Significant temporal changes in glacio-isostatic adjustment in Iceland during the 1950s to present

Halldór Geirsson[1], Guðmundur Valsson[2], Benedikt G. Ófeigsson[3], Erik Sturkell[4], Thóra Árnadóttir[1], Peter C. LaFemina[5], Sigrún Hreinsdóttir[6], Vincent Drouin[7], Peter Schmidt[8], Björn Lund[8], and Finnur Pálsson[1]

1: Institute of Earth Sciences, University of Iceland; 2: National Land Survey of Iceland; 3: The Icelandic Meteorological Office; 4: Gothenburg University, Sweden; 5: The Pennsylvania State University, US; 6: GNS Science, New Zealand; 7: ÍSOR – Iceland Geosurvey; 8: Uppsala University, Sweden

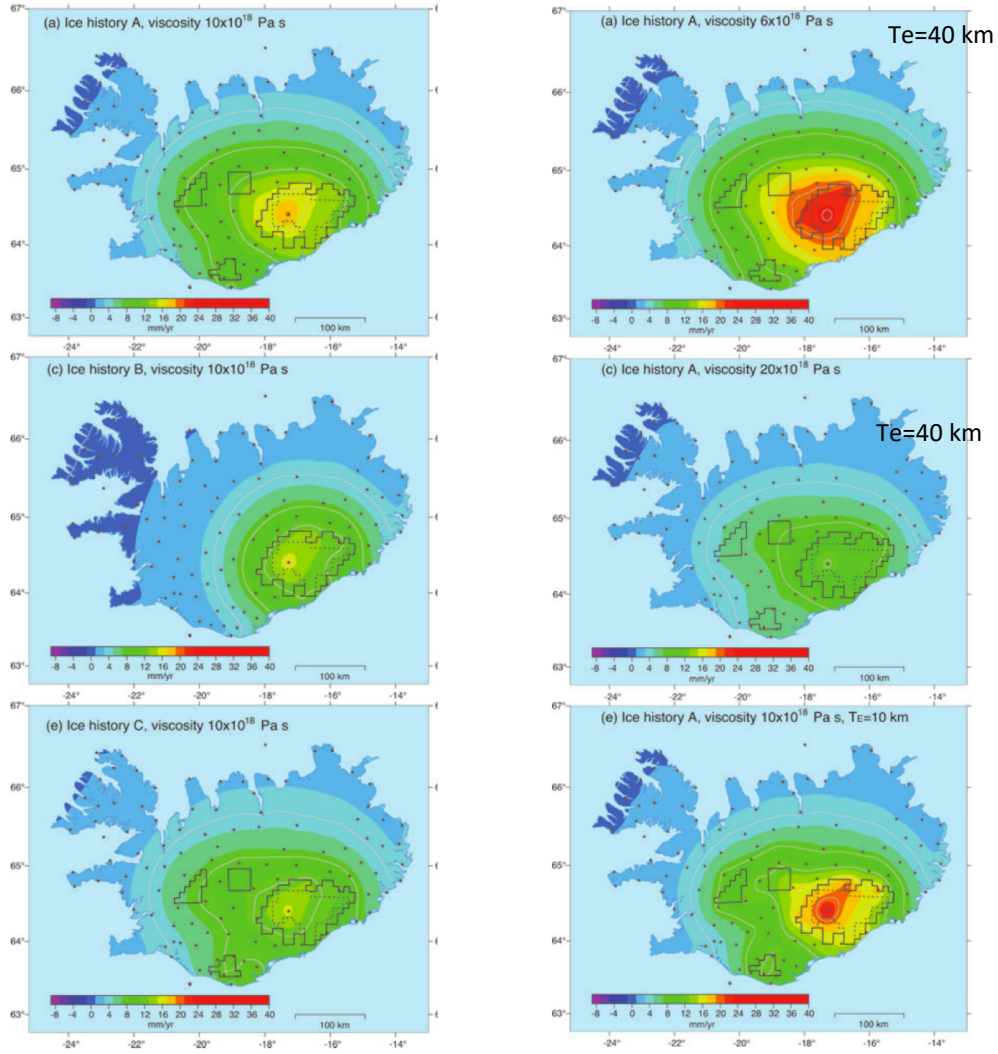
UNIVERSITY OF ICELAND
INSTITUTE OF EARTH SCIENCES

