Stress analysis of plate motions

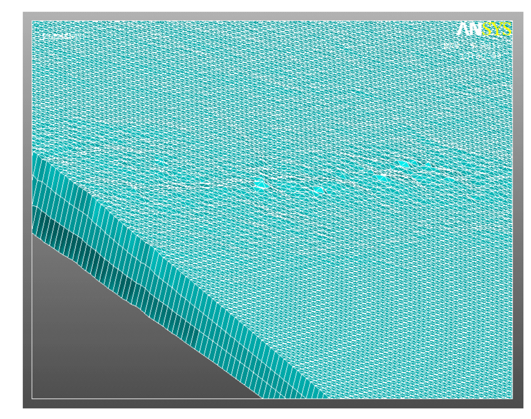
M. Kollár[1], Z. Minarechová[1]
[1]Slovak University of Technology in Bratislava, Dept. of Mathematics- Faculty of Civil Engineering, Bratislava, Slovak Republic
Contact: kollarm@math.sk

Abstract

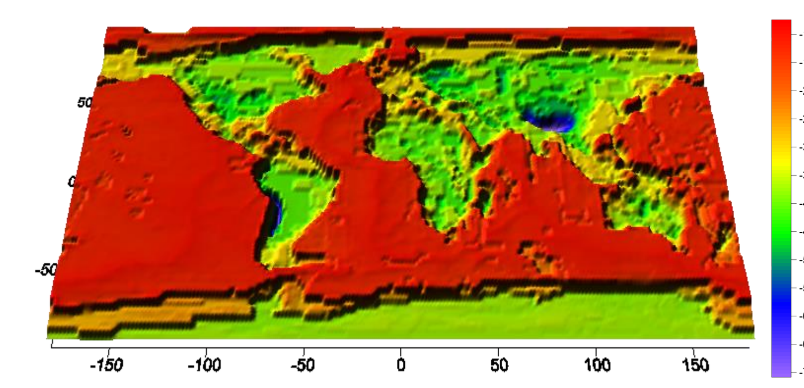
The work deals with a study of the stress and strain fields resulted from the plate motions. The theoretical part is devoted to causes and types of plate motions and deformations, then it presents the basics of elasticity theory with the derivation of Lame`s equations of 3D elasticity and their solution by the finite element method. The practical part discusses the numerical experiments, where the 3D computational domain is bounded by the real Earth's surface from above and by the Moho surface from bellow. The input boundary conditions applied on the upper boundary are in the form of displacement vectors obtained by HS3-NUVEL1A, while on the lower one we suppose the symmetry boundary conditions, i.e. displacement vector component perpendicular to this boundary is zero. For numerical implementation, the 3D linear elements in FEM (Finite Element Method) software ANSYS are used and several local refinements in chosen fault regions are presented as well. Results are represented in the form of components of stress tensor.

CRUST 2.0

Crust 2.0 represents a density and thickness model for earth's crust with discretization 2x2 degree. Whole model consider 7 layers: ice, water, soft sediments, hard sediments, upper crust, middle crust and lower crust. From this model we obtain a thickness and average density of each of three layers of our model.



Detail of computational domain with three layers division



Crust thickness from model CRUST 2.0 [m]

