

Geodetic Observing Systems: tools in observing the Glacial Isostatic Adjustment

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Glacial Isostatic Adjustment

- Land uplift is just one consequence of the physical process called the Glacial Isostatic Adjustment, GIA
- GIA-related phenomena originate to the large-scale mass transportation; Waxing and waning of the Northern hemisphere glaciers in about 100 000 year cycles cause up to 135 m of global sea level rise and fall. This corresponds about 5×10^{19} kg of mass
- The mass transportation causes cyclic variation on the surface load resulting in the viscoelastic mantle flow and elastic effects on the upper crust
- No single technique or observing network will give enough information on all aspects and consequences of GIA

Glacial Isostatic Adjustment

- GIA with its unique temporal signatures is one of the great opportunities in geosciences to retrieve information about earth processes.
- GIA contains information about recent climate forcing, being dependent on the geologically recent on- and off-loading of ice sheets.
- GIA gives a unique chance to study the dynamics and rheology of the lithosphere and asthenosphere with an increasingly detailed modelling
- GIA is of fundamental importance in geodesy, since reference frames, physical heights, Earth rotation and polar motion are influenced by it.

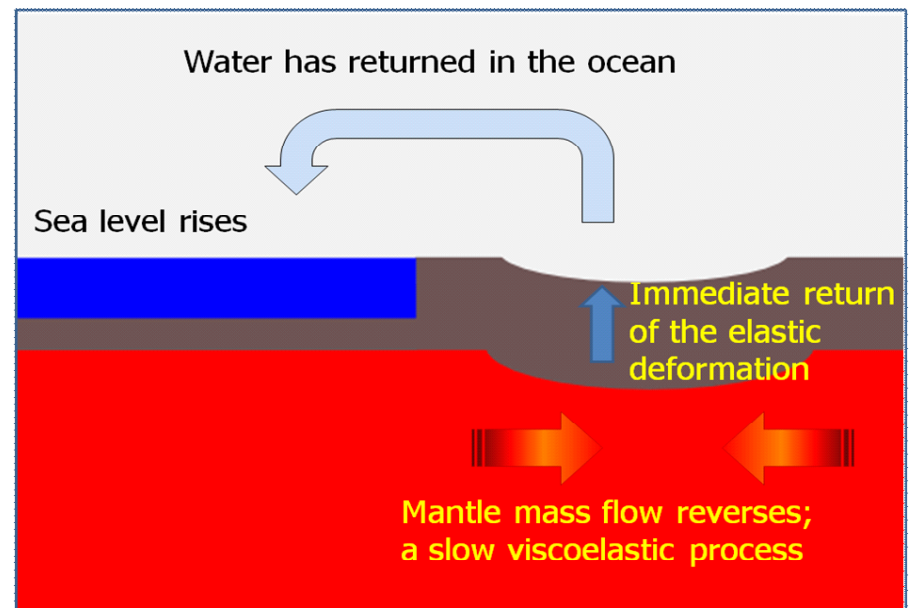
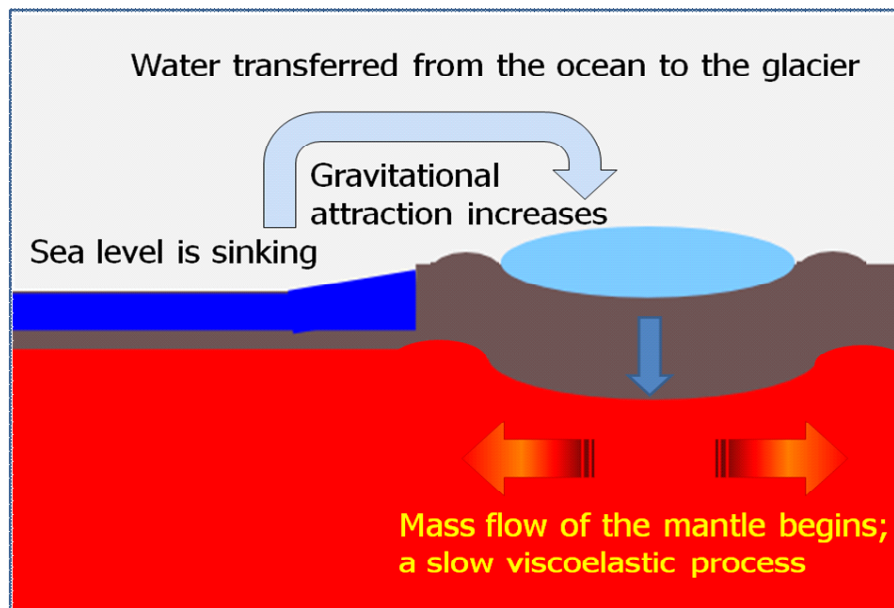
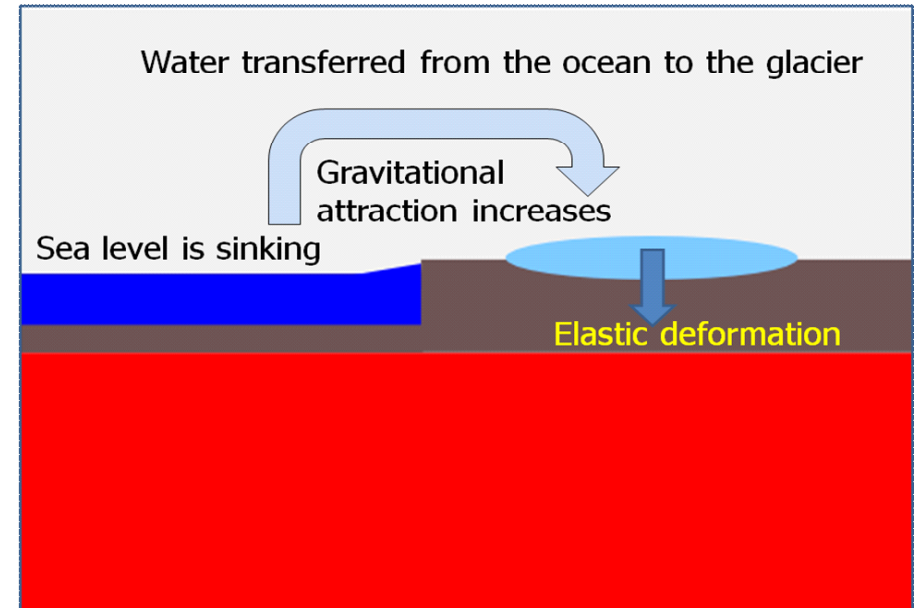
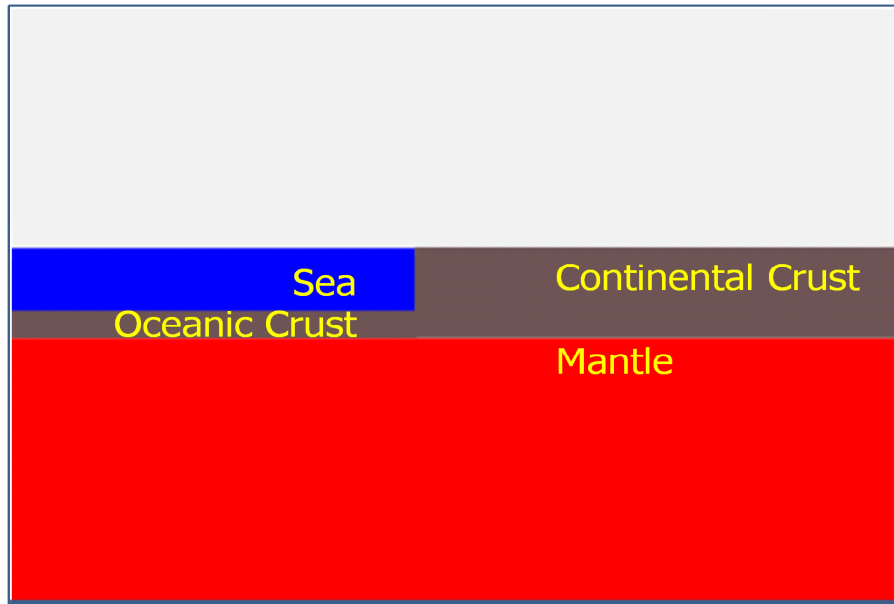
Phenomena and disciplines affected by GIA

