A floating transient electromagnetic system to acquire dense data on volcanic lakes

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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 new electromagnetic system (FloatTEM) was developed. The FloatTEM system was successfully used to image the hydrothermal system and CO2 outgassing areas around the Furnas volcanic lake on the Azorean islands down to 180 m depth [1]. Recent Audio-magnetotelluric (AMT) geophysical data revealed a conductor in 500 m depth which is interpreted as related to hot fluids near boiling point [2]. However, no data was measured on the lake itself; the spatial dimension of the conductor (C3) 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 system to image the Furnas volcanic lake. The modified system combines fixed loop FloatTEM and grounded dipole transmitter configurations with floating and anchored receivers. Modelling studies show that the proposed configuration is capable of resolving the deep conductor. The original floating and modified semi-floating TEM system are a new approach to look into the depth of a volcano.

II. Furnas volcanic lake - AMT and FloatTEM result

- 3D AMT results [2]: good conductor in 500m depth (C3) and shallow conductor (C1) near the fumaroles as related to hot fluids near the boiling point; very consistent image but no data on Furnas lake.
- 3D FloatTEM results [3]: very dense data around fumaroles (500 soundings). No reliable results obtained for shallow conductor (C1).
- CT extends below the Furnas lake (CT)
- floatCT system as mobile receiver

III. Original FloatTEM system for shallow imaging

- 3D modeling study with and without conductor C3
- assumption of the TEM setup in Fig. 6(a) with a large loop (TxL) and multiple receivers at the surface (black dots). The 3D model is displayed as xy- and yz-sections in Fig. 6(b).
- the received secondary magnetic field at the surface is symmetric for an early transient recording time t=5s-4s. At later times the secondary magnetic field distribution becomes very asymmetric with respect to the transmitter loop.
- the relative difference of the received signal at the surface with and without continuous conductor C3 in Fig. 6(b) is larger than the typical error floor for secondary magnetic field transients at late times.
- the response curves and the relative differences are shown in Fig. 7a – b for two locations, S1 and S3. We can clearly distinguish the situation with continuous C3 interrupted C3 and complete removal of C3.
- the asymmetric behavior of the response in Fig. 7b indicates that the proposed system can resolve the spatial shape of C3 below lake Furnas.

IV. Modified FloatTEM → imaging deep conductor

- We propose a modified FloatTEM system combining large sources and multi-receiver sites in order to investigate the spatial extent of the deep hydrothermal system (conductor C3) below lake Furnas
- Modified FloatTEM receiver system
- depth of exploration: 1000 m
- fixed large loop and dipole transmitters around lake
- use FloatTEM frame as mobile receiver with 3-component induction coil receivers (Ux,Uy,Uz) in waterproof pressure cases mounted on inner tube frame
- additional electric field receivers (Ex, Ey, Ez) mounted on top frame
- GPS at frame corners → fast/dense data acquisition
- additional underwater tripods for anchored soundings → improved S/N
- 2-3 operators and logger unit inside boat
- second boat for taxi and stabilizing system

V. Modeling study of a deep conductor below Furnas lake

- 1D modeling study with and without conductor for cooperation at furnace
- assume the 1D model in Fig. 5(a)
- the secondary magnetic field in the center of a large transmitter loop (TxL, location S1) indicates a strong response stronger than the measured Furnas noise level (cf. Fig. 5(c))
- the response outside the loop for location S3 is also strong enough to detect conductor C3 (cf. Fig. 5(e))
- the large loop setup is well suited to detect the depth of the conductor C3.

VI. Conclusion & Outlook

- FloatTEM can image the shallow Furnas hydrothermal system down to 200 m depth.
- modified FloatTEM images the conductivity structure of a volcanic lake down to 1000 m depth with sufficient resolution to image a deep conductor below Furnas lake
- both approaches are new and can be easily adopted to different cases.

References