This project has received funding from the European Union Agency for the Space Programme under the European Union’s Horizon 2020 Research and innovation programme under grant agreement No 101004181.

RTK+OSNMA based positioning for road vehicle applications

A comparative experimental performance assessment

Susanne Schweitzer, ENC 2023, 31.05.2023

ESRIUM

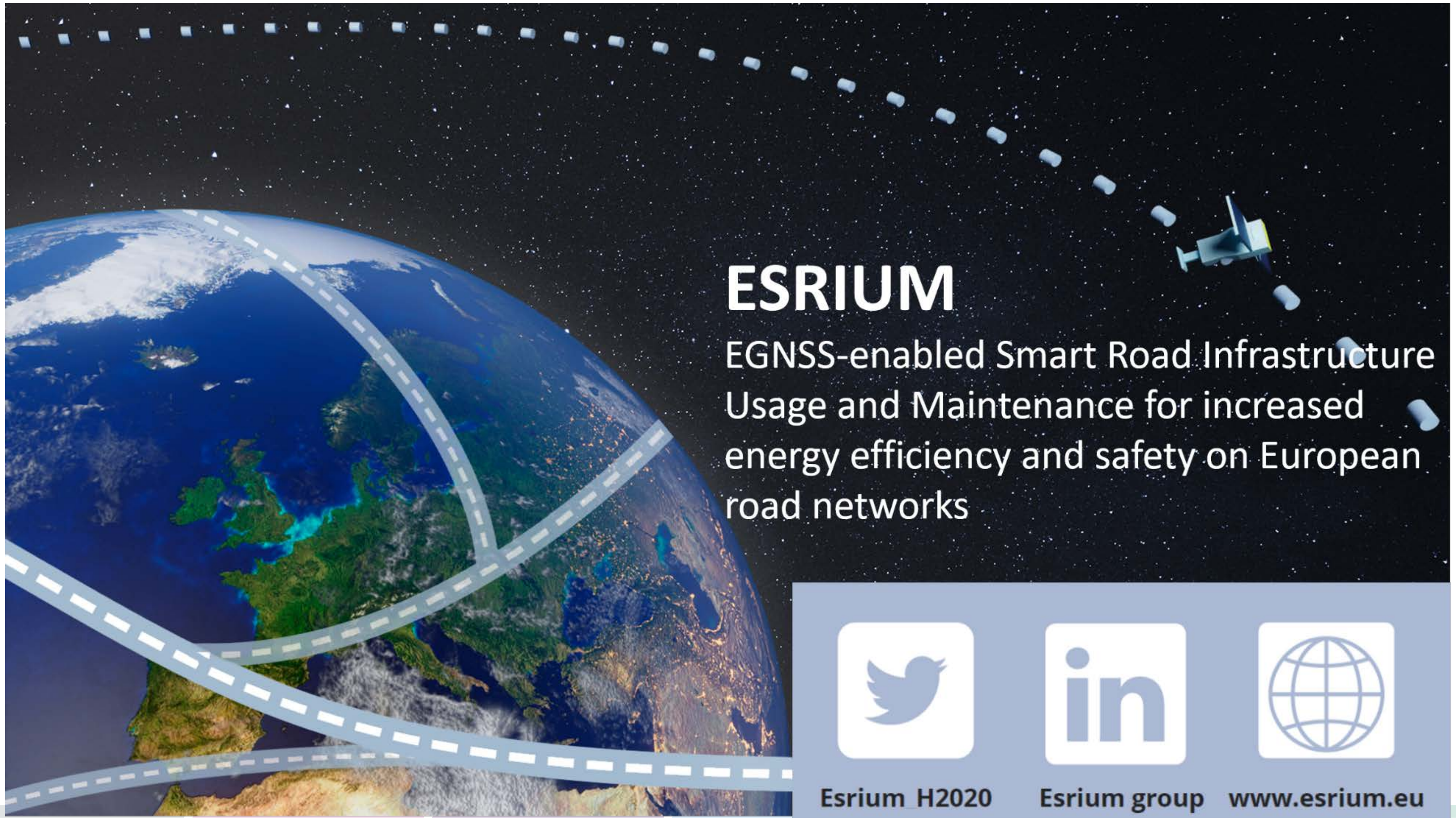
SAFE AND EFFICIENT ROADS

Background

- GNSS signals are used in many modern devices & applications
  - Surveying, mapping, communication, emergency, localisation-based services, precise time services
- Robustness and resilience of GNSS signals are important
- Authentication of signals enables prevention of spoofing
- OSNMA is the first service providing authenticity check in the civilian sector
- OSNMA provides a feature for assured PVT with respect to spoofing
- OSNMA may play a vital role in road vehicle navigation

Background - The ESRIUM project

- Investigation of various aspects of highly accurate, reliable, and assured EGNSS localisation information for road vehicles (automated driving)



Source: Virtual Vehicle

The ESRIUM project

Our Objectives

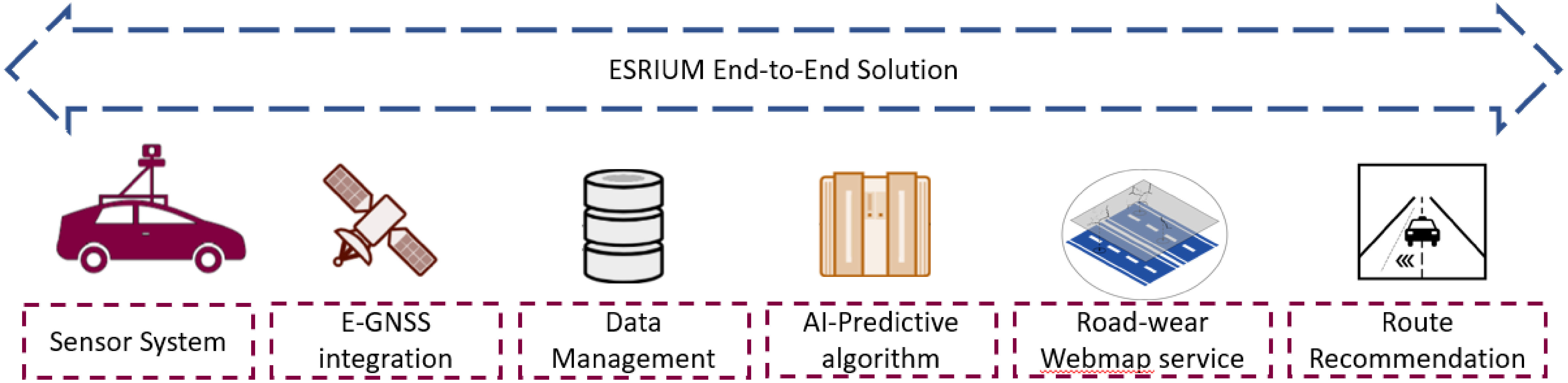
Objective 1	Objective 2	Objective 3	Objective 4
Create a highly detailed EGNSS-referenced digital road wear map	Create a new mid-priced sensor system for detecting road damage	Implement EGNSS-localization system to provide accurate, authenticated yet low-cost position information in real-time.	Broadcast precision routing recommendations

Objective 5	Objective 6	Objective 7	Objective 8
Broadcast potentially dangerous locations	Provide road damage state and evolution	Develop a business-case based on the ESRIUM services	Demonstrate smart automated routing based on broadcasted information

