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Greenhouse Induced Changes in the North

Atlantic - Implications for Fisheries

by

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Abstract

The paper considers climatic models, their accuracy, errors and assumptions, the CO_2-problem and changes in the ocean as derived from these models. Possible consequences for fishery in the North Atlantic Ocean are discussed.

Introduction

Climatic changes are considered to have serious impacts on mankind within the near future. Meetings and conferences, held in recent months, point at various scenarios which might happen in the next 50 or 100 years. It might therefore be useful to consider possible impacts of world climatic changes, for example impacts on the ocean and the fishery.

Climatic Models

Climatic models are, in the ideal case, mathematical descriptions of physical, chemical and biological processes in the entire climate system. Climatic models should therefore cover all components and their interrelations. In reality, we have today coupled atmosphere/ocean models which contain the general circulation of the atmosphere, and dynamic ocean circulation models (**MIKOLAJEWICZ et al., 1990**). At present there are no comparable biological models available. Only reaction scenarios can be made for these purposes.

Errors of Climatic Models

The basic equations of climatic models are equations of continuum physics which are valid for volume elements. These models may derive statistical *properties like temperature*, but no structures, like turbulence elements

(GRASSL, 1988). Are the equations averaged over larger volumes with structures, the hydrodynamic-thermodynamic system of equations is no longer closed, since the averaged equations contain unknown correlation products of fluctuating properties. The temporal integration over these partial differential equations, closed in such a manner, results in approximations. These approximations are the more drastic, the lesser a climatic model resolves spacially. Therefore already the enlargement of the computer improves the quality of the climatic model.

Climatic Models and Greenhouse-Gas Increase

The development of greenhouse-gas concentration cannot be forecasted. It is dependent of the development of world economics, of anthropogenic climatic relevant activities, as well as of natural variabilities. For given changes of greenhouse-gases, climatic models give evidence that:

- a latitude dependant warming of global temperature is to be expected; relatively moderate warming in the tropic, strong warming in higher (northern) latitudes.

- a change of seasonality is to be expected; temperature increase is very large in the winter season and may reach in high latitudes more than +10°C.

The Ocean as CO_2-sink

Based on a dynamic global ocean circulation model **MAIER-REIMER and HASSELMANN (1987)** discuss the flux relation of CO_2 at the ocean/atmosphere interface. Biological sources and sinks are not implicated in this model. In principle, the model gives a realistic distribution of CO_2 in the ocean surface layer. In biotic productive upwelling areas, however, the model indicates its weakness: The pCO_2 order of magnitude is underestimated by a factor of 1.5. This results from non-consideration of the so-called **biological pump** (see below). According to the model results, the crucial point for the effective CO_2-storing capacity of the ocean, is the time slope of anthropogen CO_2-emissions.

Reaction of the Ocean on Greenhouse Warming

Sea Level Rise

Statements on sea level rise differ from author to author. The sign is, however, undisputed **(GRASSL, 1988)**. Accordingly, the global sea level rise during the past 100 years amounted to 20±5cm. The increase continues, an acceleration could not be observed clearly. On a global scale a further increase of 20cm in the next 50 years is expected, for the North Atlantic Ocean the increase amounts to 35cm. Reasons for this increase are many-fold: melting of glaciers, expansion of the warming ocean water, global tectonic changes, especially through isostatic relief of the large ice shields about 15000 years ago. Whether the still existing large ice shields of Greenland and Antarctica contribute to the tectonic rise or not, is unknown. For a given portion of a coast, sea level rises might be even much larger.

For *model computations* concerning sea level rise, the Hamburg large-scale-geostrophic ocean general circulation model (OGCM) makes the following assumptions **(MIKOLAJEWICZ et al., 1990)**:

Mean global temperature changes according to a linear exponential function, and reaches 2.9°C after 50 years (Fig. 1). The model has a dynamic active sea surface. Changes in the displacement of the surface result from current divergence, thermal expansion and river run-off. A thermodynamic one-layer sea-ice model with advection is included. The model contains a realistic mean thermodynamic circulation. Surface temperature changes have a poleward increase of temperature gradient during the winter season due to ice-albedo feedback effects. Neglection of atmospheric feedback, anomalous wind stress and fresh water flux, as well as the assumption of time-independant distribution patterns of surface temperature is a large simplification in the model experiment. The authors stress, however, that their model is a "Zero-Order-Test" which represents the sensitivity of the oceanic circulation on a specified forcing. The model results yield, however, valuable insights into typical sea level changes which were not presented so far.

