NORTH ATLANTIC TEMPERATURE ANOMALY

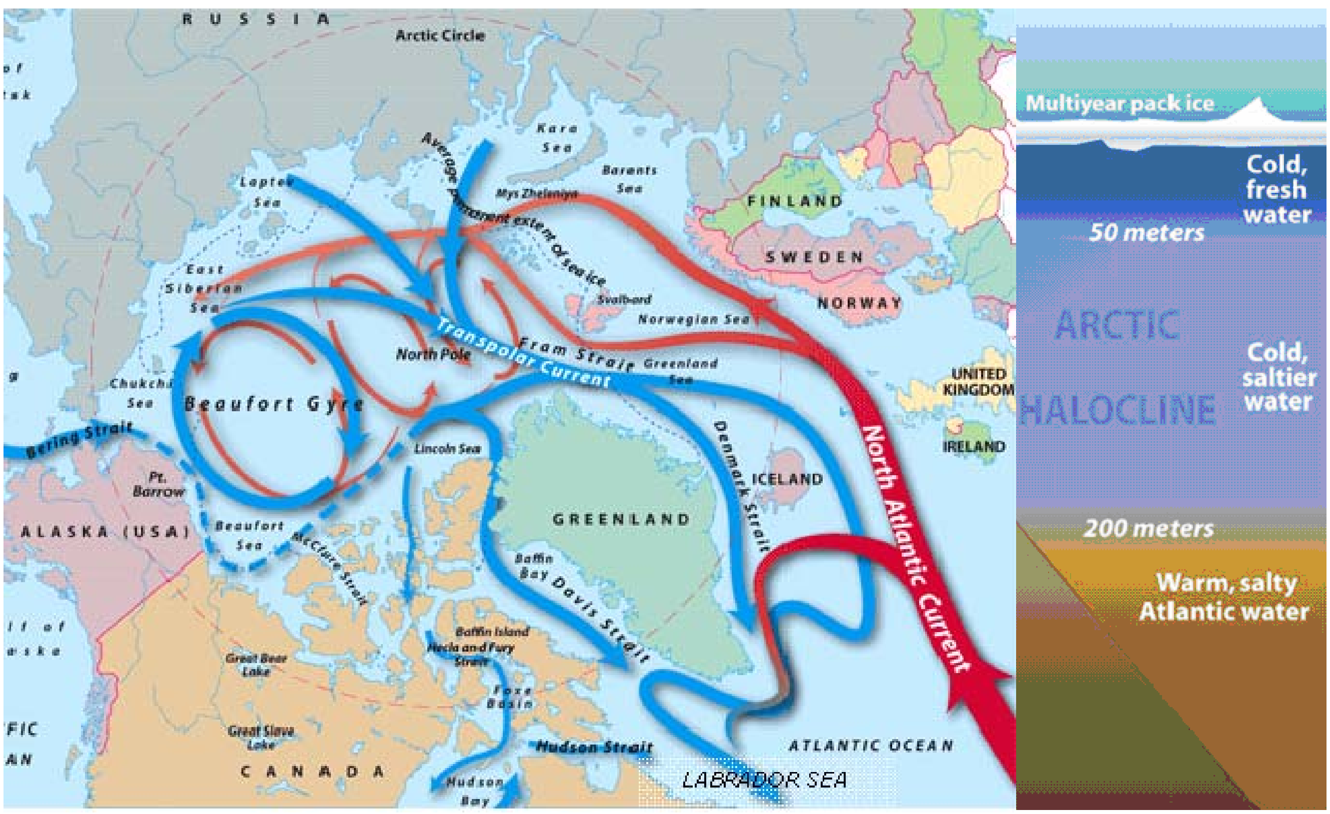
M.A. Vukcevic M.Sc. 2009

Abstract: The author postulates the existence of a high correlation between North Atlantic Temperature Anomaly and the variations of magnetic field over the Hudson Bay region. Post-glacial uplift and convection in the underlying mantle uplift (as reflected in changes of the area's magnetic intensity) are making significant contribution to the Atlantic basin climate change.

North Atlantic Currents

Arctic Ocean is unique among the world's oceans for many reasons. It is largely ice-covered (much of it year-round, the rest seasonally) and it is relatively isolated from the rest of the world's oceans. Cold and relatively less salty water enters the Arctic Ocean through the narrow Bering Strait between Alaska and Siberia.

In winter, the cold air freezes seawater into sea ice releasing salt into surface waters. These cold, salty waters become denser and sink, creating a layer known as a halocline. Halocline waters lie atop a deeper layer of saltier, denser and warmer waters that flow into the Arctic from the Atlantic Ocean. The halocline layers lie atop the warmer waters and act as a barrier preventing them from melting the sea ice.



Cold waters of the Beaufort Gyre exit into the North Atlantic Ocean through three gateways (Denmark, Davis, and Hudson Straits).

The two main constituent water masses of the deep North West Atlantic water circulation are the deep warm water current, branching of North Atlantic Current in the Nordic Seas and the Labrador Sea cold currents at an intermediate level.

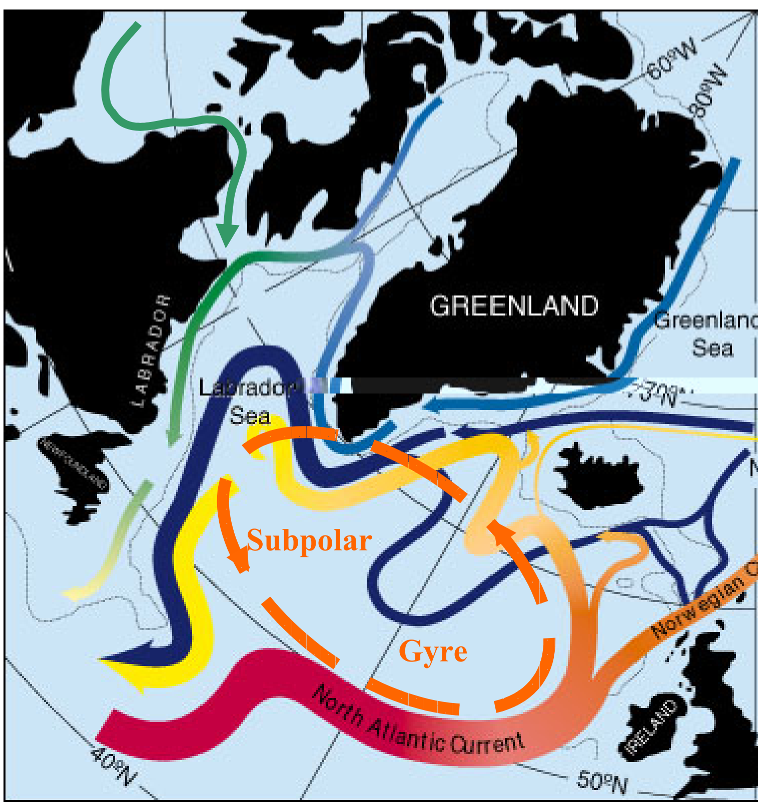
These two currents tightly govern the strength of the North Atlantic currents and via it global ocean circulation and the associated heat transport across the North Atlantic Ocean.

