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Brain'07 and BrainPET'07

Osaka, Japan, May 22, 2007

Multi-resolution Bayesian regression for parametric imaging of $[^{18}F]$FDG brain studies

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Introduction

FDG model

$$K_I = \frac{K_1 \cdot k_3}{k_2 + k_3} \qquad rCMR_{glc} = \frac{C_p}{LC} \cdot K_I$$

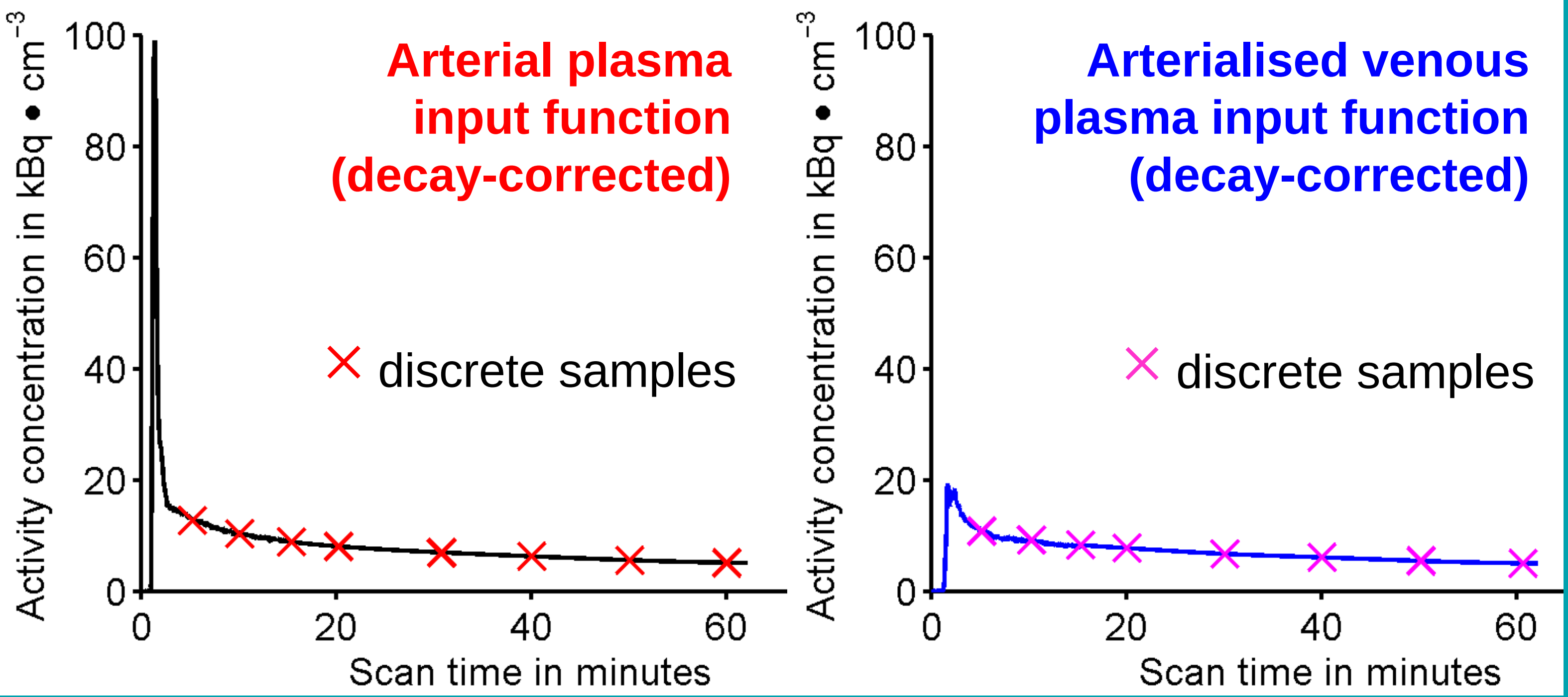
Three approaches to obtain estimates of K_I

1. Compartmental model → region of interest (ROI) analysis only,
2. Spectral analysis (SA) → ROI analysis and parametric images,
3. Graphical analysis (GA) of irreversible binding:
   a) Traditional → ROI analysis and parametric images,
   b) Multi-resolution Bayesian regression (MBR) → parametric images only.

Data acquisition

- After bolus administration of 185 MBq [^{18}F]FDG, dynamic 3D PET data were acquired for 60 min on the ECAT EXACT HR+ scanner.
- Images (28 frames) were reconstructed using filtered backprojection.
- The plasma input functions were generated using an online blood detector during the initial 15 min of the scan and 2 discrete samples for cross-calibration only, plus 6 additional discrete samples.

