Proceedings of the Ninth International Conference on Permafrost
University of Alaska Fairbanks
June 29–July 3, 2008

Ninth International Conference on Permafrost

Edited by Douglas L. Kane and Kenneth M. Hinkel

Volume 2

Institute of Northern Engineering
University of Alaska Fairbanks
2008

Ninth International Conference on Permafrost
Edited by Douglas L. Kane and Kenneth M. Hinkel

Printed in the United States of America

Elmer E. Rasmuson Library Cataloging in Publication Data
International Conference on Permafrost (9th : 2008 : Fairbanks, Alaska)
Ninth International Conference on Permafrost /
edited by Douglas L. Kane and Kenneth M. Hinkel.
— Fairbanks, Alaska : Institute of Northern Engineering,
University of Alaska Fairbanks, 2008.
2 v., : ill., maps ; cm.
Includes bibliographical references and index.
June 29–July 3, 2008
1. Permafrost–Congresses. 2. Frozen ground–Congresses.
I. Title. II. Kane, Douglas L. II. Hinkel, Kenneth M.

GB641.I6 2008

ISBN 978-0-9800179-2-2 (v.1)
ISBN 978-0-9800179-3-9 (v.2)

Cover Photo: Low-Centered Polygons, North Slope, Alaska
© 2007 Steven Kazlowski / AlaskaStock.com

Production Editors: Thomas Alton and Fran Pedersen

Kane, D.L. & Hinkel, K.M. (eds). 2008. *Ninth International Conference on Permafrost.* Institute of Northern Engineering, University of Alaska Fairbanks (2 Vols.), 2140 pp.

Soil and Permafrost Temperature Data Obtained During the First International Polar Year, 1882–1883

Kevin R. Wood
Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, USA
Dmitry A. Streletskiy
Dept. of Geography, Center for Climatic Research, University of Delaware, Newark, USA

Abstract

Synoptic meteorological data from Arctic stations established during the first International Polar Year (IPY-1) have recently been collected and digitized. The research program at seven of fourteen stations included ground temperature observations at regular depth intervals. We have analyzed data obtained at the IPY-1 stations at Jan Mayen, Sodankylä, Finland, and at Malyye Karmakuly and Sagastyr, Russia. Descriptive records and more fragmentary data are available for most stations. Initial comparisons indicate that ground temperatures are consistent with surface air temperature (SAT) observations obtained using well-calibrated standard instruments. Using these data, we compare ground-temperature observations with contemporary measurements made at nearby locations.

Keywords: climate change; ground temperature; historical data; permafrost; Polar Year.

Introduction

Ground temperature measurements were recorded at seven of fourteen research stations established in the Polar Regions during the first International Polar Year (IPY-1) (Fig. 1) (Heathcote & Armitage 1959). Time series data were collected in soil at four or more levels down to 1.6 or 2.0 m depth where possible. Measurements were made with calibrated instruments and recorded values tracked variations in surface air temperature (SAT) as expected. The two U.S. stations were not equipped for systematic observation of ground temperature, but at Point Barrow a shaft was sunk to a depth of 37.5 feet for the purpose of obtaining the temperature of the earth, which at the bottom was reported to be a near-constant 12°F (-11.1°C) (Ray 1885). Descriptive observations covering a wide range of cryosphere-related features are commonly found in expedition reports, including notes on ice and ice-processes that were features of the regional landscape. All data obtained during IPY-1 were published *en extenso* by each of the national expeditions. There has been renewed interest in historical data of this type in recent years due to the potential value they hold for improving our understanding of climate change and its impact on the environment.

We present an analysis of the four most complete ground temperature data sets recorded during IPY-1 in the Northern Hemisphere. These were obtained by the Austro-Hungarian expedition at Jan Mayen (von Wohlgemuth 1886); the Finnish expedition at Sodankylä (Lemström & Biese 1886); and by the Russian expeditions at Malyye Karmakuly, on Novaya Zemlya, and Sagastyr, in the Lena River delta (Lenz 1886a, 1886b). Descriptive records obtained at these locations are discussed. Data and an extensive image collection are available at: www.arctic.noaa.gov/aro/ipy-1.

