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The digital zenith camera as an additional technique for quasi-geoid model determination of Latvia

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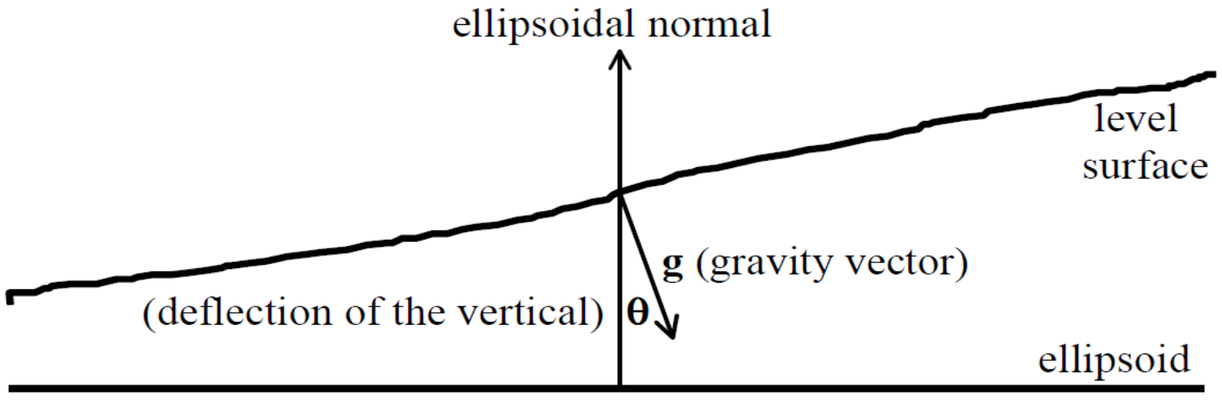
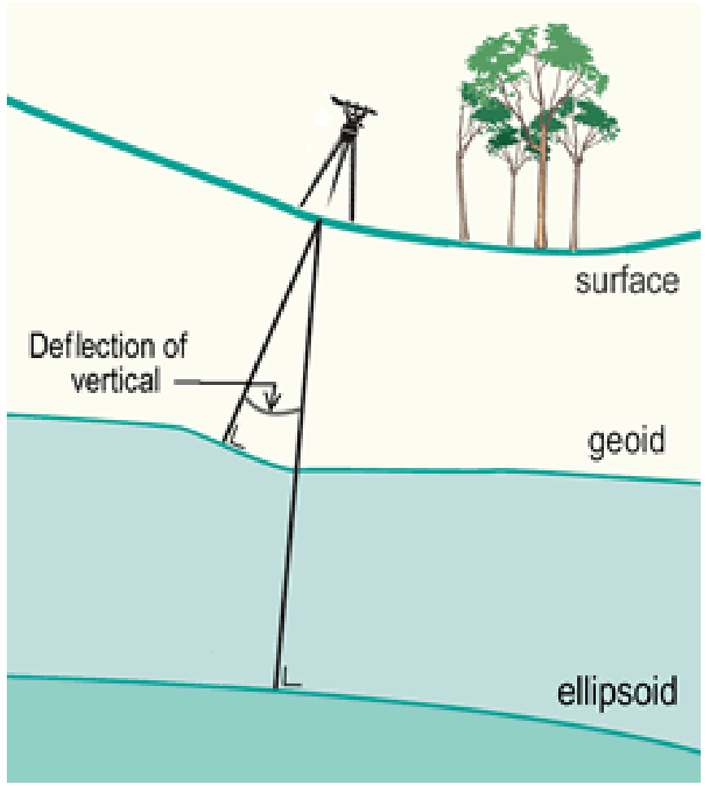
Definition

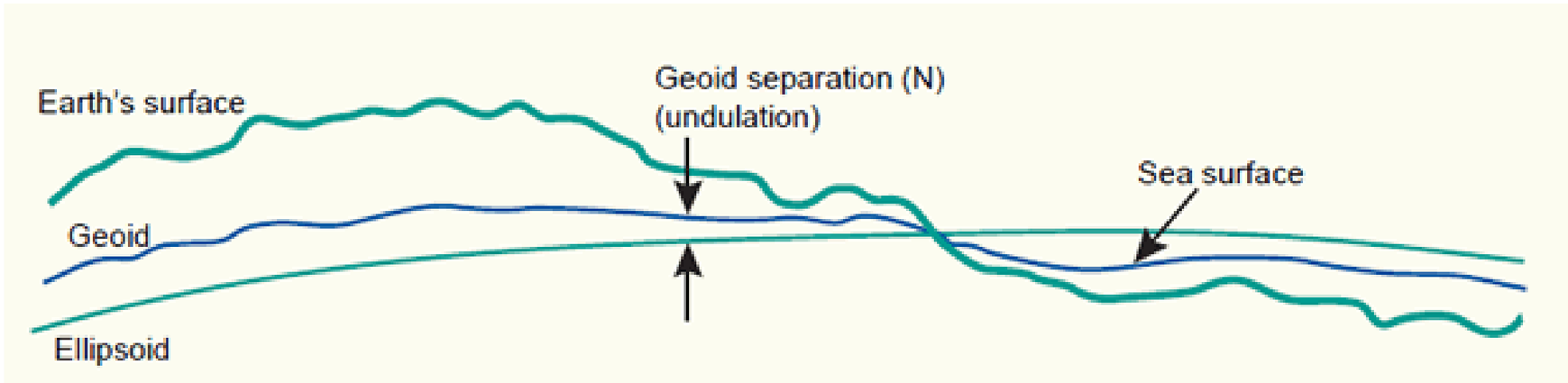
- Instrument for measurements of vertical deflection - difference between direction of the plumb line (the normal to the geoid) and the vertical direction on the ellipsoid (the normal to the ellipsoid).





- Vertical deflection represents inclination of geoid surface to reference ellipsoid surface.

- Amplitude of vertical deflection is typically about 10 arcseconds, can reach arcminute in mountain regions.



Two main reference surfaces are used to approximate the shape of the Earth: geoid and ellipsoid.

Digital Zenith Camera

Portable astrometric instrument for vertical deflection measurements - between gravity field direction and normal to reference ellipsoid

Data can be used for:

- Local quasi-geoid precision improvement;
- Earth crust movement monitoring;
- Local geological structure qualities determination.

Vertical deflection measurement accuracy ~0.1 arcsecond.

