A multi-technique approach to determine temporal and spatial variability of groundwater-stream water exchange

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1) OBJECTIVE

Characterizing the spatio-temporal distribution of groundwater-surface water exchange fluxes is of paramount importance in understanding catchment behavior. The objective of this study is to quantify the spatio-temporal distribution of these exchange fluxes along the Cakit Stream (Nigde, Turkey) characterized by complex topography (Fig. 1) and geology (Fig. 2). We start with Electromagnetic Induction (EMI) survey at longer stream reaches to determine potential exchange zones. These zones were then investigated in detail using multiple techniques including fiber-optic Distributed Temperature Sensing (DTS), temperature-based vertical flux estimation, nested piezometers and water quality parameters in a hierarchical manner.

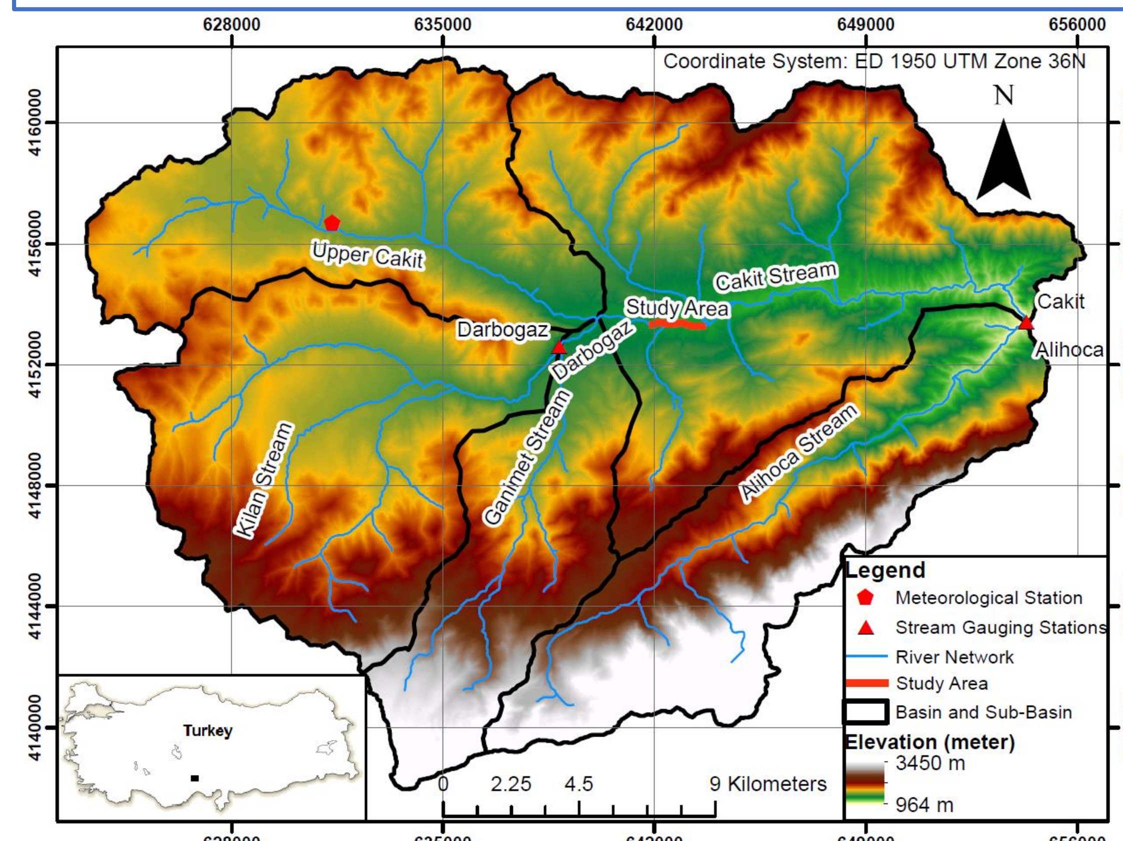

Figure 1 Study basin (529 km²)

