Multi-GNSS relative positioning with Galileo, BeiDou and GPS

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FREEDOM TO RESEARCH

Unité de Géomatique
Geomatics Unit

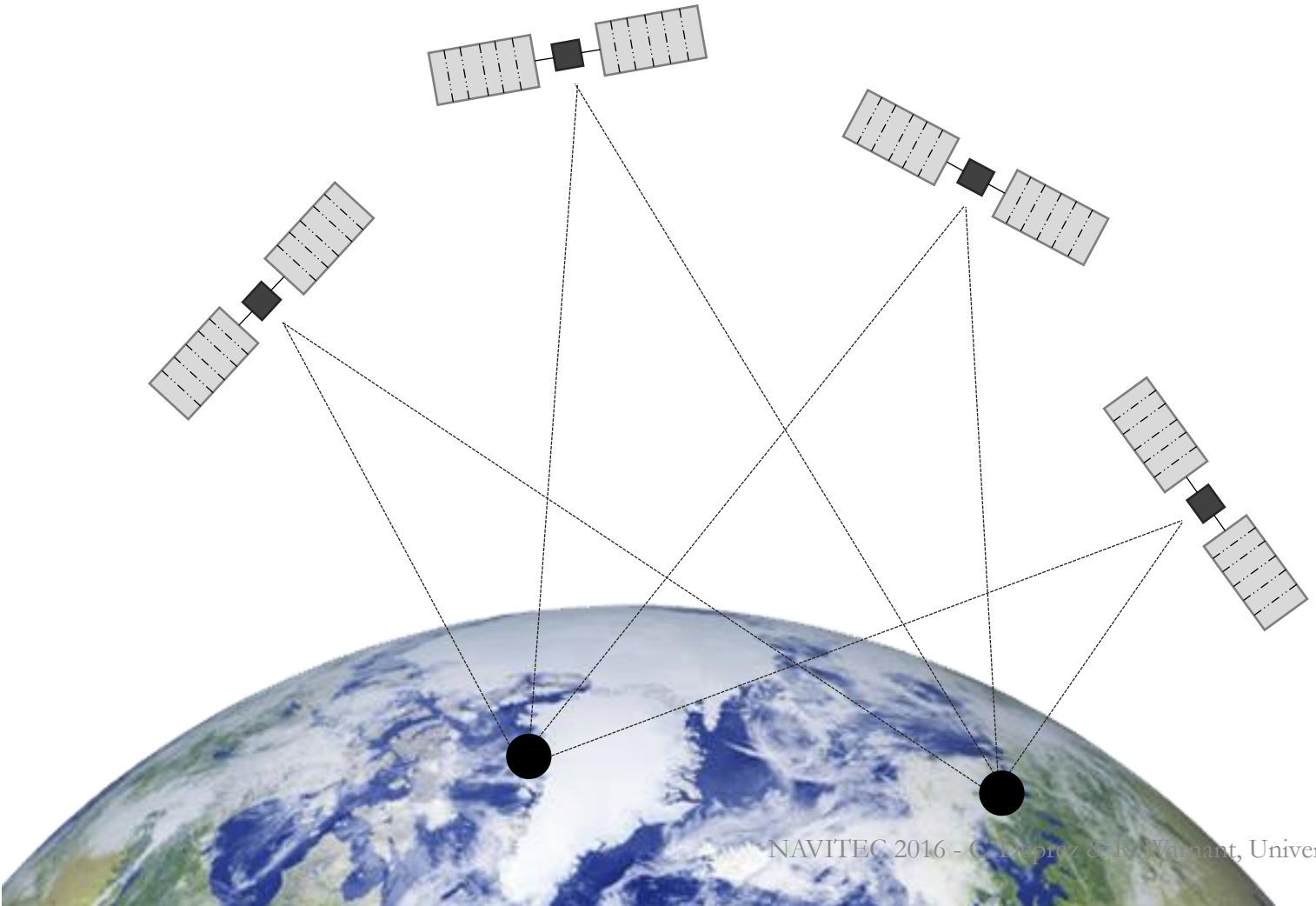
Université de Liège

Individual analysis

of the GNSS signal precisions

Double difference

eliminates **clock** errors



Relative Positioning

Short baseline

to compute

observation precisions

Baseline length:
5 metres

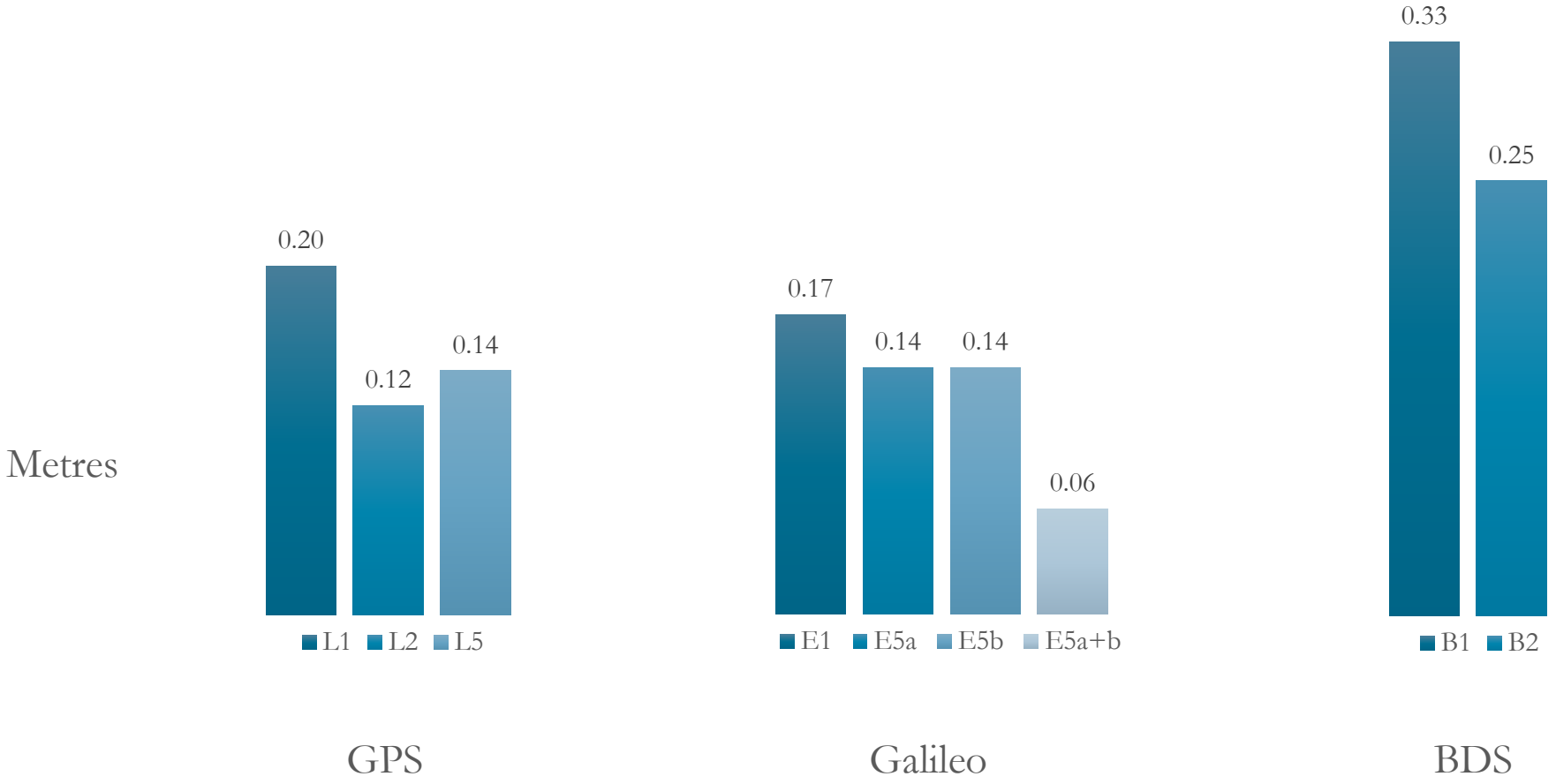
$$R - \rho = M + \varepsilon$$

Codes

$$\Phi - \rho = \lambda N + m + e$$

Phases

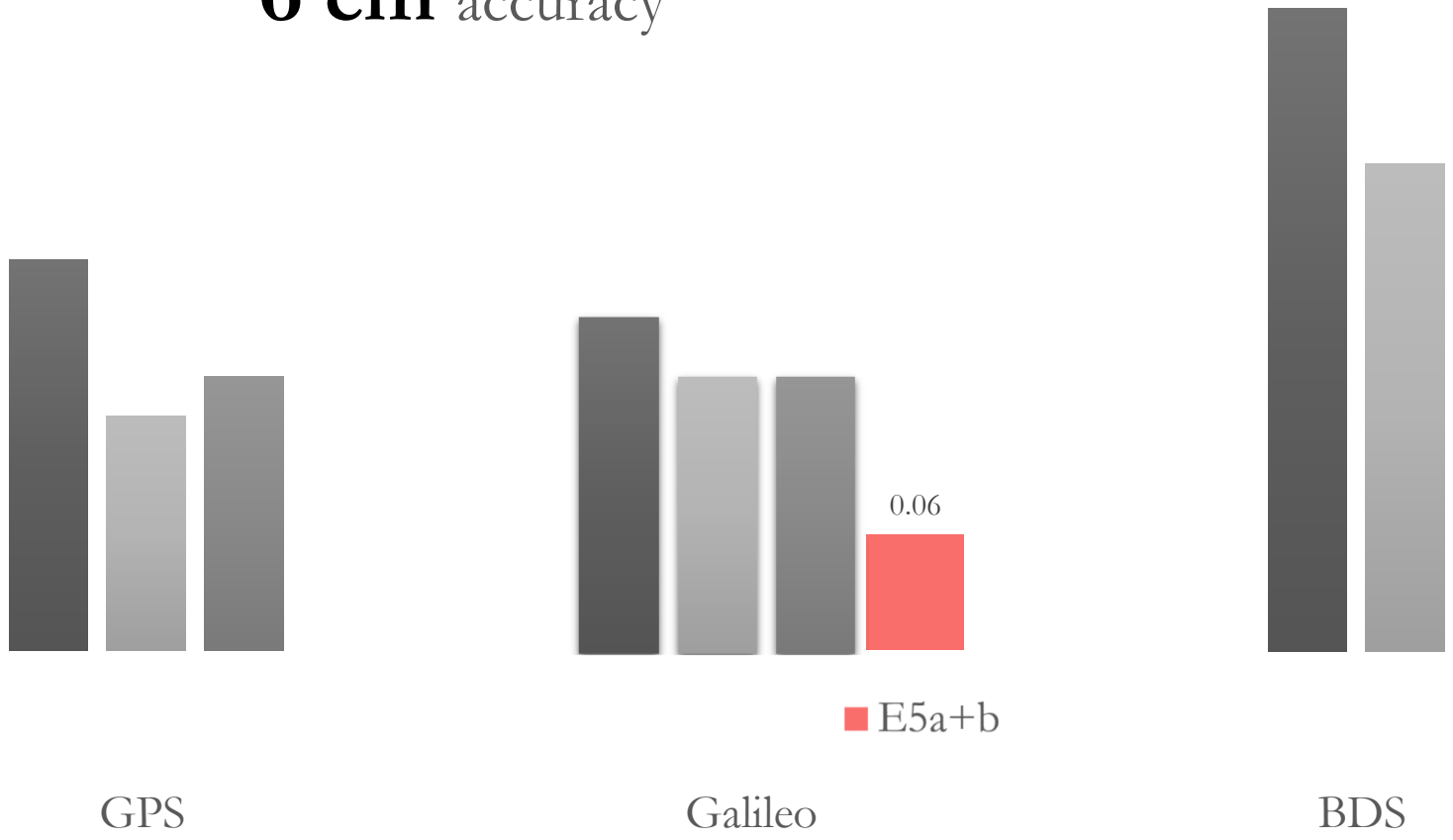
Best precisions with **Galileo** code signals



