

Holocene climatic Variability in the North Atlantic Region as shown by Peat Bog Records

Umskipti í holosena veðurlagnum í norðuratlantsøkinum, sum tað sæst av torvmýruroyndum

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Úrtak

Torvmýruroyndir kunnu vera ein kelda til upplýsingar um proxyveðurlagið í tí holosena tíðarskeiðinum. Nýggjar kanningar hava víst, at bráðligar veðurlagsbroytingar koma fyrri við jøvnum millumbilum; hetta boðar frá reglubundnum endurtøkum og móguliga sambandi við umskiftingar í sólini. Ivamál eru kortini, serstakliga í sambandi við ávirkan frá menniskjum, mótsigandi úrslitum ymsastaðni frá og óneyvum dagfestingum. Uppskot verður lagt fram um eina arbeiðshypotesu, til gransking í framtíðini.

Abstract

Peat bog records can provide proxy climate records for the Holocene period. Recent studies have shown abrupt climatic changes at certain recurring points in time, evidence of periodicity and a possible link to solar variability. Problems remain, however, notably accounting for human impact, inconsistent results from different sites and dating imprecision. A testable working hypothesis is suggested for future research.

Introduction

Evidence from raised bogs and blanket mires, in the form of plant macrofossil assemblages, peat humification analyses and microfossil content, allow inferences to be made about past mire hydrological conditions. These can then be combined on a re-

gional basis to infer palaeoclimatic changes (Blackford, 1993). The aim of this paper is to outline the overall trends shown by published palaeoclimatic evidence obtained from peat bogs around the North Atlantic region (coastal areas of north west Europe), and propose a working hypothesis for future investigations.

Research into the link between past climatic changes and peat bogs records has been conducted since the last century (see reviews by Barber 1981; 1982 and Blackford, 1993). By the early twentieth century, an apparent pattern had emerged, that of the Blytt-Sernander model, which attempted to subdivide the Holocene into broad periods of distinct climatic characteristics. The terms used- Boreal, Atlantic, Sub-Boreal and Sub-Atlantic- are still found in the literature today, despite several studies that have shown the scheme to be, at best, oversimplified (Smith, 1981).

Peat-based palaeoclimatic studies have progressed in a number of ways over the last three decades. The introduction of radiocarbon dating allowed more precise

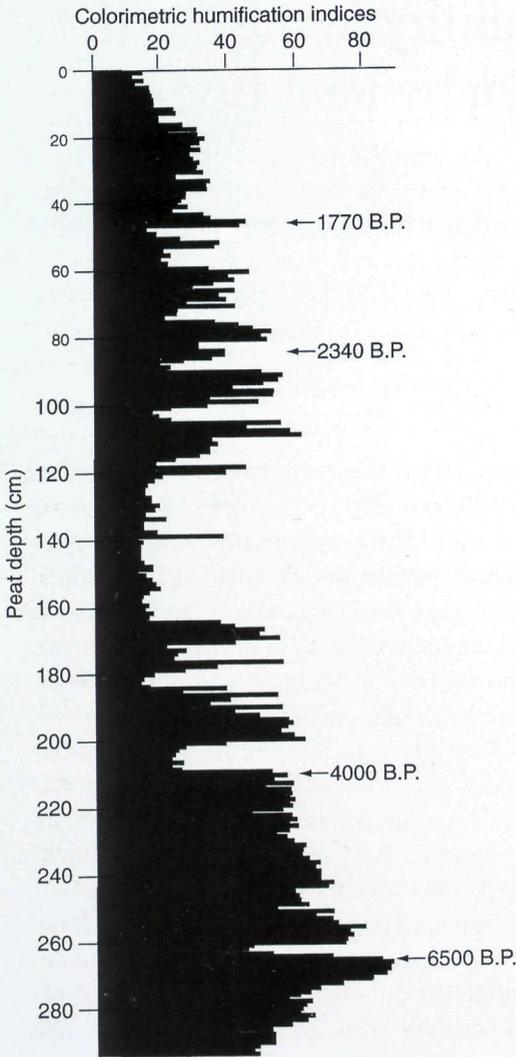


Fig. 1. Peat humification profile from Rystad, Norway (after Nilssen and Vorren, 1991). Radiocarbon ages are shown where available.