Inspired by Carl Weyprecht (1838–81), the aim of IPY-1 was to investigate those fundamental problems in geophysics which could only be studied effectively through a program of coordinated observation at a widely distributed network of stations anchored in Polar Regions (Weyprecht 1875).

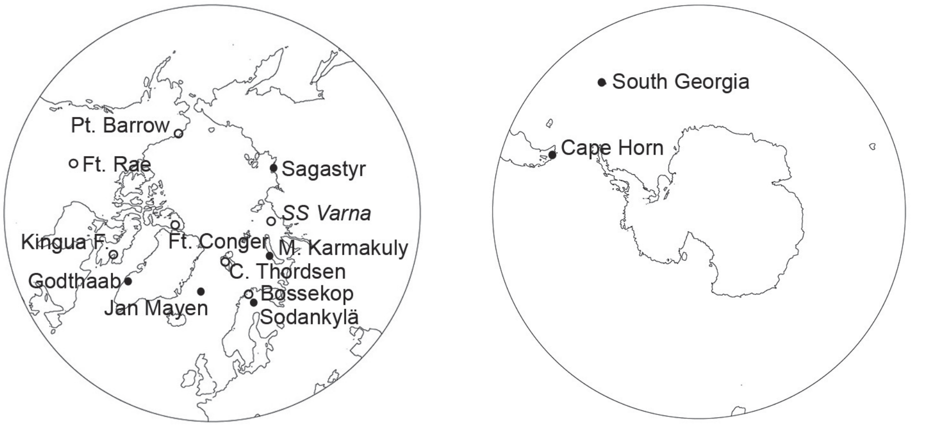

Figure 1. IPY-1 stations in the Northern and Southern Hemispheres. Filled circles indicate stations where ground temperature measurements were obtained. Open circles indicate stations where fragmentary data or descriptive observations only were obtained. The Dutch expedition (SS *Varna*) was trapped in the Kara Sea and did not reach land.

The three main fields of inquiry were meteorology, terrestrial magnetism, and the aurora. The science plan of IPY-1 also encompassed a wide range of additional subjects under the heading of optional observations. In addition to the ground temperature data discussed here, research was undertaken in a variety of subject areas including ethnology, natural history, and oceanography.

It is not surprising that ground temperature and related geocryological studies were undertaken during IPY-1 given the interest in the subject over the previous 40 or more years and the personal involvement of H. Wild, the president of the International Polar Commission (IPC) in this research area (Wild 1878), and G. Wild, president of the Russian Polar Commission and noted permafrost scientist (Baker 1982, Shiklomanov 2005).

Direct comparisons between IPY-1 and modern ground temperature regimes proved to be impossible, primarily due to a lack of modern data at these stations. Landscape transformation was also a factor, especially at Sodankylä, where a reservoir now covers the station site. Since the data were collected simultaneously, we are able to discuss the spatial variability between stations. Given the connection between upper level ground temperatures and synoptic meteorology, we also draw some tentative conclusions about where IPY-1 observations fall within the spectrum of recent monthly mean SAT variability.

Data and Methods

The most complete time series of ground temperature observations in soil obtained during IPY-1 were recorded at Jan Mayen (71.00°N, 008.47°W), Sodankylä (67.41°N, 026.6°E), Malyye Karmakuly (72.38°N, 052.7°E), and Sagastyr (73.38°N, 124.08°E). Two years of observations were recorded at Sodankylä and Sagastyr. A temperature time series in rock was obtained at Godthaab, and fragmentary data of various types were obtained at Cap Thordsen, Fort Rae, and Point Barrow. We have concentrated our analysis on the first four data sets. Data collected at the two Southern Hemisphere stations have not been addressed.

Details on the methods adopted at each station and descriptions of the ground cover and soil type are provided in the expedition reports cited above. An idea of the different environments around each station can also be gleaned from Figure 2 and other graphical information in the reports.

