How does geophysical loading affect Earth rotation? Simulations and reality

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Motivation

- Mass transport within Earth’s fluid envelope affects ERPs:
  - **angular momentum exchanges with the solid Earth**
  - **cm-level station displacements**
- Non-tidal loading induces **systematic/random errors** in space geodetic products
- $dUT1$ from intensives more sensitive to poor modelling

in this presentation

- Assess impact of non-tidal loading on IVS+QUASAR Intensives
  - **Simulated** observations
  - **Real** observations

Modelling geophysical loading displacements

Calculation of geophysical loading deformations

- Assumptions: **elastic** and **instantaneous** response
- **Patched Green's function approach** (Dill and Dobslaw, 2013; Dill et al., 2018):

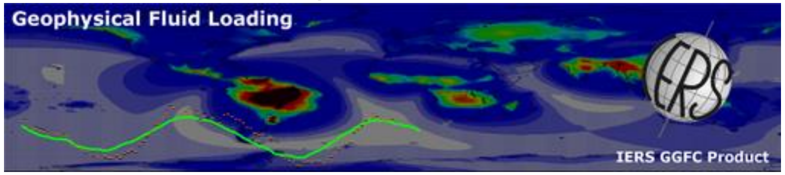
$$d_R(\vec{r},t) = \iint \delta P(\vec{r}',t)\mathcal{G}_R(\psi)\cos(\varphi')\,d\lambda' d\varphi'$$

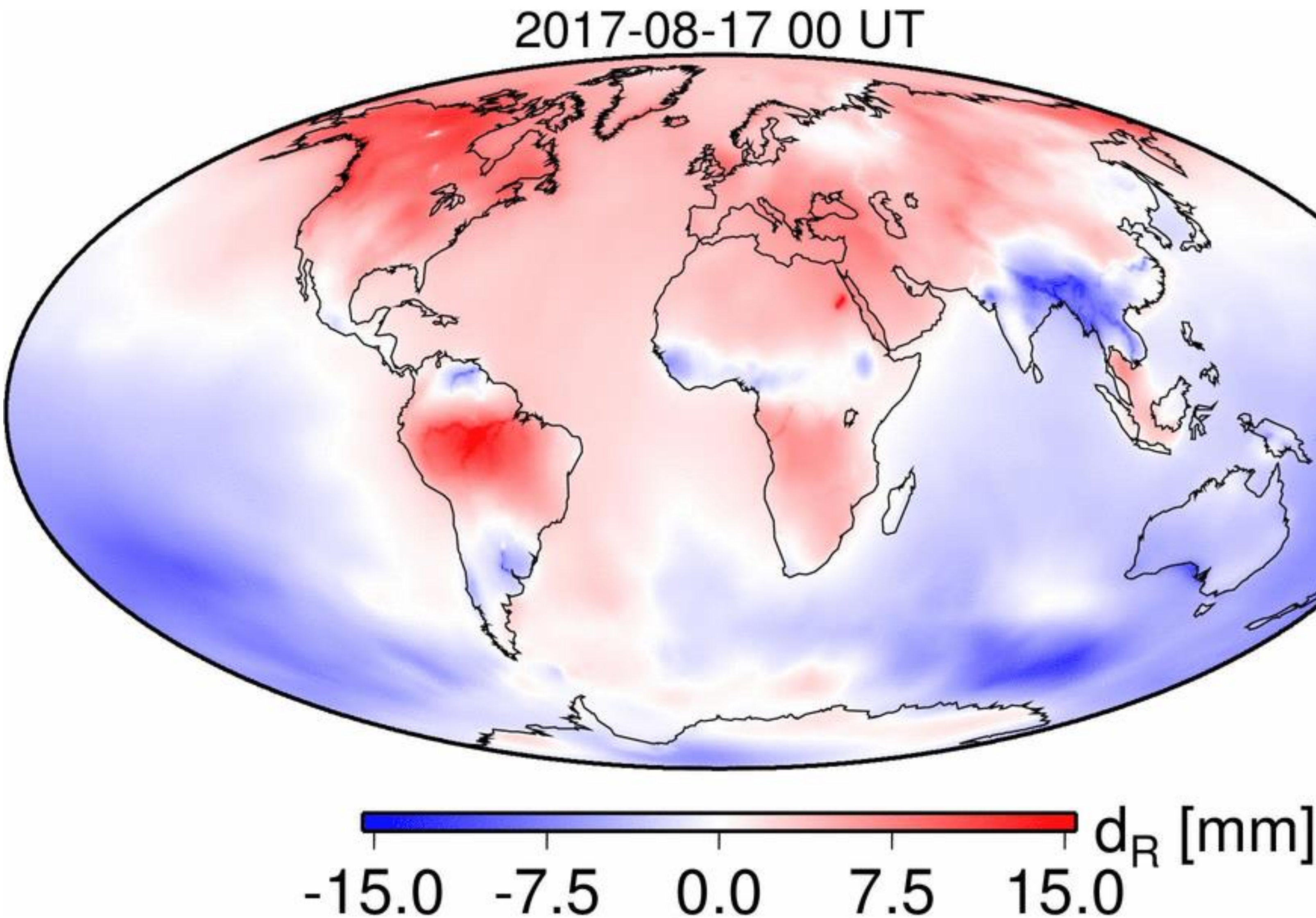
$$d_L(\vec{r},t) = \iint \hat{q}(\vec{r},\vec{r}')\delta P(\vec{r}',t)\mathcal{G}_L(\psi)\cos(\varphi')\,d\lambda' d\varphi'$$

