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Joint inversion of gravity and electromagnetic data — New constraints on the 3-D structure of the lithosphere beneath Central Mongolia

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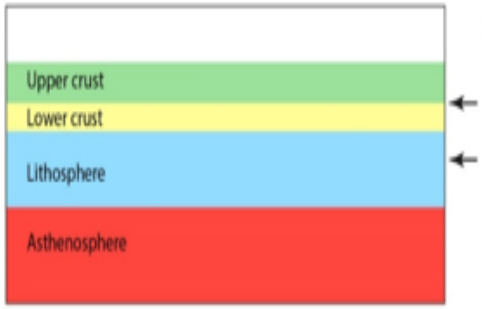
Goal: to better understand the evolution of the lithosphere

Input → Simulation → Output ↔ Evaluate

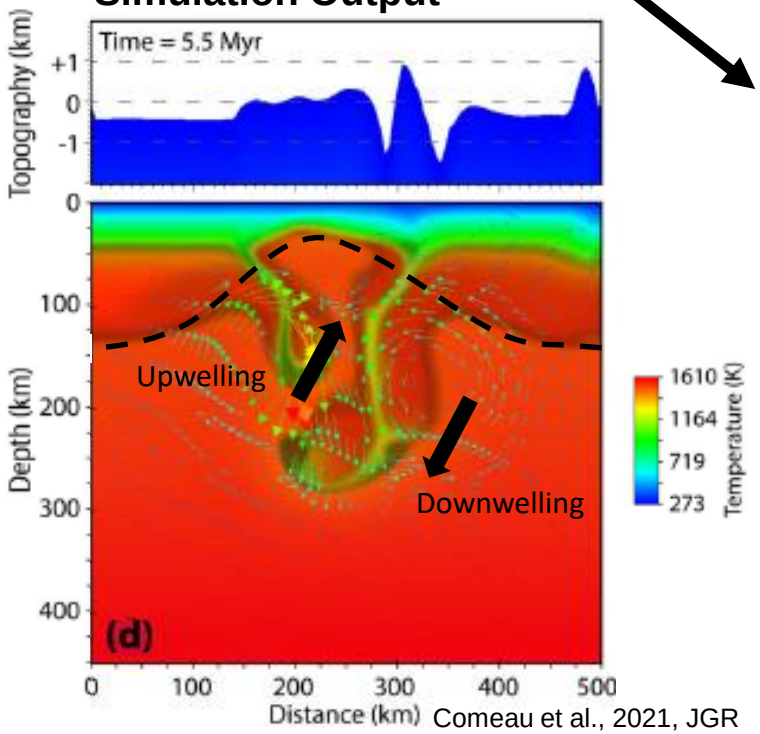
- Geodynamic modelling:
  -can provide valuable insights by simulating the temporal evolution of dynamic tectonic processes (opportunity to test various hypotheses)
- Critical point: Evaluate simulations against **reliable constraints on lithospheric properties**
- **Delamination-induced surface uplift**

Multiple models? (e.g., from Electromagnetics, from Gravity, etc)
Joint inversion / constrained inversion gives more cohesive model

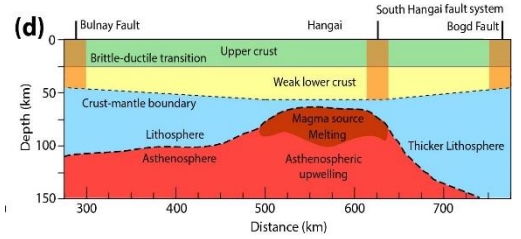


Input:
Density
Viscosity
Velocity
Temperature

Simulation Output



Comeau et al., 2021, JGR



Model to evaluate against

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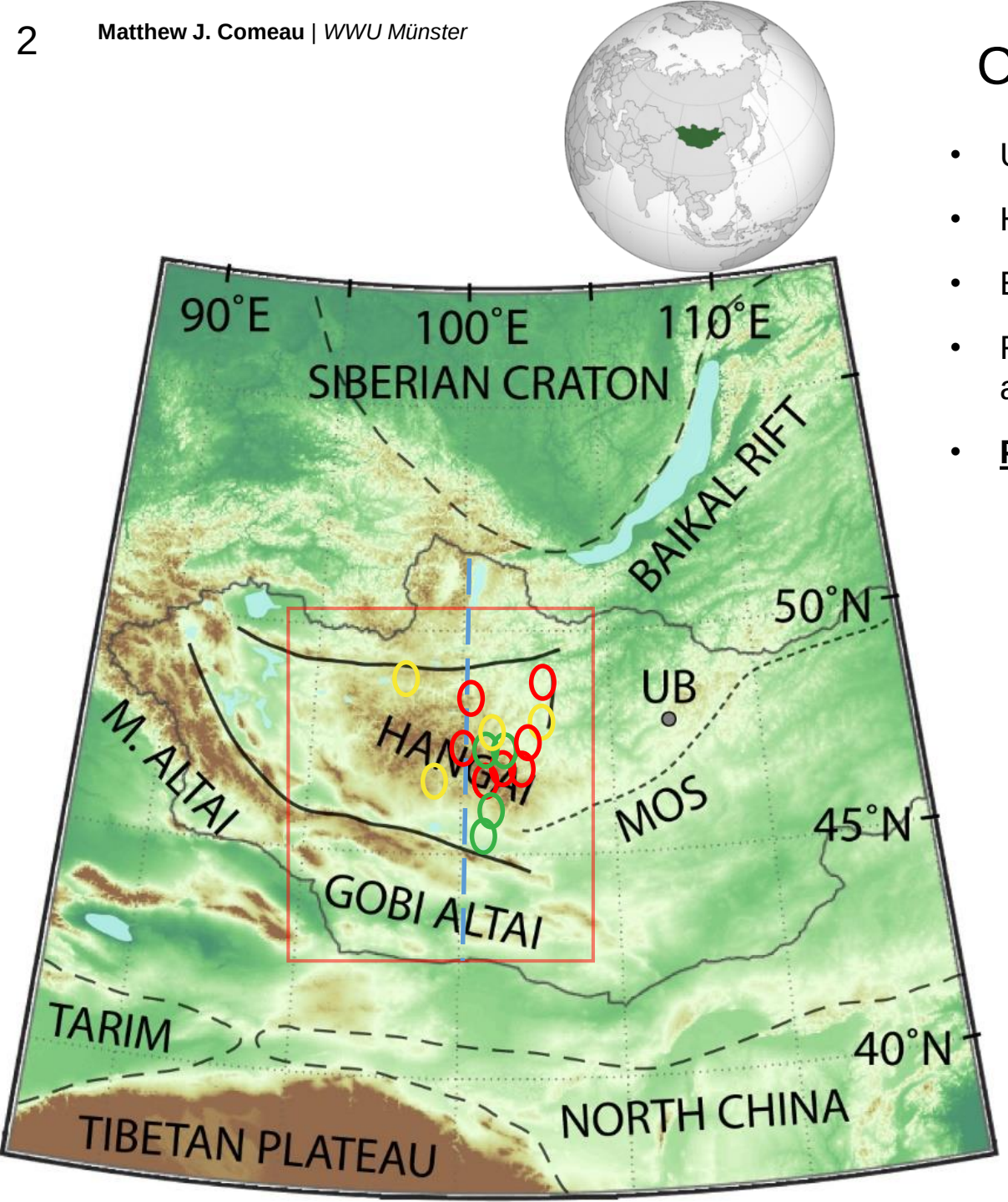
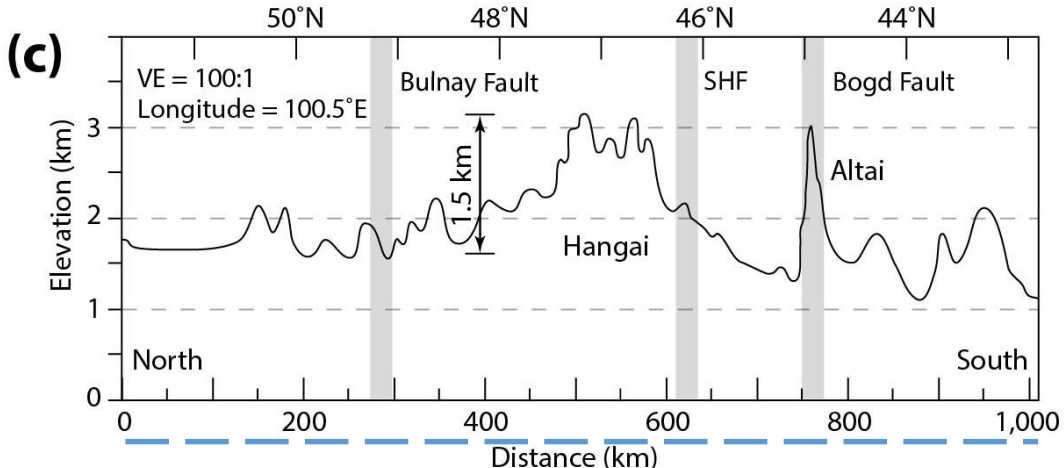
Case study: Central Mongolia

