CLIMATIC CHANGES AND HUMAN GEOGRAPHY: SCOTLAND IN A NORTH ATLANTIC CONTEXT

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The way in which many Scots have taken up today's popular concern over "Global Warming" seems somewhat paradoxical. Through much of our history, cooling rather than warming has been our problem. Nowadays, however, most people seem blythely unaware of just how near-run a thing it has been for us to have escaped a renewed glaciation of Scotland in recent centuries. Those who proclaim themselves to be Friends of the Earth appear to have missed the point that by our dirty habits we may well have polluted ourselves out of the imminent onset of another episode of the Ice Age.

In terms of the planet as a whole, the phase in which we live appears as merely one of the many intermissions (interglacials) which have temporarily intervened in the Quaternary Ice Age. This is the implication of field evidence, and of the Milankovitch radiation curves (which calculate from the changes in the geometry of the solar system just how much of the sun's energy output will benefit the earth). The Ice Age has now been going on for over two million years, and in this there have been many interglacials which have been both longer and pleasanter in their climate than the phase in which we are living. Indeed, the Holocene period we are in at the moment has every appearance of having passed its best in the so-called Climatic Optimum, over 5000 years ago. There have been ups and downs, but we have been essentially on the road downhill since then; and in places like Scotland we have been quite close to the re-establishment of glaciers during much of the medieval and post-medieval period.

Indeed, the late Professor Gordon Manley suggested that a drop in our mean annual temperature of the order of only 1 to 3 degrees Celsius would result in snow lying every year in the Cairngorm corries right through the summer, so that more would accumulate with each winter's fall. He calculated that in one lifetime of three-score-years-and-ten, if we had weather at the more miserable end of the spectrum which we now experience (needing nothing as hard as some of the individual winters we have had in living memory), enough snow would accumulate to compact into 'firn': that is granular ice, which would start oozing out from the corries under its own weight, and extending as little glaciers into the valleys below. Then even if the climate did warm up again slightly thereafter, the area of the glaciers would have an ice-box effect on the precipitation coming in off the Atlantic, and a new phase of glaciation could get underway. We appear to have come very near to this at several phases in historical times: for example when Pennant was making his tour in 1769, he noted that snow lay from year to year on places like Ben Ann.

Though we have so far escaped actual re-glaciation here during the period of written history, evidence both direct and indirect (e.g. Grove 1988, Parry 1978, Lamb 1972/1977 & 1982, Price 1983, inter al.) makes it clear that we have had variations in our climate, and that it would be unwise to neglect their practical importance for the people of Scotland. There can be little doubt, for instance, that these variations have altered the amount of land which it was reasonable to attempt to cultivate (e.g. Wigley, Ingram & Farmer [eds] 1981).

This was illustrated vividly by a study of the potential upland limits for cultivation carried out by Martin Parry in the Lammermuirs (Parry 1978, 1981, Parry and Carter 1985). To give him an objective starting point, he used data from agricultural research stations and meteorologists to define the physical limits for crop growth on the slopes there. It was found, for example, that for oats to ripen satisfactorily, a minimum of 1050 day-degrees of summer warmth above a threshold of 4.4. degrees was required. Exposure to wind, and the amount of end-of-summer wetness, were also major factors which had to be taken into account. It was calculated that if the mean temperature fell even by a fraction less than one degree, at 300m altitude frequency of crop failure increased seven-fold (from one year in twenty, to one in three), with the prospect of two consecutive crop failures being increased by seventy times. For subsistence farmers relying on their own produce, the danger was not so much the prospect of having one bad year in isolation (you could tighten your belt, and trust to get by). The real catastrophe was to be confronted with two failures in consecutive years, because then you would have to eat your seed corn, and even if the third year was better, you were still likely to starve then. In southeast Scotland, in the relatively bland period of our own lifetimes (statistics for 1931-1980) the upper climatic limit for reliable ripening of oats is around 365m (ca 1200ft), whereas during the cool period of 1661-1710 the ground over 280m (less than 920ft) was sub-marginal for oats cultivation. Above 340m, the calculation indicated a complete succession of harvest failures for all eleven years from 1688 to 1698.

