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Multi-scale thermal variability in alpine streams

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Although stream temperature plays an important role influencing the biota of alpine streams, there has been limited research upon thermal variability within these mountain river systems. To address this research gap, water column and streambed temperature dynamics have been studied at nested spatial and temporal scales in the Taillon-Gabiétous basin, French Pyrénées since June 2002. In this basin, streams are sourced from two cirque glaciers (Taillon and Gabiétous), seasonally variable snowpacks, hillslope aquifers and a karst groundwater system. Temperature loggers were deployed at up to 29 sites during the 2002 and 2003 summer melt-seasons. Year-round monitoring was undertaken at five of these locations from 2002 to 2006. This paper reports findings that illustrate the nature and extent of thermal variability and driving factors/processes operating across a range of scales (inter-annual to minutes; whole basin to sub-reach).

At the basin-scale, high thermal heterogeneity was predominantly influenced by water source dynamics, aspect and distance from source. Mean water temperature in the Taillon Glacier stream during the 2002 (2003) melt season increased from 0.4ºC (0.4ºC) close to the glacier snout to 8.8ºC (10.3ºC) $\sim$1.5km downstream. South-facing hillslope groundwater streams were typically the warmest streams in the basin reaching mean temperatures $>$14ºC in both years. With the exception of a site at the Taillon Glacier snout, karstic groundwater streams were typically coldest (4.4-5.4ºC) with the lowest stream temperature variability. Streambed temperatures (0.05m, 0.20m and 0.40m depth) were coldest and most variable in the Taillon Glacier stream, and warmest and least variable in a predominantly groundwater-fed tributary.

Inter-annually, stream temperature varied markedly as a result of meteorological con-

ditions. For example, during 2003 higher mean and maximum stream temperatures were recorded compared with 2002, 2004 and 2005. At the seasonal scale, air-stream temperatures have provided hydrological insights into river flow conditions by differentiating free-flowing, surface freezing, dewatering and snow cover. At the diurnal-scale, high-resolution (15 min) data collection has allowed for detailed examination of thermal variability, in relation to meltwater discharge fluctuations and meteorological influences. These detailed storm event observations have revealed water column temperature changes ranging from 10.4ºC decreases to 2.3ºC increases, and improved understanding of the role of antecedent conditions, precipitation event characteristics and stream discharge peaks on event-scale thermal dynamics.

Overall, our research in the Taillon-Gabiétous basin has demonstrated high thermal heterogeneity of alpine river systems at multiple spatial and temporal scales, and highlighted the need for integrated hydrometeorological studies to advance understanding of stream thermal dynamics in alpine and other environments.