Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

Evaluating the potential of combined SLR gravity field solutions

Mathis Bloßfeld[1], A. Jäggi[2], A. Kehm[1], U. Meyer[2], and K. Sosnica[3]

[1] Technische Universität München, Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)

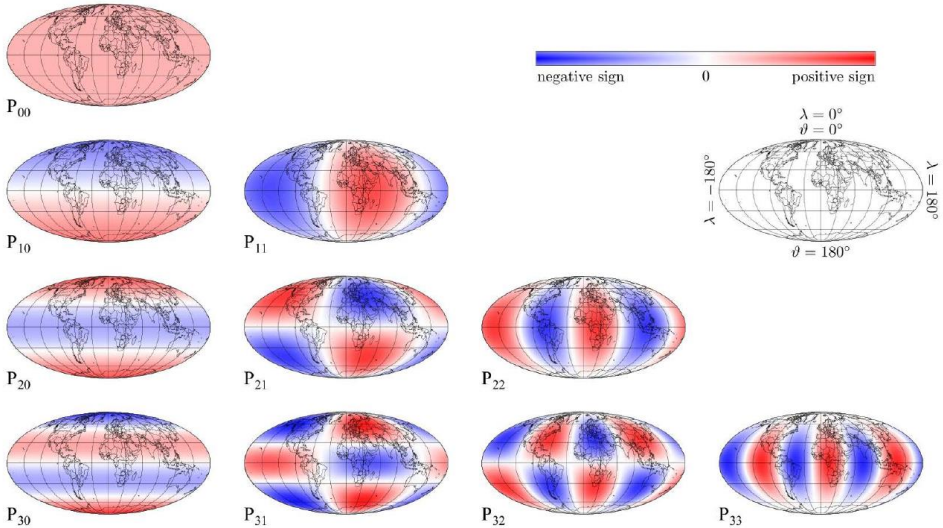
[2] Astronomical Institute, University of Bern (AIUB)

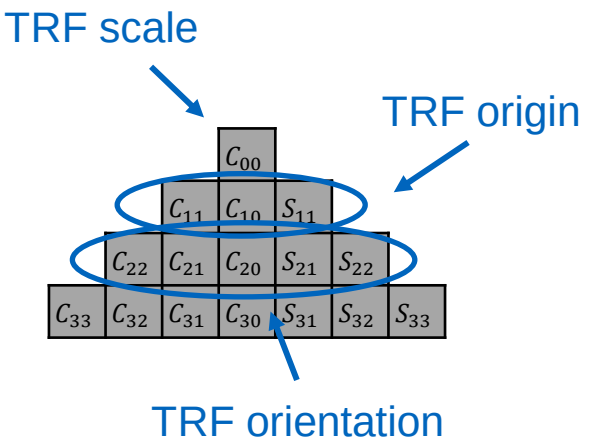
[3] Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences

21st International Workshop on Laser Ranging
Canberra, Australia, 2018-11-05

Motivation

- Up to now, the ILRS routinely provides solutions containing station coordinates and EOP
- Moreover, SLR is the unique technique to realize the **ITRF origin** and, together with VLBI, the **ITRF scale**
- SLR is also sensitive to the Earth gravity field





