Characterization and quantification of preferential flow in fractured rock systems, using resistivity tomography

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Introduction

In the use of unsaturated zone methods to estimate recharge, the basic assumption is made that recharge occurs by means of diffusive processes (i.e. piston flow occurs). In fractured environments the reliability of recharge estimate have been questionable due to preferred pathways influencing the recharge flux. These preferred pathways have been shown to occur throughout sub-Saharan Africa (Xu and Beekman, 2003).

The focus of this study is to develop improved methodologies to quantify preferential flow in fracture environments. From the quantification of preferential flow pathways it will be possible to differentiate/identify fast flowing (by-pass through fractures) and slow flowing (water in matrix) conduits. This will lead to the estimation of proportions of slow and fast flowing pathways.

Materials and Methods

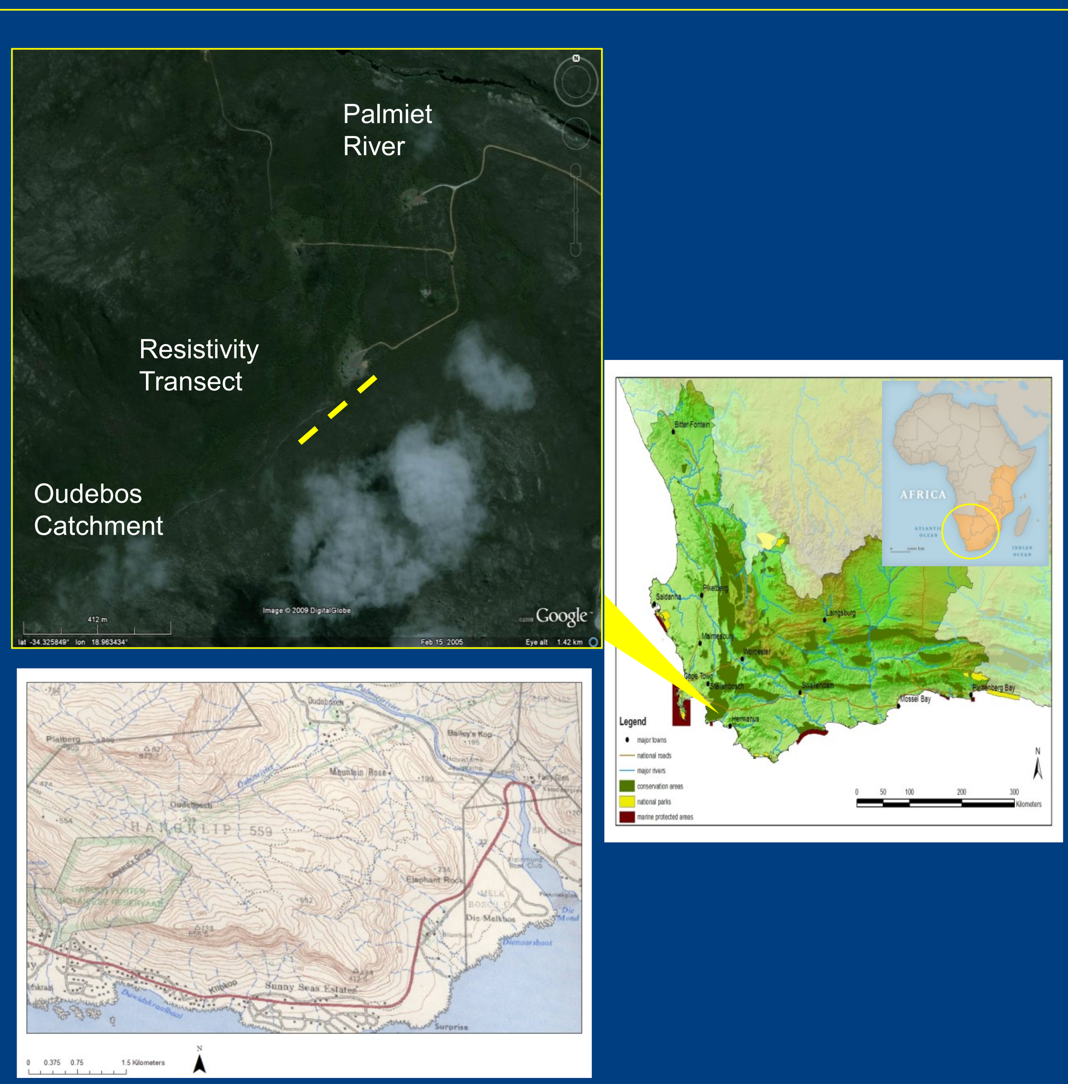

Figure 1
Location of the Oudebosch catchment in the Kogelberg Biosphere Reserve on the Western Cape map of conservation areas and topographic map of the catchment