- Earth orientation parameters: reference frames
- Post-glacial uplift, contemporary movements and gravity: heights and height systems
- Dynamic ice sheets, glaciology
- Quaternary paleoenvironments and climate
- Neotectonics and seismotectonics
- Dynamics, structure, properties and composition of the lithosphere

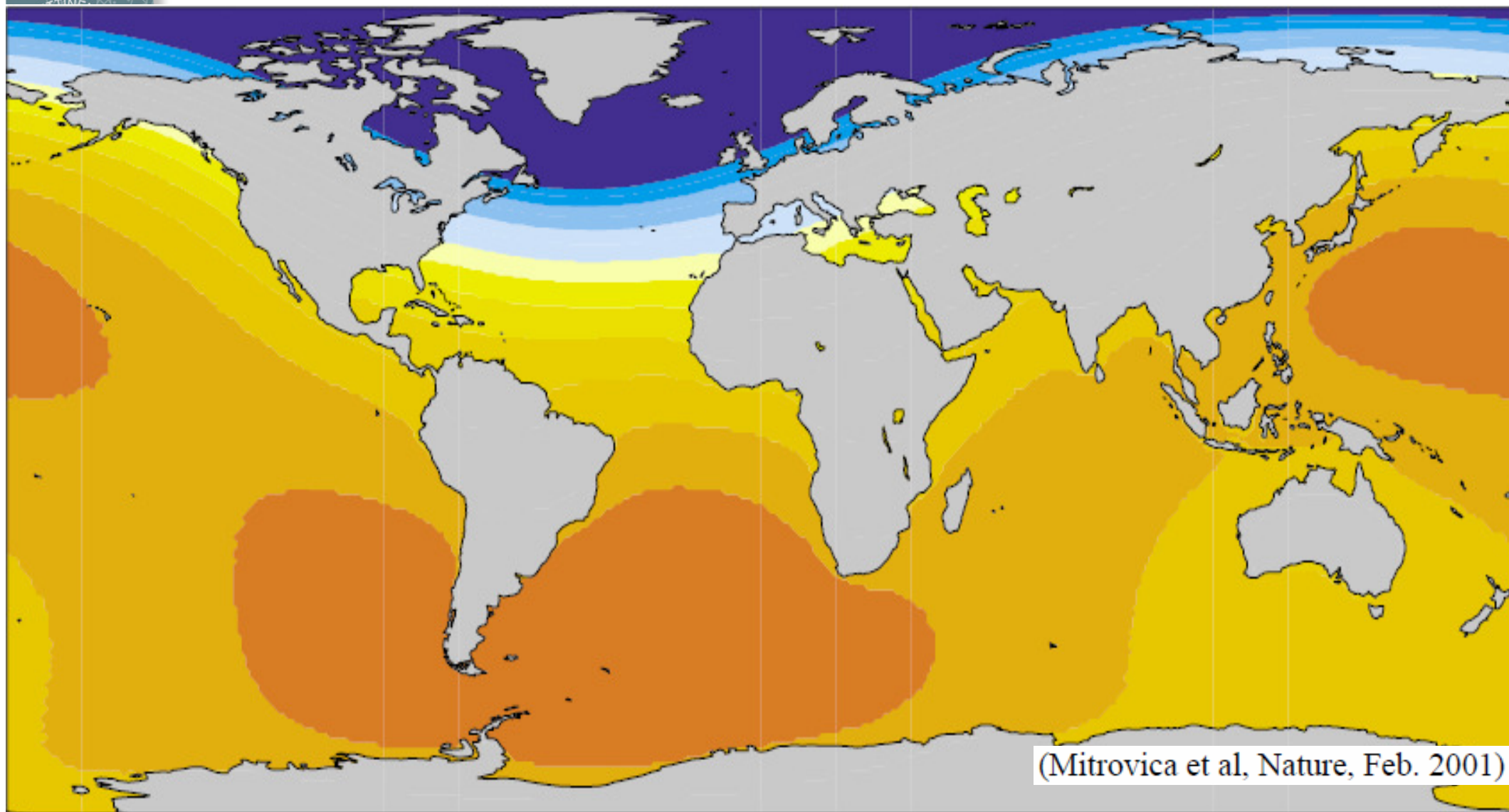
Other signals

- The GIA signal is contaminated by several other spatially and temporally varying mass changes and crustal deformation. These include seismic deformation, mantle convection and plate tectonics
- Sea level change is an example of a phenomenon which is related to GIA but mixed with other signals.
- The observed sea level change relative to the benchmark on the ground contains components of GIA related crustal vertical motion, eustatic rise of the sea level, changes in semi-permanent sea surface topography and geoid changes.

