Deriving variable travel times and aerobic respiration in the hyporheic zone using electrical conductivity as natural tracer

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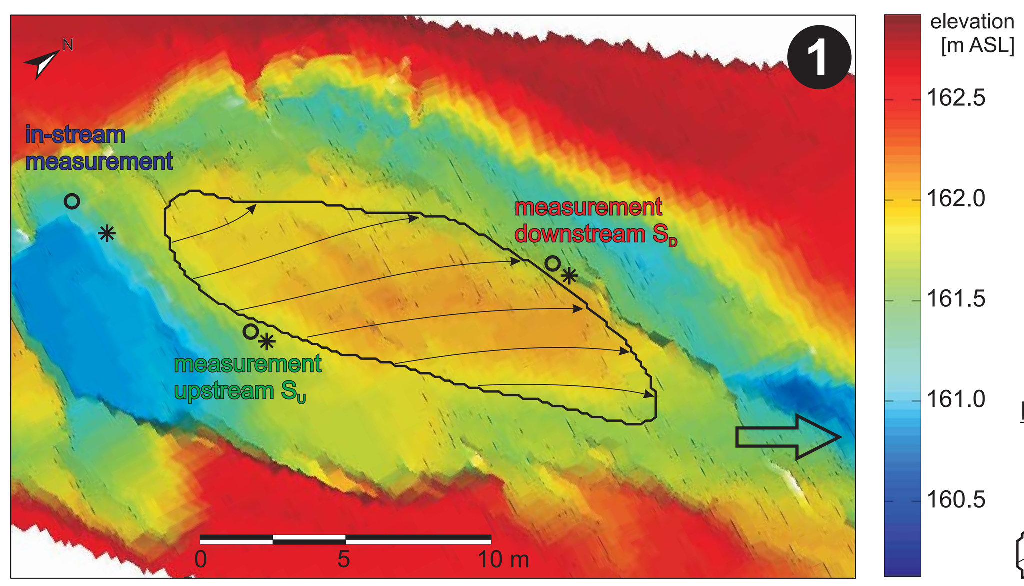
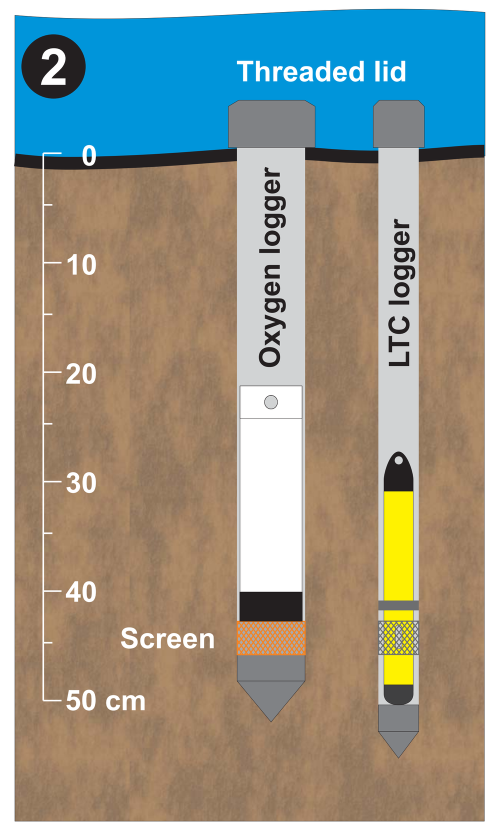
1 Introduction

Respiration is an important parameter for characterizing the ecological functioning of a stream. Hyporheic community respiration contributes a large fraction to the whole stream respiration, but is difficult to determine *in situ*. When the travel-times of the hyporheic water and the related oxygen concentrations are known, respiration rates can be derived using simple first order decay. We present a method that uses variable electrical conductivities (EC) as tracer to detect the time lag between the stream EC and the EC signal in the hyporheic sediment. The travel-times obtained by cross-correlation are then combined with *in situ* measurements of dissolved oxygen (DO) for deriving a transient aerobic respiration rate. We compared travel-times, oxygen supply, decay rates, and damköhler numbers in the sediment upstream and downstream of an in-stream gravel bar.