Tripod with detachable rotating part:

astrometric quality coma free 8-inch catadioptric telescope;

two-axis electronic HRTM tiltmeter (resolution ~0.02 arc milliseconds);

GNSS receiver (plane coordinate accuracy <0.6m with SBAS);

CCD matrix 8.3 MPx,

linear actuators with resolution of <0.01 µm;

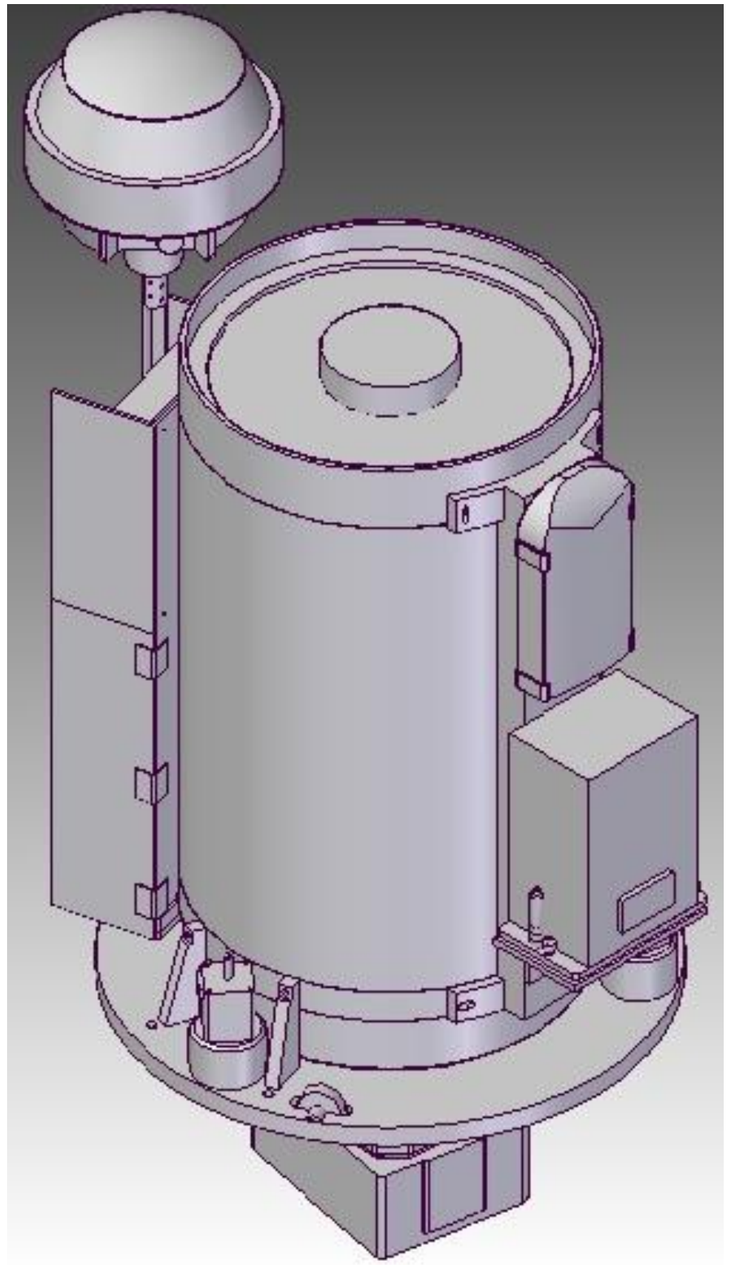
on-board computer MinnowBoard;

WLAN for communication with remote laptop;

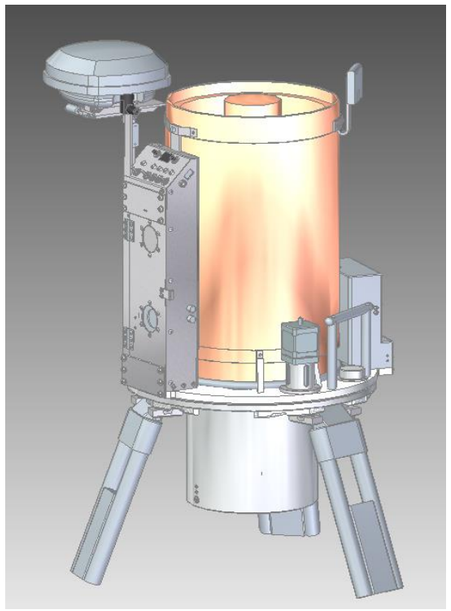
Accurate levelling, setting of azimuth and prescribed schedule of observations are done automatically.

Our design of instrument takes into account:

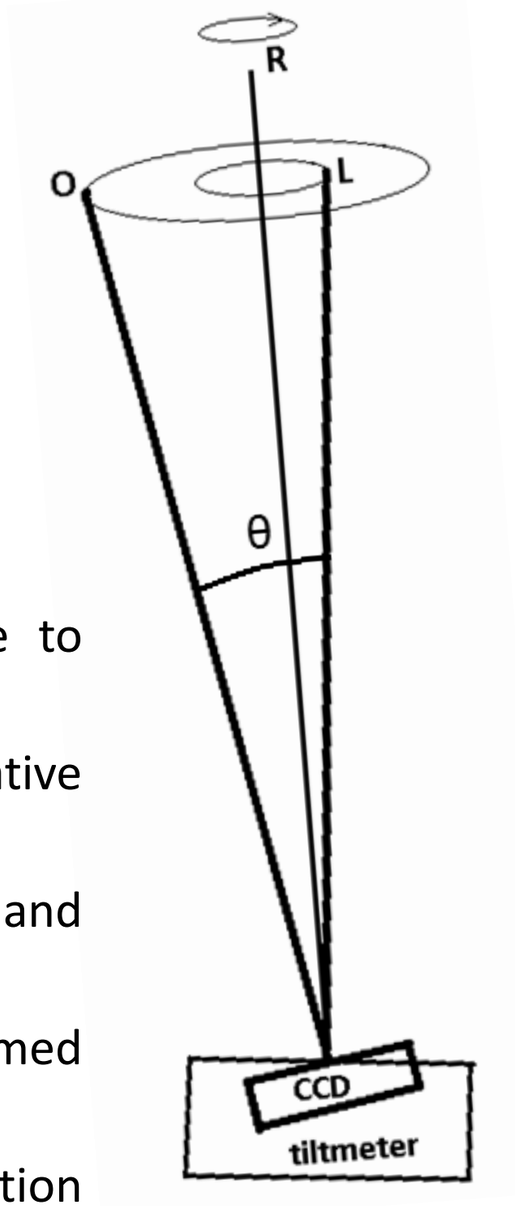
- remote control of all basic operations is necessary to avoid vibrations, convection, mechanical influence of cabling;
- leveling in all measurement positions is necessary to minimize effects of tiltmeter scale uncertainty, axes misalignment;
- tiltmeter position adjustment mechanism allows simple and independent adjustment related to main axis for both measurement planes;
- rotation mechanism supports any rotation angle.



