SLR contributions to time-variable gravity field and thermospheric neutral density estimates

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SLR monthly gravity solution and satellite combination

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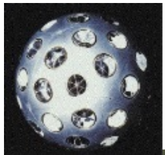
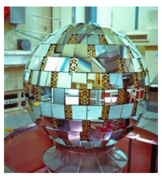
SLR-derived gravity solution

	CSR (Cheng et al., 2011)	AAS (Maier et al., 2012)	HIT-U (Matsuo et al., 2013)	GSFC (Lemoine et al., 2014)	AIUB (Sosnica et al., 2015)	DGFI (Bloßfeld et al., 2015)
Software package	UTOPIA	GEODYN-II	c5++	GEODYN	Bernese	DOGS-OC 5.4
Satellites	LA-1/2, AJI, STE	LA-1/2, ET-1/2, AJI, STE, STA, LTS, LRS, BTS	LA-1/2, AJI, STA, STE, LRS	LA-1/2, AJI, STE, STA, LTS, LRS	LA-1/2, ET-1/2, AJI, STE, STA, LTS, LRS, BTS, WP1, BEC	LA-1/2, ET-1/2, AJI, STE, STA, LTS, LRS, BTS, WP1
Time span	1992 Oct. - 2011 May	1992 - present	1991 Jan. - present	1992 – 2011	2002 - 2014	1993 - present
Estimated degree and order	5×5	5×5	6×6	5×5	10×10	5×5
Data availability	ftp://podaac.jpl.nasa.gov/allData/tellus/preview/L2/deg_5/ (up to d/o 5)	http://geodesy.iwf.oeaw.ac.at/d_slr_monthly.html (up to d/o 2)	not online available	not online available	http://icgem.gfz-potsdam.de (up to d/o 10)	not online available

SLR data, time span, estimated degree and order


1976- : STARLETTE (STRL)


1976- : LAGEOS-1 (LAG1)


1986- : AJISAI (AJI)


1992- : LAGEOS-2 (LAG2)


1993- : STELLA (STEL)

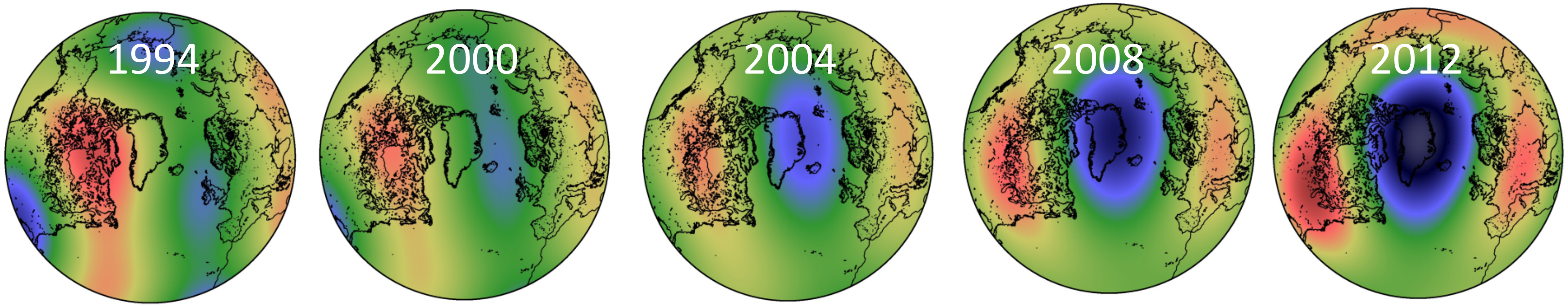

2012- : LARES (LARS

Computation period :
1994 Jan. – 2015 Dec.

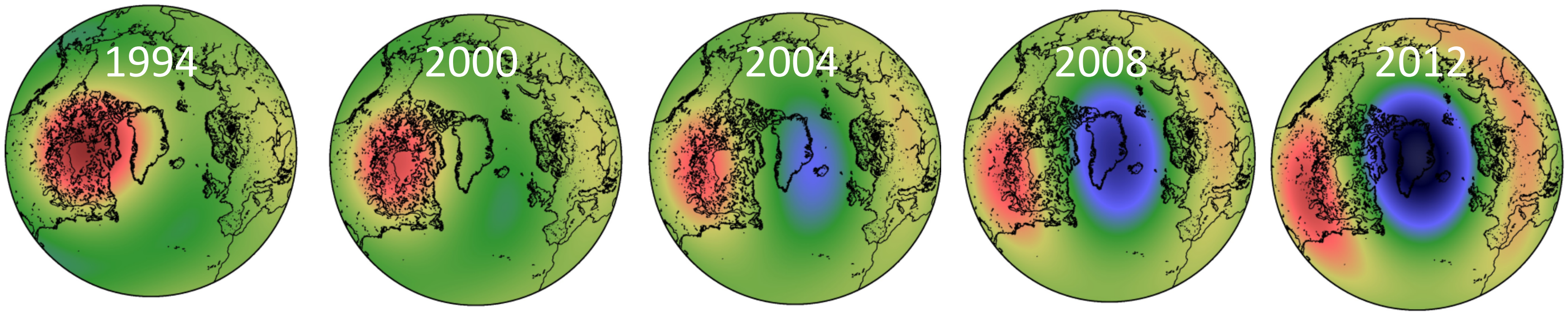
Stokes coefficients up to degree and order 6 are estimated.

