GALILEO: POSITIONING EVOLUTION

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2005 - 2008

DEVELOPMENT

SYSTEM TESTED

GIOVE A – B

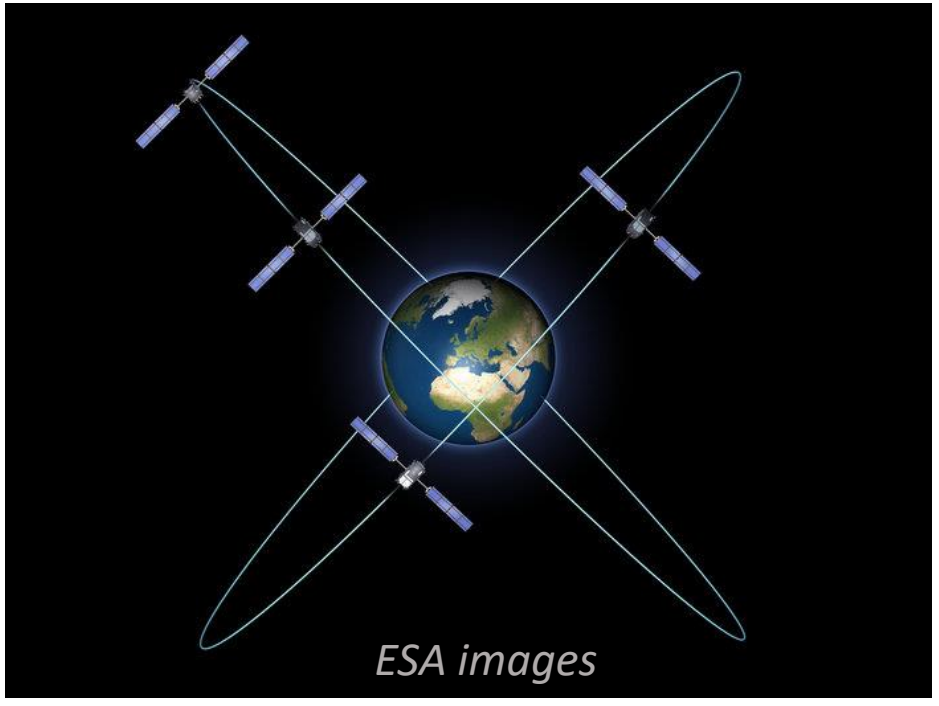
2013

IN-ORBIT

VALIDATION PHASE

4 IOV satellites

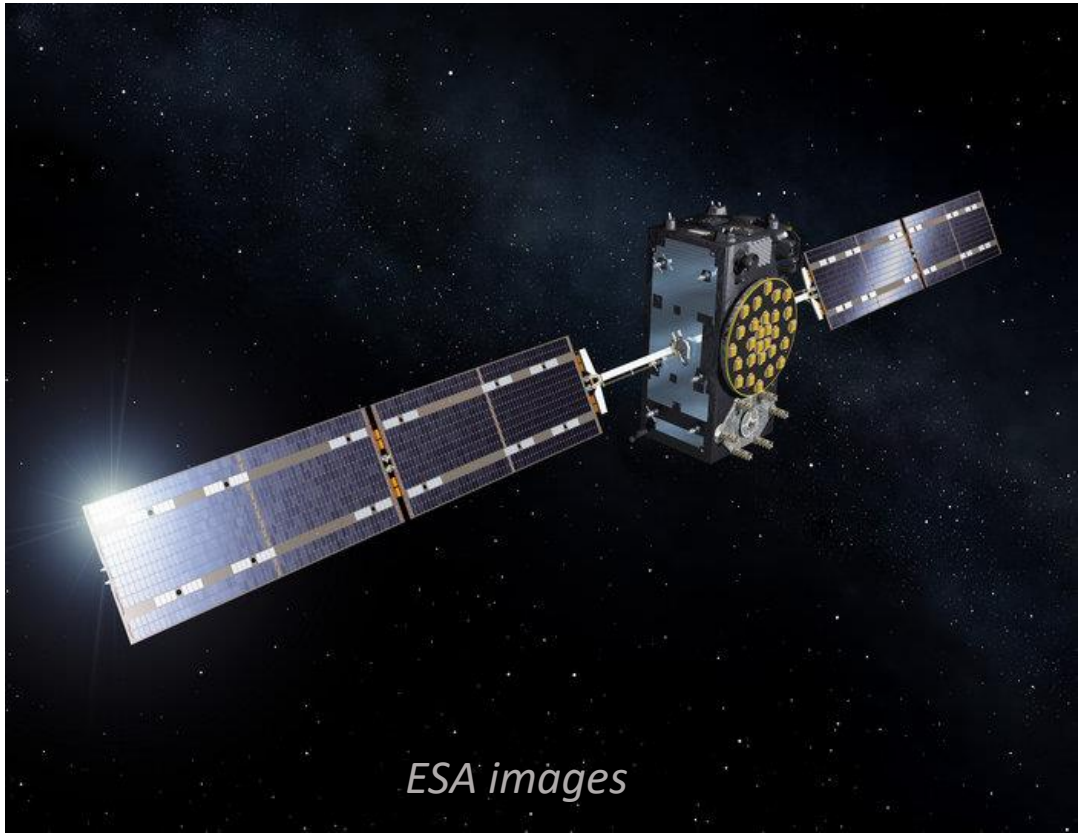
Initial ground infrastructure



2016

INITIAL GALILEO SERVICES

OS, SAR, PRS, CS demonstration



2014 - 19

DEPLOYMENT PHASE

FOC system deployment

2020

FULL OPERATIONAL CAPABILITY

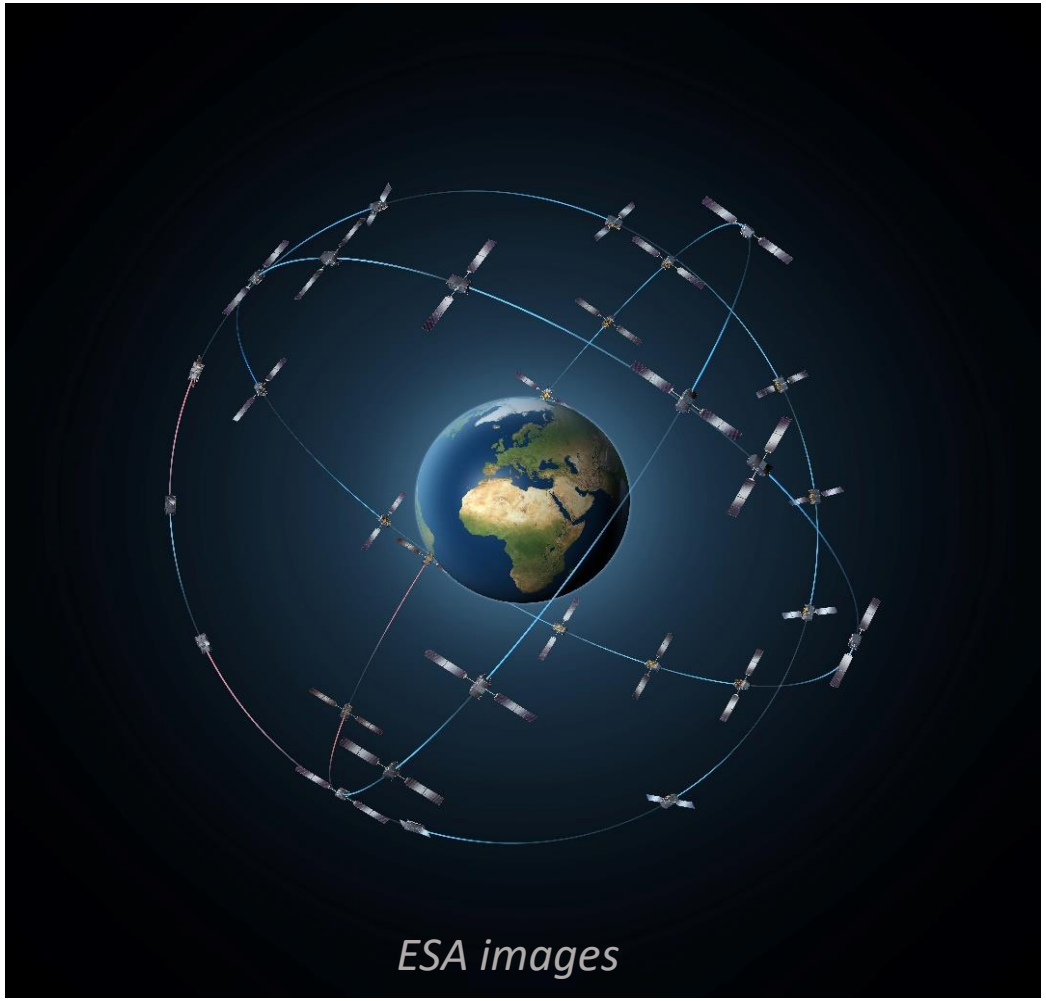
24 operational satellites

+

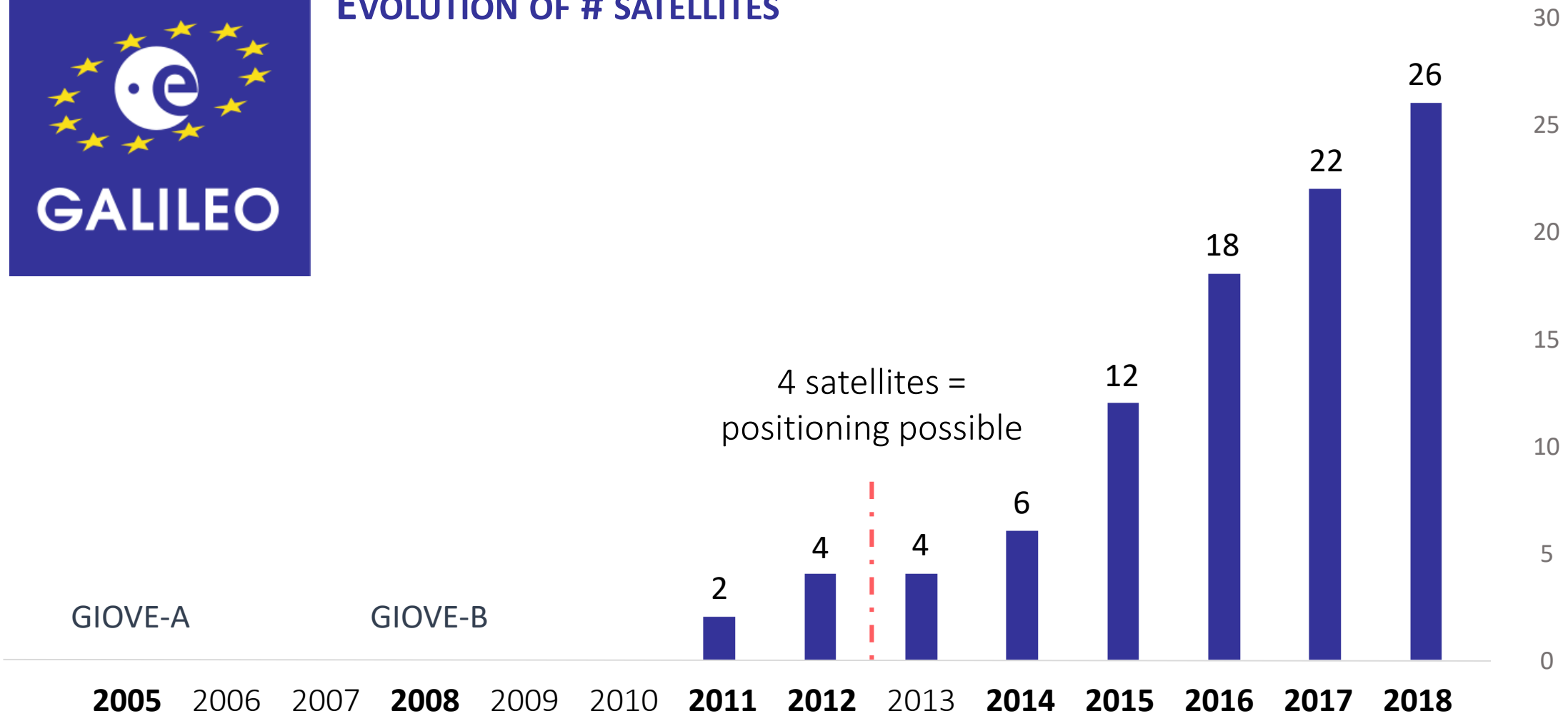
6 spares satellites

+

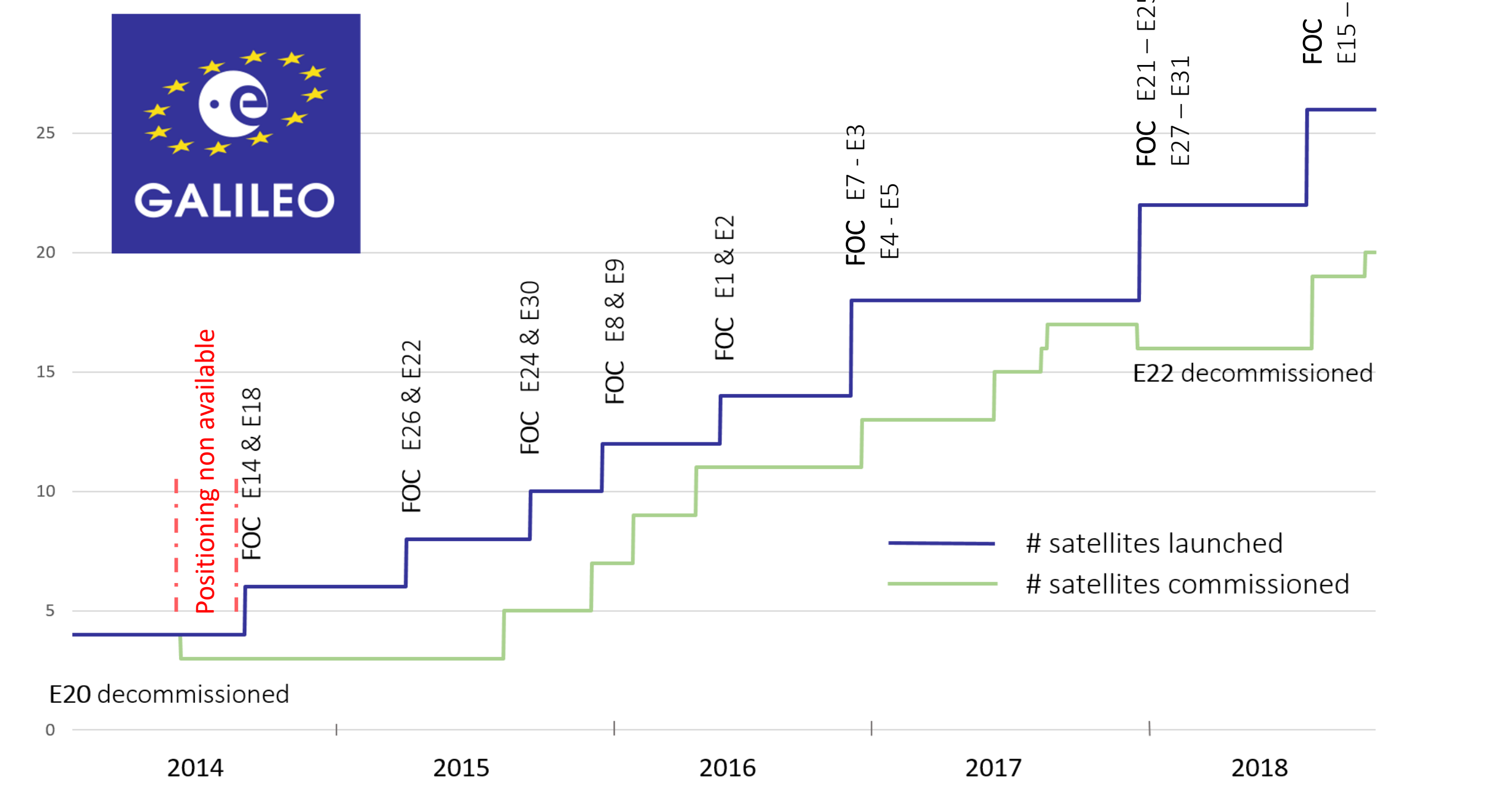
Complete ground infrastructure



EVOLUTION OF # SATELLITES



TEST PROTOTYPES | **IOV** | **FOC**


GALILEO
25
20
15
10
5
0
2014
2015
2016
2017
2018
Positioning non available
FOC E14 & E18
FOC E26 & E22
FOC E24 & E30
FOC E8 & E9
FOC E1 & E2
FOC E7 - E3
E4 - E5
FOC E21 – E2
E27 – E31
FOC
E15 –
E22 decommissioned
E20 decommissioned
satellites launched
satellites commissioned

