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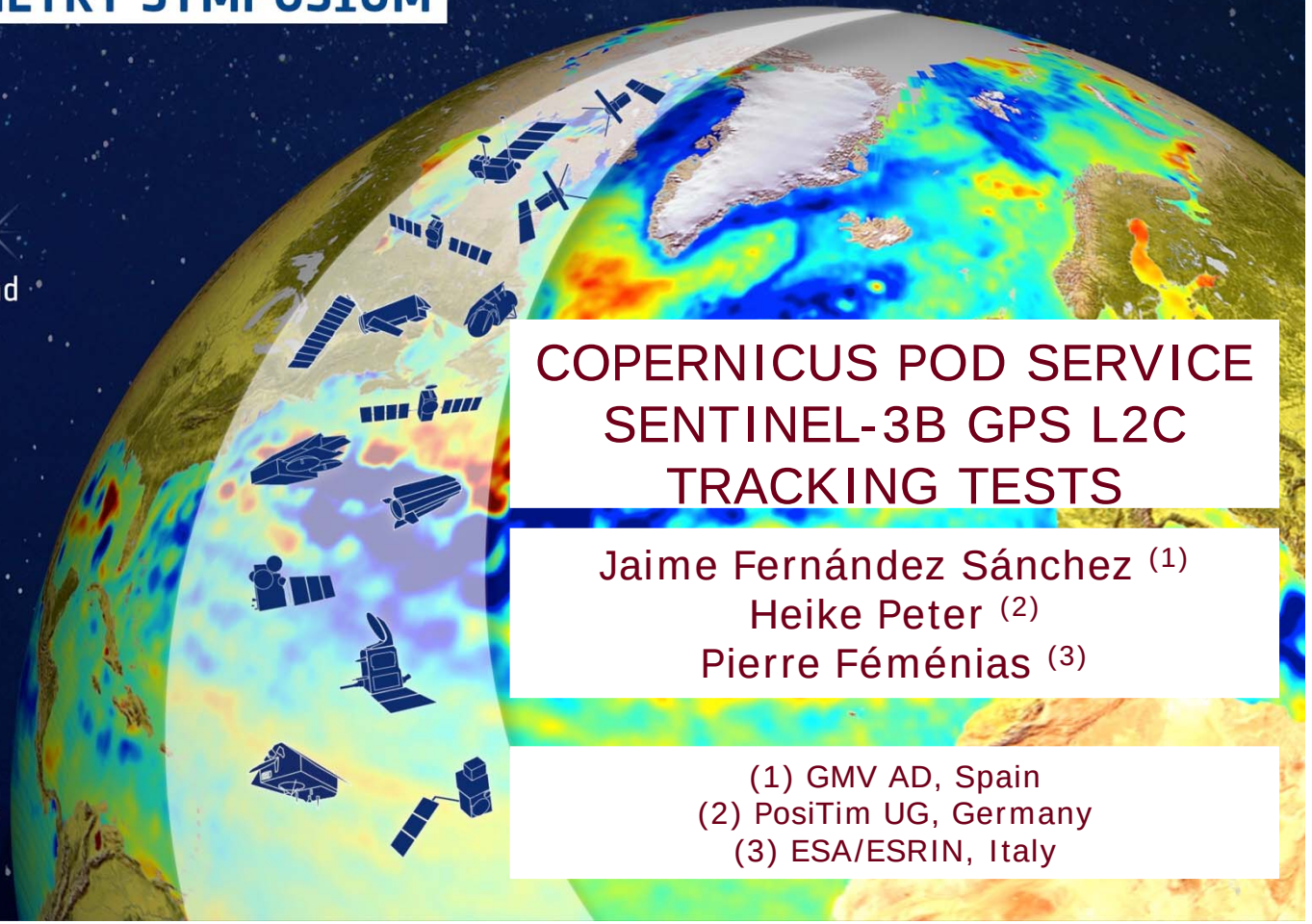
CENTRE NATIONAL D'ÉTUDES SPATIALES

esa
European Space Agency

→ 25 YEARS OF PROGRESS
IN RADAR ALTIMETRY SYMPOSIUM

OSTST MEETING

24–29 September 2018
Ponta Delgada, São Miguel Island
Azores Archipelago, Portugal



COPERNICUS POD SERVICE SENTINEL-3B GPS L2C TRACKING TESTS

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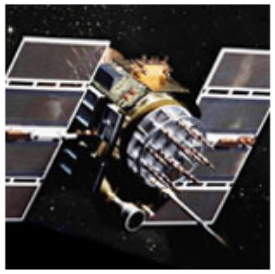
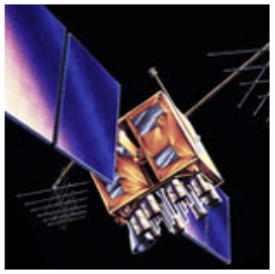
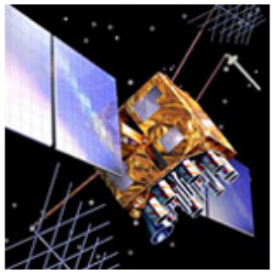
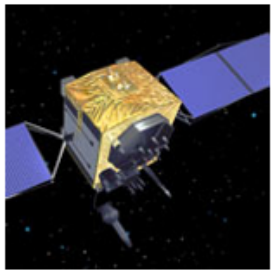
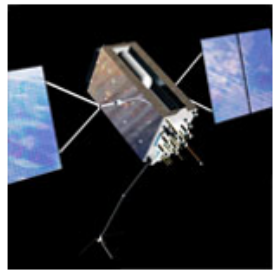
GPS CONSTELLATION STATUS

