Analysis of Iceberg Density in North Atlantic Waters - Causes and Trends
Brown, J.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/8895130
Student Report, 2007

DOCUMENTATION PAGE

REPORT NUMBER	NRC REPORT NUMBER	DATE		
SR-2007-08		April 2007		
REPORT SECURITY CLASSIFICATION Unclassified		**DISTRIBUTION** unlimited		
TITLE **Analysis of Iceberg Density in North Atlantic Waters – Causes and Trends**				
AUTHOR(S) Jeffrey S. Brown				
CORPORATE AUTHOR(S)/PERFORMING AGENCY(S) Institute of Ocean Technology – National Research Council of Canada				
PUBLICATION				
SPONSORING AGENCY(S) Institute of Ocean Technology – National Research Council of Canada				
IMD PROJECT NUMBER		**NRC FILE NUMBER**		
KEY WORDS Iceberg Drift, North Atlantic Oscillation		**PAGES** 17	**FIGS.** 10	**TABLES** 0

SUMMARY

The report analyses some key factors associated with iceberg drift into southerly waters, including the North Atlantic Oscillation (NAO), Sea Surface Temperature (SST), and air temperature. The report attempts to identify how each factor effects iceberg drift and identifies some trends associated with climate changes in the north Atlantic.

ADDRESS

National Research Council
Institute for Ocean Technology
Arctic Avenue, P. O. Box 12093
St. John's, NL A1B 3T5
Tel.: (709) 772-5185, Fax: (709) 772-2462

National Research Council Canada
Conseil national de recherches Canada

Institute for Ocean Technology
Institut des technologies océaniques

ANALYSIS OF ICEBERG DENSITY IN NORTH ATLANTIC WATERS - CAUSES AND TRENDS

SR-2007-08

Jeffrey S. Brown

April 2007

Table of Contents

List of Figures and Charts

1.0 Introduction

This report attempts to find a coherent relationship between the environmental conditions of the North Atlantic, and the relative iceberg density south of latitude (lat) 48N, established from iceberg data collected between the years of 1890 and 2003. Several sources suggest the presence of a phenomenon called the North Atlantic Oscillation (NAO) and its direct effects on wind speed and direction, precipitation levels and temperature in the north Atlantic regions. This leads to speculation that the NAO has some bearing on the drift and lifespan of icebergs, or general density of icebergs south of 48N. Given data from the NAO index, air temperature recorded at St. John's Newfoundland and Northern Hemisphere Sea Surface Temperature (SST) data, this report attempts to explain some of the conditions, which determine iceberg density in the North Atlantic. The report will focus on the mechanism of iceberg drift, and draw some conclusions as to the effects of the environmental conditions on iceberg movement in the North Atlantic.

In the past relatively heavy ice years are known as years where large numbers of icebergs drift south of 48N, therefore this report analyzes iceberg numbers in that area specifically. 48N is a generic cutoff point for associations like the International Ice Patrol, who consider icebergs above the point generally harmless to trans-Atlantic shipping lanes. To increase the validity of this analysis, the same cutoff point is used. The report also takes a quick look at some of the climate trends, which may affect iceberg movement in the future.

1.1 North Atlantic Oscillation (NAO)

The NAO is a product of two semi permanent pressure systems located over the Atlantic region. The Icelandic low and the Azores high, both located in their respective regions. A quantitative measurement system has been established to measure the strength of the system, know as the NAO index. The index is based on the absolute difference in pressure of the two systems; a negative index corresponds to a small system gradient (both pressure systems close to regular atmospheric pressures, while a positive index corresponds to both systems deviating strongly from atmospheric pressure. (Extreme low and extreme high.)

