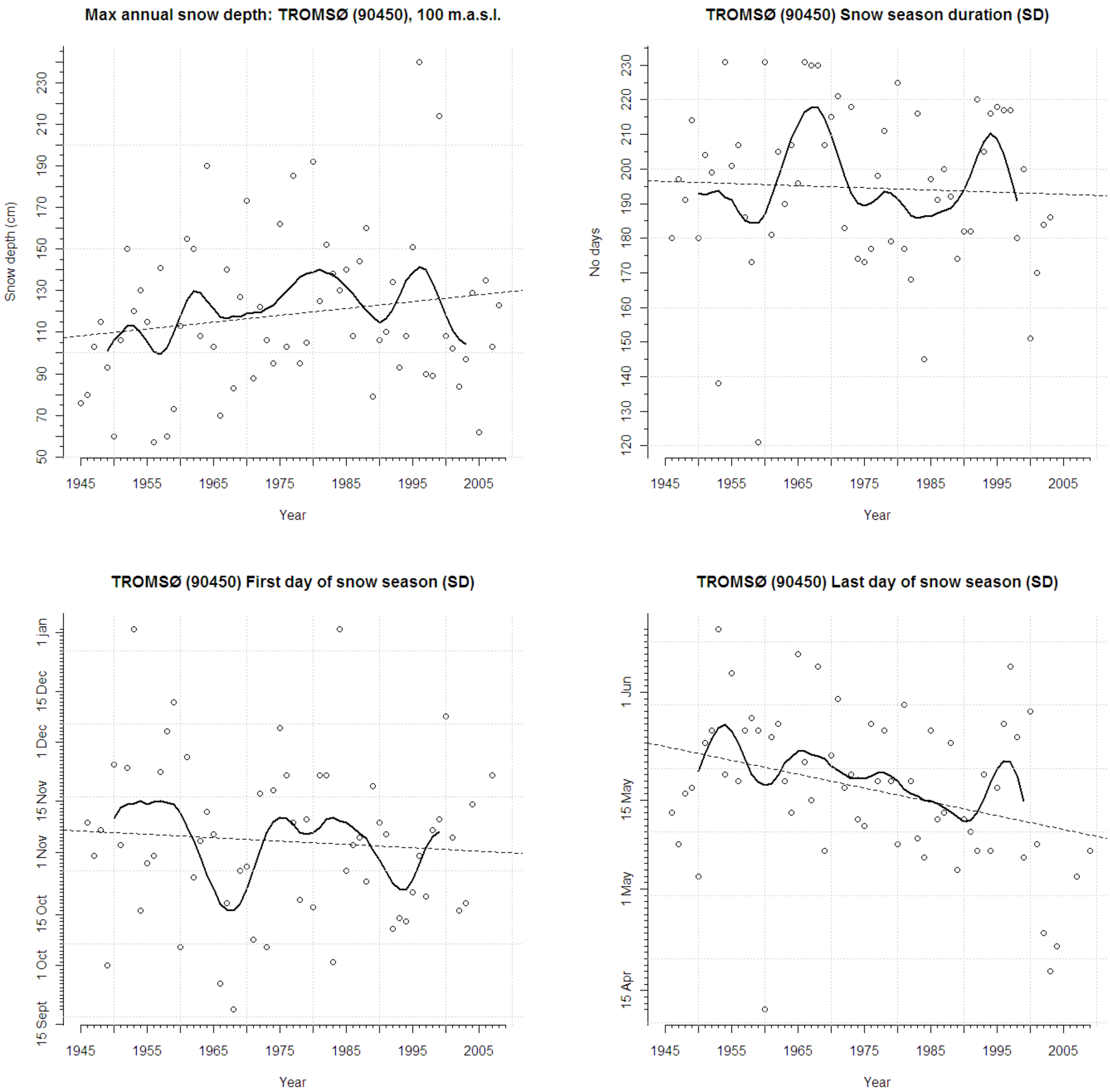

Figure 4: *Tromsø meteorological station: Snow.*

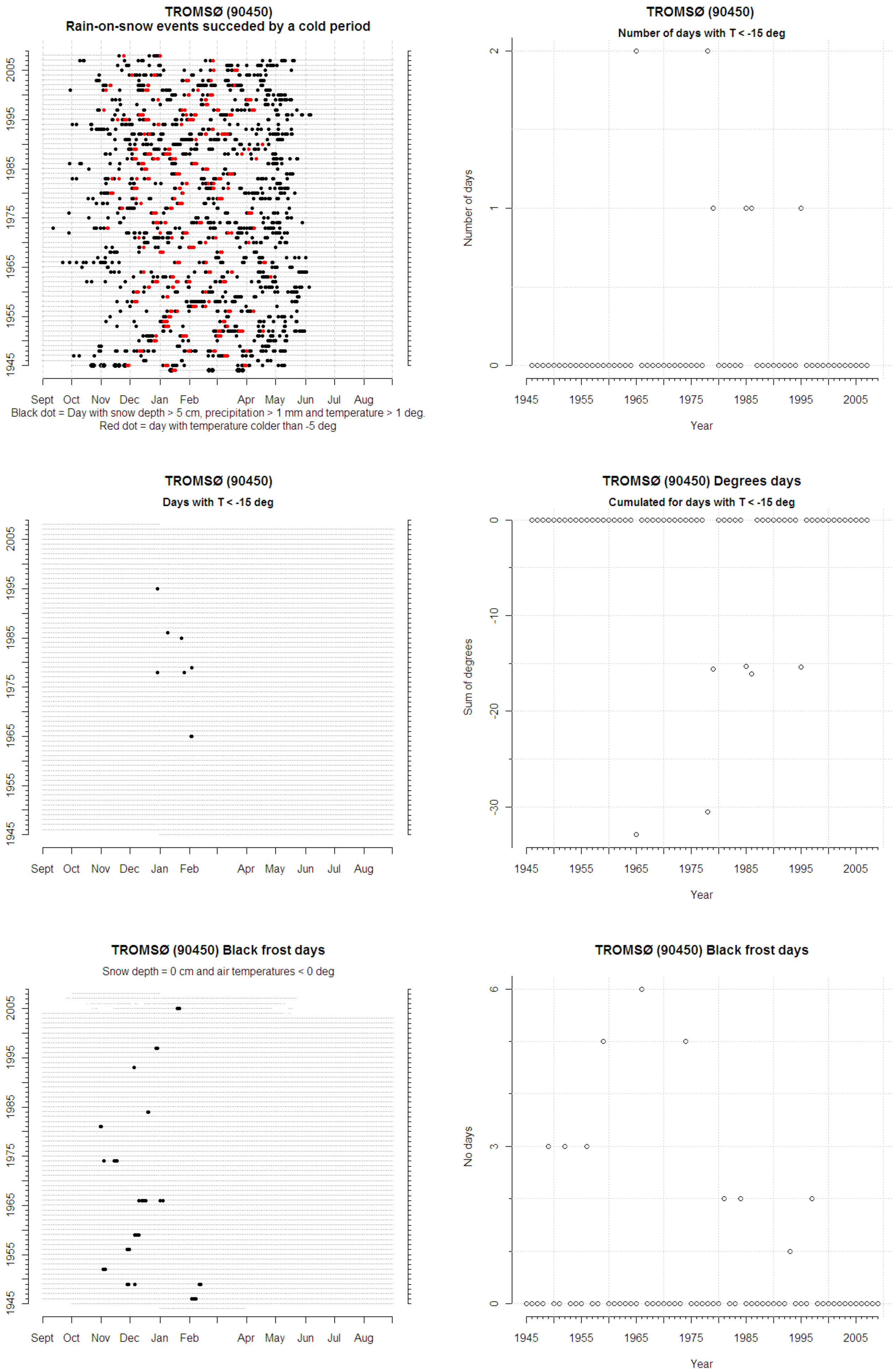

Figure 5: *Tromsø meteorological station.*

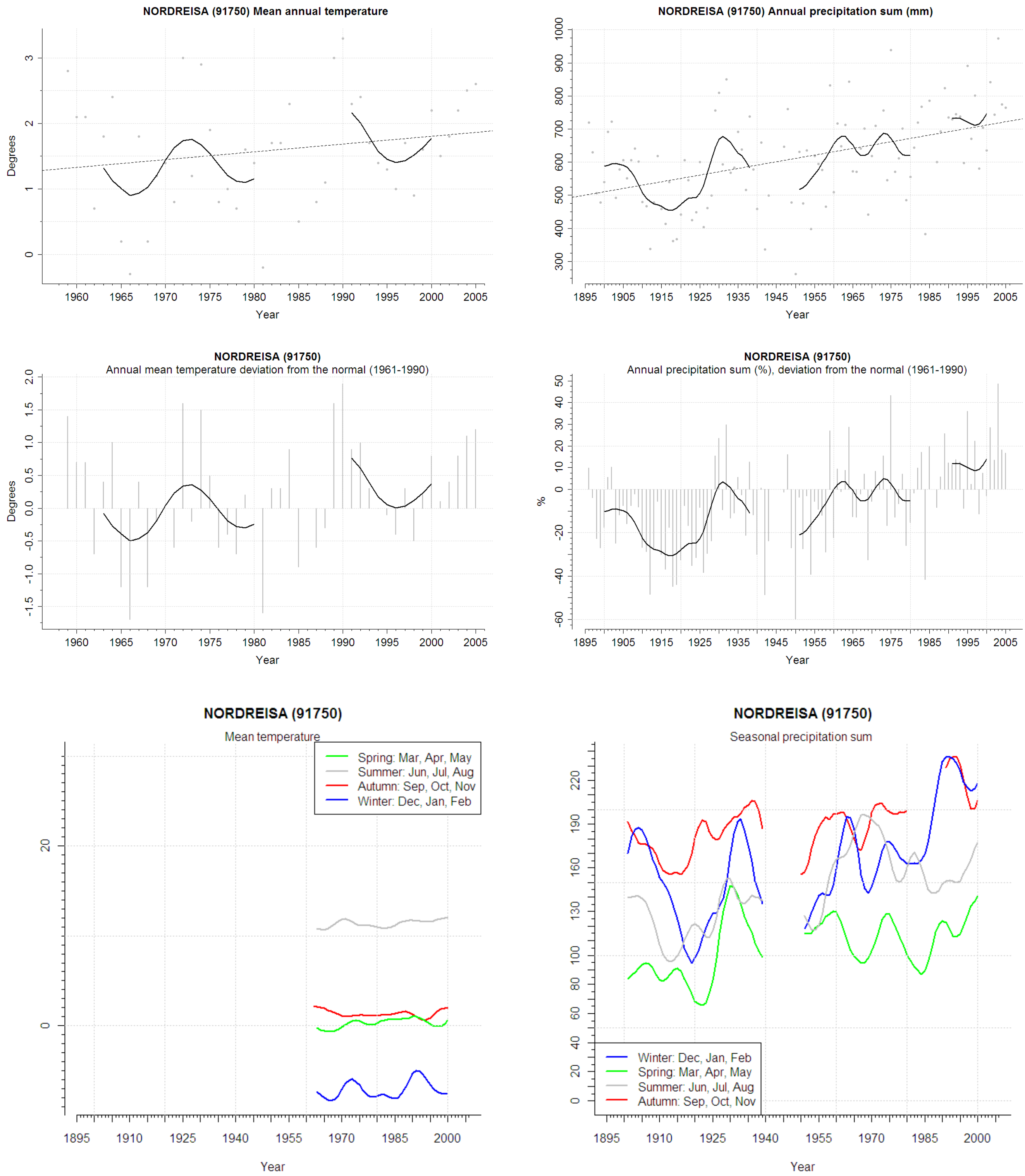

Figure 6: *Nordreisa meteorological station: Temperature and precipitation.*

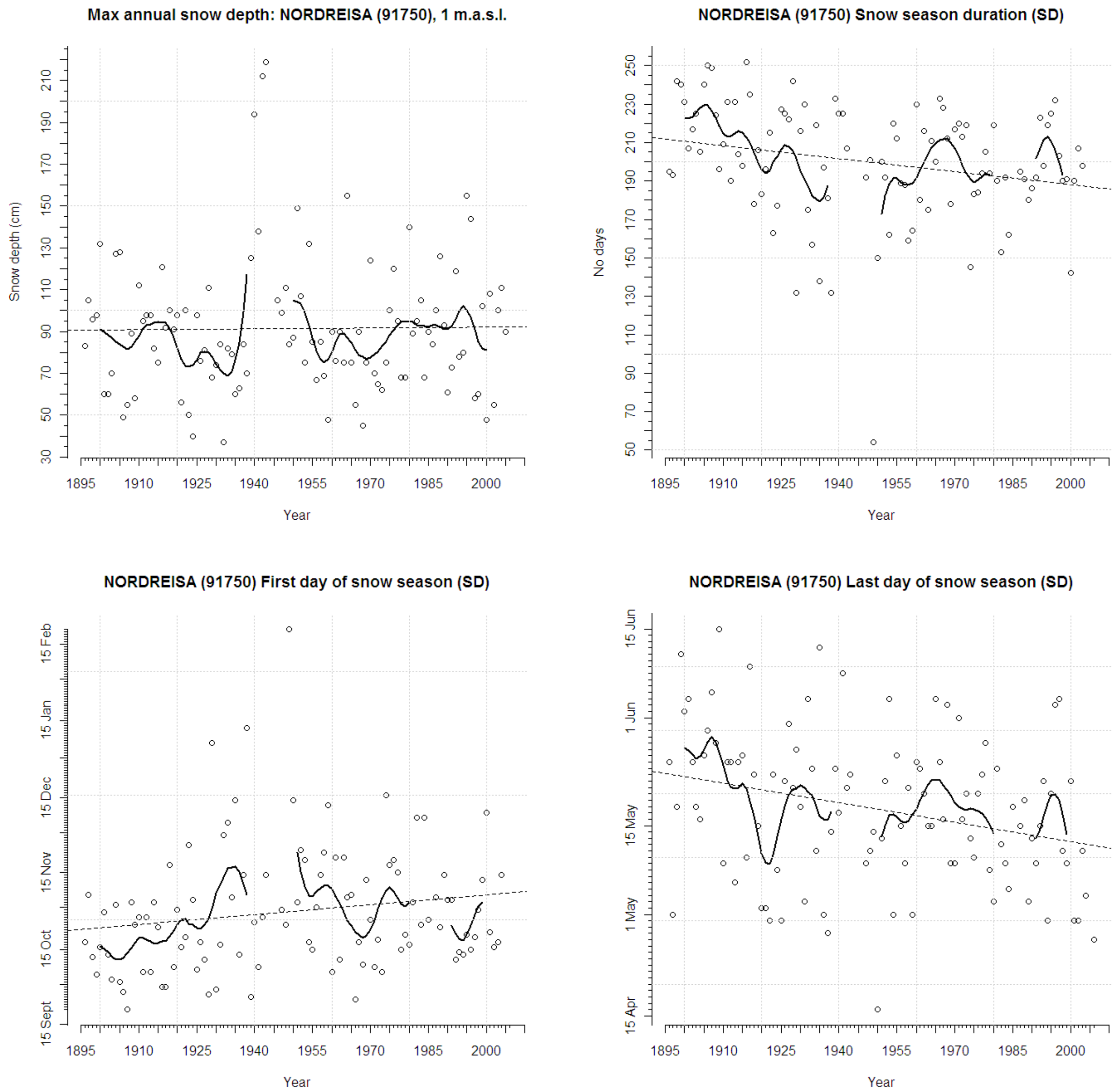

