European Gravity Service for Improved Emergency Management

Validation of daily EGSIEM gravity fields with GNSS

Overview of validation work within WP5

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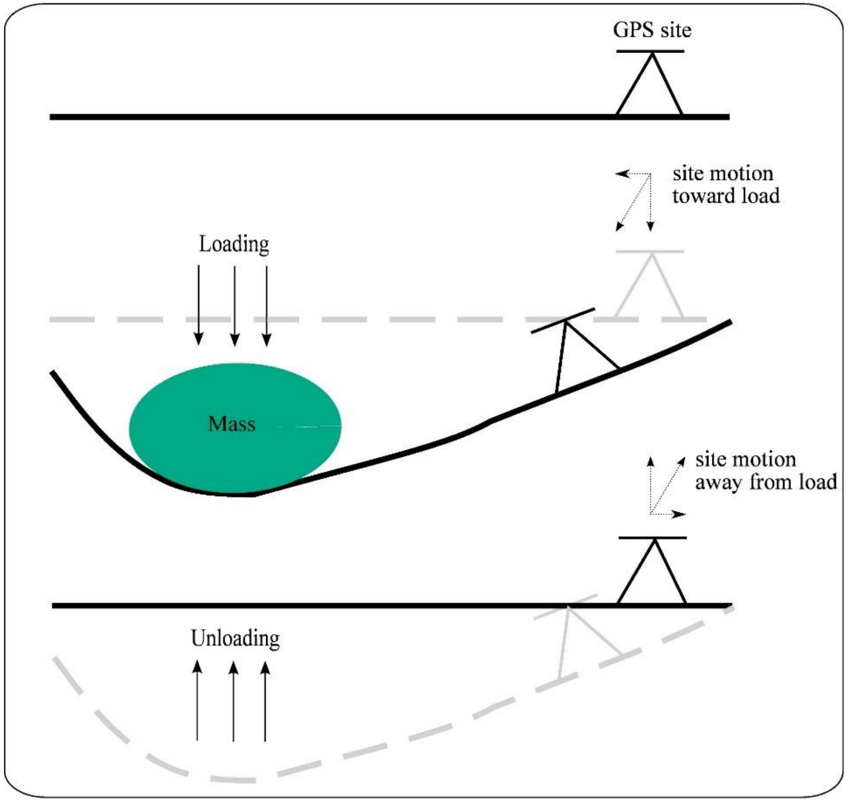
EGSIEM Final Project Meeting

8-9 February 2018

Objectives

- Validation of EGSIEM daily gravity fields from TUG and GFZ
  - 2002.04.04~2016.12.31
- Validation of EGSIEM NRT gravity fields from TUG and GFZ
  - 2017.04.01~2017.07.31

Concept of Validation



- GNSS observed vertical displacements
- GRACE-derived vertical displacements

$$u_r(\theta_P, \lambda_P) = R \sum_{n=0}^{\infty} \frac{h'_n}{1+k'_n} \sum_{m=0}^{n} \tilde{P}_{nm}(\cos\theta_P) \cdot (\Delta C_{nm} \cos(m\lambda_P) + \Delta S_{nm} \sin(m\lambda_P))$$

  - R: Earth's radius
  - h'_n, k'_n: loading Love numbers
  - $\tilde{P}_{nm}$: normalized Legendre functions
  - $\Delta C_{nm}, \Delta S_{nm}$: gravity spherical harmonic coefficients from GRACE

Metrics

- Correlation
- WRMS reduction and its variants
  - Degree WRMS reduction
  - Accumulative degree WRMS reduction

$$\textit{Degree}\ \mathrm{WRMS}\ \textit{reduction} = \frac{\mathrm{WRMS}\left[h_i^{\mathrm{GPS}}\right] - \mathrm{WRMS}\left[h_i^{\mathrm{GPS}} - h_i^{\mathrm{GRACE}^n}\right]}{\mathrm{WRMS}\left[h_i^{\mathrm{GPS}}\right]}$$

Degree WRMS reduction at the i^{th} GPS station

Compute GRACE-derived displacements using SH *at only degree n* **OR** *up to degree n*

Validation of daily EGSIEM gravity fields

Datasets

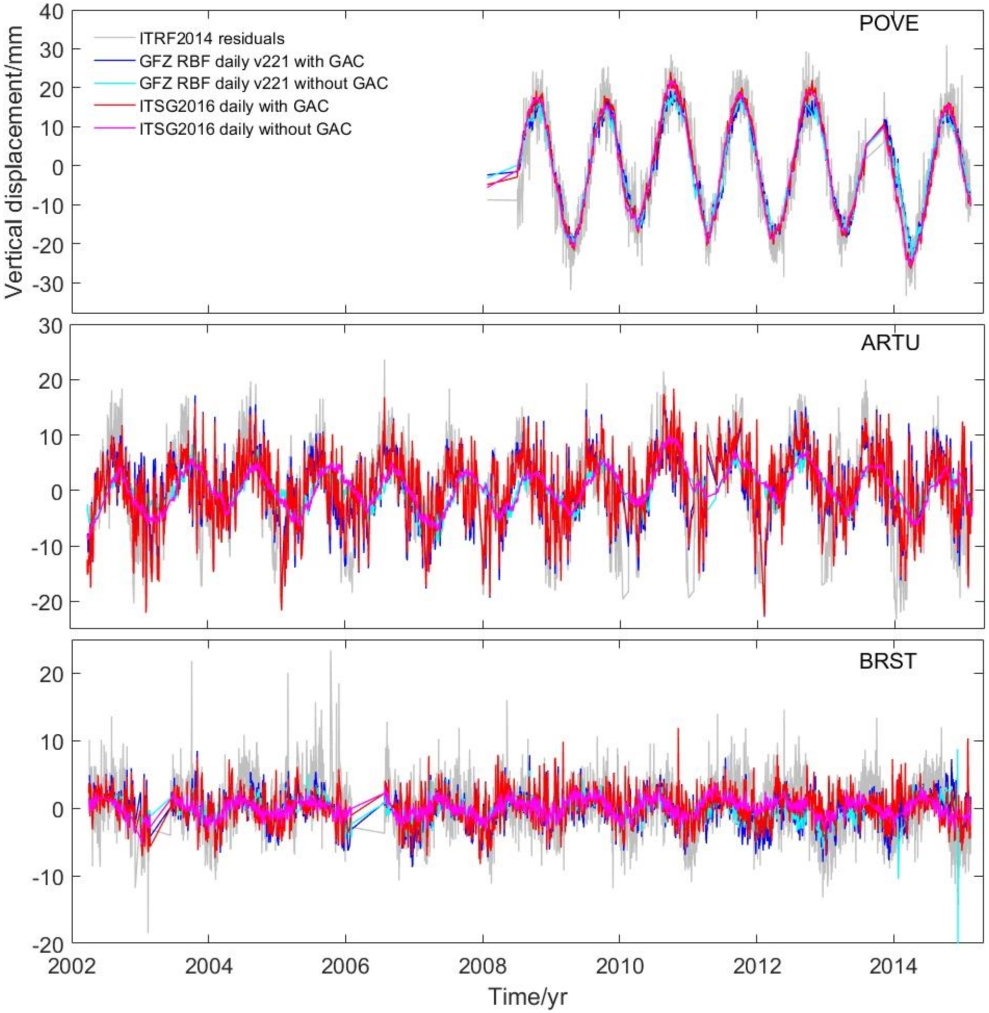
- Daily gravity Models
  - ITSG2016 daily gravity fields
  - GFZ RBF daily gravity fields
    - V100, V101, V200 (feedback at the forth project meeting, Bern)
    - V201, V211, V221 (feedback at the fifth project meeting, Munich)
    - modified V221 (after the fifth project meeting)
- GNSS data
  - Daily reference frame data (EGSIEM)
  - Daily ITRF2014 time series (IGN, France)
  - Daily JPL GNSS time series (Public available)
- Other external datasets
  - WGHM models
  - GLDAS models

