Single Trial Analysis of Event Related Potentials – Sensitivity of the Subspace Regularization Based Methods to the Value of Regularization Parameter

Perttu O. Ranta-aho[1,†]

Mika P. Tarvainen[1]

Anu S. Holm[2]

Pasi A. Karjalainen[1]

[1]University of Kuopio
Department of Applied Physics
Kuopio, FINLAND

[2]Brain@Work -laboratory
Finnish Institute of Occupational Health
Helsinki, FINLAND

[†]E-mail: Perttu.Ranta-aho@uku.fi
http://venda.uku.fi/research/biosignal

INTRODUCTION

- Event related potentials (ERPs) are used for studying sensory and cognitive processing of the brain.
- Variation of the responses from stimuli to stimuli carries valuable information.
- This information can be used for example in the analysis of mental work load.
- Signal-to-noise ratio is typically very low thus traditional method has been averaging of time locked responses $\Rightarrow$ information of single responses is lost.
- Described subspace regularization based method is an effective way to calculate estimates for single responses i.e. single trial ERPs.

METHODS
Subspace regularization

- We use linear model for the ERPs

$$z = s + e = H\theta + e$$

- Generalized least squares solution for the parameters θ is

$$\hat{\theta} = \min_\theta \left\{ \|(z - H\theta)\|^2 + \alpha \|L\theta\|^2 \right\}$$

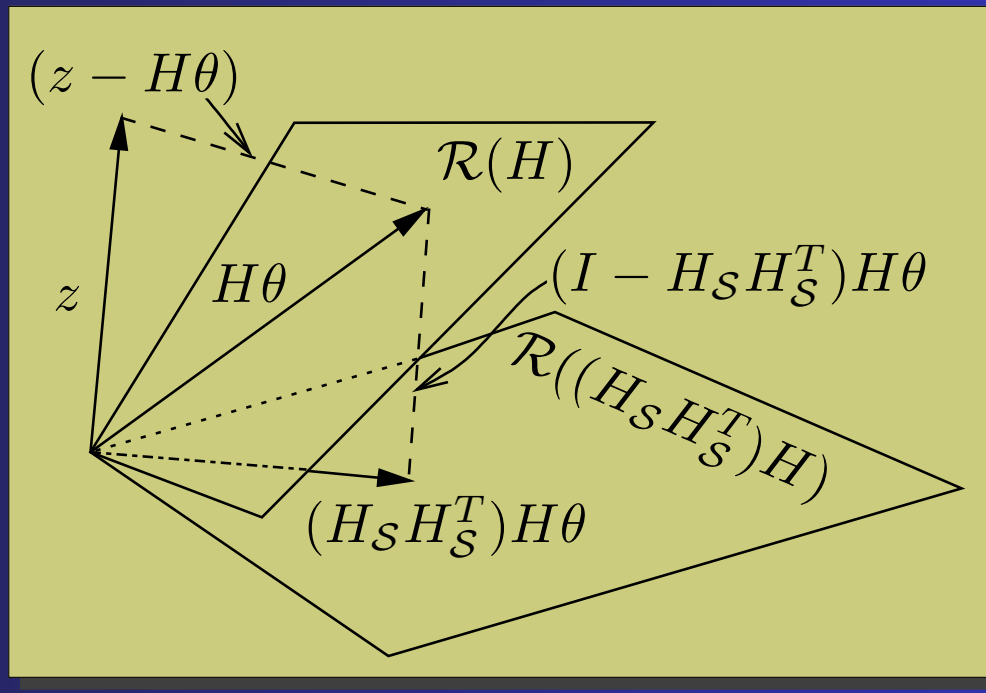
- The regularized solution can be written in the form

$$\hat{\theta} = (H^T H + \alpha^2 L^T L)^{-1} H^T z$$

- The side constraint $\|L\theta\|$ is based on the eigenvectors of the data correlation matrix.

METHODS
Subspace regularization II

- We want our estimates to be close to the subspace $\mathcal{S}$ spanned by the first p (typically $p = 4$) eigenvectors of the data correlation matrix. Let these eigenvectors be the columns of the matrix $H_{\mathcal{S}}$.
- Appropriate selection for side constraint is then $L = (I - H_{\mathcal{S}} H_{\mathcal{S}}^T) H$.



