3. ALTERNATIVES TO PROPOSED ACTIVITY

Several alternative locations and designs have been examined for the construction of the new station, taking into account scientific, environmental, logistical, engineering, health and safety requirements.

3.1. Do not go alternative

The Belgian Science Policy, guided by the conclusions of the Evaluation panel of foreign Experts ('The Belgian Antarctic Programme 1985-2002: findings of the evaluation panel, final report') takes the view that there are compelling scientific and logistical grounds for the construction of a new station.

With the construction of Base Roi Baudouin on a floating ice shelf near the Breid Bay Polynia in 1958 at the occasion of the IGY, Belgium joined a number of countries (Norway, Japan, South Africa and Russia) in opening this part of Eastern Antarctica (Dronning Maud Land) for exploration and scientific research. Conceptually these expeditions followed the footsteps of the famous Norwegian-British-Swedish Antarctic Expedition (1949-1952) at Maudheim (71°03'S; 010°55'W) which pioneered modern scientific research and international collaboration in Antarctica. After the withdrawal of Belgium in 1967 and the closing of the Roi Baudouin base, its role was temporarily taken over by Japan with the establishment of Asuka Station (1986-1992). Although this station was situated 122 km inland from the Belgian station, the Breid Bay Polynia was still used as access area to this part of the Southern continent. With the closing of Asuka station in 1992, the 20-30 degrees east sector of Antarctica became again a vast territory having witnessed up to now only brief periods of systematic investigation.

In 1985 Belgium resumed its scientific activities with emphasis on Antarctica's role in the earth system. Since then Belgian research projects have been run for many years in conjunction with other National Operators, usually based at their facilities and utilizing their logistics. Although this situation led to a number of important and sustainable collaborations with other countries, this was not a comfortable situation as Belgium could not give an adequate return for the support, while it limited the areas of research to those of the host countries.

With the realisation of the DROMLAN Network an instrument became available for multiple visits to Dronning Maud land during the summer season and to optimize the use of a scientific platform in this region. Making use of modern technology to reduce energy consumption and waste disposal as well as technical staff, Belgium decided to offer to the international scientific community a new state of the art Antarctic research station allowing geophysical monitoring and field research in an area where the closest permanent research stations are situated at a distance of 684 km (Syowa) and 431 km (Novolazarevskaya). With the realisation of this new research station Belgium also wants to take up its full responsibilities with respect to environmental monitoring and protection of Antarctica.

It is very unlikely that there will be increased activity by the Belgian scientific research community if the project does not happen. The use of existing research stations, such as Novolazarevskaya and Syowa, could be an option, but the distance of these facilities from the proposed area of research would implicate a greater use of flight or over-snow vehicles to gain access to research sites. The proposed technologically advanced station, benefiting from modern efficient and low energy technologies, will likely have no more impact than using existing facilities.

Belgium considers this decision in line with its position as one of the original signatories of the Antarctic Treaty. The "Do not go alternative" is considered as opposed to the philosophy of growing importance of Antarctica's key role in Global Change and increased concern about the state of its environment.

3.2. Alternative locations

Next to the Utsteinen Nunatak site (see **Section 2.2.1**), several other possible construction sites were identified from aerial photographs and surveyed during the Belare 2004 expedition (**Fig. 3.1**):

