University of BRISTOL

GLOBAL MASS

A novel global GPS data set for GIA modelling and validation

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GLOBAL MASS Attributing global sea level rise to its component parts

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Outline

1) Motivation

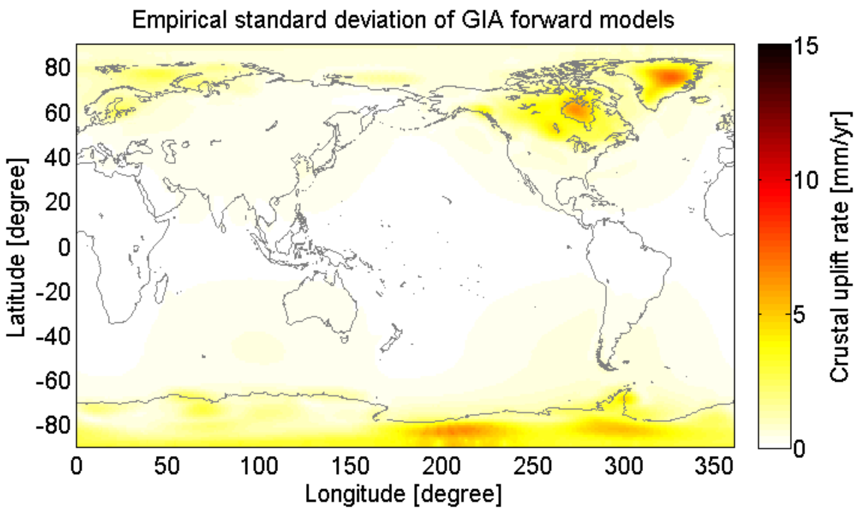
2) Data set: Post-processing of the Nevada Geodetic Laboratory (NGL) Data
   a. Challenges
   b. Fully-automatic post-processing strategy
   c. Special treatment of data within Antarctica and Greenland

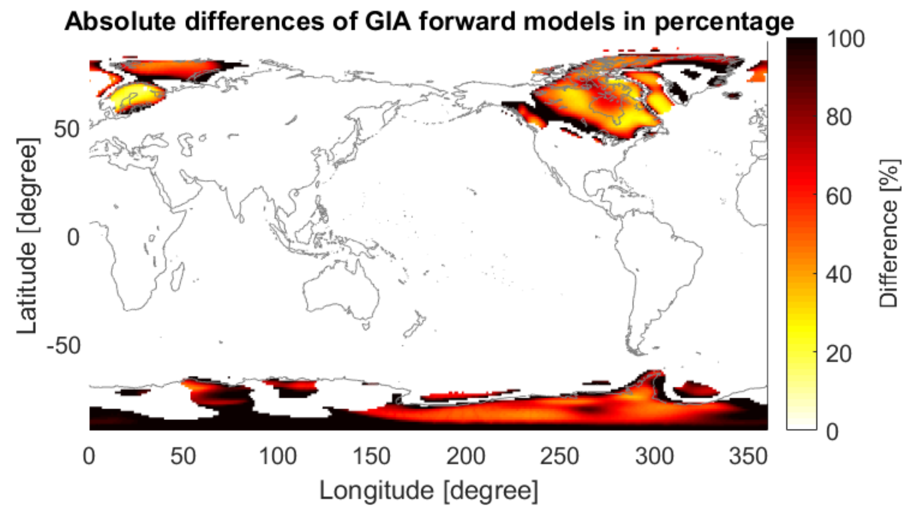
3) Novel global GPS data set
   Comparison to 13 GIA forward model solutions

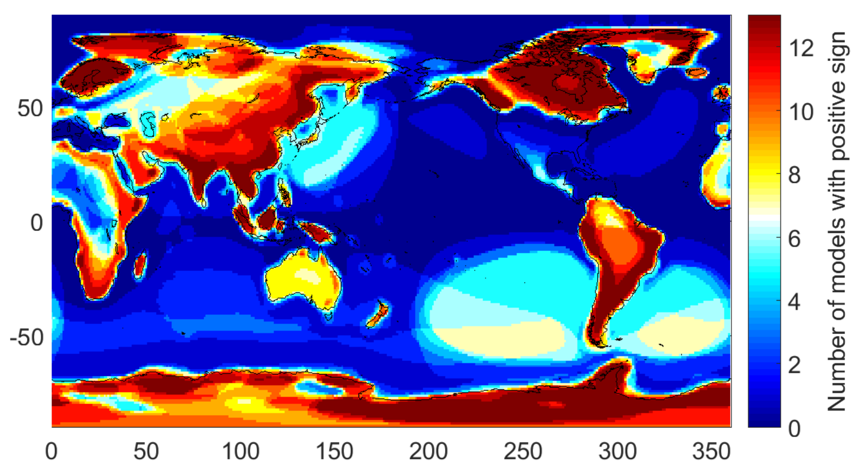
4) Conclusions and outlook

Motivation

Evaluating 13 GIA forward model solutions*







Motivation for data-driven GIA solution:

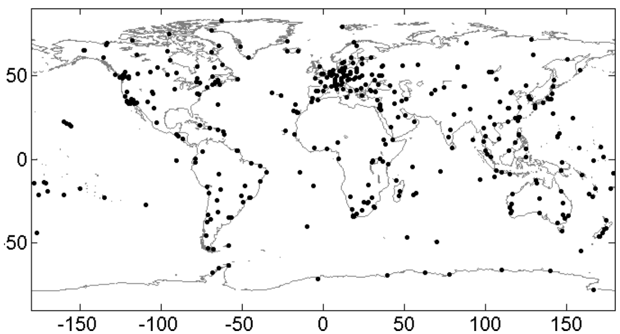
- Permanent GPS data (since ~1980)
- GRACE data (since 2002)

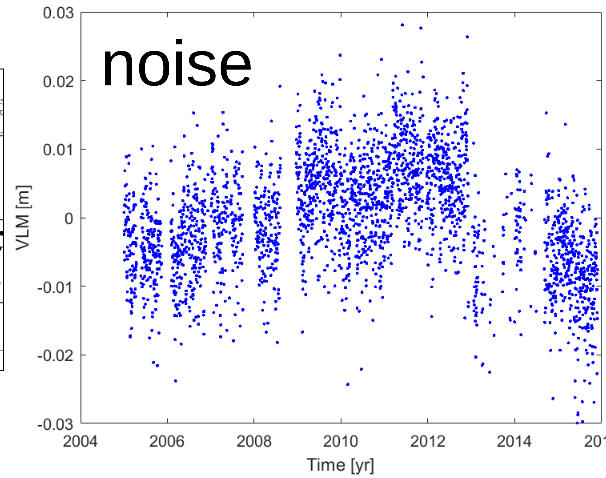
*provided by Chaoyang Zhang (Guo et al., 2012)

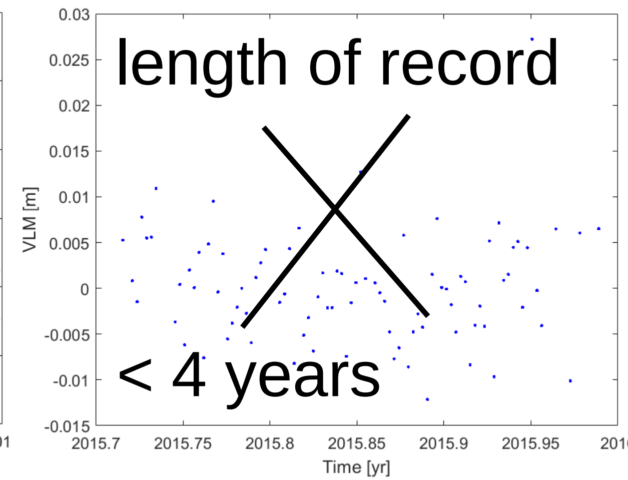
Data set:
Post-processing of the NGL data

