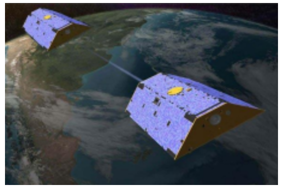
Towards a new and consistent release of GRACE and GRACE Follow-On monthly gravity field solutions from AIUB

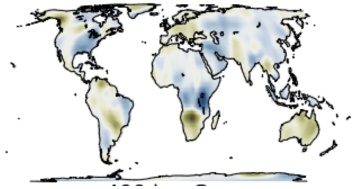
Martin Lasser, Ulrich Meyer, Daniel Arnold and Adrian Jäggi

28th IUGG General Assembly 2023, 11 – 20 July 2023, Berlin, Germany

Starting Point

Monthly gravity fields – parametrisation





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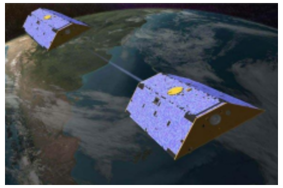

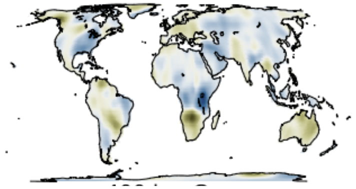

Basic parametrisation

- Initial conditions 2x[6]
- Accelerometer bias 2x[3] | [6]
- Accelerometer scaling 2x[3] | [9]

Parameters per arc 24 | 42

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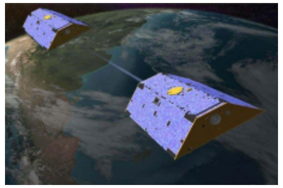

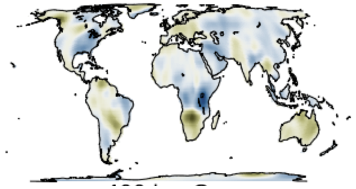

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GRACE: full scale matrix estimated

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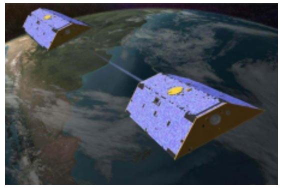

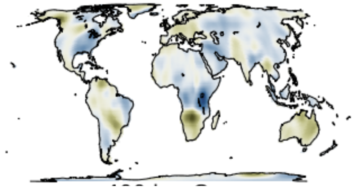

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Additional parameters

- 15 min PCA per satellite in
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  - along-track 2x[96]
  - cross-track 2x[96]

Parameters per arc 576

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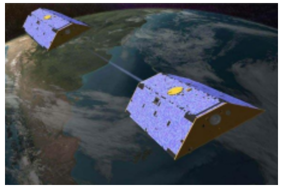

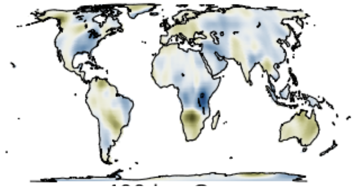

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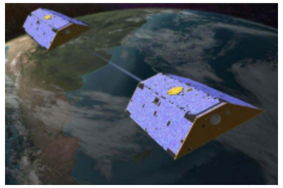
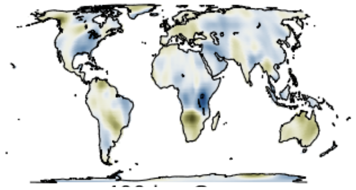
in daily arcs (30 days):
~ 18000 ‹orbit› parameters
+ 9405 gravity field d/o=2..96

Starting Point
Background force modelling





Force models	
Gravity field	AIUB-GRACE03S static
Astronomic bodies	JPL DE421 (all planets)
Mean pole	Linear
Solid Earth tides	IERS2010
Solid Earth pole tides	IERS2010
Ocean tides	FES2014b (+ admittances from TUG)
Ocean pole tides	Desai
Atmospheric tides	AOD RL06
Atmospheric & oeanic dealiasing	AOD RL06
Relativistic effects	IERS2010

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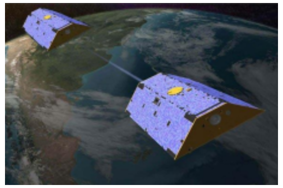

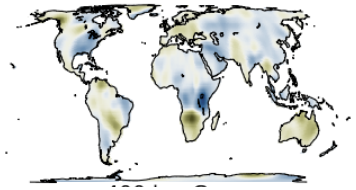

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??

