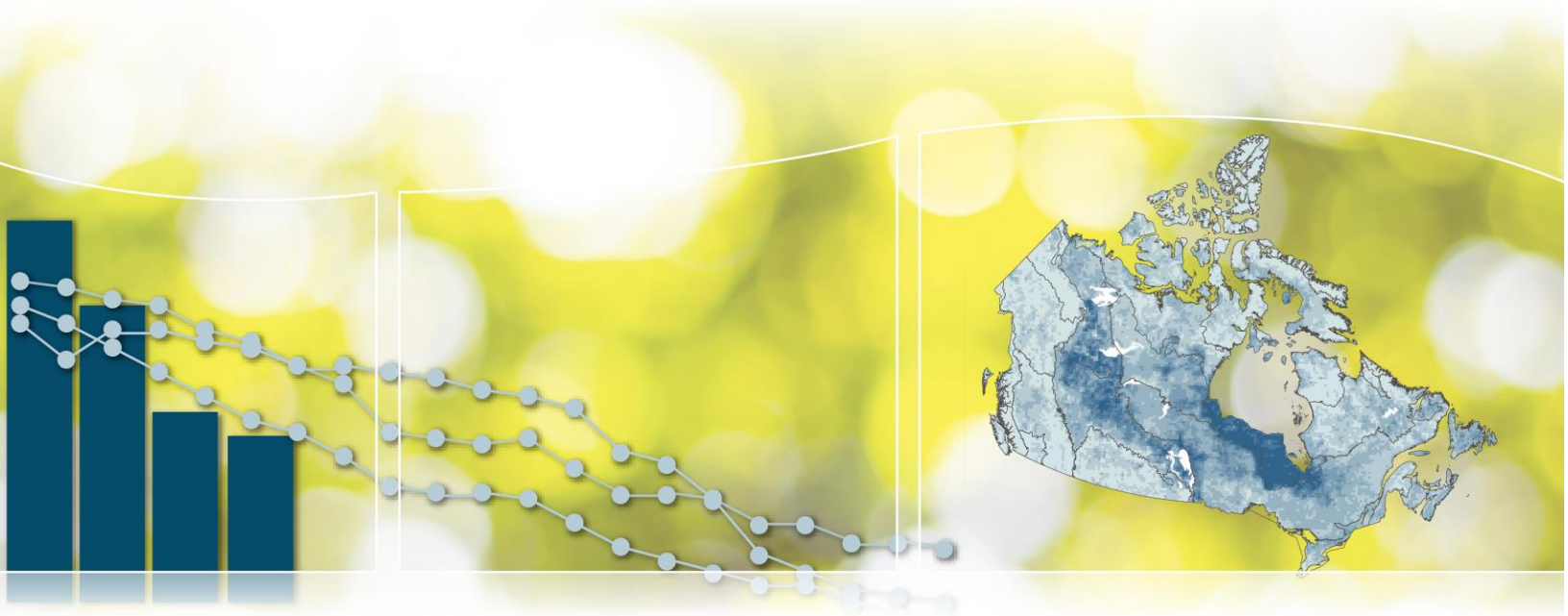
Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canadian Environmental Sustainability Indicators

Snow cover



Canada

Suggested citation for this document: Environment and Climate Change Canada (2018) Canadian Environmental Sustainability Indicators: Snow cover. Consulted on *Month day, year*. Available at: www.canada.ca/en/environment-climate-change/services/environmental-indicators/snow-cover.html.

Cat. No.: En4-144/84-2018E-PDF
ISBN: 978-0-660-24482-2

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Canadian Environmental Sustainability Indicators

Snow cover

February 2018

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Snow cover indicators

Canada is a snowy country and snow cover affects our climate, water flows and wildlife. Snow cover naturally varies with temperature, precipitation and climate cycles, such as El Niño. Over the long term, trends are primarily controlled by changes in temperature and precipitation. Information on snow quantities and snow cover duration is important for understanding how climate change is influencing snow cover in Canada.