Source: Virtual Vehicle

ESRIUM – Use Cases, products and services

- AI-based ***road damage prediction*** to support enhanced road maintenance planning
- ***Routing recommendations*** based on the road wear map, provided via C-ITS messages
- C-ITS Message ***'GNSS-correction data' provision***
- ***Road wear map content provision***



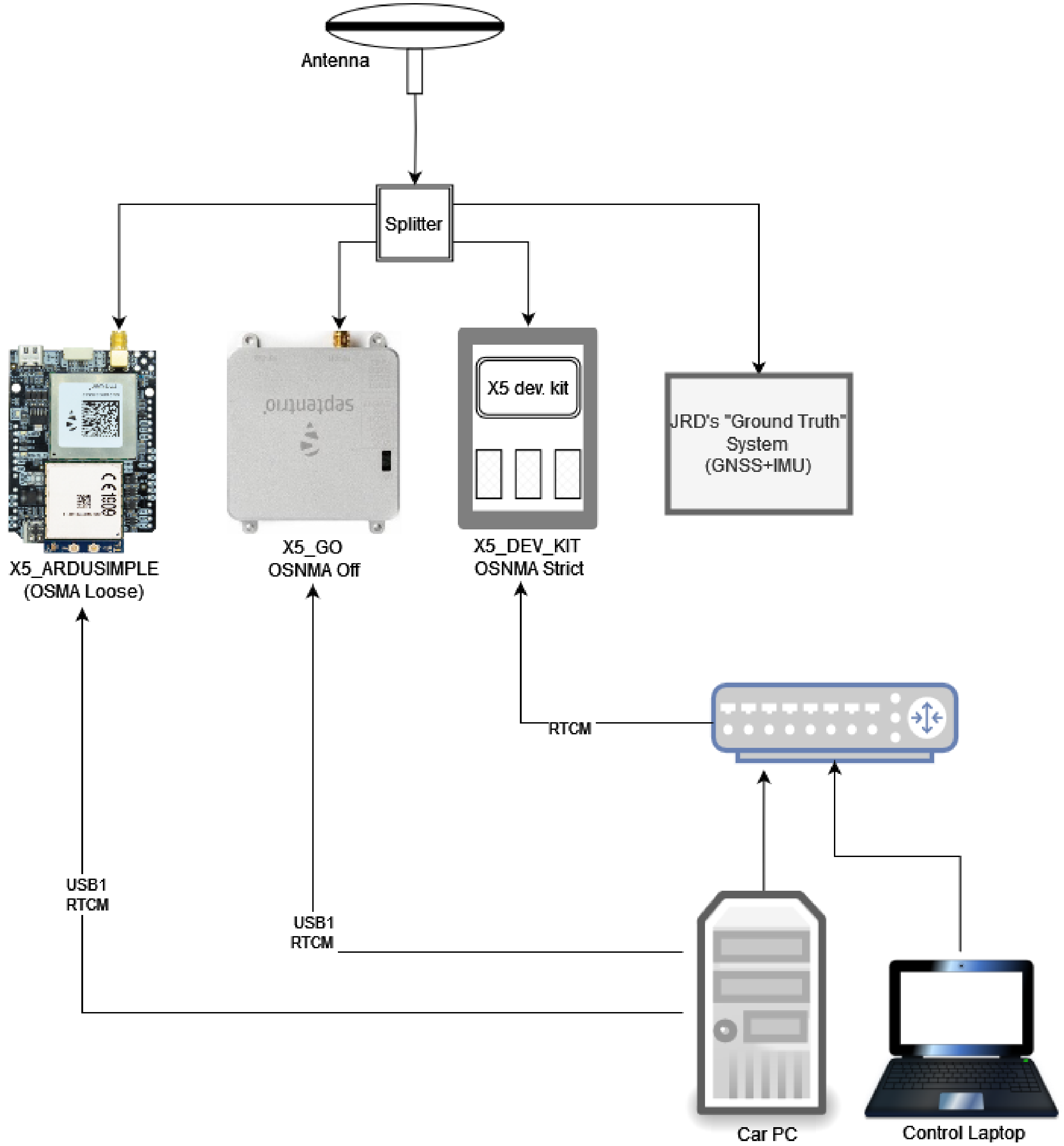
Performance tests

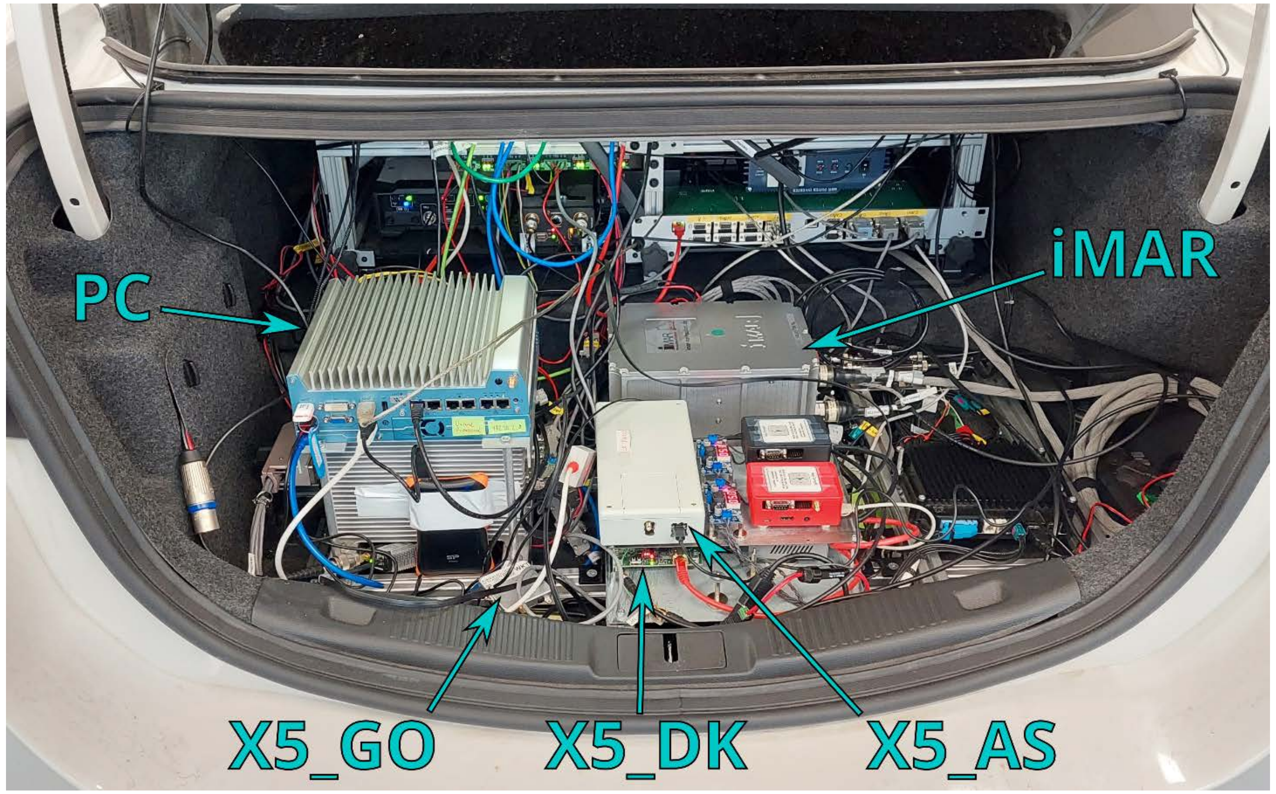
- Test drives under different GNSS reception conditions
  - > 8 hours, three testing days in Dec 2022 / Jan 2023 in Graz (Austria)
  - Different driving environments (open sky, motorways, rural roads, hilly & forested, suburban, urban)
- Special focus on using the Galileo OSNMA service
  - Used three receivers operated in different OSNMA configurations:
    Off, ***loose*** and **strict** use of OSNMA
  - Use of mass-market Septentrio Mosaic-X5 receivers (multi-frequency and multi-GNSS receivers)
- Validation and localisation performance analysis (off-line, post processing)
  - Analysis of the achievable accuracy, reliability and availability of the mass-market receivers
  - Assessment of the overall performance aggregated over all the environments, regarding the proportion of RTK solutions and the horizontal position error (this paper)
  - Reference trajectory calculations from high-end EGNSS/IMU system for validation