Figure 1.1

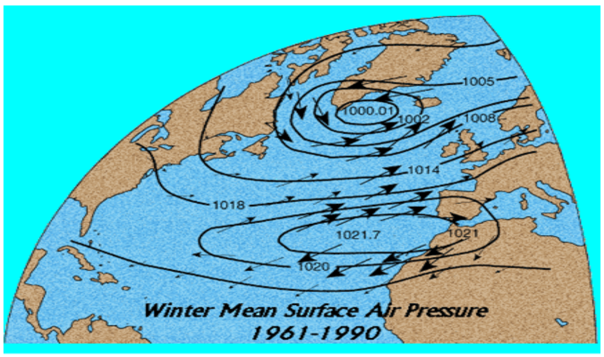


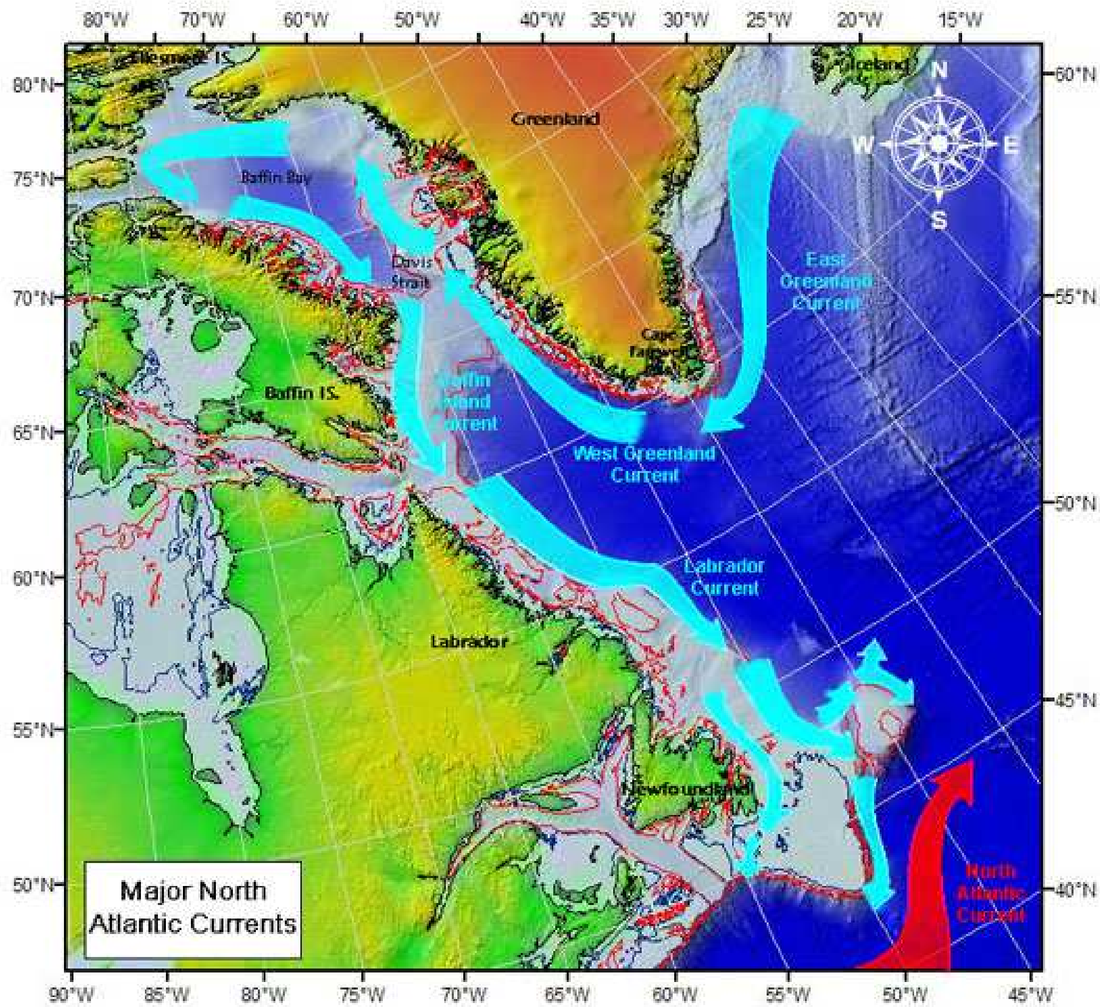
Figure 1.1 Shows relative high and low pressure systems of the NAO and wind directions

The NAO is considered to be a driving force for North Atlantic weather. As low-pressure systems promote counter-clockwise wind directions around the center of the low, and highs promote clockwise wind directions around its center, as seen in figure 1.1. As the index for the NAO increases it causes strong westerly winds along Newfoundland and through the North Atlantic Ocean. It has also been linked to colder temperatures and higher precipitation in these areas, as the winds create a storm track.

The question then arises: what effect does the NAO, specifically the NAO index values have on iceberg drift in the north Atlantic?

1.2 Mechanism of Iceberg Drift

Figure 1.2



Shows the major paths for icebergs, which correspond to the major currents in the north Atlantic. The Labrador Current has the largest effect on bergs around Newfoundland.

Figure 1.2 showing the main drift paths of icebergs in north Atlantic waters. With 90% of the mass of any iceberg below water currents in the North Atlantic greatly effect iceberg drift. (IIP) This is the strongest driving force for iceberg drift; conveniently the above currents are semi permanent and usually predictable from year to year. Yet we can still notice a huge variation from year to year of icebergs drifting south into oil and gas operations and trans-Atlantic shipping lanes. This leads to speculation that there are other factors which effect the drift of icebergs. Winds and temperature are the first that come to mind. Temperatures are generally thought to be the largest driving factor for iceberg lifespan, while wind speed and directions have a small effect on drift speeds and directions.

1.3 Data and methods

The Canadian government Program for Energy Research and Development (PERD), which deals with the issue and dangers related to the presence of floating ice in the North Atlantic, specifically for offshore oil and gas safety, published an extensive ice database. This database contains iceberg-sighting information obtained mainly from the International Ice Patrol (IIP). In 1998 Mr. Brian Hill began a continuation of the PERD project, and extended the PERD database from 1960 back to the early 1800's using several published sources like the New York Maritime Register (NYMR), The Monthly Weather Review (MWR), Lloyds List (LL), The Hydrographic Bulletin (HB) and a few others, along with the data from IIP extending back to the early 1920's.

The International Ice Patrol has categorized 3 main eras of iceberg sighting, ship reconnaissance, aircraft reconnaissance and radar reconnaissance. They extend up to 1945, from 1946 to 1982 and from 1983 onward respectively. Obvious differences between the 3 eras have been observed, especially since in the implementation of the radar iceberg detection on the IIP aircraft. From 1983 onward the mean number of iceberg sightings more than doubled that of either era. It is not established whether this era actually had more icebergs, however an obvious difference is present. This change in techniques only allows us to analyze trends relative to the immediately surrounding years to establish relationships between air temperatures, NAO index values, SST and the number of iceberg sightings per annum.

