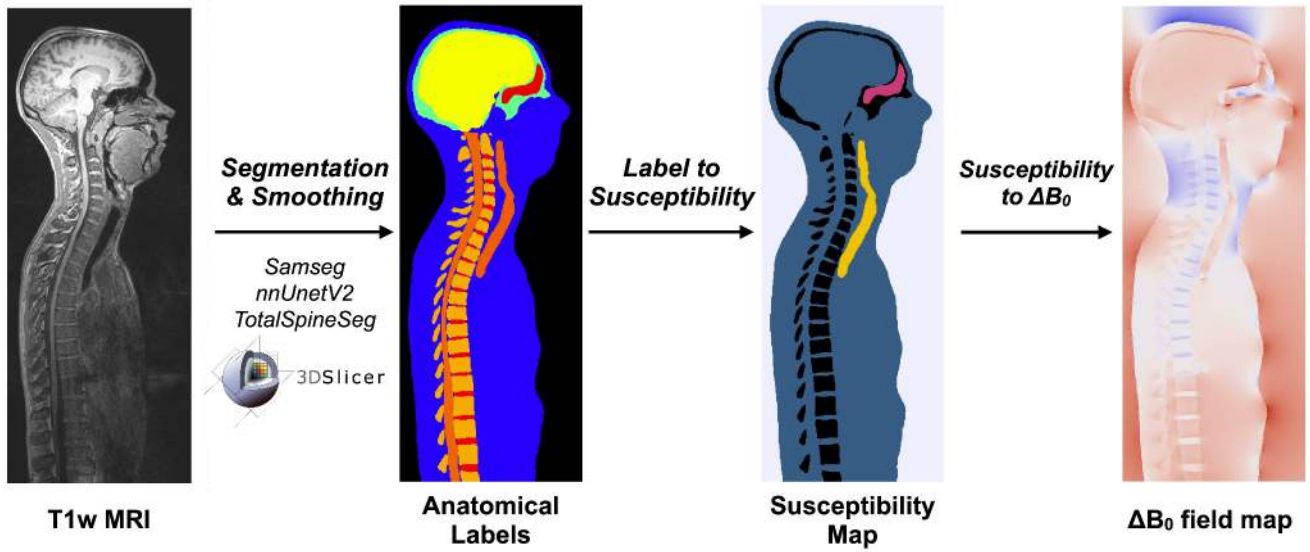
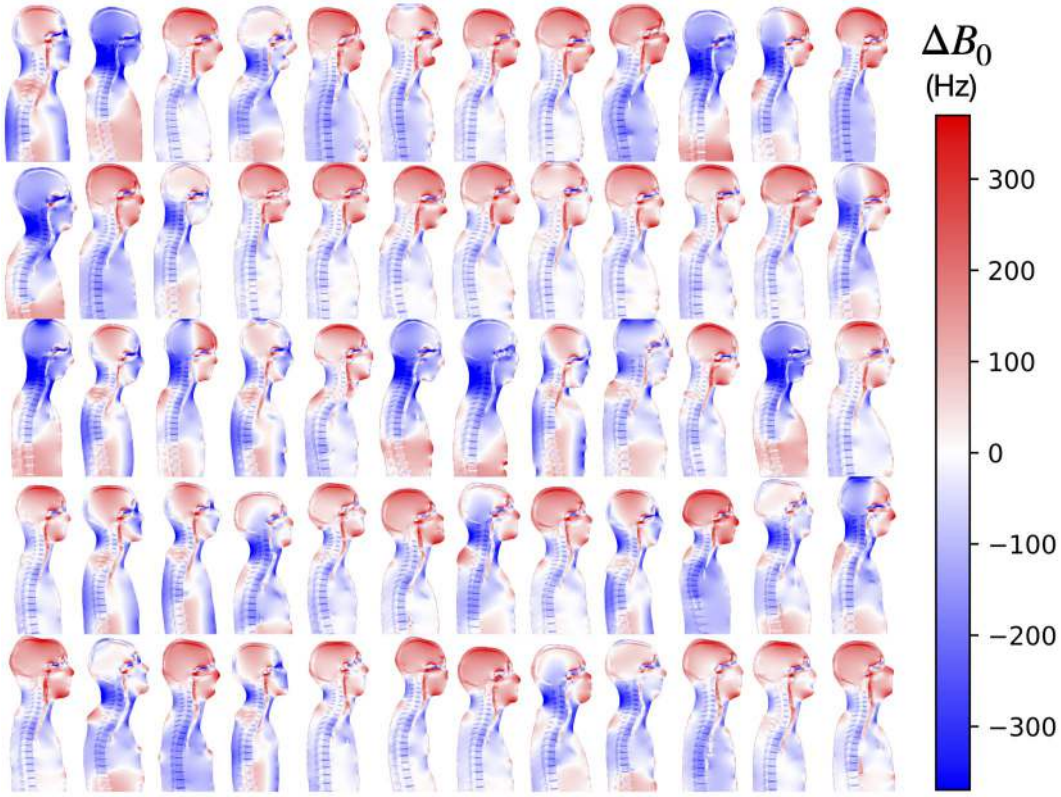
Study design



