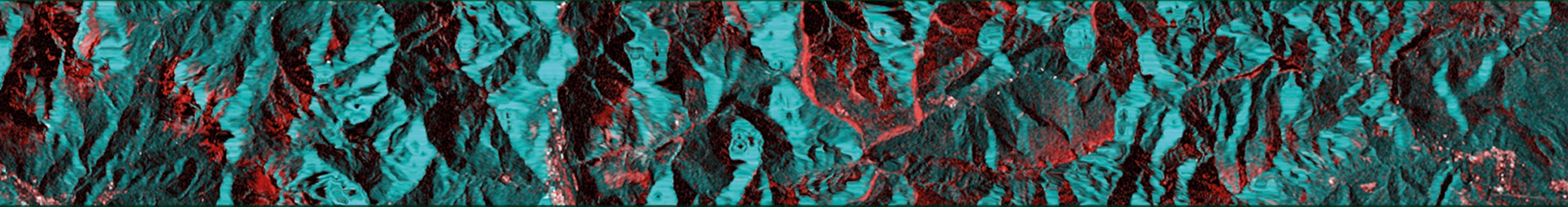
→ EO 4 ALPS

The Alps from Space Workshop



27–29 June 2018 | Innsbruck, Austria

Defining Alps Structure and Dynamics Through Terrestrial and Satellite Gravity

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Outline

Introduction

Alpine range is a dynamic system

Ongoing process: Mountain uplift and basin subsidence

Problem: determine gravity change rate

Estimate hydrologic mass changes as competing signal change

Observation of these gravity changes through present and future Satellites

Gravity field introduction

Gravity field observations: variations of the earth gravity acceleration in space and time

Gravity senses mass deficit or surplus in underground.

Use gravity observations to solve open problems in the Alps

- Volume of Glaciers and hydrologic resources
- Mountain building process

Alps-Array gravity

European research group

Coordination: Hentenyi, Braitenberg, Götze. CB representative for Italy

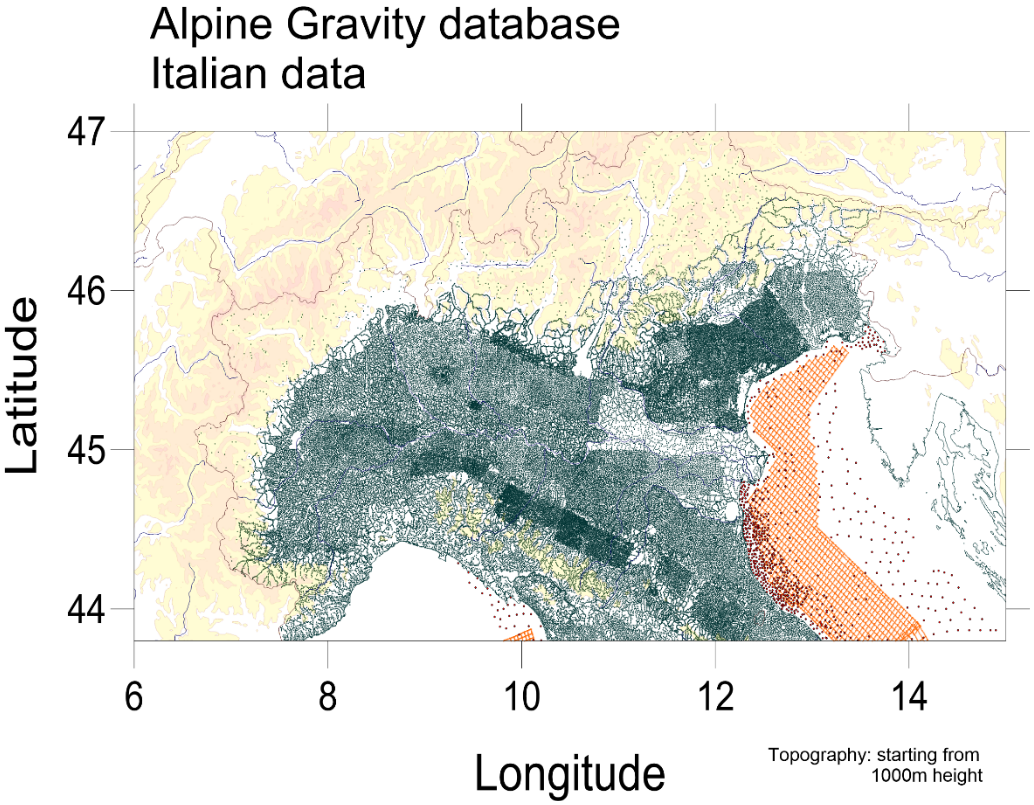
Goal: Alpine wide- uniformly processed terrestrial-satellite gravity field

Processing not started yet- planning phase

Participants: all countries touching the Alps, Universities, Geodetic and Geologic State Agencies, BGI

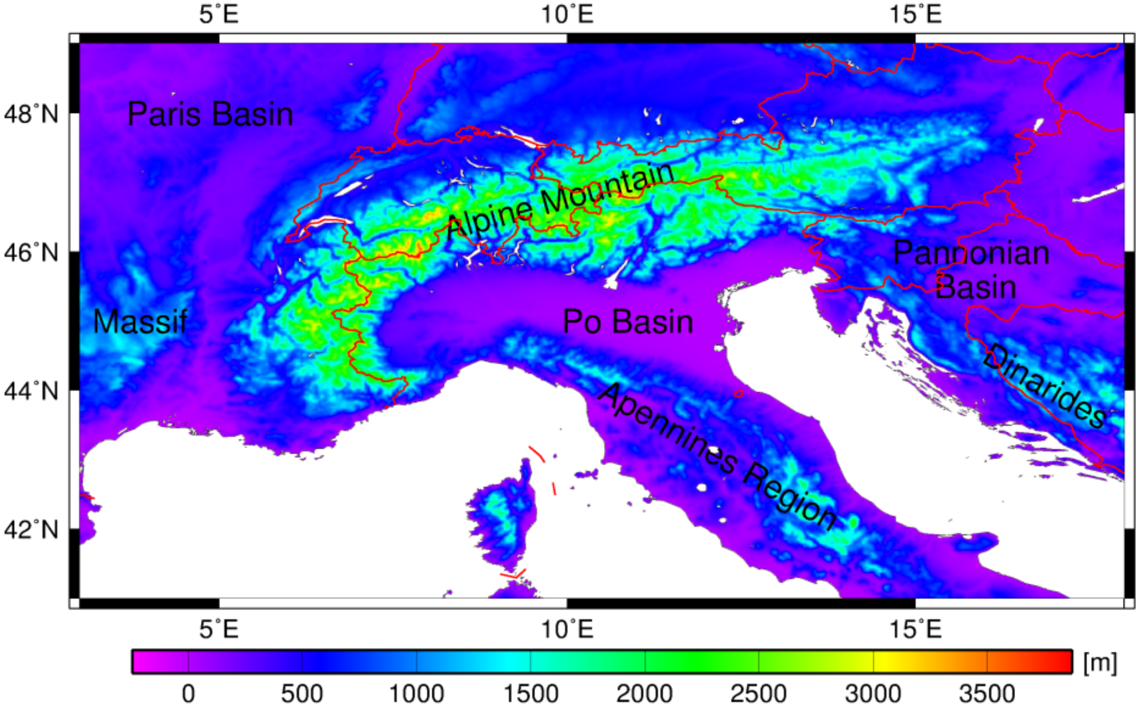
9 member countries: France, Italy, Switzerland, Germany, Austria, Slovenia, Slovakia, Hungary, Croatia,

Italian gravity data base (proprietary ENI-agreement for use in AlpsArray Gravity)



