2D Joint Inversion for Semi-Airborne and LOTEM Data: A Data Application from Eastern Thuringia, Germany

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1. Introduction

A 2D joint inversion was developed in order to couple spatially dense sampled data from semi-airborne frequency- domain electromagnetic (EM) measurements and long-offset transient electromagnetics (LOTEM) .

The novel semi-airborne frequency-domain electromagnetic system were developed and tested successfully within the BMBF/DESMEX project (Fig. 1.1 and 1.2) (Smirnova et al., 2019; Becken et al., 2020; Mörbe et al., 2020). It takes advantages of both ground and airborne techniques by combining ground based high power sources with spatially dense data. However, the method usually has reduced signal-noise ratio compared to ground based method. For example, compared to LOTEM, the semi-airborne technique has a smaller depth of investigation due to the data quality and offset limitations.

We developed a 2D joint inversion algorithm to combine the advantages of each method. The 2D joint inversion on field data combines the characteristics from both individual inversion results. Even though not all the discrepancies observed between the single method inversions can be explained due to possible 3D, anisotropic or IP effects, the joint inversion result could be generally validated in the following synthetic studies. Moreover, we conducted a synthetic study for investigating the possible 3D effects in 2D inversions.

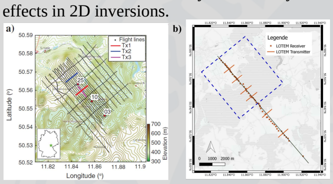


Fig 1.1: Location of the (a) semi-airborne (Smirnova, et al., 2019) and (b) LOTEM (Mörbe, et al., 2020) measuring configurations in eastern Thuringia, Germany (2016).

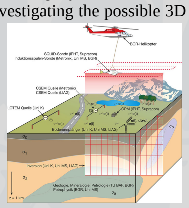


Fig 1.2: Sketch of semi-air borne EM and DESMEX project (Mörbe, 2021).

2. 2D inversion of field data

	LOTEM	Semi-airborne
Domain	Time	Frequency
Component	Ex (Step-on)	Re(Tz) & Im(Tz)
Transmitter (Tx) position	Land	Land
Receiver (Rx) position	Land	Air
Offset	500~4000m	500~2000m

- MARE2DEM is modified for realizing the 2D joint inversion of frequency- and time-domain data (Key, 2016; Haroon et al., 2018; Cai, 2020). The field data were acquired in the survey shown in Fig 1.1.

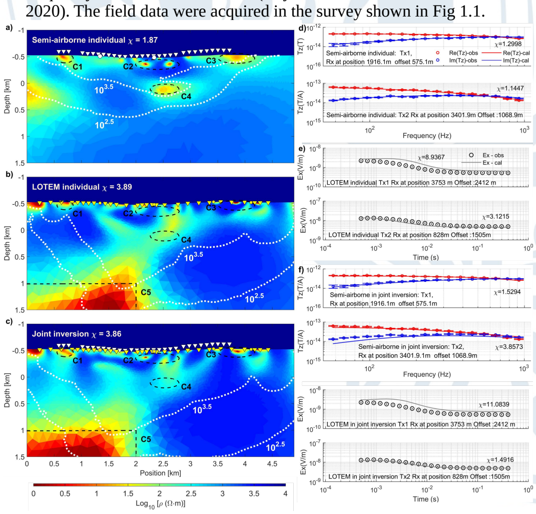


Fig 2.1: 2-D inversion results for the field data.

- The 2D joint inversion converged. Characteristics from semi-airborne result can be found in shallow parts of Fig 2.1c, while characteristics from LOTEM dominate the deep parts.
- Obvious discrepancies between the individual inversion results (Fig 2.1a and b) are still not explained.
- Synthetic studies were conducted to understand these discrepancies.

3. 2D Inversion of synthetic data for validation

- In order to validate the joint inversion model and understand the discrepancies between 2D individual inversions in Fig 2.1, the calculated data of the model in Fig 2.1c were inverted individually for each method.