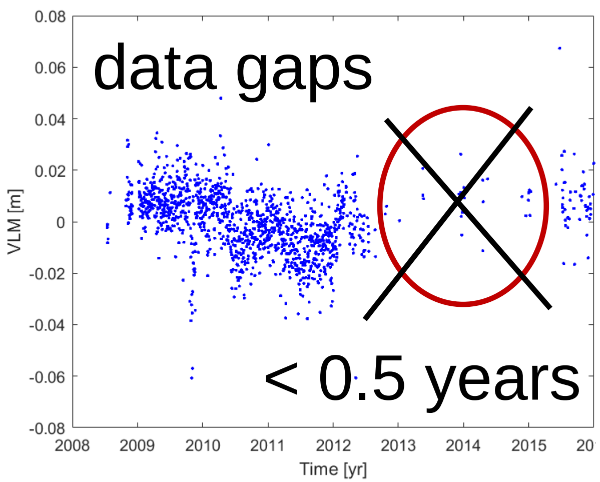
Challenges

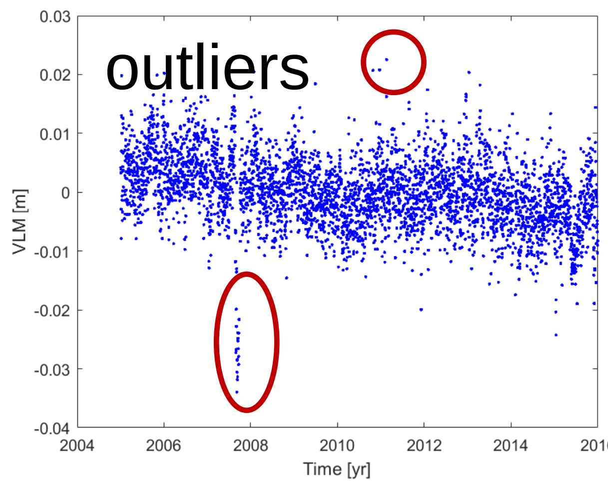
selection of stations

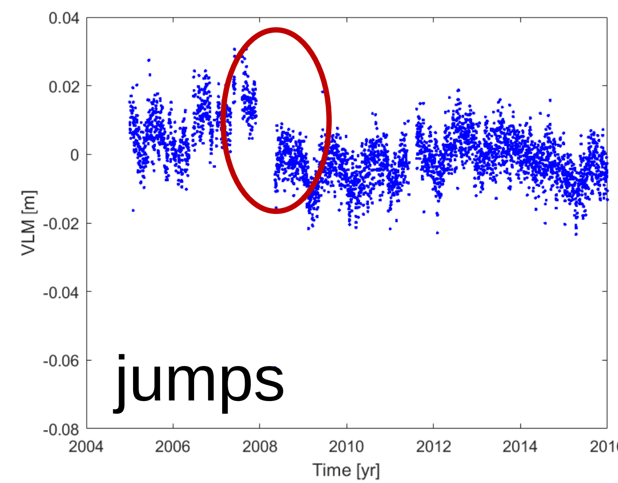












Post-processing Strategy

1) Outlier detection

2) Jump detection and removal

3) Noise

4) Station selection

fully automatic

5) Quality control

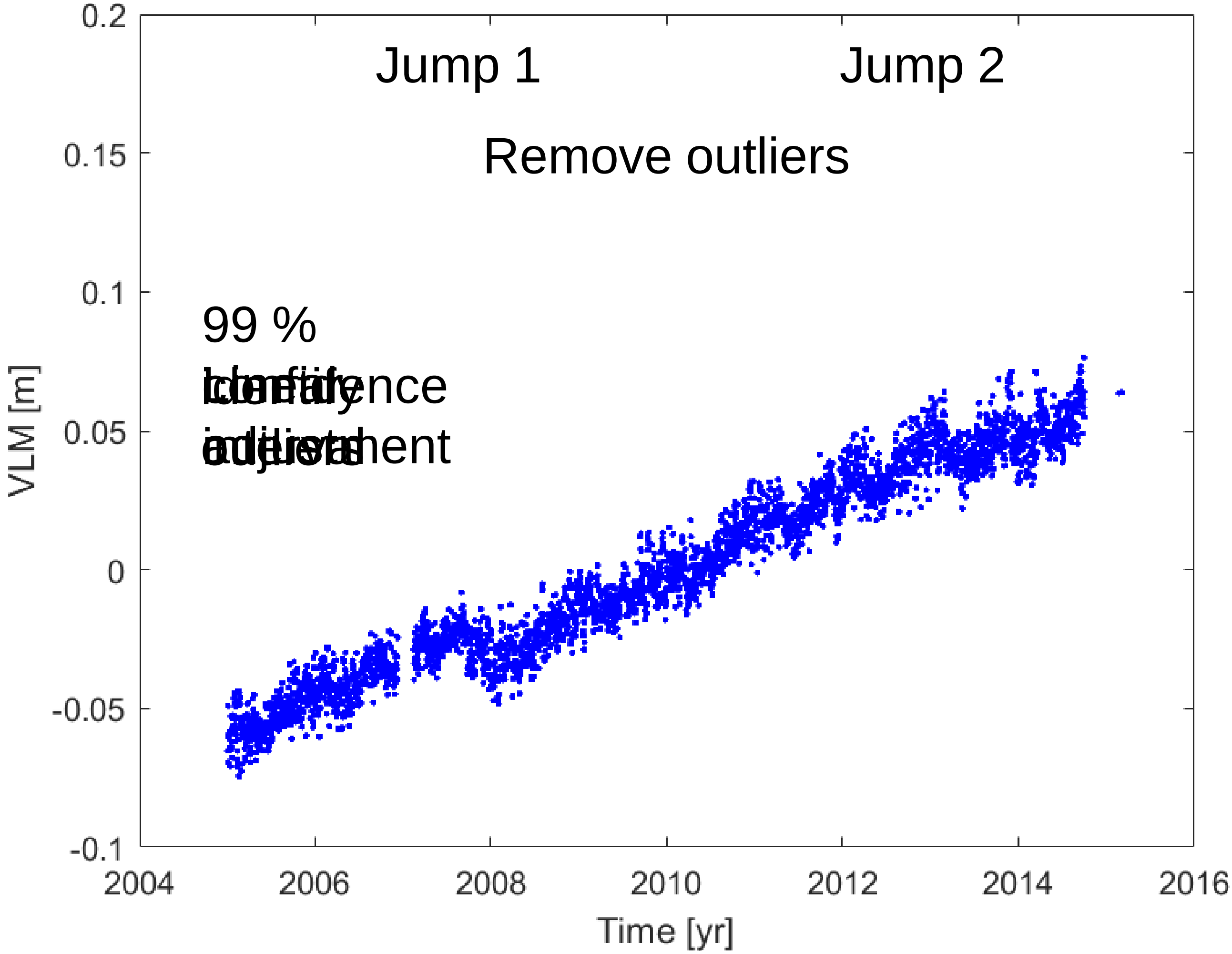
some manual intervention required

6) Correct Elastic Deformation
(Antarctica and Greenland)

external data sets

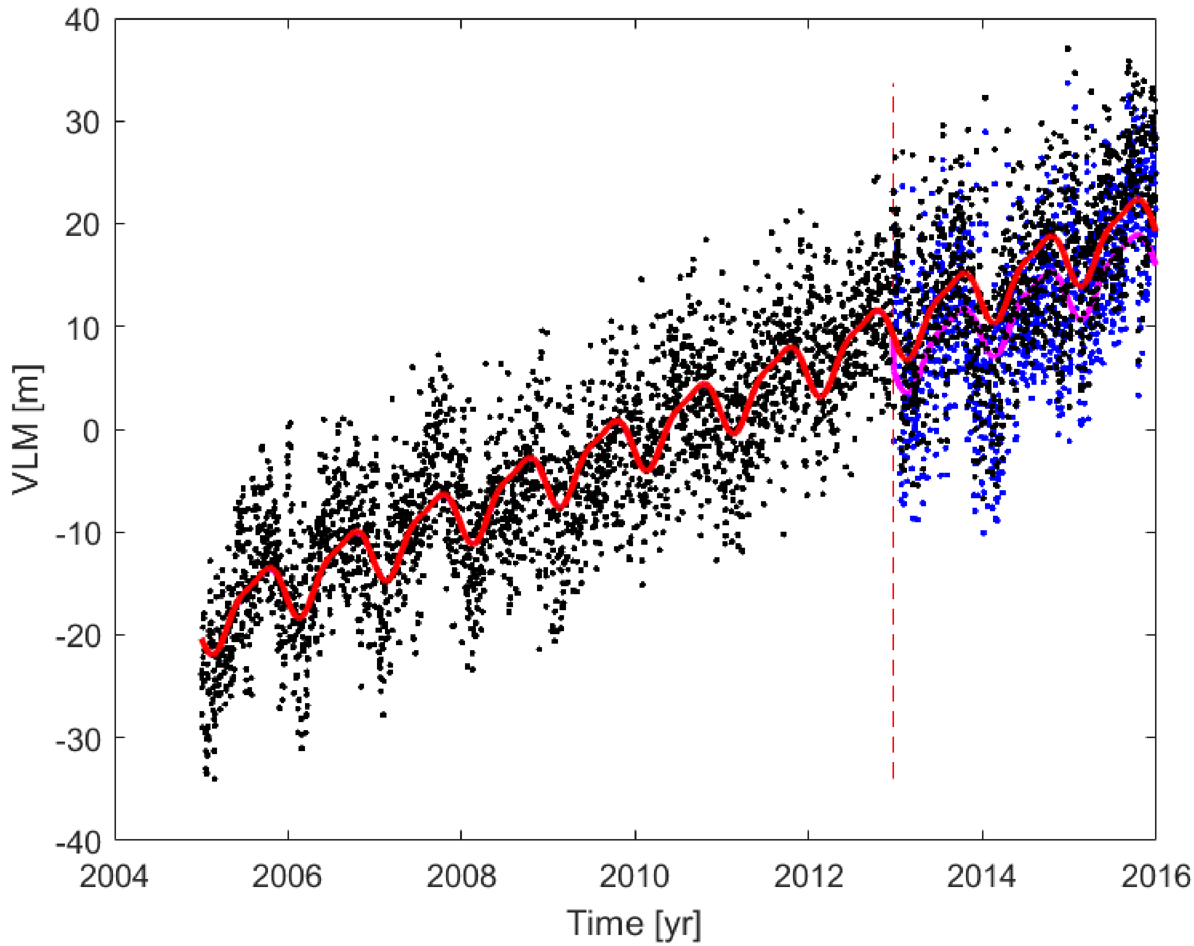
Outlier Detection

Based on residuals w.r.t. linear trend for each ‘jump period’



