Australian Government

Geoscience Australia

Real-time challenges of an Australian National Positioning Infrastructure

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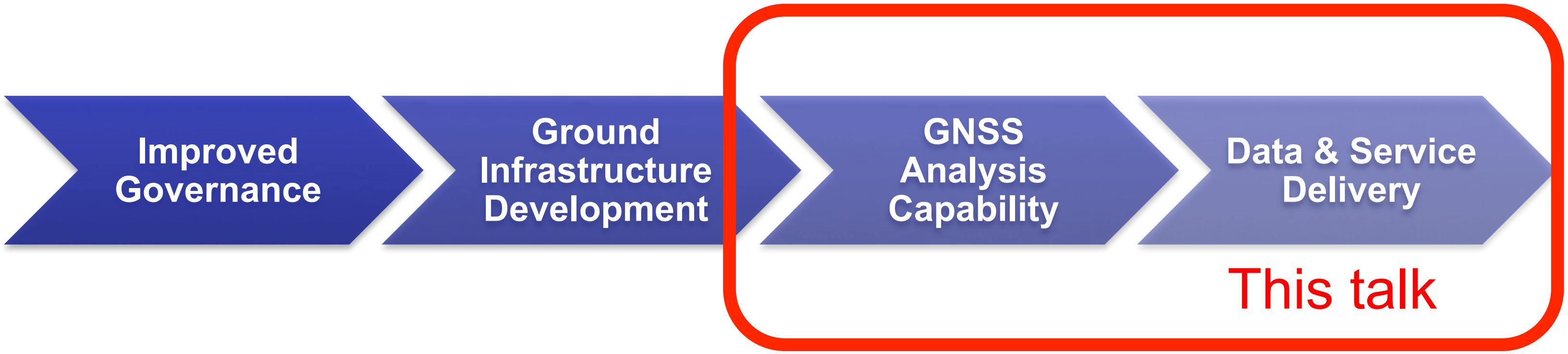
IGS 2016, Sydney, AUS

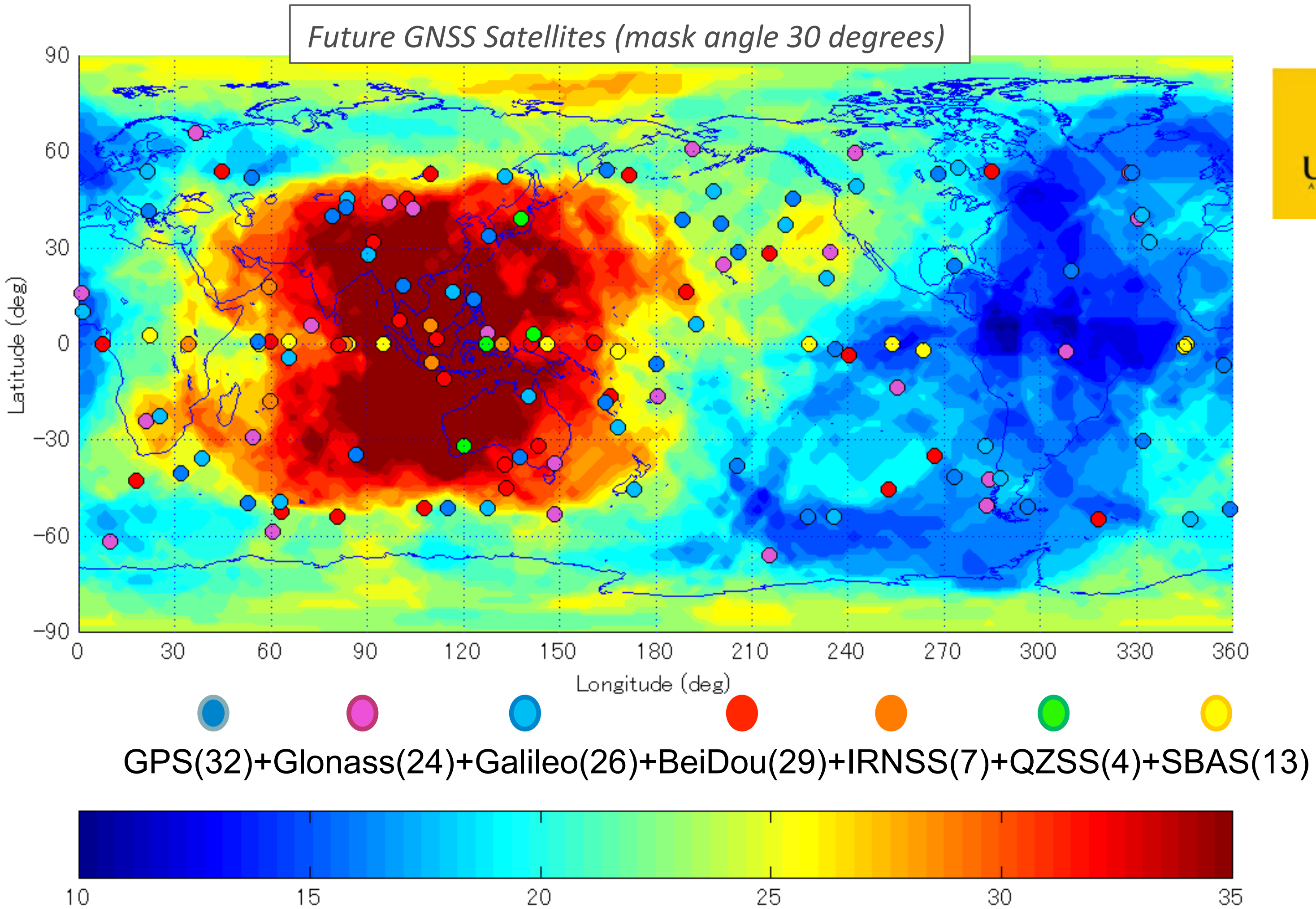
Overview

→ Australian NPI Strategic Planning Framework

http://www.industry.gov.au/INDUSTRY/IndustrySectors/SPACE/Pages/default.aspx



Australia's NPI : GPS to multi-GNSS



PPP-RTK services & products

(Type of service based on RTCM definition 021-2015-SC104-879)

