Combined SLR-derived gravity fields for EGSIEM

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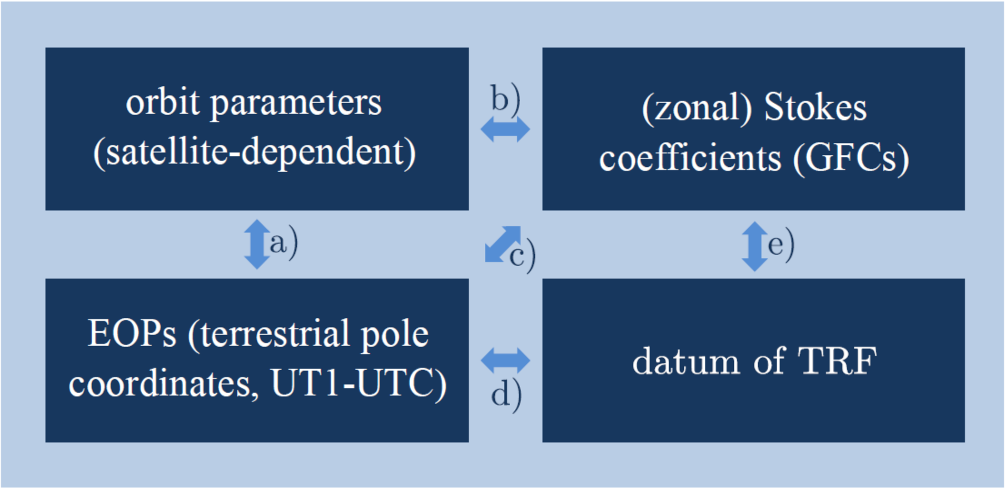
EGSIEM consortium meeting
Bern, Switzerland, 20 January 2017

Motivation

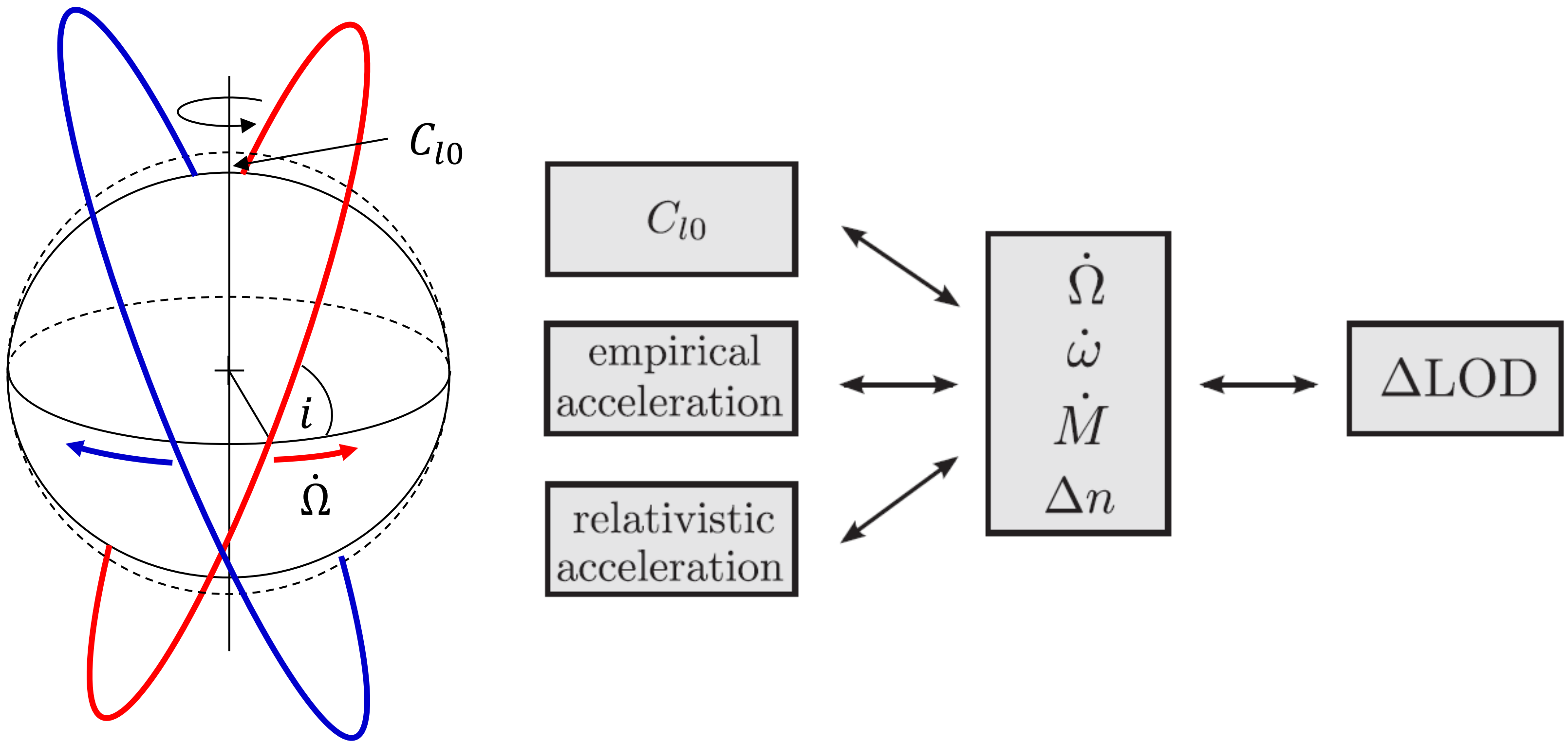
- Due to the high sensitivity of SLR observations to the fundamental geodetic parameters, correlations falsify reliable estimates



