NATIONAL REPORT OF POLAND TO EUREF2019

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EUREF2019 MAA-AMET

Main geodetic activities at the national level in Poland since 2017

- 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

Activities in the horizontal and vertical control

Head Office of Geodesy and Cartography (GUGiK)

continuation of field inspection of geodetic control network;

- **be completed in 2019**

continuation of preparations for a new levelling campaign in Poland

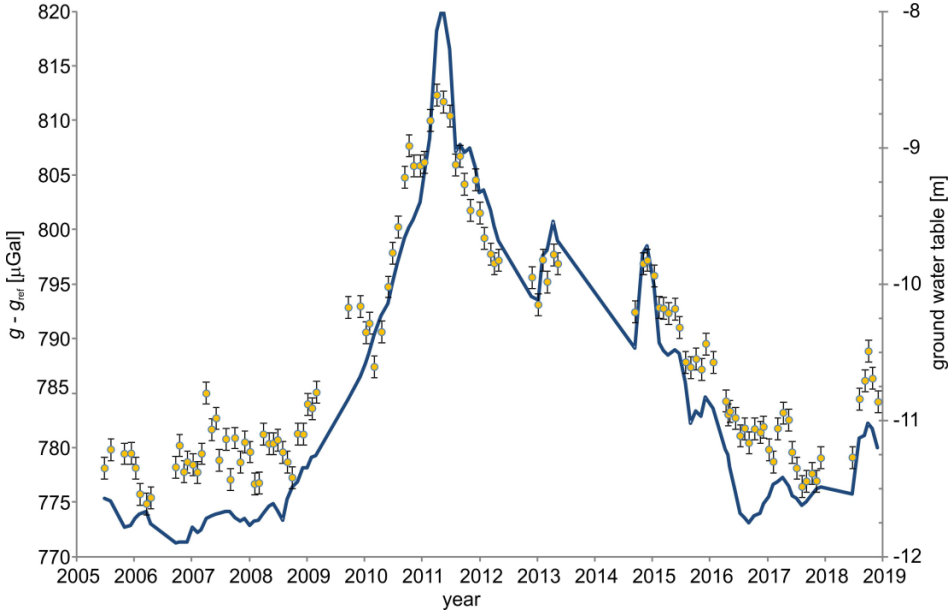
- **campaign planned to start in 2020**

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

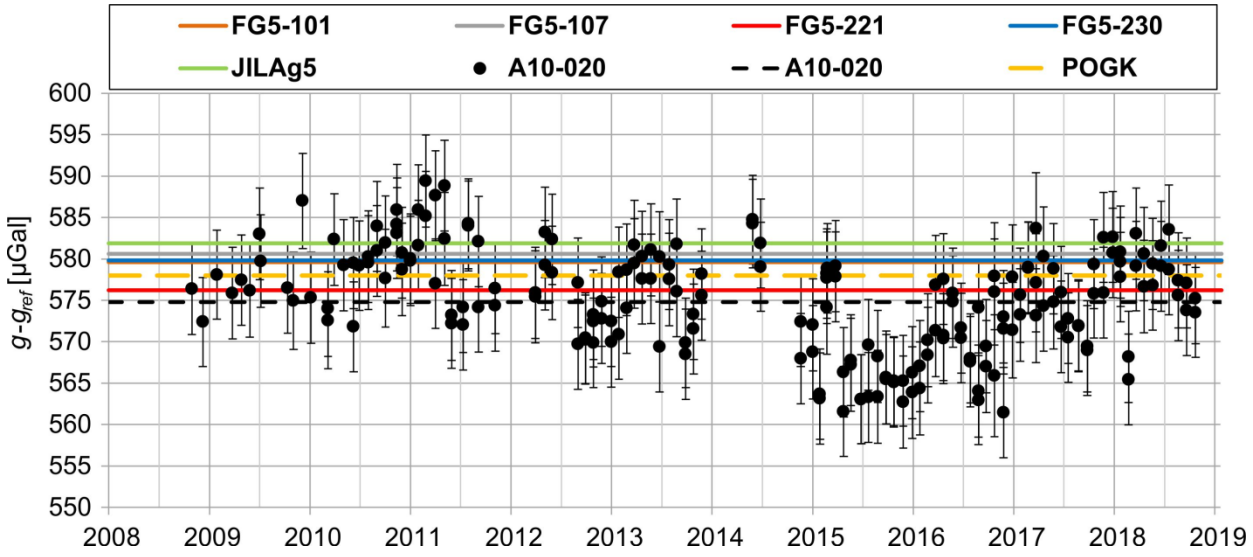
quasi-permanent absolute gravity measurements with FG5-230



Maintenance of national gravity control (2)

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

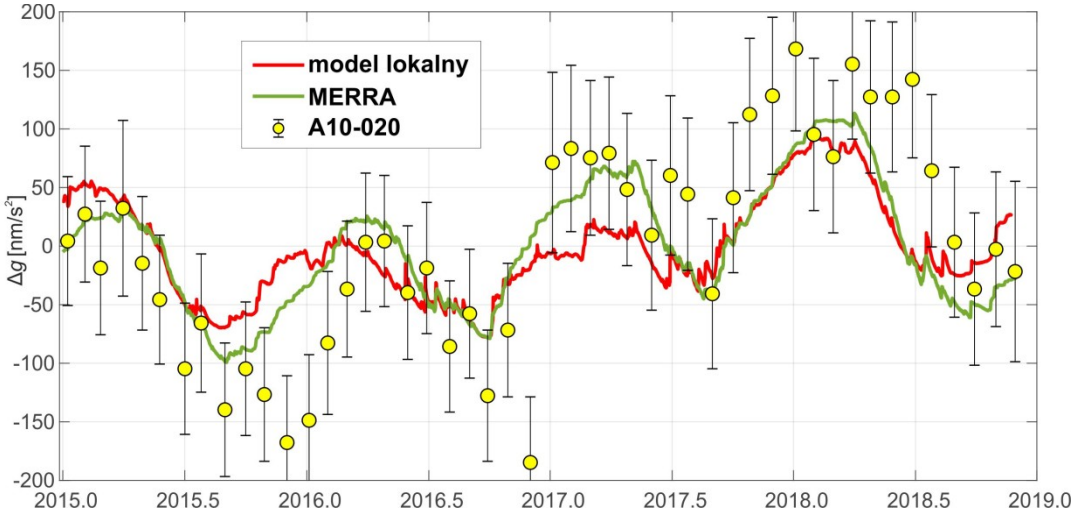
quasi-permanent absolute gravity measurements with A10-020



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

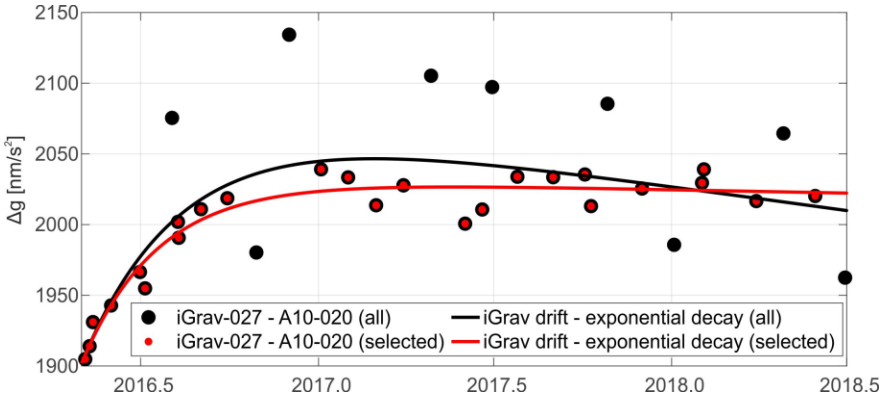


Maintenance of national gravity control (4)