PPP-RTK/SSR-CSx

PPP/SSR-DQ2

IN : ORB+CLK

OUT : PPP client with float ambiguity

PPP-AR/SSR-CQx

IN : ORB+CLK + USDs

OUT: PPP client with ambiguity fixing and long convergence

IN : ORB+CLK + USDs + atm. corr.

OUT : PPP client with instantaneous AR

PPP vs PPP-RTK

Wübbena et al. ION 2005

Ionosphere-free PPP-AR methods

Fractional Cycle Bias – FCB - (Geng et al. 2010; Geng et al. 2012)

IRC (Integer Receover Clock) - Mercier and Laurichesse (2007), Laurichesse and Mercier (2007)

DSC (Decoupled Satellite Clock) - Collins et al. (2008)

PPP-AR methods (w ionosphere)

Common Clock (CC) - Teunissen and Khodabandeh (2015)

Distinct Clock (DC) - de Jonge (1998), Odijk (2002) and in Teunissen et al. (2010)

	PPP	*PPP-RTK*
network size	global	local/regional/ global
primary state information		
satellite orbits	provided	provided
satellite clocks	provided	provided
ionosphere	corrected	provided
troposphere	estimated	provided
receiver clock	estimated	estimated
phase ambiguities & signal		
L1 / L2 / L0	- / - / +	+ / + / +
integration time	30 ... 1800 s	10 ... 50 s
accuracy		
static 3D	~ 5 cm	1 ... 3 cm
RTK 3D	15 ... 20 cm	1 ... 3 cm

Tab. 1 Characteristics of PPP and PPP-RTK

Coordination of CRCSI research outcomes

crc•si

Pre-defined outputs of the following CRCSI positioning programs:

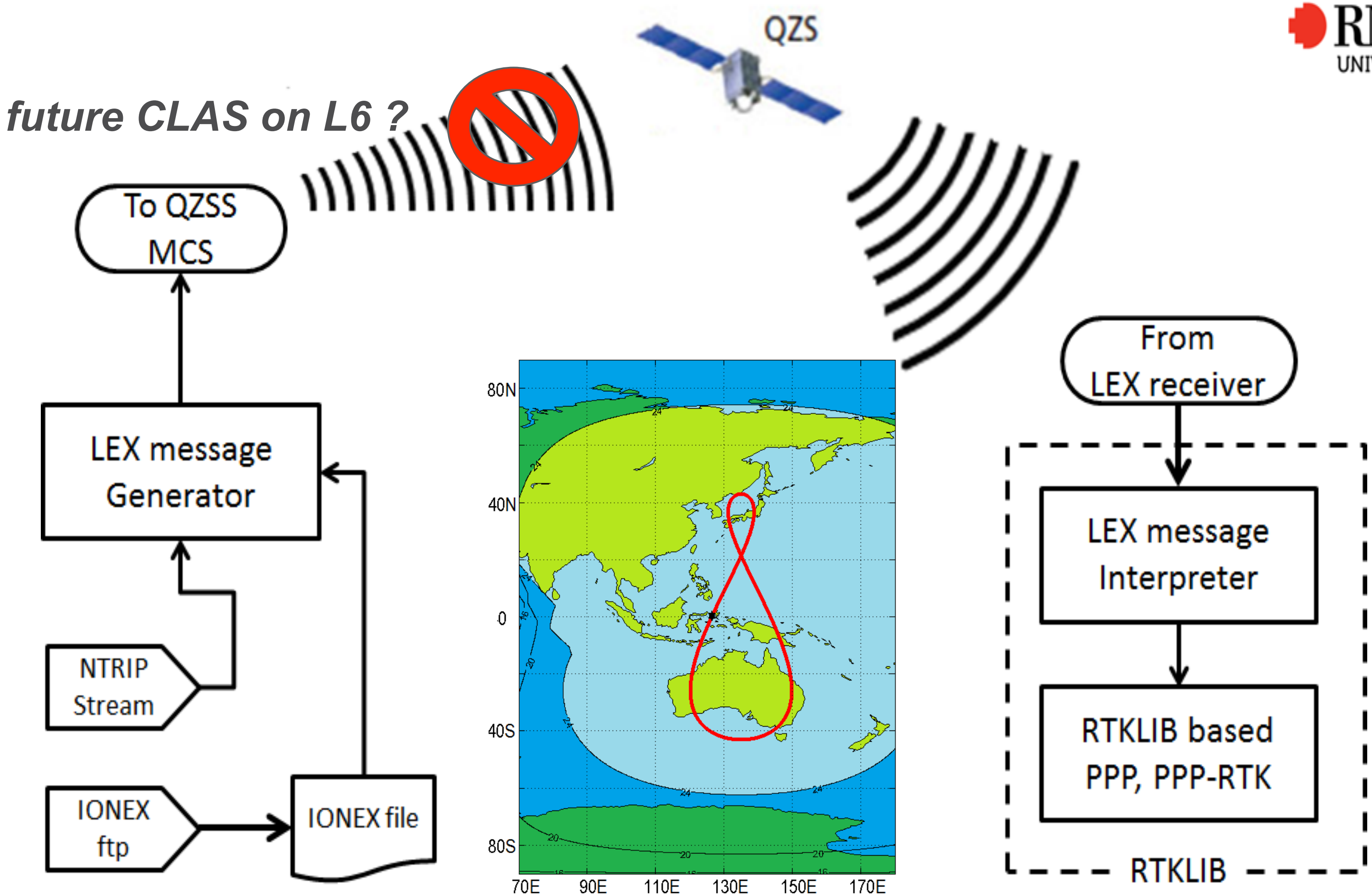
"*High Accuracy Real-time Positioning Utilising the Japanese Quasi-Zenith Satellite System (QZSS) Augmentation System*" [**RMIT**]

