Importance of static and dynamic head drivers of hyporheic exchange: evaluation of a spectral modelling approach

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1. INTRODUCTION

The multidimensional process of hyporheic exchange flow (HEF) is driven to a large extent by longitudinal variations in static and dynamic head at the stream bottom. Static head variations drives the exchange where the water surface follows the stream topography and dynamic head variations are dominant where stream bottom fluctuations exists but are not transformed into fluctuations in the surfce water profile, instead causing pressure variations related to the flow separation. We hypothesize that static and dynamic head driven HEF coexist in many streams, only acting on different spatial scales. In this study, we investigate this hypothesis using a multidimentional mechanical model. We also evaluate the dominant driver, at the reach scale, in 11 small Swedish stream reaches (R1-R7 in result plot) with varying hydro-morphological character.

2. METHODS

Eleven stream reaches of different slope, discharge, bottom material and land use were selected. HEF was evalutaed in all reaches using two independent methods:

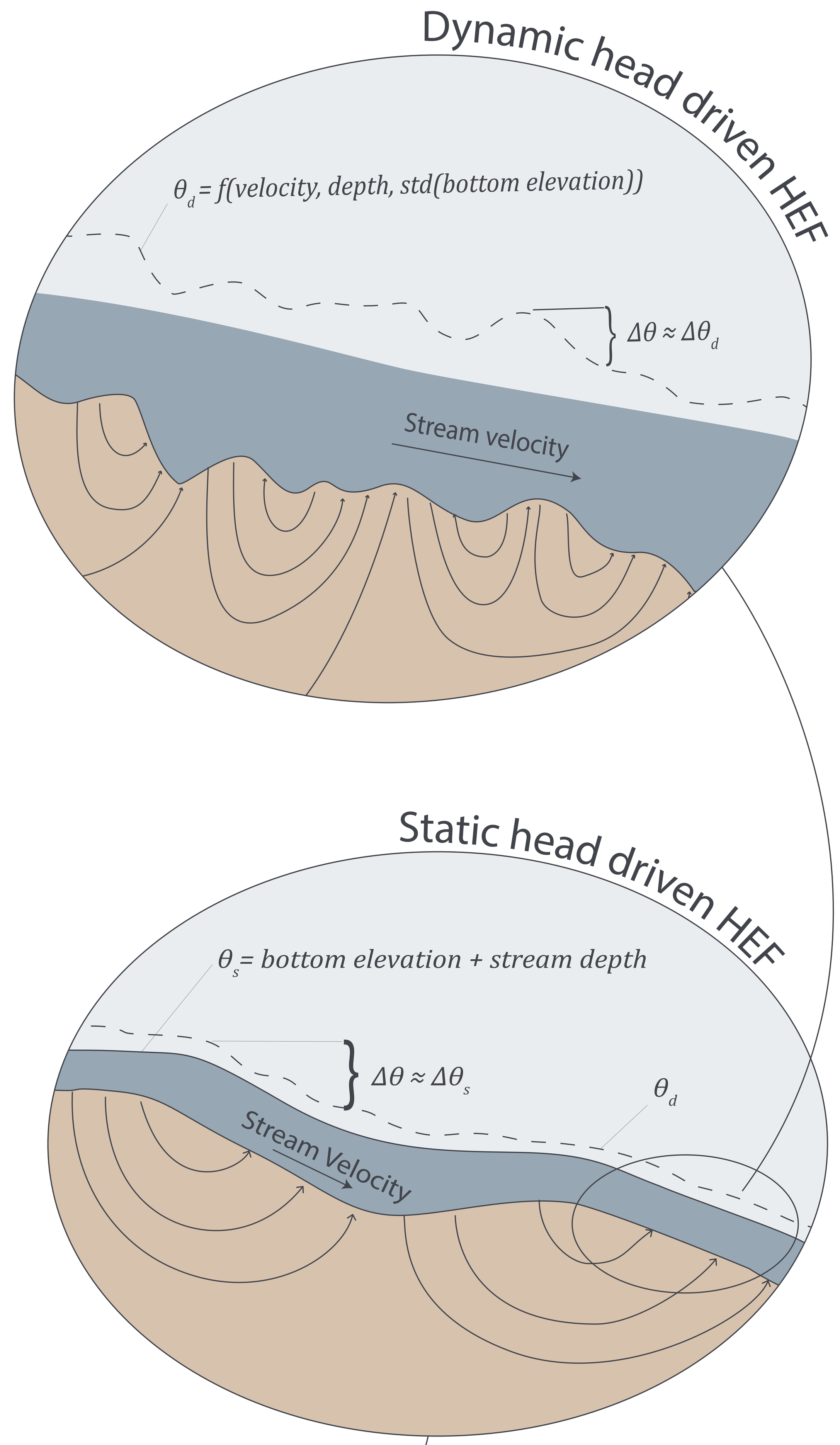
1. A multidimensional mechanical model, which decomposes HEF, and its driving mechanisms, into all relevant spatial scales (λ). Input data was collected in an extensive field study and included:

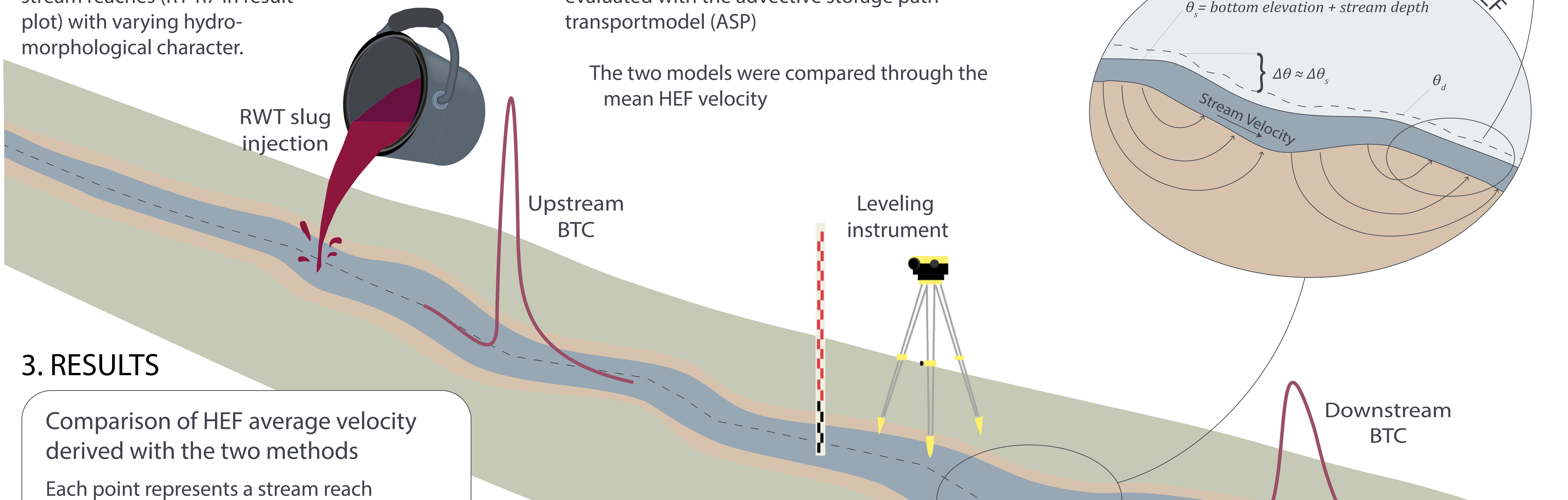
   a. Longitudinal stream bottom topography and suface water profiles measured every 0.5 m, which was used to estimate fluctuations in the stati head (θ_s) and dynamic head (θ_d) at the stream bottom (y_b).

   b. Distributed hydraulic coductivity measurements used to define the geological damping of deep HEF pathways.