Based on the *thermal expansion* a global sea level rise of 19cm in 50 years is expected. This is primarily based on effects in the oceanic surface layer (0-100m). Sea level rise in Northwest Europe is estimated to 35cm, i.e. about twice the global value (Fig. 2).

Generally, the sea level rise changes regionally like the regional warming differences. It is much lesser in the Antarctic Ocean, e.g. in the Ross Sea, than on the gobal mean.

Changes in *Ocean Circulation*

The thermodynamic circulation of the North Atlantic Ocean seems to slow down according to model results. This means that the northward heat transport in the North Atlantic Ocean will be reduced.

MIKOLAJEWICZ et al. (1990) reveal significant changes in the oceanic circulation, caused by a global temperature increase as a result of CO_2-increase of the atmosphere. In regions of former deep water formation (e.g. Greenland Sea) sea surface temperature will increase little, or even decrease in comparison to the zonal mean (Fig. 3). The formation of North Atlantic Deep Water will decrease much more than the formation of Antarctic Bottom Water (AABW). The consequence is an effective cooling of the deep water layers of the North Atlantic Ocean. The cooling process is accompanied by a decrease of surface salinity in the North Atlantic and higher surface salinities in lower latitudes (Fig. 4).

The decrease in the global deep water production rates must have a strong implication on the atmospheric CO_2 content. At present, a considerable portion of the emitted CO_2 is transported to the depths of the world ocean via newly formed deep water. *If deep water transport and storage mechanisms are* reduced, the increase of atmospheric CO_2 will strengthen.

If we reduce the rate of increase in the use of fossile resources by 50%, we postpone the point of time until the CO_2 content in the atmosphere is doubled. The main CO_2-sink ocean gets more time to transport CO_2 to the abyssal, and the percentage of CO_2 remaining in the atmosphere (50% at present), is reduced (GRASSL, 1988).

Vertical Convection

The forecasted cooling process in the North Atlantic, accompanied by a decrease of surface salinty, will reduce vertical convection. The vertical density stratification will more and more be characterized by a light surface layer which rests on more saline water. This leads to higher stability coefficients in the oceanic surface layer. According to **MEYER (1968)** and **STEIN and BUCH (1985)** high stability coefficients in the oceanic surface layer off West Greenland might have negative influences on the development of cod larvae.

Increased Storm Activity

In the frontal zone of cooling polar air masses of the North Atlantic Ocean and the warmed air masses of subtropical origin, with an increased uptake of latent energy, strong temperature gradients will occur. The two energy niveaus will level out by deepening of low pressure systems during winter, which results in higher frequencies of hurricanes. Influences on the performance of fishery vessels are to be expected. To which degree storm induced variability in the oceanic surface layer influences the general stability of water masses in polar regions, cannot be estimated at present.

Plankton

Through the formation of particle aggregations the marine plankton forms micro zones in the ocean which have an essential influence on the chemistry of ocean and atmosphere. Additionally, these aggregations are fast vehicles for the vertical mass transport, especially carbon, and thus play a decisive role in the regulation of the CO_2 balance of ocean and atmosphere. The sinking of biotic particles from the oceanic surface layer (0-100m water depth) to the abyssal layers is an essential process for the mass balance of our planet: Planktonic algae grow in the upper euphotic zone and incorporate the dissolved carbon (CO_2). It was assumed that the greatermost part of algae is taken by the zooplankton, and the organic incorporated carbon is distributed to great depths by feacal pellets. It was observed recently that at times the algae themthelves sink in tremendous masses, and thus remove the incorporated carbon from the surface layer. Since ocean and atmosphere are in an equiliorium state, the carbon, as removed by the algae by fast sinking to greater depths, is refilled by CO_2 from the atmosphere. This process, the so-called **"biological pump"** is assumed to be the main mechanism for removing CO_2 from the atmosphere. The amount of carbon buried in this way since the beginning of the industrial epoch, must be considerable. It is, however, at present unknown.