- Unique position between Siberian craton and China/Tibetan Plateau
- Hangai Dome: intracontinental plateau; far from tectonic margins
- Enigmatic intracontinental volcanism (~2-8 ka to ~35 Ma)
- Rich set of geological, geochemical,
  and geophysical data (electromagnetics, seismic, gravity, magnetics…)
- **<u>Present-day lithospheric structure is open question</u>**



Ancuta et al., 2018



Joint inversion toolbox

Travel time tomography

Rayleigh wave dispersion

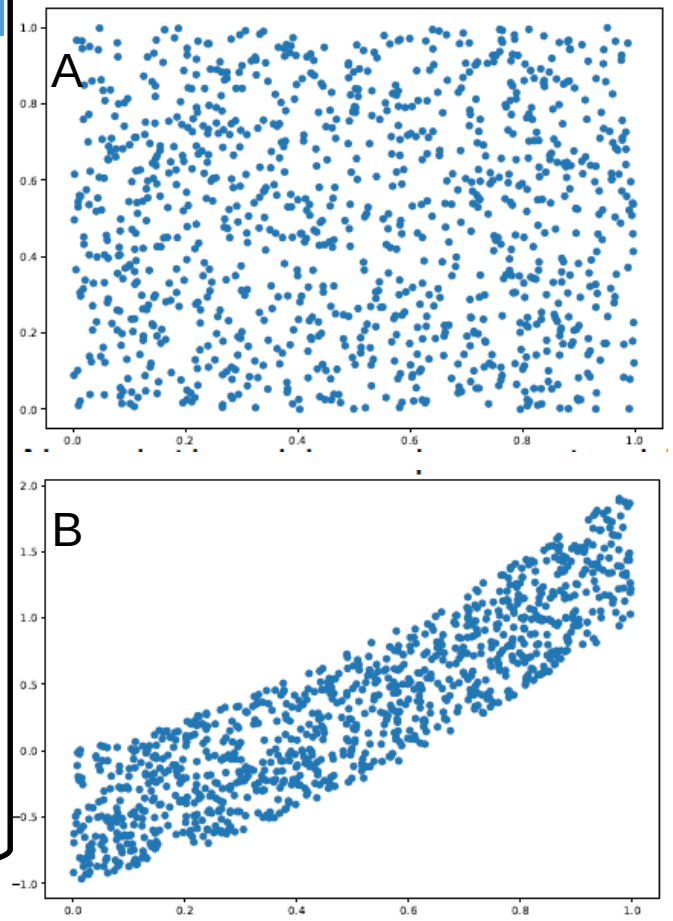
Magnetotellurics

Gravity

Total field magnetics

DC resistivity

jif3D



Max Moorkamp

jif3D: Joint inversion framework in 3D (Moorkamp et al, GJI 2011)

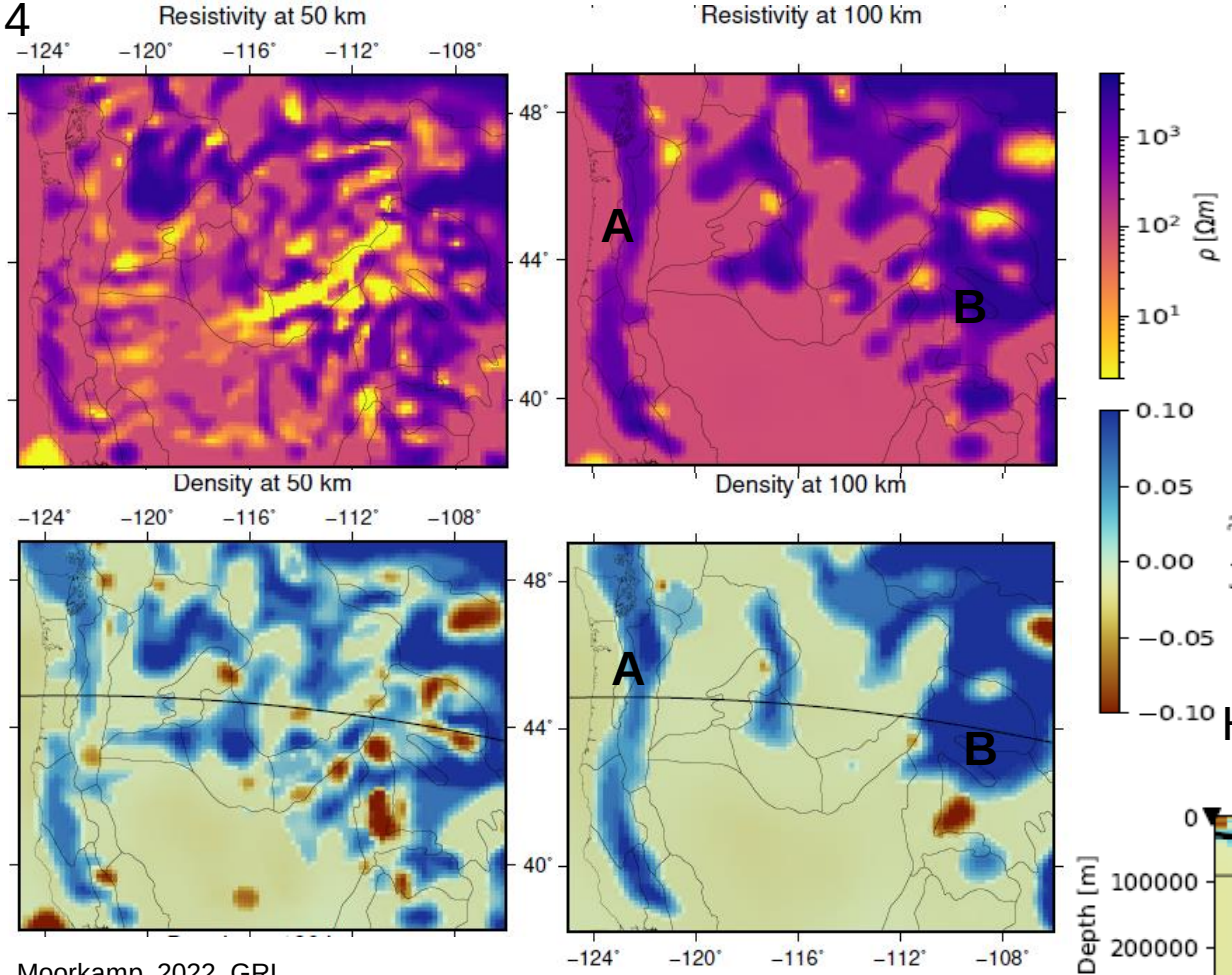
- Parallel computations
- Flexible to incorporate new methods
- Arbitrary combinations possible

