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Comments on long-term variations of sea surface temperatures of the European shelf seas

by

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Abstract

The monthly temperature mean values from the stations "Helgoland", "Noordhinder", and "Faroes", as well as from the sea areas "ICES Region F1" and "Biscay" were investigated climatologically. The temperature series were filtered in order to eliminate the yearly wave which superimposes itself over all, and also shorter variations. Coherence of the climatic oscillations of the individual sea areas was investigated. An harmonic analysis of the filtered series showed no statistically significant spectral energy concentrations. The mean values so filtered were treated with a second filter, which allowed through only variations with periods longer than ten years. There were temperature variations and periods between 11 and 15 years in length in all five series. The variations were not stationary. A connection with the sun-spot cycles could not be proved. All the sea areas considered showed a clear temperature increase since about the turn of the century.

Résumé

Des valeurs mensuelles moyennes de la température, obtenues des stations "Helgoland", "Noordhinder" et "Féroé" ainsi que des régions marines "ICES Region F1" et "Biscaye" ont été examinées climatologiquement. Les séries de température ont été filtrées afin d'éliminer la variation annuelle qui couvre tout et des fluctuations encore plus courtes. On a étudié les cohérences des oscillations climatologiques dans les régions marines respectives. Une analyse harmonique des séries filtrées n'a pas révélé de concentrations spectrales d'énergie qui soient assurées statistiquement. Les valeurs moyennes ainsi filtrées ont été traitées à l'aide d'un deuxième filtre qui n'a fait passer que des fluctuations aux périodes de plus de 10 années. On a constaté des fluctuations de la température aux périodes entre 11 et 15 années pour toutes les cinq séries. Les fluctuations n'étaient pas stationnaires. Une liaison avec des cycles de taches solaires n'a pu être démontrée. Toutes les régions marines considérées ont révélé une hausse de la température depuis environ le tournant du siècle.

Introduction

Reliable secular series of meteorological parameters have been available for a long time. On the other hand, to date, only a few long-term series of hydrographical parameters are known. In order to study the long-term variations or climatic changes the water temperature is a particularly suitable parameter, because this also shows only a weak daily variation within the surface layer and, in general, errors due to radiation or evaporation effects are minimal. Smed (1962), especially, has tried to compute long-term temperatures for the North Atlantic. These are geographical observations from areas, generally in 5° fields, which have been summarized into a series of monthly mean values. The space-time variability of oceanic sea surface temperatures is normally small enough, in order to be able to study long-term changes without great errors.

Tomczak (1967) has investigated climatic changes in the North Sea from such series. For our investigations, series were available for the positions, resp. regions, shown in Fig. 1.

A. Colebrook has summarized and homogenized temperature measurements for a region (45° to 50° N; 5° to 10° W) West of the English Channel. The series begins in 1854 and closes in 1974. This series presents large gaps during the world wars. This region has a double influence upon the climatological variations of the North Sea. The advection of water from this area through the English Channel has a direct influence in long time scales upon the southern North Sea. On the other hand, it

is supposed that the meteorological coupling has an influence upon the North Sea.

B. A temporally homogeneous temperature series exists, which began in 1884, taken by the Dutch light vessel "Noordhinder". The light vessel's position was changed several times. For long-term variations, however, this could be disregarded.

C. A series from Heligoland in the German Bight exists, which began in 1872, and which was broken off between 1944 and 1960 (Goedecke, 1952). However, the gap could be filled with data from the light vessel "Elbe I" which is positioned in the vicinity. In an earlier work, (Becker and Kohnke, 1977) it has been shown that the German Bight, with reference to long-term temperature variations, can be viewed as an homogeneous region.

D. A series by Smed (1952) has been computed from the area 56° to 60° N and 0° to 3° W. This area includes the Scottish coastal water and lies in the direct inflow of Atlantic water into the North Sea. Unfortunately, this series is also broken off, as are those from the Bay of Biscay, during the world wars.

E. Series from the Faroes are available from three stations from overlapping periods of time;* so that an homogeneous series can be compiled from them. This series began in 1867 and ended in 1969.

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* The data has been kindly placed at our disposal by H.H. Lamb.

