NEW HORIZONTAL INTRAPLATE VELOCITY MODEL FOR NORDIC AND BALTIC COUNTRIES

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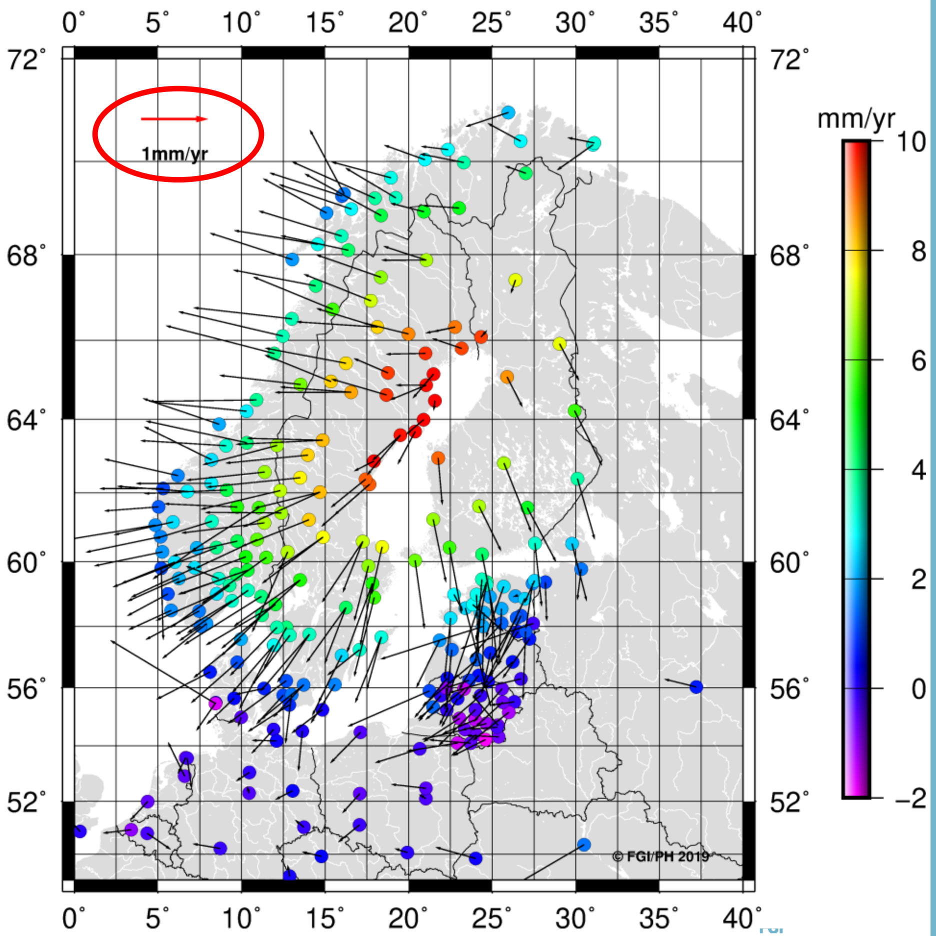
INTRAPLATE VELOCITIES

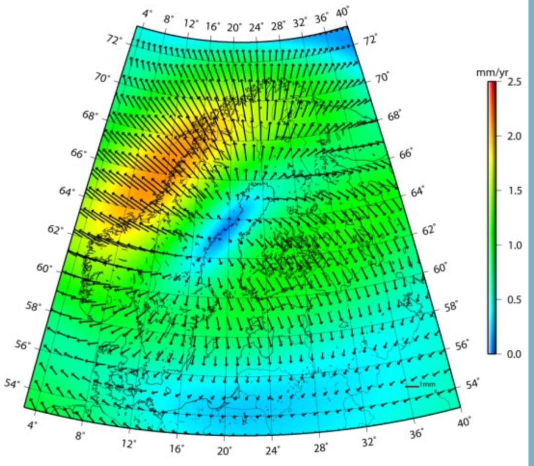
- Intraplate velocities caused mainly by Glacial Isostatic Adjustment (GIA)
  - Horizontal up to ~2 mm/yr
  - Vertical up to ~10 mm/yr
- Together with time span from establishment of national ETRS89 realizations (mostly in the 90s) and intraplate (residual) velocities too large to be omitted in maintenance of the national ETRS89 realizations

