A floating Transient Electromagnetic System to Acquire Dense Data on Volcanic Lakes - Investigation of the Furnas Hydrothermal System, Azores

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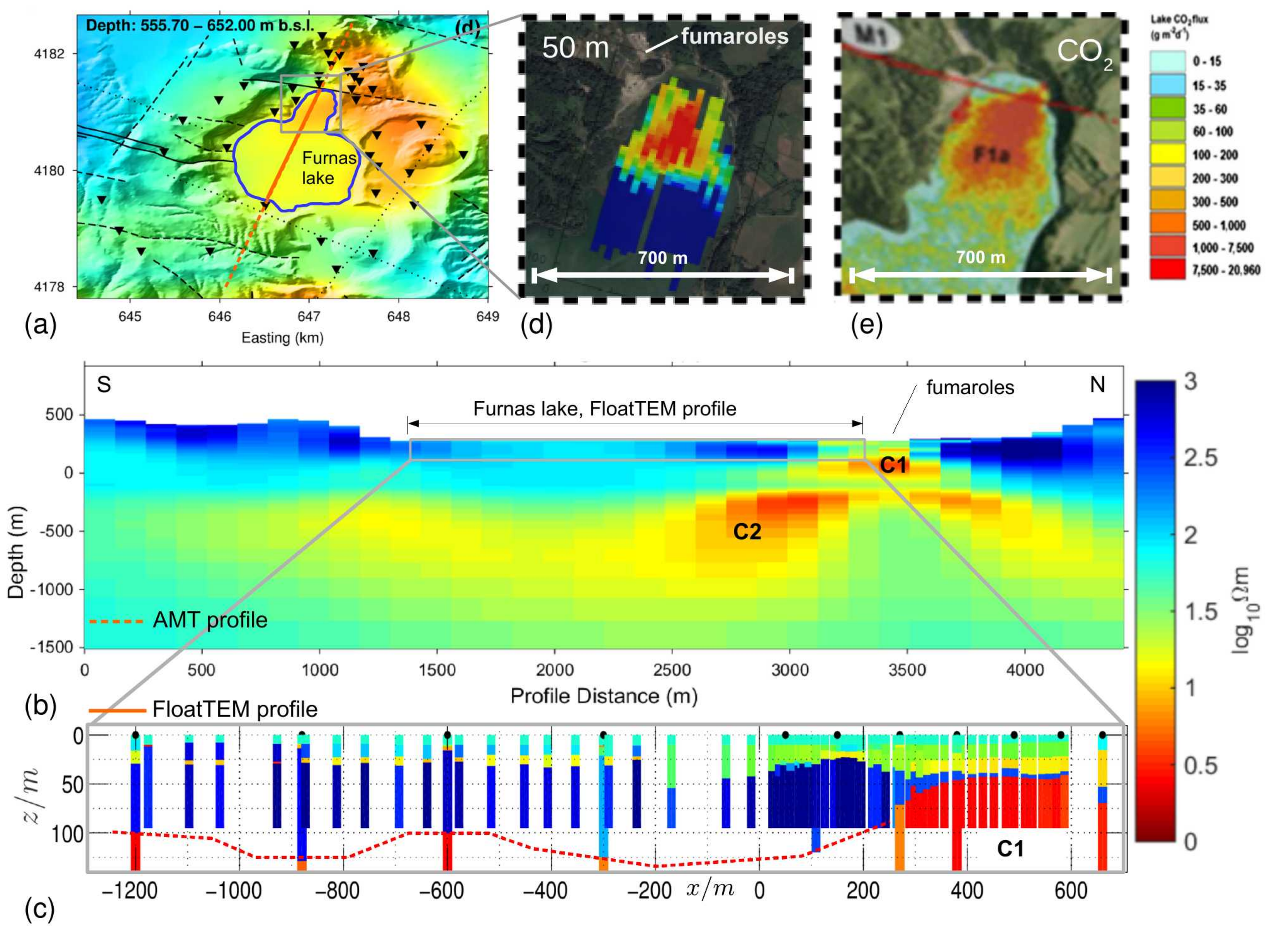
I. Introduction