d_R/d_L: radial/lateral displacement at $\vec{r}$, δP: mass anomaly at $\vec{r}'(\varphi',\lambda')$, $\mathcal{G}_R/\mathcal{G}_L$: radial/lateral Green's function, ψ: spherical distance between $\vec{r}$ and $\vec{r}'$, $\hat{q}$: unit vector from station to point load

- Loading displacements by GFZ Potsdam, Earth System Modelling, forced by **ECMWF**'s high-resolution model (9 km):
    - **Analysis** (latency one day)
    - **Forecasts** (up to 6 days ahead)

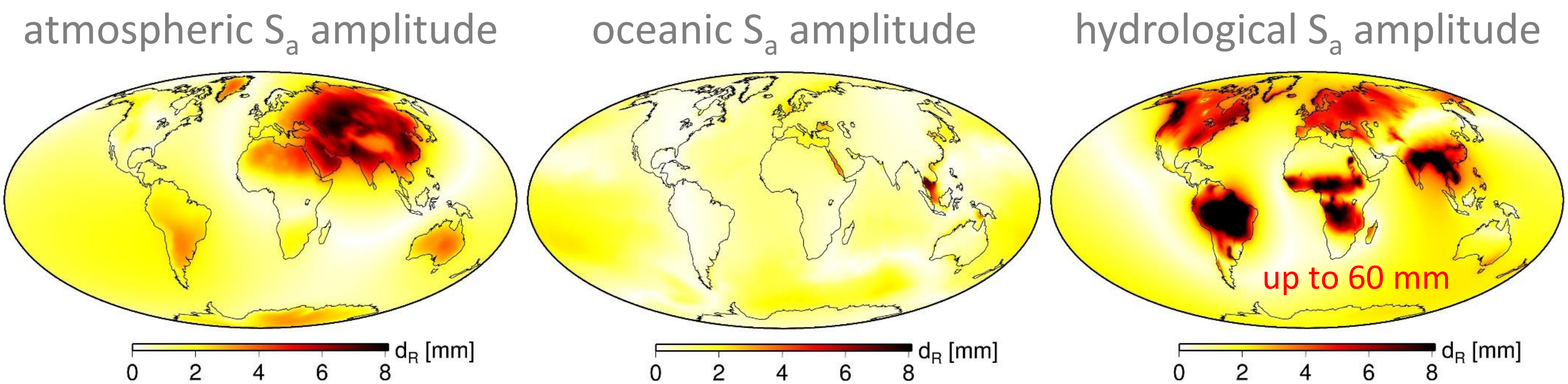
ftp://esmdata.gfz-potsdam.de/LOADING




2017-08-17 00 UT
-15.0
-7.5
0.0
7.5
15.0
d_R [mm]

