NATIONAL REPORT OF POLAND TO EUREF 2017

Jan Krynski

Institute of Geodesy and Cartography, Warsaw

Jerzy B. Rogowski

Gdynia Maritime University

Main geodetic activities at the national level in Poland since 2015

- activities in the horizontal and vertical control
- maintenance of the gravity control
- maintenance of the magnetic control
- operational work of permanent EPN/IGS stations
- data processing at Local Analysis Centres at WUT and MUT
- activities of MUT and WUT EPN Combination Centre
- status of the ASG-EUPOS network in Poland
- modelling precise geoid
- the use of data from satellite gravity missions
- validation of GNSS orbits using SLR
- GNSS for meteorology
- monitoring of ionosphere
- monitoring gravity changes and geodynamics
- activities in SLR

Activities in the horizontal and vertical control

Head Office of Geodesy and Cartography

Continuation of field inspection of geodetic control network;
in 2016 visited (damage in last 15 years)

- **horizontal - 3850 benchmarks (445 damaged – 11.6%)**
- **vertical - 2820 benchmarks (657 damaged – 23.3%)**

University of Warmia and Mazury, Olsztyn UWM

Local mean geopotential value W_0^L determined from

- **three campaigns of Baltic Sea Level Project**
- **GNSS campaign 2015 together with tide gauge data (3 stations)**

and

- **EGM2008 GGM**

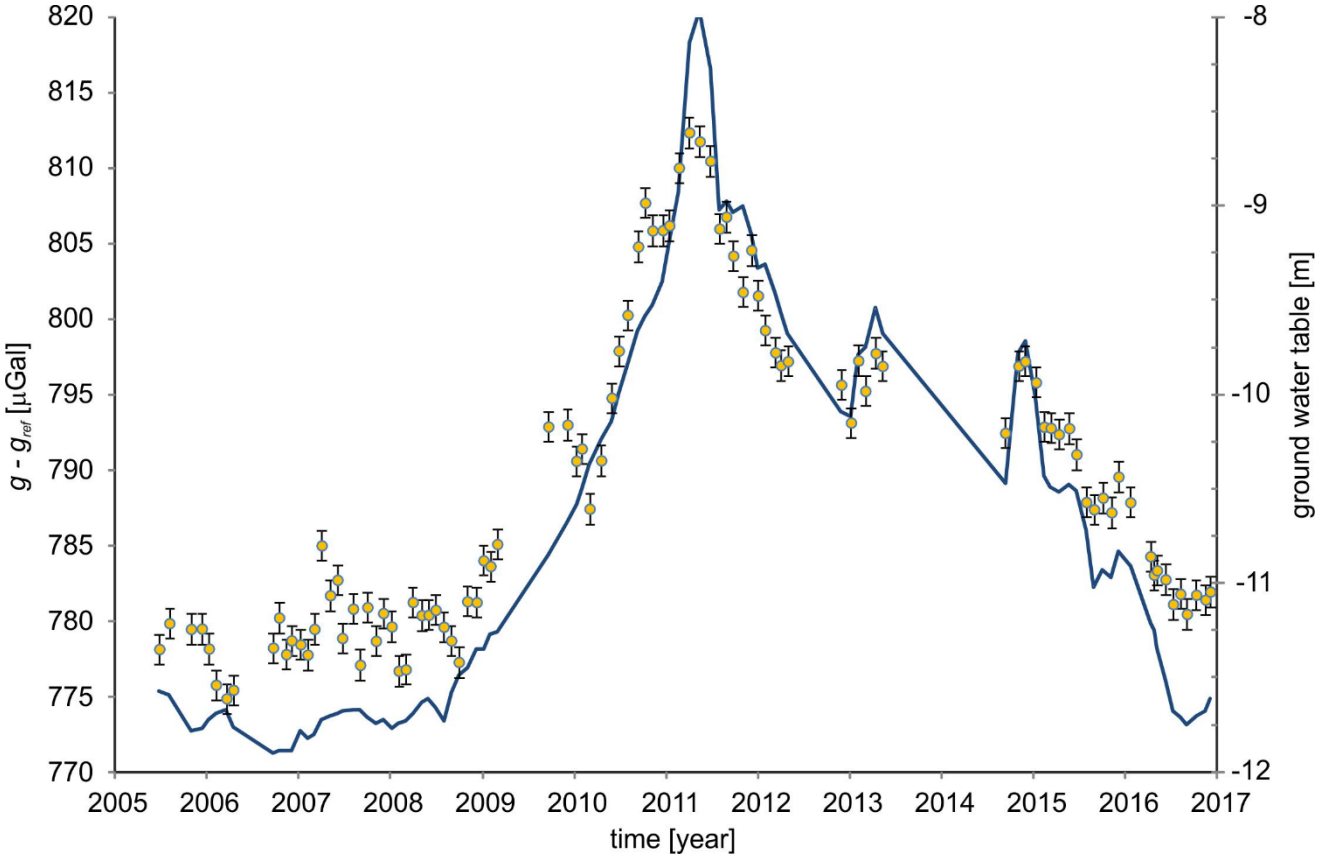
Best estimate obtained form GNSS campaign 2015)

$$W_0^L = 62636857.45\ m^2\ s^{-2} \pm 0.01\ m^2 s^{-2}$$

Maintenance of national gravity control (1)

Jozefoslaw Astrogeodetic Observatory, Warsaw University of Technology WUT

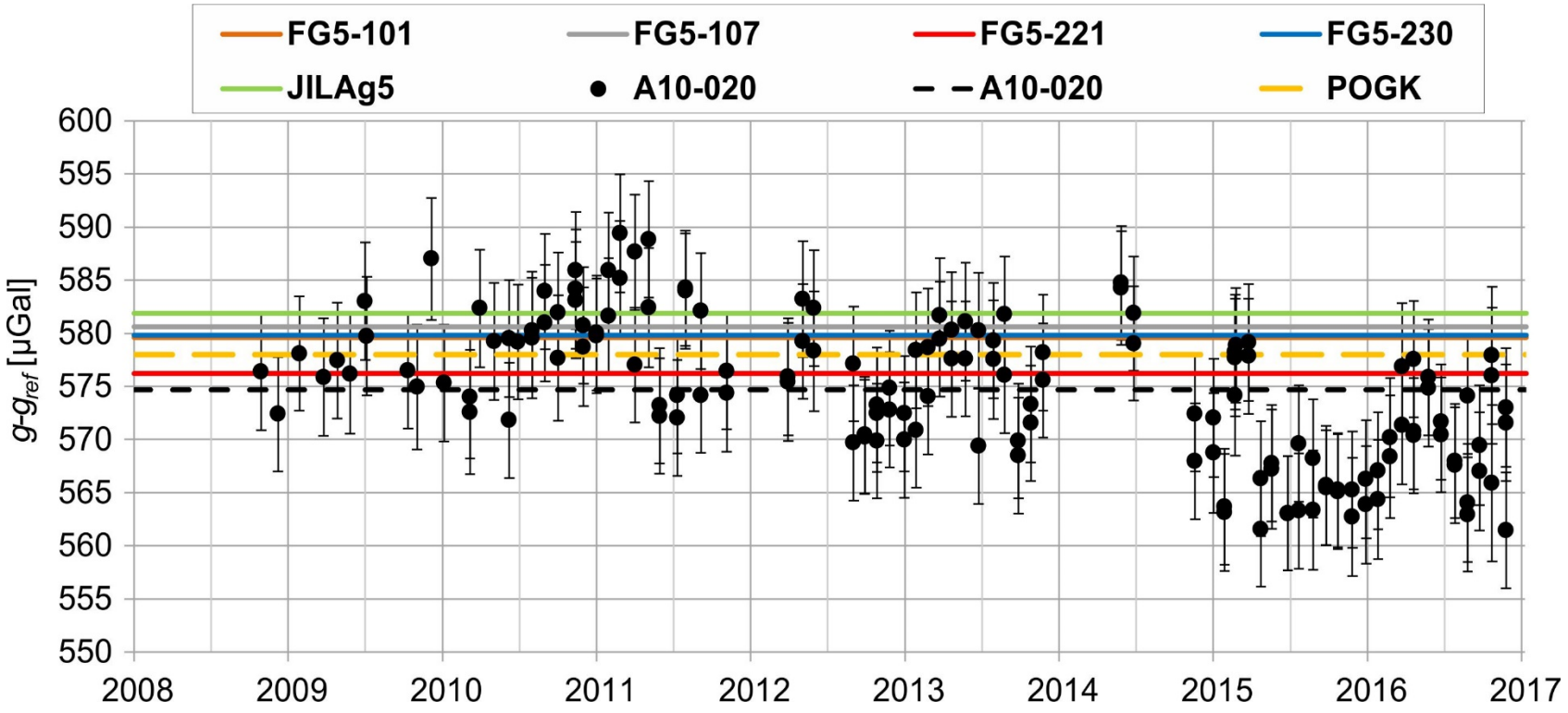
quasi-permanent absolute gravity measurements with FG5-230



Maintenance of national gravity control (2)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