Figure 7: *Nordreisa meteorological station: Snow.*

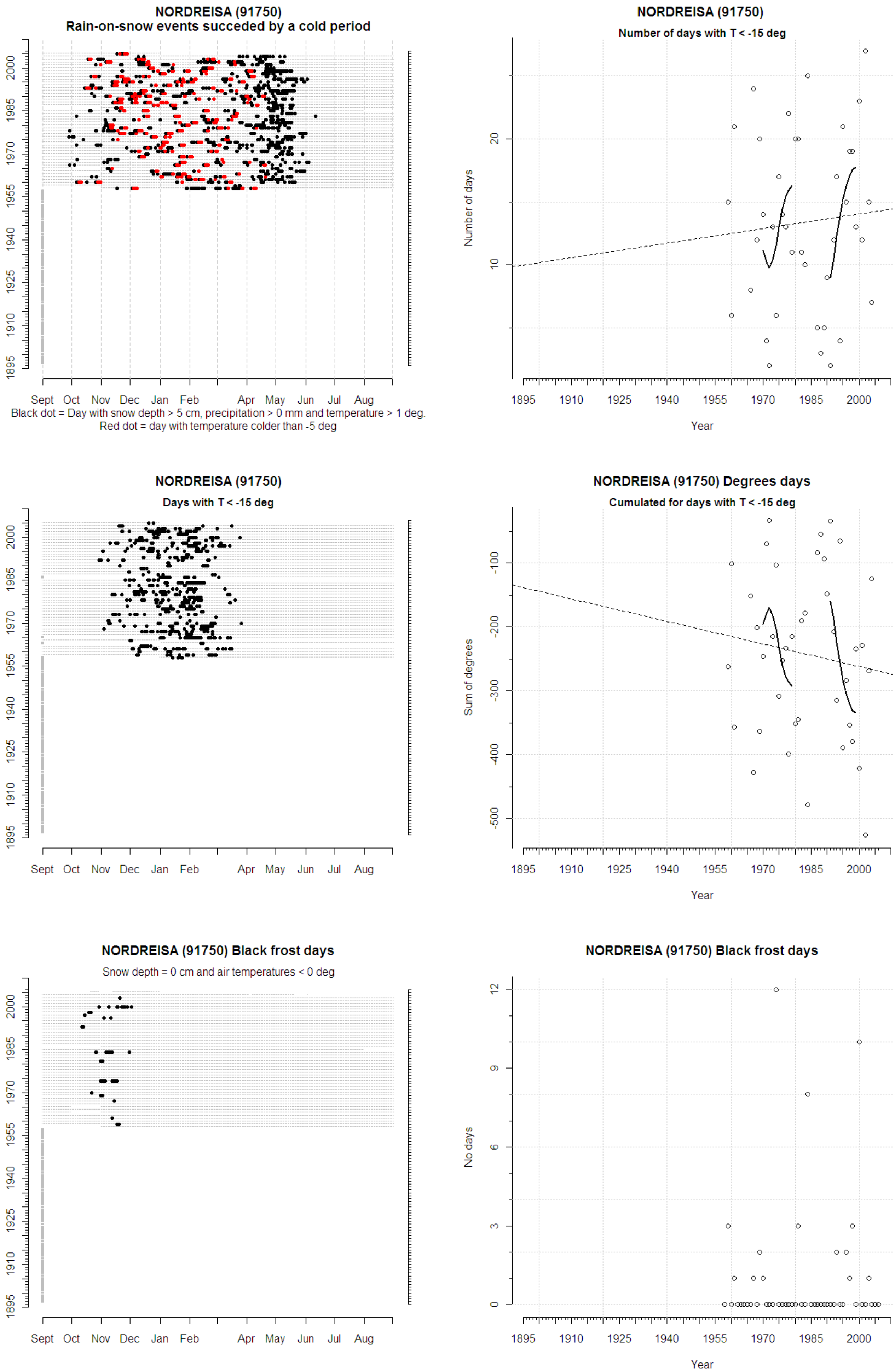

Figure 8: *Nordreisa meteorological station.*

Figure 9: *Nordreisa meteorological station: Temperature and precipitation.*

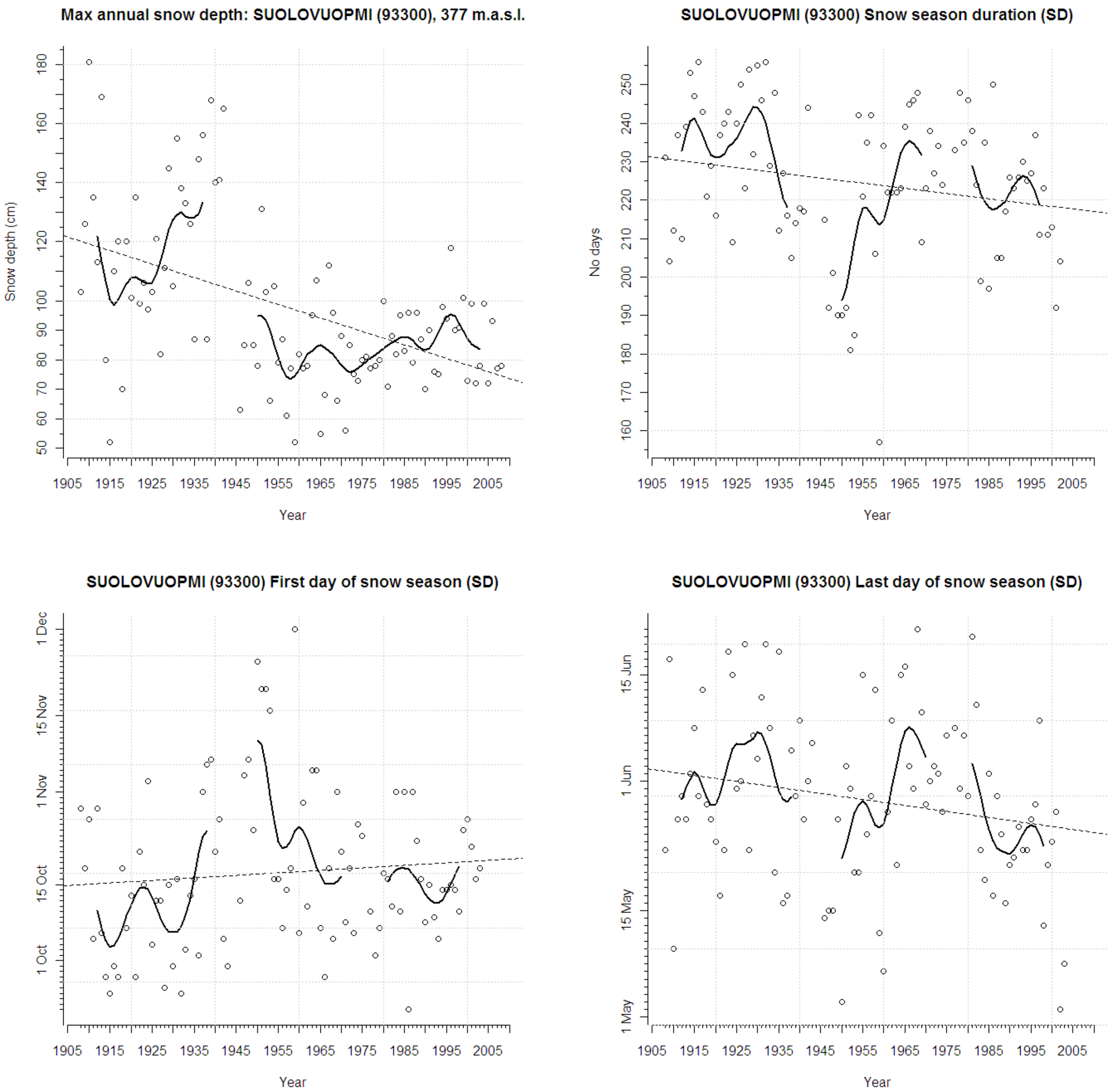

Figure 10: *Nordreisa meteorological station: Snow.*

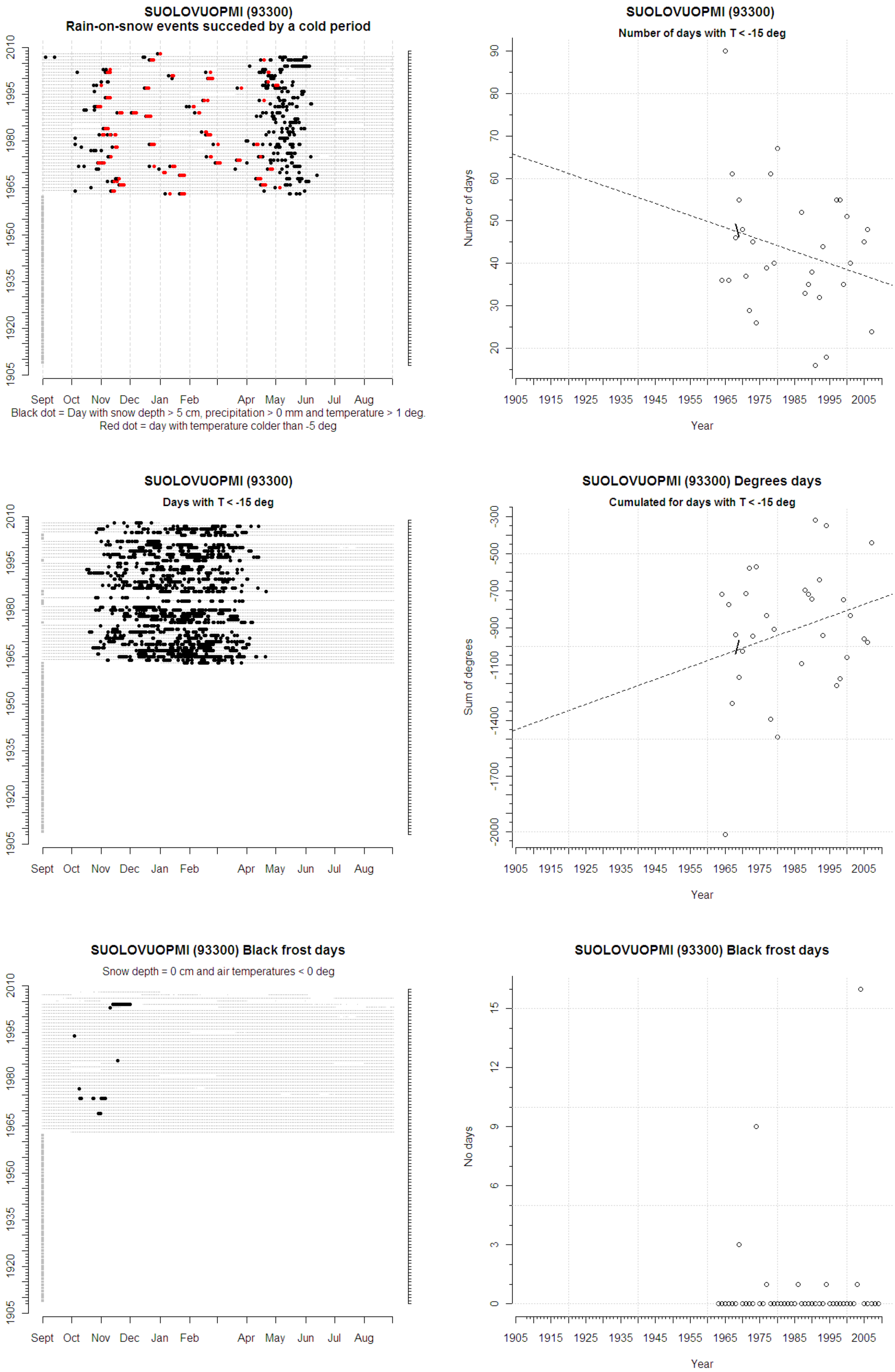