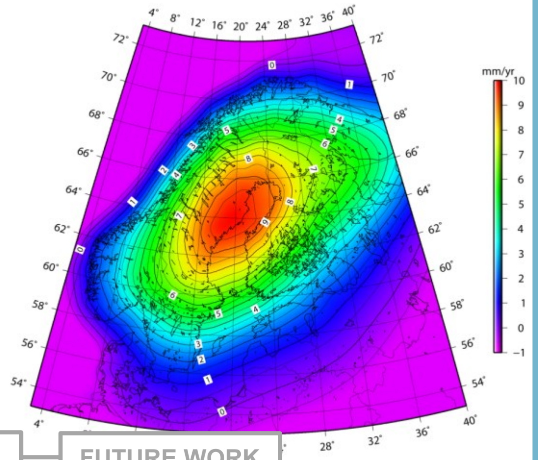


NKG MODELS AND TRANSFORMATIONS

- Common interest for all Nordic and Baltic countries → co-operation under Nordic Geodetic Commission (NKG)
- 2005-2006: **intraplate models** NKG2005LU and NKG_RF03vel and **transformation** ITRF2000→Nat.ETRS89
  - NKG2005LU: vertical land uplift motions, used for data reductions e.g. in Nordic height systems (EVRS realisations)
  - NKG_RF03vel: 2D+1D model describing intraplate (land uplift) motions, vertical model equals with NKG2005LU_abs
- 2016: Updated **NKG**(2008) **transformation** between ITRFxx and national ETRS89 realizations
- 2016: NKG decided to release a new land uplift model package: **NKG2016LU_abs/lev, NKG_RF17vel and NKG2016LU_gdot**

NKG_RF03vel (NKG2005LU_abs)

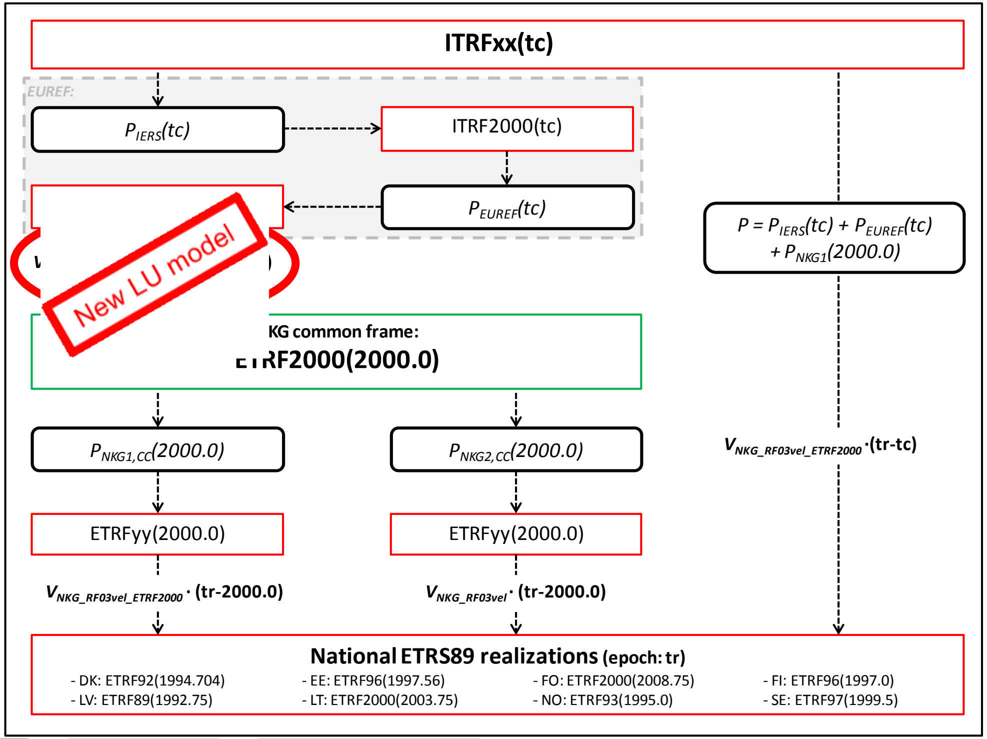




HOW DO WE USE THE MODELS: CASE NKG TRANSFORMATION

- Latest NKG transformation released in 2016, see figure
  - Still utilizes the old NKG_RF03vel model
  - New vertical land uplift model NKG2016LU released in 2016
  - Horizontal model to be updated too

→ Topic of this talk: **horizontal** (land uplift) **intraplate velocities of the NKG_RF17vel model**



DATA FOR HORIZONTAL INTRAPLATE VELOCITIES

- Nordic land uplift models include observations from several measurement techniques and predictions from GIA models
- Horizontal model is a combination of **GNSS** and **GIA** velocities
- GNSS velocities based on Continuously Operating Reference Stations (CORS) and their sufficiently long observation time series
  - Through GNSS data enables absolute velocities in a global terrestrial reference frame (TRF) – used for reference frame alignment
  - CORS network however pretty sparse for describing local motions – to densify velocity field, can be complemented with:
    - more dense geodetic observation data (even other measurement techniques) – empirical model
    - geophysical data: for Fennoscandian land uplift glacial isostatic adjustment (GIA) model – semi-empirical model
- GIA models (along with chosen combination procedure) bring details to the GNSS velocity field (”fills the gaps”)

