LECHNER TUDÁSKÖZPONT

INTEGRATED GALILEO REFERENCE NETWORK FOR POSITIONING AND ENVIRONMENT MONITORING

ESA CONTRACT NO. 4000138838/22/NL/RR

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FINAL PRESENTATION

ONLINE, 11 JUNE 2024

INGRIM IS ABOUT TO

(1) REALIZE A COMPLETELY NEW HEIGHT REFERENCE INFRASTRUCTURE

- Traditional leveling benchmarks → MULTI-TECHNIQUE stations with MULTIPLIED application opportunities;
- exploiting **multi-GNSS** and InSAR (Galileo & Earth observation)

(2) DEFINE AND REALIZE THE SEMI-KINEMATIC HEIGHT REFERENCE

- == vitrual height reference surface for converting spatial coordinates into the local frames
- static world → (semi)-kinematic HEIGHT REFERENCE, modeling the ground motion from a given reference epoch

(3) PROPOSE RECOMMENDATIONS FOR MULTI-GNSS HEIGHTING

- Traditional leveling → GNSS heighting (on medium term);

GANTT-DIAGRAM

August 2022

February 2024

+3 months

WP	Activity	Duration (month)																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
WP1	Management and Outreach	KO			PM 1			PM 2			MR					AW		UM	FR
WP2	Site selection, preparation																		
WP3	GNSS procurement																		
WP4	InSAR analysis																		
WP5	GNSS analysis																		
WP6	Geoid computation																		
WP7	Database and technology																		
WP8	Field test and validation																		
	Milestones										MS 1					MS 2			MS 3

Legend: Critical Path (CP) ——→

Parallel actions ·····→

KO: Kick Off meeting; MR: Mid-term report; AW: Assessment Workshop;
UM: User Group Meeting; FR: Final report; PM1-2: Progress meetings
MS 1-3: Milestones

WORKPACKAGES

WP1 - PROJECT MANAGEMENT AND REPORTING

WP2 - SITE SELECTION AND PREPARATION

WP3 - STATION INSTALLATION & GNSS PROCUREMENT

WP4 - InSAR ANALYSIS

WP5 - GNSS ANALYSIS

WP6 - GEOID DETERMINATION

WP7 - TECHNOLOGY AND RECOMMENDATIONS

WP8 - FIELD TESTS AND VALIDATION

THE WORK IN ALL WPs HAD BEEN SUCCESSFULLY COMPLETED!

WP2 - STATION BUILD PROCESS

MBAJ

MPAK

MSEN

MPOG

WP2 - STATION BUILT

MKEK

MKKH

MPOG

MSZE

MPAK

MBAJ

MSEN

WP3 - station procurement
7 monuments and 5 multi-GNSS equipment

- The call for tender was published on 11 November 2022
- Deadline for submission: 25 November 2022
- Contract signature 19 January 2023
- **Contract winner: Leica Geosystems Hungary**
- **Contracted price: 77 470 000 HUF**

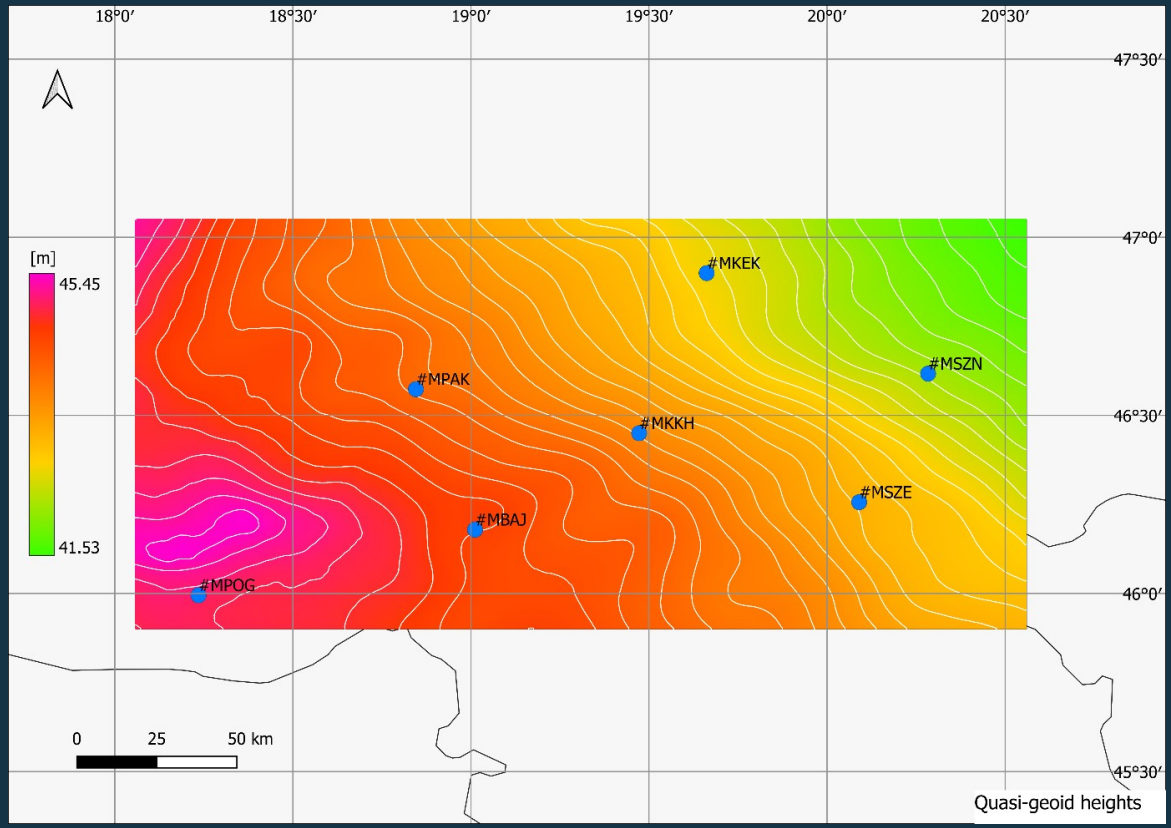
  According to the actual EUR / HUF exchange rate it was 12 kEUR over the planned budget, therefore it had to be covered by LTK
- **Contracted equipment: LEICA GR50 receiver and LEICA AR20 antenna**