Simulated maps



Data available on Open Neuro: doi.org/10.18112/OPENNEURO.DS005616.V1.0.1

Pipeline code: github.com/shimming-toolbox/b0-fieldmap-realistic-simulation

Field simulation tool: github.com/shimming-toolbox/susceptibility-to-fieldmap-fft

Anatomy-Based Simulations of B_0 Field Maps: A Large Database for Head and Spine Shim Coil Development

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Declaration of Financial Interests or Relationships

Speaker Name: Alexandre D'Astous

I have the following financial interest or relationship to disclose with regard to the subject matter of this presentation:

Company Name: Philips
Type of Relationship: Research funding and training

Objective

To create a comprehensive and open-source database of human B_0 maps simulated from segmented anatomical MRI images encompassing the head and torso.

Motivation

Respiration alters B_0 fields in the **spinal cord**.

Simulated B_0 maps could help guide anatomy-specific **shim design**.

Similar work has been done using **anatomical templates**[2] and for the **heart**[3]

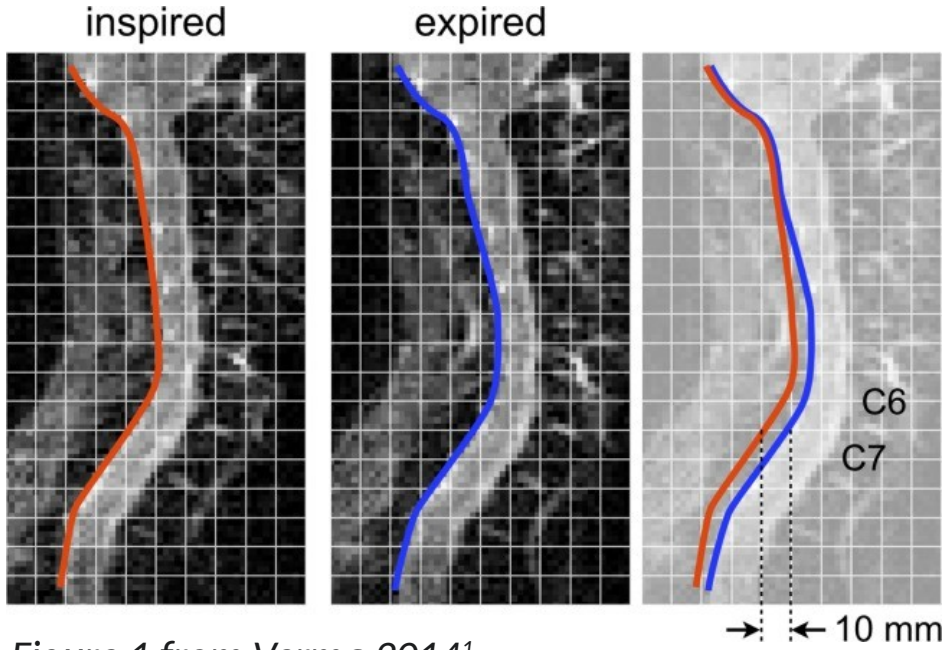


Figure 1 from Verma 2014[1]