2014

December 10, 2014

GPS

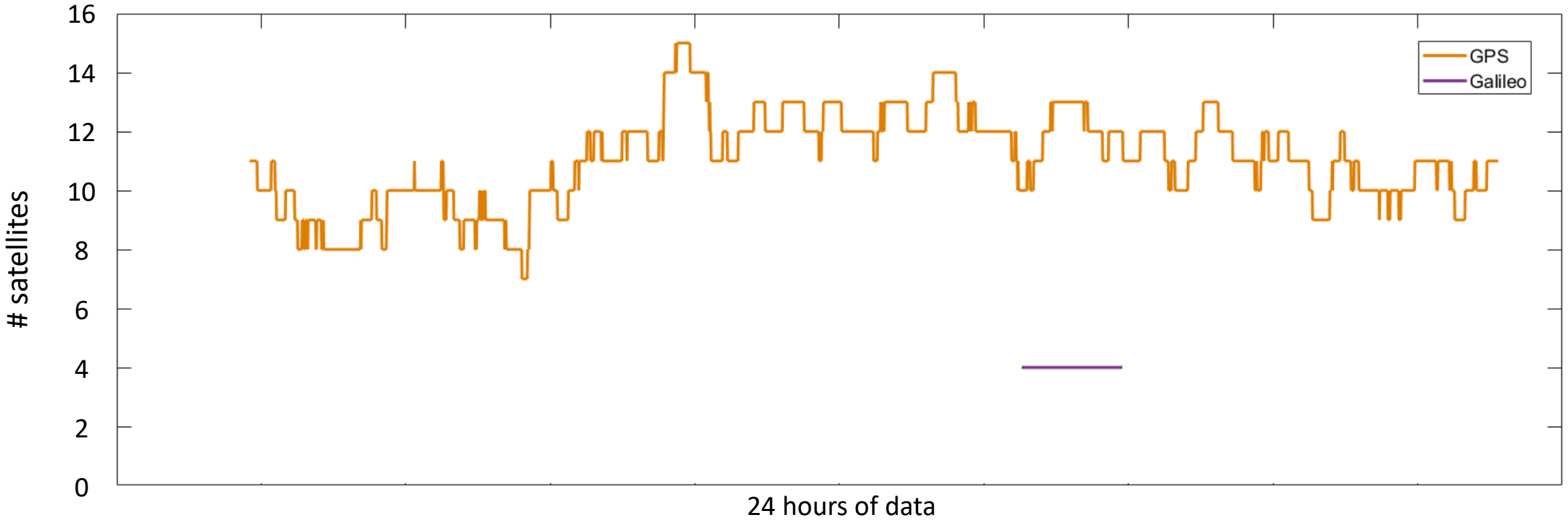
Mean # of satellites: **11**

Observation duration: **24h**

Galileo 5 visible satellites

Mean # of satellites: **4**

Observation duration: **1h56**



Elev min: 0°

2015

December 27, 2015

GPS

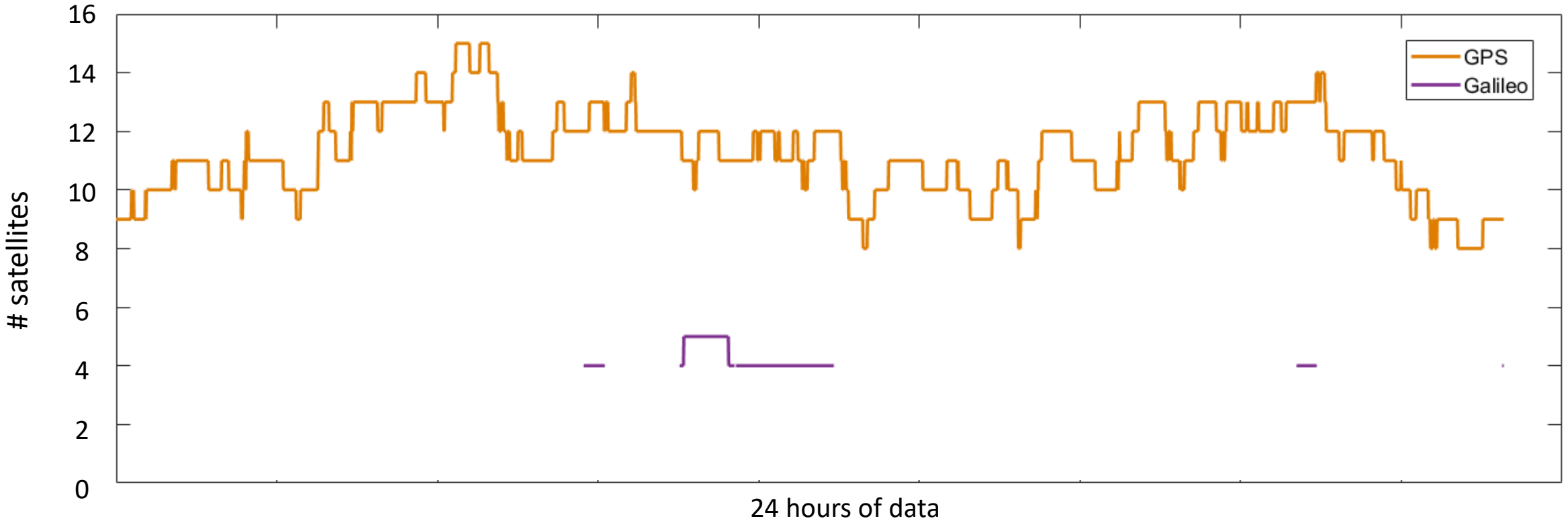
Mean # of satellites: **11.3**

Observation duration: **24h**

Galileo 9 visible satellites

Mean # of satellites: **4.2**

Observation duration: **3h25**



Elev min: 0°

2016

December 1, 2016

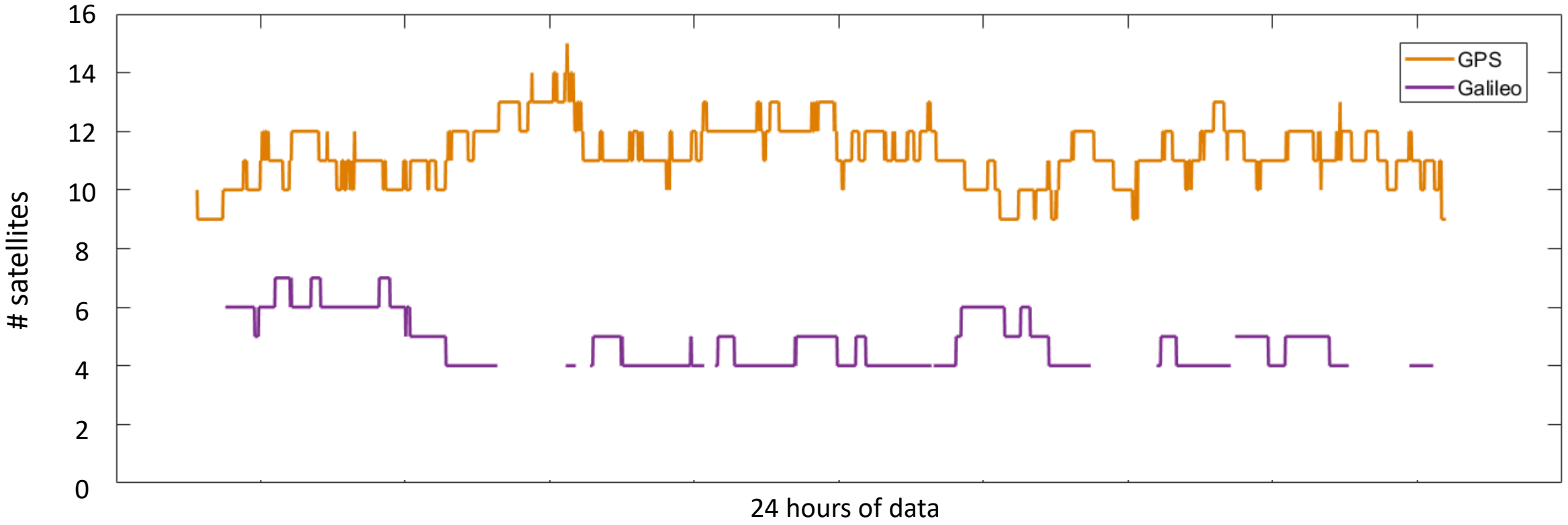
GPS **Galileo** 13 visible satellites

Mean # of satellites: **11.3**

Observation duration: **24h**

Mean # of satellites: **4.8**

Observation duration: **18h55**



Elev min: 0°

2017

November 16, 2017

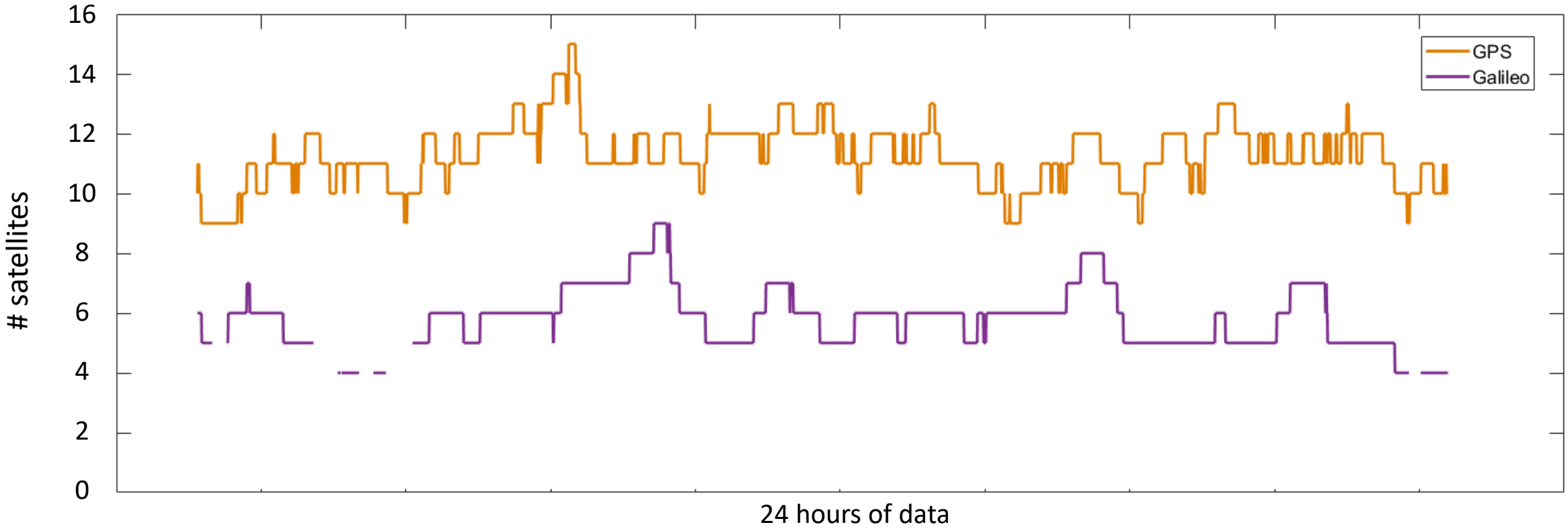
GPS **Galileo** 17 visible satellites

Mean # of satellites: **11.3**

Observation duration: **24h**

Mean # of satellites: **6.2**

Observation duration: **22h43**



Elev min: 0°

