Surface deformations of a 3D elastic self-gravitating Earth

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Motivation

- Surface geology and seismic tomography show that properties of the Earth's internal structure vary laterally.
- Lateral heterogeneity in viscosity structure has been demonstrated to have considerable effect on surface deformation, geoid and sea level; However, few studies are trying to address the effects of lateral heterogeneity in elastic structure (e.g. Dill et al 2015).
- Demand for improved global deformation mapping for instantaneous to annual mass loading is rising due to increased accuracy of geodetic observation systems like GNSS and an integrated interpretation of earth system processes.
- Goal: the impact of lateral heterogeneity in elastic moduli of upper mantle on surface deformation for ocean tidal loading.

Methodology and models

1. Methodology

- Spectral–finite-element method (Martinec 2000; Tanaka et al. 2019)

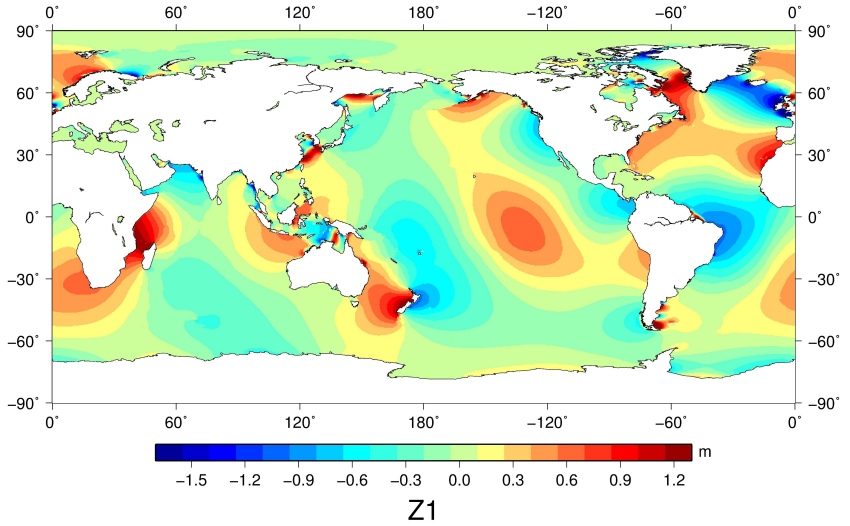
2. Elastic structure

- Upper mantle is deviation from 1D PREM applying 3D Q model QRLW8 (Gung and Romanowicz 2004).
- Remaining is elastic 1D PREM (Dziewonski and Anderson 1981).

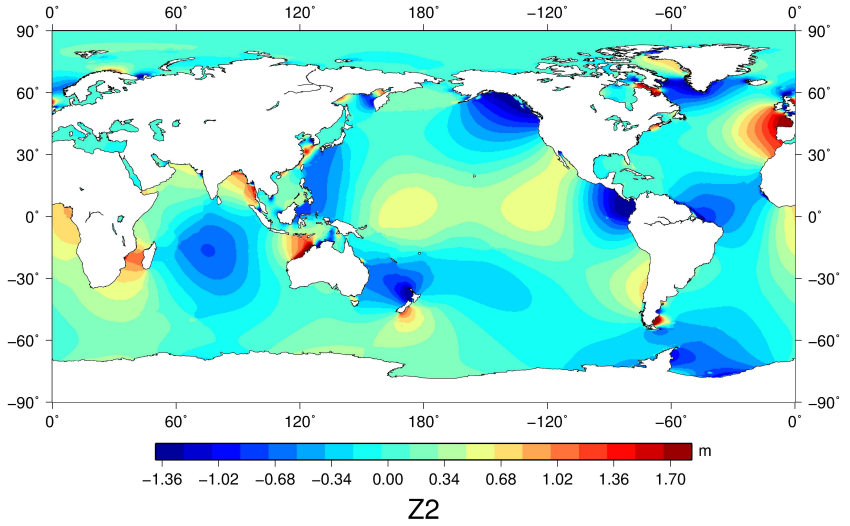
3. Ocean tidal Loading M2 (Weis et al. 2008)

