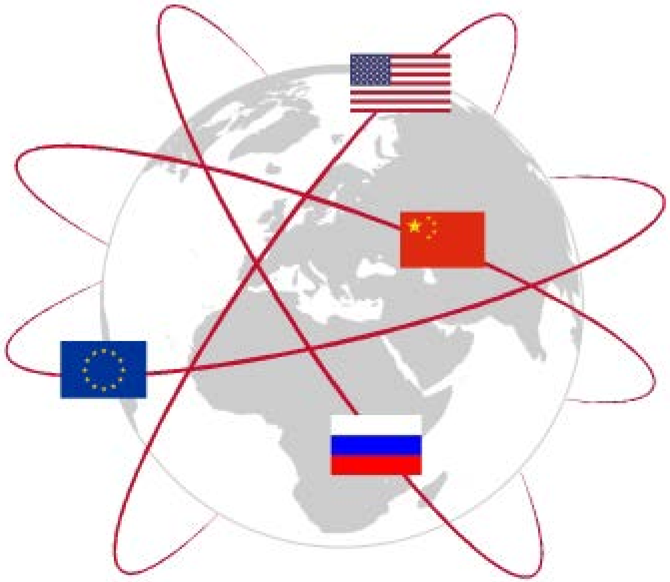
Offshore Positioning with GNSS: Where are we today?

Matthew Goode, Fugro Intersite B.V.

NOSP Evening Event, 9 September 2015, Stavanger, Norway

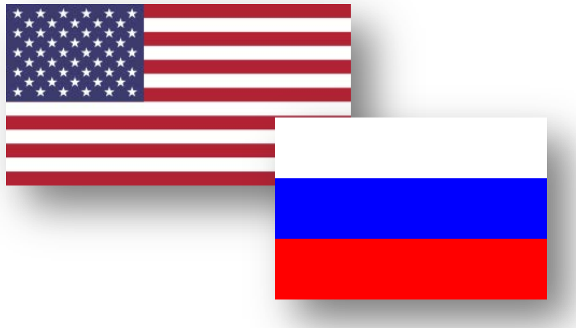
Contents

- Multi-constellation GNSS
- PPP with integer ambiguity resolution
- Future developments



Multi-constellation GNSS

- GPS constellation of 31 satellites
- GPS IIF-9 launched 24 March
  - Improved accuracy
  - L5 signal
  - Enhanced performance
- GLONASS constellation of 24 satellites
- GLONASS-K1 satellite launched 30 November 2014
  - Improved accuracy
  - CDMA signals



System	Type	#	Notes
GPS	Block IIA	4	-
	Block IIR	12	-
	Block IIR-M	7	-
	Block IIF	8	-
GLONASS	M	24	-
	K1	2	Flight tests only
	K2	0	Launches from 2018

Galileo

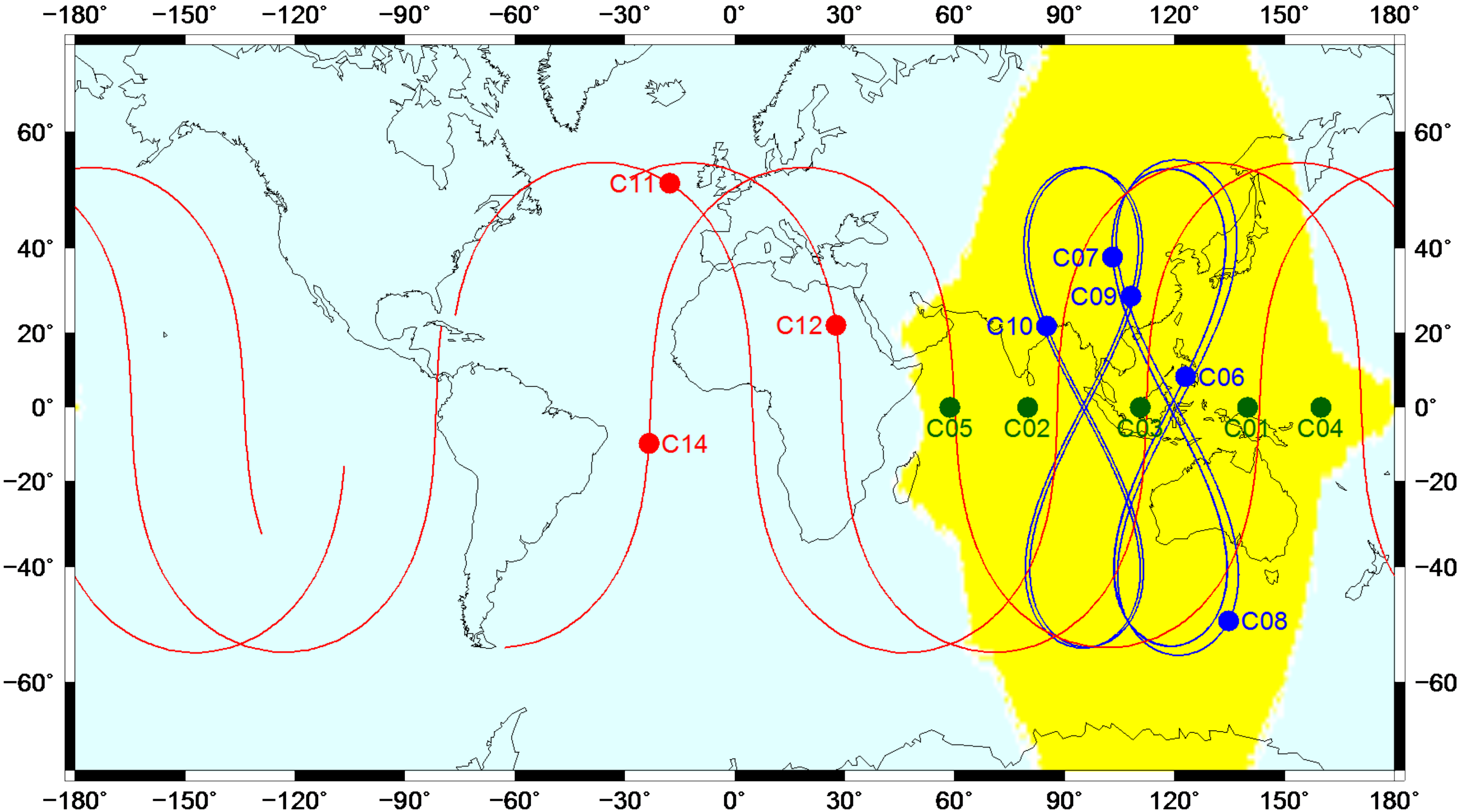
- First two Full Operational Capacity (FOC) satellites launched into wrong orbit.
- Recovery mission to place them into non-nominal orbit successful.
- Decision to be made whether they will be used for navigation purposes.
- Third and fourth FOC satellites launched successfully and undergoing initial check.
- Fifth and sixth FOC satellites scheduled to launch in September 2015.

