A new global GPS dataset for testing and improving modelled GIA uplift rates

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1. Motivation

- Providing an observational estimate of vertical land motion (VLM) due to global glacial isostatic adjustment (GIA).
- Developing a novel fully-automatic post-processing strategy to deal with the challenges of GPS time series analysis in general, and for GIA purposes in particular (see Fig. 1).
- Comparing our data-based solution, GlobalMass (GM) GPS dataset, with 13 global GIA solutions (see Figs. 2 and 3).

2. Data: GPS VLM and GIA models

Global GPS data set
- GPS time series provided by the Nevada Geodetic Laboratory (NGL; http://geodesy.unr.edu/).
- Up components for >15,700 sites (IGS08 reference framework).
- List of jump locations provided.

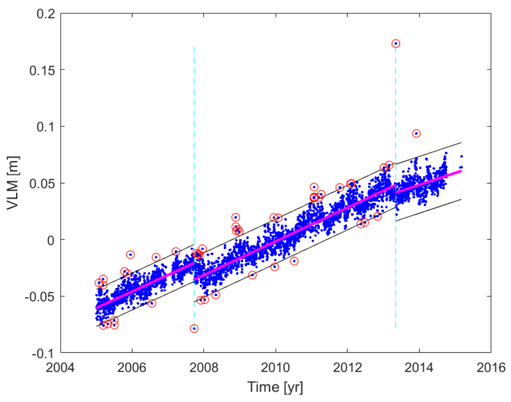
Antarctica
- Uplift rates from regional A-NET dataset at 65 GPS sites.
- Provided in the ITRF2008 reference frame.
- Various corrections applied (e.g., atmosphere, elastic VLM).

Greenland
- Uplift rates from regional G-NET dataset at 54 GPS sites.
- processed in the IGS08 reference frame.
- corrected for atmosphere, elastic VLM, etc.

13 GIA forward models
- Different assumptions and model parameters lead to different spatial fields of GIA.
- We compare our results with 13 different GIA models (from Guo et al., 2012, J Geodyn).

3. Method: Post-processing strategy

Linear fit and 99% confidence interval applied to each jump period



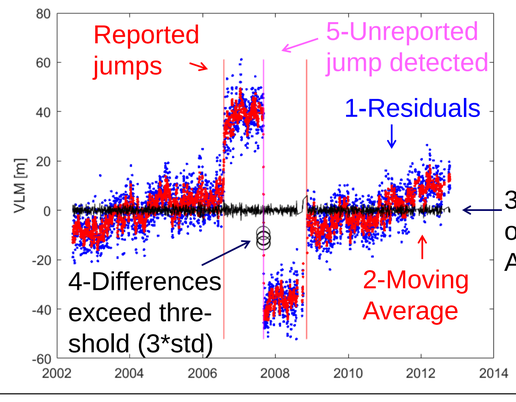
1. Post-processing GPS time series

Outlier Detection

Jump Detection

Atmospheric Correction

Trend and Bias Estimation



We use data provided by the International Mass Loading Service (http://massloading.net/) to compute the atmospheric loading at the GPS site locations considered in this study. The atmospheric re-analysis product MERRA2 (available from 1980 onwards) was selected.

Linear regression:

$$\underbrace{\mathbf{y}}_{\text{data}} = \underbrace{a_0 + a_1\mathbf{t}}_{\text{trend}} + \underbrace{a_2\sin(2\pi\mathbf{t}) + a_3\cos(2\pi\mathbf{t})}_{\text{annual signal}} + \underbrace{a_4\sin(4\pi\mathbf{t}) + a_5\cos(4\pi\mathbf{t})}_{\text{semi-annual signal}} + \underbrace{\mathbf{Bb}}_{\text{jumps}} + \underbrace{\mathbf{r}}_{\text{residuals}}$$