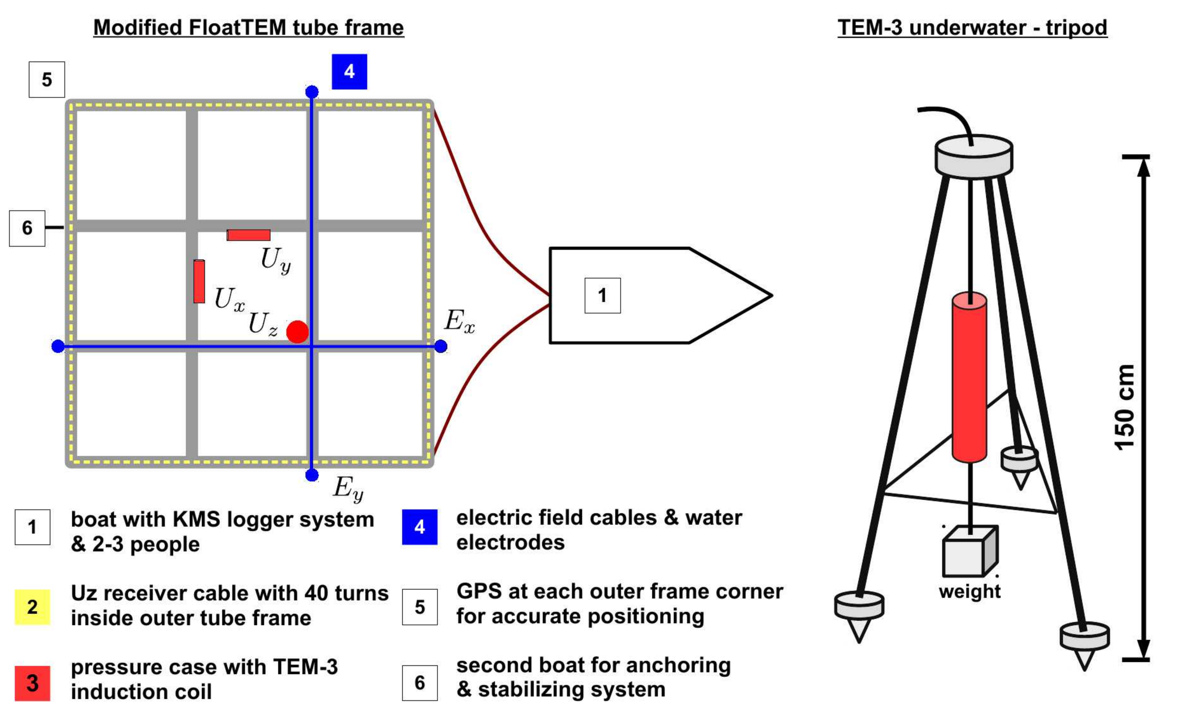
Often geophysical surveys leave out water covered areas due to inaccessibility, leading to a lack of resolution in derived subsurface images and consequently leading to interpretation uncertainty. For measurements on volcanic lakes a floating transient electromagnetic system (FloatTEM) was developed. The FloatTEM system was successfully used to image the hydrothermal system and CO_2 outgassing areas of the Furnas volcanic lake on the Azores islands down to 180 m depth [1,3]. Recent Audio-magnetotelluric (AMT) geophysical data revealed a conductor in 500m depth which is assumed to be related to hot fluids near the boiling point [2]. However, as no data was measured on the lake directly, the spatial dimension of the conductor (C2) is not known precisely. Due to the latter and due to the limited depth resolution of the current FloatTEM system, we propose a modified TEM setup to image the Furnas volcanic system. The modified system combines large fixed loop TEM and grounded dipole transmitter configurations with floating and anchored receivers. Modeling studies show that the proposed configuration is capable of resolving the deep conductor. The modified semi-floating TEM system is a novel approach to look "into the depth of a volcano".