Jump Removal

Based on jump database provided by NGL



$$t_i)\Big] \begin{bmatrix} \alpha \\ \beta \\ \gamma \\ \delta \\ \eta \\ \nu \end{bmatrix} + [1][b_1] + \varepsilon$$

Noise

Batch Mean Approach

- Jumps removed first
- Monthly means of daily data
- Residuals of daily data to monthly mean = errors
- Formal error propagation to linear trend errors

Data Thinning

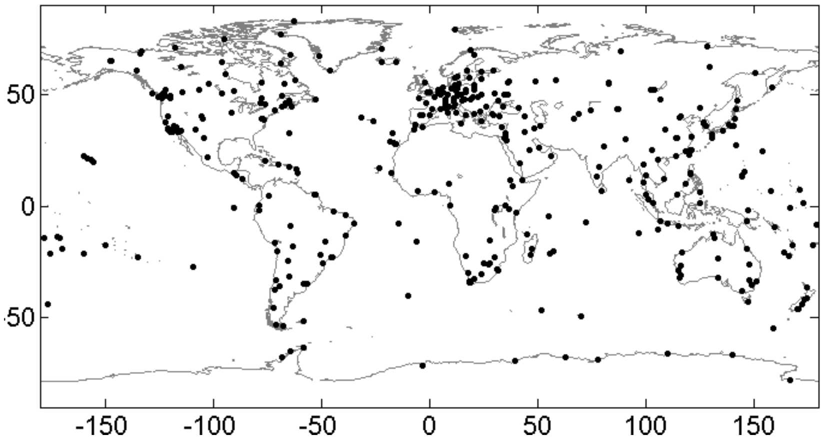
- Simultaneous linear trend estimate and jump removal
- More realistic (errors of jump removal included)
- Only every 15th data point considered to account for temporal error correlations

Alternative: Power Law Noise

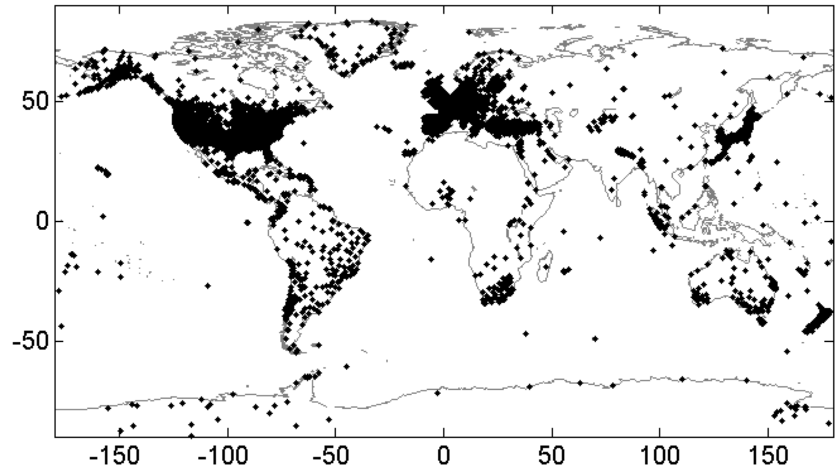
- To be investigated

Station Selection

Version 01: contributing to ITRF



Version 02: > 15,000 stations



Version 01:

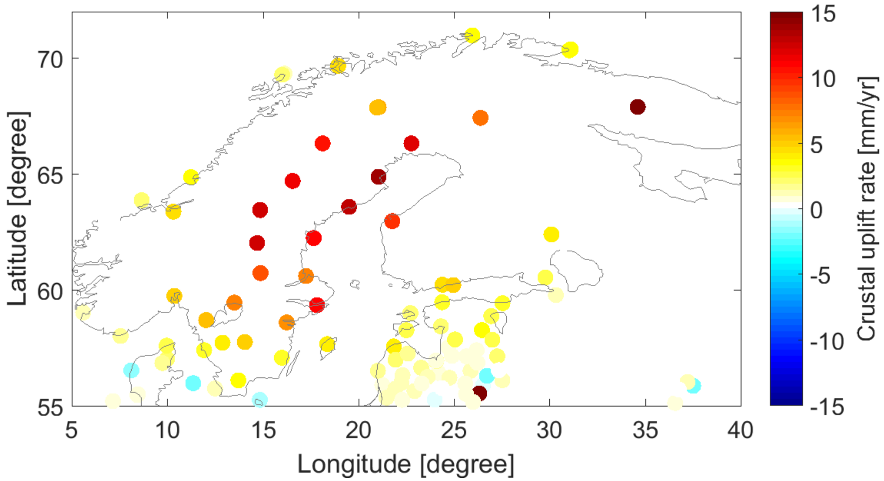
- Clean signal (local effects not included)
- Replacing stations over Antarctica and Greenland → elastic deformation

Version 02:

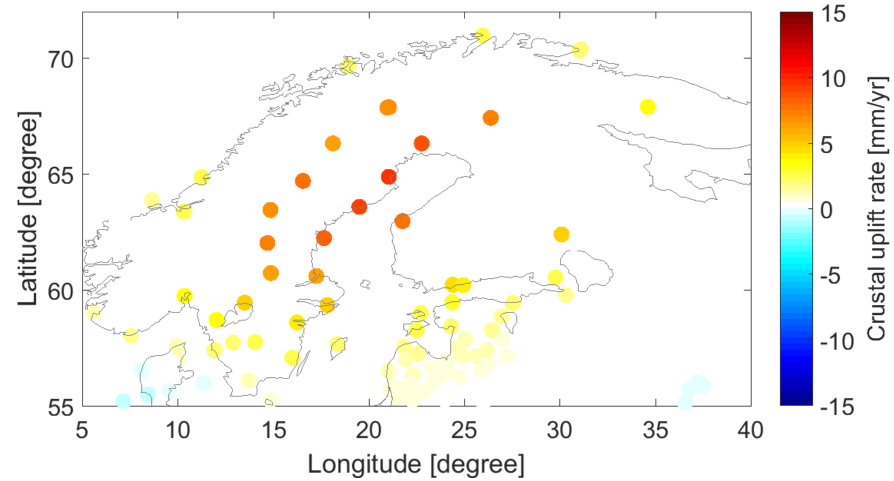
- Local effects included → spatial low-pass filtering
- Replacing stations over Antarctica and Greenland → elastic deformation

Median and mean filter

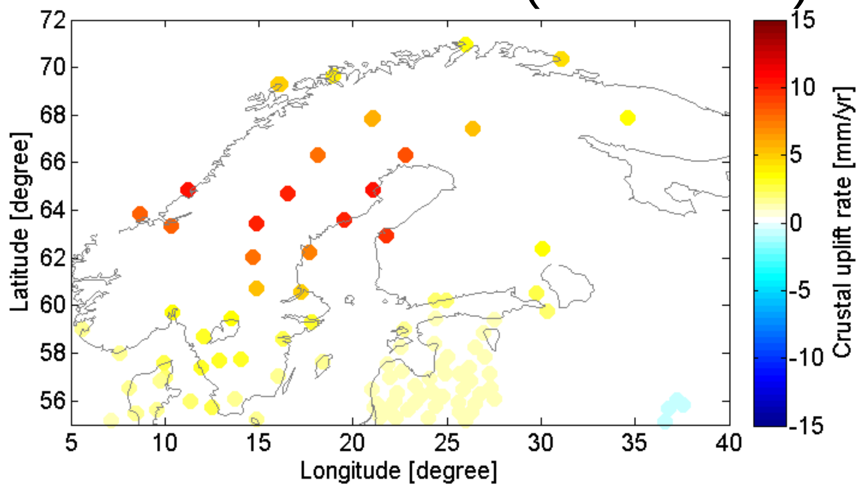
GPS



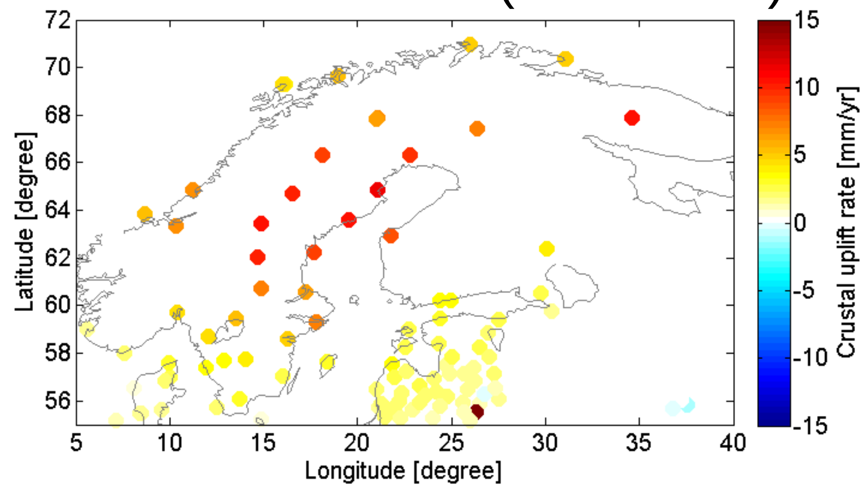
GIA mean field



GPS: Median filter (r = 500 km)



GPS: Mean filter (r = 500 km)

