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Letter to the Editor

Temperature anomalies in high northerly latitudes and their link with the El Niño/Southern Oscillation

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Abstract. I report the discovery of a low frequency temperature oscillation in the eastern North Atlantic (NA), which was significantly correlated with the Southern Oscillation Index (SOI) in the tropical Pacific, but led the latter index by a number of months. This discovery is significant, because it demonstrates a link between the tropical Pacific and the high northerly latitudes which cannot readily be explained in terms of El Niño/Southern Oscillation (ENSO) feedbacks from the tropics, and opens up the possibility that ENSO and temperature anomalies in northerly climes, may actually have a common origin within, or even external to, the global climate system.

Key words. Meteorology and Atmospheric dynamics (ocean-atmosphere interactions) · Oceanography: general (climate and interannual variability) · Oceanography: physical (air-sea interactions)

Introduction

The El Niño/Southern Oscillation (ENSO) phenomena is the single most prominent signal of interannual climatic variability both inside and outside the tropics (Philander, 1990), and has received widespread attention because of its influence on the global climate (Klaßen *et al*., 1994; Fraedrich and Müller, 1992; Diaz and Kiladis, 1992; Philander, 1990). Coupled Ocean-atmosphere General Circulation Models are now capable of reproducing many of the important changes associated with ENSO events in the tropical ocean-atmosphere system (Barnett *et al*., 1991). However, the rich variety of coupled phenomena simulated in these models, and the apparent presence of more than one source of interannual variability, means that at present, there is no definitive explanation for ENSO occurrence. This leaves open the possibility that other, hitherto, unrecognized factors have a role in ENSO phase development.

Here I report the discovery of an ENSO – like signal in Irish meteorological records which led extremes in the Southern Oscillation Index (SOI) by a number of months, and prompted the suggestion that ENSO and this northern signal share a common origin within, or even external to, the global climate system.

Data

Comprehensive data sets comprising twice-daily SST readings and hourly wind directional and velocity measurements (in each 10° sector) were available for one monitoring station on the north-west coast of Ireland, i.e. Malin Head (55° 22′ N and 7° 20′ W). These provided continuous time series of coastal SSTs and concomitant surface wind conditions between January 1961 and April 1991, and seemed ideal for investigating relationships between SST and wind parameters, particularly during winter when the former (SST) would have been least affected by variability in the solar radiation budget (Cayan, 1992).

The SST readings were made from Portmore pier (Malin Head) some 30 m offshore, in a tide gauge well with an inlet/outlet valve for sea water 1 m above the sea floor (i.e. approximately 2 m below mean sea level). Initially, the readings were made by suspending a sea-protected thermometer to the depth of the inlet/outlet valve; but subsequently, from November 1971 until April 1991 (when the well was demolished), they were made by measuring the temperature of samples collected at 1 m above the sea floor (in the well) using a standard (metal) meteorological sea bucket. Wind frequency and velocity measurements were recorded at a meteorological station about 100 m from the pier.

Average annual and monthly values (smoothed using 3 month running means) for the SOI, as defined by the anomalous sea level pressure differences between Tahiti (French Polynesia) and Darwin (Australia), for the period January 1923 to December 1996, were obtained from the Queensland Department of Natural Resource's 'Long Paddock' webb site.

Results

As part of a climate modelling study, winter (Jan–Mar) SSTs at Malin Head were plotted against the combined frequencies of westerly, north-westerly and northerly (W-NW-N; 240 °-30 °) winds, which are the principal agents of ocean cooling in the northern North Atlantic (NA) (Cayan, 1992), to see if fluctuations in the frequencies (*f*) of these (W-NW-N) winds explained the variability in SST. Surprisingly, three diverging linear relationships were identified which essentially separated E1 Niño, non-ENSO and La Niña event years (Fig. 1 and Table 1). The observed differentials in SST between the three relationships were directly proportional to f (i.e. they declined with decreasing wind frequency), which suggested that they had arisen because of fundamental differences in the average heat contents of these NA wind types; inter-group differences in W-NW-N wind velocity and in the component frequencies and velocities of cold 'Arctic' NW-N-NE and warm 'tropical' SE-S-SW wind types being non-significant (data not shown). Assuming that the slope (b) of relationship 'y' (Fig. 1) is representative of the 'average' (ocean) cooling influence of the W-NW-N winds per unit frequency, and that each of the 31 points in Fig. 1 represent different relationships with different slopes (b_n), but all intercepting the y-axis at the same point (i.e. 8.4 °C), then an index of the variability in the cooling properties of these winds, attributable to fundamental differences in heat content, is given by the difference in the slopes ($b_n - b$). This difference, termed the North Atlantic Index (NAI), can be calculated as follows:

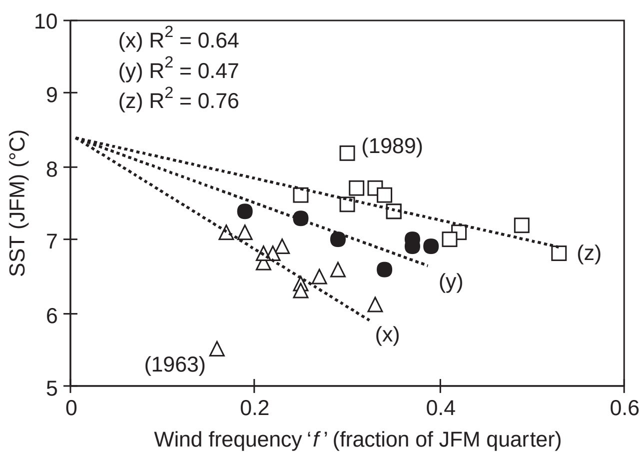

Fig. 1. Relationships between SST and W-NW-N (240 °-30 °) wind frequency (*f*) during the first quarter (JFM) of each calendar year between 1961 and 1991. Data for the exceptionally cold winter of 1963, when anticyclonic blocking conditions prevailed over the NA (Barry and Chorley, 1992), and for the exceptionally warm winter 1989, when an anomalous poleward displacement of the Gulf stream took place (Ginkul and Gavrilyuk, 1991), were not included in the regression analyses. The regression relationships were forced through a common intercept (8.4 °C) in keeping with their divergent tendency

Table 1. Compositions of the three groups of years (x, y and z) in Fig. 1, together with ENSO classifications for each year (W weak, M moderate, S strong, and VS very strong)

Set x El Niño	Set y Non ENSO	Set z La Niña
1963 El Niño (W)[a]	1962 Non ENSO	1961 La Niña (M)[d]
1964 *La Niña* (W)[b]	1965 *El Niño* (M)[a]	1967 La Niña (W)[d]
1966 El Niño (M)[a]	1974 Non ENSO	1968 La Niña (W)[d]
1969 El Niño (M)[a]	1975 *La Niña* (S)[d]	1970 La Niña (S)[d]
1972 El Niño (S)[a]	1978 Non ENSO	1971 La Niña (W)[d]
1977 El Niño (M)[a]	1980 Non ENSO	1973 La Niña (S)[d]
1979 El Niño (W)[a]	1984 Non ENSO	1976 *El Niño* (M)[a]
1982 El Niño (VS)[a]		1981 *Non ENSO*
1985 *Non ENSO*		1983 La Niña (W)[f]
1986 El Niño (M)[a]		1988 La Niña (S)[d]
1987 El Niño (M)[a]		1989 La Niña (W)[e]
1991 El Niño (M)[c]		1990 *Non ENSO*

[a] Quinn (1992)
[b] Halpert and Ropelewski (1992)
[c] Bigg (1995)
[d] Diaz and Kiladis (1992)
[e] Chiswell *et al.* (1995)
[f] Philander (1990)

$$\mathrm{NAI} = b_n - b = (SST_n - pSST_n)/f_n$$

where SST_n is observed SST; and $pSST_n$ is that predicted on the basis of actual wind frequencies (f_n), using relationship 'y'.

Using lag correlation analysis, time series of mean annual SOI values and winter NAI values were found to be significantly correlated ($P < 0.01$), but only when the lag between the two series was zero (Figs. 2a and 2b). The exercise was repeated, using individual smoothed (three) monthly values for the SOI in separate time series, i.e. with consecutive January values in separate series to consecutive February values, and so on. As shown in Fig. 3a, correlations with the NAI (which is centred on February of each year) only reached statistical significance ($P < 0.05$), when the SOI lagged the former index by between 3 and 13 months. The best correlation ($P < 0.001$) was obtained with the November (+9 month) SOI series, when 42% of the variance in the latter index was explained by fluctuations in the NAI (Figs. 3a and 3b)

Discussion

It is well known that ENSO events can influence conditions over much of the globe (Diaz and Kiladis, 1992), including the high northerly latitudes (Klaßen *et al.*, 1994; Fraedrich and Müller, 1992); but only in their mature phases (i.e. towards the end of year 0), and not during their initiation in the northern spring of year 0 (Wilby, 1993). For example, enhanced cyclonic (*anticyclonic*) circulation patterns have been observed over western and central Europe during winters immediately following warm (*cold*) ENSO extremes in the tropics (Wilby, 1993; Fraedrich and Müller, 1992).