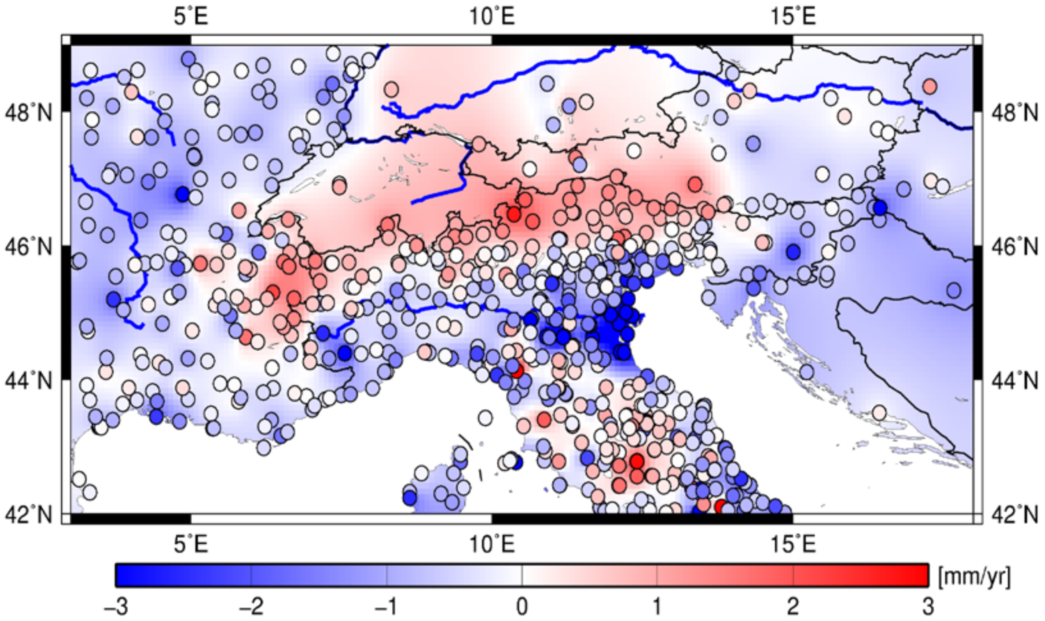
Integration with satellite data is necessary over large parts of Alps.

Alps –Appennine-Dinarides topography



Chen, Braitenberg, Serpelloni, 2018, Glob. Planet. Change

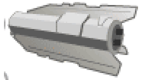
Alps GPS derived uplift



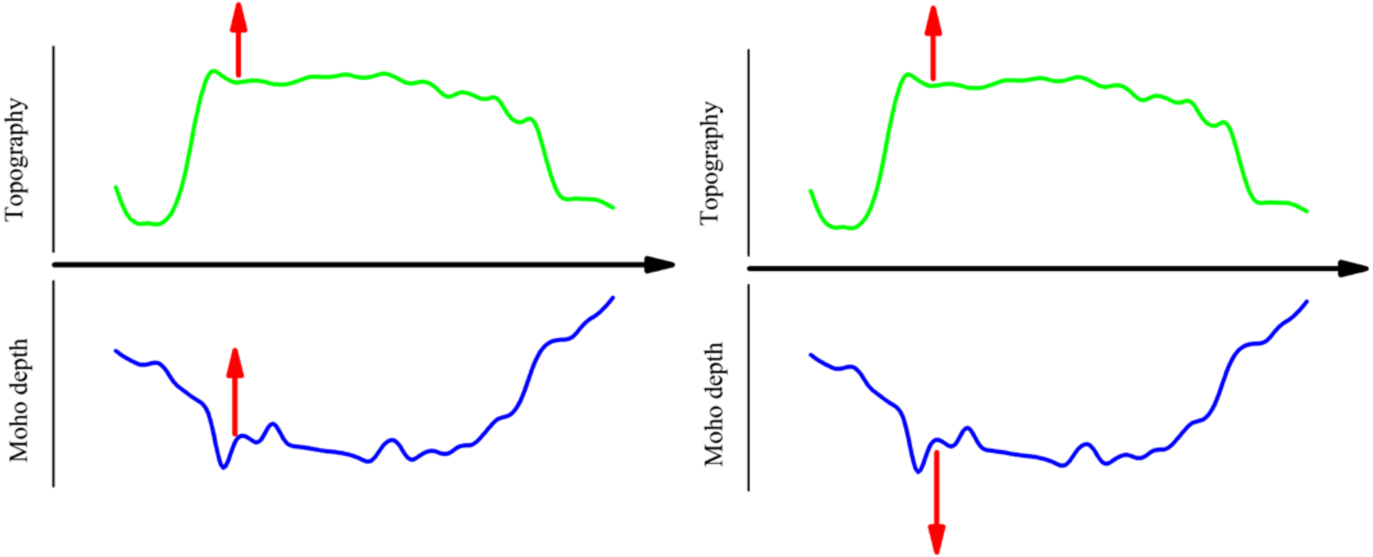
Selection from 800 stations. Average time span= 8 years up to yr 2016.
Tied to global ITRF/IGS Center of mass reference frame.
Consistent to frame of geodetic satellites.
Max 2.5 mm/yr central and western Alps uplift.
Po basin max -7mm/yr subsidence

Updated data after Serpelloni et al. 2013; 2016

Two end-member models



GOCE, GRACE satellite



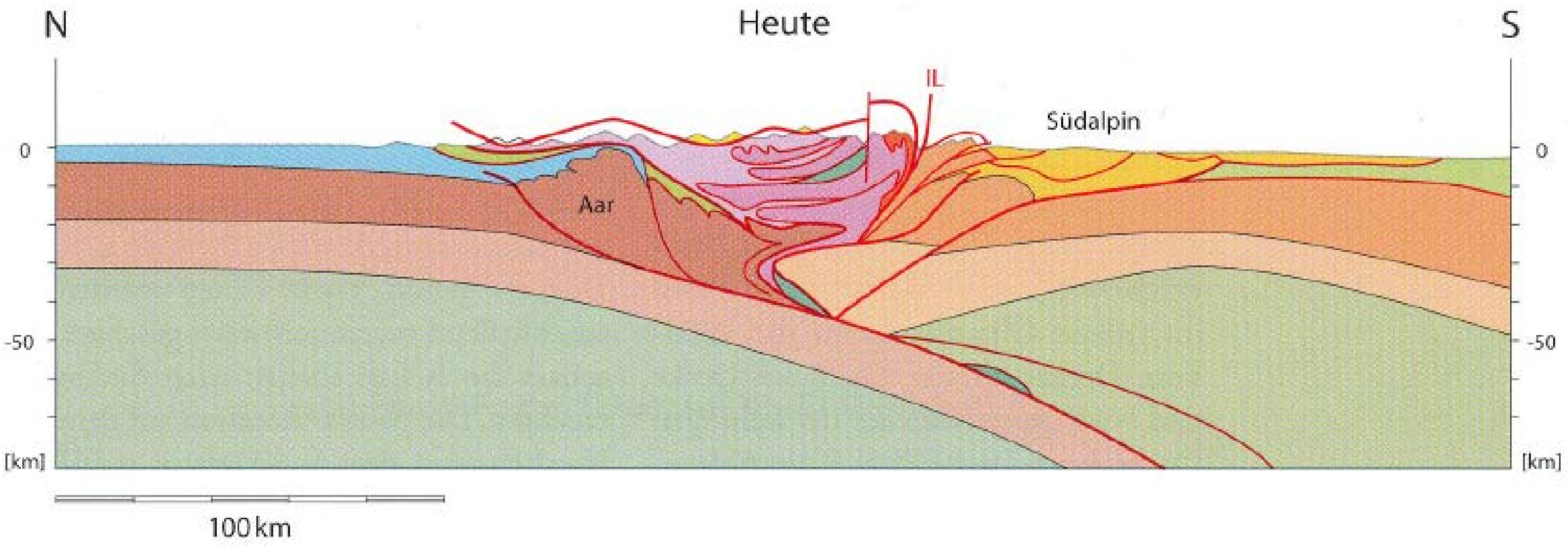
Topographic uplift driven by mantle processes (Faccenna et al. 2014)

