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Performance of the Automatic Balloon Launcher of Radiosonde Station 04360 Tasiilaq, November 2012 – June 2015

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Station 04360 Tasiilaq, 6 October 2012. Photo: Thomas Nedergaard.

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Content

Abstract

The first 32 months of automated radiosonde operation by DMI in Greenland showed an overall availability of 87,3%. When it came to availability of observations with satisfactory quality only, availability dropped to 66,8% for the six months period investigated for this.

Various causes for low availability and quality were identified.

The greatest improvement will be obtained by finding solutions as to:

- Improved performance of humidity and temperature sensors of the radiosondes.
- Operations procedures for taking remedying action to prevent successive missing observations after one, initial problem. The procedures should be in function also on holidays and outside of ordinary working hours in both Greenland and Denmark.
- Improved reliability in communication between station and sonde.

Resumé

De første 32 operationelle måneder af DMI's første, grønlandske radiosondeautomatisering udviste en samlet regularitet på 87,3%. Hvad angår regularitet udelukkende af sonderinger med tilfredsstillende kvalitet blev dette undersøgt for en 6 måneders periode, og denne viste at kun for 66,8% af de forventede terminer var en tilfredsstillende sondering kommet brugerne i hænde.

Der blev identificeret diverse årsager til manglende sonderinger og lav kvalitet.

Den største forbedring kan opnås ved at gøre følgende:

- Forbedre kvaliteten af fugt- og temperaturmålingerne i sonderingerne.
- Forbedre procedurerne for afhjælpning af fejl, sådan at yderligere, manglende observationer i træk, undgås. Procedurerne skal også fungere på helligdage og på tidspunkter udenfor almindelig arbejdstid, både i Grønland og Danmark.
- Forbedre datakommunikationen mellem sonde og station.

1. Introduction

DMI operates presently five radiosonde stations in Greenland, cf. Figure 1 and Table 1.

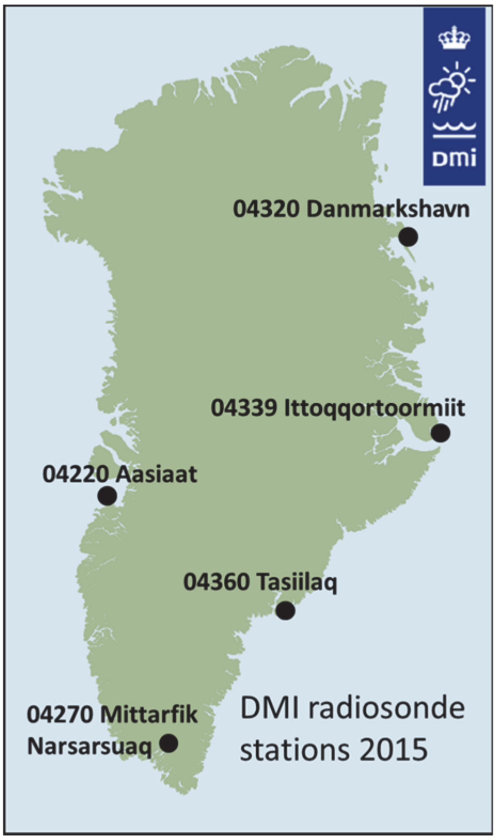

Figure 1 The five radiosonde stations operated by DMI in Greenland.

WMO id IIiii	Name	Start	End	Lat (N)	Long (E)	height
04220	Aasiaat	01 February 1949	22 October 1974	68,70000	-52,86667	27
04220	Aasiaat	23 October 1974	-	68,70806	-52,85167	40
04270	Mittarfik Narsarsuaq	01 October 1987	-	61,15750	-45,44000	4
04270	Mittarfik Narsarsuaq	16 November 1958	01 October 1987	61,15000	-45,43333	4
04320	Danmarkshavn	05 November 1948	-	76,76944	-18,66806	14
04339	Ittoqqortoormiit	01 October 1980	-	70,48444	-21,95111	68
04360	Tasiilaq	26 October 1947	16 October 1948	65,61667	-37,65000	39
04360	Tasiilaq	16 October 1948	-	65,61111	-37,63667	50

Table 1. Location history of the five DMI radiosonde stations presently operational in Greenland.

In 2012 the first, and so far the only, of these stations was automated, when DMI installed a Modem Automatic Balloon Launcher (ABL) at the radiosonde station 04360 Tasiilaq. The ABL passed site acceptance test 10 October 2012 and DMI made dissemination of the radiosonde bulletins from the ABL operational as the radiosonde bulletins of station 04360 Tasiilaq 8 November 2012.

The purpose of this report is to share the DMI operations experiences with other National Meteorological Services.

The following is reported:

- Availability of radiosonde measurements
- Quality in radiosonde measurements
- Technical operations scheme

For climatology at Tasiilaq cf. Cappelen et al. 2001 and Laursen 2010.

Figure 2. Station 04360 Tasiilaq. Left: October 6, 2012. Right: September 19, 2014. Photo: Thomas Nedergaard.

2. Availability

The overall availability of the automatically launched radiosonde observations during November 2012 - June 2015 was not satisfactory compared to the EUCOS target, cf. Table 2.

For the 32 months period, November 2012 – June 2015, taken as a whole, a total of 1698 observations were received out of the expected 1944, yielding an overall availability of 87,3%.

Availability 04360 Tasiilaq as of 1 July 2015

Year	[%][*)]	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year	EUCOS Target[**)]
2015	Avail.	95,2	73,2	90,3	91,7	96,8	93,3	-	-	-	-	-	-	-	95%
	100hPa	76,3	73,2	87,5	56,4	66,7	92,9	-	-	-	-	-	-	-	97%
	50 hPa	66,1	43,9	60,7	47,3	43,3	76,8	-	-	-	-	-	-	-	95%
2014	Avail.	82,3	85,7	90,3	80,0	77,4	98,3	85,5	82,3	66,7	74,2	88,3	83,9	82,9	95%
	100hPa	90,2	83,3	80,4	70,8	79,2	94,9	94,3	98,0	75,0	84,8	79,2	78,8	84,5	97%
	50 hPa	52,9	64,6	53,6	50,0	58,3	86,4	92,5	82,4	65,0	71,7	73,6	59,6	67,9	95%
2013	Avail.	83,9	87,5	93,5	91,7	80,6	93,3	83,9	96,8	95,0	82,3	91,7	93,5	89,5	95%
	100hPa	86,5	91,8	91,4	90,9	86,0	98,2	96,2	95,0	98,2	88,2	85,5	87,9	91,4	97%
	50 hPa	78,8	81,6	89,7	83,6	68,0	96,4	94,2	95,0	96,5	76,5	72,7	69,0	83,8	95%
2012	Avail.	*98,4*	*100,0*	*95,2*	*100,0*	*100,0*	*98,3*	*100,0*	*100,0*	*96,7*	*96,8*	100,0	83,9	97,7	95%
	100hPa	*96,7*	*98,3*	*94,9*	*96,7*	*100,0*	*96,6*	*98,4*	*100,0*	*96,6*	*94,1*	82,1	90,4	97,3	97%
	50 hPa	*91,8*	*98,3*	*88,1*	*93,3*	*100*	*96,6*	*96,8*	*98,4*	*94,8*	*91,8*	79,1	65,4	93,3	95%
2011	Avail.	*98,4*	*96,4*	*91,9*	*95*	*98,4*	*100*	*100*	*98,4*	*100*	*100*	*100*	*100*	*98,8*	95%
	100hPa	*95,1*	*90,7*	*93*	*94,7*	*96,7*	*98,3*	*98,4*	*100*	*98,3*	*96,8*	*93,3*	*95,2*	*94,8*	97%
	50 hPa	*95,1*	*79,6*	*84,2*	*93*	*95,1*	*96,7*	*93,5*	*91,8*	*96,7*	*96,8*	*90*	*82,3*	*90,2*	95%
2010	Avail.	*98,4*	*98,2*	*96,8*	*98,3*	*98,4*	*98,3*	*100*	*100*	*98,3*	*98,4*	*98,3*	*98,4*	*98,5*	95%
	100hPa	*95,1*	*98,2*	*93,3*	*91,5*	*100*	*86,4*	*91,9*	*98,4*	*96,6*	*98,4*	*93,2*	*93,4*	*93,3*	97%
	50 hPa	*73,8*	*90,9*	*86,7*	*84,7*	*96,7*	*84,7*	*88,7*	*91,9*	*89,8*	*95,1*	*81,4*	*86,9*	*86,3*	95%

Yellow box:	**Automated launch** since 8 November 2012 Purely automated since 1 January 2013	*Italic:*	Purely Manned launch

*) **Avail.:** The percentage radiosonde observations received out of the expected number, regardless of burst height.
100 hPa: The percentage out of the received radiosonde observations to reach at least 100 hPa.
50 hPa: The percentage out of the received radiosonde observations to reach at least 50 hPa.