INGRIM STATIONS IN GNSSnet.hu

WP6 -Geoid computation

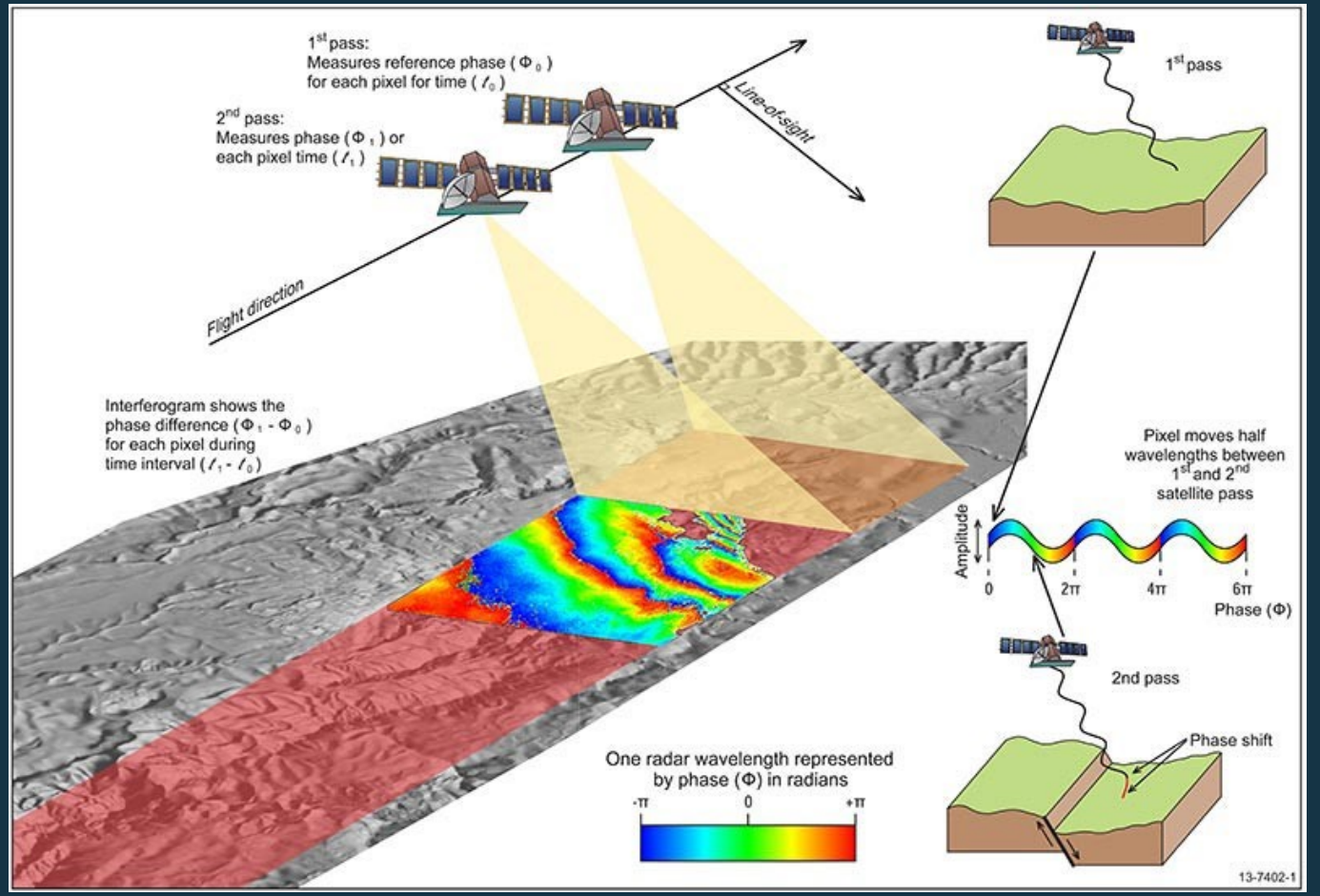
- Dedicated new gravimetric geoid based on Radial Basis Function approach
- Integration with existing GPS/leveling data measured in **2014** to remove reference frame biases.
  This date defines the epoch!
- Represents the static part of the height reference

  H(lev)=h(ell)-N(hr)