Increased mass change

crustal thickening due to horizontal compression

Smaller mass change

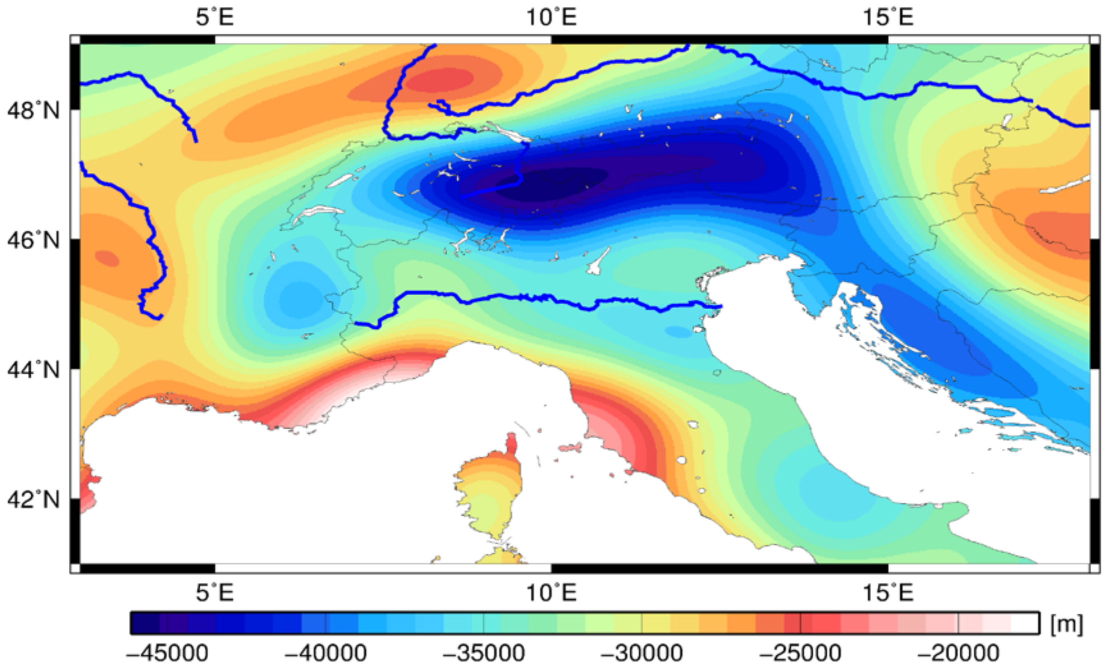
Mantle viscosity introduces time lag: not relevant for steady state process



Uplift due to a) compression or due to b)unloading

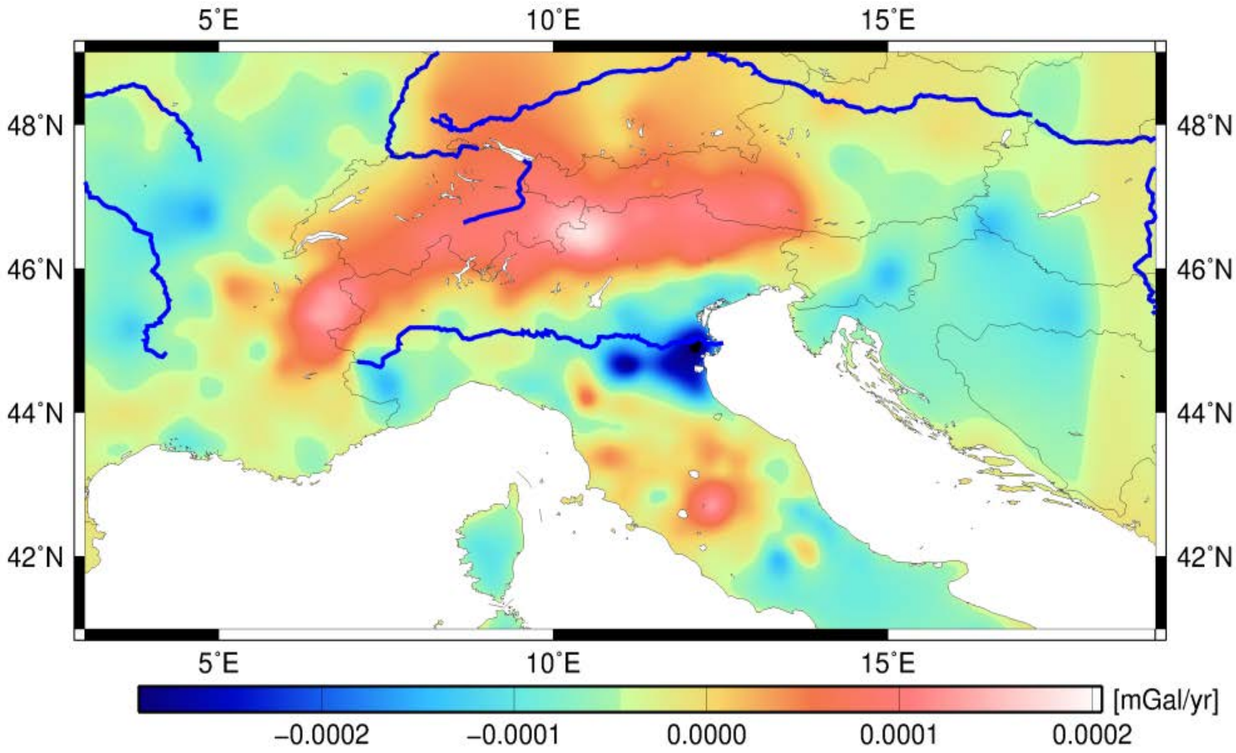
Scheme after Pfiffner(2014)

Crust 1.0 Moho reference-depth



Calculation height: 10km. Isostatic equlibrium maintained.
Topography change grom GPS rates.
Crustal density: 2670 kg/m^3
Mantle density: 3200 kg/m^3