Global numerical experiment

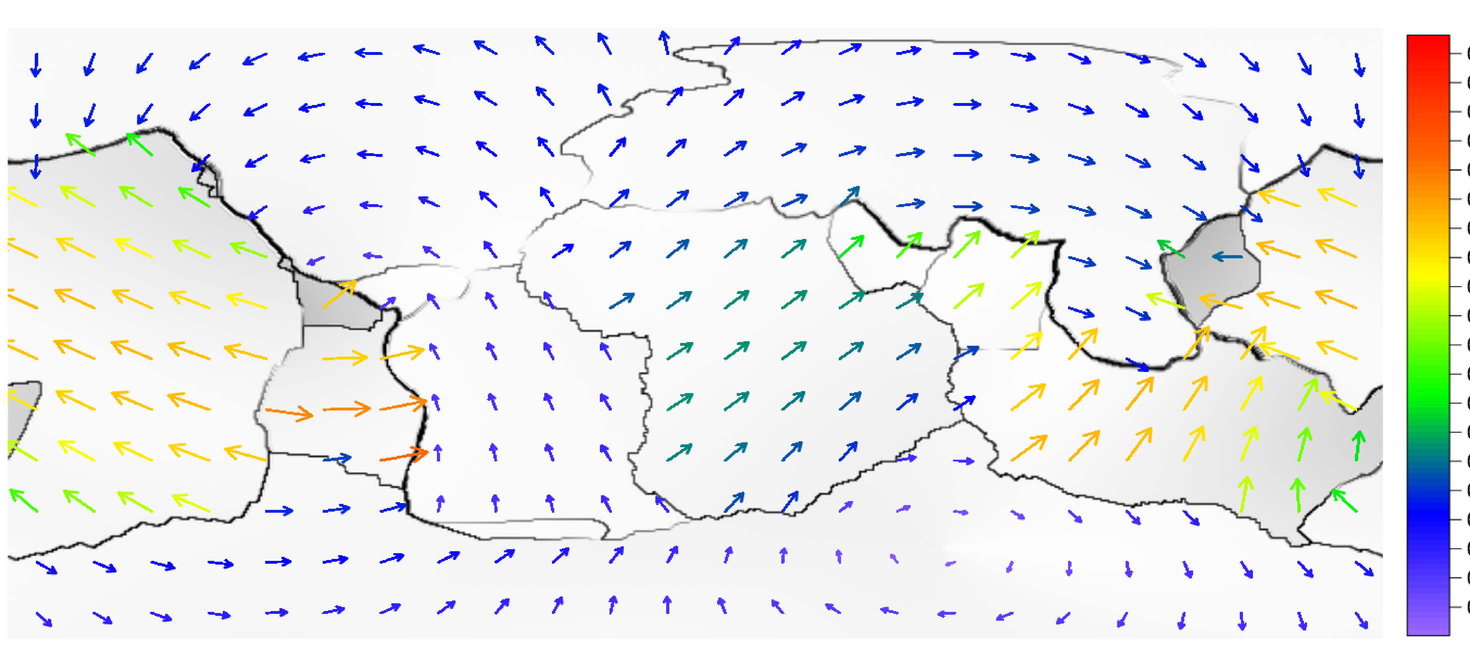
Global experiment deals with calculation of components of stress tensor in nodes on whole Earth surface. For a boundary conditions was used data from model HS3-NUVEL1A (model of absolute global displacements velocity). All results are in topographic coordinate system.

Material properties:

- Young's modulus: $E = \rho V p^2 \frac{(1+\sigma)(1-2\sigma)}{3\sigma}$ (ρ – density, Vp - velocity of p-wave, σ - Poisson's ratio)
- Poisson's ratio: 0.25

Total nodes	1 033 928	Total unknowns	3 101 784
Total elements	1 550 880	Discretization of Earth Surface	0.5° x 0.5°
Total nodes on Earth surface	258 482		

Statistic of global experiment

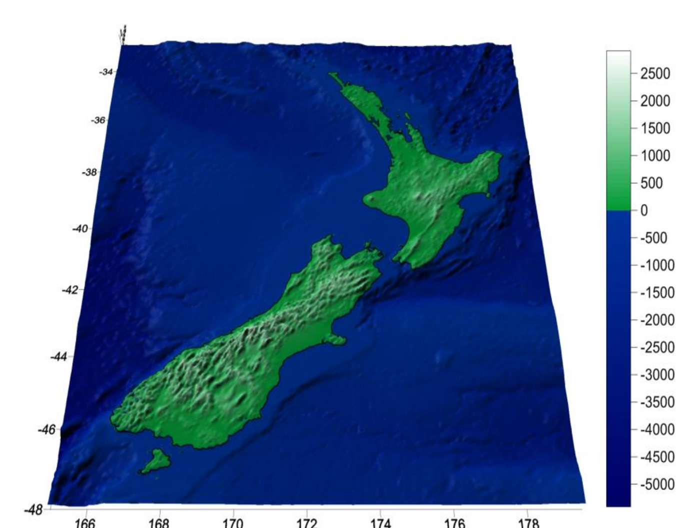


Vector visualization of displacements of lithospheric plates [m/year]