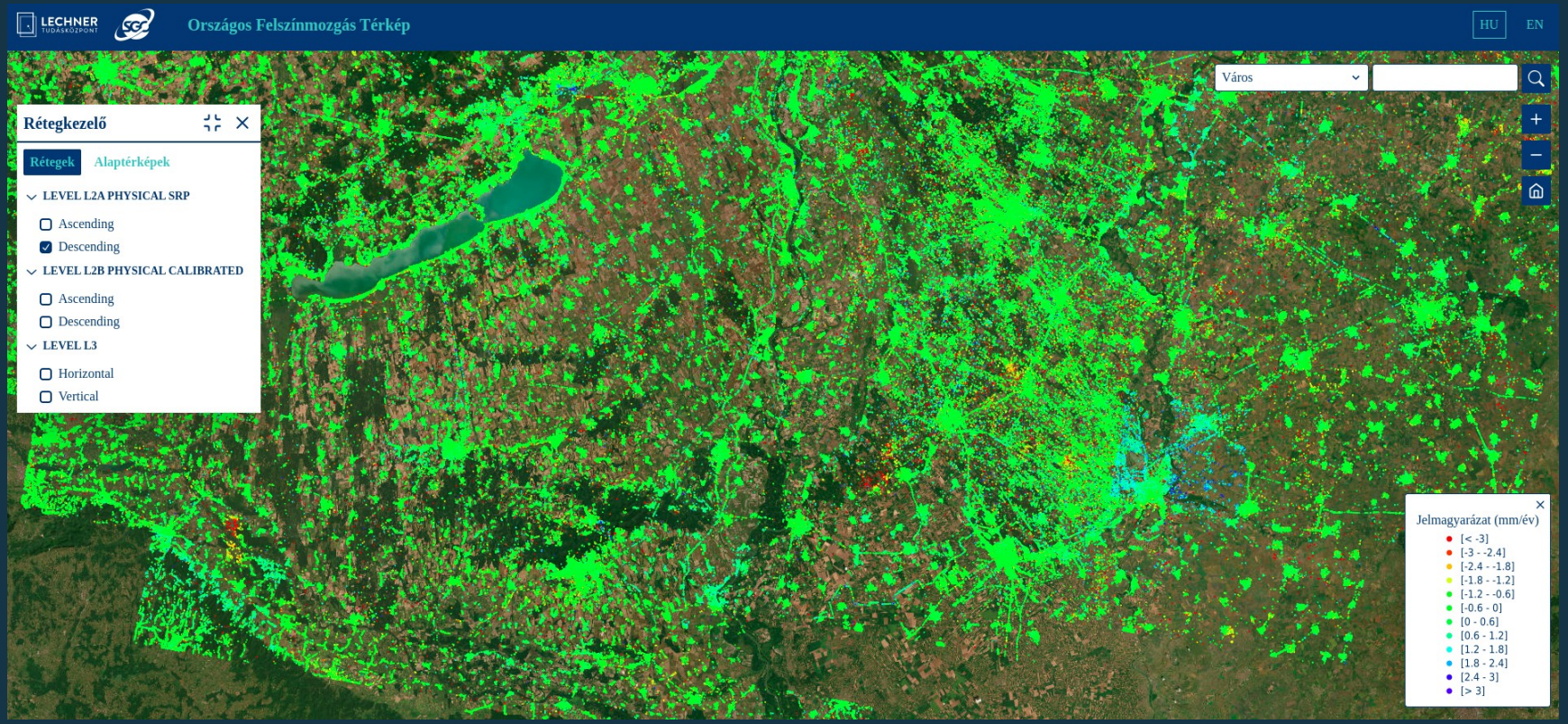


WP4 - InSAR ANALYSIS

- **data:** satellite emits and observe reflected radar signal from Earth surface;
- Interferometric signal phase processing - mm precision;
- Sensing ground motion (see EGMS by EEA);
- Relative technique, needs GNSS velocities;
- Copernicus Sentinel-1a-b mission data (2015-)



WP4 - InSAR ANALYSIS



Detected “line of sight” ground motion

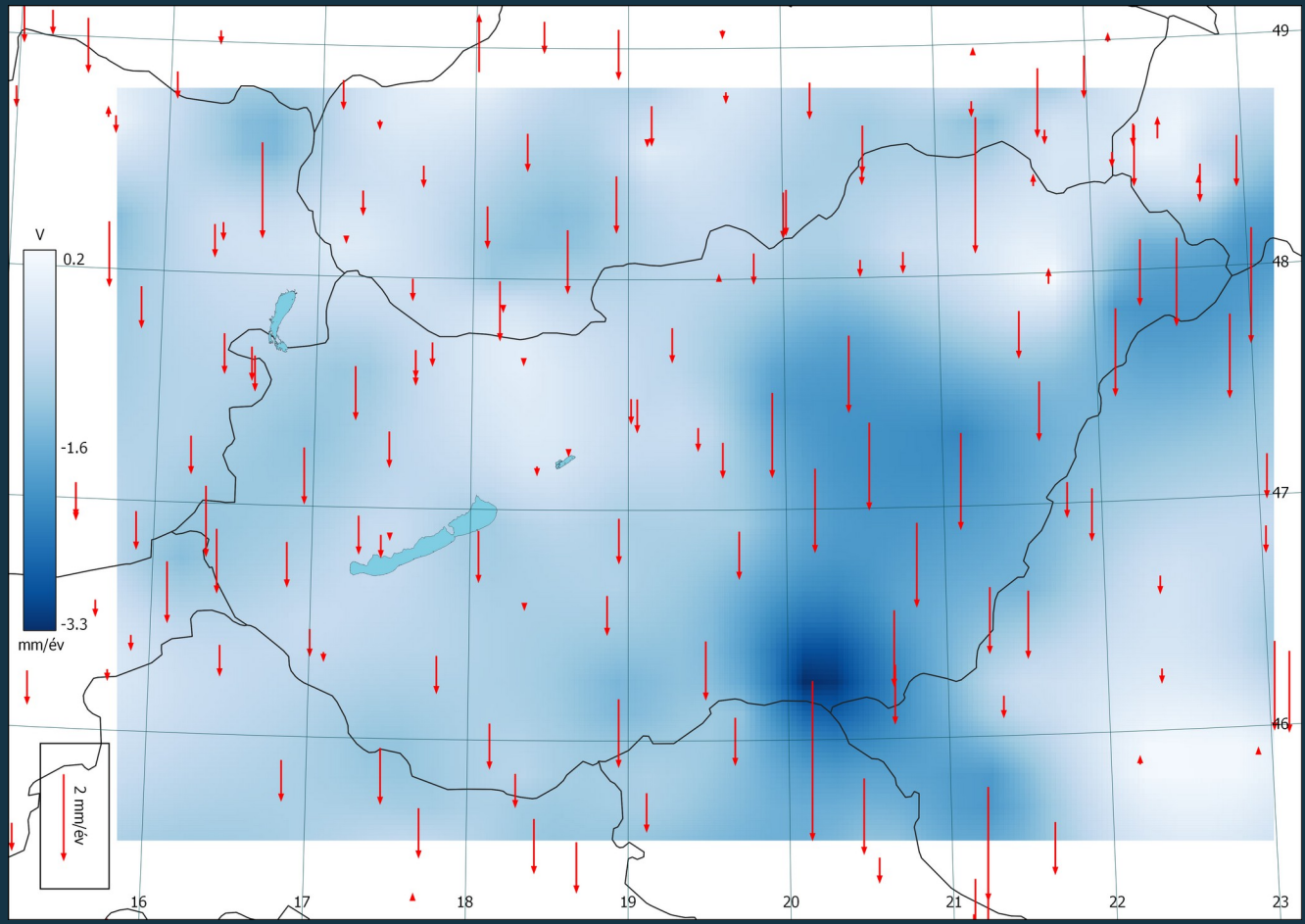
WP5 – multi-GNSS analysis

GNSS RTK service and scientific analysis

- Processing of GNSS real-time streams and RTK correction delivery
  - networked RTK: GNSMART2 - sw fully operational
  - single baseline corrections
- Post-processing of RINEX GNSS data for science
  - BERNESE 5.4 - fully operational
  - reprocessing of historic data
  - **kinematic station data for reference velocity modeling**

WP7 /1: GNSS velocity model

- Velocity grid generated from existing historic GNSS data (actual INGRIM data still cannot be used -"too young")
- Grid based on the European scale EPND solution (SGO product)
- Extended LS Collocation with smoothing
- Also serve as background model for the InSAR analysis
- Only for InSAR reference