Gravity due to Topography uplift

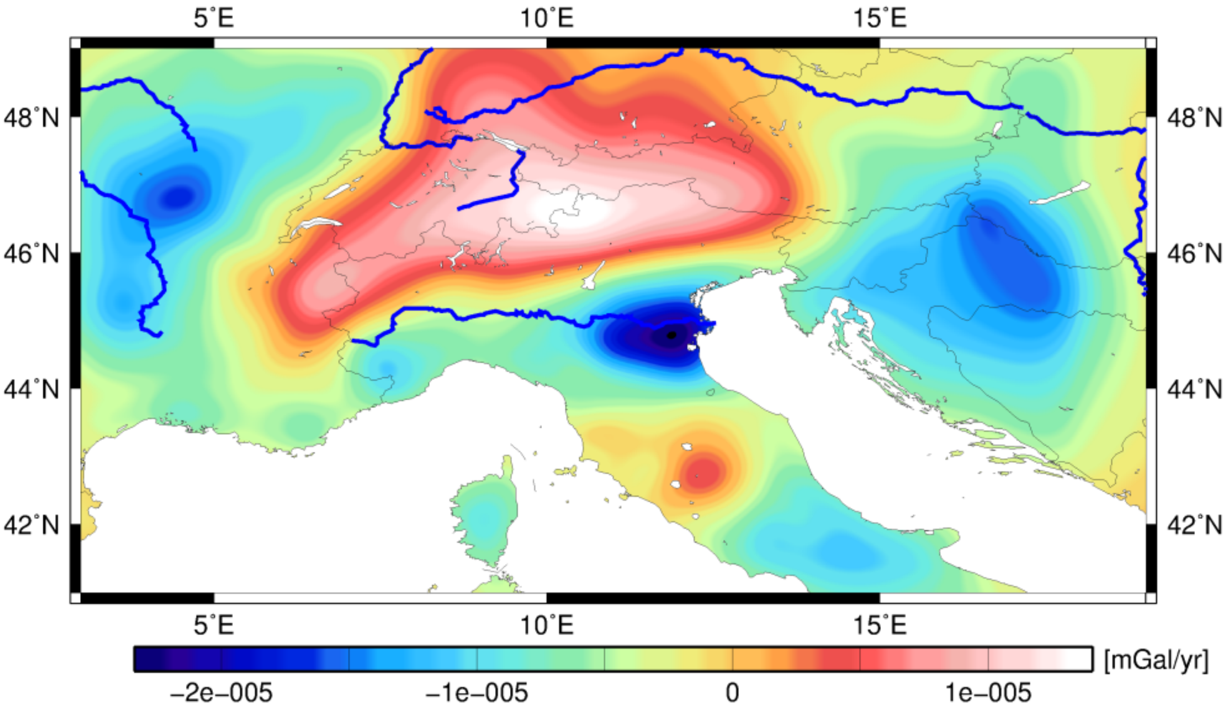


Scale: up to 0.2 /-0.3 microGal/year

Crustal density: 2670 kg/m^3

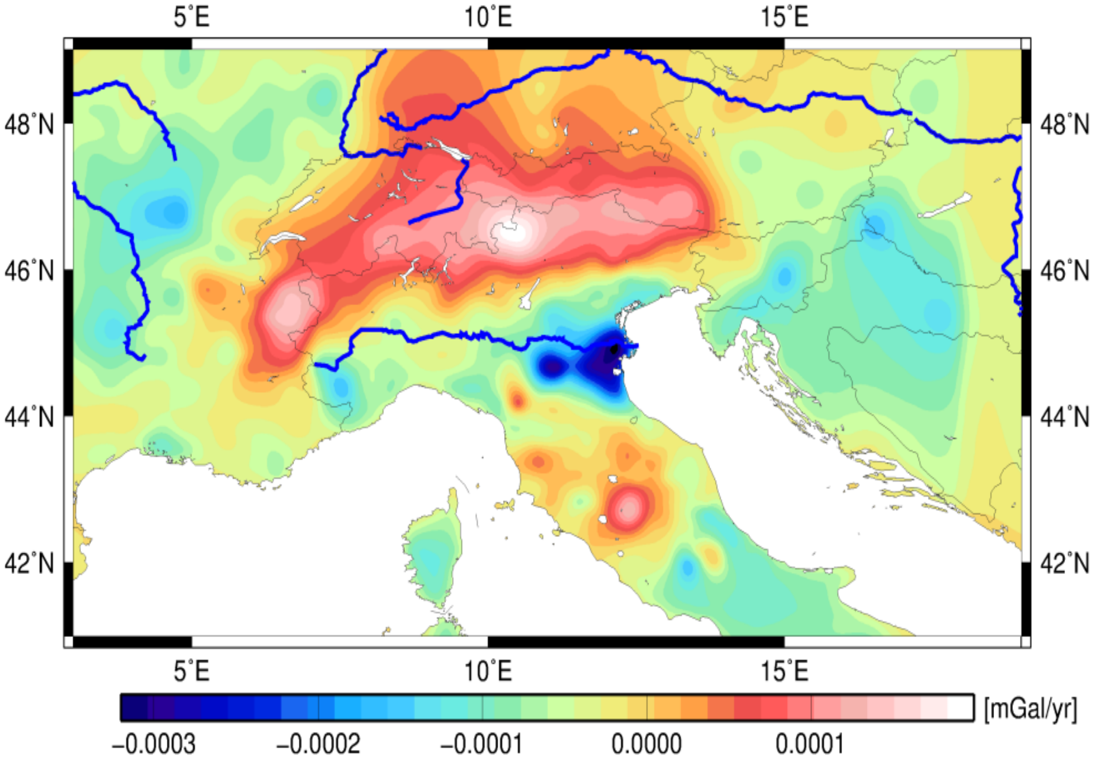
H= 10km

Gravity due to Moho uplift



Scale: up to 0.02 microGal/year

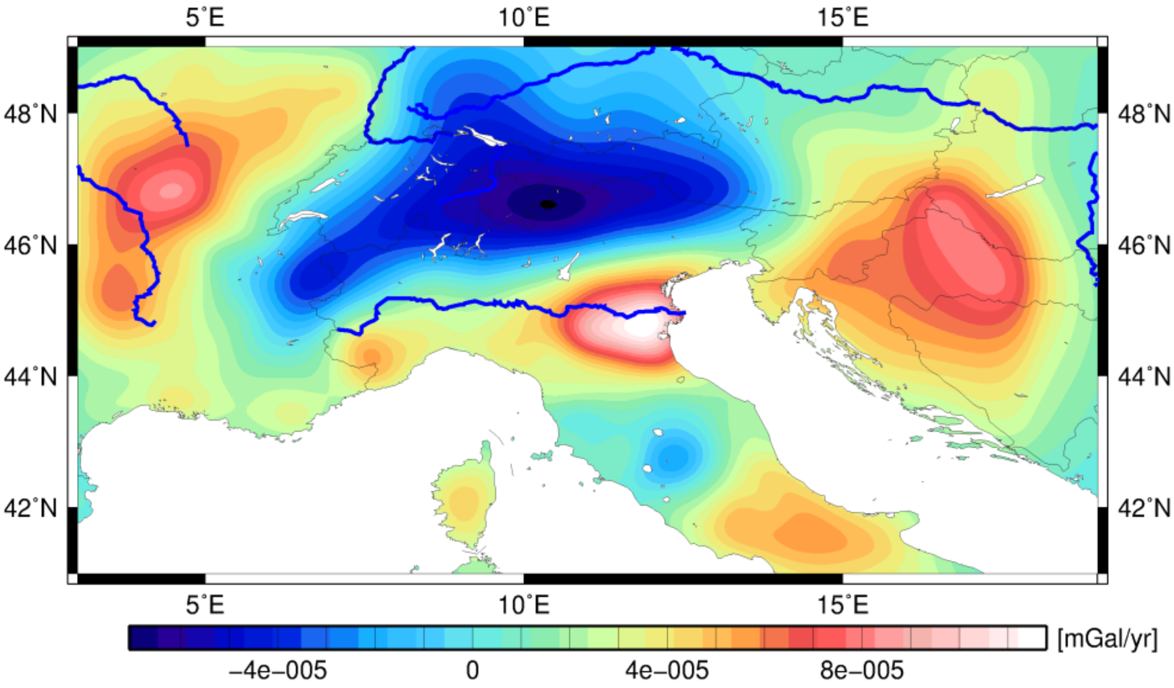
Combined Moho with topography



Scale: slightly increased due to Moho contribution

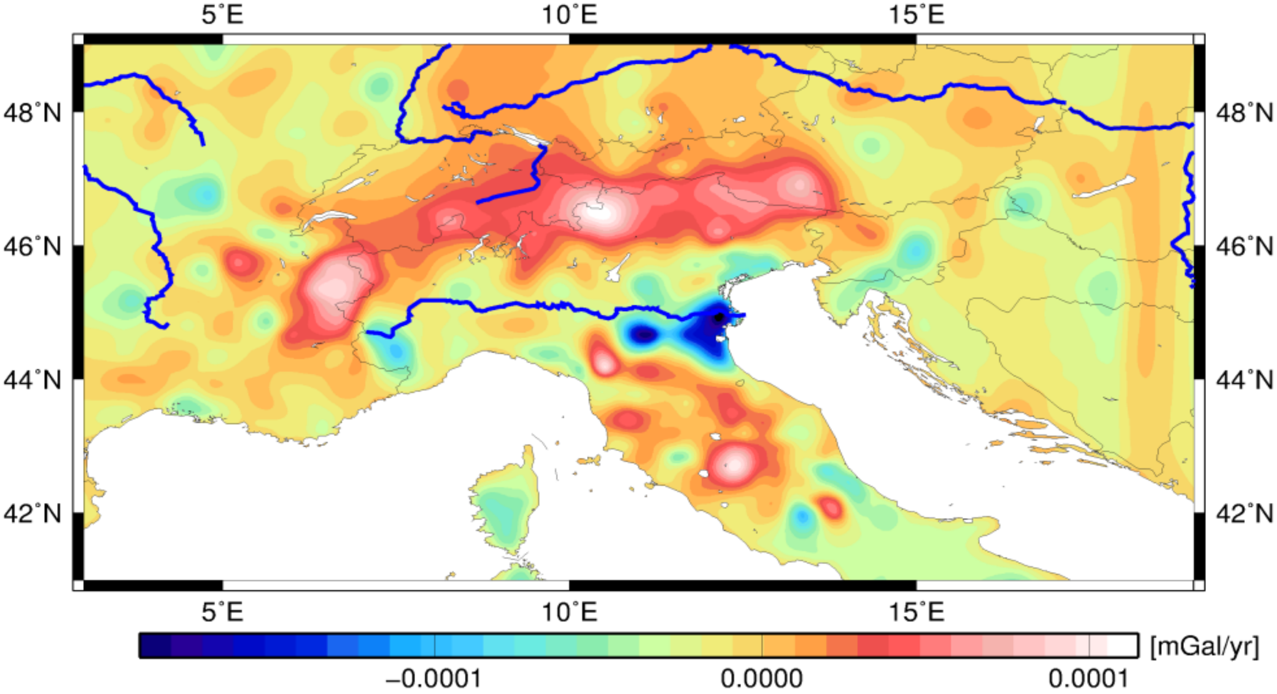
0.3 microGal/year

Crustal thickening gravity effect



Signal: 0.08 microGal/year

Topography uplift and crustal thickening



Main features remain, but ampliude reduces to less than 0.1 microgal/year

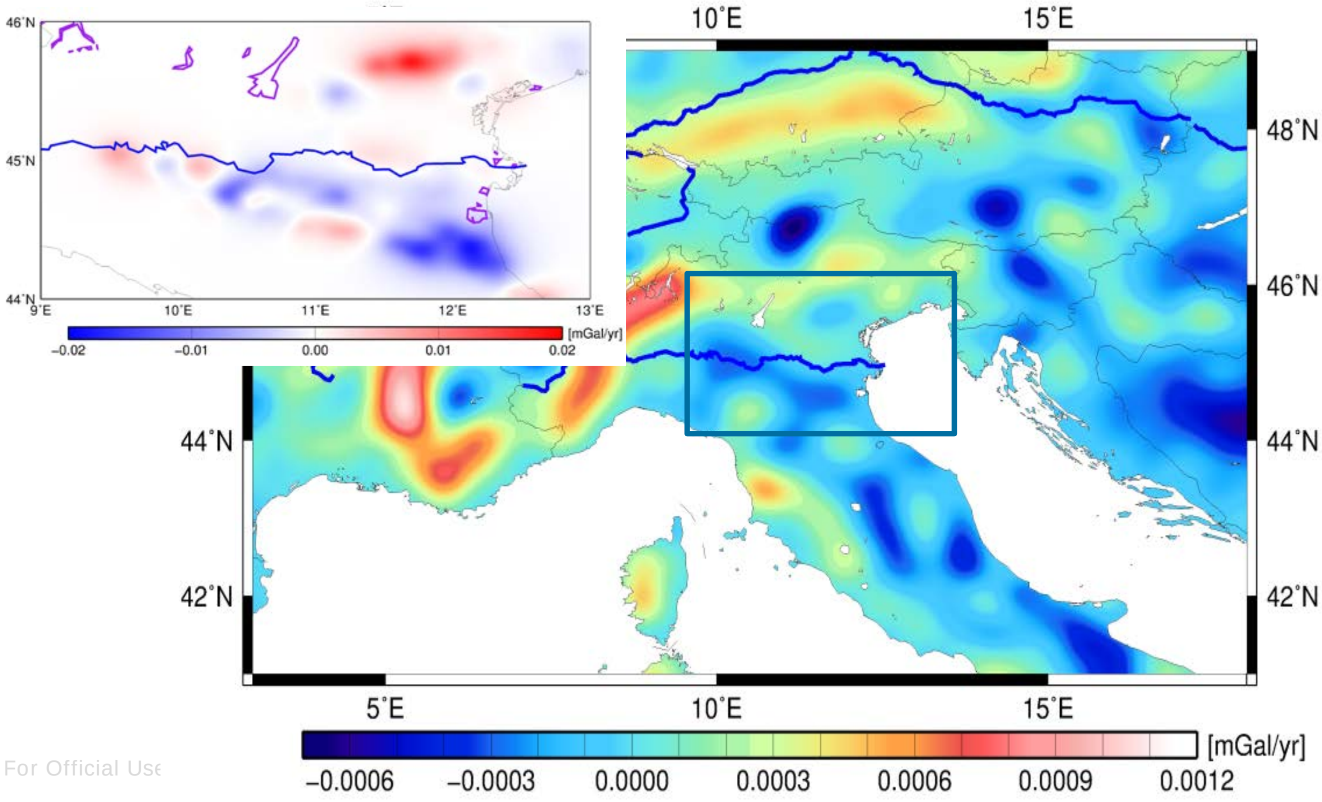
Hydrologic mass change 1 / 2

