

# Processing Strategies and Performances Analysis for Beidou Precise Orbit Determination based on GAMIT

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# Outlines

- Research Background
- GAMIT BDS POD Platform
- Processing Strategies and Experimental Setup
- Preliminary BDS POD Solutions
- Future Works

# Research Background

*This project is to develop an indigenous capability for computing and delivering real-time, regionally enhanced orbit and clock products to support multi-GNSS real-time positioning in Australia and New Zealand.*

**Output 1: A regional GPS/GLONASS orbit enhancement system that can process data streams from global and national CORS networks to provide high-rate GPS/GLONASS clock and orbital corrections in real-time**

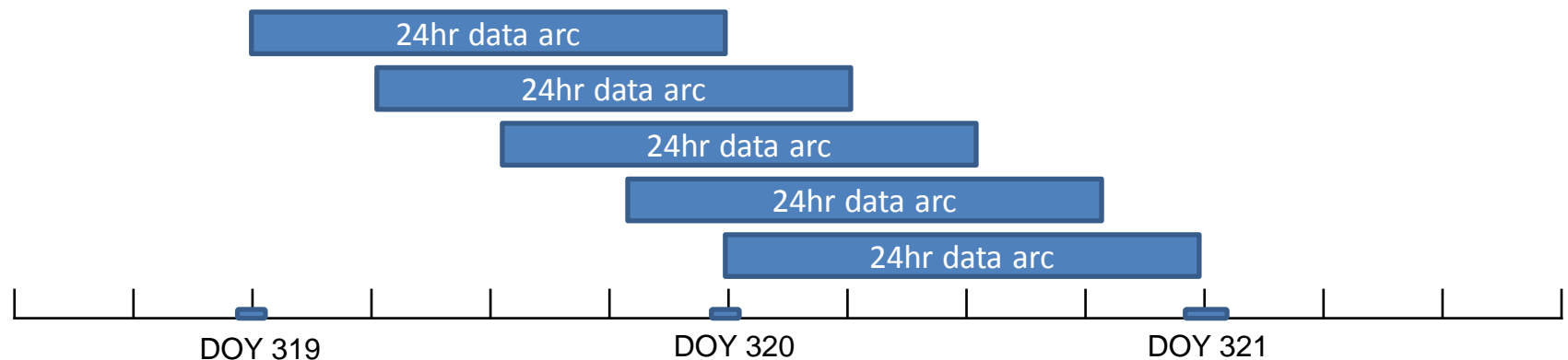
**Output 2: A regional COMPASS/QZSS orbit analysis platform that can process QZSS and COMPASS data streams from ground tracking stations in the Asia-Oceania region and provide orbit and clock solutions in near real-time at an accuracy better than their broadcast ephemerides**

# Research Background

- Develop the Precise Orbit Determination (POD) processing capabilities based on GAMIT-GLOBK.
- Evaluated the impact of the regionally enhanced orbit solution for supporting real-time positioning.
  - The accuracy improvements depends on how well the regional stations can better fill in the gaps of the global networks, rather than the number of additional stations.
  - Regional orbit solution provide decimetre level of accuracy within network converge, however significantly degraded for the rest of region and the orbit prediction.
  - Recommended to use an evenly distributed global network of ~100 stations with ~20 stations within.

# GAMIT BDS POD Platform

- Modifications are made to utilize the current GAMIT structure/source code as much as possible.
  - BDS data processing support
  - BeiDou satellite tables
  - BeiDou modelling (attitude/yaw, SRP)
- Sliding Window (SWIN) routine processing



# GAMIT BDS POD Platform

**INPUTS**

Station Coord.  
 Station Info.  
 Session Info.  
 Analysis control files

Raw/RINEX  
 Sat. orbit IC  
 Sat. & station clock

Others:

- Luni-solar ephemerides
- nutation
- EOP (UT1, wob)
- Satellite characteristics
- Receiver/Ant. characteristics
- Ocean tide grid
- Atmospheric loading grid
- Tropo. mapping function/grid
- DCB
- Leap seconds
- PCV, PCO

