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Supporting Information for

Comparison of Different Coupling Methods for Joint Inversion of Geophysical data: A case study for the Namibian Continental Margin

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Introduction

This supporting information includes material about performed synthetic inversions. The setup for these inversions follows the setup of the acquired data set presented in the main article. This includes model grid, station location, inverted frequencies, data errors, and the chosen weighting parameters in the objective function. The synthetic inversions were performed, to:

a) investigate the influence of the constraining models and data in JI1 (MT inversion cross-gradient constrained with fixed density model by Maystrenko et al. (2013)) and JI2 (cross-gradient coupled joint inversion of MT and satellite gravity data);
b) to examine the influence of a 3D inversion with a 2D survey setup;
c) to perform additional tests for the conductive model features C1, C2, and C3 in the main article;

d) and to constrain the original inversion model's resolution capabilities, especially concerning a lower boundary of the high resistivity body, i.e. electrical Moho.

The synthetic gravity data are created through a forward calculation of the main article's inversion starting model described in section 3, which is structurally based on the density model by Maystrenko et al. (2013). The synthetic MT data for Syn01 to Syn04 data are created through forward calculation of simple resistivity models which are based on the same structural boundaries. Resistivity values are summarized in table S1. Additionally, for the synthetic data Syn04, the forward model's sediment layer thickness was multiplied by 1.5, and a ridge-parallel, 10 km thick conductor (5 Ωm) north of Walvis Ridge was added to mimic a conductor linked to the Florianopolis fracture zone (FFZ). For each of the four synthetic data sets, the three inversion approaches MT-only, JI1, and JI2 were conducted as the most optimistic cases with no Gaussian noise added. Errorbars to the synthetic data were set to the same value as the observed data error. Figures S1 and S2 display vertical (profile 100) and horizontal slices for the synthetic inversion Syn01 for all inversion approaches (MT-only, JI1, JI2) to show the different coupling method's impact. Figure S3 shows slices through the final JI2 inversion models along profile 3, as direct comparison of the 4 different synthetic data sets Syn01 to Syn04. Text S1 gives a summary of the key observations acquired with these synthetic inversions concerning the points a) to d), above.

<table>
<tr><th></th><th></th><th colspan="4">Layer resistivity [Ωm]</th></tr>
<tr><th></th><th>Structure</th><th>Sediments</th><th>Crust</th><th>Lower crust</th><th>Mantle</th></tr>
<tr><td>Syn01</td><td>Reference</td><td rowspan="4">5</td><td rowspan="4">Oceanic:
500

Continental:
100</td><td rowspan="4">2000</td><td>1000</td></tr>
<tr><td>Syn02</td><td>Reference</td><td>100</td></tr>
<tr><td>Syn03</td><td>Reference</td><td>2000</td></tr>
<tr><td>Syn04</td><td>Reference, with sediment thickness multiplied by 1.5 and conductor north of WR</td><td>2000</td></tr>
</table>

Table S1. Summary of the model setup for synthetic data inversions. Syn01 to Syn04 are four synthetic data sets created by forward calculation of the resistivity models described in this table. Reference structure is the density model by Maystrenko et al. (2013), shown in Figures 9, 10 & 11c and S1 & S2e. Their sediment layers where combined to one layer for the forward resistivity model (5 Ωm resistivity). The layer thicknesses for continental-, oceanic,- and high density lower crust were not altered. Mantle resistivity values were varied between 100 and 2000 Ωm.