EGU2020-17390, session G3.2

Motivation 1: GIA response depends on the load history, m(x,y,t), and Earth's elastic and viscoelastic properties. In regions experiencing current mass changes the deformation rates are higly affected by the elastic part of GIA

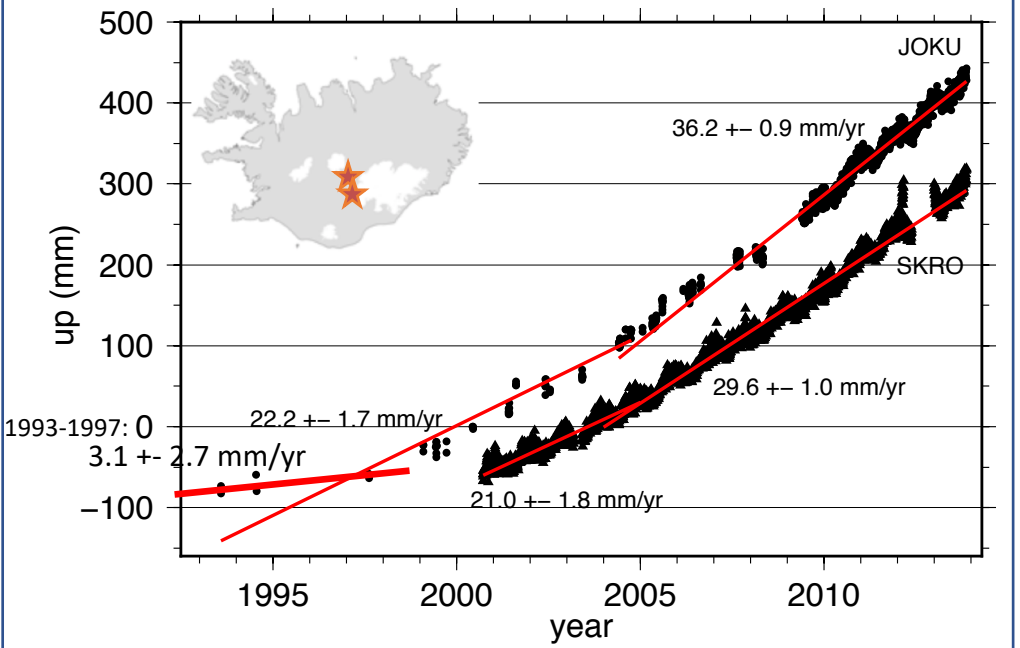
Motivation 2: Current GIA models, mostly based on GPS velocities from 1993-2004, fit current deformation observations poorly, causing problems for deformation studies of volcanoes, plate motion, earthquakes, etc. that require good GIA corrections.

Goal: Estimate how much the GIA response (vertical and horizontal motion) is varying on decadal timescales in Iceland for feeding into GIA models



