Augmenting GNSS Precise Point Positioning (PPP) for Improved Performance

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* **Disclaimer:** Any opinions expressed in this presentation are solely the author's.

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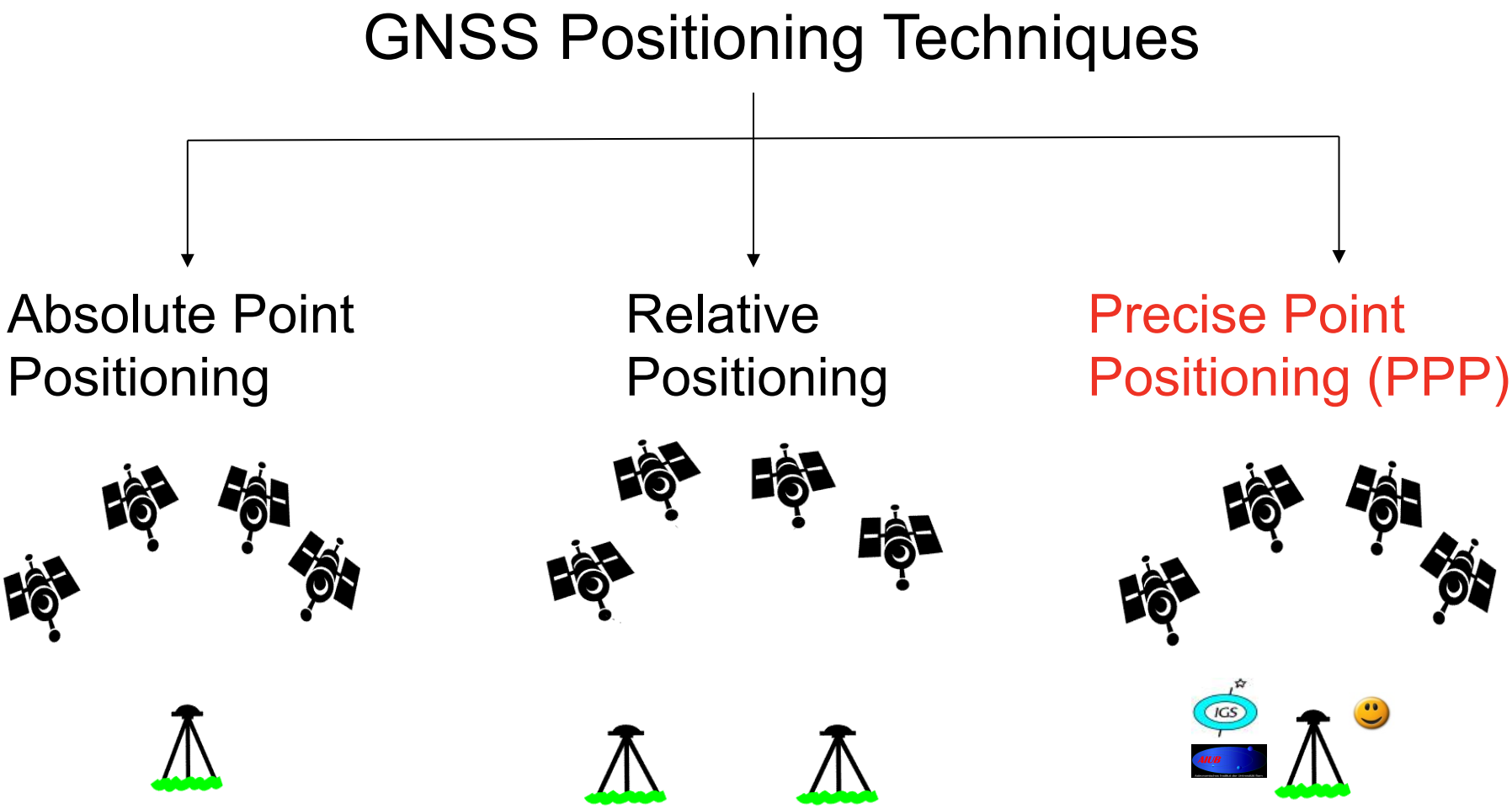
2. Australian National Positioning Infrastructure
3. Augmenting PPP
   - Multi-GNSS PPP, Multi-frequency PPP
   - Augmenting PPP with ionospheric corrections, PPP-RTK
4. Summary

