Canadian Ice Service Digital Archive (CISDSA): Trends and variability in summer sea ice cover 1968-2008

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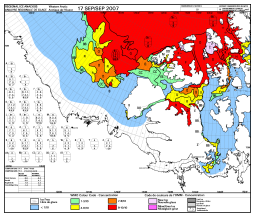


ABSTRACT

The Canadian Ice Service Digital Archive (CISDA) is a compilation of weekly ice charts that cover Canadian Waters. During the IPY the 1968-present (semi-real time) data was made available on the CIS web site along with analysis tools to provide support to the research community and the public through the development of the Ice Graph tool. The archive was extended and improved by the addition of the Historical Charts data set which allowed the examination of ice conditions in some areas back as far as 1960 and improved the reliability of the archive data for 1968-74. This additional data also allowed the assessment sea ice trends and variability.

The data revealed that between 1968 and 2008, summer sea ice cover has decreased by -8.9% ± 3.1% per decade in Hudson Bay, -2.9% ± 1.2% per decade in the Canadian Arctic Archipelago, -8.9% ± 3.1% per decade in Baffin Bay, and -5.2% ± 2.4% per decade in the Beaufort Sea. In general, these reductions in sea ice cover are explained by increases in early summer surface air temperature (SAT). Within the Canadian Arctic Archipelago and Baffin Bay, the El Niño-Southern Oscillation (ENSO) index correlates well with multi-year ice coverage (positive correlation) and first-year ice coverage (negative correlation) suggesting that El Nino episodes precede summers with more multi-year ice and less first-year ice. Extending the trend calculations back to 1960 along the major shipping routes through the Canadian Arctic revealed significant decreases in summer sea ice coverage ranging between -11% -and -15% per decade along the Arctic Bridge and -6% and -10% per decade along the southern route of the Northwest Passage. No significant trends were found along the northern Western Parry Channel route of the Northwest Passage.

What is CISDA?

The CISDA is a comprehensive sea ice data set derived from weekly ice charts. The data is more accurate and provides more detail, particularly in the narrow straits of the Canadian Arctic Archipelago, than the widely used passive microwave derived sea ice concentration maps. There are three types of ice charts: 1) Regional Ice Charts (1968 to present) that are produced weekly during the shipping season; 2) Historical Ice Charts (1958 to 1974) that were produced at t the end of the operational season specifically for climatology (e.g. right of title); 3) Polar Continental Shelf Project (PCSP) Ice Charts (1961 to 1979) that cover the Arctic only and were based on ice reconnaissance flights designed to gather climatological ice information (e.g. Figure 1). All data is digitized with the exception of the PCSP charts which are currently being prepared for digitization.

As part of the IPY, the Canadian Ice Service focused on extension of the record and data homogenization in the CISDA; the data can now be used for climatological studies in support of interdisciplinary Arctic research.

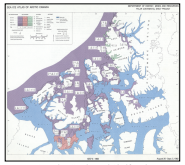


Figure 1: Polar Continental Shelf Project Ice Chart for the period between August 26 and September 5, 1962.

CISDA data quality and climate studies

Sea Ice Regime Regions & Data Quality Index

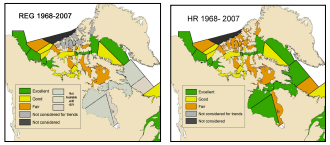


Figure 2: Qualitative Quality Index (QI) scores for Average Ice Concentration (AIC) : suitability for trend analysis

The CIS Ice Regime Regions (CISIRR) define unique ice regimes and boundaries (see Figures) that are drawn to reflect changes in ice conditions and forcing factors such as ocean currents, synoptic climatology and topography. A qualitative quality index (QI) was developed to portray the variability in data quality over space and time. The QI are evaluated for each of the CIS Ice Regime Regions. The QI maps (Figure 2) show the improvement in data quality resulting from the addition of the historical charts to the regional chart database. The right hand chart shows that the addition of the historical charts increases the data quality in most regions, particularly in the high arctic. There is no data in the Hudson Bay region prior to 1971 in the regional ice charts.

Addition of Historical Charts Extends Period for Trends

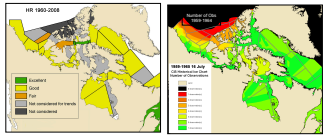


Figure 3: a) QI (left) and frequency of observations, b) (right) support trend analysis of AIC along shipping routes from 1960

The addition of the historical charts extends the record suitable for trend analysis back **50 years** to 1960 in some areas. These areas are generally located along shipping routes. The QI chart for 1960-present (Figure 3a) shows areas designated as suitable for trend analysis of total concentration: including Lancaster Sound, the southern Northwest Passage route and the shipping route into Churchill. Figure 5b shows areas where aerial reconnaissance was predominant during the 1959 to 1964 period (max 7 years) for 16 July (well before the full extent of the NWP route opens up) and further illustrates the areas for which sufficient data is available for trend analysis.

Assessment of Potential Bias: Changing Sensors over Time

The introduction of Radarsat-1 in 1996 is the most notable change in source data in the CISDA. To test for a potential bias in the data, comparison is made with the SSMR and SSM/I passive microwave derived sea ice concentration data set. This data set was used sparingly in chart preparation. No significant shifts were detected in the (CIS-SSMI)/SSMI metric for all ice types combined and multi-year ice.

