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Towards a Eurasia-scale stress model: updates of the gravitational potential energy forces

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Introduction

The sources of stress may be summarized as follows (Kusznir, 1982): (1) lateral density and topography contrasts (e.g. passive continental margins or subduction zones); (2) thermal stresses (e.g. cooling stress within oceanic lithosphere); (3) asthenosphere flow drag on lithosphere; (4) lithosphere bending and flexure; (5) membrane stresses.

We focus on the horizontal gravitational stresses/Gravitational buoyancy forces resulting from lateral variations in gravitational potential energy, which are particularly relevant in the context of the Eurasian plate because there are no major slabs attached to it (i.e., no slab pull force).
In the work of Warners-Ruckstuhl et al., 2013, the misfit between observations and numerically obtained stresses and velocities is shown.

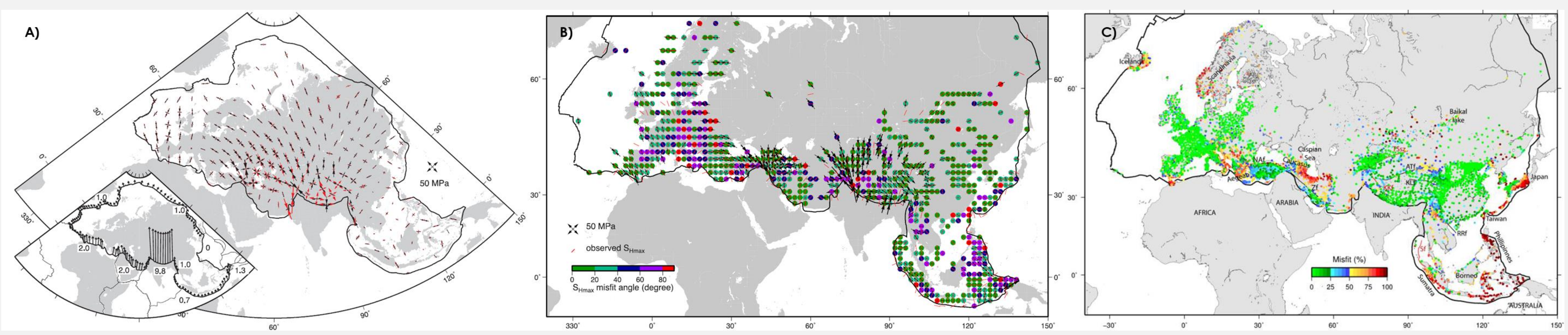

Figure 1: A) stresses field for boundary forces model of Warners-Ruckstuhl et al., 2013 (black axes), B) Comparison of stress results (stress axes) for force model with observations (red stripes). Colours represent local misfit angles. C) misfit between velocity results with observations from Candela et al., 2014