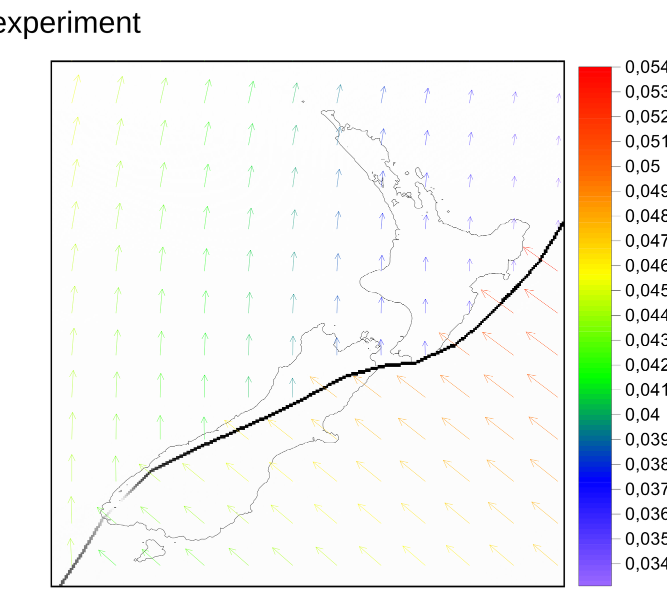
Regional experiment – New Zealand

Total nodes	350 364	Total unknowns	1 051 092
Total elements	522 000	Discretization of Earth Surface	0.05° x 0.05°
Total nodes on Earth surface	87 591		