) **EUCOS target: To receive 95% of the expected radiosondes. That 97% of the received radiosondes reach at least 100 hPa. That 95% of the received radiosondes reach at least 50 hPa.

Table 2 . Availability of radiosonde observations from station 04360 Tasiilaq. Expected: 2 obs/day. 2013 is calculated based on DMI data reception. The other years are based on the EUCOS Quality Monitoring Portal. Observations up until October 2012 are purely manned launches and shown for comparison. Observations since January 2013 are purely automated launches. Green: meets EUCOS target.

From Table 2 may further more be summarized:

26 out of 32 months, November 2012 – June 2015, did not meet the EUCOS target of 95% availability from expected launches.

29 out of 32 months, November 2012 – June 2015, did not meet the EUCOS target of 97% of the available radiosonde observations to reach 100 hPa.

29 out of 32 months, November 2012 – June 2015, did not meet the EUCOS target of 95% of the available radiosonde observations to reach 50 hPa.

During the 32 months, November 2012 – June 2015, observations were missing for various reasons, cf. Table 3.

Cause for missing observation	**Number of missing observations,** *(% of missing)*		
	November 2012 – December 2013	January 2014 – June 2015	**Entire period**
Too strong winds	4 *(4,5%)*	1 *(0,6%)*	**5 *(2,0%)***
Roof of ABL frozen; it remains closed or takes too long to open for a launch	6 *(6,8%)*	20 *(12,7%)*	**26 *(10,6%)***
Software and electronics	8 *(9,1%)*	34 *(21,5%)*	**42 *(17,1%)***
Persistent automatic cancellation of launch due to an unfixed problem from a previous launch, e.g. inflation tube not empty, roof still frozen and open, ground computer in need of reboot, no sonde available in the carousel due to missing refill of carousel.	19 *(21,6%)*	73 *(46,2%)*	**92 *(37,4%)***
Balloon burst inside the ABL or leak of hydrogen	6 *(6,8%)*	5 *(3,2%)*	**11 *(4,5%)***
No Internet connection in Tasiilaq	0 *(0,0%)*	5 *(3,2%)*	**5 *(2,0%)***
Unknown	45 *(51,1%)*	20 *(12,7%)*	**65 *(26,4%)***
Total (%)	**88 *(100%)***	**158 *(100%)***	**246 *(100%)***

Table 3. Various causes identified for observations to be missing November 2012 – June 2015. The table shows number of observations missing for the various causes (given in the brackets as percentage out of the missing). Figures for the entire period are shown in the column to the far right. To show possible development in types of errors following the duration of operation, two separate periods, November 2012- December 2013 and January 2014 – June 2015, are also shown.

Some causes for missing observations were eliminated in the first months of operation through e.g. software updates. Others, like missing observations due to computer failure were remedied by repeated replacements of computers. But apparently new causes have kept showing up. Among the causes for missing observations that are plausible to be still occurring are:

- **Roof blocked by frost**. Most recent, the roof was prevented of its automated operation by frost in 9 separate instances during the period January – April 2015.
- **Inflation tube blocked** by balloon from previously automatically cancelled launch. Typically, after frost has prevented the roof to operate on a non-working day, 1-3 observations thereafter are also missed, before local help manually removes the inflated balloon from the tube.
- **Electronics problems** (unknown origin) occur on non-working days and remedy action (typically manually reboot of computer or electronics racks by local help) is subsequently not taken immediately, thereby causing several consecutive missing observations.
- **Problems with the Internet connection** in Tasiilaq. According to Table 3 only five missing observations were caused by the recent Tasiilaq Internet problems of 9 January 2015 and 21 June 2015. However, it cannot be ruled out that local

Internet problems is the cause behind other problems categorized as “Software and Electronics” or “Unknown” in Table 3.

- **Lack of maintenance**. E.g. three observations were missing 25-26 May 2014 due to dirt on one of the infrared sensors.
- **Rarely occurring situations**, such as
  - Too high wind speeds. Has only occurred once January 2014 – June 2015.
  - Leak of hydrogen, when filling balloon. Has occurred once January 2015 – June 2015.
- **‘Unknown’**: This category includes e.g.:
  - 13 missing observations in 2013 that, for an unidentified reason, had the automated error message ‘IR2010 Not ready’ at the station.
  - 15 observations discrepancy in 2013 between what was reported successfully sent from the station and what was actually successfully received by EUCOS.
  - 13 observations in 2014, that were sent from the station, but without time stamp, and therefore not received by EUCOS.

Table 2 shows that the height level of the radiosondes received in the automated period was not satisfactory, since only 3 out of 32 months, November 2012 – June 2015, actually met the EUCOS target of 97% of the available radiosonde observations to reach 100 hPa.

Some of the causes for the low height observed in many of the received observations are identified and listed in Table 4.

Cause for low height obtained	November-December 2012	2013	2014	January – June 2015	Total; entire period
Connection between station and sonde lost after launch, but before burst	18	87	29	35	**169**
Computer breakdown after 100 hPa was reached, but before burst	0	0	5	0	**5**
Temperature sensor failure before burst (only measurements up until the failure are included in the bulletin)	1	2	8	6	**17**
Humidity sensor failure before burst (only measurements up until the failure are included in the bulletin)	0	1	0	0	**1**
Total number	*19*	*90*	*42*	*41*	*192*
Percentage of received	*17,1%*	*13,8%*	*6,9%*	*12,5%*	*11,3%*

Table 4. Number of observations attributed to known causes for obtaining low height. *Please note* that the table does not explain all instances of low height. I.e. for 2014 this table reports causes for low height in 42 instances, whereas the total number of observations received in 2014 without reaching at least 100 hPa was 94.

Figure 3 shows more details behind the 41 instances of known causes of low height obtained listed in Table 4 as being explicitly recorded during the January – June 2015. From Figure 3 the problem appears to be severe, as it was seen that during the 41 instances of this most recent period, January – June 2015, half of these obtained only 300 hPa or higher pressure and nearly a third only 700 hPa or higher, as the lowest value.

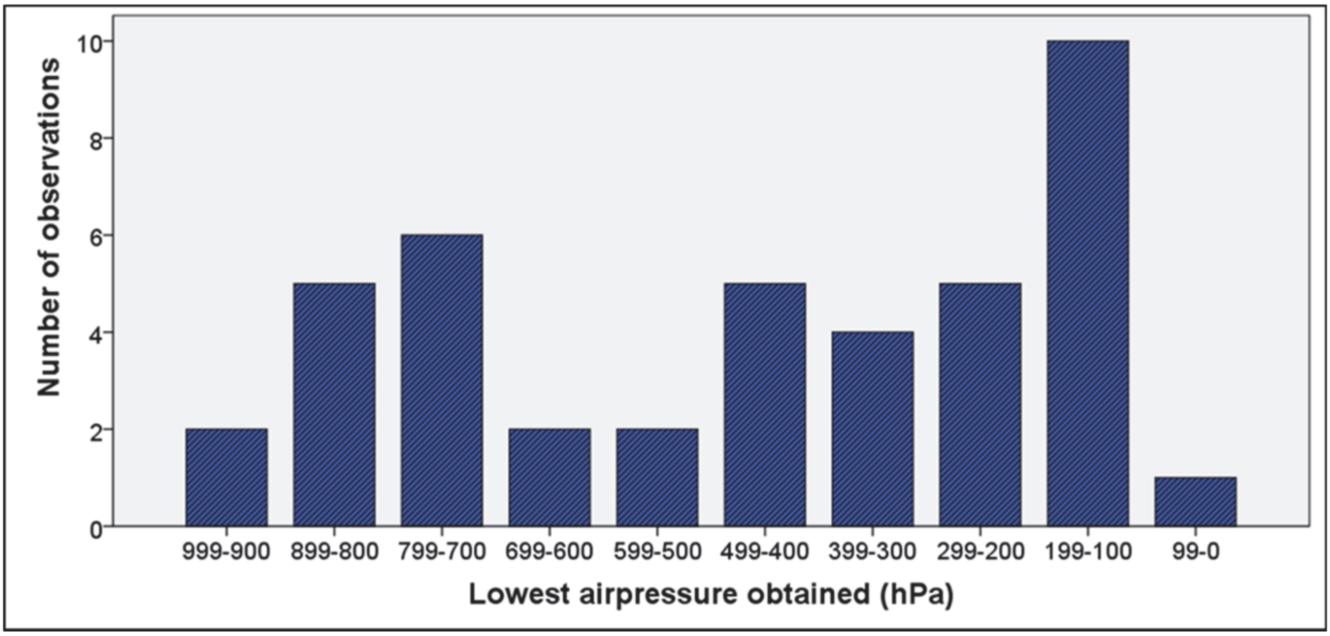

Figure 3. Distribution of lowest obtained airpressure of the 41 observations during the period January – June 2015 reported by cause in Table 4.

