Mixed field methods help capture spatial variation in surface-groundwater interaction

HYDROLOGY

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MOTIVATION

Surface-groundwater interaction (SGI) can contribute significantly to groundwater recharge (losing streams) or be a major source of stream discharge (gaining streams).

Thereby, the hydraulic gradient between stream and aquifer can vary strongly in time and within short distances.

Accurate estimates of SGI are important for groundwater management in terms of quantity and quality – especially in the context of recent droughts in Germany.

Here we explore different field methods to investigate SGI

AREA OF RESEARCH

- Three medium-sized streams (average discharge: 0.5-6 m³/s)
- Streams often fall dry in summer (intermittence)
- Located near the city of Freiburg, south-west Germany
- Flow from Black Forest Mountains (hard rock) into the Upper Rhine Valley (alluvial sediments)
- Connected to aquifers supplying the area with drinking water
- Intensive agricultural land-use poses risk of pollution

LOCALISATION

Identify areas with strong stream-aquifer-connectivity, based on readily observable phenomena e.g.:

→ low distance between surface and groundwater table

→ stream intermittence depending on season

→ streams running dry and reappearing further downstream

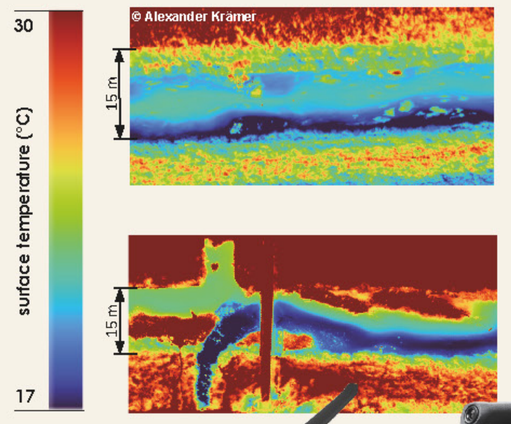
...with THERMAL IMAGING

Thermal images taken via UAV help to identify spatial patterns, e.g.:

- groundwater intrusion (top)
- side streams with strong groundwater signature (bottom)

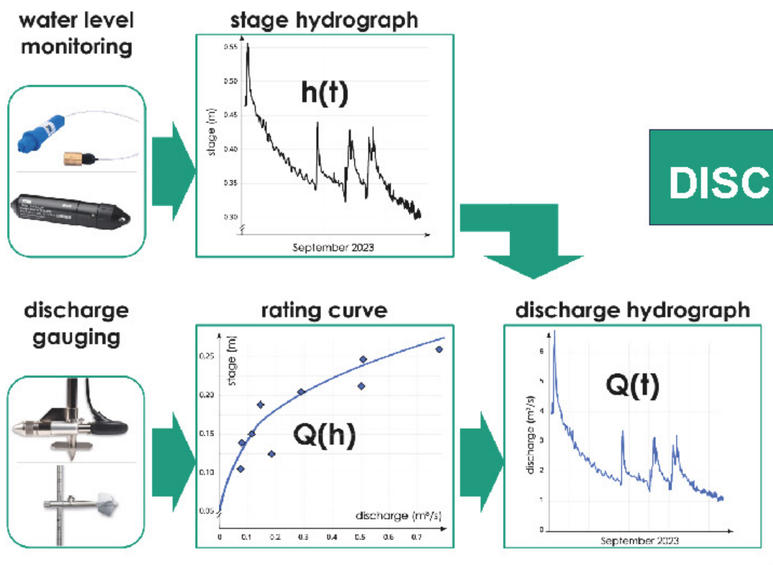
Works best in seasons with high temperature difference (summer & winter)

Calibration with irradiance is necessary to obtain absolute values.



