EGU General Assembly 2009, Vienna Session HS 9.5, A282 Geophysical Research Abstracts, Vol. 11,EGU-10570, 2009

Groundwater-surface water interaction along the Upper Biebrza River, Poland applying heat transport analysis

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1. Introduction

- Quantity and distribution of water and energy transport across the interface determines contact times, reaction and feedback processes in river and wetland ecosystems
- Water fluxes are essential for the estimation of fluxes of solutes, particles and dissolved matter
- Usage of heat as a natural tracer is a simple and fast tool quantification of groundwater-surface water interaction
- Temperature gradients are analyzed with a heat transport model applying the FEMME ecosystem model platform
- Allows modeling of spatial and temporal patterns on a local scale
- Combination with hydraulic head data and seepage meter measurements increase the reliability of the simulations

2. Methodology

- One- dimensional, vertical, anisothermal flow of an uncompressible fluid through homogeneous, porous media

$$k\frac{\partial^2 T}{\partial z^2} - v_z c_w \rho_w \frac{\partial T}{\partial z} = c\rho\frac{\partial T}{\partial t}$$ (Suzuki, 1960; Stallmann, 1965)

k……thermal conductivity of the rock- fluid matrix
T……temperature at any point z at any time t in the soil
c_w….volumetric heat capacity of the fluid
ρ_w….density of the fluid
v_z….component of darcian fluid velocity in the soil in z direction
c….volumetric heat capacity of the rock- fluid matrix
ρ….wet- bulk density (density of the rock- fluid matrix)

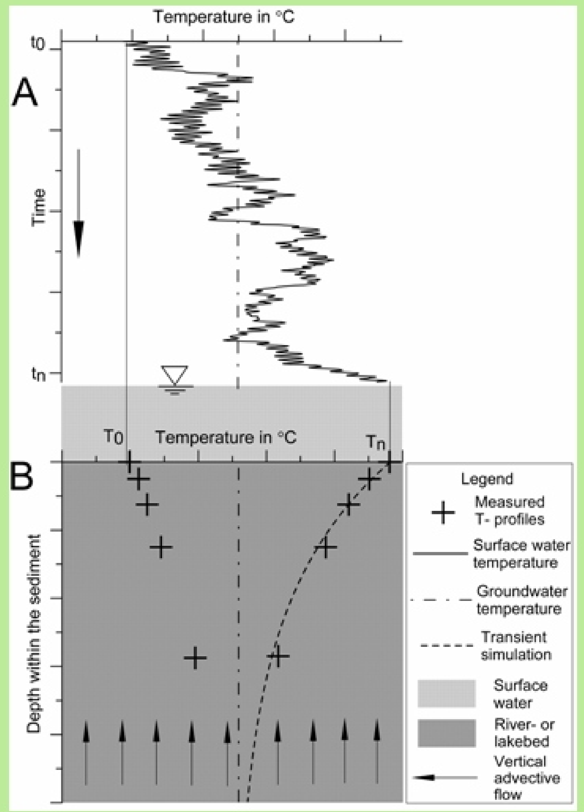


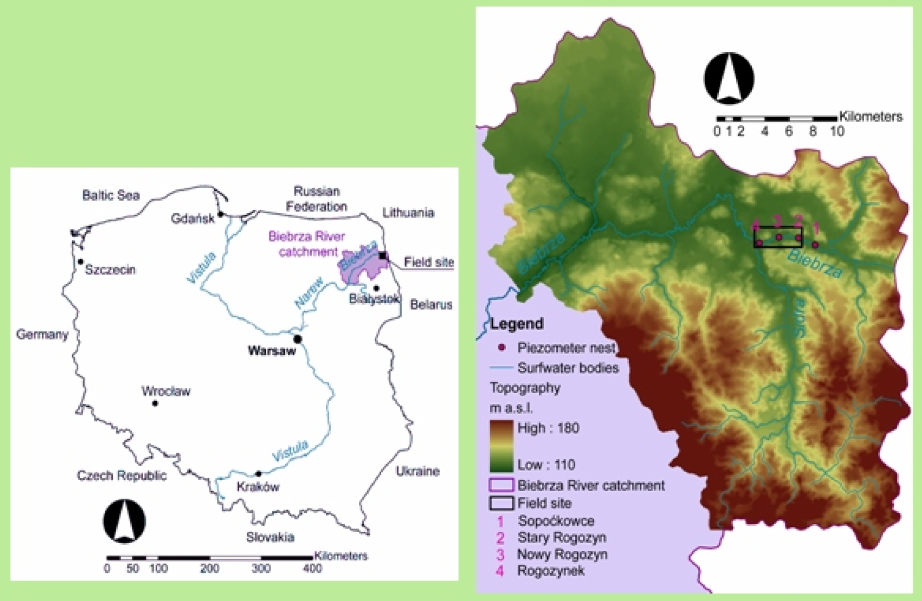
Fig.1 Concept of heat transport modeling in the riverbed

