Response to the Editor of Solid Earth Discussions: June 26, 2014

In the comment by Taras Gerya, the thermal expansion coefficient for Periclase is found using a Gibbs based equation of state, (Gerya, T. V., Podlesskii, K. K., Perchuk, L. L., and Maresch, W. V.: Semi-empirical Gibbs free energy formulations for minerals and fluids for use in thermodynamic databases of petrological interest, Phys. Chem. Minerals, 31, 429-455, 2004). His values are positive at all temperatures and pressures. His equation of state is based on the Gibbs distribution given by statistical mechanics of partition functions. In contrast we have based our equation of state on linear elasticity while realizing that materials at very high pressures will include nonlinear effects. Hooke's Law is an equation of state which relates volume to pressure and temperature. Hooke's law mandates that the temperature dependence of the compressibility predicts a zero and even negative thermal expansion coefficients at higher pressures as shown in our figure 1 and well described in the manuscript.

In our revised manuscript, we have shown that there are two parts needed to describe the thermal expansion coefficient at conditions deep in the Earth: first is used in linear elasticity i.e., the temperature dependence of the compressibility which reduces the thermal expansion coefficient for increasing pressures. This first effect is not in doubt even with nonlinear equations of state, see our equation 12. It is the second part i.e., that which is described in our equations 19 and 22; where the *pressure* dependence of the isobaric heat capacity dictates the *thermal* dependence of the thermal expansion coefficient. There is an important point described below about the heat capacity.

The isobaric heat capacity has two parts (using the notation in our manuscript)

$$C_p(p,T) = C_v(p,T) + \frac{\beta^2 vT}{\kappa}$$

The first term is the constant volume heat capacity, $C_v(p,T)$ and the second which is generally small is given above by the last expression on the right. At high temperatures, we expect $C_v(p,T) = 3R$ with R the gas molar constant. This expression is the Delong-Petit Rule; as such it has no pressure dependence and no thermal dependence. Thus, the *thermal* dependence of the thermal expansion coefficient is dictated by the *pressure* dependence of the term $\beta^2 vT/\kappa$. The pressure dependence of this term is very central to describing whether minerals have near zero thermal expansion at high temperatures and pressures.

We have shown in our response to both earlier reviewers that even very sophisticated equations of state may not always describe the thermal expansion coefficients accurately at high pressures. The *pressure* dependence of the difference between the isobaric and isochoric heat capacities is what will dictate whether the Earth has a deep layer with near zero thermal expansion coefficients.