Detection of river channel infiltration using joint inversion of resistivity imaging and refraction tomography

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Abstract

A single geophysical method is limited in providing adequate model accuracy and resolution for the inversion of subsurface structure. Multi-geophysical methods with varying subsurface structural sensitivity complement one another and produce more accurate results. We numerically model river water recharge based on on-field electrical resistivity tomography (ERT) result. We use ERT and seismic refraction tomography (SRT) data to detect water recharge zones during the dry and wet seasons. This study also estimates volumetric contents, such as water saturation, air content, and rock matrix. The field ERT detects river water recharges and identifies subsurface structures in dry and wet conditions. The recharge flow path is more effectively traced in the joint inversion. When compared to single inversion, joint inversion estimates volumetric fractions more accurately. This research demonstrates how joint inversion can trace river water recharging and quantify volumetric fractions, thereby reducing interpretation ambiguity.

Introduction

The joint inversion of two datasets from different methods can reduce the inherent inversion uncertainty of the individual methods (Garofalo et al., 2015). Seismic and resistivity methods are complementary and often employed in various ways. For instance, Wagner et al. (2019) developed a joint inversion for permafrost using ERT and SRT data. We apply joint inversion for a three-phase (rock matrix, water, and air) volumetric fraction to trace the river water recharge.

Method

The ERT field survey is carried out across the Choushui River (Taiwan) to assess water recharge during dry and wet seasons; the dry season is illustrated in Figure 1. We develop a conceptual recharge model based on the ERT results using HYDRUS-based simulation (Fig. 2). For the true model presented in Figure 4a; we numerically perform joint inversion of ERT and SRT data. To create resistivity and seismic models, we use the empirical equations of Archie (1942) and Timur (1968). We follow the Wagner et al. (2019) approach for apparent numerical data formulation and inversion. Besides, we use Rücker et al. (2017). Open-source pyGIMLi algorithm. We perform river water recharging simulations for the dry and wet seasons, but only the dry season simulation is presented.

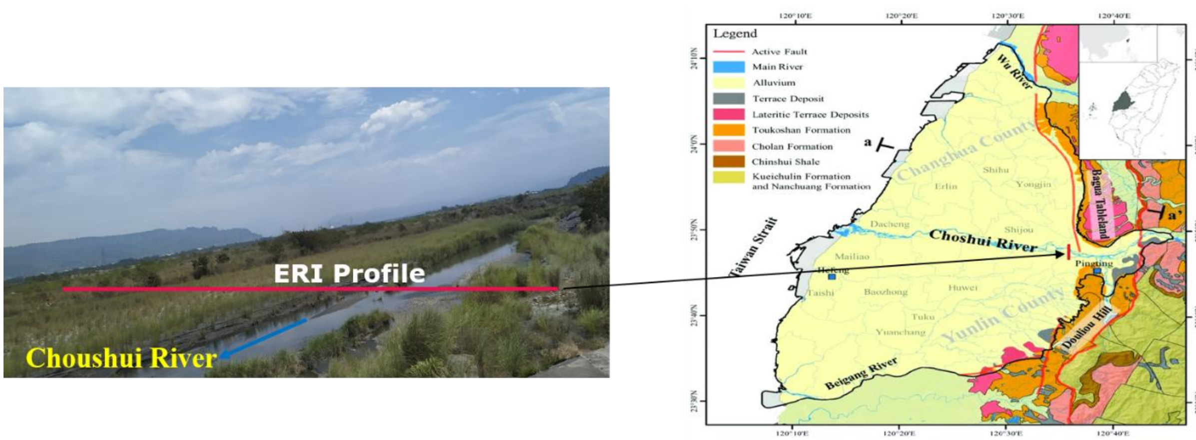

Figure 1 Survey area and ERI profile across Choushui River.

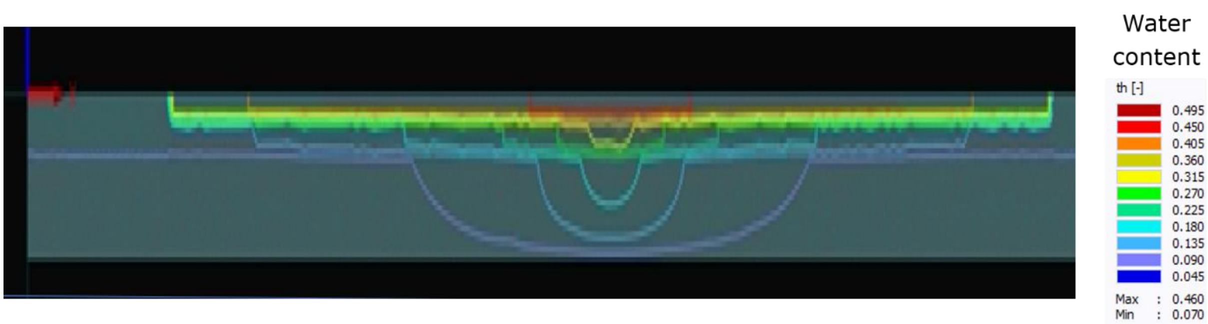

Figure 2 Choushui River water flow simulation for the dry season using HYDRUS.

