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Tidally-induced thermal runaway on extrasolar Earths: 3D results and scaling

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Recent detections of low mass exoplanets suggest that the discovery of Earth-like planets is within our reach. As the detection probability decreases with the star-body distance, these planets are likely to orbit in a close distance of their parent stars. Due to strong tidal interaction of such short-period planets, they are likely to be tidally locked. Moreover, a huge production of internal energy by tidal friction may occur. Here, we concentrate on the effect of tidal heating on the interior of extrasolar Earth-like planets. Owing to the strong temperature dependence of the mechanical properties of both the tidal deformations and the long-term evolution, these two processes are coupled. For significant tidal dissipation rates, strong positive feedback occurs if the system is not vigorous enough to transfer the heat out of the system. The strong tidal heating then leads to thermal runaways and large-scale melting is predicted. In order to describe this behavior and the three-dimensional nature of both the tidal forcing and the temperature anomalies, a full 3D approach solving the two processes simultaneously is employed (Běhounková et al., 2010). We consider an extrasolar planet having the internal properties similar to the Earth. By varying the parameters of the orbit (eccentricity, orbital period and the resonance type), we investigate the thermal stability of such planets and runaway timescales of thermal runaways (see Běhounková et al., 2011). Two modes for heat transfer are modeled through the choice of convective parameters (Rayleigh number and temperature dependence of viscosity, amount of radiogenic heating): a relatively effective plate-tectonics-like regime and a one-plate (stagnant lid) regime. In order to relate full 3D results with classically used parameterizations, a scaling that relates the global dissipated to a internal characteristic properties (temperature, pressure) and to the orbital parameters is proposed for various rheologies (Arrhenius law, Frank-Kamenetskii approximation). The results of numerical simulations shows that the reciprocal value of runaway timescales depend linearly on the initial global tidal dissipation for models sharing the same initial conditions and the same convective parameters. The proposed scalings are employed in order to investigate larger parametric space especially in the context of habitability around low mass stars.