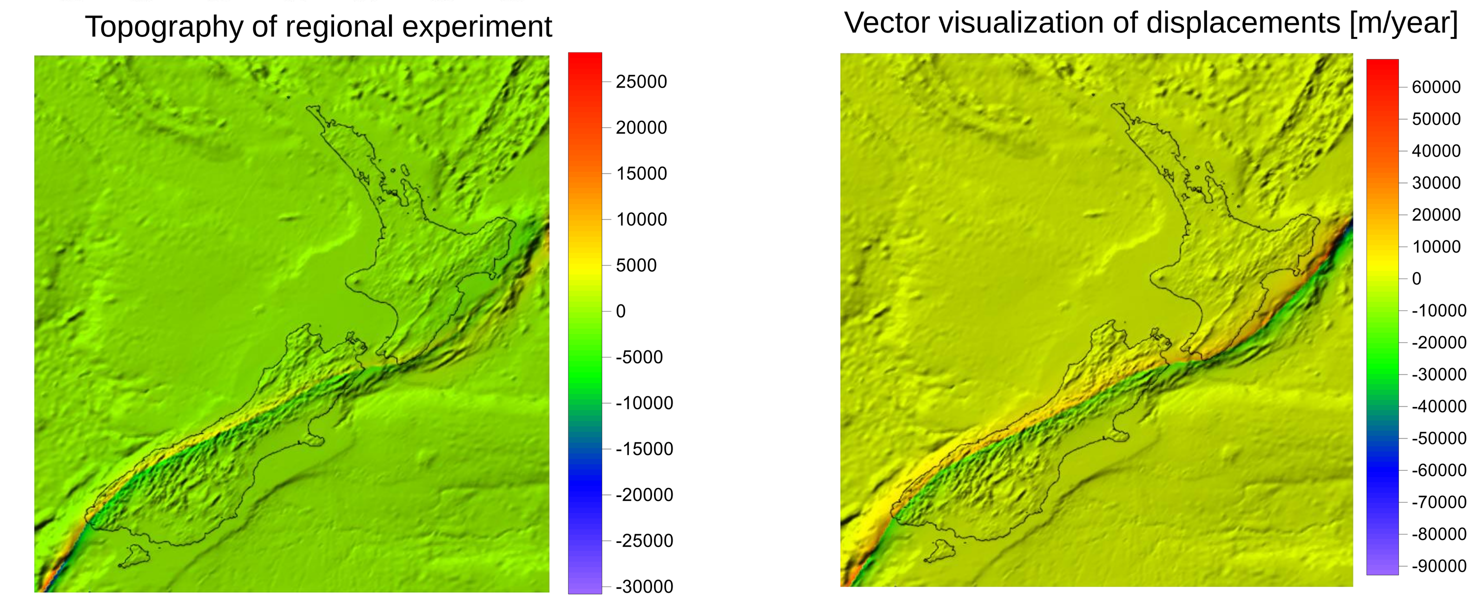
Statistic of regional experiment



Topography of regional experiment



Vector visualization of displacements [m/year]