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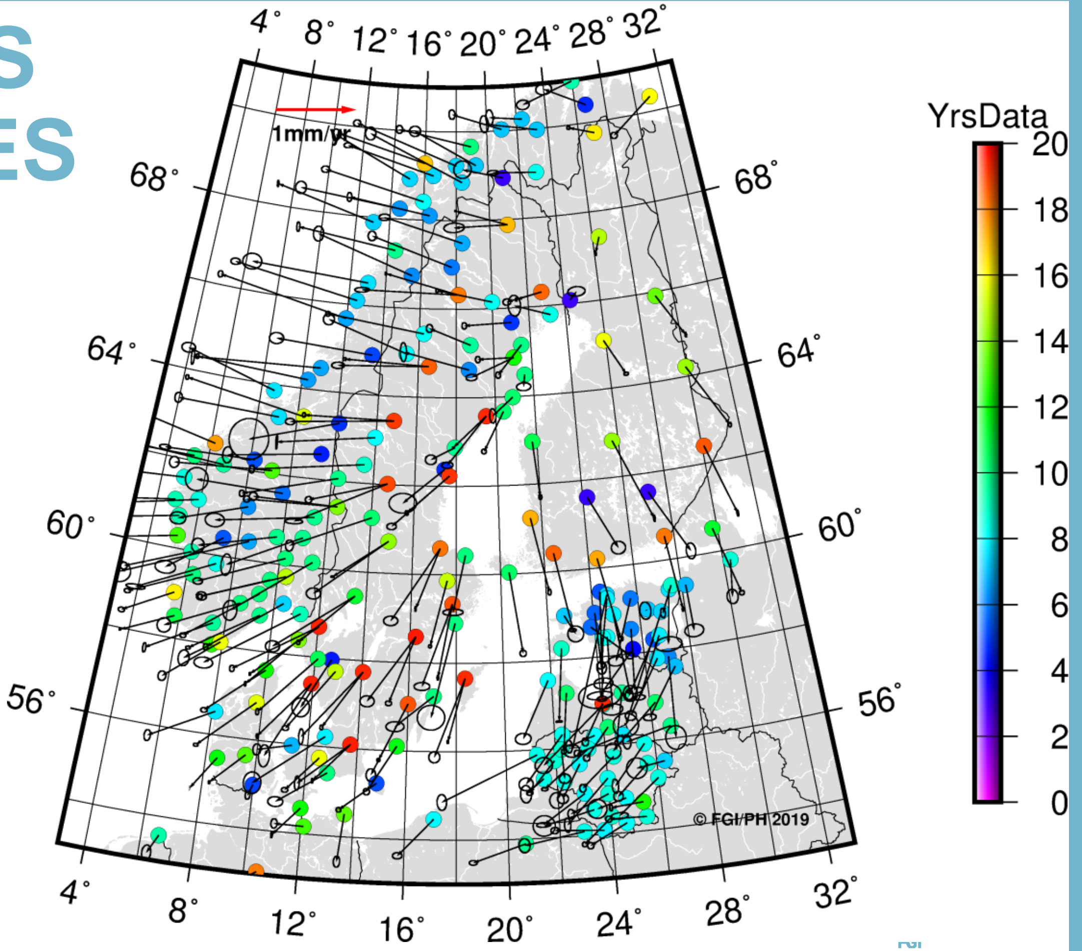
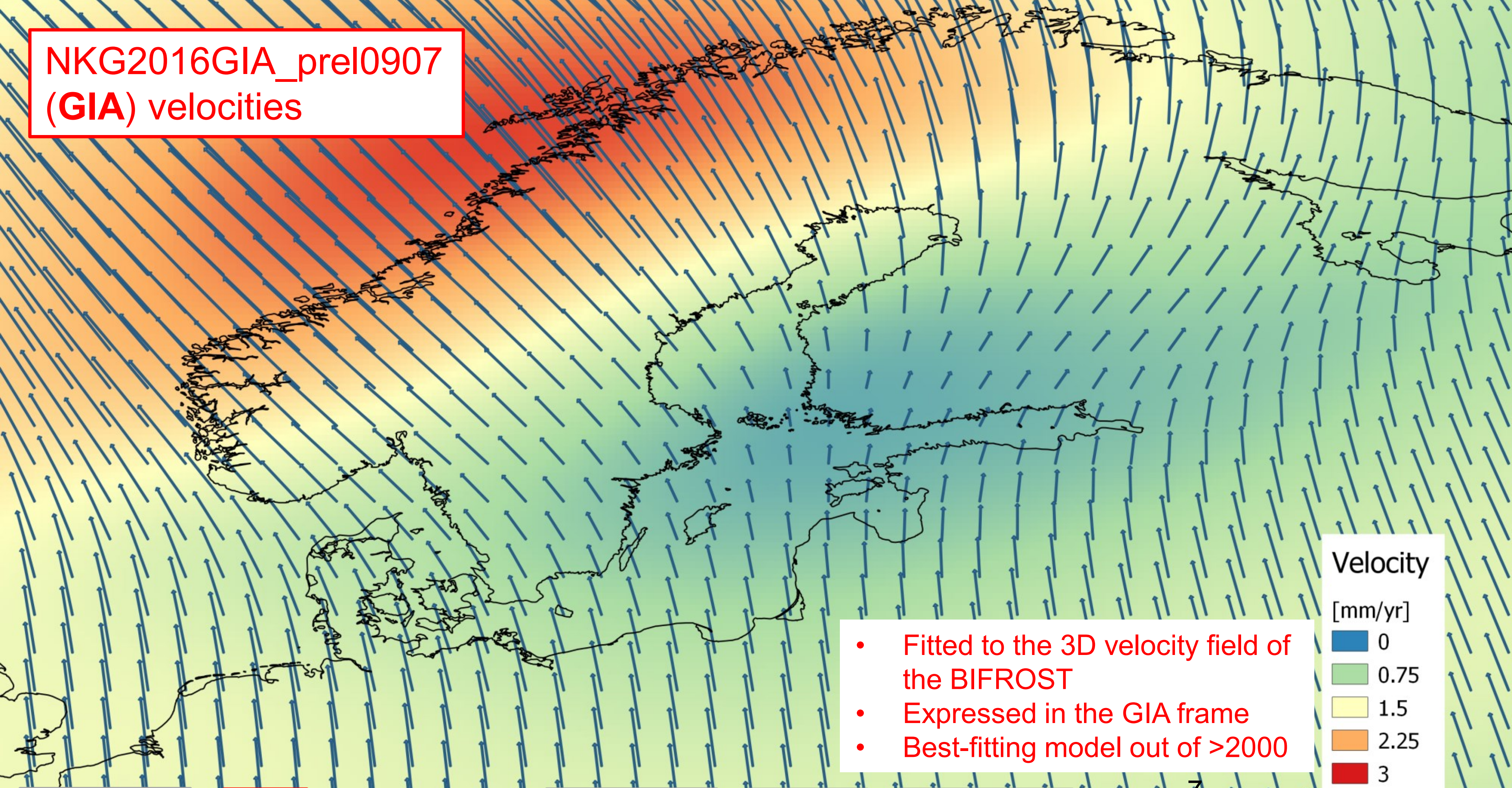
GNSS VELOCITIES W/ UNCERTAINTIES

