Historical climatology – a state of the art review

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Documentary evidence from historical times for the pre-instrumental period is one of major sources of evidence available for the study of past climates. It complements and generally provides support for evidence available from a wide variety of natural archives (tree rings, ice cores, corals etc.). For an extensive discussion of the latter see Jones and Mann (2004). Documentary evidence is generally limited to regions with long written traditions, such as Europe (Le Roy Ladurie, 1971; Bradley and Jones, 1995; Martin-Vide and Barriendos, 1995; Pfister *et al.,* 1998*;* Rodrigo *et al.,* 1999; Ogilvie and Jónsson, 2001), eastern Asia (Wang and Zhao, 1981; Zhang and Crowley, 1989; Wang *et al.,* 2001), and more recently from North America (Bradley and Jones, 1995; Druckenbrod *et al.,* 2003; Overland and Wood, 2003) and South America (Quinn and Neal, 1992; Ortlieb, 2000). Additional examples to be added to this list appear later in this special edition with examples ranging from Japan and the Philippines to the North Atlantic Ocean and Central Europe.

An extensive review of the subject is provided by Brázdil *et al*. (2005), emphasizing studies from Europe. The types of sources include written records of frost dates, droughts, famines, the freezing of water bodies, duration of snow and sea-ice cover, and phenological evidence (e.g. the dates of flowering of plants, and crop yields). All can provide insight into past climate conditions (Wigley *et al*., 1981; Bradley and Jones, 1995; Bradley, 1999; Luterbacher *et al*., 2002a, b). Most temperature-driven evidence relates to the warm (growing) season as it is phenological in nature (i.e. consisting of vine and crop harvest dates etc.), but evidence about past springs (blossom dates) and winters (freezing of rivers, days of snow lying) is also reasonably plentiful. Indications of the temperature during the autumn, however, are rare (Pfister, 1992). Complementary indices have also been derived for precipitation (wetter/drier seasons) but these tend to highlight the extreme (floods/droughts) nature of precipitation variability (Brázdil *et al*., 2005).

Evidence is not limited to terrestrial regions as logbooks from European maritime nations, such as Spanish Galleons crossing the Pacific Ocean during the sixteenth to nineteenth centuries, provide possible insights into variations in the strength of the prevailing winds (García-Herrara *et al*., 2001). Information from ships' logbooks from as early as the late seventeenth century have provided new insight into the nature of marine climates of the past (García-Herrera *et al*., 2005; Wheeler and Suarez-Dominguez, 2006). Documentary information from South America enables a chronology of El Niño to be developed over the past few centuries, complementing evidence provided by natural proxies, such as tree rings and corals. Reconstructions of phenomena such as the El Niño/Southern Oscillation (ENSO) enable the series to have much wider importance than purely of local interest (García-Herrara *et al*., 2008). Human accounts (e.g. through artistic depictions) of mountain glacier retreats and advances during past centuries provide evidence of climate change on more low-frequency timescales. Emphasis in this article, however, is given to documentary evidence that enables long series to be developed, as opposed to isolated and less continuous information, which is less useful and has less climatic relevance. Some of the most well-known anecdotal information, which has led to popular beliefs about the last 1000 years in Europe and the North Atlantic region, are discussed in comparison to the long, continuous time series in the second part of this article.

Problems of developing long documentary series

Historical documentary information tends to emphasize extreme conditions as these were generally the most important phenomenon that deserved recording. Information from different observers may be further biased as the qualitative standards used to reflect climate conditions are likely to be observer-dependent. Does the 'coldest winter in living memory' have the same meaning to observers living at least a century apart? The best measures are those that are objective and less dependent on individual observers (frost day and snow day counts, freezing of rivers, crop harvest dates and yields), with the more direct temperature proxies in winter providing the more useful spatially extensive indices, especially when compared to flood levels which can be localized in their impacts.

Development of long series, therefore, needs to be undertaken with care and in a consistent and repeatable way. The principal keys to developing long series of reliable climatic measures are the selective use of contemporarily reported material (Ingram *et al*., 1981) with a rigid control of dating, together with rigorous inter-comparison of sources, building up a basic reliability measure for each individual reporter and type of evidence. Modern analysts of documentary evidence (exemplified by Bell and Ogilvie, 1978) stress the need to consult the original sources and not to use early-twentieth century compilations (such as those of Easton, 1928 and Britton, 1937). Well-known climatologists (Bryson, 1962; Lamb, 1965) pioneering the use of documentary climate histories in the 1960s often used less than reliable sources of information taken from these questionable compilations (Ogilvie and Farmer, 1997).