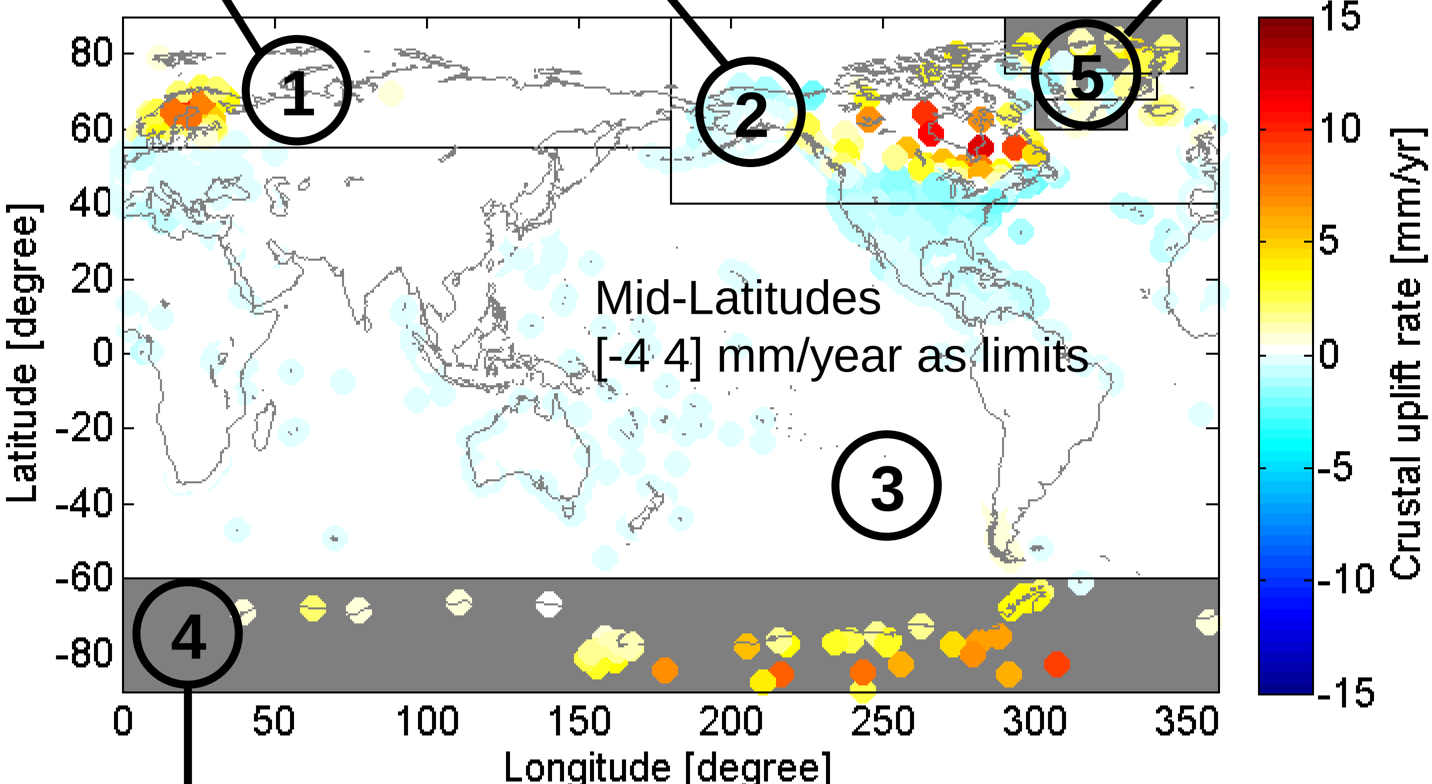


Quality Control Classes

GIA uplift rates in Northern Europe/Asia [-6 16] mm/year as limits*

Replace data in Greenland with elastic corrected regional dataset

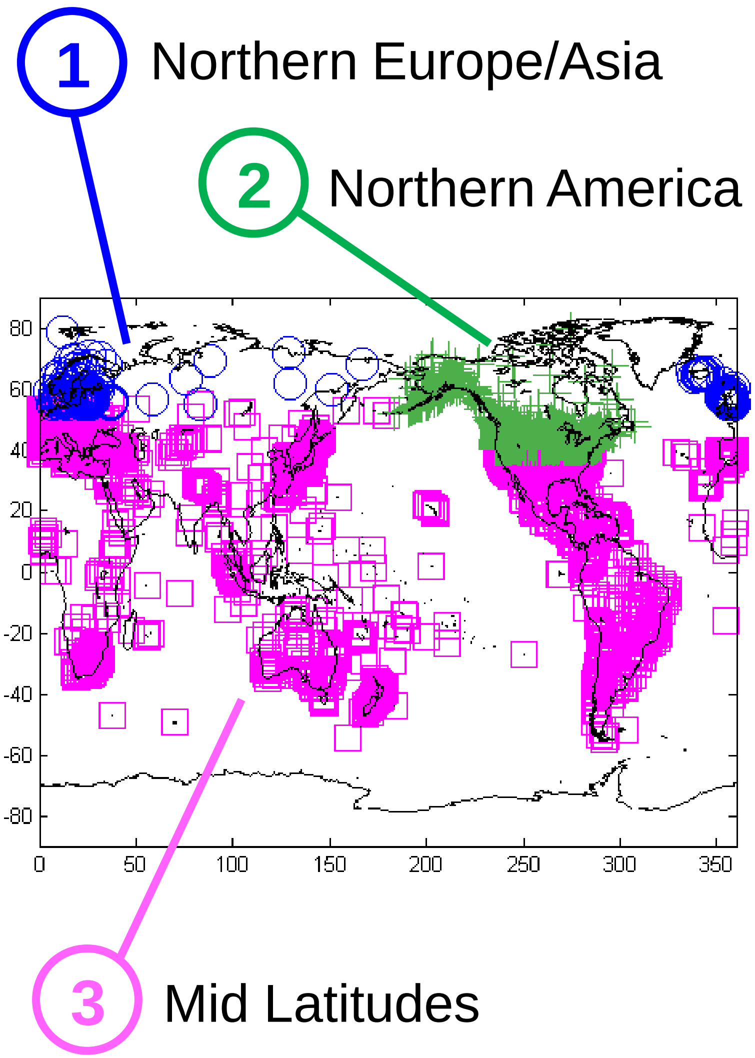
GIA uplift rates in Northern America [-10 24] mm/year as limits

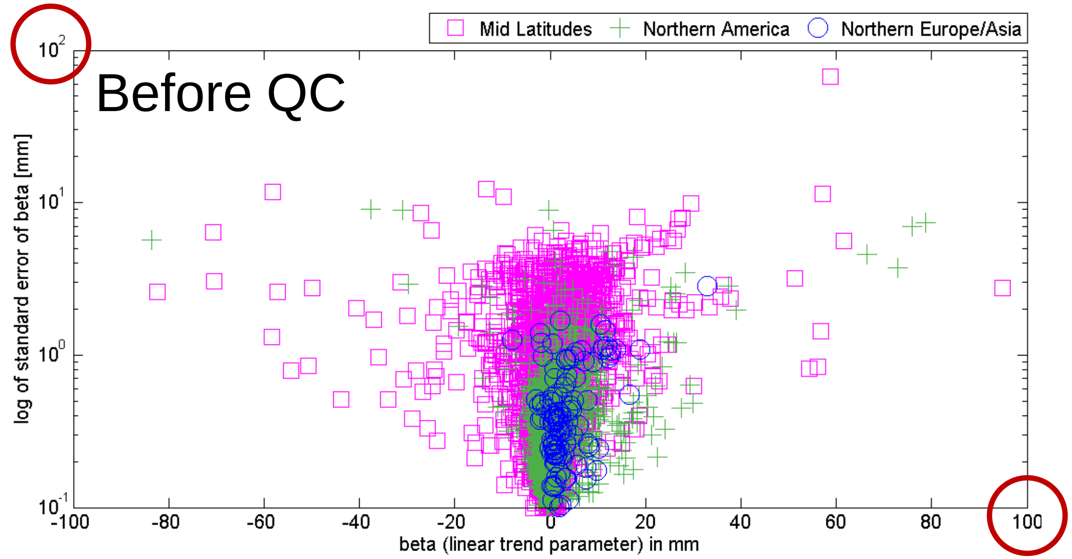


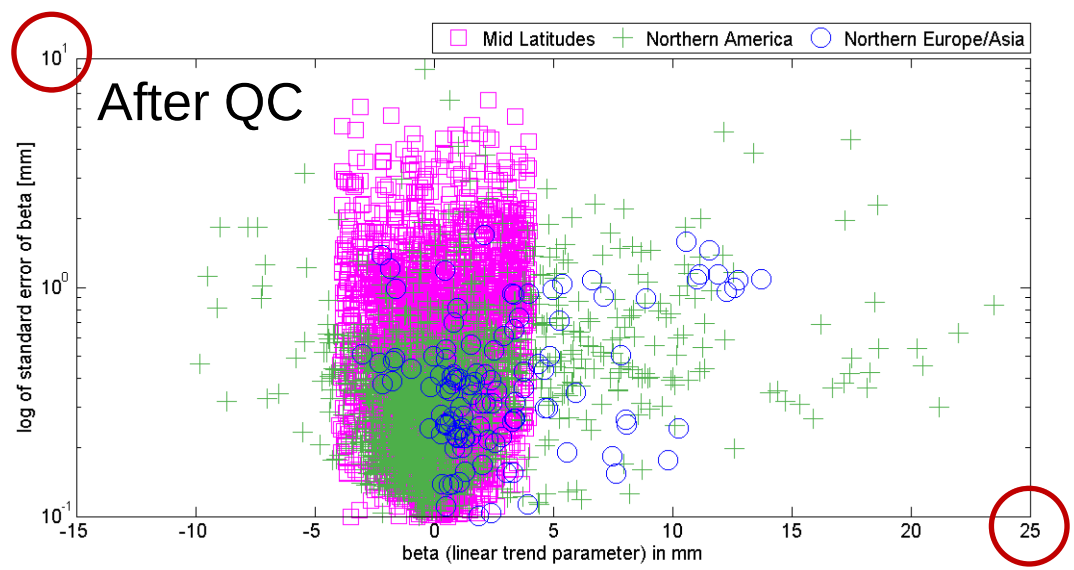
Replace data in Antarctica with elastic corrected regional dataset