The most detailed metadata available for the four stations relates to the Russian station at Sagastyr. Given that procedures at this station and the stations at Malyye Karmakuly, and Sodankylä were all initiated by H. Wild, IPC president and director of the Central Physical Observatory in St. Petersburg, we can expect that many particulars are common to these three stations. In general, separate holes were excavated to 40, 80, and 160 cm and either glass or wooden tubes inserted. The earth thermometers themselves were enclosed in brass cylinders with their bulbs embedded in a mixture of brass filings and tallow. The cylinders were then attached to wooden sticks that were placed in each tube.

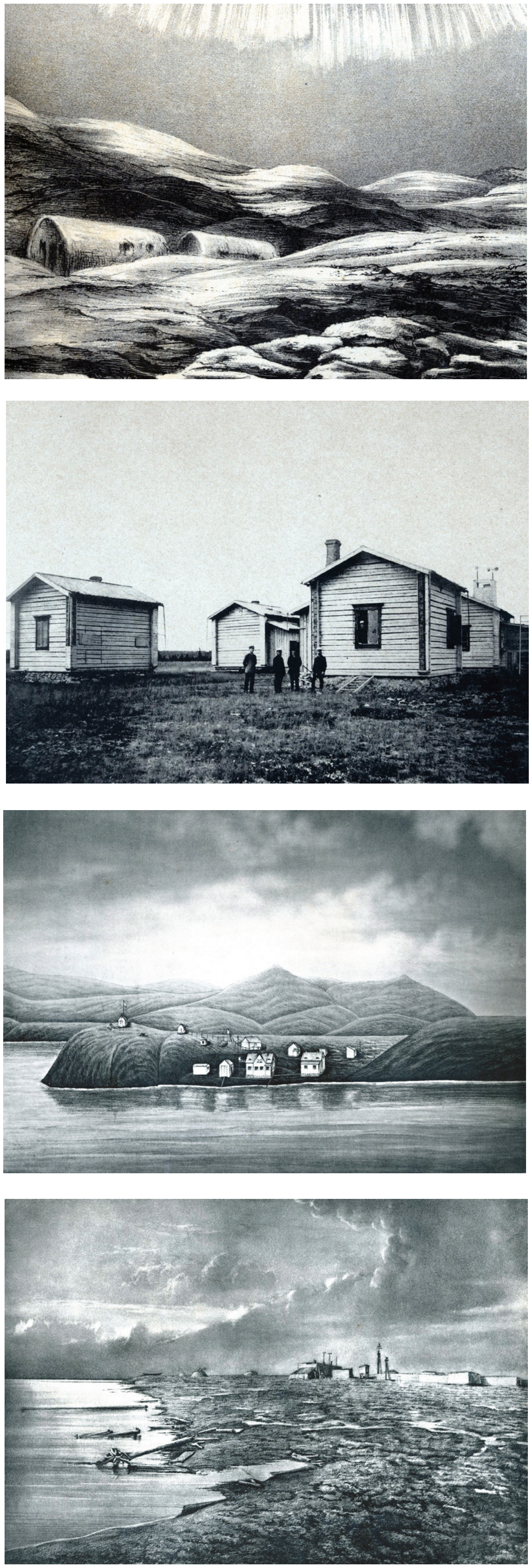

Figure 2. IPY-1 stations and surrounding terrain (from top): Jan Mayen, Sodankylä, Malyye Karmakuly, and Sagastyr.

The tubes were then closed with brass caps. Thermometers at the ground surface were installed horizontally, usually on two small brackets. Surface instruments were often buried in snow and were susceptible to breakage when the snow was removed each time they were read. Instruments on the surface and at 40 cm were read hourly, while the deeper ones were read less frequently (either 3x or daily). Thermometers were calibrated at a range of temperatures against standard instruments at the Central Physical Observatory and verified more frequently at the station at the 0°C calibration point.