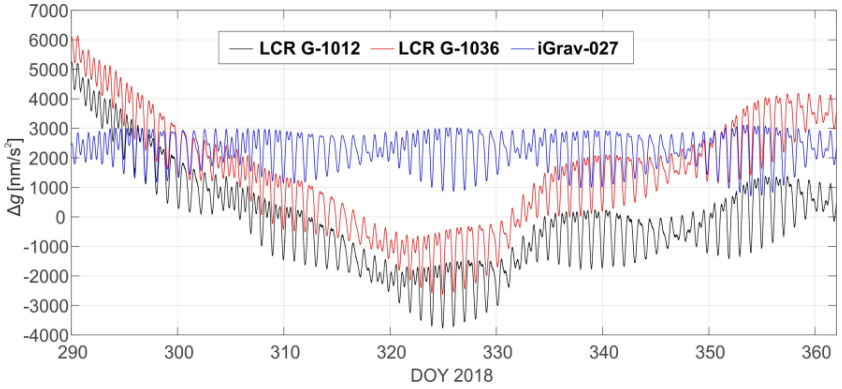
Borowa Gora Geodetic-Geophysical Observatory
Institute of Geodesy and Cartography IGiK, Warsaw

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

drift of the iGrav-027



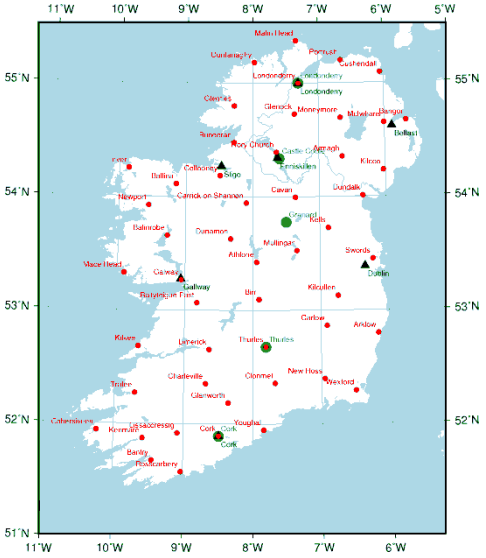
records of two relative LCR gravimeters and the iGrav-027 gravimeter



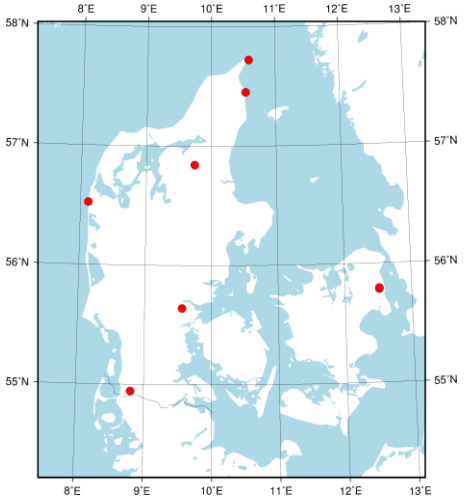
Maintenance of national gravity control (5)

gravity control survey in the Ireland island and in Denmark with the A10-020 gravimeter

27 of 67 stations in Ireland surveyed in 2018



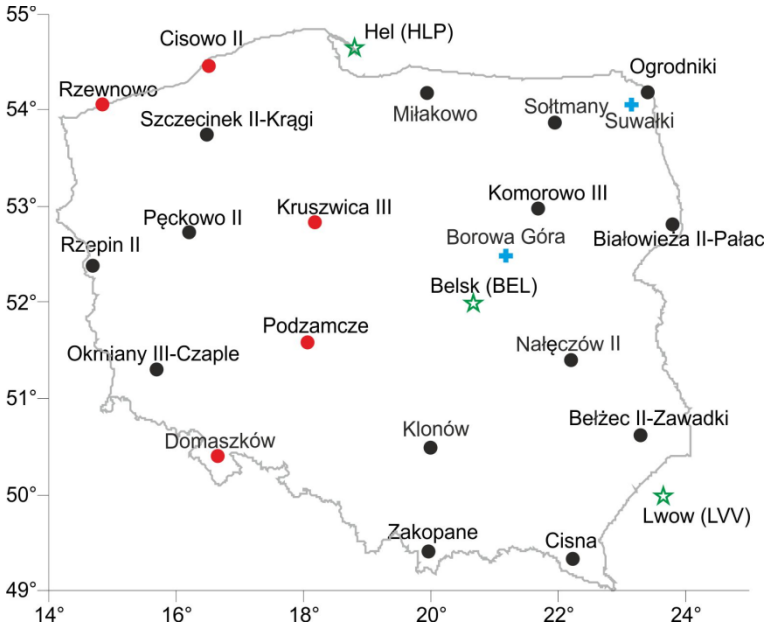
8 stations in Denmark surveyed in 2018



Maintenance of magnetic control

IGiK

repeat stations, permanent stations and magnetic observatories



3 independent components of the magnetic intensity vector measured at

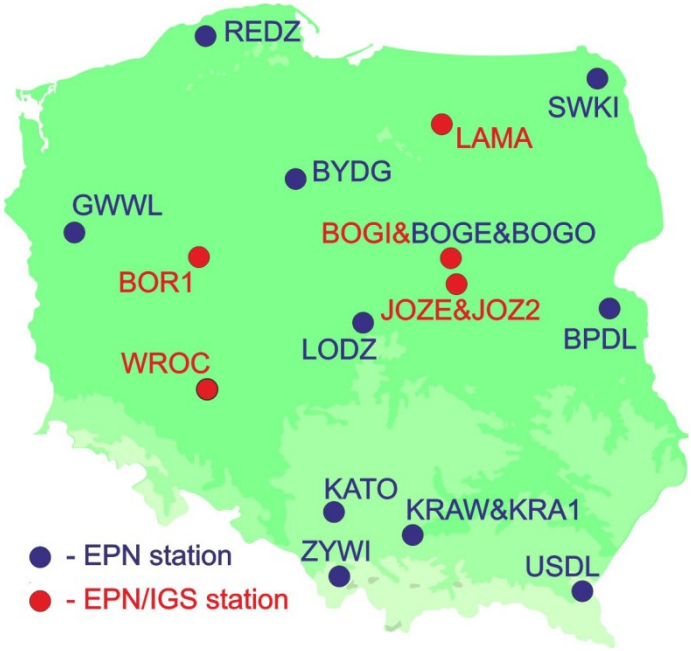
- **5 repeat stations**

Operational work of permanent GNSS IGS/EUREF stations

EPN stations in Poland

- Biala Podlaska (BPDL)
- Borowa Gora (BOGE)
- 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 project



Data processing at LACs

WUT

data from 128 EPN stations routinely processed

MUT

data from 145 EPN stations routinely processed

MUT–WUT EPN Combination Centre

16 ACs were submitting SINEX solutions for the weekly EPN combination

- **since 17 December 2017 (GPS week 1980)**
  the troposphere modelling was harmonized among ACs
  VMF1/ECMWF approach is used
  better consistency between AC coordinate solutions was observed for some stations
  scale differences between the combined solution and solutions provided by BKG, IGE and ROB ACs were noticeably decreased
- **analysed impact of including Galileo observations into EPN AC products on combined EPN station positions**