Satellite	PRN	Launch	Status
IOV PFM	E11	Oct 2011	OK
IOV FM2	E12	Oct 2011	OK
IOV FM3	E19	Oct 2012	OK
IOV FM4	E20	Oct 2012	Unavailable
FOC FM1	E18	Aug 2014	Non-nominal orbit
FOC FM2	E14	Aug 2014	Non-nominal orbit
FOC FM3	E26	Mar 2015	OK
FOC FM4	E22	Mar 2015	OK
FOC FM5	-	Sep 2015	-
FOC FM6	-	Sep 2015	-
FOC FM7	-	Dec 2015	-
FOC FM8	-	Dec 2015	-

BeiDou

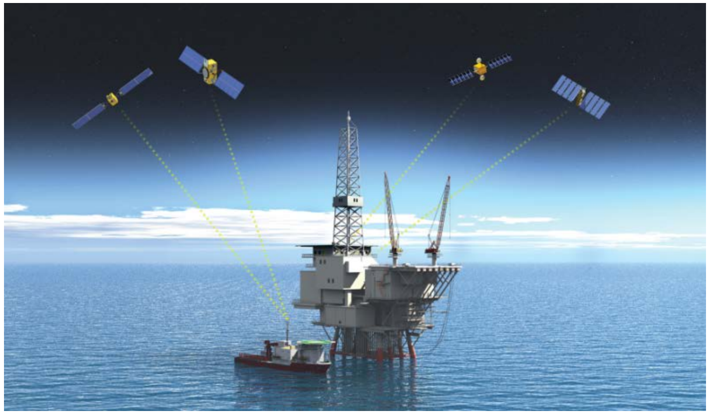
- Regional coverage in Asia
  - 3 medium-earth orbit (MEO)
  - 5 geostationary orbit (GEO)
  - 5 inclined geostationary orbit (IGSO)
- Full worldwide coverage expected by 2020
  - Speculation accelerated to 2017
- First BeiDou-3 satellite launched 31 March
- FOC achieved for regional constellation

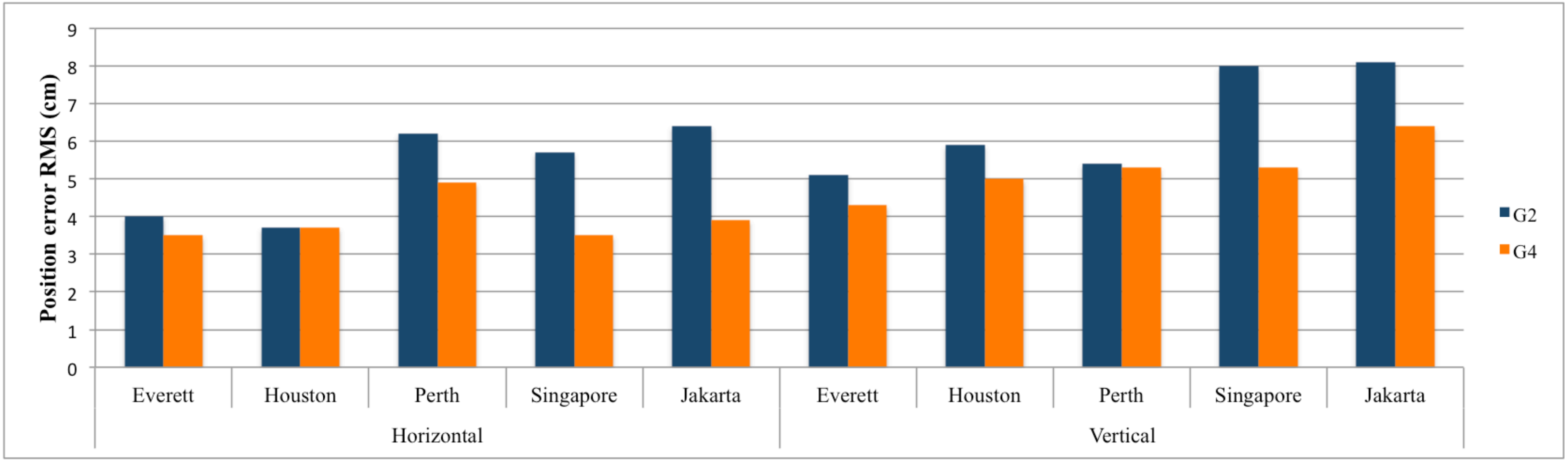
Regional coverage in Asia and West Pacific region



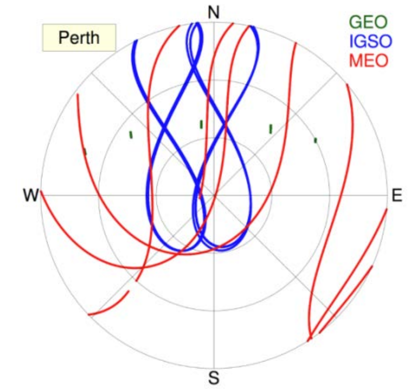
Advantages

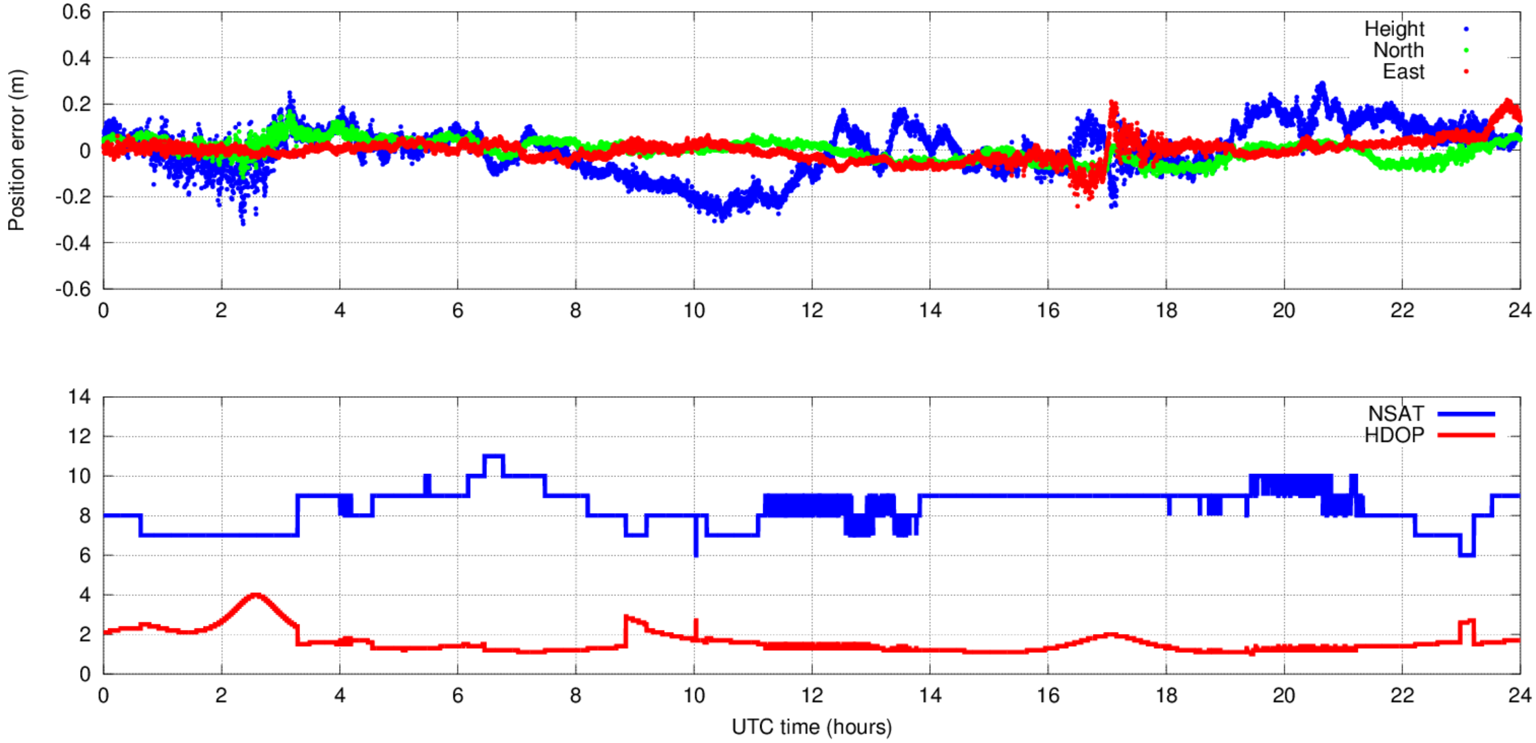
- Increased accuracy
- Reduced convergence time
- More robust against interference
- Better protection against scintillation
- Better sky visibility
- Improved outlier detection