3. Study area

- Biebrza River, Biebrza National Park, Poland

Characteristics:
- Total river reach length 170.6 km (examined reach 5.6 km)
- Drainage Area 7057 km²
- Average discharge 39.2 m³/s (≈ 0.5 m³/s at piezometer nest No.4)

- At the study area:
Average water depth 1.1m
Width ≈ 6-7 m



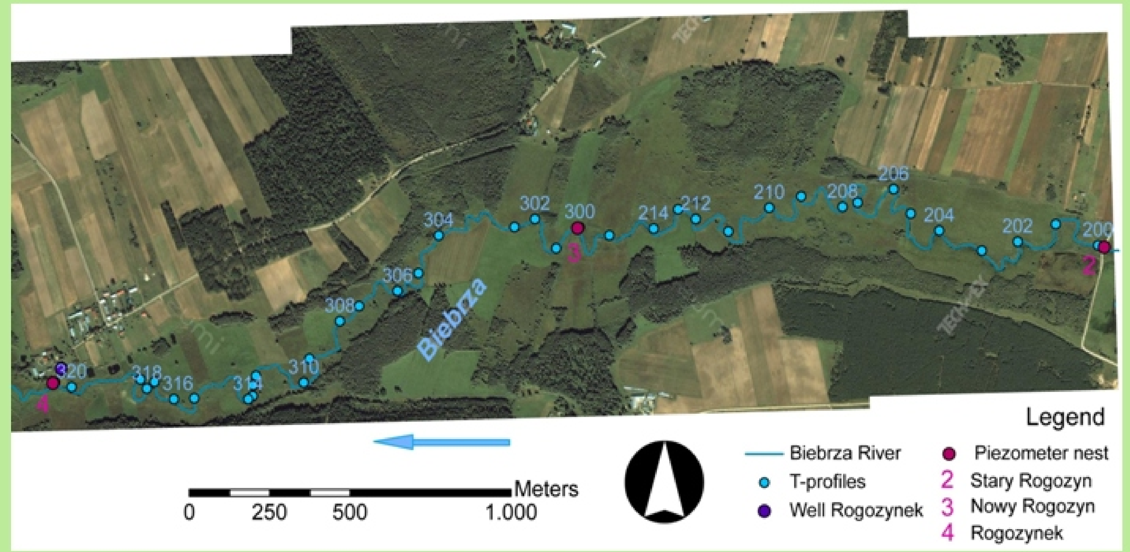


Fig.2 Study area Biebrza River

4. Measurements and results

- Quasi-steady state thermal analysis:
temperature profiles along the river reach measured with the T-stick instrument
- Transient thermal modeling:
Continuous measurements of T in piezometer nests using data loggers in different depth
- Hydraulic head data combined with thermal modeling delivers vertical conductivity values
- Seepage meter measurements 16/06/2006-20/06/2006 at location No.4:
v_z = -25 mm/d