Results such as these can be obtained by combining information from botany and meteorology on the one hand, with information on the sequence of climatic changes on the other. The main difficulty lies in securing the latter, when researching the period before direct meteorological observations were recorded scientifically. In attempting to use indirect lines of evidence, there is a great danger of circular argument, not least if one attempts to deduce climatic change from fluctuations in the upland limits of cultivation. It is not merely a matter of the scope for mis-dating unexcavated settlement sites, and the notorious diffficulty of dating field systems at all precisely. There is the basic problem that even when securely dated, the pattern of remains on the ground may reflect very different criteria from those sought by the climatologist. What people actually choose to do is of course by no means necessarily synonymous with what is theoretically possible in terms of their physical environment.

For example, people may farm farther up the hill even in climatically difficult periods because they rate the risks of using climatically more marginal land as being less dangerous than the human hazards of living down in the lowlands in time of strife: a very real factor in Scotland with its history both of foreign invasion and of endemic factional disorder.

Alternatively, people may descend from the hills even in times of better climate, if more land becomes available in lowland areas, for instance because of forest clearance, improved drainage, or stripping of peat from carselands, say.

Furthermore, the pattern of pressure on available land resources may change through factors such as the Black Death, or demographic trends must less dramatic than that.

Similarly, local changes in spatial patterns may arise from alterations in the balance between subsistence agriculture and more commercially oriented types of land use. These in turn may reflect either regional economic and social changes, or international initiatives (such as, say, the development of wool trade by the Cistercians).

The problem of distinguishing actual variations in the general climate from local phenomena is further exacerbated by the way that people and their animals can change microclimates by altering the ground cover. For example, in much of Scotland, when the mature 'climatic climax' forest cover which had evolved over millennia has been destroyed (either deliberately or inadvertantly), this has given rise to wind-blasted moorland, where it is difficult for trees to re-establish themselves. Climatic deterioration has sometimes exacerbated the situation, but on finding tree-roots beneath moor peats, it would be wrong to jump to the conclusion that there had necessarily been a simple change in the general climate of the country (e.g. Morrison 1983).

In an area with as complex a human history as Scotland, it can thus be very difficult to reach any secure conclusions about climatic change *per se*, by looking at the evidence of any one locality. A sequence of quite dramatic changes in the patterns of settlement and land use may be apparent, but on the evidence of that single area, it may very well be impossible to dissect out the role of climatic change from amongst a whole range of other potential causal factors. This of course does not mean that we can afford to disregard the possibility that climatic effects may have been significant in human terms. The best solution seems to be to take a wider view, and to compare areas, examining any convergences in the sequences which they exhibit. This approach has in fact been proving profitable, and there is now broad agreement that a coherent pattern of climatic changes can be recognised world-wide, for recent millennia. The expression of this sequence of changes inevitably varies between different types of climatic zones, but it appears to do so in understandable ways.

Let us look at the type of internal variation which we have to allow for within Scotland, before exploring the overall sequence of changes which current research is establishing for our North Atlantic environment. As Scotland's farmers and crofters well know, the detailed patterns of the terrain can produce significant differences in the weather which is experienced, even over short distances. It is not only a matter of exposure to the wind, but also the orographic (hill-influenced) rainfall, cloud cover, and hence the amount of sunshine getting through to warm and dry the ground, and to ripen crops. Not only slope steepness but aspect can be critical: in these northerly latitudes, a south-facing slope may be almost half as warm again as a north-facing one (Taylor 1967). In marginal areas, the upper limits of viable cultivation can vary markedly on different sides of a ridge, or from one side of a glen to the other. Thus even figures quoted for a particular area, such as those calculated for the Lammermuirs, can be taken only as generalised indicators for that region. However, because they inter-relate in consistent ways, the factors leading to local diversity in climate are not anarchic. Instead they have tended to produce mosaics of landscape units in which characteristic tesserae recur as a result of the interplay between terrain, climate, and the cultural level at a given period (Morrison 1983).

