Evaluation of the impact of atmospheric pressure loading modeling on GNSS data analysis

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COST Action: ES0701 – improved constraints on models of glacial isostatic adjustment
Geodetic observation-level modelling and systematic biases (WG1)
Velocity determination/reference frame realization (WG2)

Vienna University of Technology, Vienna, Austria; 16 to 17 November 2010

Motivation

Order of magnitude of time–variable station deformations for the vertical component:

5 dm	
	Solid Earth tides
1 dm	
	Ocean tidal loading
5 cm	
	Atmospheric non-tidal loading
1 cm	Ocean non-tidal loading
5 mm	
	Atmospheric tidal loading (S1/S2)
1 mm	...

The real magnitude of these effects depends on the location of the particular station.

Motivation

Order of magnitude of time–variable station deformations for the vertical component:

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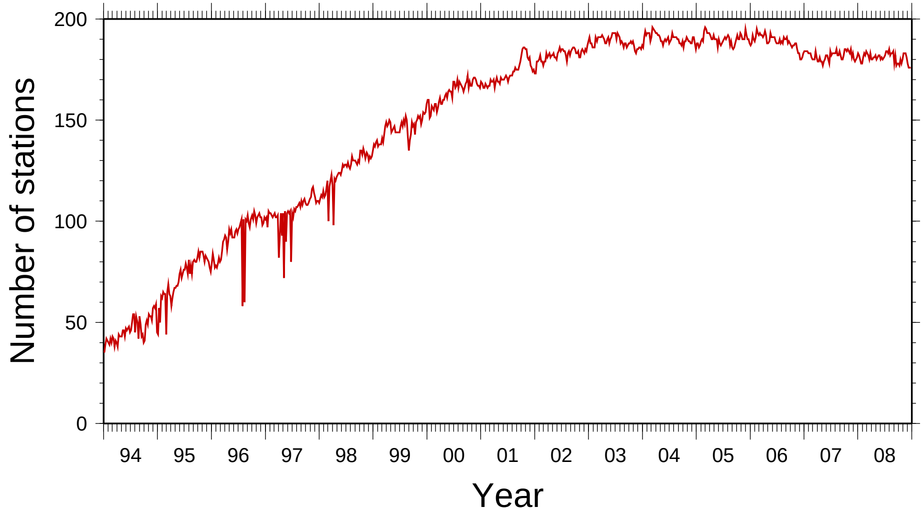
The real magnitude of these effects depends on the location of the particular station.

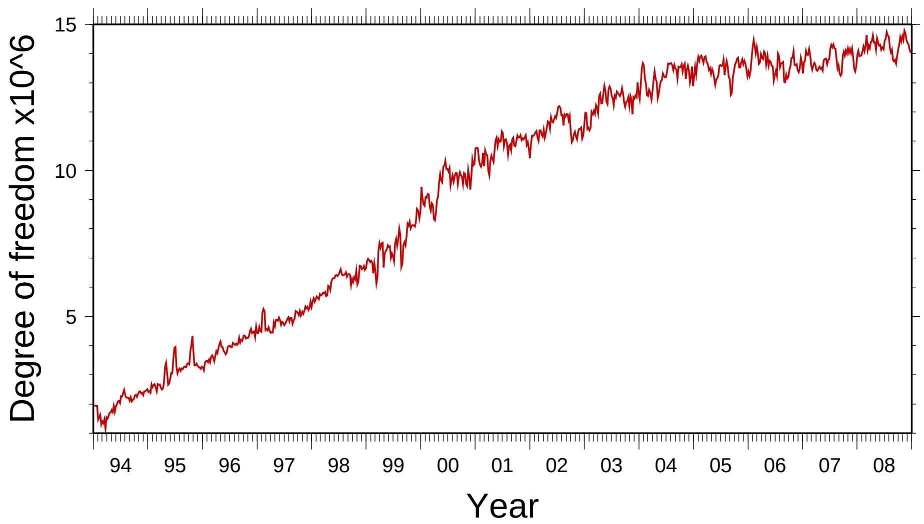
Outline

- Introduction: CODE contribution to the IGS reprocessing effort (repro1).
- Atmospheric pressure loading model: e.g., Petrov and Boy (2004)
- How to apply atmospheric pressure loading corrections?
  - based on weekly solutions, on observation level, or with a scaling factor?
- Validation of the model by estimating scaling factors.
- Influence of atmospheric pressure loading on other GNSS–related parameters.
- Conclusions and outlook

Generation of the GNSS solution

- starting with observation files from CO1 repro. (GPS–only)
- CODE standard processing is solving for CRD, TRP, ORB, ERP modeling: latest hardisp and troposphere VMF1/ECMWF
- daily solution $\rightarrow$ weekly NEQs
- cumulative solution from NEQs significant outliers and discont. using the FODITS–tool of BSW
- NNR–condition for coordinates and linear velocities on IGS05 reference frame sites

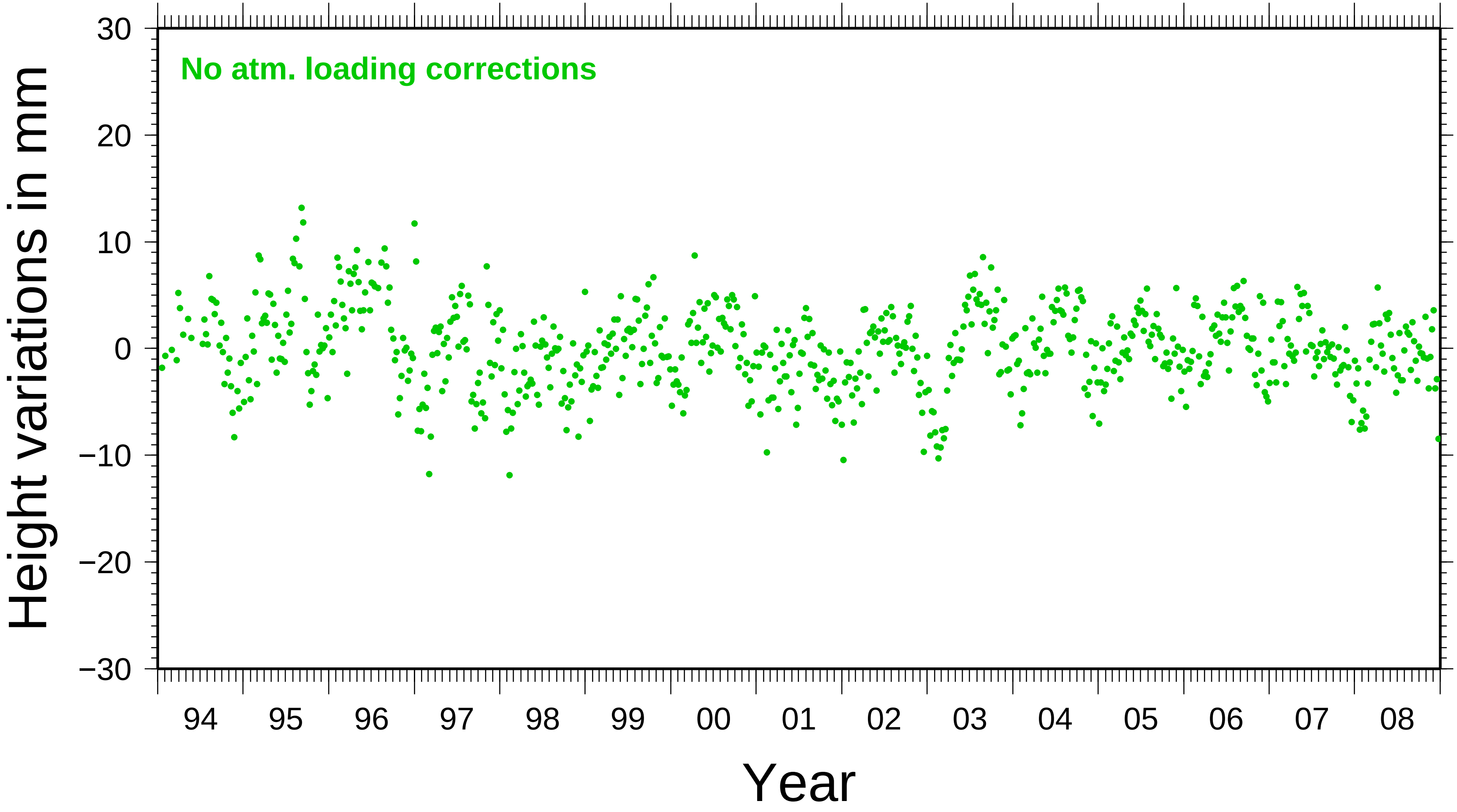




Coordinate time series

Repeatability of the weekly solutions

Example: Zimmerwald (ZIMM), Switzerland



Pressure loading model: evaluation 1

Can atmospheric pressure loading explain these seasonal variations?

- Example: Atmospheric pressure loading model from Petrov and Boy, 2004
  consists of two components
  - S1/S2 tidal pressure loading coefficients
  - 2.5×2.5 grids for the non–tidal component every 6 hours

- What impact on a GNSS solution can be expected from the model?

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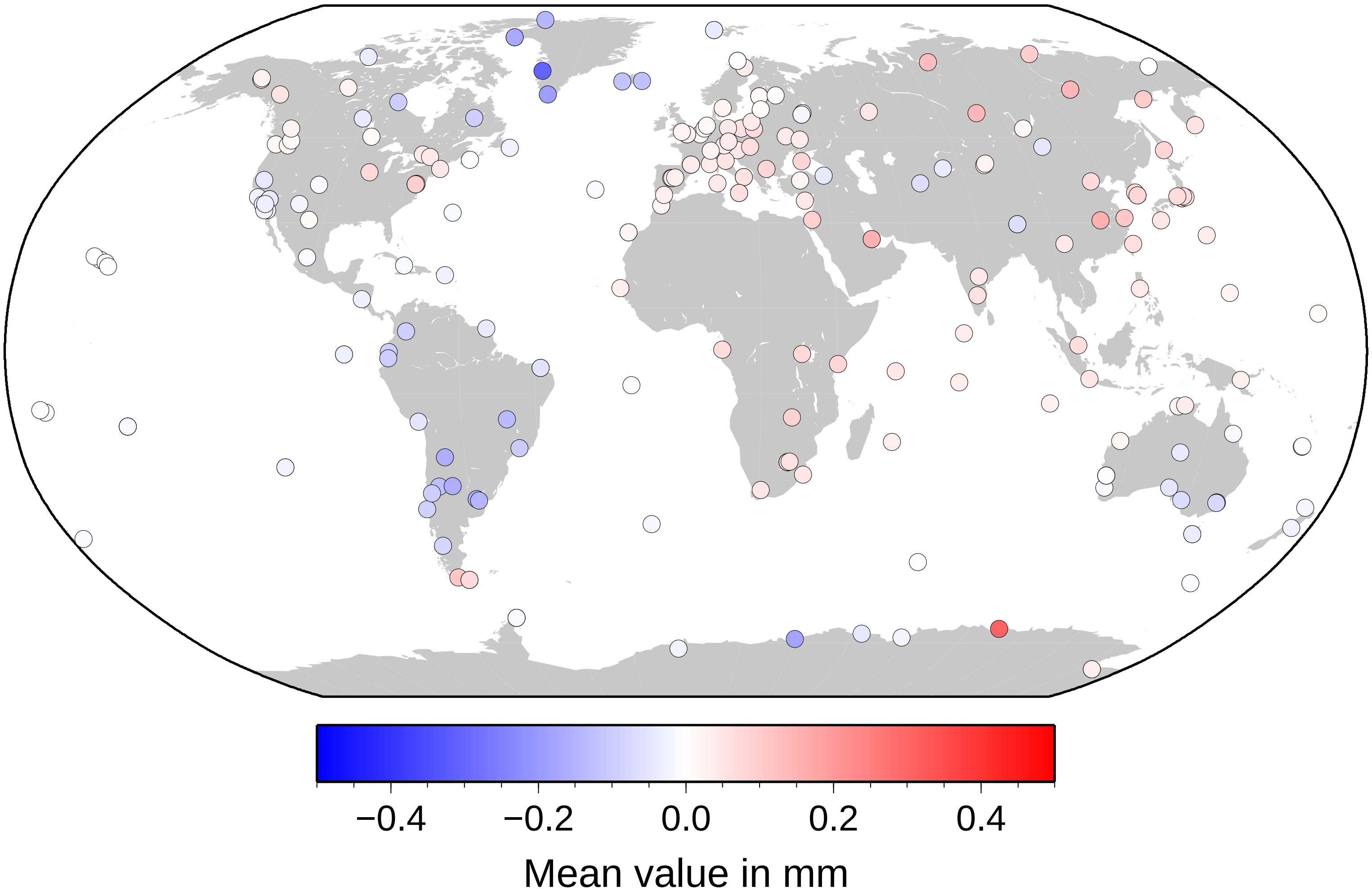
Evaluation 1:

- What impact on a GNSS solution can be expected from the model?

