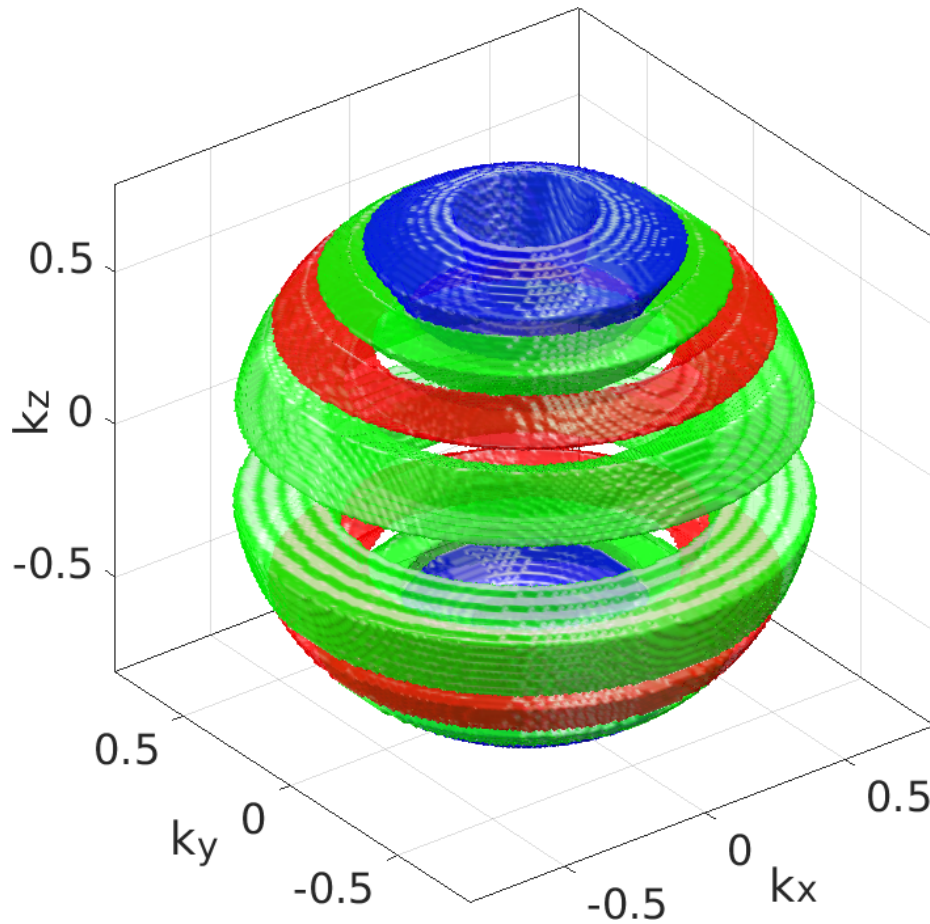# Comparison of parameter optimization methods for Quantitative Susceptibility Mapping

Carlos Milovic, Claudia Prieto, Berkin Bilgic, Sergio Uribe, Julio Acosta-Cabronero, Pablo Irarrazaval, Cristian Tejos
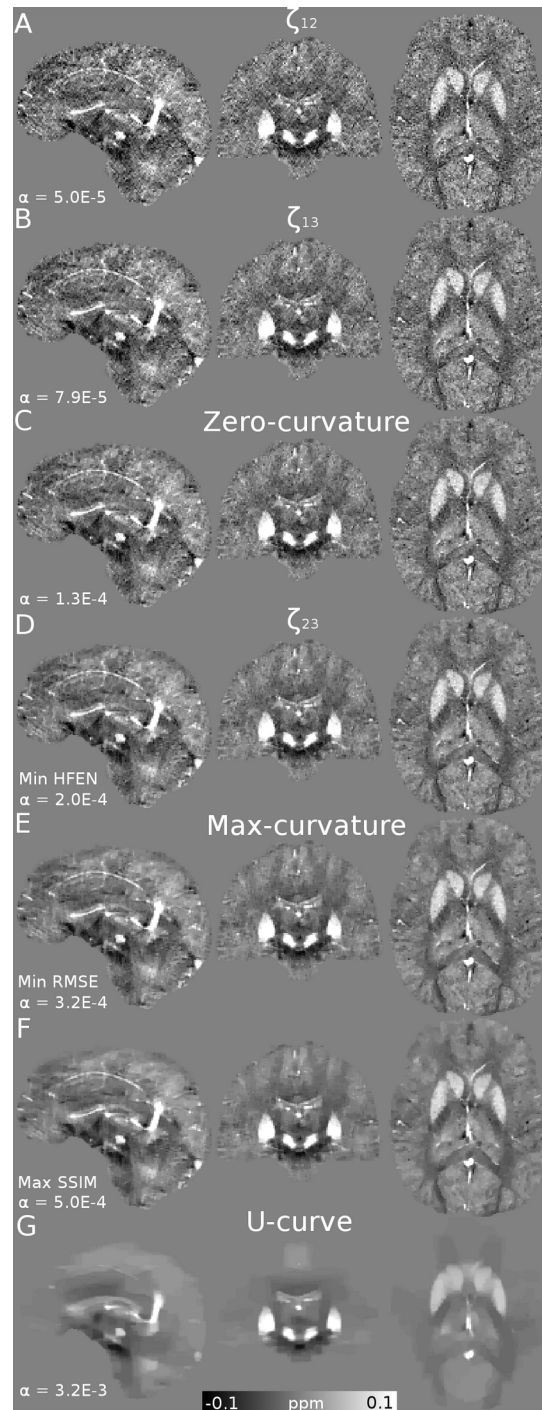
Supplementary Material