2018

October 15, 2018

GPS

Mean # of satellites: **11.1**

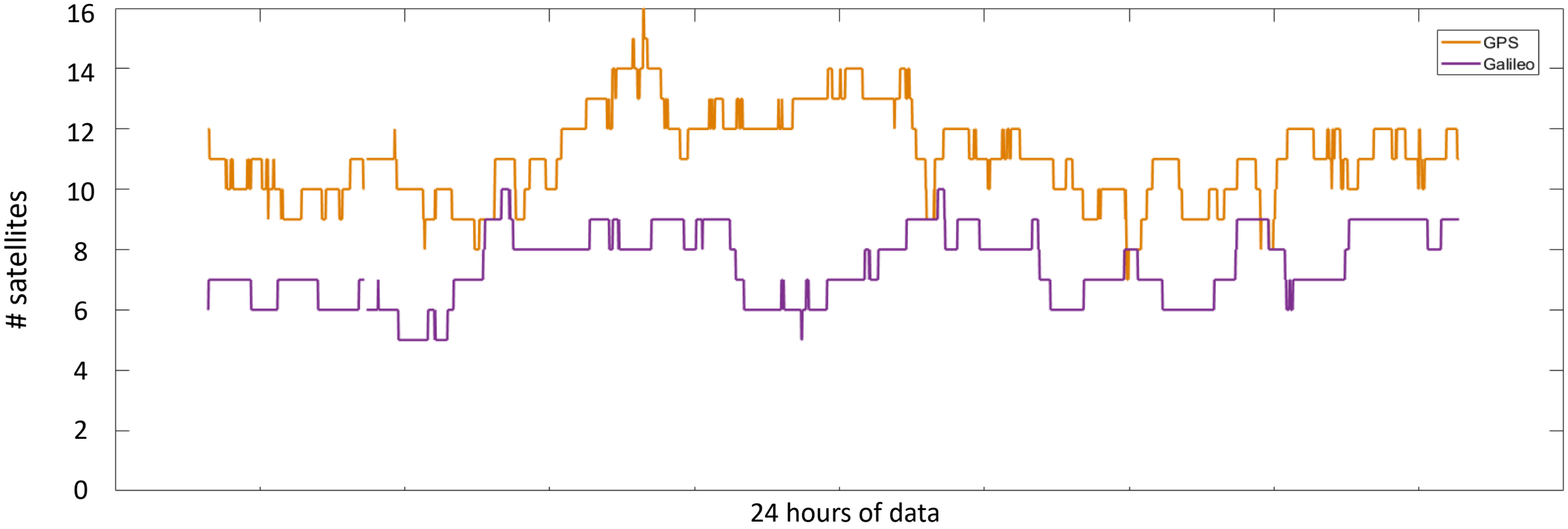
Observation duration: **24h**

Galileo

Mean # of satellites: **7.4**

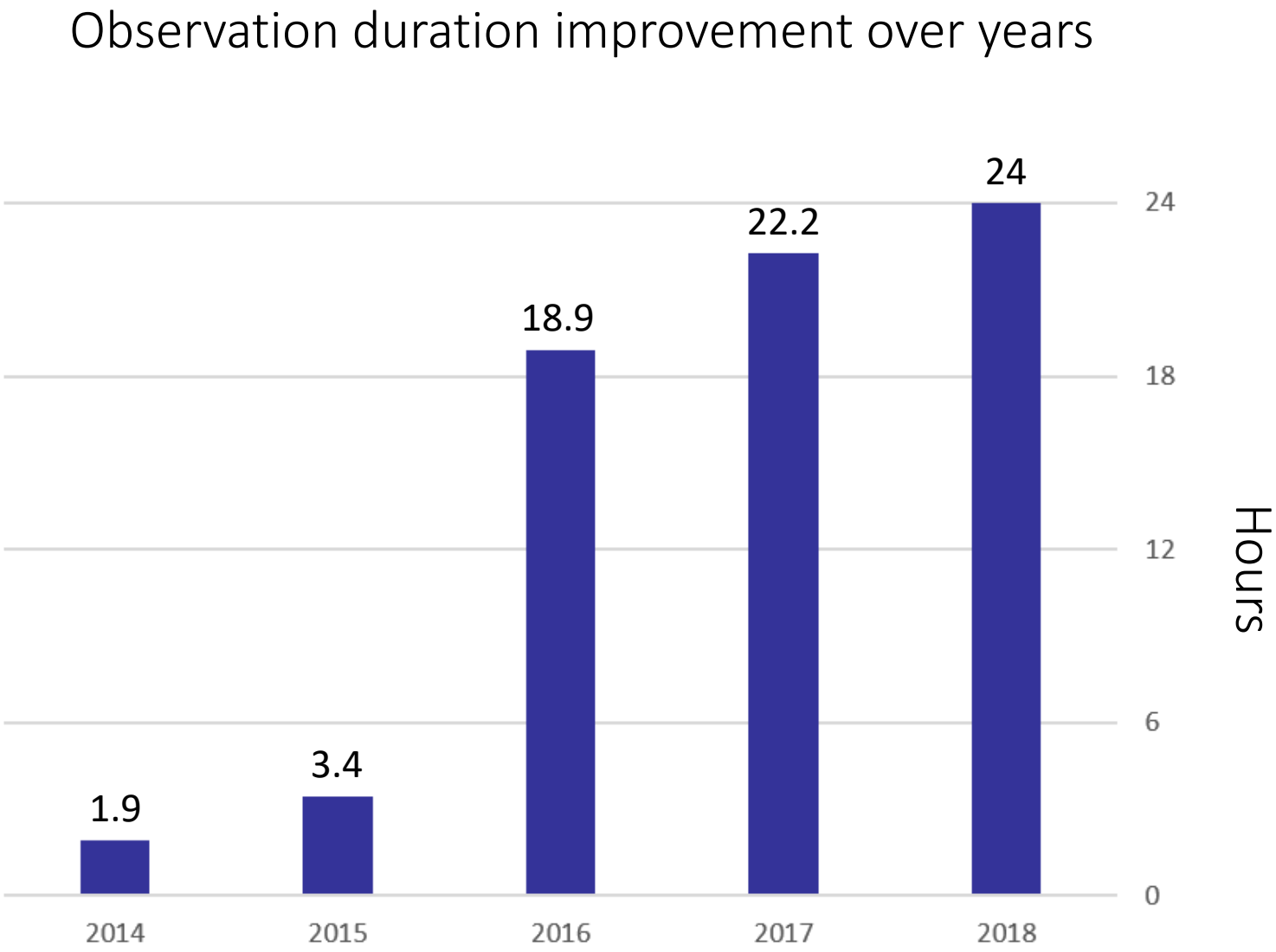
Observation duration: **24h**

24 visible satellites



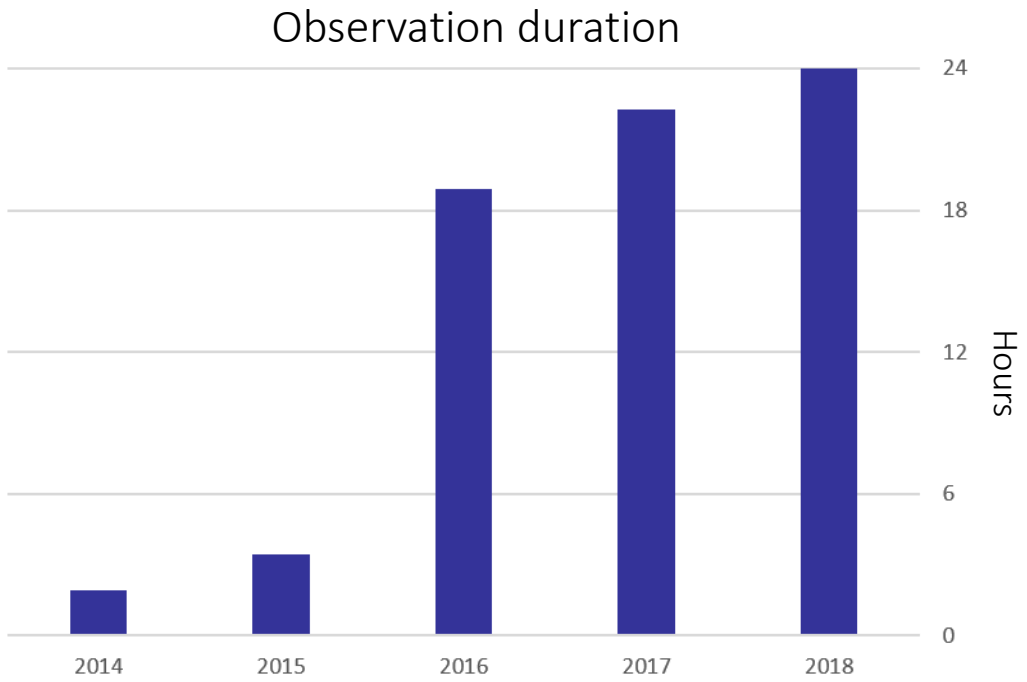
Elev min: 0°

Summary:


Observation duration improvement over years
1.9
3.4
18.9
22.2
24
2014
2015
2016
2017
2018
0
6
12
18
24
Hours

2018 conclusions :

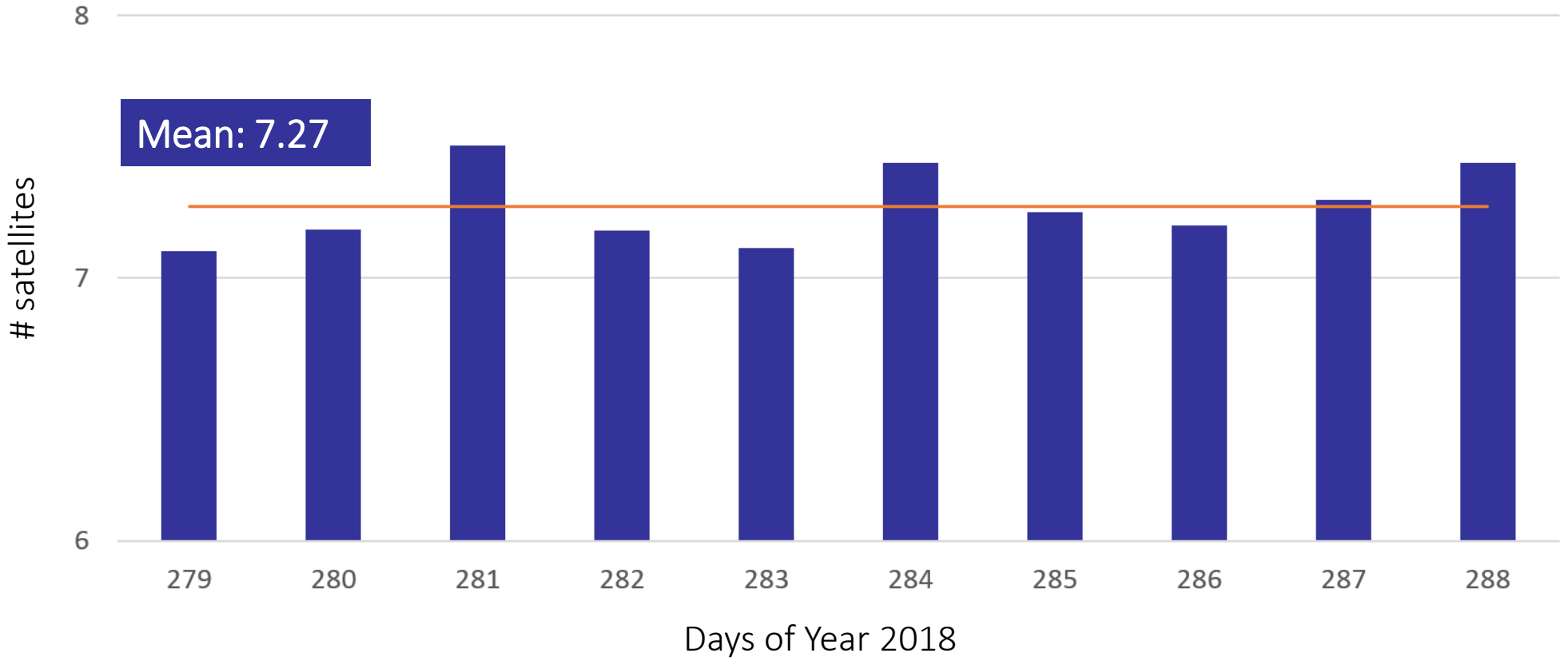
- **24** visible satellites : **24h** observation!
- Average # visible satellites/day : **7.4**
  [GPS : 11.3]
  - Min # visible satellites : **5**
    [GPS : 7]
  - Max # visible satellites : **10**
    [GPS : 16]



⟶ Positioning with **Galileo-only** possible anytime during the day

Evolution of the mean # satellites visible/day over 10 days in 2018:

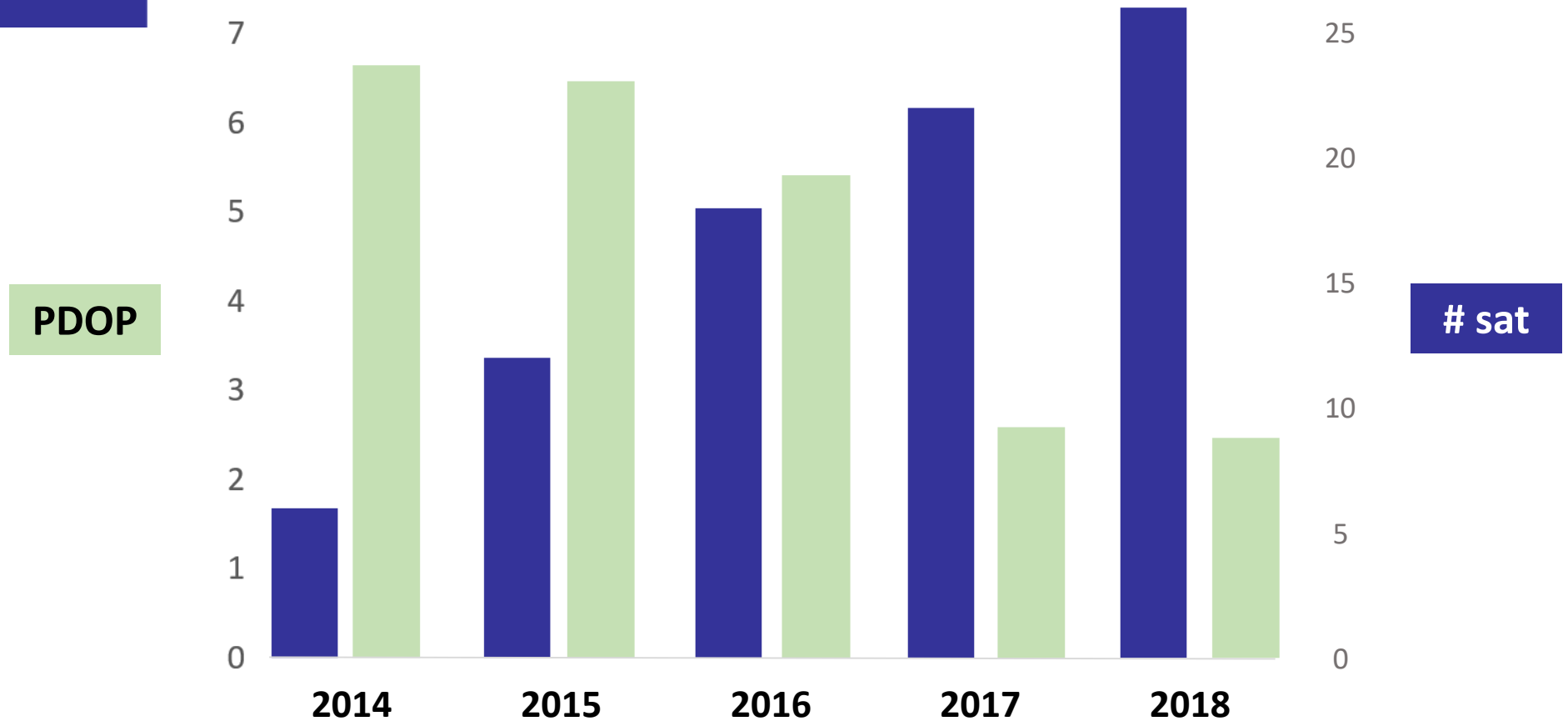
Galileo = 10 days periodicity



EVOLUTION OF GEOMETRY [PDOP]