PPP: Precise Point Positioning
RTK: Real-Time Kinematic

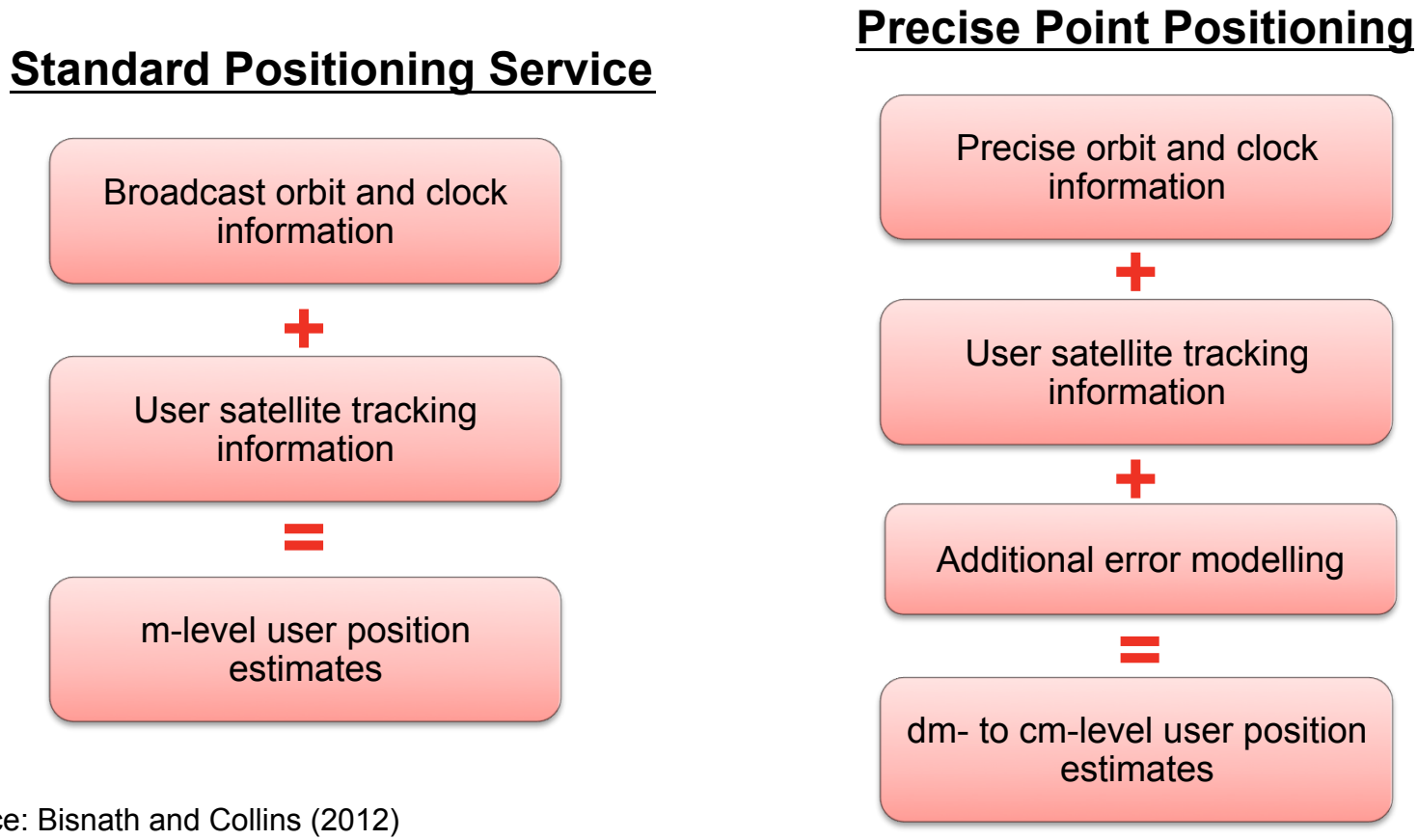
1. Introduction to PPP

Introduction – GNSS Positioning Techniques



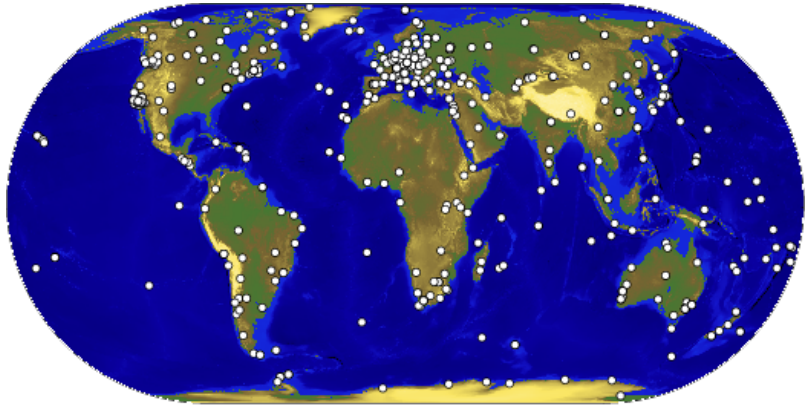
Anatomy of PPP

- **Precise Point Positioning (PPP)** allows a single GNSS receiver user to determine position at the decimetre / centimetre error level in kinematic / static mode using precise satellite orbits and clocks



Source: Bisnath and Collins (2012)

International GNSS Service (IGS)



– IGS orbits and satellite clocks

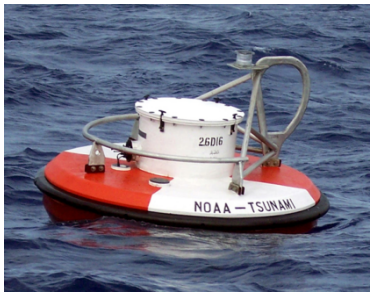
Type		Accuracy	Latency	Updates	Sample Interval
Broadcast	orbits	~100 cm	real time	--	daily
	Sat. clocks	~5 ns RMS ~2.5 ns SDev			
Ultra-Rapid (predicted half)	orbits	~5 cm	real time	at 03, 09, 15, 21 UTC	15 min
	Sat. clocks	~3 ns RMS ~1.5 ns SDev			
Ultra-Rapid (observed half)	orbits	~3 cm	3 – 9 hours	at 03, 09, 15, 21 UTC	15 min
	Sat. clocks	~150 ps RMS ~50 ps SDev			
Rapid	orbits	~2.5 cm	17 – 41 hours	at 17 UTC daily	15 min
	Sat. & Stn. clocks	~75 ps RMS ~25 ps SDev			5 min
Final	orbits	~2.5 cm	12 – 18 days	every Thursday	15 min
	Sat. & Stn. clocks	~75 ps RMS ~20 ps SDev			Sat.: 30s Stn.: 5 min
Real-time IGS	Orbit Clock	< 10 cm 0.15 ns	10-20 secs		

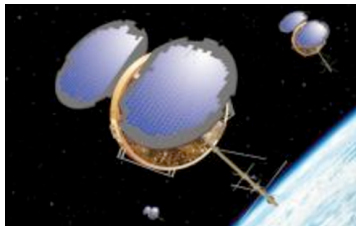
Source: IGS

Use and Applications

- Commercial applications:
  - Trimble CentrePoint™ RTX™
  - NavCom Global StarFire™ Service
  - Fugro's Precise (Point) Positioning Service
    - XP, G2
  - Veripos Ultra (Ultra²) and APEX (APEX²) Service



PPP is **feasible** for positioning and navigation in **remote areas** or regions of **low GNSS reference stations**

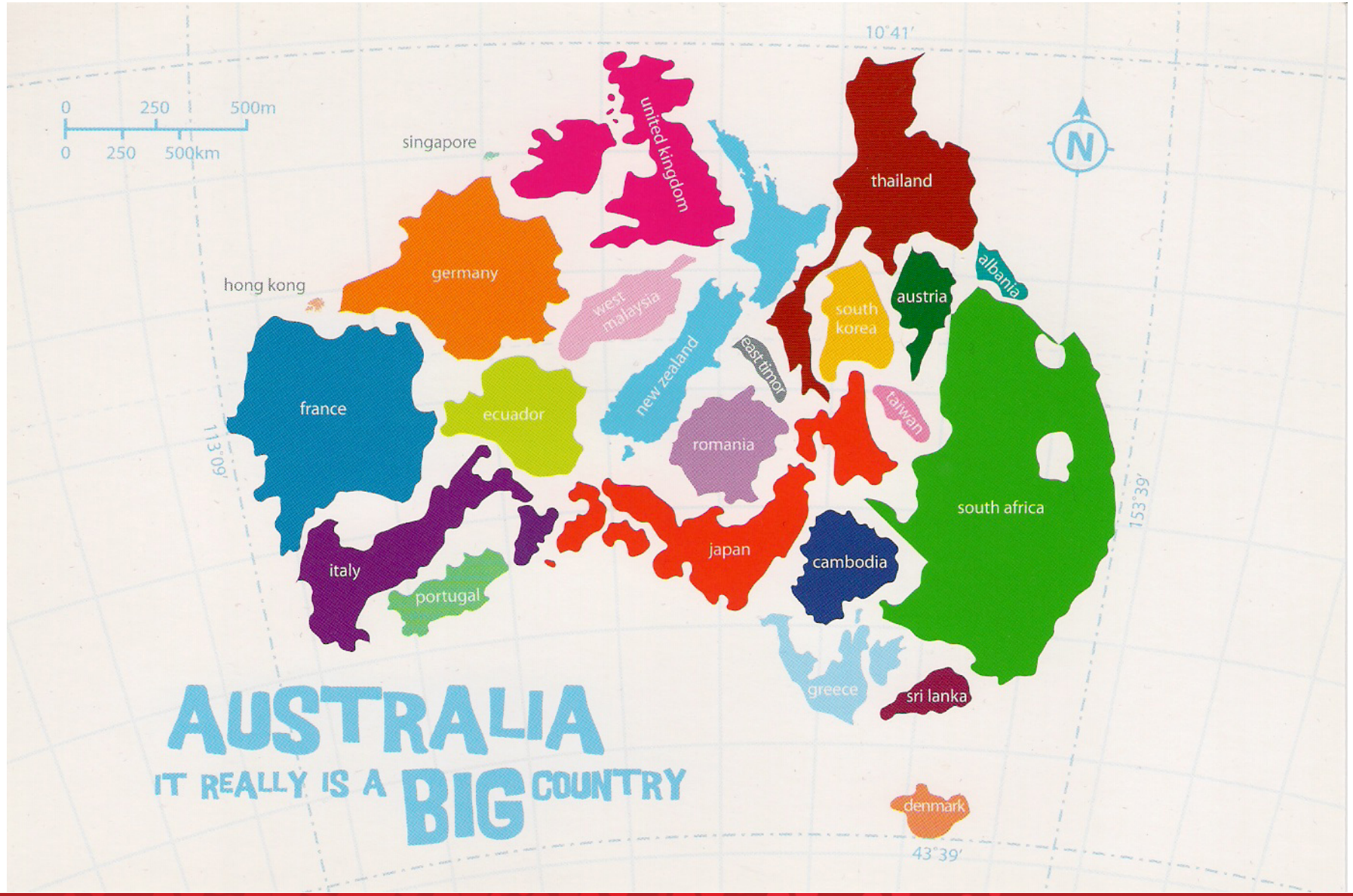
2. Australian National Positioning Infrastructure

