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An Analysis of the Local Weather Around Longyearbyen and an Instrumental Comparison

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Every cloud must have a silver lining

George A. Norton (1880–1923)

Abstract
Three different studies have been made; an analysis of the general weather situation at three weather stations in Svalbard, close to the main settlement Longyearbyen; an instrumental comparison between three weather stations operating at nearly the same place during a few days in October 2006; and a case study of a weather station at the mountain Breinosa compared to the station in the valley beneath.

The analysis of the general weather at the three stations, Adventdalen (data used from 2004-2006), Svalbard Airport (data used from 1994-2004) and Gruvefjellet (data used from 2002-2005) showed that it is clear that the local surroundings do contribute to a more locally produced weather. The mean wind speed in Adventdalen was shown to be 5.1 m/s and the wind direction was mostly from inland towards the coast. Channelling effects dominates the winds in the valley, resulting in high wind speeds. The channelled winds from Adventdalen often reach Svalbard Airport (average wind speed 4.8 m/s). At the Airport there is also a contribution of winds (mostly in summer) originating from the sea, e.g. sea breeze. In times when the weather at Svalbard Airport was more continental, Adventfjorden and Isfjorden were likely to be covered by ice. The higher location of Gruvefjellet most often contributes to low temperatures and an average wind speed of 3.9 m/s. However, the temperature at Adventdalen and the Airport are often colder than at Gruvefjellet due to the frequency of temperature inversions.

The instrumental comparison concerned three stations in Adventdalen. Data from the stationary weather station was compared with data from two temporarily stations during 4-7th October 2006. It is apparent that the stationary station needs calibration, at least when looking at the pressure measurements, where there clearly is an offset in the data.

The third study was a case study concerned data from a station at the mountain Breinosa and Adventdalen. A new weather station will be put up during 2007 and data (16th December 2005 until 12th January 2006) from a temporarily station was used when determining the differences from the station down in the valley (Adventdalen). The wind speed is often just as high in the valley as at Breinosa due to channelling effects. The temperature in Adventdalen seems to be affected by the temperature at Breinosa. The air is chilled and sinks down to be channelled through the valley. There are some occasions when the temperature at the mountain is higher than beneath. During those events the wind speed is low and a temperature inversion develops at the ground.

Sammanfattning

Tre olika studier genomförts; en analysering av data från tre väderstationer på Svalbard; en instrumentell jämförelse mellan tre väderstationer på Svalbard nära huvudorten Longyearbyen; en fallstudie av data från en väderstation på berget Breinosa jämfört med situationen i Adventdalen nedanför.

Undersökningen av generella vädersituationen vid de tre stationerna, Adventdalen (data från 2004-2006), Svalbard Flygplats (data från 1994-2004) och Gruvefjellet (data från 2002-2005) visade tydligt att den lokala omgivningen bidrar mycket till hur vädret formas. Medelvindhastigheten i Adventdalen var 5,1 m/s och vindriktningen mestadels längs dalen ut mot fjorden. Kanaliseringseffekter dominerar vindarna i dalen och bidrar till de höga vindhastigheterna. Kanaliserade vindar från Adventdalen når ofta Svalbard Flygplats (medel vindhastighet 4,8 m/s). Vid Flygplatsen finns också ett visst bidrag från vindar utifrån havet (mestadels under sommaren), d.v.s. sjöbris. I situationer då vädret vid flygplatsen varit mer kontinentalt så har Adventfjorden mest troligt varit täckt av is. Gruvefjellets höga placering bidrar till låga temperaturer och en medelvindhastighet på 3.9 m/s. Dock är temperaturen är ofta lägre i Adventdalen och vid Flygplatsen på grund av att det ofta förekommer temperaturinversioner i marknivå.

Den instrumentella jämförelsen berörde tre stationer i Adventdalen. Data från den stationära stationen jämfördes under 4-7 oktober 2006 med data från två temporära stationer. Det är tydligt att den stationära stationen är i behov av kalibrering. I alla fall är det uppenbart vid studien av lufttrycket som tydligt är förskjutet och visar ett lägre tryck.

Tredje studien var en fallstudie och data undersöktes från berget Breinosa och Adventdalen. En ny väderstation kommer att monteras på Breinosa under 2007 och data (16 december 2005 till 12 januari 2006) från en temporär station användes i studien. Vindhastigheten är ofta lika hög i dalen som på berget på grund av kanaliseringseffekter. Temperaturen i dalen förefaller vara påverkad av temperatursituationen på berget. Avkyld luft sjunker och kanaliseras ner i dalen. Det finns några tillfällen då temperaturen på berget Breinosa är högre än nere i dalen. Under de situationerna avtar vindhastigheten och en temperaturinversion bildas i marknivå.

Contents

1. Introduction and Background

1.1 The Arctic Region

There are several ways of describing the Arctic area such as, for example, based on geography, climatology and botany. Some researchers find it almost impossible to actually define the region and the borders are somewhat flexible depending on the purpose of the viewer. The variability in the Arctic boundary, associated with the different definitions, is illustrated clearly in figure 1. The boundary "1" defines the Arctic as the area where the mean isotherm of the warmest month is 10°C, while boundary "2" according to Nordenskjöld (1928) may better describe the area. He considered that the coldest month could be warmer than 10°C and consequently, this definition includes a larger seawater area. A third way, shown by "3", describes the Arctic in terms of net radiation and the area where this radiation is below 62.7 kJ/cm^2/year. The area covered with permafrost is another method of defining the region (boundary 4). In year 1985 the authors of 'Atlas Arktiki' described the area by using mean long-term values of more or less all meteorological elements (boundary 6) (Przybylak, 2003).

However, Przybylak (2003) argues that scientists within the same discipline should use a universal definition. His main reason for this is that if for example climatologists do not have the same definition of the region, the estimations of the mean Arctic trends may be too unclear to see in the era of global warming. Serreze and Roger (2005) define the Arctic as the region north of the Arctic Circle, i.e. above 66.5°N, a region which consists mostly of the Arctic Ocean (boundary 5 in figure 1). This area experiences 24-hour daylight during summer and 24-hour darkness during winter. Przybylak is of the same opinion i.e. that geographical latitude is the main factor when determining the weather and climate.

No matter which of the definitions of the region used, the Arctic is an ocean surrounded by land and one always finds Svalbard within the region. With the exception of the Greenland ice sheet, the Arctic is a low lying area covered with snow during a large part of the year.

The snow plays an important role in the Arctic climate; its high albedo affects the net radiation of the surface. The high infrared emissivity of snow is the cause of common temperature inversions near the surface. Snow also has insulating properties, thus affecting heat transport. A snow depth larger than 15 cm can fully stop heat transport between the atmosphere and land/sea ice (Przybylak, 2003). The sea ice can also significantly influence the Arctic climate, since it has a high albedo and good insulation ability. Therefore it absorbs less radiation than open water, limiting the exchange of both heat and moisture. Sea ice plays an important role when it comes to latent heat and functions as a thermal reservoir. In this way the ice delays the seasonal temperature cycle (Przybylak, 2003).

Most of the year, both land and sea ice is covered by snow and the ground is frozen *all year* round. Permanent land ice is found only on Greenland and smaller ice caps and glaciers can be found for example at Svalbard.

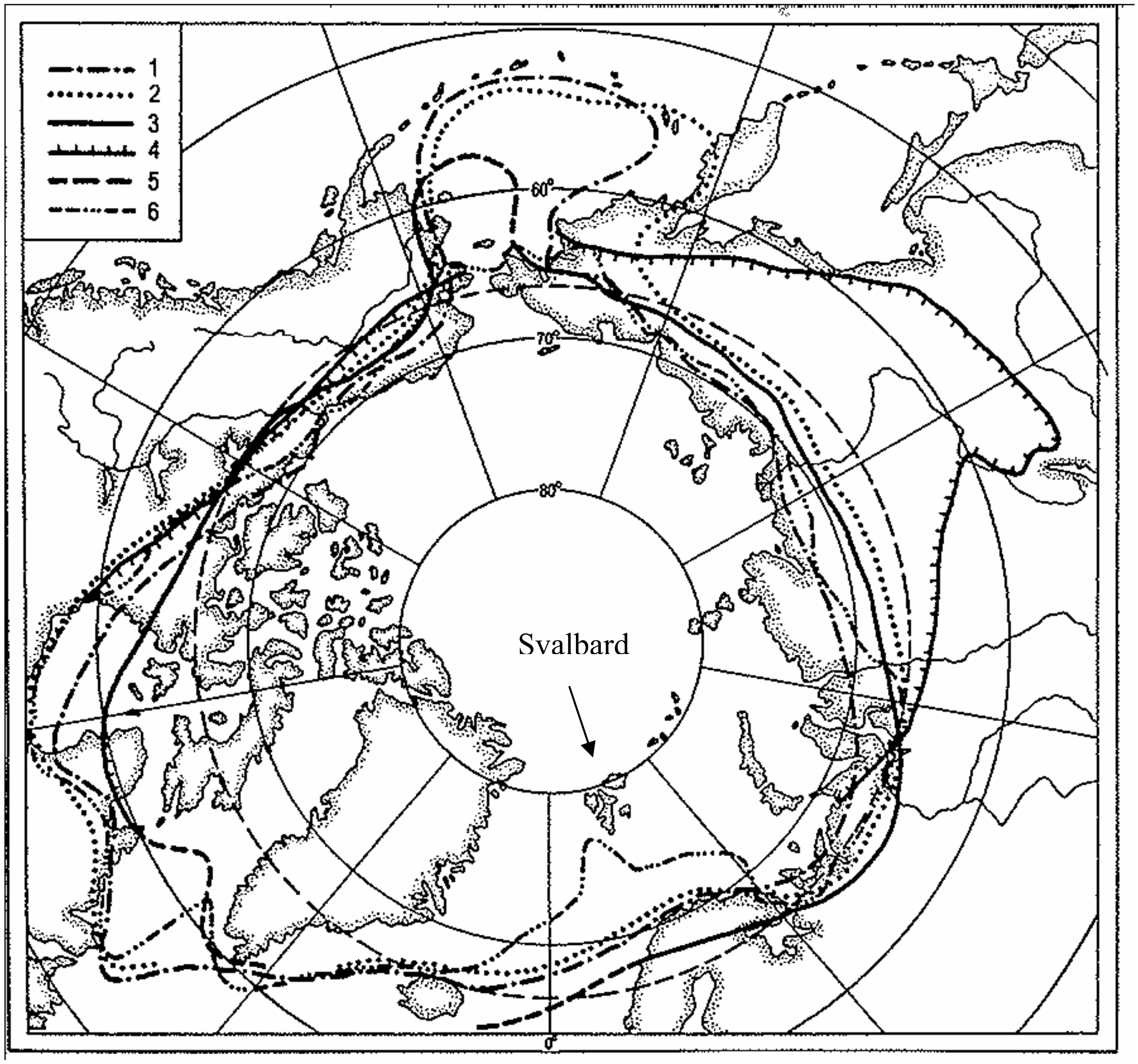


Figure 1 *Boundaries of the Arctic. 1) Isotherm of the warmest month 10°C, 2)Boundary according to Nordenskjöld, 3) line representing net radiation of 62.7kJ/cm²/year 4) Boundary of the permafrost, 5) The Arctic Circle, 6) Boundary according to Atlas Arktiki. (From Przybylak, 2003)*

Surface air temperatures vary in the Arctic depending on both region and season. In the Köppen system the Arctic area falls under the E-group, i.e. the polar climate, which means that the mean temperature of all months is below 10°C. The polar climate is subdivided into *tundra* and *ice cap climate*, where the tundra climate is the warmer of the two. The ice cap climate consists of areas where ice covers the ground all year and is classified as the area where the mean temperature for the warmest month does not exceed 0°C. In the Arctic area this climate is found at for example Greenland. Because of the large amount of ice the air above becomes very cold which then inhibits precipitation. The cold air on these continental glaciers becomes very dense and due to gravitation it flows down the canyons in the ice as *katabatic* winds, which can be extremely strong (Aguado and Burt, 2004).

In the tundra climate vegetation can be found, but since the permafrost thaws only in a shallow layer of the soil during the summer the plants are only of the low growing vegetation type. In the Arctic the tundra climate is found for example at Svalbard. During wintertime the sun is under or just above the horizon leading to low temperatures and strong stable stratification; because of this precipitation is inhibited. During summer, daylight is present at most places day and night, but since the sun never gets very high above the horizon the temperatures remain mild (Aguado and Burt, 2004).

1.2 Svalbard

The climate in the Arctic area is of interest, as it experiences changes more rapidly than other parts of the world. At Svalbard, an archipelago in the Arctic Ocean ranging from 76°-81° N and 10°-35° E (figure 1 and 2), the weather is largely affected by the local climate. It can be very variable depending on topography, closeness to water, glaciers and valleys. Svalbard experiences midnight sun during summer and no sun at all during winter. This means that the seasonal variability is much larger than the diurnal variability. The landscape is characterized by high glaciers, low lying valleys and fjords. The topography of the region often leads to locally-created winds (Serreze and Roger, 2005). The topography also affects the temperature distribution. The amount of clouds and wind speed are the key parameters. During cloud free and calm days the temperature will be higher on a mountain than down in a valley due to high radiation from the ground (Bogren et al., 1999).

Both warm and cold sea currents have an effect on the climate in Svalbard. The West Spitsbergen Current runs by from the south passing on the west coast of Svalbard bringing warmer water from the south (Serreze and Roger, 2005). This warm current creates the northernmost area of open water in the Arctic. Therefore Svalbard is a more enjoyable place to live in for humans compared to other places at the same latitude, e.g. Northern Greenland (Hanssen-Bauer et al., 1990).

The prevailing winds at Svalbard are easterly to north easterly. The large scale circulation over the Northern Atlantic Ocean is determined by the low pressure near Iceland and the high pressure above Greenland. Between Iceland and Scandinavia the prevailing winds are westerly or south westerly and the anticyclones bring milder air transported to higher latitudes. There it meets the prevailing winds (north easterly and easterly) around Svalbard, creating a large temperature gradient between the air masses. The combination of this temperature gradient with periods of sea ice and open sea leads to a large variation in the weather and temperature conditions (Hanssen-Bauer et al., 1990).

Proximity to the ocean does not always affect the climate in a maritime way; a winter with a well developed ice sheet can lead to a more continental climate. Hence the temperature conditions are very dependent on the ice situation. Normally during winter, the sea ice extends south-ward from the North Pole. It reaches the northern and eastern coasts of Svalbard, causing a more continental climate, particularly when the prevailing winds are northern or north easterly. However, when the northern and eastern parts of Svalbard border to open water, air from the north is heated whilst passing over open sea.

It causes a more unstable stratification and weather that is cloudier with increasing precipitation (Liljequist, 1970).

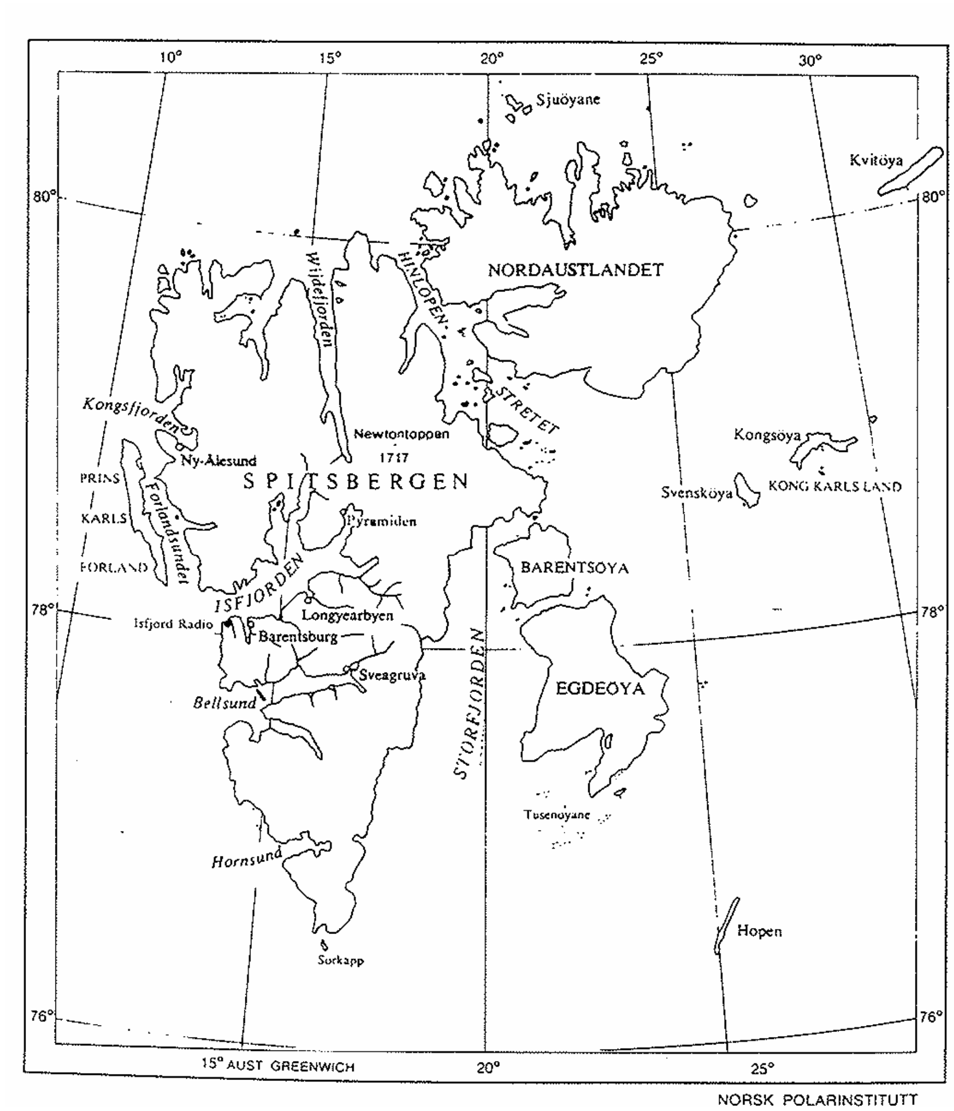


Figure 2 Map of Svalbard. (From Hanssen-Bauer et al., 1996)

The southern and western part of Svalbard most often experience open water or a small separation zone of water between the land and sea ice during the winter. Therefore these parts of the archipelago are more affected by the ocean with more precipitation compared to the northern parts (Liljequist, 1970). Exactly when Isfjorden and its branches normally are covered with ice is variable. The sea ice usually forms in January and February, but some years already in December. The two later years (2006 and 2007) the fjords have not been covered by ice at all. Commonly the sea ice melts during May-June (F. Nilsen, personal communication)

Most cyclones pass just south of Svalbard and the prevailing wind direction during times of precipitation are therefore south to southeast. This means that the southern and eastern parts of the archipelago receive most of the precipitation while in the north and west the precipitation is lower. The topography greatly determines the distribution of the precipitation (Liljequist, 1970).

