UNIWERSYTET PRZYRODNICZY WE WROCŁAWIU

The Presence of Geophysical Earth Crust Deformation Signals in the GNSS Coordinates Time Series

Adrian Kaczmarek, Bernard Kontny

Institute of Geodesy and Geoinformatics

Wroclaw University of Environmental and life Sciences

Poland

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Outline

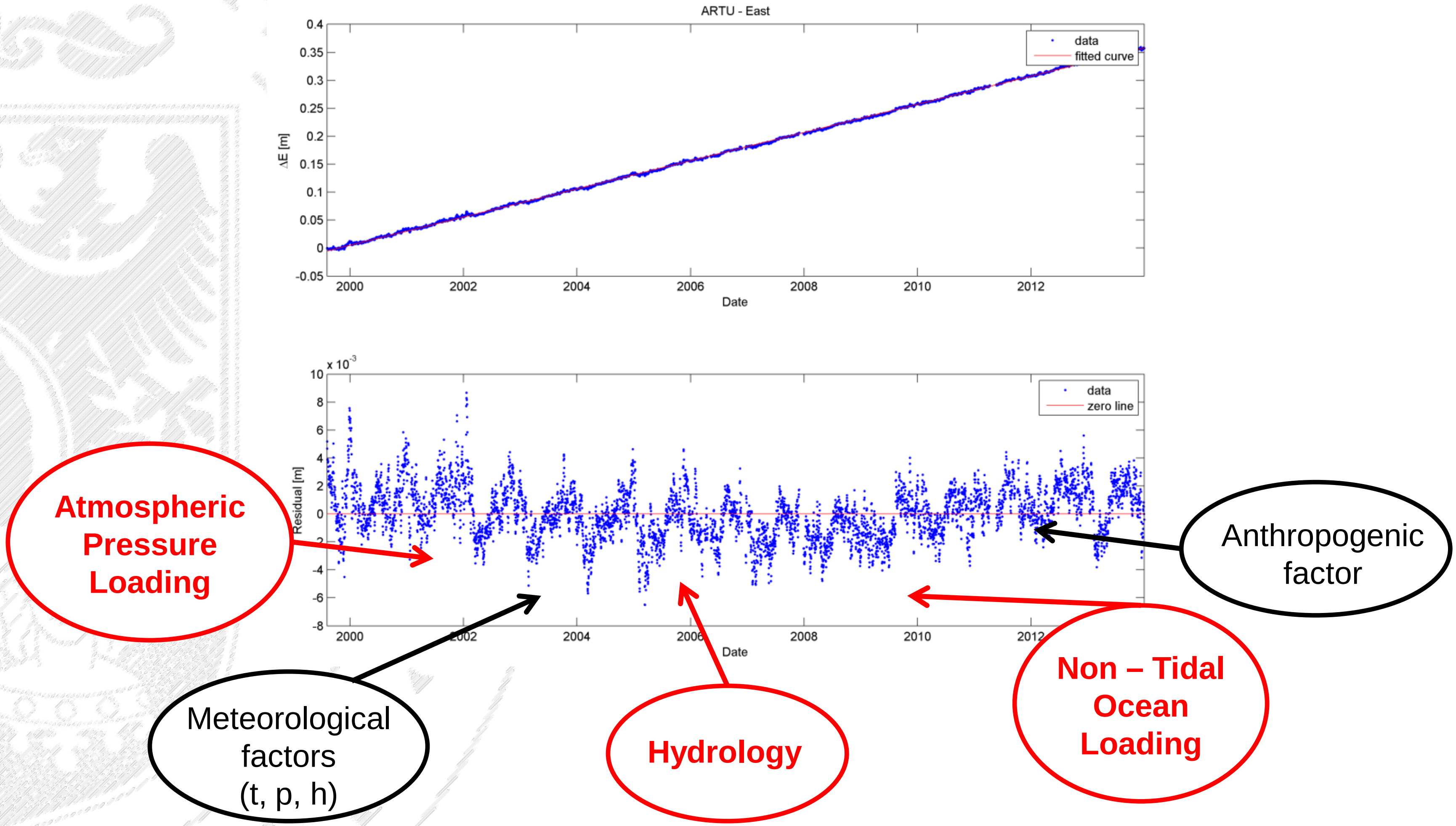
1. Introduction
2. Input data
3. Analysis
4. Conclusion

Introduction (1a)

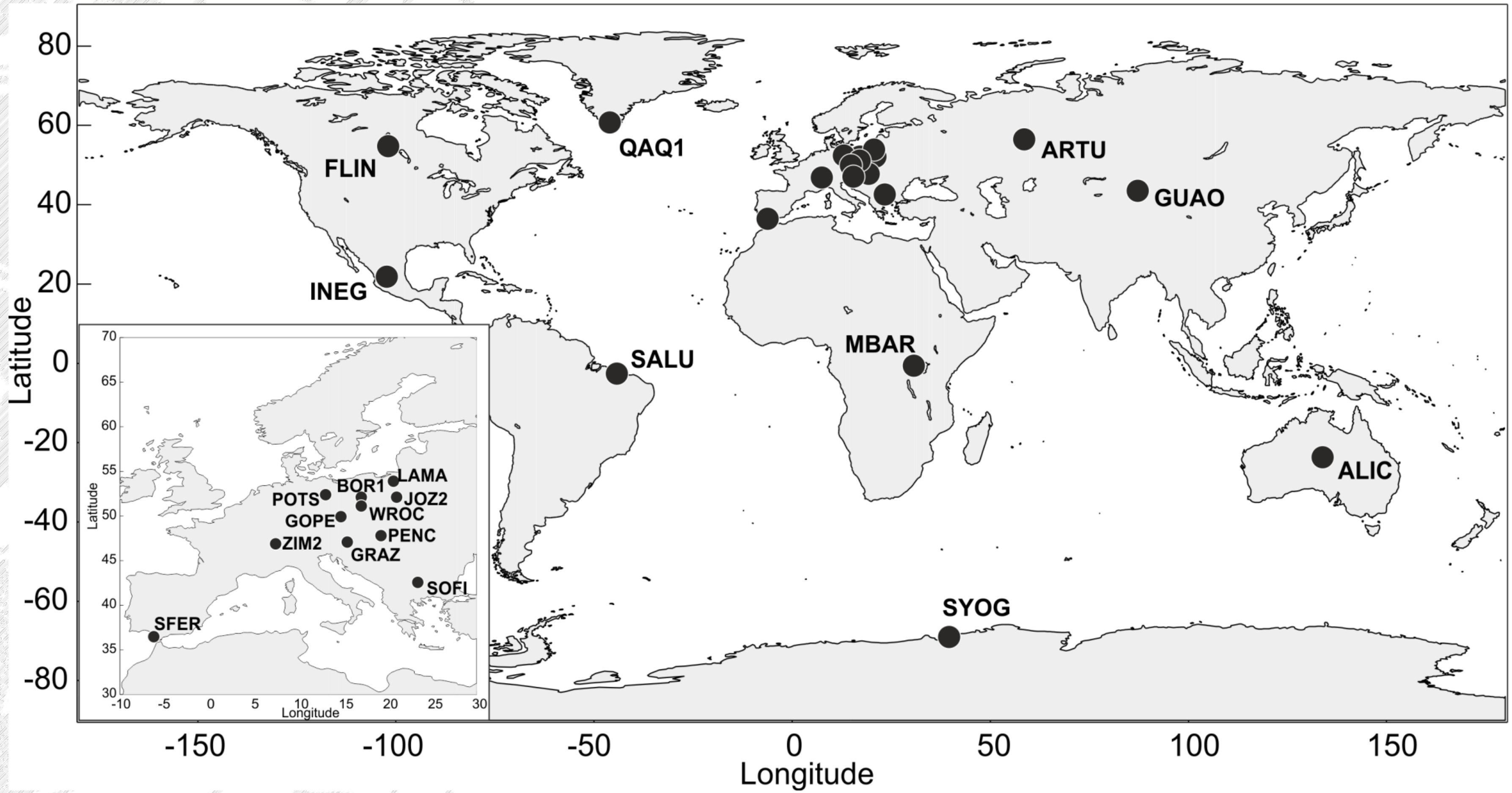
- Coordinate time series are using among others:
  - velocities estimation of GNSS stations,
  - determining of continental plates motion
  - local of geodynamic analysis,
  - forecasting of earthquaces.

- Interferencing in coordinate time series may be caused by:
  - meteorological factors, hydrology,
  - local geological surface character, tectonics
  - antropogenic factors,
  - changing of measurement equipments (anntenas , receivers),
  - snow cover loading.