Precise GNSS Transforming Australian Industry

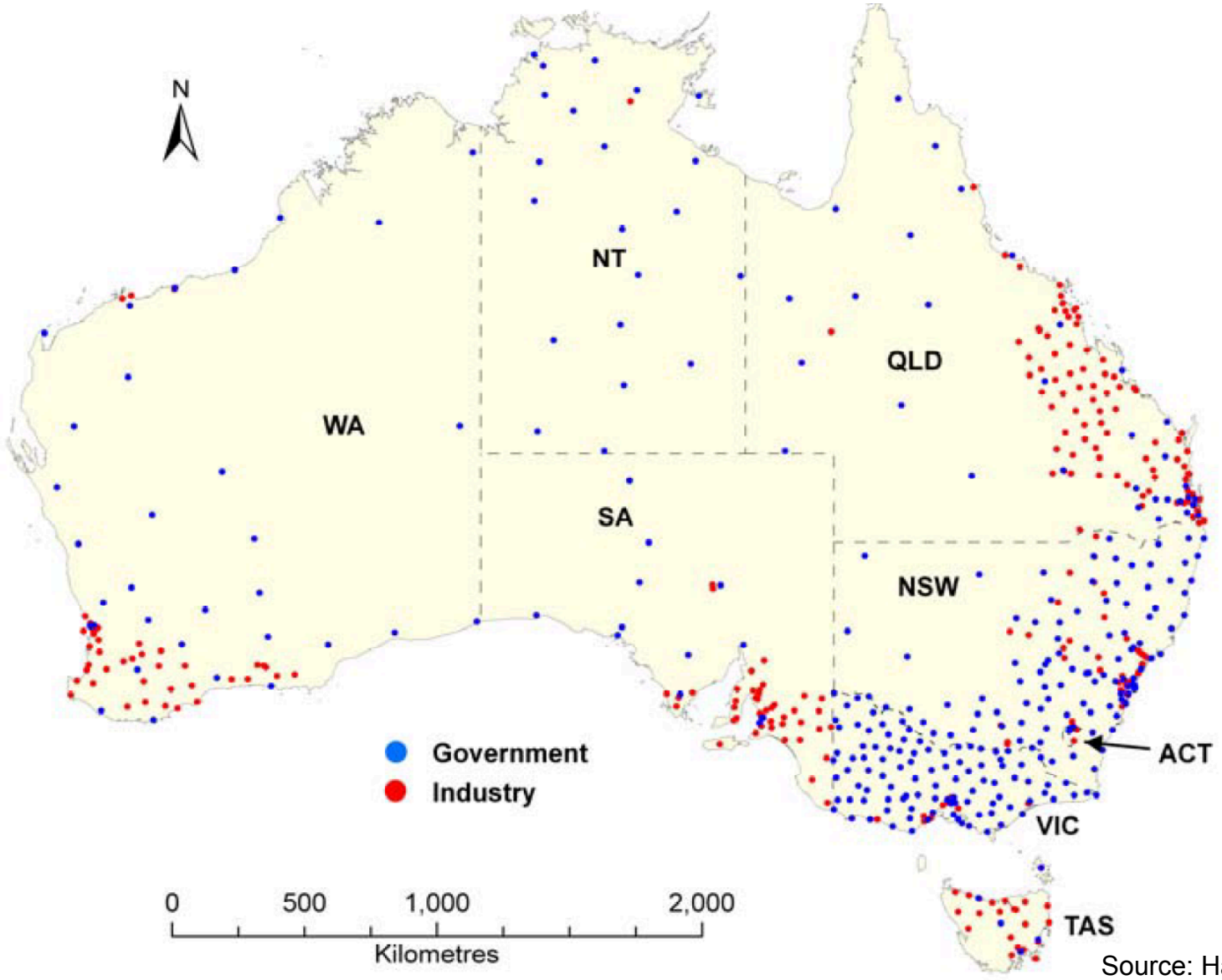
Precise satellite positioning has delivered economic benefits to Australian industry through productivity gains and efficient use of resources. In 2012, it was estimated that $2.3-3.7 billion was added to Australia's GDP and this will rise to $7.8-13.7 billion by 2020 (Acil Allen, 2013).

Source: Geoscience Australia

How Big is Australia?