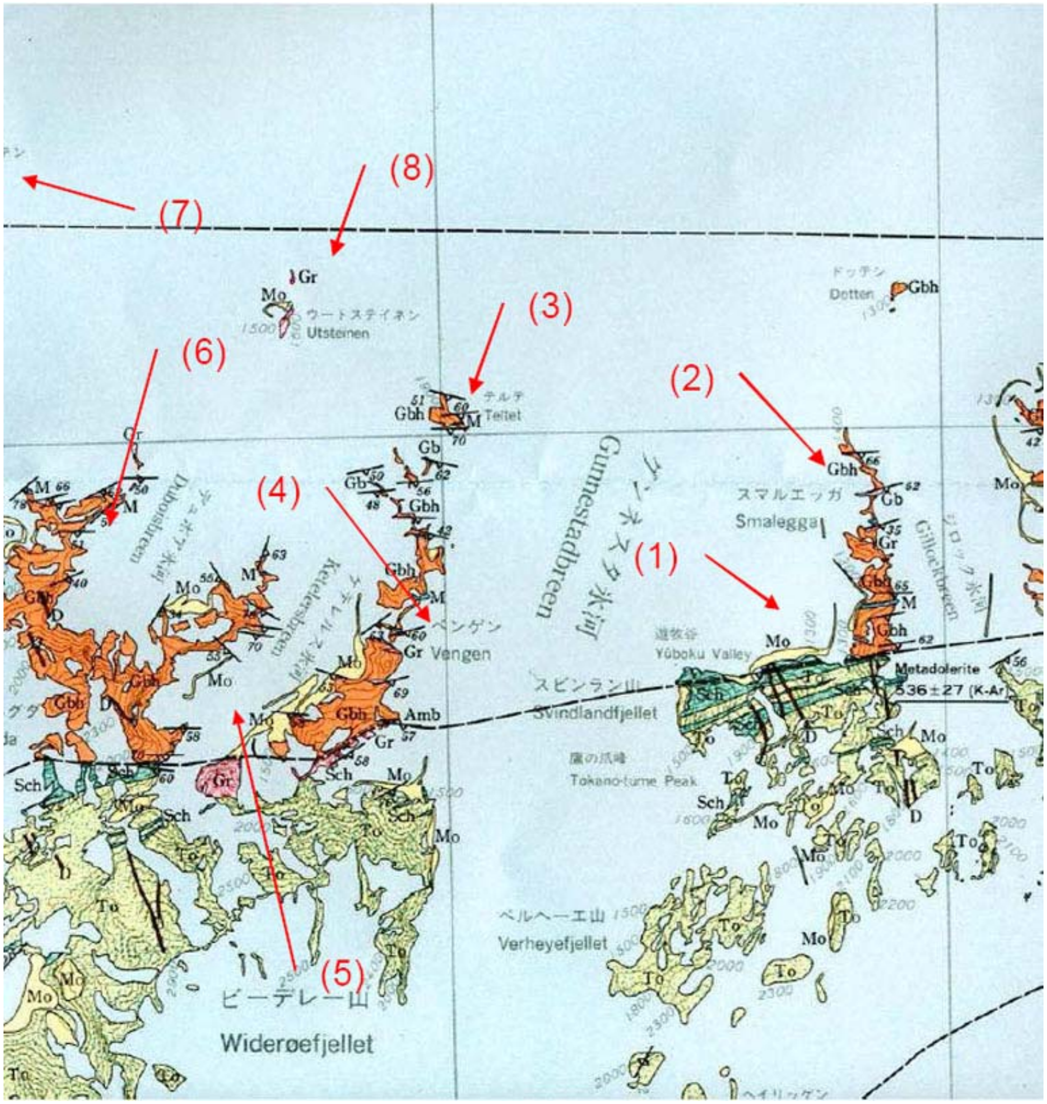

Fig. 3.1: Part of the geological map in the vicinity of Utsteinen, with Gunnestadbreen lying in the central and giving access to the polar plateau. Overview of the alternative sites and Utsteinen:
(1) Jan Valley - Southern Smalegga; (2) Northern part of Smalegga; (3) Teltet; (4) Vengen - South of Teltet; (5) Valleys inside the mountain range; (6) Northern part of Vikinghøgda; (7) Pingvinane; (8) Utsteinen.
(Source: NIPR, Tokyo, Japan, 1997)

Jan Valley

Situated in southern Smalegga it is the most eastern site visited, lying protected from the wind within a small valley. Some supraglacial lakes are present but frozen over early in the season (as is the case with Utsteinen). There is no exposed and flat bedrock in the vicinity, only moraines and ice-cored moraines. The site is more protected than Utsteinen from the wind, but the wind direction changes frequently. The latter prevents the use of wind as an energy source for the station. Accessibility is more difficult, as the ice is sloping and very slippery and dispersed rocks are found; there is a good access for small aircraft.

Vengen
Situated south of Teltet; a small ridge of exposed bedrock was present. Access is more difficult due the presence of large wind scoops. Wind direction varies frequently and gusts are quite common. The ridge is very small and cannot sustain large building facilities.

Northern part of Vikinghøgda
This site consists of a flat surface of exposed bedrock and is easy accessible. The site has one major inconvenience, i.e. the snow surface surrounding the site is an erosional surface (with a lot of sastrugi). The latter hampers the use of snow for water production. The erosional surface also points to major action of katabatic winds and wind gusts in particular.

Other valleys
Valleys that are within the mountain range suffer from similar problems to those encountered with the sites at Jan Valley or Vengen, i.e. poor accessibility and the lack of exposed bedrock (and not moraine). Another factor remains the lack of wind for energy use through summer.