Introduction (1b)



Introduction (1c) – Analysis area



Input data (2a) – geophysical deformation models

Compilation of available (August 2014) geophysical fluid model grids

Atmosphere

	Temp. Res.	Spatial Res.	TimeSpan	Model
Uni Luxembourg	6 h	2.5 °	1980 - 2014	NCEP
NASA GSFC	6 h	2.5 °	1976 - 2014	NCEP
TU Vienna (V4)	6 h	1 °	1994 - 2014	ECMWF
Uni Strasbourg	3 h 3 h 6 h	0.5 ° 0.5 ° 0.5 °	2001 - 2014 2002 - 2013 1979 - 2014	ECMWF + IB ECMWF + MOG2D ERAinterim + IB
International Mass Loading Service (IMLS)	6 h 3 h 3 h 3 h	1 ° 1 ° 1 ° 1 °	2000 - 2014 2012 - 2013 2013 - 2014 2013 - 2014	MERRA GEOS-57 GEOS-FP GEOS-FPIT

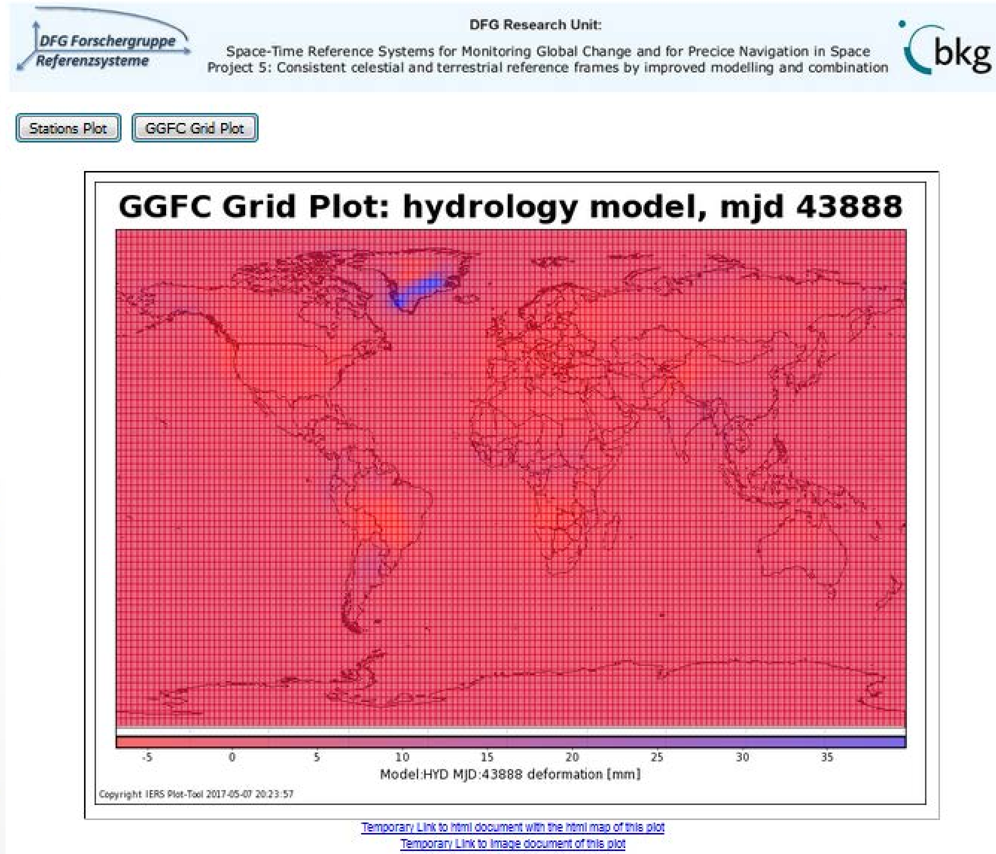
Ocean

	Temp. Res.	Spatial Res.	TimeSpan	Model
Uni Luxembourg	12 h	2.5 °	1993 - 2012	ECCO1 / JPL
NASA GSFC	12 h	1 °	1993 - 2013	ECCO1 / JPL
International Mass Loading Service (IMLS)	6 h	1 °	2012 - 2014	OMCT

Hydrology

	Temp. Res.	Spatial Res.	TimeSpan	Model
Uni Luxembourg	1 month	2.5 °	1979 - 2012	GLDAS/NOAH 1°
NASA GSFC	1 month	1 °	1979 - 2014	GLDAS/NOAH 1°
Uni Strasbourg	3 h 6 h	0.5 ° 0.5 °	2001 - 2014 1979 - 2014	GLDAS/NOAH 0.25° ERAinterim
International Mass Loading Service (IMLS)	3 h 3 h 3 h	1 ° 1 ° 1 °	2013 - 2014 2012 - 2014 2013 - 2014	MERRA GEOS-FPIT GLDAS/NOAH 0.25°

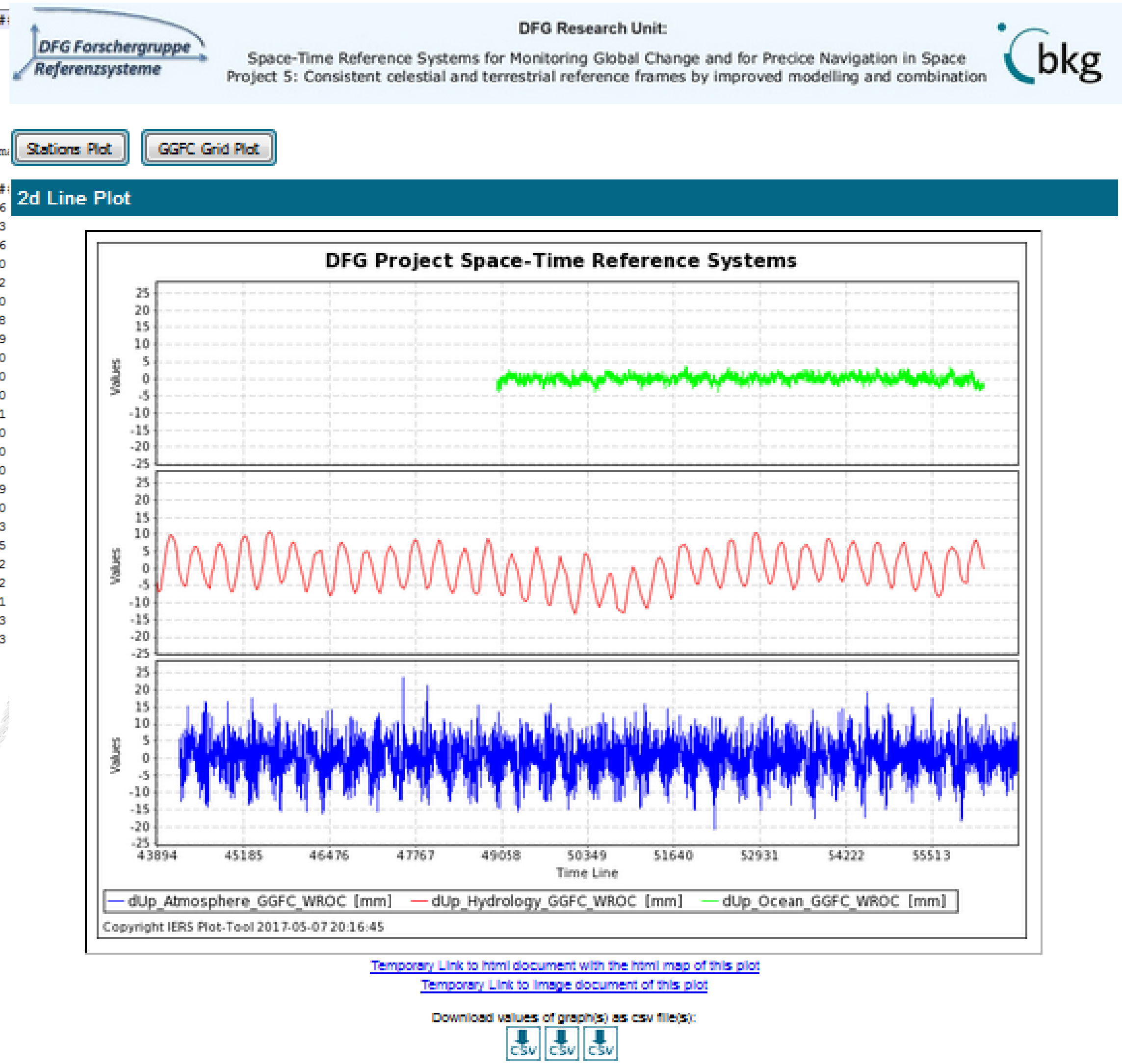
http://ww2.erdrotation.de/EN/ProjectPortal/Projects/PN5/Results/results_node.html



