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High precision techniques for Earth's crust movement observations in Latvia

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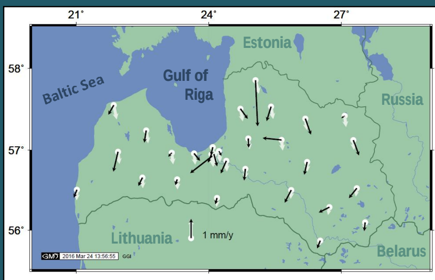
Introduction

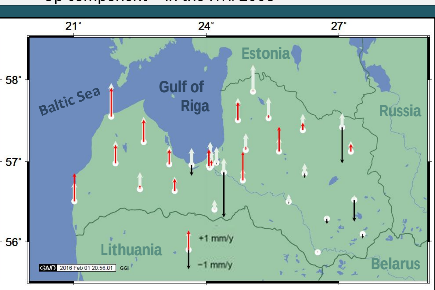
The application of two principal space geodetic techniques: **Global Navigation Satellite System (GNSS)** and **Satellite Laser Ranging (SLR)**, is under discussion in this study. The objective is to discover geodynamic processes of the Earth's crust in the territory of Latvia, placed at the coast of the Baltic Sea and at the edge of Fennoscandian land uplift phenomenon, by analysing GNSS time series obtained from Latvian GNSS permanent stations with reference to EUREF Permanent Network (EPN), and to develop additional observation device for relation to International Laser Ranging Service (ILRS) network.

Latvian GNSS station velocity fields

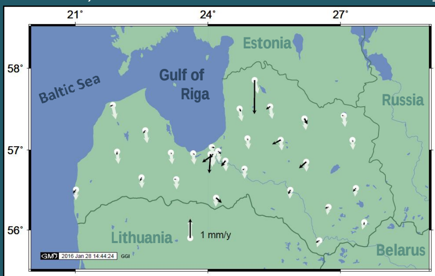
EUPOS®-Riga and LatPos station displacements have been summarized for the period of 8 years – from 2008 to 2015. Two solutions are presented: EUPOS® Combination Centre (ECC) cumulative weekly solution (2008-2014) and re-processed daily solution (2012-2015).

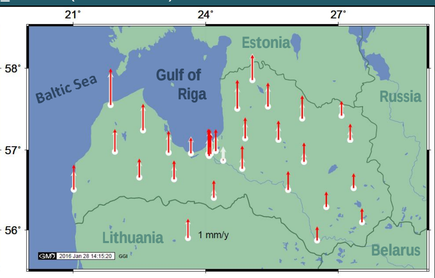
Steps	Institution	Additional description	ECC cumulative weekly solution (2008-2014)	GGI daily solution (2012-2015)
Data processing	GGI	Software	Bernese GPS Software version 5.0	Bernese GNSS Software version 5.2
		Data sets	IGS and CODE databases	CODE database
		Observations	GPS	GPS and GLONASS (since 1st day of 2015)
		Fiducial stations	5 – 7 EPN (A and B-class)/IGS stations	9 EPN (A-class)/IGS stations
Station coordinates and transformations	ECC/GGI	-	Daily solutions in IGS05/08: composed to weekly SINEX solutions and submitted to ECC for further combination into a single weekly EUPOS® solution	Daily solutions in IGb08: ITRF2008-to-ETRF2000 one-step transformation using 14 transformation parameters according to (Boucher and Altamimi, 2011)
Time series analysis and trend derivation	ECC/GGI	-	-	Corrections for offsets, outlier elimination
Station velocities and RMS values	ECC/GGI	-	Horizontal velocities are expressed in the ETRF2000 frame, and velocities for Up component – in the ITRF2008	





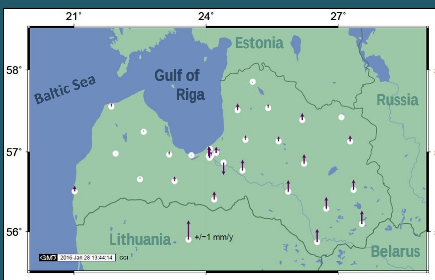
Latvian GNSS station cumulative horizontal (left) and vertical (right) velocities from EUPOS® observation set (till GPS week 1830) and velocities from the deformation model NKG_RF03vel (white vectors)



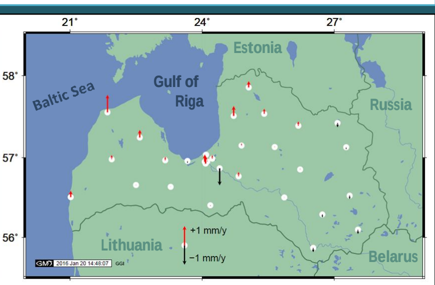


Latvian GNSS station horizontal (left) and vertical (right) velocities obtained from the daily solution (2012-2015) and velocities from the deformation model NKG_RF03vel (white vectors)

Results of **ECC cumulative weekly solution** have shown a positive tendency of vertical movements in the western and central parts of Latvia, and negative – in the eastern part. The resulting range of vertical velocities, after outstanding data elimination, is **2.05 mm/year**; it is **from -0.56 to 1.49 mm/year**.
In the case of **daily solution** vertical velocity field is more homogeneous. Vertical velocities have positive sign for all stations. Resulting range is **1.16 mm/year: from 0.73 to 1.89 mm/year**.
According to the **deformation model NKG_RF03vel** vertical velocities of Latvian GNSS stations have range of **1.68 mm/year**, with the minimum **0.04 mm/year** and the maximum **1.72 mm/year**.
Vertical velocities of western GNSS stations from the daily solution correspond to the data of NKG_RF03vel. The highest velocity differences in vertical component are more pronounced in the case of stations located in south-eastern part of Latvia, however, these differences are less than 1 mm/year.
Station horizontal displacements have similar orientation for both solutions; velocities are mostly oriented to the South, but vectors have different magnitudes, however, values don't exceed 1 mm/year.