Measurement method



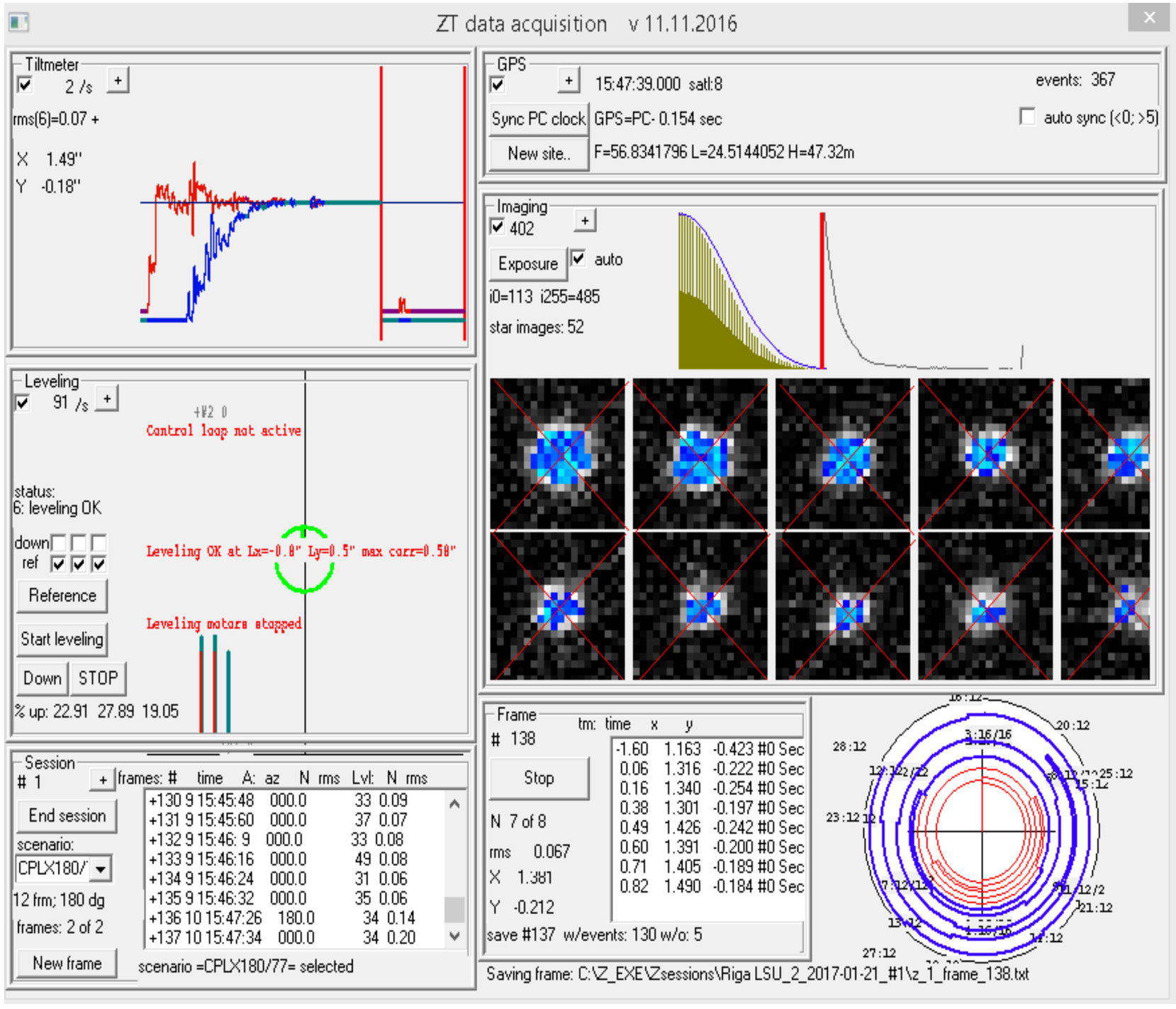
- Instrument consists of vertically oriented telescope, equipped with sensitive tiltmeter; assembly can be rotated around vertical axis.
- GNSS provides geocentric coordinates (15-20 cm) of instrument site in precise (10 mks) UTC time so that direction of reference ellipsoid's normal in astrometric coordinate system can be calculated.



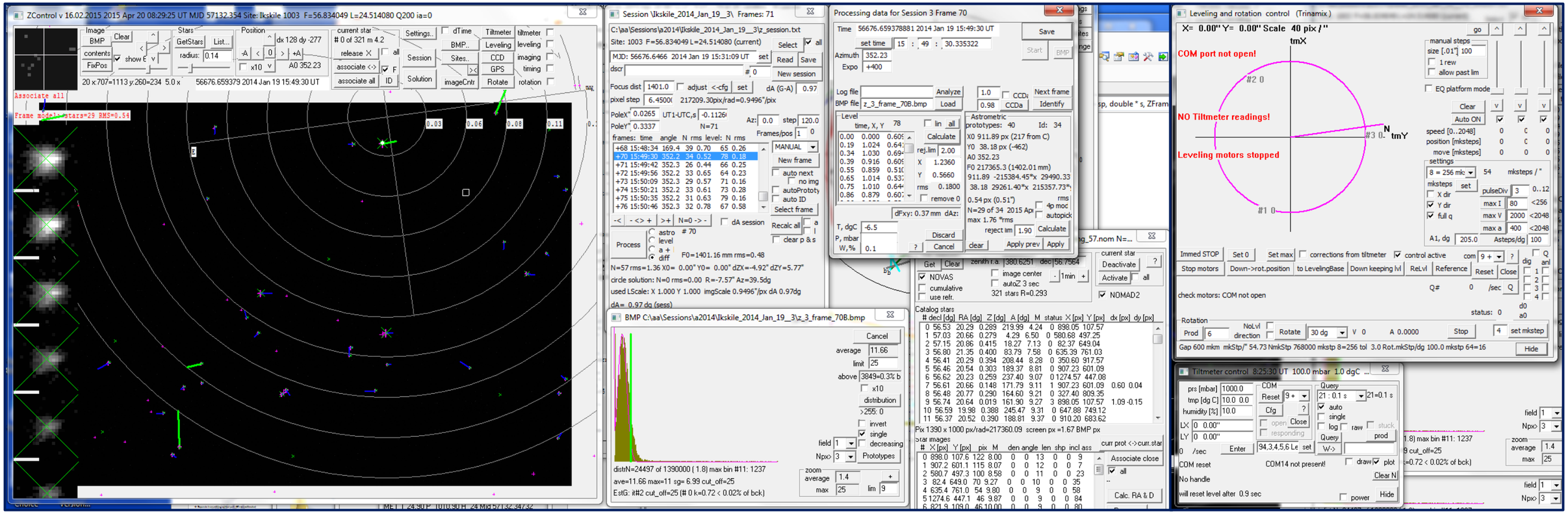
- Reference star observations provide position of instrument main axis relative to reference ellipsoid's normal.
- Tiltmeter readings provide inclination corrections for the instrument main axis relative to plumb line.
- Difference of these positions would make vertical deflection, if all alignments and tiltmeter zero-points would be accurate.
- In reality, a number of measurements in different rotation positions must be performed to exclude alignment and zero-point errors.
- Directions of plumb line (L) and ellipsoid's normal (O) describe conuses around rotation axis (R) in rotating coordinate system of instrument main axis; their difference also is a conus, width and phase of it gives vertical deflection value.