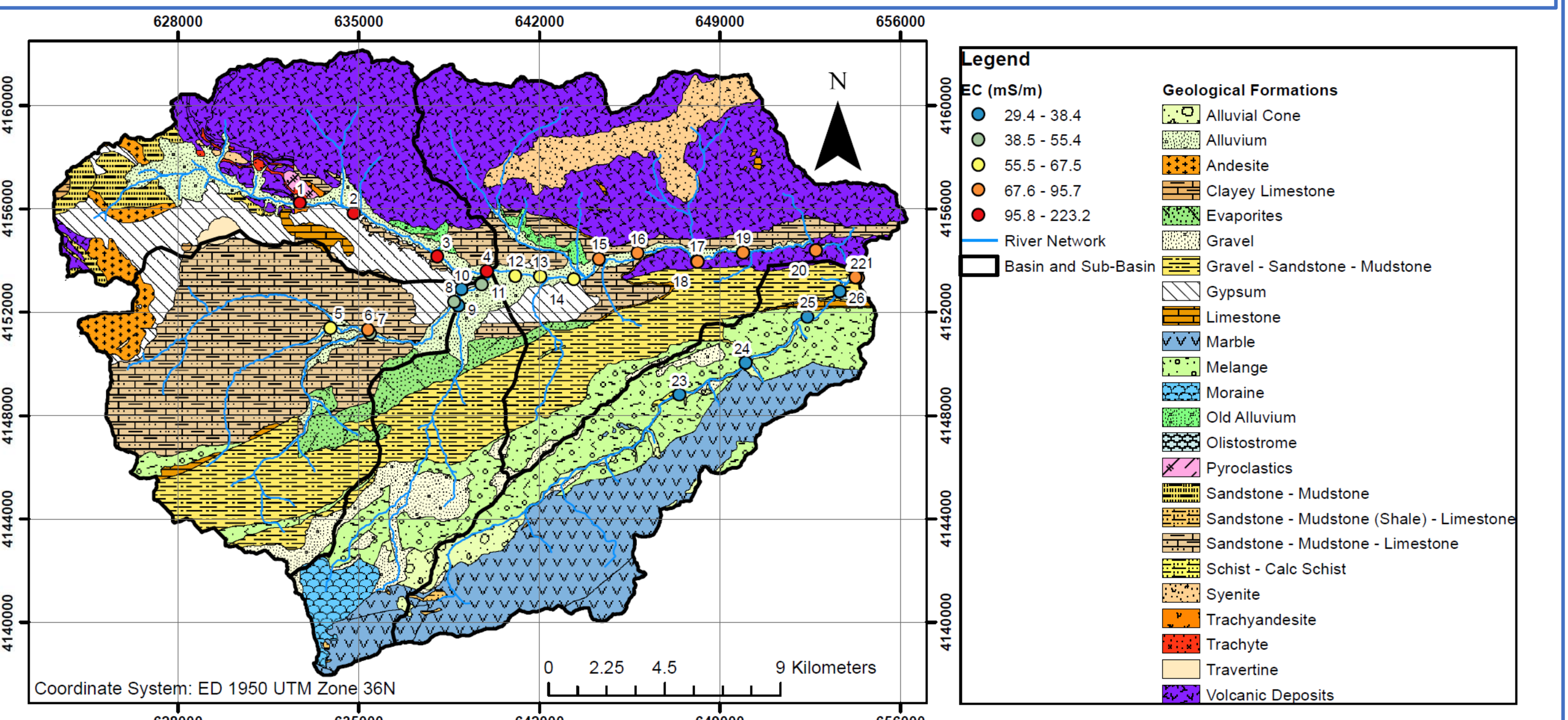

Figure 2 Geology of the basin. EC (mS/m) values are shown at sampling points

2) METHODOLOGY

EMI surveys were performed over long reaches of Cakit Stream to pinpoint potential groundwater upwelling sections along the streambed (Fig. 3). Electrical Conductivity (EC) of the streambed sediments is estimated from the EMI surveys by considering the EC variation and depth of the water column. EC anomalies guided our focus to a 600 meter-long reach of the stream (Fig. 4). Along this selected reach, fiber-optic DTS system was utilized to investigate streambed-temperature variations at fine spatial and temporal scales (Fig. 5 & Fig. 6). Furthermore, nested piezometers and iButton temperature loggers (Fig. 7) were installed at three potential locations to investigate vertical hydraulic gradient (Fig. 8) and exchange fluxes (Fig. 9 & Table 1).

