Quantification of location errors for mining induced seismicity in New Ollerton, UK, using 3D Monte Carlo body wave tomography

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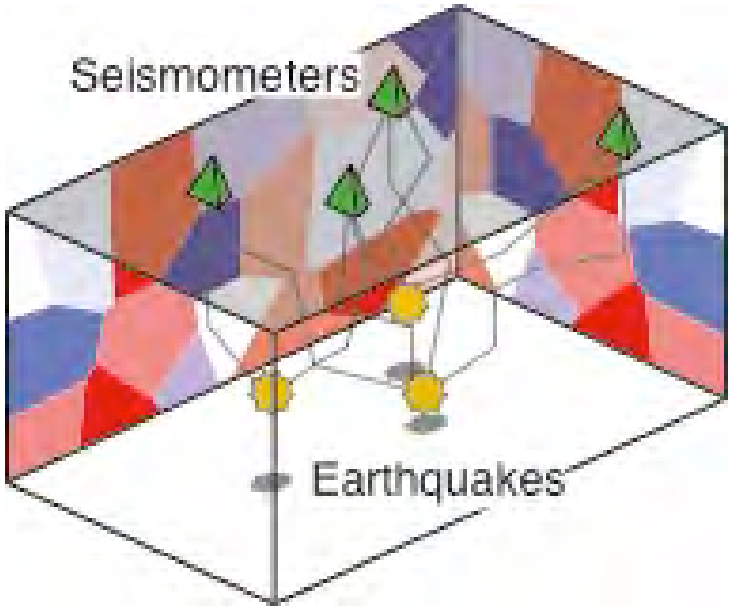
REMIS – Reliable Earthquake Magnitudes for Induced seismicity



Short-coming in existing methods of magnitude estimations

- Need to know velocity model and source locations
- Trade-off between velocities and and source locations

<u>Goal</u>: Joint hypocenter-velocity inversion and calculation of interlinked probability distributions and uncertainties of earthquake locations and seismic velocities, magnitudes

=> Monte Carlo Markov Chain approach

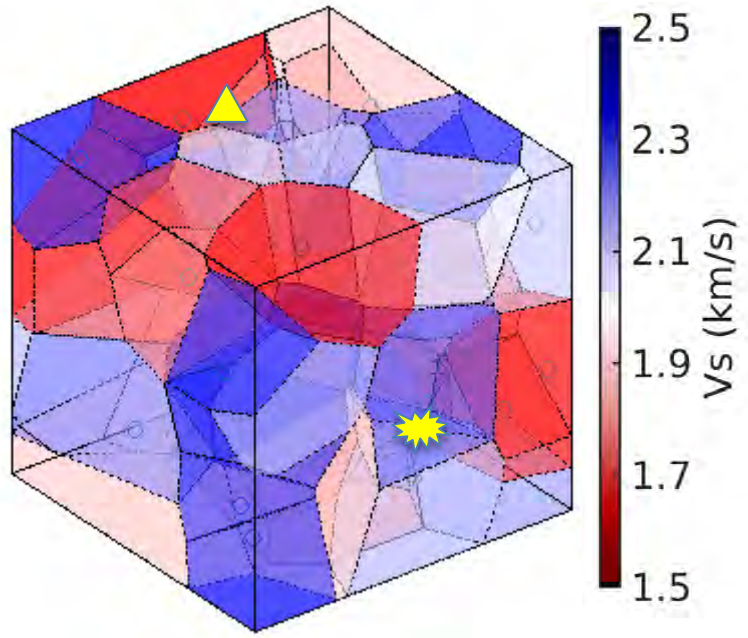
The rj-McMc algorithm

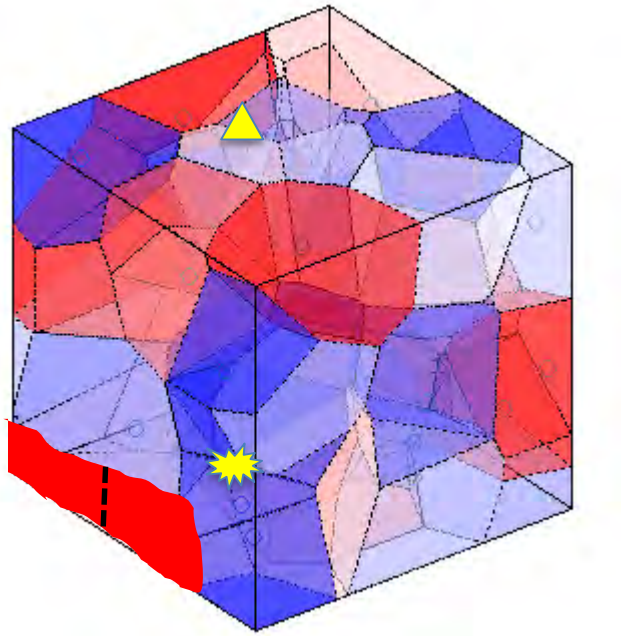
Initial randomly choosen model **m**

Calculate raypaths & Travel times for **m**

Propose a new model **m'**

- Perturbation of velocity/position of cells **or**
- Perturbation of source location
- **or** cell Birth/death





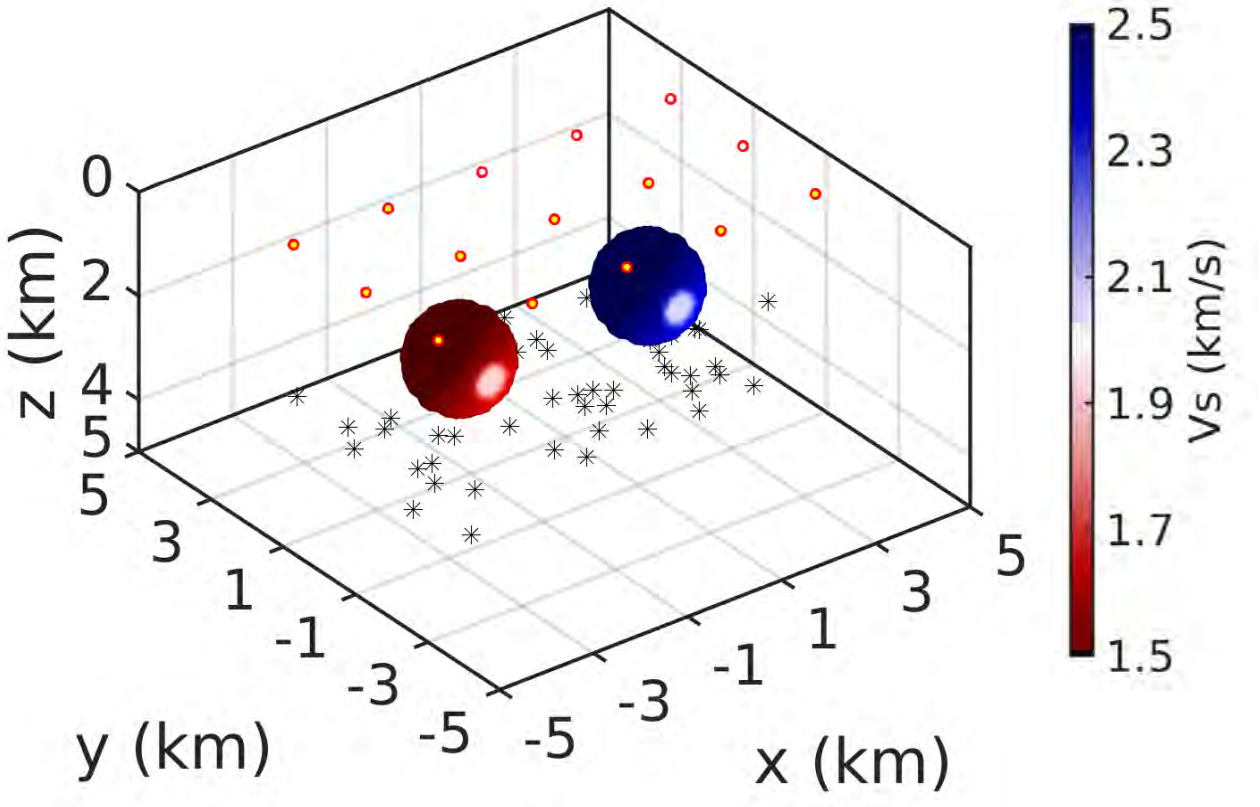
- Transdimensional
- hierarchical

m = m'

Calculate raypaths & Travel times for **m'**

Accept or reject m'

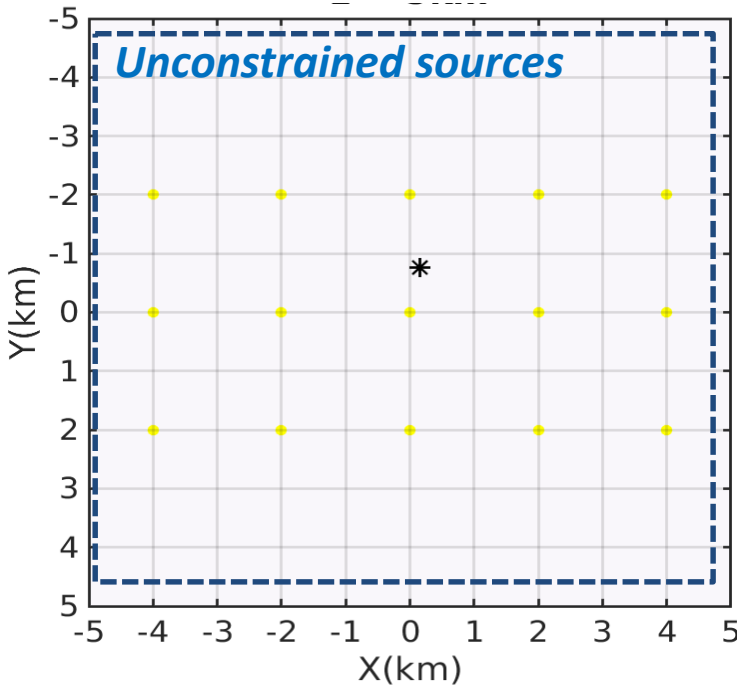
Synthetic test



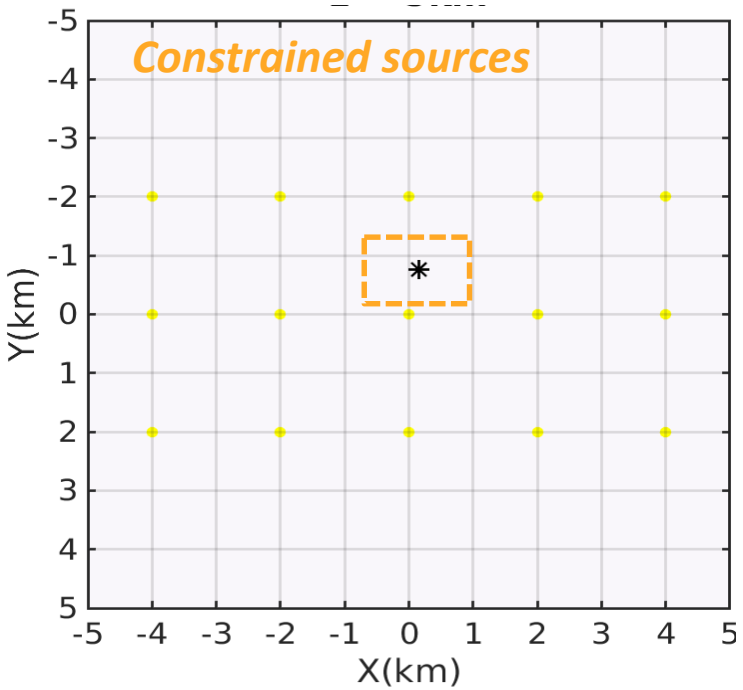
- 15 stations
- 50 sources

- 750 P&S Travel times + 2 % gaussian noise
- Source locations (x,y,z,t) + Gaussian noise
- ~ 1.5 million sampled models
- Burn-in of 500.000 models
- 20 Markov chains
- **Constrained/unconstrained source locations**

