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Temperature observations from northernmost Greenland, 2006-2010

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Air-, surface-, and subsurface temperatures were recorded by automatic weather stations in Bliss Bugt and Moore Gletscher, Johannes V. Jensen Land, North coast of Greenland from 2006-2010. The mean annual surface temperature is -12.1 ℃ in Bliss Bugt and -13.8 ℃ at Moore Gletscher. In 20 cm depth below the surface at Moore Gletscher, the mean annual temperature is -13.2 ℃ (2007-2008). High-amplitude fluctuations of the winter temperature at the surface and in 20 cm depth at Moore Gletscher indicate that the surface has little or no snow cover, possibly due to catabatic winds from the glacier. In contrast, in Bliss Bugt, c. 5 km to the north, the surface temperature series only shows low-amplitude variations during the winters. This indicates a significant snow cover in Bliss Bugt, persisting throughout the winter. The surface temperature series reveals that the surface is snow free from mid-late June to late August in Bliss Bugt.

Keywords: Surface temperature, soil temperature, Bliss Bugt, Moore Gletscher, North Greenland

1. Introduction

Instrumental temperature records from the High Arctic are characterized by few observation points, very uneven geographical distribution of observation points, and short temporal coverage of the observations (Bekryaev et al., 2010). The instrumental temperature record of the north coast of Greenland only extends back to 1980 with data from an automatic weather station located at Kap Morris Jesup (Fig. 1; 83°39'N lat.; 33°22'W long., 4 m a.s.l.; WMO station ID 4301; Cappelen et al., 2000) and operated by the Danish Meteorological Institute. The temperature series from this station suffers from several data gaps and the completion is only 65% for the period 1980-1999 (Box, 2002). This means that additional short time series of air and ground temperature observations from this very remote region add important information that might be used for studies of the cryosphere, e.g. glacier mass balance, snow cover, the thermal state of permafrost, and validation of remotely sensed data (Braithwaite et al., 1998; Christiansen et al., 2008; Romanovsky et al., 2010; Urban et al., 2013; Williamson et al., 2014).

During a field campaign in North Greenland in 2006, two automatic weather stations were deployed in Bliss Bugt and in front of Moore Gletscher, both located in Johannes V. Jensen Land at the central north coast (Fig. 1). The stations were configured to measure air temperature 2.5 m above the ground, precipitation, surface temperature, and soil temperature in 20 cm depth (in front of Moore Gletscher). Data were recorded from 2006-2010, and retrieved during field work in the summer of 2016. The aim of this paper is to present the temperature data series from Bliss Bugt and

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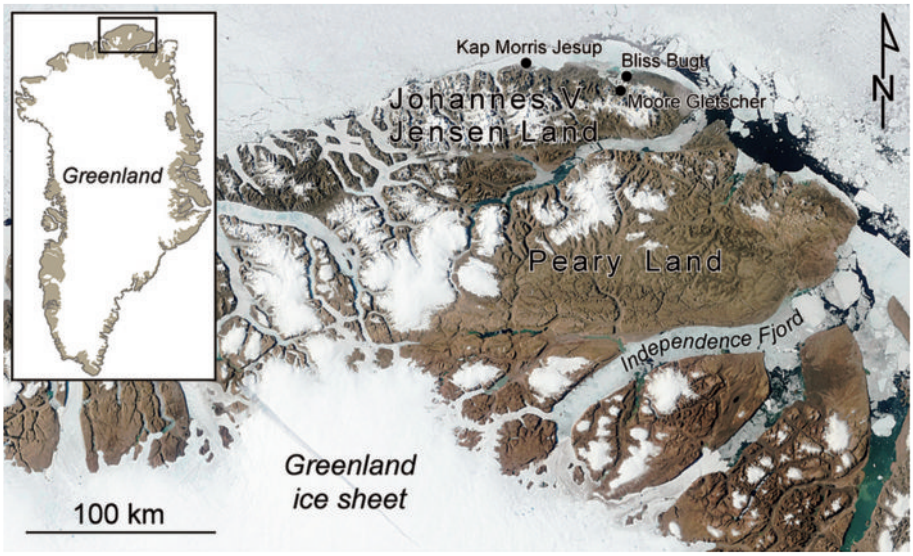

Figure 1 : Map of North Greenland. The two automatic weather stations were located in Bliss Bugt and Moore Gletscher in Johannes V. Jensen Land. The location of the meteorological station at Kap Morris Jesup is also shown.

Moore Gletscher.

