The boundary layer in Finland during winter

Introduction

When high pressure is dominant across Finland in winter, the atmosphere is characterised by a near permanent temperature inversion. This regulates the exchange of fluxes between the boundary layer and the free atmosphere and influences the turbulent, radiative and cloud processes within the boundary layer. The low sun angle and short days do not allow enough heat to erode the inversion in Finland during the winter.

Stratus clouds are one of the most significant regional climatic features in Finland during winter. They play an important role in the vertical transfer of heat, moisture and momentum in the boundary layer. Numerical models such as ECMWF and HIRLAM quite often experience significant difficulties in reliably forecasting inversions and low cloud over Finland through the winter months.

Forecasts of inversions, fog and stratus during these events are always challenging for a forecaster and require careful inspection of numerical guidance, weather observations and the satellite data. Here is a short study of the Finland's climate and some of the boundary layer phenomena in winter.

Finland's climate

One important factor influencing Finland's climate is the country's geographical position between 60N and 70N within the Eurasian coastal zone. Characteristics of both a maritime and a continental climate are experienced, depending on the direction of the airflow. The mean temperature in Finland is several degrees higher (as much as 10°C in winter) than that of many other areas at these latitudes, e.g. Siberia and south Greenland.

Table 1. Monthly statistics for 1971-2000 in Sodankylä (67° 22`N 26° 37`E), located in the middle part of Northern Finland.

SODANKYLÄ 1971-2000											
	Lämpötila °C Temperature °C					**Lämpöt.päivät kpl/no** T-days		**SADE (mm)** Precip.		**LUMI (cm)** Snow	
Kk Month	**Keskimääräiset Mean**	**Max**	**Min**	**Abs. max**	**Abs. min**	**T max > 25°C**	**T min < 0°C**	**Keskim. Avg**	**Max** /month	**15.pvä 15 th**	**Viim.** Last
1	-14,1	-9,5	-19,6	6,5	-49,5		31	35	71	54	62
2	-12,7	-8,3	-18,2	6,5	-44,4		28	29	72	70	72
3	- 7,5	-2,6	-13,0	8,5	-42,7		31	29	66	76	79
4	- 2,0	2,6	- 7,4	14,6	-31,6		26	28	79	71	52
5	4,9	9,6	0,0	26,9	-17,8		15	35	79	14	
6	11,6	16,6	6,4	30,5	- 3,7	2	1	57	113		
7	14,3	19,4	9,1	30,9	- 0,6	3		63	128		
8	11,2	16,1	6,6	28,2	- 5,5	1	2	61	136		
9	5,8	9,8	2,1	23,0	-11,4		10	47	103		
10	- 0,6	2,3	- 3,7	13,5	-28,0		21	50	86	2	8
11	- 7,7	-4,3	-11,8	9,2	-34,5		28	40	70	16	26
12	-12,4	-7,9	-17,4	10,3	-41,0		31	35	77	34	44
Vuosi Year	**- 0,8**	**3,6**	**- 5,6**	**30,9**	**-49,5**	**6**	**224**	**507**			

Since Finland is located in the zone of prevailing westerlies where temperate and polar air masses meet, weather types can change quite rapidly, particularly in winter. The synoptic regimes known to influence Finnish weather are associated with the low-pressure systems usually found near Iceland and zones of high pressure over Siberia and the Azores. The position and strength of these systems vary, and any one of them can dominate the weather for considerable periods.

The coldest day of winter often occurs around the end of January, well after the winter solstice, except in the islands and coastal regions where the slower cooling of the sea delays the coldest period until the beginning of February (see Table 1). The lowest temperatures in winter range between -45°C to -50°C in Lapland and eastern Finland and -25°C to -35°C in the islands and coastal regions. The lowest temperature recorded at any weather station in Finland was -51.5°C in 1999.

The intensity of solar radiation

The intensity of solar radiation varies significantly over the course of a year ranging from zero during the polar winter to a maximum of 900-1000 watts per square meter (W/m^2) in the summer.

The maximum altitude of the sun depends of course on time of year and latitude. North of the Arctic Circle, part of the winter is the period known as the polar night, when the sun does not rise above the horizon at all. In the northernmost extremity of Finland, the polar night lasts for 51 days. Around midsummer, the sun changes little in altitude over the course of a day and there is daylight for 24 hours (Table 2).