Growth and decay of a glacier

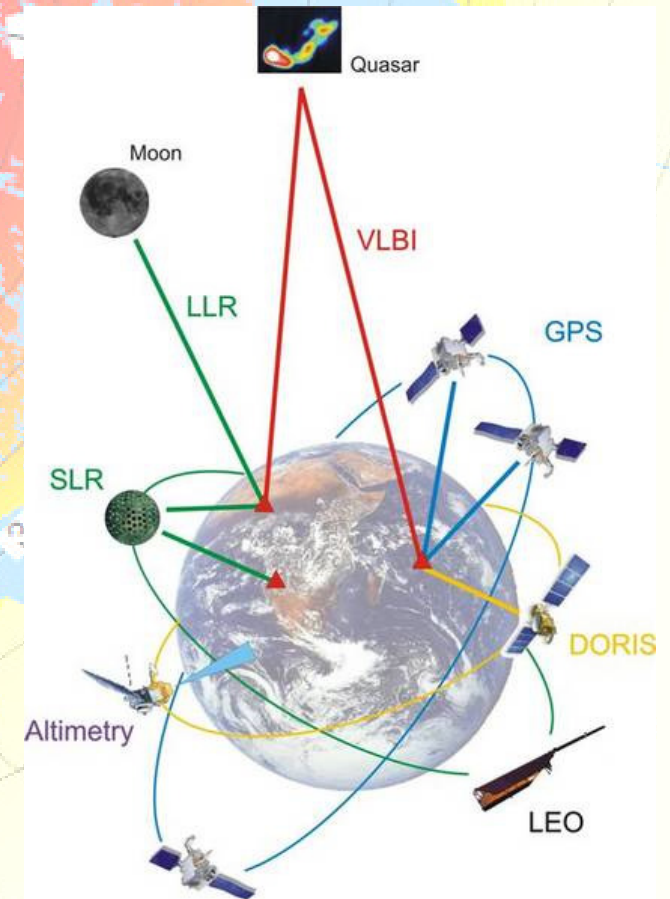


Scenario if the Greenland glacier is melting



Geodetic Observing systems and multi technique sites

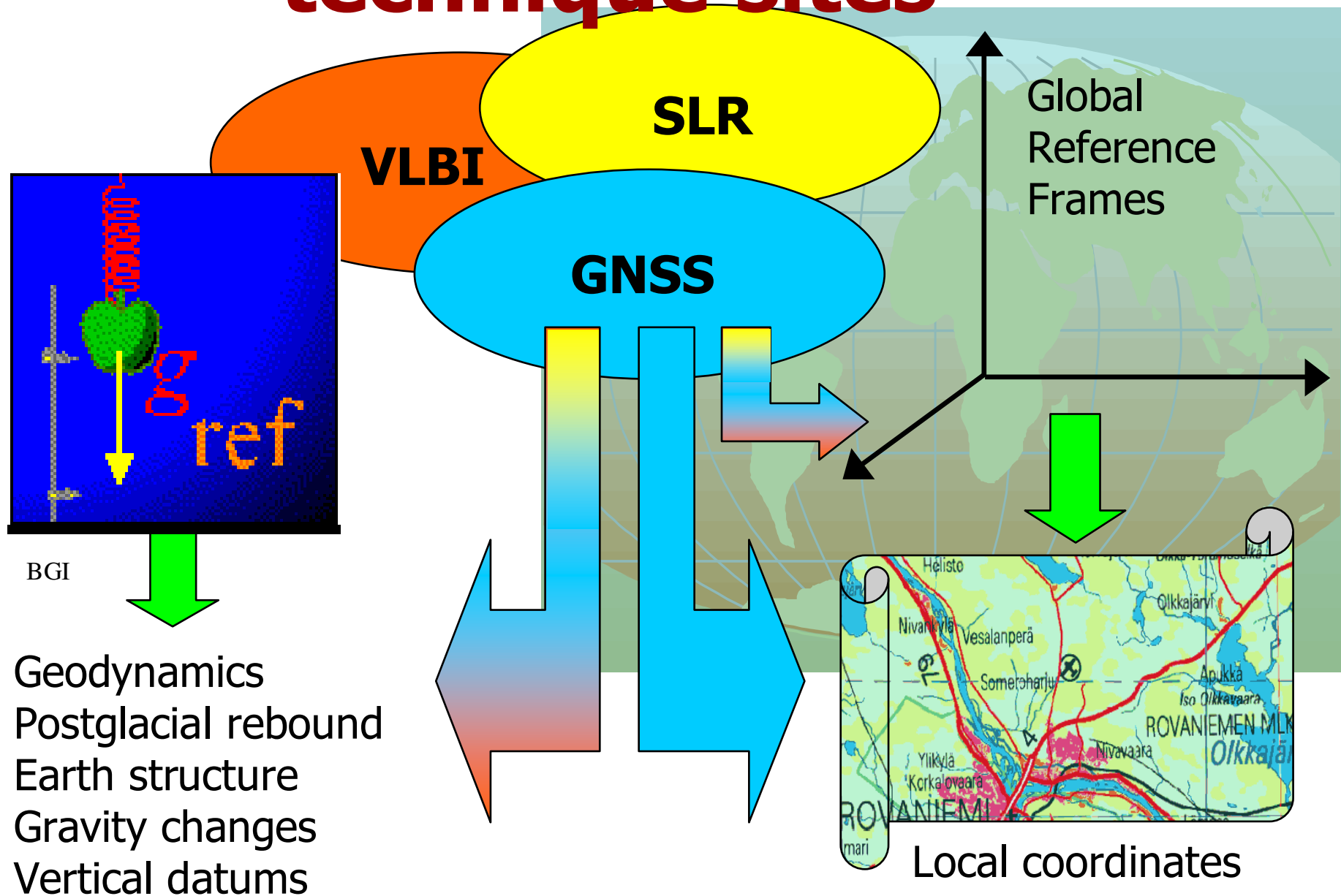
- To observe various aspects of GIA we need several techniques; in geodesy we observe 3D-motions, gravity, EOP, sea level, ...
- This implies: GNSS, SLR, VLBI, AG, SCG, levelling, relative gravimetry, altimetry, InSAR, ...
- Geodetic Observing Systems: GGOS, ECGN, NGOS, ...
- Special projects (BIFROST, COST ES0701, DynaQlim...)