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

- **4089** active licenses
  for RTK service
- **3400** 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 and tide gauge data for monitoring Baltic Sea level changes

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

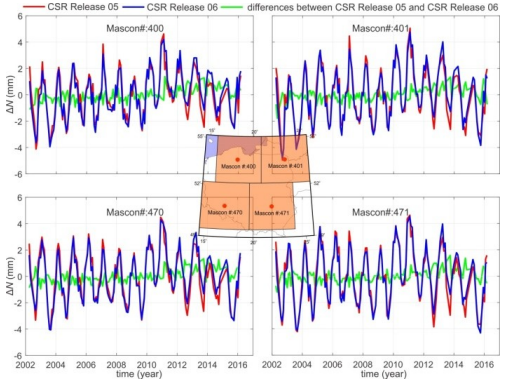
WUT

- new quasigeoid with the use of the existing GNSS/levelling networks, GGMs and the European Gravimetric Geoid Model – EGG2008

Use of data from satellite gravity missions (1)

IGiK

- **evaluation** over the area of Poland of 3 GGMs developed in 2016-2017
  - high precision GNSS/levelling data (*100 ASG-EUPOS stations*)
- **temporal variations of geoid heights** obtained from RL06GRACE-based GGMs over the area of **Poland** represented by 4 subareas



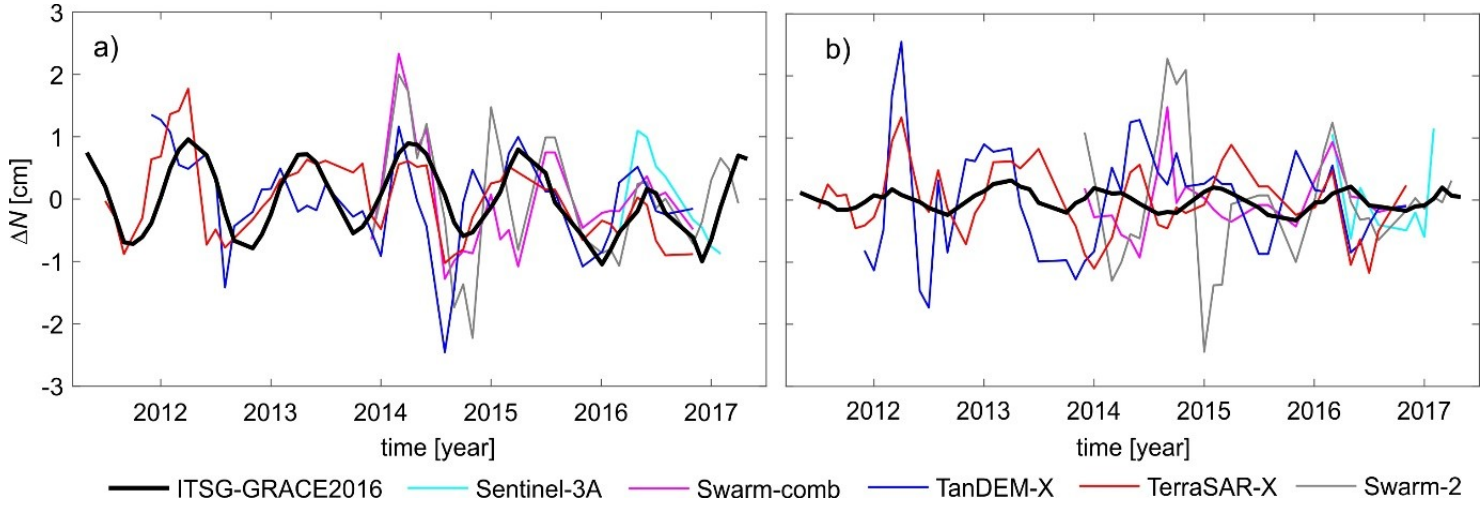
as well as in **Turkey**

Use of data from satellite gravity missions (2)

IGiK

- **suitability of data from Non-Dedicated Gravimetric Satellite Missions (NDGSM)**
  - to determine temporal changes the geoid height
  - to investigate the ability to reliably supplement the time series of changes in the mass distribution during the gap between GRACE and GRACE-FO missions

a) – Amazon **b) Poland**



Use of data from satellite gravity missions (3)

UWM

- comparison of long-term absolute gravimeter observations with GRACE-derived and global hydrology models
- analysis of the water budget using GRACE-derived and global hydrology models
- investigation of variability of the atmospheric energy balance and its impact on the surface fluxes observations using GLDAS models

WUT

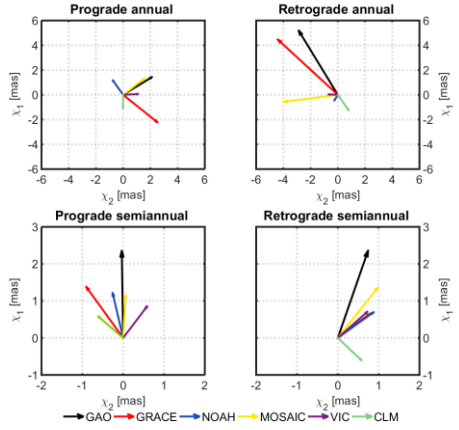
- compliance in gravity changes observed by satellite method with those determined with absolute gravity measurements

Use of data from satellite gravity missions (4)

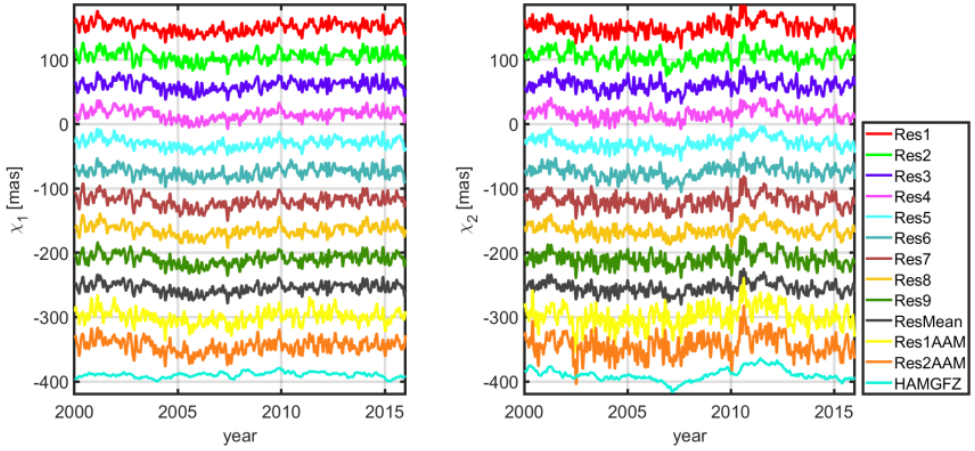
Space Research Centre of the Polish Academy of Sciences SRC PAS

