ION GNSS 2014

REAL-TIME PPP WITH GALILEO, PAVING THE WAY TO EUROPEAN HIGH ACCURACY POSITIONING

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SESSION E2: NEXT GENERATION GNSS POSITIONING

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OUTLINE

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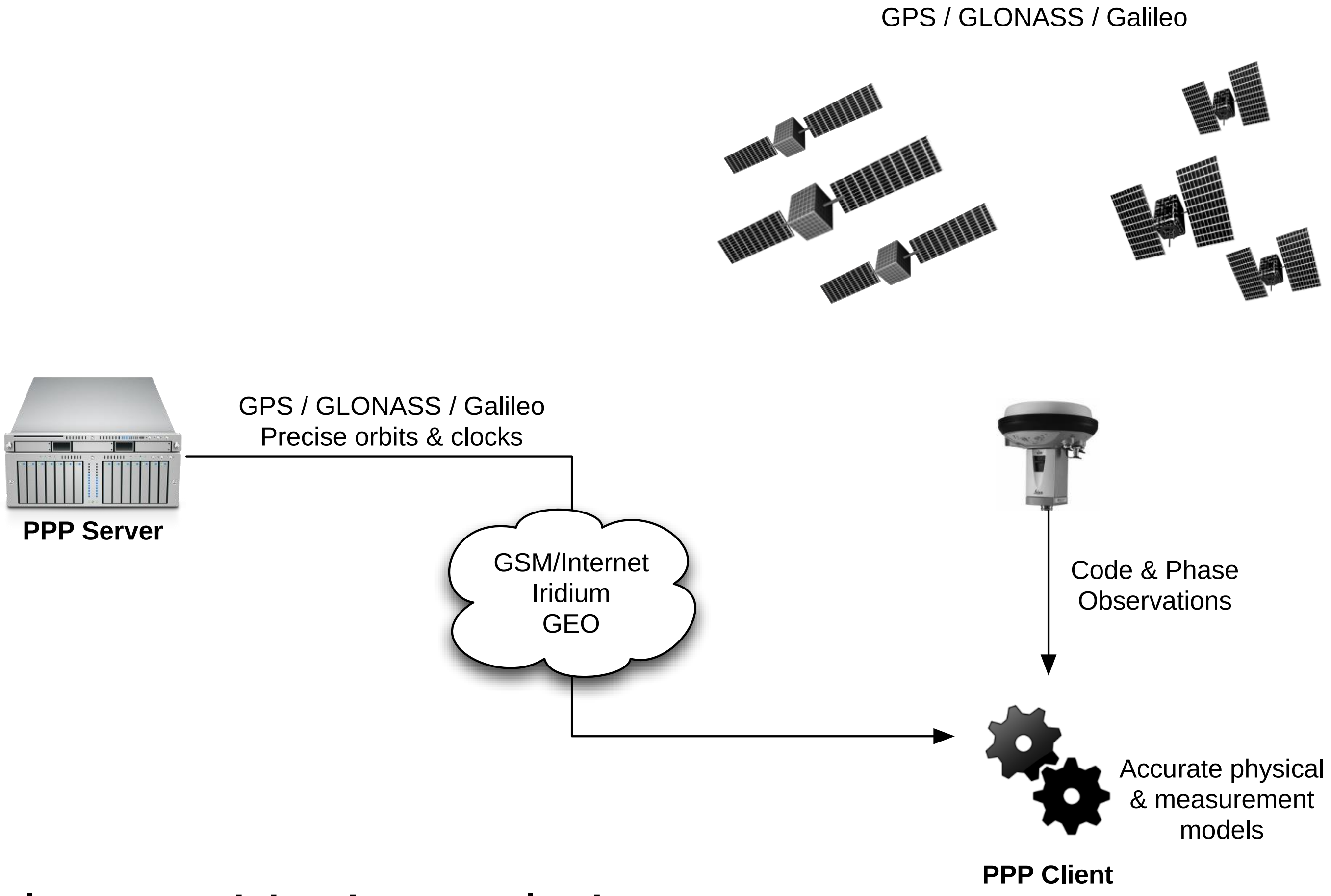
  - Motivation
- *magicGNSS* PPP Infrastructure
  - Server
  - Client
- IGS' MGEX Project
- Galileo contribution to High Accuracy
- Conclusions and future work

