NATIONAL REPORT OF POLAND TO EUREF 2018

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Main geodetic activities at the national level in Poland since 2016

- monitoring the **terrestrial reference frame**
- 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**
- GNSS for **meteorology**
- monitoring of **ionosphere**
- monitoring **gravity changes** and **geodynamics**
- activities in **SLR**

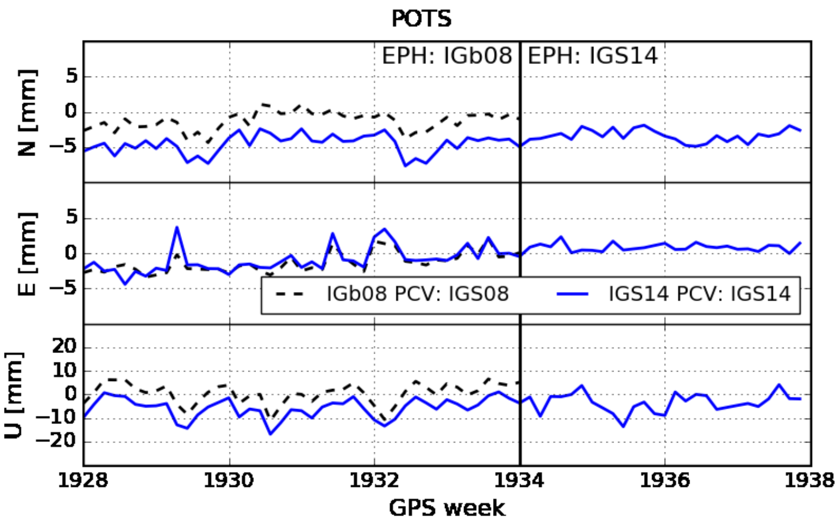
Monitoring the terrestrial reference frame

Gdansk University of Technology GUT

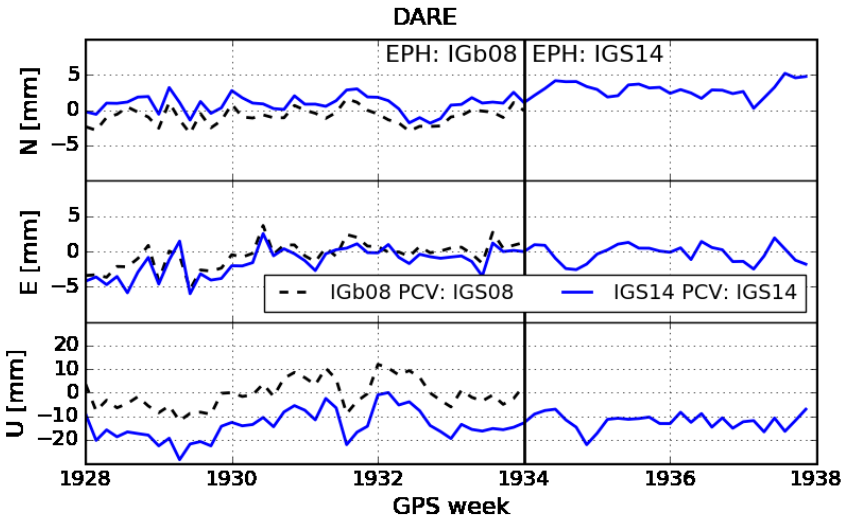
The ITRF2014 solution investigated at IPN stations

- **high consistency with the ITRF2008 solution**
- **non-negligible differences in station positions due to new satellite and ground antennae phase centre calibrations in IGS14**

Potsdam, Germany



Daresbury, UK



Activities in the horizontal and vertical control

Head Office of Geodesy and Cartography GUGiK

Continuation of field inspection of geodetic control network;

- **about 50% of geodetic control stations was already visited**

Initiated in 2017 preparations for a new levelling campaign in Poland

- **campaign planned to start in 2020**

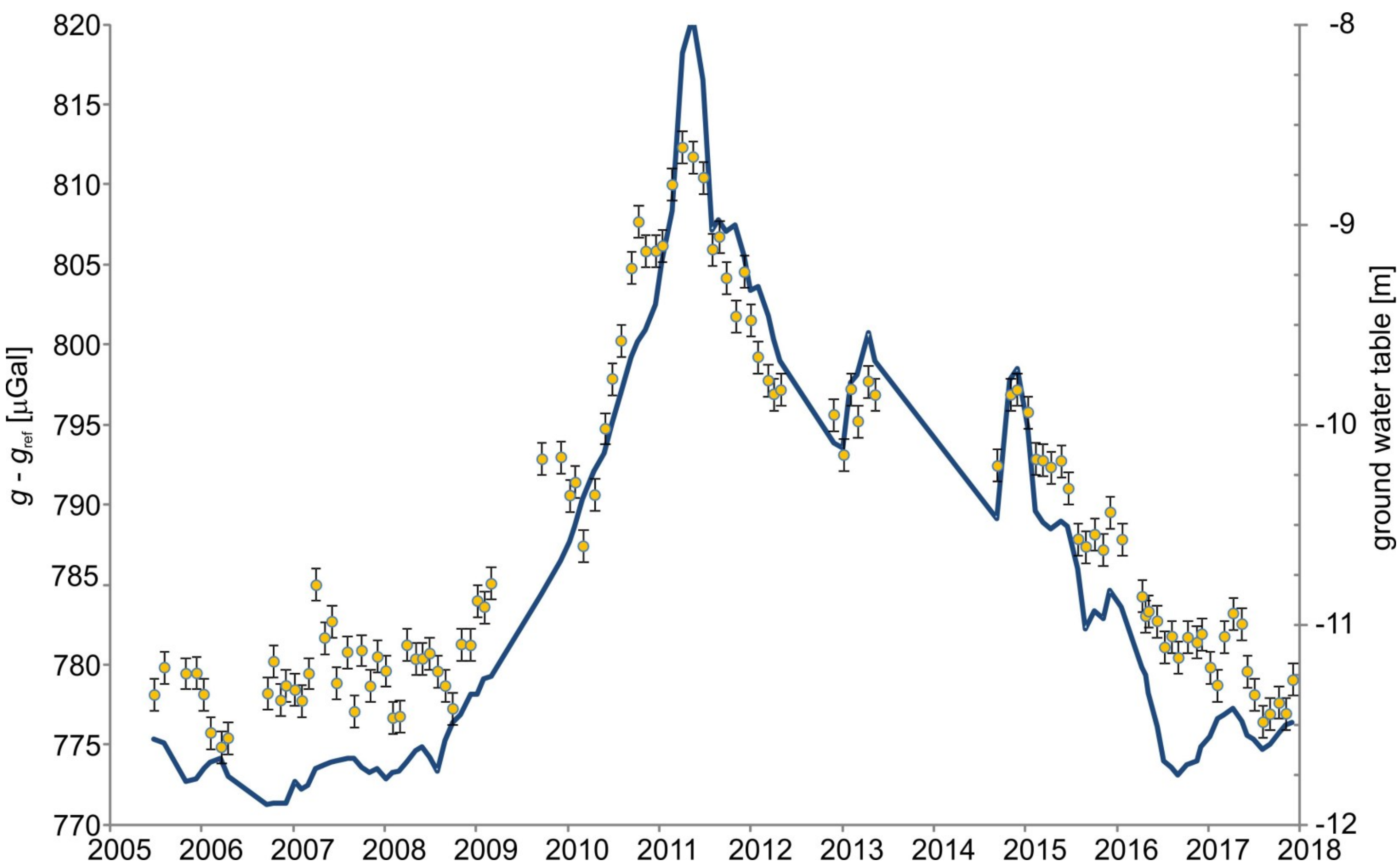
Noted major advantages of combining levelling networks with state-of-the-art GNSS measurements and gravity field models in Poland

EVRF2007 solution should be locally implemented in Poland by the end of 2019

Maintenance of national gravity control (1)

Jozefoslaw Astrogeodetic Observatory, Warsaw University of Technology WUT

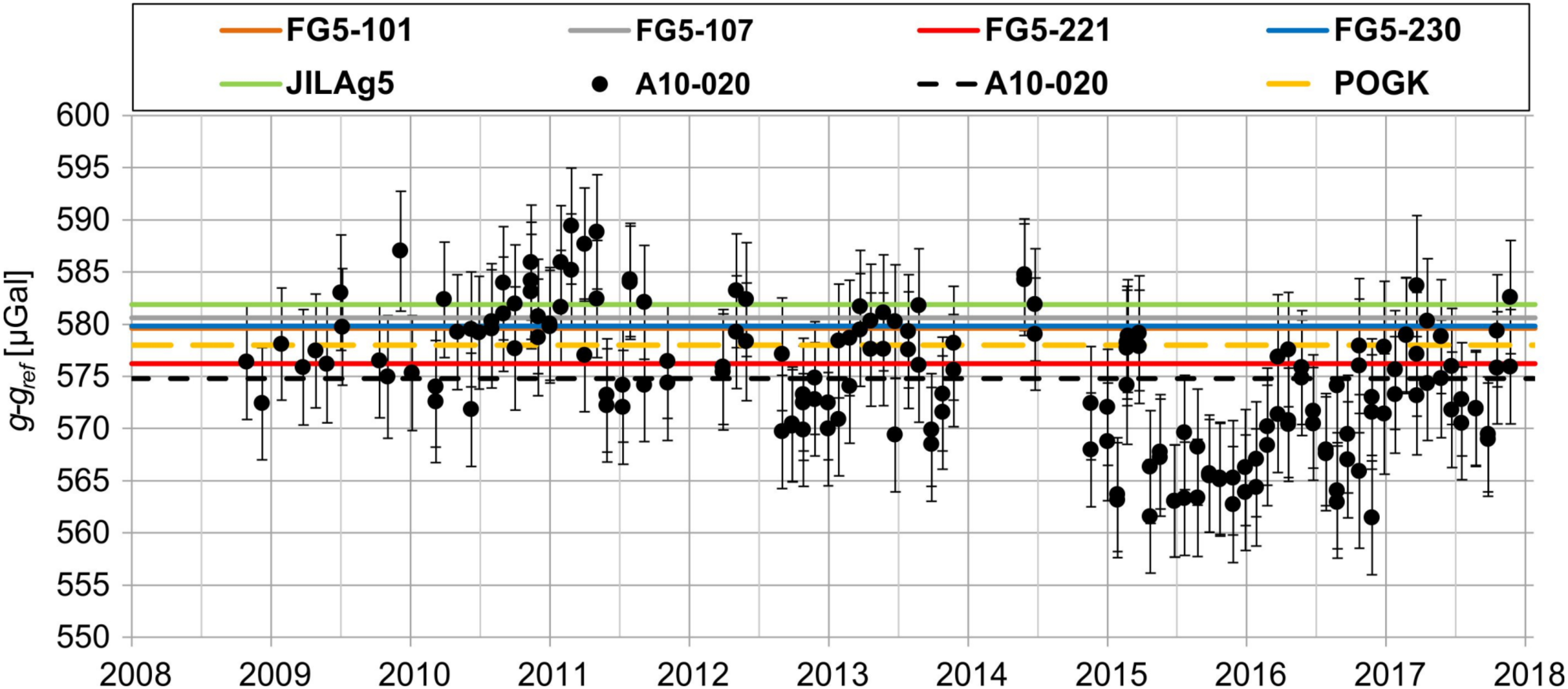
quasi-permanent absolute gravity measurements with FG5-230



Maintenance of national gravity control (2)

Borowa Gora Geodetic-Geophysical Observatory
Institute of Geodesy and Cartography IGiK, Warsaw

