THE COURSE OF ECOLOGICAL SEASONS IN NORTH EUROPEAN IN THE MIDDLE AND NORTH BOREAL REGIONS OF NORTHERN EUROPE FOR CLIMATE CHANGE DURING THE LAST 25 YEARS. THE EXAMPLES OF SVARTBERGET (SWEDEN) AND OULANKA (FINLAND)

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Abstract

By means of daily temperature data records of two research stations in North European middle and north boreal regions (Svartberget in Northern Sweden resp. Oulanka in Northern Finland) from 1981 to 2005 the changes in time spans of the five ecological seasons (snow winter, pre-spring with snow melting, snow-free spring, climatic growing season, snow-free autumn) are presented. A remarkable increase in the duration of the growing season and an intense decline in the duration of the snow winter can be stated. The transitional seasons show slight variations, too, but not as important as the two main seasons.

1. Introduction

The recent global increase of air temperatures (*global warming*) since the Late-Glacial and during Holocene is well-documented by means of proxy and meteorological data and explained by sustainable models (CGCM2, CSM_1.4, ECHAM4/OPYC3, GFDL-R30_c, HadCM3) (KÄLLÉN & KATTSOV 2005, LECKEBUSCH et al. 2006). These model calculations show a more intensive global warming in high latitudes (arctic, subarctic, and boreal regions) in comparison to the rest of the world: As the global average for increasing air temperatures is predicted to be between 3 und 5 K in 2100; the amount of global warming in areas north of 60° N will be up to 7 K in 2100. The increase of the annual mean temperature in the continental regions of Northern Sweden and Northern Finland is generally supposed to be by 0.5 K per decade (increase of the mean winter temperature by 0.6 K per decade; increase of mean summer temperature by 0.3 K per decade) (JÓHANNESSON et al. 1995, see also BERNES 1996).

However, to give assessments for bio- and geoecological consequences caused by an increase of air temperatures a more detailed analysis of thermal conditions is necessary than it is generally done in global change models using exclusively annual mean temperatures and mean seasonal temperatures (see LANGER & VENZKE 2006). For instance, for scientific work on ecological and agricultural questions the temporal and spatial development of growing season (time of photosynthesis) is of greatest interest (SAXE et al. 2001; AHAS et al. 2002). In addition the temporal and spatial differentiated snow cover plays an increasing role for the development of vegetation and the formation of ground water after the melting processes during the lately winter-/early springtime (see ODIN & DEGERMARK 1990; NYBERG et al. 2001; LINDSTRÖM et al. 2002).

2. Study areas

The study areas of Svartberget and Oulanka are situated and can be described as follows (see fig. 1):

The area around the Forest Research Station Svartberget, run by the Swedish University of Agriculturalal Sciences in Umeå is located in the northeastern part of Sweden (64° 14’ N, 19° 46’ E) and is administratively appropriated to the community of Vindeln in the province of Västerbottens Län. According to climatological and vegetation aspects Svartberget lies in the middle boreal subzone (after AHTI, HÄMET-AHTI & JALAS 1968) at approximately 230 m a.s.l.. Due to physical geographical classifications of natural landscapes the region is located either in the zone of hilly middle boreal forest areas" (southern type) and in zone of "coastal plains and valleys with marine sediments at the Gulf of Bothnia" (NORDISKÅ MINISTERRÅDET 1984) (description of the station see SIREN & BÄRRING 1974, ANON. 1985, VENZKE 1990 und ODIN & DEGERMARK 1990).

The area around the Research Station Oulanka, run by the University of Oulu, (see *http://cc.oulu.fi/~oba/indexe.html*), is located in the northeastern part of Finland within the Oulanka National Park approximately 20 km south of the Arctic Circle (66° 20' N) and very close to the Finnish-Russian border (29° 22' E). The southern part of the Oulanka National Park is administratively appropriated to the province of Oulun Lääni and the northern part to Lapin Lääni. Within the natural landscape of "spruce-dominated forests in the Kuusamo Upland" (NORDISKÅ MINISTERRÅDET 1984) the region lies at approximately 160 m a.s.l. east and of the Maanselkä watershed between the Gulf of Bothnia in the West and the White Sea in the East to where all water courses of the region drain (KOUTANIEMI 1983, see also SCHWANTZ 2006). Due to climatological and vegetation aspects Oulanka belongs to the northern boreal subzone (after AHTI, HÄMET-AHTI & JALAS 1968).