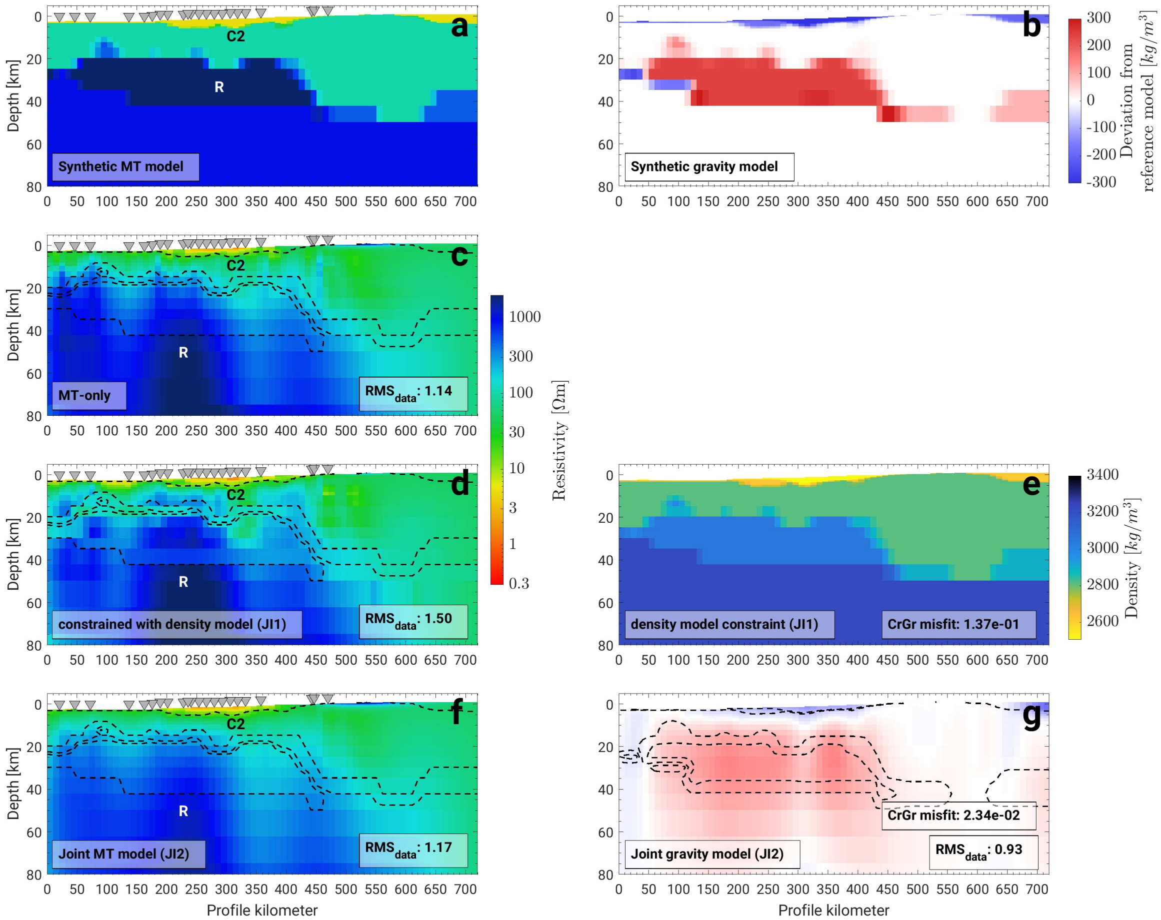

Figure S1. Vertical slices through physical Syn01 synthetic inversion models along coast-perpendicular profile 100. Shown are: a) resistivity & b) density anomaly forward models used to create synthetic data; c) MT-only, d) JI1 & f) JI2 final resistivity models from inversions with the synthetic MT data Syn01; e) JI1 density constraint model by Maystrenko et al. (2013), and g) JI2 density anomaly model from inversion with the synthetic gravity data. Black dashed lines indicate the models used for synthetic data creation (a & b). Anomaly R presents the large mid-to-lower crustal resistor associated to magmatic underplating. Conductor C2 images a sedimentary basin. Grey triangles denote the positions of MT stations.