Legacy Satellites		Modernized Satellites		
				
Block IIA	**Block IIR**	**Block IIR(M)**	**Block IIF**	**GPS III**
0 operational	12 operational	7 operational	12 operational	In production
- Coarse Acquisition (C/A) code on L1 frequency for civil users - Precise P(Y) code on L1 & L2 frequencies for military users	- C/A code on L1 - P(Y) code on L1 & L2	- All legacy signals - 2nd civil signal on L2 (**L2C**)	- All Block IIR(M) signals - 3rd civil signal on L5 frequency (**L5**)	- All Block IIF signals - 4th civil signal on L1 (**L1C**)
- Launched in 1990-1997	- Launched in 1997-2004	- Launched in 2005-2009	- Launched in 2010-2016	- Launch starting in 2018

	IIR	IIRM	IIF	III	Total
C/A	12	7	12	0	31
P(Y)	12	7	12	0	31
L2C	0	7	12	0	19
L5	0	0	12	0	12
L1C	0	0	0	0	0

Launch	Block	SVN
2018	IIIA	74
2019	IIIA	75
2019	IIIA	76
2020	IIIA	77
2020	IIIA	78

Launch	Block	SVN
2021	IIIA	79
2021	IIIA	80
2022	IIIA	81
2022	IIIA	82
2023	IIIA	83

GPS CONSTELLATION STATUS

(source: https://www.gps.gov/technical/codeless)

- It is expected that 24 operational satellites broadcasting L2C will be available by 2020
- The USG commits to maintaining the existing GPS L1 C/A, L1 P(Y), L2C, and L2 P(Y) signal characteristics that enable codeless and semi-codeless GPS access until at least **two years after there are 24 operational satellites broadcasting L5**. … Twenty-four satellites broadcasting the L5 signal is estimated to occur in **2024**.

	IIR	IIRM	IIF	III	Total
C/A	12	7	12	0	31
P(Y)	12	7	12	0	31
L2C	0	7	12	0	19
L5	0	0	12	0	12
L1C	0	0	0	0	0

Launch	Block	SVN
2018	IIIA	74
2019	IIIA	75
2019	IIIA	76
2020	IIIA	77
2020	IIIA	78

Launch	Block	SVN
2021	IIIA	79
2021	IIIA	80
2022	IIIA	81
2022	IIIA	82
2023	IIIA	83

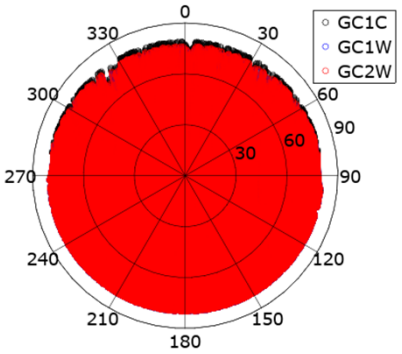
S-3B REDUNDANT GNSS RECEIVER EXPERIMENT

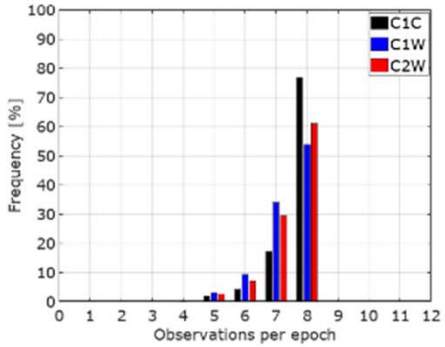
- During the S-3B Commissioning Phase, its redundant GNSS receiver was switched on twice as an experiment:
  - From 07/06/2018 at 14:14 UTC until 15/06/2018 at 14:05 UTC
  - **From 03/09/2018 at 11:14 UTC until 18/09/2018 at 13:04 UTC**

- This presentation is focused on the second period, where the redundant receiver tracked only C/A – L2C codes.
- The impact of the redundant GNSS receiver data in the orbital accuracy and estimated parameters computed during this period will be assessed.
- For that purpose, two configurations have been used:
  - **NOM:** using only the nominal GNSS receiver data (tracking P1 + P2)
  - **RED:** using only the redundant GNSS receiver data (tracking C/A – L2C codes) and applying the Differential Code Biases (DCBs).

S-3B GNSS SENSOR PERFORMANCE (I): TRACKING ANALYSIS

Nominal receiver (NOM)





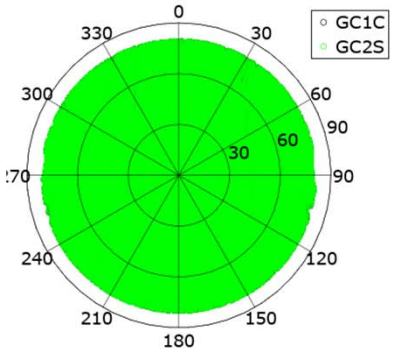
An elevation cut off angle of about 10° was selected.

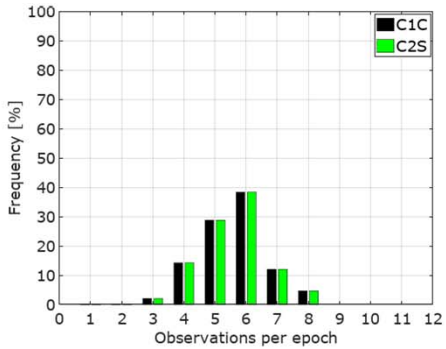
C1C (**L1 C/A**) observations are available slightly before than **C1W** (**L1 P(Y)**) and **C2W** (**L2 P(Y)**) ⟶ higher number of C1C observations.

