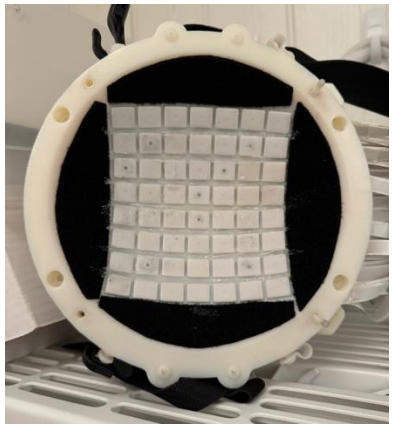
Automated Coregistration of MEG Using Cortical Constraints

Stephen E. Robinson, Amaia Benitez-Andonegui, Allison C. Nugent
MEG Core Facility, NIMH
Biomag 2024, Sydney
29 August 2024

Why is it Necessary to Refine Coregistration?

- Development of MagnetoCorticoGraph (MCoG) for non-invasive cortical mapping
- OPMs can record high spatial frequencies
- Source solution resolution can be improved by using cortical normal vectors
- Present coregistration methods are not sufficiently accurate for using normal
- Available coregistration methods using ***external*** features include:
  - head coils & MRI markers
  - images of head, markers, and MRI (e.g., BrainSight™)
- ***These methods do not account for postural changes in brain position***

- We introduce coregistration using the MEG data with ***internal*** (cortical) anatomy



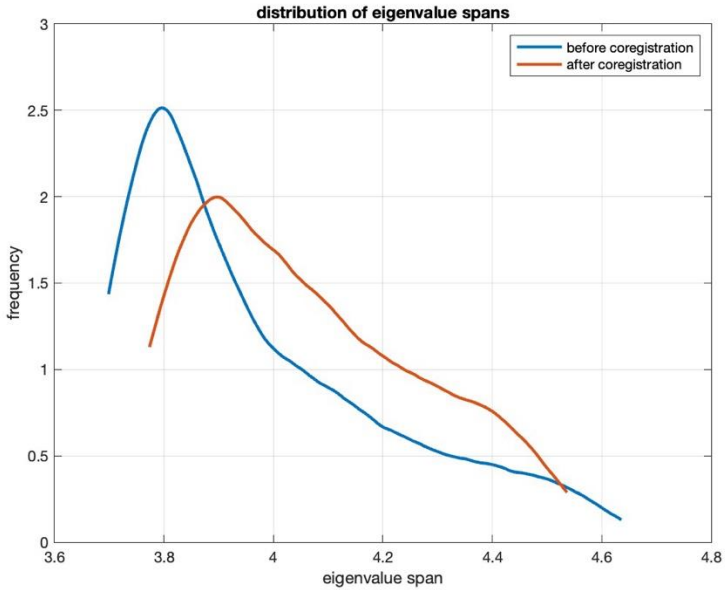
56 primary sensors
In 7x8 array
+ 3 references

subject with sensor array placed over left sensorimotor cortex

Principle: alignment of cortical images derived from constrained & unconstrained moment vectors

- Coregistration is based upon comparison of the anatomical cortical normal vectors (constrained moment vector) with that (unconstrained moment vector) computed from the MEG data using an eigensystem solution
- The reliability of the MEG moment vector estimates are related to the span of the eigenvalues of the eigensystem solution:

$$\mathbf{L}_r^T\mathbf{C}^{-2}\mathbf{L}_r\boldsymbol{e}_k=\lambda_k\mathbf{L}_r^T\mathbf{C}^{-1}\mathbf{L}_r\boldsymbol{e}_k, \text{ where } \mathbf{C}=\mathrm{E}[\mathbf{M}\mathbf{M}^T]$$