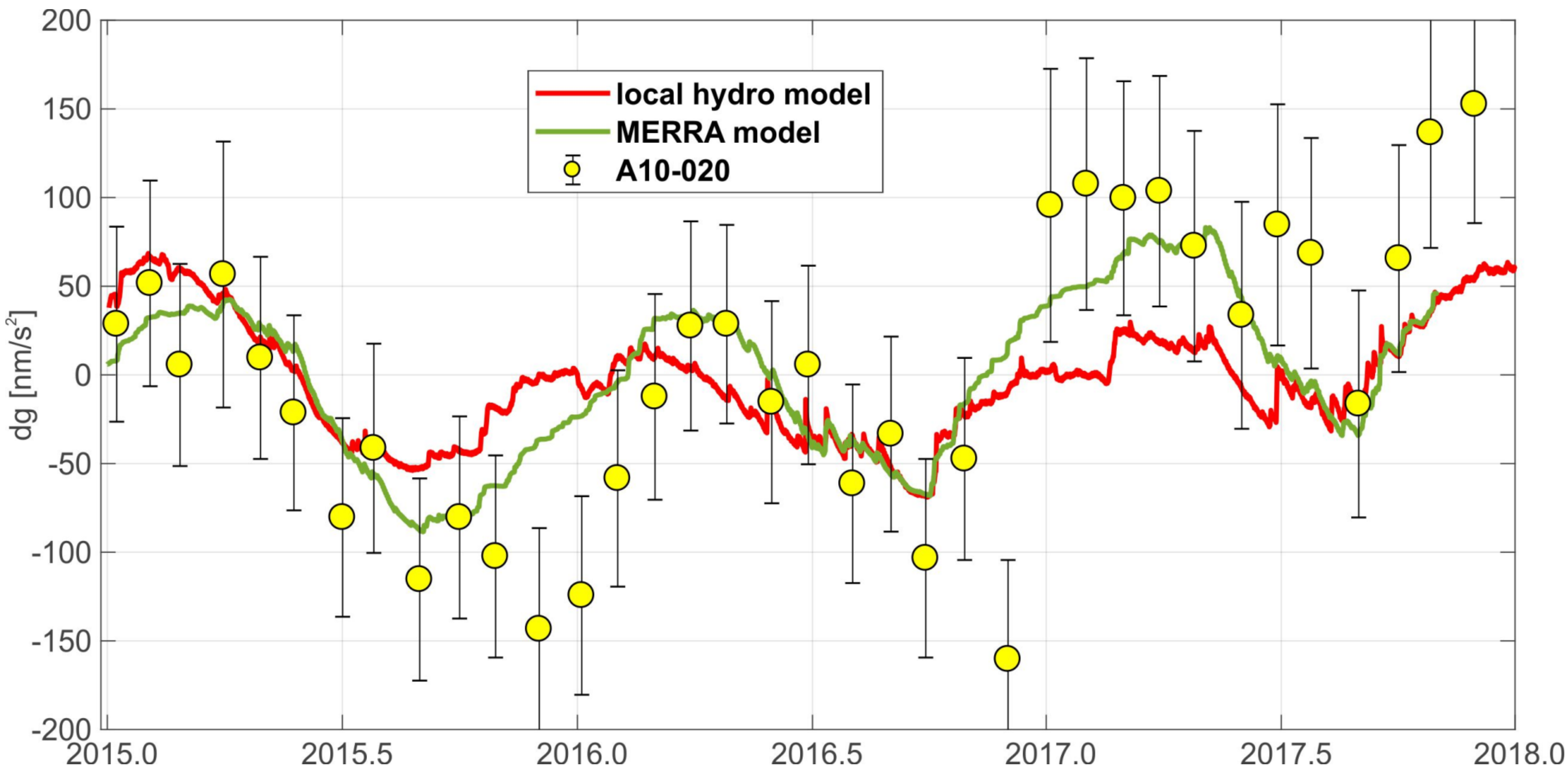
quasi-permanent absolute gravity measurements with A10-020



Maintenance of national gravity control (3)

Borowa Gora Geodetic-Geophysical Observatory
Institute of Geodesy and Cartography IGiK, Warsaw

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

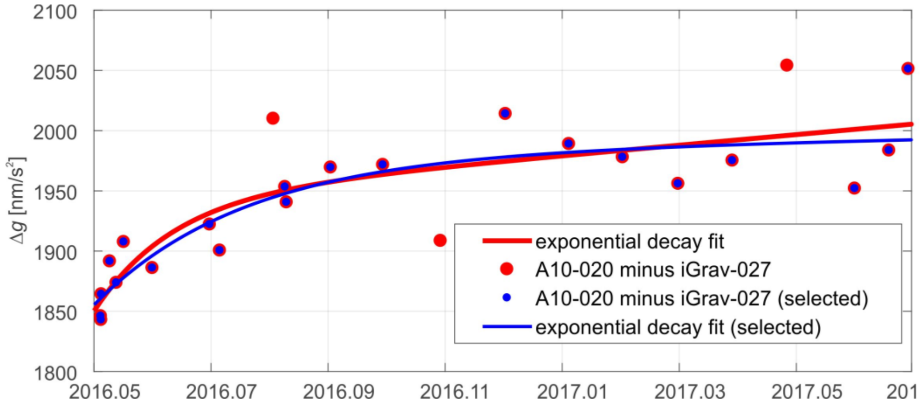


Maintenance of national gravity control (4)

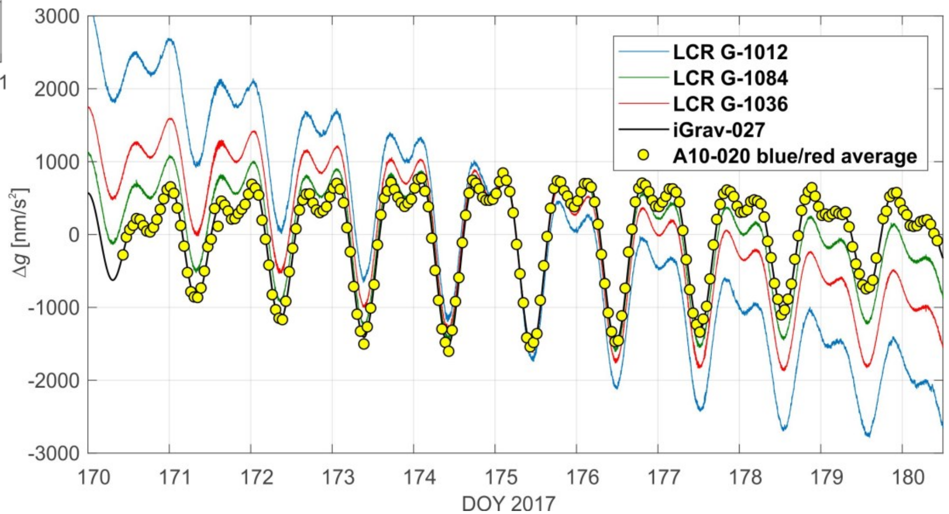
Borowa Gora Geodetic-Geophysical Observatory
Institute of Geodesy and Cartography IGiK, Warsaw

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

drift of the iGrav-027



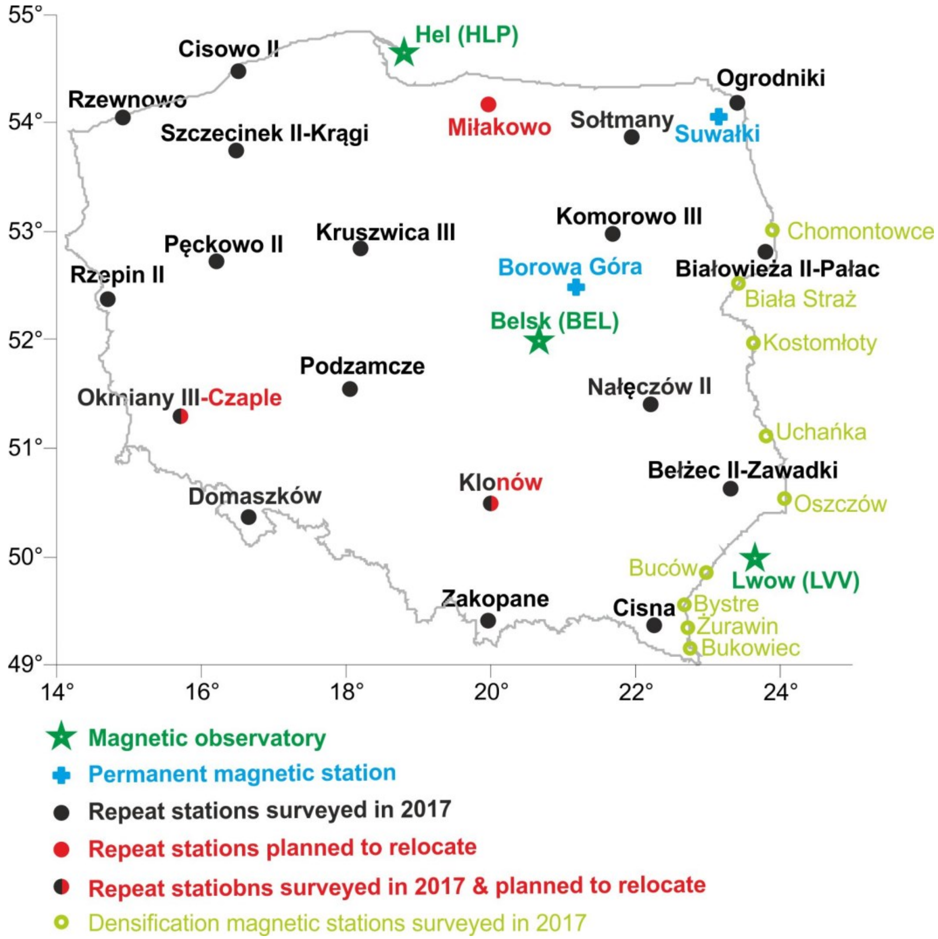
calibration of the iGrav-027



Maintenance of magnetic control

IGiK

repeat stations, permanent stations and magnetic observatories



3 independent components of the magnetic intensity vector measured at

- **17 repeat stations**
- **8 densification stations**

The need for the establishment of the magnetic repeat stations on the Baltic Sea was investigated

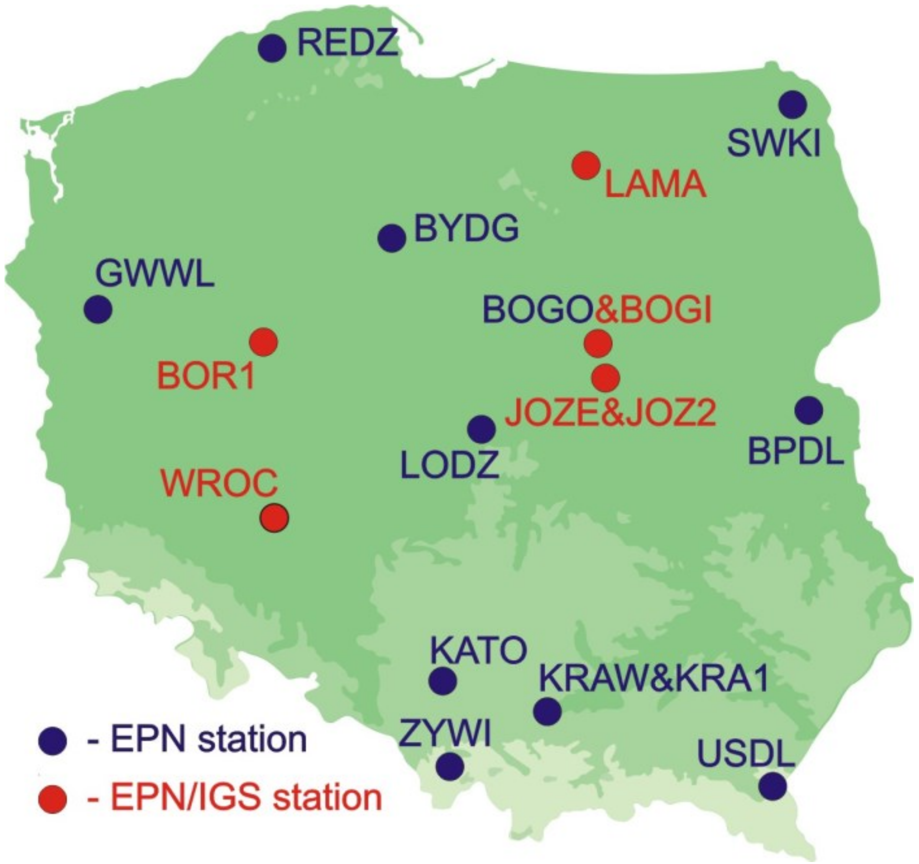
Operational work of permanent GNSS IGS/EUREF stations

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

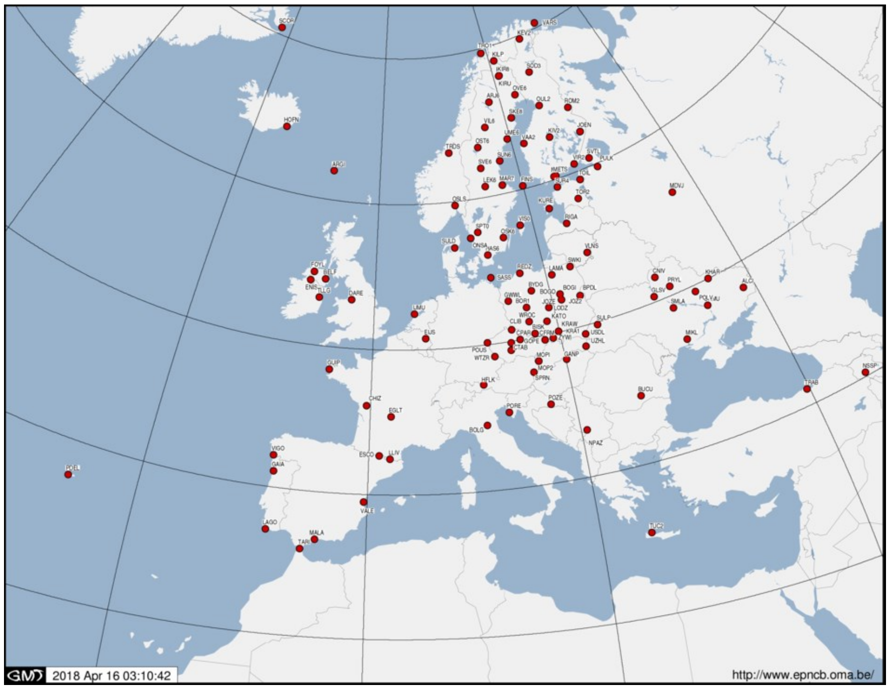
♥ BOG ♥ BOR1 ♥ JOZ2 ♥ KRA1 ♥ KRAW
♥ LAMA ♥ WROC



