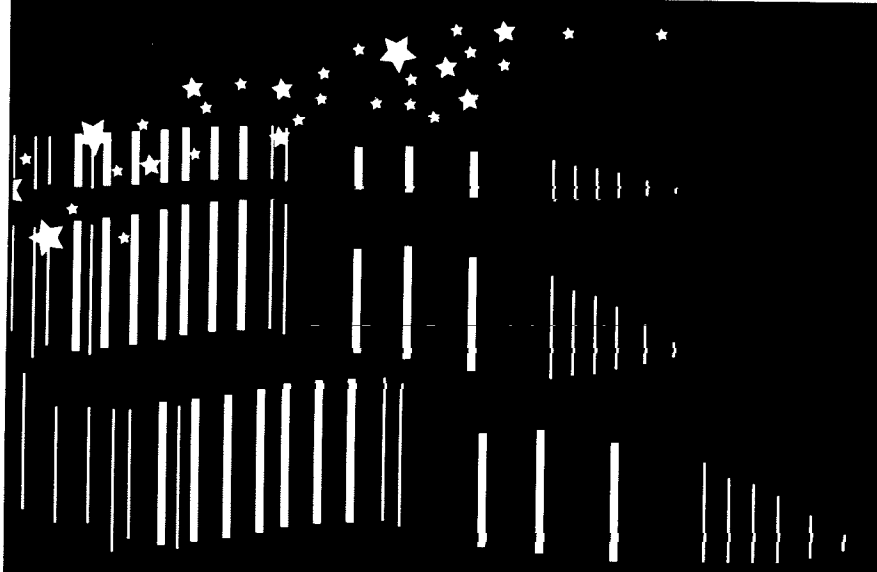

The Polar Night

Chris Burn
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NORTHERN RESEARCH INSTITUTE
Yukon College

Scientific Report No. 4
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Foreward

The Aurora Research Institute's Scientific Report Series is an effort to provide scientific information in a style and language that can be understood by the general reader. This report is the fourth in the series and the first since the merger of the Science Institute of the NWT with Aurora College. It is also the first report co-sponsored with the Northern Research Institute, Yukon College.

Aurora College and The Aurora Research Institute would like to thank Dr. Burn for preparing this report.

Copies of this report may be obtained by writing to the address on the cover or to:

Inuvik Research Centre
The Aurora Research Institute
Box 1430
Inuvik, NT
X0E 0T0
Tel: (403) 979-3838
Fax: (403)979-3570

e-mail: invklab@internorth.com
maad@inukshuk.gov.nt.ca
lkutny@inukshuk.gov.nt.ca

About the Author

Chris Burn is an Associate Professor in the Department of Geography, and the Ottawa-Carleton Centre for Geoscience Studies at Carleton University. He is also a Research Associate of the Northern Research Institute, Yukon College. He has been conducting research on the physical geography of northwest Canada since 1982, concentrating mostly on permafrost and ground ice. Much of his work has been near Mayo, Y.T., but since 1987 he has also been working in the Mackenzie Delta area. Studies in the Delta occur throughout the year, and are based at the Inuvik Research Centre of the Aurora Research Institute, and the Polar Continental Shelf Project, Tuktoyaktuk.

In 1994, Dr. Burn became a Research Associate of The Aurora Research Institute and in this capacity has lectured and taught workshops for the Inuvik Research Centre and Aurora College.

Dr. Burn can be contacted at:

Department of Geography
1125 Colonel By Drive
Carleton University
Ottawa, Ontario K1S 5B6
CANADA

Tel: (613) 520-2600 ext. 3784
Fax: (613) 520-4301
e-mail: crburn@ccs.carleton.ca

Glossary*

IMPORTANT WORDS TO KNOW

**Words found in the glossary are italicized in the main section of the report.*

Anthropologist is a researcher who studies people, concentrating on their culture and sometimes on their history.

The Arctic Circle is a line of latitude at 66°33'N. On the shortest day of the year, the centre of the Sun does not rise above the horizon at this latitude.

