Deutsches Geodätisches Forschungsinstitut (DGFI-TUM)
Technische Universität München

The Role of Laser Ranging for the Global Geodetic Observing System GGOS

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The Global Geodetic Observing System (GGOS)

GGOS …

- is the geodetic observing system of the **International Association of Geodesy** (IAG)
- focuses on **an order of magnitude improvement** in the quality of fundamental geodetic products (**essential geodetic variables**)
- supports the **improvement of the geodetic ground-** and **space-based infrastructure**
- **integrates** the geometric and gravimetric aspects of geodesy
- addresses important **geophysical questions** and **societal needs** (e.g., sea level rise / disaster management / natural hazards)

The main goal of GGOS is to provide **accurate geodetic products** with an accuracy of **1 mm** and **0.1 mm/yr** to the users

The Global Geodetic Observing System (GGOS)

- „3 pillars“ of geodesy:

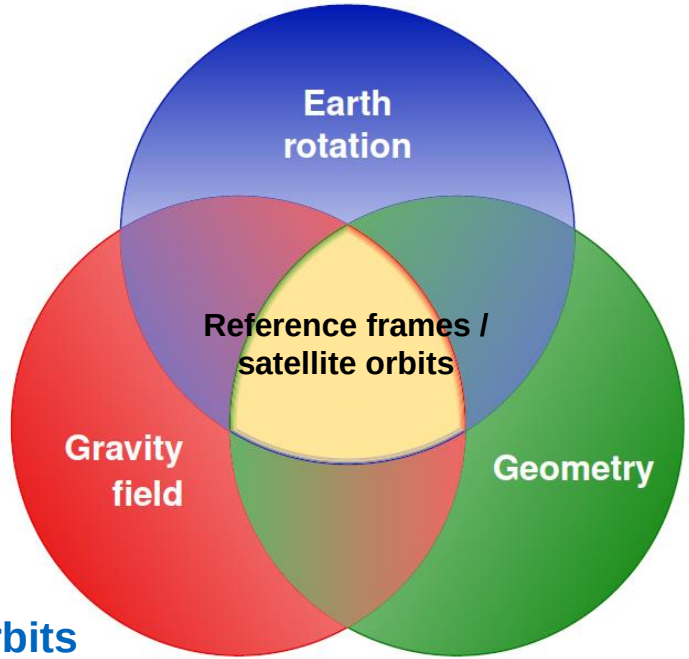
IERS products

Geometry and its kinematic
Shape of the Earth and its variation

Orientation and rotation
Rotation of the Earth and its variation

no formal IAG products

Gravitational field
Static and time-variable Earth’s gravitational field



[acc. Rummel, 2000; Plag & Pearlman, 2009]

- Prerequisite for the integration:
  highly accurate reference frames and satellite orbits

The GGOS parameter space

Integration by GGOS

IERS/ IGFS	Geodetic and geophysical target parameters	VLBI	SLR	GNSS	DORIS	LLR	Altimetry	CHAMP, GRACE, GOCE, …
ICRF	Quasar coordinates	X						
	Satellite orbit parameters		X	X	X		X	
	Lunar orbit parameters					X		
EOP	Nutation	X	(X)	(X)	(X)	X		
	Polar motion	X	X	X	X	X		X
	UT1-UTC	X		(X)	(X)			
	Length of day	X	X	X	X	X		X
ITRF	Station coordinates / velocities	X	X	X	X	X	(X)	X
Gravity field, phys. heights	Center of Mass / Stokes coefficients of degree 2		X				(X)	X
	Earth's gravity field (Stokes coefficients with degree > 2)		X	(X)	(X)	(X)	X	X
	Sea level (e.g., SSH)						X	
Atm.	Thermosphere (density)	X	X	X	X		X	X
	Ionosphere (TEC)	X		X	X		X	X

+ others (e.g., SAR, terr./air-borne gravimetry)

