Post-glacial rebound with lateral viscosity variations and transient rheology

L. Fleitout, G. Cailletaud

Purpose of the study:

The study of the sea-level during the Holocene provides the main constraints on the geometry through time of the main ice-sheets. It is an important ingredient of our understanding of present sea-level variation (correction of present day gravity data or of 20th century tide gauges, understanding of the parameters governing the evolution of a large ice-sheet)

The mechanical properties of the mantle are an important parameter in the link between the ice-sheet history and the observed RSL. We argue here that several ingredients often neglected may affect the inferences from the RSL.

Some paradox related to classical post-glacial rebound models:

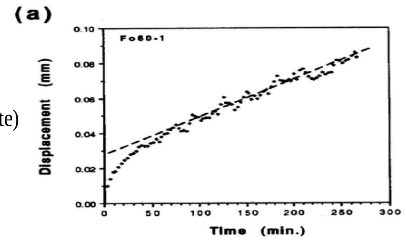
-Post-glacial rebound models involve a thin (100kmthick) lithosphere, difficult to reconcile with the thick cratonic lithosphere.
-Most of them use a Maxwell rheology which might be inappropriate for a heterogeneous mantle (see right panel).
-Some of them propose a low increase of viscosity between lower and upper mantle in contradiction with large scale geoid models.

The models below try to include these geophysical constraints in post-glacial rebound models .
The role of mantle phase transitions will also be considered.

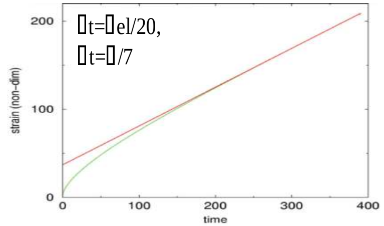
An heterogeneous mantle cannot have a Maxwell rheology

Experimental creep of an aggregate (60% forsterite, 40% enstatite)

Ji et al; tectonophysics 2001

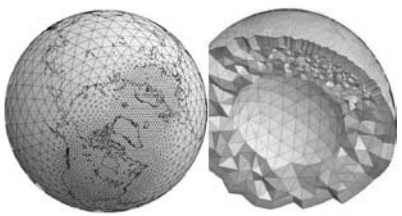


Simulation of the mechanical properties of a mantle, mixture of maxwell materials, with two scales of heterogeneity (grain scale, □1/□2=10, larger scale □1/□2=10).
To simulate the viscoelastic response, the elastic modulus for a self-consistent mixture are replaced by their complex value

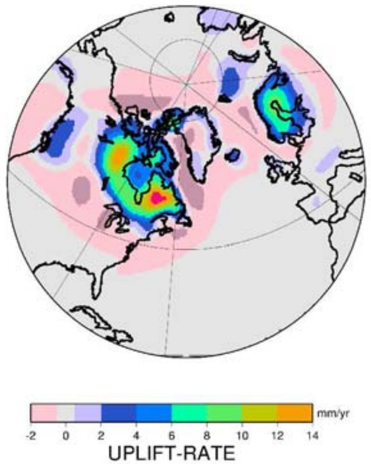


(see also Ivins and Samis, GJI 1995)

Finite element models with lateral viscosity variations

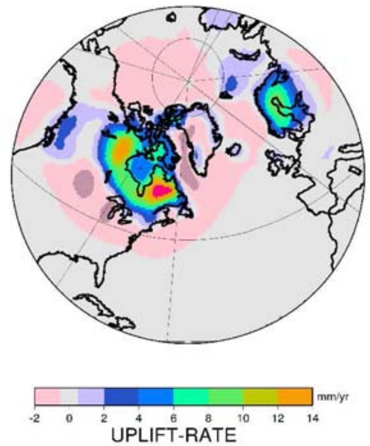


Grey areas correspond to high viscosity cratonic roots



Cratonic lithosphere everywhere

,



Eta asthenosph.=3. 10^{19} Pas below oceans and young continents

Simplified Earth model, Lambeck ice history.

Models with lateral viscosity variations:
The mantle with lateral viscosity variations behaves almost like a mantle with a cratonic root everywhere.
Is this cratonic root incompatible with the observations of PGR?

