



NLS
FINNISH GEOSPATIAL
RESEARCH INSTITUTE
FGI



Aalto University
School of Engineering

Towards a fully integrated gravity change rate model for Fennoscandia

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Background

- ① Long history of studying the Fennoscandian postglacial rebound (PGR) phenomenon
- ② Crucial to constrain GIA modelling with gravity data
- ③ Terrestrial gravity measurements since mid-20th century
- ④ Satellite gravity observations cover over 20 years
- ⑤ Time series start being long and accurate enough to make geophysical interpretation of the PGR feasible!

Things that need clarification

- Can gravity time series be improved by correcting for non-GIA loading?
- Shape and peak amplitude of the Fennoscandian PGR gravity signal
- Gravity change signals in the zero-uplift and forebulge zones
- Can we detect additional non-GIA related long-term trends?
- Is the ratio between gravity and vertical changes rates constant?

Plan: Combine all gravity observations and a GIA model and create a fully integrated model of the GIA-induced gravity changes in Fennoscandia

GraFePor - Project

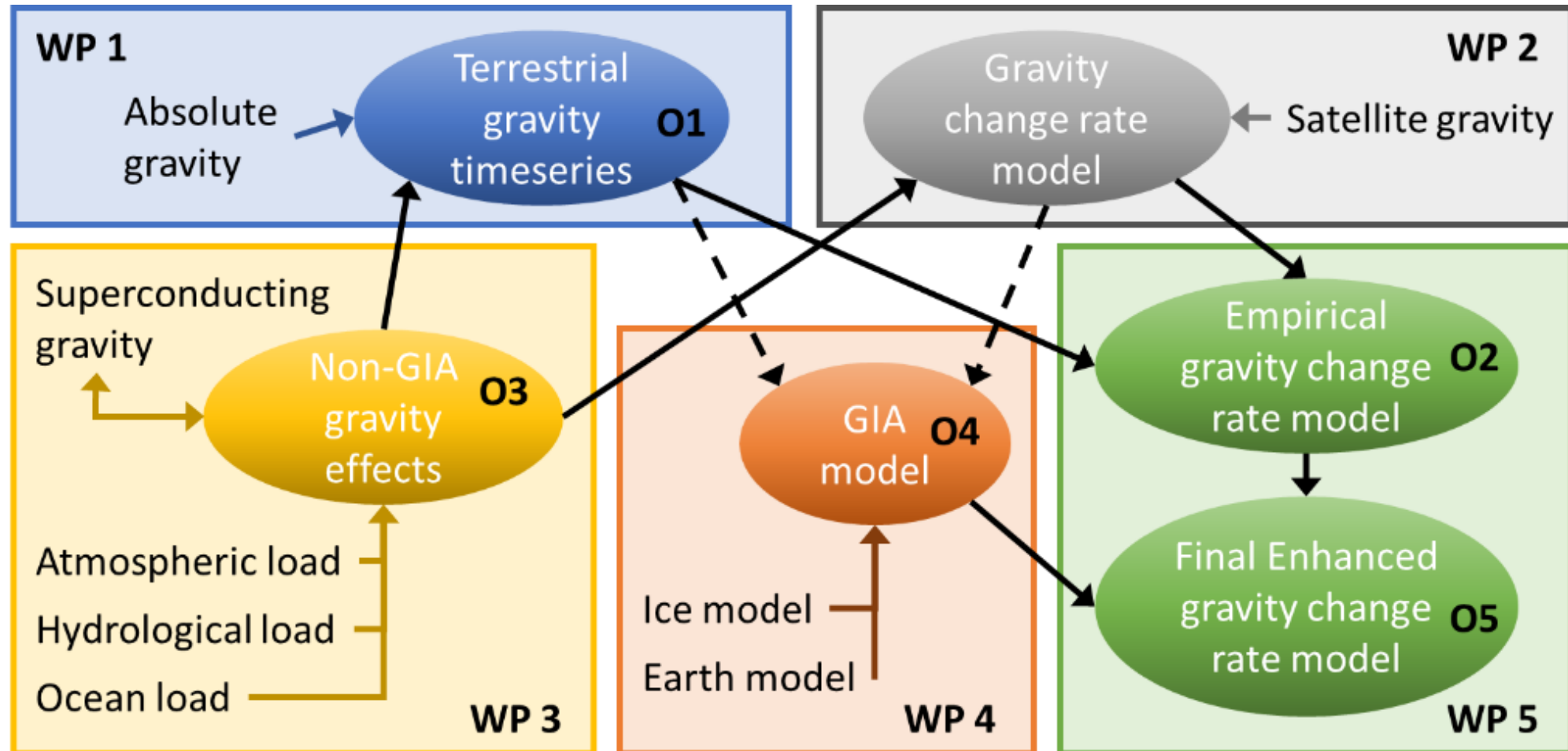


Satellite and terrestrial gravity data Fusion for Enhanced Post-glacial Rebound Modelling

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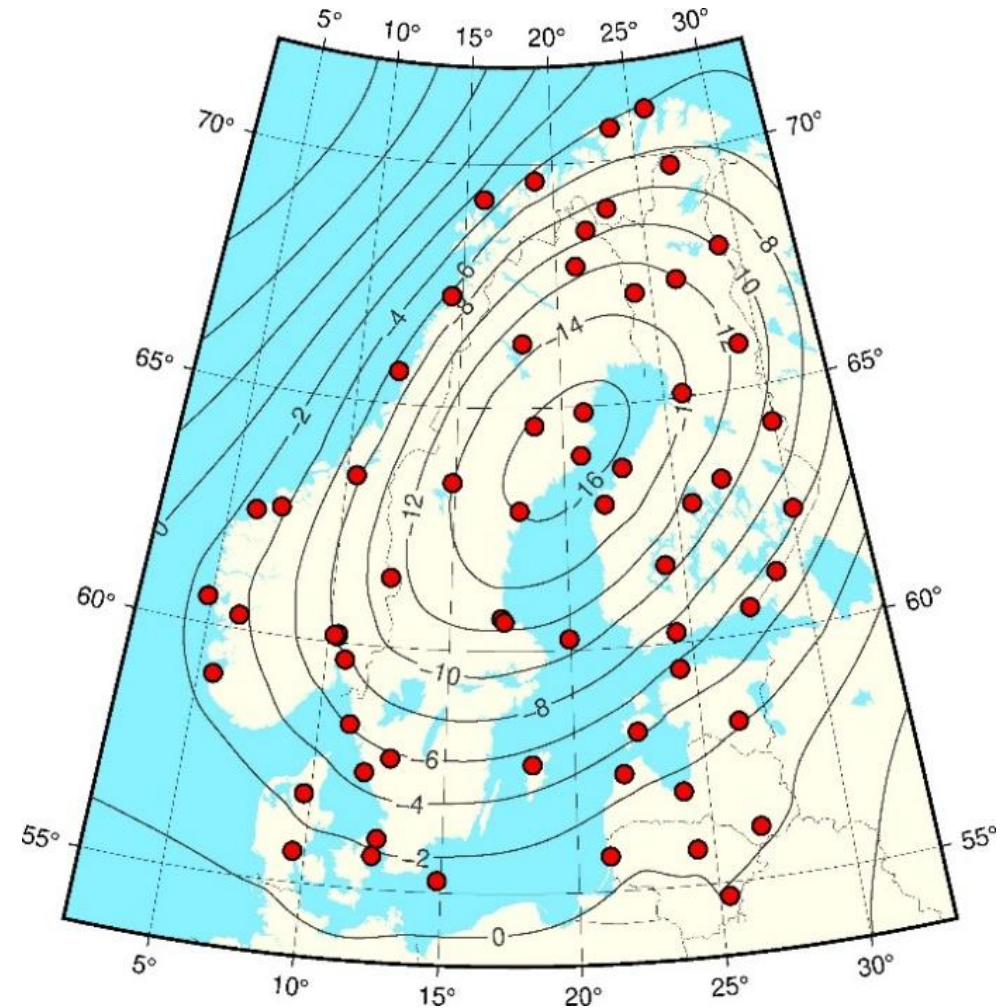
GraFePor - Project



Absolute gravimetry (FGI)

- Collect all available AG data in Fennoscandia
- Yearly AG measurements in Finland (FGI own) and up to 5 stations elsewhere (GraFePor)
- Analyze time-series, correct for non-GIA signal
- Calculate trends and evaluate stability of trends
- Analyze trends and determine dg/dh ratios

Outcome: Updated AG timeseries
AG change rates and ratios



(Olsson et al. 2019)

Absolute gravimetry

Starting point:

Olsson et al. (2019)

Bilker-Koivula et al. (2021)

- Inventory of new data
- Calculate trends and evaluate stability of trends
- Request for all countries to provide:
 - Overview of AG data – by 30.11
 - Updated AG data – by ??