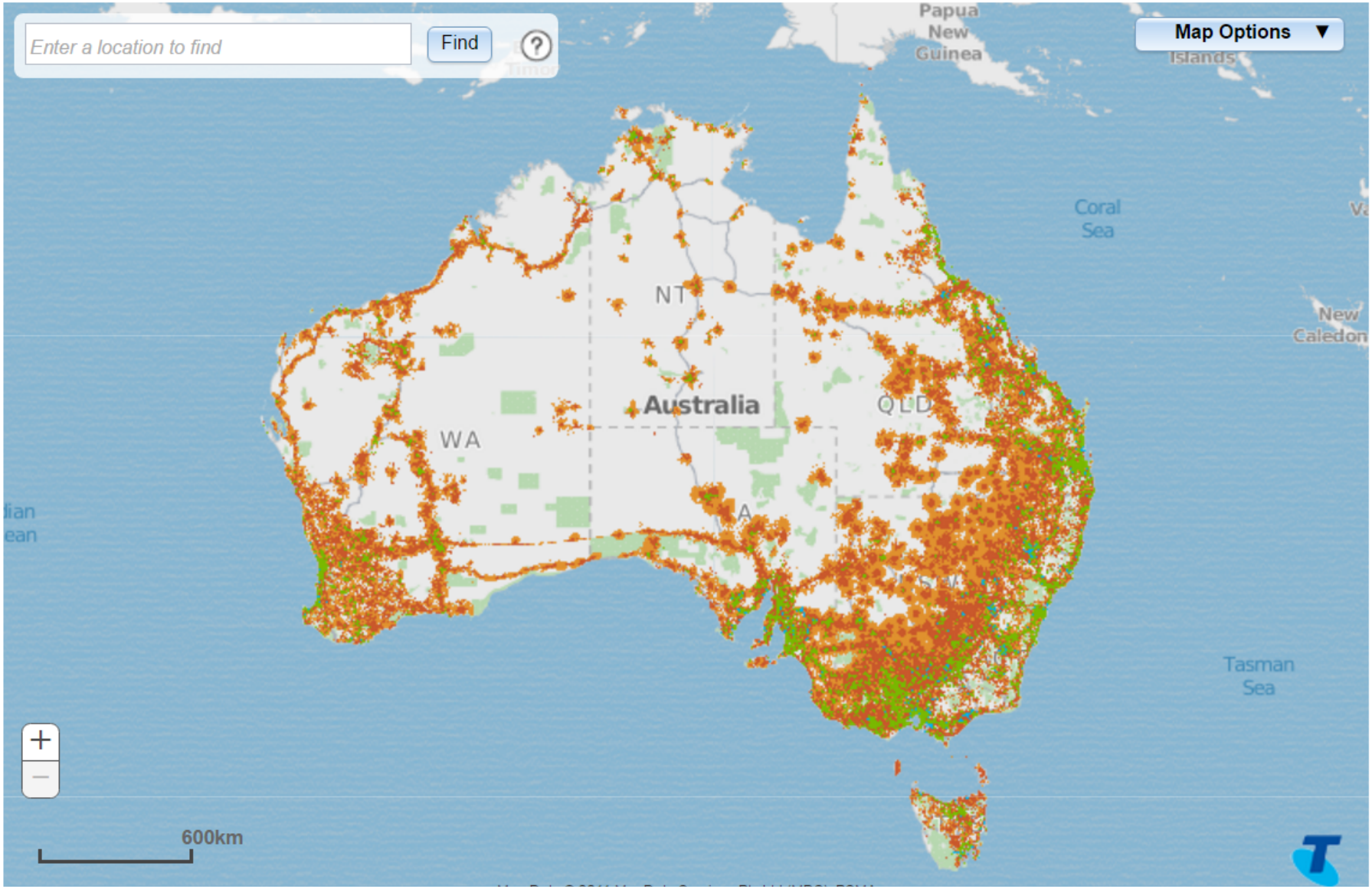


GNSS CORS Coverage

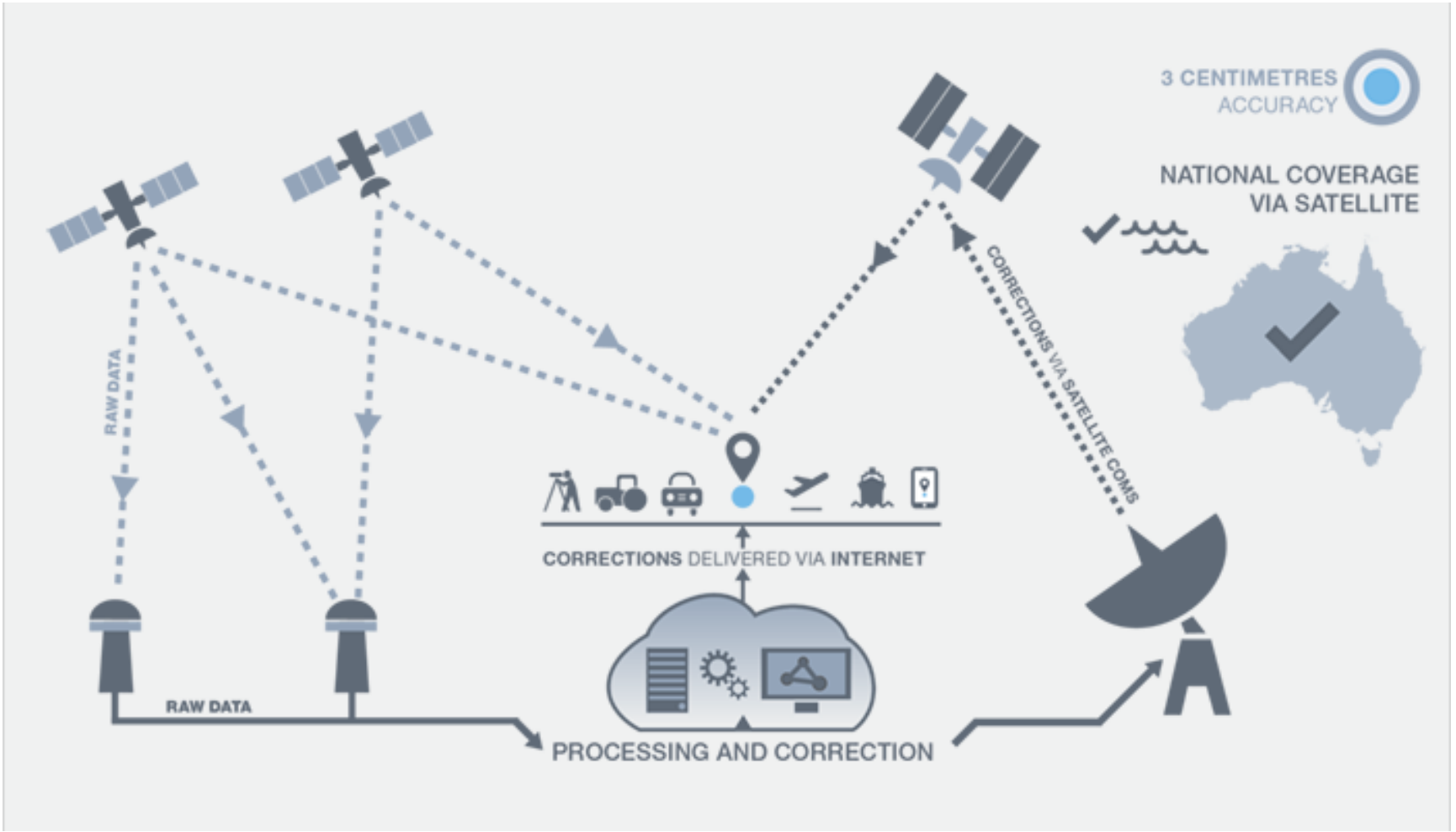


Source: Hausler (2014)

Mobile Connectivity



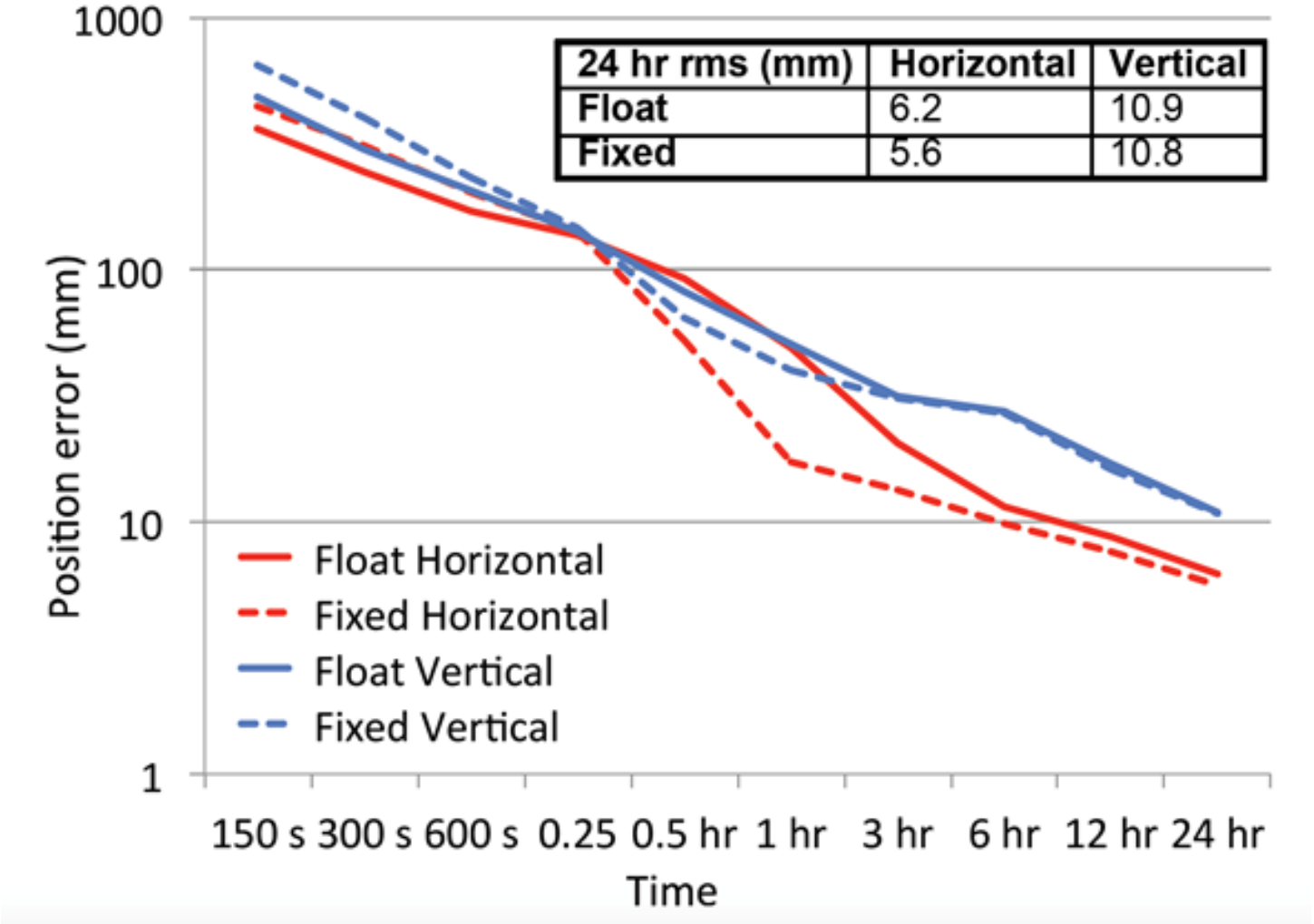
Australian National Positioning Infrastructure



Vision: instantaneous, reliable and fit-for-purpose access to precise positioning and timing information anywhere outdoor and at anytime within Australia.