Measurement Control

- All observation functionality within single interface window,
- Automatic mode supported,
- Measurement sequence specified in scenario script,
- 16 bit image intensity preserved,
- Support of uneven background intensity distributon analysis, improving twilight performance,
- GPS coordinates recorded for each session



Data processing Software

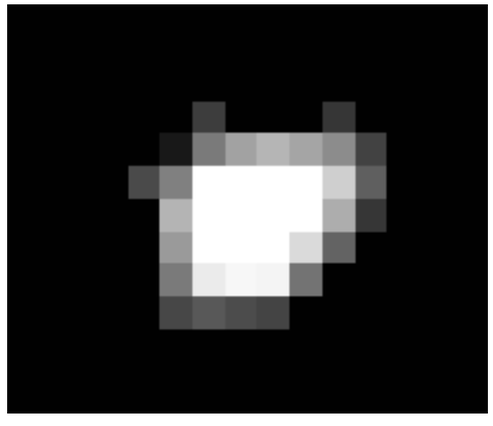


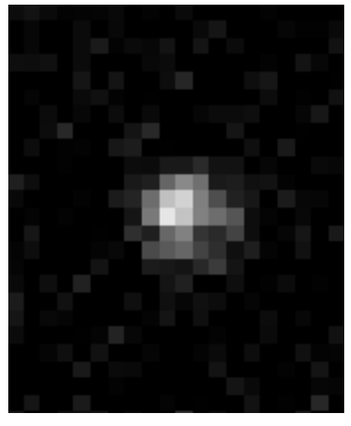
- C++ program, executing in Windows 8 environment.
- A subset of NOMAD (Naval Observatory Merged Astrometric Dataset) star catalog is used.
- NOVAS (Naval Observatory Vector Astrometry Software) package used for astrometric apparent places calculation.
- Automatic mode option is implemented for both measurements and data processing.
- Automatic reference star identification.
- In case of high vibrations data collecting is automatically interrupted.

Star images

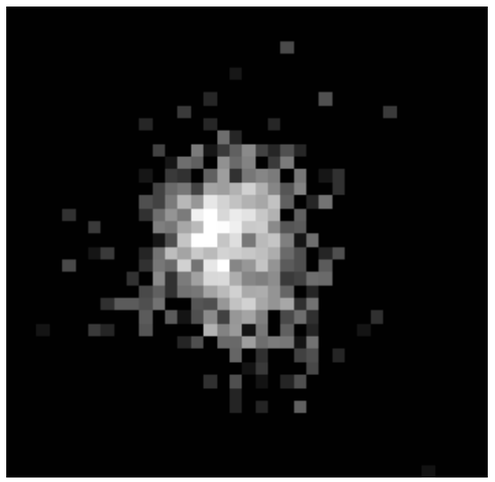
➢Aim: to obtain symmetrical image of good quality