Experimental settings

- NAX 3G+C antenna
- connected via splitter to three Septentrio receivers and the GNSS/IMU system

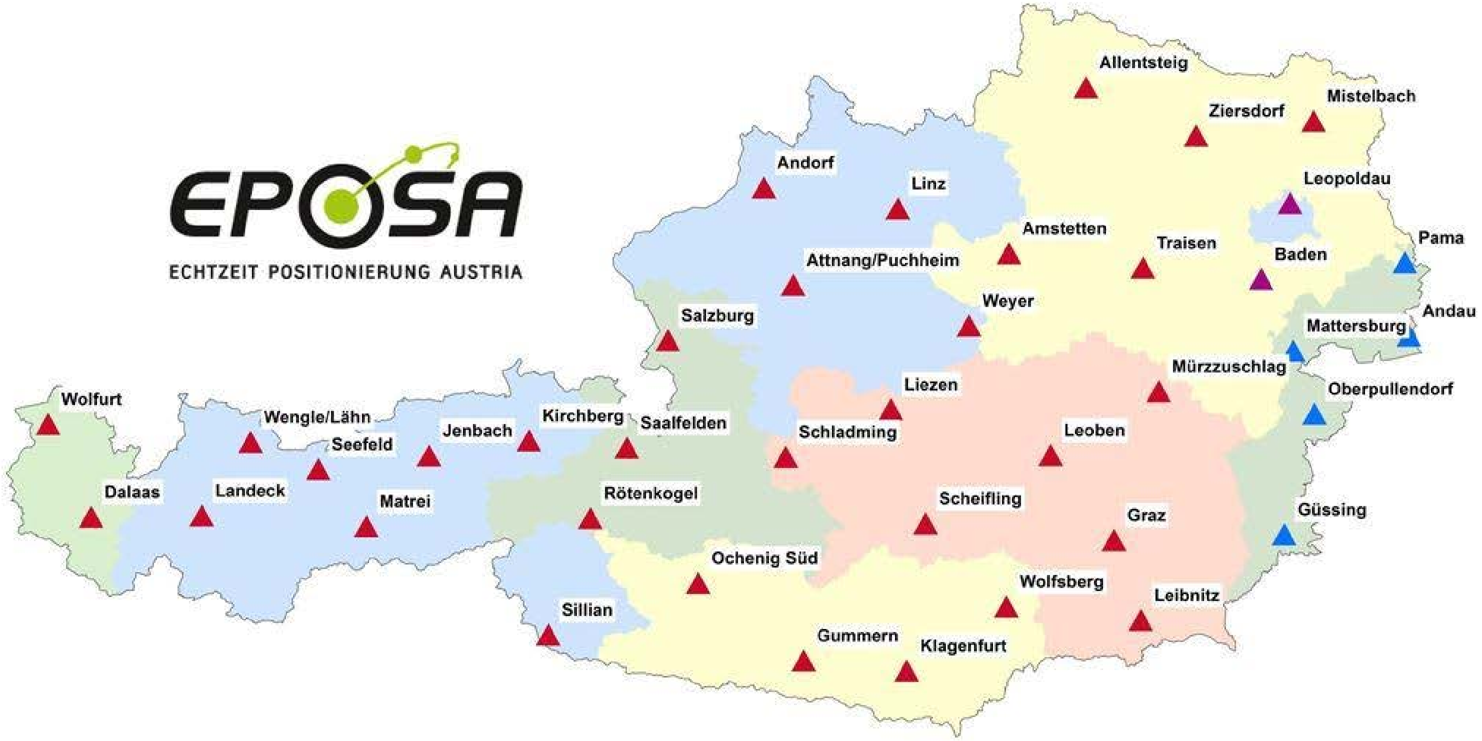
Experimental settings





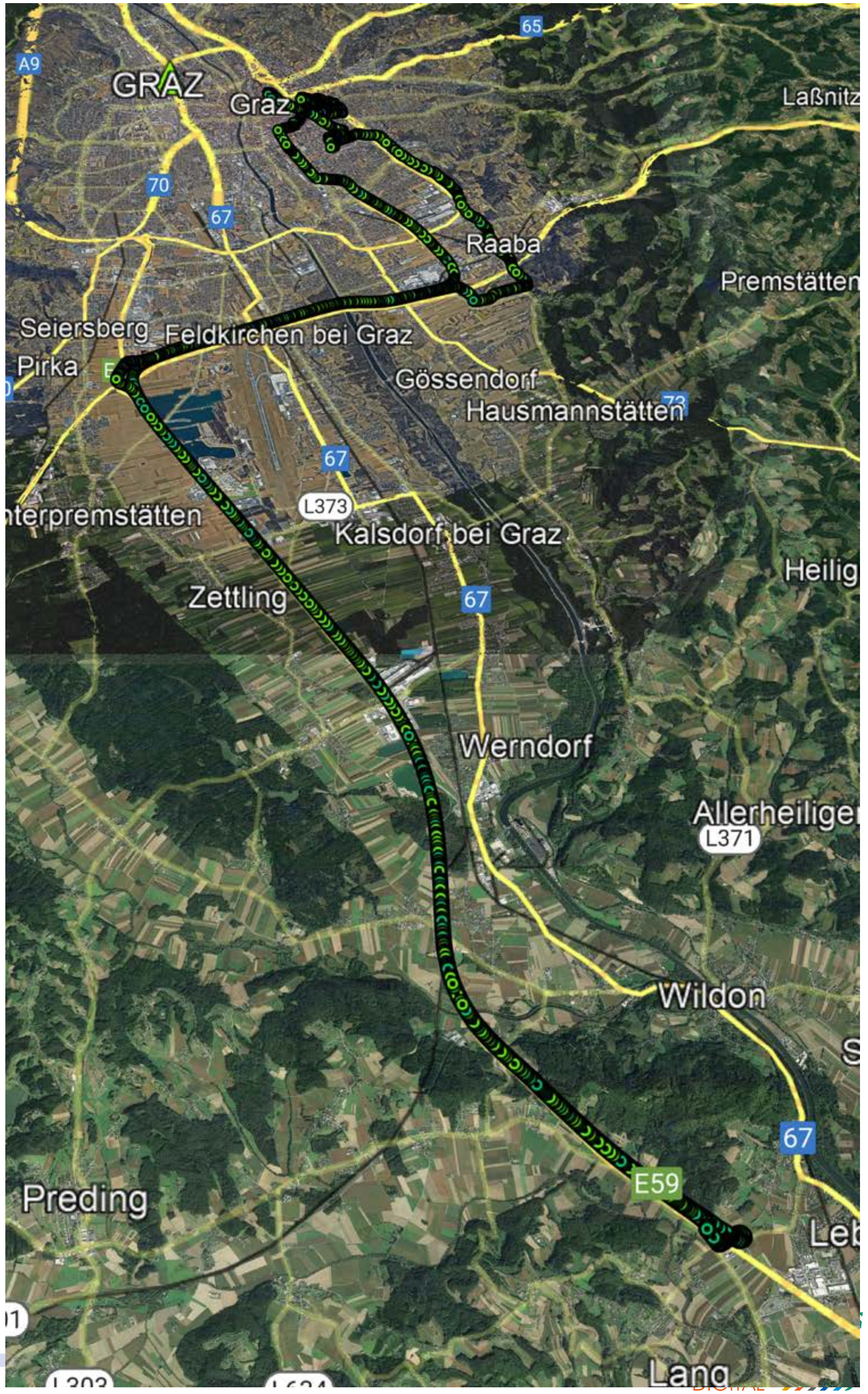
RTK localisation correction data

- RTK localization correction data was derived from the EPOSA network
- Download in RTCM 3.1/3.2 format for ITRF & ETRS89 over 4G modem
- EPOSA: “**E**chtzeit **POS**itionierung **A**ustria”

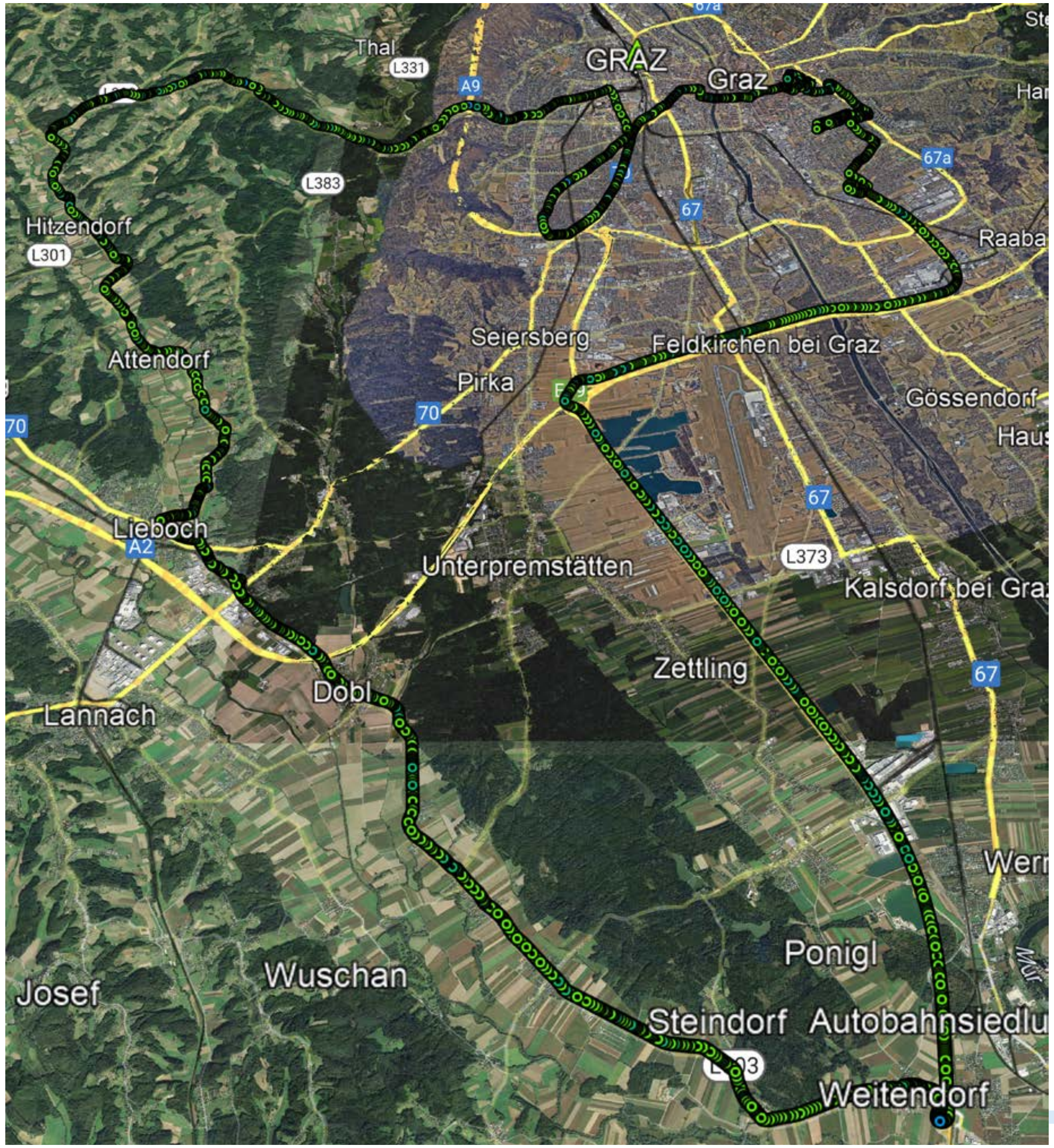


Test drives

- Goal: Performance assessment of authentication based positioning in different driving environments (incl. hilly, urban, open sky)
- OSNMA in three modes:
  - Off: use of all GPS L1/L2 + Galileo E1/E5a satellite signals for PVT solution
  - Loose: use of all GPS signals and Galileo signals from satellites with authenticated navigation messages or unknown status
  - Strict: no us of GPS signals, but only authenticated Galileo signals
- OSNMA loose should give an estimate of the final performance of Galileo OSNMA.