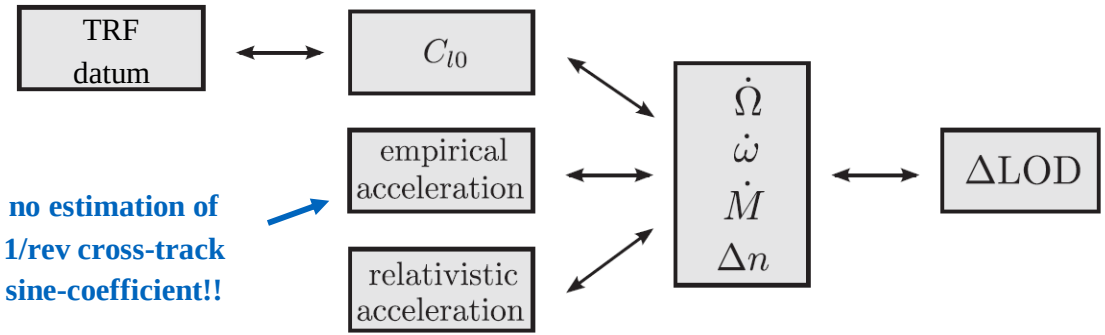
Motivation

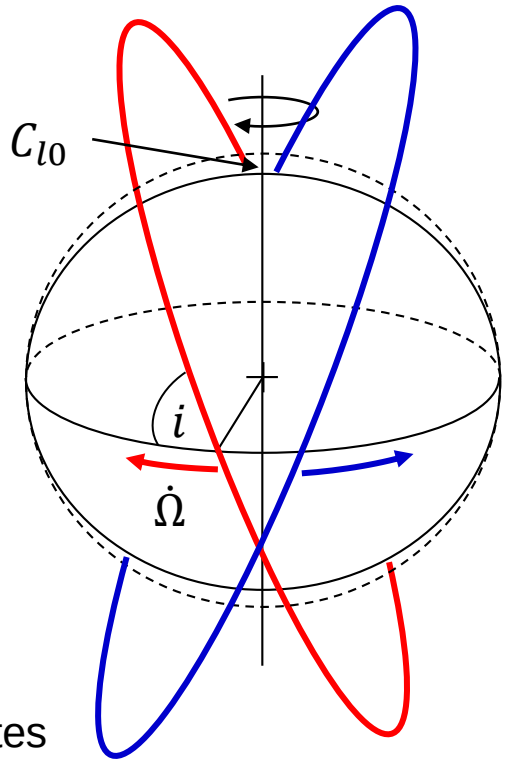
- SLR is the unique geodetic space technique to determine the very low-degree spherical harmonics of the Earth's gravity field **with high accuracy**
- Institutions which currently provide publicly available **SLR-only gravity field time series**
  - DGFI-TUM (Germany)
  - AIUB (Switzerland)
  - BKG (Germany)
  - GFZ (Germany)
  - WUELS (Poland)
  - OEAW (Austria)
  - GRGS (France)
  - Hitotsubashi University (Japan)
  - NASA GSFC (USA)
  - CSR (USA)

Is there a need for a combined SLR gravity field solution?

Motivation

- **Yes, there is!** → combined product should be beneficial!
- ILRS-ASC pilot project: inclusion of LARES as 5th satellite for routine POS+EOP solution → gravity field needs to be estimated!
- BUT: parameters are correlated!