- 1) Water table observation in wells in basin (selection with minimum 8 years)
- No water table observations in the mountains.
- Data available in smaller area than full Alpine range.
- Fitted with linear trend + sinusoidal oscillation

Hydrologic mass change 2 / 2

- 2) GLDAS soil moisture (Rodell et al., 2004)
- 0.25 degree resolution - monthly solution. Years 2003 to 2013.
- Fitted with linear trend + sinusoidal oscillation.
- Converted to spherical harmonic degree expansion

Hydrology direct and GLDAS



GOCO05S combined model

static+linear trend+yearly oscillation. Trend centered on year 2008. N=250 and N=100

GOCE: Gradiometer complete mission period 2009-2013

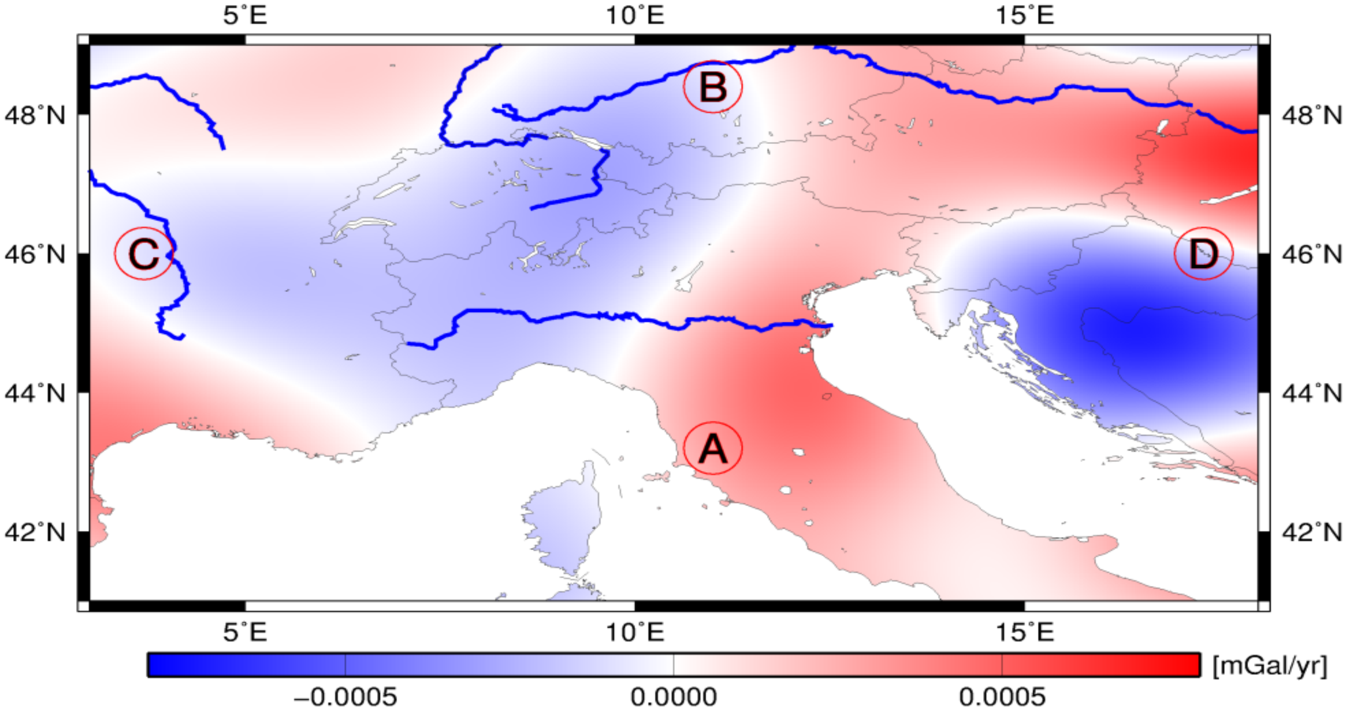
GRACE: ITSG-Grace2014s (2003-2013)