Supporting Information Figure S1. 3D representation of the ROIs used for the frequency analysis of susceptibility reconstructions. In red, M1: $0 <= |D| <= 0.085$ at the magic angle. M2: $0.15 <= |D| <= 0.3$ in green and M3: $0.35 <= |D| <= 0.6$ in blue.
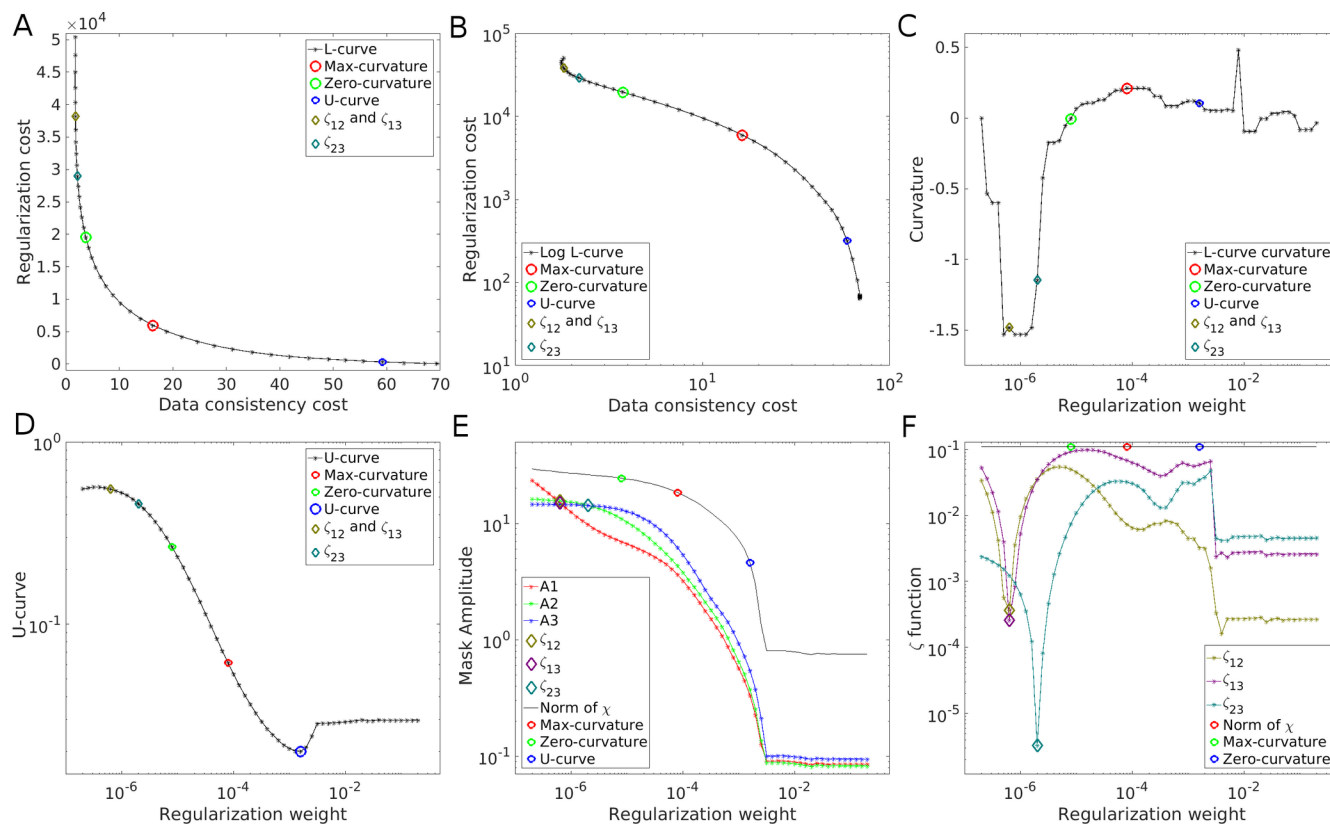
Extended results

