LIÈGE université
Sciences

Precise positioning in multi-GNSS mode

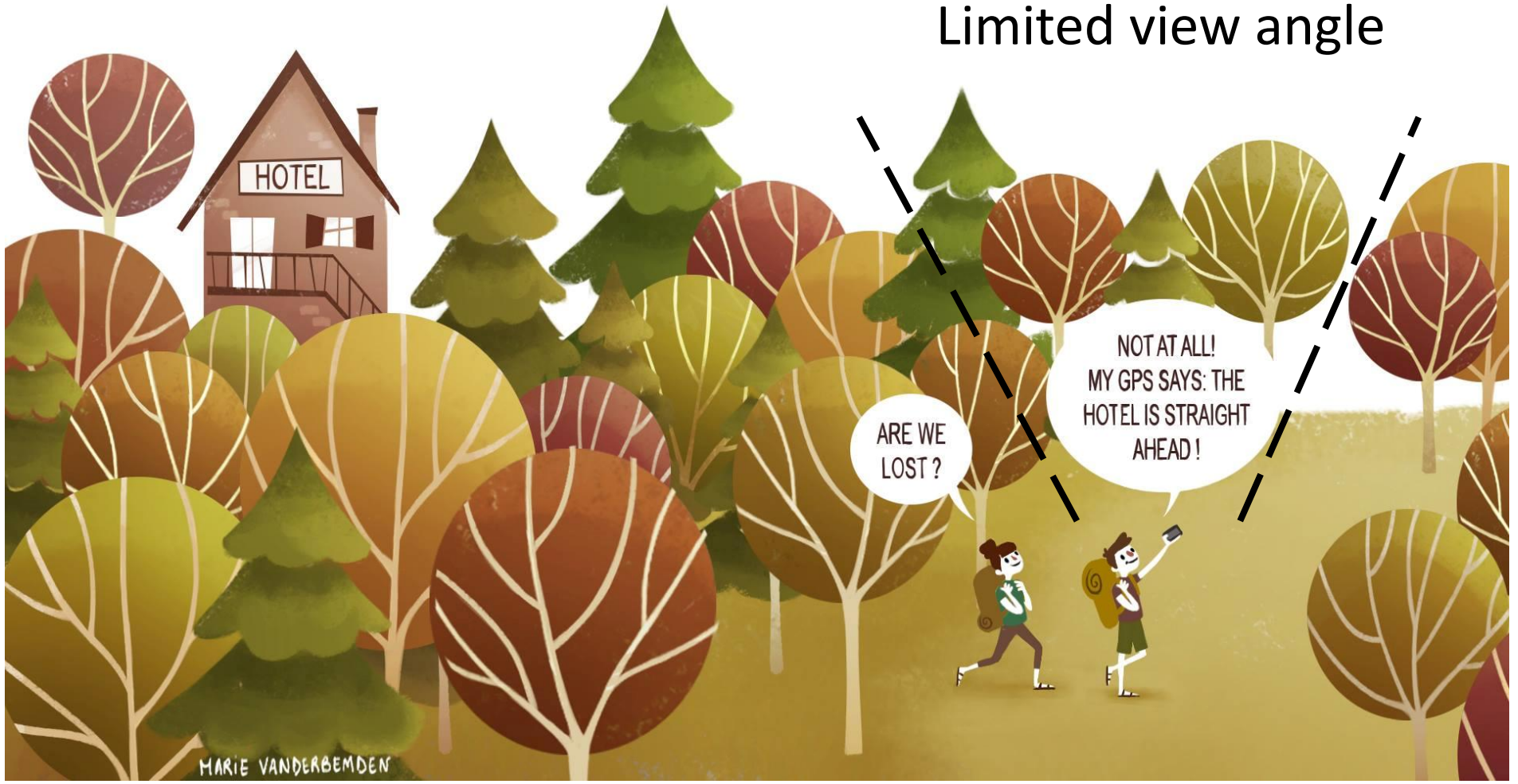
Cécile Deprez

fnrs
LA LIBERTÉ DE CHERCHER


HOTEL
MARIE VANDERBEMDEN

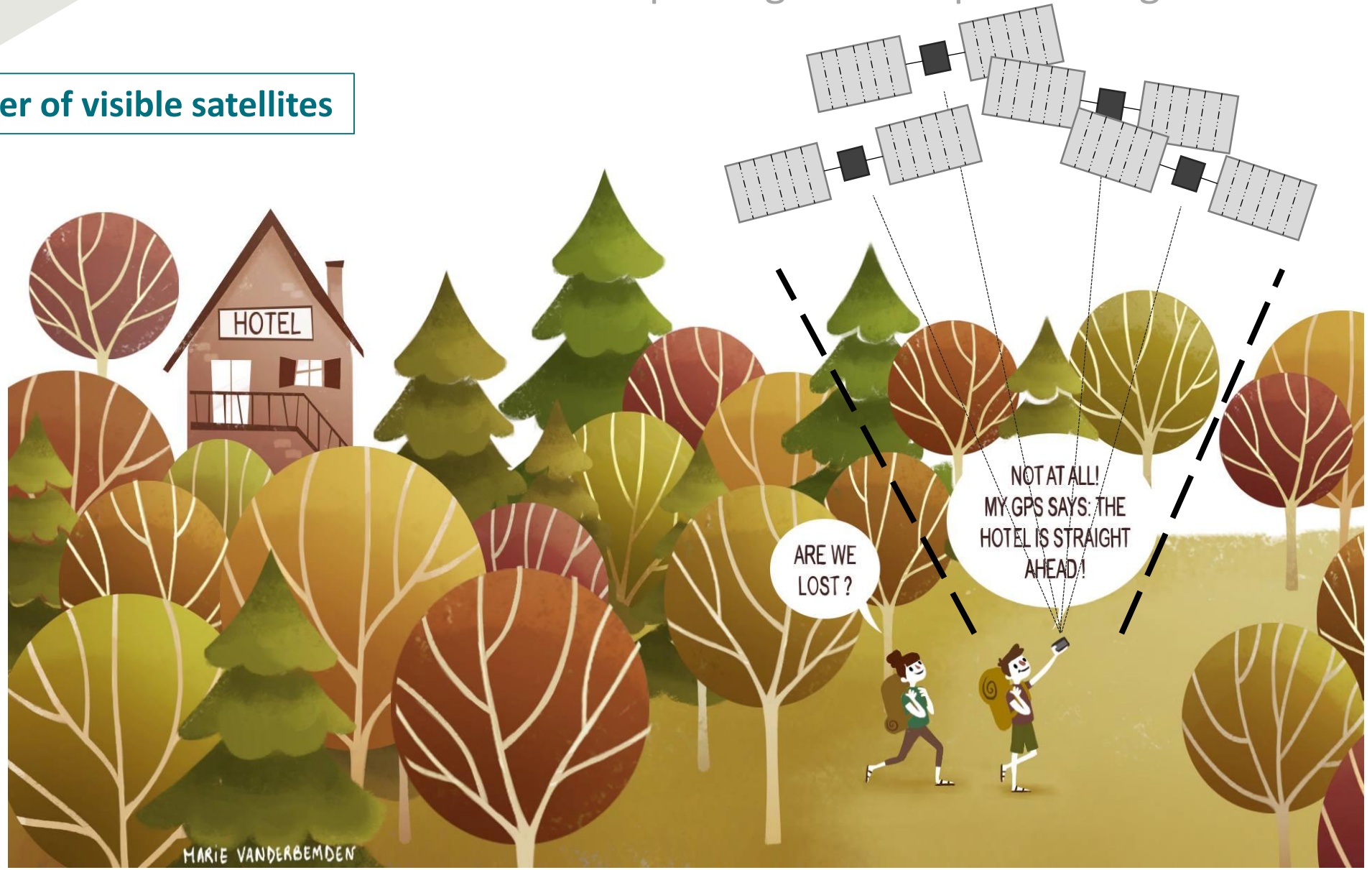
What are the factors impacting satellite positioning?

What are the factors impacting satellite positioning?



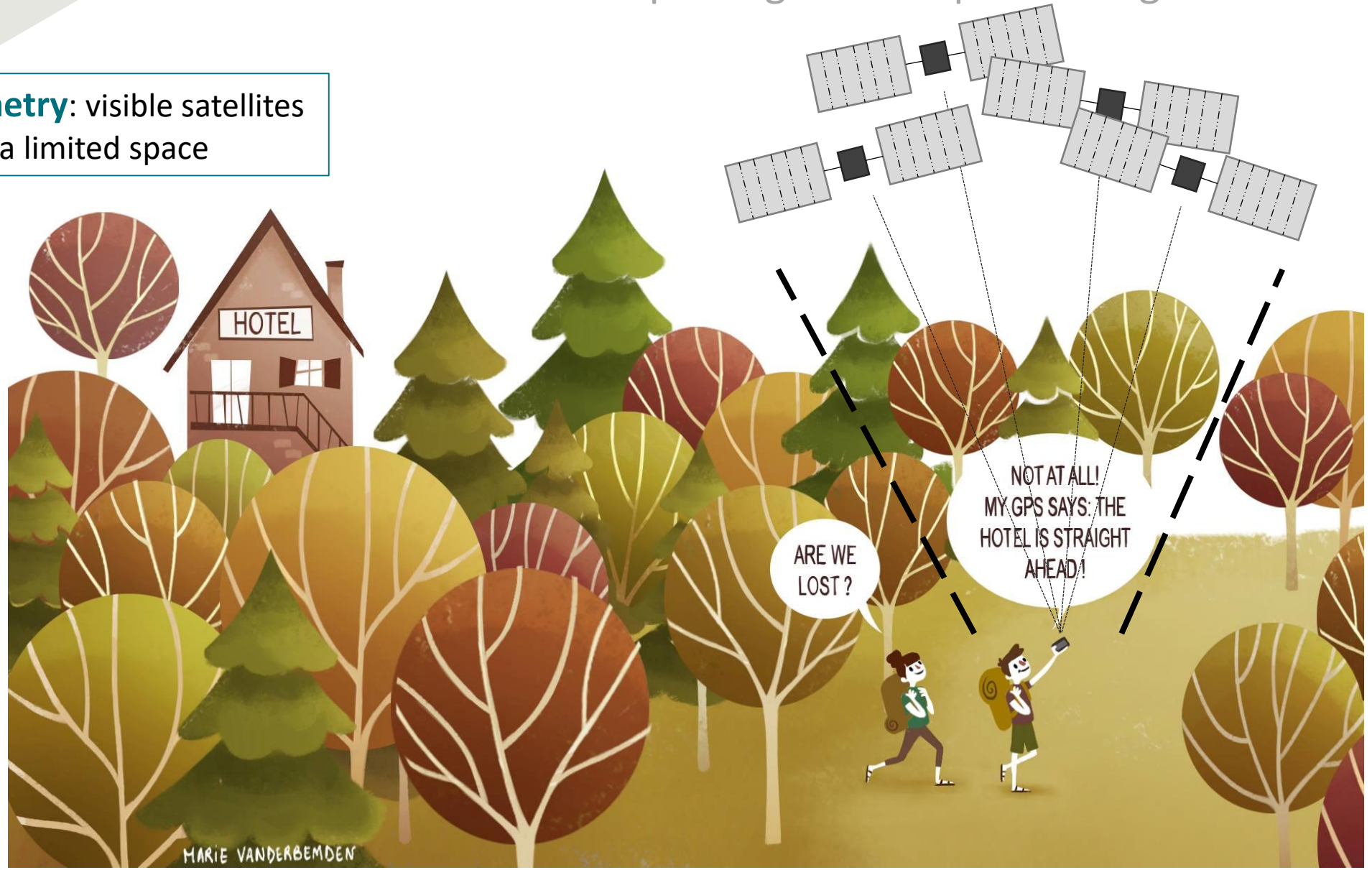
What are the factors impacting satellite positioning?