Atmospheric loading model

Atmospheric pressure loading model from Petrov and Boy, 2004

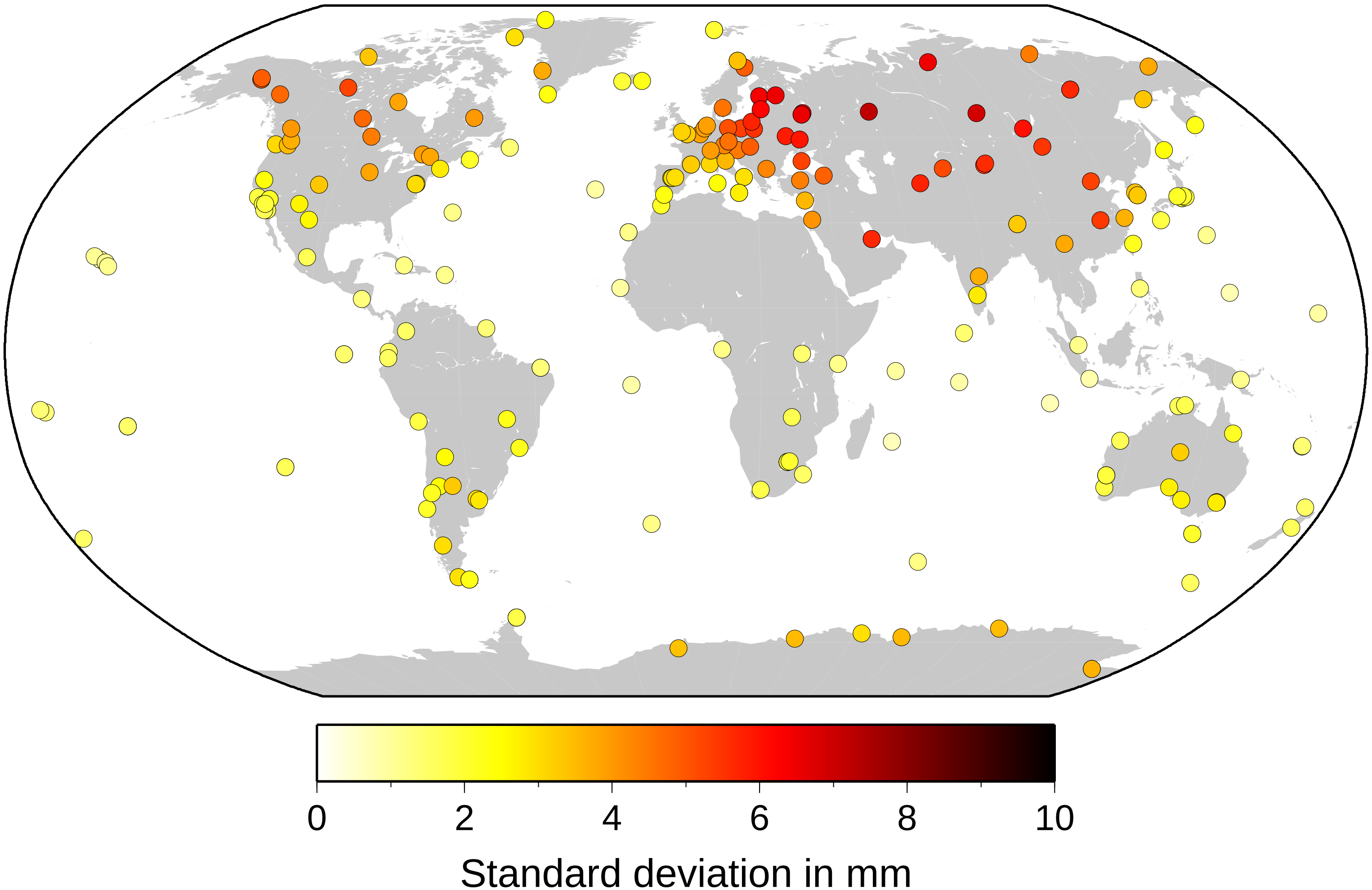
Mean non–tidal correction over 15 years



Atmospheric loading model

Atmospheric pressure loading model from Petrov and Boy, 2004

RMS of the non–tidal correction over 15 years



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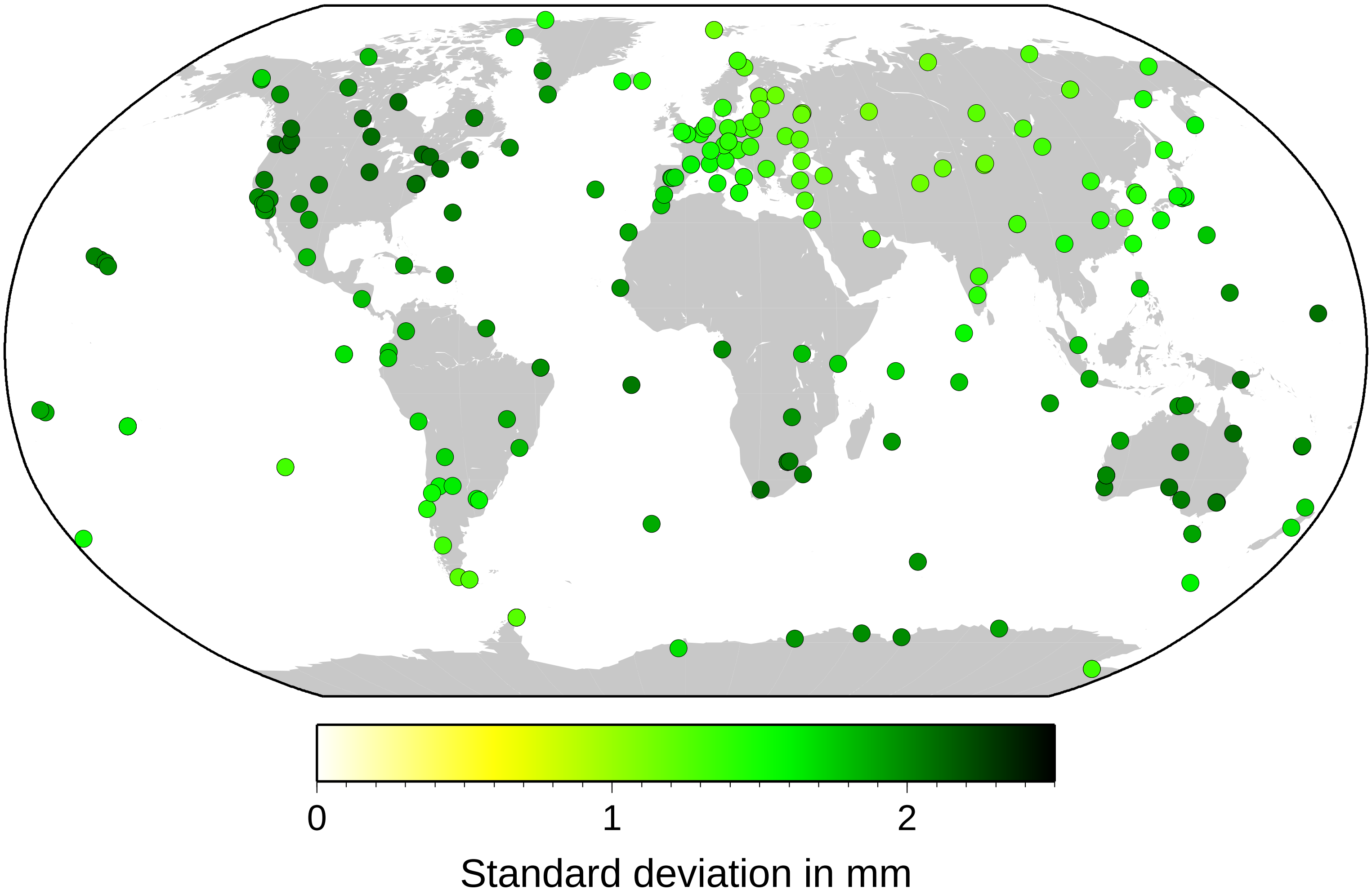

Atmospheric loading model

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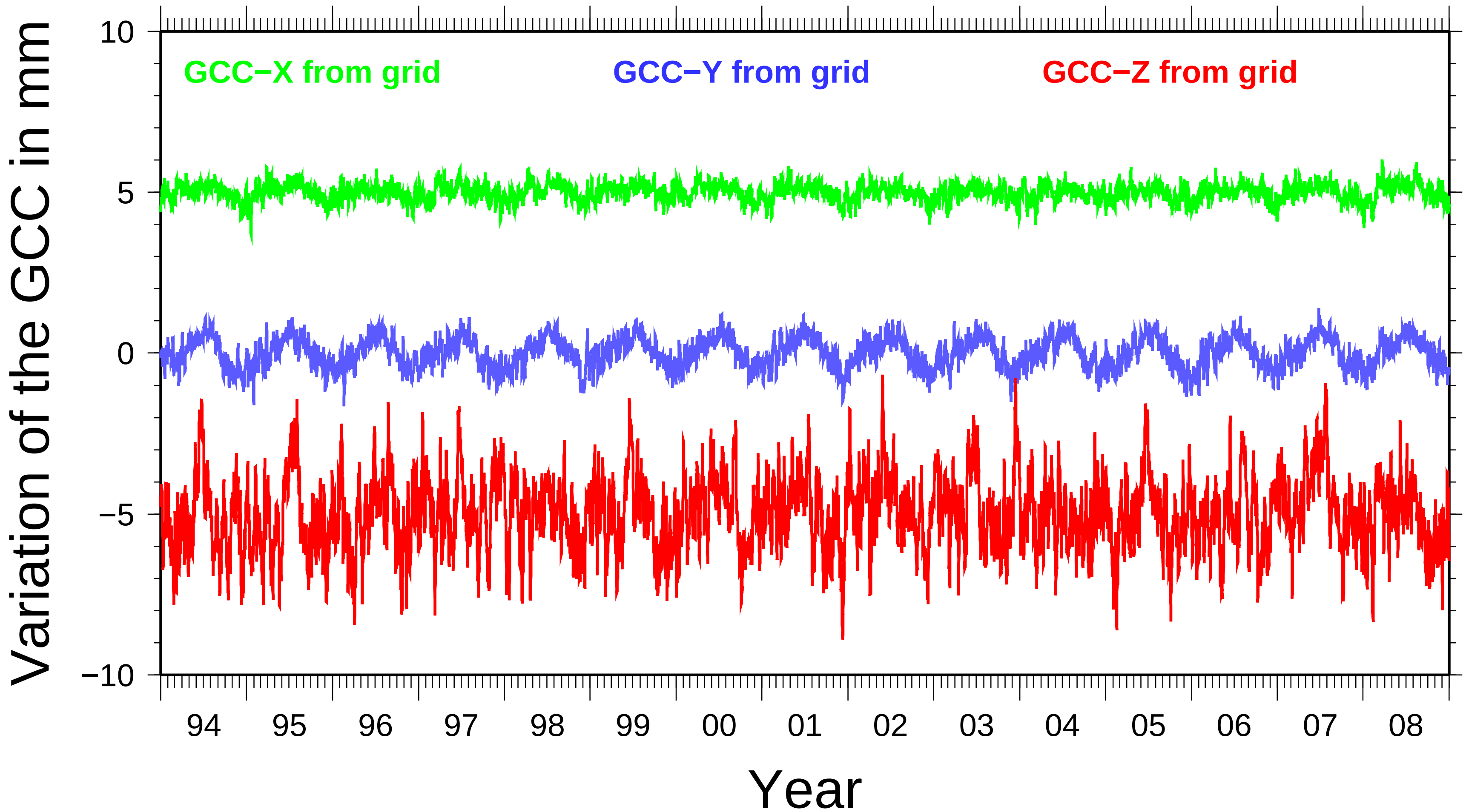
How does the pressure loading model translate into the geocenter?



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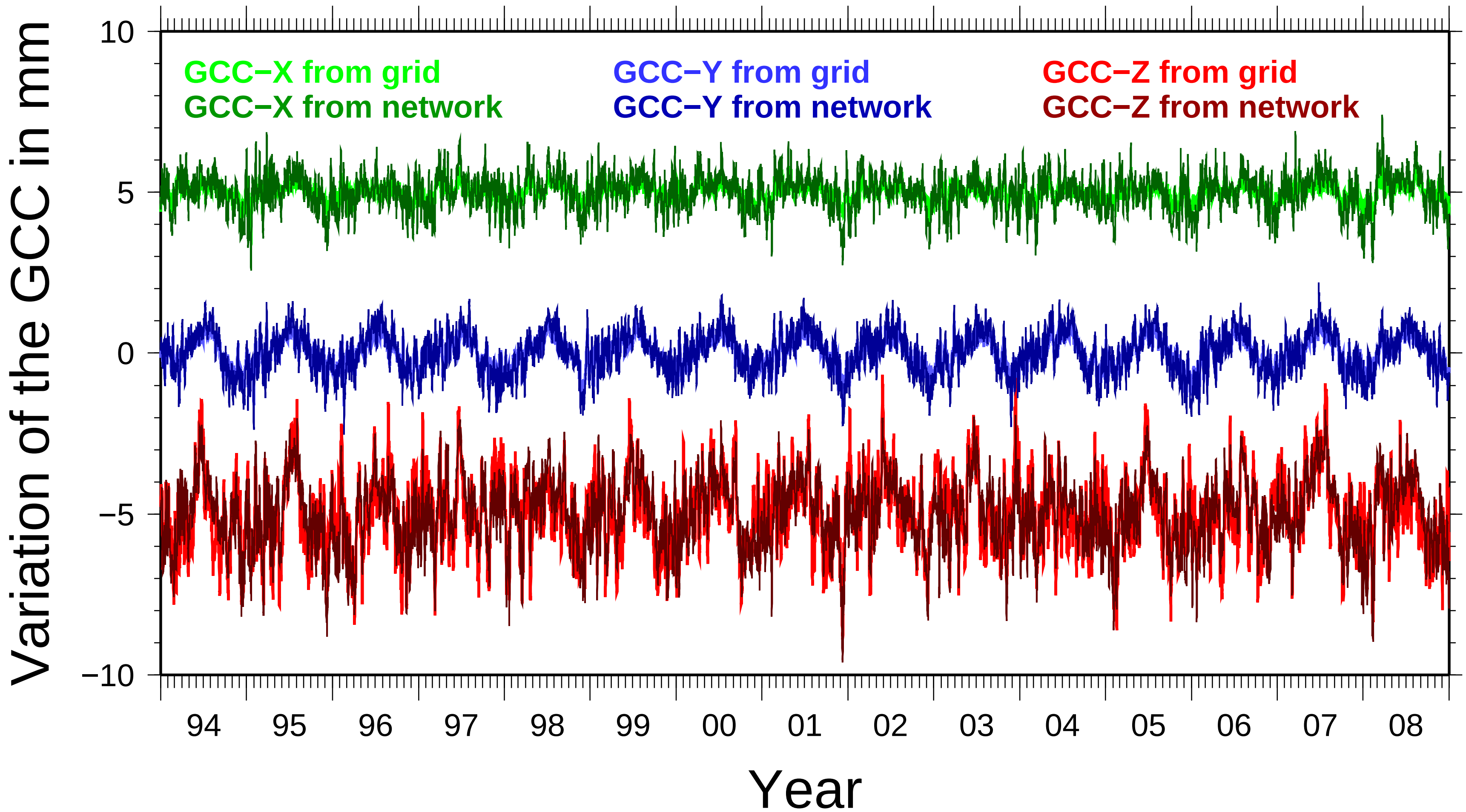

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Pressure loading model: evaluation 2

Can atmospheric pressure loading explain these seasonal variations?

- Example: Atmospheric pressure loading model from Petrov and Boy, 2004
  consists of two components
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  - 2.5×2.5 grids for the non–tidal component every 6 hours

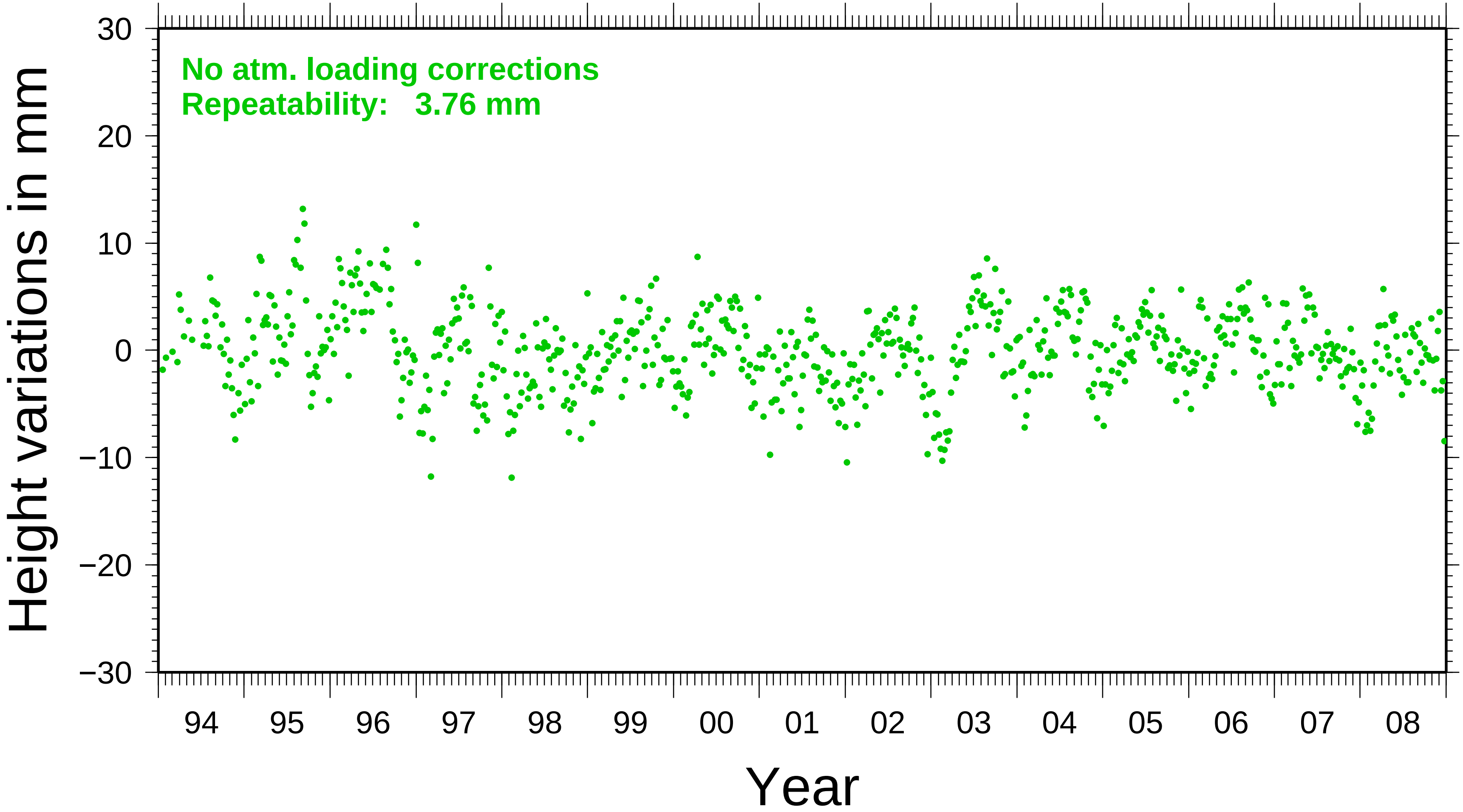
Evaluation 2:

- The non–tidal part is averaged for each station over one week
  if the station was available for this week.
- The regression factors between the weekly mean effect from the model and the coordinate time series is evaluated.

