

New mean gravity field model CNES_GRGS.RL05MF_combined_GRACE_SLR_DORIS

IDS AWG, 2023/04/18

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Main Features

- **Data used:**

- DORIS+SLR mascons from January 1993 to March 2002
- GRACE+SLR RL05 monthly gravity field time series between April 2002 and October 2022
- GOCE-DIR5 for the static part between dg 91 and 300

The DORIS+SLR mascons solution uses:

- SLR data from Lageos1, Lageos2, Starlette, Stella, Ajisai and Lares satellites
- DORIS data from all DORIS-carrying satellites, from Topex to HY2A and Saral
- The mascons solution was converted to spherical harmonics between degree 1 and 40

- **Extrapolation:**

- The retrograde extrapolation of the trend coefficients (pre-1993) is obtained from a regression on the DORIS+SLR mascons
- The prograde extrapolation of the trend coefficients (post-2022) is obtained from a regression over the GRACE era (2002-2022)

There are two corrections to the slope of degree 2 before 1993:

- The slope of C20 (+0.2e-10 /year) is obtained from a SLR-based determination of C20 between 1980 and 1992
- The slope of C21/S21 (-6.82e-12 /year ; +1.40e-11 /year) is imposed to follow the conventional linear drift of the mean pole

Main Features

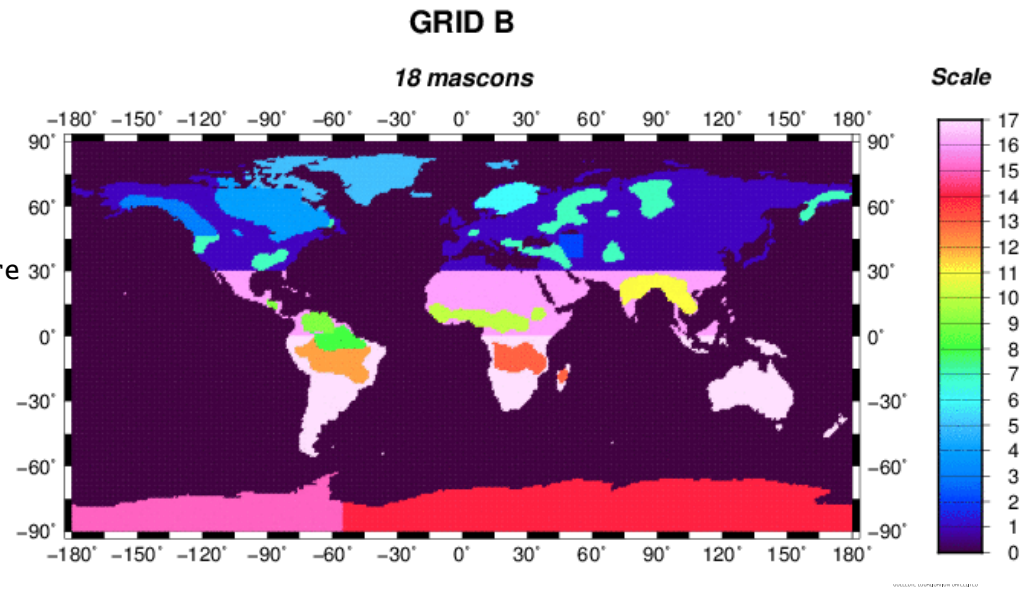
- **CNES_GRGS.RL05MF_combined_GRACE_SLR_DORIS** is complete to d/o 300. It contains:

- 1,135,000 time-variable coefficients
- 82,532 static coefficients (above degree 90)

- **DORIS + SLR “super mascons”**

- Based on 20 years of GRACE and GRACE-FO data, a map was drawn of places “where mass change is occurring”

```
Zone: n°, Surface in km² and Name
------------------------------
Zone  0 359573646 Oceans
Zone  1  45000727 Continents Lat. > 30°
Zone  2   1011712 Caspian
Zone  3   2012042 Alaska
Zone  4   5530774 Canada (snow + GIA)
Zone  5   3648537 Greenland, Ellesmere, Iceland
Zone  6   1530344 Scandinavia (snow + GIA)
Zone  7   7474177 Snow and hydrological load Winter/Summer Northern Hemisphere
Zone  8   2197075 Amazon River
Zone  9   1690452 North tropical zone America
Zone 10   4290448 North tropical zone Africa
Zone 11   3950213 North tropical zone Asia
Zone 12   4551727 South tropical zone America
Zone 13   3581172 South tropical zone Africa
Zone 14  10139466 Antarctic Continent
Zone 15   3457258 West Antarctica
Zone 16  25800744 Continents 0° < Lat. < 30°
Zone 17  24630434 Continents Lat. < 0°
```



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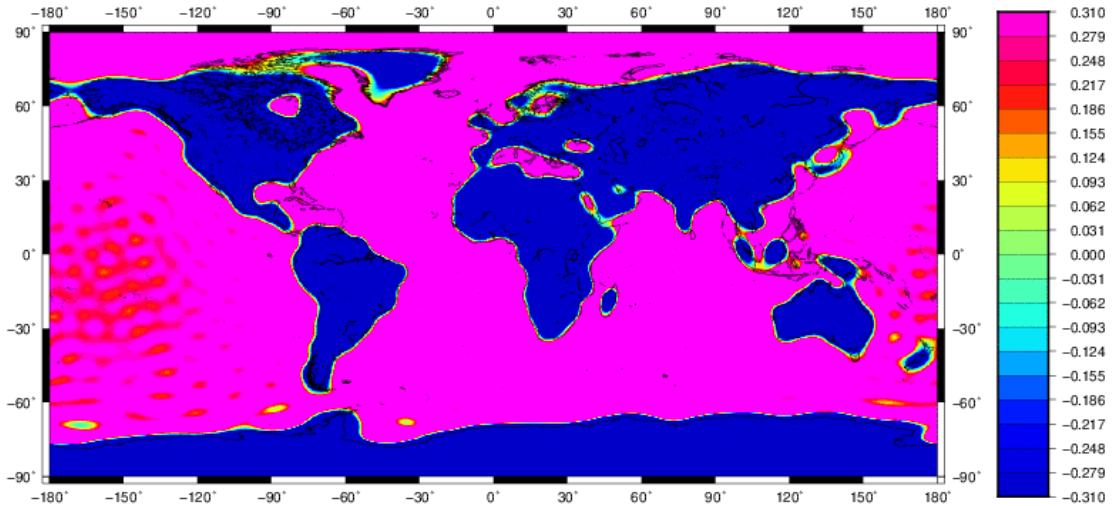
DORIS + SLR super mascons