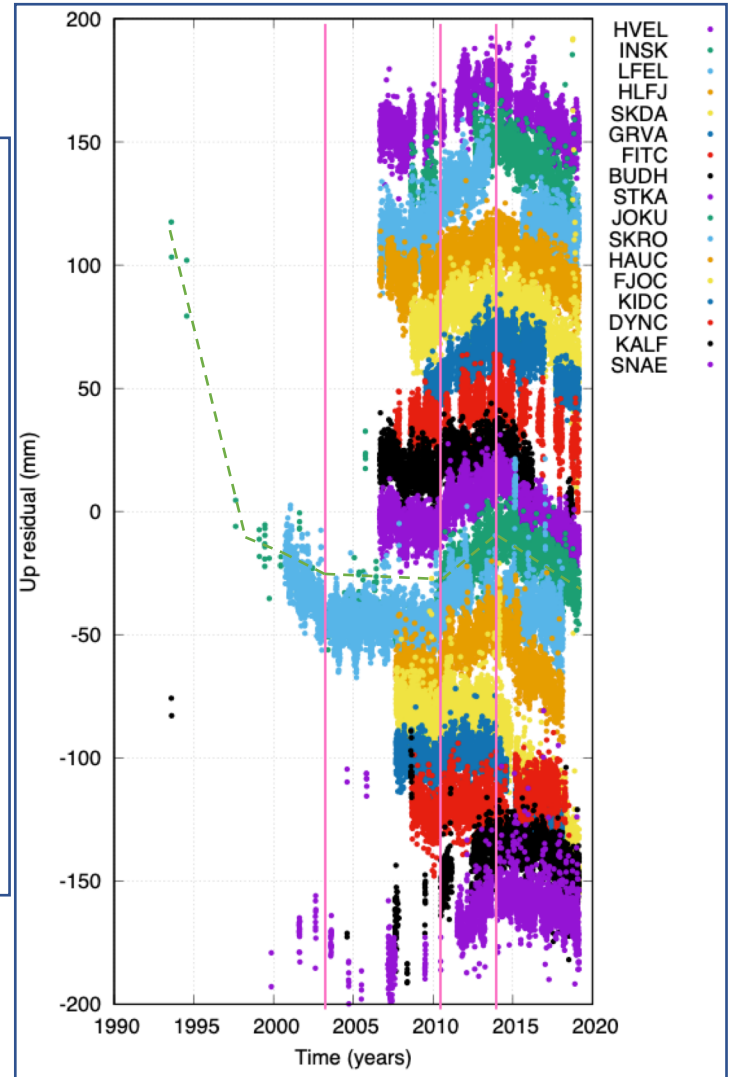
Examples of uplift due to different load histories and Earth models for Iceland [Árnadóttir et al. 2009]

GNSS data: Campaign and continuous data 1993-present



Vertical time series for GNSS stations JOKU and SKRO along with velocity estimates for different time periods

