The climate of northern Finland

JYRKI AUTIO AND OLAVI HEIKKINEN

Autio, Jyrki & Olavi Heikkinen (2002). The climate of northern Finland. *Fennia* 180: 1–2, pp. 61–66. Helsinki. ISSN 0015-0010.

The North Atlantic in the west and the Asian continent in the east regulate the general features of the climate in northern Finland. Especially in the low areas in the west, the smaller amounts of precipitation are largely due to the Scandic föhn effect. The weather conditions and microclimate in the fells differ from those in the lower areas. Temperature inversion is a common phenomenon on the slopes. Heavy snow loads in the crowns of the trees are a prominent feature of the southern fells and the eastern highlands.

Jyrki Autio & Olavi Heikkinen, Department of Geography, P. O. Box 3000, FIN-90014 University of Oulu, Finland. E-mails: jyrki.autio@oulu.fi, olavi.heikkinen@oulu.fi

Introduction

In Köppen's climate classification (Köppen 1936: 14), northern Finland (here taken to signify roughly the province of Lapland and the eastern parts of the province of Oulu) belongs almost entirely to the area of a snow and forest climate characterised by moist, cold winters. The northern climate itself, and the influence of the North Atlantic in the west and the great Asian continent in the east, chiefly regulate its general features. The Atlantic, heated by the Gulf Stream, evens out the temperatures through its oceanic influence and generates low pressure systems which belong to the Polar front and often bring grey and drizzly weather to Finland. The Arctic Ocean similarly has a levelling effect on temperatures. This is most prominent in the fell area of northern Lapland and around the Inari basin. High pressures coming from the east sometimes make the Finnish climate more continental for weeks on end, which means sunshine and heat in summer and bitterly cold weather in winter.

The Scandes also affect the climatic features of northern Finland. After crossing these mountains, the Atlantic air masses are dry and warm – a föhn effect that can raise the temperature in the Tornio river valley by several degrees. Internal factors, such as altitude, water bodies, and vegetation, naturally give rise to local variations in climate (Heino 1994).

Thermal climate

The degree of continentality and oceanity can affect a climate more than the geographical latitude. One indicator of continentality is the difference between the mean temperatures of the warmest and coldest months of the year, which is small in oceanic areas and increases as the climate becomes more continental (Kalliola 1973: 57). By this reckoning, the most oceanic areas of northern Finland are situated in the very north, where the presence of the Arctic Ocean is felt most prominently. The climate is most continental in the east (Laaksonen 1977: 88), where this temperature difference can be up to 30 degrees centigrade (ºC).

The mean annual temperature varies from –3 ºC in northeastern Lapland to 1 ºC on the coast of the Gulf of Bothnia (Fig. 1). The mean temperature of the warmest month, July, is 10–15 ºC and that of the coldest month, January, –13... –17 ºC. The lowest temperature recorded in Finland during the twentieth century, –51.5 ºC, was measured in the village of Pokka in Kittilä in January of 1999 (Sää ja ilmasto 2001a). In general, the continental eastern part of northern Finland is colder than the west, with the exception of the Kilpisjärvi area, where greater altitude reduces the temperatures.