2. Setting

The north coast of Greenland is characterized by a High Arctic, arid climate. There is perennial sea ice cover at the Arctic Ocean along the north coast. Kap Morris Jesup annually experiences 154 days of midnight sun and 143 days of polar night. Some of the coldest temperatures ever measured in Greenland (outside the Greenland Ice Sheet) are from North Greenland. The coldest temperatures recorded in Greenland in November and December in the period 1980–1999 were measured at Kap Morris Jesup with −45 ℃ and −48.9 ℃, respectively (Cappelen et al., 2000). The mean monthly temperatures at Kap Morris Jesup from 1980–2013 are presented in Fig. 2. Based on years with complete temperature records, the mean annual air temperature at Kap Morris Jesup is −17.3 ℃ from 1980–2013. Cappelen et al. (2000) report a mean annual air temperature of −18 ℃ at Kap Morris Jesup from 1980–1999. Positive mean monthly air temperatures only occur in June, July, and August (JJA). The mean summer (JJA) air temperature is 0.3 ℃ at Kap Morris Jesup based on months with a complete record in the period 1980–2013.

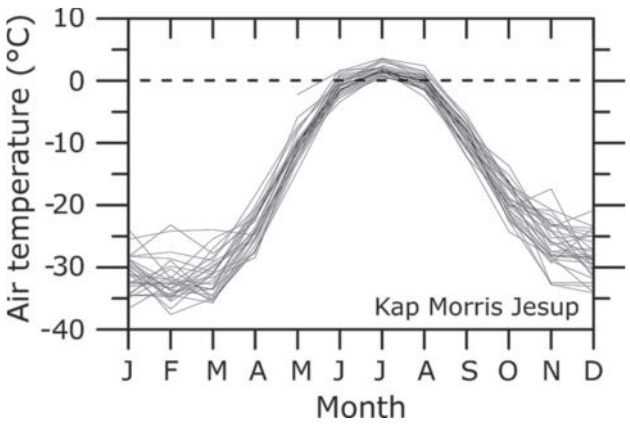

Figure 2 : Stacked curves of monthly mean air temperatures from Kap Morris Jesup from 1980–2013. Data from the Danish Meteorological Institute.

3. Data and methods

In Bliss Bugt, an automatic weather station was deployed at 83°31' N lat.; 28°47' W. long.; 17 m a.s.l. (Fig. 1). It was operated from July 30, 2006 and recorded hourly until April 19, 2010 when the datalogger memory was full. Air and ground surface temperatures were recorded with Gemini Data Loggers TinyTag Plus2 TGP-4020 with a PB-5001-1M5 10 K NTC thermistor. For positive temperatures, the accuracy of the sensor is 0.2 ℃, and for negative temperatures it ranges from 0.2–0.4 ℃. The air temperature was measured 2.5 m above the ground and the thermistor was mounted in a

Figure 3 : Photograph of the automatic weather station in front of Moore Gletscher, August 4, 2006. The surface and sub-surface temperature sensors are not visible. Persons for scale.

white plastic solar radiation shield. The ground surface thermistor was radiation shielded by well-ventilated rocks. Temperature range of the thermistors is reported to −40 to 125 ℃ by the manufacturer although they did return colder measurements. This station did not measure temperature below the surface.

A second automatic weather station was deployed c. 700 m from the Moore Gletscher terminus at 83°29'N lat.; 28°55'W long; 10 m a.s.l. (Figures 1 and 3). It was deployed on August 4, 2006 and recorded hourly until February 2, 2010 when the datalogger memory was full. This station was equipped with similar instruments as Bliss Bugt, but additionally it measured soil temperature at 20 cm depth below the surface.

Both stations were also equipped with an automatic precipitation gauge. However, one was missing when the stations were visited in 2016, and another did not return meaningful data. Table 1 provides an overview of the recovered data series from the two stations.

4. Results and discussion

The two air temperature sensors only recorded data from July/August 2006 to November 2006/April 2007, respectively (Table 1). They stopped recording data for unknown reasons. The Danish Meteorological Institute automatic weather station at Kap Morris Jesup was also not recording data from January 2006 to July 2009, and the only overlap between our temperature observations and Kap Morris Jesup is from July 2009–April 2010.

The air temperature data from Bliss Bugt reached a minimum of −43.2 ℃ on December 2006. This series also shows that the 2006–2007 winter air temperatures range between 0 ℃ and −43.2 ℃. The surface temperature in Bliss Bugt, however, is characterized by much smaller amplitude during the winters (Fig. 4A; Table 2). The four recorded winters all show a similar trend where temperature drops below zero in mid-late August and does not reach positive temperatures until mid-late June the following year. The lowest surface temperature of −28.7 ℃ in Bliss Bugt was recorded on March 12, 2007. We interpret the low-amplitude winter surface temperatures in Bliss Bugt as evidence of a significant snow cover that does not allow the short-lived air temperature fluctuations to penetrate to the ground surface (Christiansen et al., 2008). This is also supported by the slow transition from negative to positive ground surface temperatures in mid-late June each year. The ground surface temperature first rises steeply to 0 ℃ in June each year and stays at c. 0 ℃ for 1–2 weeks. This is interpreted as the final period of snowmelt.