The water temperature in the region of the Faroes can still be viewed as representative for the North Atlantic Current which, as an extension of the Gulf Stream, also exerts a deciding influence upon the European Shelf seas.

Methods

To illustrate the long-term variations, it is customary to build up mean values over time intervals of very different lengths, which in this case extended from one to thirty years (v. Rudloff, 1967).

Equally-weighted, running mean values function as digital filters which do not falsify the trend. This process, however, weakens, strengthens, or causes periodicities, so that statements concerning variations hold true only with absolute caution. If, instead of the equally running mean values, weighted mean values are used, these difficulties can be avoided or, at least, are reduced. The energy density of the annual temperature wave stands out above all other periodic processes (Webster and Farmer, 1976). During spectral investigations upon longer time series, in order to avoid energy leakages from the annual harmonic, low-pass filters were used which permitted the amplitudes of the annual waves to disappear and minimized the energy density in the higher frequency part of the spectrum.

The low-pass filter must possess the property of not changing the trend of the time series. Furthermore, no changes should take place in the longer periodical part of the spectrum, or at

least be only negligible.

Huber (1975) conceived a filter which possessed the characteristics desired. Fig. 2 shows the spectrum of this filter. The curve of the spectrum of this filter crosses the abcissa by ~366 days. At periods of about five years, the amplitudes receive the maximum exaggeration of 2 %. As the amplitudes of these variation periods are smaller than 0.5° C, a 2 % exaggeration would lie below the accuracy of measurement and can, therefore, be disregarded. Through this filter, 12 months' mean values were lost at the beginning and end of each series.

Fig. 3 shows the spectra of an original series (Noordhinder) and the corresponding filtered series. The spectra were smoothed, so that the amplitudes were weakened.

The comparison of the spectra shows that those in the longer periodical part correspond one to the other, apart from small differences, however, that with periods of about 20 months a steep decrease in the amplitudes results. The peaks in the higher frequency part reflect the high frequent variations caused by the filter, which - however - remain far below the accuracy of the measurement series.

In order to make the longer periodic parts of the series clearer, another new filter was conceived and used for the series in the same manner. This second filter is an extreme low-pass filter which lets through only periods of above ten years.

Results

The time series (monthly mean values of the sea surface temperature) which were treated with the aforementioned filter (366 days) is shown in Fig. 4. In order to be better able to distinguish between the five oscillating curves, the "Region F1" temperature curve is shifted by -4° C.

The filtered series of Fig. 4 do not represent monthly or annual mean values, and they are also not monthly or annual deviations of a respective mean value. On the contrary, they represent the total from the non-harmonic remains of the annual wave and all longer-lasting variations.

In all five filtered series, the great variations in the period range between about two and five years are worthy of note, the signals of which overlie longer continuous phenomena, so that in Fig. 4 these are not immediately recognizable. The spectral analyses give no indication of stationary periodical variations (K. Hasselmann, 1976). A high level of coherence exists between "Helgoland", "Noordhinder", and the "Biscay Region". A high coherence is also to be seen between the series from the "Faroes" and the "Region F1", which is certainly heavily reduced after 1947. From that time onwards, the two curves in part even proceed contrary to one another. A similar behaviour of vanishing coherence is also shown by the three southerly stations, from 1969 onwards.

"Helgoland", as the land-nearest station, shows the greatest

disturbance in fluctuation of temperature. This station, of all the other areas investigated, is the most subjected to the continental influence. The most salient phenomena in the "Helgoland" and "Noordhinder" series are the strong, sudden falls in temperature. They are purely weather-dependent, predominantly in virtue of extremely colder winter months. That kind of stronger, negative climatic deviations are not to be observed in the region "Biscay".

Upon closer observation, at all five stations, one can distinguish between periods with relatively small variations in temperature and those with higher fluctuations. This temporary difference clearly manifests itself in the "Faero" series (and also in the "Region F1") where, between 1893 and 1947 only few higher frequent climatic oscillations occurred. In contrast to that, before 1893 and after 1947, variations with larger amplitudes were observed. The relatively undisturbed temperature course between 1893 and 1947 coincided with a zonalisation of the atmospheric circulation (H.H. Lamb, 1973). The Central European region was rather characterized by oceanic summers during this period (H. v. Rudloff, 1967) which may have had a moderating effect upon the amplitudes. Before this period of time, above average, frequent meridonal air circulation took place over North-West Europe (H. v. Rudloff, 1967) which led to climatic oscillations with increased amplitudes.