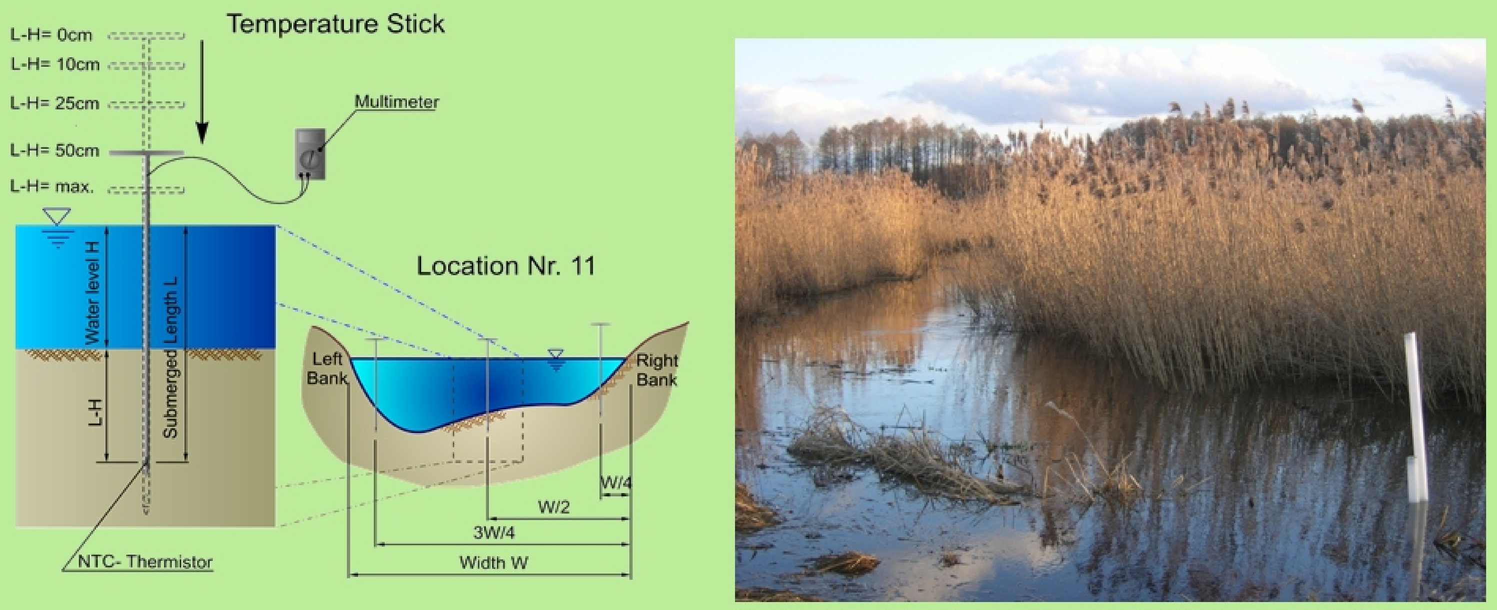


Fig.3 Instrumentation: A) T-stick instrument; B) Piezometer nest equipped with data loggers

4.1 Temporal distribution

Transient simulation between 05/03/2008-20/06/2008:
Vertical hydraulic conductivity determined using hydraulic head and heat transport modeling: kv = 0.16 m/d
- Hydraulic head differences yield an average flux of -69 mmd^{-1} (gaining river reach; standard deviation 21 mmd^{-1})
- Heat transport modeling delivers an average flux of -87 mmd^{-1} (standard deviation 16 mmd^{-1})
- Average deviation between the models is 24 mmd^{-1}