Analysis of the alternative sites indicates that substantially more work will be required to construct a station, consequentially, there is likely to be a greater environmental impact during construction and possibly during operation. The alternative locations for the site of the new station have been rejected because there are no scientific, operational or environmental benefits.

3.3. Alternative designs/technologies

Within the design constraints outlined in **Section 2.4**, several designs for the station were considered. Each design was evaluated for environmental effect, logistic implications for construction and operation, decommissioning and ability to meet the planned scientific programme. In order to evaluate alternative design proposals a number of key parameters were used (see also **Section 2.4.2:** Station design):

1. Accessibility for construction
2. Anchoring conditions
3. Orientation versus prevailing wind
4. Orientation versus sun
5. Compactness
6. Energy efficiency
7. Accessibility operational
8. Expected snow accumulation
9. Compatibility with program

In the process a weighted trade-off table was used.

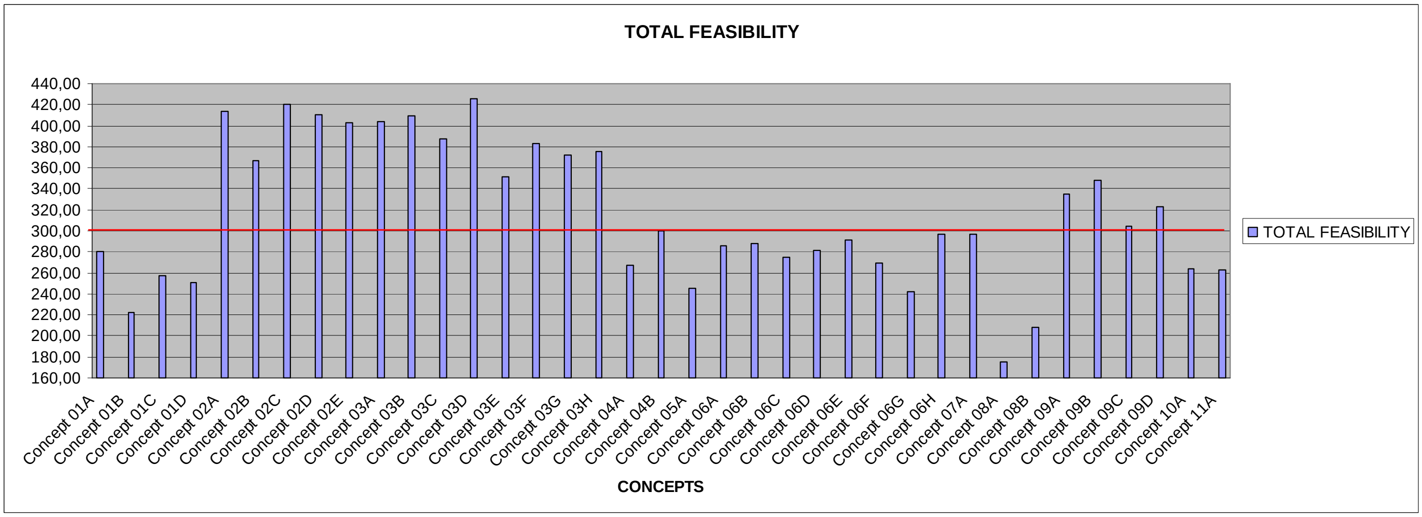

Table 3.1: Design trade-off

The overall performance (total feasibility) of the different concept proposals is summarised in **Table 3.1** above. Note that with the outcome of this study no less than 6 alternative designs were selected for further elaboration. Further analysis reduced the choice to three designs, and the best features of these were combined into the final layout. Aerodynamic tests (see **Section 2.4.5**) were used in the final choice to determine which design had the least effect on snow accumulation, consistent with operating and maintaining the station.

The final three designs had, in all other respects, similar environmental costs and benefits and had no significant environmental advantage over the chosen design.

3.4. Alternative transport

The construction site can be accessed by different means; the diagram below illustrates the possibilities.