- Increase in # satellites improves geometry

  → Precision of positioning improved : $\sigma_{POS} = \sigma_{OBS} . DOP$



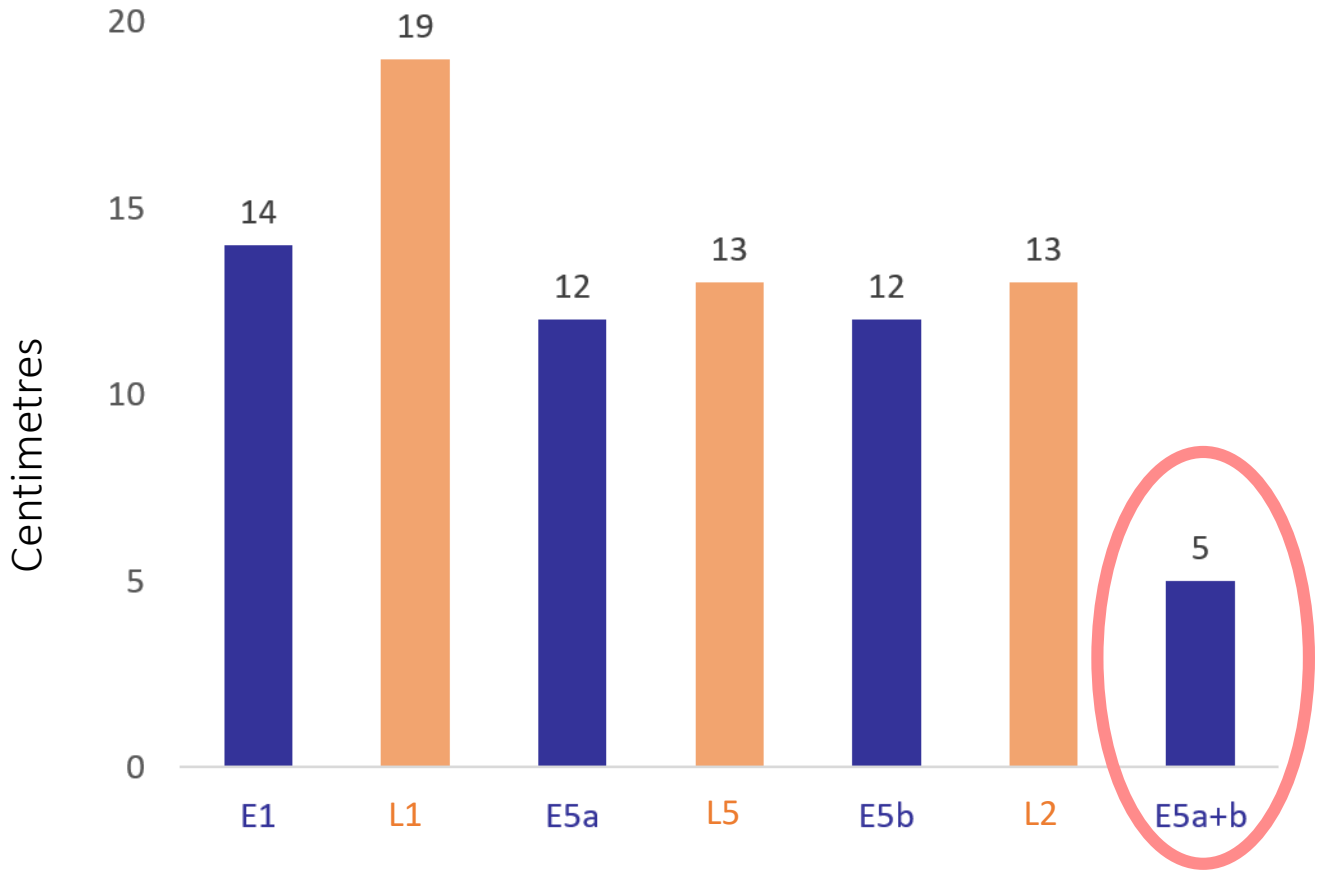
Signals

- Galileo E1
- Galileo E5a
- Galileo E5b
- Galileo E5a+b

All users

- Galileo E6

Signal quality : Codes

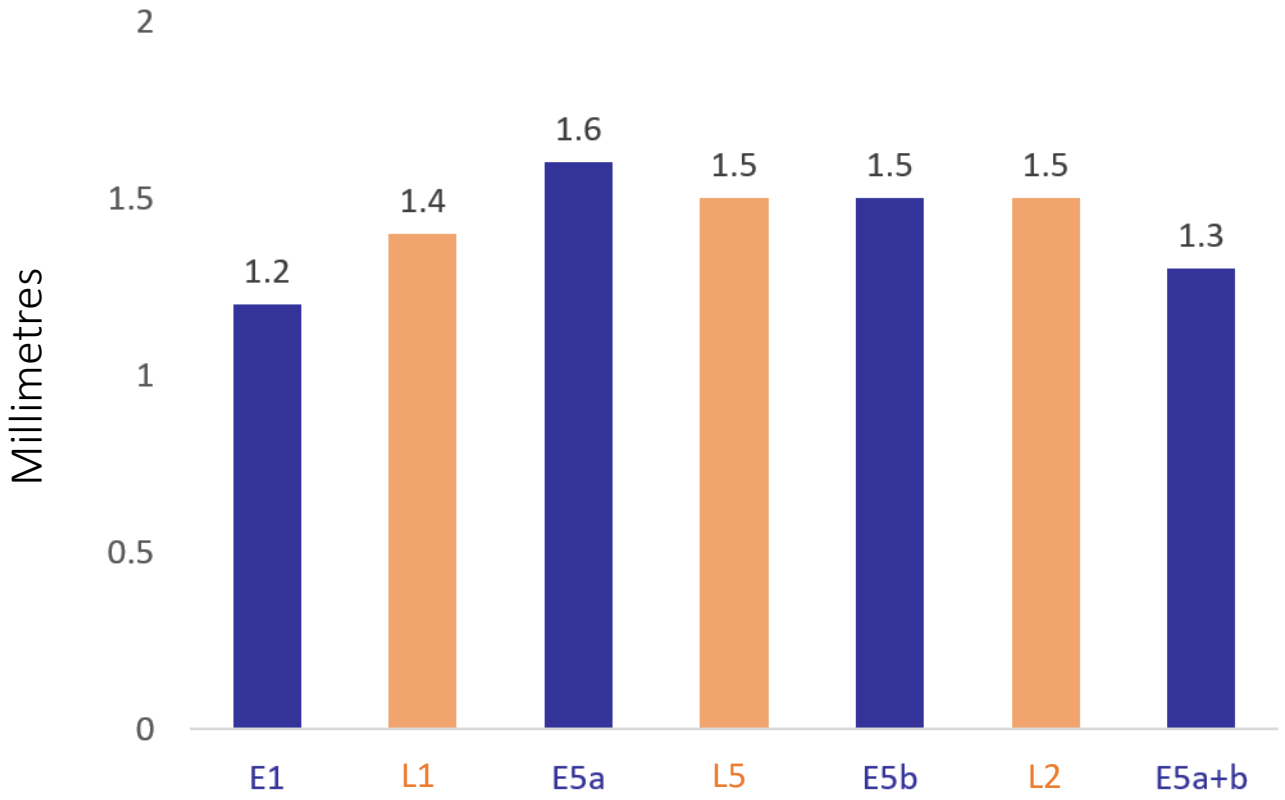


Galileo

GPS

Short baseline (5.6 m) between two Septentrio X4 connected to two choke ring Trimble antennas

Signal quality : Phases



Galileo

GPS

Short baseline (5.6 m) between two Septentrio X4 connected to two choke ring Trimble antennas

Positioning techniques

	Codes	Phases
One receiver	Single Point Positioning **(SPP)**	Precise Point Positioning (PPP)
Expected 3D precision	~ 5-20 m	~ 0.01 m
Two receivers	**DGNSS (DGPS)**	Real Time Kinematic **(RTK)**
Expected 3D precision	~ 1-3 m	~ 0.10 m

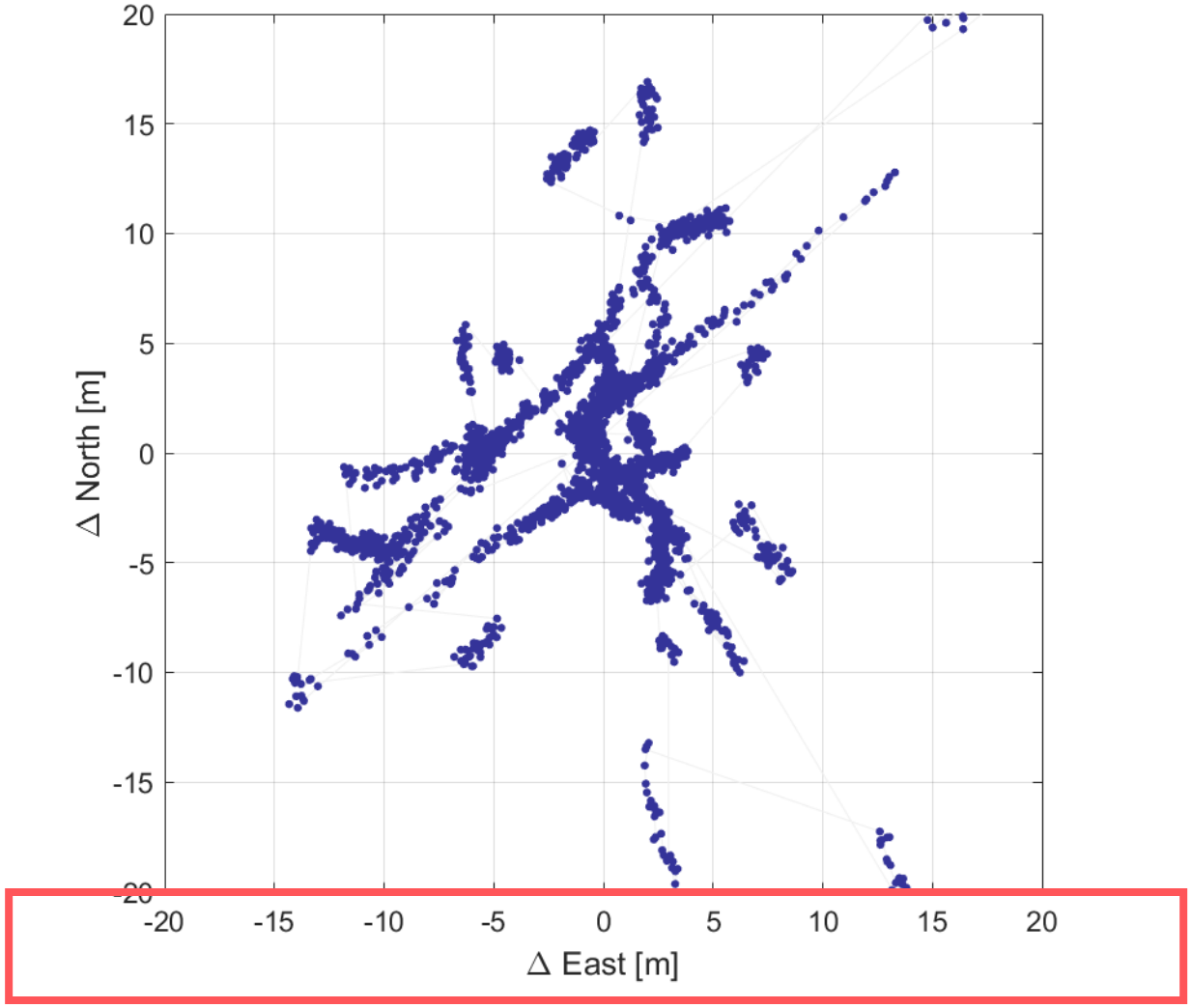
Values given in reference to ellipsoid WGS84

Short baseline (5.6 m) between two Trimble NetR9 connected to two choke ring Trimble antennas

Positioning with Galileo

SPP

Galileo E1:

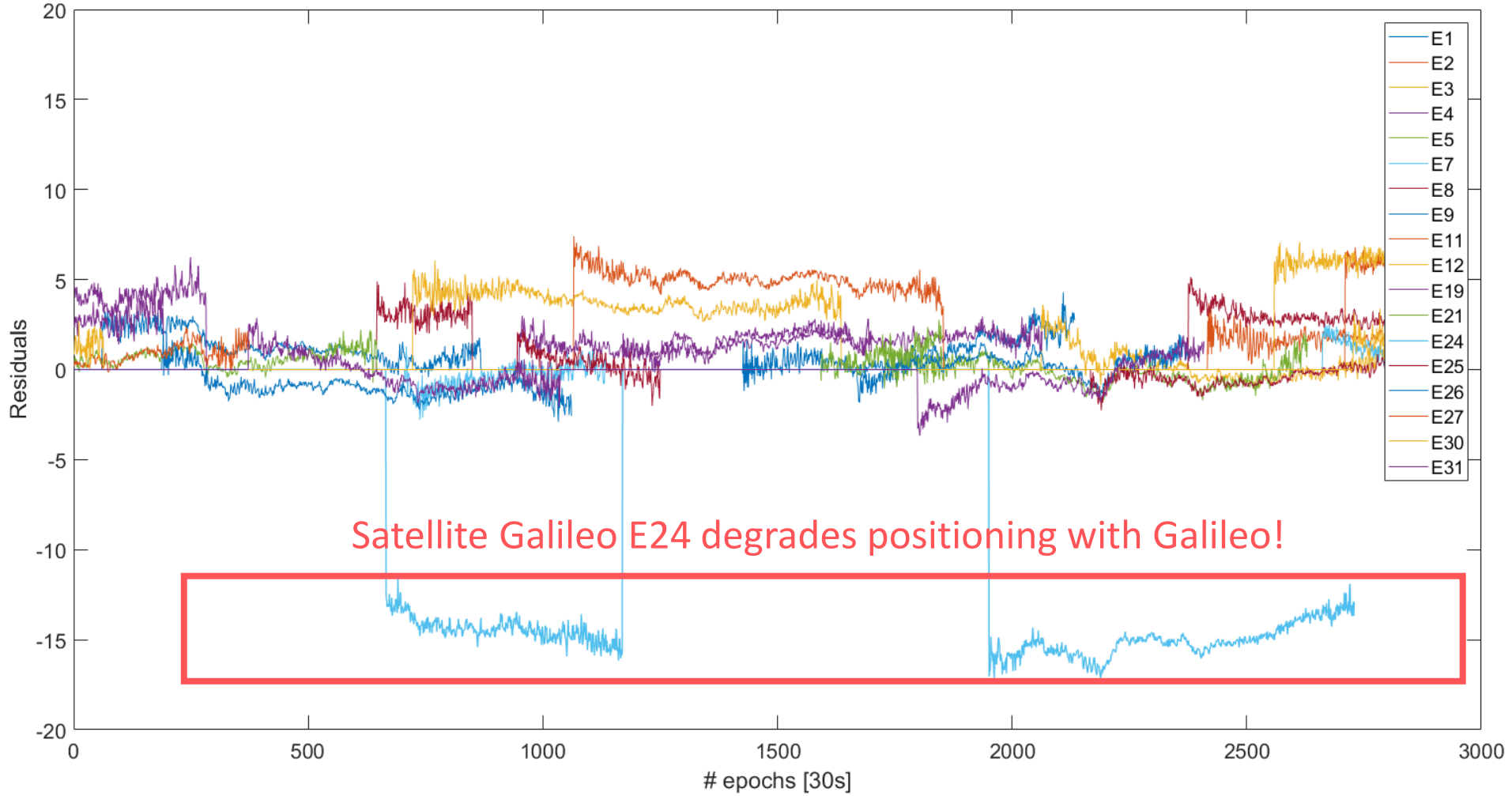


Galileo E1

Position 3D: 10.79 m

Positioning with Galileo

SPP

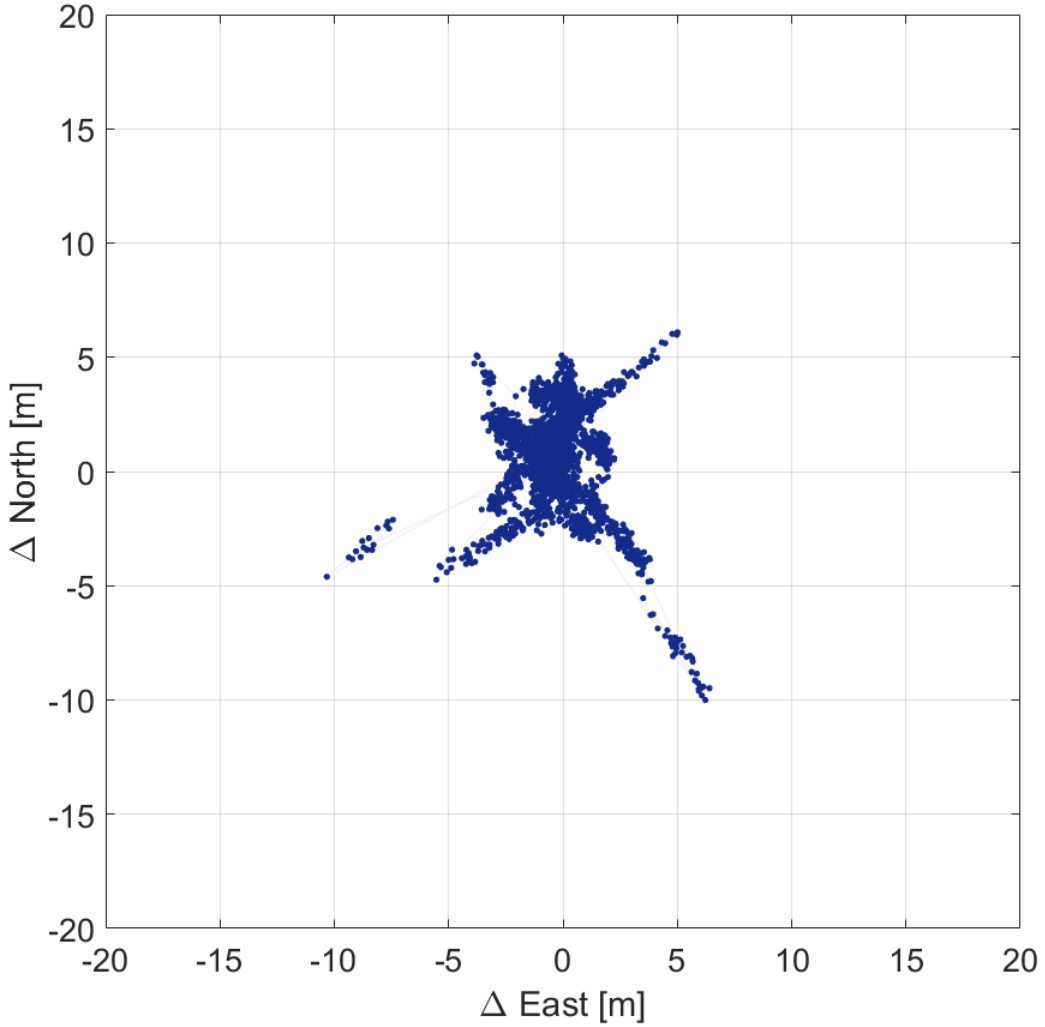


Positioning with Galileo

SPP

Satellite Galileo E24 removed !

