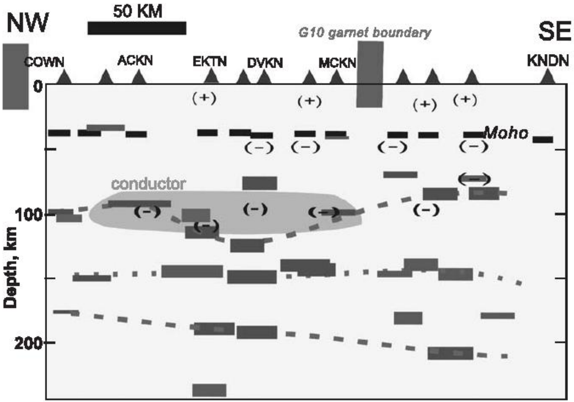
Joint inversion of receiver functions, surface wave dispersion and magnetotelluric data

M. Moorkamp[1,2], A. G. Jones[1], S. Lebedev[1], S. Fishwick[2] and E. Roux[1]

1) Dublin Institute for Advanced Studies, Dublin, Ireland
2) University of Leicester, Leicester, UK

Barcelonette, 18 June 2015

The Slave craton



Joint interpretation shows good correlation of structures (*Snyder et al., Lithos, 2004*)

Outline

The datasets

MT: Sensitive to resistivity ρ,
resolves broad conductivity structure

Receiver functions: Sensitive to changes in shear wave velocity V_S,
little sensitivity to absolute velocities

Rayleigh waves: Absolute velocity information,
resolves broad velocity structure

Two types of joint inversion

Same parameters, different methods

- Stabilize inversion
- Improve resolution
- Should sense identical structures

Different parameters, different methods

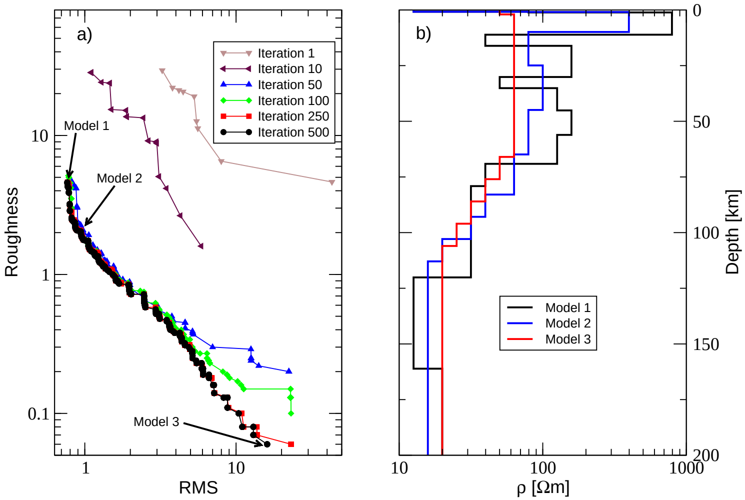
- Stabilize inversion
- Obtain more information
- Possible incompatibility

Different parameters ⇒ Need an indicator of compatibility

The inversion method

- NSGA-II (*Deb et al. 2002*): Modern multi-objective Genetic Algorithm
- Global search algorithm
- Does not require weighting of datasets
- Produces trade-off between fitting the datasets (L-curve)
- Computationally expensive

