# DETECTING CHANGES IN CLIMATE AT A LOCAL LEVEL

John Harrison

## The broad picture of climatic change

Changeability is a major characteristic of the Scottish climate, but it is the presence of detectable long-term changes throughout the 20th century and the prospect of further changes through the 21st that are currently major issues. The climatic record for Scotland is relatively sparse but from what is available it has been possible to identify significant trends when information from a number of locations is aggregated. The most marked changes have been since the 1970s (Table 1a). Available climatic models suggest that many of these changes are part of an ongoing trend that is driven primarily by the enhancement of the Greenhouse Effect (Table 1b). Taking aside the deficiencies of climatic data, and the limitations of the climatic models the key question to address is how such large scale changes will be manifested at a local level. Will everywhere in Scotland experience the same changes, and what does the future hold for the weather in, for example, Stirling, Falkirk, Callander, or Aberfoyle?

Problems begin when attempts are made to scale down from a national and regional level to a local level. The simple answers to the above questions are that it is certain that there will be considerable spatial variation in changes in climate, and that climatologists are not sure what changes will occur for every location in Scotland. If attempting to predict climatic change at a local, rather than global or national level, there are two fundamental problems to be overcome, these being the (a) the need to scale down the currently available climatic models and (b) the ever present, and largely unquantifiable, local factors.

## Scaling down Climatic Models

The models that are used to predict climate have until recently been capable of making predictions at only the broadest scale, just two large grid squares covering the whole of Scotland in the 1998 predictions from the Hadley Centre. While modelling is improving and the scale in recent models has come down to 50 km in Regional Climate Models, change at a local level requires predictions at 1 km scale or better. At this spatial resolution the climatic processes become complex. There are a number of major climatic controls at this scale such as the effects of open water (coasts and lakes), topography (altitude, aspect, slope, exposure), and land use (urban areas and vegetation/crops for example).

While climatologists have a reasonable understanding of how these effects operate, surfaces are too complex to model and models are also not universal. Brunsdon *et al.* (2001), for example, found that the effects of altitude on rainfall in the United Kingdom varies considerably from one location to another.

One alternative is to use a combination of climatic analogues linked to Digital Elevation Modelling in a Geographic Information System (GIS). Such a technique has been used to estimate how snow cover may change in Scotland (Harrison, *et al.* 2001). Winters were chosen from the existing climate record to match as closely as possible the temperature and precipitation predictions relating to the different climatic scenarios. Spatial patterns of the total number of winter days with snow lying were then produced for each winter using crude geographical models which related days with snow lying to latitude, longitude and altitude. The resulting maps at 1 km resolution provided a measure of prediction at a local scale but the precision is spurious and all that can be gained from such an exercise is a broad indication of possible changes in the future.

It has been a common assumption that suitable climatic data will exist for any location and that climatic trends can be readily detected and cross-checked against climatic prediction. This is far from being the case. Spatial coverage by climate stations in Scotland is poor. Many are located on the coasts while there are virtually none in the mountains. Climate stations mostly have a limited lifespan, operating for a few years only. Consequently there are relatively few from which the longer term trends of change can be determined. Little is still known about how the climate is changing in, for example, mountain and hill areas, which are crucial as these are marginal environments for many species of plants and animals.

The conclusion must be that it is difficult to scale down from current climatic models, which will remain the case for some considerable time to come. However, it is reasonable to conclude that what is predicted at a regional or national level may be manifest in a different set of changes at a particular locality. One question that can be answered for the Stirling area is, given the nature of changes in the general nature of climate over Scotland, do local climatic records indicate similar changes or are effects damped or magnified by local conditions?

**Local climatic trends**

The Stirling University Climate Station, inappropriately named Parkhead, is one of the few climatological stations in the Stirling area with any length of record. The station was established in 1970 by the Department of Biology and data were first published by the Meteorological Office in 1971. The station remains open, so there was an uninterrupted 32 year record by the end of 2002. When it was first established there were stations at Batterflats in Stirling and at Earl's Hill, but these closed in 1982 and 1980 respectively. The only local addition in recent years has been the station at Stirling Sewage Works which was opened in 1984.

The site at Parkhead is far from ideal. It is very sheltered from between NW and NE and there has been one change of site in 1995 when the station was moved a little over 100 m to its current location (Harrison, 2001). Both old and new stations were run simultaneously for nine months to make sure that records would be homogeneous. There was little obvious change in air temperature and rainfall resulting from the change of site. The question is whether the Parkhead data can provide any insight into trends in the local climate in the Stirling area.