The initial idea was to take resistivity measurements in two hour sessions during rainfall events. However, due to the difficulties in predicting the timing of rainfall events of a sufficient magnitude, it was decided to take resistivity measurements immediately after rainfall events. Each measurement takes approximately one and a half hours, depending on possible error interruptions during the survey (common errors are bad or no connection and negative resistivity readings). The proposed method is to study the changes in resistivity of the subsurface as the wetting front moves.

Studying these changes over time is often done by using time-lapse analysis (where time-lapse analysis is the study of resistivity over a certain period of time). Previously this has been used to study the flow of water through the vadose zone as well as flow changes due to water extraction[6] from boreholes.

The method used to acquire survey profiles is after Loke (2001). The standard Wenner Array (Loke, 2001) with 64 electrodes spaced two meters apart were used for the surveys.

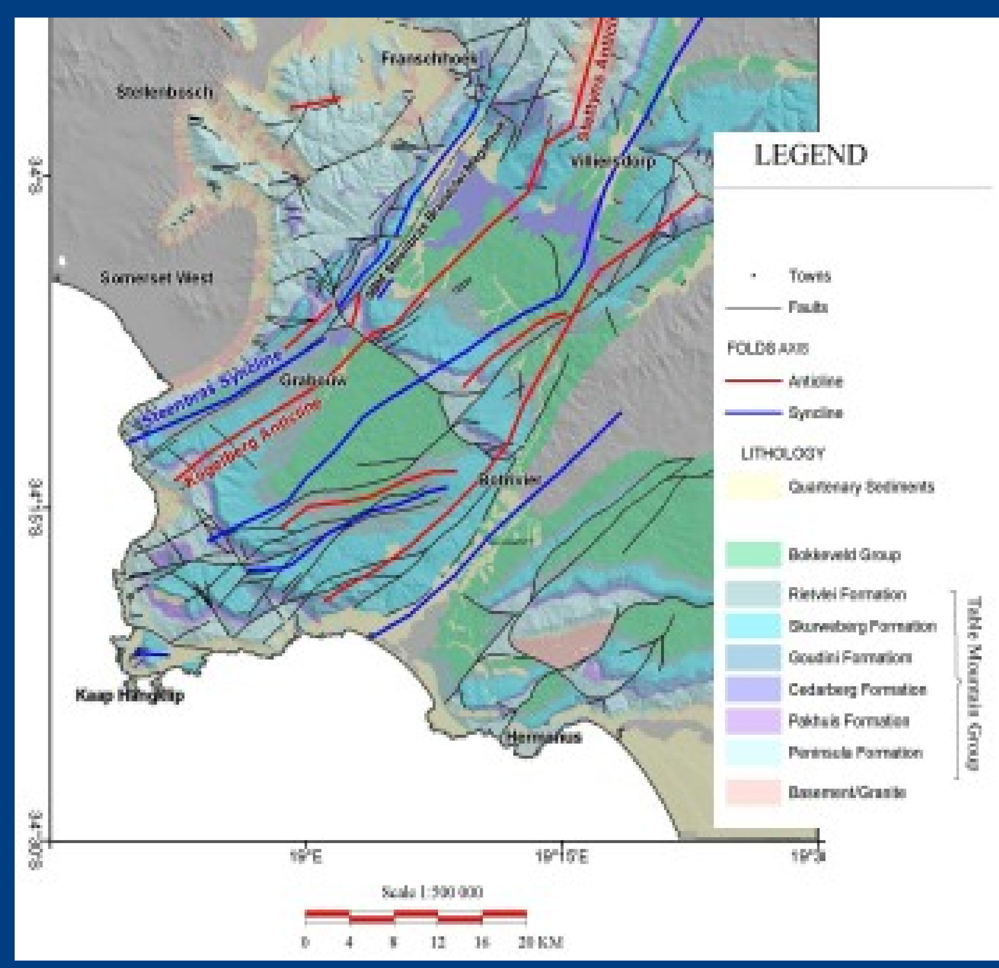

Figure 2
Geological map of study area (Colvin *et al.*, 2009)