The man-made total CO_2-emission (deforestisation, burning of fossile hydrocarbons) is provable in the atmosphere by only 50%. The remainder is probably taken by the ocean via the "biological pump". The ocean has a reservoir of CO_2 which is fifty times larger than that of the atmosphere. It can be assumed that small changes in the atmospheric CO_2-content, will cause tremendous variations in the atmospheric CO_2-content (**NÖTHIG et al., 1988**).

With the afore mentioned critical CO_2-equilibrium in mind, it seems rather questionable, whether a large-scale model experiment, as planned by the USA in polar regions, is the right way to tackle the CO_2

problem. Tons of iron powder shall fertilize the surface waters to produce giant plankton blooms. This anti-greenhouse wapon is a dangerous illusion. Instead of reducing the CO_2 emissions, man fumbles at our ill planet.

Fish Stocks and Climate Variation

Fish stocks and plankton are relevant indicator organisms of the oceanic ecosystem. Palaeontological as well as recent observations indicate that fish and plankton react on climatic variations **(ANON., 1990)**. Investigations in this field are rare. Early in 1990 an international group of experts has met in Bergen, Norway, to establish a five-year study on the relation between variability in North Atlantic cod stocks and climatic variations (ANON., 1990).

Three sources of information on cod and environment are available but not yet connected in a coordinated form:

- time-series on cod stock fluctuations
- biology, physiology and ecology of larval and adult cod
- global and regional models of the physical environment

Whereas this study on interrelations between the mentioned sources of information has to take into account the other members of the trophic web and their interaction - which is already a giant problem - it is highly questionable whether the third source of information, the models, are really available on these scales, and if, whether their results have a touch of reality.

Greenland: Climate Varation and Cod Stocks

From the waters off West Greenland time-series on environmental variaton and year-class strength of cod are available **(STEIN and MESSTORFF, 1990; STEIN and BUCH, 1990)**. The latter authors reveal that according to the selected time-window, the conditions in this area are influenced by positive or negative temperature trends in the ocean and the adjacing atmosphere. Although air temperature time-series of Nuuk indicate a minimal, linear warming trend for the entire time-series since 1876, it is dominated by negative temperature trends during the past 30 years , and especially during the last decade (fig. 5).

STEIN and WEGNER (1990) find a warming trend in the oceanic surface layer off West Greenland between 1984 and 1988. In the deep water layers (1100m to 1500m) of this region the warming trend is not clearly documented. Whereas the warming amounts to 0.1°C/year for the Cape Farewell region (South Greenland), recent observations made by **STEIN (1990)** reveal a negative temperature trend for the 1989 autumn season. This situation might point at the high variability of the ocean/atmosphere climatic system off West Greenland.

STEIN and MESSTORFF (1990) show that cod year-classes with relevance to the West Greenland cod stock, are linked to warming phases observed in the waters off West Greenland. One recent example are the 1984 and 1985 cod year-classes which essentially contributed to the stock after a period of catastrophic cooling by nearly 2°C below normal in the oceanic surface layer (0-200m).

Conclusions

The climatic scenarios as shown by the models, as well as trends observed in the world ocean and atmosphere (fig. 6) indicate changes in the hydrosphere and atmosphere. The cooling of surface water masses in the North Atlantic Ocean would imply catastrophic consequences for the fish stocks in this area, especially around Greenland. Observations from the early eighties show the complete failure of stock reproduction, presumably influenced by the environmental desaster caused by a lethal cooling of the surface layer by 2°C below normal (fig. 7). The cooling trends as forecasted by the models for the area off East Greenland would imply completely failure of recruitment due to changes in stability by cold, diluted surface water masses and increased outflow of polar water through Denmark Strait. As a consequence of reduced vertical convection during winter the euphotic layers will contain lesser nutrients, the food web cannot be built up. The increase of hurricaine activities will hamper the Greenland fishery, especially in winter months. Due to cooling of the surface waters in the northwest Atlantic current system sea ice formation will increase. This will result in hindrance by sea ice off East Greenland, but also off the West Greenland coast and in Labrador/Newfoundland waters.