Data processing at LACs

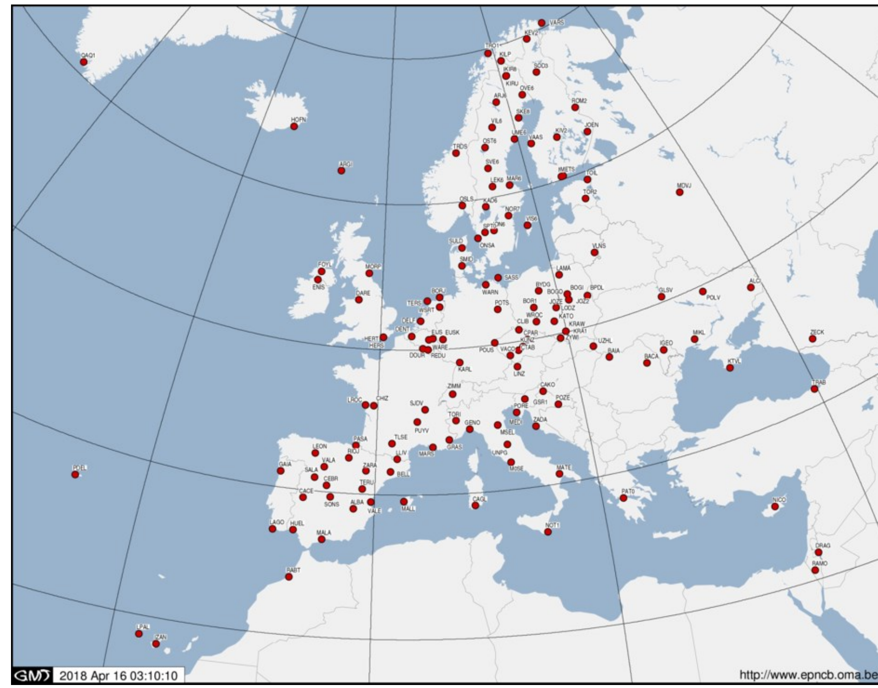
WUT

data from 119 EPN stations routinely processed



MUT

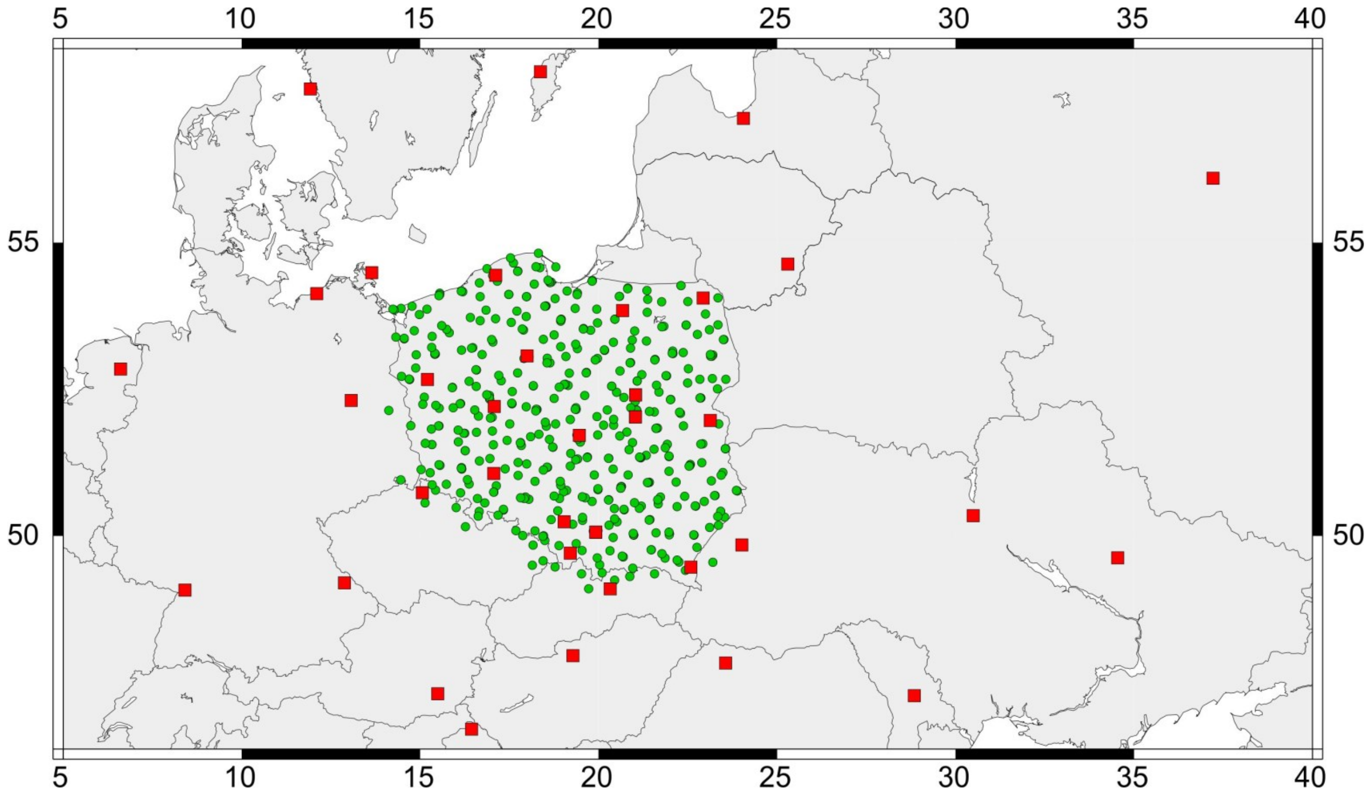
data from 142 EPN stations routinely processed



Station monitoring service at MUT

GNSS networks monitored

- **national network ASG-EUPOS**
- **private networks**
  - **VRSnet.pl**
  - **SmartNet Poland**
  - **TPI NetPro**



MUT–WUT EPN Combination Centre

- 16 ACs were submitting SINEX solutions for the weekly EPN combination
- since 29 January 2017 (GPS week 1934)
  - the EPN ACs started to use the IGS14/epn_14.atx framework during GNSS data analysis
  - all EPN combined coordinate solutions are aligned to IGS14 reference frame
- since GPS week 1980 (17–23 December 2017)
  - the use of the VMF1/ECMWF approach is mandatory for all EPN ACs
- products
  - final positions weekly and daily
  - rapid daily solutions
  - ultra-rapid solutions
  - graphs and maps presenting coordinate consistency of AC daily solutions with respect to daily combined solutions for each station and day of the last combined week

EPN Combination Centre products on web page (http://www.epnacc.wat.edu.pl)

ASG-EUPOS network in Poland

Head Office of Geodesy and Cartography GUGiK

reference stations (125) of ASG-EUPOS network

- **125** stations track
  GPS + GLONASS
- **107** stations track
  GPS + GLONASS + Galileo
- **86** stations track
  GPS + GLONASS + Galileo +BDS

- **3613 active licenses**
  for RTK service
- **2100 users**
  every working day

Modelling precise geoid

IGiK

- use of scattered/sparse absolute gravity data for
  - validation of Global Geopotential Models (GGMs)
  - improving quasigeoid heights determined from satellite-only GGMs

Koszalin University of Technology

- use of altimetry data for monitoring elevations of continental surface water

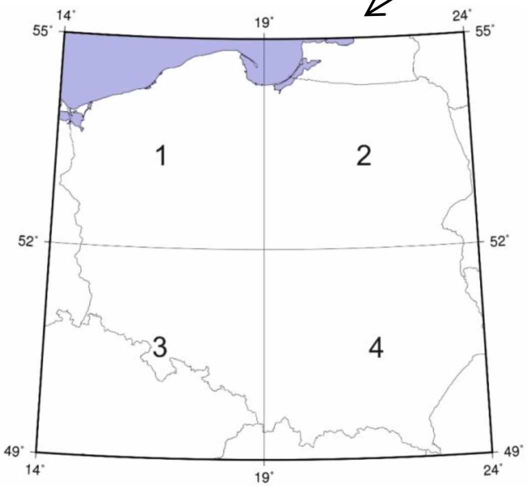
University of Warmia and Mazury in Olsztyn UWM

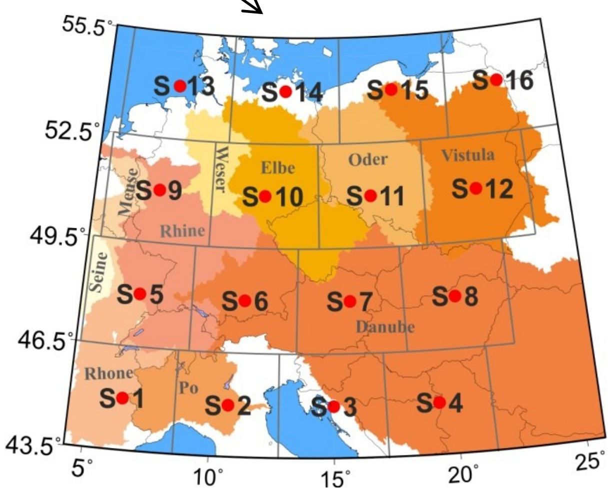
- validation of gravity anomalies from the available shipborne and airborne gravity data along the Polish coast and in the Baltic Sea with the use of satellite altimetry models
- developing the new gravimetric quasigeoid model for Poland

Use of data from satellite gravity missions (1)

IGiK

- evaluation over the area of Poland of 5 GGMs developed in 2016-2017
  - high precision GNSS/levelling data (*100 ASG-EUPOS stations*)
- use of the Principal Component Analysis/Empirical Orthogonal Function (PCA/EOF) method for the analysis and modelling temporal variations of geoid heights
- temporal variations of geoid heights obtained from RL05 GRACE-based GGMs
  - over Central Europe represented by 16 subareas
  - over the area of Poland represented by 4 subareas





Use of data from satellite gravity missions (2)

UWM

- research on ground water variations and water balance in the area of the Sudety Mountains on the basis of GRACE data and a high resolution hydrological GLDAS data
- searching for most suitable method for the computation of the water budget and accuracy assessment of the ground water level determination
- investigation of seasonal variability of the atmospheric (energy) and water budgets in Poland in terms of total water storage using the GLDAS and MERRA-2 models

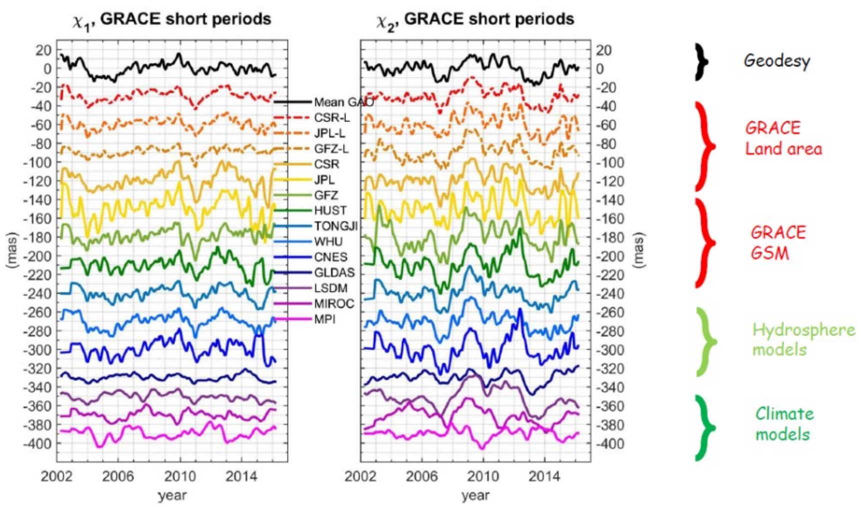
Use of data from satellite gravity missions (3)

Space Research Centre of the Polish Academy of Sciences SRC PAS

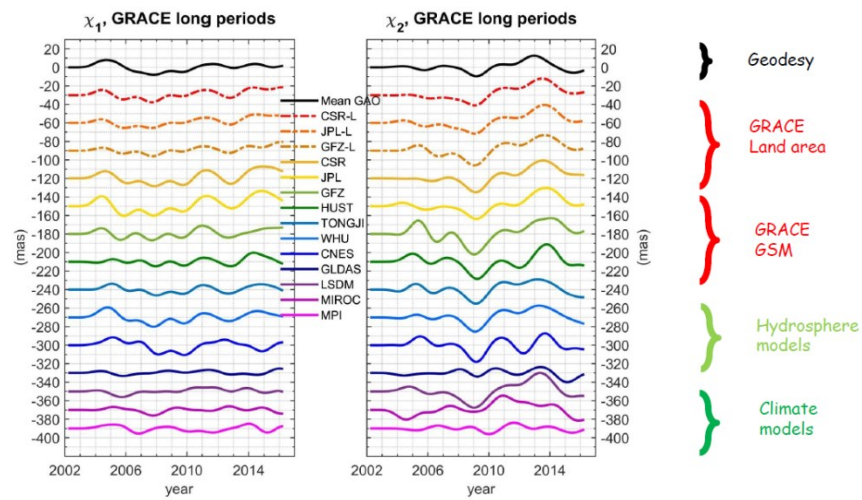
- **re-estimation of hydrological polar motion excitation functions using the most recent GGMs developed in seven processing centres on the basis of GRACE data**

variations of χ_1 and χ_2 components of geodetic residuals (GAO) with gravimetric (CSR, JPL, GFZ, HUST, TONGJI, WHU, CNES) and hydrological (GLDAS, LSDM, MIROC, MPI) excitation functions

short period



long period



GNSS for meteorology (1)