Unconstrained/constrained source locations

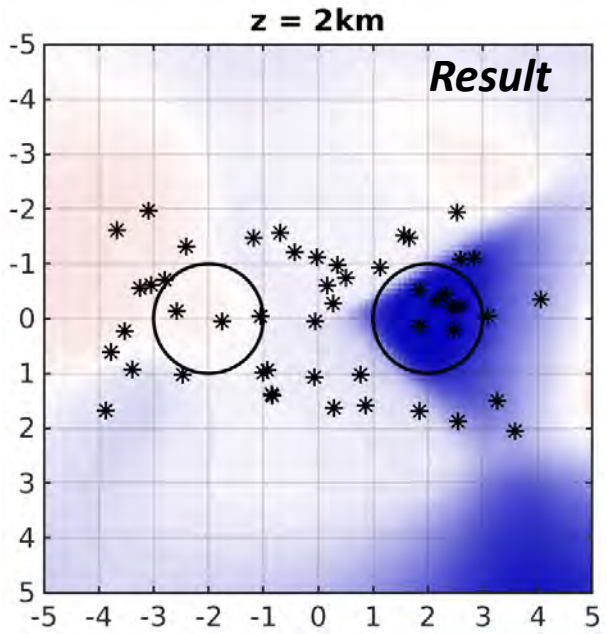


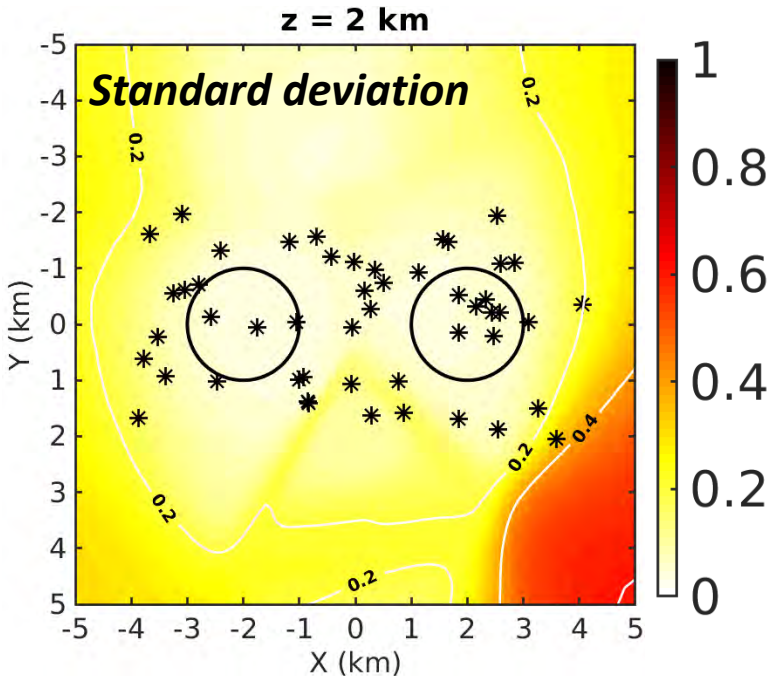
- Start at randomly chosen position in the model space
- wide priors
- Each chain initializes the source at different locations

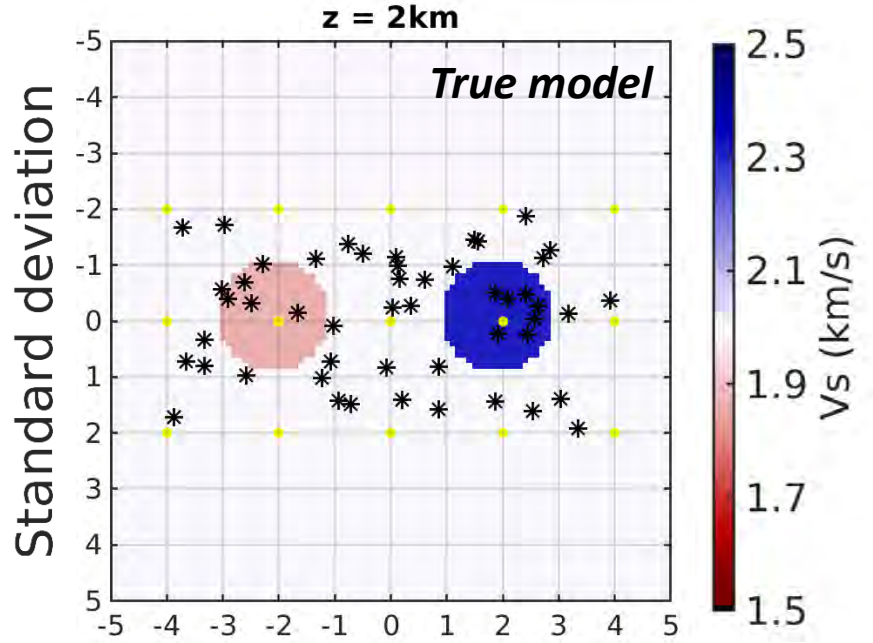


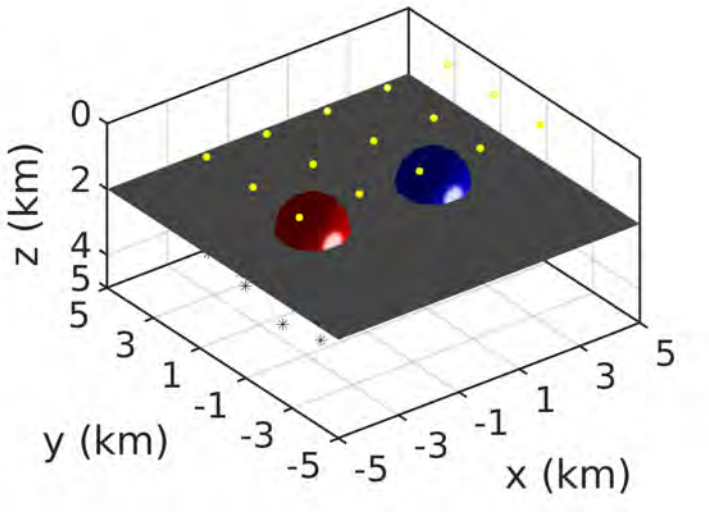
- Start from a position close to a given location
- Narrow priors, e.g +- 1 km in x,y,z
- Assume source locations are already well known

