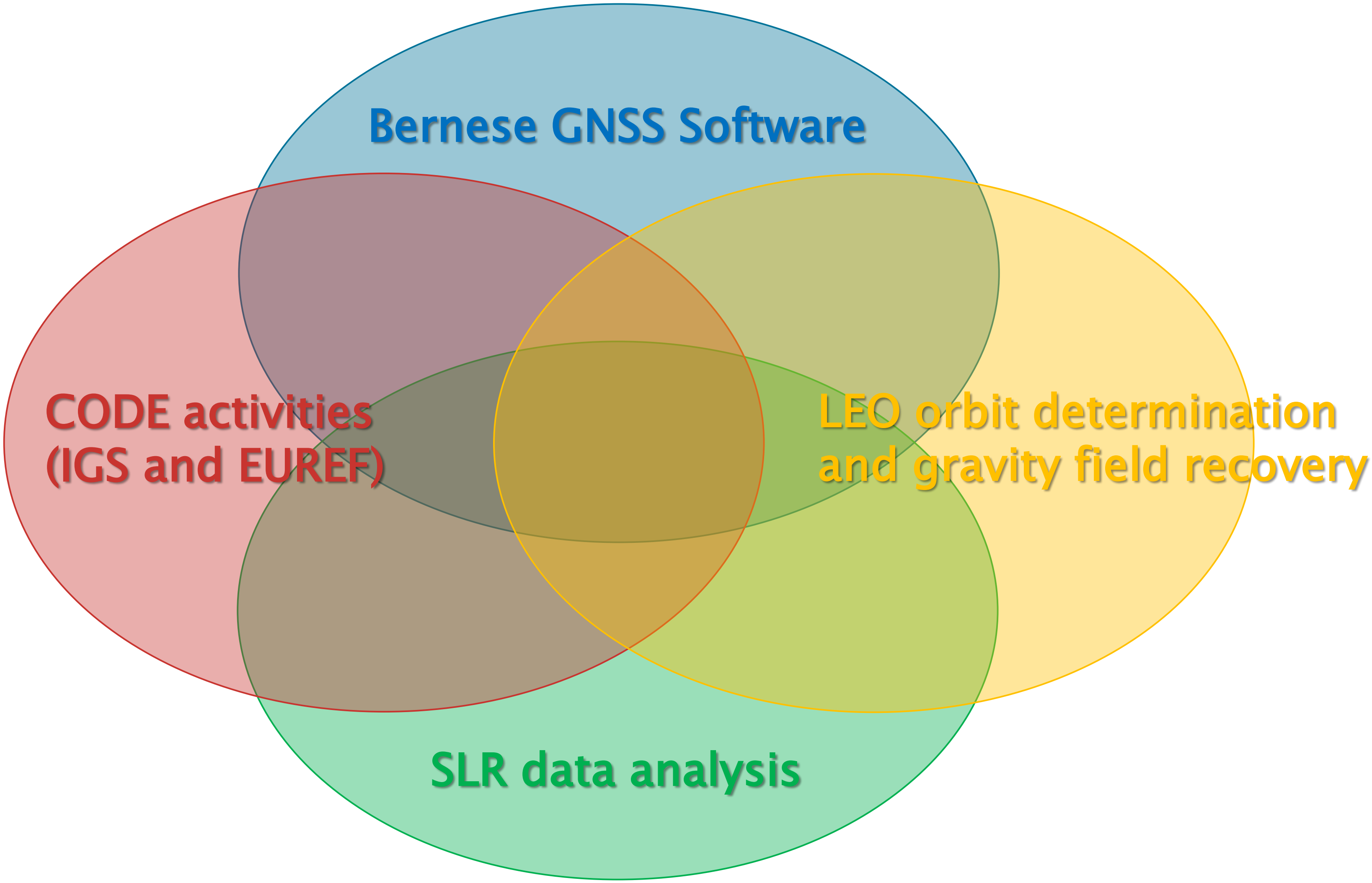
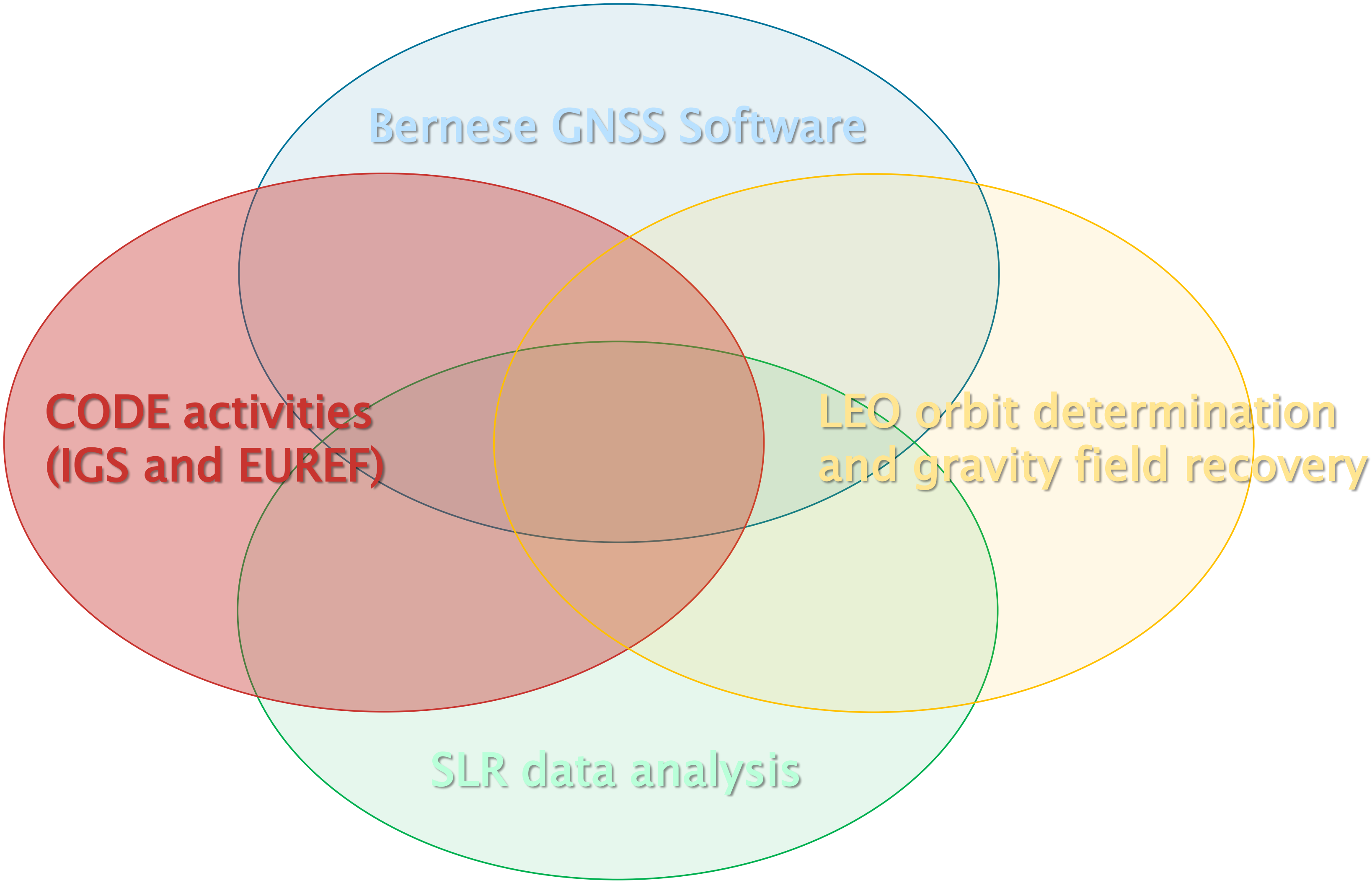
Activities at AIUB