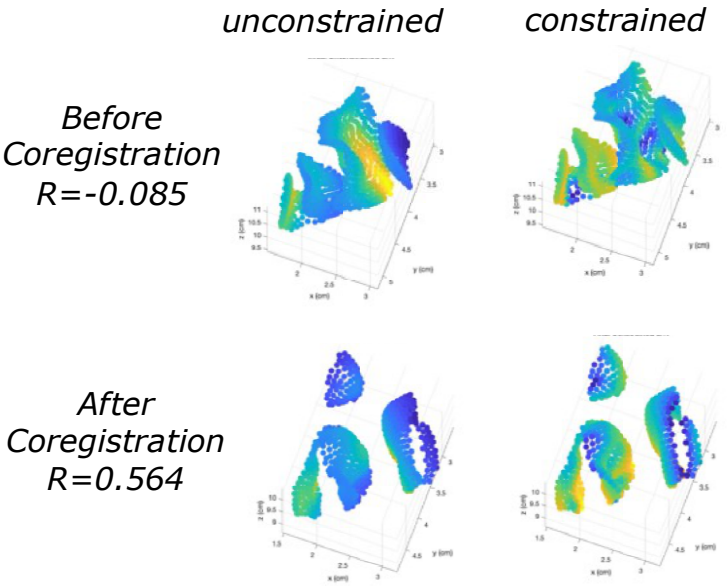
Principle (cont'd): cortical image alignment

- Comparison of constrained & unconstrained moment vectors are ambiguous in $2\boldsymbol{\pi}$
- Instead, derive cortical surface images using:

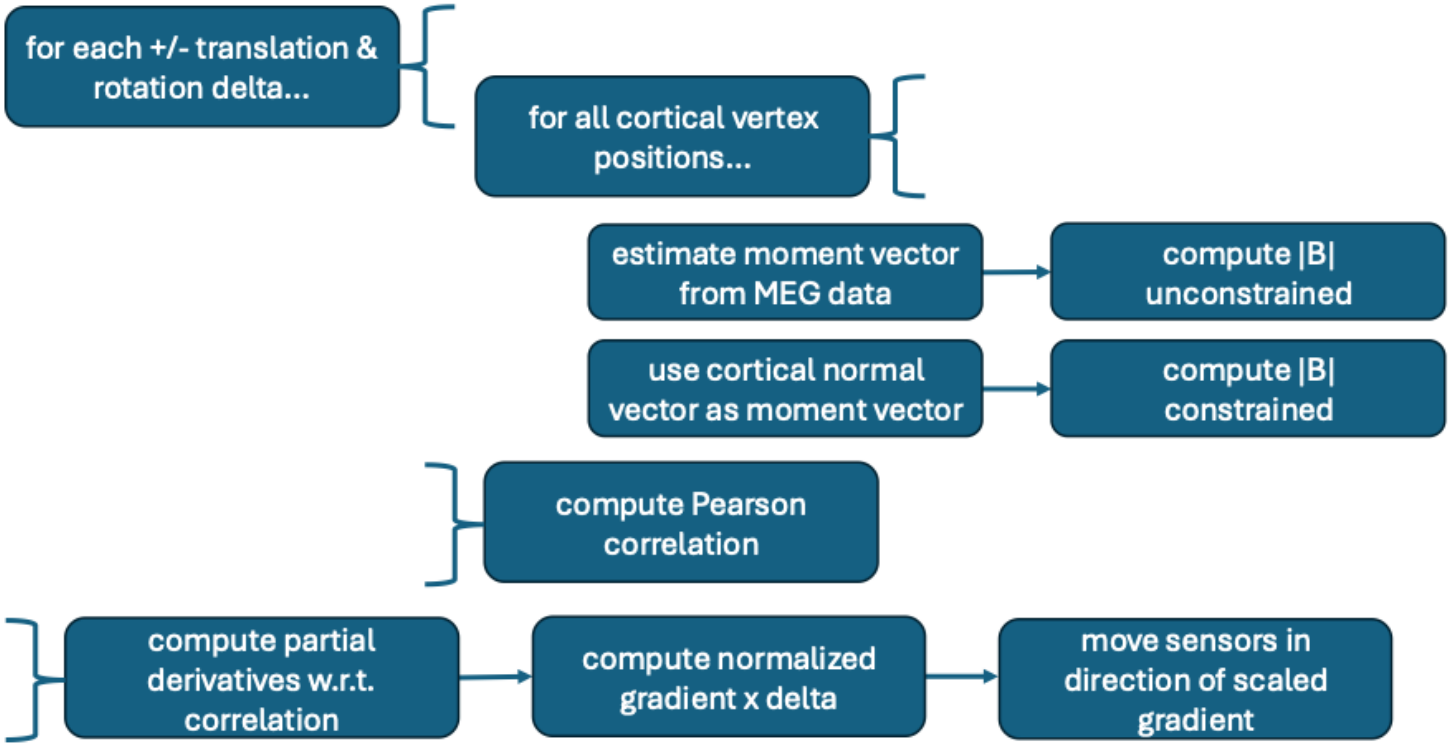
$$b_{constrained} = \|\mathbf{L}_r \boldsymbol{u}_{vertex}\|$$
$$b_{unconstrained} = \|\mathbf{L}_r \boldsymbol{e}_{min}\|$$