- Correlations related to Stokes coefficients
  - b) correlations of orbit parameters and Stokes coefficients
  - c) correlations of LOD and C_{l0}; x_p/y_p with C_{21}/S_{21}
  - e) correlation of TRF scale with C_{00}; origin with $C_{10}/C_{11}/S_{11}$; orientation with $C_{21}/S_{21}/C_{22}/S_{22}$

Motivation

- ❑ Single-satellite solution: high correlation of various parameters (especially between zonal coefficients, satellite orbit parameters and LOD)



- ➢ Multi-satellite solution (MSS): de-correlation of parameters due to combination of inclinations (e.g. C_{l0} and Ω) → reliable estimates of zonal coefficients

SLR decorrelation and sensitivity tests (I)

- In order to obtain reliable estimates of the Stokes coefficients, it is essential to de-correlate the orbital parameters and the coefficients of the Earth's gravitational field.

- **Test 1**: De-correlation of orbit parameters and C_{20} (taken from Bloßfeld et al., 2015)

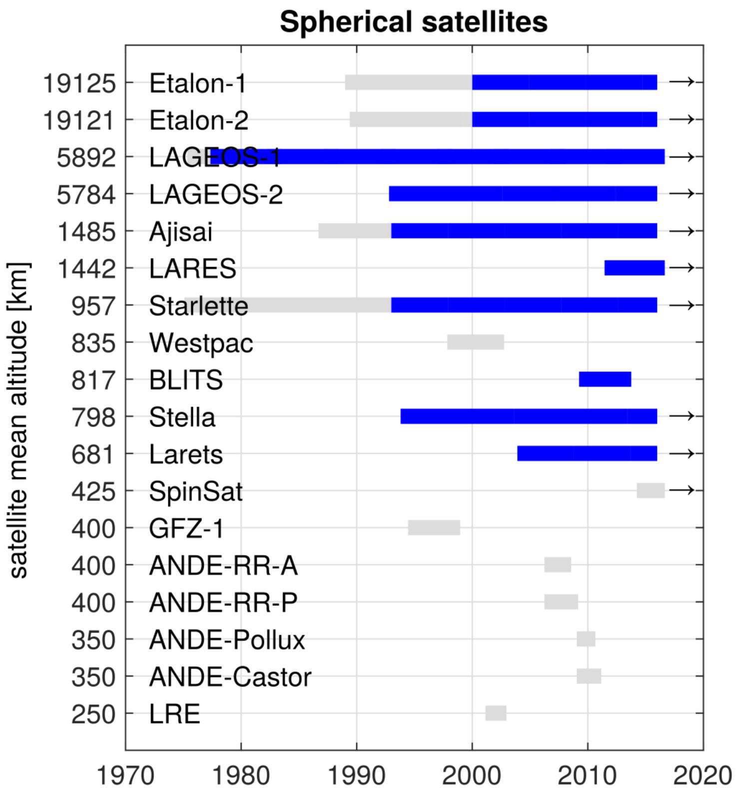


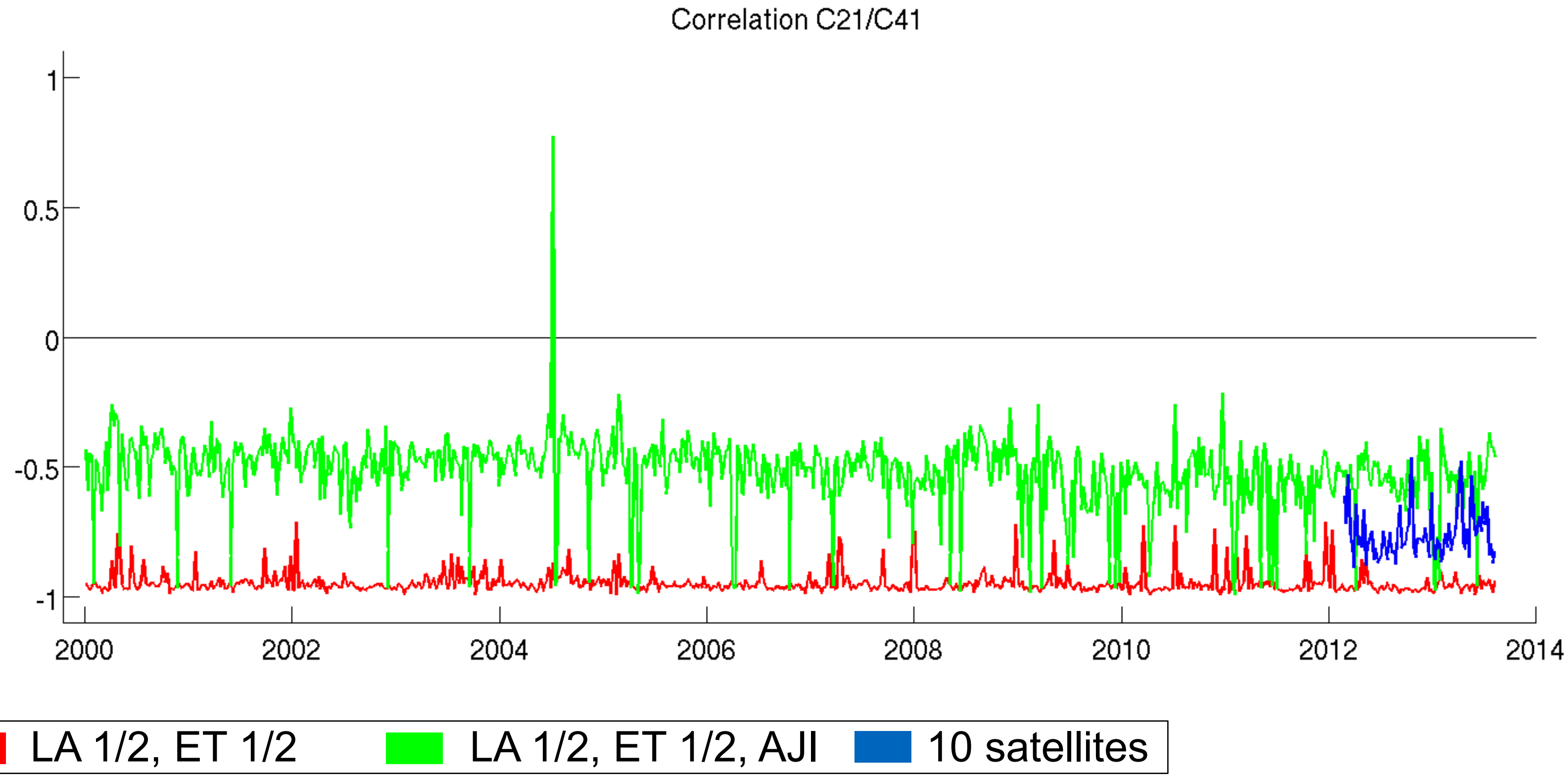
Table 8 Correlation coefficients of C_{20} and the right ascension of the ascending node of LA1 (Ω_{LA1}) at CW 51 of 2012.