- **investigation of geophysical interpretation of polar motion based on the GRACE data and hydrological models**

phasor diagrams of prograde and retrograde seasonal (annual and semiannual) variation in χ1 + iχ2 for GAO and HAM functions



comparison of non-seasonal components, χ1 and χ2, of various geodetic residuals

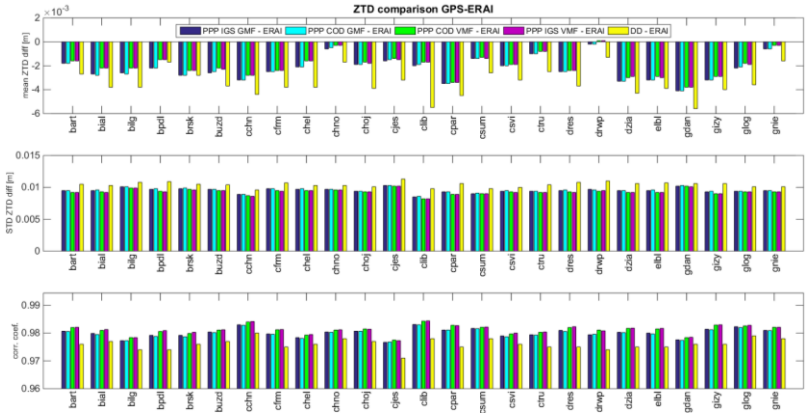


GNSS for meteorology (1)

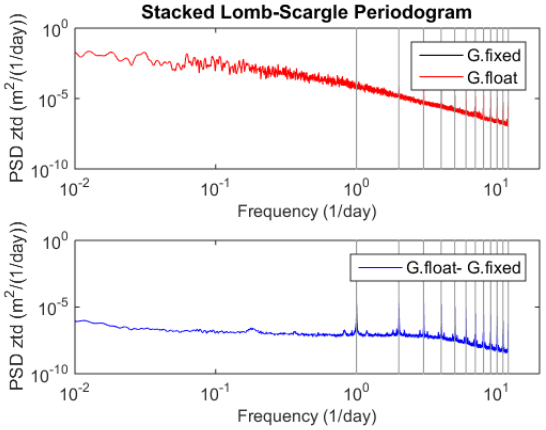
UWM

- assessment of the impact of some not much investigated so far GNSS data processing aspects on the quality the derived ZTD series for climate applications - cooperation with IGN LAREG)

mean, standard deviation of ZTD differences and correlation coefficient between ERA-Interim and GPS solutions



stacked Lomb-Scargle periodograms and ZTD, and ZTD difference, PPP fixed and float solutions

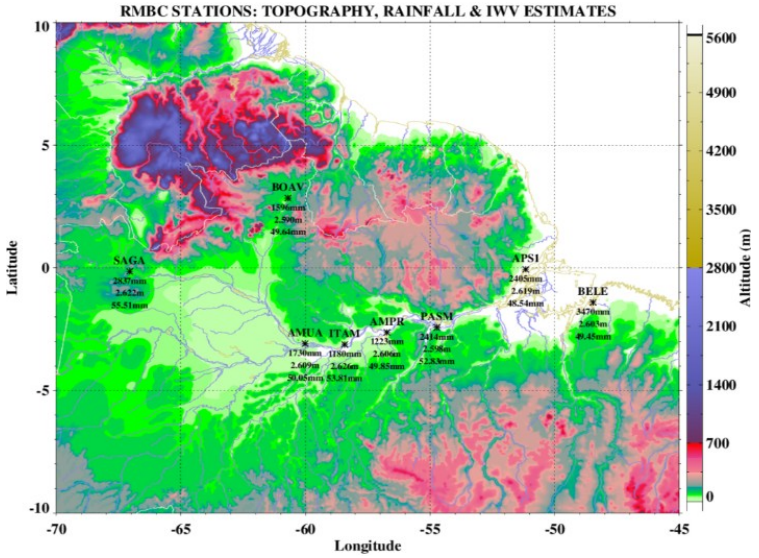


GNSS for meteorology (2)

UWM

- research on the assessment of GNSS IWV over central and north-eastern Amazonia - cooperation with the Shanghai Astronomical Observatory (SHAO) of the Chinese Academy of Sciences (CAS) and Federal University of Pará, Brazil

topography, mean rainfall [mm/year], mean ZTD [m], and mean IWV [mm] for the samples available from July 2017 to August 2018



GNSS for meteorology (3)

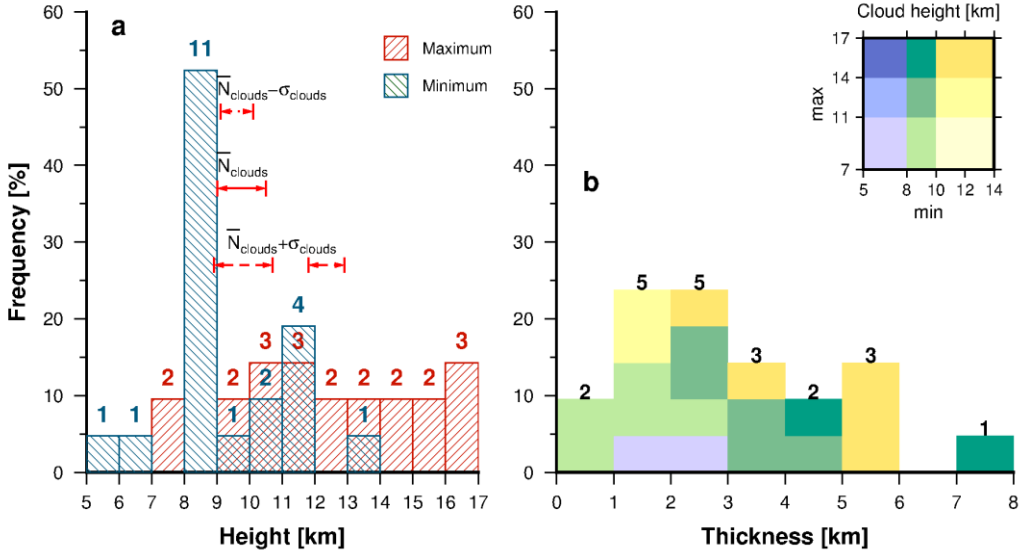
WUELS

- analysis of sensitivity of the GPS Radio Occultation (RO) profiles to cloud water and ice content within tropical cyclones in 2007-2010

histograms for single clouds' detection ranges:

(a) minimum (blue) and maximum (red) heights. Detection ranges for mean cloud contribution are presented as red horizontal arrows

(b) thickness of detection ranges

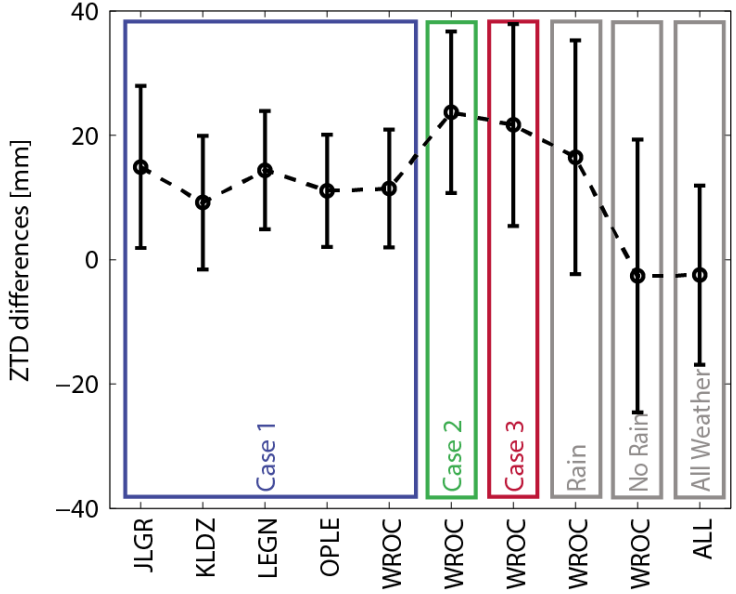


GNSS for meteorology (4)