Galileo E1:



Galileo E1

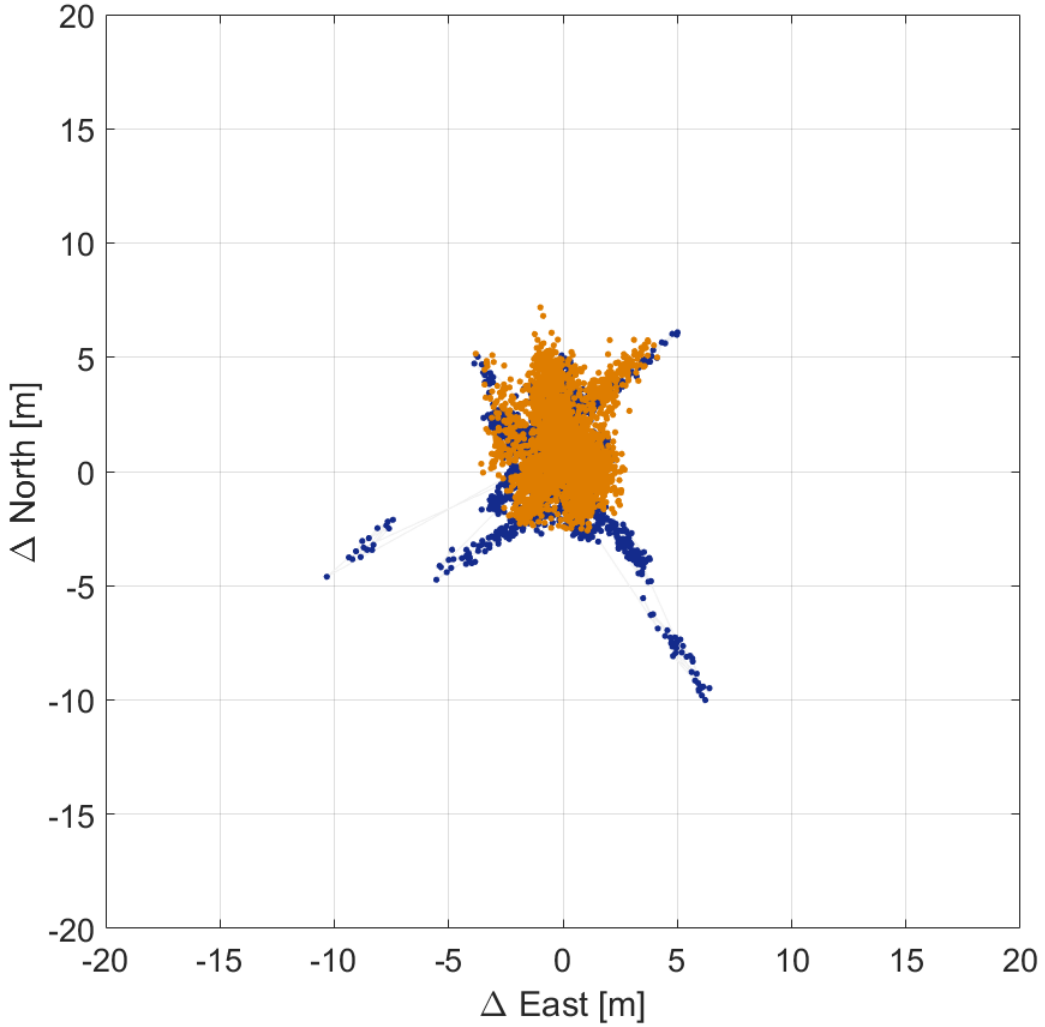
Position 3D: 4.96 m

Positioning with **GPS**

SPP

Galileo E1:

GPS L1:



Galileo E1

Position 3D: 4.96 m

GPS L1

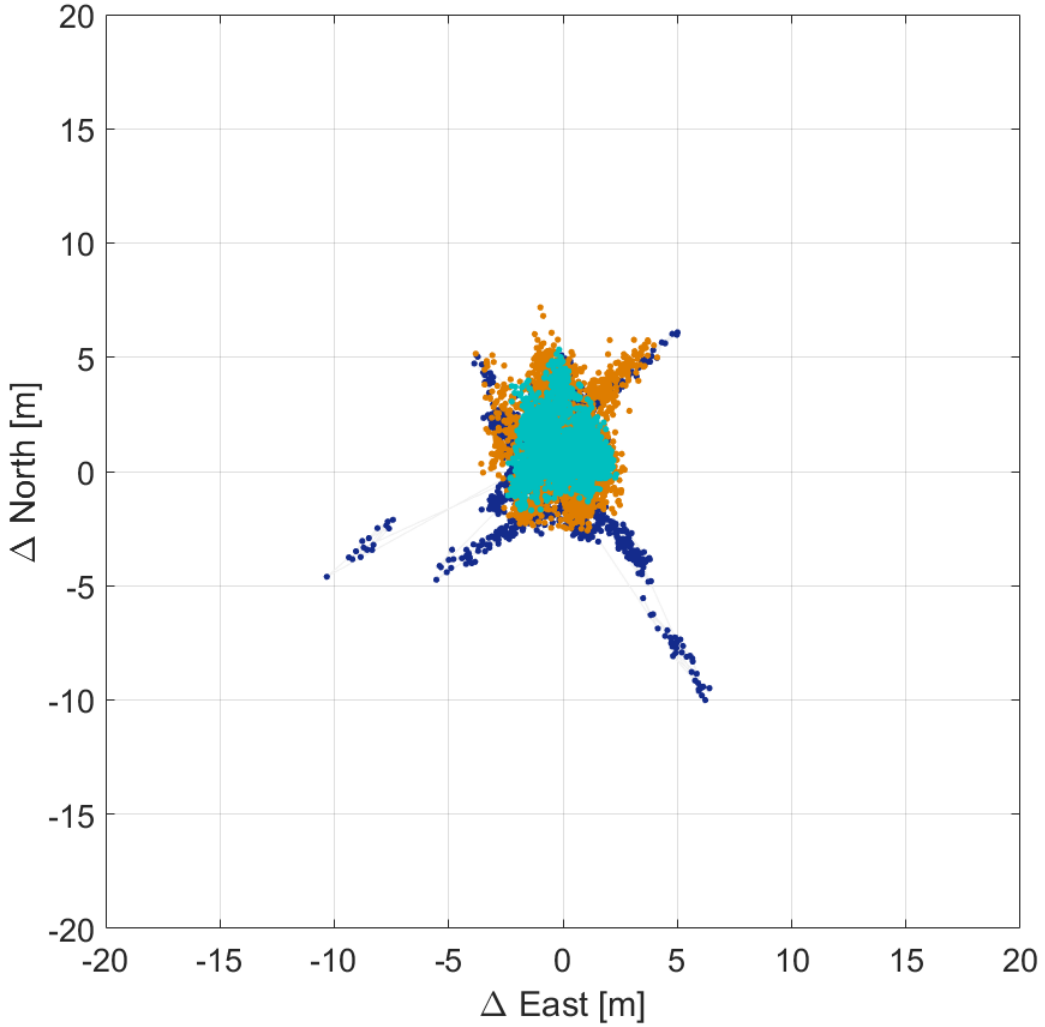
Position 3D: 4.33 m

Positioning with **Galileo** + **GPS**

SPP

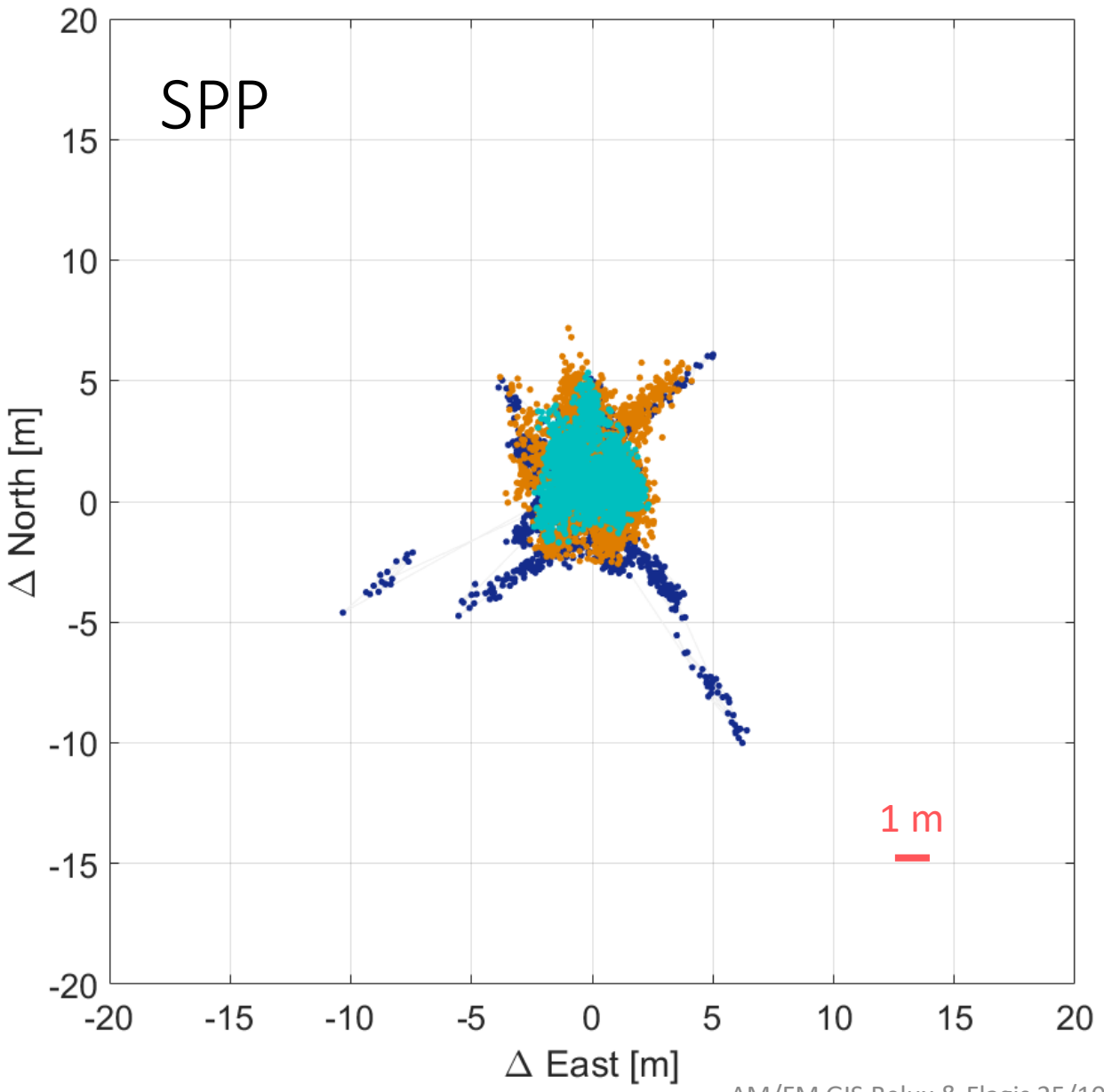
Satellite Galileo E24 removed !

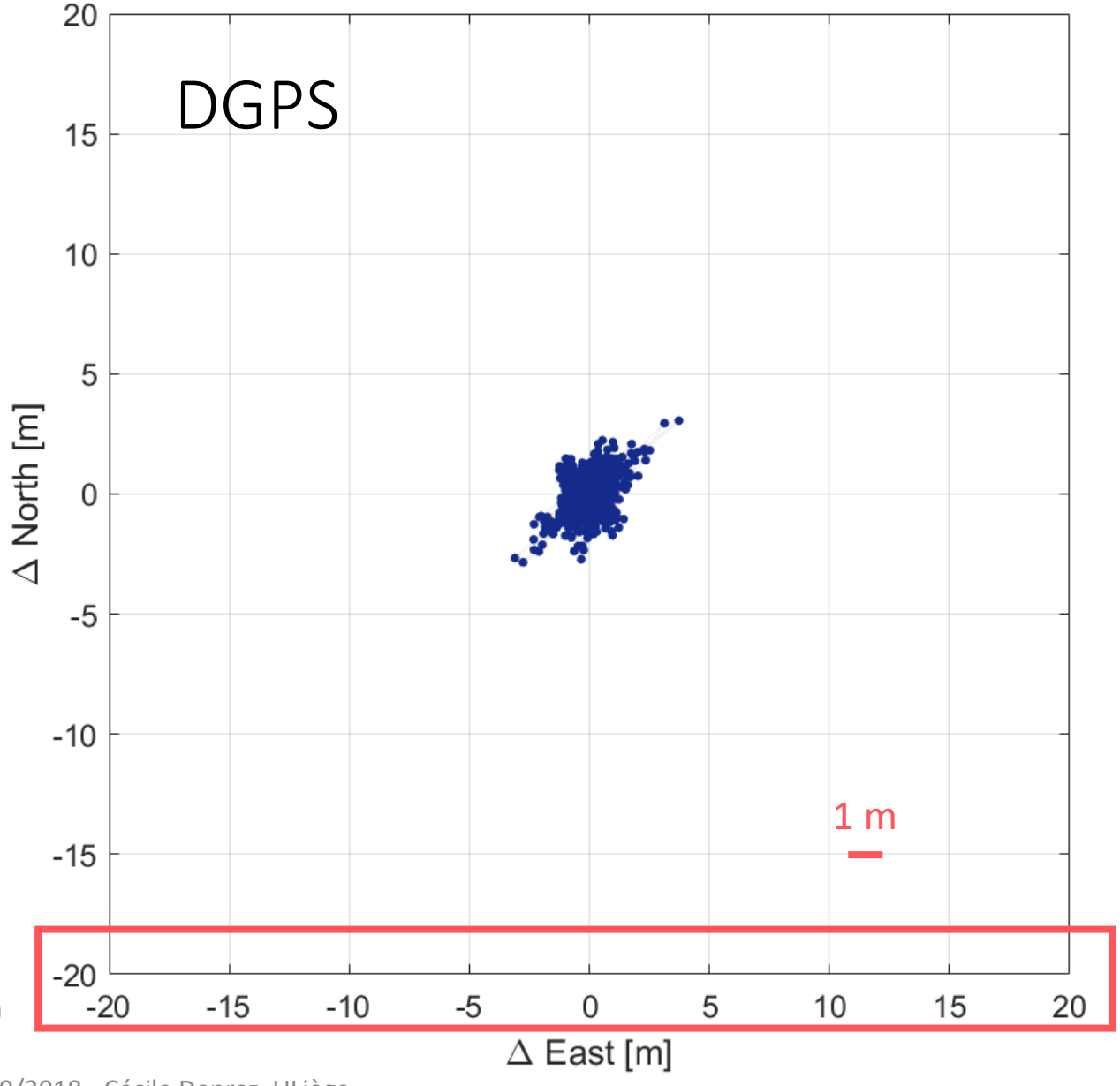
Galileo E1
+
GPS L1 :



Galileo E1
+
GPS L1

Position 3D: 3.32 m

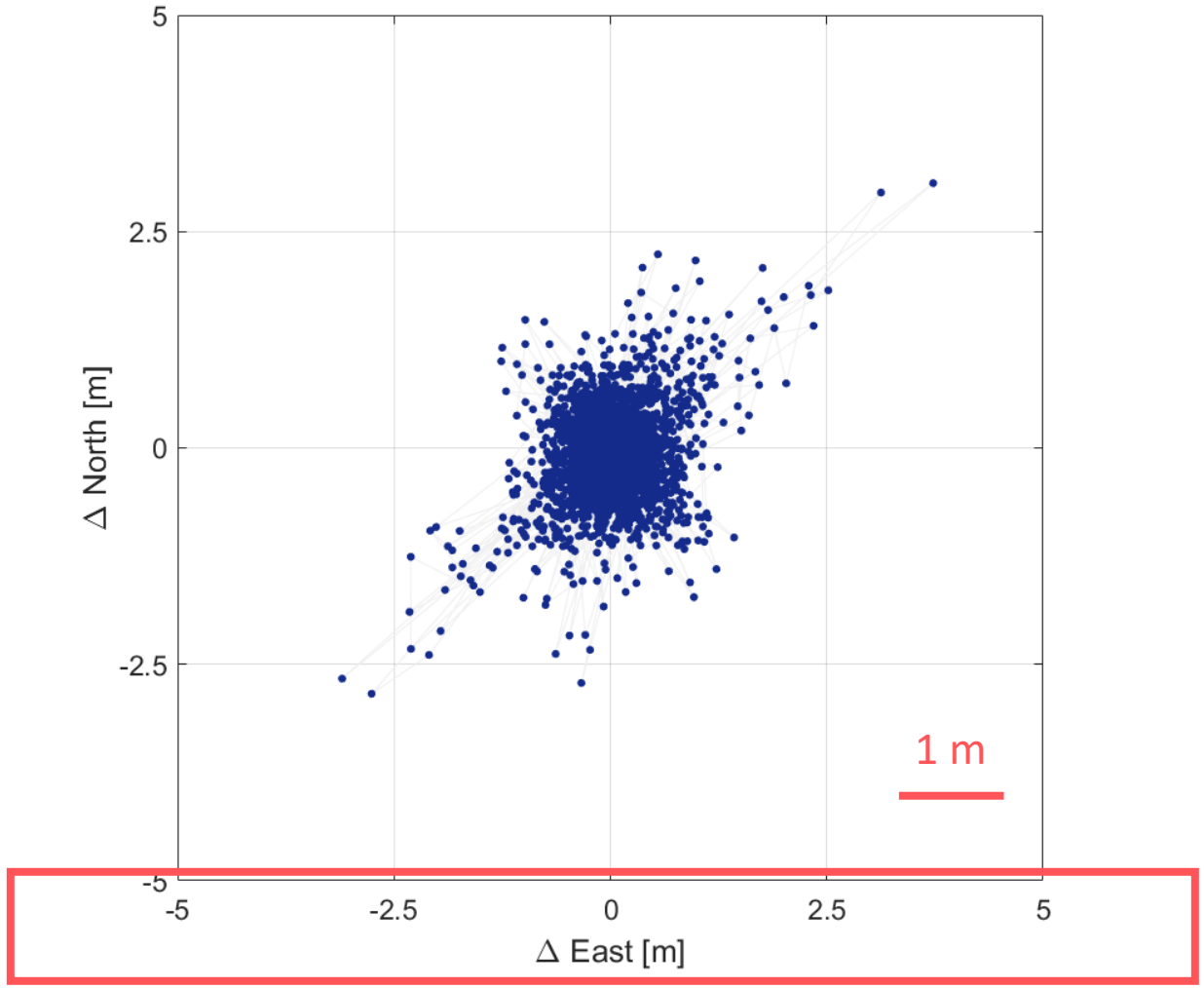

SPP
20
15
10
5
0
-5
-10
-15
-20
Δ North [m]
-20
-15
-10
-5
0
5
10
15
20
Δ East [m]
1 m