Calibration of the documentary information is generally achieved by the use of a 'scaling or grading' procedure. Evidence is grouped (generally for seasons) into a number of 'categories' ranging from the coldest to the warmest or from the wettest to the driest. The number of categories is determined subjectively by the amount and quantity of the documentary evidence available and is usually in the range 5–10 (see the extensive discussion in Pfister, 1984 and van Engelen *et al*., 2001). Greater discriminating power (more categories) is usually possible in more recent centuries, when more evidence is available. Documentary series developed in this way rarely extensively overlap with instrumental series, as the recorders/diarists were keen to use the newly developed instruments and quickly abandoned their narrative accounts. For the instrumental period, analysts 'degrade' the modern instrumental data into the same number of categories used for the documentary period (Pfister, 1984; van Engelen

et al., 2001). Users should be mindful of this aspect when developing multi-proxy compilations (Jones *et al.*, 1998; Mann *et al.*, 1998, 1999; Mann, 2001) as it is clear that the quality of the pre-instrumental part of any documentary series must be poorer than the modern instrumental part, which is essentially 'degraded' instrumental data (Jones *et al.*, 2003).

Anecdotal evidence for the last millennium

So far, this article has emphasized the work of historical climatologists who have combined detailed information and rigorous statistical techniques in order to develop long, continuous and well-replicated series. Despite these extensive research efforts, anecdotal evidence concerning the last millennium based on factually dubious beliefs is still rife. There are three specific examples, each of which is repeatedly cited as providing evidence about earlier periods: (1) the freezing of the River Thames in London in past centuries, (2) the cultivation of vines in Medieval England, and (3) the settlement of Iceland and south-western Greenland about 1000 years ago. Each is examined in turn compared to documentary and early instrumental data.

River Thames freeze-overs (and sometimes frost fairs) only occurred 23 times between 1408 and 1814 (Lamb, 1977) when the old London Bridge constricted flow through its multiple piers and restricted the tide with a weir. Figure 1 shows the character of Old London Bridge with its many arches and obstructions to flow. Not all the 23 events had strong enough ice for frost fairs. After the Bridge was replaced in the 1830s, the tide came further upstream and freezes no longer occurred, despite a number of exceptionally cold winters. 1962/1963, for example, was the third coldest in the Central England temperature (CET) record – the longest instrumental record anywhere in the world extending back to 1659 (Manley, 1974; Parker *et al.*, 1992; Jones, 1999), yet the river only froze upstream of the present tidal limit at Teddington. Freeze-overs before 1408 are less well reported given the sparser evidence that far back in time, but there are some records of dates and durations available (http://en.wikipedia.org/wiki/River_Thames_frost_fairs). Note should be taken of the earlier discussion on the need to consult the original sources to ensure adequate dating practice and contemporaneous reporting.

Figure 2 shows CET and Low Countries winter temperature values from 1251, together with the dates of the 23 freeze-overs of the Thames in London up to 1814 (the more extensive of which led to frost fairs, although these weren't named as such until the winter of 1607/1608). The different character of the instrumental series (CET) and the 'categorical' documentary series (Low Countries)

Figure 1. The frozen River Thames during December 1676 by Abraham Hondius. (Reproduced by kind permission of the Museum of London.)

should be immediately obvious. The latter has nine different (index) possibilities which have been transformed back to degrees Celsius using a conversion scale given by van Engelen *et al.* (2001). The lack of more detailed winter-to-winter temperature averages in this latter case does not appear to have an impact on the low-frequency character of the series, as both show similar variations – as would be hoped for.