Test drives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Pirka
Gössendorf
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Lieboch
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Unterpremstätten
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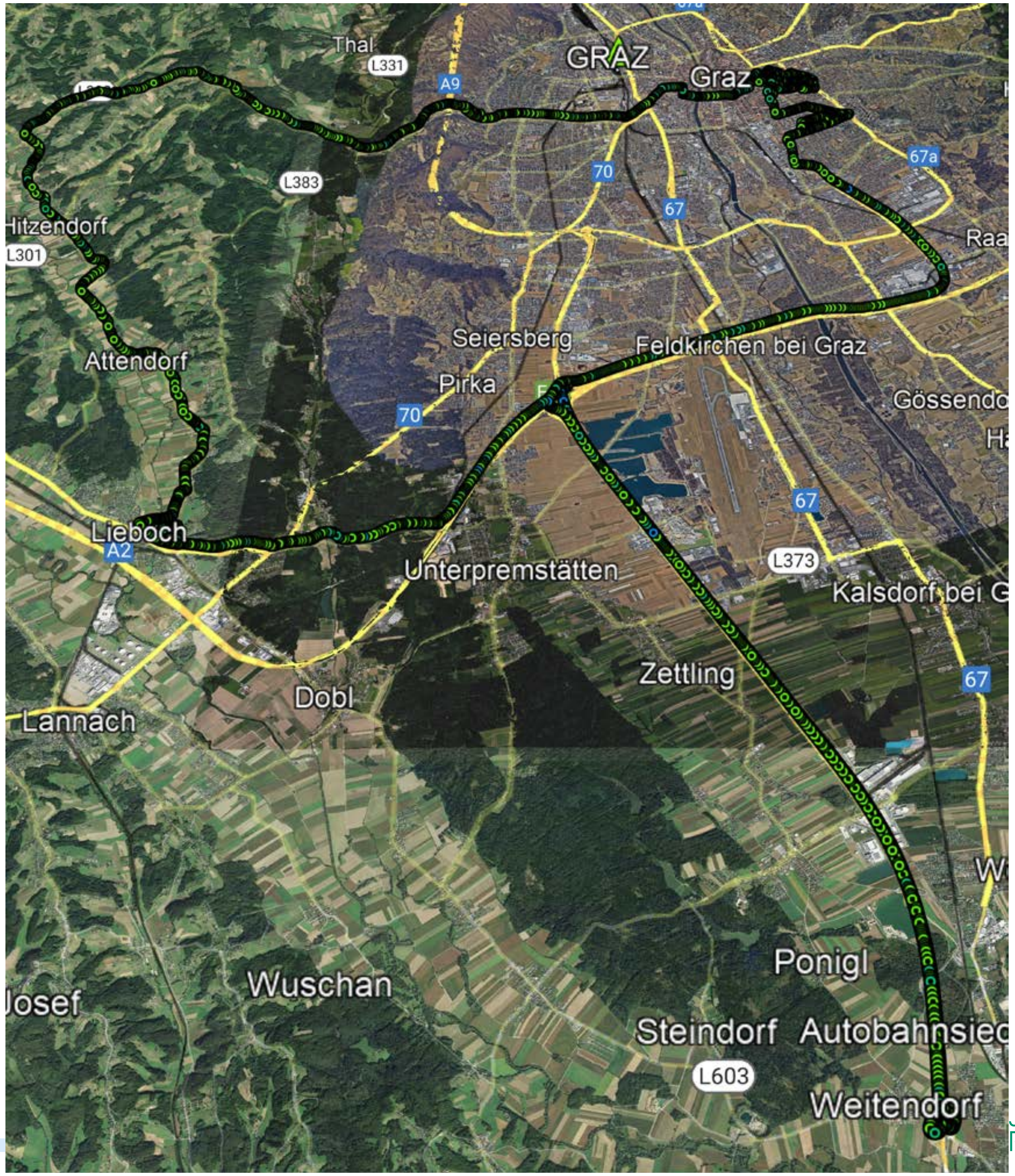
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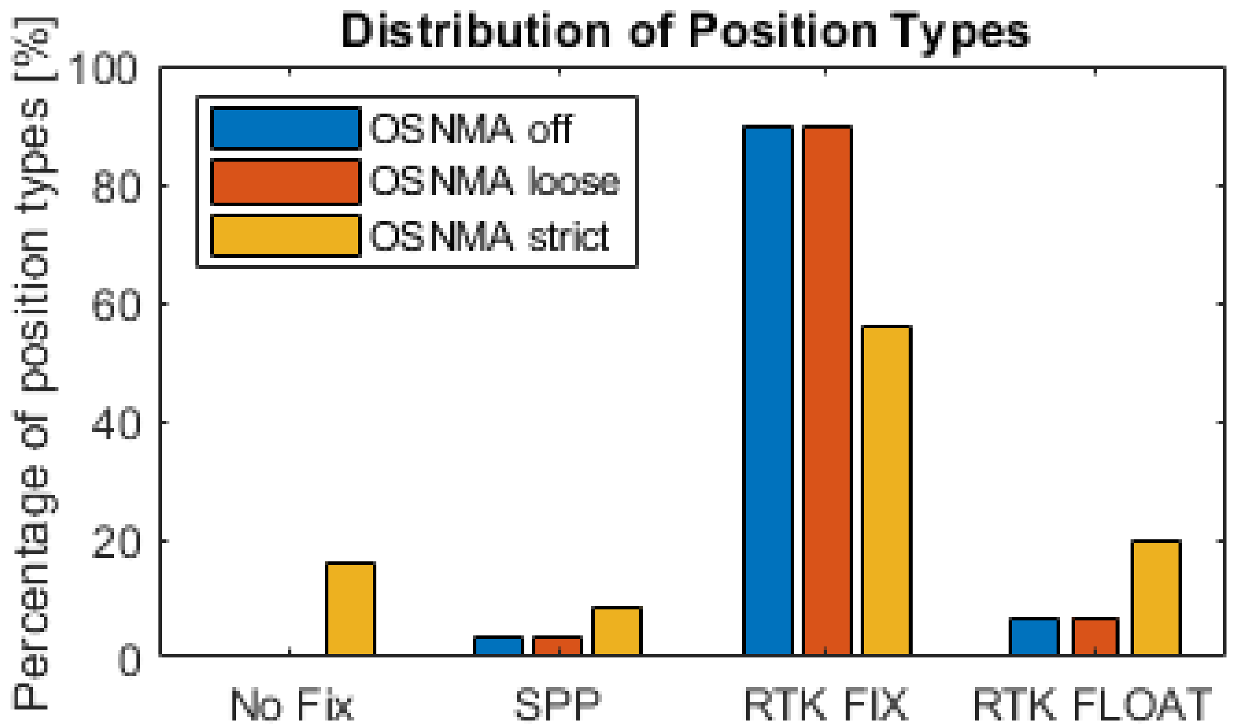
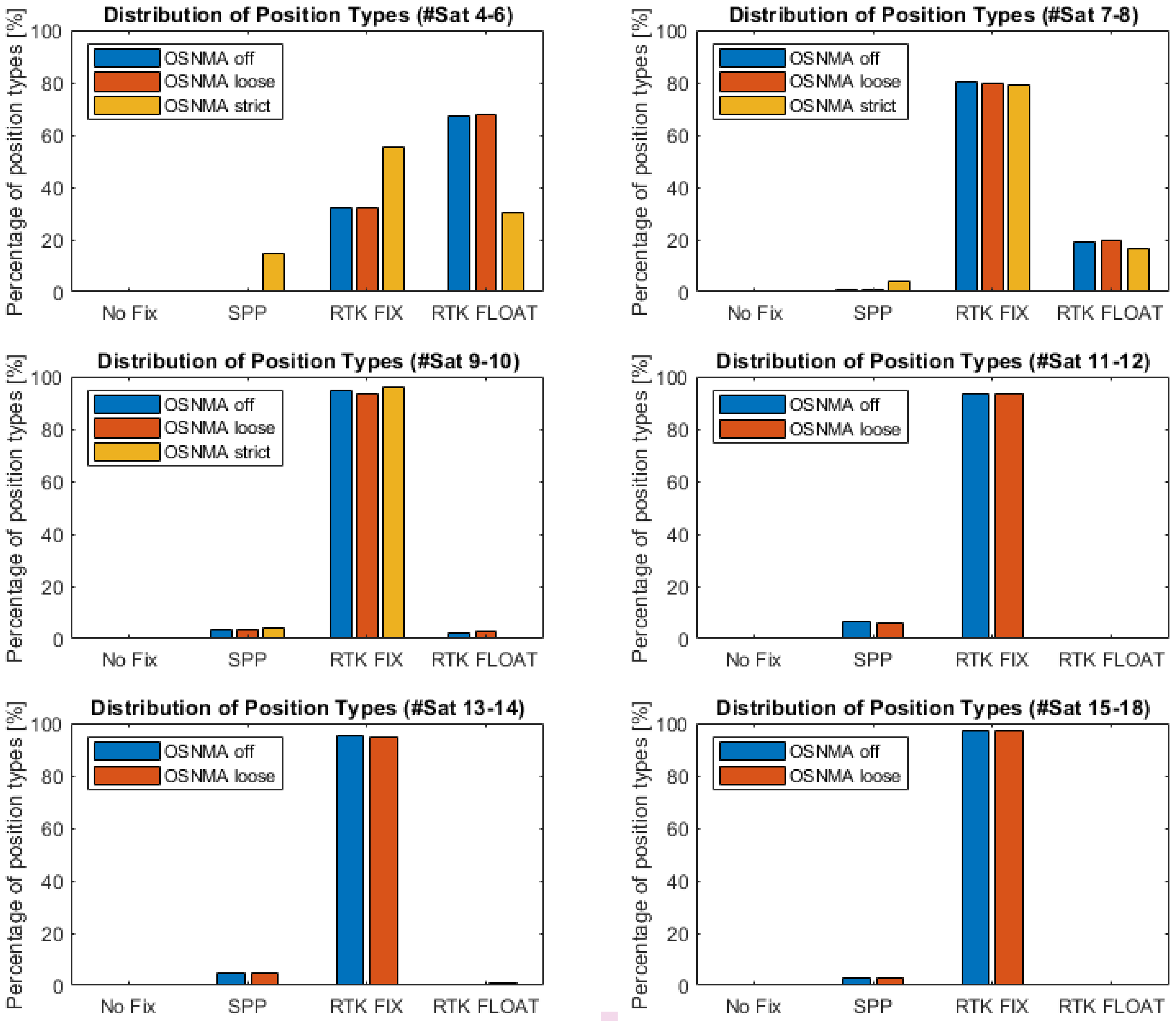
Results: Proportion of position types