Kinematic orbit: Swarm A+B+C, TerraSarX, Tandem-X, CHAMP, GRACE A+B, GOCE

SLR: LAGEOS, LAGEOS 2, Starlette, Stella, Ajisai, Larets

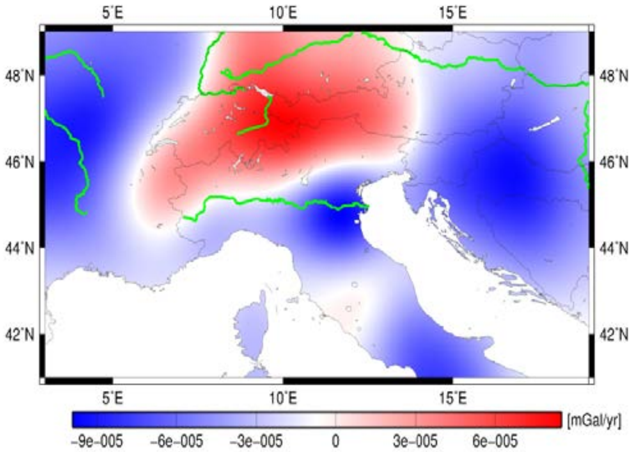
Mayer-Gürr T., et al. 2015, **The combined satellite gravity field model GOCO05s;** presented at EGU General Assembly, Vienna, April, 2015.

Observed gravity change ratec

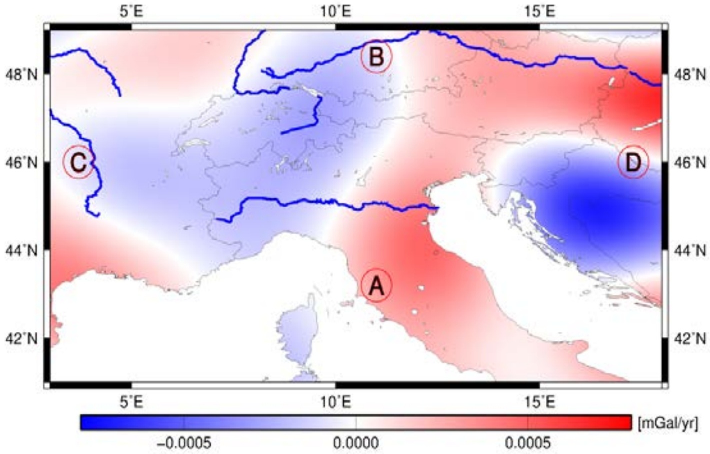


Scale: up to 0.8 microGal/year

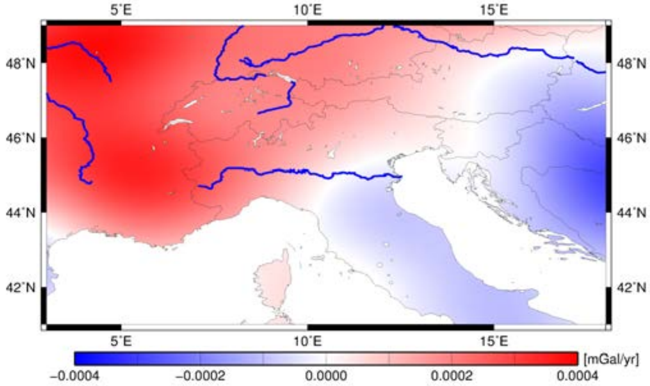
Moho with topography



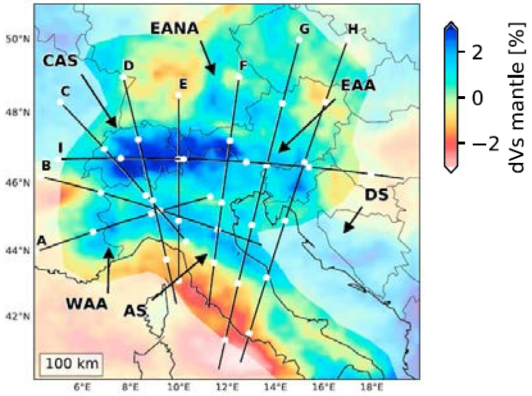
Observed gravity



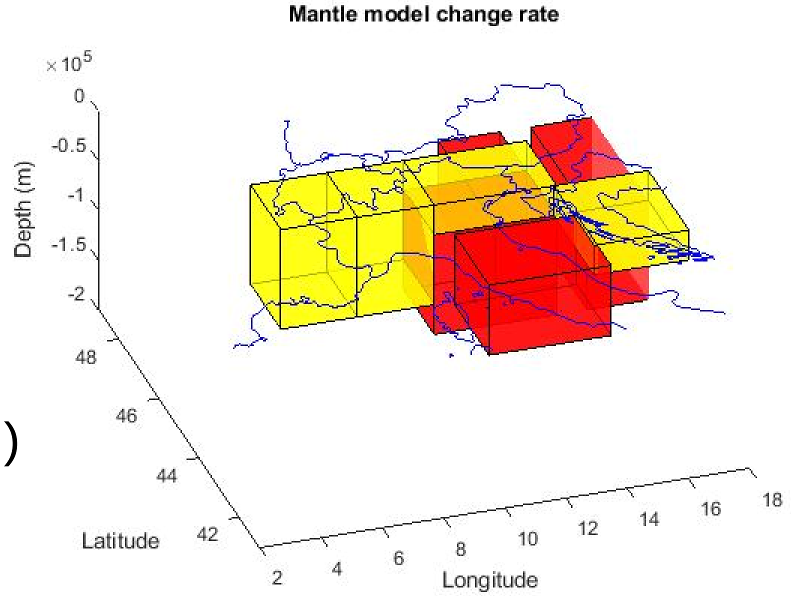
GLDAS soil moisture



Low pass filtered nominal 500km Gaussian filter to comply with resolution of satellite derived gravity (Spherical harmonics D/O N=100)



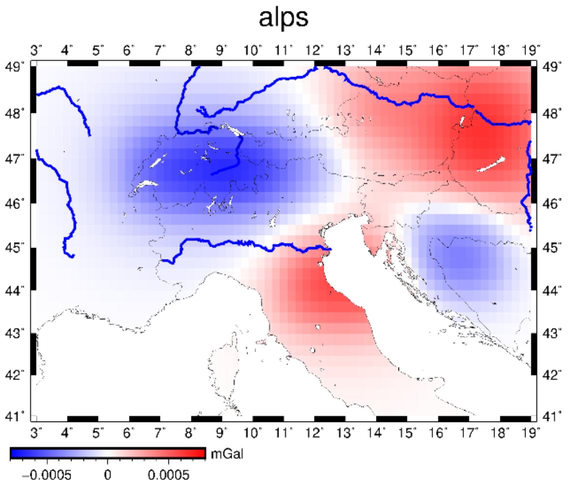
(Kästle et al. 2018, JGR)

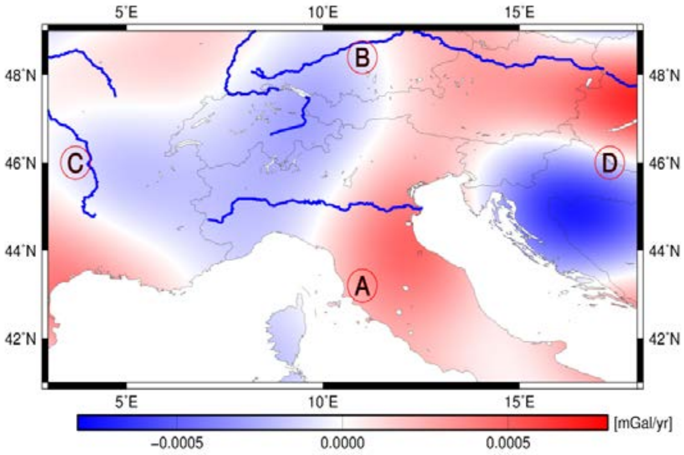

Mantle model change rate

Yellow: density decrease rate
Red: density increase rate

Mantle mass change can be made to fit the observations. Would explain total absence of correlation to Alpine topography.