3) RESULTS

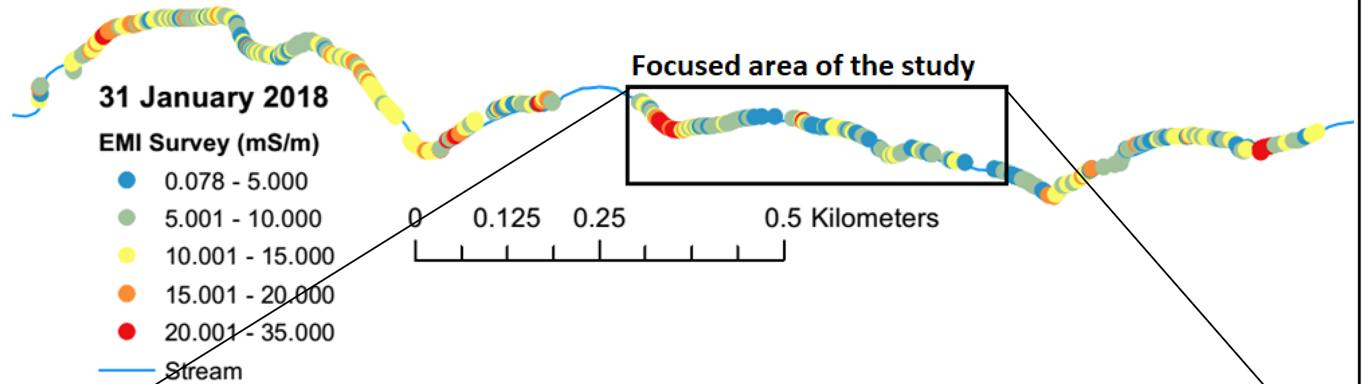

Figure 3 First EMI Survey (31 January, 2018)

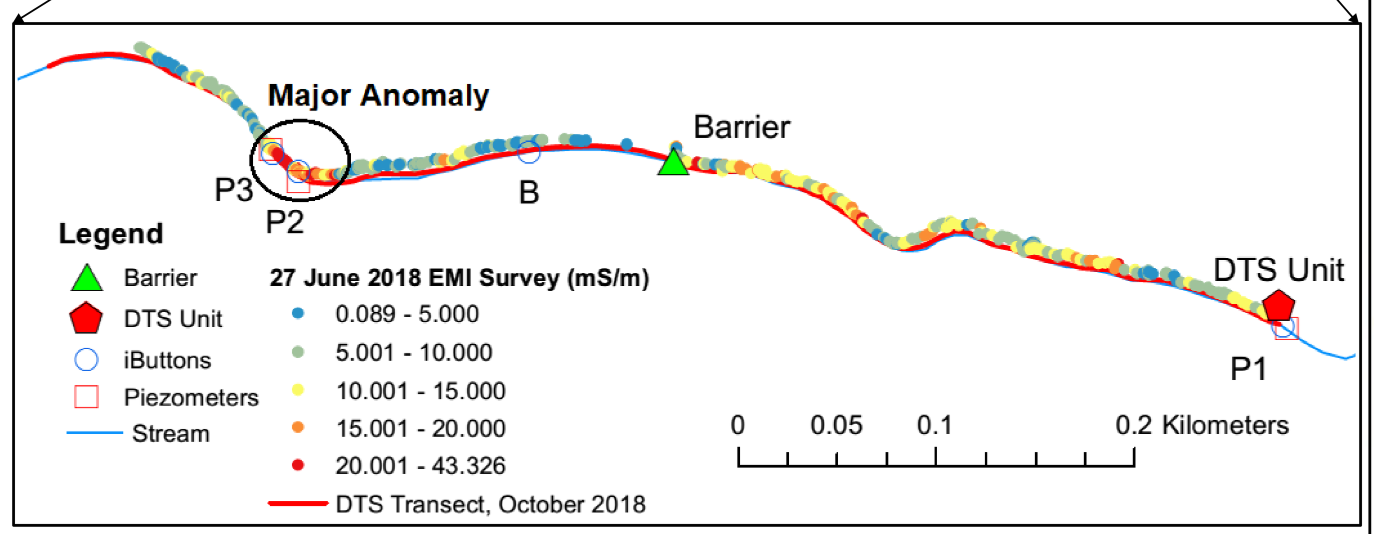

Figure 4 Location of nested piezometers, vertical temperature profiles (iButtons) and DTS transect along with EMI Survey conducted on 27 June, 2018