Fig. 1. Location of the study areas Svartberget and Oulanka

3. Methods

During a period of nearly 40 years daily air temperature data and daily data about different snow depths were collected in Svartberget and Oulanka. Based on these data ecological seasons for the boreal regions in Northern Europe can be defined as follows (after ODIN et al. [1983]; see table 1).

Table 1. Definition of ecological seasons in the boreal regions in Northern Europe (after ODIN et al. 1983).

Code		**Swedish name**
sWi	snow winter with closed snow cover	*Snövinter*
sSp	early spring with a transition from a closed snow cover to a completely snow-free areas (including snow melting)	*Vårvinter*
sfSp	snow-free springtime with daily mean air temperatures <+5 °C	*Barmarksvår*
GS	growing season with daily mean air temperatures >+5 °C	
sfA	snow-free autumn with daily mean air temperatues <+5 °C	*Barmarkshöst*

Due to a lack of data in the time period 1966 to 1980 only daily mean air temperature data and snow depth data from 1981 to 2005 were studied.

4. Results

Both in Svartberget and in Oulanka a clear superiority of the ecological seasons sWi and GS in comparison to the other three ecological seasons can be stated (see table 2; see also fig. 2 and fig. 5), which is an indication for the continentality of the specific climate regime. Thereby the mean number of days in sWi in the more continental part of Northern Finland exceeds the mean number of days in sWi in Northern Sweden by 32 days (see table 2). In contrast to that the time of growing season in Svartberget is in average 5 days longer than in Oulanka (see table 2). In addition in Svartberget the duration of the three transitional ecological seasons is obviously higher than in Oulanka (91 days in Svartberget compared to 64 days in Oulanka; see also table 2). The observation of the ecological seasons between 2001 and 2005 in comparison to the time period 1981 to 2005 shows a decline of 10 days in the mean number of days in sWi both in Svartberget and in Oulanka (see table 2), which means a percentual decrease of 7.7 and 6.2 %, respectively. In contrast the time period of growing season increased by almost that amount (+9 and +11 days which is 6.3 and 7.9 %), whereas the mean number of days within the other three ecological season was relatively constant (see table 2 and fig. 3, 4 and 6).

Table 2. Mean number of days in the different ecological seasons for Svartberget and Oulanka during the time period 1981 - 2005 and 2001-2005 as well as their mean date of beginning and ending (1981-2005).

	Svartberget		**Oulanka**	
	1981-2005	**2001-2005**	**1981-2005**	**2001-2005**
sWi	130 *(12.11.-21.3)*	120	162 *(1.11.-11.4.)*	152
sSp	35 *(21.3.-28.4.)*	37	14 *(11.4.-9.5.)*	8
sfSp	13 *(28.4.-8.5.)*	10	19 *(9.5.-17.5.)*	22
GS	144 *(8.5.-29.9.)*	153	139 *(17.5.-30.9.)*	150
sfA	43 *(29.9.-12.11.)*	45	31 *(30.9.-1.11.)*	33

