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## 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

The 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.



Cold waters of the Beaufort Gyre exit into the North Atlantic Ocean through three gateways (Fram, Davis, and Hudson Straits). layers, which lie atop the warmer waters and act as a barrier preventing them from melting sea ice.

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.

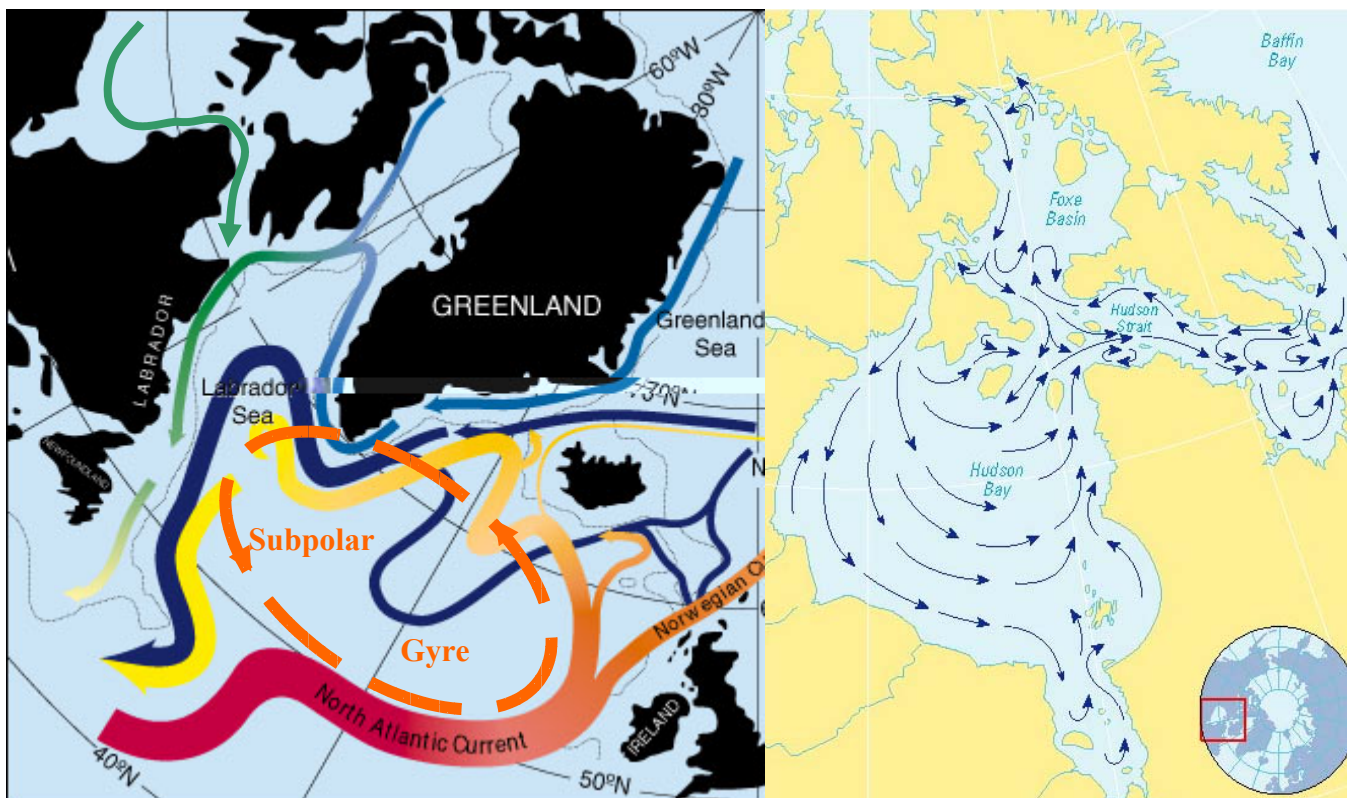
These two currents tightly governs the strength of the North Atlantic currents and via it global ocean circulation and the associated heat transport across the North Atlantic Ocean.

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 contribution of two major flows through Fram, Davis Straits, and a minor Hudson Straits current. They form part of a current, known as the sub polar gyre, which has weakened in the past has continued to do. Whether the trend is part of a natural cycle or a result of other factors it is unknown to 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 (Fram and Davis) can be, on medium time scale measured in decades, considered constant, while Hudson Strait currents are subject to continuous change on annual as well as on multi-decadal scale.

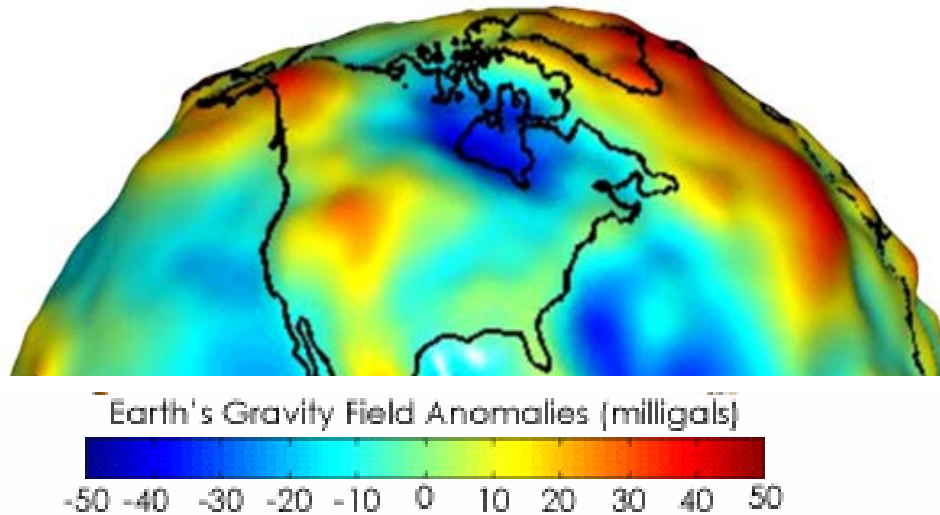


Hudson Straits circulation has complex water flows and is greatly affected by mainly anticlockwise circulation within Hudson Bay itself. Hudson Bay tributaries, major source of the fresh water inflow, via Hudson Straits, into North Labrador Sea. H.b fresh water supply