Post-processing daily gravity fields

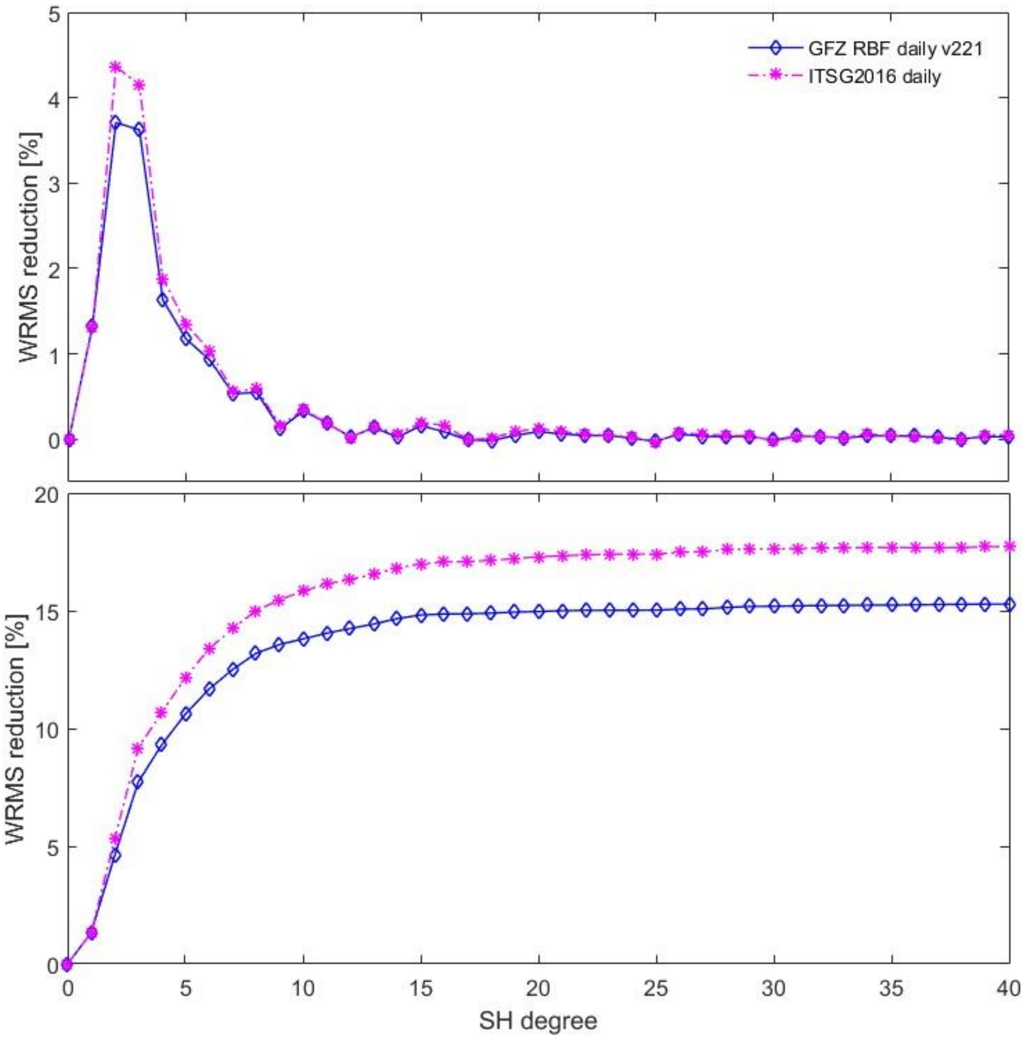
	ITSG-Grace2016 Kalman n=40	GFZ daily RBF solutions v221,n=50
• replace C20 from SLR	-	-
• subtract a priori GIA model	-	-
• restoring interpolated degree-1	X	X
• applying filtering	-	-
• adding back GAC product removed during de-aliasing	X	X
• displacement in CF	X	X
• fit & remove mean & trend	X	X

Comparison of time series

- POVE (Brazil)
  - GFZ v221 (**64.7% with** GAC vs **62.8% without** GAC)
  - ITSG2016 (**66.8% with** GAC vs **64.6% without** GAC)
- ARTU (Siberia)
  - GFZ v221 (**39.4% with** GAC vs **8.2% without** GAC)
  - ITSG2016 (**39.6% with** GAC vs **7.7% without** GAC)
- BRST (Brest, France)
  - GFZ v221 (**-1.5% with** GAC vs **4.6% without** GAC)
  - ITSG2016 (**3.4% with** GAC vs **10.9% without** GAC)

