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

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Central loop TEM - short recall of method

- 1D case:
  - pure TE mode E-fields
  - no horizontal components for central loop
- EM fields focused under Tx-loop
- 1D inversion of loop TEM data is conventional approach and often sufficient

[Nabighian & Macnae, 1991]
The Furnas System & Preliminary Work done

- AMT, DCR & CO2 mapping
- 3D AMT model provided by DIAS
- FloatTEM survey with DOI down to 190 m
The Original FloatTEM system
The Original FloatTEM system

fumaroles
New modified 3D FloatTEM system

Modified FloatTEM tube frame

1. boat with KMS logger system & 2-3 people
2. Uz receiver cable with 40 turns inside outer tube frame
3. pressure case with TEM-3 induction coil
4. electric field cables & water electrodes
5. GPS at each outer frame corner for accurate positioning
6. second boat for anchoring & stabilizing system

TEM-3 underwater - tripod

150 cm
Proposed 3D FloatTEM system
1D Modeling of top of the deep conductor C2

(a) lake $\text{H}_2\text{O}$; $\rho = 62 \ \Omega \text{m}$

C1 $\rightarrow$ from TEM models

C2 $\rightarrow$ from AMT models

(b) loop source Txl
Uz component offset = 0 m
location S1 in-loop

with C2
no C2

TEM noise

(c) loop source Txl
Uz component offset = 1000 m
location S3 separate loop

with C2
no C2

TEM noise

(d) lake

S3
TxL
S2
S1
TxD2
S0
TxL

(e) dipole TxD1
Ex component offset = 500 m
location S1

$rd \approx 15\%$

(f) dipole TxD1
Ex component offset = 1000 m
location S2

$rd \approx 45\%$
1D Modeling of lower boundary of conductor C2 / dipole setup

→ lower boundary only resolved with E-fields and with limited resolution
3D Modeling of deep continuous/discontinuous conductor C2
3D Modeling of deep continuous/discontinuous conductor C2

→ distortion effects clearly visible in soundings
→ asymmetric 3D response along profile line
1D inversion of 3D data - discontinuous conductor C2

1D inversion
→ data fitted optimal
→ false/wrong models
→ miss-interpretations if no 3D inversion applied
Effect of sensor attitude / sensor rotation - dipole source

- receiver system affected by motion (yaw, pitch, roll)
  
  \[
  U_{x,\alpha} = \sqrt{(\sin(\alpha)U_z)^2 + (\cos(\alpha)U_x)^2} \\
  U_{z,\alpha} = \sqrt{(\cos(\alpha)U_z)^2 + (\sin(\alpha)U_x)^2}.
  \]

- E.g. small effects for Uz in-loop; large effects of separate loop data

- dipole source data is affected stronger

- correction of sensor attitude required (processing approach follows Nittinger et al. 2017 as used in DESMEX project for Semi-airborne data)
Effect of sensor attitude / sensor rotation - loop source

- Figure (a): $U_z$ for different tilt angle $\alpha$ for loop source TxL, Uz component, offset = 10 m, location S1, in-loop.
- Figure (b): $U_x$ for different tilt angle $\alpha$ for loop source TxL, Ux component, offset = 10 m, location S1, in-loop.
- Figure (c): $U_z$ for different tilt angle $\alpha$ for loop source TxL, Uz component, offset = 1000 m, location S3, separate-loop.
- Figure (d): $U_x$ for different tilt angle $\alpha$ for loop source TxL, Ux component, offset = 1000 m, location S3, separate-loop.
Effect of sensor attitude / sensor rotation - dipole source
Summary / Conclusions

→ 3D FloatTEM concept presented
  → currently AMT / FloatTEM data lack deep resolution below lake
  → reconstruction of deep hydrothermal reservoir below lake Furnas
→ dense multi-source & multi-component EM data
→ new / innovative approach for EM on water
→ combination of land-based sources with floating receivers
→ dipole & loop sources for increased resolution for conductive and resistive structures