Pressure loading model: evaluation 2

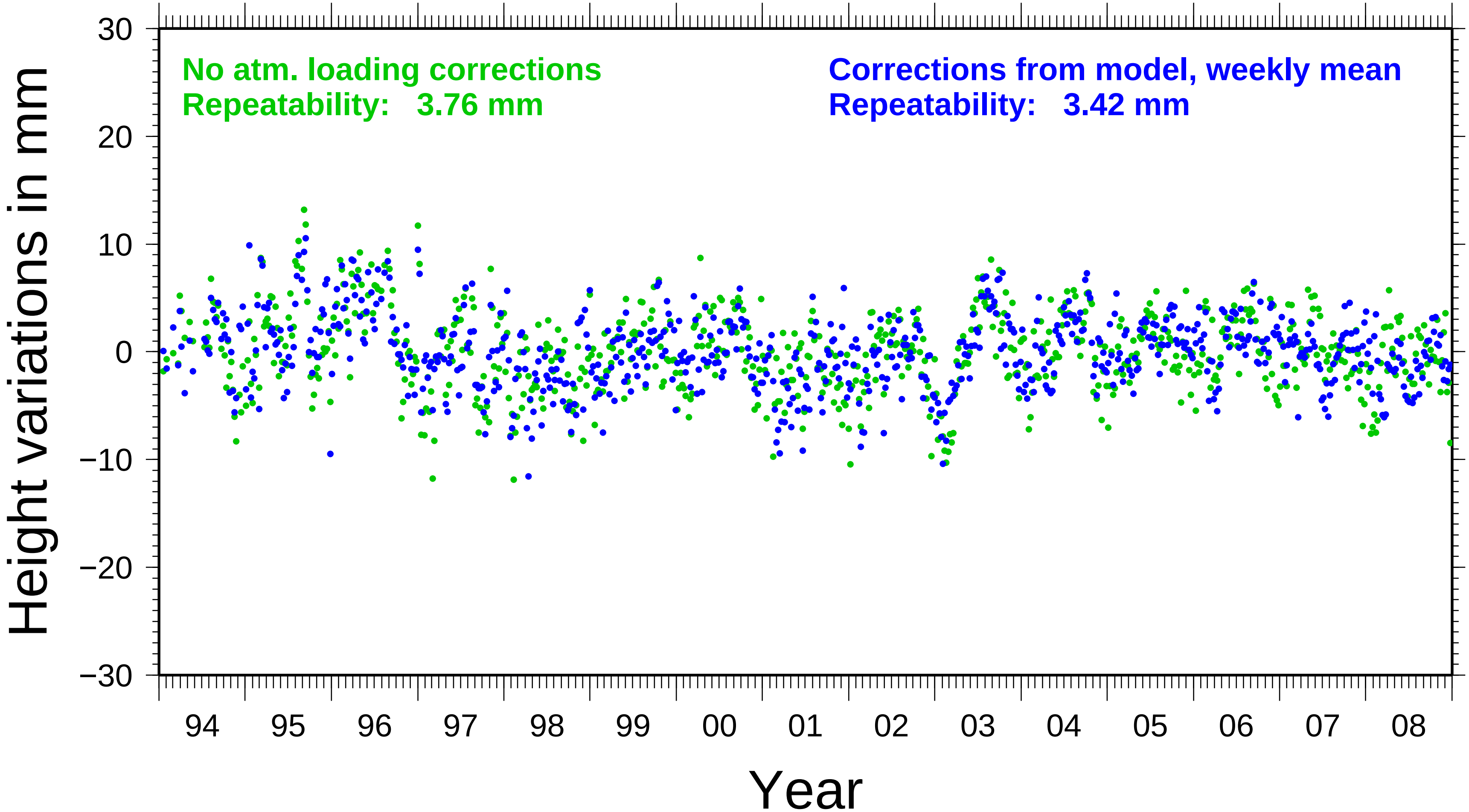
Repeatability of the weekly solutions

Example: Zimmerwald (ZIMM), Switzerland



Repeatability of the weekly solutions considering atm. loading

Example: Zimmerwald (ZIMM), Switzerland



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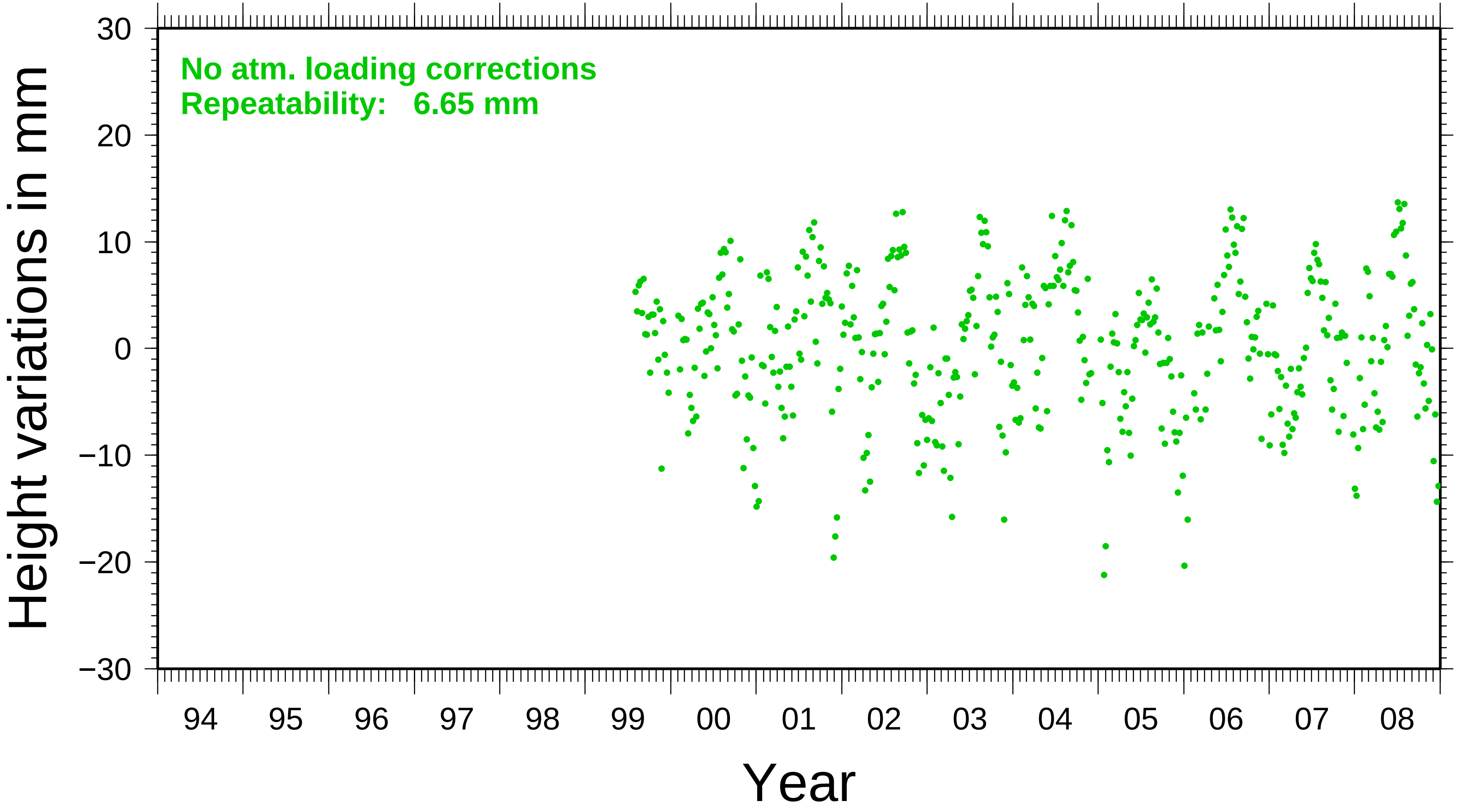
Pressure loading model: evaluation 2

Repeatability of the weekly solutions

Example: Arti (ARTU), Russia



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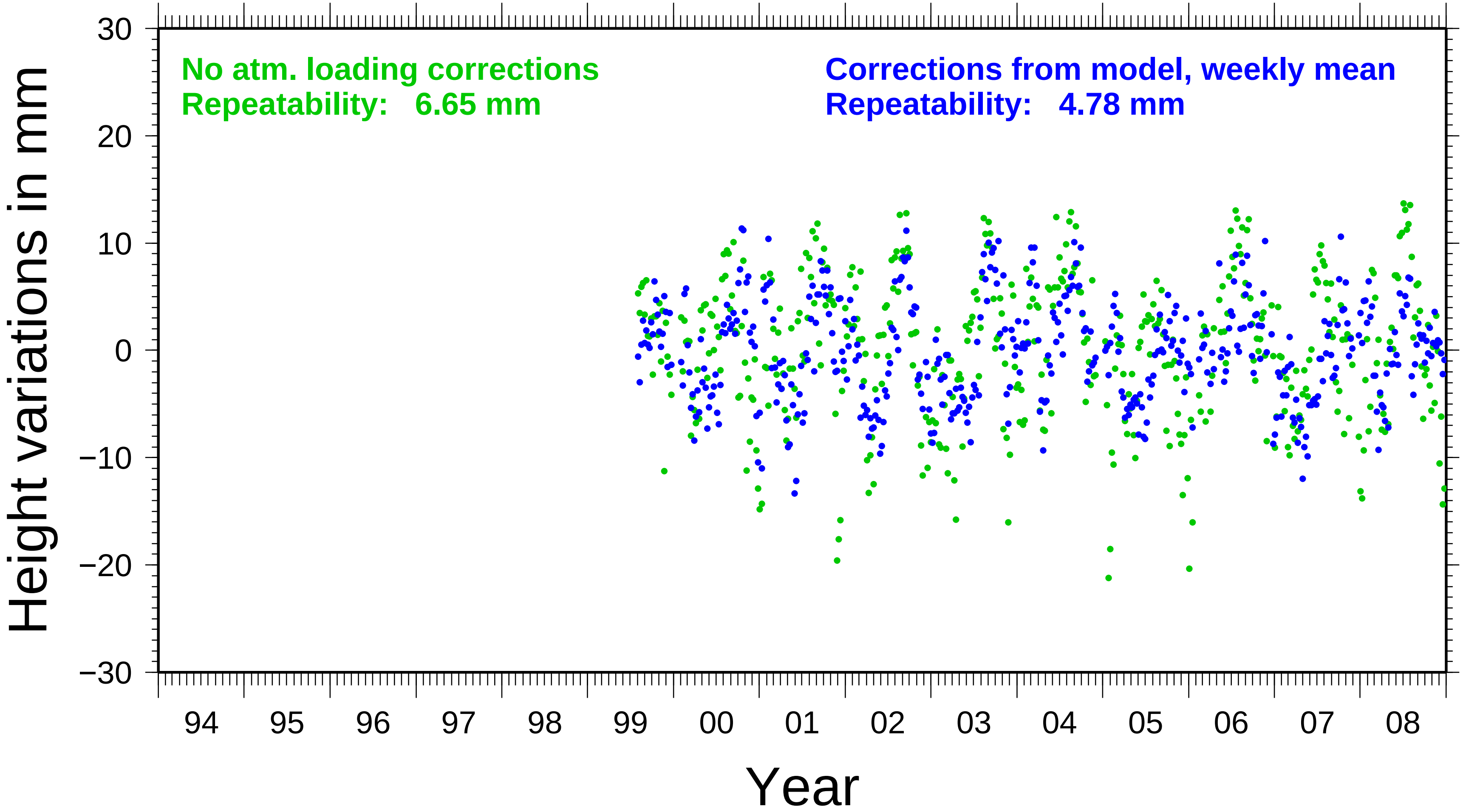
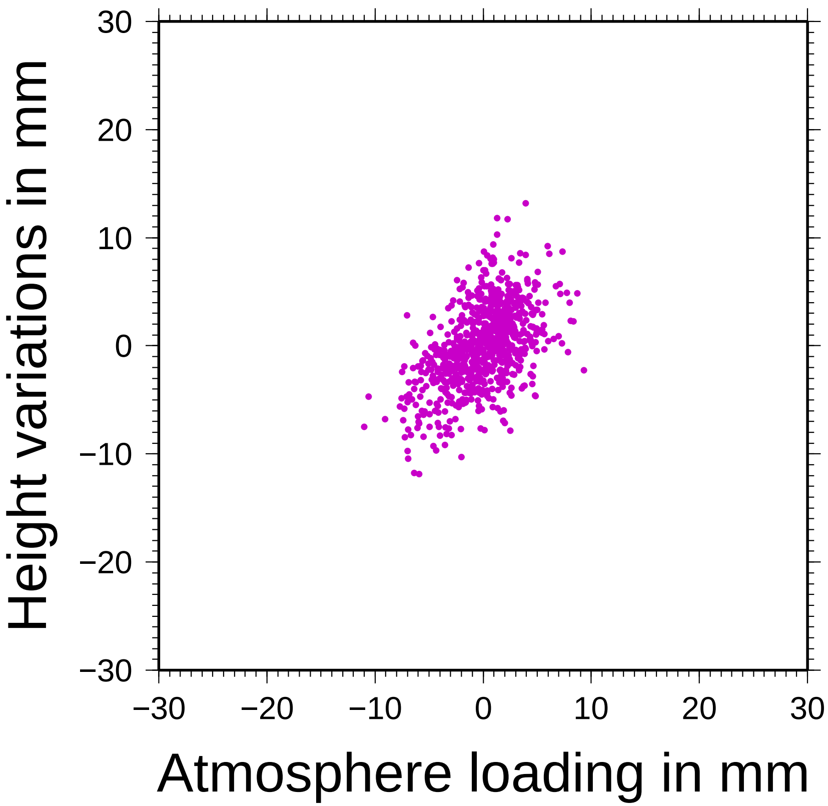


Pressure loading model: evaluation 2

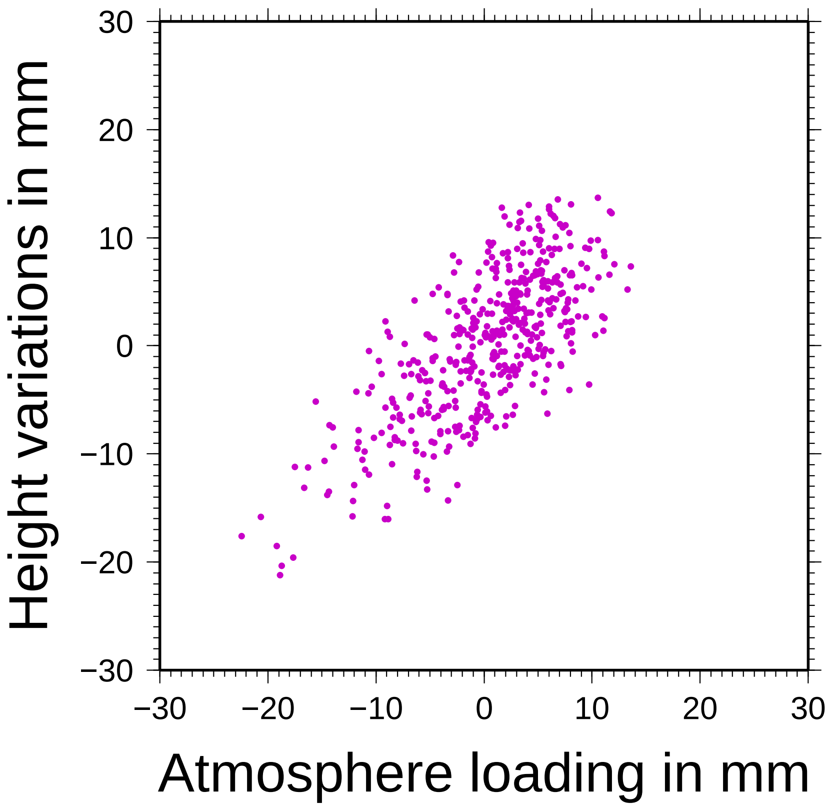
Correlatogram between height variations and pressure loading

Zimmerwald (ZIMM), Switzerland



Regression coefficient: 1.30±0.04

Arti (ARTU), Russia



Regression coefficient: 1.27±0.03

Pressure loading model: evaluation 3

Can atmospheric pressure loading explain these seasonal variations?

- Example: Atmospheric pressure loading model from Petrov and Boy, 2004
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  - S1/S2 tidal pressure loading coefficients
  - 2.5×2.5 grids for the non–tidal component every 6 hours

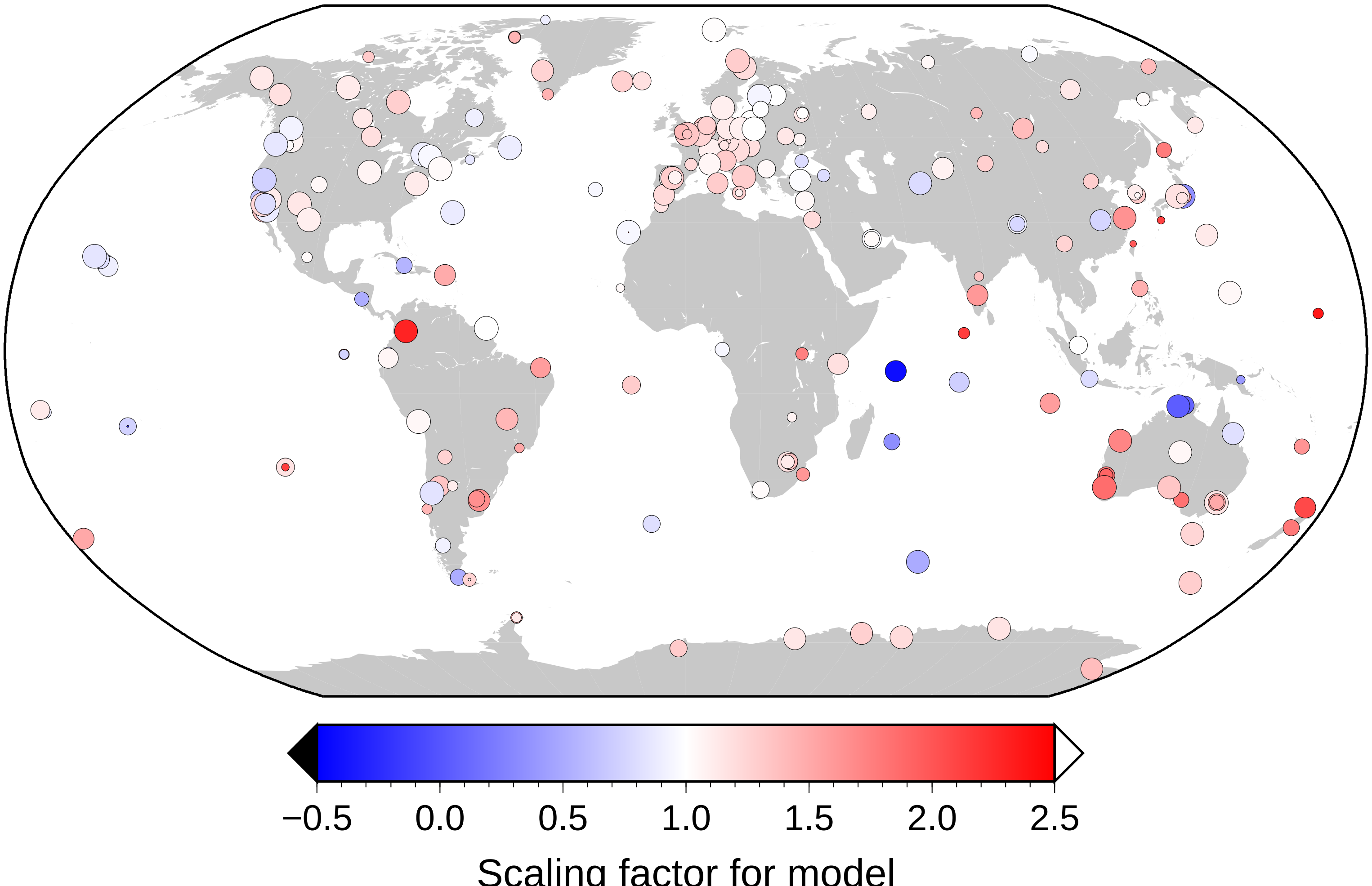
Evaluation 3:

- Tidal component is directly applied to the observations
- Evaluation of the non–tidal loading model by estimating scaling factors for each component and station
  - scaling factor of one: model is fully confirmed
- These scaling factors are introduced as “usual” parameters in the analysis process and stacked on NEQ–level in the cumulative solution.