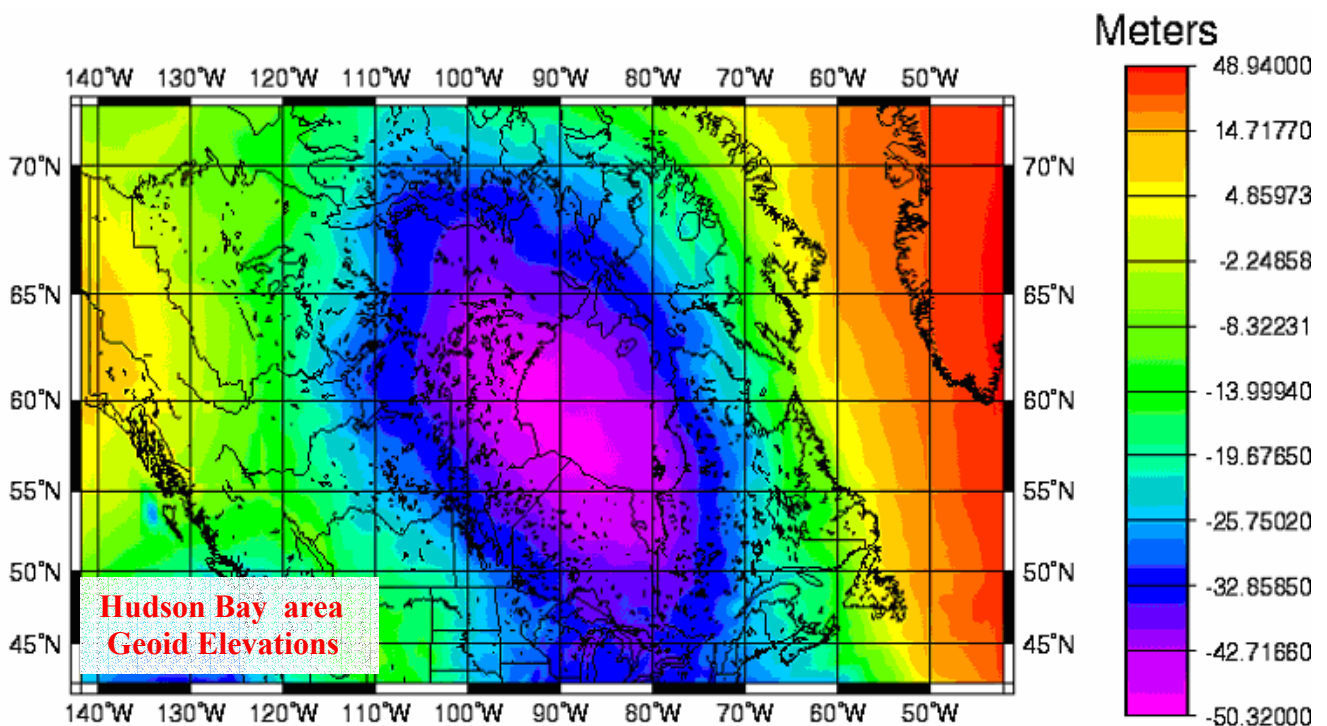
This study will concentrate on causes and consequences of possible changes in the currents intensities within Hudson Bay and Hudson Strait which in turn affect Subpolar gyre circulation.

## Gravity anomaly and post-glacial uplift

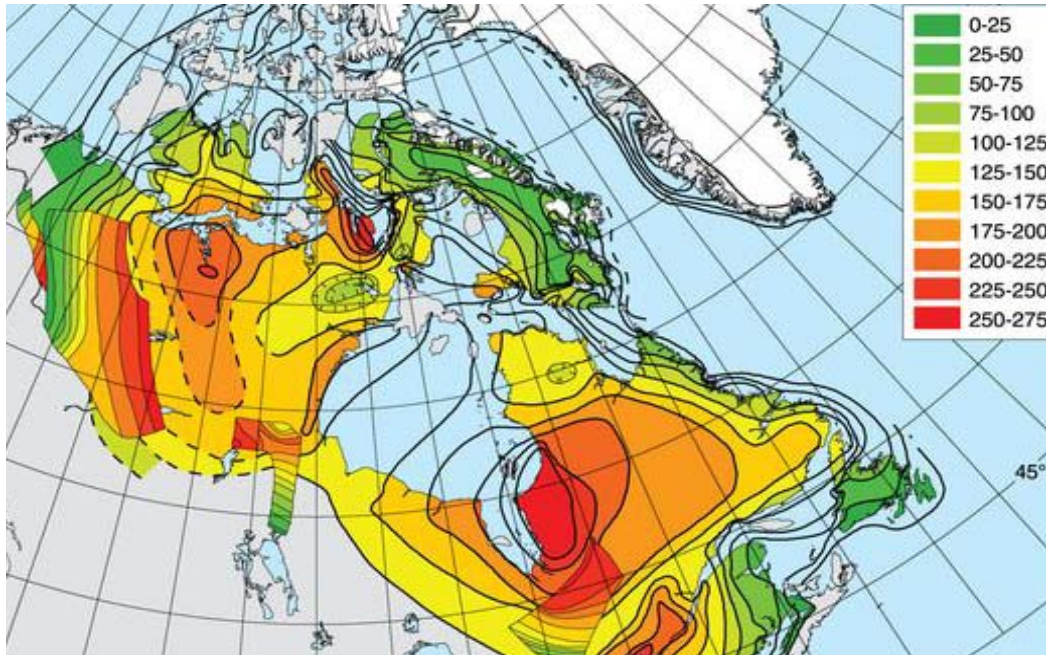
Gravity over planet's surface changes on many different time scales, from a matter of weeks to centuries. But major changes are due the movement of plates below Earth's crust. Differences in gravity can be mapped by tracking the movement of two orbiting satellites, As the Earth's gravitational pull increases 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:



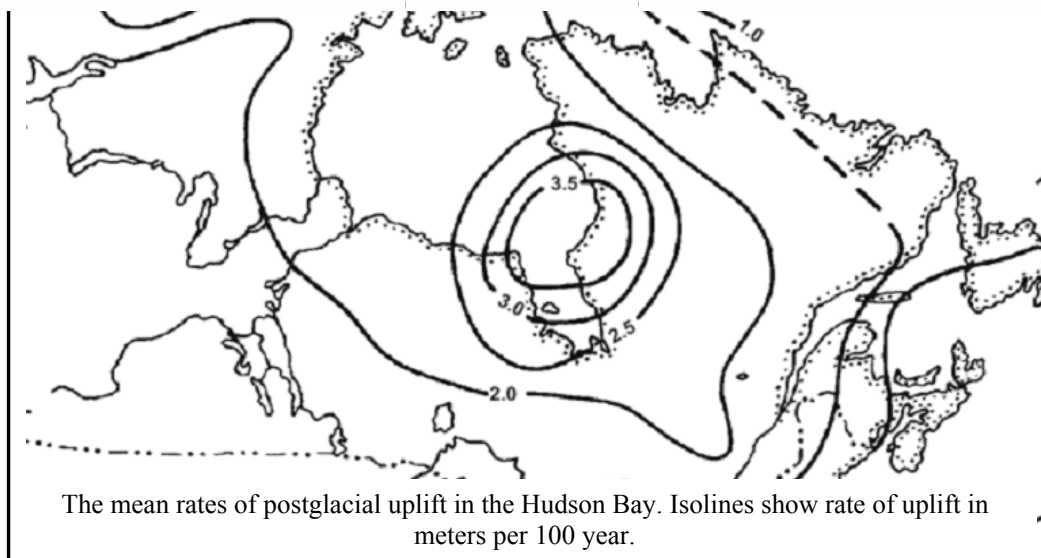
Gravity anomaly is the difference between the observed gravity and its theoretical value, which is calculated at the surface of a global spheroid. Miligal is a unit of acceleration commonly used in geodetic measurements, equal to  $10^{-3}$  Galileo, or  $10^{-5}$  meter per second square ( $10^{-5}$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



Some 25,000 years ago, Hudson Bay 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 surface of Earth down. The vast majority of the ice eventually melted at the end 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.



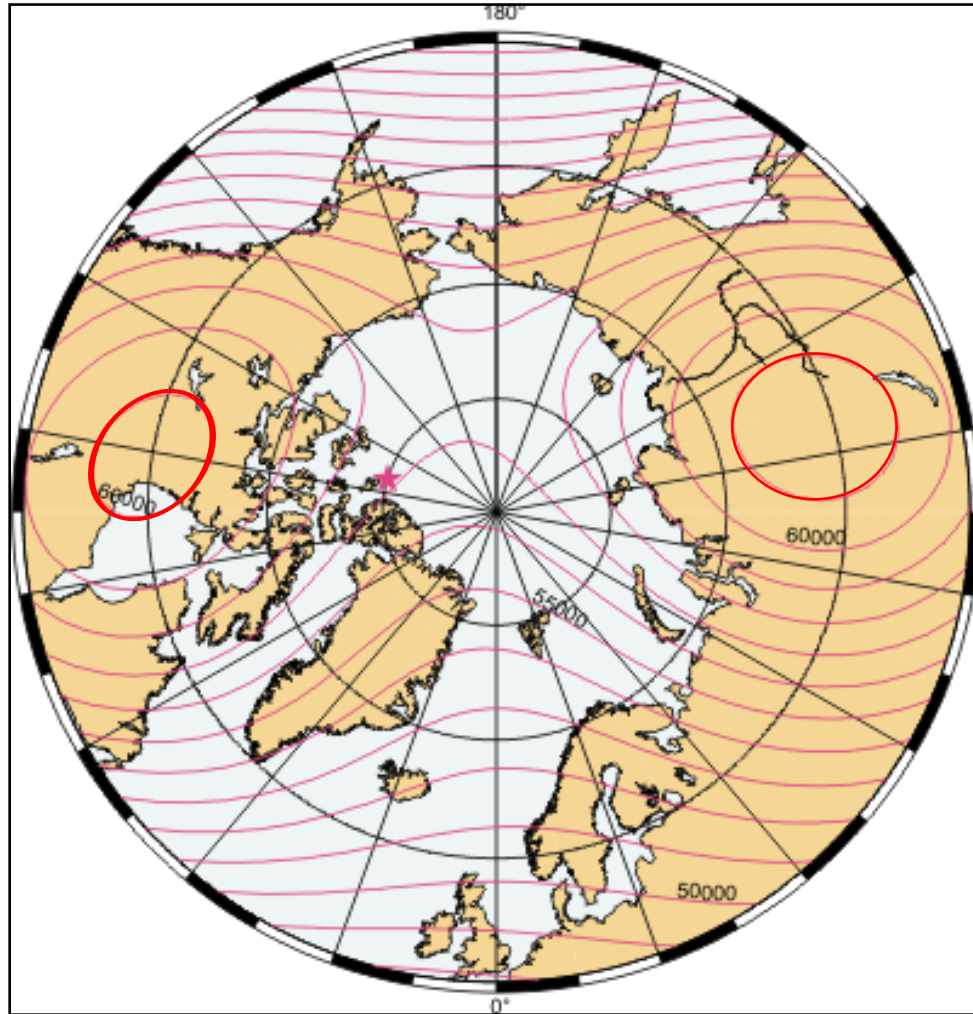
Deglacial marine limit surfaces. The marine-limit isolines are at 25-m intervals



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.