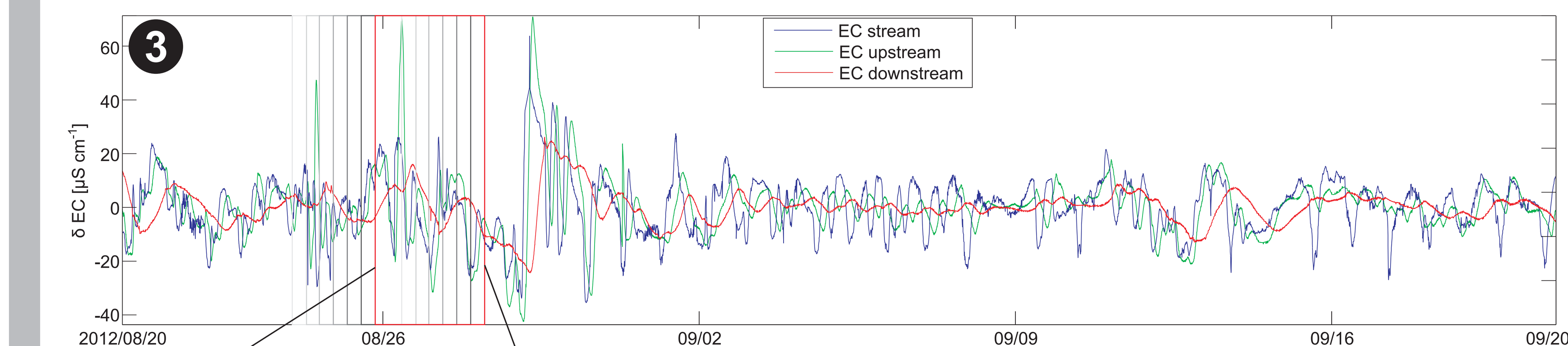
2 Field measurements

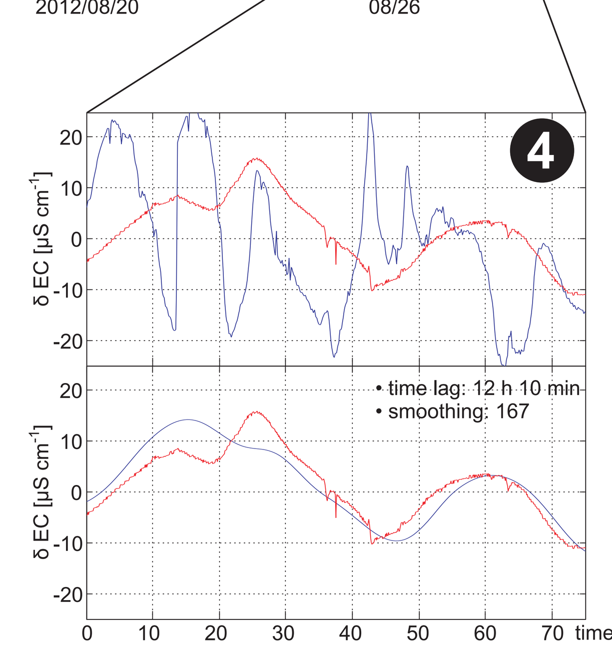
LTC Logger and optode based oxygen logger were installed in the stream and in the sediment at 45cm depth [2]. Streambed adapted probe rods with a screened section of 2cm are designed to ensure a highly responsive and localized measurement whilst minimizing the potential disruption of the HZ. The positioning in the sediment upstream (S_U) and downstream (S_D) beside an in-stream gravel bar should capture different respiration characteristics within the same morphological unit [1]. The placement of both sensors was only 40cm apart and the measuring interval was set to 5 minutes.