The Sagastyr station was established on a small island on the northern edge of Lena River delta. A. Bunge, one of the expedition scientists, noted the dynamic effects of the river upon the terrain in the delta (Lenz 1886a). Old islands were continually being eroded and new ones created. The ground was generally composed of sandy soils overlaid with peat, the thickness of which Bunge suggested was proportional to the length of time the place was undisturbed. The vegetation around the station was dominated by mosses and lichens, with sparse dwarf-shrubs (mostly *Salix polaris*). The data record was interrupted in the summer of 1883 due to meltwater infiltrating from the surface and refreezing in the tubes at deeper levels which prevented the extraction of the thermometers. The location was also moved at this time to an area less susceptible to the building-induced snow drift that was problematic during the first year. Several reported changes of equipment produced small inhomogeneities in the record, but these had minimal influence on the interpolated mean annual ground temperature (MAGT) at particular depths.

The expedition to Malyye Karmakuly was dispatched hurriedly and was not prepared for as thoroughly as the others (Barr 1985). Here, soil temperatures were measured at the standard depths in gravelly soil characteristic of the island.

Wooden tubes rather than glass were used. Continuous snow cover at the measurement site was registered from 6 October 1882 to 25 May 1883. The measurements at 160 cm were interrupted on 30 May, again due to the infiltration and freezing of meltwater, as was the case in Sagastyr.

The metadata for Sodankylä is sparse. The earth thermometers were located about 20 m south of the buildings shown in Figure 2, on flat grassy terrain about 300 m from the Kitala River. Instruments at the surface and 40 cm were read hourly; others were read at least daily but the interval was not clear in the report. In the second year, observations were taken three times daily (0600, 1400, and 2200). Training

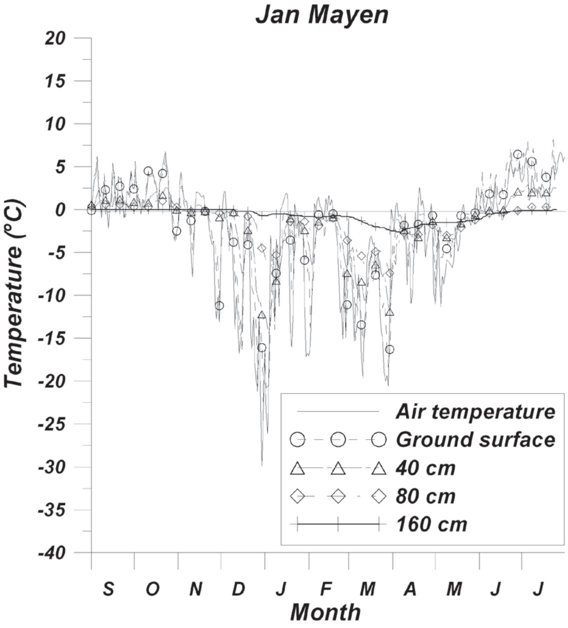

Figure 3. Air and ground temperatures observed at Jan Mayen, 1882–1883. Markers are placed at 10-day intervals throughout.