WP7 - Database and technology

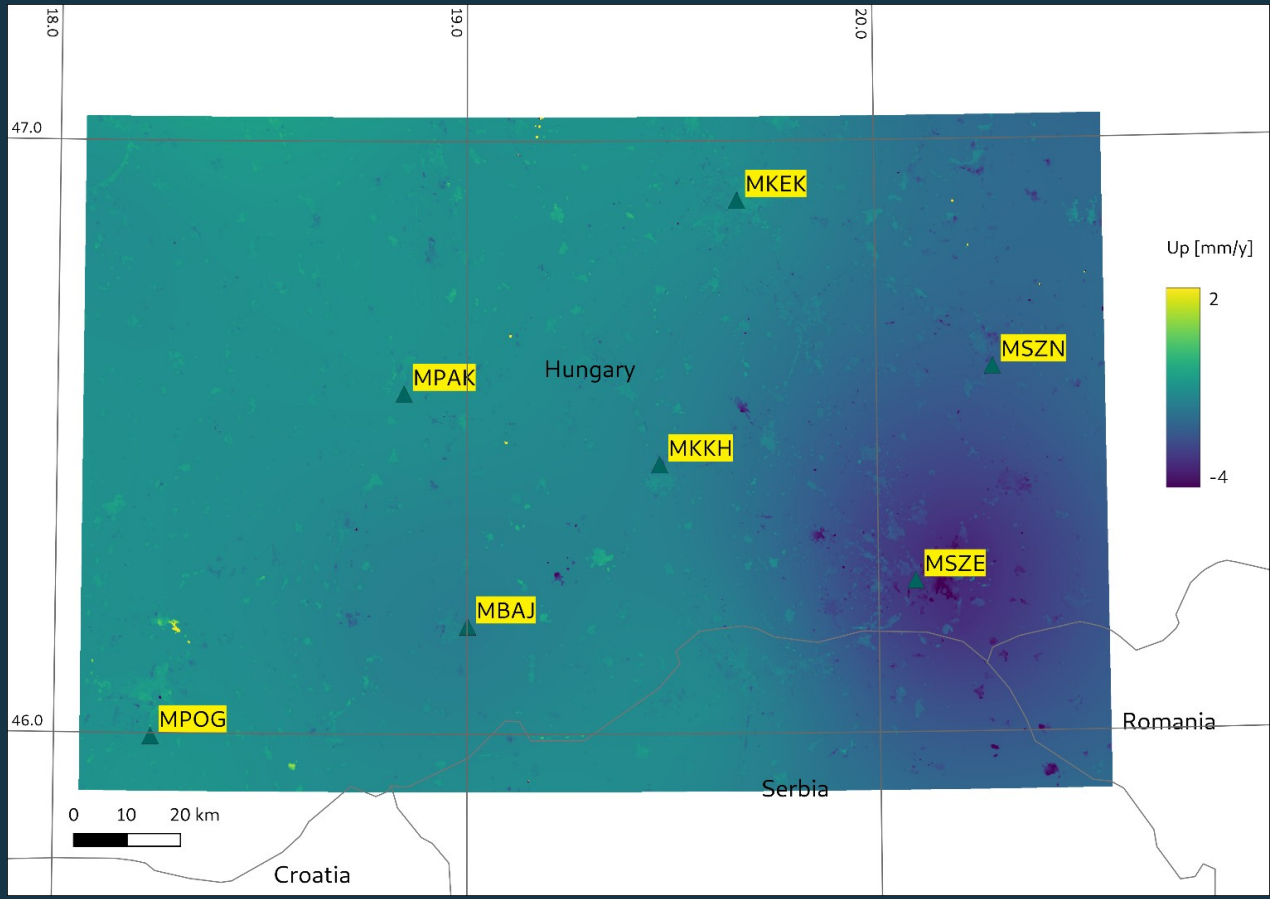
Hybrid height reference grid:

- static part from the geoid
- epoch dependent component from GNSS/InSAR velocity grid : t0 + (t-t0) x V
- t0 is 2014 from geoid GPS leveling combination

→ semi-kinematic solution: annual grid update

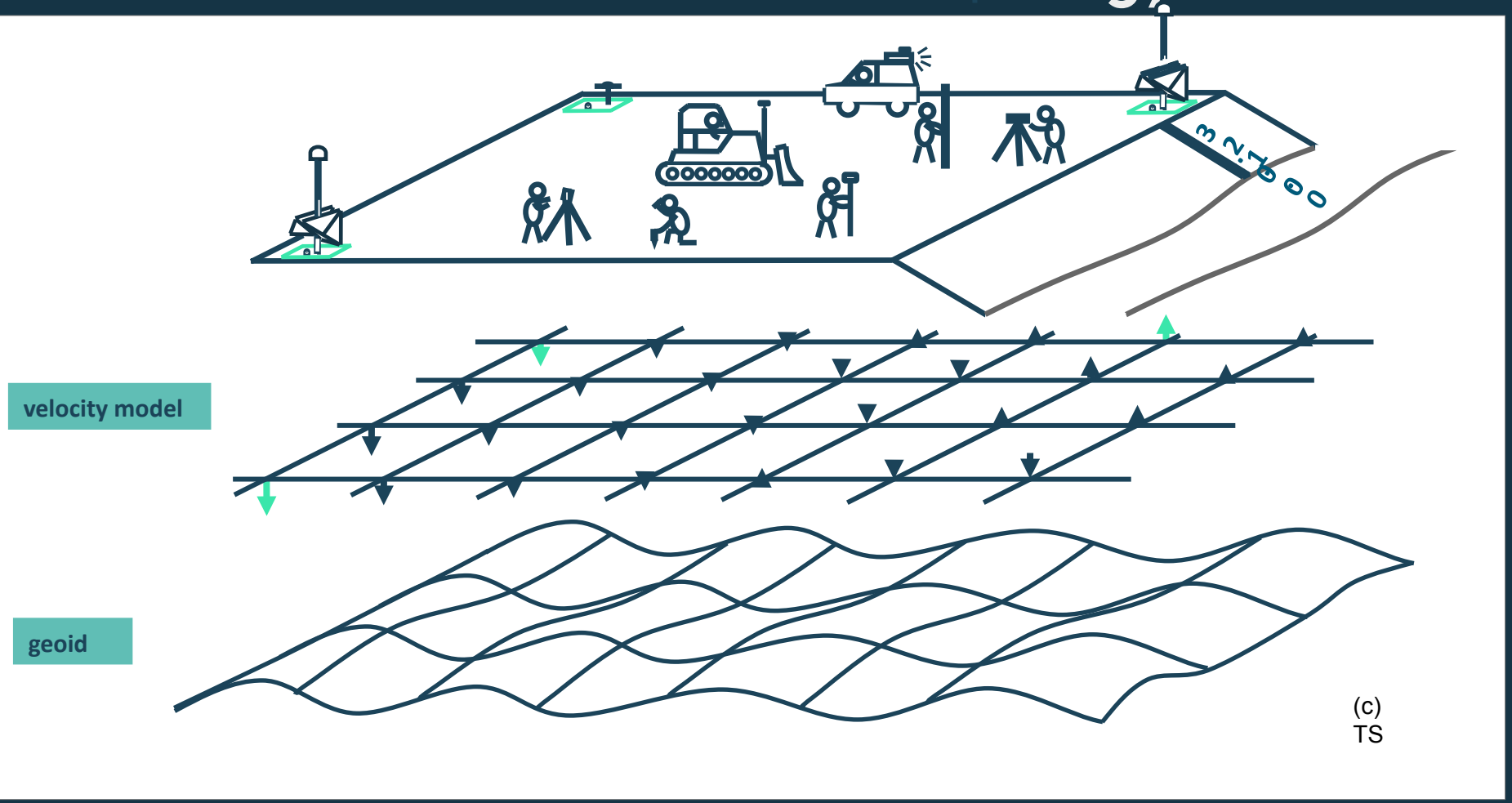
H(lev)=h(ell)-N(hybridHR)