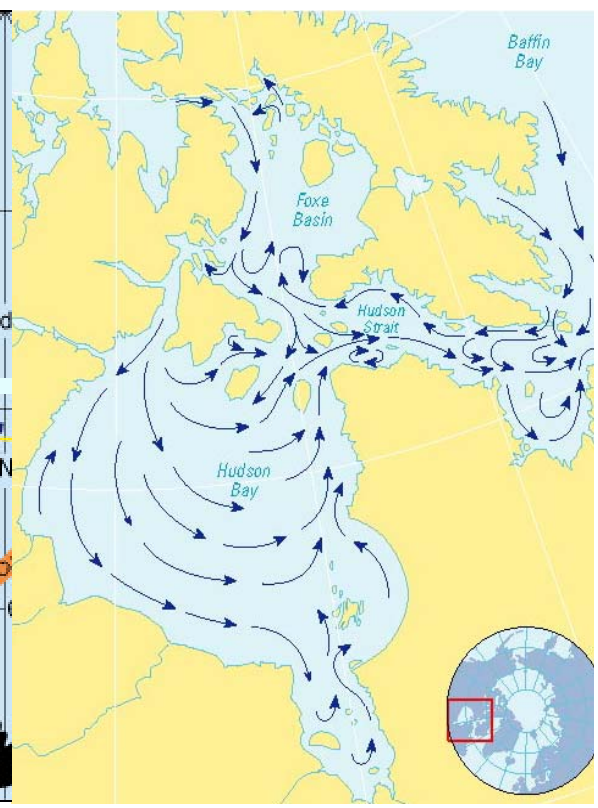
It has been shown that if relationship of these two water masses is altered, by changes in the Labrador Sea cold current, is a significant contributor to the global climate change.

Labrador Sea cold current is made from contributions of two major flows through Denmark, Davis Straits, and a minor Hudson Straits current. They form part of a current, known as the Subpolar gyre, which has weakened in the past and continues to do so. Whether the trend is part of a natural cycle or a result of other factors it is unknown in the current understanding. If this trend continues, it could indicate reorganization of the ocean climate system, perhaps with changes in the overall world climate. Computer models have shown the slowing and speeding up of the Subpolar gyre can influence the entire ocean circulation system.

The Subpolar gyre can take up to 20 years to complete its route. Warm water runs northward through the Gulf Stream, turns westward near Iceland and the tip of Greenland. The current loses heat to the atmosphere as it moves north. After cold Labrador Sea winters, the water in the current becomes cold, salty and dense, plunges beneath the surface, and heads slowly southward back to the equator. The cycle is extremely sensitive to the buoyant fresh waters flowing out of Hudson Bay.

Cold water flows in the two larger Arctic contributing currents (Denmark and Davis) can be considered to be constant, measured on decadal time scale, while Hudson Strait currents are subject to continuous change on annual as well as on multi-decadal scale.



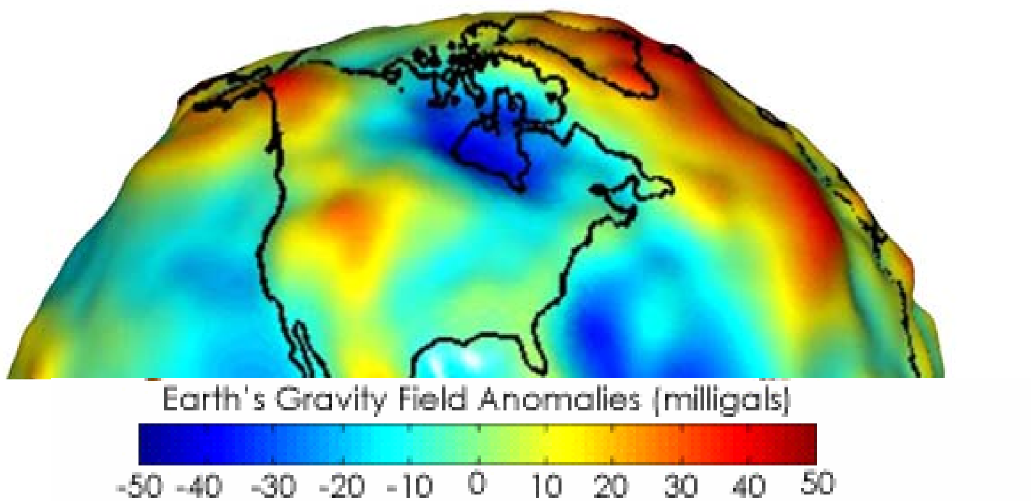


Hudson Straits circulation has complex water flows and is greatly affected by mainly anticlockwise circulation within Hudson Bay itself. Hudson Bay tributaries, major source of the fresh water inflow, via Hudson Straits, into North Labrador Sea. H.b fresh water supply

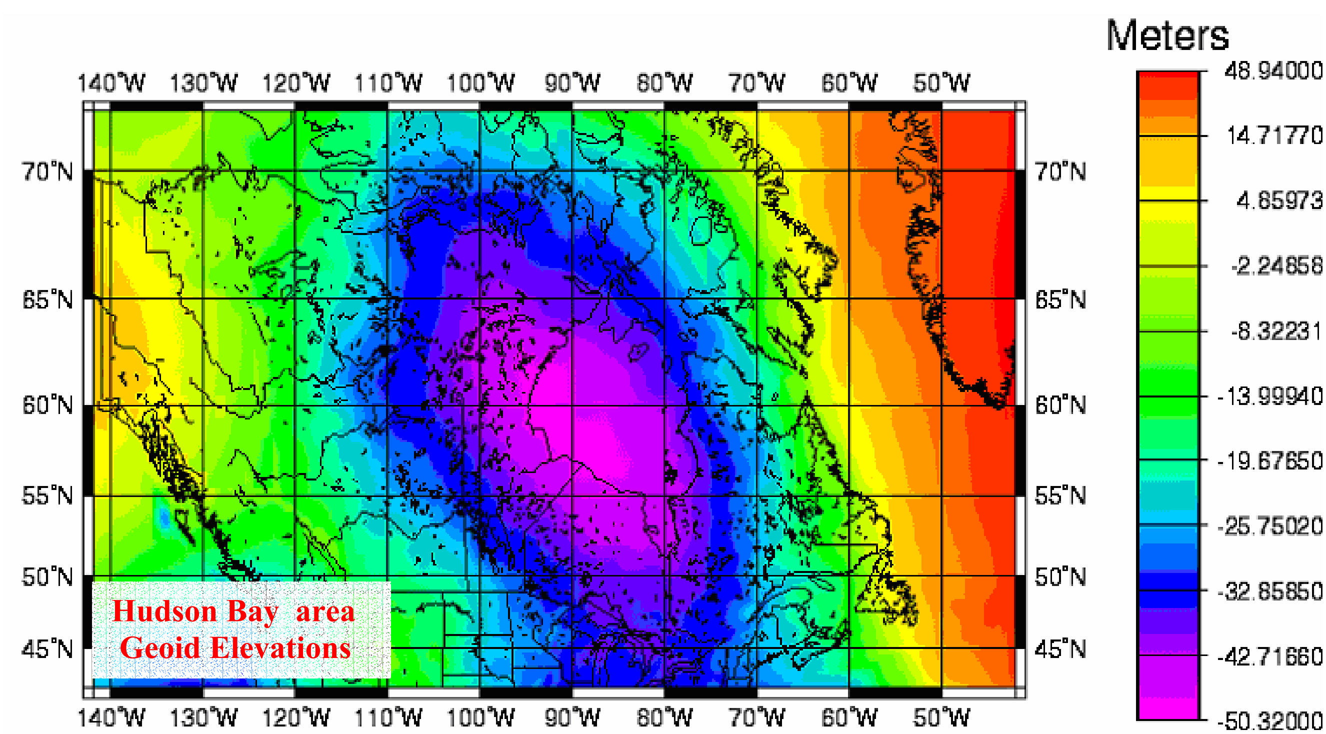
This study will concentrate on causes and consequences of possible changes in the currents intensities within Hudson Bay and Hudson Strait which in turn affect Subpolar gyre circulation.