Figure 11: *Nordreisa meteorological station.*

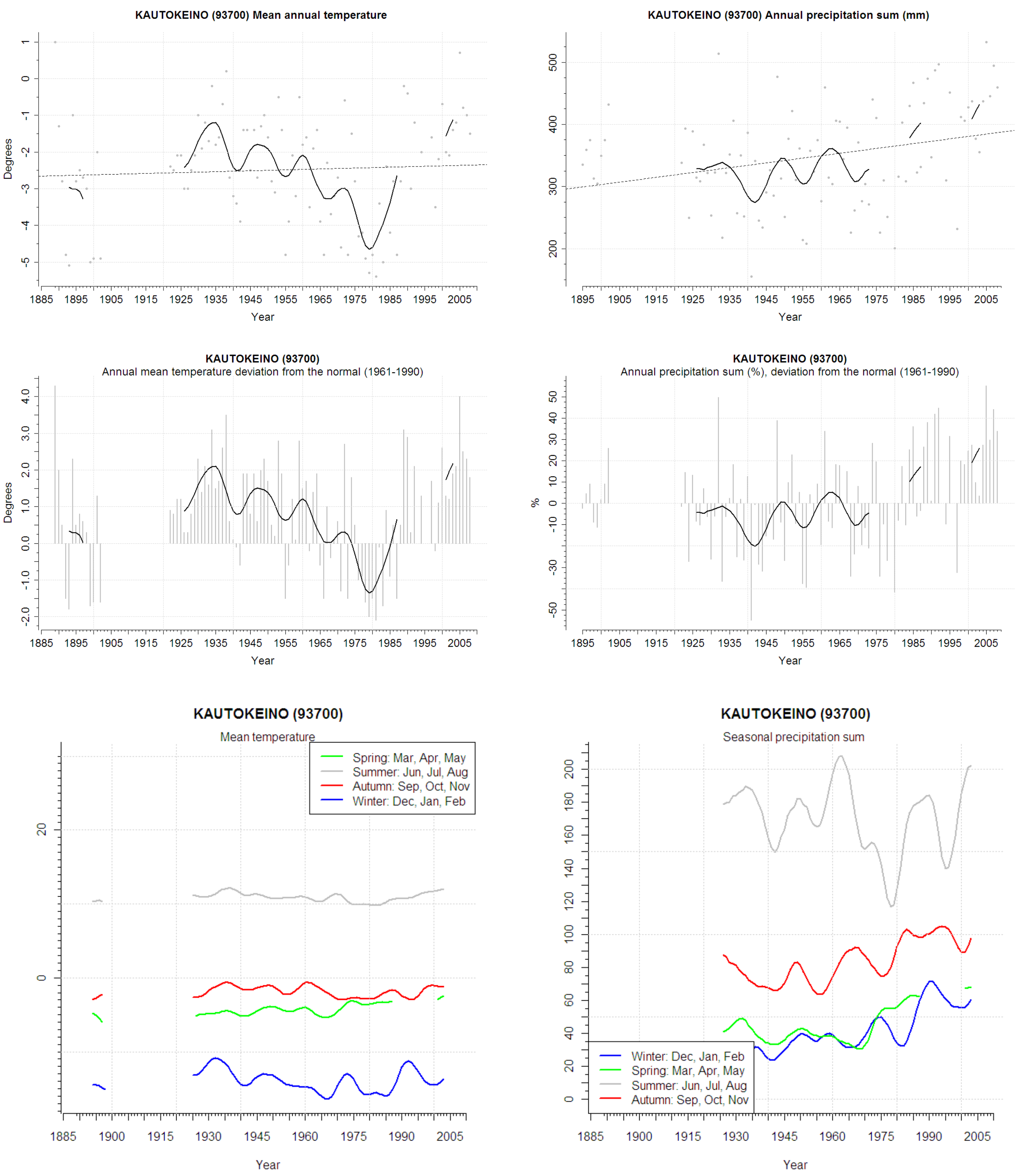

Figure 12: *Kautokeino meteorological station: Temperature and precipitation.*

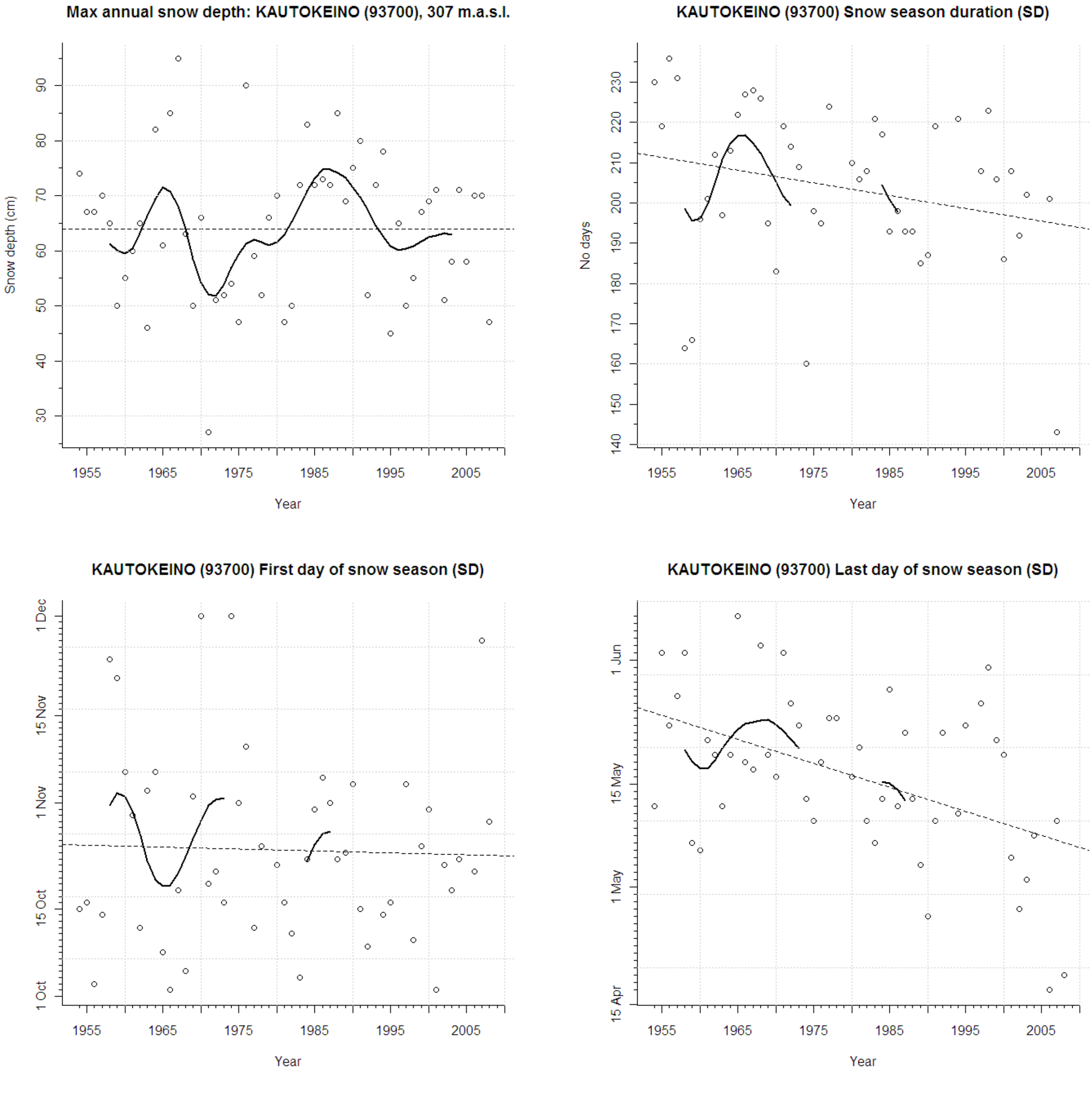

Figure 13: *Kautokeino meteorological station: Snow.*

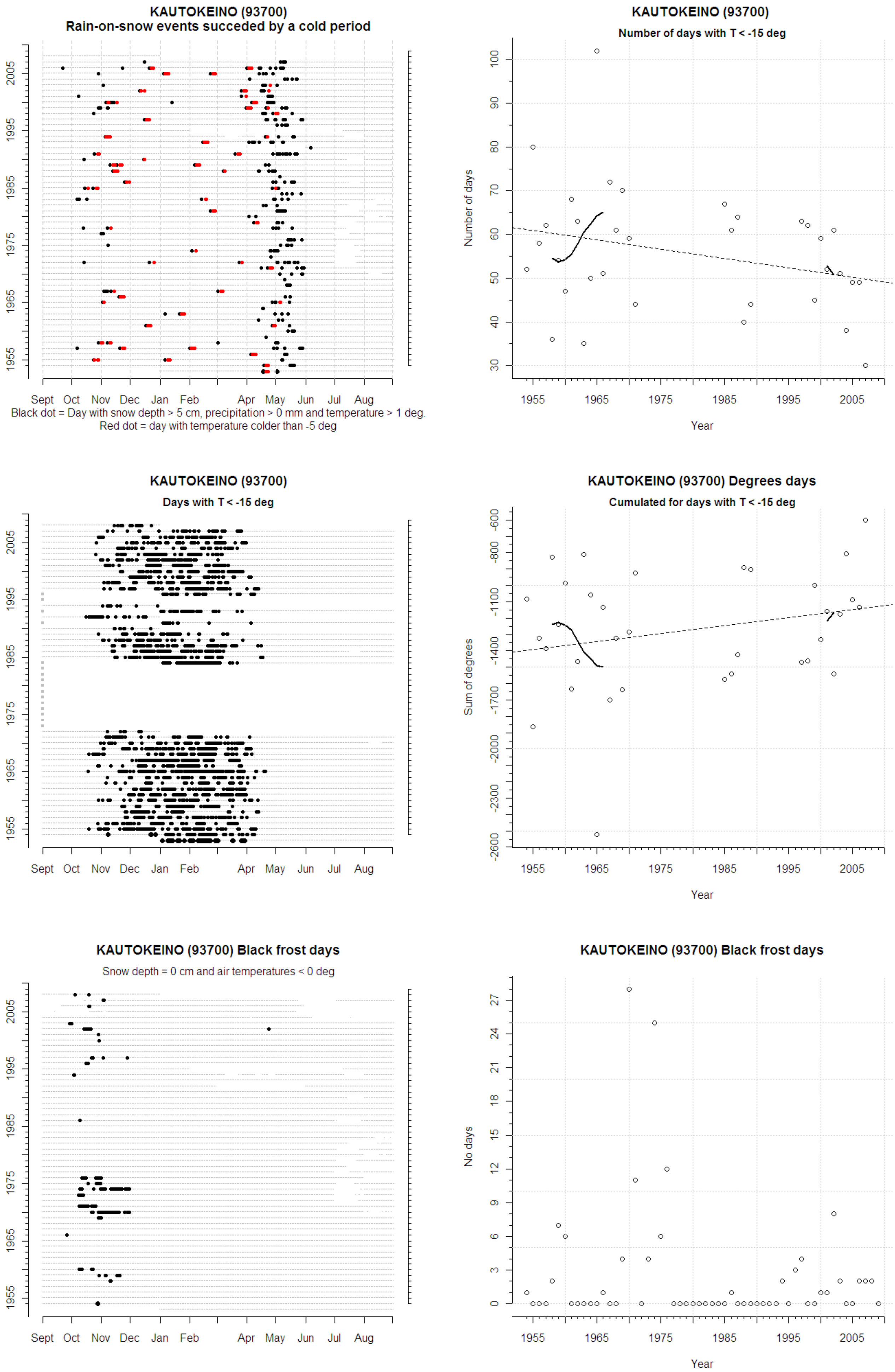

