Structure and deformation of the oceanic upper mantle from surface waves

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We will discuss the seismic structure of the oceanic lithosphere and asthenosphere from our recent S-wave tomographic models of the upper mantle.
We observe that on average, the deepening of fast S-wave velocities with age follows approximately the trend predicted by the square root of age cooling model. However, for ages larger than 100 Myrs, some flattening of the isotherms may be inferred, as predicted by thermal models where a constant heat flux is provided at depth.
Both radial and azimuthal anisotropies are significant in the uppermost 200-250 km of the upper mantle, and peak in the oceanic asthenosphere, between 100 and 150 km depths.
The correlation of azimuthal anisotropy with the actual plate motion in the shallow oceanic lithosphere is very weak. A better correlation is obtained with the fossil accretion velocity recorded by the gradient of local seafloor age. The transition between lithospheric and active anisotropy occurs across the typical square root of age isotherm that defines the bottom of the thermal lithosphere around 1100 C. The azimuthal anisotropy projected onto the direction of present plate motion shows a very specific relation with the plate velocity; it is very weak for plate velocities smaller than 3 cm yr^{-1}, increases significantly between 3 and 5 cm yr^{-1}, and saturates for plate velocities larger than 5 cm yr^{-1}. Plate-scale present-day deformation is remarkably well and uniformly recorded beneath the fastest-moving plates (India, Coco, Nazca, Australia, Philippine Sea and Pacific plates). Beneath slower plates, plate-motion parallel anisotropy is only observed locally, which suggests that the mantle flow below these plates is not controlled by the lithospheric motion (a minimum plate velocity of around 4 cm yr^{-1} is necessary for a plate to organize the flow in its underlying asthenosphere).
A broad region with a stronger than average S-wave attenuation is observed near 150 km depth in the middle of the Pacific ocean. This anomaly is not correlated with the age of the oceanic lithosphere. It could be explained by higher than average temperatures, possibly due to the upwelling of hot material, which would have a stronger effect on seismic attenuation than on seismic velocities.

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