Asema	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	
Metsähovi	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	O	O	O	O
Kevo			X	X		X	X	X	X		X				X					X		X					O	
Savukoski												X		X		-	X			X			X				O	
Sinettätunt.																X	-	X		X			X				O	
Kolari																X	X			X			X				O	
Sodankylä			X	X		X		X	X		X			X			X			X			X				O	
Ahvenanmaa																			X	X		X				O		
Orivesi																	X	X			X		X			O		
Virolahti										X		X			X			-	X			X				O		
Oulu												X		X			X		X			X				O		
Kuusamo AB				X		X		X		X					X				X			X				O		
Romuvaara															X	X			X			-	X			O		
Kivetty												X		X		X			X			X			O			
Vaasa AA	X	X	X	X	X	X		X		X				X			X				X				O			
Vaasa AB	X	X	X	X	X	X		X		X				X			-	X	X									
Vaasa AC																		X	X		X				O			
Joensuu	X	X	X	X	X	X		X		X				X			-	X	X		X				O			
Maaninka																	X	X			X				O			
Imatra																	X	X			X				O			
Pietarsaari																	X	-	X						O			

Satellite gravimetry (FGI)

- Use monthly GRACE(-FO) models
- Experiment with filtering and de-stering techniques as well as cut-off degrees
- Optimize trend estimation of data with data gaps
- Restore background model for ocean variability and apply Baltic Sea corrections
- Study effects of non-GIA signal
- Compare results with absolute gravity and GIA modelling results

Outcome: Gravity change rate model from satellite gravimetry

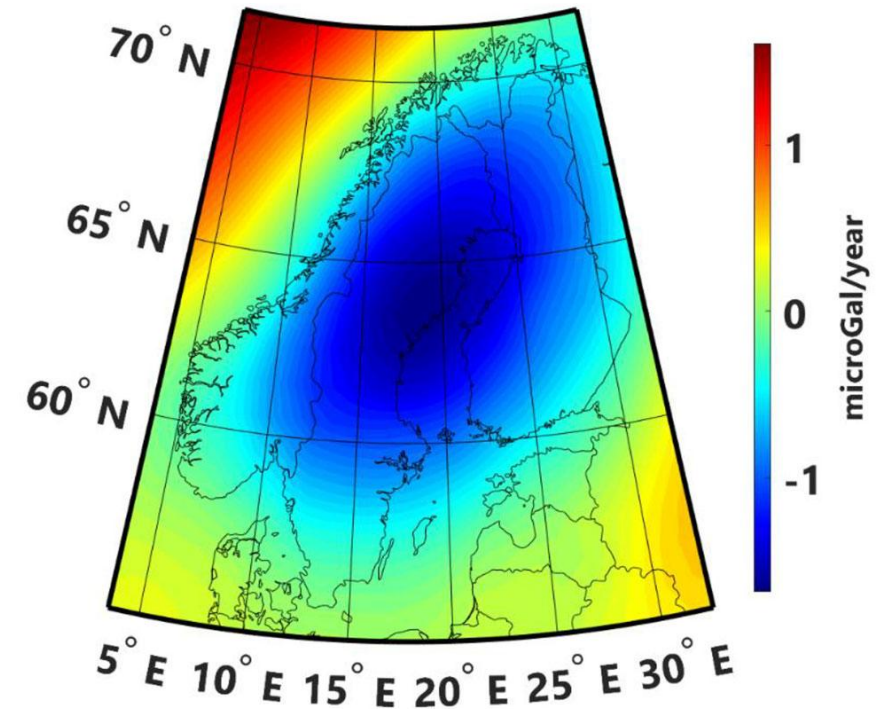
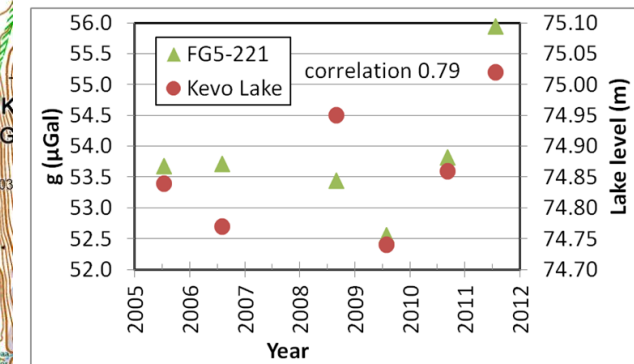
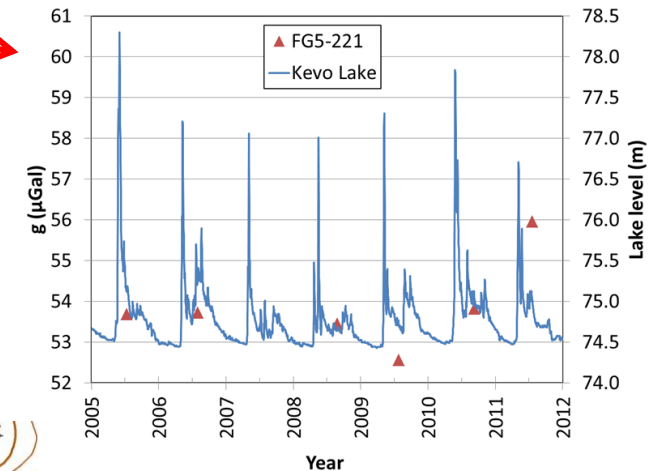
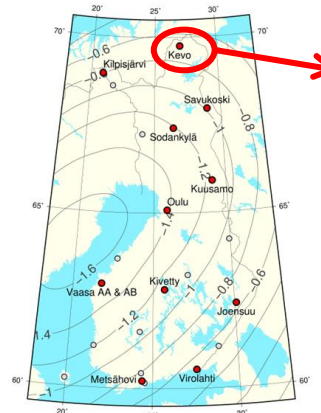