**NET\_1**

Makexp and makex – data preparation

Arc – orbit al ephemeris with partials

Yawtab – satellite attitude values

Grdtab – atmospheric and loading

Model – residuals and partials

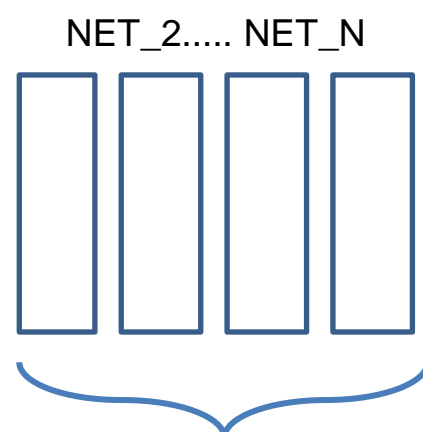
Autcln – automatic edit of residuals

Solve – lease squares analysis solution

Model – updated residuals and partials

Autcln – automatic edit of residuals

Solve – final LS analysis solution



Final station coordinates  
 H-file (covariance matrix)  
 ZTD estimate

**GAMIT**  
 Process

Combine quasi-observations “H-files” (loosely constrained solutions & covariance ) from multiple networks and/or epochs:

- Time series of station coordinates
- Station velocity
- Orbit and EOP

**GLOBK**  
 Combination

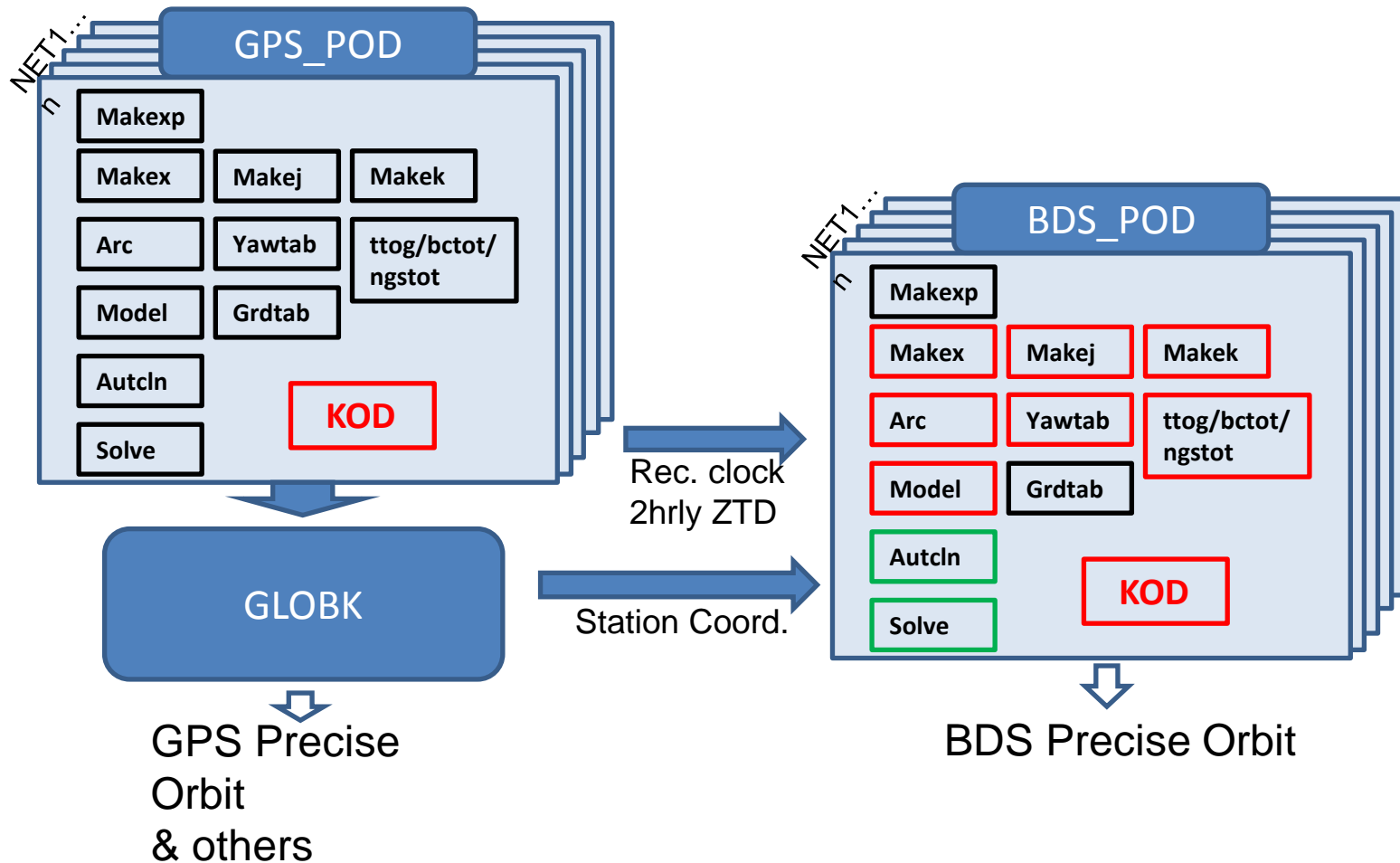
# GAMIT BDS POD Platform



- GAMIT modifications:
  - BDS data processing support
    - Conversion of Rinex3 to Rinex2 format
    - Satellite system processing selection (makex)
    - Read, write RINEX and SP3, i.e.
    - Definition for BDS frequencies (B1, B2, B3) and gm & erate constant
    - Broadcast navigation message BDST time adjustment
    - BDS GEO position calculation from broadcast navigation message
  - BDS modelling (attitude/yaw, SRP)
    - Beidou GEO yaw-fixed control
    - Beidou IGSO/MEO yaw-fixed to yaw-steering dual control mode
  - Beidou satellite tables (yaw rate, mass, antenna offset, pcv)
  - Refine data processing control settings