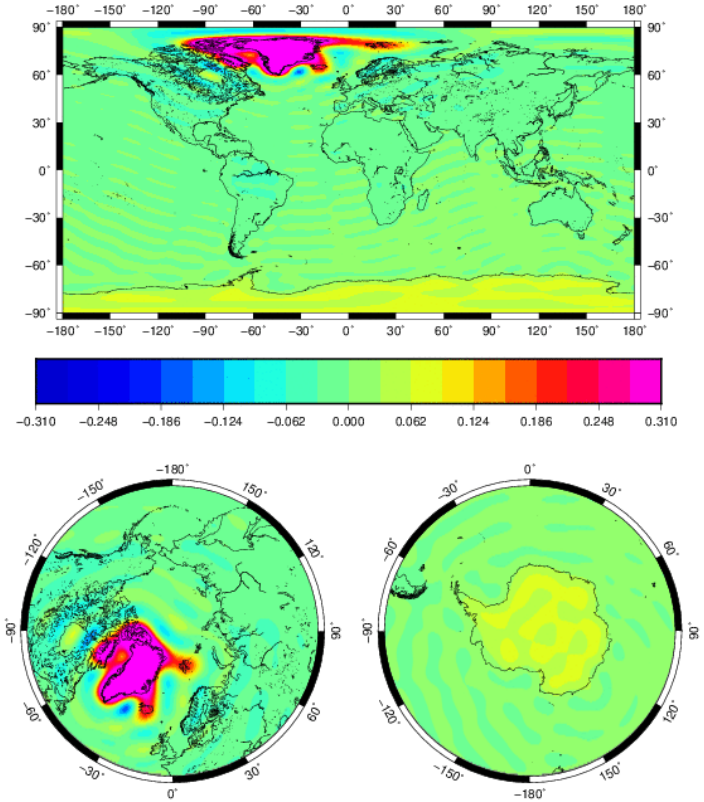
- **Constraints between spherical harmonics and “super mascons”**

- For each 1°x1° cell of the geographical grid, we write the linear equation linking each of the spherical harmonic coefficients (up to d/o 40) with the mass anomaly of the cell, expressed in equivalent water height (EWH)
- The 64800 equations form a “constraints NEQ”
- Examples:



“Oceans” super-mascon

“Greenland, Ellesmere, Iceland” super-mascon



SLR and DORIS data

- As part of CNES's participation in ITRF2020, we dispose of 30 years of weekly or half-weekly normal equations containing the partial derivatives of the gravity field in spherical harmonics:

- Up to d/o 30 for the SLR satellites
- Up to d/o 40 for the DORIS satellites

SLR

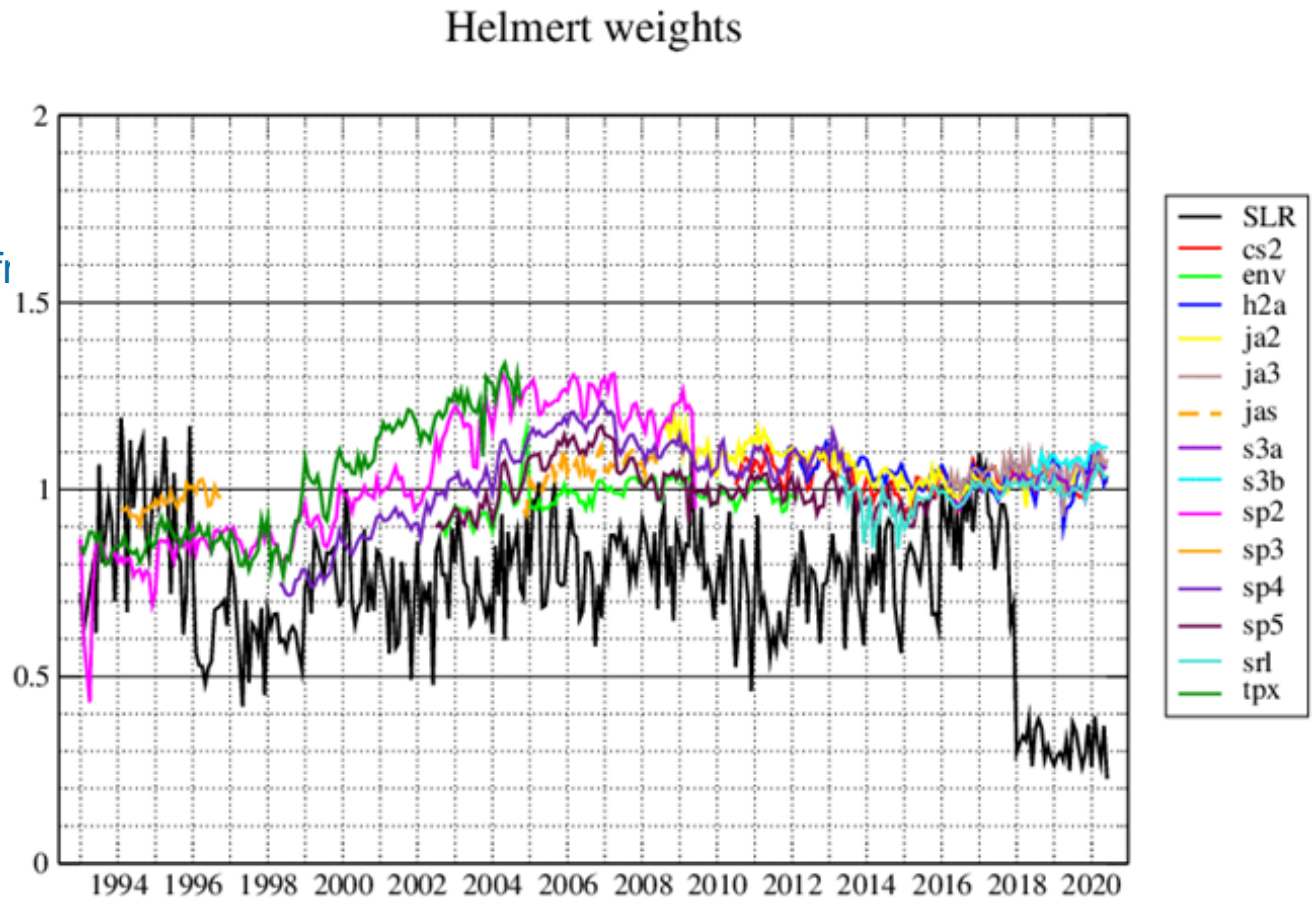
- 1993.0 – 2023.0 = Lageos-1, Lageos-2, Starlette
- Ajisai from May 1993, Stella from October 1993, Lares fr