"*Multi-GNSS PPP-RTK Network Processing*" [**CUT**]

"*Ionosphere modelling for PPP-RTK*" [**BoM**]

*"Precise BDS **SRP and Attitude** modelling for real-time PPP-RTK"* [**GA**]

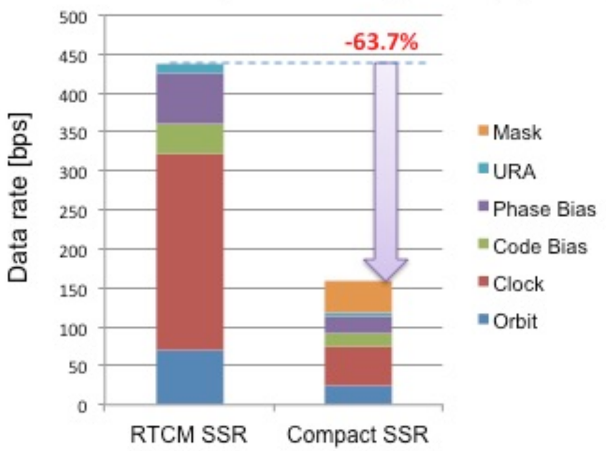
PPP-RTK transmission by LEX



Compact PPP-RTK corrections

Group Name	Sub-Group Name	Message Type *
Common Correction	Compact SSR Mask	4073,1
	Compact SSR GNSS Orbit Correction	4073,2
	Compact SSR GNSS Clock Correction	4073,3
	Compact SSR GNSS Satellite Code Bias	4073,4
	Compact SSR GNSS Satellite Phase Bias	4073,5
	Compact SSR GNSS URA	4073,6
Local correction	Compact SSR STEC correction	4073,7
	Compact SSR Gridded Correction	4073,8
Service Information	Compact SSR Service Information	4073,9

Multi-GNSS (14SV: GPS(8), GAL(3), QZS(3), 3 bias)



RTCM SC104 meeting
Sep 2015
Rui Hirokawa

PPP-RTK corrections from a network in a Common Clocks v.1 (CC-R) S-system

Corrections in PPP-mode

Odijk et al. 2015 JoG , CRCSI patent

$$d\tilde{t}^s = dt^s + d^s_{IF} - dt_1 - d_{1,IF}$$

Estimable biased satellite clocks

Recovering the integerness of the user ambiguities

$$\tilde{\delta}^s = \delta^s + \Lambda^{-1}\{\mu(d^s_{GF} - d_{1,GF}) - e(d^s_{IF} - d_{1,IF})\} - \delta_1 - z^s_1$$

Estimable biased satellite phase biases

Applicable to multi-frequency mode only

$$\tilde{d}^s_{,j} = (d^s_{,j} - d^s_{IF} - \mu_j d^s_{GF}) - (d_{1,j} - d_{1,IF} - \mu_j d_{1,GF});\ j > 2$$

Estimable biased satellite code biases

Speeding up the user IAR

$$\tilde{\iota}^s = \iota^s_{\bar{r}} + d_{\bar{r},GF} - d^s_{GF}$$

Biased slant ionospheric delays

Condition (1st epoch)

All n stations see all m satellites – Not valid for global networks

Multi-GNSS Inter System biases

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Curtin University

Multi-GNSS setup:

$$s = 1, \ldots, m_A, m_A + 1, \ldots, m_A + m_B$$

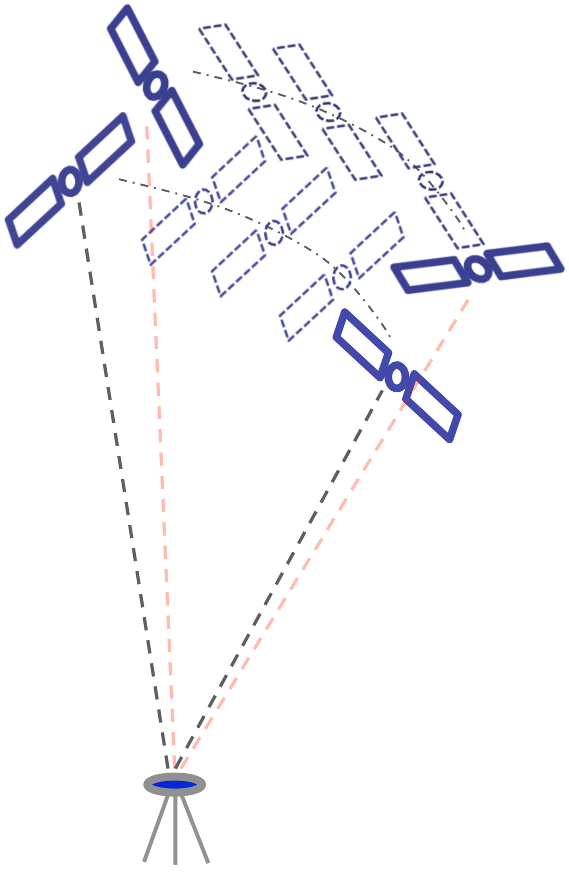
Question: *What would happen if* ***network-derived estimable ISB*** *corrections are a-priori available?*

