# The Polar Night



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# Introduction

Polar Night 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 21$^{st}$ or 22$^{nd}$. 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.

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.

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 21$^{st}$ and 22$^{nd}$ 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.

# 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 center 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.

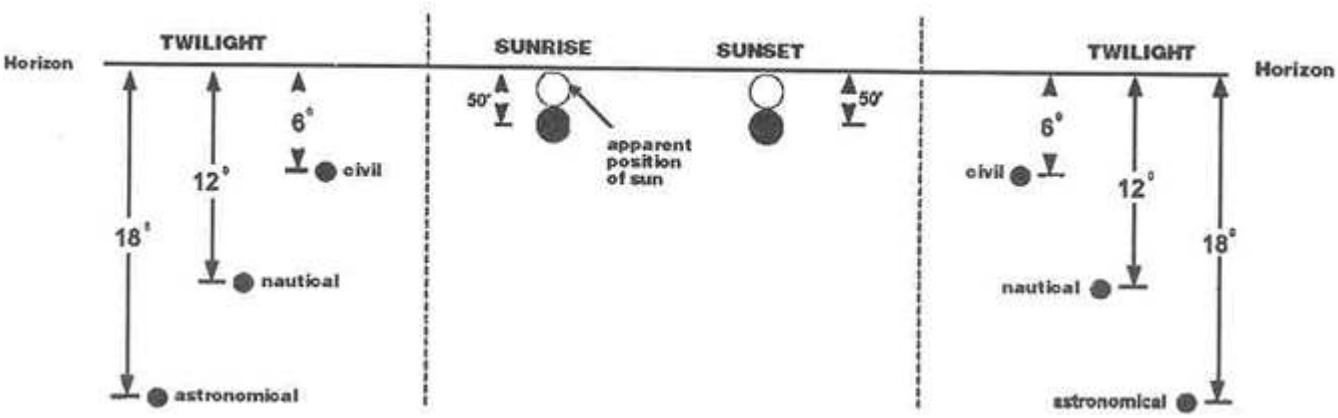


Figure 2. Location of the Sun with respect to the horizon at sunrise and sunset and during periods of twilight.

During the winter solstice the center 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.

| 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, YT | 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 | - | - | - |

*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.)*

# 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 center 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 center 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 center 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.

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

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.

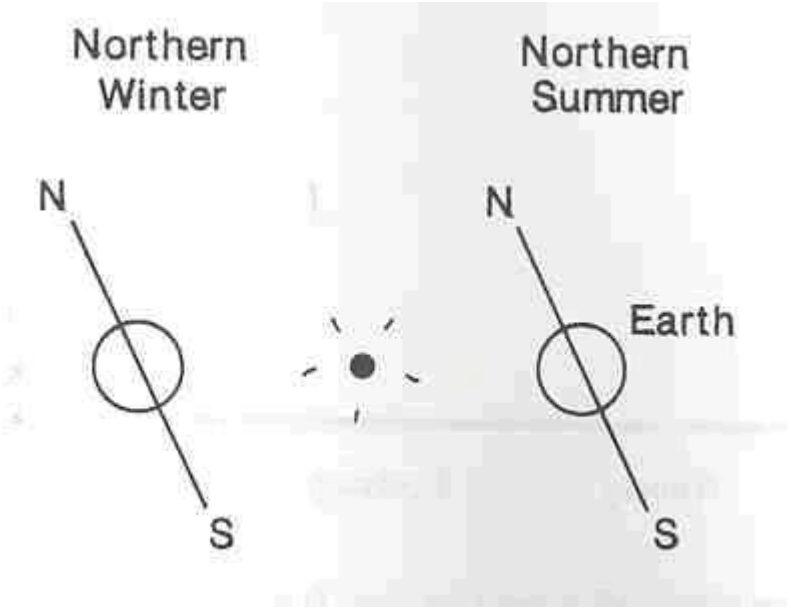


Figure 4. Position of the Earth with respect to the Sun in the northern winter on the left side of the box, an in the northern summer, on the right side.

The geometry of the Earth and Sun (as 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.