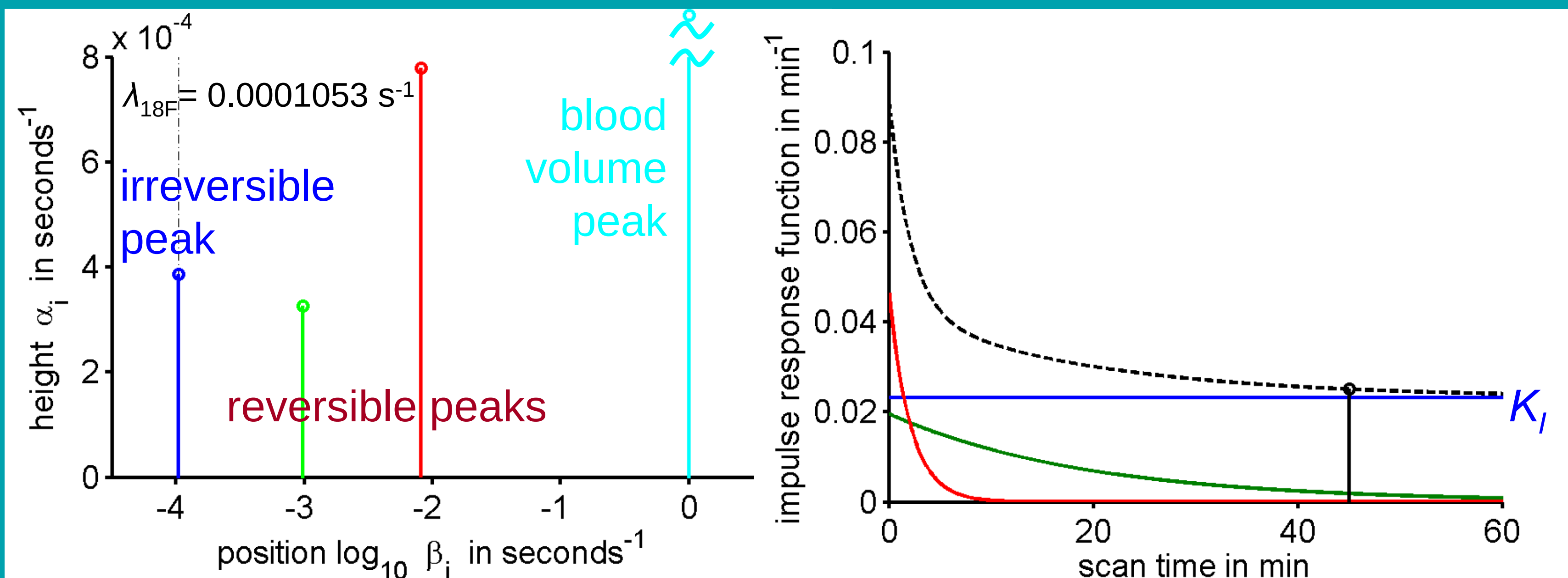
The same subject scanned on two occasions



Spectral Analysis

Cunningham and Jones, *JCBFM* **13** (1993), 15 -23.

- Deconvolution of the tissue response function with the arterial input function to obtain the impulse response function (IRF),
- Separates the signal into high and low frequency components,
- For irreversible systems: $\lim_{t \to \infty} \mathrm{IRF}(t) = K_I$.



SA was used with 100 basis functions logarithmically spaced between 0.0001053 s^{-1} and 0.1 s^{-1} to generate parametric maps of the IRF at 45 min.

