

ION GNSS 2014

PPP FOR ADVANCED PRECISE POSITIONING APPLICATIONS, INCLUDING RELIABILITY BOUND

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SESSION E4: HIGH PRECISION GNSS POSITIONING

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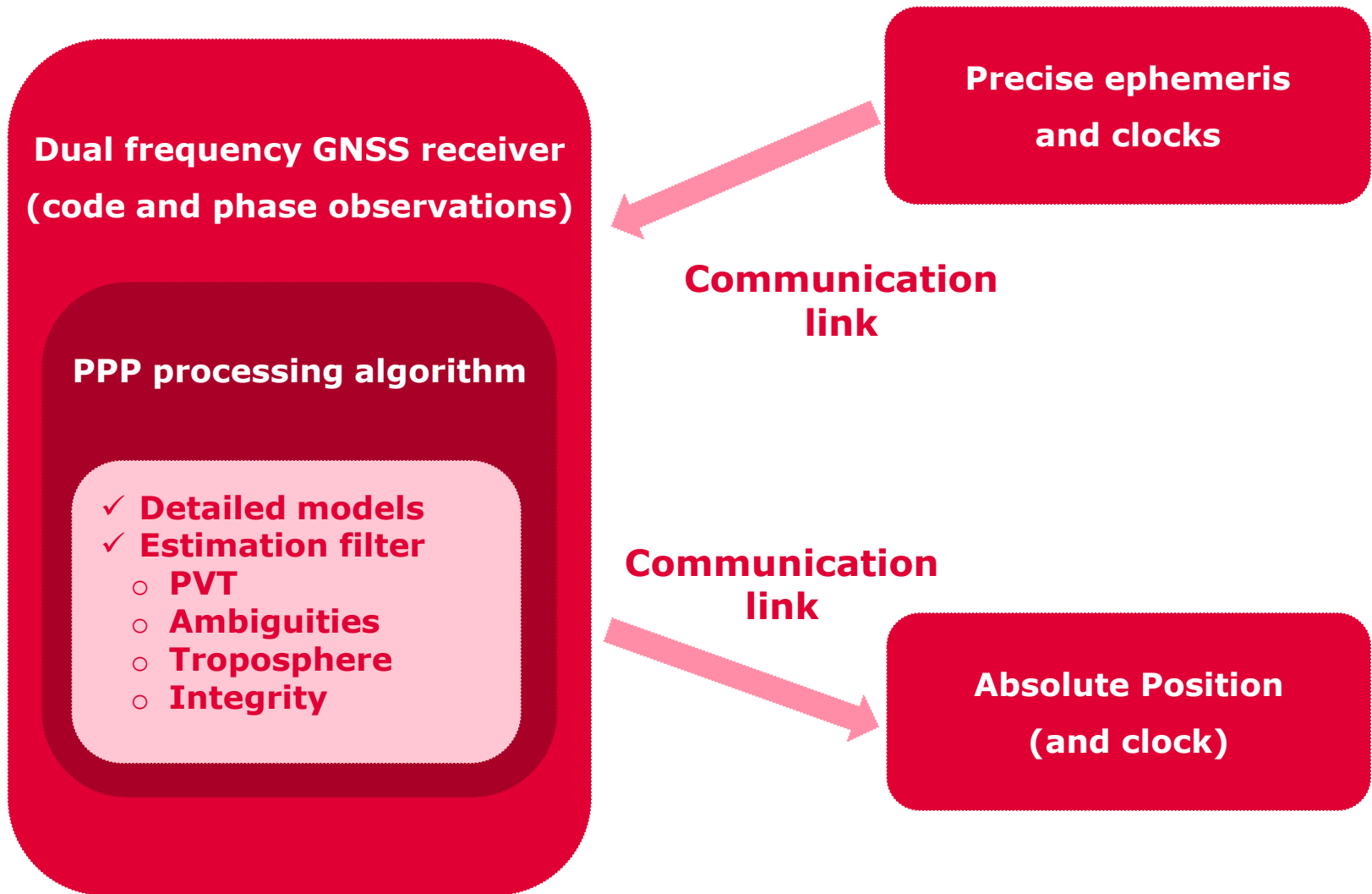


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- Improved Reliability Bound for PPP
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PPP INTRODUCTION

PPP TECHNIQUE

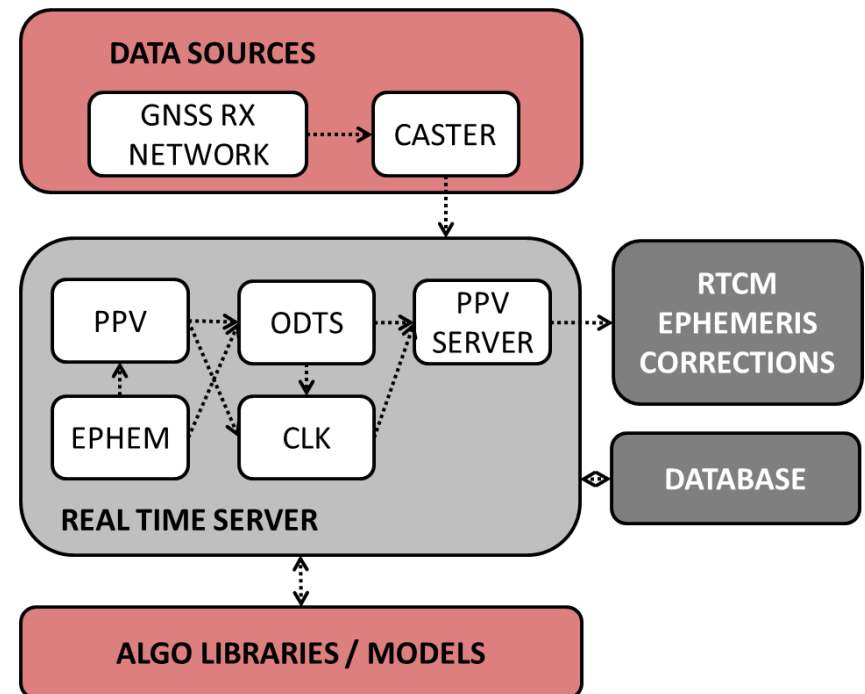


MAGICGNSS REAL-TIME INFRASTRUCTURE



PPP DEMONSTRATOR SERVER

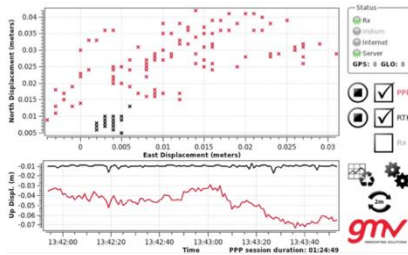
- Infrastructure for generation of:
 - Precise multi-GNSS orbits and clocks for real time and post-processing applications
 - RTCM ephemeris corrections for HA positioning in Real-Time
- Modular architecture for distributed processing
- Data retrieval, from a worldwide RTCM station network via NTRIP
- Configurable in Real-Time by means of a database
- Accepts connections from multiple PPP clients