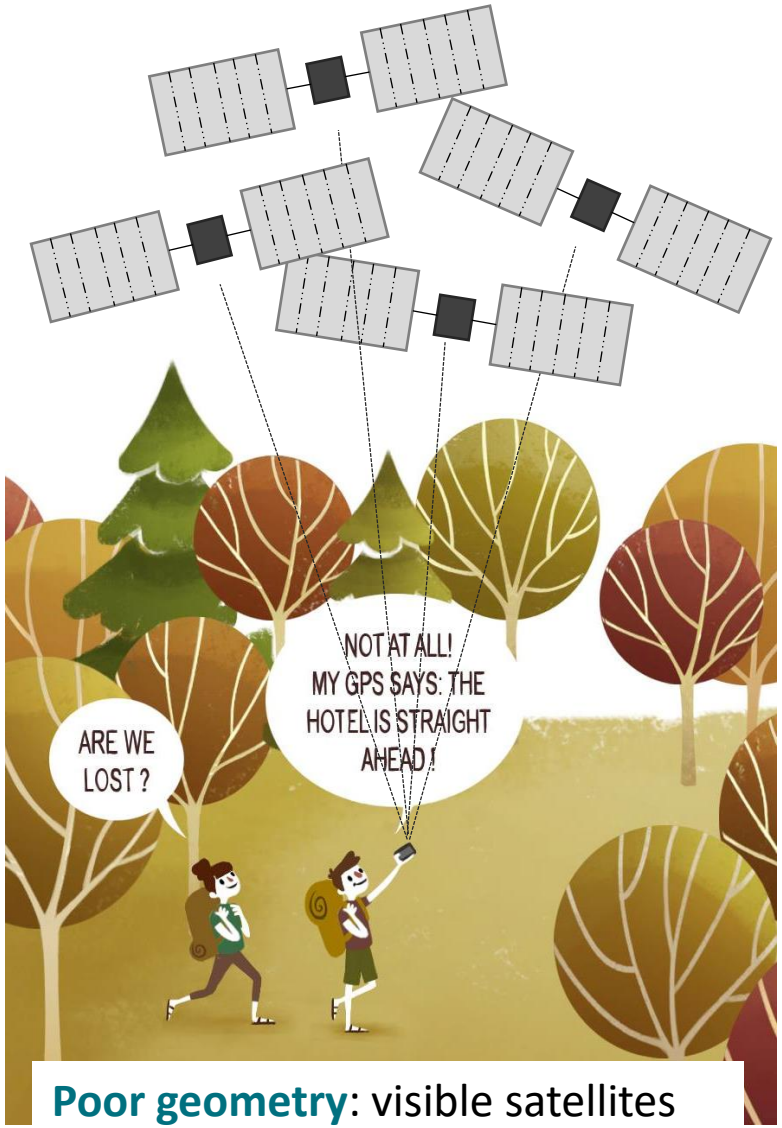
Low number of visible satellites



What are the factors impacting satellite positioning?

Poor geometry: visible satellites gathered in a limited space





Poor geometry: visible satellites gathered in a limited space

High PDOP

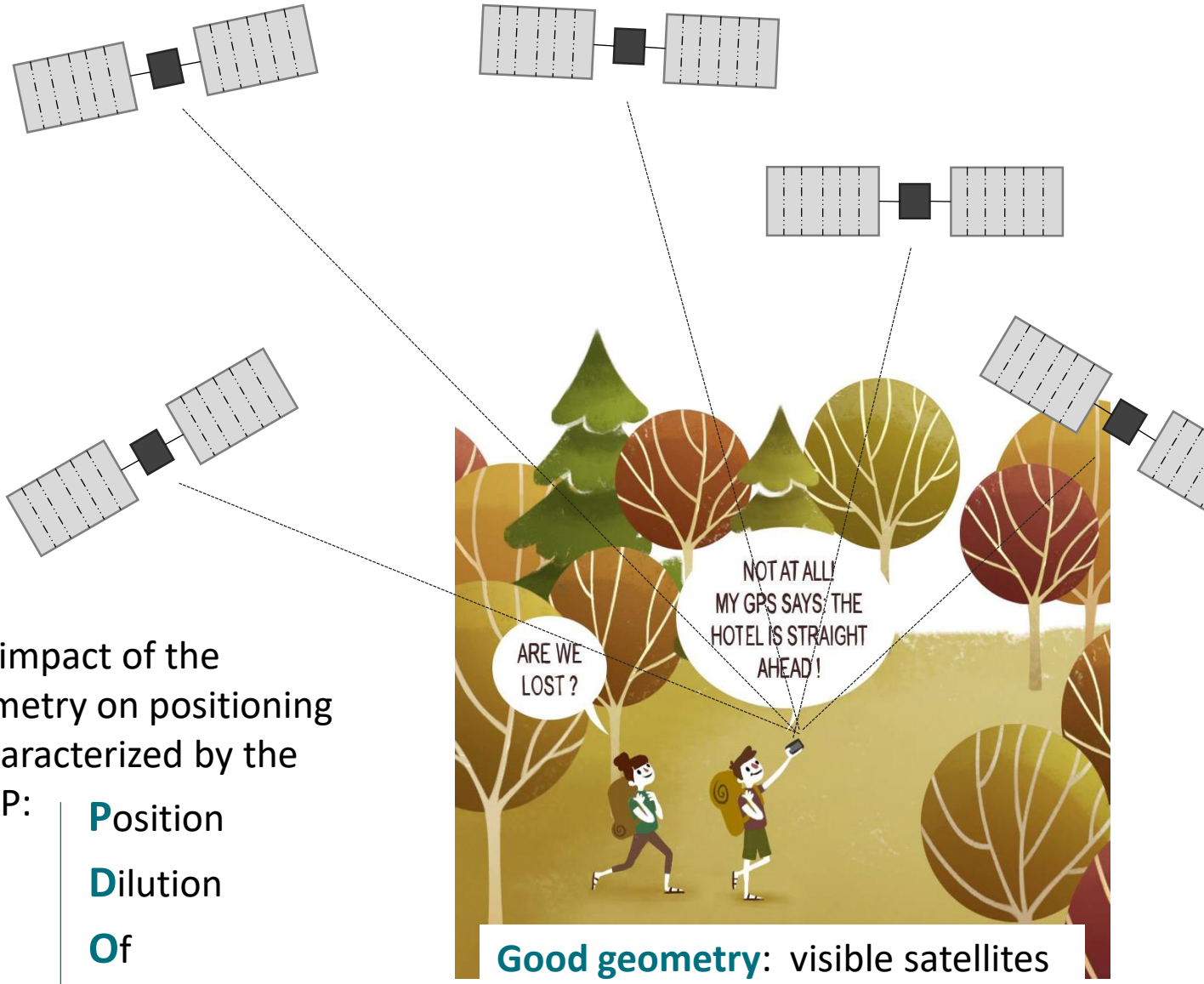
The impact of the geometry on positioning is characterized by the PDOP:

Position

Dilution

Of

Precision



Good geometry: visible satellites spread around the receiver

Low PDOP

The **geometry** of the satellites affects the positioning precision :

$$\sigma_{POS} = \mathrm{PDOP} \,.\, \sigma_{OBS}$$

PDOP = **P**osition **D**ilution **O**f **P**recision

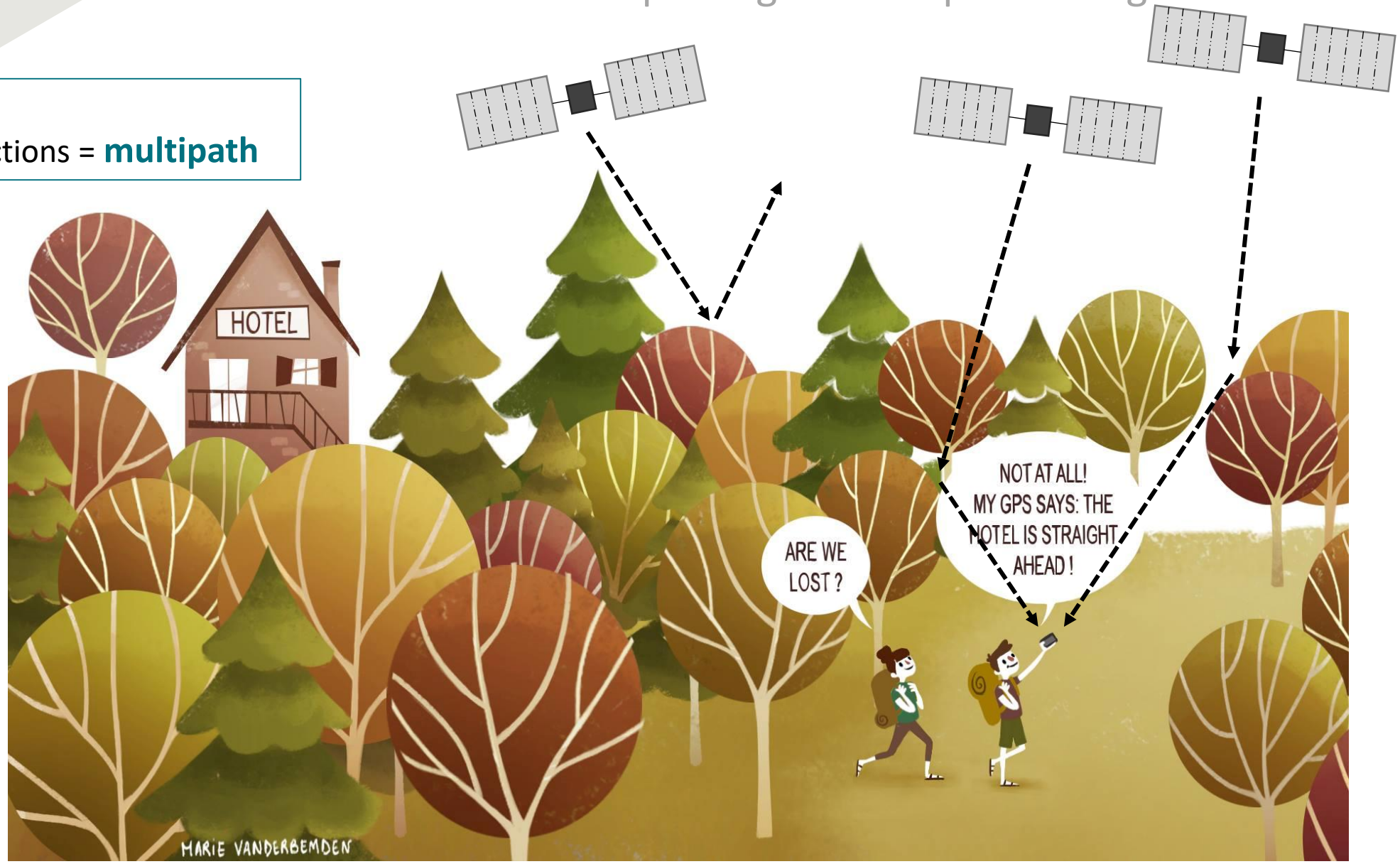
= Impact of satellite geometry

High PDOP values **degrade** the positioning precision

POSITIONING ALTERATIONS

What are the factors impacting satellite positioning?

Forest, city -
Signal obstructions = **multipath**



What are the factors impacting satellite positioning?

Receiver quality

How could **multi-GNSS improve** this situation?

GNSS : Global Navigation Satellite Systems

American: **GPS**

Russian: **GLONASS**

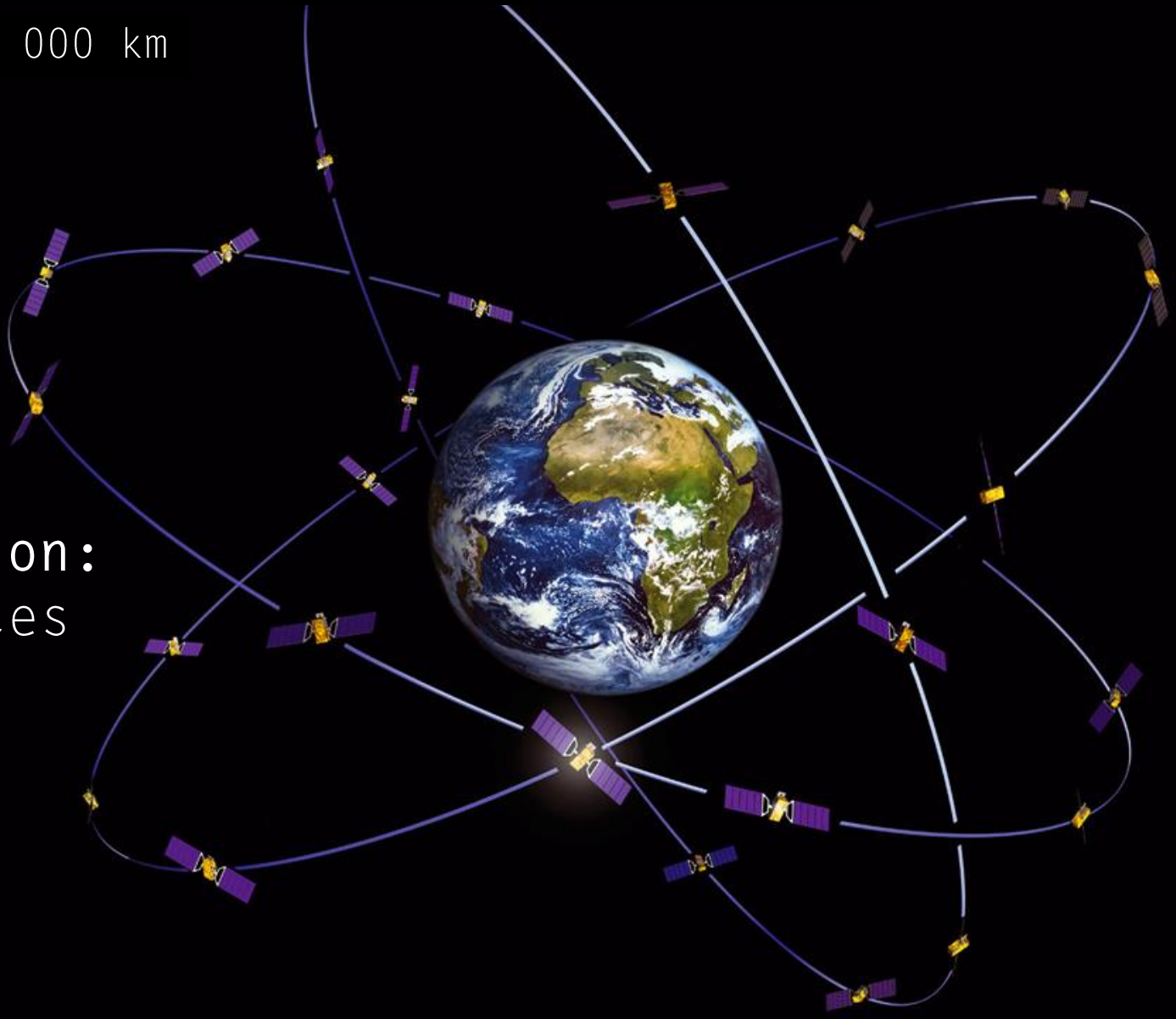
European: **Galileo**

Chinese: **BeiDou**

ESA images (https://www.esa.int)