Key: epoch harmonization



Kinematic part of the reference: GNSS velocity grid + InSAR analysis

WP7 - Database and technology



WP8 - Field tests and validation

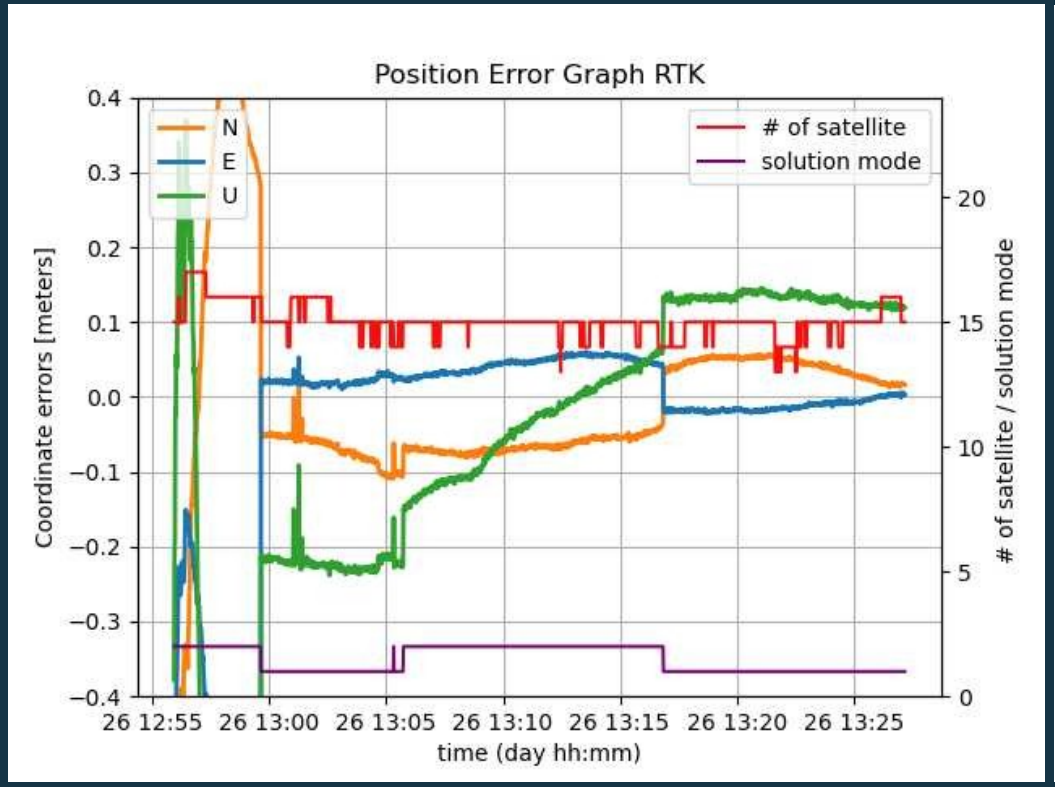
Two campaigns + in situ measurements

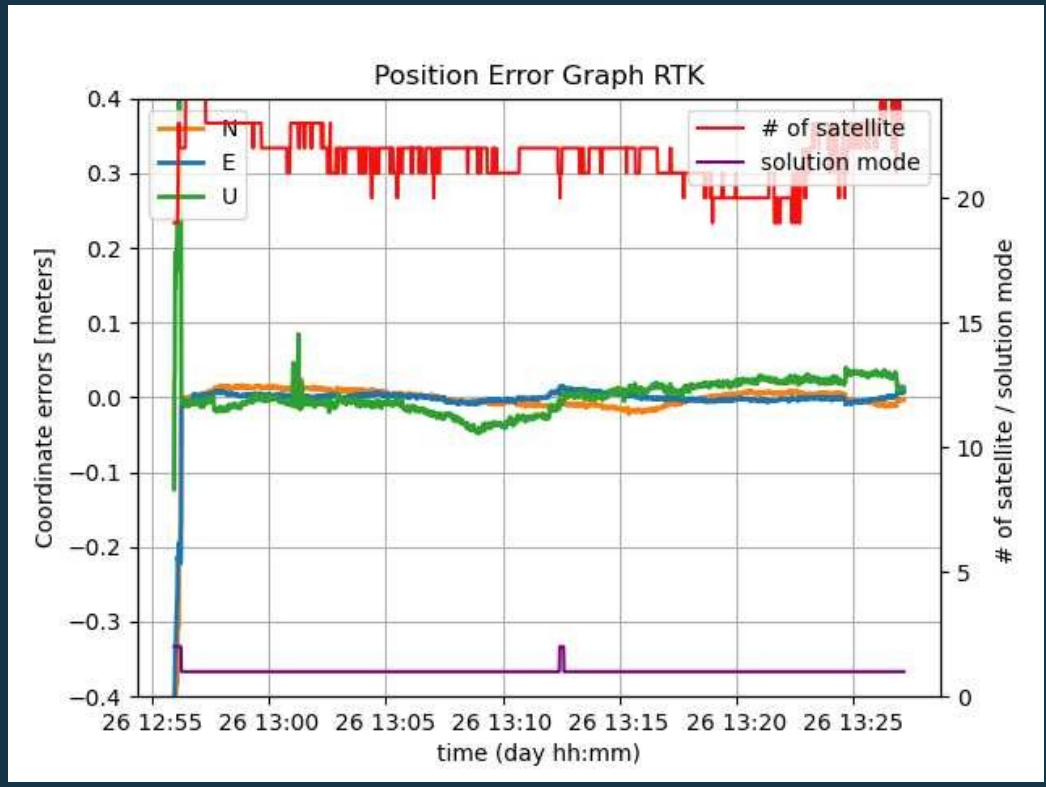
- static measurements, covered the full pilot area
  - 4 multi-GNSS equipment, 50+ benchmarks,
  - centered antenna setup, 45 min measurement periods,
  - RINEX postprocessing.
- RTK campaign
  - 18 points in Szeged city,
  - 3 minutes standard RTK sessions, repeated for checking;
  - eccentric measurements