Superimposed on the details of the mosaic are the broader country-wide trends which influence the regional combinations of landscape units and the altitudes at which they occur. The 'habitability' of Scotland owes much to the North Atlantic Drift, which brings relatively warm water from the Gulf Stream all the way across to the northeastern part of the Atlantic. Along with our dominantly westerly winds, this gives notably warmer winters than at points at the same latitude on the other side of the ocean. For example, New York often has bitter winter weather, due to the cooling of the great continental landmass up-wind of it. It is often much colder there than in Shetland, though the city is twenty degrees of latitude farther south. Snow seldom lies long in Shetland, though at 60 to 61 degrees north the islands are on the same latitude as Cape Farewell in Greenland. Unfortunately, however, the moderating influence of the ocean is less beneficial for Scotland in the spring and summer, since it inhibits the rise of temperature in the season crucial for crop growth and ripening. It is then that more 'continental' climates tend to be advantageous.

Even within Scotland, there have always been notable contrasts between the 'oceanicity' of the west coast and the islands, and the relative 'continentality' of eastern mainland regions, facing the European landmass across the shallow North Sea. Easterly parts of the country tend to have snell winters, compared to, say, the blander southwest of Scotland. On the eastern side, however, even as far north as Aberdeenshire, cereal crops can be grown successfully at much higher altitudes than in, say, Galloway. This seeming paradox is due to the way in which the great mass of ocean water acts as a heat-sink in summer time. The continental landmasses can heat up quite rapidly, with their temperature curves rising sharply above the threshold temperature required for crop growth. Crops ripen reliably in the Alps and other inland continental locations (including parts of Sweden) at greater altitudes than in Galloway, let alone Shetland. It is striking that all of Scotland is classified as having a more marginal climate for cereal cropping than southern Finland (Parry 1978), despite the severity of Helsinki's winters.

Where the curve of annual temperature is flattened by the moderating effect of the Atlantic, and rises only marginally above plant growth thresholds, rates of growth are low and there is greater vulnerability to quite minor variations in warmth and precipitation. Thus a general climatic change of given magnitude can have much more serious human implications in some areas of Scotland than in others. In the more oceanic habitats, everything tends to be more marginal. Exposure to high winds becomes an important factor; and insolation is reduced not only by the latitude but by the persistence of cloud cover (the Tourist Board tends not to bruit it abroad that some of the Hebrides have more than 300 days-with-rain per year...). With the slow rise of temperature in spring, not only is there less scope for evaporating soil moisture, but the rate of decrease in the length of growing season with increasing altitude is serious. Even in Galloway, with its popular image of lush farmland, upland bleakness starts low (improved land there reaches only to about 150m, 500ft). Even right down at sea level in the Outer Hebrides or Shetland, the growing season is no more than that up at 350m (1150ft) in Grampian, at Dalwhinnie, say (Spence 1979). At just 1000ft in Orkney or Shetland, the mean summer temperature is the same as at 2500ft in the Central Highlands. On Ward Hill on Hoy and on Ronas Hill in Mainland Shetland, Arctic-Alpine flora and a whole range of periglacial geomorphological phenomena are to be seen even now. These include stripes and other shapes sorted in loose stones. They are formed by frost-heaving on gale-blasted ground, and are found down to sealevel in the Arctic and Antarctic, though they tend only to develop at relatively high altitudes elsewhere. On the Keen of Hamar on Unst, however, they exist at only 60m above sea level, emphasising the narrowness of the climatic margins between which some of our forbears contrived to subsist.

Although many other factors influence our climate, the importance of the ocean and in particular the North Atlantic Drift seems clear, because of its effects on both winter and summer temperatures and on cloudiness and precipitation. This holds true for Iceland, Faeroe and Norway as well as Scotland (e.g. Thorarinsson 1987; Williamson & Kallsberg 1970; Teitsson 1981). Clearly, natural phenomena which alter the patterns of the oceanic and atmospheric circulation are crucial to the climate of these lands set around and in the North Atlantic. The processes which drive the changes may be influenced by an extraordinary variety of factors, ranging from variations in the sun's energy input into the system (tied in with both orbital geometry and sunspot activity), to factors affecting the receptivity of differing zones of the planet to the sun's radiation. These may range from geomagnetic variations, and the reflectivity of ice cover, to carbon dioxide levels, and variation in the transparency of the atmosphere.