☺ ***Multi-constellation can be treated as one single-constellation***

$$q = 1, \ldots, m_B$$

$$s = 1, \ldots, m_A$$

$$s = 1, \ldots, m_A, m_A + 1, \ldots, m_A + m_B$$



Multi-GNSS user corrected observation model:
(ISB-corrected)

More redundancy, better precision and integrity, higher IAR success-rates

Odijk et al. 2012, Odolinski et al. 2015

BDS Inter system biases

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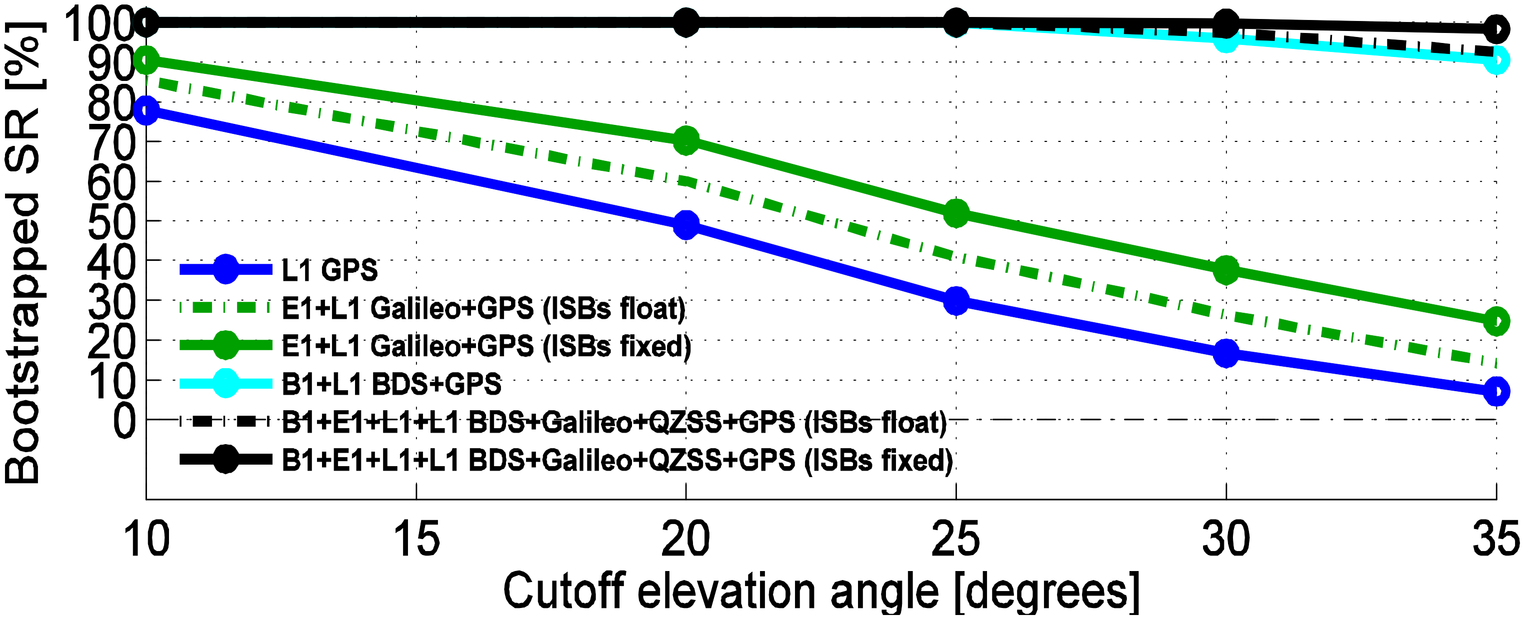
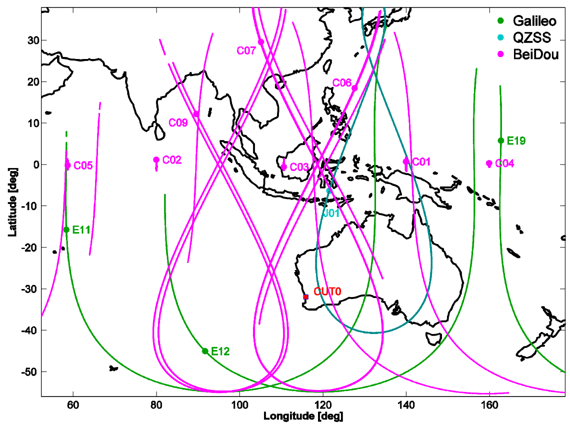




$$\phi_{12,j}^{s_*} - \bar{\delta}_{12,j}^{G*} = -c_2^{s_* T}\Delta x_{12} + d\tilde{t}_{12} + \tilde{\delta}_{12,j}^{G} + \lambda_j \tilde{z}_{12,j}^{1_G s_*}$$ ISB fixed

$$\phi_{12,j}^{s_*} = -c_2^{s_* T}\Delta x_{12} + d\tilde{t}_{12} + \tilde{\delta}_{12,j}^{G} + \tilde{\delta}_{12,j}^{G*} + \lambda_j \tilde{z}_{12,j}^{1_* s_*}$$ ISB float