The summer surface temperature in Bliss Bugt shows much larger amplitude than the winter temperature and follows closely the air temperature fluctuations in 2006. The maximum ground surface temperature was 24.7 ℃ recorded on August 1, 2008 and the

Table 1 : Overview of automatic temperature recordings in North Greenland, 2006–2010.

Station name	Position	Parameter	Start date	End date
Bliss Bugt	83°31'N; 28°47'W	2.5 m air temp.	July 30, 2006	April 24, 2007
Bliss Bugt	83°31'N; 28°47'W	Surface temp.	July 30, 2006	April 19, 2010
Moore Gletscher	83°29'N; 28°55'W	2.5 m air temp.	August 4, 2006	November 14, 2006
Moore Gletscher	83°29'N; 28°55'W	Surface temp.	August 4, 2006	February 2, 2010
Moore Gletscher	83°29'N; 28°55'W	20 cm soil temp.	August 10, 2006	December 3, 2009

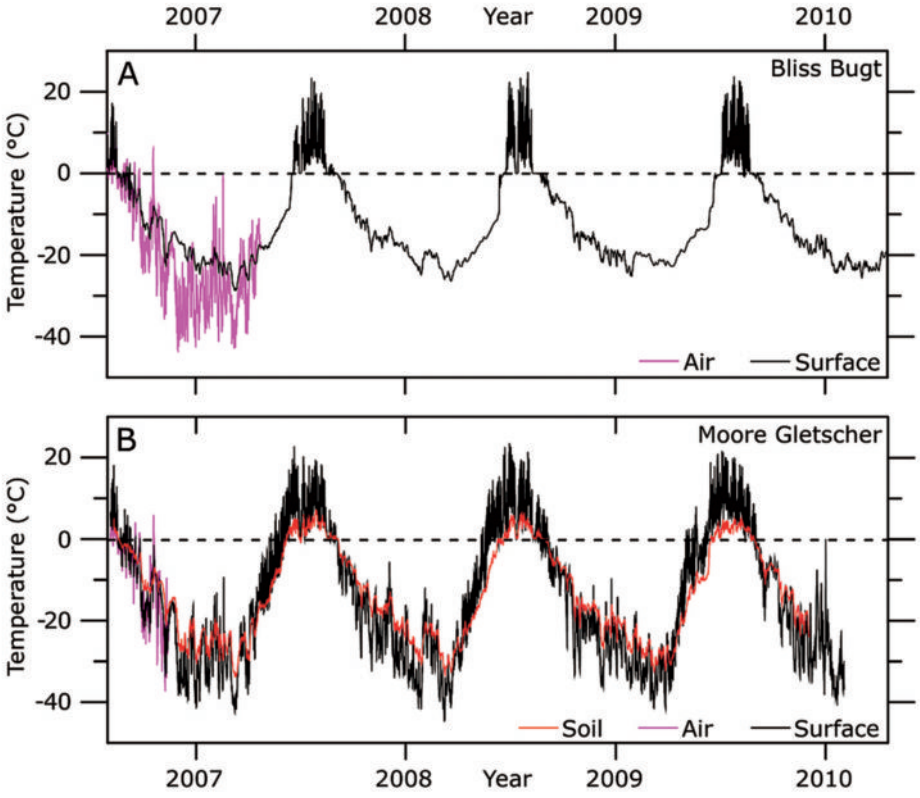

Figure 4 : Temperature records from 2006–2010 from the automatic weather stations at the North coast of Greenland. A. Bliss Bugt. B. Moore Gletscher.

Table 2 : Summary of data from automatic temperature recordings in North Greenland, 2006–2010.

Station name	Parameter	T_{mean} (2007; ℃)	T_{mean} (2008; ℃)	T_{mean} (2009; ℃)	T_{max} (℃; date)	T_{min} (℃; date)
Bliss Bugt	2.5 m air temp.	No data	No data	No data	10.5; August 10, 2006	-43.2; December 1, 2006
Bliss Bugt	Surface temp.	-12.0	-12.4	-11.8	24.7; August 1, 2008	-28.7; March 12, 2007
Moore Gletscher	2.5 m air temp.	No data	No data	No data	10.4; August 10, 2006	-37.3; November 8, 2006
Moore Gletscher	Surface temp.	-13.6	-13.9	-14.0	23.5; June 29, 2008	-44.6; March 8, 2007
Moore Gletscher	20 cm soil temp.	-12.8	-13.6	No data	7.0; July 27, 2007	-33.9; March 9, 2007

temperature ranges between 0 ℃ and 24.7 ℃ during the summers (Table 2). The mean annual ground surface temperature in Bliss Bugt is -12.1 ℃ based on the complete years 2007, 2008, and 2009.