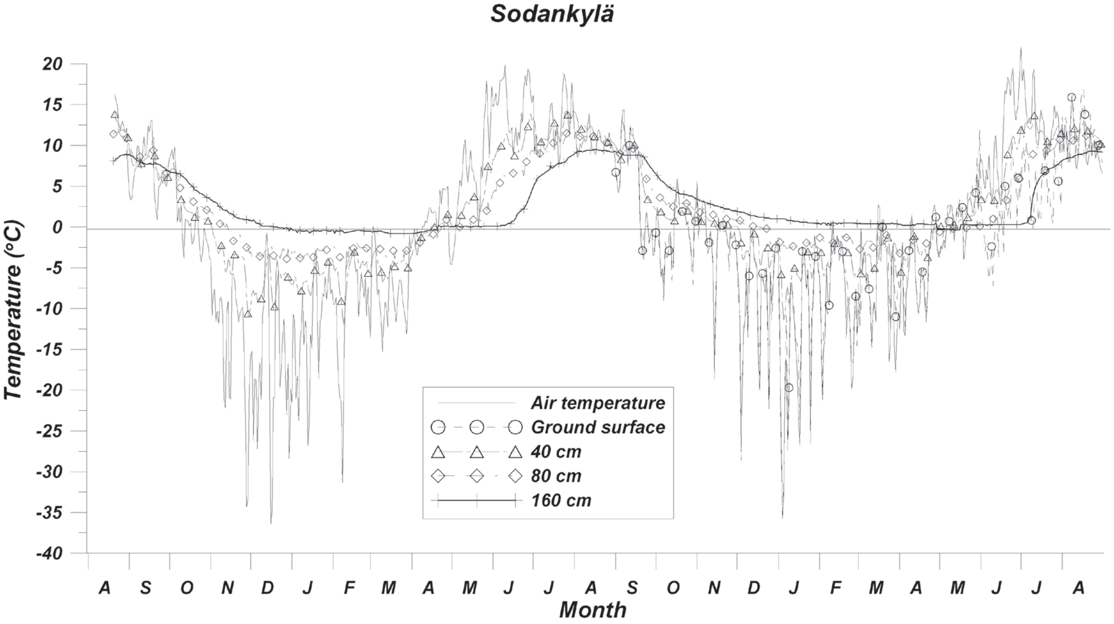

Figure 4. Air and ground temperature measurements at Sodankylä, 1882–1884. Note the difference between the years, which is especially clear in the 160 cm temperature curve. During the second year, the temperature at this level remained above freezing, but then did not warm appreciably until 7 July, nearly four weeks later than in 1883. This is a hallmark of a warmer, snowier winter followed by a cold spring.

and equipment, including glass tubes and thermometers, were provided by the Central Physical Observatory in St. Petersburg. The methods followed at Sodankylä most likely resembled those used at Sagastyr.

At Jan Mayen, rather different procedures were used. Temperatures were recorded at 6 levels down to 1.56 m depth, but the thermometers were graduated in whole degrees and read once per day at 1130. The thermometers were constructed such that they could be buried vertically in the ground while their scales remained above the surface where they could be read. Frozen ground was encountered at 80 cm depth. The expedition's standard thermometers were verified at the Kew Observatory in Great Britain, and they were, in turn, used to calibrate the earth thermometers at the station. We have interpolated the Jan Mayen data to match the standard depth intervals used at the other three stations.

The four stations were located where distinct types of climate and permafrost occur in the Arctic, from seasonal freezing to low temperature permafrost. At Jan Mayen and Sodankylä, the climate can be generally characterized as maritime type, with relatively warm winters and cool summers, even though both are geographically within the Arctic. The milder climate at these stations is due primarily to the dynamics of the atmospheric circulation over the North Atlantic and the influence of the warm ocean currents of the Atlantic Drift. The climate of Fennoscandia is more sensitive to fluctuations in large-scale circulation of the sort indicated by the North Atlantic Oscillation (NAO) (e.g., Thompson & Wallace 2001). The climate at Malyye Karmakuly, and especially Sagastyr, tends toward the more severe arctic-continental type with low temperatures and high amplitude variability. At the latter station, the Siberian high-pressure area is an important factor in winter, which tends to limit the influence of warm advection from the West.

Analysis

Four time series plots of ground temperature data were produced and these are briefly interpreted with respect to mean SAT and other key factors. Differences between subsequent years are pointed out. Gaps in the data were interpolated between other depth levels with data using standard polynomial interpolation.

Jan Mayen

The mean annual air temperature (MAAT) below -2.0°C that was registered at Jan Mayen was enough to form a thin layer of frozen ground (Fig. 3). Despite this there is a sharp attenuation of climatic signal with depth which implies that this layer is unstable to climatic fluctuations. It is possible that the ground at 150 to 200 cm depth was frozen for more than two years, meaning that permafrost was present. This would be consistent with the fact that frozen ground was encountered below 80 cm during the placement of the earth thermometers, but it is also possible that this layer could thaw completely during a warmer year. An interesting feature is the prolonged presence of a zero-degree curtain at 160 cm. Assuming that there was no instrumental error involved, one possible explanation is that there was a massive body of ground ice present below the study site.