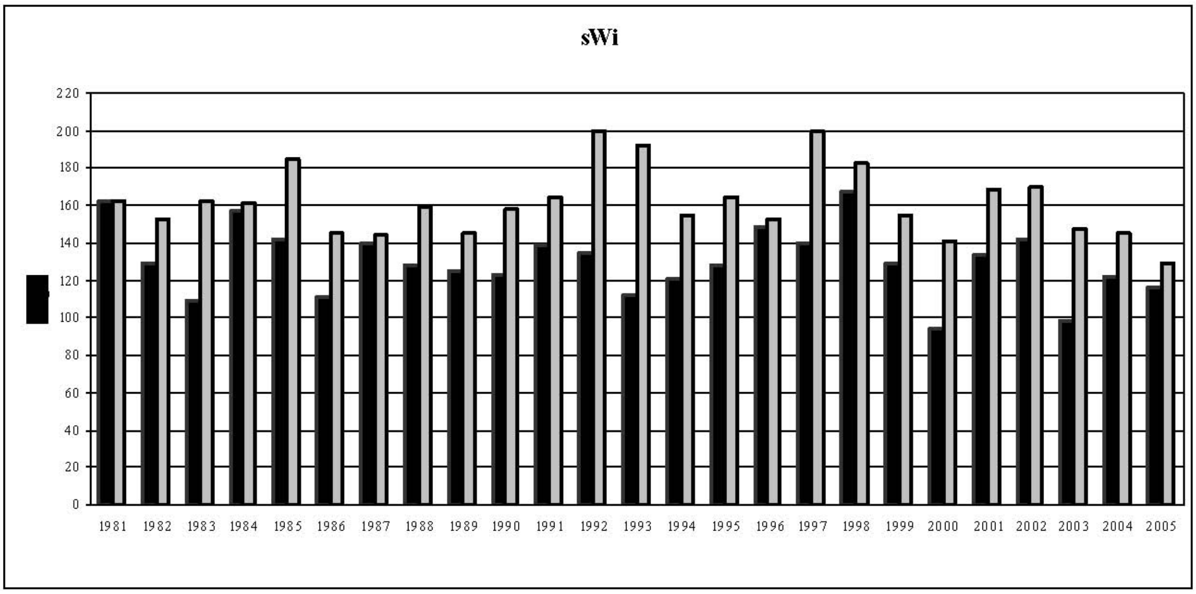

Fig. 2. Course of snow winter (sWi) in Svartberget (black) and Oulanka (grey) during 1981 – 2005.

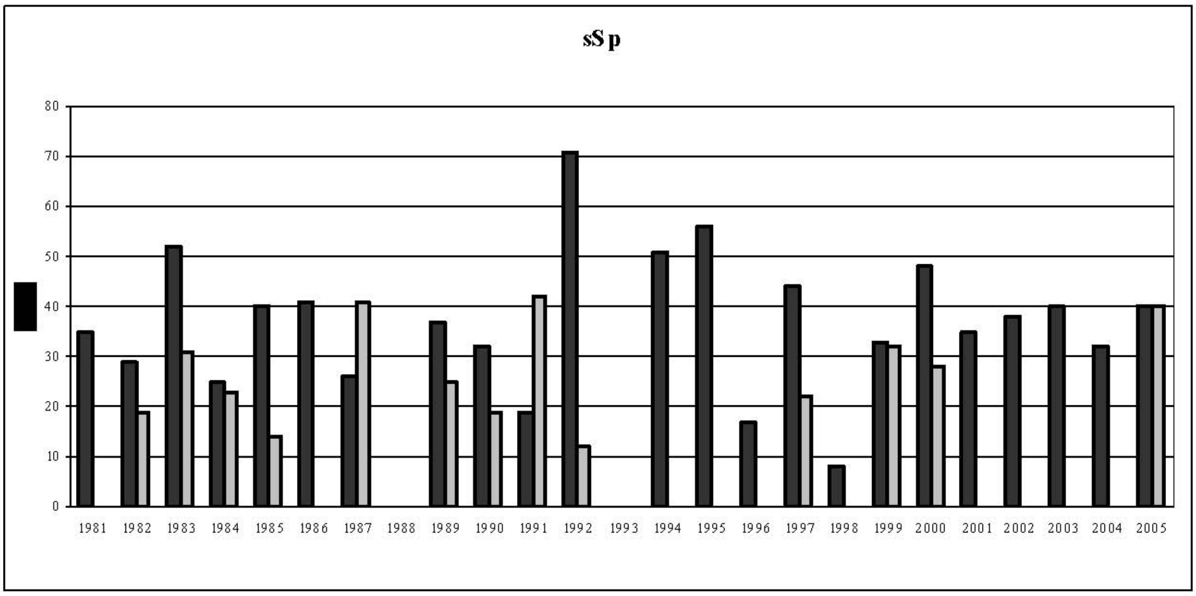

Fig. 3. Course of early snow spring (sSp) in Svartberget (black) and Oulanka (grey) during 1981 – 2005.

