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Scales of Variability in West Greenland Waters

by

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Introduction

Variability of the atmosphere-ocean-kryosphere environment is believed to influence variations in fish stocks. This variability is dependant on various parameters, like solar radiation input and backscattering, ice cover, tides, atmospheric forcing. During the past 4 decades oceanographic research off West Greenland has brought forward our knowledge on scales of this complex systems of action and reaction. It is the aim of the present paper to enumerate some of the bits and pieces of this complex scenario and to give indication on possible inter-relationships between processes and forces which form the existing picture of West Greenland Waters.

Scales Of Variability

West Greenland Waters are a compositum of the large-scale circulation of the North Atlantic Ocean, the meso-scale co-existence of warm and cold current components of the West Greenland Current system, and small-scale events like the shifting of water mass fronts, generation of *meanders and eddies*. Variability in the North Atlantic circulation was recently shown by **DICKSON et. al. (1988)**. Accordingly they describe "the Great Salinity Anomaly in the North Atlantic Ocean as largely an advective event, traceable around the Atlantic subpolar gyre for over 14 years from its origins north of Iceland in the mid-to-late 1960s until its return to the Greeland Sea in 1981-1982. The overall propagation speed around this subpolar gyre is estimated at about $3cm\ s^{-1}$." Whereas this variability is in the range of decades, the meso-scale variabilty in West Greenland waters is visible in the semi-annual signal of the two current components, the cold East Greenland component, and the Irminger component. **BUCH (1982)**, and **STEIN and BUCH (1985)** note that the cold , near-coastal component attains its maximal influence on the West Greenland Current in early summer (June), whereas the warm component is of maximal influence in late autumn (November). On the small-scale the influence of changing wind direction on the Ekman layer has been shown by **STEIN and BUCH (1985a)** and is discussed by the same authors in a recent paper **(STEIN and BUCH, 1989)**. They observed that due to changing wind direction advective processes took place which affected on the time-scale of less than two hours the upper 20-30m of the water column.

Solar heating is acting on all three scales (Fig. 1). As shown by **BUCH (1986)** "the warm conditions in the twentieth century are extraordinary, and we must go about 1000 years back in time to find similar conditions, i.e. at the time when Eric the Red colonized Greenland." The climatic time series displayed in the paper, covers the time range from 553-1975 A.D. and is based on isotop measurements on ice cores from the Greenland Icesheet **(DANSGAARD, 1985)**. It shows several positive temperature anomalies during the past 1200 years, i.e. between 700 and 800, around 1000, in the 13th century, and in the present century. These large-scale fluctuations are superimposed on the variations which we observe during the past decades. Solar heating is thus acting on time-scales from hours to ice-ages, it influences the weather and the climate. As analyzed by **BUCH (1987)**, the temperature of the surface layer, as well as its interannual variations, are very much dependent on the heat exchange between ocean and atmosphere. During the anomalous cold early eighties the extreme conditions found at West Greenland were due to a locally placed cold air mass, with the center near the city of Egedesminde, West Greenland. The extremely cold conditions in the atmosphere had cooled the upper water masses in the Davis Strait, resulting in negative heat flux and negative temperature anomalies of 1 to 2° C throughout the year as well as in formation of great amounts of ice **(STEIN and BUCH, 1985)**. Compared to sea ice normals, during the winters of 1982/1983 and 1983/1984 the maximum ice cover persisted about three months longer. The modification of the hydrographic environment caused by the formation of sea ice is illustrated in Fig. 1. Surface layer warming /cooling initiates vertical and horizontal diffusion processes which are acting on different time and space scales (Fig. 1). Their variabilty feeds back into the variability on the space scales from the North Atlantic circulation to eddies. Results of this complex mechanism of air-sea interaction, variability of the West Greenland climate, may be deduced from **STEIN and BUCH (1989)**. The displayed time series of Godthaab mean air temperature from January 1876-1989 gives an impression of scales on which air temperatures varied during the past 114 years in this area. Trend analysis of these data yields a sequence of warm and cold winters at Godthaab (Fig. 2a). Especially around 1900 January temperatures were at a very low level for about two decades. It would appear that variability of winter air temperatures was less expressed during the first twenty years of the time series than it was observed in the thirties, sixties and especially in this decade (Fig. 2b). Statistically significant warming is observed in West Greenland air temperature based on the long-term time series. It amounts to 0.03°C/year **(STEIN and BUCH, 1989)** for the January data. In the same paper the authors discuss the hypothesis that ocean surface layer (0-200m) temperature trends in West Greenland waters may be deduced from trends in air temperature at West Greenland. It would appear that the time scale of such interaction is about 3 months. Compared to recently published satellite-derived sea-surface-temperature trends **(STRONG, 1989)** ,there is a global ocean warming of about 0.1°C/year. For the North Atlantic Ocean these data indicate even 0.21°C/year. **STEIN and WEGNER (1989)** obtain a warming coefficient of about 0.1°C/year for the slope water region off West Greenland. Since these water layers are isolated from the local sea surface to obtain their variable thermal fate via air-sea interaction, this variability must be an imported variability, advected from the large- and meso-scale circulation entering the Labrador Sea off Cape Farewell.