Campaign GPS measurements at a nunatak on Vatnajökull glacier

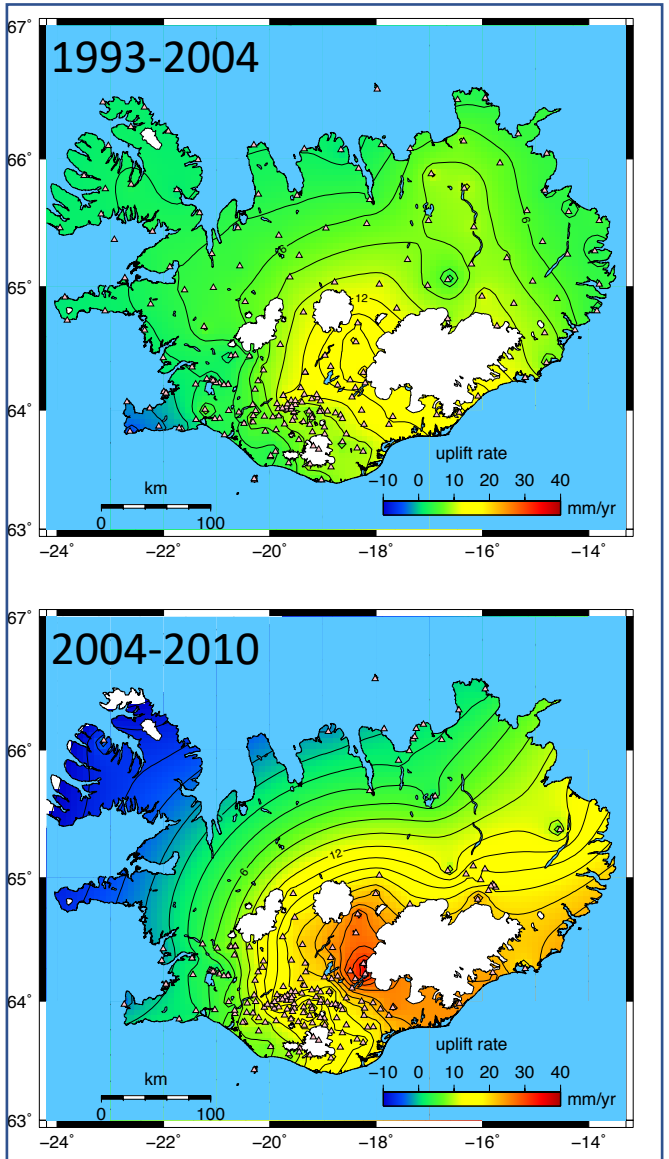


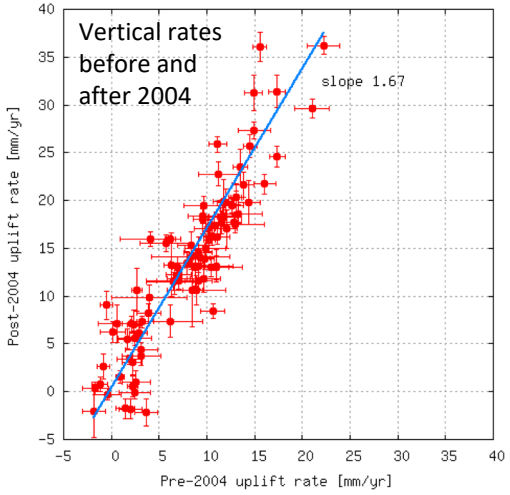
Detrended time series for continuous and selected campaign stations in central Iceland. Slope changes show changes in velocity. Seasonal signals have been estimated and removed from the time series.

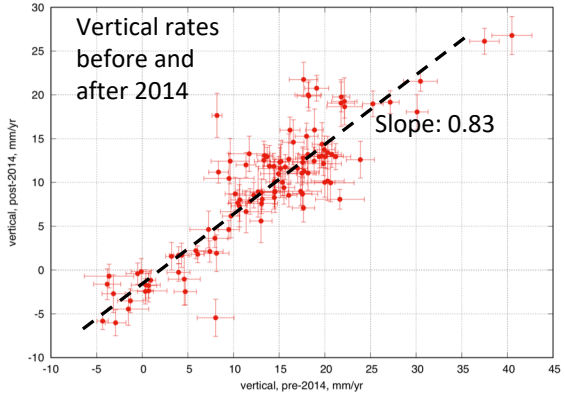
The GNSS data show:

- Low uplift rates in early 90s (still uplift!)
- Uplift increases from ~2000, yet faster uplift from ~2004
- Increased uplift in 2010 (ash from Eyjafjallajökull increases ice melt)
- High uplift rates (up to 5 cm/yr) 2010 until 2014
- Slower uplift rates since 2014 (also noted by Compton et al. 2017)