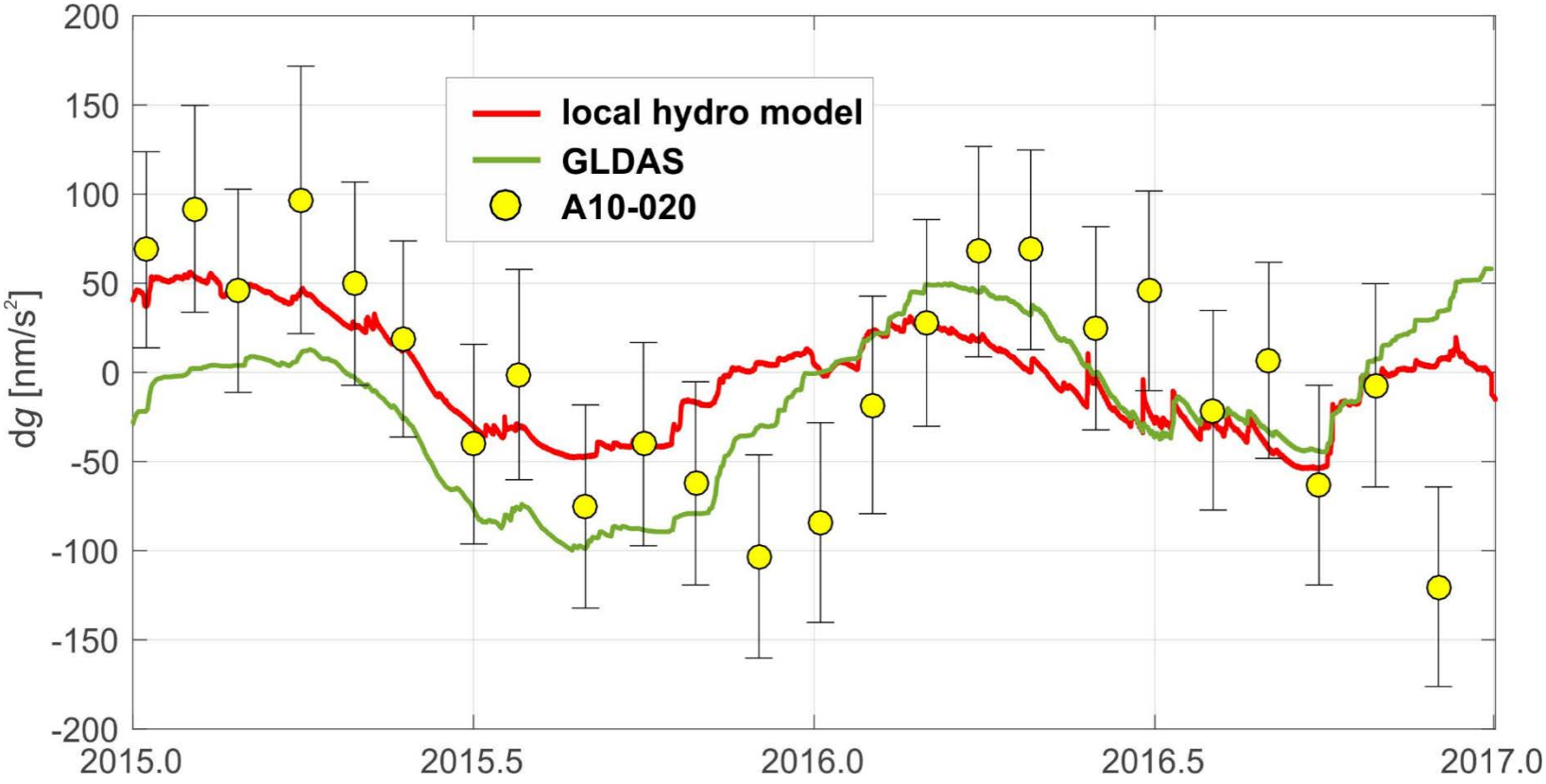
quasi-permanent absolute gravity measurements with A10-020



Maintenance of national gravity control (3)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

absolute gravity variations from the survey with the A10-020 at the field station 156 at Borowa Gora and from local as well as GLDAS hydrological models

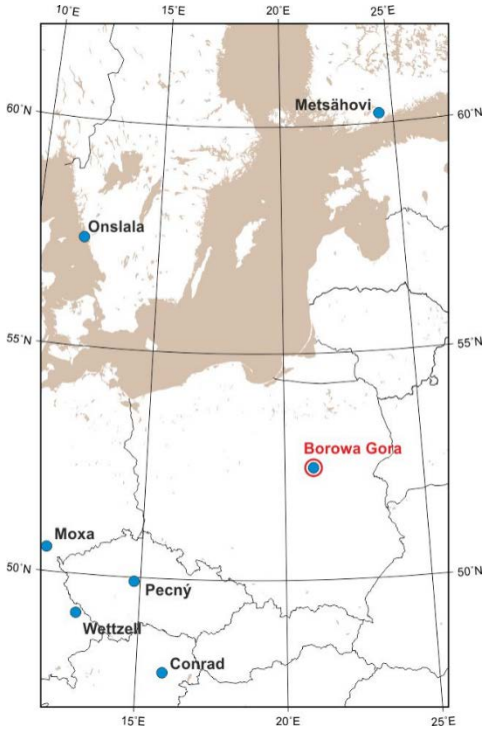


Maintenance of national gravity control (4)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

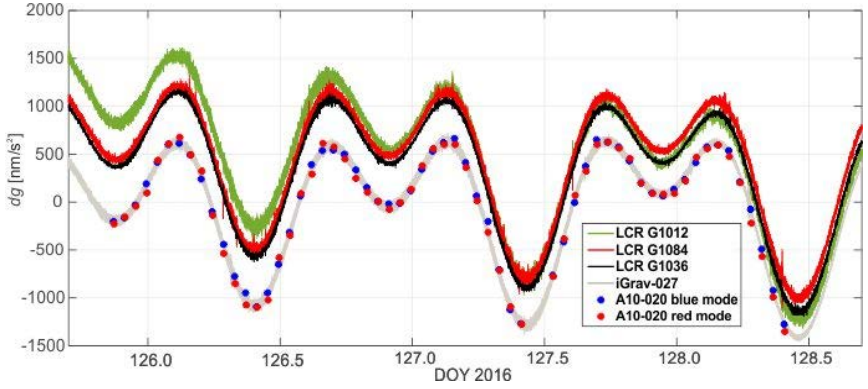
since May 2016 the iGrav-027 superconducting gravimeter operates at Borowa Gora

location of SGs



iGrav-027

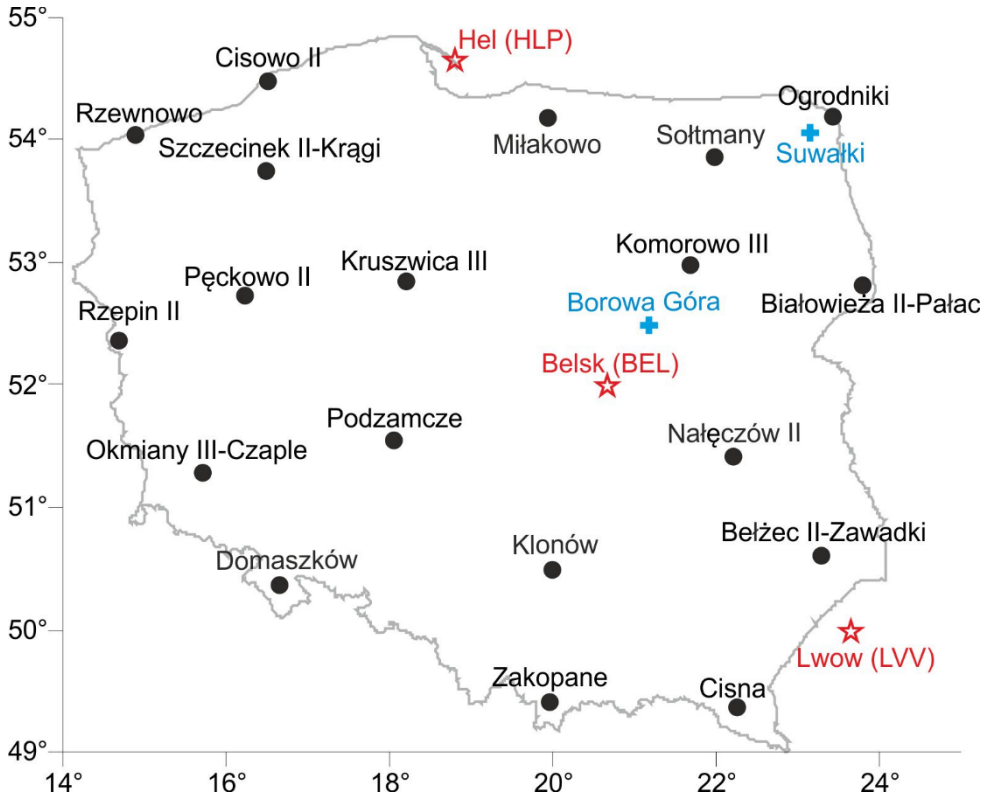
initial calibration of the iGrav-027



Maintenance of magnetic control

Institute of Geodesy and Cartography (IGiK), Warsaw

repeat stations, permanent stations and magnetic observatories



- **every 2-4 years**
- **3 independent components of the magnetic intensity vector at the repeat stations measured**

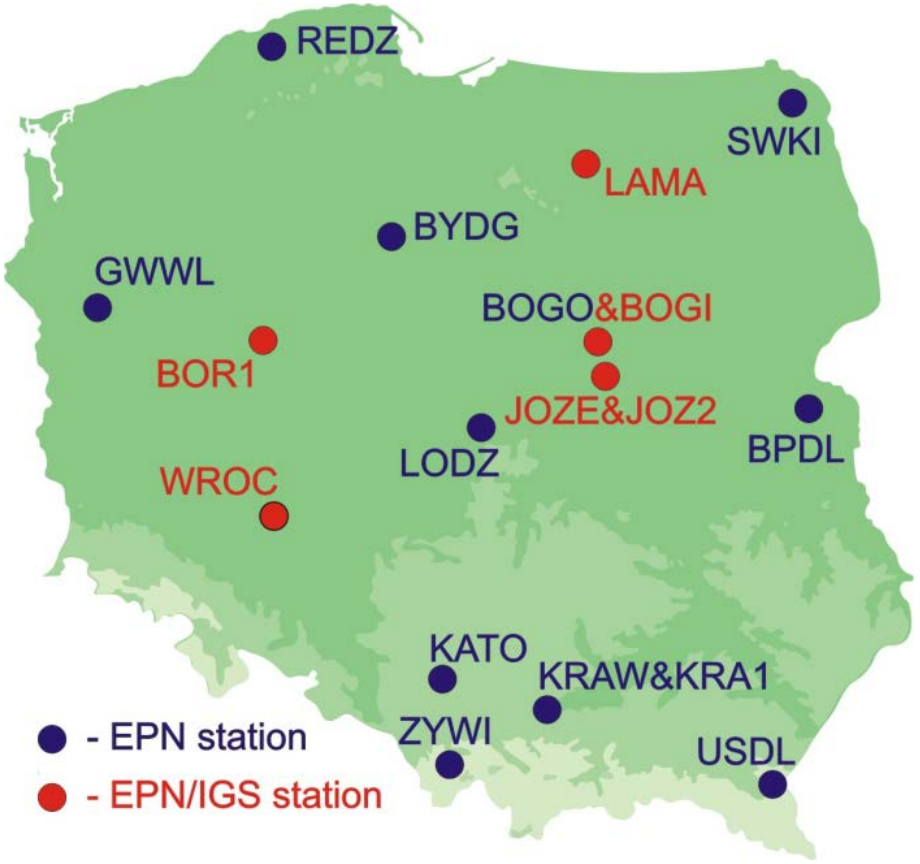
Operational work of permanent GNSS IGS/EUREF stations

EPN stations in Poland

- Biala Podlaska (BPDL)
- Borowa Gora (BOGI)
- Borowa Gora (BOGO)
- Borowiec (BOR1)
- Bydgoszcz (BYDG)
- Gorzow Wielkopolski (GWWL)
- Jozefoslaw (JOZE)
- Jozefoslaw (JOZ2)
- Katowice (KATO)
- Krakow (KRAW)
- Krakow (KRA1)
- Lamkowko (LAMA)
- Lodz (LODZ)
- Redzikowo (REDZ)
- Suwalki (SWKI)
- Ustrzyki Dolne (USDL)
- Wroclaw (WROC)
- Zywiec (ZYWI)