- Iteratively coregister the MEG & MRI by transforming the sensor array position & orientation so that the unconstrained and constrained vertices are maximally correlated

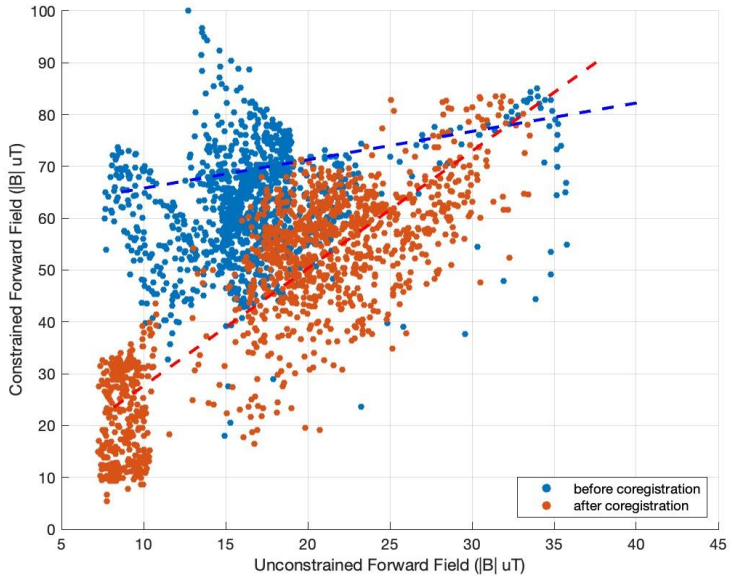
cortical surface forward solutions under MCoG array



Flow Diagram for Each Iteration



SEF Subject – Pial Surface Scattergram



Results after 500 iterations:

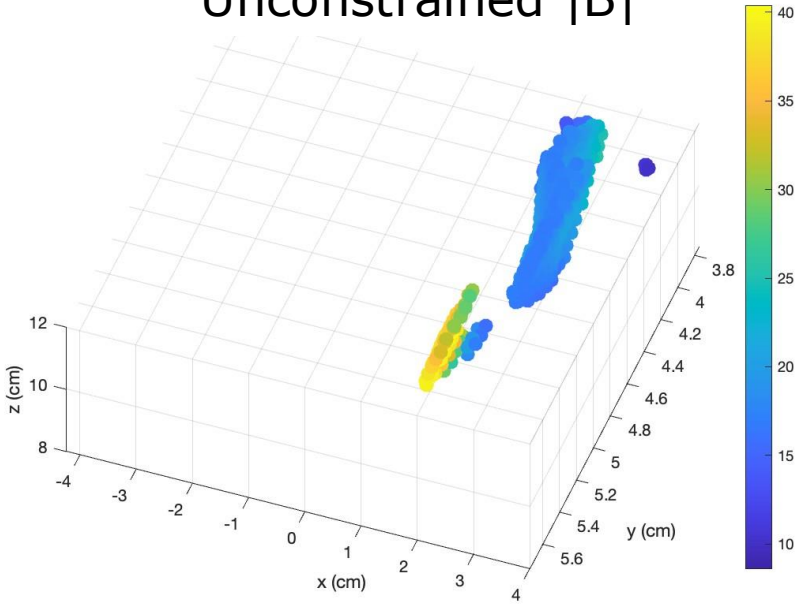
x (mm)	y (mm)	z (mm)	θ (deg)	ϕ (deg)
0.714	**5.553**	**2.817**	**0.313**	**-0.870**