The already mentioned trends of the annual mean as well as the summer mean and winter mean air temperatures are found in the ecological seasons, too. Thereby during the period 1981 to 2005 the dates of beginning of the sfA and sWi have nearly shifted backwards by two weeks (see fig. 6, 2 and 7). On the other hand the dates of beginning of the sSp, sfSp and GS at the end of the observational period are three to seven days earlier compared to the beginning of the observation period (see fig. 3, 4, 5 and 7). It is interesting that in Oulanka no date of beginning and no date of ending of sfSp are mentioned, because in most of the years a direct transition of sSp to GS was observed. This circumstance of fast temperature rise after the snow melt can be valued as an indication of continentality, too. The trend courses show a shift of the beginning dates of GS and sfA backwards both in Svartberget (13.4 days and 12.6 days) and in Oulanka (4.5 days and 9,8 days), respectively. In comparison the ending dates of sWi and the sSp have shifted forward in Svartberget (6.9 days and 4.6 days) and in Oulanka, however diminished (2.7 days and 0.2 days; see fig. 2, 3 and 7).

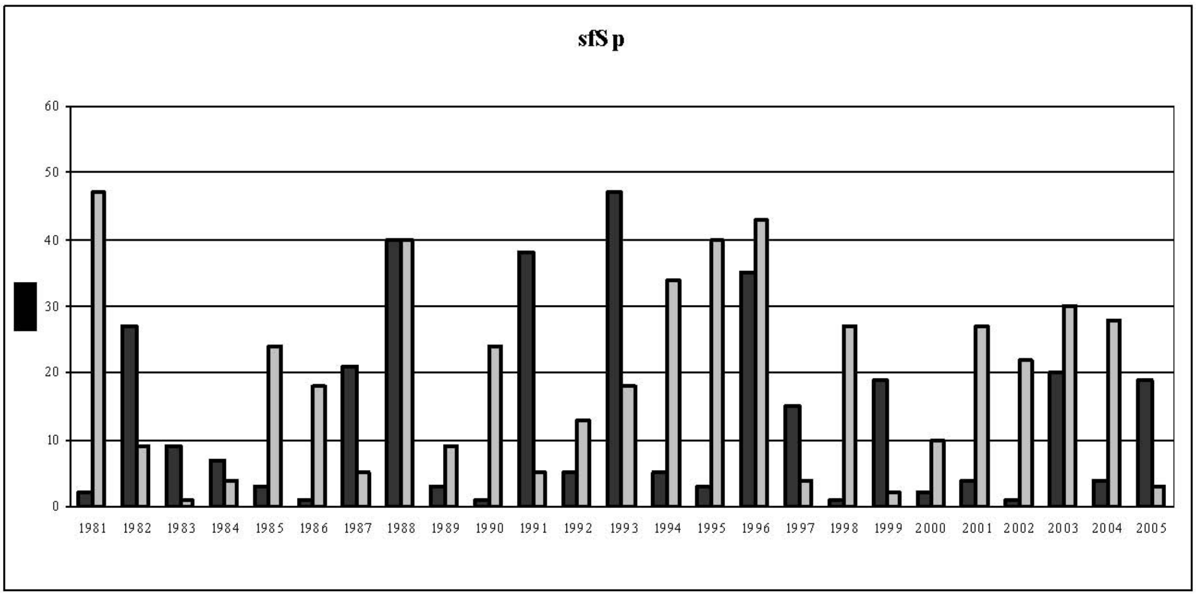

Fig. 4. Course of snow free spring (sfSp) in Svartberget (black) and Oulanka (grey) during 1981 – 2005.