WUT

- **water vapour retrieval**

Tested three independent techniques

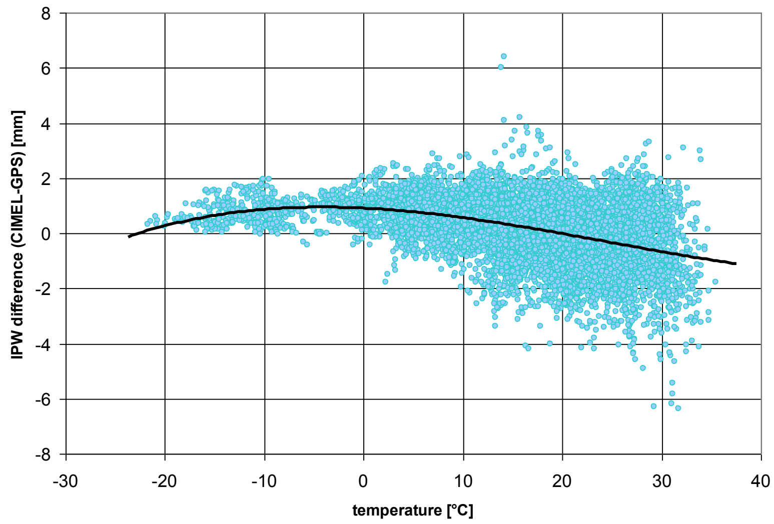
GPS solution

radiosounding

CIMEL sunphotometer

used to obtain Integrated Precipitable Water (IPW)

correlation of IPW bias and local atmospheric temperature signals some systematic deficiencies in solar photometry as IPW retrieval technique

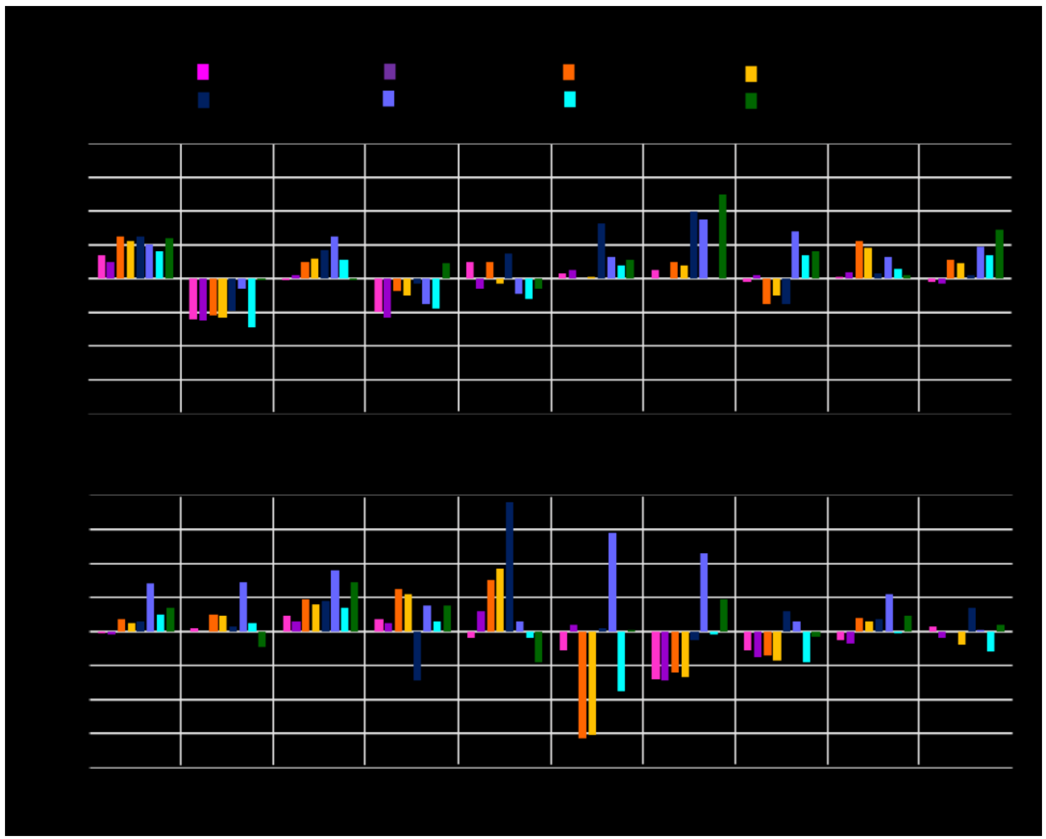


GNSS for meteorology (2)

MUT & GUT

• **use of GNSS data to sense the dynamics of the atmosphere**

differences in IWV linear trend value between analysed GNSS solutions and radiosounding

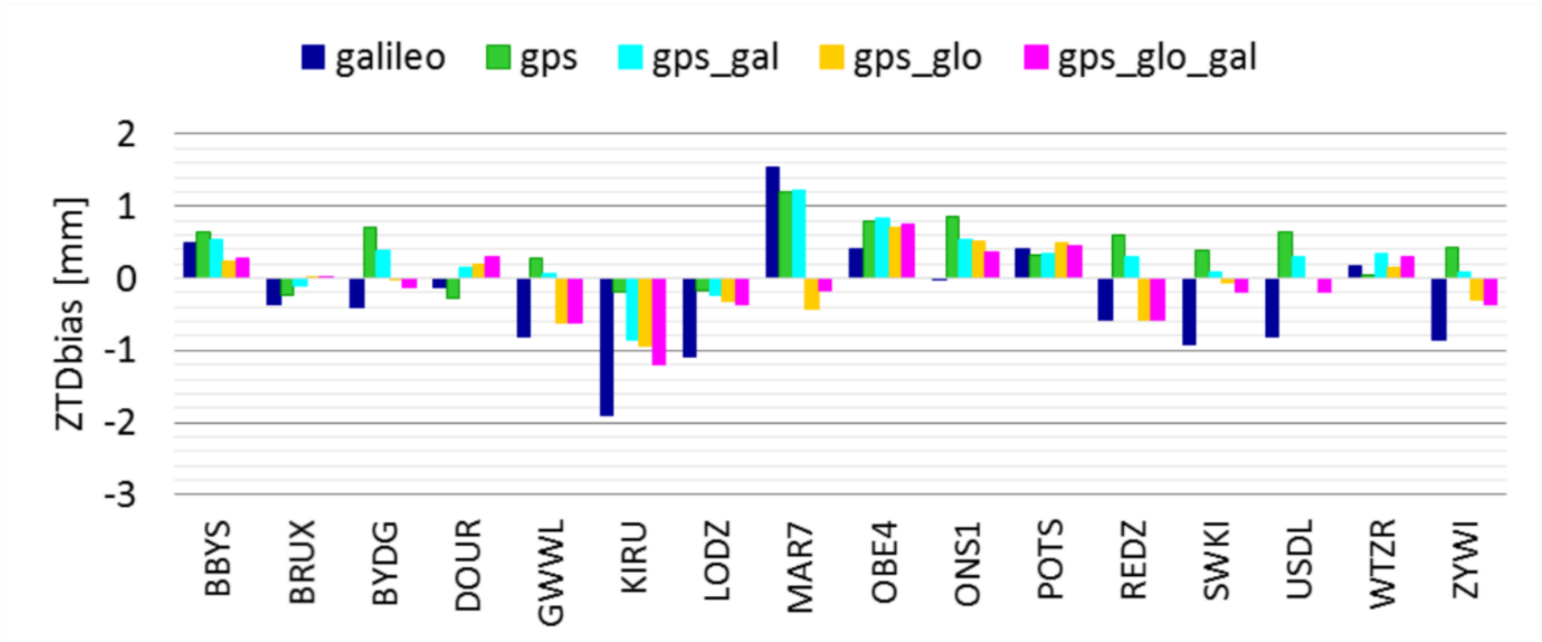


GNSS for meteorology (3)

MUT & GUT

• **influence of multi-GNSS constellations on the GNSS troposphere products**

mean ZTD bias (w.r.t. the reference solution) for analysed EPN stations and various constellations (10.2016 – 01.2017 time span)

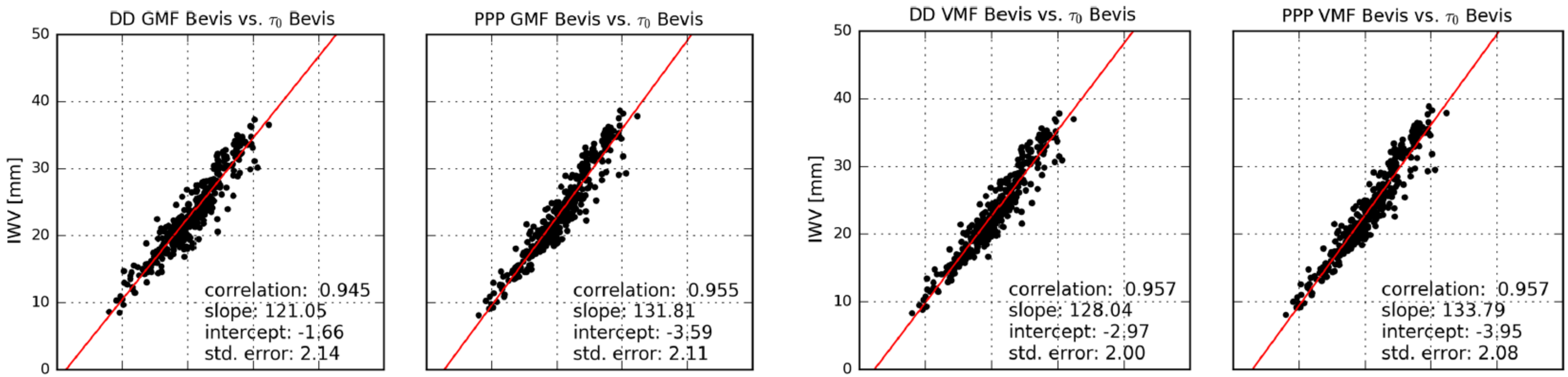


GNSS for meteorology (4)

MUT & GUT

- impact of Galileo observations on tropospheric parameters and tropospheric gradients
- impact of GNSS processing strategies on the long-term parameters of 20 Years IWV time series
- estimation of atmospheric opacity (τ_0) for VLBI applications basing on integrated water vapour (IWV) derived from GNSS observations

correlation between IWV and τ_0 derived from GNSS data



GNSS for meteorology (5)

UWM

- search for optimal GNSS data processing and post-processing methodology for the estimation of tropospheric parameters
- impact of GNSS processing strategies on the long-term parameters of 20 Years IWV time series
- estimation of atmospheric opacity (τ_0) for VLBI applications basing on integrated water vapour (IWV) derived from GNSS observations

correlation between IWV and τ_0 derived from GNSS data

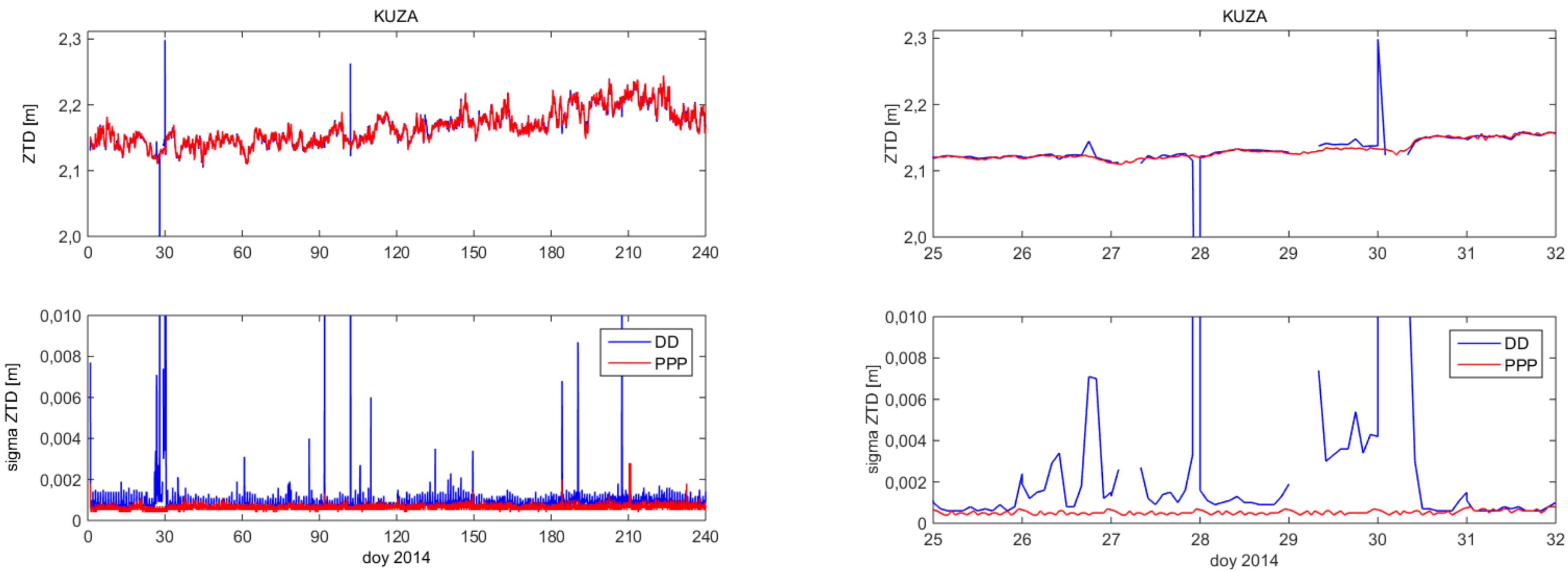
Strategy	Times Max Std(ZTD)	Times Max Std(sigma)	Rejected data	Data used	Mean Std(ZTD) [m]	Mean Std(sigma) [m]
"light screening": range check on ZTD [0.5 m; 3.0m], on sigma [0 m; 0.1m]						
Standard	62	81	148	468332	0.0142	0.00119
Obs-Max	31	17	109	**471666**	0.0133	**0.00067**
New	**11**	**6**	**84**	469534	**0.0129**	0.00079