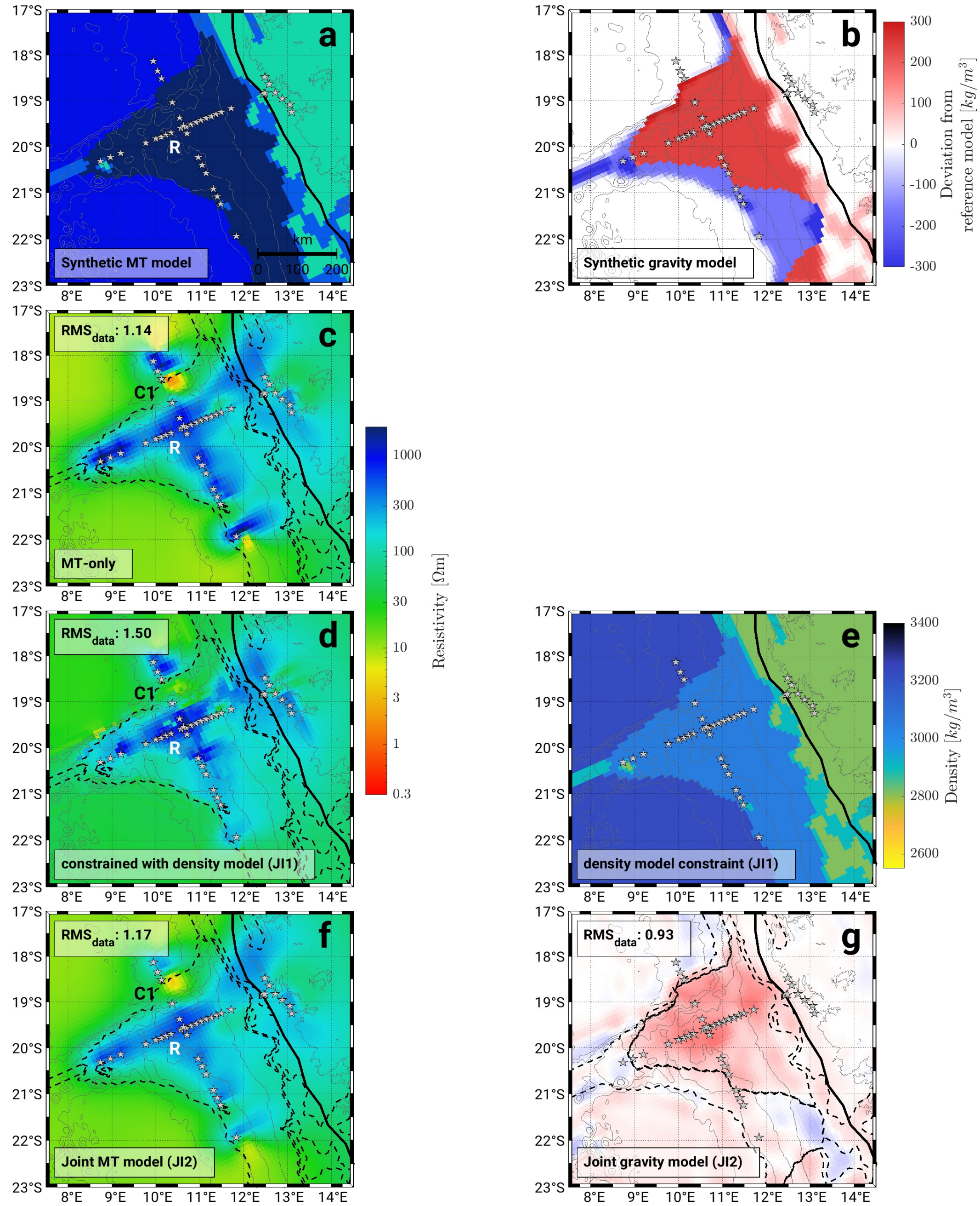

Figure S2. Horizontal slices through physical Syn01 synthetic inversion models at 25 km depth. Shown are: a) resistivity & b) density anomaly forward models used to create synthetic data; c) MT-only, d) JI1 & f) JI2 final resistivity models from inversions with the synthetic MT data Syn01; e) JI1 density constraint model by Maystrenko et al. (2013), and g) JI2 density anomaly model from inversion with the synthetic gravity data. Black dashed lines indicate the models used for synthetic data creation (a & b). Anomaly R presents the large mid-to-lower crustal resistor associated to magmatic underplating. Conductor C1 coincides the Florianopolis fracture zone. Grey lines are bathymetry. Grey stars denote the positions of MT stations.