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

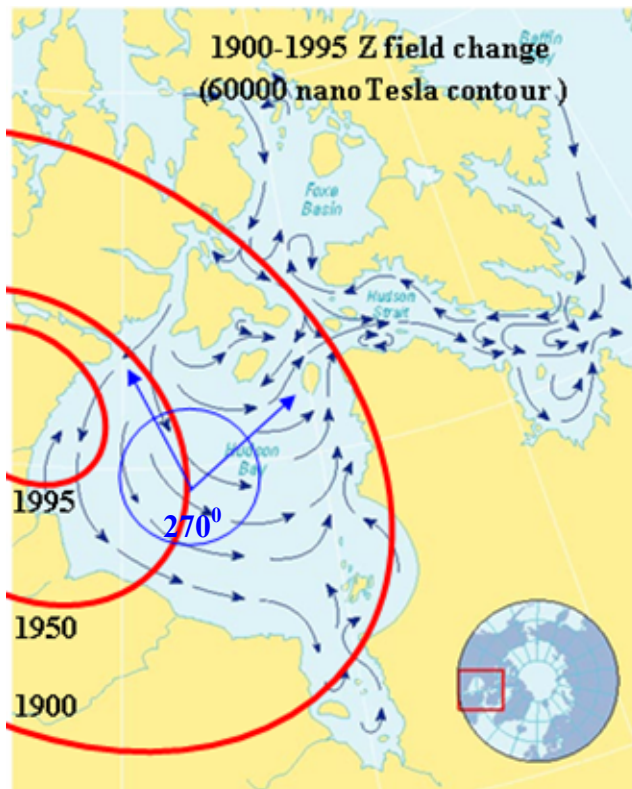
If Earth magnetic field is modelled by an imaginary bar magnet than, rather than customary I it would be a Y shaped bar.

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, but the balance of intensities of the field has changed; apparent location is calculated as an overall mean.

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°N to 70°S) for period from 1900 to 2005.

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

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



coupling between geomagnetic field and the Hudson Bay circulation was greater in 1900 than 1950 or 1995.

### Ocean currents electromagnetic effects

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 S/m (Siemens =  $1/\Omega$  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.

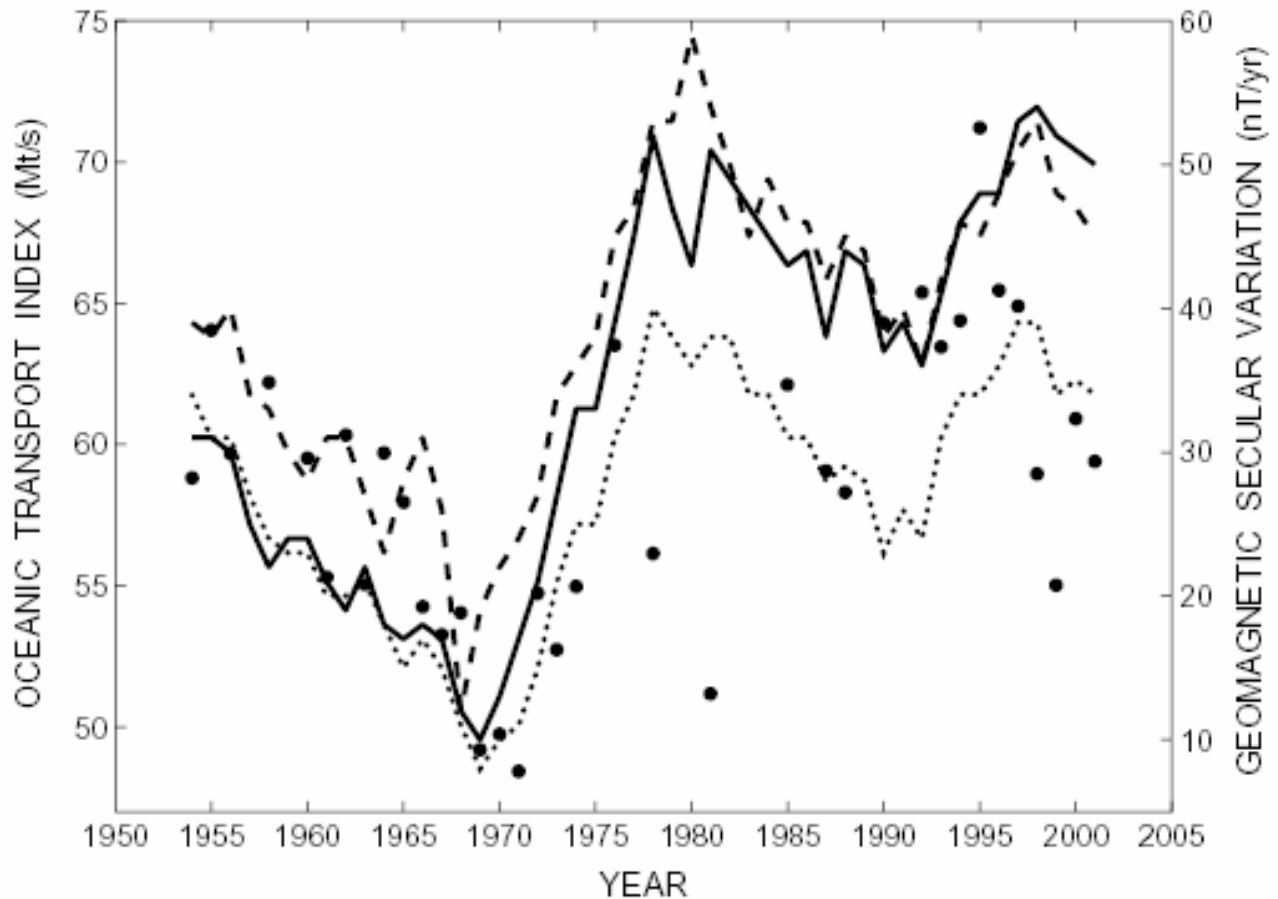
**Motional induction:** When the ions are carried by ocean flow through the Earth's magnetic field, they are deflected by the electromagnetic Lorentz force, positive and negative ions are deflected into the opposite direction. This separation of charge sets up large-scale electric fields. Depending on the conductivity structure of the ocean and solid Earth, 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.