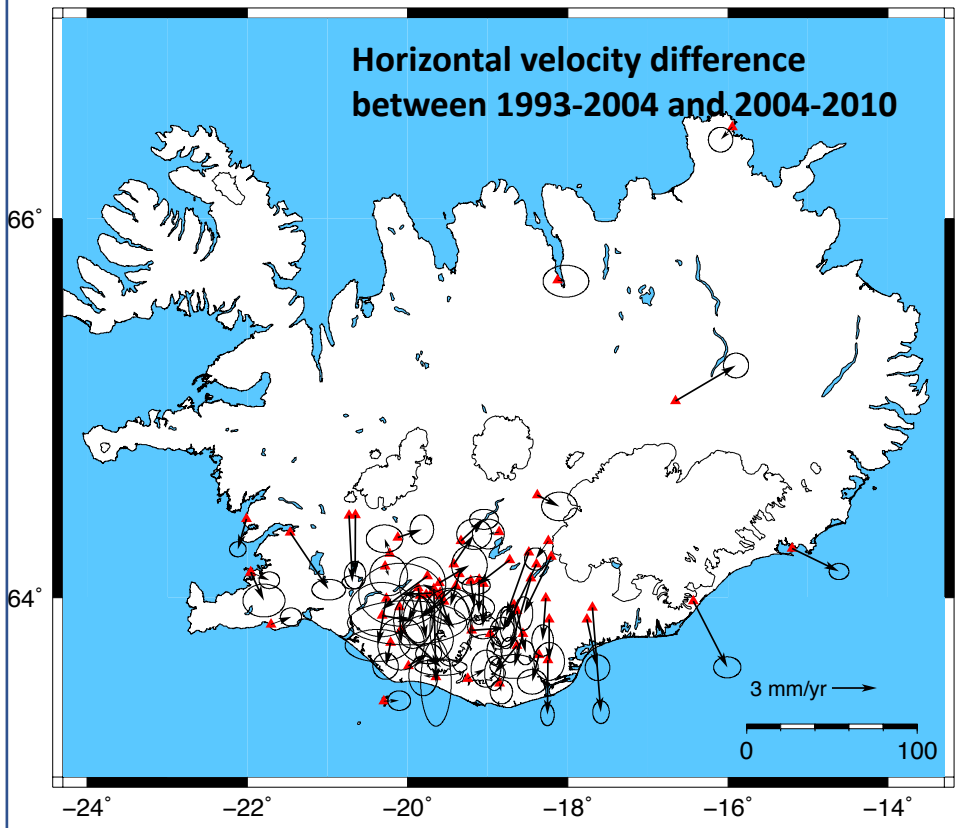
GNSS: Vertical velocity 2004-2010 increased by ~67% compared to 1993-2004







Comparison of uplift rates before and after 2004 and 2014 shows mean velocity change between different periods