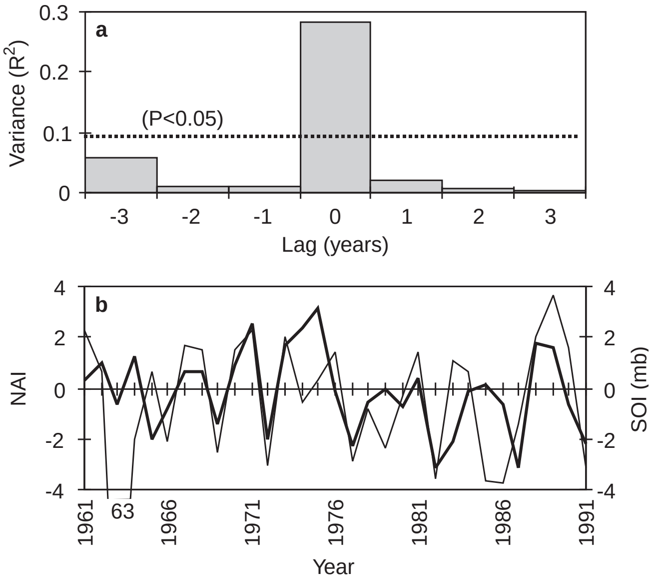

Fig. 2. **a** Results of a lag correlation analysis (omitting data for 1963 and 1989) showing the variance in the mean annual SOI explained by the NAI, when the latter index led or lagged the SOI by up to 3 years; **b** Superimposed time series of the NAI (*light line*) (the 1963 value of −12 being off scale), and the mean annual SOI (*heavy line*)

Moreover, recent work has linked changes in the position of the Gulf Stream with changes in the SOI some two years previously (Taylor *et al.*, 1998). Surprisingly therefore, the results of the present study suggest that extremes in the NAI led, rather than lagged, those in the SOI. Furthermore, the annual (winter) fluctuations in the NAI accounted for between 35 and 42% of the variance (Fig. 3a) in the SOI during its mature phase from October of year 0 to January of year + 1; which is considerably more than the variance (about 10%) in northern extratropical winter (year + 1) conditions attributed to ENSO feedbacks from the tropics (Hurrell, 1996; Wilby, 1993).

These results are quite remarkable, and stand in marked contrast to those of other comparable studies. Normally, ENSO signals propagate polewards from the tropics, and by the time they penetrate the higher latitudes, are considerably diminished in strength, and lag the tropical episodes by anything up to five years (Dickey *et al.*, 1992; Fraedrich and Müller, 1992; Hurrell, 1996; Taylor *et al.*, 1998). However, this was clearly not the case as regards the ENSO signal in Irish coastal waters (NAI). On the other hand, though, it is highly unlikely that temperature anomalies in either this, or adjacent regions of the NA, could have influenced ENSO periodicity, since the precursor conditions necessary for El Niño or La Niña initiation typically appear in the tropical climate record almost two years prior to event onset (Philander, 1990; Dickey *et al.*, 1992), and hence would have led, rather than lagged, the extremes in the NAI. A causal link between ENSO and the NAI, therefore, cannot be envisaged. It is conceivable, however, that both phenomena share a common origin, within, or even external to, the global climate system. One suggestion is that cyclic fluctuations in solar magnetic activity may have triggered changes in climate dynamics across all latitudes (Mendoza *et al.*, 1991).

Finally, it has to be acknowledged that the temperature oscillation identified off the North Irish coast, has not been identified in climatic data from other regions of the NA. However, this does not preclude its existence in these regions, but instead, may simply mean that the data in question need further examination.

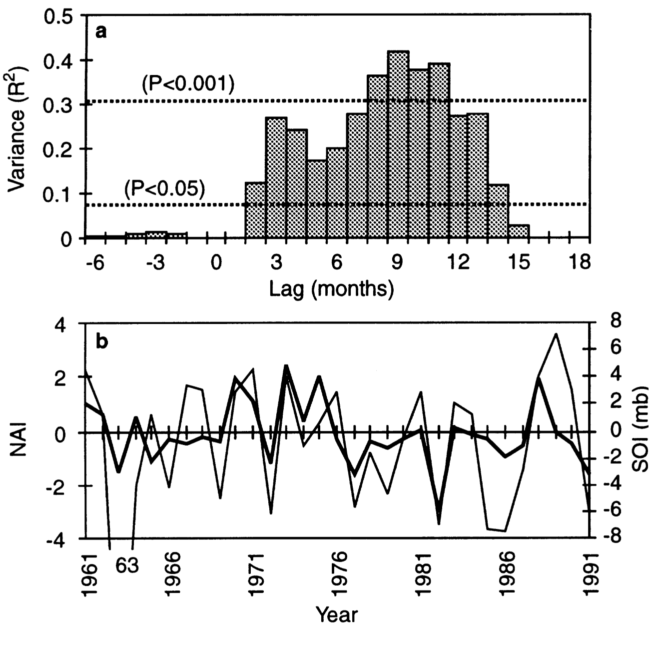

Fig. 3. **a** Results of a lag correlation analysis (omitting data for 1963 and 1989) between time series of the NAI and the SOI (using separate SOI series for separate months in each year), showing the variance in the SOI explained by the NAI, when the latter index (centred on February) led the SOI by up to 18 months, or lagged it by up to 6 months; **b** Superimposed time series of the NAI (*light line*) (the 1963 value of −12 being off scale), and the November SOI series (*heavy line*)

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