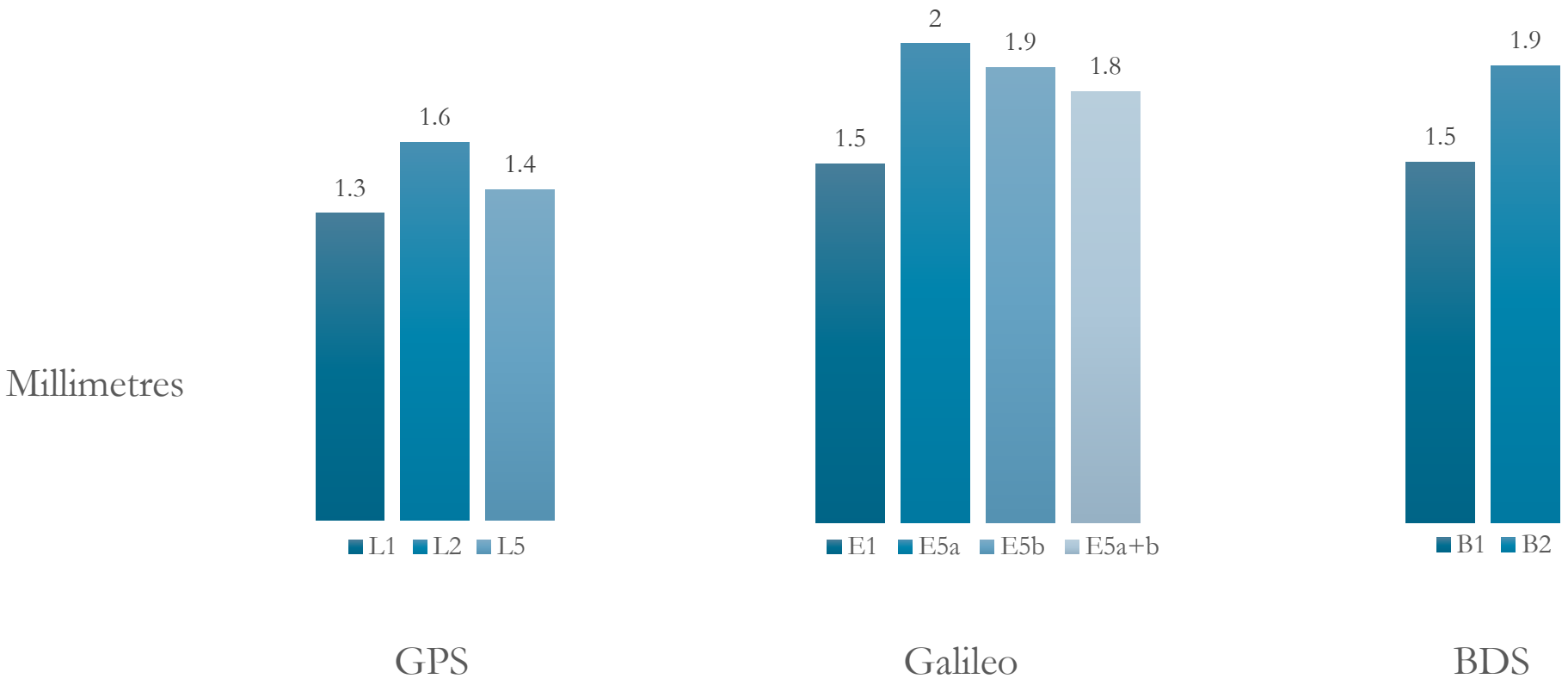
Galileo **E5a+b**

reaches

6 cm accuracy



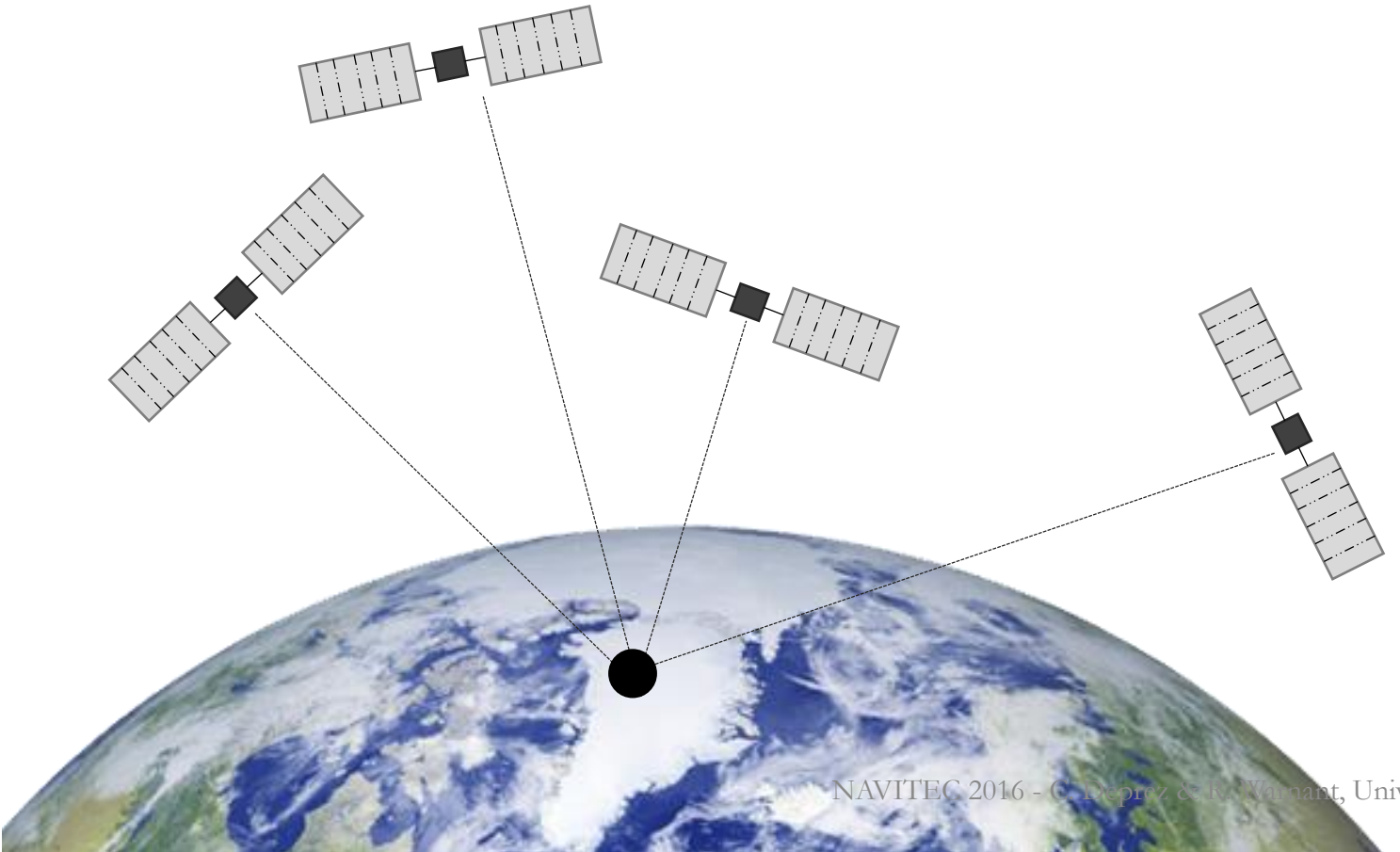
Similar phase precisions

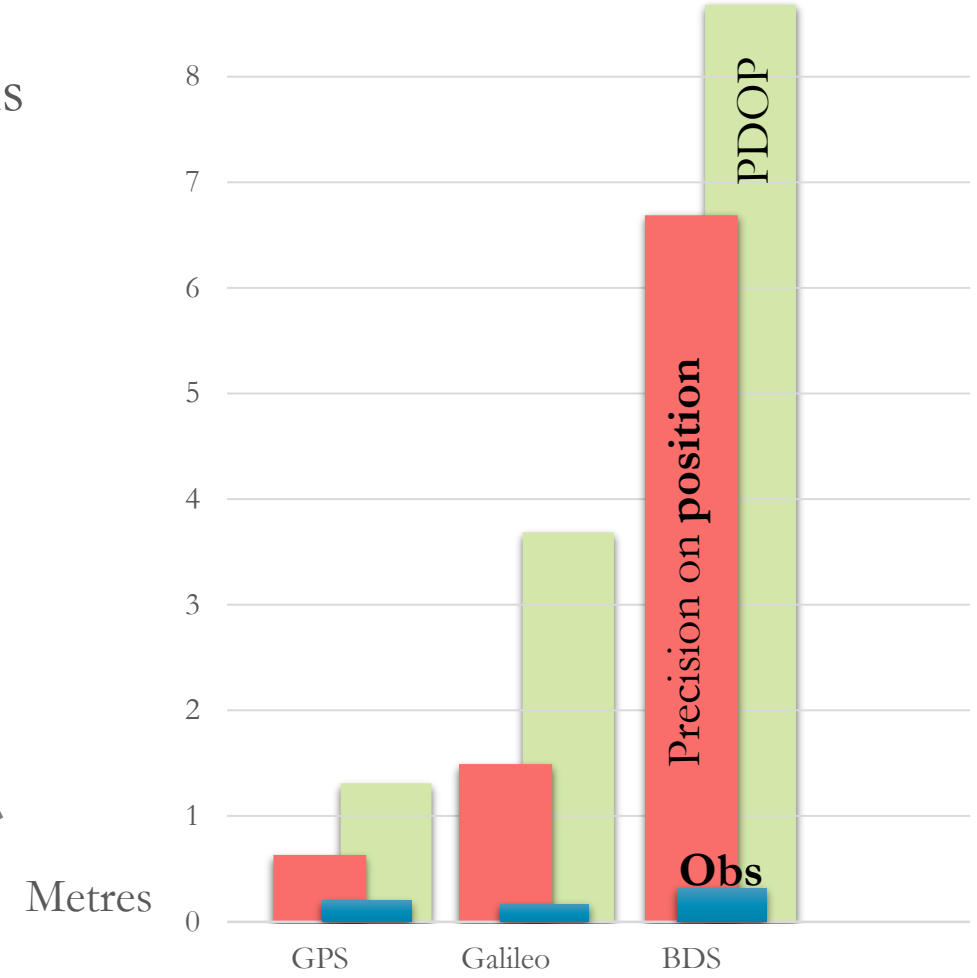


PDOP

decreases **position precisions**

of **smaller** constellations





Multi-GNSS analysis

Estimation of the inter-system biases