In spite of the relative high amplitudes of the higher frequent oscillations, all five curves indicate longer-lasting temperature variations (longer than 10 years). In order to make

these phenomena clear, the series shown in Fig. 4 were filtered again. The gaps in the observations in the regions "Biscay" and "F 1", which occurred during the two world wars, were filled by linear interpolation of the filtered values in Fig. 4. The second filter possessed the characteristic of letting through only periods of longer than 10 years. At the beginning and at the end of the series to be investigated, in each case, 180 monthly values would be lost by the employment of a filter of that type. In order to avoid that loss, the series were artificially lengthened by reflecting 180 values, in each case, at both ends of a series.

The spectrum shown in Fig. 5 of the series "Noordhinder", which was treated by the second filter, shows very clearly that periods of less than 10 years have completely disappeared. An accumulation of energy became conspicuous in the period range between 11 and 15 years. Variations of these durations can be clearly recognized also in the twice-filtered measurement series of all stations (Fig. 6). These climatic variations, however, are not stationary. A correlationship with the relative number of sun-spots does not exist.

The "oceanic stations" ("Faroes", "F 1", and "Biscay") show good conformity in amplitudes and phases. It is to be supposed that, during periods greater than 10 years, the three stations mentioned were influenced by the North-East Atlantic Current to the same degree. The approximately same sized amplitudes at "Faroes" and "Biscay" indicate more an advective influence than a direct meteorological influence, although both regions are

about 1,500 km apart from one another in a meridional direction. However, to provide confirmation of this hypothesis, no analogous investigations exist from the Gulf Stream which feeds the North-East Atlantic Current.

The curves of the stations "Helgoland" and "Noordhinder" differ from those of the "oceanic regions" by variations with larger amplitudes. This can be traced to a stronger meteorological and - possibly - to a weakened advective influence. Even between the two "continental stations", "Noordhinder" and "Helgoland", there exists a considerable difference in the long periodicity. Coherence investigations of these two series indicate that the coherence in the periodic range decreases above five years. The coherence below this margin is very high, and for individual frequencies it almost reaches 1. If the short-periodic meteorological climatic oscillations (between 1 and 5 years) take effect upon these two stations in a like manner, it should also be expected all the more in the long periodicity. A comparison of the long periodic temperature courses at "Helgoland" and "Noordhinder", however, indicates - in part - clear deviations from one another. The greatest differences appear in the period from about 1905 to 1938. Whereas, the temperature at "Noordhinder" had three maxima (1912, 1924, and 1935) and two minima (1919 and 1928), only two maxima (1915 and 1934) and two minima (1905 and 1925) took place at "Helgoland" during the same period of time. In the course of the two temperature curves there also exist during those time intervals phase differences, which in the time period following up to the present have completely disappeared again. A comparison of the long temperature variations at the

five "stations" clearly showed that between 1905 and 1938 exceptional sea surface temperature conditions must have prevailed near "Helgoland". Between 1937 and the end of the series, a high coherence existed between the long periodic variations, although the higher frequent parts of the temperature variations at "Noordhinder" and "Helgoland" after 1968 - in fact - are opposite one to the other (Fig. 4).

At present, one is unable to make definite statements concerning causes for those kind of intermittent shifts in phase of the long-lasting sea surface temperature variations. It is especially still obscure if the unusually large amplitudes near "Noordhinder" between 1911 and 1921 (Fig. 4) (when compared with those near "Helgoland") must be explained by local meteorological changes or with advections through the English Channel into the North Sea. A correlationship of the mean values of the salinity - as calculated by R.R. Dickson (1971) - in the Southern Bight with the filtered temperature values at "Noordhinder" produced no definite indication of an intensified advection. That must not necessarily indicate a lack of advection. K. Wyrtki (1952) has already stated that a correlationship between current direction in the English Channel and salinity anomalies apparently does not exist.

