Gravity change rate of tectonic signals of mountains

Tommaso Pivetta, Dora F. Barbolla and Carla Braitenberg

Department of Mathematics and Geosciences, University of Trieste.

tpivetta@units.it, dora.barbolla@gmail.com, berg@units.it

dipartimento di matematica e geoscienze

UNIVERSITÀ DEGLI STUDI DI TRIESTE

Objectives

- Evaluate the gravity contribution due to tectonics in the High Mountains of Asia (HMA) region. Two end member models of crustal deformation are considered:

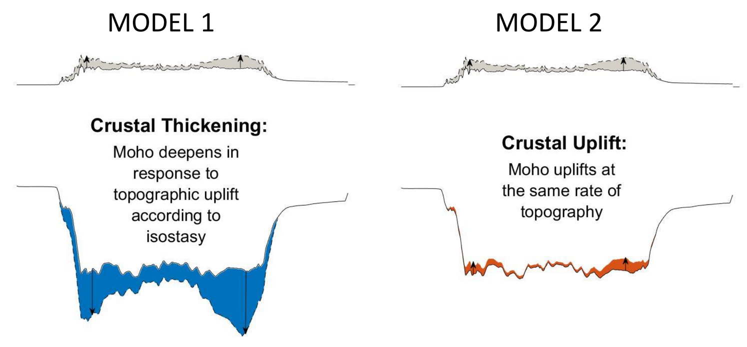


Figure 1: Cartoon showing the 2 end member models of crustal thickening and crustal uplift.

- Compare with amplitudes and wavelengths of the other time variable signals: hydrology and ice thickness variations
- Compare the observed signals with the error curves of future gravity missions (MOCASS mission)

1) Tectonic effects

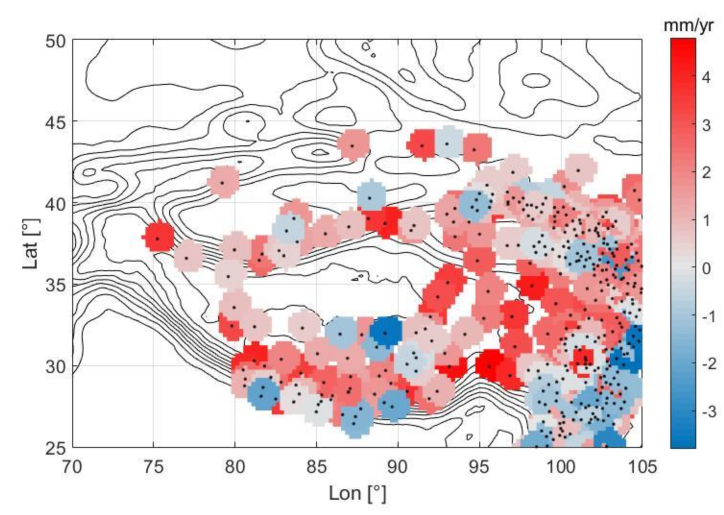


Figure 2: Map of GNNS observations in the HMA region. Dots show the GNSS observations in the area. The map shows also the average displacement calculated on circular area of 2° radius.

- About 500 GNSS stations considered [1,2] for constructing a map of the vertical movements for the HMA area
- Central Tibet area is scarcely covered by GNSS observations
- The HMA shows mainly an uplift in the central areas, while the south eastern area is characterized by subsidence
- An average displacement is calculated on circular areas of 2° radius

