Three Decades of Altimetry Orbits: Consistent DORIS-Based Orbit Series and Validation

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1 Introduction

Motivation:

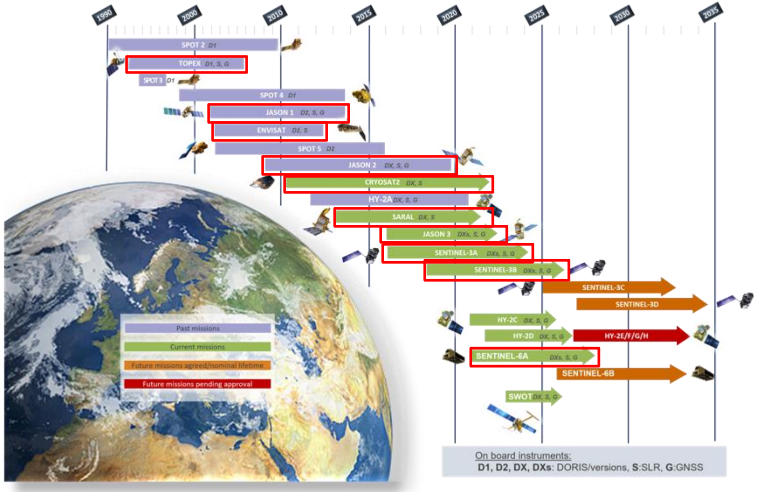
- DORIS-based orbits generated at the GFZ IDS AAC showed geographic patterns in comparison to reduced dynamic GPS-based orbits

What was done:

1. Investigation on the cause of the geographic patterns
2. Test of new processing set up

Aim:

- Generate an improved consistently processed DORIS-based time series for altimetry satellites



- CryoSat-2
- ENVISAT
- Jason-1
- Jason-2
- Jason-3
- SARAL
- Sentinel-3A
- Sentinel-3B
- Sentinel-6A (MF)
- TOPEX/Poseidon

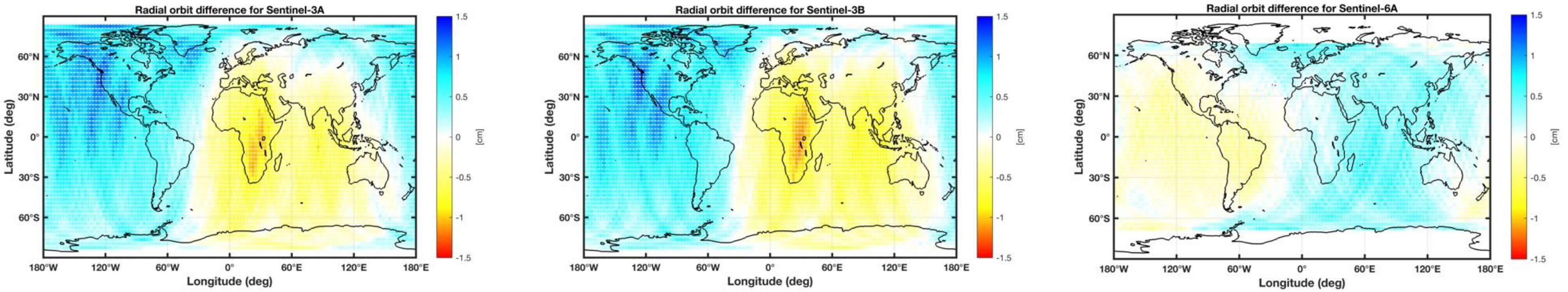
Time Span:

- 1993-2023

2 Processing Strategy

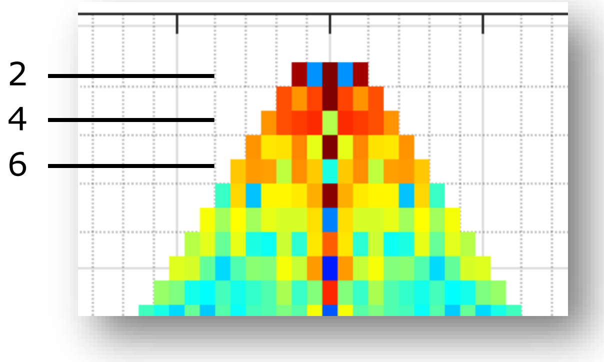
- Regional geographic patterns were discovered in DORIS-based orbits in comparison to internally processed reduced dynamic GPS-based orbits
    - DORIS and GPS processing is fully consistent in terms of background models etc.
    - But: Different dynamic parameterization

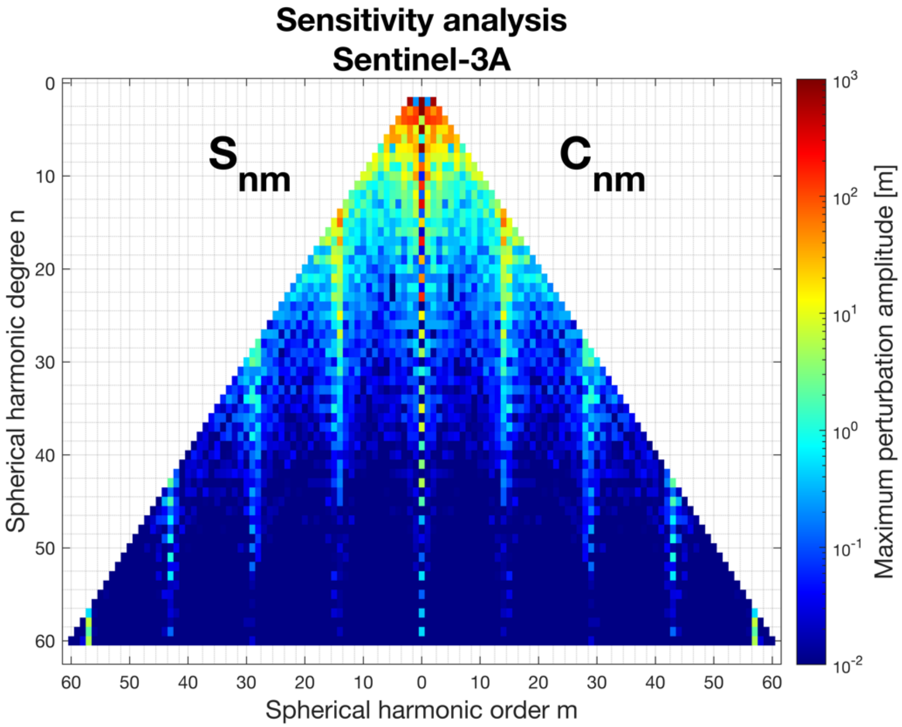
➢ Optimize the processing for DORIS-based orbits to reduce geographic patterns