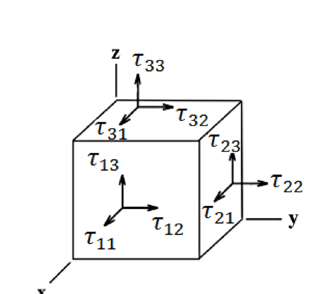


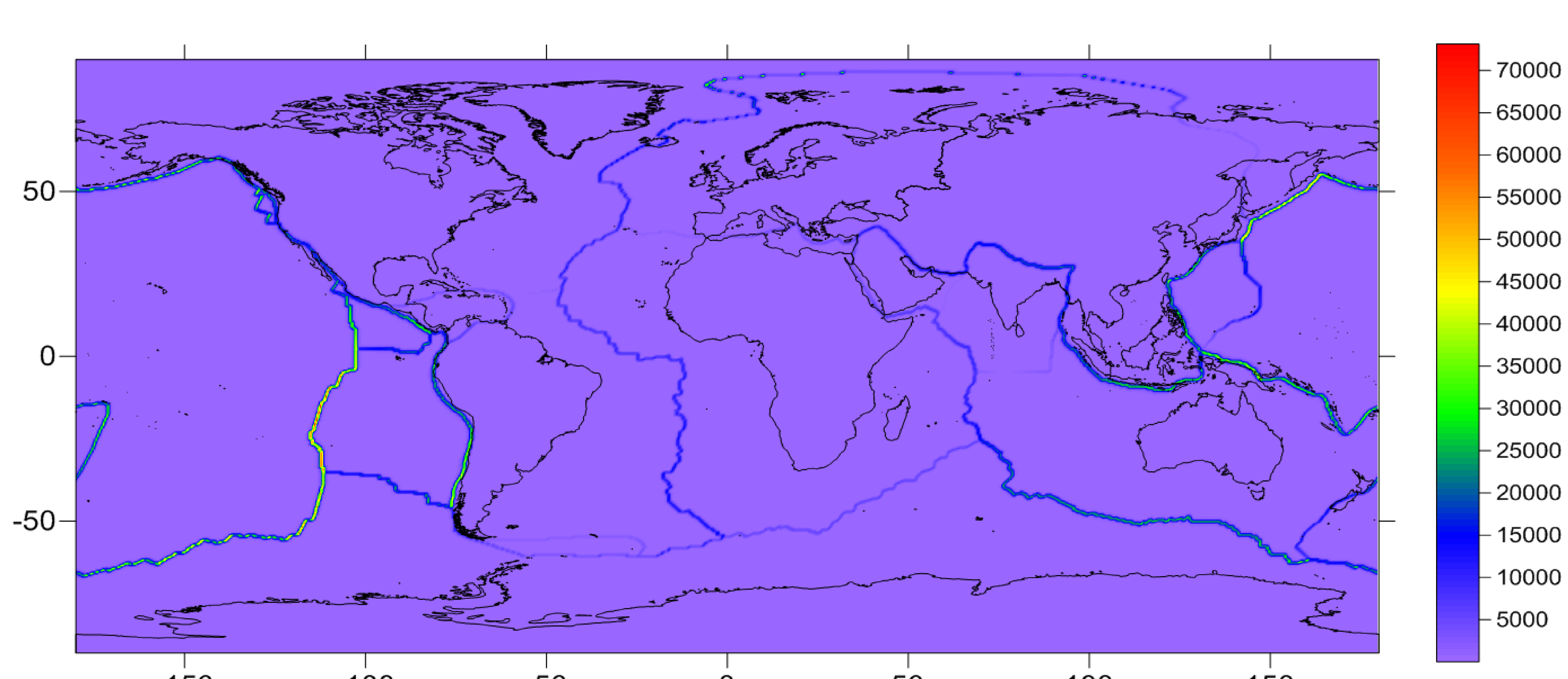
Tangential stress τ_{13}, τ_{23}

Global numerical experiment results

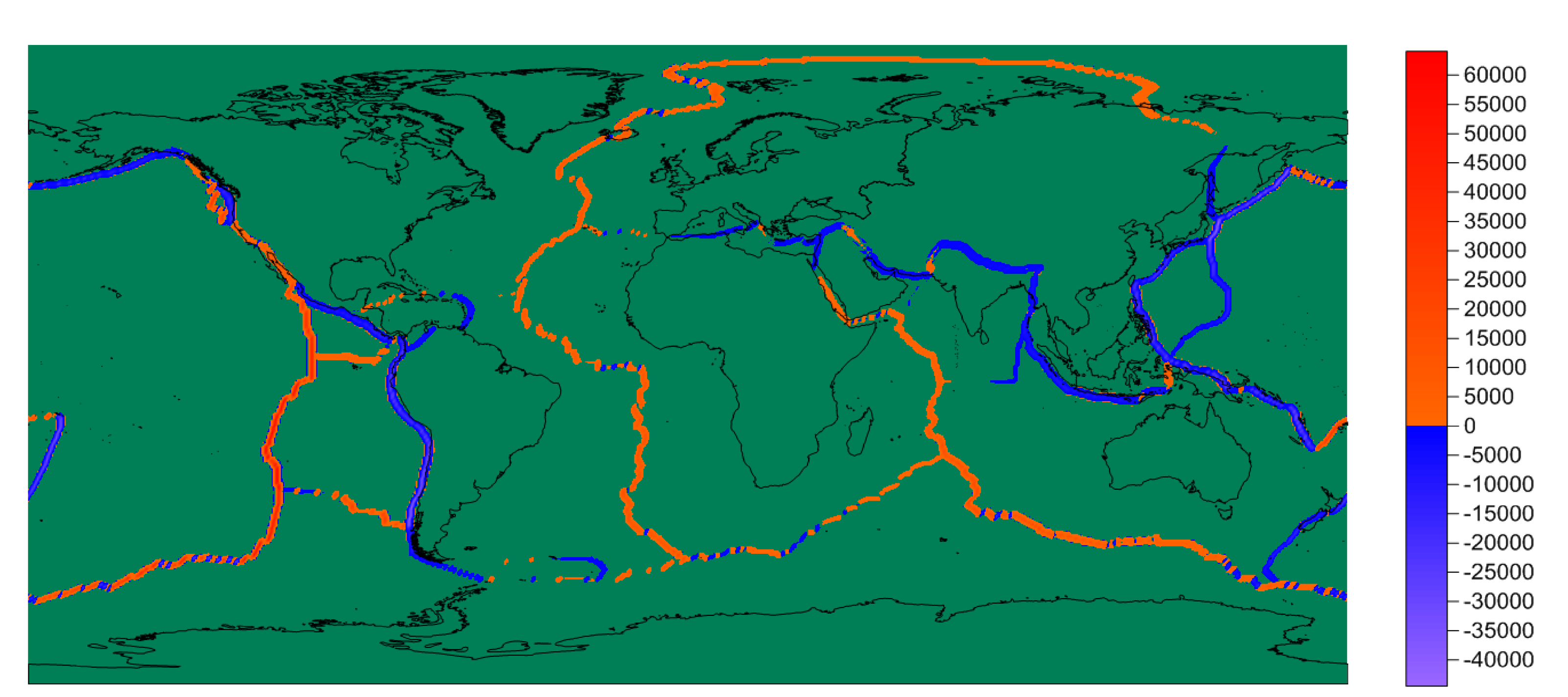
von Misses stress: $$\tau_v = \sqrt{\frac{1}{2}\left[(\tau_{11}-\tau_{22})^2+(\tau_{22}-\tau_{33})^2+(\tau_{33}-\tau_{11})^2+6({\tau_{12}}^2+{\tau_{23}}^2+{\tau_{31}}^2)\right]}.$$

