Tectonic and climate induced mass changes- competing signals in long term gravity signals

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1. Introduction

- Aim of the study: estimate the three principal competing mass variations
- Hydrologic mass, Ice mass, mass change due to tectonic uplift and subsidence
- Tectonic uplift usually neglected, but GPS demonstrates uplift rates.
- Define detectability through geodetic gravity satellite mission as GRACE-FO and innovative gravity mission

2. Methods

- Gravity simulations constrained by:
  - Hydrology constraints: GLDAS model of integrated moisture mass for first 2m of soil (Rodell et al.,2004)
  - Glaciers outlines: Randolph database (Pfeffer et al., 2014)
  - Glaciers rates: satellite altimetry (Gardner et al., 2013)
  - Tectonic constraints: GNSS uplift rates from Liang et al. (2013) and Fu and Freymueller (2012)
  - Moho: models range from isostatic crustal compensation rates to pure crustal uplift
- Gravity Modelling: Tesseroids (Uieda et al., 2016)
- Compare the observed signals with the error curves of GRACE-FO and future gravity missions

3. Spectral estimates

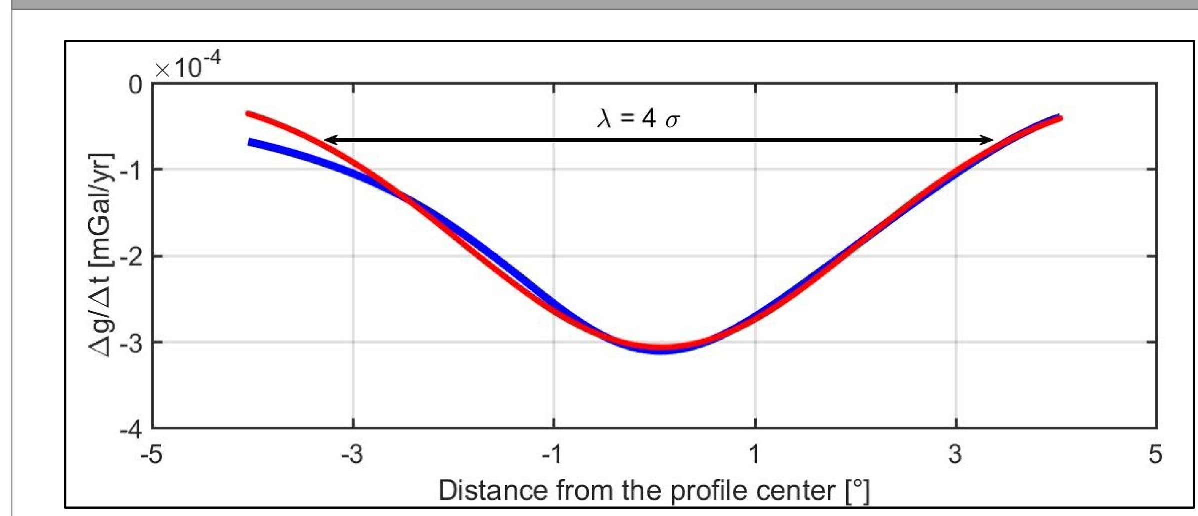

Figure 1: Satellites are defined through their error spectral curves. The signal must be above the error curve to be observed. The signal is fitted with a Gaussian function, for which characteristic wavelength is defined through the Gaussian dispersion value.