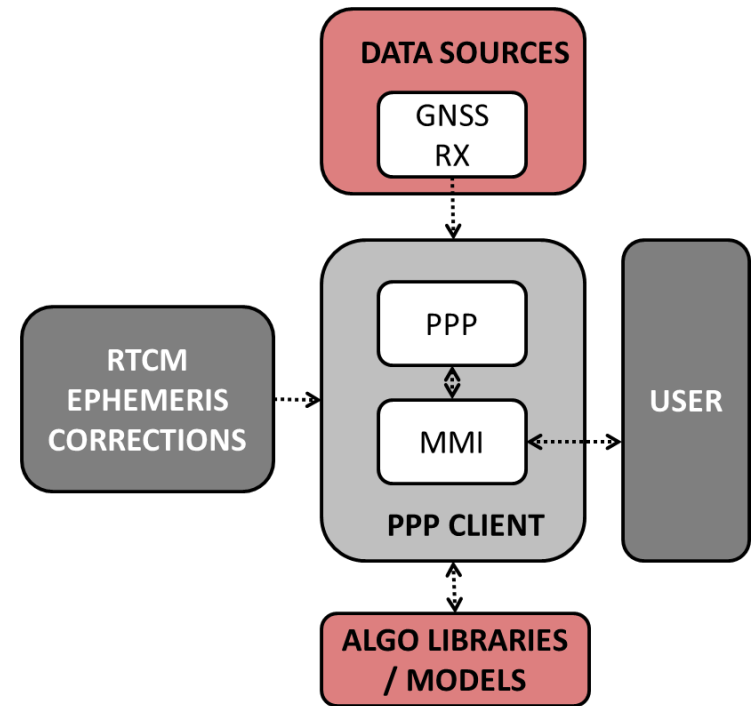
RT PPP DEMONSTRATOR CLIENT

- PPP module able to compute HA user position in Real-Time based on:
 - RTCM observations and ephemeris coming from a GNSS receiver via serial port
 - RTCM ephemeris corrections coming from an external service provider

- User logs and runs the PPP client by means of an MMI

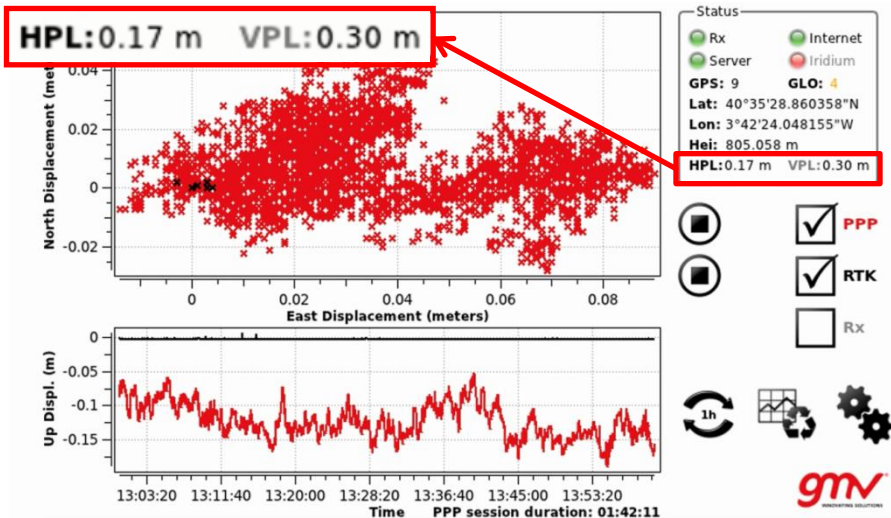


- Position generated in NMEA format
- Allows running RTK by means of rtklib



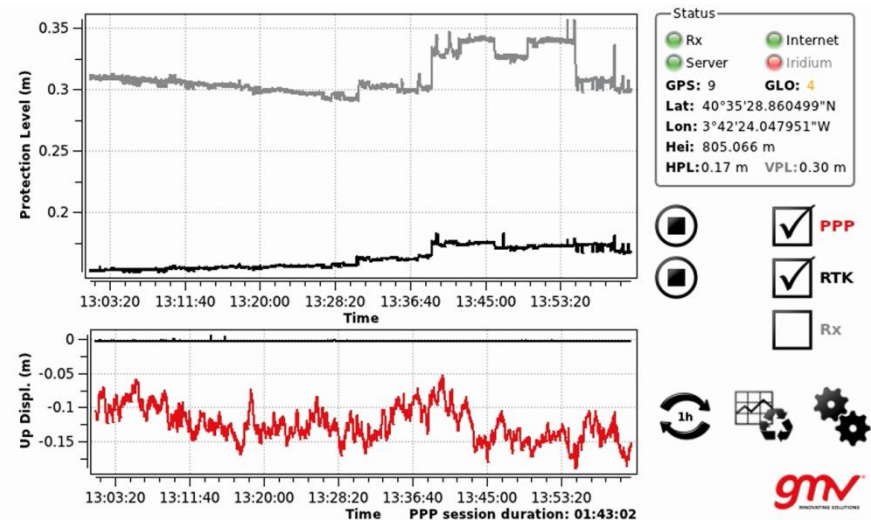
RT PPP RELIABILITY BOUND

- Together with the HA positioning solution, the PPP client provides horizontal and a vertical reliability bounds. Concept introduced *M. D. Laínez, M. M. Romay, "In-The-Field Trials for Real-Time Precise Positioning and Integrity in Advanced Applications, "Proceedings of the ION 2013 Pacific PNT Meeting"*
- The provided reliability indicators or protection levels (PL_H, PL_V) have been computed taking into account the following factors:
 - Constant term for compensating the uncertainty associated to the definition of the reference frame
 - Covariance indicators coming out from the PPP estimation filter
 - Residuals of the position estimation process
 - Additional margin aimed at compensating for the strong correlations during the initial convergence period



RT PPP RELIABILITY BOUND

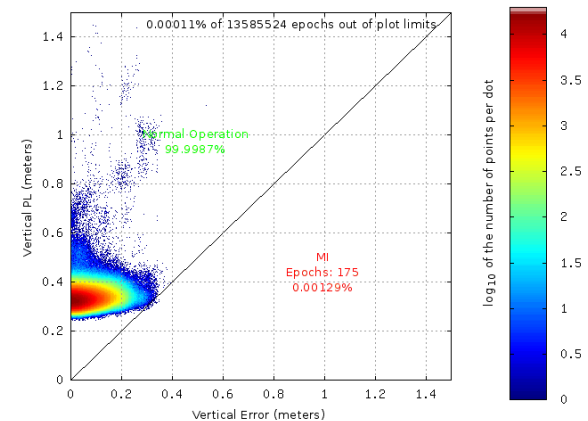
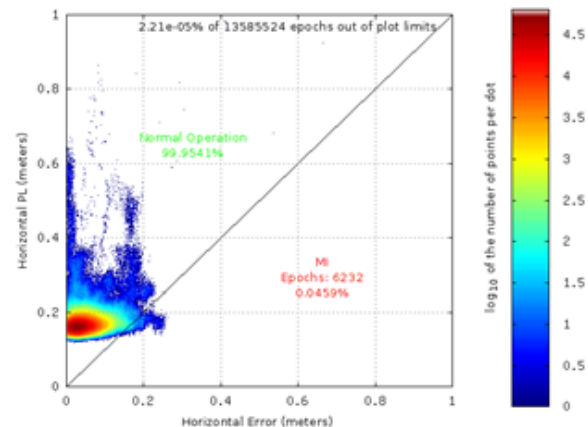
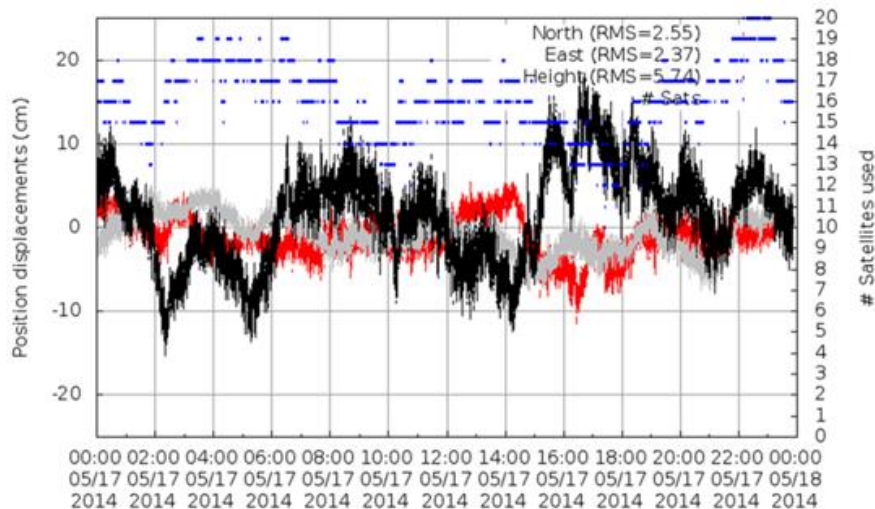
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PPP PERFORMANCES