- Use **satellite constellation** + **fix TRF/EOP** → best gravity estimates

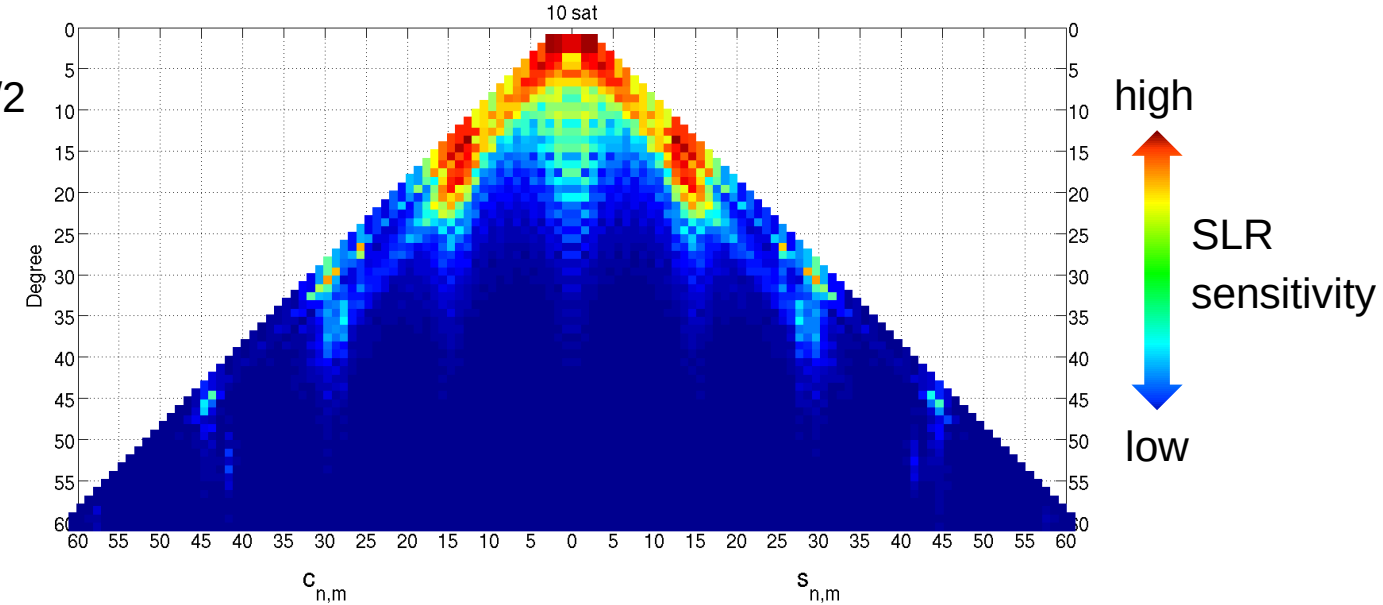
Combination scenarios

- **DGFI-TUM**/**AIUB**/**WUELS**: combination of multiple laser-tracked satellites at NEQ-level
  - combination of up to 11 satellites (ILRS setup + additional 7 satellites)
  - usage of common standards (taken from EGSIEM-initiative)
- **DGFI-TUM**: combination of SLR-only time series at NEQ-level
  - DGFI-TUM + AIUB + WUELS multi-satellite SLR NEQs (distributed via SINEX)
  - relative weighting using VCE
  - test period: 2006 - 2008
- **AIUB**: combination of GRACE (K-band/GPS) and SLR at NEQ-level
  - refined combination instead of simple replacement of C_{20}
  - different weights used for SLR in combination with GRACE (**K-band**) and GRACE (**GPS**)

Combination of multiple satellites - Sensitivity of SLR solutions

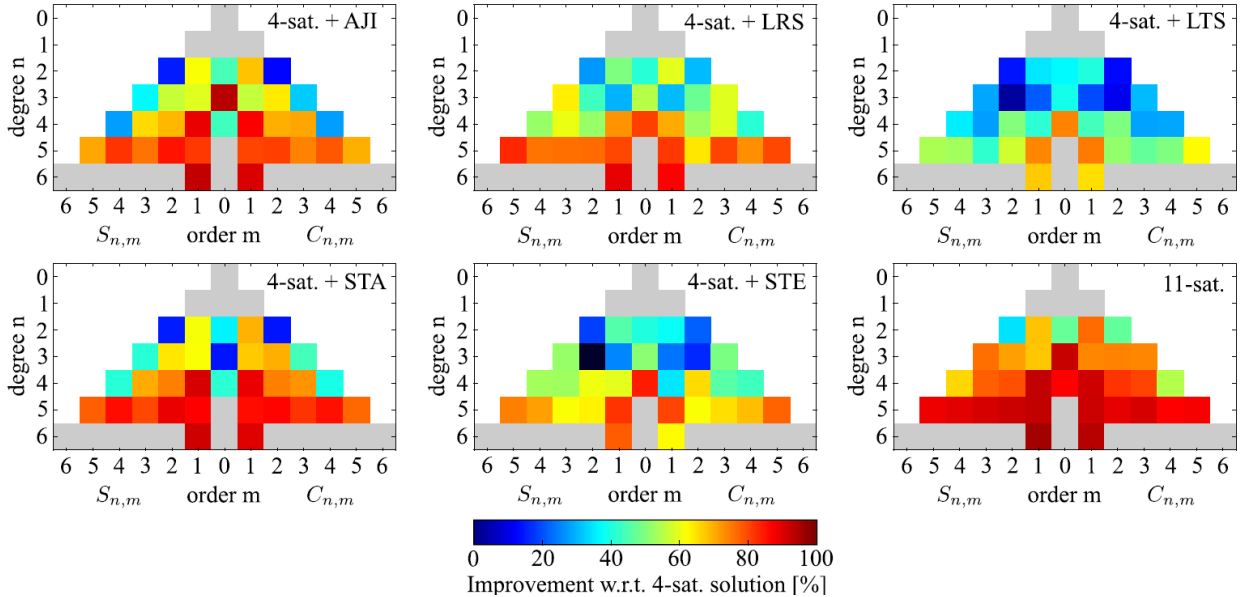
- Test by Floberghagen (2002) → sensitivity of SLR-only NEQs on spherical harmonics

LA 1/2
+ ET 1/2
+ AJI
+ STA
+ STE
+ LTS
+ BTS
+ LRS



Combination of multiple satellites - Parameter improvements

- Significant improvements (**up to 100%**) can be achieved if multiple satellite are combined!