EPN Stations participating in EUREF-IP

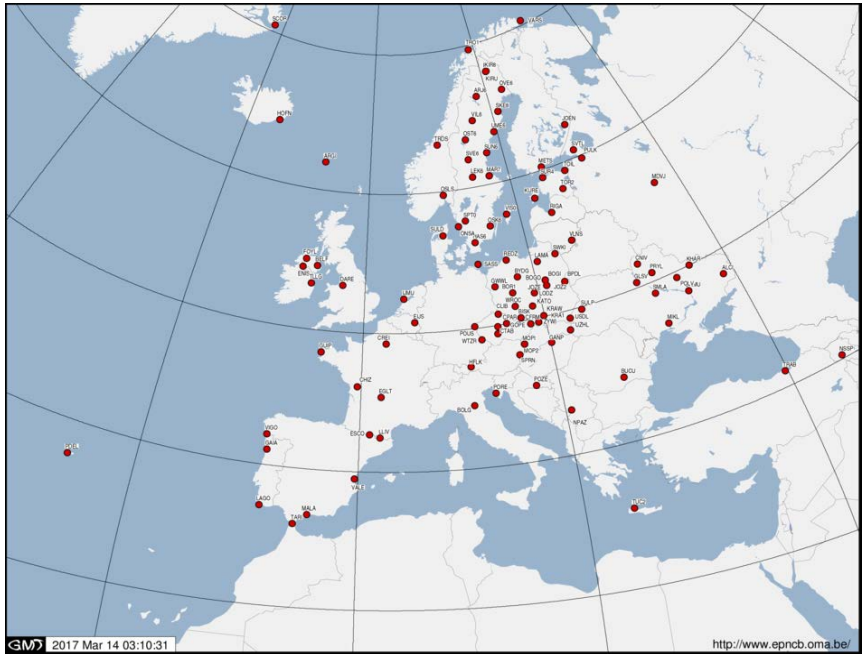
♥ BOG ♥ BOR1 ♥ JOZ2 ♥ KRA1 ♥ KRAW ♥ LAMA ♥ WROC



Data processing at LACs

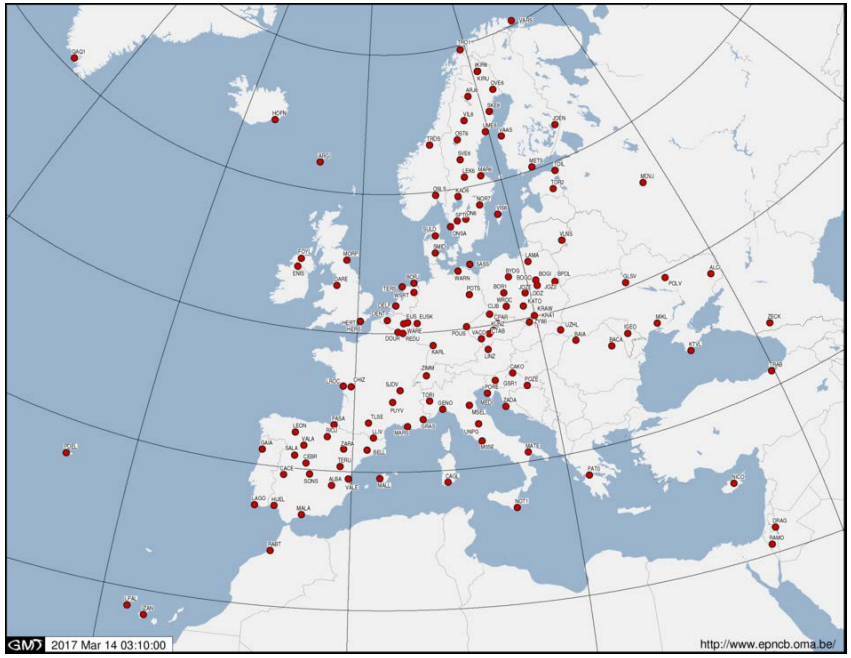
WUT

data from 106 EPN stations routinely processed



MUT

data from 141 EPN stations routinely processed



MUT – WUT EPN Combination Centre

- **16 ACs were submitting SINEX solutions for the weekly EPN combination**
- **all combinations are performed with Bernese v.5.2**
- **products**
  - **final positions weekly and daily**
  - **rapid daily solutions**
  - **ultra-rapid solutions**
- **change of methodology for creating weekly combined EPN solutions**
  - **daily solutions are first combined and then stacked into a weekly solution**
- **Repro2 reprocessing completed**
  - **daily and weekly solutions computed by 5 EPN ACs for the period 1996-2013 were combined**

Results of final, rapid and ultra-rapid combinations on web page (http://www.epnacc.wat.edu.pl)

ASG-EUPOS network in Poland

Head Office of Geodesy and Cartography

reference stations of ASG-EUPOS network

- **125 stations**

- 2 **new stations** established
- 13 stations – **new receiver and antenna**

- 4 **new RTN data streams** for providing GPS+GLONASS Network RTK data for most area of Poland

- **3478 active licenses** for RTK service
- **1900 users** every working day

Modelling precise geoid

IGiK

- **new gravimetric quasigeoid model GDQM-PL16 for Poland**

Data:

- **1'×1' mean Faye Δ*g***
- **deflections of the vertical (Poland)**
- **Δ*g* (neighbouring countries)**
- **GECO**

Method:

- **remove-compute-restore (RCR)**
- **least squares collocation with planar logarithmic covariance function of Δ*g***

Fit to GNSS/levelling (control traverse; ASG-EUPOS):

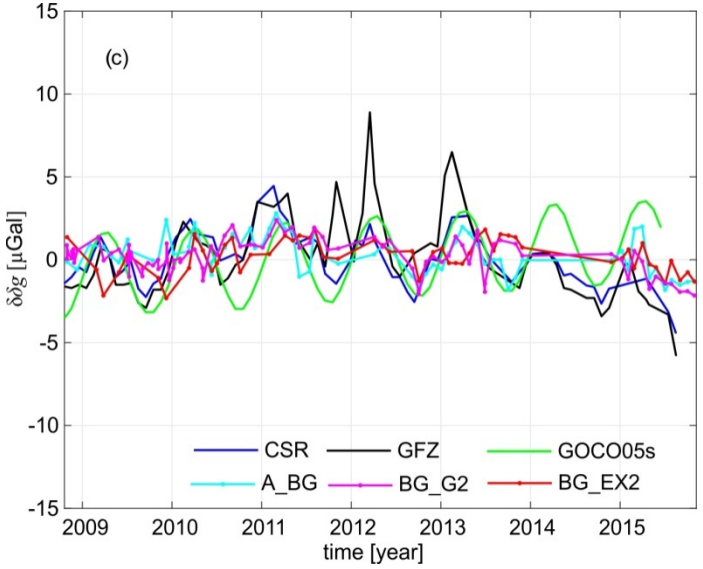
- **1.3 – 1.9 cm**

Use of data from satellite gravity missions (1)

IGiK

- **evaluation** over the area of Poland of 15 global geopotential models (GGMs) developed in 2014-2016
  - absolute gravity data (*168 stations of national gravity control*)
  - high precision GNSS/levelling data (*100 ASG-EUPOS stations*)
- **calibration of RL05 GGMs** using the series of absolute gravity measurements with the A10-020 gravimeter at Borowa Gora

Time series of gravity variations at Borowa Gora obtained from the CSR and GFZ RL05 GRACE-based GGMs, GOCO05s and the smoothed/reduced gravity data obtained from the measurements with the A10-020 reduced and smoothed using the local hydrology and the moving average

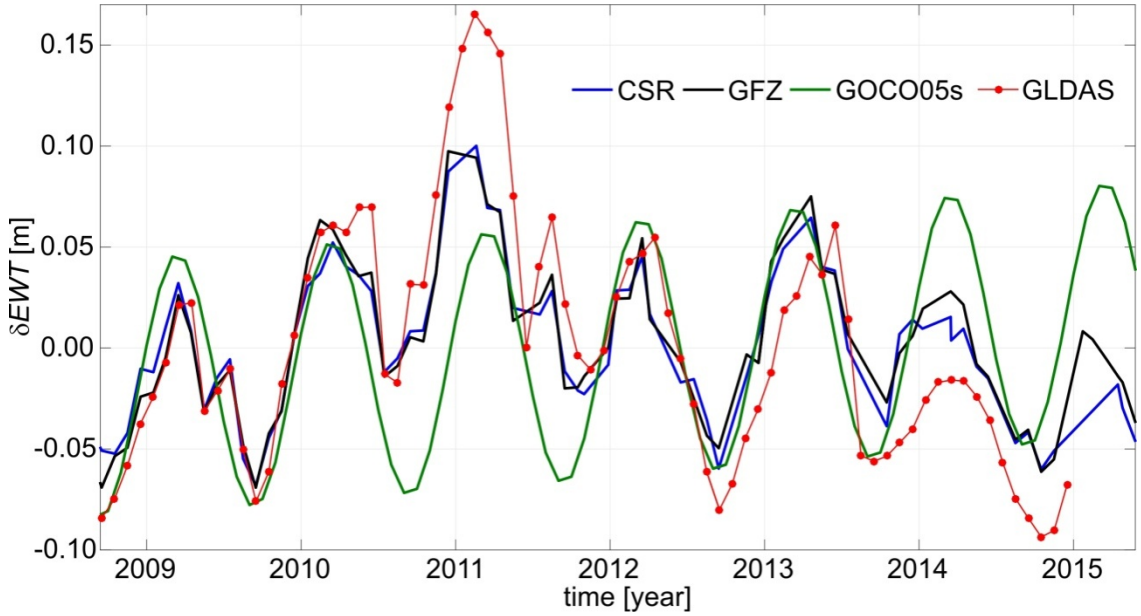


Use of data from satellite gravity missions (2)

IGiK

- **temporal gravity field variations over the area of Poland using 5th release GRACE-based GGMs**
  - **suitability of GRACE data to study short term mass variations**

Time series of δEWT at the Borowa Gora obtained from the CSR and GFZ RL05 GRACE-based GGMs, the GOCO05s and GLDAS hydrological models

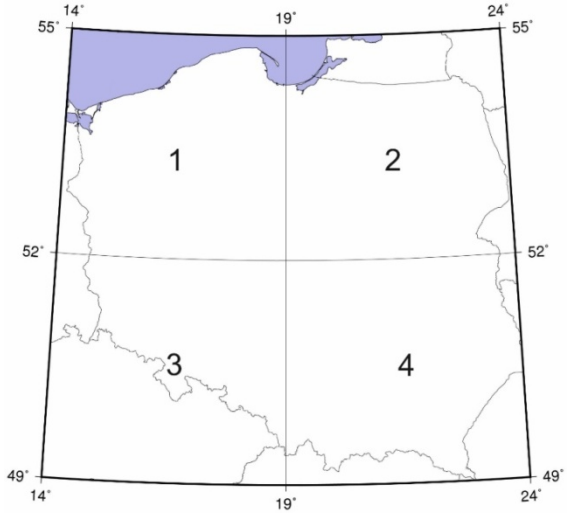


Use of data from satellite gravity missions (3)