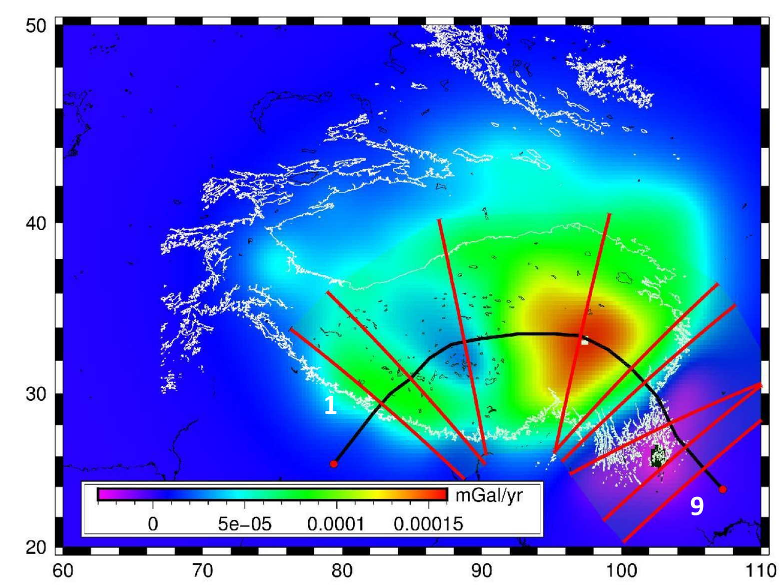
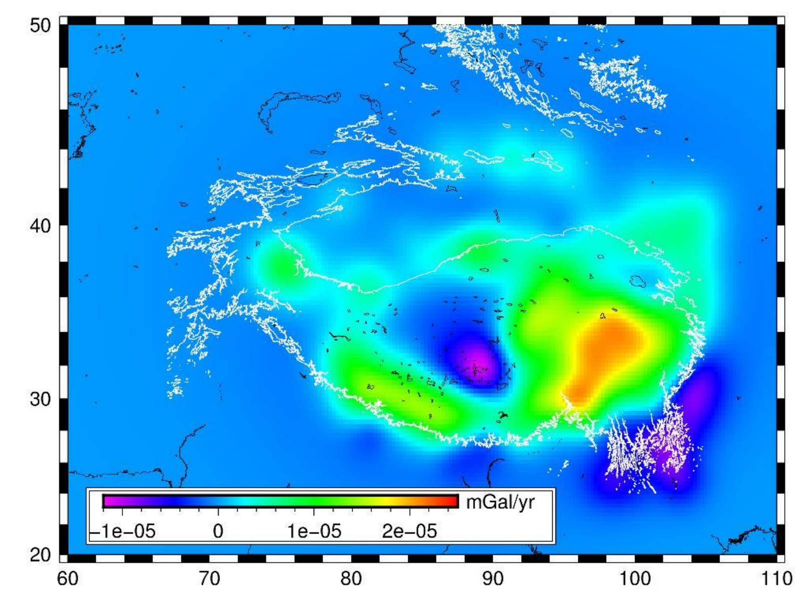


Figure 3: Gravity effect of crustal uplift model. Calculation height 250km. Red lines show traces of profiles used for estimate the signal wavelength and amplitude (see section 5).

Figure 4: Gravity effect of crustal thickening model. Calculation height 250km. An Airy response is assumed as isostatic compensation mechanism.



- Tesseroids discretization [3] was employed to calculate the gravity effect of the topographic movements and the gravity effect of the Moho response according to crustal uplift (Figure 3) and crustal thickening (Figure 4) models