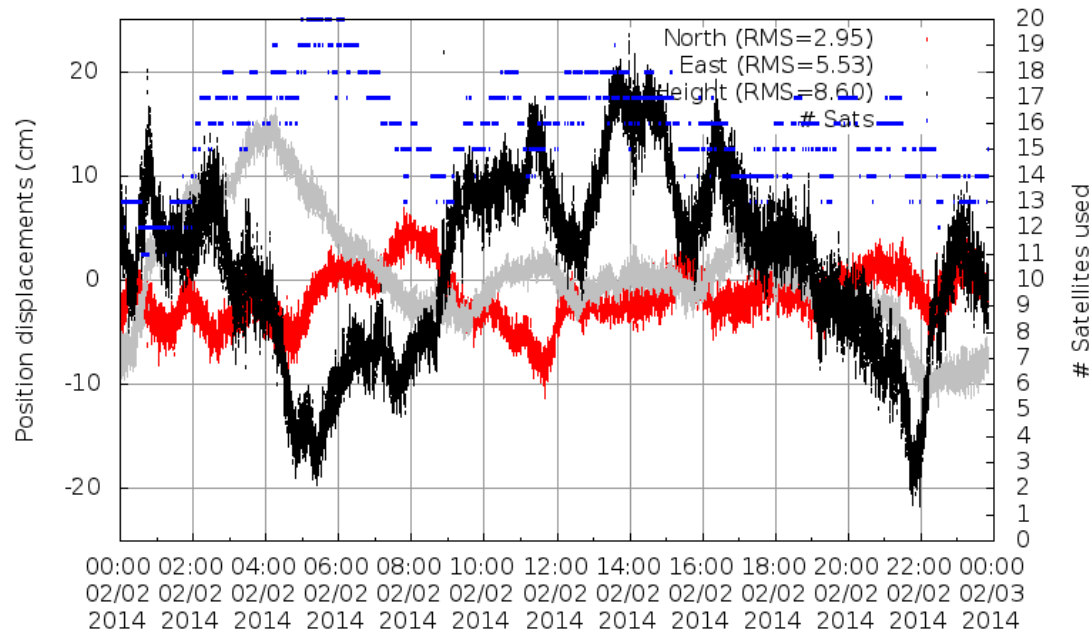
REAL-TIME STATIC PERFORMANCES

- 6-month-long analysed period
- Horizontal accuracy <10 cm and Vertical accuracy <15 cm, 95%
- Horizontal PL < 20 cm and Vertical PL < 40 cm, 95%
- Still margin for improvement



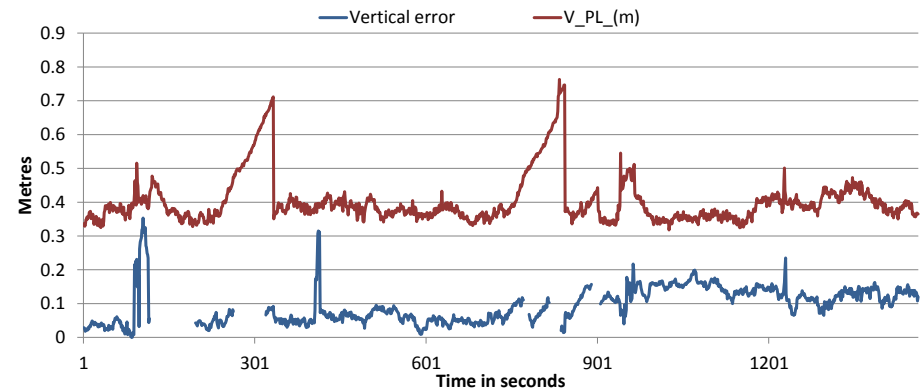
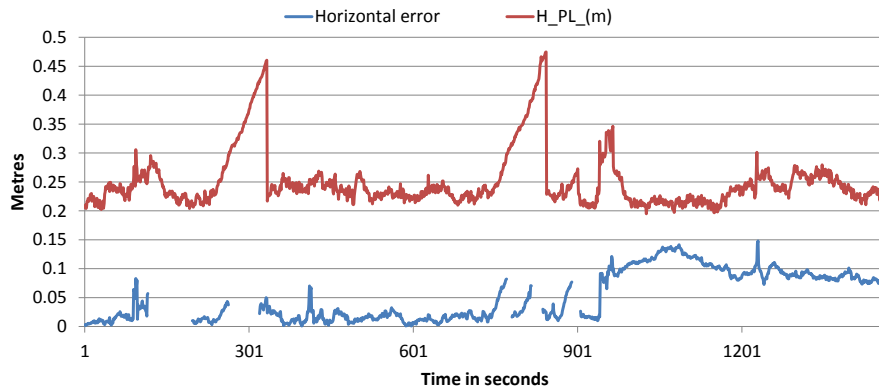
Percentile	H_Err (cm)	V_Err (cm)	PL_H (cm)	PL_V (cm)
68	4.89	6.70	16.85	32.82
95	8.67	14.7	18.79	37.42

REAL-TIME STATIC PERFORMANCES (2)



- PPP performances not uniform throughout time. PPP position displacements, mainly caused by a combination of:
 - Geometry
 - Orbit and/or clock product accuracy

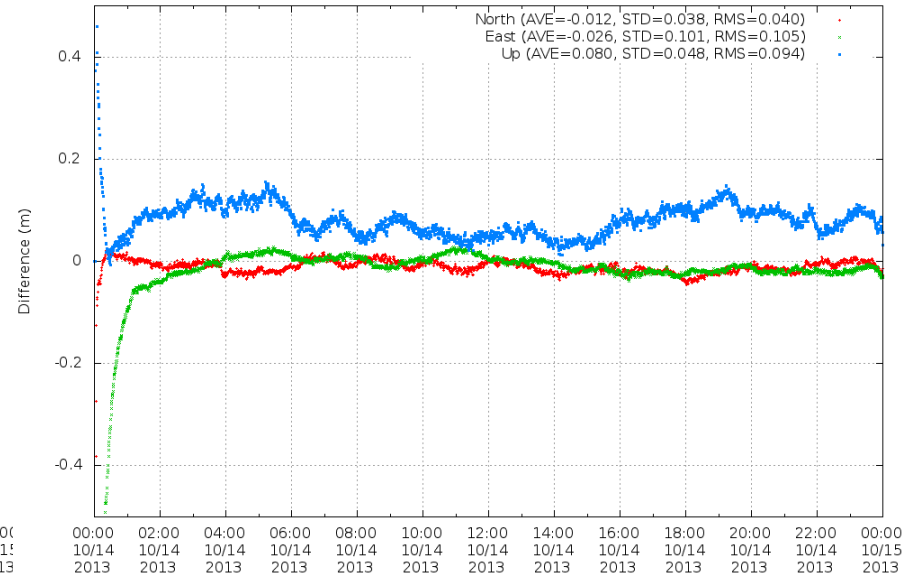
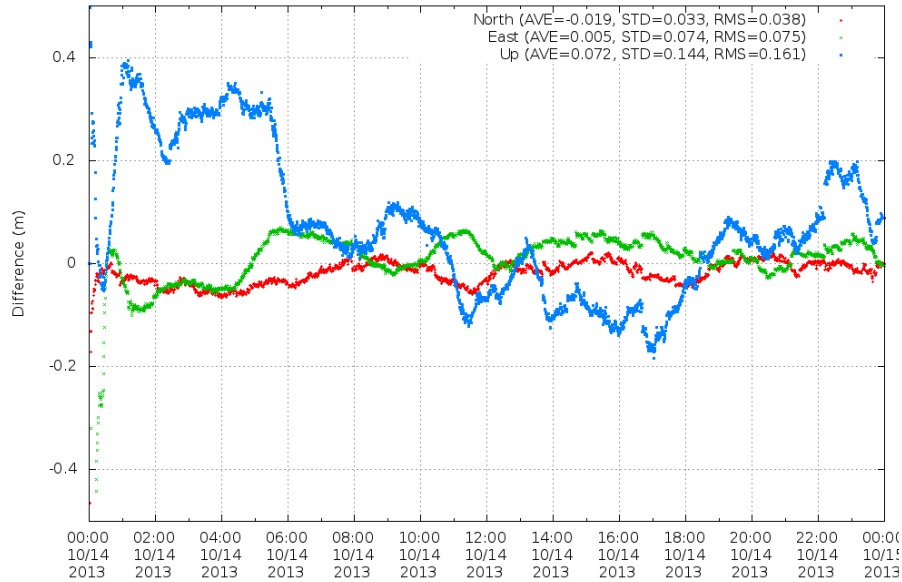
REAL-TIME KINEMATIC PERFORMANCES