GGOS - challenges

- non-common standards
- inter-technique biases

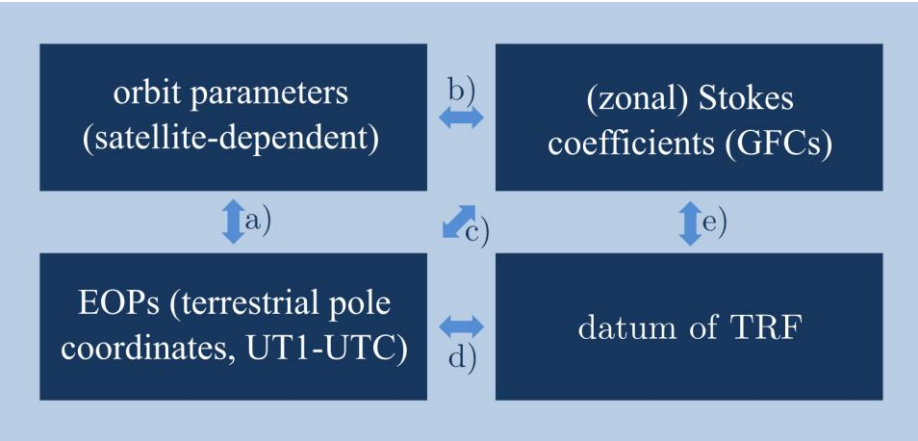
} **GGOS Bureau for Products and Standards (BPS)**

- non-homogeneous ground-based infrastructures

} **GGOS Bureau for Networks and Observations (BNO)**

- high correlations between different parameter groups

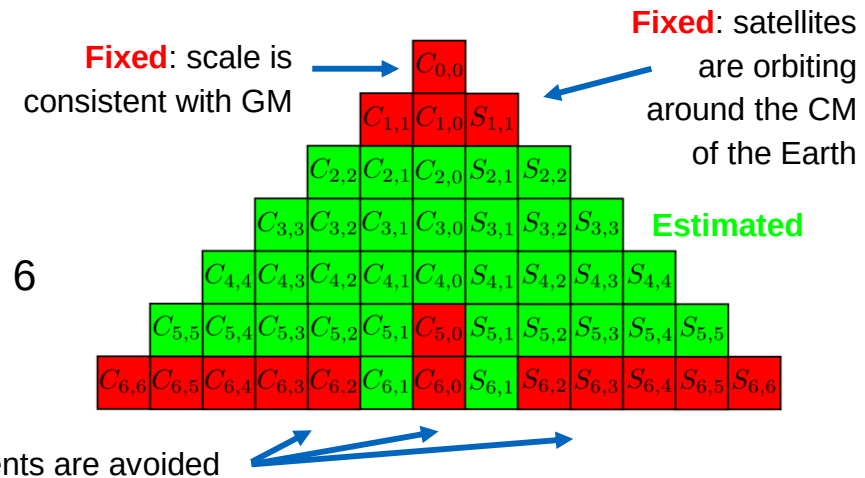
} **this talk**



[Bloßfeld et al., 2015]

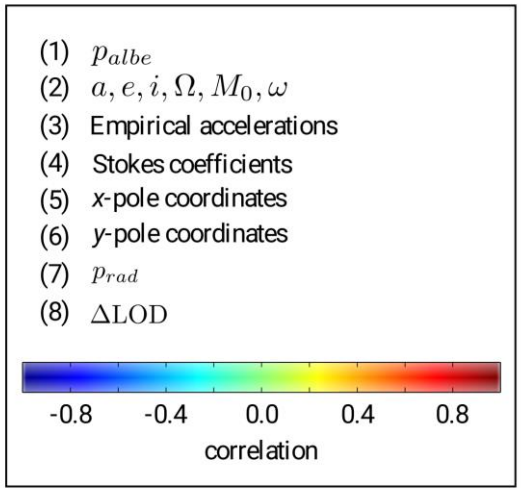
SLR – the tool to realize GGOS!