There is also a slight change in the iceberg distribution between the sighting years. There are fewer sightings above latitude 48N as you go further back in time. Previous to aircraft sightings and IIP patrol ships, iceberg sightings were based solely on trans-Atlantic liners and local shipping vessels reporting icebergs passed en route to their destinations. This causes the vast majority of iceberg sightings prior to 1920 to be located generally in the vicinity of the major shipping lanes, near north Atlantic ports or icebergs grounded near populated areas. (Generally centered around lat 48N.) This fact forces analysis of percent drift south of lat 48N to be constrained to later iceberg years, 1960 and up, due to the possible inaccuracies of iceberg sighting prior to that point in time.

The remainder of the data was obtained online. (See 5.0 for URLs and sources) The Temperature air data was taken out of St. John's Newfoundland (very close to latitude 48N), and was obtained from 1890 to 2003. There are a few missing years in the 1930's but overall the data is complete. Air temperature was analyzed for the first 4 months of the year only. Likewise, the NAO data was averaged for the same monthly range (Jan – April) from 1890 to 2003. SST data, was taken over the entire northern hemisphere from a climate monitoring website, each point is expressed as a deviation from a 1901-2000 average. Points are given for each month of the year, then averaged over the course of a year. The data for SST is used mainly for trend comparison reasons, given the range the data spans, it is difficult to accurately determine its effect on iceberg drift in such a specific area.

The data was analyzed mainly using excel graphs and VersaMap (VMap) plots (software used to graph iceberg sighting locations by latitude, longitude on a user defined map of the North Atlantic.) The plots taken from excel and VMap were analyzed for visual correlation. And tentative conclusions were drawn from this. The analysis was generally comparative in nature; each set of data was compared directly to the number of icebergs south of latitude 48N. Further comparisons were made if necessary.

2.0 General Analysis

General analysis was used as an effort to determine which environmental conditions have an effect on iceberg drift south, or iceberg production. (However the brunt of the analysis focuses on drift, as the mechanism for iceberg production is much more complicated and is beyond the scope of this report.) Line graphs for each of air temperature, SST, and NAO index were created with comparison to iceberg sightings below lat 48N. The charts to follow were developed in excel, with iceberg re-sights and duplicates eliminated.

Chart 2.1 shows a fairly strong visual correlation as relative berg maximums correspond with relative temperature minimums. The chart also shows a variable yet constant trend in winter air temperatures over the past century, and allows a visual of the change in iceberg sightings over the periods of iceberg sighting technology improvements. It also establishes the first 20 or so years of the 1900's as inconsistent and for the most part irrelevant, as they do not compare well with future years. However correlation between temperatures and iceberg sightings may be strong, but is not 100%. And does not determine how temperature effects icebergs.

2.1 Temperature Vs. Icebergs South of 48N

Chart 2.1

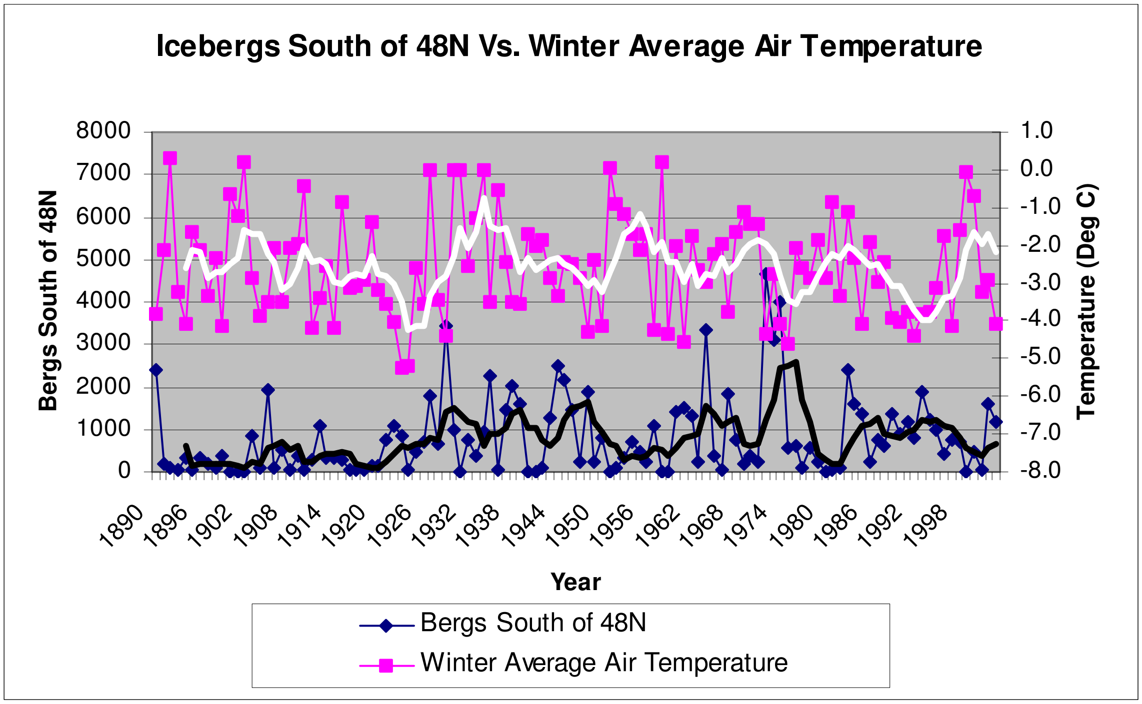


Chart shows correlation between winter average temperature and iceberg populations, 5-year running averages are used for the trend lines seen in black and white