Inverting for the ice-sheet volume and for the mantle rheology

Inversion

Using a 'spectral model', we predict the sea-level variations during the last 20Kyr. Sea-level equation, change of the axis of rotation, compressibility of the mantle are taken into account.

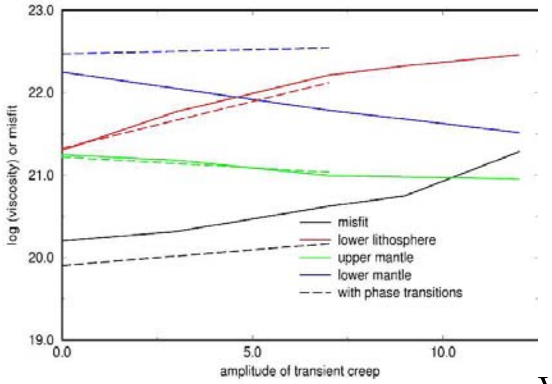
We use sea-level data from the NOAA databank and from Fleming et al. 1998.

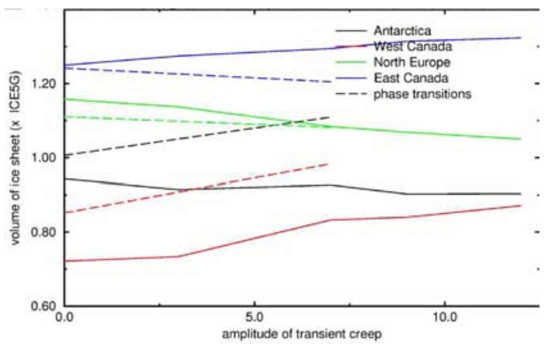
A genetic algorithm determines the mechanical parameters and the volume of each ice-sheet which provide the best-fit to these data:

- -Thickness of the elastic lithosphere
- -Viscosity between the base of the elastic lithosphere and 250km
- -Upper mantle viscosity
- -Lower mantle viscosity
- -proportionality constant independant of time and space multiplying the ice-sheets (here ice5g) over East and West Canada, Europe and antarctica

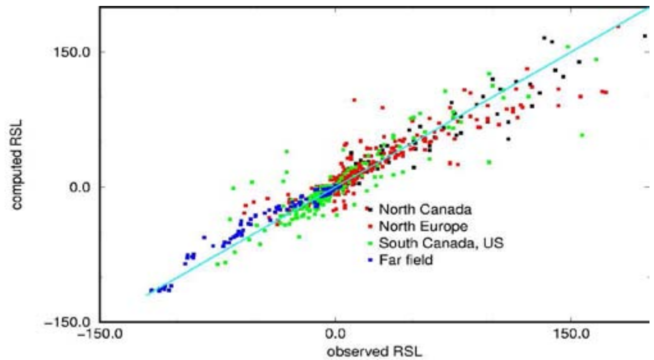
This computation is performed for various amplitudes of the transient creep and phase transition behaviour.

Value of the inverted parameters for various amounts of transient creep

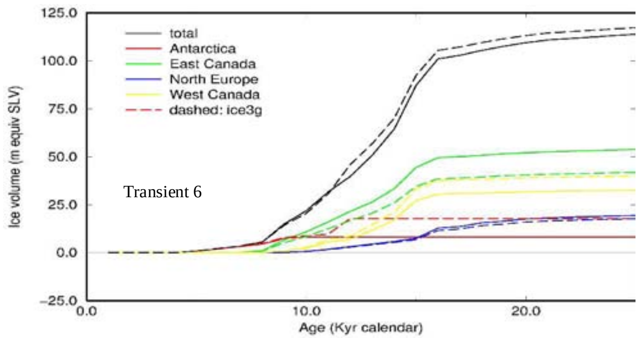




Fit of computed vs observed RSL



Volume of the various ice sheets through time



Conclusion

-It is possible to fit the post-glacial rebound data with models involving a transient rheology, lateral viscosity variations and long-term viscosities compatible with other geodynamical constraints (thick cratonic roots, increase of viscosity in the lower mantle).

-The amount of ice over West-Canada proposed by ICE5G seems overestimated. That over East-Canada underestimated.

-A total melting of ice over Antarctica of less than 10m equivalent RSL is compatible with the global data of RSL during the last 10 Kyr.