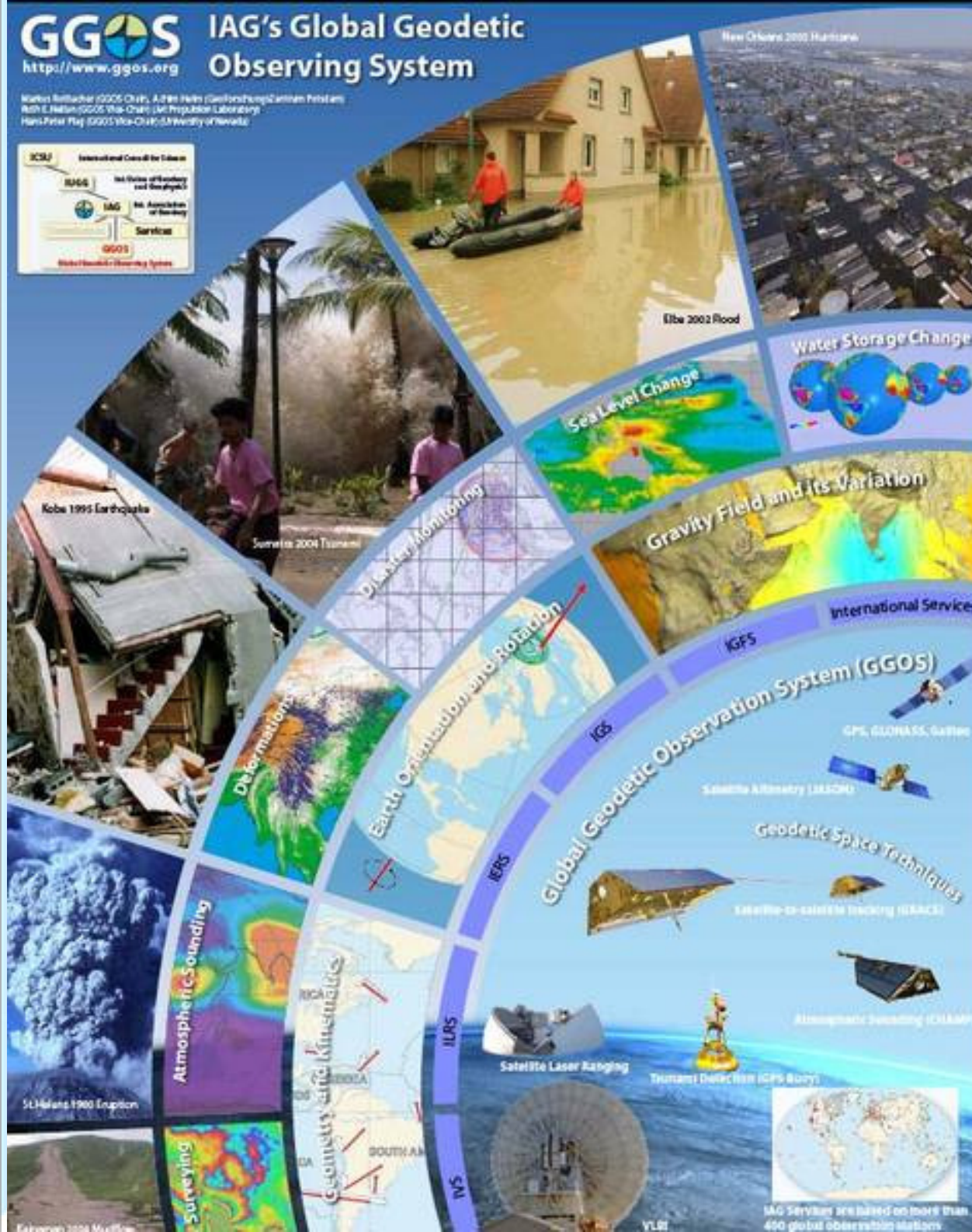


+ terrestrial

levelling, AG, SCG,
rel.g, tide gauges, ...

Motivation for multi-technique sites





www.ggos.org

GGOS integrates different geodetic techniques, different models, different approaches in order to ensure a long-term monitoring of the geodetic observables in agreement with the Integrated Global Observing Strategy (IGOS).

GGOS provides the observational basis to maintain a stable, accurate and global terrestrial reference frame, to link it to the celestial reference frame and to monitor the Earth's kinematics and dynamics. In this function GGOS is crucial for all Earth observation and many practical applications.

European Combined Geodetic Network

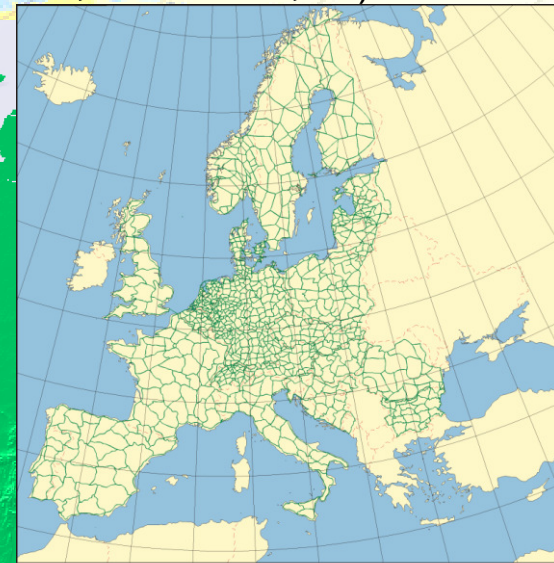
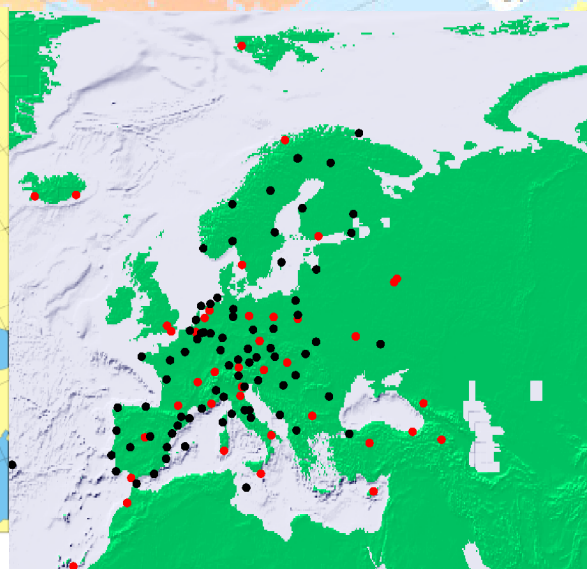
ECGN

Objectives of the ECGN as an integrated European Reference System for Spatial Reference and Gravity are:

- Realization of a terrestrial reference system and maintenance of long time stability with an accuracy 10^{-9} for Europe especially in the vertical component
- In-situ combination of space geodesy (GPS) with Earth gravity parameters (gravity, heights)
- Modelling of influences of time depended parameters to TRF (of the solid Earth of the Earth gravity field, the atmosphere, the oceans, the hydrosphere)
- Modelling of terrestrial gravity field components to validate satellite gravity missions
- Geodetic platform in Europe for geo-initiatives (GMES, INSPIRE, ...)