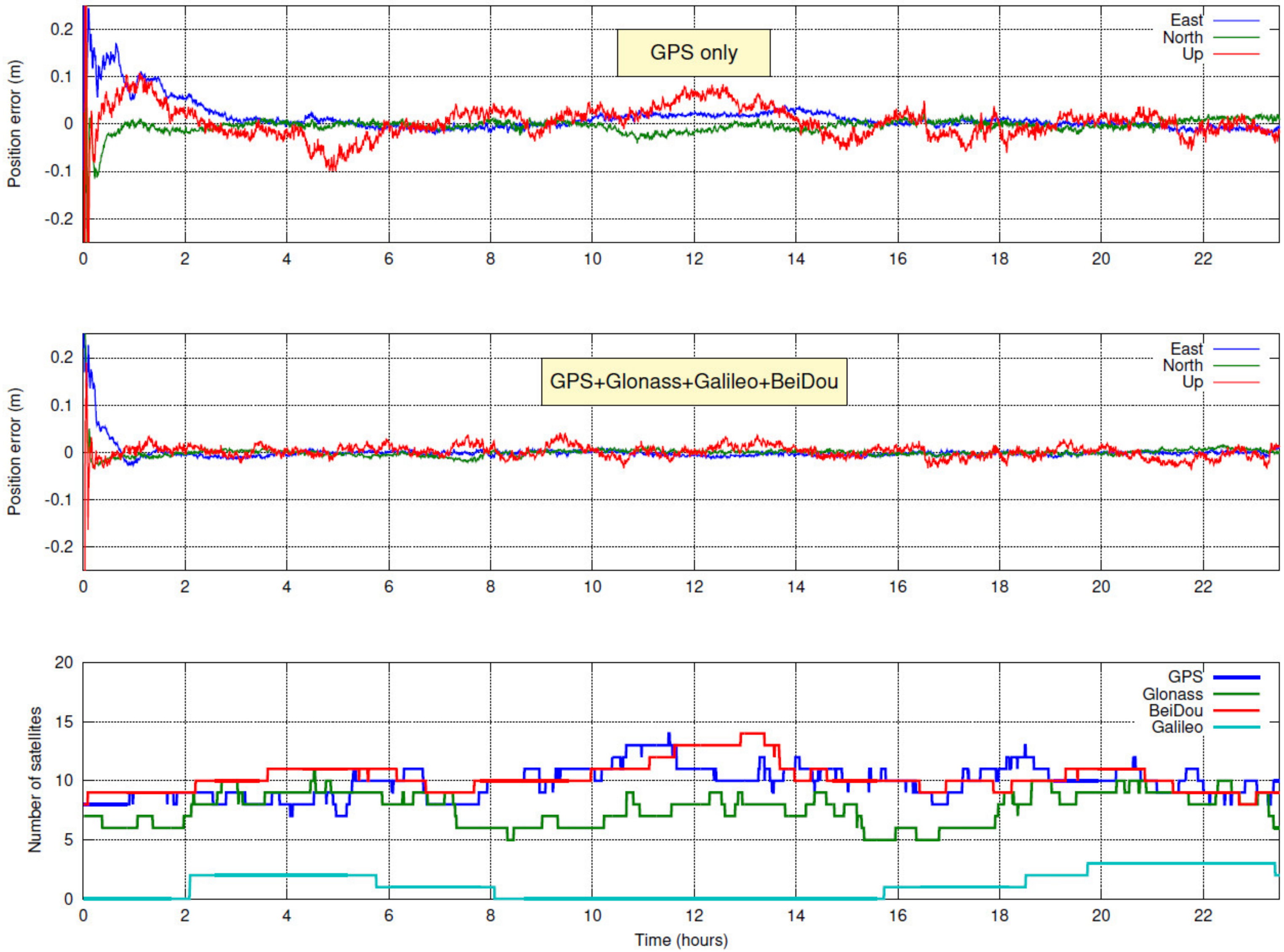


- Possible in Asia and West Pacific region.
- Data collected at Perth, Australia on 9 March 2015.