Estimated scaling factors for the model

Estimated scaling factors for the atmospheric loading model

Mean scaling factors over 15 years



Scaling factors for the model

Estimated scaling factors for the atmospheric loading model

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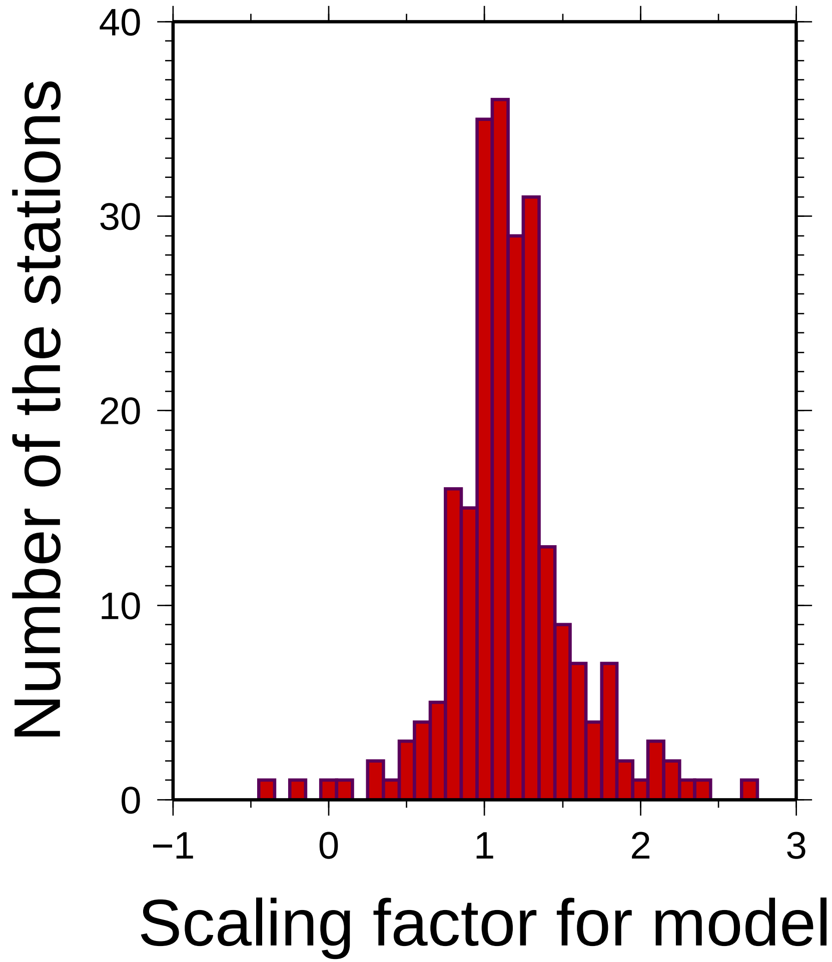

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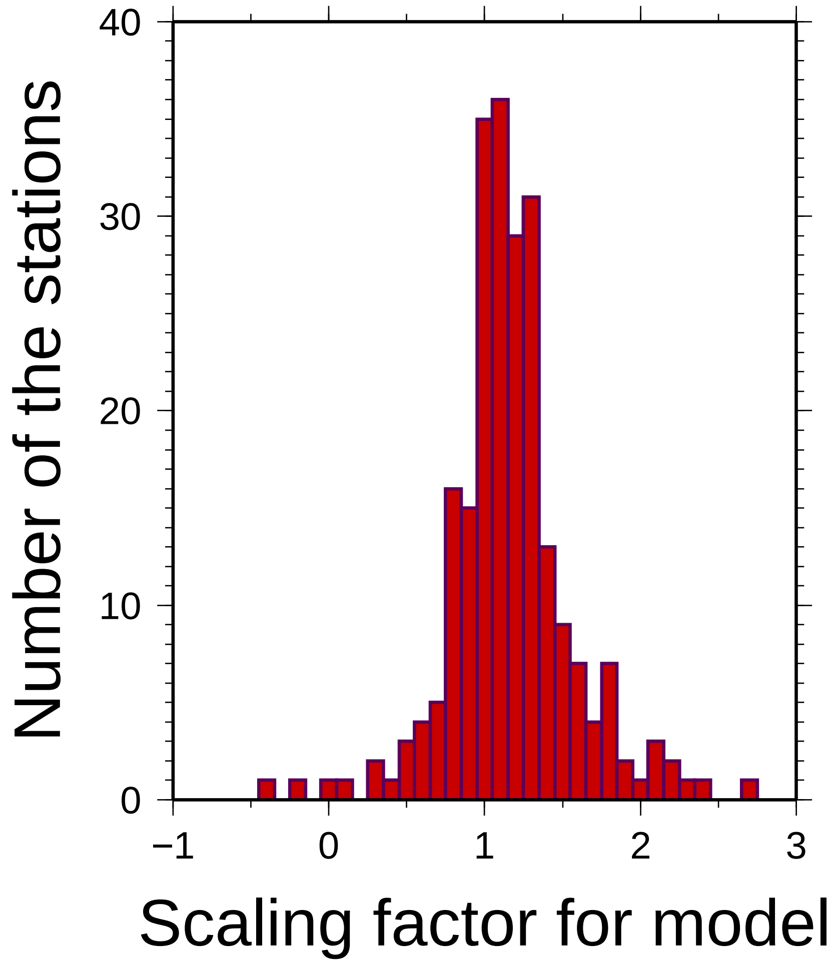
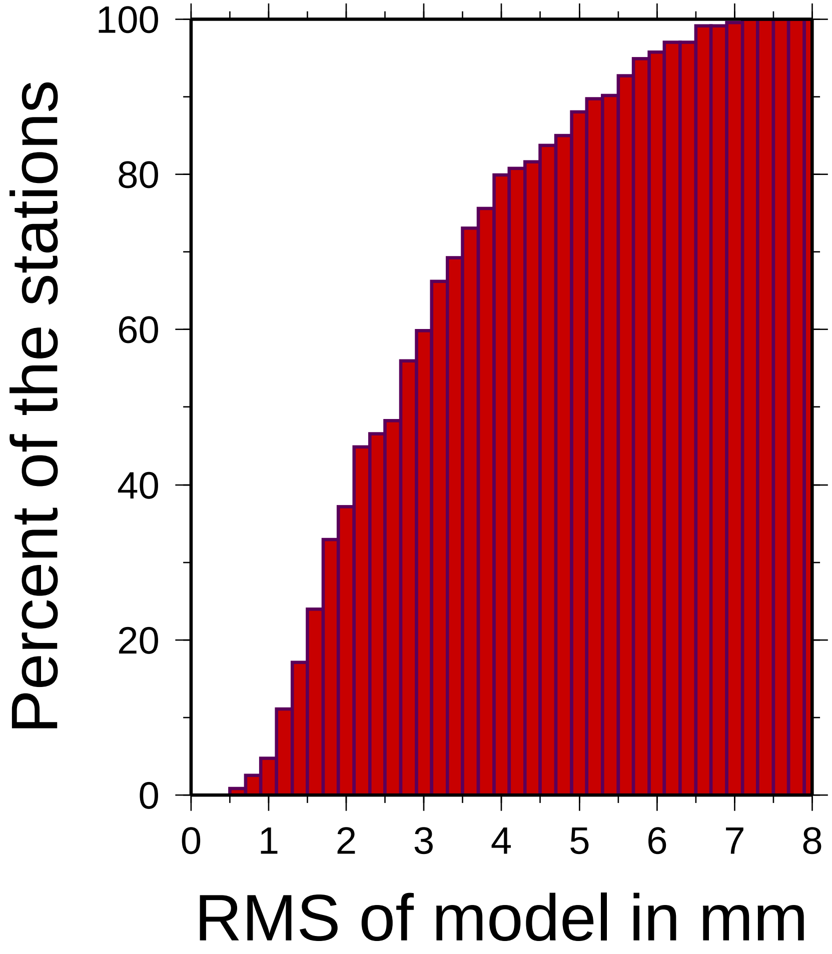


RMS of the corrections over 15 years



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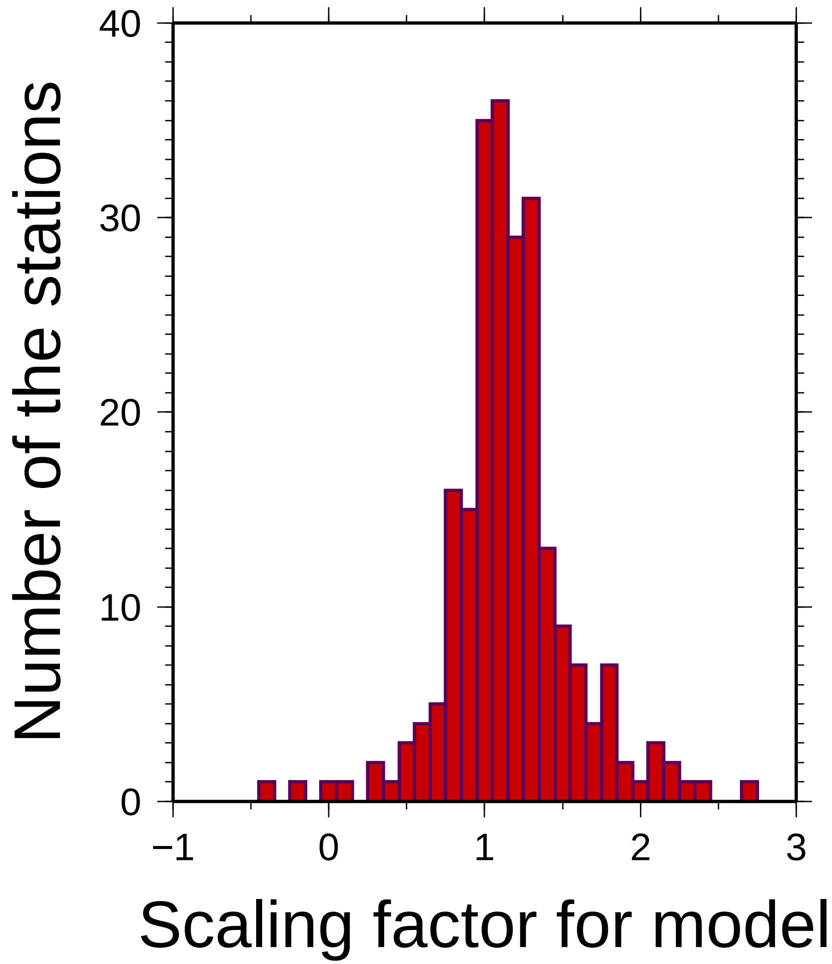
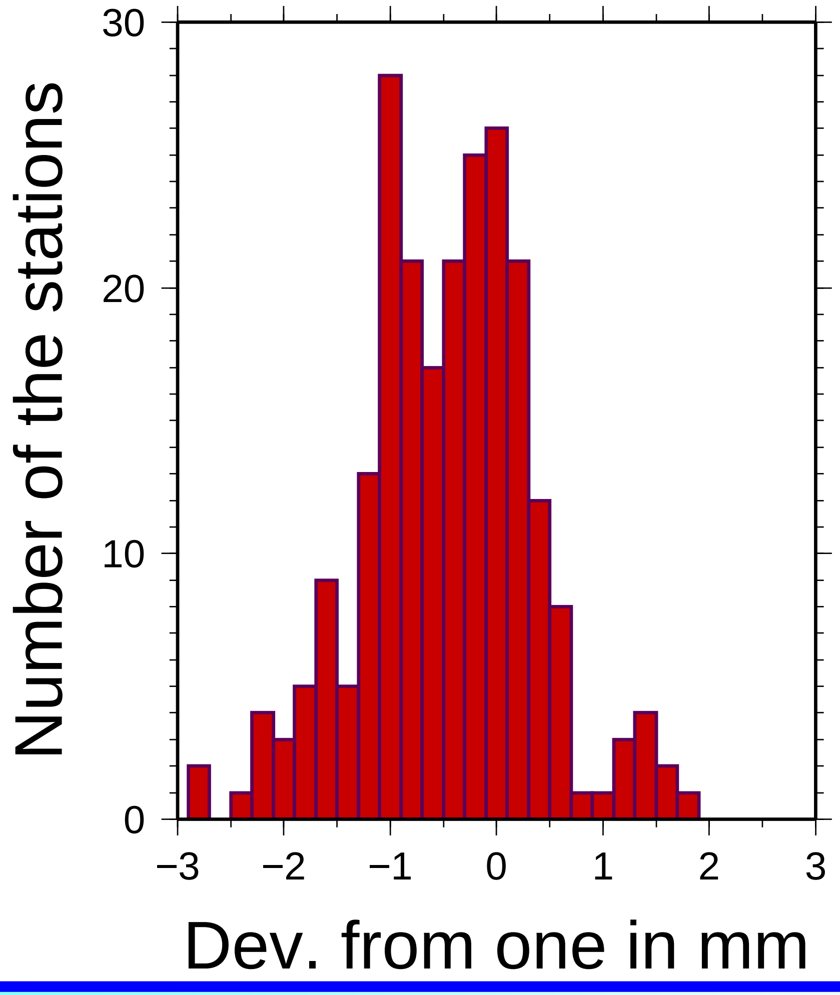
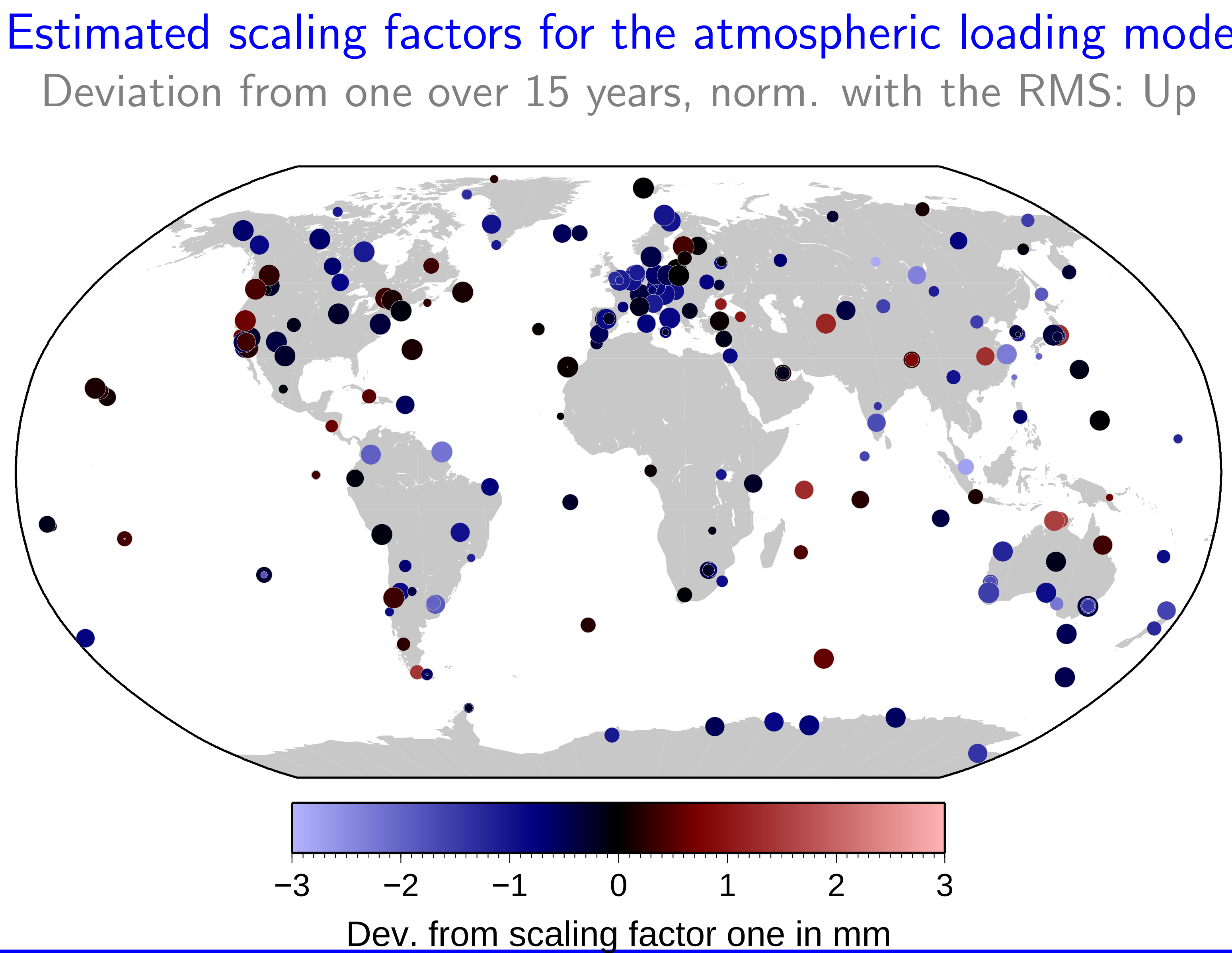