- Good PPP performances, accuracy and reliability
- Communication losses up to several min do not affect the solution
- Possible enhancements for increasing robustness of PPP in partially obstructed scenarios:
 - Low cost receivers equipped with high sensitivity chip sets
 - Single-frequency PPP approach
 - Integration of PPP with inertial sensors

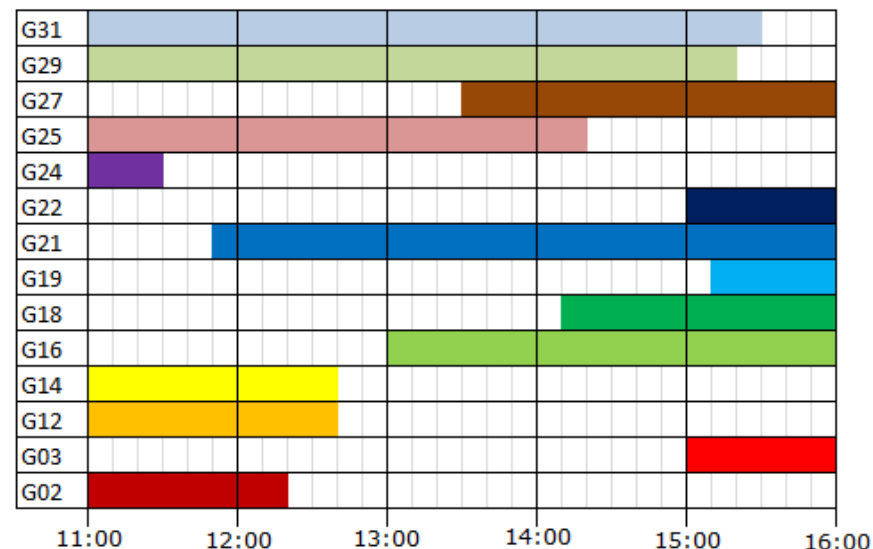
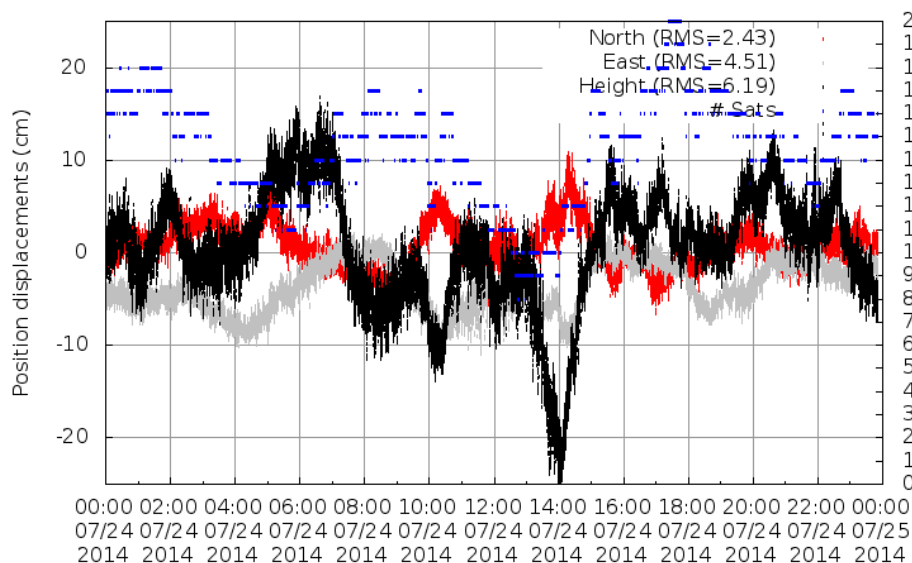
PPP LIMITATIONS

ORBIT & CLOCK PRODUCTS QUALITY IMPACT



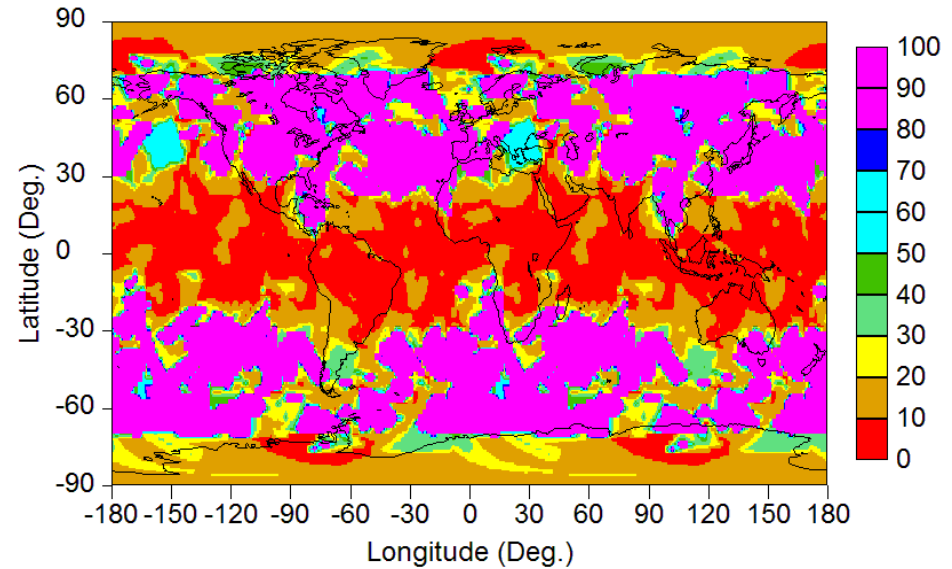
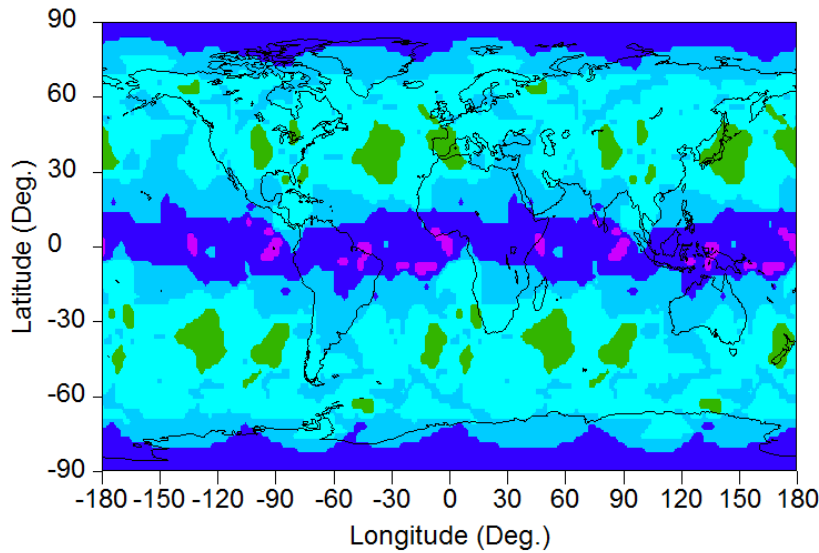
- PPP position displacements are notably reduced when post-processed off-line products are used
- Improvement: enhance orbit and/or clock products accuracy