Astronomisches Institut

Satellite Geodesy Research Group



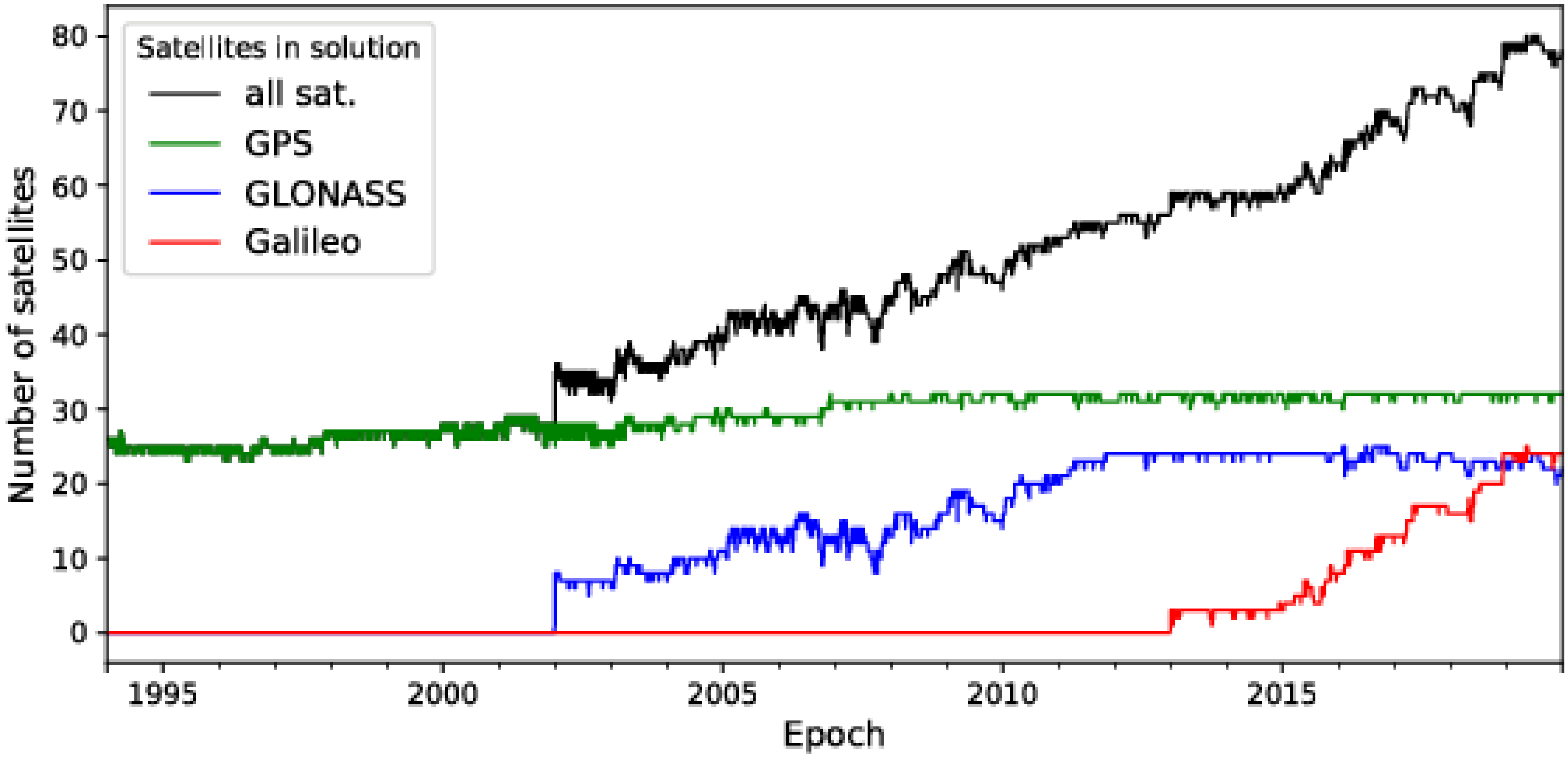
Satellite Geodesy Research Group



Selected improvements in the daily processing

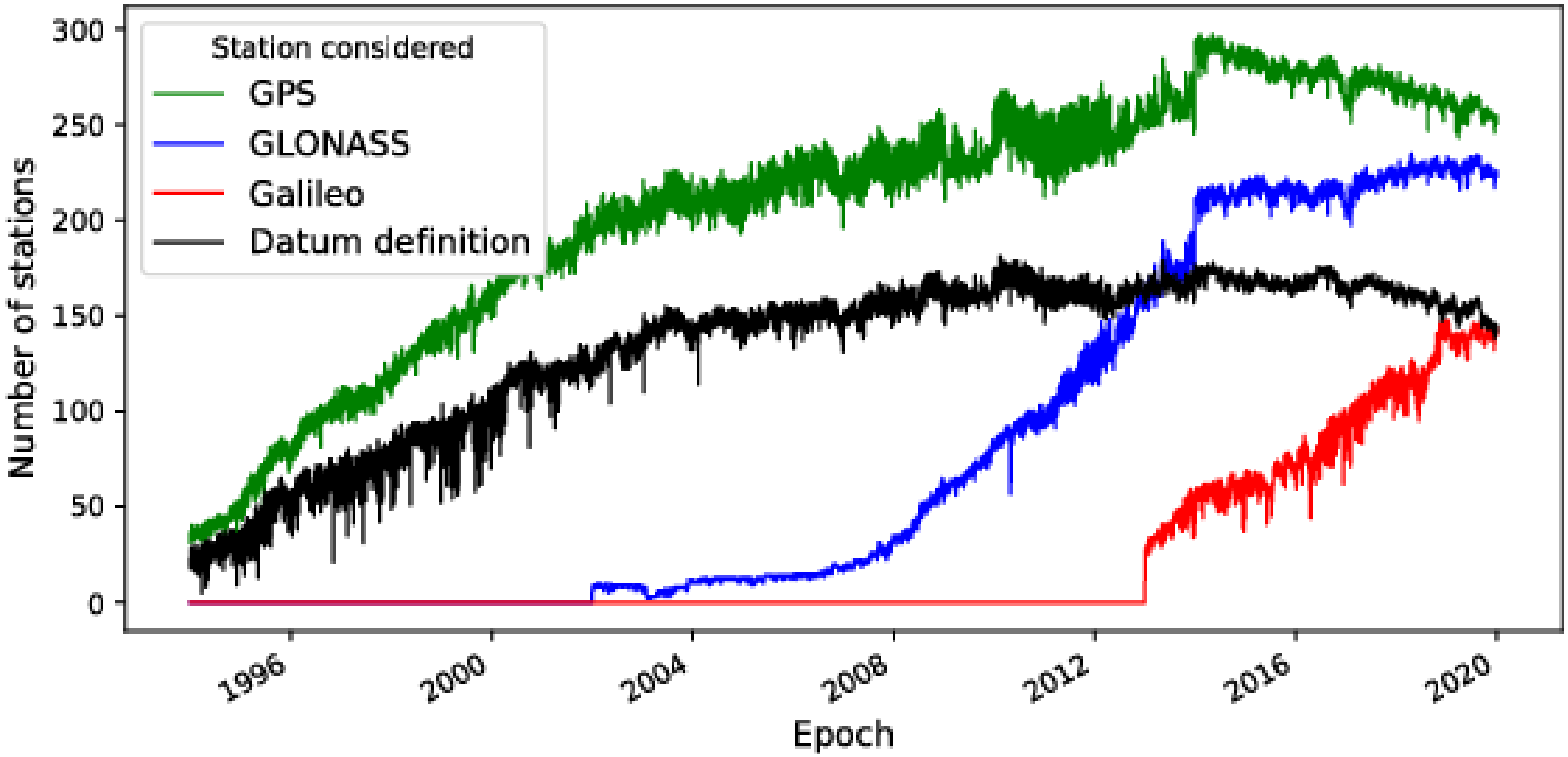
- Updates for international formats
  - troposphere SINEX and
  - clock RINEX
- Bernese internal advances
  - improving the numerical stability for reference ambiguities for GLONASS
  - developing some programs for an easier import of (multi-GNSS) broadcast ephemeries
  - unifying the structures of GPSEST and ADDNEQ2
  - ...

CODE reprocessing for ITRF2020



- **Orbits for GPS back to 1994; GLONASS starts in 2002 and Galileo in 2013**

CODE reprocessing for ITRF2020



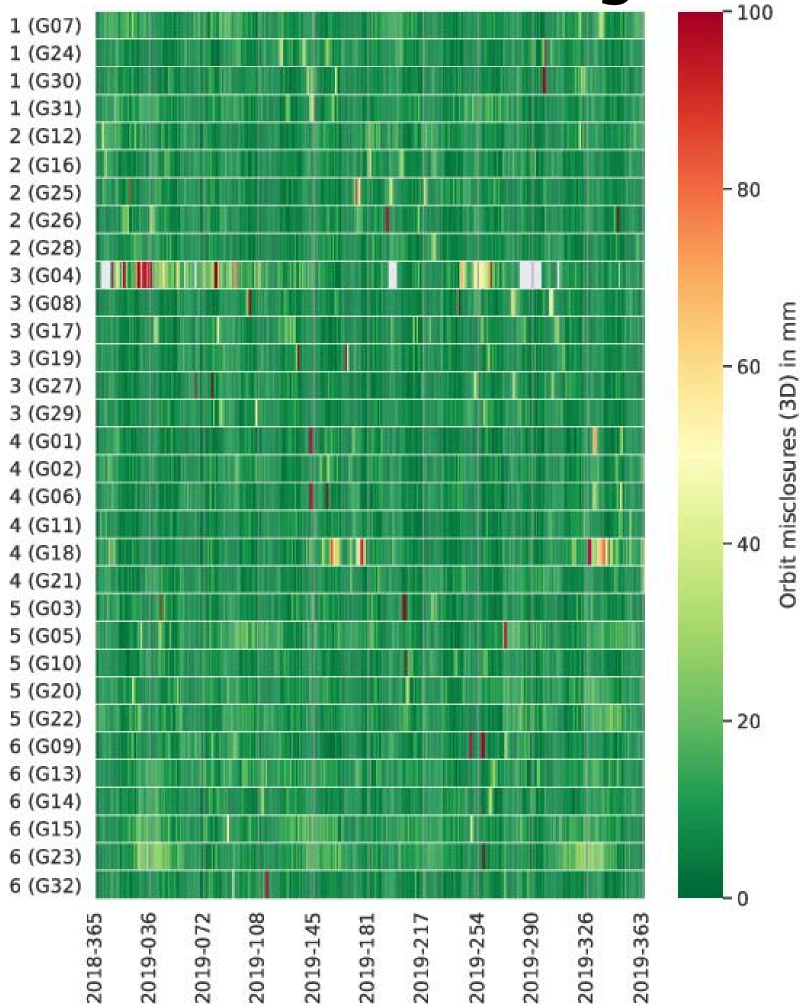
- **A limited number of stations track the constellations at the beginning; long-arc solution is helpful.**

CODE reprocessing for ITRF2020

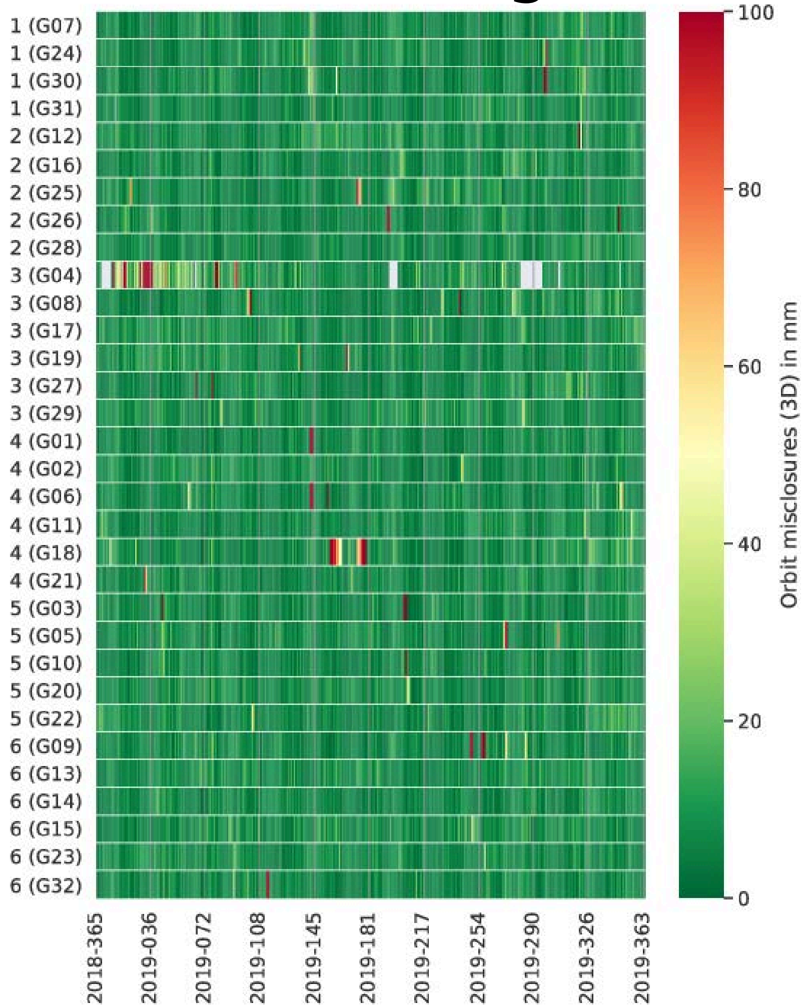
- As reported last year, a new set of calibrations for the receiver antennas has been established by Geo++.
- The set of calibrated antennas allows:
  - to exclude observations for systems where no separate calibration is available (COPIED FROM GPS)
  - to deselect stations without calibrated radoms; with the exception of a few stations before 2000 (COPIED FROM NONE)