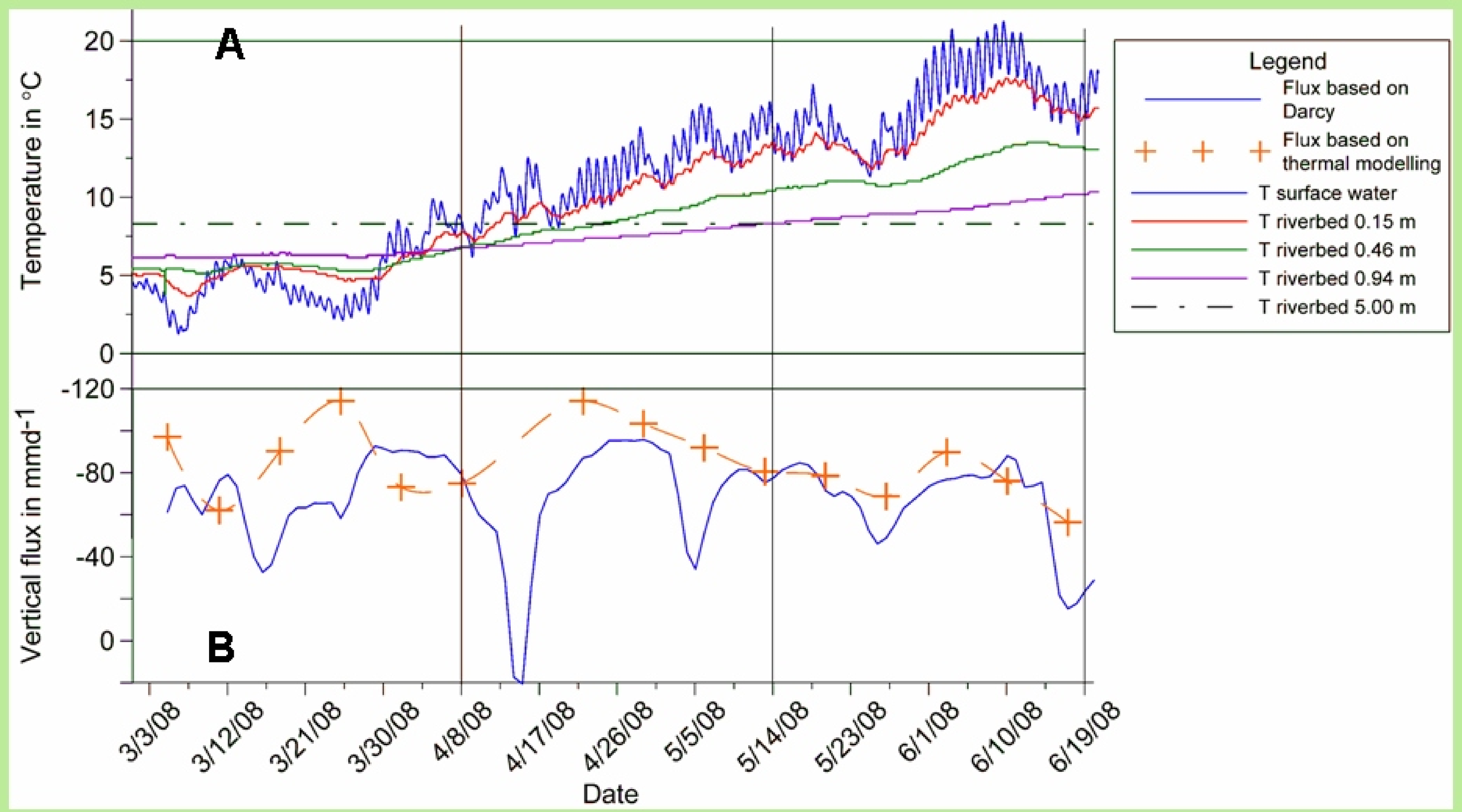
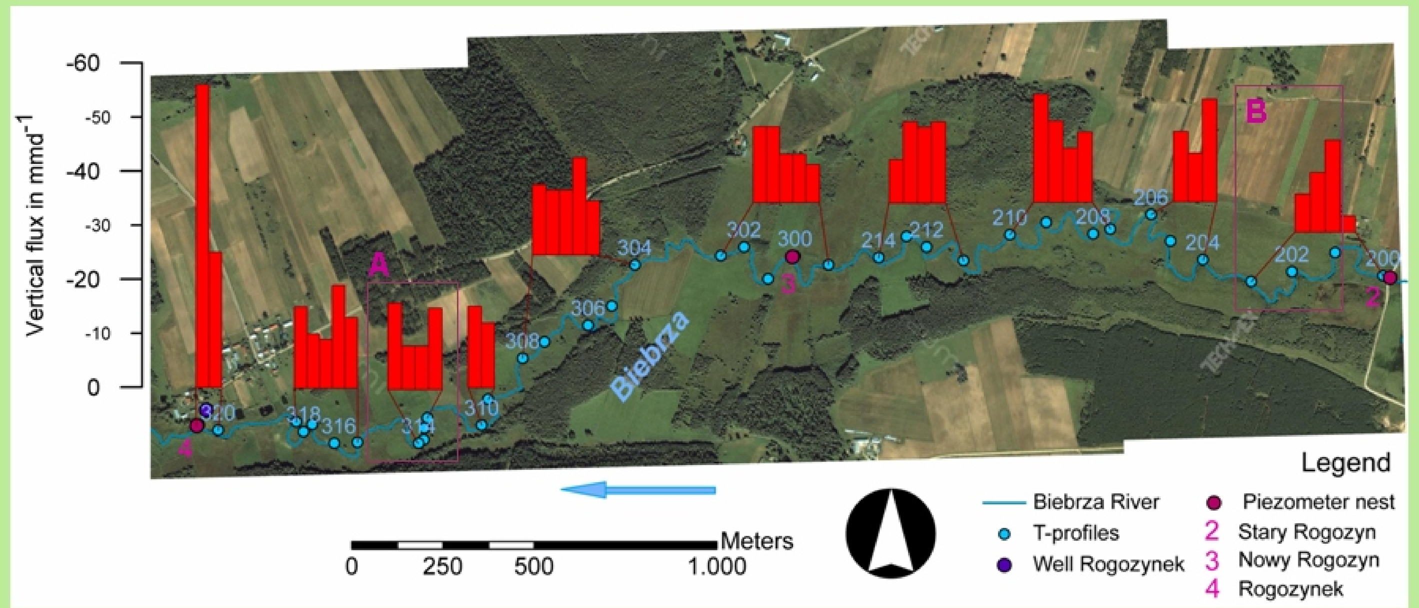


Fig.4 Line graphs showing A) input data of the heat transport model and B) vertical flux values of piezometer nest No.4

4.2. Spatial distribution



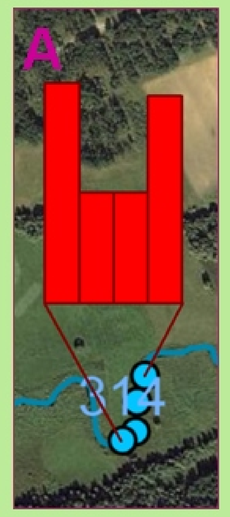


Fig.5 Quasi-steady state thermal analysis of points along the river reach (05/-06/03/2008);
A) influence of the river morphology, and
B) position of the river with respect to the extend of the floodplain

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FWO VLAANDEREN

Acknowledgement:
This scientific project is financed by FWO, the Flemish Research Foundation
Project number: **G.0306.04**

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