Climate change and changing snowfall patterns in Scotland

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Executive Summary

Introduction

The principal objective of the Report was to examine how snowfall patterns are expected to change in the light of climatic change scenarios and to review the possible socio-economic and environmental implications of such changes. An overview has been provided of the effects of changes in the duration of winter snow-lie on key activities within the socio-economic sector, and on key mountain habitats. The changes are such that adaptation strategies are required.

The study was undertaken between March 2000 and April 2001 by Dr John Harrison and Dr Sandy Winterbottom of the Department of Environmental Science at Stirling University, and Dr Richard Johnson of Mountain Environments Consultancy in Callander, Perthshire. The study comprised four parts:

An analysis of changes in Scottish snowfall patterns over the latter part of the 20th Century

Obtaining, by questionnaire survey, expert opinion from key stakeholders on how the Scottish economy and environment have already responded to changes in snowfall

Prediction of future changes in snowfall patterns driven by Greenhouse Effect enhancement over the course of the 21st Century

Identification of key issues and adaptation strategies for dealing with such changes

Climate change

The IPCC Report (1996) indicated a reduction in the spatial extent of snow cover in the Northern Hemisphere of approximately 10% between 1973 and 1994. Although there is considerable regional and inter-annual variation in snow cover, there has been a significant trend towards reduced snow depth and cover duration since the 1970's. This has been most marked at lower altitudes, while at higher altitudes no such trend is apparent in many locations. Since the late 1970's there has been a significant reduction in the average number of days with snow lying, based on a sample of climatological stations at altitudes between 100m and 400m. The average rate of change has been 12 days per decade, which has been associated with changes in mean temperature during the winter months. The average number of days with snow lying across Scotland as a whole during the winter (November to April) is reduced by 9 days for every 1.0oC increase in mean temperature.

Scottish snowfall data

Data on snow cover in Scotland are relatively sparse and there is a need to improve the snow-monitoring network. The primary database comprises the record from climatological stations at which a routine observation is made of days with snow lying at 0900 GMT. A limitation on the value of these data is that most stations lie at relatively low altitudes. Long records of snow lie exist for locations such as Braemar (339m). The Snow Survey of Great Britain has also provided additional data on days with snow cover in addition to estimates of snow-lines and days with snow observed to be lying in the mountains, but the data can be rather subjective. Ski-centres, avalanche warning services, and mountaineering groups also collect specific data on snow cover. Remote sensing has provided further information on snow cover since the 1970's. Analysis of changes in Scottish snowfall patterns has been based on the recorded number of days with snow lying at 36 climatological stations.

Modelling snowfall patterns

Given the spatial and temporal variability which is characteristic of the Scottish climate, much of the essential detail in the pattern of snow cover, particularly in upland areas, is lost in both Global (GCM) and Regional (RCM) climate model predictions. The approach taken to prediction was thus to use climatic analogues rather than physical models, together with spatial models of snow cover duration. The latter were based on the geographical variables of height above sea-level, latitude and longitude and the frequency of winter days with snow lying at 36 climatological stations. The basis of analogue modelling is the underlying assumption that contained within the existing climatic records are individual winters which are similar in nature to those which are to be expected as a result of climatic change. Selection of analogue winters was based on the UKCIP98 predictions which identify four climatic scenarios, these being Low, Medium Low, Medium High and High.

Spatial models were generated using Stepwise Multiple Regression and the performance of the models was checked against observations of days with snow lying reported in the Snow Survey of Great Britain. Maps of the spatial pattern of the 1961-1990 average number of days with snow lying over Scotland and of changes in the number of days under Medium Low and Medium High climatic scenarios for the 2020s, 2050s and 2080s were produced using Geographic Information System (GIS) software. The spatial resolution was 1km. These indicate that warming of the Scottish climate will result in a general reduction in the average number of days on which snow lies and a rising of snow-lines during the winter months. The greatest absolute reductions will occur at an altitude of 400m + 100m , with the smallest absolute changes occurring on both low ground and the highest parts of the Scottish Highlands. Expressed in relative terms, the models imply an almost total disappearance of the snow risk in lowland southern Scotland but a decreasing percentage reduction as altitude increases.