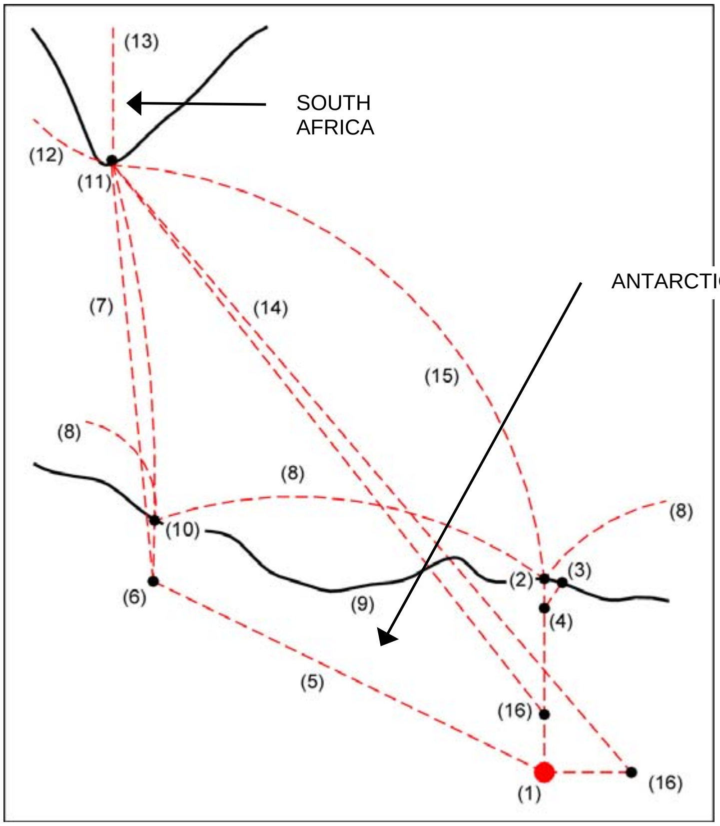

Fig. 3.2: Overview of accessibility options:
(1) Utsteinen (building site); (2) Preferred unloading site at coast; (3) Alternative unloading site at coast (Polarhav Bay); (4) Inland depot area (former Japanese L0 point); (5) Connection to Novolazarevskaya (+/- 430km), by air or over land; (6) Novolazarevskaya; (7) Intercontinental flight and ship route to Cape Town; (8) Ship access from other stations to the East and West; (9) Ice Shelf edge (coast line); (10) Novolazarevskaya coast unloading site (at 60km); (11) Cape Town; (12) Intercontinental ship route Europe-Cape Town; (13) Intercontinental flight route Europe-Cape Town; (14) Intercontinental flight route Cape Town-blue ice fields; (15) Intercontinental ship route Cape Town-Breid Bay; (16) Blue ice fields.

All transport will transit in Cape Town South Africa. Both goods and passengers can be flown in or go by ship. The following list summarizes the different possible scenarios:

Air transport only

1. Cape-Town => Novolazarevskaya => Utsteinen

Air transport + over land transport

2. Cape-Town => Blue ice field => Over land transport to Utsteinen
3. Cape-Town => Novolazarevskaya => Over land transport to Utsteinen

Ship transport + over land transport

4. Cape-Town => Breid Bay => Over land transport to Utsteinen
5. Cape-Town => Other stations => Breid Bay => Over land transport to Utsteinen
6. Cape-Town => Coast at Novolazarevskaya => Over land transport to Novolazarevskaya => Over land transport to Utsteinen

Ship transport + air transport

7. Cape-Town => Coast at Novolazarevskaya => Over land transport to Novolazarevskaya => air transport to Utsteinen

Feasibility of the proposed scenarios:

1. Feasible but costly and the highest limitations on volume and weight. Best use for passengers unless long transition time on ship is acceptable.
2. This is not a short term option since a possible blue ice field runway has not been validated for the time being.
3. Vehicles and sledges can be flown in but the over-land route needs validation (has not been done before), this will take time. This could be an interesting option to bring in small amounts of heavy goods such as vehicles and transport sledges. Bringing in the bulk of the building materials is not feasible because of the high cost and long transition time to the building site. Furthermore apart from the obvious safety issue the longest over-land route means more risk of damaging building materials (vibration and shocks).
4. Feasible and essential for the future viability of the station. It is advisable to build up experience in unloading at this area.
5. As 4 but may be more economical. Good option when transport volumes are not too big and timing is flexible.
6. Cheaper than scenario 3 but remarks on over-land route remain.
7. Feasible but costly and highest limitations on volume and weight but nevertheless probably less costly then scenario 1. Can not be used for transport heavy equipment (vehicles, sledges, etc.).

Preferred scenario:

Scenario 1 is for passengers, scenario 5 is for cargo.