8 satellites are tracked on all signals > **50%** of the time

For C1C, 8 satellites are tracked > **75 %** of the time

Redundant receiver (RED)





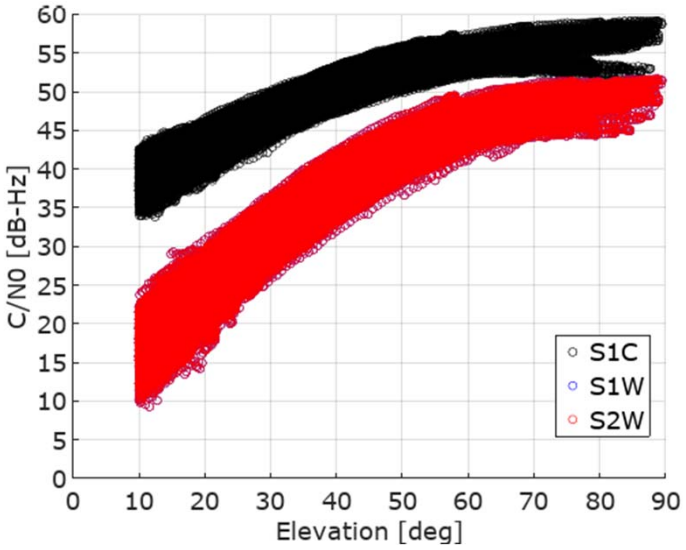
An elevation cut off angle of about 10° was selected.

C1C (**L1 C/A**) observations are available at the same time than **C2S** (**L2C**).

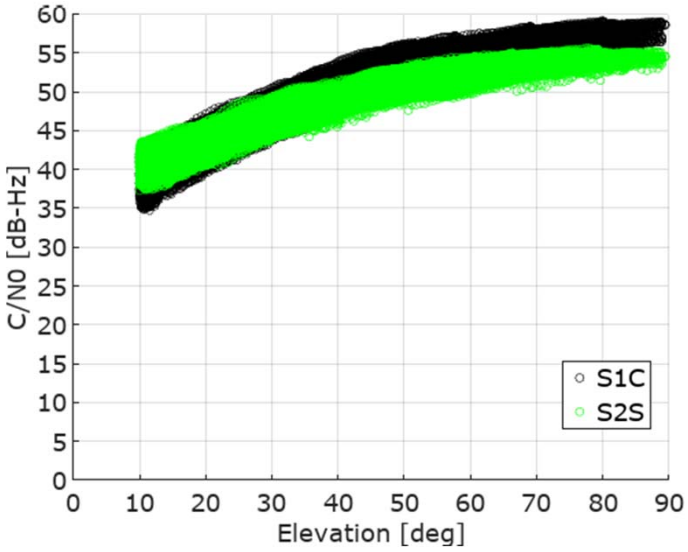
6 satellites are tracked on all signals ~ **40%** of the time

S-3B GNSS SENSOR PERFORMANCE (II): SIGNAL STRENGTH ANALYSIS

Nominal receiver (NOM)



Redundant receiver (RED)

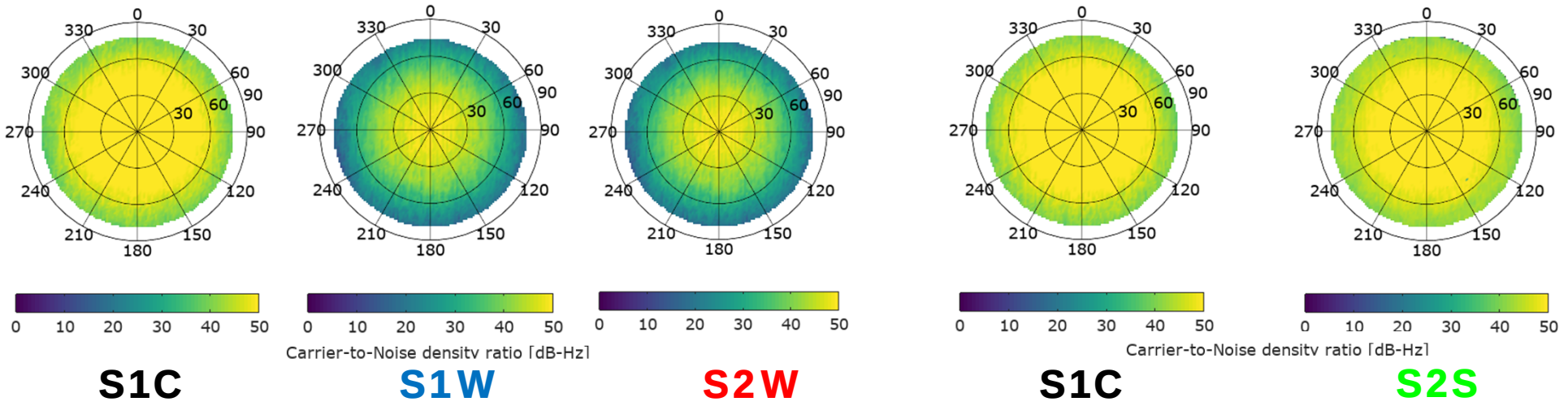


- In primary antenna, **S1C** C/N_0 is ~55 dB-Hz near zenith and ~40 dB-Hz near cut-off angle. **S2W** (and **S1W**) C/N_0 is ~47 dB-Hz near zenith and ~17 dB-Hz near cut-off angle, showing faster losses (explained by squaring losses of P(Y)-C/A).
- In redundant antenna, **S2S** C/N_0 is ~53 dB-Hz near zenith and ~40 dB-Hz near cut-off angle. The measured losses are in good agreement with expectations.