Odolinski and Odijk 2015

Improved Ionospheric Modelling

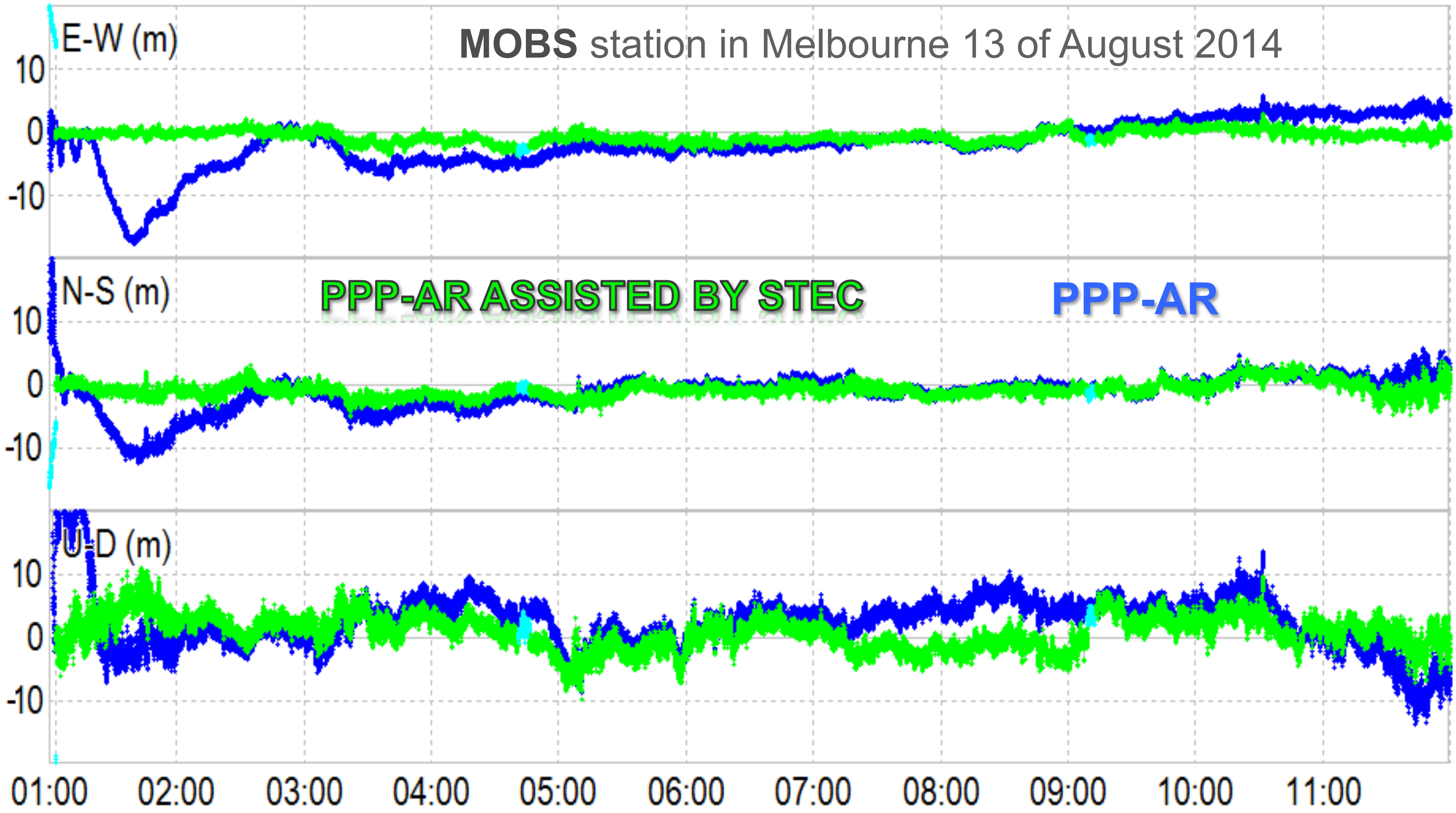
Australian Government
Bureau of Meteorology