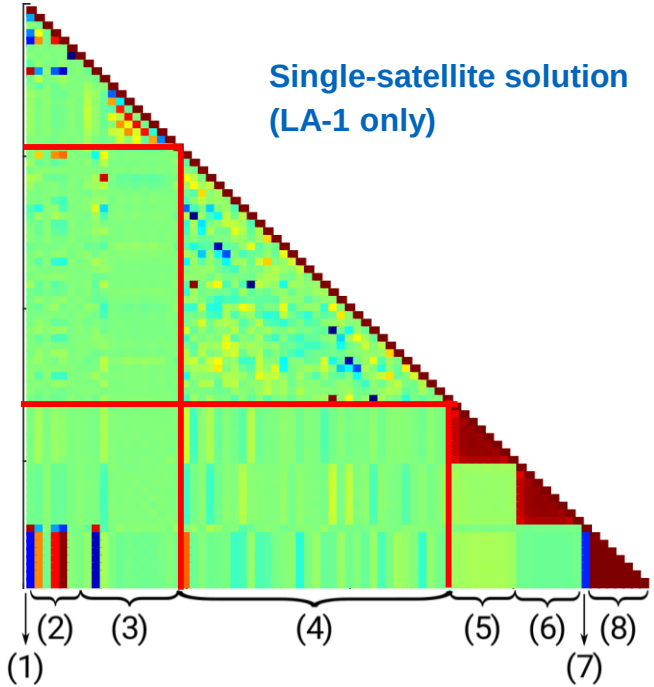
- SLR provides the ability to **study existing parameter correlations** since it is
  - sensitive to the reference frames (**TRF**) and **EOP**
  - sensitive to the long wavelengths of the **Earth's gravity field**
- **SLR multi-satellite constellation** solution can be used to evaluate potential
- Estimated parameters within this solution
  - Weekly 3-D station coordinates (TRF)
  - Daily Earth Rotation Parameter (x_p, y_p, ΔLOD)
  - Weekly Stokes coefficients up to degree/order 6



Parameter correlations

- Correlation matrix comprising orbit parameters (LA-1 only), GFC, and EOP (TRF not shown)





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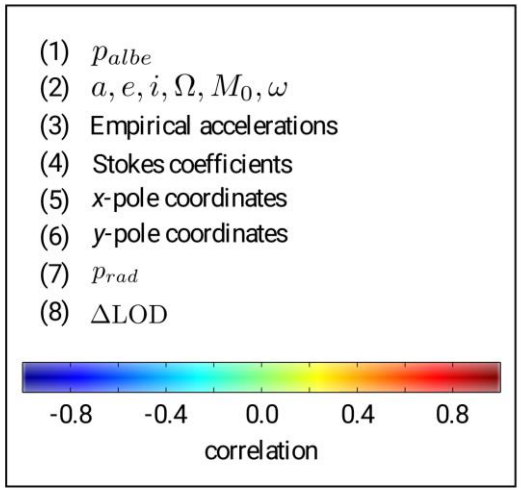