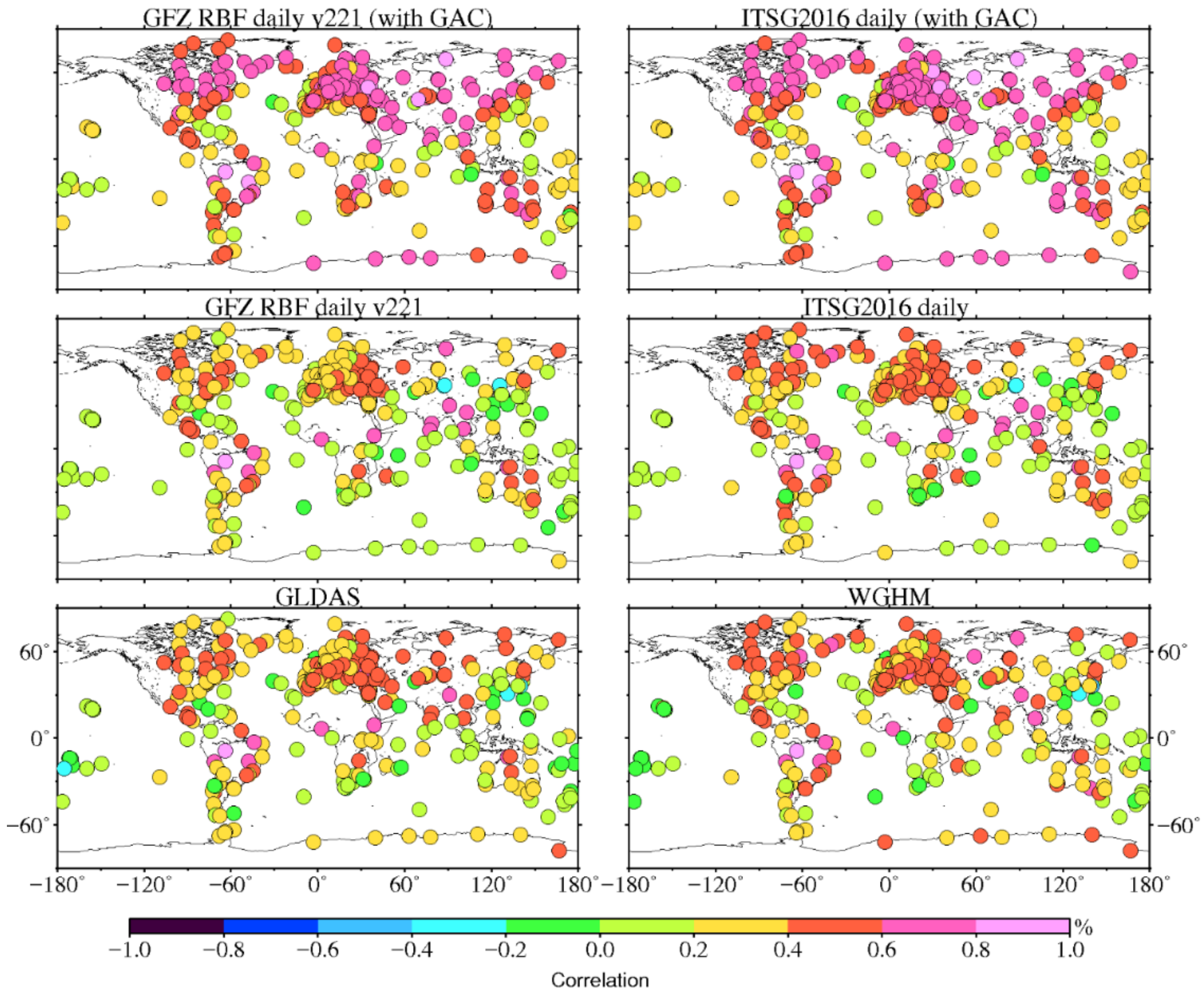


Degree WRMS reduction – full signal level

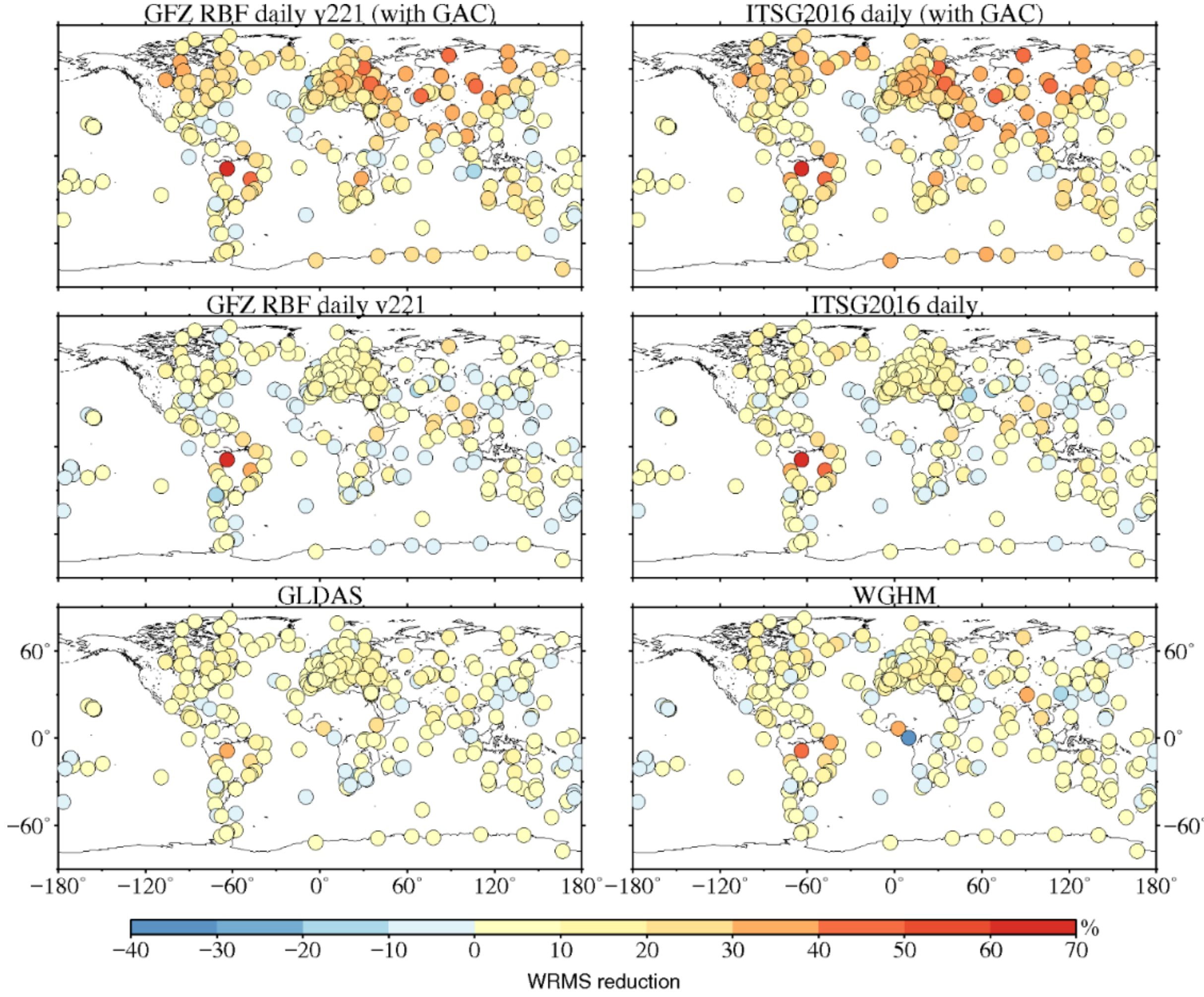


Horizon2020

Correlation – full signal level



WRMS reduction – full signal level



WRMS reduction – **with** GAC restored

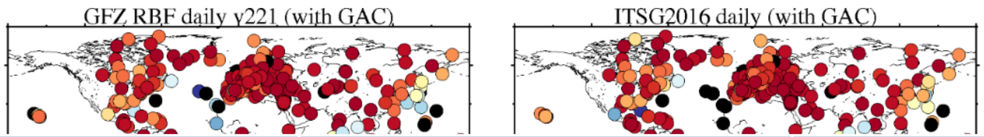
	WRMS reduction [%]				Positive WRMS reduction [%]
	min	max	mean	median	
GFZ RBF daily v221	-10.7	64.7	15.3	**15.0**	90.6
ITSG2016 daily	-12.2	66.8	17.7	**16.9**	94.4
Combination of models	-	-	-	11.5	90.7

models: a combination of NCEP, ECCO and GLDAS, see Weiwei Li et al., (EGU 2016)

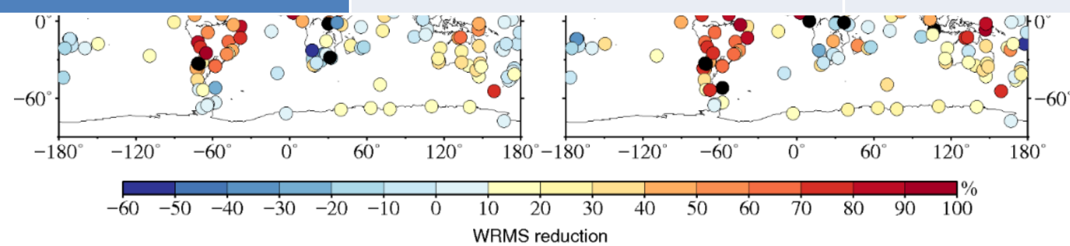
WRMS reduction – **without** restoring GAC

	WRMS reduction [%]				Positive WRMS reduction [%]
	min	max	mean	median	
GFZ RBF daily v221	-16.7	62.6	5.6	4.5	82.2
ITSG2016 daily	-17.2	64.6	**6.5**	**5.7**	82.7
WGHM	-14.8	42.80	5.5	4.4	84.5
GLDAS	-12.5	33.4	5.1	3.5	80.9

WRMS reduction – annual signal level



	Median WRMS reduction [%]	Positive WRMS reduction [%]
GFZ RBF daily v221 (with GAC)	80.1	90.1
ITSG2016 daily (with GAC)	79.9	90.1
GFZ RBF daily v221	44.8	87.8
ITSG2016 daily	45.9	82.0
WGHM	47.2	81.4
GLDAS	33.8	80.9



See more detail in D3.3

Validation of NRT gravity fields

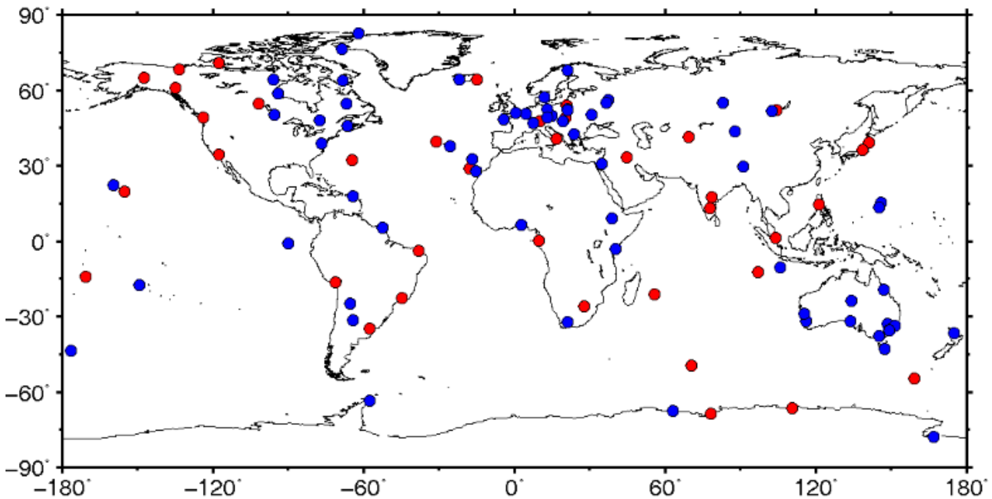
Datasets

- GNSS data
  - JPL and SOPAC daily data
  - Rapid solutions from UBERN
- Gravity models
  - NRT daily GRACE products from GFZ from 01.04.2017 to 31.07.2017
    - The same post-processing as v221
  - NRT daily GRACE products from TUG from 01.04.2017 to 23.09.2017
    - The same post-processing as daily ITSG2016