- RTK fix: carrier phase ambiguities could be solved > best positioning accuracy
- RTK float: carrier phase ambiguities could be estimated as float values only > less accurate position information
- SPP: When the receiver could not compute RTK positions



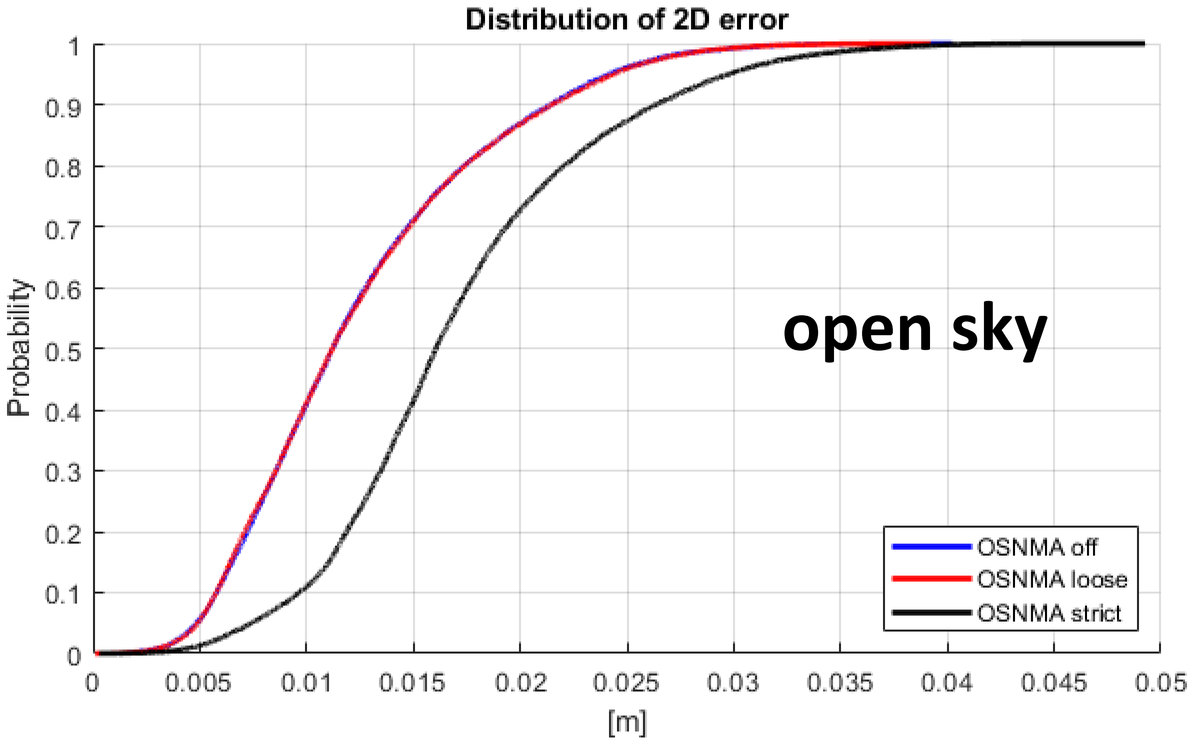
- RTK fix:
  - 89.92% for OSNMA off
  - 89.59% for OSNMA loose
  - only 55.77% for OSNMA strict (reduced number of available satellites)
- SPP: probability of loose and strict half as small as for off.