- Coupling
- Direct parameter relationship
  -Possible, if known, not used
- Cross-gradient
  -Most popular approach
  requires directions of changes to match
- Mutual information
  -Novel
  -Medical imaging technique
  -Measures amount of information
  contained in variable X about variable Y

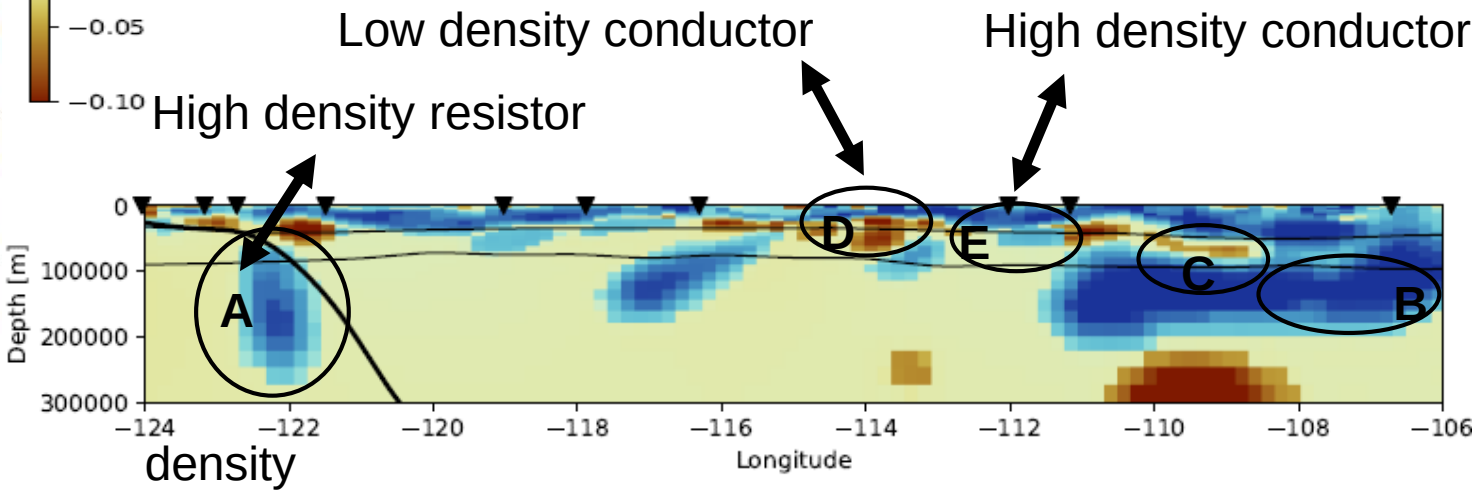
-No relationship -> low mutual information
-Variable relationship / trend
→ higher mutual information
-Not 1-to-1

Example: North America

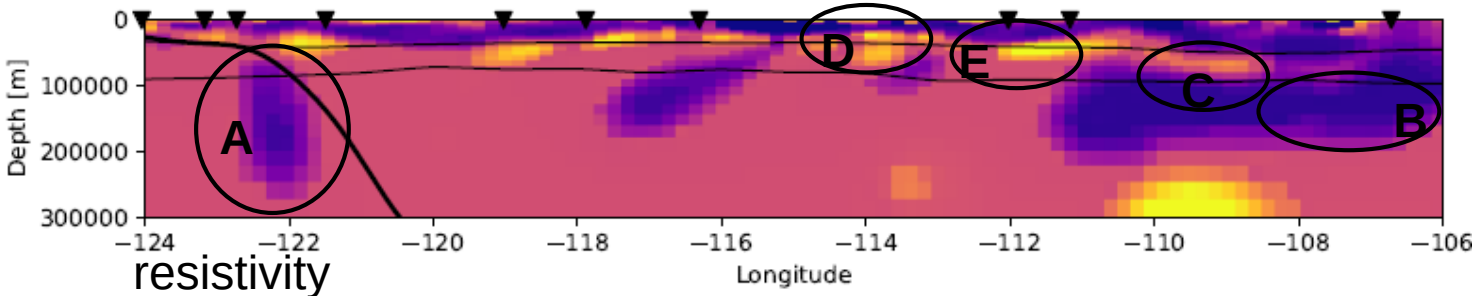
- Electrical conductivity & Density joint inversion using **Mutual Information** approach