Synthetic test – constrained sources

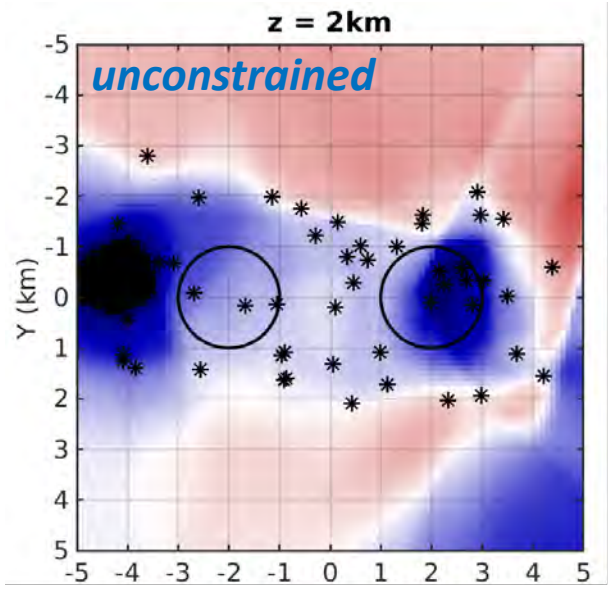


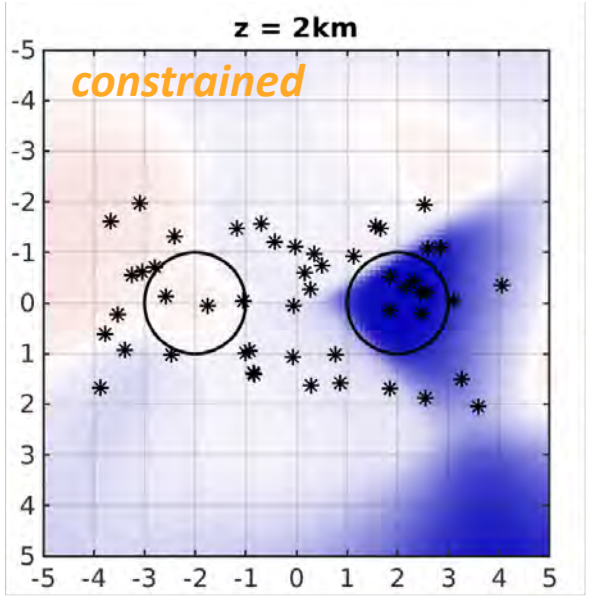


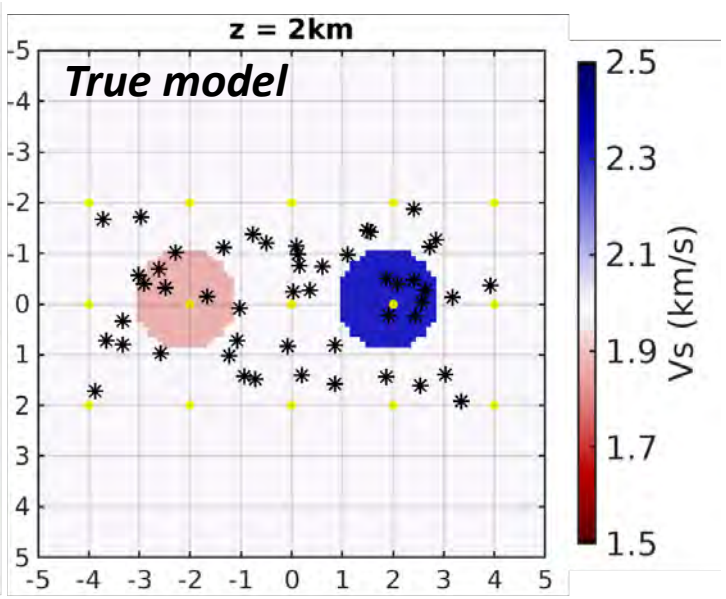


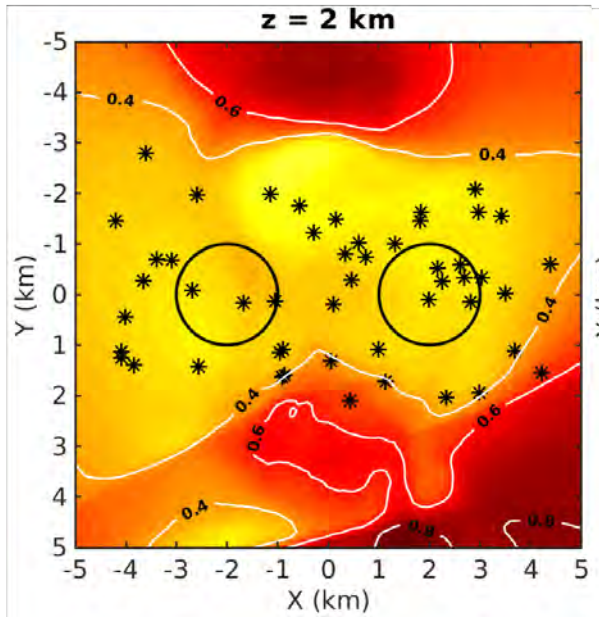


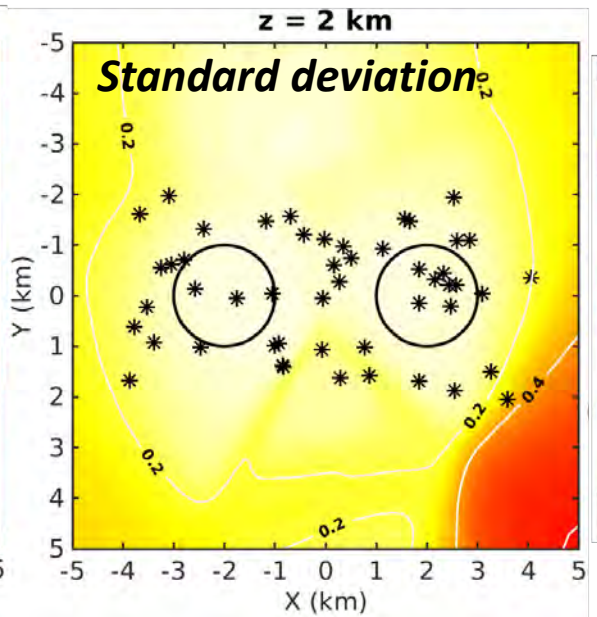
Synthetic test – Results

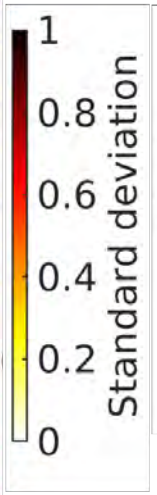


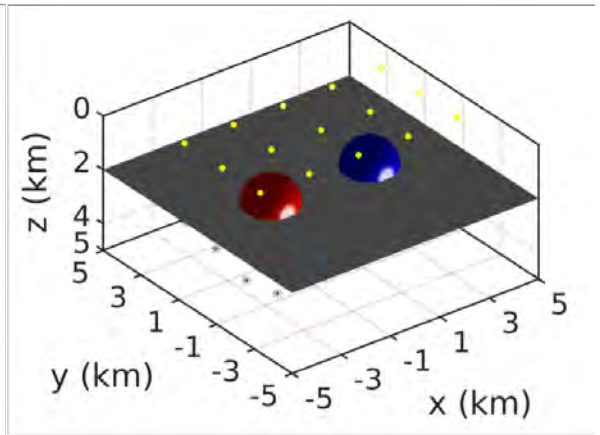






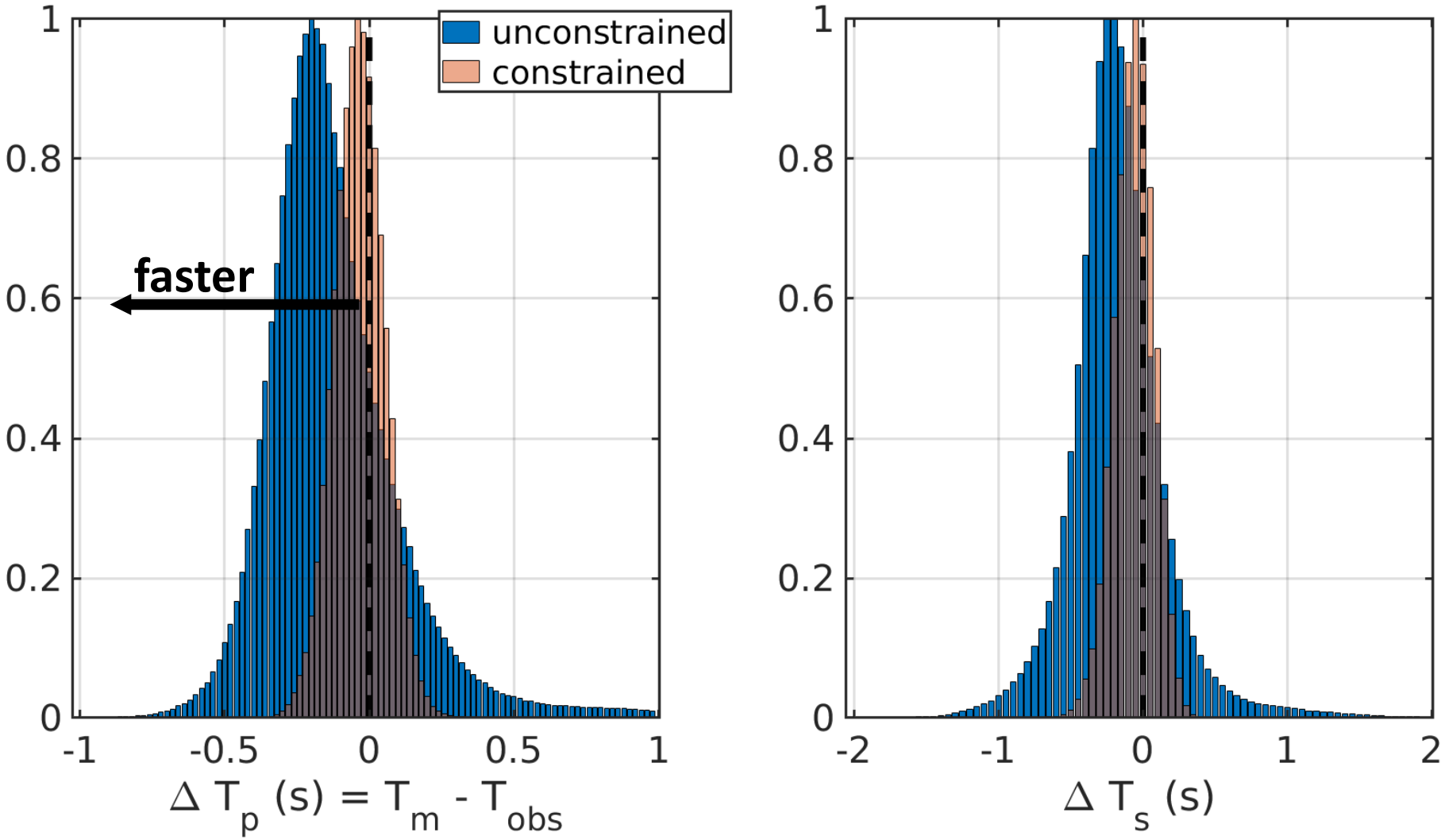




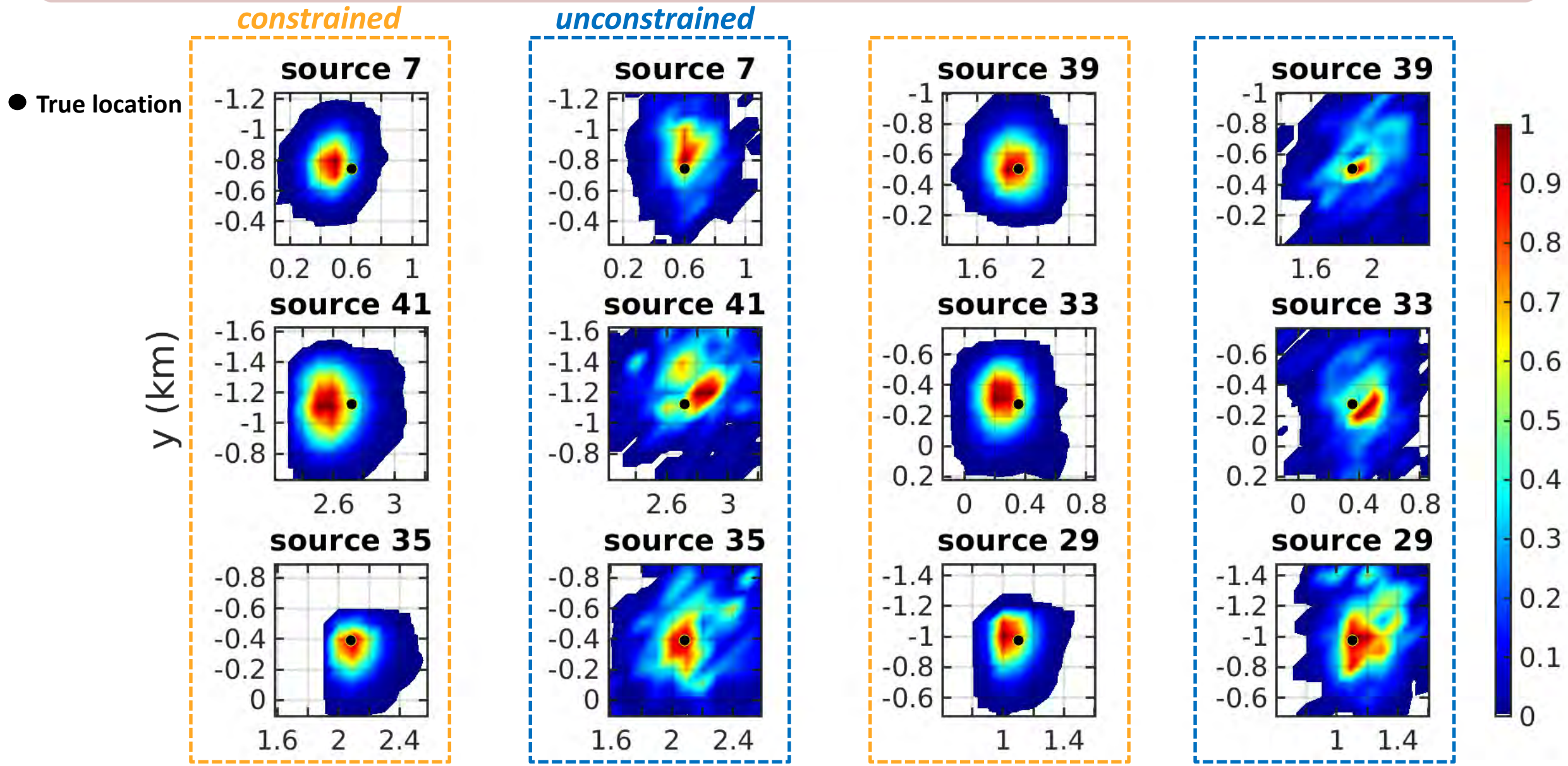


P&S Traveltimes

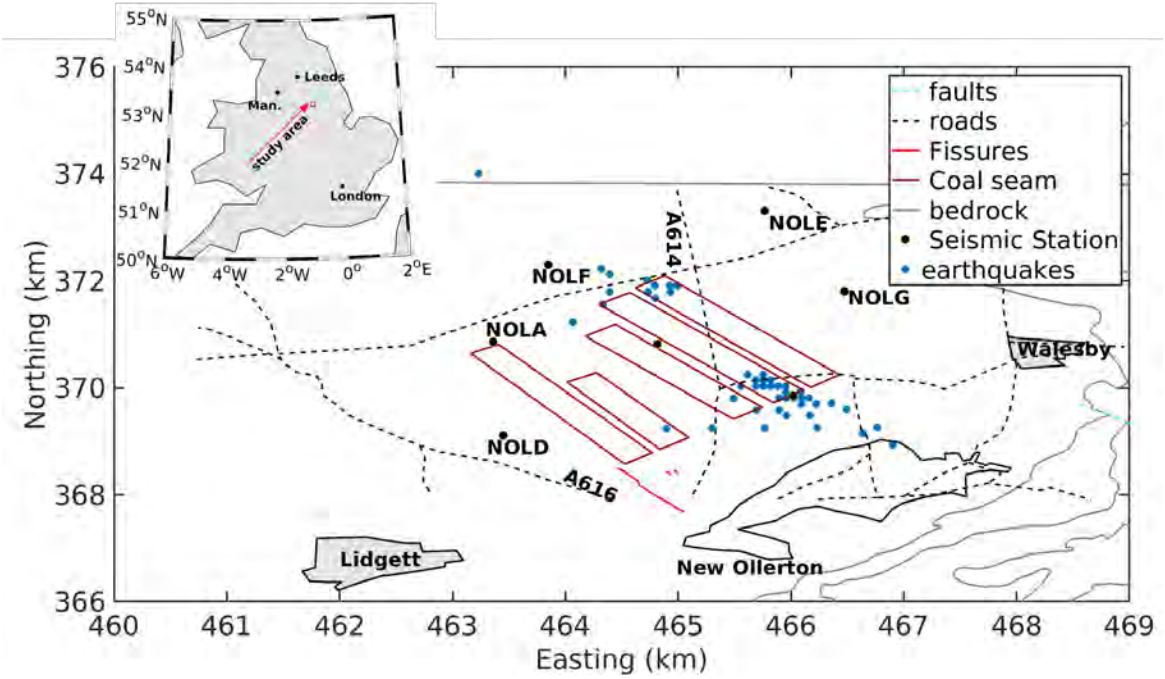
Traveltime differences calculated T_m - T_{obs} for models after the burn-in for all 20 chains