Source: Geoscience Australia

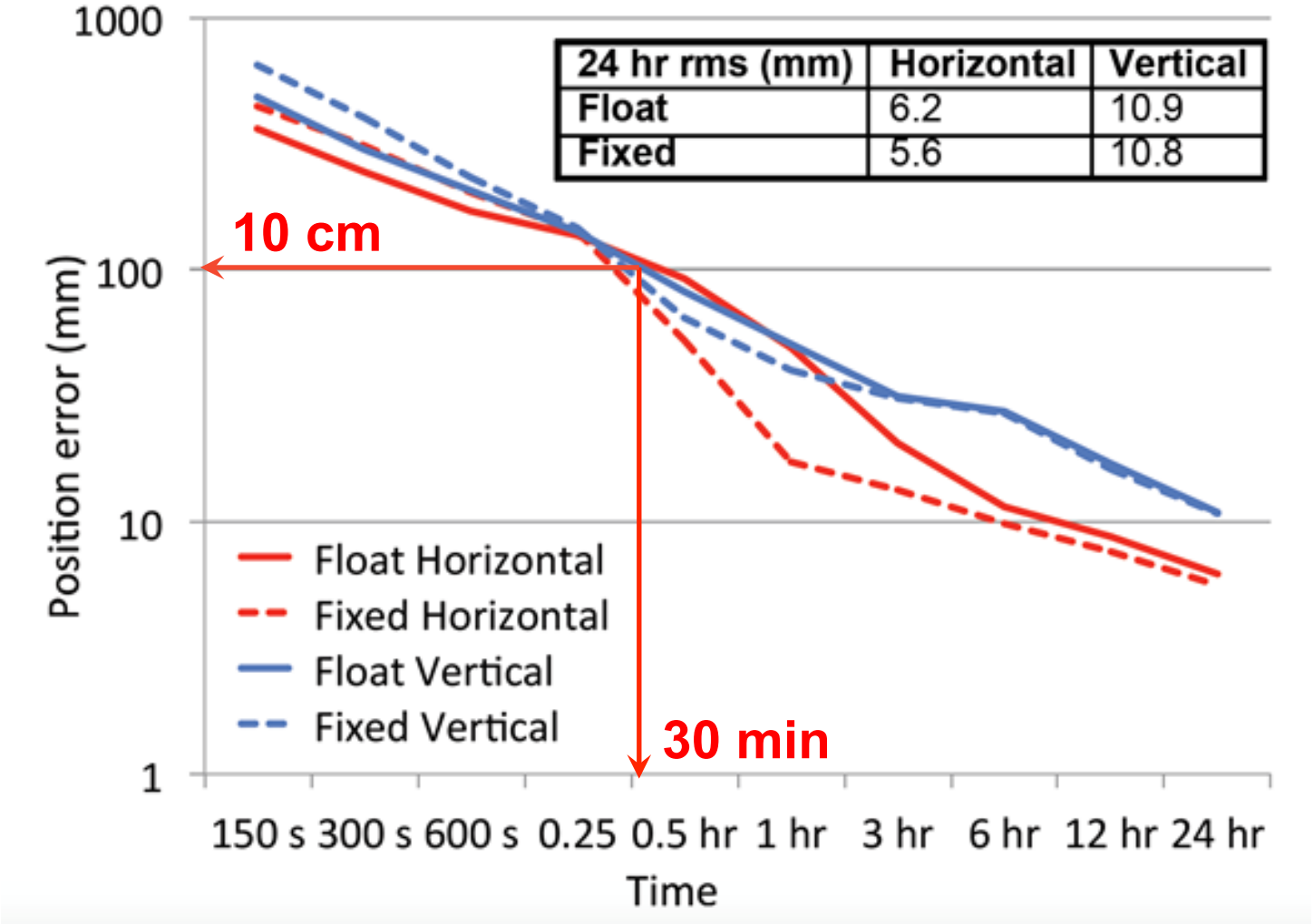
How Good is a PPP Solution?



24 hr rms (mm)	Horizontal	Vertical
Float	6.2	10.9
Fixed	5.6	10.8

Source: Choy, Bisnath and Rizos (2016)

How Good is a PPP Solution?

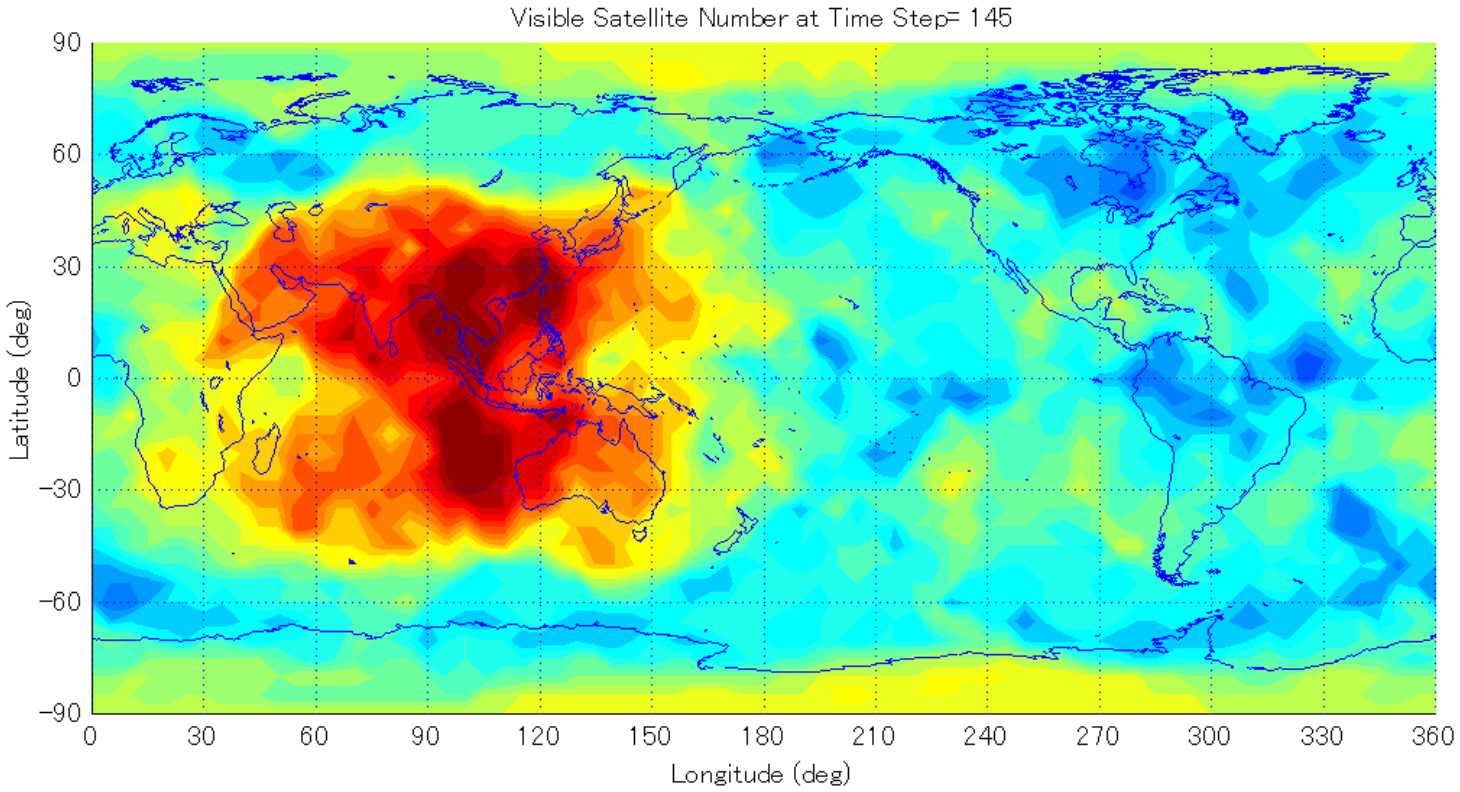


Source: Choy, Bisnath and Rizos (2016)

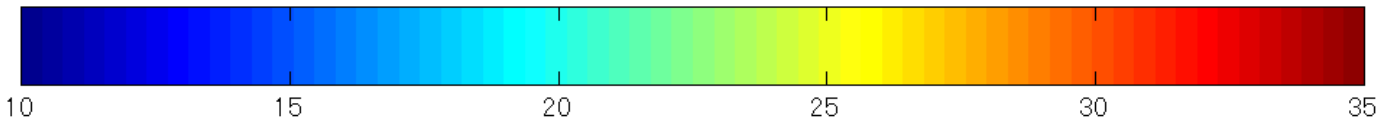
3.1 Augmenting PPP: Multi-GNSS, Multi-frequency PPP

A Multi-GNSS Future

Visible satellite number (mask angle 30º)