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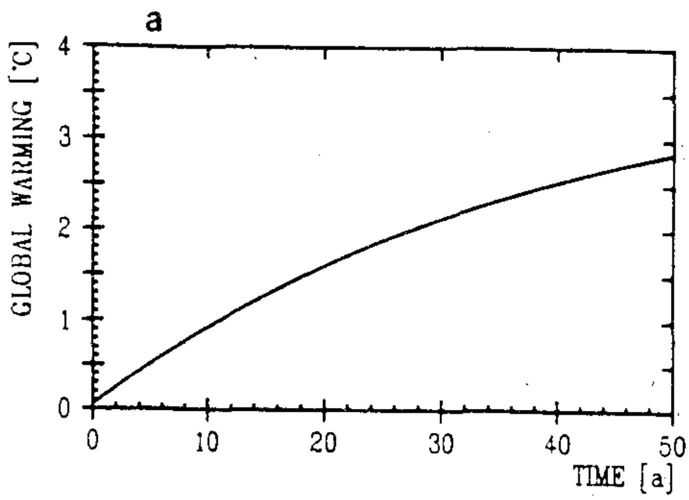

Fig. 1 Time evolution of annual mean globally averaged surface air temperature anomaly imposed on the OGCM (from: **MIKOLAJEWICZ et al. (1990)**)

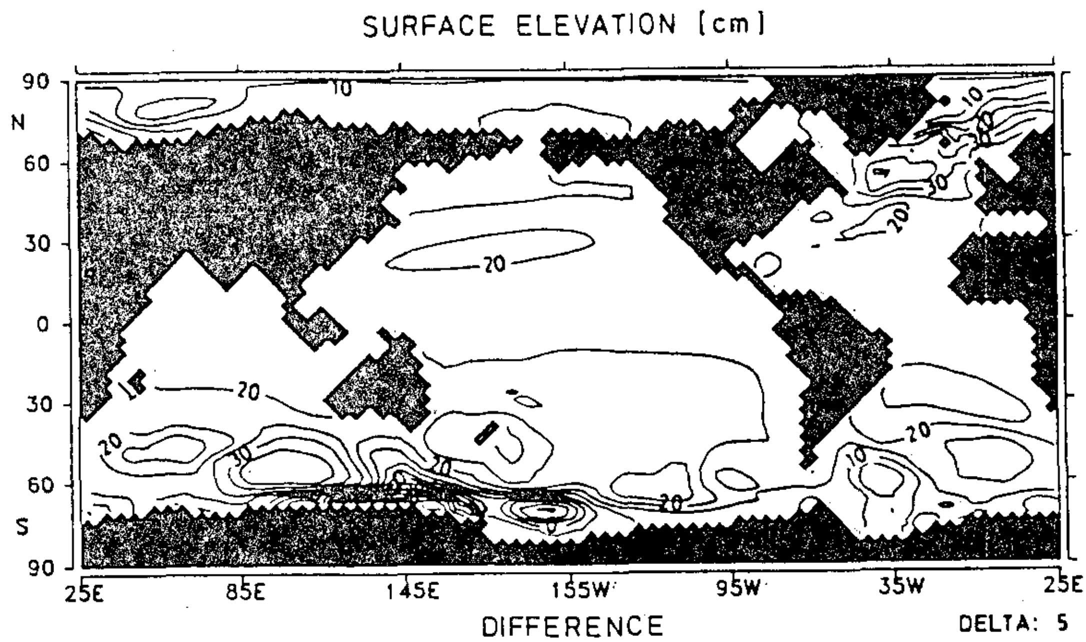

Fig. 2 Pattern of changes in sea surface elevation for year 50 relative to the control experiment. Note that changes in the Ross Sea are negative (from: **MIKOLAJEWICZ et al. (1990)**)