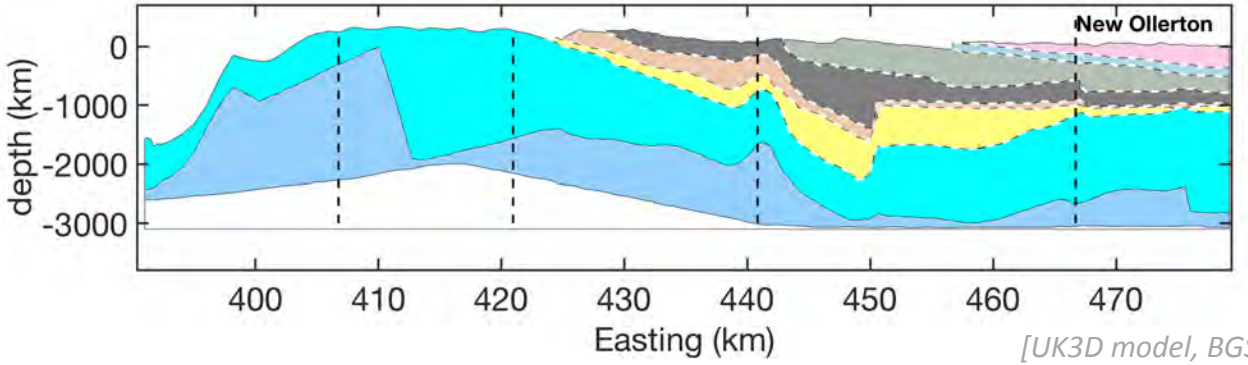


Source locations



Inversion of real data – Thoresby Colliery Case study





[UK3D model, BGS]

MUDSTONE, SILTSTONE AND SANDSTONE
DOLOMITISED LIMESTONE AND DOLOMITE
MUDSTONE, SILTSTONE, SANDSTONE, COAL, IRONSTONE AND FERRICRETE
MUDSTONE AND LIMESTONE,
LIMESTONE
LOWER PALAEOZOIC ROCKS,

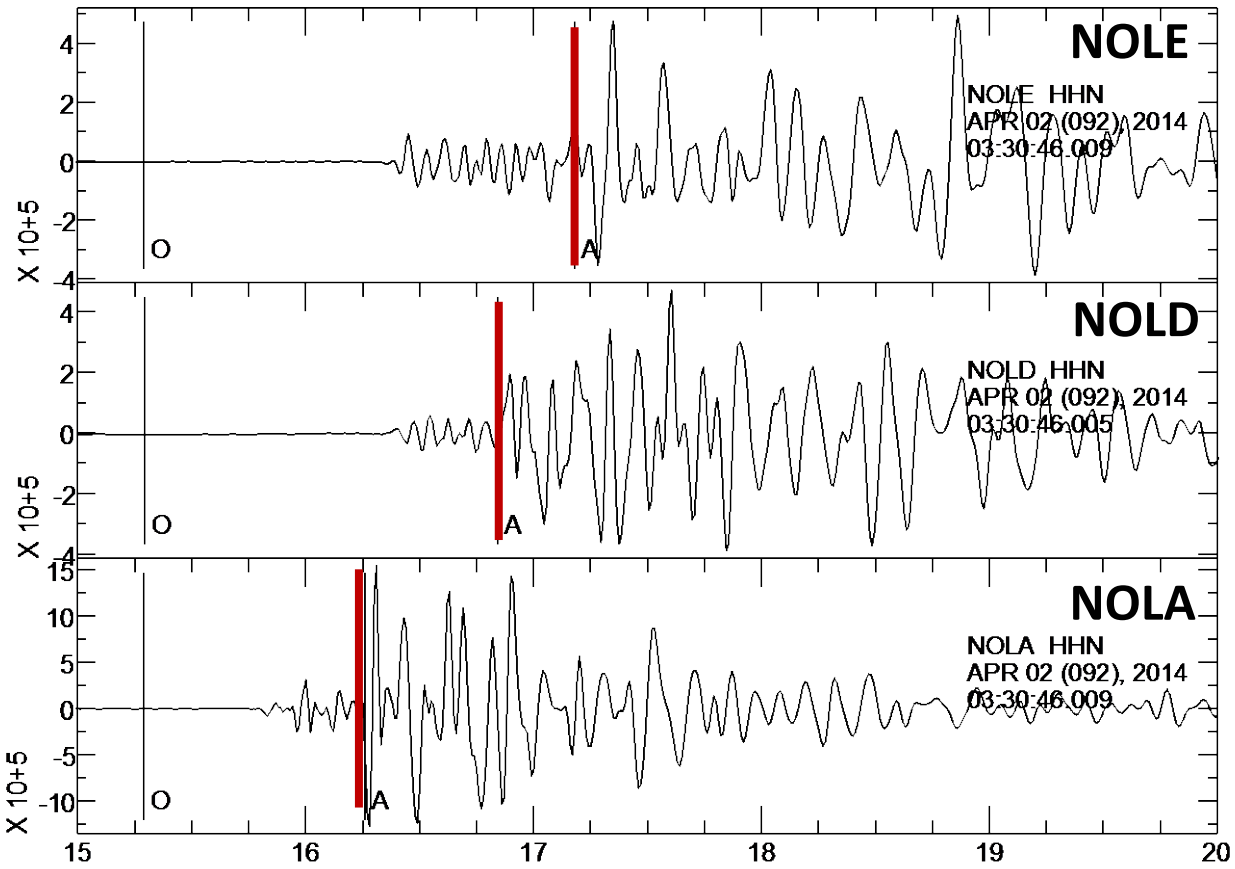
Earthquakes 2014

- 0.1 km < depth < 2.6 km
- 0.3 < M_L < 2.3
- 7 stations ; 61 earthquakes

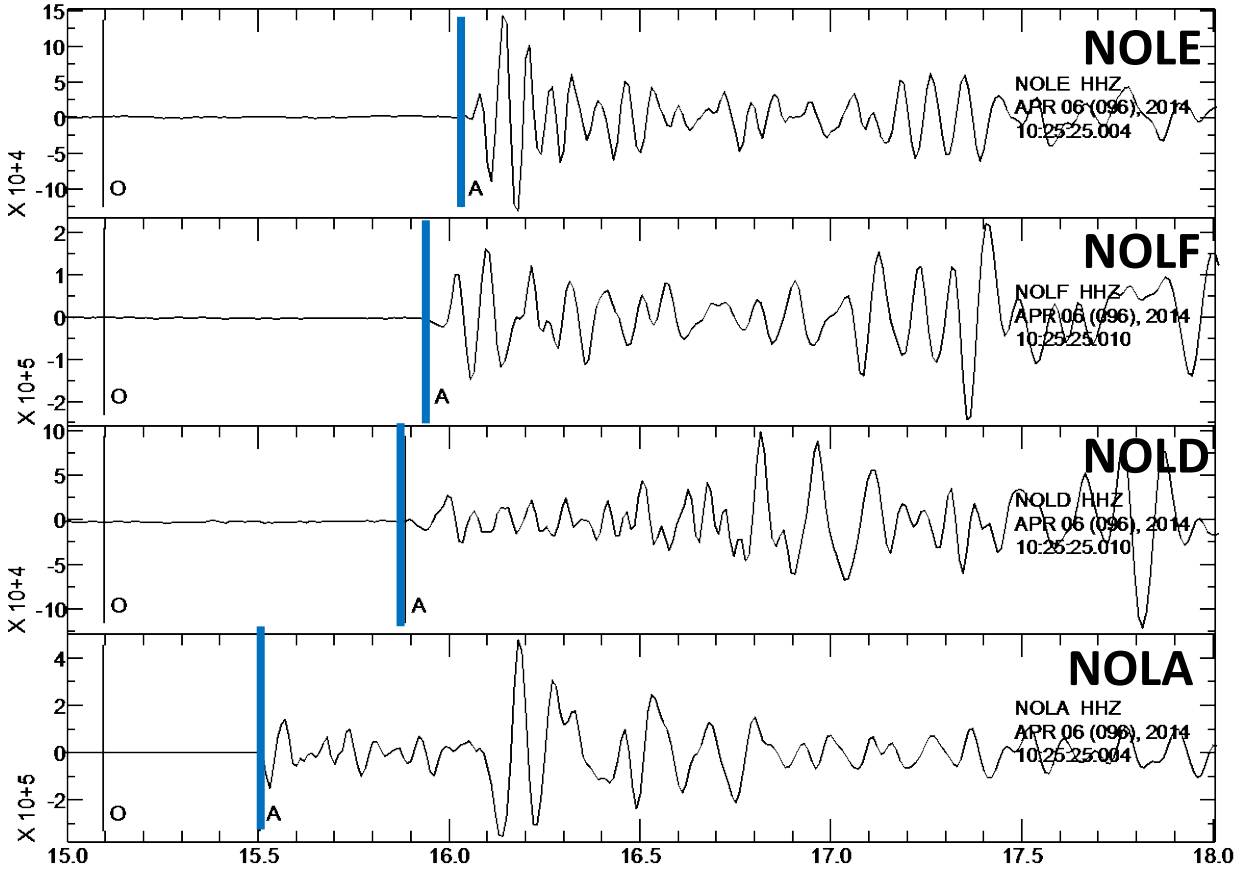
- **Constrained sources**
- 20 Markov Chains
- 500.000 models burn-in ; ~ 2 million sampled models