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Graphical Analysis

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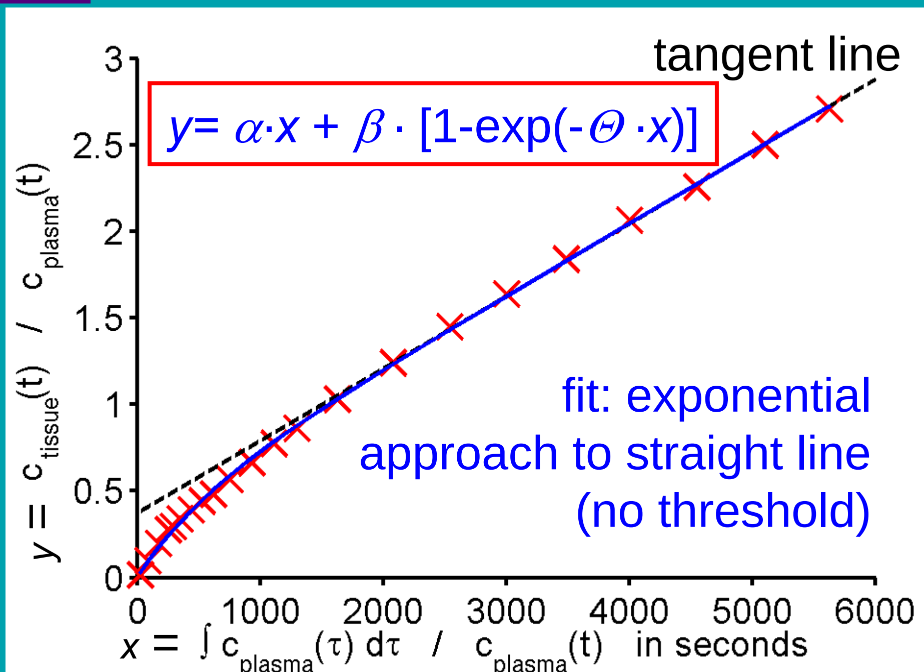
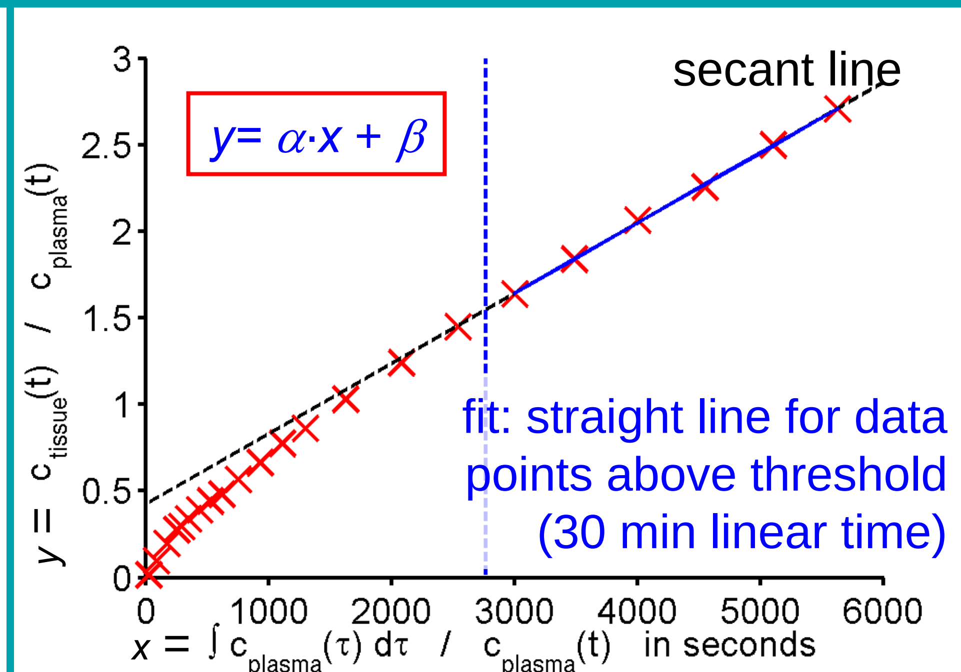
Gjedde, *J Neurochem* **36** (1981), 1463 - 71.
Patlak *et al*., *JCBFM* **3** (1983), 1 - 7.
Patlak and Blasberg, *JCBFM* **5** (1985), 584 - 590.
Wong *et al*., *JCBF* **6** (1986), 137 - 146.

Blood volume fixed. How to chose appropriate weights for the data points?

Nonlinear fit.



Linear fit.



threshold: $\exp(-\Theta \cdot x^*) < \varepsilon$, e.g. 10^{-3}

bigger intercept β and smaller slope α.

For the linear fit, data of the last 6 frames between 30 and 60 min were used.