Astronomical Polar Night is a period of the arctic winter, north of 84°33'N, when there is no trace of light in the southern sky, and even the faintest stars can be seen.

Astronomical Twilight is the darkest period of evening twilight, before the only light in the sky is from stars and chemical reactions in the atmosphere. The Sun is over 12° below the horizon during astronomical twilight.

The Atmosphere is the thin blanket of gases around the earth.

Civil Polar Night is a period of the arctic winter, north of 72°33'N, when there is no civil twilight daily.

Civil Twilight occurs while the Sun is below, but less than 6° below, the horizon. Most outdoor activities do not require artificial light during this period.

Equinox is the time of year when the sun is overhead the equator, and day and night are equal. Spring equinox is on about March 20 and fall equinox is on about September 22.

Geometry is the arrangement of points, lines, areas, and volumes.

The Horizon, or **Skyline**, is the line at which the earth and sky appear to meet.

Illumination is the amount of light in the sky.

Lines of Latitude are imaginary lines around the Earth, joining points of equal distance north or south of the equator. Latitudes are given in degrees, indicating the angle between two lines drawn to the centre of the Earth, one from the equator, and one from the point of interest (see Fig. 5).

Light Intensity refers to the amount of light in the sky. The sensitivity of the human eye to light varies as the intensity of light changes by powers of 10, i.e. by the logarithm of light intensity. Logarithms measure the change by a factor of ten, so that, for example, as the light intensity increases a thousand times, the logarithm rises by three (ten x ten x ten).

Nautical Polar Night is a period of the arctic winter, north of 78°33'N, when the most light is a faint glow in the southern sky, but it is impossible for an observer to make out any horizon.

Nautical Twilight occurs while the Sun is between 6° and 12° below the horizon. At the end of nautical twilight it is not possible to make out the horizon.

The Northern Hemisphere is the portion of the Earth which lies north of the equator.

The Polar Night is the period of winter lasting more than 24 hours, when there is no twilight.

The Poles are the most northerly and southerly points on the Earth. Once each day the Earth spins around its axis, which is a straight line, through the Earth, between these poles.

Radiation is electromagnetic energy which travels as a wave. Radios and TVs receive programmes by radiation. Light is also transmitted by radiation.

The Solstice occurs when the tilt of the Earth is in line with the direction between the Earth and the Sun. Summer solstice occurs on the longest day of the year; winter solstice occurs on the shortest day.

The Southern Hemisphere is the portion of the Earth which lies south of the equator.

Twilight is light from the sky which we receive each day just before the Sun rises or just after it sets. It is caused by the Sun's rays being reflected down from upper levels of the atmosphere.

Introduction

Polar Nights are periods of darkness lasting more than 24 hours which occur during winter near the Earth's *poles*. The shortest day of the year, or *winter solstice*, is either December 21st or 22nd. Often people believe that it is dark on and north of the *Arctic Circle* (66°33'N) on this day. This idea is popular outside the polar regions, and, perhaps, originated from reports written by arctic explorers.

However, residents and travelers in the arctic know that on the winter solstice, there is sufficient *twilight* in many places for normal outdoor activities (see Figure 1). There is often enough natural light for reading, and a flashlight is not needed outdoors. The arctic *anthropologist* Diamond Jenness who traveled in the Coppermine area - well north of the Arctic Circle - wrote in his diary for December 22, 1914, "an hour later it was just growing dark..." indicating that it had been "light" earlier in the day. Twilight occurs when the Sun is below, but near, the *horizon* (skyline). Its rays are then received in upper levels of the *atmosphere*, from where the light is scattered and reflected by atmospheric gases and particles towards the ground.

Near the time of winter solstice the Sun may not rise in parts of our North, but it may be close enough to the horizon for periods of twilight. During twilight, Transport Canada permits aviation under visual flight rules (VFR). For instance, VFR flights are allowed for over 5 hours on and near 21st and 22nd December at Inuvik (68°21'N), north of the Arctic Circle. The purpose of this paper is to discuss twilight in the northern winter, and to provide the periods of Polar Night for communities in the Canadian Arctic.