Due to the larger temperature gradient between the equator and poles in winter, the pressure gradient is also larger, leading to more rapid changes in the wind. During wintertime the cyclone tracks are located further north than during summertime. This also explains why Svalbard has larger differences in both temperature and wind during the winter (Liljequist, 1970).

Since the local surroundings largely influence the weather at Svalbard it is of interest to know how much the weather really differs within a smaller area, and also what the differences depends on. The aim of this study is therefore to describe the diversities and what they depend on.

Three different studies have been made:

1. An analysis and comparison of the general weather situation with data from three different stations close to the main settlement Longyearbyen at Svalbard; the station in Adventdalen, where the winds are channelled through the sides of the valley; Svalbard Airport which is located close to the fjord and therefore often experience maritime conditions; and the station at Gruvefjellet which is located at 464 m a.s.l. and is relatively non-disturbed by its surroundings.

2. An instrumental comparison; data from the station in Adventdalen is frequently used, e.g. on the local TV-channel and the Internet. The station has been in operation since 1993. A new station is to be deployed further up the valley on the mountain Breinosa during 2007. The instrumentation at Breinosa will be of a different type and it is of interest to know the differences between the two set up of instrumentation. This also gives a test of how reliable data from the station in Adventdalen is, since these instruments have never been calibrated since 1993.

3. Data collected at a temporary deployed weather station on the mountain Breinosa during 16th December 2005 until 12th January 2006 has been compared to the station in Adventdalen. It is of interest to know the differences between these two locations for future comparisons.

Since so much of the weather at Svalbard is determined by local topography a description of locally created winds and the Arctic inversion is to be found in section 2. In section 3 a short description of the different sites is made. Here the instrument sensors also are being presented. The results from the studies described above are presented in section 4. At last, some concluding remarks to summarize the results from section 4 are given in section 5.

2. Theory

2.1 Locally Created Winds

Strong winds are commonly channelled between mountains, mountain passes and in gaps, and are created by a combination of terrain-forced flow and diurnal-formed mountain winds. The airflow behaves differently depending on the stability and speed of the approaching air and also depending on the characteristics of the obstacle. While neutrally and unstable stratified air is easily carried over an obstacle, stable stratified air is more likely to flow around the mountain, channelled through gaps or even totally blocked by the barrier (Whiteman, 2000). Whiteman and Doran (1993) describe four processes that connect valley winds with the winds aloft; *thermal forcing*, *downward momentum transport, forced channelling* and *pressure-driven channelling (section 2.1.1). See breeze* and l*and breeze* (section 2.1.2) are examples of locally created wind systems that occur in coastal areas. See breeze occur mainly during summer in the Arctic. Then there is a strong thermal gradient between warm land and the relatively cold sea water. Land breezes occur mainly during wintertime when the warm open water comes into contact with the cold land coasts or pack ice (Pryzbylak, 2003).

2.1.1 Mountain winds

Thermal forcing develops when a temperature difference occurs near the surface, resulting in local pressure-gradients forming along the valley, and a hence wind is created. Gravity waves or vertically turbulent mixing above a valley can create a strong downward transport of momentum in the valley, creating a wind that has nearly the same wind direction as the geostrophic wind above.

Forced channelling causes the winds from above to be channelled by the sidewalls of the valley so that the winds blows parallel with the axis of the valley (Whiteman and Doran, 1993), as illustrated in figure 3. This phenomenon is most likely to occur under neutral or unstable conditions when strong winds at a higher altitude have the same direction as the valley axis. As a result, this often takes place during daytime, beginning in the morning when the temperature inversion, created during night time is being destroyed, producing a sudden increase of wind speed in the valley. Winds caused by forced channelling effects are most common in high terrain areas near passes and gaps than in low-lying areas within a valley (Whiteman, 2000).

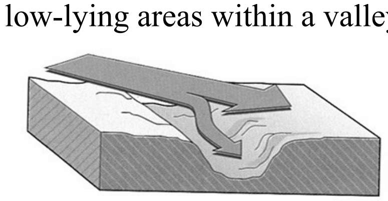


Figure 3 *Forced channelling occurs when the geostrophic wind is forced down in the valley by the topography. (From Whiteman, 2000)*

Pressure-driven channelling winds are caused by a strong horizontal pressure gradient aligned with the axis of the valley or gap and the geostrophic wind above blows almost perpendicular to its axis. As illustrated in figure 4 this channelling is strongest when the pressure gradient is parallel with the valley and the wind blows from the high pressure end towards the low pressure end of the valley (figure 4a and 4b). In figure 4c no pressure-driven wind is created in the valley since the pressure gradient is perpendicular to the axis of the valley.

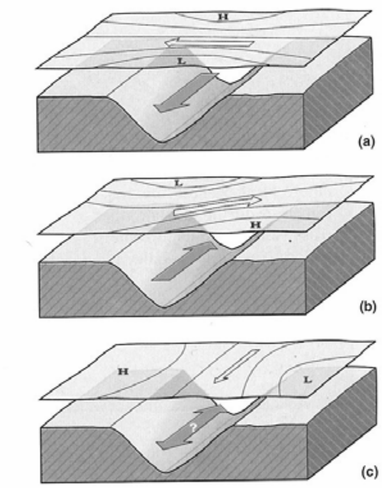


Figure 4 *In pressure driven channelling winds blow from the higher to the lower pressure of the valley and the geostrophic wind blows along the isobars with the lower pressure to the left (Northern Hemisphere). In a) the pressure gradient aloft is situated along the valley and the geostrophic wind blows nearly perpendicular to the valley while the surface wind is situated down the valley axis. b) the surface wind blows up the valley axis. c) the pressure gradient along the valley is very small and no pressure driven channelling takes place. (From Whiteman 2000)*

The actual pressure gradient can originate from either synoptic-scale pressure systems or from a variation in temperature and density between the air masses on either side of the gap or valley. This means that the wind direction depends more on the location of the synoptic highs and lows relative to the valley. Pressure-driven channelling is not a fast changing process since the movement of the synoptic systems is slow moving (Whiteman, 2000). Winds that occur from pressure-driven channelling, also known as 'gap winds', occur in areas with low roughness length and low friction with the surface (Smedman and Bergström, 1995).Therefore they are most likely to occur in shallow valleys and affecting the entire valley (Whiteman, 2000).

2.1.2 Sea and land breeze

Heating of water behaves differently compared to heating of land. Oceans have a larger heat capacity and therefore heating of land is a faster process. The most efficient heating of land takes place during summertime. This leads to convection and a high pressure is created hundreds of meters above the ground. As seen in figure 5 the air at a higher elevation flows out over the ocean. The pressure over the ground then decreases, while the pressure above the water increases. The difference in pressure produces airflow toward the coast, a sea breeze. Analogously during wintertime the sea water is warmer relatively the landmass. A wind can occur blowing from land towards the water, creating a land breeze, which is less strong than a sea breeze (Bogren et al., 1999). Similar to the land breeze is the ice breeze. In areas with ice covering the ocean a wind will blow from the ice edge towards the ocean (Chu, 1987).

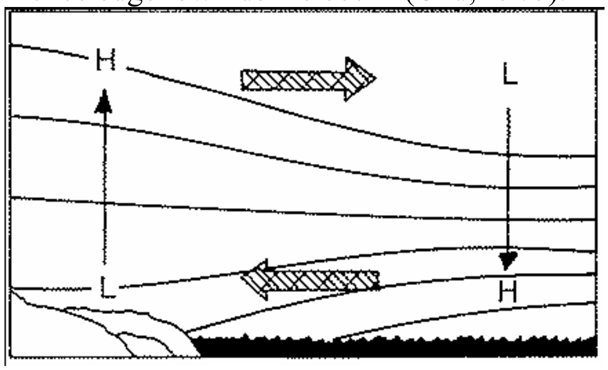


Figure 5 *Sea breeze circulation. (from Bogren et al., 1999)*

2.2 The Arctic Inversion

At higher latitudes the annual variation in light conditions is more marked than the diurnal variation, since here continuous daylight is present 3-4 months during summer and continuous darkness 3-4 months during winter. During the dark winter period the Arctic usually have low cloudiness which leads to considerable radiation heat loss from the ground. During summer cloudy conditions are common resulting in only a few days with sunshine (Hanssen-Bauer et al., 1990).

When the surface is cooler than the air a stable boundary layer (SBL) is formed. This often occurs during night but also by advection of warmer air over a cooler surface. The winds within the SBL can be very complex. In the lowest layer cold air will drain down hill. The wind direction within such a layer will then be determined mainly by the local topography. In flat areas or in valleys the wind speed is usually very low. At higher levels in the SBL, synoptic and meso-scale forcings become important. Wind speed can increase with height and reach a maximum near the top of the stable layer called low-level jets. Katabatic winds (drainage winds) are formed within SBL when cold dense air is accelerated down a slope by gravity. Since the slope doesn't have to be very steep for this phenomenon to occur one can expect these drainage winds everywhere within SBL over land (Stull, 1988).

If the stratification is stable enough, the temperature will increase with height (inversion) (Stull, 1988). In the Arctic this is common, with strong low-level temperature inversions during winter. These inversions tend to extend up to 1000-1200 m. By April the solar flux is large, but the surface net radiation remains small because of the high surface albedo. From April to June, most of the net radiation is consumed in snow melt and the strength and frequency of inversions decline as the sensible heating becomes stronger. During summer the ground is mostly free from snow and the soil is heated. Temperature inversions are still frequent in summer although shallower, weaker and somewhat elevated from the ground, than during wintertime. Temperature inversions in the Arctic represent strong static stability, limiting the depth of vertical mixing of sensible heat and moisture (Serreze and Barry, 2005). Przybylak writes that inversions are most frequent and intensive during clear sky periods in winter. In turn, the upper inversions show an opposite pattern; they are most pronounced in summer and are connected with great amounts of cloud.

3. Measurements

3.1 The Sites

Four different sites have been used, Adventdalen, Svalbard Airport, Gruvefjellet and Breinosa (see figure 6). All stations are placed on the west coast of Svalbard close to Longyearbyen, but with different height above sea level and different surroundings. All the sites have midnight sun from April until August while the dark season starts in October and ends in February.

3.1.1 Adventdalen

As seen in figure 6 at point 1, Adventdalen is a wide valley surrounded by mountains and runs from southeast towards northwest where is meets the water in Isfjorden. The distance from Longyearbyen is approximately 5 km. There are several narrower valleys out from the wider Adventdalen. The weather station, at approximately 20 m a.s.l., has been in operation since 1993.

3.1.2 Svalbard Airport

Svalbard Airport has been recording weather data since August 1975. As presented in figure 6 at point 2 the Airport is located at Hotellneset by the coast of Isfjorden 28 m a.s.l. To the south Svalbard Airport is facing the Plateau Mountain and mainly in all other direction it is facing water.

3.1.3 Gruvefjellet

Gruvefjellet weather station is located 464 m a.s.l. as seen in figure 6 at point 3. The station has been operating since August 2001. The station is relatively unaffected by its surroundings because of the high placement. It is facing the settlement Longyearbyen on its western side down in the valley and Adventdalen in the northeast.

3.1.4 Breinosa

The Breinosa Mountain is to be found further in Adventdalen (figure 6). The weather station is situated at a height of approximately 500 m. It is a large plateau mountain approximately stretched 7 km from north to south and 5 km from west to east including several glaciers. On both the western side and eastern side two narrow valleys are sited and the distance to Adventfjorden is just about 10 km.

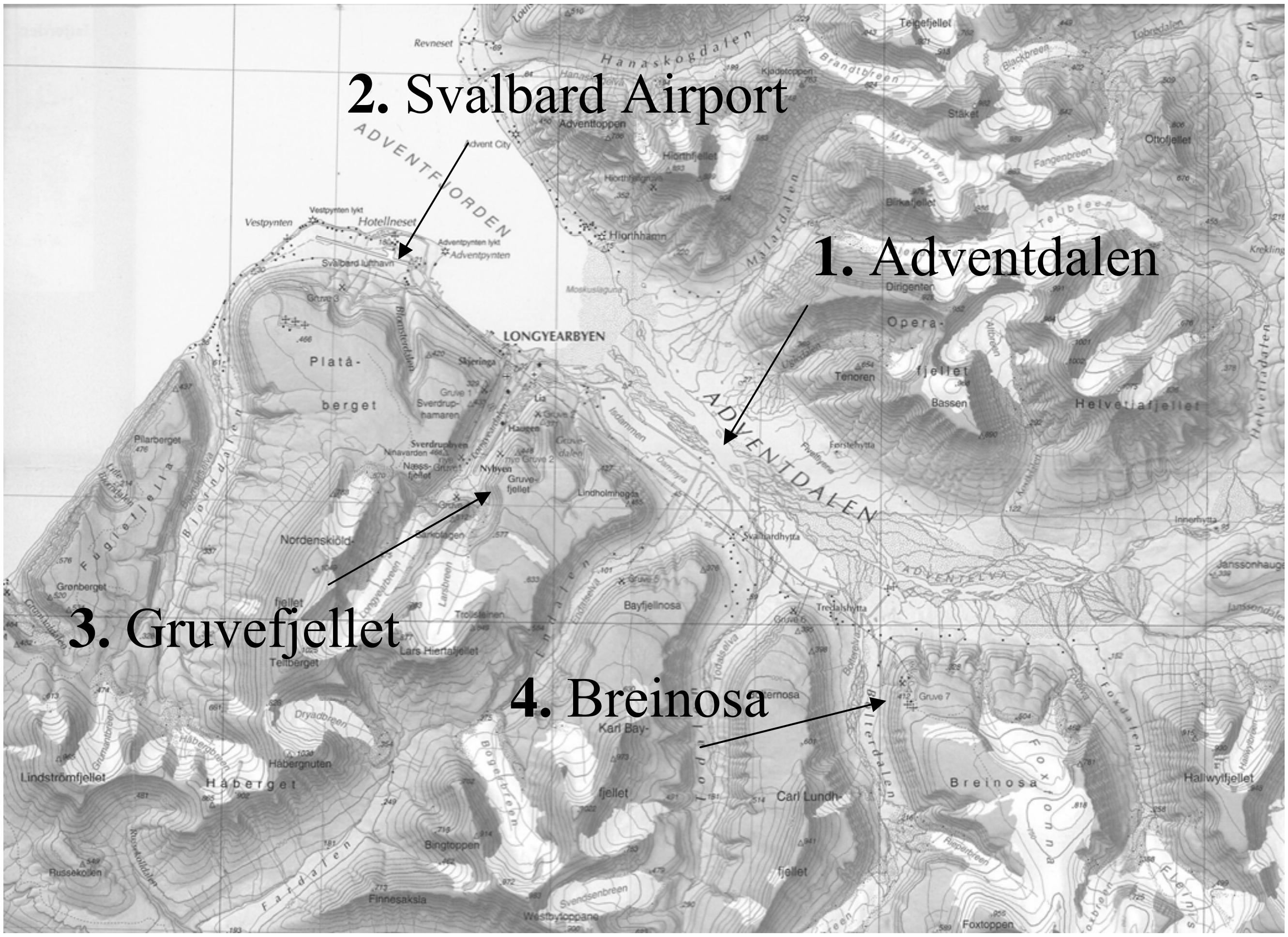


Fig 6 *Map over the three stations, Adventdalen (1), Svalbard Airport (2), Gruvefjellet (3) and Breinosa (4).*

3.2 Data

The parameters measured are air temperature, relative humidity, wind speed, wind gust, wind direction and air pressure. The data has been corrected manually for errors.