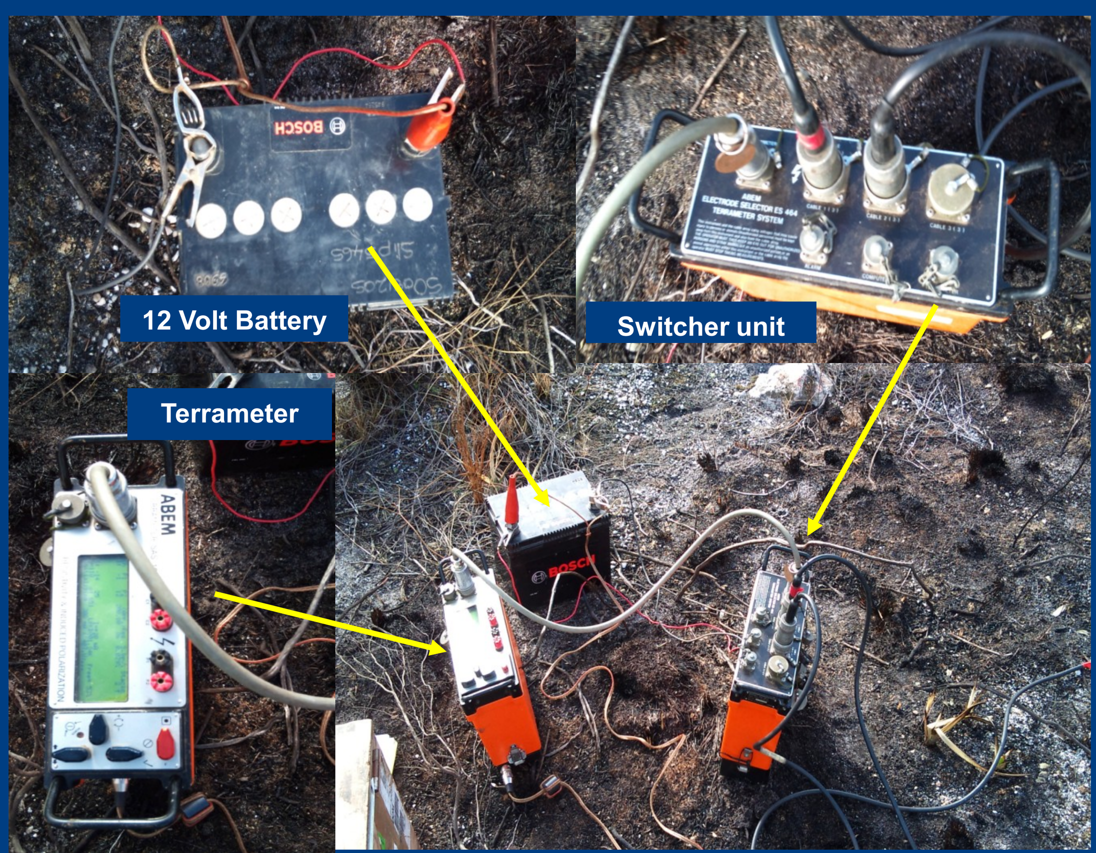

Figure 3
Equipment used for resistivity survey

Figure 4
Equipment used for resistivity survey

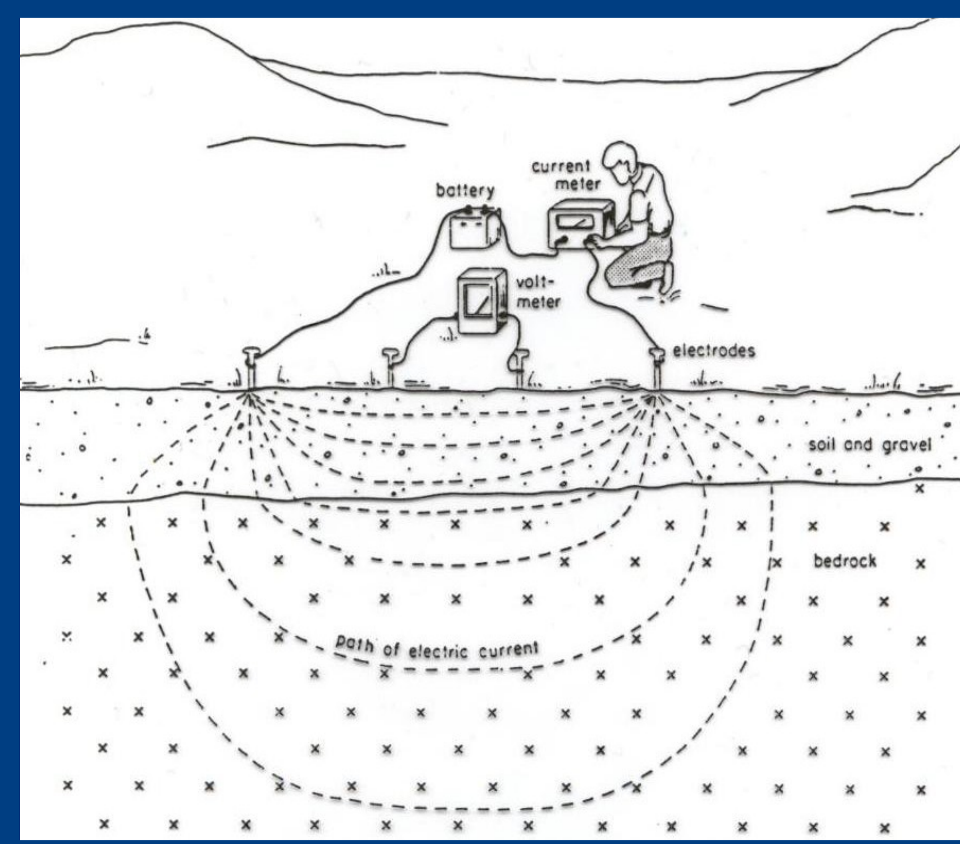

Figure 5
Typical resistivity survey construction. Diagram illustrates the basic equipment and physical set up needed to conduct resistivity surveys (Marescot, 2009)