Gravity anomaly and post-glacial uplift

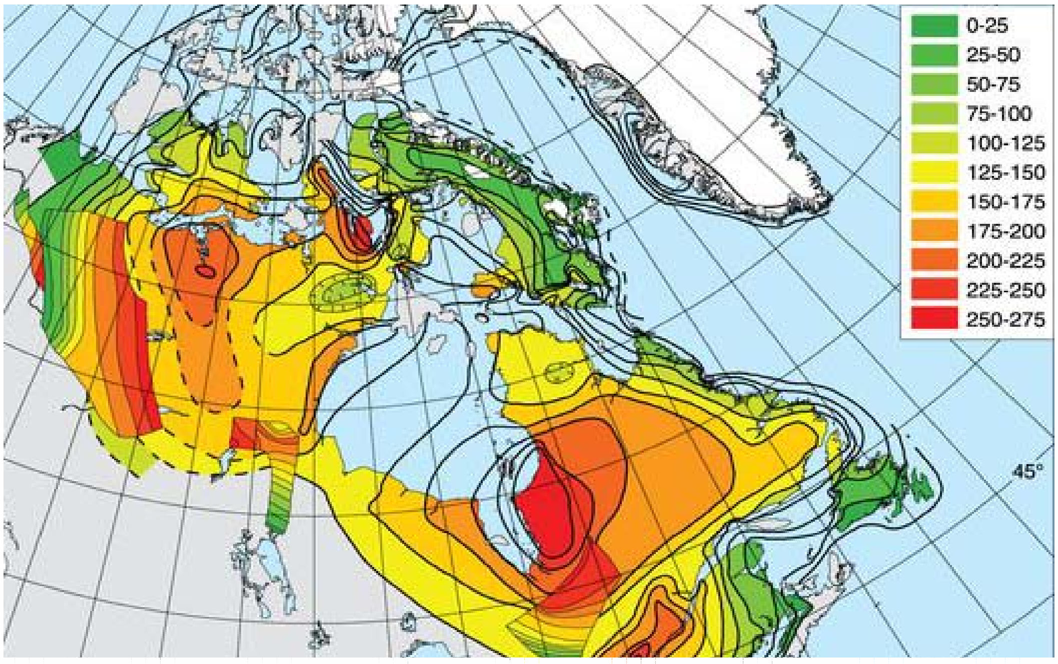
Gravity over planet's surface changes on many different time scales, from a matter of weeks to centuries. But major changes are due the movement of plates below Earth's crust. Differences in gravity can be mapped by tracking the movement of two orbiting satellites, As the Earth's gravitational pull increases and decreases, the position of the satellites also changes. The changes in distance between the satellites can be translated into a map of the Earth's gravitational field, showing gravity anomalies as shown in this illustration:



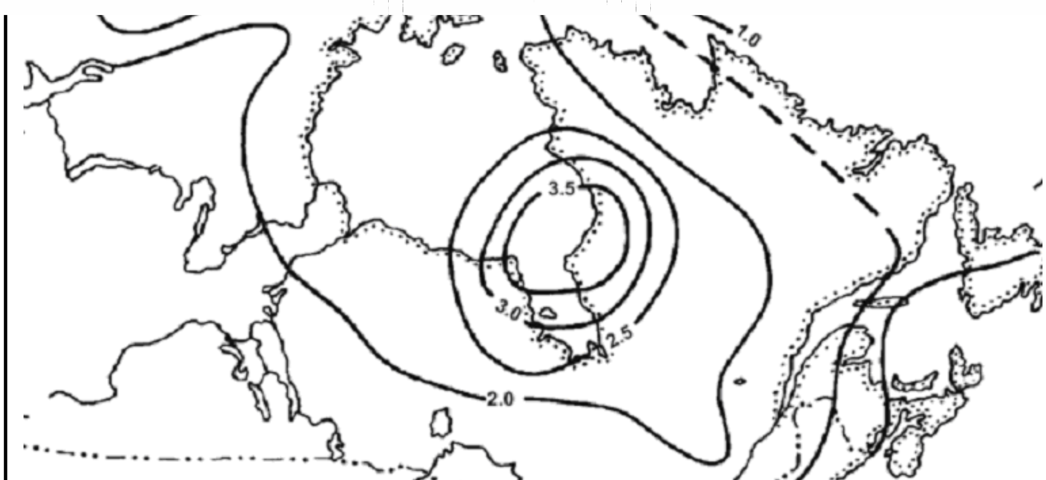
Gravity anomaly is the difference between the observed gravity and its theoretical value, which is calculated at the surface of a global spheroid. Miligal is a unit of acceleration commonly used in geodetic measurements, equal to 10^{-3} Galileo, or 10^{-5} meter per second square (10^{-5} m/sec^2).
One of the largest negative gravity anomalies (the attractions of gravity being less than average) is centred over Hudson Bay.



Some 25,000 years ago, Hudson Bay area was at the centre of a huge glacier, known as the Laurentide ice sheet, with a thickness of several kilometres. The weight of the ice bowed the Earth's surface down. The vast majority of the ice eventually melted at the end of the Ice Age, leaving a depression in its wake. While this depression has endured for thousands of years, it has been gradually recovering or "flattening itself out." The term "glacial rebound" refers to this exact behaviour, whereby the land in formerly glaciated areas rises after the ice load has disappeared.