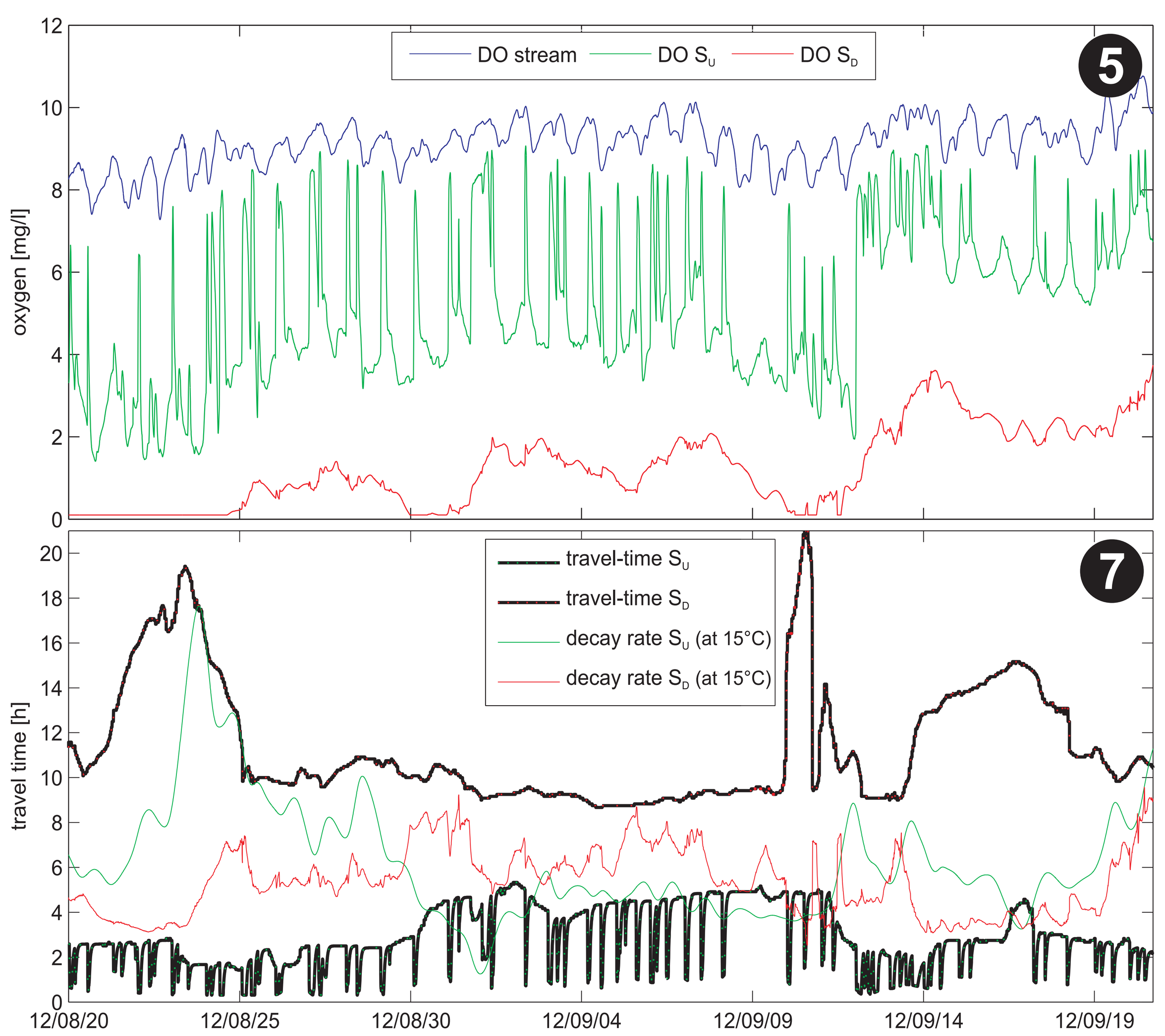
3 EC windowed cross-correlation





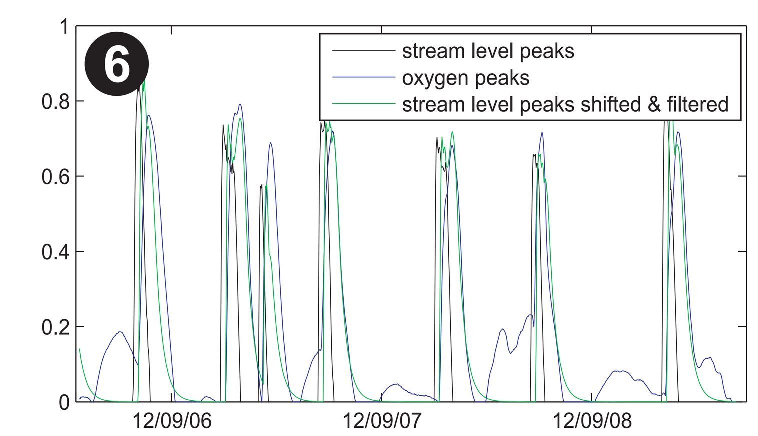
The EC time series are split into heavily overlapping windows [3] where a cross-correlation is performed to identify a transient time shift. For each time-step the stream EC was individually smoothed to optimize the correlation between the stream and the sediment EC signal [4]. The maximal Pearson correlation coefficient (PCC) indicates the optimal time-shift for each window. The results vary depending on the chosen window length, so we used the median travel-time from several window lengths between 36h and 72h.