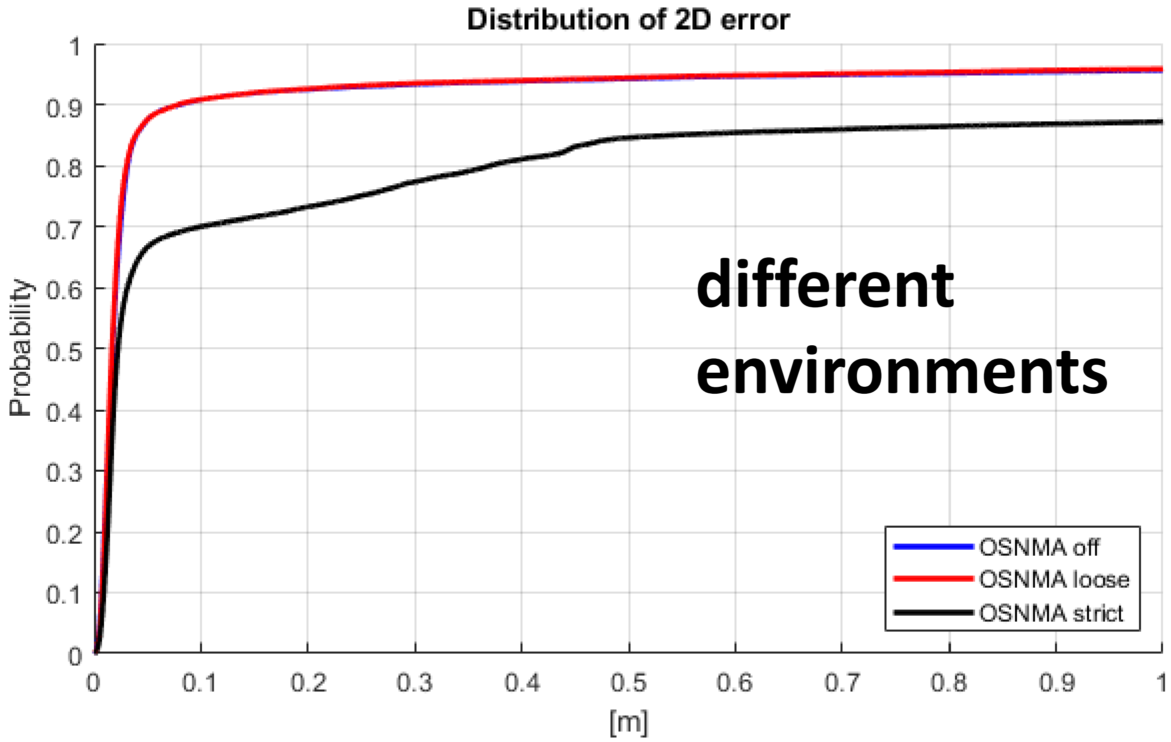
Results: Proportion of position types depending on number of satellites



- proportion of RTK fixes increases with the number of satellites (simultaneously, RTK float decreases)
- authenticated fixes become better the more authenticated satellites are available
- most RTK-fix solutions in OSNMA loose configuration (→ 97.06 %). This value displays the performance that can presumably be achieved with the final Galileo OSNMA service.
- Off and loose perform similar

Results: Localisation accuracy

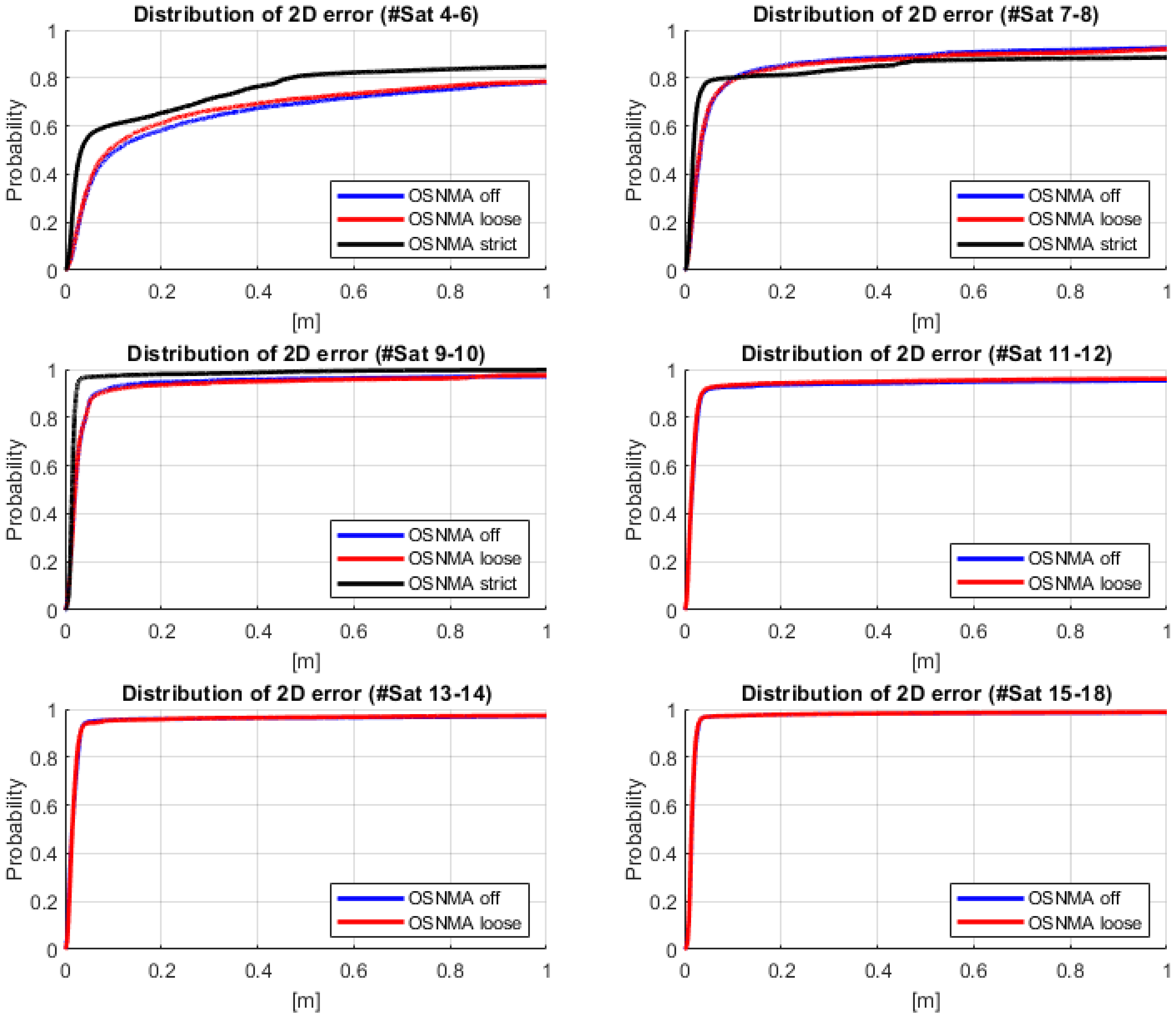




- localisation accuracy always better than 5 cm
- 2 cm: strict 72.62%, loose 86.75%, off 86.86%

- Larger errors due to challenging environment
- 20 cm: only 73.2% strict (limited visibility), off 92.47%, loose 92.55%

