Evaluating the effectiveness of ERT for assessing subsurface structure at the Landscape Evolution Observatory

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Introduction

- **Electrical resistivity tomography** (ERT) uses pairs of electrodes inserted in ground to inject current and measure voltage simultaneously, allowing for measurements of subsurface resistance.
- ERT conversion methods solve the Poisson equation, transforming measured resistances into fields of resistivity (inverse), or vice-versa (forward).
- Resistivities can then be related to subsurface properties using **Archie's law:**

$$\rho = \phi^{-m} S^{-n} \rho_{fl}$$

- ρ = resistivity [Ω.m], ϕ = porosity [-], S = relative saturation [-], ρ_{fl} = resistivity of the pore fluid [Ω.m],
- m = cementation factor, n = saturation exponent

Objectives

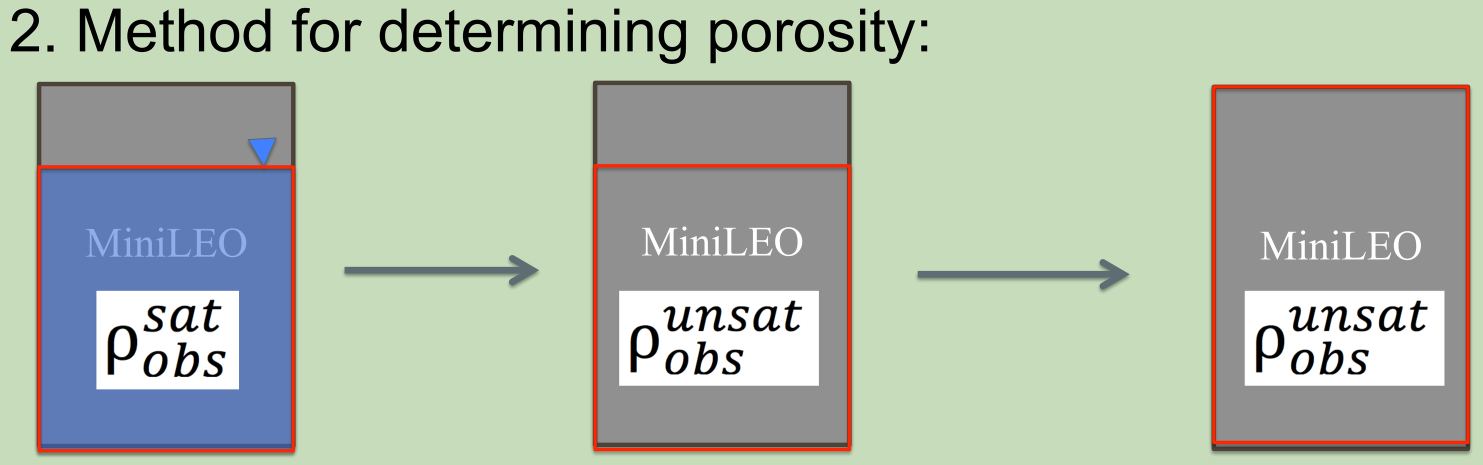
- Determine porosity from theoretical data using Archie's law
- Determine the effects of some sources of error on the retrieved porosity field
  - Error in ERT inversion
  - Error in measured transfer resistances

Methods

1. Obtaining resistivity field with simulated random error:

ρ_{true} → Forward, add noise → R_{obs} → Inverse → ρ_{obs}

2. Method for determining porosity:



Solve for porosity in saturated region

Now unsaturated, vary m, solve for n

With m and n, solve for porosity of whole cross section

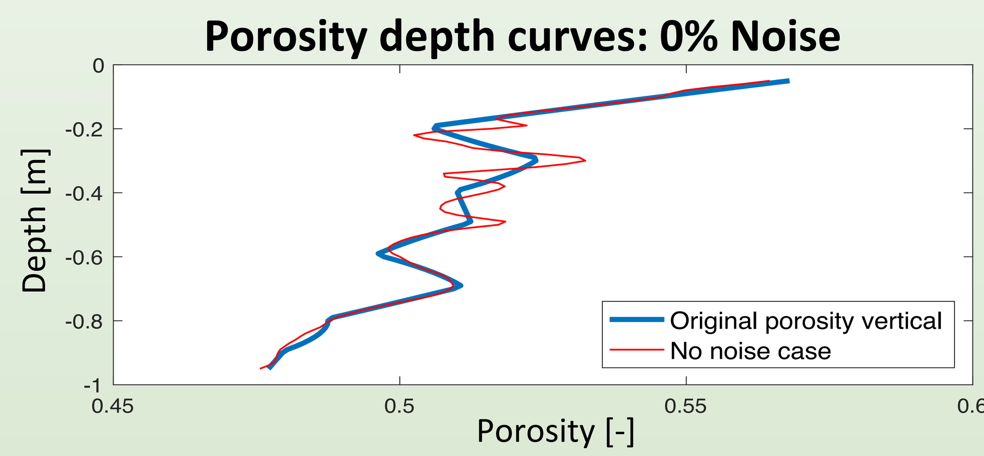


Figure 2. Depth averaged porosity for the true and no noise cases at 1 cm vertical resolution. There is evidence of inversion artifacts.