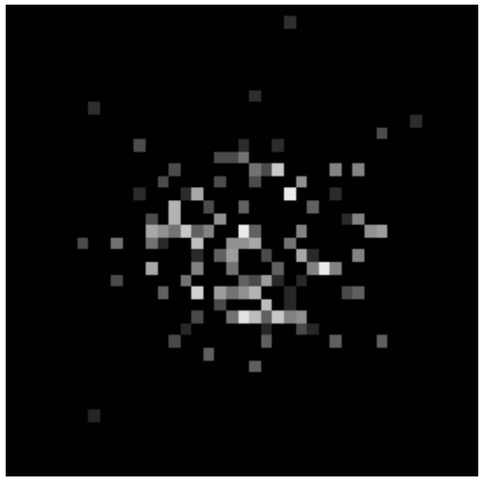
Good conditions



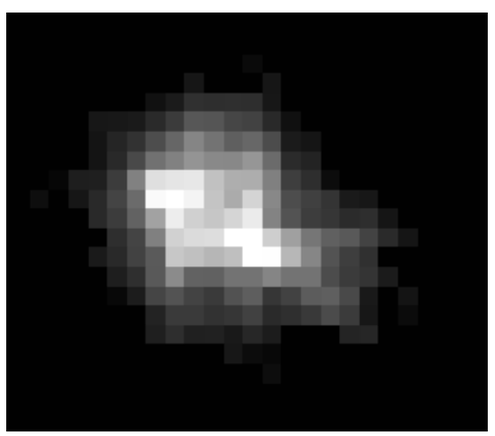


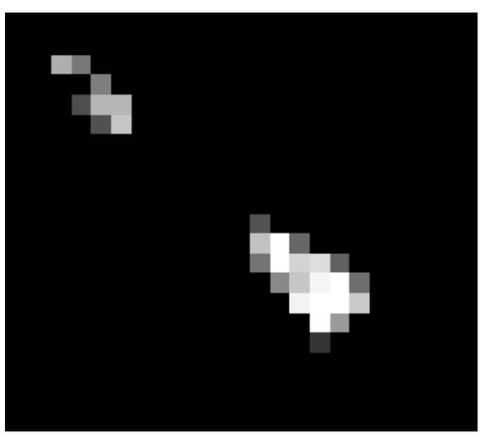
Convection



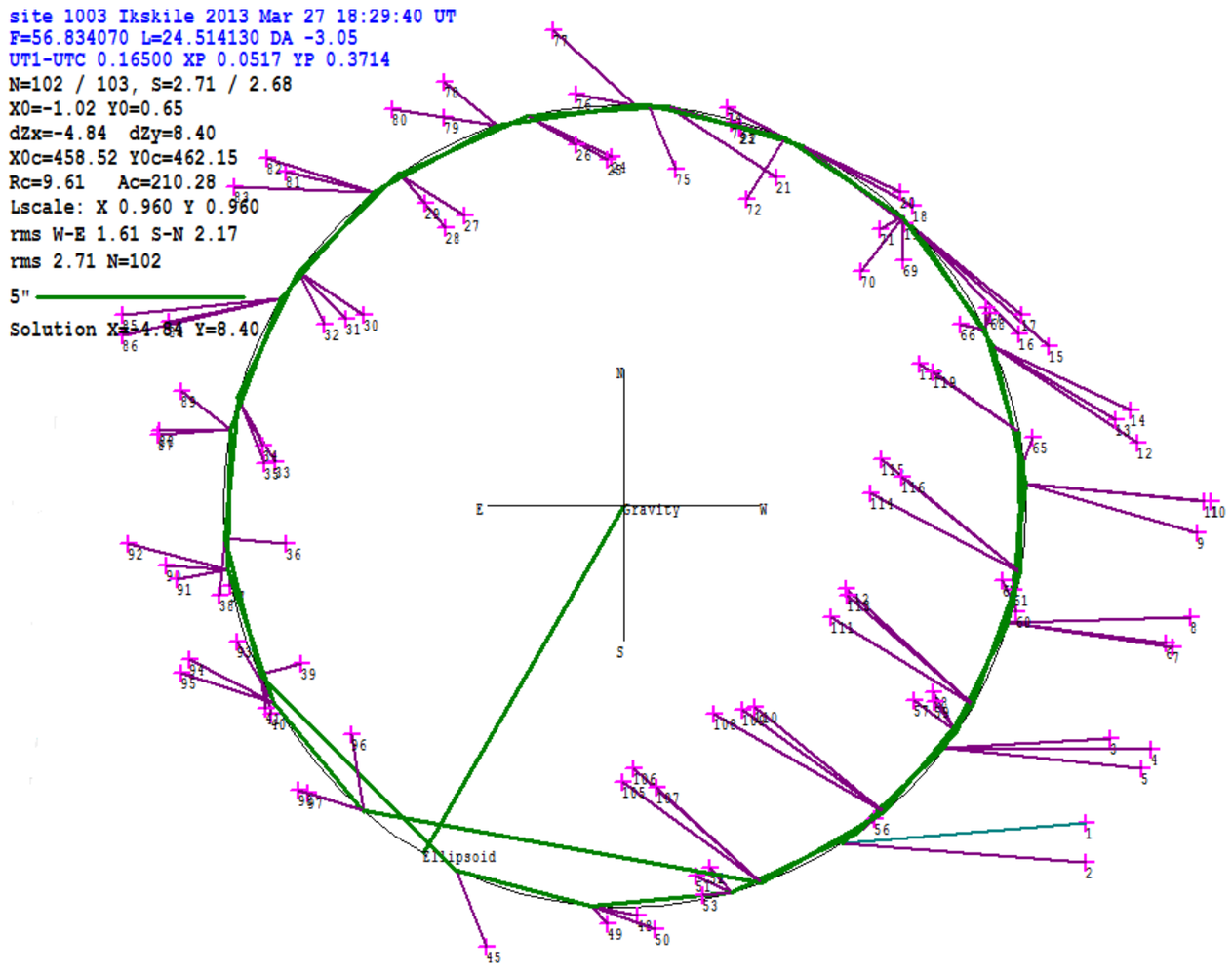


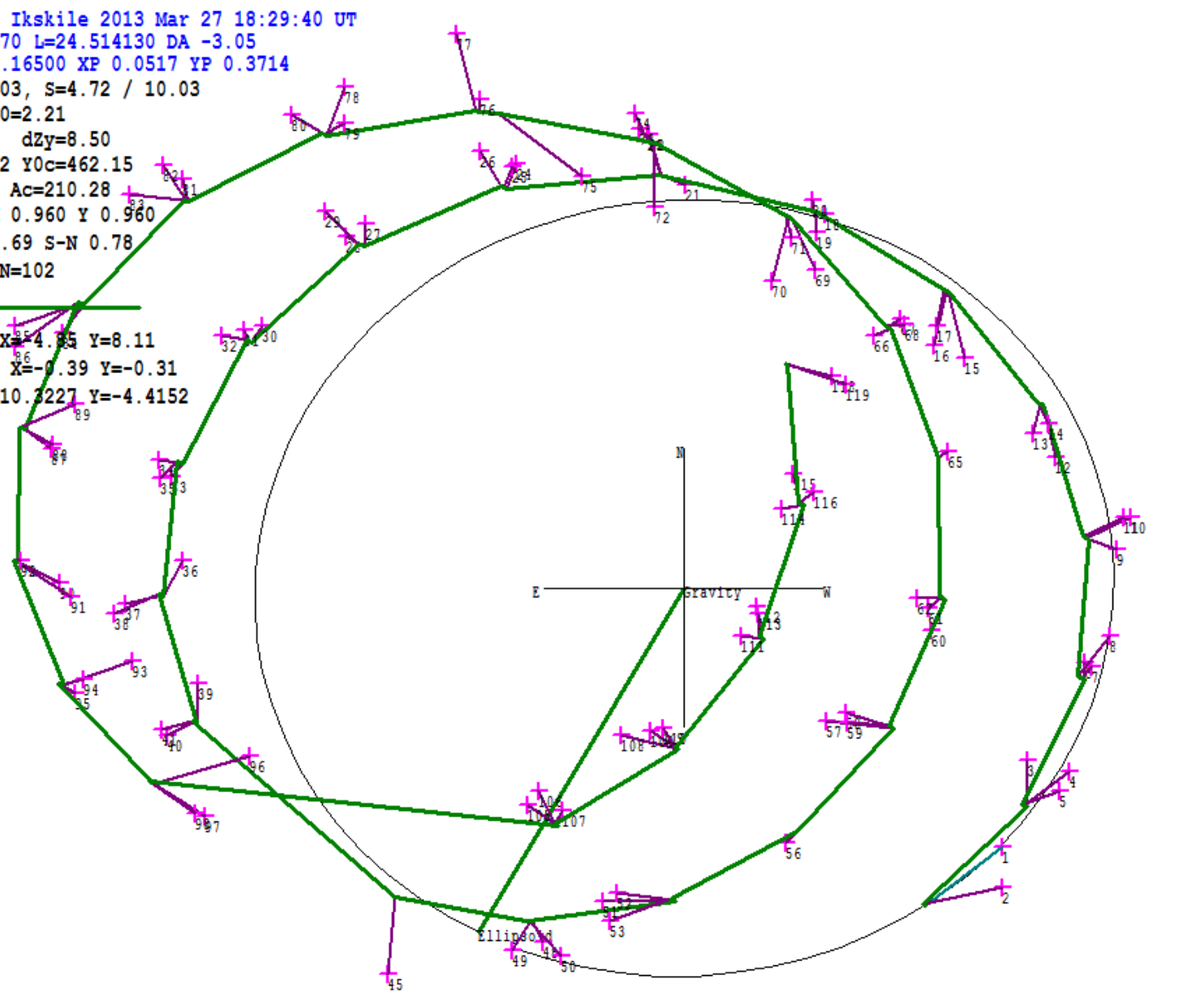
Vibrations





The impact of linear drift of position (~10”/h)





- In ideal conditions measurements should make **circle with radius of vertical deflection value.**
- In reality, thermal deformations change tiltmeter axis direction relative to optical system, resulting in spiralling trajectory.
- If dependence of deformations on time is close to linear, evaluation of simple compensating drift model is possible.