***Figure 1**. Arrival of flight CP 444 at Inuvik Airport (68°18'N) at 1330 on 23 December 1993. The photograph was taken under natural light without special equipment (100ASA film, exposed for 1/60th of a second at f2.8) by Alan Fehr, Inuvik Research Centre.*

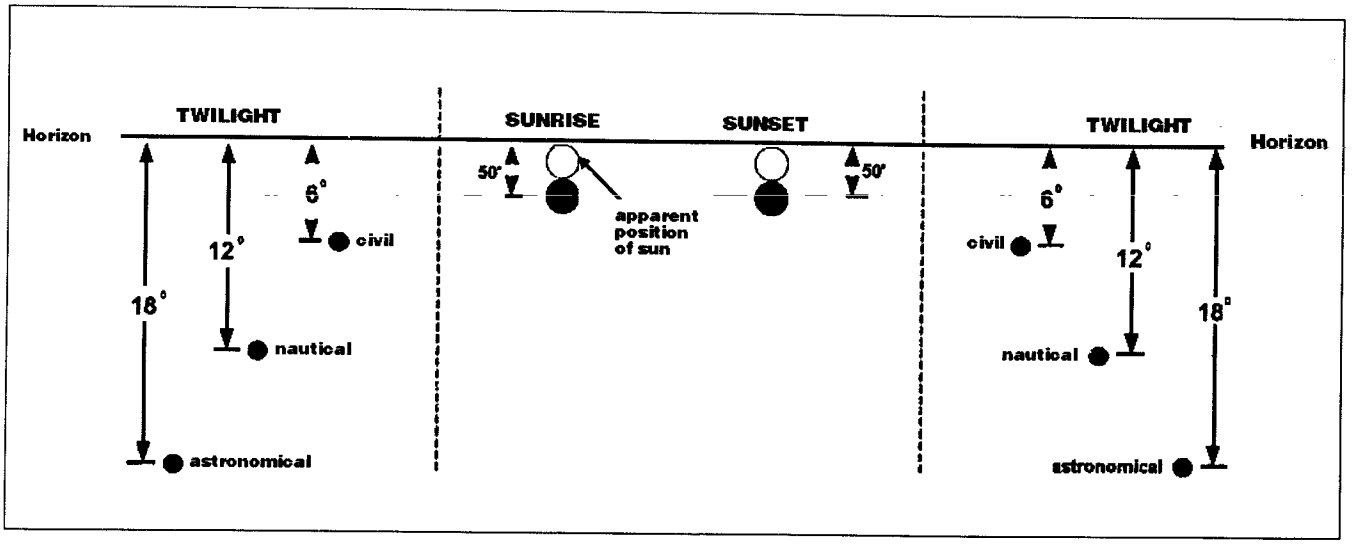

***Figure 2**. Location of the Sun with respect to the horizon at sunrise and sunset and during the periods of twilight.*

Sunrise and Sunset

Sunrise (or sunset) is the time when the top of the sun is on the astronomical horizon. The astronomical horizon is the horizon seen by an observer at sea level looking over an unobstructed surface. Sunset and sunrise actually occur when the centre of the Sun is 50 minutes, or about one degree below the horizon (Figure 2). Most of these 50 minutes (50') are due to bending of the Sun's rays when they enter the atmosphere at low angles, such as at the beginning and end of the day. In the arctic winter, when the Sun remains at low levels for a relatively long time, small changes in atmospheric conditions may cause large changes to the length of the day or duration of twilight.

During the winter solstice the centre of the Sun reaches the horizon at the Arctic Circle, so the Sun rises and sets north of the Circle on this day. The *latitude*, north of which there is no sunrise or sunset on December 21st/22nd is 67°23'N (66°33' + 50'). Table 1 lists the communities in Canada north of 67°23'N, where there is no sunrise on at least one winter day. All but Old Crow, Yukon Territory, are in the Northwest Territories.