# GAMIT BDS POD Platform

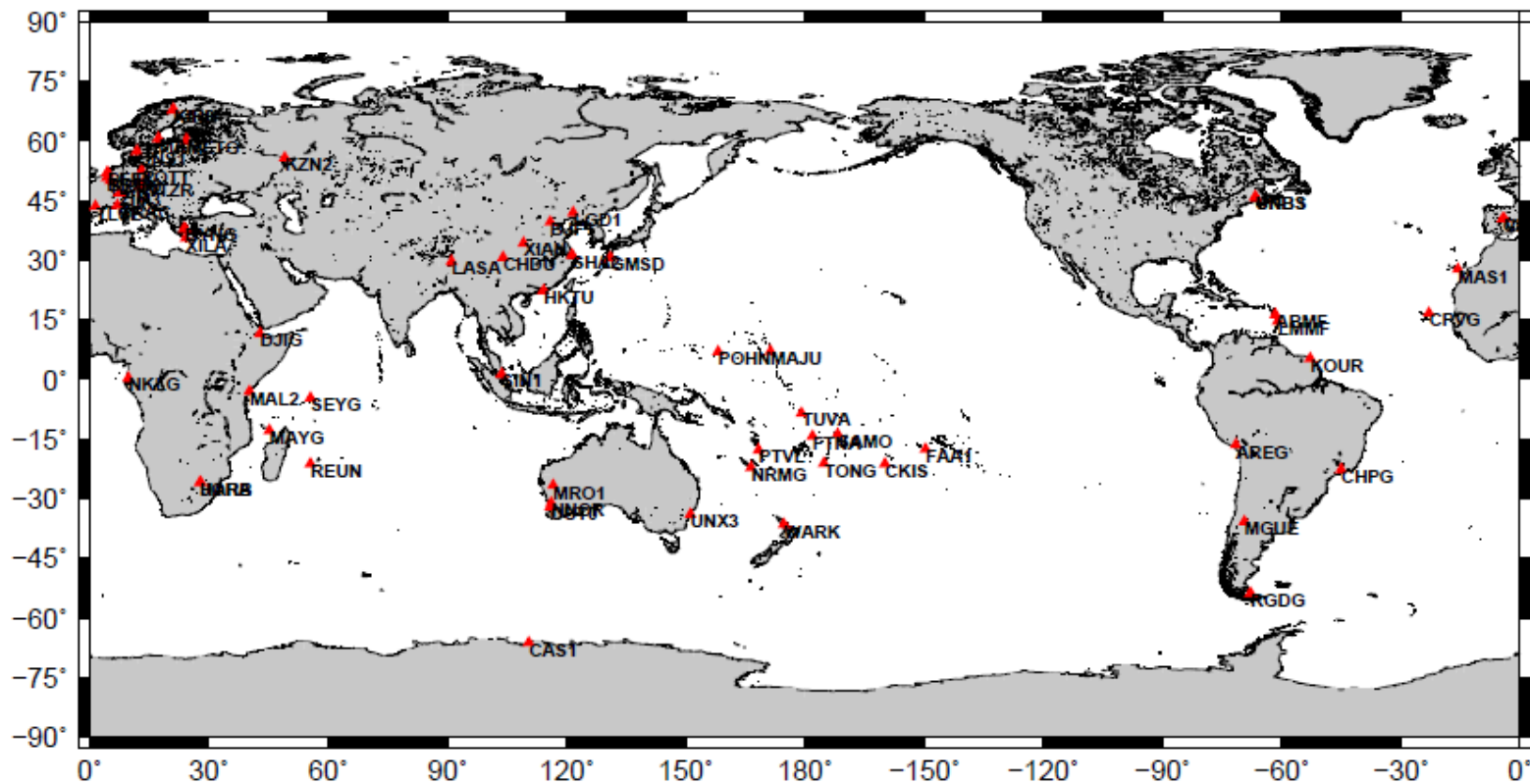
Two step BDS processing strategies





# Processing Strategies and Experimental Setup

- Campaign duration: 7 days, DOY 180-186, 2014
- Data from MGEX and BETS network
  - Total of 63 stations