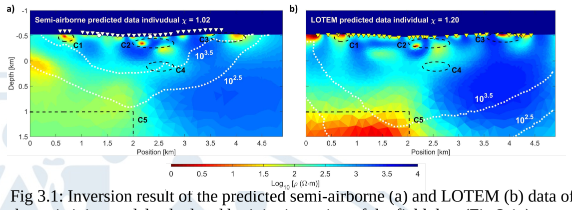
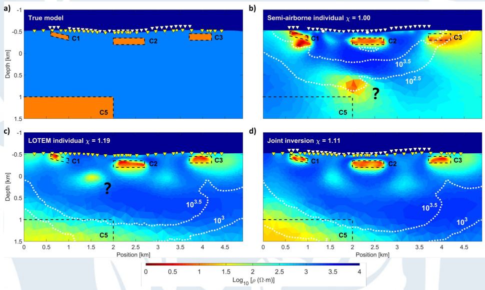


Fig 3.1: Inversion result of the predicted semi-airborne (a) and LOTEM (b) data of the resistivity model calculated by joint inversion of the field data (Fig 2.1c).

- The shallow part achieved by inverting semi-airborne predicted data are similar to those in semi-airborne field data single inversion result (Fig 2.1a).
  - ➢ The discrepencies in shallow region shown between Fig 2.1a and c are possibly influenced by different resolution.
- The discrepencies in deep region still cannot be explained. Could the deep anomalies C4 and C5 be resolved by the used field set-up ?
- Aiming at a clearer analyses, a simplified model is designed based on the field-data of 2D joint inversion result (Fig 2.1c), the synthetic data were inverted individually and jointly.



- Artefacts occur in individual inversions.
- Joint inversion resolve targets better without significant artefacts.
- If C5 exist, it can be resolved by LOTEM with the used field configuration.

Fig 3.2: 2D inversion results for the synthetic model shown in (a).

4. Possible 3D effects in 2D inversions

- 3D effects could be one important factor leading to un-explained discrepancies in Fig 2.1.
- Use custEM (Rochlitz et al., 2021) for 3D forward modelling.

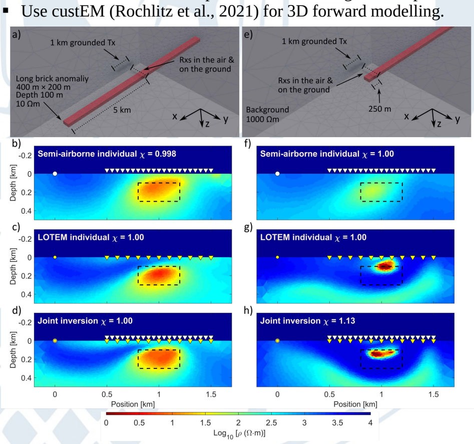


Fig 4.1: Modelling study of 3D effects in 2D inversions. The model descriptions are given in (a) and (e). (a) depicts an approximate 2D case; (e) is a 3D case; (b) to (d) present the 2D inversions for model (a); (f) to (h) present the 2D inversions for model (e).

- Model (a) depicts an approximate 2D case with Rx profile far away from the 3D boundary;
- Model (e) is a 3D case with Rx profile 250 m away from the 3D boundary.
- For the synthetic data of Model (a), all the three inversions reveal the target well with χ = 1.0 with no artefact.
- For the synthetic data of Model (e), the two individual inversions cannot depict the true model well.
- The joint inversion result in (h) cannot achieve a optimal χ.

5. Conclusions

In the inversion of field data, characteristics from both individual inversion results can be found in the 2D joint inversion result. The consequent synthetic studies validate the 2D joint inversion result generally. However, part of structures in 2D inversion results still cannot be fully explained. The modelling studies show that the 3D effects can be one explanation.