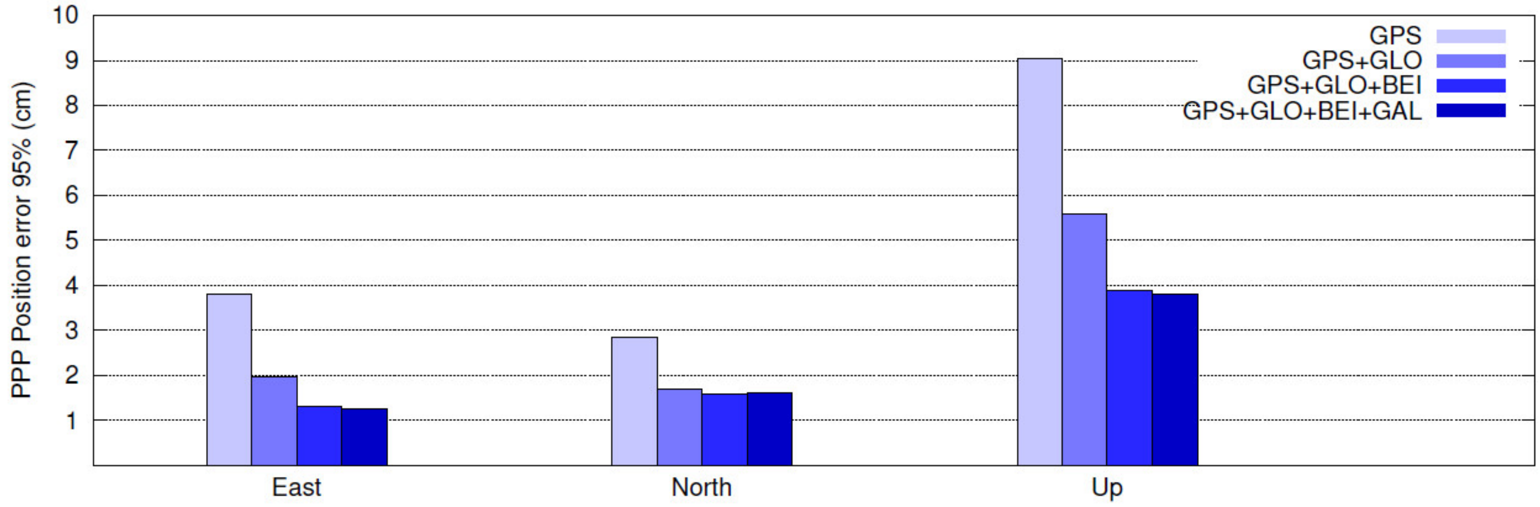


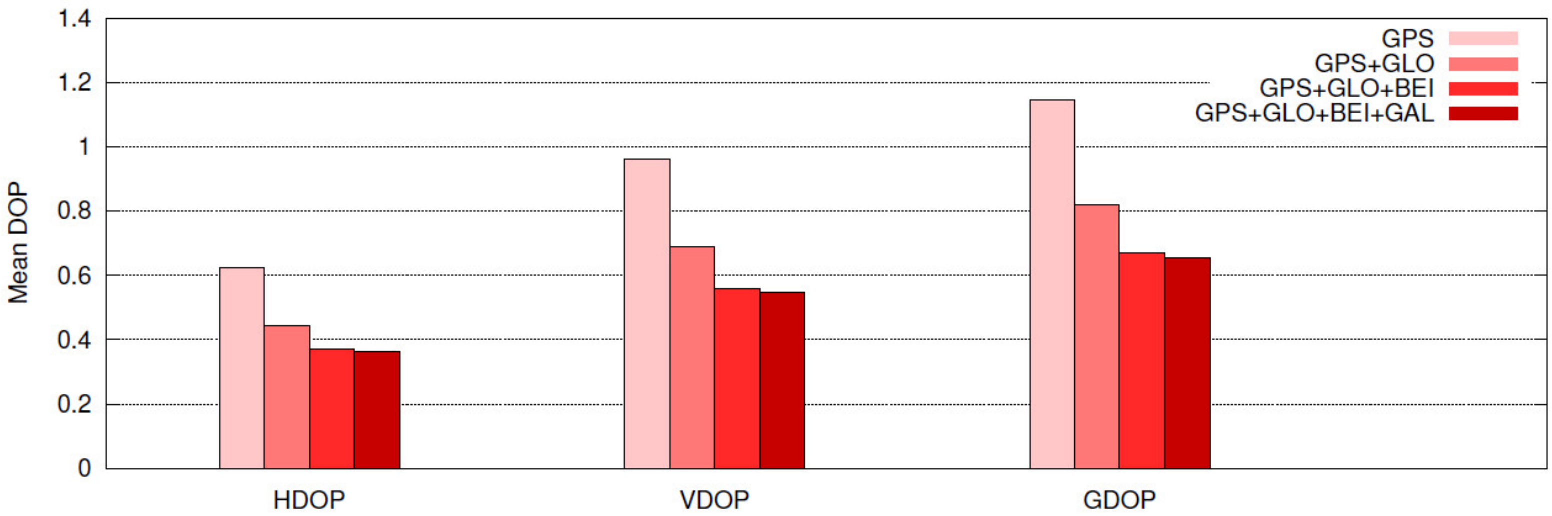


Static results



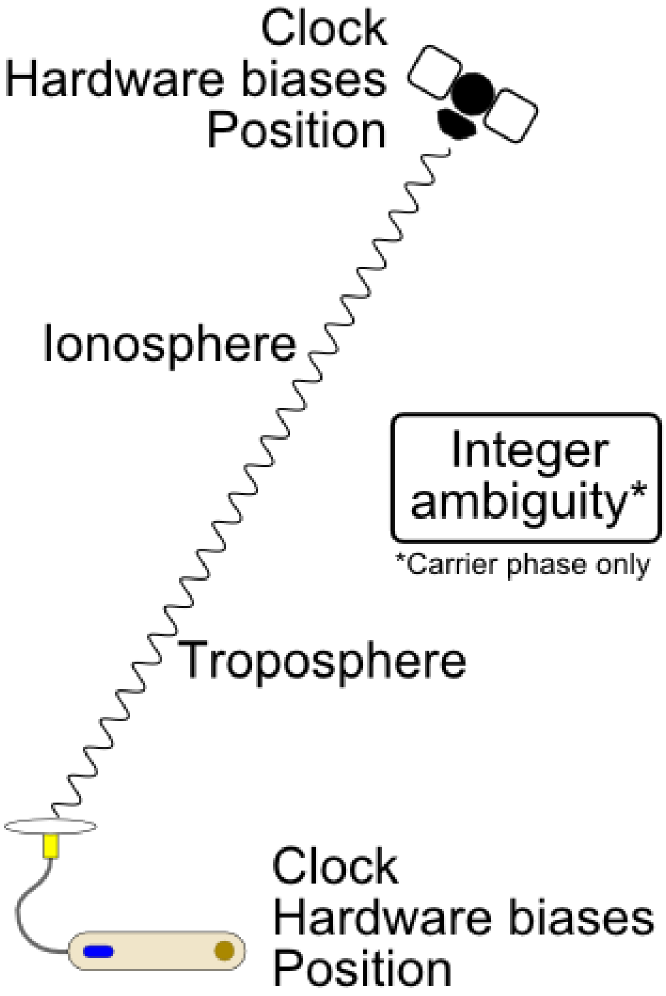
Static results





PPP
with
integer
ambiguity
resolution

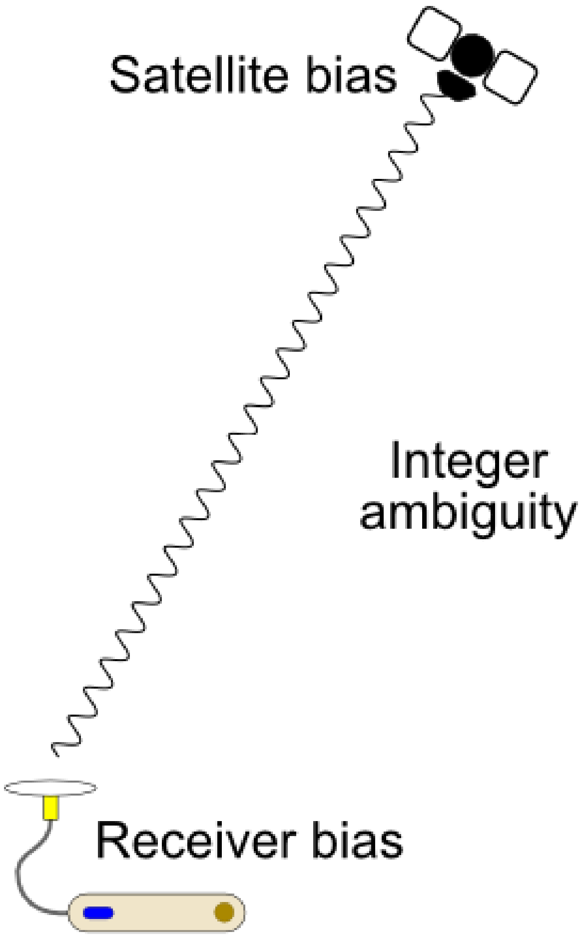
- Uses dual frequency code and carrier phase measurements.
- Considering the listed parameters:
  - Precise satellite position known
  - Precise satellite clock known
  - Unknown receiver position of most interest
- Integer ambiguity for carrier phase measurements cannot be separated from the hardware biases, so estimated as lumped real valued parameter.
- Fixing ambiguity to an integer would yield cm-level accuracy.