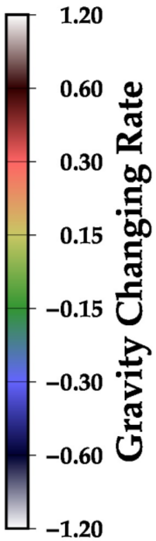
Gravity changing rate in Greenland

SLR new solution [6×6]

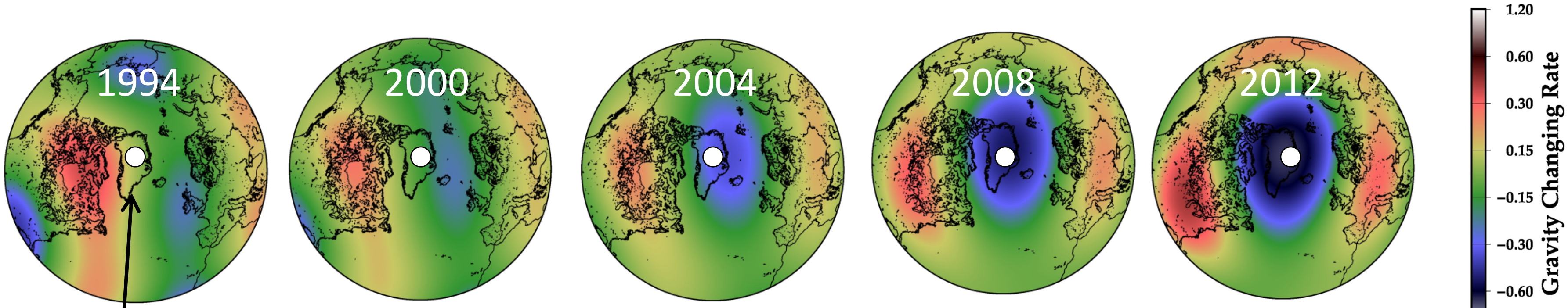


Model [6×6] (1994-2000) and GRACE [6×6] (2004-2012)