Results

The field result of ERI has partly identified subsurface geologic structures and water zone (Fig. 3).

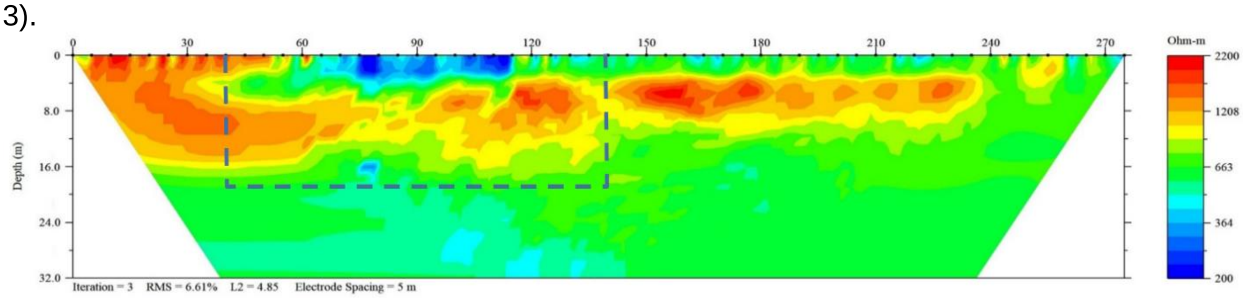

Figure 3 ERI inverted results for the dry season across the Choushui River. Numerical modelling for ERI and SRT joint inversion is performed for the dashed box zone.

Inverted resistivity imaging and refraction tomography results are shown in Figure 4b. Inversion indicates that the river water recharge zone is not detected adequately for separate inversion, particularly seismic refraction. The shallow river zone is not appropriately recovered in SRT but is recovered better in ERI. Joint inversion results for ERI and SRT are shown in Figure 4c. The joint inversion resolves river water recharge better than a single inversion. In addition, the joint inversion model recovers transformed water saturation, air content, and rock matrix (Fig. 4c).

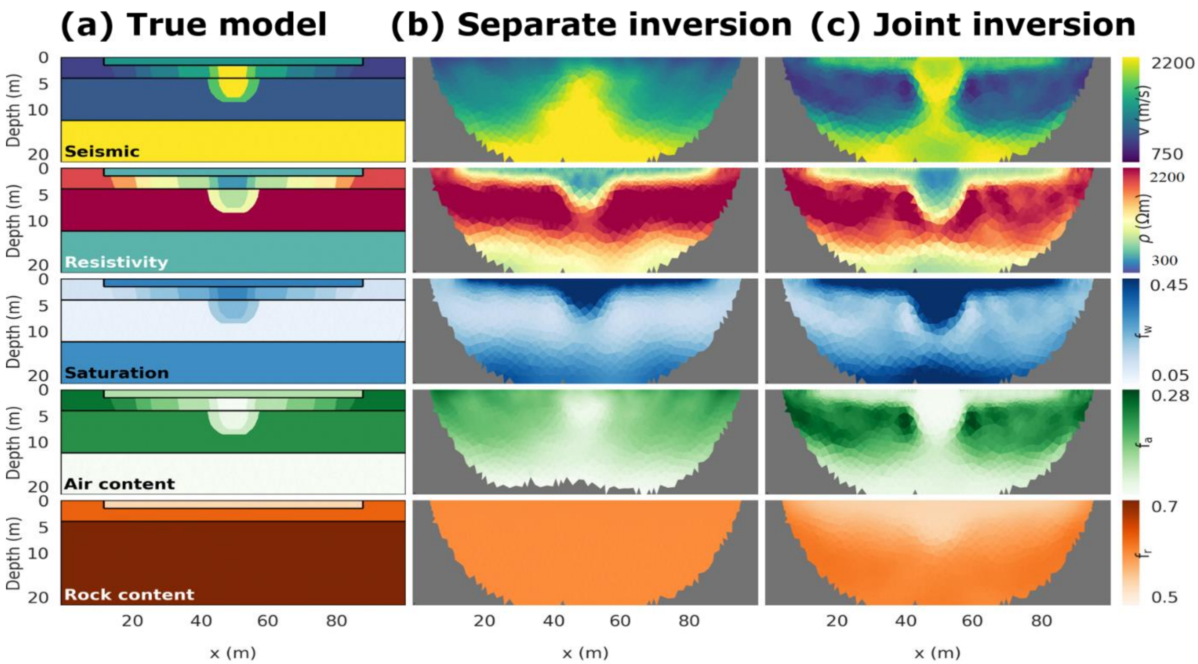

Figure 4 Numerical modelling for dry season river water recharge: seismic, resistivity, saturation, air content, and rock content models, from top to bottom.

Conclusions

This study investigates the use of ERT and SRT joint inversion to detect river water recharge zones. Because the ERT and SRT have different sensitivities, joint inversion improves model resolution. Numerical modeling was carried out based on field ERI results. The recharge flow path can be traced more effectively in joint inversion than in single inversion. Joint inversion improves resolution, traces river water recharges accurately, and quantifies volumetric fractions.

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