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Teaching machines to find mantle composition

Suzanne Atkins (1), Paul Tackley (1), Jeannot Trampert (2), and Andrew Valentine (3)

(1) ETH Zürich, Department of Earth Sciences, Zürich, Switzerland , (2) Utrecht University, Department of Earth Sciences, Utrecht, The Netherlands, (3) Australian National University, Research School of Earth Sciences, Canberra, Australia

The composition of the mantle affects many geodynamical processes by altering factors such as the density, the location of phase changes, and melting temperature. The inferences we make about mantle composition also determine how we interpret the changes in velocity, reflections, attenuation and scattering seen by seismologists.

However, the bulk composition of the mantle is very poorly constrained. Inferences are made from meteorite samples, rock samples from the Earth and inferences made from geophysical data. All of these approaches require significant assumptions and the inferences made are subject to large uncertainties.

Here we present a new method for inferring mantle composition, based on pattern recognition machine learning, which uses large scale in situ observations of the mantle to make fully probabilistic inferences of composition for convection simulations.

Our method has an advantage over other petrological approaches because we use large scale geophysical observations. This means that we average over much greater length scales and do not need to rely on extrapolating from localised samples of the mantle or planetary disk.

Another major advantage of our method is that it is fully probabilistic. This allows us to include all of the uncertainties inherent in the inference process, giving us far more information about the reliability of the result than other methods.

Finally our method includes the impact of composition on mantle convection. This allows us to make much more precise inferences from geophysical data than other geophysical approaches, which attempt to invert one observation with no consideration of the relationship between convection and composition.

We use a sampling based inversion method, using hundreds of convection simulations run using StagYY with self consistent mineral physics properties calculated using the Perple_X package. The observations from these simulations are used to train a neural network to make a probabilistic inference for major element oxide composition of the mantle. We find we can constrain bulk mantle FeO molar percent, FeO/MgO and FeO/SiO_2 using observations of the temperature and density structure of the mantle in convection simulations.