The trade-off curve

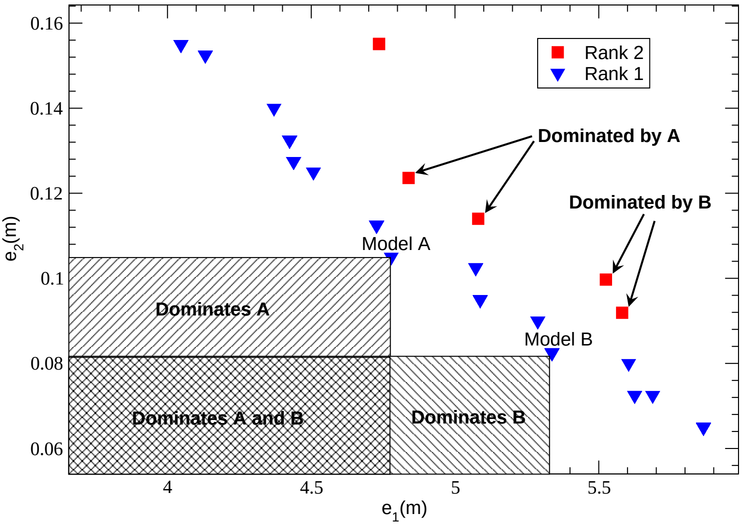


Setting up the inversion

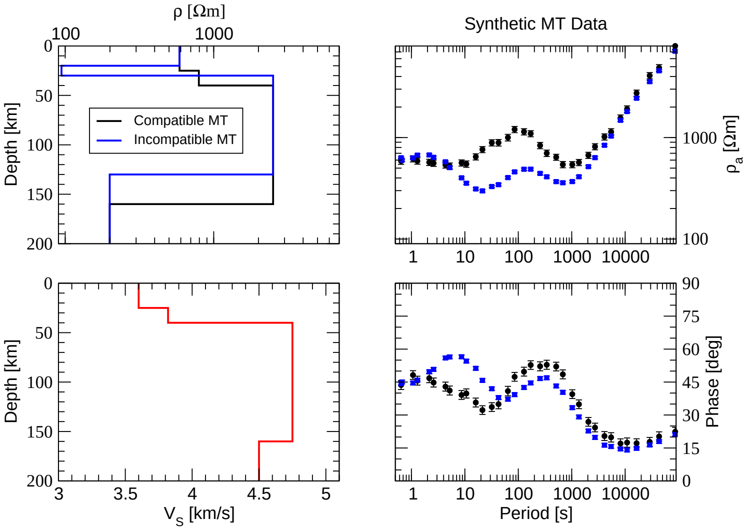
- 1D inversion of Magnetotelluric, receiver function and surface wave dispersion data
- Invert for resistivity ρ, S-wave velocity v_s and layer thickness t.
- Layer thickness is the same for seismic and MT forward model
- No direct relationship between ρ and v_s assumed