2.1 Influence of Gravity Field (1)

- Analytical Earth gravity field sensitivity analysis
- Highest sensitivity in degree 2, 3 and 4
- Correlations between odd zonal coefficients

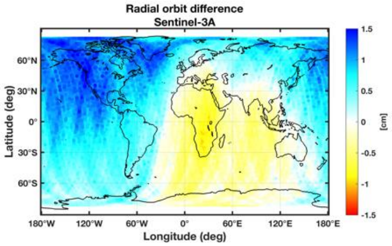




2.1 Influence of Gravity Field (2)

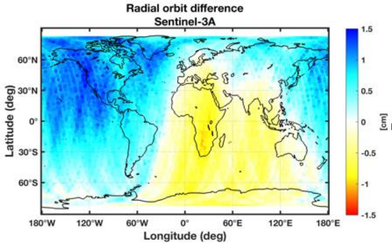
- Co-estimating the SH coefficients shows the highest improvement in low-degrees (deg. 3)

RMS = 0.57 cm



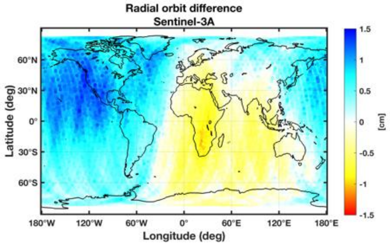
GOCO-06s

RMS = 0.58 cm



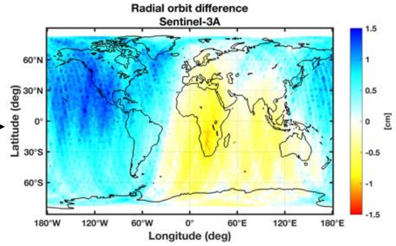
$+C_{2,0}$

RMS = 0.54 cm



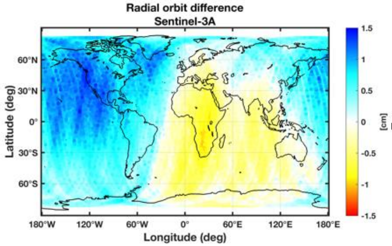
$+C_{3,0}$

RMS = 0.54 cm



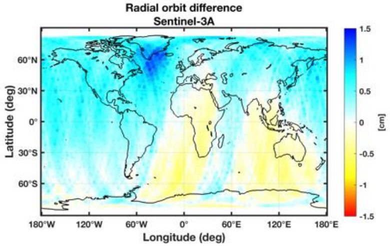
$+C/S_{2,2}$ $(IERS\ Meanpole\ used)$

RMS = 0.55 cm



$+C_{5,0}$

RMS = 0.35 cm

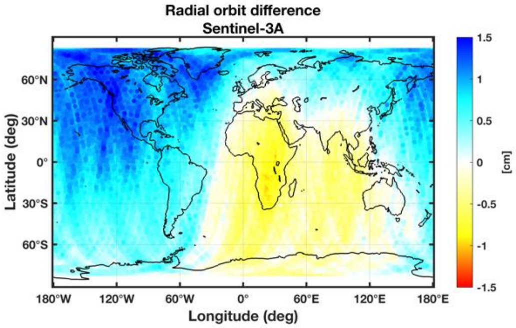


+ all degree 3 and $C_{7,0}$

2.1 Influence of Gravity Field (3)

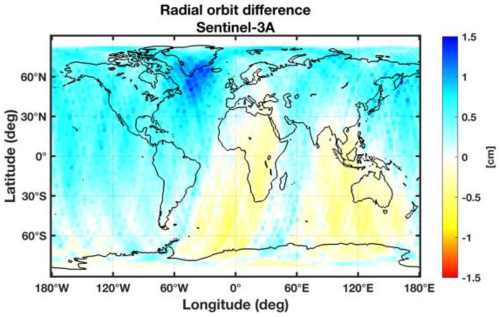
- Co-estimating low-degrees helps to reduce geographic patterns in the orbit
- Adapted gravity field needed
  - Static part of GOCO-06s + new time variable information from EIGEN-GRGS-RL04 and COST-G

