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# Influence of Realistic Head Modeling on the EEG Forward Solution


Vorwerk, J.[1], Cho, J.-H.[2], Oostenveld, R.[4], Rampp, S.[3], Hamer, H.[3], Knösche, T.[2], Wolters, C.H.[1]

[1]Institut für Biomagnetismus und Biosignalanalyse, Westfälische Wilhelms-Universität Münster, Germany
[2]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany
[3]Epilepsy Center, Department of Neurology, Universitätsklinikum Erlangen, Erlangen, Germany
[4]Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behaviour, Nijmegen, The Netherlands

j.vorwerk@uni-muenster.de

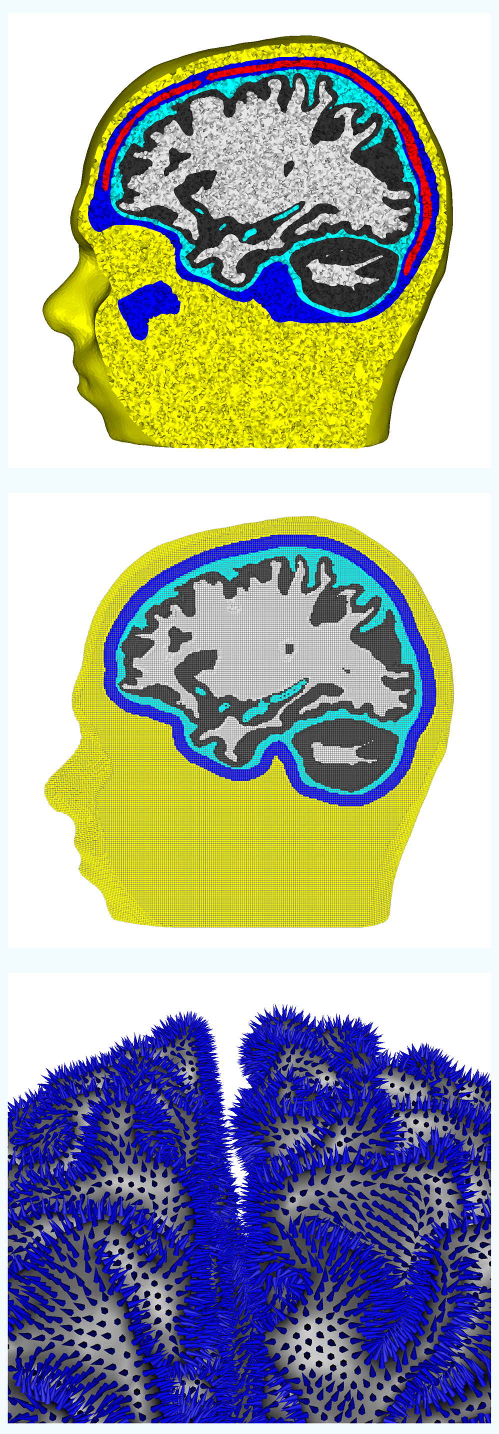

## Introduction

To be able to reconstruct the generators of the signal measured with EEG it is necessary to solve an ill-posed inverse problem. The achieved accuracy of the solution heavily depends on the accurate simulation of the EEG signal generated by an atomic current source inside the brain volume, the so-called forward problem of EEG. Here, the simulation accuracy strongly depends on a detailed modeling of the human head, i.e. it is necessary to model the, possibly complex shaped, compartments of different conductivity inside the human head as detailed as possible.

Several studies have investigated the influence of modeling certain conductivity features of the human head on the accuracy of the forward solution, e.g. modeling of the CSF (Wendel et al. 2008; Lanfer et al. 2012), distinction between gray and white matter (Ramon et al. 2004), distinction between skull compacta and spongiosa (Dannhauer et al. 2011) or incorporation of the highly anisotropic structure of the white matter (Güllmar et al. 2010).

The goal of our study is to systematically investigate the influence of modeling/neglecting these head compartments in a state-of-the-art head model in order to identify the most important head compartments to be modeled, the most affected brain regions and relate these to the numerical error. Furthermore, we compare these effects to the accuracy that can be achieved using a simple, automatically generated five compartment head model.