3.2.The general weather

As described in section 1.2 data, from three different weather stations in Svalbard, is used to make an analysis and comparison of the general weather situation as well as how affected the stations are of their local surroundings. In Adventdalen (Aanderaa station) data is sampled each ten minute (see section 3.1.1). The data used in this comparison is January 2004 until December 2006. At Svalbard Airport (station unknown) data is sampled each third hour and the period used is December 1993 until December 2004. The weather station at the Airport is on of the official meteorological weather station at Svalbard and used by The Norwegian Meteorological Institute. The station at Gruvefjellet (Campbell station) has a sampling interval of one hour and chosen period here is December 2001 until December 2005 (table 1).

Table 1 *Periods of data used from Adventdalen, Svalbard Airport and Gruvefjellet.*

STATION NAME	Adventdalen	Svalbard Airport	Gruvefjellet
From date	1/1 2004	1/12 1993	1/12 2001
To date	31/12 2006	31/12 2004	31/12 2005

3.2.2 Instrumental comparison

Besides the weather station in Adventdalen (called A) data from two other stations were used. First an Aanderaa station which was put up by a group of students as a part of a field experiment during a course at UNIS (the University Centre in Svalbard) in the autumn 2006, (from now on named *B*). The third station, (station *C)*, with Campbell and Vaisala sensors was also put up in the same area nearby station *A* (Adventdalen) and *B* during the same time period. The instruments used will be described in section 3.3. The main wind direction during the time was along the valley, i.e. southeast out of the valley towards the water.

The data used for comparison are from 4th October at 14:00 until 7th October at 13:00 (2006) and during the end of this period a low pressure passed Svalbard. Station B sampled data every second minute, while the other two stations sampled data every ten minute. Due to the different sampling time at station B an average of five values has been used when comparing average values with the other two stations. (There was no noticeable difference by taking each fifth value compared to taking an average of five values.)

3.2.3 Breinosa and Adventdalen

At the station on Breinosa (Aanderaa station) there is data from 15th December 2005 until 19th April 2006. The data used is from 16th December 2005 until 12th of January, due to problems with missing data rest of the time and problems with the wind direction sensor which stopped working 13th of January. Breinosa measured air temperature, wind speed, wind gust, wind direction and relative humidity. Data from Adventdalen from the same period has also been used. The station at Breinosa sampled data every 30 minute and Adventdalen every ten minute. To avoid the risk of smooth any differences in the comparison, every third value from Adventdalen was chosen, instead of taking an average of each three.

3.3 Instrumentation at the Aanderaa Stations

Different sensors were used and this section contains a description of the sensors at station A (Adventdalen), station B and Breinosa, which all are Aanderaa stations with the same type of sensors.

The sensors measured wind speed, gust, wind direction, air temperature, relative humidity and air pressure. At station A (Adventdalen) the parameters were all measured at approximately 4 m height. At station B three heights where used; wind speed, wind gust, wind direction, air temperature and relative humidity were measured at approximately 10 m height, wind speed and temperature at about 5 m and wind speed, air pressure, air temperature and relative humidity at approximately 2 m height.

3.3.1 Wind speed

Wind speed and gust were measured by the wind speed sensor 2740 with a threshold speed less than 0.3 m/s. Range of the instrument is 0-79 m/s. The accuracy of the sensor is 0.2 m/s or 2% whichever is the greater one. It contains of three cup rotor on top of an aluminium housing (figure 7). The rotating part contains a magnet sensed by a magneto inductive switch located inside the housing. The sensor has two output signals which measure the average wind speed and the maximum wind speed over two seconds, i.e. the gust.

Figure 7 *Wind speed sensor 2740 from Aanderaa. (From Aanderaa, 2007)*

3.3.2 Wind direction

Wind direction was measured with a wind direction sensor (figure 8). Inside the vane there is a magnet and a magnetic compass which senses the relative angle and the average wind direction is measured in a sampling interval giving values between 0° and 360°. The accuracy of the instrument is better than 5° and the threshold speed is less than 0.3 m/s. The instrument is furnished with an N mark and this mark is supposed to be orientated towards north for receiving the true wind direction, otherwise corrections has to be made (Aanderaa, 2007).

Figure 8 *Wind direction sensor 3590. (From Aanderaa, 2007)*

3.3.3 Air temperature

An 80 mm long cylindrical air temperature 2000Ω film-type platinum sensor 3455 measuring in the range -43°C to 48°C was used. The resistance of the platinum sensor is proportional to the temperature. It has a high accuracy with the uncertainty 0.1% and resolution 0.1%. A radiation screen is surrounding the platinum resistor with the purpose to hinder heating of the sensor by direct sunshine in wind velocities down to 0.5 m/s (Aanderaa, 2006).

3.3.4 Relative humidity

The relative humidity sensor 3445 uses a capacitive polymer to sense humidity and is surrounded by a radiation screen. The sensor measured within the range 0% to 100%, with an accuracy of 2% and resolution of 0.1% (Aanderaa, 2007).

3.3.5 Air pressure

To measure the air pressure a waterproof air pressure sensor 2810 was used, which has a measuring range from 920hPa to 1080hPa, with an accuracy of 0.2hPa. Resolution is 0.2hPa. Inside the instrument there is a small silicon chip, which is exposed to air pressure on one side and vacuum on the other. Since temperature changes will alter the result the sensor is being heated by heating resistors to guarantee constant temperature. The sensor is supposed to have practically no hysteresis (Aanderaa, 2006).

3.4 Instrumentation at the Campbell Stations

The instrumentation at station C and Gruvefjellet consisted of both sensors from Campbell and Vaisala measuring wind speed, wind direction, air temperature, relative humidity and air pressure.

3.4.1 Wind speed and wind direction

For measuring the wind speed and wind direction a 05103-L R.M. Young wind monitor was used. Measuring wind speed it is functional in the range 0-60 m/s with an accuracy of 0.3 m/s and threshold starting at 1.0 m/s. The rotation produces a signal with a frequency proportional to wind speed. When measuring the wind direction a potentiometer is used and it is functional in the range 0°-360°. The output signal is an analog voltage directly proportional to the azimuth angle. The accuracy for the wind vane is 3° with a threshold speed 1.1 m/s (Campbell scientific Inc., 2006).

Figure 9 *05103-L, R.M. Young wind monitor for measuring the wind speed and wind direction. (Campbell Scientifics, Inc., 2006)*

3.4.2 Air temperature and relative humidity

To measure the temperature a Vaisala probe HMP45A with a Pt 1000 IEC 751 sensor was used, where the resistance of the platinum sensor is proportional to the temperature. The temperature sensor works in the range -39.2°C to +60°C and has an accuracy of 0.2°C. The sensor Vaisala HUMICAP® 180 measures the relative humidity within the range 0.8% to 100% and has the accuracy (at +20°C) of 2% for 0-90% relative humidity and 3% for 90-100% relative humidity (Vaisala, 2007).

3.4.3 Air pressure

The sensor used at the station for measuring the air pressure was a CS100 Setra 278 barometric pressure sensor. The sensor contains two parallel electrically isolated metallic surfaces. One of the surfaces is covered with fused glass and ceramic. A slight change in the applied pressure will be detected and converted to an analog voltage signal. The sensor is functional during following temperature conditions -40°C to +60°C with the accuracy of 0.5hPa at 20°C (Campbell scientific Inc., 2006).

4. Results

Three different analyses have been made. First a study of the general weather situation at three stations close to Longyearbyen. Second an investigation and comparison of several instruments measuring wind speed, gust, wind direction, air temperature, relative humidity and air pressure. The third case study concerns a data from a weather station operating during a shorter time at the mountain Breinosa, which was compared to the station in Adventdalen.

4.1 Analysis of the General Weather Situation Around Longyearbyen

The three stations used for the analysis of how the local effects influence the measurements were Adventdalen, Svalbard Airport and Gruvefjellet (described in section 3.1). The following classification has been used when looking at different seasons throughout the year:
Winter - December, January, February
Spring - March, April, May
Summer - June, July, August
Autumn - September, October, November

4.1.1 Adventdalen

The mean, maximum and minimum monthly average temperatures during 2004 until 2006 at Adventdalen is presented in figure 10, with a peak during July and the lowest temperature in March. The mean temperature of the coldest month is March with -14°C (the lowest temperature was registered, -35.4 °C in 12th March 2005). The warmest month is July with an average temperature of +6.7°C (temperature record 14.2 °C in 7th July 2005). Also illustrated in the figure, is the deviation in temperature which is larger during winter time. The reason for this is that during winter the temperature gradient is larger between the equator and poles and also the cyclones tend to travel further up north which gives more variable weather at those regions.

In figure 11 the seasons, winter, spring, summer and autumn, and the yearly mean temperatures are illustrated. There are two discrepancies in the figure; first during winter, the mean temperature is very similar during both 2005 and 2006, while year 2004 shows a much colder value. The reason for this has most probably to do with missing data during December year 2003. If the data from December would exist it would most likely have an increasing effect on the average temperature for the winter season 2004.

The second discrepancy in figure 11 is seen during year 2005 when spring season in average was a colder season than winter in Adventdalen. There is an indication that the wind speed during spring season year 2005 was somewhat lower than during the winter. As will be discussed below, the temperature inversion in the valley then more often was well developed due to the lower wind speed. This then caused a colder spring in general compared with the other two years.

The wind direction is mainly out of the valley towards the fjord (not shown here). The direction has to do with a channelling effect when the winds from the large-scale wind are channelled trough the valley. Also the air that is transported over the glaciers, further in the valley, is chilled and flows down into the valley.

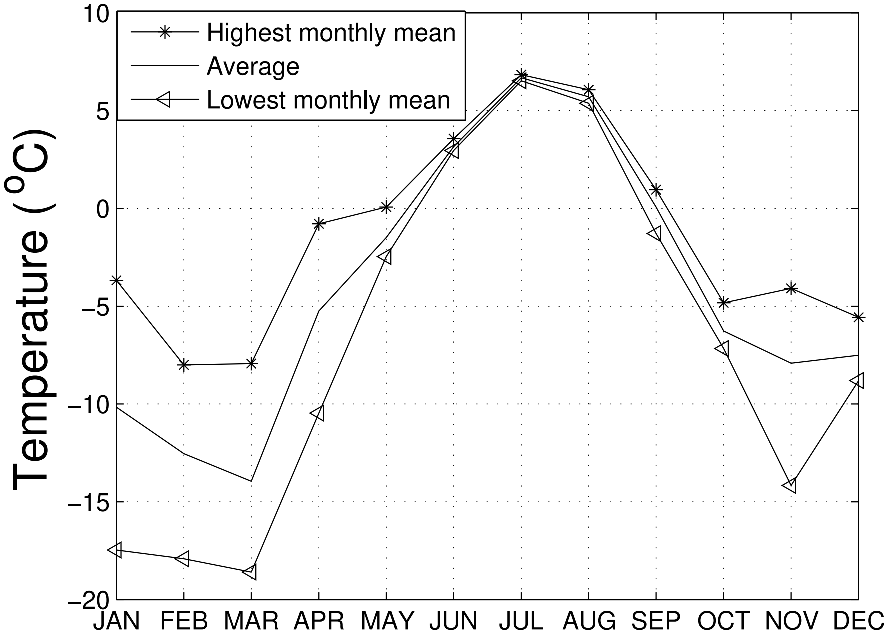


Figure 10 *Mean, maximum and minimum monthly average temperatures at the station in Adventdalen during 2004-2006.*

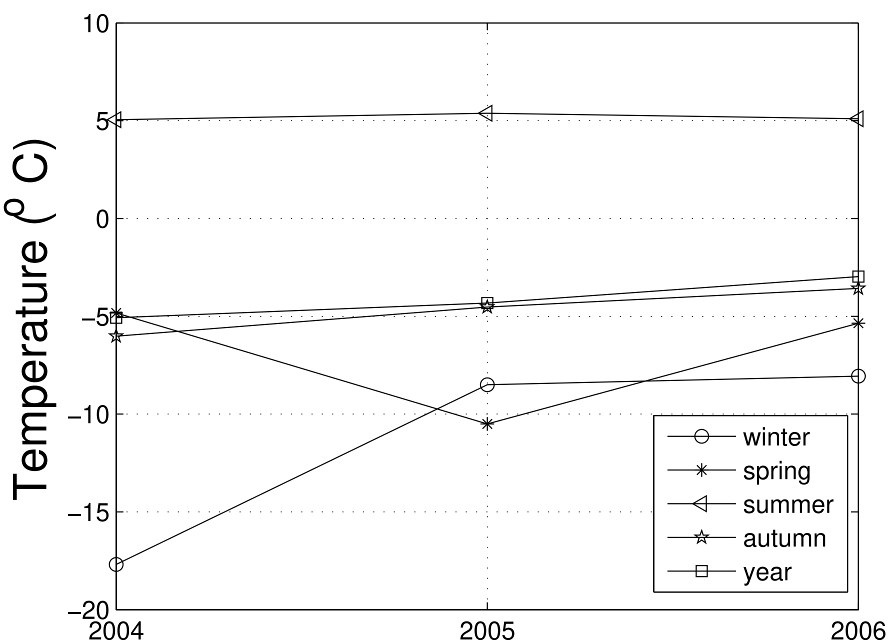


Figure 11 *Seasonal and annual mean temperatures at Adventdalen from 2004-2006.*

In figure 12 the monthly average wind speed for Adventdalen is illustrated with a mean wind speed of 5.1 m/s. The wind speed is decreasing during the summer period (average minimum close to 3.5 m/s in August) and increasing during winter and spring as expected (average maximum close to 6.5 m/s in January), since the cyclonic activity during the winter period is larger. Also the larger temperature gradient between equator and poles during the winter period contribute to an increase in wind, since the pressure gradient also increases which leads to an enhancement in wind speed.

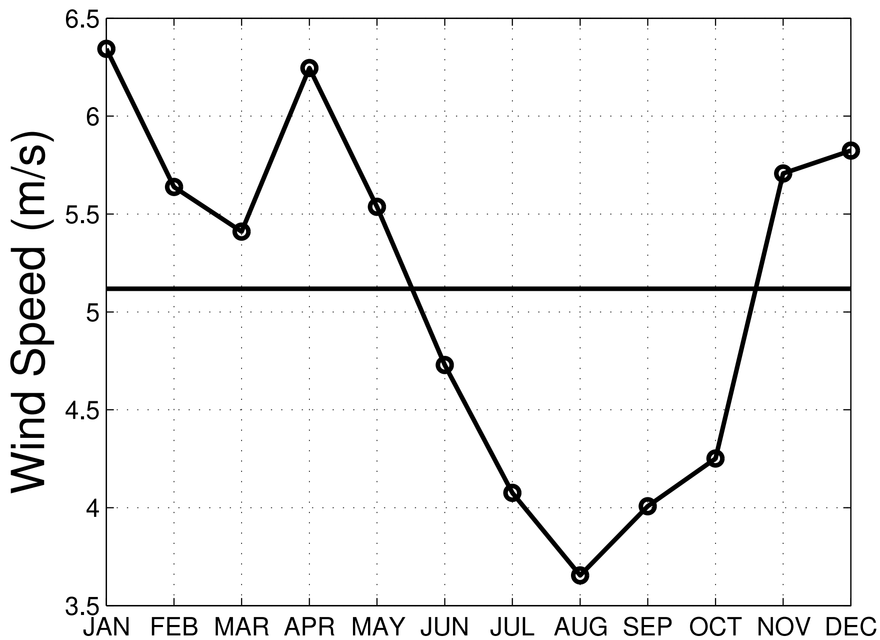


Figure 12 *Average wind speed (2004-2006) in Adventdalen for each month. Solid line shows yearly average 5.1 m/s.*

To sum up the weather situation in Adventdalen it is important to emphasize that the direction of the valley is aligned in a south easterly to north westerly direction which has a large influence on the measured wind direction. The large-scale wind field often has an easterly component and this in combination with the channelling effects of the local topography causes prevailing winds in Adventdalen to travel inland towards the fjord. The channelling effect can also combine with drainage winds to transport colder, denser air from the inland glaciers to the warmer sea, which enhances the wind speed. The average speed is 5.1 m/s. The coldest month is March (-14°C) and warmest July (+6.7°C). There is an indication that a decrease in wind speed likely leads to a decrease in temperature since a temperature inversion then more likely develops in the valley.

4.1.2 Svalbard Airport

Svalbard Airport is located close to the Advent Fjord (figure 6). In figure 13 the mean, maximum and minimum monthly average temperatures during year 1994 until 2004 is presented. The mean temperature the coldest month during the period is February with -14.6°C, the lowest temperature was registered to be -35.9 °C (12th of January 1997). The warmest month is July with an average temperature +6.6 °C (temperature record 18.4°C in 22nd of July in 1998).