The frost fair and freeze-over information only gives sporadic information about

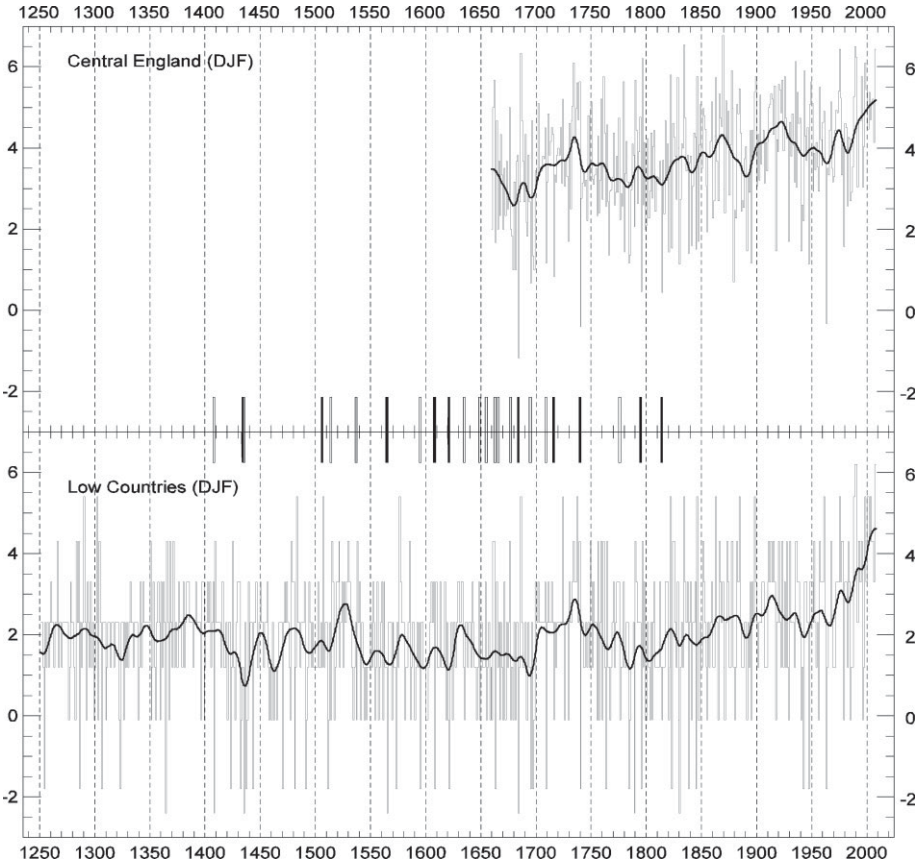

Figure 2. Winter temperatures (December to February, dated by the January) for Central England (Manley, 1974, updated) and for the Low Countries (van Engelen et al., 2001, updated). The latter series extends from 1251 to 2007, with CET spanning 1660 to 2007. The series are smoothed with a 50-year Gaussian filter. In updating the Low Countries winter temperature series, recent winters have been degraded into the documentary categories used throughout the record. In between the two series, winters where the Thames froze over in London are marked and these are filled when there is recorded evidence of a frost fair (after Lamb, 1977); 39 winters (with no assessment) have been assumed to be 'normal' (i.e. category 5 on the van Engelen et al., 2001 scale) between 1251 and 1413.