Stochastic pulses in long-arc solutions

Noon and midnight

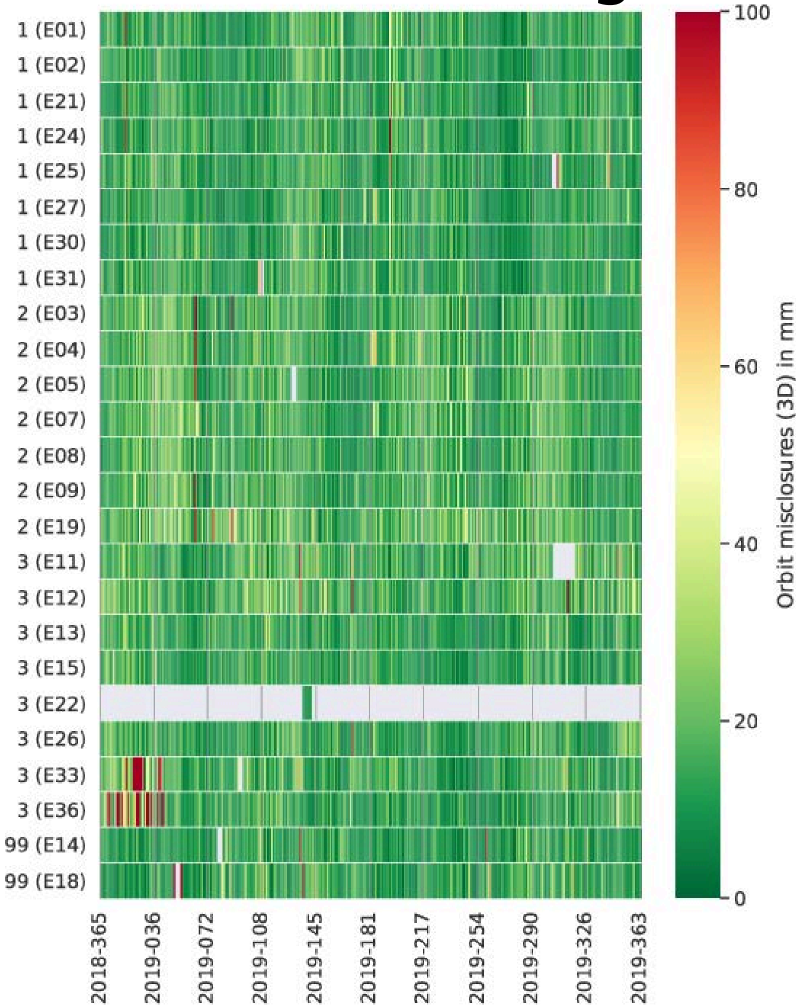


Orbit midnight

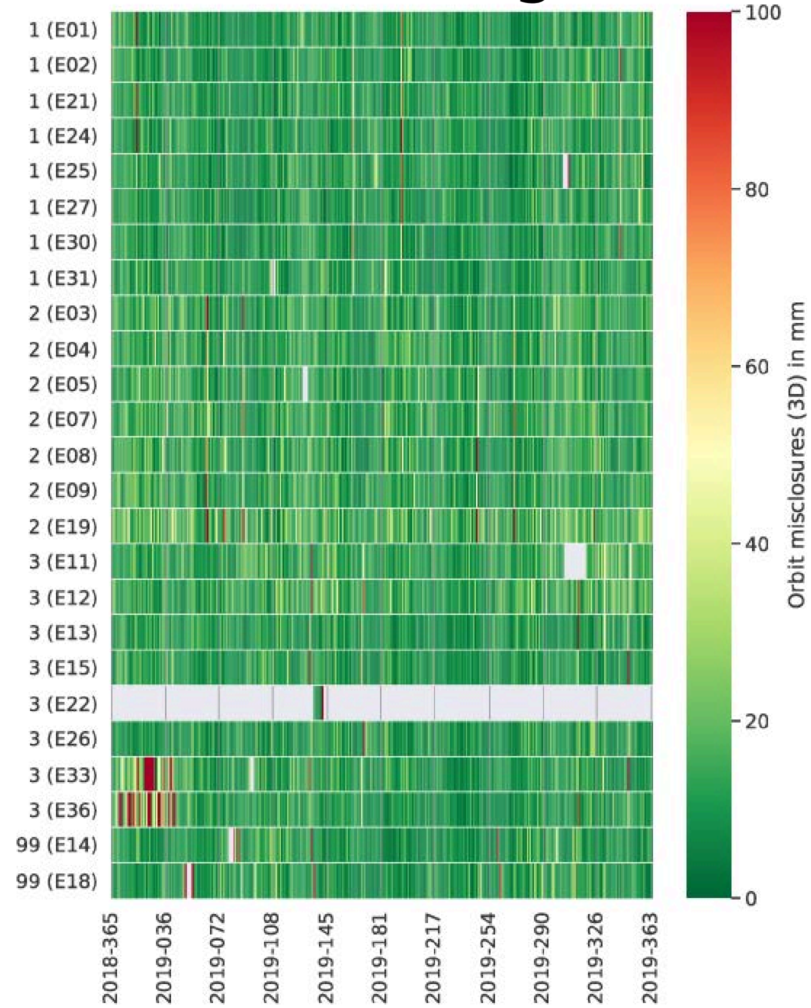


Stochastic pulses in long-arc solutions

Noon and midnight



Orbit midnight



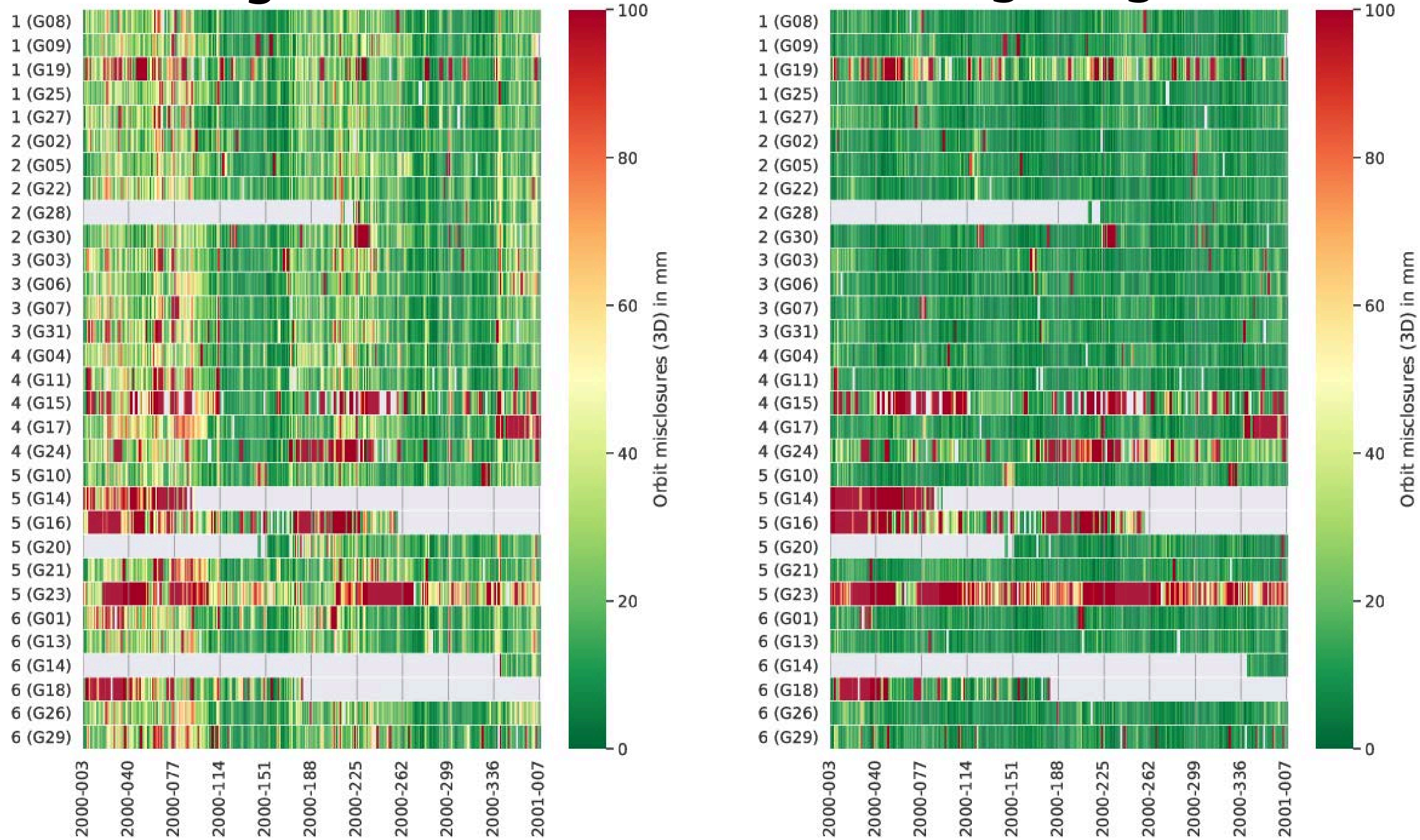
Misbehaving GPS satellites

PRN/SVN		satellite active		downweighted	
02	13	1989-06-10	2004-05-13	2001-04-10	2003-06-03
14	14	1989-02-14	2000-04-16	1996-05-16	2000-04-16
15	15	1990-10-01	2007-03-14	1999-04-21	2003-01-02
16	16	1989-08-18	2000-10-14	1996-02-08	2000-10-14
17	17	1989-12-11	2005-02-24	2000-12-03	2003-07-16
18	18	1990-01-24	2000-08-19	1996-05-12	2000-08-19
19	19	1989-10-21	2001-09-12	1996-04-29	2001-09-12
21	21	1990-08-02	2003-01-28	2000-12-31	2003-01-28
23	23	1990-11-26	2004-02-17	1995-02-01	2002-01-02
24	24	1991-07-04	2011-10-01	1997-11-15	2004-07-11
29	29	1992-12-18	2007-10-24	2001-12-02	2007-10-24

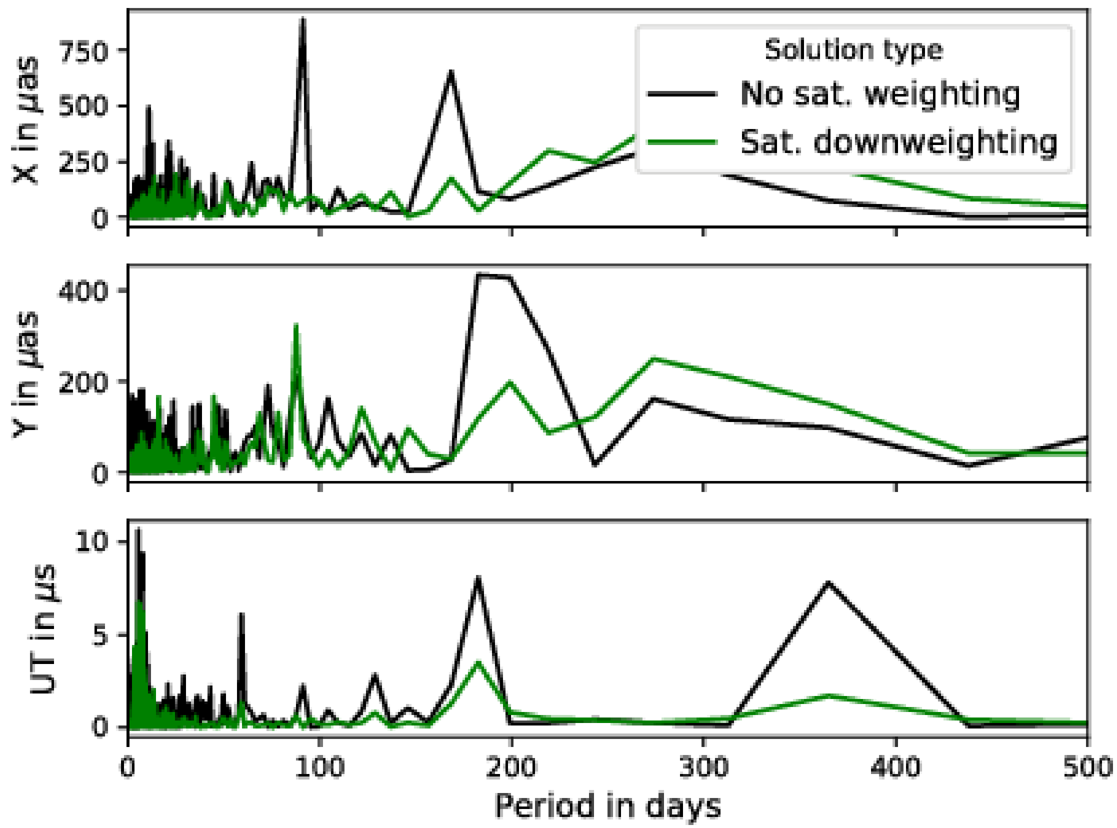
- For some of the satellites it is confirmed that there are issues with the momentum wheels; others show the similar behavior.

Misbehaving GPS satellites

Same weight for satellites / Downweighting bad sat.



Misbehaving GPS satellites



- Spectra of differences w.r.t. the C04 series computed from the years 1997 to 2002

Satellite clock corrections

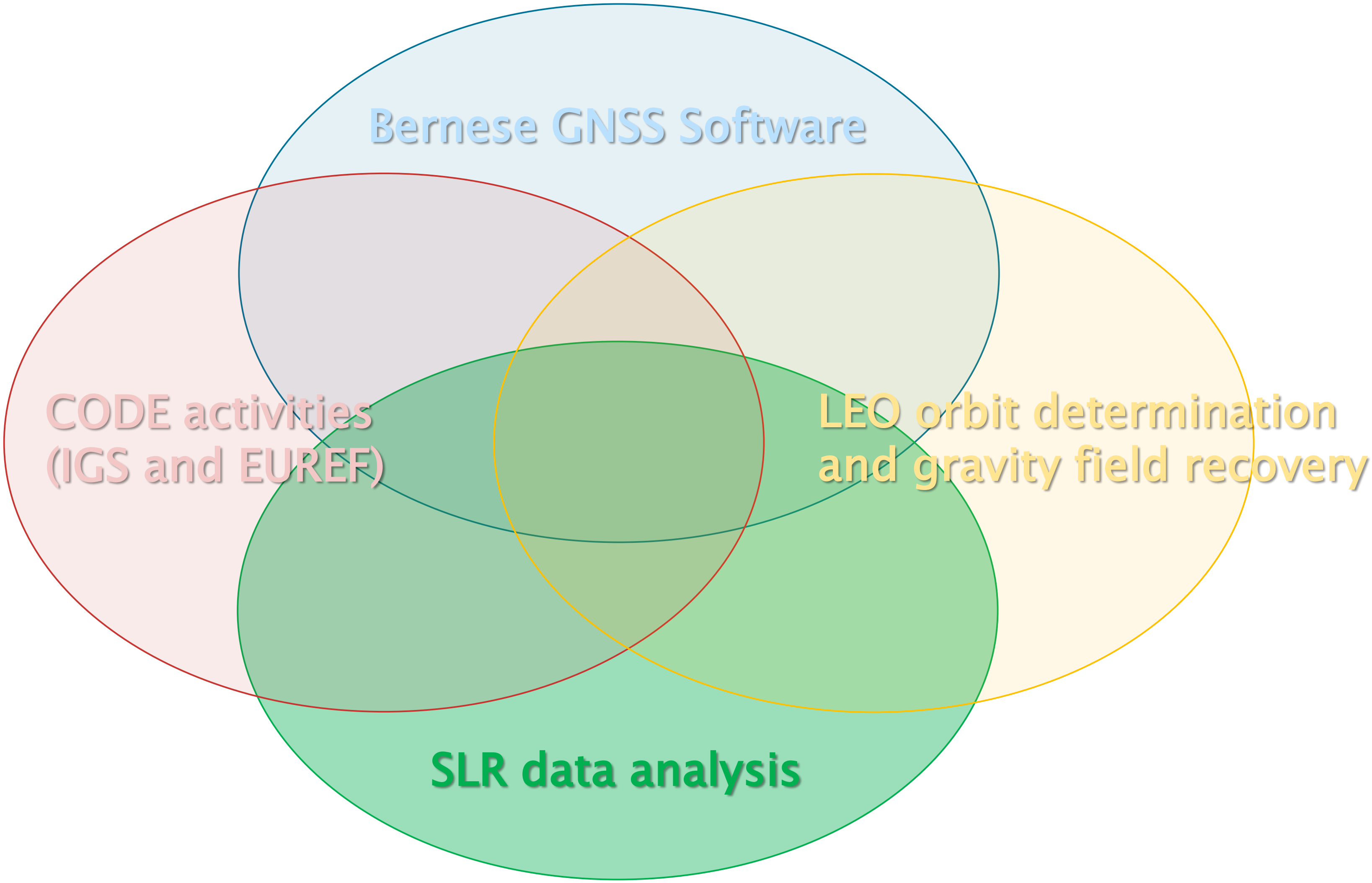
- GPS constellation:
  - since May 2000: 30s; 2005: 5s sampling
- GLONASS constellation:
  - since 2008: 30s and 5s
- Galileo
  - since 2013: 30s and 5s

- For GPS and Galileo phase bias corrections have been computed allowing for PPP-IAR.

Publication of CODEs repro results

- The computation of the geometry part was done at TUM (according to the strategy developed at AIUB). The generation of the solution for the clock corrections and phase biases was done at AIUB.
- The AIUB contribution (1994–2019) was completed and submitted to the IGS in September 2020.
- It will made available to public at
  ftp://ftp.aiub.unibe.ch/REPRO_2020/
  as soon as the combination at IGS level is finished.