* based on min/max GIA forward model mean value plus/minus 3-sigma (standard error)

Quality Control (QC)







Elastic Deformation

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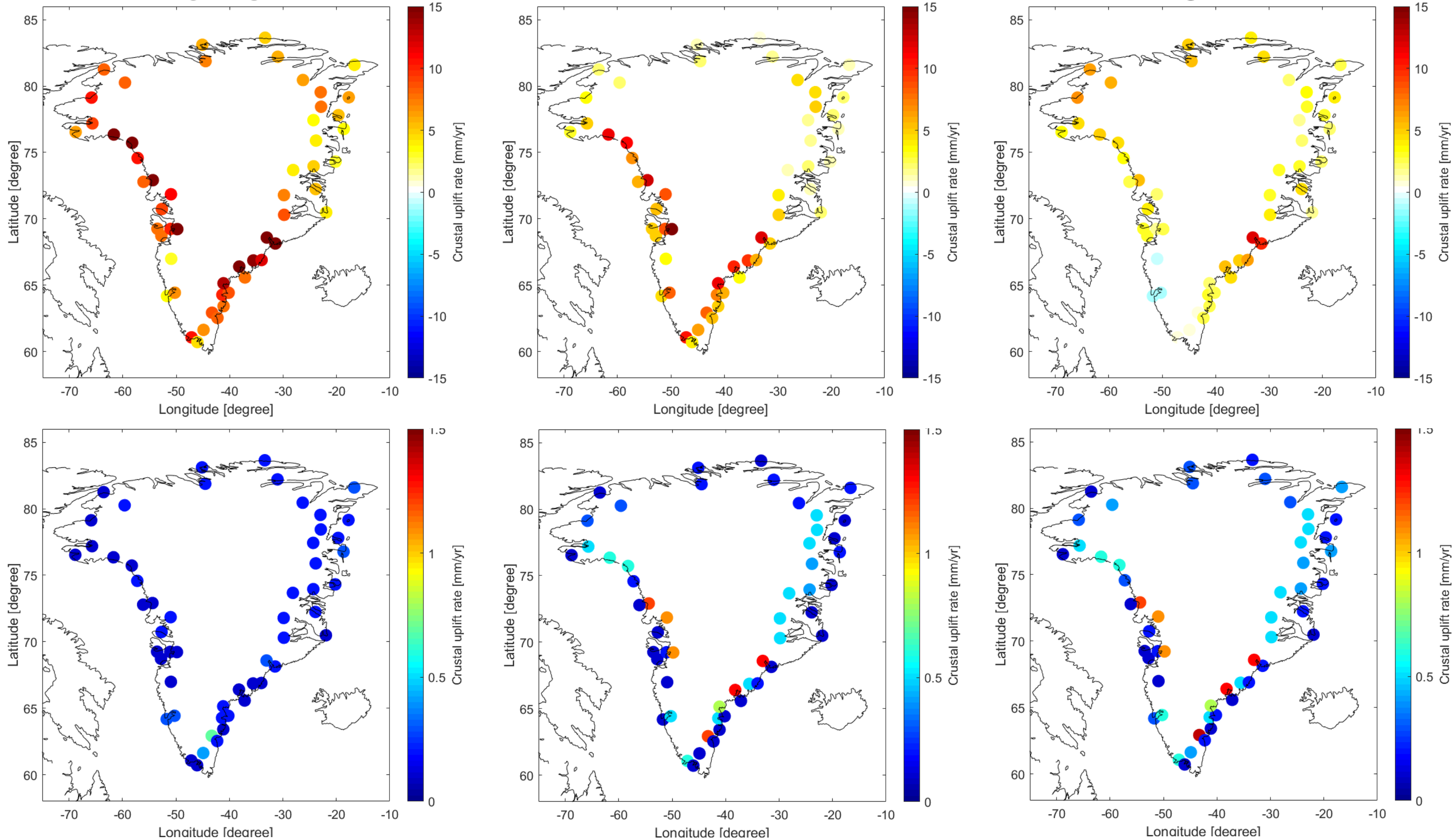
Example: Greenland (similar approach for Antarctica)

GPS | Elastic correction | GIA

Uplift rate [mm/yr]

Standard deviation

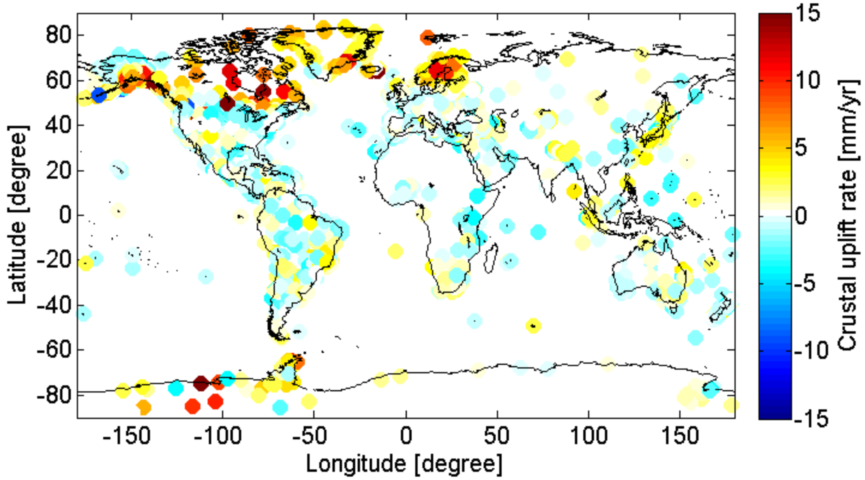


Reference: Khan et al. (2016, Science Advances; Tab. S1)

Novel Global GPS Data Set

GPS data sets

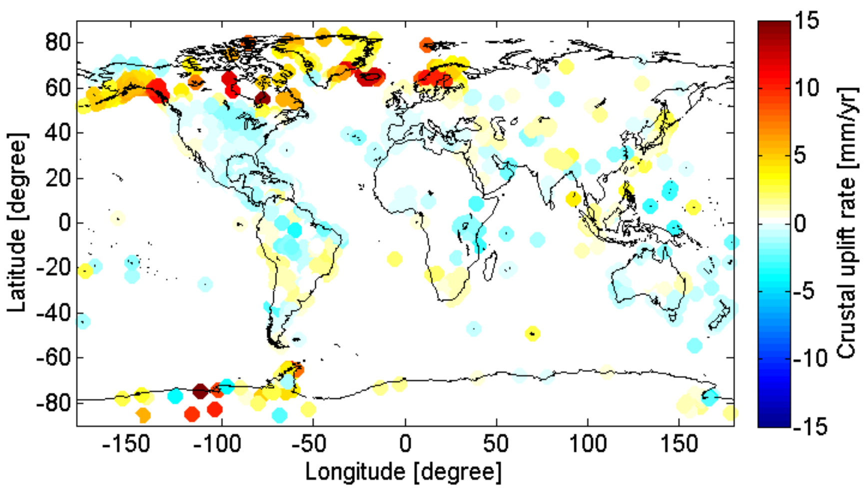
6920 stations



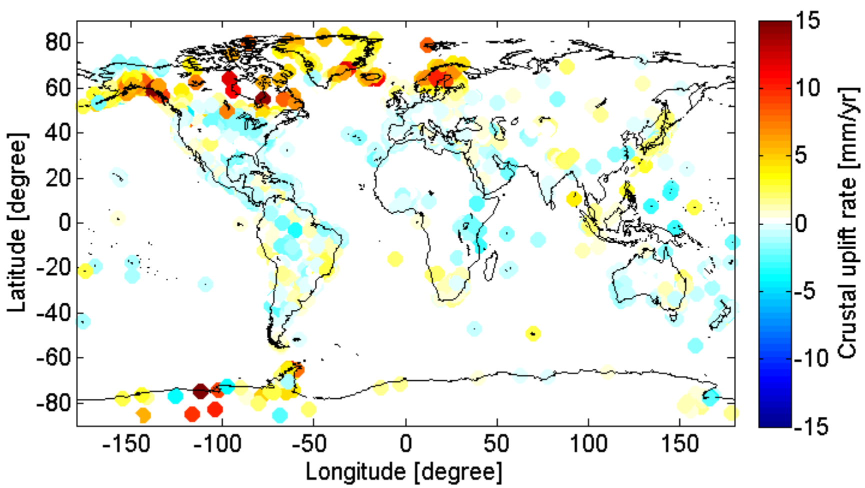
After Quality Control:

- long-wavelength show clean GIA signal
- a priori information from GIA forward models considered for quality control (i.e. selection of GPS stations)