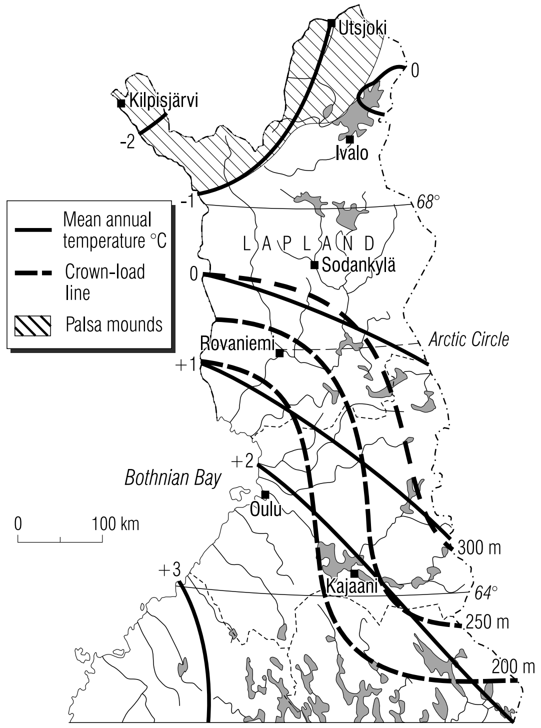

Fig. 1. Mean annual temperature in northern Finland during the normal period 1931–1960 (Helminen 1987), the lower line of tree damage caused by frequent snow loads, and the occurrence of palsa mounds. The 'crown-load line' is used to represent the altitude above which at least 30 percent of trees are damaged by snow loads in their crowns (Solantie 1974). Palsas, permafrost formations up to seven metres high, occur in peatland areas where the annual mean temperature is –1 degrees centigrade (ºC) or below. Palsas have their own life cycles: after reaching a certain size, they begin to collapse and thaw largely regardless of climatic conditions. It is therefore possible to find palsas at different stages of development in the same bog area (Seppälä 1979).

Precipitation

Mainly because of its colder climate, northern Finland receives generally less rain than the rest of the country. Precipitation is lowest in the Inari basin (400 mm) (Weather and climate 2001). Lapland is more humid than the rest of Finland despite its smaller amounts of rain, mainly due to the lower temperatures, which mean less evaporation.

Especially in the low areas of western Finland, the smaller amounts of rain are largely due to the Scandic föhn effect. In the eastern parts, with their higher altitudes, the western air masses rise once more, which leads to condensation and more rain. Rainfall is estimated to increase by five percent per one hundred kilometres from the west–northwest to the east–southeast (Solantie 1974: 86). Precipitation is highest in July and August and lowest in March. The mean rainfall in southern Finland is between 600 and 700 millimetres except on the coast, where the rainfall is slightly lower. In northern Finland the annual rainfall varies between 400 and 600 millimetres (Weather and climate 2001; Sää ja ilmasto 2001b, 2001c).

The percentage of total precipitation that is accounted for by snow increases towards the north as a rule. In northern Finland about half of the rainfalls occurs in the form of snow. Northwestern Lapland receives its permanent snow cover by the end of October and southern Lapland by the middle of November (Solantie 1987: 18, 20). The average thickness of the snow in March is 65–100 centimetres (Sää ja ilmasto 2001d), but it can exceed two metres in the Kilpisjärvi area at times.

Climatic variation after the Little Ice Age

Climates are not invariable, but show clear fluctuations on many time scales. Following the Little Ice Age, a period of colder climate that lasted for roughly 500 years and ended shortly after the mid-nineteenth century, temperatures rose, as is shown by the forestation of previously treeless areas beyond and above the timberline in Lapland.

The 1930s were exceptionally warm in the whole of northern Europe. It was then that the saplings which later formed the present treeline first appeared on the Finnish fells (Hustich 1958). The temperature rise is also documented in the statistics on the break-up of the ice on the Tornio River. Observations since 1693 show that this has begun to take place approximately two weeks earlier (Kauppi & Kämäri 1996: 148).

The climate in northern Finland was roughly 0.5 ℃ colder during the normal meteorological period 1961–1990 than in the period 1931–1960. This cooling is clearly reflected in the 0 ℃ curve, for example: it had been roughly at the latitude of Sodankylä during the previous normal period (Fig. 1), but later moved southwards by about one hundred kilometres. This average climatic change based on mean annual temperatures is largely due to the colder winters (Solantie 1992; Tuhkanen 1996) and, apparently, does not properly indicate how favourable the conditions are for plant life during the growing season. According to many climate models (Gates et al. 1996; Holopainen et al. 1996: 53–68), temperatures in northern Finland should rise in the coming decades due to the intensification of the greenhouse effect.

The fell climate

The weather conditions and microclimate in the fells differ from those in the lower areas. The fells are colder on average than the valleys, because in the standard atmosphere, a hundred-metre rise in altitude will bring about a temperature decrease of 0.65 °C. Often, however, the fells are actually warmer than the valleys. This meteorological effect is known as *ground surface temperature inversion* (Fig. 2).