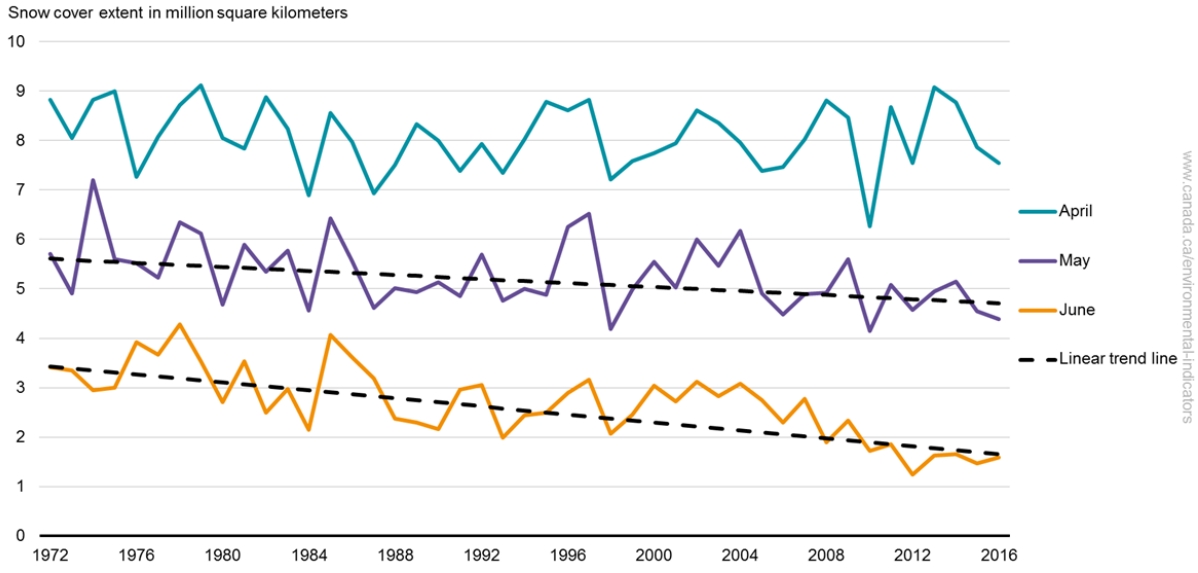
Snow cover extent

Snow cover extent is the area of land with snow on the ground.[1] Snow cover extent is closely linked to air temperature, which means it has a strong seasonal cycle, and varies from year-to-year.

Key results

- Since the early 1970s, snow cover extent has decreased significantly in Canada during the months of May and June in response to a warming climate.
- In 2016, snow cover extent for May and June was at its third lowest since 1972, and at its eleventh lowest point for April.

Figure 1. Annual variations in spring (April, May and June) snow cover extent, Canada, 1972 to 2016



Data for Figure 1

Note: The dashed line indicates a statistically significant trend based on the Mann-Kendall and Sen methods at the 95% confidence level.
Source: Environment and Climate Change Canada (2017) Climate Research Division, Climate Processes section. Rutgers University Global Snow Laboratory (2017) Northern Hemisphere Snow Cover Extent Climate Data Record dataset.

Decreasing trends of 4% and 11% per decade were detected for Canadian snow cover extent in May and June, respectively, over the 1972 to 2016 period. Recent decreasing snow cover extent,

[1] Snow cover extent is defined as the area of grid cells having 50% or more snow cover for the gridded data sets used for the indicator.

especially in the spring period, is linked to warming air temperatures over the Northern Hemisphere and Canada during the same time period. The reductions are greater in June because at that time of year, most of the snow is located in the Canadian Arctic, where warming has been the strongest over recent decades. More rapid warming of the Arctic relative to lower latitudes is explained by a phenomenon known as "polar amplification"[2] and is projected to continue. Reductions in high latitude spring snow cover extent across Canada are consistent with similar observed decreases in Alaska and northern Eurasia.