Moorkamp, 2022, GRL



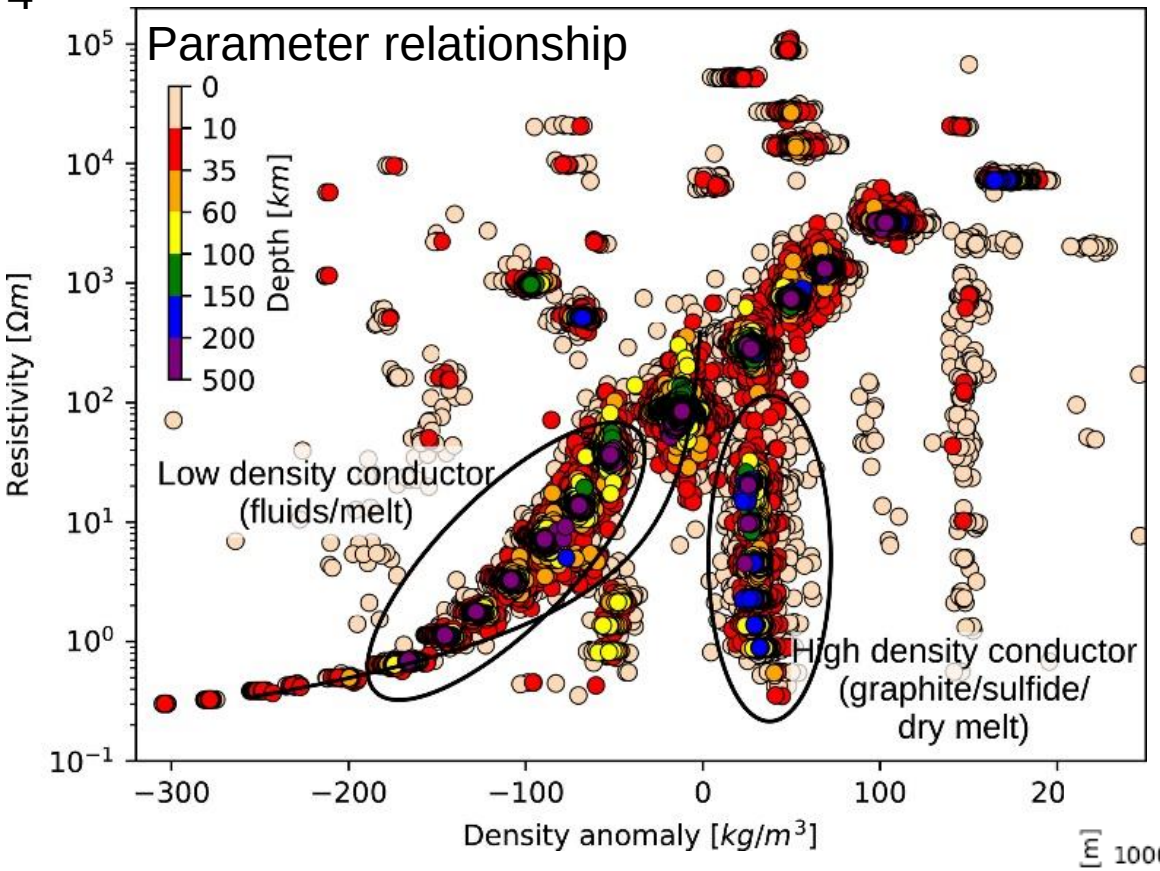
density



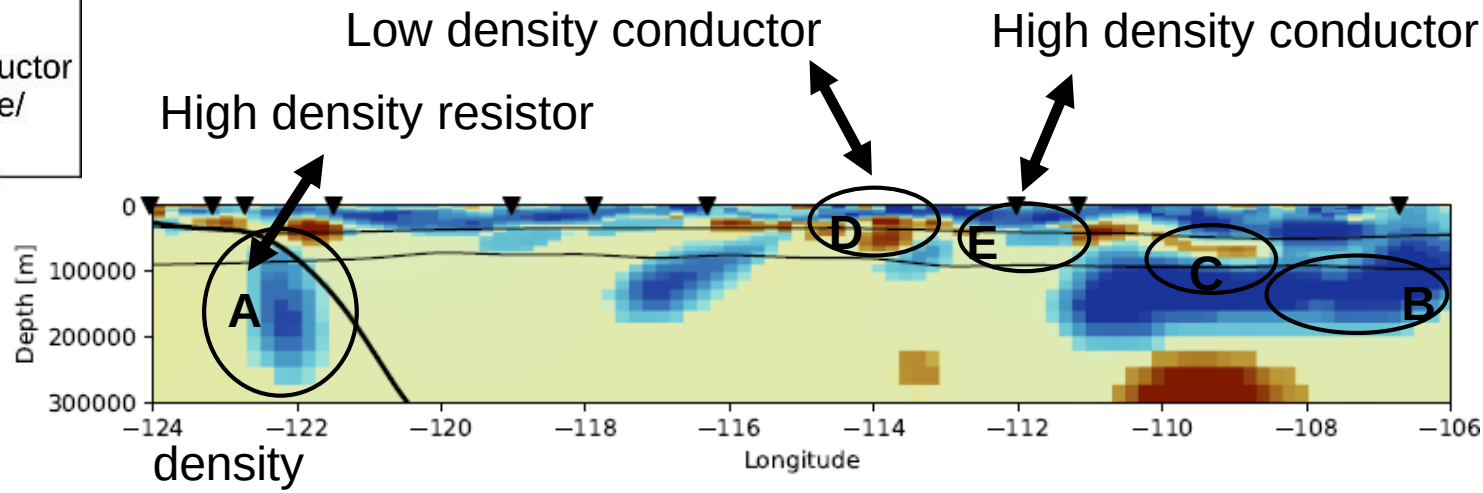
resistivity

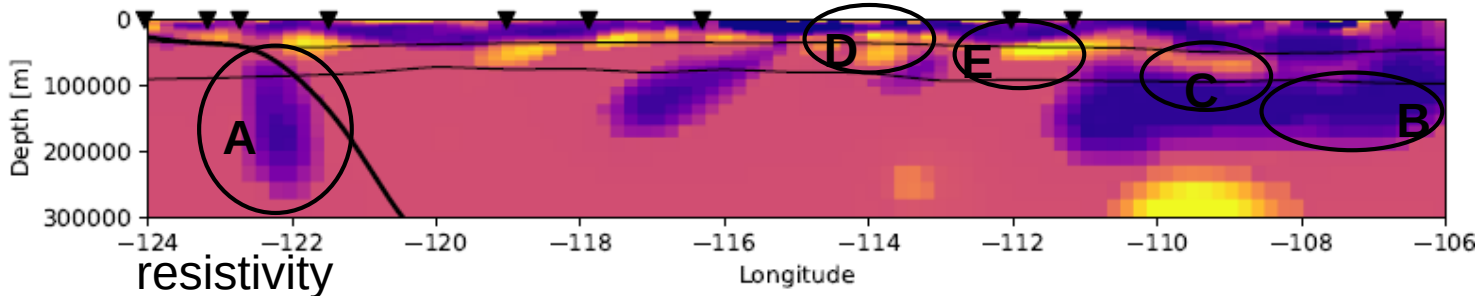
Example: North America

- Electrical conductivity & Density joint inversion using **Mutual Information** approach
- What can we learn? → Helps to interpret results!