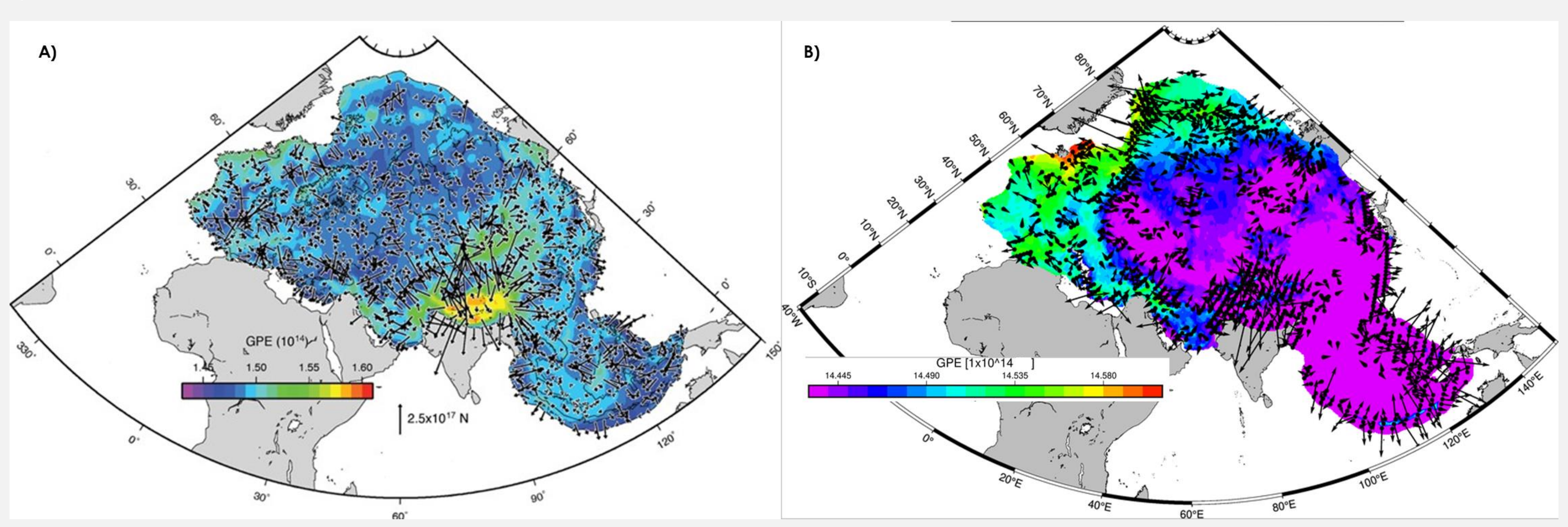

Figure 2: Horizontal gravitational stresses (HGS) arrows and GPE contour from: A) Warners-Ruckstuhl et al., 2012, B) Gutierrez et al., 2024 (in preparation)

Horizontal gravitational stresses (HGS)

Horizontal gravitational stresses (HGS) arise from lateral variations in geopotential energy (GPE) of the lithosphere, which is caused by lateral variations in the topography and (vertical) density structure of the lithosphere. The net horizontal force (HGS) generated by lateral density variations is the horizontal gradient of the GPE.

In Figure 3, Horizontal gravitational stresses (HGS) from the lithospheric model of WINTERC-G (Fullea et al., 2021) are shown for schools of thought assuming compensation depths of: A) LAB model (300 km), B) Crustal model (68 km), C) 100 km.

Histograms of the Horizontal gravitational stresses (HGS) magnitude and directions are shown in Figure 4. As can be inferred, models with compensation depths of 68 km and 100 km are underestimating HGS magnitudes. Additionally, Directions are slightly difference.

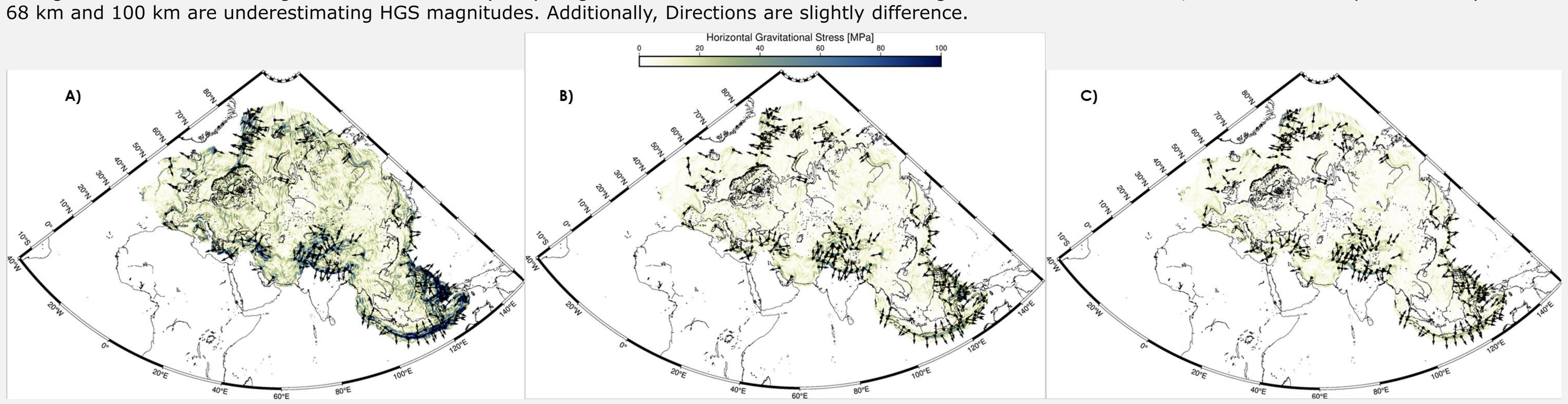

Figure 3: Horizontal gravitational stresses (HGS) for schools of thought assuming compensation depths of: A) LAB model (300 km), B) Crustal model (68 km), C) 100 km