Difference between directions to reference ellipsoid normal and plumb line in rotating imager coordinate system, where drift of relative component orientation has been almost linear during 40 minutes.

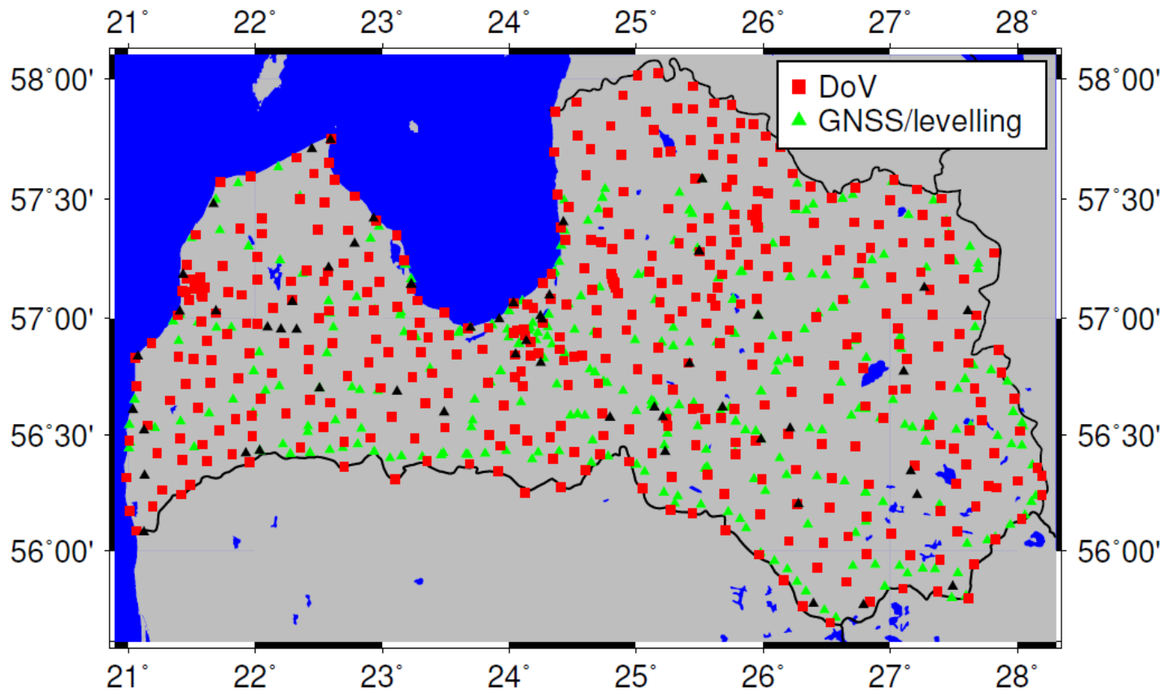
DZC-2019 (improvements)

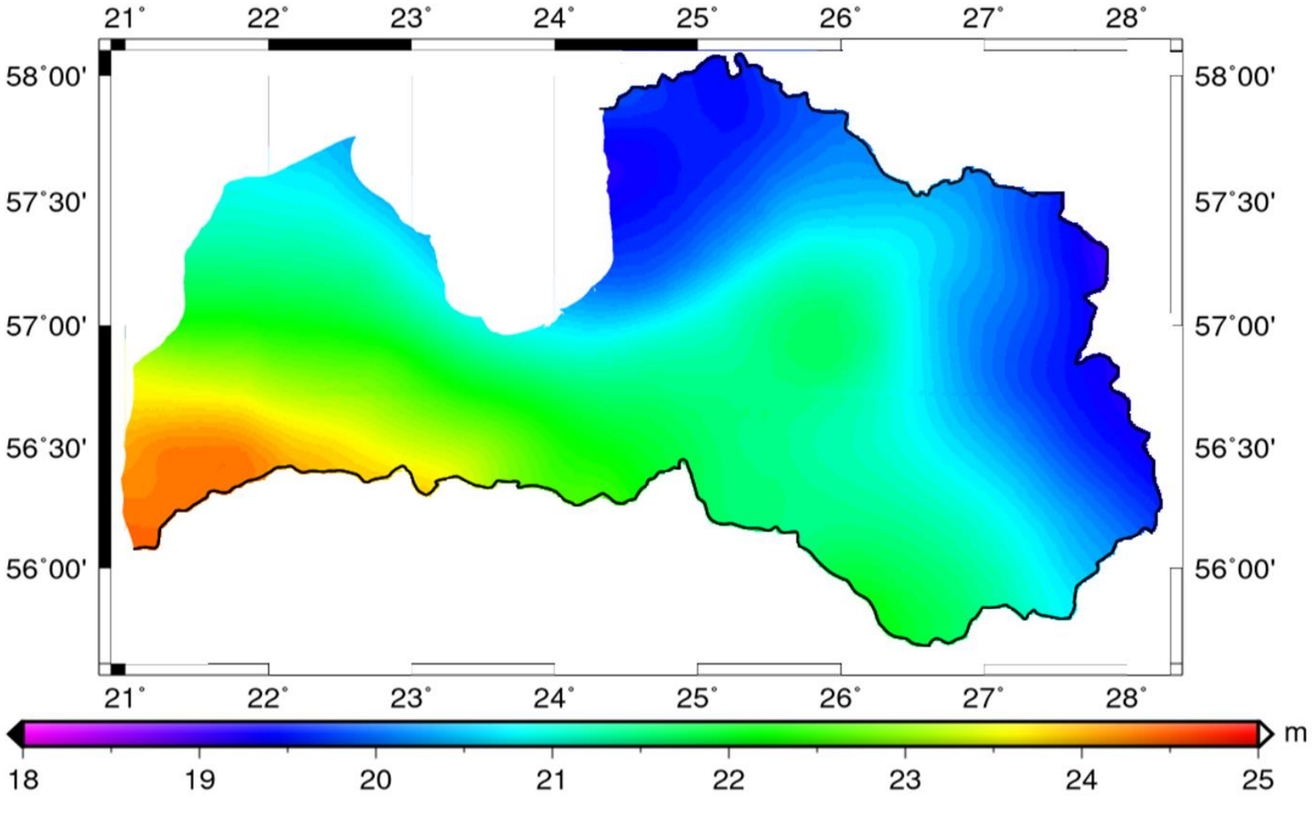
- Elaboration of measurement methodology,
- Measurement control software corrections and complements,
- Data processing improvements and automation,
- Transition to GAIA data release 2 star catalog,
- Revision of mechanical design, development of a new model,
- Currently 4 cameras are manufactured
- Commercial agreement with Louisiana State University