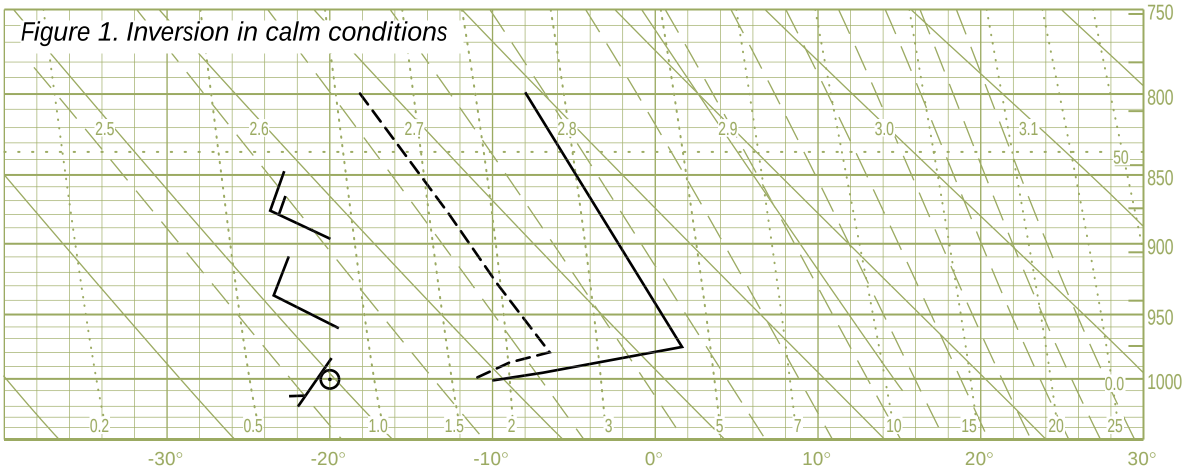
Month	Sunrise (local time)	Sunset (local time)	Length of day (hours)
1st January	11:31	13:04	1:33
1st February	9:25	15:30	6:05
1st March	7:32	17:21	9:49
1st April	6:26	20:12	13:46
1st May	4:19	22:06	17:47
1st June	-	-	**24:00**
1st July	-	-	**24:00**
1st August	3:37	22:59	19:22
1st September	5:41	20:44	15:03
1st October	7:25	18:40	11:15
1st November	8:18	15:35	7:17
1st December	10:31	13:34	3:03

Table 2. A length of a day in hours, time of sunrise and sunset in Sodankylä

Boundary layer in winter

In winter, Arctic weather is dominated by the frequent occurrence of inversions (when warm air lies above a colder air layer near the surface). The inversion layer decouples the surface wind from the stronger upper layer wind. For this reason, surface wind speeds tend to be lower in winter than one might expect (Figure 1).