Probably only correspondingly long series of observations of the current velocities could contribute to a clarification of the question of whether direct meteorological or advective influences have led to the climatological differences observed.

Over the whole of the observational time, at all five measurement series, a general average increase of the surface water temperature is recorded. As the spectral analysis of climatological series normally shows a continuous variance distribution (K. Hasselmann, 1976), it must be assumed that this warming-up is part of a long-periodic, non-stationary, climatic variation (periods larger than 200 years).

The "Region Biscay", since the relative temperature maximum in 1946 (Fig. 6), has cooled down by 0.8° C and, presumably, is at present close to a minimum.

By way of contrast, it appears that the present temperature niveau in the North Sea has a relative maximum. Not only the curves from "Noordhinder", "Helgoland", and the "Region F1", but also that from "Faroes" - however, with restrictions because of the early termination of the series - from 1965 onwards show a vigorous increase of temperature. According to the course of the curves during the past 100 years, a renewed relative temperature minimum is to be expected in the North Sea between 1980 and 1985.

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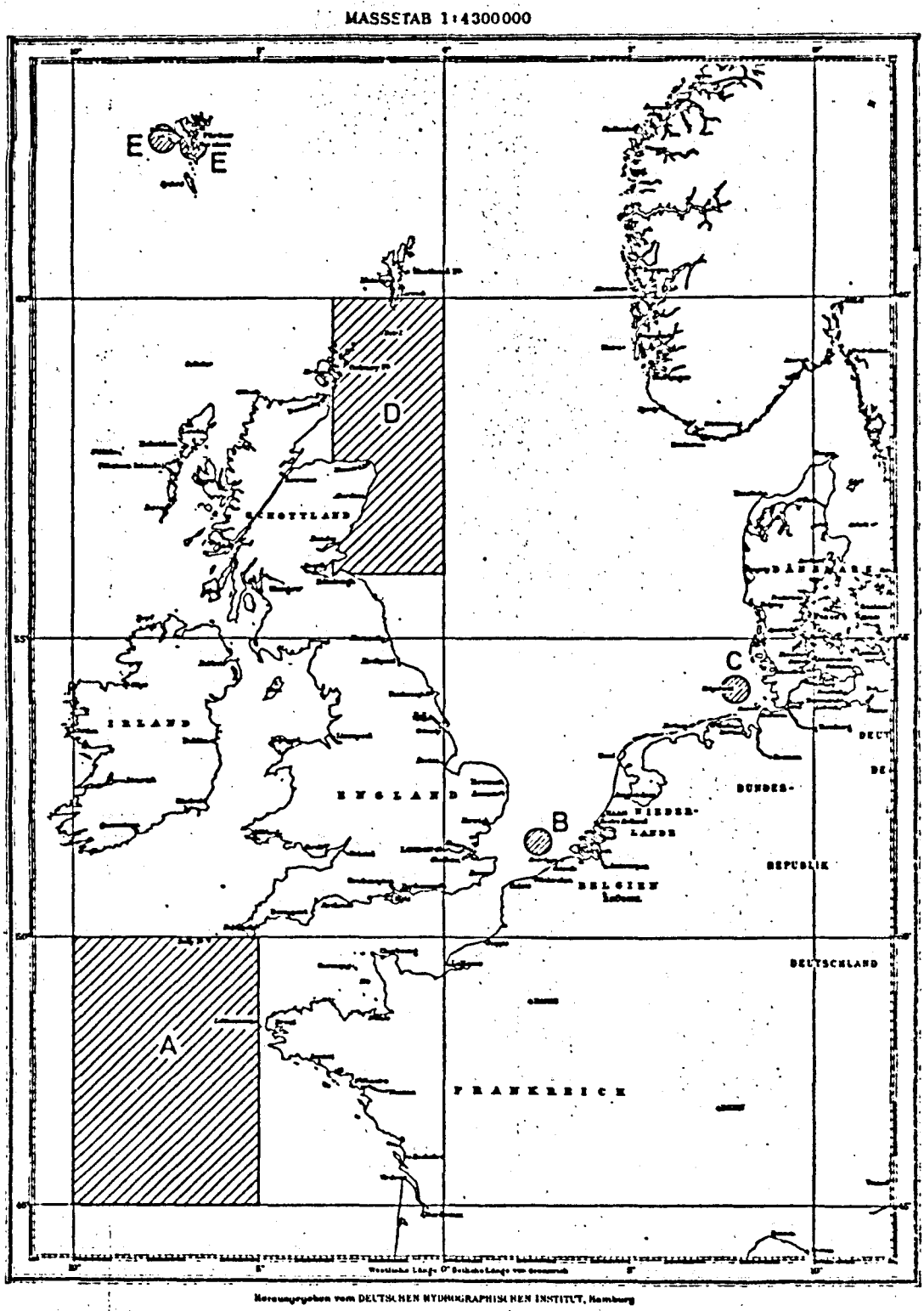

