RECONSTRUCTING THE LAST 1000 YEARS OF SCOTLAND'S CLIMATE
A History of Weather and Climate in the North Atlantic Region

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Introduction

Much has been written on the history of Scotland. Yet despite, the countless books and papers that trace the footprints of Scottish history to the present, very few documentary accounts have been investigated to extract information on past weather and climate. This is somewhat surprising given our preoccupation with weather and more widespread concerns in respect of 'global warming'. The lack of attention to climate and weather in Scottish history is well illustrated through inspection of virtually every history textbook where there is scarcely any mention of past weather or climate. This is all the more surprising since Scotland has experienced famine on many occasions during the recent historical past – are we thus to assume that all such famines were due to social and political factors – surely not! In the following introductory account, attention is focused on four aspects of the climate and weather of the North Atlantic region that are important in shaping Scotland's climate. Changes in air temperature are considered first. These are followed by a discussion of changes in North Atlantic storminess. Thereafter the role of the North Atlantic ocean in effecting climate change is discussed since the interaction of ocean and atmosphere is so vital an influence on our climate and weather – here we consider firstly the significance of oceanic sea ice and secondly the significance of sea surface temperatures on climate change across the North Atlantic. This brief account, therefore, should serve mark out the starting point of a very complex yet fascinating subject that has an important bearing on the cultural development of Scotland since the time of the first settlers ca. 9,000 years ago.

Chronologies of former air temperature

The first detailed and continuous records of daily weather for Scotland are available from 1867. Prior to this, daily weather records are available for a number of sources but each is restricted to shorter intervals of a few years in length. For example, weather records are available for the Isle of Raasay from 1855 until 1910 (although there are some missing years) while earlier records for Edinburgh are available for the period 1800-1832 from the measurements of Adie. Similarly, a ten year record of air temperatures for the Duke of Buccleuch estate of Branxholm is available for the period 1773-1783. Prior to this record, other accounts are available from diaries, for example those of Turnbull of Alloa (ca. 1690s) and Lamont of Edinburgh (ca. 1650s) although these tend to give monthly temperature summaries. Popular newspapers such as the *Scots Magazine*, first published in the 1740s, contain air temperature data, principally for Edinburgh. The author is not aware of any diary written prior to that of

John Lamont that provides detailed air temperature data for any part of Scotland.

Prior to the 1650s, therefore, it is difficult to reconstruct in any detail, patterns of weather for Scotland. However, there is a very valuable source of proxy weather data for the North Atlantic region contained within the ice of the Greenland ice sheet. Drilling projects undertaken during the 1980s by American and European scientists recovered several thousands of metres of ice. Within the frozen cores are contained various indicators of past weather and climate. For example, measurements of the isotopes of oxygen within the ice give information on past seasonal changes in air temperatures across Greenland. Measurements of concentrations of sodium ($Na+$) that accumulated through the deposition of sea salt on the ice sheet surface provides a past record of North Atlantic storminess. Similarly, measurements of the chlorine chemistry through each ice core have provided valuable information on periods of time when sea ice was extensive across the Greenland Sea and northern North Atlantic. Measurements of deuterium likewise have provided valuable information on past changes in North Atlantic sea surface temperatures.

One must never assume, however, that past increases and decreases in annual air temperature over Greenland were paralleled by changes of similar sign across Scotland. The existence of a climate 'see-saw' between western Greenland and northern Europe has been known for over 200 years. For example, van Loon and Rogers (1978) quote the missionary Hans Egede Saabye who described in a diary kept during the years AD 1770-78 that *"…In Greenland all winters are severe, yet they are not alike. The Danes have noticed that when the winter in Denmark was severe, as we perceive it, the winter in Greenland in its manner was mild, and conversely"*. Similarly, it has been observed that mild winters in western Greenland frequently correspond with reduced winter temperatures in northern Europe.