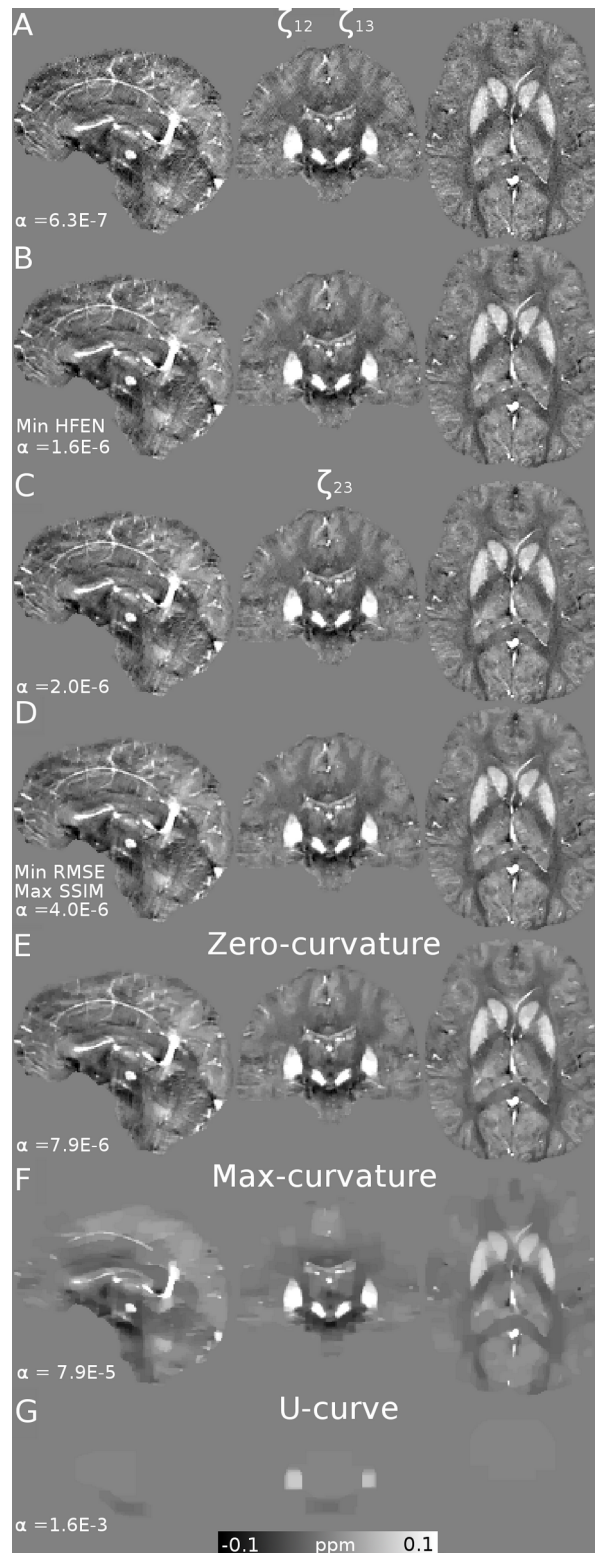## COSMOS-brain numerical simulations (SNR=40)

Supporting Information Figure S2. Optimal reconstructions and regularizations weights (α) of SNR=40 simulations, using the Frequency (A, B and D), L-curve (C, E) and U-curve analysis (G). Also represented here are the best scoring HFEN (D), RMSE (E) and SSIM (F) results.

COSMOS-brain numerical simulations (SNR=128)

Supporting Information Figure S3. Parameter optimization strategies on the COSMOS-brain simulations at SNR=128. The L-curve in linear (A) and logarithm (B) representations, with its curvature (C). The U-curve (D). Frequency analysis using the amplitude estimations A1, A2 and A3 (E) and the ζ cost functions (F).

Supporting Information Figure S4. Optimal reconstructions and regularizations weights (α) of SNR=128 simulations, using the Frequency (A, C), L-curve (E, F) and U-curve analysis (G). Also represented here are the best scoring HFEN (B), RMSE and SSIM (D) results.

In vivo results

Single orientation – 2016 QSM-RC dataset.

Supplementary Information Table S1

Global metric scores (RMSE, HFEN, and SSIM) for the proposed reconstructions using COSMOS as ground truth.

|	ζ_{12} - ζ_{13}	ζ_{23}	Zero Curv.	Max Curv.	U-curve
α(Reg. Weight)	4.00E-06	6.30E-06	2.50E-05	1.00E-04	1.00E-03
RMSE	105.8	94.5	69.1	69.7	90.8
HFEN	108.8	95.1	63.2	72.9	95.9
SSIM	0.818	0.842	0.876	0.783	0.719

Please note that due to significant discrepancies between the single-orientation acquisition and the multi-orientation ground-truth used in the context of the QSM Challenge, over-regularized solutions tended to be promoted (achieve lower error scores). This was generated by the presence of anisotropic and micro-structural contributions not properly accounted in the provided ground-truths (Milovic et al, MRM 2020).

