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Mare2DEM on land: MT Data from the Cape Fold Belt (South Africa) revisited

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INTRODUCTION

Mare2DEM is a parallel adaptive finite element code for 2D forward and inverse modelling for electromagnetic data (Key & Ovall, 2011), which is now being made freely available. Mare2DEM was originally designed with marine controlled-source electromagnetic (CSEM) and marine magnetotelluric (MT) applications in mind, but it can also be applied to onshore data. Important features of Mare2DEM are:

- automatic mesh generation and refinement
- triaxial (intrinsic) anisotropy
- topography

To test this inversion code with onshore MT data we use the data set measured in 2005 in the Cape Fold Belt, South Africa. The stations are aligned along a ~ 100km long profile with significant topography and a close-by ocean. Several stations indicate the existence of electrical anisotropy in the subsurface through phases > 90°. Commonly, these phases out of quadrant are explained by an anisotropy strike oblique to the main conductivity structures.
While in earlier inversion studies only data without 3D/anisotropy effects were inverted using WinGLink, we can now compare inversion results of this study, in particular how Mare2DEM deals the anisotropy effects in the MT data.

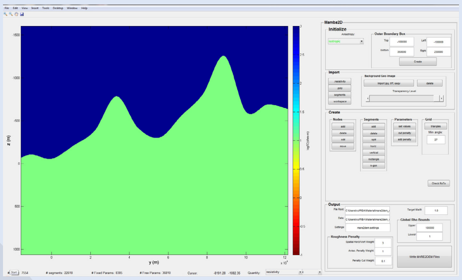
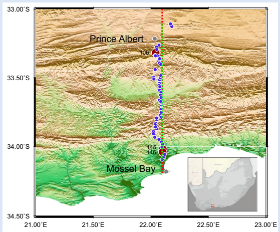
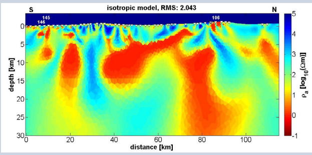


Figure 1
User interface Mamba2D for Mare2DEM to specify the following settings:
- grid dimensions
- isotropic / anisotropic conductivities
- import a priori information, e.g. topography
- create and modify nodes and segments
- set conductivities / lock cells
- generate mesh
- target rms
- conductivity bounds
- regularization parameters

Figure 2
Map of the study area in South Africa. The blue dots show the location of the MT-Stations, which were projected onto the . dashed profile line. The MT profile consists of 54 stations and was measured in 2005. It crosses the Cape Fold Belt in South Africa between Prince Albert and Mosselbay.



2D Models



error floor: TM 50%, TE 200%, phases: 3%,
starting model: 10 Ωm halfspace with bathymetry & topography

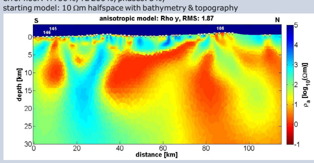
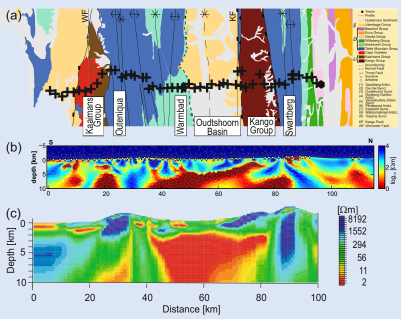


Figure 3
Isotropic conductivity model calculated with Mare2DEM [Key and Ovall, 2011]. White triangles show the location of the MT stations. The topography was included with 50m resolution together with the Ocean (rough bathymetry) at the southern end of the profile. Total rms: 2.04

Figure 4
Anisotropic conductivity model allowing for triaxial anisotropy. Here we present the y component of the conductivity which shows similar features compared to the isotropic inversion. The anisotropy introduced did not exceed a ratio of 2, but phases >90° cannot be modelled. Total rms: 1.87

Figure 5
Comparison between (a) surface geology, (b) 2D isotropic inversion model (Mare2DEM) and (c) 2D isotropic inversion model (RLM2DI) [Weckmann et al., 2012]. Prominent conductors e.g. under the Oudtshoorn Basin are included in both inversions, but have different shapes. FE inversion shows more structures (overfitting?), but vertical anomalies seem to correlate with positions of syn- and anticlines and might image fluid pathways. Including topography in FE inversion was vital to improve data fit. While the FD inversion did not include structures outside the station coverage, 2 stations north of the profile had to be included an a-priori conductivity structure beneath fixed.



MT Data & fit

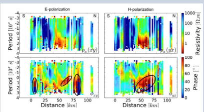


Figure 6
Pseudo-sections of TE and TM apparent resistivity and phase. Phases >90° (circled) are observed in the middle of the profile at periods >1s in both modes [Chen, 2012].

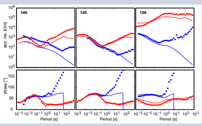


Figure 7
MT data & fit (lines); Phases > 90° could not be fit.

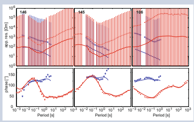


Figure 8
Data fit (lines) of the inversion after omitting data with phases >90°. The total rms improved, but phases approaching or higher than 90° usually correlate with decrasing resistivities. The apparent resistivites can be fitted, but not the phases approaching 90°.

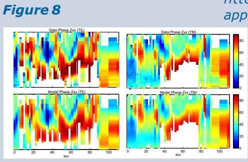


Figure 9
Pseudosections of observed and modelled TE and TM mode phases along the profile. White areas at long periods show the omitted data due to phases >90°. Because of static shift, apparent resistivities were downwaited in the inversion and not shown here. Therefore only phases are presented, which could be explained well by the inversion model.

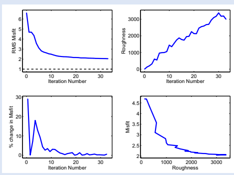


Figure 10
Development of total rms and roughness during the inversion run. While the rms does not change a lot after the 20th iteration the model includes more complex structures. The final iteration and „reasonable" inversion results have to be compared, to prevent overfitting of the data.

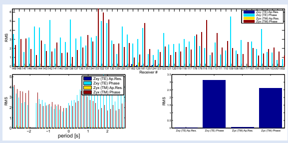


Figure 11
rms for each
- station (in dependance of data type)
- period (in dependance of data type)
- data type

Conclusions & References

- Mare2DEM works with land MT data.
- Only triaxial anisotropy --> phase values over 90° cannot be reproduced.
- Anisotropic inversion absorbes 3D effects
- topography has improved data fit
- Development of rms and roughness as indicator for overfitting
- General conductivity structure comparable to FD inversion, but shapes seem to be more detailed and complex.

Chen, X.: *Two-dimensional anisotropic inversion of magnetotelluric data, 2012*
Key, K.: *MARE2DEM: Tutorial and Training, Scripps Institution of Oceanography, UC San Diego, 2014*
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