- NKG Repro1 (see presentation by Lahtinen et al.) complemented with the latest BIFROST GNSS solution
- Time series >3 years, mostly ~10 years or more (see colored circles in figure)
- Velocities in ITRF2014, from which rigid Eurasian plate motion removed → ETRF2014
- More realistic uncertainties e.g. with colored noise modelling and outlier analysis

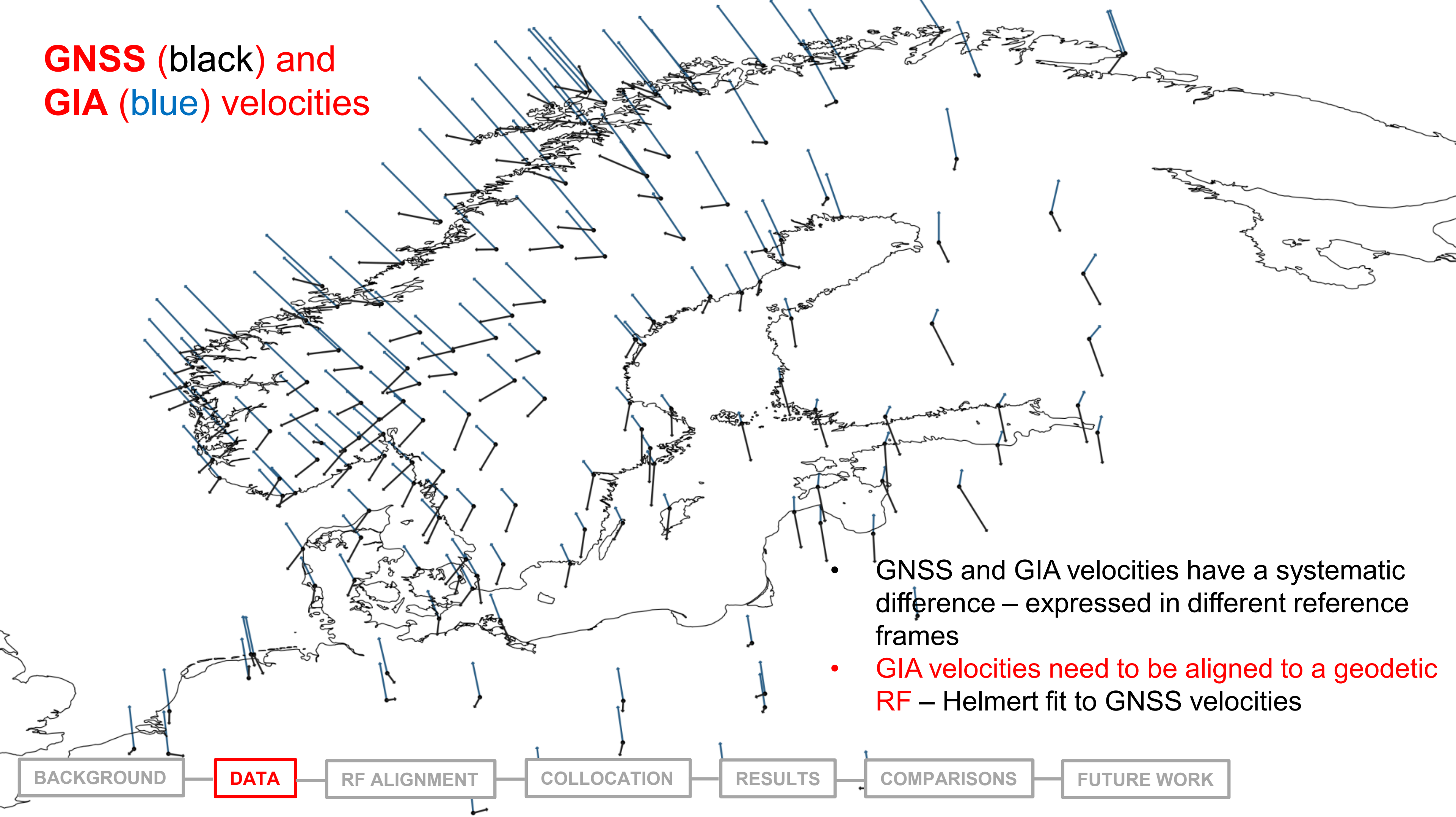