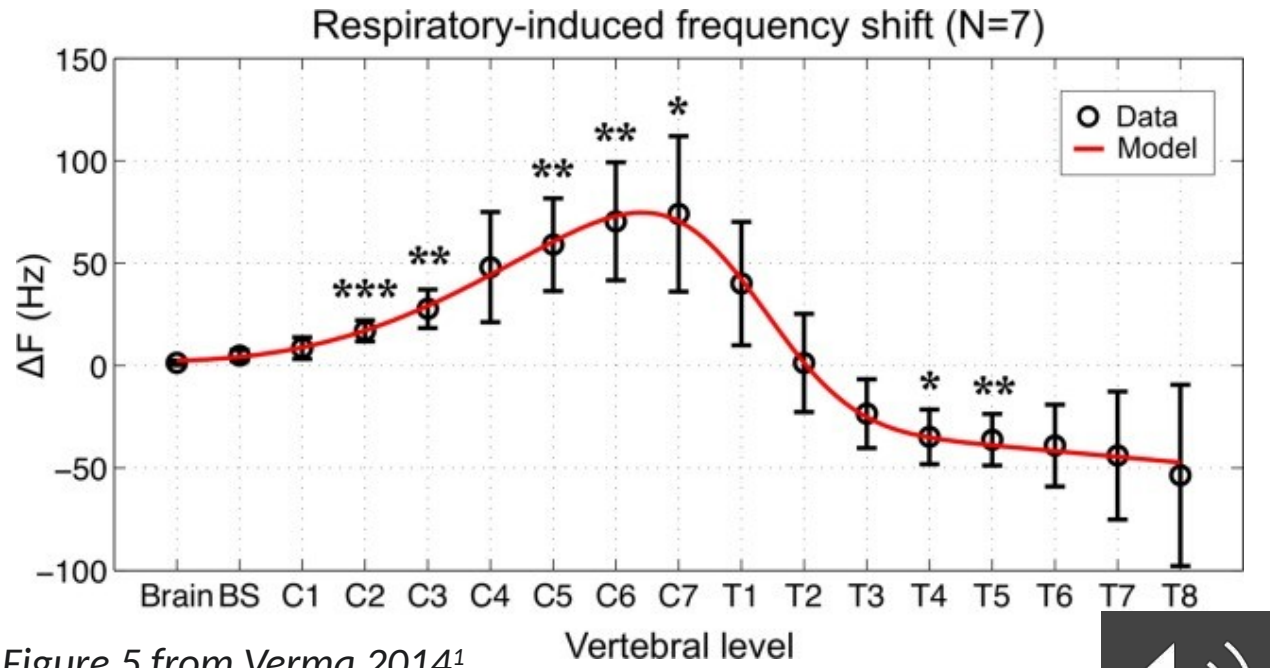


Figure 5 from Verma 2014[1]

[1]Verma, T. and Cohen-Adad, J., MRM (2014) doi.org/10.1002/mrm.25075

[2]Shi et al., MRM (2018) https://doi.org/10.1002/m...0

[3]Shang et al. NMR in Biomedicine (2022) doi.org/10.1002/nbm.4739

Study design

T1w MRI

Segmentation & Smoothing

Samseg[1]
nnUnetV2[2]
TotalSpineSeg[3]

3DSlicer[4]

Anatomical Labels

Label to Susceptibility

Custom pipeline[5]

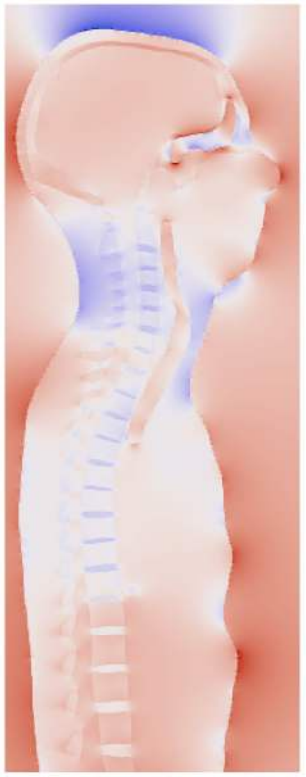
Susceptibility Map

Susceptibility to ΔB_0

Custom pipeline[5]

Padding

50 voxels / surface
Edge values except
dorsal (constant = 0)



ΔB_0 field map

[1]Cerri et al.,Neuroimage (2021) doi.org/10.1016/j.neuroimage.2020.117471
[2]Isensee et al., Nat. (2021) doi.org/10.1038/s41592-020-01008-z
[3]Warszawer et al., Zenodo (2024) doi:10.5281/ZENODO.13894354
[4]Gering et al., J. Magn. Reson. (2001) doi.org/10.1002/jmri.1139
[5] github.com/shimming-toolbox/b0-fieldmap-realistic-simulation