Dev. from one, norm. with RMS



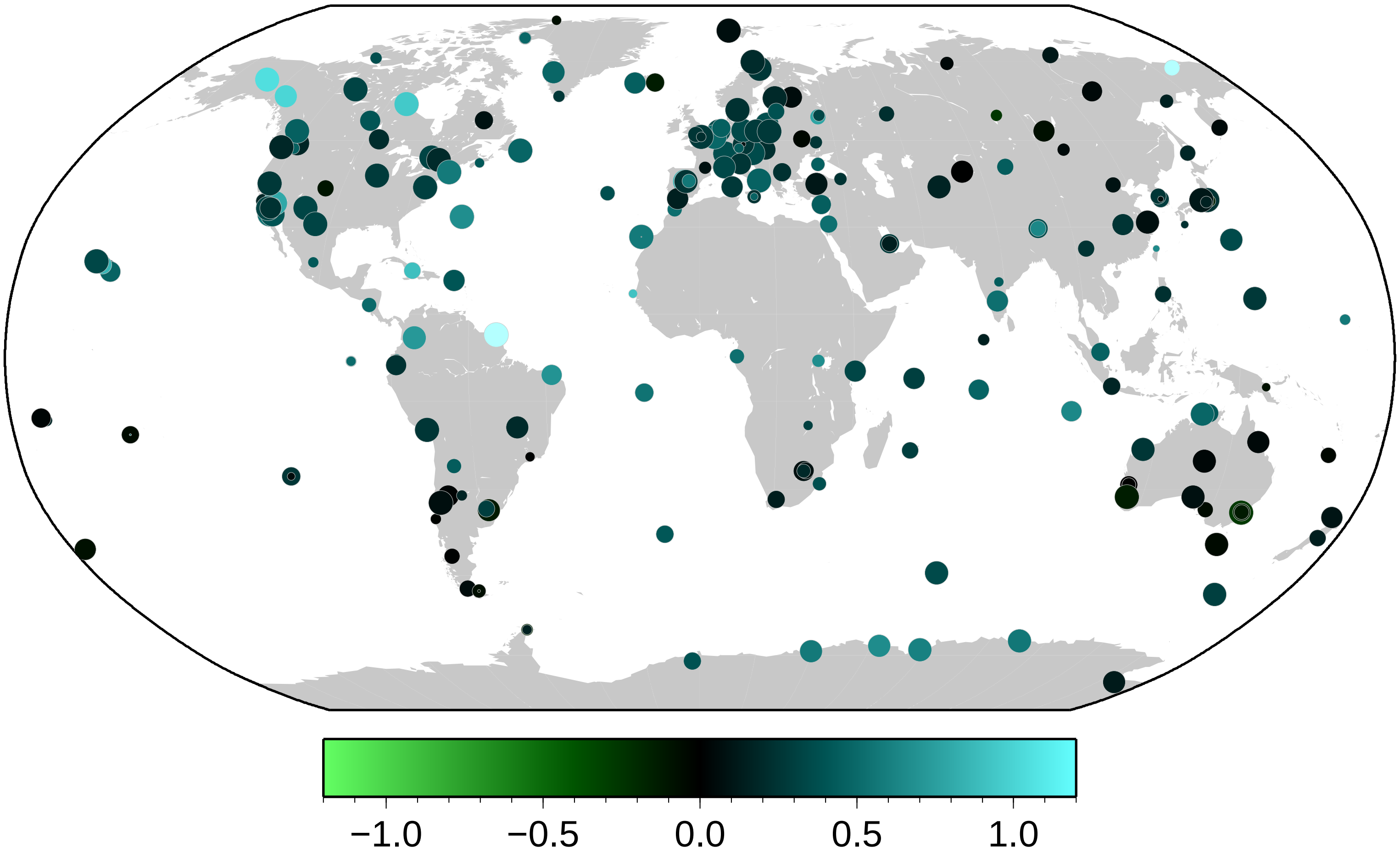
Estim. scaling factors for the model, norm. by RMS



Estim. scaling factors for the model, norm. by RMS

Estimated scaling factors for the atmospheric loading model

Deviation from one over 15 years, norm. with the RMS: North



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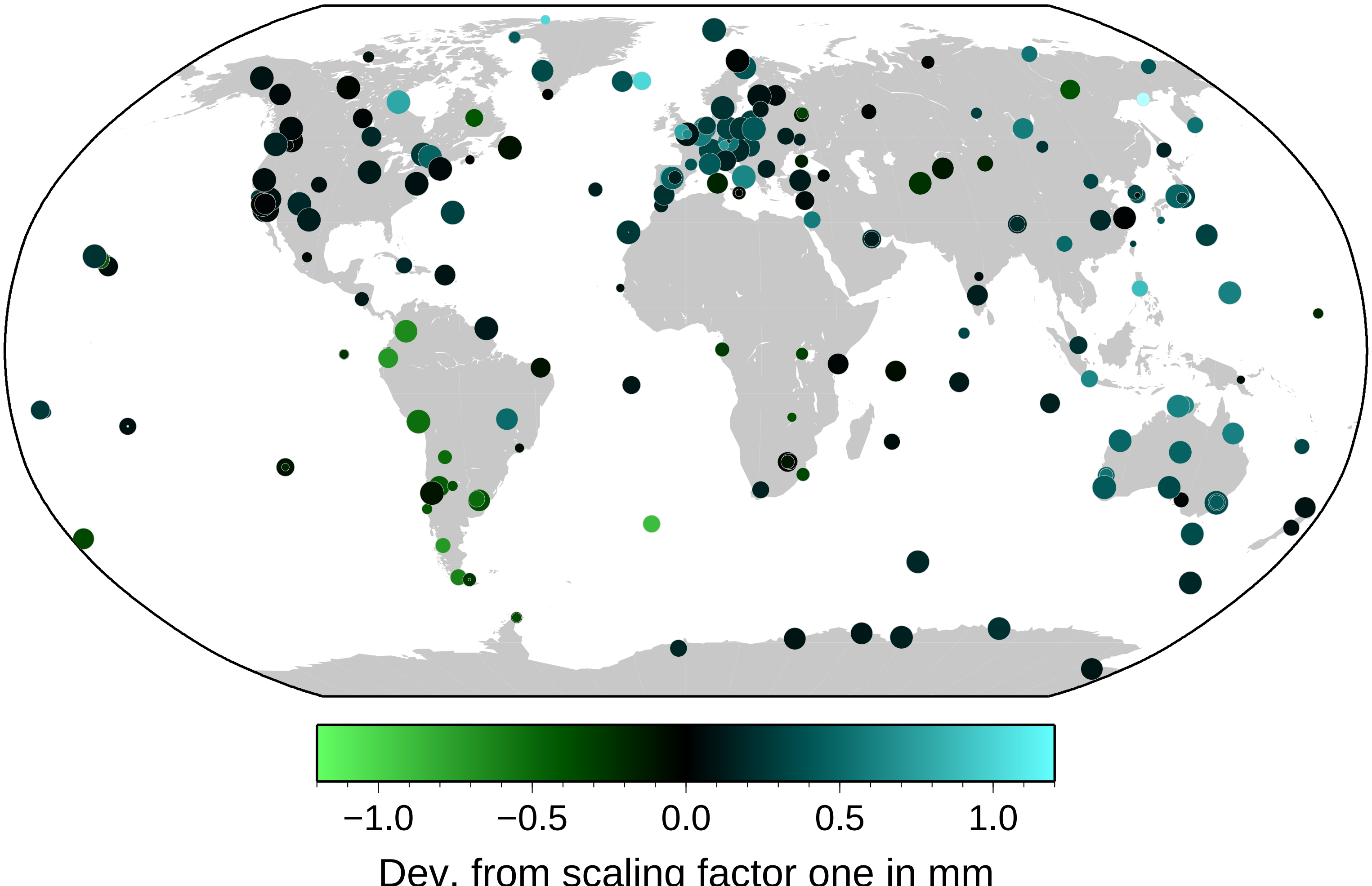
Estimated scaling factors for the atmospheric loading model

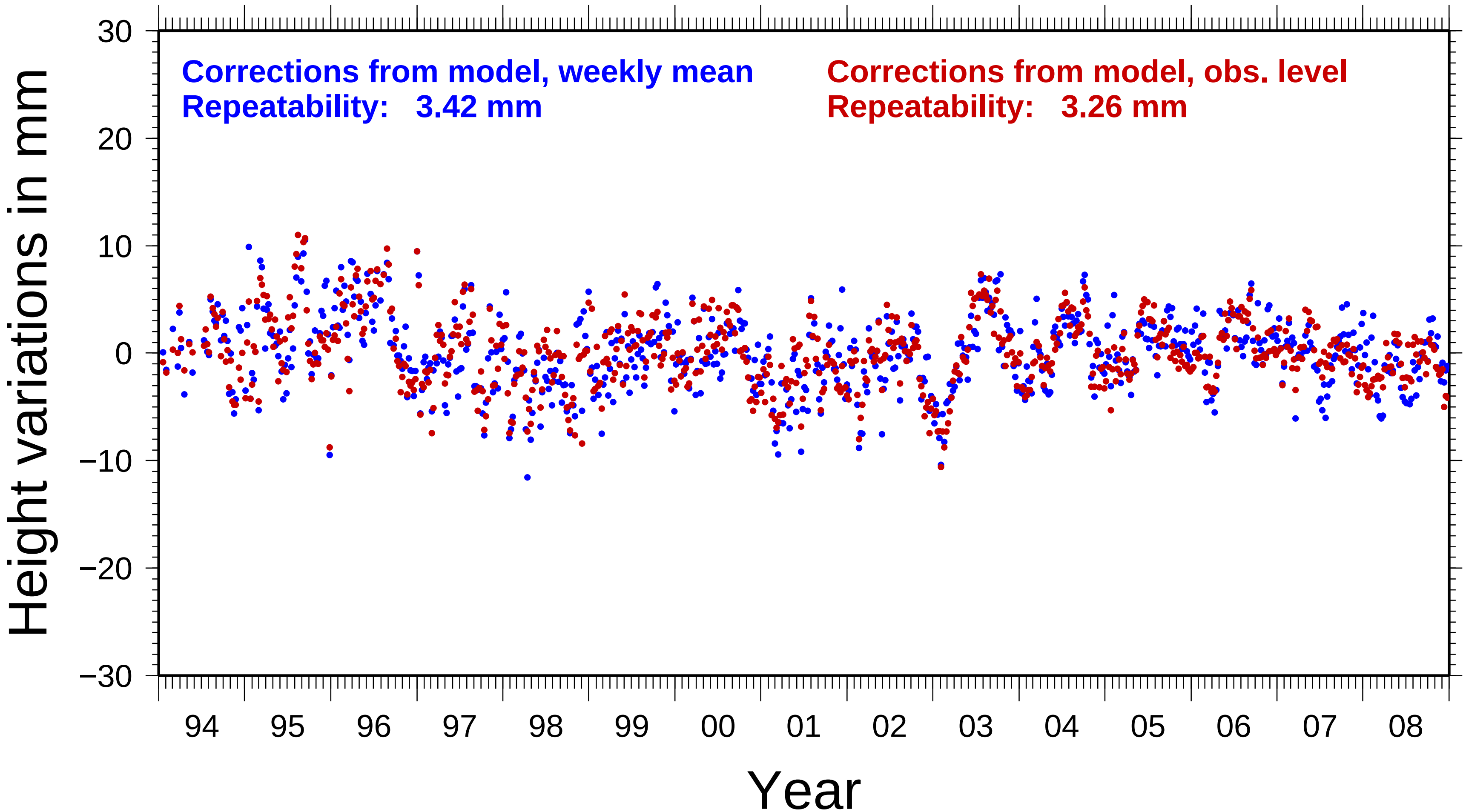
Deviation from one over 15 years, norm. with the RMS: East



Scaling factors for the model

Repeatability of the weekly solutions considering atm. loading

Example: Zimmerwald (ZIMM), Switzerland



Scaling factors for the model

Evaluation of the scaling factors for the atm. loading model

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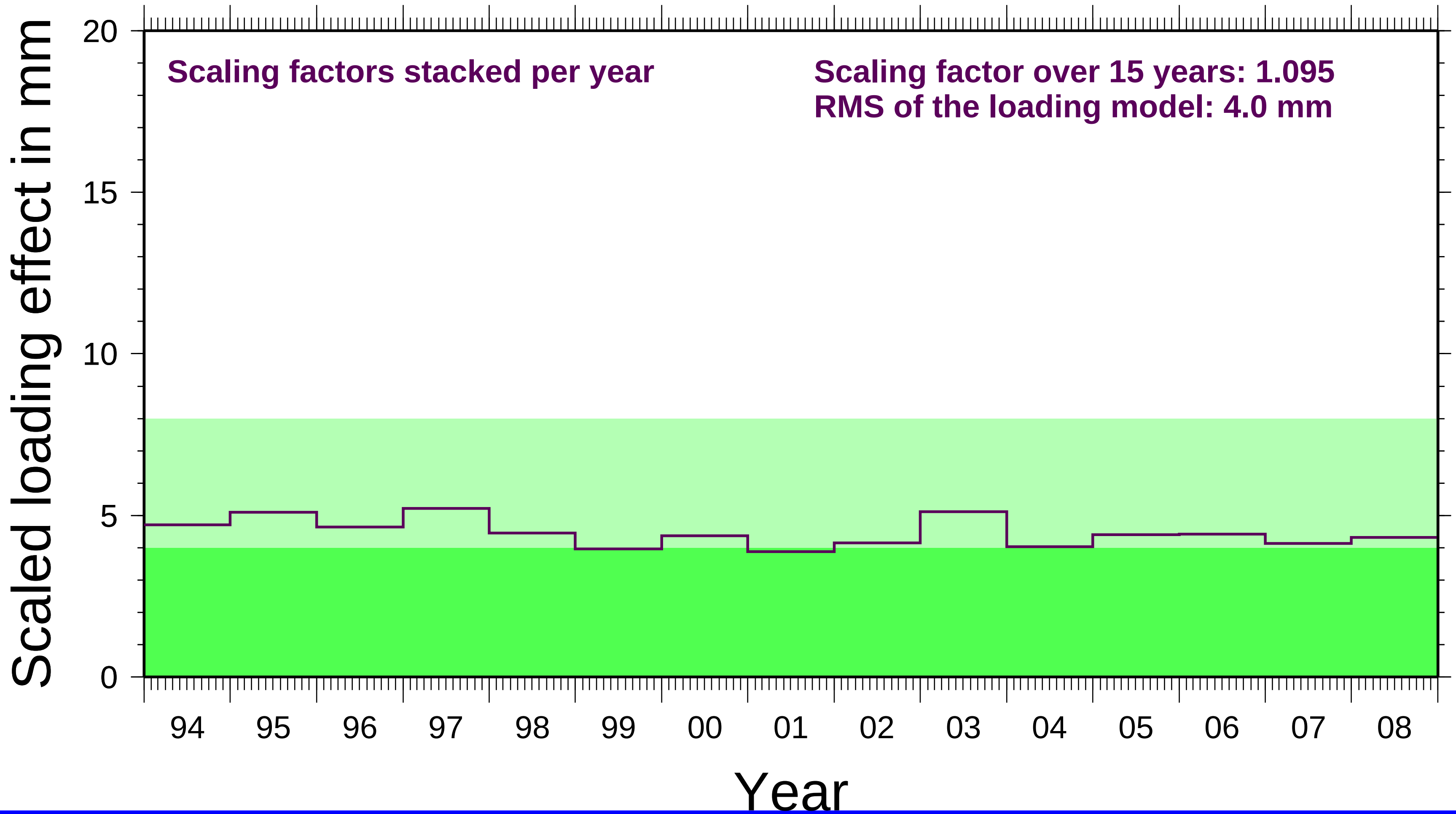

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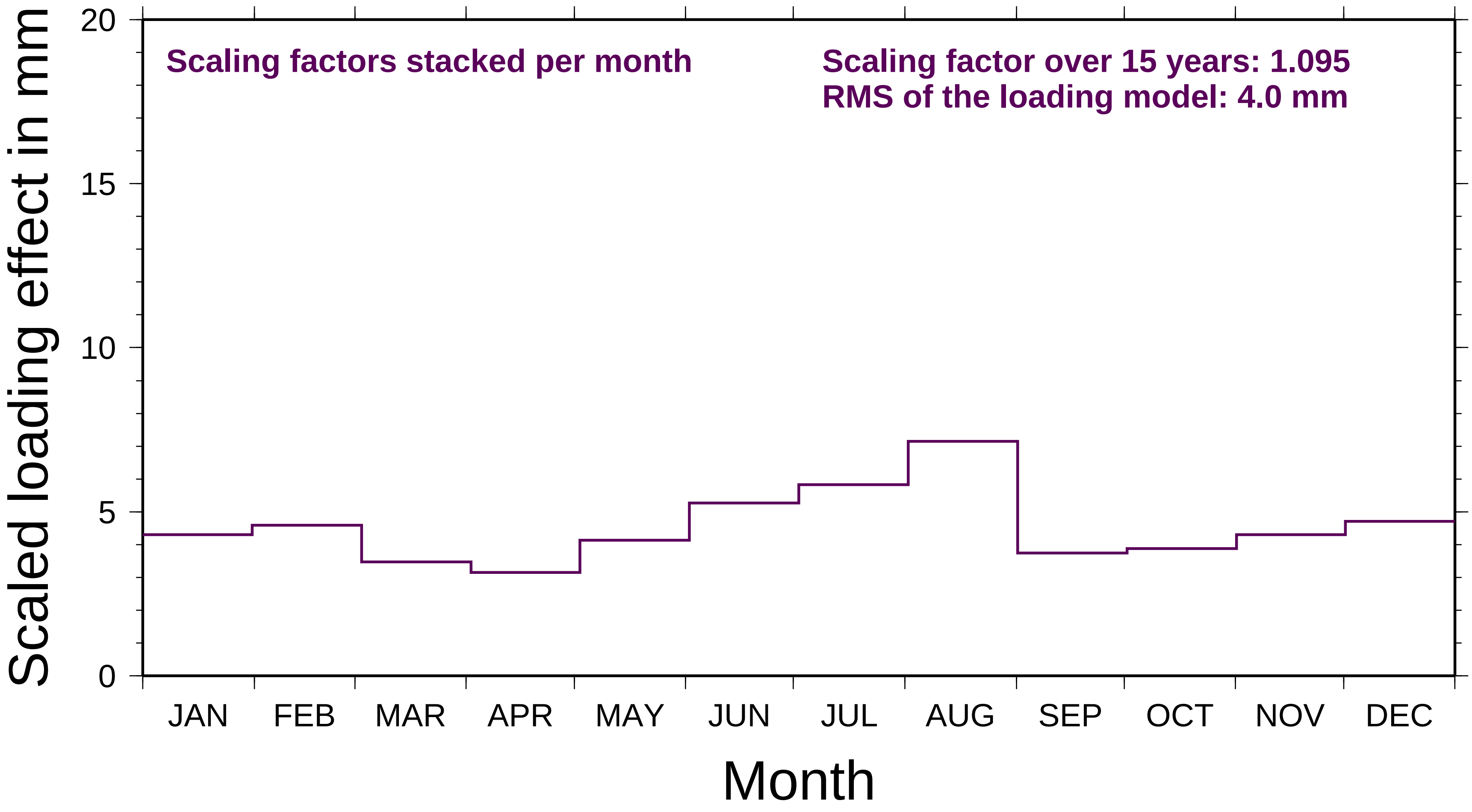