NKG2016GIA_prel0907 (**GIA**) velocities



- Fitted to the 3D velocity field of the BIFROST
- Expressed in the GIA frame
- Best-fitting model out of >2000

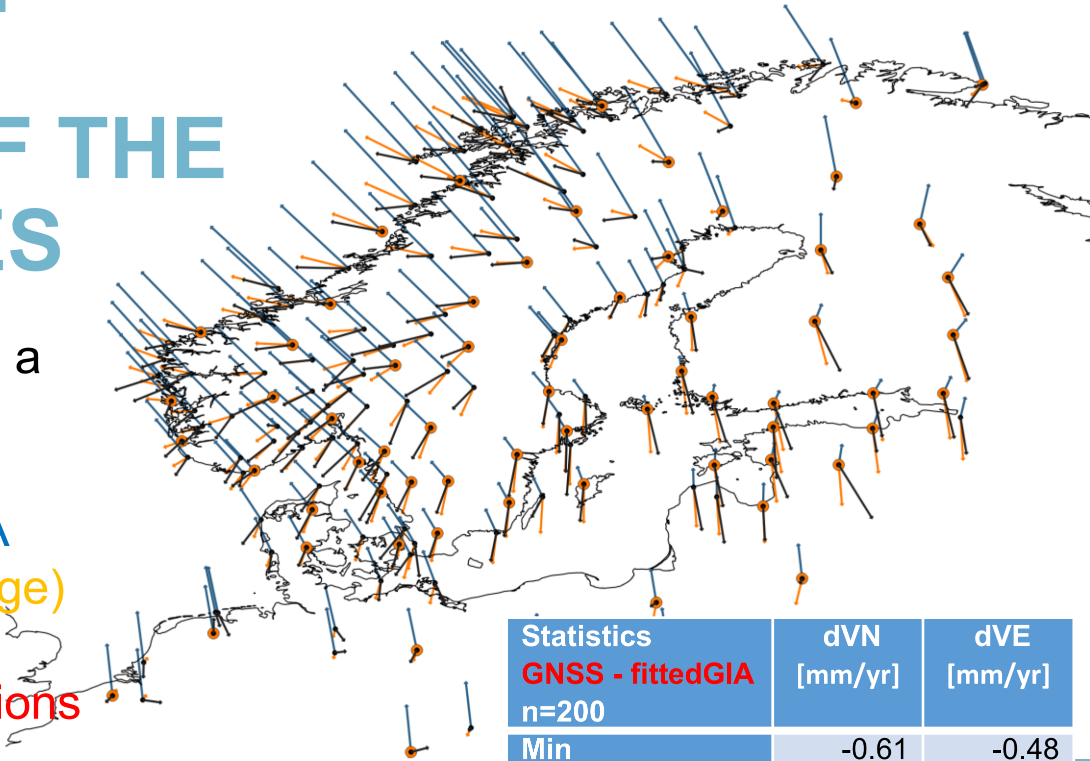
GNSS (black) and GIA (blue) velocities



- GNSS and GIA velocities have a systematic difference – expressed in different reference frames
- GIA velocities need to be aligned to a geodetic RF – Helmert fit to GNSS velocities