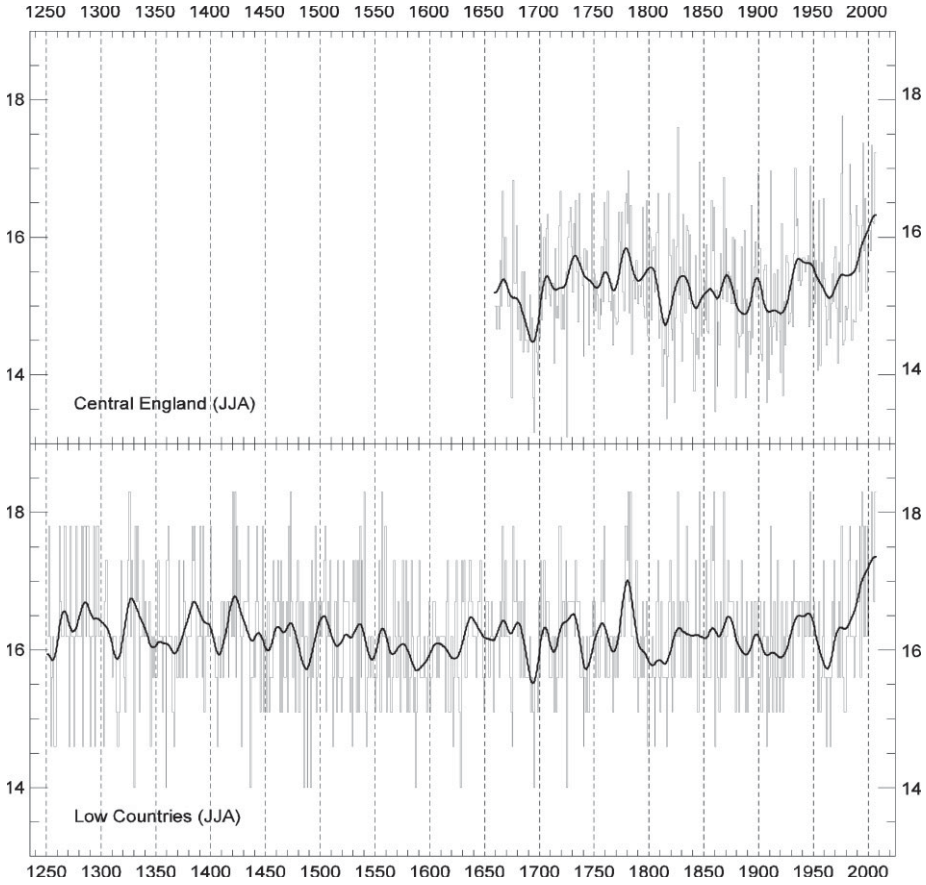

Figure 3. Summer temperatures (June to August) for Central England (Manley, 1974, updated) and for the Low Countries (van Engelen et al., 2001, updated). The latter series extends from 1251 to 2006, with CET spanning 1659 to 2006. The series are smoothed with a 50-year Gaussian filter. In updating the Low Countries summer temperature series, recent summers have been degraded into the documentary categories used throughout the record; 20 summers (with no assessment) have been assumed to be 'normal' (i.e. category 5 on the van Engelen et al., 2001 scale) between 1251 and 1446.

winter severity. The series shown in Figure 2 provide much more useful and continuous information. For example, the frost fairs indicate two dates (1716 and 1740) as major events. In between these dates, most winters were mild with a strong warming trend (Jones and Briffa, 2006). After 1740 there were no further events until 1776 and 1795, but for this period there was a marked cooling trend from the 1730s through to the 1780s. It is also clear that some freeze-over events do not always correspond to markedly cold winters in the Manley (1974) series.

Both of the series indicate a long-term trend towards warming throughout much of the period from about 1800 onwards. Over the yet longer term from 1250 to about 1800, winters in the Low Countries showed no overall change, rather periods of gradual warming punctuated by shorter periods of more rapid cooling are clear. The period of rapid warming from the late-seventeenth century to the late-1730s has been discussed in Jones and Briffa (2006). Finally, in the Low Countries series, it can be seen that only two winters were classified by van Engelen *et al*. (2001) as category 1 (mildest) between 1251 and 2000 – those of 1988/1989 and 1989/1990. In updating the series to include the most recent winters, that of 2006/2007 has also been classified in the mildest category. It was the warmest on record since instrumental records began in 1706 and 0.5 deg C warmer than the previous record in 1989/1990.

Monks in Medieval England grew vines as wine was required for the sacrament of communion. With careful husbandry vines can be grown today and indeed vineyards are found as far north as southern Yorkshire. There are in fact a considerably greater number of active vineyards in England and Wales today (roughly 350) than are recorded during medieval times (52 in the Domesday Book of AD 1086), exposing as distinctly curious the claims sometimes made that evidence of vine growing in Medieval England provides evidence of unusual summer warmth at that time. Vine growing persisted in England throughout the millennium. Thus, the oft-cited example of past vine growing in England reflects little, if any, on the relative climate changes in the region since medieval times and emphasizes the importance of long-term derived series such as the Low Countries series.

Figure 3 shows the summer (June to August) season variations for CET and the Low Countries. The coolest summers for both series occurred in the 1690s, with the mildest recently and in the late 1770s and early 1780s. The character of the Low Countries series changes before about 1300, as there is less discriminating power in the historical documents to be able to classify into more than just three categories, as opposed to the nine categories for most years from 1300 onwards. As with the winters for these two series, there is little evidence of long-term change beyond that for milder summers in recent decades and in the trend shared with the winter series. All of the recently updated summers are in the 'warm' categories with 2003 and 2006 being in the 'extreme warmest' category.

The third piece of anecdotal evidence often cited about the early centuries of the millennium relates to evidence from Iceland and Greenland. Iceland was settled mainly from Norway and the northern British Isles beginning ~ AD 871. The further migration to south-west Greenland approximately one century later, by a small group of Icelanders, was the result primarily of a political and economic need to leave Iceland (Ogilvie and Jónsson, 2001). Climate was not a factor in their decision despite claims otherwise that still appear in the literature (Soon and Baliunas, 2003; Soon *et al.,* 2003). The south-western Greenland settlements survived for many centuries, but in the mid-fourteenth century the more marginal and more northerly located 'Western' Settlement was abandoned (Figure 4 shows part of what remains of the 'Eastern' Settlement). There were a number of reasons for this, including cultural and economic factors. It seems likely, however, that climate did play a part in the abandonment. The focus of their economy on animal husbandry denied them the advantages of hunting marine and other mammals that ensured the survival of their Inuit neighbours. A series of unusually late springs and cold summers may have helped to make an already marginal situation untenable (Barlow *et al.,* 1997). The more southerly 'Eastern' Settlement survived to around the mid-fifteenth century (Buckland *et al.,* 1996).