GPS : Global Positioning system

Altitude: ±20 000 km



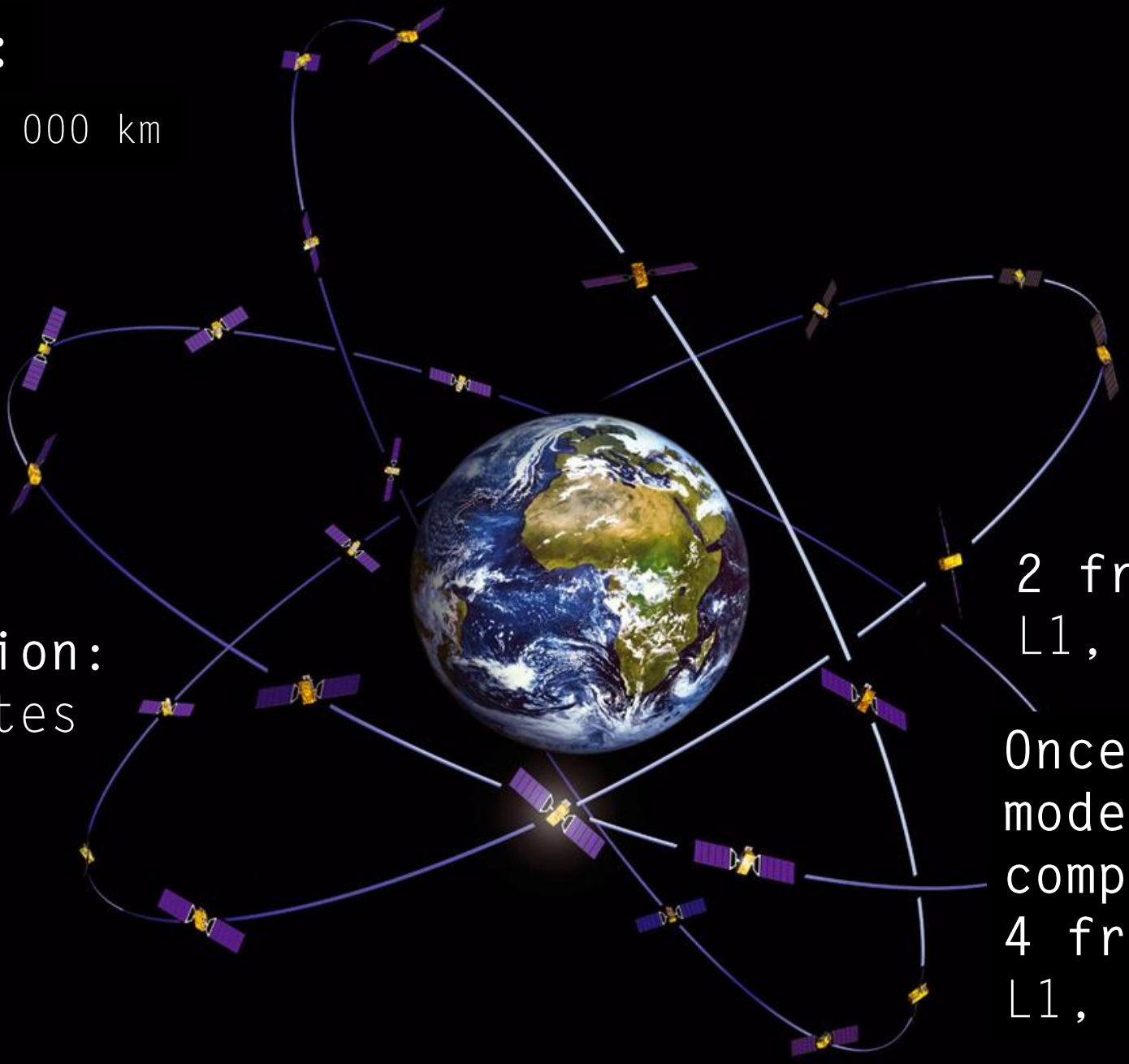
Constellation:
30 satellites

3 frequencies:
L1, L2, L5

ESA images (https://www.esa.int)

GLONASS :

Altitude: ±19 000 km



Undergoing modernization:
24 satellites

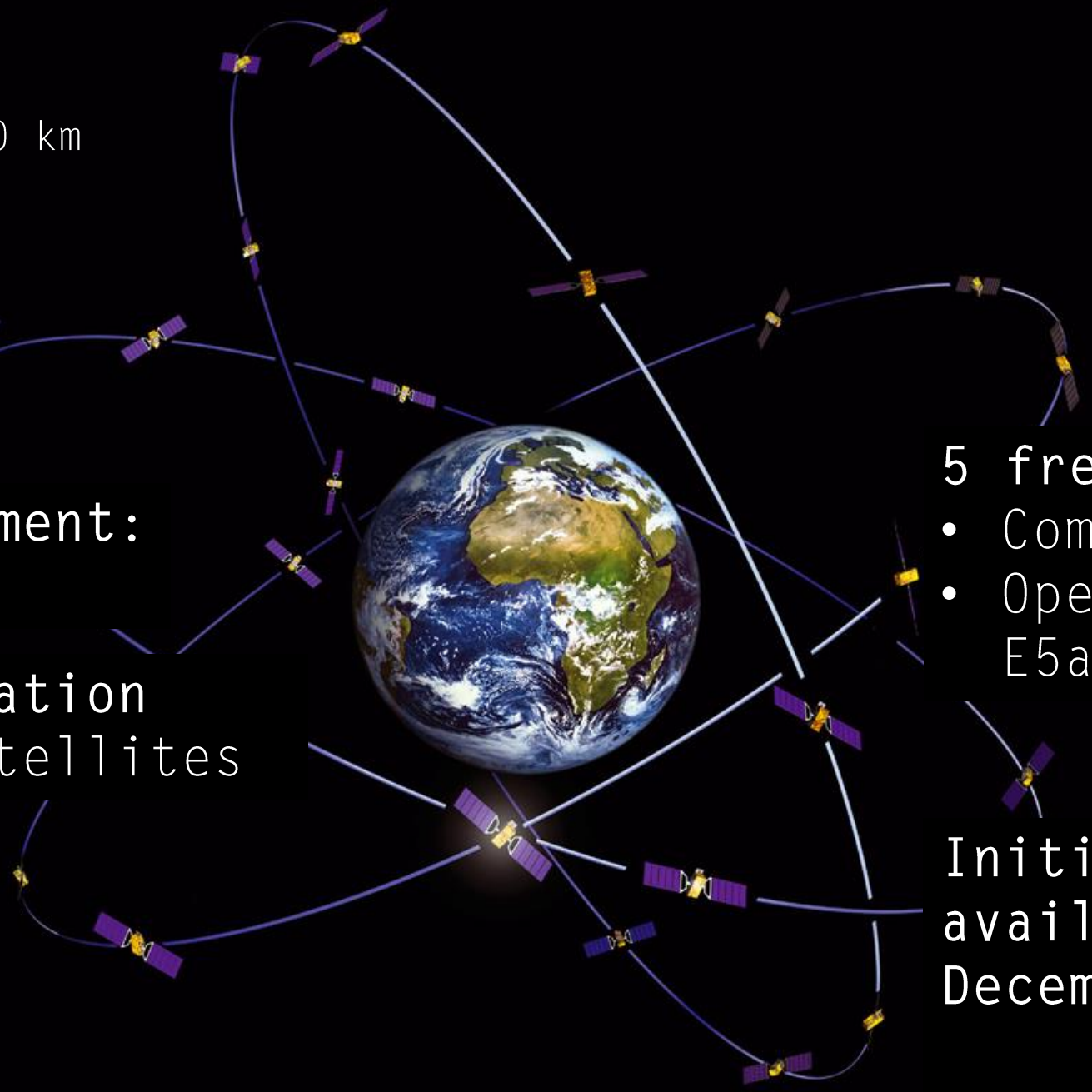
2 frequencies:
L1, L2

Once the modernization complete,
4 frequencies:
L1, L2, L3, L5

ESA images (https://www.esa.int)

Galileo

Altitude: ±24 000 km



Under development:
22 satellites

Full constellation (2020): 30 satellites

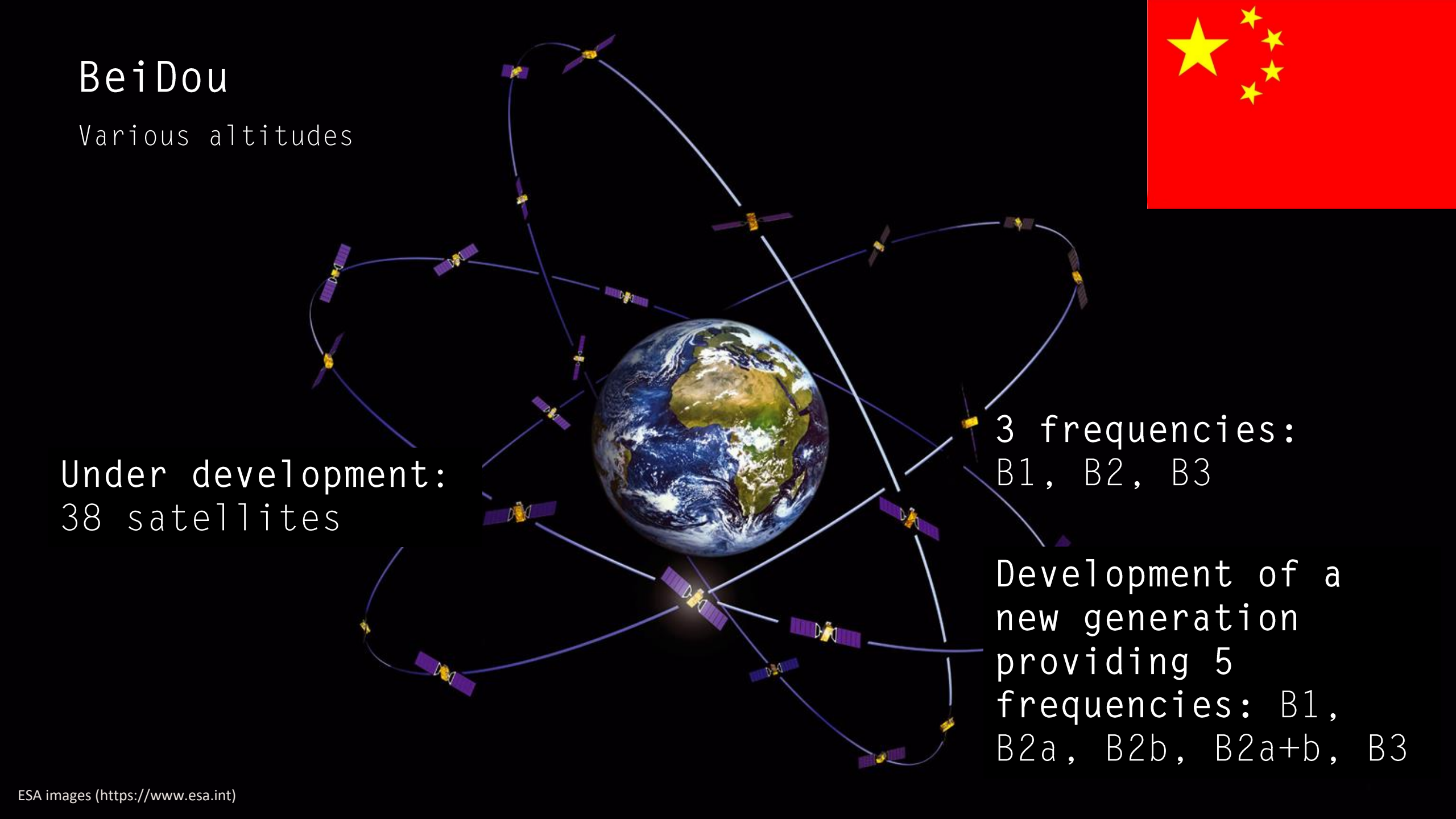
5 frequencies:
- Commercial: E6
- Open access: E1, E5a, E5b, E5a+b