See also: TotalSpineSeg ISMRM oral
Abstract: #624
Date: Tuesday May 13, 15h45
Room: 310

Dataset

Sixty volunteers

- 32 male/18 female/10 undisclosed
- age: 27.1 ± 6.5 [21-56] years
- weight: 66.7 ± 9.5 [45-90] kg
- height: 175.6 ± 8.8 [155-192] cm)

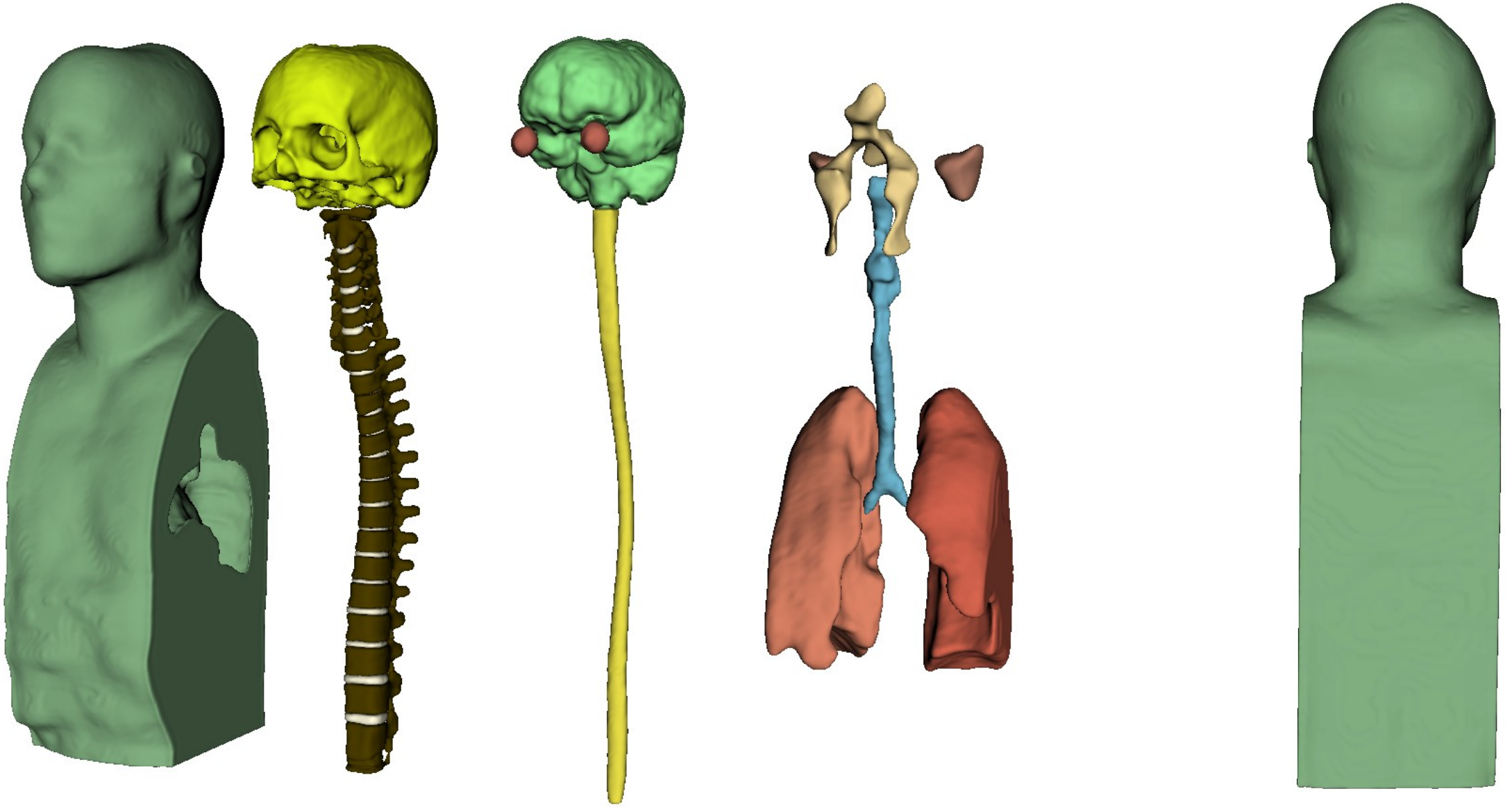
Two 3T scanners (MAGNETOM Tim Trio and Verio, Siemens) with the product **head, neck, and spine coils**.