Data example

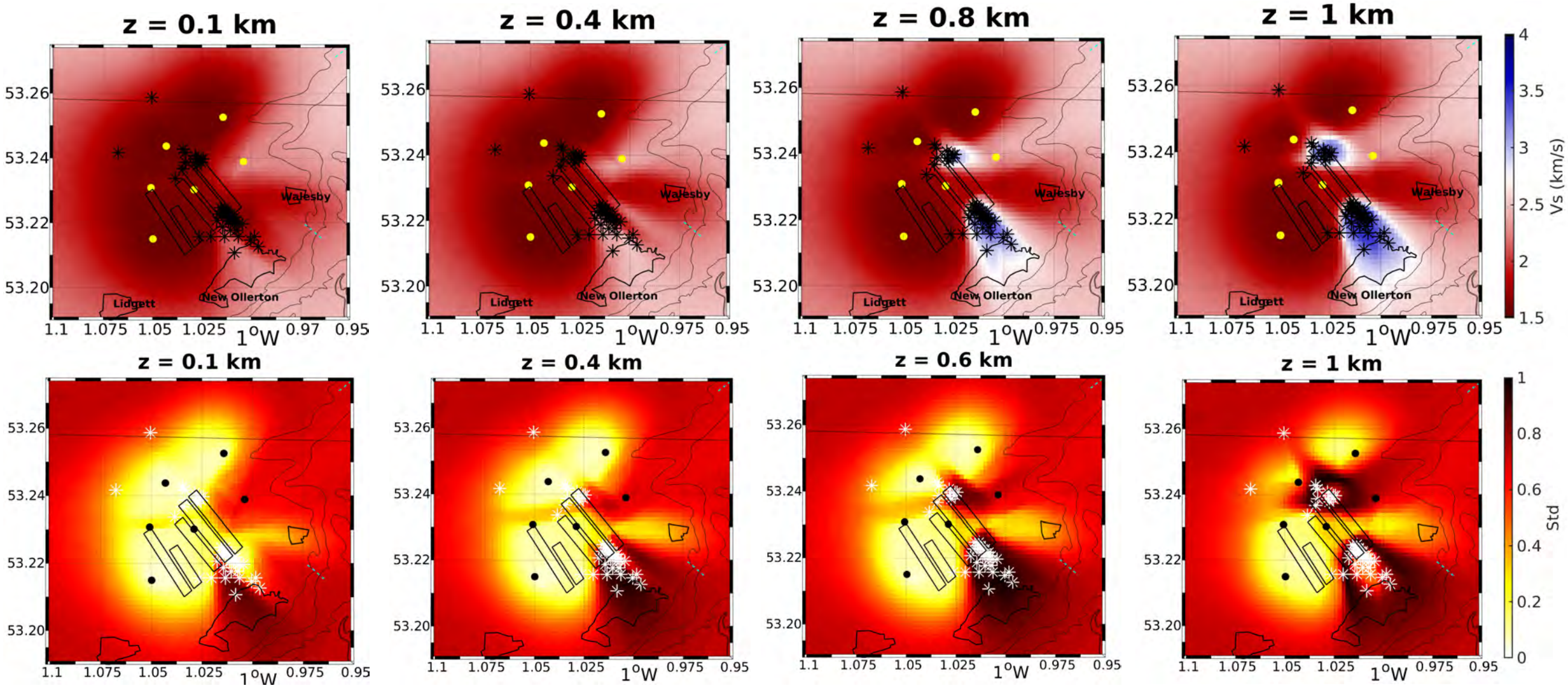
S-wave arrivals



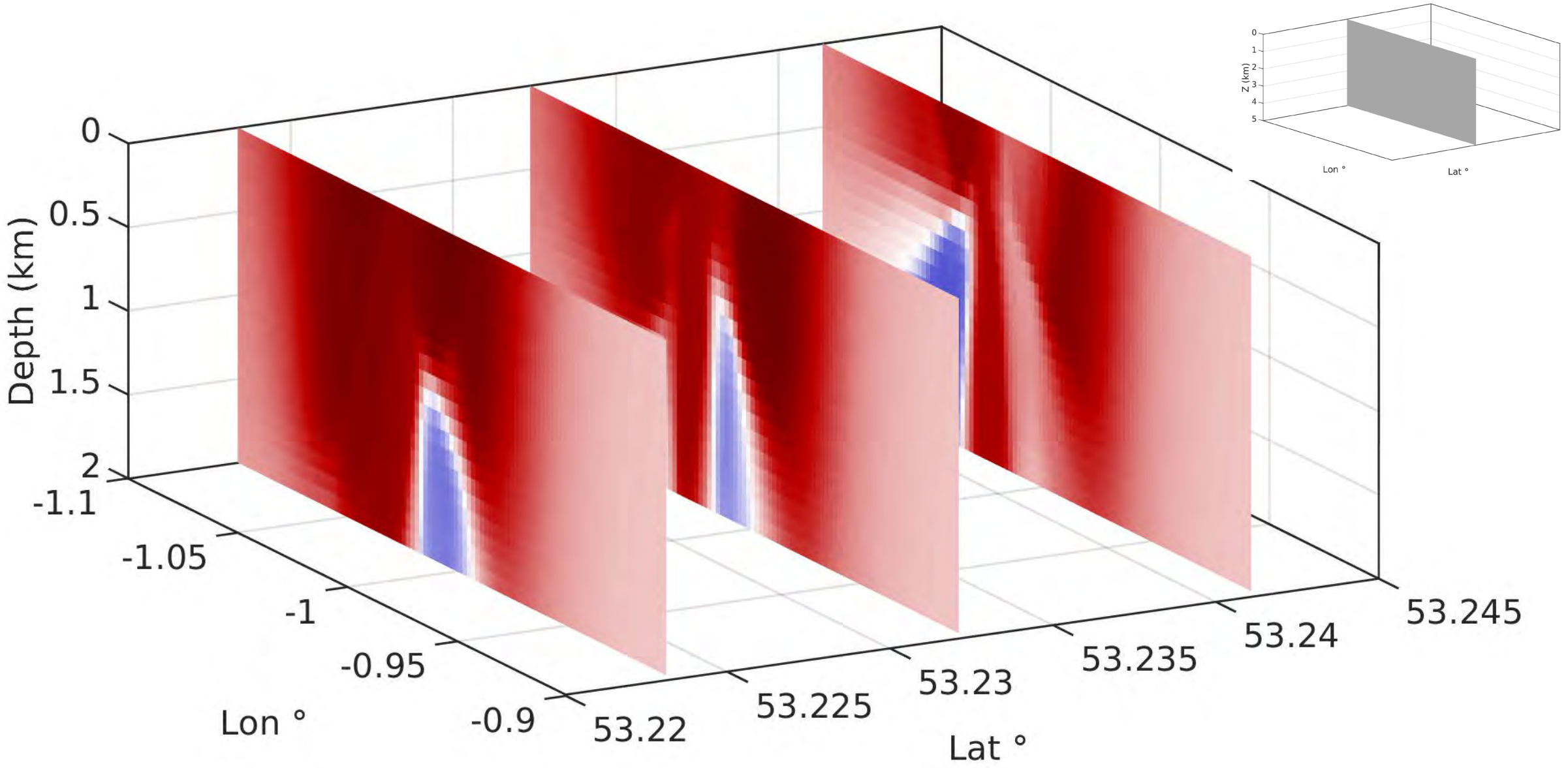
P-wave arrivals



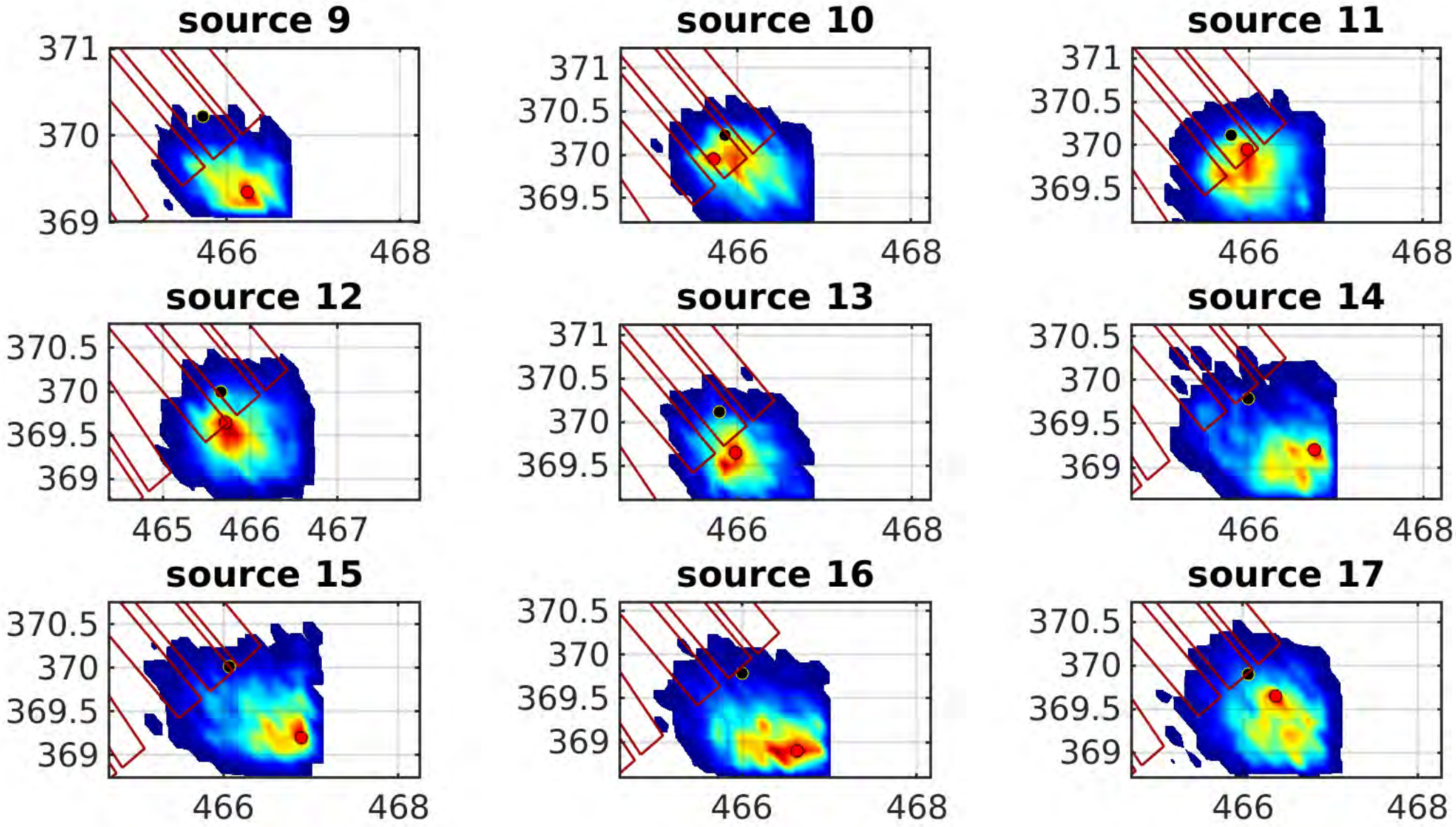
New Ollerton – Depth slices



New Ollerton – Vertical slices



Source location examples



Conclusions

- McMC body wave tomography for two synthetic tests with constrained/unconstrained source locations

  - more realistic uncertainties for unconstrained inversion

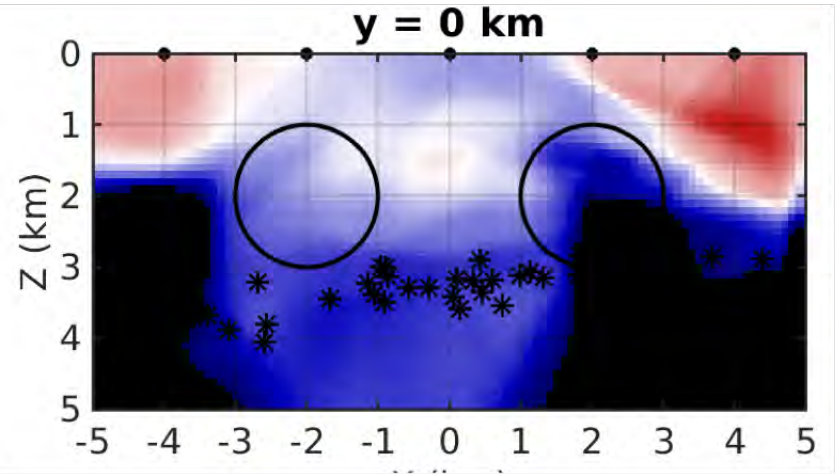
  -

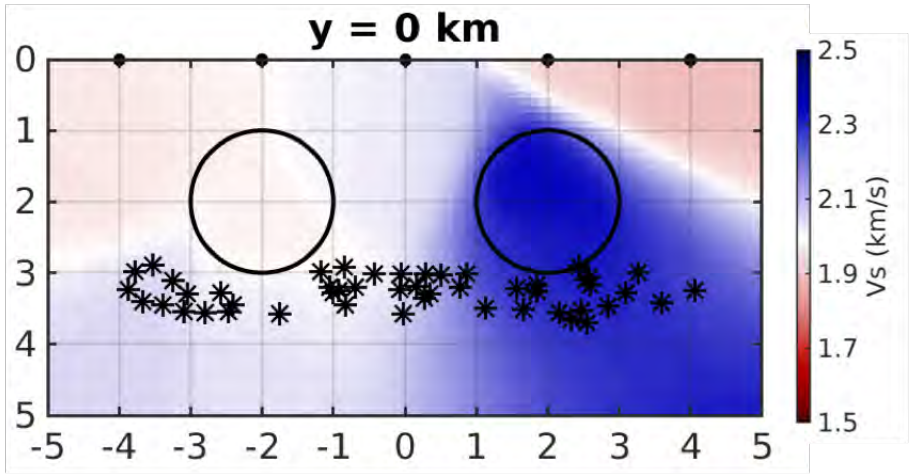
- Application to coal mine with constrained source locations
  - two fast velocity perturbations (as a result of the source constrains ?)