*Rainfall*

The national climatic trends and models indicate a tendency towards wetter winter months over Scotland, particularly in the west of the country. Winter (December/January/February) rainfall totals for Parkhead were analysed and over 30 years there was a statistically significant increase in winter rainfall (Figure 1). The equation generated for the straight line leads to an inferred 47 % increase in winter rainfall. If this is extrapolated forward to 2080 the inference is that rainfall will be almost doubled, which is well in excess of the 20 % predicted by climate models (Hume and Jenkins, 1998) under worse-case scenarios, but it is likely that percentage changes will be higher towards the west and lower towards the east of the country.

*Summer Temperature*

Models and trends suggest we should expect a warming of the summer months. Although not statistically significant, the trend of summer maximum temperature (June-September) suggests an increase of 0.8°C over 30 years (Figure 2). The changes in the summer temperature have been driven most strongly by a statistically significant increase in September temperatures. Extrapolating trends to 2080 implies that summer days will become a litte over 2.0°C warmer on average. This is consistent with predictions for Scotland (Hulme and Jenkins, 1998).

*Growing Season*

Minimum temperatures are most often interpreted in terms of frost occurrence. The time elapsed between the last air frost in spring and the air first frost of autumn marks the length of the frost-free season. Although there is not a statistically significant trend in season length, the data appears to suggest an increase in the length of the growing season of 28 days, which tends to match with people's own experiences and with monitored changes in key habitats (Figure 3). An analysis of the dates of the last and first frosts, indicates that there has been a marginally greater extension of the season at the autumn end, this having been extended by more than a fortnight.

*Heating within buildings*

It is reasonable to suppose that if winter temperatures are improving then less heat will be required to maintain internal temperatures within the University buildings. Daily maximum and minimum temperatures were converted into heating day-degrees below 15.5°C for the entire Parkhead record and the values accumulated from the start of a nominal academic year on October 1st. The number of days elapsed before totals of 500, 1000 and 1500 day-degrees were reached were derived. If winters are getting warmer the number of days should increase through time. Of these the number of days to reach 1500 day-degrees showed a significant increase. In the early 1970s the total was reached on average in the third week of February whereas in 2002 it falls in the first week of March. (Figure 4.) Breaking this down into components reveals a significant increase in the time interval between reaching 1000 and 1500 units which suggests a significant warming between approximately the middle of December and mid-late February which is consistent with the earlier start to the thermal growing season.

## Conclusion

Despite reservations about its quality, the local climatic data from Parkhead would appear to be broadly consistent with what has been happening nationally. In this case, Stirling should expect a further lengthening of the frost-free season, warmer summers, wetter and milder winters, and heating bills should decrease.

## References

Brunsdon, C., McClatchey, J. and Unwin D.J. (2001). Spatial variations in the Average Rainfall – Altitude relationship in Great Britain: An approach using geographically weighted regression *International Journal of Climatology* 21 (4) 455-466.

Harrison, S.J. (2001). Thirty years of weather observations at Parkhead. Forth *Naturalist and Historian* 24, 15-22.

Harrison, S.J. and Kirkpatrick, A.H. (2001). *Climatic change and its potential implications for environments in Scotland*. In. *Earth Science and the Natural Heritage.* (ed. J.E. Gordon and K.F. Leys) pp296-305. Edinburgh: The Stationery Office.

Harrison, S.J., Winterbottom, S.J. and Johnson R.C. (2001). Climatic Change and Changing Snowfall Patterns in Scotland *Scottish Executive Central Research Unit Environment Group Research Finding 14.* Edinburgh: The Stationery Office.

Hulme, M. and Jenkins, G.J. (1998). Climate change scenarios for the UK: scientific report. *UKCIP Technical Report No. 1* Climate Research Unit, Norwich 80pp.

TABLE 1a
Recent Changes in the Scottish Climate since the early 1970s
(from Harrison and Kirkpatrick, 2001).

**Hours of Bright Sunshine**
- An imperfect measure of insolation, but indications are of a significant decrease during the winter months, particularly in the west.
- Some weak evidence of an increase in the east during winter and over the whole of Scotland during the summer and autumn.