WP8 - Field tests and validation

- prove the superiority of multi-GNSS, including Galileo;
- check environment dependency („free" horizon vs covered environment);
- compare the old database with the new INGRIM solution;
  - expected agreement was not better than +- 3 cm due to outdated reference data (levelling 4 decades ago …);
  - outliers above 6 cm were removed;
  - improved agreement and better statistics with the INGRIM model

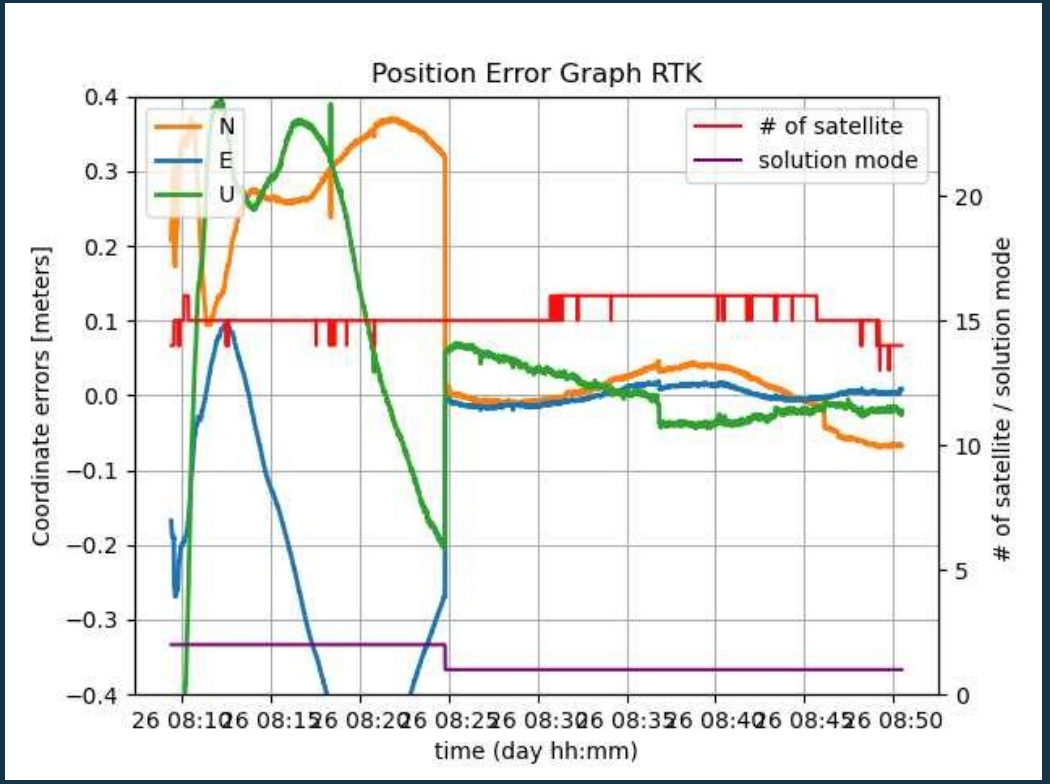
GNSS vs multi-GNSS

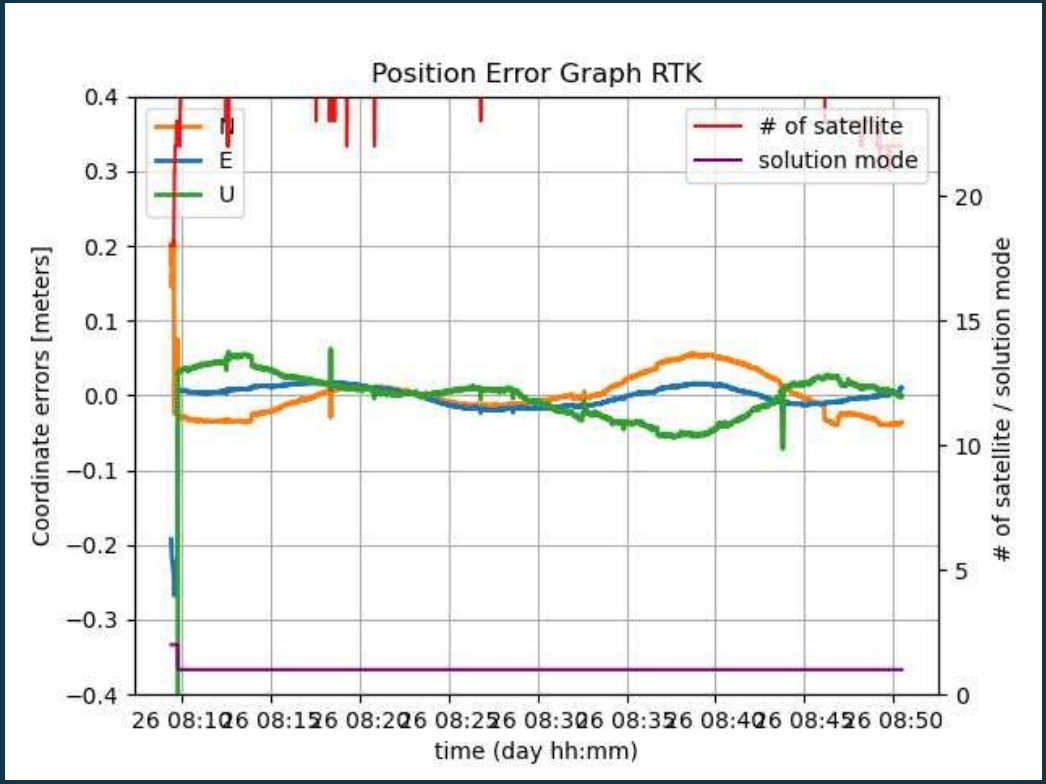




Positioning performance with RTKlib in difficult environment