2. Rhodamine WT (RWT) slug injection tracer tests, evaluated with the advective storage path transportmodel (ASP)

The two models were compared through the mean HEF velocity

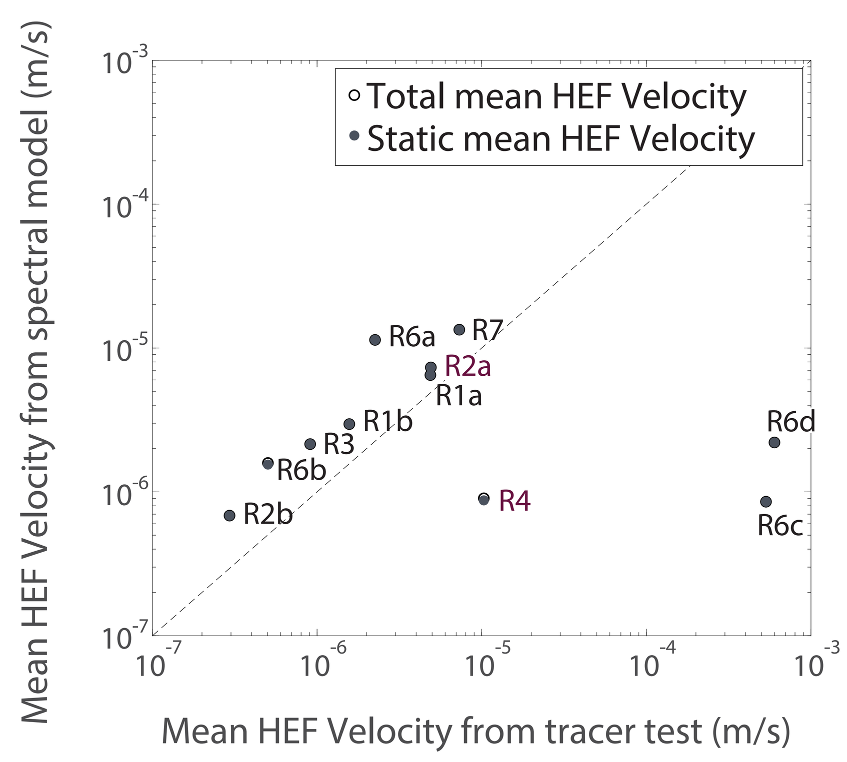




3. RESULTS

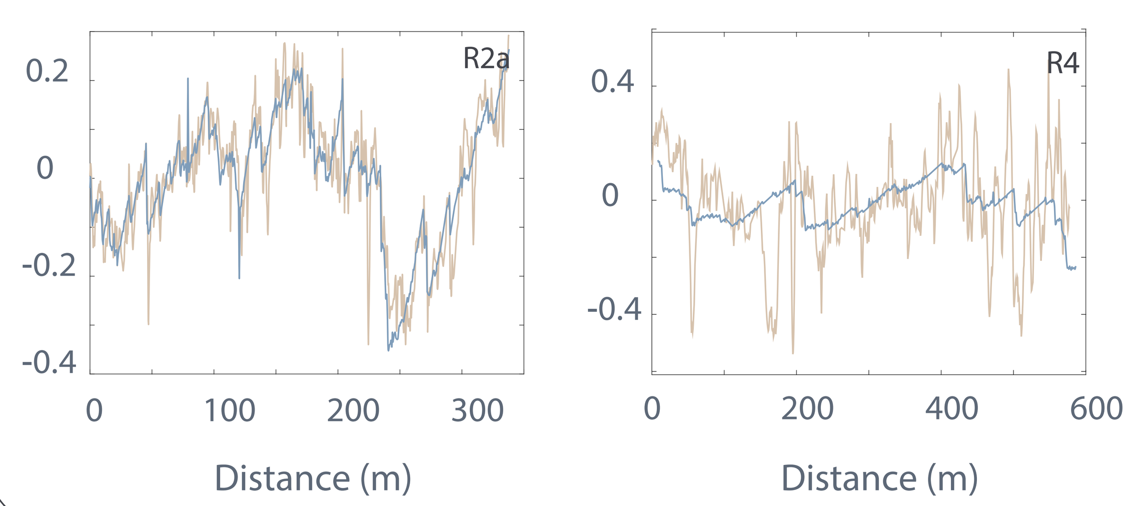
Comparison of HEF average velocity derived with the two methods