Independent **GNSS** constellations

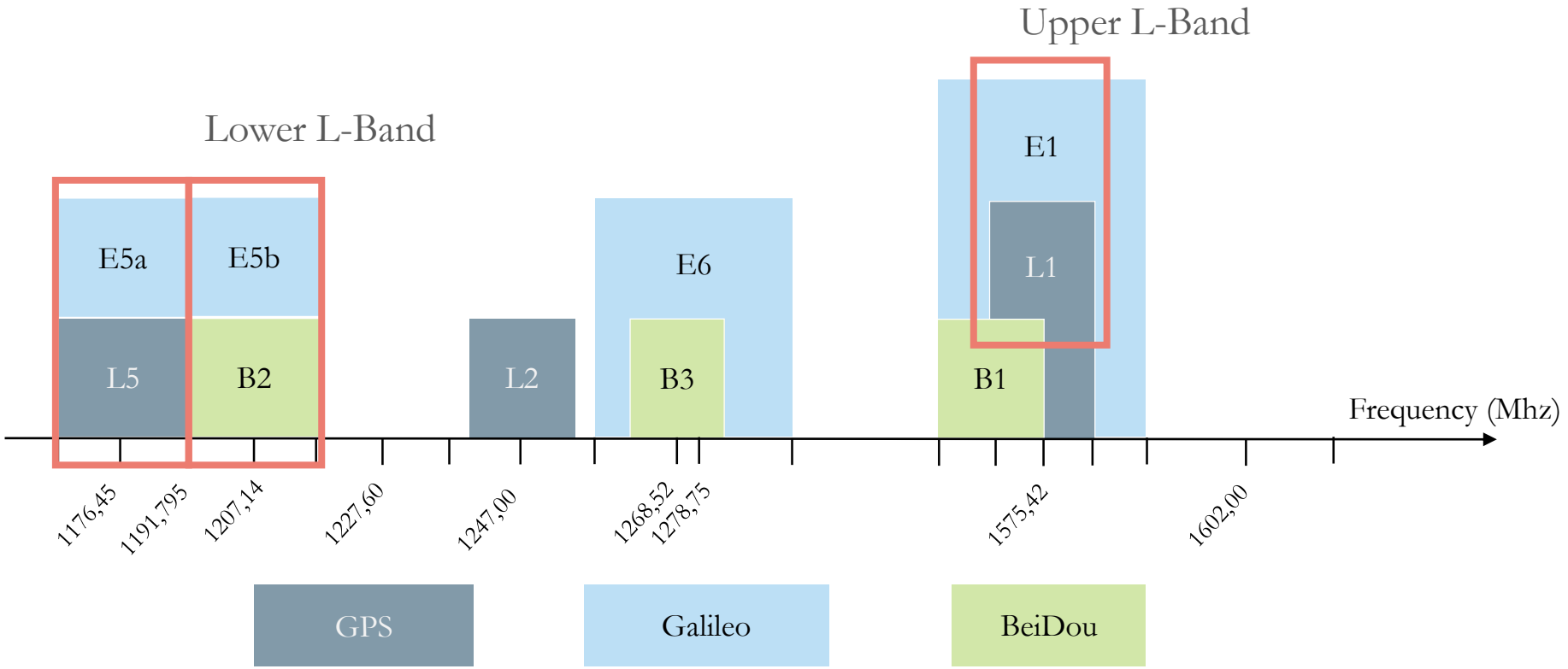
Multi-GNSS

GPS
31 satellites

BeiDou
23 satellites

Galileo
18 satellites

GNSS constellations are **compatible**



The **combination** of GNSS leads to a **new error :** **ISB**

Codes

$$R_{12}^{GG} = D_{12}^{GG} + \varepsilon_{12}^{GG}$$

$$R_{12}^{GE} = D_{12}^{GE} - d_{12}^{(GE)} + \varepsilon_{12}^{GE}$$