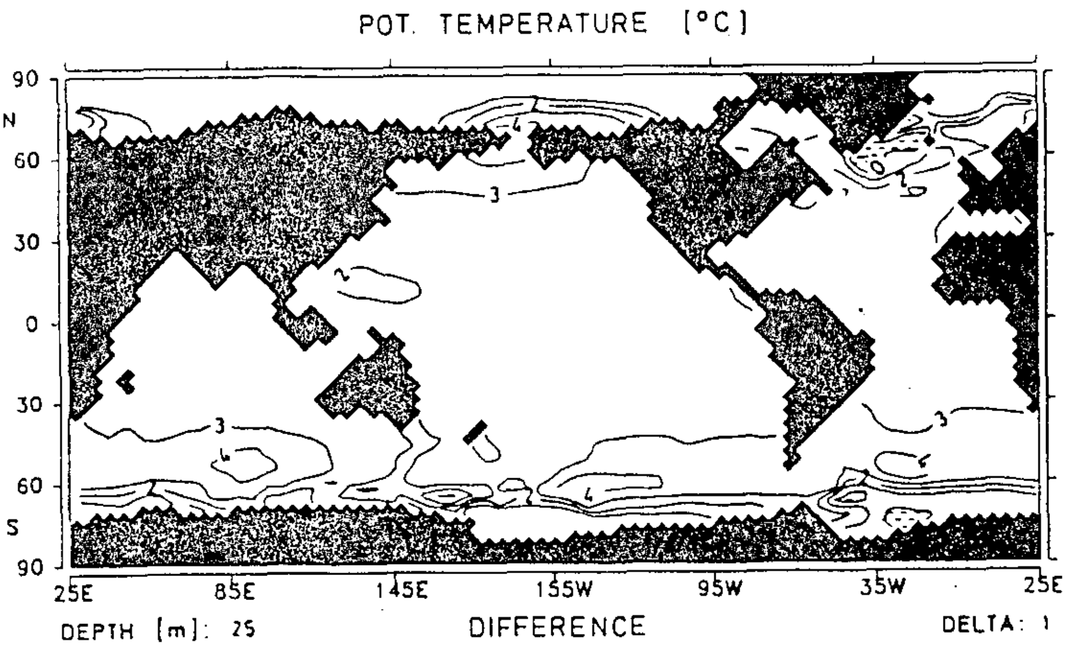

Fig. 3 Geographical distribution of changes in SST in year 50 relative to the control experiment. Shading indicates negative values (from: **MIKOLAJEWICZ et al. (1990)**)

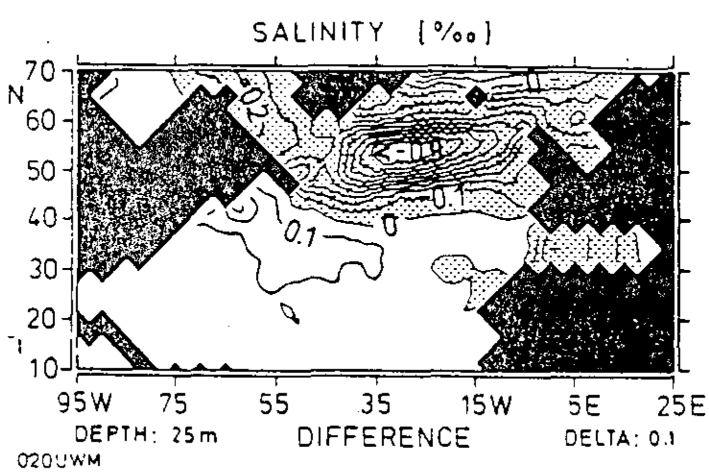

Fig. 4 Geographical distribution of changes in the surface salinity in the North Atlantic in year 20 relative to the control experiment. Shading indicates negative values (from: **MIKOLAJEWICZ et al. (1990)**)