3T Siemens

Acquisition and preprocessing details: 3T Siemens Trio MRI system, 32-channel head-array, 1-mm^3 isotropic resolution, fully-sampled acquisition (no acceleration), 240×192×120 matrix, flip angle=25°, TE/TR=24.8/35 ms, bandwidth=100 Hz/pixel, T_{acq}=13:30 min. Phase unwrapping and background subtraction were performed with Laplacian (30) and Laplacian boundary value (31) (LBV) methods, respectively.
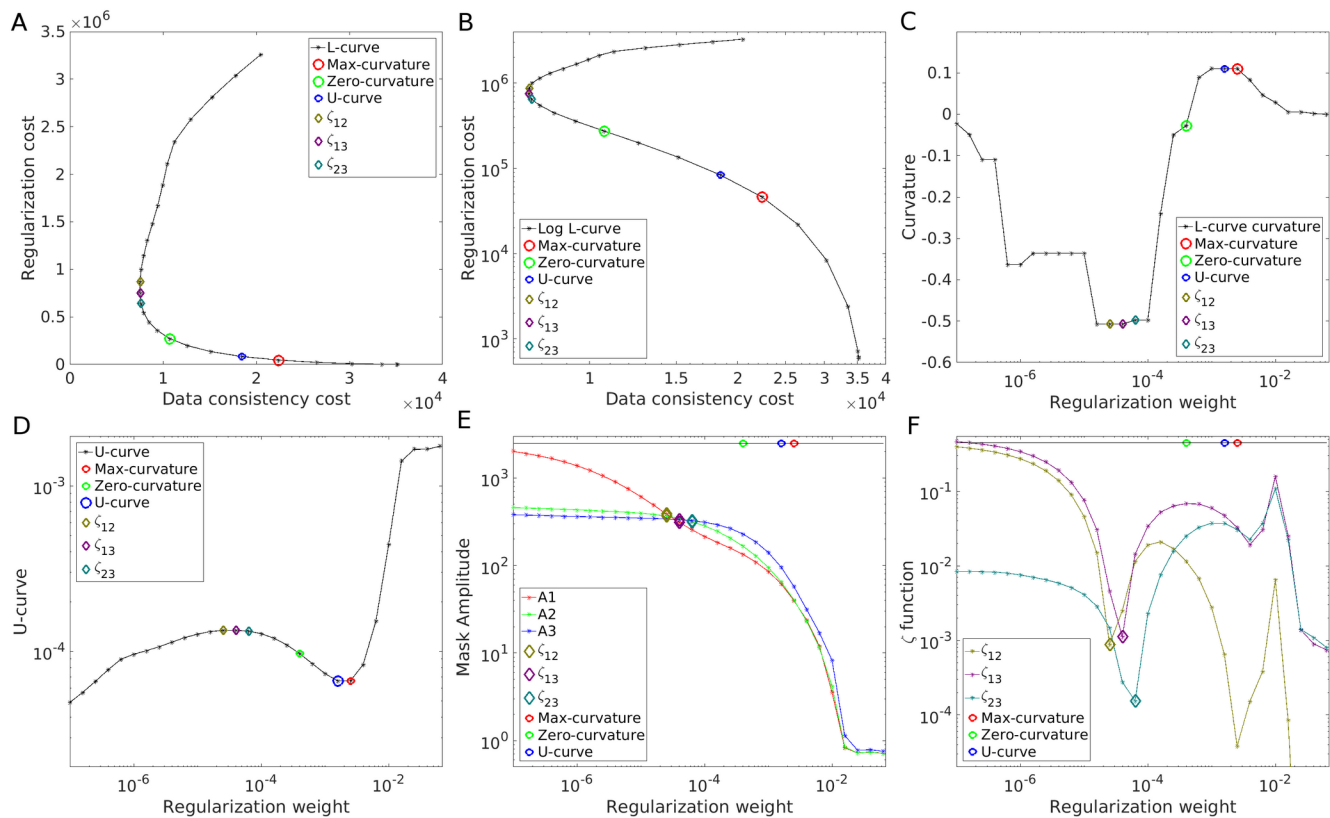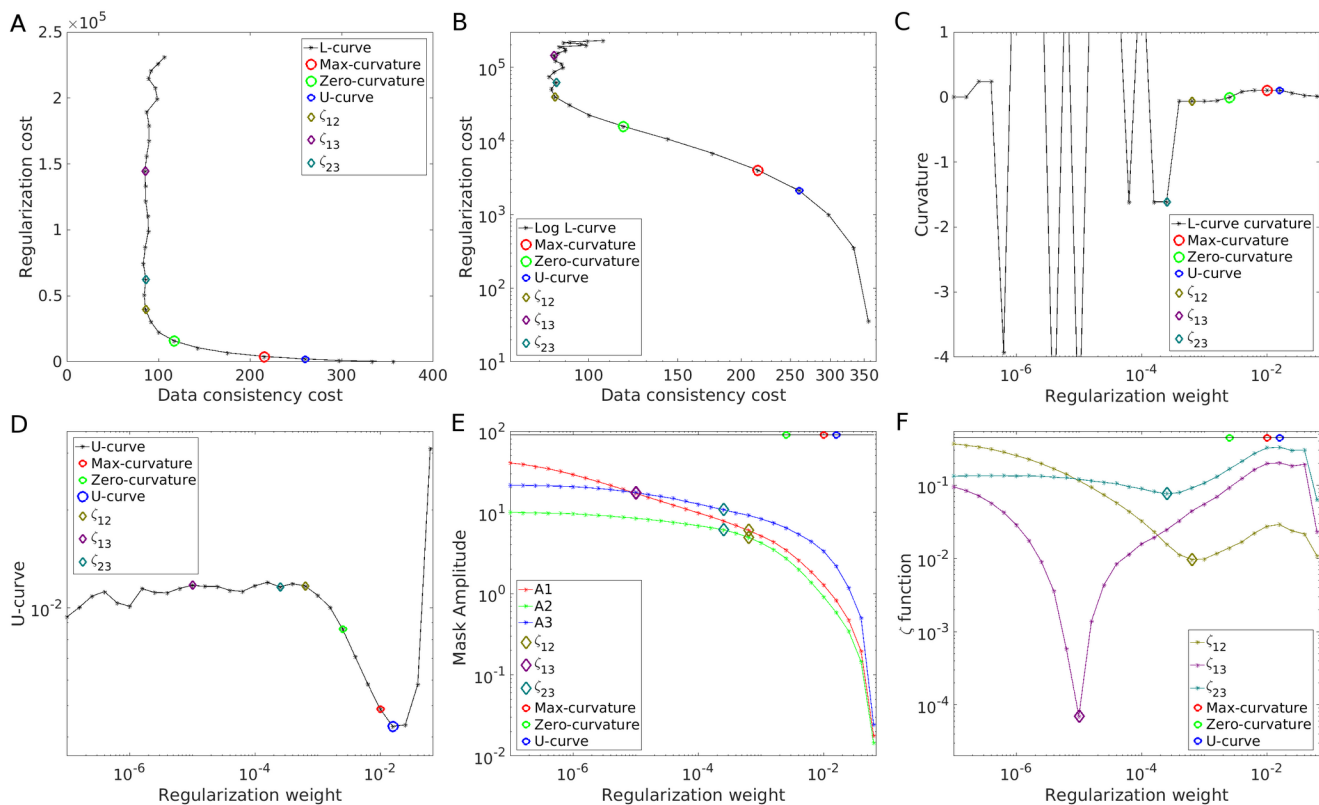