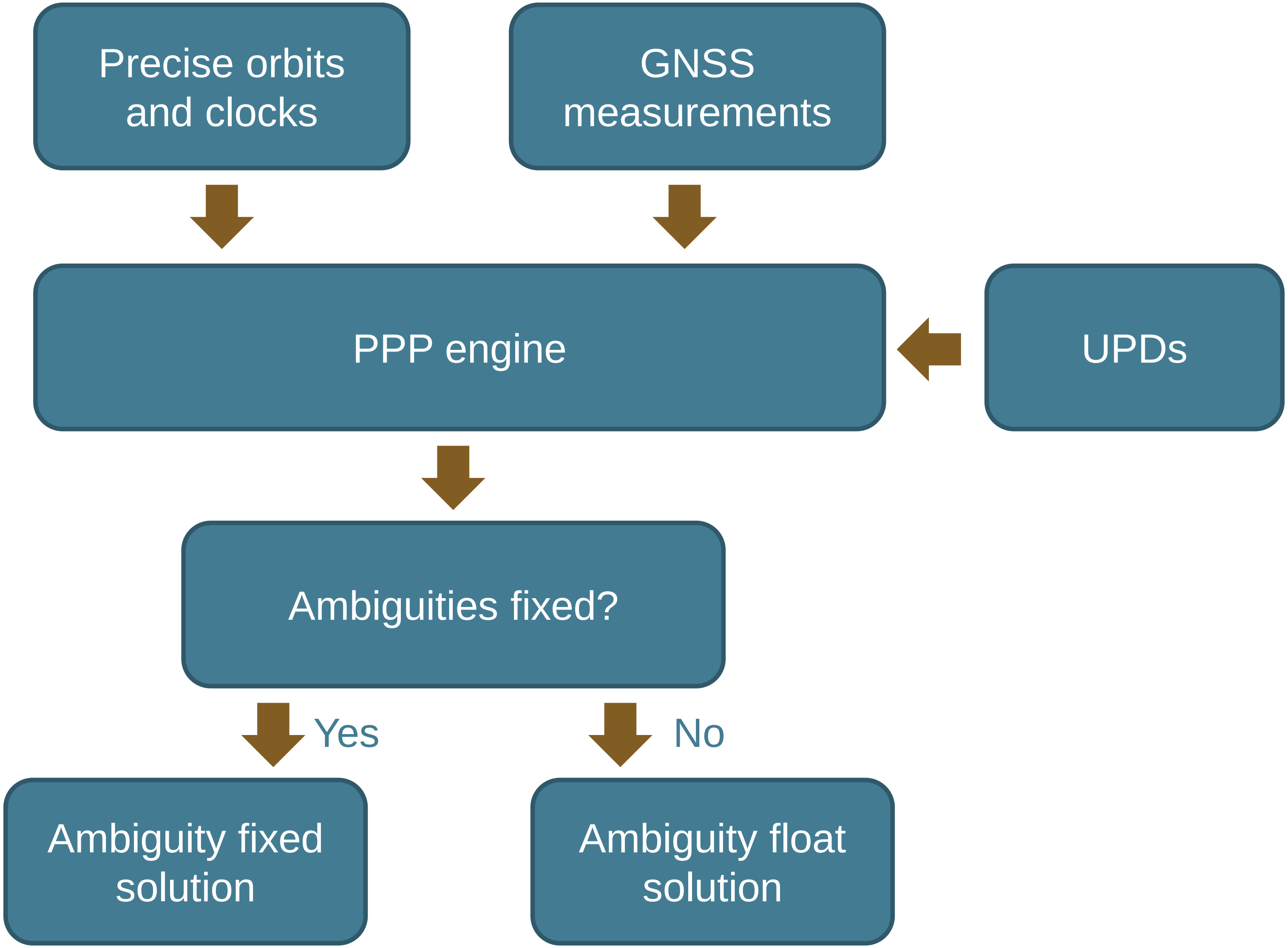
PPP with integer ambiguity fixing

- Satellite biases common for all receivers in a network.
- Estimate bias, known as the uncalibrated phase delays (UPDs), using reference station network and supply the to the user.
- Single differencing using a reference satellite removes receiver biases.
- Remaining estimated ambiguity is now mathematically integer.
- Attempt to fix to the correct integer value for cm-level accuracy.
- Ability to fix ambiguities to integer value is dependent on observation conditions.