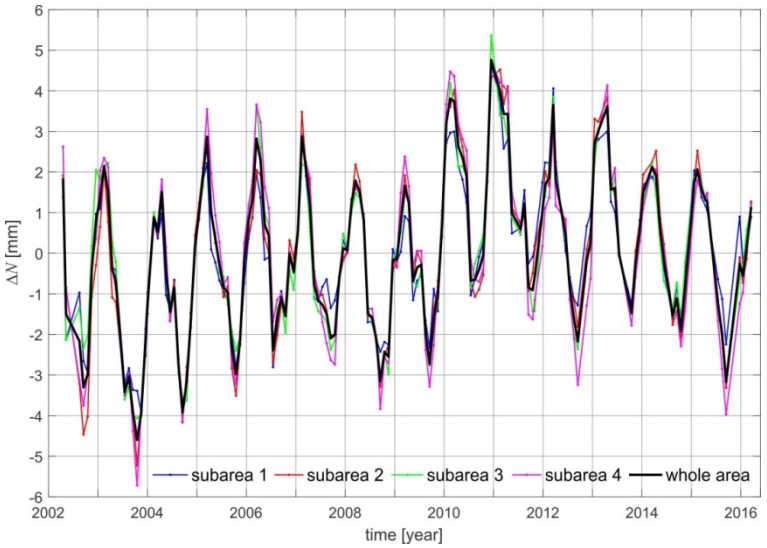
IGiK

- **temporal geoid height variations over the area of Poland using 5th release GRACE-based GGMs**

Subareas in Poland for which geoid height variations were investigated



Time series of geoid height variations in subareas investigated



University of Warmia and Mazury in Olsztyn (UWM)

- **research on ground water level changes and water budget evaluation on the basis of GRACE data and a high resolution hydrological GLDAS data**

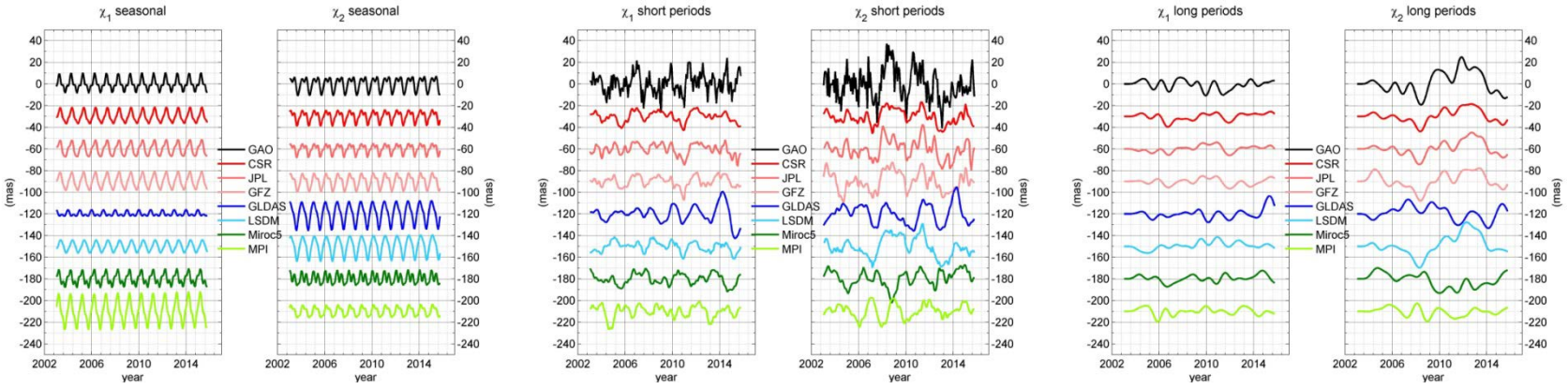
Use of data from satellite gravity missions (4)

Space Research Centre of the Polish Academy of Sciences (SRC PAS)

- **influence of land hydrosphere on polar motion excitation functions at seasonal time scales**

Variations of χ1 and χ2 components of geodetic residuals (GAO) with gravimetric (CSR, JPL, GFZ) and hydrological (GLDAS, LSDM, MIROC, MPI) excitation functions

seasonal **short period** **long period**

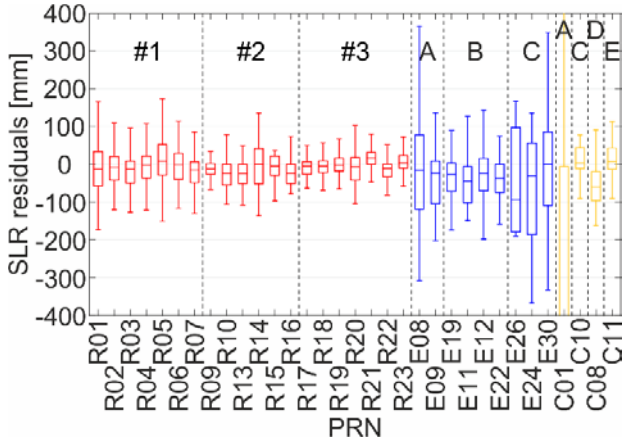


Validation of GNSS orbits using SLR (1)

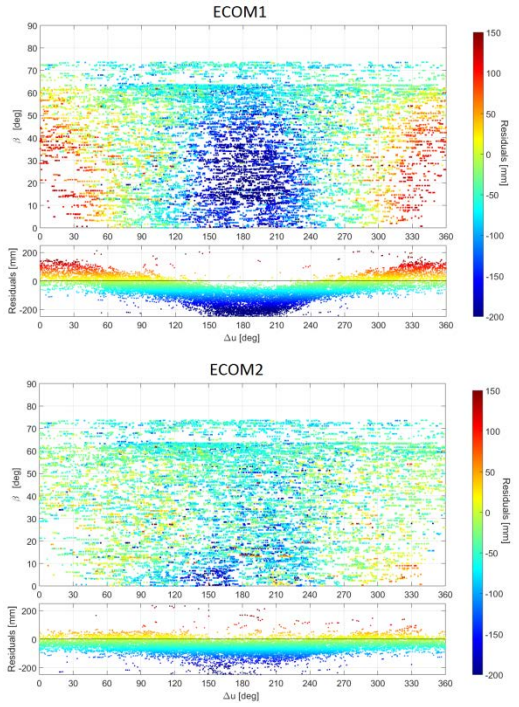
Wroclaw University of Environmental and Life Sciences (WUELS)

- **validation** of final **IGS orbits**
- **validation** of real-time streamed **orbits used for Precise Point Positioning**
- **validation** of solar **radiation pressure models**

Validation of real-time CNES orbits using SLR observations with a distinction between different orbital planes for GLONASS (red), Galileo (blue) and BeiDou (yellow)



validation of final CODE Galileo orbits using the classical ECOM1 model (top) and the extended ECOM2 model (bottom) using SLR data from 2014



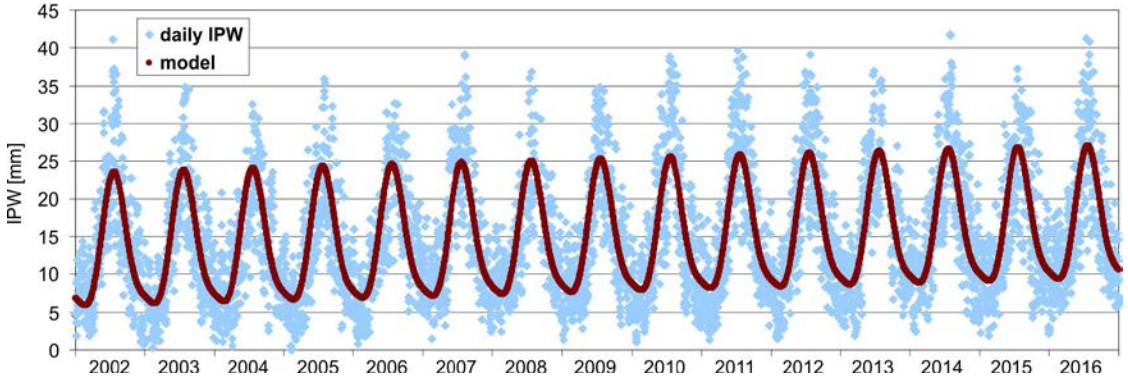
on-line web service for the validation of GNSS orbits using SLR (http://www.igig.up.wroc.pl/igg/)

GNSS for meteorology (1)

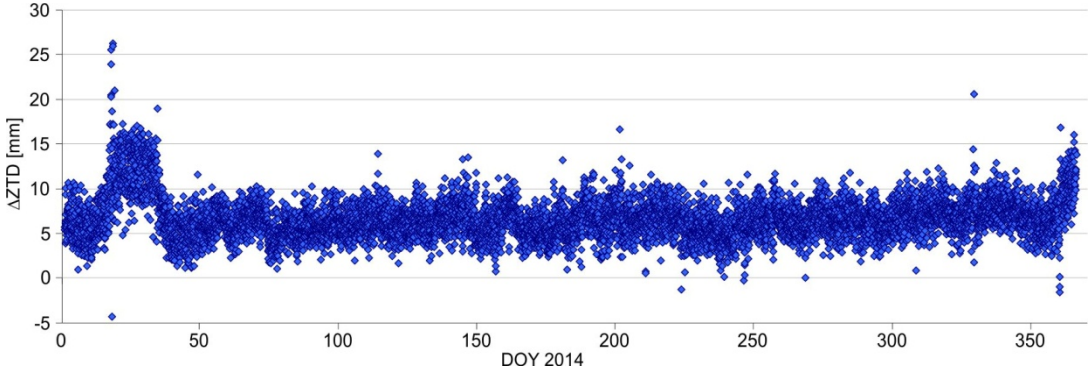
WUT

- **the seasonal model of IPW change**

IPW for JOZE (Jozefoslaw, Poland) and a model with 2 oscillations (annual and semi-annual) for 2003-2015



Differences between tropospheric delay estimates for two permanent GNSS stations JOZE (on the ground pillar) and JOZ2 (on the roof of the building)