Supporting Information Figure S5. Parameter optimization strategies on the 3T Siemens in vivo data. The L-curve in linear (A) and logarithm (B) representations, with its curvature (C). The U-curve (D). Frequency analysis using the amplitude estimations A1, A2 and A3 (E) and the ζ cost functions (F).
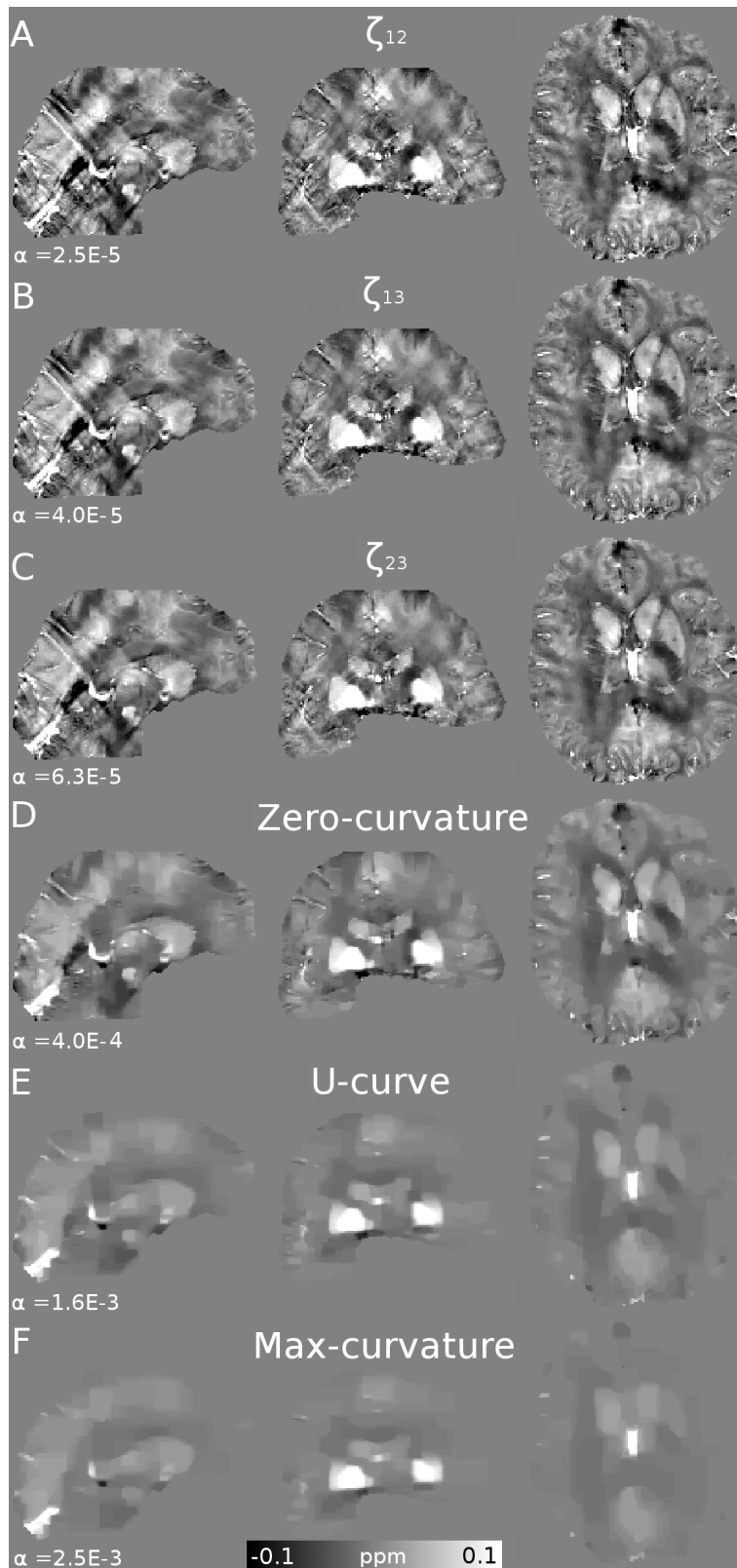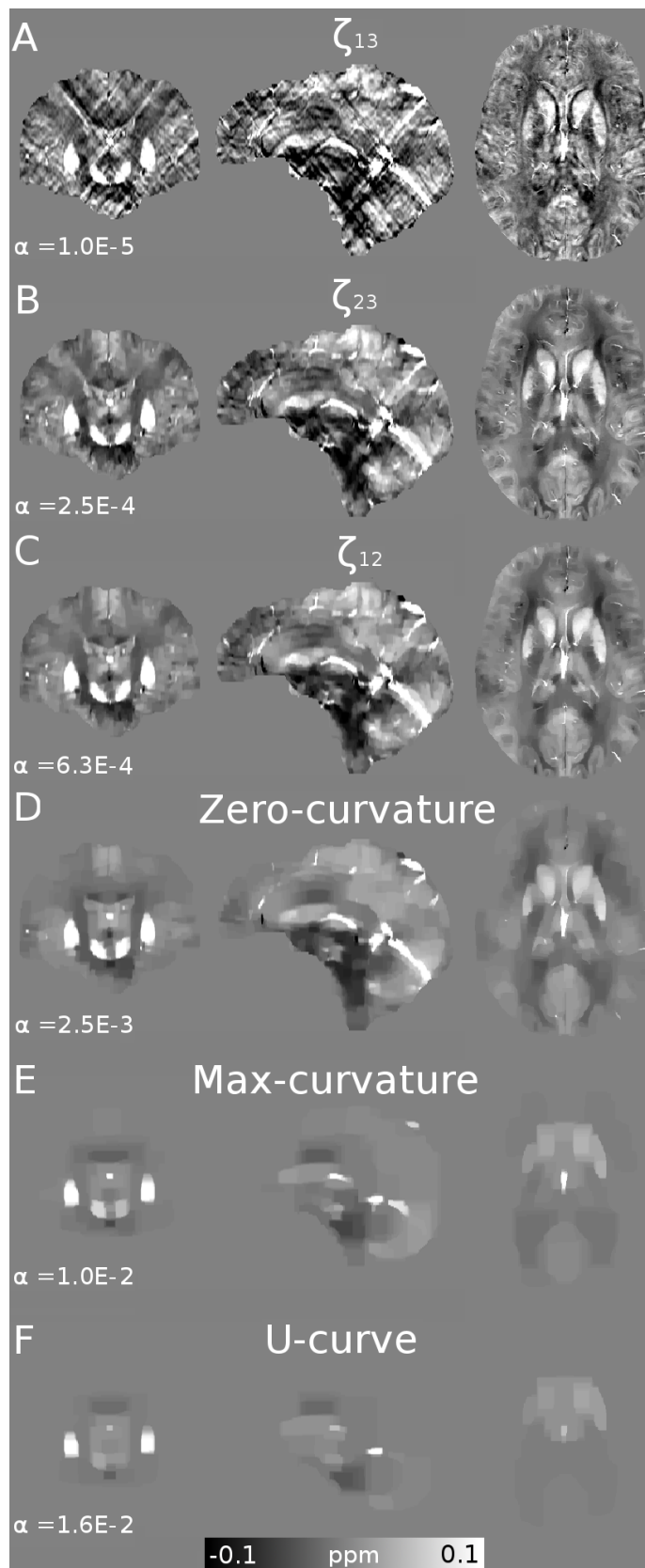
Supporting Information Figure S6. Optimal reconstructions and regularizations weights (α) of the 3T Siemens in vivo data, using the Frequency (A-C), L-curve (D, E) and U-curve analysis (F).