Carrier phase hardware bias

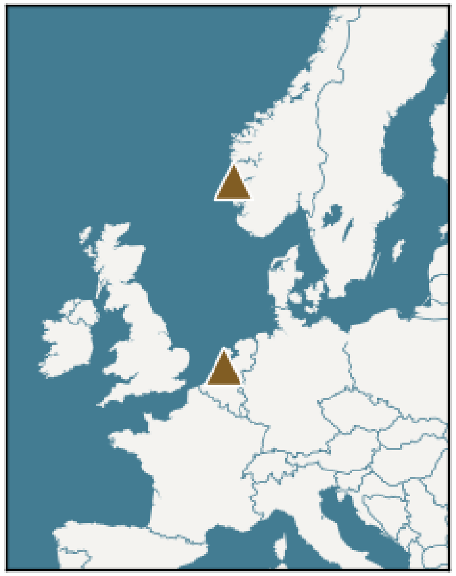


PPP-IAR approach

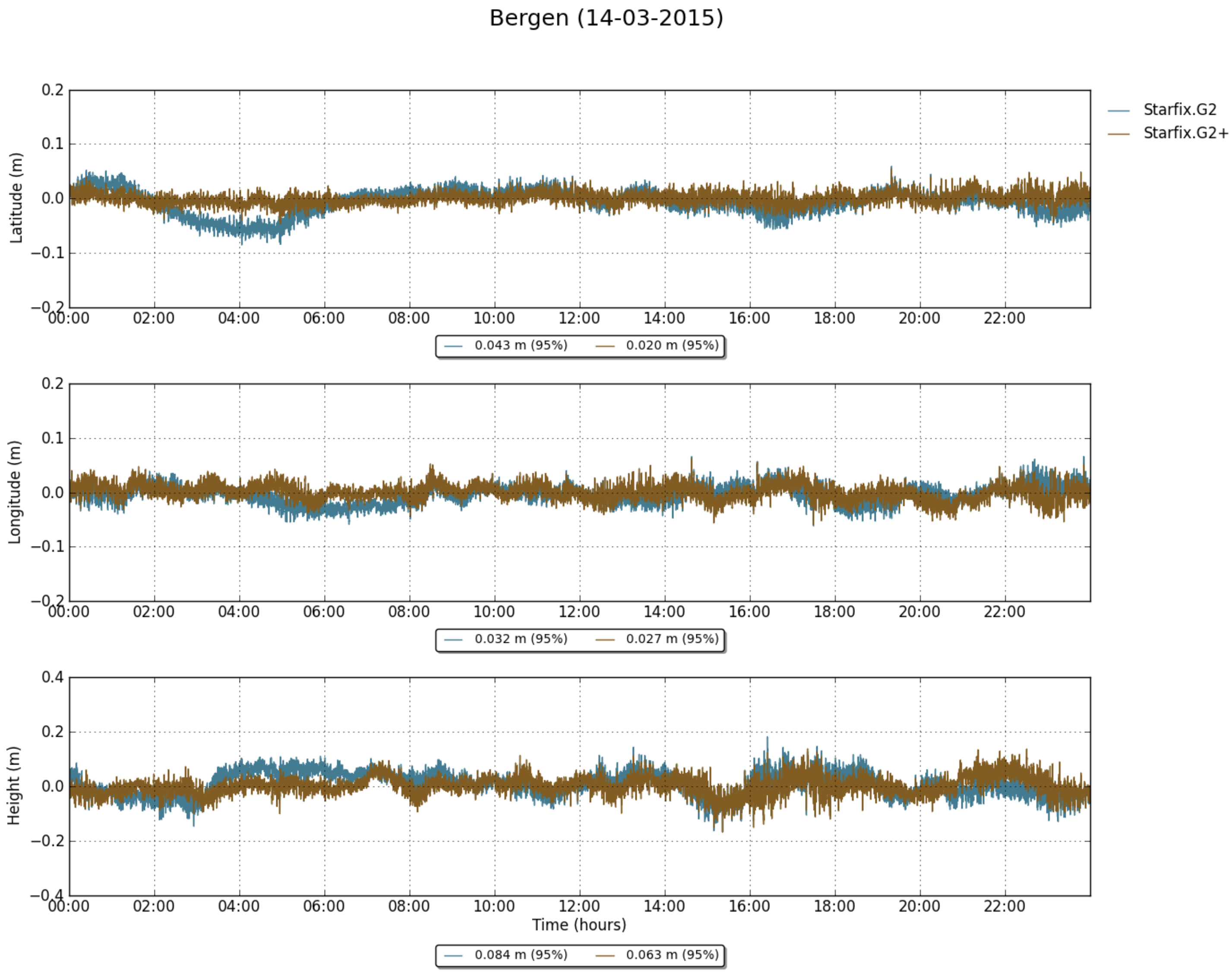


Static results

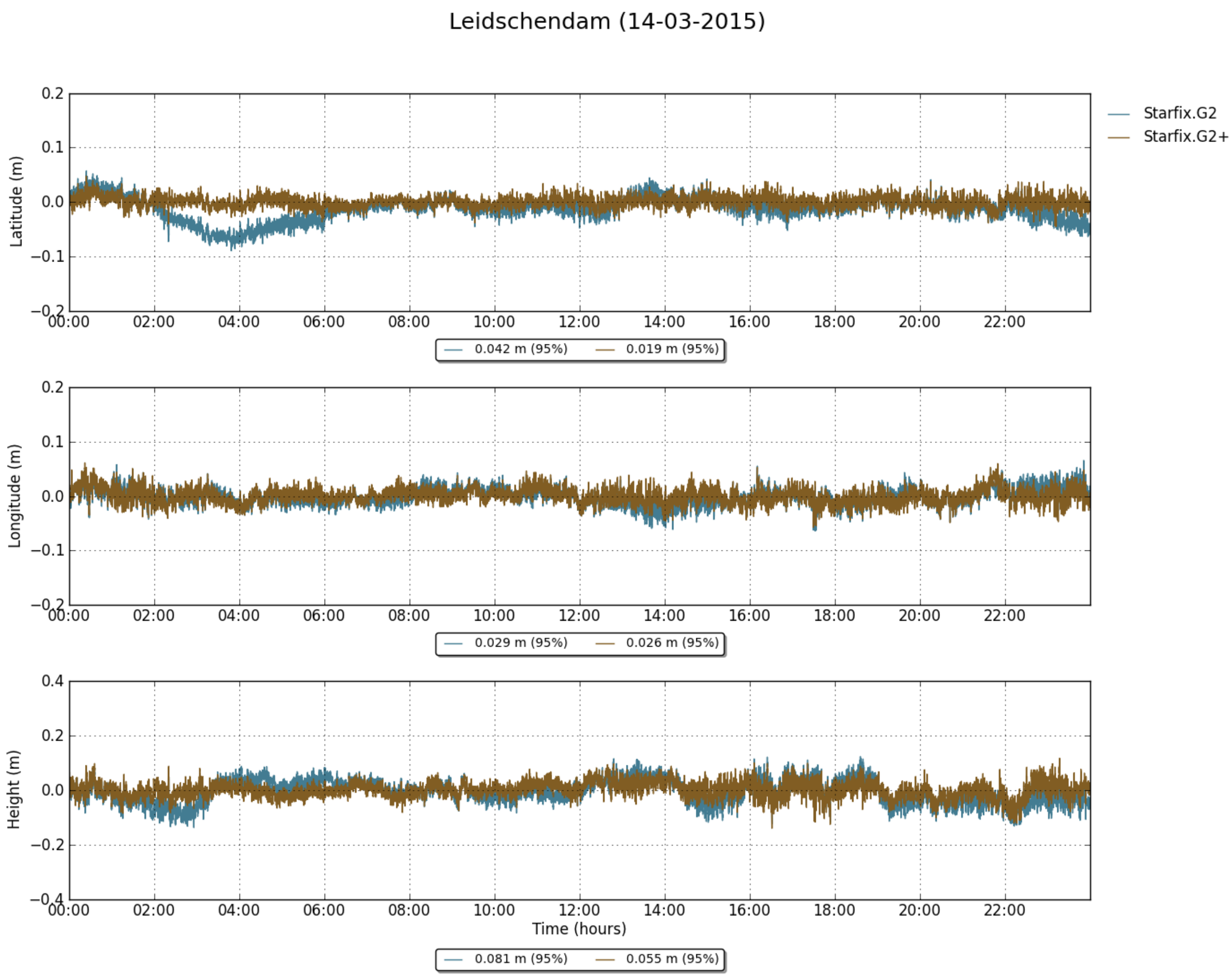
- StarPack receivers located at Fugro reference stations.
- Starfix.G2+ real-time orbit, clock and UPD corrections received through L-band link.
- Identical set-up as used in the field.
- 95% accuracy of 3.5 cm in horizontal and 8 cm in vertical achieved.



Static results: Bergen, Norway



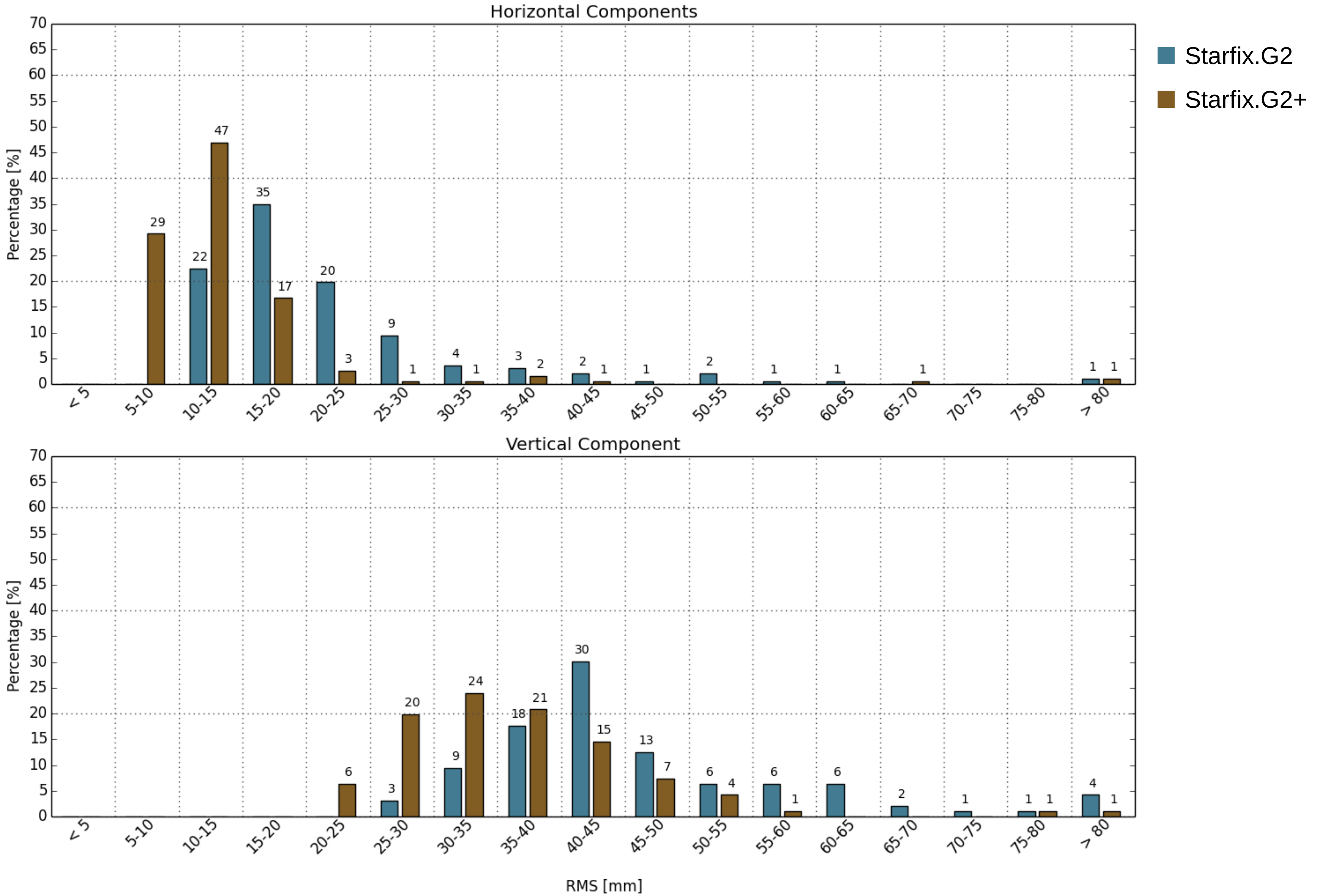
Static results: Leidschendam, The Netherlands