S-3B GNSS SENSOR PERFORMANCE (III): SIGNAL STRENGTH ANALYSIS

Nominal receiver (NOM)

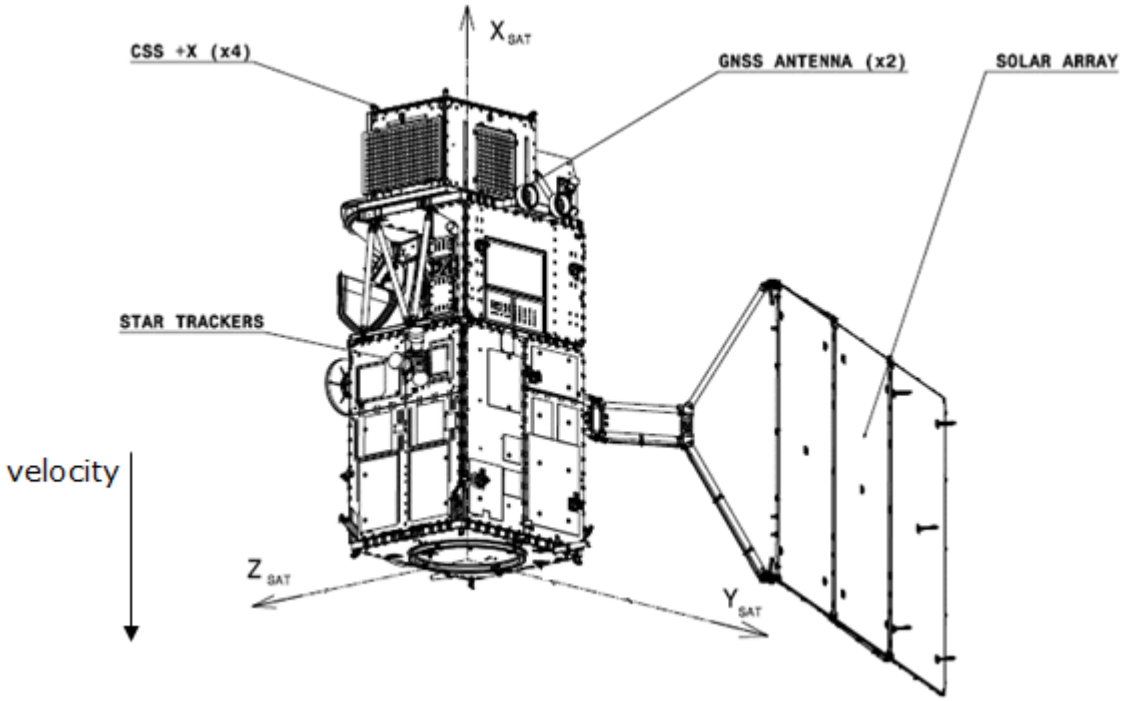
Redundant receiver (RED)

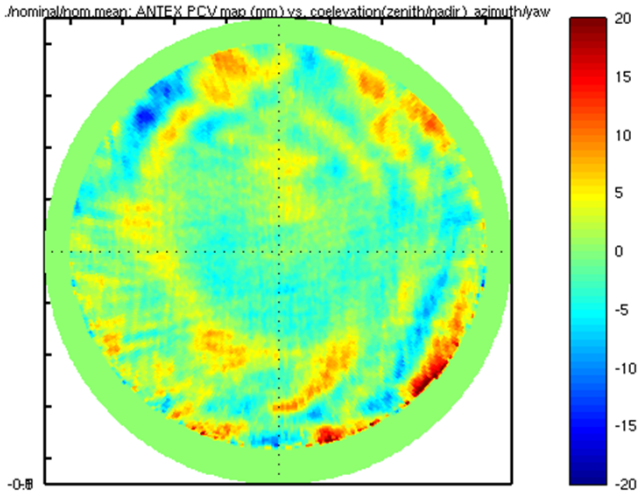


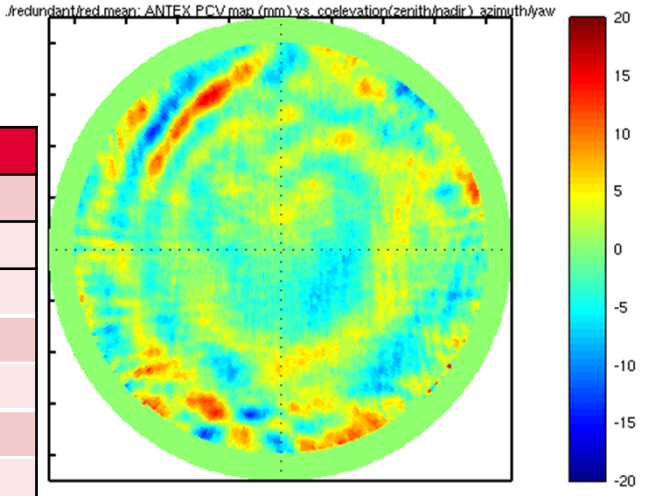
S1C **S1W** **S2W** **S1C** **S2S**

- Analysing the primary & redundant antenna C/N_0 in a polar plot, they show a high level of rotational symmetry with minor distortions at low elevations.