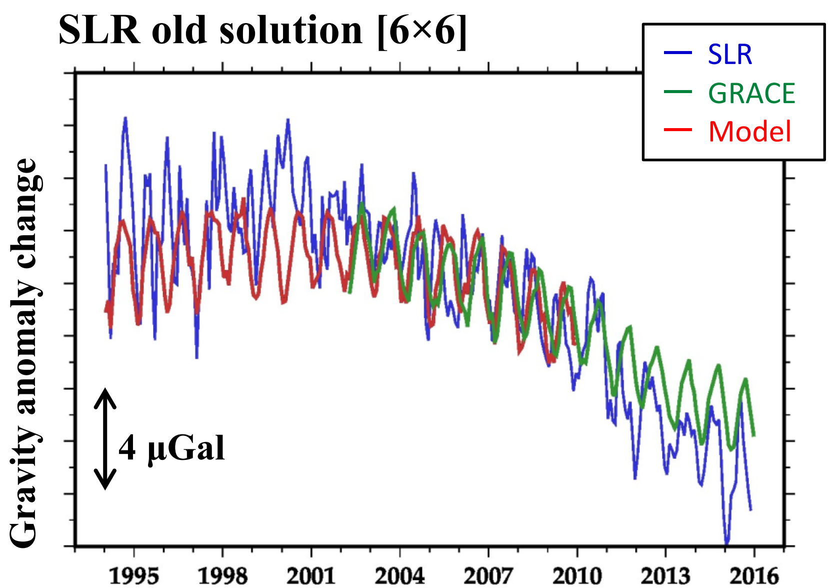


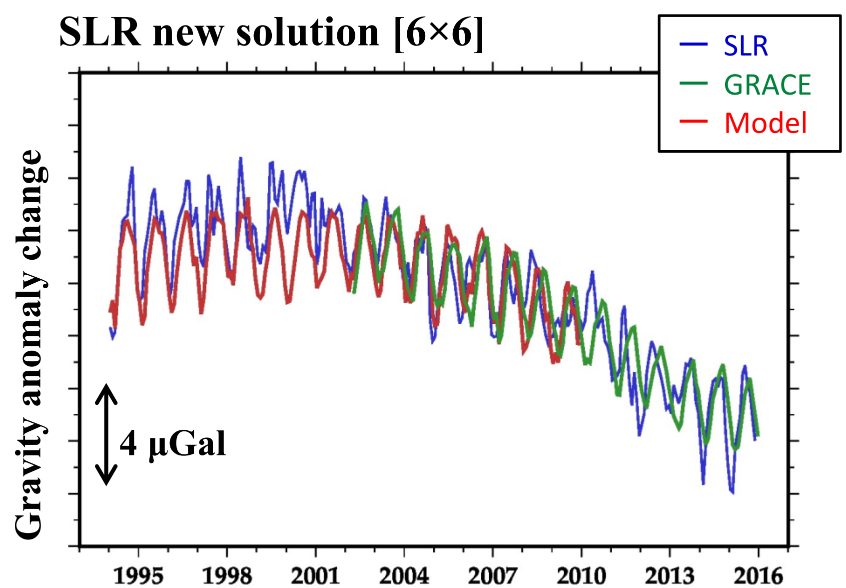


Gravity changes in Greenland



Gravity anomaly change at (Lat. 75N, Lon. 33W)





More satellites? (C_{20})

CSR:
SLR up to 5x5
+ C/S 61

C5++:
SLR up to 6x6

SLR (c5++)
SLR (CSR)

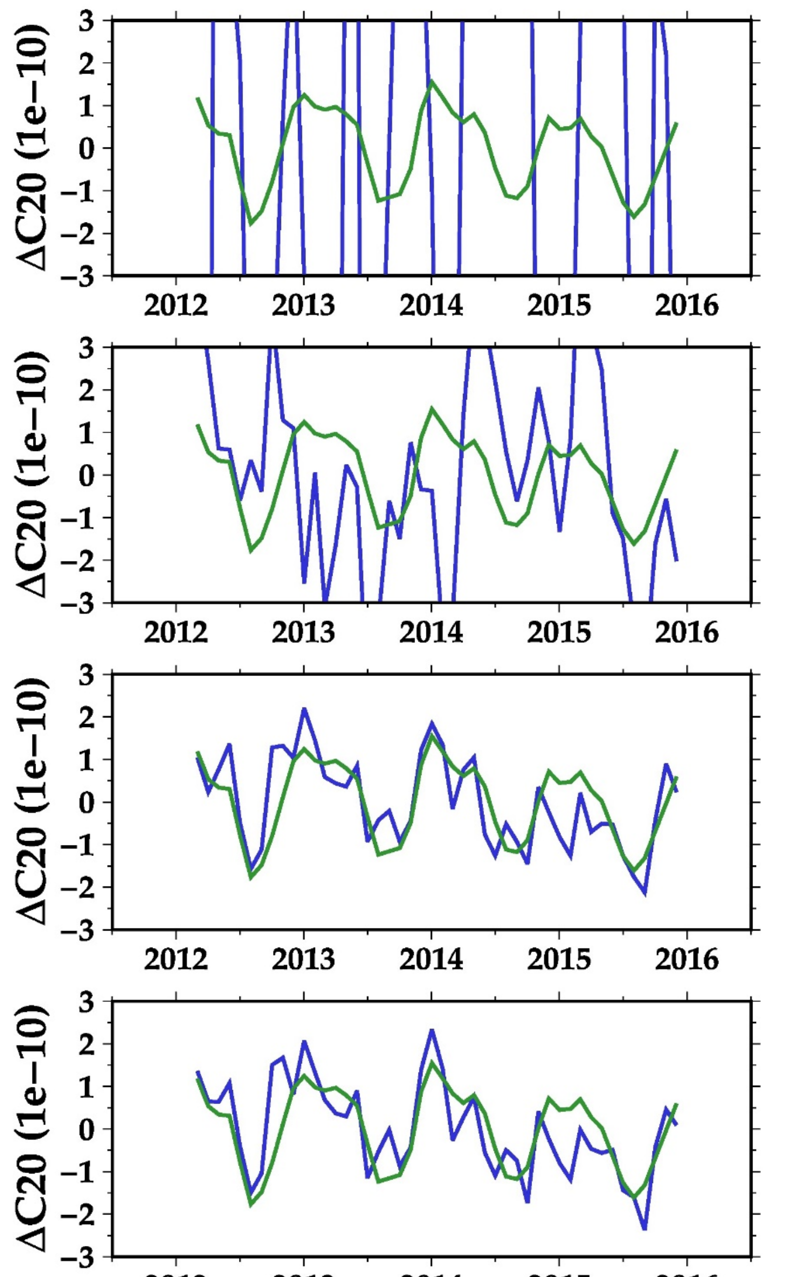
ΔC20 Time–Series

LAG1, LAG2

LAG1, LAG2, LARS

LAG1, LAG2, LARS, STRL, STEL

LAG1, LAG2, LARS, STRL, STEL, AJI



More satellites? (C_{50})