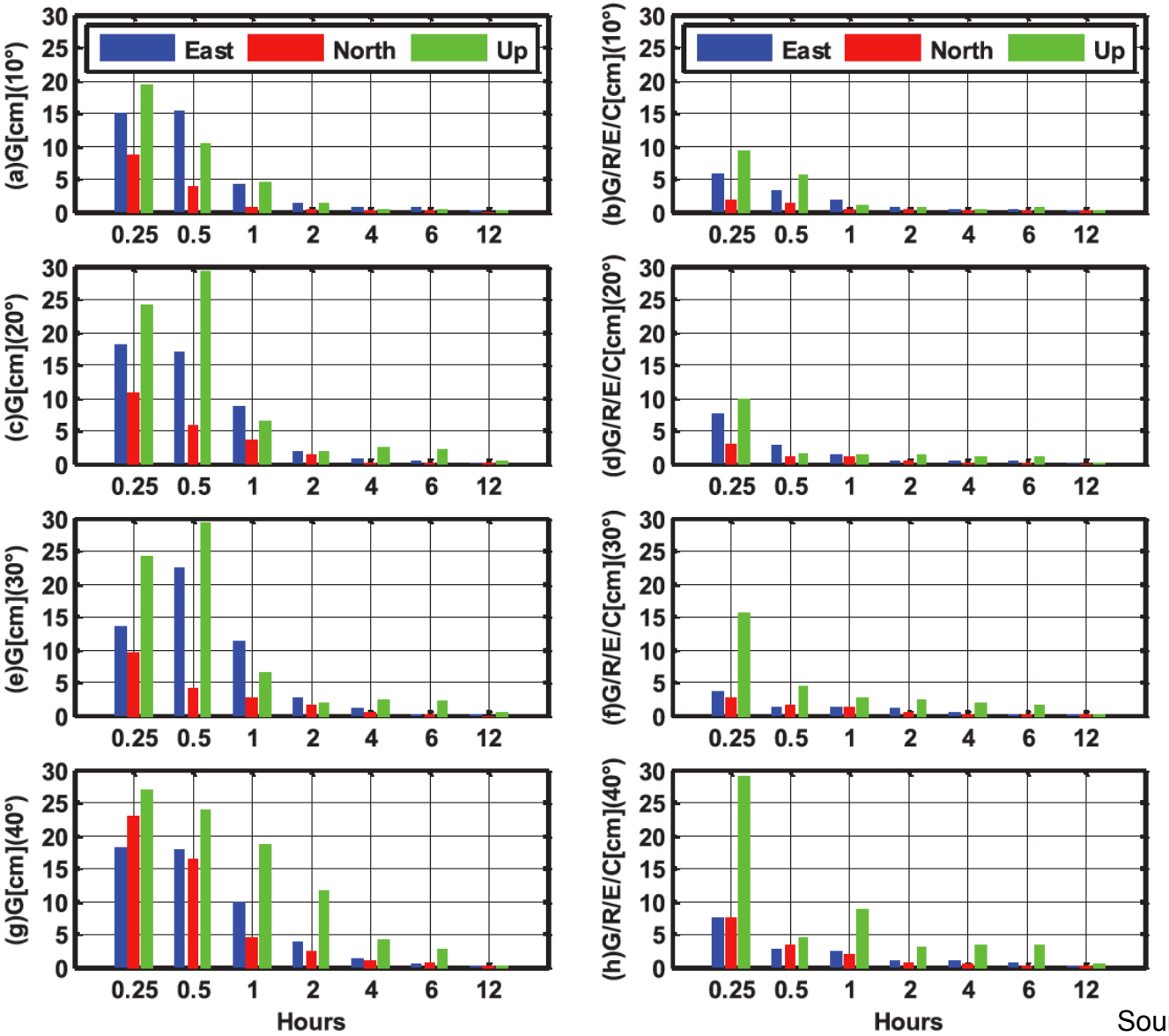


GPS(27)+Glonass(24)+Galileo(30)+BeiDou(35)+QZSS(3)+IRNSS(7)+SBAS(7)



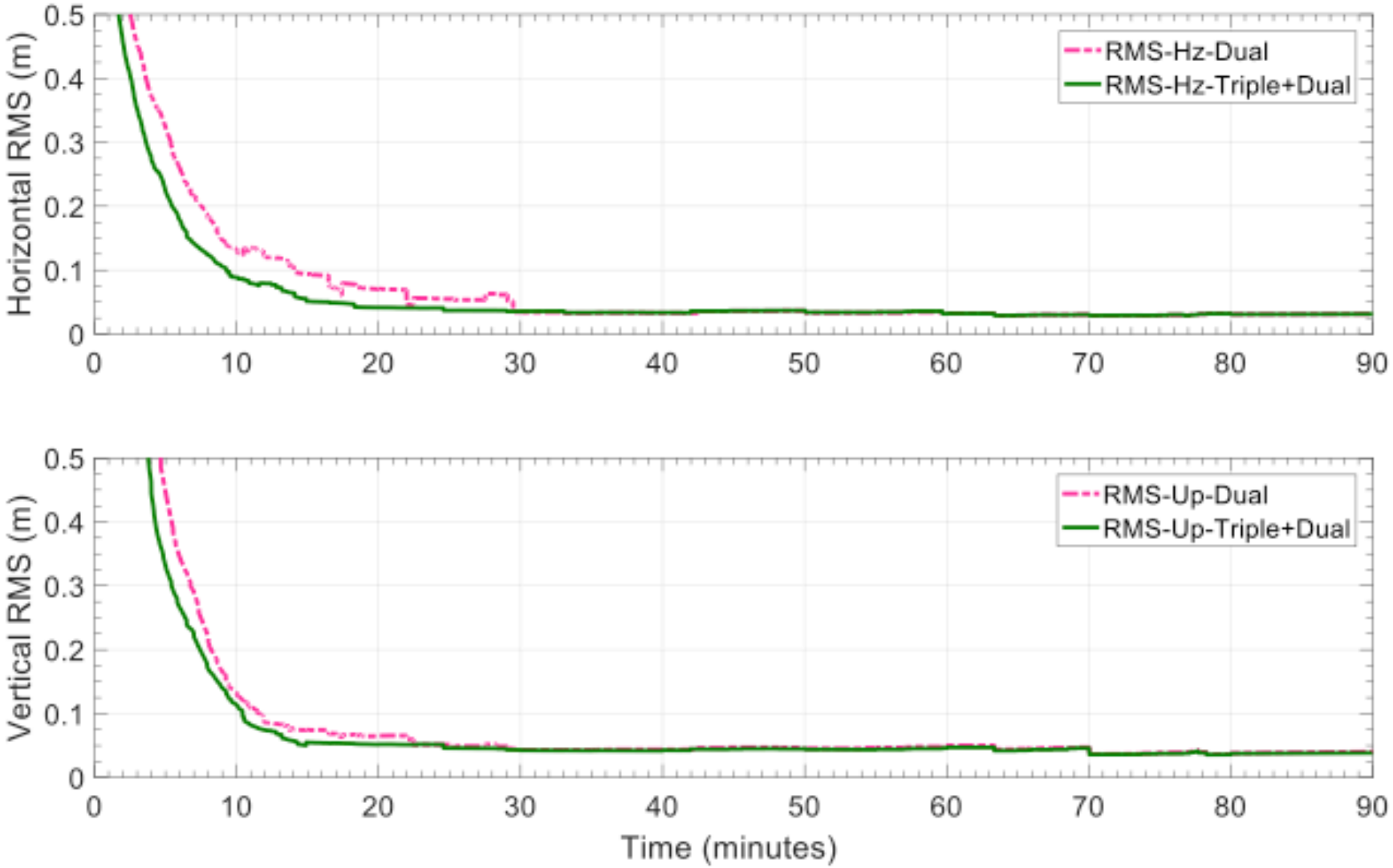
Source: UNSW

Multi-GNSS PPP



Source: Li et al (2015)

Multi-frequency PPP (GPS L1+L2+L5)