DGPS
20
15
10
5
0
-5
-10
-15
-20
Δ North [m]
-20
-15
-10
-5
0
5
10
15
20
Δ East [m]
1 m

Positioning with Galileo

DGPS

Galileo E1:



Galileo E1

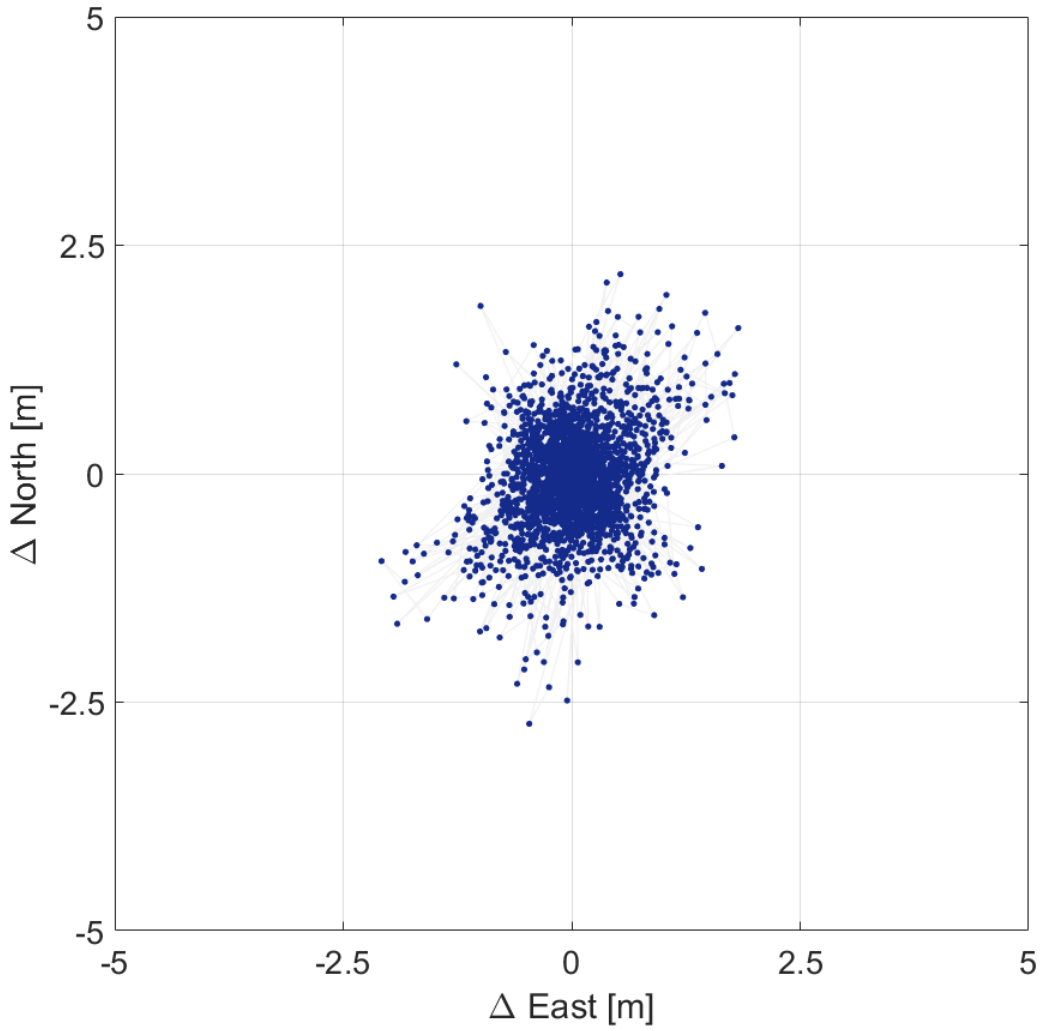
Position 2D: 0.72 m

Position 3D: 1.13 m

Positioning with Galileo

DGPS

Satellite Galileo E24 removed



Galileo E1:

Galileo E1

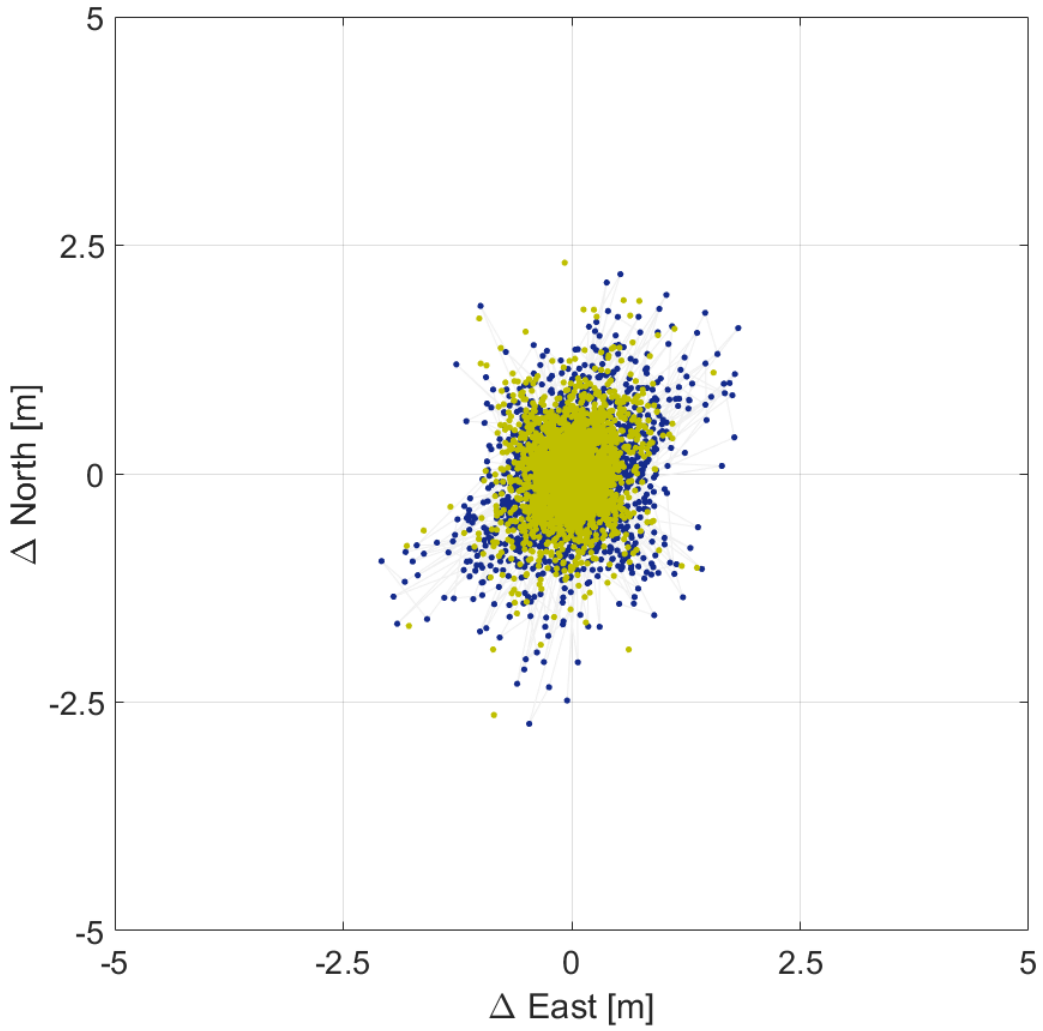
Position 2D: 0.71 m

Position 3D: 1.10 m

Positioning with Galileo

DGPS

Satellite Galileo E24 removed



Galileo E1:

Galileo E5a:

Galileo E1

Position 2D: 0.71 m

Position 3D: 1.10 m

Galileo E5a

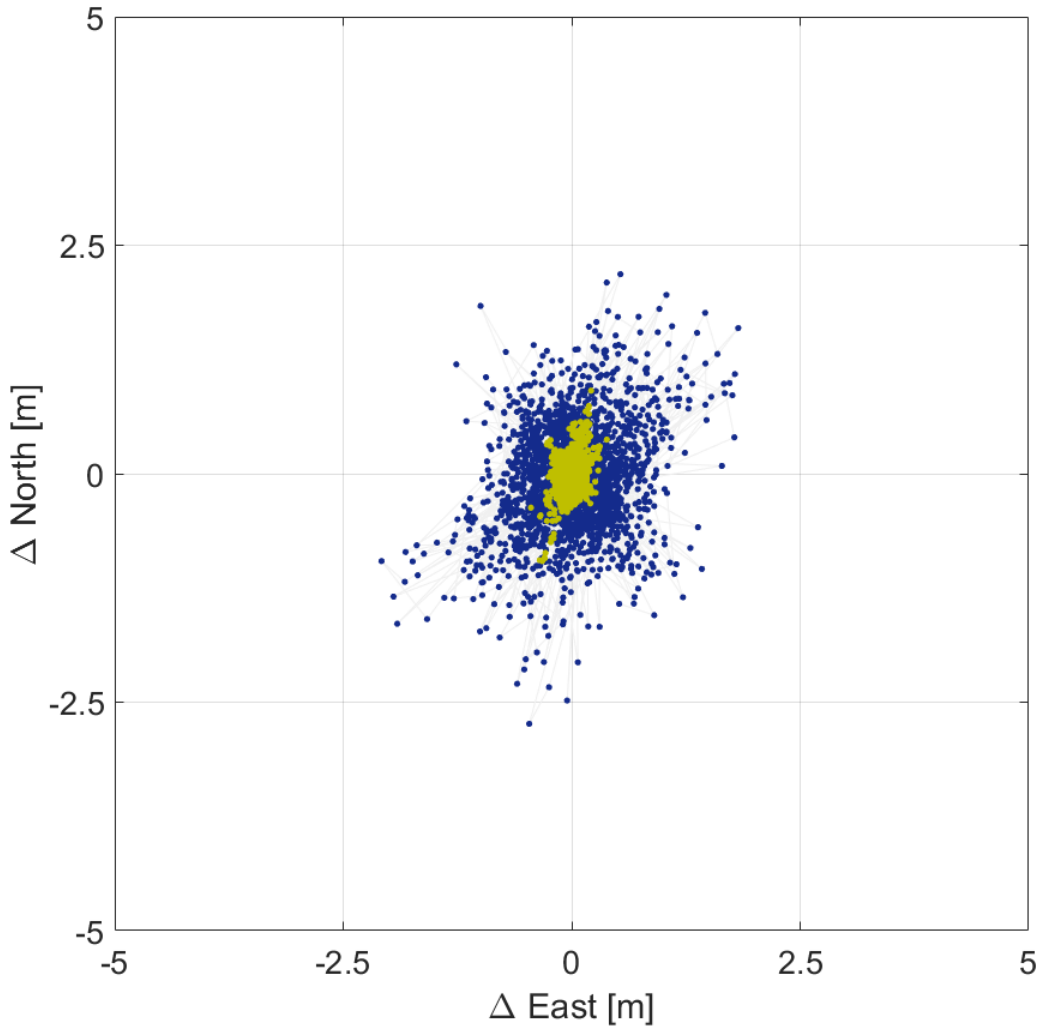
Position 2D: 0.55 m

Position 3D: 0.86 m

Positioning with Galileo

DGPS

Satellite Galileo E24 removed



Galileo E1:

Galileo E5a+b:

Galileo E1

Position 2D: 0.72 m

Position 3D: 1.13 m

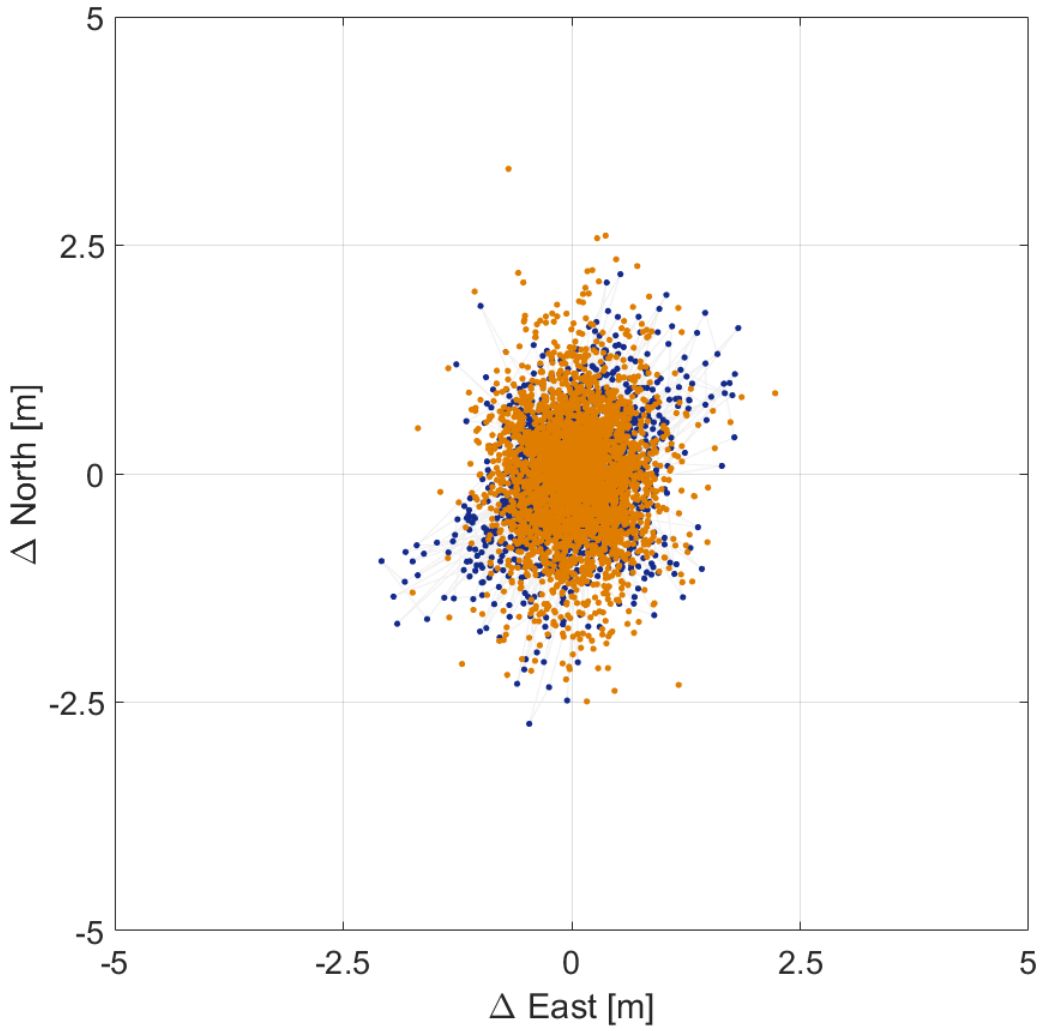
Galileo E5a+b

Position 2D: 0.16 m

Position 3D: 0.25 m

Positioning with **GPS**

DGPS



Galileo E1:

GPS L1:

Galileo E1

Position 2D: 0.72 m

Position 3D: 1.13 m

GPS L1

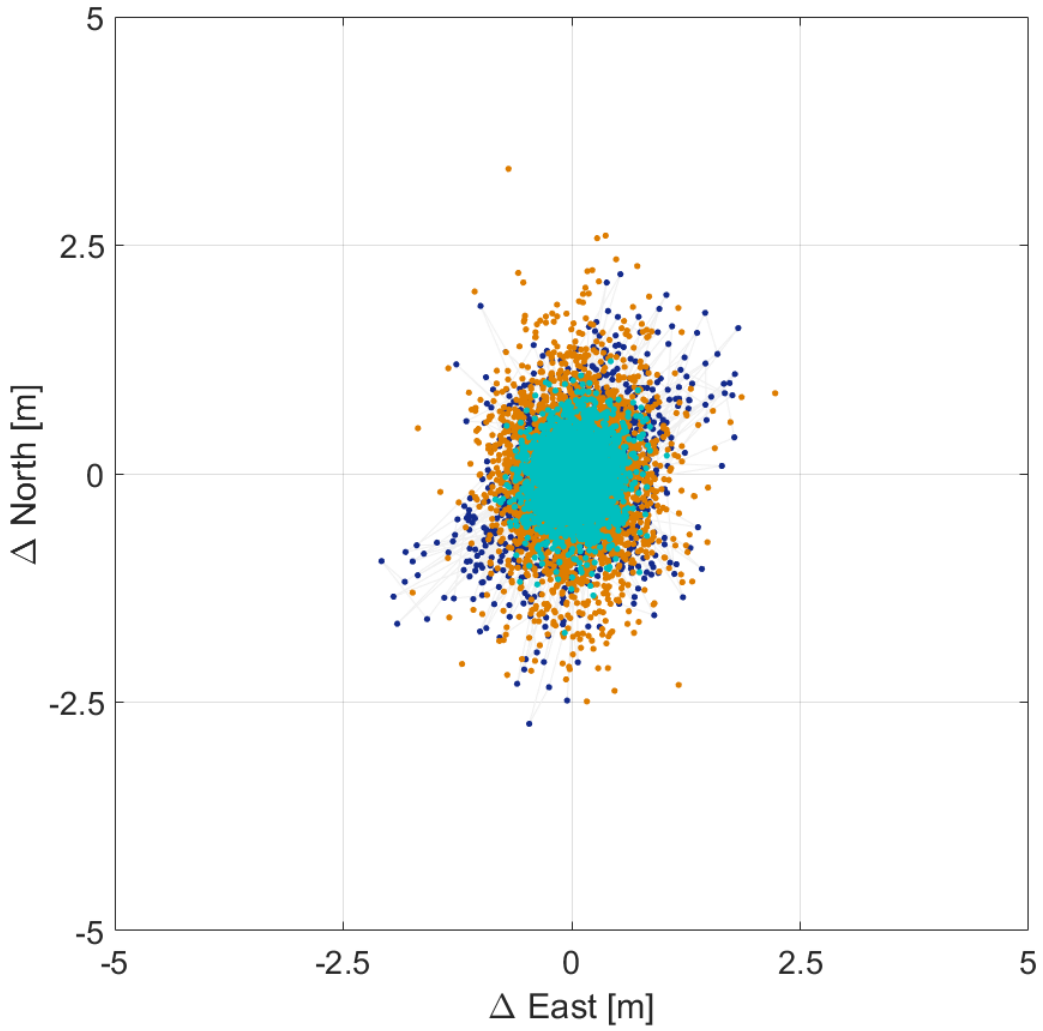
Position 2D: 0.81 m

Position 3D: 1.32 m

Positioning with **Galileo** + **GPS**

DGPS

Galileo E1
+
GPS L1 :



Galileo E1
+
GPS L1

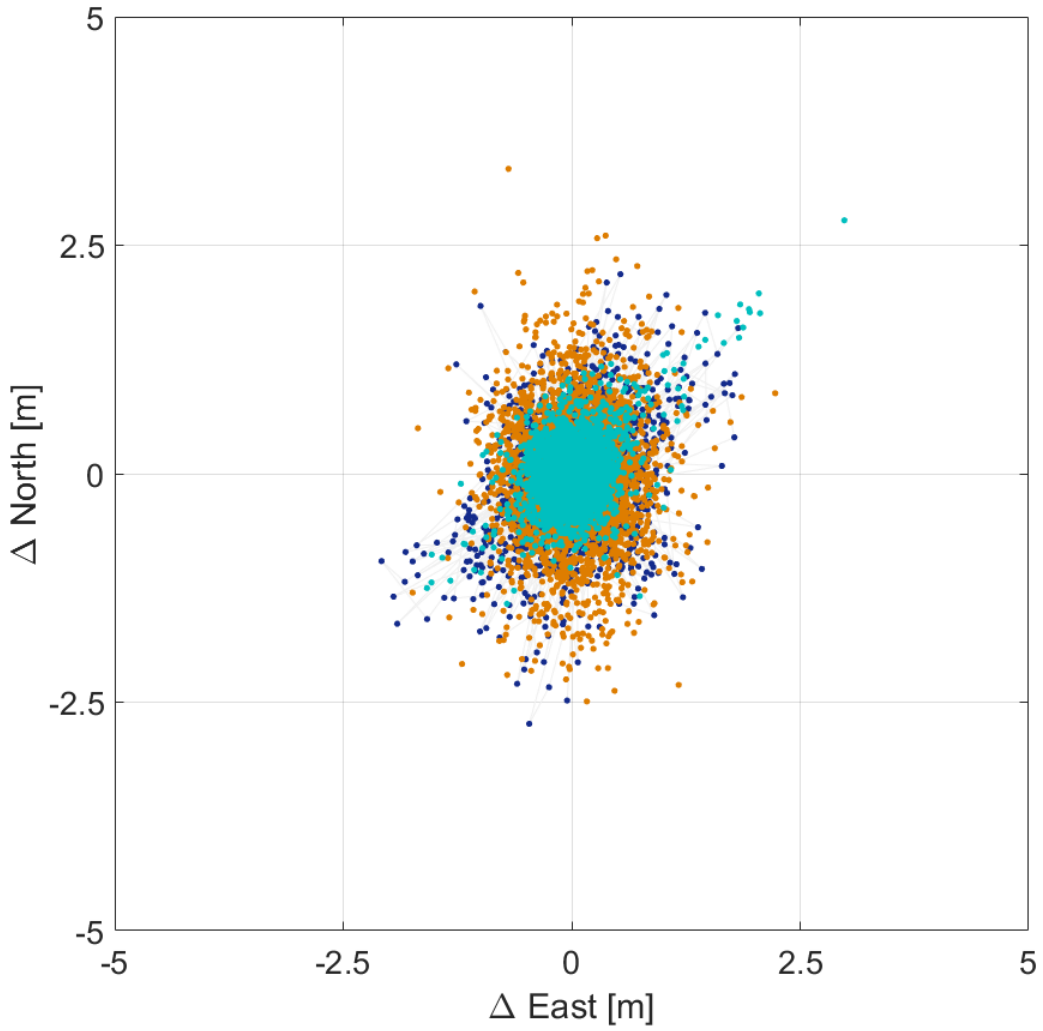
Position 2D: 0.43 m
Position 3D: 0.85 m

Satellite Galileo E24 removed

Positioning with **Galileo** + **GPS**

DGPS

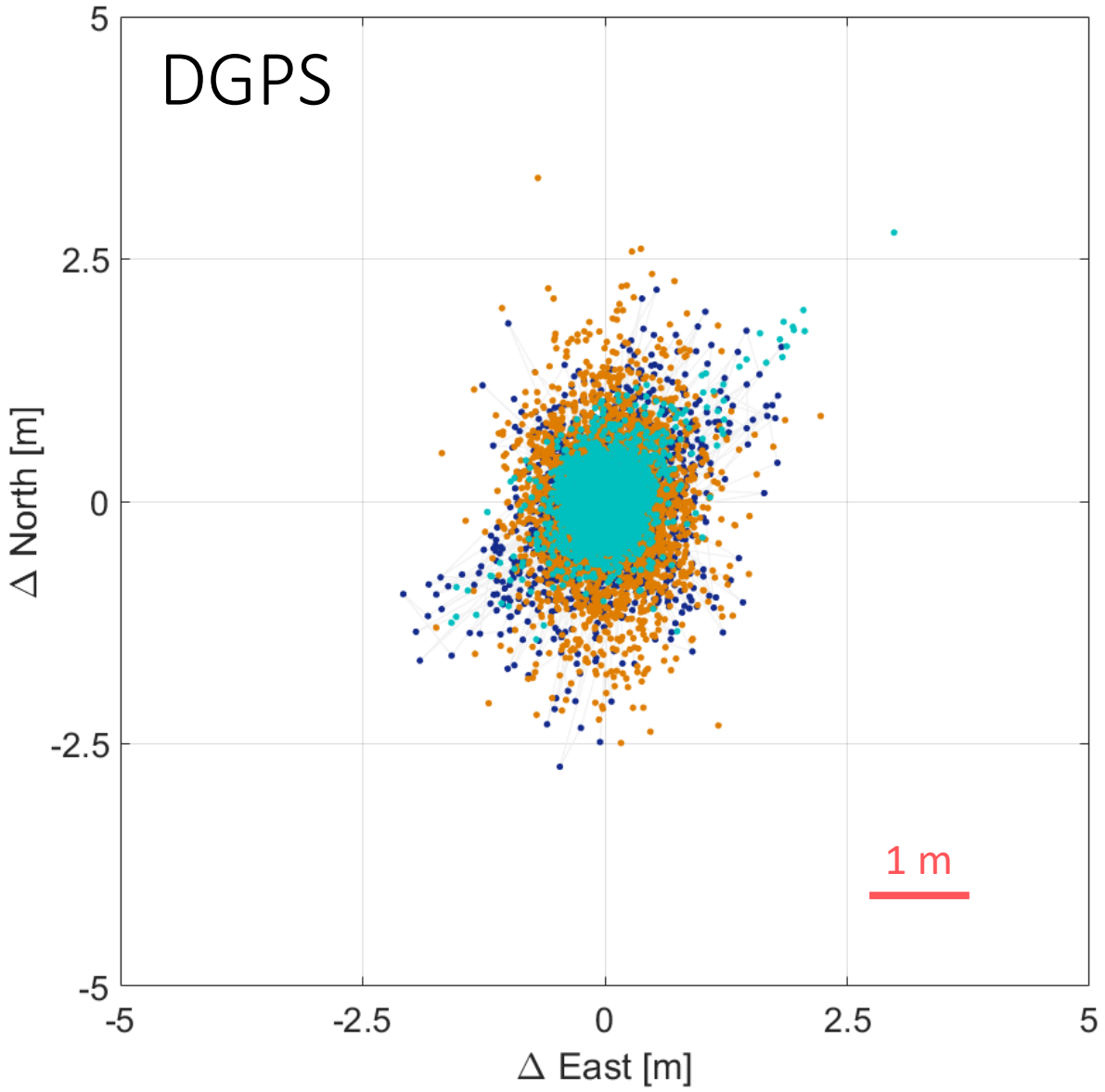
Galileo E5a
+
GPS L5 :