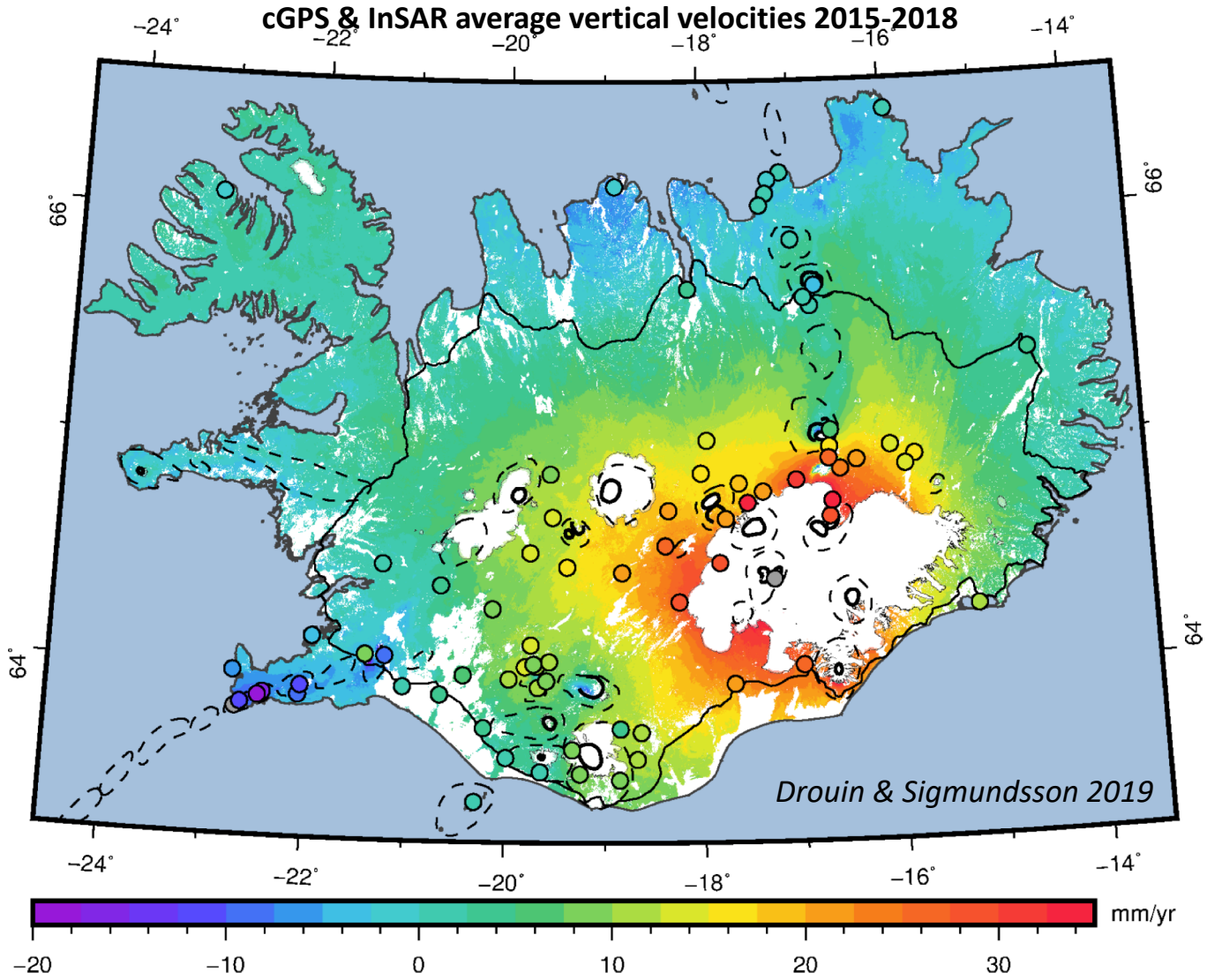


We also observe significant changes in horizontal velocities, up to ~6 mm/yr

The spatially most dense information comes from InSAR.

The future is bright with Sentinel !

However, with all of the data care must be taken for which of the signal is from GIA and which part is from volcanoes, earthquakes, plate motion, and geothermal energy production