◆ Heights of the mean sea level 1997 above the GPS/Levelling quasi geoid of EUVN



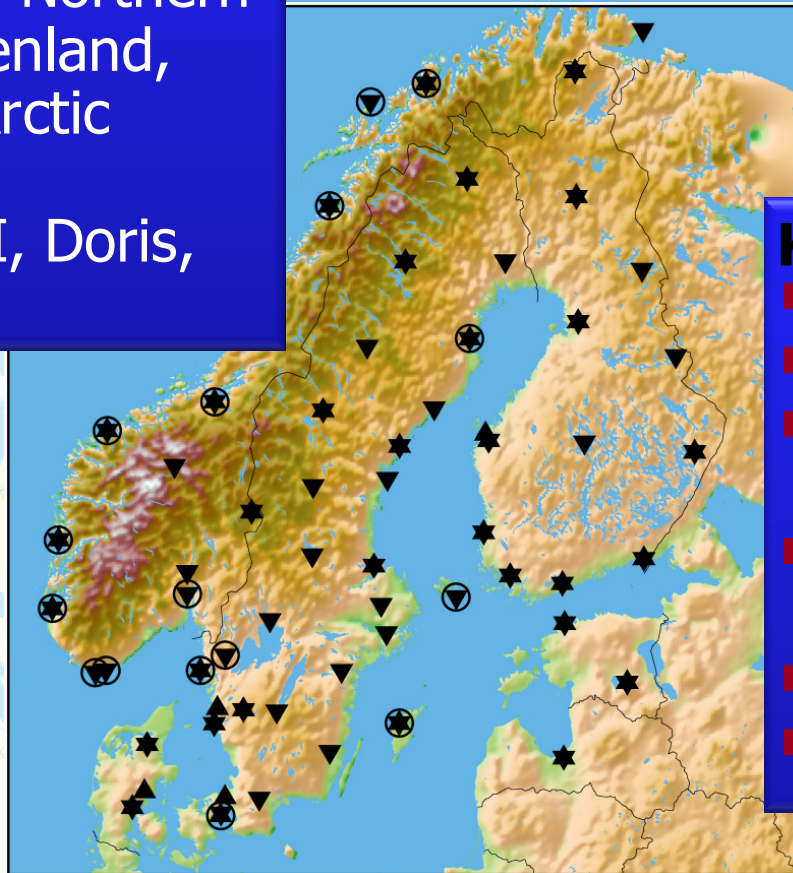
October 2003

The Nordic Geodetic Observing System (NGOS)

- Established by the Nordic Geodetic Commission; NKG Task Force
- Formerly and presently ice covered areas in Northern Europe and Greenland, North Atlantic, Arctic areas
- GNSS, SLR, VLBI, Doris, SCG, AG, TG,

Key parameters

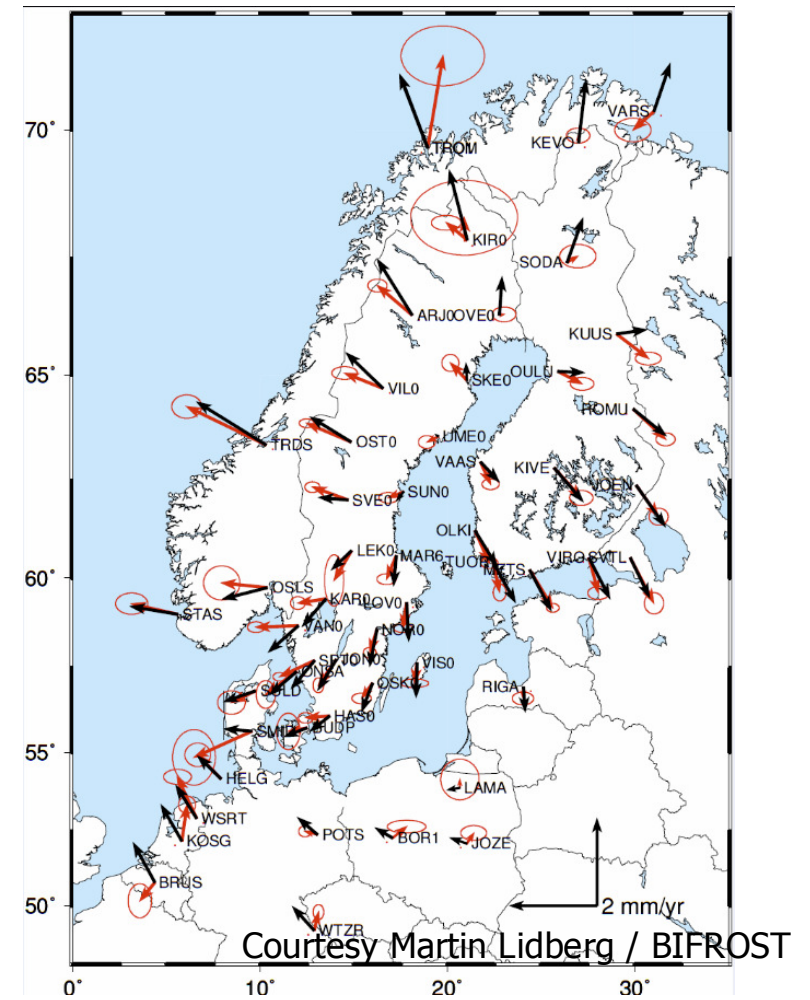
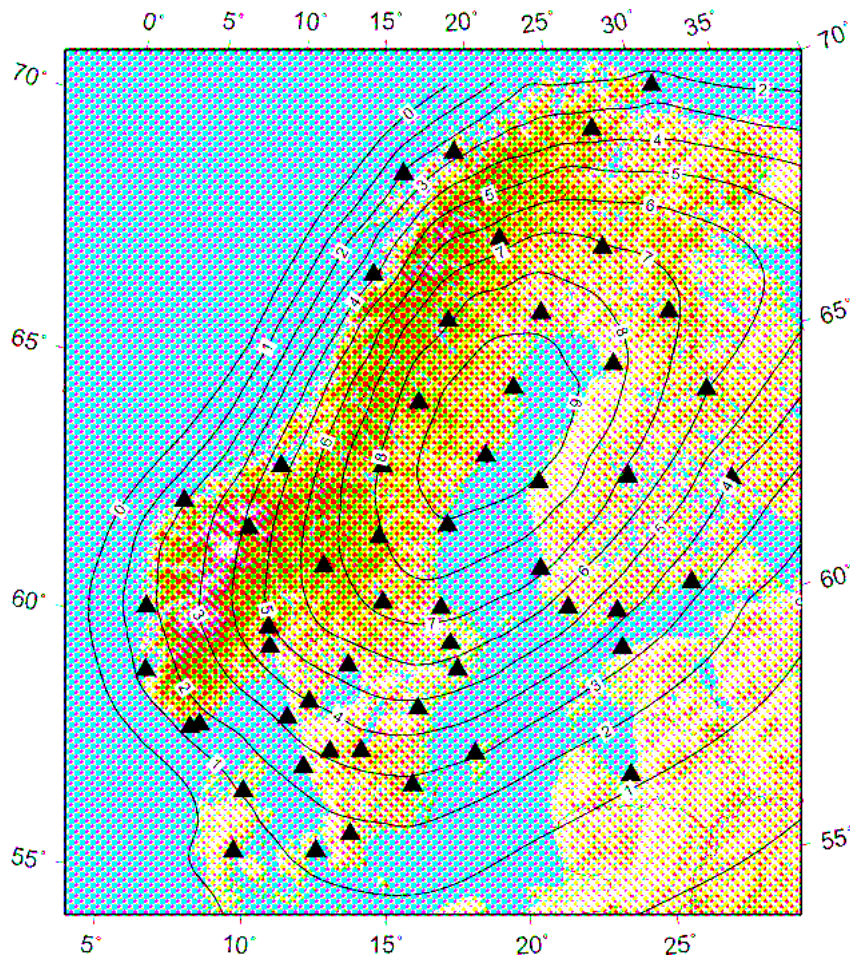
- Height / height systems
- Sea Level
- Geodetic position, reference frames
- Geopotential and gravity anomalies
- Temporal gravity change
- Postglacial rebound