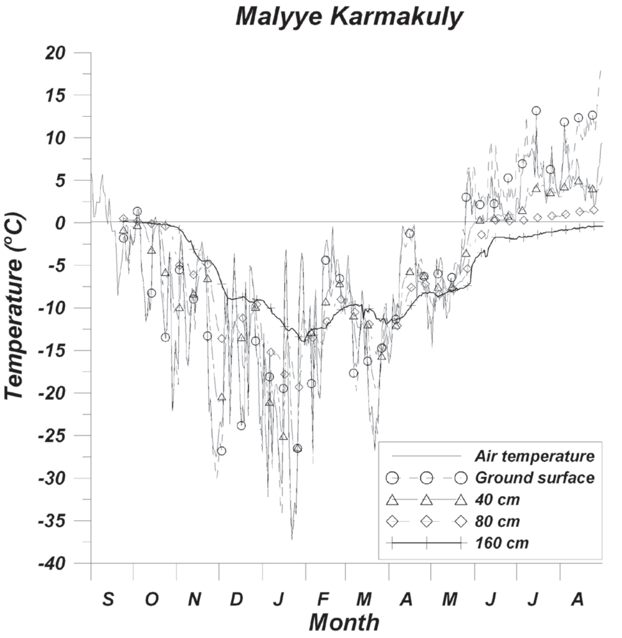

Figure 5. Air and ground temperature observations at Malyye Karmakuly, 1882–1883.

Sodankylä

Despite its position above the Arctic Circle, the climate at Sodanklyä is relatively mild, with MAAT just below 0°C. Even though MAAT during IPY-1 was slightly above the value of the reference climatology (1968–1997) the winter cold signal was enough to create seasonal freezing during the two years of observation. The depth of freezing was down to 165 cm during the first winter and 190 cm during the second (Fig. 4). The difference can be attributed to the fact that the cold climatic signal expressed as Degree-Days of Freezing (DDF) of the second winter was less than 80% of the first winter. This resulted in less penetration of cold into the ground.

A marked difference in meteorology between 1882–83 and 1883–84 was noticed by both scientists and the local inhabitants, who considered 1882–83 much more representative of the typical climate than the following year. The second winter was warmer than the first, but the spring and early summer were much colder. There were also 201 days of rain or snow precipitation during the second year compared to 134 days during the first, which could also have affected the ground temperature regime (GTR).

Malyye Karmakuly

Malyye Karmakuly is located on the west coast of Novaya Zemlya, where North Atlantic circulation patterns also influence the climate, but to a somewhat lesser extent than in Fennoscandia. The MAAT observed in 1882–83 was -6.6°C, which is 1.4° below the reference climatology value of