Empirical Geophysical Loading Model

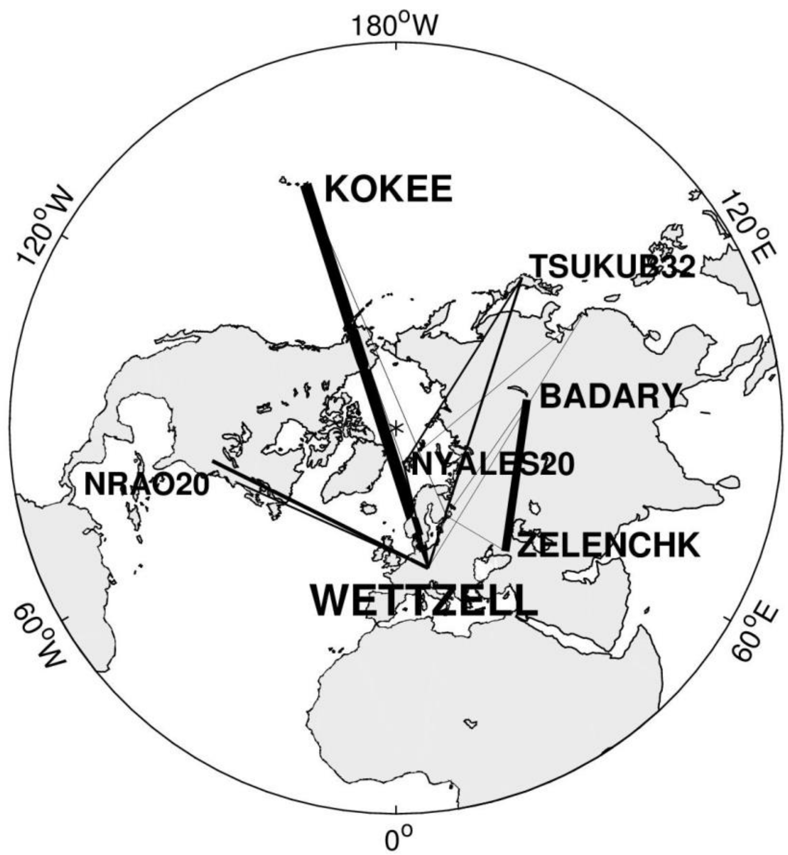
- Seasonal fit (5-yr, annual and overtones)
- 40 years of GFZ loading models (Dill and Dobslaw, 2013)