# Processing Strategies and Experimental Setup

<b>GAMIT-GLOBK Version</b>	<b>10.50</b>
<b>Observation</b>	Compress daily rinex
<b>Sampling interval</b>	30sec
<b>Observation period</b>	24 hours
<b>Cut-off elevation angle</b>	7/10 degrees
<b>Elevation-dependent weighting</b>	Yes
<b>Navigation</b>	BRDC
<b>Precise orbit</b>	WHU
<b>Ocean-Tidal</b>	Yes
<b>Tropo_MFN</b>	GMFH/GMWH
<b>Zenith delay estimation</b>	Yes / 2hr
<b>Zenith Constraints</b>	0.5m
<b>Atomspheric gradients</b>	Yes
<b>Number gradients</b>	2
<b>Met obs source</b>	GPT 50
<b>Radiation Model for ARC</b>	BERNE / BERN2
<b>Reference System for ARC</b>	EGM08
<b>Antenna Model</b>	AZEL
<b>SV antenna model</b>	ELEV

# Processing Strategies and Experimental Setup

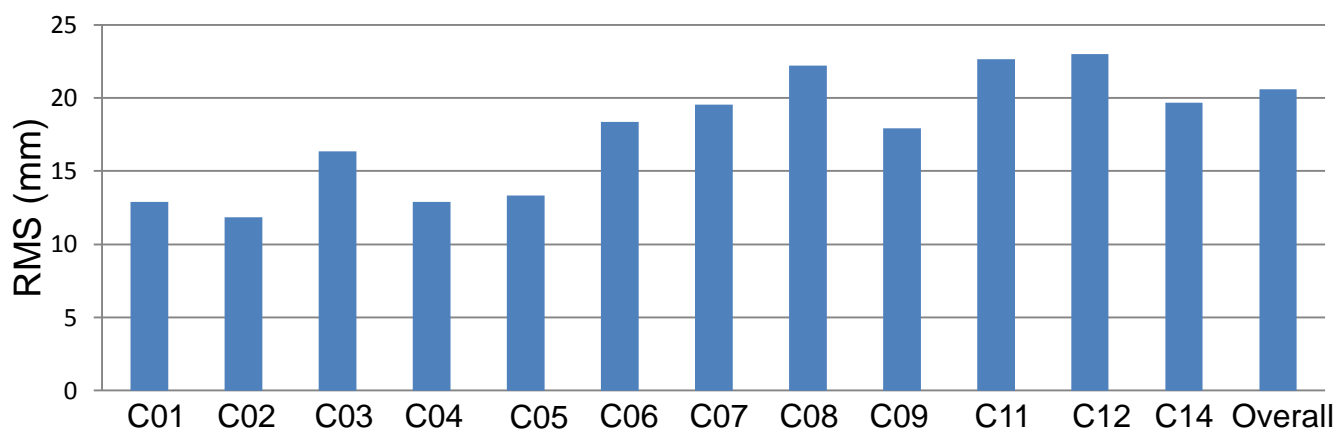
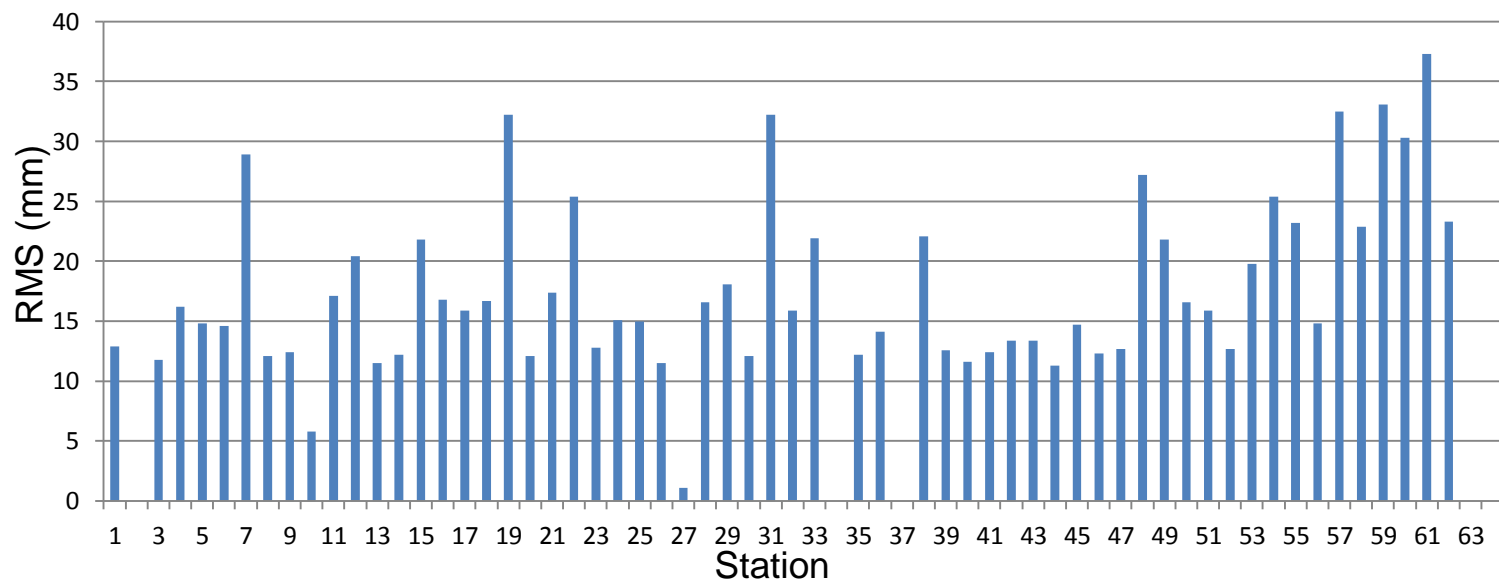
- BDS satellite PCO setting
  - MGEX convention:
    - X-PCO [600mm], Y-PCO [0.0mm], Z-PCO [1100mm]
  - WHU/ESA recent results:
    - Improvements in the MEO satellites is significant in the cross-track direction.
    - No obvious improvement for IGSO satellites