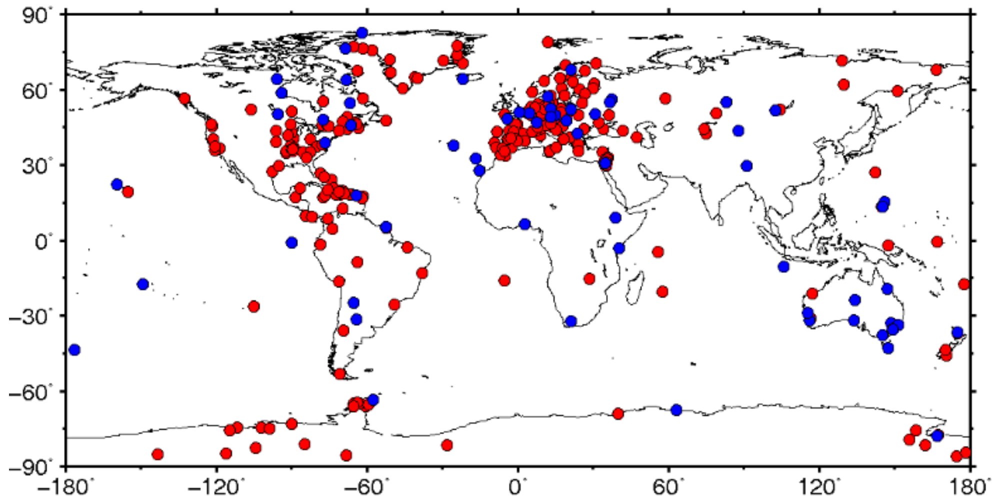
Post-processing GNSS time series

	JPL and SOPAC	Bern Rapid
• raw XYZ to NEU	-	X
• removing stations with data less than 60 common days	X	X
• removing stations affected by earthquake	X	X
• removing stations with gaps bigger than 15 days	X	X
• removing offsets	-	X
• removing outliers	X	X
• fit & remove mean & trend	X	X

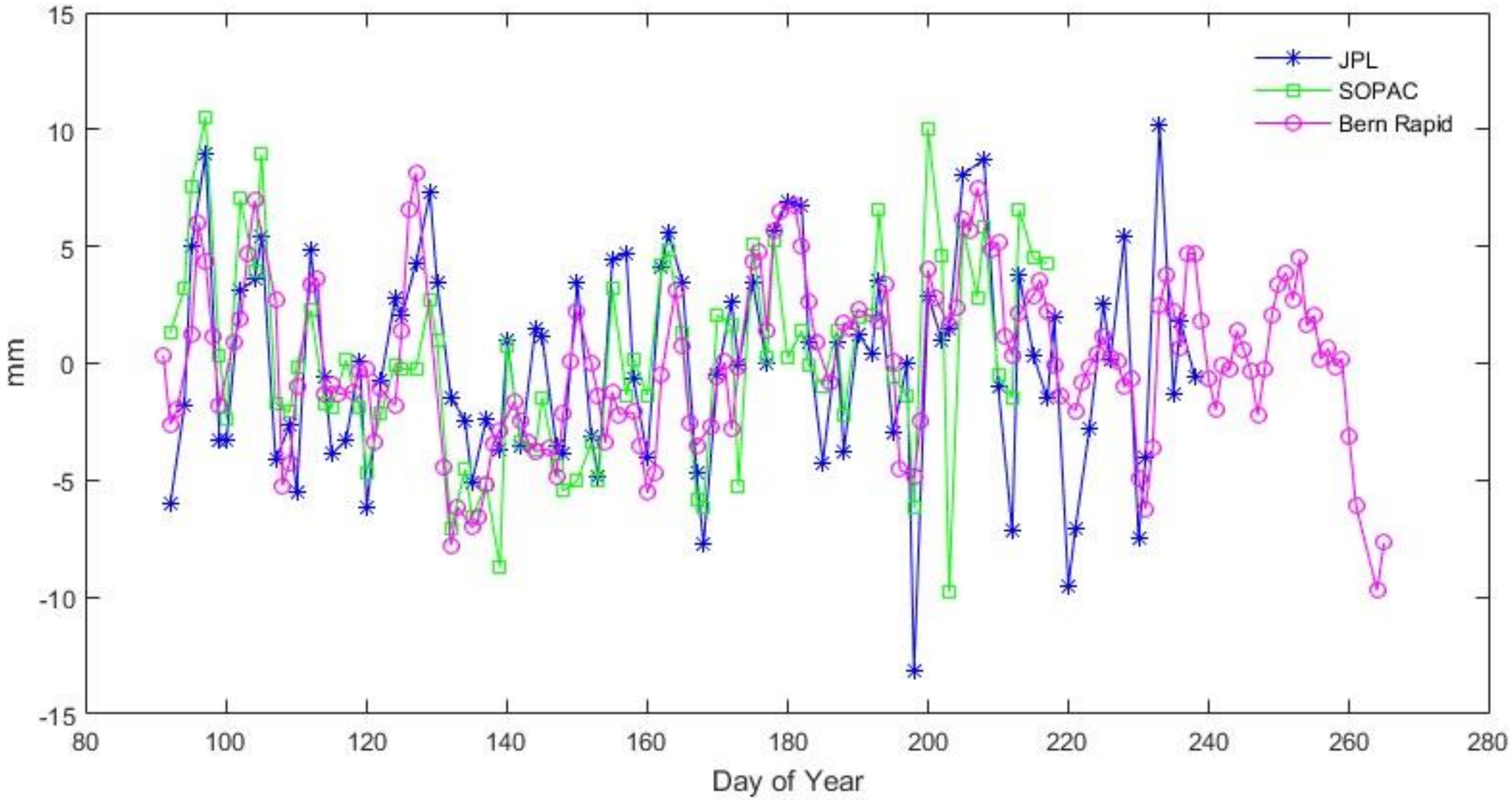
Daily GNSS time series: stations



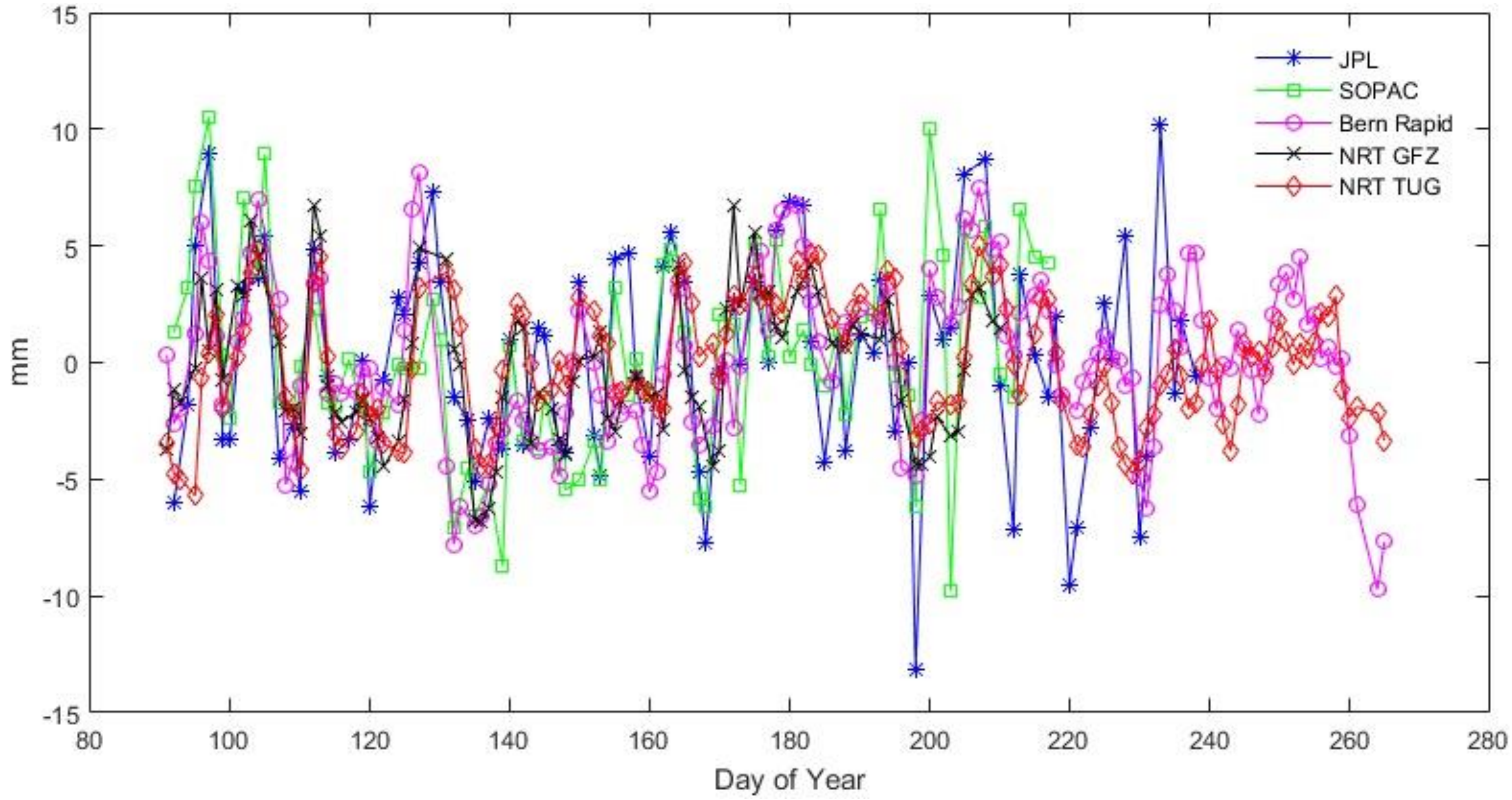
- 109 Rapid GNSS stations (Top left)
- 340 JPL and SOPAC stations (Bottom right)
- 68 in common with JPL and SOPAC