Spring snow cover trends are of significant interest because of the wide range of impacts (for example, hydrology, ecosystems and wildfire risk) and because positive feedbacks in the climate system are strongest during this season.

Snow cover duration

The duration of snow cover influences climate through the insulating and reflecting properties of snow. Snow cover duration is controlled by the timing of the onset of snow cover in fall/winter and melt in the spring, as well as thaw periods in between.

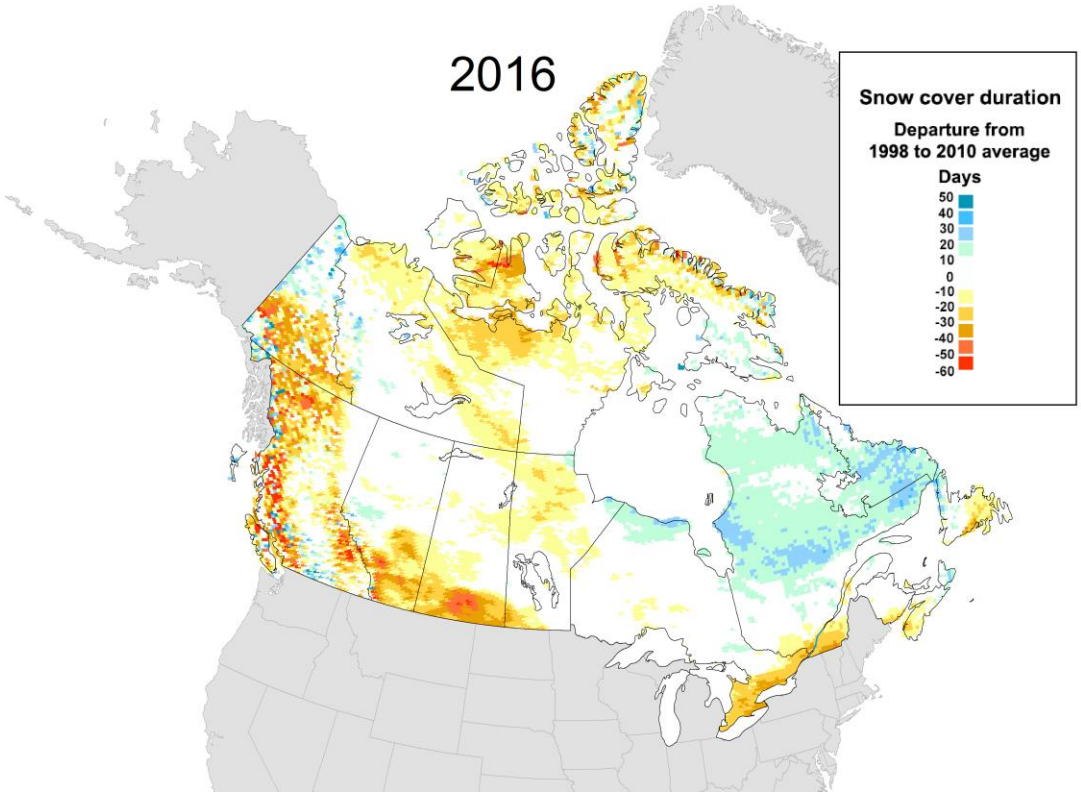
Key results

- The number of days with snow for the year 2016[3] were below average for most of Western Canada, the Prairies, southern Ontario, southern Quebec and most of the Atlantic provinces.
- A substantial part of northern Quebec and Labrador, and smaller areas of northern Yukon and Ontario, experienced above-average snow cover duration.

[2] National Snow & Ice Data Centre (2017) Climate Change in the Arctic.

[3] In the context of this indicator, a snow season is defined as the period starting from July 1 of the previous year to June 30 of that year. The snow season is assigned to the year corresponding to the end of the snow season. For example, 2016 corresponds to the July 2015 to June 2016 snow season.