Environmental issues:

The various scenarios present different environmental issues. All the overland components will produce more emissions than the shortest route, from Breid Bay to the proposed site. The operation phase will not normally require a dedicated vessel to service and where possible, sharing of logistics will be used, such as during ship transport to Antarctica.

The alternatives to the proposed ship-overland route to the site for station construction will not bring any environmental benefits and these have been rejected.

4. INITIAL ENVIRONMENTAL REFERENCE STATE OF THE SØR RONDANE

4.1 Location

The proposed site (Lat.: 71°57'S; Long.: 23°21'E; alt.: 1397 m) of the Belgian Antarctic station lies in the Western part of the Sør Rondane Mountains in Dronning Maud Land. It is situated at the foot of the mountains, approximately 1 km north of Utsteinen Nunatak on a small relatively flat granite ridge ('Utsteinen Ridge'), sticking out of the snow. The ridge – oriented in a more or less N-S direction – is 700 m long and a few meters large and elevates 20 m above the surrounding snow surface in the accumulation zone, although a number of blue ice fields occur in the vicinity as summer meltwater lakes. Utsteinen Nunatak is a few kilometres north of the Sør Rondane Mountains. This granite rock consists of two peaks and culminates at an elevation of 1564 m a.s.l. The SE side of Utsteinen has a large wind scoop. The area has been briefly visited by Belgian (1958-1967) and later by Japanese (1987-1991) field expeditions and more recently by the site survey expeditions in preparation of the new station, in 2004 and 2005. Although the Utsteinen area itself is pristine, a small number of depots and litter can be found elsewhere in the Sør Rondane, left by field parties during the pre-Madrid Protocol period. Drawing up an inventory and clean up of these artefacts of previous human activities will be on the agenda of Belgian activities, once the base is installed.

Fig 4.1: Field depot and litter left behind by previous expeditions.

The ice sheet to the north of the Sør Rondane rises smoothly from the grounding line situated a few tens of kilometres South of the coastline of Breid Bay towards the first nunataks, where the surface attains 900 – 1000 m a.s.l. This inland slope area is well known and relative crevasse free due to the damming effect of the mountains and has been used in the past by Belgian and Japanese expedition members as main route from the coast towards the interior. It is entirely situated in the accumulation zone (average mass balance of 0.4 m of ice, Pattyn et al., 1992)

Breid Bay is a prominent feature on satellite images, situated over a – for Antarctica – relative shallow continental shelf (200-300m). It is also the place of a coastal polynia, characterised by the frequent occurrence of open water or low ice concentration between the fast ice and the pack ice during the whole year (Ishikawa, 1996). In summer an open water lead along the coast allows ice strengthened cargo ships to reach the coastline. Breid Bay is composed of several smaller inlets, in which the fast ice frequently stays until January.

The ice shelf to the south of Breid Bay moves in a NW direction at a relative slow speed of some 50 m/yr. Base Roi Baudouin was situated on this ice shelf at a distance of 11 km from one of the inlets (Leopold III Bay) and at an altitude of 38 m. Further to the east, where the sea floor has a depth of 400-700 m, the movement of the ice shelf is much greater reaching values of 200-350 m/yr (Pattyn et al., 2005), between the Roi Baudouin ice shelf and the ice rise further to the east (Derwael ice rise).

4.2 Geology

4.2.1 Geology of the Western Sør Rondane

Geological and geomorphological surveys of the western part of the mountains including the site area of the new base were performed by Belgian expeditions during 1958 to 1967 (Van Autenboer, 1969). Following the reconnaissance survey in 1984, Japanese expeditions conducted field surveys until 1991 (Kojima and Shiraishi, 1986; Shiraishi et al.,1991,1992) (see also **Fig. 3.1**).

The Sør Rondane Mountains are underlain by the late Proterozoic to Paleozoic igneous-metamorphic complex which is related to the formation of the Gondwana Super-continent. Outcrops in the western part of the Sør Rondane Mountains are represented by various kinds of metamorphic and plutonic rocks and minor mafic (dolerite) dykes. Amphibolite-facies gneisses derived from semi-pelitic and volcanic rocks are the dominant metamorphic rocks. Thin layers and lenses of calcareous and mafic rocks also occur in many places. Plutonic rocks which range from granite to diorite are sporadically distributed as masses and stocks of km size. Foliation of the gneisses generally strikes E-W and dips monoclinally to the south. The most remarkable major structural feature in the surrounding area is a pronounced E-W trending shear zone (Main Shear Zone). All rock types except for some granites and dyke rocks in the surrounding area show various degree of mylonitization.