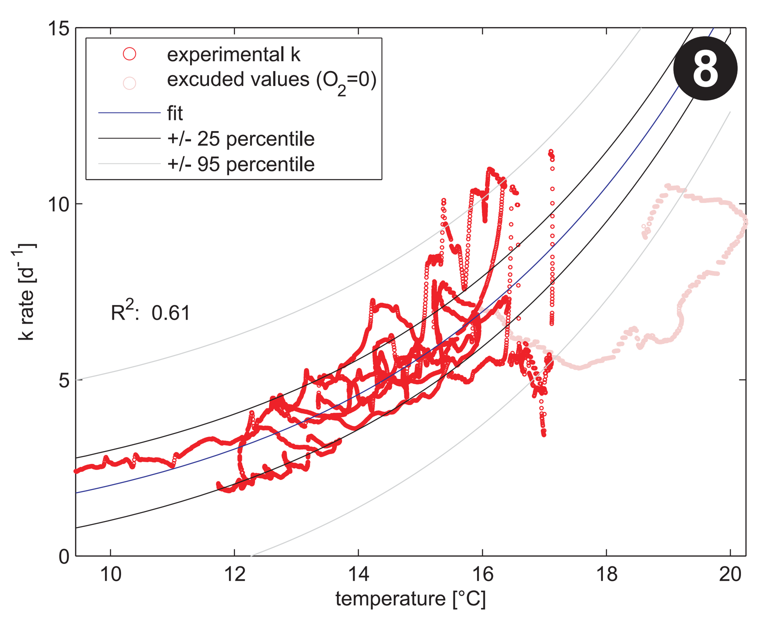
4 Aerobic respiration results



The DO concentrations at S_U are higher and more variable than those at S_D [5]. The distinctive peaks at S_U can be attributed to changes in water level induced by an upstream water mill [6]. Rapidly increasing water levels of up to 15cm for a duration of about 120min result in significantly shorter travel-times. This high travel-time variability could not be resolved by the cross-correlation alone, so peaks of short travel times were estimated from the water level peaks [6&7].