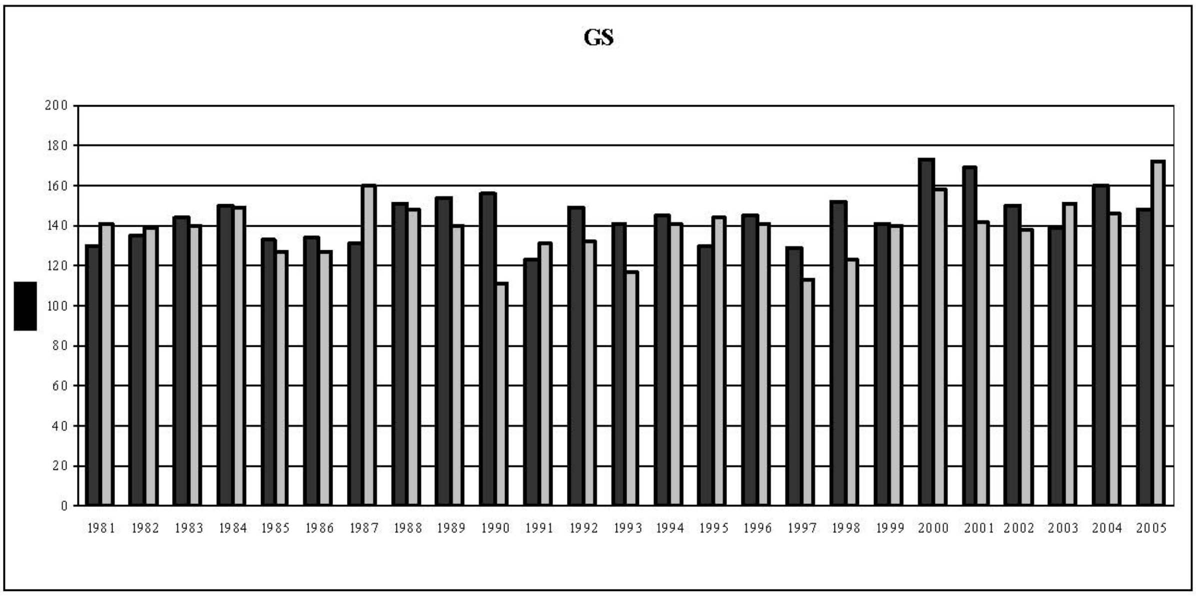

Fig. 5. Course of growing season (GS) in Svartberget (black) and Oulanka (grey) during 1981 – 2005.

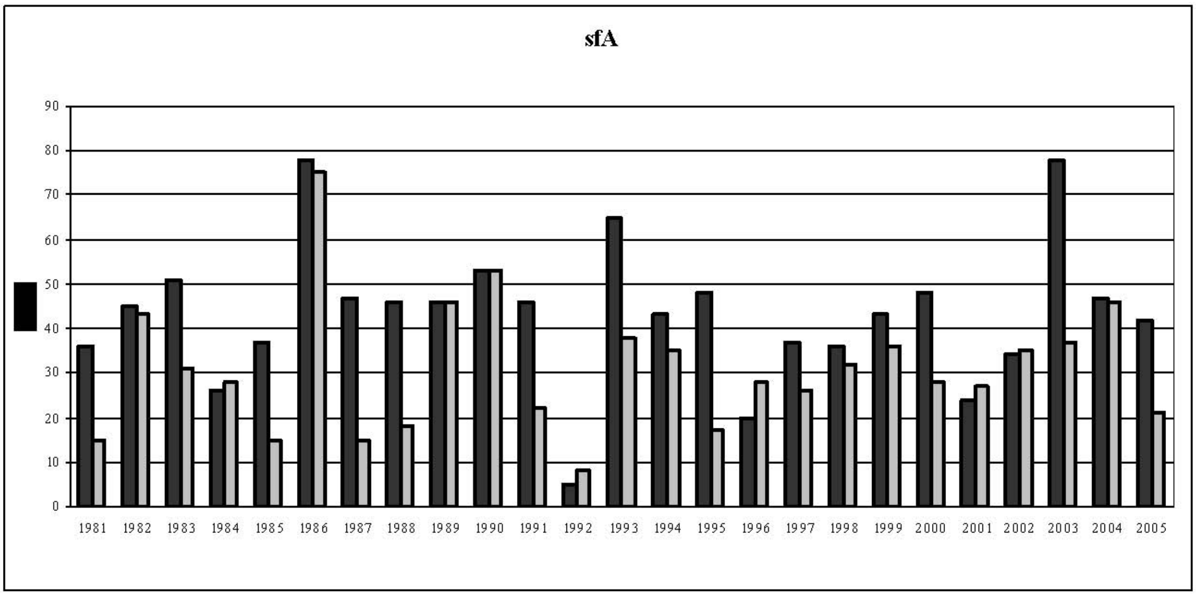

Fig. 6. Course of snow free autumn (sfA) in Svartberget (black) and Oulanka (grey) during 1981 – 2005.