Satellite Geodesy Research Group



Multi-satellite cannonball SLR solutions

Estimated parameters		SLR solutions
Estimated parameters		LAGEOS-1/2, Starlette, Stella, AJISAI, LARES, Blits, Larets, Beacon-C
Orbits	Osculating elements	$a, e, i, \Omega, \omega, u_0$ (LAGEOS: 1 set per 10 days, LEO: 1 set per 1 day)
	Dynamical parameters	LAGEOS-1/2 : S_0, S_S, S_C (1 set per 10 days) Sta/Ste/AJI : C_D, S_C, S_S, W_C, W_S (1 set per day)
	Pseudo-stochastic pulses	LAGEOS-1/2 : no pulses Sta/Ste/AJI : once-per-revolution in along-track only
Earth rotation parameters		X_P, Y_P, UT1-UTC (Piecewise linear, 1 set per day)
Geocenter coordinates		1 set per 30 days
Earth gravity field		**Estimated up to d/o 10/10** (1 set per 30 days)
Station coordinates		1 set per 30 days
Other parameters		Range biases for all stations (LEO) and for selected stations (LAGEOS)

Analysis of ERP Parametrizations

PWC:

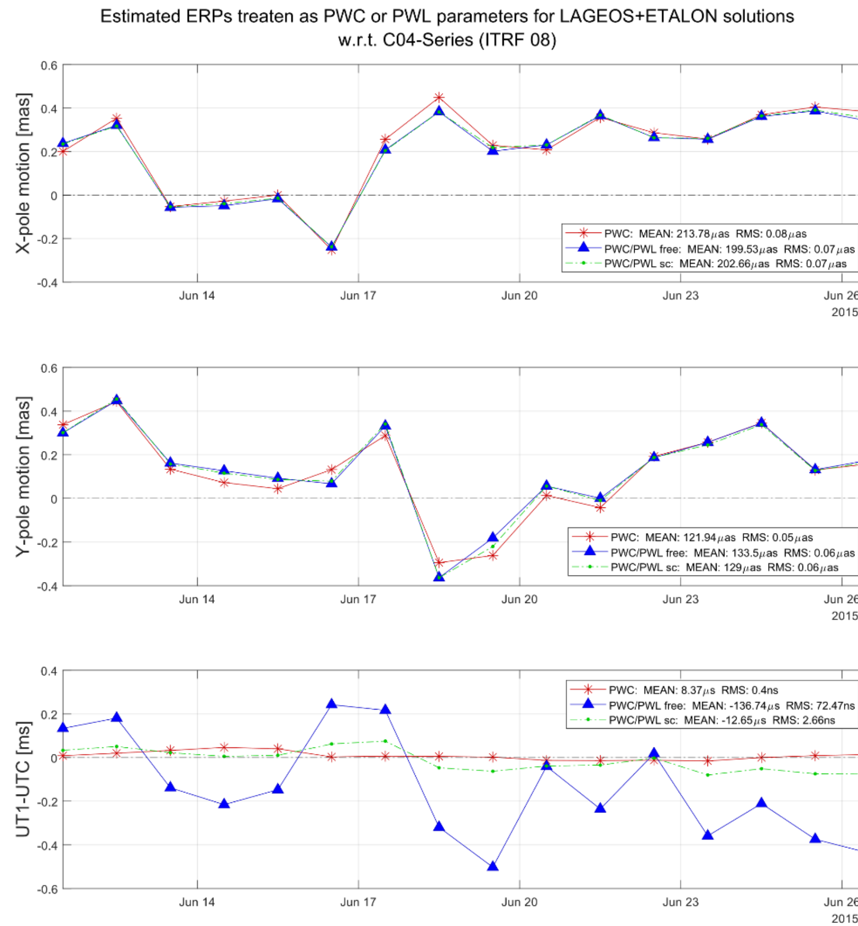
Component	A priori sigma	Unit
X-POLE	30,0	mas
Y-POLE	30,0	mas
UT1-UTC first (4.para)	0,00001	ms
UT1-UTC other	0,00001	ms
LOD	2,0	ms/d

PWC/PWL* free:

Component	A priori sigma	Unit
X-POLE	30,0	mas
Y-POLE	30,0	mas
UT1-UTC first (4.para)	0,00001	ms
UT1-UTC other	0,0	ms
LOD	0,0	ms/d

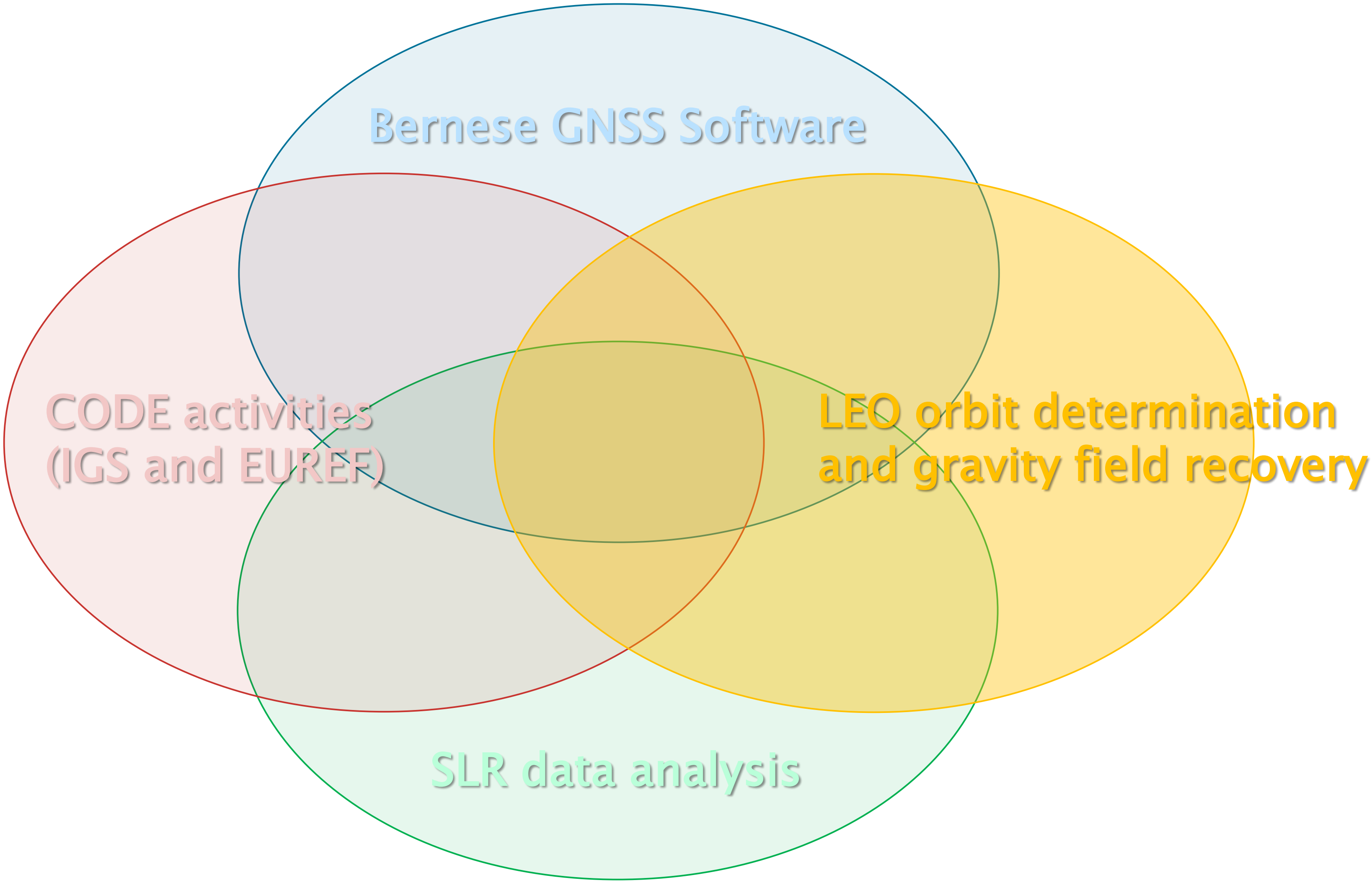
PWC/PWL* sc (strong constraint):

Component	A priori sigma	Unit
X-POLE	30,0	mas
Y-POLE	30,0	mas
UT1-UTC first (4.para)	0,00001	ms
UT1-UTC other	0,1	ms
LOD	0,0	ms/d



*PWC/PWL : pole motion is piecewise-constant, only UT1-UTC is piecewise-linear

Satellite Geodesy Research Group



Copernicus POD Service

At AIUB precise orbits of all Sentinel satellites are computed

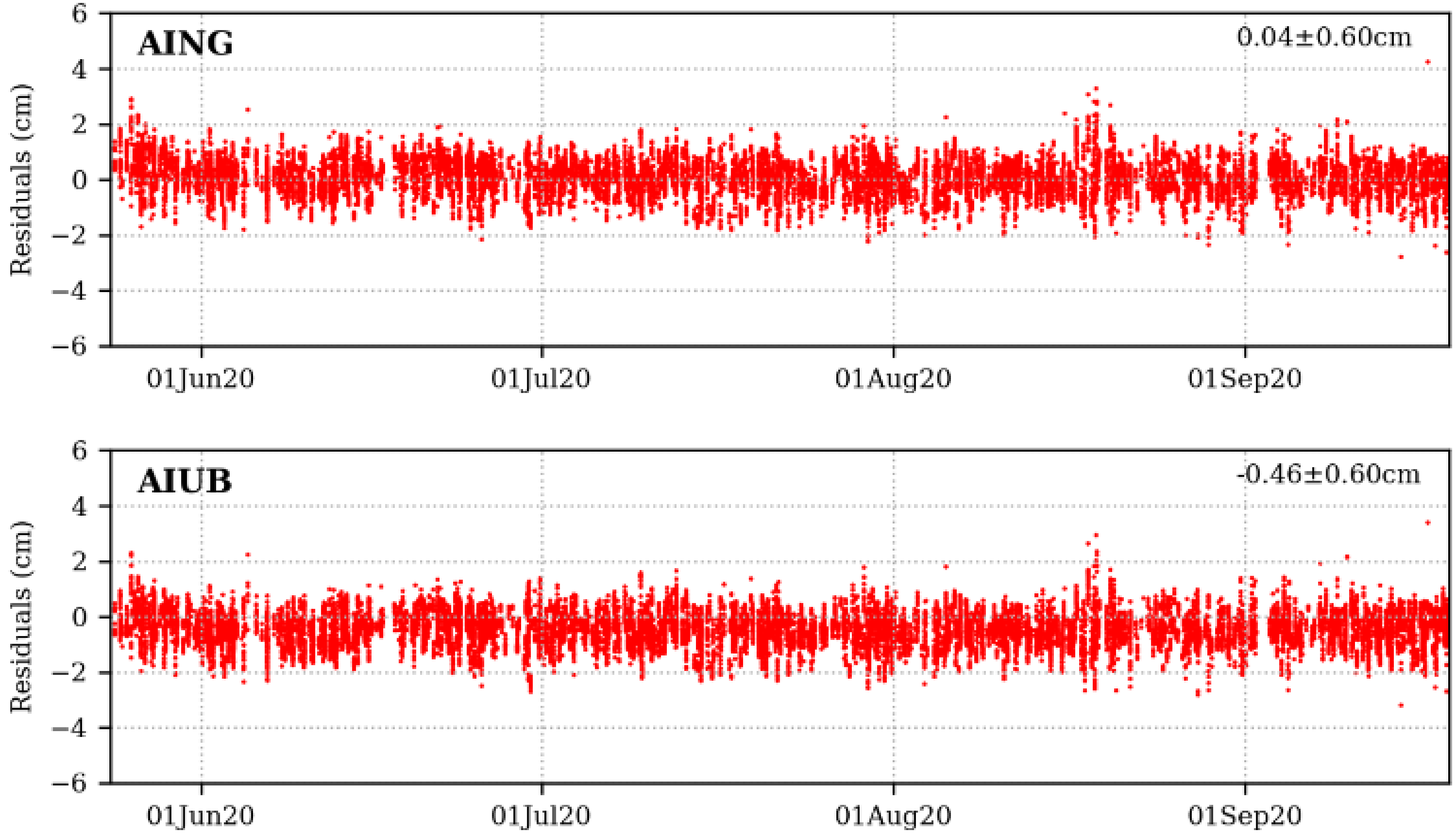
Sentinel-1A
Sentinel-1B

Courtesy: ESA

Sentinel-2A
Sentinel-2B

Sentinel-3A
Sentinel-3B

Copernicus POD Service



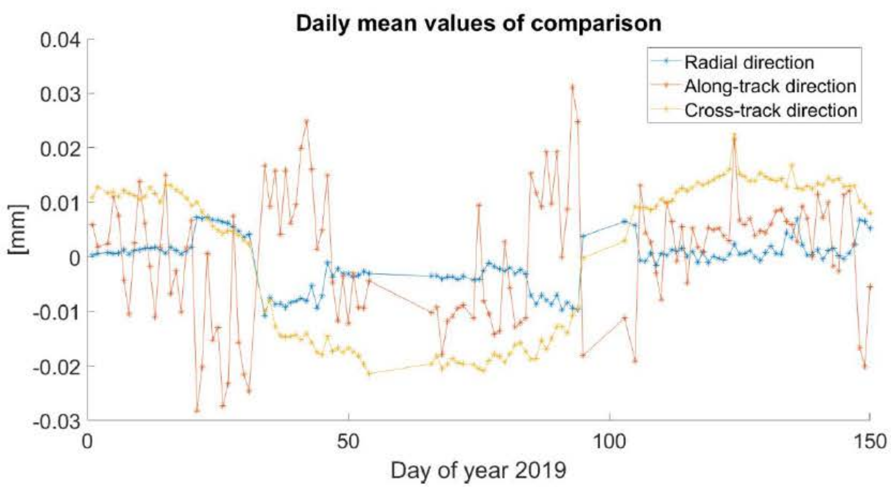
Results from Copernicus POD Regular Service Review (RSR) #018 show that AIUB solutions for Sentinel-3A are, e.g., performing best in the SLR analysis performed by GMV (biases fixed by GMV).