Deglacial marine limit surfaces. The marine-limit isolines are at 25-m intervals

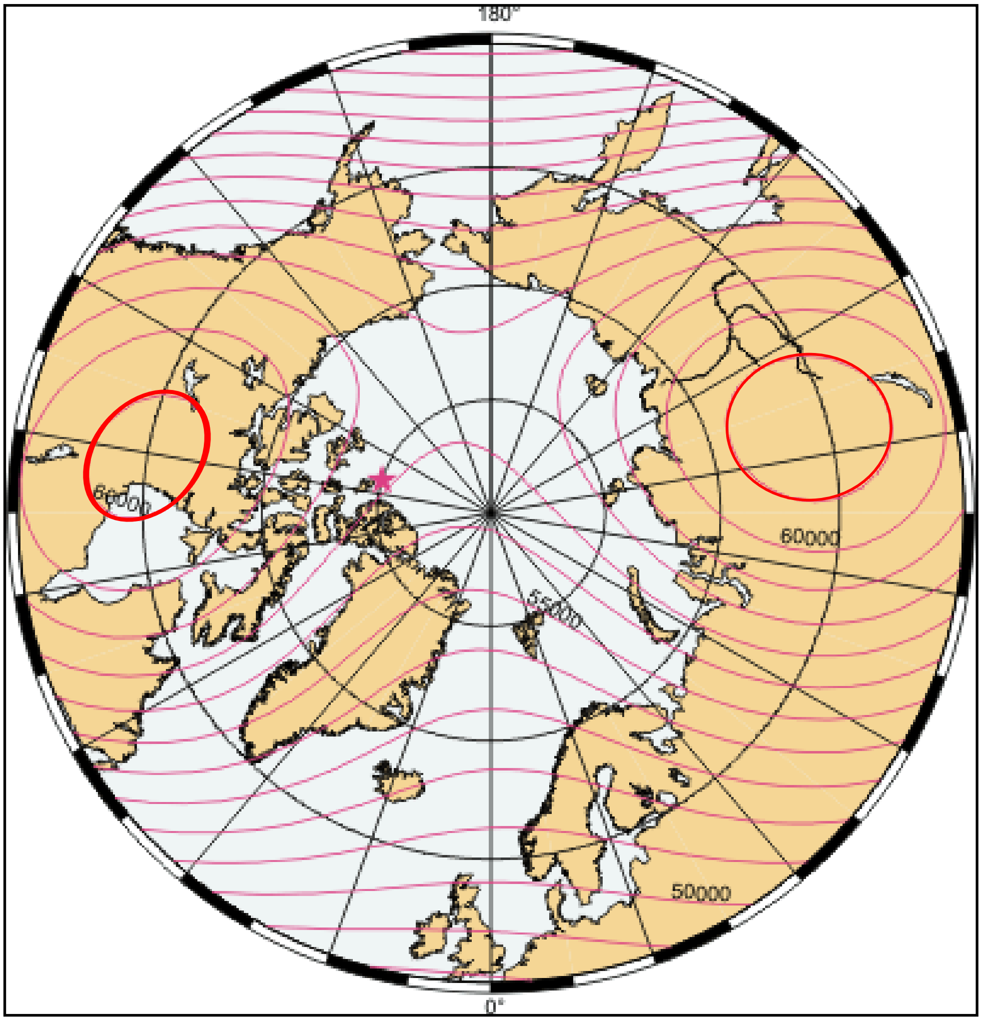


The mean rates of postglacial uplift in the Hudson Bay. Isolines show rate of uplift in meters per 100 year.

Evidence of this is seen in coastlines located near the centre of the former ice sheet. These coastlines have already risen several hundred meters and will continue to rebound. The researchers have created models that predicted that about 30% percent of the Hudson Bay gravitational signal was due to the uplift. It is thought that convection in the underlying mantle may be contributing the remainder.

The uplift in the area of Nastapoka Arc is about 3.5 meters per 100 year period. Changes in the gravitational anomaly (tendency of objects to move from lower into higher gravity area), and the changes in the ground uplift, may affect the intensity of water outflow from Hudson Bay

Magnetic Anomaly



Earth's magnetic poles are on permanent move, while the overall strength of the field has been gradually declining during last 150 years.

The South magnetic pole's maximum strength is concentrated in a single area and its decline has been relatively even, while the North magnetic pole's magnetic distribution is more complex, its maximum strength is split in two prongs, thousands of miles apart, one located in the general area of Hudson Bay and the other in the central Siberia, north of Baikal Lake.

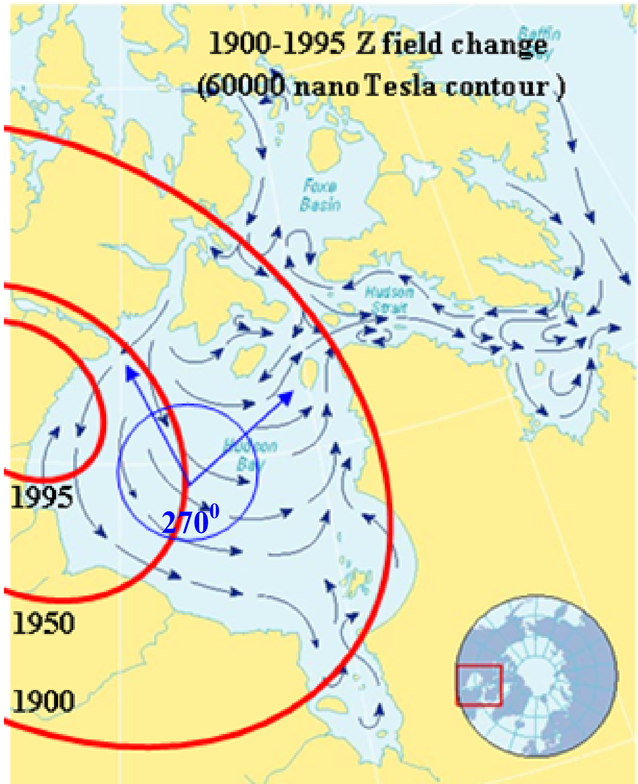
If Earth magnetic field is modelled by an imaginary bar magnet than, rather than customary I shaped, it would be a Y shaped bar.

While the South pole's area of maximum intensity is moving its location, two areas associated with the North pole's two positions of maximum intensity have stayed fixed during last 100 years, but the balance of intensities of the maximum field has changed; and the apparent location of North magnetic pole is between two.

National Geophysical Data Center for the Earth's geomagnetic field has selection of magnetic field maps, with approximate strength, covering most of the globe (70^0N to 70^0S) for period from 1900 to 2005.

Year	North-total Hudson Bay	North-z Hudson Bay	North-total Siberia	North-z Siberia	South total	South-z
1900	64000	63000	61000	60000	69000	69000
2005	59000	59000	61000	60000	67000	66000

Approximate intensity for the total field and its vertical (z) component in nanoTesla



Only vertical z component (one out of 3) of the magnetic field will be considered, as it can be more accurately defined. There are no data for a longer term gravitational anomaly or uplift changes for the Hudson Bay area. What is available are relatively accurate magnetic data. It is assumed that changes in the convection of the underlying mantle is reflected in the magnetic variations of the larger area, and it may be in some way related to the gravitational and uplift changes over longer period of time.

Magnetic intensity for period of 105 years in Hudson Bay area (60°N 90°W) has dropped from 63 to 58 microTesla or nearly 8%. From maps of gravitational anomaly and surface geo-uplift for North East Canada, it can be seen that the extremes are within the Hudson Bay itself. Magnetic variation could be due to number of factors, but for a relatively small (in terms of total Earth surface) localised area, could be mainly due to iron content and its temperature. If location of the maximum magnetic intensity is accurately mapped than coupling between geomagnetic field and the Hudson Bay circulation was greater in 1900 than 1950 or 1995.

Electromagnetic effects of ocean currents

The oceans play a special role in electromagnetic induction due to their relatively high conductivity and the dynamo effect of ocean currents. Sea water is a very good conductor with typical conductivity between 2.5 to 6.0 S/m (Siemens =1/Ω per meter}; carriers of charge in the oceans are the hydrated ions of the dissolved salts. Electrical currents are induced in the oceans by two different effects: Induction by time varying external fields and induction by motion of the sea water through the Earth's magnetic field.