Fig. 1 Surface gravity change ($\dot{g}$) obtained using CSR GRACE and GRACE-FO RL06 data (from January 2003 to November 2023) in Fennoscandia (Bagherbandi & Sjöberg, 2024)

Non-GIA gravity signal modelling (Aalto & FGI)

- Install iGrav SG in Northern Finland
- Model hydrological signal
- Model hydrographical signal
- Validate results with SG data in Metsähovi, Onsala and Northern Finland
- Find optimal solution for input into absolute and satellite gravity time series

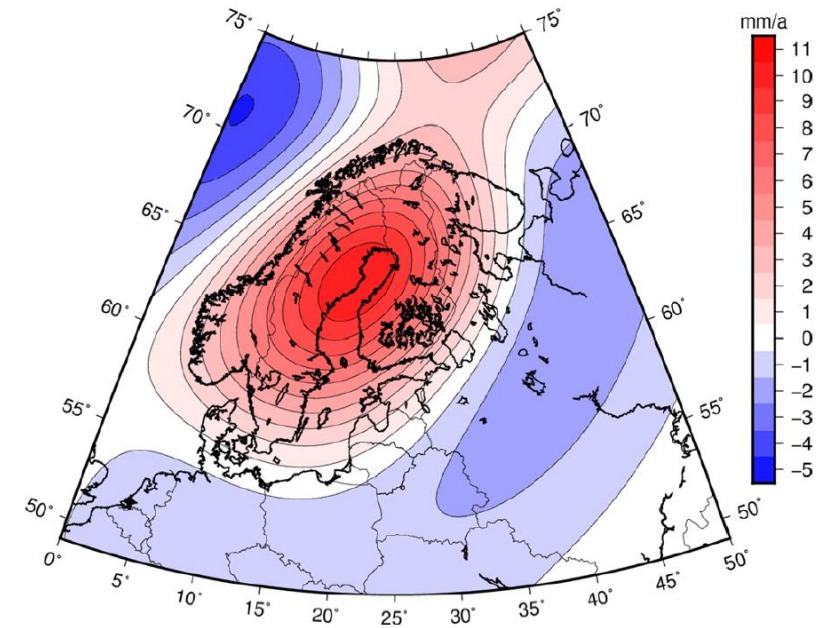
Outcome: Optimal non-GIA signal for AG and GRACE