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

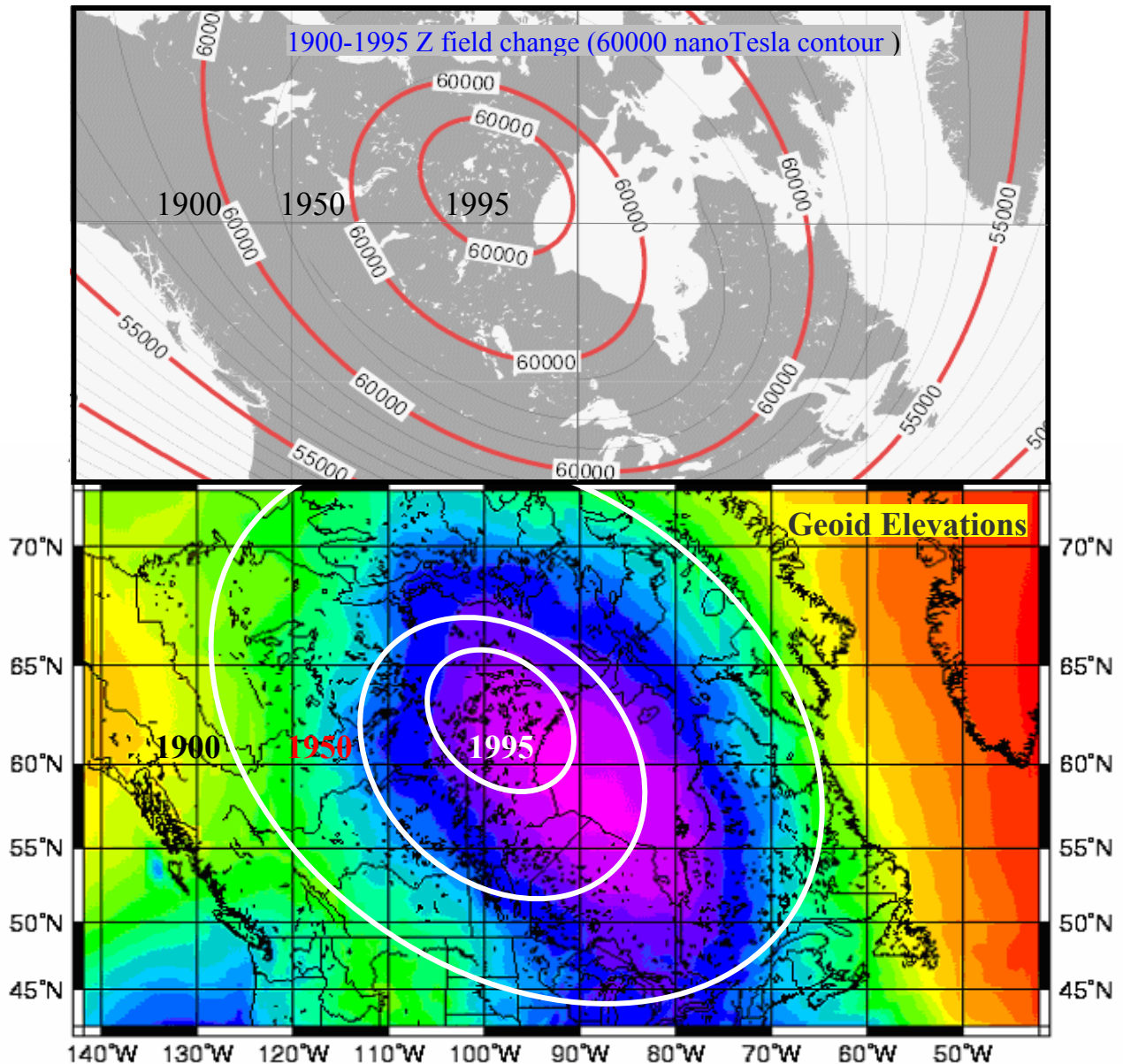
It is conceivable that the geomagnetic record from land and satellite observatories has captured oceanic signals. Another task before ocean and geomagnetic records can be linked, however, is to isolate the oceanic signal from the records which are known to be swarmed with magnetic signals from many other sources. How can we know that measured magnetic variations are due to variations in the ocean induction and not due to sources in the ionosphere or earth's core? This is a difficult problem, but there may be some ways to resolve it. Variations in ocean circulation or conductivity are rather slow compared to the rapid magnetic storms and most other variations due to external sources. Also the external effects at the earth's surface tend to have large spatial scales which allows removal using techniques such as 'remote referencing' as done by Lilley et al. (1993). With regard to sources in the earth's core, the geometric and electromagnetic filtering by the mantle are thought to prevent all but the lowest frequencies from reaching the earth's surface. Hence, it is conceivable that at the earth's surface, magnetic fields due to the earth's core can only appear as relatively smooth, slowly-varying fields with periods of decadal scale and longer. Hence, there is probably a fortuitous 'spectral window' through which we can view interannual variations in the ocean-induced fields. It is also important that the accuracy in measuring the time rate of change of the magnetic field on these time scales is greater than the accuracy of the field values (at least at the land observatories). This is because when differencing the magnetic series, errors in the baseline drift are reduced. Hence, it is probable that fluctuations in the ocean-induced magnetic fields would be easier to detect than the steady-state fields.



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).