GEOMETRY QUALITY IMPACT



- Large PPP position displacements under weak geometry conditions (4 GPS satellites in view in the example)
- Improvement: constellation optimization, multi-constellation

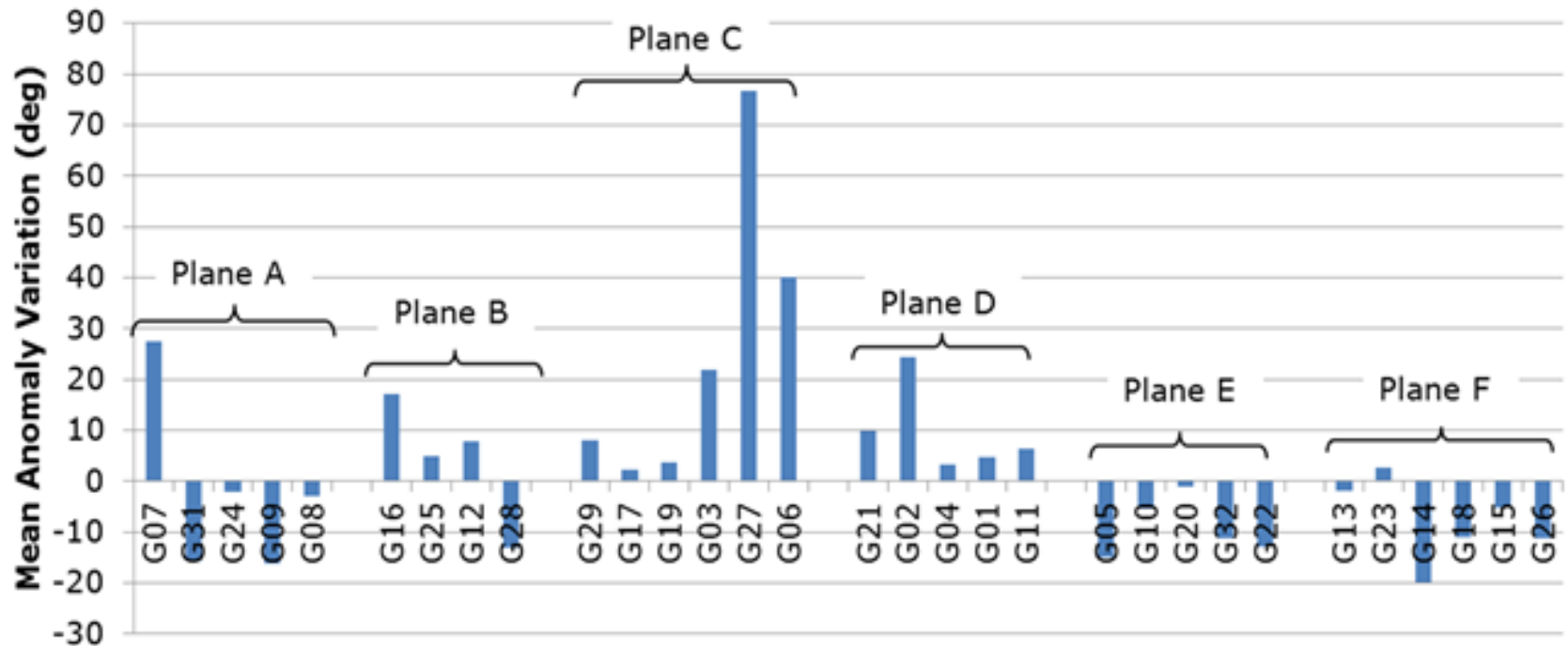
REAL GPS CONSTELLATION



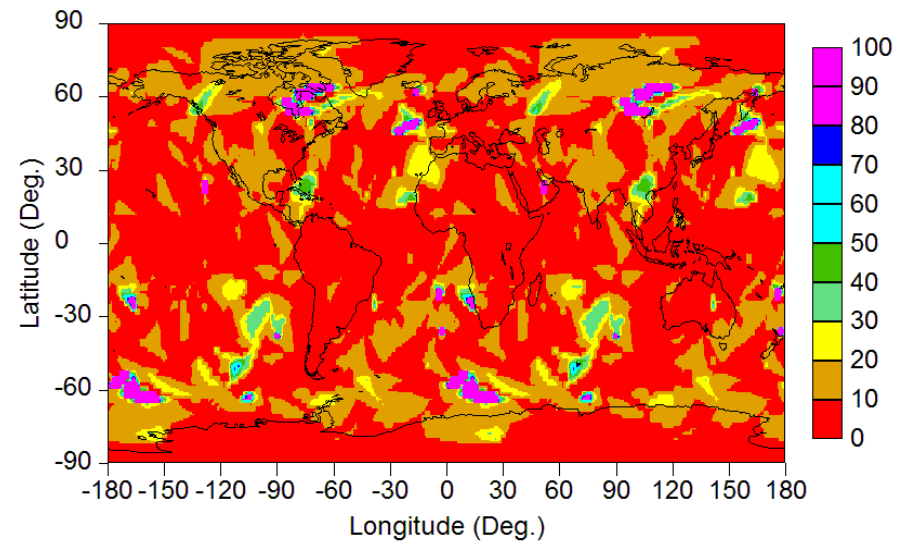
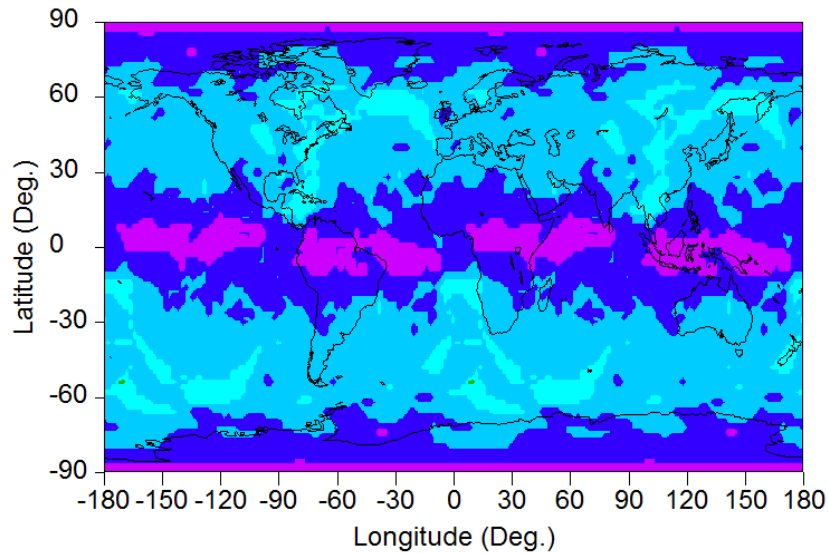
- Certain areas with 4 minimum number of satellites in view
- Large areas with too large PDOP values in case of one satellites failure (100% availability level)