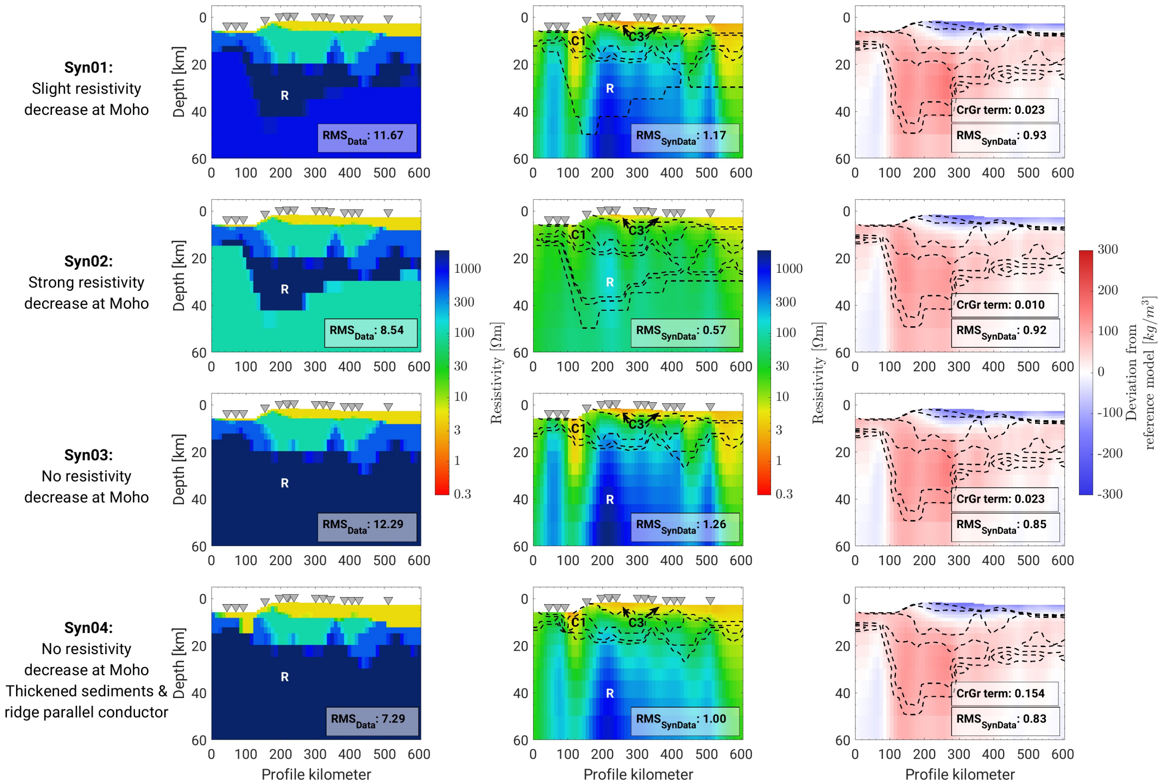

Figure S3. Vertical slices through physical synthetic JI2 inversion models along coast-parallel profile 3. Shown are: First column – models used to create synthetic MT data; Second column – final resistivity models from inversions with the synthetic data; Third column – final density anomaly models from inversions with the synthetic data. The rows correspond to the 4 different synthetic data sets Syn01 to Syn04, respectively. Black dashed lines indicate the models used for synthetic data creation. Grey triangles denote the positions of MT stations. RMS_{Data} in the first column represents the fit of the forward model to the observed MT data. $RMS_{SynData}$ in columns two and three represents the misfit of the synthetic inversions, i.e. misfit between synthetic- and model response data.

Text S1.