Moorkamp, 2022, GRL





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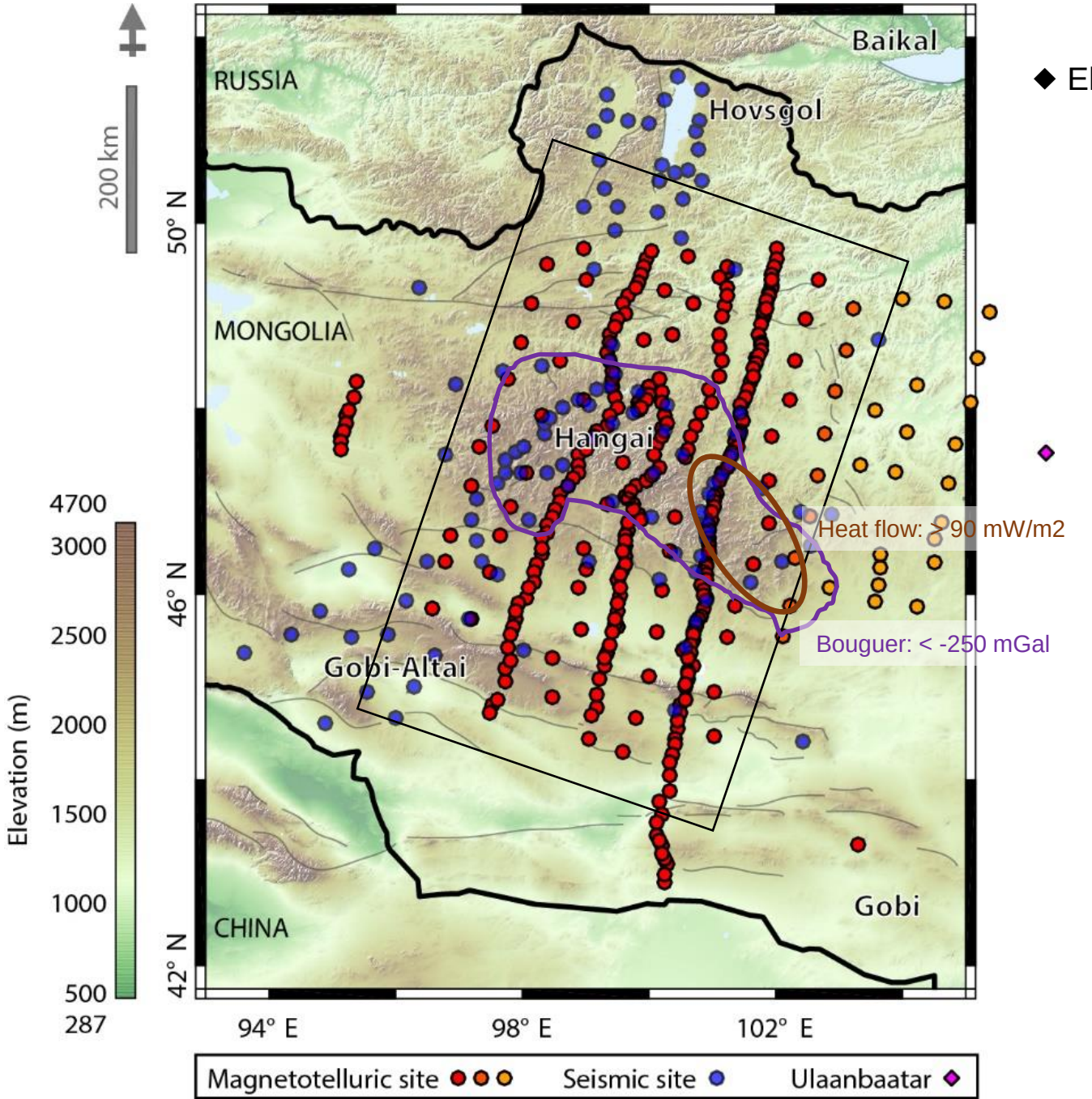
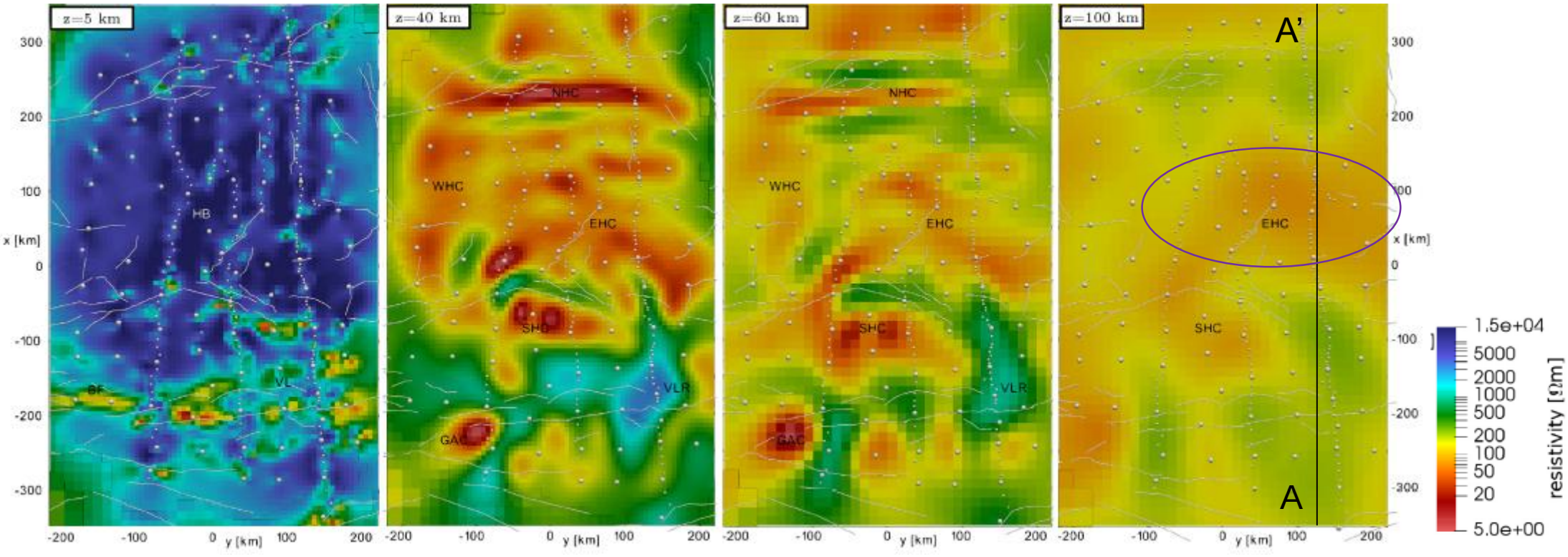
Mongolia: Electromagnetic model