2.2 NAO index Vs. Icebergs South of 48N

Unlike temperature the NAO can vary greatly from month to month, an average is used to for analysis in this case, however it may be inaccurate as the possibility of one outlier shifting the average greatly is possible. This may lead to several outliers and a large degree of variance in the visual analysis of its relationship to icebergs south of lat 48N. Very little or no visual correlation can be observed from chart 2.2. However a close analysis will reveal that the vast majority of above average ice years correspond to positive NAO values, negative values tend to correspond to light ice years.

Chart 2.2

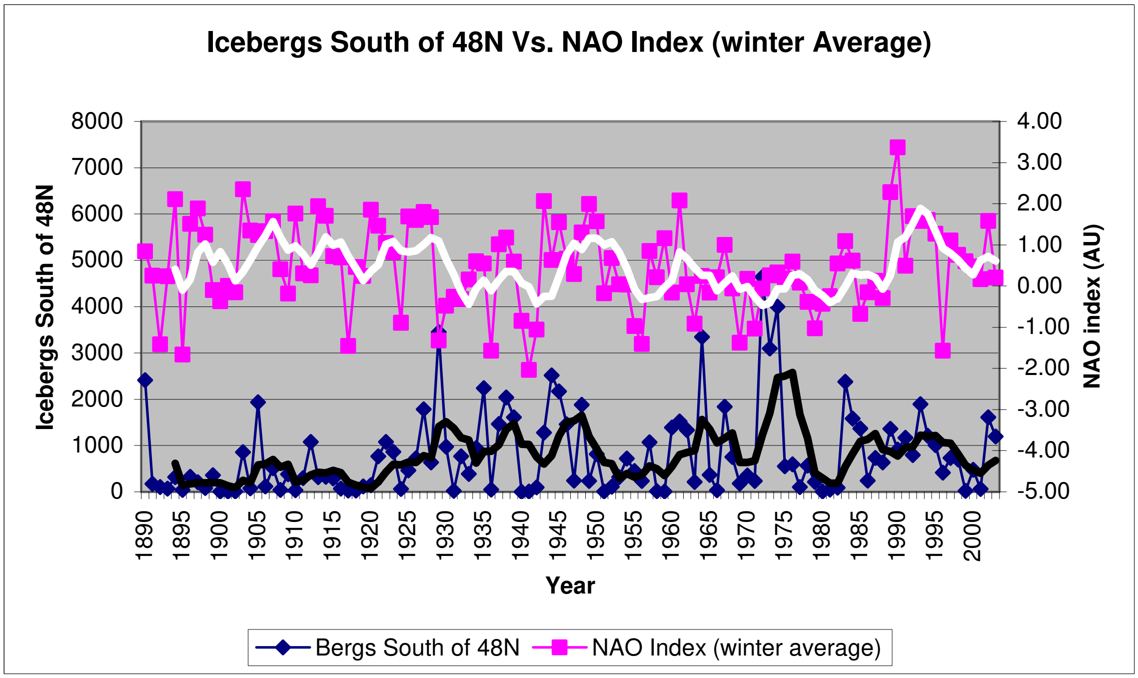


Chart shows a small degree of correlation between NAO index and berg populations, 5-5-year running averages are used for the trend lines seen in black and white.

2.3 SST Deviations Vs. Icebergs South of 48N

In a paper published by the department of fisheries and ocean by I. Peterson, a correlation between sea ice extent and iceberg populations was made using similar iceberg sightings data. I. Peterson went as far as to create a prediction method using linear regression, which was fairly accurate. This leads to speculation that SST has a large bearing on the iceberg populations. Chart 2.3 shows a strong correlation between iceberg populations and SST. One must keep in mind that we do not have accurate data for early years of iceberg sightings, which makes it difficult to estimate trends for iceberg populations as we have very little idea of what actual numbers of iceberg populations are like. However, a fairly obvious visual trend is shown from 1970 onward. (Increasing SST, decreasing iceberg populations) The SST data also suggests an obvious climate