Combination of SLR-only time series - used standards

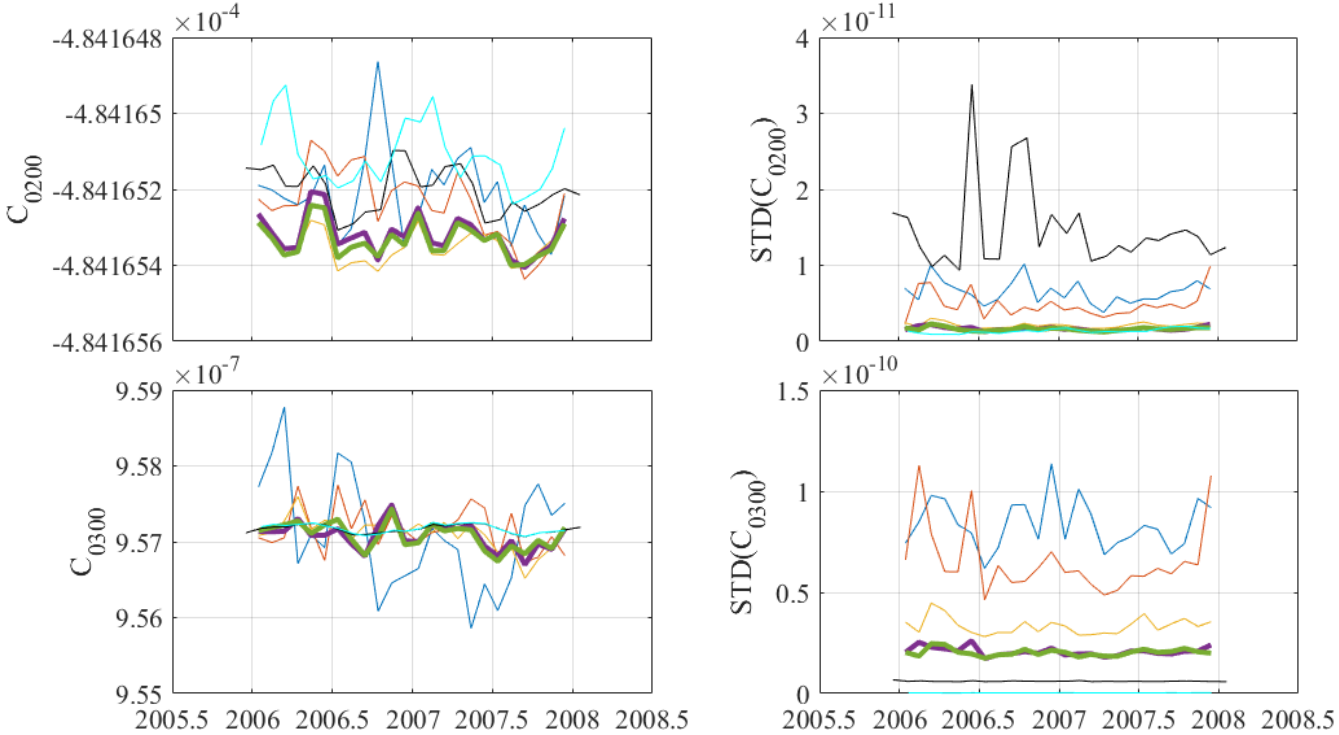
- Agreement on commonly used standards (some background models are not specified to avoid their errors mitigate into the combined solution)

institution	estimate d/o 1 terms	maximum d/o	apply AOD at observation level	non-unify a priori dynamic models	constrain GFCs	number of satellites	time span
DGFI-TUM	no	selection <	possible (gravity +	EOT11a	unconstrained	13	2006 -
AIUB	**(yes)**	**10**	**any NT-L model applied (gravity + loading)**	**any**	**unconstrained**	**4 - 13**	**2006.0 – 2008.0**
WUELS	?	10	loading)	EOT11a	?	6	2008