Figure 14: *Kautokeino meteorological station.*

Figure 15: *Sihccajavri meteorological station: Temperature and precipitation.*

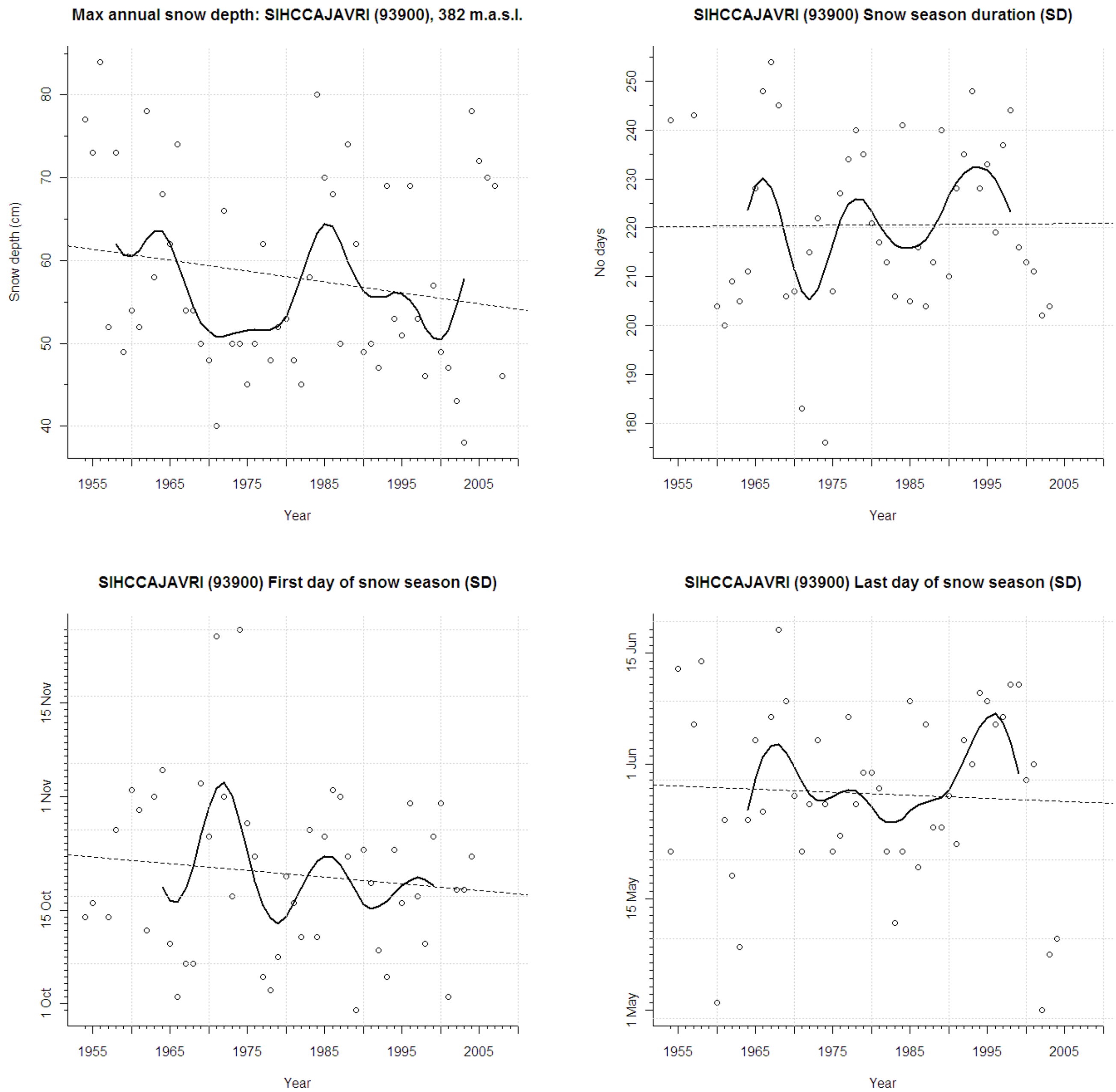

Figure 16: *Sihccajavri meteorological station: Snow.*

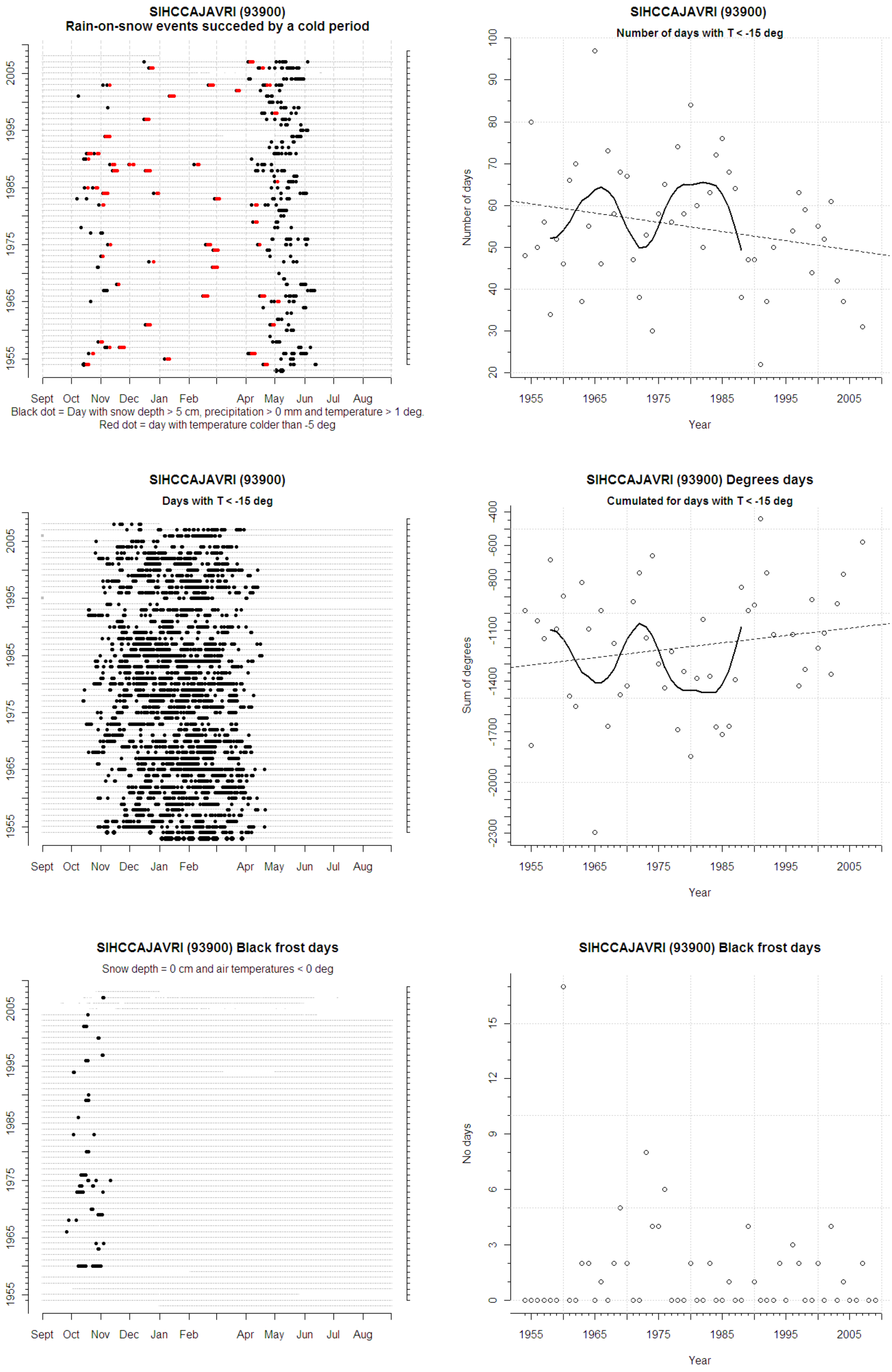

Figure 17: *Sihccajavri meteorological station.*

Figure 18: *Karasjok meteorological station: Temperature and precipitation.*