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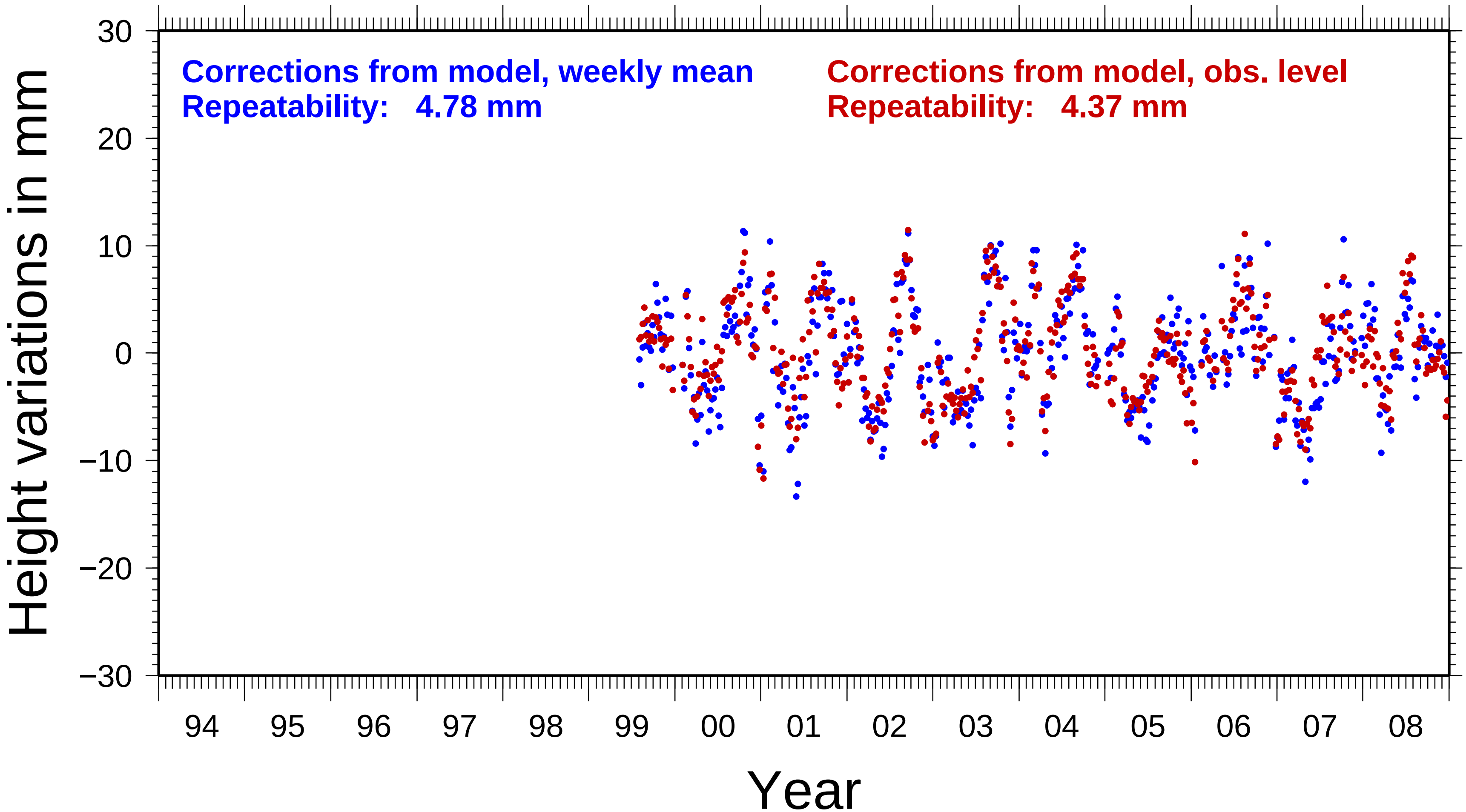

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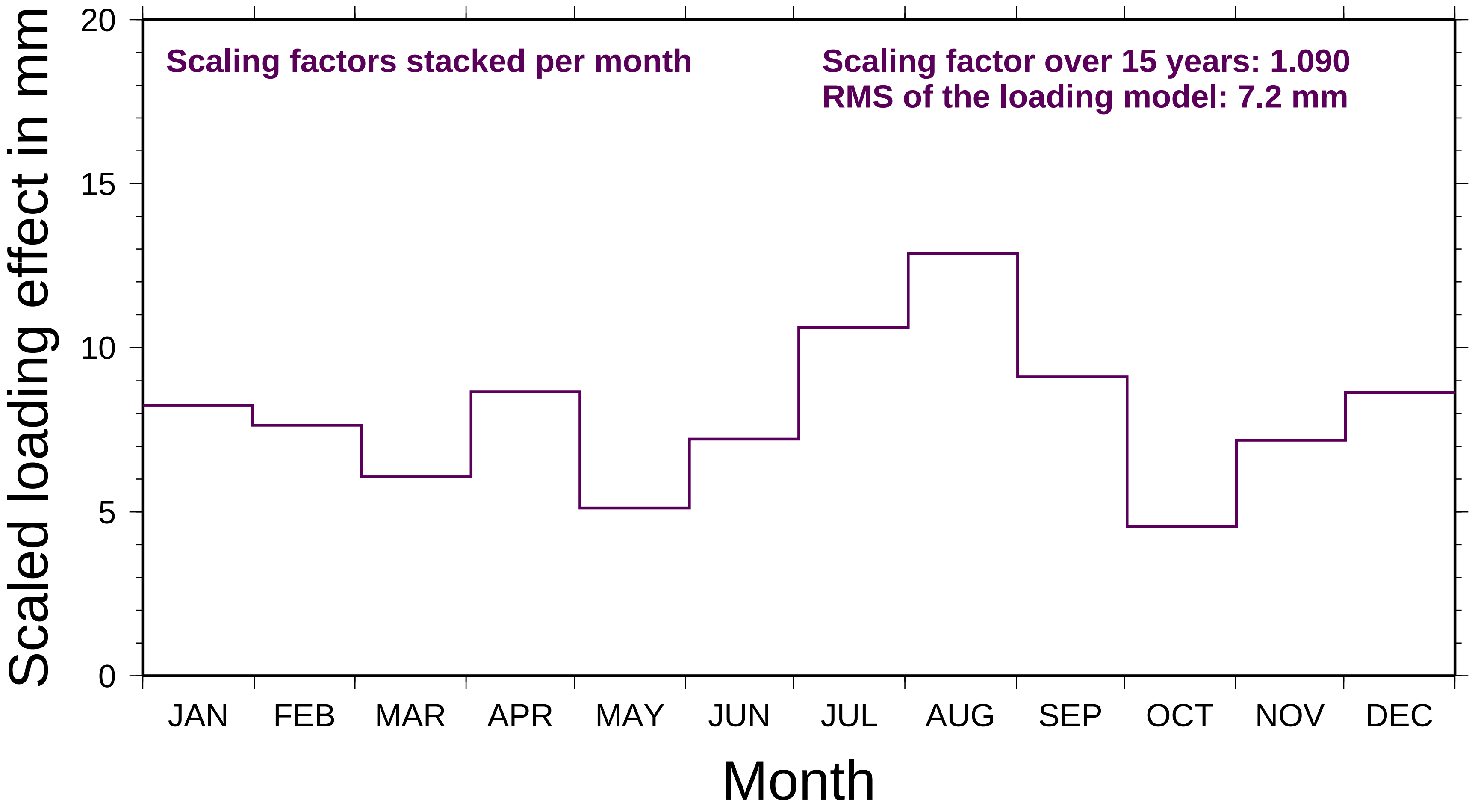
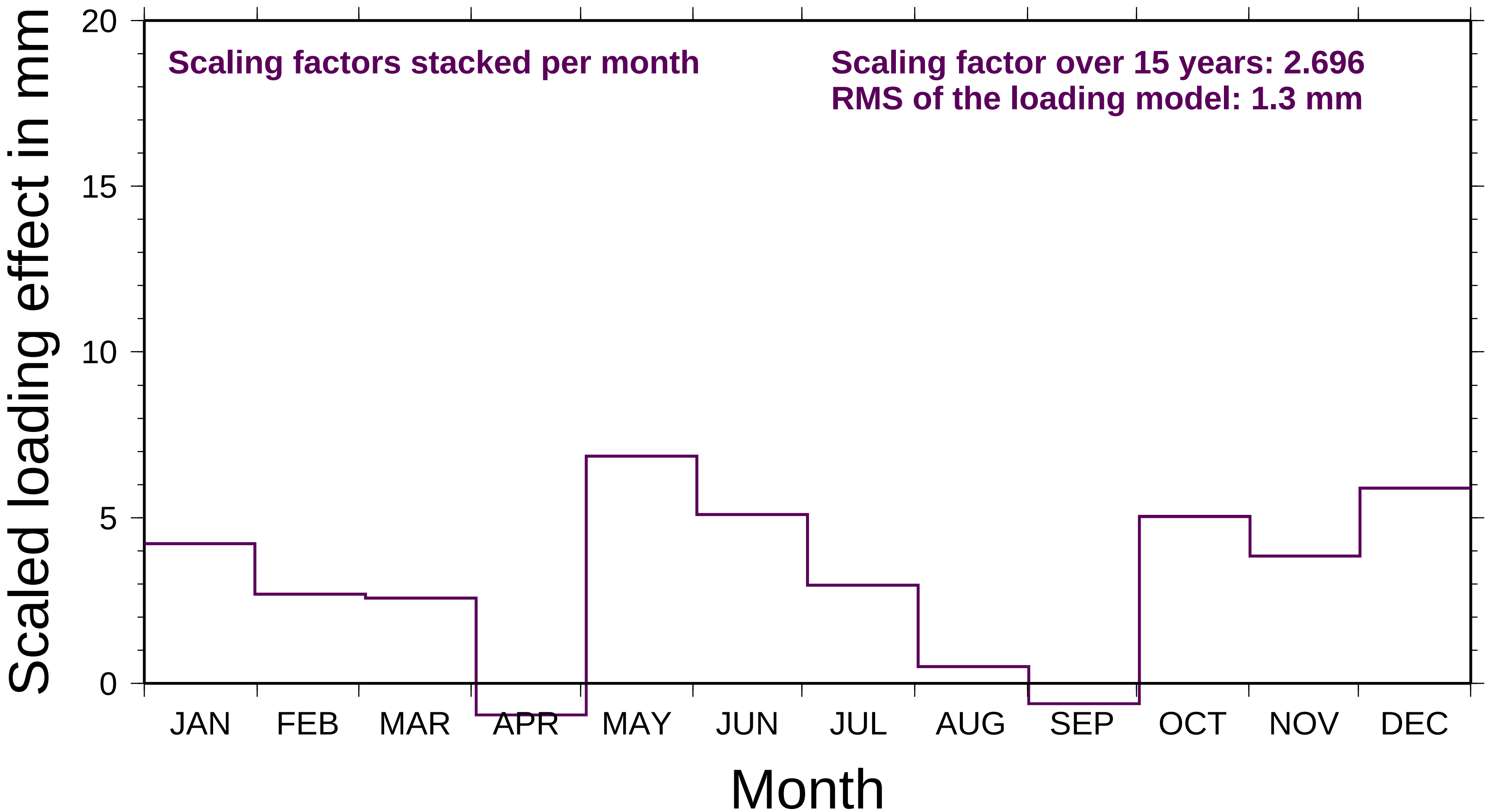


