Constraining the continental crust radiogenic heat production with a gravimetric Moho

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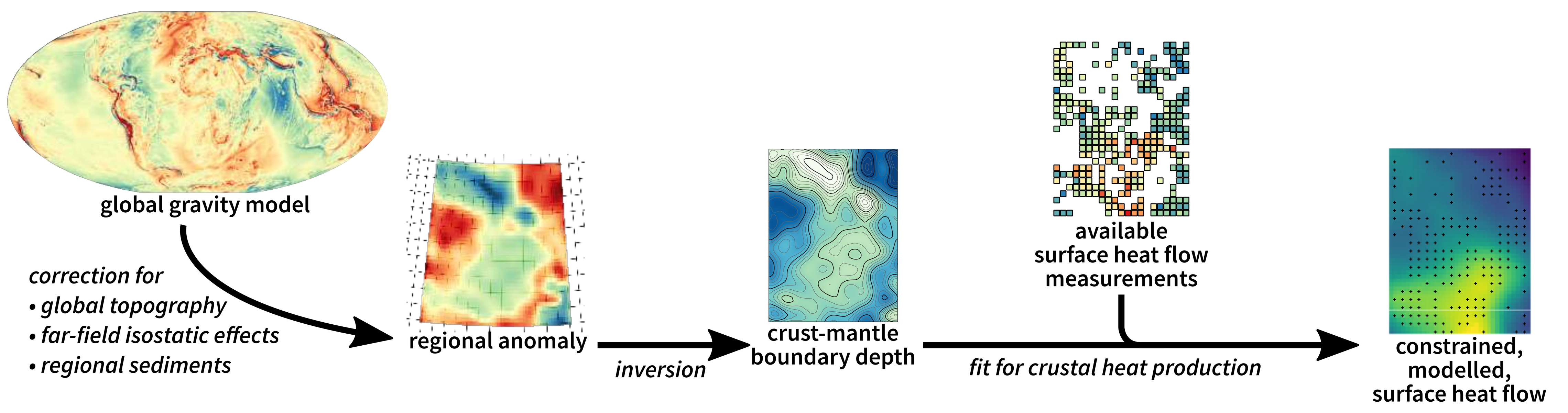
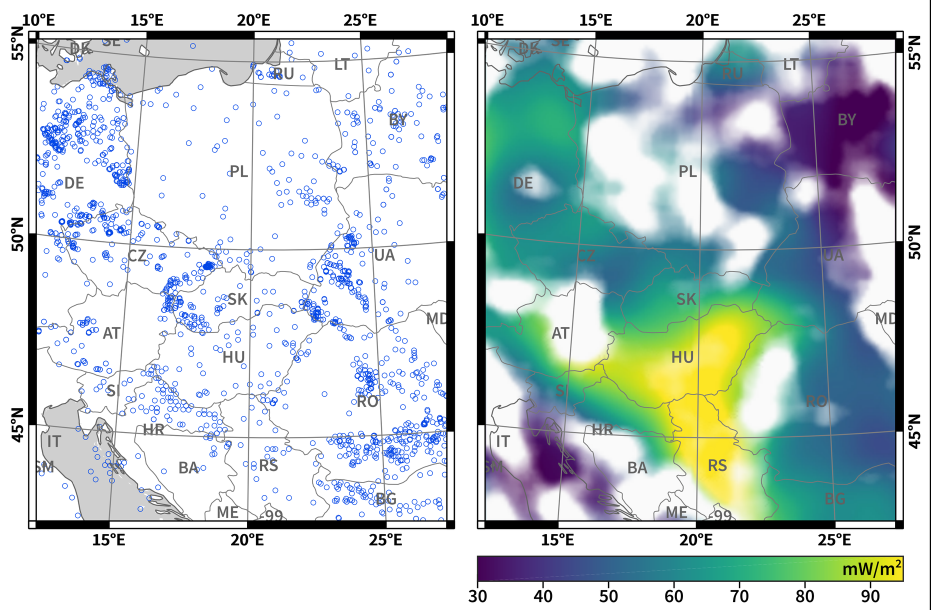


1. Introduction

Heat flow is a direct observable of the planetary thermal state, a complex superposition of contributions. Among those, the heterogeneity in crustal radiogenic heat hinders both the estimation of sub-crustal temperatures and the interpolation of surface measurements. These are irregularly sampled, as is often the case with terrestrial data.