Phases

$$\Phi_{12}^{GE} = D_{12}^{GE} - d_{12}^{(GE)} + N\lambda_{12}^{GE} + e_{12}^{GE}$$

Zero baseline

ISBs are **receiver-dependent**

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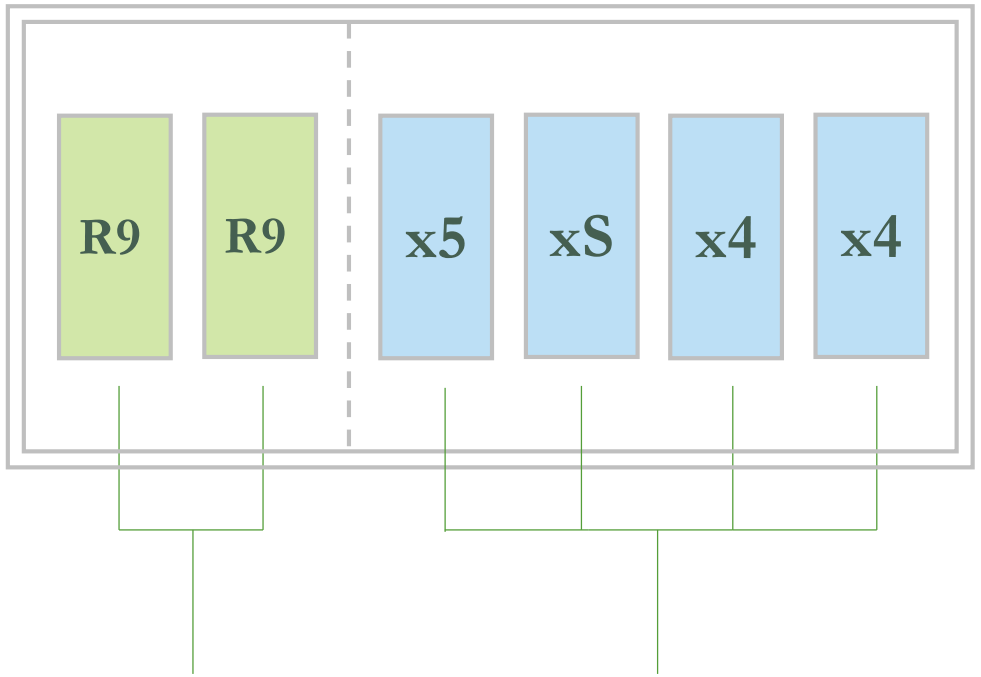
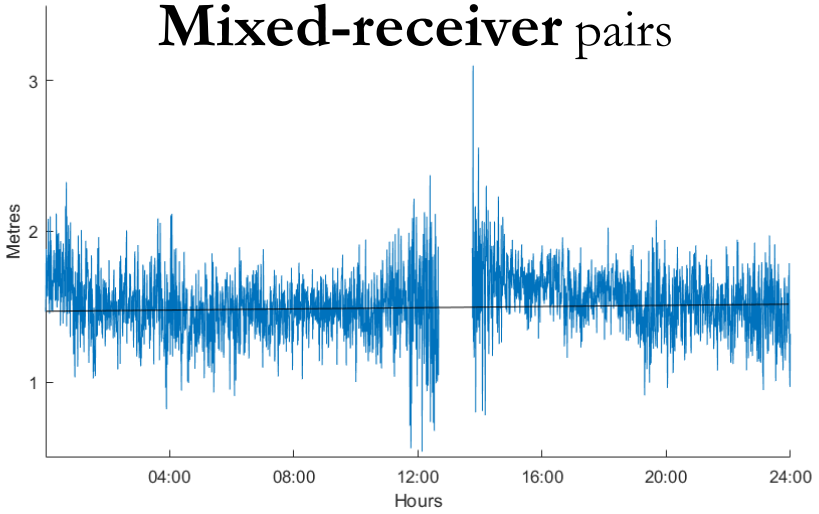
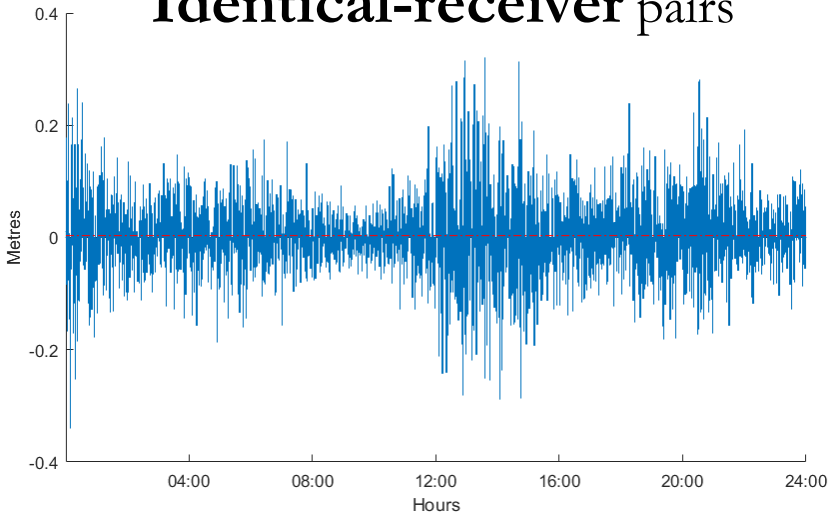