Related myths exist for the North American continent. Overland and Wood (2003), for example, have recently demonstrated that, despite past claims that the extreme cold of the 'Little Ice Age' impeded the navigation of the Northwest Passage in the Canadian Arctic during the early nineteenth century, an exhaustive study of nineteenth century explorer logs for the region yields no evidence of unusually cold conditions. It is interesting to note that the recent demise of sea-ice cover across much of the Arctic has enabled the Northwest Passage to be navigable in most recent summers, although this is much easier with information from satellites!

The final comparison in this article compares documentary evidence in Iceland with an oxygen isotope record from Greenland and recently extended winter tempera-

Figure 4. The last written record giving contemporary information concerning the Greenland Norse is to be found in an entry in the Icelandic Annals for 1408. This documents the wedding of Sigríður Björnsdóttir and Thorsteinn Ólafsson, both from Iceland. This photograph shows the ruin of Hvalsey church adjacent to Hvalsey ('whale island') fjord where the marriage was celebrated on 19 September 1408. The location is the Eastern Settlement area of the Greenland Norse (modern-day Qaqortoq). The ruins of some 14 structures are also to be found close by, and probably represent a major farmsite. (By courtesy of Jette Arneborg (National Museum of Denmark).)

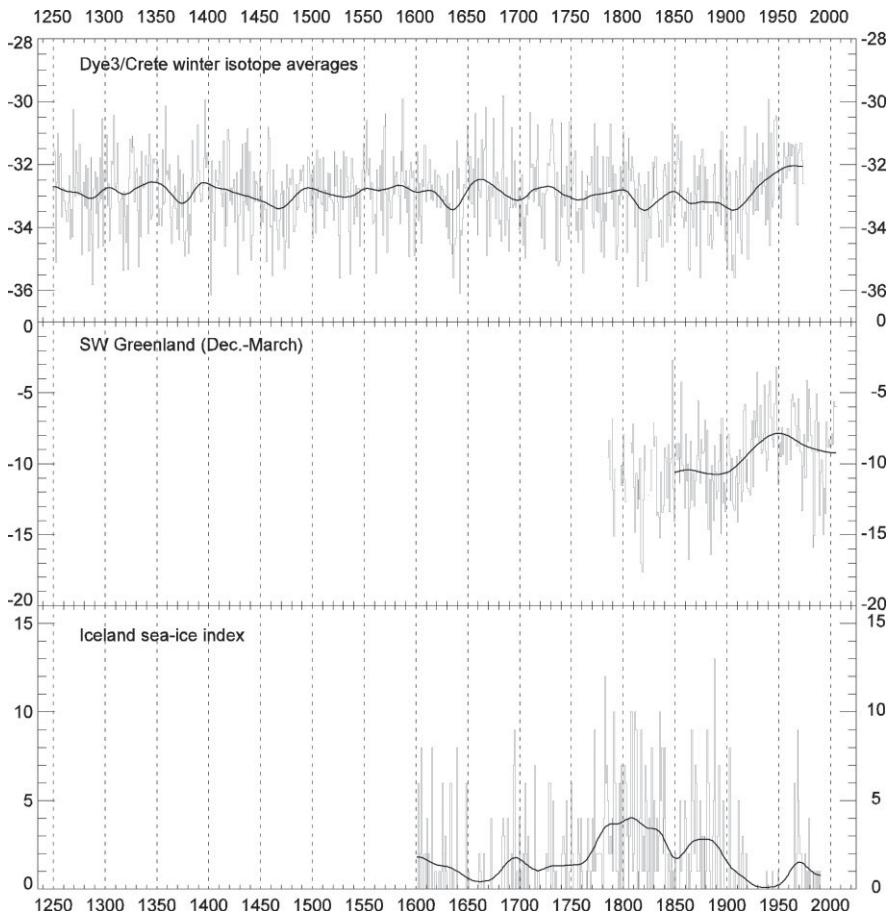

Figure 5. Winter isotope values for southern Greenland (average of the Dye 3 and Crete ice cores, see Vinther et al., 2006), south-west Greenland winter temperatures from instruments (December to March from Vinther et al., 2006) and an Icelandic sea-ice index from Ogilvie and Jónsson, 2001, for 1601–1850, updated based on a regression over the 1801–1850 period using the updated Koch, 1945 index). The ice-core series extends to 1973 and the sea-ice index series to 1990. The series are smoothed with a 50-year Gaussian filter.