GNSS for meteorology (6)

UWM

- **relative or precise point positioning (PPP) is more suitable for achieving high accuracy, stability, and homogeneity in the estimated tropospheric parameters?**

comparison of ZTD estimates and formal error for the DD and PPP solutions (left two graphs); zoom on period when the DD solution has outliers due the geometry of the network (right two graphs)

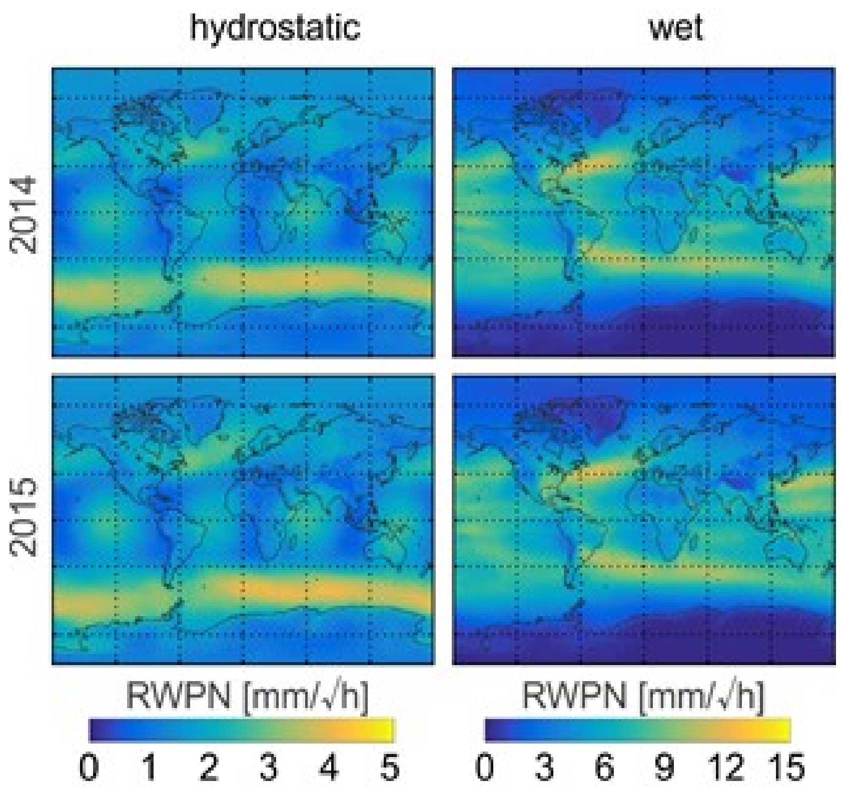


GNSS for meteorology (7)

WUELS

- estimation of **zenith wet delay (ZWD)** using numerical weather prediction models and archived VMF1-G data

hydrostatic (left) and wet (right) yearly mean RWPN grids over 2012-2015

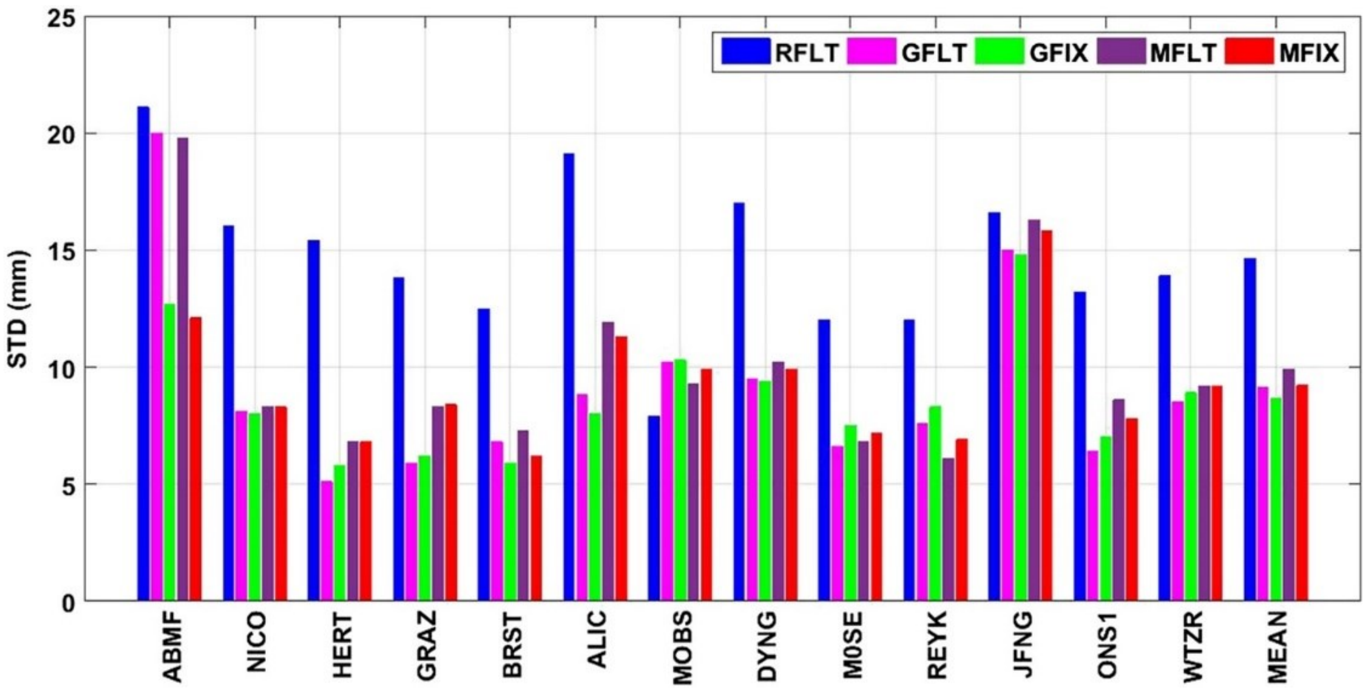


GNSS for meteorology (8)

WUELS

- **establishment of real-time GNSS troposphere estimation operational system using a modified version of PPP-WIZARD software**

STD of RT ZTD errors with respect to the radiosonde observations in all data processing modes

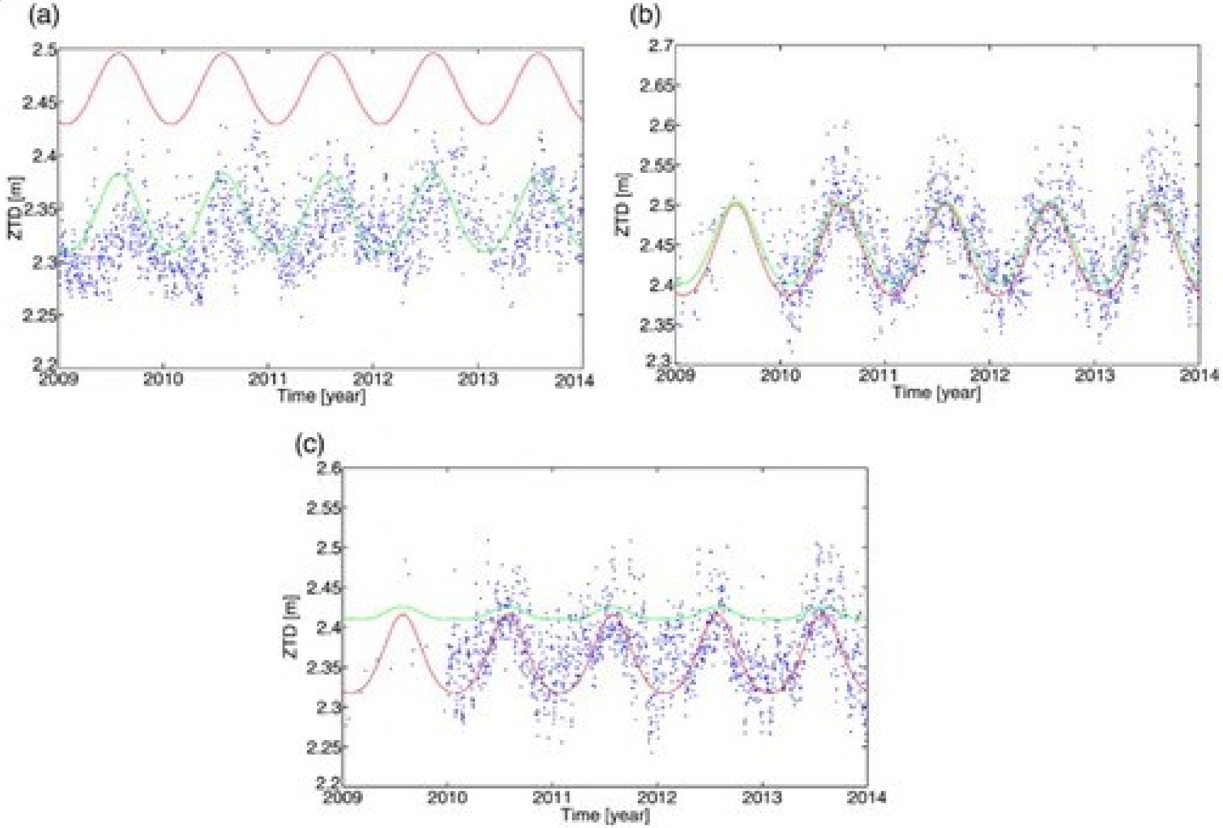


GNSS for meteorology (9)

WUELS

- **improvement of the EGNOS GNSS augmentation**

ZTD estimation results for UNBe.eu (green) and UNB3m (red) model:
a) ID 62414, Lat = 23.9700, Lon = 32.7800, H = 194.0 m,
b) ID 7761, Lat = 41.9200, Lon = 8.8000, H = 5.0 m,
c) ID 3005, Lat = 60.1300, Lon = −1.1800, H = 82.0 m, blue dots – ZTD calculated



Advanced methods for satellite positioning (1)

UWM

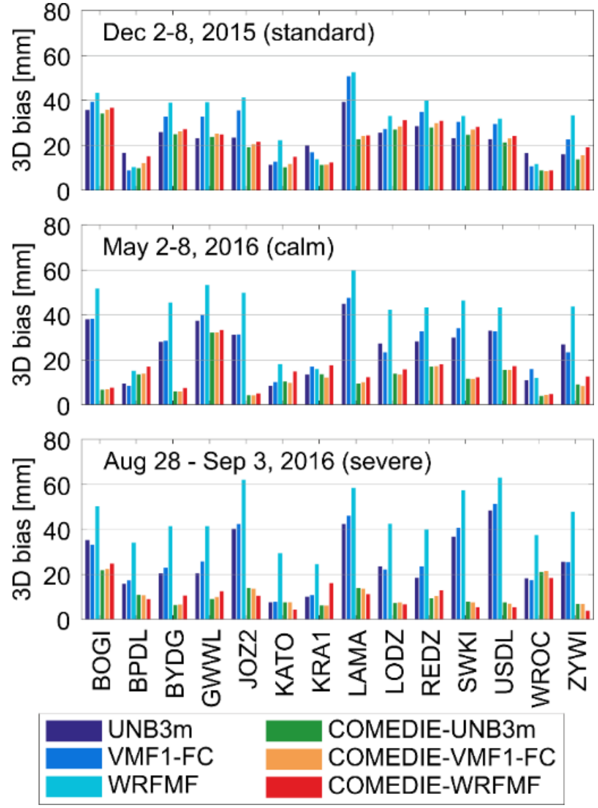
- theoretical analysis and practical assessment of the selected models for integration of multi-constellation signals
- theoretical foundations and performance assessment of instantaneous medium-range GPS+BDS RTK based on real signals collected at the territory of China
- estimation of the effect of higher-order ionospheric effects models on the determined coordinates
- developed algorithms for practical application of the GNSS technology to the determination of ground deformations as well as dynamic displacements including those of engineering structures