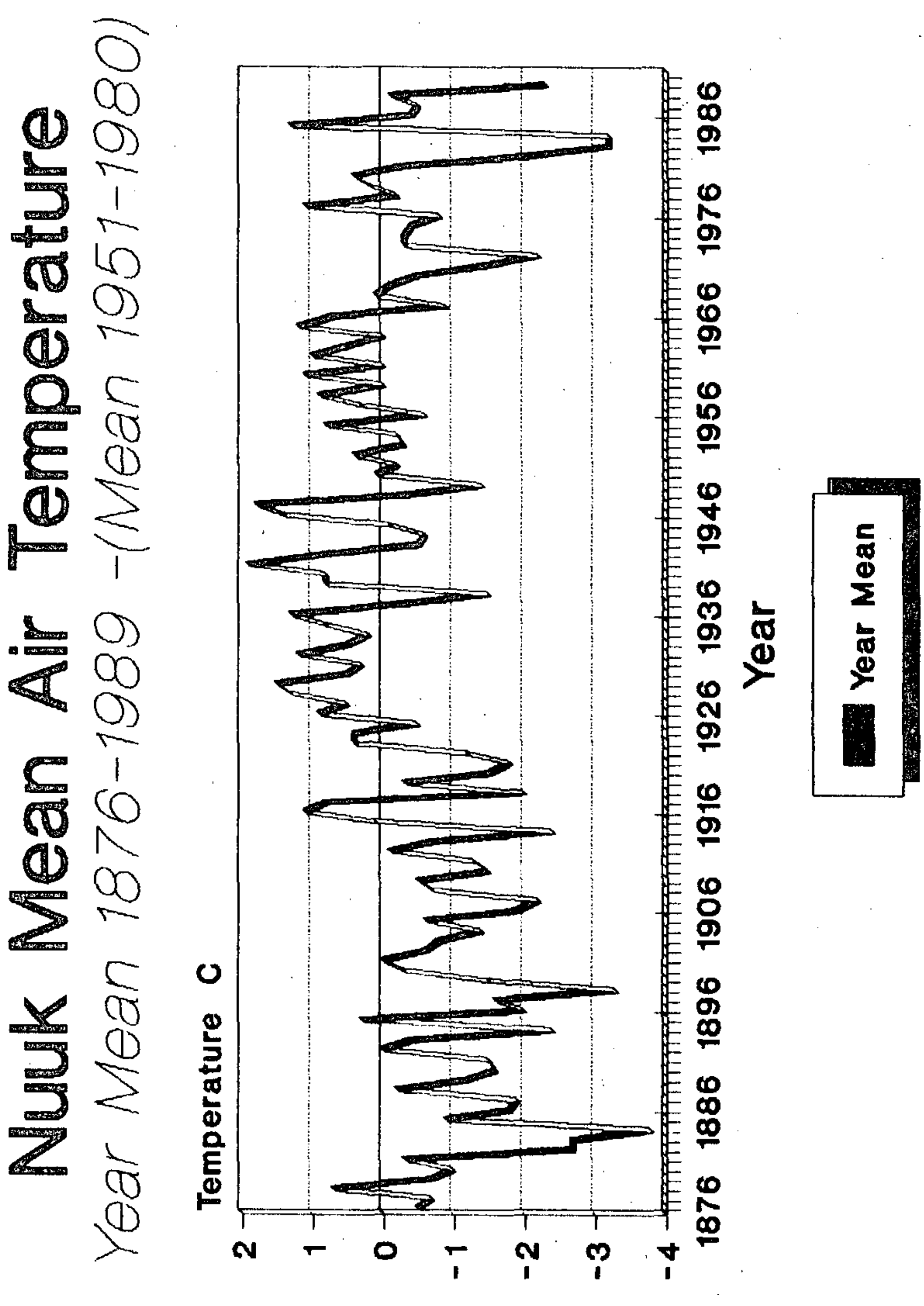

Fig. 5 Nuuk mean air temperature, year mean - mean(1951-1980)