Twilight

Twilight occurs just before sunrise and just after sunset (Figure 2). Three periods of twilight are generally recognized: civil, nautical, and astronomical twilights. *Civil twilight* occurs while the centre of the Sun is between 50' and 6° below the horizon. In the evening, darkness forces us to stop normal outdoor activities towards the end of civil twilight, but even then it is not pitch black. In southern Canada, street lights are not usually turned on until half an hour after sunset, at the end of civil twilight. Twilight lasts considerably longer in the arctic winter, because the Sun rises and sets at a much gentler angle, and so takes longer to drop 6° below the horizon. *Nautical twilight* begins in the morning and ends in the evening when the centre of the Sun is 12° below the horizon. At this point it is usually impossible to make out the horizon.

Astronomical twilight occurs while the centre of the Sun is up to 18° below the horizon. In the Arctic there is generally no trace of the twilight glow in the southern sky when the Sun is this far below the horizon. In the evening, once the astronomical period is over, light from starlight and airglow, from chemical reactions 60 to 200 km above the Earth's surface, may be about twice that from scattered sunlight.

Table 1. *Canadian communities north of 67°23'N, the period without sunrise, and the period of the Polar Night. The Polar Night only occurs north of 72°33'N. (These dates may vary by a day or two from year to year because the astronomical year is not quite the same as a calendar year.)*

Community	Latitude	Day(s) without sunrise			Day(s) with Polar Night		
		First	Last	Total	First	Last	Total
Aklavik	68°13'N	Dec. 8	Jan. 5	29	-	-	-
Alert	82°30'N	Oct. 15	Feb. 27	136	Oct. 30	Feb. 13	107
Arctic Bay	73°02'N	Nov. 13	Jan. 29	78	Dec. 12	Jan. 2	22
Broughton Island	67°33'N	Dec. 16	Dec. 28	13	-	-	-
Cambridge Bay	69°07'N	Dec. 1	Jan. 11	42	-	-	-
Clyde River	70°27'N	Nov. 24	Jan. 19	57	-	-	-
Coppermine	67°50'N	Dec. 3	Jan. 10	39	-	-	-
Eureka	79°59'N	Oct. 22	Feb. 20	122	Nov. 7	Feb. 4	90
Fort McPherson	67°26'N	Dec. 19	Dec. 25	7	-	-	-
Gjoa Haven	68°38'N	Dec. 5	Jan. 8	35	-	-	-
Grise Fiord	76°25'N	Nov. 2	Feb. 9	100	Nov. 20	Jan. 22	64
Hall Beach	68°46'N	Dec. 4	Jan. 9	37	-	-	-
Holman	70°44'N	Nov. 23	Jan. 20	59	-	-	-
Igloolik	69°23'N	Nov. 30	Jan. 13	45	-	-	-
Inuvik	68°21'N	Dec. 7	Jan. 6	31	-	-	-
Mould Bay	76°14'N	Nov. 2	Feb. 9	100	Nov. 20	Jan. 22	64
Nanisivik	73°02'N	Nov. 13	Jan. 29	78	Dec. 12	Jan. 2	22
Old Crow, Y.T.	67°34'N	Dec. 16	Dec. 28	13	-	-	-
Paulatuk	69°21'N	Nov. 30	Jan. 14	46	-	-	-
Pelly Bay	68°32'N	Dec. 5	Jan. 7	34	-	-	-
Polaris Mine	75°30'N	Nov. 5	Feb. 7	95	Nov. 25	Jan. 18	55
Pond Inlet	72°42'N	Nov. 15	Jan. 28	75	Dec. 17	Dec. 27	11
Resolute	74°15'N	Nov. 9	Feb. 3	87	Dec. 2	Jan. 11	41
Sachs Harbour	71°59'N	Nov. 17	Jan. 25	70	-	-	-
Taloyoak	69°32'N	Nov. 29	Jan. 14	47	-	-	-
Tsiigehtchic	67°27'N	Dec. 19	Dec. 25	7	-	-	-
Tuktoyaktuk	69°27'N	Nov. 29	Jan. 13	46	-	-	-