RMS = 0.59 cm



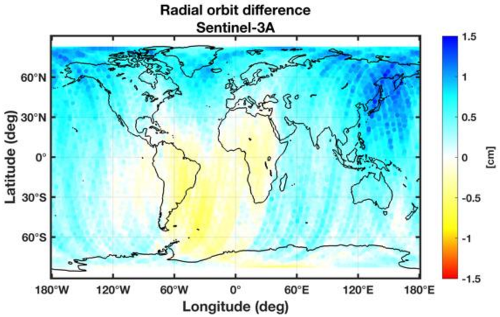
GOCO-06s

RMS = 0.35 cm



GOCO-06s
+ low degrees estimated

RMS = 0.39 cm



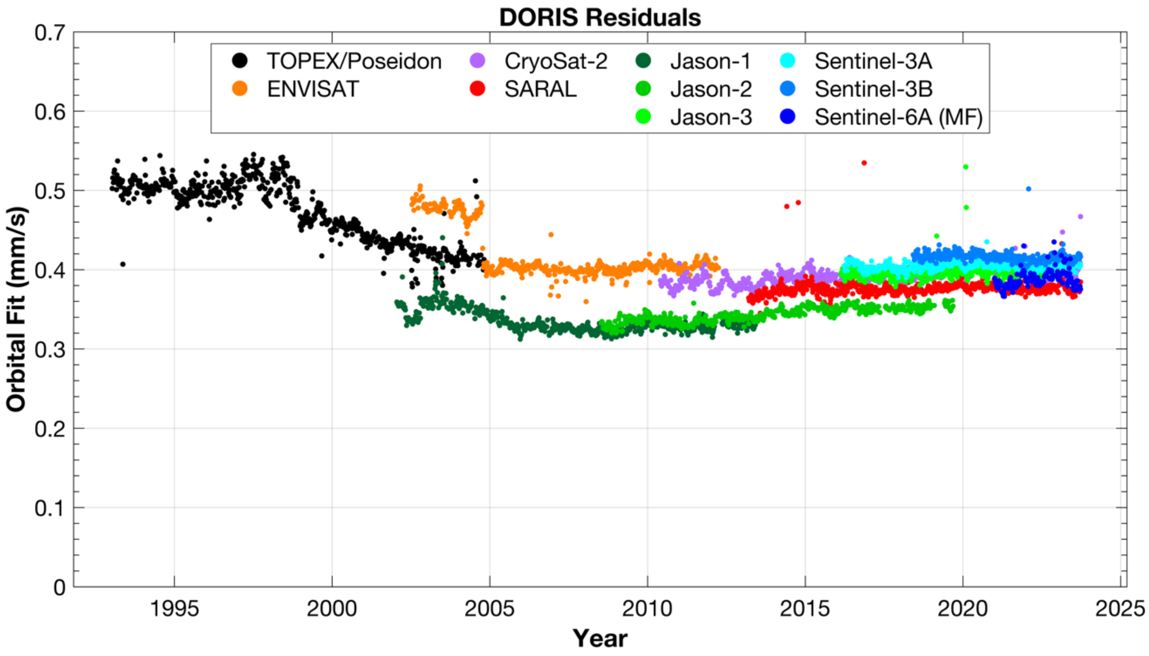
GOCO-06s (only static)
+ new time variable information

3 Internal Orbit Validation (1)

Internal Orbit Validation

- Optimized processing used for all satellites
- Analysis of DORIS and SLR residuals
- Analysis of estimated parameters

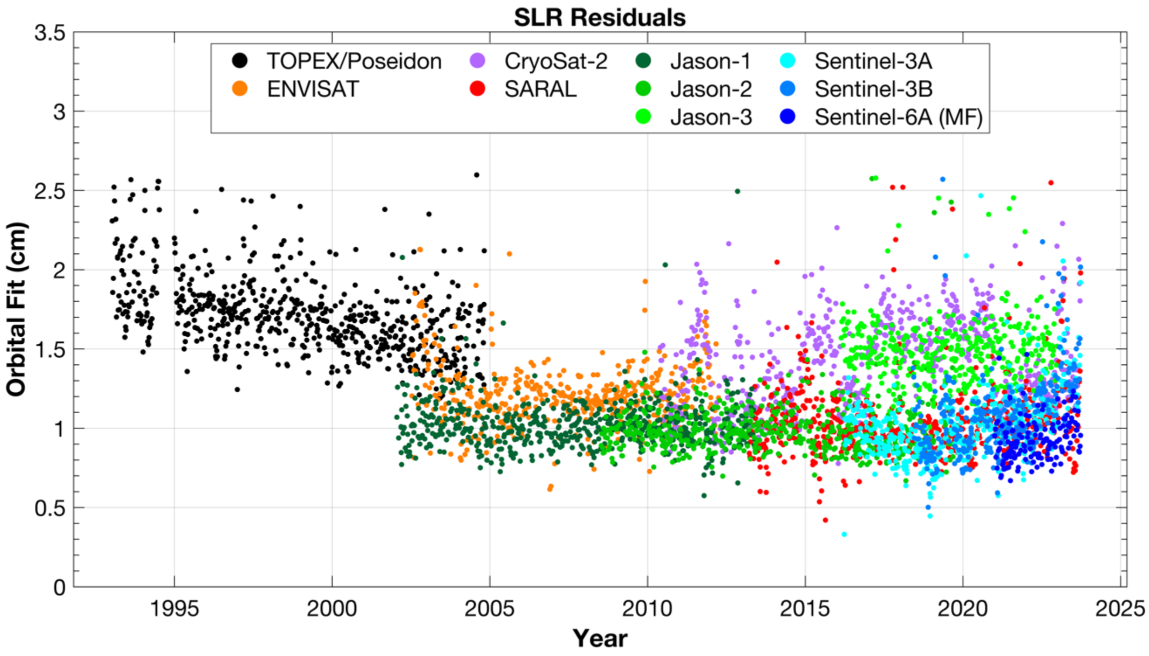
- Global mean DORIS RMS is approximately 0.4 mm/s and below
- **Jason-1** and **Jason-2** perform better