	X-PCO	Y-PCO	Z-PCO				
	[mm]	[mm]	C06	C07	C08	C09	C10
WHU	586.4	0.0	2513.7	2721.9	3440.0	3551.9	4087.0
ESA	549.0	0.0	3049.0	3236.7	3842.6	3973.6	3882.1
	X-PCO	Y-PCO	Z-PCO				
	[mm]	[mm]	C11	C12	C13	C14	Galileo-IOV
WHU	575.0	0.0	1990.7	2249.1	2025.9	2144.3	
	0.0	0.0					1125.0
ESA	549.0	0.0	2069.5	2313.5	2201.8	2311.7	

(Dilssner, 2014, Guo, 2015)

# Processing Strategies and Experimental Setup

– Station phase residual: ~20mm



# Processing Strategies and Experimental Setup

- Receiver clock jumps:
  - Frequent receiver jump doesn't appear to have much effect on the POD. However, data from BETS network and CUT0 seems to be unreliable and unstable from past experience.

DOY 180, 2014

BJF1	67	CHDU	69	CUT0	26
HKTU	78	JOHA	60	LASA	41
LEID	57	LGD1	12	POTT	13
UNBS	1	UNX3	150	XIAN	78

XILA 45

- Cut-off angles:
 

Elevation cut-off angles setting of 7 or 10 degrees have no obvious impacts on BDS POD

# Processing Strategies and Experimental Setup

- Orbit fitting with BERNE (9 parameters) / BERN2 (5 parameters + 1 periodic once per rev sine part in Z-axis direction)

```
Reference T-file: t14180.tmp
External T-files: twhr17990.sp3
Reference T-file span: 28.5 hrs
```

PRN	Total	delta-X	delta-Y	delta-Z	d-Radial	d-Along	d-Cross
1	0.00928	0.01179	0.00827	0.00714	0.01111	0.00914	0.00716
2	0.00604	0.00494	0.00725	0.00572	0.00693	0.00535	0.00573
3	0.01100	0.01126	0.00972	0.01189	0.01069	0.01020	0.01201
4	0.00736	0.00878	0.00666	0.00642	0.00884	0.00660	0.00640
5	0.00844	0.00931	0.00523	0.00999	0.00728	0.00778	0.01001
6	0.00496	0.00448	0.00689	0.00252	0.00354	0.00462	0.00633
7	0.00386	0.00440	0.00434	0.00256	0.00384	0.00454	0.00307
8	0.00737	0.00655	0.00650	0.00881	0.00792	0.00954	0.00300
9	0.00418	0.00462	0.00513	0.00221	0.00304	0.00415	0.00510
11	0.00370	0.00404	0.00312	0.00389	0.00327	0.00322	0.00449
12	0.00457	0.00347	0.00552	0.00449	0.00538	0.00475	0.00333
14	0.00223	0.00194	0.00289	0.00167	0.00200	0.00125	0.00305
MEAN	0.00658	0.00701	0.00626	0.00645	0.00683	0.00649	0.00642