- The desired solution for the parameters θ can be written in the form

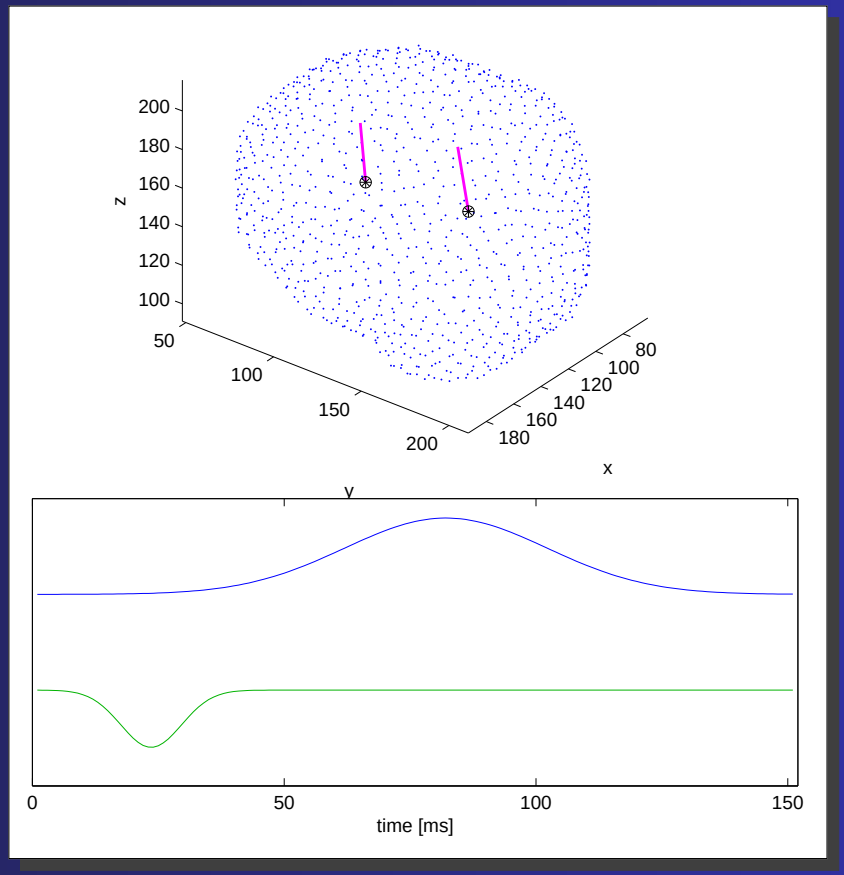
$$\hat{\theta} = (H^T H + \alpha^2 H^T (I - H_{\mathcal{S}} H_{\mathcal{S}}^T) H)^{-1} H^T z$$

METHODS
Multi channel approach

- In the case of multi channel measurements we can take the coupling between the channel into account by concatenating measurements from different channels together.
- The data correlation matrix will then also contain information about coupling between different channels. We will use diagonal block matrix as observation matrix H, in which each block is equal to single channel case.
- This way our observation model does not depend on the properties of the head or on the locations of the electrodes.