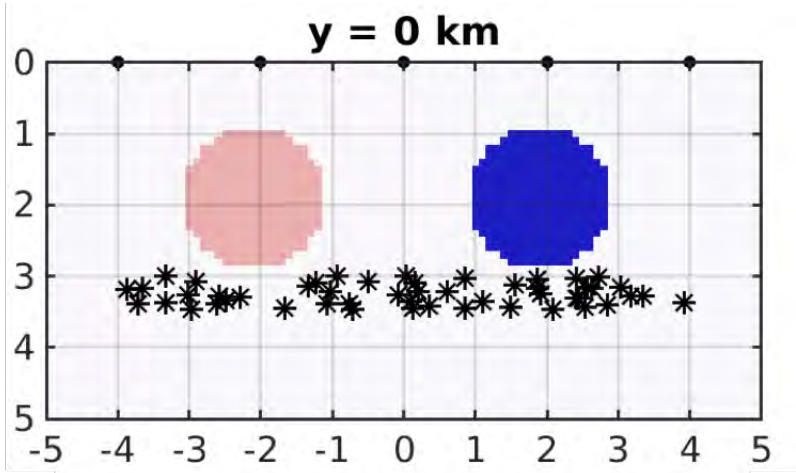
Thank you !

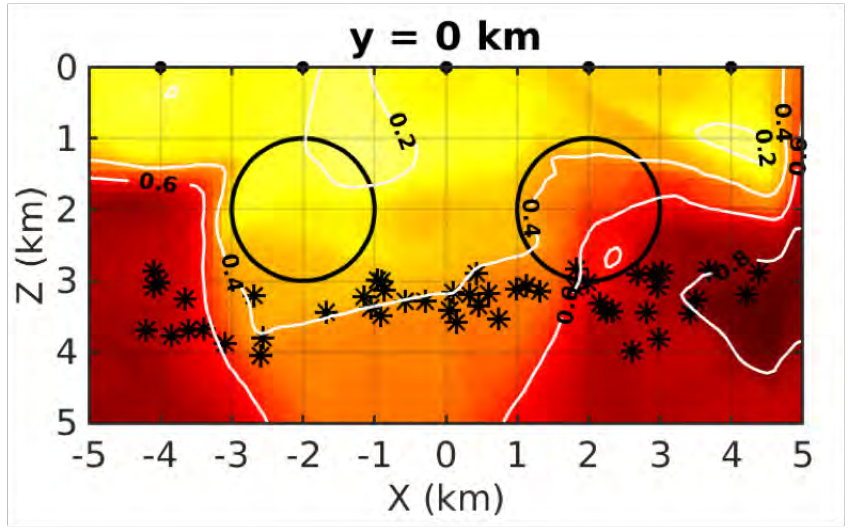
Backup

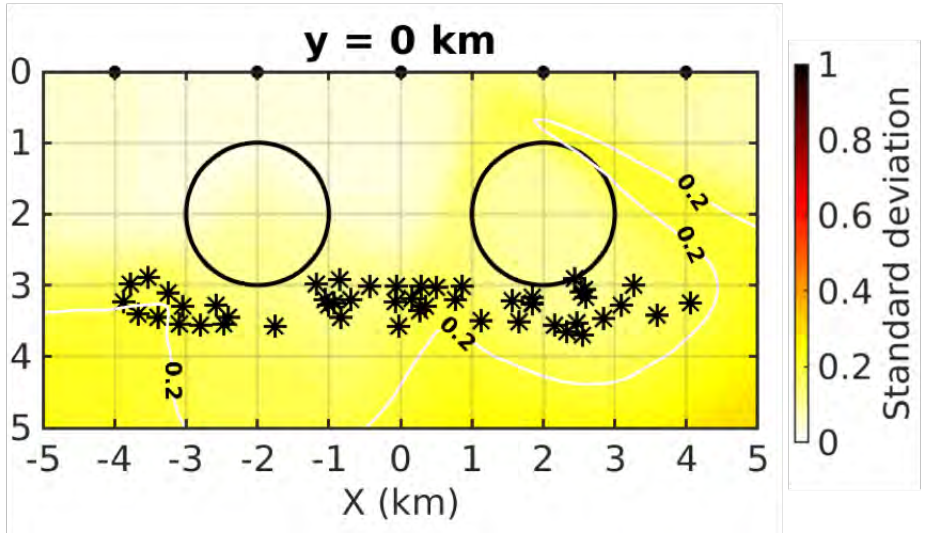
Synthetic test –

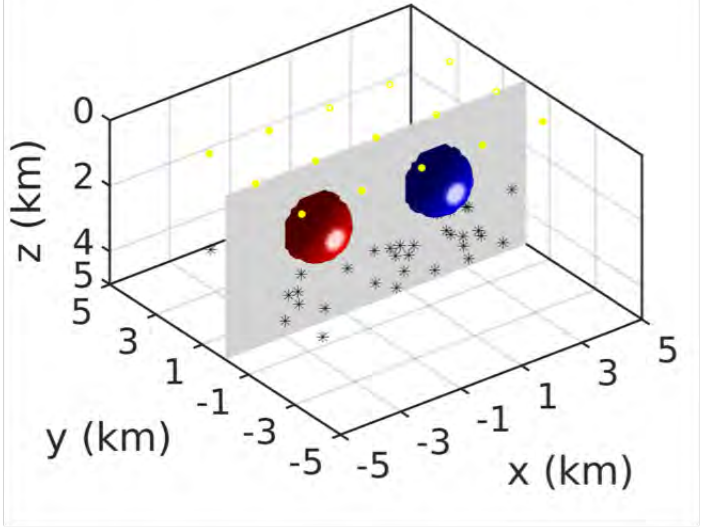




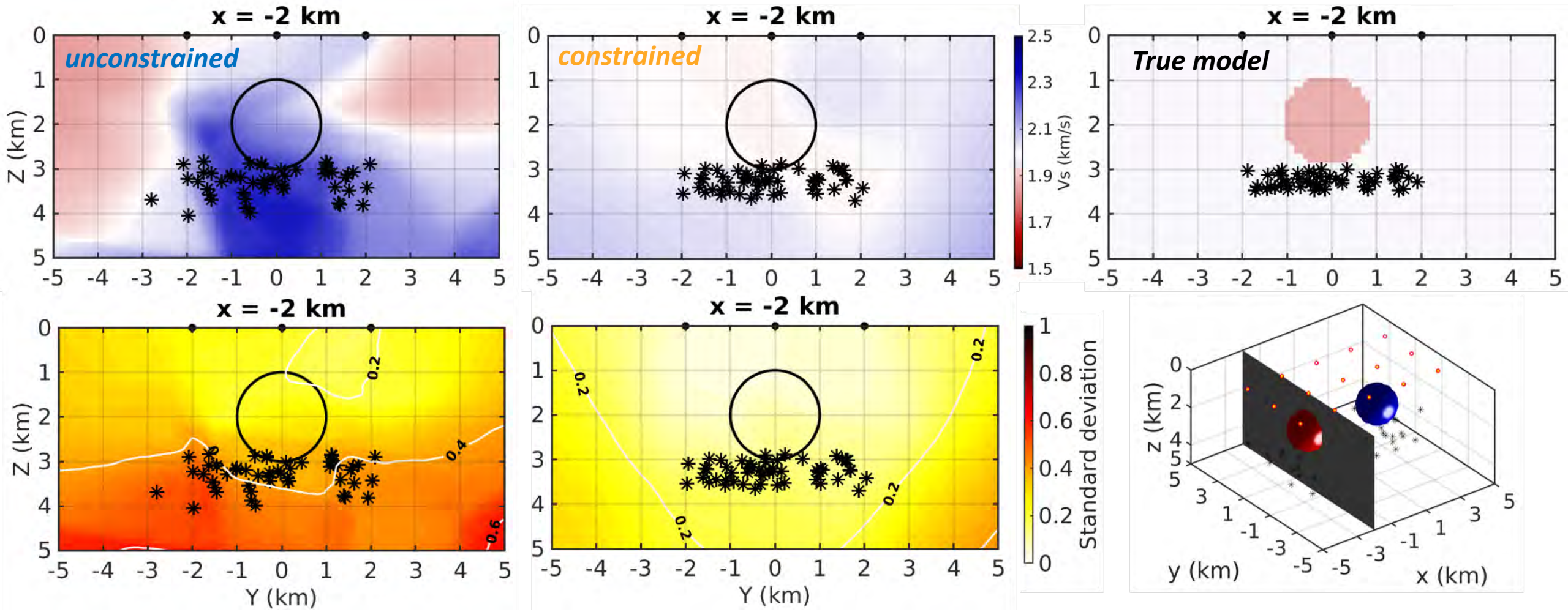




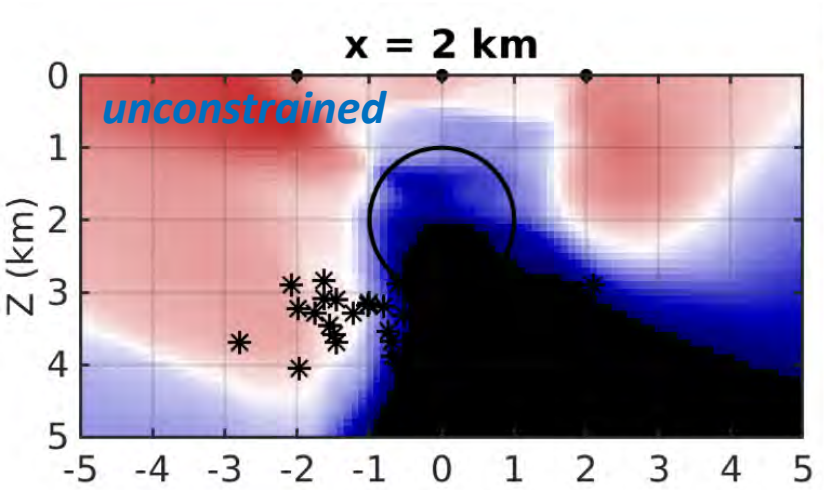


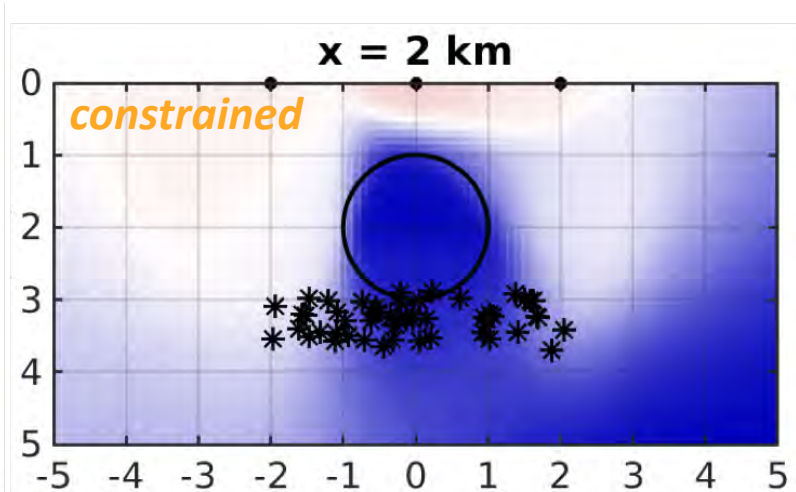


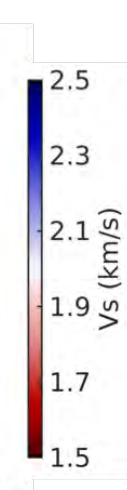