This last can be affected by volcanic eruptions, not least of those of Iceland's Hekla and Katla. Their eruptions have not only ruined fields and poisoned livestock in Iceland. Their effects have often been much more widely apparent, with ashfalls sufficiently heavy to occasion comment in mainland Scandinavia and the Scottish Northern Isles. For example, there are graphic descriptions of the arrival of Katla ash in Norway in AD 1625, and in Shetland in 1755, and of fallout from Hekla in Orkney in 1845. Current research suggests that Icelandic discharges may have influenced the climate at least as far afield as Ireland, America and perhaps even the Mediterranean.

Besides being involved as a causal factor, the volcanic fallout is a useful aid to research: microscopic ash fragments sprinkled through our peat beds give synchronous horizons which allow close dating of changes in climate shown by the pollen (e.g. Dugmore 1990a; 1990b). As indicated above, there are often real difficulties in attempting to deduce climatic changes for the period before modern meteorology provided instrumental observations. However, over the last two decades much ingenuity has been expended on developing approaches both from the natural science and the document-based sides. Ladurie showed the way (1971), finding related patterns in the timing of variations in the Alpine glaciers and in medieval monks' records of the productivity of their vineyards. There were vineyards in England in some warmer phases. Here in the North Atlantic realm, Teitsson instead turned to analyses of Icelandic kirk's stocks of polar bear skins, while Lamb and others have found a valuable source in the log books of whalers and Hudson Bay Company ships, detailing where and when they encountered pack ice. These and records of the seasonal patterns of sea ice around Iceland serve as diagnostics of the interplay in the North Atlantic of the warm and polar currents (also to be seen in fisheries records). More can be deduced from information on harvest failures, the availability of grazing, and fluctuations in cattle numbers in Norway. The range of evidence is comprehensively reviewed by Grove (1988).

Throughout, as emphasised above, the aim in the research is to avoid relying on any single area or class of evidence, but (with due precaution against circular arguments) to seek out and evaluate convergences between different lines of evidence. This is true not only of evidence affected by human decisions, but also of many types of natural science evidence. For example, most glaciers increase in size in cold phases, and melt away in warmer ones, but some may shrink in cold phases if this means less precipitation feeds them because less moisture is picked up off cold sea surfaces; other may surge forward in warm phases. The record of what has happened may be pursued by a whole range of techniques: from tree rings and lichenometry, to analysis of the garden diary of an 18th century ancestor (Pearson 1976, 1978).

Research is now going ahead on many fronts, and momentum seems likely to be kept up because of the interest in using the record of recent centuries for assessing the current preoccupation with Global Warming. New results are coming out rapidly. The following attempt to summarise the sequence of changes should therefore be regarded as essentially provisional. However, it is hoped that by using this overview in combination with the suggestions offered above as to how the pattern of climate varies around Scotland, members of the society (with their wide range of interests in different periods and places) will find interest in identifying cases where their local evidence appears either to conform to, or diverge from, the model offered here. For those wishing to pursue the matter further, one of the best single volume sources is certainly Dr Jean Grove's recent and magisterial 500 page book, "The Little Ice Age" (1988). With its comprehensive bibliographies, it provided guidance and reference material for much of what follows.

PROVISIONAL OUTLINE OF THE BROAD SEQUENCE OF CHANGE

During the Holocene "Climatic Optimum", which ran from about 6500 to 3000 BC, annual temperatures over western Europe were probably at least a degree-and-a-half higher than they have ever been during the last two millennia. Then in the 3rd and 2nd millennia BC there was probably a trend towards cooler and drier conditions in northern Europe. During the last millennium BC, from about 900 to 450 BC there was instead a very wet maritime climate. Particularly in the parts of the British Isles dominated by the Atlantic, mild winters were partnered by particularly cool sodden summers. There was much growth of bogs then.