3. Quality in radiosonde measurements

Introduction

WMO has in the CIMO-Guide: Part I. Measurement of meteorological variables, Chapter 12 Measurement of upper-air pressure, temperature and humidity (WMO 2012), published guidelines as to the quality of radiosonde measurements required for various purposes, cf., e.g. the requirements for operational purposes cited in Text box 1.

ANNEX 12.A

ACCURACY REQUIREMENTS (STANDARD ERROR) FOR UPPER-AIR MEASUREMENTS FOR SYNOPTIC METEOROLOGY, INTERPRETED FOR CONVENTIONAL UPPER-AIR AND WIND MEASUREMENTS

Variable	*Range*	*Accuracy requirement*
Pressure	From surface to 100 hPa 100 to 10 hPa	1 hPa to 2 hPa near 100 hPa 2 per cent
Temperature	From surface to 100 hPa 100 to 10 hPa	0.5 K 1 K
Relative humidity	Troposphere	5 per cent (RH)
Wind direction	From surface to 100 hPa	5°, for less than 15 m s^{-1} 2.5° at higher speeds
	From 100 to 10 hPa	5°
Wind speed	From surface to 100 hPa	1 m s^{-1}
	From 100 to 10 hPa	2 m s^{-1}
Geopotential height of significant level	From surface to 100 hPa	1 per cent near the surface decreasing to 0.5 per cent at 100 hPa

Text box 1. From the CIMO-guide (WMO 2012) are here shown the accuracy requirements for the operational use intended of the 04360 Tasiilaq radiosonde observations.

As discussed in the CIMO-Guide (WMO 2012), quality evaluation of radiosonde observations is challenging.

Within EUMETNET, of which Denmark is a member, EUCOS supervises the EUCOS radiosonde station data quality as part of the EUCOS Quality Monitoring Portal. This is performed by a comparison of observed values to results by numerical weather prediction, cf. target values listed in Text box 2.

The results of the comparison to NWP are published on the EUCOS Quality Monitoring Portal for daily averages. Each single daily value is an average of all levels of all soundings on the site at the given day (Kleinert, 2015). At the moment The Quality Monitoring Team performs the comparison only for the TAC coded data[1], and for these only the mandatory levels are selected. For humidity the Team is even more restrictive and use data only up to 300 hPa but not above.

[1] TAC: Traditional Alphanumeric Code Forms. As opposed to TDCF (Table Driven Code Forms). TAC radiosonde observations are distributed in FM 35 TEMP. TDCF radiosonde observations are distributed in BUFR or CREX using the WMO template B/C25 – Regulations for reporting TEMP, TEMP SHIP and TEMP MOBIL data in TDCF. For documentation refer to WMO-No. 306 Manual on Codes.

The deviation is the difference between the observed parameter (e.g. radiosonde temperature on a certain level at a given time) and model forecasted parameter (i.e. an interpolated temperature at the position, vertical level and time of the radiosounding in the 3-dimensional field of modelled temperature).

Comparison results of radiosonde observations against NWP

currently used model: **ECMWF**

Parameter	Description	EUCOS targets	
T count	Number of temperature observations compared against NWP	-	
T bias	Temperature bias (K)	-	
T rmse	Temperature RMSE (K)	> 1.0 K	> 3.0 K
WIND count	Number of wind observations compared against NWP	-	
WIND mvd	Wind Mean Vector Difference (m/s)	-	
WIND rmsvd	RMSE of Wind Mean Vector Difference (m/s)	> 5.0 m/s	> 8.0 m/s
HUM count	Number of humidity observations compared against NWP	-	
HUM dq/q*	Specific Humidity (%)	|> 10 %|	|> 20 %|
HUM RH rmse	RMSE of Relative Humidity (%)	-	
O-B GPH count	Number of 100 hPa observations compared against NWP	-	
O-B GPH @ 100 hPa	100 hPa Geopotential Height Difference (m) (currently unavailable)	|> 65 m|	|> 100 m|

EUCOS - 05.05.2015

Text box 2. Radiosonde accuracy targets of EUCOS (EUCOS Quality Monitoring Portal 2015). Prior to the current ECMWF model (since 5 May 2015), the COSMO-EU (DWD) model (since 16 November 2010) was used.

In addition to the averaged EUCOS quality monitoring, DMI has looked into the quality of individual soundings. The investigation of quality of individual soundings gave a more clear indication of usability than the averaged approach, therefore it is the investigation of individual soundings that is reported in the following.

During Spring 2015 DMI made an investigation on the quality of the radiosonde observations from station 04360 Tasiilaq with regard to observations during the period 1 July – 31 December 2014. The investigation is reported in the next section.

Investigation of data quality 1 July – 31 December 2014

The investigation of the data quality was performed in the following steps:

1. Identification of missing observations, as received by EUCOS. These were marked by grey colour in a work sheet like the one added as ANNEX B.
2. Visual inspection of tephigrams of all observations received. The visual inspection was performed by operational DMI meteorologists that utilize the Greenlandic radiosonde observations in their everyday work. The tephigrams were made by the meteorologists using their ordinary tool for showing archives radiosonde observations. The tool is called 'ObsShow' it's developed by DMI. It's an old tool, not handling BUFR and to be replaced by visualization in NinJo, but since DMI as yet has not installed a facility to show archive radiosonde observations in NinJo, the low resolution TEMP of ObsShow was used for this purpose. As part of the visual inspection each radiosonde observation was categorized with respect to (cf. details in ANNEX B):
    - Immediately OK quality (1=yes)
    - Immediately unrealistic 'parallel course of Dew point and Temperature' (1=yes)
    - Immediately unrealistically high humidity in the stratosphere (1=yes)
    - Immediately unrealistically dry radiosonde (Dew point and temperature almost doesn't meet when there are clouds) (1=yes)
    - Other problems or remarks
3. Evaluation. For this report, Table 5, the following conclusions were made (cf. details in ANNEX B):
    - Two instances of radiosonde observations received by EUCOS, but not to be found in the DMI ObsShow archive, were categorized as 'Immediately OK quality (1=yes)'
    - Since many of the instances of 'Immediately unrealistic 'parallel course of Dew point and Temperature'' were looking similar to, or also counted as 'Immediately unrealistically high humidity in the stratosphere' a category consisting of both types were made.
    - Pdf-files were made of all observations pointed out as 'not immediately OK' by remark or category using the same software as the meteorologists used for the visual inspection. The pdf-files are shown, with added header and footer, in ANNEX A.

The results on the data quality are summarized in Table 5. When combining availability and the data quality screening, what is found is that for the half year period, 1 July – 31 December 2014 only 66,8% out of the expected observations were immediately satisfactory for the operational use of the meteorologists, since out of 368 expected observations 73 were missing and 49 were received with quality not immediately OK.

For examples of the individual types evaluated as 'not Immediately OK', cf. Figure 4-Figure 8.

For the half year period 246 observations were evaluated by the meteorologists to be 'immediately OK'. These are not included in the report. But to give an indication of what level of quality was evaluated as 'immediately OK' 4 examples are included as Figure 9-Figure 12. The radiosonde observation of 11 December 2014 12 UTC shown in Figure 11 burst at 8112 m and 326 hPa. This is not a satisfactory height compared to EUMETNET targets. The, not uncommon, example was picked upon among the 'immediately OK' observations to show the tendency that the meteorologists in this investigation only evaluated very unsatisfactory observations as 'immediately not OK'.