The 'see-saw' in winter air temperatures is linked to interannual variability of the Icelandic low pressure cell and the North Atlantic Oscillation (an index based on an analysis of a time series of monthly air pressure differences between Iceland and the Azores). Thus severe winters in northern Europe occur when westerly winds in the North Atlantic region are weak and, there is a blocking ridge of high pressure across the eastern Atlantic and where air temperatures are higher than average across western Greenland. During such periods, northerly flow of air around the east side of the ridge advects cold, polar air from the Arctic across Europe. By contrast, when a cold northerly airstream on the eastern flank of the winter Canadian anticyclone moves over western Greenland, there is marked increase in cyclone frequency across the northern North Atlantic and Scotland experiences its stormiest winters with a dominance of SW winds and an increase in winter air temperatures.

In Scotland, the fragmentary accounts that are available point to a sustained decline in air temperatures during the late 17th century. In particular, the decade of the 1690s is well known for the famines associated with the poor weather and is sometimes referred to as *"...the lean years of dear King William..."*.

The decline in air temperatures enabled the establishment in the 1770s of the Edinburgh Skating Society and it may be the case that such lowered temperatures may have persisted until the close of the 19th century. Remarkably, the derived air temperature time series for central Greenland based on oxygen isotope analysis does not show a clear signal of the Little Ice Age having occurred in central Greenland. Remarkably, two of the coldest winters in central Greenland during the last 2000 years occurred during the winters of AD 1982-83 and 1983-84. During these two winters the average winter air temperatures were respectively –8.6 and -9.0°C below the long term average. By contrast, the same winters were associated in Scotland with average winter air temperatures +0.9 and +2.0°C above the long term average. This simple illustration demonstrates very clearly that it is a big mistake to imagine that past trends in air temperature are of the same sign everywhere – even across such a relatively small area of the earth such as the North Atlantic marked regional differences are very evident.

Changes in North Atlantic storminess

Whereas the oxygen isotope record from central Greenland represents a record of air temperature changes over central and West Greenland, the sodium (Na+) concentrations (sea salt) time series represents a chronology of regional changes in North Atlantic storminess. Plots of the Na+ series for the last 2000 years show a dramatic increase from about 1400-1420. Prior to this period, the winter climate of the North Atlantic was almost unrecognisable from that of today since rarely were there large storms. After 1400-1420, North Atlantic winter storminess became commonplace and this pattern has continued until the present. If one was to select a point in time when the Medieval Warm period (associated with Viking expansion) ended and the Little Ice Age started, it would be at this time. Although distant from Scotland, it should not be forgotten that the last records of Viking settlement in Greenland date to the 1420s. After this time all contact with the Vikings in Greenland was lost. Thus we can envisage the first settlement in Greenland during the 980s as having taken place during a mild episode of the Medieval Warm period during which time winter storminess was at minimum – it would not be inaccurate to suggest that similarly milder winter weather prevailed in Scotland at this time. In Scotland, the dramatic change in winter weather to Little Ice Age conditions marks the time when winters started to become markedly stormier. For example, the accounts by Stevenson of lighthouse construction around the coastline of Scotland provide graphic account of many storms during the late 18th and early 19th century. Other storms left profound marks on Scottish history. For example, a huge storm smashed and scattered the Spanish Armada as far afield as Fair Isle during 1588 while a summer hurricane in 1832 destroyed the haaf fishery fleet off the Shetland Isles.

Changes in sea ice extent

In the 1880s the Royal Geographic Society in London received a report from a Captain Gray of Peterhead on the state of sea ice cover across the northern North Atlantic. The purpose of Captain Gray's report was to draw attention to