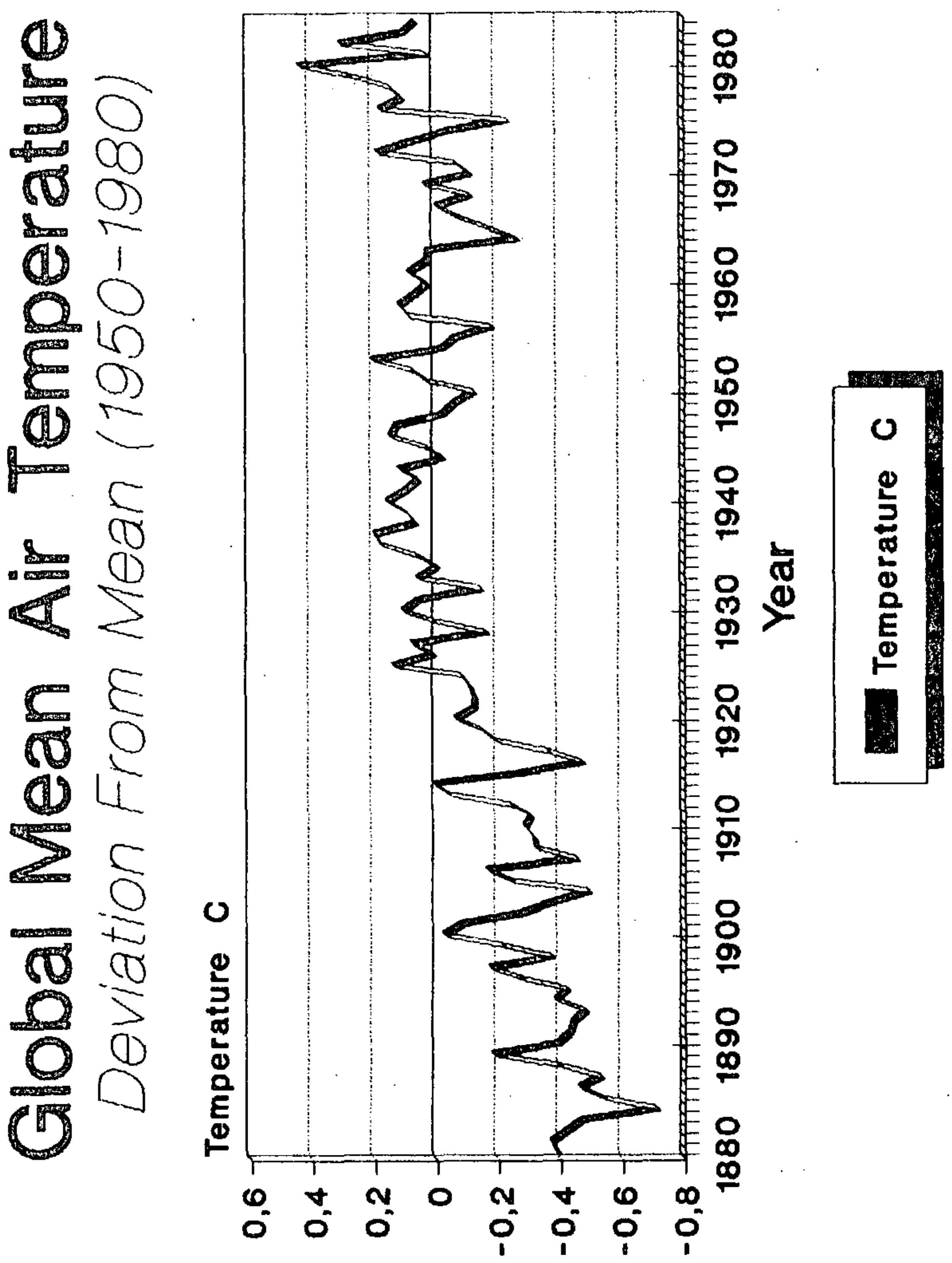

Fig. 6 Global mean air temperature, deviation from mean(1950-1980) (redrawn after HOUGHTON, R.A.; WOODWELL, G.M., 1989)