S-3B CONFIGURATION FOR POD

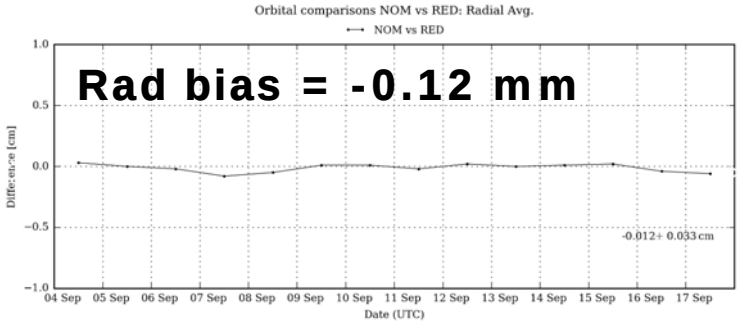


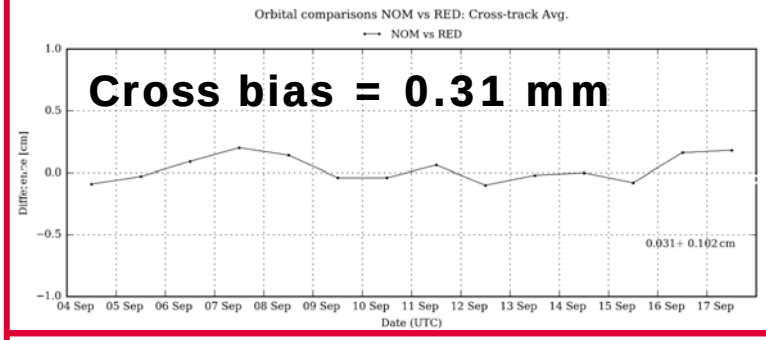


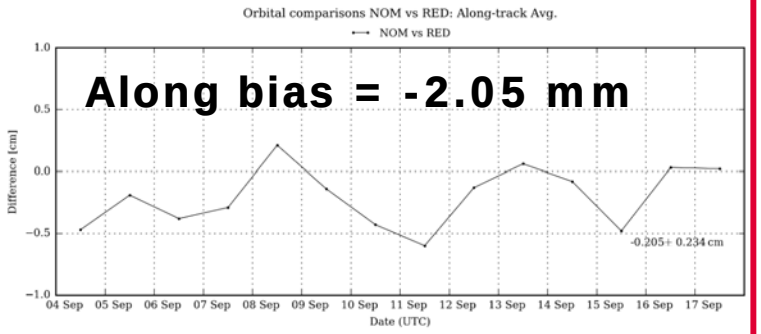


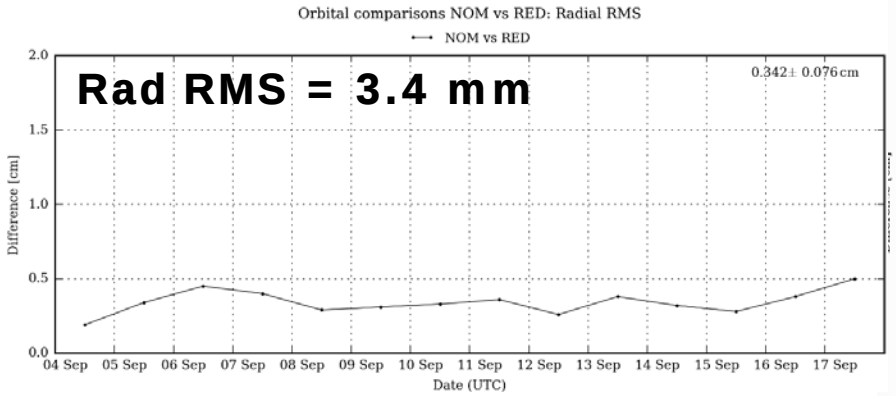
Parameter	Elements	Nominal Configuration
Software used		NAPEOS
Arc length		32 hours
Surfaces forces and empiricals	Radiation Pressure model	box-wing model with re-radiation
	Earth radiation	albedo and infra-red applied
	Radiation pressure coefficient	1 per arc
	Atmospheric density model	msise90
	Drag coefficients	10 per day
	1/rev empirical	2 sets per day (along/cross-track directions, sine/cosine)

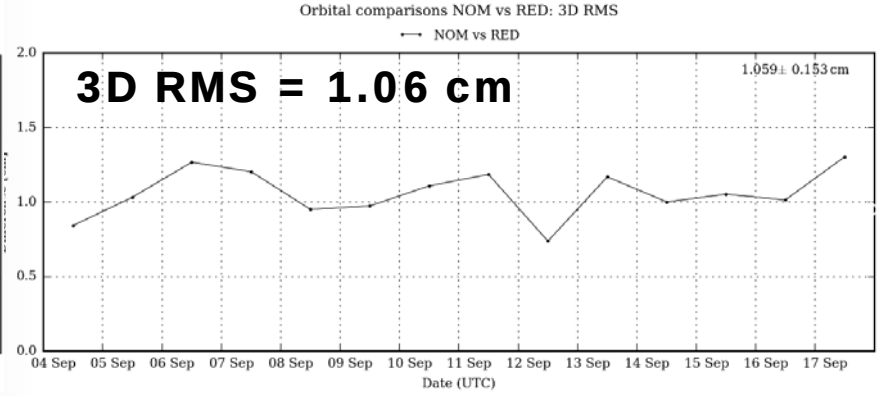
S-3B ORBITAL ACCURACY (NOM vs RED)



