Paired water and air temperature analysis coupled with distributed temperature sensing (DTS): a tool for groundwater-surface water interaction zones characterization in tropical streams

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Abstract: Temperature, as a natural tracer, and distributed temperature sensing (DTS), using fiber optic cables, has been highlighted as a tool for monitoring and evaluating groundwater-surface water interaction. The analysis of temperature signals allows the distinction of interaction zones with shallow and deep waters since water from different sources has different thermal characteristics. One of these methodologies is the paired analysis of water and air temperature signals, evaluating their amplitudes and phases over time. In this sense, this work aims to present an experience of long-term monitoring and analysis of water temperature data and its relationship with air temperature to establish a tool for characterizing groundwater-surface water interaction zones in tropical areas. From water temperature data measured with a DTS device in a tropical watershed (Onça Creek Watershed – Brotas, São Paulo, Brazil), we determined the amplitude ratio and phase difference of this temperature signal and air temperature in different seasons of the year. We recurrently observed that low amplitude ratios and high phase differences can indicate deep groundwater discharge, while shallow groundwater presents behavior closer to air temperature. These results highlight how temperature can be used as a tracer to monitor groundwater surface-water interactions in tropical areas and how this kind of analysis can help to identify the water source depth.

Keywords: groundwater-surface water interaction, temperature, fiber optics, natural tracers.

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MATERIALS AND METHODS

The study area of this work is the Onça Creek Watershed (OCW), located in the rural area of Brotas, state of São Paulo, in the Southeast region of Brazil (WENDLAND et al. 2022). Distributed temperature measurement was used, with fiber optic cables (SELKER et al. 2006; LOWRY et al. 2007), to measure the temperature of about 1300 m along the main stem of the basin. The cables are split into two segments, upstream and downstream, from where they are connected to the distributed temperature sensing device. Six weekly temperature monitoring campaigns were carried out at the site, in different seasons of the year, between 2021 and 2022 (Autumn (1): May/21 **|** Winter (1): june/21 **|** Winter (2): july/21 **|** Spring: December/2021 **|** Summer: January/2022 **|** Autumn (2): May/22). Water temperature data were paired with the air temperature data (HARE et al., 2021; HARE et al., 2023), collected from an automatic meteorological station available at the OCW (Monte Alegre Station). We calculated to parameters on a daily scale: the ratio between the amplitudes of the temperature signals and the phase difference between them. We used these parameters to differentiate zones along the river length that presented different behaviors indicative of groundwater discharge from different depths.

RESULTS AND DISCUSSION

We observed that low amplitude ratios between the temperature signals indicates interaction zones with deep groundwater (Figure 1). While the air temperature varies with higher amplitudes during days and nights, groundwater temperature tends to stabilize in deeper layers with lower temperature amplitudes. When discharging at the surface, groundwater keeps that feature, allowing this zone distinction. Intermediate values of amplitude ratios indicate hyporheic zone flows derived from the mixture of surface water and groundwater at small depths. Along the river length, water can infiltrate in a given section and discharge in further downstream regions causing minor temperature anomalies. When evaluating the phase difference, we observe that water temperature signals are generally out of phase with the air temperature signal. Interaction zones with deep water tend to present the major phase difference, considering that the temperature fronts act in different directions. While groundwater discharging transport heat to the surface by advection, surface heat tends to advance in depth by conduction, which lags water temperature signal in the interaction zones.

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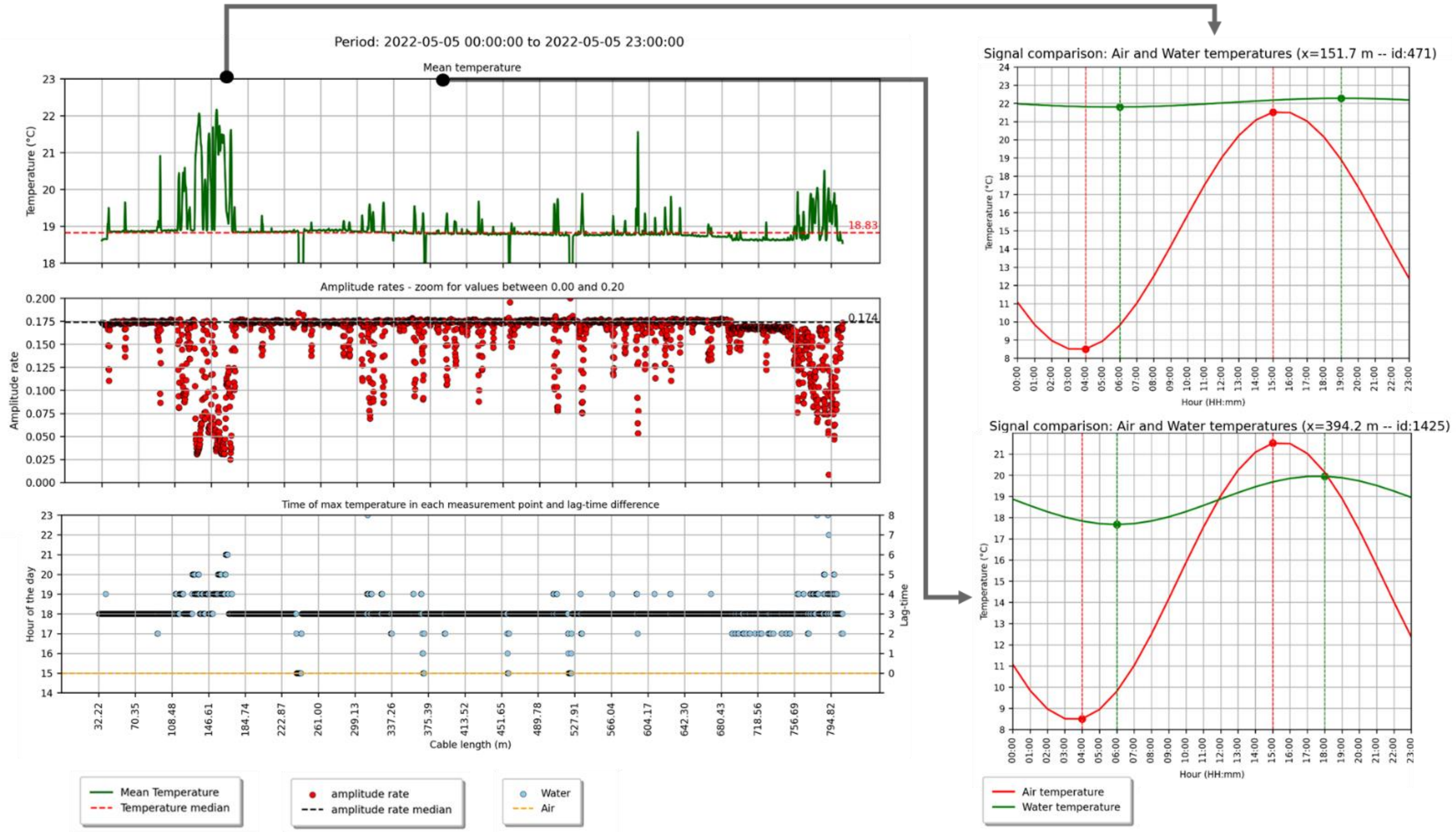
Figure 1 – Results of amplitude ratios (red dots) and phase difference (difference of maximum temperature occurrence) of the water and air temperature signals, monitored on May 5th, 2022. Detail the temperature signals over time (right side of the figure) for interaction points with deep water (top) and shallow water (bottom).



Source: Authors (2023)