Chart 2.3

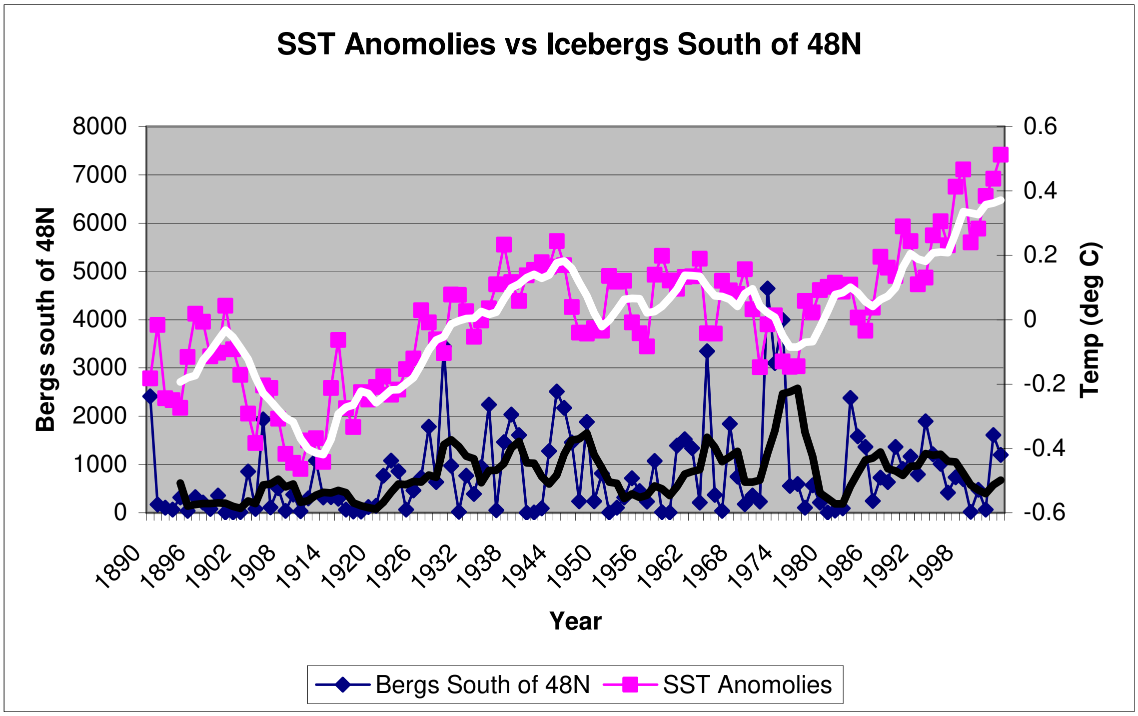


Chart shows a comparison between heavily trended SST data and berg population south of lat 48N. 5-year running averages are used for the trend lines seen in black and white

change over the past 2 decades. One can speculate with a reasonable degree of certainty that SST should have a fairly large effect on iceberg drift. The reason that icebergs do not make it to southerly waters is because they tend to melt in warmer water. This given, one would expect iceberg life span to increase as the water gets colder. Therefore we can expect icebergs to drift further south as waters are colder. One can also guess that air temperature has a small effect on above sea iceberg melting, and that the NAO winds can effect Iceberg drift direction and speeds. This chart furthers the speculation of inconsistent iceberg numbers from 1930 back, as we would expect very high numbers of icebergs to drift south over those years. (Assuming trend continues into the past.)

2.4 General Analysis Conclusions

The strongest visual correlation exists between the number of iceberg sightings below 48N and St. John's air temperature. The NAO index values are difficult to distinguish from the above line graph, most likely due to the large variation in the data from month to month. This prompts a further analysis of its effect. Also, the data from early 1900's is again difficult to draw conclusions from. It is excluded. The data was separated into two groups, above and below average ice years, from 1930-2003 by the mean value for each sighting period. The comparisons are shown visually in charts 2.41 and 2.42.

Chart 2.41

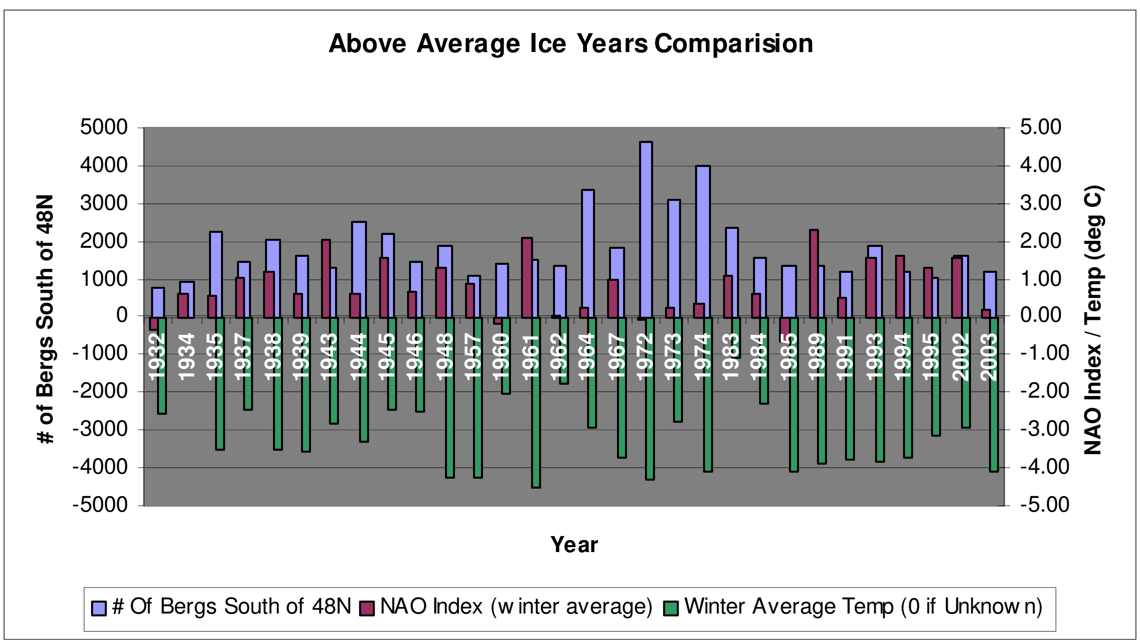


Chart shows the comparison of three variables, NAO index, temperature and berg populations for above average ice years. A very strong trend is obvious