DORIS

- All available satellites are used

  except Cryosat-2 because of an oscillation at 482 days
- The relative weighting of the satellites is done through

  an optimal weighting scheme



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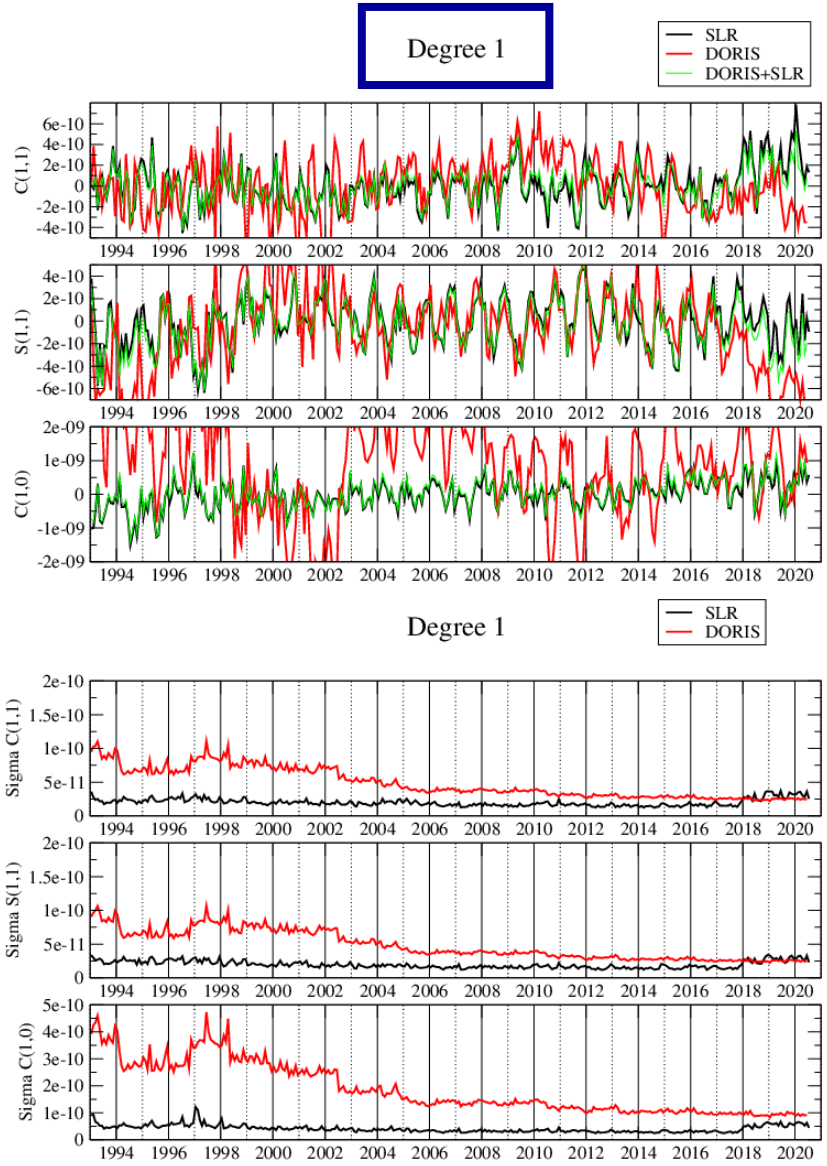
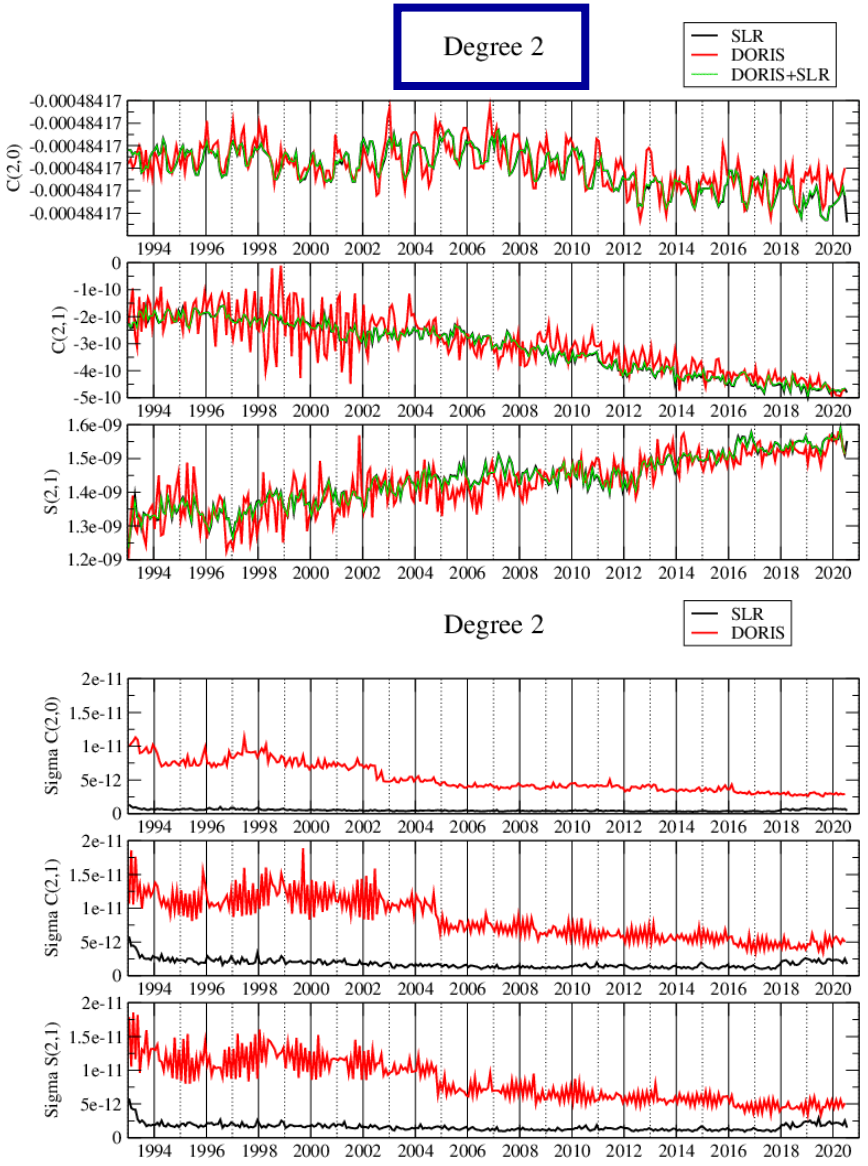
DORIS + SLR super mascons solutions