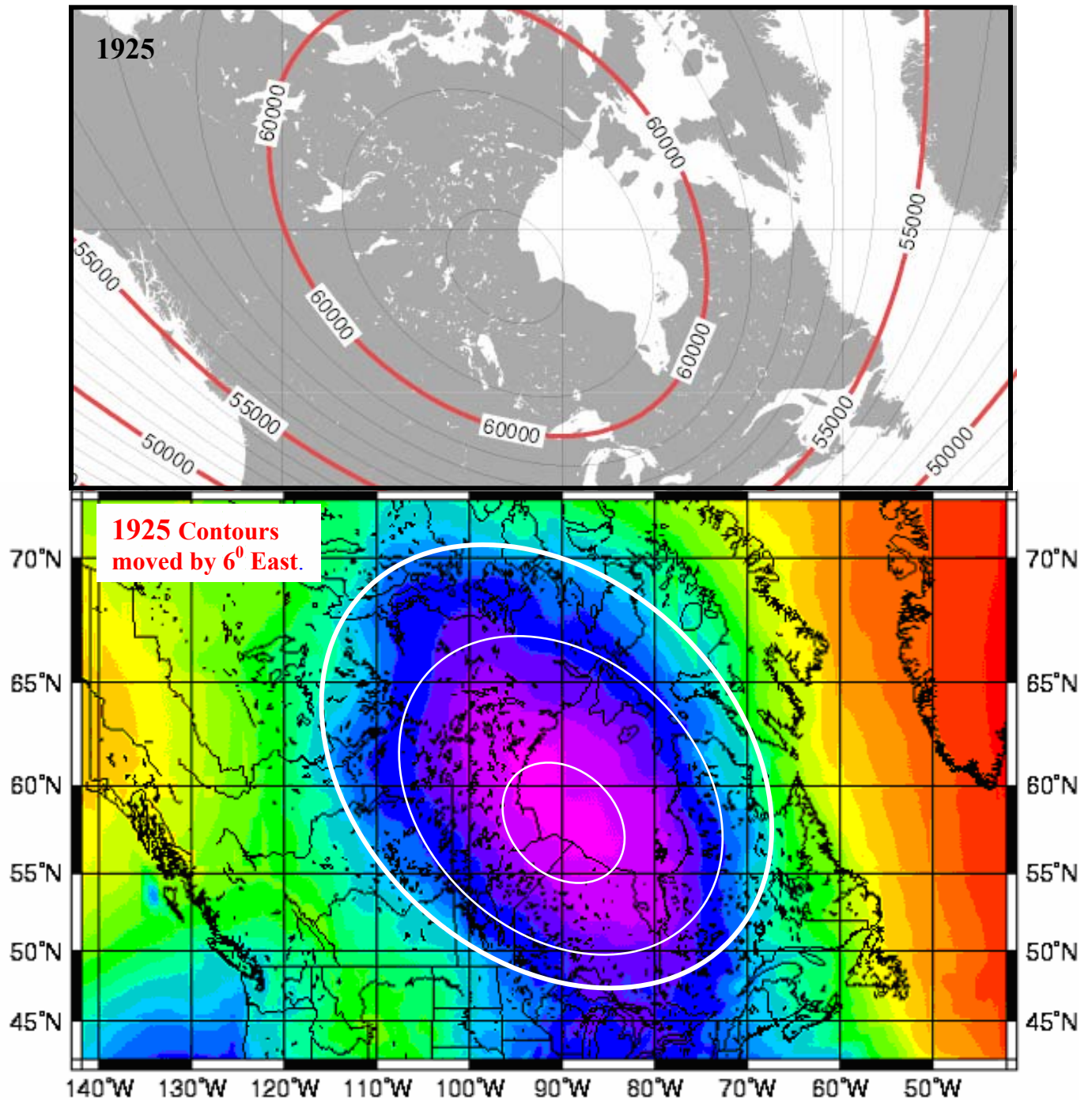
The magnetic contour lines are superimposed on the (lower) the Geoid elevations map.

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.



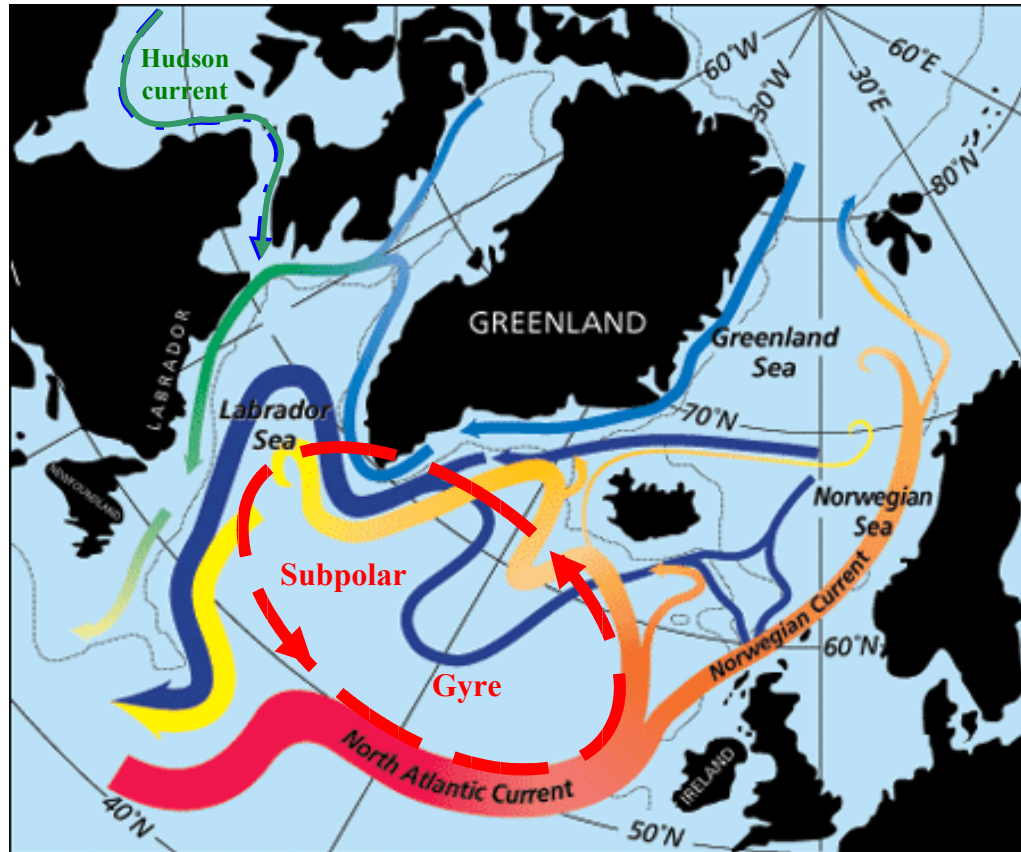
It appears to be an odd coincidence that the maximum strength of one of two prongs of the Magnetic North should be located so close to the centre of Geoid depression, and remained more or less fixed to same location, despite weakening intensity and the 'apparent' moving of the magnetic North pole during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