Figure 1. Inversion in calm conditions



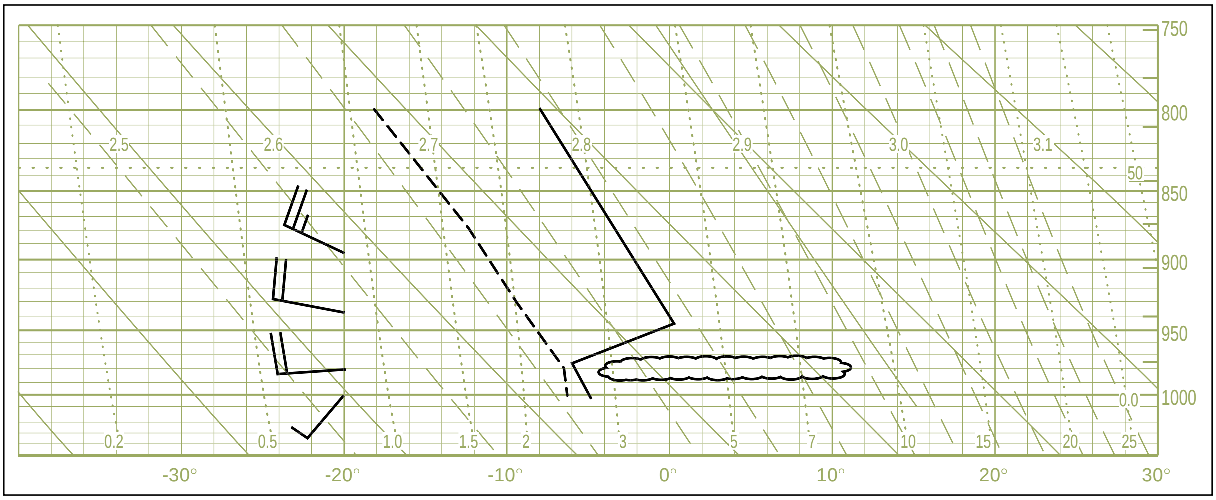


Figure 2. Inversion in a weak wind regime

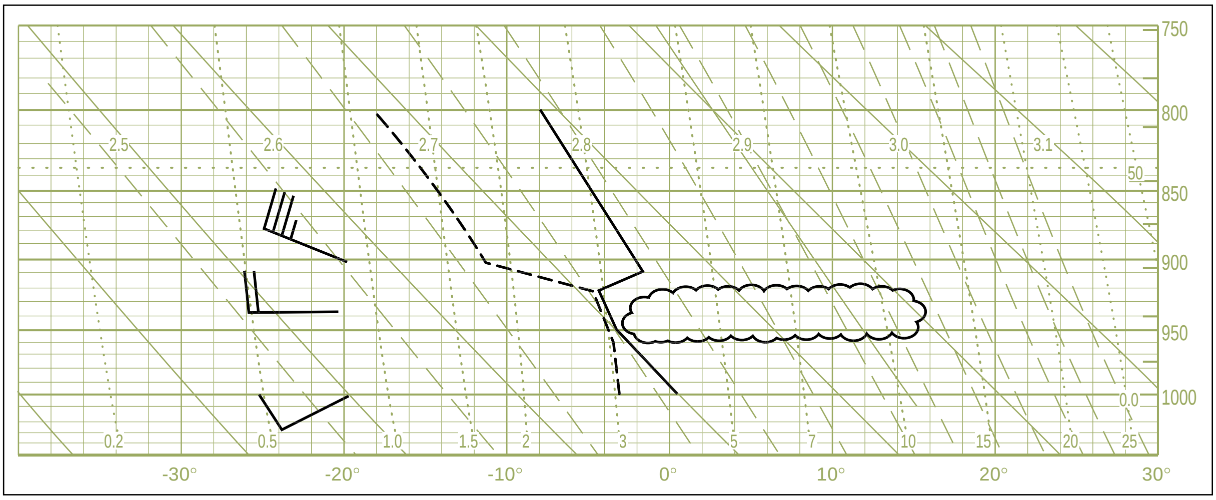
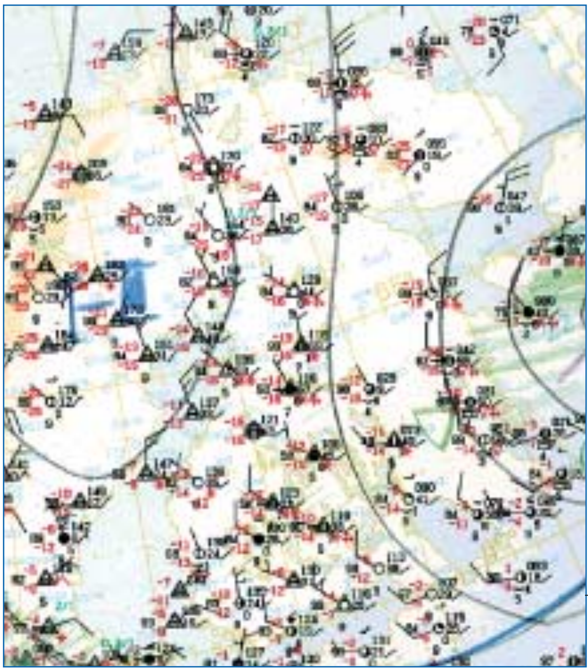


Figure 3. Inversion in a moderate wind regime



Boundary layer (mixed layer) height is an important meteorological parameter for aviation, for instance. The temporal evolution and spatial distribution of boundary layer height depends on many factors, including the synoptic conditions, local circulation patterns, cloud cover, and surface characteristics (Figures 2 and 3).