solution	correlation coefficient
LA1	1.00
2-sat.	0.44
4-sat.	0.44 (current ILRS setup)
4-sat. + AJI	0.24
4-sat. + STA	0.28
4-sat. + STE	0.31
4-sat. + LTS	0.41
4-sat. + BTS	0.43
4-sat. + LRS	0.24 (future ILRS setup)
6-sat.	0.24
7-sat.	0.22
8-sat.	0.21
9-sat.	0.21
10-sat.	0.08

SLR decorrelation and sensitivity tests (II)

- In order to obtain reliable estimates of the Stokes coefficients, it is essential to de-correlate the orbital parameters and the coefficients of the Earth's gravitational field.

- **Test 2**: De-correlation of different Stokes coefficients using multi-satellite SLR solution



SLR decorrelation and sensitivity tests (III)

- ❑ In order to obtain reliable estimates of the Stokes coefficients, it is essential to de-correlate the orbital parameters and the coefficients of the Earth‘s gravitational field.

- ➢ **Test 3**: Sensitivity analysis w.r.t. Stokes coefficients

- ➢ This test is based on the PhD thesis of R. Floberghagen (2002);

$$[0; 1] \, \epsilon \, diag(N^{-1}N) = (A^T PA + \alpha K)^{-1}(A^T PA)$$

- ➢ **Important:** sensitivity coefficient equal to one means that the Stokes coefficient is fully determinable from the observations

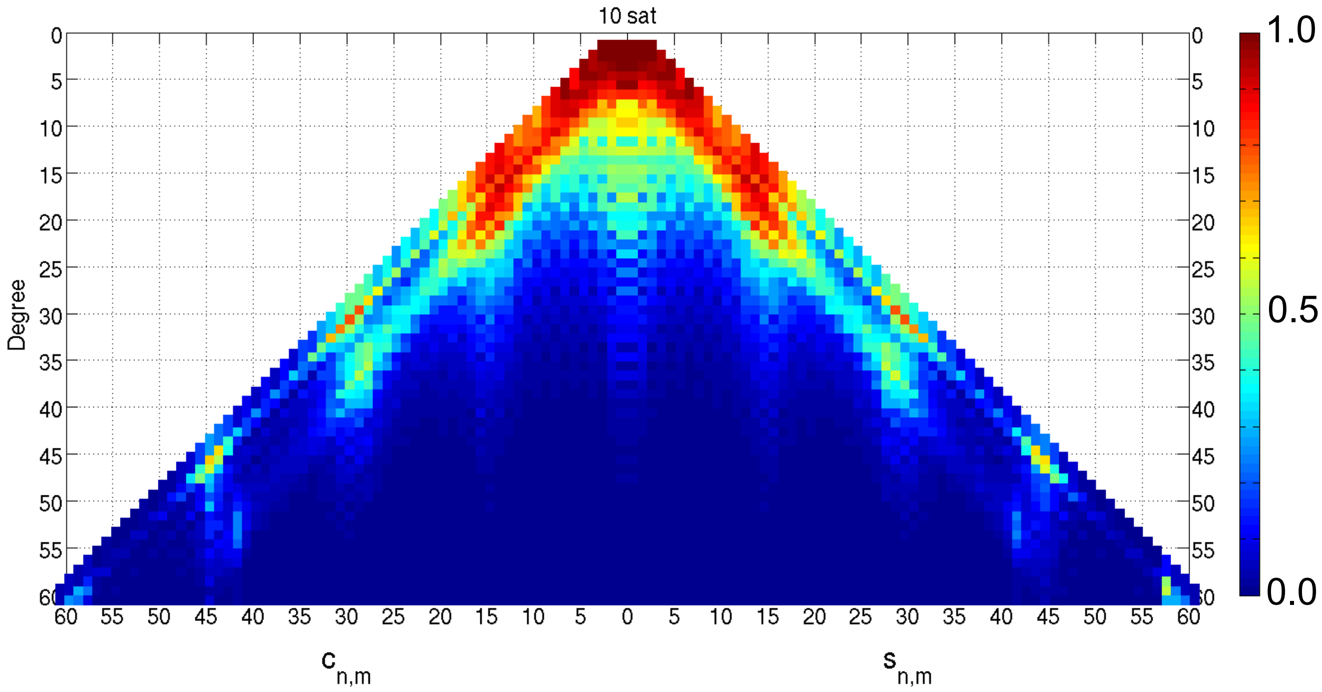
- ➢ **BUT:** some coefficients are highly correlated (Haberkorn et al., 2014) and therefore only a linear combination of them (Kaula, 1966) can be estimated (e.g., even zonal low degree Stokes coefficients)

