Cooling in down-slope peat ecosystems due to accelerated glacial melting in Higher Himalaya, India

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High-resolution paleoclimate data and numerous instrumental records report that, at higher elevations, Himalayan temperatures over the last ca. 100 years have been rising (Liu and Chen 2000, Thompson et al. 2000). However, many instrumental records from various lower elevation localities are reporting cooler temperatures in recent decades (Balling 2001). This recent cooling trend is not only opposite to the global warming trend but also with the accelerated retreat of the Himalayan glaciers. The effect that warming conditions and melting glaciers have on down-slope ecosystems has not been fully explored. Here we present compelling evidence that, over the last 200 years, accelerated glacier retreat and increased melt waters have played a central role in changing the ecology (and perhaps local climate) of down-slope sites.

The Pinder Valley (~30°50' - 30°52' N, 78°47' - 78°51'E) of the Kumaon Higher Himalaya, receives precipitation from the Asian monsoon predominantly during the summer but also during winter seasons. The valley climate is also influenced by hanging glaciers (viz. Sunder Dunga, Pindari, and Kaphni), situated along the valley head. An ~ 125-cm thick peat deposit situated in oak dominated mixed evergreen forest 2650-m altitude, was trenched and continuously sampled at 2-cm intervals. Well-dated multi-proxy paleoclimate record (pollen, diatoms, phytoliths, % organic matter, and magnetic susceptibility) from this peat sequence revealed past ca. 3500-year high-resolution climate history of the area.

At the beginning of the peat sequence (ca. 3500 to ca. 3300 cal yr BP), the pollen assemblage was almost exclusively represented by conifers suggesting that the regional climate was cool and wet. A sudden increase in the dominance of grass, alder (*Alnus nepalensis*) and brown oak (*Quercus semecarpifolia*) pollen at ca. 3300 cal yr BP indicates an abrupt climatic shift towards drier conditions that continued until ca 2300 cal yr BP. The increase in silver fir (*Abies pindrow*) and other conifers [Himalayan spruce (*Picea smithiana*) and blue pine (*Pinus wallichiana*)] at the expanse of grasses, and the first appearance of diatoms ca. 2300 cal yr BP mark the end of the dry period. The progressive decrease in grass pollen for the following ~200 years reveals the improved wetness of climate until ca. 2100 cal yr BP. Variations in our proxy indicators throughout the remainder of the peat sequence suggest a stepwise increase in wetness until the present.

A major shift in all of the proxy indicators at ca. 680 cal yr BP (~ 1320 AD) indicates an increase in SW monsoon at 1300 AD, evidence of which is widespread throughout the Asian monsoon region (Morrill et al. 2003). Around this time the once dominant *Fragilaria* diatoms abruptly diminished to trace abundances, *Navicula minima* appeared for the first time in the record in relatively high abundances, and epiphytic diatom taxa became more prominent.

Circa 1580 to 1730 AD, a substantial cooling was inferred with a reduction to trace levels of the epiphytic proportion of the diatom assemblage and the strong re-appearance of *Fragilaria* species to abundances of 80 – 90%, not seen before or afterwards in the peat profile. A comparison of the last ~400 years of the peat record with reconstructed spring temperature trend derived from a series of 12 Himalayan tree-ring chronologies (Yadav and Singh 2002) is consistent with our proxy-based inferences from ca. 1600 AD onwards.

The high rate of glacier melting over the last few centuries in the Himalayan mountains is a clear demonstration of a warming climate. Our data show that increased glacial melt-waters under this warmer climatic scenario has had a substantial impact on down-slope ecosystems. It appears that the glacial retreats are consistent with the global climate scenario but the resulting melt waters are having localized to regional cooling effects at lower elevation sites over the last few decades.

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