PPP: PRECISE POINT POSITIONING



- Absolute positioning technique
- Precise orbits & clocks + observations + detailed models
- Sparse network of reference stations

MOTIVATION

- Background: GNSS POD
  - PPP is a natural evolution
  - Algorithm development, product generation

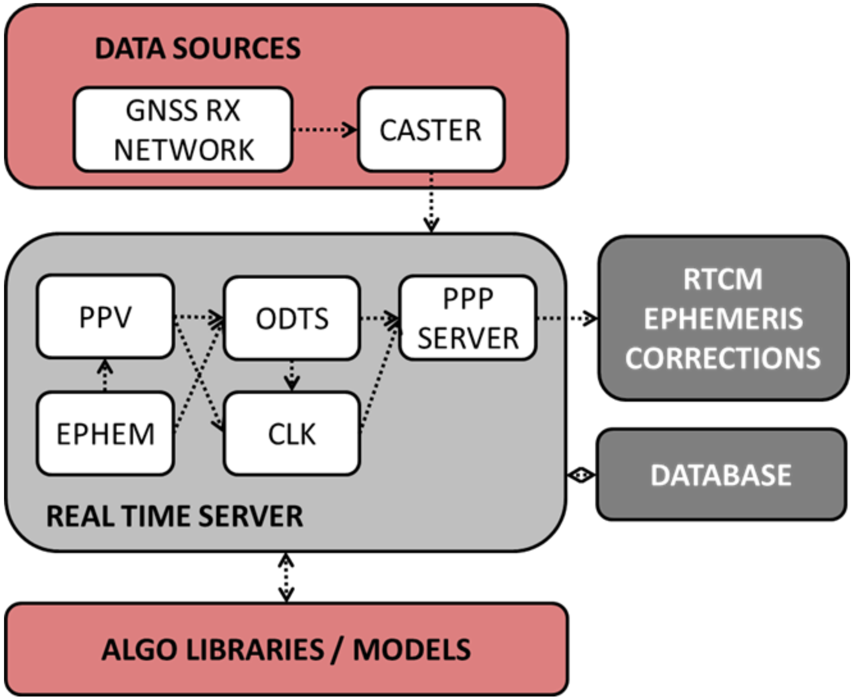
- Evaluate real-time PPP performances in the field
  - Realistic scenarios
  - Static and kinematic

- Learn and overcome the challenges associated to the end-to-end process
  - Communications
  - Robustness and Reliability

- Learn and overcome the challenges associated to implementing the PPP algorithm in portable devices
  - CPU and memory load
  - Power consumption