Advanced methods for satellite positioning (2)

WUELS

• investigated impact of three different tropospheric models and mapping functions on the position accuracy and convergence time

mean 3D biases of kinematic coordinate residuals for 14 Polish EPN stations for three data periods and all kinds of troposphere augmentation methods



Advanced methods for satellite positioning (3)

WUELS & Ohio State University

- research on positioning of slow-moving platforms by UWB technology in GPS-challenged areas

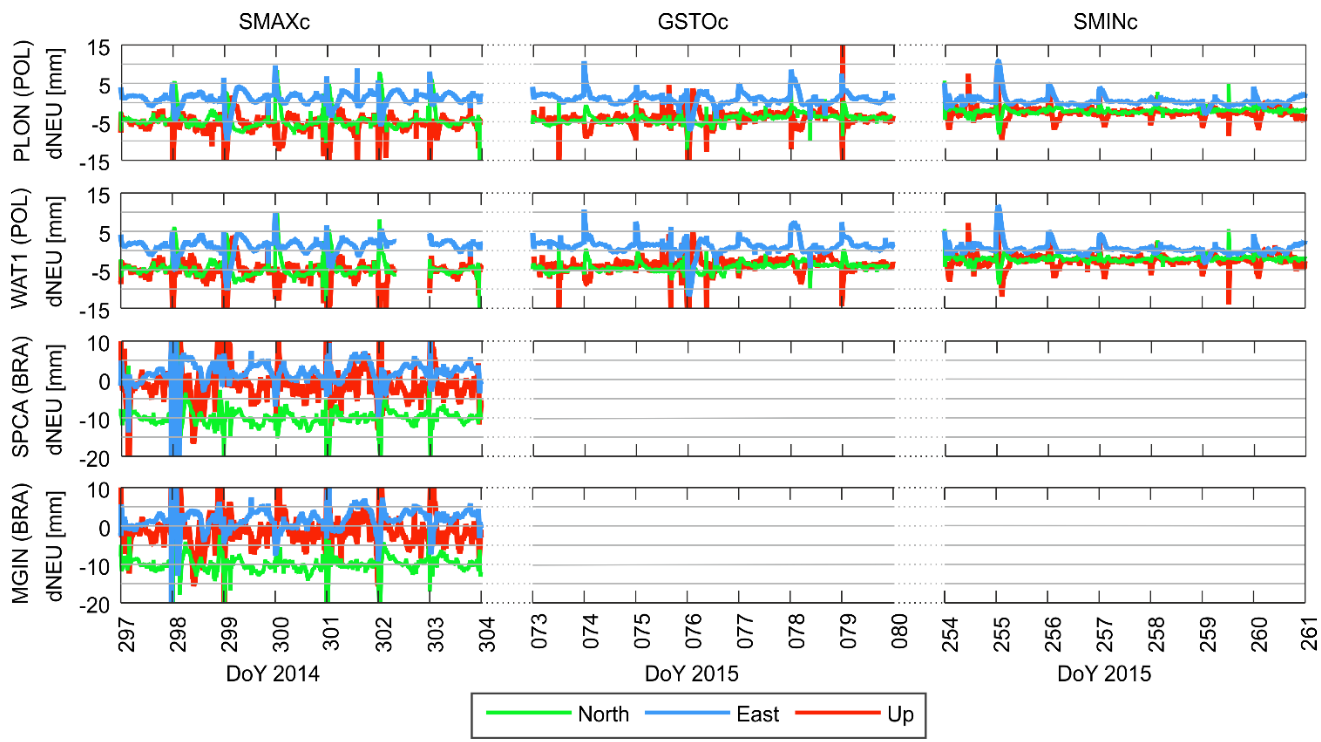
slow-moving vehicle and measurement setup

Advanced methods for satellite positioning (4)

WUELS

- development of a **consolidated model to correct second- and third-order ionospheric terms**, geometric bending and differential STEC bending effects in GNSS data

time series of kinematic coordinate differences between the solutions without and with I2+ corrections for selected test sites: PLON, WAT1 (in Poland), SPCA and MGIN (in Brazil) over 3 test periods

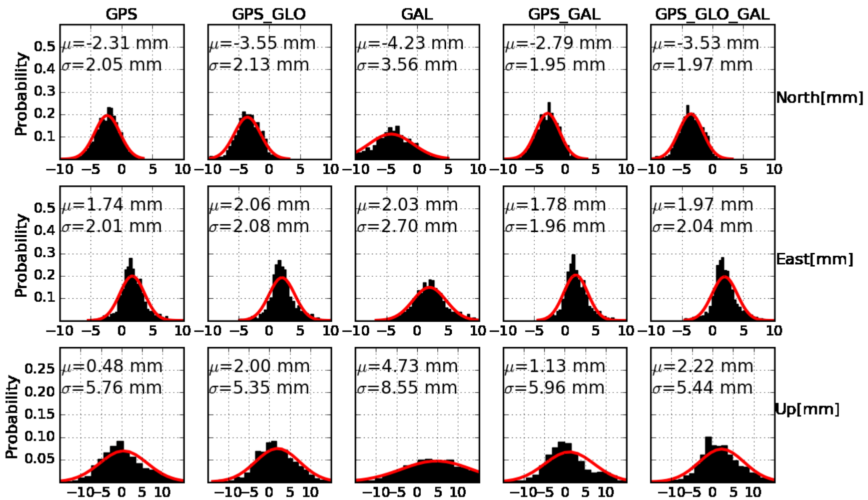


Advanced methods for satellite positioning (5)

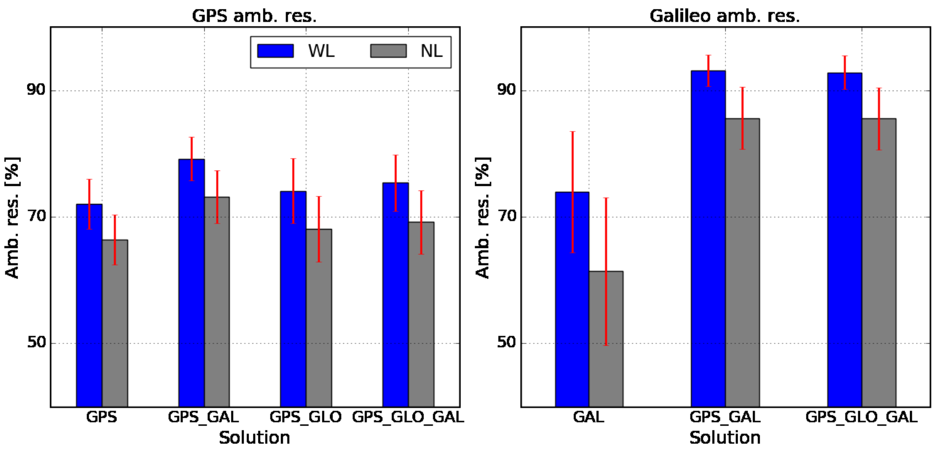
GUT

• investigation of the impact of Galileo observations on multi-GNSS positioning and products

residuals for analyzed solutions after week 1920



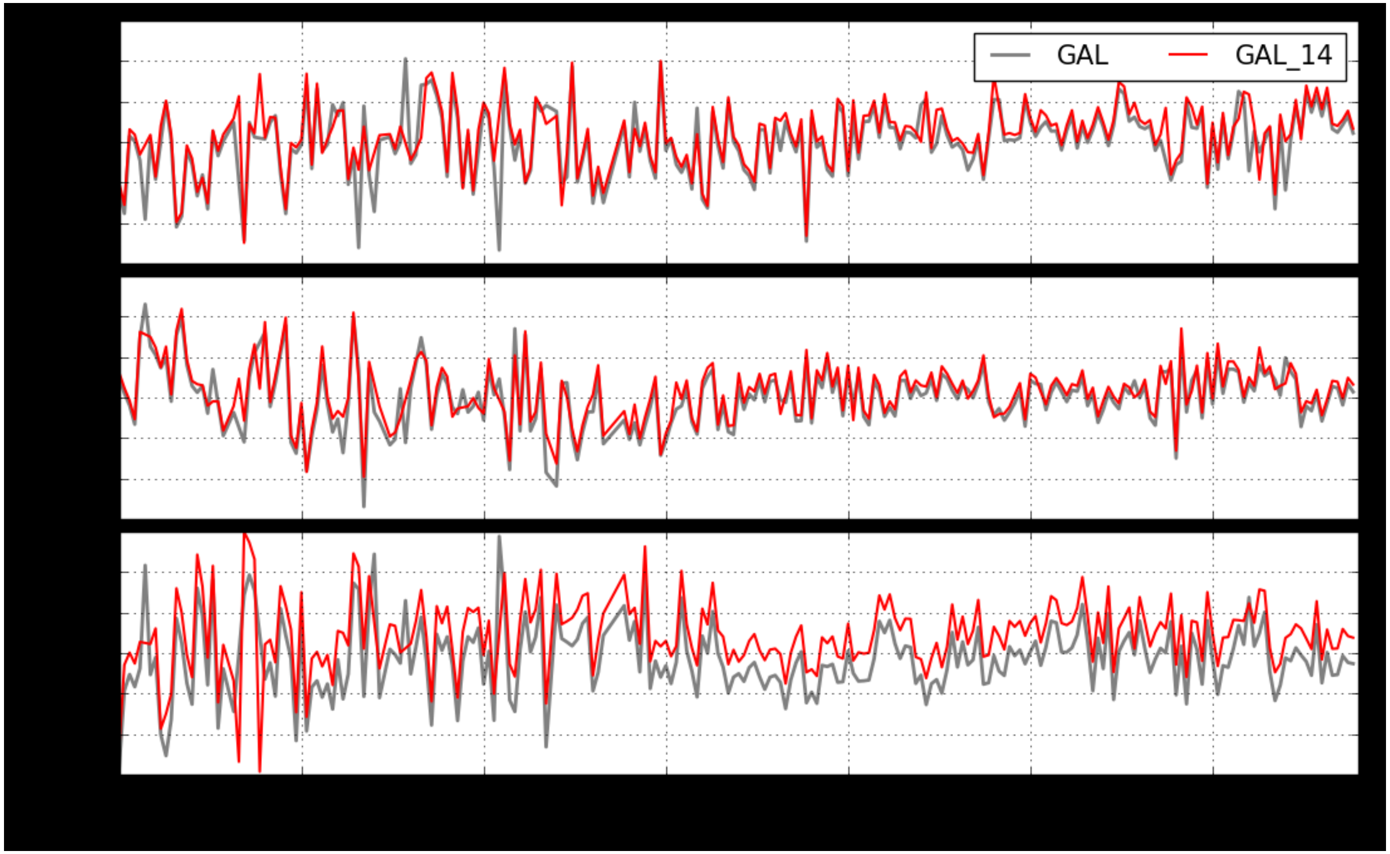
mean percentage of GPS and Galileo WL (blue) and NL (grey) ambiguity resolutions for tested solutions



Advanced methods for satellite positioning (6)

GUT

Galileo only positioning results for BRUX station for two solutions: with IGS14 antenna model - GAL_14 (red line); GAL (grey line)

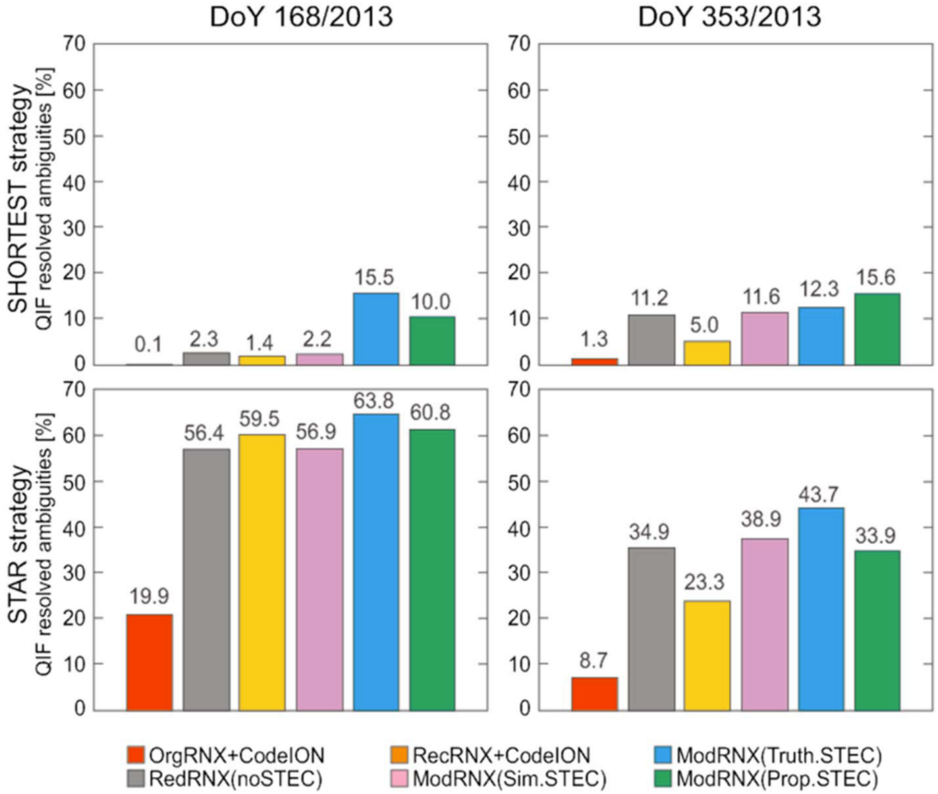


Monitoring ionosphere (1)