BDS orbit with BERNE SRP model

PRN	Total	delta-X	delta-Y	delta-Z	d-Radial	d-Along	d-Cross
1	0.03948	0.04180	0.03259	0.04321	0.04432	0.02897	0.04328
2	0.09007	0.07522	0.07279	0.11568	0.09071	0.05212	0.11573
3	0.08379	0.08114	0.05192	0.10855	0.08097	0.05019	0.10948
4	0.03763	0.05382	0.02524	0.02672	0.04480	0.03880	0.02710
5	0.05119	0.04280	0.03623	0.06867	0.04791	0.02864	0.06888
6	0.03744	0.03977	0.03520	0.03722	0.04581	0.02888	0.03570
7	0.04551	0.05421	0.04787	0.03136	0.03385	0.02913	0.06495
8	0.12827	0.14644	0.11861	0.11767	0.11794	0.11811	0.14659
9	0.03492	0.03879	0.02588	0.03852	0.03900	0.03583	0.02921
11	0.02871	0.03951	0.01316	0.02717	0.02343	0.01542	0.04105
12	0.02418	0.03550	0.01231	0.01848	0.01426	0.00575	0.03895
14	0.02122	0.02327	0.02027	0.01997	0.02256	0.00829	0.02782
MEAN	0.06037	0.06426	0.05001	0.06560	0.05844	0.04624	0.07334

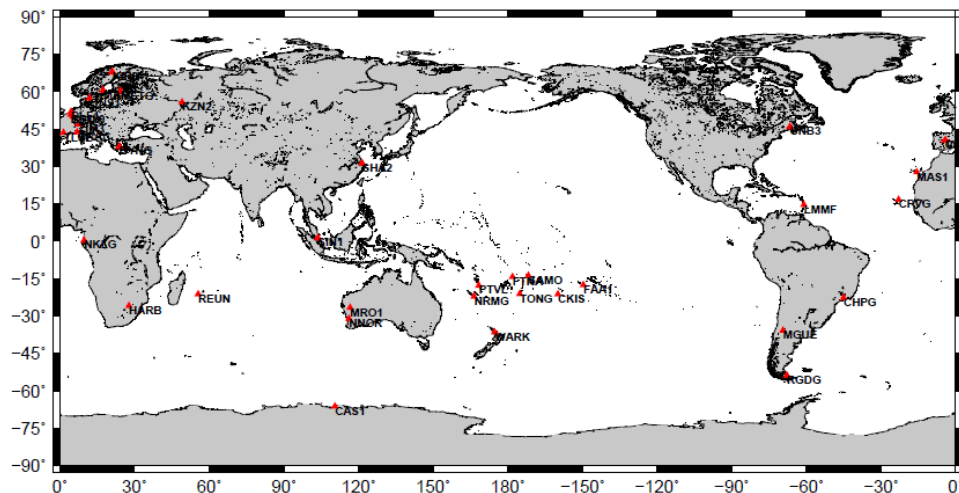
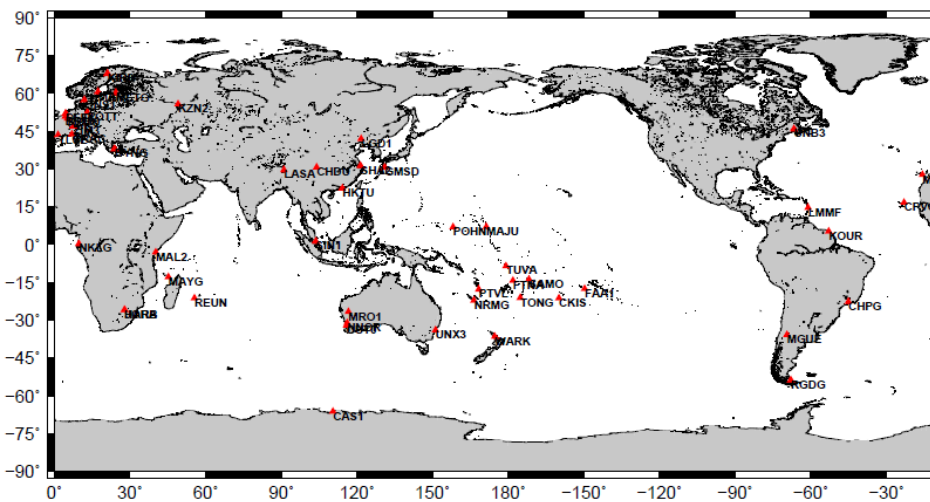
BDS orbit with BERN2 SRP model