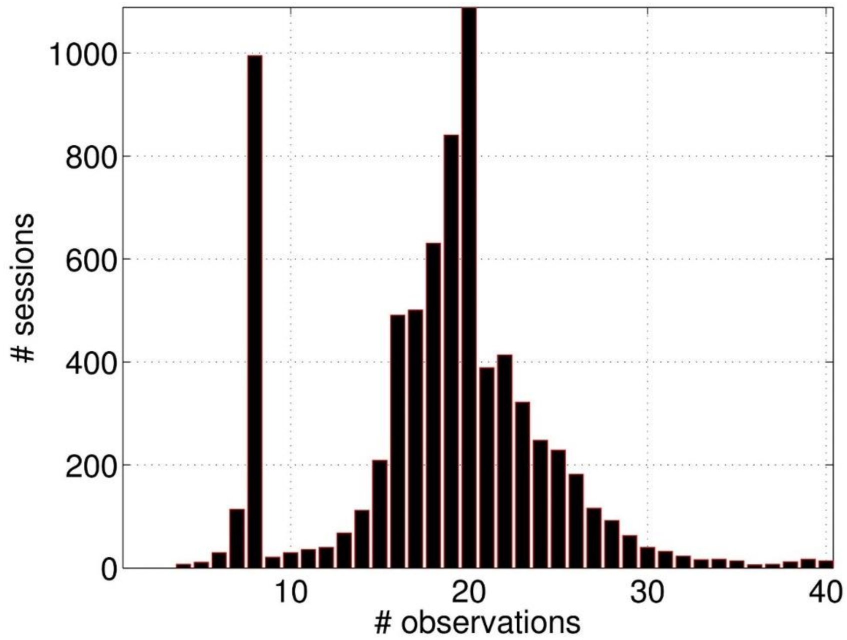
Intensive VLBI sessions

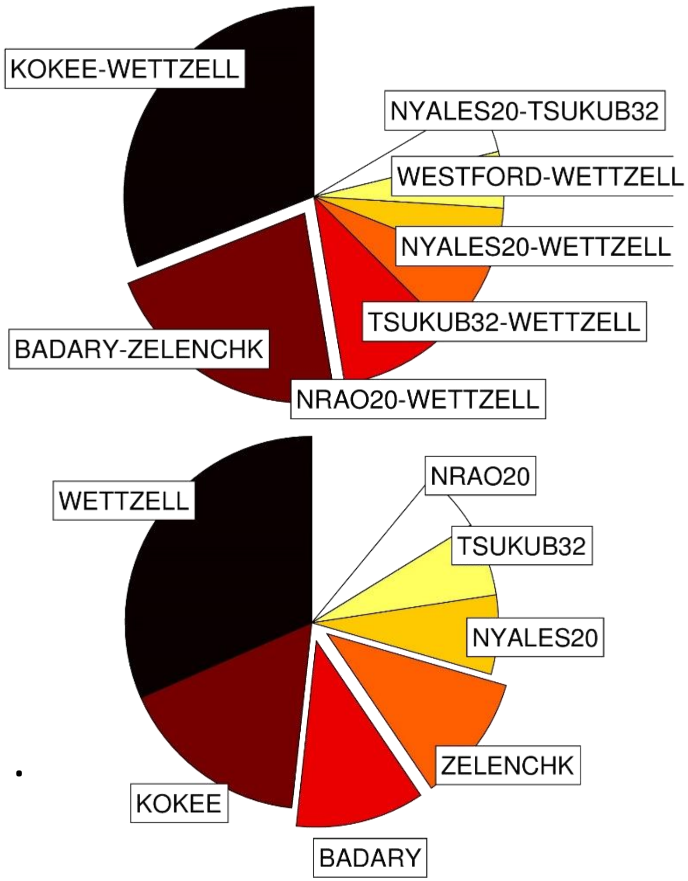
IVS and Quasar Intensives

- 93% single-baseline
- 6% baseline-triplet



IVS and Quasar Intensives (cont'd)



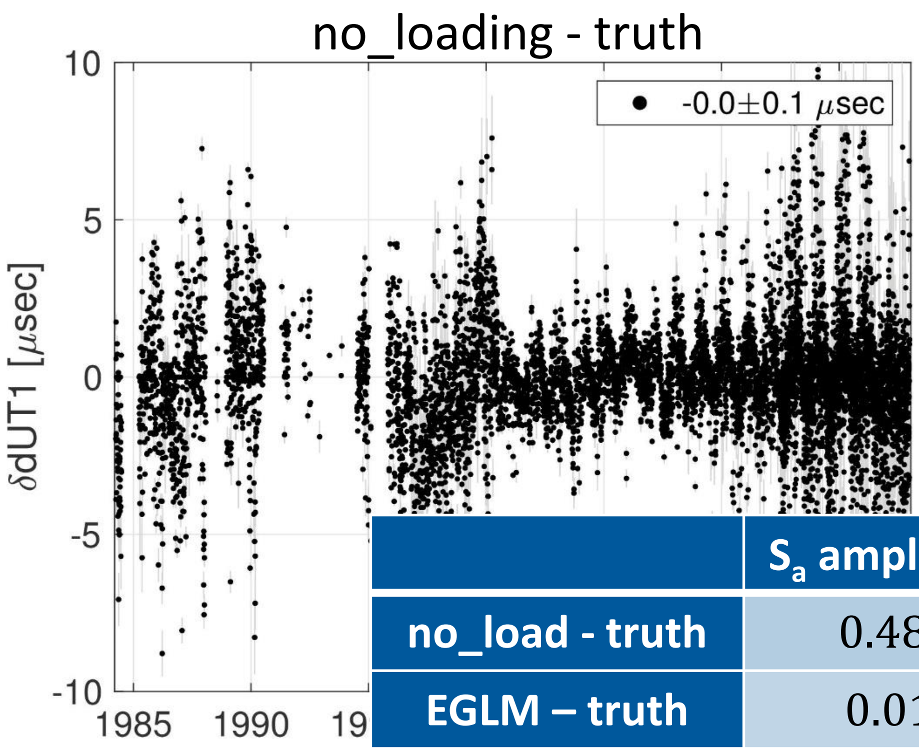


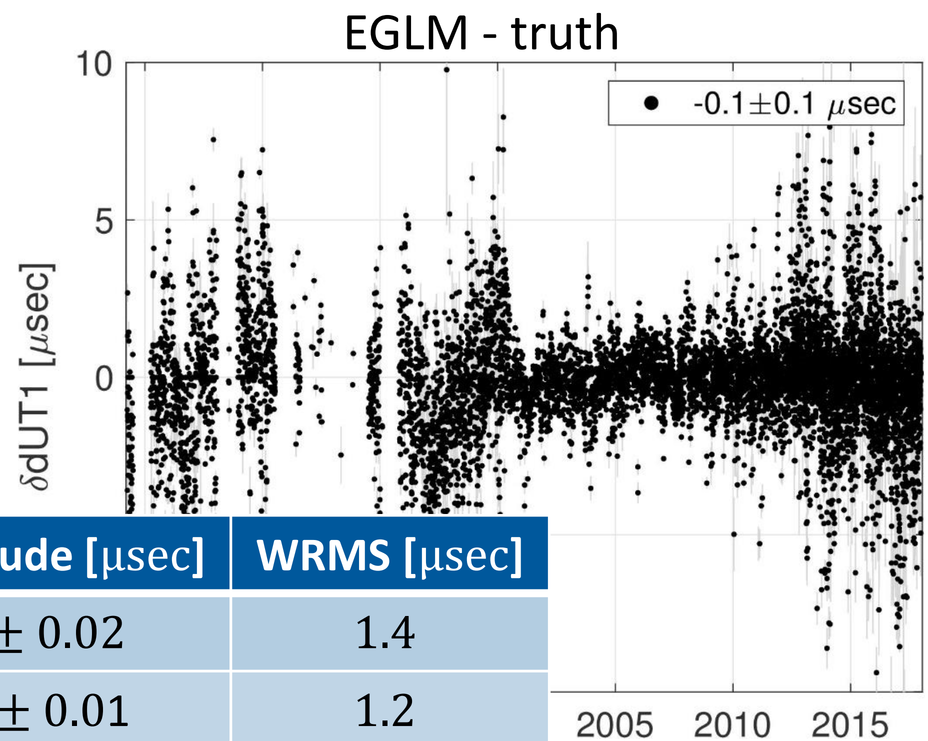
- ❑ Observations (~210000), obs/session (~20)
- ❑ Kk-Wz (31%), Bd-Zc (22%), Gn-Wz (10%), . . .
- ❑ Wz (32%), Kk (17%), Bd (11%), . . .