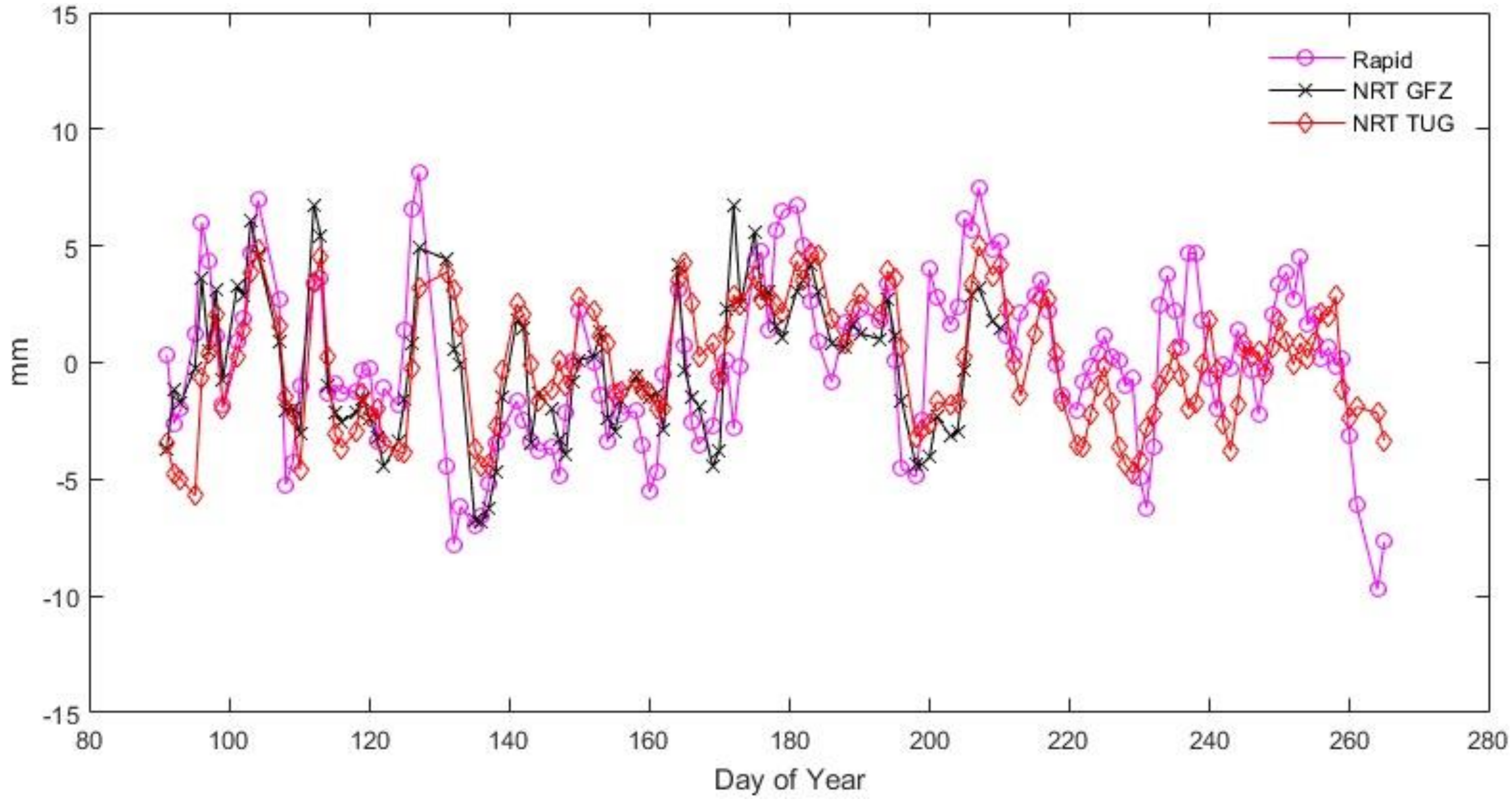
Daily vertical GNSS time series: GLSV



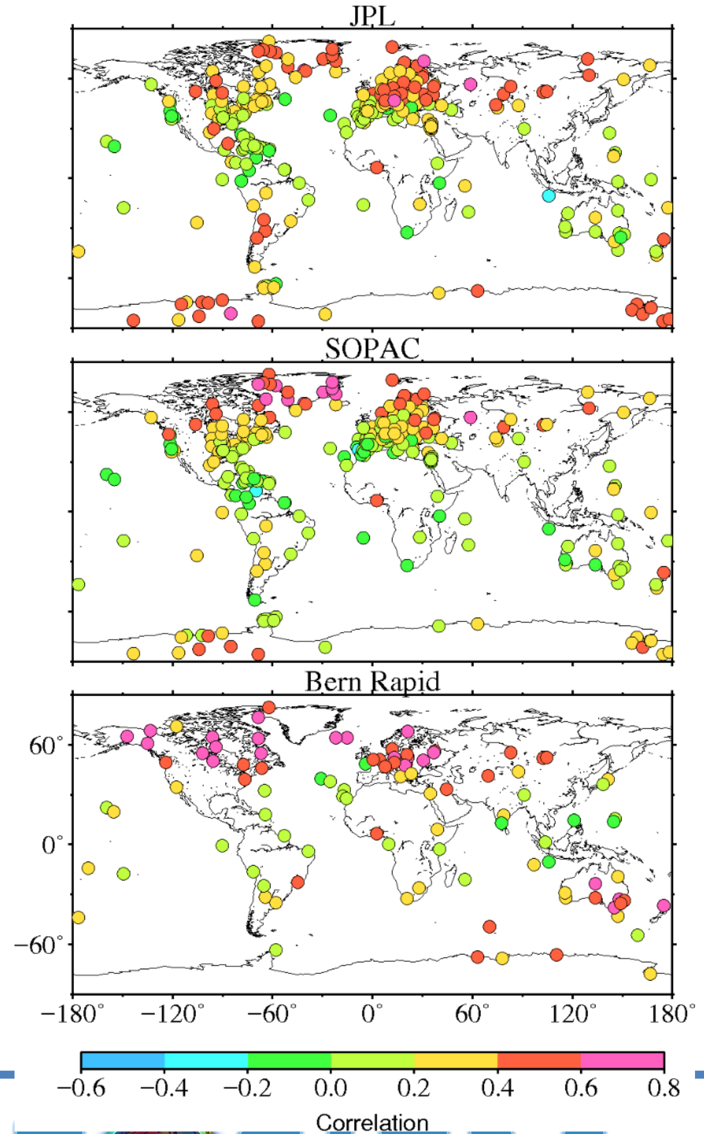
Daily vertical GNSS time series: GLSV



Daily vertical GNSS time series: GLSV

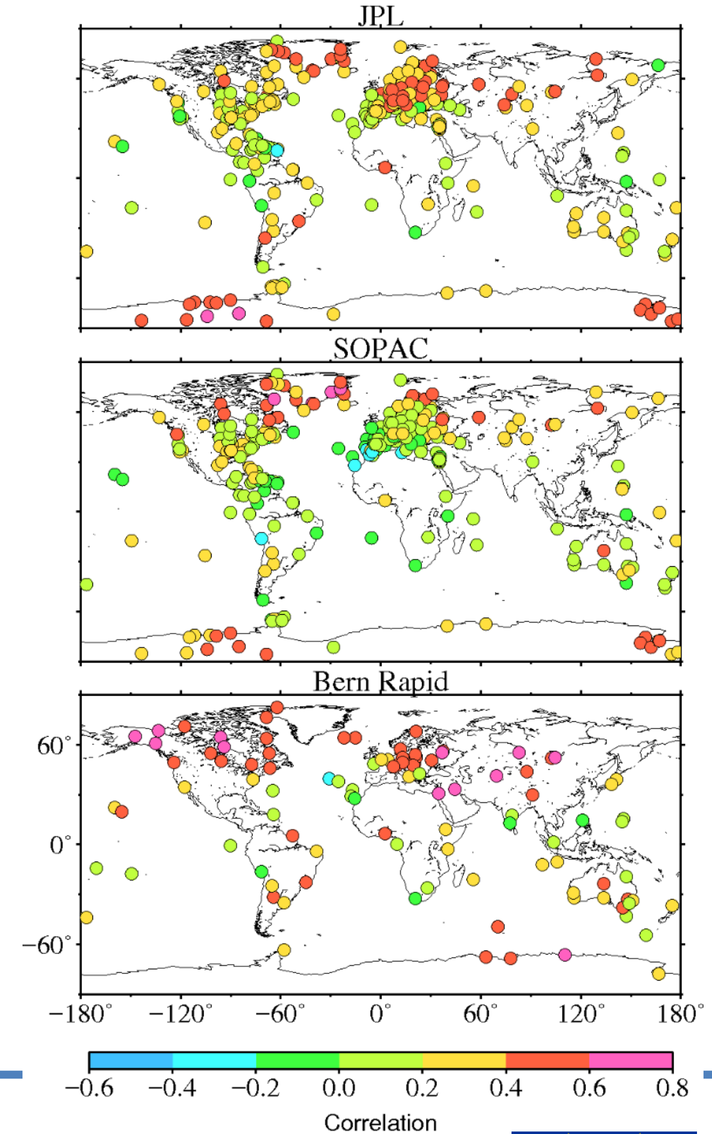