http://ida.bkg.bund.de/refsys/public/2dLine.php

Input data (2b) – coordinates and geophysical deformation models

```
###########################################################################
#
# Station      : ARTU
# Station      :  CODE
# Date & Time  : 2016-06-16 12:35:23
# Software     : snx2crd
# Format       : GTS (GITSA native format)
# Format desc. : decimal year, year, day-of-year, [x, y, z], [x, y, z sigma
#
###########################################################################
1999.5959 1999 218  1843956.8457  3016203.0679  5291261.7193      0.00046
1999.5986 1999 219  1843956.8475  3016203.0700  5291261.7209      0.00043
1999.6014 1999 220  1843956.8482  3016203.0698  5291261.7196      0.00036
1999.6041 1999 221  1843956.8487  3016203.0707  5291261.7199      0.00040
1999.6068 1999 222  1843956.8476  3016203.0687  5291261.7162      0.00032
1999.6096 1999 223  1843956.8465  3016203.0670  5291261.7160      0.00030
1999.6123 1999 224  1843956.8473  3016203.0672  5291261.7168      0.00028
1999.6151 1999 225  1843956.8468  3016203.0679  5291261.7196      0.00029
1999.6178 1999 226  1843956.8482  3016203.0696  5291261.7216      0.00030
1999.6205 1999 227  1843956.8485  3016203.0696  5291261.7255      0.00030
1999.6233 1999 228  1843956.8491  3016203.0696  5291261.7247      0.00030
1999.6260 1999 229  1843956.8492  3016203.0692  5291261.7230      0.00031
1999.6288 1999 230  1843956.8491  3016203.0691  5291261.7205      0.00030
1999.6315 1999 231  1843956.8475  3016203.0678  5291261.7201      0.00030
1999.6342 1999 232  1843956.8488  3016203.0691  5291261.7222      0.00030
1999.6370 1999 233  1843956.8481  3016203.0686  5291261.7229      0.00029
1999.6397 1999 234  1843956.8484  3016203.0695  5291261.7244      0.00030
1999.6425 1999 235  1843956.8484  3016203.0683  5291261.7235      0.00033
1999.6452 1999 236  1843956.8482  3016203.0693  5291261.7219      0.00035
1999.6479 1999 237  1843956.8489  3016203.0710  5291261.7210      0.00032
1999.6507 1999 238  1843956.8476  3016203.0703  5291261.7183      0.00032
1999.6534 1999 239  1843956.8474  3016203.0701  5291261.7182      0.00031
1999.6562 1999 240  1843956.8481  3016203.0685  5291261.7175      0.00033
1999.6589 1999 241  1843956.8489  3016203.0693  5291261.7205      0.00033
```



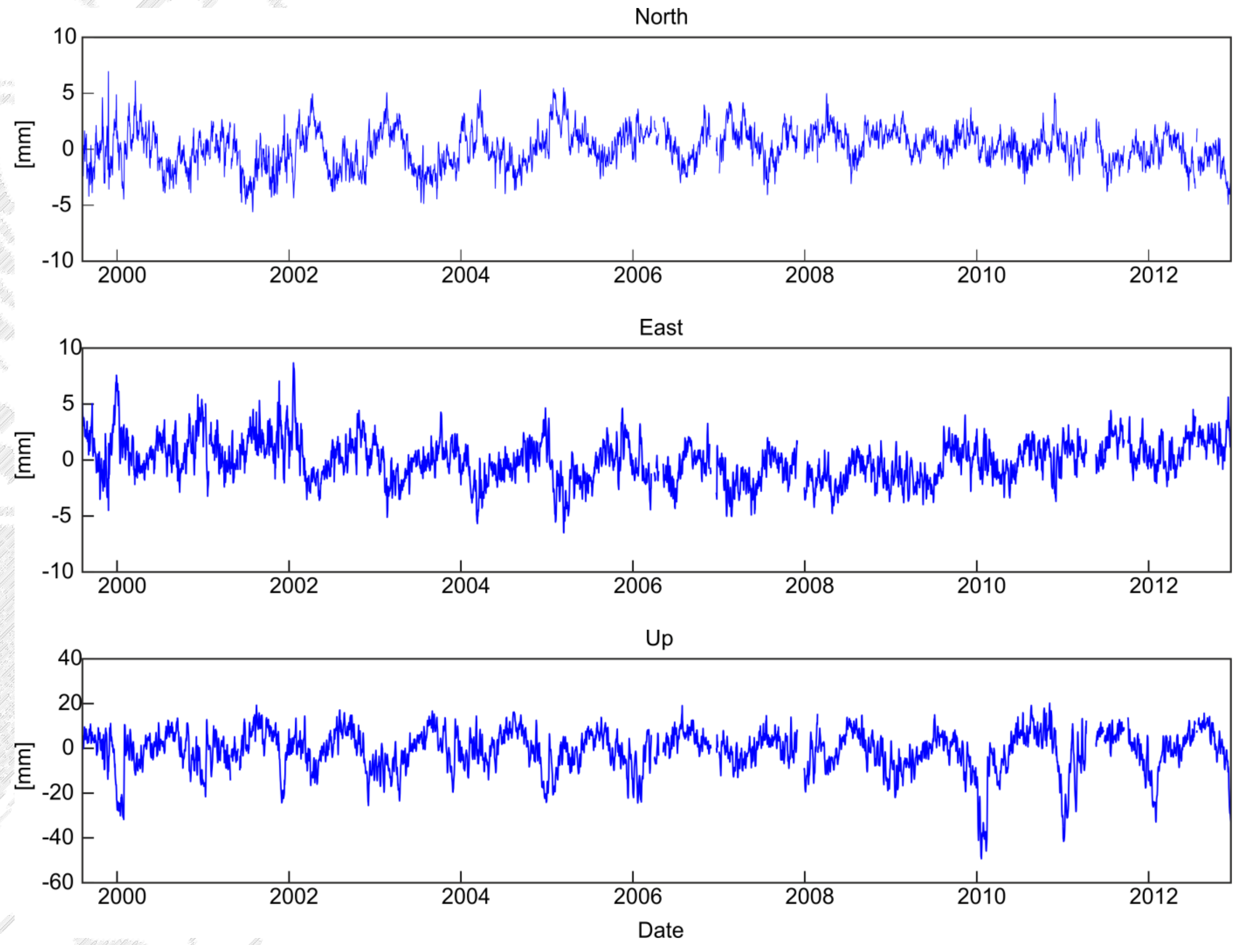
http://ida.bkg.bund.de/refsys/public/2dLine.php

Input data (2c) – GNSS reprocessing stretegy – CODE Repro2013 - (Non-tidal loadings)

```
|                  | Atmospheric tides     : S1+S2 tidal corrections from the|
|                  |                         Vienna atmospheric pressure     |
|                  |                         model                           |
|-------------------------------------------------------------------------------|
| Non-tidal        | Atmospheric pressure  : Non-tidal components from the    |
| loadings         |                         Vienna atmospheric pressure     |
|                  |                         model with three scaling factors|
|                  |                         for validation  purposes.       |
|                  |                         The product files are generated |
|                  |                         without considering the non-    |
|                  |                         tidal pressure loading by       |
|                  |                         forcing the scaling factors to  |
|                  |                         zero.                           |
|                  |-------------------------------------------------------|
|                  | Ocean bottom pressure: not applied                     |
|                  |-------------------------------------------------------|
|                  | Surface hydrology     : not applied                     |
|                  |-------------------------------------------------------|
|                  | Other effects         : none applied                    |
|-------------------------------------------------------------------------------|
| Earth orientation| Ocean tidal: diurnal/semidiurnal variations in x,y, &   |
| variations       |              UT1 applied according to IERS 2010, Tables|
|                  |              8.2a, 8.2b, 8.3a, 8.3b                      |
```

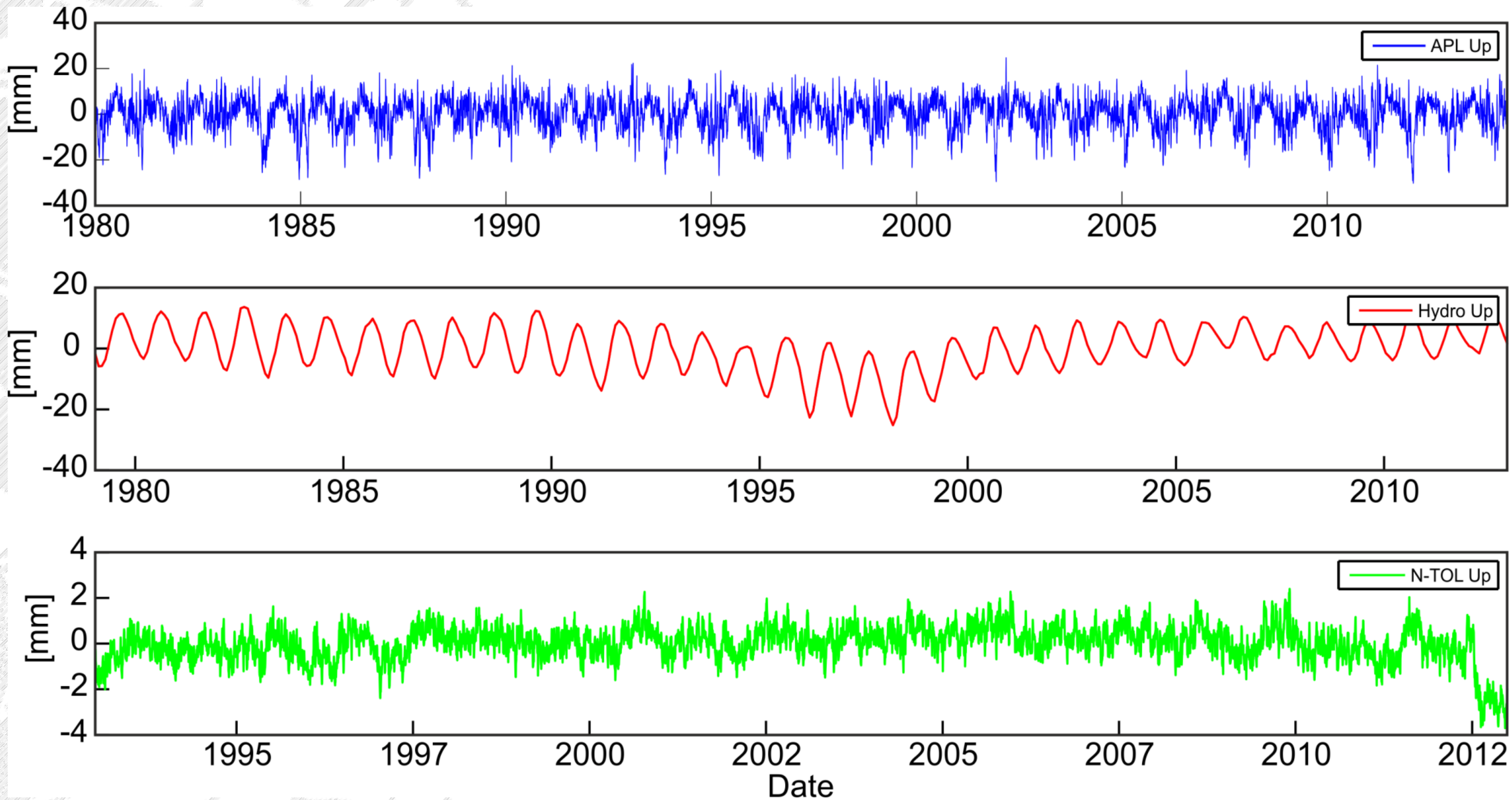
ftp://ftp.aiub.unibe.ch/REPRO_2013/CODE_REPRO_2013.ACN