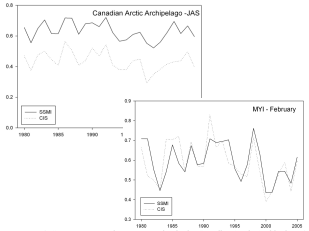


Figure 4: Summer average ice concentration in the Canadian Arctic Archipelago (top) and February multi-year ice concentration for the Eastern and Western Arctic (bottom). Data is from CISDA (CIS) and SSMR-SSM/I (SSMI)

Trends in Summer Sea Ice 1968-2008

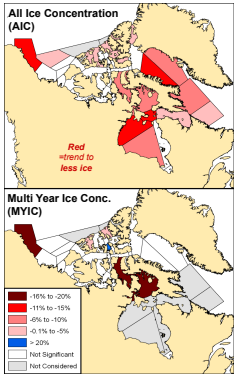


Figure 5: Trends in summer AIC (top) and MYIC (bottom) from 1968 to 2008; units are percent change per decade. Only trends significant to the 95% confidence level are shown.

There are declining trends in summer sea ice coverage in most regions; the greatest reductions are in the seasonal ice zones (Figure 5 (top)). Changes in multi-year ice coverage are confined to only a few regions (Figure 6 (bottom)). Over the study period there were also significant increases in surface air temperature (Figure 6).

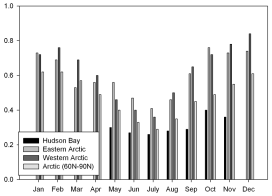


Figure 6: Trends in regional and pan-Arctic NCEP surface air temperature by season 1966-2007; trends are expressed in ^{0}C decade^{-1} and only trends significant at least to the 95% confidence interval using the standard f-test are shown. The data is averaged over five month periods and is plotted centered on the middle month; the regions correspond to the CIS regional chart areas.

Trends in Summer Sea Ice: 1960-2008

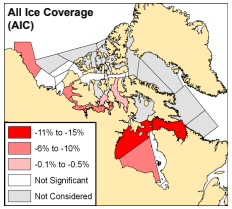


Figure 7: Trends in summer AIC from 1960 to 2008; units are percent change per decade. Only trends significant to the 95% confidence level are shown.

Over the 50 year period the maximum declining trend in ice coverage is seen along the shipping route to Churchill (Figure 7). The 50 year time series from Northwestern Hudson Bay (Figure 8) shows that light ice conditions began in the mid 1980s. The Beaufort Alaska area also maintains a declining trend in coverage when the trend period is extended back to 1960 and the declining trend becomes significant in the southern portion of the Northwest passage (Figure 7).

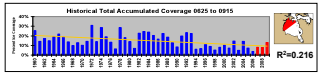


Figure 8: NW Hudson Bay average ice concentration: summer season

Inter-annual Variability Linked to ENSO

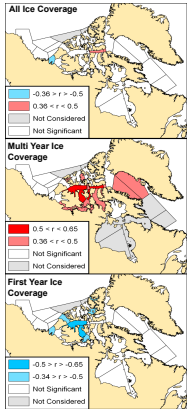


Figure 9: Correlation coefficients between the NDJFM averaged ENSO index and AIC (top), MYI (middle) and FYI (bottom).

Strong correlations between the winter index of the El Nino Southern Oscillation (ENSO) and summer multi-year (MYI) and first-year (FYI) ice concentrations suggests that ENSO may contribute to inter-annual variability in summer sea ice cover (Figure 9). Positive (negative) correlations between MYI (FYI) and ENSO suggest that winter El Nino events precede summers with more (less) MYI (FYI). We suggest the likely reason for the relationship is the opposing response of MYI and FYI to El Nino events; warming over the Arctic decreases the FYI but allows for increased MYI import. The surface air temperature (SAT) composite of El Nino events (Figure 10) is characterized by anomalously warm temperature over the whole arctic with the strongest anomaly over the southern Canadian Arctic Archipelago.

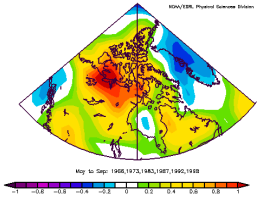
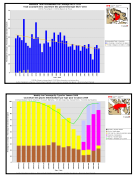
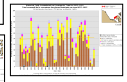


Figure 10: Composite summer (MJJAS) surface air temperature departure from 1968 to 1996 normal during strong El Nino events (Figure 4.17). Data is from NCEP/NCAR Reanalysis [*Kalnay et al.*, 1996].

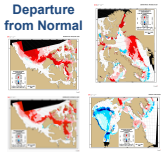
Dissemination of CISDA data and products



Ice Graph Tool



Departure from Normal



http://ice-glaces.ec.gc.ca

- **The interactive ICE GRAPH TOOL has been implemented which allows individuals to query historical ice conditions in Canadian coastal waters over the past 35 years and put current conditions in context in near real time in both tabular and graphical formats**
- **Departure from normal charts are available in near real time for Regional Chart areas.**

ACKNOWLEDGEMENTS

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DATABASE REFERENCES

1. Tivy, Adrienne, Stephen Howell, Bea Alt, Steve McCourt, Richard Chagnon,Greg Crocker, Tom Carrieres and John Yackel (accepted) Trends and variability in summer sea ice cover in the Canadian Arctic based on the Canadian Ice Service Digital Archive. Accepted for publication by Journal of Geopysical Research - Oceans
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