Jason-3 Precise Orbit Determination

Jason-3 POD using Bernese GNSS Software

POD using Ambiguity-float GPS carrier phase observations
POD using Ambiguity-fixed GPS carrier phase observations

Comparison of AIUB orbit solutions (ambiguity-fixed) to solutions computed by NASA Jet Propulsion Laboratory (JPL):



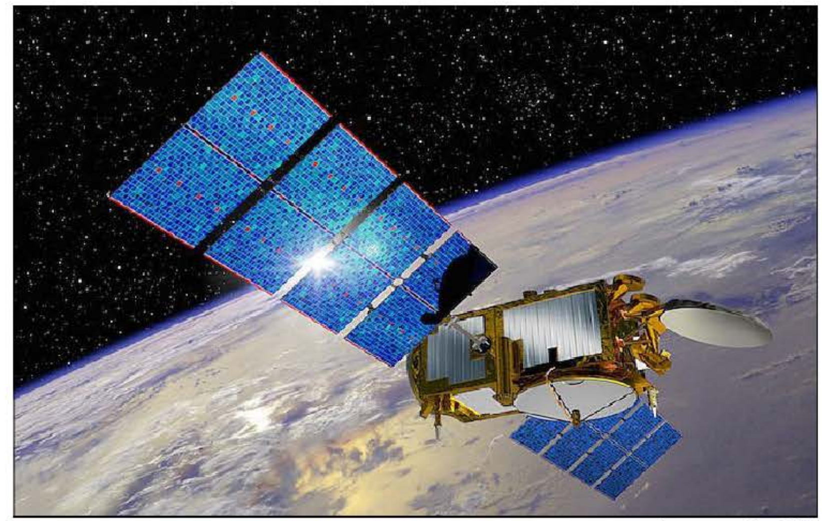


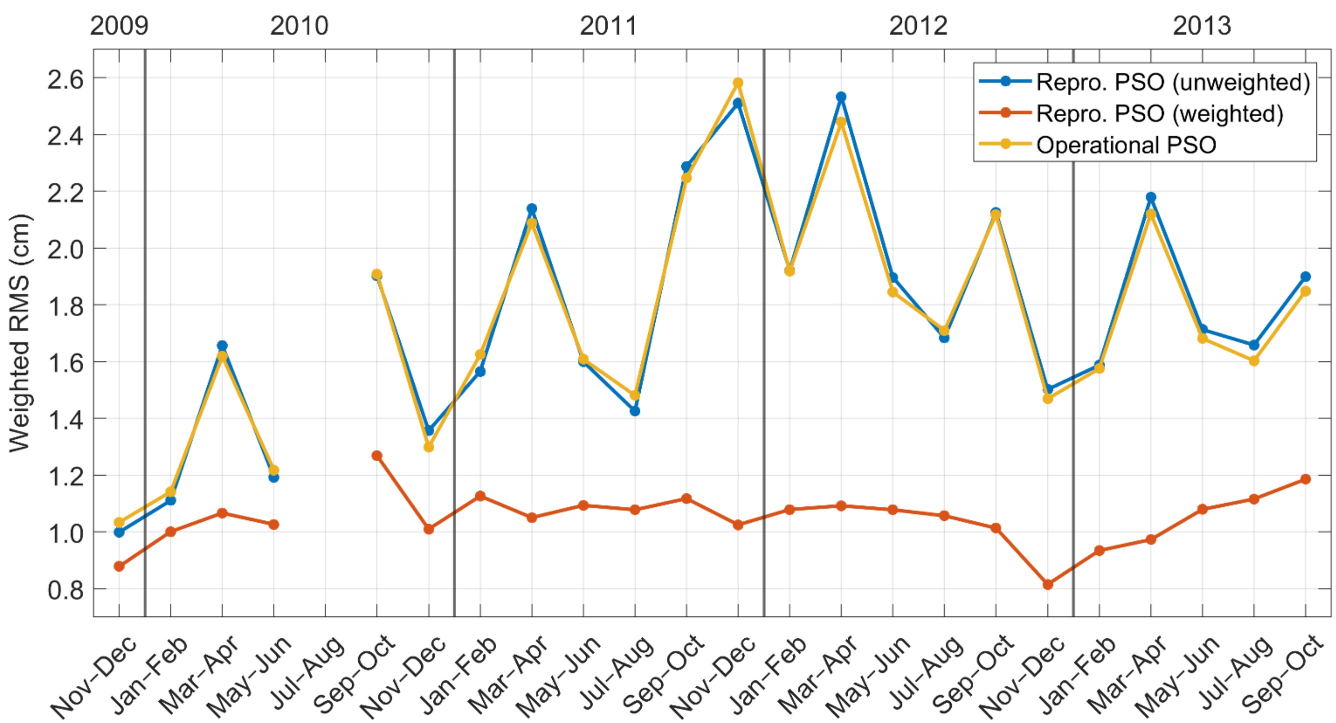
Image credit: CNES

Orbital parameters:

Semi-major axis	7,715.8 km
Inclination	66.04°
Period	112.42 minutes
Eccentricity	0.0007824

Credit: https://www.nesdis.noaa.gov/jason-3/mission.html

GOCE Reprocessing

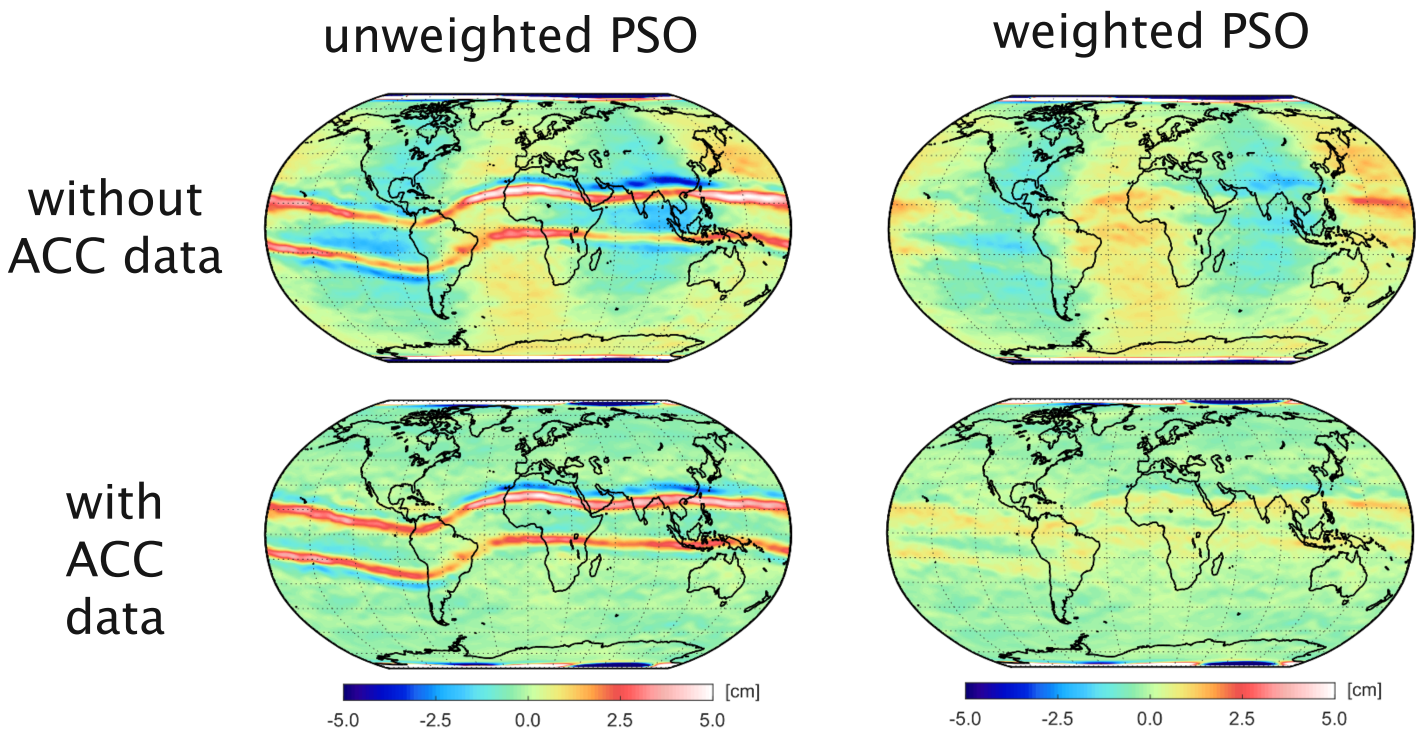


Geoid height differences w.r.t. ITSG-Grace2018

(300 km Gauss- filtered)

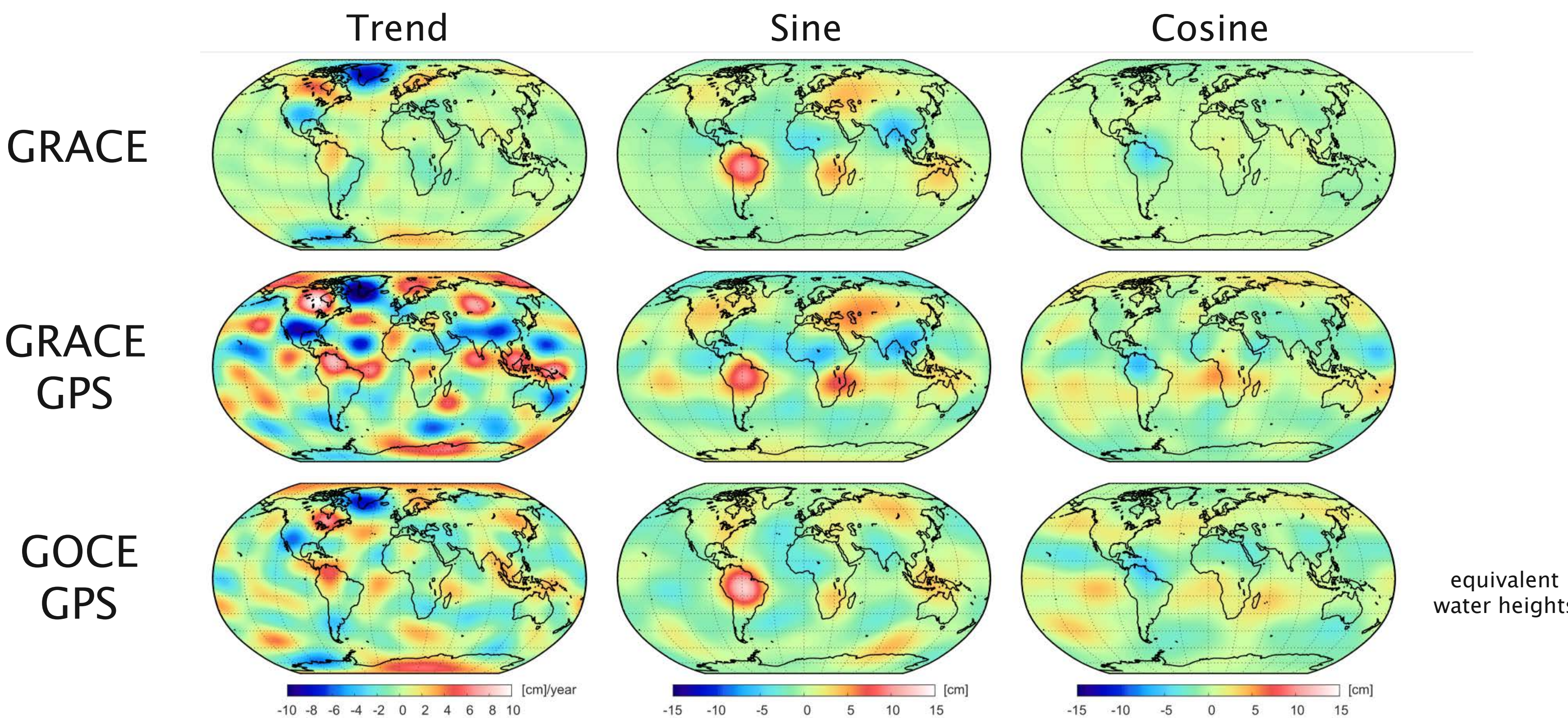
Significant improvement of bi-monthly GOCE GPS-only gravity field solutions due to weighting problematic GPS data in the reprocessed kinematic positions of the GOCE Precise Science Orbits (PSO).

GOCE Reprocessing



Artifacts are also significantly reduced in long-term solutions covering the science phase of the GOCE mission (Nov 2009 – Oct 2013).