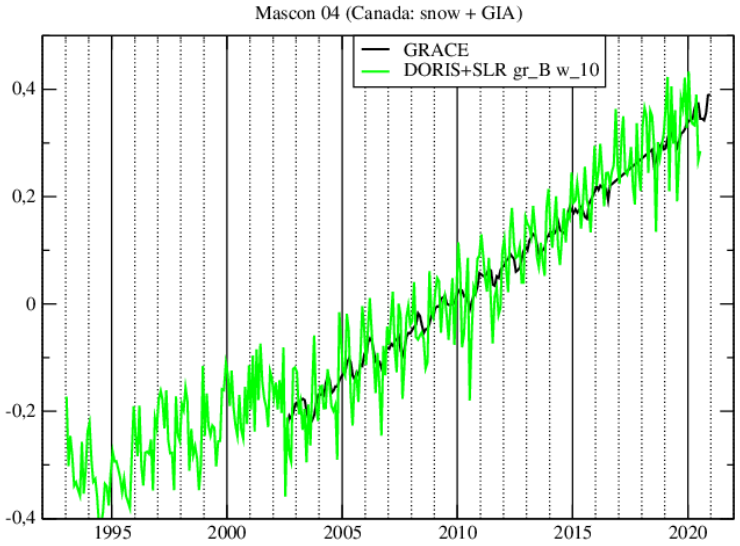
- **Low degrees**



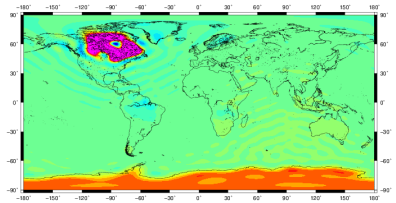


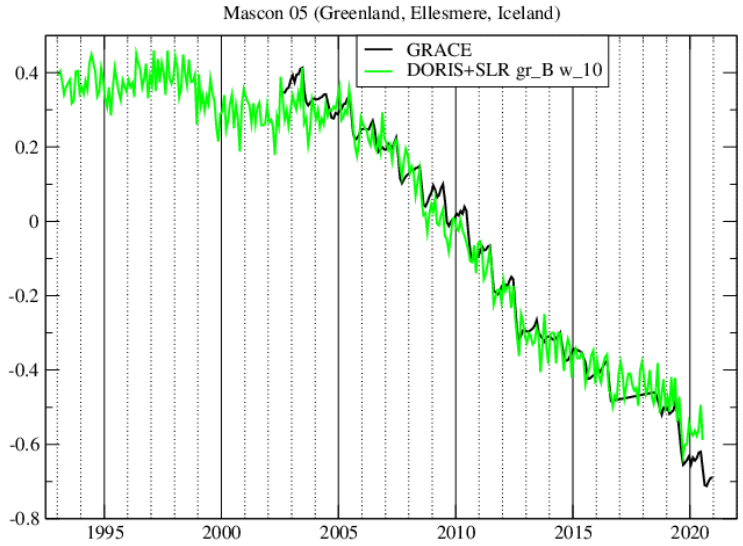
DORIS + SLR super mascons solutions

- **Comparison to GRACE/GRACE-FO time series**
  - For most super mascons there is a “rather good” agreement between DORIS+SLR and GRACE/GRACE-FO
  - Examples:

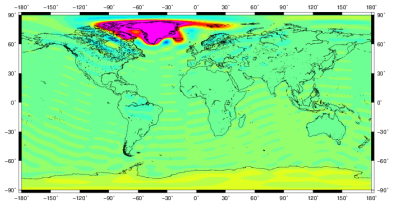


“Canada” super-mascon

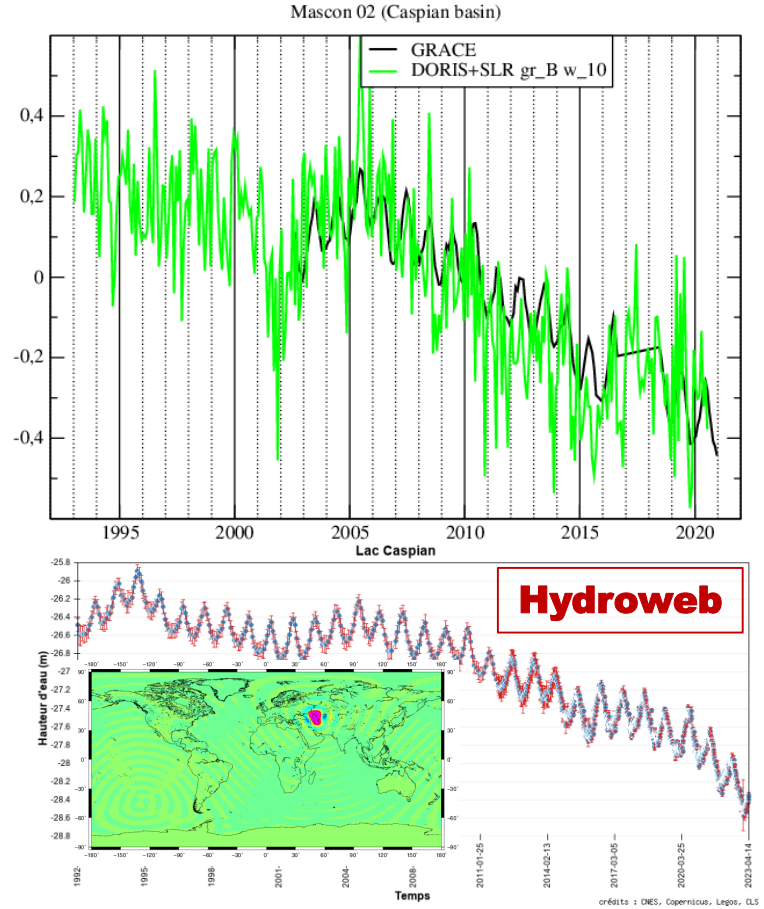




“Greenland, Ellesmere, Iceland” super-mascon



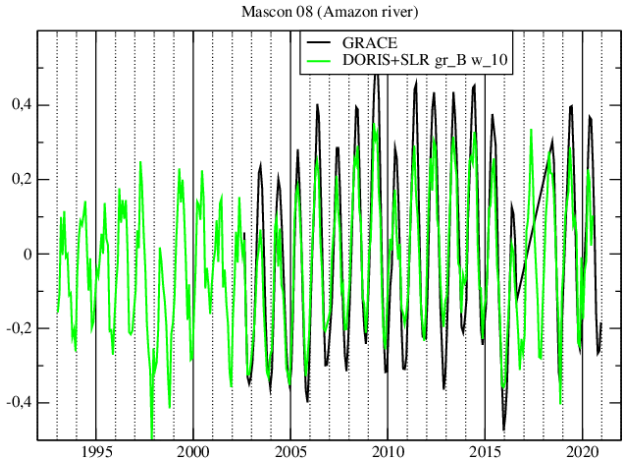
“Caspian basin” super-mascon



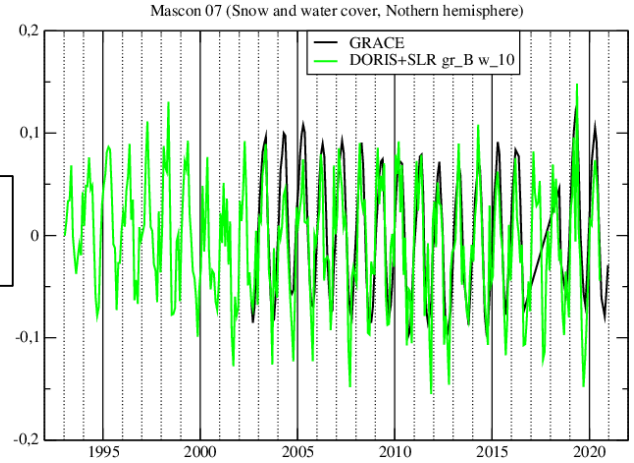
DORIS + SLR super mascons solutions

- Also good agreement for most places where there is a strong annual signal

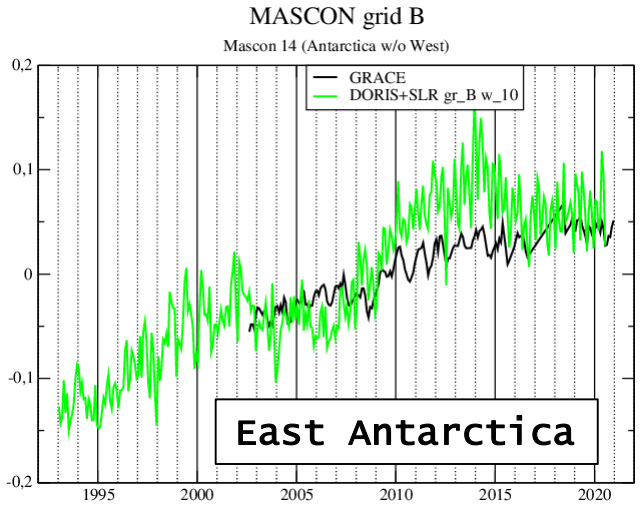
Amazon basin

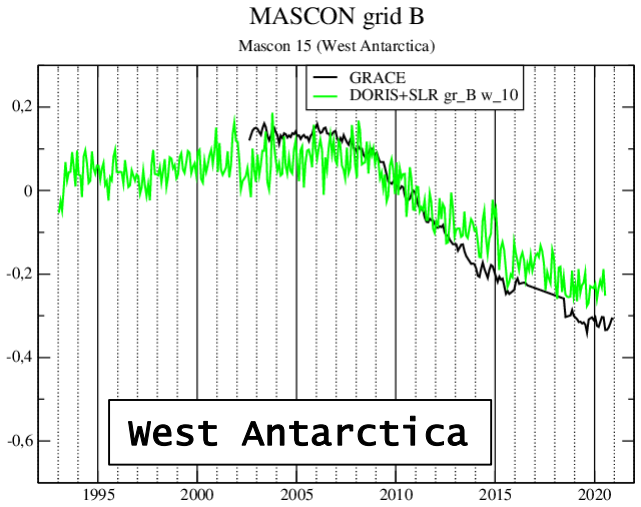


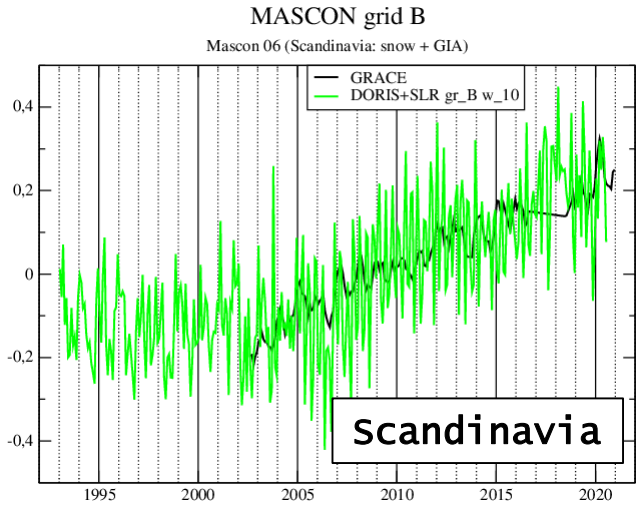
Snow cover
Northern hemisphere



- "Not so good" for only a few super mascons







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CNES_GRGS.RL05MF quality assessment

- **GSFC** SLR+DORIS POD tests (2008.5-2023) on Jason-2, Jason-3, and Sentinel-6a
  - Thanks Nikita Zelensky!

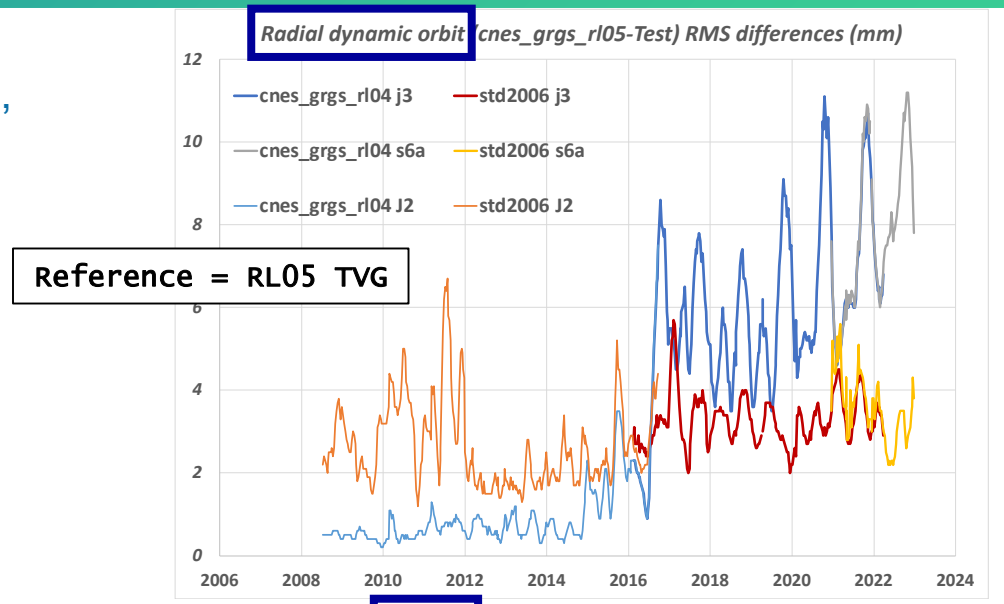
- **CNES/CLS** POD & altimetry tests on Topex/Poseidon (1992-2004) and Cryosat-2 (2018-2023)
  - Thanks Eléonore Saquet!