SLR decorrelation and sensitivity tests (III)

- ❑ In order to obtain reliable estimates of the Stokes coefficients, it is essential to de-correlate the orbital parameters and the coefficients of the Earth‘s gravitational field.

- ➢ **Test 3**: Sensitivity analysis w.r.t. Stokes coefficients

LA 1/2
+ ET 1/2
+ AJI
+ STA
+ STE
+ LTS
+ BTS
+ LRS
+ JA2



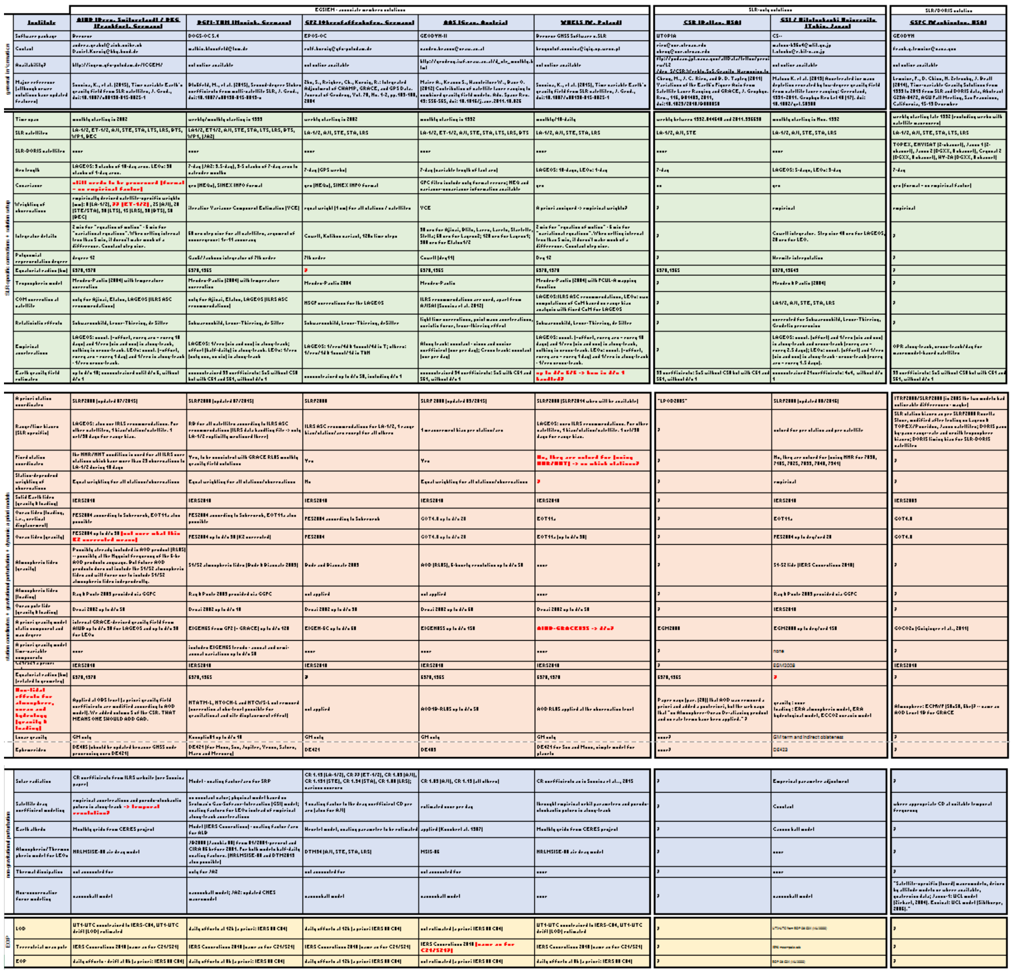
Possible contributions to EGSIEM (by DGFI-TUM)…