- Tidal elevation:

$$Z(t) = Z_1 \cos(\omega t) + Z_2 \sin(\omega t)$$

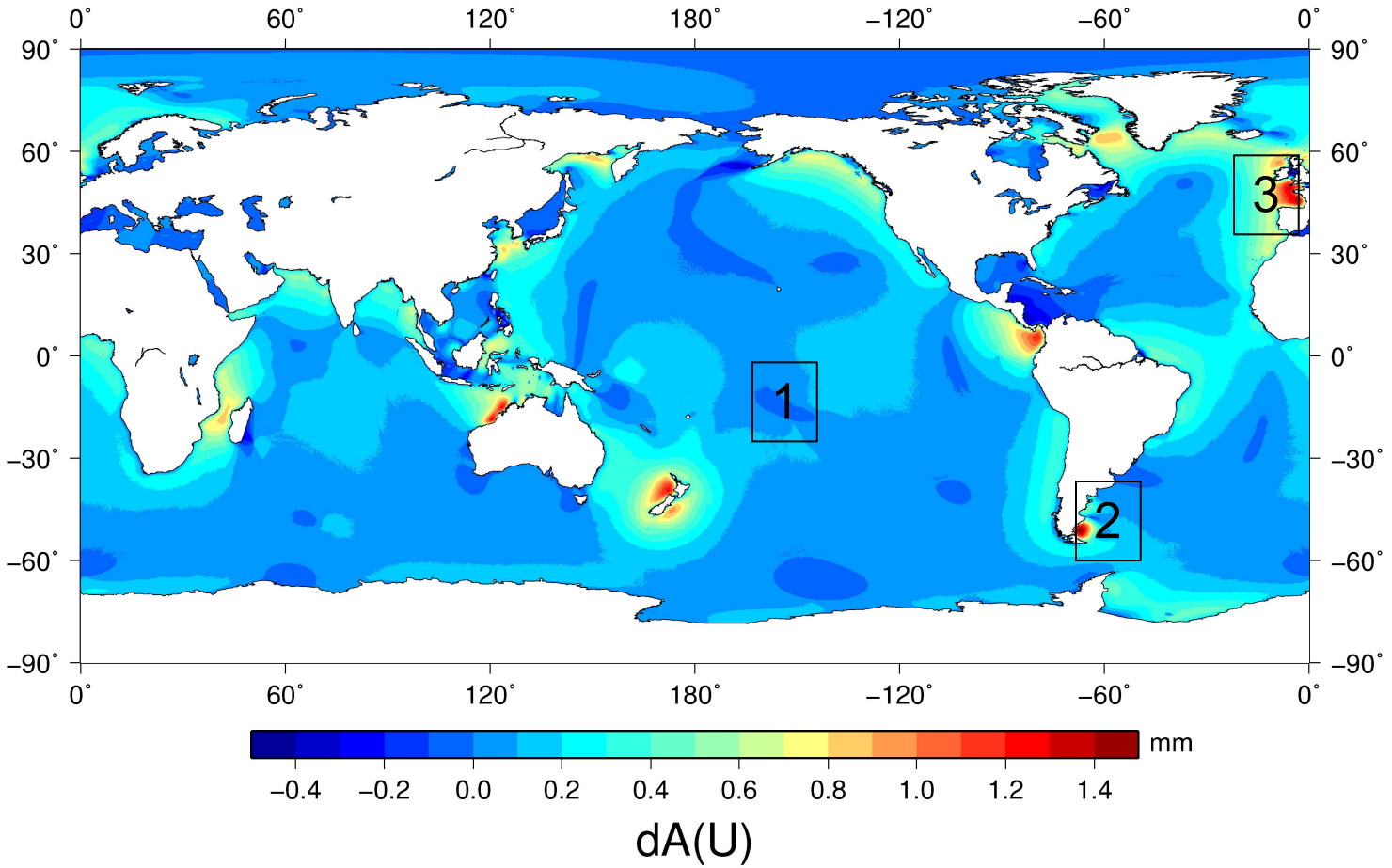


Z1



Z2

Results: deviation in amplitude of vertical displacement U caused by 3D structure



- Positive and negative deviations exist
- Open ocean region 1: deviation < 0.5 mm
- Shelf regions 2 and 3: deviation > 1 mm
- Largest deviation: 1.5 mm

Conclusion

- 3D structure modifies surface vertical displacement due to ocean tidal loading M2 at the order of 1 mm, reaching up to 1.5 mm.
- The impact can be positive or negative, depending on local 3D structure.

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