Dominance

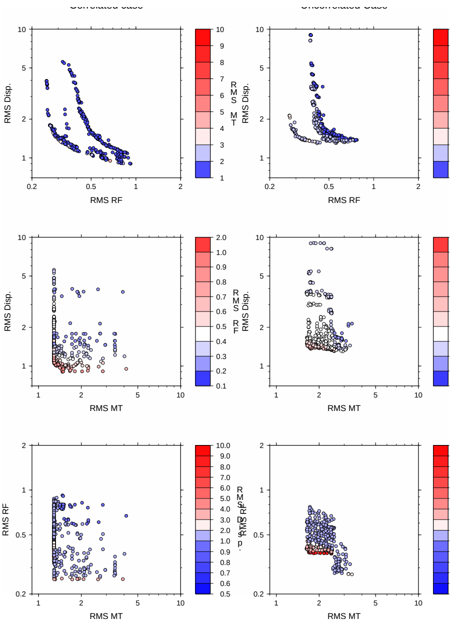
Illustration of dominance



A test with synthetic data

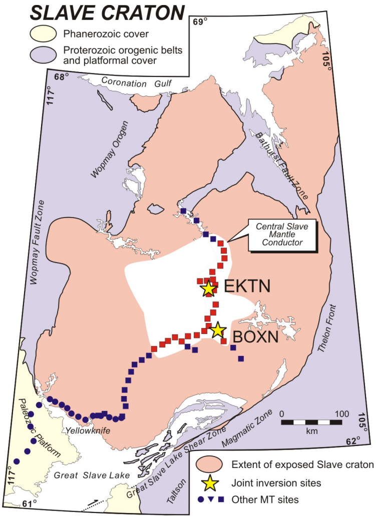


Trade-off for synthetic data



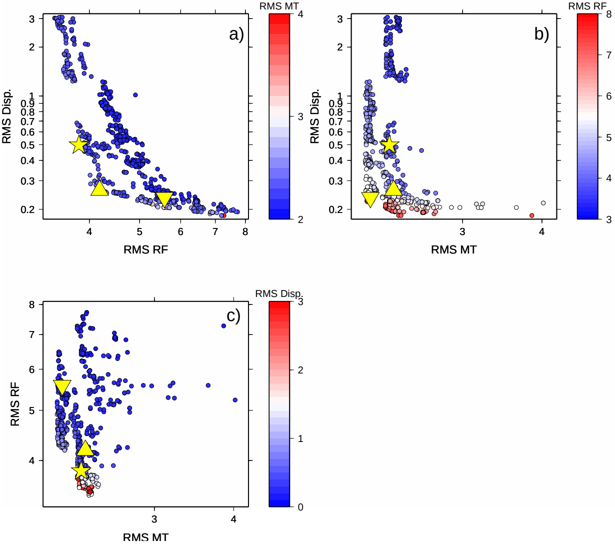
- Trade-off indicates noise
- Can be used to identify compatibility

The Slave craton

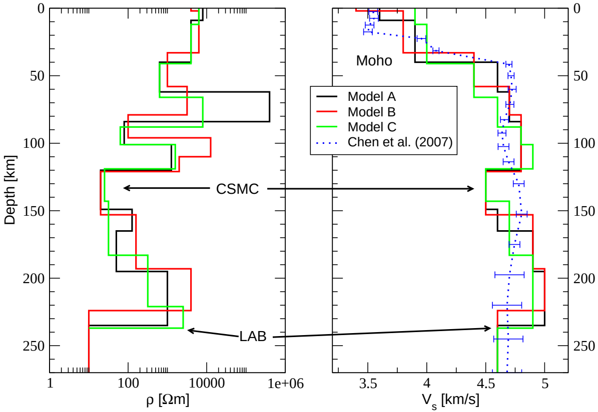


- Site EKTN located on CSMC
- Good data quality for all datasets
- Only weak 2D effects for MT

Examining the trade-off

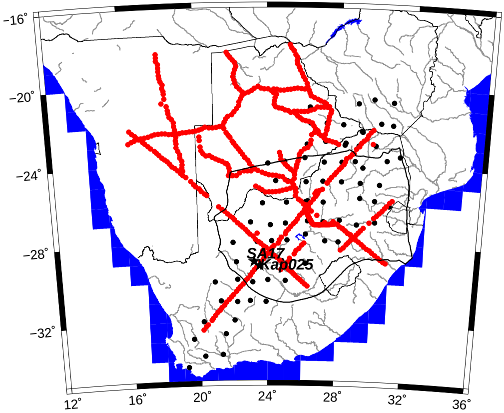


A joint model



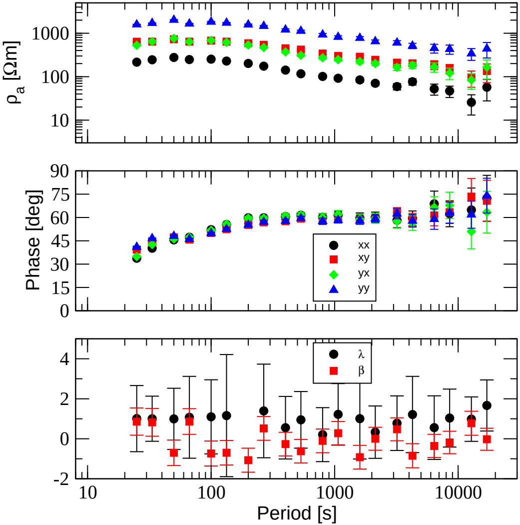
- Similar to results im *Moorkamp et al.*, 2007
- Less pronounced low velocity zone
- Poor crustal velocity resolution