- DGFI-TUM can provide SLR normal equations (NEQs) …
  … which comprise SLR observations to **numerous spherical** and/or **non-spherical satellites**
  … which cover the time interval from **1978 until 2017** (laser data)
  … which are based on various arc lengths (**weekly, 2-weekly, monthly**)
  … which include station coordinates/EOP/**Stokes coefficients**/etc…
  … which are based on **numerous different a priori models** (solid Earth/ocean tides, non-tidal loading effects, relativistic effects, etc…

- BUT: not only DGFI-TUM is able to contribute to EGSIEM with SLR data!
- A. Jäggi invited a group of (European) institutes which have SLR expertise to contribute to EGSIEM

EGSIEM SLR processing standards

- ❑ in order to be most consistent with the EGSIEM processing standards for GRACE, we compiled a table summarizing all existing SLR solution setups



institutions:

- ➢ DGFI-TUM (Germany)
- ➢ AIUB/BKG (Switzerland/Germany)
- ➢ GFZ (Germany)
- ➢ WUELS (Poland)
- ➢ OEAW (Austria)
- ➢ GRGS (France)

- ➢ Hitotsubashi University (Japan)

for comparison:

- ➢ NASA GSFC (USA)
- ➢ CSR (USA)

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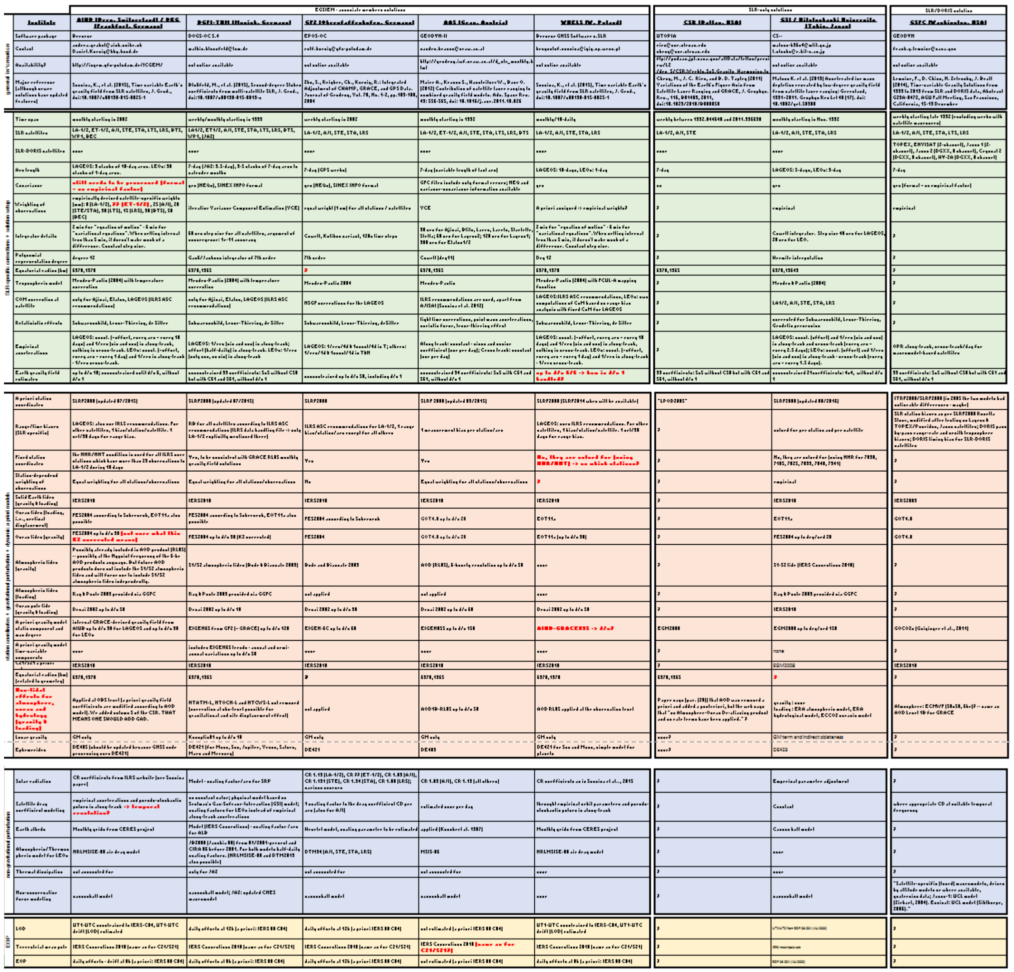