Motional induction: When the ions are carried by ocean flow through the Earth's magnetic field, they are deflected by the electromagnetic Lorentz force, positive and negative ions are deflected into the opposite direction. This separation of charges sets up large-scale electric fields. Depending on the conductivity structure of the ocean these fields drive electric currents, which in turn generate secondary magnetic fields.

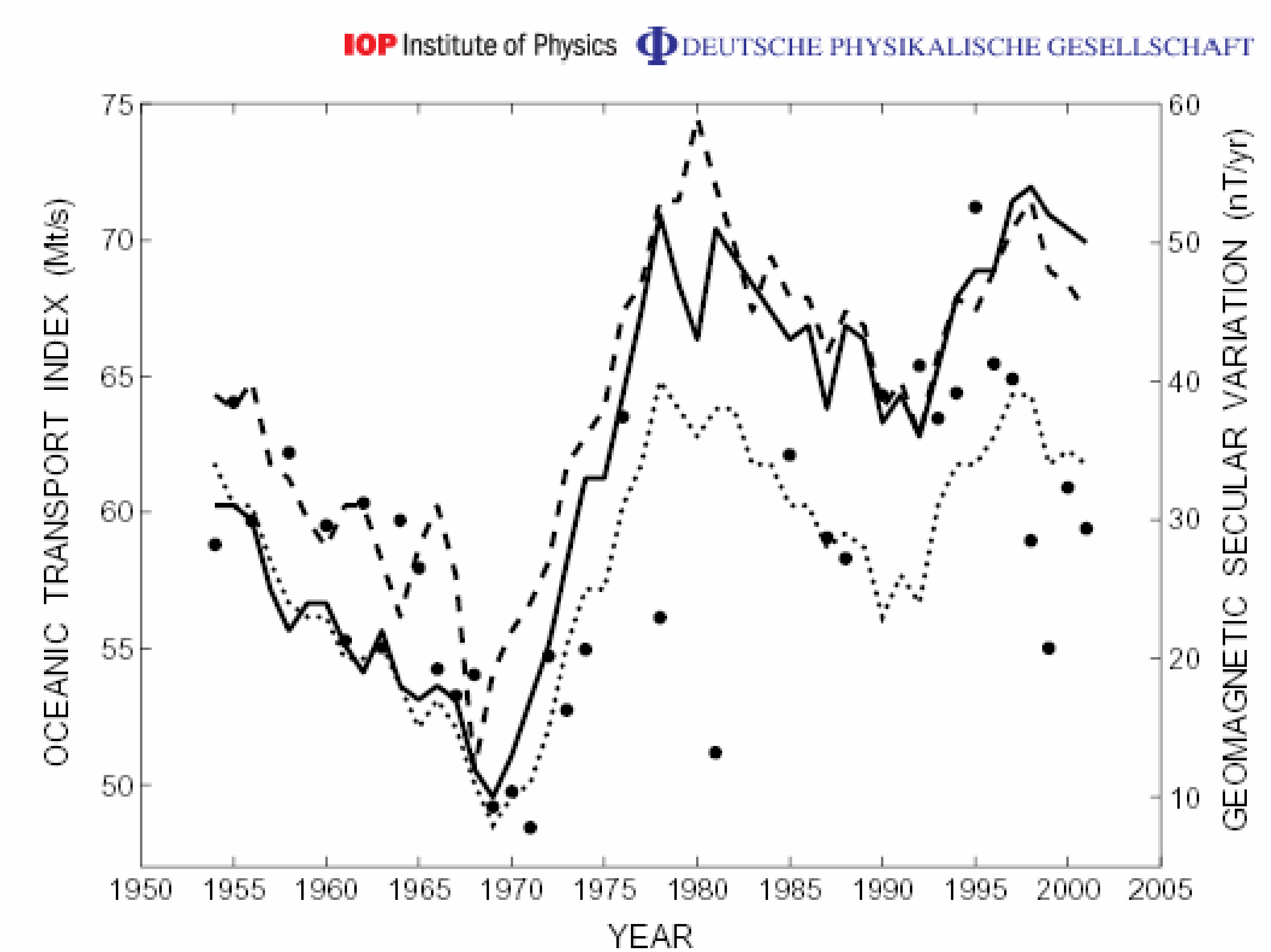
Induction by external magnetic fields: External magnetic fields, generated in the ionosphere and the magnetosphere vary strongly in time, exhibiting regular daily variations and occasional strong magnetic storms caused by coronal mass ejections from the sun. These time varying magnetic fields induce electric fields and currents in the oceans, generating secondary induced magnetic fields.

While daily variations during solar quiet conditions generate significant induction in the oceans, a much stronger effect is caused by magnetic storms. Strong magnetic storms generate ocean induced magnetic fields reaching magnitudes of more than 100 nT.

Both types of ocean current induction create counter emf (electromotive force), affecting ocean currents flows, particularly effective in the areas of strong geomagnetic field such as the Hudson Bay area.

Isolating the oceanic magnetic induction signal from those in the ionosphere or the Earth's core presents a problem, but it can be resolved. Variations in ocean circulation or conductivity are slow compared to the rapid magnetic storms, ionosphere and most other variations due to external sources. It is assumed that the mantle prevents all but the lowest frequencies (of the Earth's internal magnetic variations) from reaching the Earth's surface. It can be assumed that magnetic fields due to the Earth's core appears as relatively smooth, slowly-varying fields with periods of decadal scale and longer. Hence, it is probable that fluctuations in the ocean-induced magnetic fields would be found somewhere between two, very slow Earth's core fluctuations and the rapid ones due to the external sources.