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Parametric images

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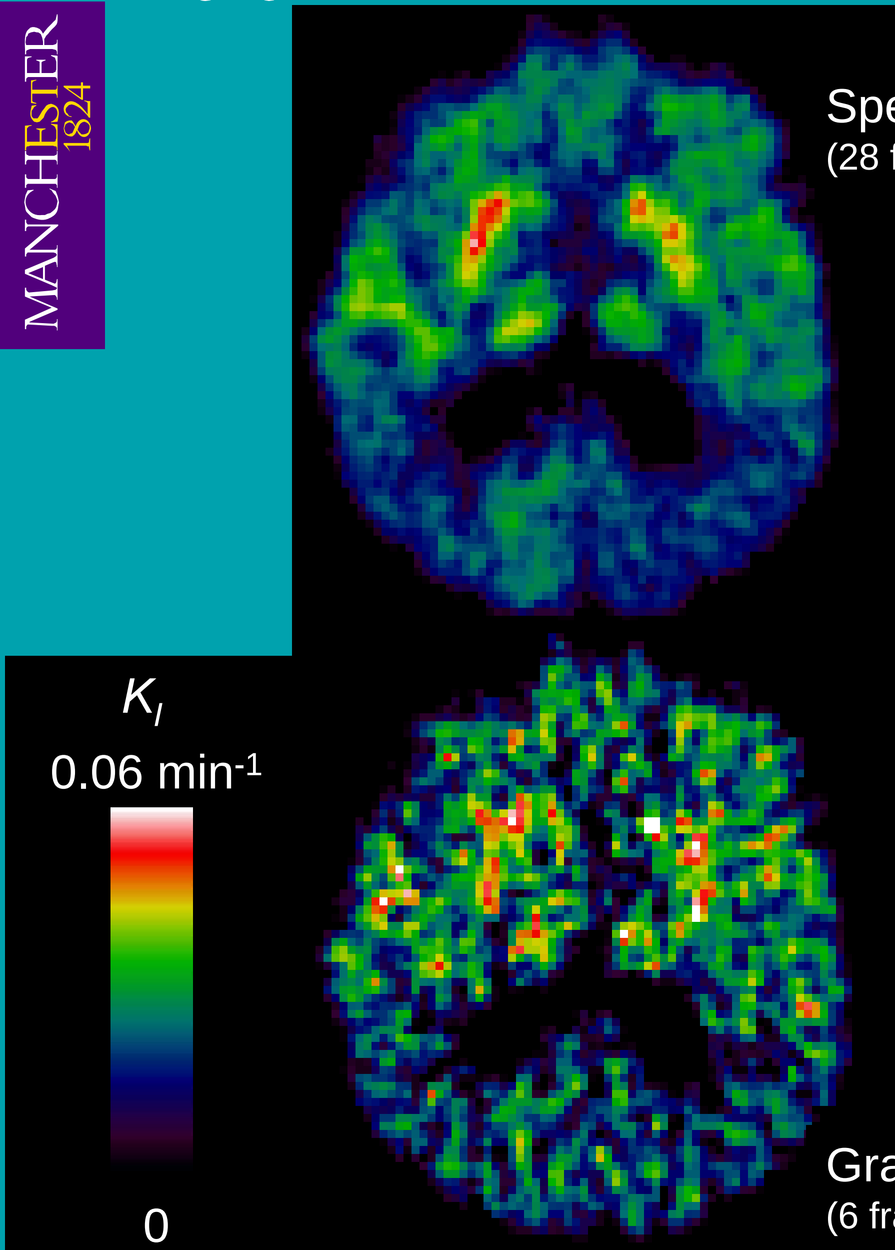
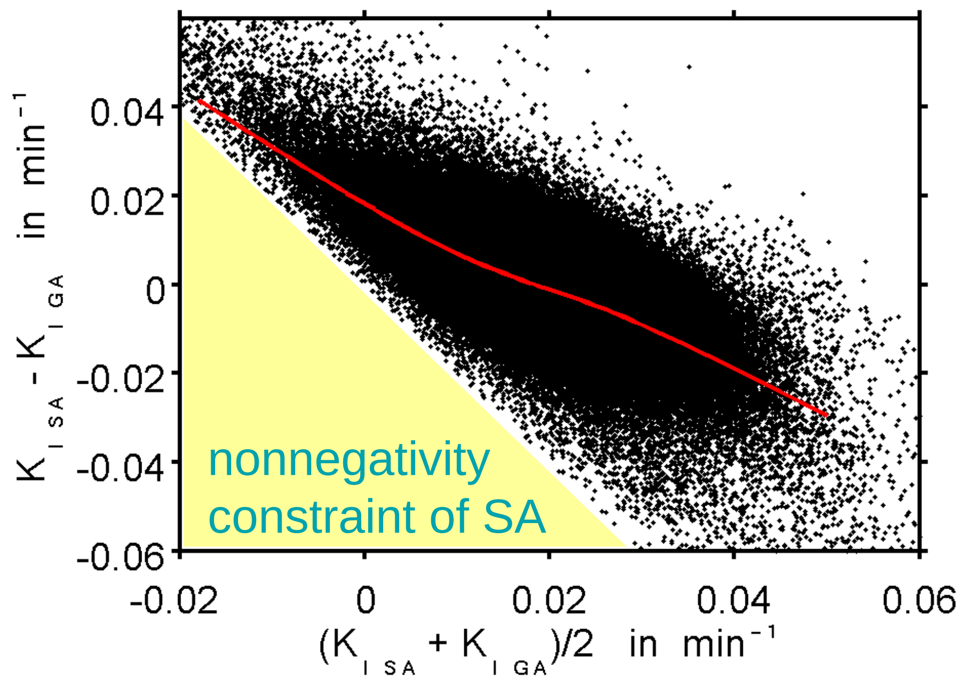


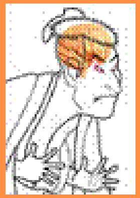
Spectral Analysis (SA), IRF 45 min
(28 frames)

Bland Altman Plot



Locally weighted polynomial regression (LOESS)

Graphical Analysis (GA), slope
(6 frames)



Multi-resolution Bayesian regression

Turkheimer *et al.*, *Neuroimage* **32** (2006), 111 - 121.

Idea

Looking at the brain as an organ, i.e. exploiting its self-similarity.

How is it done?