Charts 2.41 and 2.42 makes the effect of the NAO much more visible. They show the direct correlation between the air temperatures and the iceberg population below lat 48N. Cold temperatures coupled with positive index values tend to promote heavy ice

Chart 2.42

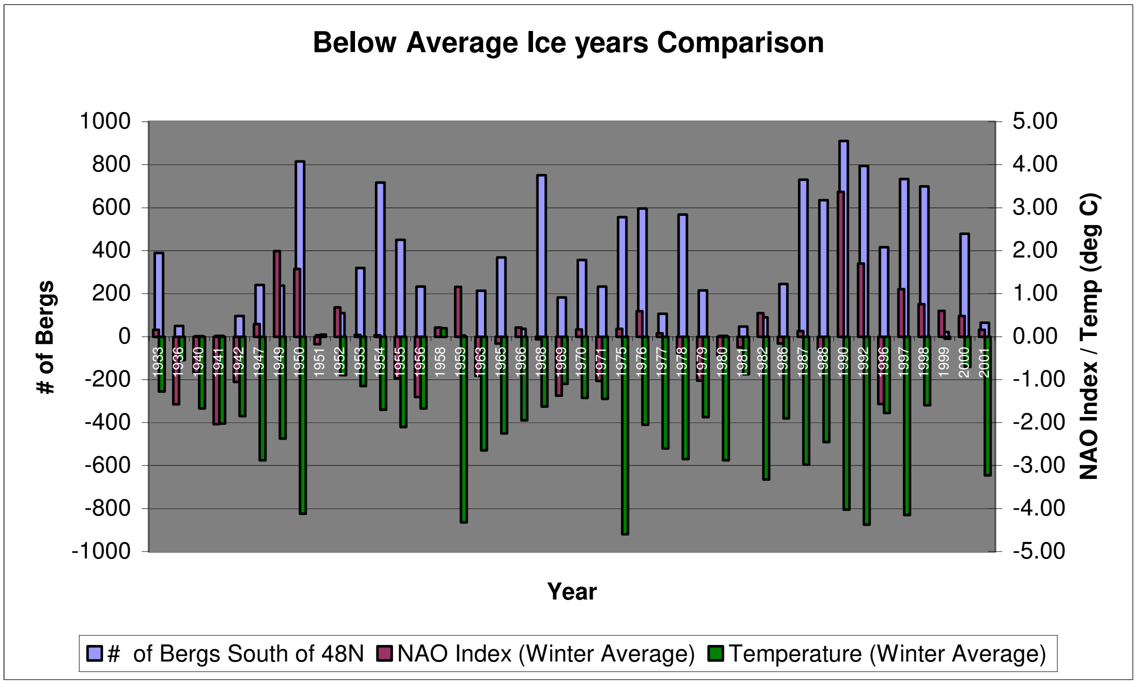


Chart shows the comparison of three variables, NAO index, temperature and berg populations for below average ice years. A trend is obvious

years. This makes logical sense, as seen in figure 1.1, positive NAO index values promote winds along the north coast of Newfoundland, towards the south west, forcing icebergs to travel along the same path as the currents. It also tends to produce winds, which force the icebergs off shore, and prevents them from grounding along the coast. Temperature has an obvious effect, cooling waters and prolonging iceberg lifespan. This allows them to survive longer in the warm water of the Gulf Stream as they travel southwards.

From chart 2.42 one can identify several outliers. (Years with cold temperature and positive NAO index values as well as small ice years.) These years, however, still follow a similar correlation; they are generally higher in icebergs than the vast majority of light ice years. This allows a general conclusion, which relates temperatures and NAO index values to the variation from year to year of iceberg populations south of lat 48N. Colder temperatures and positive NAO index values promote heavier ice years south of lat 48N, while warmer temperatures or negative NAO index values promote lighter ice years south of 48N. This does not however differentiate between iceberg drift and iceberg production off the Greenland ice shelves and glaciers. A further analysis of iceberg drift is needed.