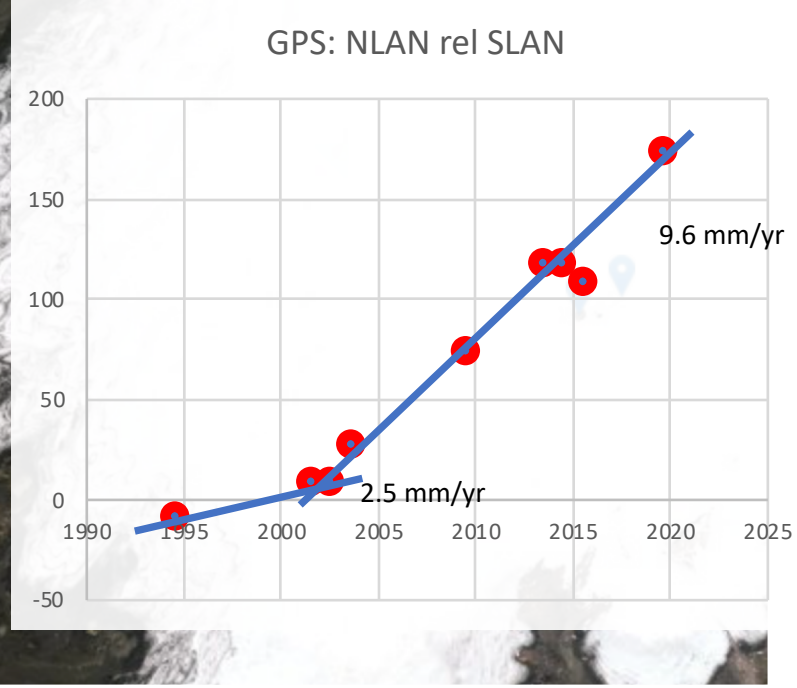
Looking backwards to 1959

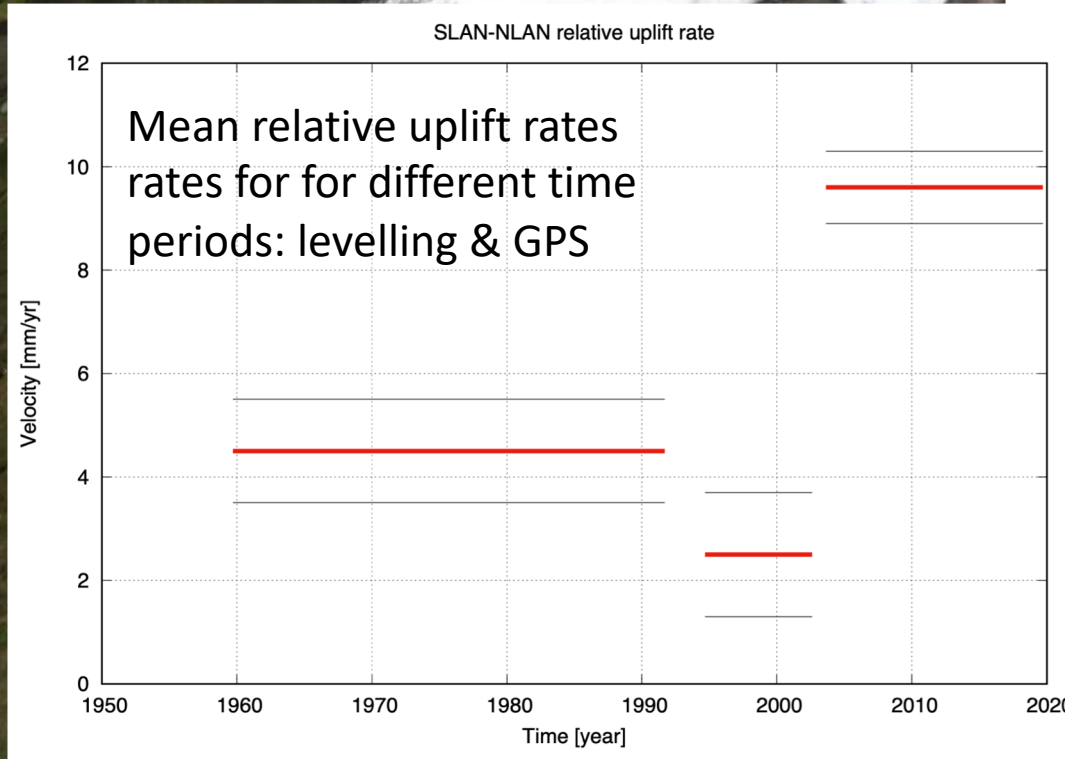
- Example: Sigmundsson et al., 1992, levelling:
  Uplift of NLAN relative to SLAN, 1959-1991: **4.5 mm/yr**
  → Can compare to relative rates from GPS and/or InSAR
  → **can extend uplift history of benchmark pairs**

NLAN

SLAN

5 km





Conclusions

• GIA response in Iceland is highly variable! “Current” mass balance has a large effect. The elastic part of the signal is important.

• Uplift rate is lower in the 90s compared to average uplift rate 1959-1991. The uplift rate increases in 2000, reaches a maximum near 2010-2014, and decreases somewhat in 2014.

• Mass balance of glaciers varies in time and space; in Iceland the changes in deformation follow broadly changes in mass balance.

• Maximum vertical GIA velocity is currently ~35 mm/yr .

• Accounting for GIA is important for plate boundary and volcano deformation models.

• Implication for Iceland GIA models: most current models are estimated assuming fixed average melting rates from ~1900 and uplift rates of 1993-2004. Is that representative? No. → need to redo the models!