04360 Tasiilaq: Quality of radiosonde observations 1 July – 31 December 2014		
Overall	**Number of observations**	**% of expected**
Received and quality immediately OK	246	66,8
Received and quality immediately not OK	49	13,3
Missing	73	19,8
Total	***368***	***100***
Details on ’Not immediately OK'-Category	**Number of observations**	**% of received**
Insufficient height	15	5,1
Too parallel in troposphere and/or too humid in stratosphere	32	10,8
Unrealistically dry	2	0,7
Total	***49***	***16,6***

Table 5. Quality of 04360 Tasiilaq radiosonde observations 1 July 2014 – 31 December 2014. The quality control was performed manually in March and April 2015 by visual screening by the operations meteorologists of the DMI weather service department in Kangerlussuaq, Greenland, using the DMI developed software ‘Obsshow’. Tephigrams of all 49 observations from the ‘Not immediately OK’-category are added to this report as ANNEX A. For examples of the individual types cf. Figure 4-Figure 8.

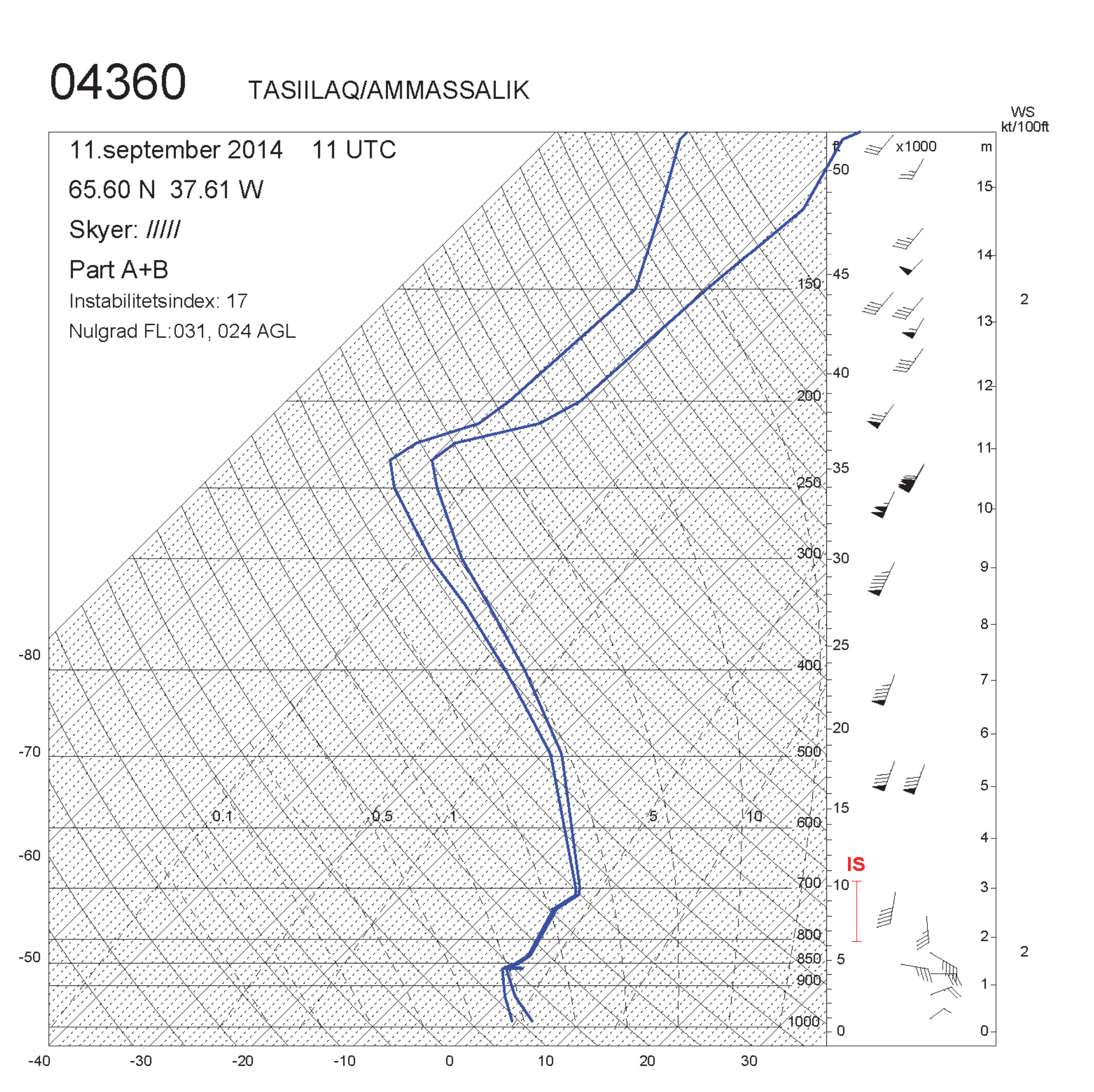

Figure 4 Example of radiosonde observation evaluated as 'Immediately unrealistically high humidity in the stratosphere'

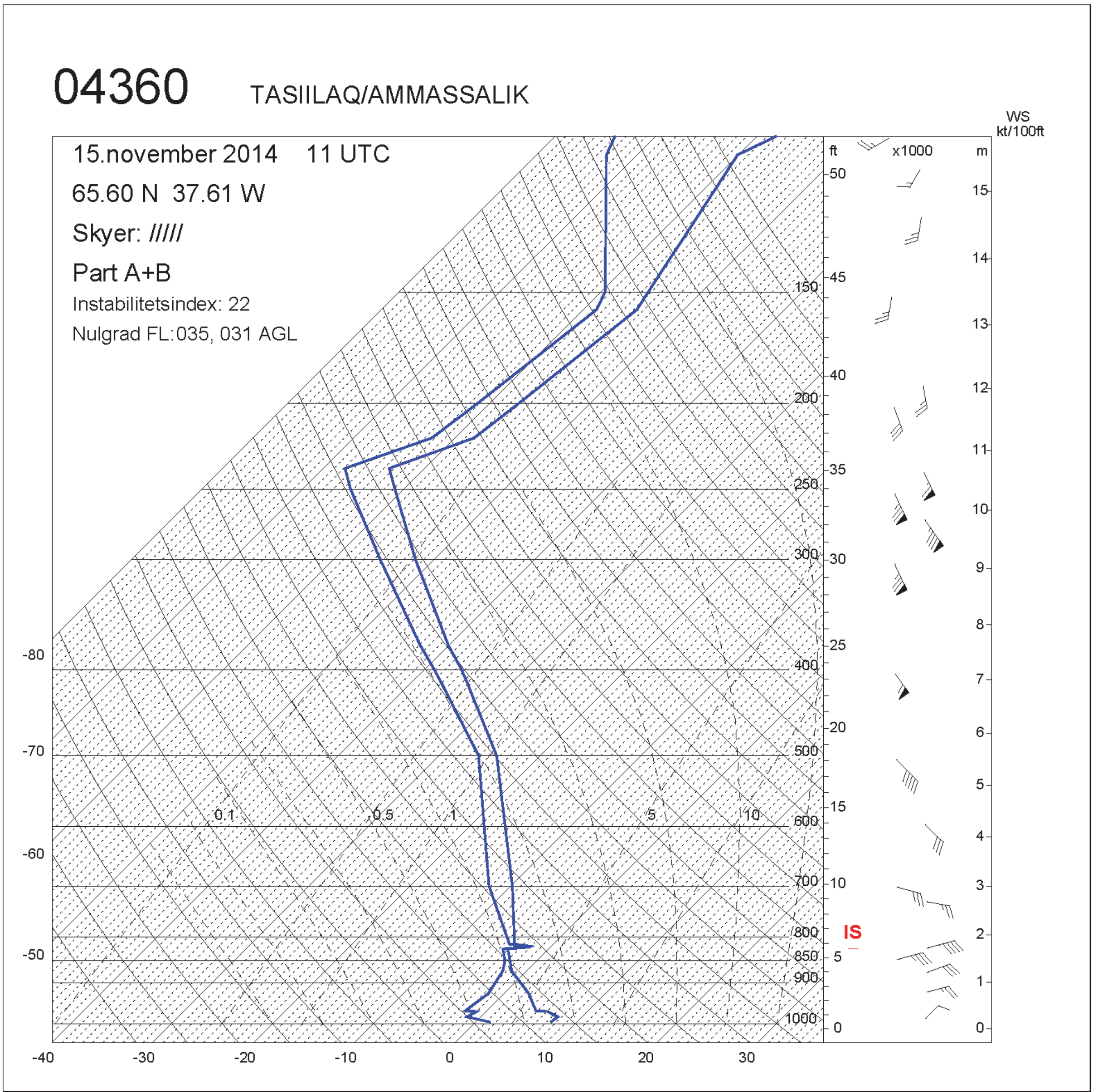

Figure 5 Example of radiosonde observation evaluated as both 'Immediately unrealistic 'parallel course of Dew point and Temperature'' and 'Immediately unrealistically high humidity in the stratosphere'.