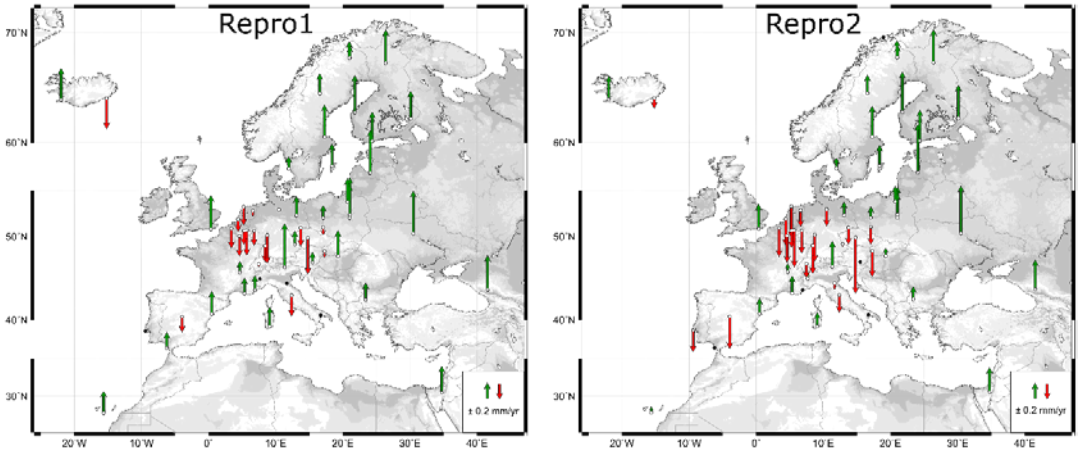


GNSS for meteorology (2)

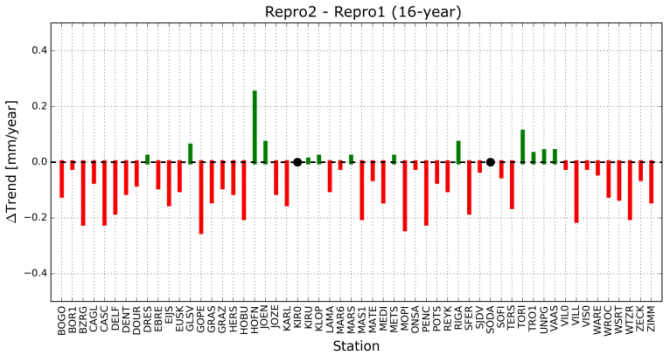
MUT

- **impact of the processing strategy on the long-term changes of the ZTD by comparing the results of two reprocessing campaigns Repro1 and Repro2**

ZTD trend for 16-year time series (01.1998-12.2013) obtained from the Repro1 and the Repro2 campaigns



Differences between the values of the linear trends in 16-year time series obtained from the Repro2 and Repro1 campaigns

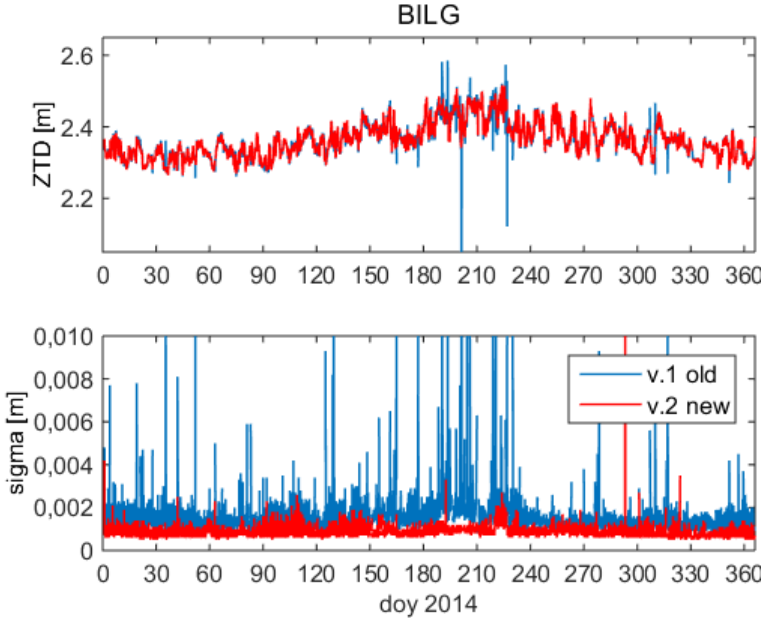


GNSS for meteorology (3)

WUELS

- **improvement of the processing strategy to reprocess GNSS data for meteorology and climatology**

Time series of ZTD and formal error of ZTD for station BILG, standard/old (blue line) and new (red line) strategies; most spikes present in the standard solution are avoided with the new strategy



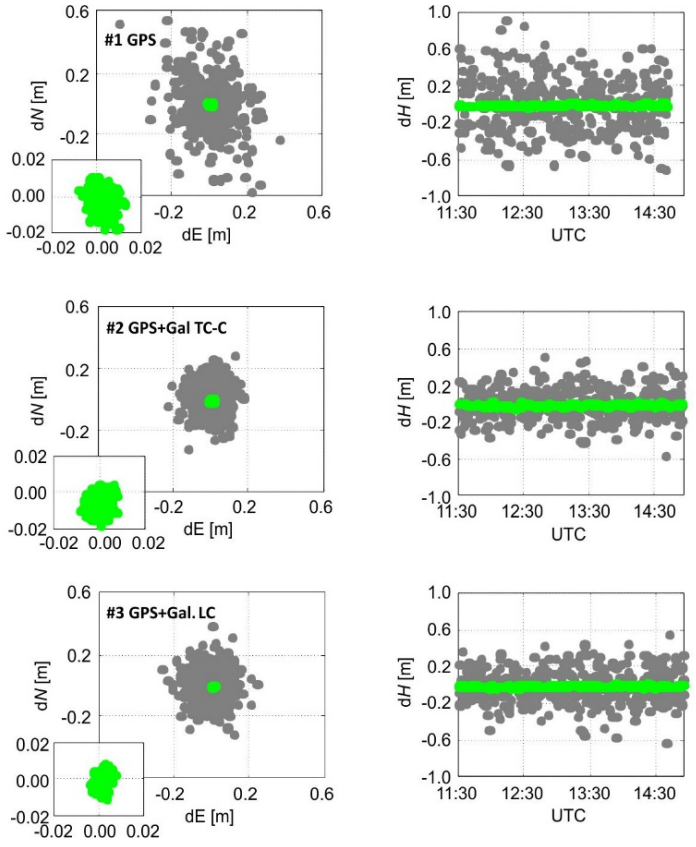
The developed strategy together with screening procedure help to improve significantly the quality of GNSS tropospheric parameters estimated in national and regional networks for meteorology and climatology

Advanced methods for satellite positioning (1)

UWM

- **development** of **algorithms and software for precise relative positioning** with the use of multiple GNSS antennas and receivers configuration on a common moving platform
- **study** on **integration of multi GNSS observations** in relative positioning was continued

Rover coordinate residuals for float (grey) and fixed (green) solutions (single GPS system – #1, GPS+Galileo tightly combined with calibrated ISB – #2, GPS+Galileo loose combined – #3)



Advanced methods for satellite positioning (2)

UWM

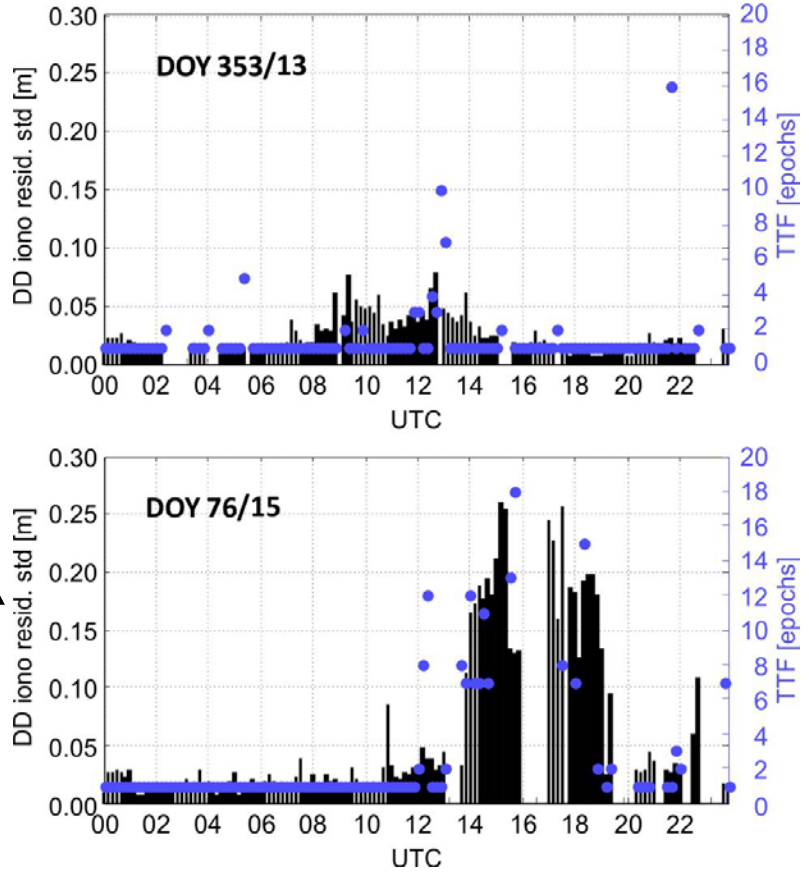
- **algorithm** for **mitigation of the influence of strong Total Electron Content**
- **study** on the impact of the **accuracy of the network ionospheric corrections** on time-to-fix in RTK-OTF positioning

Double-differenced ionospheric delays on L1 frequency for TREO–LYNS baseline obtained from geometry-free solution with fixed ambiguities for

original observations

and

RTC-corrected observations

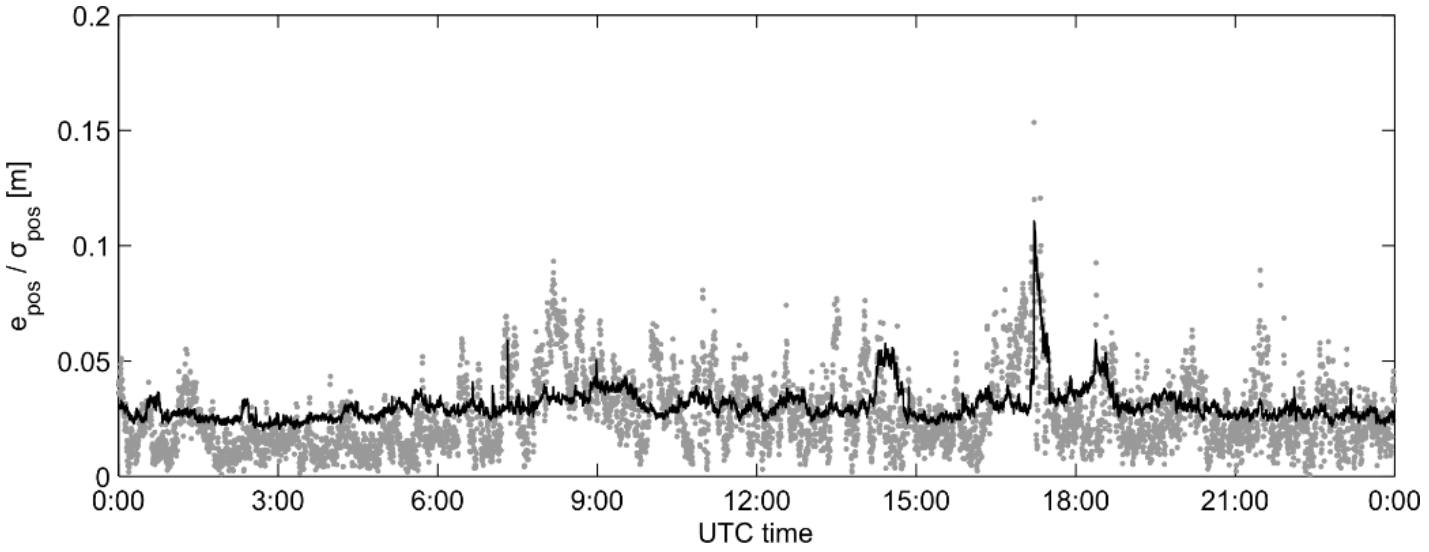


Advanced methods for satellite positioning (3)