Initial services available since December 2016

ESA images (https://www.esa.int)

BeiDou

Various altitudes



Under development:
38 satellites

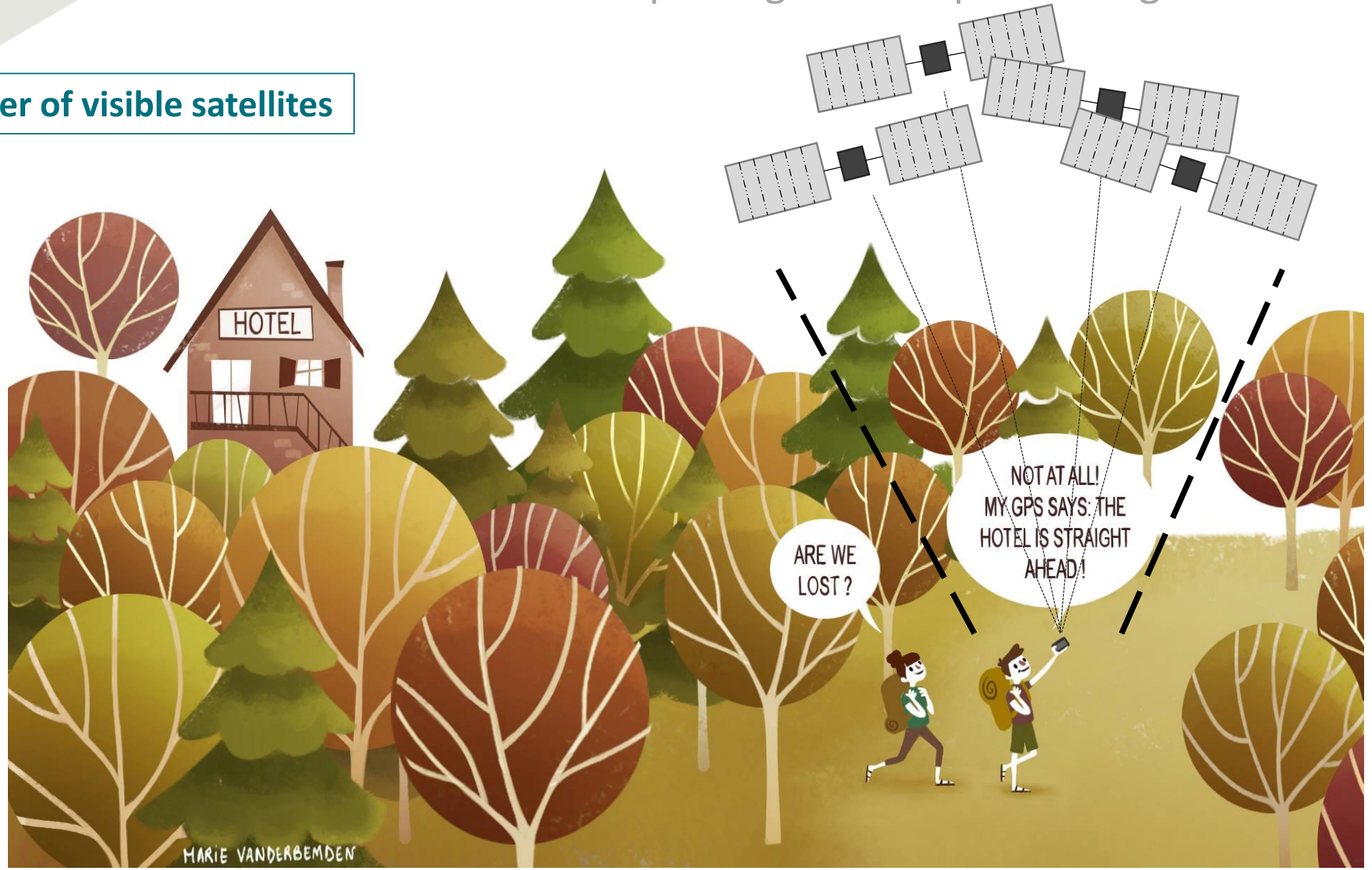
3 frequencies:
B1, B2, B3

Development of a new generation providing 5 frequencies: B1, B2a, B2b, B2a+b, B3

ESA images (https://www.esa.int)

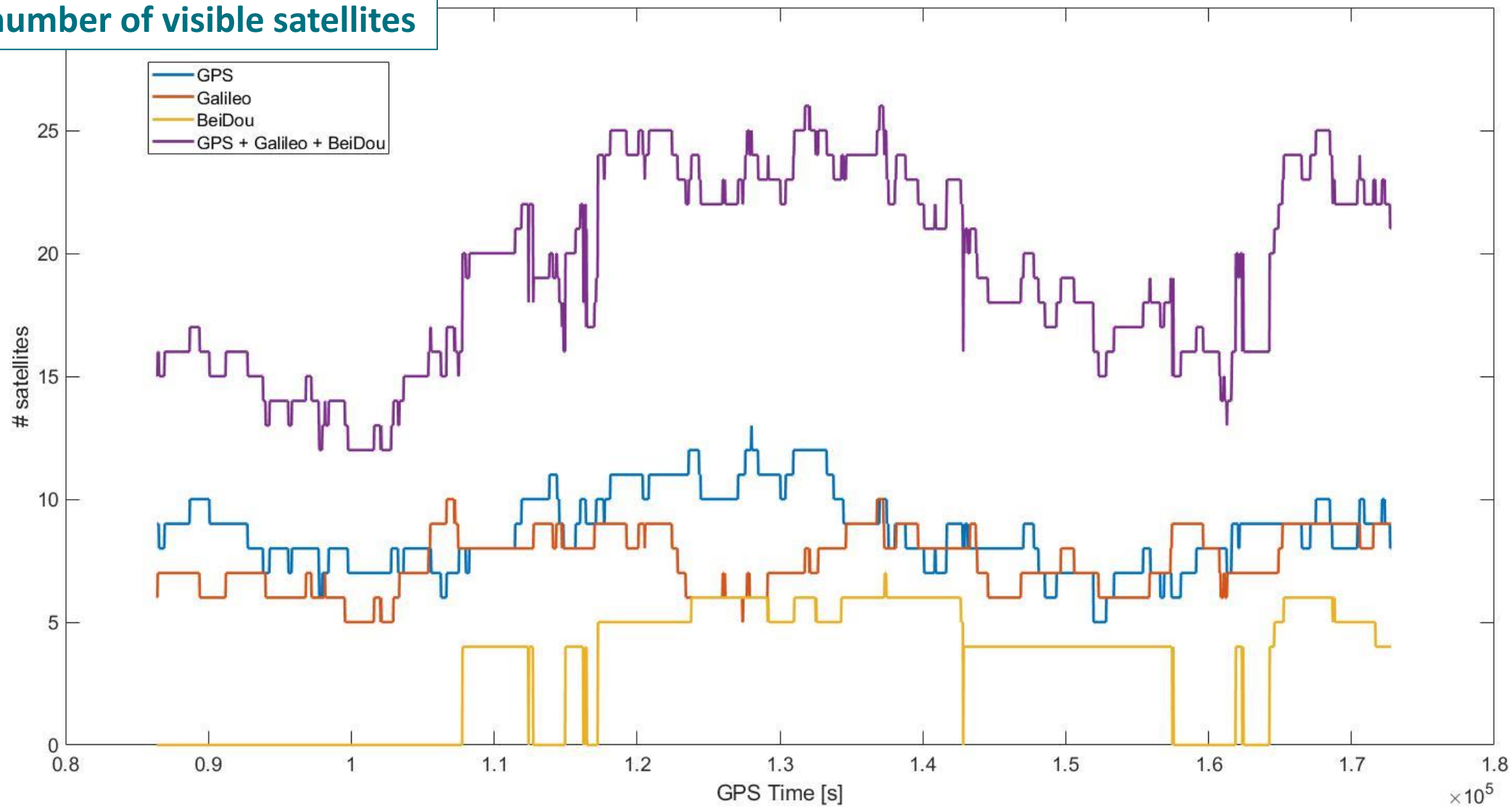
What are the factors impacting satellite positioning?

Low number of visible satellites



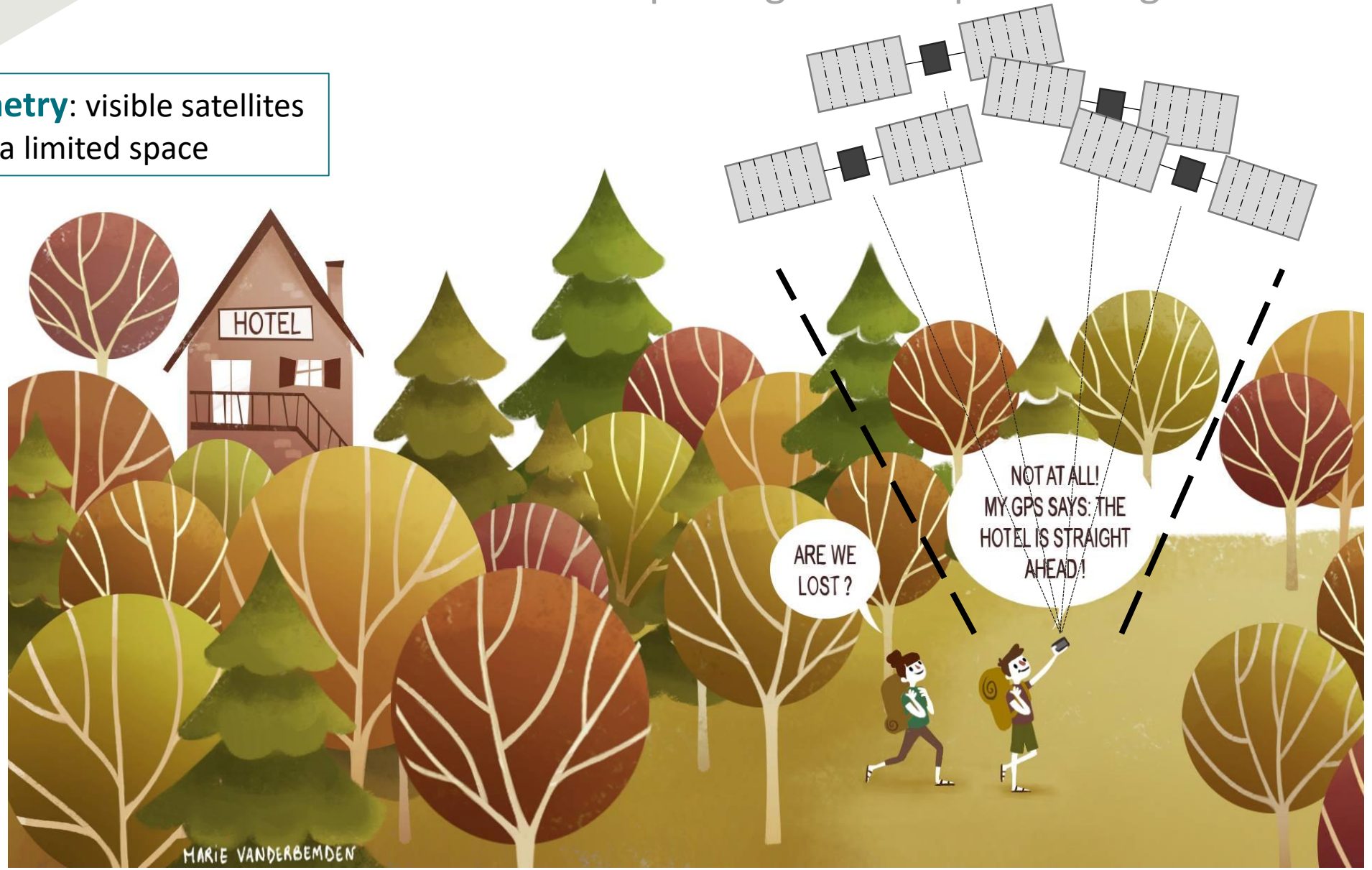
MULTI-GNSS
IMPROVEMENTS

Low number of visible satellites



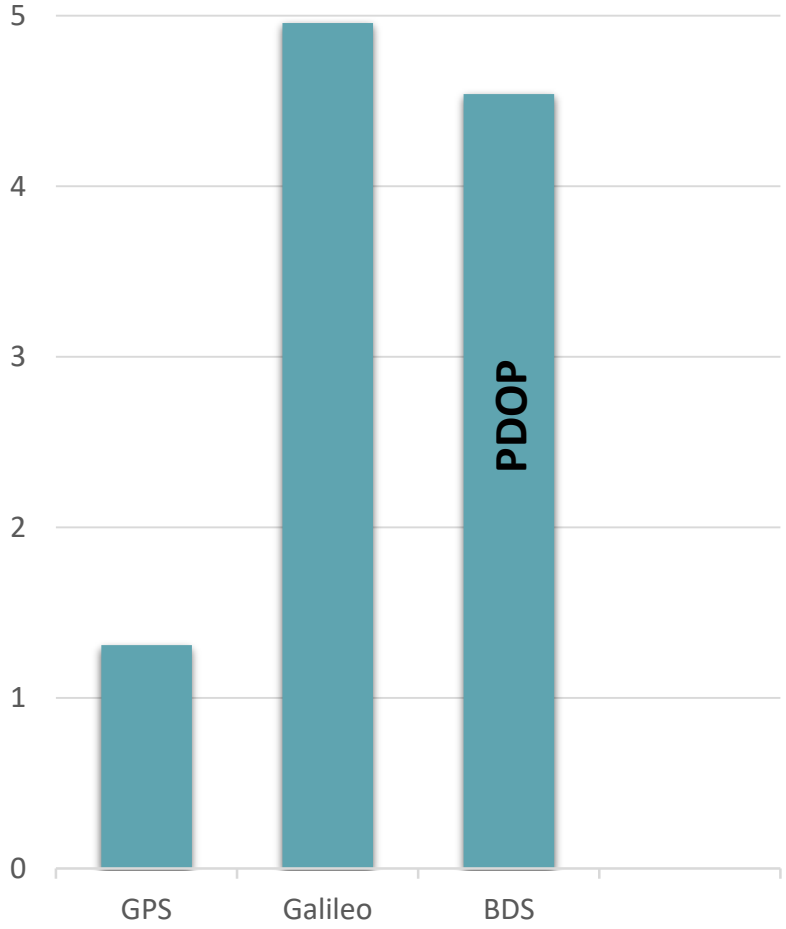
What are the factors impacting satellite positioning?