OPTIMISED GPS CONSTELLATION

- GPS constellation can be optimised (allowed the variation of the mean anomaly of the satellites in each one of the orbital planes)
- Needed modifications of up to 70 degrees

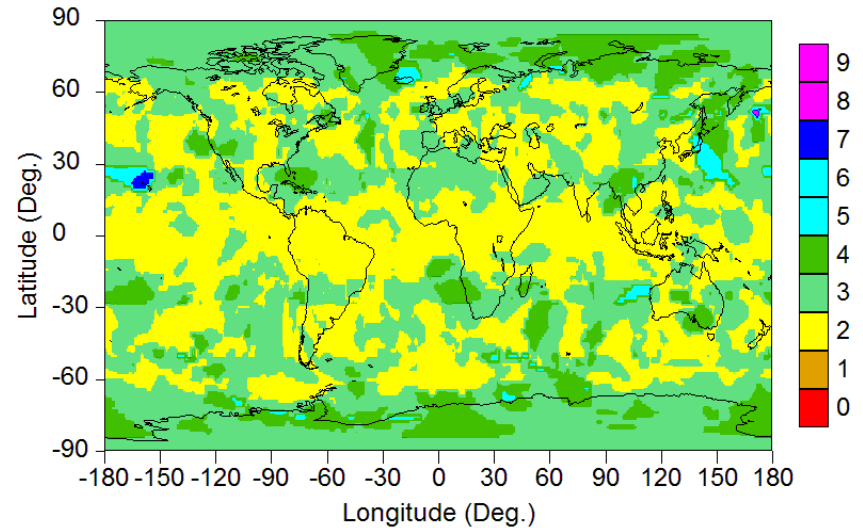
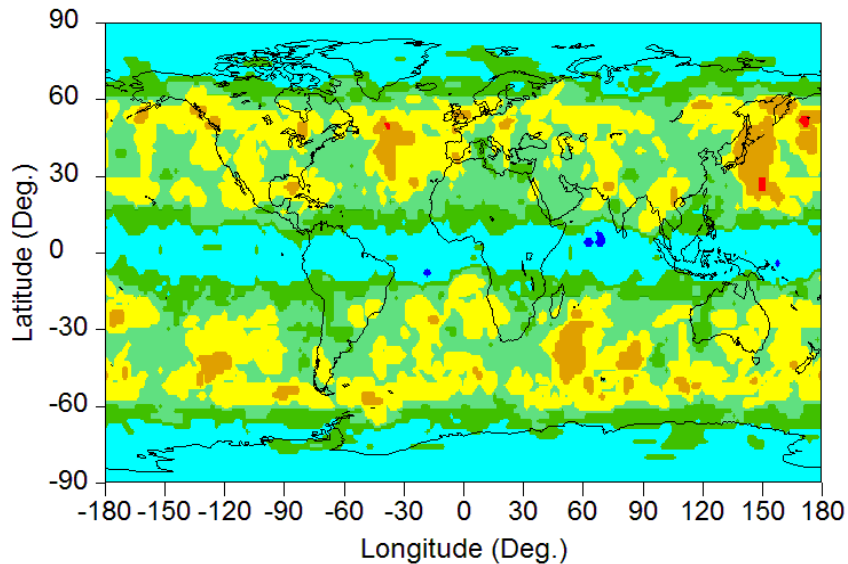


OPTIMISED GPS CONSTELLATION



- Minimum number of satellites in view increased from 4 to 5
- Notable reduction of areas with too large PDOP values in case of 1 satellite failure

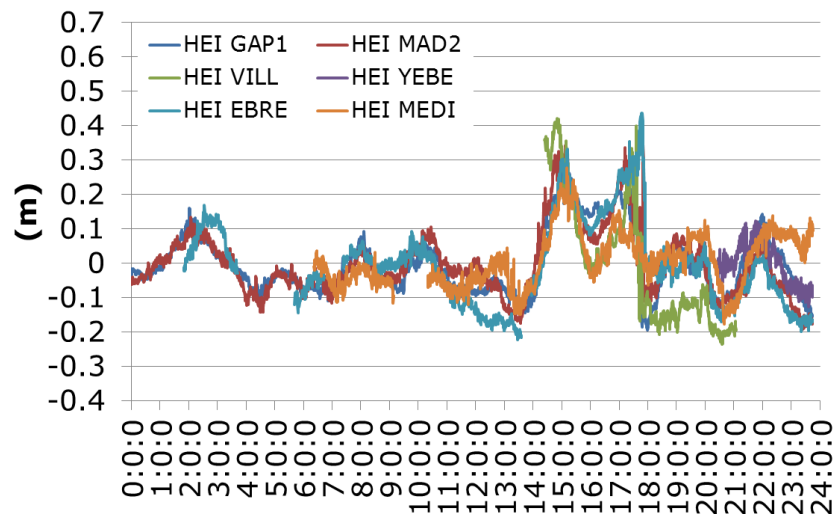
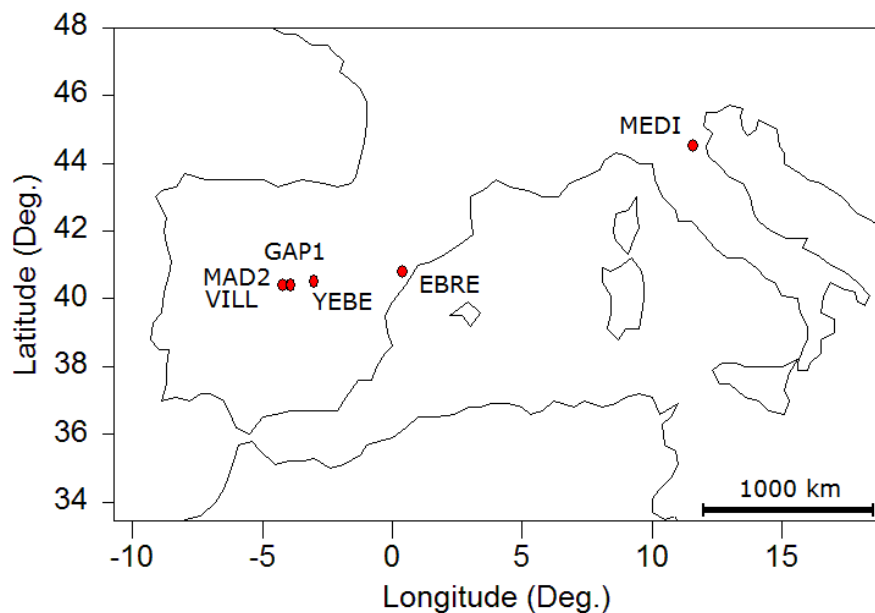
MULTI-CONSTELLATION: GPS + GALILEO



- Future combined use of GPS + Galileo
- Minimum number of satellites in view: 8
- Excellent world-wide PDOP values in case of 1 satellite failure (below 4 most of the times)