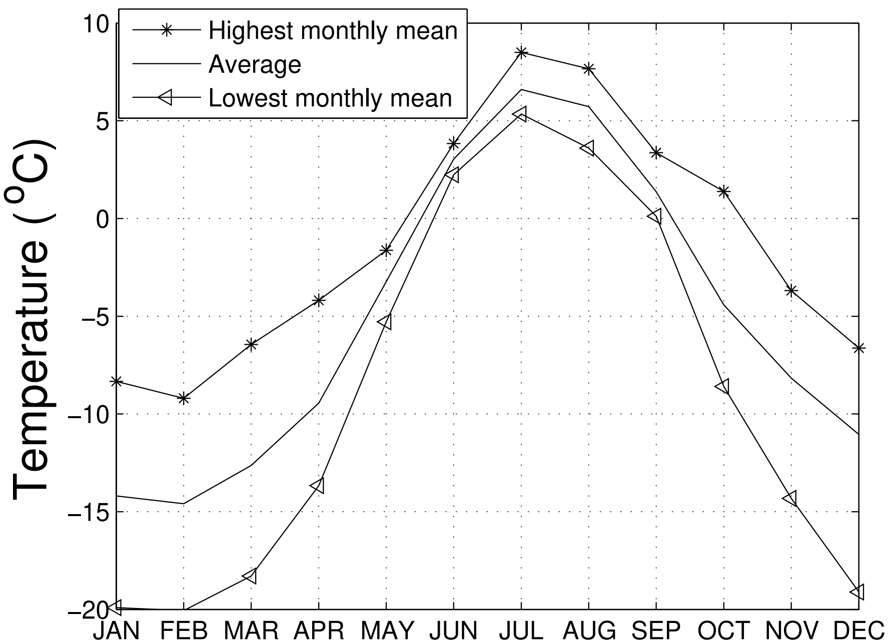


Figure 13 *Average, maximum and minimum monthly temperatures at Svalbard Airport during year 1994 until 2004.*

In figure 14 the average temperature for each season including mean temperature for each year is presented. Summer is a period with an average temperature close to +5°C and autumn around -5°C while the other seasons winter and spring are more variable as expected. As seen during year 2000 and 2001 the Airport experiences a warmer winter, in fact the winter on average is warmer than spring. And also year 1999, 2002 and 2003 have a somewhat warmer winter compared to the other years. Looking at the wind direction during winter time those “milder” years, the wind direction is mainly east to southeast i.e. the winds have travelled over Adventfjorden. The other years when the winter period is colder there is a larger contribution also from other wind directions i.e. from inland and from an ice covered Isfjorden. Ice maps show an indication that when Isfjorden (figure 2) is covered with ice, the temperature at the Airport is lower than years with less ice.

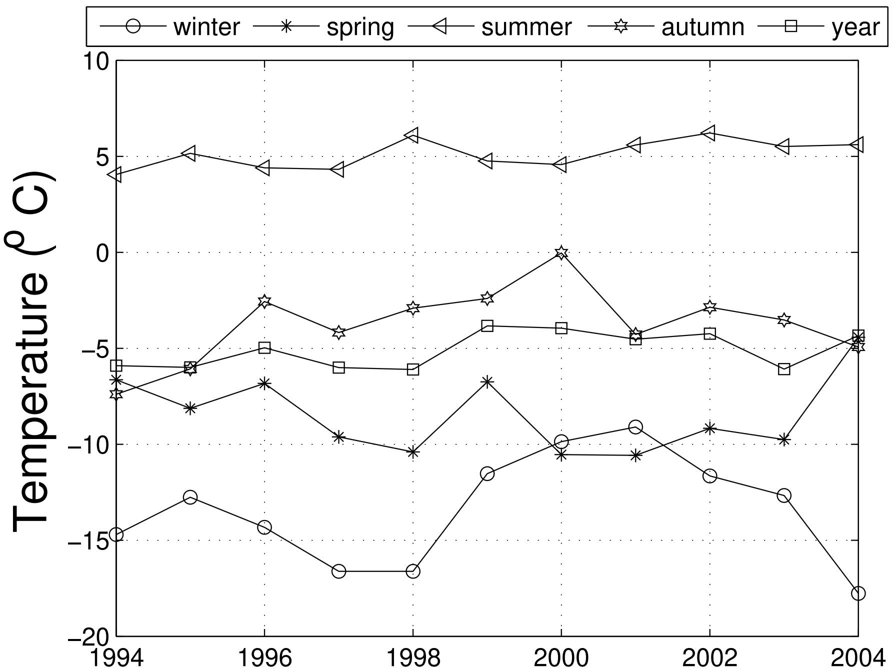


Figure 14 *Seasonal and annual mean temperatures (1994-2004) at Svalbard Airport.*

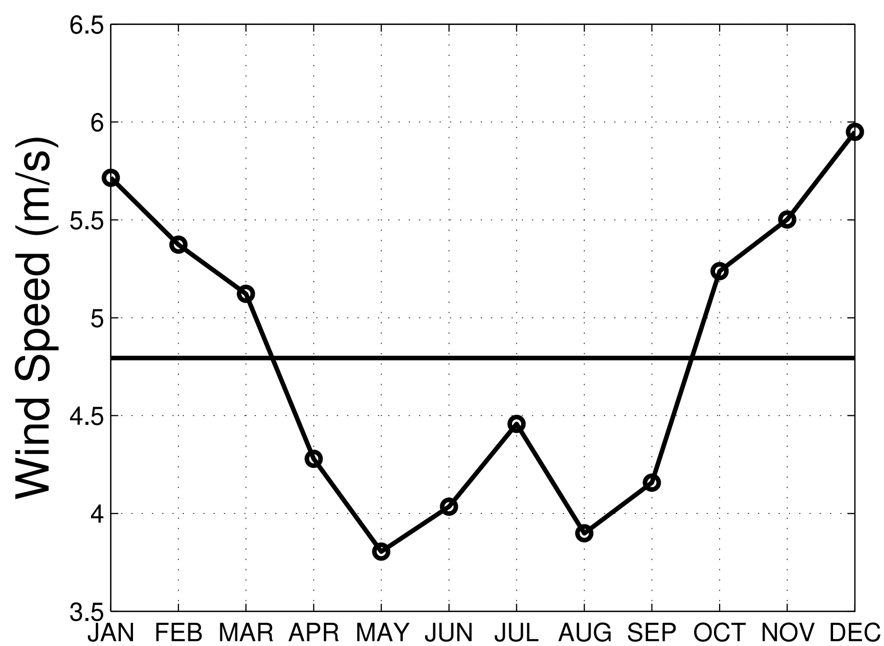


Figure 15 *Average wind speed (1994-2004) at Svalbard Airport for each month. Solid line shows yearly average 4.8 m/s.*

In figure 15 the average windspeed during each month is presented with a yearly mean of 4.8 m/s and a maximum average speed in December about 6 m/s, while the lowest wind speed in May is less than 4 m/s. The wind speed in general decreases during the summer period. The general wind direction is on average south easterly (not shown here), but there is also a contribution from southwest to west, mostly during summer. This means that the most common winds travel through Adventdalen out to the Airport, but that there also is a contribution of winds travelled over water. This mostly happens during summer when the sea breeze circulation is strengthened.

In summary, from the general weather at Svalbard Airport one can easily see that it experiences a large effect from the channelled winds coming from Adventdalen and the average wind speed is 4.8 m/s. But the winds also originate from the water, especially during summer when the regional wind speed is lower. This leads to a more favourable situation for a development of a sea breeze circulation. Isfjorden can however affect the weather situation also during winter and spring. In situations when the ice has appeared late and the winter then experienced longer periods of open or very little fjord ice, spring has been colder than winter. The monthly maximum is in July (+6.6°C) and minimum in February (-14.6°C)

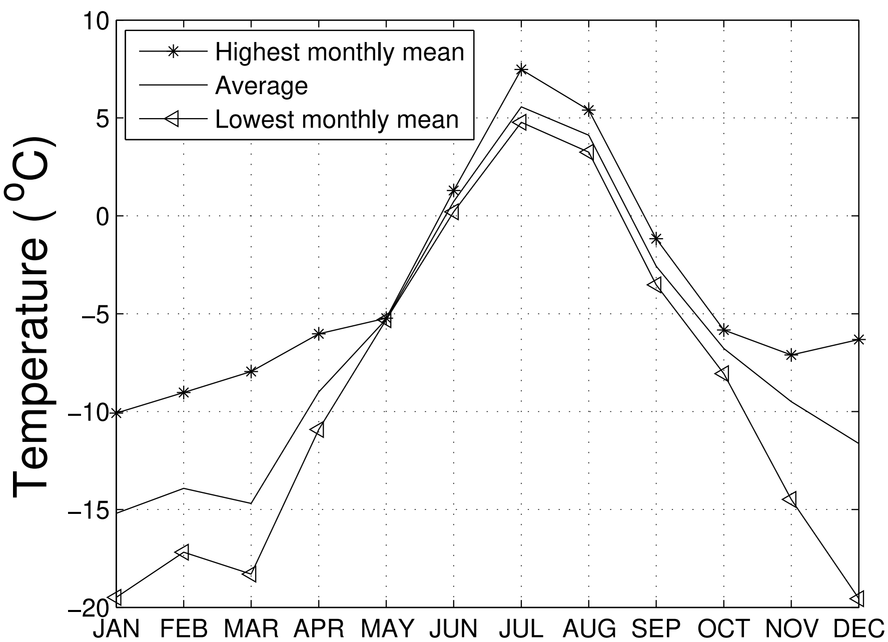


Figure 16 *Average, maximum and minimum monthly temperatures at Gruvefjellet during year 2002 and 2005.*

4.1.3 Gruvefjellet

As described in section 3.1.3, the station at Gruvefjellet is located at a higher altitude than the other two stations. The mean temperatures for each month during 2002 until 2005 is presented in figure 16 with lowest in January (-15.2°C) and highest temperature in June (+0.7°C). In July 7th 2005, the warmest temperature during the years was registered with +17.5°C while the lowest was observed 13th January 2004 with -32.0°C. Similarly with the other two stations the deviation in temperature is larger wintertime.

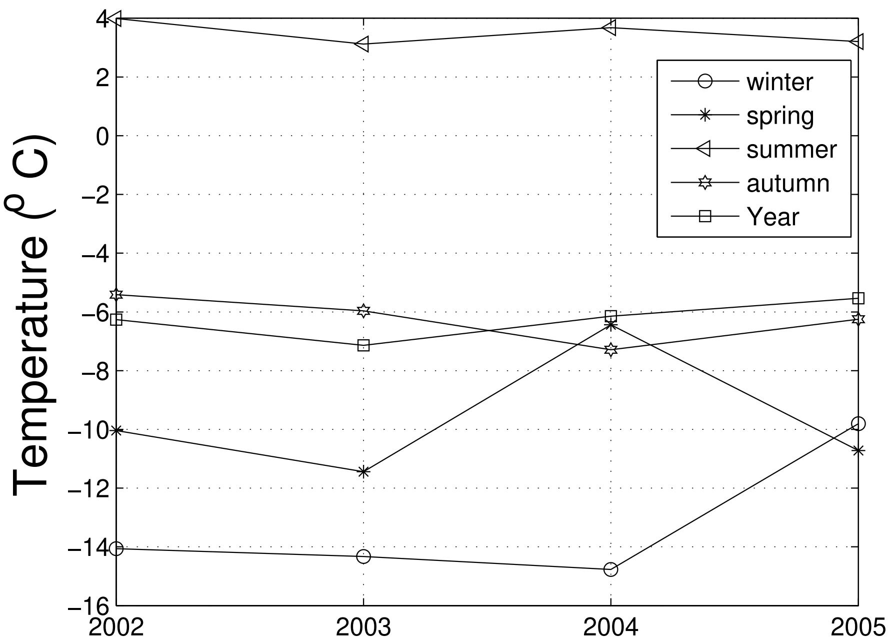


Figure 17 *Seasonal and annual mean temperatures (2002-2005) at Gruvefjellet.*

The average temperatures during the different seasons at Gruvefjellet are illustrated in figure 17. Two discrepancies is to be found; year 2004 spring is warmer in average than autumn; during 2005 winter was (in average) warmer than spring. The largest part of the wind blowing at Gruvefjellet is coming from southeast and east, but winds from all directions do occur. The first discrepancy with a warm spring can be explained by looking at wind direction. Normally the winds during spring have travelled over large areas of glaciers. During spring 2004 there was less contribution of those winds leading to a warmer weather. As for the second discrepancy there is no apparent indication in wind speed or wind direction which could clarify the differences. More frequent cloudiness could be an explanation. Then the cooling of the ground is somewhat prevented leading to milder temperatures.

Figure 18 shows the average wind speed distribution at Gruvefjellet with an average speed of 3.9 m/s, a highest average wind speed during February close to 5.5 m/s and lowest in June of less than 2.5 m/s. The largest part of the wind blowing at Gruvefjellet is coming from southeast and east, but winds from all directions do occur.

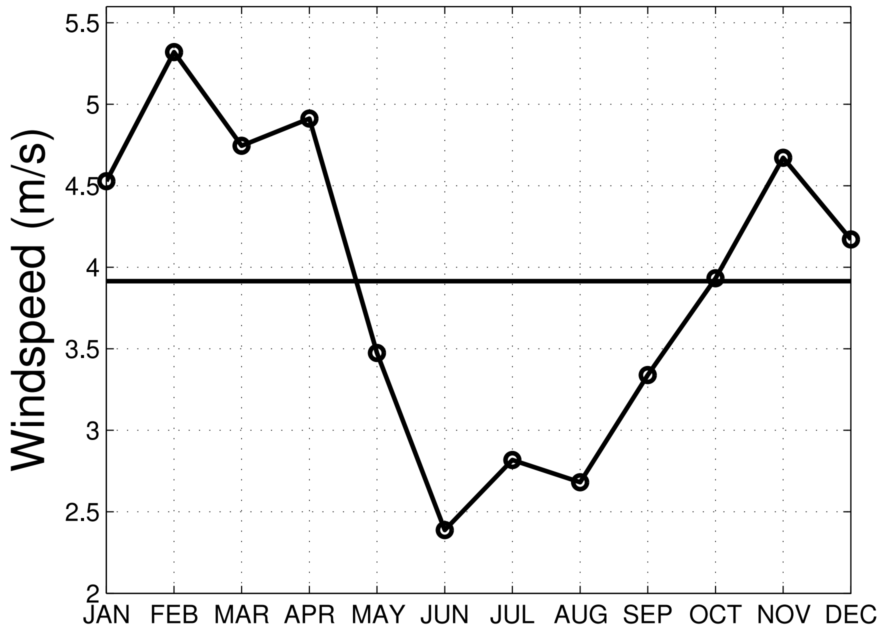


Figure 18 *Average wind speed for each month (2002-2005) at Gruvefjellet. Solid line shows yearly average 3.9 m/s.*

In summary, the characteristics at Gruvefjellet illustrate that the altitude very much determines the type of weather experienced. The temperature then is often colder than at a lower altitude, due to the large outgoing radiation and cooling of the surface and that the temperature normally decreases with height. The monthly temperature maximum is in June (+0.7°C) and minimum in January (-15.2°C). The wind speed at the mountain is in average 3.9 m/s.

4.1.4 Comparison

Adventdalen, Svalbard Airport and Gruvefjellet all have differences and similarities when looking at the general weather. The local effects influence the measurements in different ways.

4.1.4.1 Temperature

The variability of the annual mean temperature is large at Svalbard. The reason for this high variability has clearly to do with the vigorous cyclone activity and the maximum deviation in temperature that occurs in winter. Mean summer temperatures has the smallest variability due to three reasons: the thermal differentiation between the air masses is clearly lower; small daily difference in the altitude of the sun (polar day); and periods with melting snow and sea ice which tend to stabilize the situation especially over the Arctic Ocean (Przybylak, 2003).

Nordli and Kohler (2004) discuss that boundary layer inversions can result in significant temperature differences between stations even at slightly different elevations. Gruvefjellet has a yearly average temperature of -6.3°C compared to Adventdalen with -4.1°C and Svalbard Airport with -5.1°C (table 2). All stations have a large deviation in temperature. The station having the largest deviation in temperature is Adventdalen (table 3) with 2.5°C compared to the Airport and Gruvefjellet which both have a standard deviation of 1.5°C. Inversions are predominant in the Arctic. The reason for the valley to have a high variation in temperatures depends on the low placement which often is exposed to periods with and without inversions. Depending on weather Isfjorden is covered with ice or not the temperature at Svalbard Airport also varies. In times with no ice the lower temperatures near ground are heated by the fjord. Gruvefjellet location at a high altitude also contributes to the high variability in temperatures.