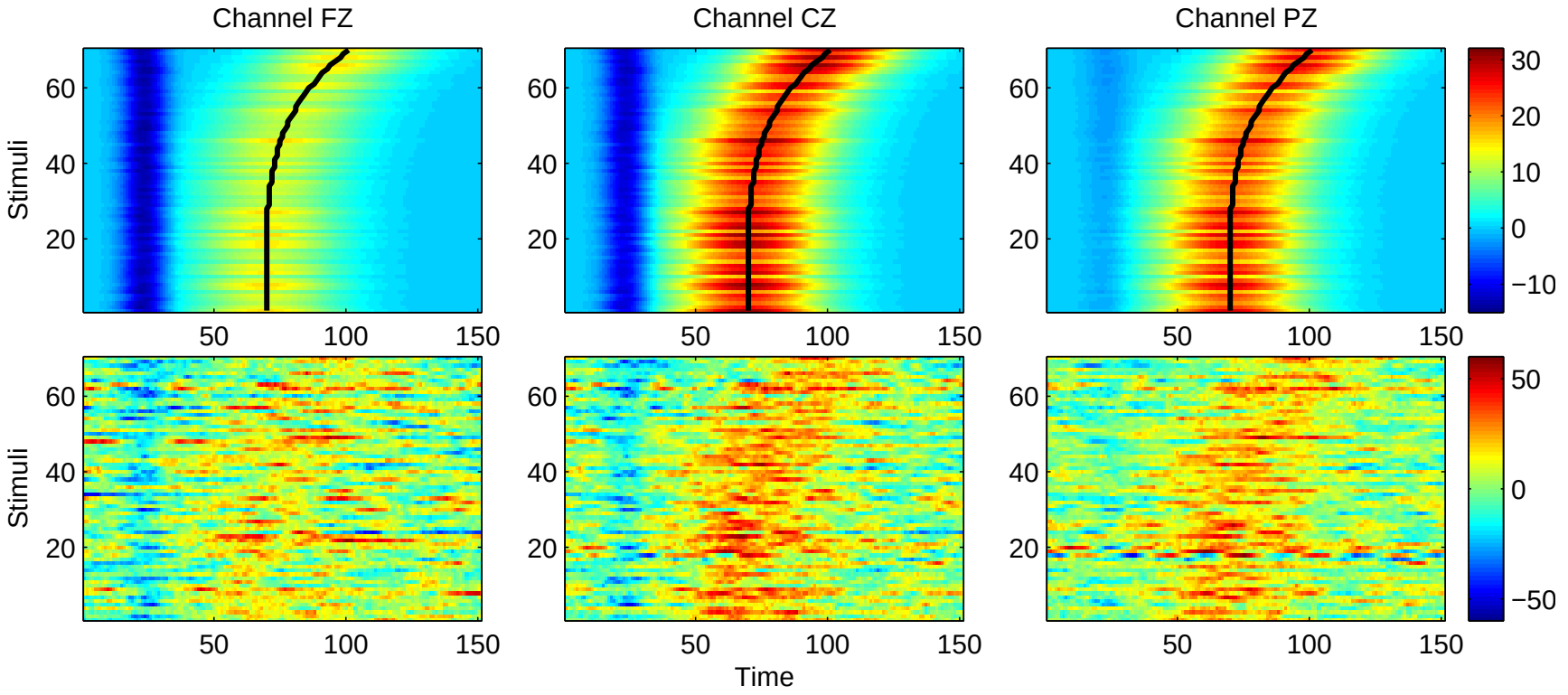
SIMULATION

- ERPs are modeled by calculating the potential field on the surface of the head caused by two dipole sources as their magnitude varied as function of time.
- Background EEG is taken from real measurements.