II. FloatTEM and AMT Results



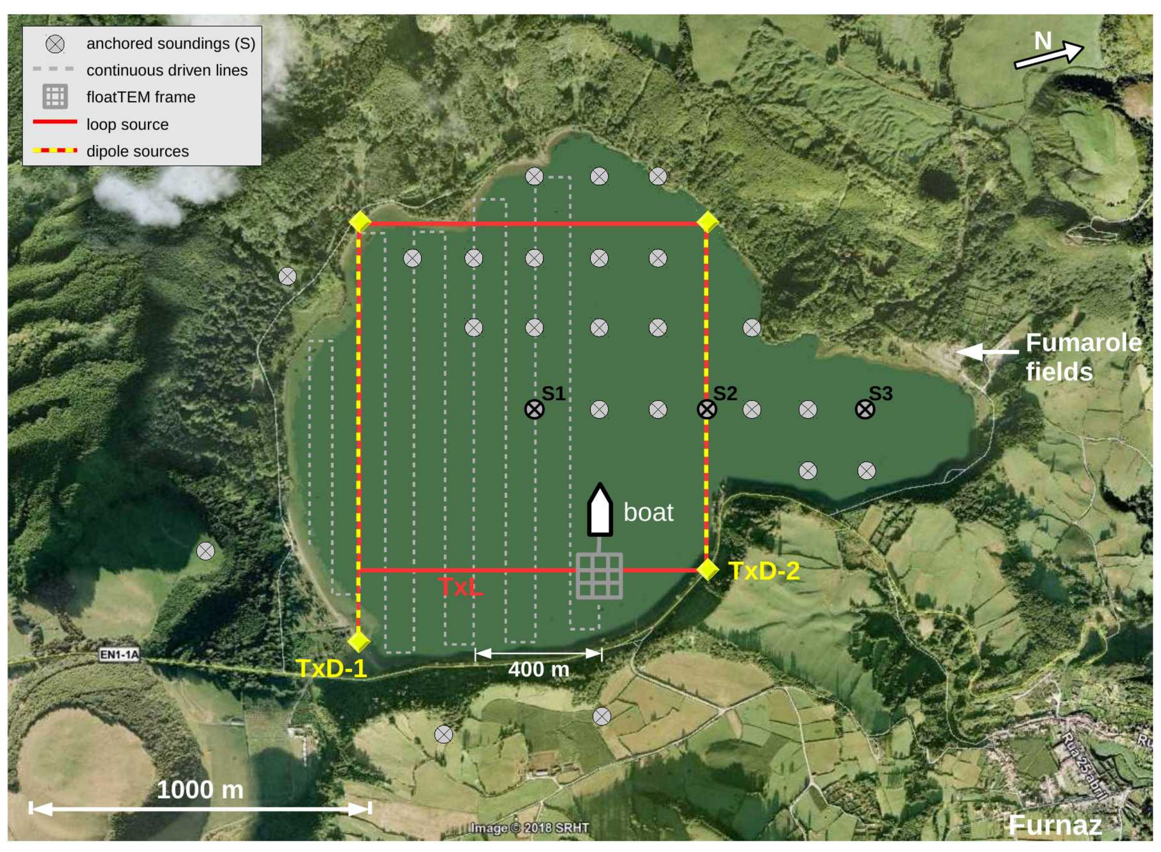
- 3D AMT results in (a,b): show deep conductor in 500 m depth (C2) and shallow C1 close to fumaroles
  - → C1/C2 Interpreted as related to hot fluids near the boiling point
- FloatTEM results (c,d): very dense data (~500 soundings)
  - → shallow conductor C1
  - → C1 extends below lake
  - → structure not in AMT
  - → well correlated to CO2 outgassing maps (e)

III. Modified 3D-FloatTEM System



Modifications

- DOI more than ~500 m
- fixed large loop and dipole transmitters around lake
- use mobile Rx with 3-component receivers (Ux,Uy, Uz)
- electric field receivers (Ex, Ey)
- GPS at frame corner and tilt-sensors at coils
- underwater tripods for high S/N soundings
- 2 - 3 operators with KMS-820 inside boat