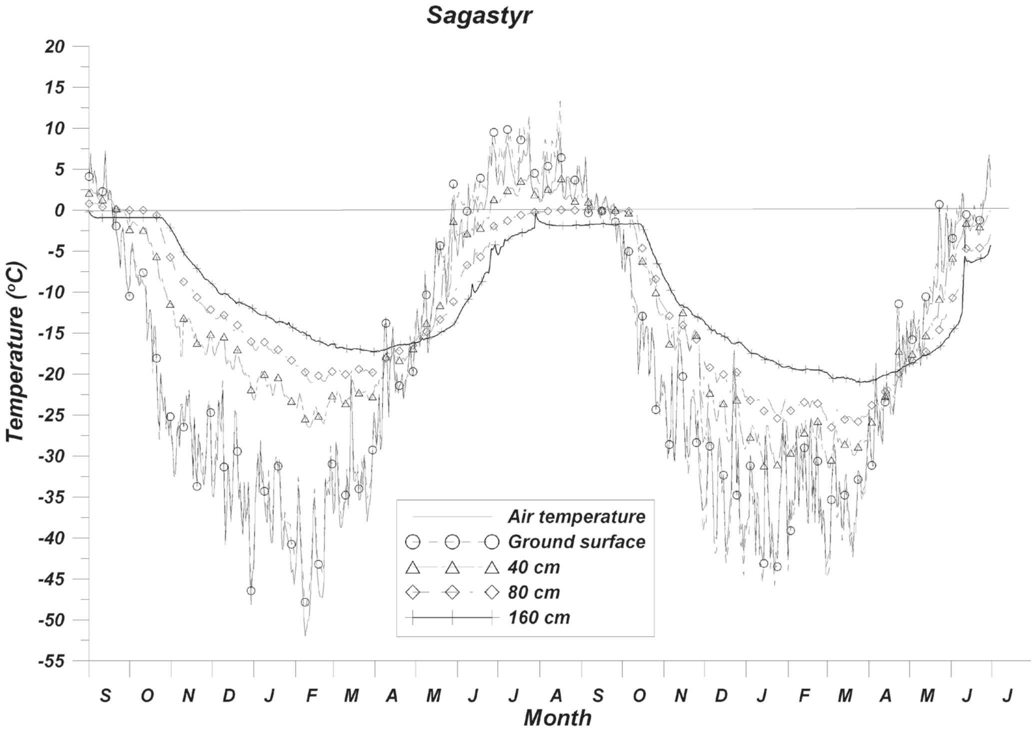

Figure 6. Air and ground temperature measurements at Sagastyr, 1882–1884. While there were differences in the meteorology of the two years, the difference in GTR is primarily due to the reduction in snow cover resulting from the relocation of the instruments away from an area of building-induced snow drift.

-5.1°C. The GTR at this location was more favorable for the formation of permafrost than either Jan Mayen or Sodankylä. This is because of the lower MAAT and greater range of air temperature expressed as Mean Annual Amplitude (MAAA) here. The mean annual ground temperature (MAGT) at 160 cm was -6.0°C at this location, but daily values were still highly sensitive to synoptic meteorology. There was no zero-curtain feature like in the locations discussed previously. Based on the ground temperature gradient, the interpolated permafrost depth was about 12 m in 1883.

Sagastyr

The overall pattern of variability in SAT anomalies at Sagastyr over the two year period was similar to the pattern observed at Sodankylä. The second winter was warmer than the first, especially February, while the spring was cooler. Notwithstanding the warmer winter, MAGT was lower during the second year. This is most likely the result of the drastic change in snow cover that resulted from the shift in location. During the first year, the depth of the snow drift next to the thermometers reached nearly 2 m compared to an accumulation of ~25 cm in the open tundra. The GTR at the second location was quite different due to much less snow cover. MAGT the second year was more than 3.0°C colder even though MAAT was 0.6°C warmer. This clearly demonstrates the critical role snow cover plays with respect to the GTR.

It is also quite interesting to note that SAT in all seasons at Sagastyr was apparently much colder than the mean of the recent climatology (1968–1997). There were no positive anomalies in the entire 22 months of record, and 18 months were more than one standard deviation below the reference means. SAT records at every other IPY-1 station in the Northern Hemisphere showed fluctuations about the mean of the reference climatology that were generally consistent with month-to-month variations in the large-scale atmospheric circulation patterns, particularly the NAO. The nearest modern station with data comparable to Sagastyr was Tiksi, about 200 km south, but an average displacement of more than ~2.5°C in the reference anomaly values would be required to bring Sagastyr observations into line with the rest of the IPY-1 monthly anomalies.

Discussion

There were distinct differences in GTR evident between the IPY-1 stations studied. Both SAT and ground temperatures decreased toward the north and east, consistent with regional climatology. The GTR at Jan Mayen and Sodankylä was much warmer than either Malyye Karmakuly or Sagastyr where MAGT ranged between -5°C and -10°C. Expected exponential attenuation of the temperature signal with depth and delayed phase shifts proportional to depth below the surface can be seen in the data.

If the GTR data from IPY-1 are broadly representative, then we can see that permafrost landscapes situated in the Atlantic-maritime climate zone would have been more sensitive to climate fluctuations even at that time than those toward the East with a more polar-continental type climate. This speculation is supported to some extent in that marked changes in permafrost landscapes were reported during the climate warming that occurred in this region early in the 20th century (Jensen 1939, Wood & Overland, in prep.). This region has certainly experienced changes in vegetation, hydrological regime, and geomorphologic processes during the recent period, and this process would likely expand in the case of increased warming as the boundary of the less-sensitive region to the eastward shifted in response.