Scaling factors for the model

Evaluation of the scaling factors for the atm. loading model

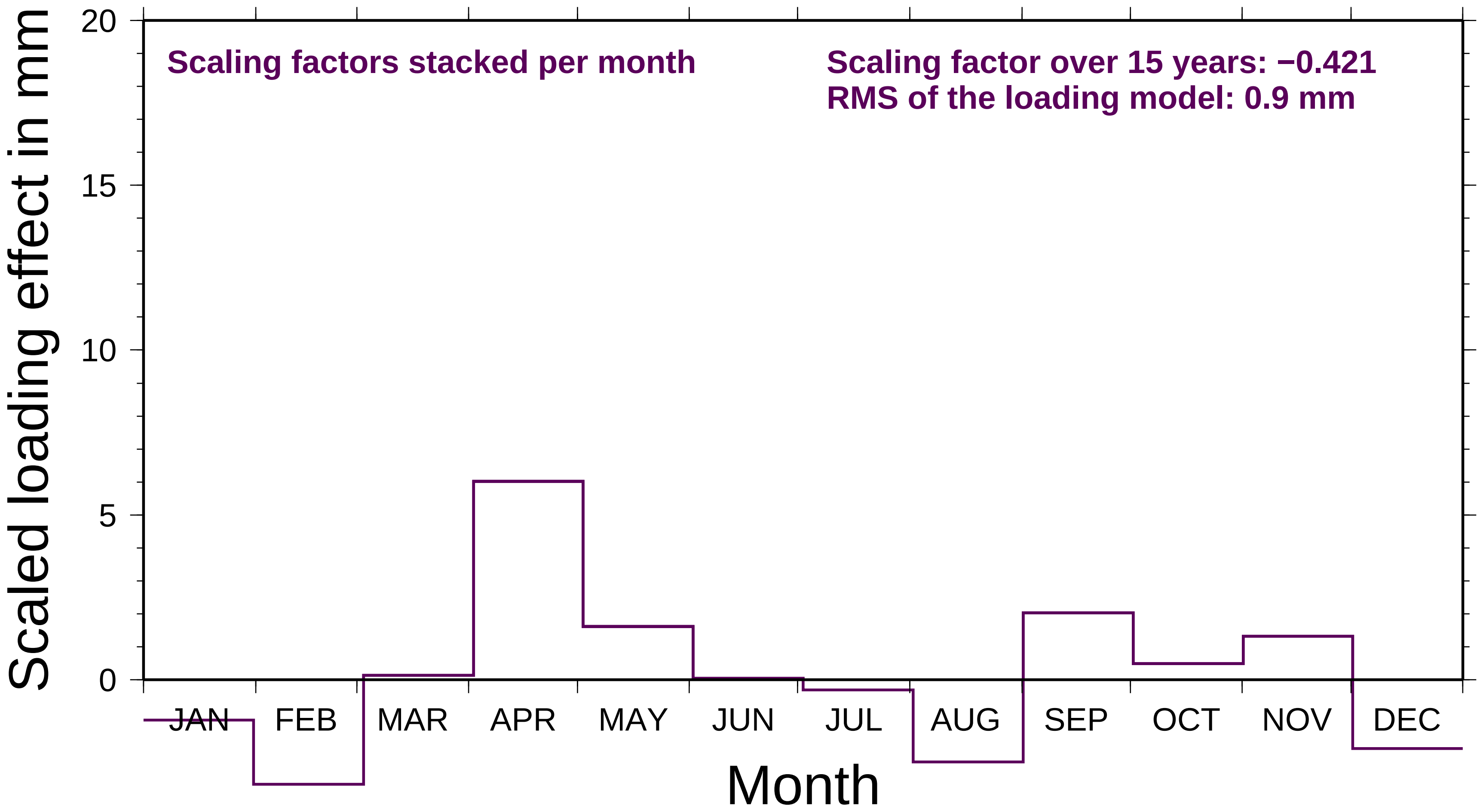
Example: Kourou (KOUR), French Guyana



Scaling factors for the model

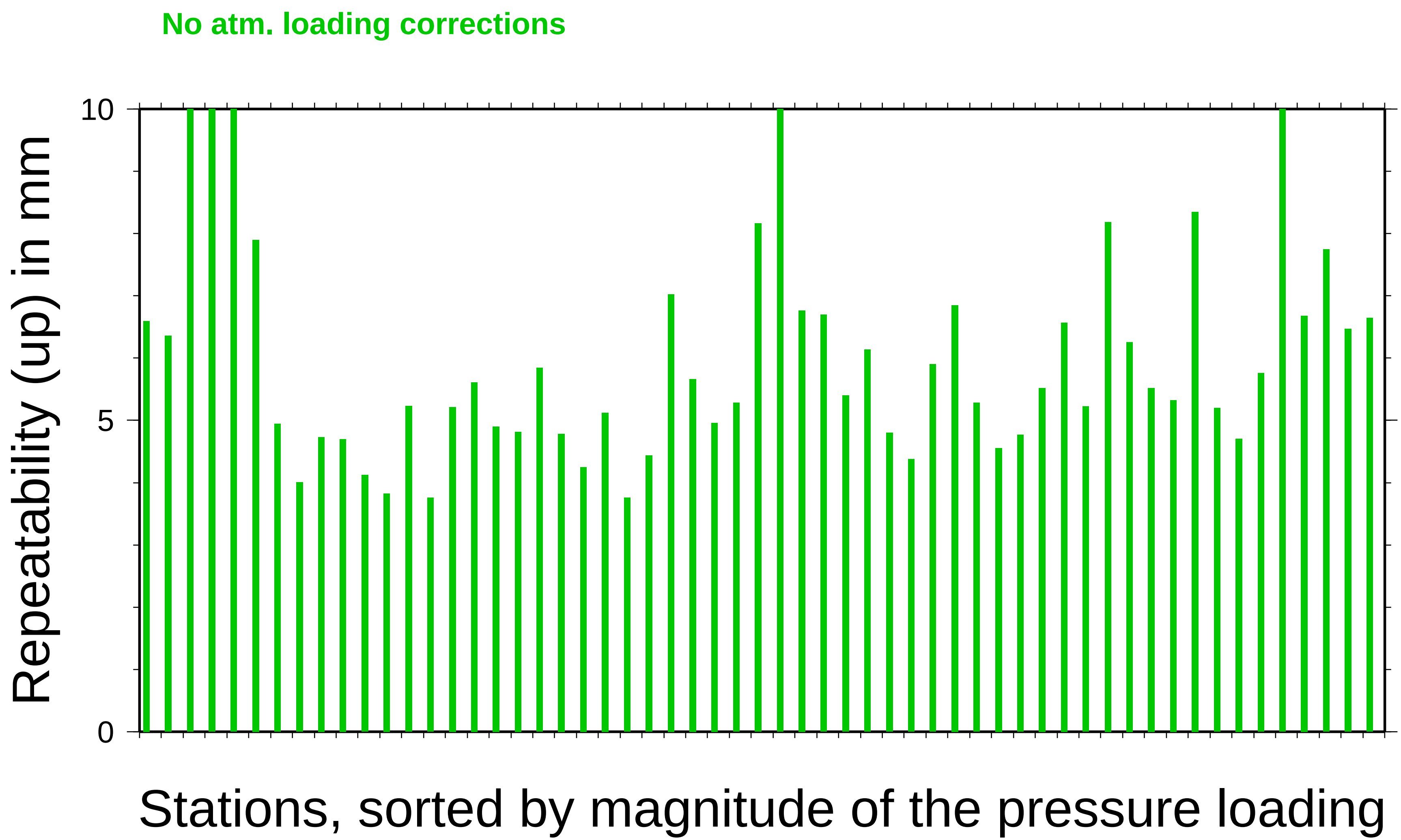
Evaluation of the scaling factors for the atm. loading model

Example: La Misere (SEY1), Seychelles



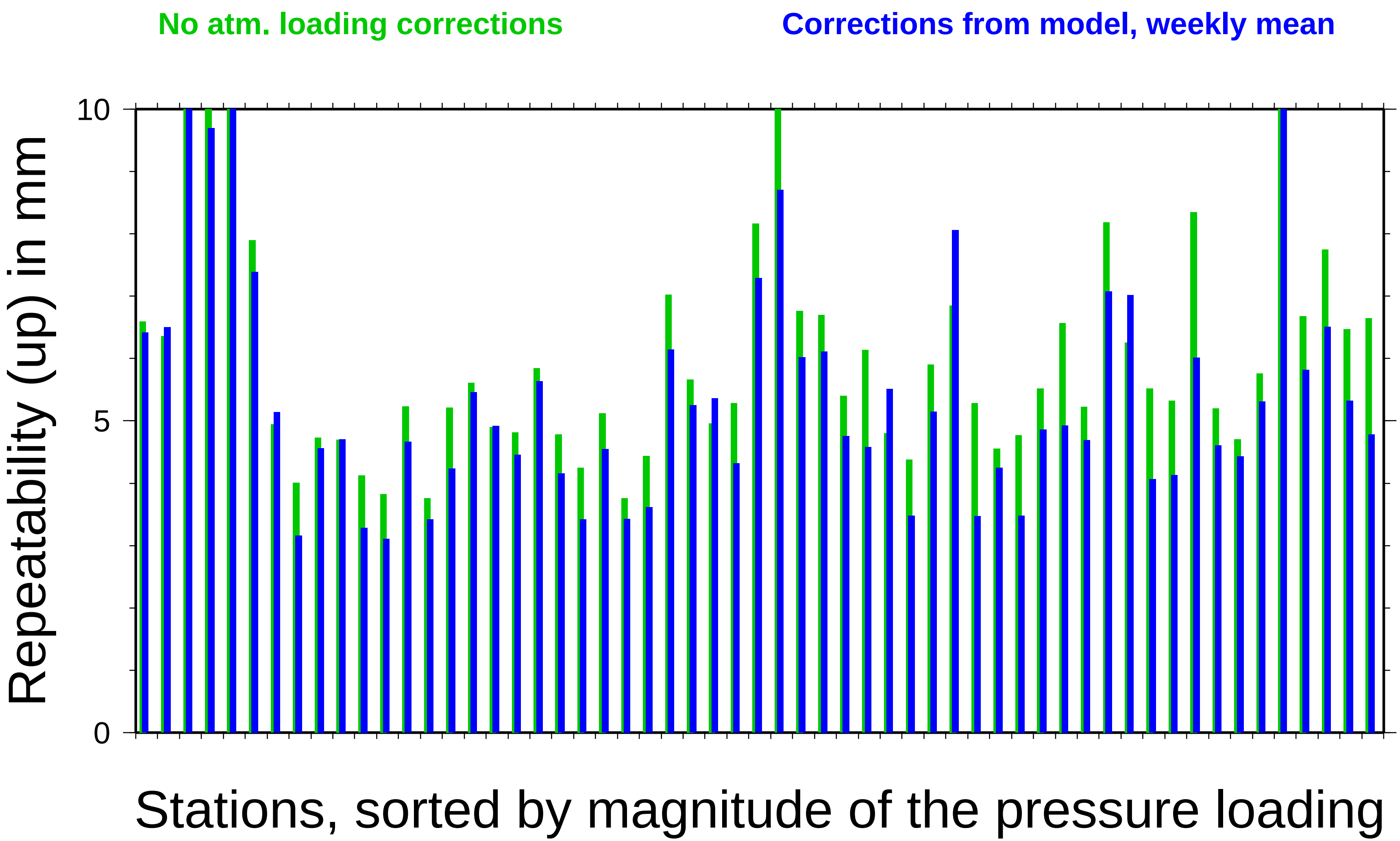
Repeatability of the coordinate solution

Repeatability of the weekly solutions



Repeatability of the coordinate solution

Repeatability of the weekly solutions considering atm. loading



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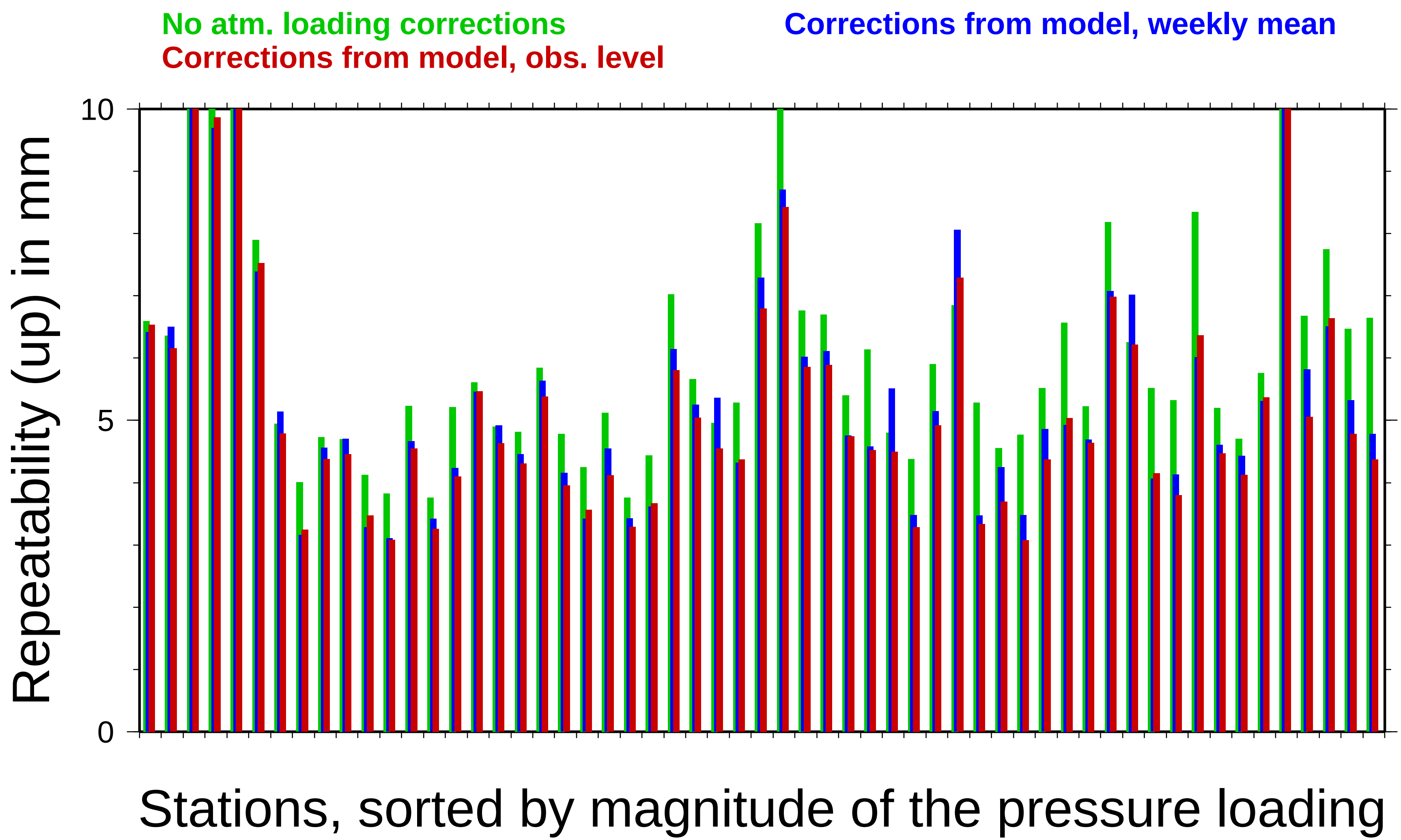

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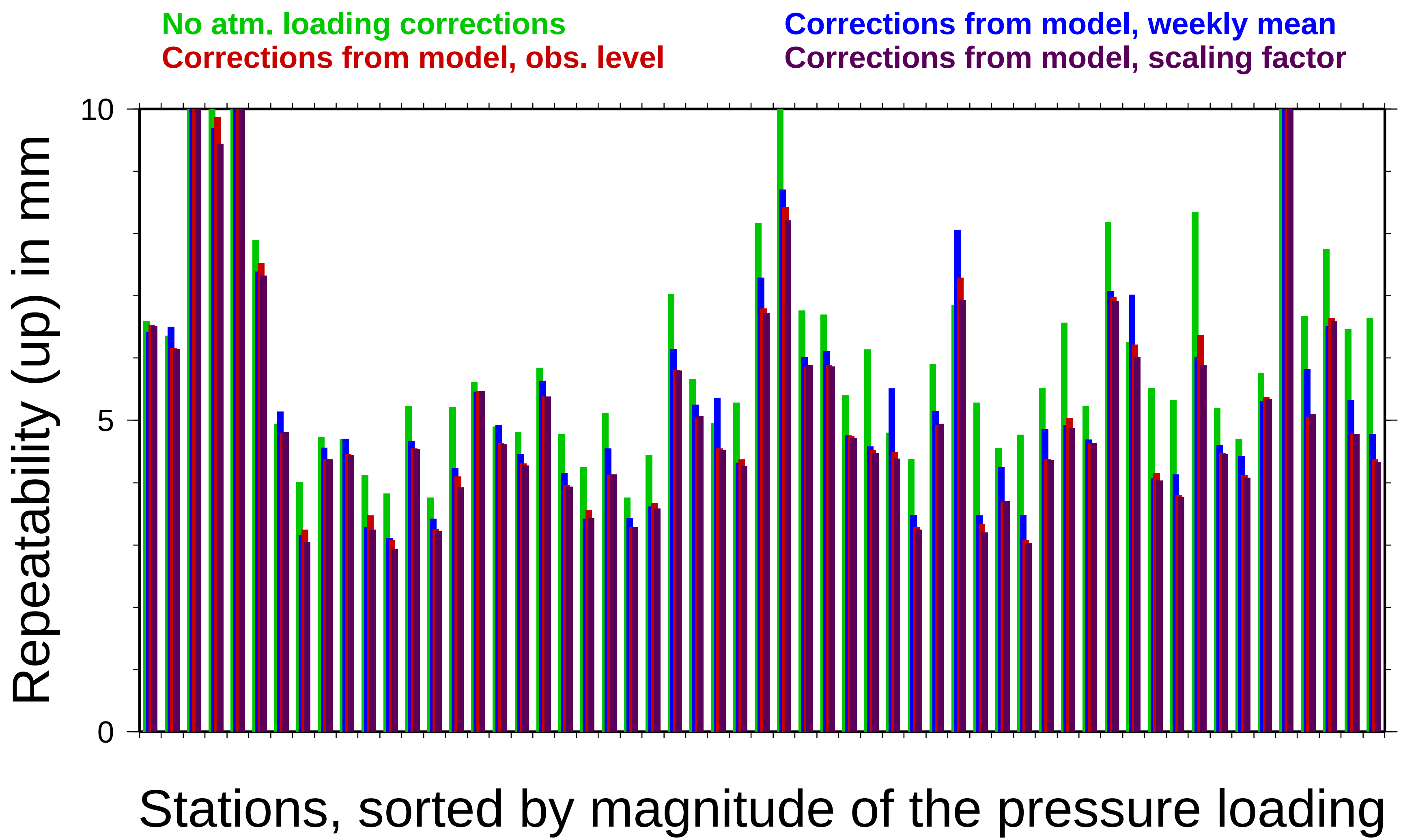
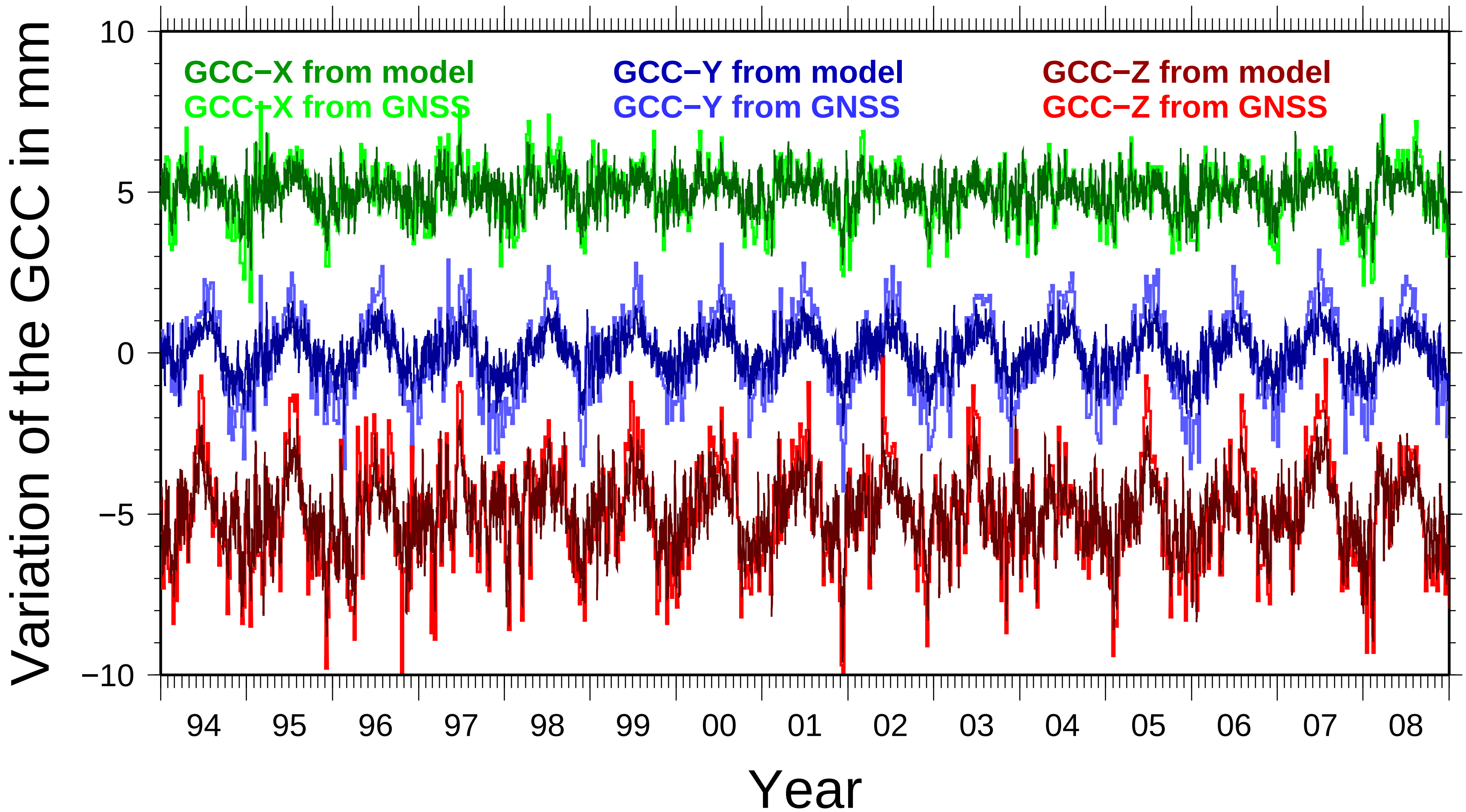


Fictive Variation of the Geocenter

Comparison between the model and the solution

GNSS: difference of the translation parameters with/without atm-load model



Pressure loading model: results for far

Can atmospheric pressure loading explain these seasonal variations?