The SAMTEX and SASE experiments



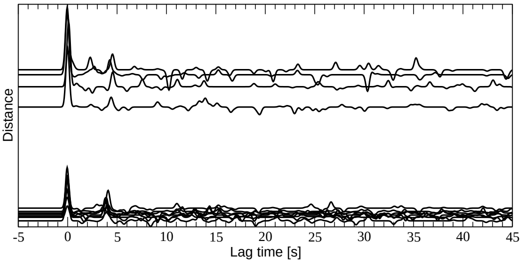
- SAMTEX: > 550 MT sites
- SASE: 80 seismic sites
- Cover most of Kaapvaal Craton and adjacent terranes

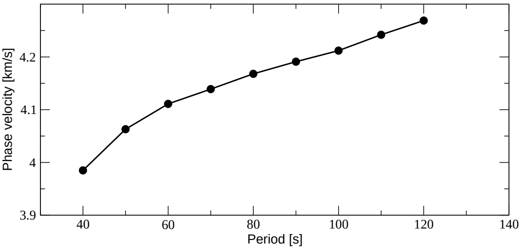
MT data



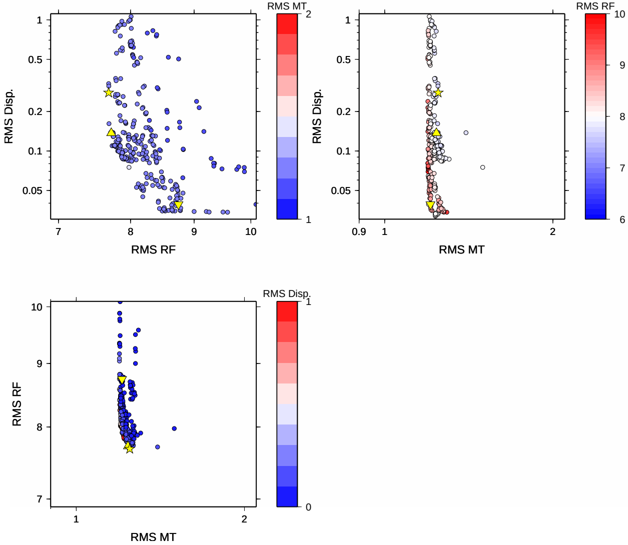
ρa [Ωm]
1000
100
10
Phase [deg]
90
75
60
45
30
15
0
xx
xy
yx
yy
λ
β
4
2
0
-2
10
100
1000
10000
Period [s]

Seismic data

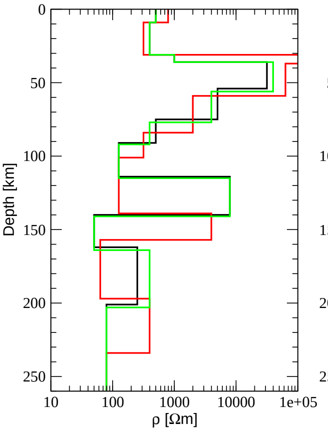




Looking at the trade-off



A joint model for site KAP25



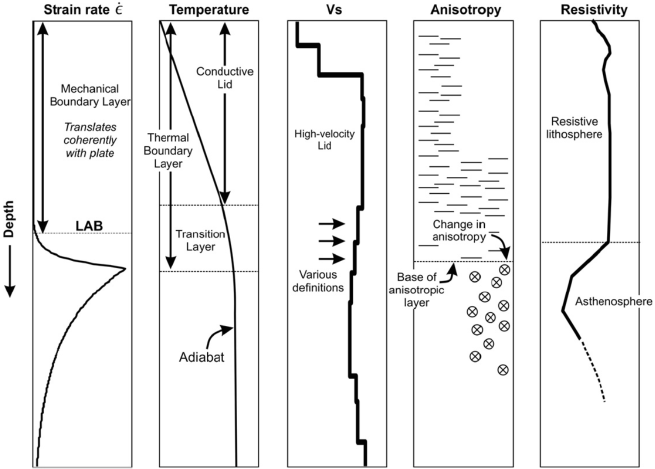
Similar low velocity, low resistivity zone as in the Slave Craton.

