CHANGES IN THE SUMMER CLEARING OF SEA ICE IN NORTHEASTERN BAFFIN BAY, 1981–2011

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Abstract

The sea ice concentrations in northeastern Baffin Bay have undergone major reductions over the past 31 years (1981-2011) in the eastern portion of Baffin Bay from Disko Island off central west Greenland to Melville Bay in Northern Greenland. Since the late 1990s, there has been a very large reduction in total ice concentration in the month of July.

The average break-up date over the past 13 years has occurred in late June which is equivalent to an advance in ice clearing of three weeks from the earlier period. The trend toward reduced ice concentrations in the central areas of northeastern Baffin Bay has persisted through the summer months and into early autumn.

The changes in the early summer ice regime began quite abruptly in 1996–1998. Prior to the mid-1980s, much higher ice concentrations prevailed. This change coincided with a marked decrease in the winter North Atlantic Oscillation (NAO) index, computed as the normalized difference in sea level pressure between southwest Iceland and Gibraltar.

Previous Studies

Parkinson and Cavalieri, (2008):

- Large reduction in Baffin Bay/ Labrador sea ice extents over the years 1979–2006: -9.0 ± 2.3%/decade.
- The largest reductions occurring in summer: -16.0 ± 4.8 %/decade.

Mysak et al. (1996):

- related the years of heavy ice conditions to El Niño episodes (1983/1984 and 1991/92) but not for 1997/98.
- Teleconnections between ENSO and the North Atlantic Oscillation (NAO).

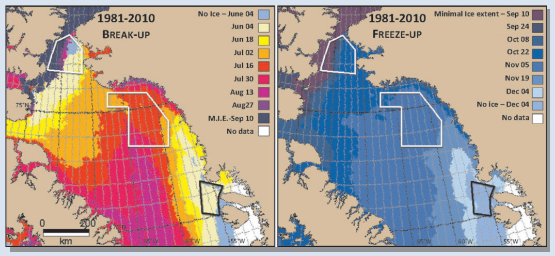
Marine Activities in Baffin Bay

Northeastern Baffin Bay is the main shipping route into the Canadian Arctic in early summer due to ice-clearing patterns. In recent years, northeastern Baffin Bay has become an active area for oil and gas exploration.

Icebergs are also important to marine operations. Although icebergs are not discussed in this paper, sea ice concentrations are important in determining the mobility, range and deterioration of icebergs (Marko et al., 1994).

Northeastern Baffin Bay: Break-up and Freeze-up Patterns

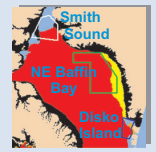
The average break-up and freeze-up dates for sea ice as derived from the CIS digital ice charts for the period 1981–2010 are as follows. Also shown are the license areas for oil and gas exploration in the northeastern Baffin Bay region.

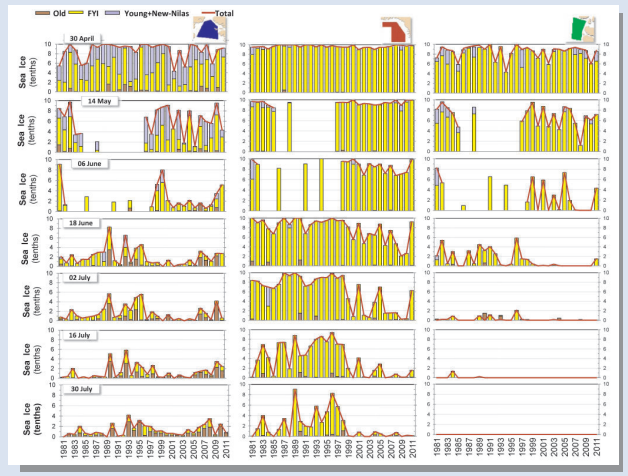


Changing Sea Ice Conditions, 1981–2011

Data Source: CIS Weekly Digital Ice Charts

The sea ice concentrations (tenths) for each year from 1981 to 2011 inclusive for the three Areas of Interest (AOIs) for the weekly ice charts of April 30, June 18, July 2, July 16 and July 30. The total ice concentrations are presented (red line), as well as the partial ice concentrations for old, first year ice (FYI), and the combined young/new/nilas ice type categories.





Results:

Ice clearing of northeastern Baffin Bay began to the southeast off Disko Island and to the north in Smith Sound (due to the Northwater Polynya). On April 30, the nearly complete (> 9-tenths) ice coverage of the winter and early spring remained in place.

By June 18, partial clearing occurred in some years to ice concentrations as low as seven-tenths in the 1980s and 1990s and more clearing in the 2000s with ice concentrations as low as two-tenths (2009).

The seasonal progression toward lower sea ice concentrations continues through July, with considerably larger reductions in the most recent 13 year period from 1999–2011. The dramatic decrease in ice concentrations, from well over five-tenths to two-tenths or less in early and mid-July, occurred abruptly starting in 1999.