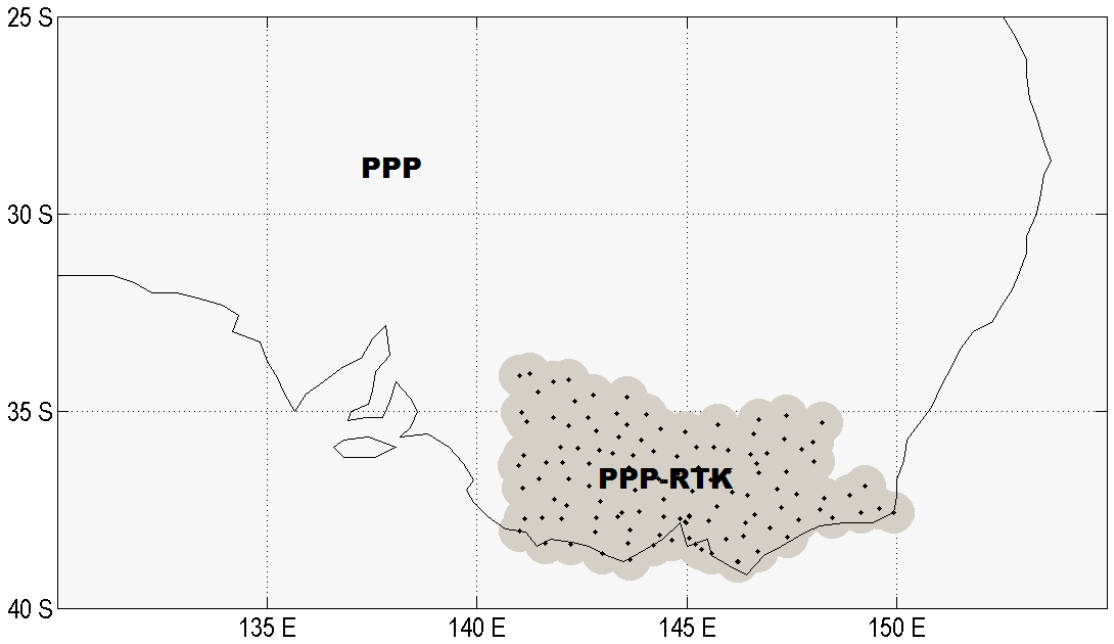


Source: Duong et al (2016)

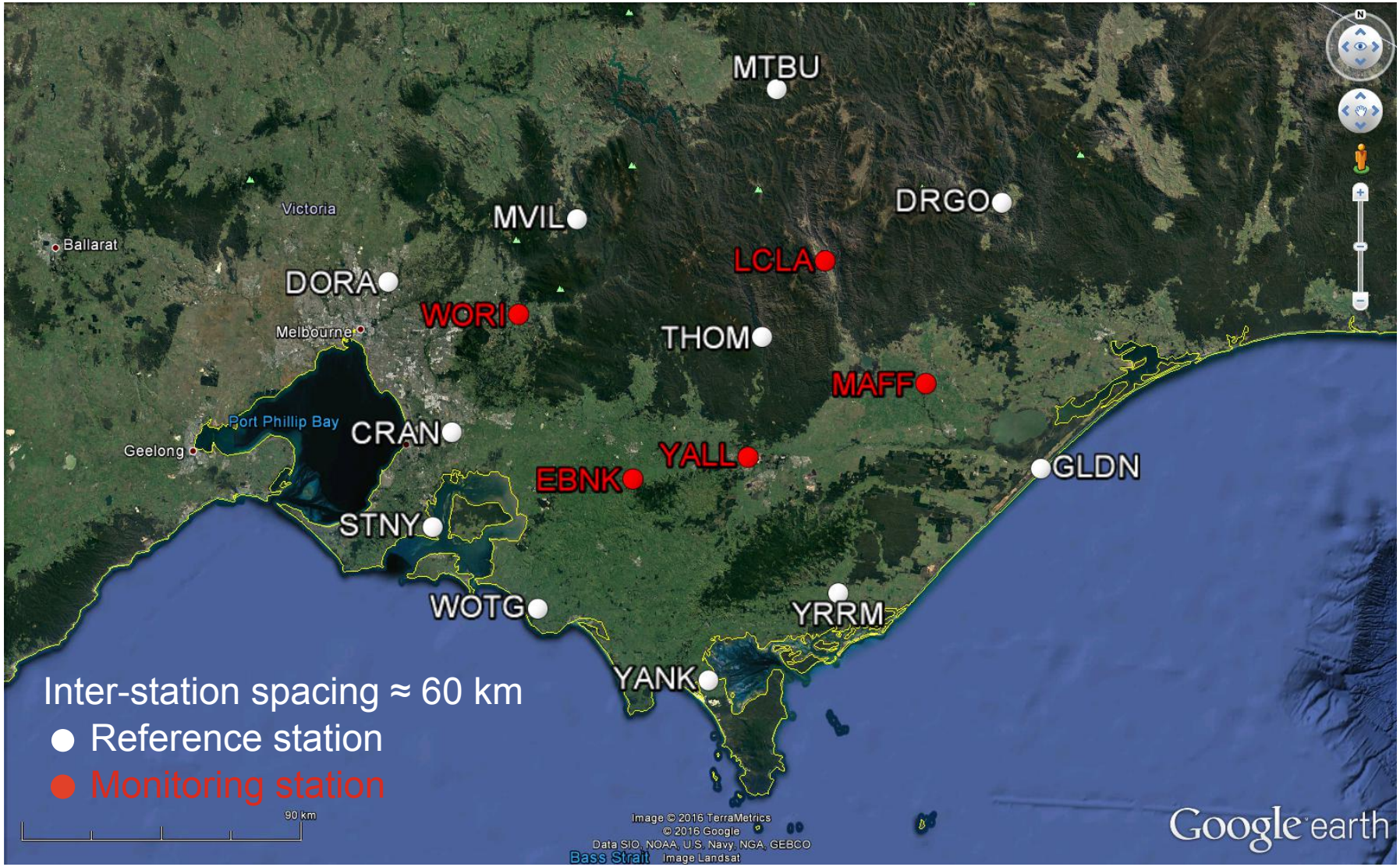
3.2 Augmenting PPP with Local Ionospheric Corrections – PPP-RTK

Local Augmentation for PPP

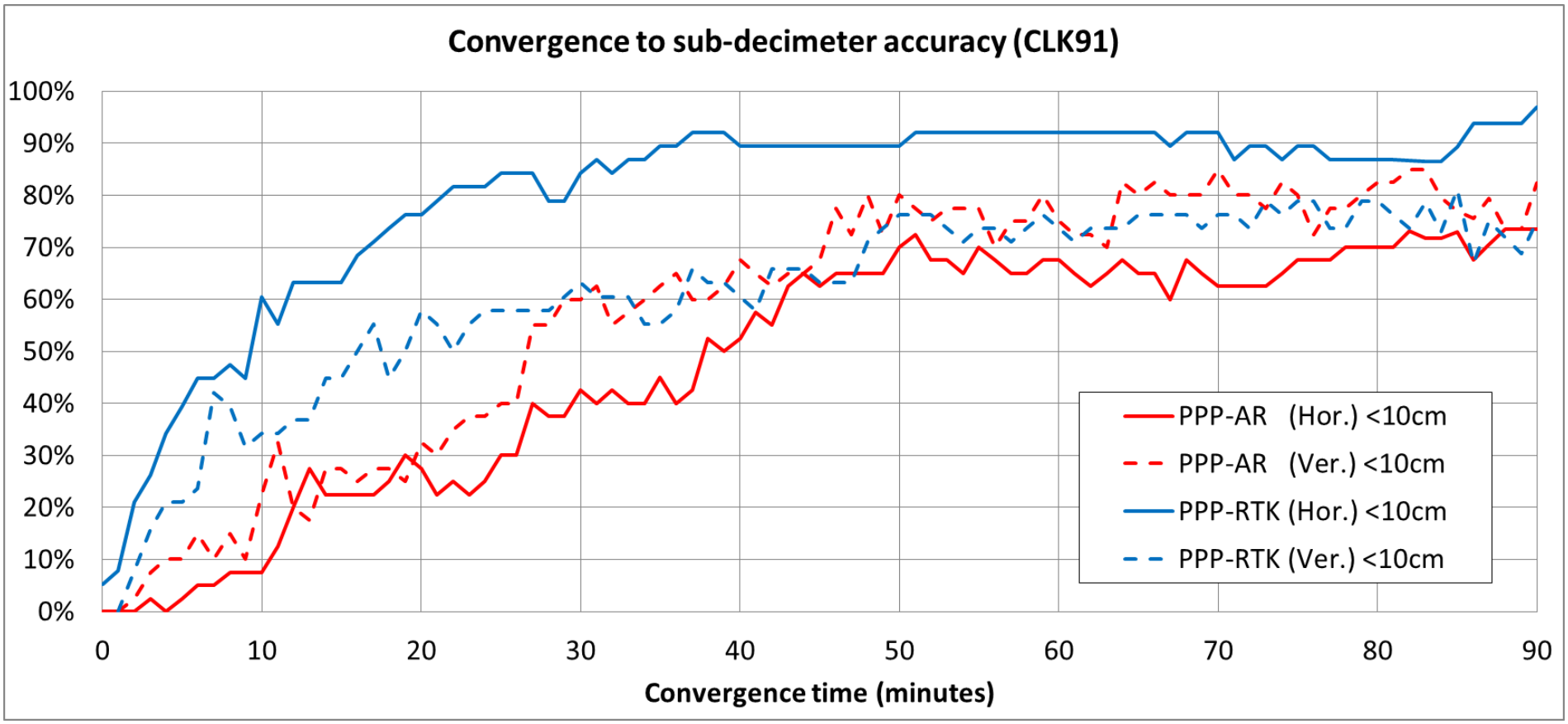
- **Challenge:** precise ionospheric corrections are required for rapid convergence
- Global precise ionospheric delay estimations for PPP-RTK are not yet available
- They are impractical for satellite transmission for nationwide coverage
- Using CORS networks to generate a local augmentation to global PPP products:
  - RTK-like performance inside or near network
  - PPP performance over wide area coverage
  - Seamless positioning