1mm^3 T1w **MPRAGE** volumes with a **FOV extending from head to torso**

Available in **BIDS** format and shared on **OpenNeuro**[1].

[1] doi.org/10.18112/OPENNEURO.DS005616.V1.0.1

Anatomical labels



Susceptibility values

Anatomical Structure / Material	Susceptibility χ (ppm)
air	0.35
sinus & ear canals	-2
trachea & lungs	-4.2
brain	-9.04
body and eyes	-9.05
spinal canal and disks	-9.055
skull and vertebrae	-11

Buch et al, Magn. Reson. Med. (2015) doi.org/10.1002/m
Gimsa, Enc. Cond. Mat. Phys. (2017) doi.org/10.1016/b978-0-323-90800-9
Wei et al. Magn. Reson. Med. (2017) doi.org/10.1002/mrm.26596

github.com/shimming-toolbox/tissue-to-MRproperty

Magnetic Field Calculation from a 3D Susceptibility Distribution

The Fourier transform of the **dipole magnetic field** is:

$$FT\{B_{d,z}(\boldsymbol{r})\} = \mu_0 \left(\frac{1}{3} - \frac{k_z}{|\boldsymbol{k}|^2}\right)$$

For a **susceptibility distribution** $\chi(\boldsymbol{r})$, the magnetic field is the **convolution** of the dipole response with the magnetization:

$$B_z(\boldsymbol{r}) = B_d(\boldsymbol{r}) * M_z(\boldsymbol{r}), \text{ where } M_z(\boldsymbol{r}) \approx \left(\frac{B_0}{\mu_0}\right)\chi(\boldsymbol{r}): \chi \ll 1$$

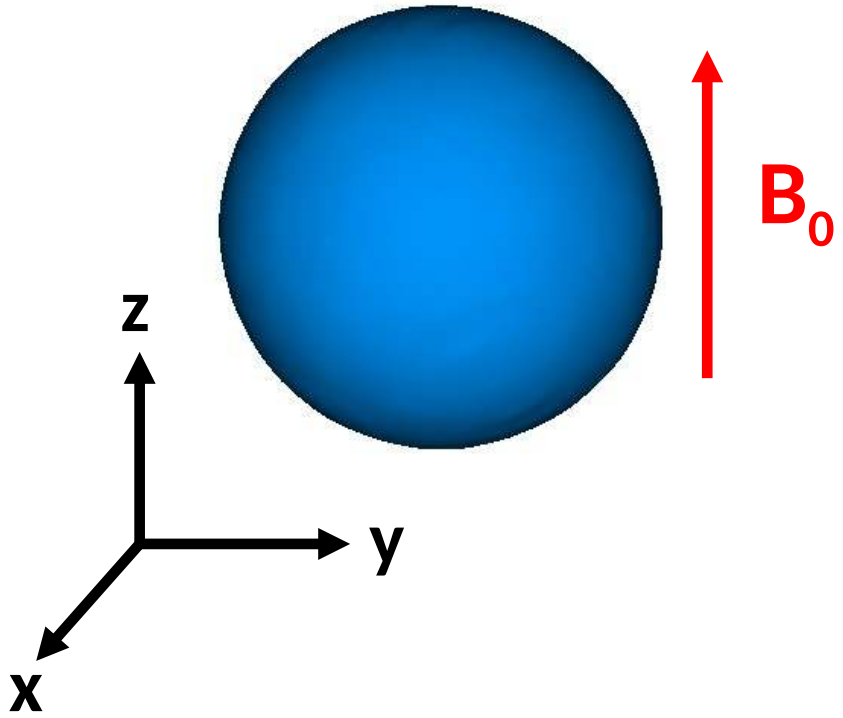
This convolution is efficiently computed in the **Fourier domain via multiplication**. The resulting field, **normalized to the external field B_0,** is:

$$\frac{B_z}{B_0} = FT^{-1}\left\{\left(\frac{1}{3} - \frac{k_z}{|\boldsymbol{k}|^2}\right) \cdot FT\{\chi(\boldsymbol{r})\}\right\}$$