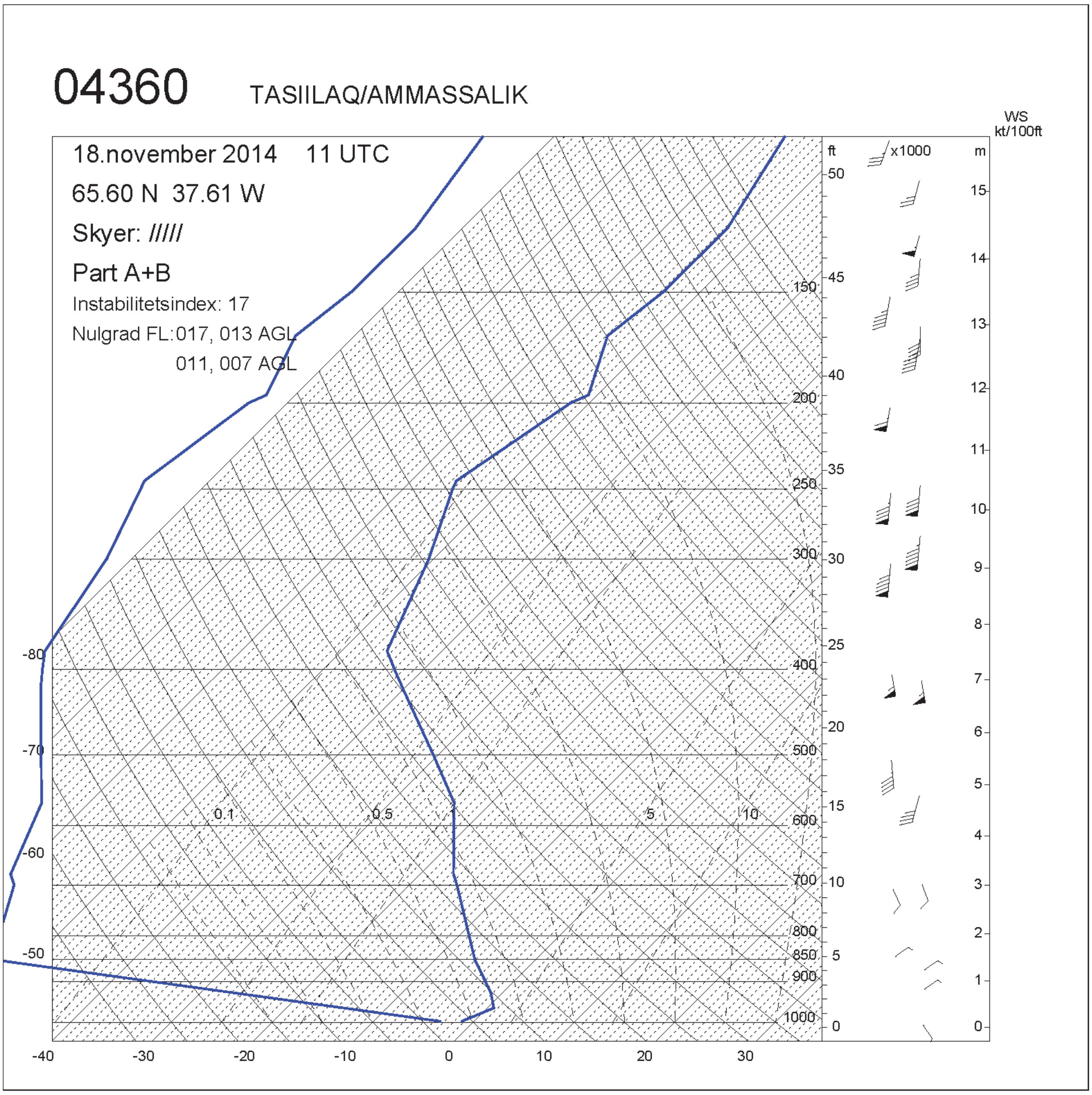

Figure 6 Example of radiosonde observation evaluated as 'Immediately unrealistically dry radiosonde (Dew point and temperature almost doesn't meet when there are clouds)'.

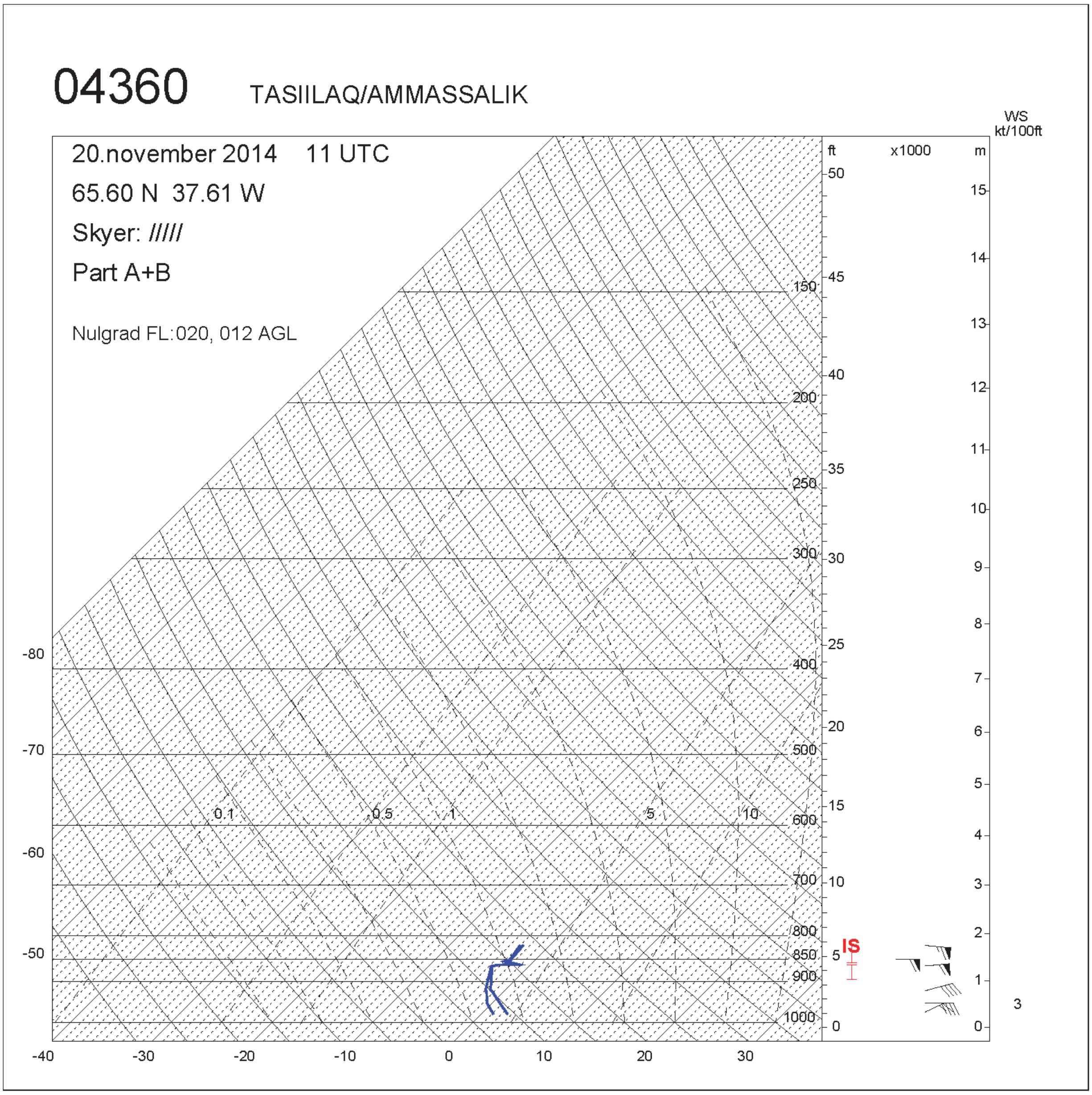

Figure 7. Example of radiosonde observation evaluated as 'Not immediately OK' because of insufficient height obtained. I.e. the bulletin of this particular launch was sent before burst, because of failure of the sonde temperature sensor at 1521 m 815,6 hPa. This information may be looked up in ANNEX B, in the column 'Print outs from robot sonde log file' for the hour of observation 20 November 2014 12 UTC.