ESTABLISHED: Stage-Discharge Relation

- Measure water stages continuously at fixed defined cross-sections (water capacitance or pressure logger)
  → h(t)
- Field campaigns to measure discharge in relation to stage (electromagnetic induction meter or current meter)
  → pointwise discharge $Q_i(h_i)$
- Establishing relation between stage and discharge
  → empirical rating curve Q(h)
- Computing continuous discharge
  → Q(t)



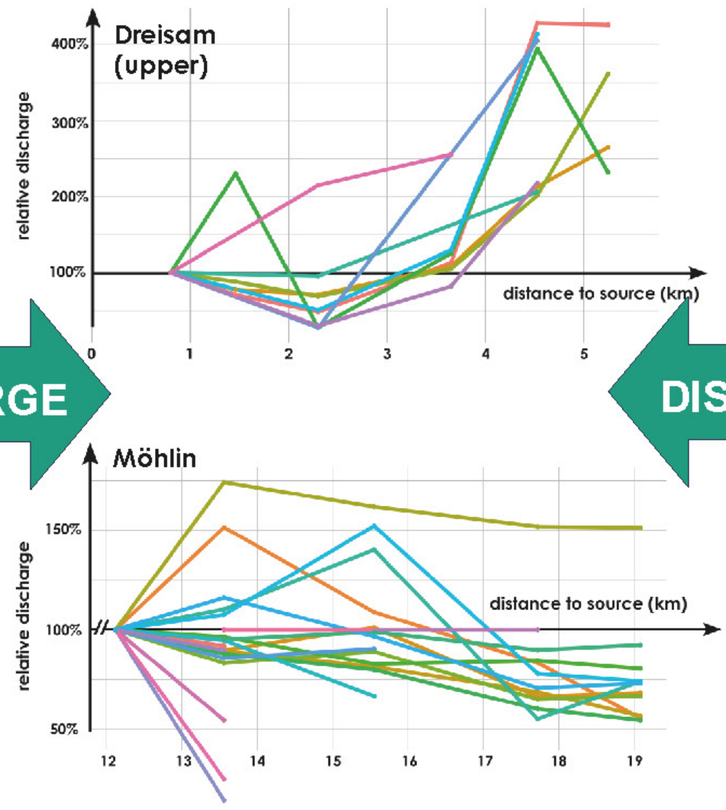
DIFFERENTIAL GAUGING

Dividing streams into 0.5 – 2.0 km segments

Comparing discharges of stream segments gives information about sections with net gains and losses of water.

River sections can be classified into “gaining” or “losing”.

Classifications depend on external factors such as discharge history of groundwater levels.



INNOVATIVE: Particle Tracking Velocimetry (PTV)

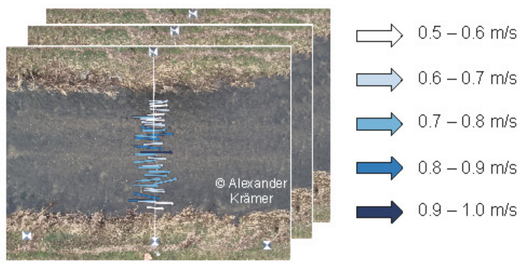
1. Remote sensing of surface velocities

Seeding with floating particles (e.g. wood chips)

Sequential photos from a fixed position via UAV

Tracking individual particles between frames

→ speed and direction of surface flow (v_i)



2. Computing discharge at cross-section

Determine fraction of individual vectors parallel to main stream flow

Convert surface velocity to mean velocity using velocity index α (site specific)

Multiply with depth at each vertical

→ stream discharge Q_i

CONCLUSIONS

Differential gauging provides continuous information about SGI of multiple river sections.

Stage-discharge relations for continuous discharge estimates are well established, but error-prone during high-flow conditions. Then floating debris can damage or destroy stage measurement stations.

Drones as supplementary tool:

Thermal drone footage can identifying hotspots and provide spatial overviews. But absolute temperature accuracy is still too low to calculate discharge quantities via temperature mixing.

Particle tracking velocimetry allows for quick non-intrusive discharge measurements, but overall accuracy and applicability for SGI quantification is still to be determined.

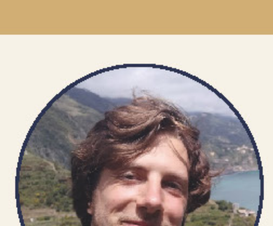
stressRES

LURCH Grundwasser nachhaltig bewirtschaften

FONA Forschung für Nachhaltigkeit

Wasser: N

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung



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