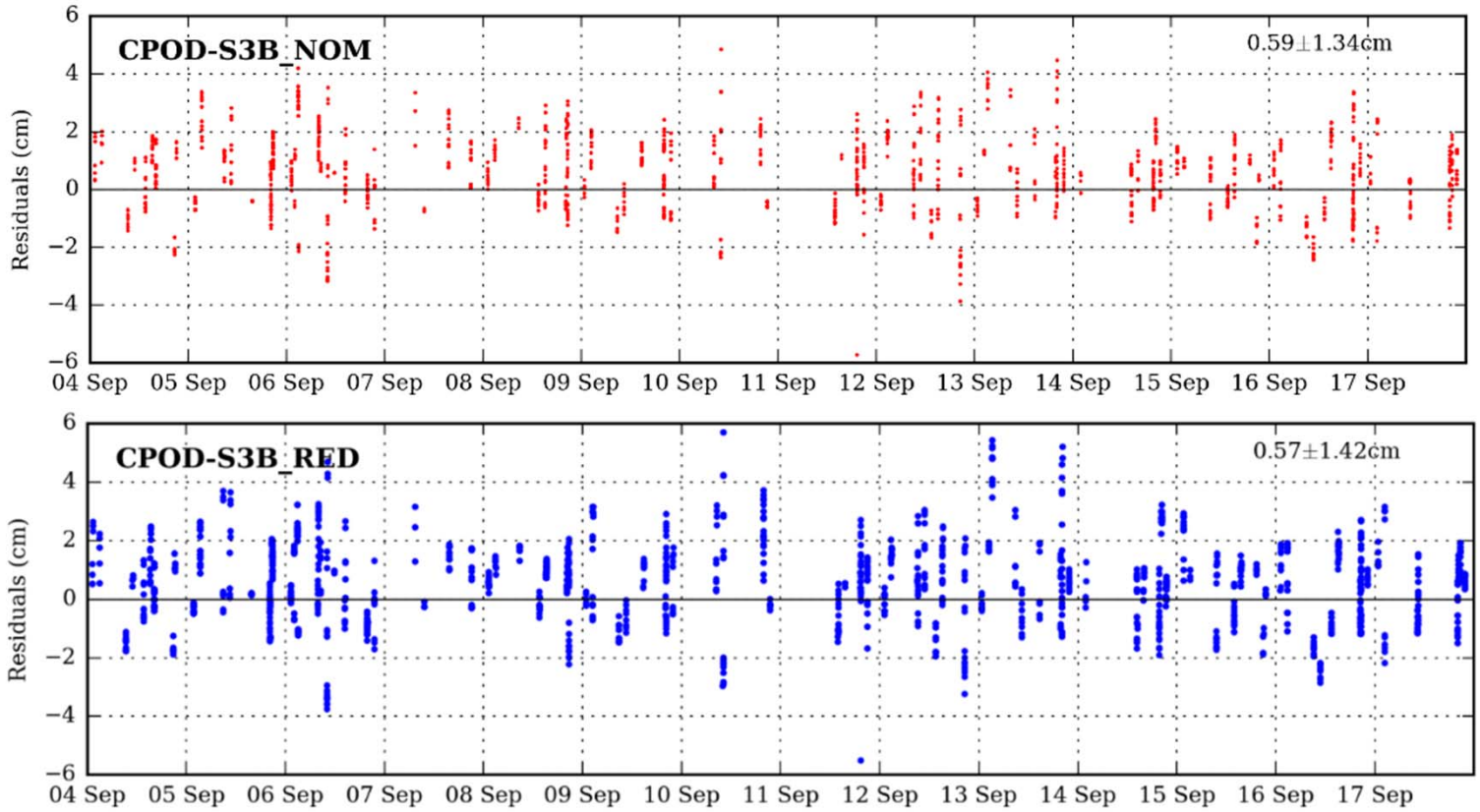






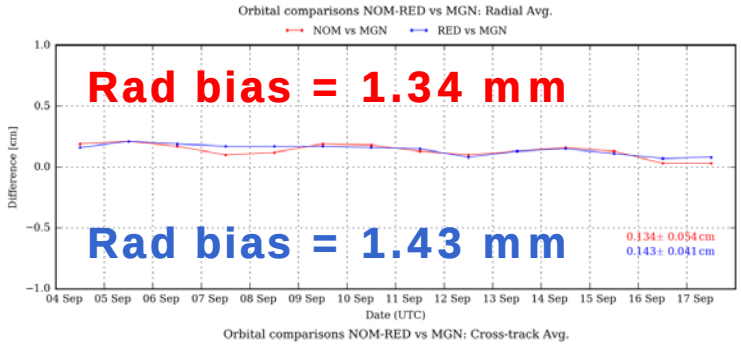


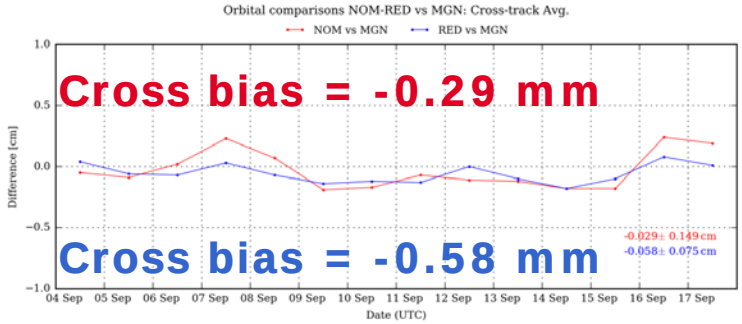
S-3B SLR RESIDUALS

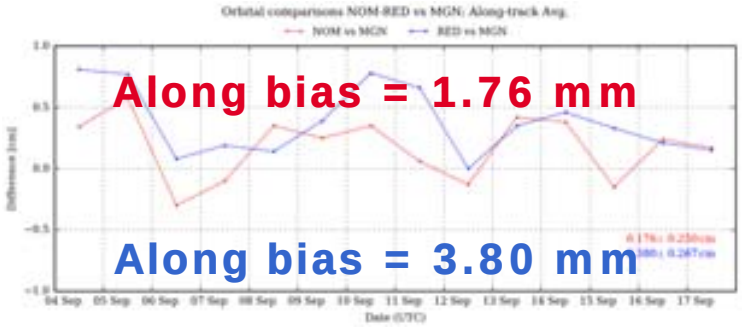


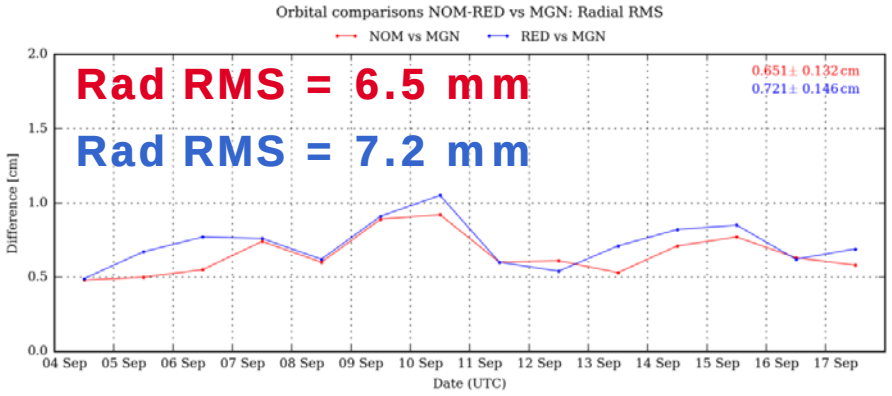