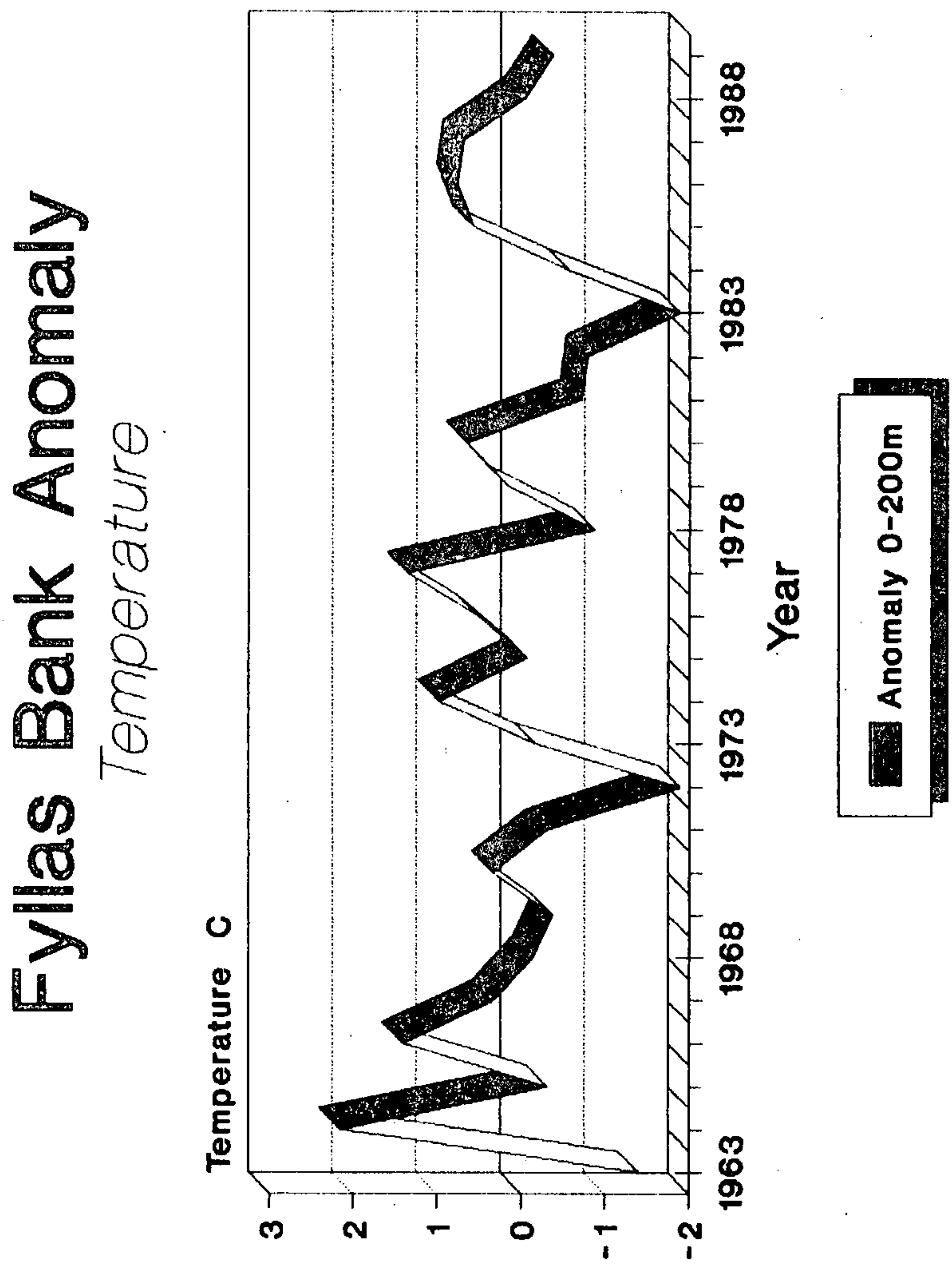

Fig. 7 Fylla Bank Temperature Anomaly 0-200m Autumn