2) Glaciers signal

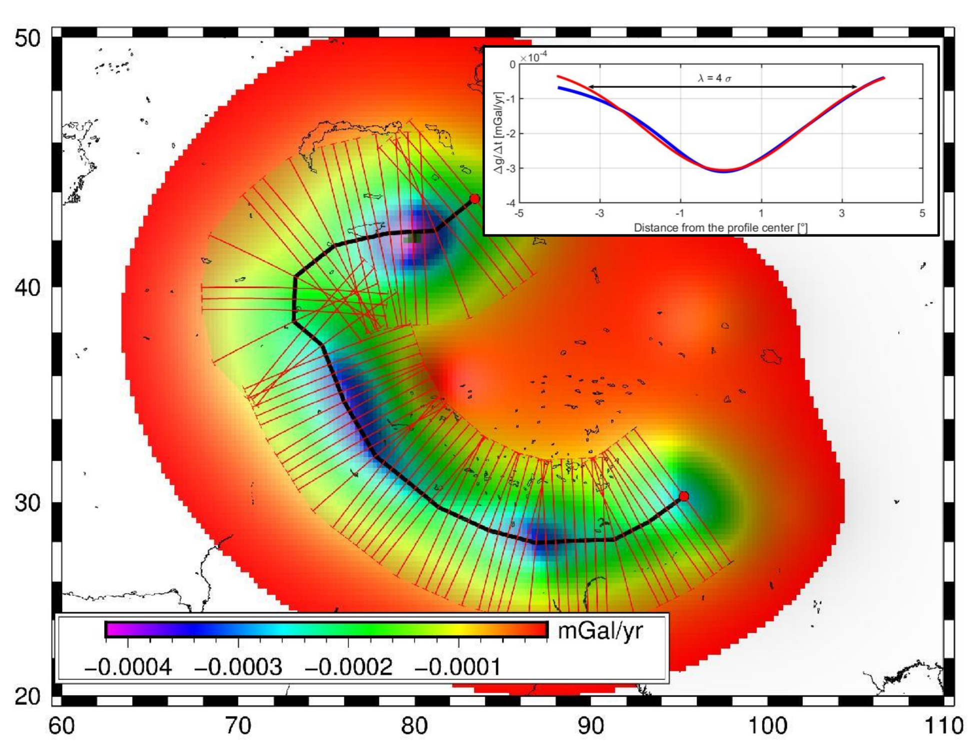
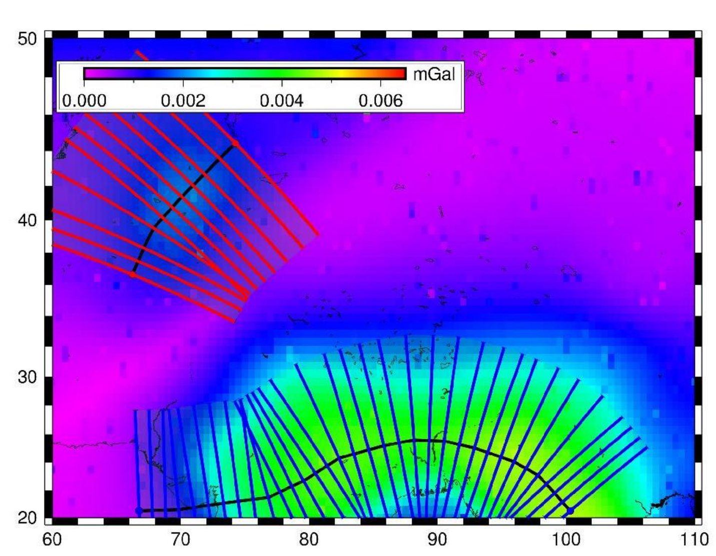


Figure 5: Yearly gravity change due to HMA ice thickness variations. Calculations at 250km height. Red lines show the position of the profiles. The inset shows a profile across the gravity minimum and the fitted Gaussian.

- Gravity variations calculated by discretising the yearly mass change in Tesseroids (Figure 5).
- To construct the density model, the RGI catalog [4] 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. [5]

3) Hydrologic Signal



- Each gravity timeseries was then fitted through a linear trend and an annual oscillation.
- Figure 6 shows the annual seasonal component while Figure 7 the long-period hydrologic trend

Figure 6: Annual seasonal oscillation amplitude due to hydrologic water mass variations. The blue and red lines report the location of profiles discussed in section 5. Blue= India and Bangladesh; Red= Uzbekistan.

- Hydrologic effects estimated exploiting the GLDAS [6] catalogue which provides monthly water mass variations in terms of soil moisture
- Gravity effects calculated for each month with spatial resolution of 0.25°

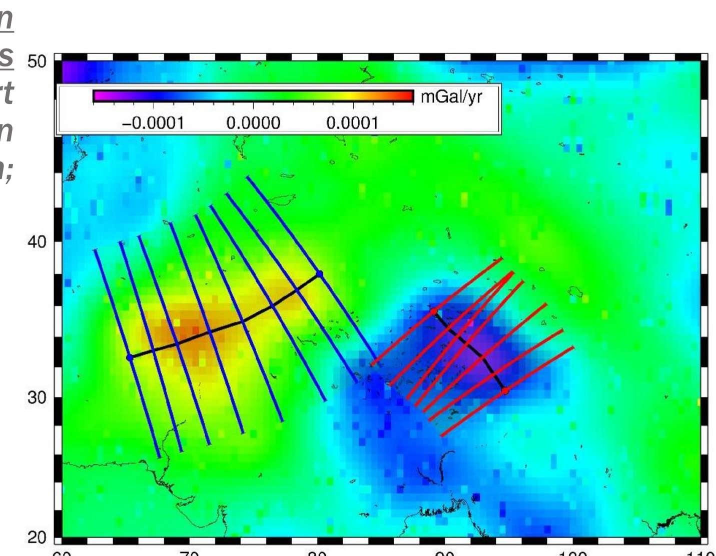


Figure 7: Long period water mass variations at 250km. The blue and red profiles are the traces discussed in section 5. Blue Pakistan; red Eastern Tibet.