WUELS

- analysis of estimated GNSS delays in weather-specific conditions

differences in ZTD from GNSS and ray-traced delays for
Case 1: moderate clouds and rain;
Case 2: clouds;
Case 3: heavy rain and weather-specific conditions (grey panels)

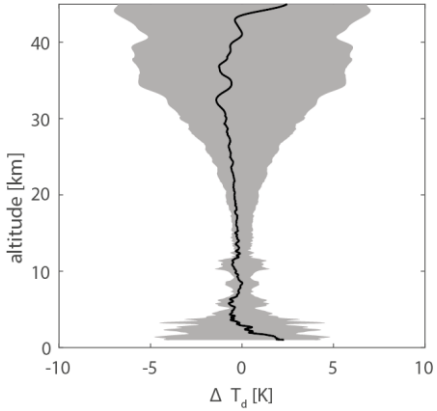


GNSS for meteorology (5)

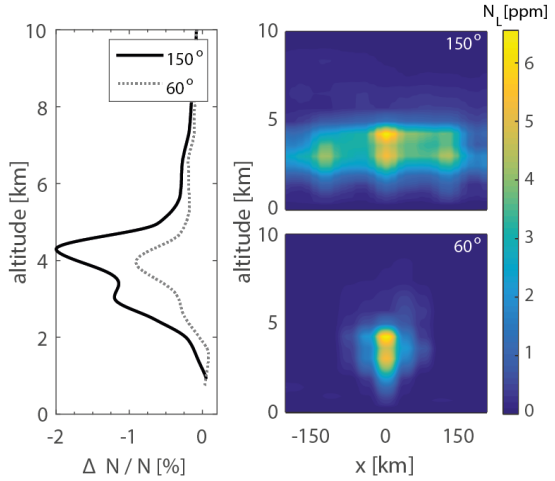
WUELS

- developing a **software for profiling the neutral atmosphere** with RO technique – in cooperation with NCU, Taiwan

differences in the dry temperature between official and retrieved profiles in terms of mean bias (black line) and one standard deviation (grey area)



refractivity fractional errors simulated for the liquid water at different cross-sections: 60 degree (dashed grey line) and 150 degree azimuth (black solid line)

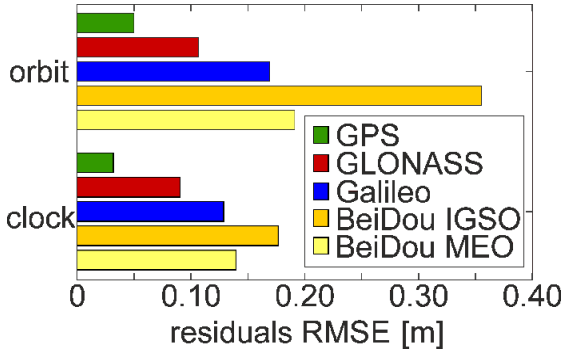


GNSS for meteorology (6)

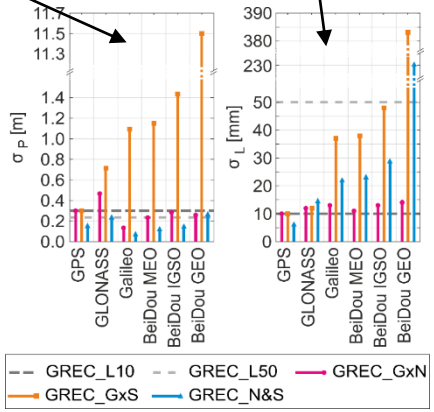
WUELS

- the comprehensive analysis of availability and quality of multi-GNSS real-time corrections
- developing observation weighting schemes, that are suitable for real-time multi-GNSS PPP

RMSE of real-time orbits and clocks compared to the CODE MGEX solutions for 1–30 April 2016



comparison of weighting schemes for pseudoranges and carrier-phase measurements



GNSS for meteorology (7)

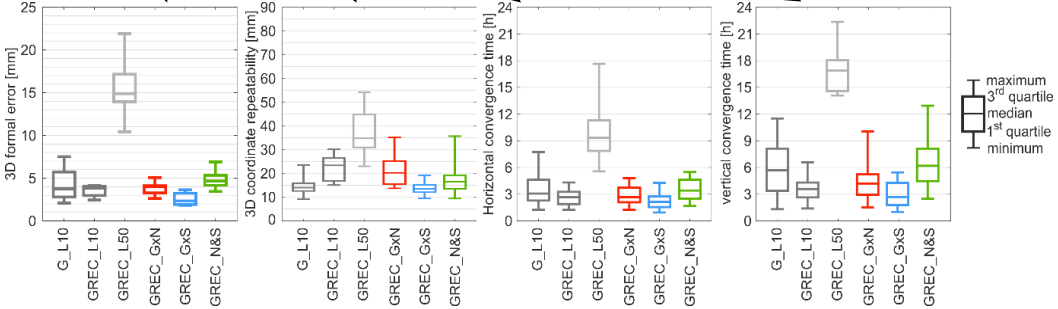
WUELS

3D formal errors of coordinates

3D coordinate repeatability

horizontal convergence time

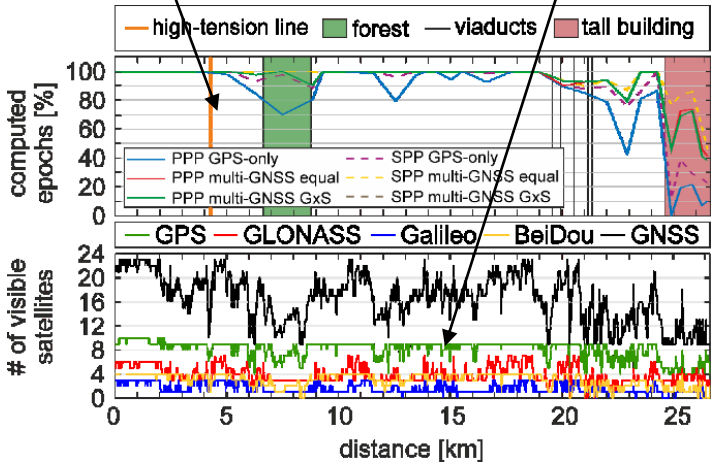
vertical convergence time



in static PPP using different weighting schemes

number of epochs with proper solution

number of visible satellites



Monitoring ionosphere (1)

UWM

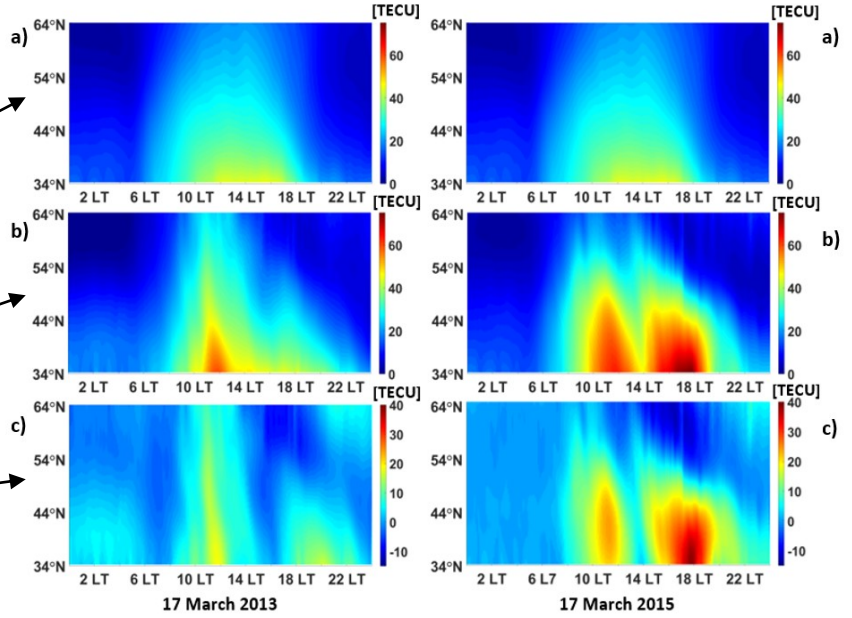
- development of regional UWM-TEC ionosphere maps
- investigating the use of available ionospheric maps with the temporal resolution of 1-2 hours and low spatial resolution for a detailed analysis of momentary effects of the storm

changes in the condition of the ionosphere, observed by the UWM-TEC model

(a) calm ionosphere

(b) disturbed day (17 March)