On the other hand, global gravity models provide uniform coverage, regardless of previous exploration, and satellite-only solutions including data from GOCE (ESA) have been proved suitable in retrieving the crustal geometry at regional scale [1].

What if we tie a heat production estimate to a grav-Moho depth?



Surface heat flow measurements in central Europe, as available in the global heat flow database (heatflow.und.edu).

Gridded surface heat flow, by kriging and low-pass filtering (330 km Gaussian). Blank areas, wich rely on fill-in, are obtained with a grid of *distance to nearest measurement*. 100% white = more than 40 km.

2. Methods

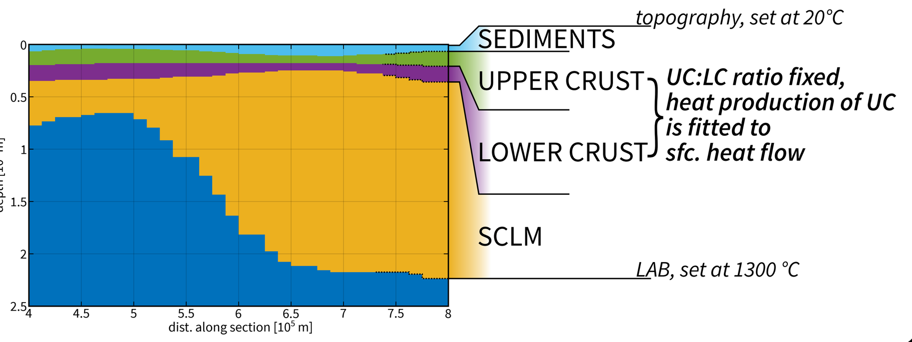
Processing of gravity data:
- GOCE-only global model (GO_CONS_GCF2_TIM_R5) [2]
- Reduction for far-field effects [3] of topography, isostasy and regional sediments. All effects 8 km over GRS80, S.A.

GGM		topo. eff.		isost. eff.		SEDS eff.
up to N=250 (grav. dist.)	–	up to N=250 dV_ELL_RET2014 [4]	–	up to N=30 RWI_ISOS_2012 [5]	–	of 0.25x0.25 deg tesseroids

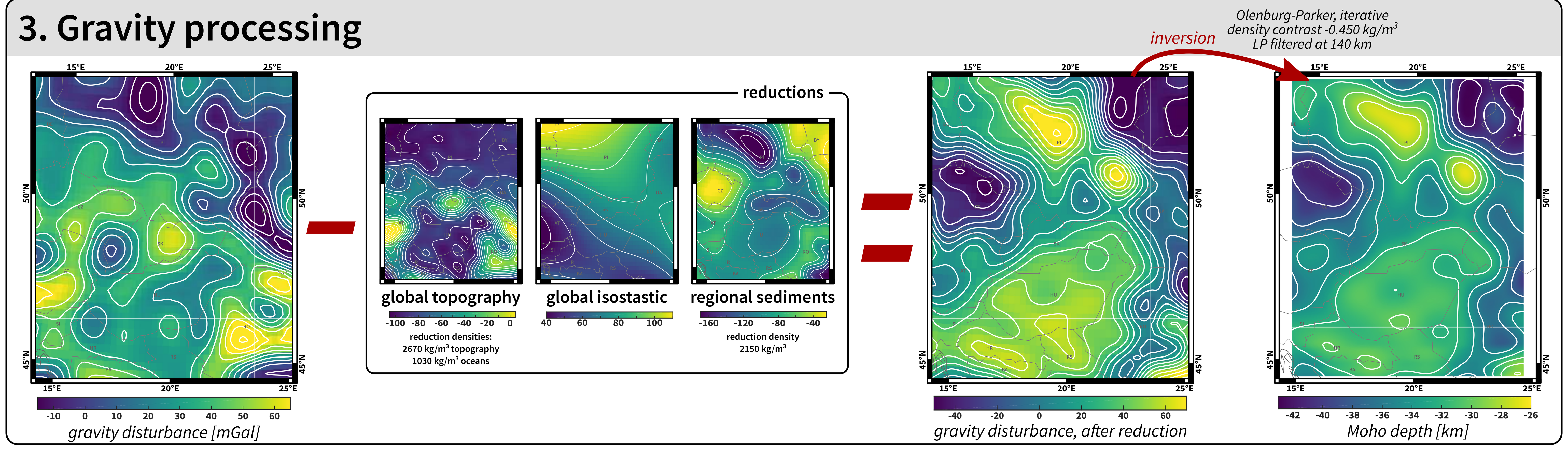
Processing of heat flow data: we filter out short wavelengths, pertaining them to near surface heat transfer regimes (e.g. fluid circulation), and re-grid the measurements to a 20x20 km reticule of cell medians.