ALIGNMENT OF THE GIA VELOCITIES

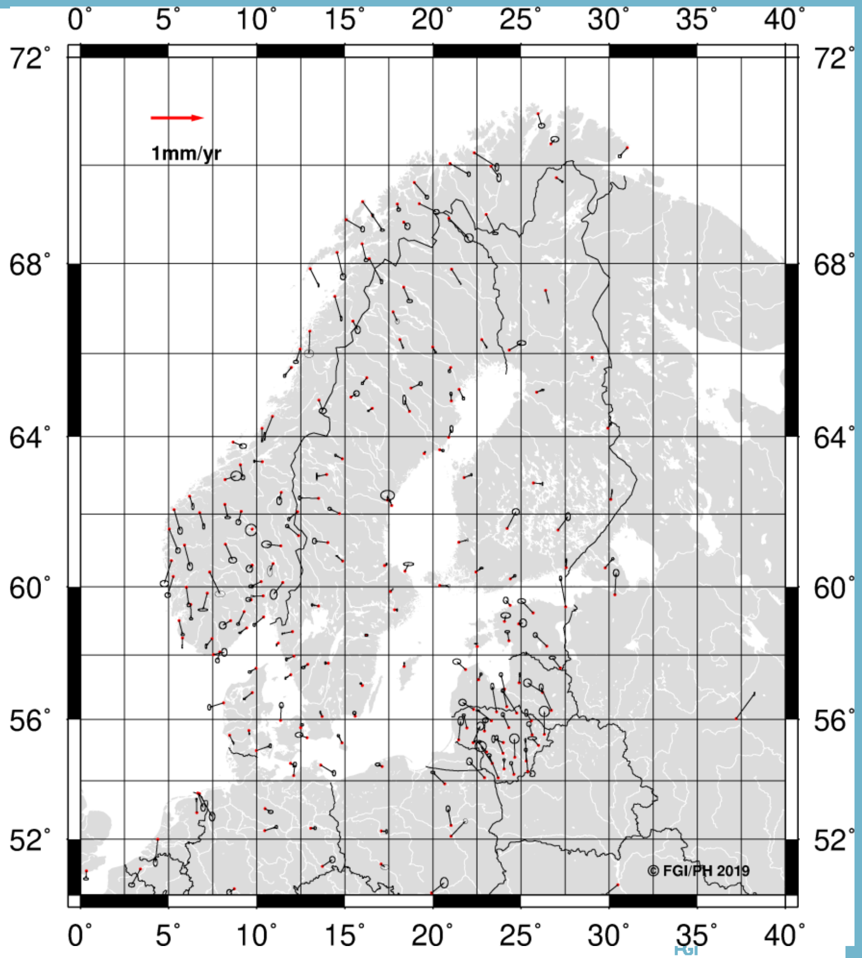
- GIA velocities aligned with a subset of stations (orange circles)
- Figure: GNSS (black), GIA (blue) and fitted GIA (orange) velocities
- Helmert fit with three rotations



Statistics GNSS - fittedGIA n=200	dVN [mm/yr]	dVE [mm/yr]
Min	-0.61	-0.48
Max	0.72	0.57
Mean	-0.01	0.00
Stdev	0.29	0.20
rms	**0.29**	**0.20**
95%	0.58	0.38