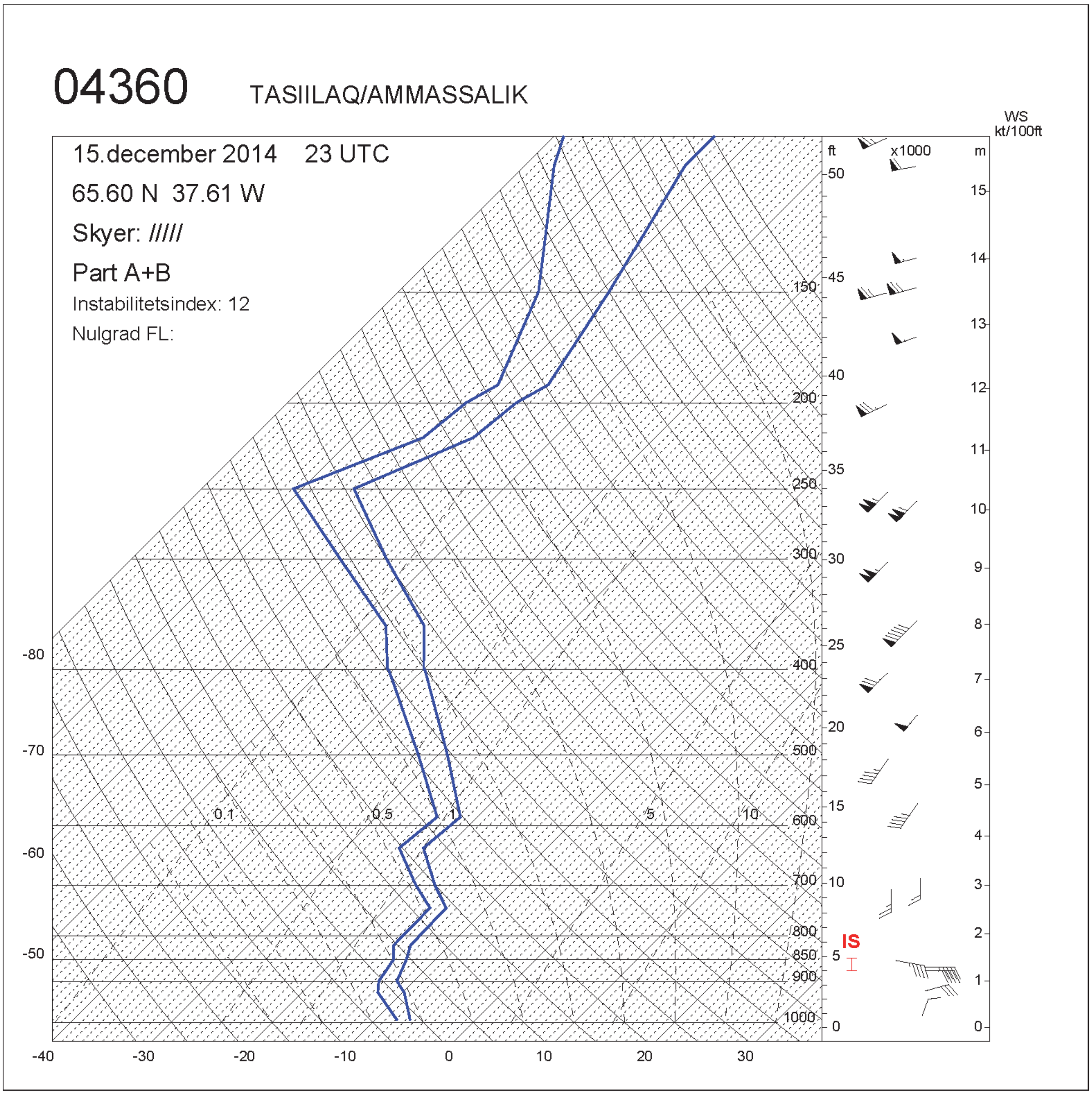

Figure 8 Example of radiosonde observation evaluated as having 'Immediately unrealistic 'parallel course of Dew point and Temperature''.

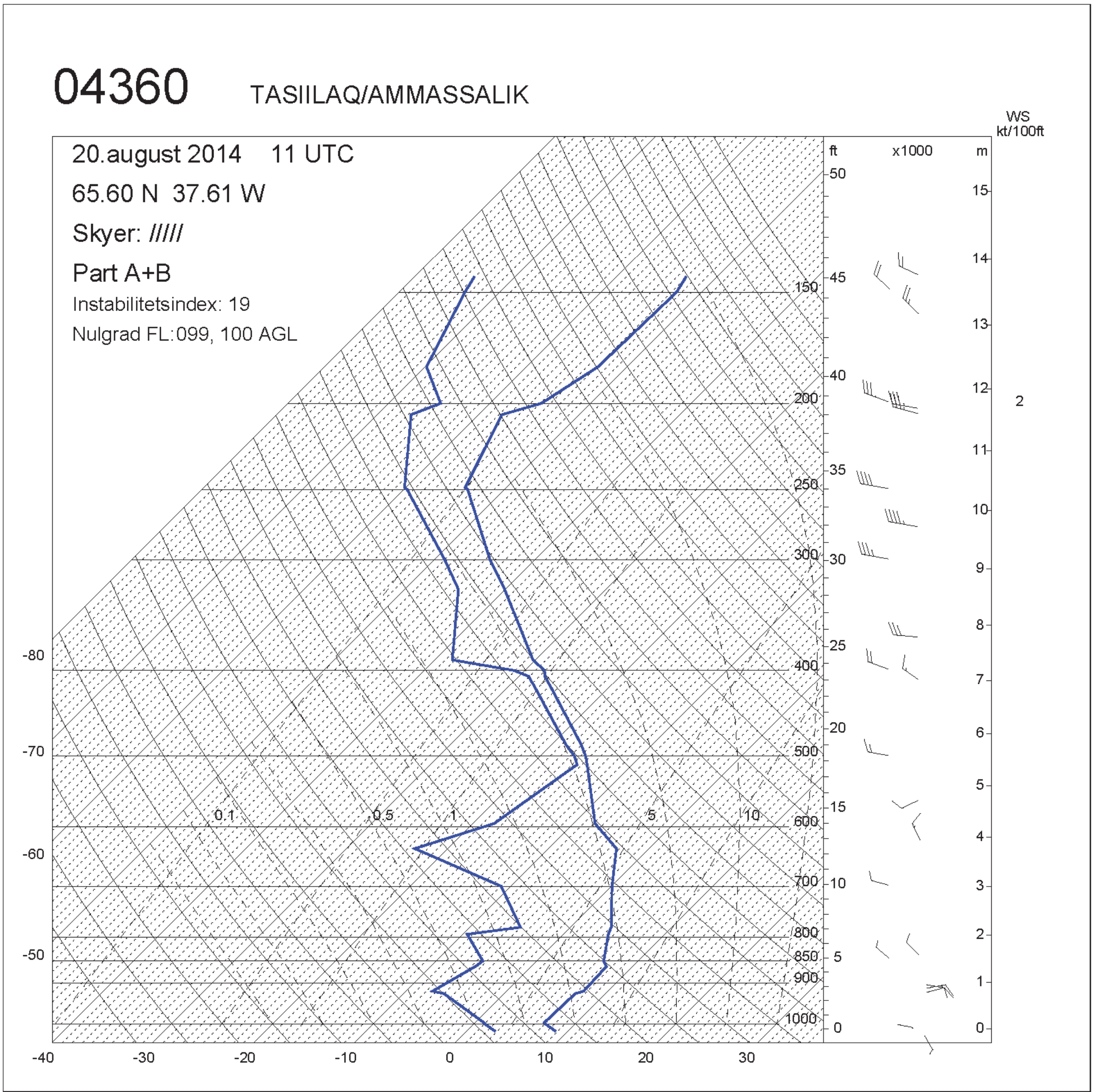

Figure 9. Example of quality level evaluated as 'immediately OK'.