New satellite mission with higher accuracy is needed!





Simulations of hydro-glaciers-tectonic effects for future gravity missions

MOCASS: ASI-funded project in cooperation with Milano Polytechnic University and University of Firenze.

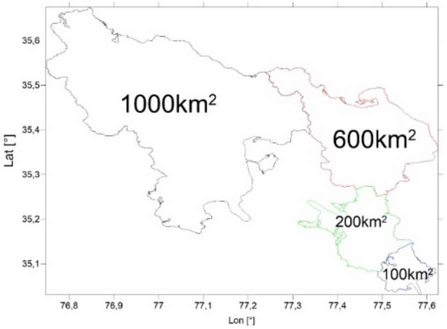
Atom Gravimeter on board a GOCE-type satellite.

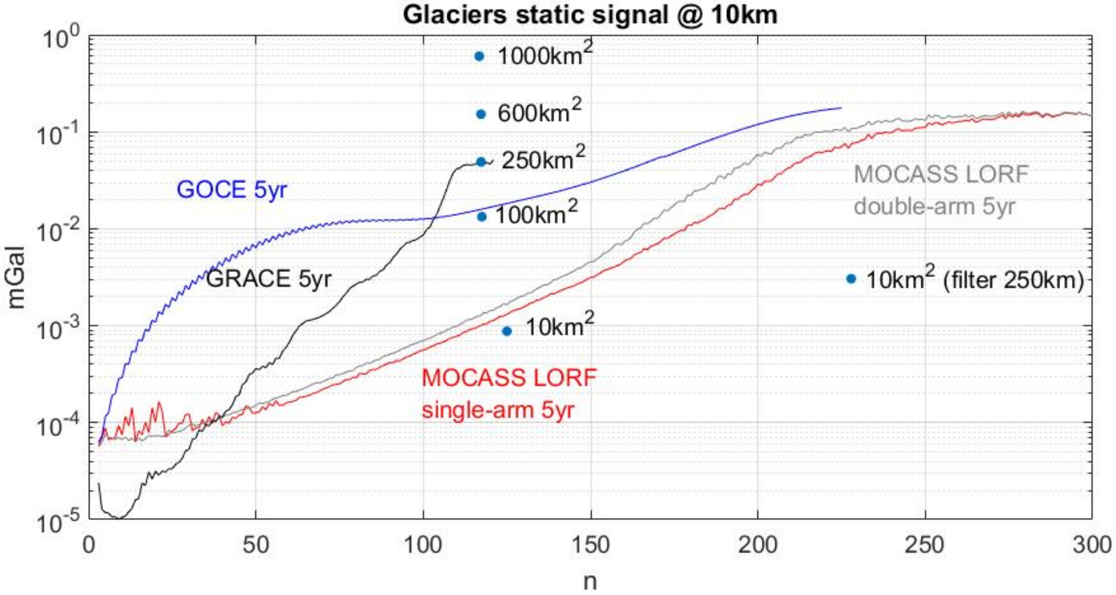
MOBILE: Mass variation OBservIng system by high-Low inter-satellitE links.

Proponent Roland Pail, TU Munich. In Response to

Call for Proposals for Earth Explorer Mission EE-10 (ESA/EXPLORER/EE-10, September 2017)

Glaciers static signal detection- five year observation

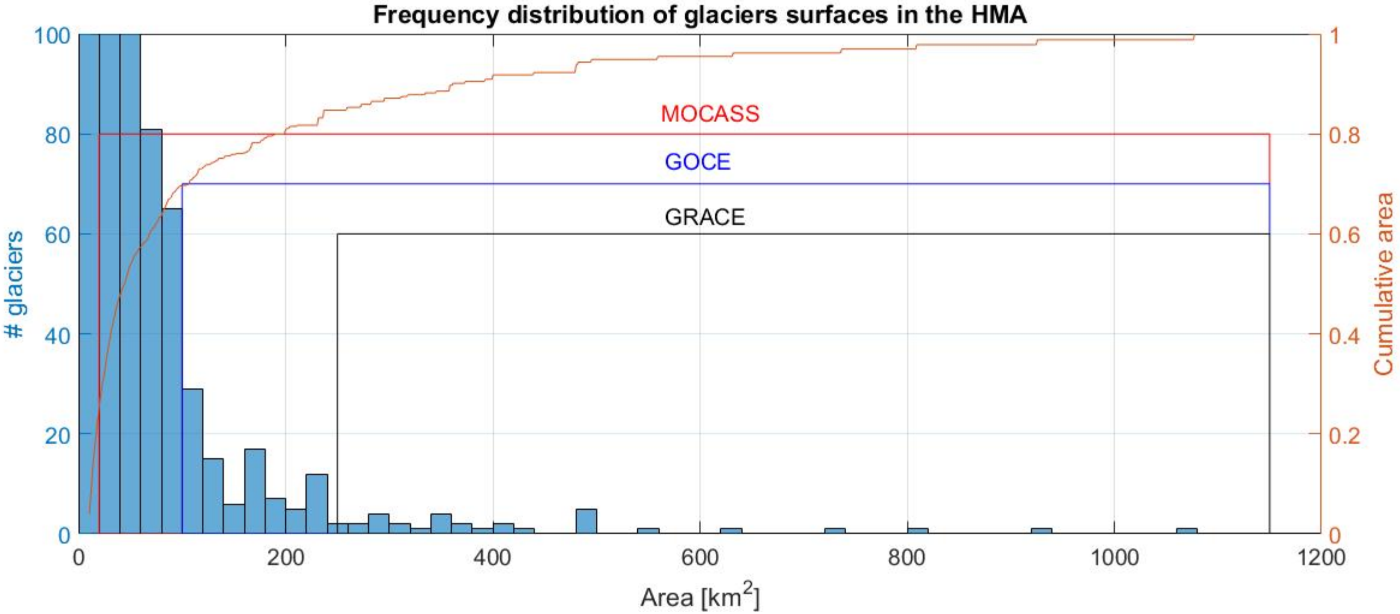




Volume estimate from glacier surface: $V = 0.03S^{1.36}$

Bahr et al., 2015

With respect to previous missions significative jump in sensitivity for glaciers



Randolph DB

Statistical distribution of number of glaciers versus size in High Mountains of Asia. Results apply also to the Alpine glaciers.

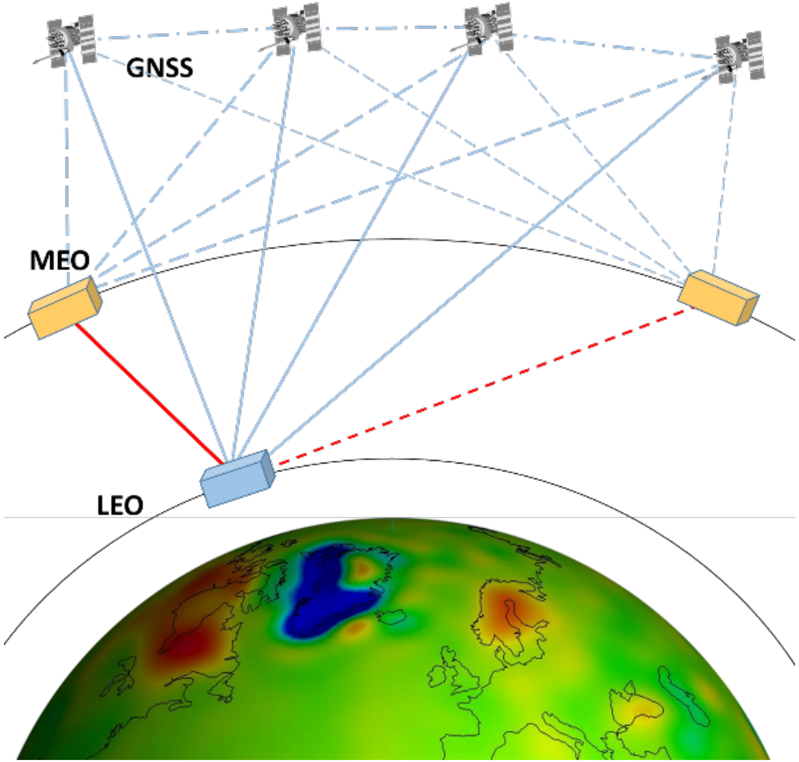
Results for glacier sensitivity of innovative gravity mission