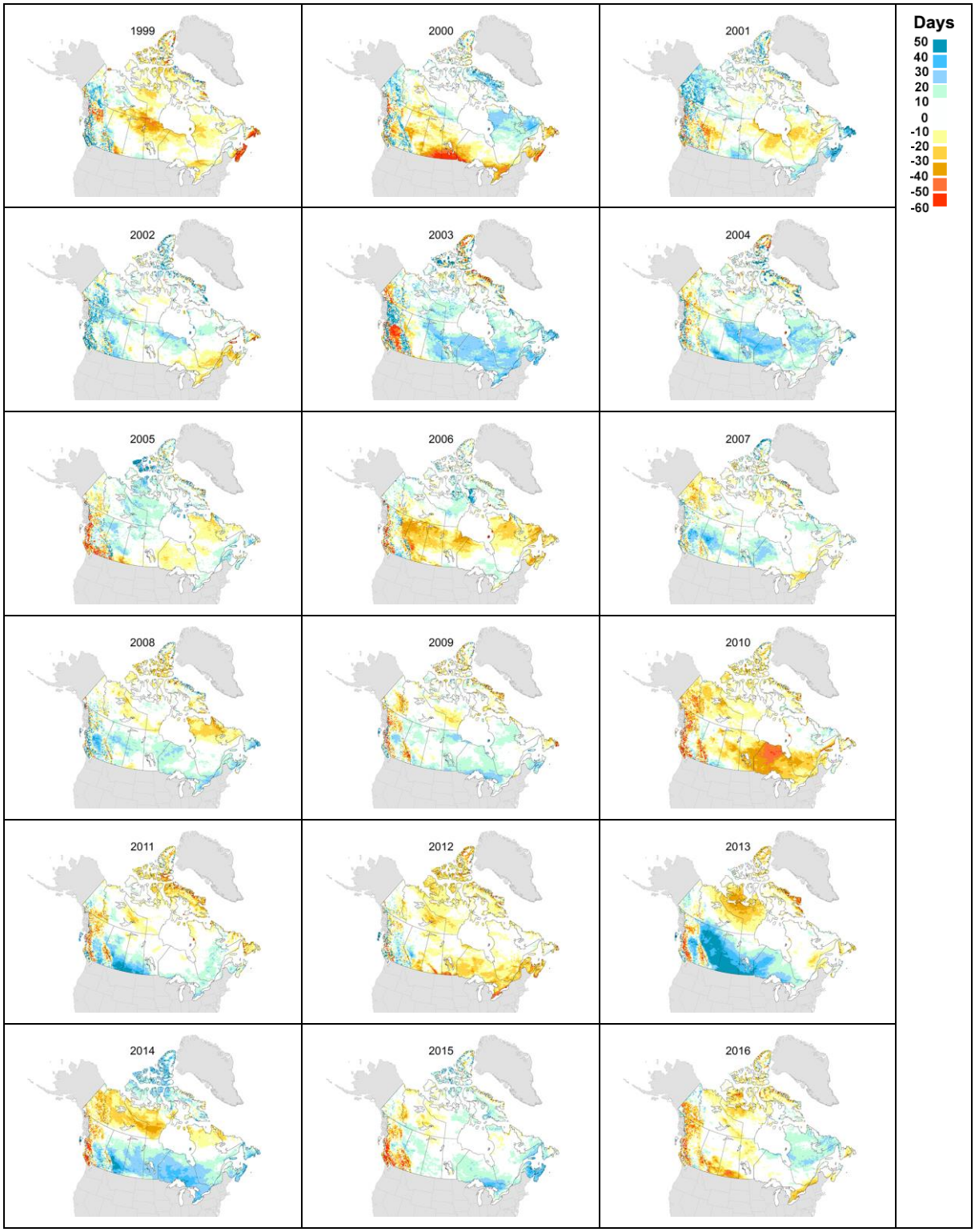
Figure 2. Snow cover duration departures for the year 2016 relative to the reference period