Mynd 1. Tvørskurður av torvvæting úr Rystad í Noreg (eftir Nilssen og Vorren, 1991). Kolevni 14-aldrar síggjast, har teir eru tøkir.

time-scale construction and correlation, and the development of additional methods of reconstruction (quantitative macrofossil analysis, analyses of non-pollen microfossils such as testate amoebae, fungi and algal remains) has increased the precision of palaeoenvironmental inferences. There remain a series of basic assumptions, however, that apply to most palaeoclimatic work on peat bogs. These include the following:

Mire vegetation assemblages respond to changes in the water table, which is itself responsive to changing climate.

The sub-fossil remains of that vegetation, preserved in mires, are a true reflection of the original vegetation cover at the time of peat deposition.

More decomposition occurs when the mire surface is dry, resulting in more humified peat, a darker colour and fewer identifiable remains than in peat that accumulates when the mire surface is relatively wet.

Reliable age-estimates of the peat profiles, and each point within the profiles, can be obtained.

Coincident dates

A body of published and unpublished research now exists including studies of mires from northern Norway to the south of the British Isles, and from western Ireland to Germany and Poland. The north-south axis forms a discontinuous transect along the eastern coast of the North Atlantic, with clusters of data from some areas, particularly in Norway (Nilssen and Vorren, 1991), Scotland (Anderson *et al.*, 1998; Chambers *et al.*, 1997), northern England

(Barber, 1981; Barber *et al.*, 1994a, b) and Ireland (Blackford and Chambers, 1995). The aim of these studies has been to identify points in the peat profile where the surface environment became wetter, or changed to a drier state. The data show some evidence of palaeoclimatic changes that occur in a number of sites at approximately the same time- within the constraints of the current dating framework- although other apparent changes are less widespread. Some changes in peat bog hydrology appear to have been local features, not consistently represented on a local or regional basis.

Certain dates within the last 5,000 years appear to occur frequently, implying widespread change in peat-forming conditions, the most likely explanation of which is a regional-scale climatic change towards wetter, and /or cooler conditions. These dates are centred around 550, 1,000, 1,400, 2,100, 2,700, and 3,500 radiocarbon years BP (before present, uncalibrated). The evidence for some is greater than others, for example the change at around 2,700 BP has been precisely dated from the Netherlands (Kilian *et al.*, 1995; van Geel, 1996), whereas most ages are based on conventional radiocarbon dating of bulk peat samples, often with a standard deviation in the range 50-80 years (Blackford and Chambers, 1991). The exact, precise, correlation of profiles from different sites is not yet possible, although the introduction of wiggle-matched dating (van Geel, 1996) and tephrochronology (Chambers *et al.*, 1997) to multi-proxy studies makes such correlation likely in the near future. Fig. 1 shows

the humification curve from Rystad, northern Norway (after Nilssen and Vorren, 1991). There are clear points in the profile where abrupt changes to wetter conditions are shown. However, not all of the most common recurrent dates are recorded here.

Evidence for cyclic or periodic patterns

Many peat-derived proxy climate curves appear to have a periodic component. Fig. 2, for example, shows a proxy for degree of decomposition from blanket peat at Migneint, north Wales, UK. Changes in the profile appear regular and rhythmic when smoothed using an unweighted, 3-sample running mean. Quantitative analysis of peat-derived time-series has shown a variety of different signals. Wijnstra *et al.* (1984) suggested a 210-year signal in a combination of peat and pollen data from the Netherlands. Aaby (1976), had found what appeared to be a 260 year cycle in peat data from Denmark, and Barber *et al.*, (1994a) suggested an 800 year cycle in *Sphagnum* macrofossil data from Bolton Fell Moss, northern England. Chambers *et al.* (1997) produced a radiocarbon-dated blanket peat humification curve from southern Scotland, and spectral analysis of the curve showed a 208 year recurrent interval. Although these studies show the likelihood of a recurrent pattern from a number of sites, there are some problems also. Why, for example, do different periodicities appear to occur at different sites? Part of the answer may lie with the dating uncertainty and part with the differences between sites, with some being more 'sensitive' (close to detectable environmental