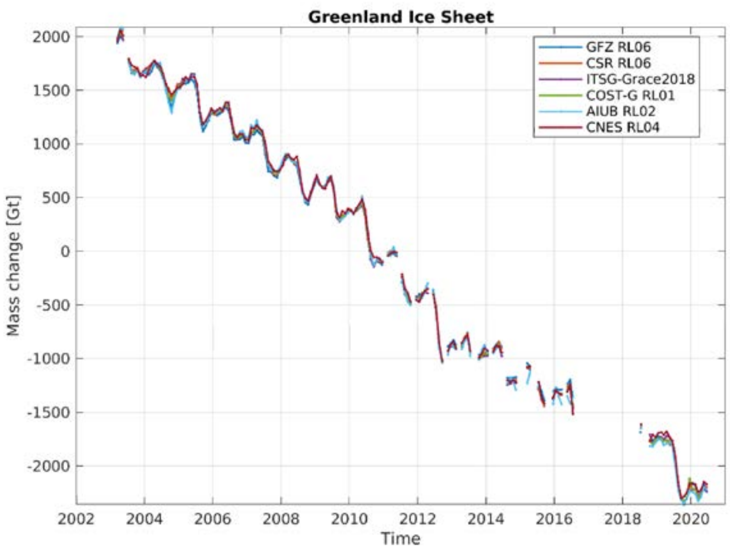
GOCE Reprocessing

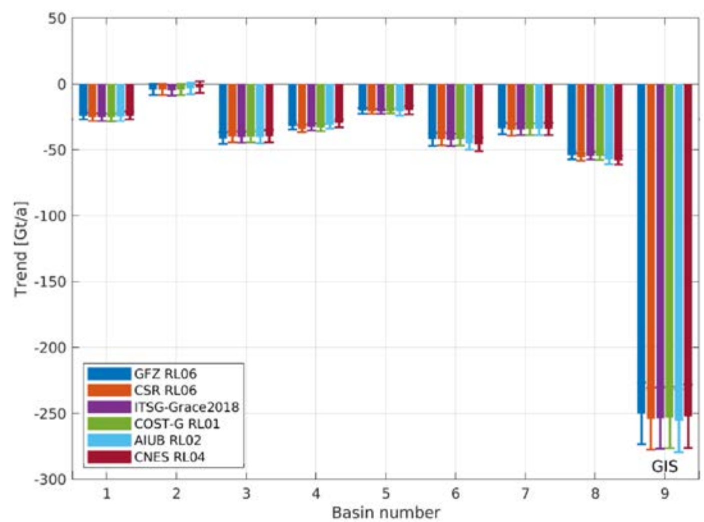


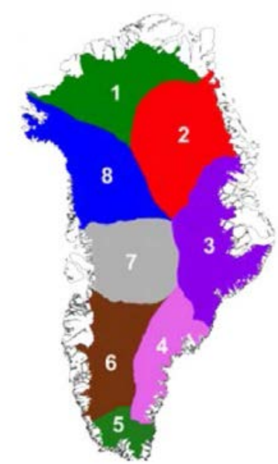
Despite the relatively short GOCE mission duration even the largest time-variable signals may be recovered from the analysis of the reprocessed kinematic GOCE PSOs.

Time-variable gravity field recovery

- Monthly gravity fields from GRACE Follow-On are routinely derived at AIUB and published on ICGEM (Lasser et al., 2020).
- Monthly gravity fields from various GRACE/GRACE-FO analysis centers are combined at AIUB in the frame of COST-G (Combination Service of Time-variable gravity fields, Jäggi et al., 2020).

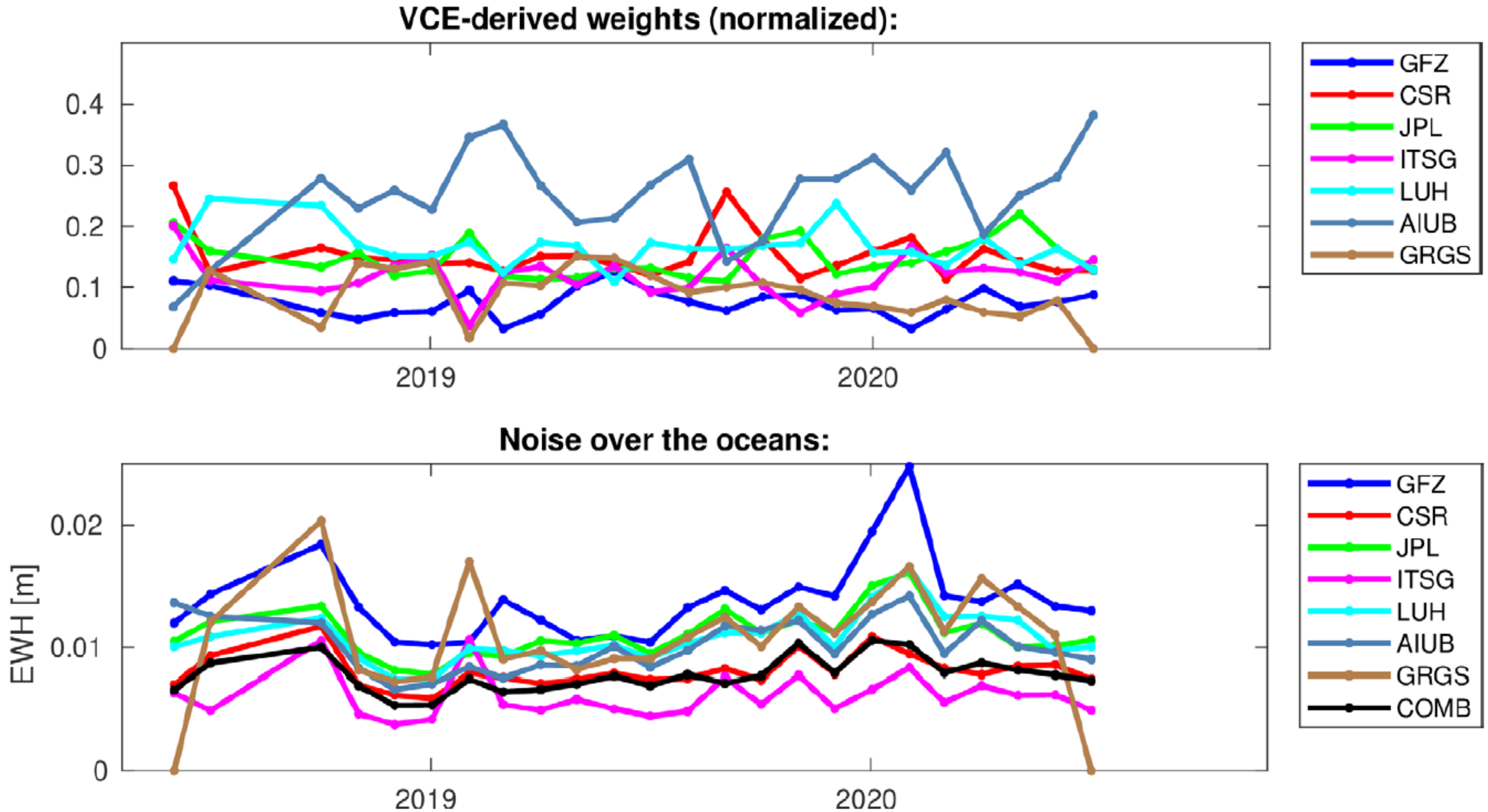






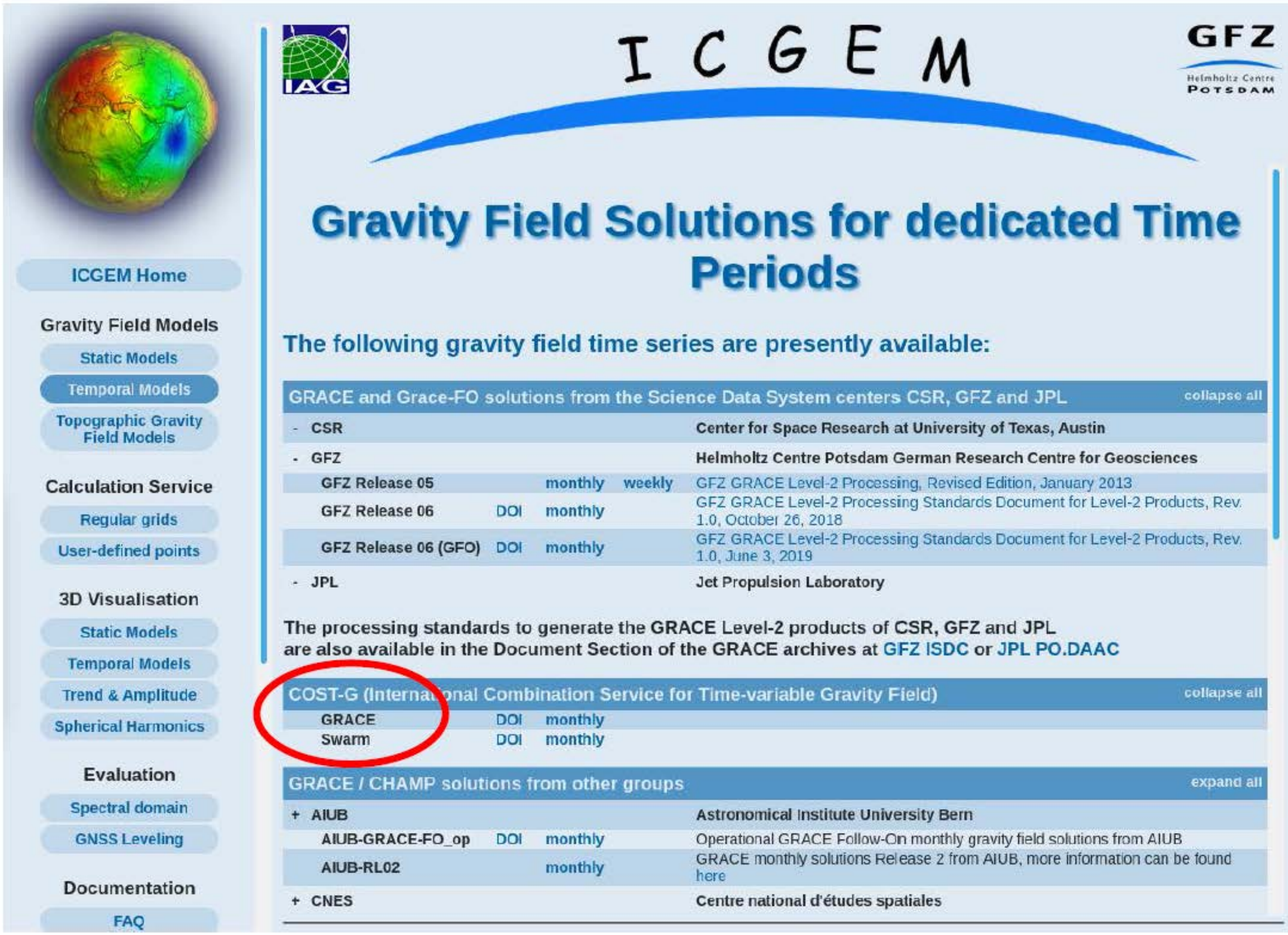
(Meyer et al., 2020, Groh et al., 2020)

COST-G



AIUB solutions get the largest weights in the combination performed on solution level by using Variance Component Estimation (VCE).

COST-G Level-2 Products



COST-G Level-3 Products

GFZ Helmholtz Centre Potsdam

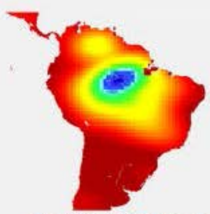
GravIS Gravity Information Service

Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences

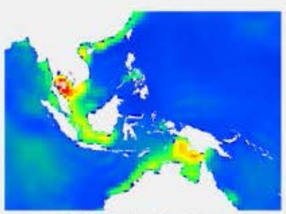
TERRESTRIAL WATER STORAGE | OCEAN BOTTOM PRESSURE | ANTARCTIC ICE-MASS CHANGE | GREENLAND ICE-MASS CHANGE | CORRECTIONS AND AUXILIARY PRODUCTS | RELATED LINKS

Welcome to GravIS, the Gravity Information Service of the German Research Centre for Geosciences (GFZ), in collaboration with the Alfred-Wegener-Institut (AWI) and Technische Universität Dresden. Data products derived from the gravimetric Earth observation satellite missions GRACE and GRACE-FO are widely used by scientists and other interested users to study mass variations in the Earth system. However, processing of GRACE/GRACE-FO data into user-friendly products for dedicated geophysical applications is nontrivial, neither when starting from original satellite observations nor from the level of gravity field products. In order to enable the usage of satellite gravimetry data for a broader community, user-friendly ('Level-3') products are generated by various institutions.

GravIS visualizes and describes Level-3 products based on the most recent GRACE and GRACE-FO data release from GFZ. In addition, Level-3 products based on the most recent release of combined GRACE models from COST-G are offered as well. The products presented at GravIS are available for download at GFZ's Information System and Data Center (ISDC).