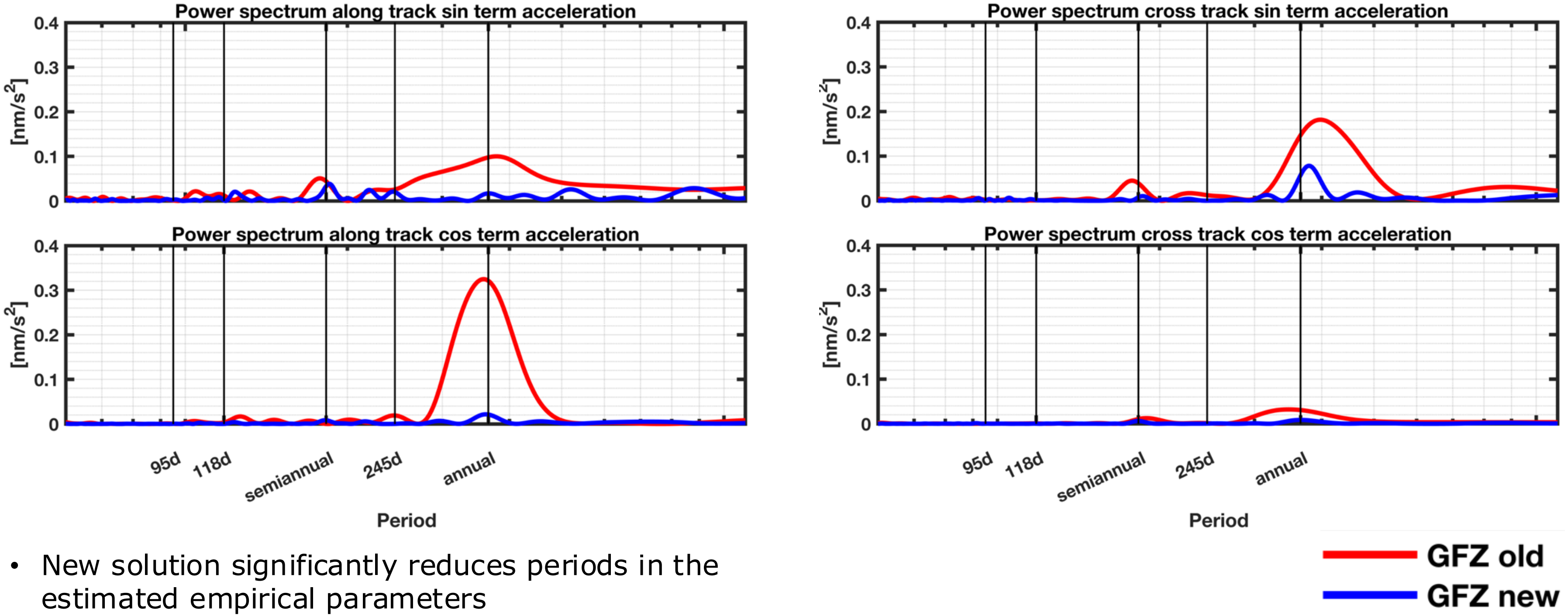
3 Internal Orbit Validation (2)

SLR is used down-weighted for validation

- Global RMS for most of the missions close to 1 cm
- **TOPEX/Poseidon** shows slightly larger RMS
- **CryoSat-2** and **Jason-3** show slightly increased values



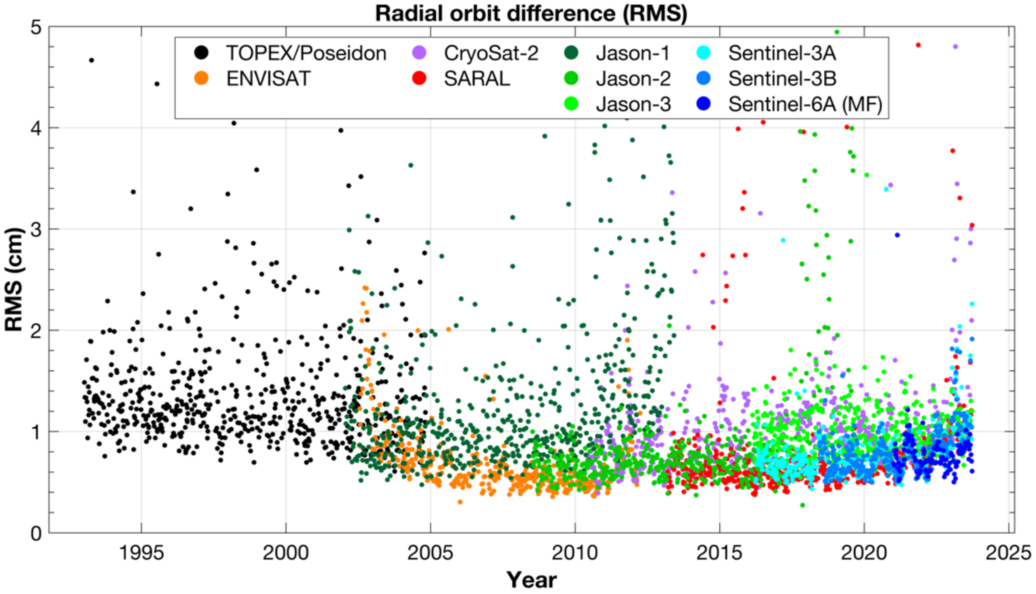
3 Internal Orbit Validation (3)



- New solution significantly reduces periods in the estimated empirical parameters

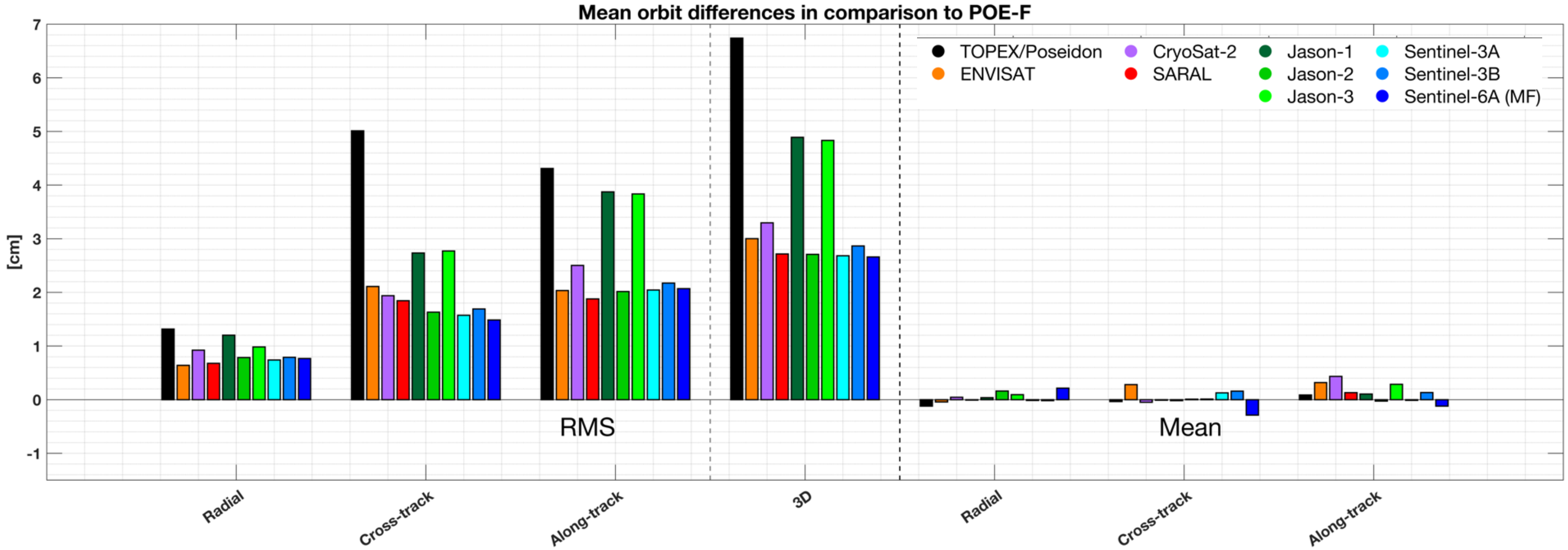
4 External Orbit Validation (1)