### Figure 1



6CI (top) and 5CI_ft (middle) head model, source space (bottom)

## Methods

Forward simulations are computed using the **Finite Element Method (FEM)** in **SimBio**

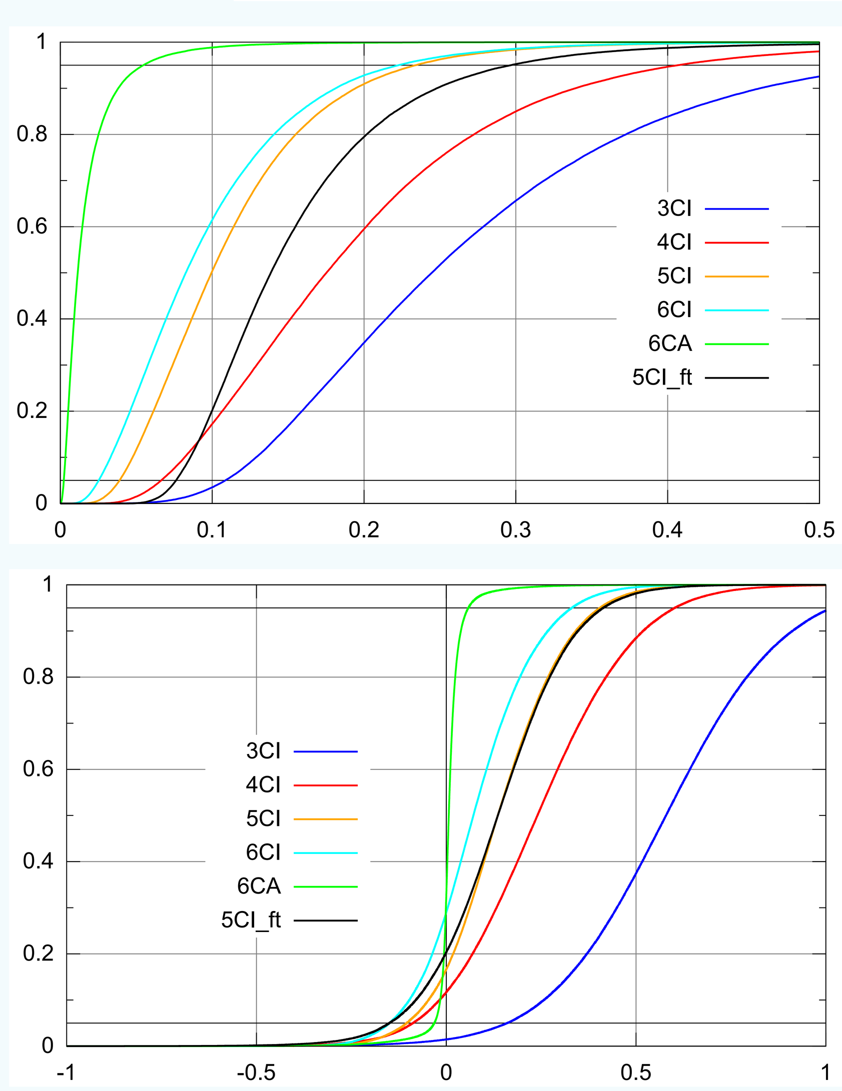
The effects of modeling/not modeling different conductive features are evaluated using a variety of head models:

**3CI - 6CI** Isotropic head models with 3 - 6 compartments:
*starting from a three compartment model (skin, skull, brain), we subsequently distinguish CSF, gray/white matter, skull compacta/spongiosa*
**6CA** 6CI model with additional anisotropic white matter
**6CA_hr** high resolution version of 6CA as reference to estimate the numerical error
**5CI_ft** simplified 5 compartment head model generated with FieldTrip-SimBio

We use two difference measures to quantify the effects of volume conductor changes:
**RDM** - effect on signal topography **lnMAG** - effect on signal magnitude

We calculate the effects both comparing different models directly and in relation to the reference model. The results are visualized using histograms of cumulated relative frequencies (Fig. 2), surface plots and heatmaps (Fig. 3-6).