WUT

- developed approach on estimation of reliability of GNSS Network Real-Time Kinematic (RTK) positioning using two indices as quality indicators: solution accuracy and solution availability

Positioning accuracy of the fixed solution for the test baseline – instantaneous values of the accuracy index: black—estimated errors (1σ), gray—actual errors

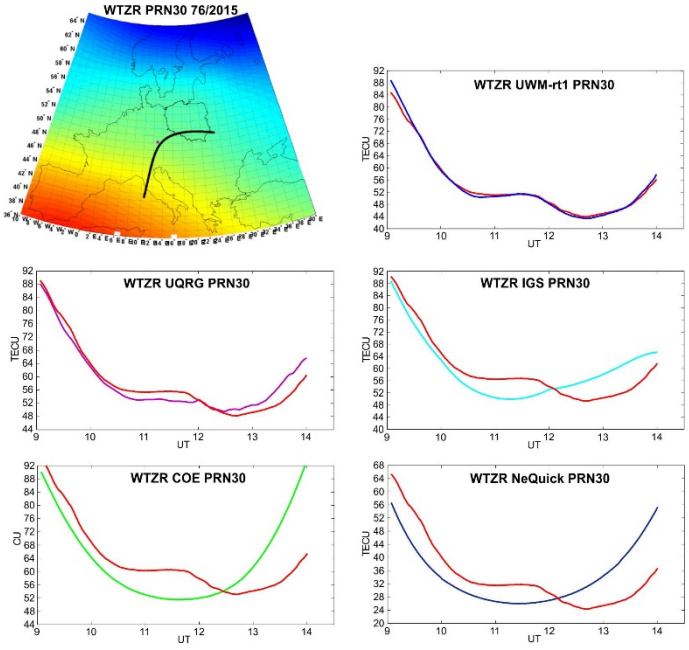


Monitoring ionosphere (1)

UWM

- **new method (UWM-rt1) for accurate regional ionospheric TEC modelling based on processing of GPS carrier phase data**
  - **selection of different TEC interpolation methods**
  - **generation TEC maps for Europe with high temporal and spatial resolution**

Comparisons of VTEC for PRN30: red line represents fitted geometry-free (L4) observations, other colours represent different analysed models



RMS of post fit residuals for the analysed TEC map

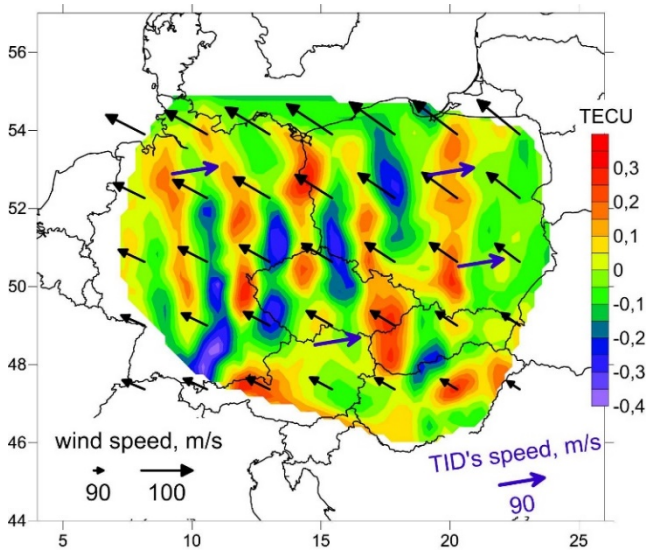
DOY	UWM – rt1	UQRG	IGS	CODE	NeQuick
73	*0.84*	1.28	1.15	2.65	2.92
74	*0.87*	1.27	1.14	2.98	2.49
75	*0.97*	1.38	1.22	2.23	2.04
76	*1.09*	1.93	2.37	3.88	7.18
77	*0.39*	0.84	1.11	2.12	3.23
78	*0.38*	0.92	1.18	2.91	3.42
79	*0.33*	0.84	1.16	1.88	2.27

Monitoring ionosphere (2)

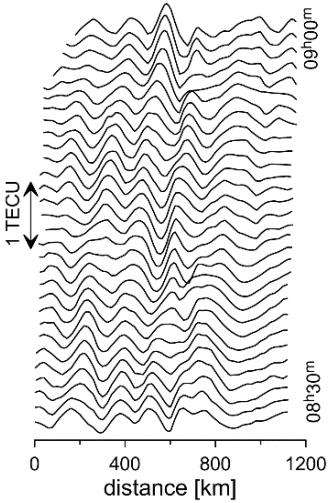
MUT & Institute of Radio Astronomy NAS of Ukraine, Kharkiv

- **new technique** of the orthogonal projection of variations of electronic content of the ionosphere (OPVECI) for the **mapping of TEC**
  - visualization of the ionospheric irregularities

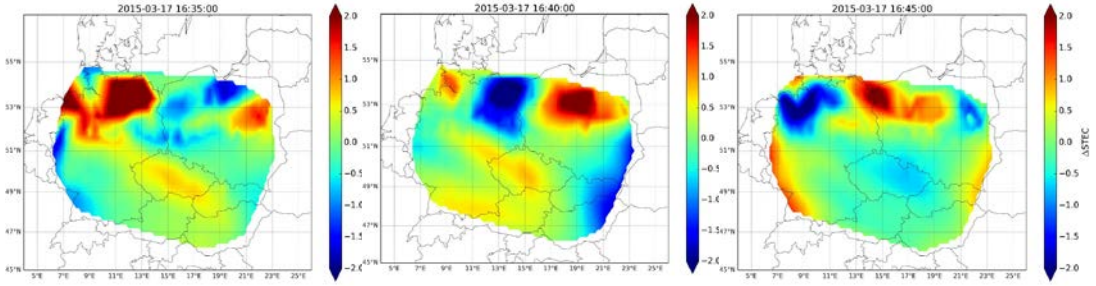
Map of TEC variations over Central Europe on 13 March 2013 08h 50m



Profiles of TEC variations along the 50° parallel from 08h30m to 09h00m on 13 March 201



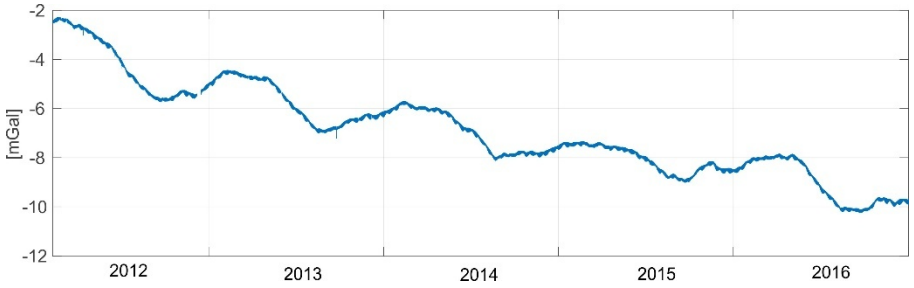
Maps of TEC variations from 16h35m to 16h45m on 17 March 201



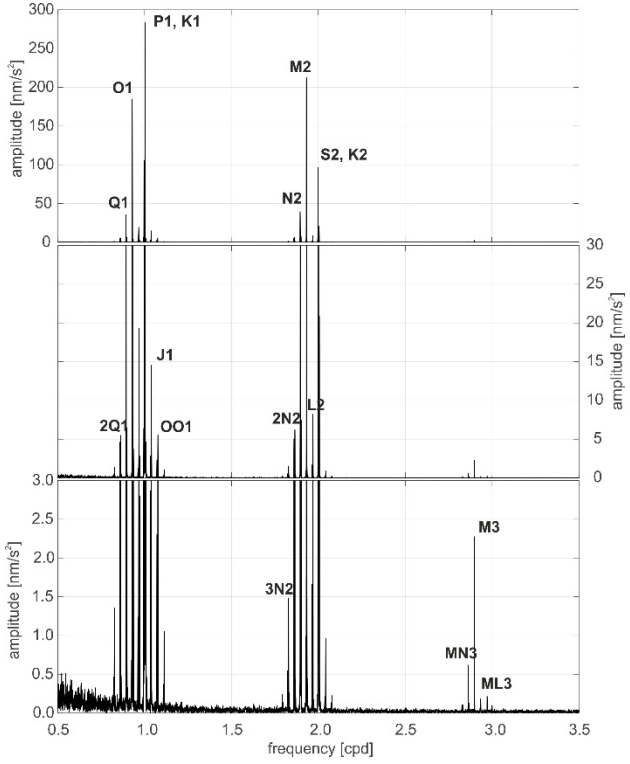
Monitoring gravity changes (1)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

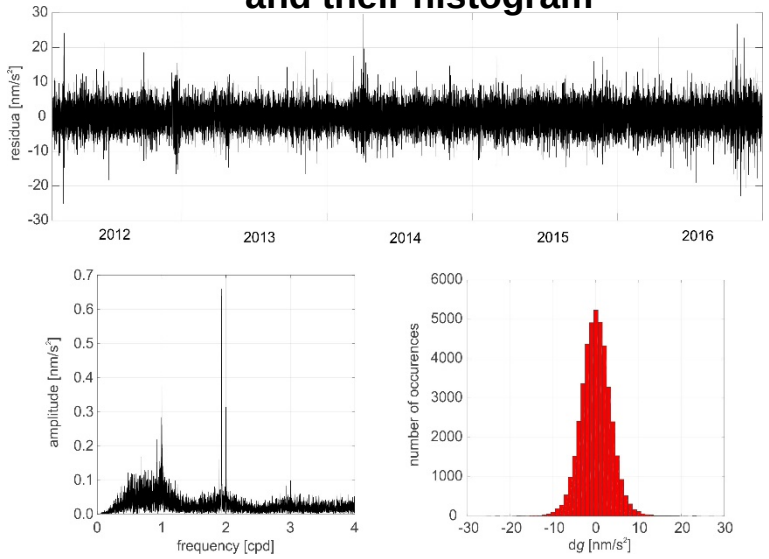
- **gravity record using LCR G1036 from 2012-2016 was analysed**