Fig.1 : Location of stations and regions of which temperature time series were analyzed

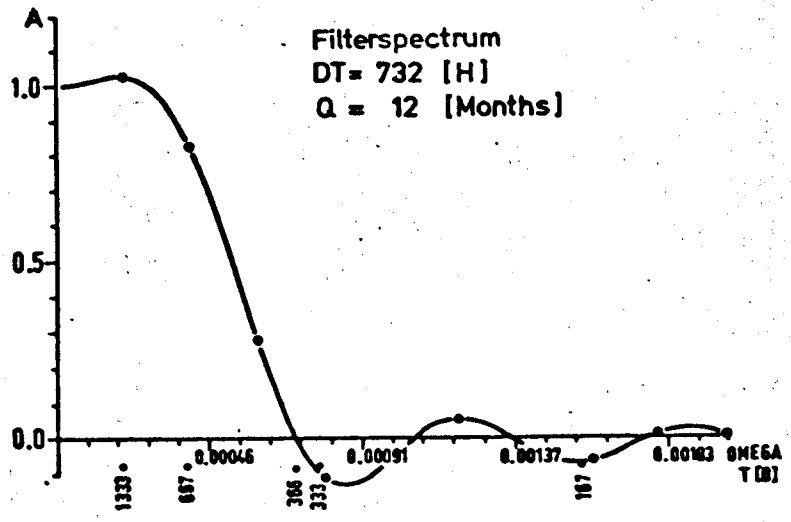

Fig.2 : Spectrum of the low-pass filter
(n = 12 months)