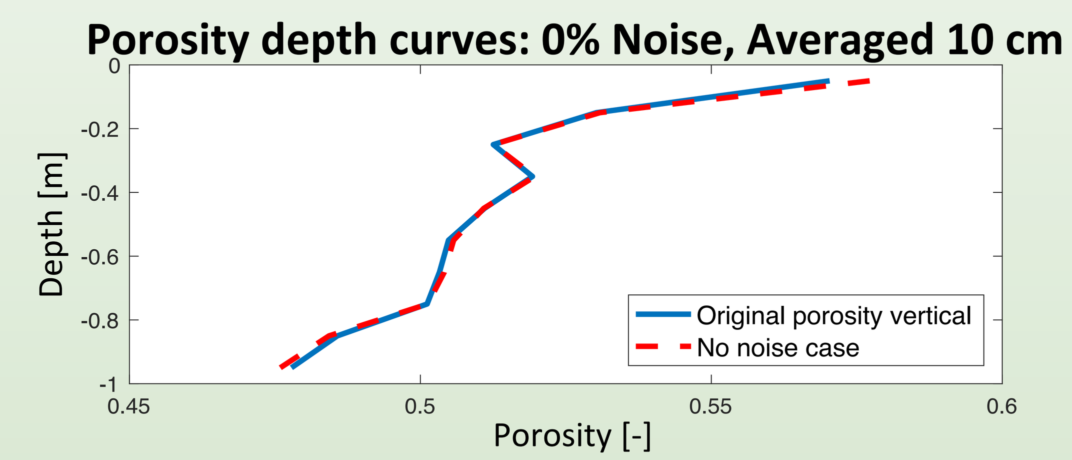


Figure 3. Depth averaged porosity for the true and no noise cases at 10 cm vertical resolution. Artifacts are no longer apparent.