Analogue modelling is at best indicative and is dependent upon both the particular weather conditions during the selected analogue year and on the rigour of the spatial models that are generated, but outcomes appear to be consistent with predictions from elsewhere in the world.

The predictions of changes in snow cover have been based on the assumption that future climatic changes will be driven primarily by enhancement of the Greenhouse Effect in the lower troposphere. As modelling is an imprecise art, predictions should not be regarded as being a definitive statement of how things will be. They represent no more than the product of a current consensus of scientific opinion that global warming will be the main force driving climatic changes through the 21st Century. There are also other mechanisms which may well exert an influence on the climate of Scotland over the following decades. These include changes in the North Atlantic Index and, of potentially greater concern, the effect increasing freshwater inputs to the North Atlantic through enhanced rainfall and melting of Arctic ice. This could greatly weaken the North Atlantic Drift in the surface waters off the west coast of Scotland and bring about a drop in air temperatures which may lead to a shift to winters in Scotland with greater snowfall by the end of the 21st Century.

Implications of changes in snowfall

Winter Tourism

The main issues are that there will be a considerably reduced average number of days with snow lying, and that snow in Scotland becomes less reliable. Reliability will be least on the lower slopes while on higher slopes reliability will be greater, but such areas are more remote from facilities. In addition, there may be a greater risk of avalanches. Visitors have already become more

opportunistic in behaviour and there will be a greater number of snow-free days when alternative mountaineering activities can take place

The principal adaptation strategies are that the winter tourism industry should continue to develop a long-term strategy to diversify, every effort should be made to encourage opportunistic visitor behaviour in response to snowfall events, related businesses need to adapt to changing conditions, access to higher slopes should be improved, avalanche monitoring and warning services should be further strengthened, and tourism management strategies should be changed to promote activities other than snow-based sports.

Transport

The key issues are that there will be a reduced number of days with snow lying but a residual risk will remain of occasionally heavy falls of snow, particularly on higher ground. At the same time, less snow exposes surfaces to freeze-thaw temperature fluctuations.

The changes in snowfall imply that there will less disruption to transport, and that fewer resources may be required for snow clearance. There will, however, be considerable regional variation in the reduction of risk. There will remain a requirement for the treatment of roads to reduce icing, which may include greater costs due to removal by melt water and winter rain.

Environment

The key issues are a reduced snow cover duration over upland areas and in isolated snow-bed environments. This will result in greater exposure to damage by low temperatures, wind, trampling and grazing. A greater demand for public access may increase trampling damage. It is likely that there will be a reduction in the area, and geographical distribution, of snow-bed communities.

The principal adaptation strategies should include improvements in the monitoring of the state of vulnerable habitats and species, and the potential effects of more intense human trampling. There should be improved public information regarding the damaging effects of trampling. Management contingency plans are required to protect habitats and species.

Land Management

The main land uses between 100m and 400m in Scotland are forestry, moorland activities, skiing and walking. The key issues are that reduced winter snow cover lengthens the season for operations such as timber haulage, there will be less snow damage to trees and the planting season will be longer. It may become necessary to improve the durability of access roads if intensity of

activity increases during the winter months. Milder snow-free winters may also encourage activities such as walking and mountain-biking which may impact on fauna.

Adaptation to change should mean that Forestry-related industries could expand uphill. Milder but wetter winters with less snow may affect fauna such as deer and grouse which may require management intervention.

Water

A greater proportion of winter precipitation falling as rain, particularly in upland areas, which may result in changes in flow regimes of Scottish rivers.

Predicted changes in snow lie may well influence the magnitude of large floods and the frequency of smaller flood events during the winter. Water resources management could become more complex, and flood forecasting and water resource management require better information about snow. A review of HEP generation practices and runoff models may be required.

Notes to readers

For the full report, go to:
http://www.scotland.gov.uk/cru/kd01/lightgreen/ccsnow_00.htm

Copies of the full report are also available from:

The Stationery Office Bookshop
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The Mountain Forum would like to thank Dr. Sandy Winterbottom for her permission to include this executive summary on the Online Library.