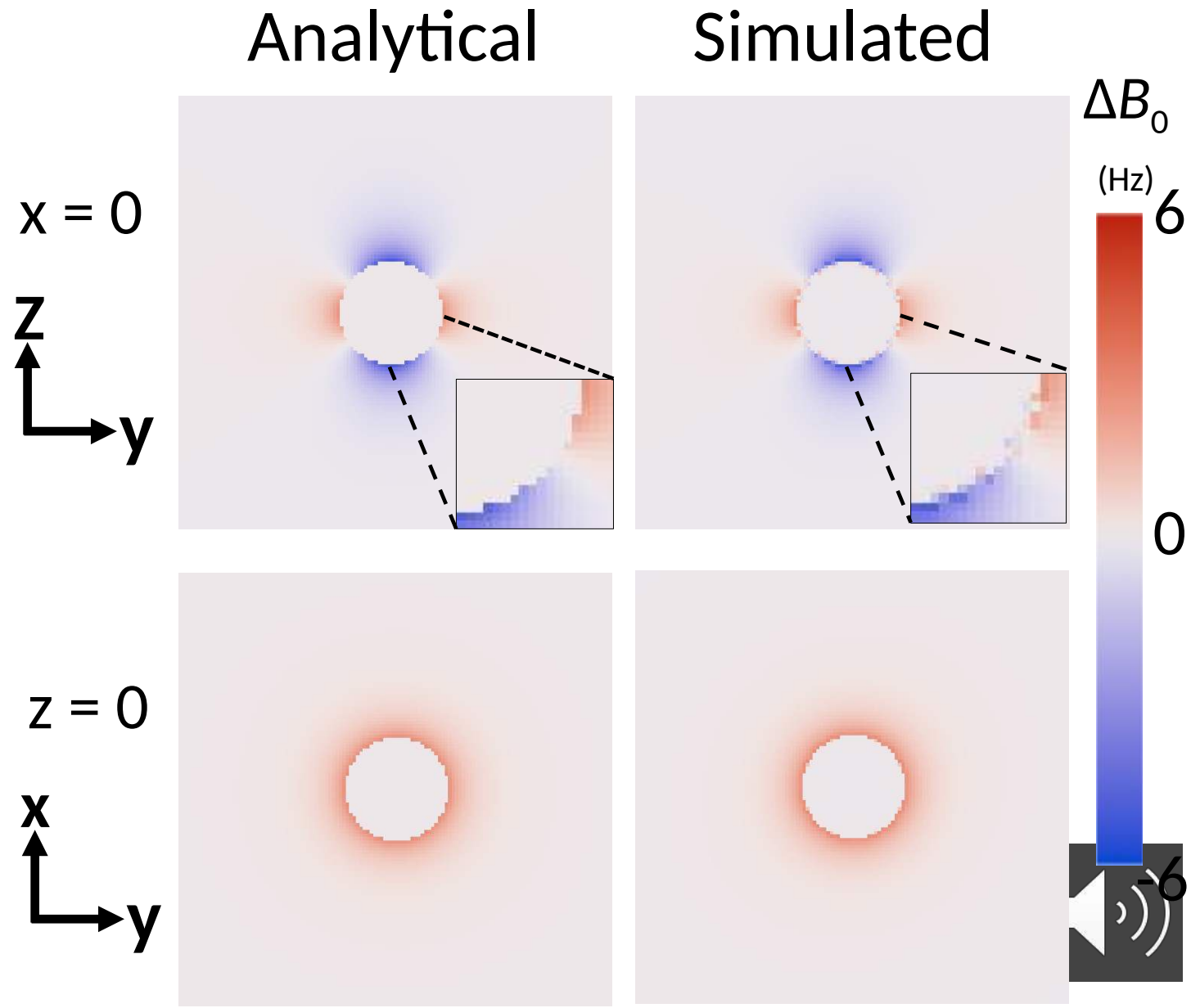
Marques & Bowtell, Concepts Magn. Reson. (2005) doi.org/10.1002/cmr.b.20034