Multi-scale decomposition of PET dynamic images in wavelet space,

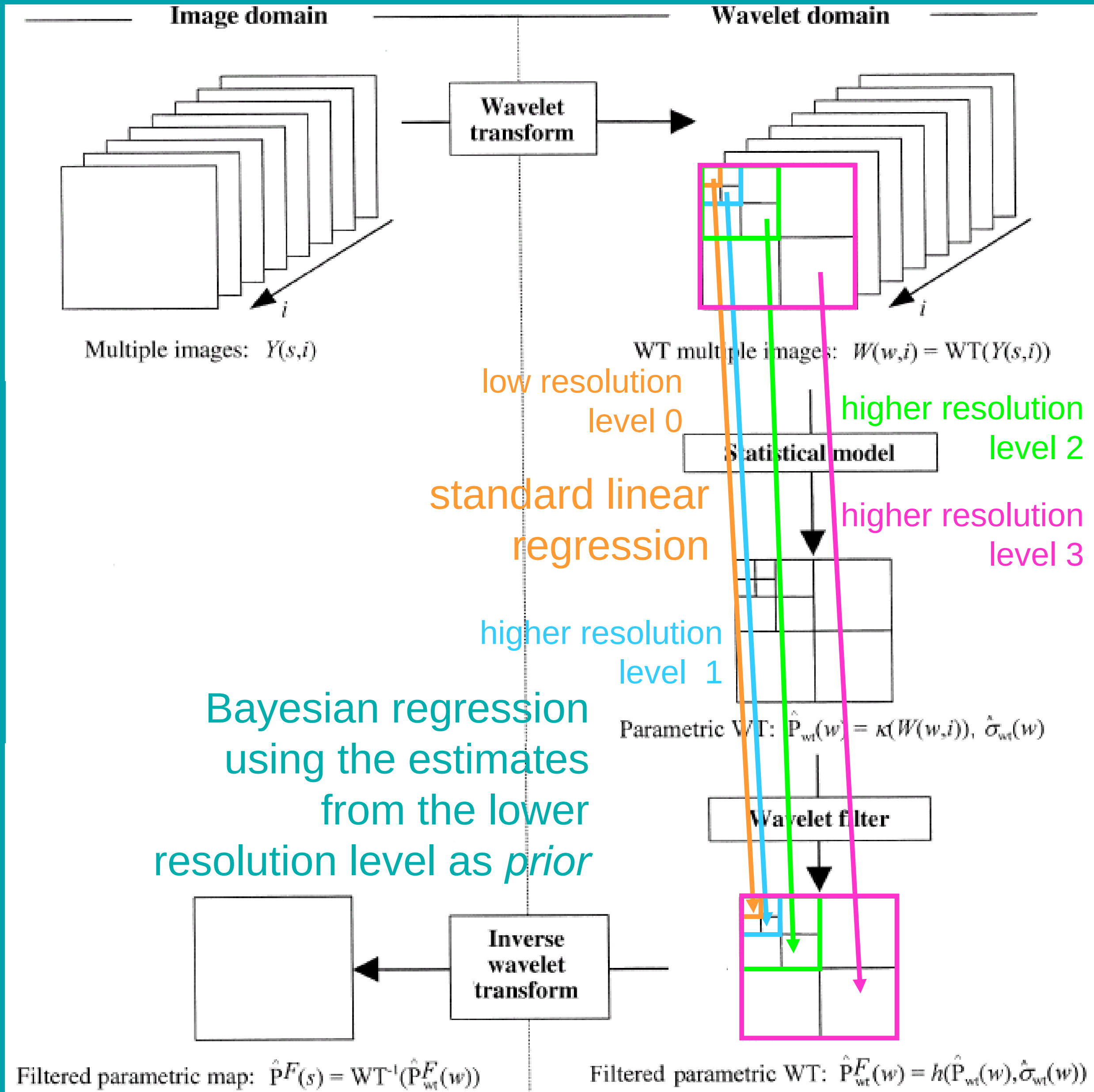
example of spatio-temporal modelling,

exploits the tree structure of the wavelet decomposition.

Which kinetic model is used?

Linear fit to straight line as in traditional Graphical Analysis of irreversible binding.

Principle of MBR



low resolution =
low noise →
estimates with
low variance

high resolution =
high noise
The priors are
used to constrain
the estimates
thus reducing
variance.

Is the bias
acceptable?