Intrinsic part of our future National Positioning Infrastructure

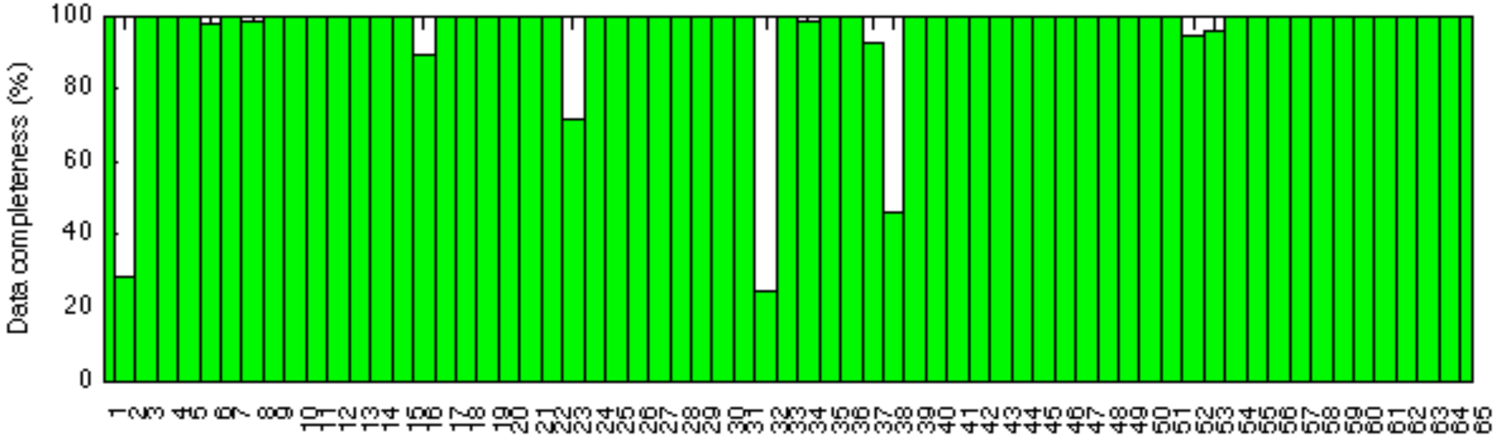
Key research questions :

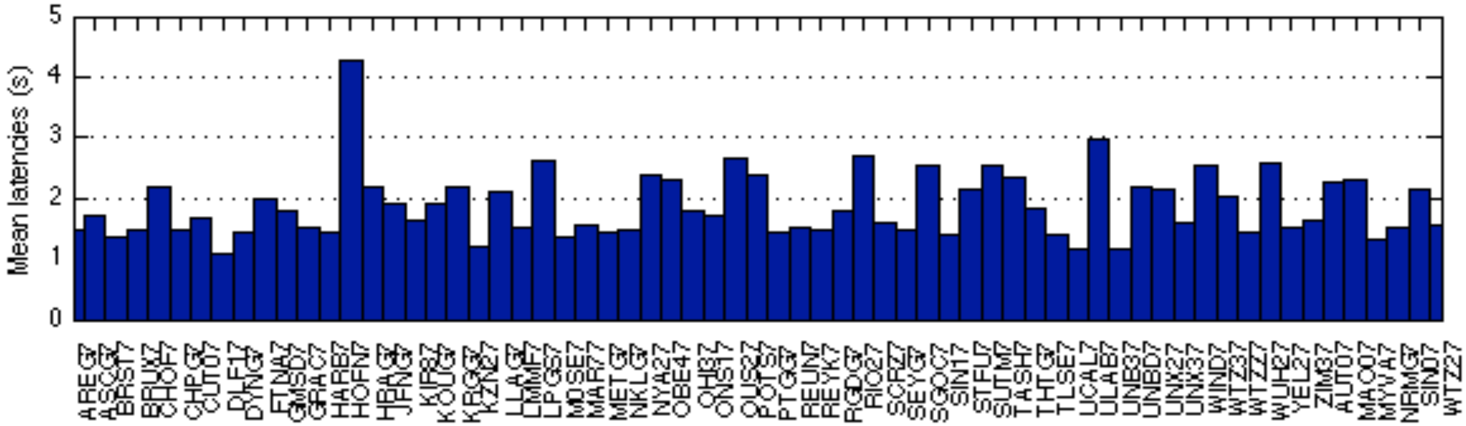
1. What is the in-principle noise floor for determining absolute slant total electron content (STEC) from existing CORS stations and available **multi-frequency** GNSS tracking data in Australia ?
2. What is the most appropriate modeling approach for **interpolation** of the STEC data from the CORS network into the required **3D ionospheric model** ?
3. What are the potential roadblocks to **delivering** the ionospheric model to **users** and how can these be overcome?

Impact of Ionospheric Modelling / SSRCS2



MGEX RTCM latency test – ACS PDE





Sum up

- Braking old Habits
- Adopting new Formats
- Adopting new Terminologies
- Building new Conventions
- Building new SW tools

Building a multi-GNSS software (ACS) capable of producing a range of PPP-RTK products based on a novel approach – CC

POD research position on
<u>BDS SRP and attitude modelling</u>
http://www.seek.com.au/Job/30354892

Contact

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http://www.crcsi.com.au/research/1-positioning/1-14-development-of-analysis-centre-software/