4) GRACE observed

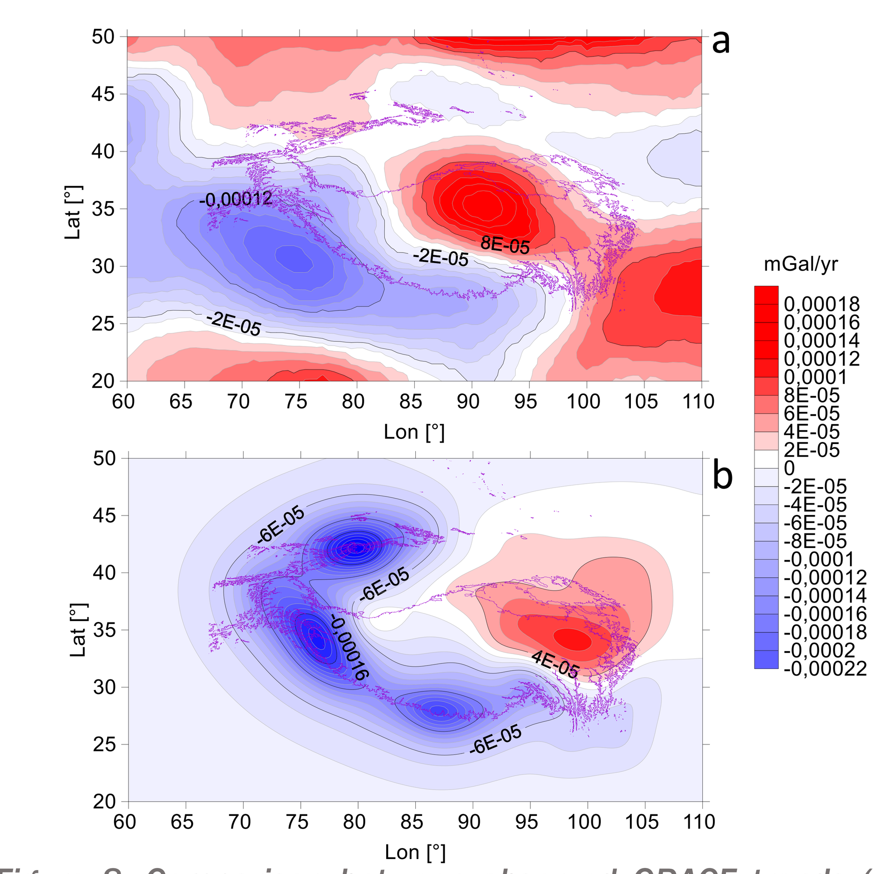


Figure 8: Comparison between observed GRACE trends (a) and modelled Glaciers and Tectonic effects. The modelled data has been filtered with a Gaussian filter with cut off wavelength of of 500km. Purple line reports the 3500m topography contour.

- GRACE data (a) corrected for GLDAS hydrologic effects
- Modelled data (b) for tectonic and deglaciation mass variations

5) Comparison with MOCASS mission

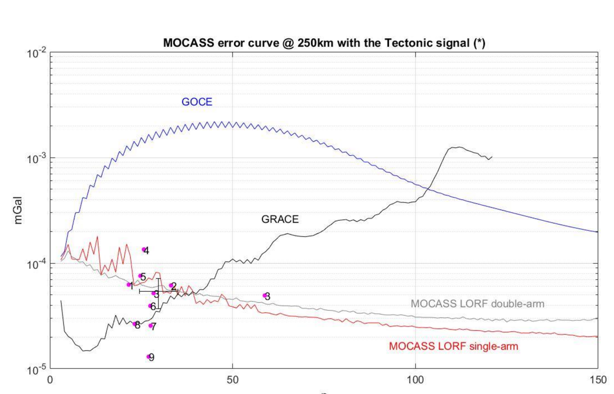


Figure 9: Yearly gravity change rate at 250km calculation height for Tibet-Himalaya due to crustal uplift (Model 2 Figure 1). The purple dots display the characteristic wavelength and amplitude for the numbered profiles shown in Figure 3.