Long Term Trends in Sea Ice Concentrations:

Statistically significant year-sea ice trends were observed for:

- NE Baffin Bay (up to 24% per decade reduction)
- Disko I.(up to 9% per decade)
- Smith Sound: no significant trends
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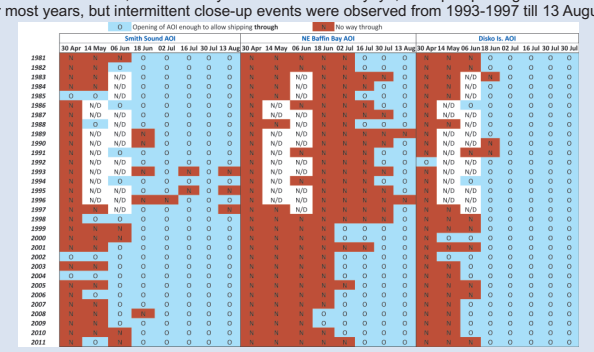
(*) if p<0.05 and two (**) if p<0.01
DC = Decadal Change; ASI = Avg Sea Ice (tenths)

1981-2011 Year-Sea Ice trends		NE Baffin Bay				Disko I.			
Sea Ice	Date	DC	p	StD	ASI	DC	p	StD	ASI
Total Ice	18Jn	-14%	**	2.2	7.8	-9%	**	1.7	1.3
First Ice	18Jn	-0.1	**	2.2	7.7	-0.1	*	1.7	1.2
Total Ice	2Jl	-24%	**	3.4	6.1				
First Ice	2Jl	-0.2	**	0.3	0.1				
Total Ice	16Jl	-16%	**	3.3	3.8				
First Ice	16Jl	-0.2	**	3.2	3.6				

Ship Passage Dates Under Changing Sea Ice Conditions

The potential for ship passages was determined according to the criteria that a passage existed over a width of many kilometers in which total ice concentrations were < 2/10. Our results show that northeastern Baffin Bay is the choke area for navigation, although a trend towards earlier potential ship passage is observed from 1998 onwards. Smith Sound, influenced by the North Water Polynya, has open passage from the beginning of June for most years, but intermittent close-up events were observed from 1993-1997 till 13 August.

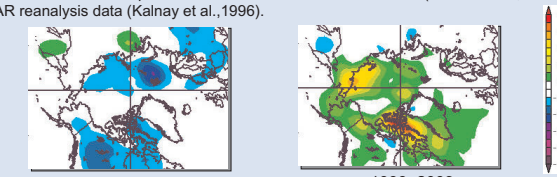


The potential for ship passages (N- not possible, O-possible, N/D – no data) for selected weeks from 1981–2011 in the three AOIs.

Underlying Processes for Reduced Sea Ice Concentrations

(a) Air Temperatures

The striking increases in air temperature during the fall-winter after 1998 may contribute to the pronounced sea ice decrease observed in the July ice plots. Composite anomalies (1981–2010 climatology) for Oct to Apr show that the 1993–1997 period was much cooler than 1999–2003 (NOAA/ESRL, 2011) using NCEP/NCAR reanalysis data (Kalnay et al.,1996).



1993–1997 1999–2003

Images provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.esrl.noaa.gov/psd/.

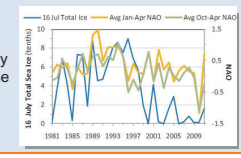
(b) NAO Index and Total Ice

NAO-Total Ice 1981-2011	30-Apr	14-Mar	6-Jun	18-Jun	2-Jul	16-Jul	30-Jul
NE Baffin Bay AOI							
Jan-Apr avg	0.51	0.66	0.08	0.05	0.15	0.05	0.06
prev Oct-Apr avg	0.31	0.47	0.26	0.11	0.16	0.03	0.21

Correlations between 1981–2011 total sea ice concentrations with the NAO winter and fall-winter index values for the years 1981–2011. A large value of the F-statistic shown in the table indicates a greater probability that the computed correlation is due to chance; values highly unlikely to arise by chance are highlighted in yellow. Similar correlation analyses were conducted for the Smith Sound and Disko Island ice concentrations from late April to late July. There were no statistically significant correlations in any of the weekly time periods considered, which suggests that the underlying factors for clearing of sea ice in these AOIs may be distinctly different than those for the northeastern Baffin Bay AOI.

Results:

Ice reductions in late spring and early summer are highly correlated with the NAO Oscillation Index from the preceding fall and winter for the northeastern Baffin Bay AOI only.



A plot of the July 16 total sea ice concentration in the northeastern Baffin Bay AOI (blue line) vs. the NAO index for January to April (orange line) and the average NAO index from October (previous year) to April (green line).

Summary

Over the last three decades, there has been a trend towards less sea ice in Baffin Bay. In this study, reductions of up to 24% per decade occur in late spring and early summer.

Since the late 1990s, ice clearing occurs approximately three to four weeks earlier than previously observed in the 80s and 90s. The starting time of potential ship passages through northeastern Baffin Bay has likewise shifted from late/mid-July to late-June.

The observed changes in the sea ice regime may be driven by many forcing factors, of which atmospheric forcing is probably the most important. We observed a high correlation between the sea ice concentrations of northeastern Baffin Bay with the North Atlantic Oscillation (NAO) index. The lower (higher) ice concentrations after (before)1998 were associated with higher (lower) fall-winter air temperatures.

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