Analysis of simulated VLBI data

$dUT1$ differences

- If *GFZ loading* and *no noise* is simulated, . . .





	S_a amplitude [μsec]	WRMS [μsec]
no_load - truth	0.48 ± 0.02	1.4
EGLM – truth	0.01 ± 0.01	1.2

EGLM reduces systematics

Analysis of real VLBI data

VLBI data analysis

- In addition to what is usually done . . .
  - VieVS@GFZ **Kalman** filter + RTS smoother (Nilsson et al., 2015; Soja, 2016)
  - **Homogenized meteorological** data (Balidakis et al., 2018)
  - **Potsdam Mapping Functions** with non-linear gradients (Zus et al., 2015; Balidakis et al., 2018)

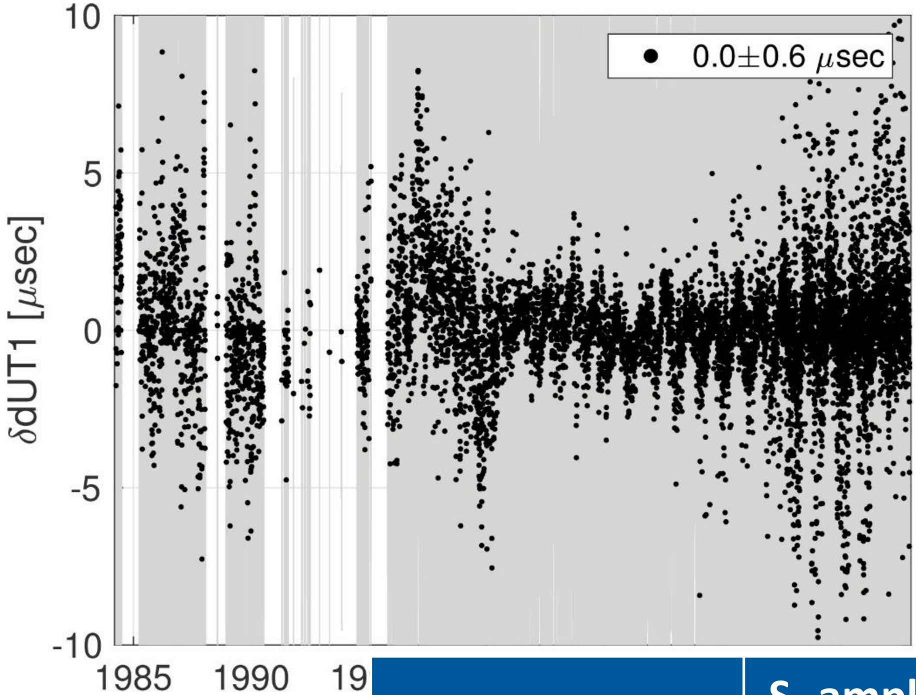
Assessment of GFZ loading models and EGLM

- ❑ **Reduced S_a amplitudes** at 80% (75%) of the VLBI and GNSS stations
- ❑ **Reduced baseline length repeatability** at 80% (78%) of baselines