4.2.2 Geology of the proposed station site

The outcrop of the proposed new station site is a northern extension of the Utsteinen Nunatak in the south (Van Autenboer and Loy, 1966). The outcrop, approx. 700 m long and 20-30 m wide, is predominantly composed of massive coarse-grained granite with minor xenolithic blocks of metamorphic rocks covering less than 10% of the outcrop. Exotic rocks and sediments (till and moraine) are negligible on the surface of the outcrop. In general granitic rocks tend to be easily weathered chemically and mechanically. However the granite in the present site is rather fresh suggesting recent (probably Holocene) exposure on surface. A set of joint system trending NNW and NE is dominant and the long and narrow outline of the outcrop is controlled by the NNW joint.

The granite is a part of the “Pingvinane granite” which is typically distributed in the Pingvinane Nunataks 10 km west of the site (Shiraishi et al., 1992). The granite is a typical alkali granite with coarse-grained equigranular texture. Mafic schlieren of 10-20 cm long are found in some places. The granite is composed mainly of K-feldspar (35-50 vol.%), quartz (20-45 vol.%), plagioclase (20-45 vol.%), hornblende and biotite (2-5 vol. %) with or without clinopyroxene (Li et al., 2003 a, b). Accessory minerals are Fe-Ti oxides, titanite, apatite and zircon. The Pingvinane granite generally has low magnetic values (3 to 8 10-4 SIU) corresponding to the ilmenite series (Shiraishi et al., 1992). The intrusive age of the granite is considered to be ～500 Ma estimated by the similar rock type in Pingvinane Nunataks. The granite contains xenolithic blocks and lenses up to several meters long in places. The boundary to the granite is sharp. They are quartz-feldspathic hornblende gneiss and amphibolite with banded and migmatitic structure.

Most of the granite along the ridge is relatively fresh and weathering only occurs over the top few centimetres. However, in some areas along the ridge the granite is more deeply weathered. These weathered zones can easily be observed from the three-dimensional view of the topography of the ridge as well, as they occur in these areas that are lying much lower. Here, the wind has weathered a large part of the rocks away. Due to the deeper weathering, the lower zones of the ridge can not support a construction without a lot of anchoring efforts. The building site is thus confined to the higher lying areas which have much better anchoring conditions (see **Section 2.2.2**).

4.3 Glaciology

Glaciological investigations were carried out by Belgian (1958-1967) and Japanese (1987-1991) field parties both on the ice shelf as in the mountains. They allowed among other things to estimate the total mass flux of ice through the mountain range (Van Autenboer and Decleir, 1974, 1978) and to map the subglacial topography of the central Sør Rondane (Pattyn and Decleir, 1995) but many parameters for a physical understanding of the glacier behaviour in the mountain range - as well as with respect to the adjacent ice shelf - are still unknown. This is even more so for the large and fast flowing ice streams contouring the damming mountain range, making the 20-30 degrees east sector one of the least known areas of the Antarctic ice sheet.

Since most of the ice flow coming from the polar plateau is blocked by the mountain range, many sheltered areas exists that are characterised by slow ice movements, as is the case with the proposed construction site. However, only a few measurements with respect to ice dynamics and mass balance have been carried out in the immediate vicinity of the Utsteinen site.

Table 4.1 lists accumulation rates and displacements measured between 2004 and 2005 for stakes set up close to the Utsteinen ridge (within 300 m). Since snow density measurements were not carried out, values are given in cm snow depth. Highest accumulation rates are found east and west from the ridge, around 45 cm/year (stakes I, II and IV). At the northern part, accumulation is half this value (20 cm/year), while in the South (stake V), ablation rules at a rate of approximately 10 cm/year. Here the snow layer is relatively thin and the stake lies in the proximity of a blue ice field.

Stake nr	Accumulation (cm snow/year)	Displacement (cm/year)
I (West)	42	5.5
II (West)	43.5	14.1
III (North)	24.5	8.7
IV (East)	47	26.2
V (South)	-9	8.0

Table 4.1: Snow accumulation and horizontal displacement obtained for the 5 stake positions near Utsteinen ridge.

Minimum displacement is found to be 5 cm/year (stake I), maximum displacement amounts to 26 cm/year (stake IV). These low values indicate that the whole area around the ridge is stable and hardly influenced by the overall ice sheet motion.