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

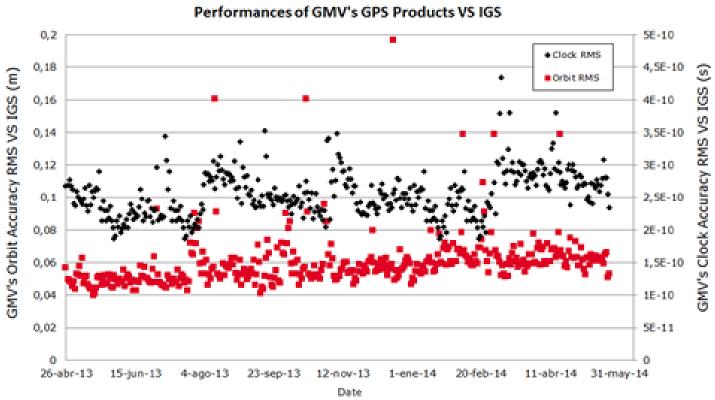


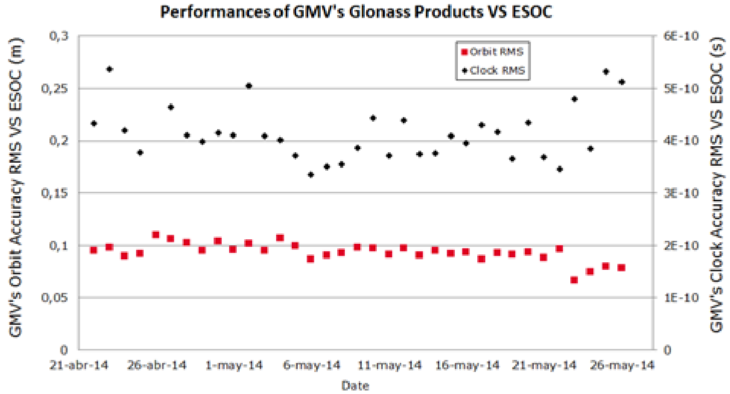
PPP DEMONSTRATOR SERVER PERFORMANCES

- Quality of the Real-Time GPS and GLONASS orbits and clocks has been assessed during the past years versus IGS in the frame of IGS' Real Time Service (rt.igs.org)

- Typical GPS orbit accuracy is about 6 cm, RMS, and clock accuracy is about 0.25 ns, RMS versus IGS rapid products

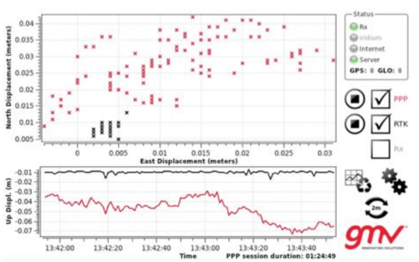
- Typical GLONASS orbit accuracy is about 10 cm, RMS, and clock accuracy is about 0.4 ns, RMS versus ESOC (European Space Operations Centre) products.