Thermal reference model: we set the sediments (topography to crystalline basement) and the sub-continental lithospheric mantle (SCLM, from Moho to LAB) to reference values of density, th. conductivity, heat production and their relationship to temperature and/or depth.

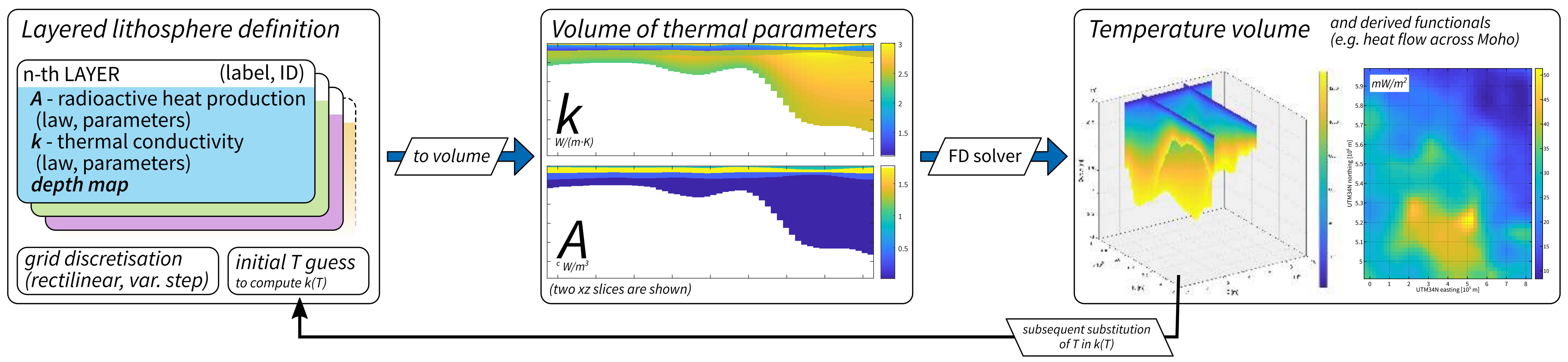
Integration with other data:
- Lithosphere-Asthenosphere boundary from LITHO1.0 [6]
- Sediments from EuCRUST07 [7]