Ice thickness measurements were carried out along an East-West transect across the ridge. Ice thickness rapidly increases to 200 m in depth away from the ridge over a horizontal distance of 500 m. Furthermore, the ridge is asymmetric in shape. The western part is deeper than the eastern side at a same distance from the ridge. Such asymmetry is also observed near the ridge extending from Utsteinen Nunatak. Further away from the nunataks previous Belgian measurements (Van Autenboer and Decleir, 1978) indicate ice thicknesses of more than 1000m and a subglacial bedrock close to or even below sea level.

4.4 Climate

4.4.1 Air temperature

The temperature record from the AWS, installed during 2005 at the site of the new station (**Fig. 4.2**), is analogous to the 1987-91 series from Asuka station, situated 55 km further north-east and 466 m lower in height. Average temperature amounts to -18°C, varying between -8°C (December) and -25°C (September). This implies that the daily maximum does not exceed zero in summer, while the daily minimum reaches -36°C in winter (**Fig. 4.3**). Although this temperature regime is relatively mild as compared to the lower lying Asuka Station and to the temperatures observed at Base Roi Baudouin (-15°C, close to sea level and 173 km further north), the yearly variation of the temperature curve shows already the typical coreless winter character of the more continental stations. It is characterized by a rapid drop in temperature in fall, a first minimum in May, a second (more important) minimum in August-September and a very steep rise towards the December-January maximum. This coreless winter results from the specific radiation conditions during the polar night. At the new site the sun stays permanently below the horizon from May 16 to July 28 (73 days) but some twilight remains around noon, even at Midwinter.

Month	Pst (hPa)	Tm (degC)	Tx (degC)	Tn (degC)	Vm (m/s)	Vx (m/s)	D (deg)	D
Jan-05	**834.7**	**-8.7**	**-3.0**	**-16.8**	**4.9**	**19.2**	**99.5**	**E**
Feb-05	**825.0**	**-12.3**	**-7.0**	**-20.2**	**6.6**	**28.6**	**105.9**	**ESE**
Mar-05	**827.1**	**-15.5**	**-7.2**	**-24.1**	**5.8**	**26.7**	**123.1**	**ESE**
Apr-05	**824.4**	**-19.7**	**-11.8**	**-29.1**	**5.6**	**31.1**	**134.9**	**SE**
May-05	**824.2**	**-22.0**	**-15.2**	**-31.4**	**6.2**	**23.2**	**125.3**	**SE**
Jun-05	**831.0**	**-21.0**	**-13.9**	**-32.4**	**8.2**	**28.9**	**118.3**	**ESE**
Jul-05	**823.5**	**-23.2**	**-15.8**	**-30.8**		**32.9**		
Aug-05	**821.0**	**-23.3**	**-15.4**	**-34.0**	**5.1**	**18.8**	**122.5**	**ESE**
Sep-05	**818.2**	**-24.4**	**-16.8**	**-33.0**	**5.9**	**30.7**	**113.2**	**ESE**
Oct-05	**823.1**	**-21.0**	**-14.5**	**-35.5**	**5.2**	**26.5**	**124.3**	**SE**
Nov-05	**832.9**	**-15.0**	**-9.9**	**-20.9**	**4.5**	**20.9**	**99.4**	**E**
Dec-05	**842.1**	**-8.4**	**-1.4**	**-17.5**	**4.5**	**18.3**	**98.1**	**E**
2005	**827.1**	**-18.0**	**-1.4**	**-35.5**	**5.9**	**32.9**	**116.2**	**ESE**

Table 4.2: Meteorological observations from the Utsteinen automatic weather station (AWS) in 2005. Monthly mean air pressure (Pst), air temperature (Tm), monthly maximum (Tx) and minimum (Tn) air temperatures, monthly mean wind speed (Vm) and wind direction (D), and monthly maximum wind speed (Vx). Mean wind speed in July is not given due to lack of measurements (temporary instrument failure).

