Rheological constraints on time scales of a few decades or less derived from the Earth's response to surface mass redistribution

Chanard K.[1], Fleitout L.[2], Greff M.[1], Couhert A.[3], Mercier F.[3], Bizouard C.[4]

1. Université de Paris, Institut de physique du globe de Paris, CNRS, IGN, France
2. Laboratoire de Géologie, CNRS UMR 8538, École normale Supérieure, PSL Research University, Paris, France
3. Centre National d'Etudes Spatiales, Toulouse, France
4. SYRTE, Observatoire de Paris, Paris, France

Over the past decades, geodetic observations have provided crucial constraints on the Earth's rheology on time scales of a decade or less, mainly through the study of postseismic deformation. Here, we review recent advances in determining rheological properties of the mantle by investigating the Earth's response to surface mass redistribution over seasonal to decadal time scales, using new geodetic observables.

First, we discuss constraints on the short-term viscosity of the asthenosphere using geodetic strain induced by seasonal surface loading, derived from the Gravity and Recovery Climate experiment (GRACE). We predict associated geodetic surface displacements for a purely elastic spherical reference Earth and for a variety of viscoelastic Earth models. We compare results to global GNSS observations and place a lower bound of 5.10^{17} Pa.s on transient asthenospheric viscosity, suggesting that values reported in some postseismic studies do not hold at the global scale.

Seasonal loading also induces pressure variations down to the mantle transition zone and can then help constraining kinetics of mineralogical phase transformations. Indeed, small pressure variations disrupt the two-phases equilibriums, inducing re-equilibration processes and volume changes. However, including the effect of potential phase transformations for the prediction of seasonal displacements at the Earth's surface does not improve the fit to GNSS observations, suggesting that the occurrence of re-equilibration processes occurs over time-scales longer than a year.

Finally, we investigate the alignment of the Earth's Figure axis and its rotation pole at decadal time scales. We take advantage of the long record (1984-2017) of accurate satellite laser tracking to geodetic spherical satellites to measure the long-term displacement of the Figure axis (degree- 2 order-1 geopotential coefficients) and the pole coordinate time series, derived mainly from GPS and VLBI data, to estimate motion of the rotation pole. By analyzing the behavior of the two time series, driven primarily by surface mass redistribution at the decadal time scales, we attempt at providing a new observable to constrain rheological properties of the Earth's deep mantle.

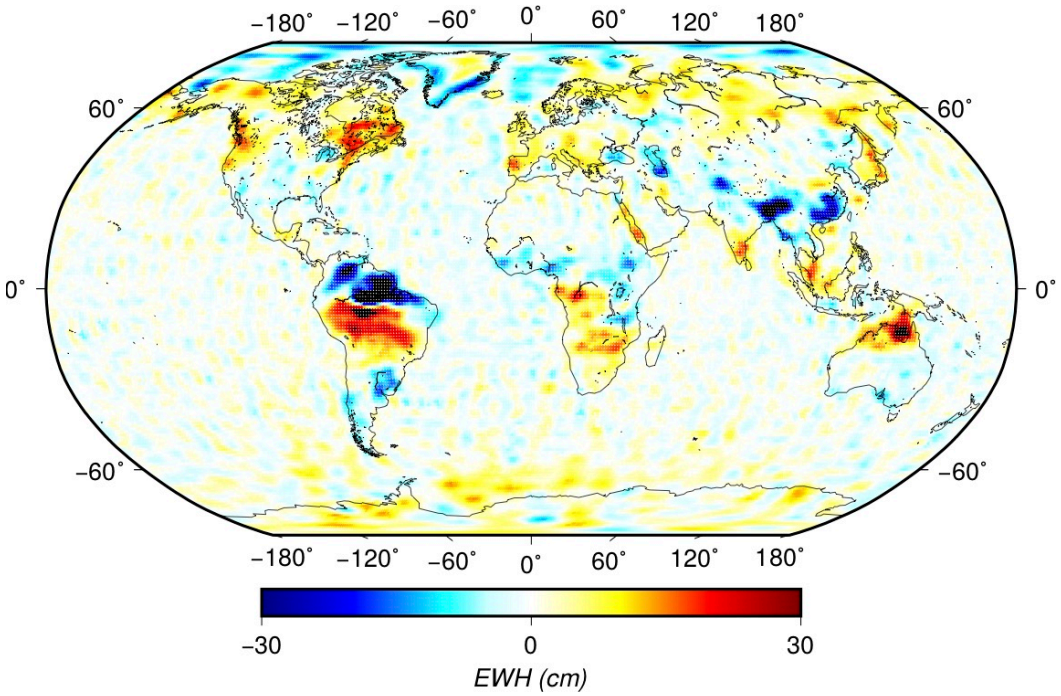

Figure: Surface mass density anomalies solutions for January 2006 relative to July 2005, expressed in equivalent water height (EWH, in cm), for the M-SSA GRACE solution (Prevost et al., 2019).