2. Post-processing GPS VLM for GIA

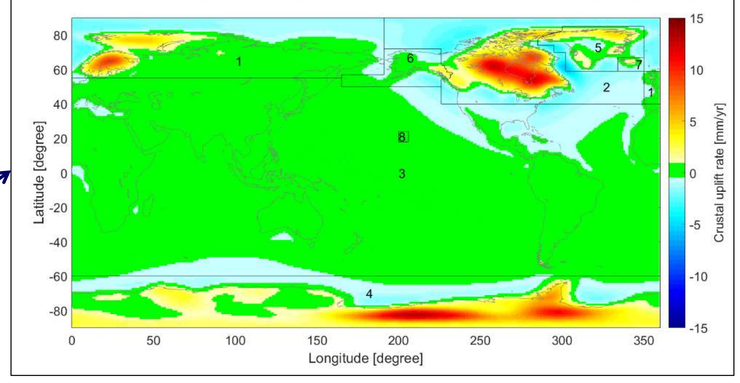
GIA model based Station Selection

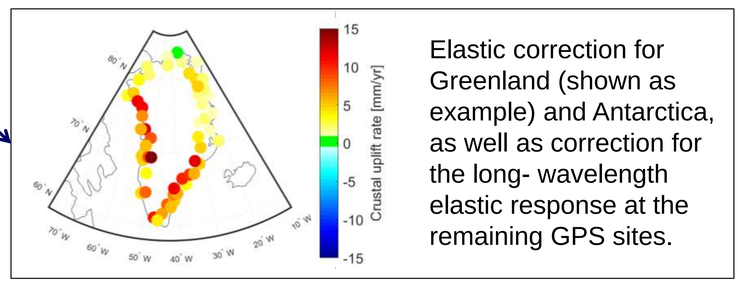
Elastic Correction

Median filter based Station Selection

Rotational Pole Change Correction

Exclude if mean ±3*std limits of 13 GIA models exceeded

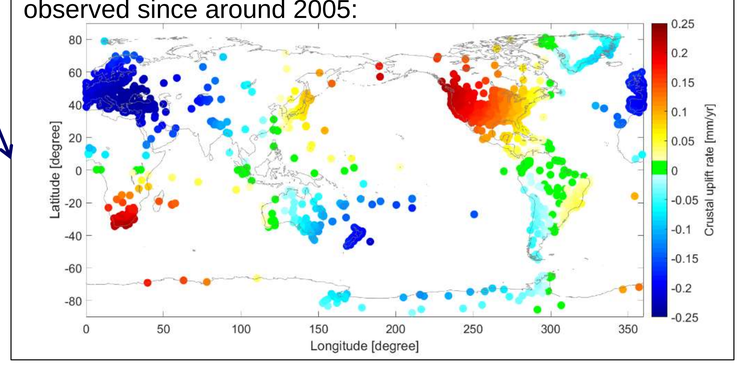




Elastic correction for Greenland (shown as example) and Antarctica, as well as correction for the long- wavelength elastic response at the remaining GPS sites.

We use a low-pass spatial filtering approach (a median filter with 500 km radius) to exclude stations that are affected by local signal, e.g. groundwater pumping or earthquakes. The median value within the predefined radius is used as a selection criterion to either keep or remove a station.

A rapid shift of the Earth's rotational pole towards the east is observed since around 2005:



3. Assessment of global GIA forward models

Transformation between coordinate systems with origins in the center of mass of the total Earth's system (CM) or the solid Earth (CE)

Fig. 1: Overview of the implemented fully-automatic post-processing strategy (left) to deal with the challenges of GPS time series analysis and (right) to generate a global GPS dataset for GIA purposes.