3. Gravity processing



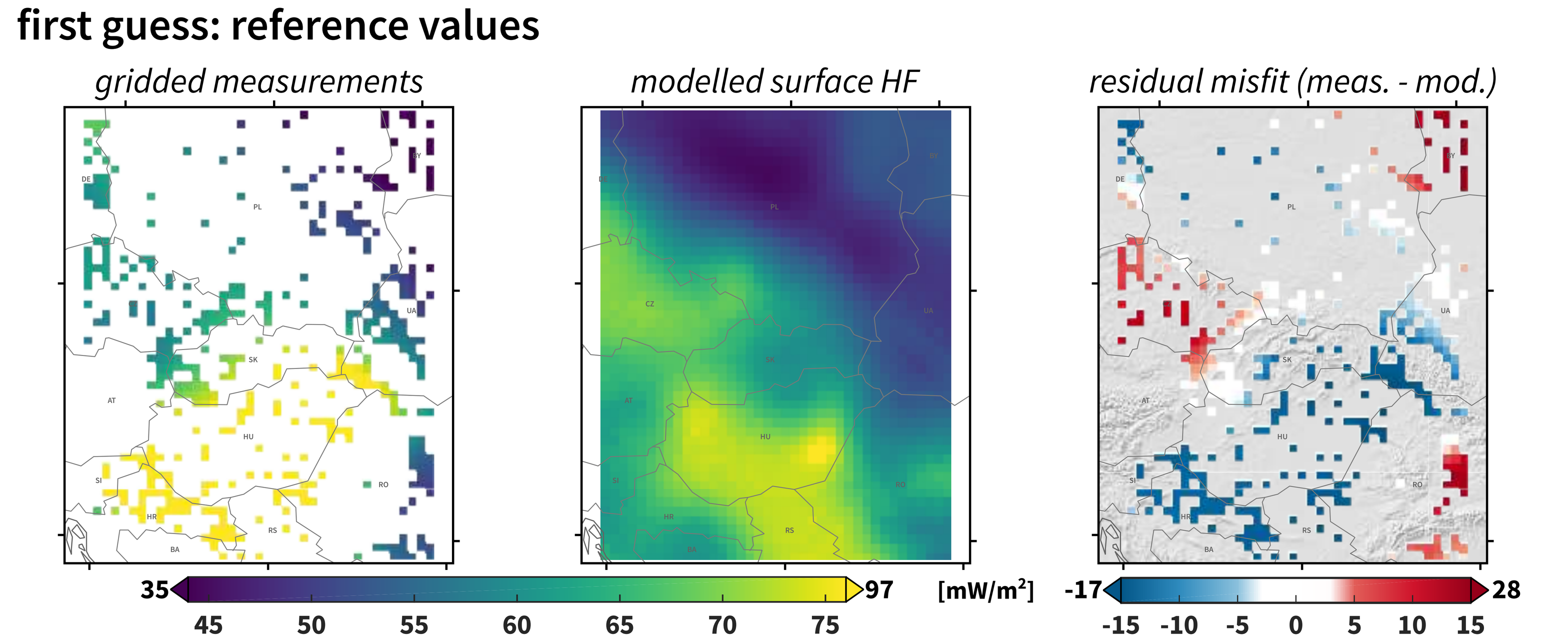
4. Thermal modelling



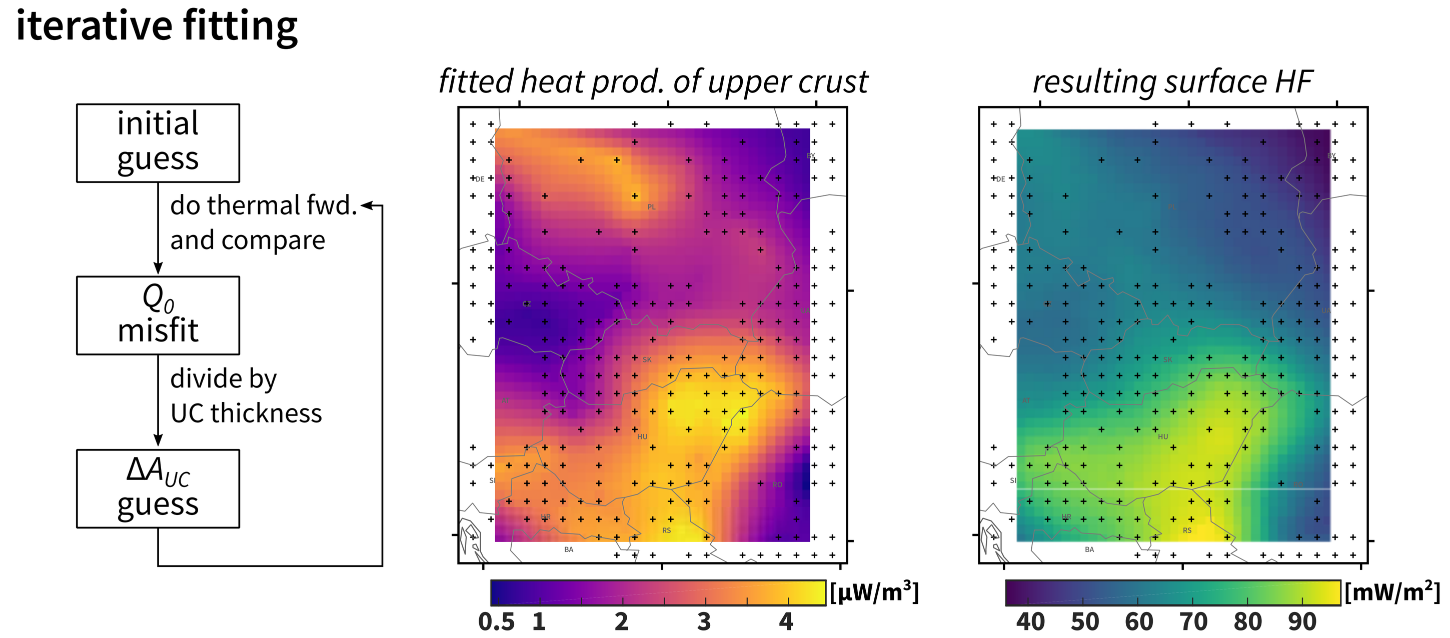
We base our thermal modelling on a steady state, 3D conduction hypothesis, surface to thermal lithosphere-asthenosphere boundary (1300 °C), allowing for non uniform heat production and thermal conductivity and non flat upper and bottom boundaries.