Correlation

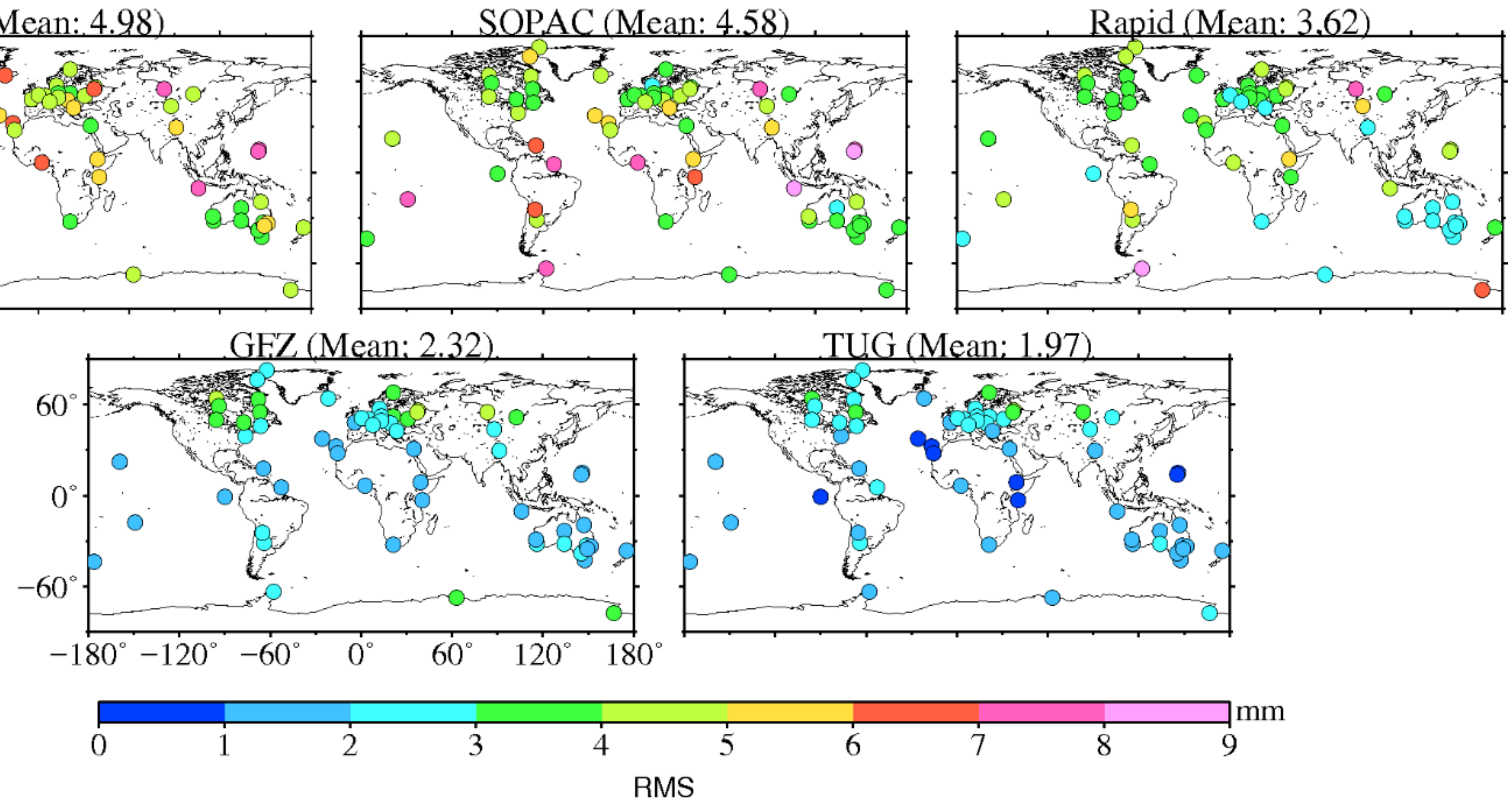


GFZ (left): mean
JPL: 0.27
SOPAC: 0.21
Bern Rapid: 0.38

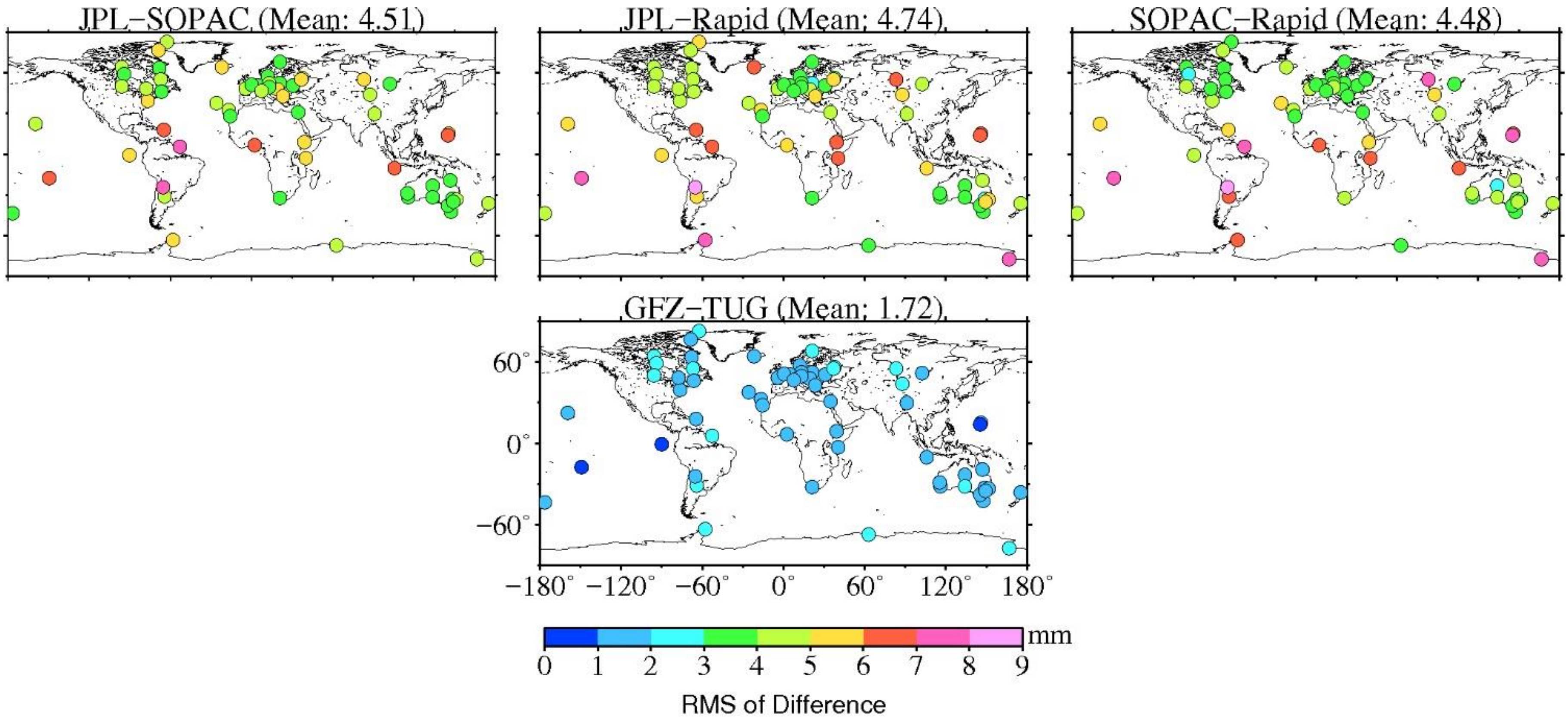
TUG (right): mean
JPL: 0.27
SOPAC: 0.17
Bern Rapid: 0.35