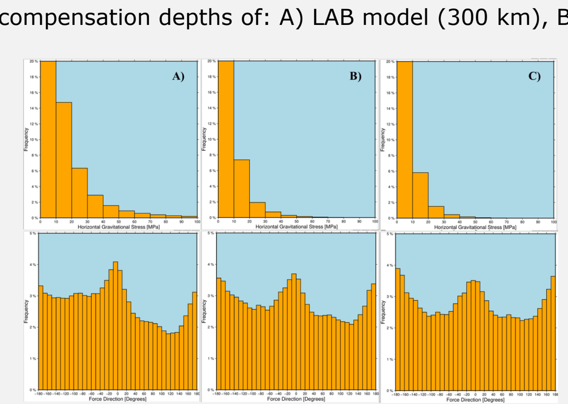

Figure 4: Histograms of Horizontal gravitational stress (HGS) magnitudes and directions for schools of thought assuming compensation depths of: A) LAB model (300 km), B) Crustal model (68 km), C) 100 km

Lithoref18 and Wintercg lithospheric models

Lithoref18 from Afonso et al. (2019) is a new global model for the Earth's lithosphere and upper mantle (LithoRef18) obtained through a formal joint inversion of 3-D gravity anomalies, geoid height, satellite-derived gravity gradients and absolute elevation complemented with seismic, thermal and petrological prior information. WINTERC-G from Fullea et al. (2019) is a Waveform tomography and Gravity (geoid and gravity anomalies and gradiometric measurements from ESA's GOCE mission) INversion for the TEmpeRature and Composition of the lithosphere and upper mantle at global scale. Figure 5 shows Horizontal gravitational stresses (HGS) for: A) Lithoref18, B) Wintercg