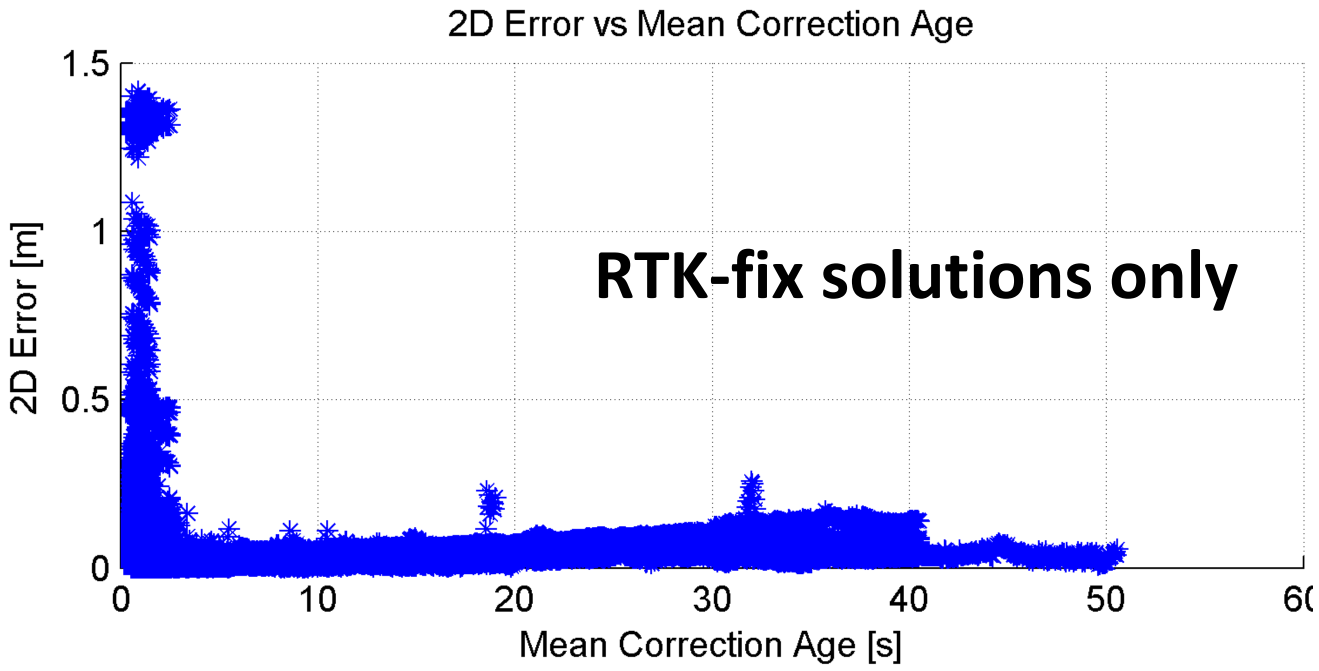
Results: localisation accuracy for different numbers of satellites

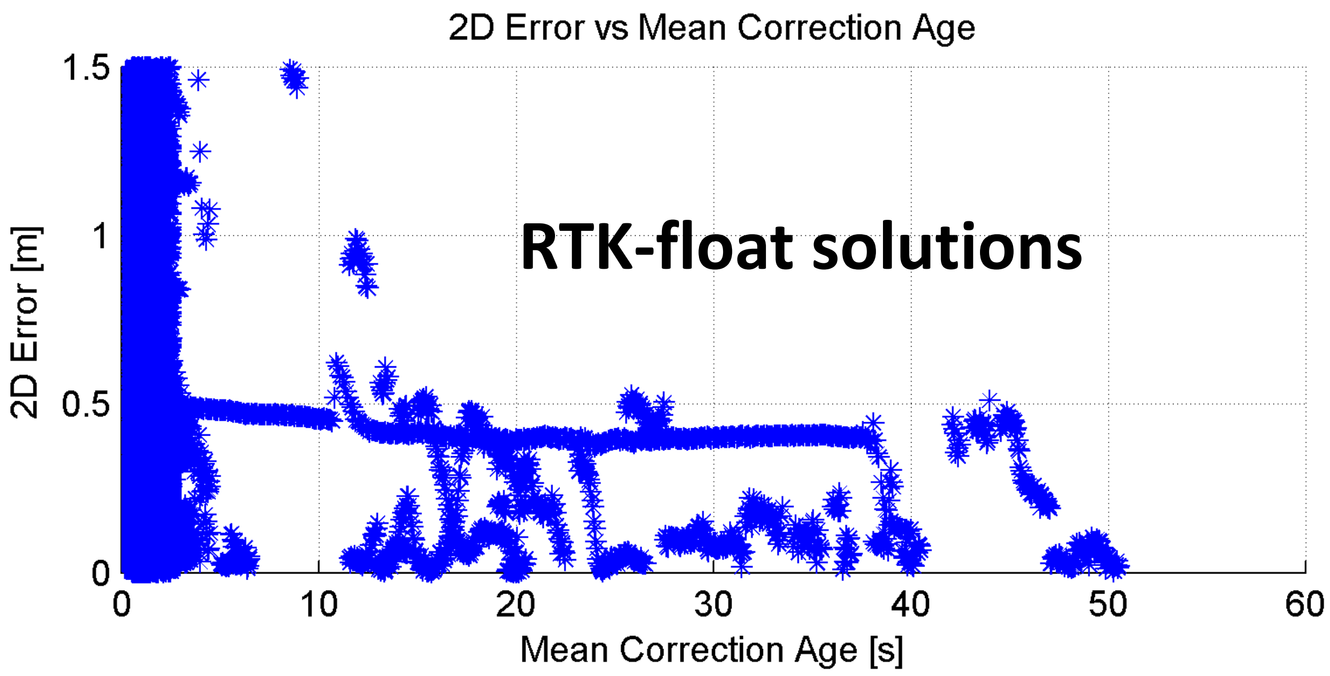


- localisation accuracy typically increases with the number of satellites
- 4-6 satellites: strict performs best
  → comprising cases in regions with better visibility
  → Galileo signals are typically better than GPS (esp. multipath)
- advantage of OSNMA strict doesn't keep for 7-8 satellites
  → reasons under investigation
- more than 10 satellites only slightly improve position accuracy
- Loose > 15 satellites: comparable performance as strict for 9-10 satellites
  → receiver in very open region
  → probably reflects the Galileo-OSNMA accuracy when it is fully operational

Results: position accuracy during periods without RTK correction data

- Receiver was configured to use base station data with ages of up to 50 seconds
- First seconds: errors that are typically encountered in urban and suburban situations
- Afterwards: influence of older correction data on RTK solution visible → mostly for highway and rural road conditions
- If RTK fix is possible, 2D position error typically stays below 20 cm up to 50 s
- RTK float: error can stay as good as 50 cm if initial solution is stable; otherwise huge errors possible (22 m observed)





Summary

- OSNMA provides very good positioning accuracy as long as sufficient satellites are available.
- A medium number of satellites, around 10, using GPS and Galileo, showed already quite good performance in the results, while more are obviously preferable.
- Even longer RTK correction data outages do not necessarily lead to critical situations in terms of 2D positioning accuracy since as long as the RTK fix can be kept, errors below 20 cm can be achieved.
- The Mosaic x5 receiver showed very good performance for a mass market receiver;
  - 92.55 % of the solutions had a position error below 20 cm.
- The Proportion of RTK-fix solutions in the OSNMA loose configuration was 97.06 %.
  This value displays the performance that can presumably be achieved with the final Galileo OSNMA service. This is a very promising result in view of autonomous driving vehicles.
- These results clearly underline that it is very important to expand the network of authenticated satellites so that the OSNMA service can be used reliably.

Acknowledgements

- This work was conducted in the scope of the ***ESRIUM Project***, which has received funding from the ***European Union Agency*** for the Space Programme under the European Union's ***Horizon 2020 research and innovation programme*** and under grant agreement No 101004181.
- ***Virtual Vehicle Research GmbH*** has received funding within ***COMET Competence Centers*** for Excellent Technologies from the ***Austrian Federal Ministry for Climate Action***, the ***Austrian Federal Ministry for Labour and Economy***, the ***Province of Styria*** (Dept. 12) and the ***Styrian Business Promotion Agency*** (SFG).
- The ***Austrian Research Promotion Agency*** (FFG) has been authorised for the programme management.
- This project was supported by the ***Austrian RTK service provider EPOSA*** (www.eposa.at) providing their service free of charge.

Thank you for your attention!

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