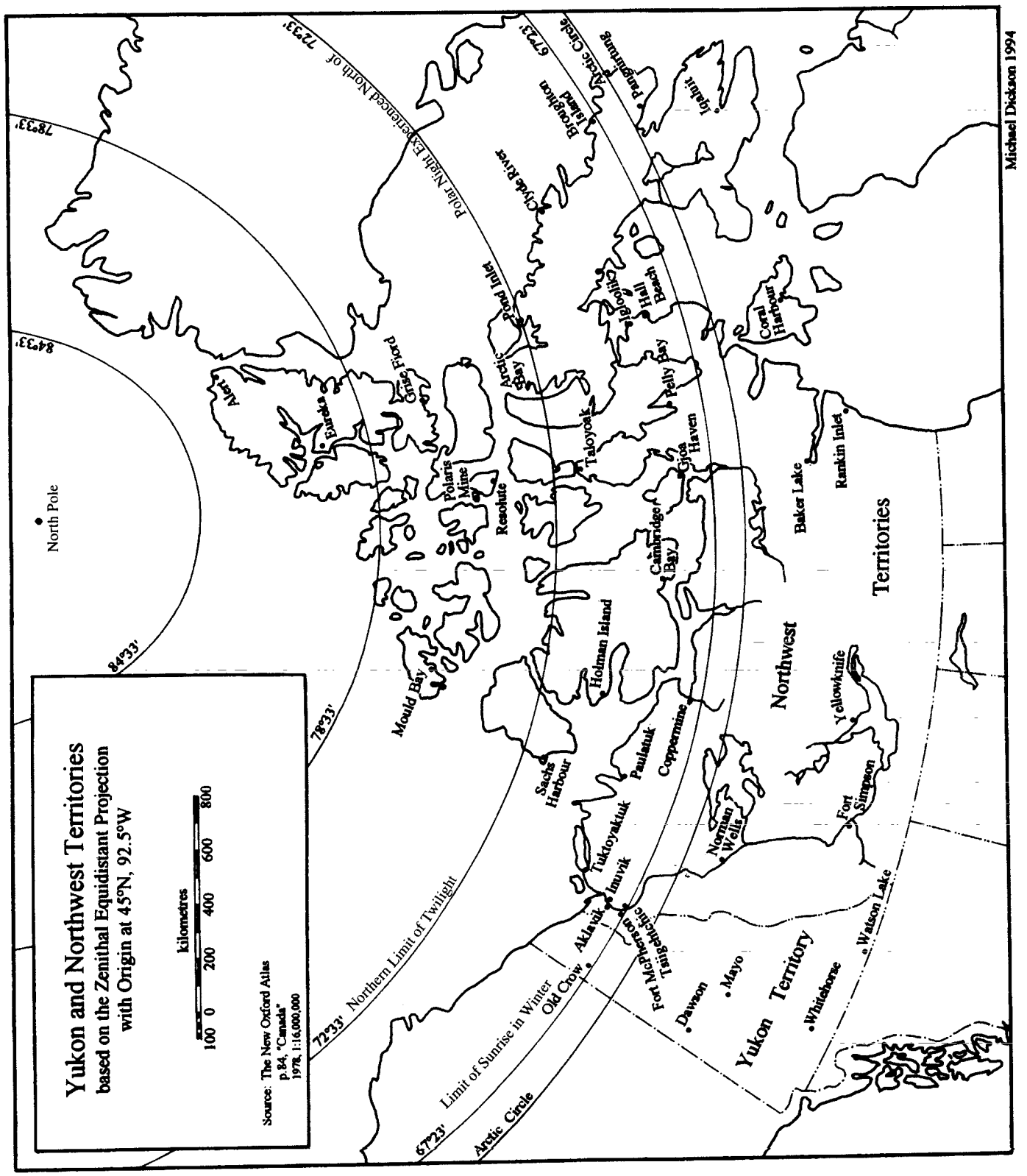

Figure 3. *Location of communities in the Canadian Arctic with respect to the critical latitudes for occurrence of twilight on December 21st/22nd.*

Astronomical Geometry

In order to determine the period of Polar Night in our communities, we must consider the arrangement of the Earth with respect to the Sun's rays. The methods described in this section of the paper allow us to determine the period of Polar Night in our communities (see Figure 3). They can also be used for any site, if its latitude is known.