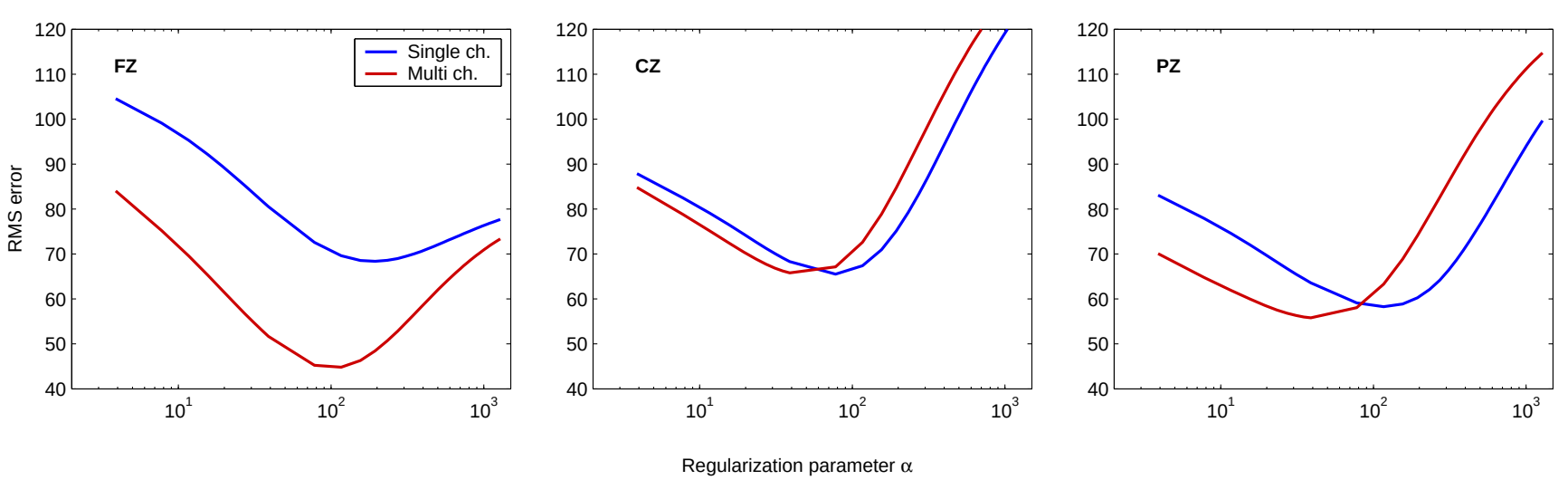
SIMULATION STUDIES

- Simulated data consist of 70 responses.
- Amplitude of positive peak varies randomly.
- Latency of positive peak has a clear trend.