From about 450 BC and on into the first millennium AD, there seems to have been a tendency for greater contrasts between summer and winter: in other words, a greater frequency of severe winters (especially over the period from AD 600 to 800) but at the same time, warmer summers. The British data seem to fit in quite well with that from elsewhere in the North Atlantic area. For example, in Iceland, from the start of the Norse colonisation in AD 870 through to about AD 1030, the climate seems to have been milder than it has been since there. Sea ice lay far from sight, most glaciers were relatively small, pasture usually grew well, and conditions were propitious for north Atlantic voyagers. Greenland had been colonised in AD 985, and even farming settlements set up there did quite well.

In fact there is good evidence from much of north western Europe of an early medieval warm phase. This seems particularly clear between circa 1150 and 1250 AD, when there seems to have been a period of frequently warm and dry summers in temperate Europe. In Britain the mean summer temperatures were probably more than half a degree higher then than they are at present, and more than a full degree higher than during the 17th century. Winters were frequently mild, being on average a little warmer than those in the first half of our present century. However they seem to have been moist rather more often than is typical today, in contrast to the summers, which were somewhat drier than in the first half of the 20th century.

After 1250 AD the climate deteriorated and conditions headed into what has been called The Little Ice Age. With varying levels of severity, this ran right through into Victorian times. Cereal crops were no longer cultivated in parts of northern and eastern Iceland from the 13th century. By about 1350, the Western Settlement in Greenland was abandoned, and by 1500 the larger Eastern Settlement was also empty. Possible explanations for the seemingly sudden end of the Western Settlement and the dying out of the Eastern one have ranged from plague or the decline of trade contacts with Europe through to attacks by Basque pirates or the Inuit. It has been suggested that the increasingly harsh climatic conditions, which certainly impoverished the Norse farming settlements in Greenland, in contrast favoured the spread of Inuit culture dependent on ice hunting. Dr Jean Grove (1988) concludes from the archaeological evidence that instead of adapting, the Greenland Norse persisted in their traditional economy (which was based on cattle keeping in the inner fjord country) and eventually succumbed to climatic stress, perhaps under the impetus of actual attack by Inuit.

Confirmation of the 13th century climatic deterioration is provided by oxygen isotope analysis of the ice core from Camp Century in Greenland. This shows strong cooling around 1200, then a further cooling around 1300. The cooling phase which occurred in the later middle ages was probably the result of a southward shift of northern Atlantic depression tracks. The increasingly maritime climate, dominated by rain bearing westerlies, saw an increased frequency of wet and cool summers. By AD 1400 these may have averaged around ¾rs of a degree cooler here than during the medieval optimum prior to AD 1250. Winters though more frequently dry became cold: on average perhaps a degree colder.

The long-term cooling phase was temporarily interrrupted by a run of mild wet winters and dry warm summers, over the period AD 1450-1530. Then the deterioration re-asserted itself, and not only in Britain. In Iceland and mainland Scandinavia, and indeed the Alps, there seems to have been a sharp decline in summer temperatures towards the end of the 16th century. After this cold snap, there was another brief amelioration. In Iceland for example there was a remarkably mild interlude from 1640 to 1660.

Despite this, through much of the 17th century the general pattern was of dry but very severe winters, and damp cool summers. This combination made it a difficult time for many communities, particularly towards the end of the century. The cold greatly intensified and reached a maximum in the last decades of the 17th century. Summers became notably cold and wet in the 1680s and early 1690s. Dr Grove describes the decade of the 1690s as one of the coldest, if not the coldest, on record in western European history. It will be recalled that Parry calculated that above 340m in the Lammermuirs, no harvest could have ripened in any of the eleven years from

1688 to 1698, though that altitude had been farmed successfully there earlier.

It seems that vulcanism contributed to this phase. Eruptions of Hekla in Iceland, and Serua in Indonesia, both in 1693, and of Aboina in Indonesia in 1694, produced readily recognisable frost rings even in trees in North America. We may take 1695 as an example of the human implications of the Little Ice Age in one of its most severe phases.

The winter of 1695 started early, and was extraordinarily hard and long in most parts of Europe. Sea ice came well south of the coast of Iceland. Both there and in Norway, glaciers bulldozed into farmland. Even well outside the northlands, lakes and rivers froze over right through spring. Snow on the mountains persisted into summer, only to thaw in June at the same time as heavy rains were spoiling the crops. The combination made lowland rivers flood destructively. The harvest was ruined, partly because the crops were retarded in growth by the wet weather, but also because they could not be dried, and rotted. Salt needed for preserving foodstuffs could not be made at the coastal sites where it was usually evaporated.