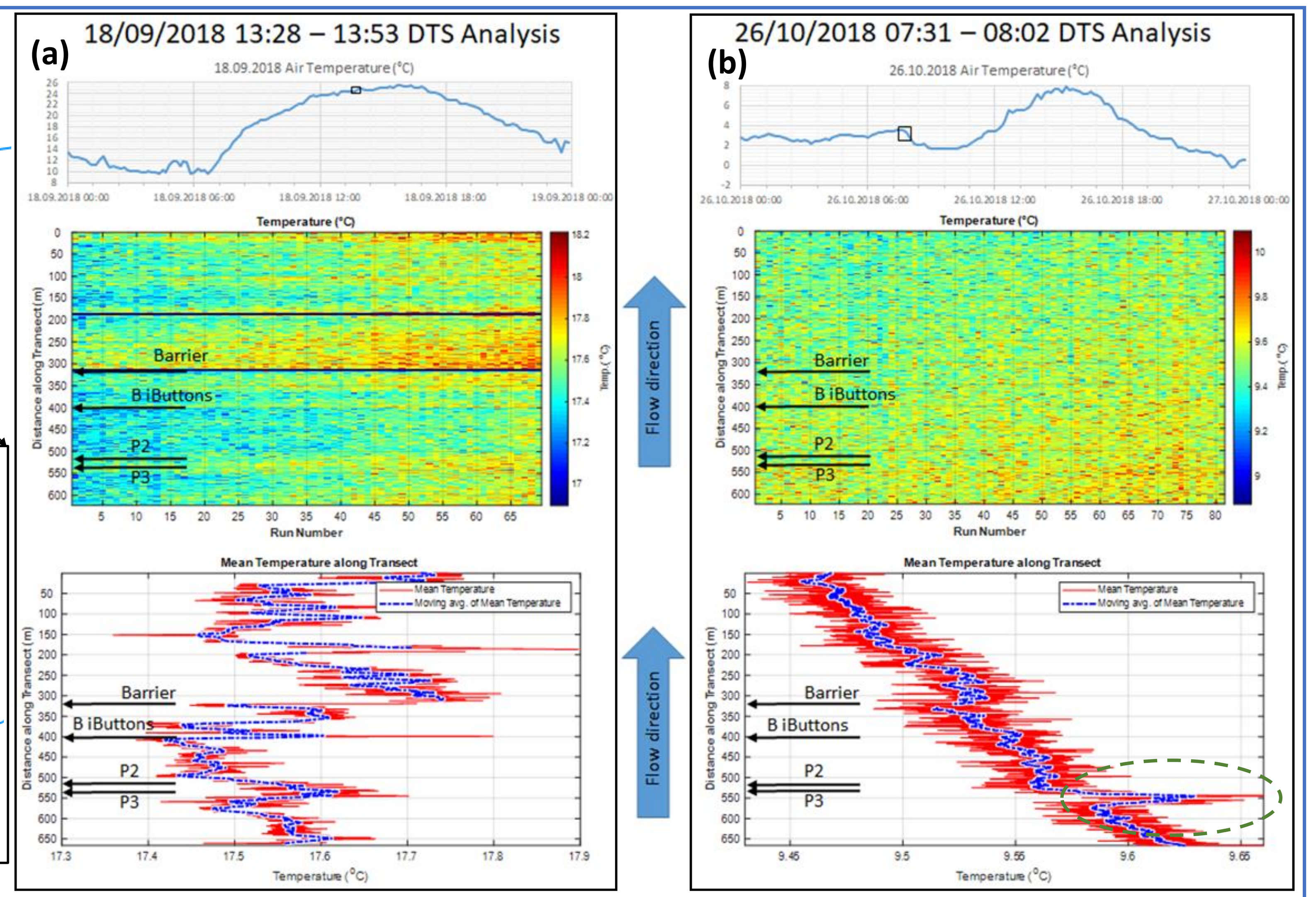

Figure 5 DTS results of two measurement periods (a) inconclusive results on 18/09/2018 13:28-13:53, (b) successful results on 26/10/2018 07:31-08:02

