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MACMA : Multiagent simulation of mantle convection with evolutive plate boundaries and continents.

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The model MACMA (MutliAgent Convecting MAntle) is designed to simulate time-dependent plate tectonics with mobile plate boundaries and with a number of plates that emerges naturally from a convective system. It includes continental and oceanic lithospheres, evolutive plate boundaries, along with ridge and subduction zones creation/vanishment mechanisms in a 2D cylindrical geometry. MACMA is based on multiagent systems in thermal and mechanical interactions. Agents are autonomous entities that collect information from their environment in order to make a decision controlled by behavior laws. These laws are included in a physical model that may be improved and complexified by any user. MACMA involves four types of agents : convection cells, lithospheric plates, continents and plate interfaces that allows for the exploration of explicit geodynamics mechanisms. The dynamics of the system is based on a force balance on each plate. It presently accounts for slab pull, ridge push, bending force and convective drag, but can be modified according to the objectives. This force balance yields velocities for individual plates and plate interfaces at all times. The geometry and the thermal state of the system are subsequently updated at each time step. A first level of description uses only cells and plates, and a second one includes buoyant insulating continents. Plate velocities, temperature and heat flux are calculated with analytical laws. In addition, our flexible method allows for empirical laws to be plugged in, in order to better match observed phenomena, such as spontaneous plate sinking, limited plate thickening, back-arc basin creation, and plate suturing in various contexts. A mechanism for plate breakup and oceanic spreading, based on in situ radiogenic heating and continental insulation, is also proposed. We obtain quantitative results for plate velocities and relative driving forces that are in good agreement with the observed dynamics of the Earth. Our approach has a very low computational cost, and real time simulations can be carried out on any personal computer. In addition, its user-friendliness makes it a powerful ressource for teaching purposes.