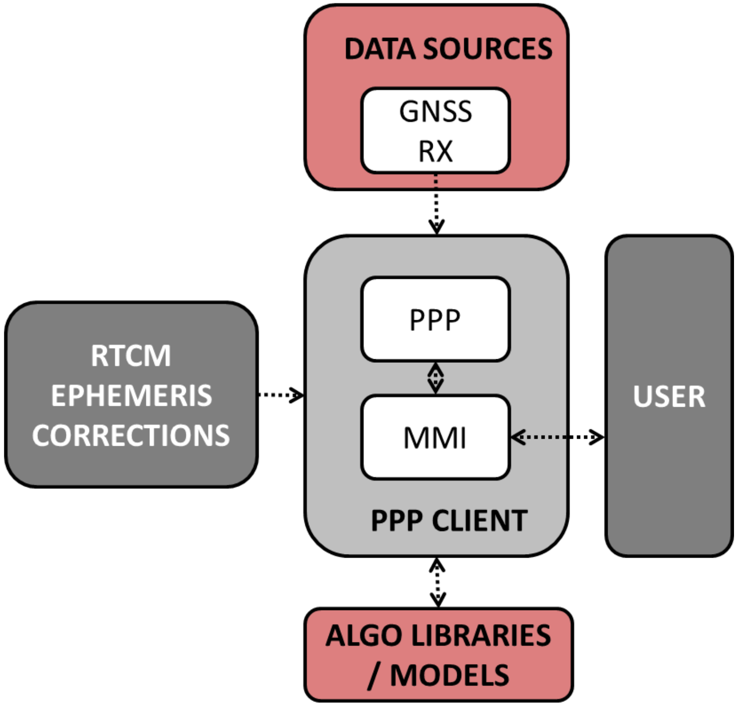




RT PPP DEMONSTRATOR CLIENT

- 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

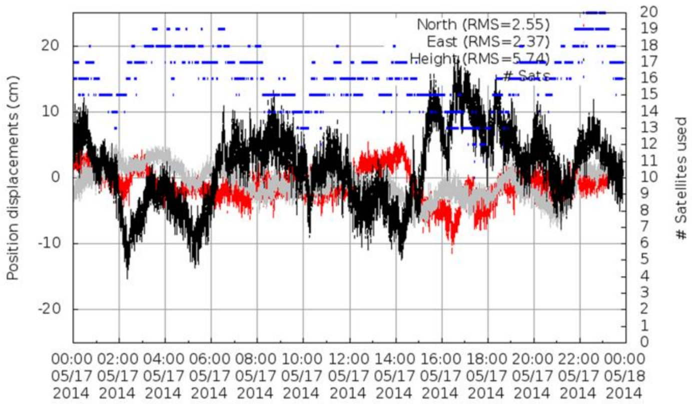




- Position generated in NMEA format
- Allows running RTK by means of rtklib

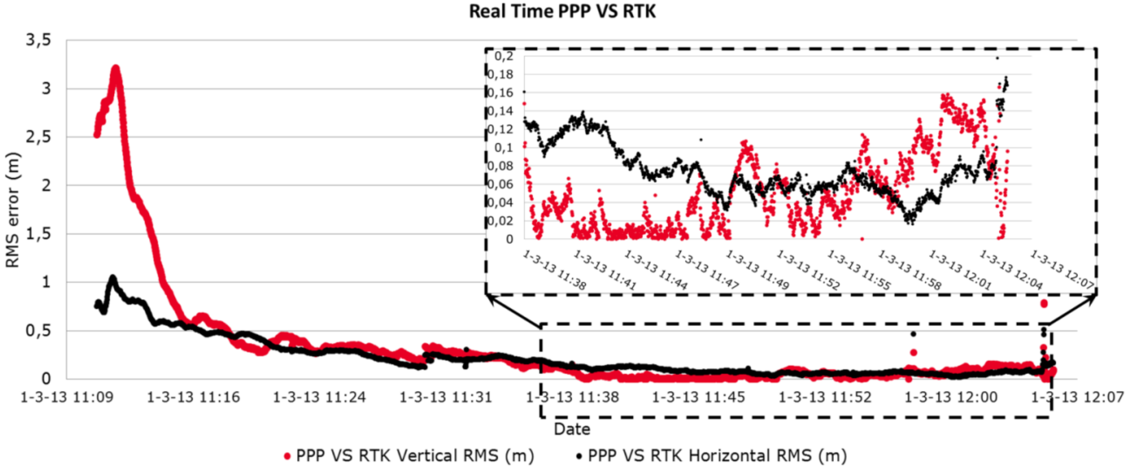
RT PPP DEMONSTRATOR CLIENT PERFORMANCES

- Base station coordinates continuously monitored



- Real-Time PPP performances assessed versus RTK in open field kinematic environments

- Centimetric consistency between RTK and PPP under nominal circumstances



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RTCM STATUS

- The latest RTCM 3.2 standard developed by the SC.104 intends to support highly accurate differential and kinematic positioning as well as a wide range of navigation applications as PPP

- For POD and PPP 3 types of RTCM messages are crucial:
  - Observations
  - Ephemeris
  - Ephemeris correction messages

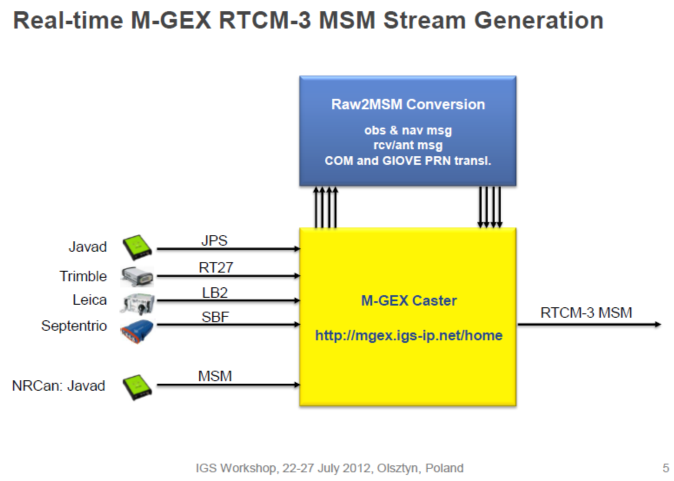
- Multi-GNSS coverage has been improved, but certain gaps persist:

	GPS	GLONASS	Galileo	BeiDou	QZSS
Observations (MSM)	YES	YES	YES	YES	YES
Ephemeris	YES	YES	YES	NO	YES
Ephemeris corrections	YES	YES	NO	NO	NO

IGS' MULTI-GNSS EXPERIMENT PROJECT

- Established to explore and promote the usage of new navigation signals and constellations within the IGS (http://www.igs.org/mgex)

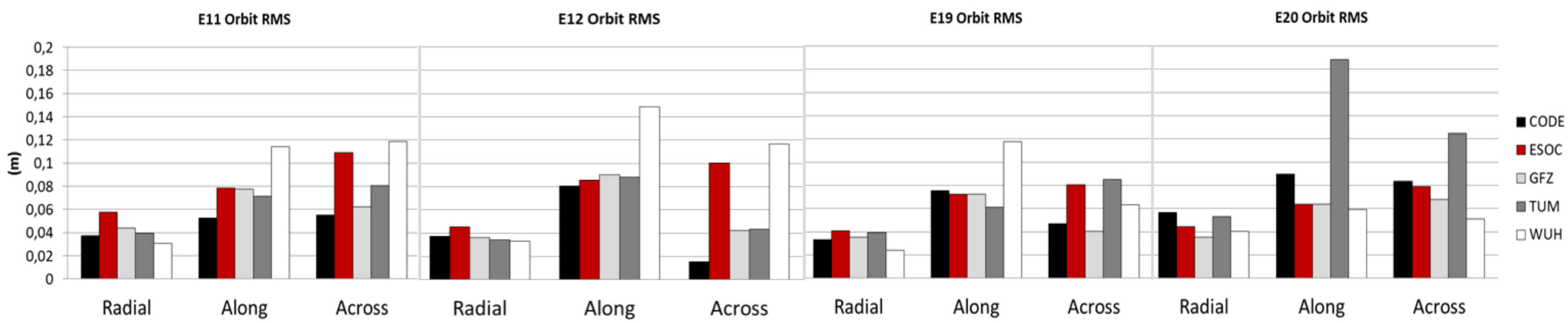
- Multi-GNSS sensor station network
  - Around 110 stations located in 90 sites
  - RTCM3-MSM real-time data streams (5 streams per registered user)
  - RINEX 3.02 data archive



- Multi-GNSS products from 5 AC`s
  - European Space Operations Centre (ESOC)
  - Center for Orbit Determination in Europe (CODE)
  - GeoForschungsZentrum Potsdam (GFZ)
  - Technische Universität München (TUM)
  - Wuhan University

MAGICGNSS’ GALILEO PRODUCTS

- Experimental *magicGNSS’* web server with MGEX stations for reference product generation
- MGEX’ products used as reference for Galileo product quality assessment
- Centimetric consistency between all the solutions



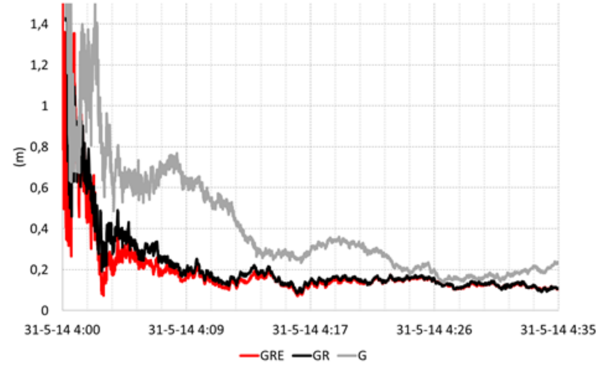
GALILEO-ONLY PPP

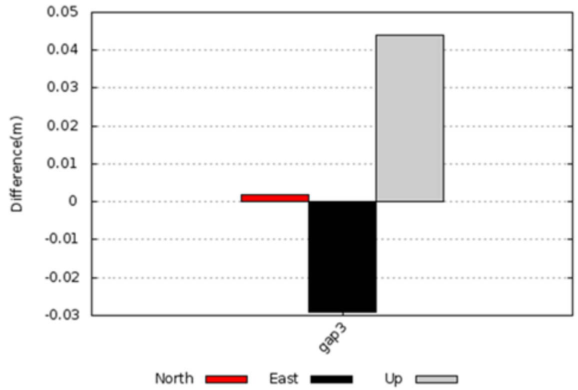
- Data recorded on May 31st 2013 during a 150 minute window with 4 IOV satellites over Tres Cantos.