Poor geometry: visible satellites gathered in a limited space

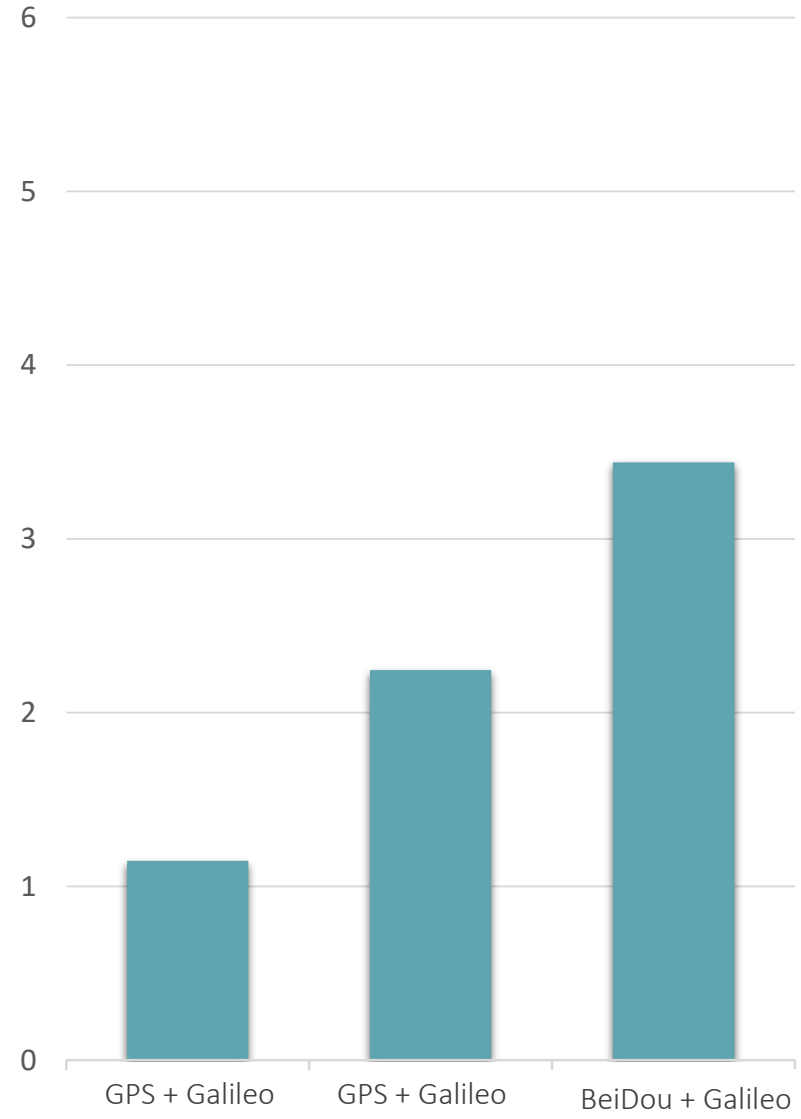


MULTI-GNSS IMPROVEMENTS

Poor geometry: visible satellites gathered in a limited space



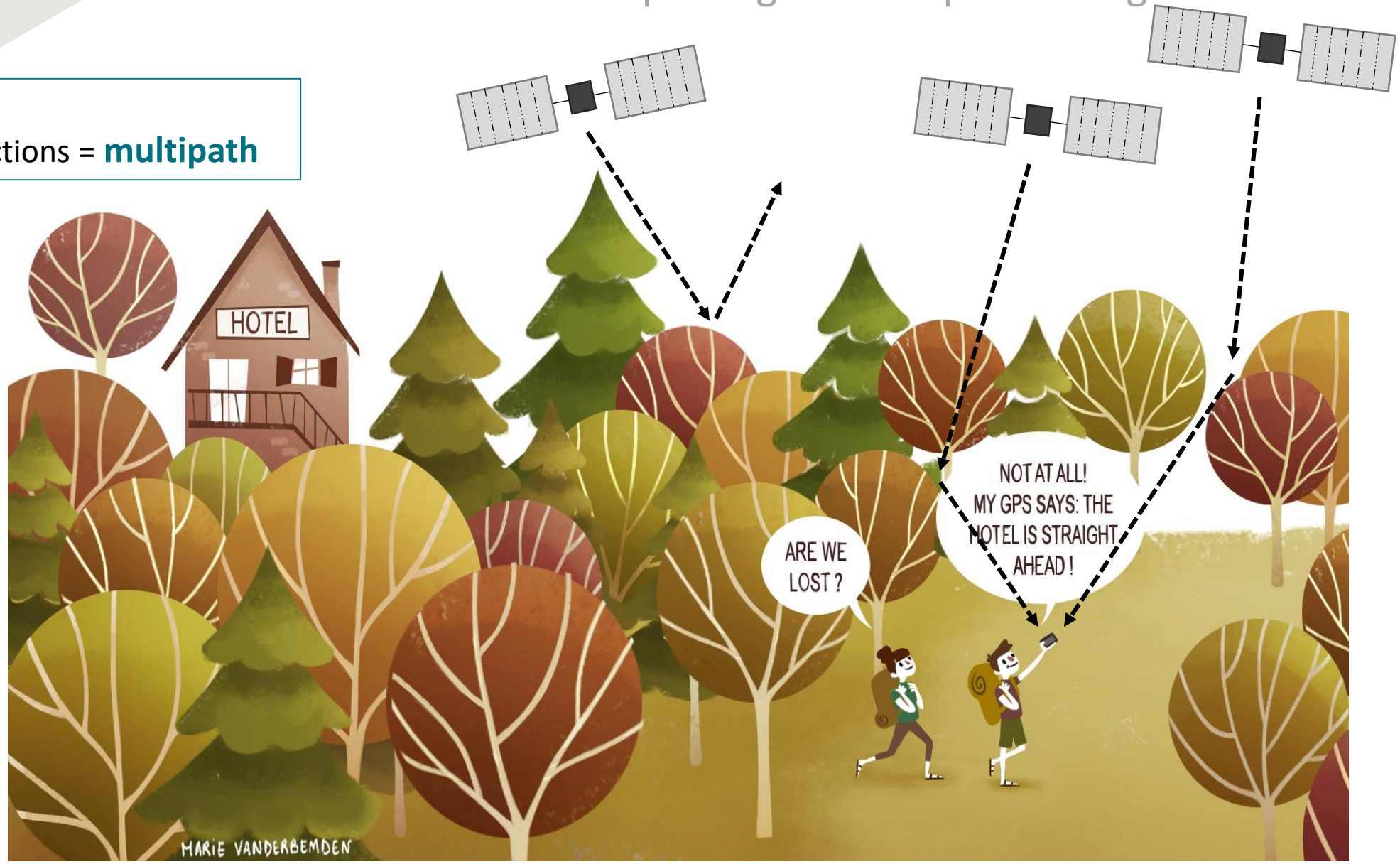
PDOP evolution



POSITIONING ALTERATIONS

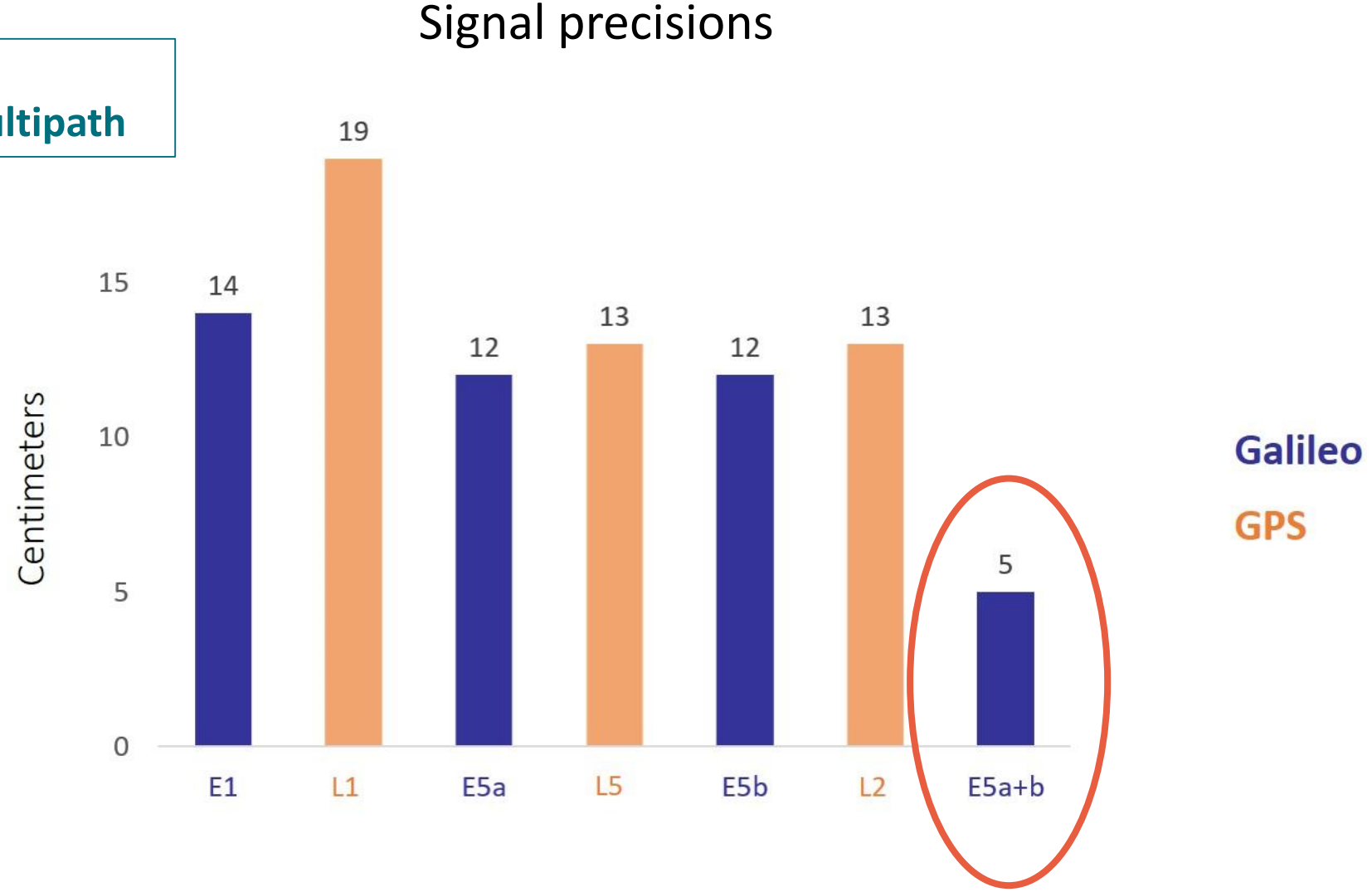
What are the factors impacting satellite positioning?

Forest, city -
Signal obstructions = **multipath**



MULTI-GNSS
IMPROVEMENTS

Forest, city -
Signal obstructions = **multipath**



What are the factors impacting satellite positioning?