GRACE: CSR RL05
C5++: SLR up to 6x6

SLR (c5++)
GRACE

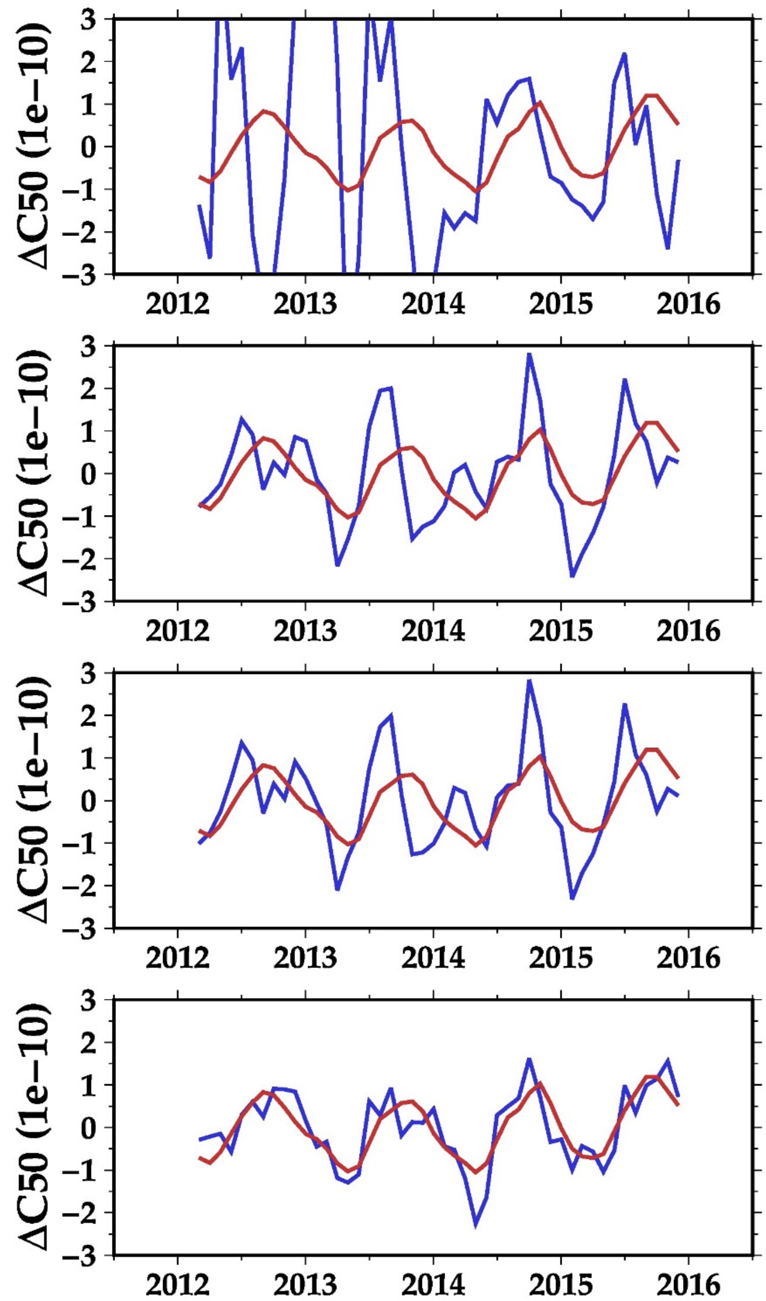
ΔC50 Time-Series

LAG1, LAG2

LAG1, LAG2, LARS

LAG1, LAG2, LARS, STRL, STEL

LAG1, LAG2, LARS, STRL, STEL, AJI



More satellites? (C61)