On clear, calm summer nights, and also during the daytime and in extended periods of extreme cold in the winter, the ground surface and lower air layers lose heat through powerful out-radiation in the absence of solar radiation. In addition, the cold air on the upper slopes, which is heavier than warm air, slowly drains down into the valleys. This creates a state of inversion where the vertical temperature distribution is the opposite of that normally found in the standard atmosphere. The situation lasts until wind or solar radiation disturbs the stability of the atmosphere. Ground surface temperature inversion can reach an altitude of 20–30 metres on summer nights, or

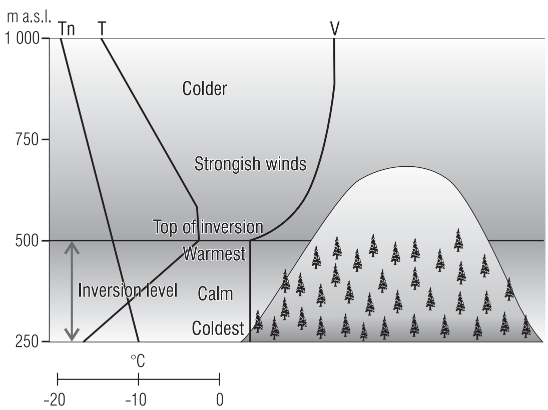

Fig. 2. The principle of ground surface temperature inversion on fells in wintertime. T = air temperature; T_n = average vertical temperature in the atmosphere (with a gradient of 0.65 ºC/100 m); V = wind velocity (m/s); m a.s.l. = metres above sea level. (Mainly after Huovila 1987 and Tammelin 1992).

hundreds of metres during long spells of winter cold. The temperature difference between a valley bottom and the inversion peak on a fell slope can be 10–20 °C or even more (Kurula & Heikkinen 1996). The heat tracks used by skiers on fell slopes make use of this phenomenon.

Temperature inversions can last for more than a month at times in winter if a high-pressure system prevails (Huovila 1987: 51), but such situations are usually of shorter duration. The longest and most pronounced uninterrupted inversion on the fell of Aakenustunturi in Kittilä in December of 1995, for example, lasted just over three days, beginning at 8 a.m. on December 18 and ending at 3 p.m. on December 21 (Fig. 3). The greatest temperature difference was recorded at 6 a.m. on December 21, when the air at the summit was 11.4 ºC warmer than in the forest.[1]

The vertical gradient in mean temperatures over a longish period of time, e.g., a whole growing season, is usually close to that for a normal atmosphere (Autio et al. 1998: 296), but the pattern for an individual month can deviate markedly from the normal (Fig. 4). Curve 1 in Figure 4 represents a fairly typical situation in early winter, in which inversions have reduced the mean temperatures to the extent that the lowest-lying places are the coldest, the warmest conditions are found part of the way up the slope, and the summit is again colder. In months like this, the vertical pattern of mean temperatures is practically the reverse of the normal. The late spring, on the other hand, is a time when the temperature gradient is steeper than normal, as in Curve 2 of Figure 4. This is because summer comes to the forested areas far more quickly than to the fell summits or forest limit zones. Towards the end of the summer (Fig. 4, Curve 3), there are scarcely any vertical differences in temperature, i.e., the slight temperature inversions that occur at night cancel out the differences between the summit and the lower-lying forests that arise during the day. It is in fact the forest limit zone on the south-facing slope that receives the most solar radiation of all in the late summer. This area thus has the highest mean temperature of all, creating a clear anomaly in the vertical gradient. This zone represents generally the most extreme temperature conditions to be found in a fell landscape in northern Finland (Autio 1995: 110).

On the fell tops, winds are unhindered by obstacles and are almost always stronger than below. The fells have no trees to stop the wind or to

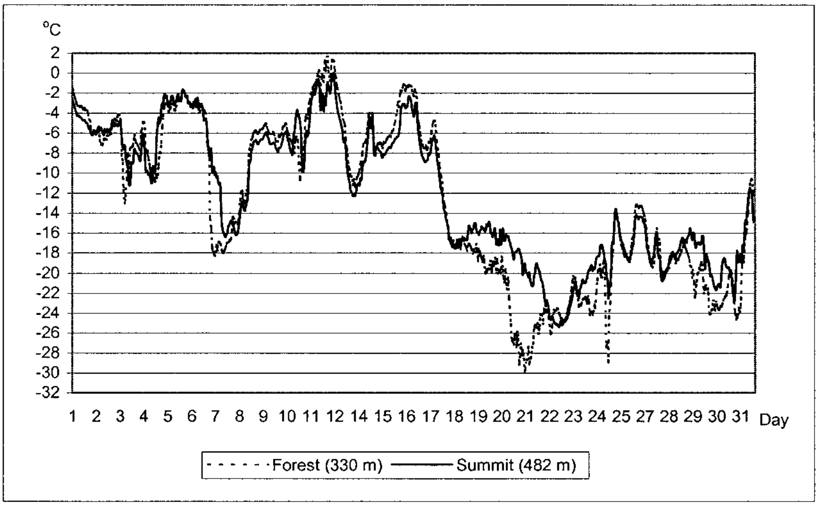

Fig. 3. Hourly variations in temperature on Vareslaki (482 m), the westernmost fell summit of Aakenustunturi (570 m), and in the forest below (330 m), in December of 1995. Measurements were made at a height of two metres above the ground. The most pronounced temperature inversion occurred between December 18 and 21 (see Note 1).