- Example: Atmospheric pressure loading model from Petrov and Boy, 2004
  consists of two components
  - S1/S2 tidal pressure loading coefficients
  - 2.5×2.5 grids for the non–tidal component every 6 hours

Results so far:

- Atmospheric pressure loading does not explain the seasonal variations.
- Nevertheless, the effect was identified in the GNSS coordinate time series:
  - confirmed by estimated scaling factors
  - improvement of the repeatability of the weekly station coordinate time series
  - a systematic impact on the estimated geocenter coordinates was found

Pressure loading model: evaluation 4

There are influences on other GNSS related parameters?

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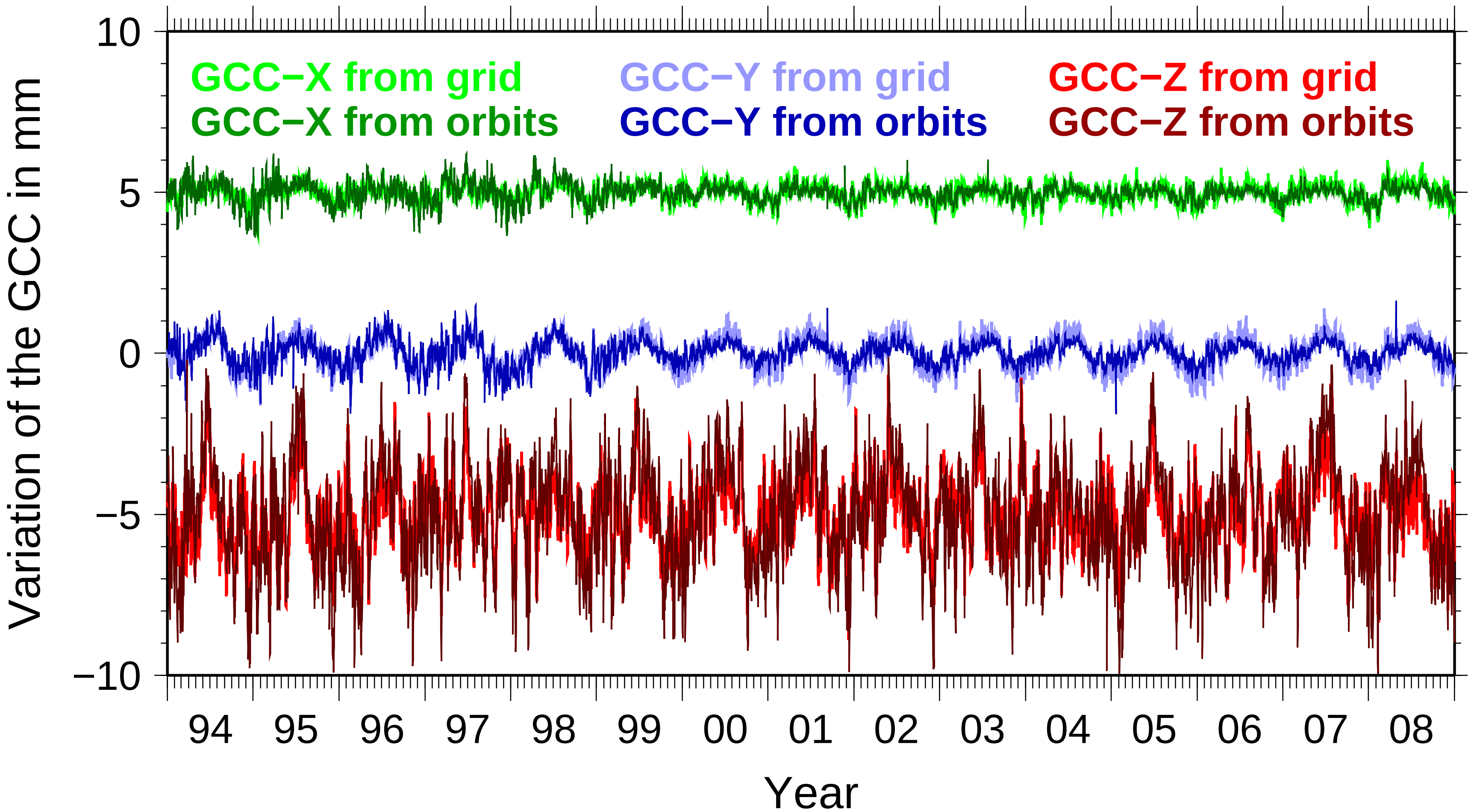
Evaluation 4: GNSS Orbits

- compensation for the variation of the GCC (daily independent GCC)
- Estimation of the GNSS orbits by 15 parameters:
  - initial conditions
  - constant and once–per–revolution in a DYX–satellite–Sun oriented system
  - no constraints to the orbit parameters

Pressure loading in the GNSS orbits

Comparison between the model and the solution

GNSS: translations between the orbits with/without atm-load model



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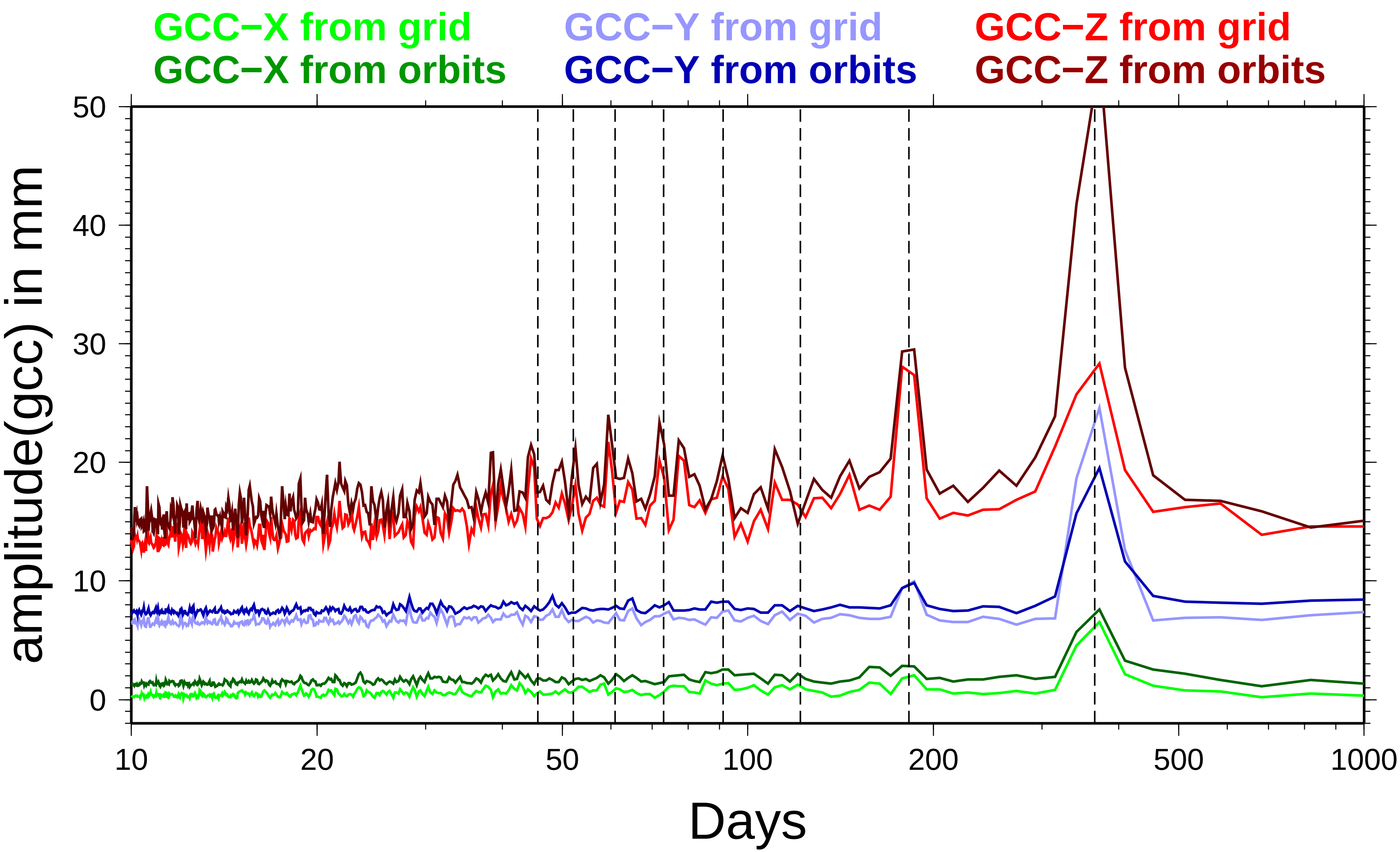

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  - with constraints to once–per–revolution parameters, as CODE

Pressure loading in the GNSS orbits

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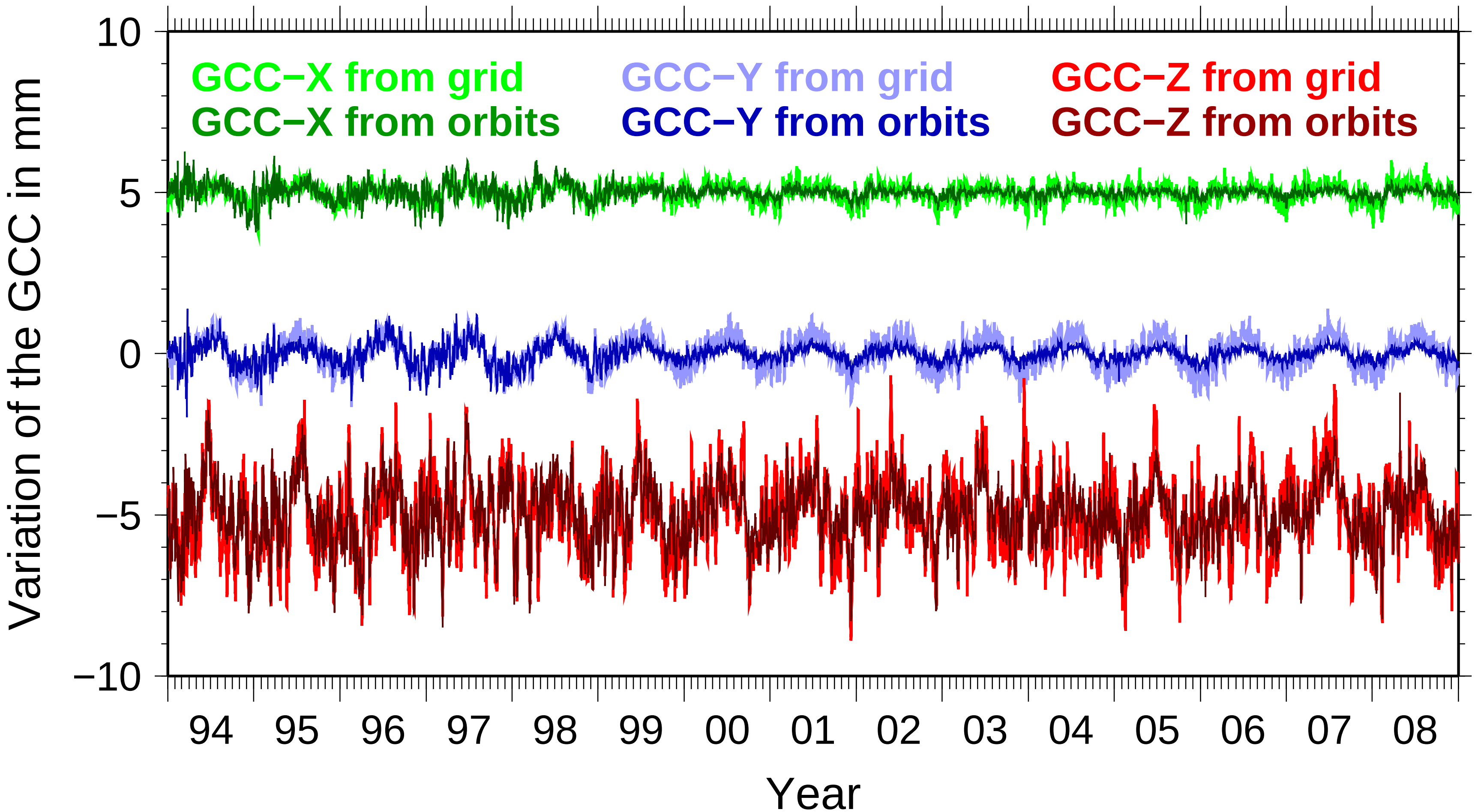

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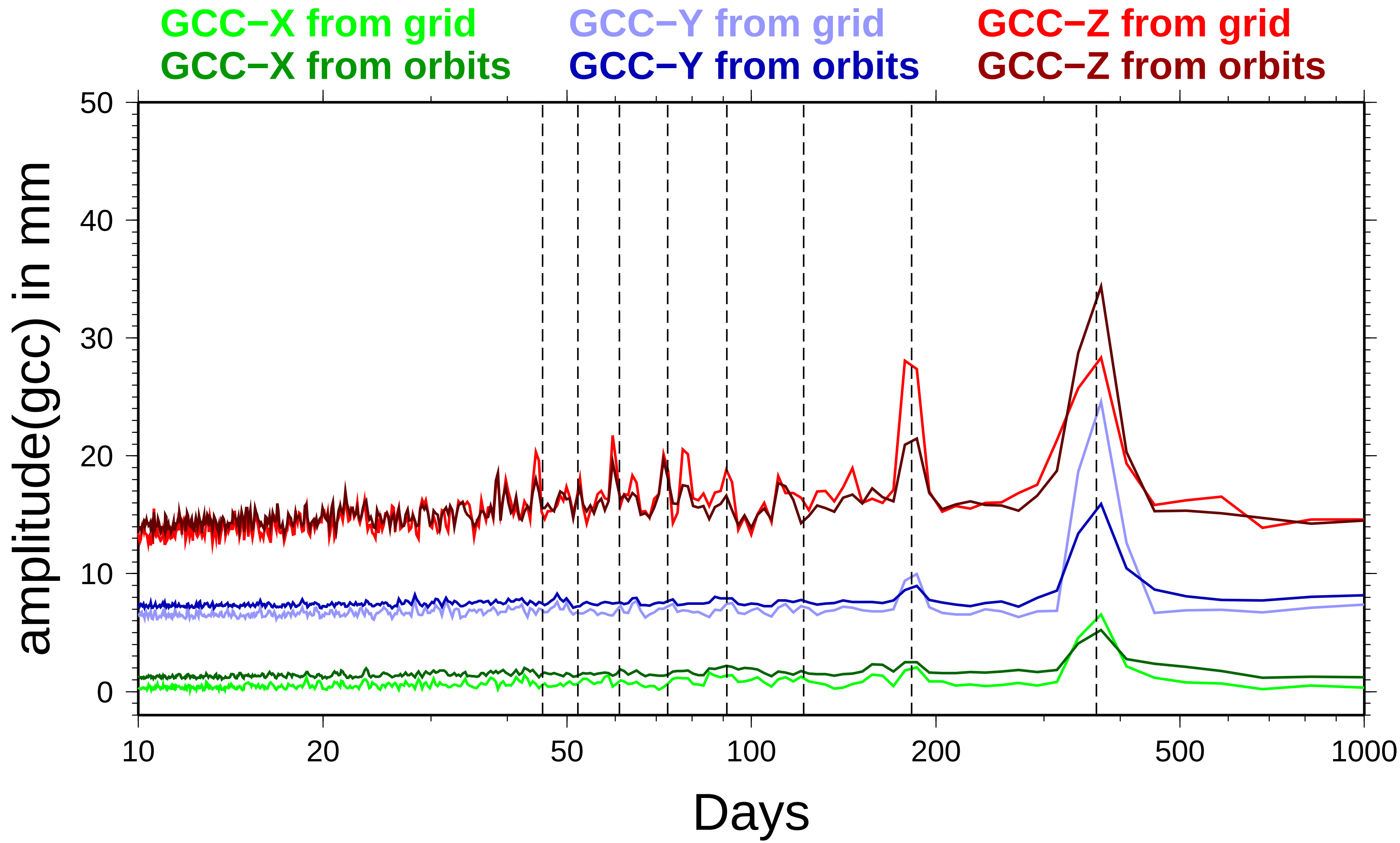

Conclusions and outlook

- The effect of atmospheric loading can be clearly seen in GNSS–derived coordinate time series (weekly solutions) and need to be corrected for to generate a reference frame.
  (compatibility between the solutions/techniques)

- Atmospheric loading models can be used to correct for this effect — an improvement of the repeatability of up to 20% can be achieved.

- The correction has to be preferably done at the observation level (at least a weekly coordinate solution is a too long interval).

- The GCC component of the atmospheric loading translates into the satellite orbits if no proper a priori constraining of the once–per–revolution parameters is introduced.

Conclusions and outlook

- The atmospheric loading model from Petrov and Boy (2004) has been confirmed by the estimation of station–wise scaling factors within the expected uncertainty range.

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- The latency of the model from Petrov and Boy (2004) is insufficient for the IGS final processing.

Technical requirements for an atmospheric loading model from the perspective of an IGS analysis center:

- consistent time series from 1994 to present
  - for other techniques even earlied
- latency less than 3 days for the finals (with exceptions up to 7 days)
  - three to four hours after midnight for the rapid