Synthetic test –

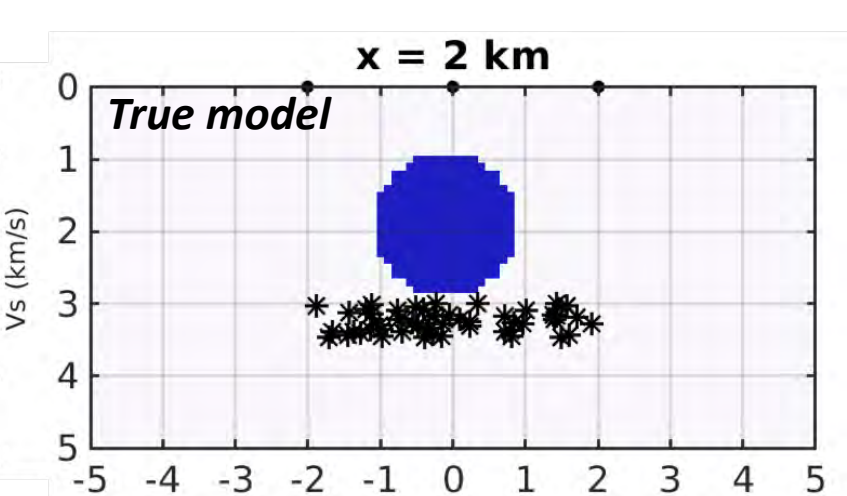


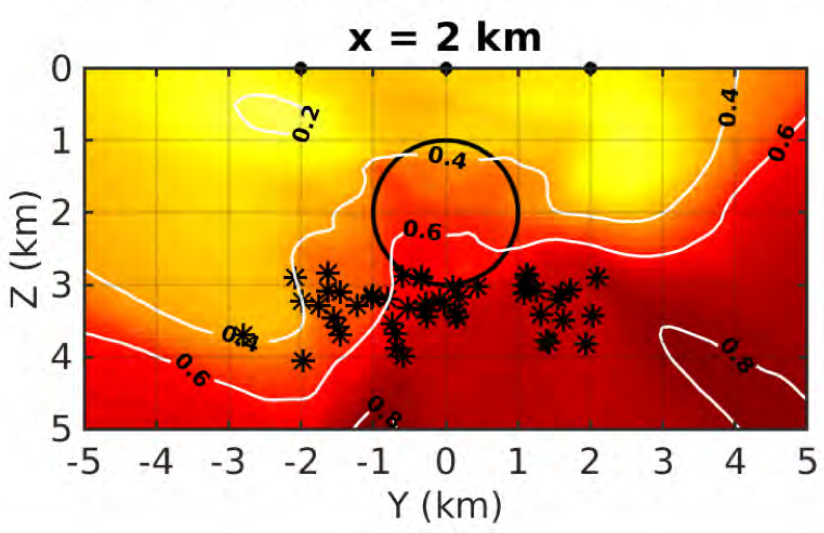
Synthetic test – Results

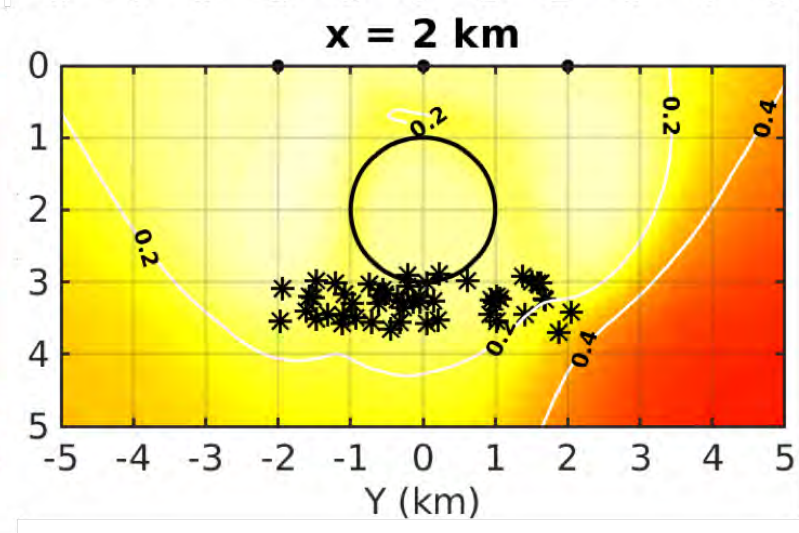


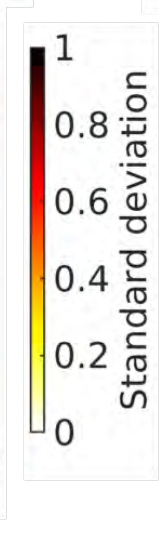


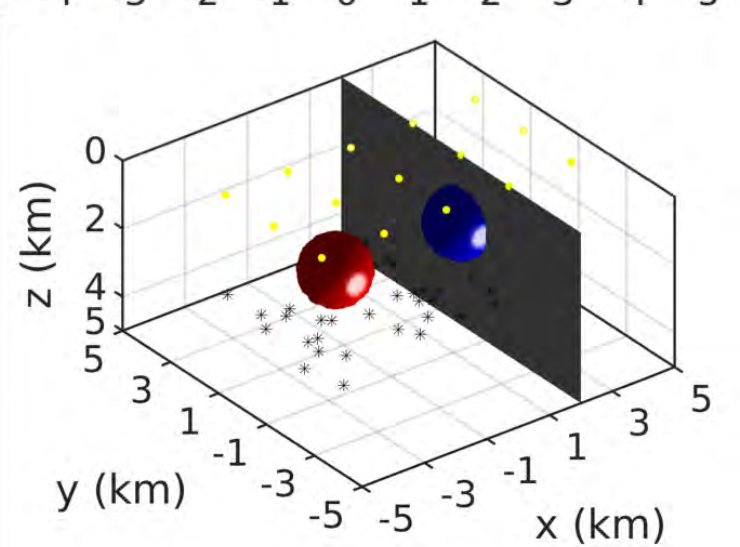




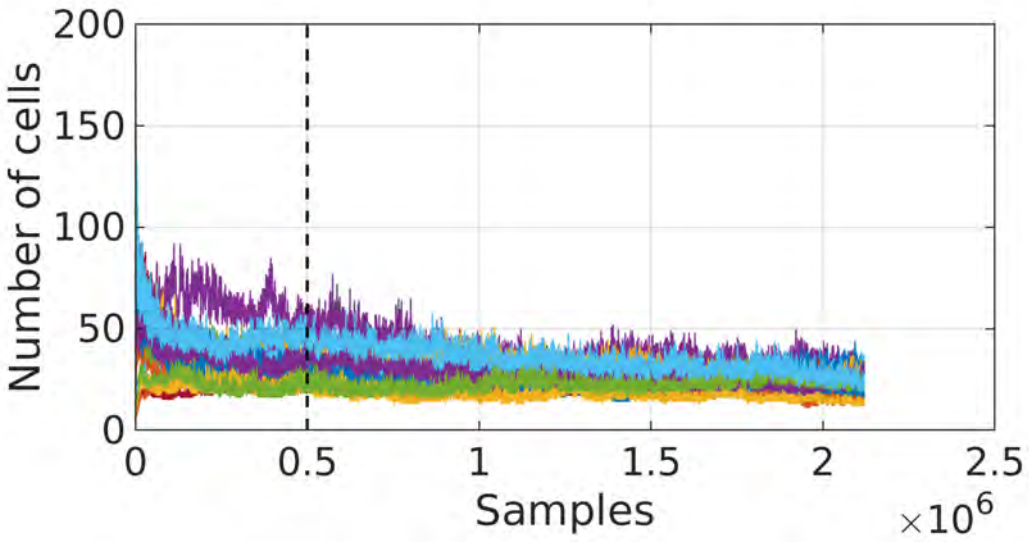


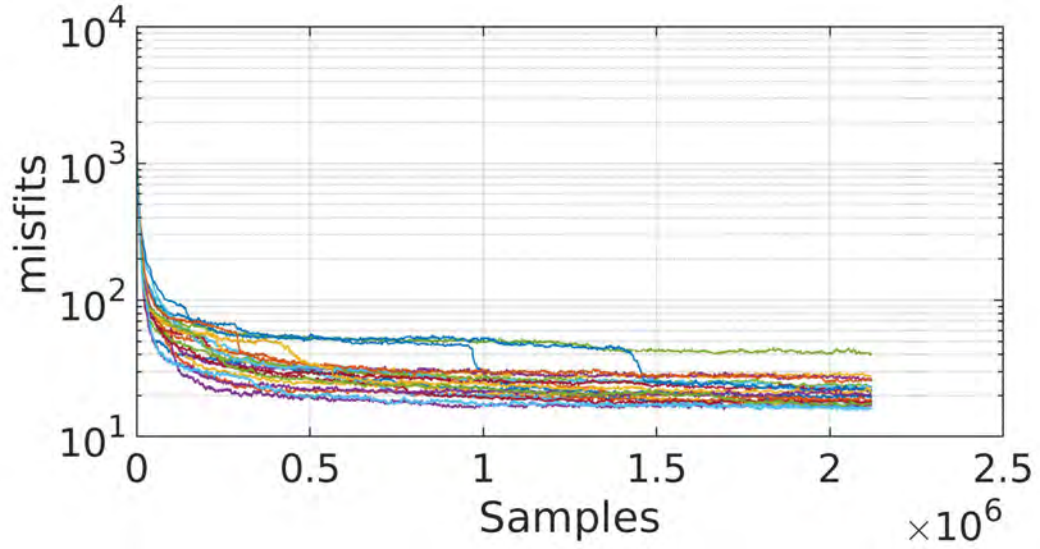






unconstrained