Static results: Standard PPP vs PPP-IAR

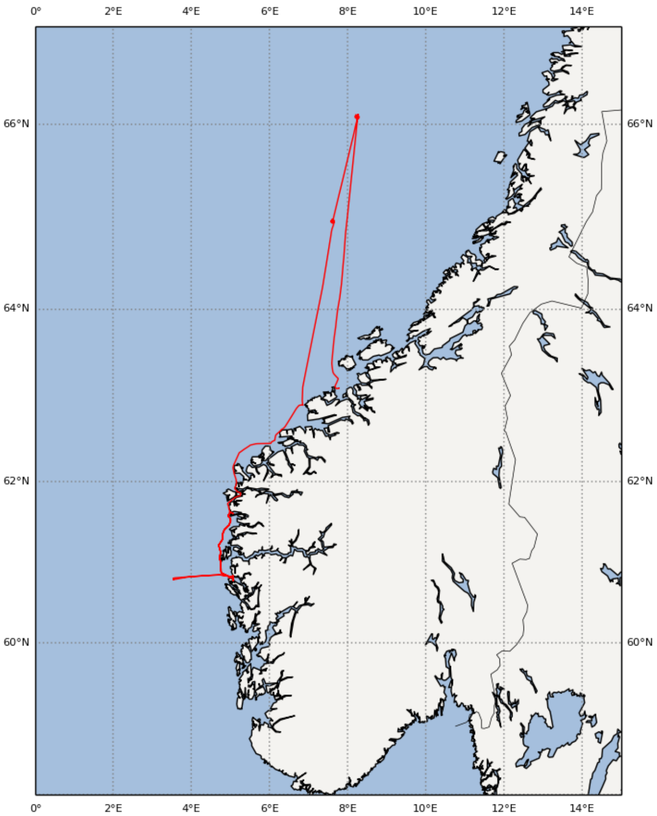
Site	Solution	Accuracy (95%)			Improvement		
		North	East	Up	North	East	Up
Bergen	Standard PPP	0.043 m	0.032 m	0.084 m	-	-	-
	PPP-IAR	0.020 m	0.027 m	0.063 m	54%	15%	25%
Leidschendam	Standard PPP	0.042 m	0.029 m	0.081 m	-	-	-
	PPP-IAR	0.019 m	0.026 m	0.055 m	55%	12%	33%

Static results: global comparison



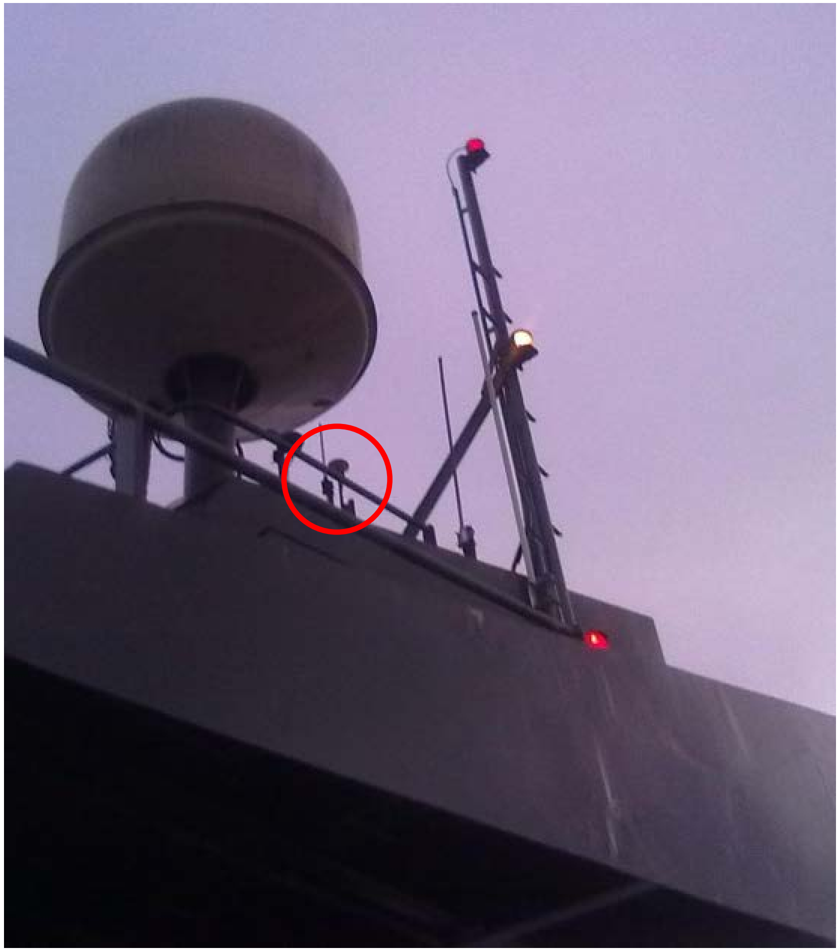
Dynamic results

- Field trial in the North Norwegian Sea
- Data collected over 18 days
- Assessment of Starfix.G2+ service in dynamic conditions
- Gain experience in performance of PPP-IAR offshore
- Antennas mounted at two levels of the ship
    - Monkey deck
    - Mast