UWM & Spain

- **development of the efficient approach to mitigate the impact of the medium-scale traveling ionospheric disturbances in precise GNSS positioning**

percent of QIF resolved ambiguities in (top row) SHORTEST and (bottom row) STAR baseline definition strategies, during (left column) summer and (right column) winter campaigns, for six different network solutions

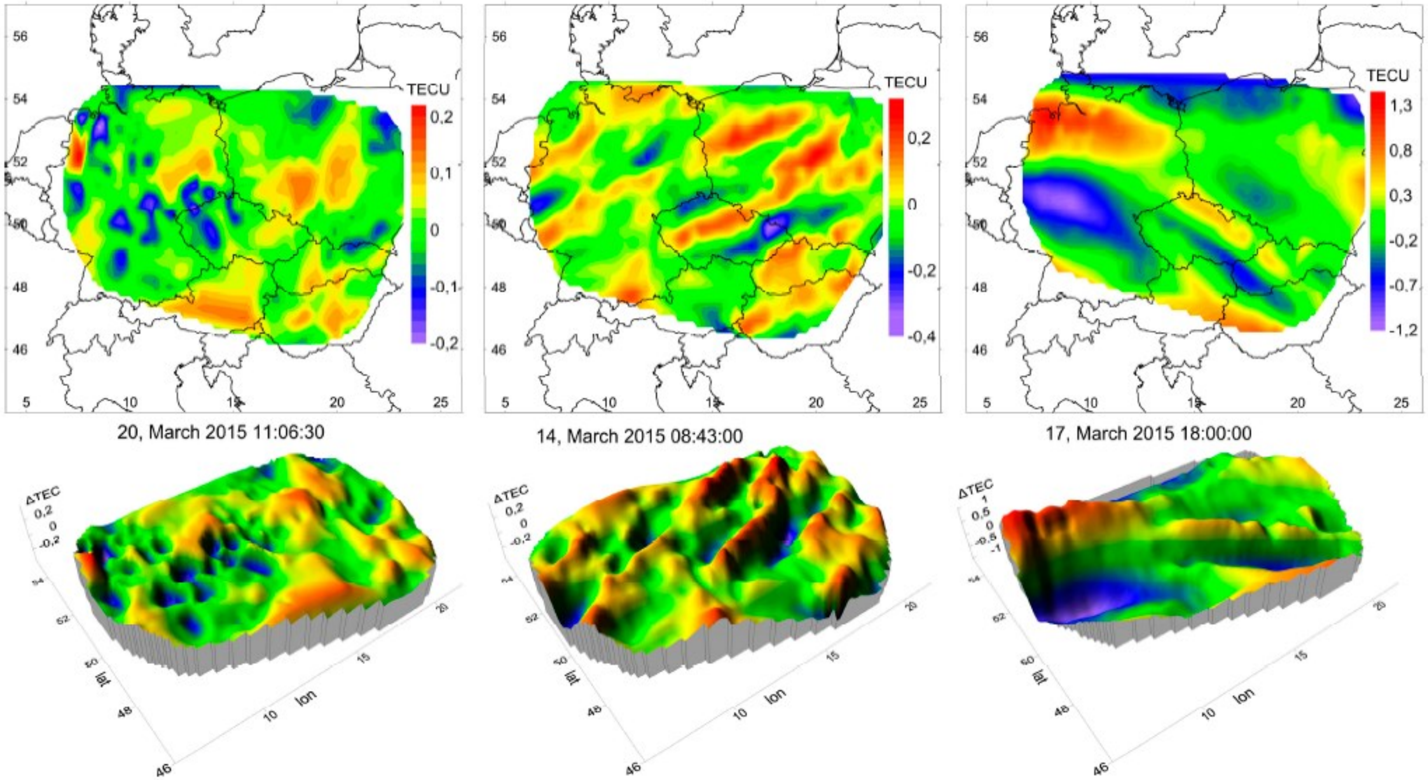


Monitoring ionosphere (2)

GUT & Institute of Radio Astronomy NAS of Ukraine, Kharkiv

- **development of the original solution for the estimation of TEC variations using satellites with elevation angles over 70°**

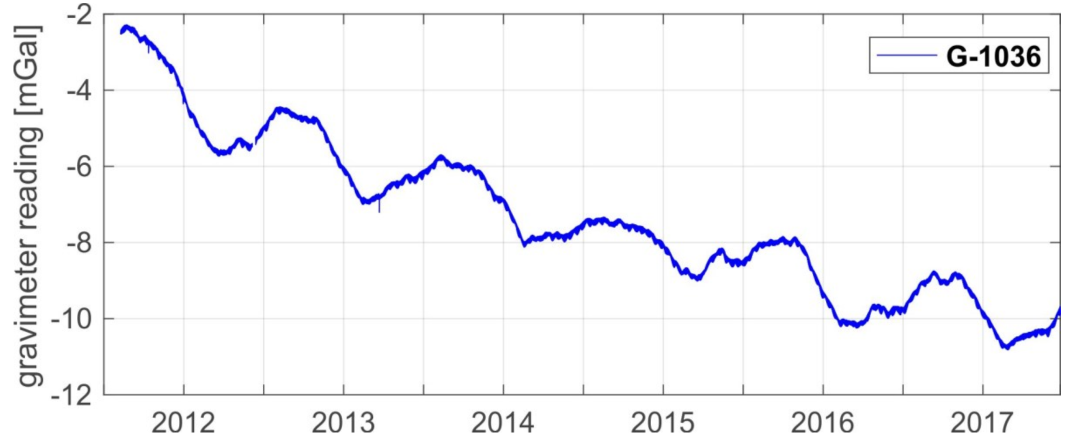
representative examples of spatial distribution of TEC variation

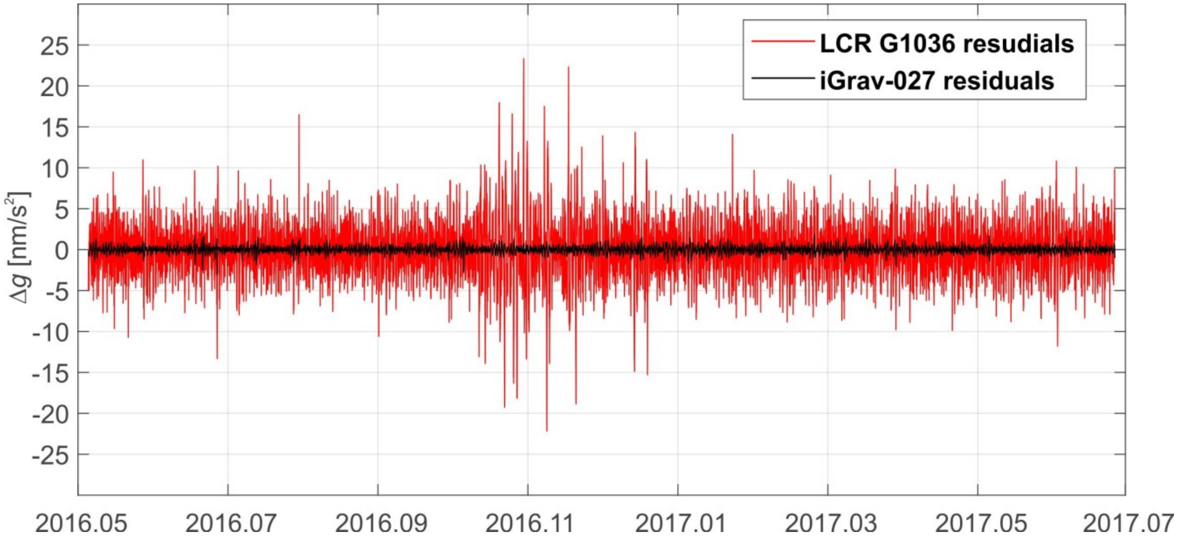


Monitoring gravity changes (1)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

- **gravity record using LCR G1036 from 2012-2017 was analysed**





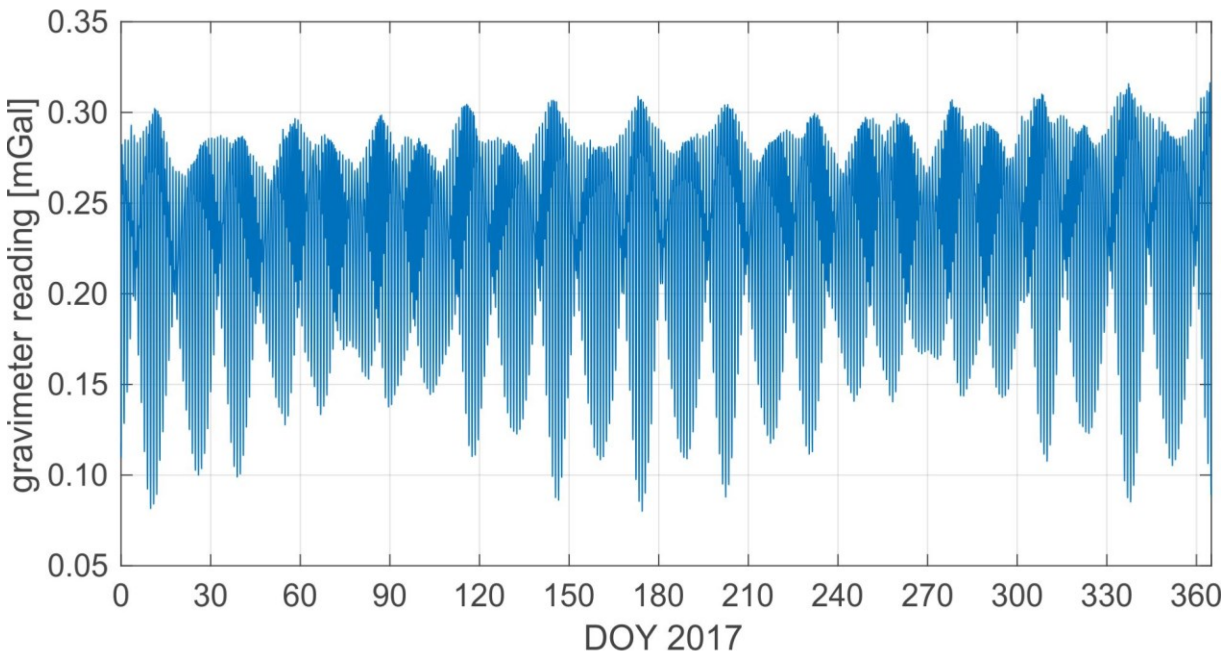
residuals from tidal adjustment with the use of high pass filter

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 2017



Satellite Laser Ranging (1)

SRC PAS

SRC PAS Borowiec station BORL tracked 36 different objects in a total of 838 full passes

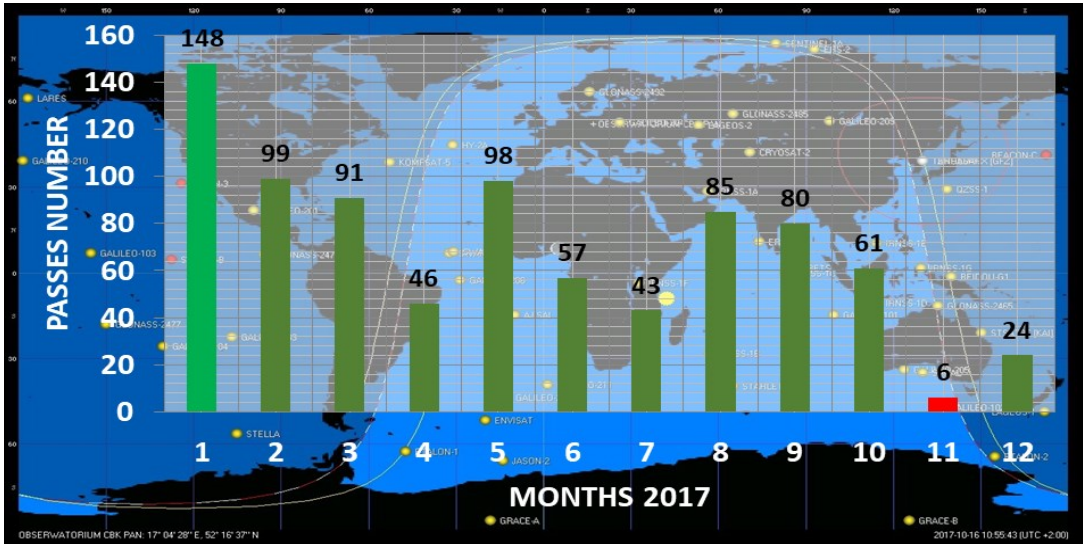
- **20 LEO and 4 MEO tracked in 2017**

  average RMS ranges from 1.28 to 6.52 cm
  (587 passes, 564 367 single good shots and 9 947 normal points)