- Electrical resistivity model derived from magnetotelluric data

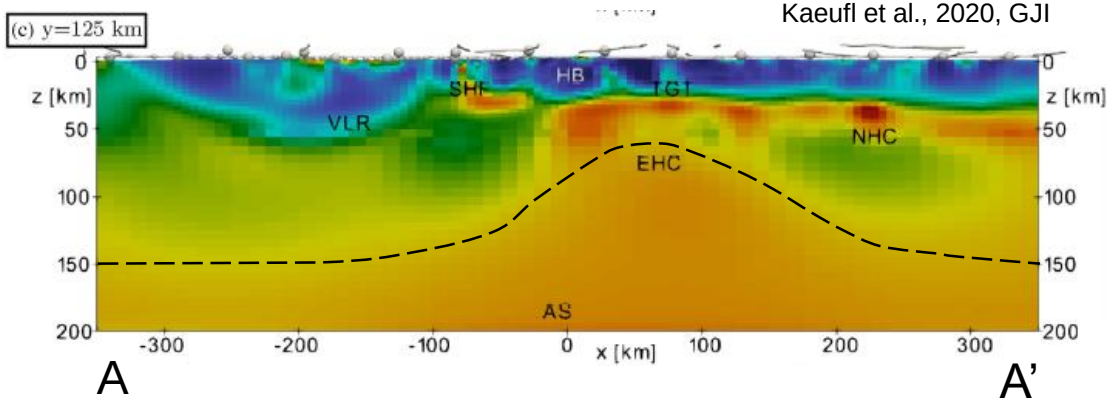


Mongolia: Electromagnetic model

◆ Electrical resistivity model derived from magnetotelluric data



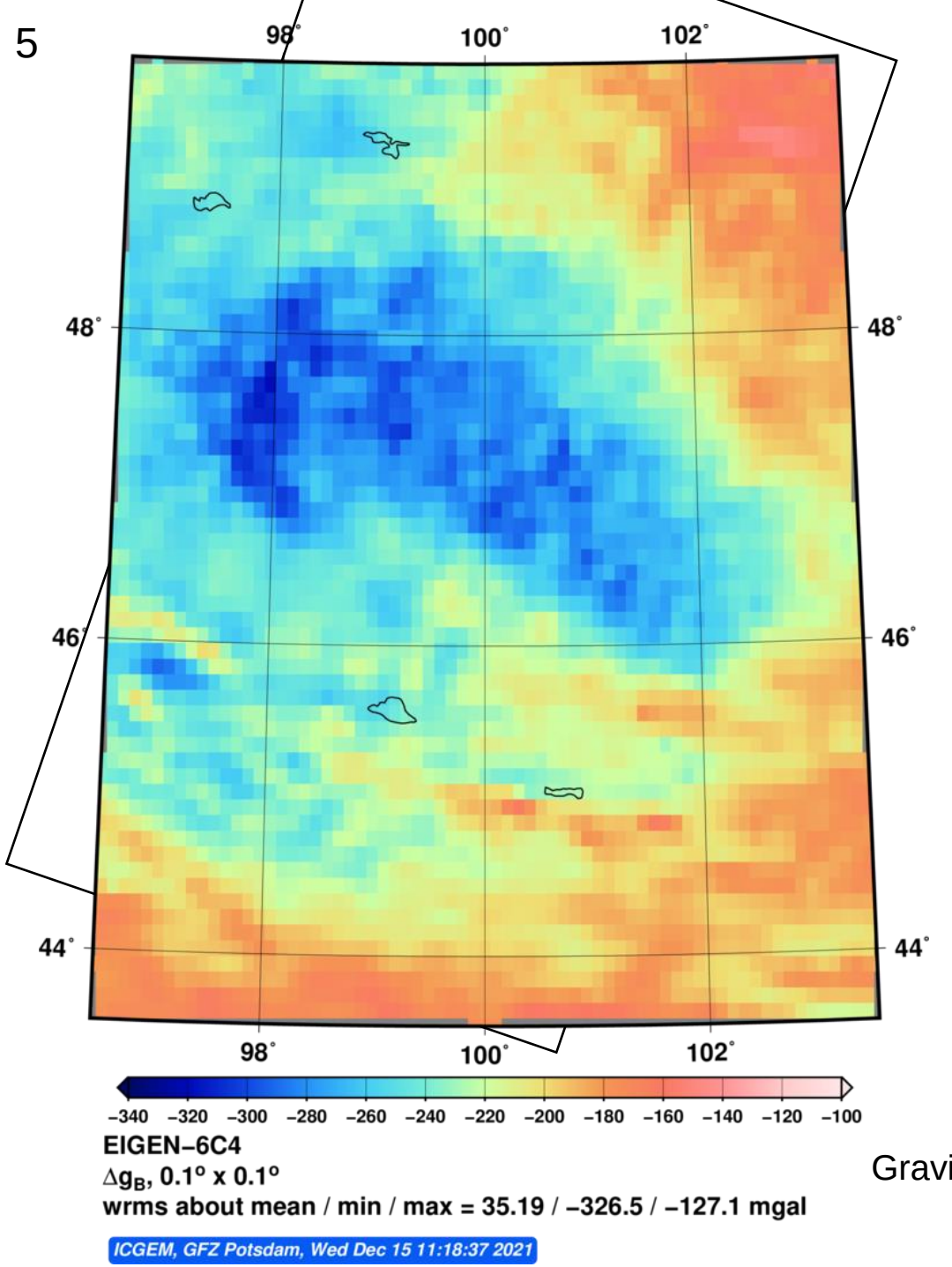
Kaeufl et al., 2020, GJI



◆ Shows bulging conductive feature in mantle
→ **mantle upwelling**

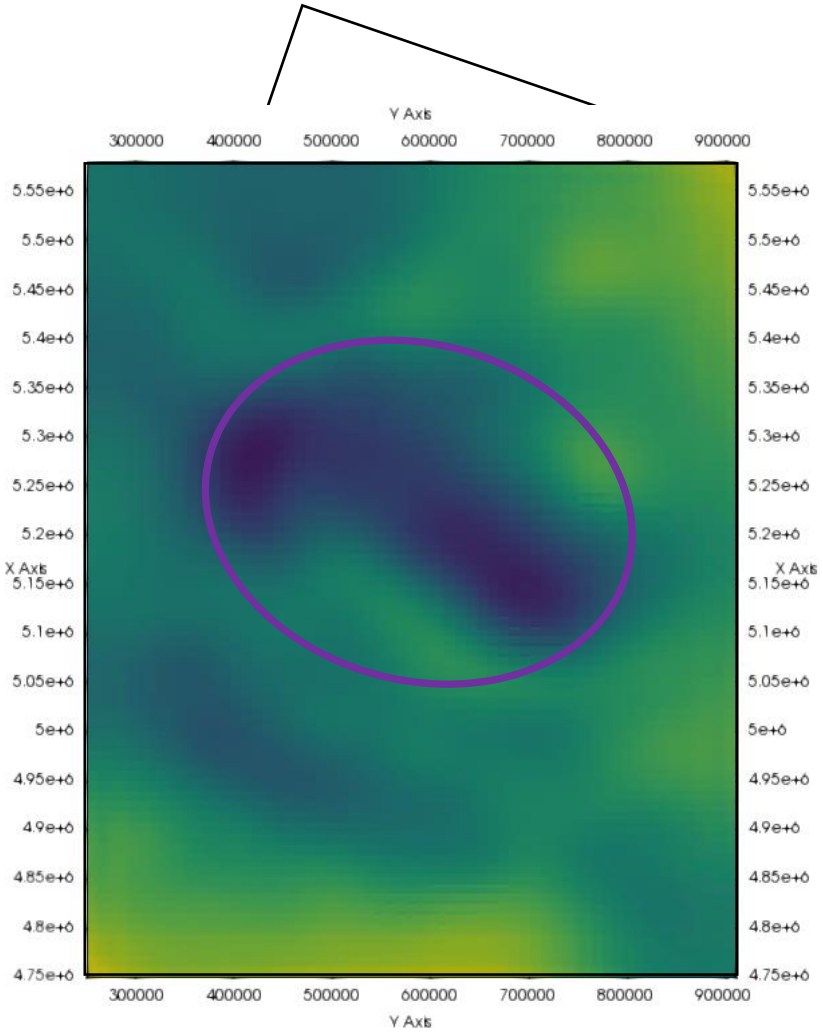
Mongolia: Satelitte gravity model

◆ Gravity data show a very low negative Bouguer anomaly (<−250 mGal) beneath Hangai region