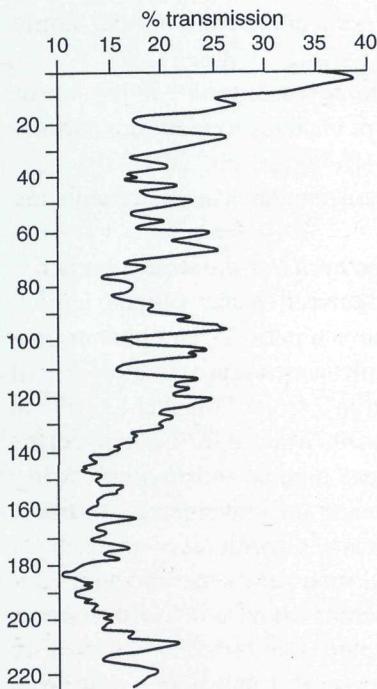


Fig. 2. Proxy peat decomposition curve (percentage transmission) from Migneint, north Wales, UK. An apparently periodic component is present throughout the profile.

Mynd 2. Farnynd av niðurbrotning av proxýtorvi (leiðing í prosentum) úr Migneint í Wales í Bretlandi. At síggja til er reglubundið tilfar tvörtur ígjøgnum allan skurðin.

thresholds) than others. In addition, it should be noted that different methodologies were used for data collection and time-series analysis in all of the studies cited above.

Solar variability and the peat record

Data from western Ireland (Blackford and Chambers, 1995) and from the Netherlands (van Geel, 1996) suggest a link between the palaeoclimatic record from peat bogs and

solar variability. The link with solar variability is not a new idea, but comes at a time of increased interest in solar output variations in the context of current global warming (Hoyt and Schatten, 1997). The suggestion is that periods of high atmospheric ^{14}C , indicative of relatively low solar 'activity', coincide with apparently wetter and or cooler conditions. This connection is suggested by van Geel (1996) as the mechanism for widespread palaeoenvironmental and archaeological changes at 2,650 BP. Other palaeoenvironmental evidence, from lake levels, tree rings, altitudinal limits of tree remains, ice core records and cosmogenic isotopes combine to show that solar variability was an important causal component of Holocene climatic variability (Chambers *et al.*, forthcoming). At times, periodic solar variations may have given rise to the type of recurrent fluctuations shown in several published peat-derived climatic proxies. For example, the Suess cycle at 210 years may be an explanation, although with time lags at different places and for different indicators, of the cycles inferred by Wijnstra *et al.* (1984) and Chambers *et al.* (1997) as discussed above.

The human impact on mires

One of the fundamental assumptions made in this field is that the mire surface represents an environment changing in connection with climatic parameters. There are other factors, however, that influence the rate of growth, vegetation assemblage and degree of decomposition of mires, and these could explain an unknown proportion of the variability shown in individual stud-

ies. One of the most important considerations is that of human impact on the mire surface. Vegetation changes can be caused by the deliberate burning of bog vegetation, by grazing of domesticated animals or herded wild animals, by drainage of the mire either deliberately in order to improve grazing or access, or inadvertently through cutting peat for fuel. People can also alter the hydrological balance of a mire by removing or planting trees. The presence of human influence can be to some extent monitored in the palaeoecological record by analysing the pollen and charcoal content of the peat at times of change (cf. Barber, 1981; Chambers *et al.*, 1997). In their review of peat profiles from Norway, Nilssen and Vorren (1991) noted a connection between increased indicators of anthropogenic impact and changes in the peat humification curve, and suggested that changes in land use may have been a result of climatic change. This suggestion can be (speculatively) developed as follows. The following sequence of events is possible:

A climate change causes the water table to fall, and the mire surface to become drier

Vegetation changes to an assemblage more suited to drier conditions

Grazing and/or hay value of the vegetation increases, and accessibility to the bog for people and animals increases

Land use practices change to take advantage of the new conditions, and vegetation is changed further by the impacts of livestock.