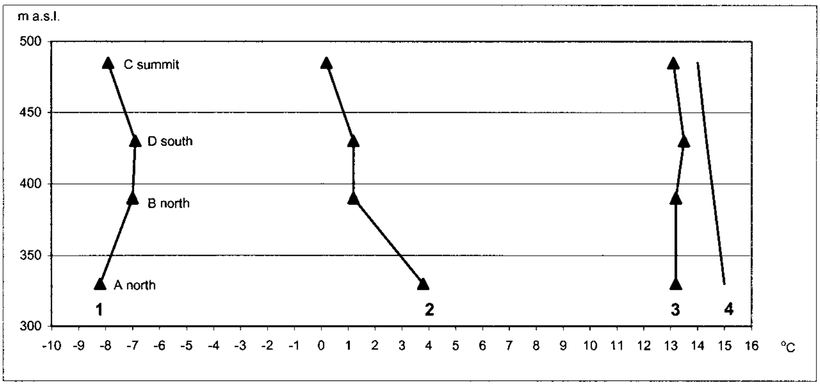

Fig. 4. Vertical temperature profiles at four meteorological stations on the Aakenustunturi fell: (A) in forest on the northern slope (330 metres above sea level); (B) at the physiognomic forest limit on the northern slope (390 m a.s.l.); (C) on the virtually treeless fell summit (482 m a.s.l.); and (D) at the physiognomic forest limit on the southern slope (430 m a.s.l.) 1 = Mean for November, 1996; 2 = Mean for May, 1996; 3 = Mean for August, 1996; and 4 = Vertical gradient in a normal atmosphere (–0.65 °C/100 m) (see Note 1).

Fig. 5. An example of variation in snow thickness. In fell terrain, the snow is thickest in deep depressions in the timberline area, where drifts of up to 4–5 metres in depth can occur. South-facing slopes lose their thinner snow cover in early summer, whereas the more shaded northern slopes can have drifts of several metres which do not melt until the end of July. The photograph shows asymmetrical snow build-up in a lateral meltwater channel on the fell of Aakenustunturi in Kittilä. (Photo: Jyrki Autio, 04/95)

give shelter from it. The windiest season on the fells of Lapland is the winter, when the wind can often exceed 21 metres per second (m/s), which marks the lower limit for a storm. In the winter of 1989, for instance, ten-minute averages of up to 39.1 m/s were measured on the peak of the Ylläs fell (Lehtonen 1992). Efforts have been made in recent years to harness wind energy by constructing wind power plants on some fell tops (Tammelin 1999).

The snow cover increases in thickness from the valleys up to the treeline (Fig. 5), but it is thin on the barren fell tops and non-existent in places, as the wind effectively compresses the snow or blows it away (Autio 1997). Heavy snow loads in the crowns of trees (Fig. 1) are a prominent feature of the fells of southern Lapland and the eastern highlands of Finland.

Future prospects for climatic research in northern Finland

Climatic research in northern Finland is closely connected with the increased interest in northern regions in general (Saarnisto 1998; Korhola 1999; Seppälä 2000), as reflected by the selection of northern conditions as one of the focal points for research at the University of Oulu (Summary 2001). The main bodies in Finland that are engaged in extensive research into northern climates are the Finnish Meteorological Institute (Developing… 2001; Research 2001), the Department of Meteorology at the University of Helsinki, and the Sodankylä Geophysical Observatory which belongs to the University of Oulu (Saarnisto 1998: 21–23). Of the current national climatic projects in progress at the Meteorological Institute, particular mention should be made of FINSKEN (Developing consistent global change scenarios for Finland), financed by the Academy of Finland (Developing… 2001). International ventures are represented by the Global Atmosphere Watch (GAW) programme and the Arctic Monitoring and Assessment Programme (AMAP), both of which have a monitoring station in the Pallas-Ounastunturi National Park (67°55′–68°20′N, 27°07′E) (Loven & Kleinhenz 1997: 7–9; Saarnisto 1998: 21). This international cooperation is also reflected in the structure of funding for such research, in that the Institute's principal source of external funding is the European Union (Research 2001).