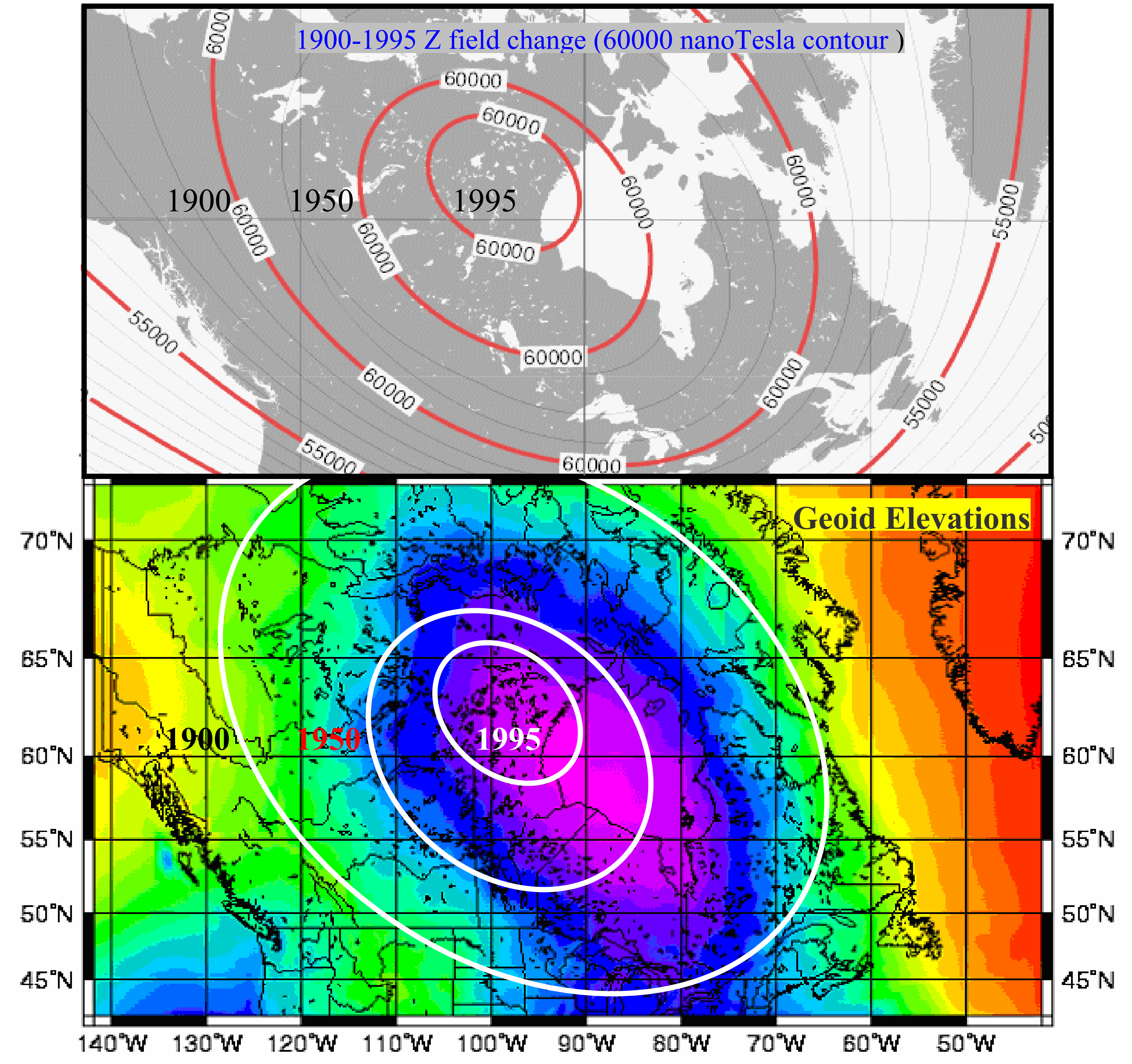
Comparison of oceanographic and geomagnetic data shows that the trend in secular variation is closely correlated with the trend in the ocean-flow intensity.



The relationship of the oceanic transport index of the North Atlantic gyre circulation and geomagnetic index variation

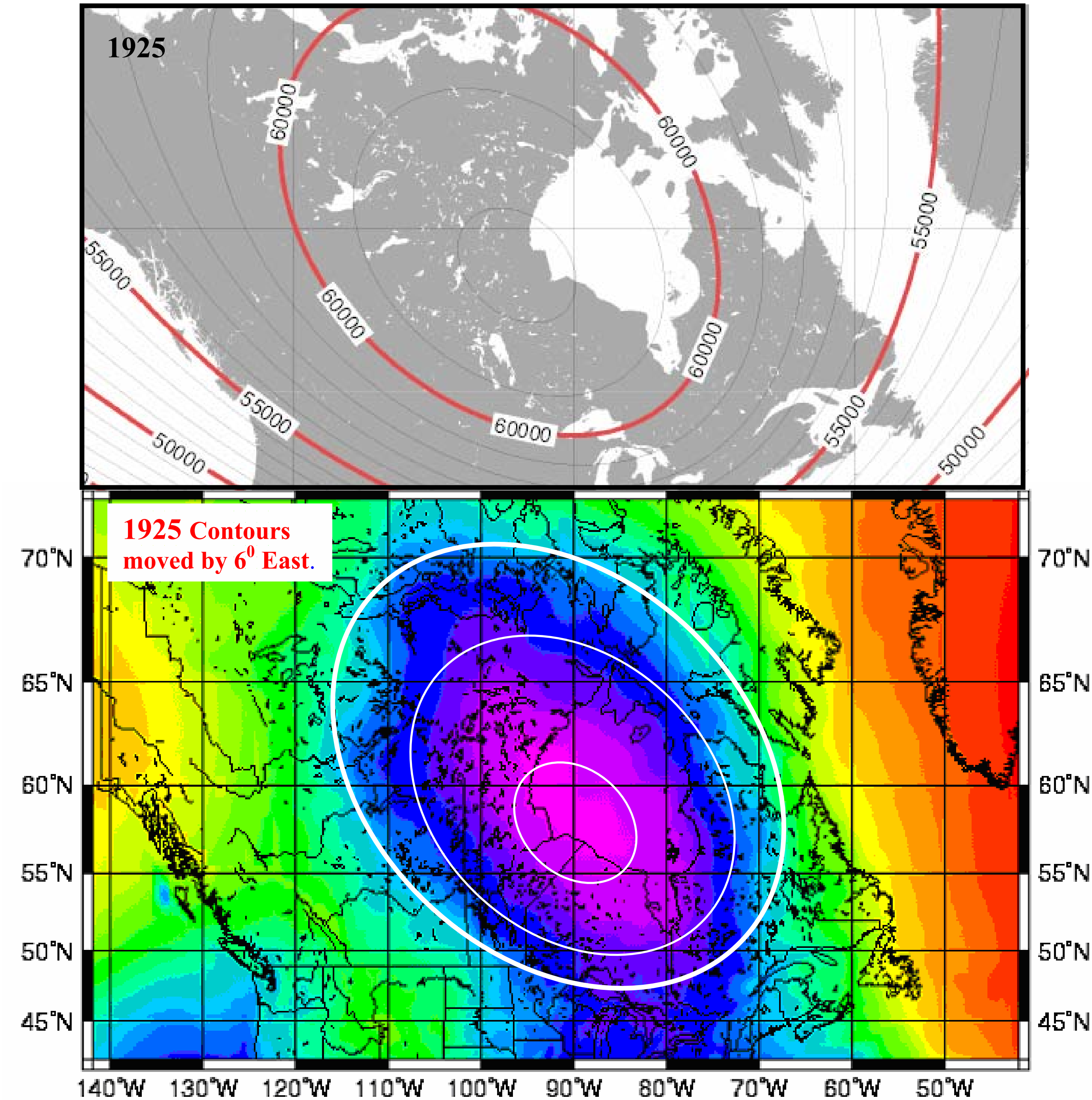
Selection of geomagnetic maps covering period from 1900 to 2005, at time interval of 5 years available from NOAA, makes it possible to track changes in the vertical z component of the geomagnetic field for any area of interest.

Magnetic map reproduced here shows 60000 nanoTesla (and above) contour for Z component of the magnetic field for years 1900, 1950 and 1995 (by 2000 magnetic intensity has fallen below 60000 nanoTesla).
The magnetic contour lines are superimposed on the (lower) the Geoid elevations map.
Magnetic intensities contours are not actually measured, but calculated by triangulation method using data from measurements by geomagnetic stations. Magnetic field intensity varies continuously, and is considerably affected by solar activity and this has to be eliminated from actual calculations.