- Relative weighting of time series is done static (equal weighting) and by Variance Component Estimation (**VCE**)
- Results are compared to **EGSIEM** and **ITSG (Graz)** time series (both GRACE)

Combination of SLR-only time series - results

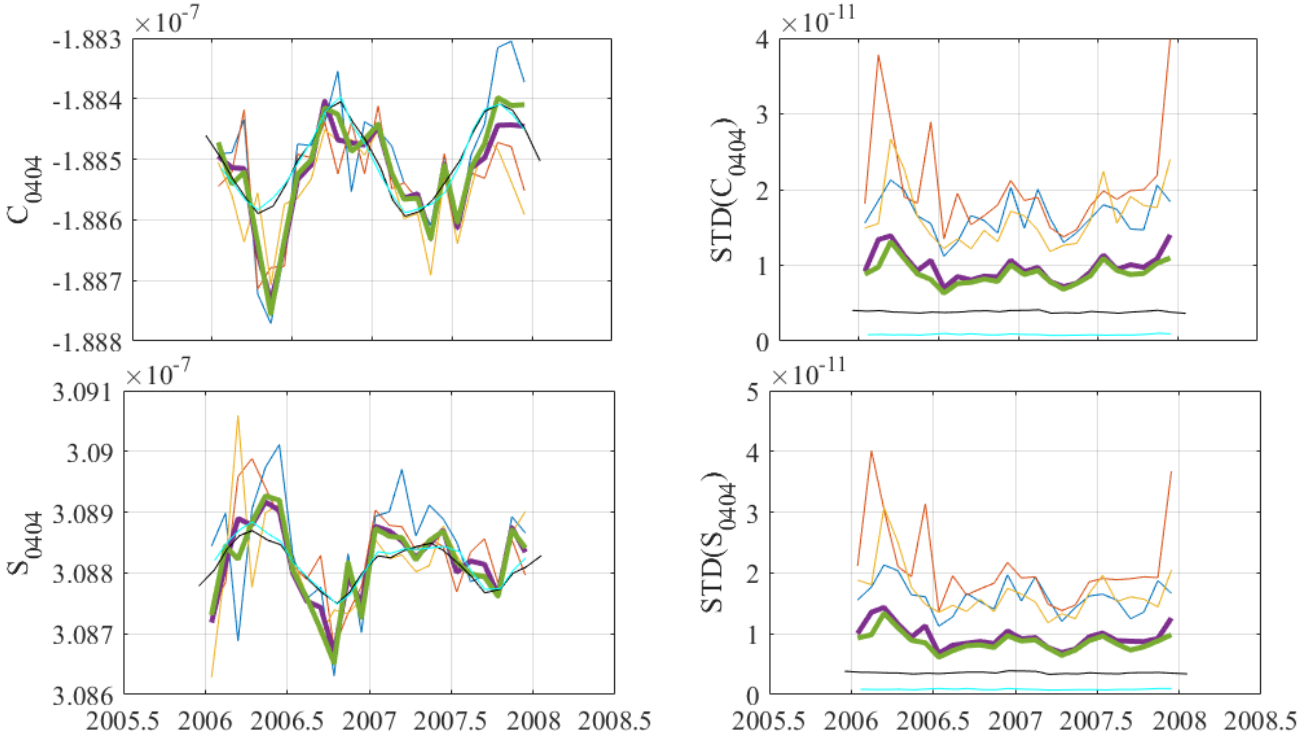
- Combined time series show reduced scatter and more stable STDs