### Figure 2




Cumulated relative frequencies of **RDM** (top) and **lnMAG** (bottom) effects relative to model 6CA_hr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For more information about the FieldTrip-SimBio integration and a tutorial visit
**http://fieldtriptoolbox.org/development/simbio**
For more information about SimBio visit
**https://www.mrt.uni-jena.de/simbio/**

## Results

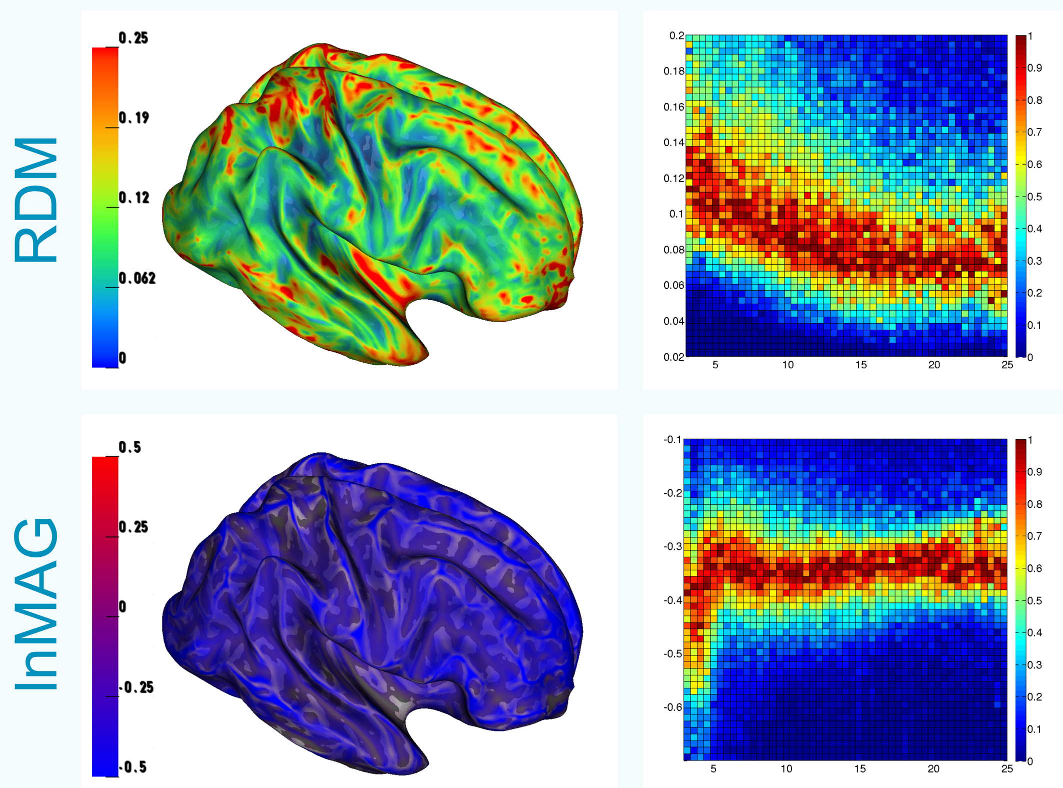
**CSF** and **gray/white matter** distinction show strong effects on both signal topography and magnitude, especially for superficial sources. **Skull spongiosa/compacta distinction** shows clearly weaker effects mainly in temporal areas. **White matter anisotropy** shows topography effects not following a clear pattern and magnitude effects mainly for deep sources.

The **numerical errors** are negligible in comparison to the influence of modeling effects. The **simplified head model** shows a good accuracy when considering the clearly reduced work effort.