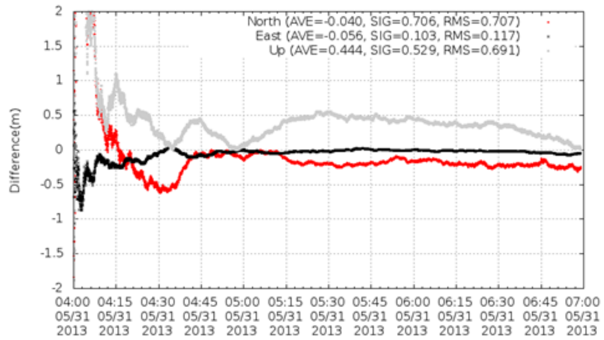
- Reference products obtained by means of *magicGNSS*' web server and MGEX data

- Addition of GALILEO reduces the convergence time w.r.t. a GPS+GLONASS PPP

- GALILEO-only PPP of the recorded RINEX 3.02 data
  - Batch PPP provides centimetric accuracy
  - Sequential PPP converges to decimetric accuracy after 45 minutes







SEQUENTIAL KINEMATIC MULTI-GNSS PPP

- Multi-GNSS data recording around Tres Cantos (close to GMV's premises in Madrid) on August 21st for around 25 minutes by means of a Trimble R10 receiver

- Recorded RINEX post-process by a sequential PPP using as reference products the ones obtained by *magicGNSS'* web server and MGEX' station network

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SEQUENTIAL KINEMATIC MULTI-GNSS PPP (2)

- L2 tracking frequently lost around wooded areas

- The number of usable satellites when driving under wooded areas drops to 5 -> GPS+GLONASS real-time PPP greatly affected

SEQUENTIAL KINEMATIC MULTI-GNSS PPP (3)