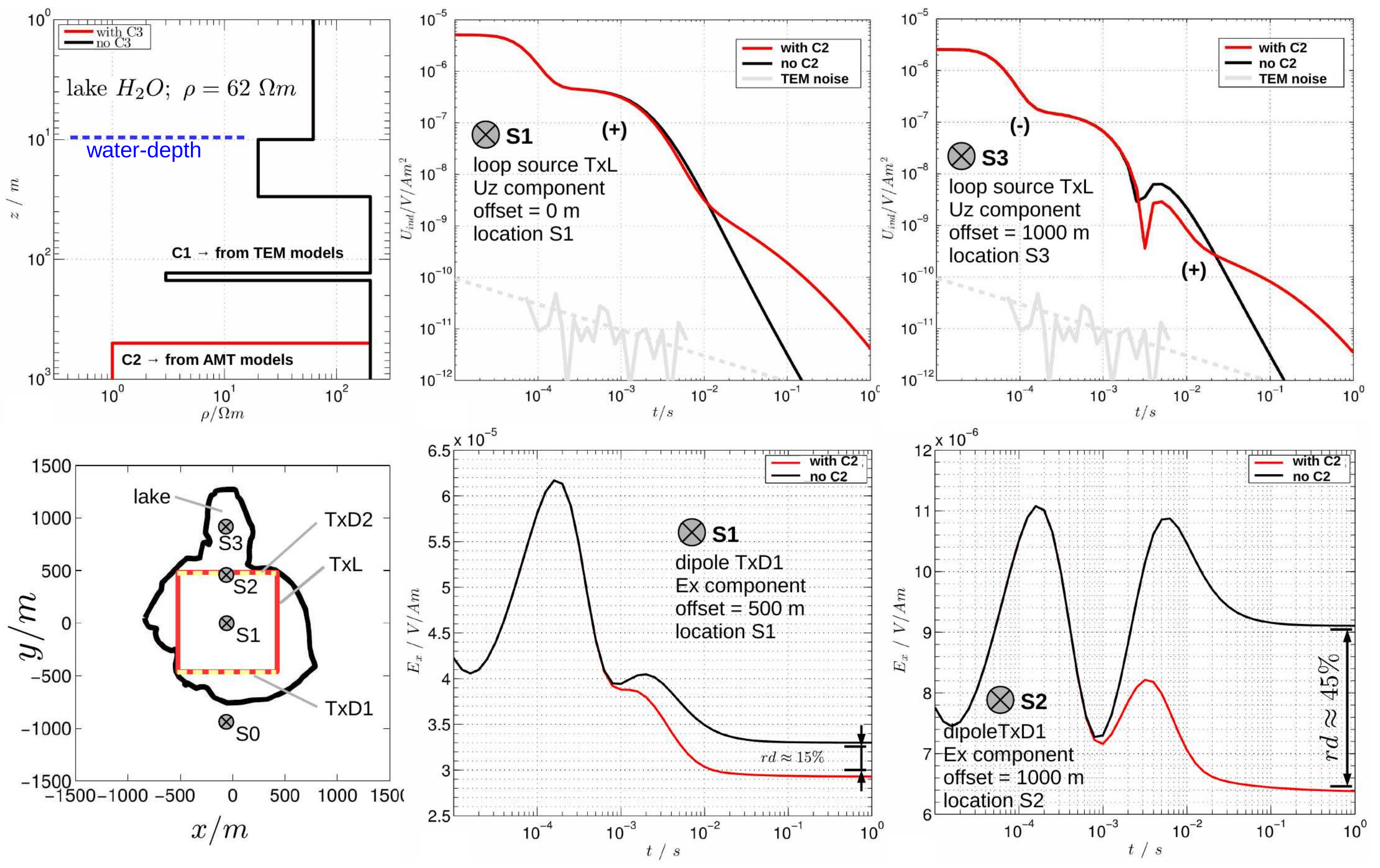
Workflow

1. deploy Tx-Rx system
   → transmit large loop TxL
2. move 3D-FloatTEM along profile lines
3. record anchored soundings
   → deploy underwater tripods
   → anchor floatTEM
   → improved S/N
   → measure land-stations
4. open large loop TxL
5. set up dipole (TxD1/TxD2)
   → partly repeat step 2. - 3.
   → improved spatial resolution