Mixed-receiver pairs



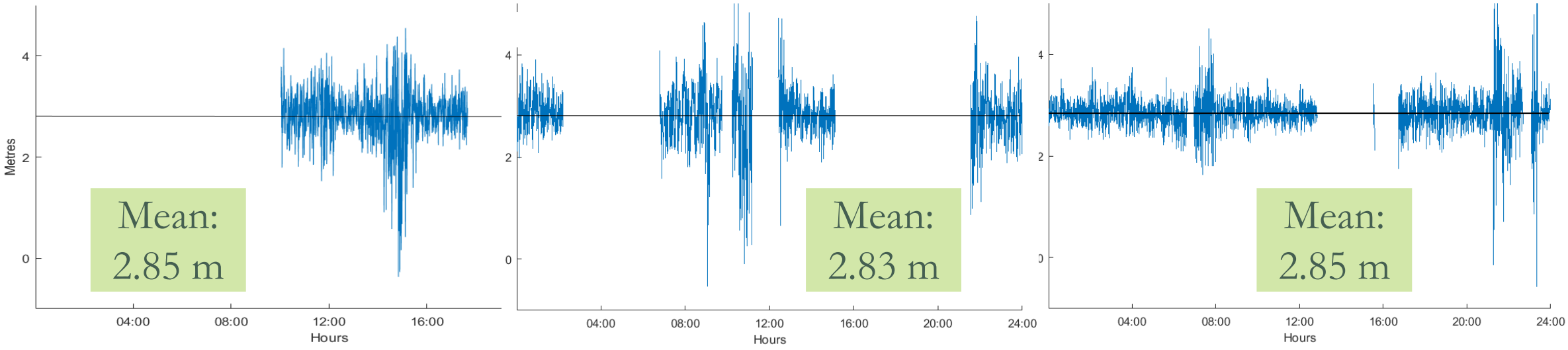
Mean: 1.52 m

Identical-receiver pairs



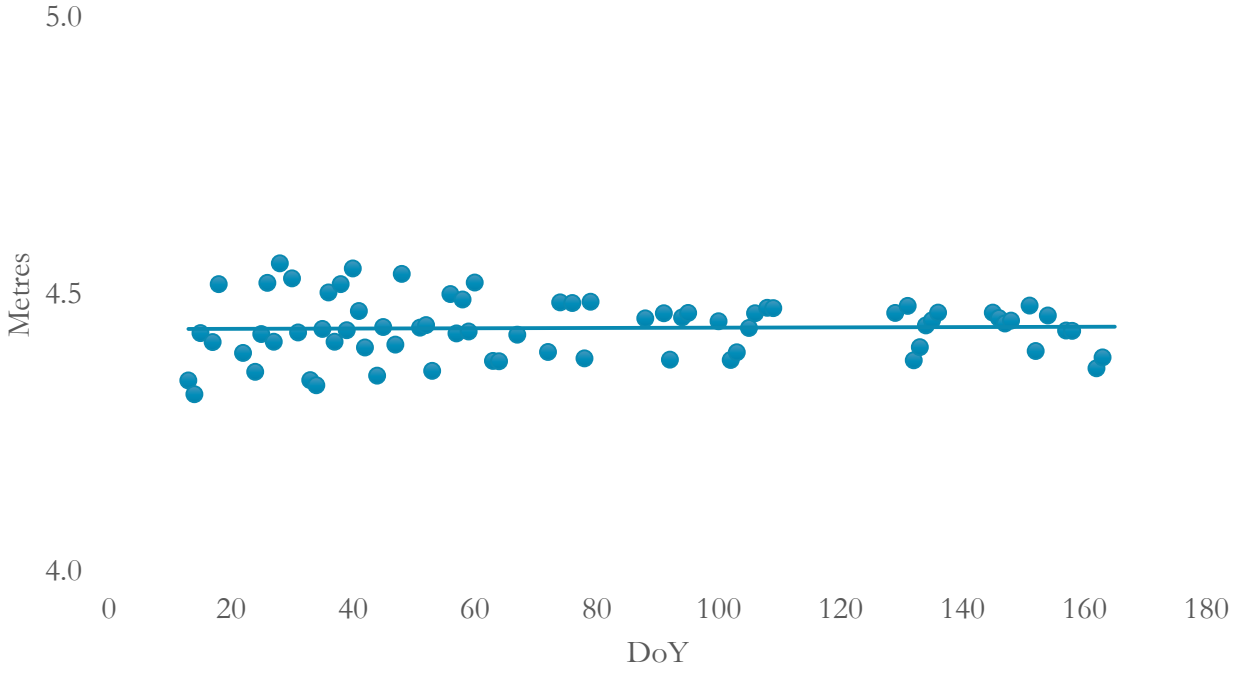
Mean: 0.00 m

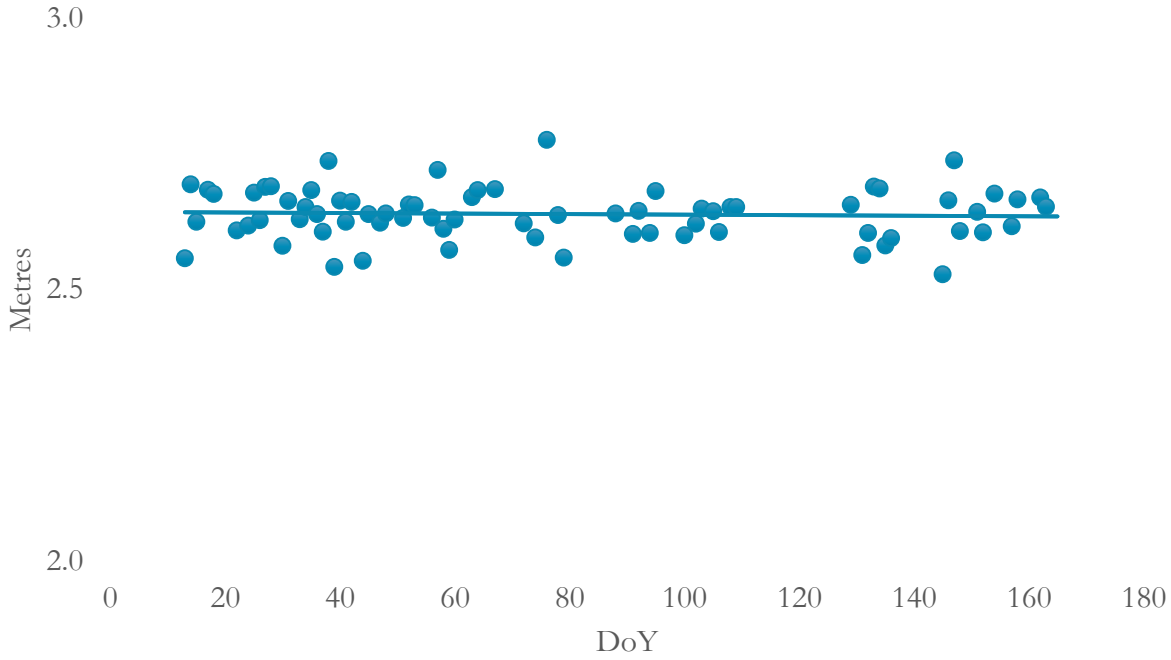
ISBs are **stable** across years



2014 **2015** **2016**