SLR (c5++)
GRACE

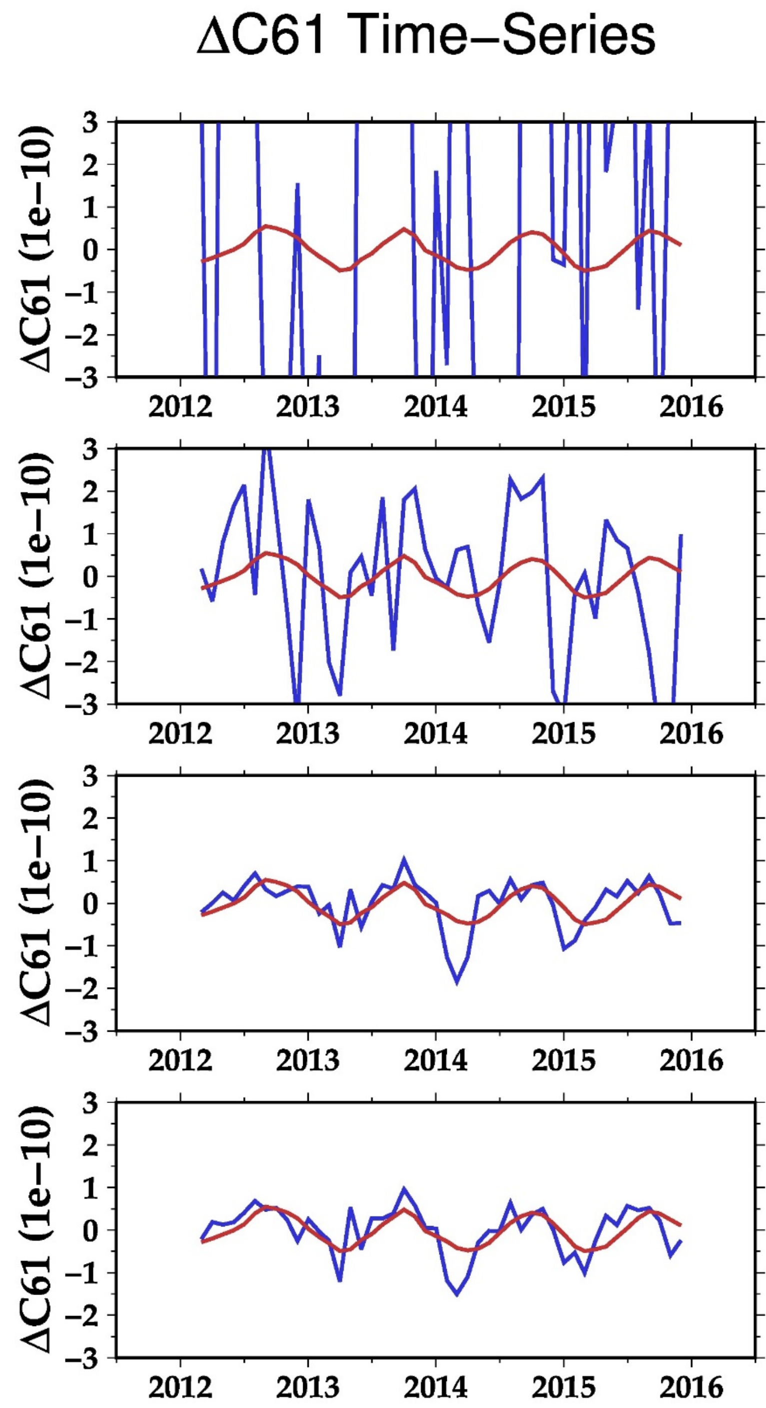
GRACE: CSR RL05
C5++: SLR up to 6x6

LAG1, LAG2

LAG1, LAG2, LARS

LAG1, LAG2, LARS, STRL, STEL

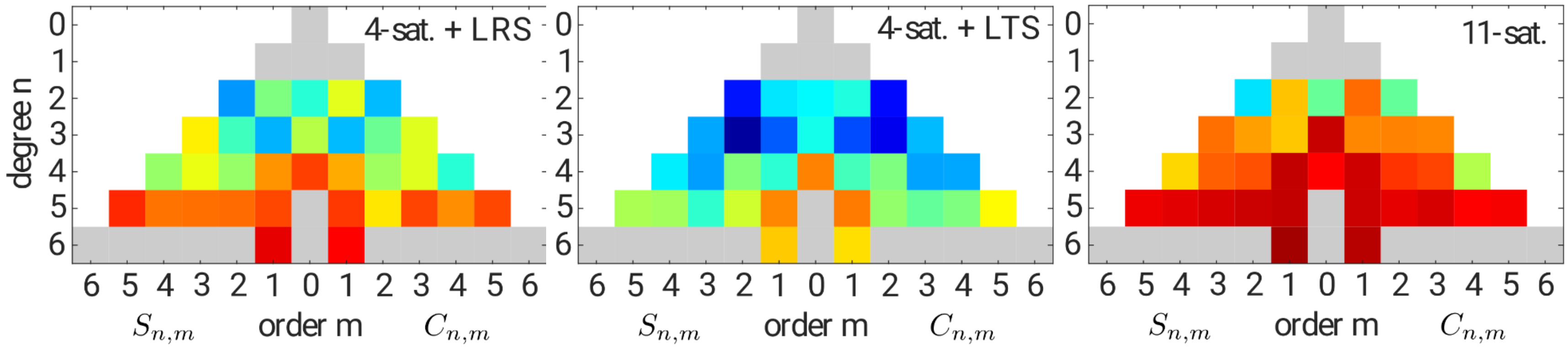
LAG1, LAG2, LARS, STRL, STEL, AJI



Summary (1st half)

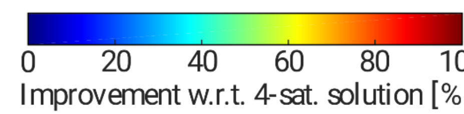
- SLR monthly solution up to degree and order 6 during 1994-2015 has been derived using the c5++ software.
- Significant long-term gravity changes have been captured especially in Greenland, Antarctica and North America.
- LEOs (LARES, Ajisai, Starlette & Stella, possibly more?) plays an important role.
- SLR gravity solution enables us to study the long-term mass variations such as GIA, ice-sheet change, sea-level change...