Spectrum of the tidal signal



Residua of tidal adjustment obtained from the using the ANALYZE software, their power density spectrum and their histogram

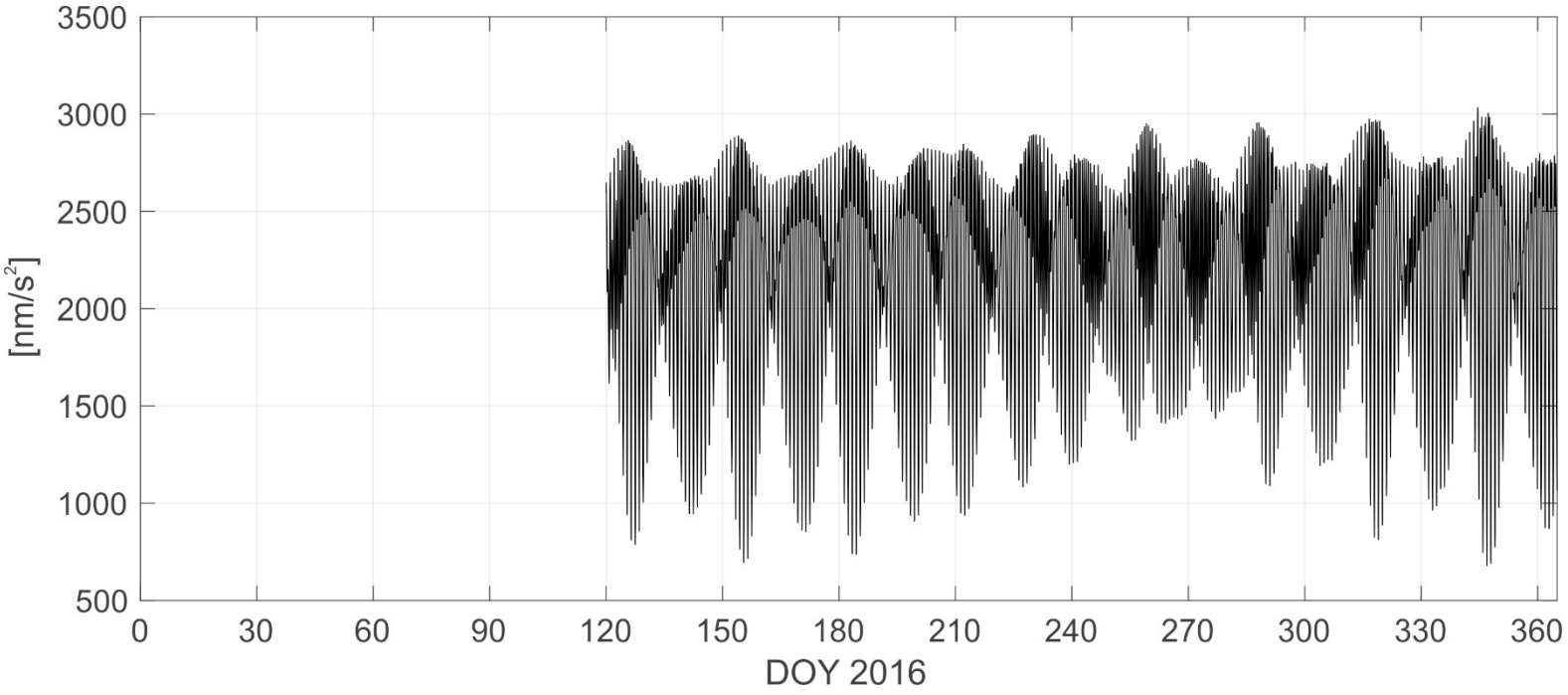


Monitoring gravity changes (2)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

- since May 2016 a **continuous gravity signal** is collected by the **iGrav-027 superconducting gravimeter**

Tidal record with the iGrav-027 gravimeter in 2016



Satellite Laser Ranging (1)

SRC PAS

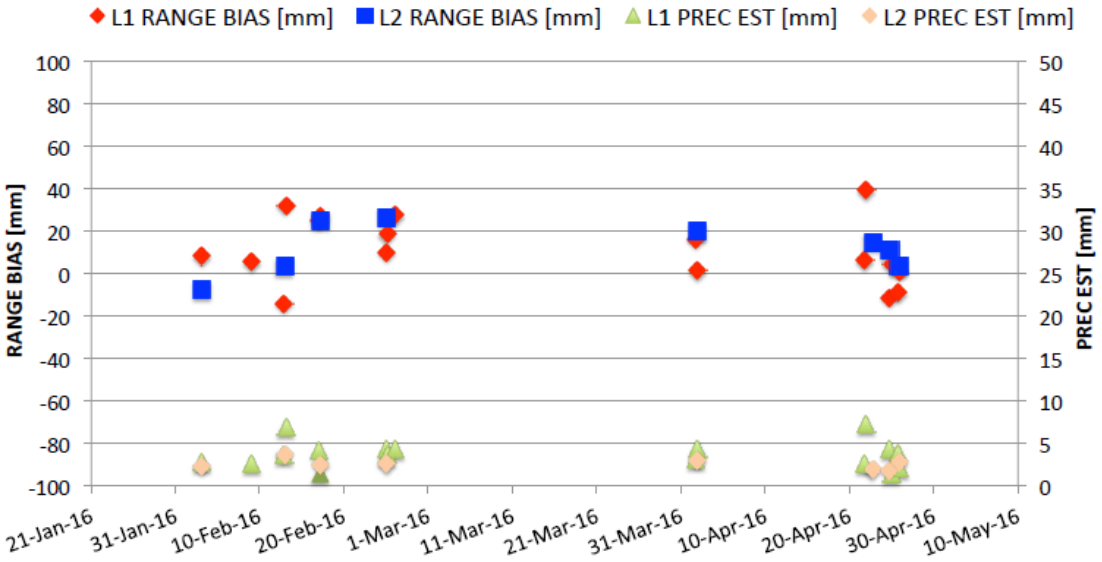
- **SRC PAS Borowiec station completed quarantine procedure provided by ILRS**

JCET/GSFC quarantine BORL bias report obtained on 26 April 2016

LAGEOS 1 & LAGEOS 2

L1 78113802	PREC EST [mm]	RANGE BIAS [mm]
Mean	3.7	11.0
STD	1.6	15.6
RMS	4.0	18.7
Point	17	17

L2 78113802	PREC EST [mm]	RANGE BIAS [mm]
Mean	2.6	12.0
STD	0.6	11.9
RMS	2.6	16.3
Point	8	8



Satellite Laser Ranging (2)

SRC PAS

- **32 satellites: 21 LEO and 11 MEO tracked in 2016**
- **average RMS ranges from 1.19 to 5.54 cm**
  (700 passes, 664 599 single good shots and 10 293 normal points)

Range bias report for SRC Borowiec laser station, 7 October 2016

```
                ILRS Combined Range Bias Report 1
                *********************************

           2016-09-27 00:00 UT - 2016-10-07 00:00 UT

           Compiled by: SLR Observatory Zimmerwald
           Date       : 2016-10-07 12:30 UT
           E-Mail     : martin.ploner@aiub.unibe.ch
```

7811 BORL Borowiec			DGFI		MCC		HIT-U		SAO		JCET	
	sat	wl	rb	pr	rb	pr	rb	pr	rb	pr	rb	pr
7811 2016-09-27 00:13	LAG1	532	-7	5	-1	5	-4	4			-1	5
7811 2016-09-27 01:20	LAG2	532	4	3	8	3	6	3			4	3
7811 2016-09-27 19:36	LAG1	532	14	4	5	4	-2	4			8	4
7811 2016-09-27 22:51	LAG1	532	-6	4	-8	4	-10	3			-4	4
7811 2016-09-27 23:27	LAG2	532	-5	5	-1	4	-1	4			6	4
7811 2016-09-29 23:36	LAG2	532	0	6	1	6	-8	5			7	6
7811 2016-09-29 23:53	LAG1	532	-15	4	-10	4	-7	3				
7811 2016-09-29 23:54	LAG1	0									*	*
7811 2016-10-04 20:31	LAG1	532	2	8	1	3	-3	7			23	7
7811 2016-10-04 22:16	LAG2	532	9	4	6	4	-10	4			-8	4
7811 Average		532	0	4	0	4	-4	4			4	4

Satellite Laser Ranging (3)

SRC PAS

- from all tracked satellites 8 - typical passive geodetic satellites (Ajisai, Etalon-2, Lageos-1, Lageos-2, Larets, Lares, Starlette, Stella) in total 385 passes, 442 135 single good shots and 4195 normal points
- regular tracking of space debris objects (inactive satellites and rocket bodies) in the frame of Space Debris Study Group (SDSG) of ILRS - average RMS ranging from 1.49 to 75.33 cm (151 passes, 137 836 single good shots and 2528 normal points)
- second independent laser system, fully dedicated for Space Surveillance and Tracking programme, developed by ESA and European Commission is under construction at SRC Borowiec

Geodynamics (1)

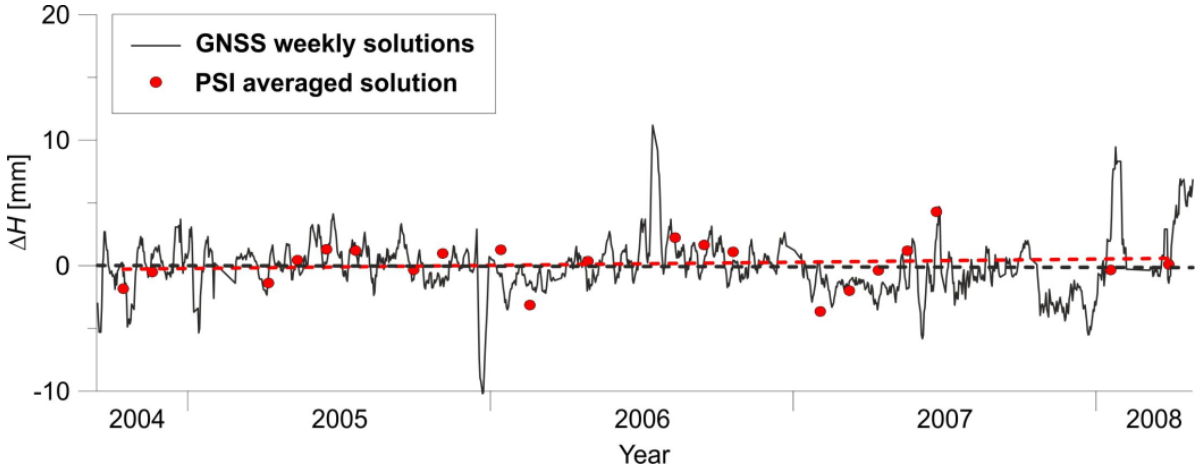
IGiK, WAT, WUELS

- **EPOS–PL project** – the Polish Earth science infrastructure integrated with the European Plate Observing System Programme (EPOS) **started** at the end of 2016