Another imported variability in West Greenland waters might be linked to the area by tele-connection. Strong environmental signals which seem to take place at about 10 year intervals **(STEIN, 1987)** are related to ENSO-events (El Niño Southern Oscillation). This phenomenon is likely to influence climate and the surface layer warming/cooling.

Some of the man-made influences affecting thermal variability in West Greenland waters is comprised in the lower box of Fig. 1. The Greenhouse Effect, plus several still unknown effects might add variability to the complex atmosphere-ocean-kryosphere scenario off West Greenland. **HOUGHTON and WOODWELL (1989)** emphasize that increasing concentrations of Greenhouse gases like CO_2, CH_4, N_2O and volatile halocarbons have already started to change the global climate (Fig. 3). Without taking into account the feed-back mechanism between all Greenhouse gases, a mean global warming of 1.5°C to 4.5°C is to expected until the mid of the next century. In middle and high latitudes, winter temperatures are supposed to increase twice as much as the global mean. In the same paper the authors reveal that based on the analysis of different isotope concentrations in the **Wostok ice core** (2200m long ice core from the USSR Antarctic station Wostok) ,temperature changed during the past 160 000 years up to 10°C. During periods of warming an increase of temperature , and increase of CO_2 content were closely linked. During periods of cooling , the CO_2 content decreased later than temperature decreased. The atmospheric CO_2 concentration thus can be used as a global thermometer which reveals the onset of the dramatic increase in temperature and CO_2 about 15 000 years ago. In contrast to the first peak in the Wostok ice core time series, which reveals dramatic warming about 130 000 years ago, the present increase in O^{-18} concentration (thermal signal) is much higher and might indicate natural warming plus man-made warming of the atmosphere. Other signs of dramatic global warming can be deduced from the glaciers in Europe which indicate melting since about 250 years. Thomas Jefferson, in former times president of the USA, stated in his weather observations "It is a common opinion that the climates of the several states of our union have undergone a sensible change since the dates of their first settlements; that the decreas both of cold and heat are moderated. The same opinion prevails in Europe. And facts gleaned from history give reason to believe that, since the time of Augustus Caesar, the climate of Italy, for example, has changed regularly at the rate of 1° of Fahrenheit thermometer for every century. May we not hope that the methods invented in latter times for measuring with accuracy the decreas of heat and cold, and the observations which have been and will be made and preserved, will at length ascertain this curious fact in physical history?"(taken from: **STOMMEL and STOMMEL, 1983**). Jefferson's interpretation of weather and climate was most likely influenced by the cooling trend incorporated in his own weather observations between 1811 and 1816. Although there are intermediate periods of cold years, like 1816, the year without summer, with snow in June, and frost in August in

New England, Canada and Europe, an event which might be linked to the Tambora volcano eruption in Indonesia during 1815, there is a significant overall trend of warming. The 0.1°C/year warming which influences sea surface, the weather and changes our climate is one of the most serious environmental problems we are facing in future. As stated by **STRONG (1989)** "we may be just beginning to witness the onset of this warming".