Input data (2d) – example of coordinate time series



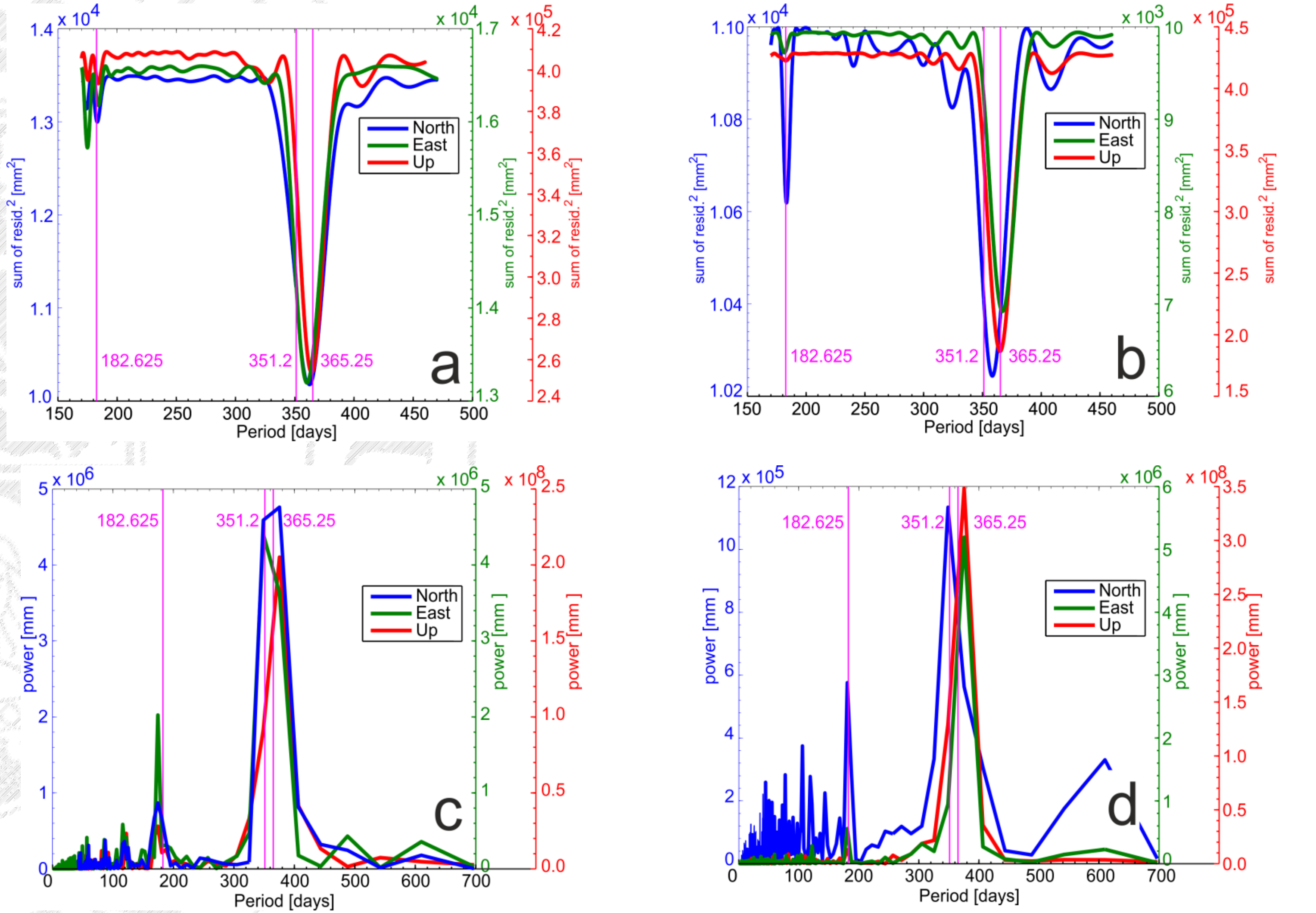
Coordinates time series for ARTU station (Russian Federation)

Input data (2e) – example of deformations time series



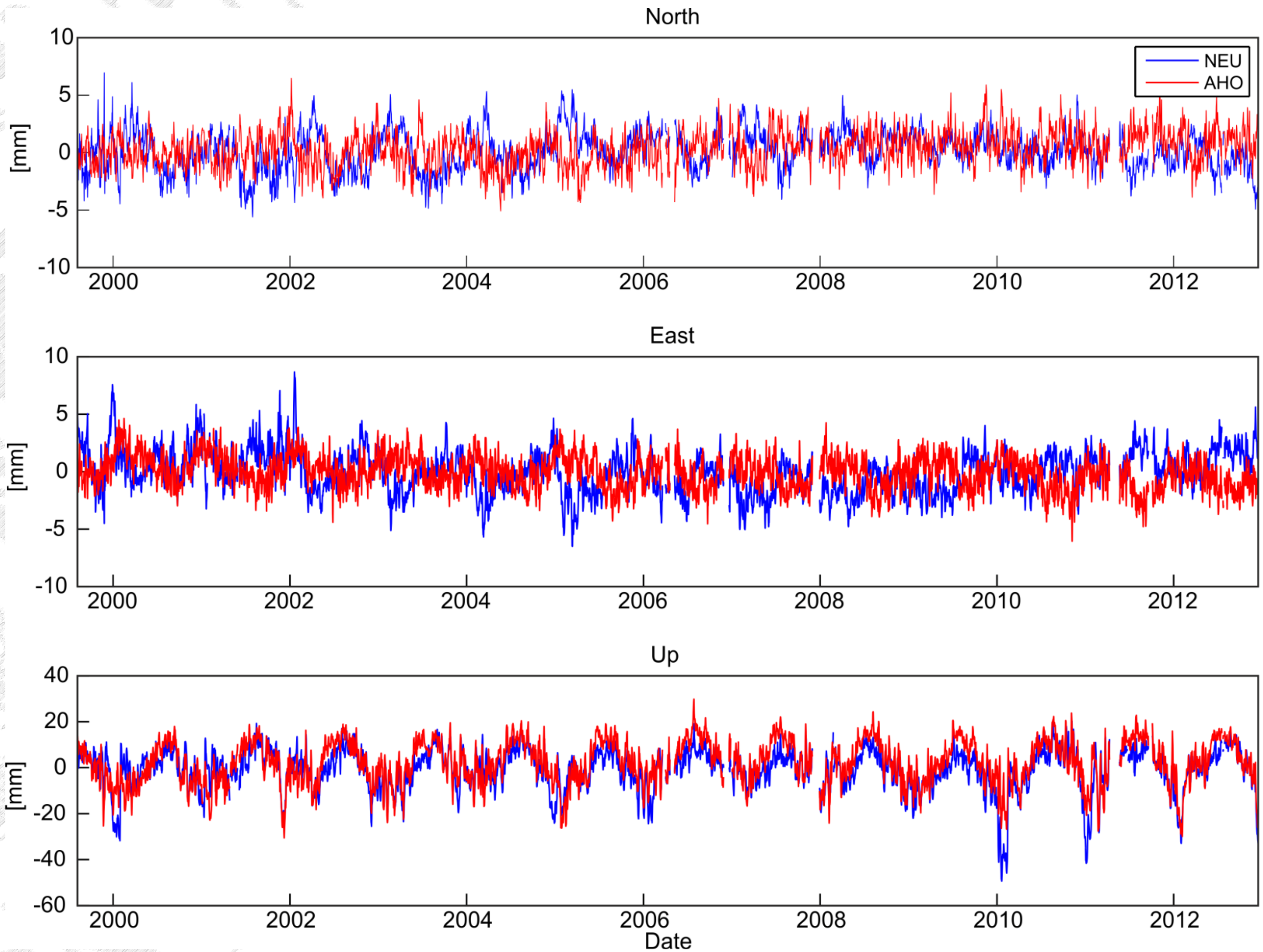
Deformations time series for ARTU station (Russian Federation) – Up component

