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Influence of climate and climate anomalies on Norway spruce tree-ring growth at different altitude and on glacier responses: examples from the Central Italian Alps

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The recent phase of climate warming is globally characterized by heterogeneous changes of the atmospheric temperature and of precipitation regimes. On the European Alps, the increase in surface temperature is about the double of the global mean and is triggering strong variations in the climatically-limited ecosystems. Physical and biological components of the high-altitude environments are therefore experiencing changes with different response times and modalities. Within the many natural indicators of climatic changes, tree rings and glaciers represent two of the most sensitive proxies of the alpine environment. Trees growing close to the upper treeline, record in their annual growth the climatic signal (especially summer temperature) and glaciers vary their mass, responding to the climatic input.

Tree-ring growth responses to climate were assessed for two *Picea abies* (L.) Karst. sites at different altitudes (at 2050 m a.s.l., close to the treeline, and at 1620 m a.s.l., at the valley bottom) from a valley of the Ortles-Cevedale Group (OCG; internal zones of the Central Italian Alps), and for the recent decades some examples of climate impact on glacier dynamics in the OCG were reported. The dendroclimatic analysis was based on Pearson's correlation and response functions. The high altitude trees resulted especially sensitive to July temperatures, whereas the low-altitude trees were also sensitive to summer precipitation: climate anomalies occurring in these months proved to

influence tree growth at the two sites differently. Summer 2003 is an example of extreme climatic conditions established over Europe and the Alps, strongly affecting physical and biological systems. Spruce responses to the climate anomaly of 2003 were more evident with a one year lag: the high-altitude site profited from the warmer growing season, whereas trees at the low-altitude site experienced water stress conditions and their growth was highly inhibited also in the following year. Glaciers are an expression of climate conditions, and as a first signal they respond almost immediately to climate anomalies consequently varying their mass. Glacier mass loss in the OCG in 2003 was the highest since yearly measurement started. Beside the climatic influence, glacier terminus variations depend on geometry and other local factors: extremely small and steep glaciers on the OCG seem to be more affected by the recent warmer climate conditions than the steep mountain glaciers, as pointed out by the total absence of advancing glaciers within the group of extremely small and steep glaciers since 1993. According to our results, biological and physical components of the alpine environment in the OCG recently showed strong and even divergent responses to the same climatic input and to climate anomalies.