ECGN Techniques

Technique	Objective	Accuracy	Component(s)
VLBI	IAG SERVICE		
SLR	IAG SERVICE		
GNSS	EPN (OK)		
DORIS	IAG SERVICE		
Levelling	UELN (OK)		
Tide gauges	PSML (OK)		
Absolute gravimeters	AG plan + archive (developing)		
Superconducting gravimeters	GGP (OK, IAG PROJECT ??)		
Spring gravimeters	Many sources, partly available		
Meta-databases, data archives, partly available			

Maps of vertical motion have traditionally been based on long time series of tide gauges and repeated precise levellings over several decades. Today we can observe 3-D motions with GNSS

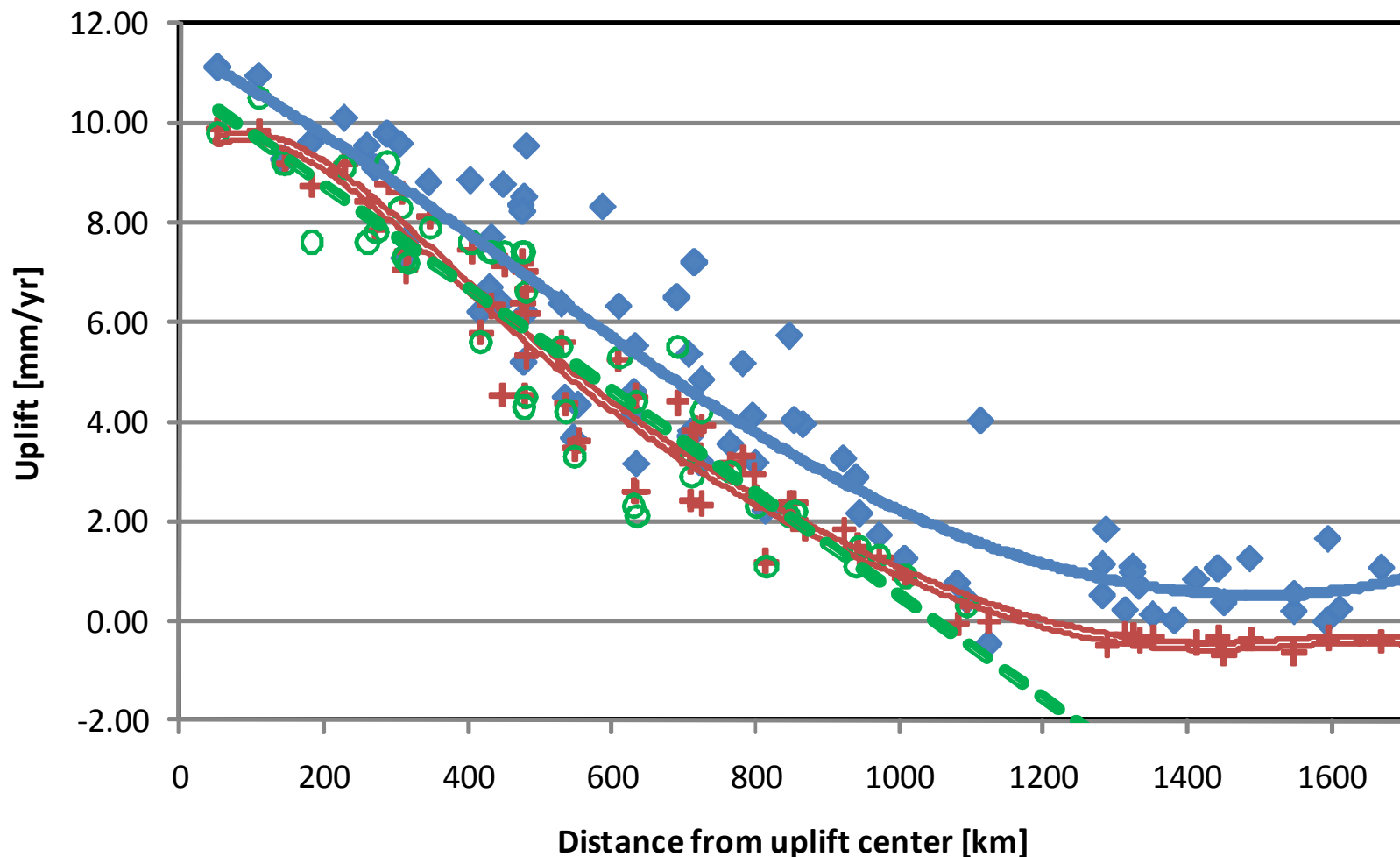


Courtesy Martin Lidberg / BIFROST

Uplift rate vs. distance

We get different values when using different techniques;

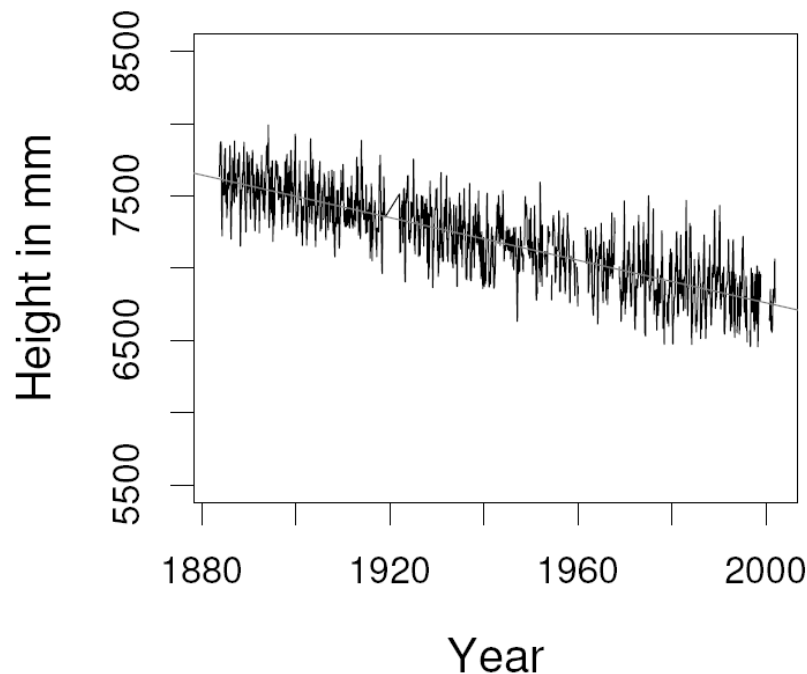
Blue = GPS time series, Green = tide gauge data, Red = model