GNSS vs multi-GNSS





Positioning performance with RTKlib in open environment

WP8 - Field tests and validation

- prove the superiority of multi-GNSS, including Galileo;
- check environment dependency („free" horizon vs covered environment);
- compare the old database with the new INGRIM solution;
  - expected agreement was not better than ±3 cm due to outdated reference data (levelling 4 decades ago …);
  - outliers above 6 cm were removed;
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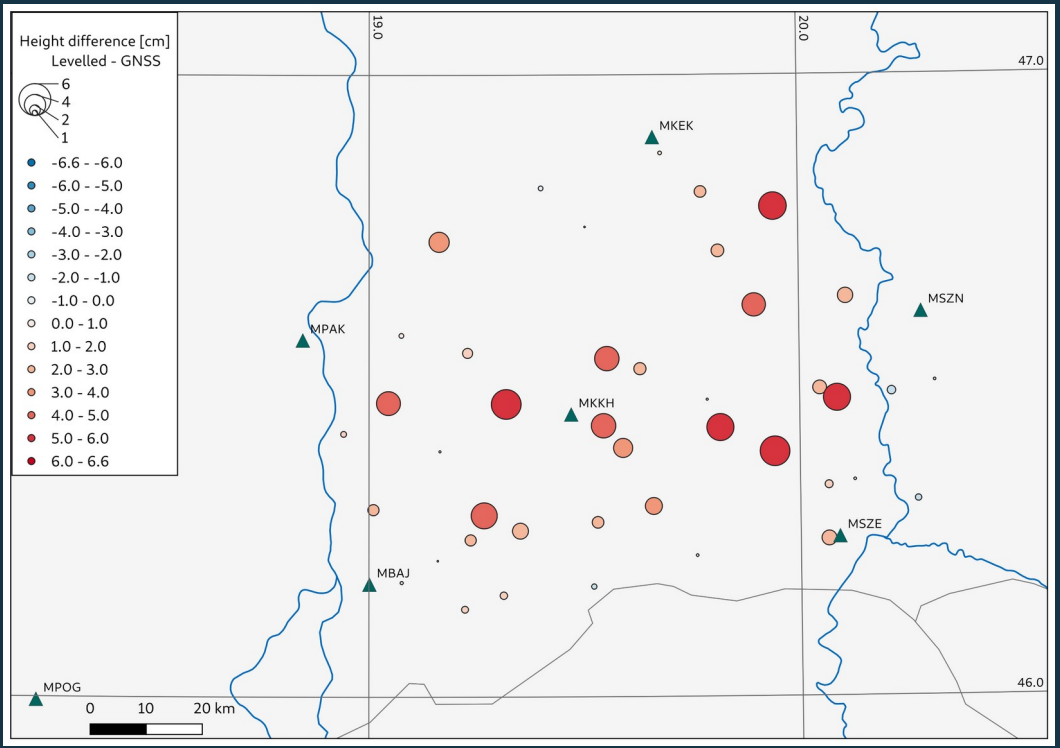
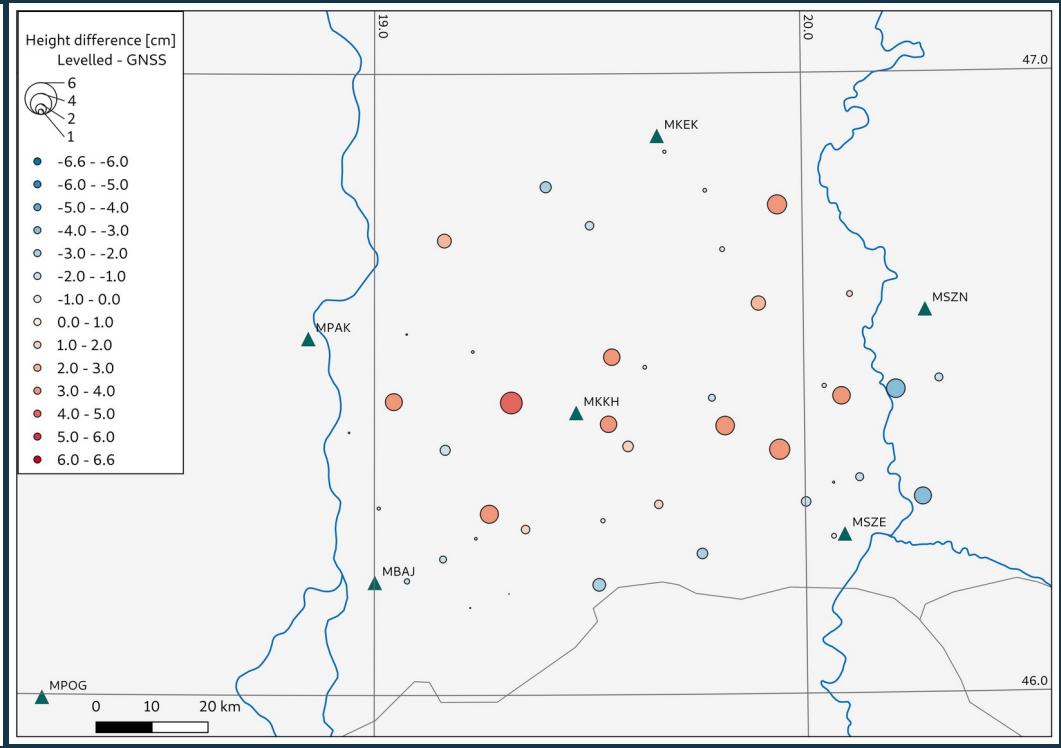
Static field campaign