DGFI-TUM AIUB WUELS comb. (static) comb. (VCE) EGSIEM ITSG-GRACE 2016

Combination of SLR-only time series - results

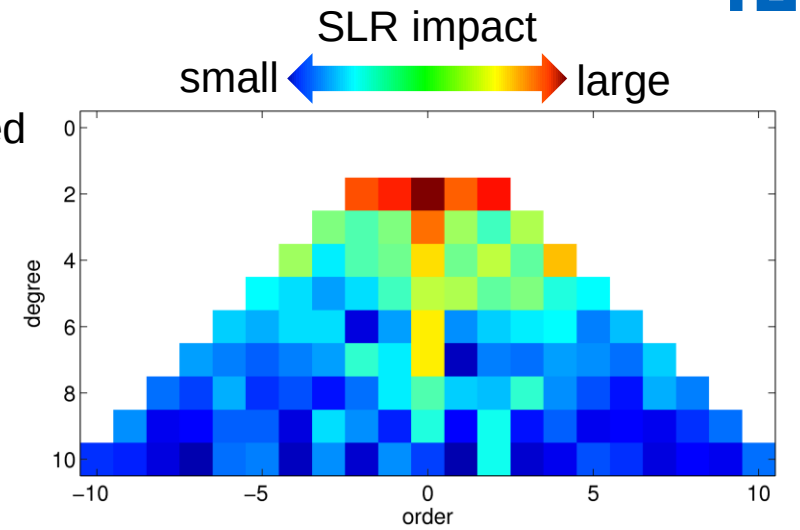
- Good agreement of annual signal in C_{44} in all SLR-only solutions

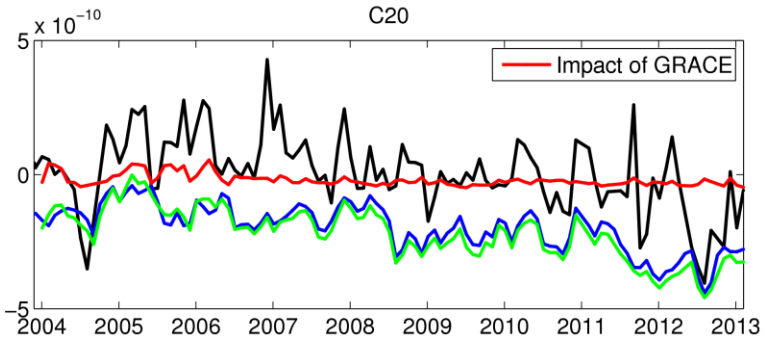


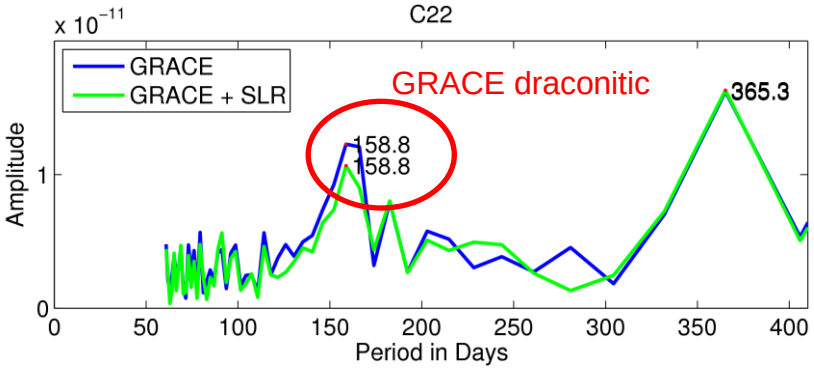
DGFI-TUM AIUB WUELS comb. (static) comb. (VCE) EGSIEM ITSG-GRACE 2016

GRACE (K-band) + SLR

- GRACE (**K-band**) measurements are combined with SLR observations at the NEQ-level
- Relative weight of SLR: 10^{-10} (diff. obs. types)
- Only degree-2 terms are influenced by SLR
- C_{20} is dominated by SLR
- C_{22} draconitic signal reduced



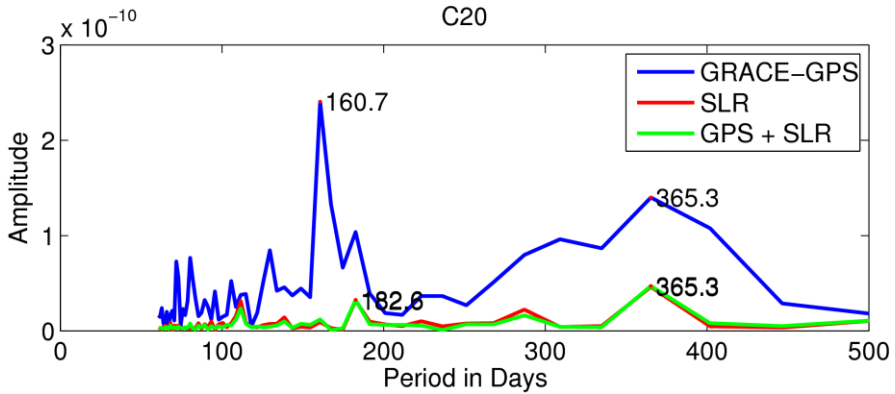




GRACE SLR GRACE+SLR SLR-(GRACE+SLR)