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° 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 are not actually measured, but calculated by triangulation method using data from data obtained by geomagnetic stations and the location may not be accurate and have idealised form.

## 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 index affecting oceanic transport index of the Hudson Bay circulation.

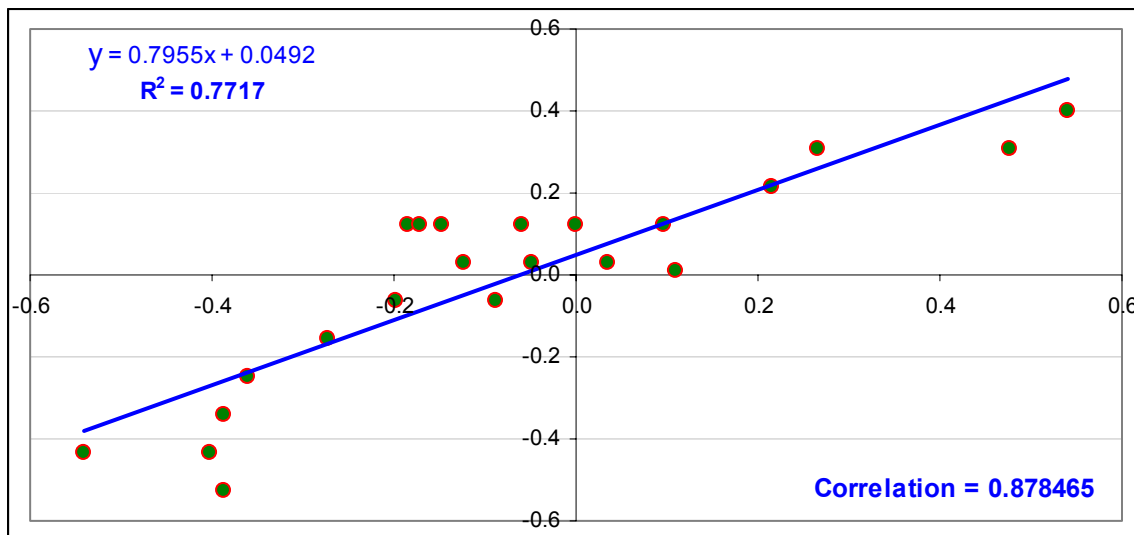
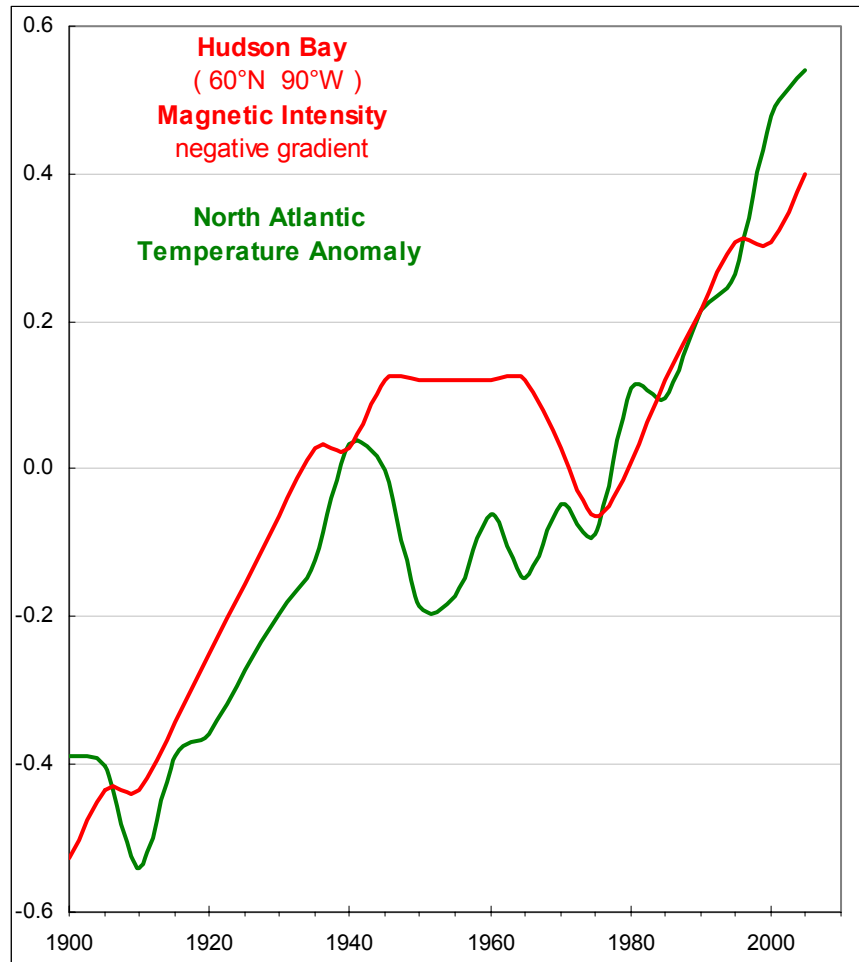
The warm water current branching of the North Atlantic Current and combination of the Arctic cold currents (the Hudson Strait current as major variable) create Labrador Sea currents; this tightly governs the strength of the Subpolar gyre's circulation, which is the engine of the heat transport across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

