RECENT CHANGES IN MID-LATITUDE MOUNTAIN CLIMATE AND SNOW COVER CONDITIONS

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MOUNTAIN CLIMATE RECORDS

The value of climatic records collected at high mountain observatories over many years is being increasingly recognised. Valuable syntheses of climate records have recently been made for the Sonnblick Observatory in Austria (Auer et al. 1990) and the Pic du Midi Observatory (2,862m) in the Pyrenees (Bücher and Dessens 1991). At the Pic du Midi, there is a mean annual temperature increase of 0.94°C/100 year (measured between 1882 and 1970) perhaps associated with an increase in cloudiness. The warming trend was most marked in spring and autumn and is shown to be greater at three mountain stations (Pic du Midi, Säntis, and Sonnblick) than at low elevation stations in western Europe. The mountain stations in the Alps (Säntis, Sonnblick, and Zugspitze) also show an increase of maximum and minimum temperatures whereas lowland stations in this area and also the Pic du Midi show that minimum temperatures increase much more than maximum values (Weber et al. 1994). This asymmetry in response merits further examination.

SNOW COVER

Records of winter snowfall and snow cover in mid-latitude mountain areas have enormous economic importance for winter tourism as well as for water supply. Most records show significant short-term anomalies, in recent years and in the past, but there are few signs of any persistent long-term trends.

A 100-year series of snow depths on January 1 at Davos, an alpine valley station in Switzerland, indicates an interval with above-average depths around 1920 and lower depths in the late 1980s, but Föhn (1990) points out that the deficit in the latter period in January was offset by delayed springtime ablation. Analysis of daily records from 1901 to 1992 at four Swiss stations (Davos 1,590m; Zurich 569m; Lugano 276m; and Säntis 2,500m) confirms the occurrence of below average snow depths in the late 1980s to early 1990s, but shows that values were still lower and snow cover duration shorter in the 1940s (Beniston et al. 1994 and personal communication 1994). Röhrer et al. (1994) note the lack of a general trend and the wide interannual variability in maximum annual snow storage at 50 stations in the Swiss Alps, with records from the 1940s. In Austria, several different snow cover indices show no significant trends during the period from 1895 to 1990 in the Tyrol, despite a general warming (Fliri 1992). In contrast , Mohnl (1991) reports a decline in daily new snowfall amounts since the late 1970s at 40/51 alpine stations following an increase after 1930 in the northern Alps between 800 and 1,800m. Higher stations exposed to the westerlies show many snowy winters between about 1900 and 1925, when the circulation over Europe was more zonal in character. Station records and empirical estimates for the Snowy Mountains of Australia also suggest high and low snowfall regimes lasting 10 to 20 years, with no apparent overall trends (Duus 1992).

Eurasian snow-depth data up to 1984 for 284 stations across the former USSR have recently been processed at the National Snow and Ice Data Center, Boulder, Colorado, USA (NSIDC 1994). Twenty-five stations have snow-depth records beginning before 1921 and a further 85 begin during the period from 1921 to 1936. Time series of mean values of snow depth and associated daily temperature and precipitation amount have been analysed for the November to April cold season at 110 stations (Barry et al. 1995). Cold-season mean snow depths in different regions of the former USSR display considerable variation between locations although some broad patterns can be detected. In the southern regions of the former USSR, mean cold-season snow depths are lower and show less interannual variability. A decreasing trend is observed from the early 1950s at stations located in the middle elevations of central Asia and in the Caucasus region, except for increased depths during the period from 1965 to 1975, the decreases were associated with warmer conditions in the cold season.

Negative correlations between snow depth and temperature for the cold season range from 0.5 to 0.7 in the southern regions of this country; the highest values are located in the Caucasus region and central Asia at elevations between 600 and 2,000m.

PROJECTED EFFECTS OF GLOBAL WARMING

Local and regional assessments have been made of changes in snow cover duration using GCM climate projections with simple indexing or changes in moisture balance and runoff via snowmelt runoff models. For the Victoria Alps, Australia, for example, Haylock et al. (1994) find snow cover duration to be highly sensitive to temperature. A 1°C warming could reduce snow cover duration by 50% or more at low to moderate elevations, with major impacts on the local skiing centers and related economy, whereas realistic precipitation changes will have a negligible effect. Corresponding studies have been published for Austria (Koch and Rüdel 1990). They calculate that snow cover duration will decrease by about 25 days per degree Celsius warming in winter. For the French Alps, Martin et al. (1994) simulate seasonal snow depth at 37 sites where observations are also available and evaluate snow cover sensitivity to a doubled CO_2 scenario. An air temperature increase of 1.8°C and modified radiation conditions are incorporated. They find that snow cover duration is reduced by 20% in the north (40% in the south), or 30-40 days at 1,500 m, but there is reduced sensitivity at higher elevations, contrary to the inference that climatic fluctuations on certain time scales may be more pronounced at higher elevations (Barry 1990).

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