(c) changes in the condition of the ionosphere in relation to the calm period for 2013 (the left panel) and 2015 (the right panel)



Monitoring ionosphere (2)

UWM

- method of modelling regional TEC model in Southeast Asia with the use of PPP and the least-squares collocation (LSC)

GUT & Institute of Radio Astronomy NAS of Ukraine, Kharkiv

- improvement of the original method for estimating TEC variations using satellites with high elevation angles

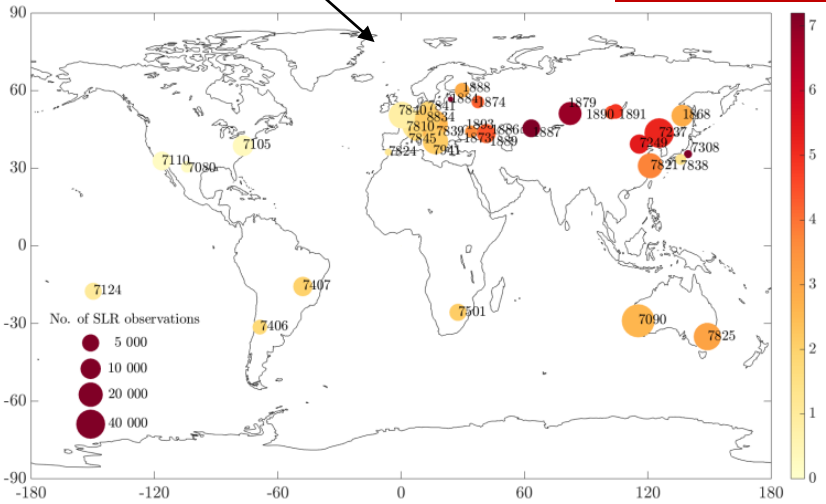
Improving consistency between SLR and GNSS solutions (1)

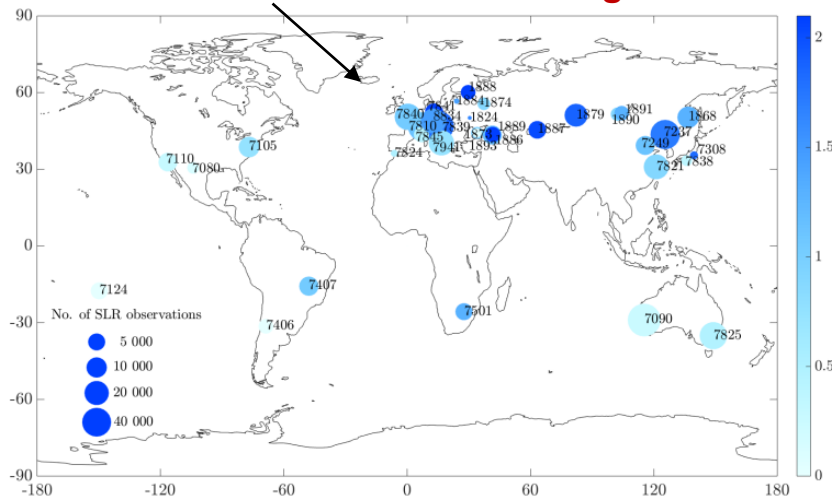
WUELS

- **the Blue-Sky effect**

amplitude of the annual signal in the deformation of the Earth's crust caused by atmospheric pressure loading

and **the Blue-Sky effect determined for laser stations tracking GNSS satellites**





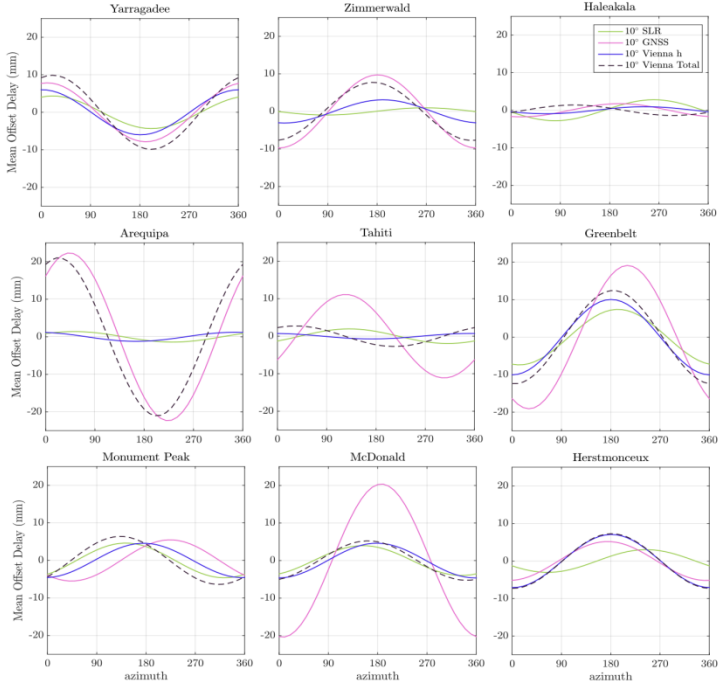
Improving consistency between SLR and GNSS solutions (2)

WUELS

- **troposphere delay modelling in SLR**

horizontal gradients of the tropospheric delay determined from SLR and GNSS observations and from hydrostatic and total tropospheric delays determined using numerical weather models

- **determination of global parameters using SLR tracking of GNSS**



Improving consistency between SLR and GNSS solutions (3)

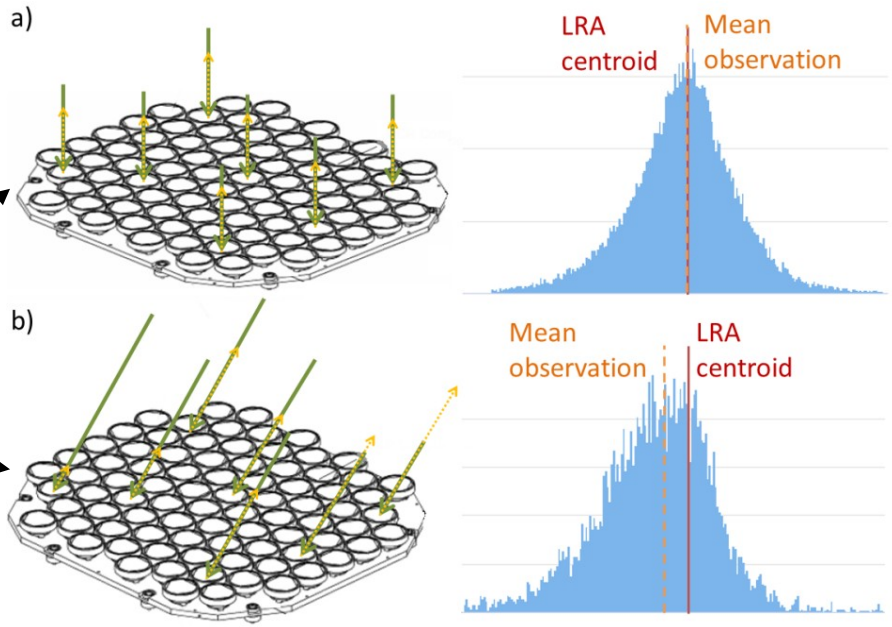
WUELS

- **SLR satellite signature effect**

visualization of the satellite signature effect in the case of multi-photon detectors in a situation where the laser beam