advantageous for combination

- 5+1 SLR software packages

main fields (colored) in the comparison

- general information
- SLR-specific corrections and solution setup
- station coordinates, gravitational perturbation, dynamic a priori models
- non-gravitational perturbations
- EOP

EGSIEM SLR processing standards

- in order to be most consistent with the EGSIEM processing standards for GRACE, we compiled a table summarizing all existing SLR solution setups

- **General information**
  - institution, software package, contact, online availability, major reference

- **SLR-specific corrections and solution setup**
  - time span, SLR (+DORIS) satellites, arc length, covariance information, weighting of observations, integrator details (step size), polynomial representation degree, tropospheric model, CoM correction at satellite, applied relativistic effects, applied empirical accelerations, Earth gravity field estimates

- **Station coordinates, gravitational perturbation, dynamic a priori models**
  - a priori station coordinates, range/time biases (SLR specific), applied constrain on station coordinates, station-dependent weighting of observations, solid Earth tides (gravity + loading), ocean tides (gravity + loading), atmospheric tides (gravity + loading), ocean pole tides (gravity + loading), a priori gravity model (static + time-variable part), C21/S21 a priori values, equatorial radius, non-tidal loading corrections (gravity + loading), lunar gravity, ephemerides

EGSIEM SLR processing standards

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- **Non-gravitational perturbations**
  - solar radiation, satellite drag modelling, Earth albedo, atmospheric/ thermospheric model for LEOs, thermal dissipation, used satellite macromodels

- **EOP**
  - LOD, terrestrial mean pole, terrestrial pole

- rough cross-checking with GRACE processing standards (together with U. Meyer)

EGSIEM SLR processing standards

- potential important (critical) issues w.r.t. EGSIEM GRACE processing standards

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	maximum time span
DGFI-TUM	no	5 + C61/S61	possible (gravity + loading)	EOT11a	unconstrained	13	1978.6 – now
AIUB/BKG	no	10	possible (gravity + loading)	EOT11a	constrained for d/o > 6	12	2002.0 – now
GFZ	yes	50	not applied	FES2004	unconstrained	6	2002.0 – now
WUELS	?	6	possible (gravity + loading)	EOT11a	?	6	?
OEAW							
GRGS							
	(yes)	**10 (in 1st iteration) and more**	**any NT-L model applied (gravity + loading)**	**any**	**unconstrained**	**4 - 13**	**2006.0 – 2008.0**
Hitotsubashi University	no	4	loading (ERA -> ATM/ CWS, ECCO -> OCN)	EOT11a	unconstrained	6	1992.8 – now
CSR	no	5 + C61/S61	not clear what was applied	?	unconstrained	4	1992.8 – 2011.4
NASA GSFC	no	5 + C61/S61	ECMWF based	GOT4.8	unconstrained	7 (SLR) + 6 (DORIS)	1992.8 – now

Roadmap for SLR contribution to EGSIEM

- How will the SLR contribution to EGSIEM be organized?

  - Collect solution setups of SLR ACs and discuss potential/necessary unification at EGSIEM meeting in Bern (**mid of January 2017**) → send SLR processing standards to A. Jäggi

  - 1st reprocessing of singular NEQs of 2006/2007 using common standards and submission (SINEX file with NEQ and SOLUTION/ESTIMATE block) to DGFI-TUM (**end of February 2017**)

  - Generation of solutions and 1st comparisons; potential re-iteration with ACs (**end of April 2017**)

  - 2nd reprocessing (if necessary) and submission of final singular NEQs to DGFI-TUM (**mid of June 2017**)

  - Final evaluation of solutions and submission of individual AC SLR-NEQs to AIUB (including weight suggestions) for combination at NEQ level with GRACE (**end of July 2017**)

  - (Extension of time series to maximum time span)

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