## Conclusion

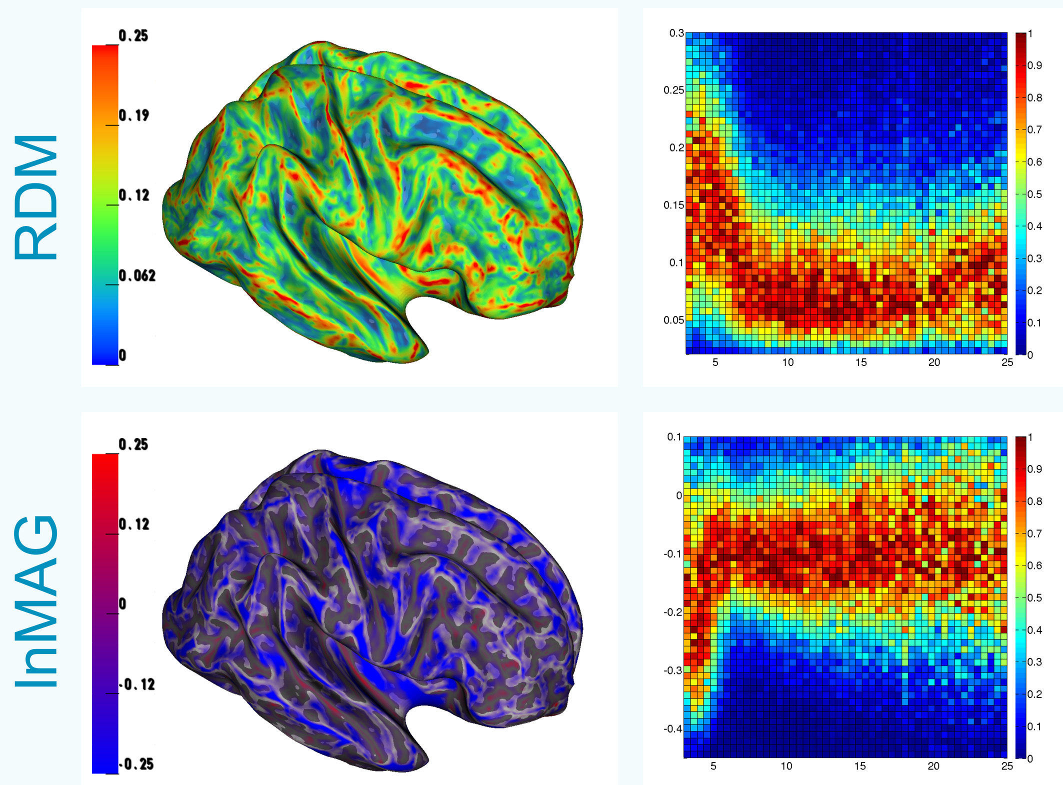
Due to the strong effect on both signal topography and magnitude and the relatively easy segmentation, **CSF** and **gray/white matter** should be distinguished in a realistic head model. Furthermore, as shown by (Dannhauer et al. 2011; Wolters et al. 2000), an accurate **modeling of the skull** is of high importance for EEG. However, in the investigated head model, the additional distinction of **skull compacta/spongiosa** has a comparatively weak effect when using an optimized conductivity value. The inclusion of **anisotropic white matter** leads to effects that are nearly as big as those for CSF and gray/white matter distinction, but also to an increased workload in model generation.