Note: Departures are obtained by subtracting the 1998 to 2010 average value from the number of days with snow on the ground during the snow season (July to June). Warm colours (yellow to orange) indicate shorter snow cover duration; cool colours (blue) indicate longer duration. Departures in snow cover duration, compared to the 1998 to 2010 reference average, are from the National Ice Centre Interactive Multisensor Snow and Ice Mapping System (IMS) 24-kilometre daily snow cover product.
Source: Environment and Climate Change Canada (2017) Climate Research Division, Climate Processes Section and National Ice Centre (2017) Interactive Multisensor Snow and Ice Mapping System (IMS).

The duration of snow cover fluctuates substantially across Canada, reflecting year-to-year variations in climate. The 2010 year is notable for extensive below-average snow cover across the country in response to record warm temperatures. The year 2010 is Canada's warmest year in the historical temperature record.

Figure 3. Snow cover duration, departure from the reference period for the years 1999 to 2016



View the animated video of the maps

Note: Departures in snow cover duration, compared to the 1998 to 2010 reference average are from the National Ice Centre Interactive Multisensor Snow and Ice Mapping System (IMS) 24-kilometre daily snow cover product.
Source: Environment and Climate Change Canada (2017) Climate Research Division, Climate Processes Section and National Ice Centre (2017) Interactive Multisensor Snow and Ice Mapping System (IMS).

About the indicators

What the indicators measure

The indicators show how Canada's snow cover is changing from year-to-year and over time. The indicators report spring snow cover extent and annual snow cover duration.

Snow cover extent is expressed in millions of square kilometres and is presented for the spring months of April, May and June. The Snow cover duration indicator shows the spatial pattern of annual (July to June) snow cover duration departure relative to the 1998 to 2010 average.

Why these indicators are important

Canada is a snowy country. Sixty-five percent of Canada's land mass has annual snow cover for more than 6 months of the year. Changes in snow cover have important and far-reaching consequences for ecological and human systems. For example, the melting of ice and snow stored in mountain snowpacks is critical for a multitude of sectors including river aquatic systems, agriculture, hydro-electric power generation, and recreational activities.

Because of its white colour, snow reflects a high proportion of incoming sunlight. Snow cover is therefore an important factor influencing the Earth's surface temperature, because it determines how much of the energy from the sun is absorbed by the Earth's surface. A decrease in snow cover in response to climate warming therefore contributes to a positive feedback, because the highly reflective snow surface is replaced by more absorptive bare soil or vegetation. This is called "snow-albedo feedback."

Snow also insulates the soil beneath the snowpack, and protects plants and animals from cold winter temperatures. The amount of winter snow and the frequency of winter thaw events have important consequences for Arctic animals such as muskox and caribou that have to travel over snow and forage through the snow to graze. Human-related activities, such as outdoor recreation, snow clearing and reservoir management, are all highly sensitive to how much snow is on the ground and when/how fast it melts.

The Intergovernmental Panel on Climate Change and the United Nations Framework Convention on Climate Change uses snow cover, among several variables, to assess long-term changes in climate. Snow cover is considered an Essential Climate Variable by the World Meteorological Organization–Global Climate Observing System.

Related indicators

The Sea ice in Canada indicators provide information on variability and trends in sea ice in Canada during the summer season.

The Temperature change in Canada indicator measures yearly and seasonal surface air temperature departures in Canada, while the Precipitation change in Canada indicator measures annual and seasonal precipitation departures.

Data sources and methods

Data sources

There are 2 indicators for Snow cover in Canada based primarily on satellite observations: Snow cover extent and Snow cover duration.

Data for the Snow cover extent indicator were obtained from the National Ocean and Atmospheric Administration (NOAA) Northern Hemisphere weekly Snow Cover Extent Climate Data Record (NOAA-CDR) maintained by the Rutgers University Global Snow Lab.[4]

Data for computing annual snow duration were retrieved from the Interactive Multisensor Snow and Ice Mapping System (IMS) daily snow chart product.