Analyses (3a) – periodicity analysis



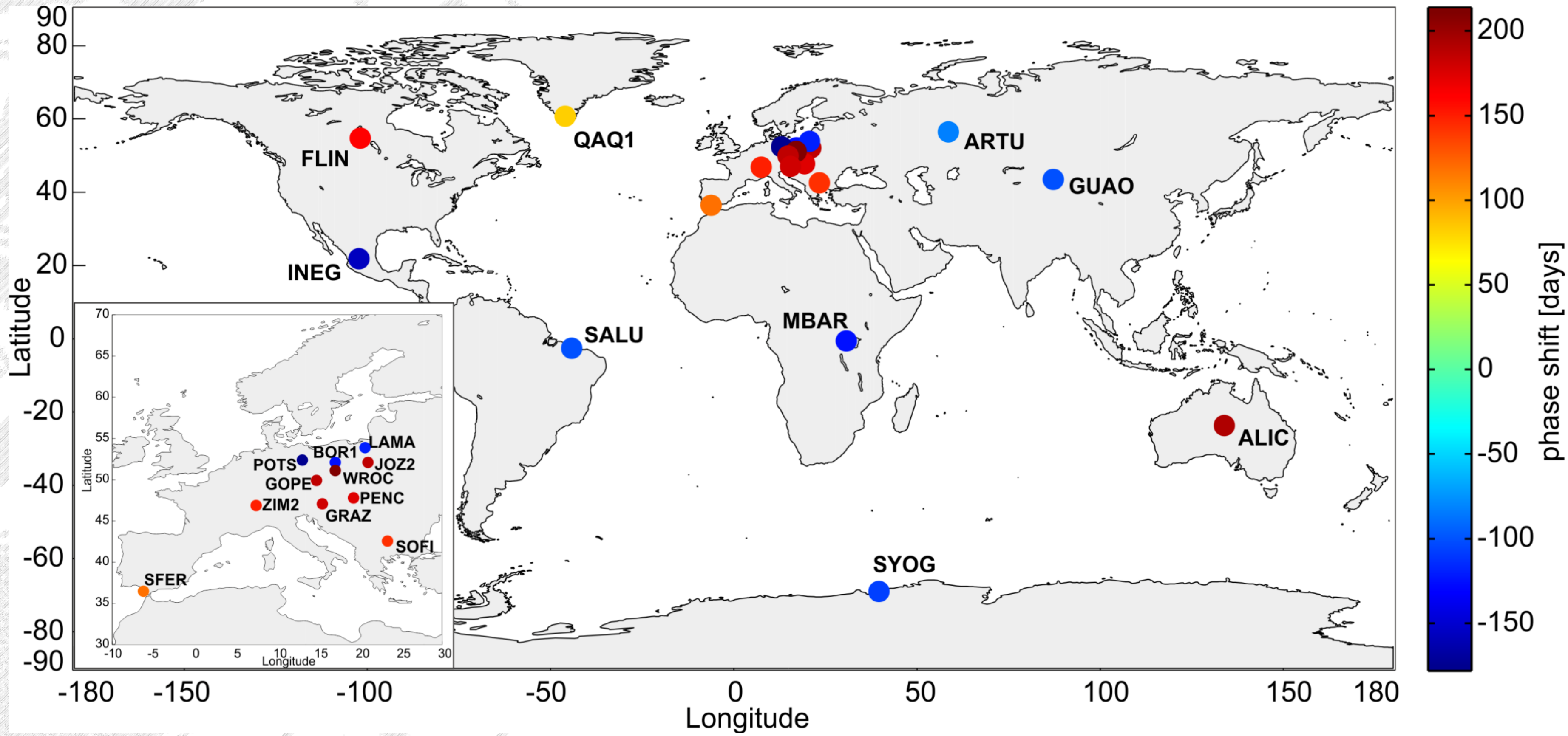
a – period analysis using iLSE (NEU), **b** – period analysis using iLSE (deformations models)
c – FFT analysis(NEU), **d** – FFT analysis (AHO)

Analyses (3b) – comparing of two time series

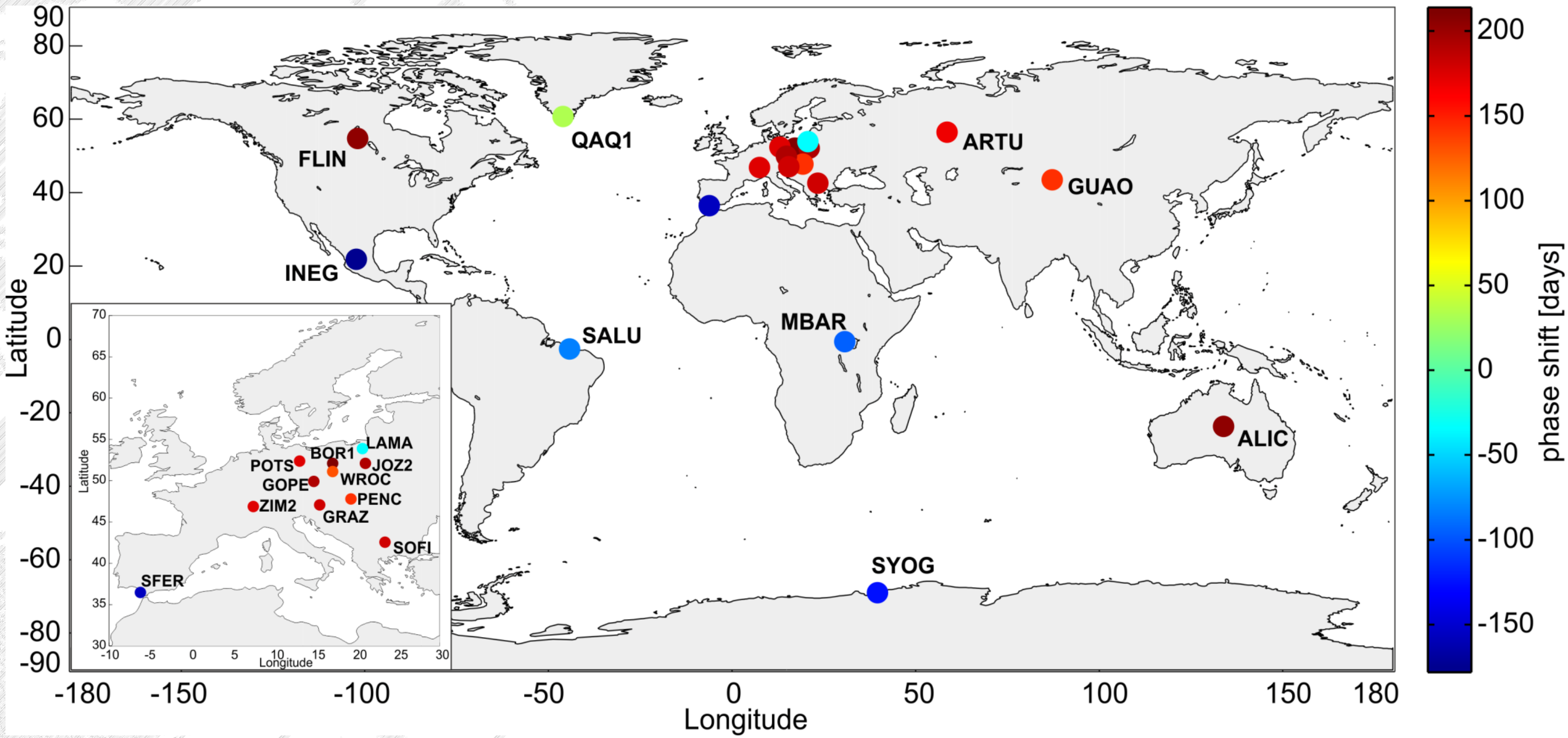


Comparing of two time series (coordinates – blue and geophysical deformations)