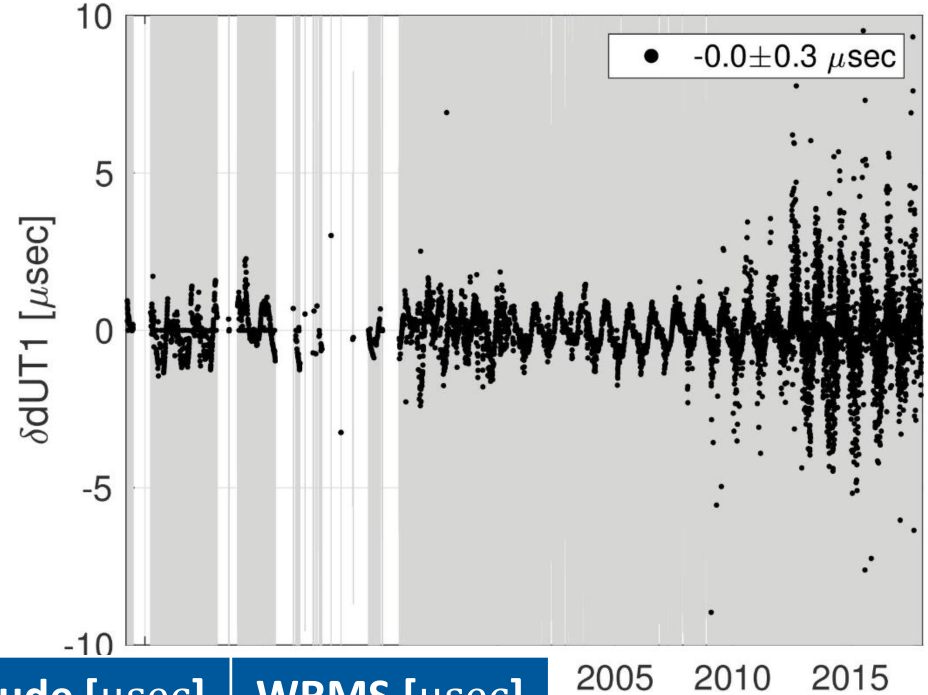
more details soon in Balidakis et al., 2019; Männel et al., 2019

$dUT1$ differences

GFZ - no_load



EGLM – no_load

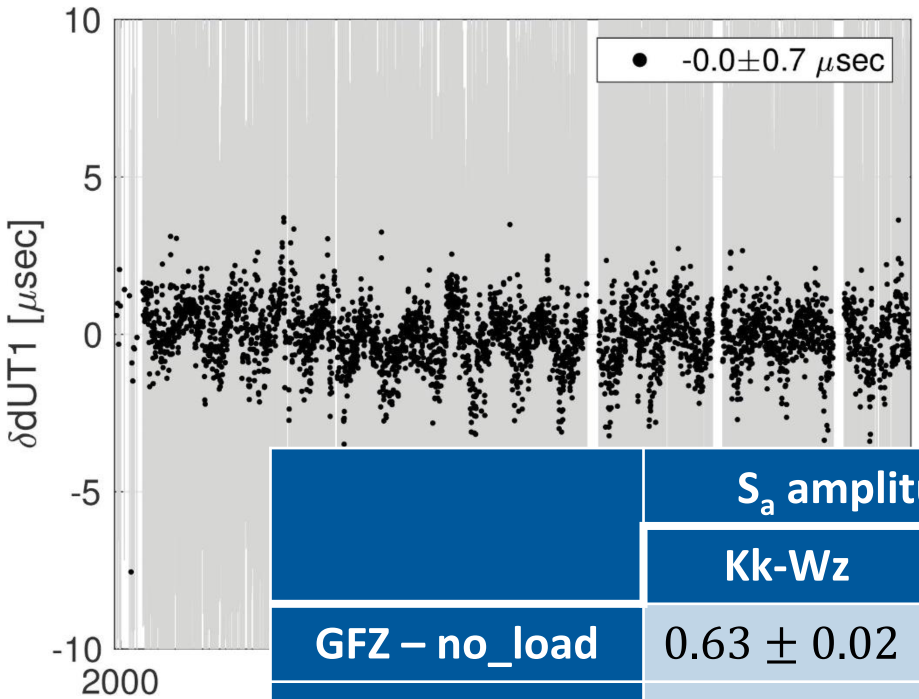


	S_a amplitude [μsec]	WRMS [μsec]
GFZ – no_load	0.50 ± 0.02	1.4
EGLM – no_load	0.53 ± 0.01	0.7

