Geophysical Research Abstracts
Vol. 17, EGU2015-6234, 2015
EGU General Assembly 2015

Earth's plate motion evolution and its link to global mantle dynamics

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Present-day plate motions provide a global dataset that allows us to infer the present convective structure of the Earth's mantle. Moreover, present geological observations combined with the kinematic principles of plate tectonics enables us to reconstruct Earth's tectonic history back until Pangaean times, which improves our understanding of how Earth has evolved to its present state. However, several aspects are not yet sufficiently well understood, for instance, how surface motions are linked to deep mantle processes or how plate motion changes over time, including those timescales of several 100 Myr that are associated with supercontinent formation and dispersal.

Here, we use global spherical models of mantle convection to investigate plate motion evolution in a general and dynamically fully consistent manner. These models include tectonic plates self-consistently evolving from mantle flow as well as Earth-like continental drift. We analyze the evolution of plate velocities over long timescales and observe fluctuations of globally averaged plate motions of a factor of 2-3, in agreement with kinematic reconstructions. The fluctuations are mainly driven by the onset of new subduction, highlighting the strong role of slab-related driving forces in the rates of plate motion. Average plate motions are increased with a stronger viscosity contrast between upper and lower mantle, partly due to an increased subduction flux into the lower mantle, which increases the driving forces of plate motion.
The motion of individual plates shows much stronger fluctuation. Continental plate motions are modulated by continental assembly and dispersal. Continents usually move slower when strongly clustered and faster during dispersal and before collision.

In a further step, we analyze changes in the direction of motion of these individual plates by calculating their Euler pole and its change with time. This allows us to characterize the variety of modeled plate reorganizations and to relate our models to Earth's recent tectonic evolution.