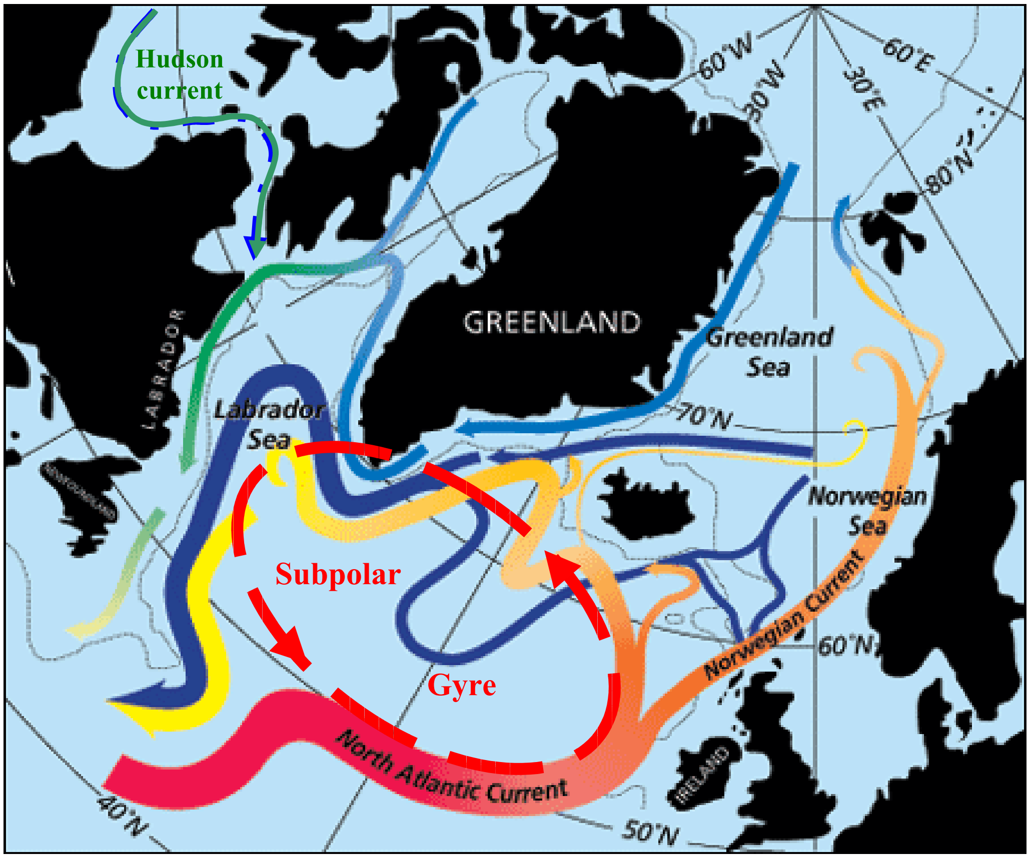
It appears to be an odd coincidence that the maximum strength of one of two prongs of the magnetic North pole should be located so close to the centre of Geoid depression, and remained more or less fixed to same location during whole of 20th century., despite weakening intensity and the 'apparent' moving of the magnetic North pole a thousand or more miles.

The coincidence is even more striking if a single magnetic configuration is considered. This illustration shows magnetic field contours for year 1925



Moving magnetic contours by 6^0 East may appear to be unjustified. However, it should be borne in mind that the Geoid elevations are obtained by satellite measurements, and can be considered to be very accurate while the contours of magnetic intensities have idealised form, are not actually measured, but calculated by triangulation method using data obtained by geomagnetic stations, suggesting that the location may not be totally accurate.

Hudson Bay Area magnetic and the North Atlantic temperature anomaly



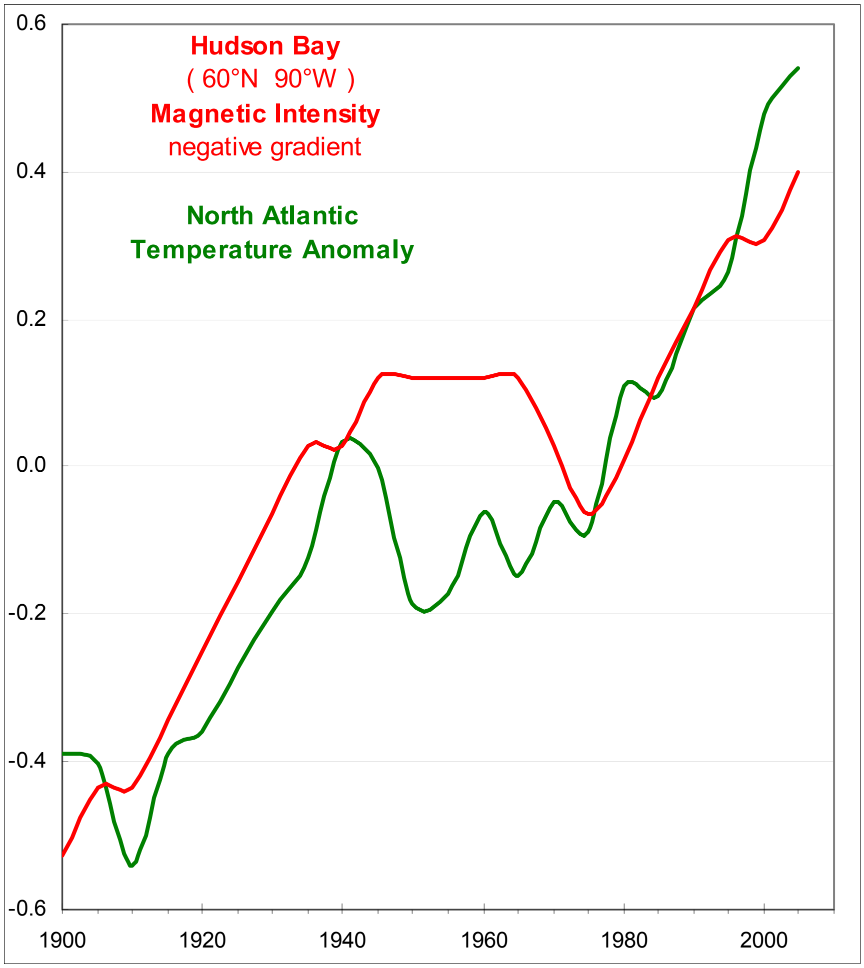
Changes in the intensity of water outflow from the Hudson Bay into the Hudson Strait have an important effect on the Labrador Sea's current formations and the Subpolar gyre's circulation.

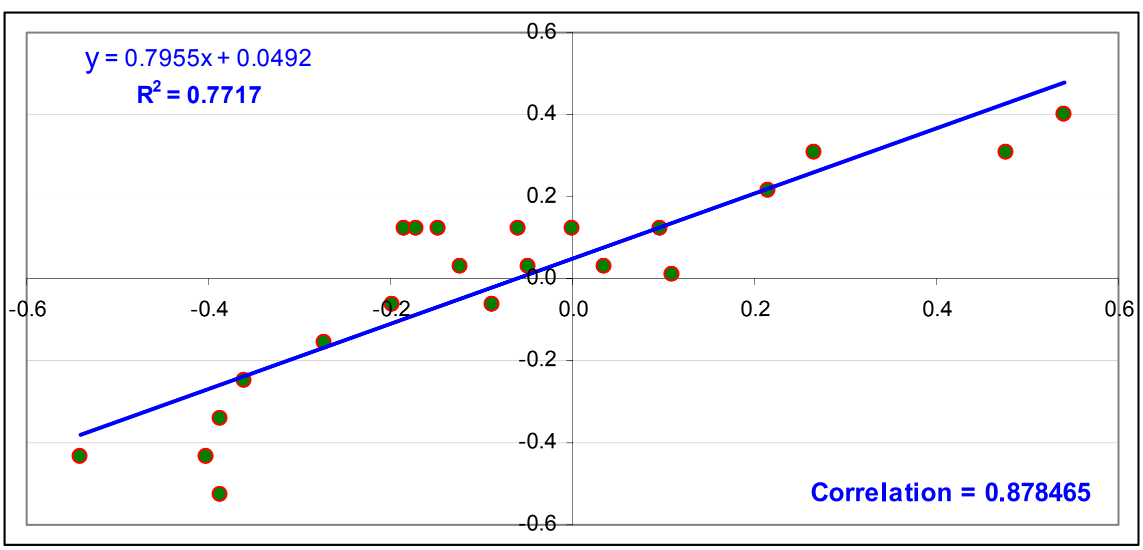
Three important factors are:
- Changes in the gravity intensity; tendency of objects to move from lower to higher gravity area.
- Changes in the ground uplift; effect on the currents flow.
- Changes in the geomagnetic strength, affecting oceanic transport out of the Hudson Bay and Strait.