4. Tectonic movements

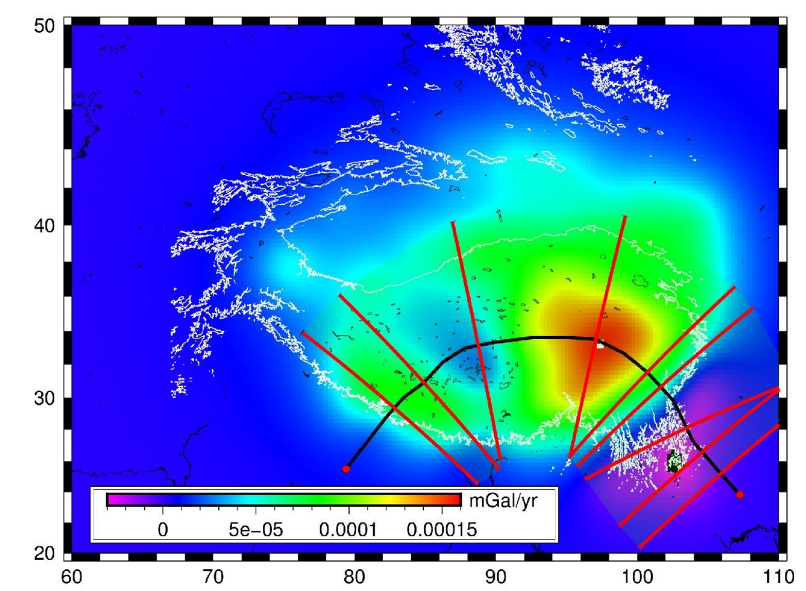

Figure 2: Map of gravity change rate at 250 km height in the High Mountains of Asia region due to tectonic uplift as observed by GNSS. Pure uplift gives maximum signal. Uplift due to crustal thickening has smallest signal. Profiles used to define characteristic wavelength and amplitude with Gaussian function.

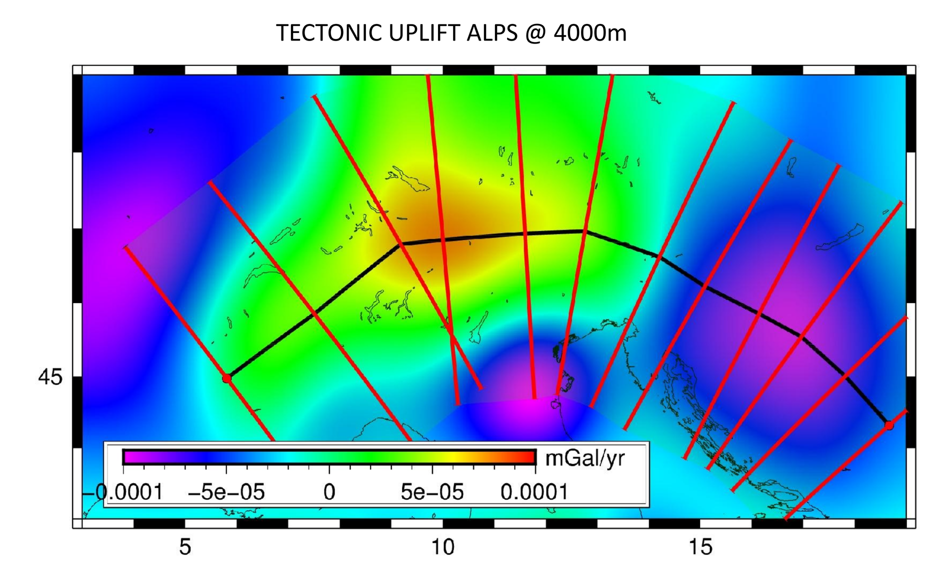

Figure 4: Map of gravity change rate at 4 km height in the Alps due to tectonic uplift as observed by GNSS. Profiles used to define characteristic wavelength and amplitude with Gaussian function.

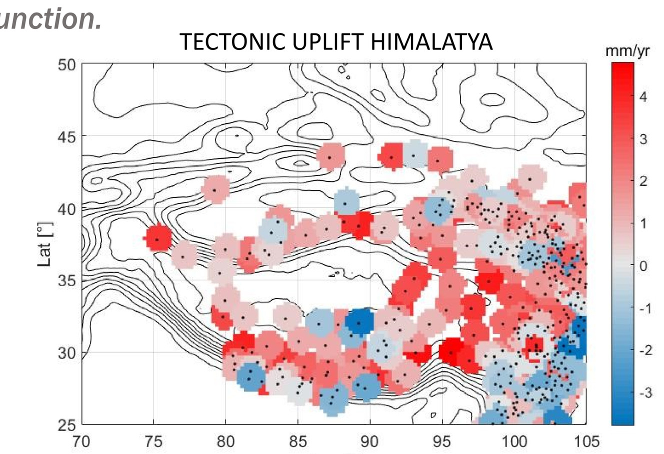

Figure 3: Map of GNNS observations in the High Mountains of Asia region. Dots show the GNSS observations in the area (Liang et al. 2013; Fu and Freymueller, 2012). The map shows also the average displacement calculated on circular area of 2° radius.