Improvement of the mean WRMS values w.r.t. 4-sat. solution



Average WRMS improvement of the **GFC** w.r.t. 4-satellite solution

4-sat. + LRS	61.7 %
4-sat.+ LTS	41.9 %
11-sat.	79.3 %



- **5-satellite solution**: different improvement patterns depending on the orbit of the additional satellite
- **11-satellite solution**: improvement by up to 93 %

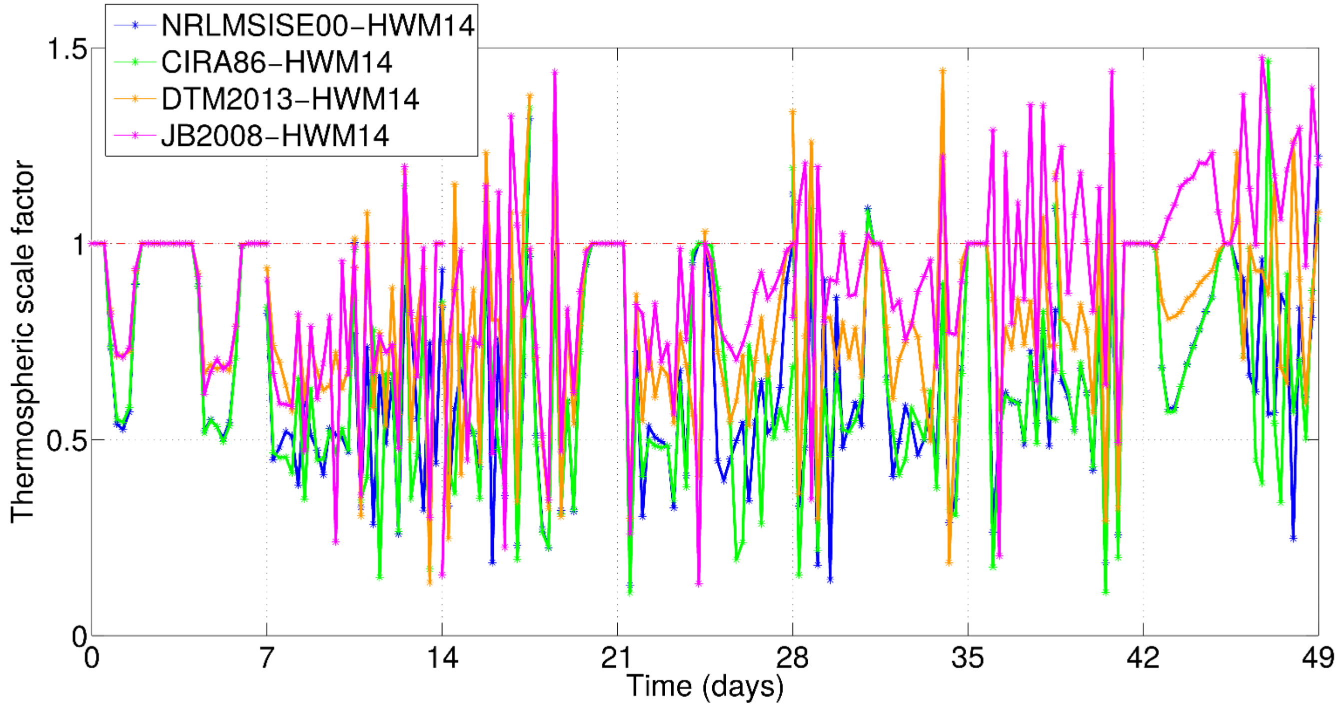
*Bloßfeld et al.: **"Consistent estimation of geodetic parameters from SLR satellite constellation measurements"*** J Geodesy (in review)

Thermospheric density estimation with SLR

- Modelling of the drag acceleration in DOGS-OC

$$\boldsymbol{a}_D = -\frac{1}{2} \cdot f_s \cdot \frac{A_{\text{ref}}}{m} C_D \, \rho \, v_{\text{rel}}^2 \, \hat{\boldsymbol{u}}_D \qquad (1)$$

- We estimate temporal highly resolved scaling factors f_s (example: 49 day interval)