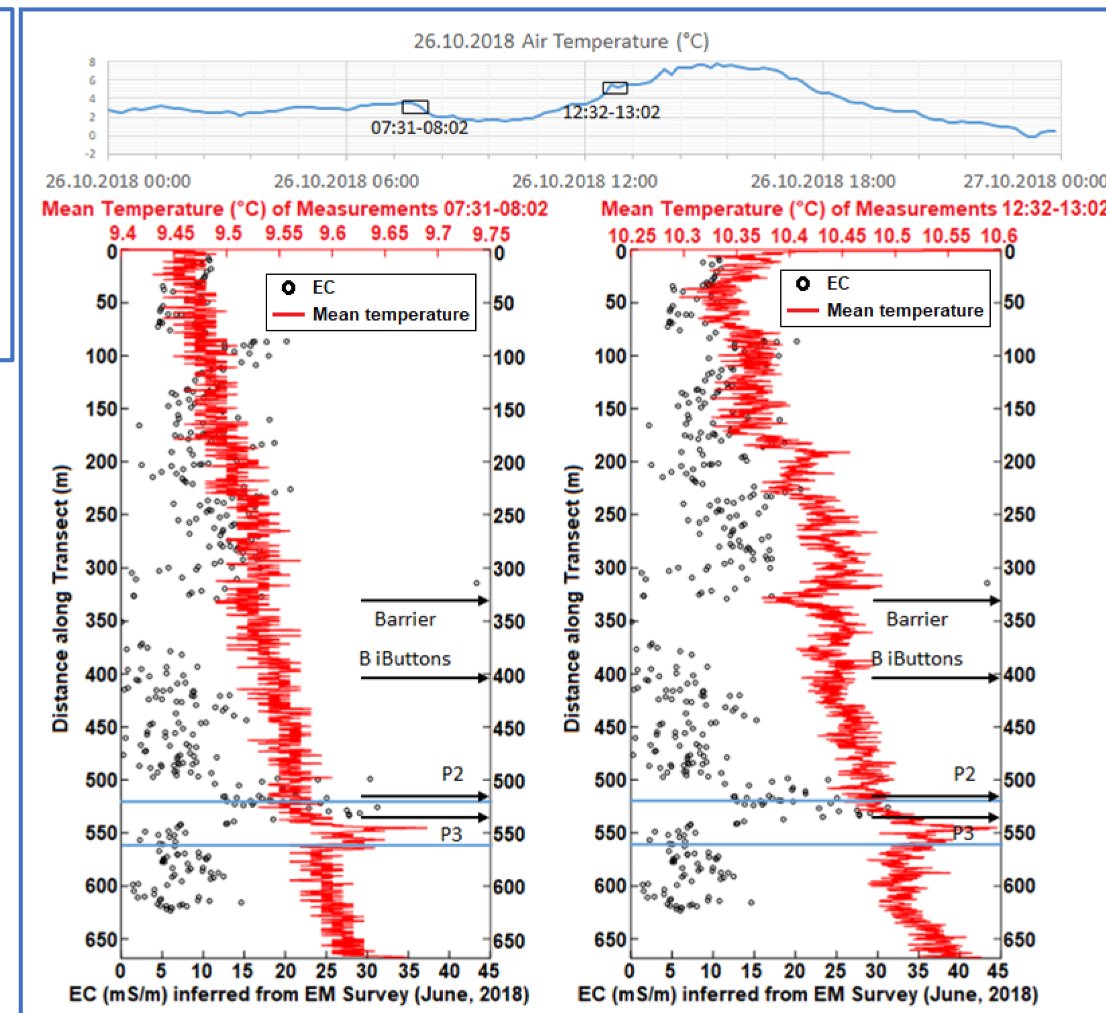

Figure 6 EC data inferred from EMI survey (June 2018), and mean temperature from DTS (26 Oct. 2018 @ 07:31-08:02 & @ 12:32-13:02)

- The instrument used for EMI survey is Electromagnetic Conductivity Meter (CMD) by GF Instruments & used with an effective depth of 1.5 m.
- The DTS unit employed was Silixa XT-DTS™. DTS measurements were taken at each 0.254 cm over 1 km length fiber-optic cable in every 23 sec. for 30 min.
- iButtons: 1-Wire Maxim Integrated DS1922L having 0.0625 °C resolution & 0.5 °C accuracy (@ -10°C to 65°C range). Temperature recorded @ 10 min interval.