Initial correlation: **0.246** for 1162 vertices

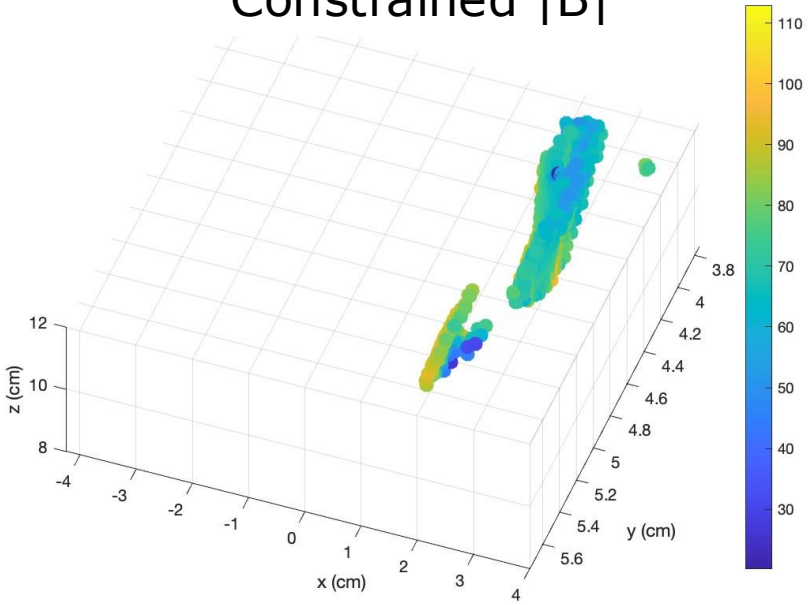
Final correlation: **0.841** for 1279 vertices

Before Coregistration: forward solution map for 1000+ vertices with the largest eigenvalue span

Unconstrained |B|

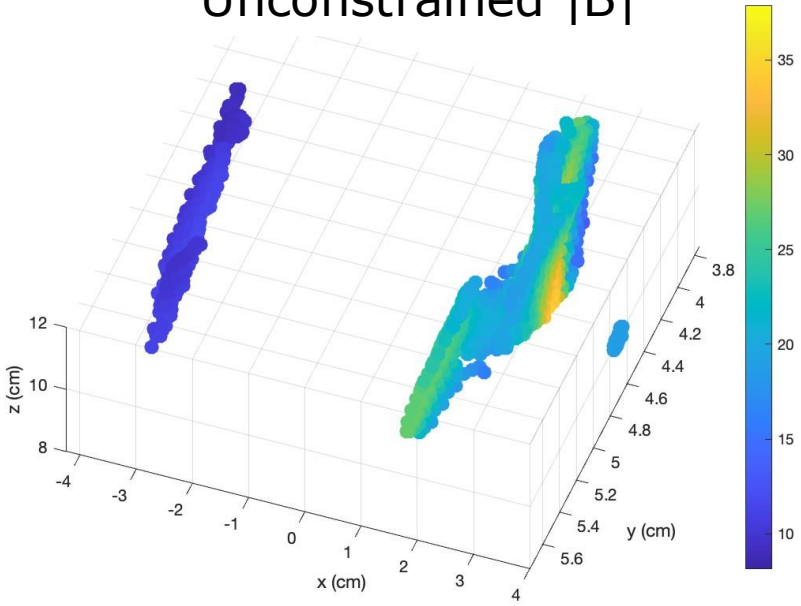


Constrained |B|

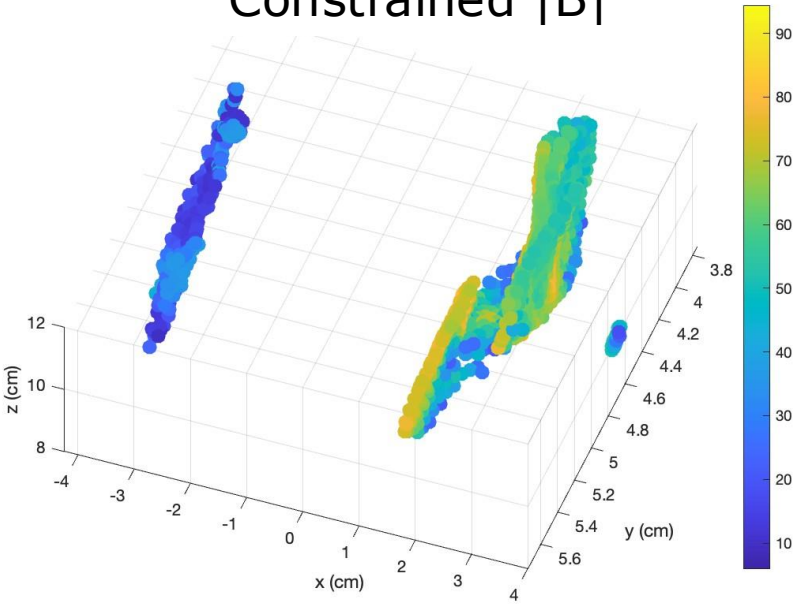


After Coregistration: forward solution map for 1000+ vertices with the largest eigenvalue span