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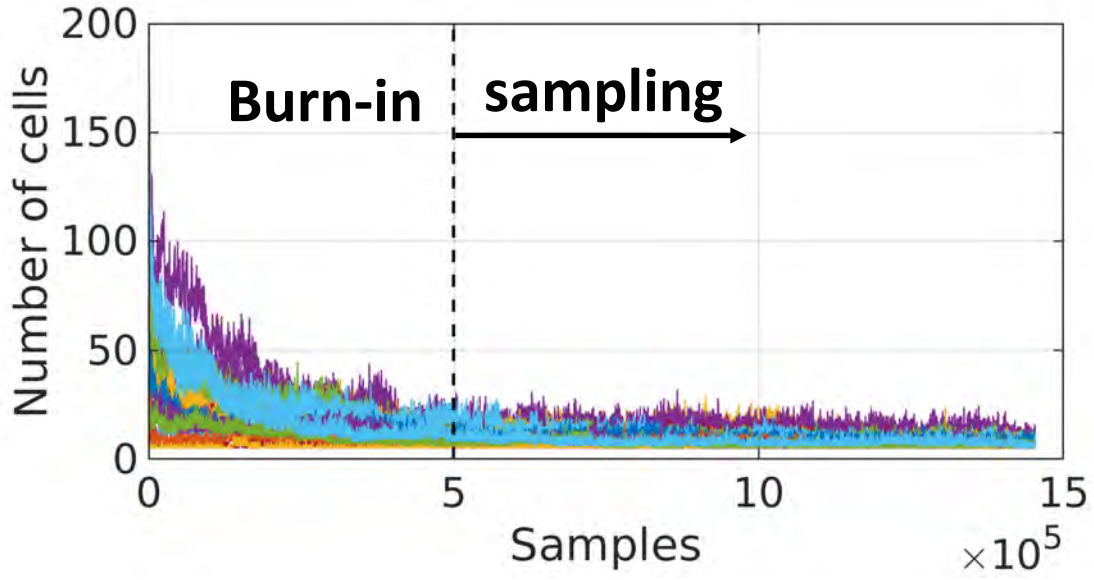
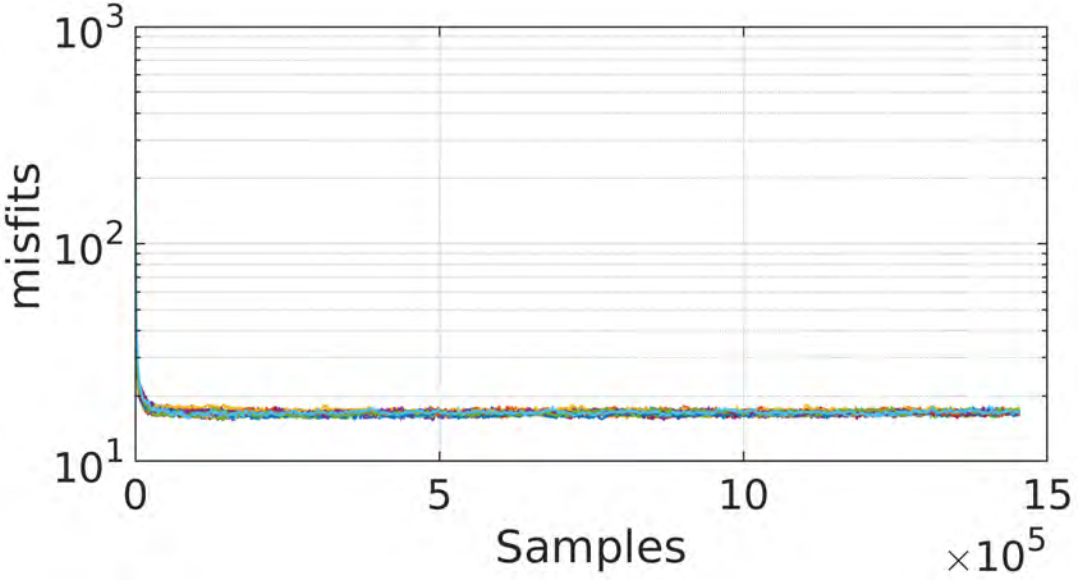
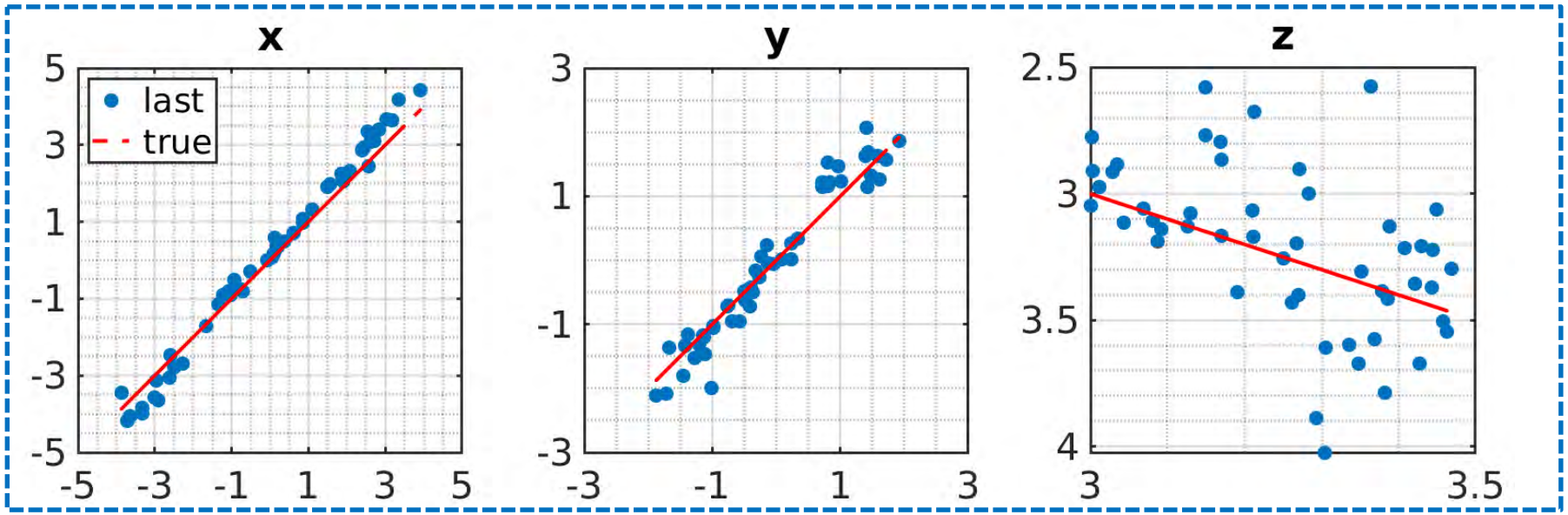
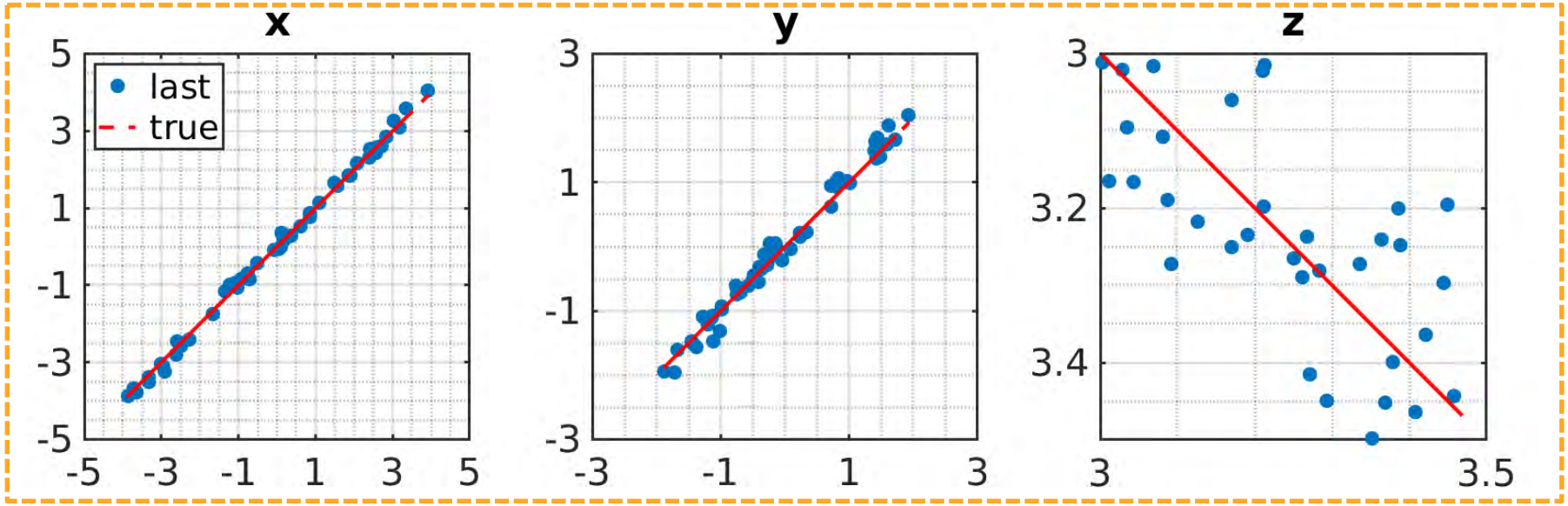




Source locations – Synthetic test

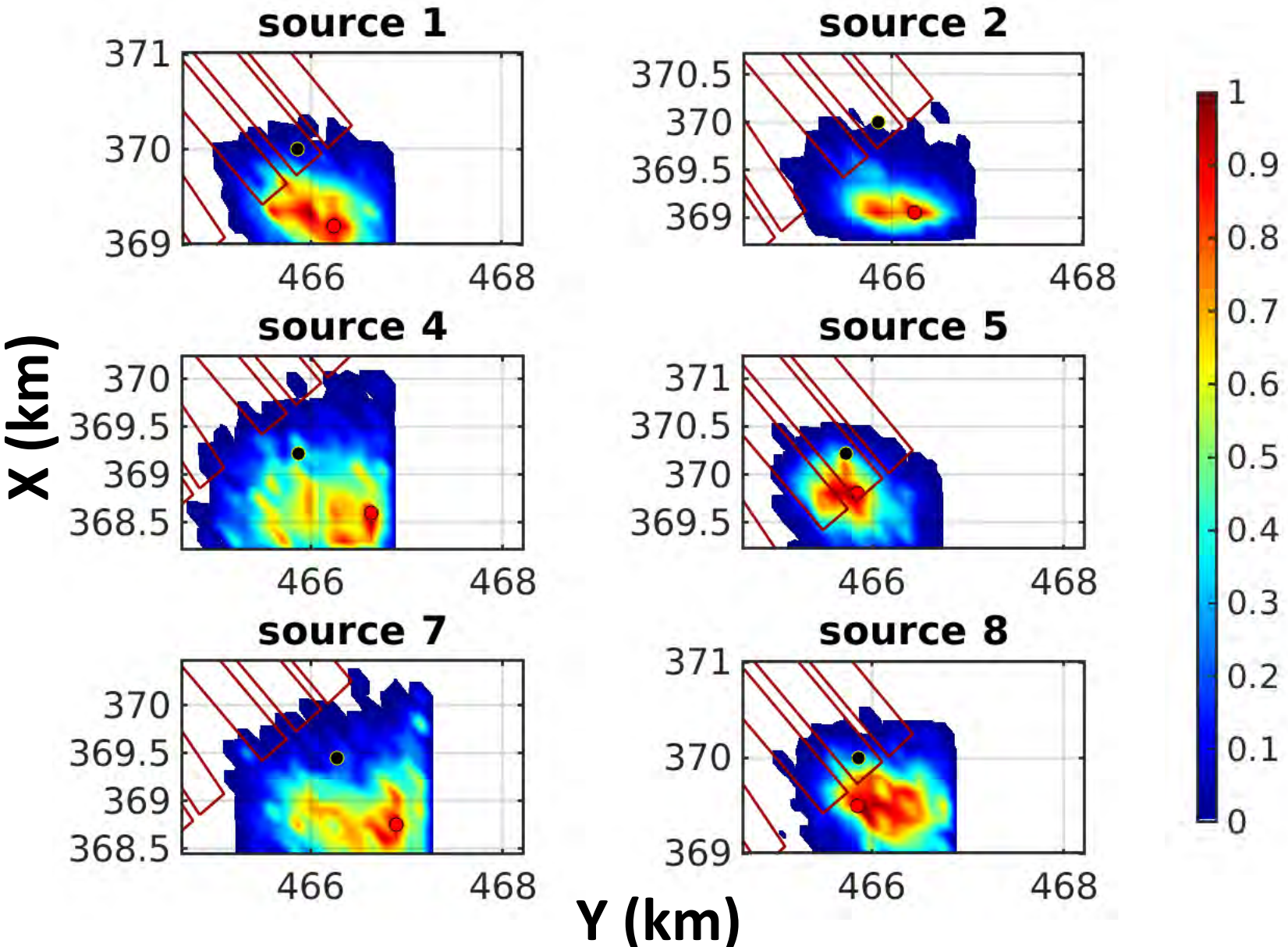


unconstrained



constrained

New Ollerton sources – xy



New Ollerton sources – xz