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Results

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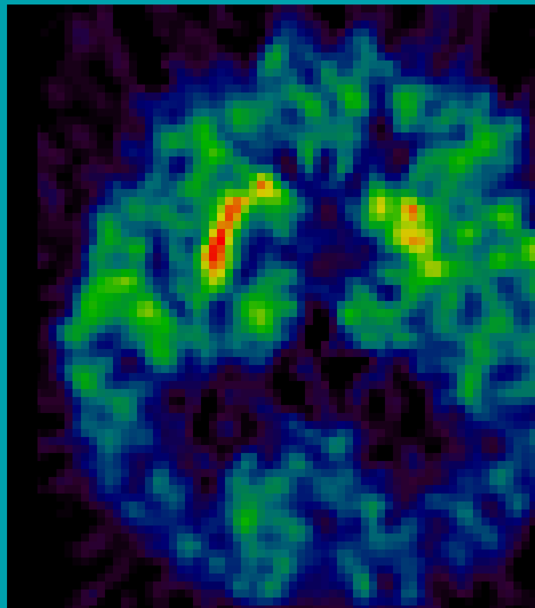
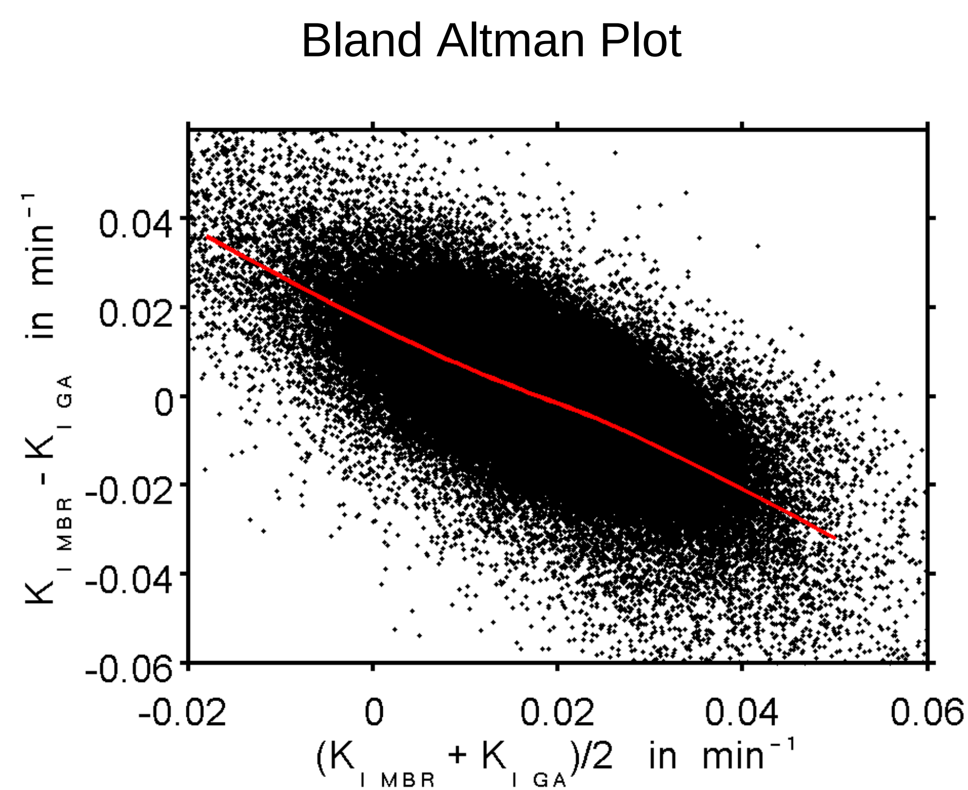
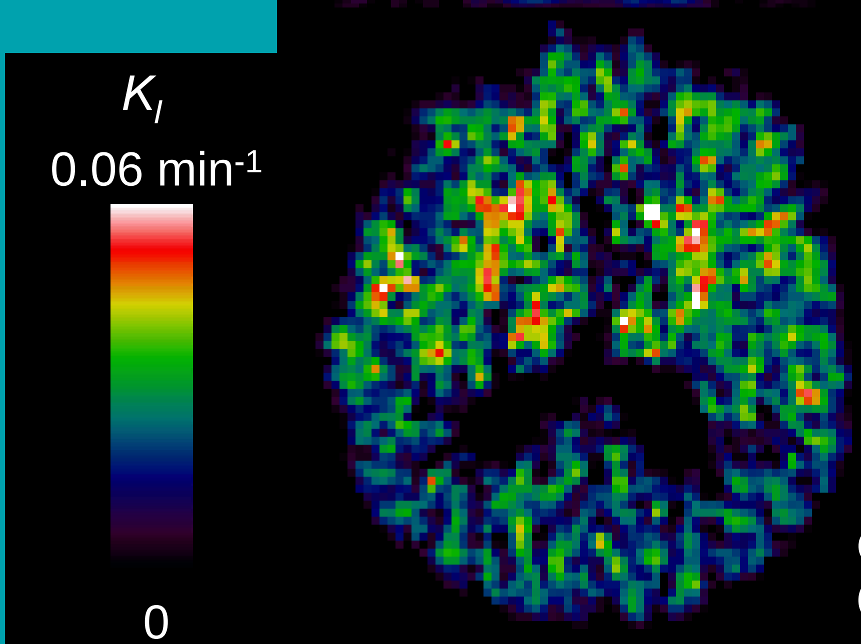


Multi-resolution Bayesian Regression (MBR), slope
(6 frames)



Locally weighted polynomial regression (LOESS)



Graphical Analysis (GA), slope
(6 frames)