Table 2 *Mean monthly air temperatures (°C) at Adventdalen (2004-2006), Svalbard Airport (1994-2004) and Gruvefjellet (2002-2005).*

STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Adventdalen	-10,2	-12,5	-14,0	-5,2	-1,5	3,2	6,7	5,7	0,1	-6,3	-7,9	-7,5	-4,1
Svalbard Airport	-14,2	-14,6	-12,6	-9,4	-3,2	3,0	6,6	5,7	1,4	-4,4	-8,2	-11,1	-5,1
Gruvefjellet	-15,2	-13,9	-14,7	-9,0	-5,3	0,7	5,6	4,1	-2,6	-6,7	-9,4	-9,4	-6,3

Table 3 *Standard deviation in temperature (°C) at Adventdalen (2004-2006), Svalbard Airport (1994-2004) and at Gruvefjellet (2002-2005).*

STATION NAME	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEAR
Adventdalen	6,9	5,0	5,5	4,9	1,4	0,3	0,2	0,3	1,2	1,3	5,5	1,7	2,5
Svalbard Airport	4,3	3,3	4,2	3,2	1,1	0,5	1,0	1,1	1,1	2,5	4,0	3,9	1,5
Gruvefjellet	4,0	3,8	4,6	2,3	0,0	0,6	1,3	0,9	1,0	1,0	3,5	2,1	1,5

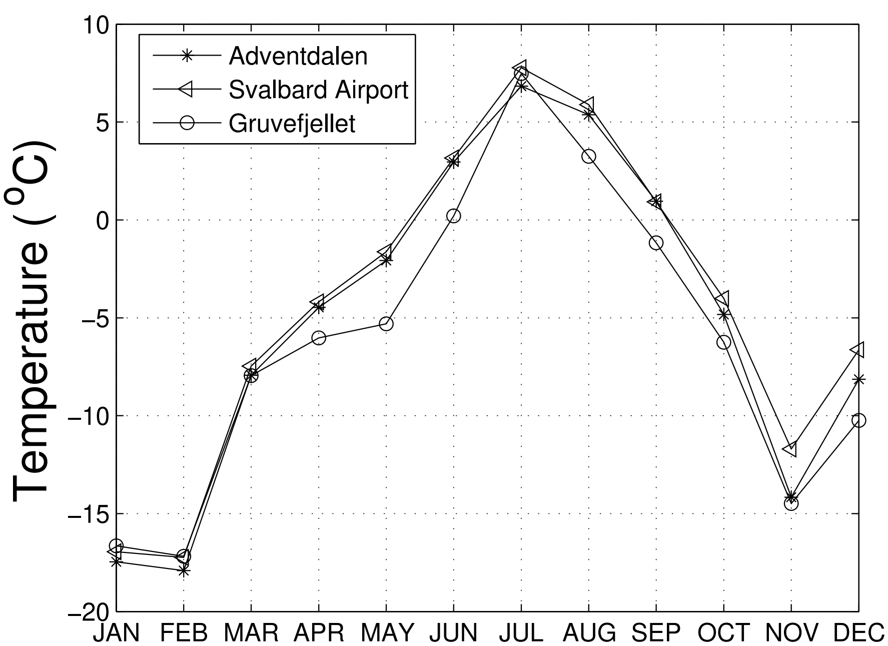


Figure 19 *Average monthly temperatures at Adventdalen, Svalbard Airport and Gruvefjellet during year 2004.*

Comparing the three stations during one year (2004), the winter temperatures at all stations are below 0°C for most of those months (figure 19). In the beginning of the year Isfjorden and Adventfjorden was mostly covered with permanent fjord ice, which leads to a more continental climate especially at Svalbard Airport. As seen in table 4 Gruvefjellet is the coldest location in average during 2004, while Svalbard Airport is the mildest. Thus, the high location at Gruvefjellet leads to low temperatures.

The reason for Adventdalen also to have relatively cold temperatures depends on the chilled air that is channelled down into the valley in combination with the frequent temperature inversions. Svalbard Airport is the mildest location, with an average of -5.0°C. The maritime influence leads to milder temperatures, but since the fjord during the beginning of 2004 was frozen the temperatures decreases. Also the cold air which is channelled through Adventdalen reaches the Airport. However, during summer the maritime influence is high. A maximum temperature of 17.3°C was measured in July at the Airport, while the valley had the lowest maximum temperature of 13.9°C and Gruvefjellet 15.0°C the same month. Thus, Gruvefjellet is the coldest location in average, but the coldest temperature was measured in the valley. This further supports the explanation that temperature inversions and channelled cold air determines the temperatures in the valley.

Table 4 *Average, maximum and minimum temperatures (°C) during 2004 at Adventdalen, Svalbard Airport and at Gruvefjellet.*

STATION NAME	Average Temperature (°C)	Maximum Temperature (°C)	Minimum Temperature (°C)
Adventdalen	-5.6	13.9	-34.6
Svalbard Airport	-5.0	17.3	-30.9
Gruvefjellet	-6.2	15.0	-31.2

Nordli and Kohler (2004) states that during April-June the inversions are weaker and less frequent around Longyearbyen and also that the lower temperatures then are to be found at higher altitudes, which is to be seen in figure 19. The differences in the figure are that the temperature at Gruvefjellet is milder than (or equal to) Adventdalen and Svalbard Airport during January until March and December. From April until November Gruvefjellet instead is the coldest station, due to fewer temperature inversions. The temperature at Adventdalen and the Airport is very similar. Both locations are at a lower altitude. However there is a difference during October until December. Remember that the fjord was *not* covered with ice during those months. Svalbard Airport shows milder temperatures than in the valley. The maritime influence at the Airport brings milder air ashore. In Adventdalen the prevailing south easterly winds brings more of 'continental' air channelled into the valley, lowering the temperature. One could expect a somewhat colder temperature during summer at the Airport compare to the other stations due to sea breeze circulation, but there is no indication of such phenomenon in the average monthly temperature.

As an example of less frequent inversions and therefore lower temperature with height, the period 4-10th May has been chosen as a typical example (figure 20). Gruvefjellet is the coldest place of the three stations. During 6-8th May the wind speed decreases especially at the Airport (figure 21), but still no strong inversion is developed.

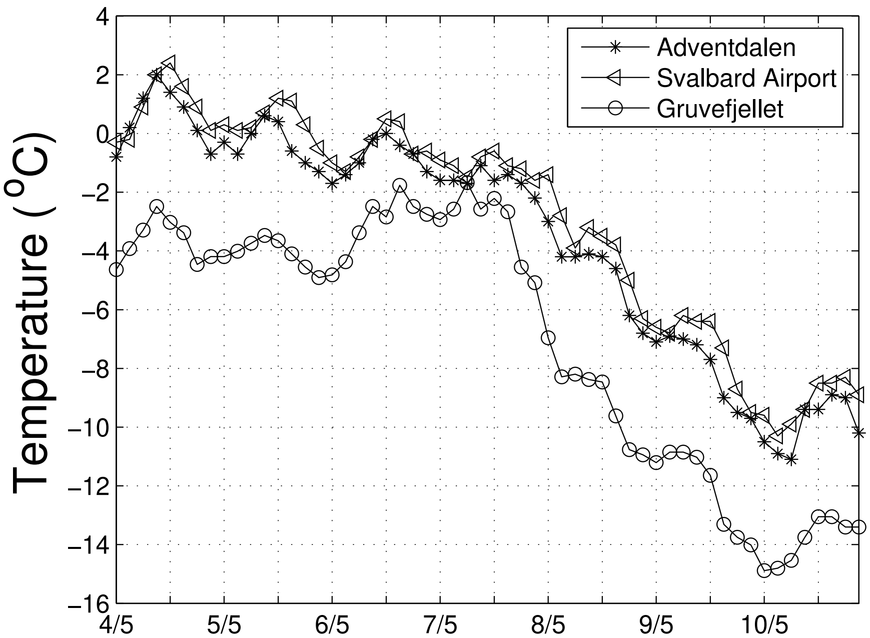


Figure 20 *Temperatures at Adventdalen, Svalbard Airport and Gruvefjellet 4-10th of May 2004.*

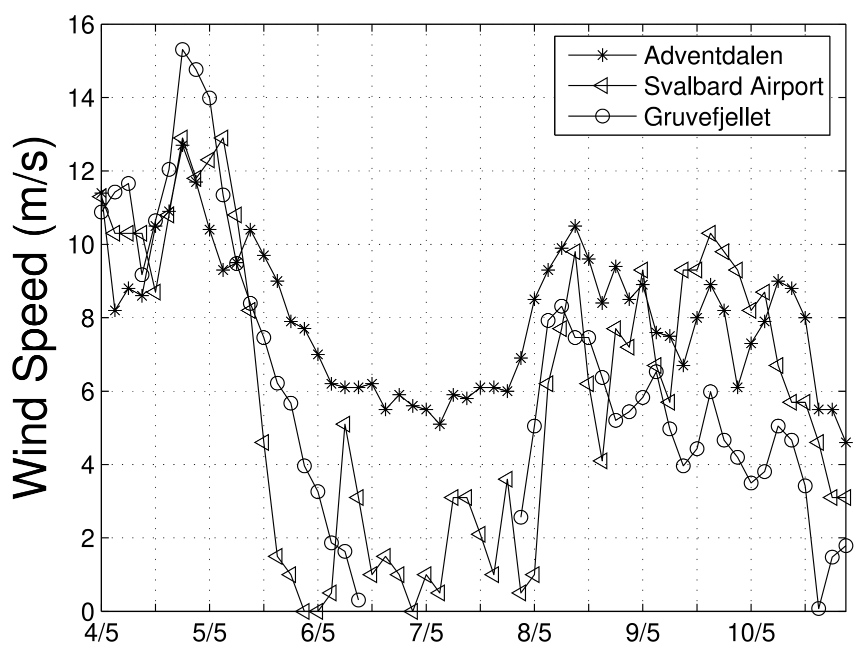


Figure 21 *Wind speed (m/s) at Adventdalen, Svalbard Airport and Gruvefjellet 4-10th of May 2004. Data missing at Gruvefjellet during 7th May and partly 8th of May.*

Looking at another example 15-20th January 2004 (figure 22) the situation is different. As seen during the first two days (15-16th January), Gruvefjellet has the lowest temperature. During the following two days (17-18th January) the temperature in the valley and at the Airport decreases and turns colder than on Gruvefjellet. By looking at the wind speed these events can be explained in the following way (see also figure 23): when Gruvefjellet experienced lowest temperatures, the wind speed is rather high at all the locations (8-12 m/s) and the air is more efficiently mixed. The temperature inversion at the ground does not develop as easily and temperature decreases with height. The result is colder temperatures at Gruvefjellet than in the valley and at the Airport. When temperature in the valley and at the Airport decreases to be lower than on the mountain (18-19th January), the wind speed at the same time decreases to below 3 m/s. The temperature inversion can freely develop in the valley and temperature increases with height. An increase in wind speed 19th January leads again to a breakdown in the inversion, resulting in a temperature decrease with height, verified by the lower temperature measured at Gruvefjellet the 20th January. A calculation of the potential temperature using standard lapse rate further supports this explanation. 15-17th of January the stability was mostly neutral to unstable compared to 18-19th January when the stratification clearly is more stable (not shown here).

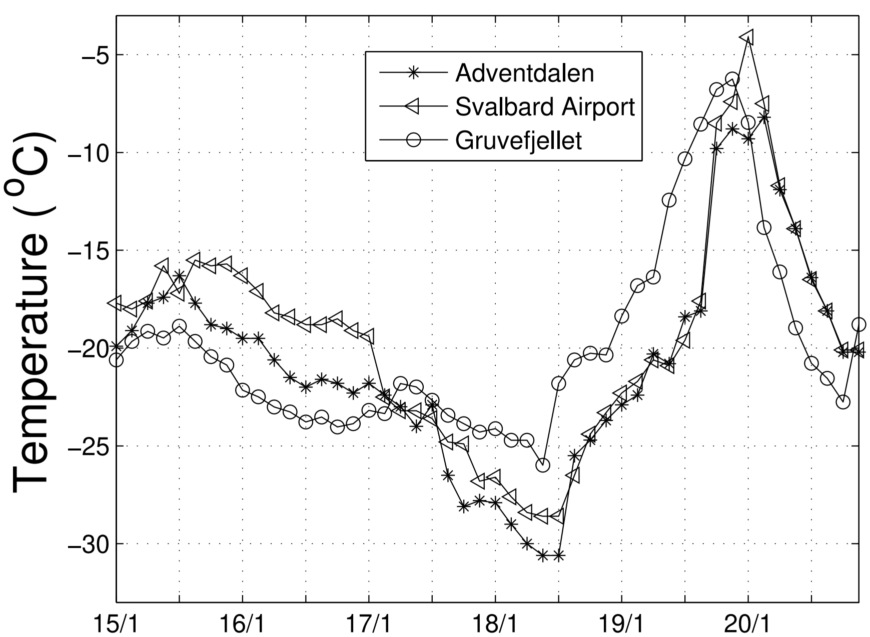


Figure 22 *Temperatures (°C) at Adventdalen, Svalbard Airport and Gruvefjellet 15-19th of January 2004.*

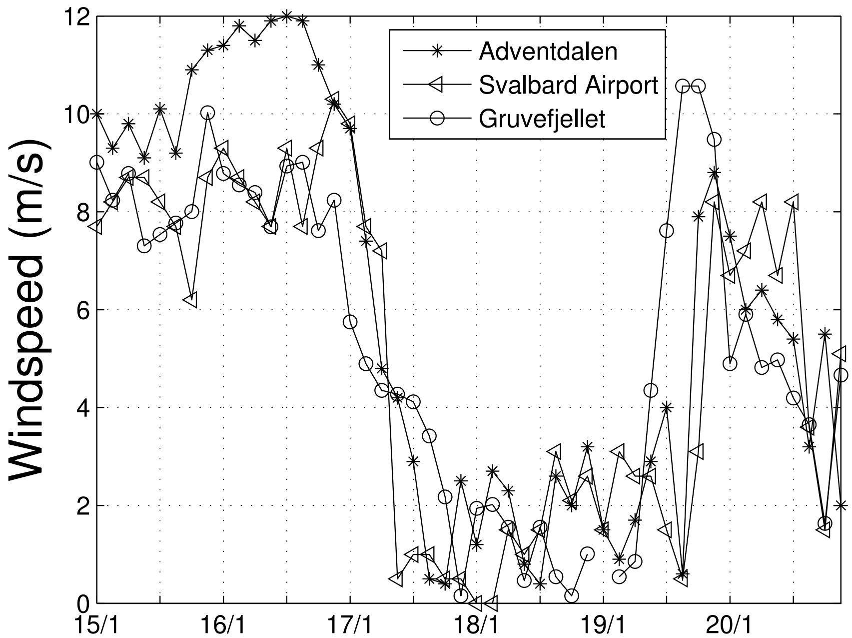


Figure 23 *Wind Speed (m/s) at Adventdalen, Svalbard Airport and Gruvefjellet 15-19[th] of January 2004.*

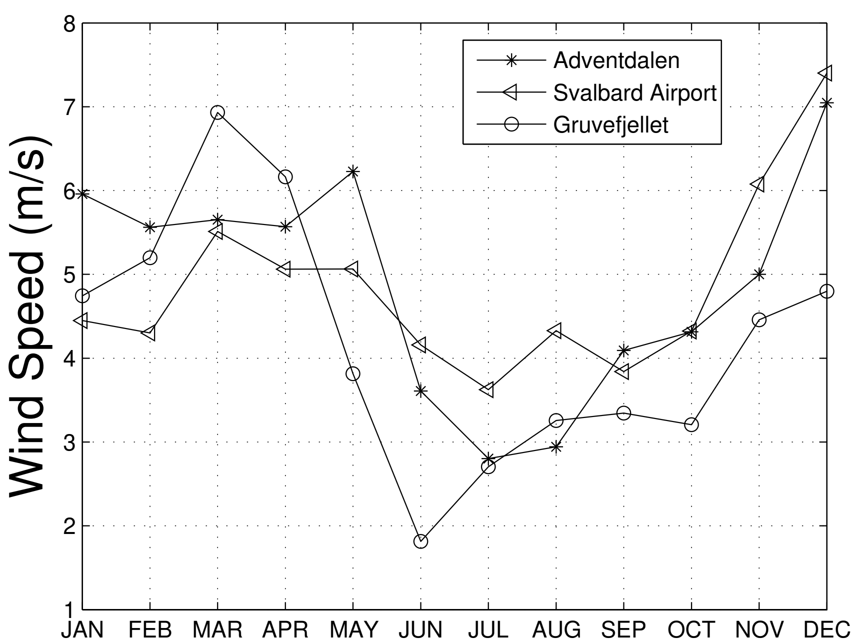


Figure 24 *Average monthly wind speed (m/s) at Adventdalen, Svalbard Airport and Gruvefjellet during year 2004.*

4.1.4.2 Wind

The wind direction (not show here) in Adventdalen is clearly dominated by flow in a south easterly direction. Svalbard Airport, close to the coast, proves to be influenced by winds from other directions as well, although the largest contribution, like at Adventdalen, is south easterly winds. The station at Gruvefjellet experiences wind from all directions due to less topographic influence, but like the other two stations the most common wind direction is from a south easterly direction. The wind speed is often high during winter and spring as illustrated in figure 24 where the average monthly wind speed for the three stations is presented. The similarity is a decrease in wind speed during summer at all locations. Though the Airport has higher wind speed during June until August due to sea breeze circulation with an average of 4.1 m/s compared to Adventdalen 3.1 m/s and Gruvefjellet 2.6 m/s. The maximum wind speed at the Airport during the summer was 14.9 m/s. From September until December Gruvefjellet has a lower average wind speed than both Adventdalen and Svalbard Airport. The air is chilled at that altitude and due to gravity it flows down hill causing the higher wind speeds in the valley and also at the Airport.