Figure 7 Arrangement of iButtons

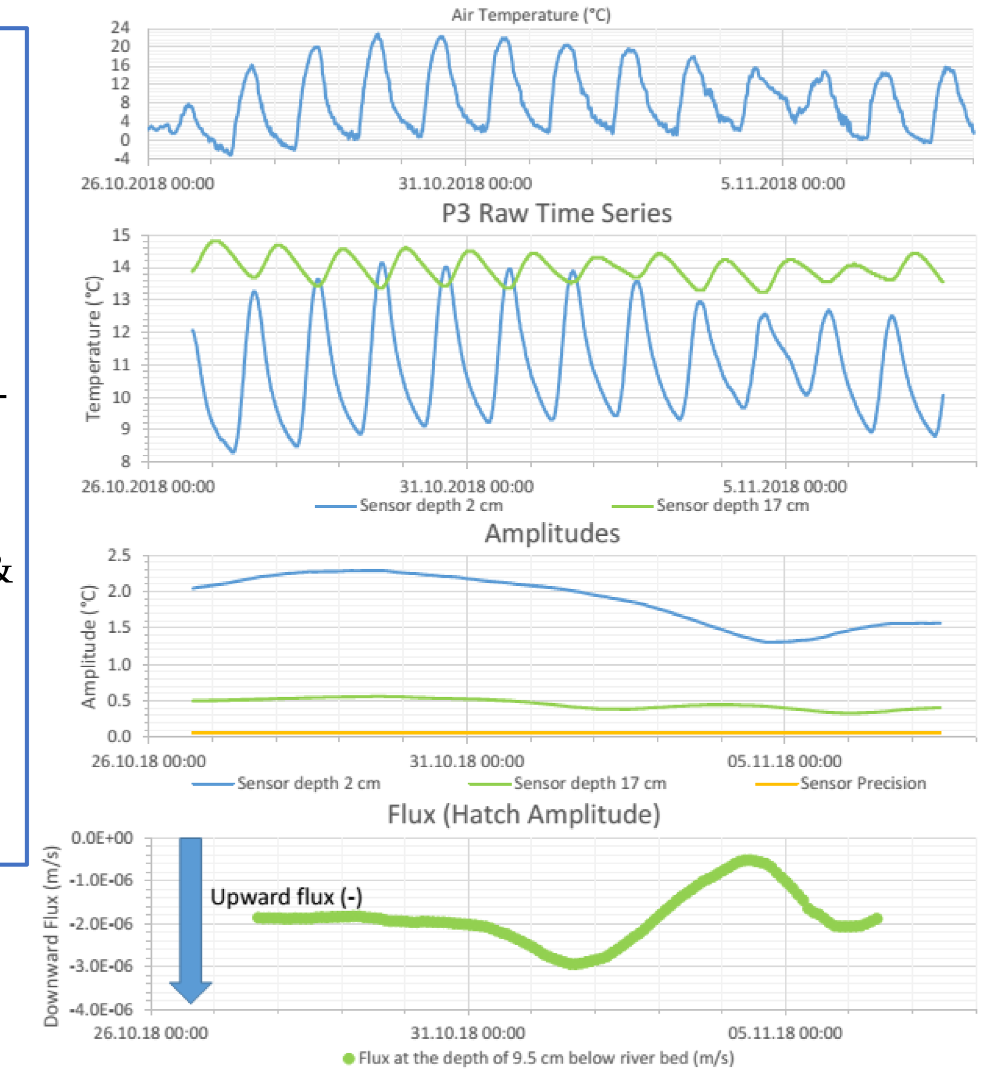

Figure 9 Vertical flow estimation @ location P3 (October 2018) using iButton vertical temperature profile data