- We estimated the typical amplitudes and wavelengths of the considered phenomena by fitting a Gaussian curve on profiles. The wavelength is expressed in terms of SH degree (n) and is calculated from the Gaussian dispersion (σ) of the curve by: $n=360/(4\sigma)$
- The dots in the figures report the estimated n and amplitude of the various geophysical phenomena

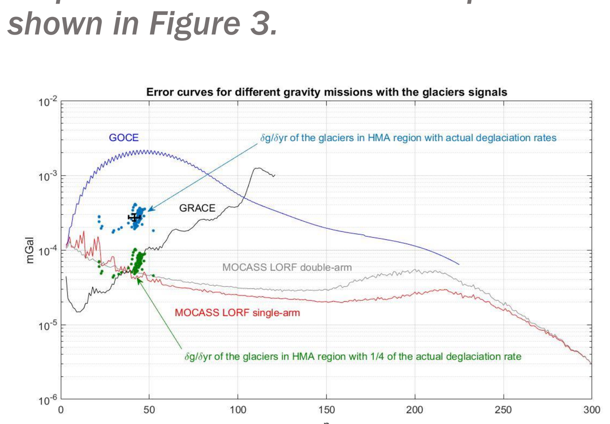


Figure 10: Spectral comparison of the simulated gravity change of the entire presence of glaciers for the profiles that cross the HMA with the error curves of satellites. Each data point corresponds to the signal along one profile (Figure 1) of the cumulated effect of glaciers.

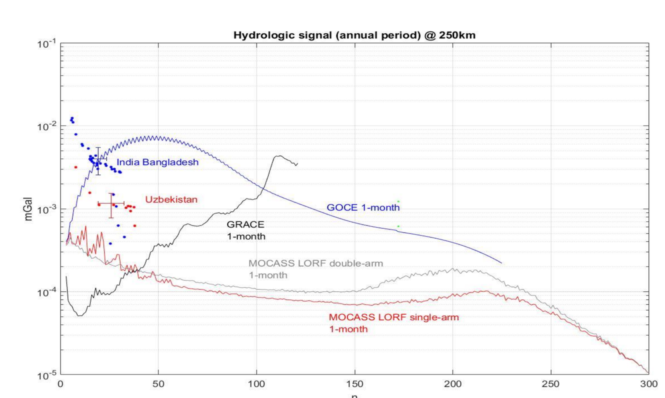


Figure 11: Hydrologic annual oscillation amplitude in the HMA region at 250km calculation height. The dots display the characteristic wavelength and amplitude for the profiles shown in Figure 6

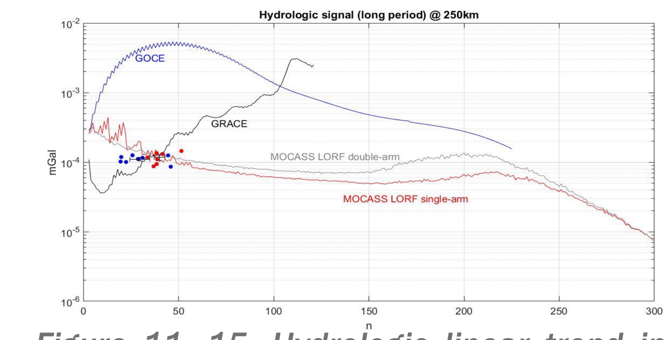


Figure 11: 15: Hydrologic linear trend in the HMA region at 250km calculation height. Blue dots are for Pakistan area; red dots are relative to Eastern Tibet.

4) Conclusions/perspectives

- Simulations showed that tectonic effects, in particular crustal uplift could generate important signals with magnitude and wavelength comparable to hydrologic long period trends
- Deglaciation effects are also relevant, producing gravity signals with amplitudes up to 0.0004 mGal/yr and wavelengths of 8°
- The simulated signals show amplitudes and wavelengths that are comparable to the observed GRACE signals for the HMA area
- MOCASS mission could greatly improve the detection of all the signals, in particular the mission is able to recover lower deglaciation trends and detect local tectonic movements

References and Acknowledgments

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