Comparison with a known analytical field responses

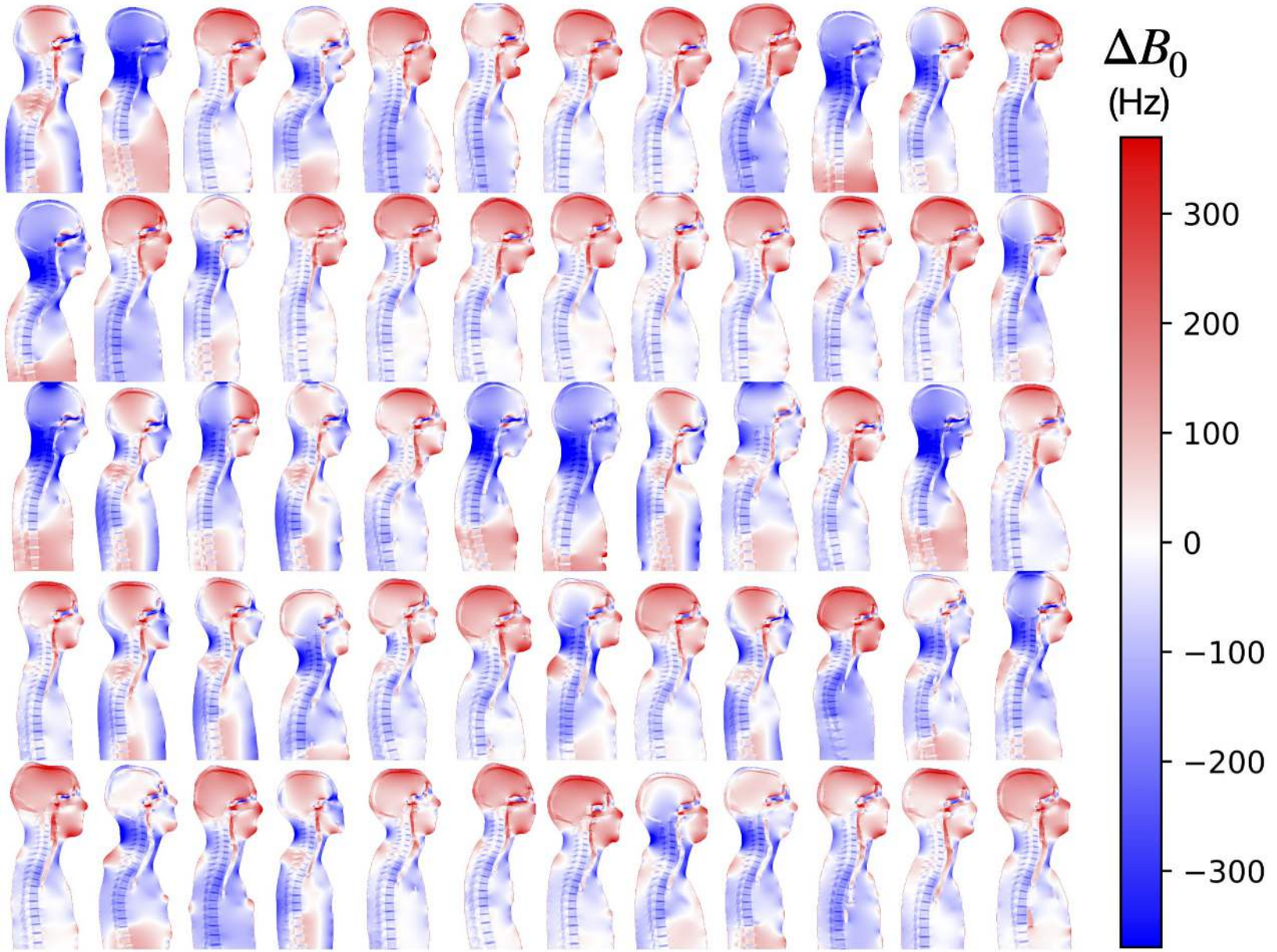
Sphere



$\chi = -9$ ppm
Matrix: 128x128x218
Resolution: 1 mm^3
Radius: 15 mm



Simulation results



Key takeaways

Open-Access B0 Field Map Database

- Simulated B0 maps from 60 subjects susceptibility-based dipole convolution.
- Covers head, spine, and torso.
- Data publicly available on OpenNeuro for shim coil design & MRI research.

Pipeline for Realistic B0 Simulation

- Combines nnUNet, Samseg, and TotalSpineSeg for multi-tissue segmentation.
- Fourier-based dipole convolution validated against analytical models.
- Adjustable for future susceptibility value updates.

Future directions

- Add legs/lateral torso to FOV for edge-field accuracy.
- Integrate measured susceptibility values (beyond literature values).
- Develop DL-based B_0 prediction from localizer scans.

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