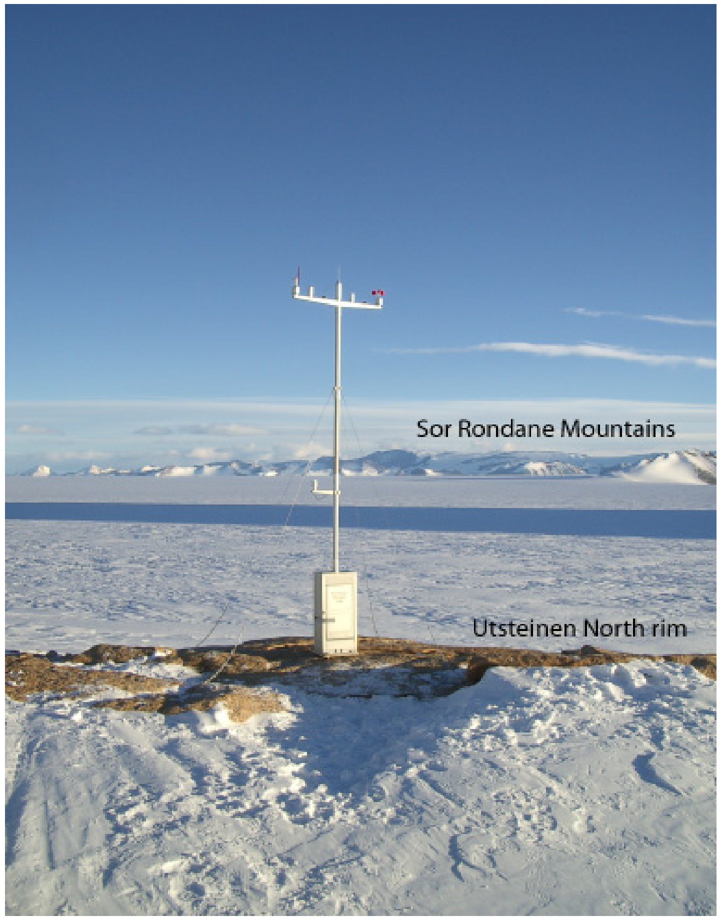

Fig 4.2: Automatic Weather Station, installed during the Belare 2005 expedition on the Utsteinen Ridge, with the Sør Rondane Mountains in the background.

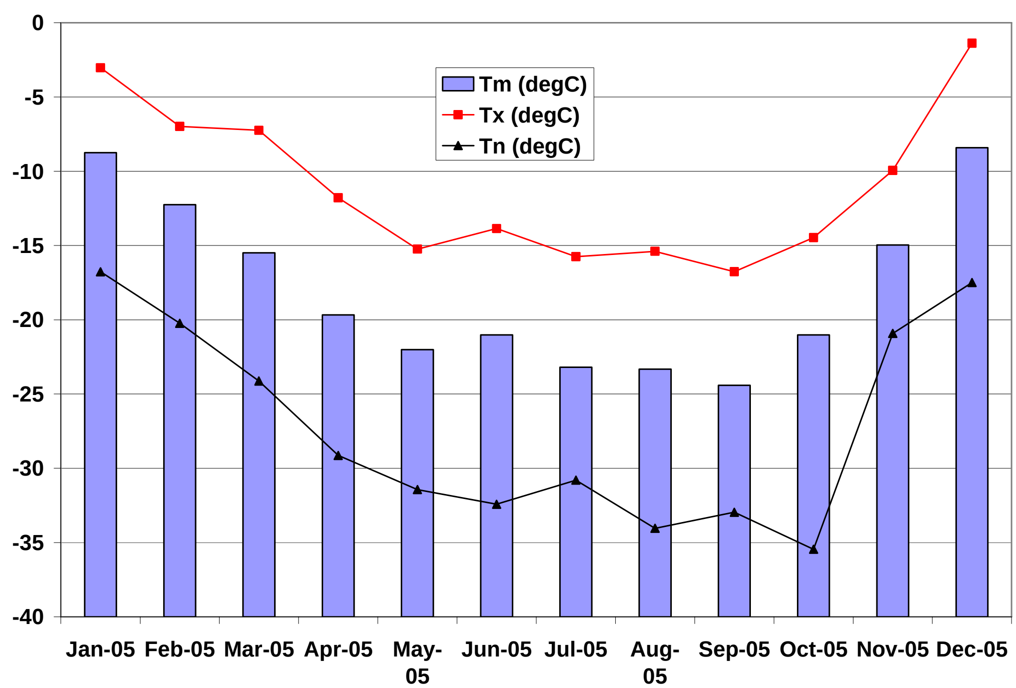

Fig 4.3: Monthly mean air temperature (Tm) at Utsteinen in 2005.
Monthly minima (Tn) and maxima (Tx) are given as well.