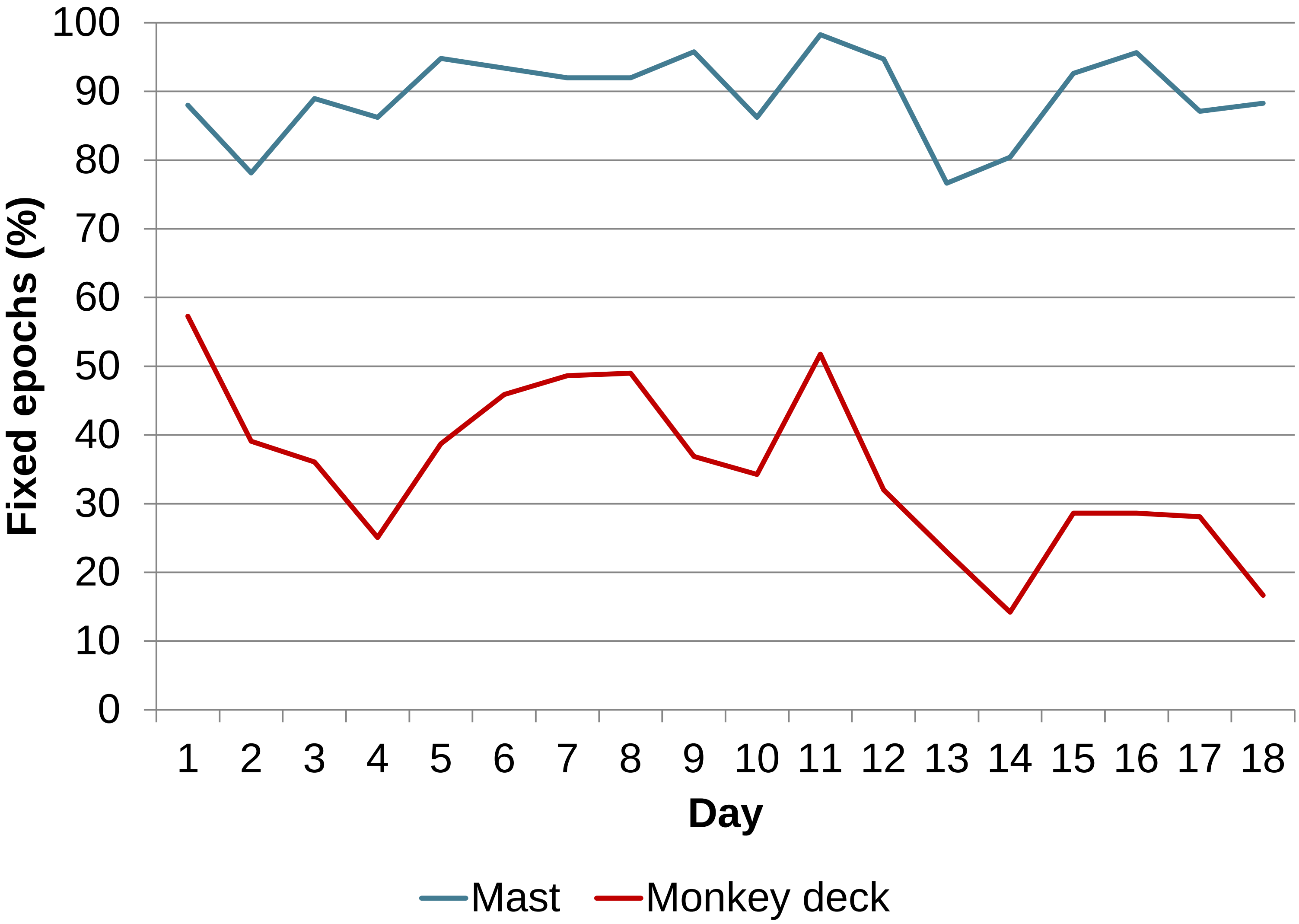
Dynamic results: Antenna locations

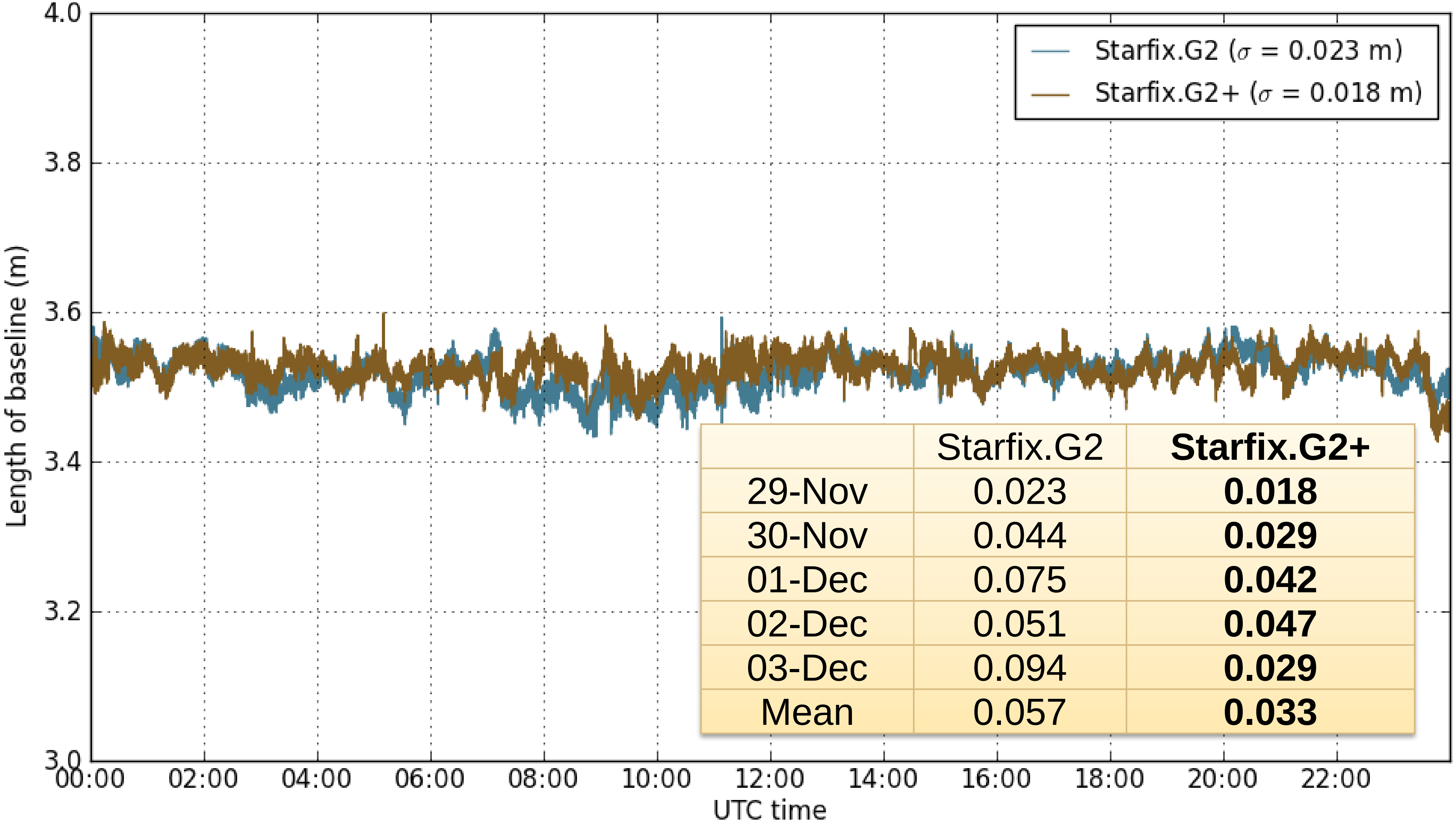
Antenna mounted on monkey deck



Antenna mounted on mast

Dynamic results: Comparison of float and fixed solutions





	Starfix.G2	**Starfix.G2+**
29-Nov	0.023	**0.018**
30-Nov	0.044	**0.029**
01-Dec	0.075	**0.042**
02-Dec	0.051	**0.047**
03-Dec	0.094	**0.029**
Mean	0.057	**0.033**

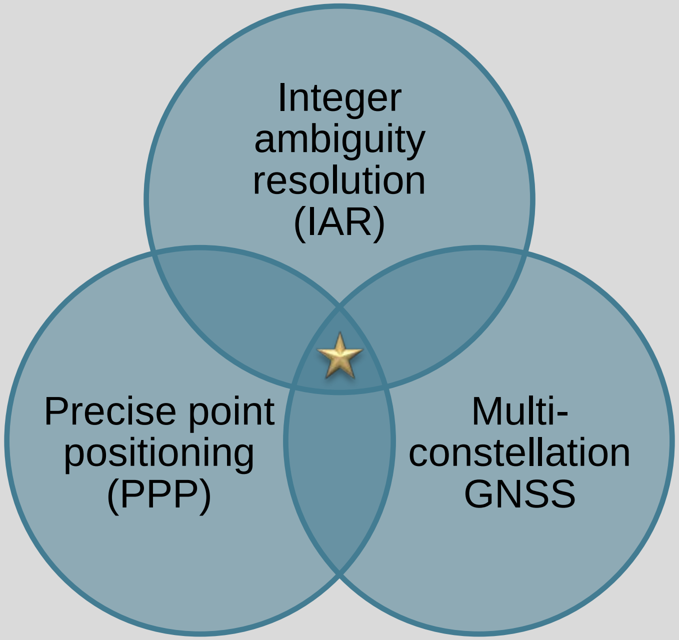
Dynamic results: Conclusions

- Concept of PPP-IAR works well in dynamic conditions, but is dependent on good observation conditions.
- Placement of antenna has a significant influence on the ambiguity fixing rate.
- Poor observation conditions lead to a poor standard PPP solution, therefore ambiguity fixing is much less likely.
- Multi-constellation PPP solution enhances the chances of being able to fix ambiguities.

Future

Multi-constellation PPP with PPP-IAR

- Combine three techniques to leverage each of their three strengths
- Glonass ambiguity resolution more challenging due to FDMA signals.
- Galileo and BeiDou ambiguity resolution theoretically possible, but reliant on good precise orbits and clocks.



Multi-frequency PPP

- Additional L5 signals from GPS Block IIF satellites.
- Additional L3 CDMA signals from new GLONASS-M and GLONASS-K2 satellites
- Third frequency also available on BeiDou and Galileo satellites

- Improved PPP convergence times
- Faster ambiguity fixing

- Challenge of additional biases to estimate

Conclusions

- Multi-constellation GNSS
  - Increased accuracy
  - Reduced convergence time
  - More robust against interference, scintillation and poor sky visibility
- PPP with integer ambiguity resolution
  - 95% accuracy of 3.5 cm in horizontal and 8 cm in vertical
  - Reduced convergence time
- Future developments
  - Multi-constellation PPP-IAR leverages both advances
  - More signals will improve ambiguity fixing and convergence

Matthew Goode
GNSS R&D team
Geodesist

Fugro Intersite B.V.
Dillenburgsingel 69
Leidschendam 2263 HW
The Netherlands

M.Goode@fugro.nl