Each point represents a stream reach



Detrended Elevation

Example: reaches R2a and R4



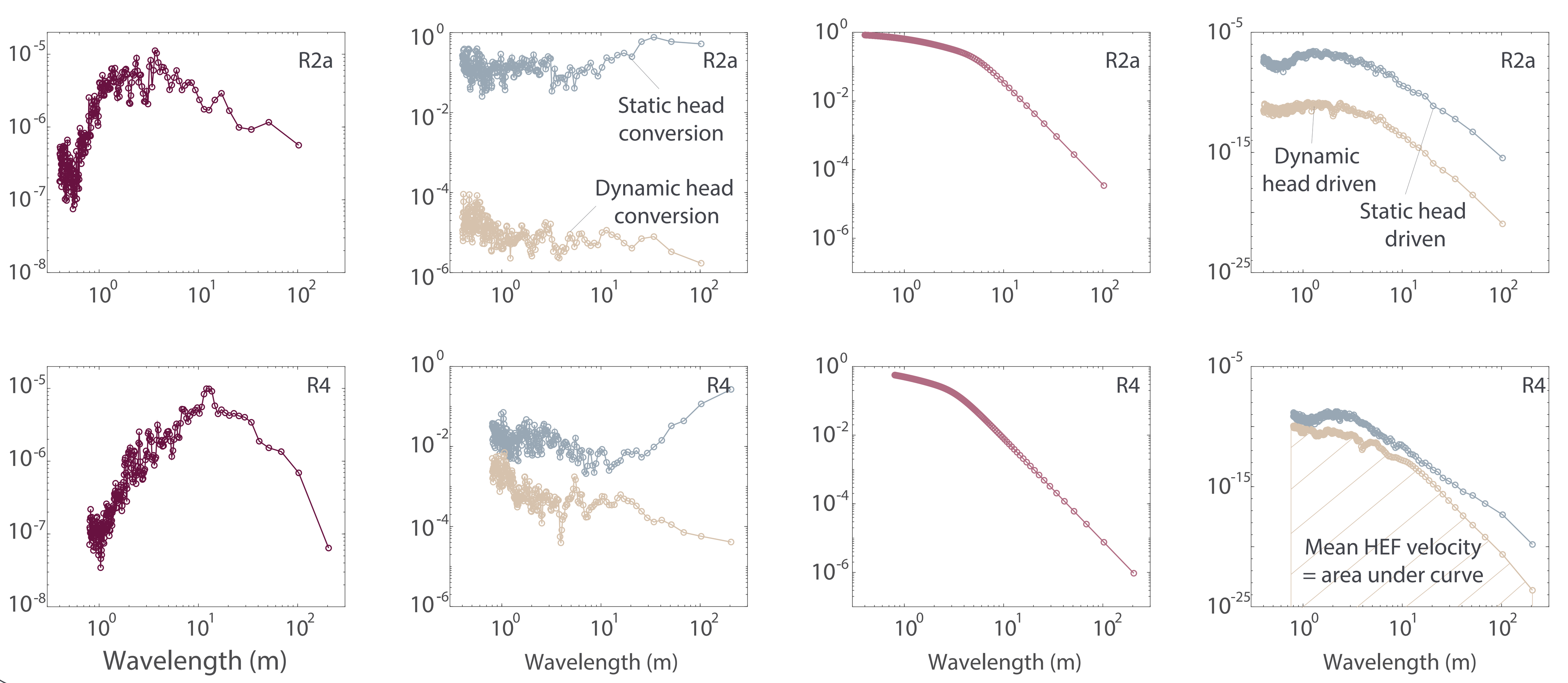
Decomposition of data and modelled parameters on wavelength, reaches R2a and R4

Gradient spectrum $G = y_b/\lambda$ (-)

Hydraulic conversion factors C_s and C_d (-)

Geological damping factor $\psi = f(depth, K0)$ (-)

Exchange spectrum $E = G^2 (C_s^2+C_d^2)\psi^2$ (-)



4. CONCLUSIONS

Similar HEF could be derived with the two independent methods, validating the usage of the multiscale mechanical model in small alluvial streams with high slope, low discharge and small stream depth.

The static head was dominating the HEF in all investigated reaches, both on average and when distributed over separate scales.

There where no significant links between spatial scale and the dominating HEF driver.

Deviations between the models were mainly seen in the streams with highest discharge and largest stream depth, thus streams where the dynamic head is assumed to dominate.

Deviations between the models may be related to the fact that small scales < 0.5 m, was not included in the input data or to uncertainties in the derviation of dynamic hydraulic head.

Our aim is to soon publish this research in a scientific paper. For more information at this stage contact: imoren@kth.se