Case Study in Victoria, Australia



PPP-RTK Results



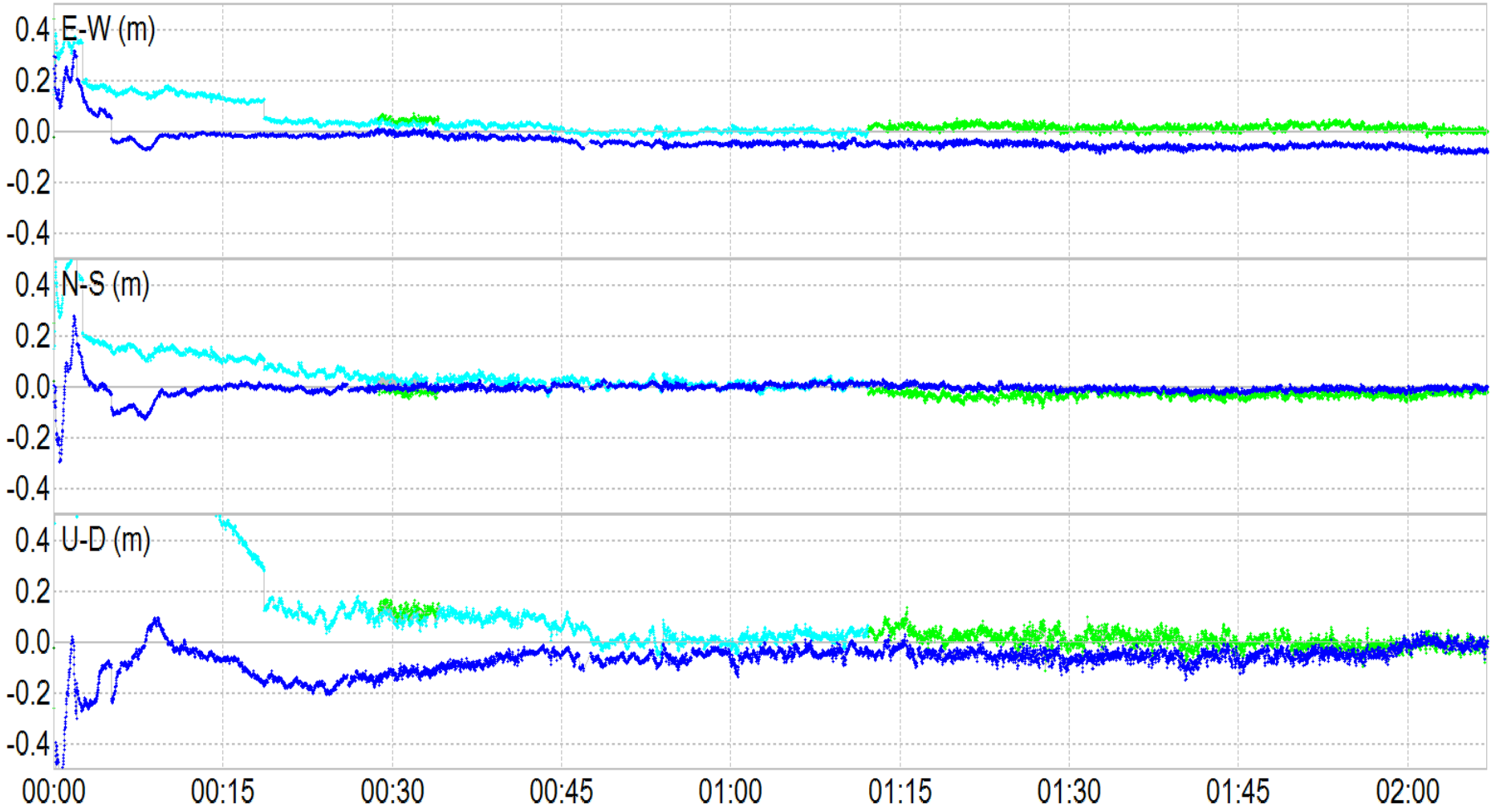
PPP-AR (red) and PPP-RTK (blue) solutions convergence times to within < 10 cm using the IGS/CNES CLK91 real-time corrections.

La Trobe Valley Coal Mine

Source: Elneser (2016), CRCSI Conference

Dynamic Tractor Results (CLK91 & MADOCA)

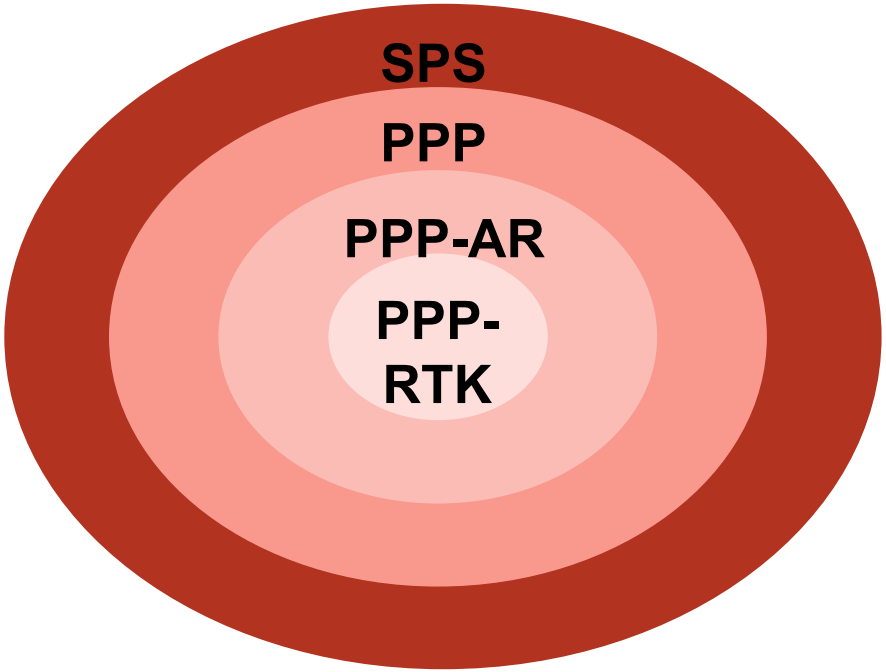
PPP-RTK results @ Yallourn Mine, 1 September 2016, 00:00 to 02:10



4. Summary

Summary: PPP Scalability

- Broadcast orbits & clocks
  - SPS
- Precise orbits and clocks
  - PPP
- Precise orbits and clocks + hardware delays
  - PPP-AR
- Precise orbits and clocks + hardware delays + local augmentation (e.g ionosphere)
  - PPP-RTK



Source: Collins (2013), PPP Workshop

Precision Agriculture: Tractor Guided by QZSS LEX/L6 PPP Solutions

Source: CRCSI (2015)

Acknowledgements

- United Nations Office for Outer Space Affairs
- Survey Department of the Ministry of Land Reform and Management of Nepal
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- French Government Space Agency (CNES), France
- International GNSS Services (IGS)

*** Disclaimer:** Any opinions expressed in this presentation are solely the author's and do not necessarily represent those of these organizations listed herein.

Thank you

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