number for sizes around 100km^2 jumps significantly with respect to larger areas

Areas < 100km^2 the number of glaciers is 20 fold,

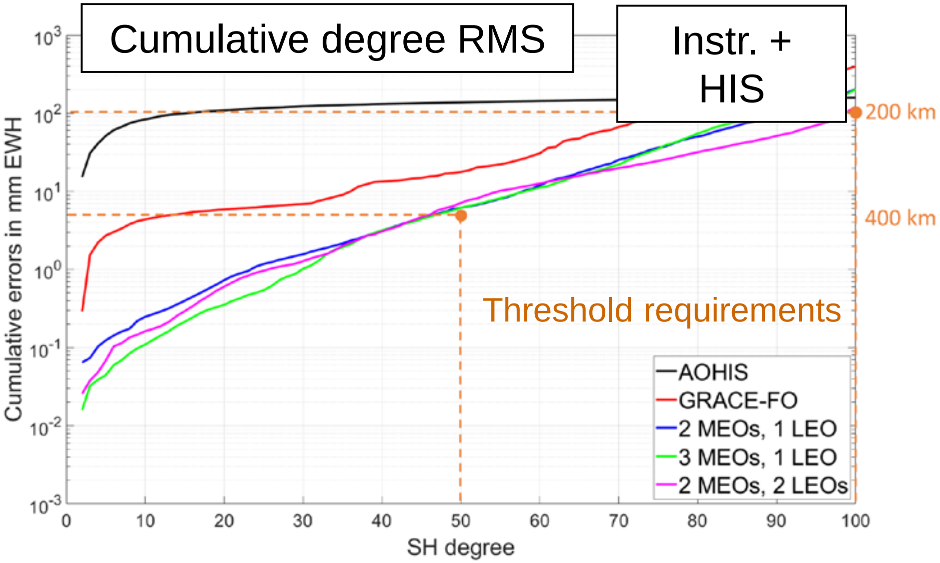
Limit of 100km^2 crosses the border between copious and scarce number of glaciers

Mission concept MOBILE Satellite

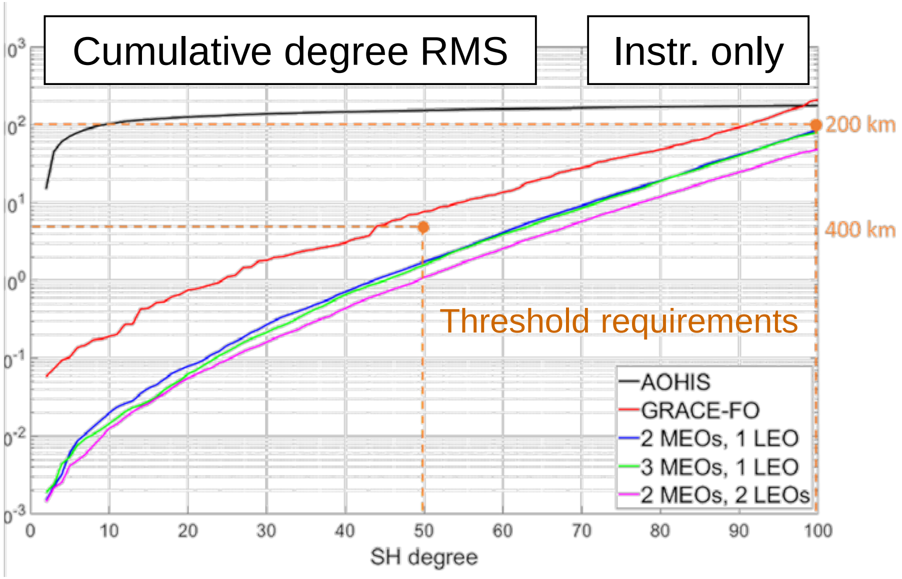


- High-low inter-satellite ranging between Mean-Earth Orbiters (MEO) and Low-Earth Orbiter (LEO) with µm accuracy
- Minimum configuration: 2 MEOs (~10,000 km) and 1 LEO (~350-400 km), in polar orbits to maintain stable configuration (no relative drift of orbit planes)
- Main instrument: LASER-based ranging system, placed at the LEO
- MEOs: passive reflectors (or transponders)
- All satellites are equipped by (electro-static) accelerometers, and tracked additionally by GNSS (for POD)
- Option 3rd or 4th MEO satellite

Case: also HIS aliasing included


Cumulative degree RMS

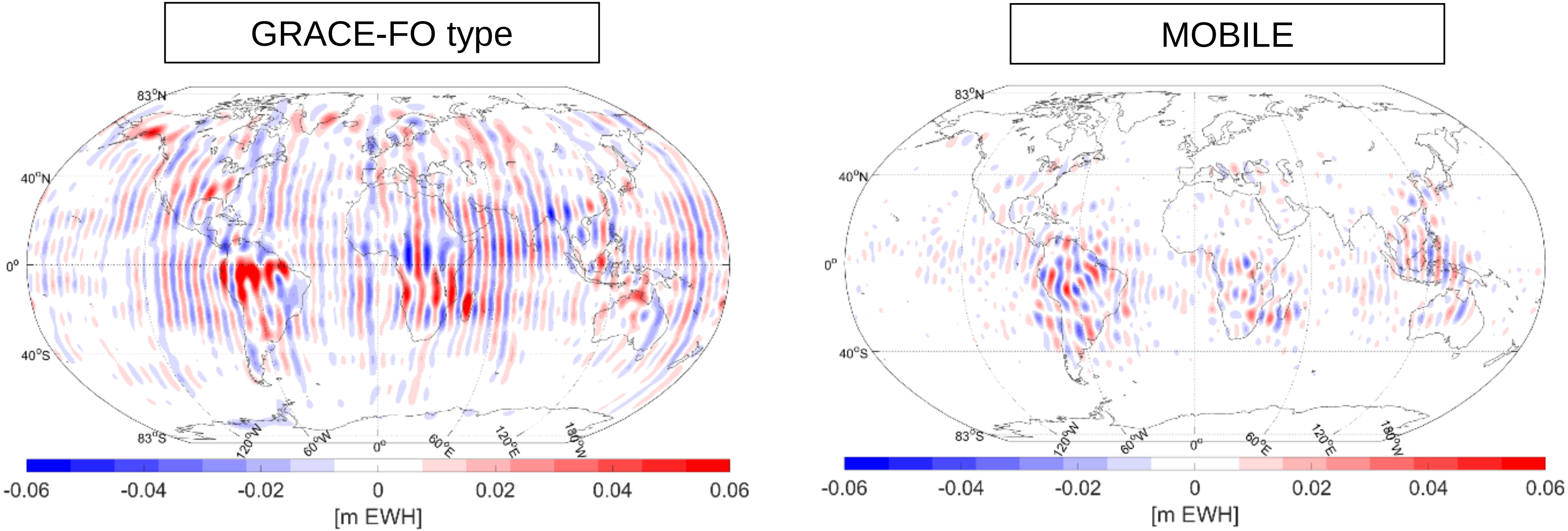
Instr. + HIS


Cumulative degree RMS

Instr. only

- MOBILE outperforms GRACE-FO by about a factor of 5
- Threshold requirements are almost achieved for minimum configuration (2 MEOs / 1 LEO)

Case: also HIS aliasing included


GRACE-FO type

MOBILE

Global grids of EWH [m] up to degree/order 50

Conclusion

Alps uplift is documented by GPS

Remote sensing of height of glaciers and lakes must be corrected

Gravity senses mass changes of glaciers, hydrology, tectonic movements.

Uplift Gravity signal contributes to up to 20% of observed amplitude.

Crustal thickening or uplift can be distinguished by gravity observation. Thickening reduces topography uplift signal by 50%.

Observed rate different from predicted by soil moisture and topography - possible solution: change rate is at lithospheric level.

Long Term: Future improved gravity mission would allow better signal resolution for Alps.

Short term: Terrestrial-satellite integrated gravity field for Alps is needed