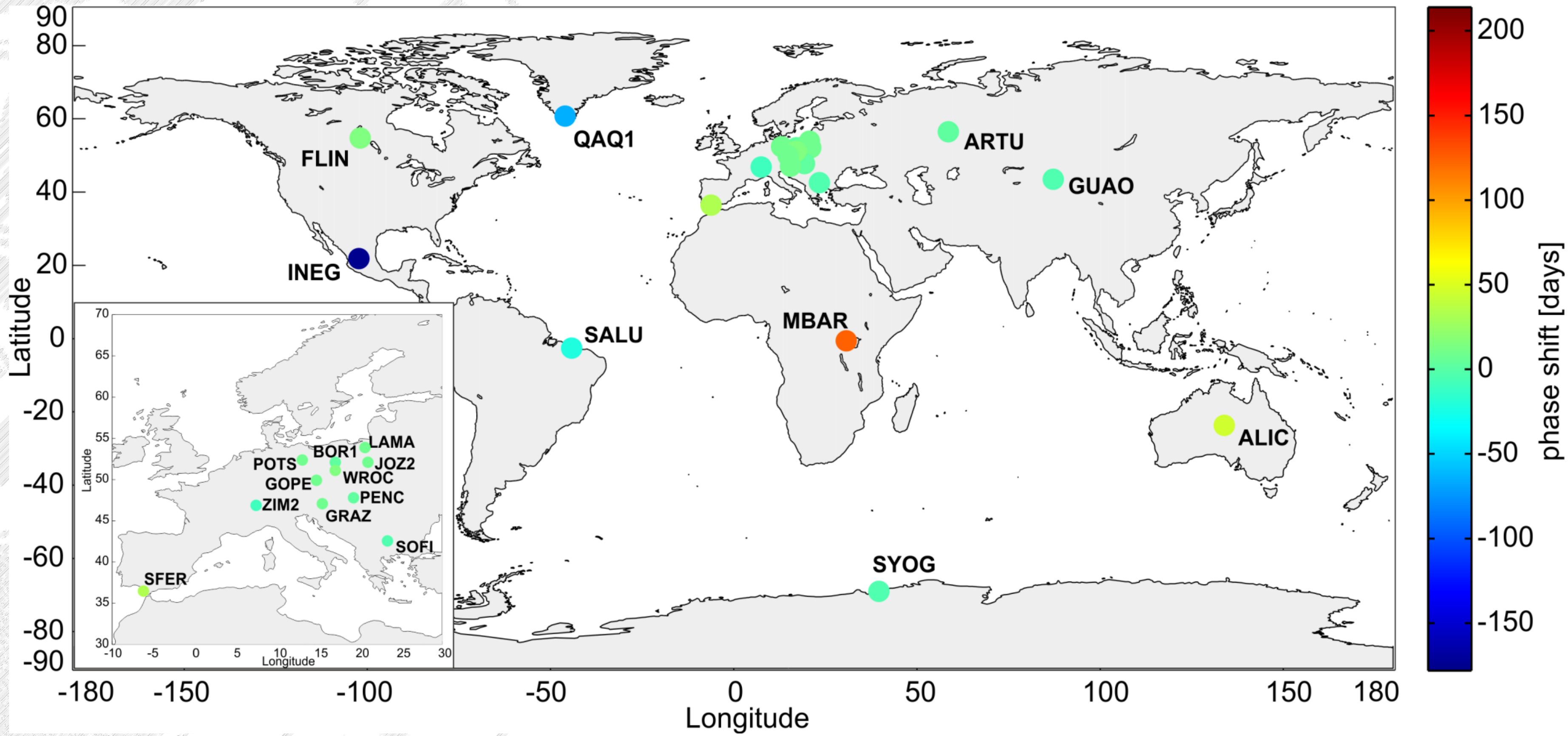
Analyses (3c) – phase shift between analysed signals – North component



Analyses (3d) – phase shift between analysed signals – East component



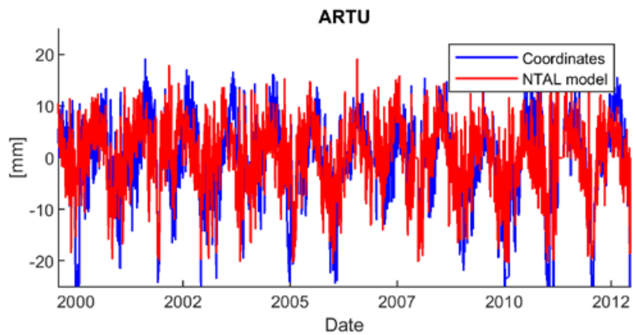
Analyses (3e) – phase shift between analysed signals – Up component