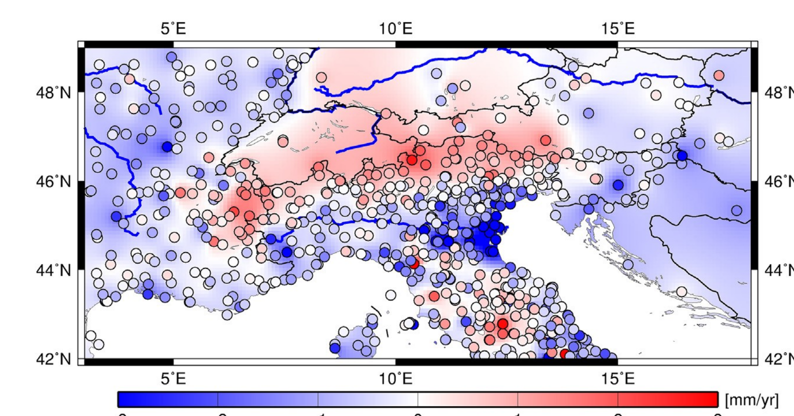

Figure 5: Map of GNNS observations in the Alps region. Dots show the GNSS observations in the area (updated rates after Serpelloni et al., 2013).

5. Hydrologic Long period variations

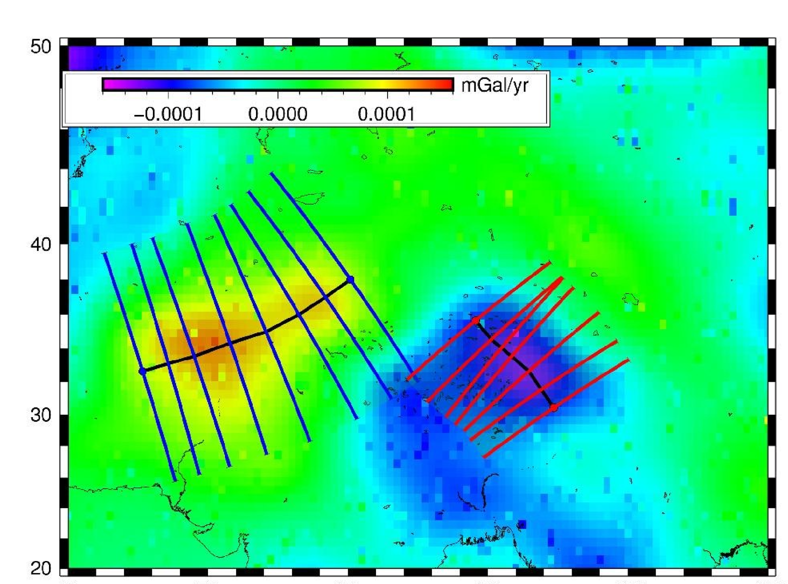

Figure 6: Long period water mass variations at 250 km Himalaya Tibet. The blue and red profiles are distinguished in the spectral error curves. Blue Pakistan; red Eastern Tibet.

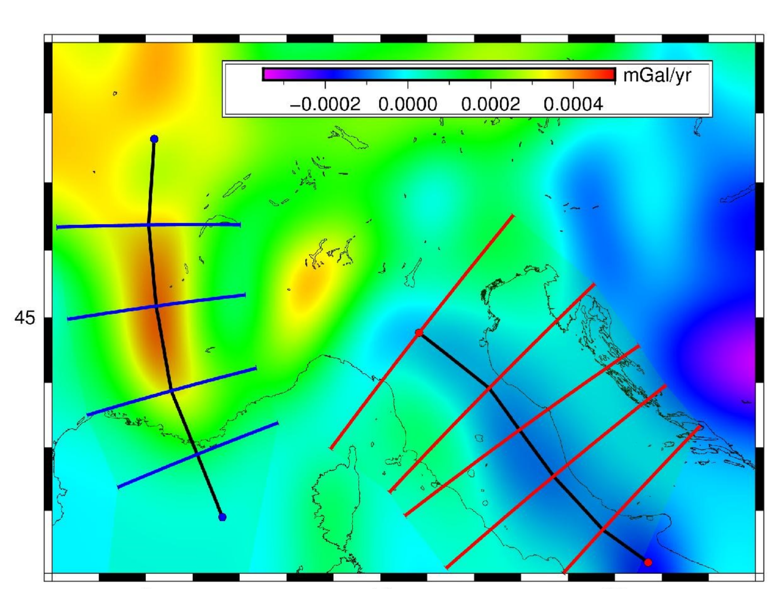

Figure 7: Long period water mass variations in the Alps at 4km. The blue and red profiles are distinguished in the spectral error curves. Blue western Alps; red Appennines.