Orbit comparison against CNES POE-F



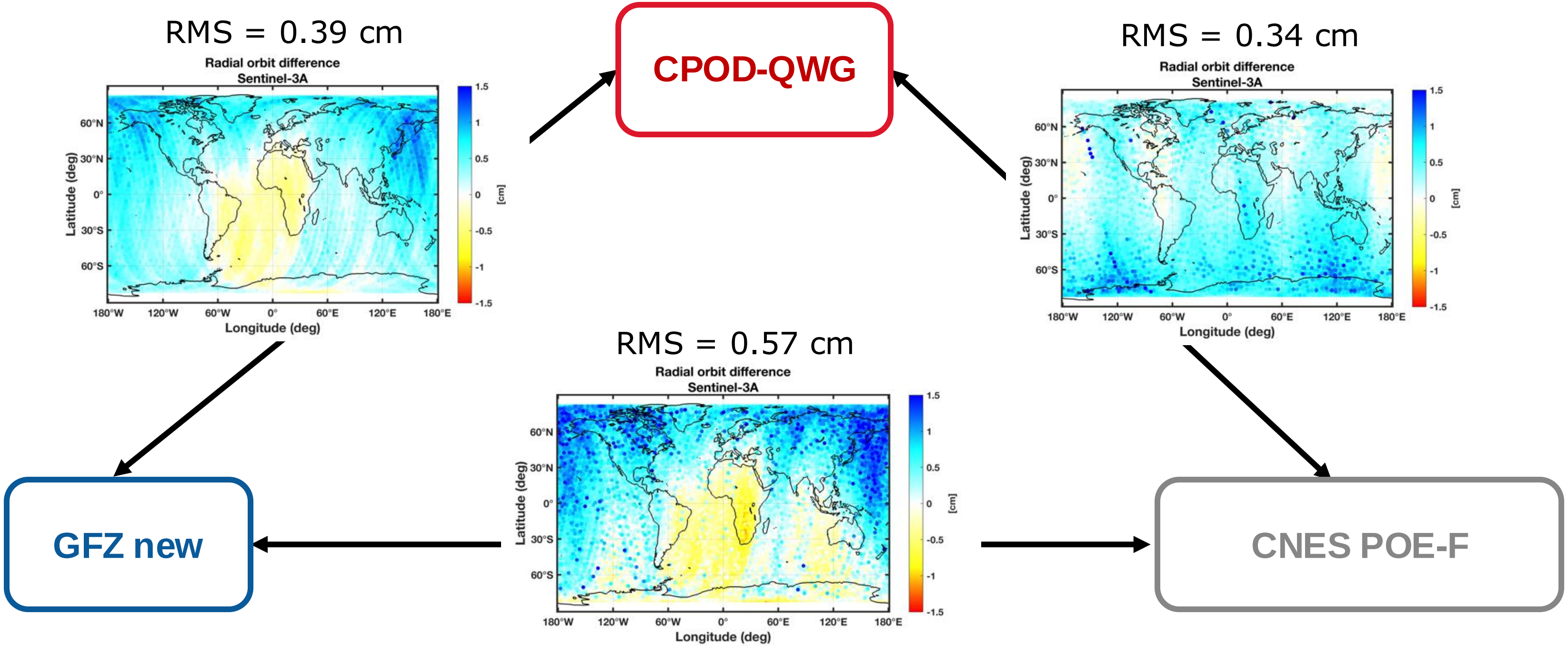
Mission	Radial Mean (cm)	Radial RMS (cm)
TOPEX	-0.12	**1.32**
ENVISAT	-0.04	0.64
CryoSat-2	0.05	0.92
SARAL	-0.01	0.68
Jason-1	0.04	**1.20**
Jason-2	0.16	0.79
Jason-3	0.09	0.98
Sentinel-3A	-0.02	0.74
Sentinel-3B	-0.02	0.79
Sentinel-6A (MF)	0.21	0.77

4 External Orbit Validation (2)



- **TOPEX/Poseidon** shows larger deviations in cross-track and along-track direction
- **Jason-1** and **Jason-3** show higher deviations than **Jason-2**