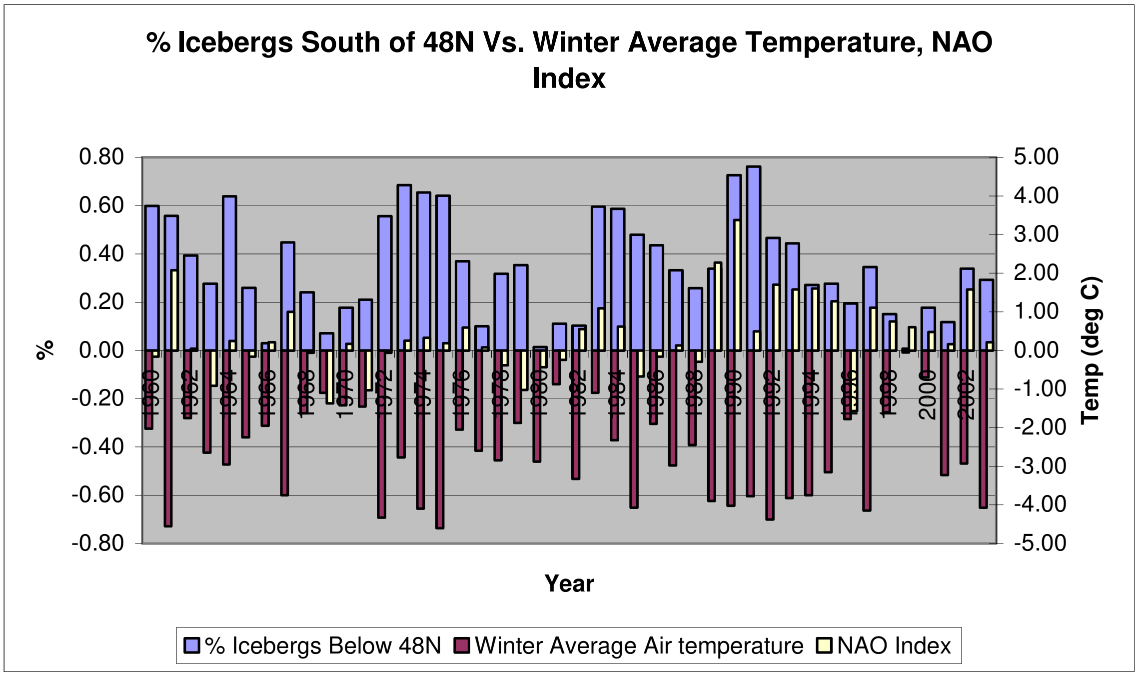
3.0 Analysis of Iceberg Drift

Given the speculation that iceberg drift may be affected by all of the factors analyzed in this report, an analysis of percent of sighted icebergs below 48N is presented. However, given the lack of certain data from the early 1900's, especially considering the fact that most ships did not travel very far above 48N the vast majority of icebergs were sighted around 48N or south, this will lead to a positive skew in the percentages nearing the early 1900's, therefore the analysis consists of the PERD database data only (1960 – 2003). These years have also been evaluated for re-sights, making the data far more accurate. A comparison of NAO index, SST and temperature is made to the percentage of bergs south of 48N.

3.1 Comparison: NAO Index, SST, Air Temperature and % icebergs south of 48N

Chart 3.1 shows a very strong visual correlation between NAO indices, average temperature in relation to the percentage of bergs south of 48N. The presence of NAO data gives a logical explanation to the presence of outliers in the temperature vs. % icebergs graph. The above chart strongly suggests that a combination of cold weather and south – westerly winds cause more icebergs to drift towards the south. This allows a somewhat general prediction for iceberg density in the shipping lanes on the north

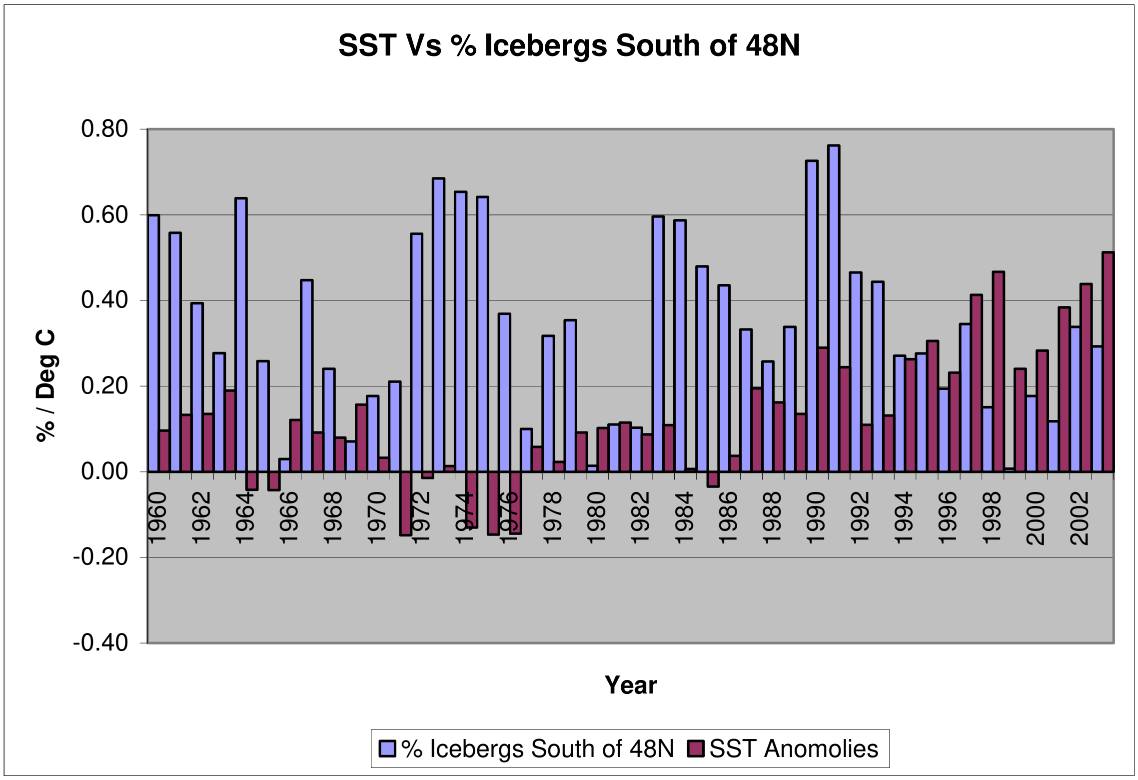
Chart 3.11



The chart shows a general trend with relation to the three variables analysed, colder temperatures and higher index values promote iceberg drift to the south