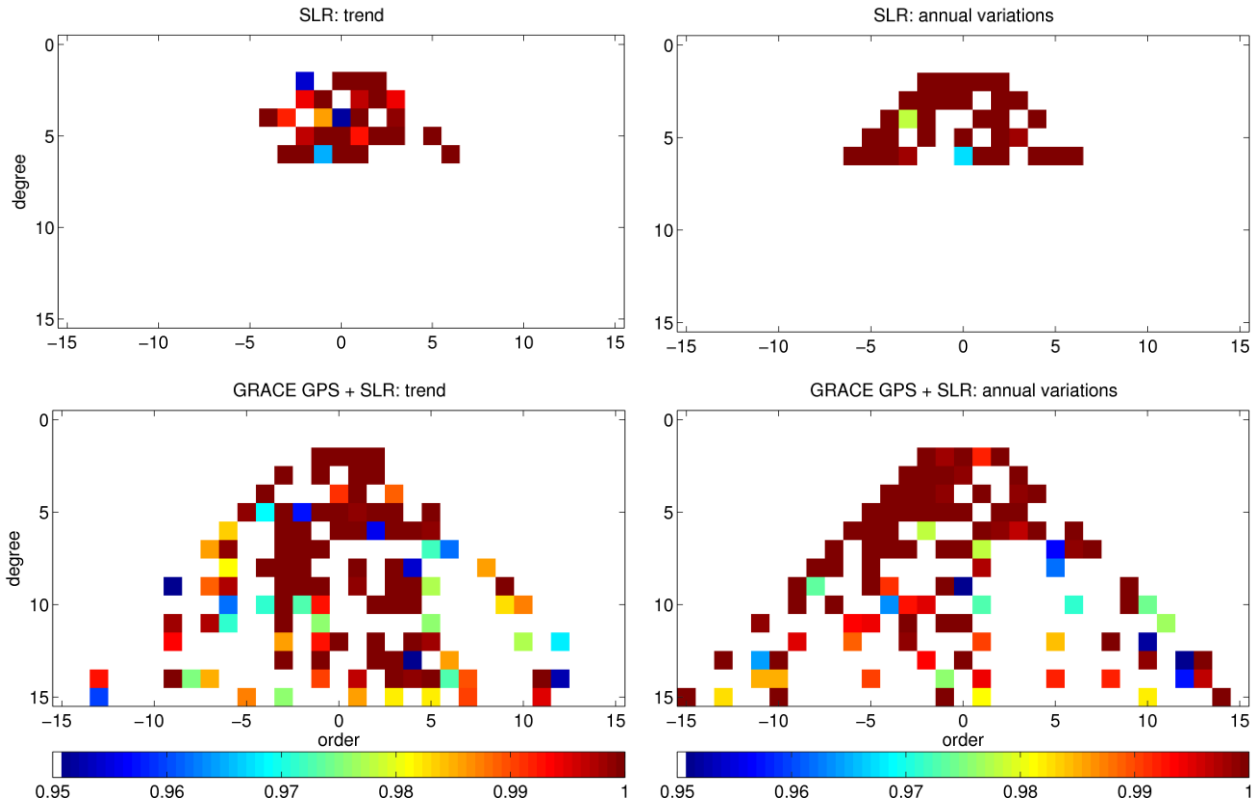
GRACE (GPS) + SLR

- GRACE (**GPS**) measurements are combined with SLR observations at the NEQ-level
- GRACE(**GPS**) was originally designed as “gap-filler” between GRACE and GRACE-FO
- Relative weight of SLR is 10^{-2}
- Artifacts in C_{20} at 160-day frequency are largely reduced
- Sensitivity for secular and seasonal variations is slightly increased at low degrees