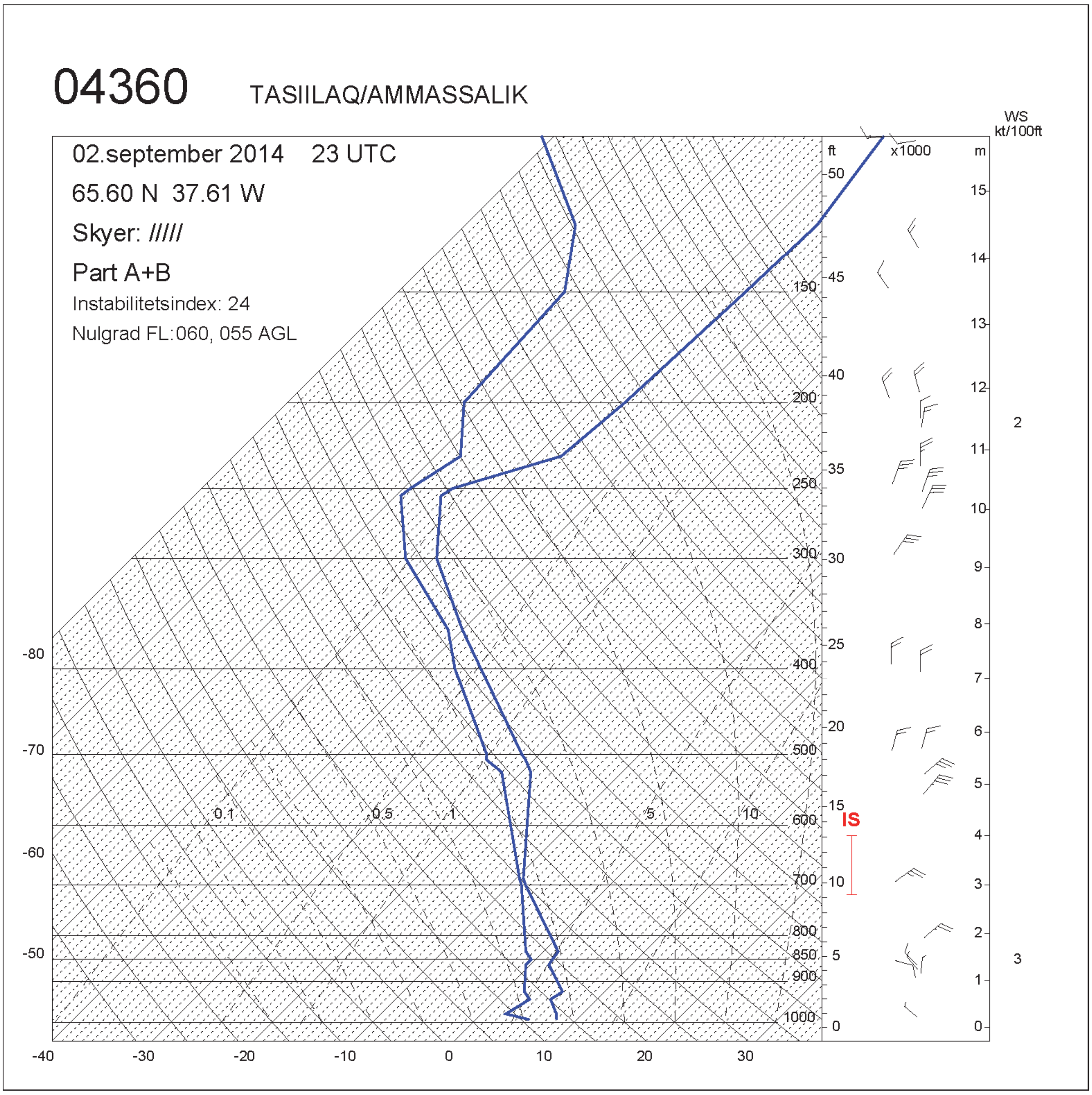

Figure 10. Example of quality level evaluated as 'immediately OK'.

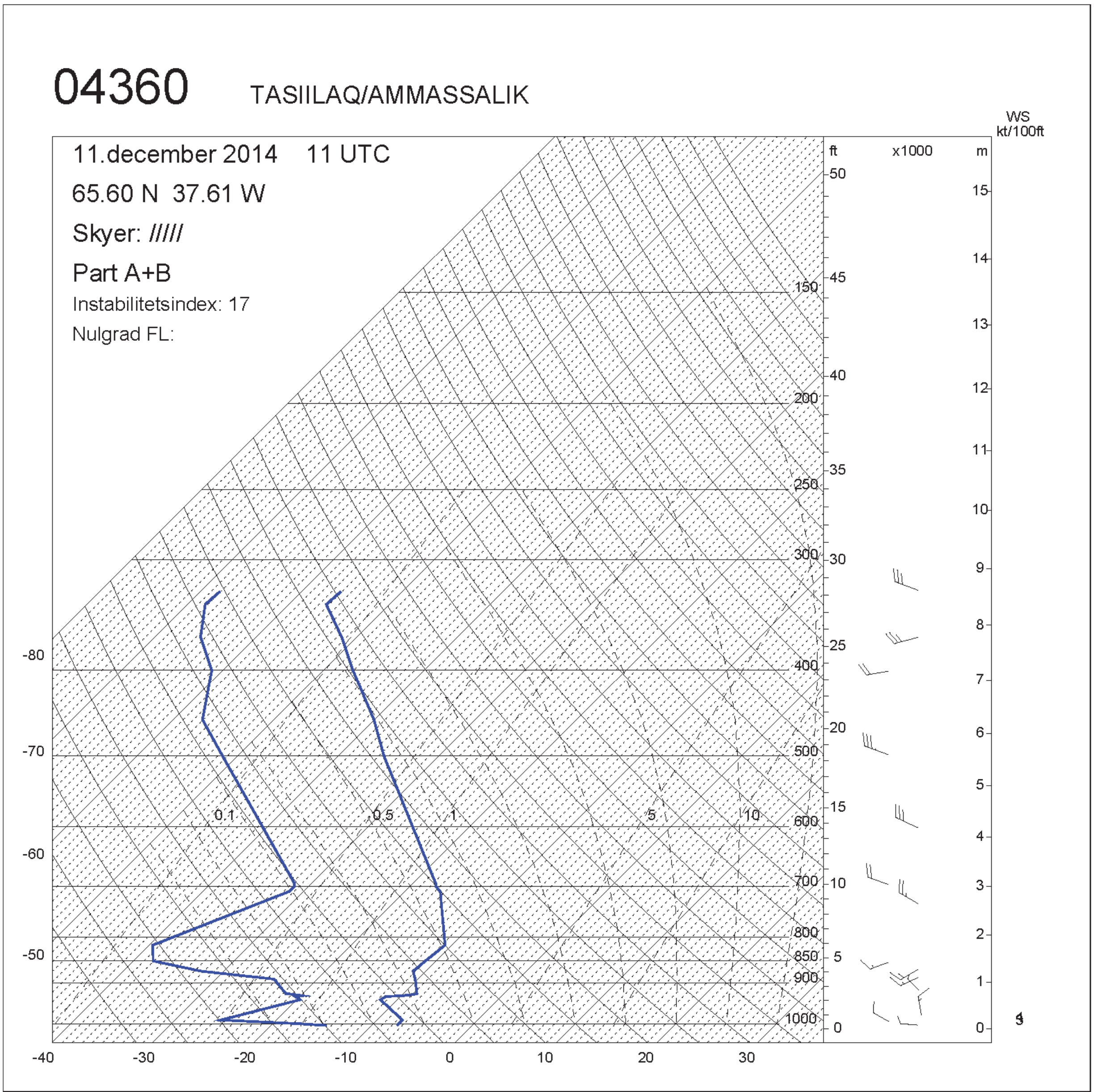

Figure 11. Example of quality level evaluated as ‘immediately OK’.