IGiK

- **developing** the **integrated system of surface deformation monitoring** caused by man-made factors, based on satellite interferometry, GNSS and precise levelling

Comparison of relative deformations in height component between Borowa Gora and Jozefoslaw obtained from GNSS (weekly solutions) and PSI (average) data

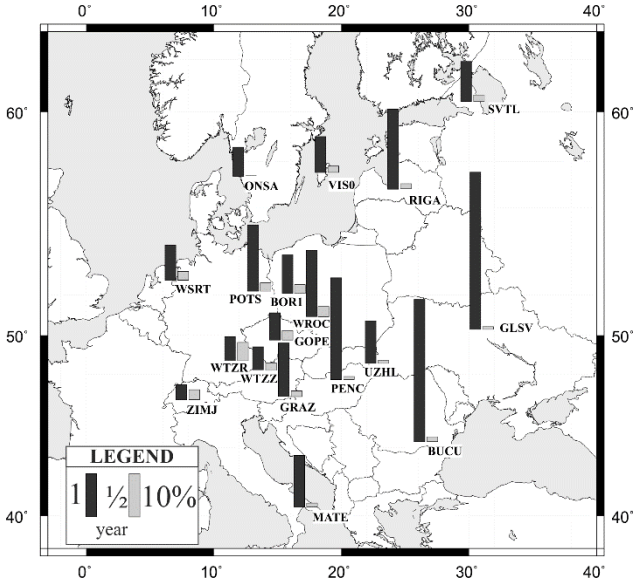


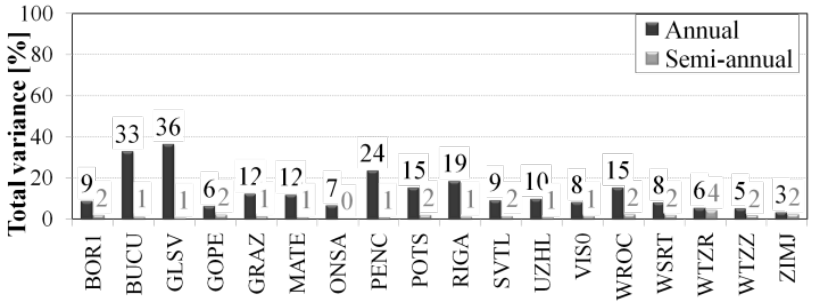
Geodynamics (2)

MUT

- analysis of time series of permanent GNSS stations coordinates to achieve the most reliable possible velocities for geodynamical studies
- seasonal signal from time series of Precise Point Positioning (PPP) daily solutions for 18 Central European stations

Contribution of annual (black bars) and semi-annual signals (grey bars) in the height time series in terms of a percentage of total variance



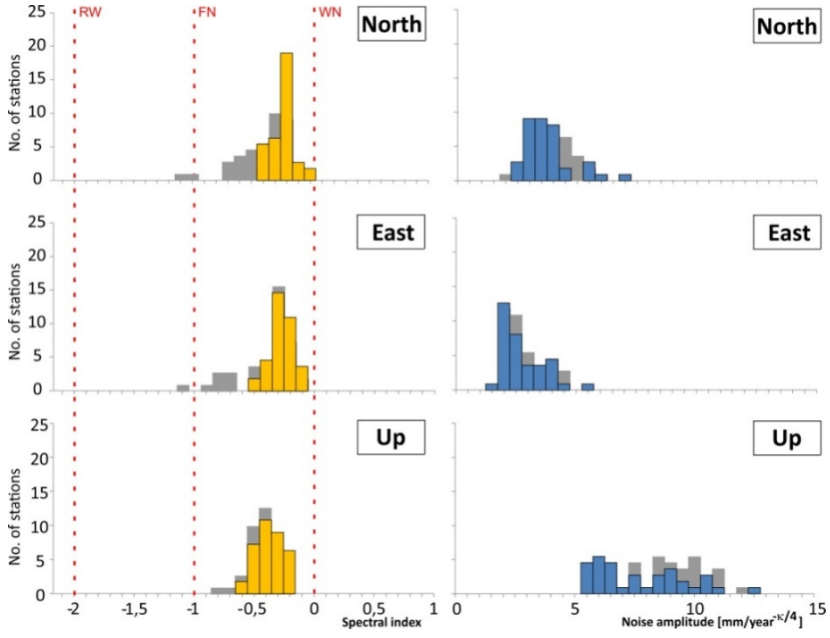


Geodynamics (3)

MUT

• **spectral indices and power-law noise amplitudes data from the solutions at the EPN Local Analysis Centre MUT for 42 European IGS stations**

The histograms for spectral indices (left) and power-law noise amplitudes (right) for topocentric components [mm/year-κ/4]; the integer spectral indices: -2, -1 and 0, marked in red, represent random-walk (RW), flicker noise (FN) and white noise (WN); the spectral indices and noise amplitudes marked yellow and blue represent the stochastic part after spatio-temporal filtering, while grey represents the noise parameters before stacking

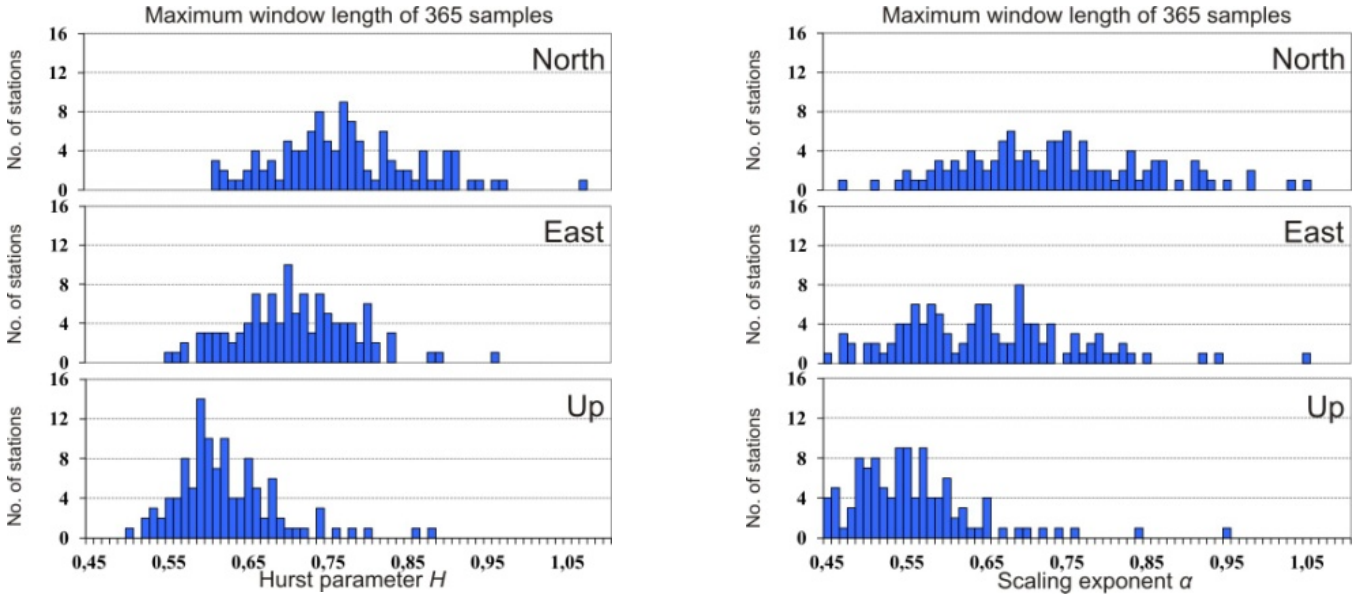


Geodynamics (4)

MUT

- **stochastic part** of GPS-derived topocentric **coordinates changes**

The Hurst parameter H (left) and the scaling exponent α (right) estimated for the North, East and Up components for all ASG-EUPOS stations

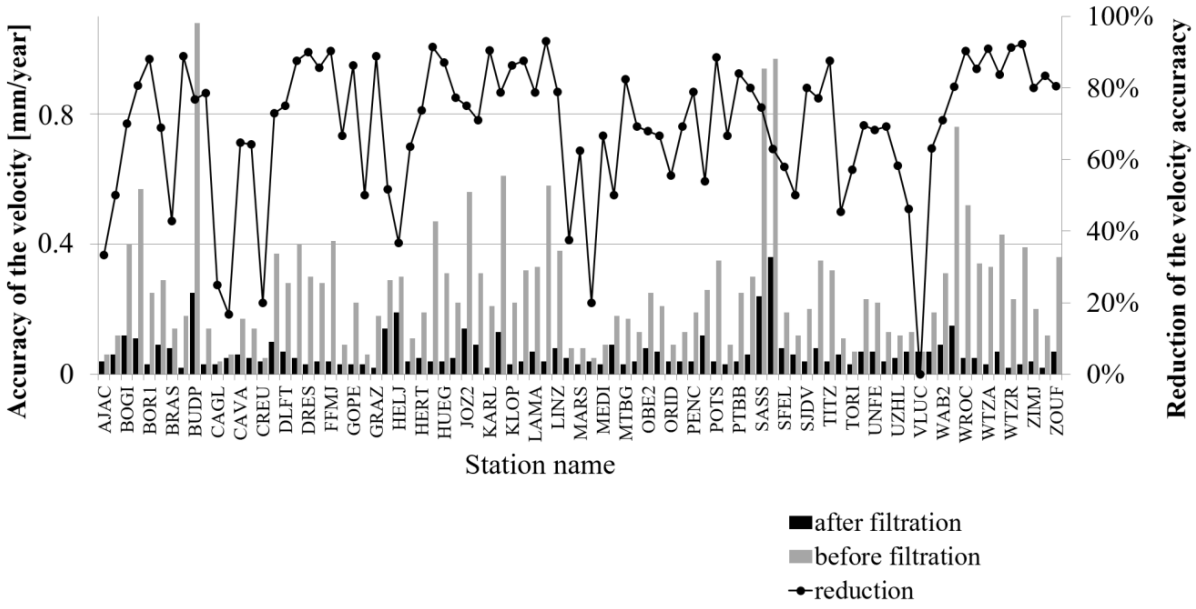


Geodynamics (5)

MUT

- investigation of the necessity of spatio-temporal filtering of time series for the determination of highly reliable velocities of permanent stations

Reduction of velocity accuracy resulting from the use of the PCA-based method of spatio-temporal filtering; bars refer to the left side axis and show the accuracy of the velocity computed before the subtraction of CME (gray) and after filtration (black); the line refers to the right side axis and exhibits the relative reduction of accuracy resulting from spatio-temporal filtering



Geodynamics (6)

WUT

• **prediction** of **pole coordinates**

The Normalized Morlet wavelet transform amplitudes as a function of periods T (σ = 1) of the differences between the *x-iy* pole coordinates data and their LS+AR predictions at 4 weeks in the future