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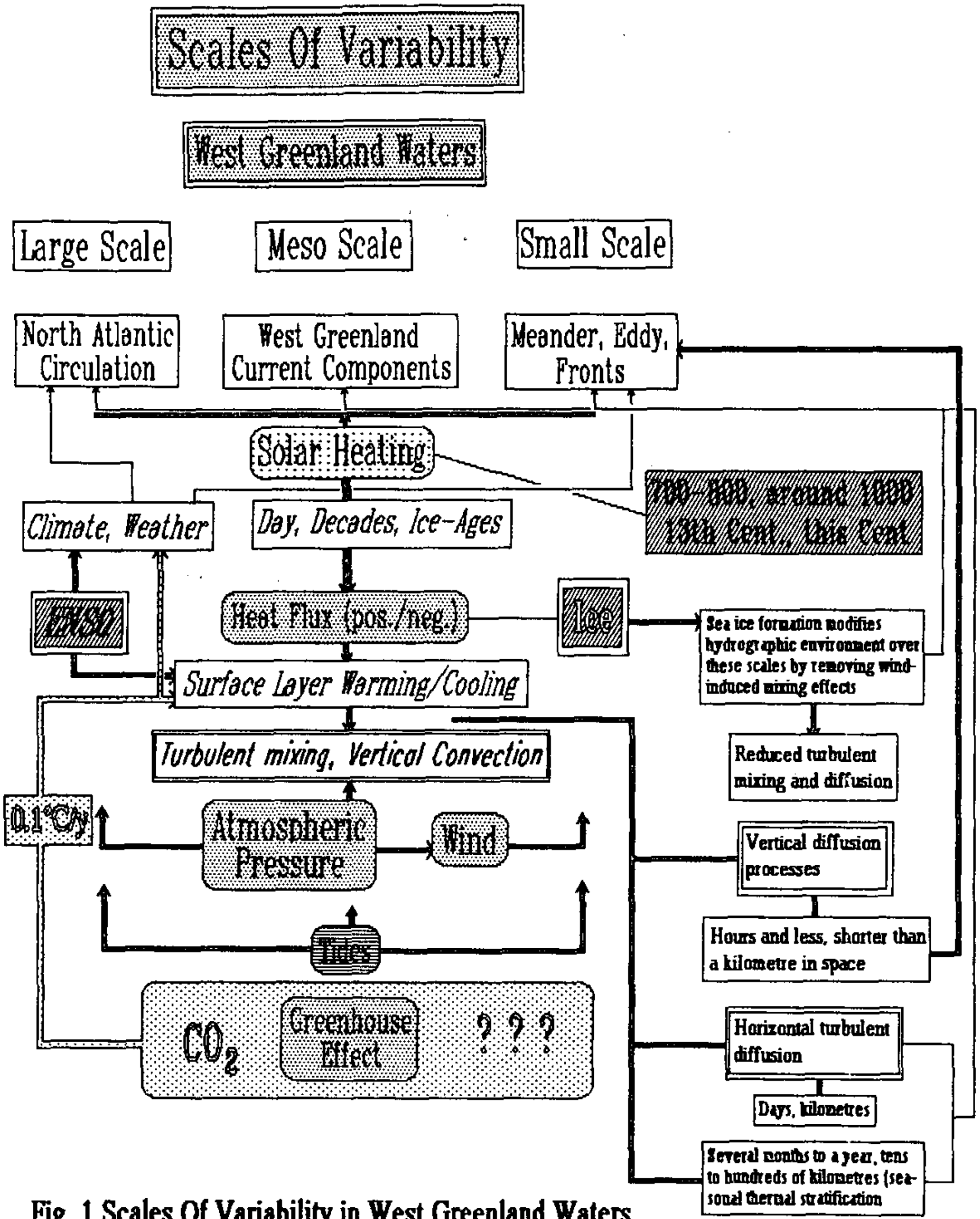

Fig. 1 Scales Of Variability in West Greenland Waters

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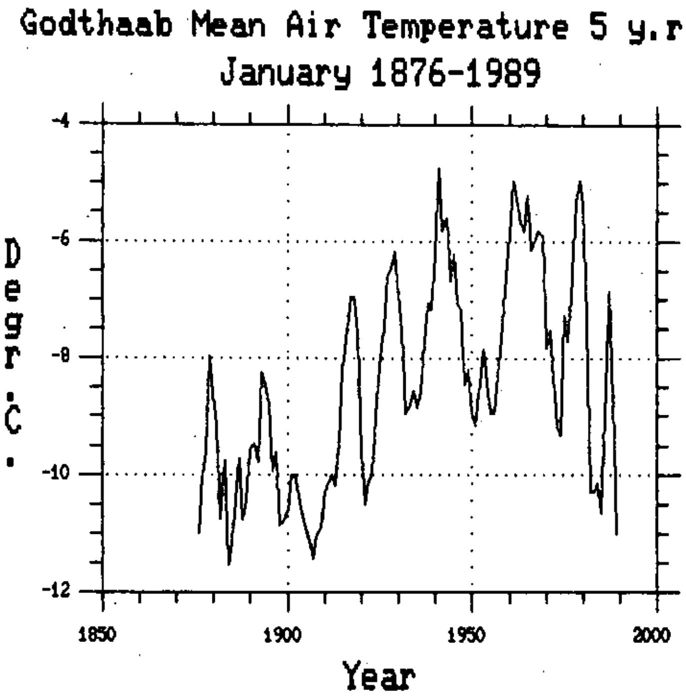