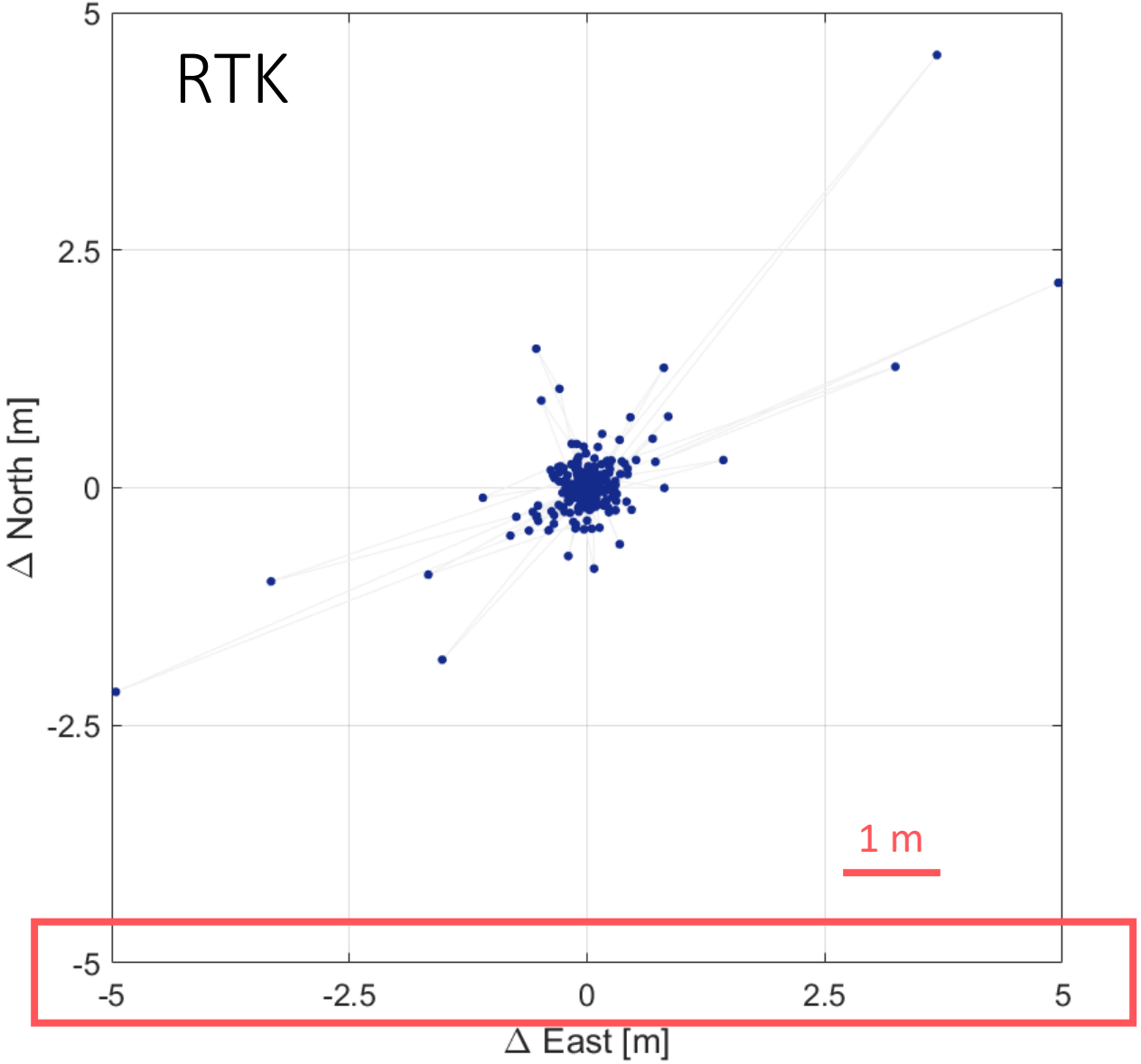


Galileo E5a
+
GPS L5

Position 2D: 0.45 m
Position 3D: 0.73 m

Satellite Galileo E24 removed

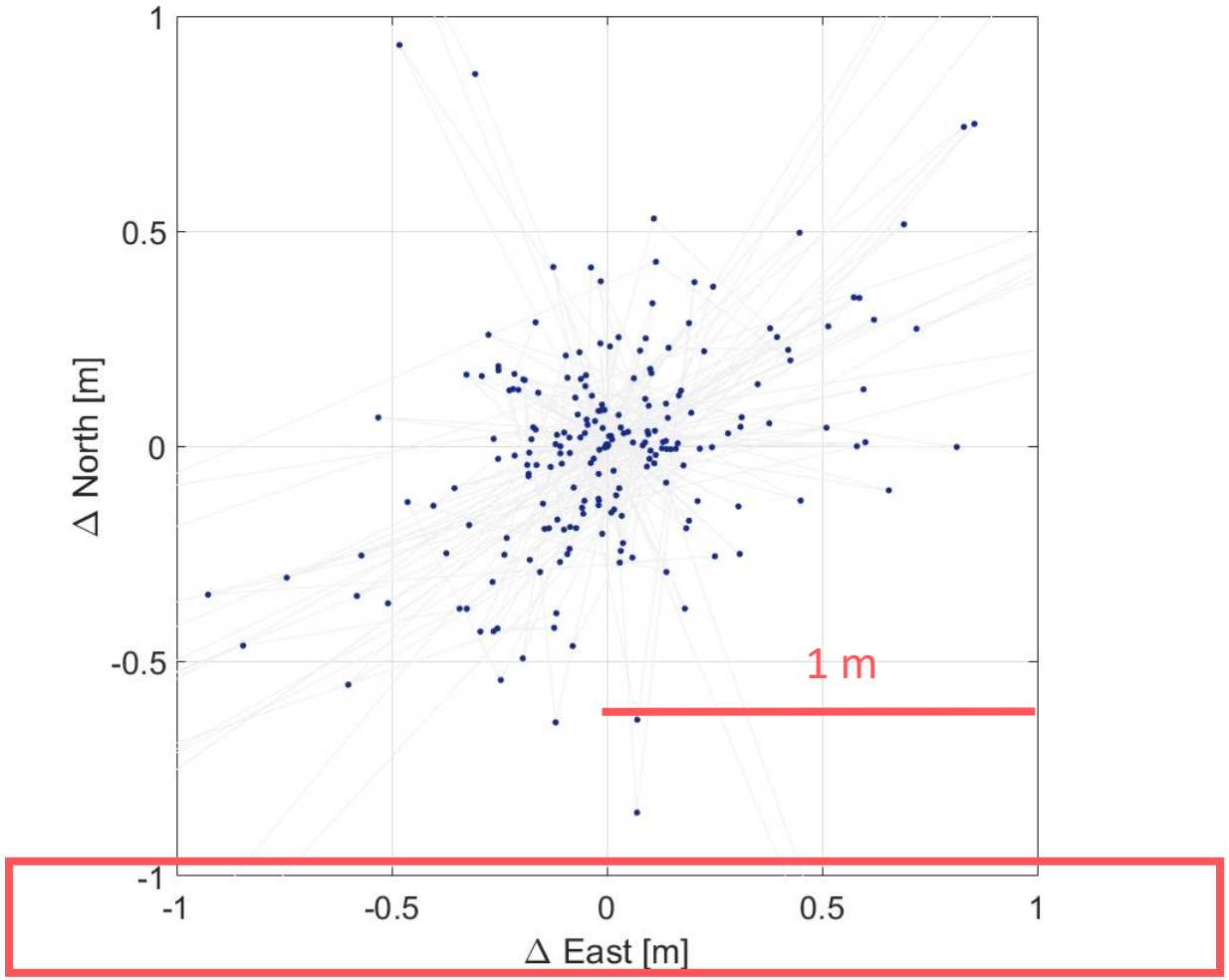

DGPS
5
2.5
0
-2.5
-5
Δ North [m]
-5
-2.5
0
2.5
5
Δ East [m]
1 m


RTK
5
2.5
0
-2.5
-5
Δ North [m]
-5
-2.5
0
2.5
5
Δ East [m]
1 m

Positioning with **Galileo**

RTK

Satellite Galileo E24 removed



Galileo E1:

Galileo E1

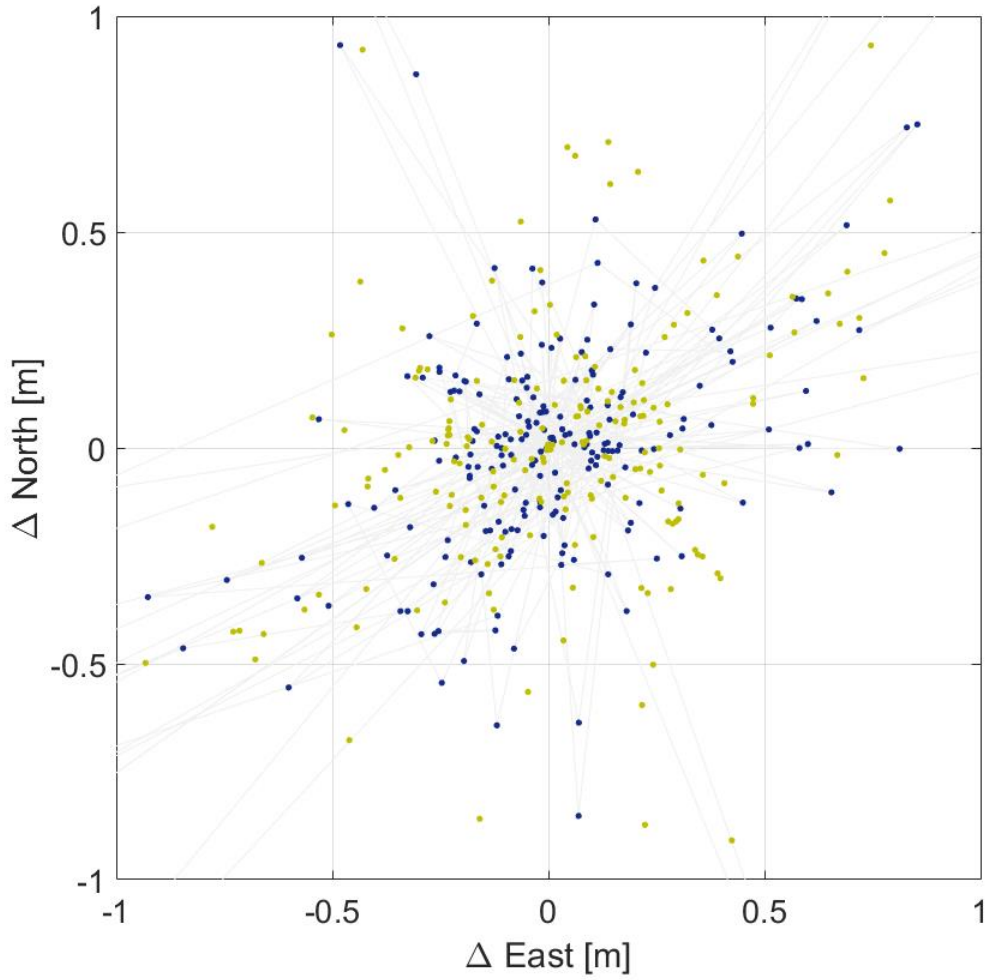
Position 2D: 0.29 m

Position 3D: 0.37 m

Positioning with **Galileo**

RTK

Satellite Galileo E24 removed



Galileo E1:

Galileo E5a+b:

Galileo E1

Position 2D: 0.29 m

Position 3D: 0.37 m

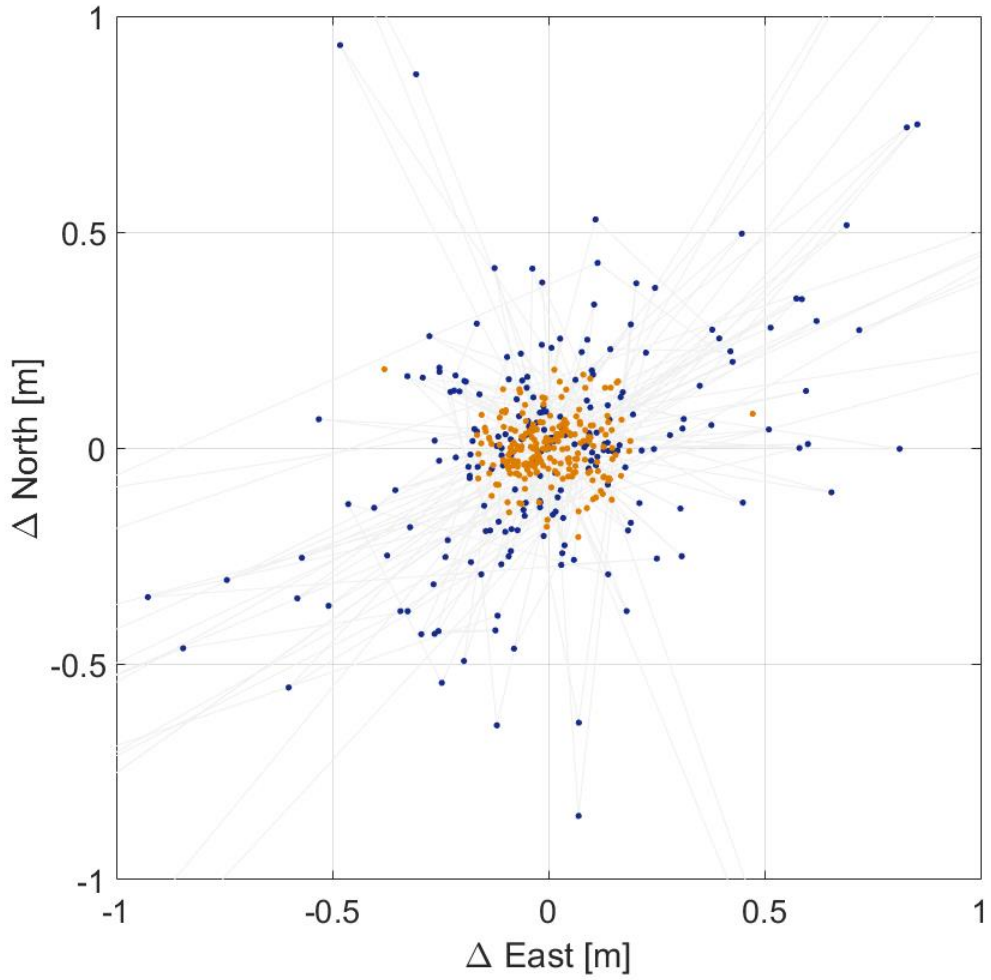
Galileo E5a+b

Position 2D: 0.26 m

Position 3D: 0.33 m

Positioning with **GPS**

RTK



Galileo E1:

GPS L1:

Galileo E1

Position 2D: 0.29 m

Position 3D: 0.37 m

GPS L1

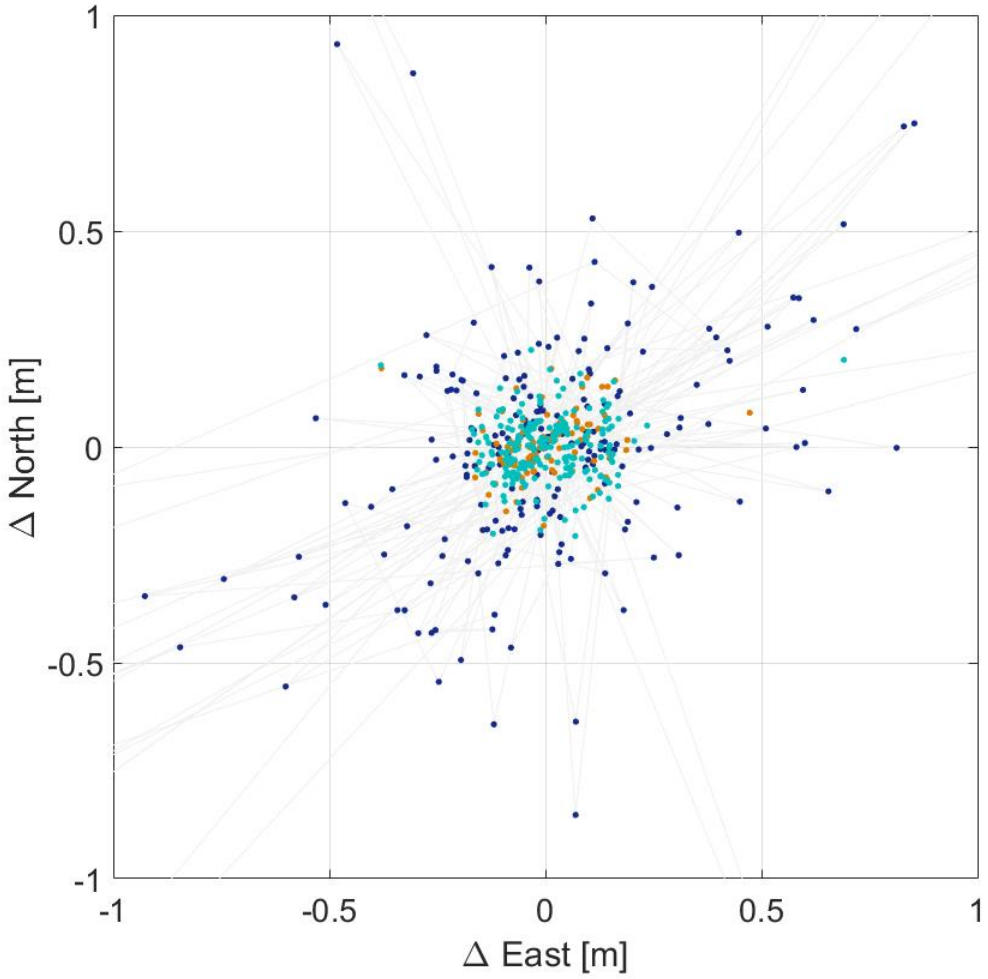
Position 2D: 0.17 m

Position 3D: 0.22 m

Positioning with **Galileo** + **GPS**

RTK

Galileo E1
+
GPS L1 :



Galileo E1
+
GPS L1

Position 2D: 0.10 m
Position 3D: 0.15 m

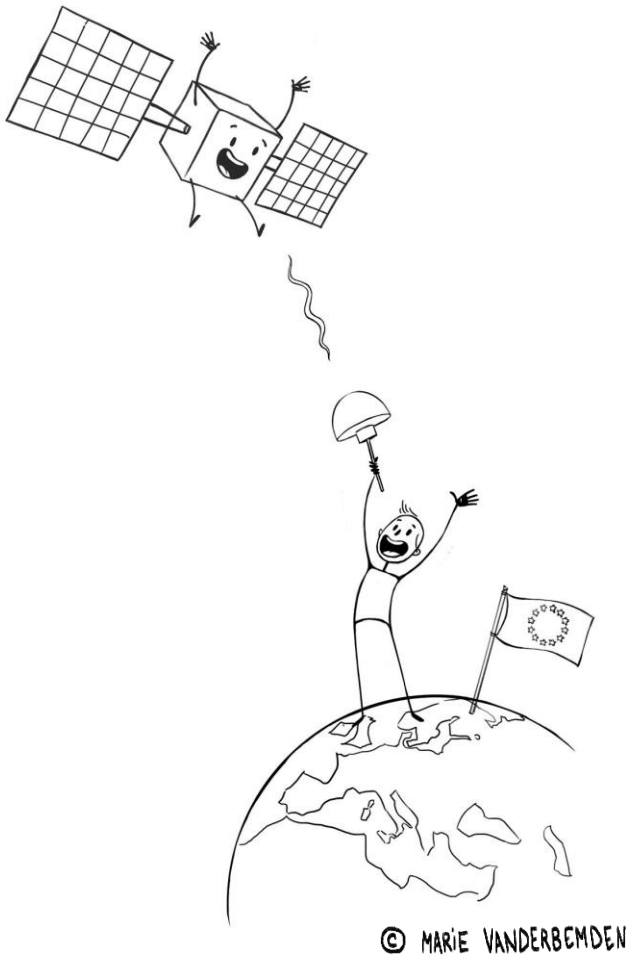
Satellite Galileo E24 removed

CONCLUSIONS

- Positioning with Galileo possible all day
- Galileo signals vs GPS signals
    - Similar precisions for codes and phases
    - Code signal Galileo E5a+b exceptional
- Quality of positioning with Galileo-only
    - **SPP** : still affected by Galileo low number of satellites (higher PDOP than GPS)
    - **DGPS :** Similar values of accuracy for both GPS & Galileo
    - **RTK**: Similar values of accuracy for both GPS & Galileo
- GPS + Galileo combination improves both GPS-only and Galileo-only solutions

LIÈGE université
Sciences

CONTACT



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