tures for south-west Greenland. Figure 5 shows 'winter' temperature 'measures' from Greenland and Iceland. These include instrumental winter (December to March) temperatures (from Vinther *et al*., 2006, back to 1784, but with some missing winters before about 1840), winter isotopes from a composite of two ice cores (Dye 3 and Crete from Vinther *et al*., 2006) and the winter/spring sea-ice extent north of Iceland from 1601 (derived from Ogilvie and Jónsson, 2001 and updated from 1851 using the updated Koch 1945 index based on a regression of the two series over the 1801–1850 period). The instrumental temperatures agree with the isotopic series producing a correlation coefficient of +0.57 for the 176 'winters' with data between 1784 and 1973. This correlation is stable over the full period of record (Vinther *et al*., 2006) and it is the most convincing relationship (principally because of its record length) shown between instrumental winter temperatures and an isotopic series anywhere in the world. The correlation is stronger than with the individual ice cores, and has been enhanced by averaging the two series and cross-dating the ice-core layers over the last millennium (Vinther *et al*., 2006). There is no correlation though between the sea-ice index's extent north of Iceland and either of the other two series. South-west Greenland winter temperatures have been shown by many (Stephenson *et al*., 2003) to be inversely related to winter temperatures over Scandinavia, so it should come as no surprise that there is little relationship with air temperatures from Iceland and the correlation between the southwest Greenland temperatures and Stykkisholmur (north-west Iceland) is a modest +0.29 based on 175 years of winter data between 1824 and 2000.

Conclusions

This Special Issue has discussed the current state of documentary evidence around the world whilst this particular article has emphasized the North Atlantic/European sector and has shown that documentary sources can be developed into very useful series, which complement and support both long instrumental records and natural proxy evidence. The principal problem for documentary climatologists is that some of their material is widely used out of context and in a very simplistic manner. This article has attempted to provide some background to the key approaches that must be understood and followed when developing useful, climatically relevant, documentary-based series. The contrast between the 'simplistic' and the 'best practice' use of documentary material is illustrated through the three most commonly referenced myths about the past millennium. Frost fairs and freeze-overs of the River Thames occurred 23 times between 1402 and 1830, and they are offered by some as

evidence of cold periods in the past. There are instrumental temperature data, however, back to 1659 for Central England and documentary data to 1251 (and earlier but less complete) for the Low Countries. The latter are always to be preferred and they provide a more complete picture, rather than limited information for a few winters from an event that principally results from the design of the first London Bridge. Equally, vines can be grown in northern England today and their productive growth was not an exclusive feature of some past 'warm period'. Again there are the same (Central England and Low Countries) long series providing continuous evidence of changes in summer conditions over north-western Europe on which to make a more definitive assessment of past warmth. Finally, there are long natural proxy and documentary records that can be used to assess long-term changes in both winter and summer climate over Greenland and Iceland, which enable the last millennium to be assessed and inter-compared and not judged on the basis of two marginal and relatively short-lived European settlements in Greenland.

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From the Archives – *Weather* 30 years ago

The July 1978 issue of *Weather* commemorated a visit to the Society from Her Majesty the Queen on 14th July. The occasion was the official opening of the Society's then headquarters at James Glaisher House in Bracknell. The issue included a number of specially commissioned articles to mark the occasion. These included a review of highlights from the Society's publications by J. S. Sawyer and a history of the Society written by Robert Ratcliffe. A biographical note on James Glaisher was written by a descendant of Glaisher, J. L. Hunt. Photographs of the visit and the associated exhibition in Bracknell College appeared in the November 1978 issue.

The issue also included one of Mr P. C. Spink's many articles on Scottish snowbeds. It was noted that after the complete loss of snow during the hot, dry summer of 1976, the following year featured the heaviest January to May snowfalls in Scotland since 1951. Amongst the contributors to the Letters pages were C. K. Folland, Cicely M. Botley, W. J. Burroughs, S. G. Irvine, G. T. Meaden and Ingrid Holford.

Editor