ISBs are **stable** over time





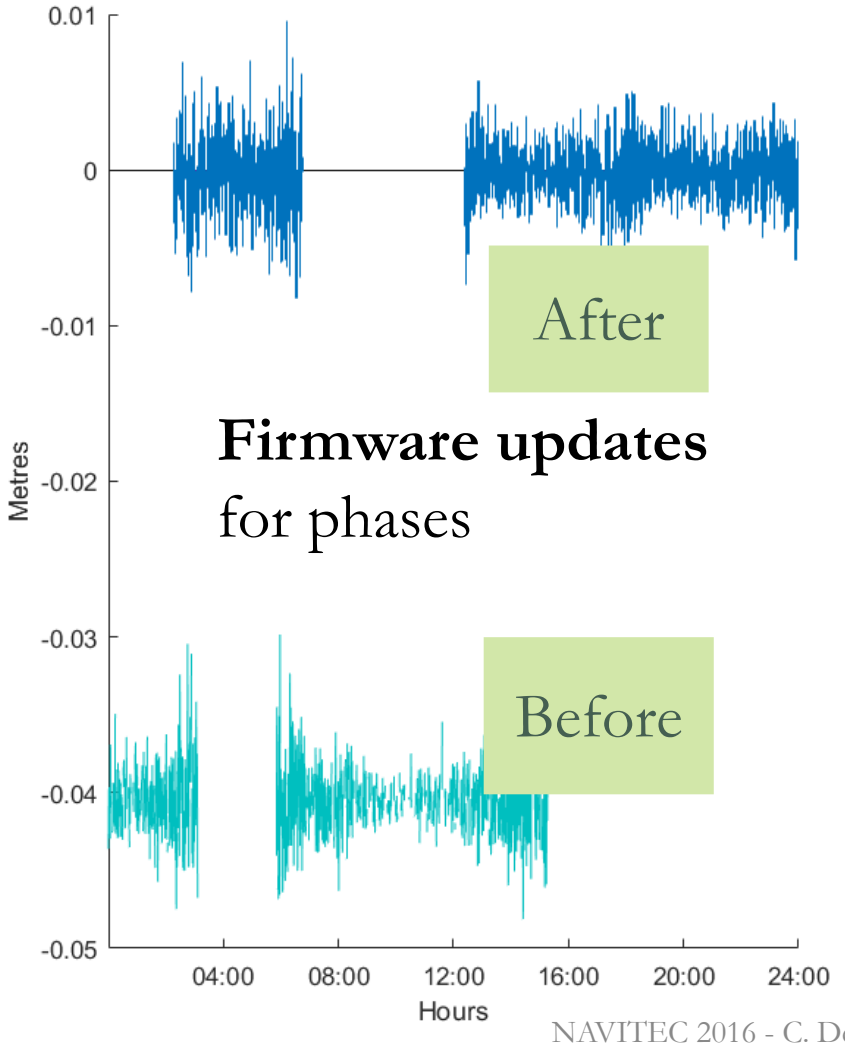
Mean: 4.44 m

Std: 0.05 m

Mean: 2.64 m

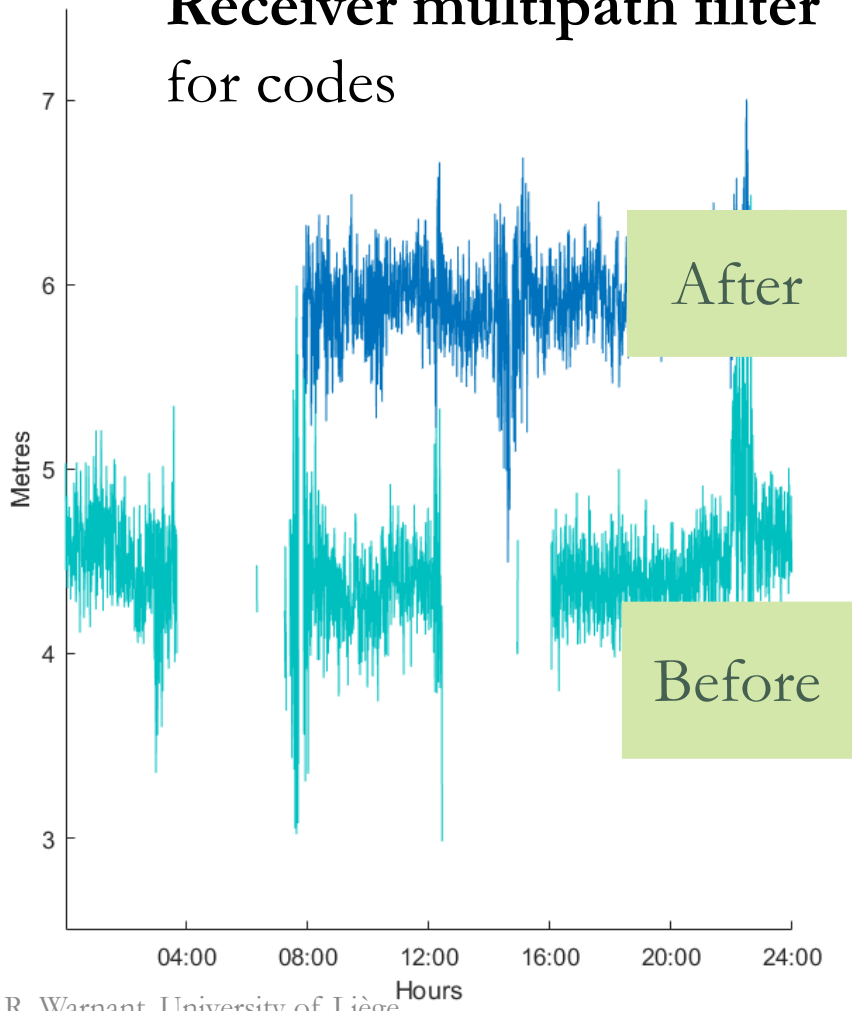
Std: 0.05 m

ISBs might be **affected** by



Firmware updates
for phases

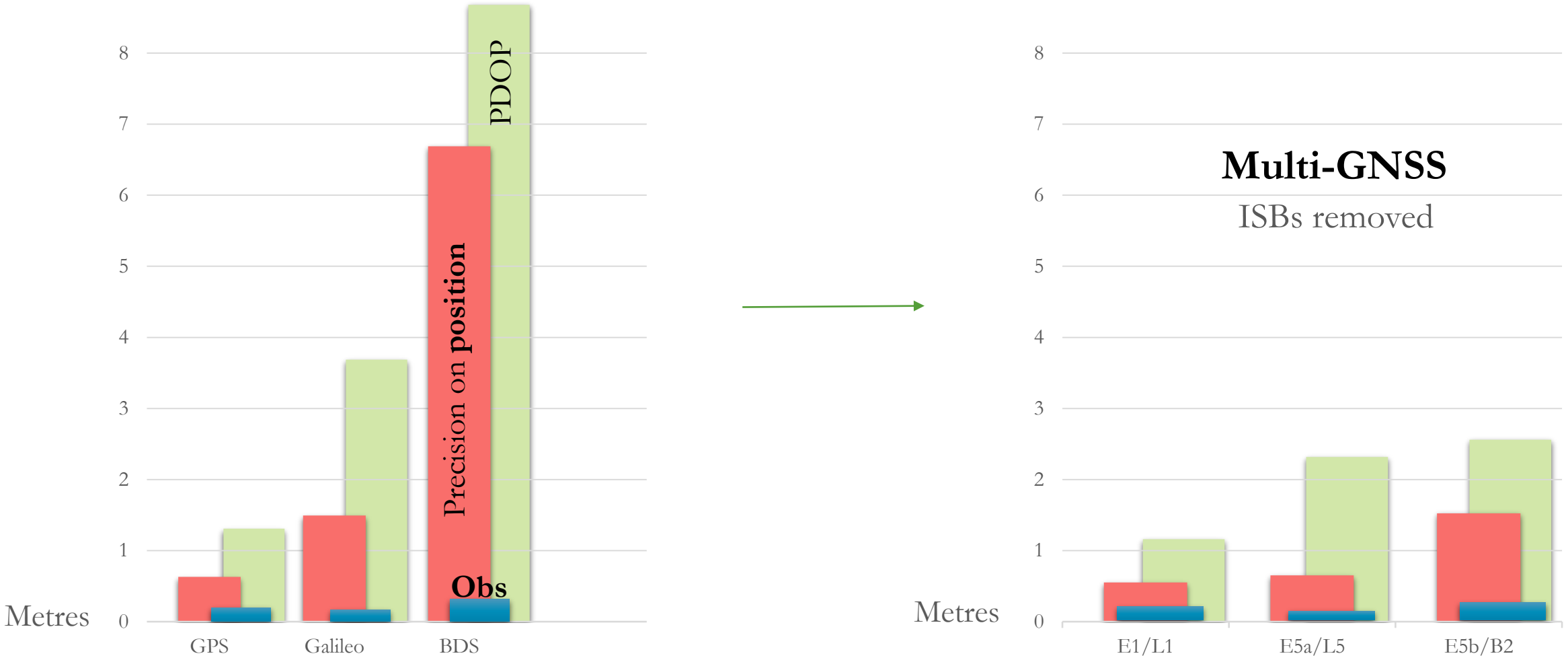
