Climate Change at High Elevation Sites: Emerging Impacts HIGHEST II

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Report on a joint NOAA/NSF/SwissNF/Swiss Academies of Sciences/NCCR-Climate Workshop, 25–28 June 2001, Davos, Switzerland

HIGHEST II invited about 40 scientists to a workshop to discuss new findings on climate change at high elevation sites since HIGHEST I in 1995. The overall aim was (1) to review recent climatic trends at different high elevation sites, (2) to evaluate the utility and reliability of ecological indicators of climate change, and (3) to evaluate impacts on biotic and abiotic resources. The full volume of abstracts is available at http://www.nccr-climate.unibe.ch. Following are some selected highlights of the workshop.

"Global moistening" rather than "global warming"

Schaer et al showed that temperature and precipitation changes must always be regarded as coupled variables. Temperature changes always depend on the proportions of latent and sensible heat flux and are modulated by mesoscale atmospheric circulation. This is a key to understanding differential temperature changes, lapse rates, freezing height levels, etc, in different locations. "Global moistening" is a more appropriate term than "global warming" since the global atmospheric moisture content (+6%/K warming) rises much faster than global precipitation increases (1–3%/K warming).

Alpine climate

Observed trends during the 20th century show that (1) mean winter precipitation has significantly increased (up to 30%), particularly in the NW Alps; (2) intense precipitation events increased; and (3) mean and peak runoff and river discharge changed while summer conditions remained remarkably stable. Since the observed trend in winter precipitation is about three times higher than what was used a decade ago for climate change scenarios for the 21st century (+10% precipitation), indications are that the impact on the Alpine hydrological cycle will also be much greater than what was expected for the next 100 years, based on previous scenarios.

Future climate scenarios suggest with remarkable agreement that the trends observed in the 20th century (mild and moist winters, increased floods) will continue. There are few observations of decreasing summer moisture in the Southern Alps and the Mediterranean. Whereas European temperature and precipitation fields are highly correlated with the NAO index, correlation of alpine temperature and precipitation with the NAO index is high only for distinct periods in winter (Wanner et al).

Temperature trends and freezing height levels

Rates of temperature change in many mountain systems exceed global average values. Mathias Vuille reported new findings from the Andes. Mean annual temperatures (surface observations) in the northern tropical Andes of Colombia increased by as much as 1.6°C in 25 years (1966–1990). Further to the south in Peru, Bolivia, and Ecuador, the overall rate of temperature increase is not as high, but it more than tripled in the last 15 years (1975–1990) compared with the previous decades (1939–1975). In Chile and parts of Argentina, warming rates during the last 3 decades (1960–1992) doubled by comparison with the period between 1933 and 1960 (Vuille et al). Little is known about precipitation changes.

In the free atmosphere (the midtroposphere is the approximate altitude of many glaciers), the temperature trend is not as clear (discussions by Dian Seidel, Henry Diaz, Mathias Vuille, and others). Surface observations and free atmosphere soundings report different signs and changes in lapse rates in different parts of the world (tropics and midlatitudes). This information is poorly understood. A comprehensive description of the problem is given by Seidel and Free (Abstract Volume 41). Research is needed to gain a better understanding of the apparent discrepancy between massive glacier retreat and increased surface temperatures at high elevation sites and the lack of large-scale warming of the lower and midtroposphere.

Glaciers and snow

About 100 glaciers have disappeared in the Alps since 1850. Observed glacial retreats in the midlatitudes are between 26–35% in area and up to 50% in volume (M. Meier, P. Föhn). Recent retreats of the South Cascade Glacier have been well outside the range of all fluctuations for this glacier over the past 5000 years.

Glacial retreat must also be regarded as a function of temperature and precipitation and other crucial factors such as seasonality. Modes of mass balance variability (summer and winter) are well related to variations in mesoscale atmospheric circulation (M. Meier).

Special emphasis was also given to tropical ice cores and analysis of chemical species and isotopic composition (LG Thompson, U Schotterer, N Graham, H Gaeggeler, K Alverson). Findings based on ice cores in Tibet (Dunde, Gulya, and Dasuopu), the Andes (Huascaran, Quelccaya, Sajama, Illimani, Chimborazo, Tapado), Africa (Kilimanjaro), Alaska, and the Alps were compared.

Hydrology

The most robust model projections and discharge data from mountains in the high- and mid-latitude Northern Hemisphere, as well as (less robust) ones from the Southern Hemisphere, show that global warming results in earlier peak runoff and smaller snowmelt-fed runoff. Natural water storage (snow, ice) capacity decreased dramatically. Middle mountains are much more sensitive to such changes than high-elevation areas.

Vegetation and biodiversity

Pavel Moiseev reported 20th century increases in the treeline in the Urals. In the South Urals, this increase was 60–80 m (for the observation period 1929–2000) and in the North and Polar Urals 40 m (for the observation period 1957–2000). This is attributed to warming (1.4°C observed on average; cold-season warming +4.3°C in the North and Polar Urals over the last century) as well as moistening. Due to the upward expansion of forests, tundra areas in the South Urals decreased by an estimated 10–30% over the last century.

Christian Koerner argued convincingly that air and soil temperatures in the root zone (not CO_2!) are the most important factors that control upper treeline elevation. Tree-ring chronologies from different mountain areas show how unusual tree growth in the 20th century was. The last 3 decades are unprecedented in the history of the last 400 years in Patagonia, the last 900 years in southwest United States, and the last millennium in Mongolia (Swetnam, Hughes, Villalba, Jacoby, Luckman et al).

Comparison of recent vascular flora with surveys in the late 19th and early 20th centuries on more than 300 alpine summits shows that warming observed during the 20th century resulted in an increase in species richness in the nival zone (Grabherr et al).

Camille Parmesan presented examples of butterfly diversity at high elevation sites. For example, the mean location of Edith's Checkerspot (western United States) populations shifted 124 m upward during the 20th century, and other mountain species (eg, Apollo's butterfly) became extinct on all mountaintops in the Jura Mountains (Europe) below 850 m in the early 1970s, while populations remained present on higher mountains.

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