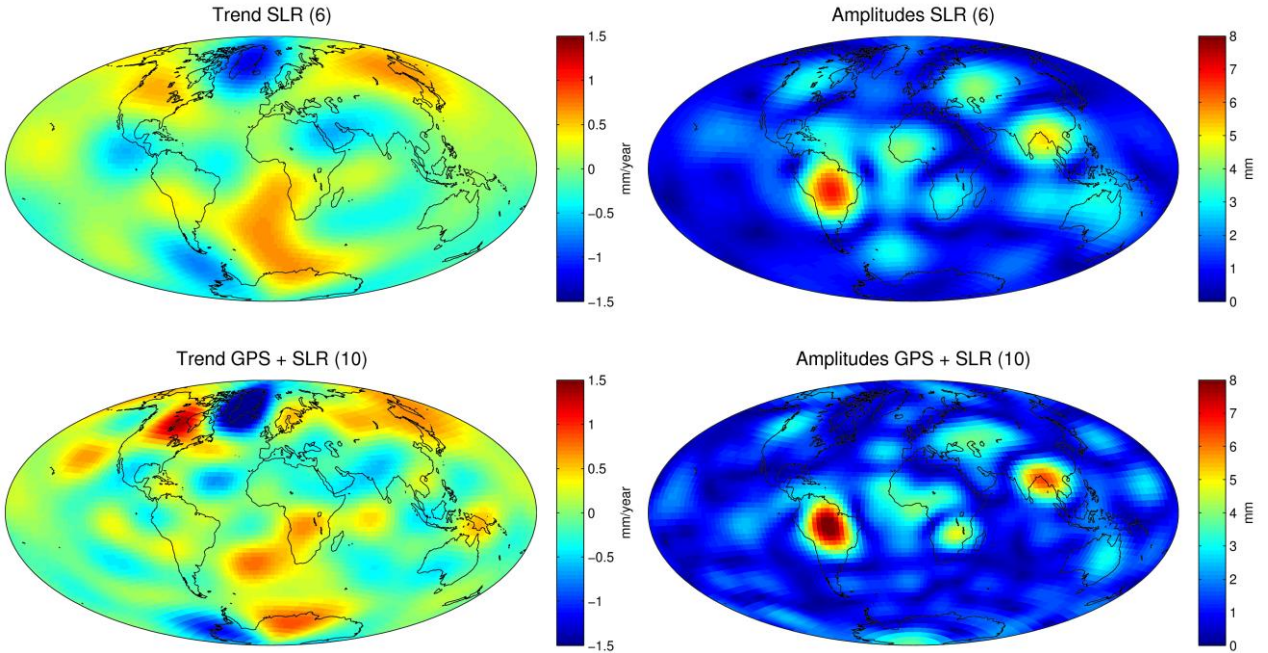
GRACE (GPS) + SLR

- Sensitivity analysis shows clearly increased sensitivity for GRACE (**GPS**) + SLR solution
- SLR-only: up to d/o 6
- GRACE (**GPS**) + SLR: up to d/o 15



GRACE (GPS) + SLR

- Analysis of signal content
- Localization of mass variations (in geoid heights) also slightly improves in GRACE (GPS) + SLR combination
- More detailed analysis of these trends will be shown by Meyer et al. (next talk)



Conclusions

- ILRS-ASC pilot project: including LARES as a 5th satellite in routine POS+EOP solution
  → Estimation of low degree spherical harmonics necessary
- If **more satellites** are included, the sensitivity of SLR to the gravity field coefficients is increased significantly (**up to 100%**)
- **Diversity of geophysical background models** beneficial → systematic errors are reduced
- SLR-only time series show good agreement → combination results in **smaller scatter** and **smoother STDs**
- C_{20} is dominated by SLR in combination with GRACE (**K-band**)
- If only GRACE (**GPS**) is combined with SLR, SLR clearly helps to increase sensitivity to the Earth's gravity field

Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

Evaluating the potential of combined SLR gravity field solutions

Mathis Bloßfeld[1], A. Jäggi[2], A. Kehm[1], U. Meyer[2], and K. Sosnica[3]

[1] Technische Universität München, Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)

[2] Astronomical Institute, University of Bern (AIUB)

[3] Institute of Geodesy and Geoinformatics, Wrocław University of Environmental and Life Sciences

21st International Workshop on Laser Ranging
Canberra, Australia, 2018-11-05