GPS orbit with igs17990.sp3; BDS orbit with whr17990.sp3

	BERNE				BERN2			
	Total	Radial	Along	Cross	Total	Radial	Along	Cross
GPS	0.0043	0.0040	0.0042	0.0040	0.0198	0.0187	0.0184	0.0093
BDS	0.0066	0.0068	0.0065	0.0064	0.0604	0.0584	0.0462	0.0733

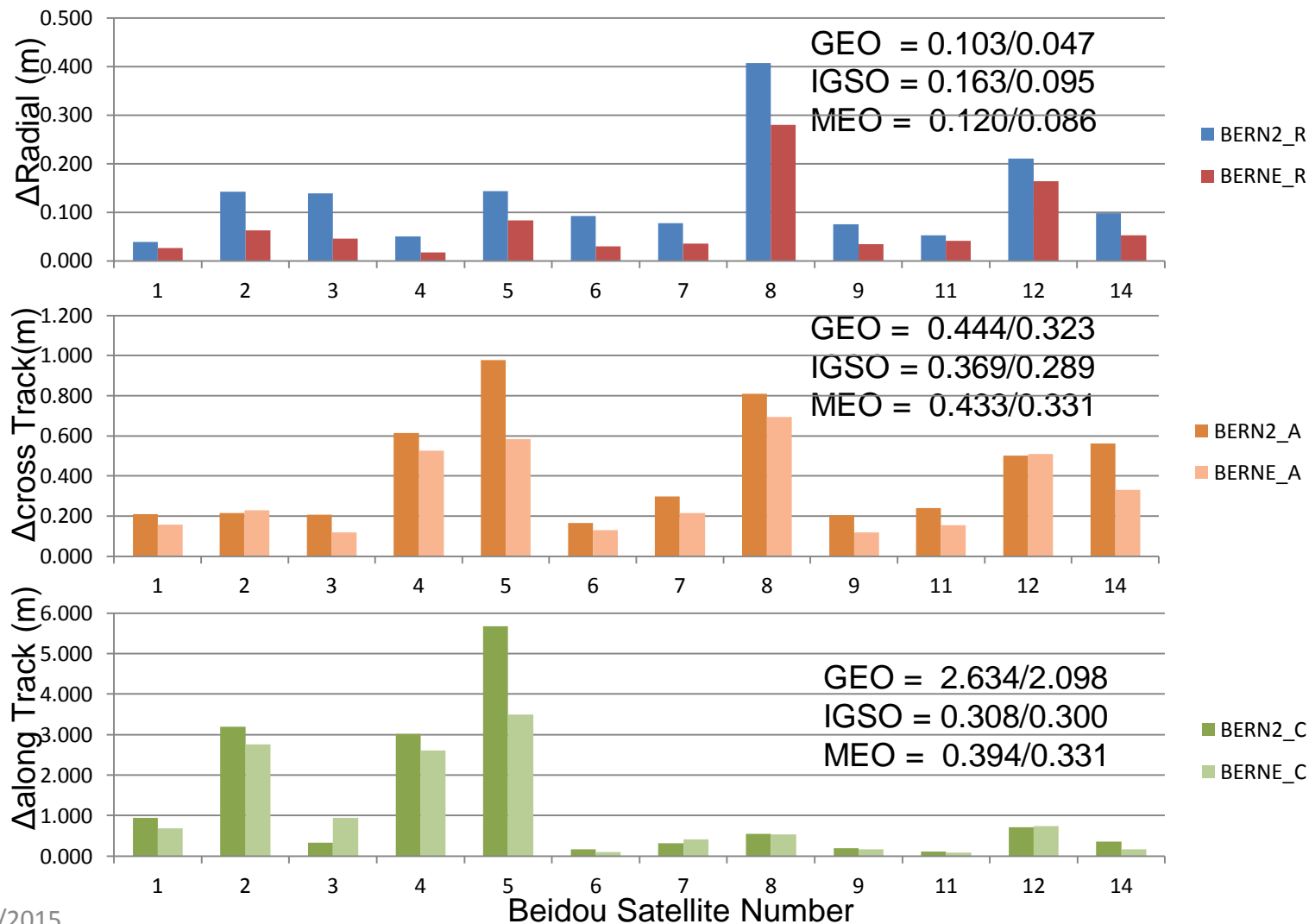
# Processing Strategies and Experimental Setup

- Three network configurations:
  1. All of the available MGEX and BETS stations (63)
  2. Evenly distributed MGEX and BETS stations, some of European and South Pacific stations are removed (54)
  3. Compacted MGEX and BETS stations from configuration 2, removing stations with frequent receiver clock jump and high phase residuals (34)