A change to a climatic regime that caused

the peat surface to become wetter could cause the following:

Climate change causes the water table to rise, and the mire surface to become wetter

Vegetation changes to an assemblage more suited to wetter conditions

Grazing and hay values decrease and the land becomes less accessible

Vegetation changes further due to reduced grazing pressure.

There are other limiting factors too- influences that to a greater or lesser extent undermine the basic assumptions listed above. One such factor is that of bog-bursts, catastrophic mass-movement events that remove material from the mire, and lower the water-table over a wider area of the bog. Bog-bursts or flows are known from raised bogs and from blanket mire at a variety of scales, but at a frequency that suggests they must have been a factor throughout the history of most mires areas (Alexander *et al.*, 1986; Carling, 1986; Warburton and Higgitt, 1998). Historical accounts suggest that bog bursts follow periods of heavy rain. This raises the possibility that an event that, in the palaeoenvironmental record, would appear to be a lowering of the water table (and therefore interpreted as a change to drier climatic conditions) could in fact result from a short-term water surplus. There is a clear need, therefore, for careful palaeoecological reconstructions at a high resolution, using pollen indicators of human impact and, where possible, more than one profile should be used.

Climatic inferences

The evidence for environmental changes in the Holocene as reconstructed from mire records suggests periods when climatic conditions became wetter, and/or cooler. Occasionally, times of drier climate have been inferred, although this is thought difficult due to the habit of mires to grow above the water table even in constant conditions. The climates of the peat areas of north-west Europe are greatly influenced by air flowing from the Atlantic, and by the tracking of low-pressure systems, with associated rain-bringing fronts across the continent's western seaboard. By exploiting the north-south 'transect' of peat deposits, it should be possible to infer where, and when, the influence of moist maritime air has been greater, and less, over the late Holocene period. This has been attempted to a limited extent by Magny (1982), who suggested that the broad sub-divisions of the Holocene could be explained by the changing influence of Atlantic-derived air masses. Thus wetter conditions in the north of the region may be associated with drier climates in the south, as depression tracks move north, or indeed the pattern may be more complex.

Peat, climate and the Faroe Islands

The climatic parameters suitable for peat growth are present throughout much of the Faroe Islands, namely an annual moisture surplus and consistent precipitation, coupled with low rates of evaporation. The peat cover has been extensively exploited for fuel however, with most valley and plateau mires having a long history of peat cutting.

Despite this, Persson (1968) described upwards of 2m of peat at several sites, including Klovinmyren (Vágar) where 2.8m of peat, dated at 6,505 (100 BP) at the base, was described. The peat sites thought most suited to palaeoclimatic reconstructions are watershedding, ombrotrophic areas. Much of the plateau areas above 250m are highly eroded, although thin peat covers and isolated pockets of deeper peat can be found. There are three distinct advantages of the Faroe Islands for studies of peat-based palaeoclimatology. First, the location, in the centre of the North Atlantic, close to the atmospheric and oceanic polar fronts, provides great potential in understanding the possible mechanisms of Holocene climatic change. Second, Persson (1968) demonstrated the existence of several tephra layers which can be used for precise dating and correlation (Blackford, 1997). The principle advantage, however, is the apparent absence of humans and large land animals until early medieval times. For the majority of the Holocene period, then, the disturbing influence of people can be discounted.

Conclusions – a testable working hypothesis

There remain a series of problems with peat-based palaeoclimatic reconstruction that need to be solved. However, even within the constraints of these limitations, it has been shown that certain key dates *do* keep recurring in different studies and from different areas. There is also evidence of periodicity in peat bog data, but as yet this has not been shown to be consistent. Further-

more, a possible link between solar variability and peat bog records has been suggested. A transect approach can be used to test the following working hypothesis:

“Periodic latitudinal shifts in average depression tracks over the North Atlantic region have caused periodic, and sometimes abrupt, changes in mire surface wetness, vegetation assemblages and rate of peat decomposition over at least the last 5,000 years”

Furthermore, it may be suggested that a component of such periodicity and abrupt changes could be a result of changes in solar output. This could be tested in turn by attempting to correlate regional proxy climate records with long-term solar proxies namely cosmogenic isotope concentrations (Blackford and Chambers, 1995).

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