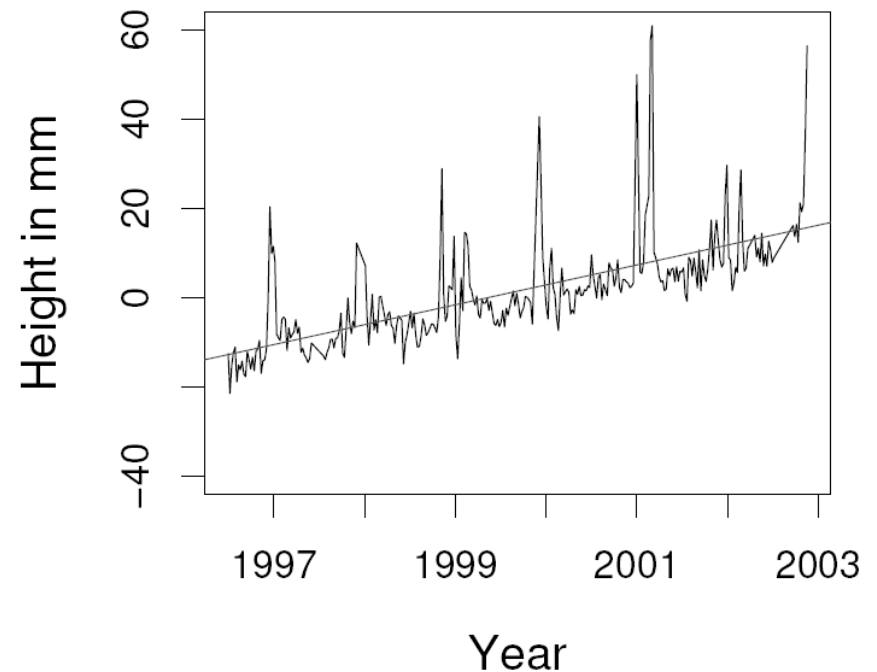
Data and noise

- Time series are noisy and contain various errors
 - Changes in trend (annual, decadal, random)
 - Outliers and environmental reasons

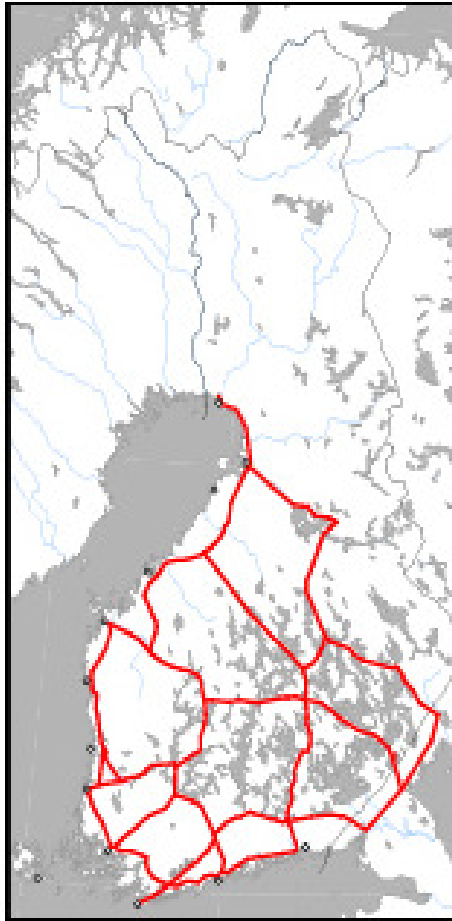
Vaasa tide gauge 1883 – 2001



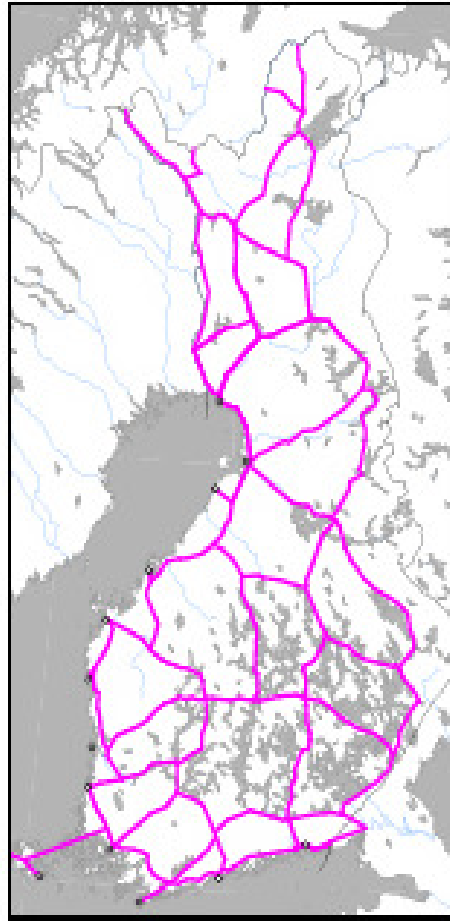
Vaasa GPS



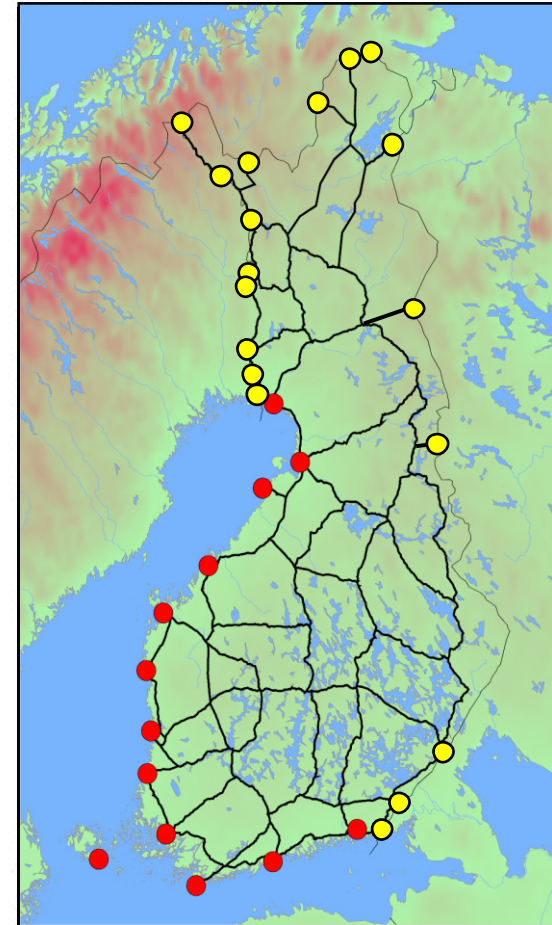
Example: three precise levellings in Finland and national height systems