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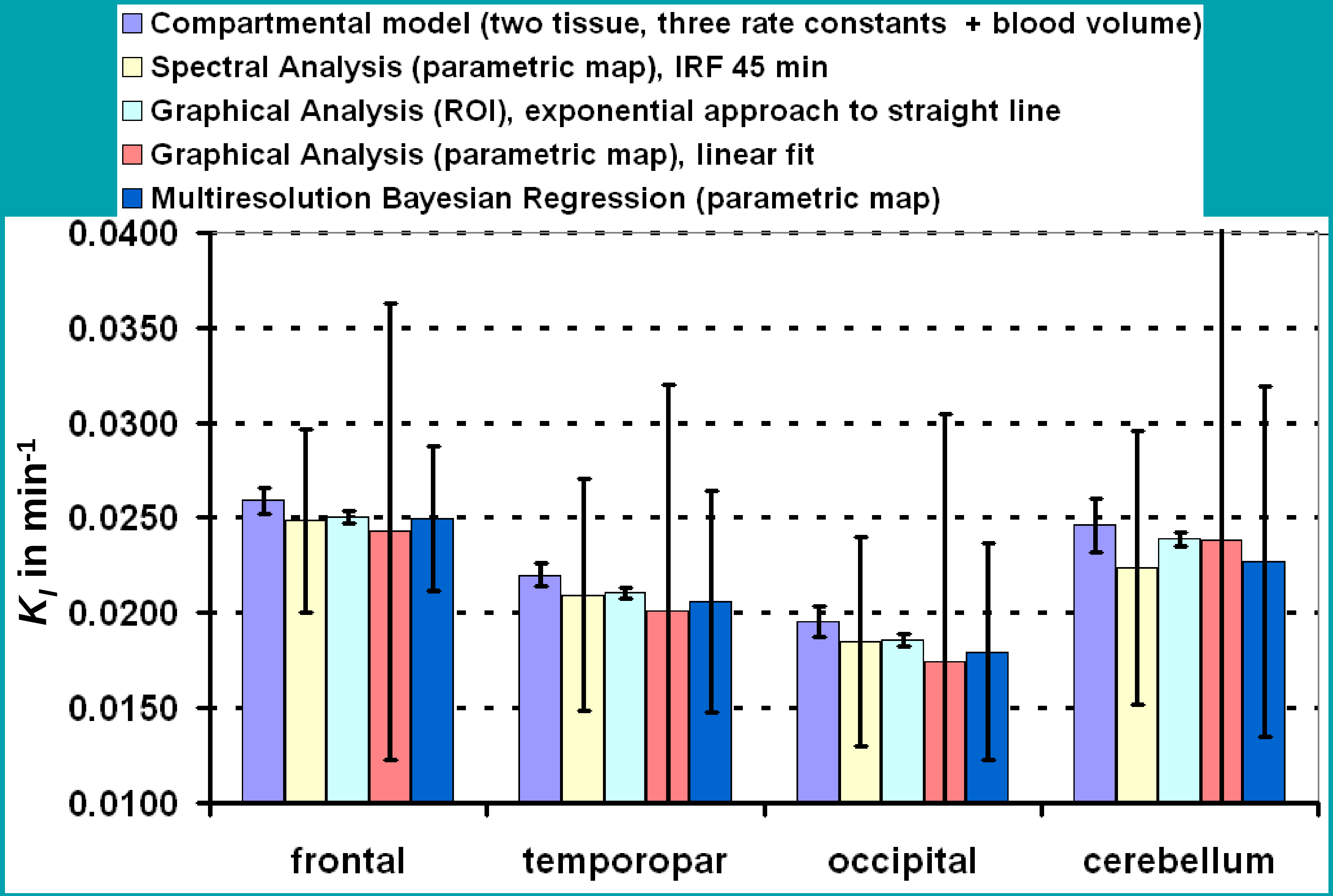
Results: bias and variance



Error bars: standard error for ROI time-activity curve fits, standard deviation for sampled pixels from parametric maps.