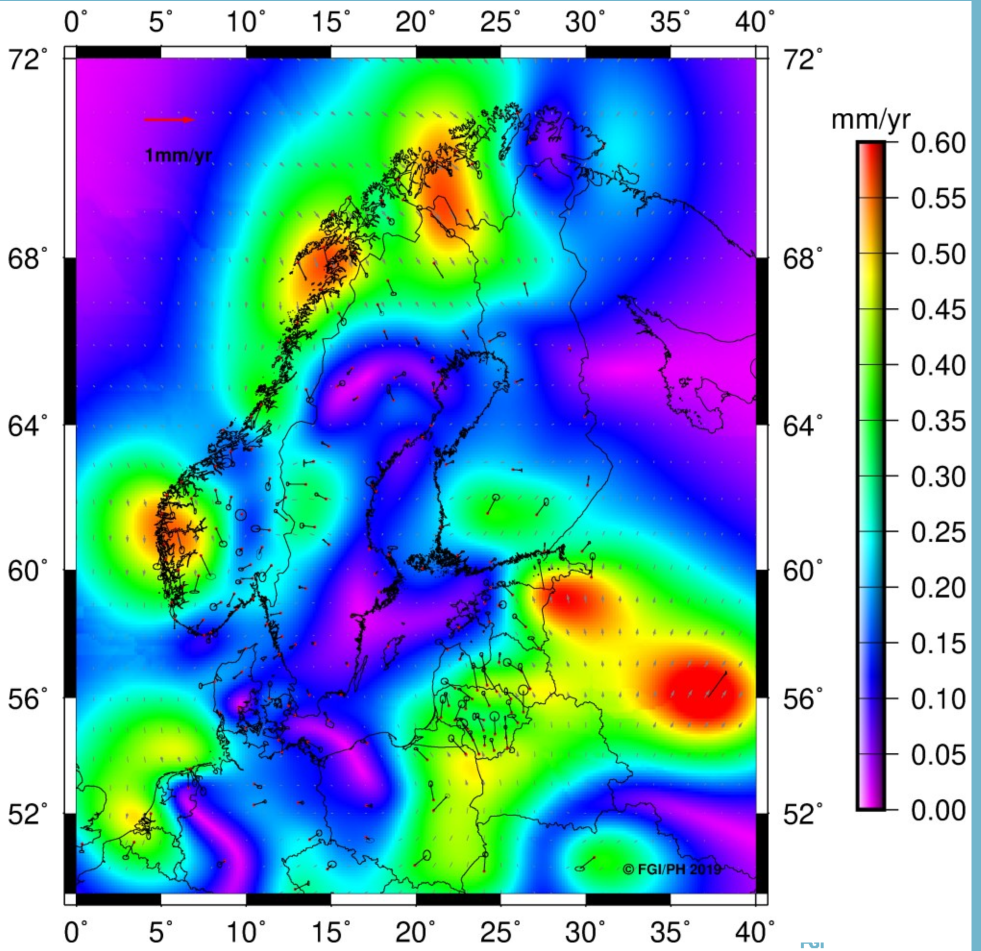
INPUT TO LSC

- RF-aligned GIA velocities agree with GNSS approx. 0.2-0.3 mm/yr level (1σ)
- To improve the alignment, input differences GNSS minus fitted GIA velocities w/ GNSS uncertainties to **least-squares collocation (LSC)** process (”remove-compute-restore”)
- Correlation length 250km
- GNSS uncertainty minimum set to 0.1mm/yr
- Iterative process (cleaning of data)



COLLOCATION SIGNAL

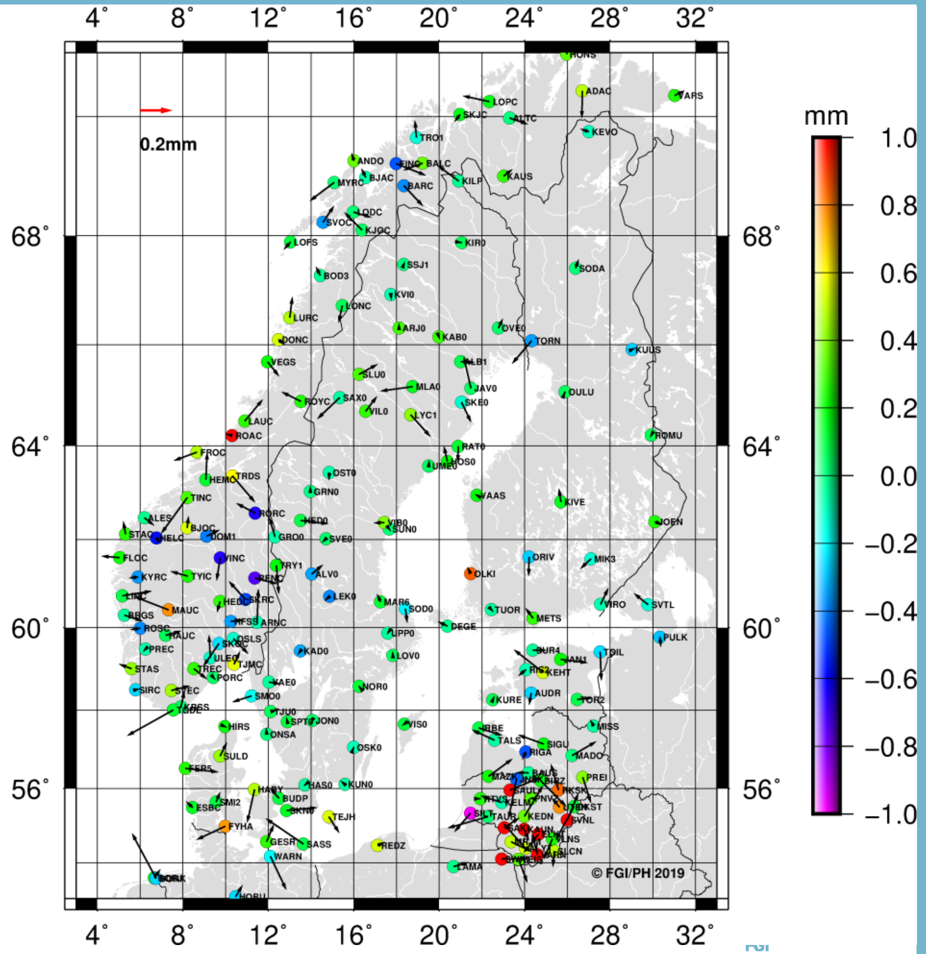
- Gridded velocity correction to Helmert-fitted GIA velocities
- Picks up signals not present in the GIA model, e.g. Baltic region had only a few GNSS data for constraining the GIA model
- Up to ~0.5mm/yr