To summarize the general weather situation at the three stations; all have similarities but also differences. Adventdalen is due to its low placement above sea level more exposed to temperature inversions, which also leads to a larger temperature variation. Due to its placement in a valley there is also a channelling effect of the winds that travel down into the valley bringing cold more dense air during winter and spring from higher elevations.

Svalbard Airport in many ways shows the same tendency in temperature and wind speed and wind direction as in Adventdalen, though the average wind speed is somewhat lower. During summer, sea breeze situations do occur and the wind speed is then higher than at the other locations bringing cooler air ashore thereby lowering the temperature.

At Gruvefjellet there is a significant cooling of the ground leading to low temperatures. The mountain is less influenced by topography than Adventdalen and Svalbard Airport, but winds travelled over large areas of glaciers contribute to the low temperatures.

During 2004 the coldest place is Gruvefjellet with a mean value of -6.2 °C, while the Airport is the mildest place with an average of -5.0 °C and Adventdalen -5.6 °C. However, looking at the mean temperatures through longer periods (table 2) Adventdalen is the mildest place, with an average of -4.1°C. An explanation could be if an even longer period had been used when calculating the average temperature at Adventdalen, a lower value would have been received during e.g. 2006 when the fjord never froze, which partly affects the valley, but of course mostly the Airport. So if data where used at the Airport from the same years as Adventdalen, the valley would probably have been the colder place. Both Adventdalen and the Airport are in average windier than Gruvefjellet. In the valley the channelling effects contribute to this result. At the Airport the cause is a combination of channelled winds from the valley and sea breeze circulation during summer.

4.2 Instrumental Comparison

As described earlier in section 1.2, three stations were placed at nearly the same place in Adventdalen close to Longyearbyen in Svalbard during four days in October 2006. An overview of temperature, relative humidity, wind speed, wind direction and pressure for the period is given in Appendix. The three stations were:
Station A – the stationary Aanderaa station.
Station B – the temporary Aanderaa station.
Station C – the temporary Campbell station.

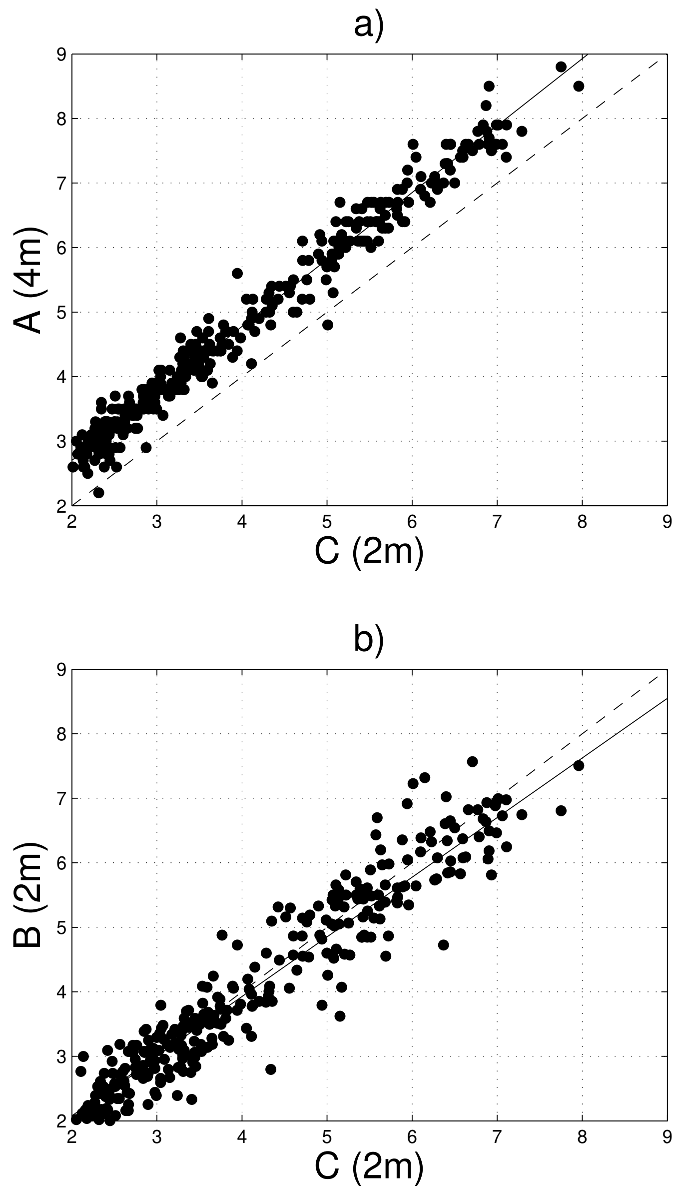
4.2.1 Wind

Station A (which is the same as Adventdalen in the previous section) measured wind speed at around 4 m, station B at about 2 m, 5 m and 10 m and station C at approximately 2 m.
The mean windspeed at the stations are presented in table 5. Station A (Adventdalen) has the highest average wind speed with 4.8 m/s at 4 m height, while the lowest is 3.4 m/s at 2 m height registered at station B.

Table 5 *Average wind speed (m/s) from station A, B and C at different measurement heights.*

Measurement height (m)	A	B	C
2	-	3.4	4.0
4	4.8	-	-
5	-	4.1	-
10	-	4.3	-

Figure 25 shows the relationship in windspeed between A (Adventdalen), B and C. The comparison between A (Adventdalen) and C is seen in 25a, with a correlation coefficient 0.99. The scattering is very small, just a few values deviates, and since station A (Adventdalen) measured the wind speed 2 m higher than C, the values are higher. Looking at B and C, which measured the wind speed at the same height (figure 25b) the scatter is relatively small with a correlation coefficient 0.96, though the scatter is somewhat larger than between A (Adventdalen) and C. The comparison between the Aanderaa stations A (Adventdalen) and B the correlation coefficient is 0.95 and the scatter is small and similar to the scatter between B and C (figure 25c).


a)
A (4m)
C (2m)
b)
B (2m)
C (2m)

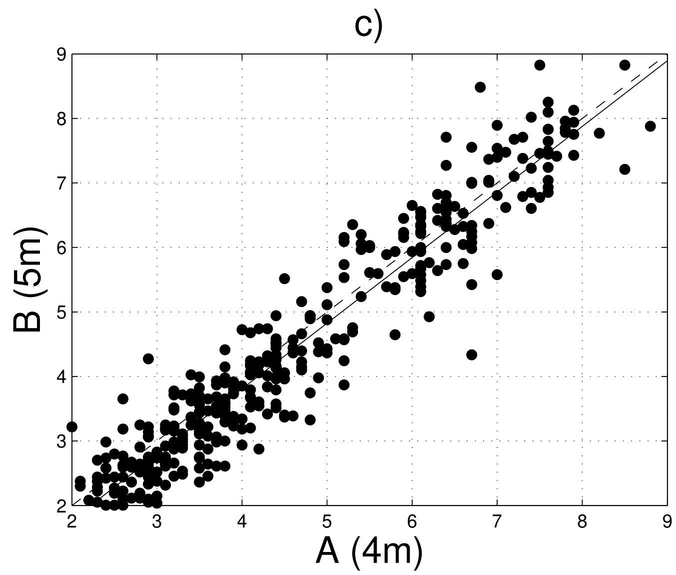


Figure 25 Relation between average wind speed (m/s) at a) A and C, b) B and C and c) B and A. Instrument heights in brackets. Solid line equals regression line and a dashed line 1:1.

In table 6 one can see that the winddirection do not differ very much between the three stations. Station C shows a 10° lower value than both A (Adventdalen) and B which both show 130°. The main wind direction throughout the whole period is south easterly, i.e. along Adventdalen towards the fjord.

Table 6 *Average Wind direction (°) at station A (Adventdalen), B and C.*

Measurement height (m)	A	B	C
2	-	-	120
4	130	-	-
10	-	130	-

4.2.2 Air temperature and relative humidity

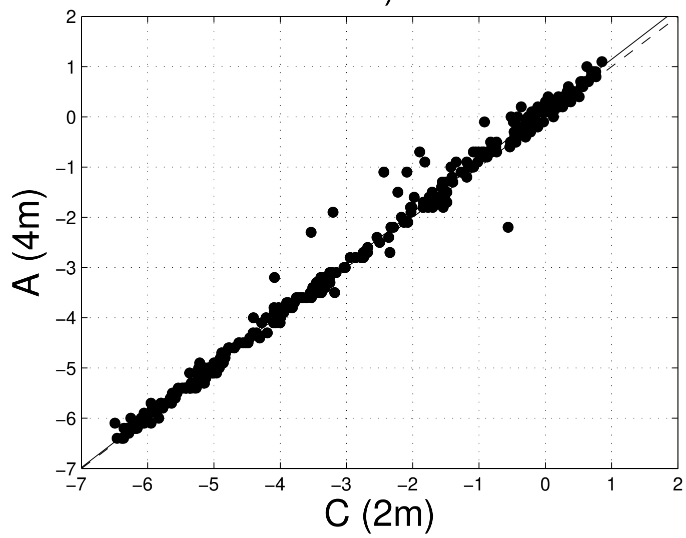
The mean temperature and absolute minimum and maximum temperatures for the three stations is presented in table 7.

Table 7 *Average, absolute maximum and minimum temperatures (°C) at stations A (Adventdalen), B and C.*

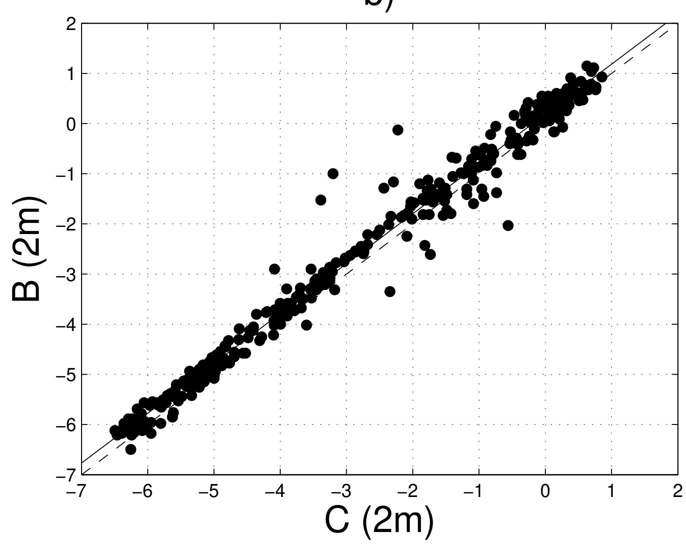
Measurement height (m)	A mean	A max	A min	B mean	B max	B min	C mean	C max	C min
2	-	-	-	-2.8	1.3	-6.3	-3.0	0.9	-6.5
4	-3.0	1.1	-6.4	-	-	-	-	-	-
5	-	-	-	-2.7	1.3	-6.5	-	-	-
10	-	-	-	-2.7	1.5	-6.3	-	-	-

In figure 26 one can see the relation for the temperature between the stations. Correlation coefficient is close to 1.0 for all stations when compared to each other. Just a few values at each comparison deviates.

a)



b)



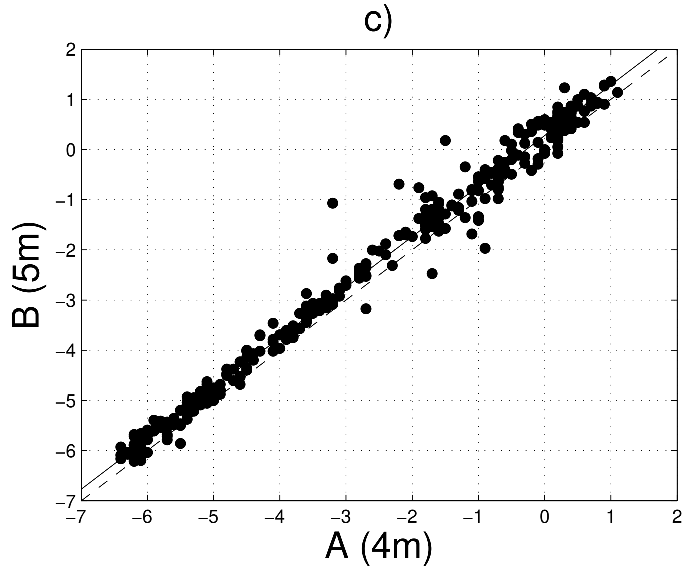
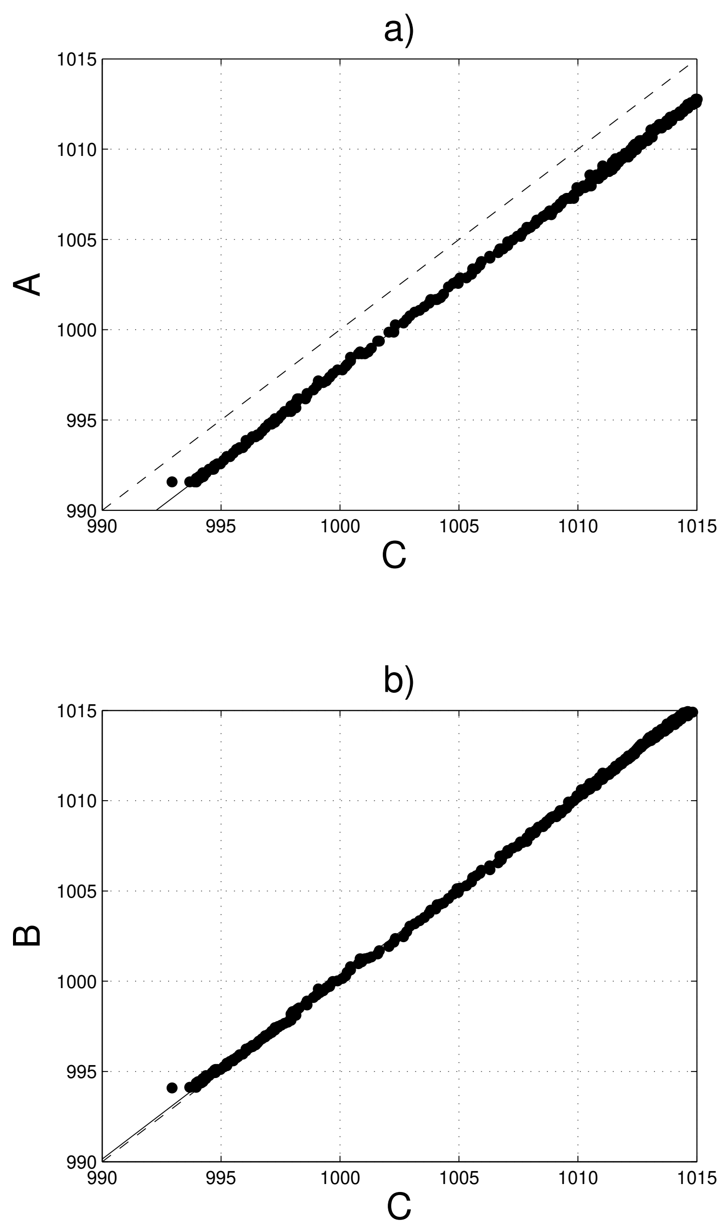


Figure 26 *Relation for average temperature (°C) for a) station A* (Adventdalen) *and C, b) B and C and c) B and A . Instrument heights in brackets. Solid line equals regression line and a dashed line 1:1.*

During most of the period the relative humidity is higher at station B (not shown here). The highest value at station B was 102.4 % which of course implies that the instrument show higher values than it should. Station B then becomes of less importance since the values can not be true. Looking at station A (Adventdalen) and C, the former one always show a lower value (4 m) than C (2 m) with correlation coefficient 0.98.