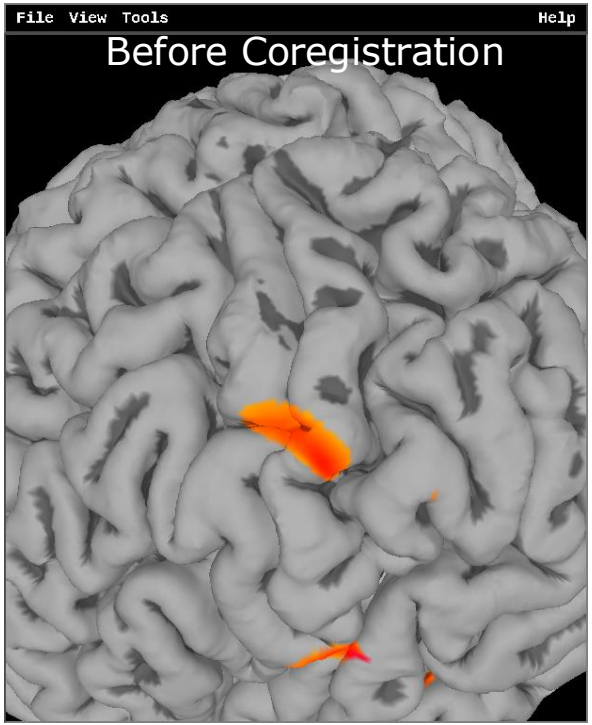
Unconstrained |B|

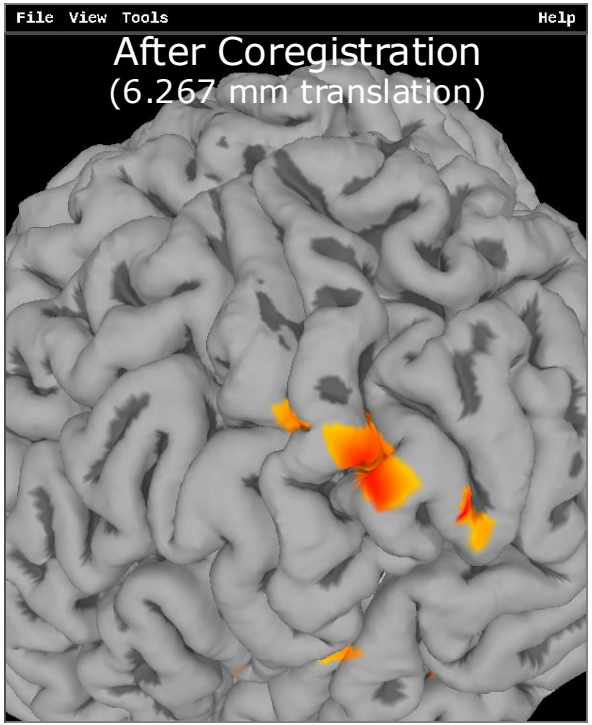


Constrained |B|



SEF Subject – Beta Band ERD





Prerequisites & Limitations

- Requirements:
  - † Sensor array must be calibrated for position, sensing vector, gain, & crosstalk
  - MRI must be free of geometric distortion
  - MRI segmentation must be high quality
  - MEG data must be free of sensor movement with respect to the head

† Presented in Symposium: Localization accuracy of OPM MEG, Wednesday 28th 10:06 - 11:27

- Grossly underdetermined problem – up to 250,000 vertices & 56 sensors
- Selection of surface – pial or smooth white matter
- Selection of number of significant vertices
- Frequency bandpass
- Interaction between translation & rotation
- Minimum eigenvalue span (reliability of unconstrained moment vector estimate)
- Minimum number of vertices used
- Cortical normal vector range used
- Dependency on cortical activity? (tbd)

OPM Team at the NIMH MEG Core Facility

Amaia Benitez-Andonegui, Allison Nugent, Tom Holroyd, Stephen Robinson

NIH Intramural Research Program
Our Research Changes Lives

**ONE PROGRAM,
MANY PEOPLE,
INFINITE POSSIBILITIES**
irp.nih.gov

Acknowledgements:
This work was supported by the NIMH Intramural Research Program (1ZICMH002889) and the NIH Brain Initiative (1RO1EB028645).