Stress tensor: $$\mathrm{T} = \begin{pmatrix} \tau_{11} & \tau_{12} & \tau_{13} \\ \tau_{21} & \tau_{22} & \tau_{23} \\ \tau_{31} & \tau_{32} & \tau_{33} \end{pmatrix}$$

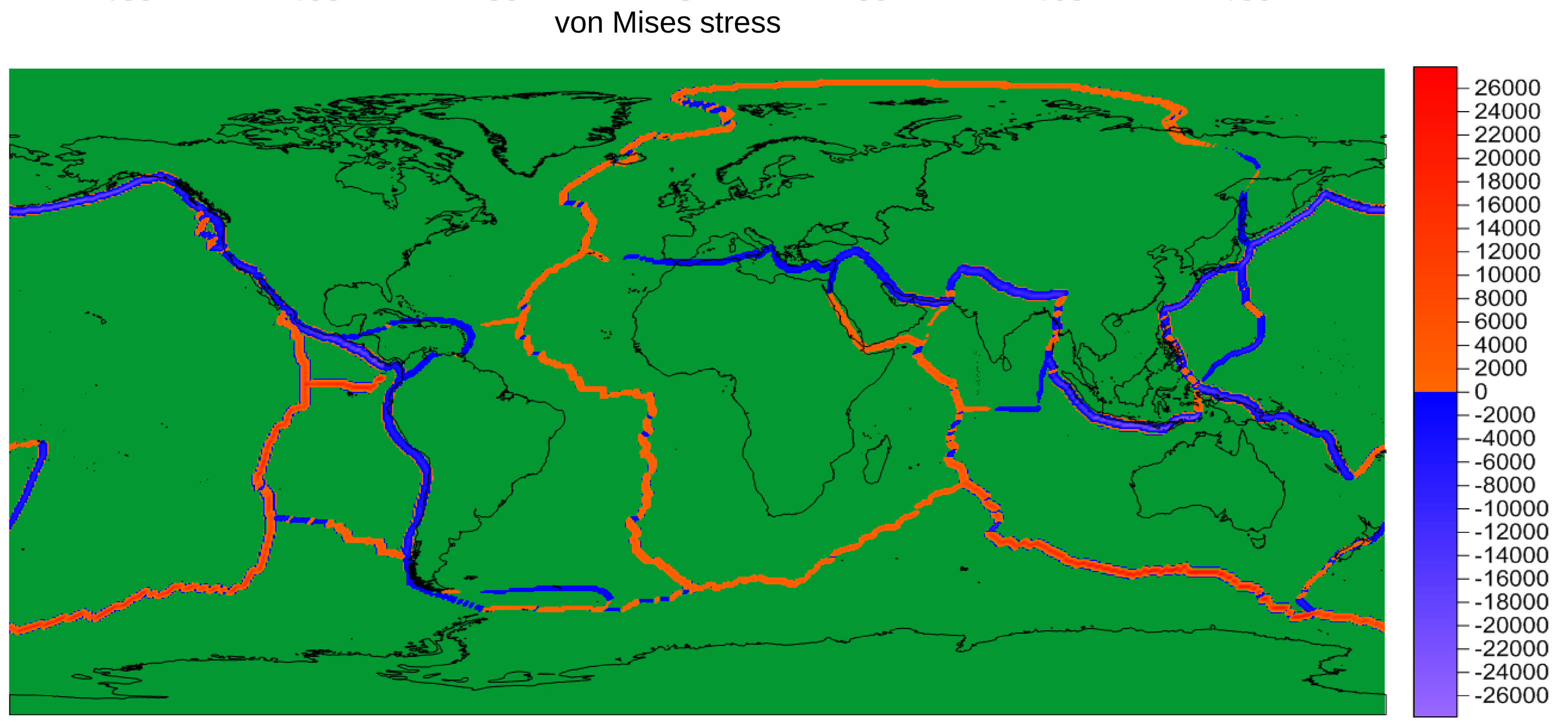




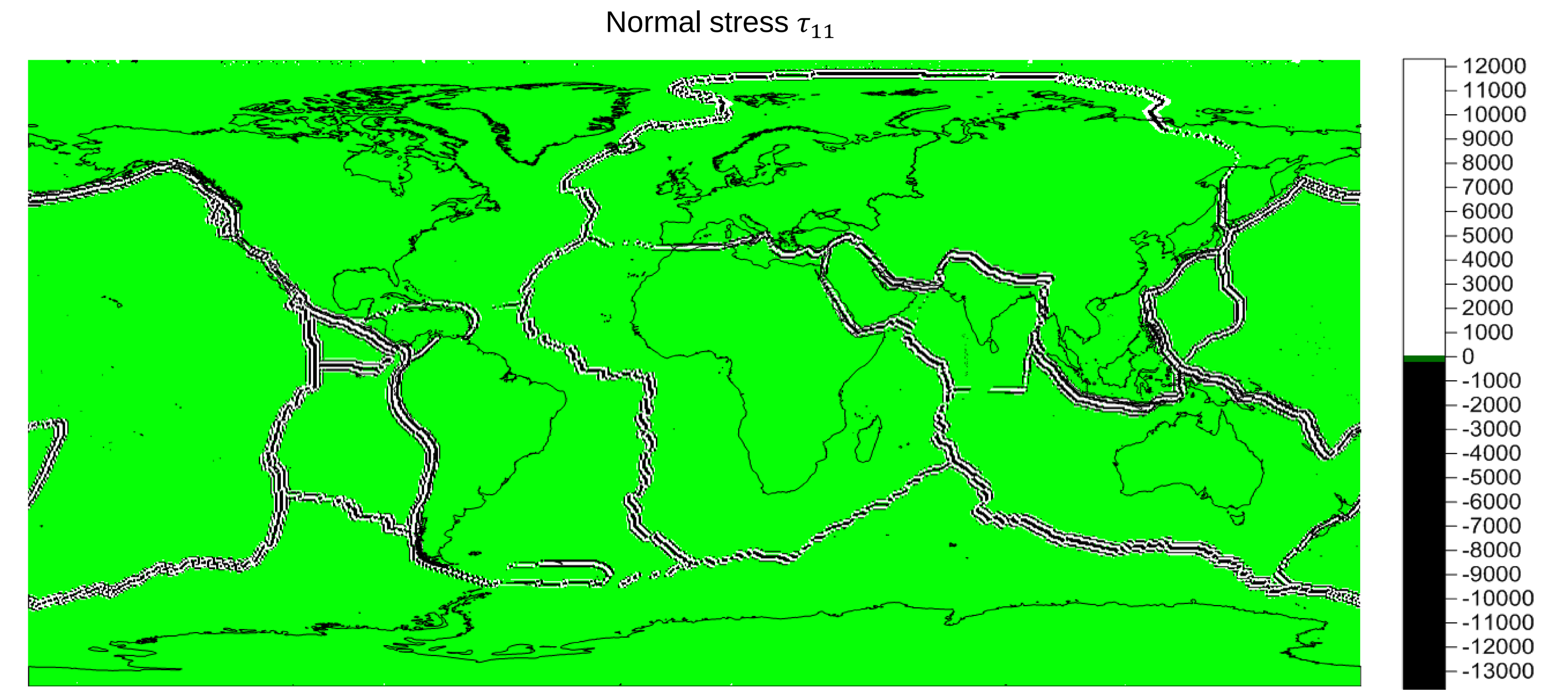
von Mises stress



Normal stress τ_{11}



Normal stress τ_{22}



Normal stress τ_{33}