Receiver quality

Receiver's Features

Geodetic receivers

$$$ (Thousands USDs)

Trimble image

Septentrio image

- Multi-GNSS
- Multi-Frequency

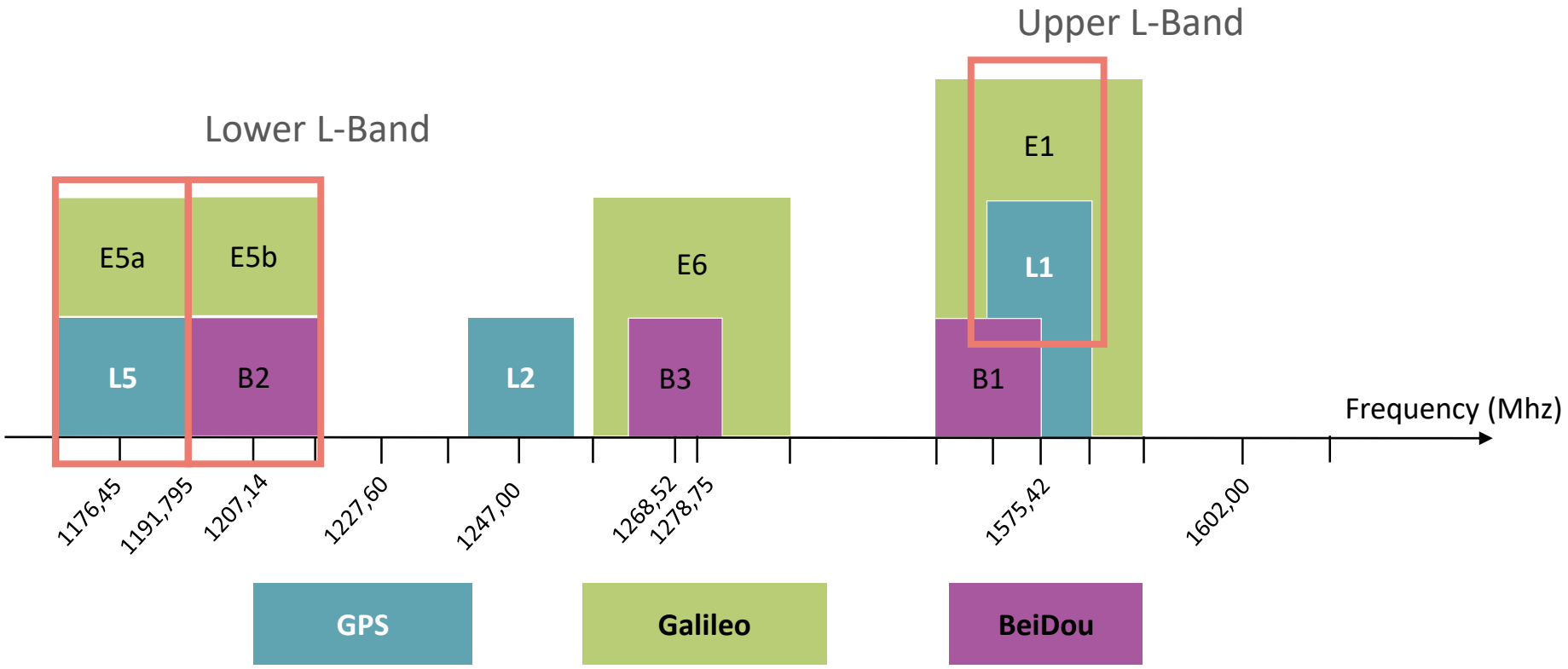
Low-Cost receivers

$$ (Hundreds USDs)

u-blox image

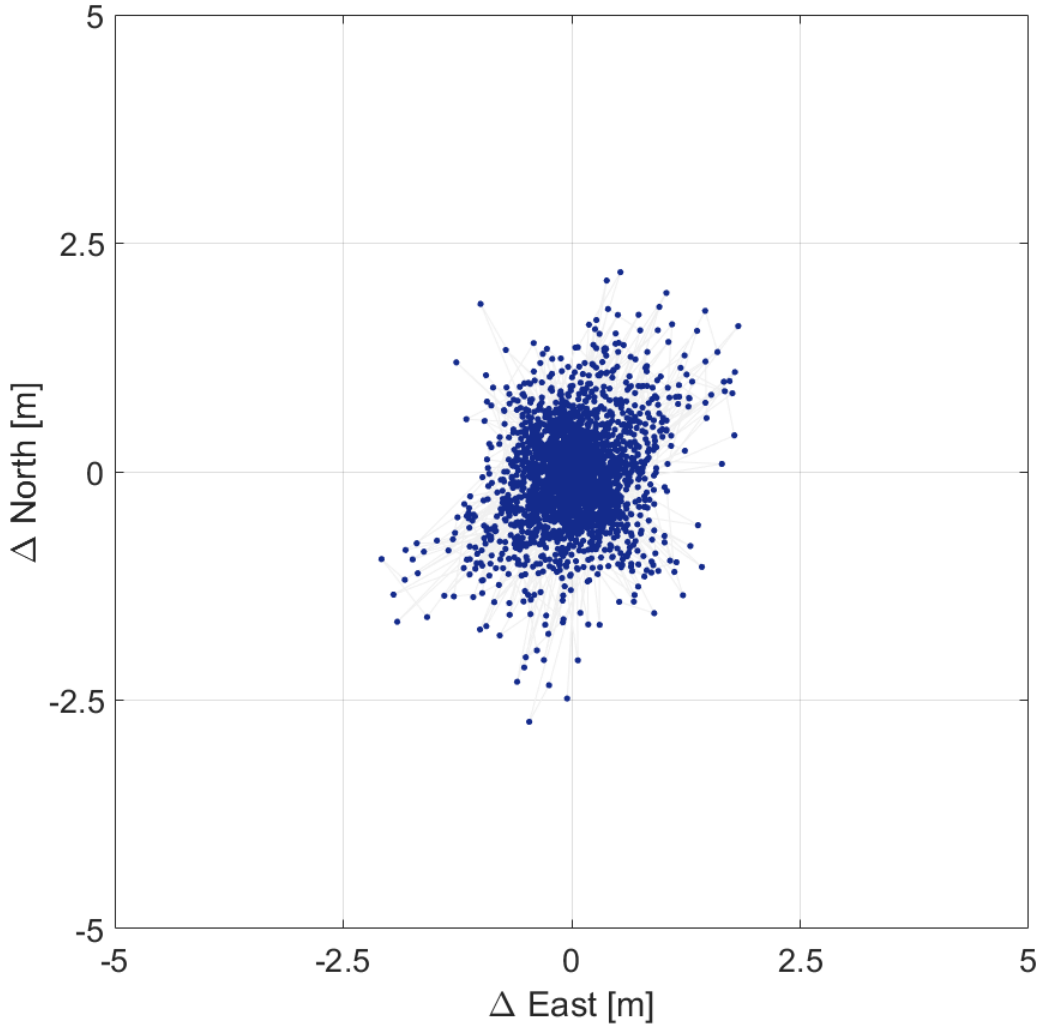
- Multi-GNSS
- Single-Frequency

GNSS constellations are **compatible**



Positioning with Galileo

Galileo E1:



Galileo E1

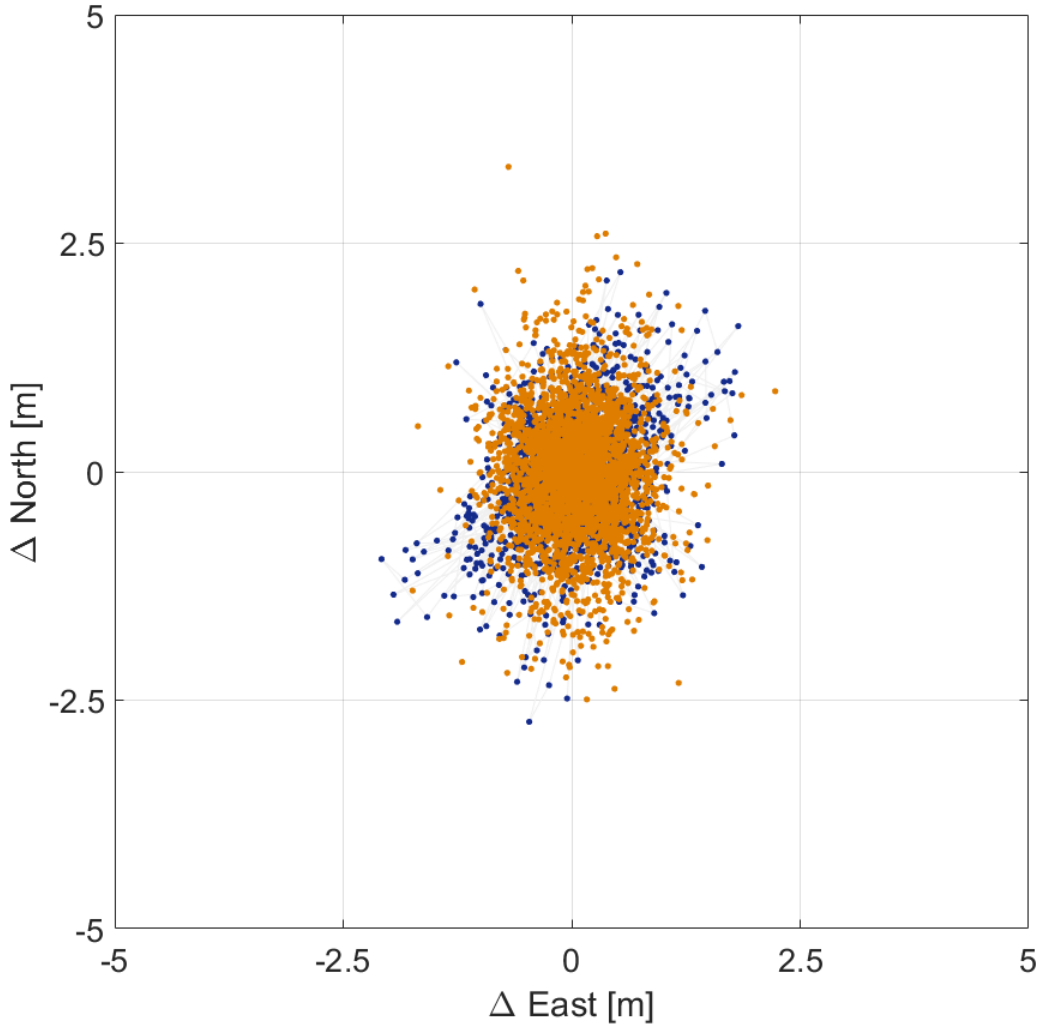
Position 2D: 0.71 m

Position 3D: 1.10 m

Positioning with **GPS**

Galileo E1:

GPS L1:



Galileo E1

Position 2D: 0.72 m

Position 3D: 1.13 m

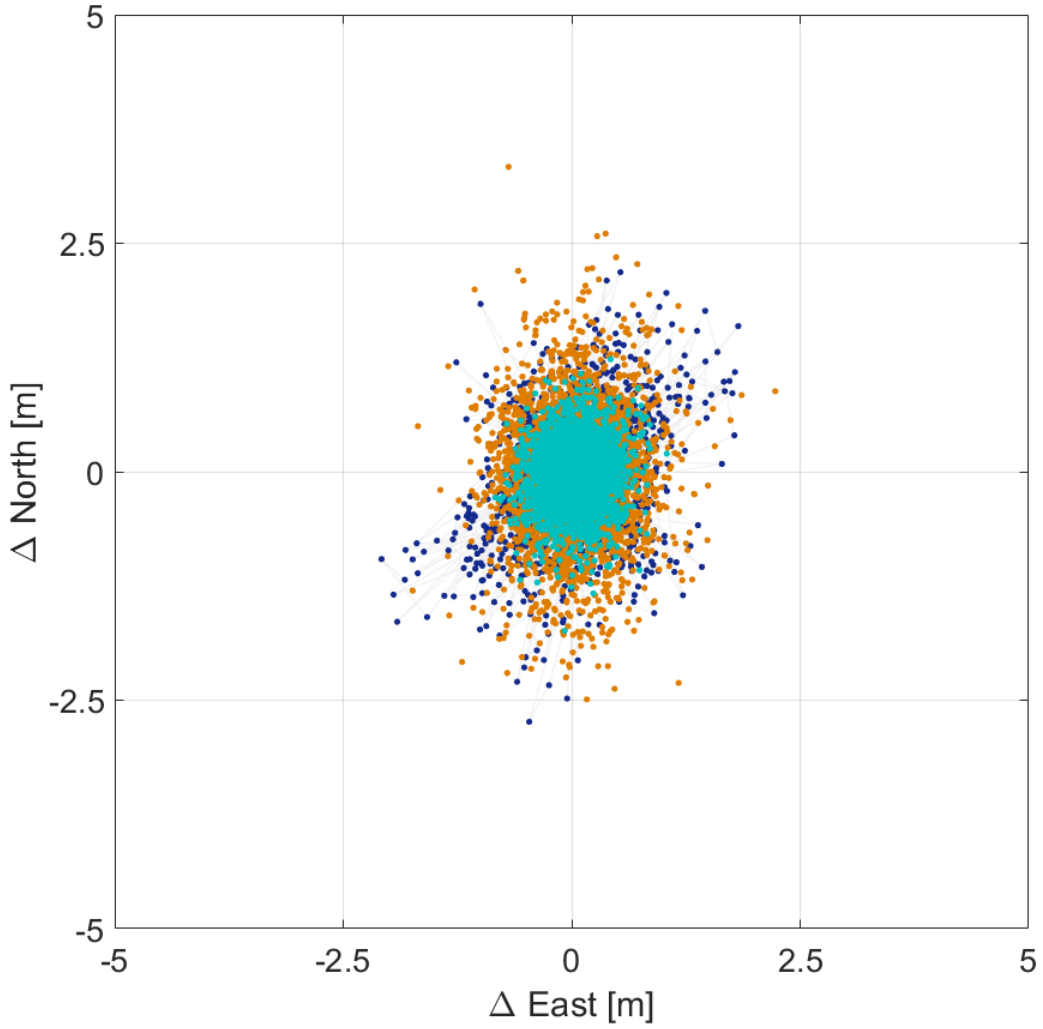
GPS L1

Position 2D: 0.81 m

Position 3D: 1.32 m

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

Galileo E1
+
GPS L1 :