4.2.3 Air pressure

In figure 27 the relation in sea level pressure between the stations shows well correlated data. Only one value between A (Adventdalen) and C (figure 27a) and between B and C (figure 27b) deviates. The pressure is especially well compared between station B and C as seen in figure 27b. Correlation coefficients for all comparisons are close to 1. However, looking at figure 27a and 27c there seems to be an offset at station A (Adventdalen), which shows lower pressure than both the other stations. Both station B and C, which only operated during a short period, was calibrated before use. They are therefore expected to show correct pressure especially since they are well correlated as seen in figure 27b. It is then obviously that there is a constant offset error at station A (Adventdalen), which a calibration of the sensor most likely would correct.


a)
A
C
990
995
1000
1005
1010
1015
b)
B
C
990
995
1000
1005
1010
1015

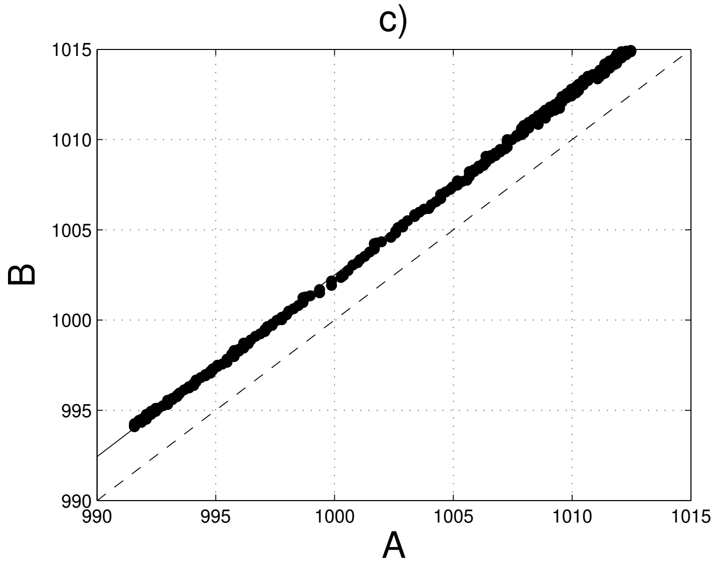


Figure 27 *The relation in sea level pressure between a) station A (Adventdalen) and C, b) B and C and c) B and A . Solid line equals regression line and a dashed line 1:1.*

In summary the stations all show well correlated data in wind speed, wind direction and temperature. Looking at pressure it is obvious that the pressure sensor station A (Adventdalen) is in need of calibration, since it is always presents a lower value.

4.3 A Case Study of Breinosa and Adventdalen

The two weather stations, Breinosa and Adventdalen (described in section 3.1), are used for the case study between 16th December 2005 and 12th January 2006. The station at Breinosa is located at approximately 500 m a.s.l. and Adventdalen approximately 20 m a.s.l.

4.3.1 Breinosa

The temperature at Breinosa varied between -19.6°C (2nd January 2006) and -1.4°C (8th January 2006) with a mean temperature -9.5 °C (table 8). The cold temperatures are expected both depending on the season (winter) and high altitude. The wind direction (figure 28) was very changeable with winds from all directions, but with a main direction from south to southwest. Since the station is very exposed at the high elevation the wind speed was high with a maximum of 16.7 m/s and an average speed 5.0 m/s (table 9).

Table 8 *Average, absolute maximum and minimum temperatures (°C) at Adventdalen and Breinosa.*

STATION NAME	Average Temperature (°C)	Maximum Temperature (°C)	Minimum Temperature (°C)
Breinosa	-9.5	-1.4	-19.6
Adventdalen	-6.3	+ 4.7	-22.3

Table 9 *Average and absolute maximum wind speed (m/s) at Adventdalen and Breinosa.*

STATION NAME	**Average Wind Speed (m/s)**	**Maximum Wind Speed (m/s)**
Breinosa	5.0	16.7
Adventdalen	5.6	18.5

4.3.2 Adventdalen

The temperature varied, as seen in table 9, between -22.3°C (18th December 2005) and +4.7°C (6th January 2006) with the mean temperature of -6.3°C. The wind direction (figure 28) was variable, but most often south easterly along the valley. The wind speed reached a maximum of 18.5 m/s and the average speed was 5.6 m/s (table 9).

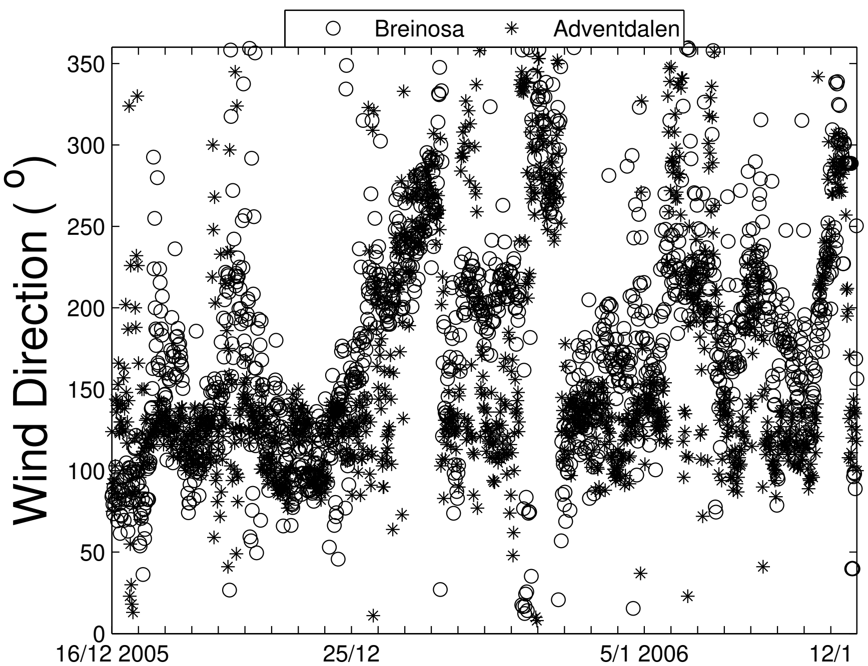


Figure 28 *The wind direction (°) at Breinosa and Adventdalen during 16th of December2005 until 12th January 2006.*

4.3.3 Comparison

Breinosa and Adventdalen are influenced by different local effects, some which are shown below.

4.3.3.1 Temperature

In figure 29 the air temperature at Adventdalen and Breinosa 16th December 2005 until 12th January 2006 is presented. The coldest and warmest temperature is registered at Adventdalen (table 8). In figure 30 the relation in temperature between Breinosa and Adventdalen is presented. Most often the temperature at the mountain is colder. A manually fitted line to figure 30 shows that there is a offset approximately around 5°C between the locations. There are some exceptions when the temperature is coldest in the valley. During most of those periods the wind speed is somewhat lower in the valley, which again results in a more favourable situation for temperature inversions to develop.

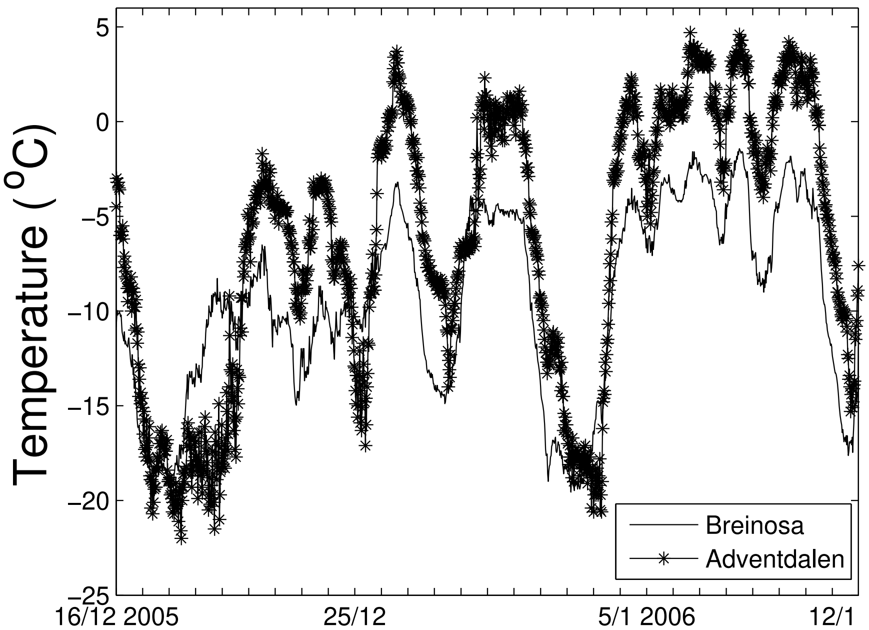


Figure 29 *The air temperature (°C) at Breinosa and Adventdalen during 16th of December2005 until 12th January 2006.*

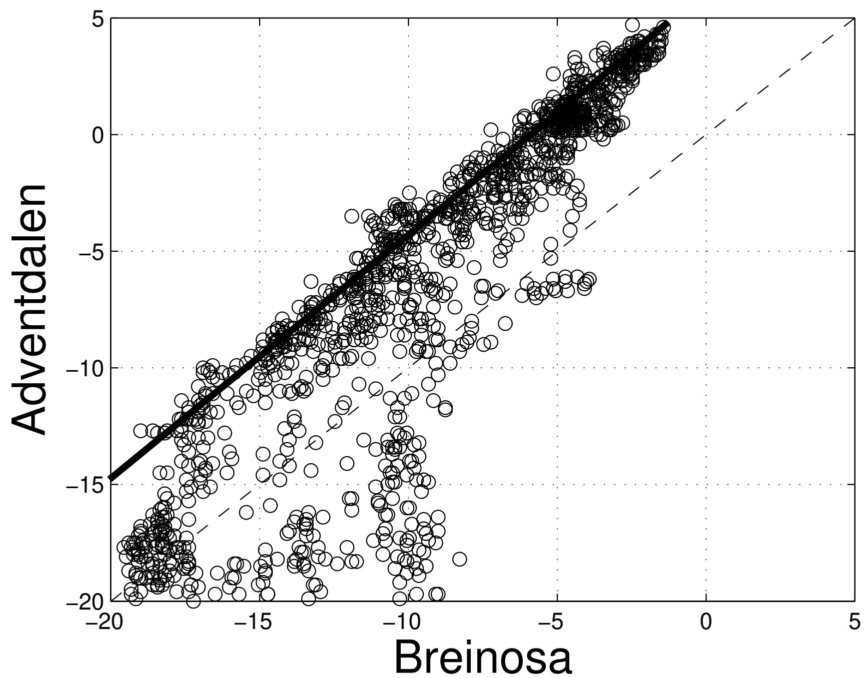


Figure 30 *The relation in temperature (°C) at Breinosa and Adventdalen during 16th of December 2005 until 12th of January 2006. Solid line equals a manually fitted line and dashed line 1:1.*

A closer look at the temperature differences between the stations is to be seen in an example between 7th and 12th of January 2006 in figure 31. When the temperature at Breinosa changes, the temperature in the valley tends to follow. One could imagine the cold flow down from the higher altitude contributes to this effect and one can se a small delay in the valley temperature.

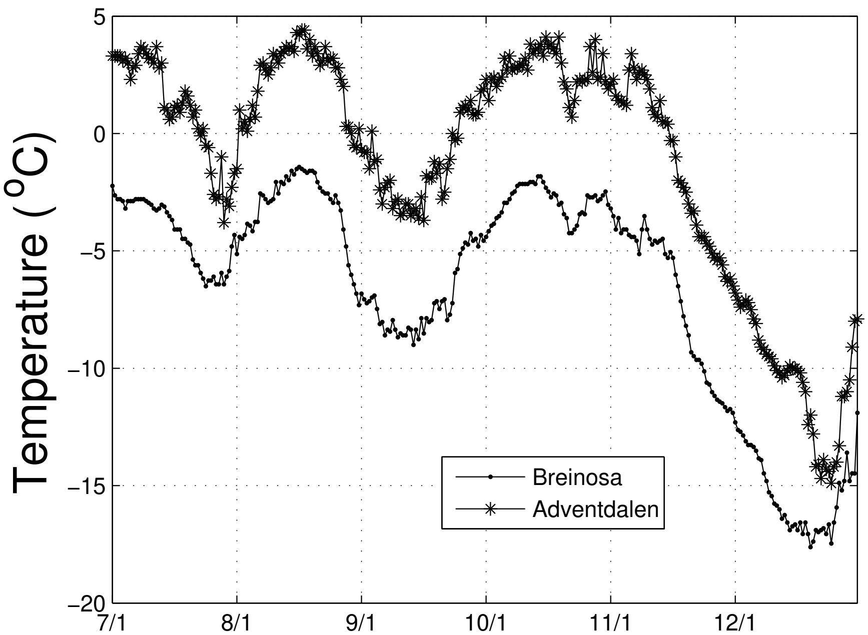


Figure 31 *Temperature during 7/1 until 12/1 2006 at Adventdalen and Breinosa.*

4.3.3.1 Wind

Often the measured wind speed in the valley is just as high as at Breinosa (figure 32). Both locations are rather windy with measured maximum wind speeds close to 20 m/s and an average speed around 5 m/s (table 9). While Breinosa often experience wind from all directions, Adventdalen, as expected, receives wind mostly from a south easterly direction i.e. in the same direction as the valley (figure 28). The winds aloft are channelled down into the valley, causing a larger wind speed than otherwise expected close to the surface. It is likely that both pressure driven, forced channelling and sinking of dense cold air combined are contributing to this effect. In figure 33 the relation in wind speed between the valley and the mountain is presented. The scatter is very large and at higher wind speeds Breinosa somewhat dominates as being the more windy location.

In summary the temperature is lower at Breinosa when no strong temperature inversion has developed in the valley. The temperature in the valley tends to follow the temperature on the mountain due to the cold dense air which flows down the mountain into the valley. Both locations experiences high wind speeds, with a mean around 5 m/s. High wind speed in the valley depends on the winds aloft, which are channelled down into the valley. Wind direction is variable at Breinosa, while rather uniform along the valley.

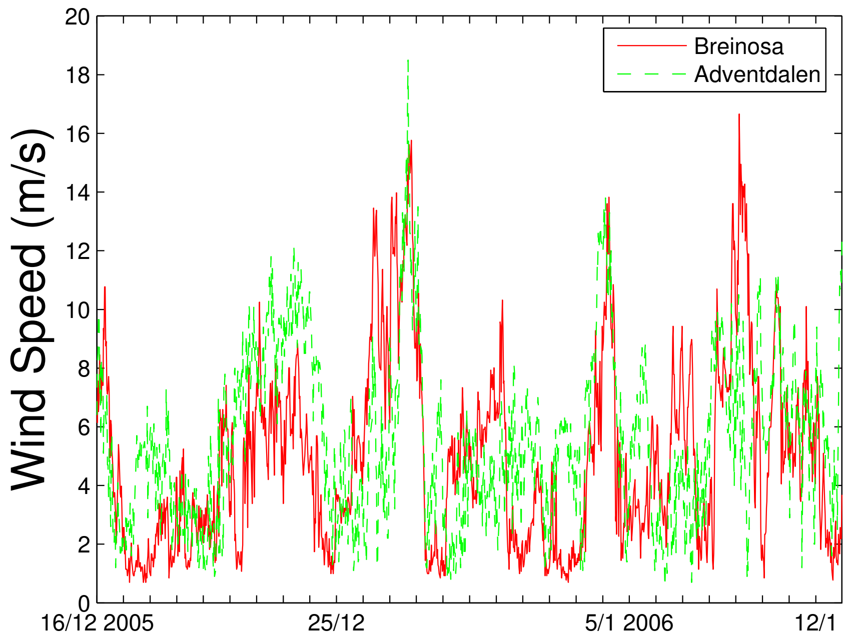


Figure 32 *The wind speed (m/s) at Breinosa and Adventdalen during 16th of December2005 until 12th January 2006.*

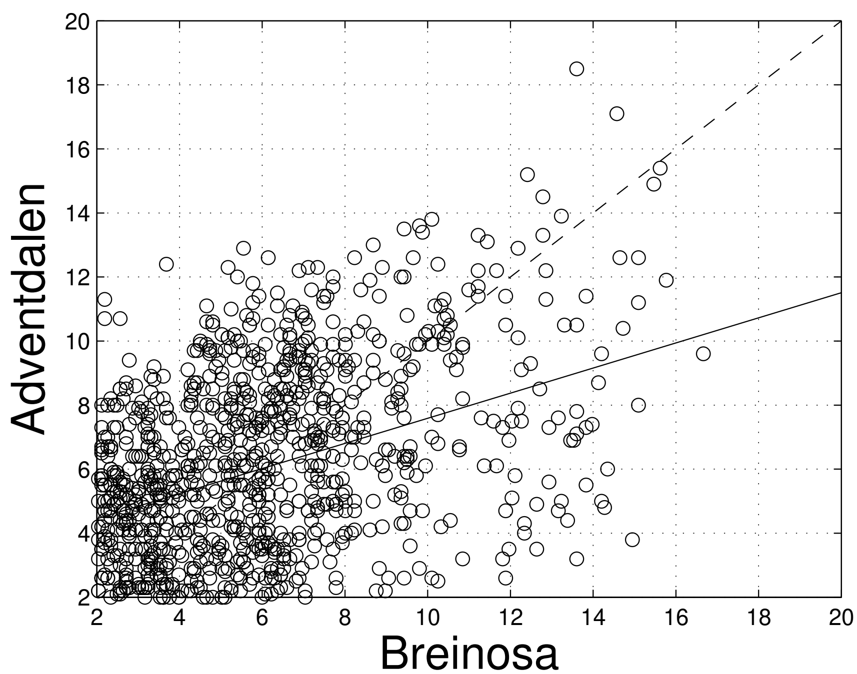


Figure 33 *The relation in wind speed (m/s) at Breinosa and Adventdalen during 16th of December 2005 until 12th of January 2006. Solid line equals regression line and a dashed line 1:1.*

5. Discussion and Conclusions

This thesis contains three different studies; analysis of general weather situation at three stations (section 4.1); an instrumental comparison (section 4.2) and case study of data from a station on the mountain Breinosa compared to the station in the valley beneath (section 4.3).