4. Results:

(a) Novel GPS data set

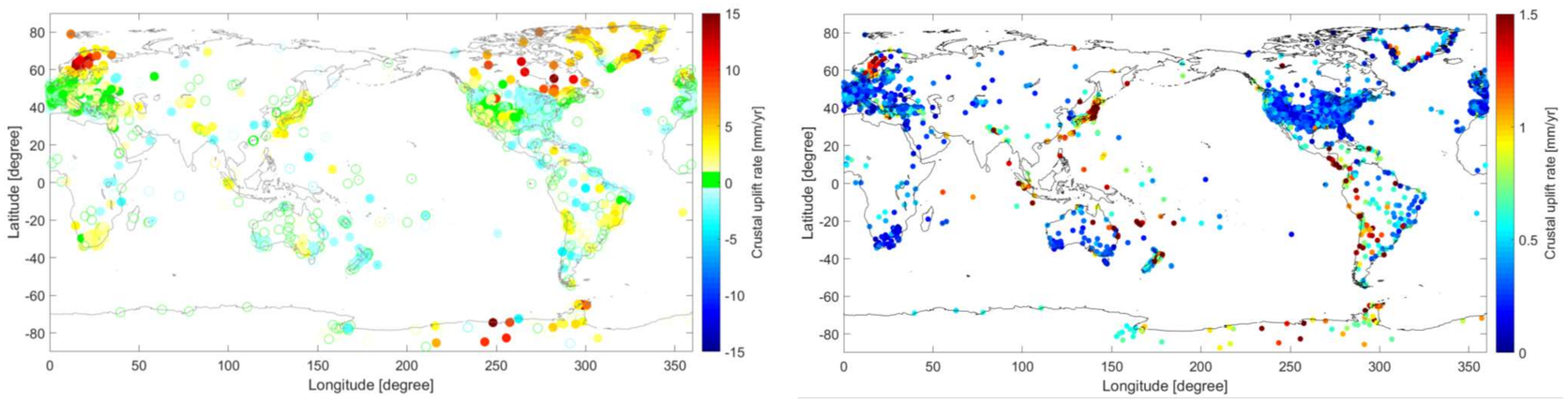


Fig. 2: The GlobalMass (GM) global GPS dataset (4072 sites): (left) GIA uplift rates in mm/yr and (right) their uncertainties. The statistically-significant (99% confidence level) rates in (a) are shown by solid (filled) circles, while rates that are not significant are shown with hollow circles.

(b) Comparison to global GIA forward models

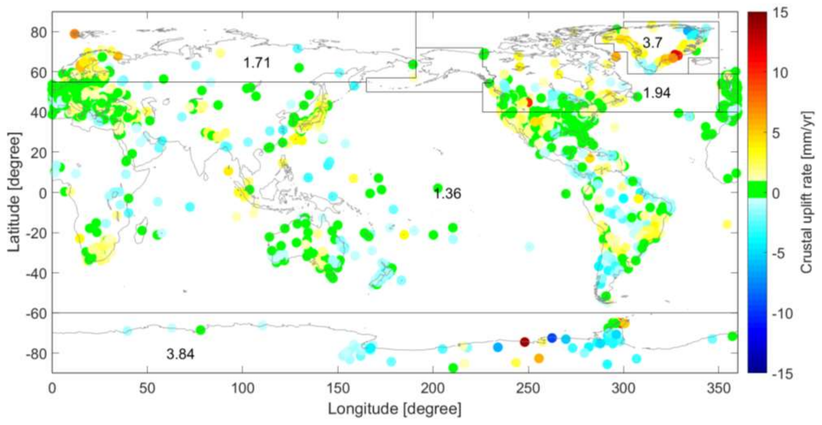


Fig. 3: (above) Assessment of the ICE-6G (Pel-6-VM5) model using the GM global GPS dataset (GPS minus ICE-6G). Spatial RMS differences averaged over five regions are shown in mm/yr. (right) Spatial RMS differences in mm/yr averaged over the entire globe and five regions for 13 global GIA models.

GIA Model	Global	Northern Europe/Asia	North America	Mid Latitudes	Antarctica	Greenland
Pur-6-VM5	1.66	1.56	1.96	1.37	3.75	3.71
Pel-4-VM2	1.81	1.98	1.96	1.38	5.07	3.01
Pel-5-VM2-R	1.79	1.70	2.18	1.37	4.63	3.78
Pel-5-VM4	1.91	2.19	2.47	1.33	4.76	4.04
Pel-6-VM5	1.67	1.71	1.94	1.36	3.84	3.70
SKM-O-R	2.09	1.87	2.47	1.56	5.98	**4.20**
S&S-1	1.95	**2.68**	2.37	1.39	4.52	4.17
S&S-3	2.04	1.94	2.15	1.47	6.60	3.31
SVv-3-REF	2.10	2.07	2.04	1.58	**6.73**	3.10
SVv-L-ALT	1.93	2.12	2.48	1.38	4.77	4.16
vdW-5	1.77	1.71	2.26	1.30	4.51	3.57
W&W-4	1.89	1.57	2.31	1.48	4.90	3.33
W&W-5	**2.31**	1.49	**3.41**	**1.68**	5.03	3.70

5. Conclusions and Outlook

Conclusions
- The final GM GPS dataset provides a clean GIA signal for more than 4000 sites and, thus, can be used to assess global GIA forward models, as well as to improve them.
- Significant disagreements are found in comparison to 13 GIA forward models, especially for Antarctica and Greenland resulting from uncertain mantle rheology and (recent) ice loading history, as well as errors in the GPS data set.
- The performance of different GIA models varies considerably between regions.

Outlook
- A Bayesian statistical framework will be used to combine the GM GPS data set, along with data on ice mass, hydrological mass and sea level changes and, as well as prior information from geophysical models, to allow new insights about the different contributors to sea level rise on a basin and global scale.

More details
- Schumacher, M., King, M., Rougier, J., Sha, Z., Khan, S.A. and Bamber, J.L. (under revision) A new global GPS dataset for testing and improving modelled GIA uplift rates. Geophysical Journal International.

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Keep in touch

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