- falls perpendicular to the retroreflector (a)

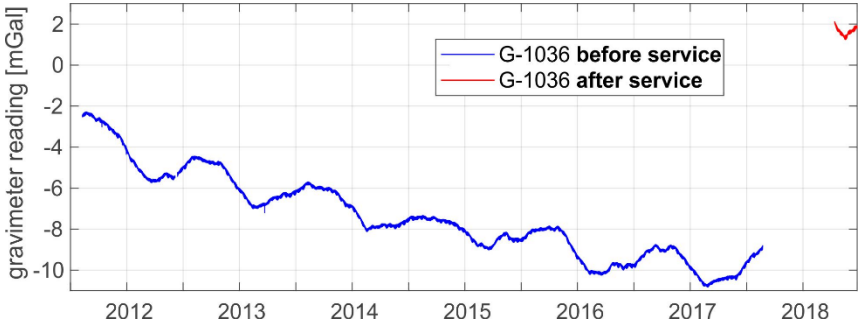
- is inclined in relation to the observer and the detector registers the majority of photons reflected from the nearest edge (b)

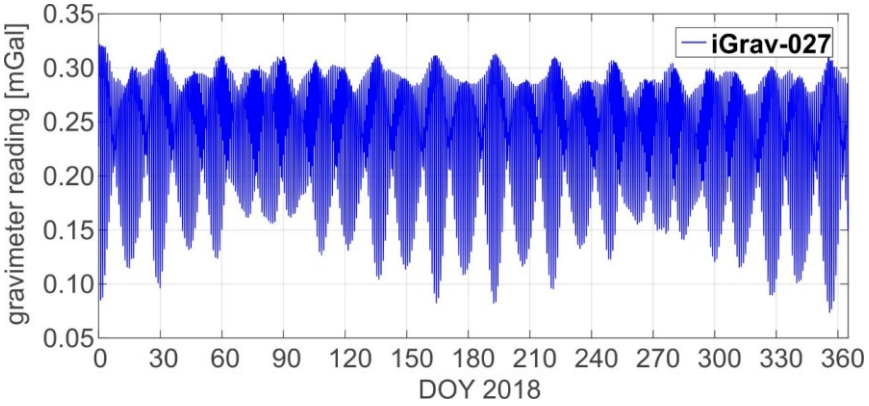


Monitoring gravity changes (1)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

- **gravity record** using LCR G1036 from 2012-2018 was **analysed**



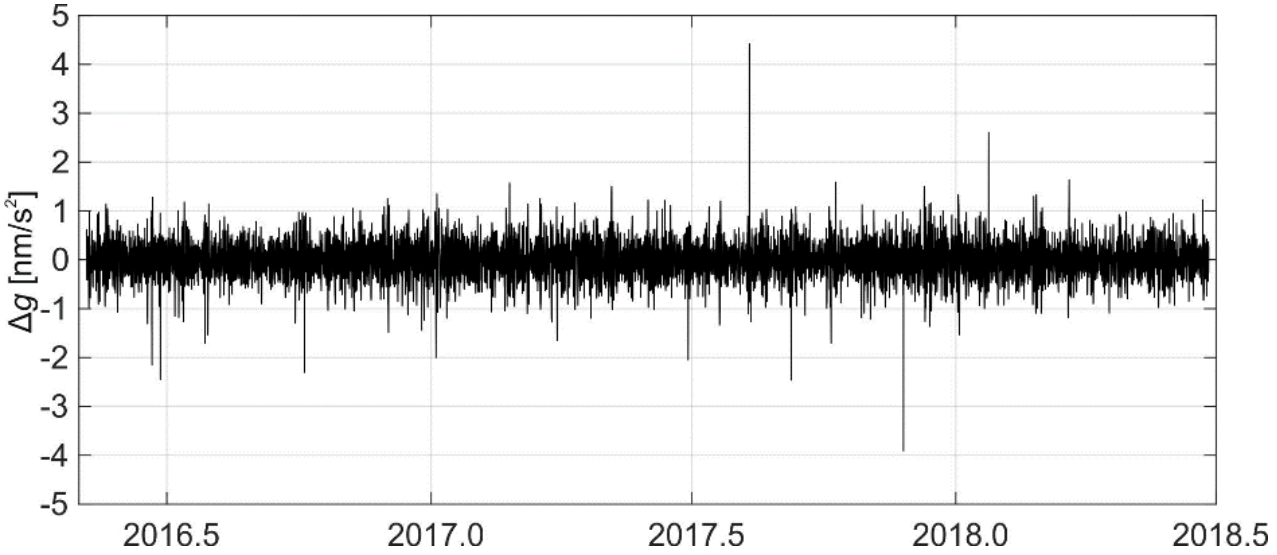


tidal record with the iGrav-027 superconducting gravimeter in 2018

Monitoring gravity changes (2)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

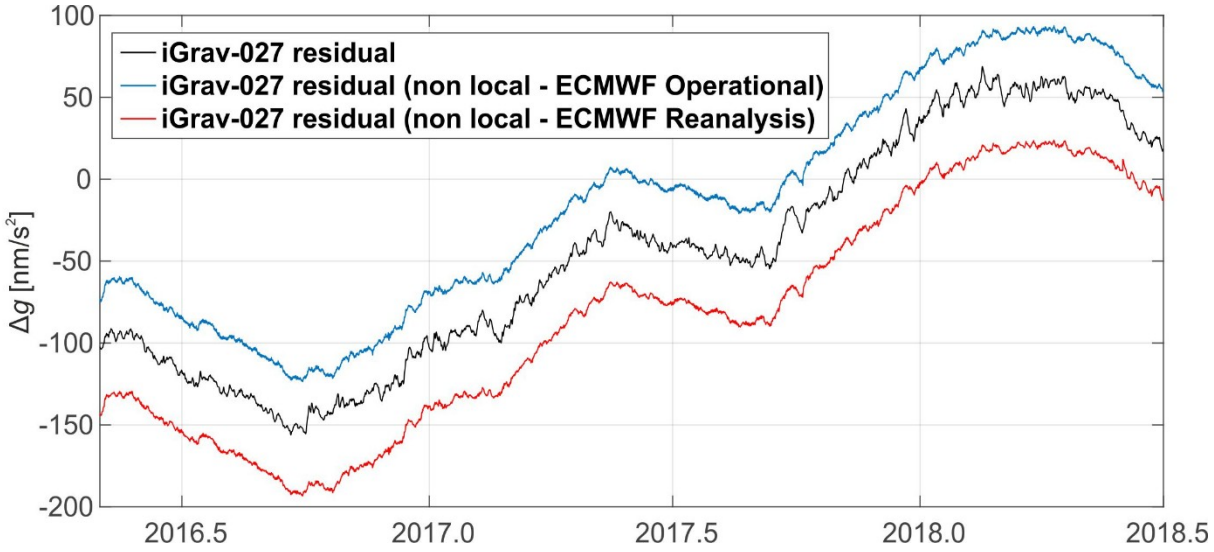
residuals from tidal adjustment with the use of high pass filter for the iGrav-027 gravimeter