IV. 3D-FloatTEM Modeling of Deep Conductor

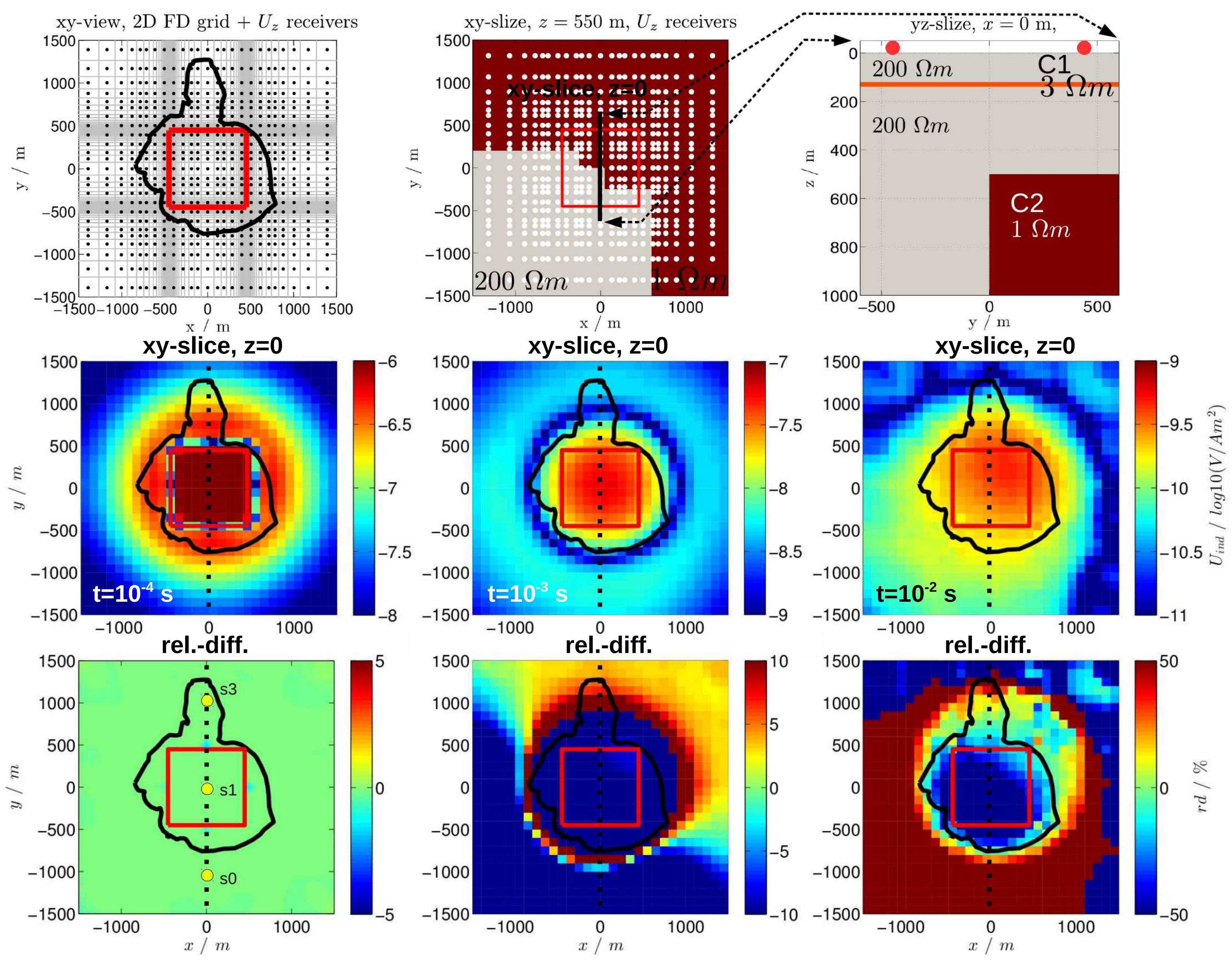
1D modeling study with and without conductive layer (C2) at 500 m depth

- Induced Voltage for TxL at locations S1/S2 indicates strong target response; significantly above the measured Furnas noise
- electric field target response is between 15% and 45% at late times



