Temporal and spatial temperature patterns of 9 braided rivers using very high resolution thermal infrared (TIR) images

Analyse spatio-temporelle des patrons thermiques de 9 rivières en tresses par imagerie infrarouge thermique (IRT) très haute résolution

Vincent Wawrzyniak[1,2*], Pascal Allemand[2], Hervé Piégay[1], Lise Vaudor[1], Philippe Grandjean[2]

[1]University of Lyon, CNRS-UMR 5600. ENS de Lyon, Plateforme ISIG. 15, Parvis René Descartes, BP 7000, F69342 Lyon Cedex 07, France.
[2]University of Lyon, CNRS-UMR 5276. Université Claude Bernard, Lyon 1 Campus de la Doua, bât. GEODE 2, rue Raphaël Dubois, F69622 Villeurbanne Cedex, France.
[*]Corresponding author e-mail: vincent.wawrzyniak@gmail.com
Zone Atelier Bassin du Rhône

RÉSUMÉ

Les rivières en tresses présentent une très forte variabilité spatiale de leurs températures. À l'échelle du tronçon, les structures thermiques sont notamment affectées par les échanges hyporhéiques et phréatiques ainsi que par la géométrie des chenaux (Arscott et al., 2001). Toutefois, cette variabilité thermique est difficile à observer en utilisant uniquement des thermomètres in situ. Dans cette étude nous avons utilisé l'imagerie infrarouge thermique (IRT) afin d'évaluer les structures thermiques de 9 tronçons de rivières en tresses, situés dans le sud-est de la France, dans le bassin du Rhône. Les images ont été acquises grâce à un paramoteur et un drone pour obtenir des données très haute résolution (~ 20 cm). Nous avons fait l'hypothèse que le type de rivières en tresses a une influence sur les structures thermiques et que ces dernières changent au cours du temps. Par conséquent, nous avons eu trois approches temporelles différentes. La première est un suivi unique de chaque site au cours des étés 2010 ou 2011 pour explorer comparativement tous les tronçons. Dans une deuxième phase, afin d'explorer la variabilité inter-annuelle, trois tronçons ont été sélectionnés pour être imagés deux fois au cours des étés 2010 et 2011. Enfin, la dernière phase consiste en une observation intra-journalière de deux sites.

ABSTRACT

Braided rivers present a very high spatial variability of water temperature. At the reach scale, thermal patterns are notably affected by groundwater-hyporheic hydrology and channel geometry (Arscott et al., 2001). This high thermal variability is difficult to comprehend using only in situ temperature loggers. In this study we used thermal infrared (TIR) images to evaluate temperature patterns of nine braided reaches. All the studied reaches are located in Southeast France, in the Rhône River basin. Images were acquired from a powered paraglider and a drone to provide very high spatial resolution data (~20 cm). We hypothesized that braided river type has an influence on the spatial patterns of water temperature and that the patterns change through time. Therefore, we had three distinct temporal approaches to characterize thermal patterns. The first one is based on a single survey of each site during the 2010 or 2011 summers to explore comparatively all reaches. In a second phase three reaches were selected and therefore imaged both in summers 2010 and 2011 to explore an inter-annual variability. Finally, the third phase is an intra-day survey of two reaches.

MOTS CLES

Braided rivers, spatial and temporal water temperature patterns, Thermal infrared (TIR) remote sensing.

1 INTRODUCTION

At the catchment scale, water temperature is influenced by geographical factors, but at the reach scale superficial and groundwater hydrology and channel geometry strongly affect thermal patterns (Arscott et al., 2001). During the last 30 years, studies have pointed out the significance and complexity of water exchanges between the channel and the hyporheic and phreatic zones. These surface-subsurface water exchanges influence water temperature patterns. Braided rivers present particular thermal conditions with very high spatial variability of water temperature. For instance, Arscott et al. (2001) observed temperature differences between aquatic habitats up to 15°C in a single reach of the Tagliamento River. TIR remote sensing provides real opportunities to study fine radian temperature patterns of braided rivers and Tonolla et al. (2010) showed that this technique is relevant to assess temperature patterns of gravel bars and flow channels in the braided section. The aims of this study are to evaluate temperature patterns of nine braided reaches at very high spatial resolution (~20 cm). We hypothesized that braided river type has an influence of the spatial patterns of water temperature and that the patterns change through the day.

2 STUDY AREA

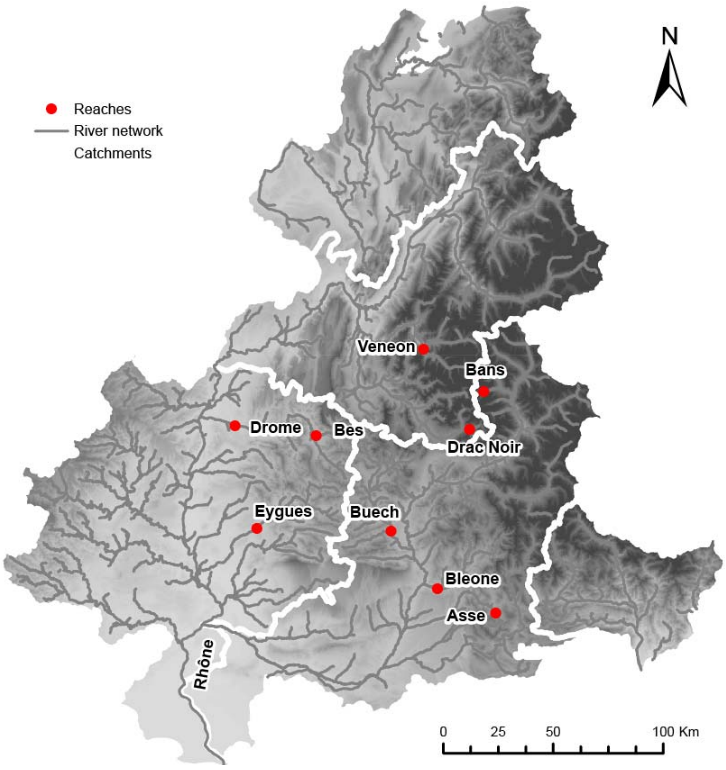

Figure 1: Studied reaches location (from Belletti et al. (in prep)).