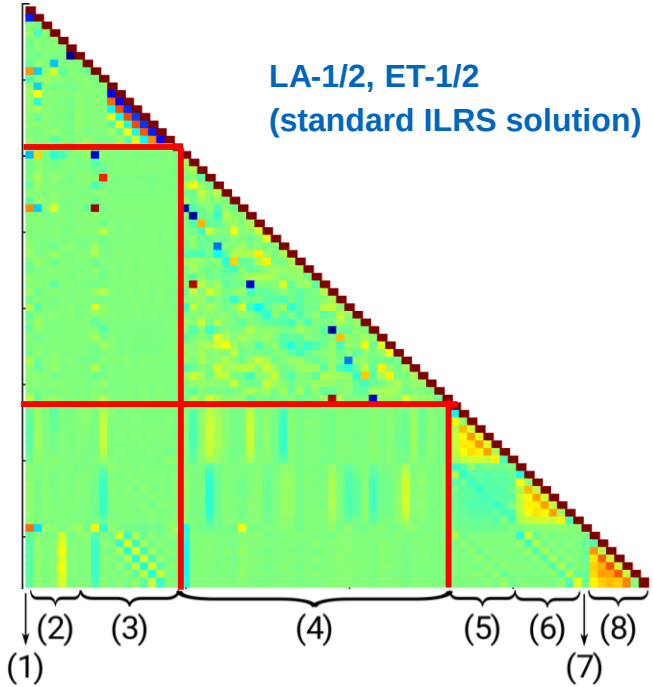

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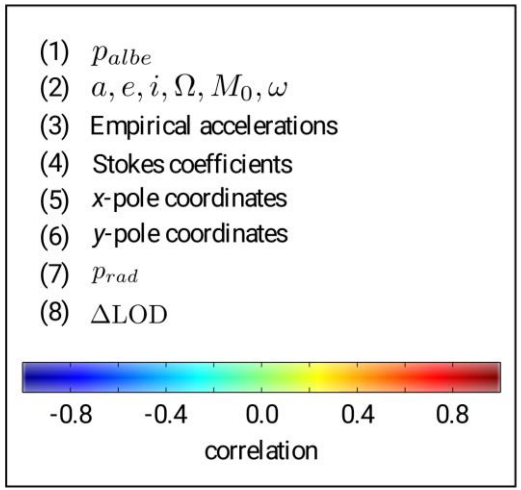
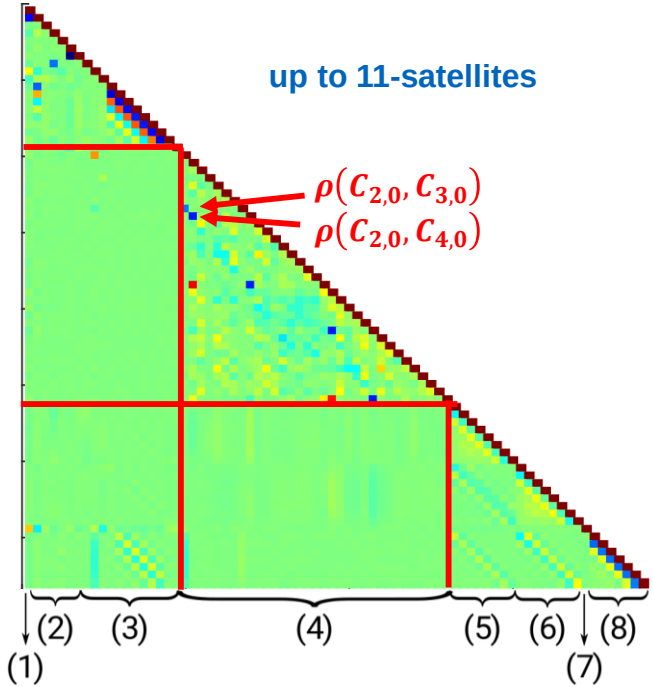
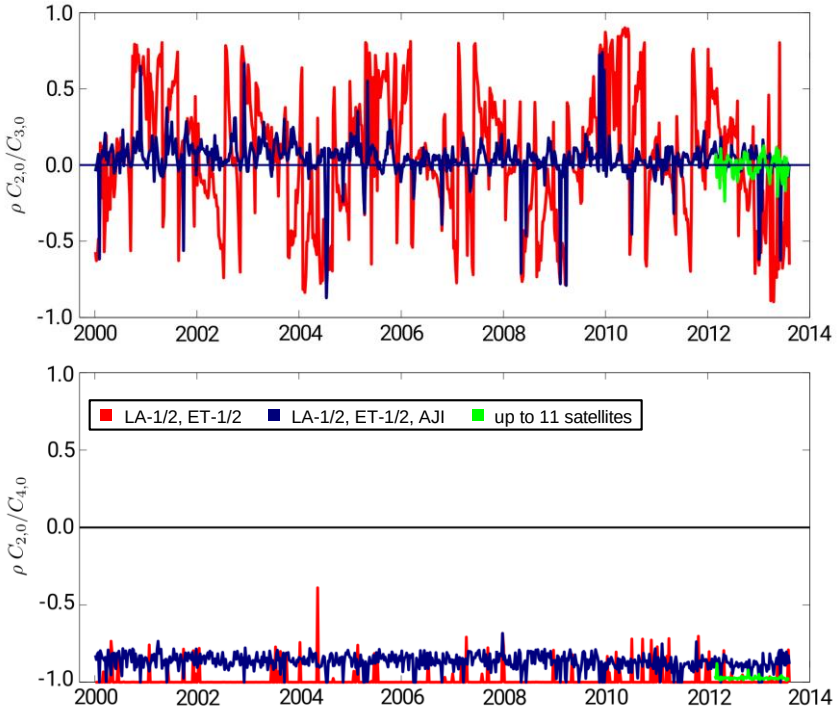