**Air Temperature**
- *Maximum temperatures:* Changes have been relatively small but there is some evidence of increases of up to 0.3°C. The most significant long-term upward trend has been in spring.
- *Minimum temperatures:* Evidence of increases >0.5°C during the late winter months. The most significant upward trend has been in spring and early summer.

**Precipitation**
- *Rainfall:* Increased totals in all seasons but only significant during the winter months, most notably in the North and West.
- *Snowfall:* Some evidence of a downward trend in the during of winter days with snow lying.

**Airflow**
- Very difficult to identify any trend in wind speed due to the nature of the available data. Indications are that gales have increased in frequency and severity. The decade 1988-1997 has seen the highest frequency of gales since the late 19th Century.

TABLE 1b
Potential changes of climate in Scotland during the 21st Century according to current collective wisdom.

Increase in near-surface air temperature

Decrease in the intensity of very cold spells in winter

Marked decrease in the frequency of frosts

Increase in annual rainfall

Marked reduction in snowfall and days with snow lying

Convective shower precipitation more frequent

Decrease in the number of rainy days
but an increase in the amount falling on each day

Possible increase in river flood frequency

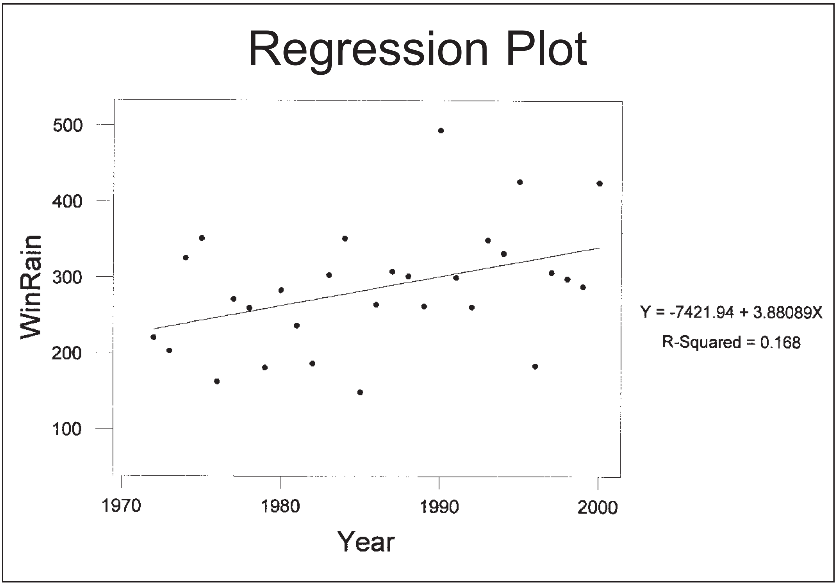


Figure 1. Changes in Winter (December, January, February) Rainfall.

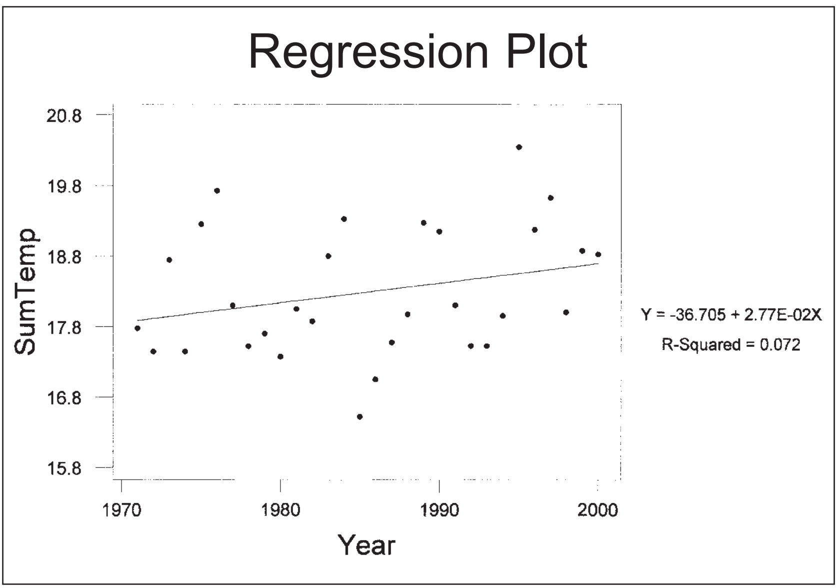


Figure 2. Changes in Summer Average Maximum Temperature (June, July, August, September).