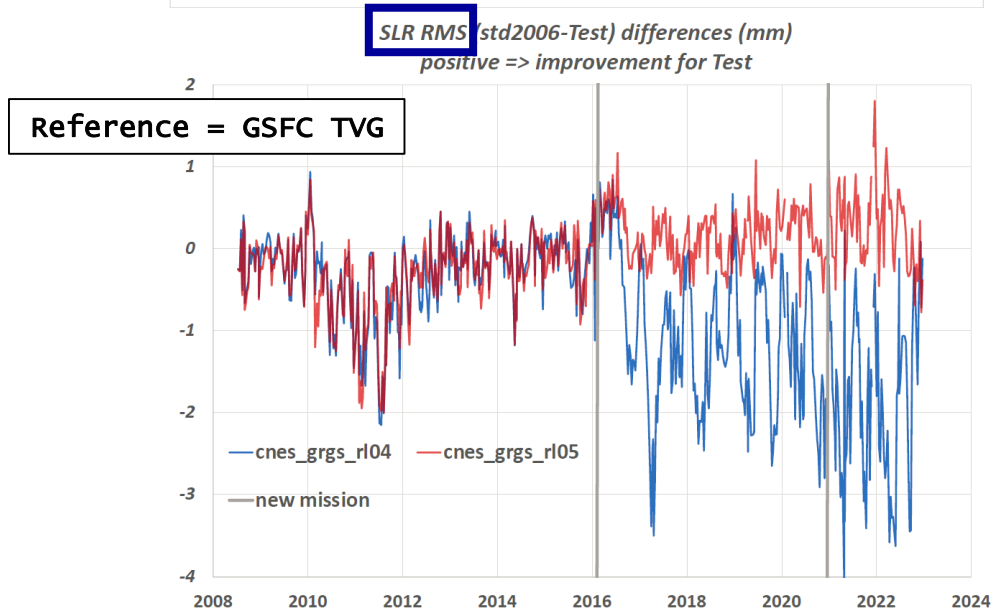
- **DGFI/TUM** SLR-only POD tests on Topex/Poseidon (1992-2005) and the Jason satellites (2002-2021)
  - Thanks Sergei Rudenko!

CNES_GRGS.RL05MF quality assessment

- **GSFC** SLR+DORIS POD tests (2008.5-2023) on Jason-2, Jason-3, and Sentinel-6a
- Comparison of CNES/GRGS RL04, RL05 and GSFC 5x5 & 4x4 TVG models

Mission	Test	Residuals		POE-F RMS orbit diff. (mm)		
		DORIS (mm/s)	SLR (mm)	Radial	Cross-Trk	Along-Trk
J2 cycles 1-303 2008.5-2016.7	std2006_cs21	0.3927	7.06	6.2	19.3	22.7
	cnes_grgs_rl04	0.3928	7.37	6.0	19.1	23.5
	cnes_grgs_rl05	0.3927	7.32	6.1	19.0	23.5
J3 cycles 1-226 2016.1–2022.3	std2006_cs21	0.3914	6.62	5.9	18.7	23.8
	cnes_grgs_rl04	0.3919	7.92	7.6	18.7	27.7
	cnes_grgs_rl05	0.3914	6.50	5.6	18.2	23.0
S6A cycles 4-079 2020.9-2023.0	std2006_cs21	0.4091	6.95	6.5	15.7	21.3
	cnes_grgs_rl04	0.4102	8.74	9.1	17.2	28.7
	cnes_grgs_rl05	0.4093	6.71	5.9	15.3	20.1

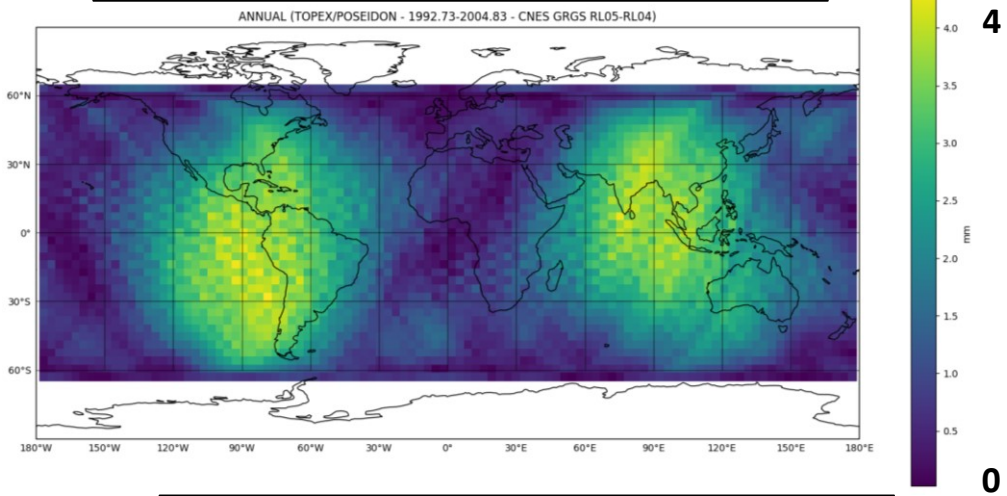




CNES_GRGS.RL05MF quality assessment

- **CNES/CLS** POD & altimetry tests on Topex/Poseidon (1992-2004)