Parameter correlations

- Correlations between gravity field coefficients

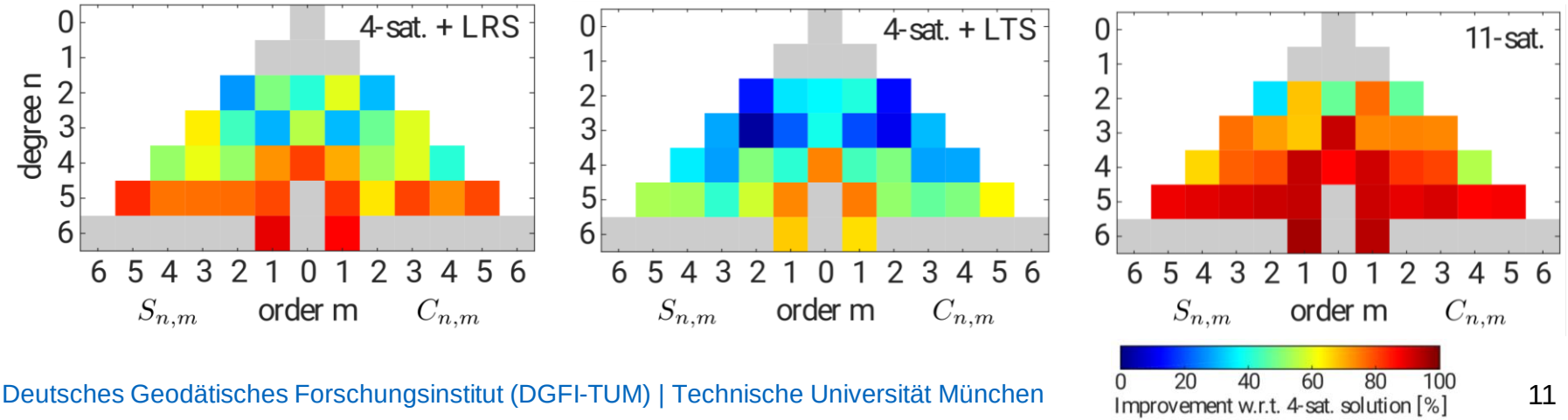


- $\rho(C_{2,0}, C_{3,0})$ can be stabilized significantly by using additional satellites.
- $\rho(C_{2,0}, C_{4,0})$ cannot be eliminated
- Reason: geometrical correlation of both coefficients

Results - gravity field

- Improvement of the mean WRMS values w.r.t. 4-satellite solution
  - 5-satellite solution: improvement patterns depending on the additional orbit
  - 11-satellite solution: individual improvement by **up to 93 %** (most valuable satellite: AJI)
  - average improvements:

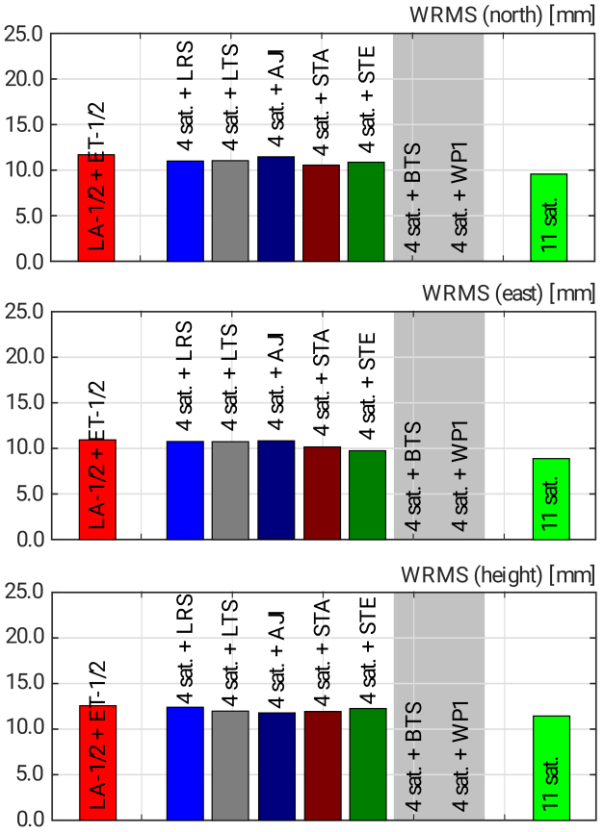
61.7 % **41.9 %** **79.3 %**

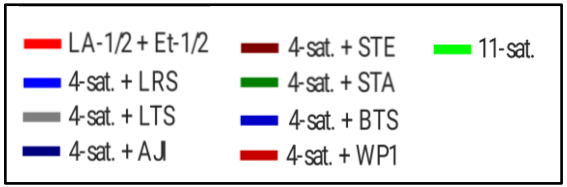


Results - TRF and ERP

short mission duration

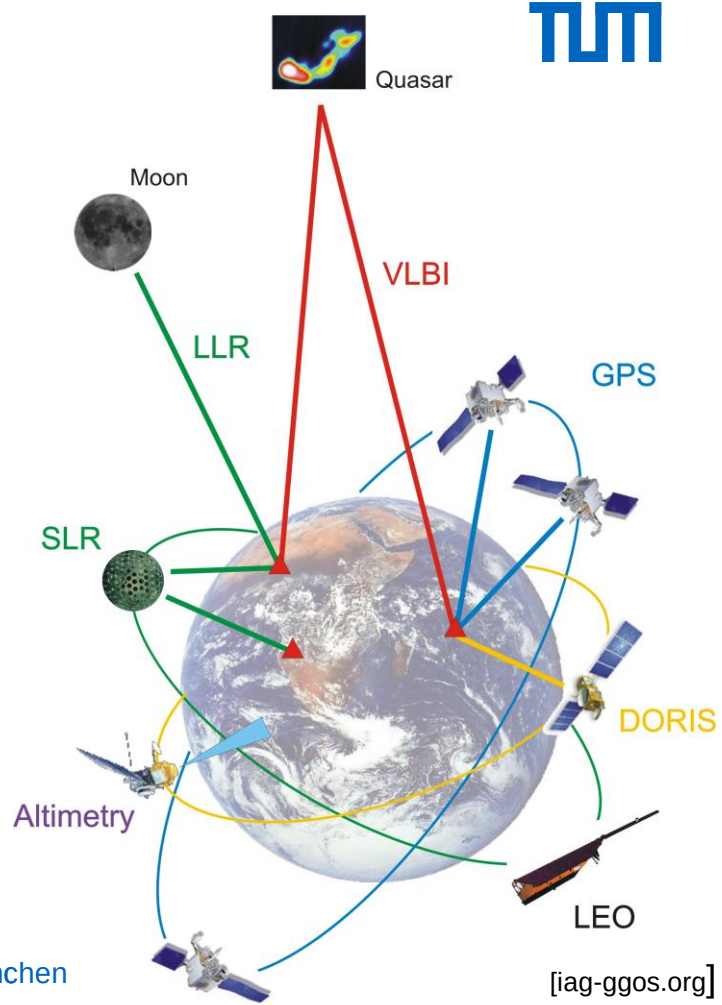
- Weekly transformation w.r.t. SLRF2014
  - Max. reduction of scatter of TRF datum: **35 %**
  - Scatter of scale significantly **increased by AJI** due to CoM error
  - Station repeatability improved by up to **22 %**
- **ERP benefit similarly** from additional satellites
  - WRMS of the ERP reduced by up to **26 %**