- **NOM: 0.59±1.34cm : Higher mean, lower dispersion**
- **RED: 0.57±1.42cm : Lower mean, higher dispersion**
- Similar performance

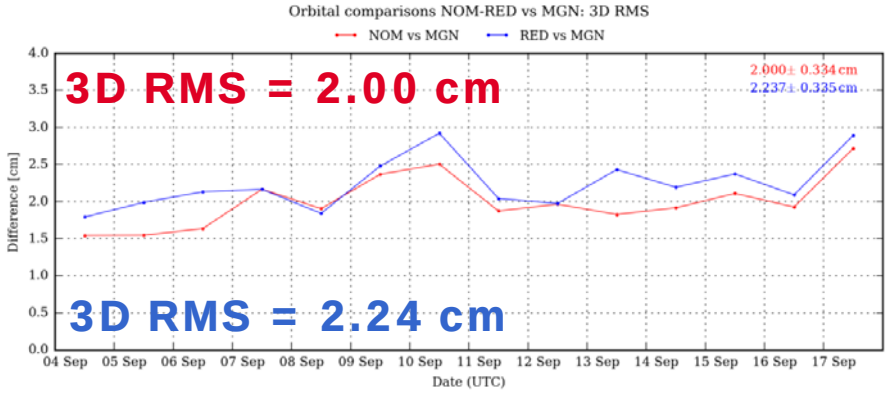
S-3B ORBITAL ACCURACY (vs CNES)