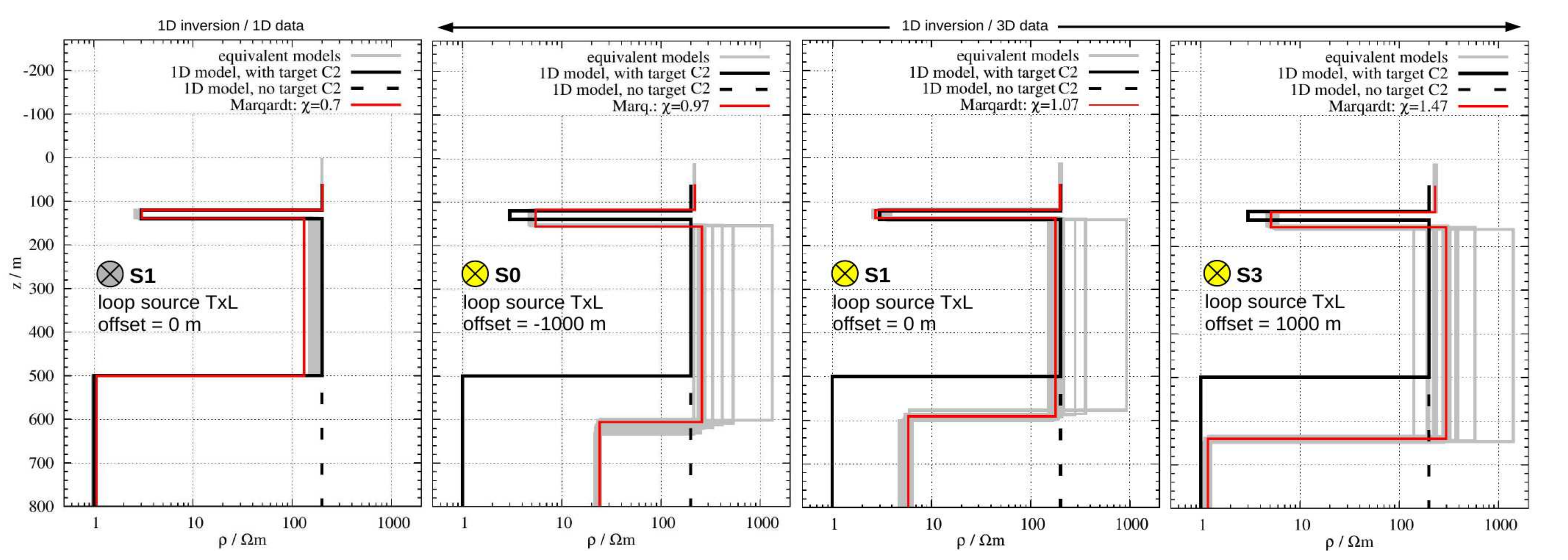
3D modeling study with discontinuous conductor C2

- asymmetric response for transient times t ≥ 1e-3 s; fields are significantly 3D affected
- relative difference to background response assuming a continuous C2 exceeds 10% for times t ≥ 1e-3 s for most Rx
- spatial geometry of the conductor at 500 m depth can be detected with the setup



1D inversion of 3D affected data

- deep subsurface resistivity structure not reproduced for all locations S1, S2 and S3
  - → data can be fitted well with $\chi \leq 1.5$; depth of C2 overestimated; resistivity underestimated
- 3D inversion scheme required to reconstruct the subsurface appropriate



References

[1] Küpper et al., 2018. Transient electromagnetic measurements using a floating setup on the volcanic lake "Lagoa das Furnas", São Miguel (Azores): Investigation of the hydrothermal system, DGG, Leoben/Austria.

[2] Hogg et al., 2017. A Three-Dimensional interpretation of short period magnetotelluric data at Furnas Volcano, Azores Islands, Geophysical Journal International 213.1: 371-386.

[3] Andrade et al., 2016. Estimation of the CO2 flux from Furnas volcanic lake (Sao Miguel, Azores), Journal of Volcanology and Geothermal Research, 315, 51–64.

V. Conclusion & Outlook

- Current FloatTEM can image the shallow Furnas hydrothermal system down to 200 m
- To image the deep conductivity structure a novel 3D-FloatTEM system is proposed that can investigate water covered areas/volcanic lakes down to more than ~500 m depth with sufficient spatial resolution
- For the Furnas case a 3D interpretation of the data is required as seen in the modeling