More information

Snow cover extent indicator (1972 to 2016)

The NOAA-CDR dataset used for the Snow cover extent indicator combines weekly 190.5-km resolution snow cover extent charts (derived from interpretation of primarily visible satellite imagery by trained analysis) over the 1966 to 1999 period[5] with a comparable weekly chart derived from daily 24-km resolution IMS snow cover extent maps from 1999 to the present.[6] The daily snow charts have been produced at the United States National Ice Center since 2008.[7]

The frequency and resolution of satellite data as well as the snow cover extent analysis methods have changed over time, meaning the NOAA-CDR may not be homogeneous in all regions and for all seasons.[8,9] The period from 1972 was used for the indicator because the NOAA-CDR has some missing data between 1966 and 1971.

Rutgers University maintains the continuity of the NOAA-CDR weekly dataset through the production of the pseudo-weekly chart and the application of a consistent land/water mask. Rutgers also processes the weekly data into monthly snow cover fraction time series. Additional information on the NOAA-CDR dataset is provided at the Rutgers Global Snow Lab.

Snow cover duration indicator (1999 to 2016)

The Snow cover duration indicator is based on 24-km daily binary (presence/absence) snow cover maps generated by the United States National Ice Center's IMS. These maps are derived from the interpretation of mainly visible satellite data but also make use of other satellite products and surface observations.

The data used for the Snow cover extent and Snow cover duration indicators are current up to 2016.

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[4] Estilow TW et al. (2015) A long-term Northern Hemisphere snow cover extent data record for climate studies and monitoring.

[5] Robinson DA et al. (1993) Global snow cover monitoring: an update.

[6] Helfrich SR et al. (2007) Enhancements to, and forthcoming developments in the Interactive Multisensor Snow and Ice Mapping System (IMS).

[7] The National Ice Center is a United States joint National Oceanic and Atmospheric Administration (NOAA), Navy, and Coast Guard collaboration.

[8] Brown RD and Derksen C (2013) Is Eurasian October snow cover extent increasing?.

[9] Mudryk LR et al. (2017) Snow cover response to temperature in observational and climate model ensembles.

Methods

The Snow cover extent indicator shows the area of Canada covered by snow during the months of April, May and June for the years 1972 to 2016. The total area of Canada's land mass covered by snow is estimated from the National Ocean and Atmospheric Administration (NOAA) Northern Hemisphere Snow Cover Extent Climate Data Record (NOAA-CDR) grid points that fall within the Canadian land mass.

The Snow cover duration indicator shows the difference (or departures) between the numbers of days with snow on the ground for a given year relative to the 1998 to 2010 reference period.

More information

Snow cover extent

The Snow cover extent indicator is based on the monthly NOAA-CDR. Only the spring months are shown because the snow cover onset period (October, November) contains an artificial increasing trend due to changes in the NOAA-CDR dataset over time.[10] Winter months, when Canada is almost completely snow-covered, are not shown.

The indicator shows the historical variation in spring snow cover extent over Canada in millions of square kilometres from 1972 to 2016. Canada's land mass is defined by a shape file provided by Statistics Canada. Snow-covered area was computed in the Climate Research Division at Environment and Climate Change Canada using grid cell areas from subroutine MSCALE in the RMNLIB software library package of Environment and Climate Change Canada.

Snow cover duration

Higher resolution information showing annual variations in snow cover duration across Canada for the 1999 to 2016 period was obtained from the 24-km Interactive Multisensor Snow and Ice Mapping System (IMS) daily snow cover product. The snow cover duration departures are calculated for each year from 1999 to 2016. In the context of this indicator, a year is defined as the period from July 1 of the previous year to June 30 of that year. For example, the year 1999 is the period beginning on July 1, 1998, and ending on June 30, 1999.