Reaches are located in Southeast France, in the Rhône basin. Despite the disappearance of about half of the braided rivers in the French Alps notably due too embankment and channelization, braided channels are still well extended in this region and present different braided patterns (Piégay et al., 2009; Belletti et al., in prep). From the 53 reaches studied by Belletti et al. (in prep), we selected rivers which present high aquatic habitat diversities, with high proportion of ponds and channels that do not have upstream connections with the main channel. The reaches (figure 1) are located in three regional areas: in the Massif des Écrins (Vénéon, Drac Noir, Bans), in the Rhône valley (Drôme, Bes de la Drôme, Eygues), and in the Southern Alps (Buëch, Bléone, Asse).

3 METHODS

Very high spatial resolution TIR images are needed for surveying braided rivers because they have multiple, often narrow aquatic features and none of the commercial satellite and aircraft thermal images can actually provide such fine spatial resolutions. Therefore, we used a drone and a powered paraglider for acquiring our thermal images. The two vector types were equipped with a thermal camera (7.5-14 µm) which can detect noise equivalent temperature differences of ±0.08°C. Based on flight and camera parameter, we collected thermal images with very high spatial resolution (10-30 cm). Visible images were also recorded and in situ measurements of water temperatures were taken.

In this study we had three distinct temporal approaches to characterize thermal patterns. The first one is based on a single survey of each site during the 2010 or 2011 summers to explore comparatively the 9 sites. In a second phase three reaches were selected and therefore imaged both in summers 2010 and 2011 to explore an inter-annual variability. The last phase is an intra-day survey of two reaches, the Drôme and Drac Noir reaches, ones is submediterranean and the second proglacial. Here, respectively four and three flights were realized within a day of the summer 2011. Figure 2 illustrated the results for the Drôme reach.

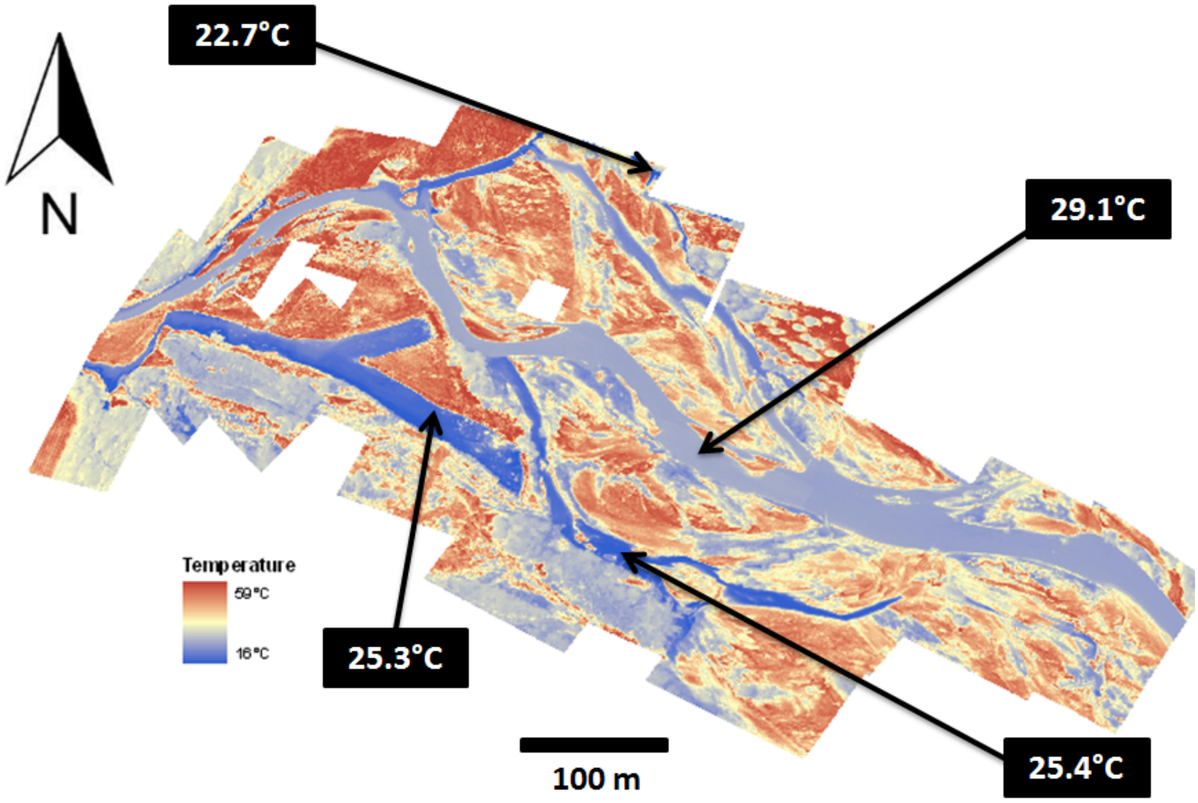

Figure 2: Mosaic of thermal images of the Drôme reach (11 July 2011 - 18:30). Blue and red represent cold and warm areas respectively.

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