Case study of a strong surface based inversion and ice fog

A cold air outbreak affected the northern part of Finland on 20th January 2003. After this occurred, a strong surface based inversion formed with local ice fog. Here is a short synoptic study of the meteorological situation.

Figure 4. Surface analysis, 20.1.2003 at 00 UTC with fronts, isobars (in hPa) and plotted observations.

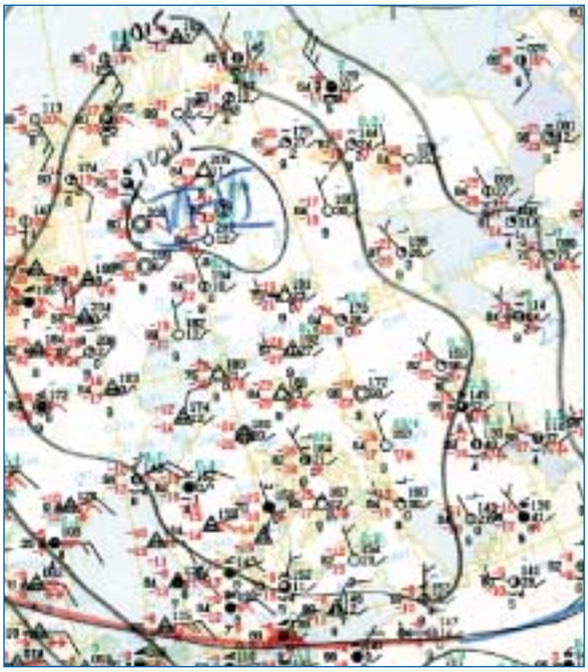


Figure 5. Surface analysis, 20.1.2003 at 06 UTC with fronts, isobars (in hPa) and plotted observations.

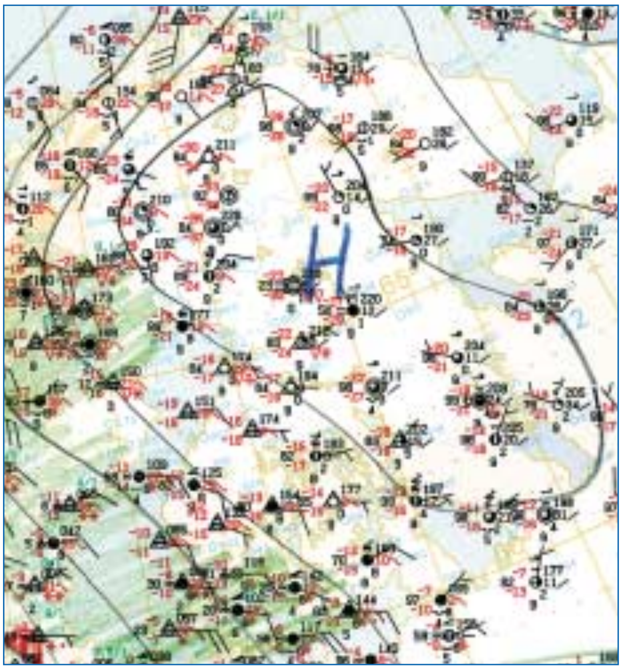
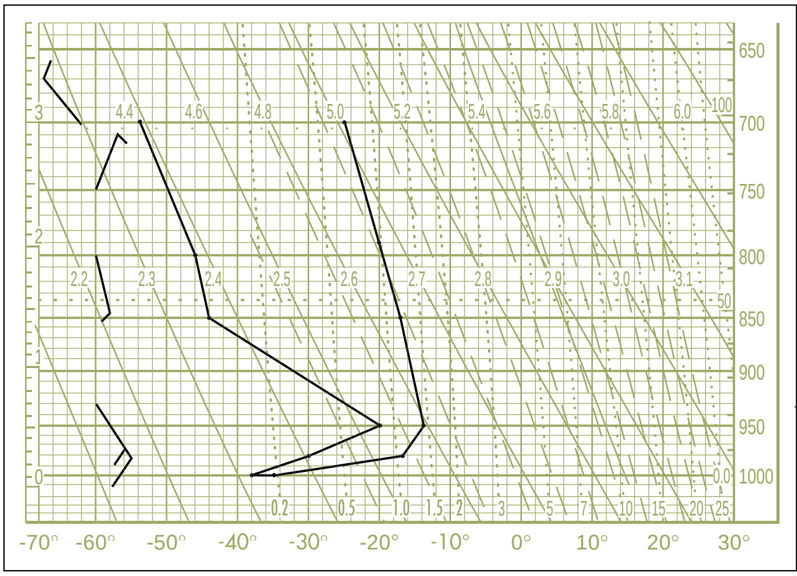