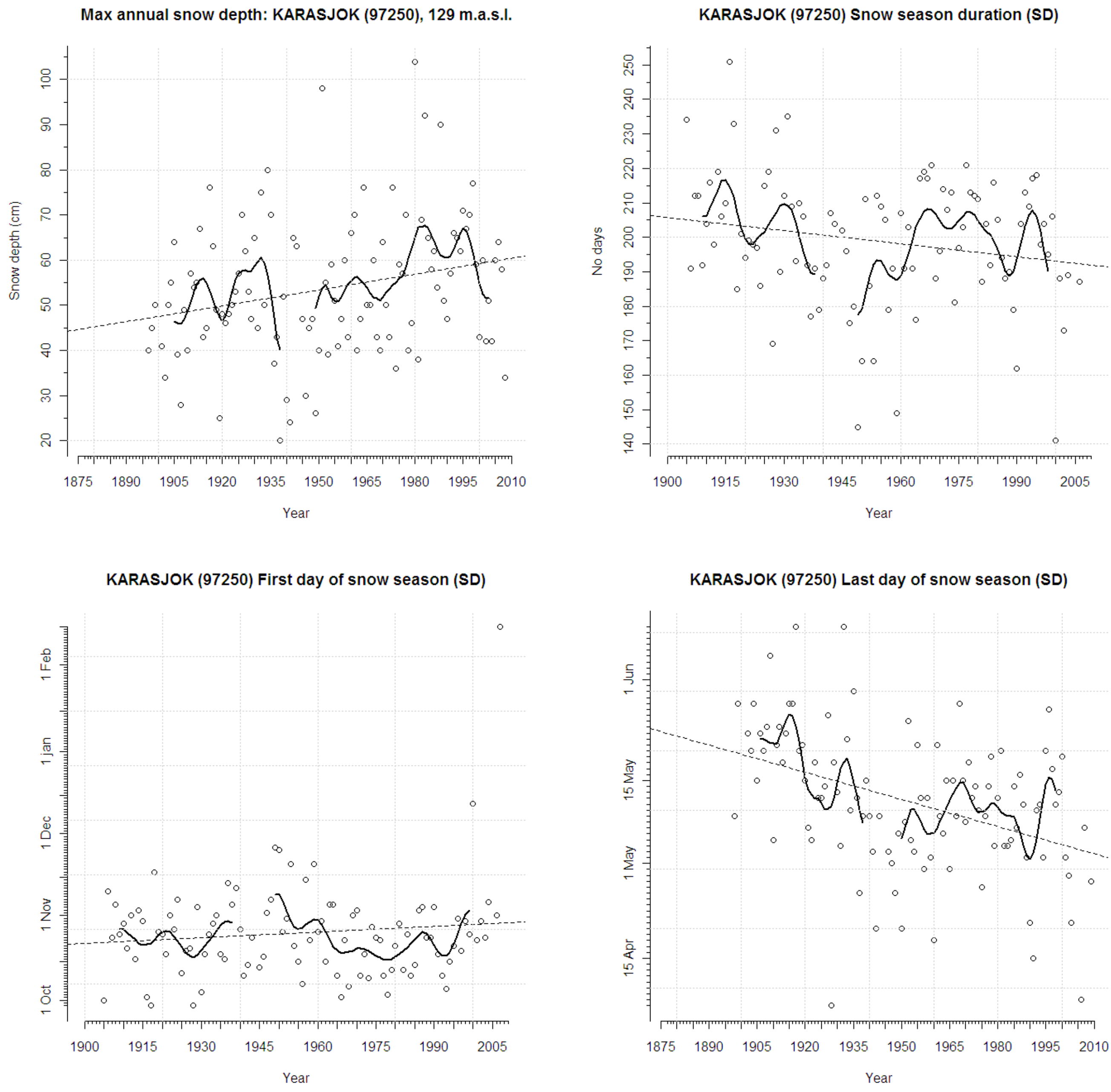

Figure 19: *Karasjok meteorological station: Snow.*

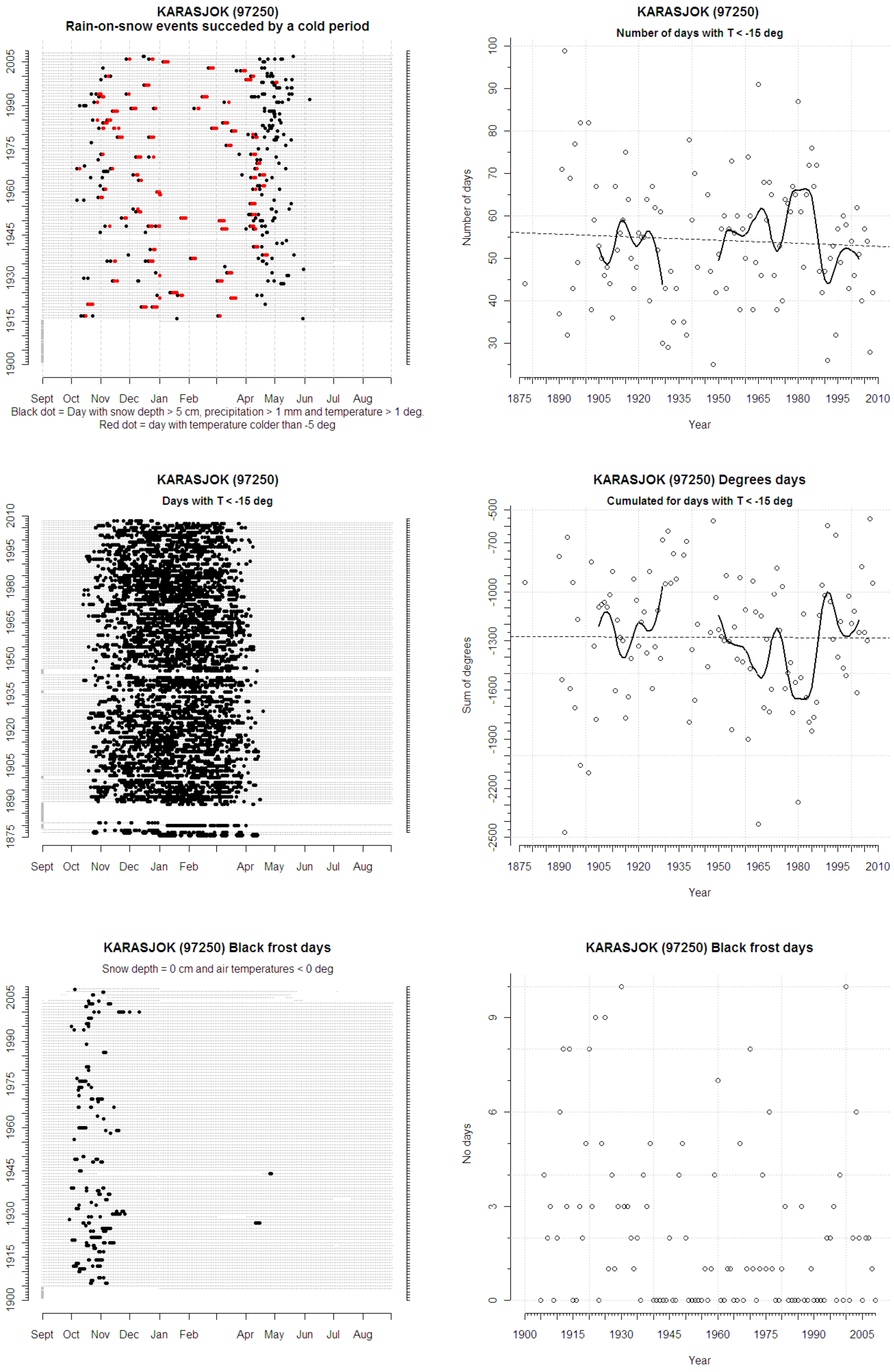

Figure 20: *Karasjok meteorological station.*

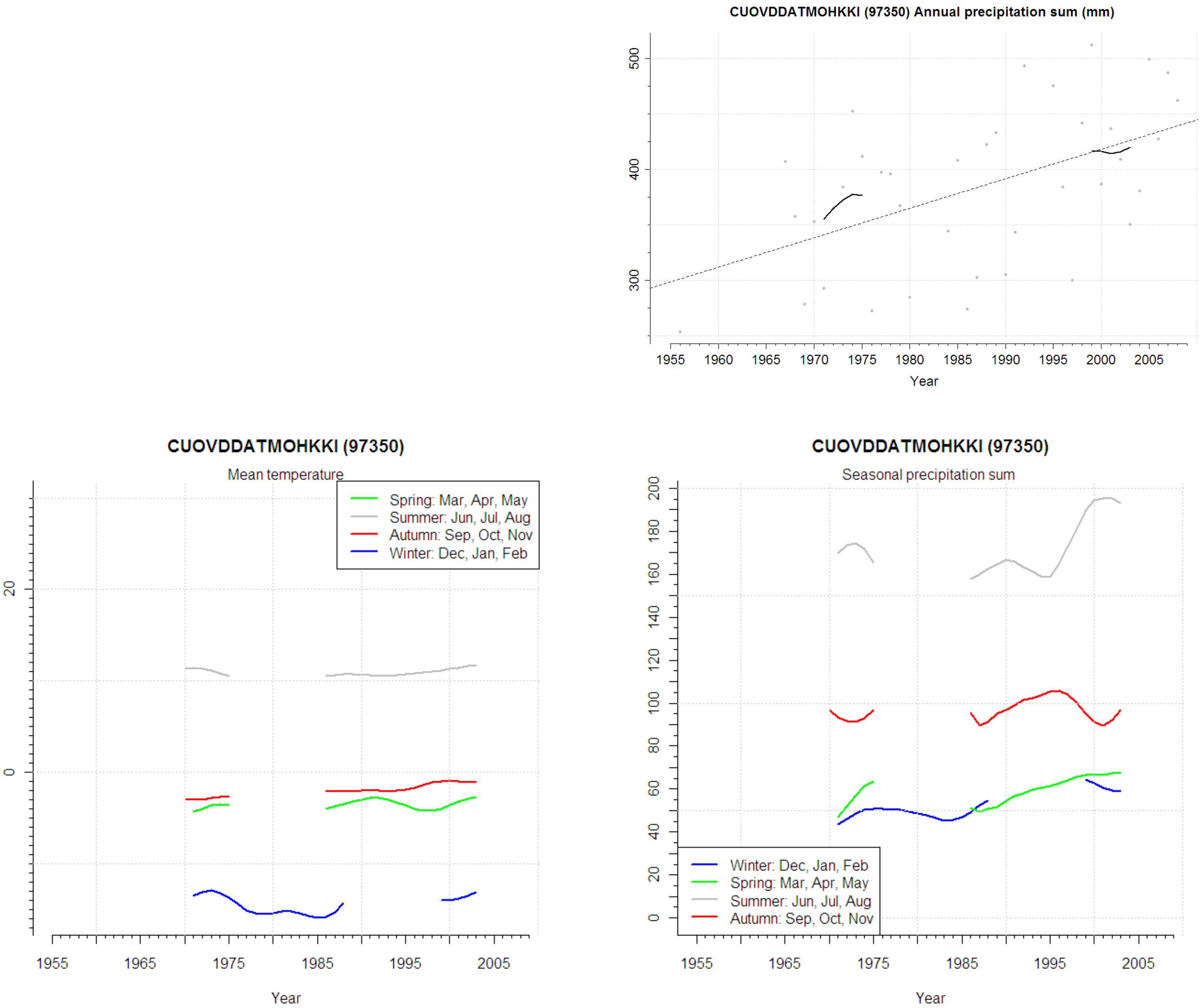

Figure 21: *Cuovddatmohkki meteorological station: Temperature and precipitation.*