The air temperature data from Moore Gletscher reached a minimum of -37.3 ℃ on November 8, 2006 before the instrument stopped recording data later that month (Fig. 4B; Table 2). The period of overlap with Bliss Bugt shows the same trend. The ground surface temperature series at Moore Glacier, however, differs significantly from Bliss Bugt (Fig. 4). The amplitude during the winters is much higher, and the ground surface temperature mimics closely the air temperature during the period of overlap in late 2006. Winter ground surface temperatures at Moore Glacier reach a minimum of -44.6 ℃ on March 8, 2007, and the amplitude reaches c. 40 ℃ in the winter of 2010. The similarity to the air temperature in late 2006 and the high amplitude of the ground surface temperature during winters compared to Bliss Bugt indicate that the surface at this locality does not have a significant snow cover (Christiansen et al., 2008). The transition from negative to positive temper-

atures is rapid in all three years, and there are no extensive periods with near-zero temperatures. This also suggests that there is almost no snow cover.

The summer surface temperature trend at Moore Gletscher is similar to Bliss Bugt. It closely follows the air temperatures in the late summer of 2006. The maximum ground surface temperature was 23.5 ℃ recorded on June 29, 2008 and the temperature ranges between 0 ℃ and 23.5 ℃ during the summers (Table 2). The mean annual ground surface temperature at Moore Gletscher is −13.8 ℃ based on the complete years 2007, 2008, and 2009.

The temperature at Moore Gletscher was also recorded 20 cm below the surface (Tables 1–2; Fig. 4B). The amplitude of this temperature series is smaller than at the surface and in the air but it follows the fluctuations recorded on the ground surface. Minimum temperature in 20 cm depth was −33.9 ℃ recorded on March 9, 2007, and maximum temperature was 7 ℃ recorded on July 27, 2007. The mean annual temperature 20 cm below the surface at Moore Gletscher is −13.2 ℃ based on the two complete years 2007 and 2008. We interpret the high-amplitude winter temperature variations in 20 cm depth as an indicator of a very limited insulating snow cover at the surface.

Notably, the ground surface temperature at Moore Glacier rises above zero 3–4 weeks earlier than in Bliss Bugt each year. Together with the high-amplitude winter temperature fluctuations, this indicates that the snow cover was limited throughout the observation period. We suggest that the limited snow cover in front of Moore Gletscher is due to catabatic winds from the glacier, blowing snow off the ground surface. The station in Bliss Bugt is located on the flat, open coastal plain at the north coast of Greenland (Larsen et al., 2010). Although this very open plain is not favorable for snow accumulation, our data show that the surface is, indeed, snow covered until mid-late June. The snow cover also explains the slightly higher mean annual ground surface temperatures in Bliss Bugt compared to Moore Gletscher (Table 2). Ground surface temperature data suggest that the surface is free of snow from mid-late June to late August in Bliss Bugt. Air, surface, and 20 cm depth temperatures all suggest that the study area hosts continuous permafrost (e. g. French, 2007; Christiansen et al., 2008). Only the upper 20–30 cm of the ground were thawed during installation of the thermistor at Moore Gletscher in August 2006.

5. Conclusions

- The mean annual ground surface temperature in Bliss Bugt is −12.1 ℃ (2007–2009) and −13.8 ℃ at Moore Gletscher (2007–2008).
- The mean annual temperature at 20 cm depth below the surface at Moore Gletscher is −13.2 ℃ (2007–2008).
- Snow free surface conditions extend from mid-late June to late August in Bliss Bugt (2007–2009).
- The lowest recorded temperature was −44.6 ℃ at the ground surface at Moore Gletscher on March 8, 2007. The highest temperature was 24.7 ℃ at the ground surface in Bliss Bugt on August 1, 2008.
- Bliss Bugt and Moore Gletscher experience very different snow cover conditions. The low-amplitude fluctuations of surface temperature in Bliss Bugt suggest that the surface is snow-covered throughout the winter. The forefield of Moore Gletscher experience high-amplitude variations in surface and subsurface temperature, indicating that the snow cover is absent or thin.

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are available from the authors.

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