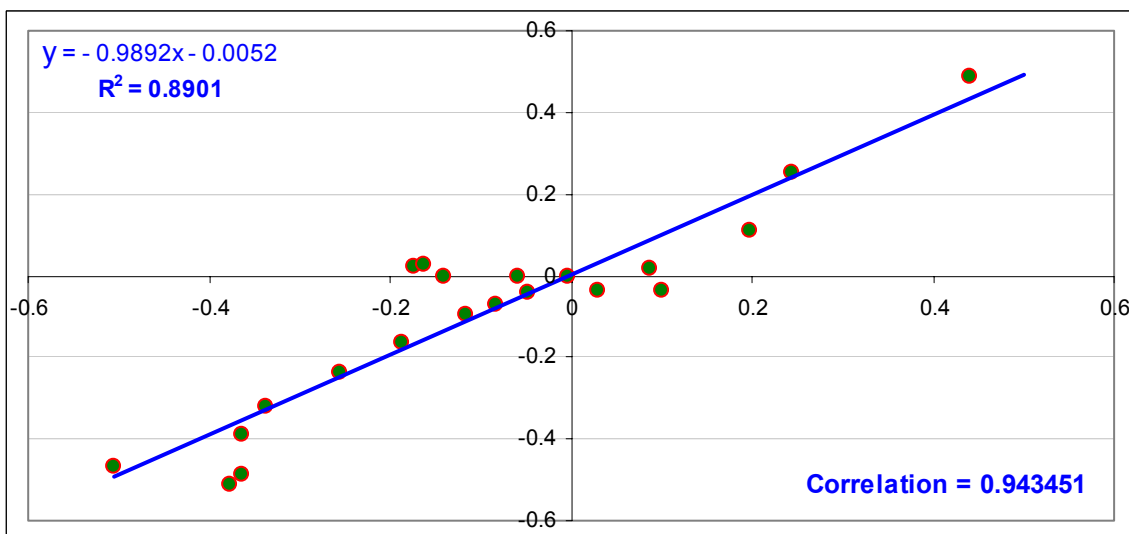
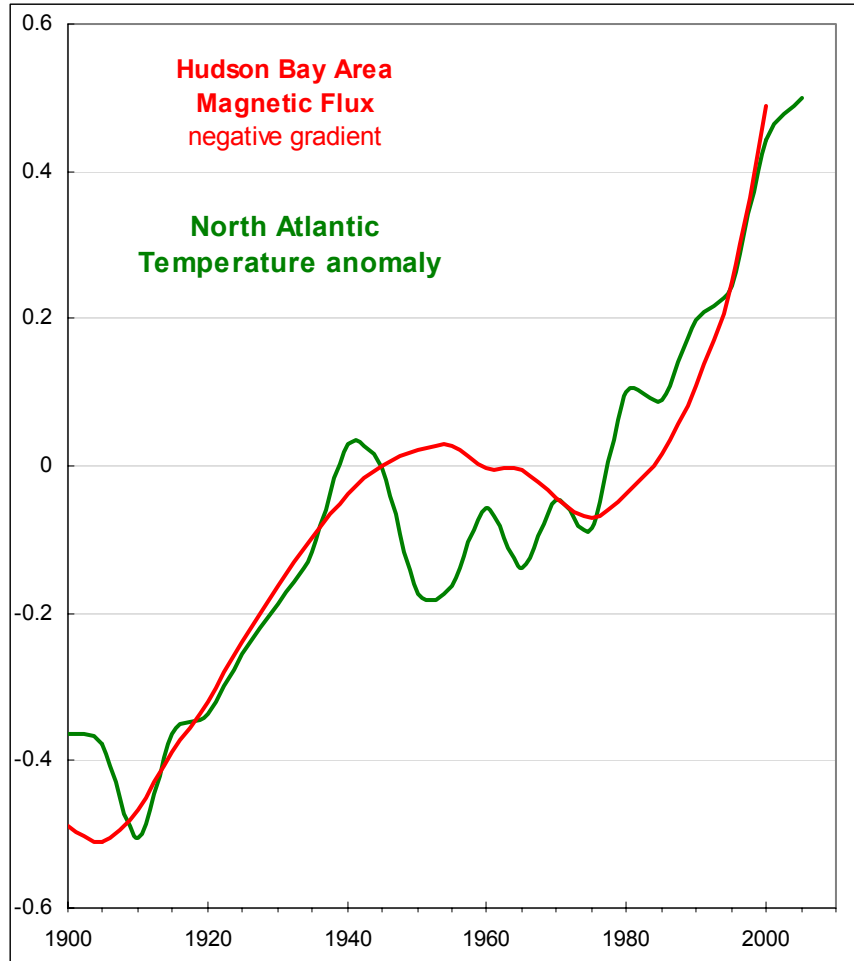
Comparing geomagnetic data for Hudson Bay area and the North Atlantic temperature variations during last 100 years gives a significant correlation.

Number of researchers has noted a possible correlation between the solar activity (including geomagnetic storms) and the temperatures variations. If there is an underlining link between two, than the effect can be expected to be strongest at the magnetic poles.

Geomagnetic variations for the vertical component of the magnetic intensity at the central area of Hudson Bay (latitude 60° North, longitude 90° West) is extracted from geomagnetic maps of the area. Normalised values of the Hudson Bay vertical magnetic intensity data to the North Atlantic temperature anomaly show a possible relationship between two.



If variations in the North Atlantic temperature are correlated to magnetic field, then the vertical magnetic flux in the area may give a more meaningful correlation. The flux is calculated as proportional to the total area within the 60000 nanoTesla contour. Normalised values of the Hudson Bay vertical magnetic flux data to the North Atlantic temperature anomaly show even closer possible relationship between two.



## **References and Acknowledgments**

( to follow)