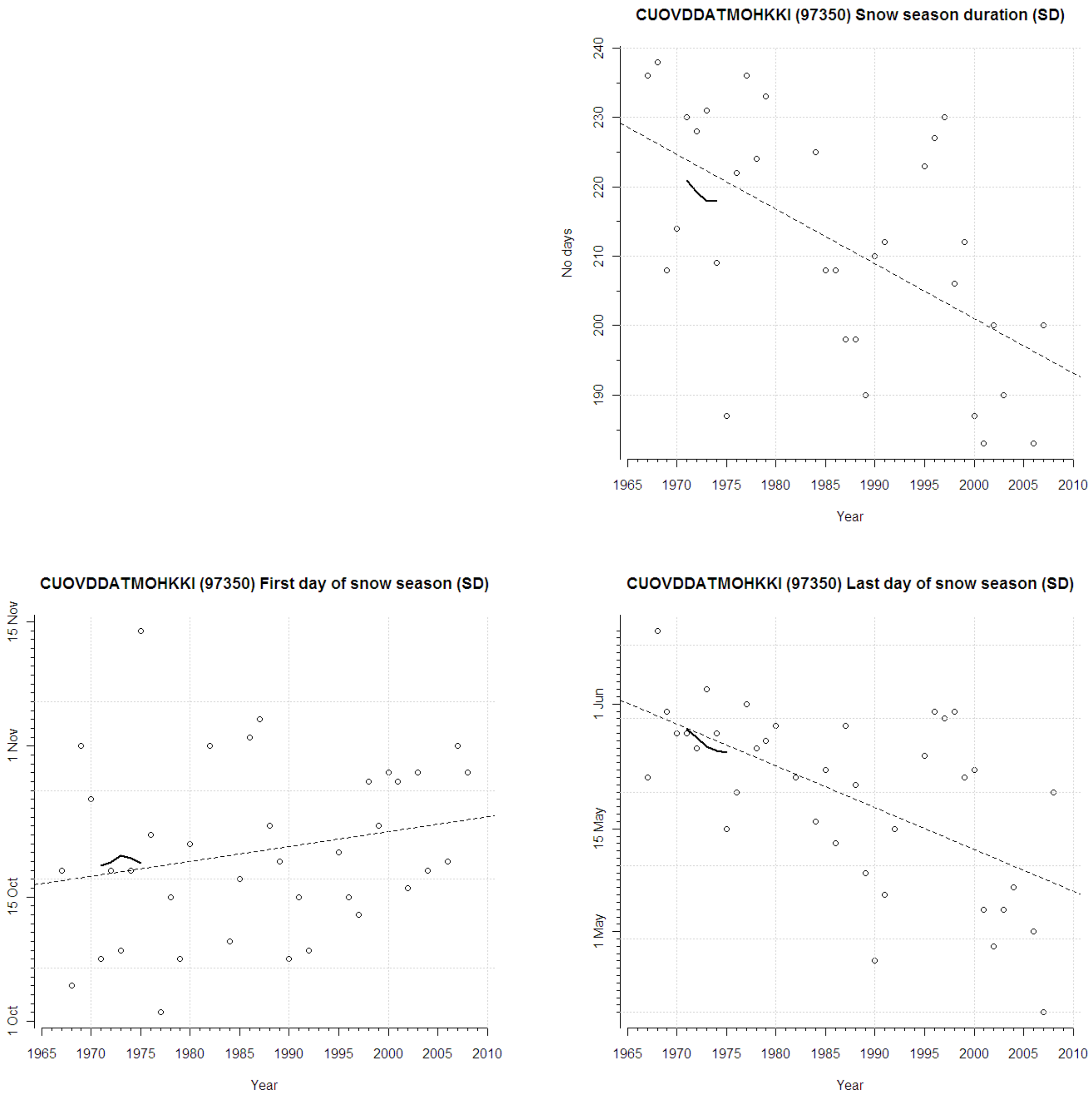

Figure 22: *Cuovddatmohkki meteorological station: Snow.*

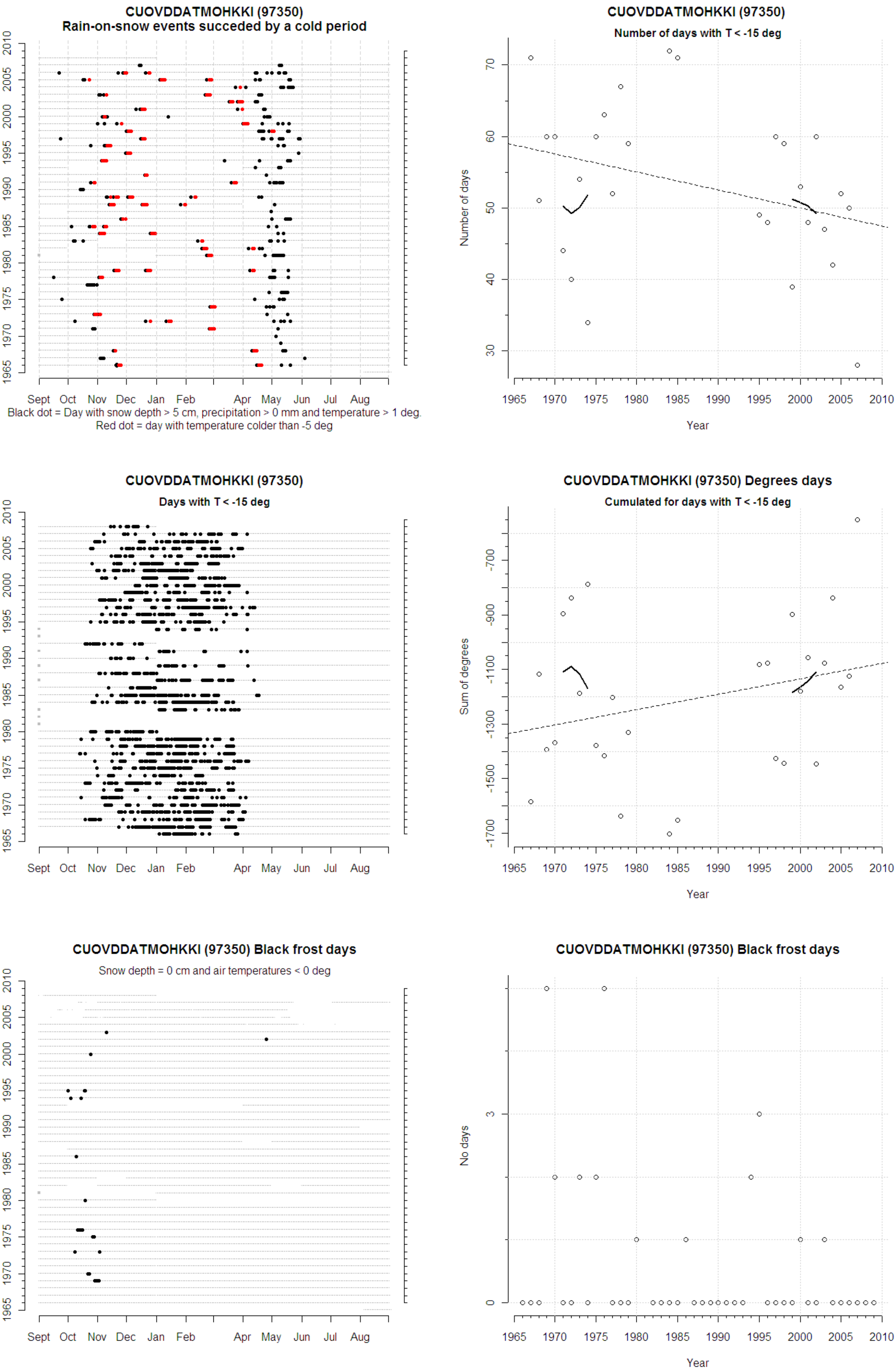

Figure 23: *Cuovddatmohkki meteorological station.*

3.2 Comparison of the climate at the meteorological stations

3.2.1 Annual and seasonal temperature

As few of the present series are 100 years long, long-term linear trends have not been listed here. According to Hanssen-Bauer (2005), however, Tromsø and Nordreisa are situated in a region ("temperature region 4") where there is a statistically significant linear trend in annual mean temperature of about 1°C per 100 years. The other stations belong to another region ("temperature region 5") where the linear trend is only half of this, and not statistically significant. A typical feature in both these regions is, however, that the decadal scale variability is large compared to the long-term trends.

The large decadal scale variability is clearly illustrated by Figure 24. Both annual and seasonal temperatures show similar variability on the decadal scale for the three meteorological stations: Karasjok, Kautokeino and Sihccajavri. Considerably higher temperatures are measures at the Tromsø and Nordreisa stations (limited observation period) in all seasons except summer, due to their coastal location. Cuovddatmohkki and Suolovuopmi are missing long series of temperature data.

The trends for the mean annual temperature can be divided in the same four periods as described in Førland et al. (2000), Hanssen-Bauer (2005) and Hanssen-Bauer et al. (2009):

1. A cold period with small trends during the early 20th century.
2. A culminating warm period in the 1930s often referred to as the "early 20th century warming".
3. A period with cooling from the 1930s to the 1960s.
4. A "recent warming" from the 1960s to present. For Finnmarksvidda this is shiftet to the 1980's.

The mean autumn, winter and summer temperatures generally show the same trends during these four periods as the mean annual temperature. However, the mean spring temperature shows overall positive trends for all four periods. These increasing spring temperatures have been observed several places in Norway and Svalbard (pers. comm. Øyvind Nordli).

Overall, the temperature curves of both coastal and continental stations are highly correlated (Table 4).

	Tromsø	**Nordreisa**	**Kautokeino**	**Karasjok**	**Sihccajavri**
Tromsø	1				
Nordreisa	0.95	1			
Kautokeino	0.85	0.27	1		
Karasjok	0.95	0.93	0.88	1	
Sihccajavri	0.95	0.93	0.89	0.95	1

Table 4: *Correlation matrix of mean annual temperature in Tromsø, Nordreisa, Kautokeino, Karasjok and Sihccajavri.*

Hanssen-Bauer and Førland (2000) indicate that a considerable part of the decadal scale temperature variability from about 1940 to 1995 may be explained by variation in atmospheric circulation.