The warm water current branching of the North Atlantic Current and combination of the Arctic cold currents (the Hudson Strait current as the major variable) create Labrador Sea currents; this tightly governs the strength of the Subpolar gyre's circulation, which is the engine of the heat transport across the North Atlantic Ocean.

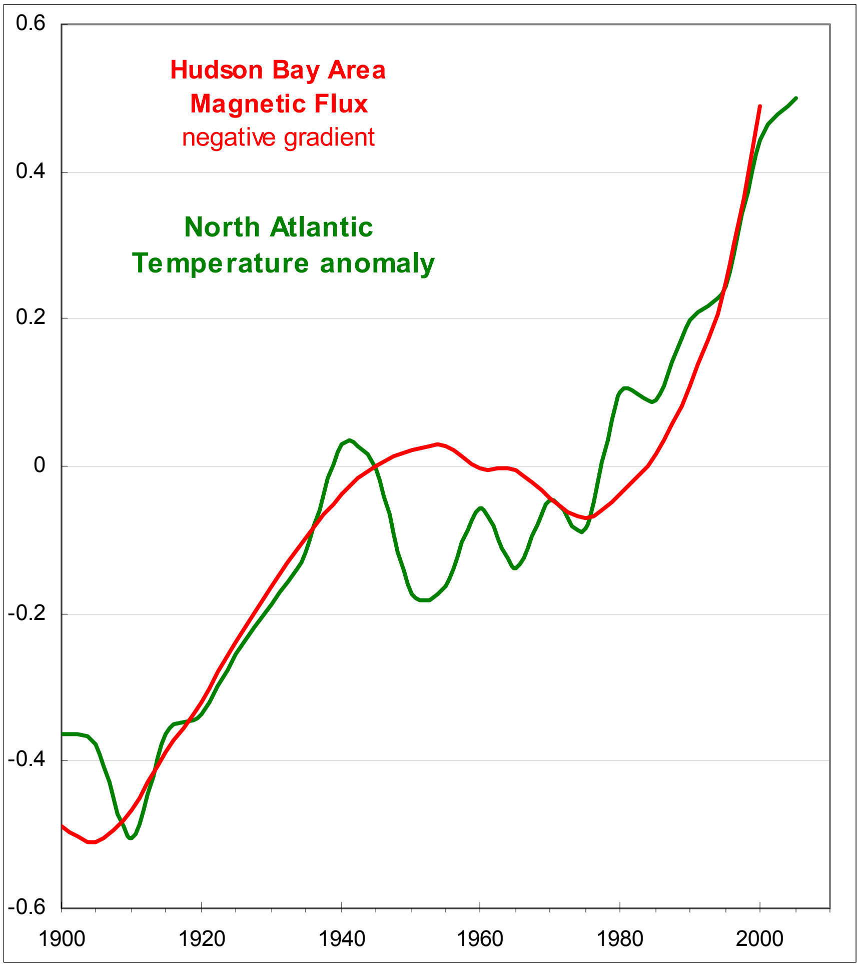
No accurate data for either the ground uplift of the Geoid elevations were available for purpose of this research. However, geomagnetic data variations for the area can be extracted from geomagnetic maps of the area.
Comparing geomagnetic data for the Hudson Bay area and the North Atlantic temperature variations during the last 100 years gives a significant correlation.
Number of researchers have noted a possible correlation between the solar activity (including geomagnetic storms, length of solar cycle etc.) and the temperatures variations, but the link appears to be questionable at best.

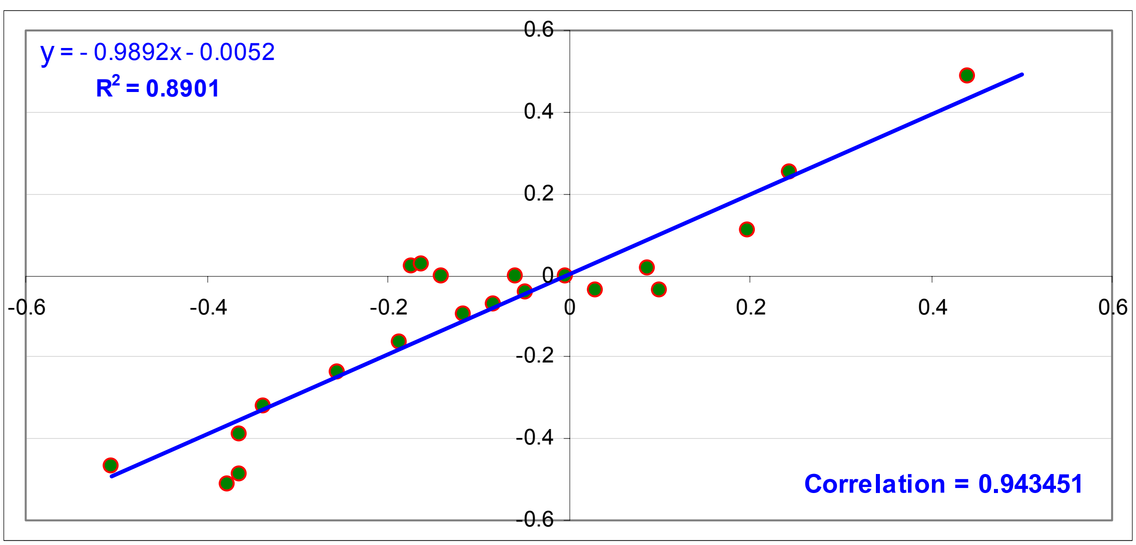
Geomagnetic variations for the vertical component of the magnetic intensity at the central area of Hudson Bay (latitude 60^0 North, longitude 90^0 West) is extracted from the geomagnetic maps of the area. Values of the vertical z component of magnetic intensity data are normalised to the North Atlantic temperature anomaly, showing a possible relationship and significant correlation between two.





If variations in the North Atlantic temperature are correlated to magnetic field, than the vertical magnetic flux for the area may give a more meaningful correlation. The flux is calculated as proportional to the total area within the 60000 nanoTesla magnetic intensity contour. Normalised values of the magnetic flux data show possibility of even stronger correlation.





References and Acknowledgments

(to follow)