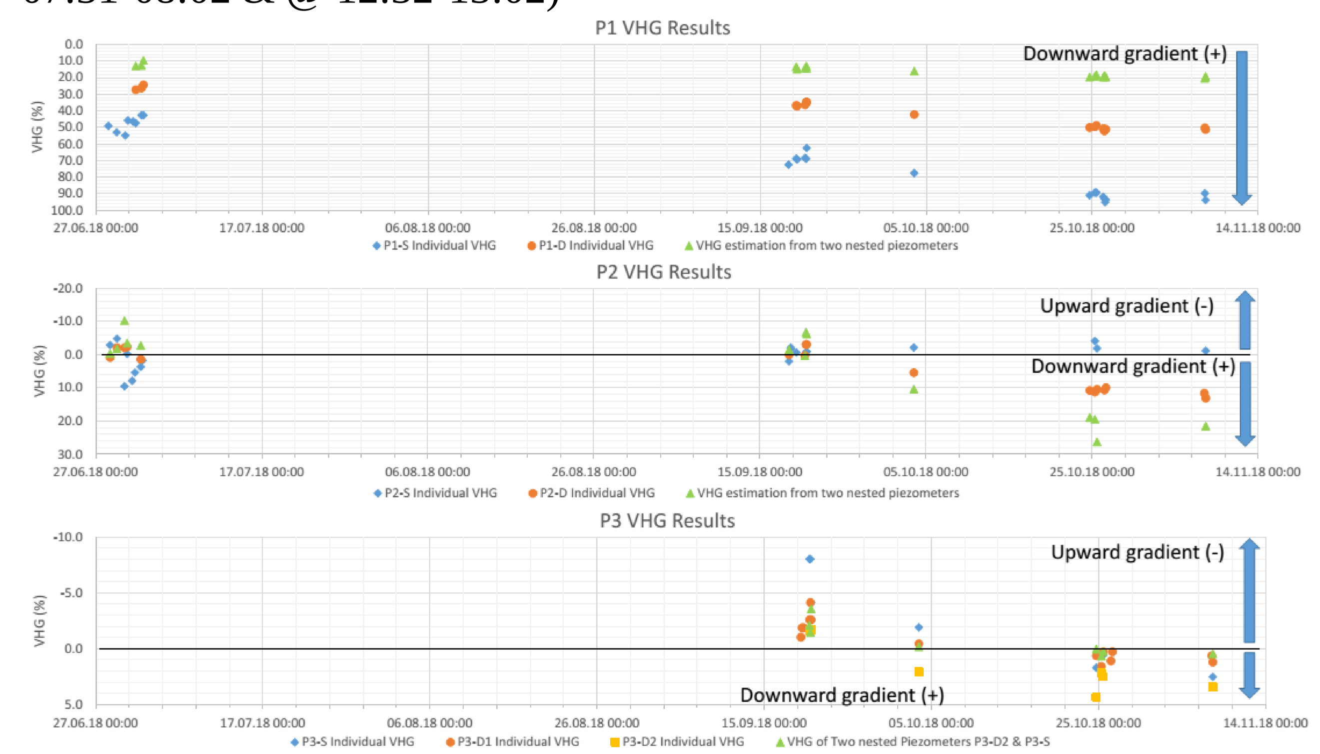

Figure 8 Vertical hydraulic gradient values from nested piezometers @ sites P1, P2 and P3 (see Fig. 5 for locations)

Table 1 Vertical flow values estimated using vertical temperature profiles (see Fig. 5 for locations)

Time Period	Site	Vertical Flow Estimates		Flow Direction
		Depth below top of streambed (cm)	Velocity (m/s)	
06.28.2018 - 07.02.2018	P1	9.5	2.2x10-6 - 2.5x10-6	Downward
09.18.2018 - 10.03.2018	P2	9.5	5x10-7 - 2x10-6	Upward
	P3	5.5	1x10-6 – 1x10-5	Upward
10.26.2018 - 11.07.2018	P2	9.5	6x10-7 – 1x10-6	Downward
	P3	9.5	2x10-6 – 3x10-6	Upward
	B	9.5	4x10-6 – 6x10-6	Upward

4) DISCUSSION

The EMI Survey was important for identifying local heterogeneities of streambed structure or pore fluid chemistry. The results obtained from the EMI surveys agreed well with the results of DTS at a location (Fig. 6). However, a marked difference in the temperature of groundwater and streamwater, low discharge rates (proper seasonal conditions), minimizing the effect of solar radiation/shading effect are important factors controlling the value of DTS for identifying influx from groundwater. Vertical hydraulic gradients (Fig. 8) and vertical temperature profiles (Fig. 9 & Table 1) provided us quantitative data to support our results. The results indicate that the downstream sections of the streambed are characterized by downwelling fluxes regardless of the season, whereas seasonal factors control the direction and magnitude of the exchange fluxes along upstream sections.

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