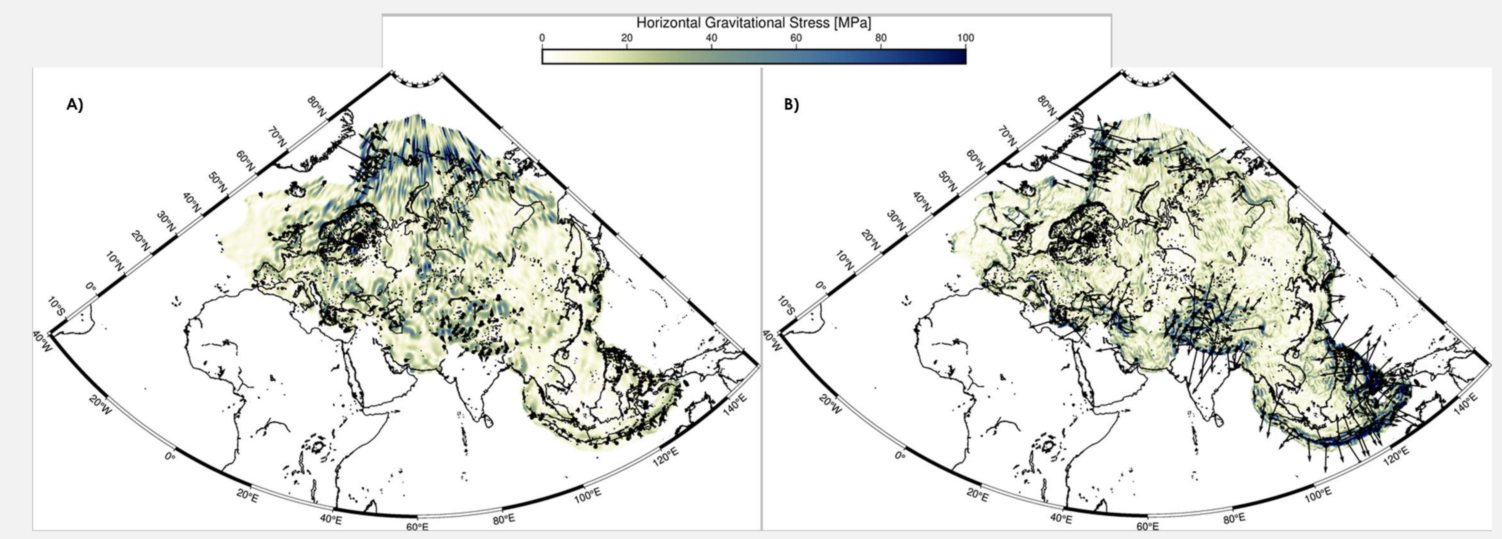

Figure 5: Horizontal gravitational stresses (HGS) for: A) Lithoref18, B) Wintercg

Figure 6 shows Horizontal gravitational stresses (HGS) for relevant regions in Eurasia.

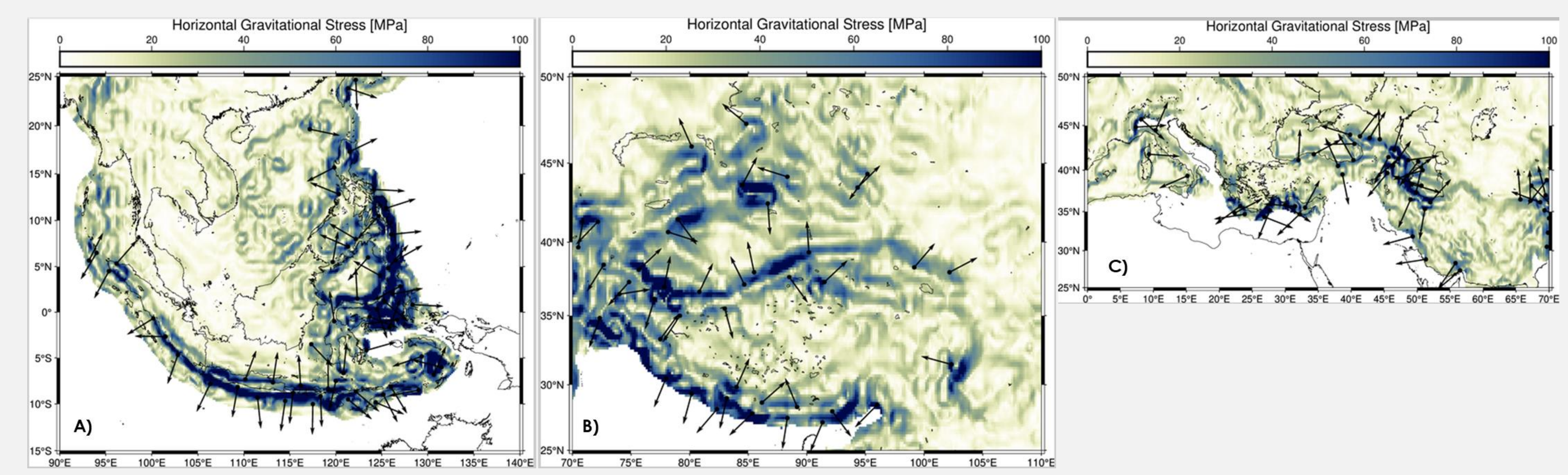

Figure 6: Horizontal gravitational stresses (HGS) for schools of thought assuming compensation depths of: A) LAB model (300 km), B) Crustal model (68 km), C) 100 km

Deformation zones, faults, and plate boundaries of Eurasia

The next step is to model the tectonic forces being applied by neighboring plates and mantle tractions with the finite element method to include other sources of stresses and compare them with observations. Figure 7 shows the update of the mechanical model starting with Hasterok et al., 2022 deformation zones, faults, and plate boundaries of Eurasia

