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What lies beneath: Unveiling the fine-scale 3D compositional and thermal structure of the lithosphere and upper mantle

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The lithosphere and sublithospheric upper mantle (above 410d) are highly heterogeneous in their chemistry, thermal structure and physical properties. Since most of the upper mantle is inaccessible to direct observation, we must rely on indirect methods to estimate its thermochemical structure. Lateral discontinuities (i.e. sharp changes in the thermal and/or compositional structure) in these regions are known to correlate with the location of seismically active zones, oil producing basins, foci of magma intrusion/production, and giant ore deposits. Understanding the fine-scale thermochemical structure of the lithosphere and sublithospheric upper mantle is therefore one of the most important goals in Geosciences.

A detailed knowledge of the thermal and compositional structure of the upper mantle is also an essential prerequisite to understanding the formation, deformation and destruction of continents, the physical and chemical interactions between the lithosphere and the convective sublithospheric upper mantle, the long-term stability of ancient lithosphere, and the evolution of surface topography. Unfortunately, with current geophysical methods, such a holistic and detailed characterisation remains a technically and conceptually challenging problem.

In this talk, I will discuss recent advancements in thermodynamically-constrained multi-observable probabilistic inversions, which have the potential to overcome the problems affecting other inversions schemes and provide realistic estimates of the present-day thermochemical structure of the lithosphere and upper mantle. I will present results for both synthetic and real case studies, which serve to highlight the advantages and limitations of our approach compared to others. I will also discuss future work towards the incorporation of such an approach into global thermo-mechanical simulations/inversions to study the intricate connections between the thermochemical structure of the upper mantle and the evolution of plates.