The heat equation is solved with a finite difference scheme on a rectilinear domain, coarsely discretised at higher depths. Temperature dependence of k is accounted for through subsequent substitution, achieving sub-degree variations at the 4th iteration.

first guess: reference values

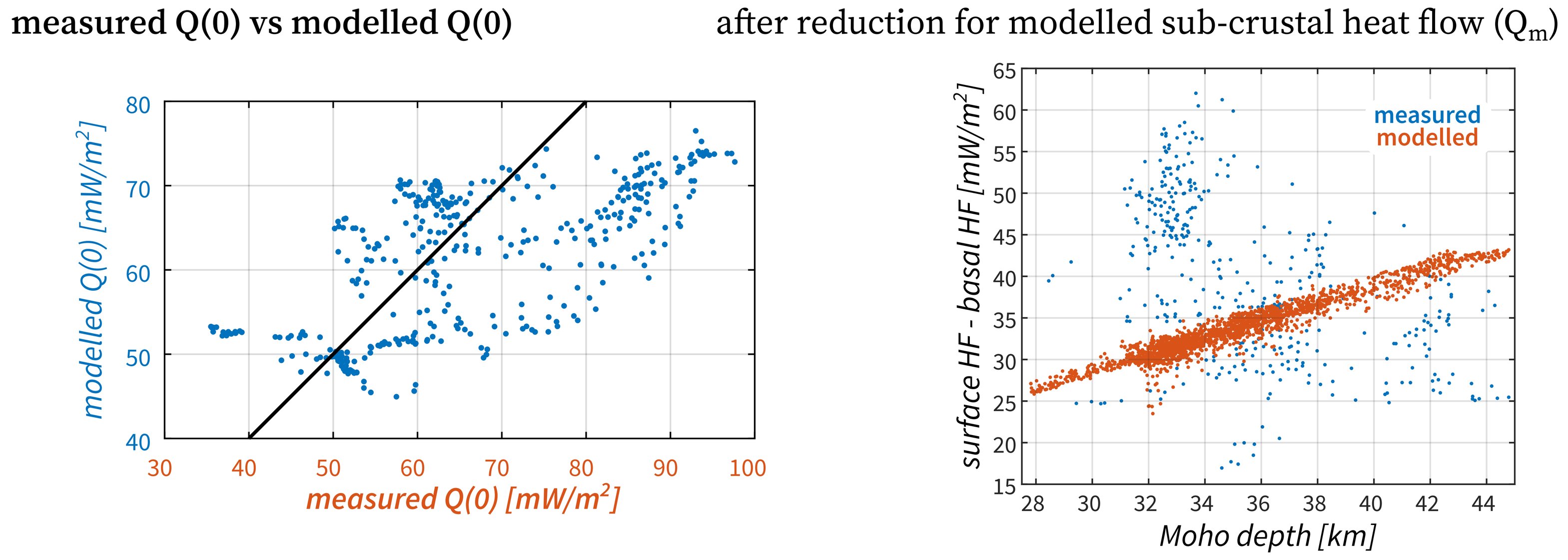


iterative fitting

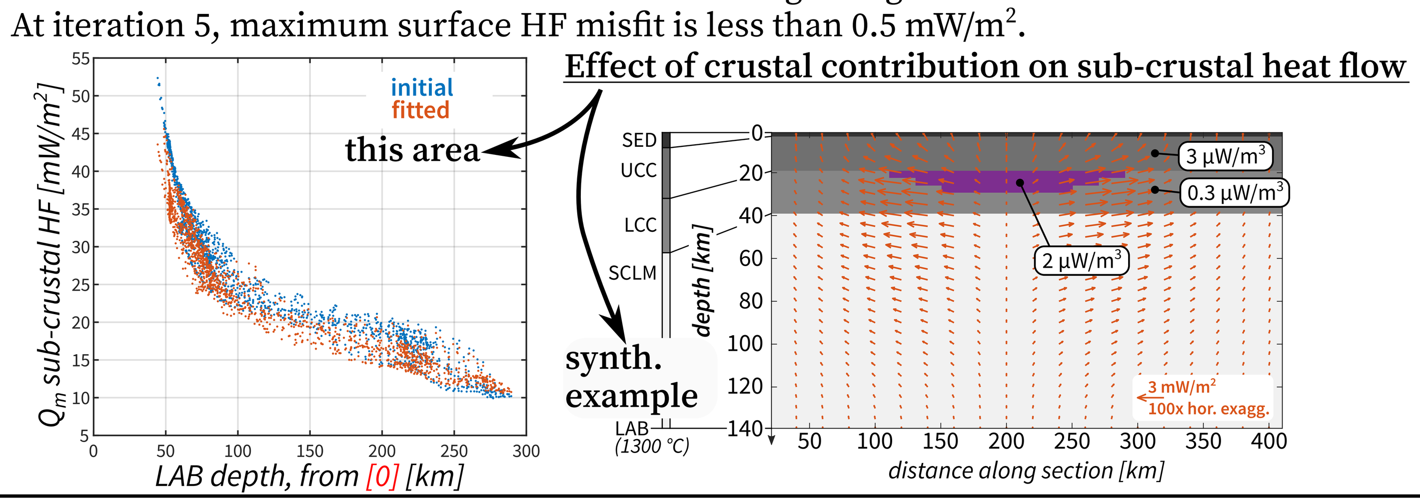


Residuals are attributed to variation in the heat production of the upper crust, unaccounted for in the initial guess. We fit it through iterative correction columns where surface measurements are available. A natural neighbor gridder fills in the others. At iteration 5, maximum surface HF misfit is less than 0.5 mW/m².

measured Q(0) vs modelled Q(0) after reduction for modelled sub-crustal heat flow (Q_m)



Effect of crustal contribution on sub-crustal heat flow



5. Discussion

OUTCOME
- Successful integration of GGM and heat flow measurements: straightforward work flow from gravity functional to thermal parameters.
- Flexible, lightweight modelling enables fast testing of lithospheric scale thermal behaviour.
- Non-linear superposition of crustal and sub-crustal heat flow contributions hinders simple back-stripping approach (no simple subtraction) - however iterative, subsequent substitution converges fast.

OPEN ISSUES
- Attributing all the misfit of a first guess to one parameter is useful, but a large simplification is involved.
- Even without parameter uncertainty, separation of crustal and sub-crustal component is ambiguous.
- External observables, independently modelled, can be integrated to validate model.
(e.g. part of this test area shows a direct crust-lithosphere thickness relationship: assigning lower crustal heat production or lower SCLM conductivity results in similar output - albeit with different surface footprints)

FURTHER DEVELOPMENT
- Evaluation of propagation of uncertainty and method stability.
- Constrain on Qc/Qm partition: geothermal (estimated) vs geodetic elastic thickness.
- Gravity segment: define a criterion for regional reduction global functionals, adopt a more versatile Moho inversion scheme.

References

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