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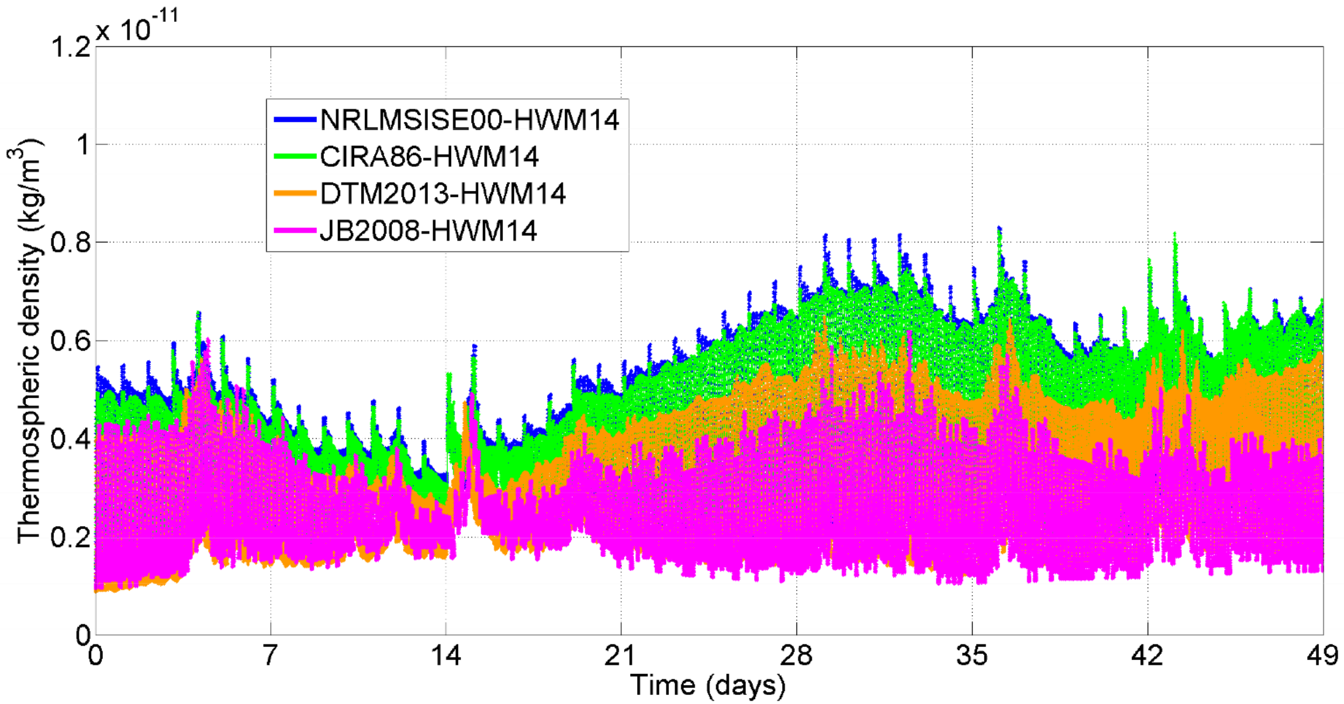

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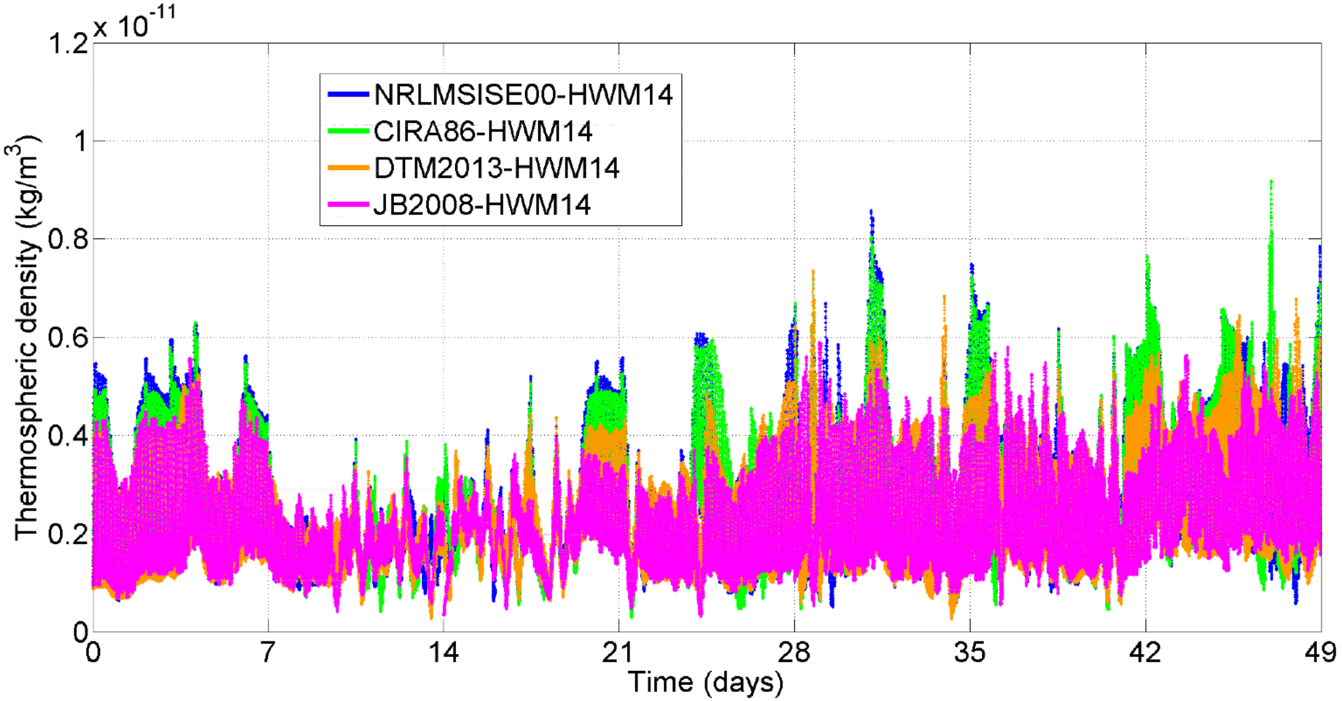