Figure 6. Surface analysis, 20.1.2003 at 12 UTC with fronts, isobars (in hPa) and plotted observations.

The synoptic situation is relatively classical for this type of cold air outbreak over the northern part of Finland in winter. A low pressure centre moved across the northern part of Finland from west to east. Following the passage of the low, the wind turned to the north and cold advection occurred with pressure then building across the northern part of Finland (Figures 4 and 5). An upper ridge at 300 and 500 hPa extended from Russia to Finland.

A discrete surface high pressure centre developed over the northern part of Finland within 12 hours (Figure 6). The sky was clear in many places and a strong surface based inversion developed. The temperature at the 950hPa level was -15°C but -35°C at the surface (a temperature difference of 20°C between the two levels - Figure 7). This is typical in Finland during the winter for this kind of meteorological situation. The strong surface based inversion was a direct consequence of the high pressure centre with calm winds, a cold air mass and the clear sky.



At low temperatures the air may become full of ice crystals with serious limitations in visibility near the surface. Ice fog occurs when the air near surface becomes saturated with respect to ice and crystals form on condensation nuclei. Visibilities of less then 1 000 metres are common and local ice fog was observed in this case.

Figure 7. Atmospheric temperature and dewpoint profile, 20.1.2003 at 12 UTC for Sodankylä upper-air sounding station.

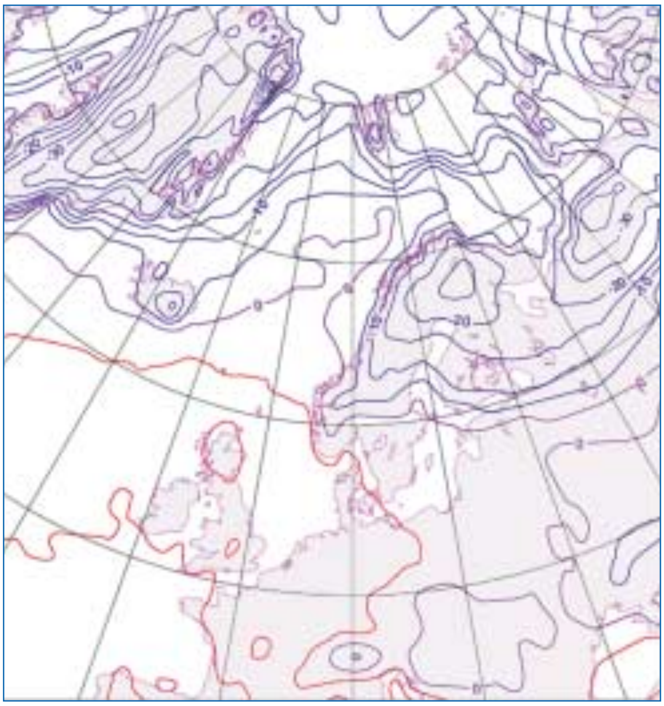


Figure 8. ECMWF 12-hour forecast of 2 meter temperature (in ° C) valid for 20.1.2003 at 12 UTC.

Northern winter problem in the ECMWF model

It is typical that predicted near-surface temperatures associated with a stable boundary layer within an Arctic airmass are too warm (e.g. in ECMWF). The difference between observed and forecast 2 m temperatures over Lapland was about 10°C at 12 UTC on 20th January 2003 (Figure 8). Such differences between observations and forecast values are common. In reality, clear sky, no significant short wave radiation, a strong surface inversion over a snow covered surface all contribute to the suppressed temperature values.

Ed – It will be interesting to see results from the higher resolution ECMWF operational model for the 2005-2006 winter over Finland.

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