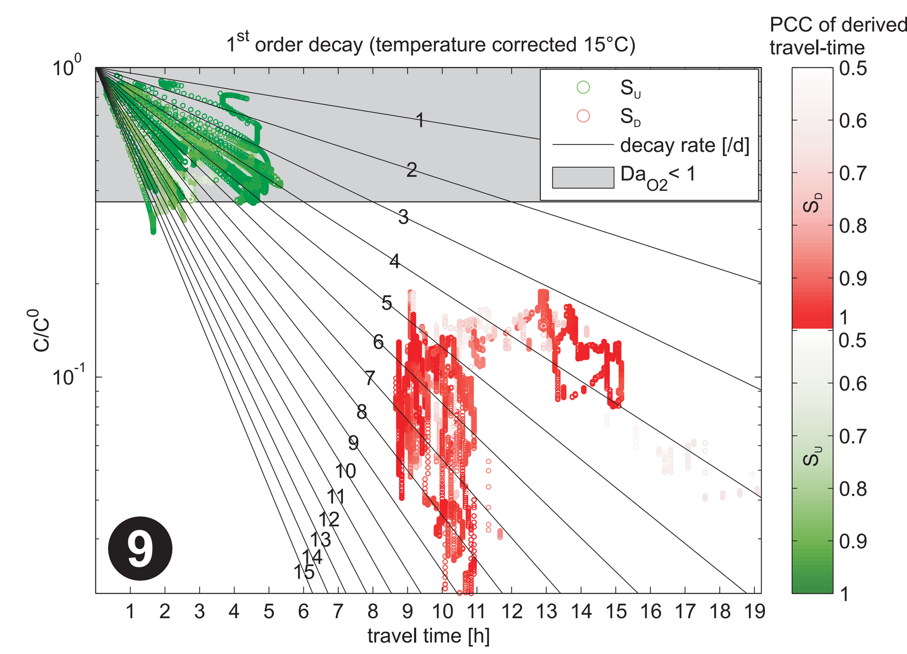
The adjusted travel-times for S_U ranging from 20-320min (μ=170min), for S_D from 520-1280min (μ=683min) [7]. An exponential relationship was found to explain 61% of the variations in the decay rates by temperature and is used for normalizing the decay rates to 15°C [8]. The resulting mean decay rate for S_U was higher (r=6.2 d^{-1}) and more variable (σ=2.7 d^{-1}) compared to S_D (r=5.2 d^{-1}, σ=1.4 d^{-1}). The relation is clearly following an 1st order decay [9].

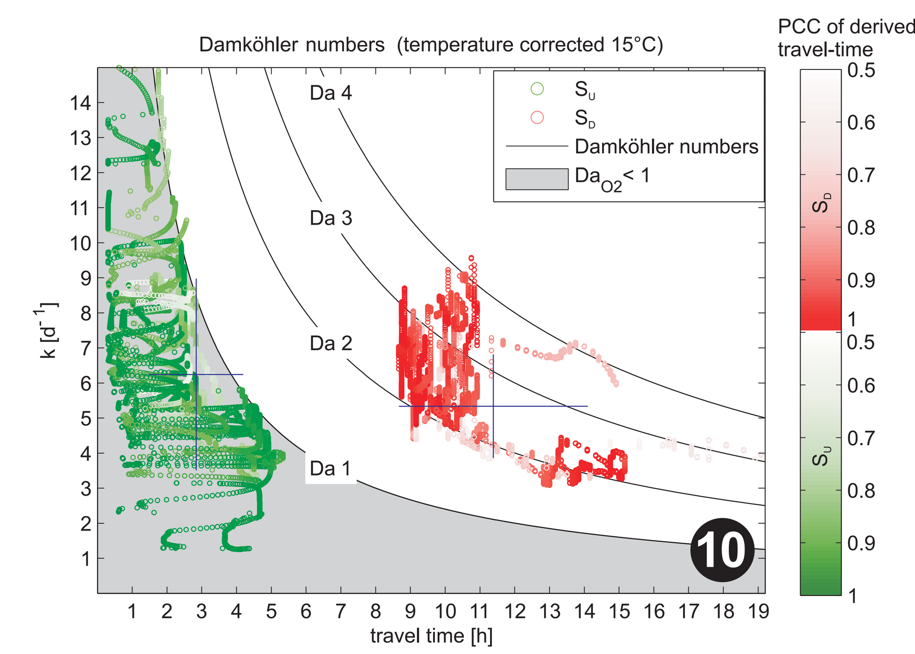




5 Conclusion

Changes in the diurnal EC signal are suitable for calculating travel-times and thus deriving transient respiration rates in the hyporheic zone. The calculation of a Damköhler number (ratio between rate and transport) revealed a more reaction limited zone S_U, caused by water level peaks which are rapidly increasing the oxygen supply [10]. On S_D the respiration becomes transport limited where longer travel times tend limiting the oxygen supply and therewith the respiration rate. We demonstrate how hydrodynamic effects and morphology can affect the respiration.





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