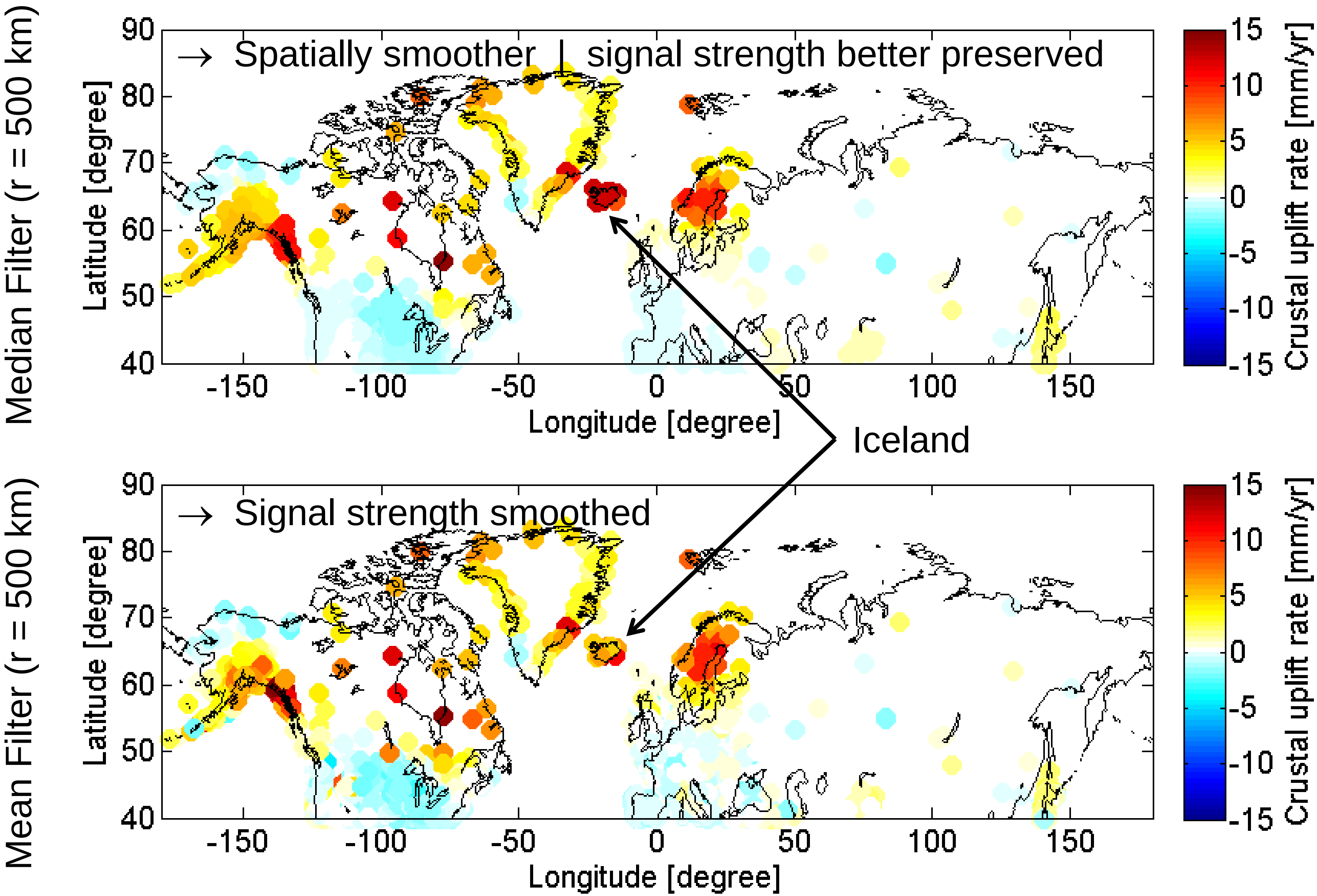
Median Filter (r = 500 km)



Mean Filter (r = 500 km)

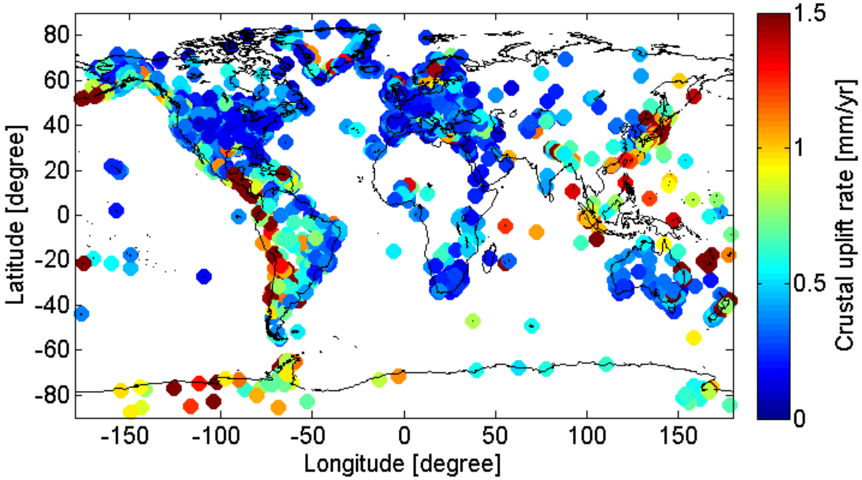


GPS data sets: Zoom



GPS data sets: Errors

Quality Controlled



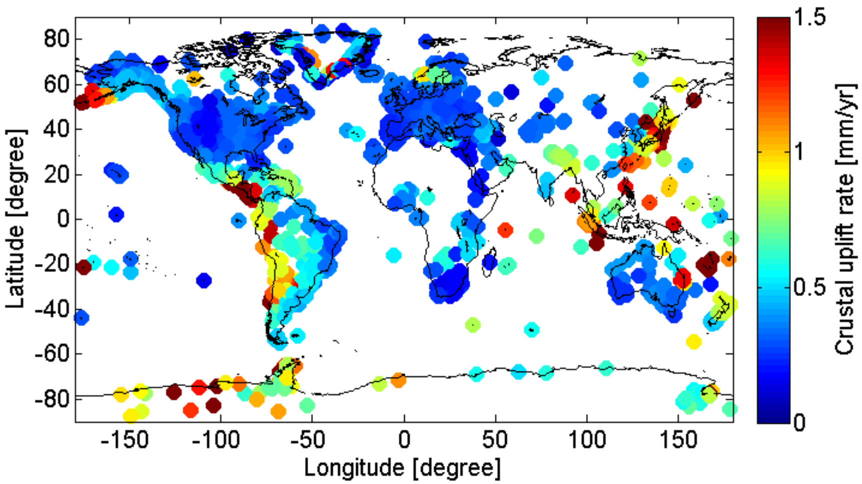
<u>Median filter:</u>

- preserves magnitudes of errors better

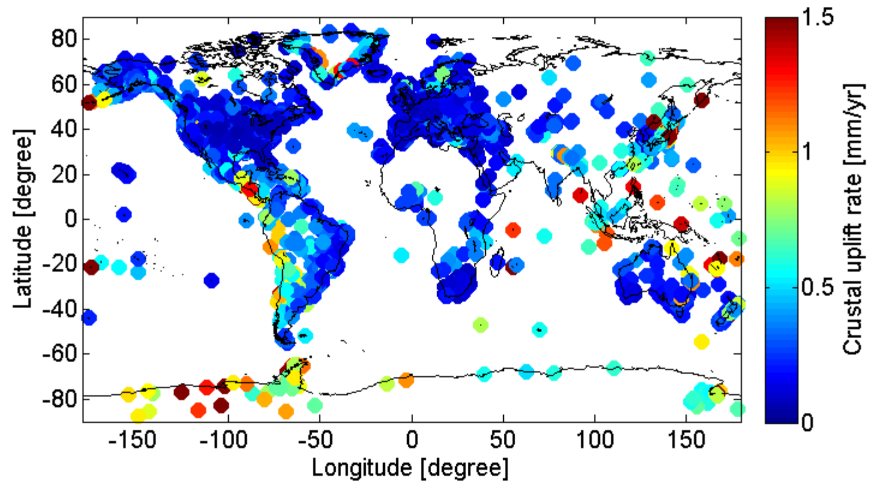
<u>Mean filter:</u>

- errors are smoothed due to applied formal error propagation

Median Filter (r = 500 km)