3T Phillips

Acquisition and preprocessing details: Phillips Ingenia 3T scanner. FFE sequence with 5 echoes. TE=7.2/6.2/32.1ms, TR=44ms, flip angle=17, 352×352×170 matrix with 0.6x0.6x1mm^3 voxels. T$_{acq}$=6:30 min. Multi-echo combination and temporal unwrapping using in-house nonlinear method. Background field removal using LVB and a 4th order polynomial fit.
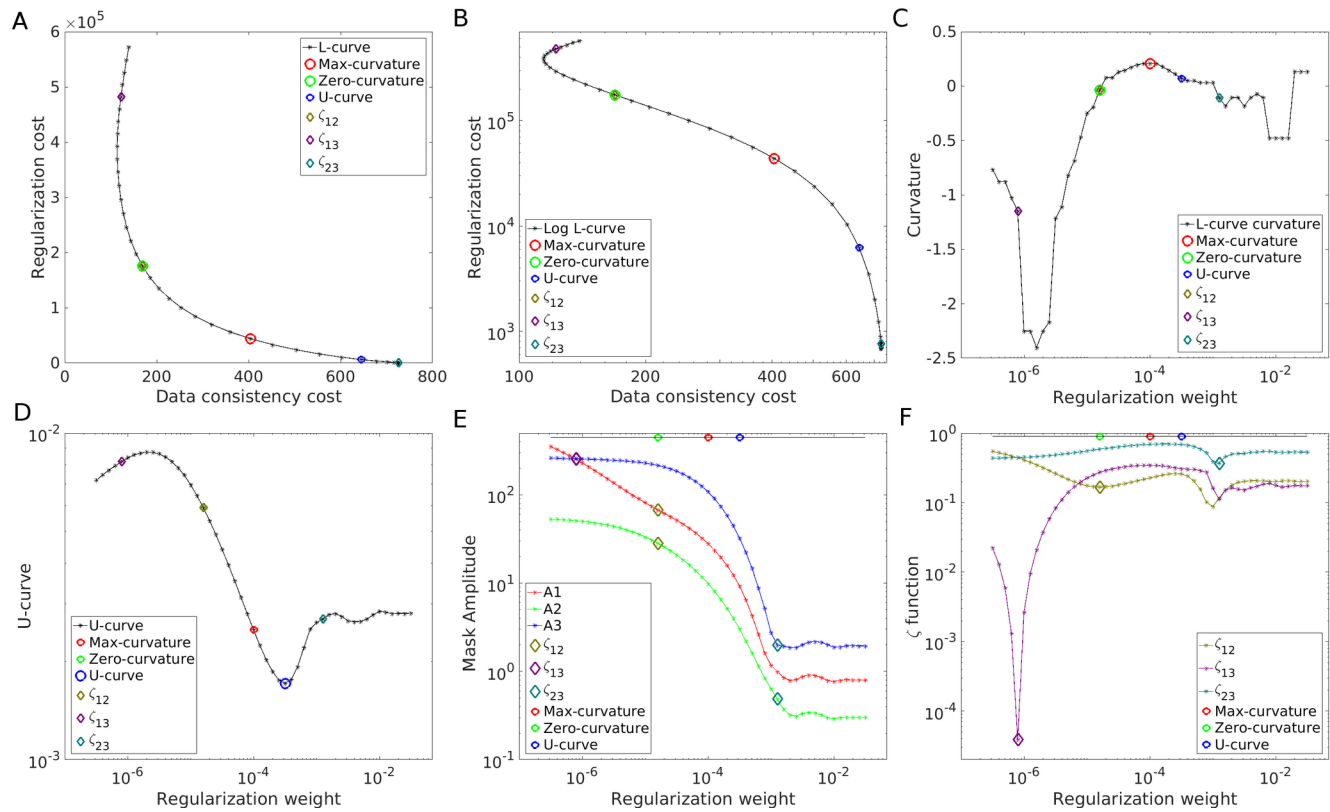