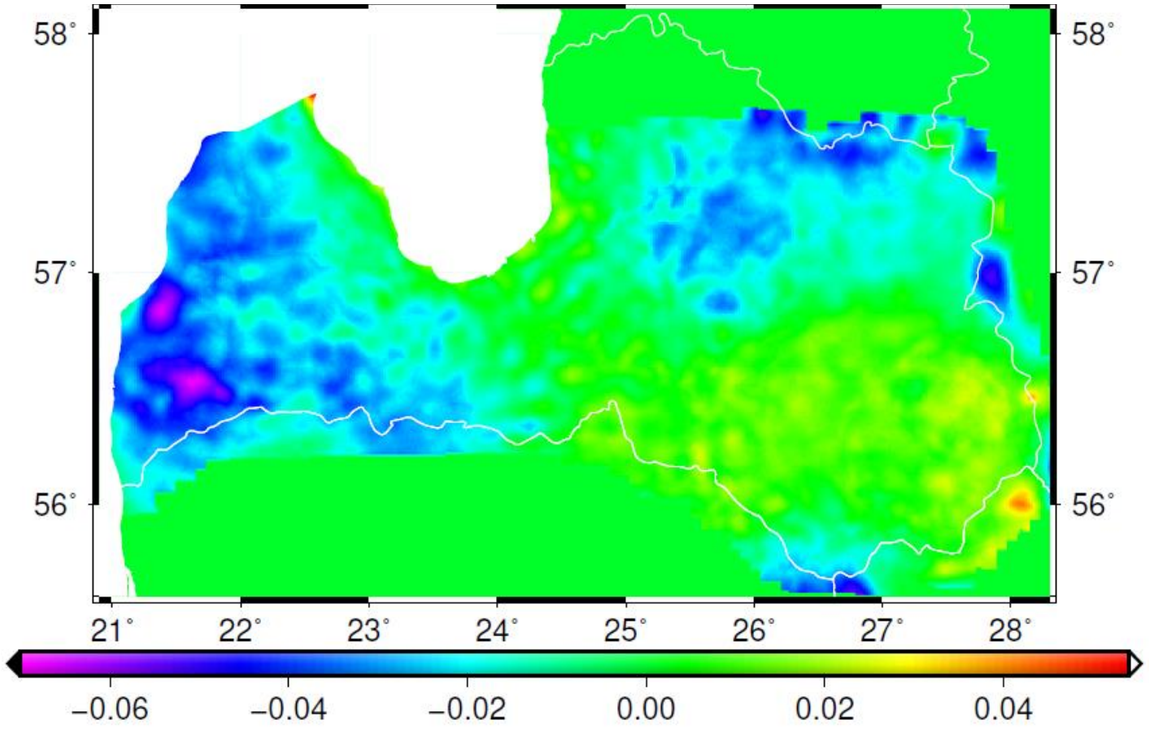
High precision quasi-geoid model for the territory of Latvia