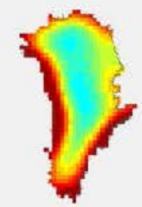
Terrestrial Water Storage



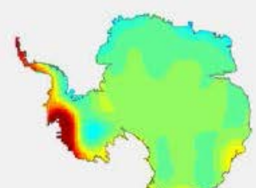
Ocean Bottom Pressure

The Gravity Recovery and Climate Experiment (GRACE; 2002 - 2017) and its Follow-On mission (GRACE-FO; launched in May 2018) typically provide monthly independent estimates of the Earth's global gravity field. Differences between consecutive months are caused by mass redistribution and mass transport in the Earth system, particularly in the geophysical fluid layers of the atmosphere, oceans, and continental hydrosphere.

GRACE/GRACE-FO data processing is structured into sensor data analysis (Level-0 to Level-1), global gravity field estimation (Level-1 to Level-2), and geophysical mass anomaly inversion (Level-2 to Level-3). Level-3 products at GravIS comprise gridded mass anomalies as well as basin average time series and are available for terrestrial water storage over non-glaciated regions, bottom pressure variations in the oceans, and ice-mass changes in both Antarctica and Greenland. In order to achieve the highest possible accuracy of the mass anomalies, several post-processing steps have been applied to the Level-2 spherical harmonic coefficients before inversion.



Greenland Ice-Mass Change

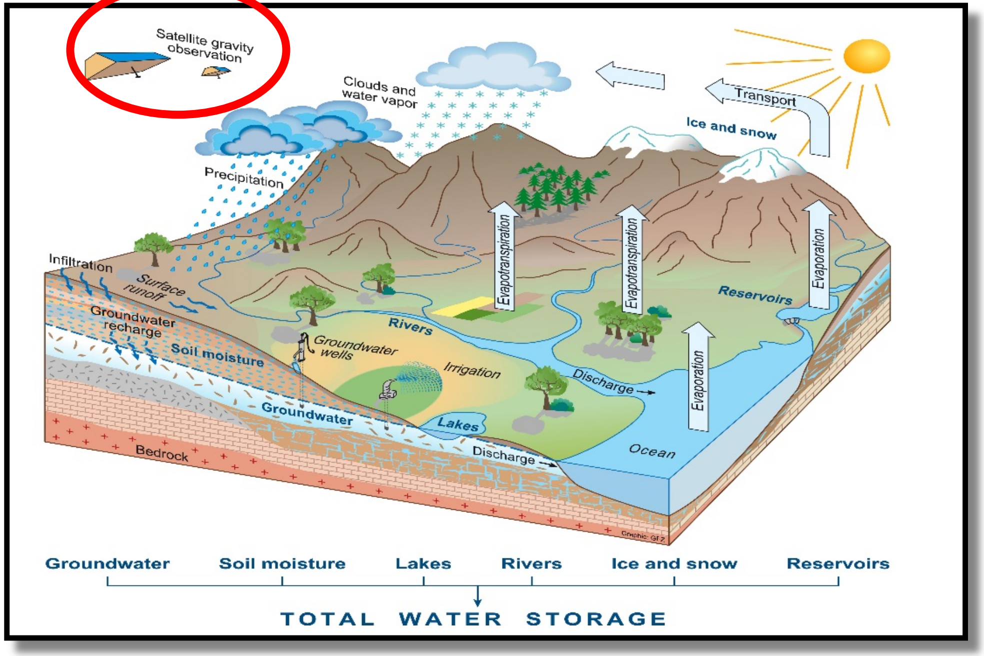


Antarctic Ice-Mass Change

Outlook – H2020 Project G3P

HORIZON 2020

- Satellite gravimetry with GRACE (2002-2017) and GRACE-FO (2018 -) is the only technique to observe Terrestrial Water Storage (TWS) variations
- Resolving for groundwater storage variations follows a subtraction approach.
- A prototype for a global groundwater product shall be established for the Copernicus Climate Change Service in the frame of a H2020 project G3P.



Groundwater = TWS − glaciers − snow − soil moisture − storage in surface water

G3P =  −  −  −  − 

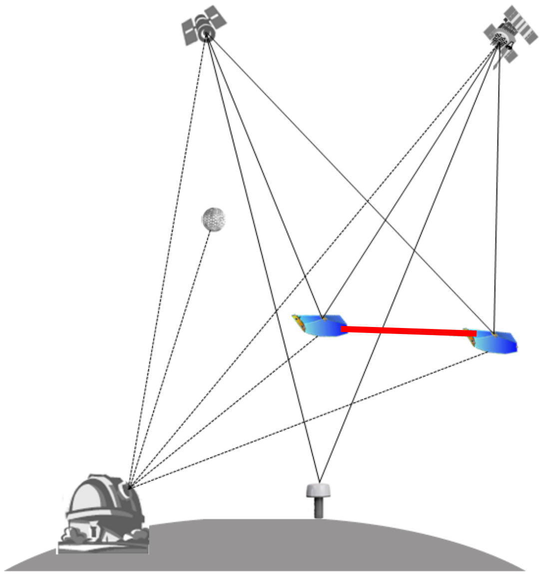
(Güntner et al., 2020)

Outlook – ERC Project SPACE TIE

Data Basis

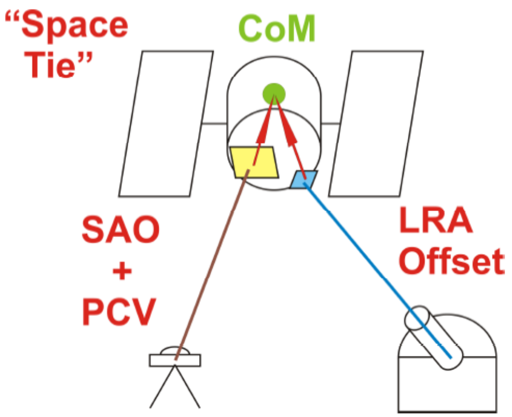
- ~ 80 GNSS satellites
- ~ 20 LEO satellites (**gravity** and **altimetry**)
- GNSS and SLR ground networks

=> A rigorous joint adjustment should be envisaged



Main Idea (in a nutshell)

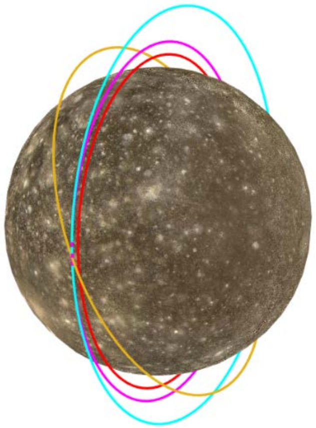
- Use of the Earth's gravity field to act as an additional global tie via satellite orbits
- Exploitation of space co-locations (space ties) on both **GNSS** and **LEO** satellites

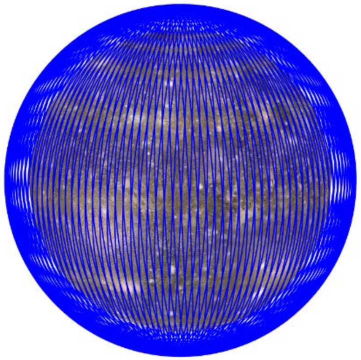


Gravity field recovery using Low Callisto/Europa Orbit

To answer the extensive interest of Jupiter's icy moons, several missions are proposing to send a low altitude orbiter around one of the Galilean moons. As **JUICE** mission will focus on Ganymede, other mission proposals are targeting Callisto with the Chinese exploration mission **Gan De** and Europa with the **Joint Europa Mission.** At AIUB, we performed closed-loop simulation to investigate the gravity field recovery of Callisto and Europa using different types of orbits:

- Elliptic orbits: polar orbits foreseen for capture around Callisto/Europa.
- Low altitude orbits for initial science investigation.
- Very low altitude orbits which would improve even more the gravity field knowledge (regular manoeuvres to counteract orbit decay).
- Sun synchronous orbits (SSO) for a permanent sunlight for the probe, and a minimization of the spectral signature due to the Sun position. They present an important polar gap and are highly dependent on the gravity field knowledge at low altitude.
- Repetitive Ground Track Orbits (RGTO) which allow repeat observations of a given point of the surface and an efficient station keeping manoeuvres. Enough repetition within a cycle low the effect of low-density ground tracks, in comparison with non-RGTO for a 3 months mission.

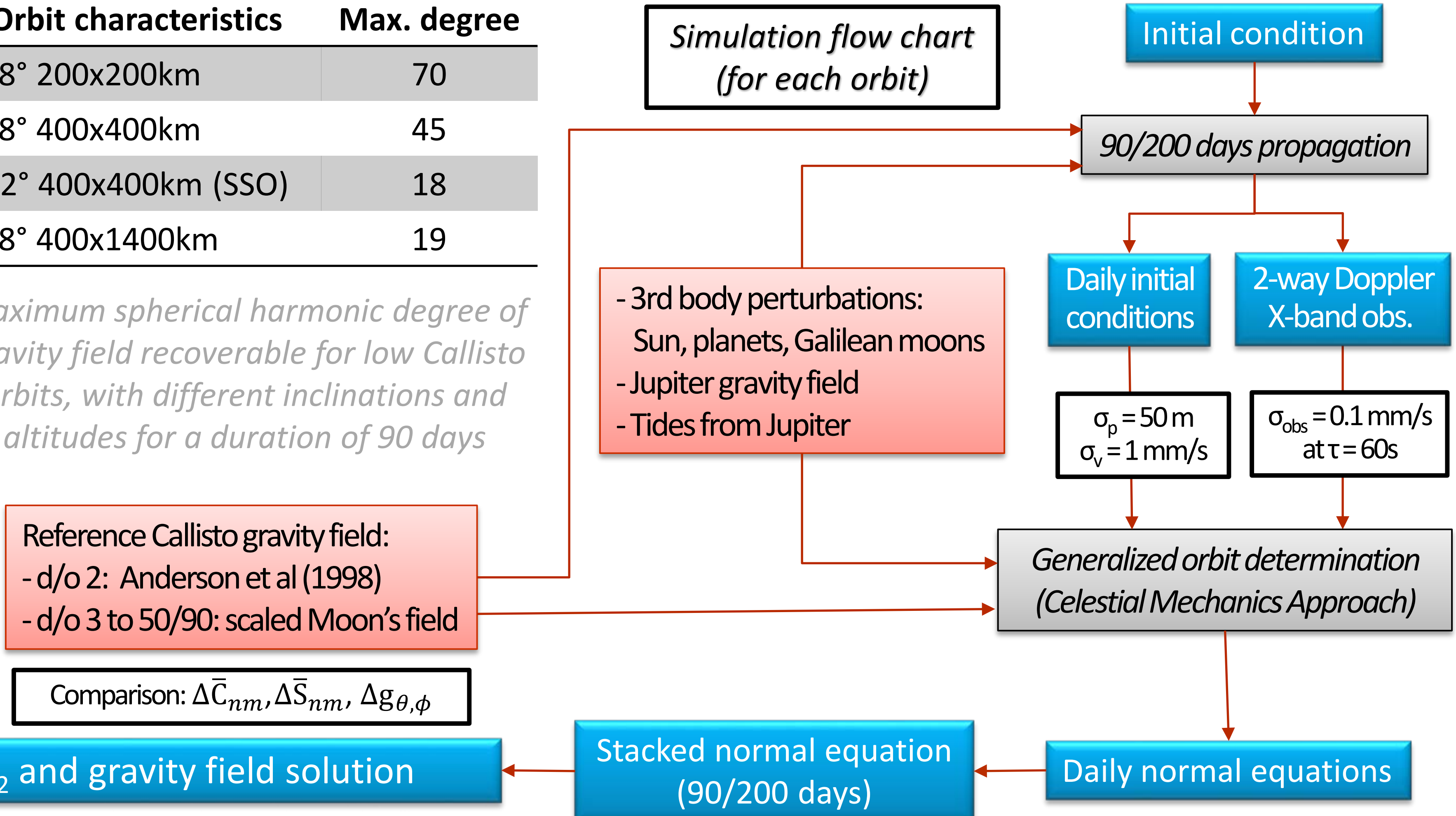




Simulation set-up and Callisto example

Orbit characteristics	Max. degree
88° 200x200km	70
88° 400x400km	45
112° 400x400km (SSO)	18
88° 400x1400km	19

Maximum spherical harmonic degree of gravity field recoverable for low Callisto orbits, with different inclinations and altitudes for a duration of 90 days



Orbit propagations in a full force model, as well as the whole gravity field recovery process were done using a development version of the Bernese GNSS Software.

Astronomical Institute University of Bern AIUB

UNIVERSITÄT BERN

Astronomisches Institut der Universität Bern

Swiss Optical Ground Station and Geodynamics Observatory Zimmerwald

AIUB

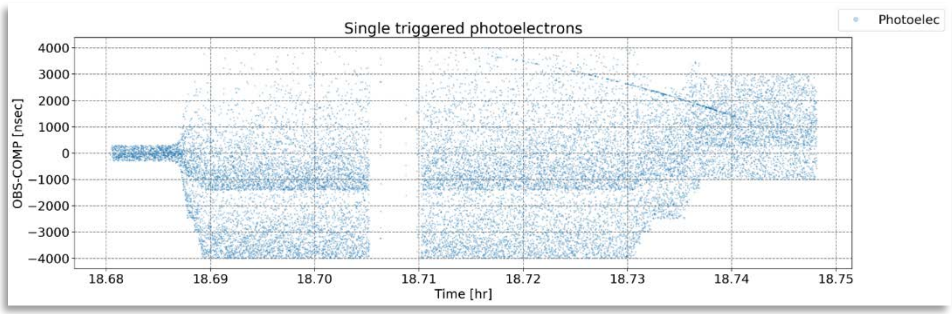
Public Outreach

ILRS Virtual World Tour 2020
November 2-6, 2020

Tuesday, November 03:	
13.00-15.00 UTC	Tour of Zimmerwald, Switzerland

Space Debris Observations (Daytime pass!)