COLLOCATION NOISE

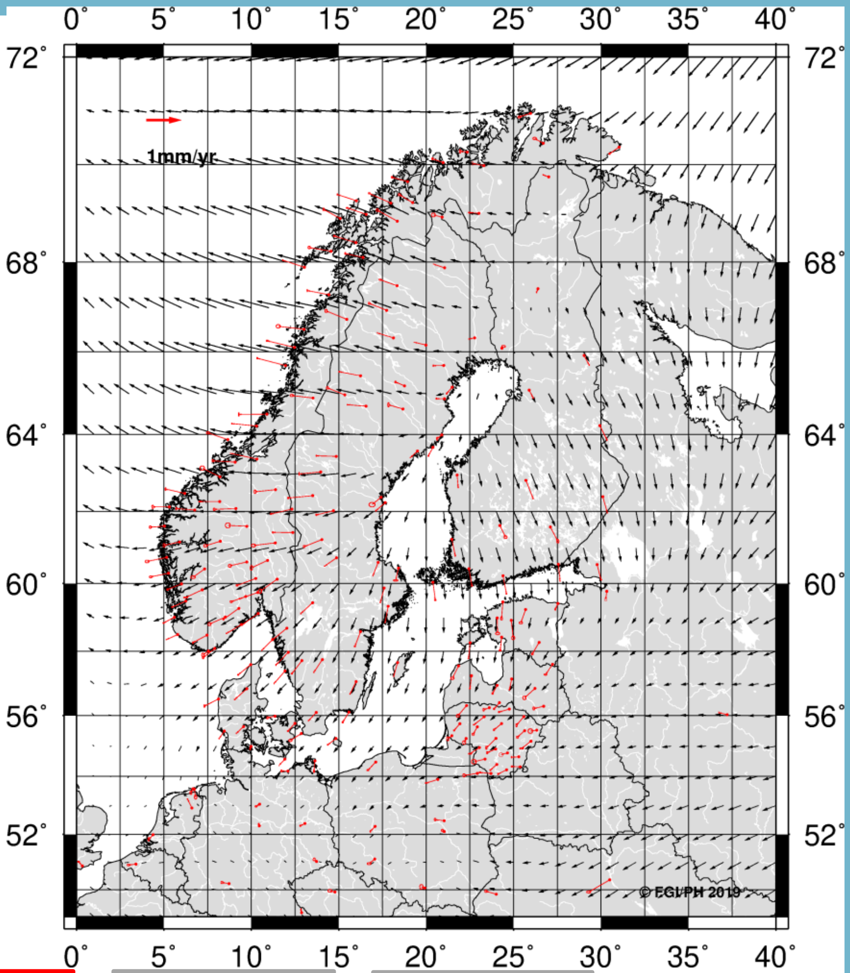
- Model minus GNSS velocities
- GNSS data cleaned, no obvious outliers anymore

Statistics **model - GNSS** (n=200)	dVN [mm/yr]	dVE [mm/yr]
Min	-0.36	-0.29
Max	0.28	0.21
Mean	-0.00	-0.00
Stdev	0.09	0.09
rms	**0.09**	**0.09**
95%	0.18	0.19



NKG_RF17vel_prel

- NKG_RF17vel_prel horizontal velocities (black vectors):
  - GNSS stn velocities (red vectors)
- Some fine tuning and cross-checking to be done – still preliminary



CONCLUSIONS AND FUTURE WORK

- Developed model is a combination of GIA and GNSS velocities
- A lot of effort used to get realistic uncertainties for GNSS velocities and for cleaning the GNSS data before LSC
- Model agrees with GNSS ~0.1mm/yr level (rms)
- Still **preliminary**:
  - Some fine tuning and cross-checking to be done before releasing the model
- Outlook
  - Implement the model into the updated NKG transformation and to PROJ
  - Now coordinate components were treated separately in the LSC, implement horizontal components into same LSC

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THANK YOU!