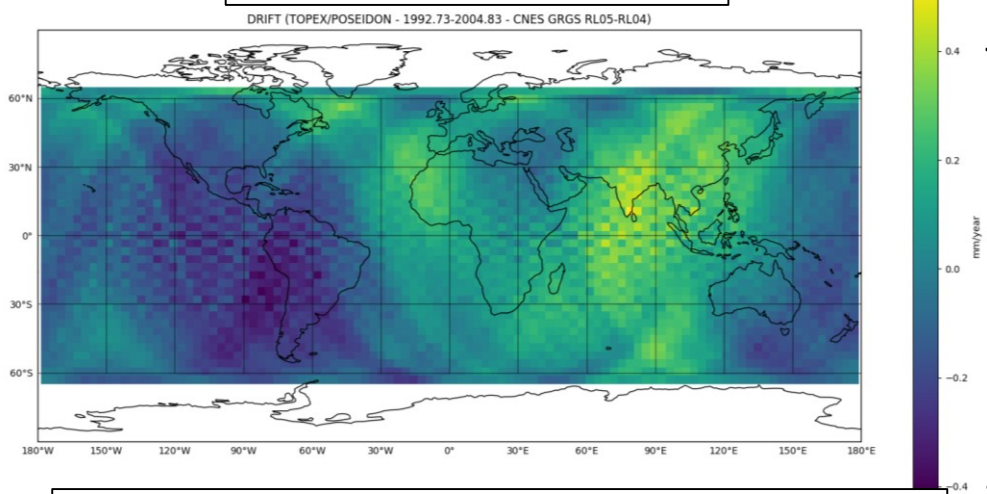
Radial ANNUAL differences RL05 vs. RL04



4 mm

0

Radial drift RL05 vs. RL04

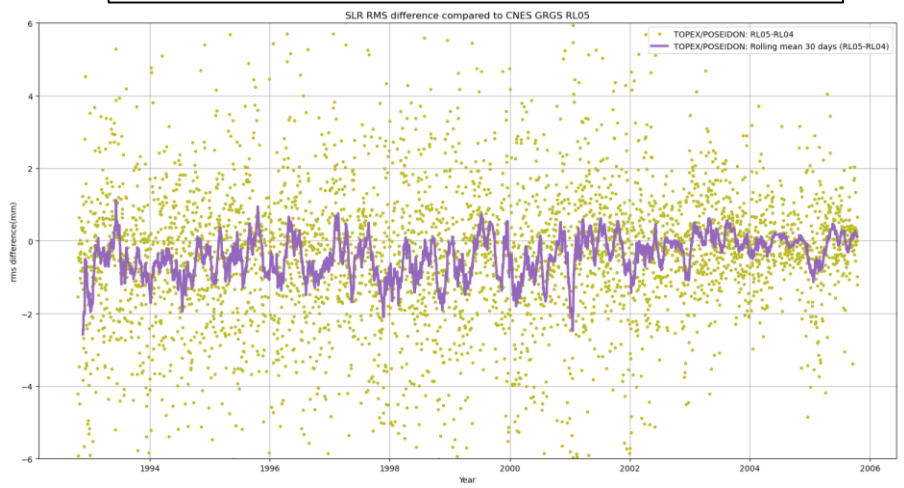


+0.4 mm/y

0

-0.4 mm/y

SLR residuals differences RL05 vs. RL04

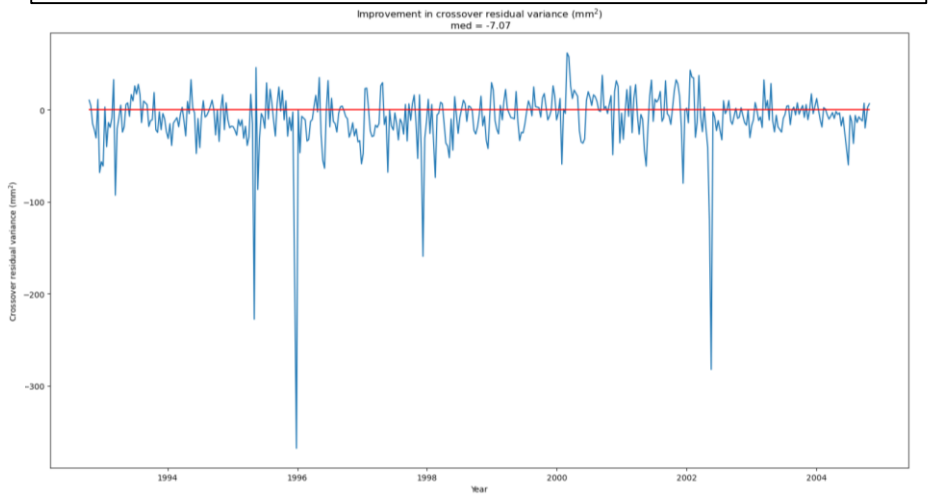


+6 mm

0

-6 mm

Improvement in xover residuals variance = -7 mm²



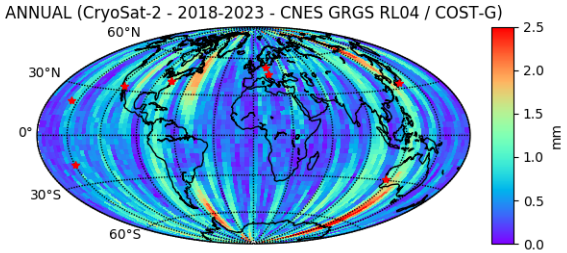
0

-300 mm²

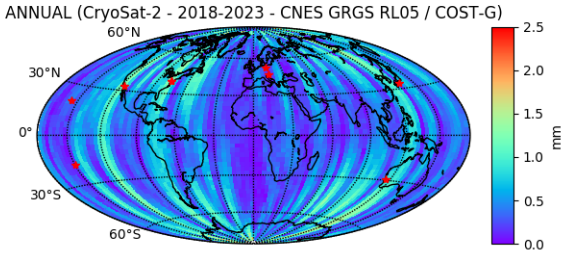
CNES_GRGS.RL05MF quality assessment

- **CNES/CLS** POD & altimetry tests on Cryosat-2 (2018-2023). Comparison RL04 / RL05 / COST-G TGV