Receiver multipath filter
for codes



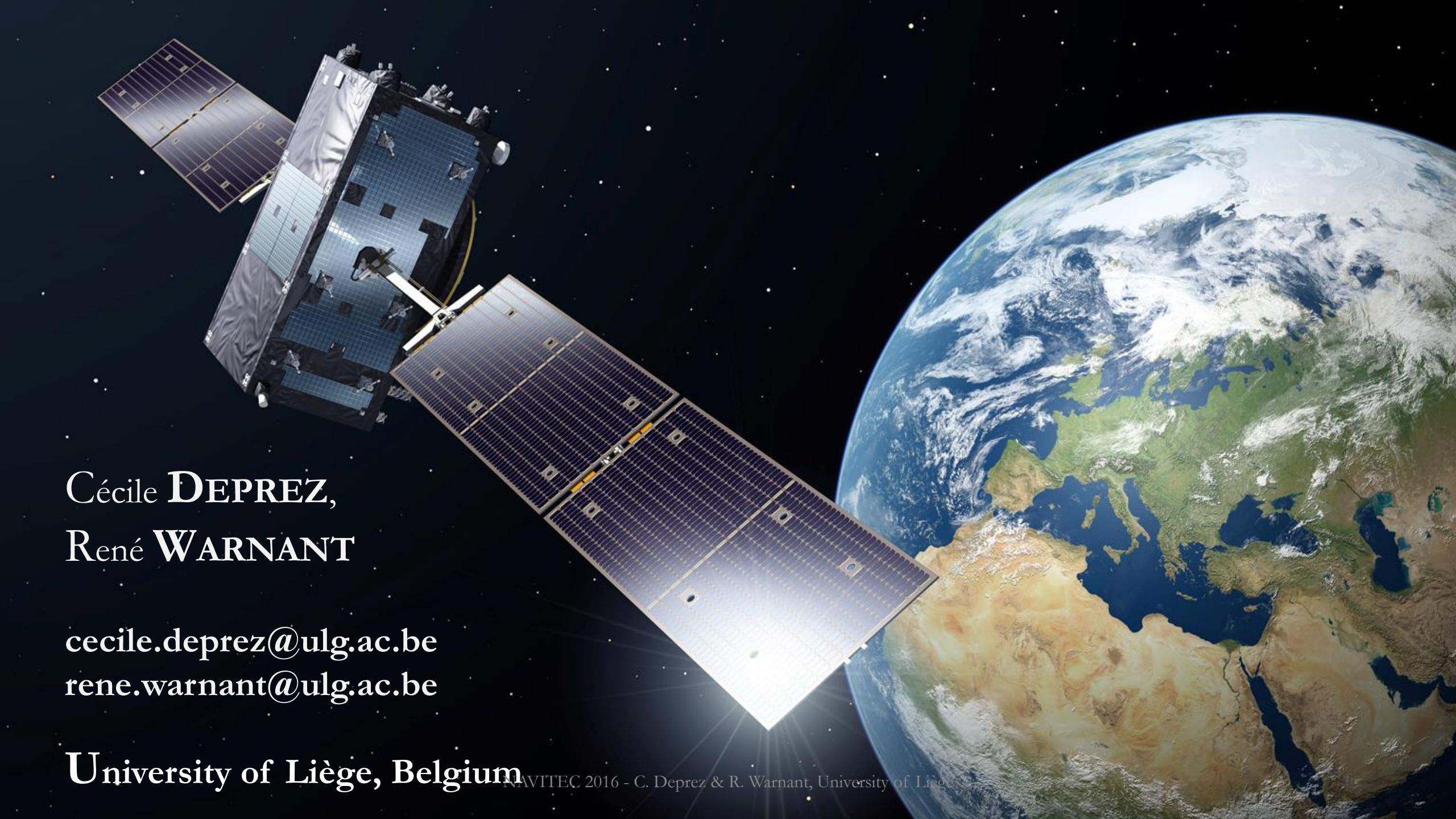
Multi-GNSS positioning

Estimation of the improvement brought by multi-GNSS

Multi-GNSS **improves** positioning results



What about **mass-market** receivers?