Figure 3. Changes in the length of the frost-free (0.0°C) season (days elapsed between the last air frost in spring and the first in autumn).

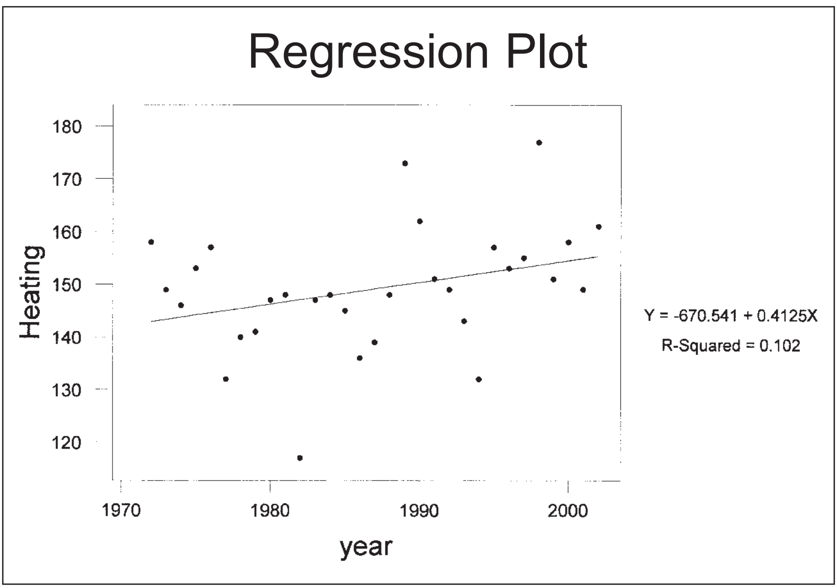


Figure 4. Changes in the number of days elapsed from October 1st to accumulate 1500 heating days degrees below 15.5°C.

## BOOK REVIEWS

**People and Woods in Scotland: a History**. Ed. T. C. Smout. 2003. Edinburgh University Press. 26opp. ISBN 0 7486 1701 9. £14.99.

From 11,500 years ago when the ice melted and trees returned bringing the birds and mammals, and soon after the first hunter-gathering humans, the book charts and explains Scotland's great loss of trees over the following millennia, the 20th century revival of forests and woodlands, and ends in examining the changes now underway.

With distinguished authors the chapters cover – prehistory to 1000BC, coming of iron to 500AD, medieval to 1600, using the woods to 1850 the 'planters' 1650 to 1900, 20th century take off, ecological impact of using, and the future. Lastly are 20pp of data on species, references, readings, index commissioned by the Forestry Commission this is a key authoritative well produced and illustrated work.

*Scottish Association of Geography Teachers Journal,* vol 31 2002. Reading the Landscape. 120pp.

Papers of the seminar at Stirling University June 2002 – incl. cultural geographies, landscape and literature, soils approach…

**Early Prehistory of Scotland.** Eds. T. Pollard and A. Morrison. Edinburgh University Press. 200pp. ISBN 0 7486 0677 7. Not priced.

**The Birdwatcher's Yearbook and Diary. 2004.** Pubn 29 Oct. Buckingham Press. £15.

**Where to Watch Birds in Scotland**. Miles Madders and Julia Welstead. 4th edn. 300pp. A. & C. Black. £14.99.

Information set out by areas – 5pp on Central Scotland, Forth Estuary…

**Scottish Birds.** Valarie Thom. Collins. 256pp. ISBN 0 00 219983 1. £9.99.

Well presented data on habitats and their birds under headings – garden, farmland, woodland, freshwater, heath and hill, coast, by the former president of SOC.

**Footpaths of Scotland**. Lomond Books. 64pp. £3.

"An illustrated guide to our 30 most beautiful walks" – includes Loch Ard Forest from Aberfoyle.

**The Story of Hillwalking.** Ralph Storer. Luath Press. 160pp. ISBN 0 946487 28 6. £7.50.

**The Waste Crisis:** landfills, incinerators, and the search for a sustainable future. Hans Tammenmagi. OUP. 280pp. ISBN 0 19 512898 2.

While its purpose is an overview of waste management in N. America, its comprehensive treatment of this huge and complex subject marks it as a good source suitable for a wide readership, general and academic, for both study and reference. It encourages readers to constantly challenge commonly held views and practices about garbage/waste, and to seek new and better ways of dealing with it.