6. Glaciers Himalayas

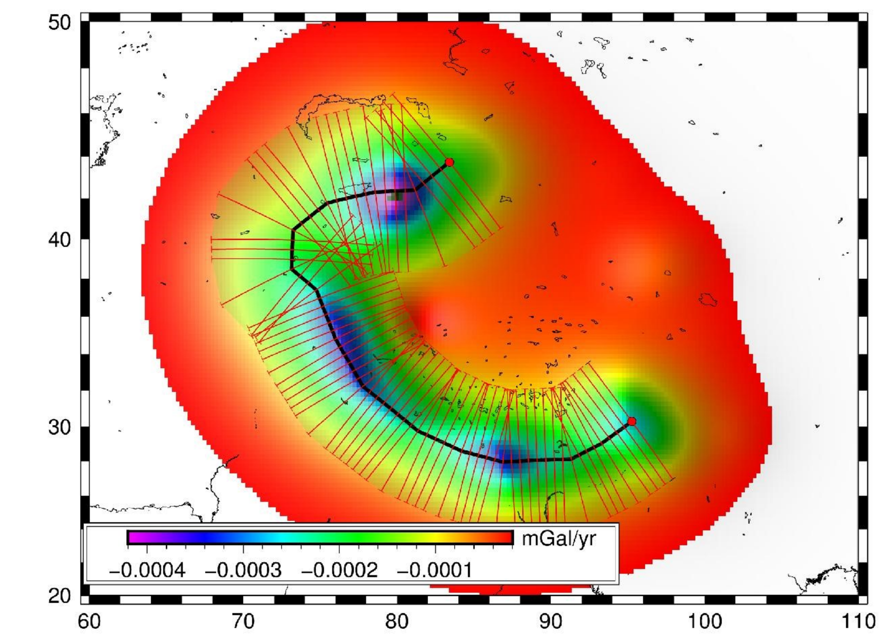

Figure 8: Yearly gravity change due to HMA ice thickness variations. Calculations at 250km height. Red lines show the position of the profiles.

- Gravity variations calculated by discretising the yearly mass change in Tesseroids.
- To construct the density model, the RGI catalog was used to obtain the glacierized areas in HMA region
- The estimates of ice thickness variations in the region were taken from Gardner et al. 2013