Radiation coming from the Sun to points on the Earth's surface depends on latitude and the time of year. We need to determine if the Sun does or does not rise on any particular day, and so we always consider the position of the Sun at noon. Time of year is represented in astronomical terms by the declination of the Sun. The declination is the tilt of the Earth away from or towards the Sun (Figure 4). At the northern winter solstice the *Northern Hemisphere* is tilted 23°27' away from the Sun, and the *Southern Hemisphere* is tilted the same amount towards it.

The *geometry* of the Earth and Sun is shown in Figure 5 for the winter period between September 22 and March 20, the *equinoxes*, when the declination is 0°. The Sun is far enough from the Earth that its light is considered to travel in parallel beams. On Figure 5, you will see that the zenith angle is equal to the latitude plus the declination, i.e.,

Equation 1:

Zenith Angle = Latitude + Declination

The zenith angle is the angle measured between the position of a body in the sky and a point in the sky above an observer. The astronomical horizon has a zenith angle of

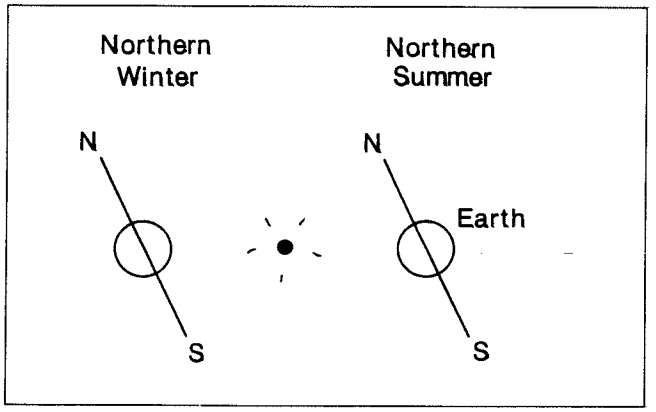

Figure 4. *Position of the Earth with respect to the Sun in the northern winter on the left side of the box, and in the northern summer, on the right side.*

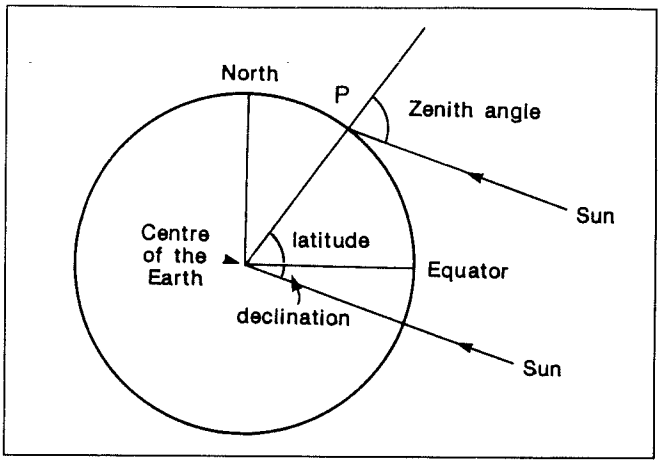

Figure 5. *Relationship of the sun and earth at solar noon during the northern winter. The zenith angle of the Sun at point P, equals the latitude at the point plus the declination of the sun, because the Sun's rays are parallel.*

90°. The zenith angle at sunset is 90°50', and at the end of civil twilight in the evening it is 96°. At the winter solstice, the declination is 23°27', and the latitude at which the Sun does not rise is, from the Equation 1:

Equation 2:

Latitude = Zenith angle - Declination

so,

Latitude = 90°50' - 23°27'= 67°23'N.