In the introduction we defined four issues a) to d), which shall be answered by the performed synthetic inversions. These points are addressed in this text, successively:

a) Influence of constraints in JI1 and JI2:

The influence of the constraining models and data of JI1 and JI2 of our four performed synthetic inversions is generally corresponding to the effects in the data inversions of the main article's inversions. Figures S1 and S2d show, that the model-constrained JI1 results in a more patchy resistivity model, while the joint MT-gravity data inversion JI2 shows little structural resistivity model changes compared to MT-only (comparison of f and c in Figures S1 and S2). RMS data misfits are similar for MT-only and JI2 inversions, while the model-constrained JI1 approach does not reach an equally low data misfit. The fixed cross-model in JI1 also helps to weaken the supposed artifact structure of conductor C1 (Fig. S2d). The pronounced horizontal separation into two conductors we see in Fig. 9b is also visible in our synthetic inversions along profile 3. As the forward model of Syn04 includes a thickened sediment cover (Fig. S3, bottom left), and contradicts the density cross-model's sediment thickness (Figs. S1 & S2e), synthetic inversion with the same weighting parameters as in our original data inversions also enforce such structural boundaries.

b) <u>Influence of a 3D inversion with a 2D survey setup:</u>

The horizontal slices in Figure S2 show a similar horizontal extent of resistivity anomalies as the original article's inversions (Fig. 11). In model areas close to MT stations, resistivity values of the synthetic models are reproduced well, while the model stays at starting model conditions (50 Ωm halfspace) further away from the station locations. Particularly, areas south-west and north-east of the profile crossing, as well a coast-parallel areas east of profile 3 should be more resistive to match the forward model (Fig. S2a) used for synthetic data creation. Thus, synthetic inversions have proved, that model interpretation should be focused to areas close to (e.g. below) MT stations.

c) <u>Behavior of conductive models features C1, C2, and C3:</u>

Concerning conductive model feature C1 (Figures 10 & 11), the synthetic inversions Syn01 to Syn04 image a similar feature (Figures S2 & S3). However it seems to be significantly reduced in Syn02, where the Moho resistivity contrast is increased and Syn04, where the forward model for the synthetic data creation actually includes such a conductive feature. This observation supports the interpretation, that this feature is likely an inversion artifact promoted by the sudden change in crustal thickness and accompanied change of crustal structure, i.e. from the northern oceanic crust to the tectonically and magmatically altered crust of Walvis Ridge. In Syn04, we mimic a conductive fracture zone, by including a ridge-parallel conductor north of Walvis Ridge. This feature is not replicated in the synthetic inversion, thus emphasizing the limited resolution further away from MT stations.

For conductive feature C2 on profile 100, the synthetic inversions show a sensitivity for sediment thickness. Generally, the synthetic inversions replicate sediment thickness from the resistivity forward models well. The density anomaly models of JI2 (Fig. S3, right column) however, image a strongly smoothed (and overestimated) sediment thickness and are insensitive to a change in the resistivity cross-model's sediment thickness. The increase in the objective function's coupling term in Syn04 shows, that the two models are less alike, but the increase is not strong enough to enforce a change in the density anomaly model, although coupling weight κ is high.

Regarding conductive anomalies C3 along profile 3 (Fig. 10), all synthetic inversions Syn01 to Syn04 image seemingly deeper sediment basins south of Walvis Ridge (Fig. S3, middle column), although no sediment thickness variation is included in any of the synthetic data's forward models. Thus, sediment thickness variation of C3 is mainly a smoothing artifact due to a deficit in MT station coverage.

d)

The main difference between the four synthetic inversions is the mantle resistivity of the forward models used for creating the synthetic data. The resulting resistivity sections (Fig. S3 middle column) clearly show, that the inversions are capable of distinguishing between a more conductive and a more resistive mantle as a comparison of Syn02 with Syn01, Syn03 and Syn04 shows. However, the distinction of the highly resistive lower crust from a slightly less resistive mantle is not possible (cp. Syn01 and Syn03, which look almost identical). This is particularly true for Syn02, where the presence of the resistive crust is not visible anymore. Here, the signal from the resistive crust is overpowered by the more conductive mantle. In general, lower crustal and mantle resistivities recovered by the inversions are lower than the resistivities of the synthetic input models. The synthetic inversions support the interpretation that abnormally high mantle resistivities are present in the survey area and that the true mantle/lower crustal resistivities might be even higher than the resistivities recovered in our inversion models.