Preliminary Results

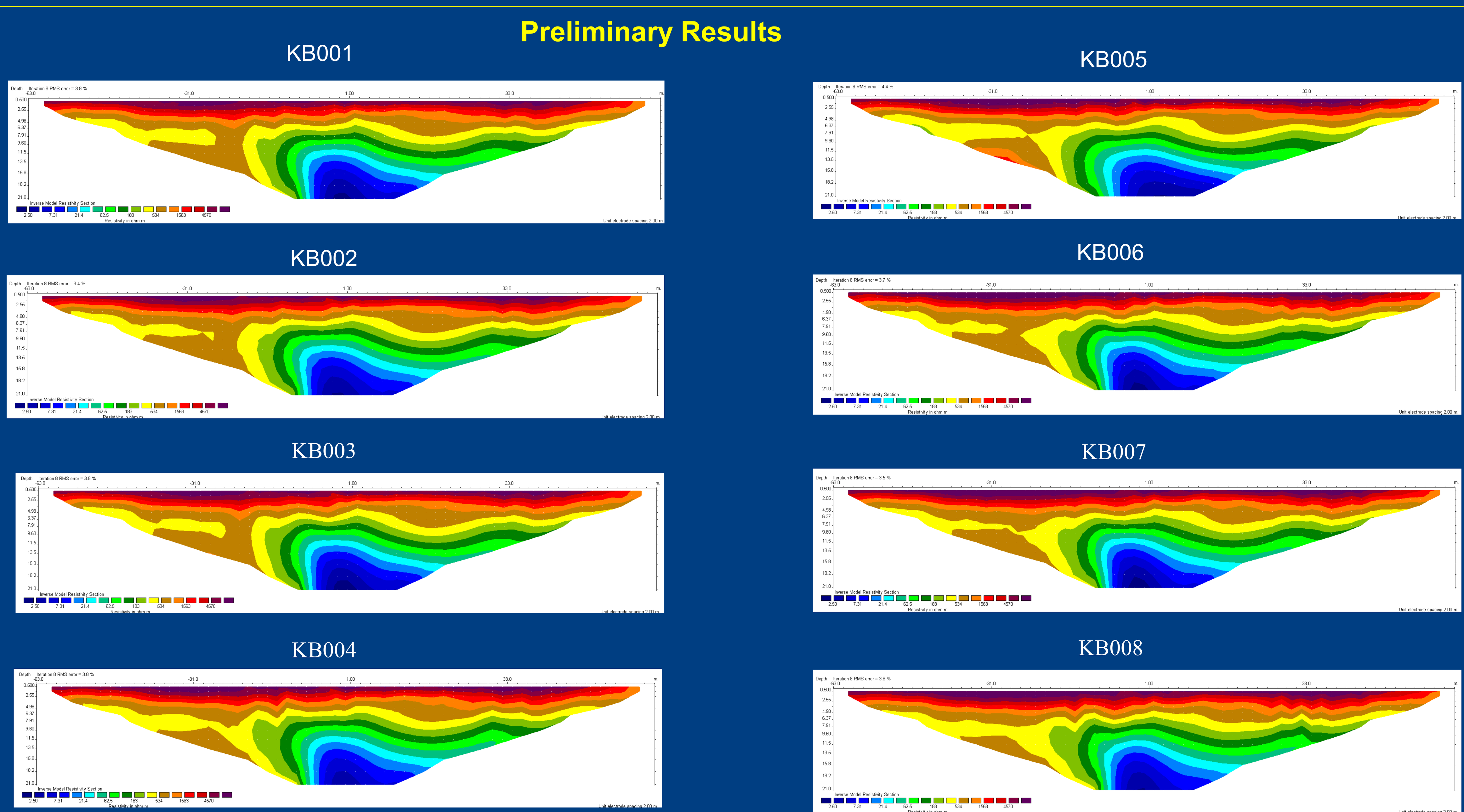

Figure 6
Resistivity images of transect taken from 27/08/2010 to 02/09/2010 see (Table 3)

TABLE 1
DATE, TIME AND WEATHER CONDITIONS DURING RESISTIVITY TOMOGRAPHY SURVEY

Survey No.	Date	Start time	End time	Precipitation (mm)	Description
KB001	8/27/2010	12H00	13H40	0.0	Sunny
KB002	8/28/2010	10H45	12H00	2.1	Windy, light drizzle
KB003	8/28/2010	13H35	15H10	2.1	Windy, light drizzle
KB004	8/29/2010	12H45	14H05	2.1	Sunny day, light wind
KB005	8/31/2010	10H30	11H50	0.0	Windy, with sunhine, turned partly cloudy
KB006	9/1/2010	10H50	12H40	0.8	Cloudy, light rain
KB007	9/1/2010	14H35	16H05	0.8	Cloudy, light rain
KB008	9/2/2010	10H40	12H30	9.0	Cloudy, light rain

Result and Discussion

In July and August 2010, rainfall was not very frequent, which resulted in fewer resistivity profiles being measured than planned. The results of the surveys completed in August and September 2010 are illustrated and discussed below. Resistivity images are shown in Figure 6. The images refer to measurements taken down to 21 m depth, in chronological order from 27/08/2010 to 02/09/2010. The measurements followed a substantial rainfall event that occurred on 21/08/2010 to 23/08/2010 (~40 mm). The measurement transect was on the North-facing slope. (Figure 1). The date, time and weather conditions for each survey are summarized in Table 3. Rainfall during the time of measurement was of a low intensity (a light drizzle).

The low resistivity (blue colour) visible in the images could be an indication of lithology or wetness (Figures 6). Slight variations in the images over time could be due to water flow and drainage. However, rainfall events were relatively small during the measuring period, the recorded variations in resistivity over time were very slight, and further data need to be collected, analyzed and interpreted to make definite conclusions on the applicability of resistivity tomography and time-lapse analysis.

Reference

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