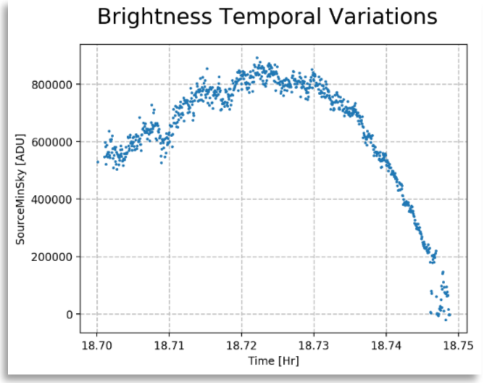
SLR Observed-Minus-Predicted



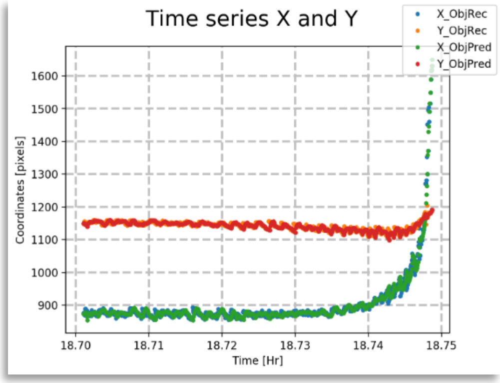
EL-55 (YF24) (Long March (CZ) 2C)
NORAD: 28480
Date 12-JUN-2020
Starting pass: 18:41 UTC
Sun elevation: 6.58°
CS: 29 [m2]
Mass: 3800 [kg]
Object class: rocket body (cyl)

Credit image: Zhipeng L. (2016)

Light curve



Tracking

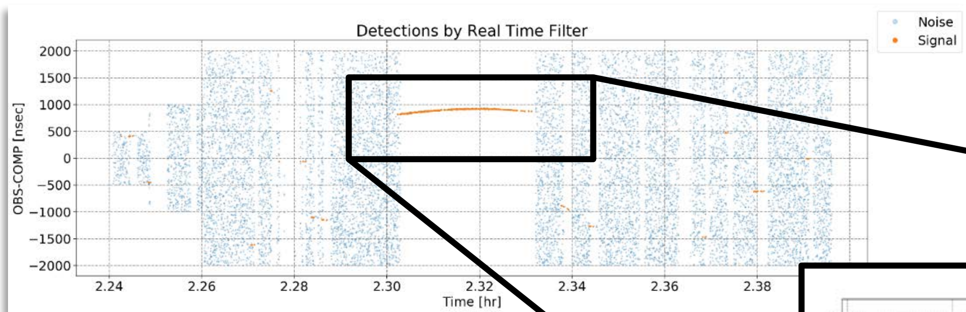


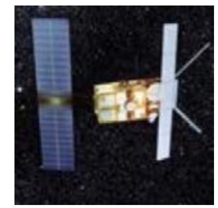
Simultaneous Real-Time Observables (4D) (!):

- Ranges
- Azimuth and Elevation
- Brightness

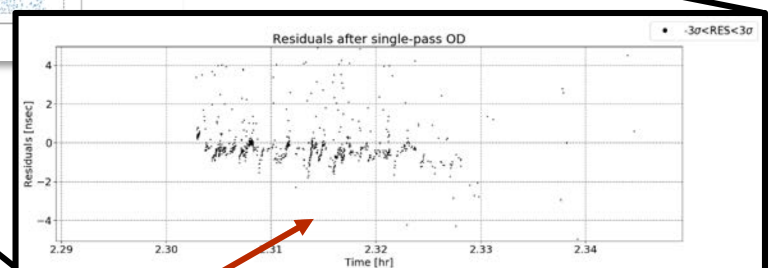
Space Debris Observations

SLR Observed–Minus–Predicted

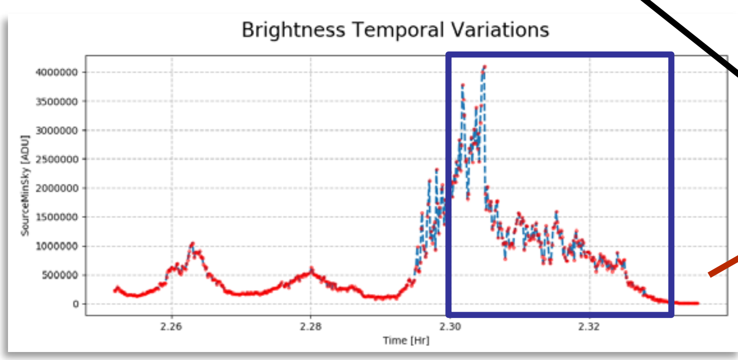




ERS–2
NORAD: 23560
Date 17–Sep–2020
Starting pass: 02:15 UTC
Object class: decommissioned

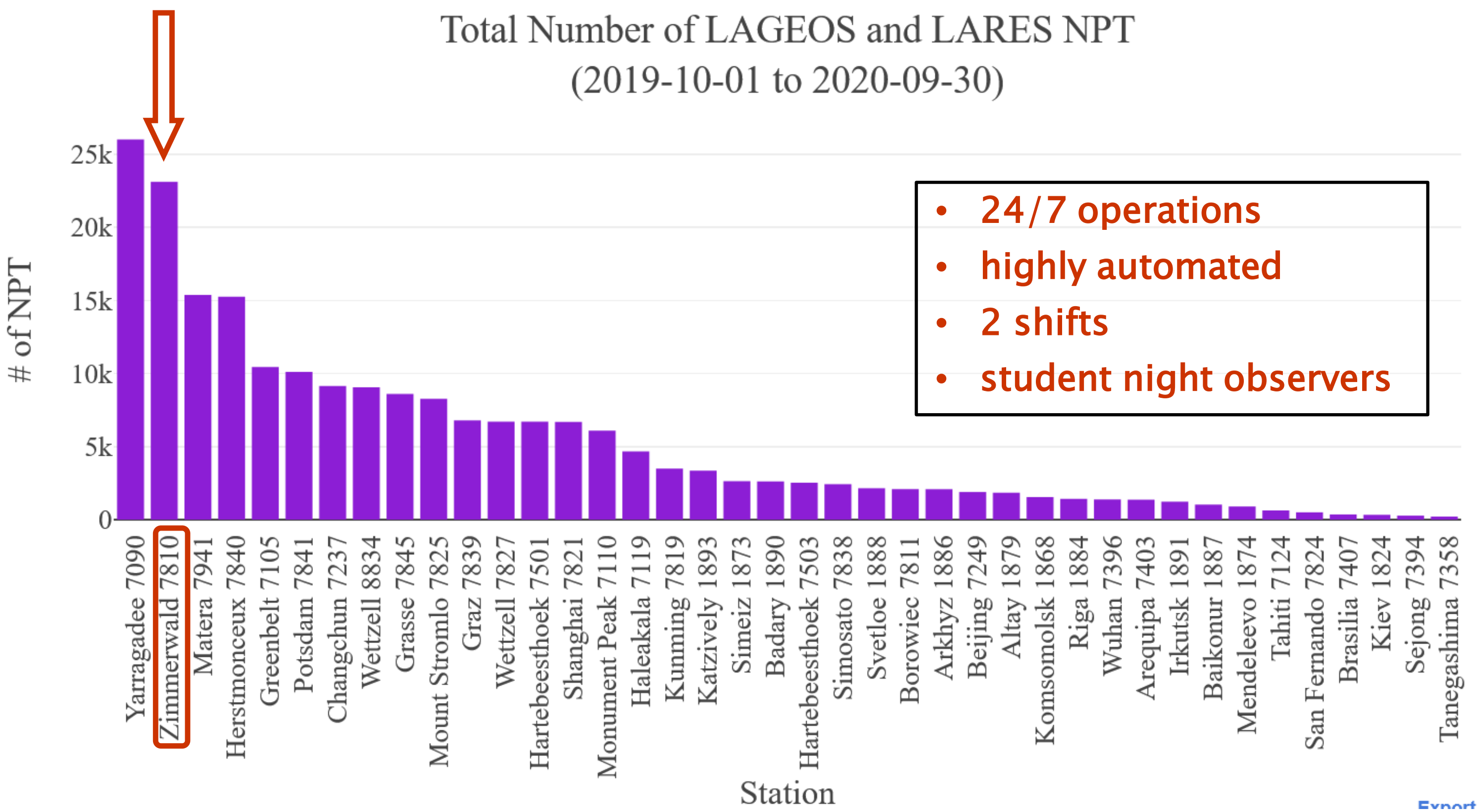


Light curve



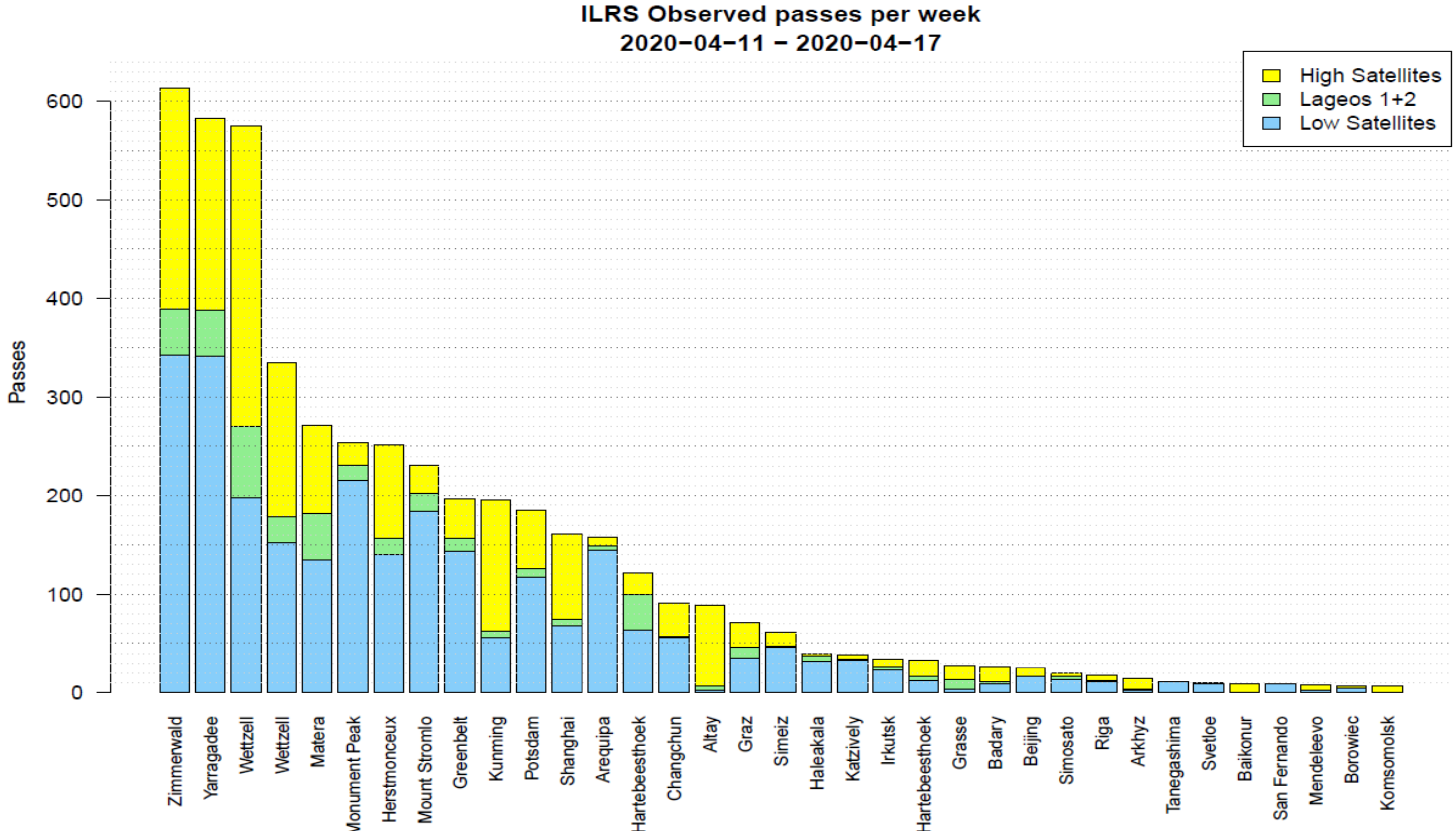
Attitude of retroreflector w.r.t the centre of mass

ILRS SLR Performance



- 24/7 operations
- highly automated
- 2 shifts
- student night observers

Best week 2020



New 1kHz 10ps Laser System

- New 1kHz, 10ps laser arrived in Bern!
- Acceptances test going on
- Will be mounted in parallel to existing laser (2021)
- Goals:
  - increase accuracy from 12mm to 2mm
  - increase number of measurements by a factor of 10