4 External Orbit Validation (3)



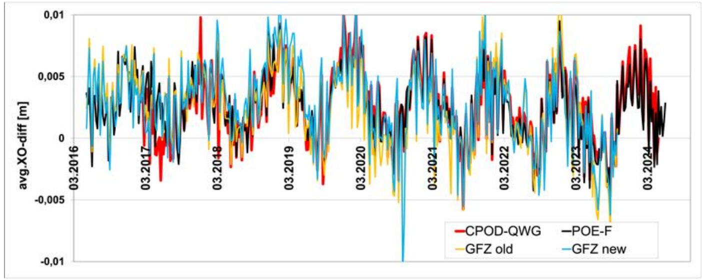
5 Altimetry Validation

Detailed altimetry analysis as an example for Sentinel-3A

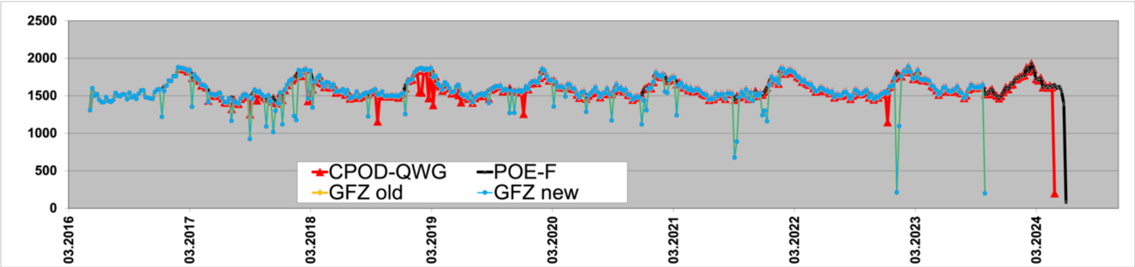
- Comparable performance for mean crossover differences and time bias between orbit and altimetry time system for all solutions

- Often slightly reduced counts for GFZ and CPOD-QWG. This is due to orbital manoeuvres

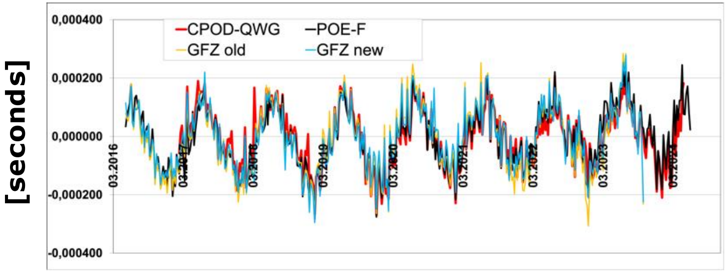
Mean of crossover differences



Counts

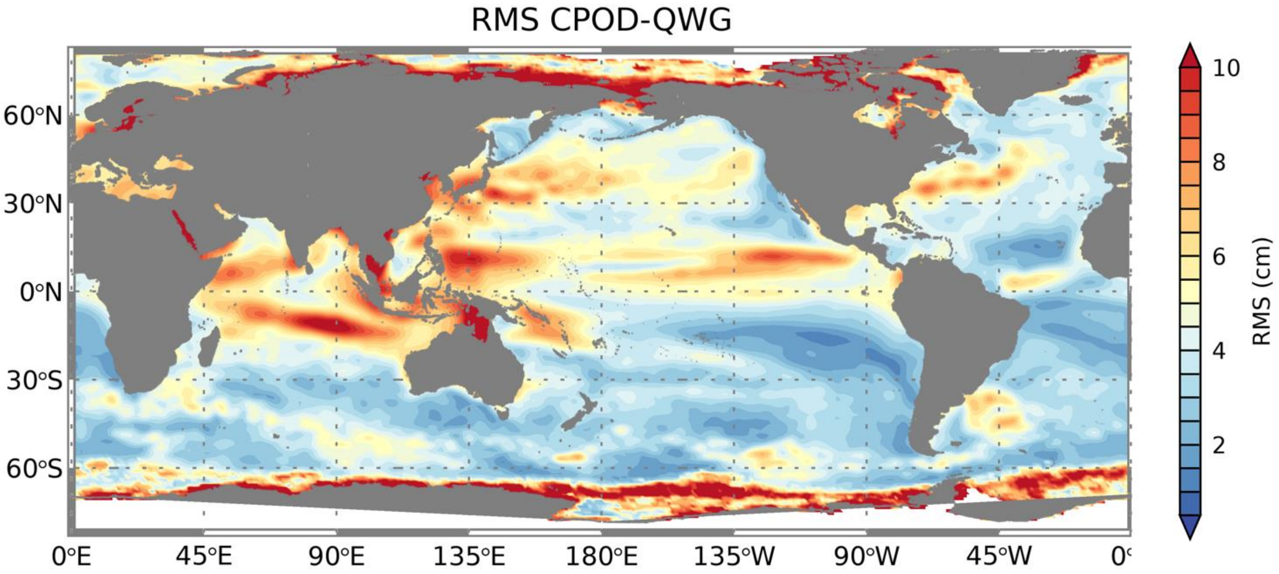


Time bias



5.1 Sea Level Anomalies (1)

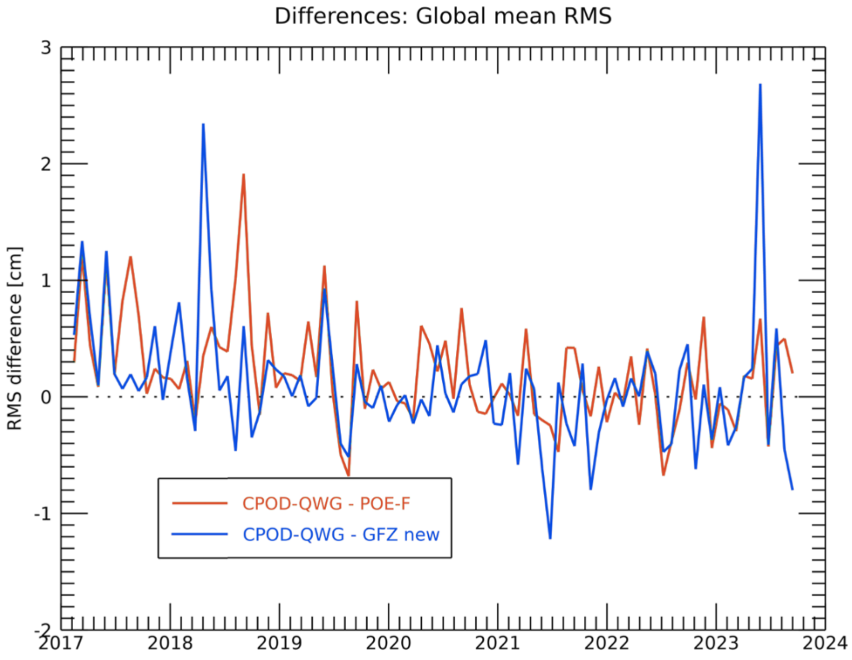
- Initial reference is the CPOD-QWG combined orbit solution