Differences between vertical velocities obtained from the daily solution (2012-2015) and from the model NKG_RF03vel

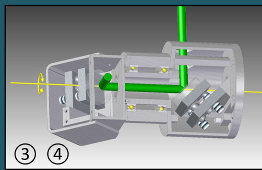


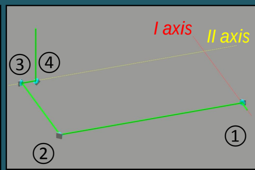
Latvian GNSS station vertical velocities obtained from the daily solution (2012-2015) and expressed in ETRF2000

Multifunctional optical tracking device for SLR purposes

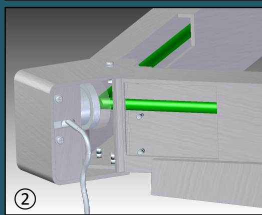
SLR is a proven geodetic technique with significant potential for contributions to scientific studies of the solid Earth, its ocean and atmospheric systems. As SLR enables most accurate determination of the geocentric positions of Earth satellites, it provides a reliable reference system for monitoring of postglacial rebound, sea level and ice volume change.
The study presents design of the universal satellite laser ranging device, as well as results of astrometric subsystem's functionality tests performed at the Institute of Geodesy and Geoinformatics (GGI) of the University of Latvia.

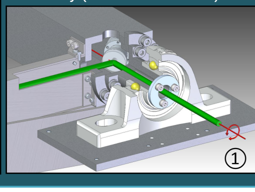
Installation of instrument





Laser path in beam turning mirrors' assembly (4 mirrors are used)

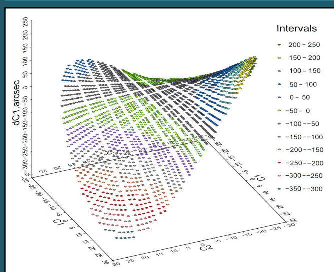


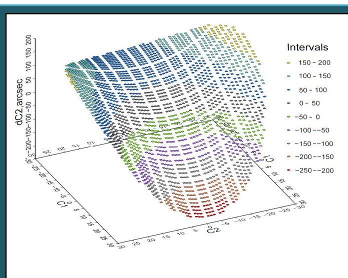


The design of separate optical units:

- Laser beam turns at the mirrors with optimised performances at 532 nm wavelength.
- Each mirror reflects 99.5 % of laser beam light.
- The first two mirrors of laser path are equipped with actuators.
- Laser beam diameter is 6 mm.

The device uses Alt-Alt mount with twin 16" (41 cm) optical tube assemblies. One of them is used for **astrometric image acquisition**, the other - as **SLR receiver**. A separate **collimator** is used for transmitted laser pulse handling.
Computer-controlled stepper motor drive is used for object tracking. Control software relies on **mount error model** to compensate mount deformations. The intended positioning accuracy is about a few arcseconds; presently 10 arcsecond accuracy level is reached. In order to improve accuracy of transmitted beam pointing, computer-controlled piezoelectric actuators are used for coudé path mirrors.
Astrometric subsystem supports **system orientation** and **object coordinate determination** in near-real-time. Position determination accuracy is up to a fraction of arcsecond. Objects up to about 15m magnitude can be observed in static mode, up to 18m – in star tracking mode. Astrometric subsystem can be used also for object guiding.
Field tests of tracking device's astrometric subsystem have shown imaging and positioning performance close to what was expected for the design. Mount error model parameters were calculated (shown below); resulting positioning accuracy is already adequate for SLR purposes.

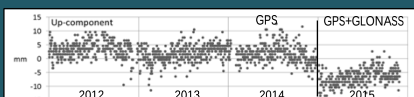




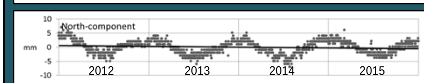
Mount error model: corrections of primary (C1) (left figure) and secondary (C2) (right figure) axis rotation as functions of position

GNSS time series and site-specific effects

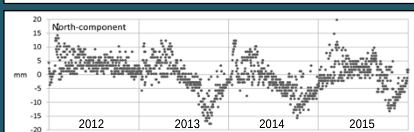
More evident outliers in coordinate time series of daily solution, usually occurred during the winter time, and single (one-day) extremes, which are out of the diapason of ±15 mm in Up component, were excluded. Time series were aligned from shifts due to GNSS antenna change and introduction of GLONASS observations in 2015.



Some examples:
Station **REZ1** time series in Up component with shift due to introduction of GLONASS observations in 2015



Station **SALP** time series in North component affected by annual variations



Station **MAZS** time series in North component. Antenna's mounting of this station differs from other; antenna is fixed on 8 meter long post