ANNUAL cycle



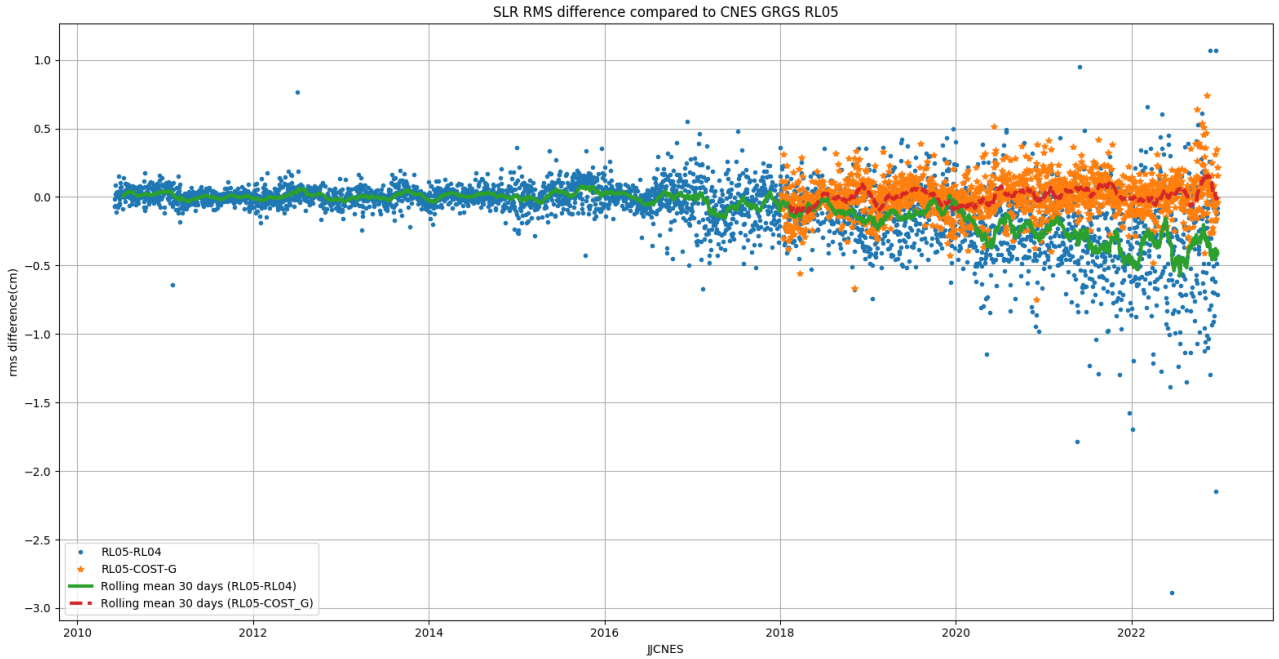
RL04 vs. COST-G



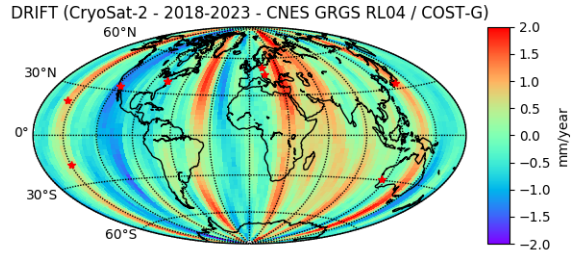
RL05 vs. COST-G

SLR residuals

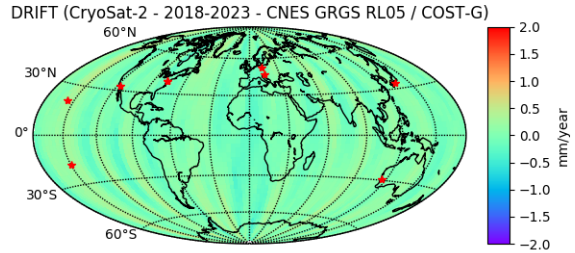
Green line = RL05 – RL04 / Red line = RL05 – COST-G



DRIFT



RL04 vs. COST-G



RL05 vs. COST-G

Summary and outlook

- **CNES_GRGS.RL05MF_combined_GRACE_SLR_DORIS** is performing clearly better than RL04

- Compared to the GSFC TVG, Nikita has shown a small drop of performance of RL04 and RL05 in 2010-2012
- Compared to the COST-G TVG (since 2018), Eléonore has shown there are very little differences
- Sergei points out a small drop of performance of RL05 compared to RL04 between 2016.5 and 2018.3 → **We need to investigate this point**

- **Other alternatives**

- GSFC 5x5 or 4x4 time series
- COST-G TVG (since 2018)
- AIUB (Krzysztof Sośnica, now in Wrocław) 10x10 SLR-based TVG ?
- DGFI/TUM (Mathis Bloßfeld) TVG ?
- The EOF approach from Anno Löcher & Jürgen Kusche (2020)

A hybrid approach for recovering high-resolution temporal gravity fields from satellite laser ranging

Journal of Geodesy (2021) 95:6
https://doi.org/10.1007/s00190-020-01460-x

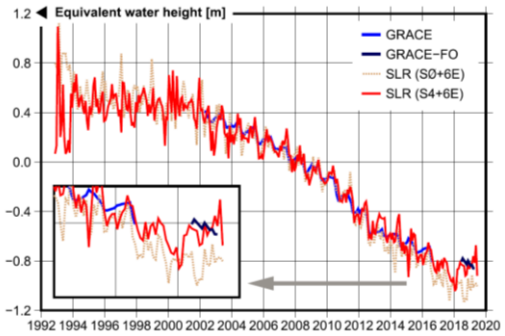


Fig. 3 Monthly mass anomalies in Greenland from GRACE, GRACE-FO and SLR solutions

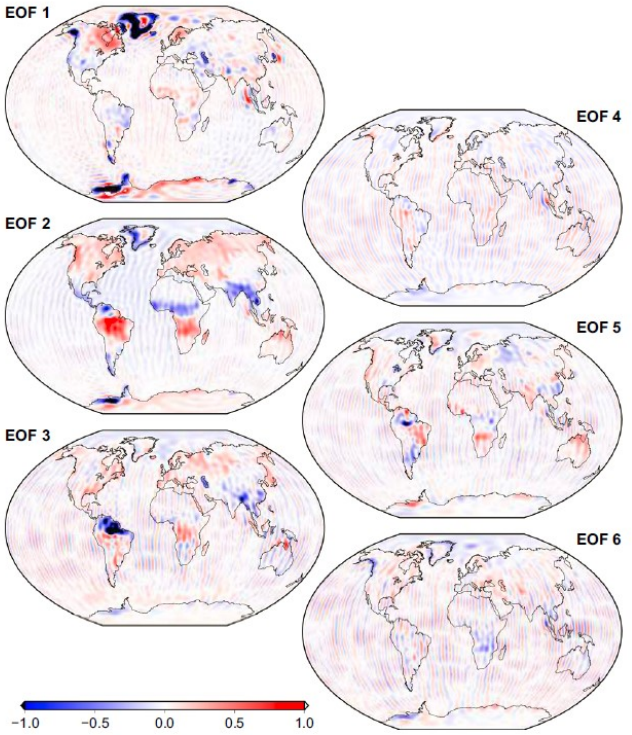


Fig. 2 Empirical orthogonal functions from ITSG-Grace2018. Individually scaled view