5.1 Sea Level Anomalies (2)

- POE-F and 'GFZ new' solution show superior performance in 2017-2018
- CPOD-QWG performs slightly better since 2019/2020

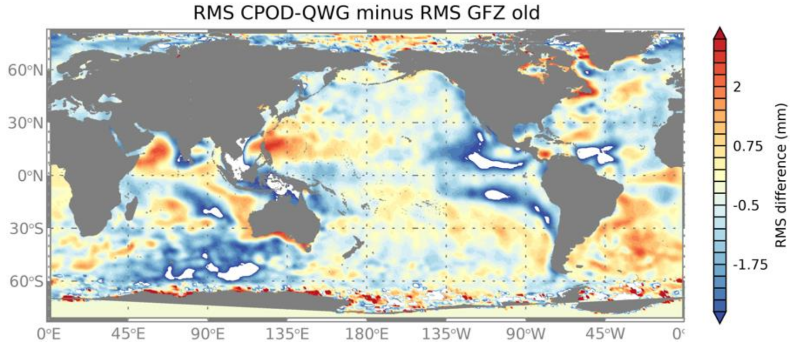
	Global RMS [cm]
CPOD-QWG	5.30
POE-F	5.33
GFZ new	5.34
GFZ old	5.36

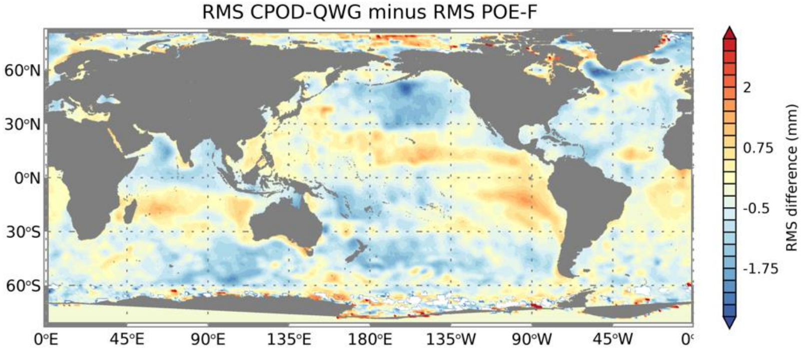


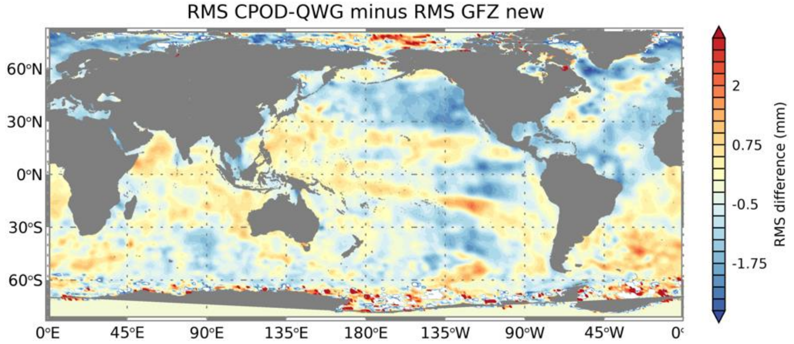
Global mean RMS differences (60°S to 60°N)

5.1 Sea Level Anomalies (3)

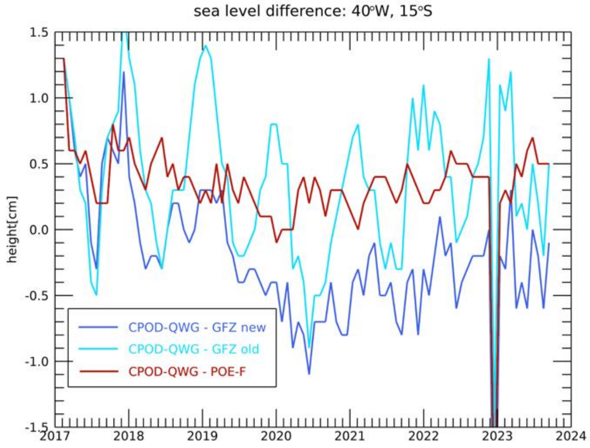
- Red indicates lower RMS compared to CPOD-QWG
  blue indicates higher RMS
- 'GFZ new' shows a more homogeneous pattern, regions with peak higher RMS could be improved
  - Indian and Eastern Pacific Ocean
- Compared to POE-F, 'GFZ new' shows slightly better performance in the Indian and South Atlantic Ocean, POE-F performs best in the East Pacific



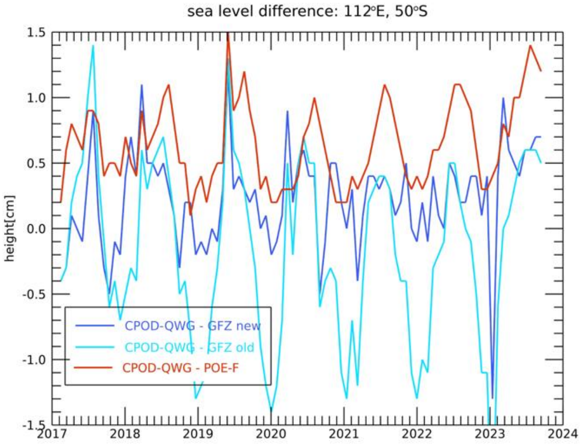




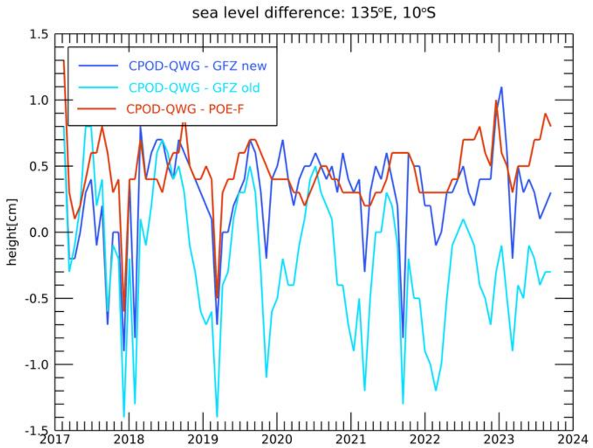
5.1 Sea Level Anomalies (4)