Conclusions

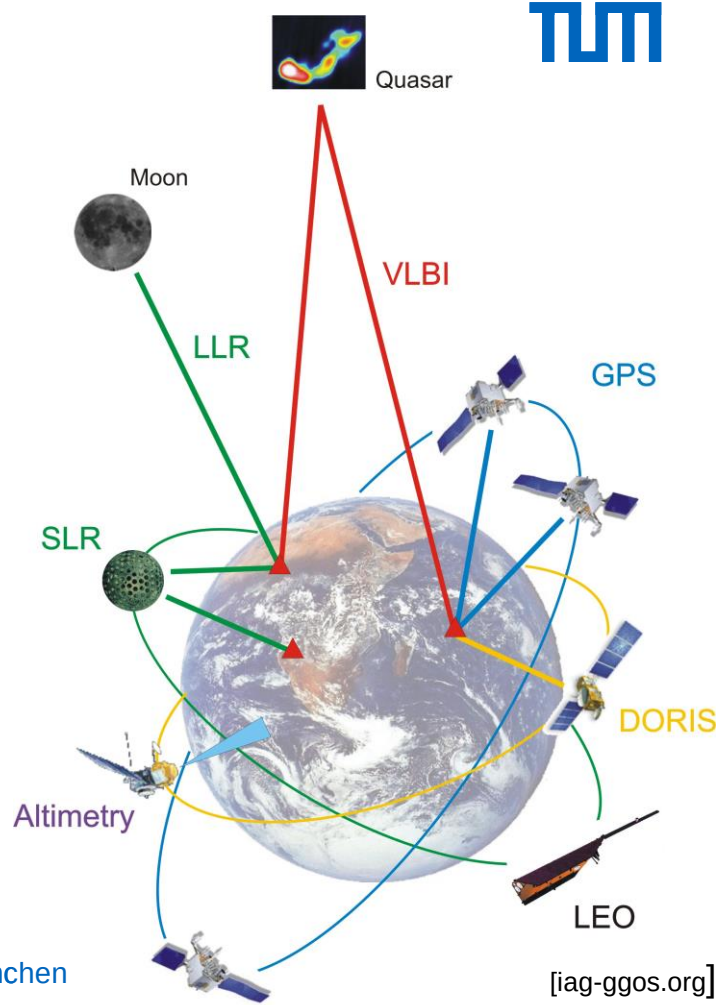
- GGOS aims the ambitious goal to **integrate geometric and gravimetric aspects** of modern space geodesy
- SLR is able to support this goal and to realize the GGOS vision
- Computing a multi-satellite multi-parameter solution allows to reduce parameter correlations
- **Gravity: up to 93 %, TRF: 22 - 35 %, EOP: 26 %**



[iag-ggos.org]

Future steps

- Contribution to **IAG Services/components**
- Further research towards the **multi-technique multi-parameter solution**
- **Integration of diverse sensor-systems** into a global observing system (GGOS)
- **Improvement of the ground segment** (geometry and performances → see talks of A. Kehm)
- Support of **new mission proposals** (such as E-GRASP/E-MOTION)
- Usage of existing **space ties** (e.g., GNSS, SLR, DORIS on Jason-2)



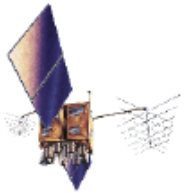
[iag-ggos.org]

Co-locations in space

- This potential is **not yet fully exploited**
- Problem: **Limited technique combinations** and **inadequate spacecraft calibrations**

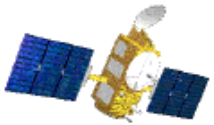
Compass
GNSS/SLR

GLONASS
GNSS/SLR



GPS
GNSS/SLR

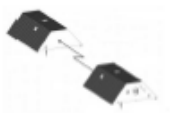
GIOVE/Galileo
GNSS/SLR



Jason
DORIS/GNSS/SLR

CHAMP
GNSS/SLR

Envisat
DORIS/SLR



GRACE
GNSS/SLR

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