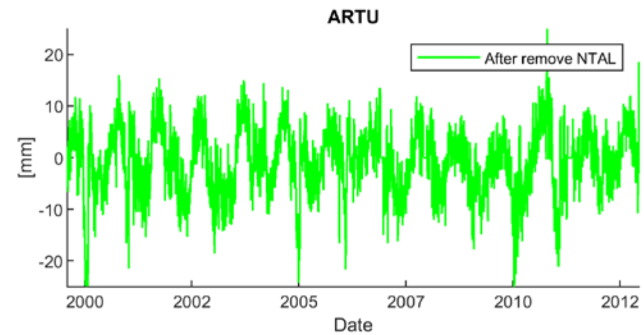


Analyses (3f) – Coordinates minus geophysical deformations (NTAL) – Up component

RMS | **RMS**

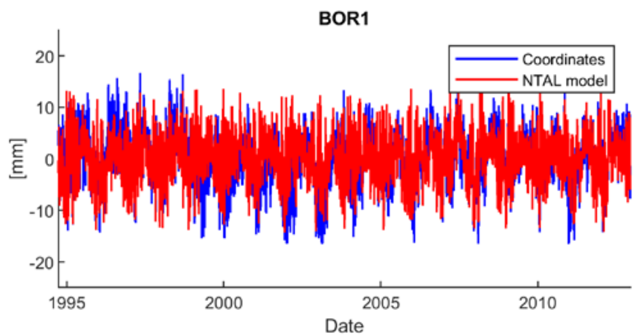
8.68 mm

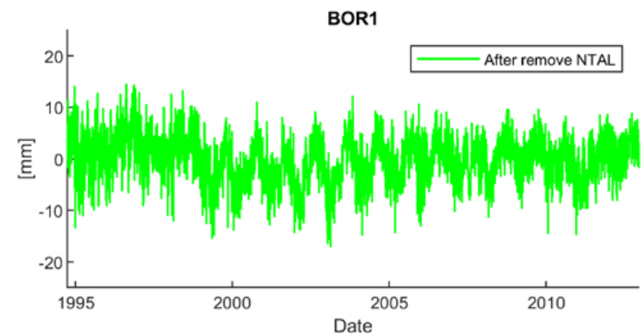




6.46 mm

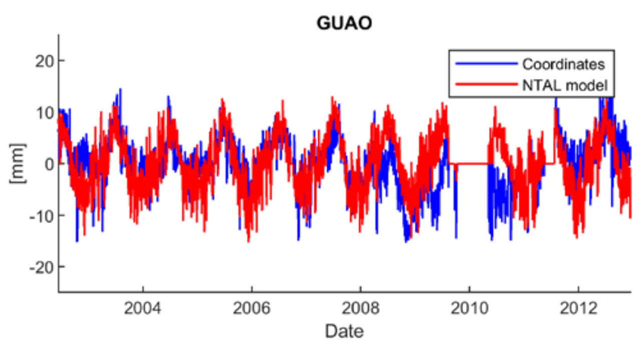
5.46 mm

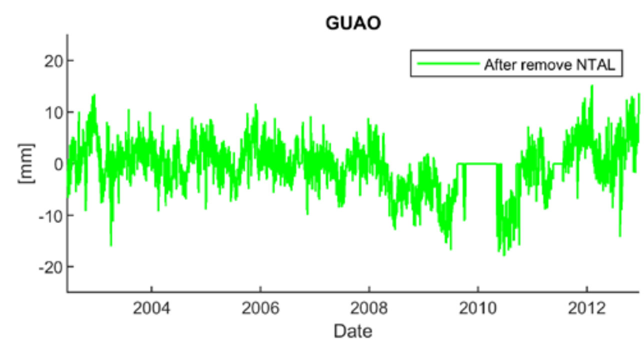




4.50 mm

5.34 mm



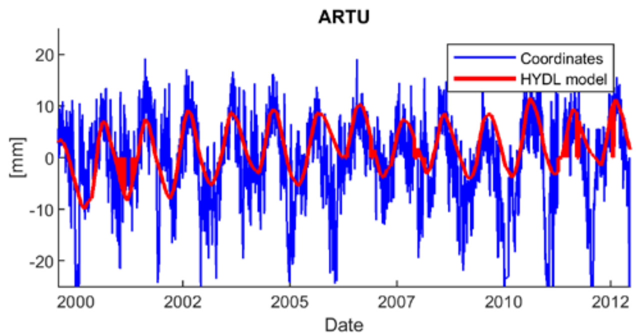


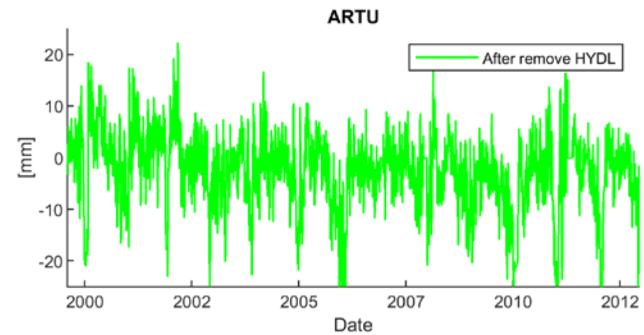
5.05 mm

Analyses (3g) – Coordinates minus geophysical deformations (HYDL) – Up component

RMS | **RMS**

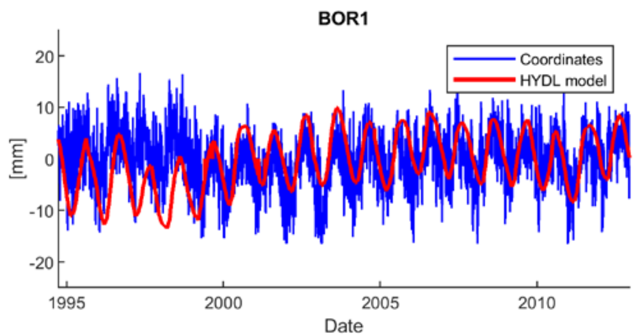
8.68 mm

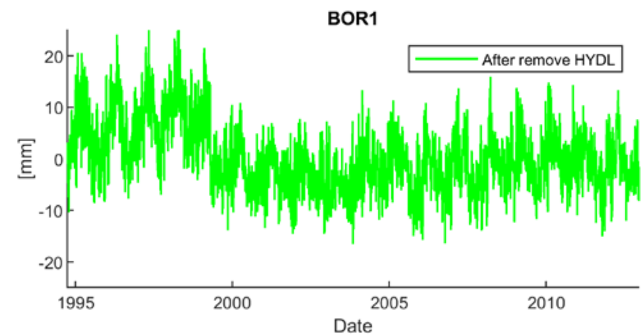




7.46 mm

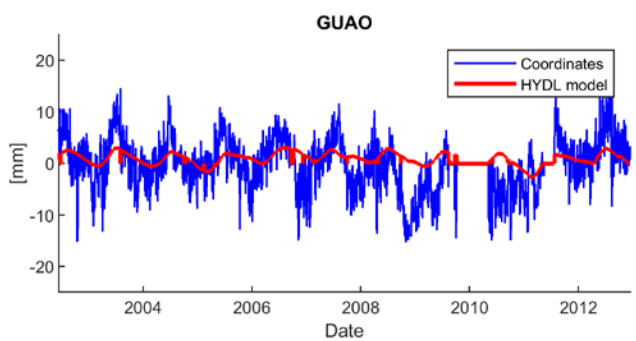
5.46 mm

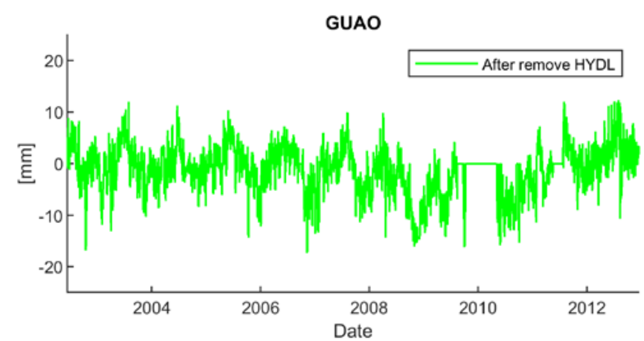




6.57 mm

5.34 mm



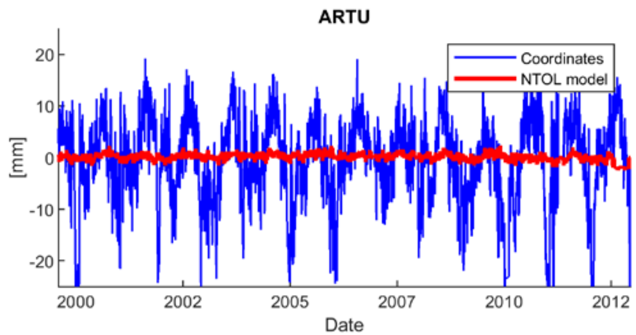


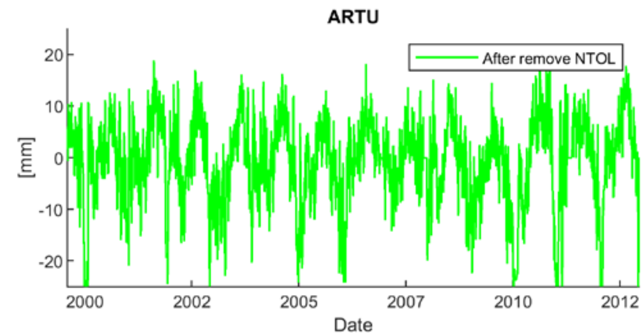
5.00 mm

Analyses (3h) – Coordinates minus geophysical deformations (NTOL) – Up component

RMS

8.68 mm

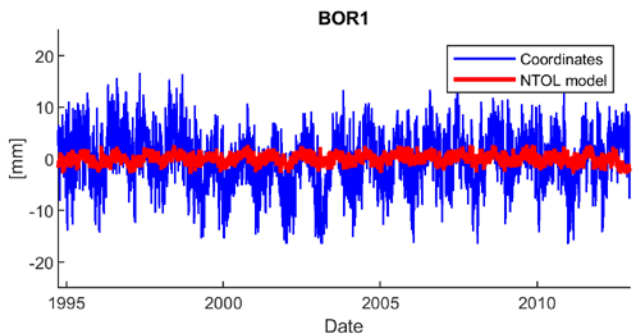


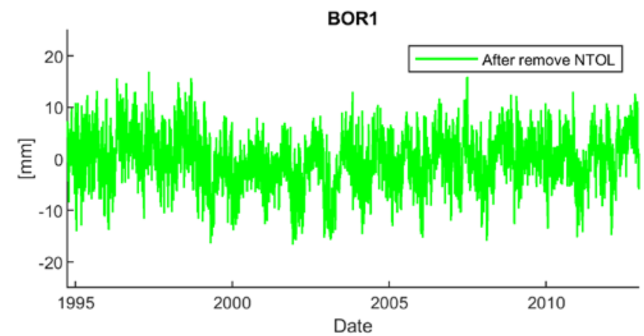


RMS

8.64 mm

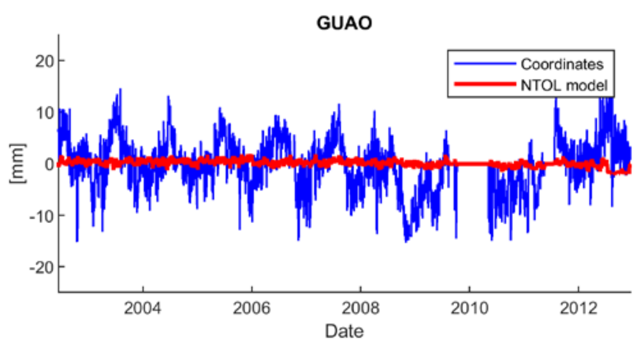
5.46 mm

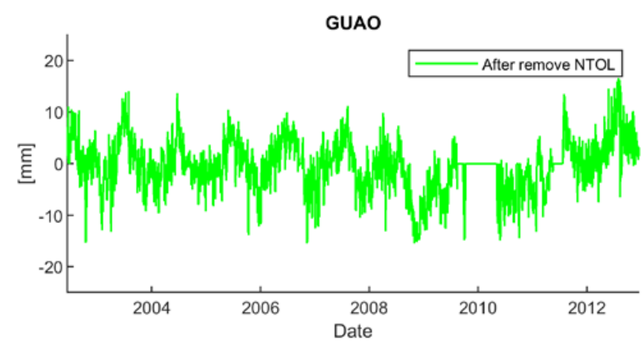




5.26 mm

5.34 mm



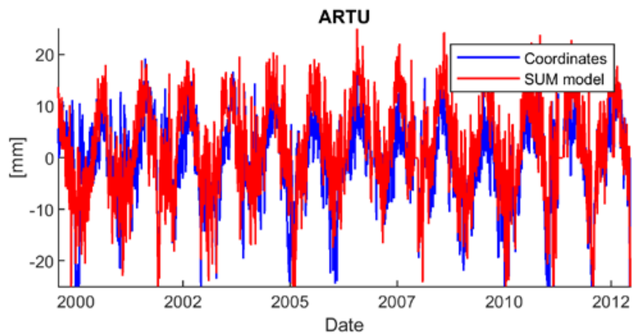


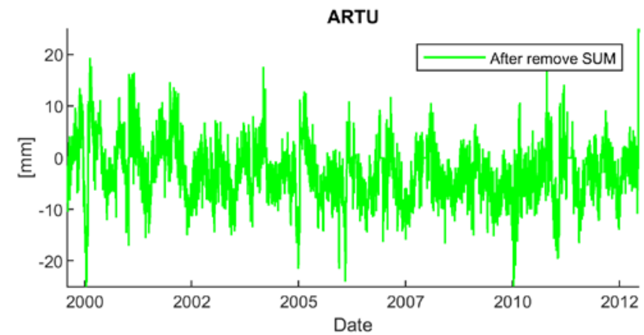
5.37 mm

Analyses (3i) – Coordinates minus geophysical deformations (SUM) – Up component

RMS | **RMS**

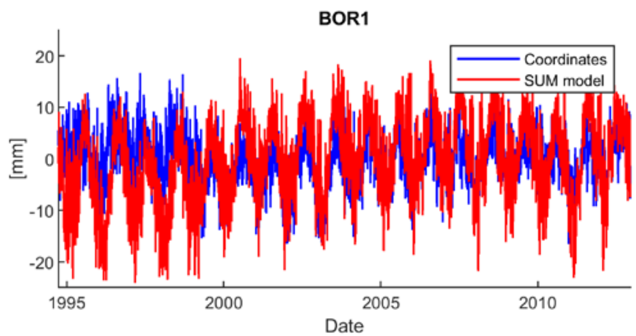
8.68 mm

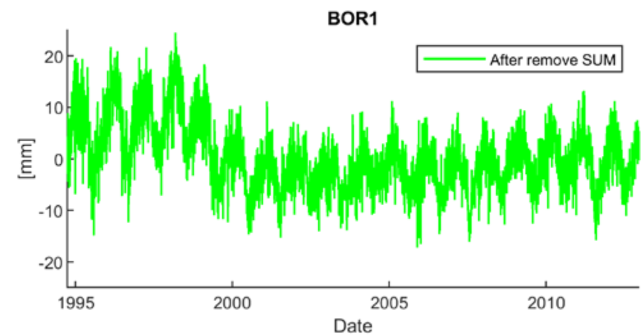




5.81 mm

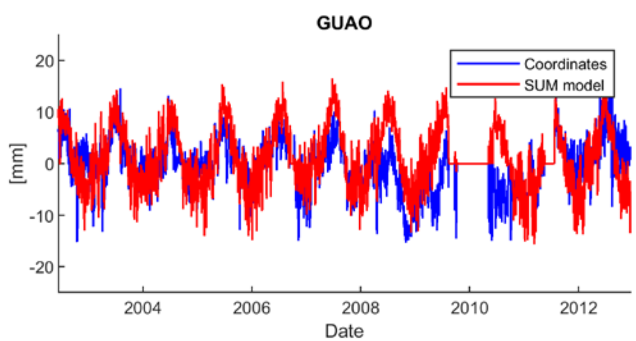
5.46 mm

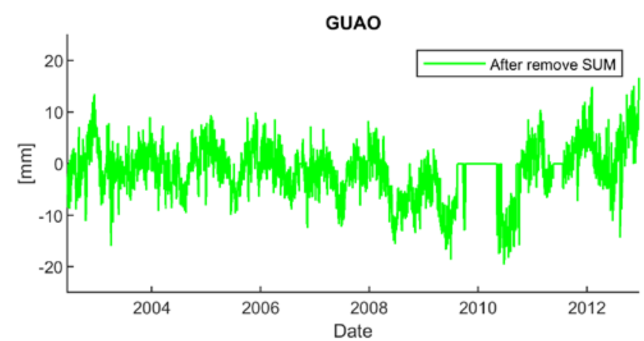




6.38 mm

5.34 mm

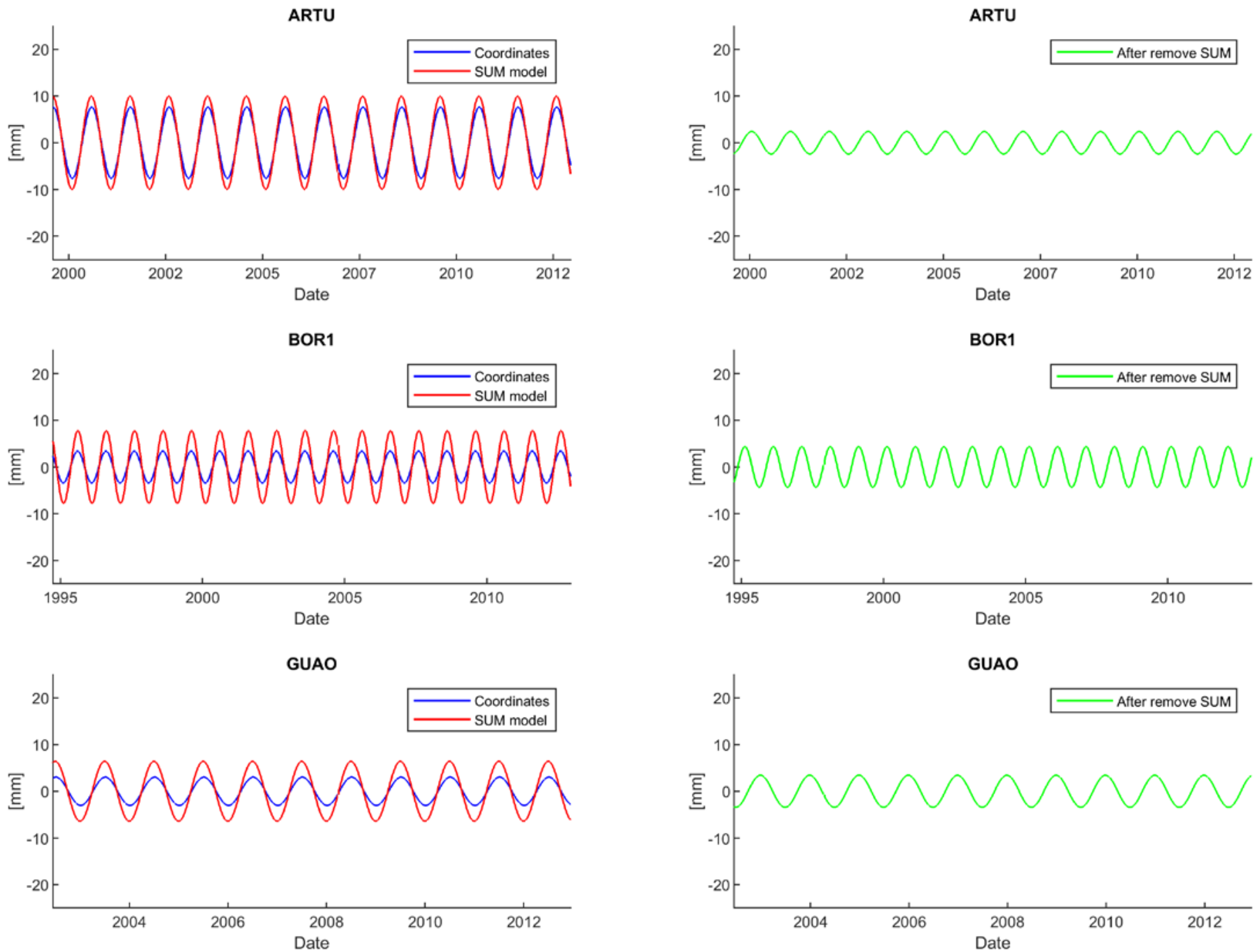




5.36 mm

Analyses (3j) – Coordinates minus geophysical deformations (SUM) – Up component (modeled signals)

RMS | **RMS**



RMS	RMS
5.37 mm	**3.48 mm**
2.42 mm	**1.91 mm**