The temperatures clearly vary more during winter than summer. This was expected since the temperature gradient between the poles and equator during winter at Northern hemisphere is larger. Furthermore the cyclones tend to travel further north, which means that Svalbard among other places experience more variable temperatures those periods. Combined with the temperature difference is the pressure gradient between the poles and the equator. This leads to an increase in wind speed and this is noticeable when looking at the Adventdalen, Svalbard Airport and Gruvefjellet. The low location of Adventdalen above sea level leads to more frequent temperature inversions especially when the fjord is frozen.

The wind direction in Adventdalen is mainly south easterly and thus channelled through the valley, causing a fairly high wind speed (average 5.1 m/s). The average wind speed at Gruvefjellet is 3.9 m/s, which is the lowest wind speed compared to Adventdalen and Svalbard Airport (4.8 m/s). The Airport is highly influenced of the wind direction from Adventdalen, but there is, especially summertime, also an influence of sea breeze circulation with winds blowing from the water side towards land. It is also during summer when the Airport has higher wind speed than Adventdalen and Gruvefjellet.

Gruvefjellet is the less influenced by topography among the three stations. With its higher position it is less affected by the surroundings and has low temperatures due to the temperature decrease with height. The temperature is (most often) mildest at Svalbard Airport, which experiences a more maritime weather. As earlier discussed the wind during winter often travels over large areas with glaciers and is channelled down into Adventdalen and further to the Airport, with an average temperature rather low (-5.1 °C). In the valley the average is -4.1°C, but a comparison during year 2004 (section 4.1.4), Adventdalen showed a colder value (-5.6°C) than the Airport (-5.0°C). A likely reason is that the years used at Adventdalen (2004-2006) for the general comparison were in general milder at both locations than the years chosen at the Airport (1994-2004). E.g. in the winter 2006 the fjord never froze, which would influenced the Airport even more than Adventdalen.

The measurements from Breinosa (section 4.3) are of too short time to be used when discussing the general weather. Although it is likely to believe that there is a connection between the temperature in the valley and at the mountain. The temperature in the valley tends to follow the changes in temperature on the mountain. Cold air flows down into the valley lowering the temperature. The wind speed is often just as high in the valley as up on the mountain due to a combination of gap winds and forced channelling effects.

The instrumental comparison (section 4.2) showed that it is of importance to calibrate the sensors regularly. Among the stations it is the two temporary stations, B and C, which are most reliable since they, unlike the stationary station A (Adventdalen), were calibrated more recently. The wind direction, which clearly is dominated by the south easterly direction of the valley, does not differ more than 10° at the most, which could just be an error during installation. The correlation, when looking at wind speed and temperature, show rather well correlated data with some scattering. The air pressure at station A (Adventdalen) differs with several units compared to B and C, which almost show the same values during the period. Station A (Adventdalen) record a lower pressure, but not at a constant rate, all along the measuring period. Different measurement height has made the comparison somewhat difficult and it would be of interest to have longer periods of data, especially from the same heights, for a more accurate comparison. The pressure sensor at station A (Adventdalen) is recommended to be calibrated or even exchanged.

To conclude, the topography highly contributes to channelling effects causing higher wind speeds near ground (Adventdalen and Svalbard Airport) than at higher altitudes (Gruvefjellet). An ice covered fjord will lead to a more continental climate, while open water is favourable for e.g. sea breeze circulation (Svalbard Airport). The boundary layer is most often stable during winter and spring leading to more frequent temperature inversions and thus lower temperatures (Adventdalen). During summer the sensible heating becomes stronger when the snow melts and the frequency of inversions decline.

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To my near and dear ones, this work would never have been finished if you had not believed in me. Erik, your visit brought gold into my life.

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Appendix

Figures from the instrumental comparison period 4th October 2006 until 7th October showing air temperature, relative humidity, wind speed, wind direction and air pressure**.**

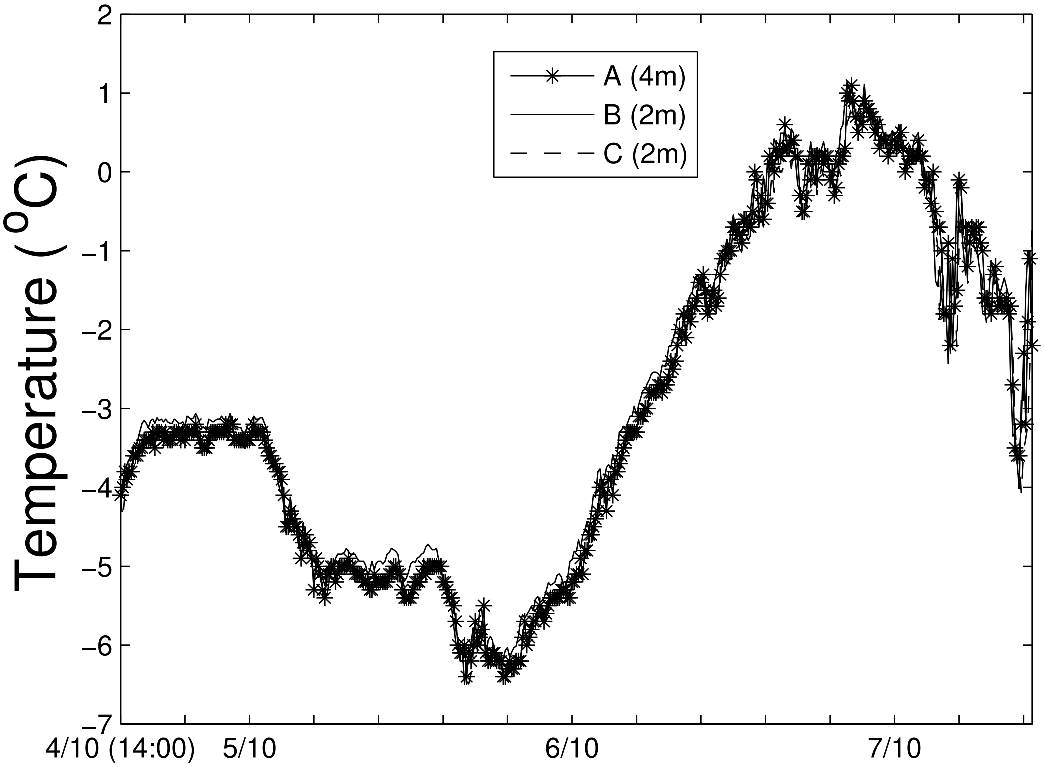

Figure A.1 *The air temperature (°C) at station A, B and C during 14:00 4th of October until 13:00 7th of October 2006. The heights in the legend are the height of the sensor at each station.*

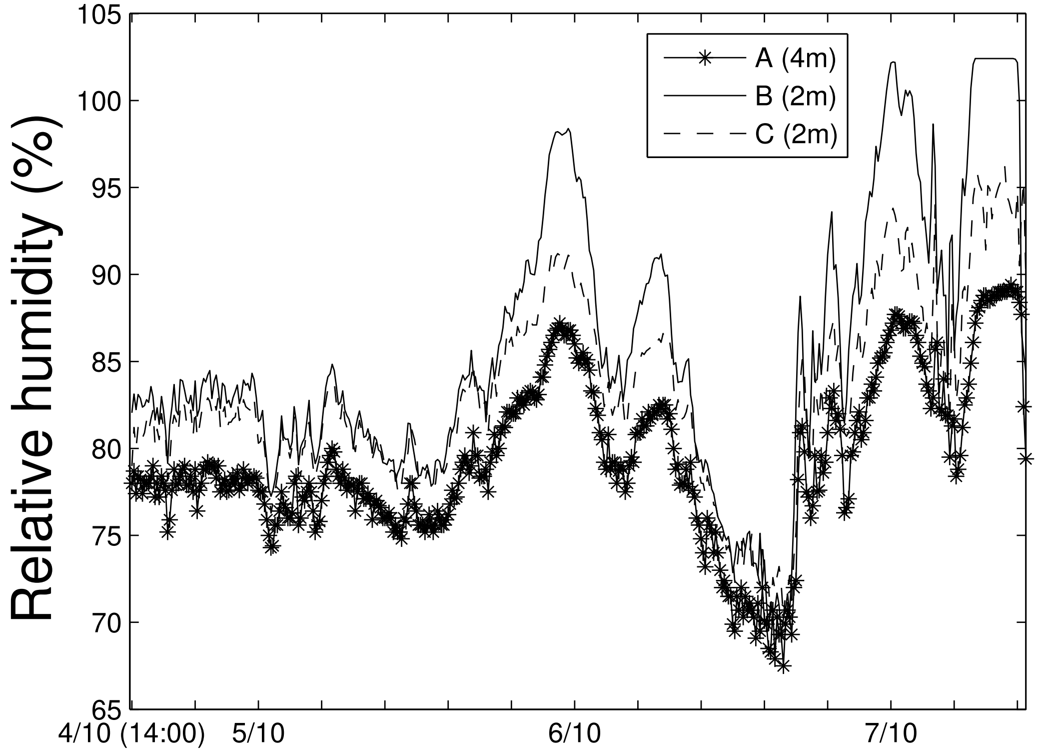

Figure A.2 *The relative humidity (%) at station A, B and C during 14:00 4th of October until 13:00 7th of October 2006. The heights in the legend are the height of the sensor at each station.*

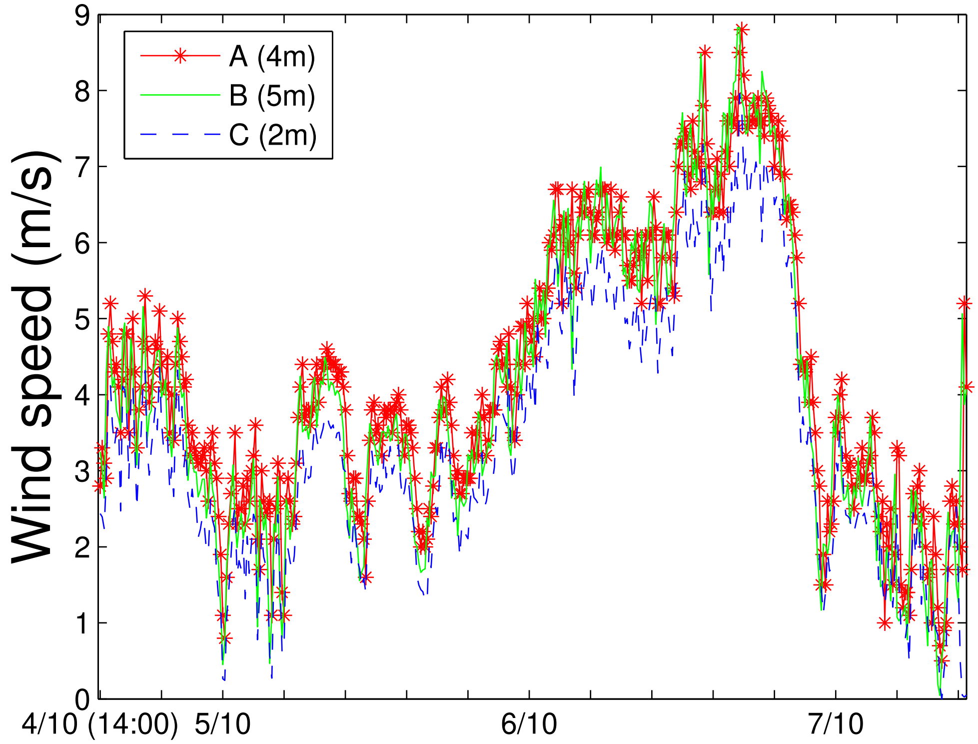

Figure A.3 *The wind speed (m/s) at station A, B and C during 14:00 4th of October until 13:00 7th of October 2006. The heights in the legend are the height of the sensor at each station.*

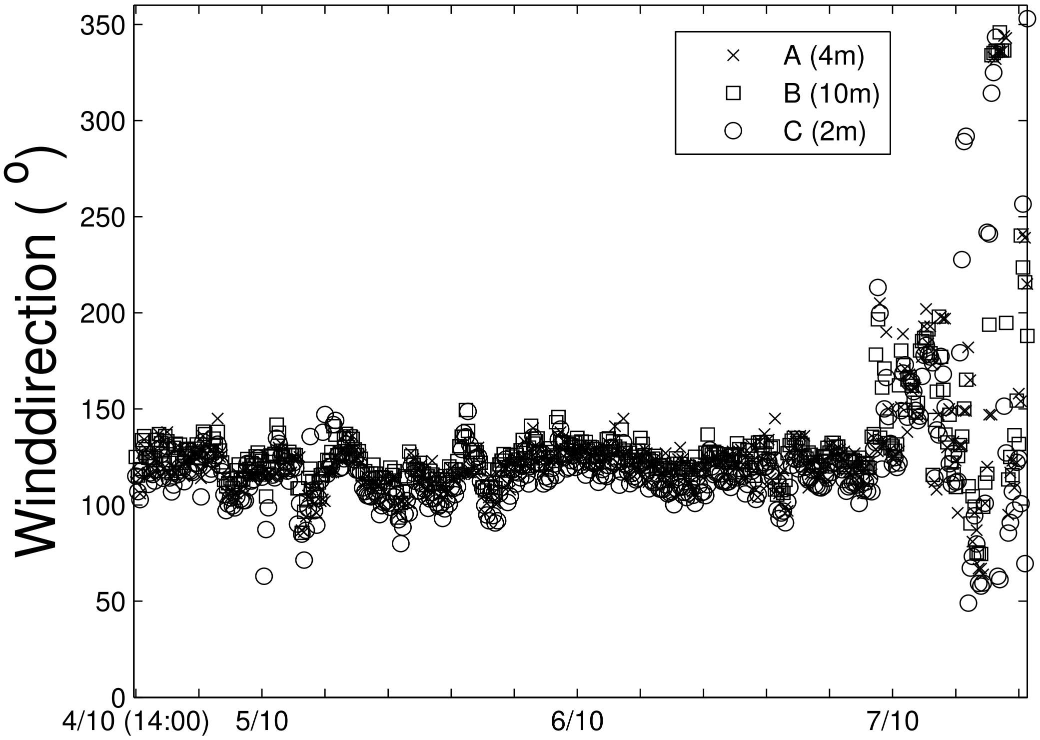

Figure A.4 *The wind direction (°) at station A, B and C during 14:00 4th of October until 13:00 7th of October 2006. The heights in the legend are the height of the sensor at each station.*

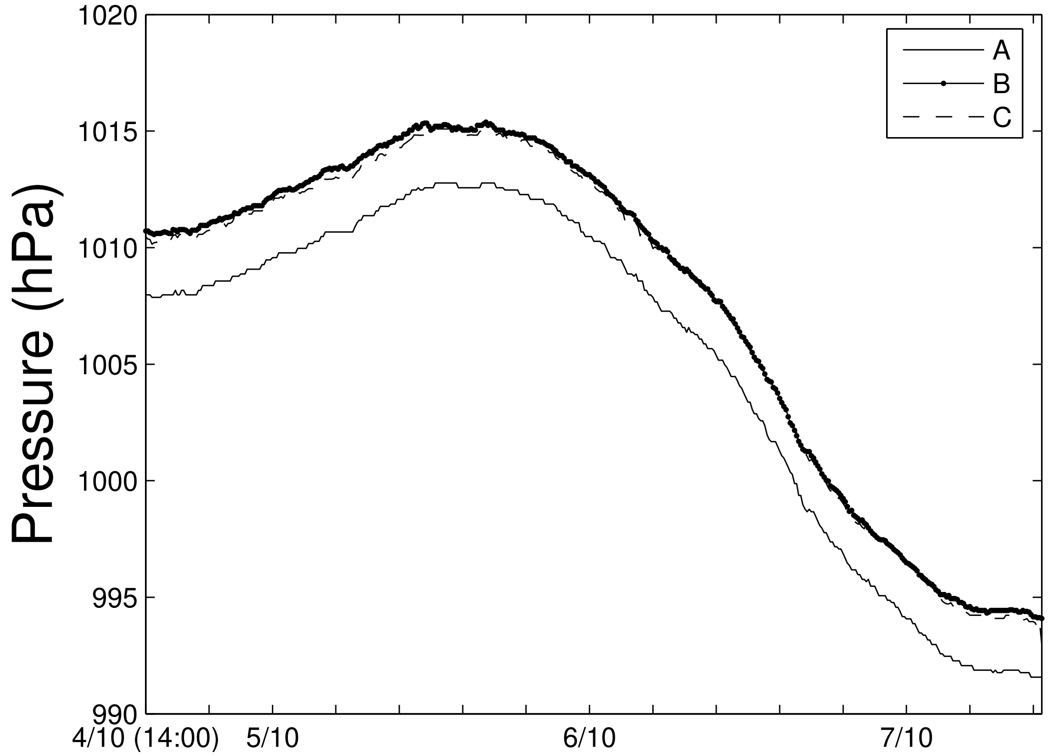

Figure A.5 *The sea level air pressure (hPa) at station A, B and C during 14:00 4th of October until 13:00 7th of October 2006.*