South Atlantic



Indian Ocean

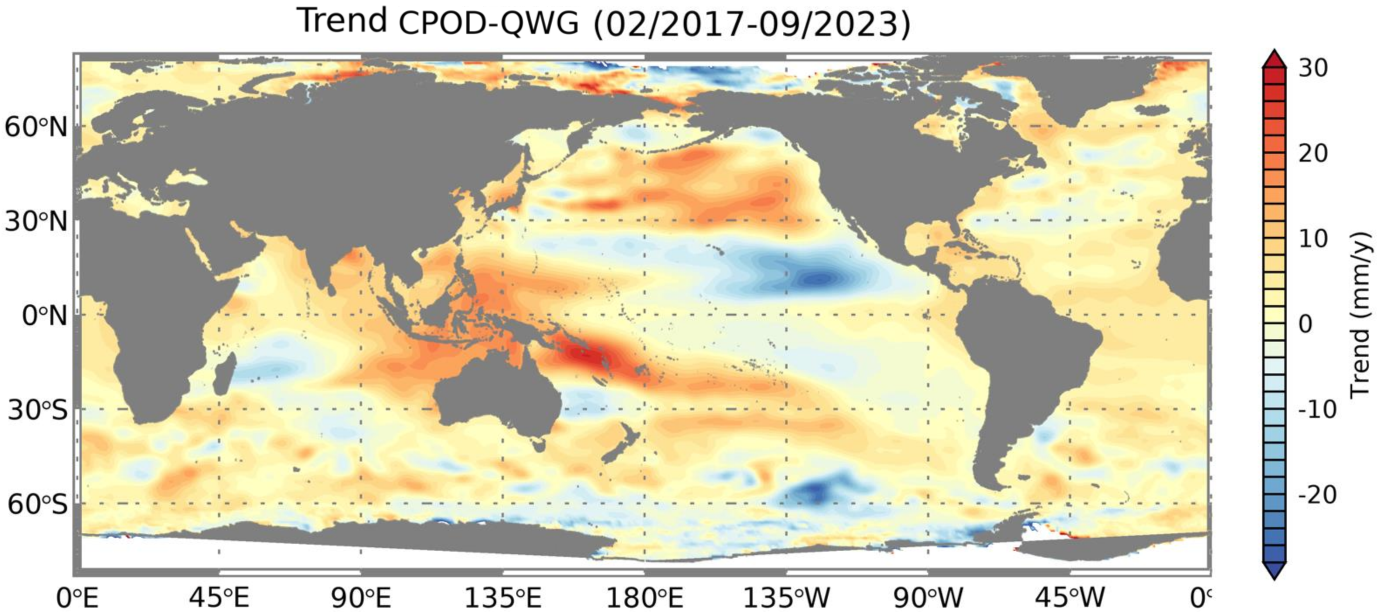


Arafura Sea

- ‘GFZ new’ shows significant reduction of regional signals
- POE-F shows stronger signal in Indian Ocean

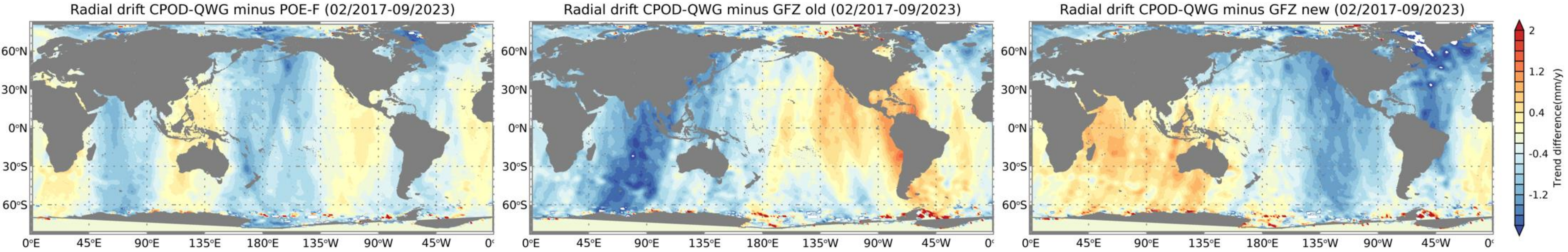
5.2 SLA Trend Analysis (1)

- Analysis of altimetry trends using the example of Sentinel-3A
- The reference trend is again computed based on the combined CPOD-QWG solution



5.2 SLA Trend Analysis (2)

- Trend differences against the CPOD-QWG combined orbit solution



Mean sea level trends (6.5 years) for different regions in [mm/yr]				
	GMSL	S Ocean	N Ocean	Trop. Ocean
CPOD-QWG	$\mathbf{3.7 \pm 0.1}$	$\mathbf{2.8 \pm 0.2}$	$\mathbf{4.2 \pm 0.2}$	$\mathbf{4.1 \pm 0.2}$
POE-F	4.0 ± 0.1	3.1 ± 0.2	4.7 ± 0.3	4.4 ± 0.2
GFZ new	4.0 ± 0.1	2.9 ± 0.2	5.0 ± 0.3	4.3 ± 0.2
GFZ old	4.0 ± 0.1	3.2 ± 0.2	4.5 ± 0.2	4.3 ± 0.2

6 Conclusion and Outlook

- Notable reduction in regional geographic patterns in the orbit
- Internal and external orbit validations confirm improved accuracy
- 'GFZ new' DORIS-only orbits achieve radial RMS values below 1 cm across all missions, in comparison to POE-F

- Global SLA RMS for Sentinel-3A now close to POE-F
- Fewer residual geographic signal differences
- Certain geographic patterns persist in the SLA trend analysis
  - ➢ Motivation for continued improvements