UNIVERSITY OF LATVIA
ANNO 1919

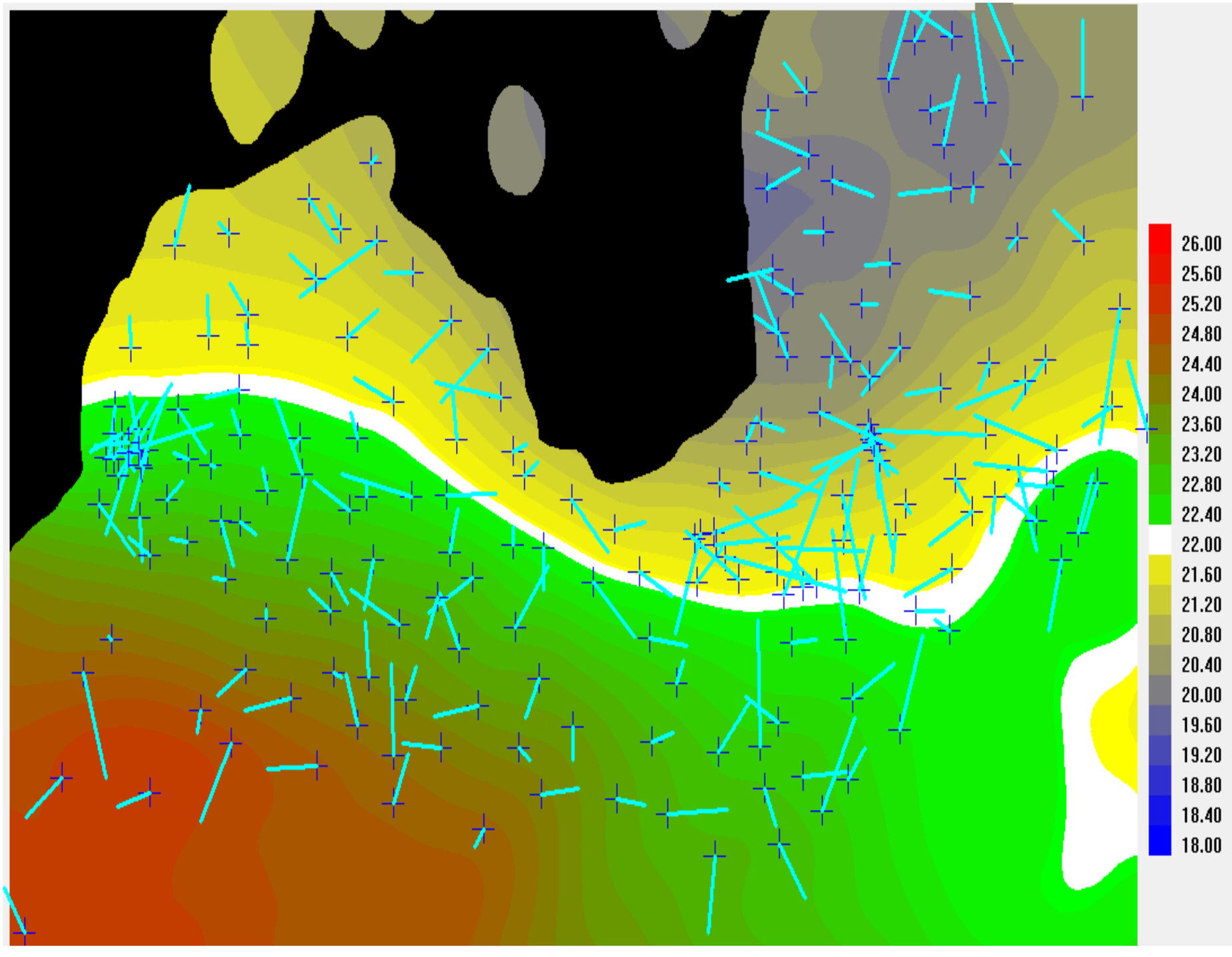
- 414 points (2017-2020)
- 1 – 1.5 hours one session
- max 6 points per night
- accuracy ~ 0.1″







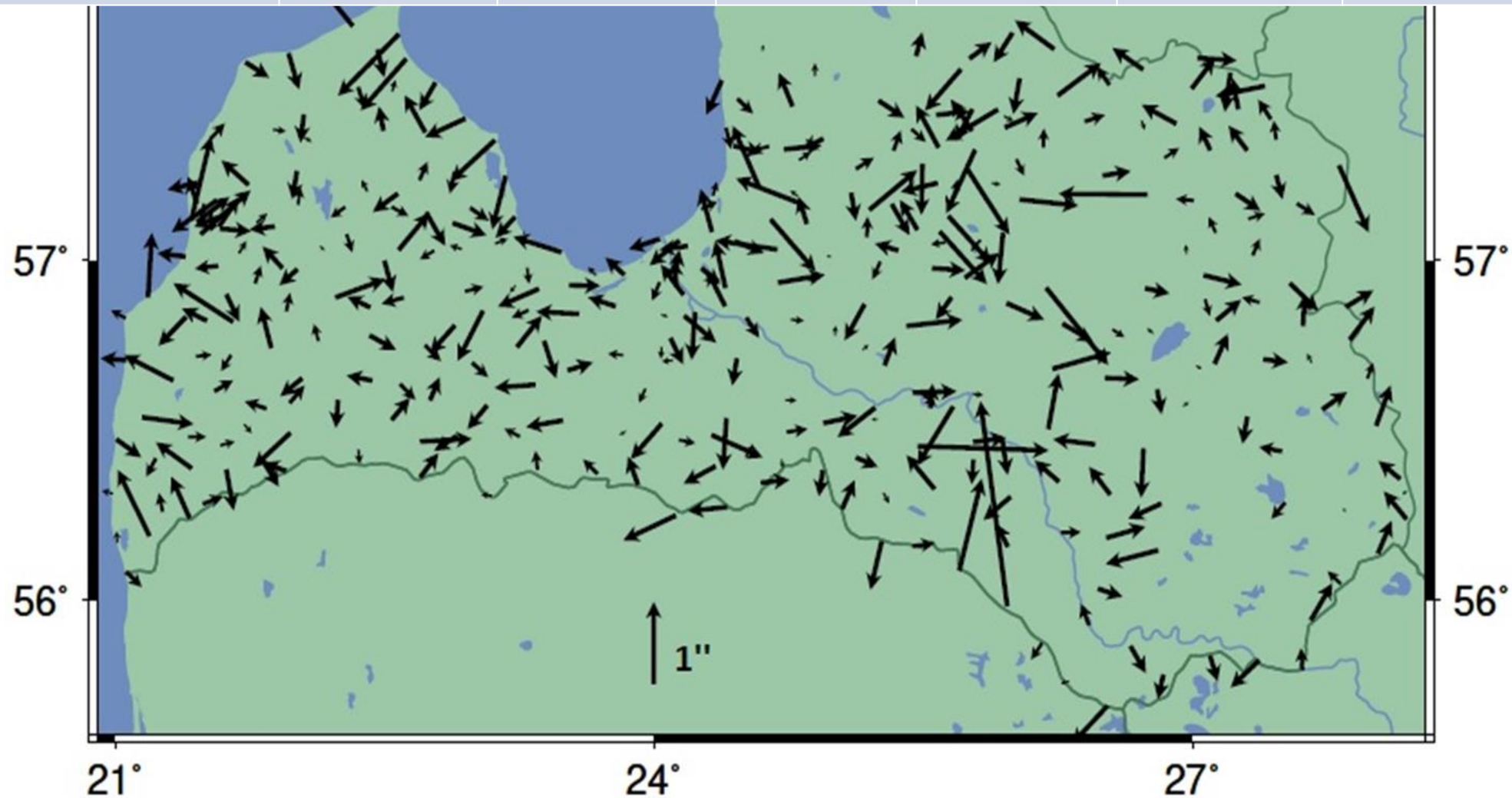
Comparison of terrestrial VD and global GGM+ model



- Comparison with GGM+:
  - average 0.02"
  - rms 0.4"
  - Amplitude up to ~1"
- Can be used for:
  - Local geoid models,

- Geological structure qualities,
  - Alternative to levelling.

	Min		Max		Avg	
	Xi	Eta	Xi	Eta	Xi	Eta
DFHRS	-0.190	-0.348	0.162	0.216	0.033	0.041
EGM2008	-1.128	-0.939	1.669	2.491	0.256	0.252



Thank you!

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