Throughout the 1690s, there were heavy losses of livestock in the winter snows, and of cereal crops that failed to ripen in the cloudy summers. In Finland, the Great Famine has been estimated to have cost a third, and Estonia a fifth, of the population. There was famine too in Norway, and in Scotland they long referred to this period of dearth and starvation as the Seiven Ill Years.

It is from this period between 1682 and ca 1700 that we get acounts of alien canoeists paddling about in the Pentland Firth, and the whole intriguing business of the Inuit Kayak in the University Museum of Aberdeen. This was apparently found offshore, with its occupant in his fur shirt still alive, in the time of Queen Anne. Inuit were certainly brought back from Greenland aboard whaling ships at various periods. It has been suggested that the kayakers sighted in Orkney waters had contrived to escape from Denmark or Holland (complete with their Kayaks!) and were attempting to paddle back home. This does not seem altogether convincing, so it is perhaps worth considering the alternative hypothesis, suggested by the way that all seven reports of kayakers fall in the period when the packice was abnormally extended by this especially cold phase. The ice reached towards Faeroe. Is it possible that they belonged to Inuit hunting parties who had been working the edge of the pack? The steps from Faeroe to Shetland, and from Shetland to Orkney, are each less than that across the North Sea on the hypothetical escape route from being exhibits at the Royal Court of Copenhagen.

After the turn of the century, there followed a brief change towards higher temperatures in both summer and winter, with in general more winter and less summer rainfall. But after this intermission in the first half of the 18th century, glaciers readvanced in Iceland and Scandinavia, (as we found for example in the

Jotunheimen) in the 1750s and 60s, in a cold spell leading into the 1770s. It was then, in the time of Rabbie Burns, that Pennant noted snowbeds persisting from year to year on Scottish mountains such as Ben Ann. There was also a lot of pack ice in the North Atlantic, as the whalers noted. There was a great deal around Iceland, and sometimes the pack could be seen from Faeroe. There is even a story of a polar bear coming ashore there.

The trend towards higher temperatures was resumed around the start of the 19th century, but it was interrupted by occasional cold spells in the early 1820s, the 1840s, and 1890s. The decadal averages of both winter and summer temperatures reached a peak from about 1940 to 1950, and by the 1960s nearly all of, for example, the Icelandic glaciers had shrunk to occupy smaller areas than at any time since the mid-17th century mild spell, or even earlier. However, there was a sudden return to sea ice in the years round 1970; some glaciers ceased to retreat, and a few even readvanced. But by the early 1980s, the general glacier retreat had been resumed.

We are now wondering about Global Warming, involving the so-called Greenhouse Effect. This arises from the increased carbon dioxide concentration in the atmosphere due to such factors as the burning of fossil fuels and the cutting away of the Rain Forest. It is possible that such man-induced changes have helped to bring the Little Ice Age to an end, and that the global rise in temperature since the middle of the last century had been caused by these increased carbon dioxide concentrations. Dr Grove suggests that a reversion to the climatic conditions of the Little Ice Age is thus perhaps less likely now than it would have been but for the burning of fossil fuel in such enormous quantities over the last few decades. Nevertheless, the fact remains that a small but distinct temperature fall affected large parts of the globe in the 1960s and 70s, and occurred despite the observed increase in the carbon dioxide concentrations. This cooling was sufficient to influence agricultural production in high latitudes, and even to have some political consequences in Iceland.

It seems that we would be unwise to assume that we understand overmuch about climatic change, even in our own high-tech era. The Little Ice Age was certainly of importance for those who depended on subsistence agriculture. But we do not live by bread alone: let's leave the last word with the Makar, William Dunbar, who lived through part of it in the 15th century:–

Here nocht abidis, here standis no thing stable,
For this false world aye flittis to and fro;
Now day up bricht, now nicht as black as sable,
Now glad, now sad, now weel, now into woe;
So dois this warld transitory go:
Vanitas Vanitatum, et omnia Vanitas.

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