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Results

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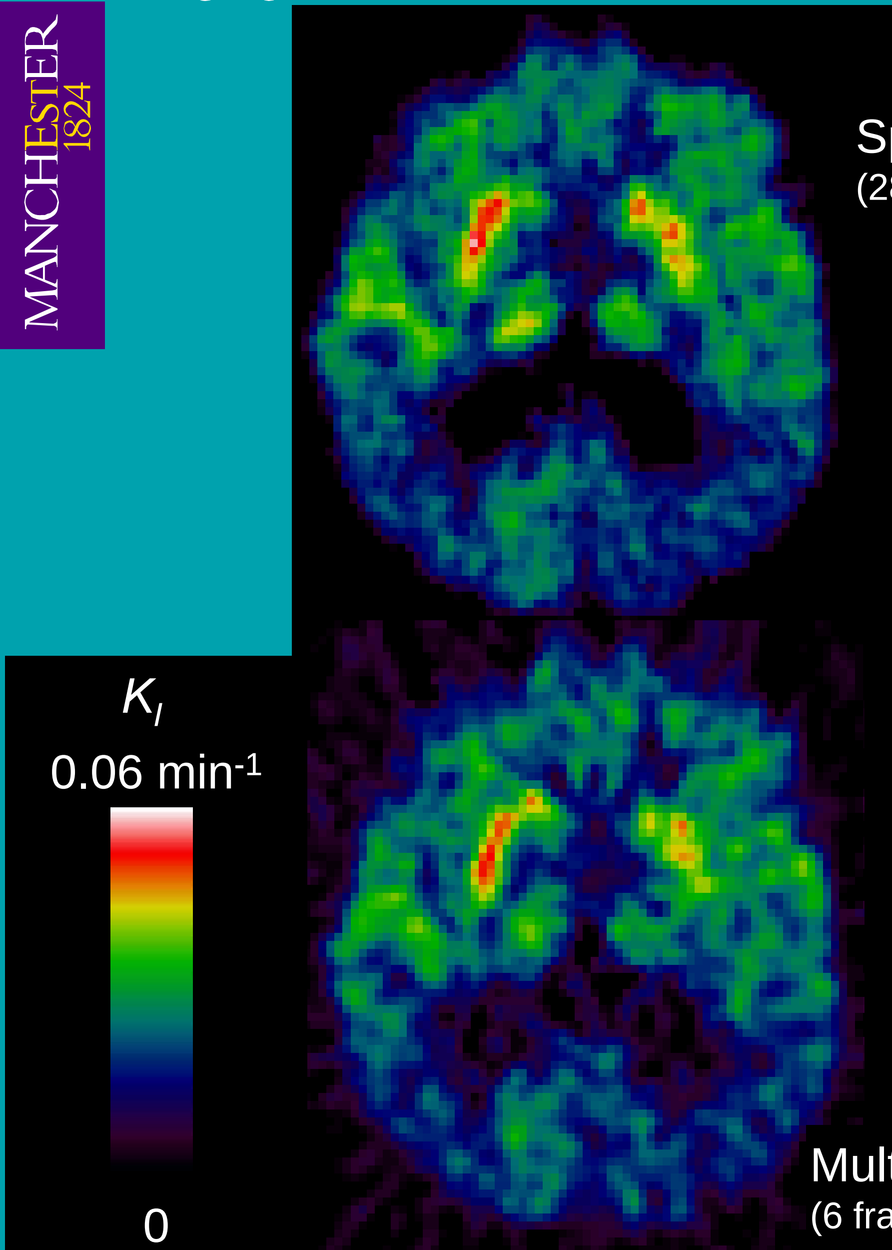
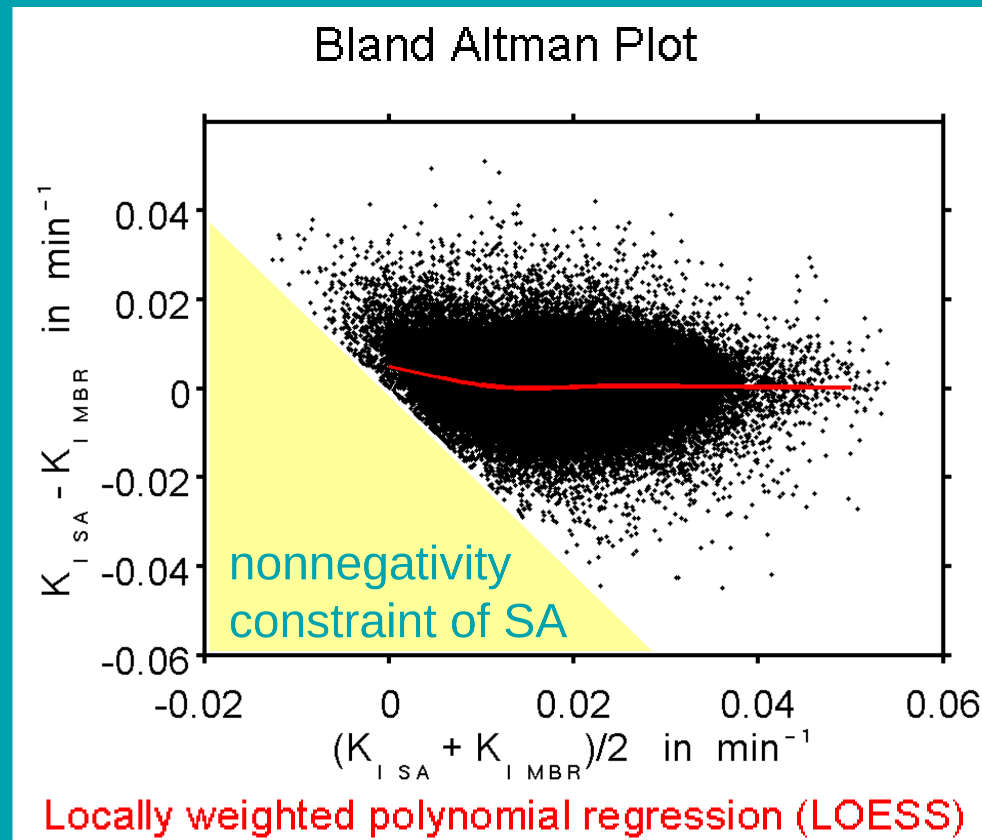
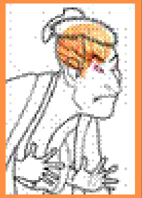


Spectral Analysis (SA), IRF 45 min
(28 frames)



Multi-resolution Bayesian Regression (MBR), slope
(6 frames)



Conclusions

The multi-resolution Bayesian regression technique used in conjunction with the linear model of Graphical Analysis generates parametric images of good visual quality.

For $K_I > 0.01$ min^{-1}, a very good agreement of the pixel values with Spectral Analysis is observed.

Advantage:

A continuously acquired arterial input function is no longer required because arterialised venous input functions are sufficient for Graphical Analysis.

Software for multi-resolution Bayesian regression (Piwave) is available. Email: federico.turkheimer@imperial.ac.uk

Future plans include the extension of MBR beyond linear models.