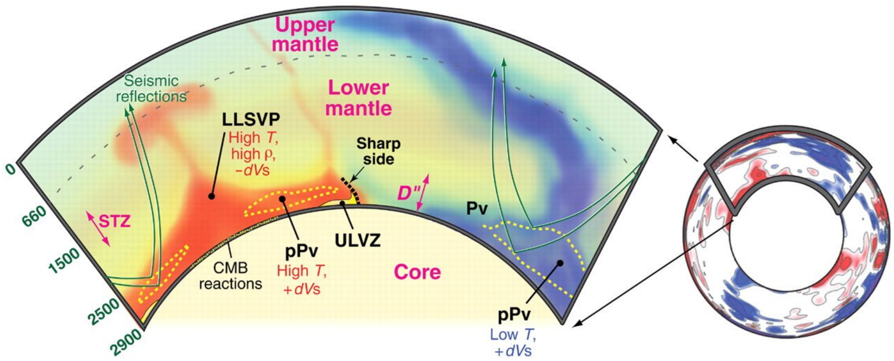
CSQ-39 Summary

Question	Knowledge Advancement Objectives	Geophysical Observables	Measurement Requirements	Tools & Models	Policies / Benefits
What is the nature of the mantle heterogeneity and the character of its convection at all depths ?	A) Map the 3D variations in the physical properties of the Earth's interior, with a high spatial resolution globally : seismic velocities, densities, viscosity, electrical conductivity.	. Gravity field and gravity gradients to constrain the mantle mass distribution • Surface topography to constrain dynamical topographies • Geomagnetic field, magneto-telluric data • Surface displacements from GNSS (for tidal tomography of the mantle). • Seismology (for seismic velocity maps, data on the depths of internal interfaces, crustal thickness)	• Current challenges: aim at high spatial resolution at all depths.	Mineral physics data (to compute density, seismic velocity, electrical conductivity corresponding to different hypotheses on the thermo-chemical structure of the mantle). Models of gravito-visco-elastic deformations of the mantle caused by internal loads. Need for models able to account for 3D variations in physical properties of the Earth (not only radial). Methods to combine all geophysical observables within a unified modelling approach. Joint inversions.	Understand the deep processes governing changes in our near-surface environment. Constrain the deep water cycle and the deep carbon cycle inside the Earth.

				Methods to separate crustal vs mantle sources.	
	B) Quantify the present-day 3D structure of the Earth's mantle, in terms of temperature, composition and melting.	. Same as above	• Current challenges: aim at high spatial resolution at all depths.	Same as above.	
	C) Interpret this present-day structure in terms of dynamical processes, that govern the circulation of heat, materials and volatiles between the surface and the top of the core.	• Same as above	• Same as above	Same as above. Mantle convection models. Ability to calculate accurately the geophysical observables predicted by a convection model.	

CSQ-39 Narrative

Obtaining a high-resolution and global image of the Earth's interior structure in 3D, and interpreting this present-day structure in terms of dynamical processes, remains an outstanding question of geophysics, in order to understand the thermal and compositional evolution of the Earth, and describe the deep geodynamical processes underlying near-surface changes. This is also a key to understand the circulation and recycling of materials and volatiles (including water) between the depths of the core and the surface, and how the internal heat is evacuated towards the surface. Examples of questions include : what is the buoyancy of the deep mantle (Romanowicz, 2017) ? What is the path of subducted slabs and how deep do they go ? Do the upper and the lower mantle convect together or separately ? An accurate image of Earth's interior temperature, melting and composition would also provide constraints on its viscosity. Around subduction boundaries, mapping the lateral variations of structure and geometry of the subducted plates in the mantle contributes to a better understanding of the segmentation of the plates interface and the existence of possible barriers to the propagation of a rupture, thus to the assessment of the seismic hazard. Current challenges consist in further advancing the joint inversions and modelling of different geophysical observables in terms of 3D thermal and compositional structure. They include seismic data (sensitive to the 3D elastic structure of the Earth at depth through maps of seismic velocities), gravity and gravity gradient data (which provide a high lateral resolution and, in the case of the gradients, an enhanced sensitivity to the morphology of the mass sources), and geomagnetic/magneto-telluric data (sensitive to the electrical conductivity, see Kuvshinov et al., 2021). All these geophysical parameters (seismic velocities, density and conductivity) are sensitive to the temperature and chemical composition in different ways, and to the presence of melt and water. Their combination remains an active area of research benefiting from the development of appropriate data analysis and modelling methods, and also from an increase in accuracy of the observations.



Right : a seismic image of Earth's interior, together with interpretative elements (right). As a first-order approximation, blue colors indicate cold material (subducted slabs) and red, hot material (upwellings). From Garnero & McNamara (2008).

References

Garnero, E.J. and McNamara, A.K. (2008). Structure and dynamics of Earth's lower mantle, *Science*, 320, 626-628.

Romanowicz, B. (2017). The buoyancy of Earth's deep mantle, *Nature*, 551, 308-309.

Kuvshinov, A., Gravyer, A., Toffner-Clausen, L. and Olsen, N. (2021). Probing 3D electrical conductivity of the mantle using 6 years of Swarm, CryoSat 2 and observatory magnetic data and exploiting matrix Q-responses approach, *Earth, Planets and Space*, 73:67.