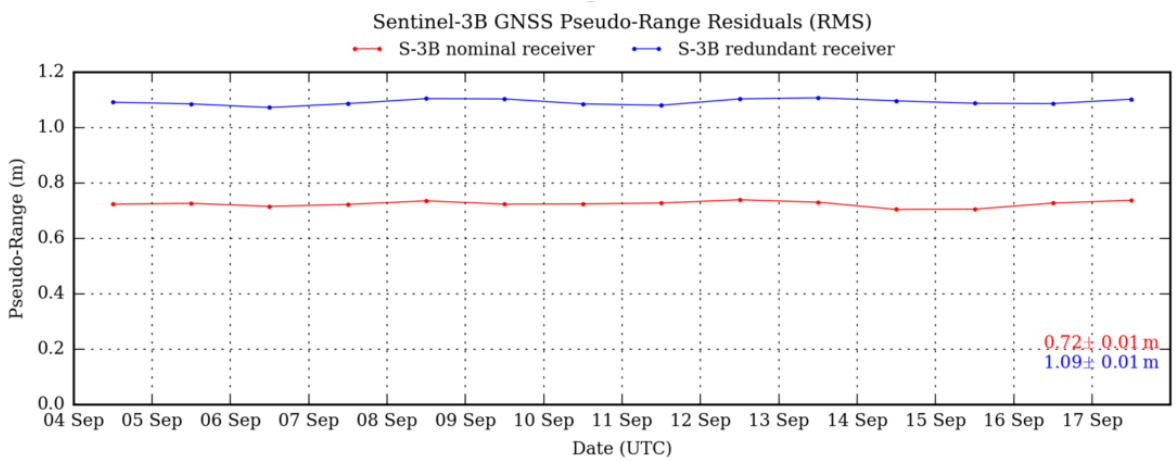








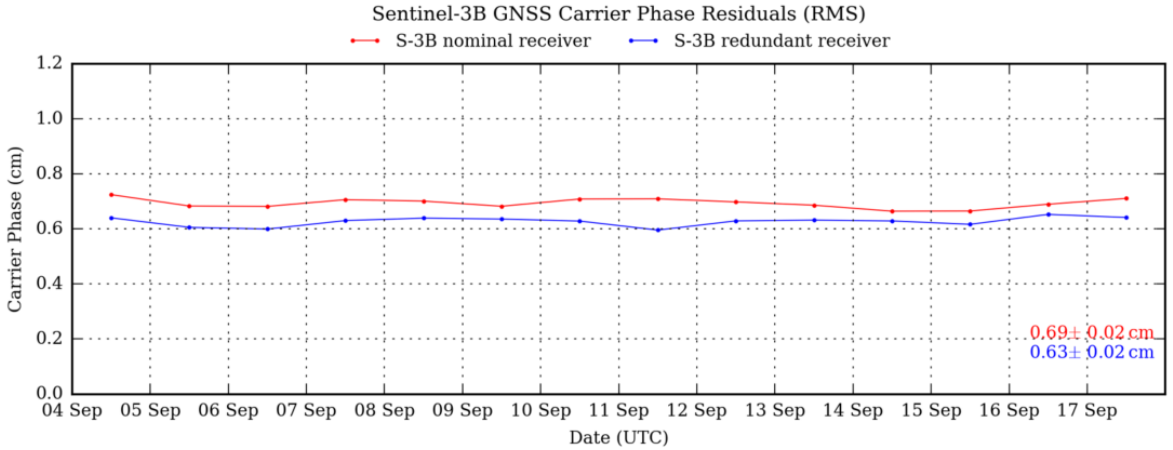
S-3B GNSS RESIDUALS



Pseudorange

NOM: 0.72±0.01 m

RED: 1.09±0.01 m



Carrier Phase

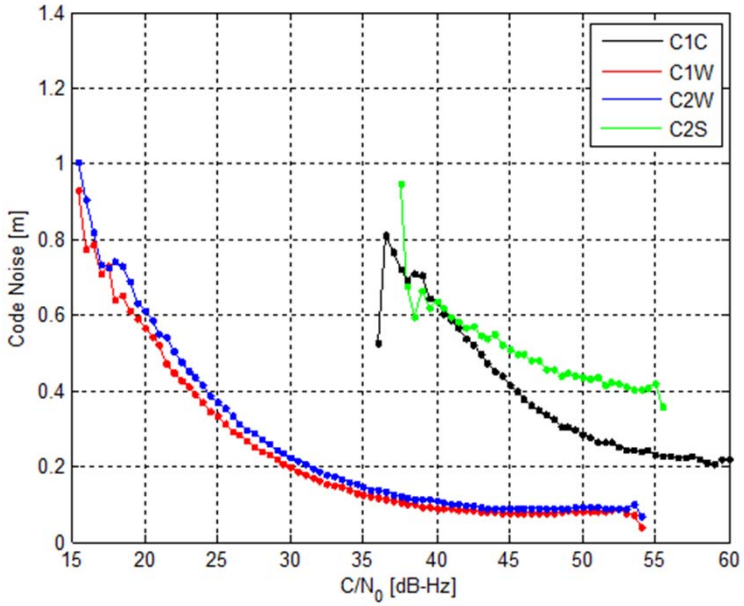
NOM: 0.69±0.02 cm

RED: 0.63±0.02 cm

Higher pseudo-range residuals, but lower carrier-phase residuals

GPS SIGNALS

	C/A	P1	P2	L2C	L5	L1C
Centre Frequency	1575.42 MHz	1575.42 MHz	1227.60 MHz	1227.60 MHz	1176.45 MHz	1575.42 MHz
Modulation	BPSK(1)	BPSK(10)	BPSK(10)	BPSK(1)	BPSK(10)	TMBOC(6,1,1/11)
Code Frequency	1.023 MHz	10.23 MHz	10.23 MHz	511.5 kHz	10.23 MHz	1.023 MHz
Components	Data	Data	Data	Data + Pilot	Data + Pilot	Data + Pilot
Chip length	293.05 m	29.31 m	29.31 m	586.10 m	293.05 m	293.05 m



$$\sigma = L_c \cdot \sqrt{\frac{B_L \cdot d}{2} \cdot \frac{1}{10^{CNo/10}} \cdot \left(1 + \frac{2}{T \cdot CNo}\right)}$$

- L_C: Chip length
- B_L: Code loop bandwidth (~ 1 Hz)
- d: Correlation spacing (0.1 – 1 chip)
- CN_0: Carrier to noise
- T: Coherent Integration time (~20 ms)

FUTURE

- L2C will be no required until, at least, 2024.

- SENTINEL-1,2,3 C/D, SENTINEL-6 : They have a new RUAG receiver capable of tracking GPS (C/A, P(Y), L2C, L5) and GALILEO (E1, E5a):
  - More data will be available (up to 18 channels)
  - Need to handle inter-system biases
  - Need to have a reliable source of accurate GPS+GALILEO orbits

- Options:
  - GPS: P(Y), C/A + L2C, C/A + L5
  - GAL: E1, E5a