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How geomorphology and groundwater level affect the spatio-temporal variability of riverine cold water patches?

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Temperature is a key factor for river ecosystems. In summer, patches of cold water are formed in the river by groundwater seepage. These patches have strong ecological significance and extend to the surface water in a well-mixed riverine system. These patches can serve as thermal refuges for some fish species during summer. In this study, the temporal variability and spatial distribution of cold water patches were explored along a 50 km river reach (the lower Ain River, France) using thermal infrared airborne remote sensing. This study examines a new range of processes acting on cold water patches at different scales that have not previously been touched upon in the literature. Three airborne campaigns were conducted during the summers of 2010, 2011 and 2014. Based on these images, a large number of cold water patches were identified using an automated method. Four types of patches were observed: tributary plumes, cold side channels (former channels or point-bar backwater channels), side seeps (located directly in the river channel) and gravel bar seeps (occurring at the downstream end of gravel bars). Logistic regression was used to analyse the longitudinal distribution of cold water patches according to geomorphologic indicators reflecting current or past fluvial process. Side seeps were found to be related to the local geology. Cold side channels were correlated to contemporary and past lateral river mobility. Gravel bar seeps were related to the current development of bars and are more prevalent in wandering reaches than in single-bed incised and paved reaches. The logistic model was subsequently used to evaluate gravel bar seep variability in the past. The model suggests larger numbers of seeps in the mid-20th century when bar surface area was higher. Interannual variability in the occurrence and spatial extent of side seeps and gravel bar seeps appear to be related to groundwater level fluctuations. Cold side channels exhibited greater interannual stability. Nonetheless, amongst all patch types, some are quite stable over time, while others are transient. These results can be used to target areas with high densities of stable and spatially extensive cold water patches that are considered ecological refuges, in the context of pronounced low flow and a rise in water temperature.

Key words: River temperature; Thermal Infrared (TIR) remote sensing; groundwater; fluvial geomorphic features; side channels; spatio-temporal variability; lower Ain River (France).