Radiative heat transfer in a hydrous transition zone

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The structure and dynamics of Earth's interior depend crucially upon heat flow and thus upon the thermal conductivity of its constituents. The bulk thermal conductivity has two components: lattice conductivity (k_{lat}) and radiative conductivity (k_{rad}) [1,2]. Whereas lattice conductivity is governed by phonon propagation, radiative conductivity arises from heat transport by emission and absorption of photons. The latter, therefore, can be indirectly measured by analyzing the visible and infrared (VIS-IR) regions of a material's optical absorption spectrum. Thermal conductivity in the mantle is controlled by temperature, pressure, the electronic structure and concentration of transition metal ions (such as iron), and the water content of the material [1,3]. The radiative component has generally been assumed to be negligible, as most ferromagnesian minerals become opaque in the VIS-IR range at high pressures due to intensification and red-shift of electronic charge-transfer bands [4, 5]. However, more recent studies have suggested that mantle minerals may, in fact, remain relatively transparent at high pressures, thereby allowing for a potentially significant contribution to thermal conductivity from the radiative component [6].
We measured optical absorbance spectra of hydrous wadsleyite and hydrous ringwoodite at simultaneous high-pressure and high-temperature conditions up to 26 GPa and 823 K in order to determine their radiative conductivities and to study the potential influence of hydration in the transition zone on thermal conductivity of the mantle. We report radiative thermal conductivities of 1.5 ± 0.2 $Wm^{-1}K^{-1}$ for hydrous wadsleyite and 1.2 ± 0.1 $Wm^{-1}K^{-1}$ for hydrous ringwoodite at transition zone conditions. The analytically derived radiative thermal conductivities of anhydrous wadsleyite and ringwoodite are 2.1 ± 0.2 $Wm^{-1}K^{-1}$ and 1.6 ± 0.2 $Wm^{-1}K^{-1}$, respectively. Our results imply that a water content of ~1 wt% H_2O lowers the thermal radiative conductivity of ringwoodite and wadsleyite by 40% or 33%, respectively. The total thermal conductivities, calculated from temperature- and pressure-dependent optical absorption measurements, maintain an energy transmission window in the infrared and visible spectral range at high pressures and temperatures. The results indicate that the mantle transition zone may contribute significantly to heat transfer in the mantle and demonstrate the importance of radiative heat transfer in controlling geodynamic processes in Earth's mantle.

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