Thermospheric density estimation with SLR

- Modelling of the drag acceleration in DOGS-OC

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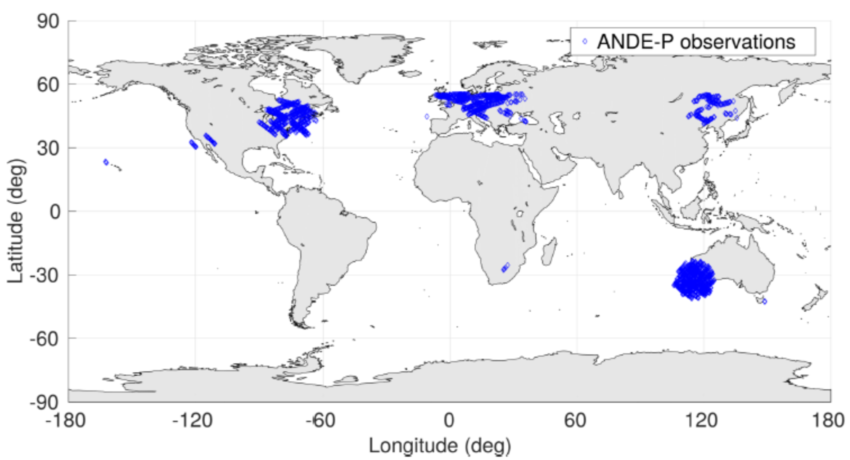
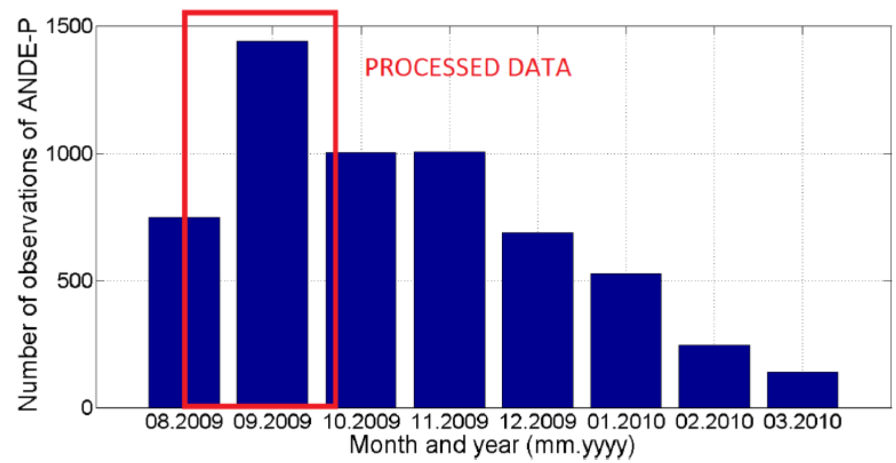
- We estimate temporal highly resolved scaling factors f_s
- Problem: bad global and temporal coverage





Panzetta et al.: **"Towards thermospheric density estimation from SLR observations of LEO satellites - A case study with ANDE-Pollux satellite"** J Geodesy (in review)

Satellite constellations for TVG and thermospheric density estimation

- <u>satellites used for TVG determination</u>
  - different inclinations and altitudes
  - frequent tracking required (day-/nighttime, ascending/descending)
  - still issues with Ajisai CoM
  - 11-satellite solution performs best
- <u>satellites used for thermospheric density estimation</u>
  - satellites at altitudes lower than 500 km
  - only short mission durations due to satellite subsidence
  - only few normal points since satellites are not easy to track