Back up Slides

RTCM SSR PPP-AR Interoperability

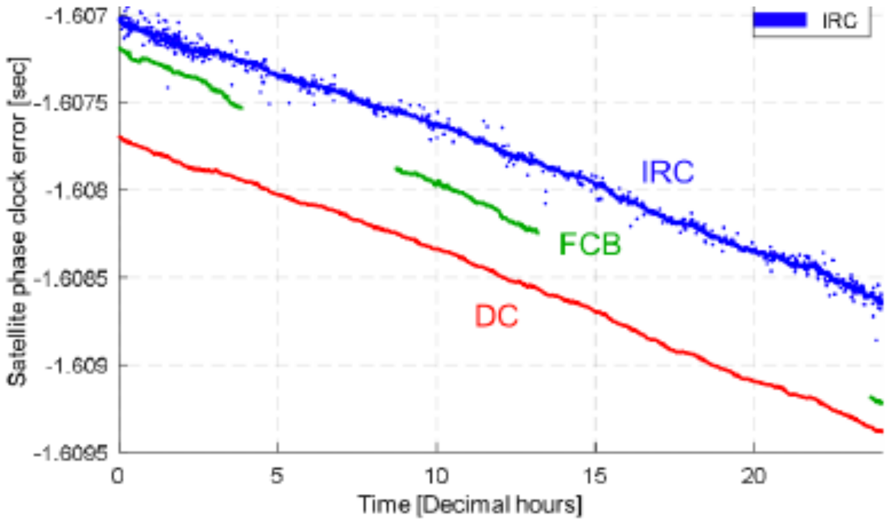
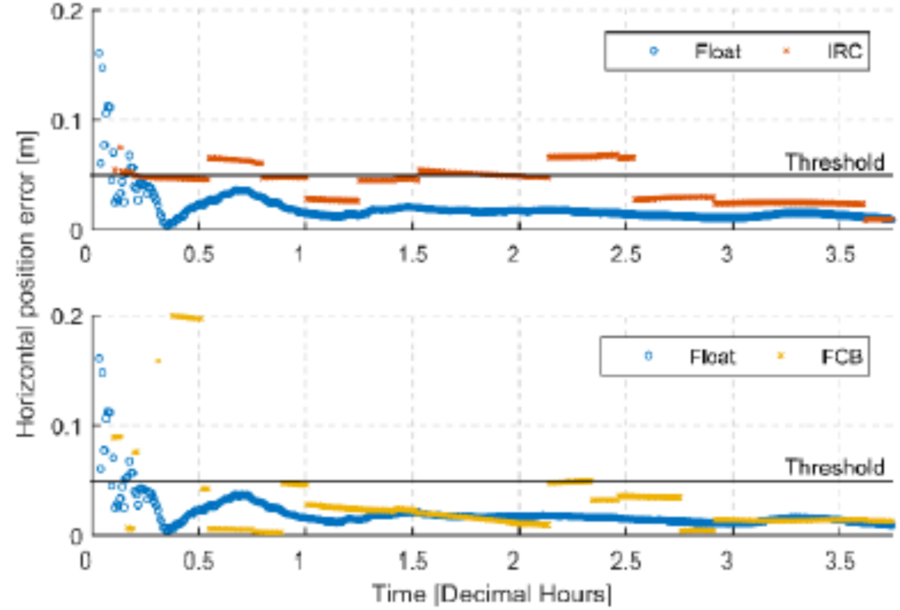


Figure 7: Transformed FCB (upper) and IRC (lower) satellite phase clock correction on DOY 28 of 2015 for



Seepersad and Bisnath ION 2015

Table 3: Summary of the different quality of products provided by public providers to enable PPP-AR

	Regional	Global	Real Time	Post processed
IRC		X	X	
DC		X		X
FCB	X		X	

PPP-RTK corrections from a network

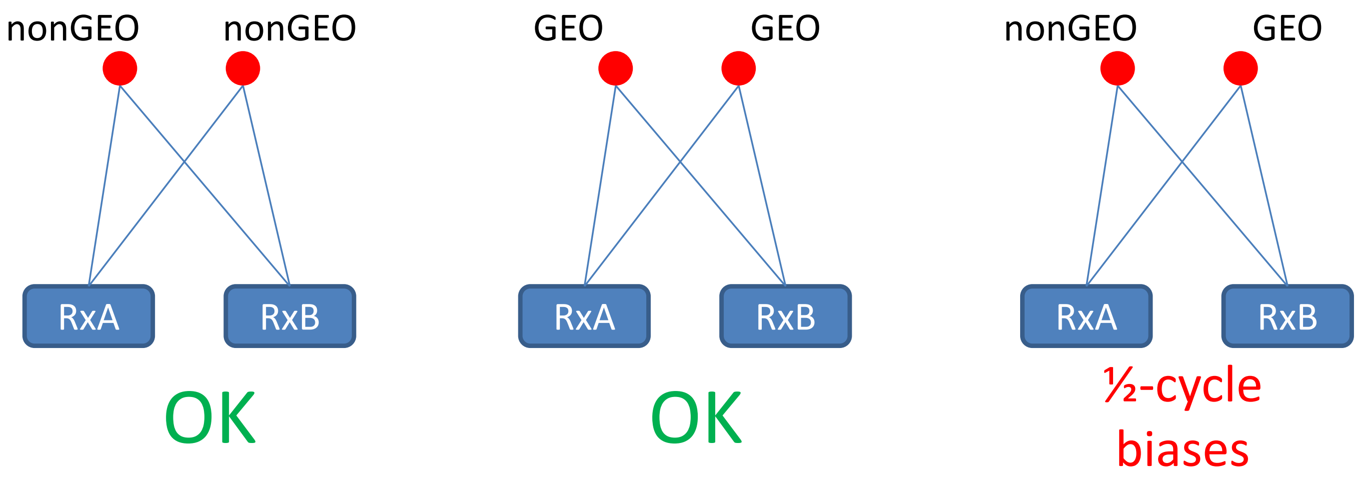
- Solve for rank deficient system of GNSS obs.eq.
  - system theory (*Baarda 1973; Teunissen 1985*) →
    - Solve dim$N(A) = n - r$ where N is the null space of design matrix A
- Proper Interpretation of the network and user parameters
- BUT not all parameters can be estimated unbiased
- in a Common Clocks (CC-S) S-system (*Odijk et al. 2015*)
  - **Satellite** and **receiver** **clocks** are parameters **common** for all phase and code observations
  - **Assumption** : all *n* receivers in the network 'see' all *m* satellites at the same time – NOT TRUE in global networks
- Functional models derived only for CDMA signals