RELATIVE PPP

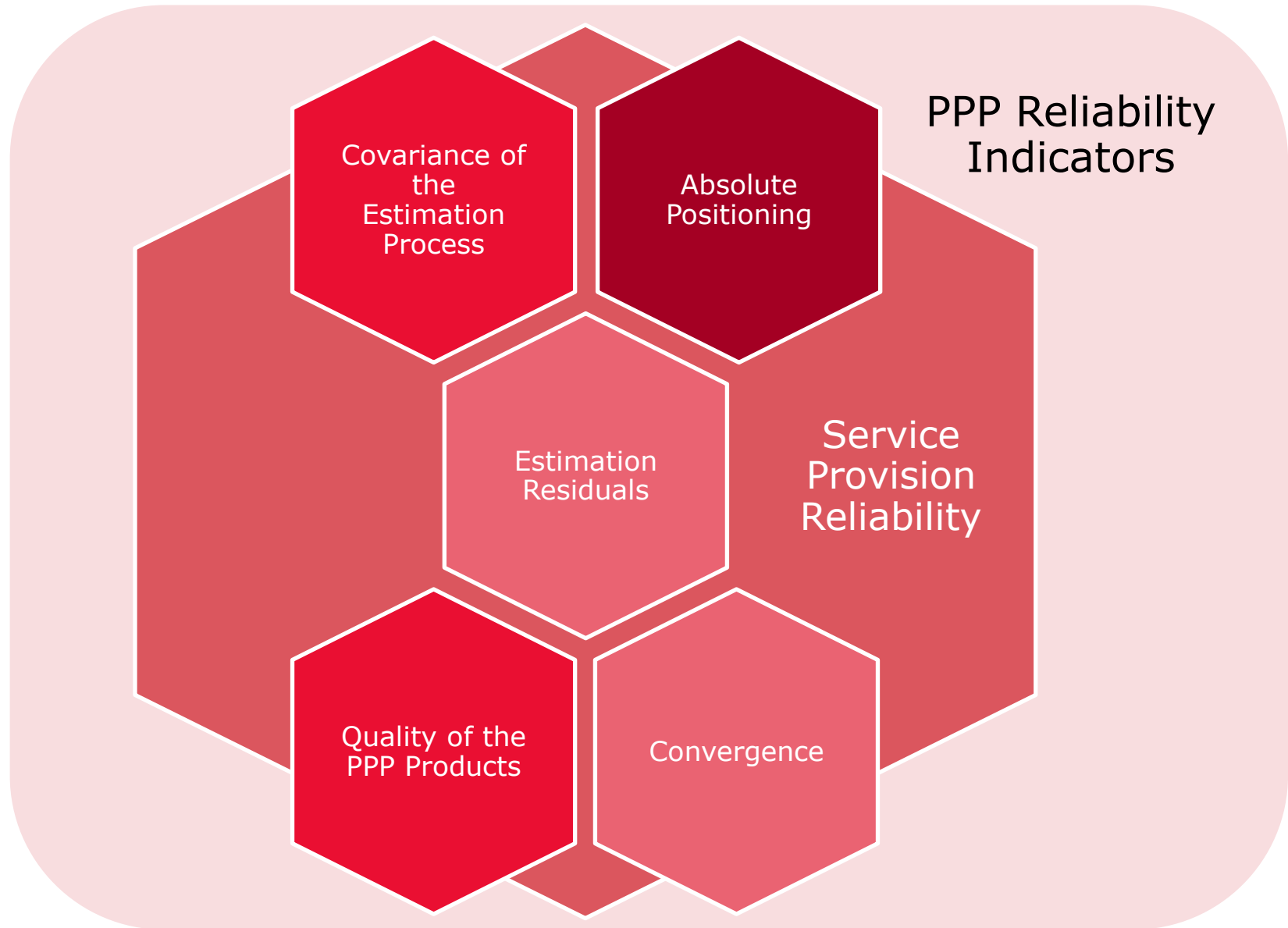
RELATIVE PPP



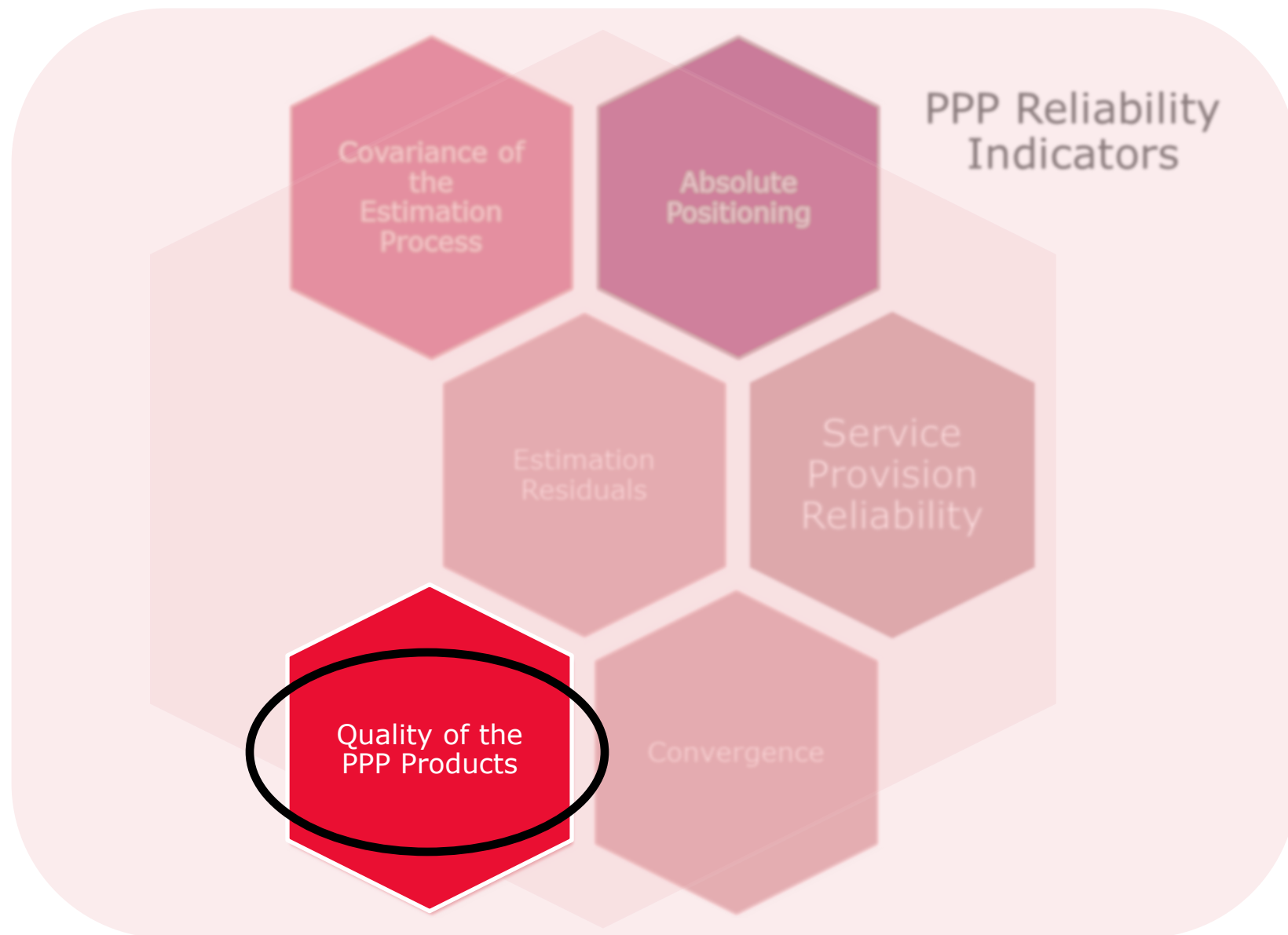
- PPP absolute positioning / RTK relative positioning
- Coherent solutions for relatively distant stations suggest relative PPP positioning could make sense
- Potential application: reliability bound enhanced with information provided by the server (at a calibrated position) – 100's km