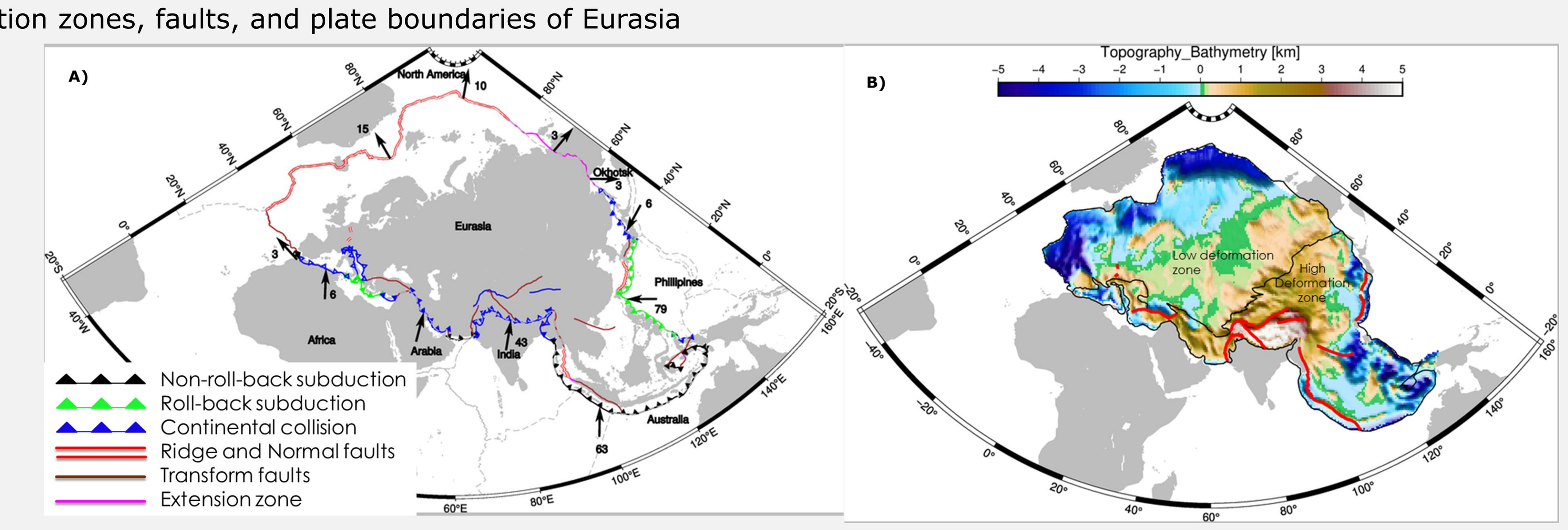

Figure 7: A) Deformation zones, faults, and plate boundaries of Eurasia. B) High and low deformation zones for our Eurasian model

Conclusions

- GPE and Horizontal gravitational stresses (HGS) are underestimated in the work of Warners-Ruckstuhl et al., 2012 and 2013.
- Horizontal gravitational stresses (HGS) are underestimated for schools of thought assuming compensation depths at the Moho or 100km depth as shown in Figures 3 and 4.
- Figure 5 shows that LITHOREF18 provides lower Horizontal gravitational stresses compare to WINTERCG, specially in the Tibetan region.

References

- Warners-Ruckstuhl, K., Govers, R., Wortel, R. (2013). Tethyan collision forces and the stress field of the Eurasian Plate Geophys. J. Int. 195(1), 1 - 15. https://dx.doi.org/10.1093/gji/ggt219
- Afonso, J. C., Salajegheh, F., Szwillus, W., Ebbing, J., & Gaina, C. (2019). A global reference model of the lithosphere and upper mantle from joint inversion and analysis of multiple data sets. Geophysical Journal International, 217(3), 1602–1628
- Fullea, J., Lebedev, S., Martinec, Z., & Celli, N. L. (2021). WINTERC-G: Mapping the upper mantle thermochemical heterogeneity from coupled geophysical–petrological inversion of seismic waveforms, heat flow, surface elevation and gravity satellite data. Geophysical Journal International, 226(1), 146–191
- Hasterok, D., Halpin, J. A., Collins, A. S., Hand, M., Kreemer, C., Gard, M. G., & Glorie, S. (2022). New Maps of Global Geological Provinces and Tectonic Plates. In Earth-Science Reviews (Vol. 231). Elsevier B.V. https://doi.org/10.1016/j.earscirev.2022.104069

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