Climatic research occupies a key role as far as arctic regions (regions lying north of the Arctic Circle, 66°32′N) are concerned, as changes are likely to make themselves felt first in this sensitive area. This confers a more general significance on such research, as the changes are soon reflected in tree growth at the timberline, i.e., at the extremes of distribution of the species concerned. The predicted warming of the climate will shift the timberlines up the slopes of the fells and towards the north, to be followed by the other vegetational zones (Holten 1990: Fig. 1; Tuhkanen 1996: 34). Research into fell climates is also needed because existing climatic models do not make adequate allowance for altitudinally and topographically determined climatic variability (Martin 1996: 3).

ACKNOWLEDGEMENTS

Among the numerous people who have helped to gather the field data, we would especially like to thank Pertti Vuolteenaho and Pekka Kauppila. Thanks are also due to Anja Kaunisoja for drawing some of the figures. The work has been financed by the the European Union, under project ENV4-CT95-0063, "Forest Response to Environmental Stress at Timberlines: Sensitivity of Northern, Alpine and Mediterranean Forest Limits to Climate (FOREST)."

NOTES

[1] The results presented in Figures 3 and 4 are based on temperature measurements made at Aakenustunturi in 1995 and 1996 in the course of a still on-going programme that was initiated in 1994. The measurements were carried out at hourly intervals at a height of two metres above the ground using a KM 1420 automatic data acquisition system. Jyrki Autio gathered and processed the material. The work was conducted as a part of the EU-funded FOREST Project (ENV4-CT95-0063). In other respects, this paper is largely based on the work by Autio and Heikkinen (1999).

REFERENCES

Autio J (1995). Local temperature differences and their relation to altitudinal vegetation zones and the location of the timberline: an example from the fell of Aakenustunturi in Finnish Lapland. *Nordia Geographical Publications* 24: 2, 103–111.

Autio J (1997). Peräpohjolan tuntureiden kasvillisuustyypit, kasvillisuuden korkeusvyöhykkeet ja metsänrajat. Unpublished Phil. Lic. thesis. Department of Geography, University of Oulu.

Autio J, A Colpaert & Y Hara (1998). Vertical summer temperature variation and phytogeographical zonation at the fell of Aakenustunturi in Finnish Lapland. *Association of Japanese Geographers* 54, 296–297.

Autio J & O Heikkinen (1999). Pohjois-Suomen ilmasto. In Westerholm J & P Raento (eds). *Suomen kartasto*, 116–117. Suomen Maantieteellinen Seura & WSOY, Helsinki.

Developing consistent global change scenarios for Finland (2001). FINSKEN. 9 May 2001. <*www.vyh.fi/eng/research/projects/finsken/*>

Gates WL, A Henderson-Sellers, GJ Boer, CK Folland, A Kitoh, BJ McAvaney, F Semazzi, N Smith, AJ Weaver & QC Zeng (1996). Climate models – evaluation. In Houghton JT, LG Meiro Filho, BA Calender, A Kattenberg & K Maskell (eds). *Climate change 1995. The science of climate change*, 229–284. Cambridge University Press, Cambridge.

Heino R (1994). Climate in Finland during the period of meteorological observations. *Finnish Meteorological Institute, Contributions* 12.

Helminen V (1987). Temperature conditions. In Alalammi P (ed). *Atlas of Finland, Folio 131: Climate*, 3–5. National Board of Survey & Geographical Society of Finland, Helsinki.

Holopainen E, M Heikinheimo & M Kulmala (eds) (1996). Ilmakehä. In Kuusisto E, L Kauppi & P Heikinheimo (eds). *Ilmastonmuutos ja Suomi*, 11–69. Yliopistopaino, Helsinki.

Holten JI (1990). Biologiske och økologiske konsekvenser av klimaforandringar i Norge. *Norsk Institut for Naturforskning, Utredning* 11.

Huovila S (1987). On temperature inversions in Finnish Lapland. *UNGI Rapport* 65, 43–52.

Hustich I (1958). On recent expansion of the Scots pine in northern Europe. *Fennia* 82: 3, 1–25.

Kalliola R (1973). *Suomen kasvimaantiede*. WSOY, Porvoo.

Kauppi L & J Kämäri (eds) (1996). Vedet. In Kuusisto E, L Kauppi & P Heikinheimo (eds). *Ilmastonmuutos ja Suomi*, 145–178. Yliopistopaino, Helsinki.