We also note that the month-to-month fluctuations in SAT and GTR during the winter were often consistent with large-scale variability in atmospheric circulation. In February 1883, for example, the NAO index was 2.4 and the SAT anomaly distribution over the Atlantic and northern Europe closely resembled the canonical pattern (e.g., Hurrell 1995). Positive SAT anomalies occurred at Jan Mayen, Sodankylä, and Malyye Karmakuly; the effect on GTR is particularly evident at the latter station. However, the effects of increased westerly advection did not extend as far as Sagastyr, where SAT was especially low during this month. It would be reasonable to expect that GTR in Fennoscandia and northern Russia would be sensitive to those fluctuations in atmospheric circulation that produce well-known SAT anomaly patterns in winter.

Historical data such as these we have been discussing are particularly interesting now in light of the large environmental impacts that have been observed in the Arctic and elsewhere associated with a warming climate. The practical use of this type of data, however, is encumbered by a number of well-known issues, not least of which is the lack of comparable site-specific modern data. Even without the ability to make direct comparisons, we can certainly use historical information to study questions suited to the material and also to discover where new investigations might be leveraged by historical resources.

Acknowledgments

This publication was supported in part by the NOAA Arctic Research Office and JISAO under cooperative agreement NA17RJ1232, Contribution #1478.

References

Baker, F. 1982. The first International Polar Year. *Polar Record* 21(132): 275-285.

Barr, W. 1985. The expeditions of the first International Polar Year, 1882-83. In *Technical Paper No. 29*, 223. Calgary: Arctic Institute of North America.

Heathcote, N.H.d.V. & Armitage, A. 1959. The First International Polar Year (1882-1883). In *Annals of the International Geophysical Year*, ed. ICSU. London; New York: Pergamon Press.

Hurrell, J.W. 1995. Decadal trends in the North Atlantic Oscillation: Regional temperatures and precipitation. *Science* 269: 676-679.

Jensen, A.S. 1939. Concerning a change of climate during recent decades in the Arctic and Subarctic regions. *Kgi. Dansk. Vid. Selsk. Biol. Medd.* 14.

Lemström, S. & Biese, E. (eds.) 1886. *Observations Fait aux Stations de Sodankylä et Kultala*. Helsingfors: L'Imprimerie des Hértiers de Simelius.

Lenz, R. (ed.) 1886a. *Beobachtungen der Russischen Polarstation an der Lenamündung*: Russischen Geographischen Gesellshaft.

Lenz, R. (ed.) 1886b. *Beobachtungen der Russischen Polarstation auf Nowaya Semlja*: Russischen Geographischen Gesellshaft.

Ray, P.H. 1885. *Report of the International Polar Expedition to Point Barrow, Alaska*. Washington, D.C.: Government Printing Office.

Shiklomanov, N.I. 2005. From exploration to systematic investigation: development of geocryology in 19th- and early 20th-century Russia. *Physical Geography* 26(4):249-263.

Thompson, D.W.J. & Wallace, J.M. 2001. Regional Climate Impacts of the Northern Hemisphere Annular Mode. *Science* 293: 85-89.

von Wohlgemuth, E.E. (ed.) 1886. *Österreichische Polarexpedition nach Jan Mayen. Beobachtungs-Ergebnisse*. Wien: Der Kaiserliche-Königliche Hof- und Staatsdruckerei.

Weyprecht, C. 1875. Fundamental principles of scientific Arctic investigation. An address delivered before the 48th meeting of German naturalists and physicians at Graz, on the 18th of September 1875.

Wild, H. 1878. Über die Bodentemperaturen in St. Petersburg und Nukuss. *Repertorium für Meteorologie* VI(4): 1-88.

Wood, K.R. & Overland, J.M. In Prep. Early 20th century Arctic warming in retrospect.