- **12 space debris tracked in 2017**

  average RMS ranges from 5.18 to 81.60 cm
  (251 passes, 230 901 single good shots and 3 529 normal points)

observational statistics (satellites + debris) for the BORL station in 2017

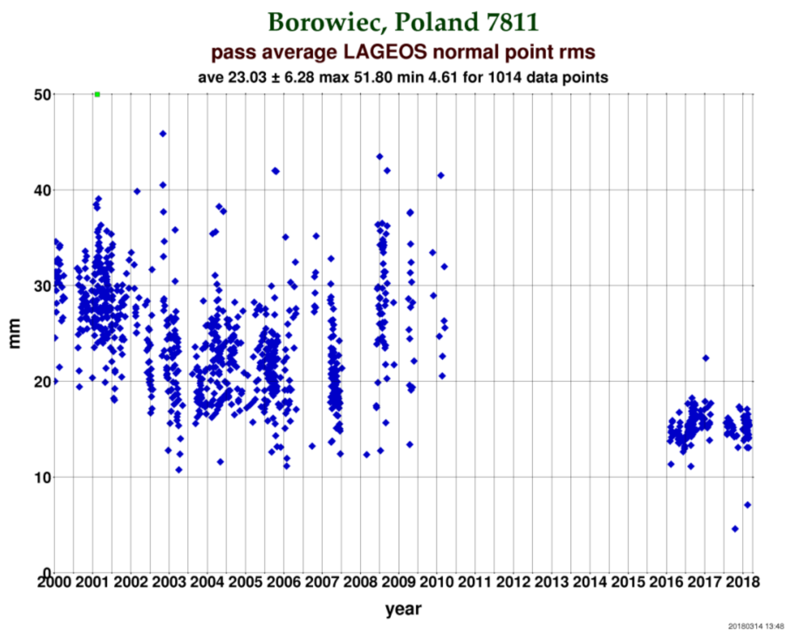


Satellite Laser Ranging (2)

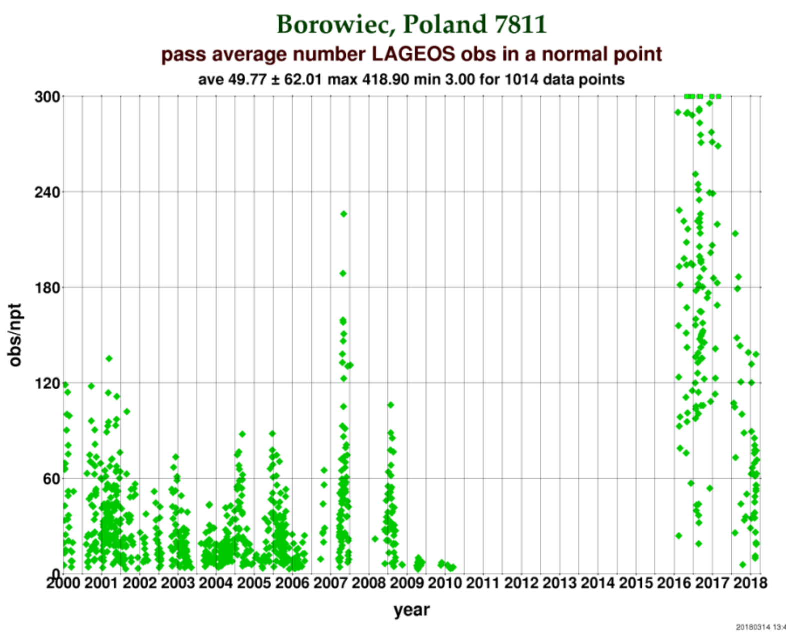
SRC PAS

- 265 passes, 294 934 single good shots and 3 154 normal points in total from all tracked satellites 7 - typical passive geodetic satellites (Ajisai, Lageos-1, Lageos-2, Larets, Lares, Starlette, Stella)

LAGEOS normal point RMS since 2000 to 2018 for BORL station



LAGEOS measurements in a normal point since 2000 to 2018 for BORL station

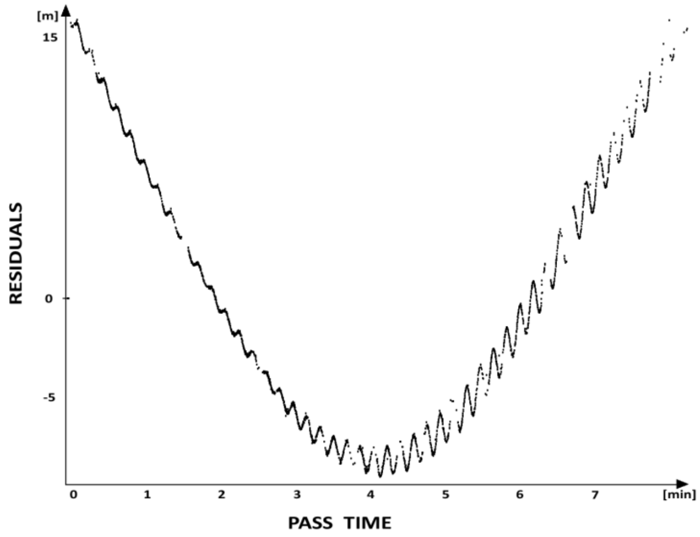


Satellite Laser Ranging (3)

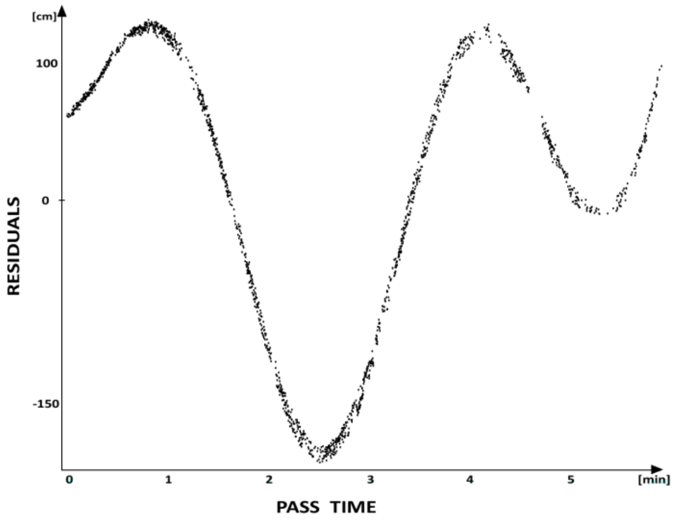
SRC PAS

• tracking TOPEX-Poseidon, ENVISAT and Jason satellites

pass of TOPEX/Poseidon over BORL station on 27 January 2017 at 03:46 UTC (2 614 returns and RMS is 38.37 cm)



pass of ENVISAT over BORL station on 28 March 2017 at 19:30 UTC (1759 returns and RMS is 3.61 cm)



Satellite Laser Ranging (4)

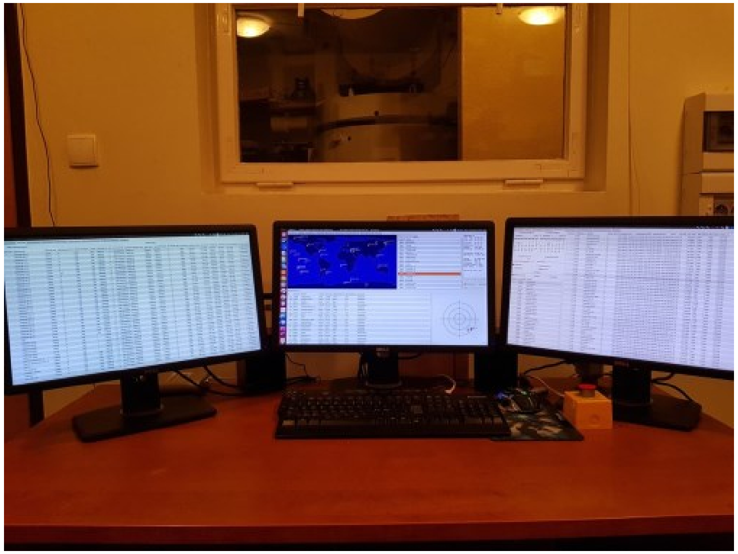
SRC PAS

Second independent laser system is under development

- situated on an azimuth-elevation mount
- with a 65 cm Cassegrain telescope equipped with servo drives (tracking accuracy below 1 arcsec)
- 20 cm Maksutov guiding telescope equipped with two fast optical CMOS cameras

second independent satellite laser system developed by SRC PAS (main telescope)

second independent satellite laser system developed by SRC PAS (operator room)



Geodynamics (1)

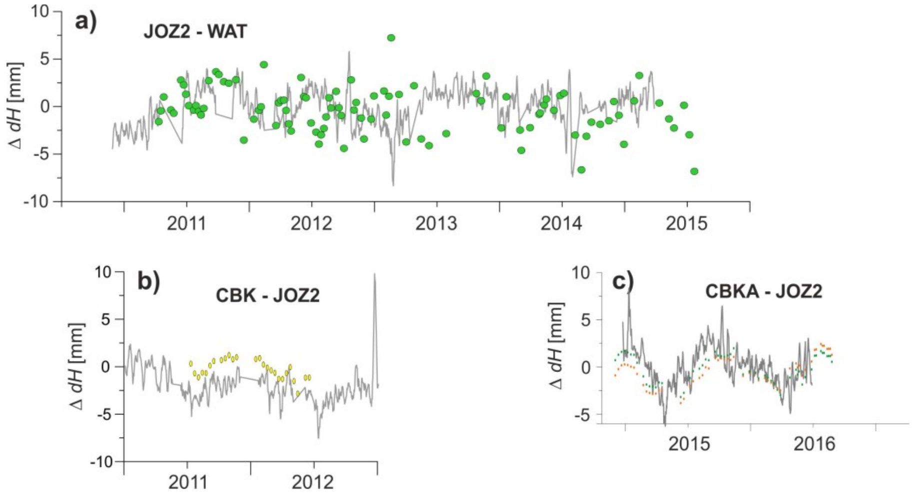
IGiK, WAT, WUELS

- **EPOS–PL project – the Polish Earth science infrastructure integrated with the European Plate Observing System Programme (EPOS) started in 2017**

IGiK

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

relative deformations in height component obtained from GNSS (weekly solutions) and PSI (average) data: Cosmo SkyMed (a), TerraSAR-X (b), and Sentinel-1 (c)

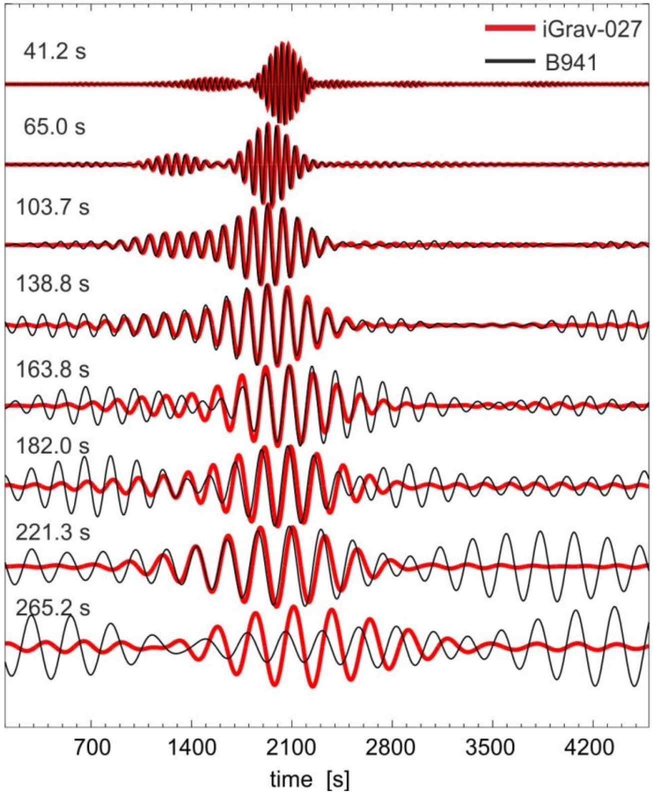


Geodynamics (2)

IGiK

- **study of a wider response for incoming seismic waves by using simultaneous seismic and gravity records at the same locations**

near monochromatic complex signal of the M6.6 Kamchatka earthquake recorded by the B941 seismometer (thin black line) and the iGrav-027 superconducting gravimeter (red line) at the Borowa Gora Observatory



Geodynamics (3)

IGiK

- **temporal variations of the vertical reference system due to temporal geoid height variations and temporal vertical displacements of the physical surface of the Earth**

temporal vertical displacements, temporal variations of geoid height and temporal variations of the orthometric/normal height at the Borowa Gora Observatory