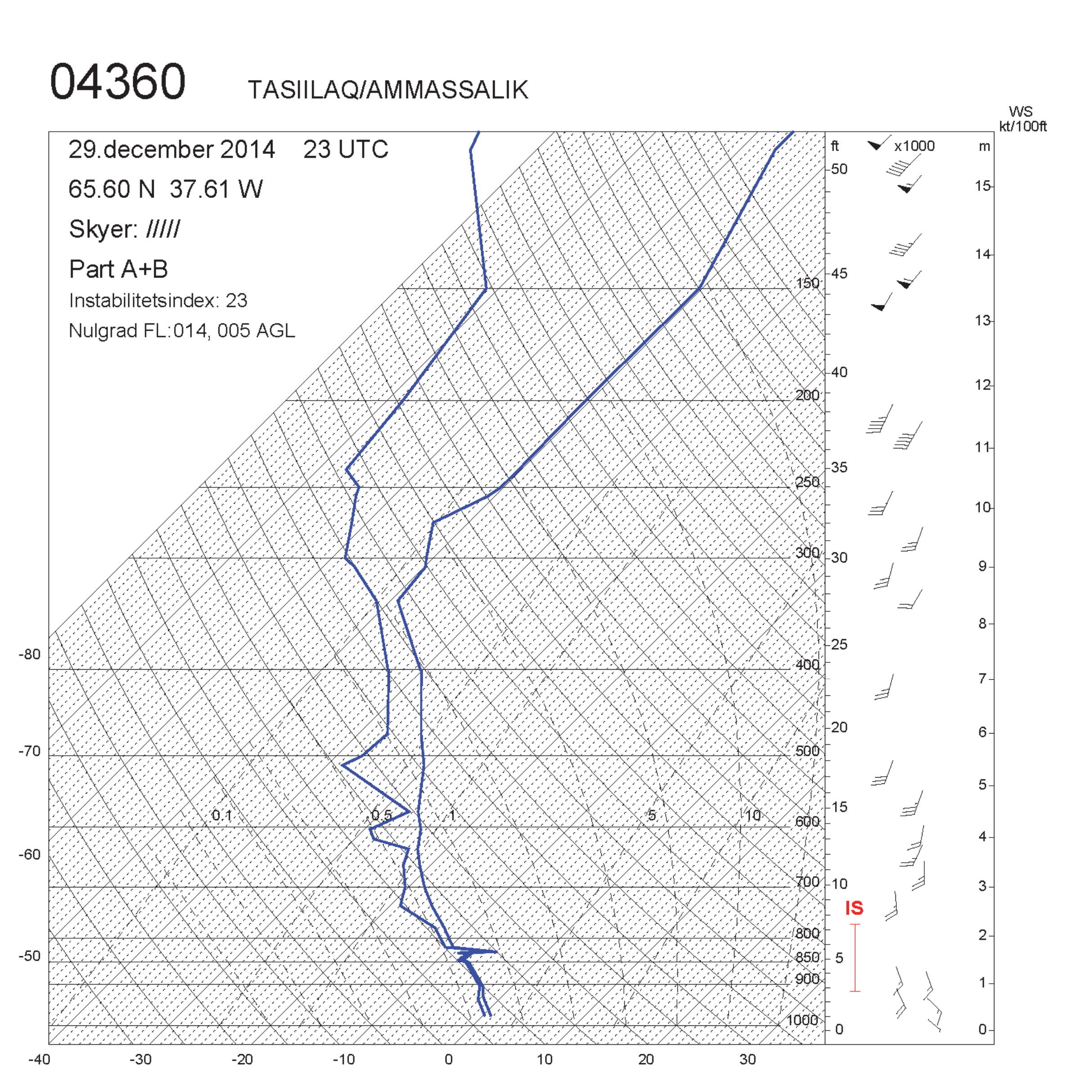

Figure 12. Example of quality level evaluated as 'immediately OK'.

4. Technical operations scheme

The DMI results with the automated radiosonde launch of station 04360 Tasiilaq so far were obtained by the following, technical operations scheme:

- The autolauncher is in operation with launches twice per day, all year.
- The autolauncher is in operation without daily operation by professional radiosonde operators.
- The operation of the autolauncher presently involves:
    - Contracted local help on regular basis to:
        - Service the autolauncher installation with radiosondes and balloons twice a week.
        - At least once a week make visual inspection of and perform ordinary service to both autolauncher and hydrogen generator.
        - Move local stock of goods to site and inspection of water-/hydrogen installation once every month.
        - Inspect the facility four times a year.
        - Fill local stock of goods twice a year.
        - During the winter season to remove snow from the autolauncher installation roof. This serves two purposes: To facilitate automated roof operation and to avoid loss of connection to GPS-signal.
    - Additional local help in the winter season to remove snow from the ground around the autolauncher installation.
    - Automated alarm to the DMI 24/7/365-operators at DMI headquarters in Copenhagen in case of missing out of dissemination of radiosonde observation.
    - Remote access to the autolauncher system, for e.g. ‘remote sounding on request’, access to log files etc.
    - On working days remote trouble shooting by available DMI Technical Staff, as required.
    - Engagement of the contracted, local help in trouble shooting and remedying action as required, when local help is available on site. The availability of local help for this is not guarantied outside of the guarantied hired, local help twice a week.
    - DMI Technical staff for additional action on site. So far this has in reality been an annual station visit, when DMI technical staff was present in Tasiilaq anyhow, because of planned or urgent service visit at the DMI SYNOP station of 04360 Tasiilaq. So far DMI staff has not visited the ABL during the winter season.

5. Conclusions

The DMI ABL Tasiilaq project demonstrates that replacement of manned radiosonde operation with automated radiosonde operation in Greenland is not in its present setup adequate for reaching the operational target with respect to radiosonde observations availability and quality.

For the 32 months of automated operation so far neither the availability or the height level nor the quality of the radiosonde observations were showing an overall satisfactory level for operational use.

Since this was a first experiment it was initially expected by DMI that quality and availability would improve with experience with the method of operation. But when comparing results of periods of varying length after the launch was automated, no improvement with time was found. On the contrary the overall availability dropped from 89,5% in 2013 to 82,9% in 2014.

Based on the identified causes for missing observations the following should have the greatest impact to further improve availability of the automated launches (prioritized):

1. Prevention of successive missing observations because of one, initial problem.
2. Fixing of the ‘frozen roof’-problem during the cold season.
3. (Entering into and) adhering to adequate service and maintenance plans.

Based on the identified cases where the connection to the radiosonde was lost before burst, the following should have the greatest impact to improve height obtained (prioritized):

1. Fixing of communication problems between ABL installation and radiosonde (cf. Table 4).
2. Radiosondes with more reliable temperature sensors (cf. the kind of sensor failure resulting in a bulletin sent before burst shown by example in Figure 7).

Based on the visual inspection quality survey of the observations of the half year period July – December 2014 the following should sufficiently improve data quality:

1. Employ radiosondes with more reliable humidity sensors.

The conclusion, based on the experiences of the first 32 months of automated radiosonde operation, is that the greatest improvement will be obtained by finding solutions as to:

- Improved performance of humidity and temperature sensors of the radiosondes.
- Operations procedures for taking remedying action to prevent successive missing observations after one, initial problem. The procedures should be in function also on holidays and outside of ordinary working hours in both Greenland and Denmark.
- Improved reliability in communication between station and sonde.

6. References

Cappelen, John, Bent Vraae Jørgensen, Ellen Vaarby Laursen, Lotte Sligting Stannius and Rikke Sjølin Thomsen: The Observed Climate of Greenland, 1958-99 - with Climatological Standard Normals, 1961-90. DMI Technical Report No. 00-18. Copenhagen 2001. Link to report: http://www.dmi.dk/fileadmin/user_upload/Rapporter/TR/2000/tr00-18.pdf

EUCOS Quality Monitoring Portal http://eucos.dwd.de/qmp/ EUMETNET Observations Quality Monitoring, Deutscher Wetterdienst, E-mail : info@dwd.de, Internet: www.dwd.de, Responsible: Stefan Klink.

Kleinert, Tanja, Deutscher Wetterdienst, Observations QM and Operations Manager. Personal email correspondence 6 August 2015.

Laursen, Ellen Vaarby: Wind statistics for stations 04360 Tasiilaq and 04361 Mittarfik Kulusuk Data December 2000 - August 2010. DMI Technical Report No. 10-14. Copenhagen 2014. Link to report: http://www.dmi.dk/fileadmin/Rapporter/TR/tr10-14.pdf

WMO-No. 8: Guide to Meteorological Instruments and Methods of Observation (CIMO-Guide), 2008 edition, updated in 2010. Published by WMO in 2012.

WMO-No. 306 Manual on Codes, Volume I.1, PART A – Alphanumeric Codes. WMO 2014 (2011 edition updated in 2014).

WMO-No. 306 Manual on Codes, Volume I.2, PART B – Binary Codes. Part C – Common Features to Binary and Alphanumeric Codes. WMO 2014 (2011 edition updated in 2014).

7. Previous reports

Previous reports from the Danish Meteorological Institute can be found on:
http://www.dmi.dk/laer-om/generelt/dmi-publikationer/