2.14 mm	**1.90 mm**

Signals were modelled using LSE apprach with constant amplitude and phase. Modelling period is equal 365.25 days)

Wnioski

- analysing the periodicity of coordinates and geophysical deformations, the annual signal is clearly the dominant period,
- the highest value of the correlation coefficient between coordinate residues and deformations occurs for the height component (Up),
- the sum of deformations clearly affects the coordinate changes for the Up component,
- analysis of individual deformation components (NTAL, HYDRO, NTOL) showed that NTAL has the greatest impact on coordinate changes and decrease RMS values for all analysed GNSS stations,
- Removing the deformation model showed that other, unidentified annual oscillations still occur. The reason for this may be imperfections in modeling geophysical phenomena and many local factors that are not applied to global models.
- geophysical deformations can also affect the variability of the Earth's mass center.

UNIWERSYTET PRZYRODNICZY WE WROCŁAWIU

Thank you for your attentnion!

adrian.kaczmarek@upwr.edu.pl

Kaczmarek, A., Kontny, B. (2018). *Estimates of seasonal signals in GNSS time series and environmental loading models with iterative Least-Squares Estimation (iLSE) approach*. Acta Geodynamica et Geomaterialia, Vol. 15 No. 2 (190). DOI: 10.13168/AGG.2018.0009

Kaczmarek, A., Kontny, B. (2018). *Identification of the Noise Model in the Time Series of GNSS Stations Coordinates Using Wavelet Analysis.* Remote Sensing, 10(10), 1161. DOI: 10.3390/rs10101611

Kaczmarek A. (2019). *Influence of geophysical signals on coordinate variations GNSS permanent stations in Central Europe,* Artificial Satellites Journal of Planetary, Vol. 54 No. 3, Warsaw, Poland 2019, pp. 57-71 DOI: 10.2478/arsa-2019-0006