# Preliminary BDS POD Solutions

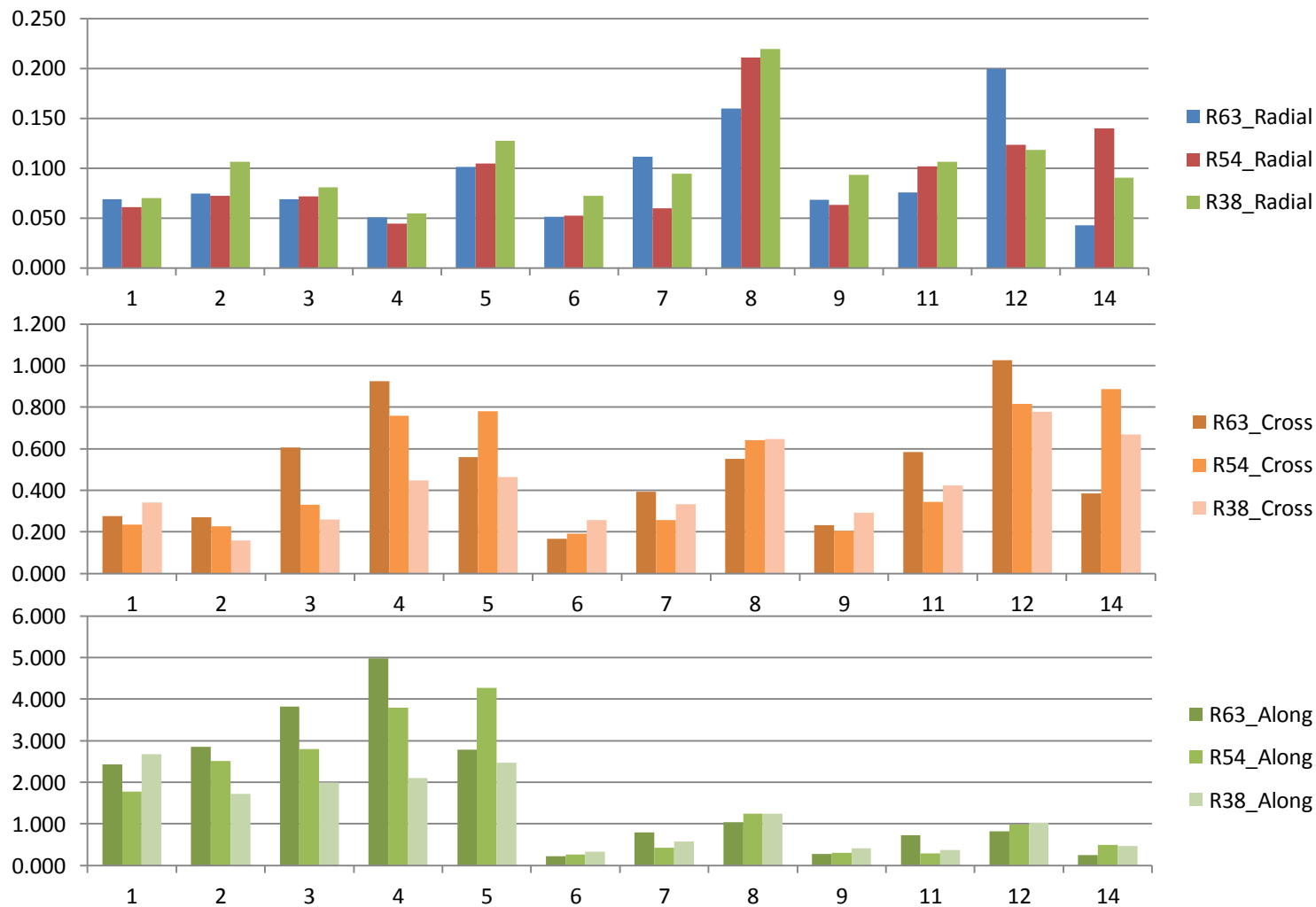
## — BERNE2 vs BERNE SRP model





# Preliminary BDS POD Solutions

– Network 63/54/38 station configurations



## Conclusion and Future Works

- BDS POD processing is achieved through the modification of GAMIT software platform.
- Processing strategies refinement with different SRP models, BDS satellite PCO, cut-off angles, receiver clock jumps and different network configurations.
- With BDS data from 54 MGEX and BETS stations, the platform can constantly deliver BDS precise orbit solution with decimetre radial orbit accuracy.

# Conclusion and Future Works

- Future works
  - Evaluate positioning performance with the derived BDS orbit
  - Further investigate BERN2 in GAMIT and explore the mix use of different SRP models for different BDS satellite type
  - Investigation to refine SRP model/processing strategies during yaw manoeuvres
  - Joint Multi-GNSS POD processing
  - Extend to other GNSS constellations

# Questions?