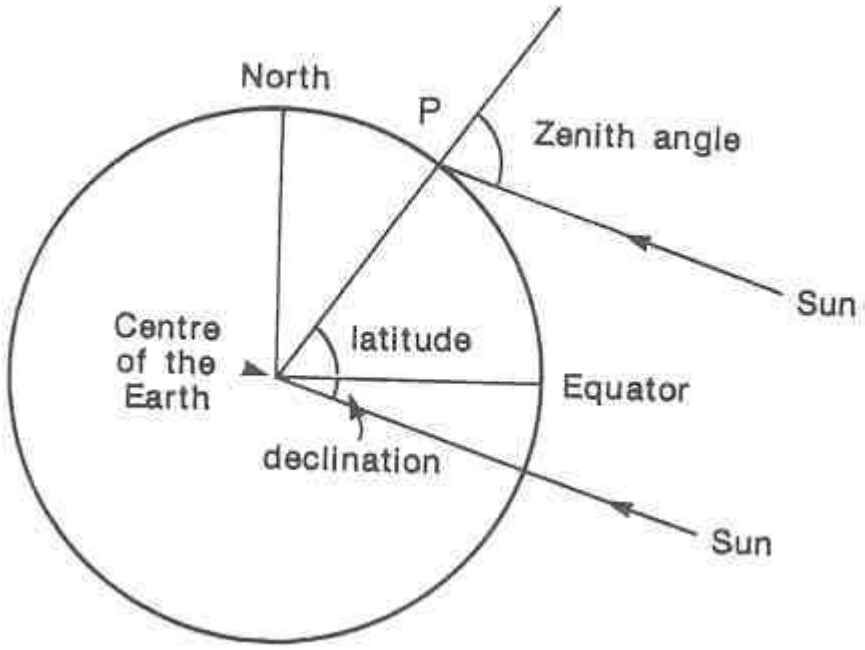


Figure 5. Relationship of the sun and earth at solar noon during the northern winter. The zenith angle of the Sun at point P, equals the latitude at the point plus the declination of the sun, because the Sun's rays are parallel.

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 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°25'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* (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.), published jointly at 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 for the communities listed in Table l. 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

The brightness of the sky varies by 100 million times between astronomical twilight and when the Sun is at the center 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.

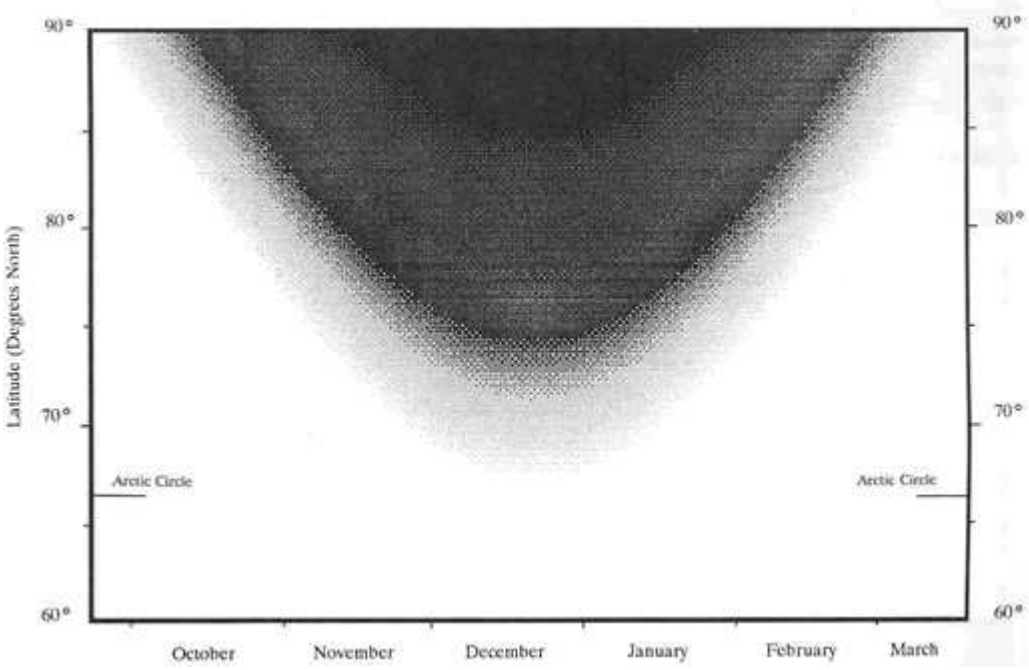


Figure 6. Representation of the darkness of polar night under clear sky conditions for latitudes from 60°N and 90°N during the winter. To produce this diagram, the light at noon was calculated for each day of the northern winter every quarter degree between 60°N and 90°N. The darkness of the shading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

# 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.

# 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.

# Glossary

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

**Arctic Circle** - is a line of latitude at 66°33'N. On the shortest day of the year, the center 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.

**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.

**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 center 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 often, 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.

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

**Polar Night** - is the period of winter acting more than 24 hours, when there is no twilight.

**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 programs by radiation. Light is also transmitted by radiation.

**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.

**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.