- E5 tracking under wooded areas more robust than for L2

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     3.02           OBSERVATION DATA    M (MIXED)           RINEX VERSION / TYPE
R10 4.84            Receiver Operator   21-AUG-14 15:32:38  PGM / RUN BY / DATE
GAP3                                                        MARKER NAME
GEODETIC                                                    MARKER TYPE
GMV                 GMV                                     OBSERVER / AGENCY
5308426580          Trimble R10         4.84                REC # / TYPE / VERS
                    TRMR10             NONE                 ANT # / TYPE
  4836348.1314  -319283.3733  4133351.6395                  APPROX POSITION XYZ
       -0.1491        0.0000        0.0000                  ANTENNA: DELTA H/E/N
G   12 C1C L1C S1C C2W L2W S2W C2X L2X S2X C5X L5X S5X      SYS / # / OBS TYPES
R   12 C1C L1C S1C C1P L1P S1P C2C L2C S2C C2P L2P S2P      SYS / # / OBS TYPES
E   12 C1X L1X S1X C5X L5X S5X C7X L7X S7X C8X L8X S8X      SYS / # / OBS TYPES
     1.000                                                  INTERVAL
  2014     8    21    15    32   38.0000000     GPS         TIME OF FIRST OBS
G L2X -0.25000                                              SYS / PHASE SHIFT
R L1P  0.25000                                              SYS / PHASE SHIFT
R L2C -0.25000                                              SYS / PHASE SHIFT
GIOVE-A if present is mapped to satellite ID 51             COMMENT
GIOVE-B if present is mapped to satellite ID 52             COMMENT
DBHZ                                                        SIGNAL STRENGTH UNIT
                                                            END OF HEADER
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> 2014  8 21 16 14 24.0000000  0 12       0.000069731000
R01  20634138.836 7 110301335.515 7        42.000    20634138.039 6 110301291.524 6        40.500    20634146.277 6  85789938.681 6        37.600    20634147.242 6  85789931.685 6        37.500
G11  21584130.570 7 113425271.274 7        45.600    21584135.258 5  88383438.769 5        31.800
G30  25082567.734 6 131809769.985 6        39.200
G32  22528817.750 6 118389833.408 6        41.400
G22  21742855.695 7 114259477.544 7        42.500    21742859.262 4  89033374.894 4        28.800
G01  22913046.945 6                        40.100
G16  23622122.961 6                        39.500
E11  25826385.242 6 135718522.937 6        41.700    25826387.566 6 101348266.657 6        40.700    25826386.066 6 103992149.822 6        41.200    25826387.223 8 102670227.345 8        48.400
E12  23485301.023 7 123416087.349 7        46.900    23485302.359 7  92161373.221 7        42.800    23485301.516 7  94565577.586 7        42.500    23485302.191 8  93363475.512 8        50.200
E19  24275407.453 7 127568137.759 7        42.100    24275411.625 7  95261938.133 7        45.600    24275410.828 7  97747023.605 7        46.000    24275411.230 8  96504564.475 8        53.300
G19  20439242.227 8 107408942.215 8        48.500    20439245.508 6  83695292.457 6        38.400
G27  20858288.211 7 109611035.653 7        47.200    20858296.297 6  85411219.257 6        38.300    20858296.086 7  85411218.263 7        45.100    20858295.582 8  81852417.888 8        51.300
> 2014  8 21 16 14 25.0000000  0 12       0.000069977000
R01  20633623.328 6 110298582.310 6        41.900    20633622.648 6 110298538.319 6        40.300    20633631.469 6  85787797.302 6        36.600    20633632.094 6  85787790.298 6        37.000
G11  21583761.711 7 113423336.773 7        45.200    21583767.020 5  88381931.357 5        31.900
G30  25082840.063 6 131811198.972 6        39.200
G32  22528230.016 5                        35.100
G22  21743255.109 7 114261575.673 7        43.900    21743258.387 5  89035009.812 5        32.100
G01  22912625.664 7 120406612.337 7        42.300
G16  23622895.203 6 124139109.586 6        39.200
E11  25826069.852 6 135716865.388 6        41.800    25826072.113 6 101347028.880 6        40.100    25826070.941 6 103990879.758 6        41.900    25826071.848 8 102668973.425 8        48.600
E12  23485285.625 7 123416006.190 7        46.900    23485286.852 7  92161312.622 7        43.200    23485286.289 7  94565515.400 7        42.700    23485286.754 8  93363414.115 8        50.500
E19  24275278.820 7 127567463.375 7        42.700    24275283.227 7  95261434.534 7        45.800    24275282.430 7  97746506.874 7        46.000    24275282.898 8  96504054.310 8        53.500
G19  20439269.719 8 107409086.792 8        48.500    20439272.676 6  83695405.116 6        38.400
G27  20858635.344 7 109612859.598 7        46.900    20858643.883 6  85412640.513 6        38.300    20858643.320 7  85412639.518 7        45.100    20858642.871 8  81853779.917 8        51.300
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- Does the addition of Galileo (even with just 3 satellites) ease the impact of the L2 tracking loses in the end PPP performances?

SEQUENTIAL KINEMATIC MULTI-GNSS PPP (4)

- Notable PPP improvement by the addition of Galileo

- Overall robustness increased by the addition of just 3 satellites

- Promising results once the full constellation is deployed

CONCLUSIONS AND FUTURE WORK

- Even with only 3 operating satellites, Galileo has proven to provide a remarkable contribution to the PPP performances increasing the PPP robustness under challenging environments

- MSM data availability and multi-GNSS ephemeris correction message definition issues need to be solved for multi-GNSS infrastructure testing in real-time

- Future work focused on testing our *magicGNSS'* real-time infrastructure to try to increase the robustness and analyse the benefits of using additional GNSS constellations

Thank you

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