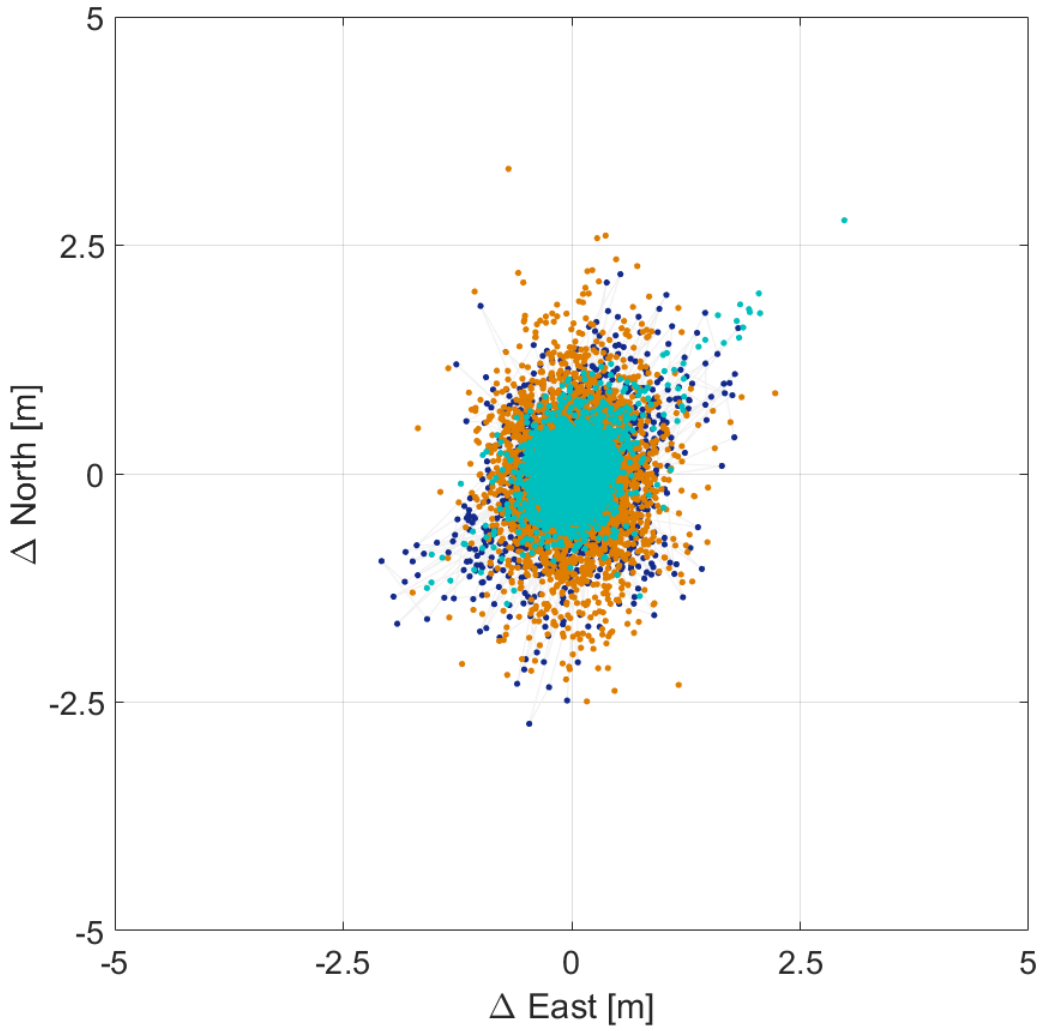
Overlapping frequencies
= single-frequency

Galileo E1
+
GPS L1

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

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

Galileo E5a
+
GPS L5 :



Overlapping frequencies
= single-frequency

Galileo E5a
+
GPS L5

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

Drawbacks of multi-GNSS positioning

Differences

between GNSS

Time systems

Coordinate systems

Hardware delays

lead to **additional biases!**

= Inter-System Biases

= ISBs

ISBs are **receiver-dependent**

Trimble NetR9

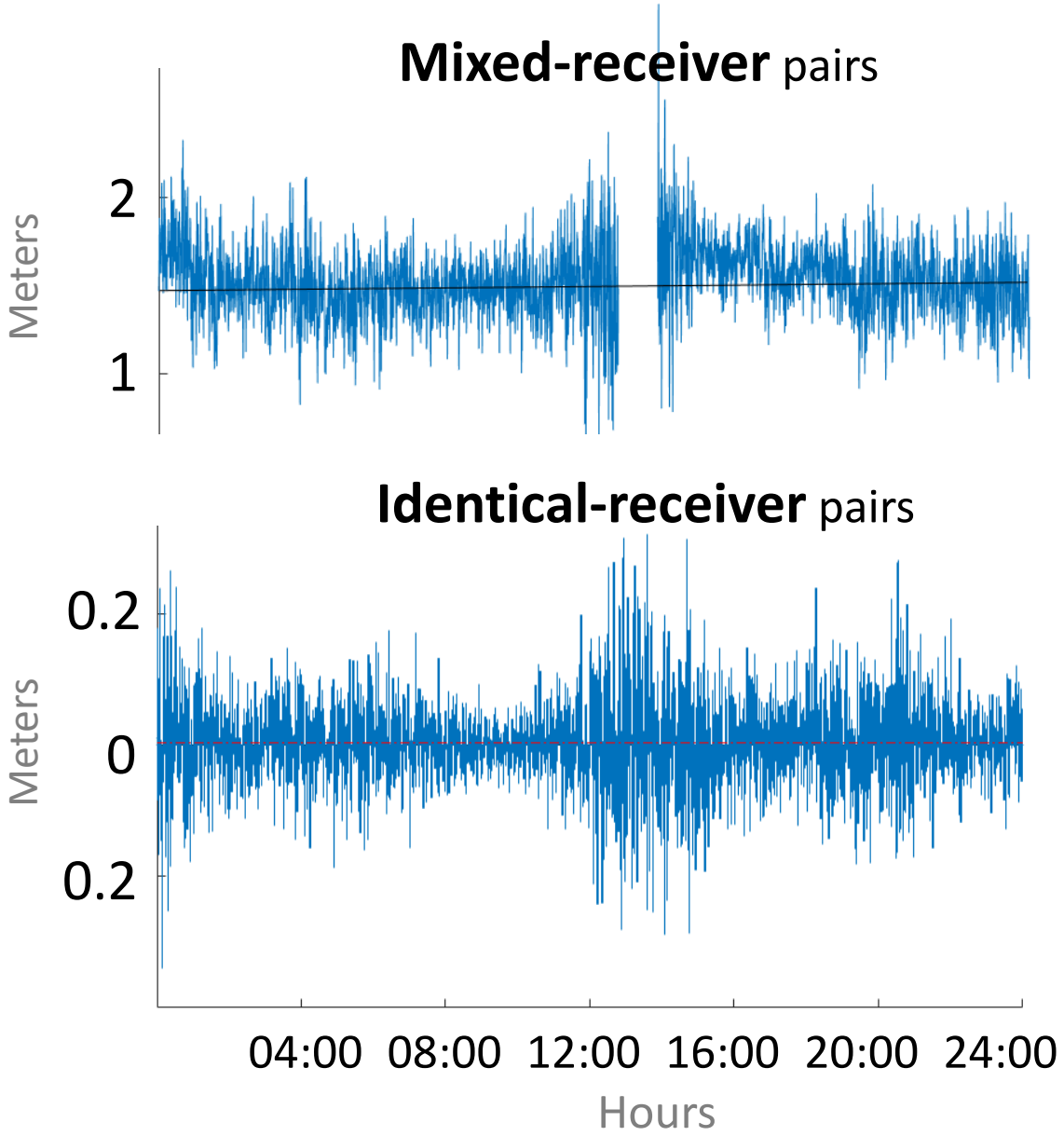
(a) +

Septentrio X4

Septentrio X4

(b) +

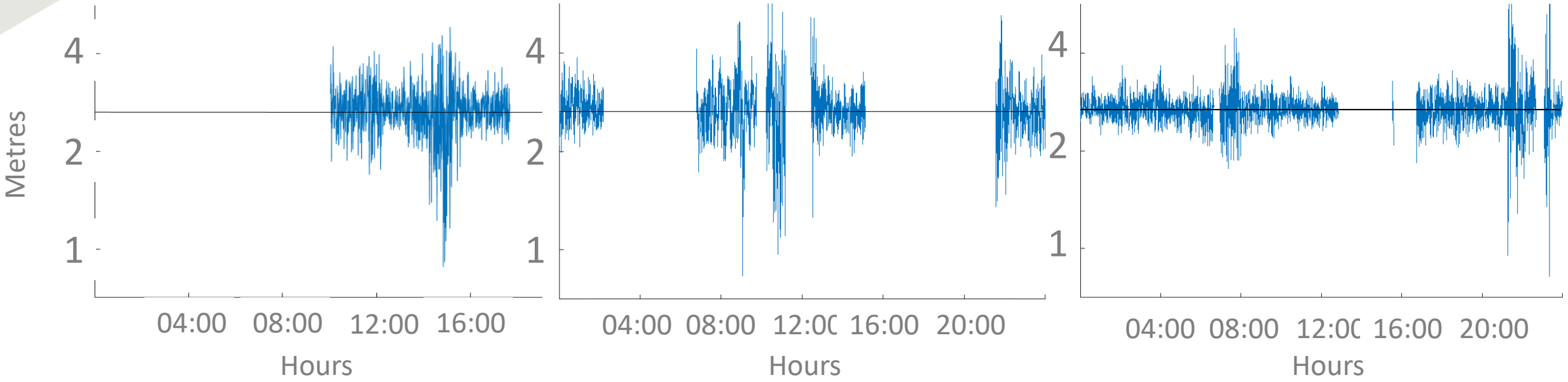
Septentrio X4



Mean: 1.52 m

Mean: 0.00 m

ISBs are **stable** over time



Mean: 2.82 m

2014 (a)

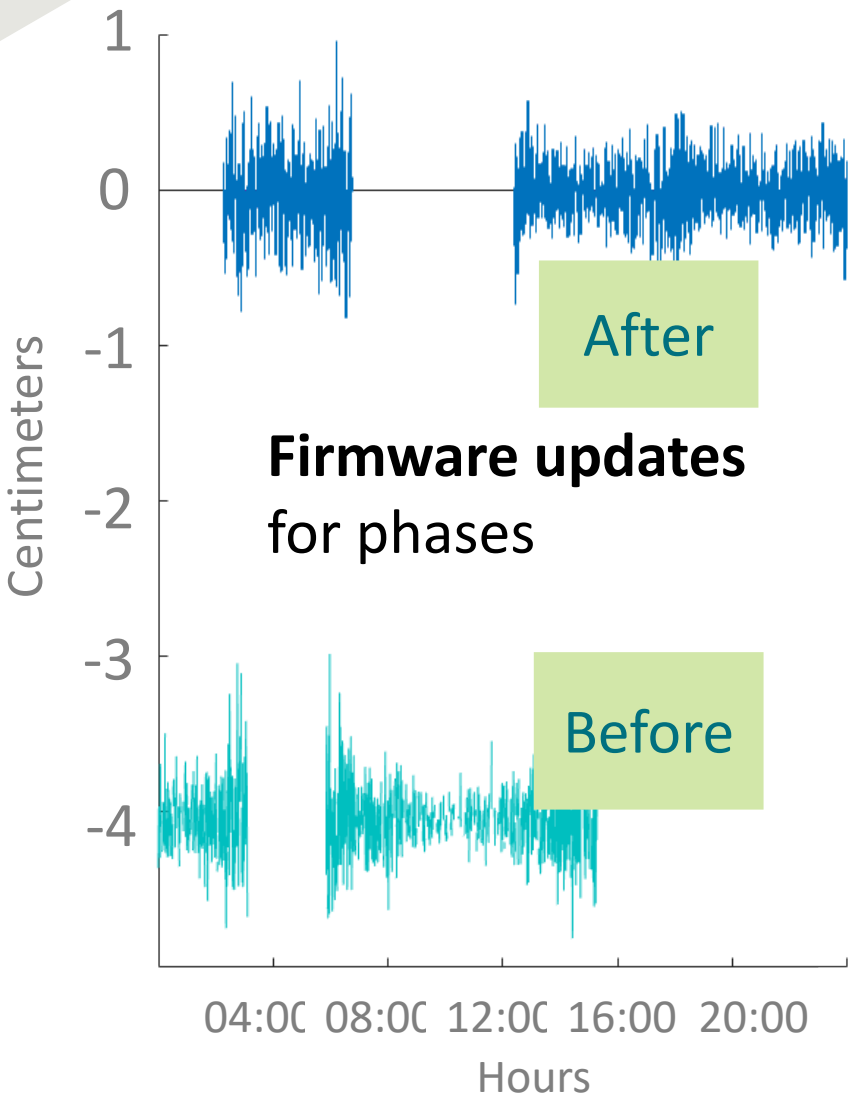
Mean: 2.86 m

2015 (b)