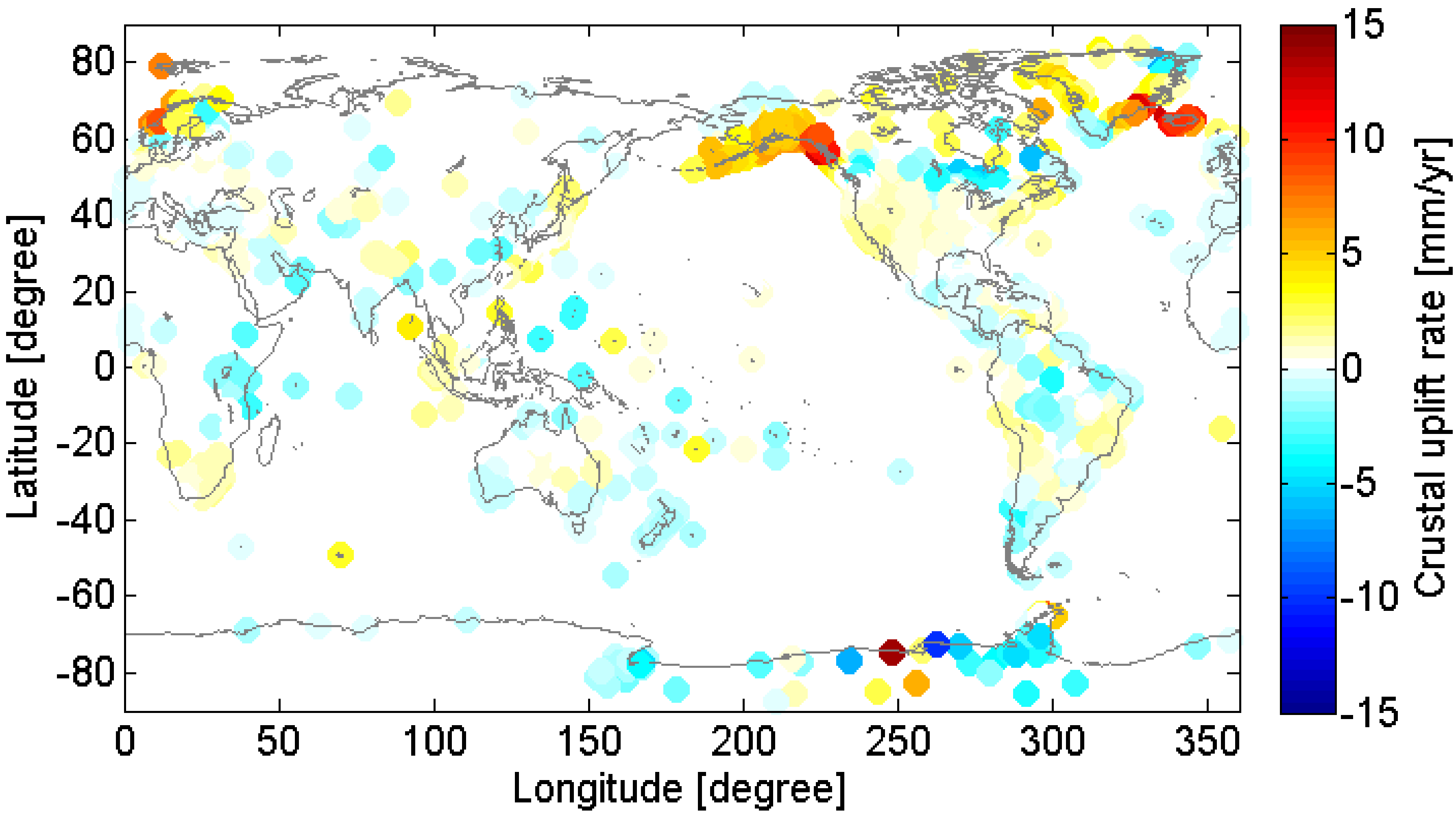


Mean Filter (r = 500 km)



GIA Model Validation (1/2)

GPS data set (median filter applied) MINUS ICE-6G*



* GPS data in center of mass (CM) reference frame; GIA models in center of Earth (CE) reference frame

GIA Model Validation (2/2)

Spatial RMSE values

Model	Global	N. EU/Asia	N. America	Mid Latitudes	Antarctica	Greenland
Pur-6-VM5	1.50	1.90	2.26	0.94	3.55	3.70
Pel-4-VM2	1.45	1.97	2.19	0.81	4.76	2.98
Pel-5-VM2-R	1.57	1.91	2.39	0.91	4.32	3.76
Pel-5-VM4	1.58	2.45	2.30	0.99	4.50	4.02
ICE-6G (Pel-6-VM5)	1.45	2.06	2.19	0.86	3.67	3.67
SKM-O-R	1.70	2.58	2.42	1.06	5.73	4.15
S&S-1	1.78	4.18	2.68	0.94	4.40	4.47
S&S-3	1.61	2.07	2.45	0.79	6.26	3.25
SVv-3-REF	1.76	1.78	2.62	1.00	6.32	2.96
SVv-L-ALT	1.46	2.48	2.21	0.78	4.60	4.19
vdW-5	1.50	2.01	2.37	0.77	4.21	3.57
W&W-4	1.70	1.79	2.63	0.97	4.70	3.29
W&W-5	2.20	2.01	3.44	1.29	4.89	3.66

Conclusions and Outlook

Conclusions and Outlook

Conclusions:

- Novel GPS data set shows clean GIA signal
- Suitable to investigate behavior of GIA forward models
- Comparison of median and mean filter:
  - Both filter smooth spatial pattern (long-wavelength signal)
  - Median filter preserves signal and error magnitudes better
- Comparison with 13 GIA forward model solutions:
  - Generally largest differences for Antarctica & Greenland
  - Pel-4-VM2 & ICE-6G (Pel-6-VM5) show globally best agreement

Outlook:

- Detecting unreported jumps (change point detection)
- Removing atmospheric pressure loading
- Correcting CM-CE for validation

Thanks for your attention !

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Attributing global sea level rise to its component parts

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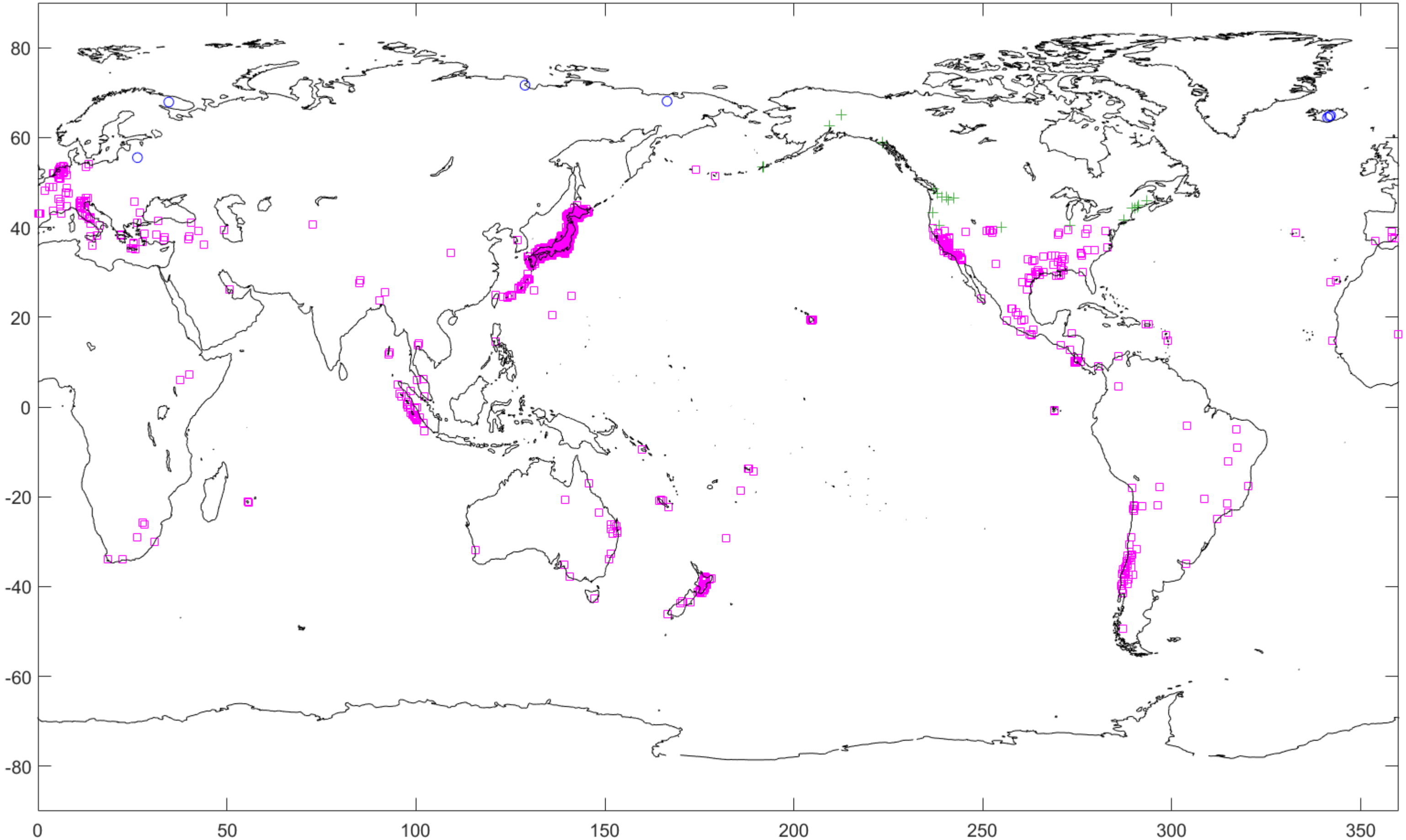
Appendix

Quality Control (QC)