1892-1910
N00



1935-1975
N60



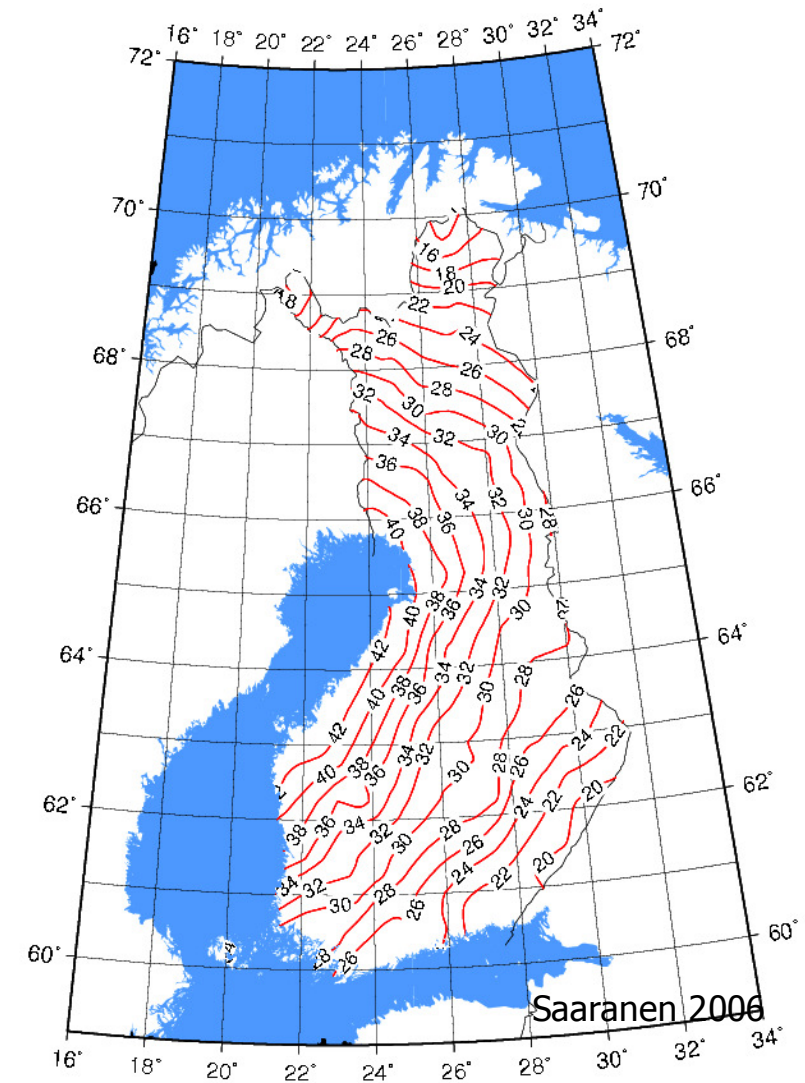
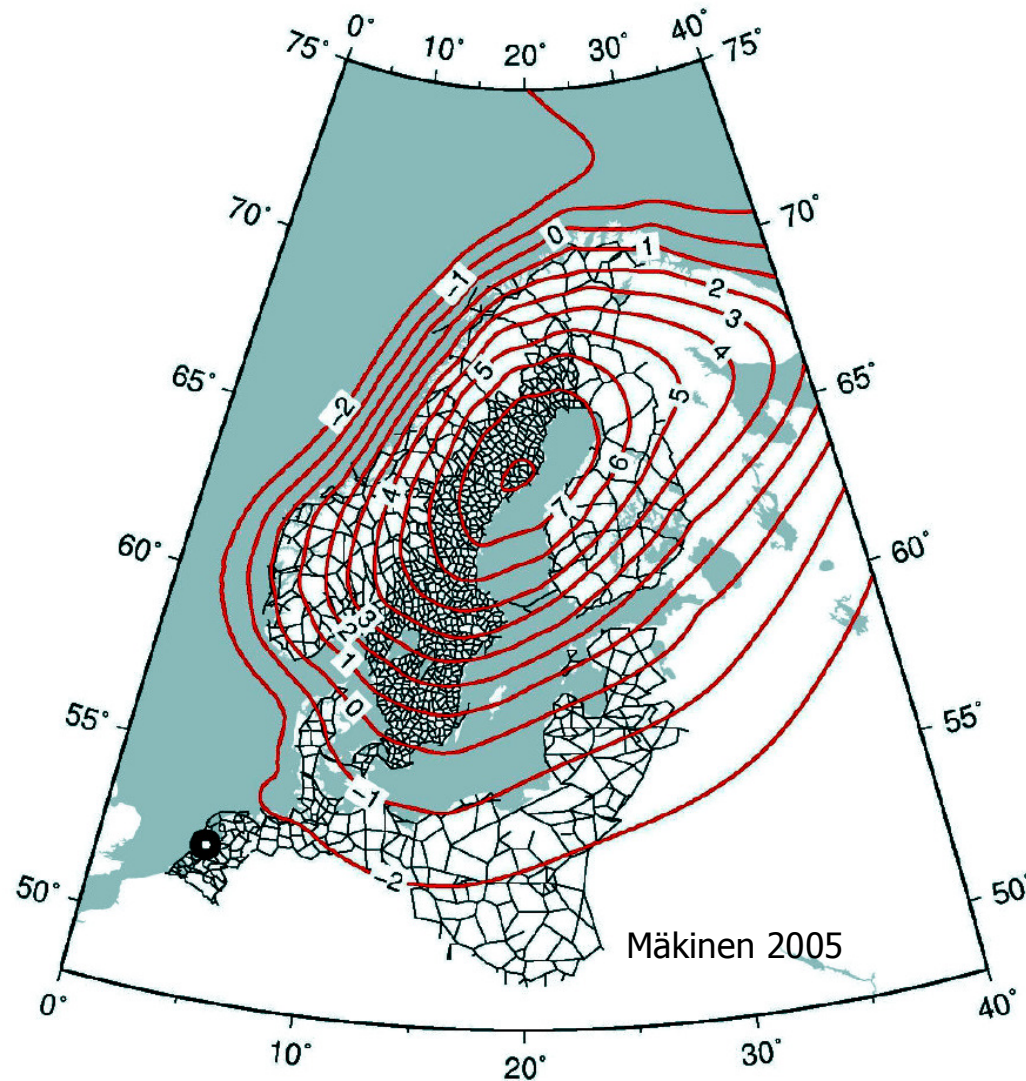
1978-2006
N2000

Due to land uplift, a new national height system is needed approximately twice / century; **How to maintain in the future?**

Common Nordic adjustment and N2000

Created as a Nordic co-operation
"EVRS compatible";

but national realisations



Land uplift is the
dominating factor in
new height readings

Summary

- GIA is very complicated in the viewpoint of precise observations and reference frames
- No single observing technique is sufficient
- Geodetic observing systems (GGOS, ECGN, NGOS, ...) offer (or will/should offer) multi-technique data/sites in a coordinated way
- Many GIA-related phenomena are global but many consequences are local and may have also serious societal aspects (sea level rise, earth quakes, ...) or which are laborous and expensive (new height systems)
- We therefore need also regional dense networks (ECGN, NGOS)
- One motivation to maintain and develop e.g. ECGN!