7. Satellite error curves and signals

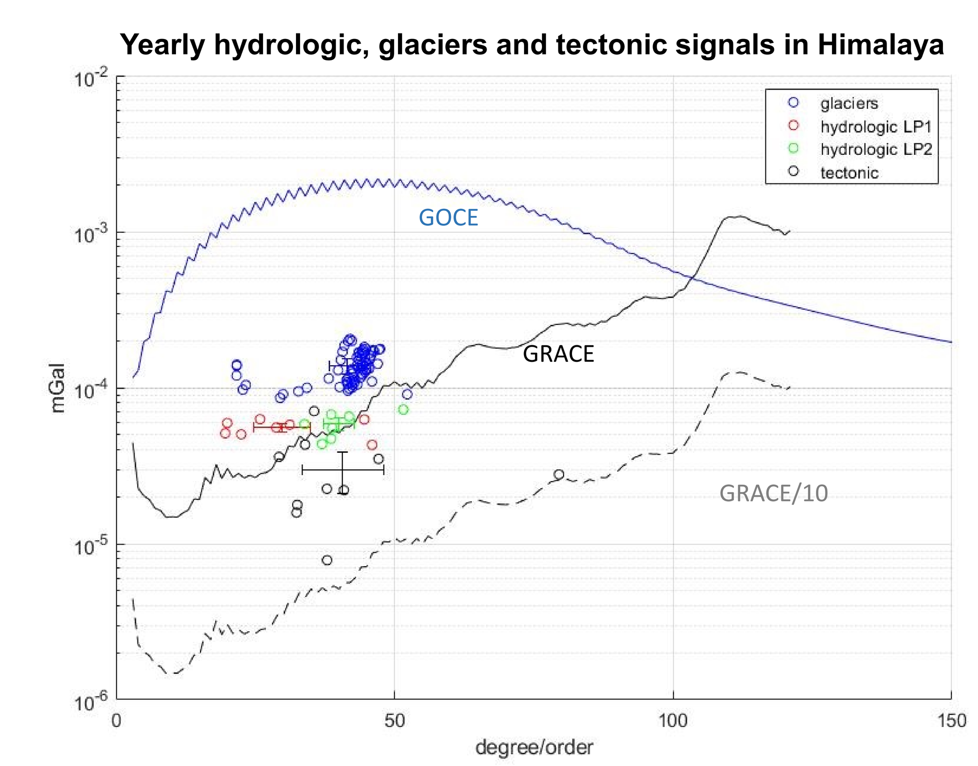

Figure 9: Gravity change in one year for realistic deglaciation rates, hydrologic mass loss and tectonic uplift rates in High Mountains of Asia, 250 km height calculation. The red and green dots refer to red and blue profiles in Figure 6. Spectral error curves for GRACE-FO and GOCE, and 10 fold improved missions @ 250 km height (1 year sampling).

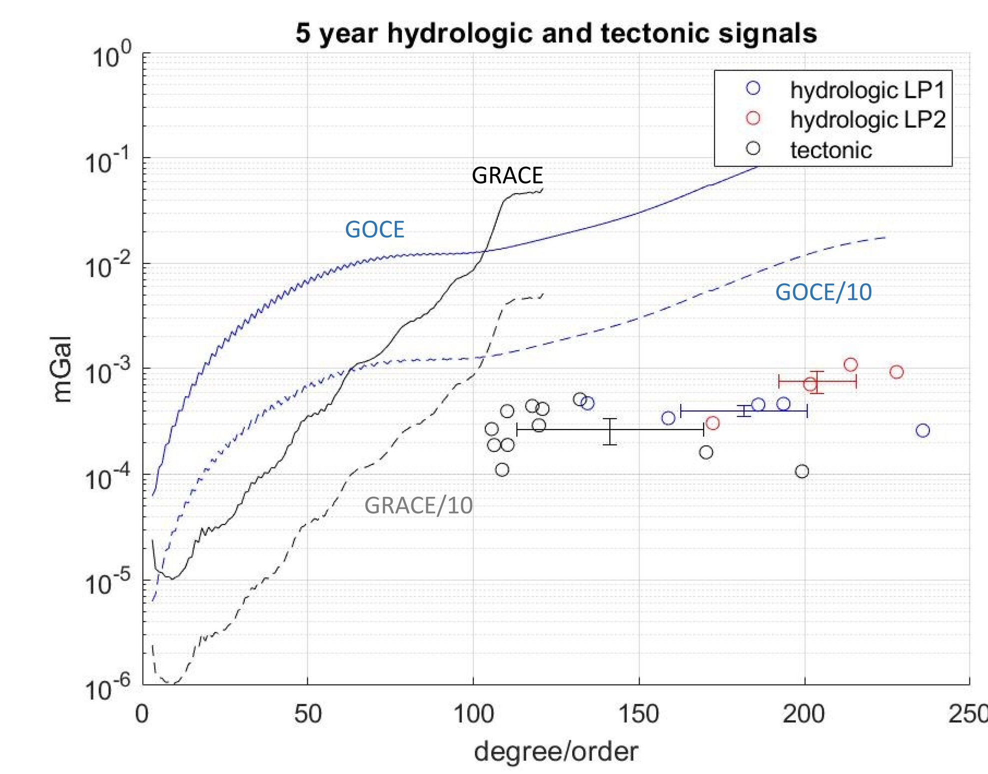

Figure 10: Gravity change in five years at 4km height for the Alps due to tectonic uplift and hydrologic mass changes. The blue and red dots refer to profiles in Figure 7. Spectral error curves for GRACE-FO and GOCE, and 10 fold improved missions (5 year sampling).

8. Conclusion

- Tectonic uplift has a small but detectable signal. It cannot be neglected.
- Hydrologic mass, Ice mass, mass change due to tectonic uplift and subsidence are detectable from satellite in High Mountain of Asia.
- Mass changes due to soil moisture and tectonic signal in Alps are below resolution of GRACE or GOCE, and require an innovative gravity measurement.
- Alps: Ice cover changes can be evaluated by remote sensing satellite observations as Sentinel multispectral and SAR acquisitions. Subsurface hydrologic budget largely unknown in mountain areas of Alps- monitoring restricted to lowlands. Gravity is a means to determine mass change otherwise not observable.

References

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