IMPROVED PPP RELIABILITY BOUND

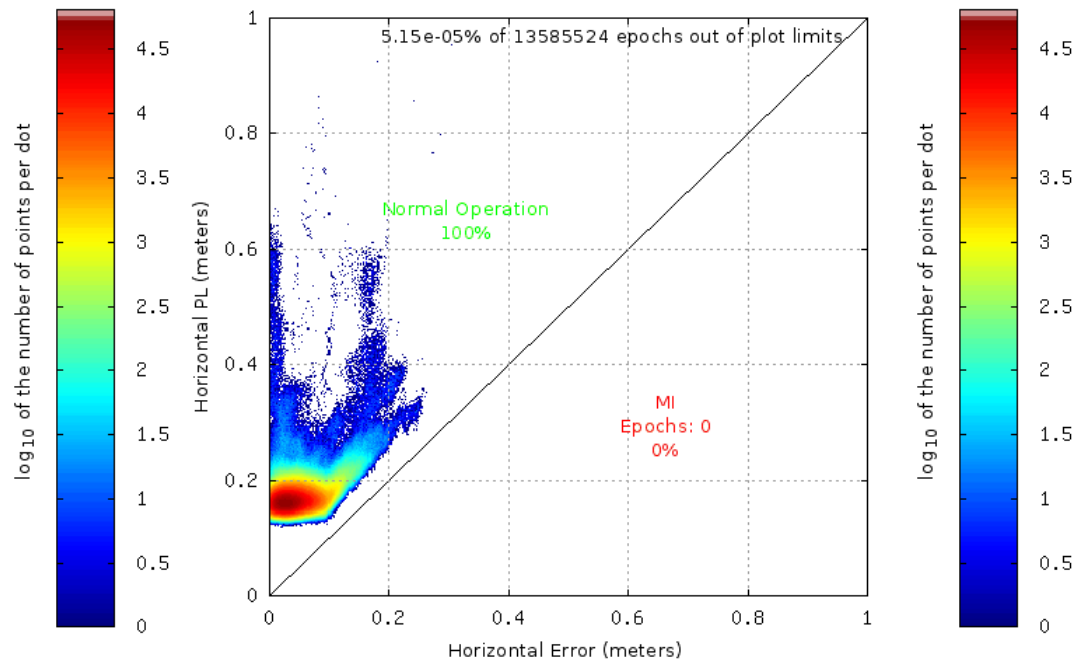
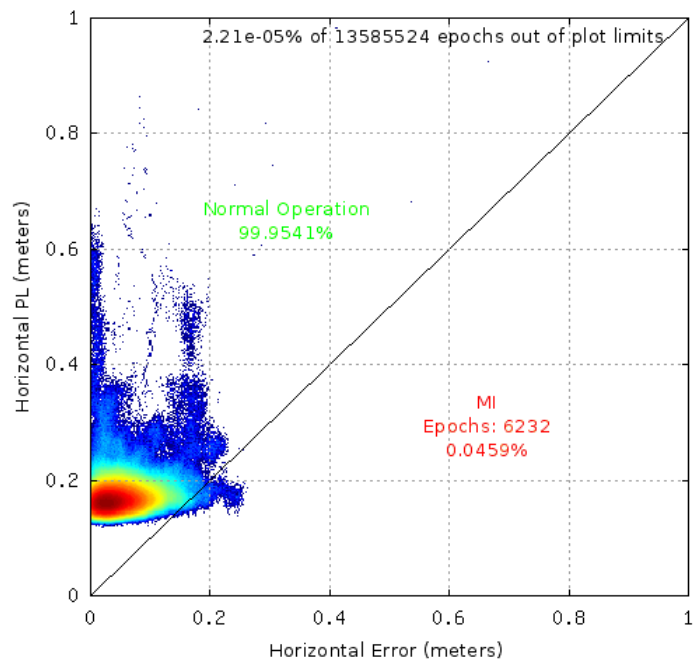
PPP RELIABILITY: INDICATORS



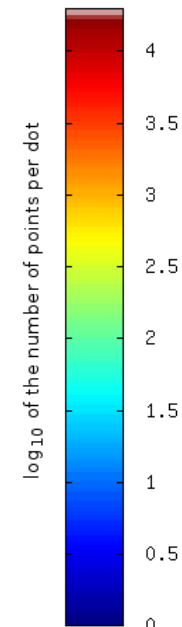
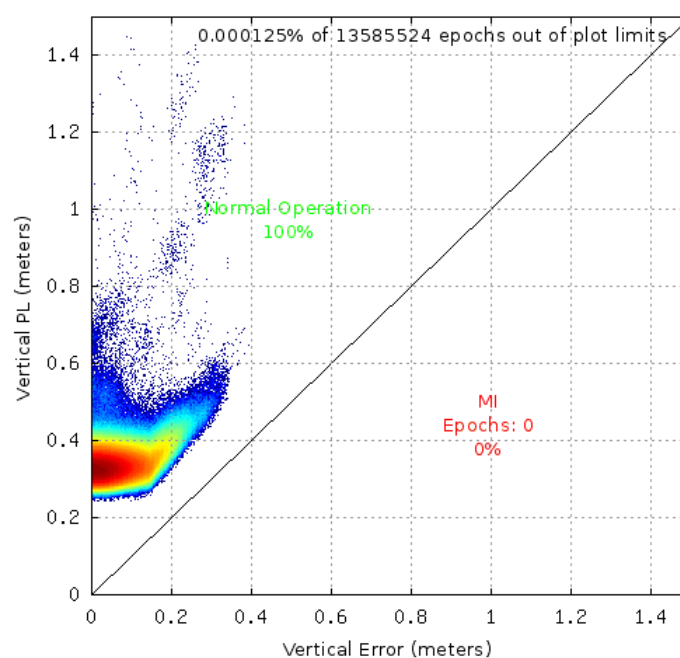
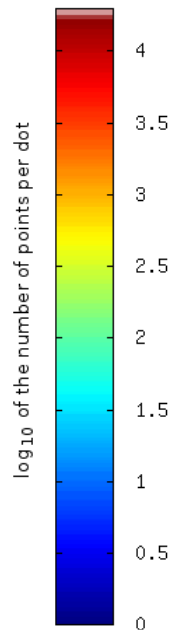
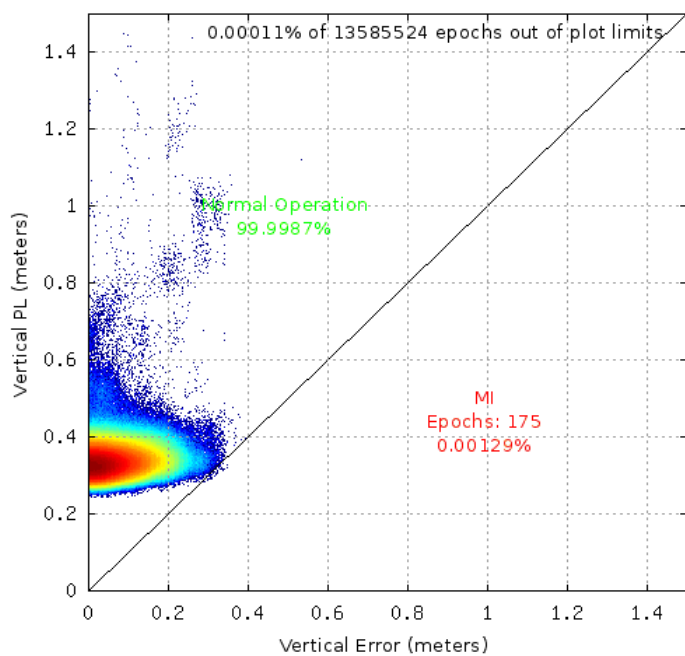
PPP RELIABILITY: INDICATORS



HORIZONTAL RELIABILITY BOUNDING



VERTICAL RELIABILITY BOUNDING



CONCLUSIONS

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- PPP positioning performances are better than 10 cm (H) and better than 15 cm (V), 95%, after 20 min convergence period
- Promising improved reliability bound computation algorithm is being defined
- Reliability bounds of a few decimeters, without integrity failures
- Still margin for improvement
- Need to define way to transmit the product quality indicator to the user for the computation of the reliability bound



Thank you

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