Atlantic. The effect of SST is very similar to that shown by the air temperature data. However it is strongly trended, whereas the data for icebergs does not extend back far enough to show any general trends for population, or bergs drifting south. Therefore it does makes visual comparison difficult. SST also tends to be fairly constant above and slightly below lat 48N; the most major change in SST is the intersection for the Labrador Current with the Gulf Stream. However as seen in chart 3.12 (below) There is an extremely strong trend between SST and the percentage of bergs that travel south. Again this is expected, as SST is the largest factor of iceberg melt.

Chart 3.12



The chart uses data from the northern hemisphere; it is expressed as a deviation from the 1901-2000 average temperature. It is unsure whether the data reflects the north Atlantic region

4.0 Discussion of Results

Figure 4.1 (Sea Ice Extents)

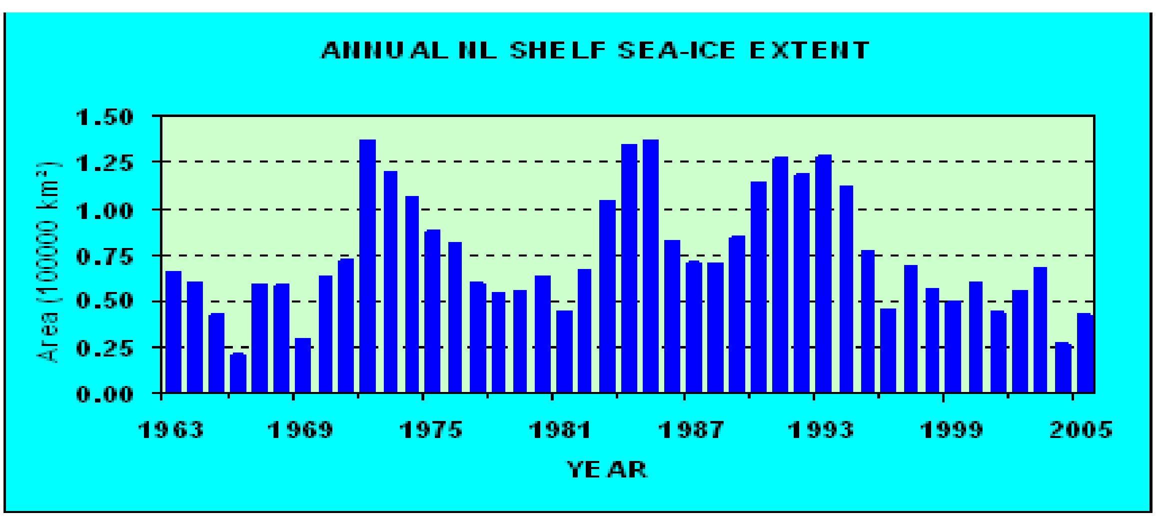


Figure courtesy of National Climate Data Center (NCDC)

The results and tentative conclusions drawn from this report are a simple analysis of visual correlation relating to the drift rates and relocation of iceberg populations to south of 48 degrees north of latitude. A great deal more statistical analysis is required to determine concrete conclusions. However we can draw some general conclusions of the above data using visual analysis. We can suggest that colder temperature (both air and sea) coupled strong winds can cause icebergs to last longer and move south more readily than years with warmer, less harsh weather. The extent if this report is the effect of environmental conditions on iceberg drift only, and offers very little support of the production of icebergs in the North Atlantic. In order to obtain trends for iceberg development, a more in depth, long-range data set would need to be collected using constant conventional means. Given that iceberg drift appears to be heavily temperature dependant, and northern hemisphere SST data suggests that there is a great deal of climate shift towards warmer weather, we can expect a decrease in the number of heavy ice years in the future.

There is also a great deal of data to suggest in a decrease of sea ice extent over the past two decades. (See figure 4.1) This can be attributed to the trend of increasing SST. I. Peterson created a 0-2 month forecasting system for iceberg populations off the grand banks. The prediction was strongly linked to the Newfoundland sea ice extent. This *could* mean that icebergs will continue to decrease as SST increases. This could also mean icebergs will drift less as years get warmer, pushing icebergs completely out of Atlantic shipping lanes and offshore oil projects. However in order to properly create a prediction method for offshore iceberg production and iceberg drift we must analyze the iceberg creation mechanism and other factors relating to iceberg drift, which is beyond the scope of this report. The most likely unexplored factor, which leads to iceberg drift, is the changes from season to season of the north Atlantic currents, generally shown in figure 1.2.

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