Supporting Information Figure S7. Parameter optimization strategies on the 3T Phillips in vivo data. The L-curve in linear (A) and logarithm (B) representations, with its curvature (C). The U-curve (D). Frequency analysis using the amplitude estimations A1, A2 and A3 (E) and the ζ cost functions (F).
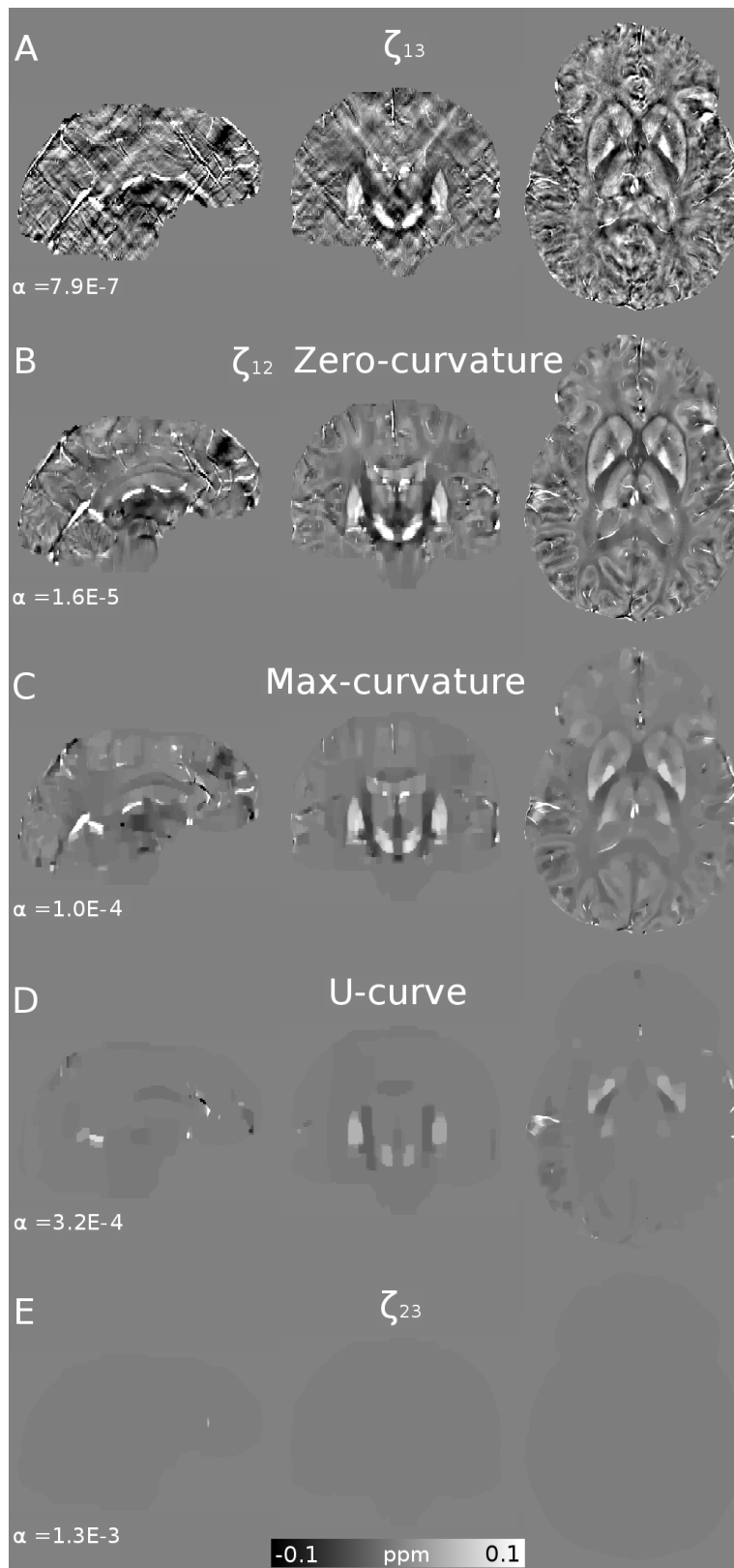
Supporting Information Figure S8. Optimal reconstructions and regularizations weights (α) of 3T Phillips in vivo data., using the Frequency (A-C), L-curve (D, E) and U-curve analysis (F).

7T Siemens (Anisotropic example)

Results with masks defined by relative ranges in frequencies.

Supporting Information Figure S9. Parameter optimization strategies on the 37 Siemens in vivo data. The L-curve in linear (A) and logarithm (B) representations, with its curvature (C). The U-curve (D). Frequency analysis using the amplitude estimations A1, A2 and A3 (E) and the ζ cost functions (F) with masks defined in a relative frequency range.

Supporting Information Figure S10. Optimal reconstructions and regularizations weights (α) of 7T Siemens in vivo data., using the Frequency (A, B, and E), L-curve (B, C), and U-curve analysis (D).