Daily maps of snow cover from the National Ice Center's IMS were converted by the Climate Research Division at Environment and Climate Change Canada into monthly snow cover duration.

The number of days with snow cover per year (from July 1 to June 30 of the following year) was obtained by adding up the monthly number of days with snow on the ground for each land grid cell in Canada (identified with the land/sea mask supplied with the 24-km IMS dataset). Annual snow cover duration departures were then computed by subtracting the 1998 to 2010 reference period average to generate a rasterized departure map. This reference period is used to be consistent with snow cover duration departures derived in the Climate Research Division of previous assessments.

Caveats and limitations

The identification of terrestrial snow cover from visible satellite data is heavily influenced by anything that obscures the surface, such as darkness, cloud cover or dense forest. Increased frequency of visible satellite coverage over time, as well as all-weather snow cover information from passive microwave satellites, means that our ability to detect and map snow nowadays is much better than it was in the first few decades of the NOAA-CDR. Therefore, some care is required when interpreting

[10] Mudryk LR et al. (2017) Snow cover response to temperature in observational and climate model ensembles.

snow cover trends from the NOAA-CDR that extend back to the 1970s. In addition, this is the reason why fall period snow cover data (October and November) are not included in the Snow cover extent indicator, because these months are known to be affected by spurious increasing trends.[11] The spring period is less affected by this problem, although recent analysis by Mudryk et al.[12] shows that NOAA-CDR has slightly stronger negative trends in hemispheric spring snow cover extent than other data sources.

The more recent IMS-24 snow cover extent data (1999 to 2016) do not have any documented homogeneity issues; so the snow cover duration departures are not affected by any fall season uncertainties. Current research in the Climate Research Division of Environment and Climate Change Canada is focused on developing multi-dataset snow cover time series[13] to better account for uncertainties and inconsistencies in individual products.

Resources

References

Blunden J and Arndt DS (2017) State of the Climate in 2016. Bulletin of the American Meteorological Society 98(8):Si-S277.

Bokhorst S, Pedersen SH, Brucker L, Anisimov O, Bierke JW, Brown RD, Ehrich D, Essery RL, Heilig A, Ingvander S, Johansson C, Johansson M, Jónsdóttir IS, Inga N, Luojus K, Macelloni G, Mariash H, McLennan D, Rosqvist GN, Sato A, Savela H, Schneebeli M, Sokolov A, Sokratov SA, Terzago S, Vikhamar-Schuler D, Williamson S, Qiu Y, Callaghan TV (2016) Changing Arctic snow cover: A review of recent developments and assessment of future needs for observations, modelling and impacts. AMBIO 45(5):516–537.

Brown RD and Derksen C (2013) Is Eurasian October snow cover extent increasing? Environmental Research Letters 8(2):024006.

Brown RD, Derksen C and Wang L (2010) A multi-data set analysis of variability and change in Arctic spring snow cover extent, 1967-2008. Journal of Geophysical Research Atmospheres 115(D16111).

Brown RD and Robinson DA (2011) Northern Hemisphere spring snow cover variability and change over 1922-2010 including an assessment of uncertainty. The Cryosphere 5(1):219–229.

Canadian Cryospheric Information Network (2016) Energy Flux: Snow Overview.

Derksen C, Smith SL, Sharp M, Brown L, Howell S, Copland L, Mueller DR, Gauthier Y, Fletcher CG, Tivy A, Bernier M, Bourgeois J, Brown RD, Burn CR, Duguay C, Kushner PJ, Langlois A, Lewkowicz AG, Royer A, Walker A (2012) Variability and change in the Canadian cryosphere. Climatic Change 115(1):59–88.

Derksen C and Brown RD (2012) Spring snow cover extent reductions in the 2008-2012 period exceeding climate model projections. Geophysical Research Letters 39(19):L19504.

Derksen C, Brown RD, Mudryk LR and Luojus K (2016) Terrestrial Snow Cover. Arctic Report Card: Update for 2016.