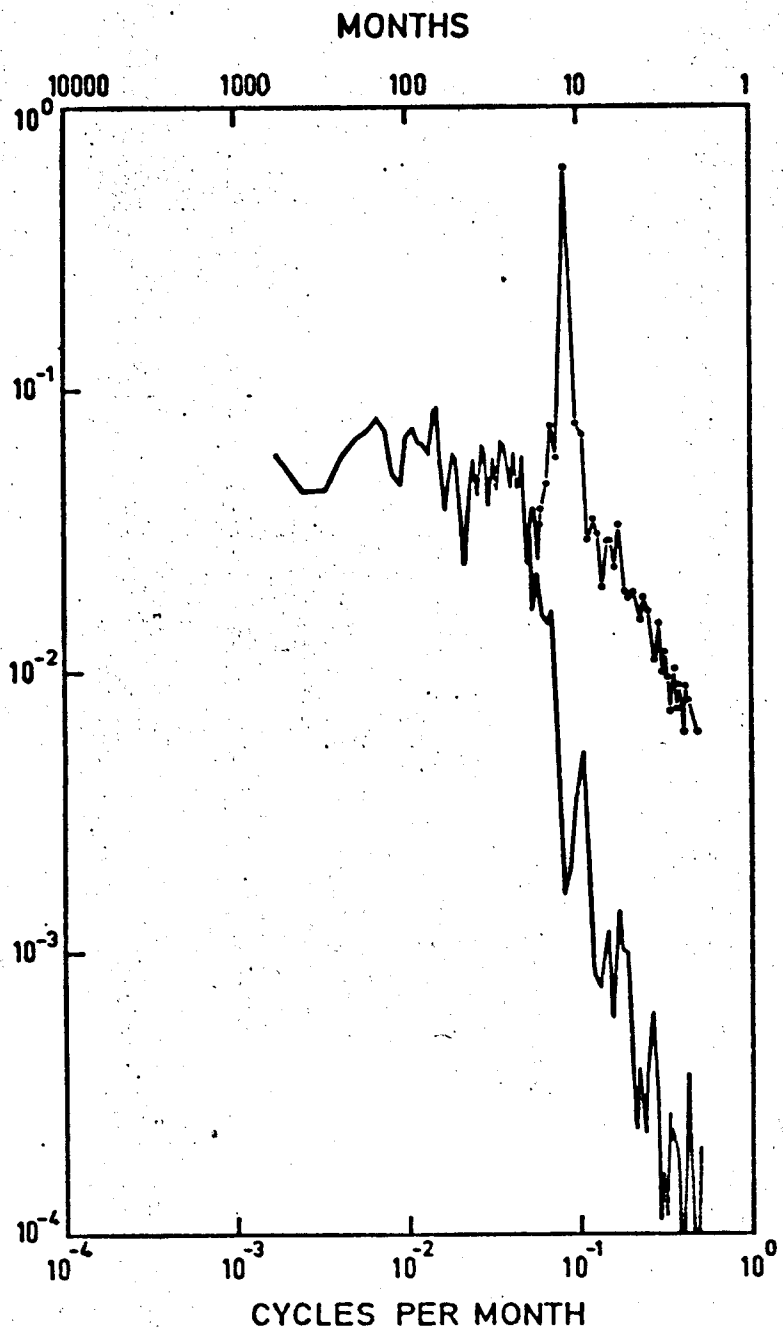

Fig.3 : Amplitude spectra of the original, and of the filtered (low-pass filter; n = 12 months), temperature time series of station "NOORDHINDER"