Fig. 2a: Godthaab Mean Air Temperature 5 year running mean; January 1876-1989

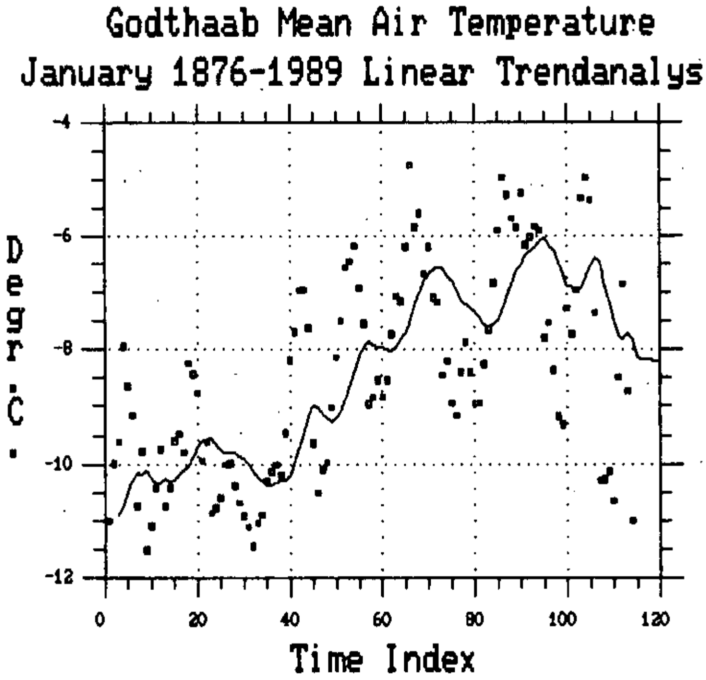

Fig.2b: Godthaab Mean Air Temperature Linear Trendanalysis; January 1876-1989

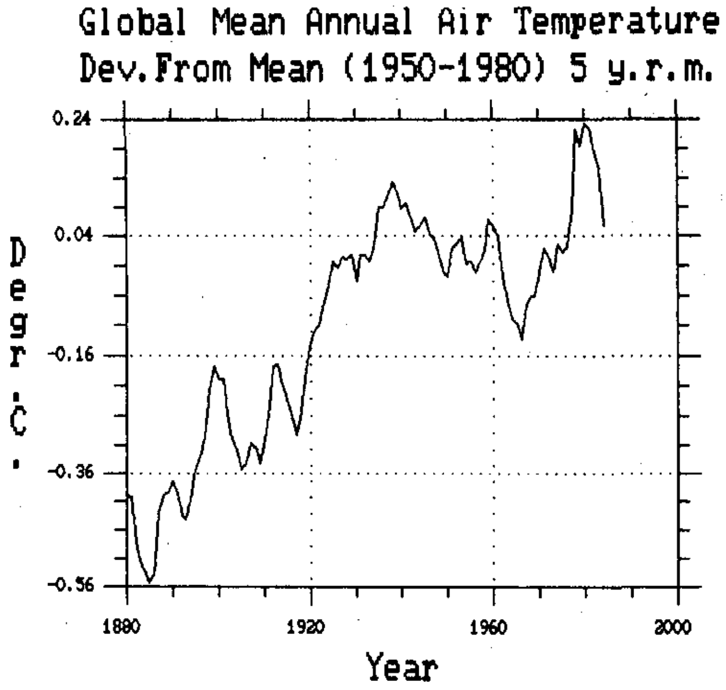

Fig. 3: Global Mean Annual Air Temperature 5 Year Running Mean 1880-1984 (data adapted from HOUGHTON and WOODWELL, 1989)