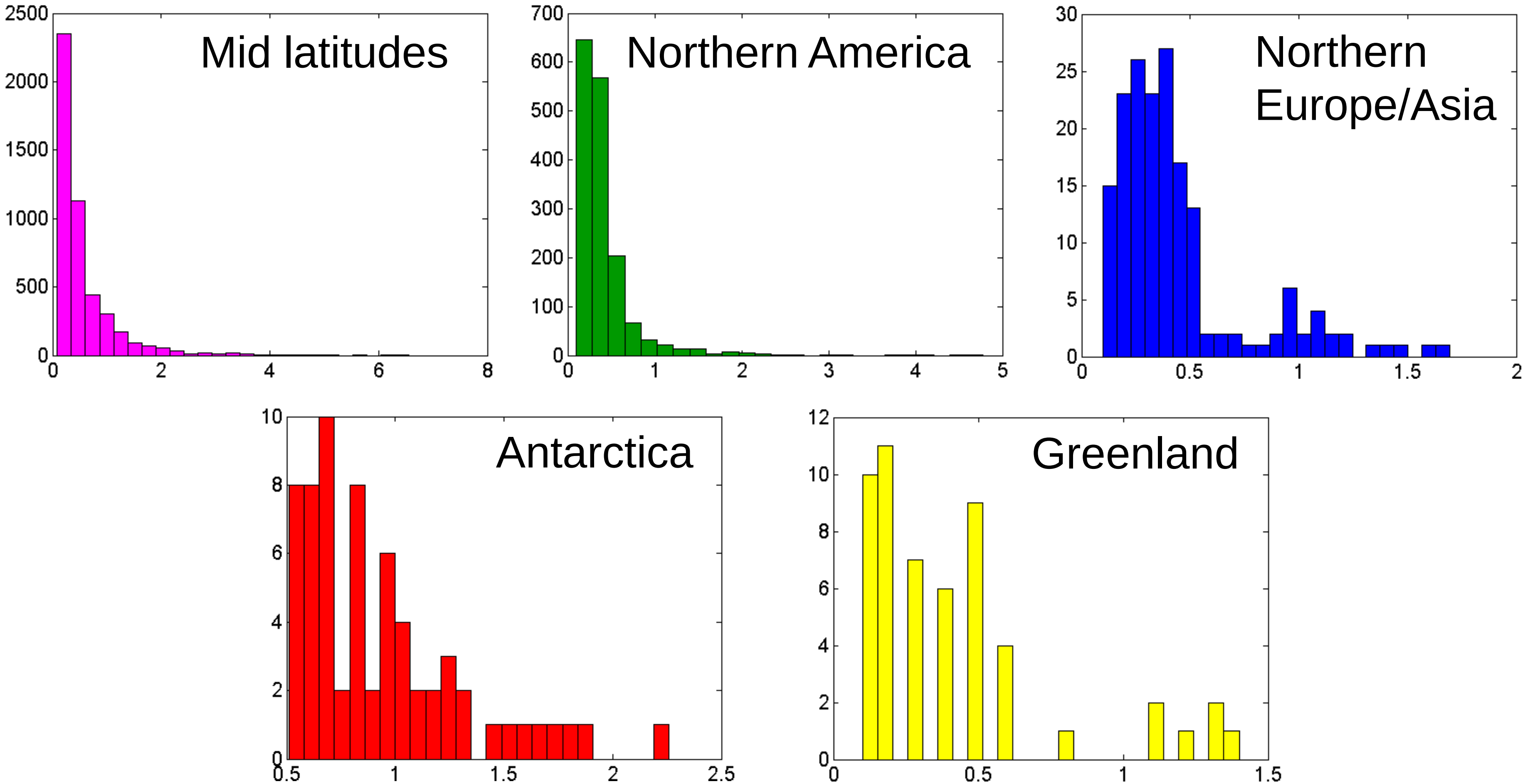
Stations that are removed after Quality Control (slide 13)



Quality Control (QC)

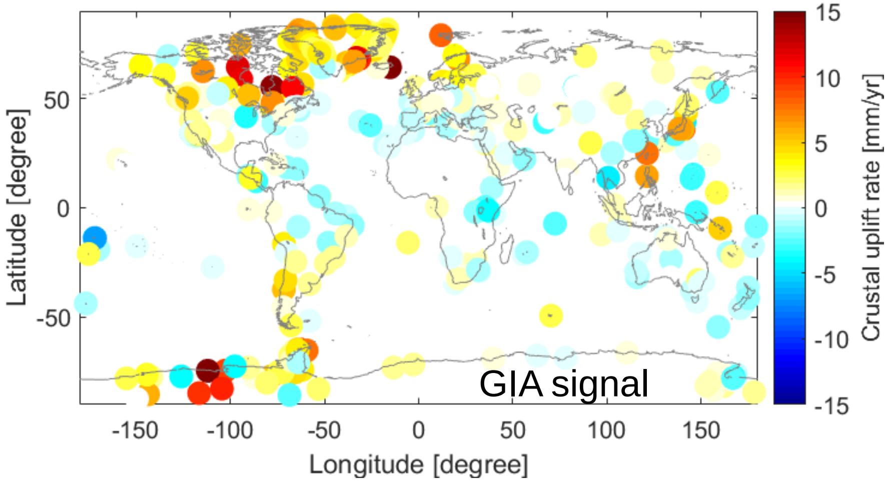
GLOBAL MASS

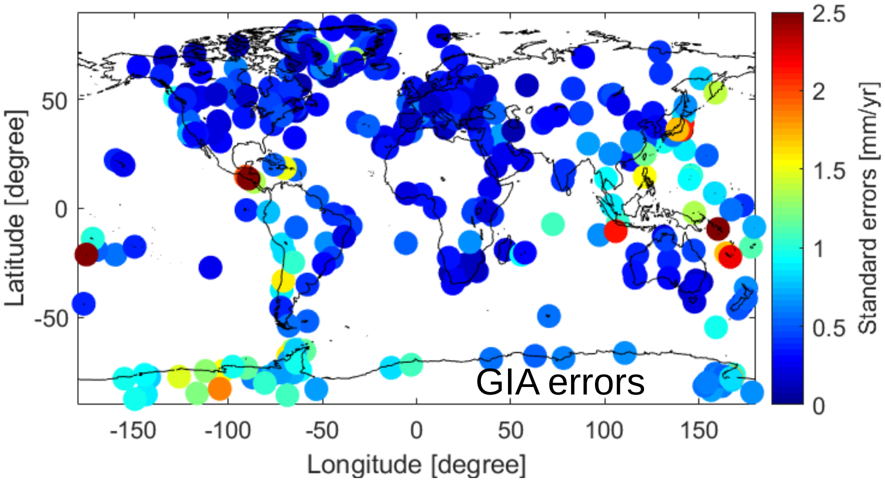
Histograms of linear trend errors (mm/yr) from GPS after QC



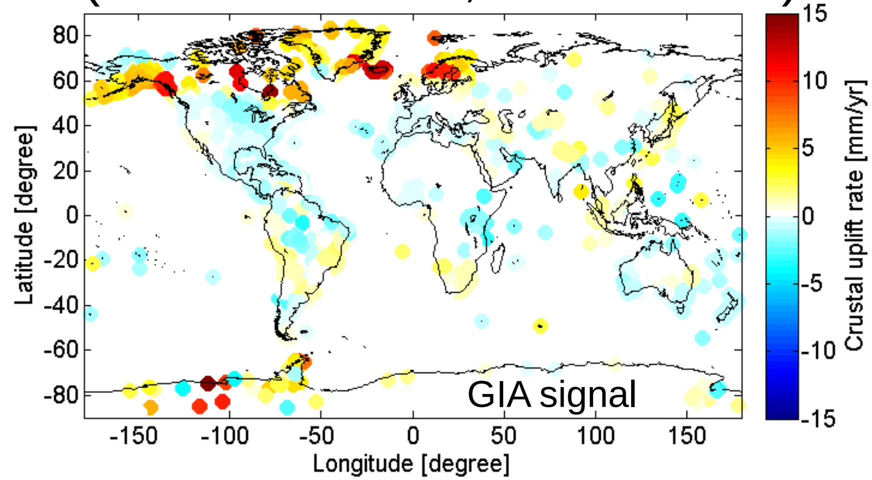
Station Selection

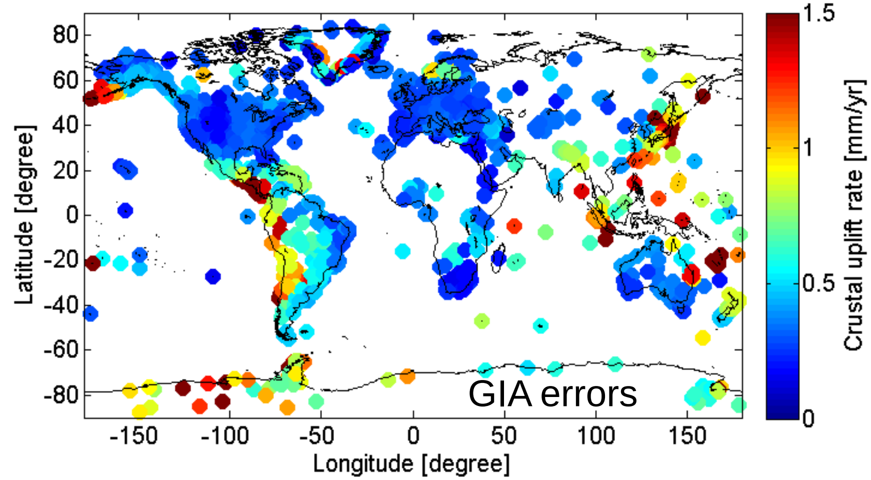
Stations contributing to ITRF
(~ 400 stations)





Selected NGL stations
(~ 7000 stations; median filter)





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