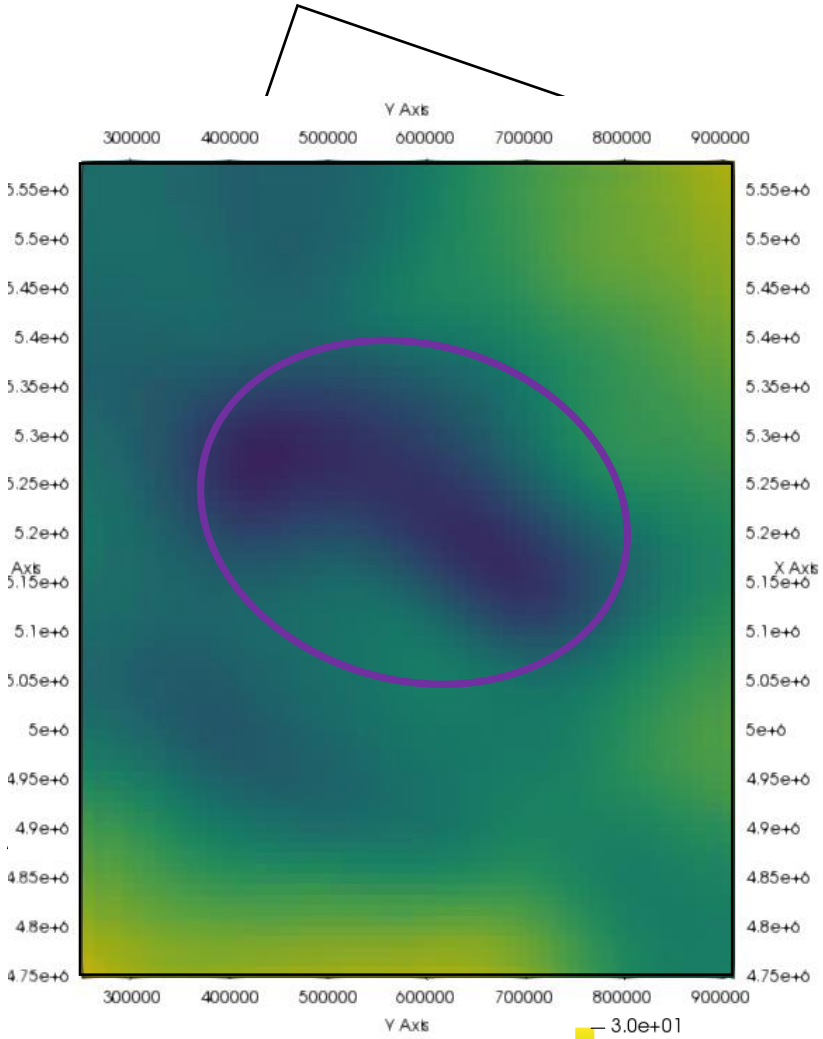


Gravity Bouguer Anomaly

Density model from joint inversion



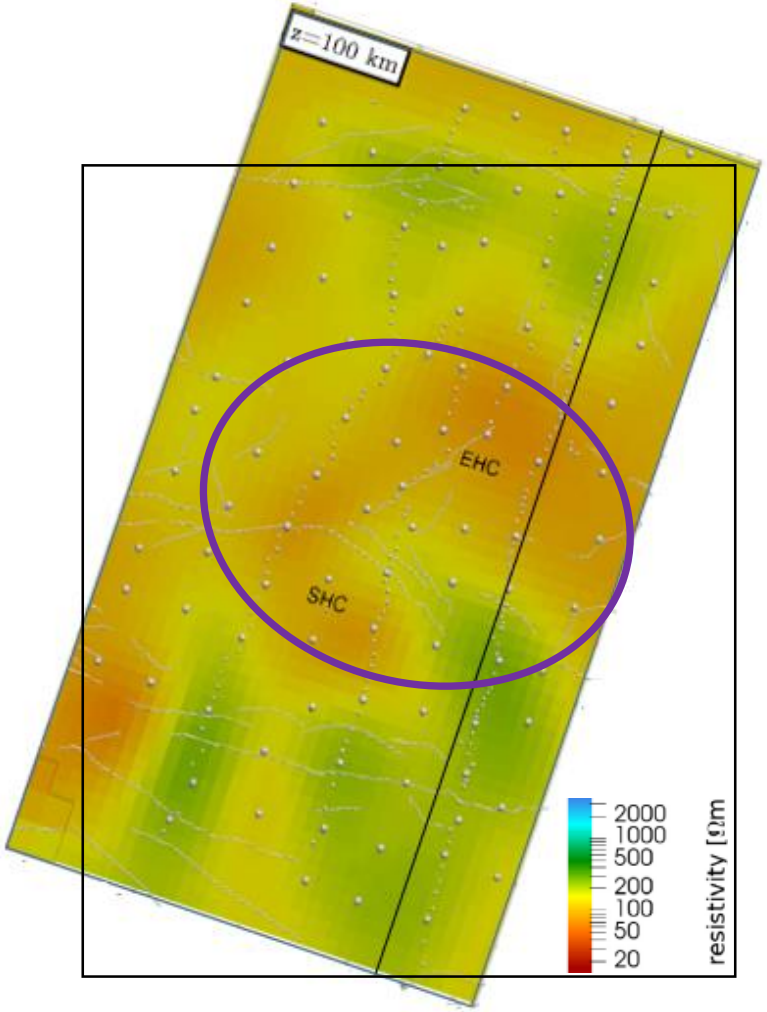
50 km -- Density



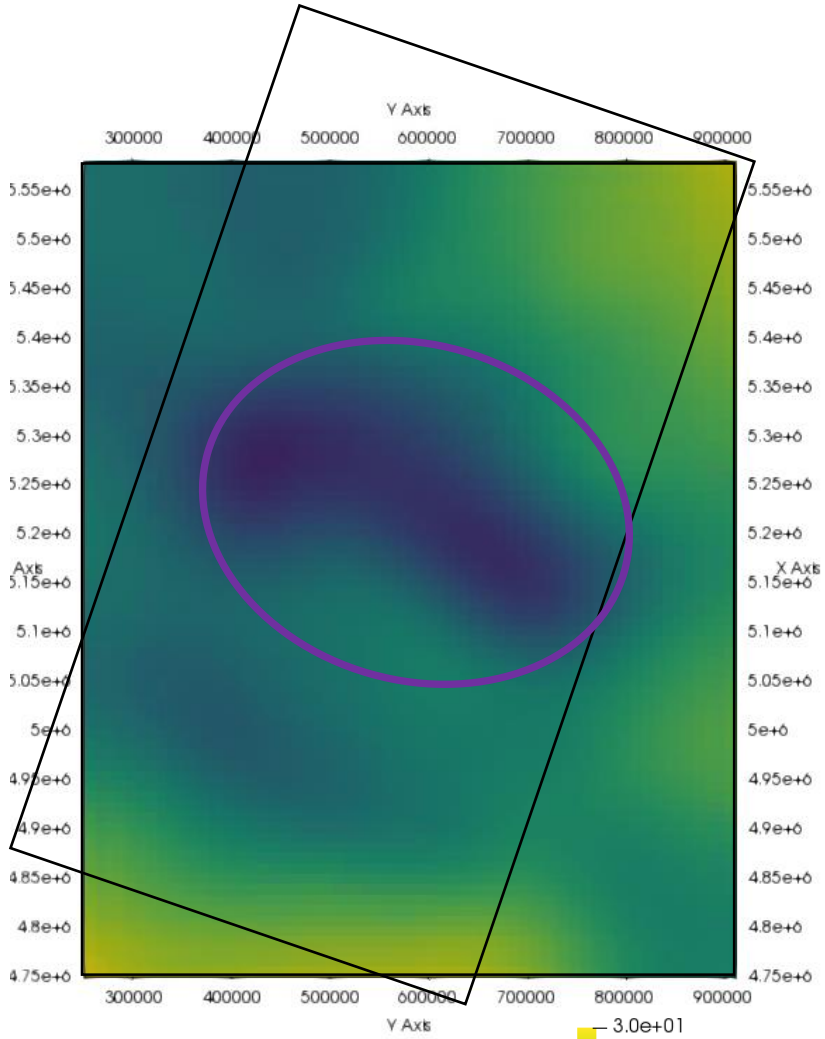
100 km -- Density

- Joint: gravity and electromagnetics
- Preliminary results are encouraging
- Provides new constraints on the 3-D structure of the lithosphere beneath Mongolia
- Much more work to do to refine models