PPP vs. PPP-RTK

PPP/SSR-DQ2	PPP-RTK/SSR-CS2
• Based on **phase** and **code** data	• Based on **phase** and **code** data
• Satellite **orbits + clocks (+ code biases for > 3 freq.)** required	• Satellite **orbits + clocks (+ code biases for > 3 freq.) +** ***phase biases*** required
• Estimable **ambiguities**: *non-integer* as they are biased by hardware biases	• Estimable **ambiguities**: *integer* as they are estimable as double differences (relative to pivot receiver network)
• Improvement in position precision if precise **ionospheric corrections** are used	• Faster time-to-fix-ambiguities if precise **ionospheric corrections** are used

Mixed receiver
Beidou Inter-Satellite System Biases

Test of BeiDou short baseline RTK with mixed receivers:



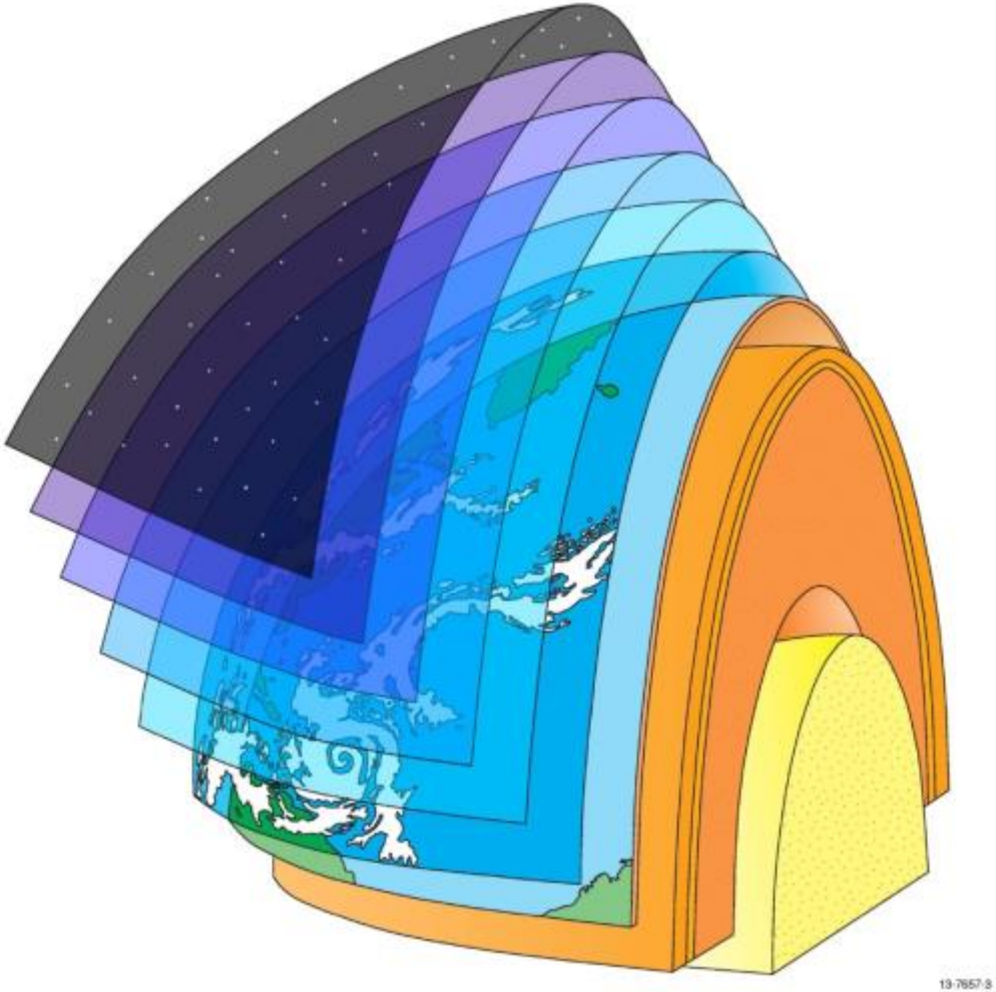
Use of different sign conventions for the secondary code of IGSO/MEO navigation messages = > 180d phase-shift => catastrophic failure of ambiguity resolution

[1] N. Nadarajah et al. 2013
[2] N. Nadarajah, et al. 2014.
[3] N. Nadarajah etc.,RTCM SC-104 Conference, May,2014,Darmstadt

Impact of Ionospheric Information

- Iono parameters depend from the chosen S-basis
- There is a rank deficiency between the slant (1^{st} order) ionospheric parameters and the phase/code biases
- The network's S-basis results in a change in the interpretation of the user ionospheric delays
- The rank-deficiency disappears in the case we consider an ionospheric model (e.g. a single layer where the slant delays have been mapped to their zenith version / station)
- In the case that a user doesn't make use of the network ionospheric model the interpretation of the user's defined ionospheric parameters will depend from the information content in the network corrections !

Improved Ionospheric Modelling



Modelling the Ionosphere

→CRCSI, BoM, Curtin, GA

→4-D ionosphere model

Modelling troposphere

→CRCSI, BoM, GA

→Operational product generation for weather forecasting