Köppen W (1936). Das geographische System der Klimate. In Köppen W & R Geiger (eds). *Handbuch der Klimatogie* 1C, 1–44. Verlag von Gebrüder Bornträger, Berlin.

Korhola A (1999). *Finland's Arctic research strategy.* Ministry of Trade and Industry, Helsinki.

Kurula T & O Heikkinen (1996). Vertical temperature inversion on the fjell Ylläs, northern Finland. *Prace Geograficzne – Zeszyt* 102, 453–458.

Laaksonen K (1977). The influence of sea areas upon mean air temperatures in Fennoscandia (1921–1950). *Fennia* 151, 57–128.

Lehtonen P (1992). Wind measurements at Ylläs broadcasting station 1982–1991. In Tammelin J, K Säntti, E Peltola & H Neuvonen (eds). *BOREAS – North wind – Pohjatuuli, an international experts' meeting on wind power in icing conditions, Hetta 10.–13.2.1992*, 1–10. Ilmatieteen laitos/ Finnish Meteorological Institute, Helsinki.

Lovén L & B Kleinhenz (1997). National park as research area for monitoring environmental change. *Finnish Forest Research Institute, Research Papers* 623, 7–12.

Martin P (1996). Regional aspects of climate change. In Peter D, A Maracchi & A Ghazi (eds). *Climate change impact on agriculture and forestry*, 33–52. European Comission, Brussels.

Research (2001). Finnish Meteorological Institute. 9 May 2001. <*www.fmi.fi/research_meteorology/meteorology_2.html*>

Sää ja ilmasto. Alimmat lämpötilat kuukausittain (2001a). Ilmatieteen laitos. 4 May 2001. <*www.fmi.fi/saa/tilastot_11.html*>

Sää ja ilmasto. Elokuun tilastokartat (2001b). Ilmatieteen laitos. 4 May 2001. <*www.fmi.fi/saa/tilastot_62.html*>

Sää ja ilmasto. Heinäkuun tilastokartat (2001c). Ilmatieteen laitos. 4 May 2001. <*www.fmi.fi/saa/tilastot_62.html*>

Sää ja ilmasto. Milloin lumipeite lähtee? (2001d). Ilmatieteen laitos. 4 May 2001. <*www.fmi.fi/saa/tilastot_10.html*>

Saarnisto M (1998). *The current state of Arctic research in Finland*. Ministry of Trade and Industry, Helsinki.

Seppälä M (1979). Recent palsa studies in Finland. *Acta Universitatis Ouluensis. Series A, Scientiae Rerum Naturalium* 82, 81–87.

Seppälä M (2000). Mikä ja millainen on arktinen alue? *Terra* 112, 162–163.

Solantie R (1974). Pohjois-Suomen lumipeitteestä. (Summary: On snow cover in Northern Finland). *Acta Lapponica Fenniae* 8, 74–89.

Solantie R (1987). Snow conditions. In Alalammi P (ed). *Atlas of Finland, Folio 131: Climate*, 8. National Board of Survey & Geographical Society of Finland, Helsinki.

Solantie R (1992). Lämpötilanmuutos Suomen "vanhasta" normaalikaudesta 1931–1960 "uuteen" 1961–90. (Summary: On the change of thermal climate in Finland between the "normal" periods 1931–1960 and 1961–1990). *Lapin tutkimusseura. Vuosikirja* XXXIII 1992 *(The Research Society of Lapland. Year Book* XXXIII 1992), 33–42.

Summary. Northern systems (2001). Thule Institute. 28 May 2001. <*www.oulu.fi/strategy/pohstrat/nsys.html*>

Tammelin B (1992). Huurrekertymät tunturien lakialueilla. (Summary: Rime accretion at the top areas of fells). *Meteorologisia julkaisuja (Meteorological publications)* 19.

Tammelin B (1999). Wind energy production on cold climate. *Boreas* 4 *(Proceedings of an international meeting, 31 March–2 April, Hetta, Finland).*

Tuhkanen S (1996). Globaali ilmastomuutos ja Fennoskandia. (Abstract: Global climatic change and Fennoscandia). *Vaasan yliopiston julkaisuja. Selvityksiä ja raportteja (Proceedings of the University of Vaasa. Reports)* 12, 19–44.

Weather and climate. Rainfall (2001). Finnish Meteorological Institute. 4 May 2001. <*www.fmi.fi/weather/climate_3.html*>