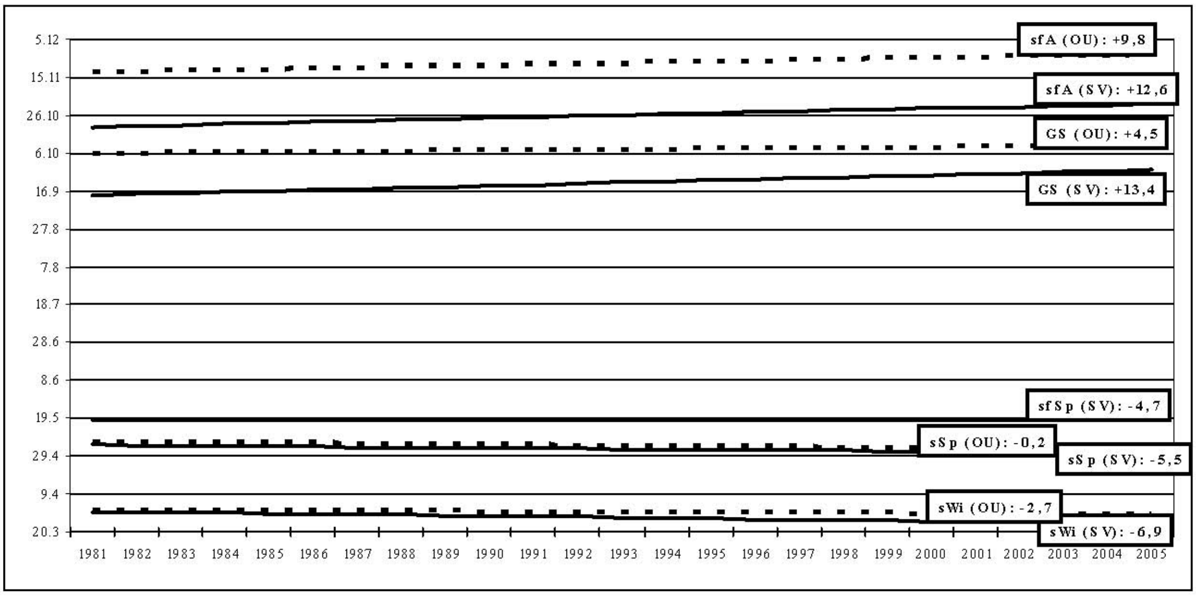

Fig. 7. Trends of the beginning and ending dates of the ecological season in Svartberget (SV: solid line) and Oulanka (OU: dotted line) during 1981 – 2005.

5. Discussion

By studying of the recorded daily air temperatures and snow depths in Svartberget and Oulanka the above mentioned trends of annual air temperatures in an ecological relevance can be verified. It turned out that global warming which is obviously in high latitudes has influenced the development of different ecological season during the last 25 years. The boreal areas will be increasingly effected by bio- and geoecological processes that predominantly occur during the growing season and by the shortened length of the winter, too. Due to a longer growing season biomass production and thereby the fixing of CO_2 will increase on one hand, otherwise CO_2 will increasingly be released due to longer periods of intensive decomposition of the organic compounds in terms of litter and peat. The ground water regeneration is very much determined by the entry of snow melting water during springtime, which happens now earlier; the entry of summer rain water will be diminished in the future, most probably, because the evapotranspiration ratio will increase and will lead to a stronger dryness stress periods for plants in the summertime.

One more important aspect should be considered: The length of growing season has obviously increased during the observation period. The earlier beginning of five to seven days as well as the backward shifting of up to 14 days implies a temporal extension of nearly 20 days. Admittedly, the mean number of days with a mean air temperature ≥ +5 °C has risen only by the half of that amount. Thus during the growing season nearly ten days occurred that have temperatures under that threshold and could even show temperatures below freezing point. Herein a certain amount of risk can be stated, because due to an earlier beginning of growing season conifers begin to reduce their frost resistance and therefore are more vulnerable to damages caused by late night frosts and daily air temperatures nearly the freezing point, respectively. Furtheron, all the leave- and needlebuds can be emerged earlier and are endangered by late frosts, too (SKRE et al. 2002). This is effective especially for young plants in afforested areas (OTTOSSON-LÖFVENIUS 1993).

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