GIA modelling (Aalto)

- Calculate Aalto model using finite element method
- Select ice and Earth models, considering full glaciation-deglaciation history, sea level equation and changes in Earth's crust
- Compare with NKG model
- Constrain with sea level indicators and absolute and satellite gravity results
- Predict gravity changes based on best fit

Outcome: New Fennoscandian GIA model constrained with terrestrial and space measurements



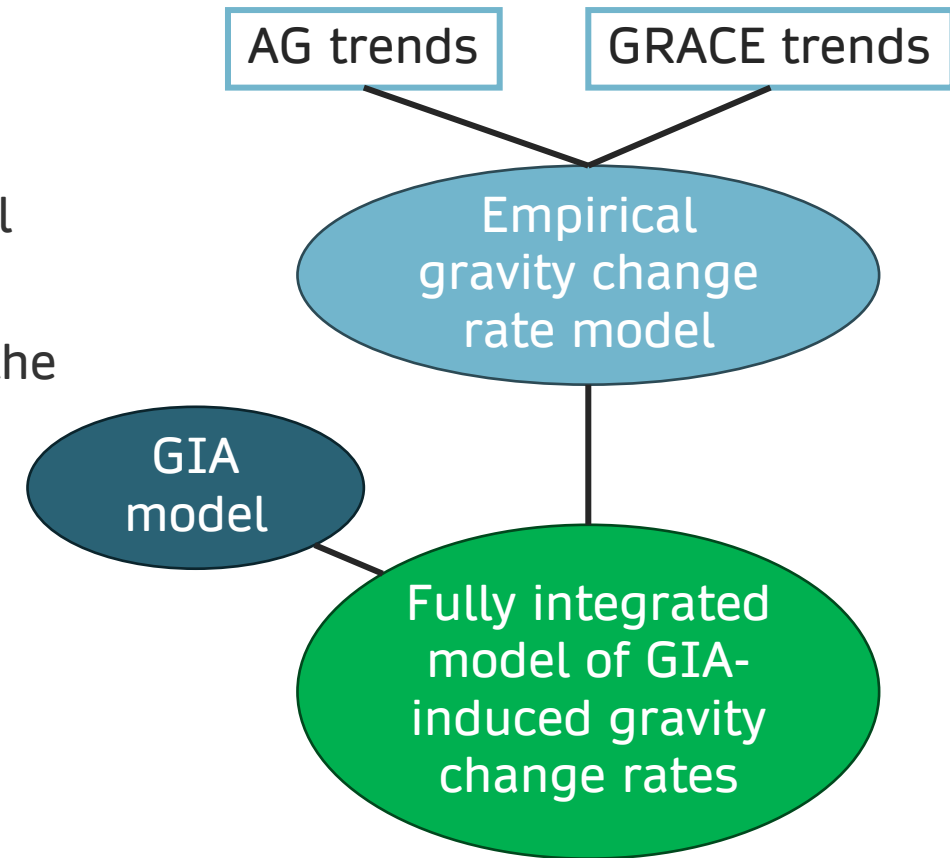
NKG2026GIA_prel0306 model (mm/yr)
(Vestøl et al. 2019)

Data fusion (FGI & Aalto)

- Correct AG trends for land uplift
- Combine gravity change rates from AG and GRACE
- Compare and combine AG/GRACE model and GIA model
- Analyze final model and derive dg/dh ratios
- Conclusions on spatial variability of ratio as well as on the gravity change in the zero-uplift and forebulge zone
- Test procedure in North-America using Canadian AG timeseries and GRACE data

Outcome:

- Empirical gravity change rate model for Fennoscandia
- Fully integrated model of the GIA-induced gravity changes in Fennoscandia
- Gravity change rate model for North America



Recap

GraFePor = 4 year project

- Comprehensive investigation of gravity changes related to postglacial rebound
- Combines terrestrial absolute gravity observations, satellite gravity measurements, and GIA modelling
- Provide new insights into the geophysical processes driving crustal rebound in Fennoscandia.

What can you do?

- Provide overview of AG data and updated AG time series

Outcome:

State-of-the-art Fennoscandian gravity change rate model integrating terrestrial and satellite gravity time series with advanced GIA modelling