Figure 24: *Temperature: Comparison of all stations. 10 year Gauss filter.*

3.2.2 Annual and seasonal precipitation

Overall, the annual precipitation curves show increasing precipitation for all meteorological stations since approx. 1915 (Cuovddatmohkki has a limited precipitation serie) (Figure 25). This is in accordance with Hanssen-Bauer (2005), who concludes that precipitation regions 11 (including Tromsø and Nordreisa) and 12 (including innland areas in Finnmark) experienced highly significant linear trends in annual precipitation during the 20th century (almost 20% increase in 100 years). Superimposen on the longterm trends, there is considerable decadal variability. Periods with low annual precipitation have occurred around 1915, 1940-45 and 1970-75.

Seasonal precipitation is also shown in the Figure 25. It is illustrated that the summer precipitation has increased since approx. 1915.

Some interesting differences are observed for coastal stations (maritime climate) and inland stations (continental climate). The coastal stations Tromsø and Nordreisa receive significantly more precipitation, annually, and for all seasons except summer, than the five continental stations Sihccajavri, Suolovuopmi, Kautokeino, Karasjok and Cuovddatmohkki. Since approx. 1950 both coastal stations received increasing precipitation during the winter season.

For this region there are considerably more differences in decadal variability between the individual stations for precipitation than for temperature (see Table 5 for correlation coefficients). This is expected since precipitation often varies more locally than temperature.

Hanssen-Bauer and Førland (2000) indicate that a considerable part of the decadal scale precipitation variability may be explained by variation in atmospheric circulation.

	Tromsø	**Nordreisa**	**Kautokeino**	**Sihccajavri**	**Suolovuopmi**	**Karasjok**
Tromsø	1					
Nordreisa	0.86	1				
Kautokeino	0.36	0.49	1			
Sihccajavri	0.05	-0.03	0.56	1		
Suolovuopmi	0.41	0.86	0.72	0.34	1	
Karasjok	0.45	0.77	0.55	0.55	0.82	1

Table 5: *Correlation matrix of annual precipitation sum in Tromsø, Nordreisa, Kautokeino, Karasjok Suolovuopmi and Sihccajavri.*

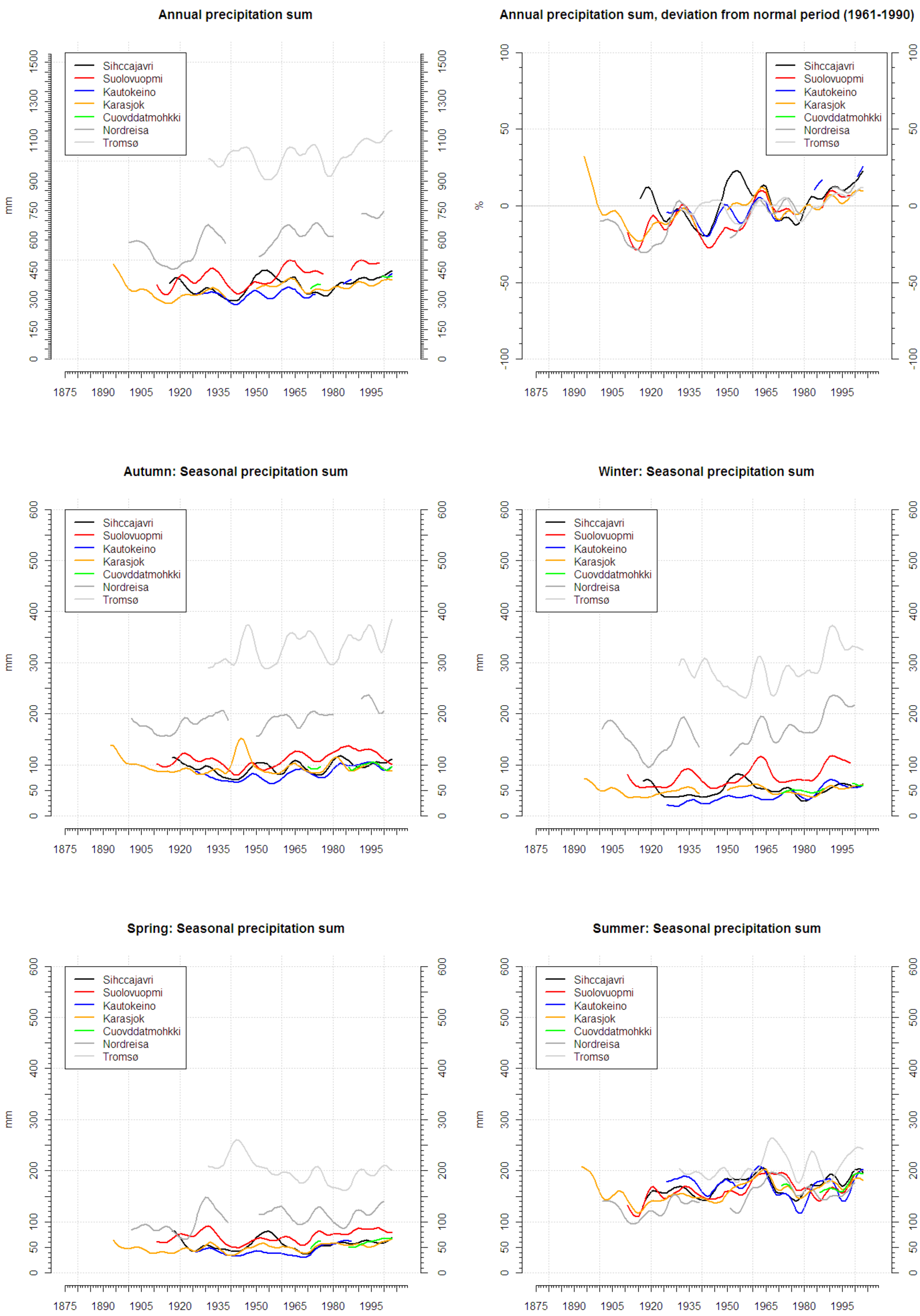

Figure 25: *Precipitation: Comparison of all stations. 10 year Gauss filter.*

3.2.3 Snow depth and snow season

Based on data from the two longest series of measurements from Suolovuopmi and Nordreisa, the trends in snow season duration can be divided in three main periods (Figure 26):

1. Decreasing snow season duration from 1900 to 1940's. The start of the snow season was shifted almost one month later. Note that this was mainly a period with marked increase in autumn temperatures, which may explain the reduction in snow season.

2. Increasing snow season duration from 1950's until the 1970. Note that both negative temperature trends in autumn and generally positive precipitation trends may have contributed to this.

3. Variable snow season duration from about 1970. There was a maximum around 1995 and reduction thereafter. Precipitation mainly increased in this period, however autumn temperatures remained relatively low until around 1995, thereafter they have increased.

For maximum snow depth (Figure 26) there are considerable differences between the Suolovuopmi, Nordreisa and Karasjok stations during the first part of the 20th century. From 1960's until 1985-95 the annual maximum snow depth increased, with a following decrease during the most recent decade. Overall, the correlation coefficients are higher between the different stations for snow season duration than for snow depth.

Generally, there are some uncertainties connected to snow depth measurements carried out for long time series. Finnmarksvidda is an area with rough climate, mostly located above the tree line. Stations may be exposed to strong winds that distributes the snow unevenly around the station. Topography and buildings affect the wind speed and wind direction and thereby the snow distribution. Snowdrift creates snow dunes and snow free areas. The snow depth will be affected by the snowdrift around the station. These factors makes the snow depth measurements more uncertain than e.g. the temperature measurements. Therefore the correlation of snow observations of the different stations are expected to be lower than the correlation of temperature observations.

	Tromsø	**Nordreisa**	**Suolovuopmi**	**Kautokeino**	**Karasjok**	**Sihccajavri**
Tromsø	1					
Nordreisa	0.89	1				
Suolovuopmi	0.64	0.58	1			
Kautokeino	0.86	0.90	0.98	1		
Karasjok	0.59	0.69	0.88	0.81	1	
Sihccajavri	0.40	0.44	0.39	0.88	0.18	1

Table 6: *Correlation matrix of snow season duration in Tromsø, Nordreisa, Kautokeino, Karasjok, Suolovuopmi and Sihccajavri.*

	Tromsø	**Nordreisa**	**Kautokeino**	**Sihccajavri**	**Suolovuopmi**	**Karasjok**
Tromsø	1					
Nordreisa	0.37	1				
Kautokeino	0	0.36	1			
Sihccajavri	-0.04	0.1	0.67	1		
Suolovuopmi	0.35	-0.25	0.38	0.08	1	
Karasjok	0.82	0.18	0.34	0.19	-0.14	1

Table 7: *Correlation matrix of maximum annual snow depth in Tromsø, Nordreisa, Kautokeino, Karasjok, Suolovuopmi and Sihccajavri.*

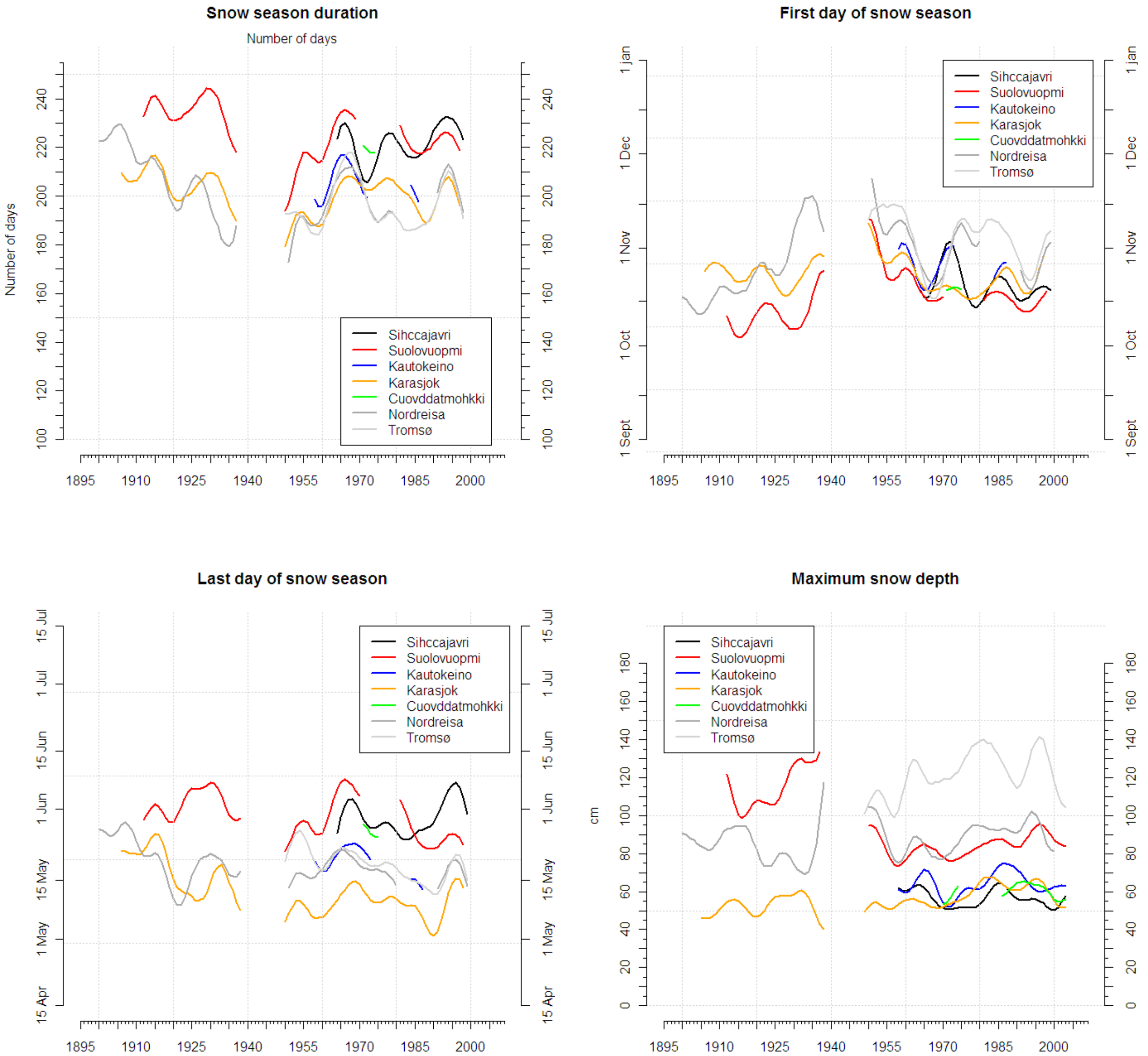

Figure 26: *Snow season and maximum snow depth: Comparison of all stations. 10 year Gauss filter.*