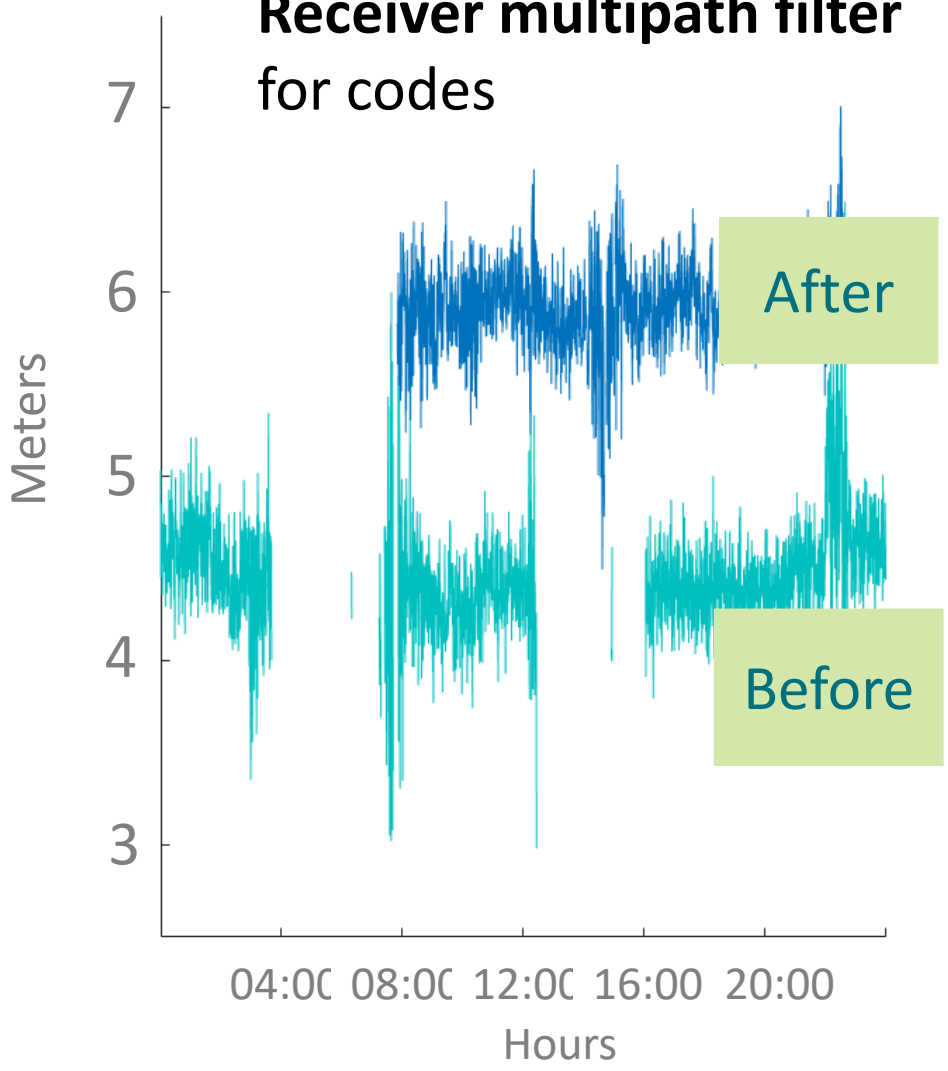
Mean: 2.84 m

2016 (c)

ISBs might be **affected** by



Firmware updates
for phases

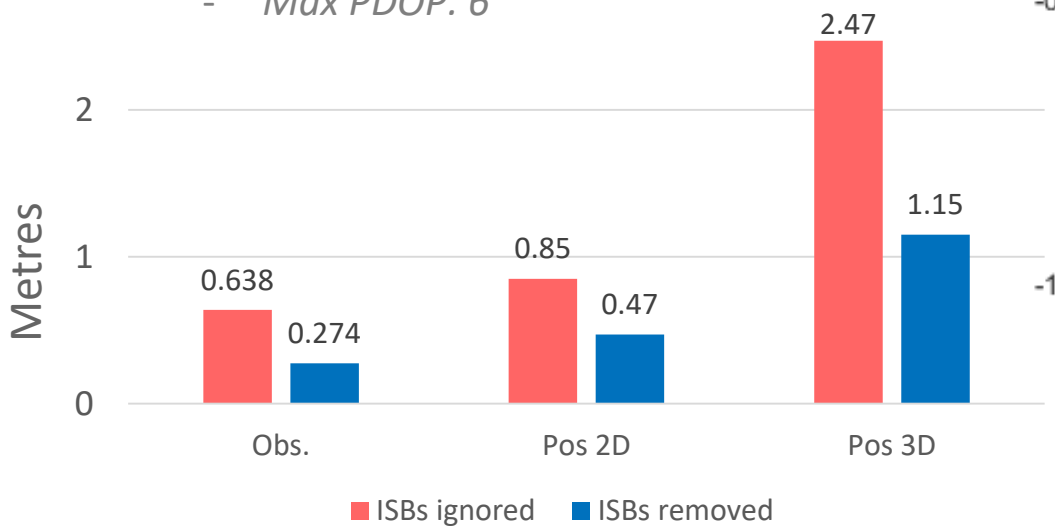


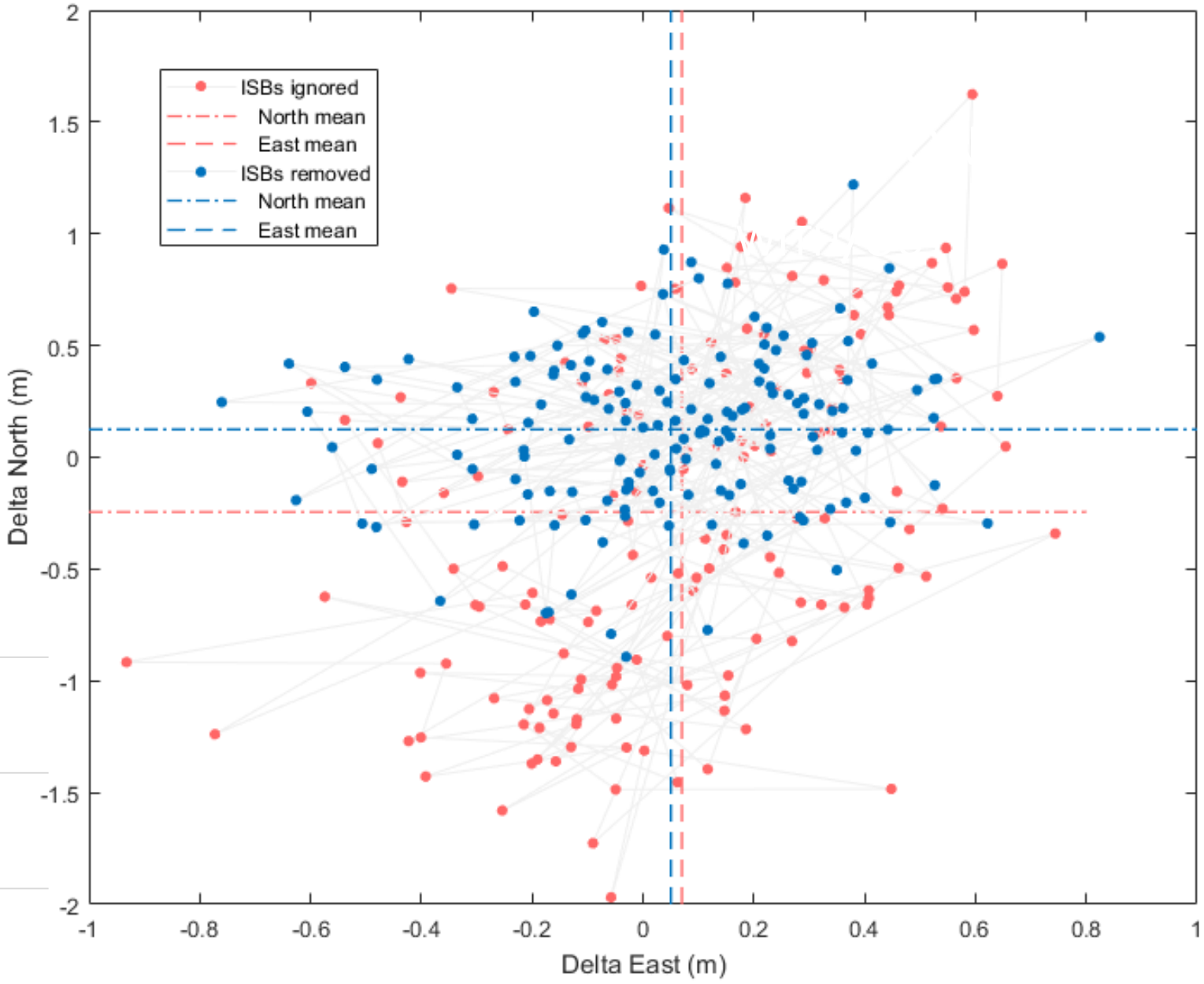
Receiver multipath filter
for codes

IMPACT OF ISBS

*ISBs removal on a DD SB **5.6 m** on DOY 32 of 2018 (E1) between u-blox and Trimble R9 :*

- *Geodetic antennas*
- *30s. data*
- *Min elevation: 10°*
- *Multipath filters OFF*
- *Max PDOP: 6*





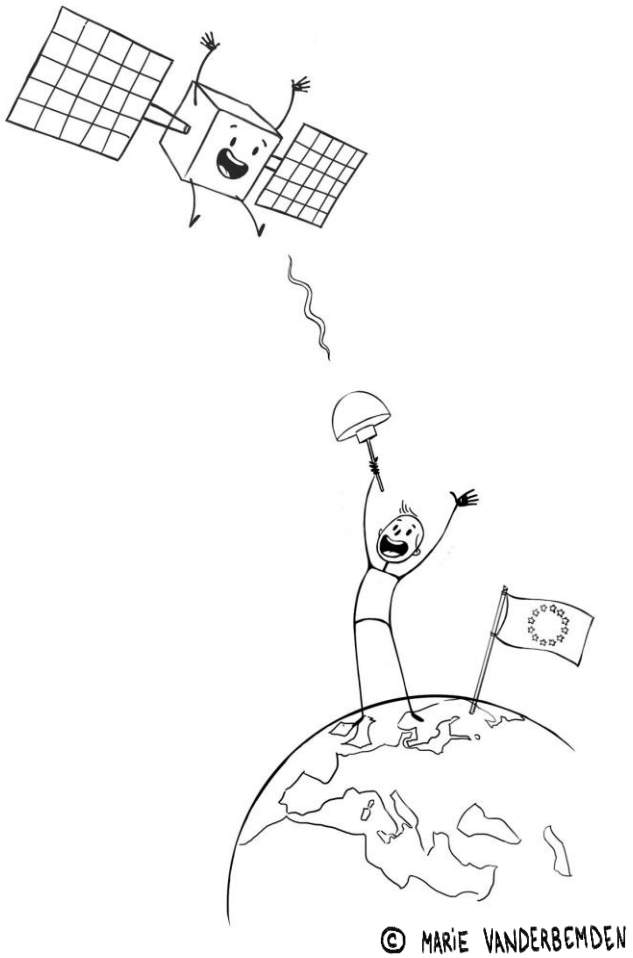
CONCLUSIONS

- **Multi-GNSS improves positioning solutions**
  - Higher number of visible satellites
  - Lower PDOP values
  - Signals of new GNSSs (BeiDou, Galileo) designed to be more robust to multipath
  - Position precision improved regardless of the receiver brand

- **Multi-GNSS solution affected by additional biases**
  - ISBs are receiver-dependent
  - Most of these biases reveal constant in time => they can be estimated and removed from positioning equation
  - Intrinsic changes on receiver modify ISBs

LIÈGE université
Sciences

CONTACT



Cécile Deprez

Doctorante en GNSS et géodésie

Unité de Géomatique - Université de Liège

Phone : +32 4 366 58 80

Email: cecile.deprez@uliege.be

LinkedIn