The lowest latitude without civil twilight at the winter solstice is, from the Equation 2, 72°33' N, i.e. 96° - 23°27'. The lowest latitude without astronomical twilight on December 21/22 is 84°33'N (108° - 23°27').

Period of Polar Night

The Polar Night is a period of continuous winter darkness, without civil twilight, which lasts for more than 24 hours. Since we know the zenith angles for twilight, e.g. 96°, and we know the latitudes of our communities (Table 1), we can determine the declination of the Sun at any community for the various twilights (from the first equation). If we know the declination of the Sun for each day of the year, we can determine the first and last days that the Sun does or does not rise, the first and last days without twilight and so on. *The Astronomical Almanac***, published jointly by the United States and United Kingdom Governments, provides the declination of the Sun for each day of the year. We have used the values in the *Astronomical Almanac* to determine the dates for first and last days without sunrise, and for the beginning and end of twilight

***U.S. Naval Office. 1993. The astronomical almanac for the year 1994. Washington, D.C., and London: U.S. Government Printing Office and Her Majesty's Stationery Office.*

for the communities listed in Table 1. The dates are only correct to within one day, because the calendar year (365 days) differs from the astronomical year by about a quarter of a day.

Illumination (Light)

The brightness of the sky varies by 100 million times between astronomical twilight and when the Sun is at the centre of the noon sky. Probably as a result of this great variation, the ability of the human eye to detect light varies as the strength of light changes. If a light has a strength of 10 units, then another light of strength 100 units appears to be twice as bright to the viewer. If a light had a strength of 1000 units, we would sense it to be three times as bright as the original 10 unit light, and so on. (See *light intensity* in the glossary for more information.)

Figure 6 presents the noon maximum *illumination* for the arctic winter at latitudes north of 60°N as a diagram. The shading represents the human eye's view of the sky brightness. The shading varies from black representing the light of the night sky only, to white representing illumination at sunrise or sunset and during daylight.

Polar Night and Polar Darkness

The dates when sunrise and sunset or the beginning and end of civil twilight both occur at solar noon are shown for settlements in the Canadian Arctic in Table 1.

Civil Polar Night is not experienced in Alaska or mainland Europe, since its limiting latitude is 72°33'. Portions of Canada, Greenland, Svalbard, Novaya Zemlya and Asiatic Russia lie on or north of 72°33', and experience Polar Night. In Canada, the only settlements north of 72°33'N are: the communities of Pond Inlet, Arctic Bay, Resolute, and Grise Fiord, N.W.T.; the Nanisivik and Polaris mines, N.W.T.; and government stations which operate year-round at Alert, Eureka, and Mould Bay, N.W.T.

Astronomical Polar Night is not experienced at any point on the Earth's land surface in the northern winter. The only settlements that experience *Nautical Polar Night* are Alert and Eureka, N.W.T., Canada, Nagurskoye and Bukhta Tikhaya, Zemlya Frantsa Iosifa, Russia, and Ny Ålesund, Svalbard.