The LAB

The lithosphere-asthenosphere boundary is defined in a variety of ways

Elastic:	Rigid layer that move coherently and supports the load.
Thermal:	Conductive vs. convective regime (depth to adiabat)
Seismic:	Low velocity zone or change in anisotropy
Electrical:	Conductive zone under resistive layer

The LAB



Eaton et al., 2009

Should all methods show the same depth?

Yes ! Because

- LAB is transition from elastic to plastic deformation.
- Plastic because it melts.
- Plastic deformation $\rightarrow$ onset of convection
- Melt lowers seismic velocity, olivine aligns for anisotropy
- Melt is conductive

Should all methods show the same depth?

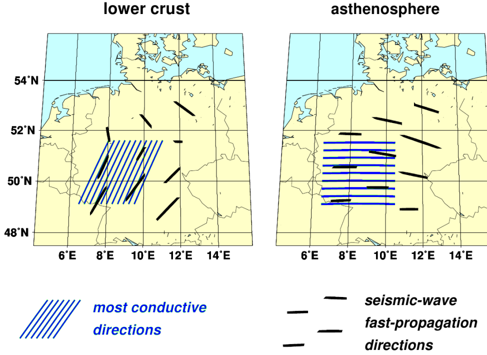
No ! Because

- Elastic thickness comes from estimates of load
- There probably is a transition layer
- There is more than just melt: water.
- Picked up differently by different methods.

But also

- We compare results from methods with different parametrization, regularization, resolution
- Do not have good estimate of model uncertainty.
- Joint inversion can help to test hypotheses

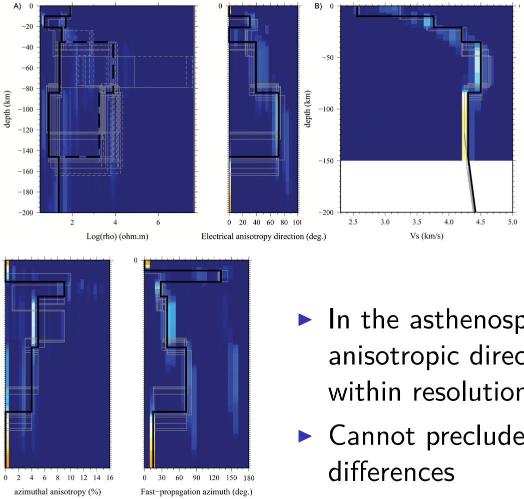
Observations in Germany



Lebedev 2007, Gatzemeier und Moorkamp 2005

- Roughly coincident directions of anisotropy
- Electrical anisotropy: 100–150 km
  Seismic anisotropy: 80–200 km

Anisotropic joint inversion



- In the asthenosphere anisotropic directions match within resolution
- Cannot preclude 5-10° differences

Roux et al. 2012

Conclusions

- Joint model reproduces known features of the Slave Craton
- No coincident seismic and electric Moho, but coherent CSMC
- Kaapvaal Craton data generally compatile within noise level
- Noise makes interpretation of Kaapvaal model difficult

Code is openly available at `gplib.sourceforge.net`

Some Ads

"Integrated Imaging of the Earth: Coupled Inversion of Multiple Geophysical Data Sets Across the Earth Sciences", book to be published by AGU and Wiley, Fall 2015

Conference **February 11/12 2015**, Burlington House London http://www2.le.ac.uk/departments/geology/news/new-advances-in-geophysics-2016