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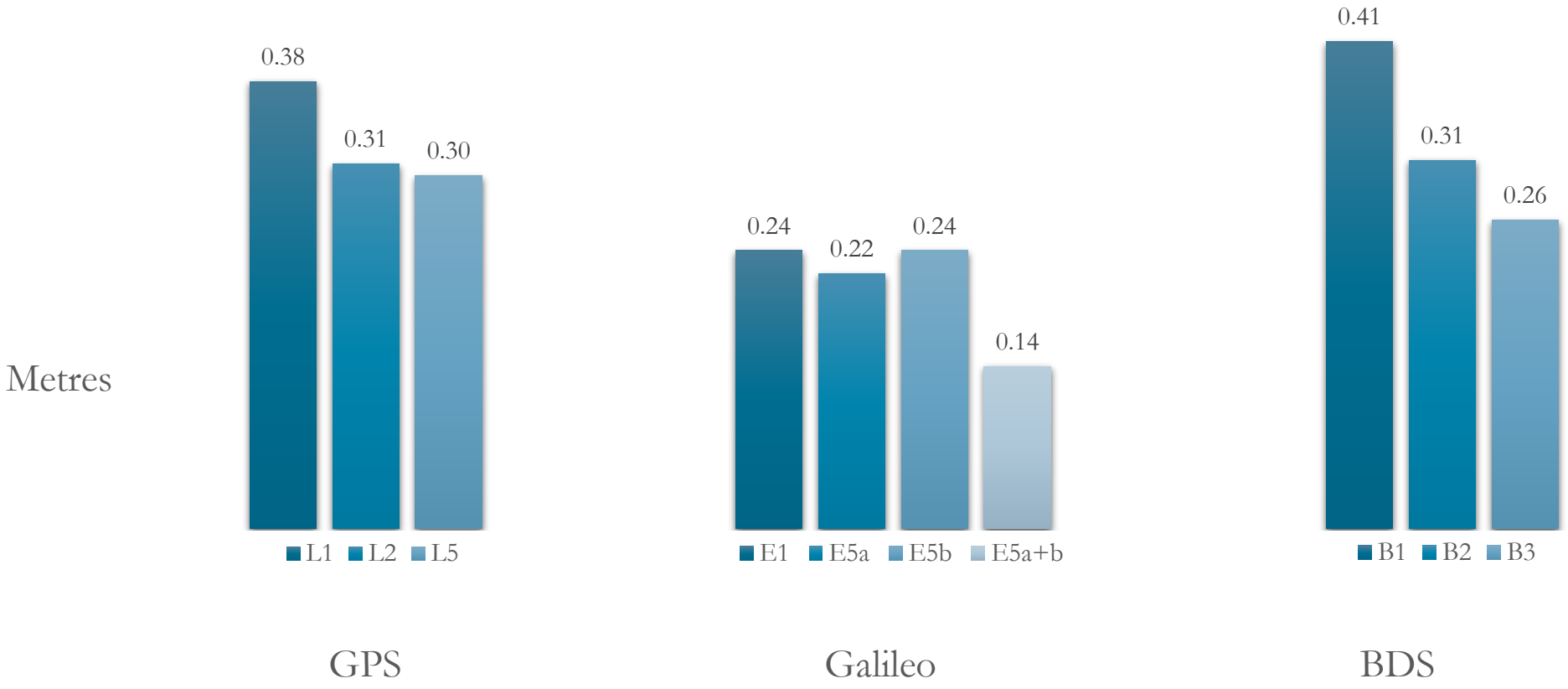
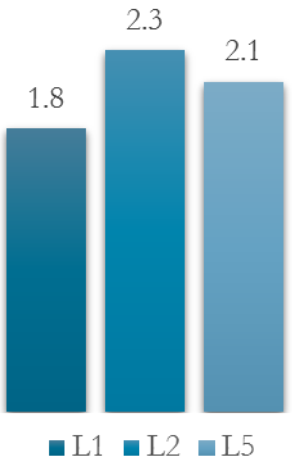
Best precisions with **Galileo** code signals

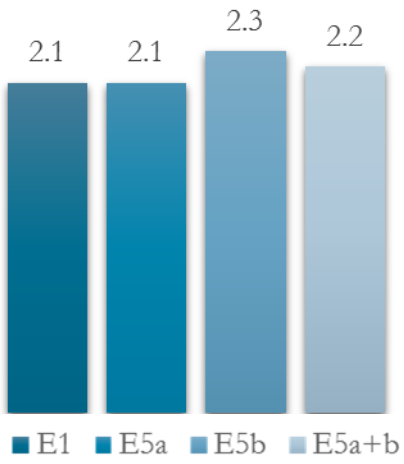


Similar precisions

Millimetres



GPS



Galileo

BDS

ISBs results

2014

	TR	X4	XS
TR	0,00	-4,44	-4,44
X4	4,44	-	-0,06
XS	4,44	0,06	-

2015

	TR	X4	XS
TR	0,00	-4,40	-4,44
X4	4,40	0,00	-0,04
XS	4,44	0,04	-

2016

	TR	X4	XS	X5
TR	0,00	-4,44	-4,49	-4,48
X4	4,44	0,00	-0,04	-0,03
XS	4,49	0,04	-	-0,02
X5	4,48	0,03	0,02	-

Galileo E5a / GPS L5

ISBs results

2014

	TR	X4	XS
TR	-	-2,82	-
X4	2,82	-	-0,06
XS	-	0,06	-

2015

	TR	X4	XS
TR	0,13	-2,92	-2,53
X4	2,92	0,02	-0,05
XS	2,53	0,05	-

2016

	TR	X4	XS
TR	0,13	-2,82	-2,57
X4	2,82	0,02	-0,04
XS	2,57	0,04	-

Galileo E5b / BeiDou B2

ISBs results

2014

	TR	X4	XS
TR	0,11	-0,49	-0,25
X4	0,49	-	0,00
XS	0,25	0,00	-

2015

	TR	X4	XS
TR	0,15	-0,39	-0,14
X4	0,39	0,00	0,00
XS	0,14	0,00	-

2016

	TR	X4	XS	X5
TR	0,15	-0,22	-0,16	-0,02
X4	0,22	0,00	0,00	-0,17
XS	0,16	0,00	-	-0,17
X5	0,02	0,17	0,17	-

Galileo E1 / GPS L1

ISBs phase results

2015

	TR	X4	XS
TR	0,00	-0,24	-0,24
X4	0,24	0,00	0,00
XS	0,24	0,00	-

2016a

	TR	X4	XS
TR	0,00	-0,24	-0,24
X4	0,24	0,00	0,00
XS	0,24	0,00	-

2016b

	TR	X4	XS
TR	-	-0,24	-0,24
X4	0,24	-	0,00
XS	0,24	0,00	-

Galileo E5b / BeiDou B2