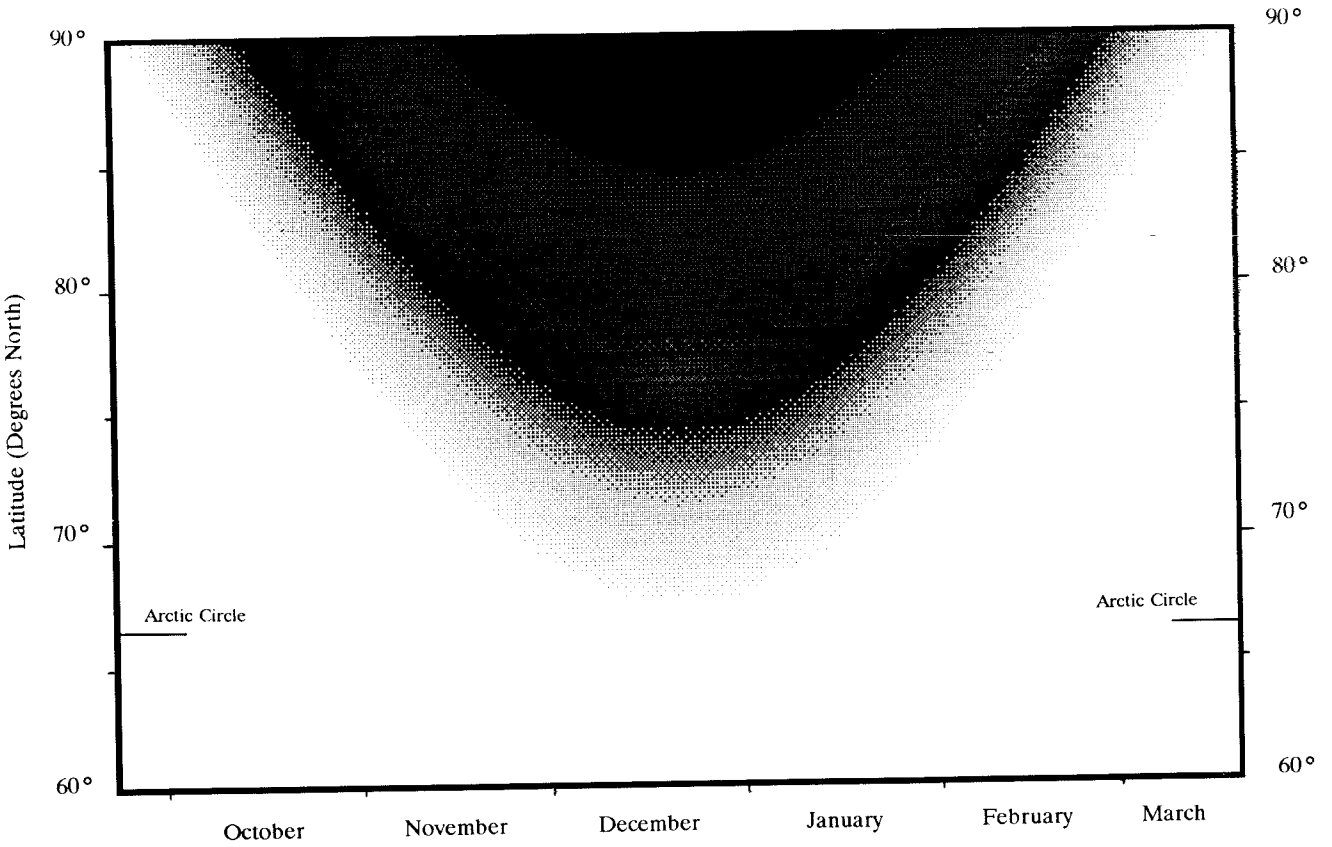

Figure 6. *Representation of the darkness of polar night under clear sky conditions for latitudes from 60°N to 90°N during the winter. To produce this diagram, the light at noon was calculated for each day of the northern winter every quarter degree between 60°N and 90°N. The darkness of the shading corresponds directly to the calculatd darkness of the sky as seen by a human eye. Steve Prashker, Carleton University, helped produce the diagram.*

Conclusion

The Sun rises and sets north of the Arctic Circle to 67°23'N throughout the year. North of the Circle, to a latitude of 72°33'N, civil twilight occurs daily in winter and night is broken. Around the clock darkness, or Polar Night, is only experienced north of 72°33'N.

Acknowledgements

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Further Reading

If you wish to read more about this topic, *Sunsets, Twilights and Evening Skies*, written in plain English by Aden and Marjorie Meinel, published by Cambridge University Press, is an excellent book to consult.

Other Titles in the Scientific Report Series

No. 1 Mackay, J. Ross and Dyke, Larry. 1990. Geological Features of the Mackenzie Delta Region, N.W.T. 16 pp. (Includes two articles, one written by each of the authors.)

No. 2 Dredge, Lynda. 1992. The Geology of the Igloolik Island Area, and Sea Level Changes. 7 pp.

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