Estilow TW, Young AH and Robinson DA (2015) A long-term Northern Hemisphere snow cover extent data record for climate studies and monitoring. Earth System Science Data 7(1):137–142.

Helfrich SR, McNamara D, Ramsay BH, Baldwin T, Kasheta T (2007) Enhancements to, and forthcoming developments in the Interactive Multisensor Snow and Ice Mapping System (IMS). Hydrological Processes 21(12):1576–1586.

[11] Brown RD and Derksen C (2013) Is Eurasian October snow cover extent increasing?

[12] Mudryk LR et al. (2017) Snow cover response to temperature in observational and climate model ensembles.

[13] Mudryk LR et al. (2015) Characterization of Northern Hemisphere snow water equivalent datasets.

Mudryk LR, Derksen C, Kushner PJ and Brown RD (2015) Characterization of Northern Hemisphere Snow Water Equivalent Datasets, 1981-2010. Journal of Climate 28:8037–8051.

Mudryk LR, Kushner PJ, Derksen C and Thackeray C (2017) Snow cover response to temperature in observational and climate model ensembles. Geophysical Research Letters 44(2):919–926.

National Snow & Ice Data Centre (2017) All About Snow.

Robinson DA, Dewey KF and Heim RR Jr (1993) Global Snow Cover Monitoring: An Update. Bulletin of the American Meteorological Society 74(9):1689–1696.

Statistics Canada (2012) Snow cover trends in Canada. Envirostats pub. 16–002X.

Related information

Climate Change

Annex

Annex A. Data tables for the figures presented in this document

Table A.1 Data for Figure 1. Annual variations in spring (April, May and June) snow cover extent, Canada, 1972 to 2016 Error! Reference source not found.

Year	April snow cover extent (million square kilometres)	May snow cover extent (million square kilometres)	June snow cover extent (million square kilometres)
1972	8.82	5.71	3.41
1973	8.05	4.91	3.35
1974	8.83	7.19	2.95
1975	9.00	5.61	3.01
1976	7.27	5.52	3.92
1977	8.08	5.22	3.67
1978	8.72	6.35	4.28
1979	9.11	6.12	3.53
1980	8.05	4.67	2.70
1981	7.83	5.89	3.54
1982	8.87	5.35	2.49
1983	8.23	5.77	2.98
1984	6.89	4.56	2.14
1985	8.55	6.43	4.07
1986	7.98	5.56	3.61
1987	6.93	4.62	3.19
1988	7.51	5.01	2.38
1989	8.33	4.93	2.29
1990	8.00	5.13	2.16
1991	7.38	4.85	2.96
1992	7.93	5.69	3.05
1993	7.35	4.76	1.99
1994	8.03	5.00	2.45
1995	8.78	4.88	2.50
1996	8.61	6.25	2.89
1997	8.83	6.52	3.16
1998	7.21	4.19	2.07
1999	7.58	4.99	2.46
2000	7.75	5.54	3.04
2001	7.95	5.03	2.72
2002	8.61	6.00	3.12
2003	8.36	5.47	2.82

Year	April snow cover extent (million square kilometres)	May snow cover extent (million square kilometres)	June snow cover extent (million square kilometres)
2004	7.96	6.18	3.08
2005	7.39	4.90	2.75
2006	7.46	4.48	2.30
2007	8.03	4.89	2.77
2008	8.82	4.92	1.90
2009	8.47	5.60	2.33
2010	6.26	4.15	1.72
2011	8.67	5.08	1.85
2012	7.55	4.58	1.24
2013	9.08	4.95	1.63
2014	8.77	5.14	1.66
2015	7.87	4.55	1.48
2016	7.54	4.39	1.59

Source: Environment and Climate Change Canada (2017) Climate Research Division, Climate Processes section. Rutgers University Global Snow Laboratory (2017) Northern Hemisphere Snow Cover Extent Climate Data Record dataset.

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