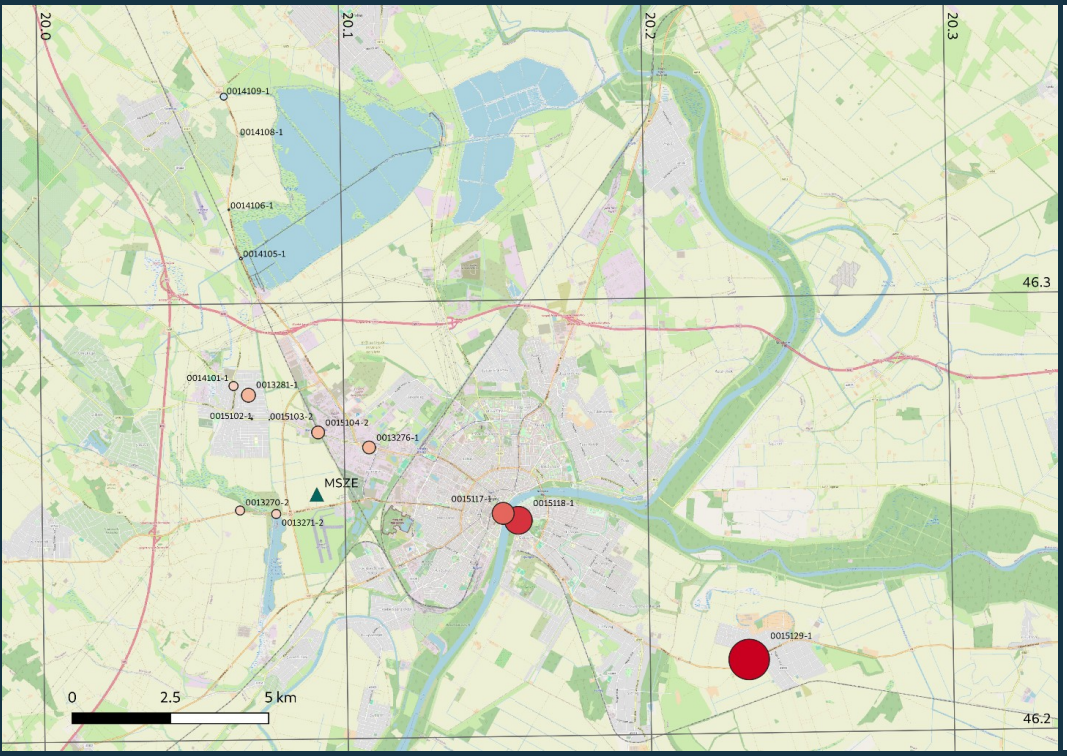


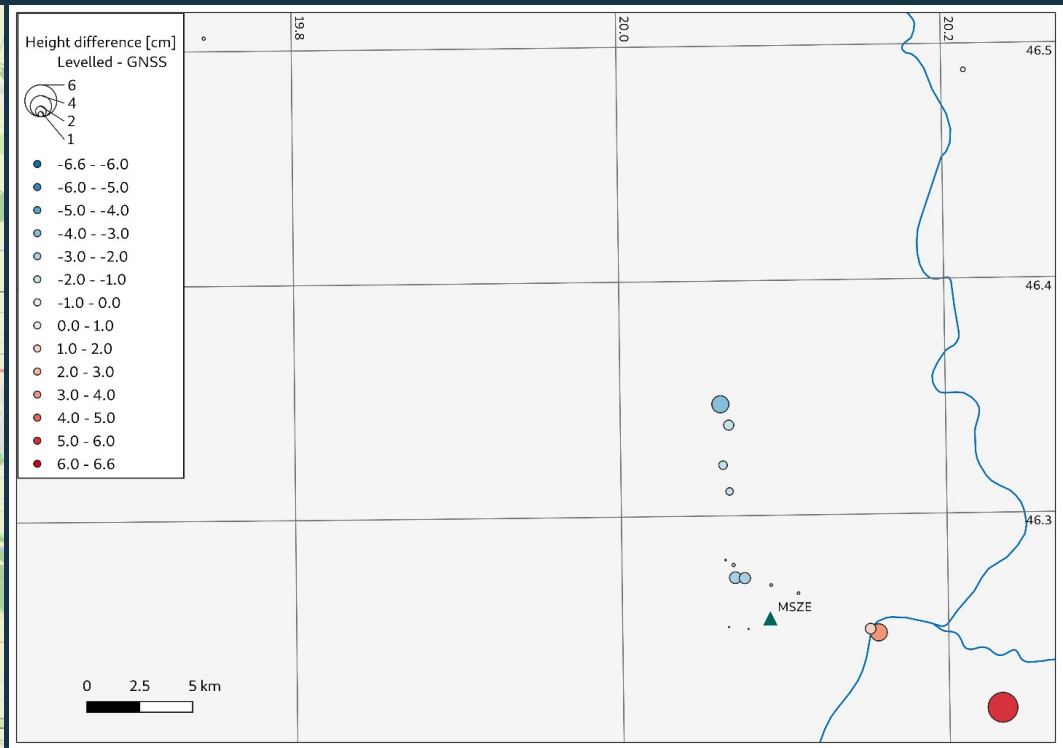
Height differences of official book-keeped values and "measured ones"

Standard transformation

INGRIM transformation

RTK campaign





Height differences of official book-keeped values and "measured ones"

Standard transformation

INGRIM transformation

SUMMARY_1

- INGRIM was a challenging, full scale project topic and task definitions, but completed successfully ;
- All hardware elements operational and serving the geodetic practice, it is a resilient background for multi-GNSS RTK positioning;
- We defined and realized a completely new, modernized, space technology-supported height reference system and its option for long term maintenance;
- The solution is highly rely on Galileo and also on Copernicus (Sentinel), flagships of ESA programs;

SUMMARY_2

- The solution had been tested and its reliability was proved;
- INGRIM was a pilot, it is partially rely on existing background information (e.g. GNSS velocity field), the new components could be used in the coming years;
- The INGRIM approach was accepted by the decision makers and its national scale extension is in progress (3 more years to go);
- The **ESA support is very much acknowledged** as it was an ESSENTIAL help to make the idea real and pushed the decisionmakers!

THANKS FOR YOUR ESSENTIAL SUPPORT!

#

LOOKING FORWARD RENEWING EOMA!