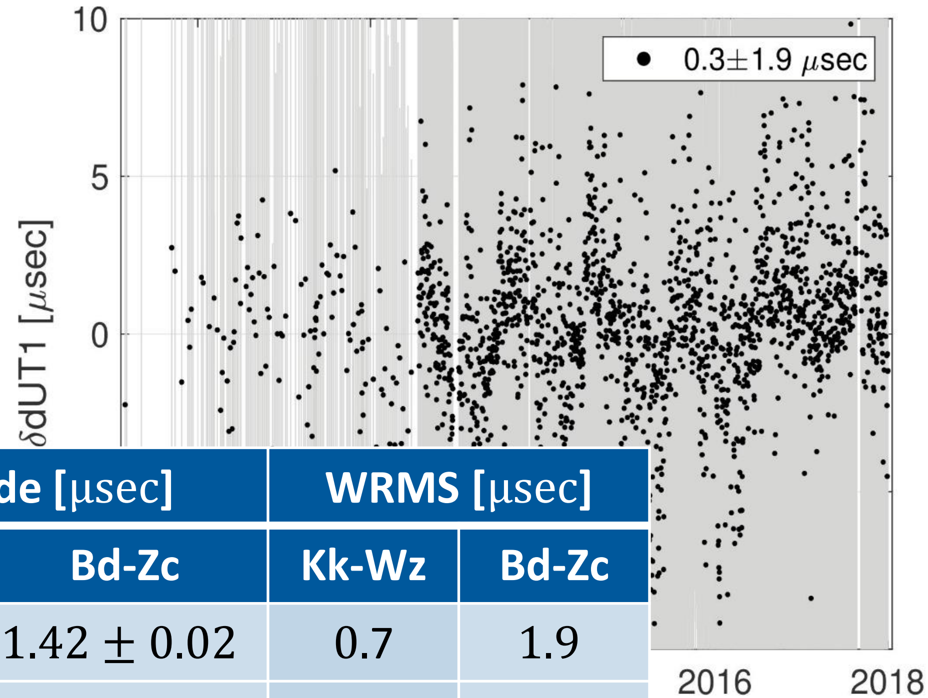
$dUT1$ differences (cont'd)

- GFZ minus no_load

KOKEE-WETTZELL



BADARY-ZELENCHK

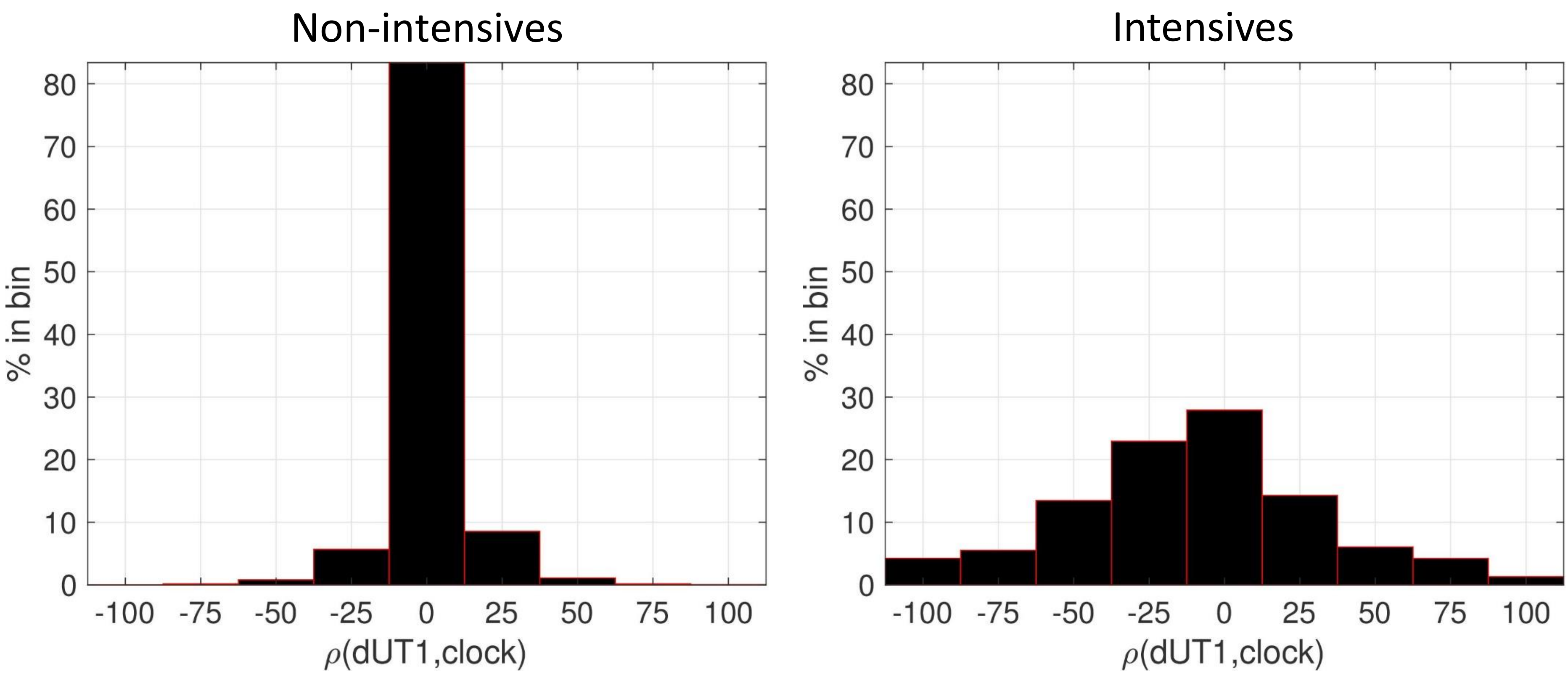


	S_a amplitude [μsec]		WRMS [μsec]	
	Kk-Wz	Bd-Zc	Kk-Wz	Bd-Zc
GFZ – no_load	0.63 ± 0.02	1.42 ± 0.02	0.7	1.9
EGLM – no_load	0.62 ± 0.01	1.63 ± 0.03	0.7	1.3