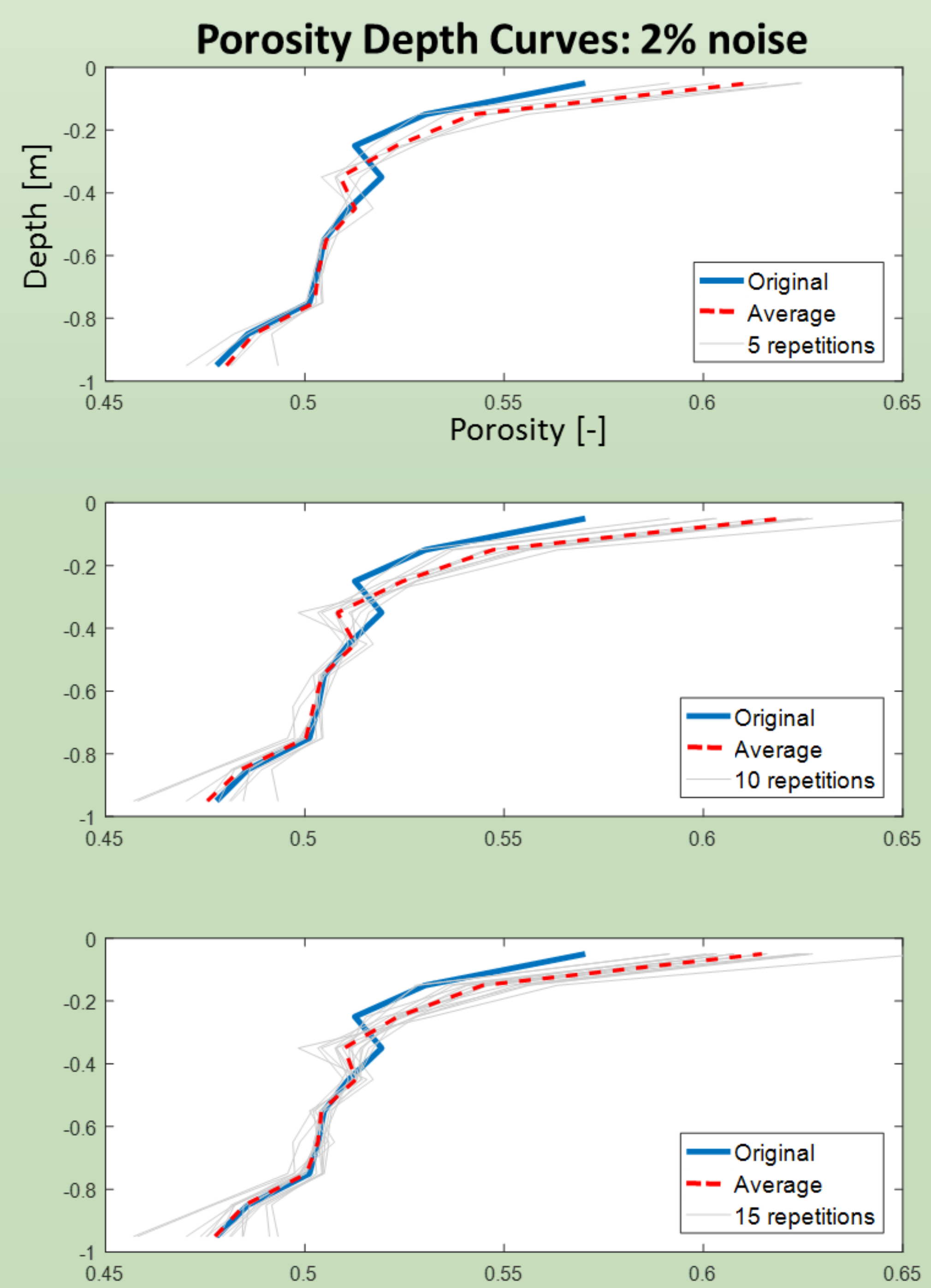


Figure 4. Depth averaged porosities are shown for 2% error and increasing repetitions. Little difference appears with increased number of repetitions.