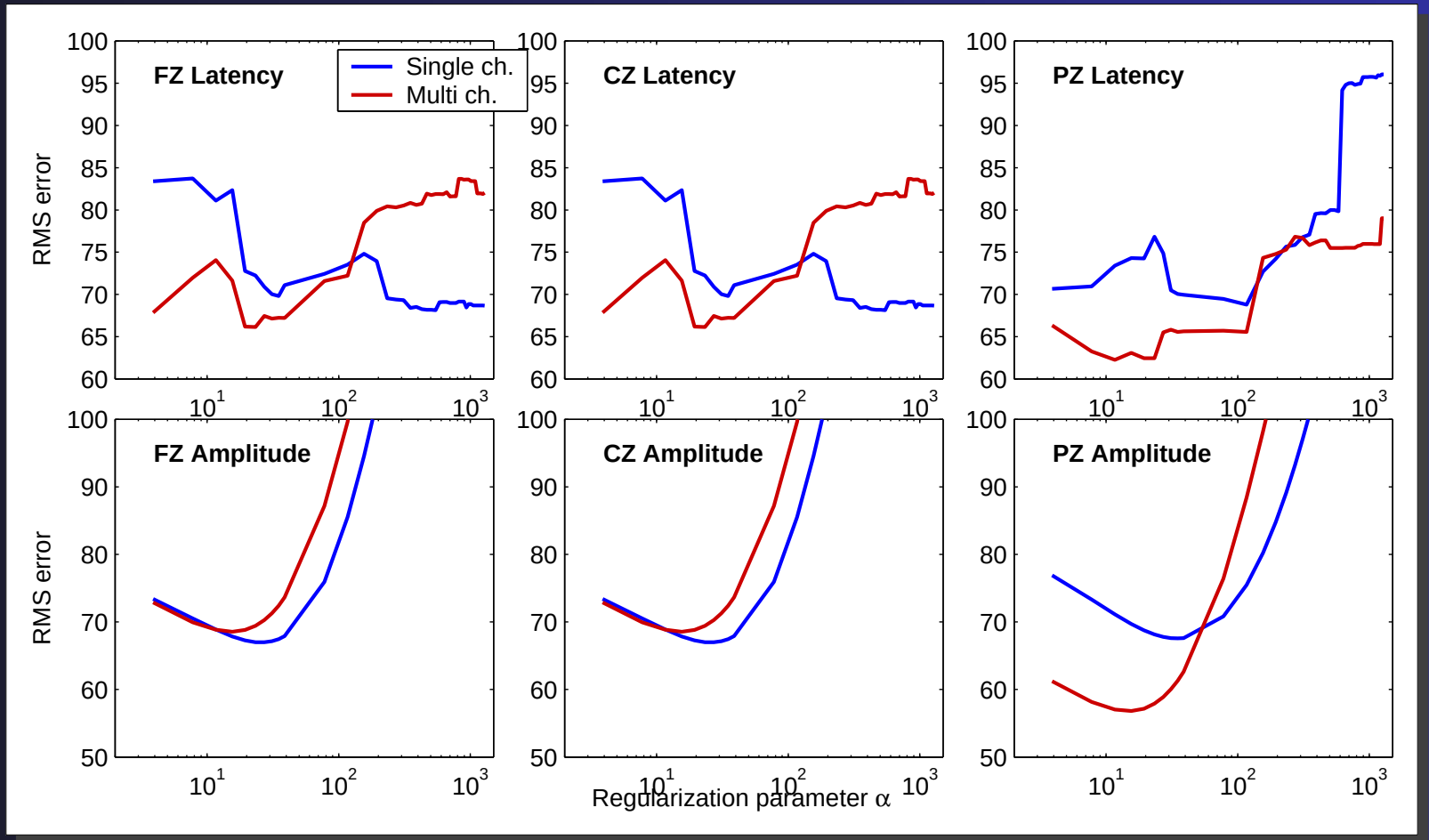
RMS Error of the estimates

- Multi channel estimates are calculated using data of five channels (FZ, C3, CZ, C4, PZ).



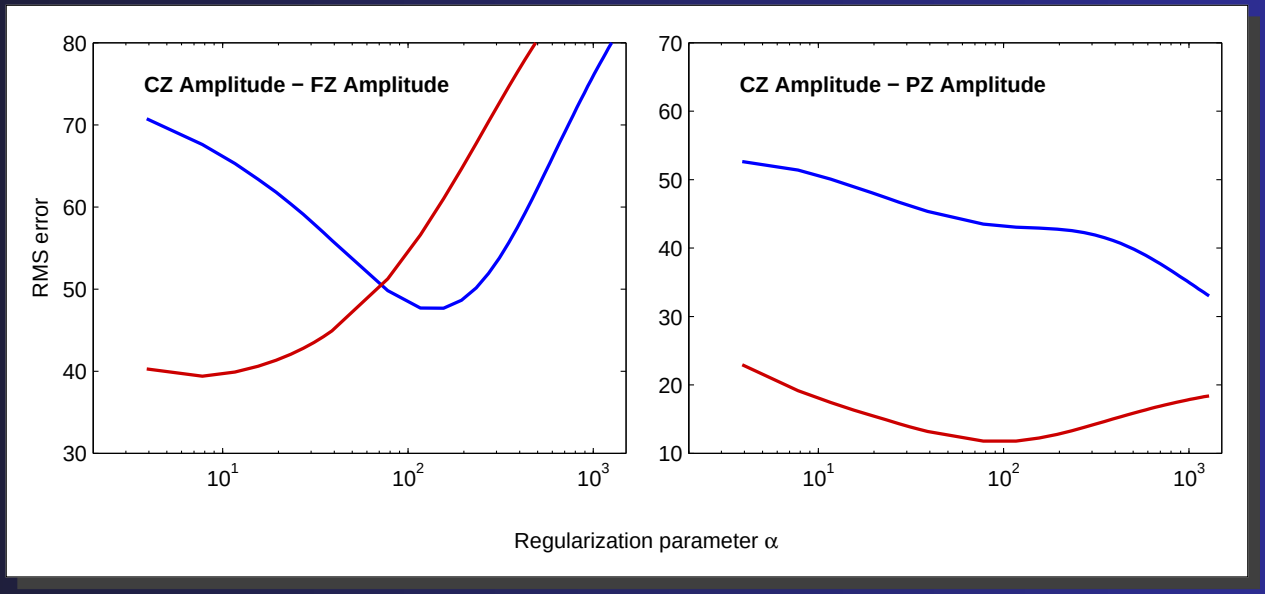
RMS Error of the Peak Estimates

- Peak estimate is simply maximum value of the estimate in predefined time window.