3.2.4 Cold season and degree days

In contrast to the coastal stations Tromsø and Nordreisa, the five meteorological stations located at Finnmarksvidda (Suolovuopmi, Kautokeino, Sihccajavri, Karasjok, Cuovddatmohkki) have a considerable number of days with daily mean temperatures below -15° (Figure 27). Long periods with cold weather favours the generation of depth hoar crystals in the snow pack (loose snow structure), and is therefore favourable for the reindeers access to food through the snow. Changes in the length of these cold periods affect the snow pack and thereby the reindeers food access. To better understand these processes, more studies are needed on changes in snow pack properties with air temperatures and effects on the reindeers food access.

Figure 27 shows that there is no clear positive or negative trend in degree days or cold season over the last 100 years. However, the graphs reveal that since 1970 both the shortest and the longest cold periods have occurred during the last 100 years:

- 1980-1985: Longest cold period.
- around 1990: Shortest cold period.

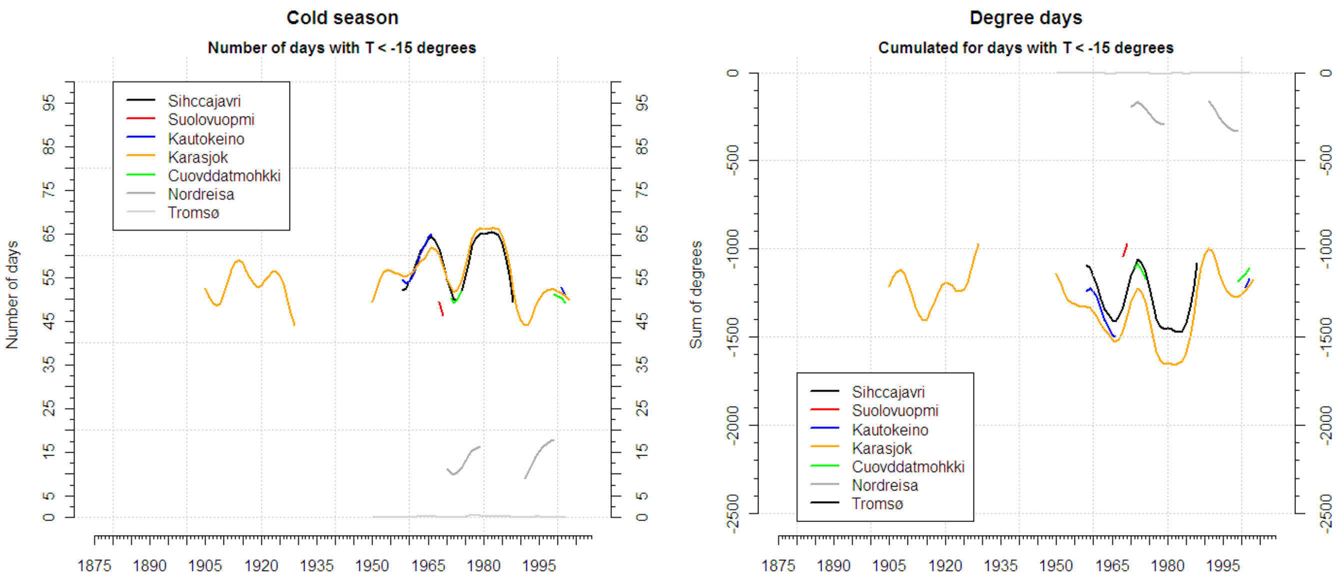

Figure 27: *Cold season and degree days: Comparison of all stations. 10 year Gauss filter.*

	Nordreisa	**Kautokeino**	**Sihccajavri**	**Suolovuopmi**	**Karasjok**
Nordreisa	1				
Kautokeino	0.71	1			
Sihccajavri	0.74	0.94	1		
Suolovuopmi	0.66	0.94	0.96	1	
Karasjok	0.63	0.88	0.97	0.91	1

Table 8: *Correlation matrix of cold season (number of days) in Nordreisa, Kautokeino, Karasjok, Suolovuopmi and Sihccajavri.*

	Nordreisa	Kautokeino	Sihccajavri	Suolovuopmi	Karasjok
Nordreisa	1				
Kautokeino	0.71	1			
Sihccajavri	0.69	0.93	1		
Suolovuopmi	0.65	0.95	0.97	1	
Karasjok	0.60	0.90	0.98	0.94	1

Table 9: *Correlation matrix of degree days in Nordreisa, Kautokeino, Karasjok, Suolovuopmi and Sihccajavri.*

3.2.5 Growing season and degree days

Since 1965 the growing season is gradually prolonged in the Finnmark area (see the Karasjok and Tromsø series in the Figure 28). A prolongued growing season increases the plant production during summer, and therefore is positive for the summer pastures of the reindeer.

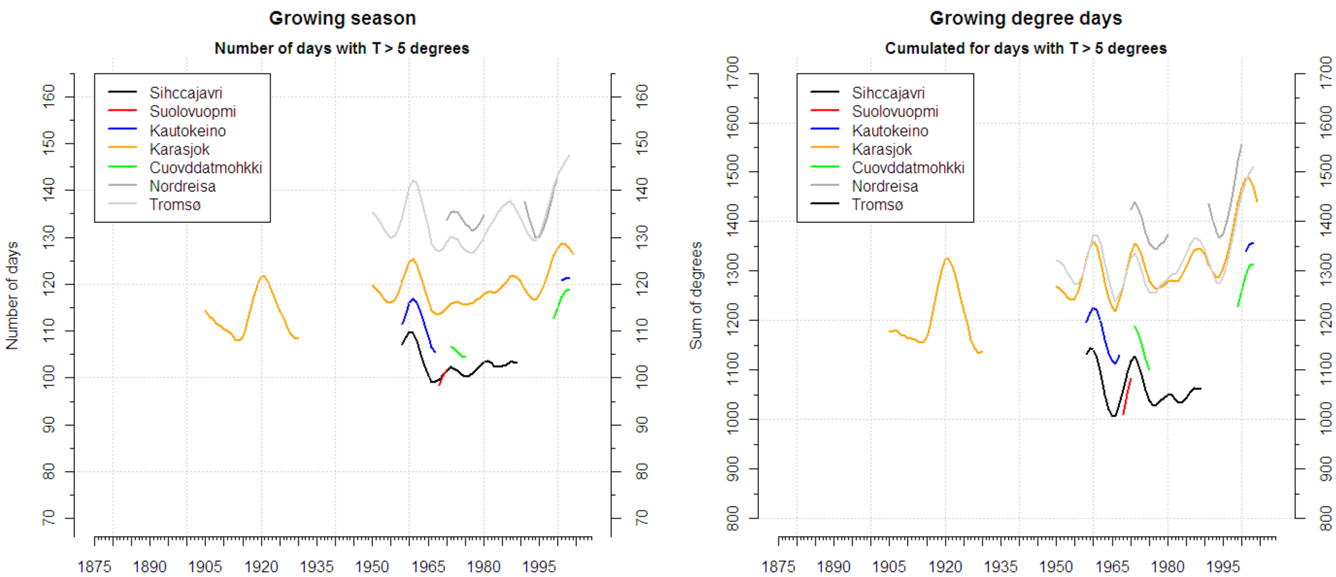

Figure 28: *Growing season and degree days: Comparison of all stations. 10 year Gauss filter.*

4 Summary and conclusions

This report presents long-term climate trends from five meteorological stations at Finnmarksvidda (Kautokeino, Karasjok, Sihccajavri, Cuovddatmohkki and Suolovuopmi) in addition to two coastal stations (Tromsø and Nordreisa). Long-term trends on air temperature, precipitation , snow season, cold season and growing season are described.

Temperature

The three continental stations (Karasjok, Kautokeino and Sihccajavri) show similar trends for annual and seasonal temperatures (summer, autumn and winter). These trends have previously been described in Førland et al. (2000), Hanssen-Bauer (2005) and Hanssen-Bauer et al. (2009):

1. A cold period with small trends during the early 20th century.

2. A culminating warm period in the 1930s often referred to as the "early 20th century warming".

3. A period with cooling from the 1930s to the 1960s.

4. A "recent warming" from the 1960s to present (1980's for Finnmarksvidda).

Hanssen-Bauer and Førland (2000) indicate that a considerable part of the decadal scale temperature variability from about 1940 to 1995 may be explained by variation in atmospheric circulation. An interesting phenomena is also the positive trends for the spring temperatures over the last 100 years.

Precipitation

The annual precipitation curves show some overall positive trends for all six meteorological stations since approx. 1915. For the individual stations there is considerably more differences in decadal variability for precipitation than for temperature, and even more for snow.

Hanssen-Bauer and Førland (2000) indicate that a considerable part of the decadal scale precipitation variability may be explained by variation in atmospheric circulation.

Snow

Data from the two longest series (Suolovuopmi and Nordreisa) show that the trends in snow season duration can be divided in three main periods:

1. Decreasing snow season duration from 1900 to 1940's. The start of the snow season was shifted almost one month later. Note that this was mainly a period with marked increase in autumn temperatures, which may explain the reduction in snow season.

2. Increasing snow season duration from 1950's until the 1970. Note that both negative temperature trends in autumn and generally positive precipitation trends may have contributed to this.

3. Variable snow season duration from about 1970. There was a maximum around 1995 and reduction thereafter. Precipitation mainly increased in this period, however autumn temperatures remained relatively low until around 1995, thereafter they have increased.

Uncertainties are connected to long-term snow depth measurements. The measurements will be affected by the snowdrift, topography and buildings around the station. These factors make the snow depth measurements more uncertain than e.g. the temperature measurements. Therefore the correlation of snow observations between the different stations are lower than the correlation of temperature observations.

Cold season

There is no clear positive or negative trend in the length of the cold season (number of days with temperatures below -15°) over the last 100 years. However, the graphs reveal that since 1970 both the shortest and the longest cold periods have occurred during the last 100 years:

- 1975-1985: Longest cold periods.
- around 1990: Shortest cold period.

Growing season

Since 1965 the growing season is gradually prolonged in the Finnmark area. This increases the plant production and is therefore positive for the reindeer's summer pasture.

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