RMS over 68 common stations

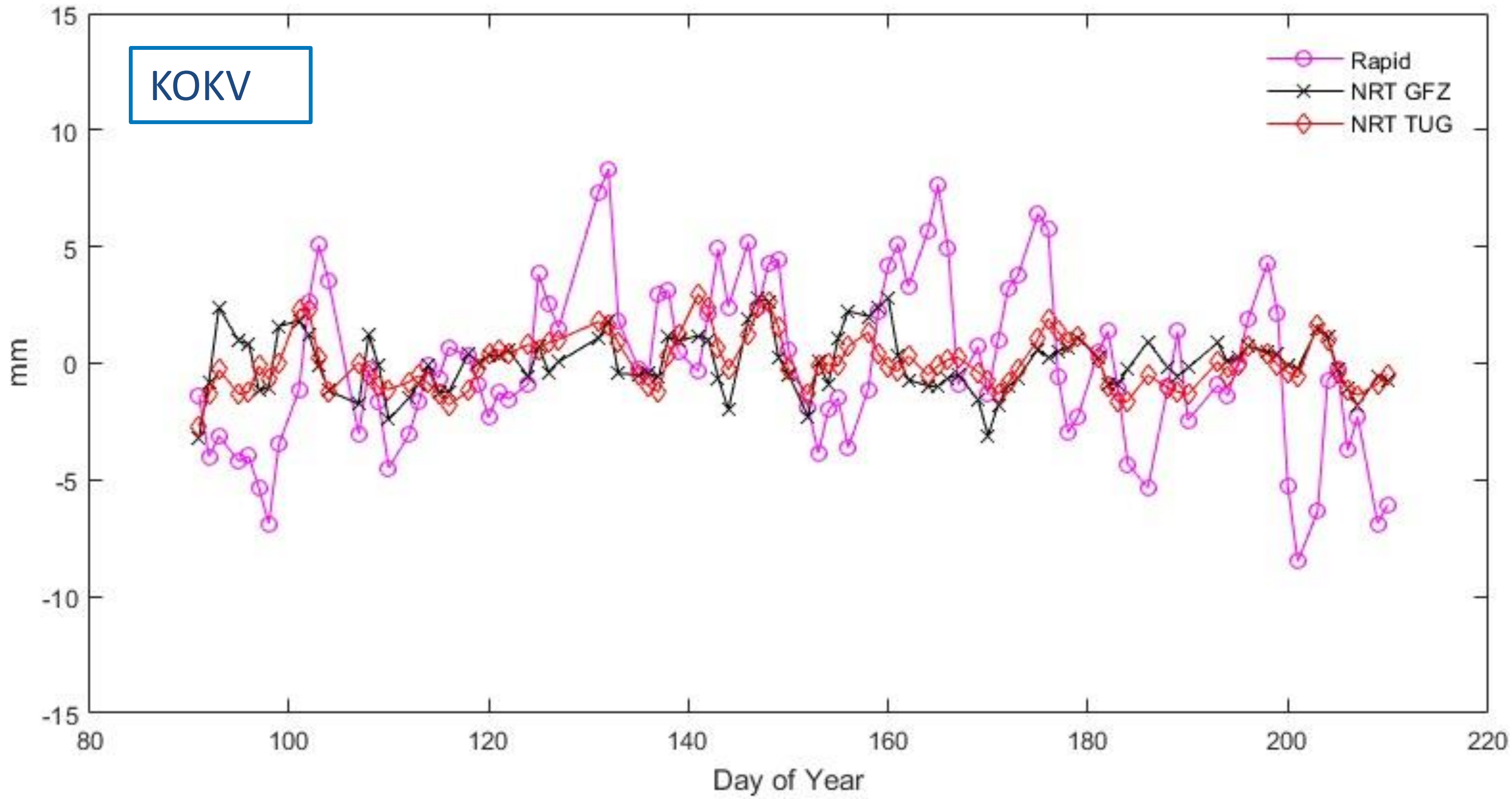


RMS over 68 common stations



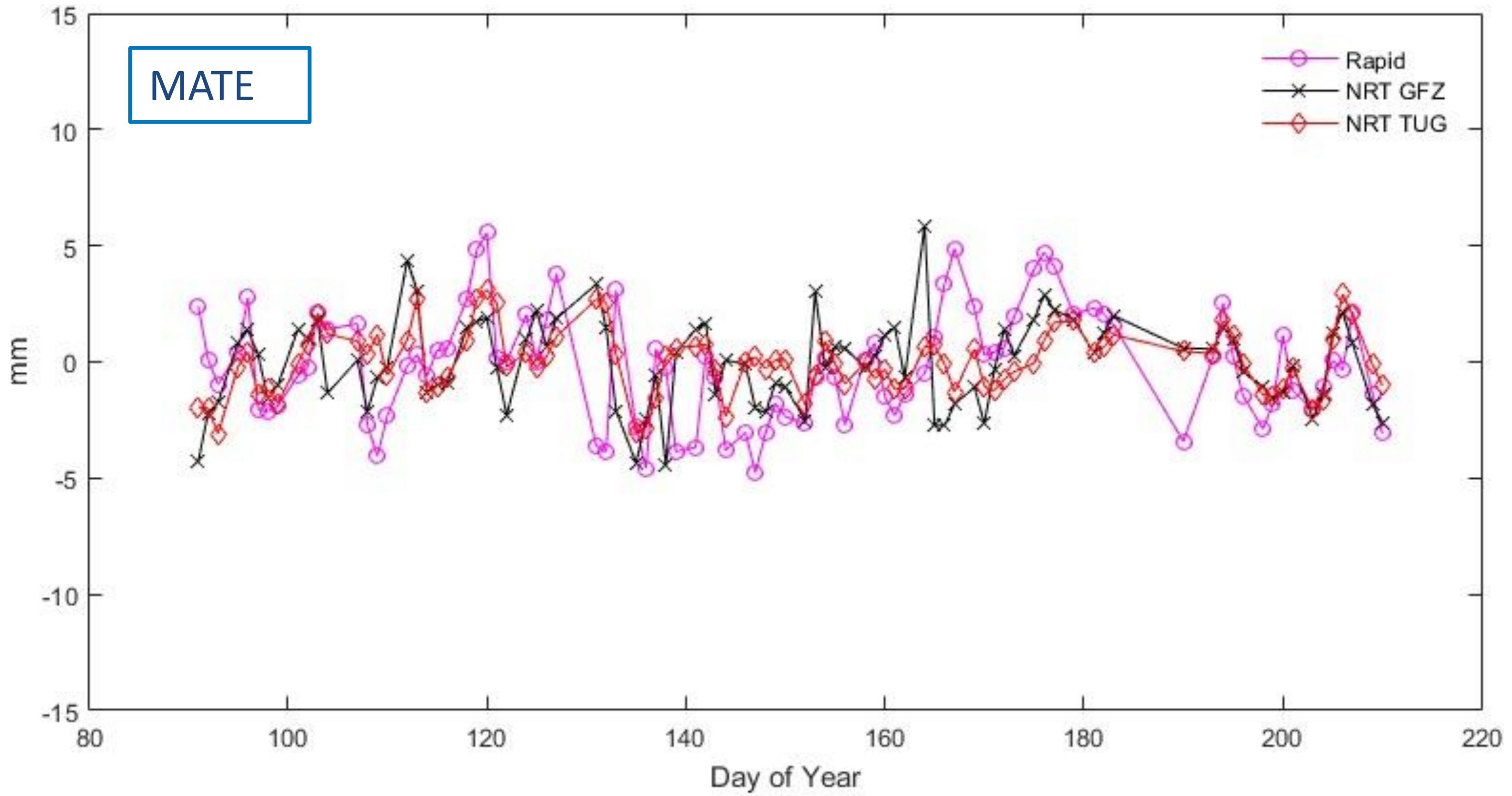
Bigger uncertainties among NRT GNSS products than NRT GRACE products