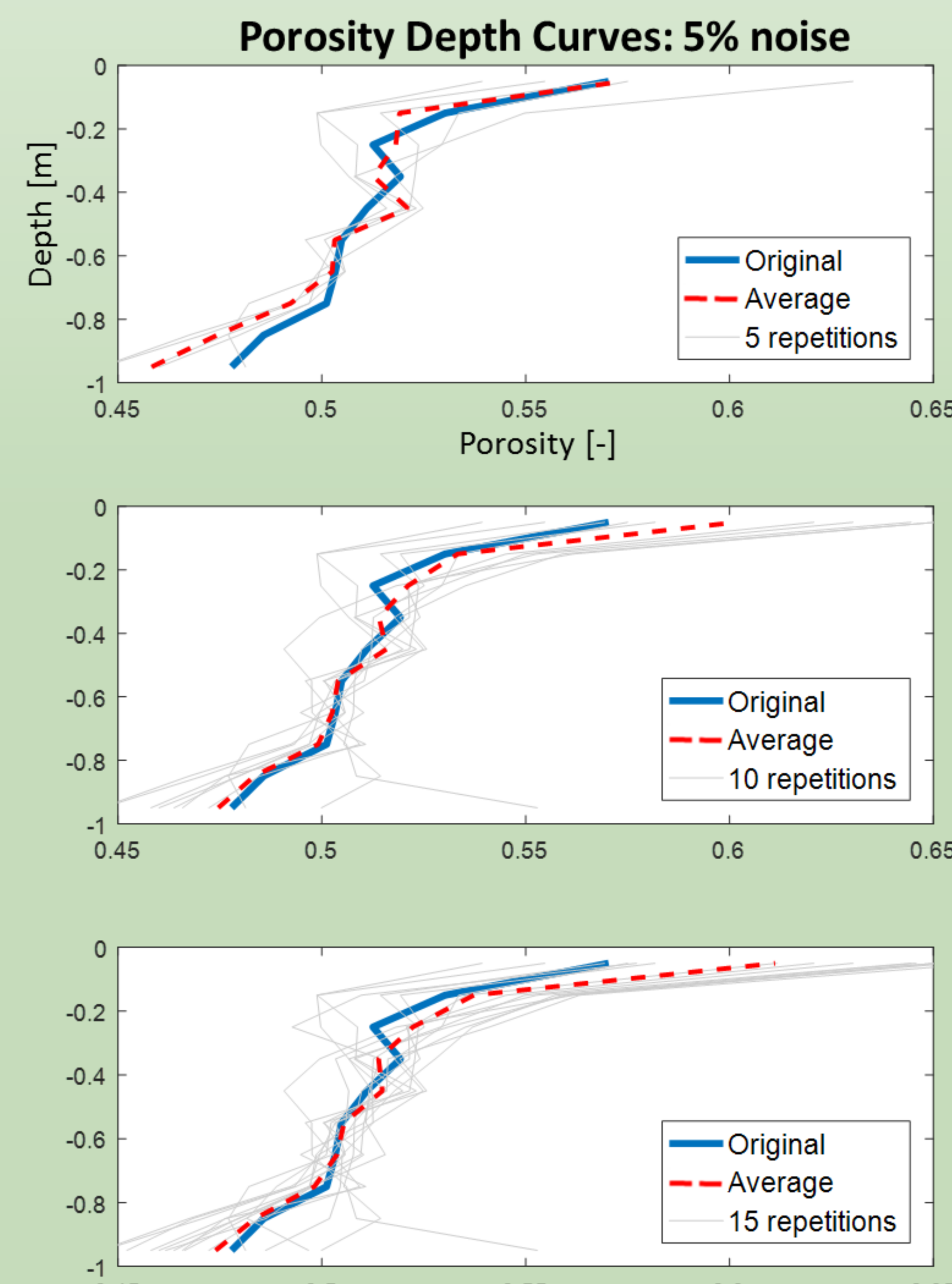


Figure 5. Depth averaged porosities for 5% error and increasing repetitions showing improved performance for 10 repetitions.

ERT - Equipped miniLEO

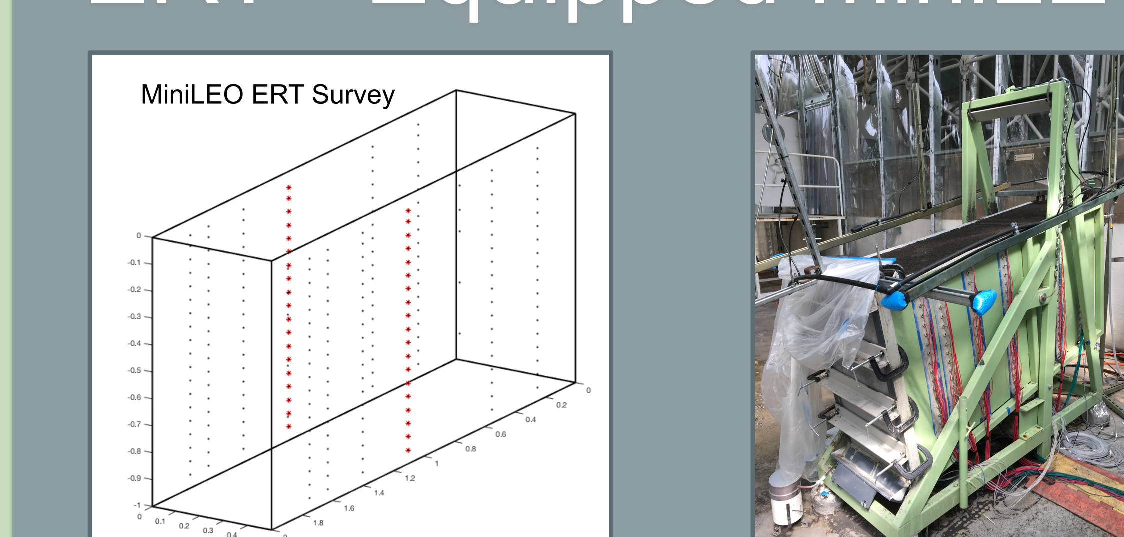


Figure 1. The MiniLEO sloping lysimeter with points (L) representing the electrodes seen connected to red wires (R).

Results

- ERT inversion error creates small deviations about the true values of porosity. Averaging 10cm depths eliminates the appearance of these artifacts.
- Transfer resistance error can have significant impacts on retrieved porosity. This is improved by averaging multiple measurements.
- 2% error case performs better than the 5% error case as expected
- 5% error case is highly improved with increased stacking (repetition).
- With 2% error, fewer stacks are necessary.

Conclusions

- Reproducing porosity is shown to be possible.
- Quantifying the error in transfer resistance measurements will be important in determining the quality of the retrieved porosity.
- Error in other terms of Archie's law must be considered before this method can come into use.

Future Work

- Determine effect of error in modeled or measured saturation and fluid resistivity on porosity
- Determine optimal ERT measurement scheme: number of electrodes and configuration versus survey time.
- Testing method for 3D inversion of miniLEO data

Acknowledgements

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