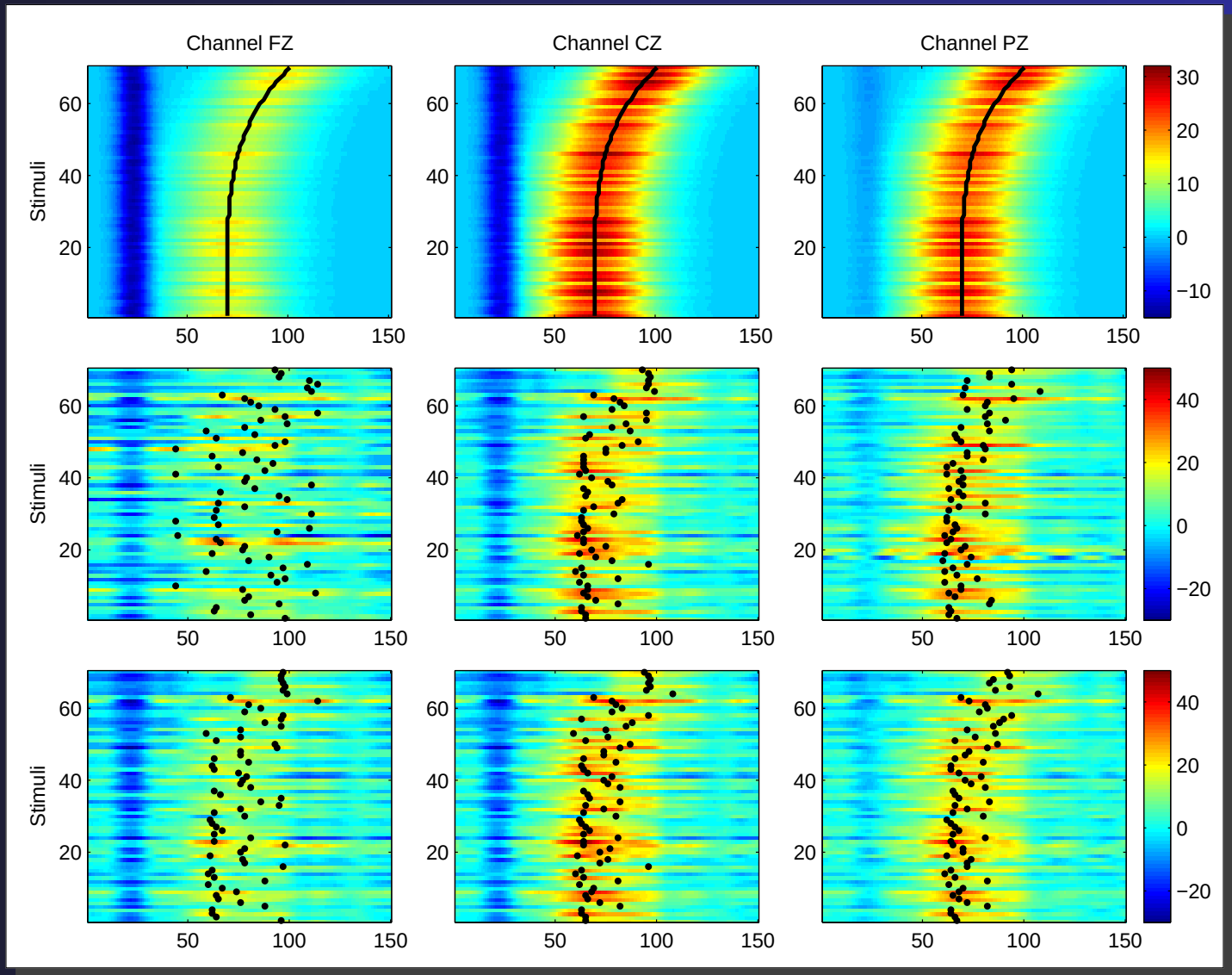


RMS Error of the Amplitude Difference of Peak Estimates

- The biggest difference between the methods is in the ability to estimate amplitude differences between channels.



Estimates


Channel FZ
Channel CZ
Channel PZ
Stimuli
60
40
20
50
100
150
30
20
10
0
−10
40
−20

Conclusions & Discussion

- Both methods are shown to be robust for small changes of the value of the regularization parameter.
- In practice it is possible to choose the value of the parameter by visual inspection of the estimates and the data.
- Peak estimates can be enhanced by using some more advanced peak picking method than simple min/max used in this study.