Vertical displacements at co-location sites: KOKB&KOKV



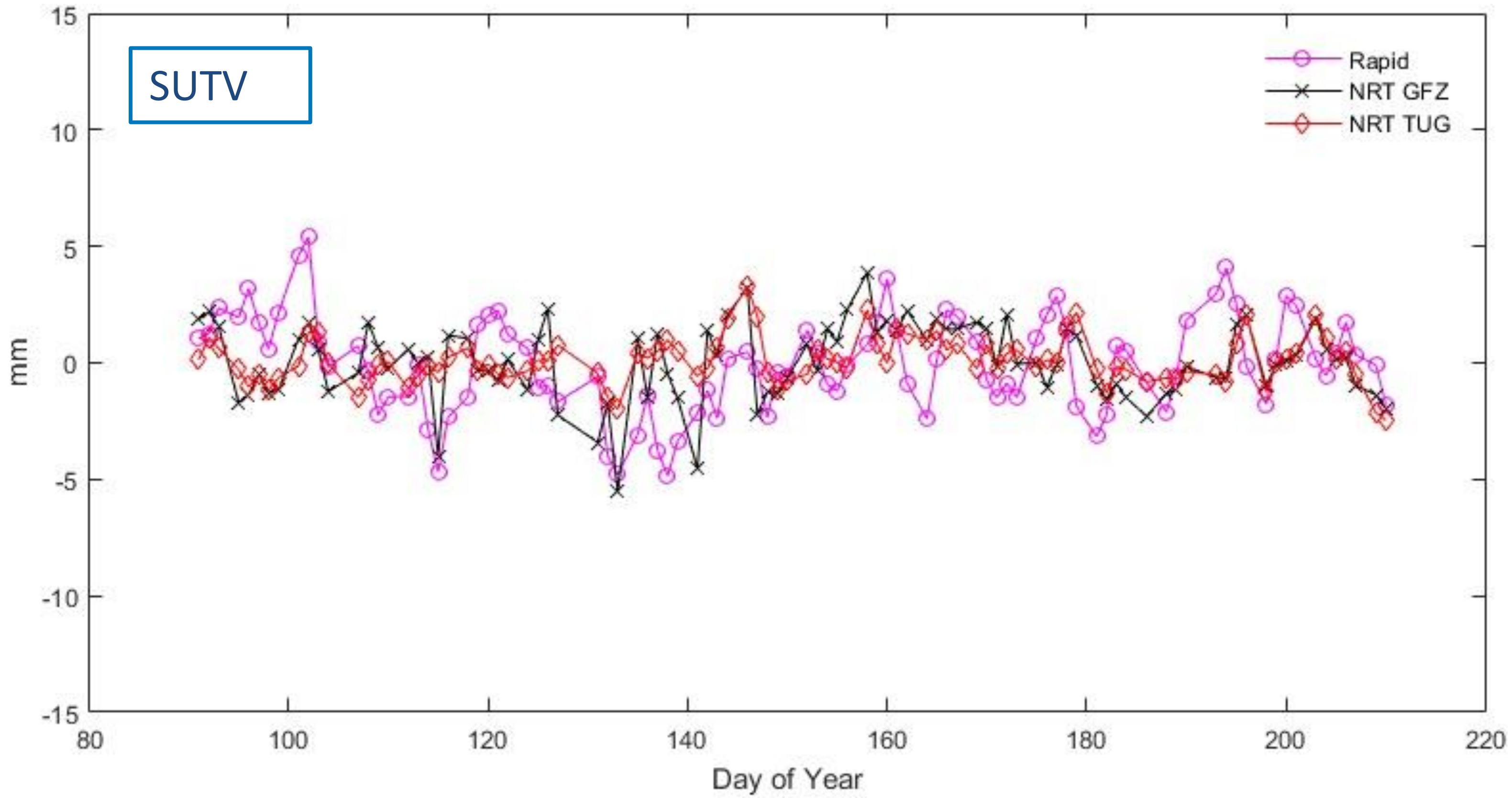
KOKB&KOKV: Hawaii, USA

Vertical displacements at co-location sites: MAT1&MATE



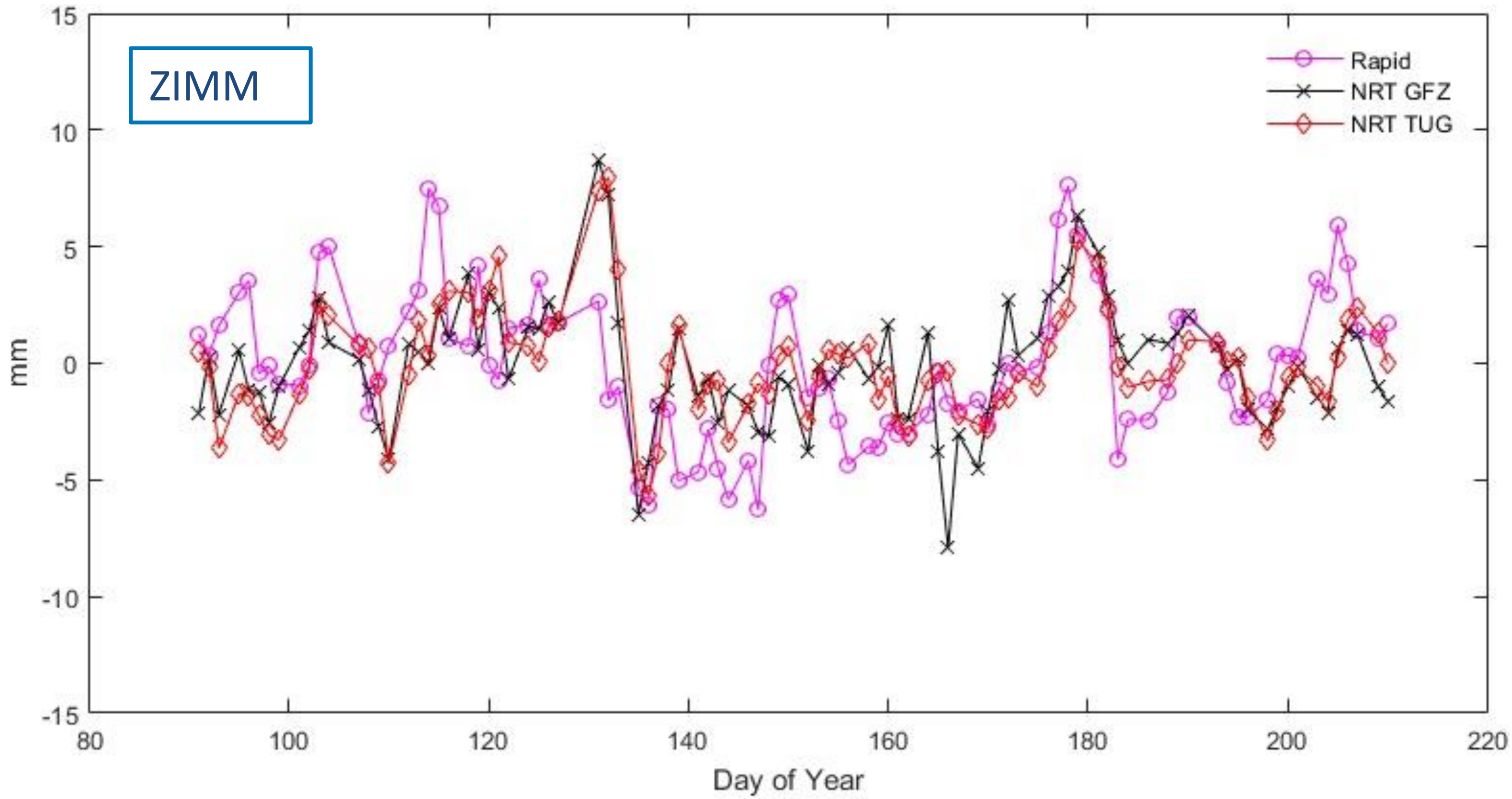
MAT1&MATE: Matera, Italy

Vertical displacements at co-location sites: SUTH&SUTV



SUTH&SUTV: Sutherland, South Africa

Vertical displacements at co-location sites: ZIM2&ZIMM



ZIM2&ZIMM: Zimmerwald, Switzerland

Summaries

- Post-processed daily gravity fields
  - Both GFZ v221 and ITSG2016 daily gravity fields demonstrate good agreement with GNSS time series.
  - Both GFZ v221 and ITSG2016 daily gravity fields outperform hydrological models.

- NRT daily gravity fields
  - Time series are too short to make strong conclusions.
  - Based on current time series, both GFZ and TUG NRT fields agree better with the rapid solutions from UBERN than the GNSS time series from JPL and SOPAC.
  - NRT GNSS time series have bigger uncertainties than NRT daily gravity fields derived displacements.