the huge increase in sea ice cover across the northern North Atlantic that had taken place during the preceding decade. His account expressed concerns that a new ice age may be imminent. Sea ice is normally no more than 1-2 m in thickness. It forms when cold air blows over the northern ocean and is of sufficiently low temperature to cause the surface salt water to freeze. As the sea ice begins to forms, it expels salt into the adjoining waters thus making them dense and causing the saline water to descend to the floor of the ocean. The sinking of this salty water and its return southward flow over the floor of the Atlantic constitutes an important part of global ocean circulation while evaporation of moisture from the northward flowing surface current provides an important part of the supply of heat to northern Europe. The development of sea ice across northern waters is thus an important mechanism in controlling the amount of water that descends to the floor of the Atlantic. It is also important since each summer its melting produced enormous volumes of fresh water that rest upon the ocean surface and only slowly mix with the underlying saline water. Periods of cold climate in Scotland in the past have thus often coincided with periods of increased sea ice cover. In the most extreme case during the last ice age ca. 20,000 years ago, sea ice during winter reached as far south as the latitude of Spain and Portugal. More recently, during the so-called Little Ice Age that affected Scotland between the 15th and 19th centuries it may have reached at its maximum extent as far south as the Shetland Isles. Indeed, according to newspaper reports of the early 1880s, it was possible to climb the hill above Torshavn, the capital of the Faroe Isles and not be able to see the ocean owing to presence of vast areas of sea ice offshore. The occurrence of vast areas of sea ice across the northern North Atlantic may also go some way to account for the arrival in Aberdeen harbour during the 1790s of two Eskimos in a kayak who had most likely been trapped in the extensive areas of sea ice that reached at that time to ca. 50-100 km north of the Shetland Isles. Much has also been written of the importance of sea ice in the demise of the Viking settlements of west Greenland during the early 15th century through its role in restricting the passage of sea vessels between Scandinavia, Iceland and Greenland.

Analysis of Greenland ice core chemistry as well as the Viking sagas has also helped to provide a remarkable record of past changes in sea ice extent. It appears that a prolonged period of reduced sea ice cover occurred between ca.AD 200 and 1400 with two possible reversals during the early 8th century and the late 10th century. For the most part, therefore, Viking expansion in Scotland took place during benign climatic conditions during which seafaring was much easier than it later became from the 15th century onwards. According to the Viking Sagas, sea ice first appeared around Iceland during the 1270s. After ca. AD 1420 there appears to have been a stepwise increase in sea ice extent that culminated as late as the 1880s.

The presence or absence of sea ice cannot be underestimated in its importance to climate changes across the North Atlantic (and hence also Scotland). Sea ice starts to form during December and reaches its maximum extent during May/June. Thus, during years when sea ice was very extensive,

its presence may have played an important role in determining the nature of summer weather across Scotland. During such times, the North Atlantic storm track was displaced farther south than normal and, under such circumstances, 'big' sea ice years were often accompanied by summer storminess. During the 19th century some of these storms took fishermen by surprise and led to loss of life, particularly in the Shetland fisheries but also notably in the case of the Eyemouth tragedy of 1881.

Changes in North Atlantic sea surface temperature

Greenland ice core data has also been used to derive annual records of past North Atlantic sea surface temperatures through the application of deuterium excess analysis. To date , this analysis has been used to reconstruct seasonal sea surface temperature changes for the last ca. 700 years. The patterns of change that have been calculated point to particular time intervals during which major and rapid changes in ocean circulation have taken place and almost certainly linked to past changes in ocean circulation. One of these changes took place between ca. 1400-1420 coincident with the sharp increase in N Atlantic storminess. During these two decades, North Atlantic ocean temperatures did not rise appreciably during summer nor did they fall during winter. The most dramatic changes, however, took place between ca. 1315-1335. During this time there was an exceptional period of ocean warmth (warmer during both during summer and winter for about 5 years) that was followed by a switch to about 5 years of ocean cooling (cooler during both during summer and winter). This pattern of change was repeated again between 1325-1335. Historical accounts of past weather show that the episodes of ocean warming were associated with exceptional rainfall (winter and summer) across the UK while the episodes of cooling were associated with drought. It remains for historians to evaluate the degree to which these remarkable changes in climate played a part in post-Bannockburn Scotland, regarded by many as a time of dearth and famine.

Summary

Information on past weather and climate for Scotland is available in most library archives. Most of this information has never been examined in any detail. Many historical diaries also contain valuable information on past weather yet few diaries have been read carefully in order to extract meteorological and climatological data. Similarly, indexed newspapers contain valuable weather records in their pages. At present these various sources of weather data are being painstakingly examined for the first time in order to piece together a chronology of past climate. The task is an onerous one but one that yields fascinating insights into the past weather events that posed such tremendous challenges to our ancestors.

Further Reading

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