Monitoring gravity changes (3)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

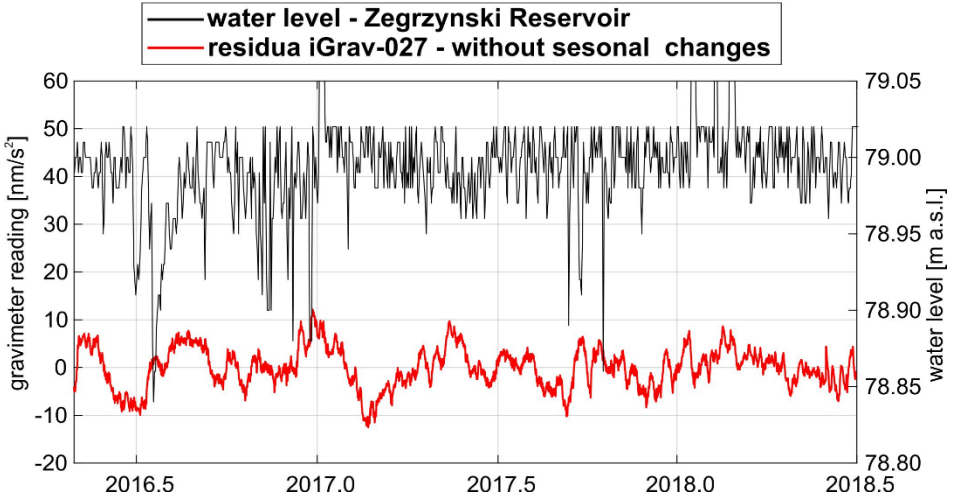
residuals of the iGrav-027 after subtracting tidal effect, drift, polar motion effect, standard atmospheric correction considering the advanced atmospheric correction



Monitoring gravity changes (4)

Borowa Gora Geodetic-Geophysical Observatory of IGiK

residuals of high pass filter for the iGrav-027 gravimeter against variations of water level of Zegrze water reservoir



Satellite Laser Ranging (1)

SRC PAS

SRC PAS Borowiec station BORL tracked 53 different objects in a total of 1857 full passes

- **29 LEO and 14 MEO tracked in 2018**

  average RMS ranges from 1.40 to 5.17 cm
  (1374 passes, 21 058 normal points)

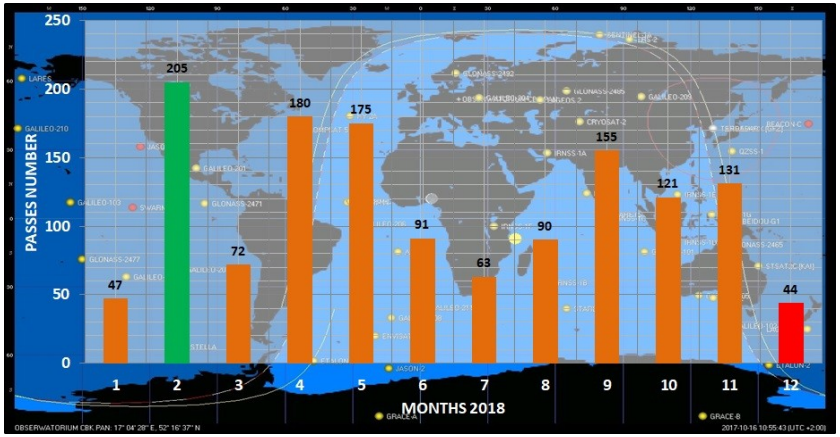
- **10 space debris tracked in 2018**

  average RMS ranges from 2.45 to 44.83 cm
  (483 passes, 6085 normal points)

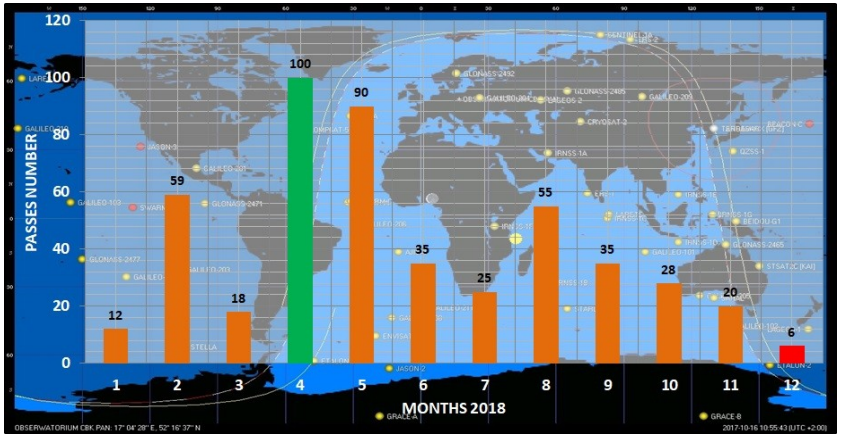
Satellite Laser Ranging (2)

SRC PAS

observational statistics of satellites for the BORL station in 2018



observational statistics of debris for the BORL station in 2018



Satellite Laser Ranging (3)

SRC PAS

observational statistics of geodetic satellites tracked at BORL station in 2018

Sat. name	Passes	Returns	Normal points	Avg RMS [cm]
Ajisai	84	125257	1174	3.71
Etalon-1	3	340	13	3.84
Etalon-2	4	561	19	3.69
LAGEOS-1	**116**	**129404**	1084	1.69
LAGEOS-2	91	85247	1083	1.72
LARETS	84	24299	574	2.06
LARES	**116**	50677	**1317**	**1.48**
Stella	29	18261	258	1.97
STARLETTE	62	44753	613	2.03

Satellite Laser Ranging (4)

SRC PAS

Second independent optical-laser system

dedicated to the Space Surveillance and Tracking (SST) programme

developed by ESA and EC

was operating at Borowiec

- able to track, in optical mode, satellites from LEO to GEO regimes

Geodynamics (1)

IGiK, WAT, WUELS

- **EPOS–PL project – the Polish Earth science infrastructure integrated with the European Plate Observing System Programme (EPOS) – continued**
  - developing centres of research infrastructure for geomagnetic and gravimetric data integrated with GNSS infrastructure
  - monitoring of Earth surface displacements using integrated multi-GNSS, gravity, seismic, and InSAR data in test areas of the Upper Silesia was initiated

IGiK & University of Warsaw

- investigation of the geophysical characteristics of the lower lithosphere and asthenosphere in the marginal zone of the East European Craton

Geodynamics (2)

IGiK & Selçuk University, Konya, Turkey

- determination of temporal mass variations determined from GRACE-based GGMs over Konya basin

MUT & WUT

- recognizing geological structures using gravity gradients from satellite missions

MUT

- interpretation of station coordinate time series
  - velocties of the permanent DORIS stations
  - use of the the Adaptive Wiener Filter methodology, the Singular Spectrum Analysis and its multivariate variant , Improved Singular Spectrum Analysis
  - application of the probabilistic Principal Component Analysis