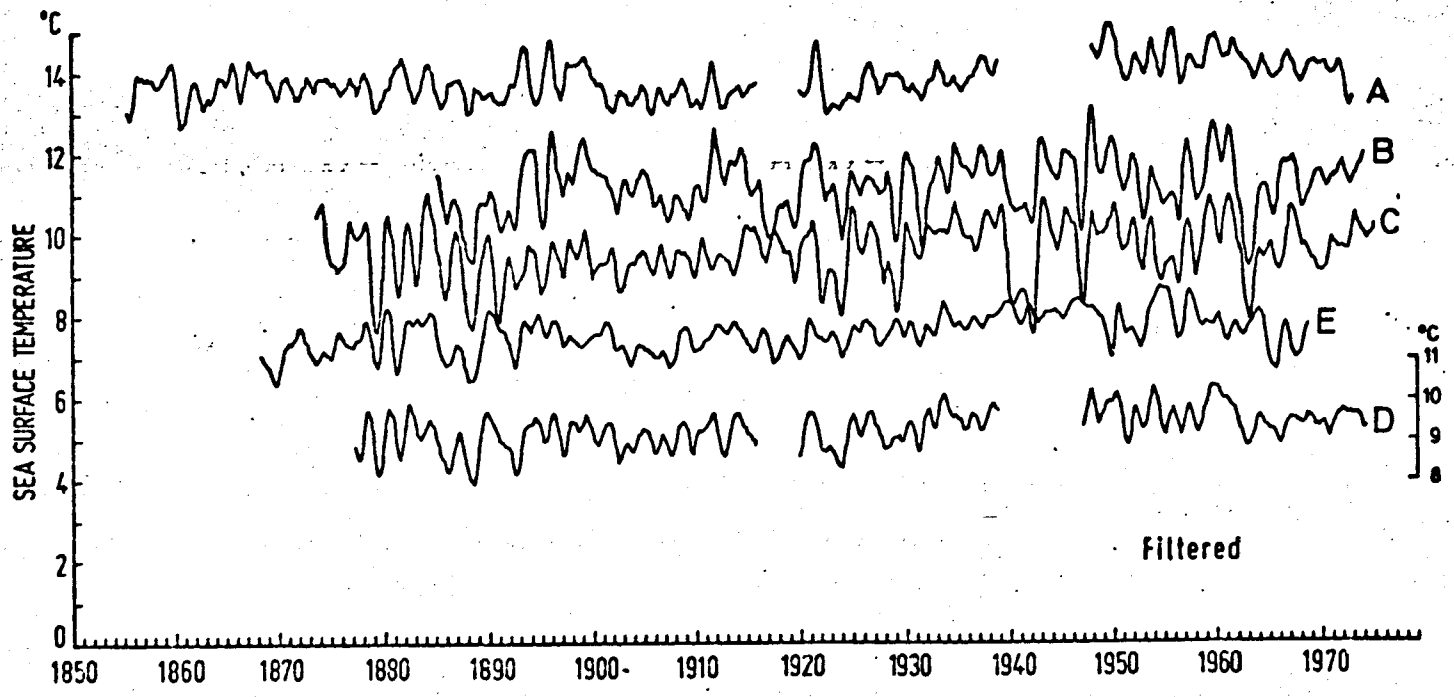

Fig.4 : Filtered temperature time series (low-pass filter; n = 12 months) of A: Region "BISCAY"; B: LV "NOORDHINDER"; C: "HELGOLAND"; D: ICES Region "F1"; E: "FAROES"

