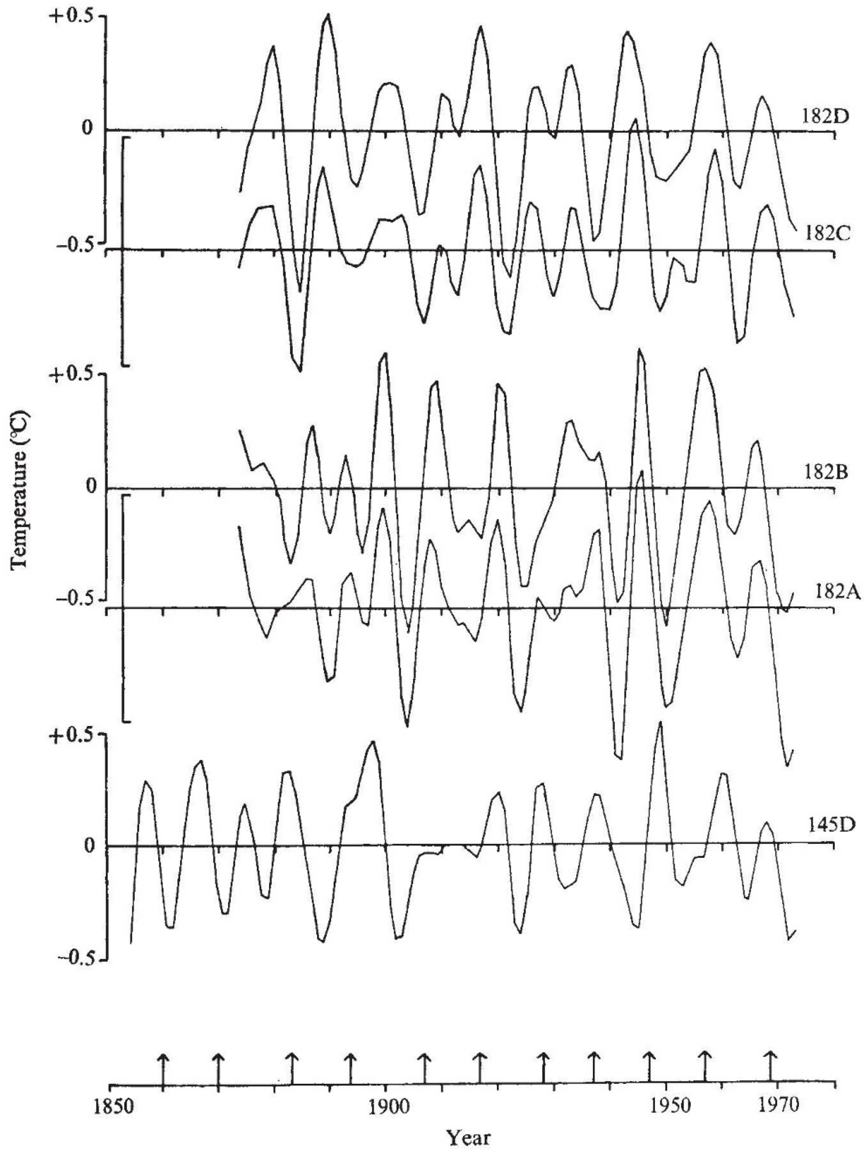


**Fig. 1** Filtered mean sea-surface temperatures for quarter Marsden squares 145 (Celtic Sea and Bay of Biscay) and 182 (Rockall area). The variables show the dominant periodic element following the removal of long term trends. Arrows on abscissa indicate years of maximum sunspot numbers.

possible relationship between solar activity and the circulation of the lower atmosphere has been discussed at some length by King[2].

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1 Colebrook, J. M. *Nature* 163, 576–577 (1976).
2 King, J. W. *Aeronaut. Astronaut.* 13, 109–118 (1975).

Colebrook replies—In the light of the very impressive correlation between sea-surface temperature and annual sunspot numbers demonstrated by Muir[1], I comment here in greater detail than was possible before[2] on the periodicities in sea-surface temperature data for Marsden squares 182 and 145. Figure 1 shows plots of filtered sea-surface temperatures representing the dominant periodic elements in the series following the removal of the long term trend. In each case there is a marked 10–11-yr periodicity. There is a fairly good phase relationship between the various temperature series and with the sunspot maxima.

It should also be noted that Cohen and Sweetser[3] detected an 11-yr periodicity in their series of frequencies of tropical cyclones in the Atlantic.

In the light of all the evidence now available there seems little doubt that sunspot numbers do have an influence on the climate of the North Atlantic Ocean.

I suggested previously[2] that the effect on sea-surface temperatures in the north-east Atlantic was produced by variations in southerly anomaly winds, involving direct heat exchange with the atmosphere. The relationship found by Muir implies an influence on the atmospheric circulation over the whole North Atlantic with a consequent effect on the Gulf Stream. This is consistent with the results presented by Maximov[4] which indicated that the 10–11-yr cycle in sea-surface temperature occurs over most of the North Atlantic Ocean.

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1 Muir, M. S. *Nature* **266**, 475–476 (1977).
2 Colebrook, J. M. *Nature* **263**, 576–577 (1976).
3 Cohen, T. J. & Sweetser, E. I. *Nature* **256**, 285–286 (1975).
4 Maximov, I. V. *Rapp. P.-v. Réun Cons. perm. int. Explor. Mer* **162**, 159–166 (1972).

## Oxygen isotope ratios in spruce cellulose

Although not affecting the practical significance of their work, Gray and Thompson's[1] finding that oxygen isotope fractionation in the cellulose of white spruce (*Picea glauca*) depends on winter rather than summer temperature warrants further discussion. It is unlikely that the tree is photosynthesising to any significant degree in the winter. I suggest here an alternative mechanism which would produce the observed results.

Two facts argue against winter photosynthesis: First, Fritts's[2] conifer, cited by Gray and Thompson, photosynthesised only when the temperature was above freezing and soil water stress was low—two conditions unlikely to hold for long periods in the Edmonton winter. Second, Norway spruce (*Picea abies*) chloroplasts function in carbohydrate synthesis only during the summer months[3]. If this is also true for white spruce, winter photosynthesis is probably not possible.

For energetic reasons a heavier isotope accumulates preferentially in that molecule having the highest bond multiplicity at the point of isotopic substitution[4,5]. Thus, when $^{16}O$ and $^{18}O$ distribute themselves between $H_2O$ and $CO_2$, the $CO_2$ (in which oxygen is double bonded) will get proportionately more $^{18}O$ than the $H_2O$ (in which oxygen is single bonded). This effect decreases with increasing temperature[6]. Therefore, if one looks at oxygen from $CO_2$ which has been in solution with $H_2O$, the $\delta\ ^{18}O$-temperature curve will have a negative slope. But, Gray and Thompson's curve has a positive slope. The oxygen in their cellulose might have come from $H_2O$ rather than $CO_2$, but this is not consistent with our current understanding of photosynthesis. Alternatively, starch may be hydrolysed to glucose within the cell during the winter. The glucose (single-bonded oxygen) would then exchange oxygen with cellular organic acids (or any other molecules containing double or

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