Density model from joint inversion



100 km -- Resistivity

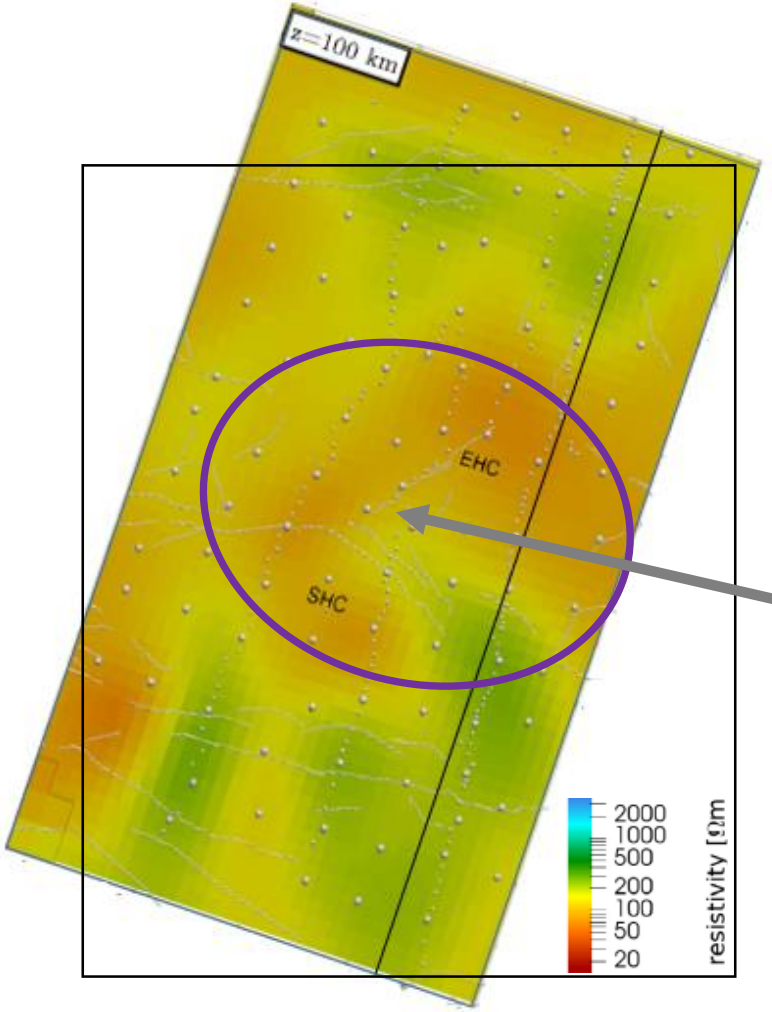


100 km -- Density

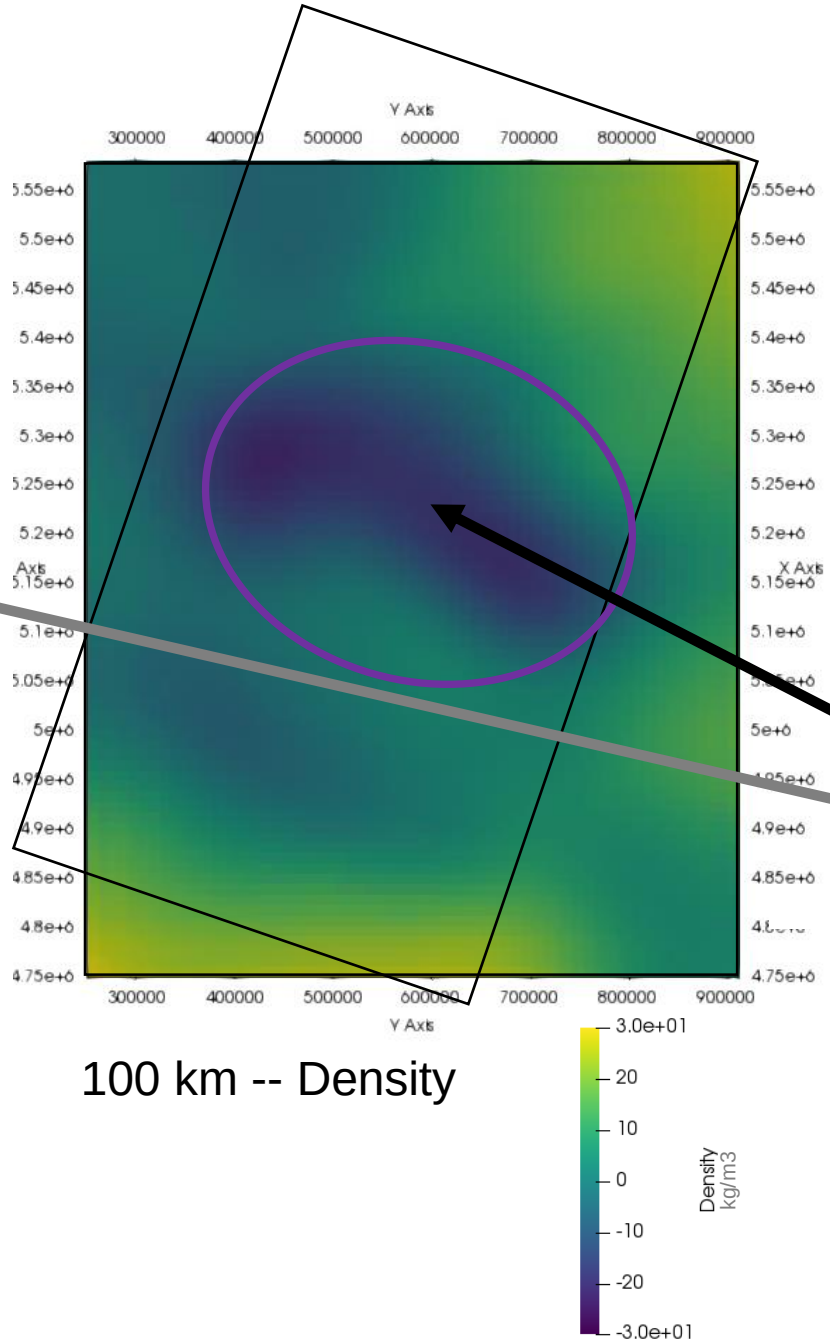
- Joint: gravity and electromagnetics
- Preliminary results are encouraging
- Provides new constraints on the 3-D structure of the lithosphere beneath Mongolia
- Much more work to do to refine models
- Comparison of density and resistivity shows strong correlation

Outlook

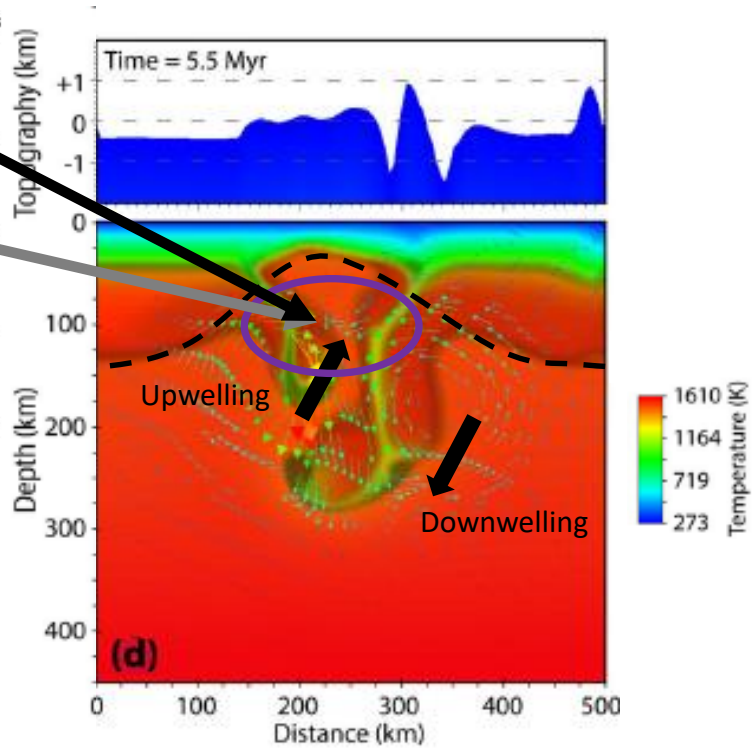
- Joint: gravity and electromagnetics
- Preliminary results are encouraging
- Does it match geodynamic simulations?
  - Density structures?
  - Density contrasts?



100 km -- Resistivity



100 km -- Density



Comeau et al., 2021, JGR