EOP differences from Non-intensives

		S_a amplitude	WRMS
GFZ – no_load	$dUT1$ [µsec]	0.5 ± 0.02	1.1
	x_p [µas]	4.0 ± 0.5	14.2
	y_p [µas]	8.0 ± 0.6	18.1
	dX [µas]	0.9 ± 0.3	8.7
	dY [µas]	0.7 ± 0.3	8.9
EGLM – no_load	$dUT1$ [µsec]	0.5 ± 0.2	0.9
	x_p [µas]	3.9 ± 0.2	11.1
	y_p [µas]	6.6 ± 0.5	13.1
	dX [µas]	1.4 ± 0.3	9.1
	dY [µas]	1.2 ± 03	8.4

Correlation between *dUT1* and *clock*

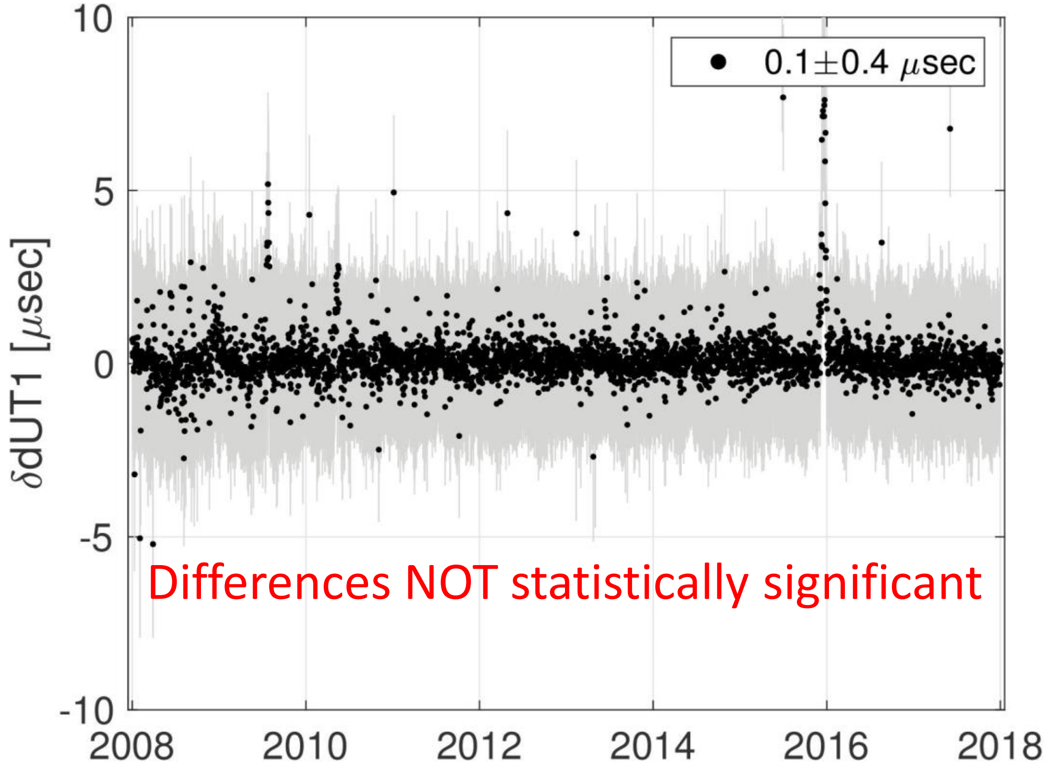


- INT: Nearly-constant baseline distortion during 60’ -> absorbed by baseline clock

GNSS data analysis

- GFZ in-house EPOS.P8 GNSS software (orbits and station coordinates estimated)

results soon by Männel et al., 2019



Recapitulation

- Neglected non-tidal loading affects EOPs
- Systematic differences (S_a amplitude):
  - dUT1: 0.5 μsec
  - Polar motion: 5 μas
  - CPO: 1 μas
- For the state-of-the-art VLBI system
  - non-tidal loading DOES NOT affect EOPs statistically significantly
- Non-tidal loading introduces systematics not acceptable for VGOS standards

Thank you!

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