### Figure 3 4CI vs. 3CI; +CSF



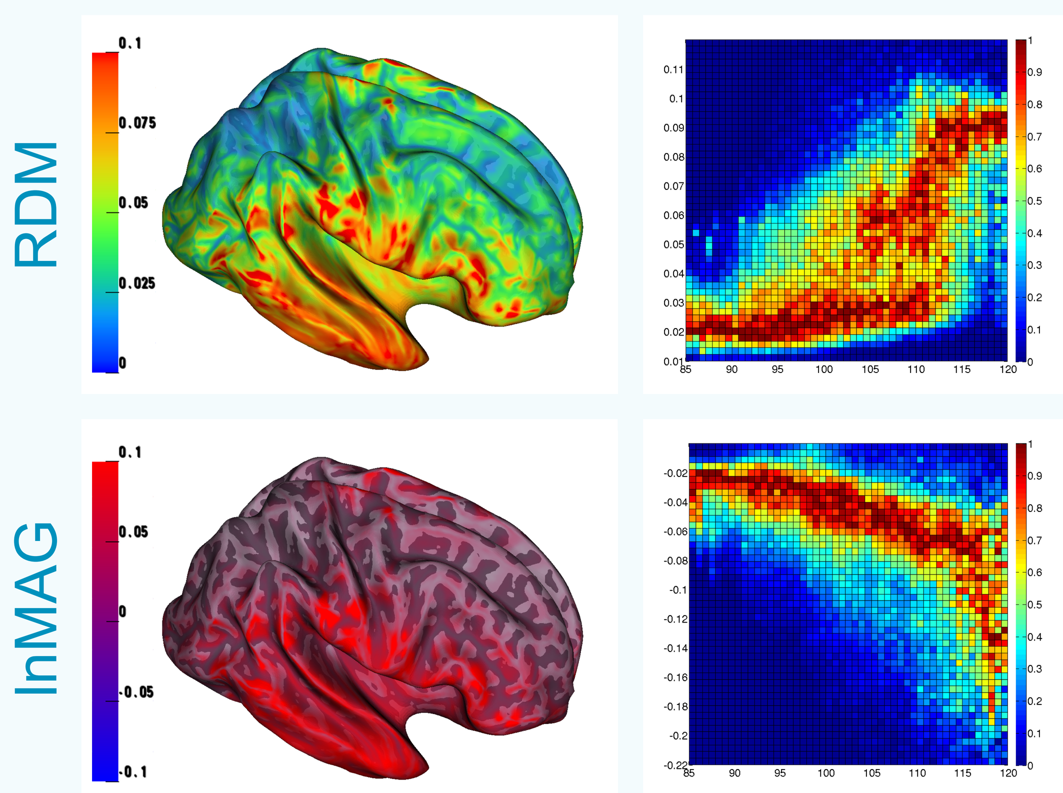

Left row: Visualization of topography (up) and magnitude (bottom) effect
Right row: topography and magnitude effect vs. source depth (in mm)

### Figure 4 5CI vs. 4CI; +gray/white matter



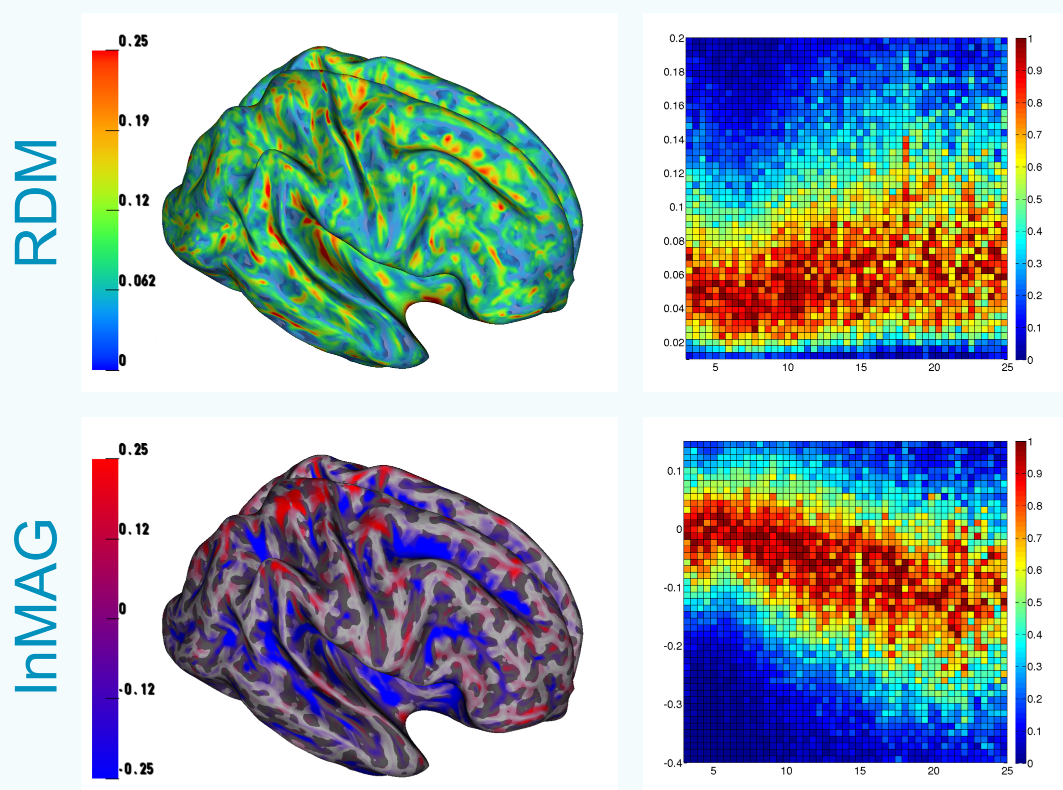

Left row: Visualization of topography (up) and magnitude (bottom) effect
Right row: topography and magnitude effect vs. source depth (in mm)

### Figure 5 6CI vs. 5CI; +skull comp./spong.




Left row: Visualization of topography (up) and magnitude (bottom) effect
Right row: topography and magnitude effect vs. median distance to elec.

### Figure 6 6CA vs. 6CI; +aniso




Left row: Visualization of topography (up) and magnitude (bottom) effect
Right row: topography and magnitude effect vs. source depth (in mm)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