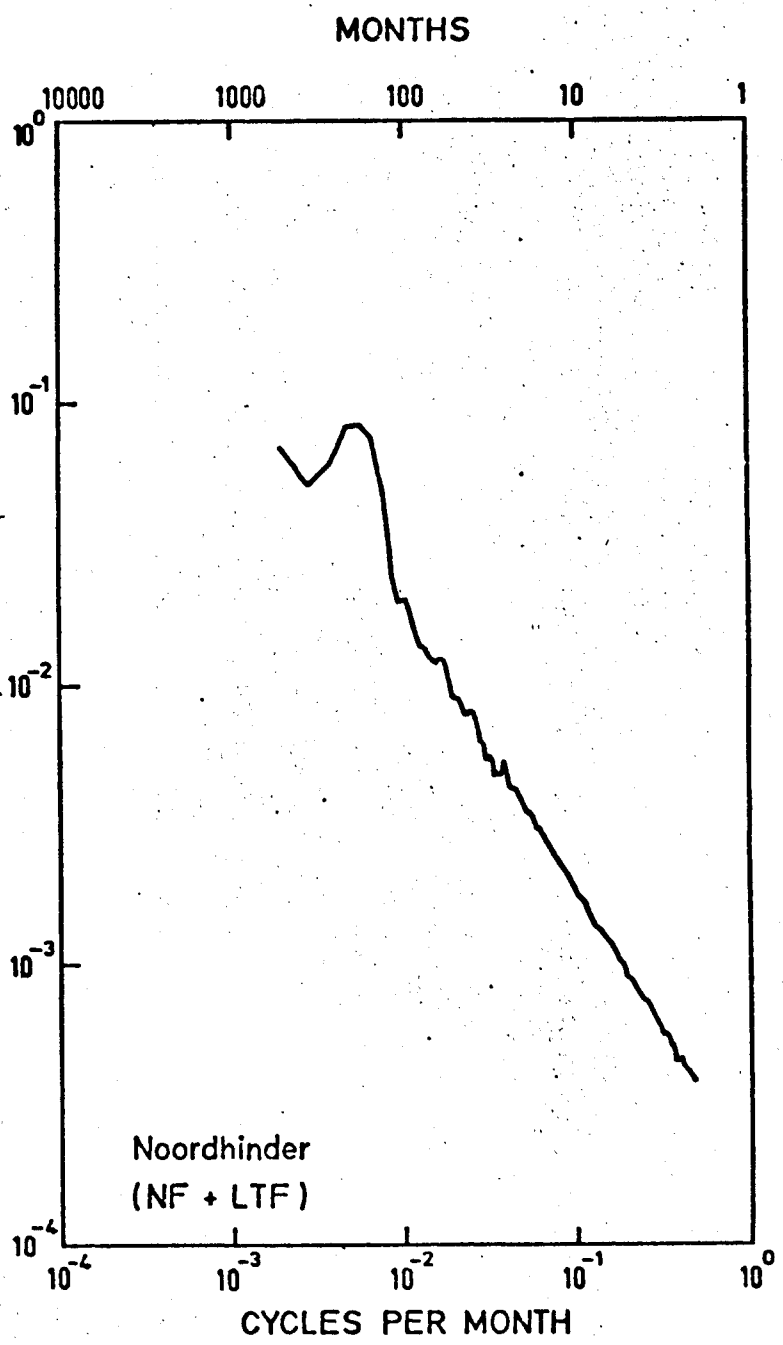

Fig.5 : Amplitude spectrum of the twice-filtered temperature time series from LV "NOORDHINDER"
(1.low-pass filter: n=12 months;
2.low-pass filter: n=180 months)

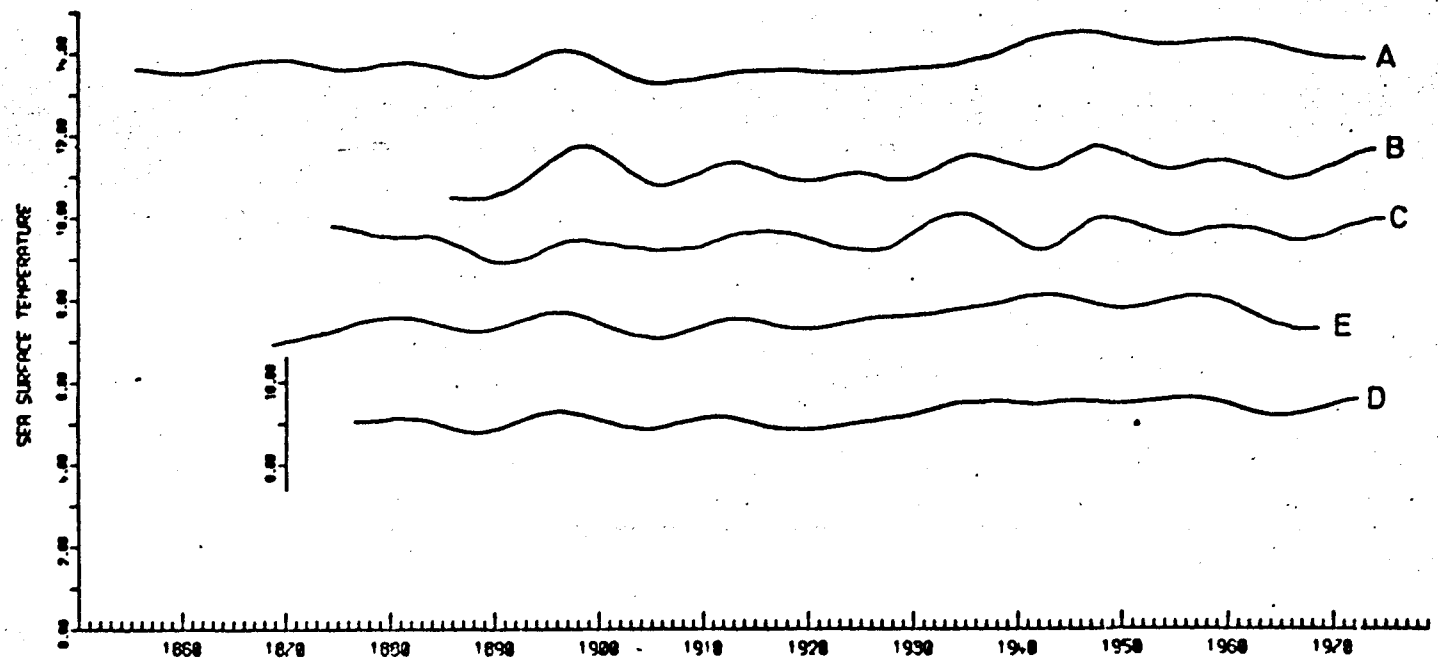

Fig.6 : Twice-filtered temperature time series (1.low-pass filter: n = 12 months; 2.low-pass filter: n = 180 months) of
A: Region "BISCAY"; B: LV "NOORDHINDER"; C: "HELGOLAND";
D: ICES Region "F1"; E: "FAROES