→ AOD RL07 is available:

- For now RL06 is used to keep consistency in the COST-G combination
- RL07 is planned together with GRACE RL04 Level-1b data

Outlier Treatment

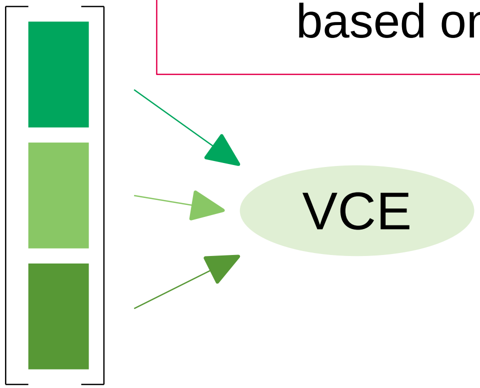
Variance Component Estimation (VCE)

$$\mathbf{N} = (\mathbf{A}^T \mathbf{P} \mathbf{A})$$
$$\boldsymbol{b} = \mathbf{A}^T \mathbf{P} \boldsymbol{l}$$
$$\Rightarrow \quad \hat{\boldsymbol{x}} = \mathbf{N}^{-1} \boldsymbol{b}$$

- The observations of each arc/block are used to set up normal equations (NEQs).
- Each arc is treated as being independent.

VCE: Each group of observations gets a weight based on its contribution to the final solution

$$\boldsymbol{l} =$$



$$r_k = n_{obs} - \frac{\sigma_0^2}{\sigma_k^2} \mathrm{tr}\left(\mathbf{N}_k \mathbf{N}^{-1}\right) \qquad \sigma_k^2 = \frac{\boldsymbol{e}_k^T \mathbf{P}_k \boldsymbol{e}_k}{r_k}$$

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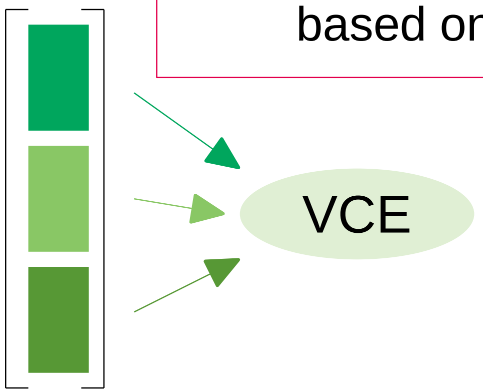

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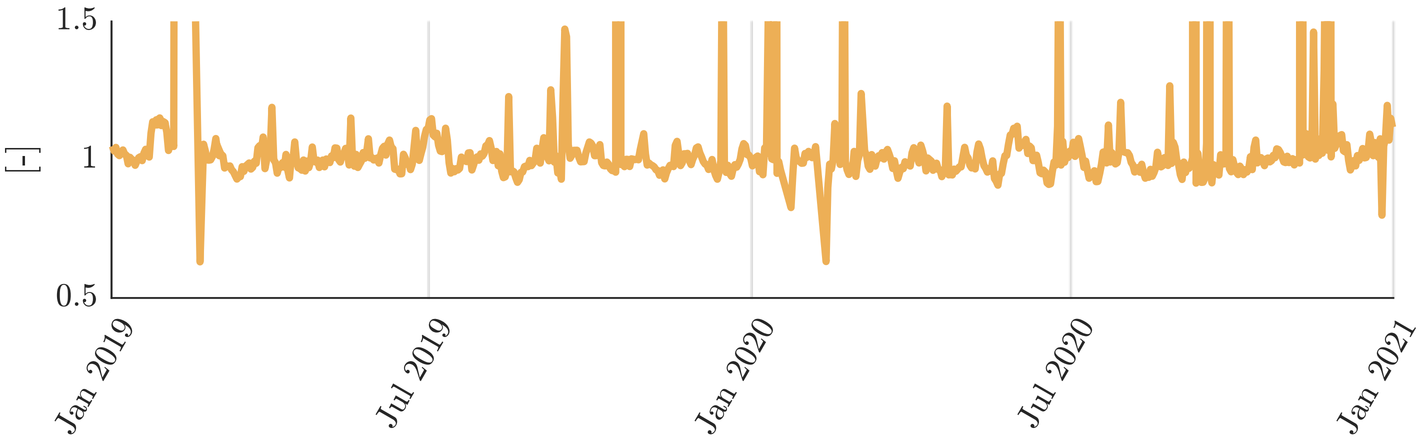
$$\sigma_k^2 \longrightarrow \hat{\boldsymbol{x}} = \left(\sum_{k=1}^{K=3} \frac{\sigma_0^2}{\sigma_k^2} \mathbf{N}_k \right)^{-1} \sum_{k=1}^{K=3} \frac{\sigma_0^2}{\sigma_k^2} \boldsymbol{b}_k$$

Outlier Treatment

VCE – results (1)



Large value
→ less contribution

- Measure for the quality of each arc/block
- Data problems on the level of each arc/block
- Large outliers on three days:
  → orbit manoeuvre (9 Sep)
  → KBR calibration manoeuvres (17 Sep and 28 Sep)

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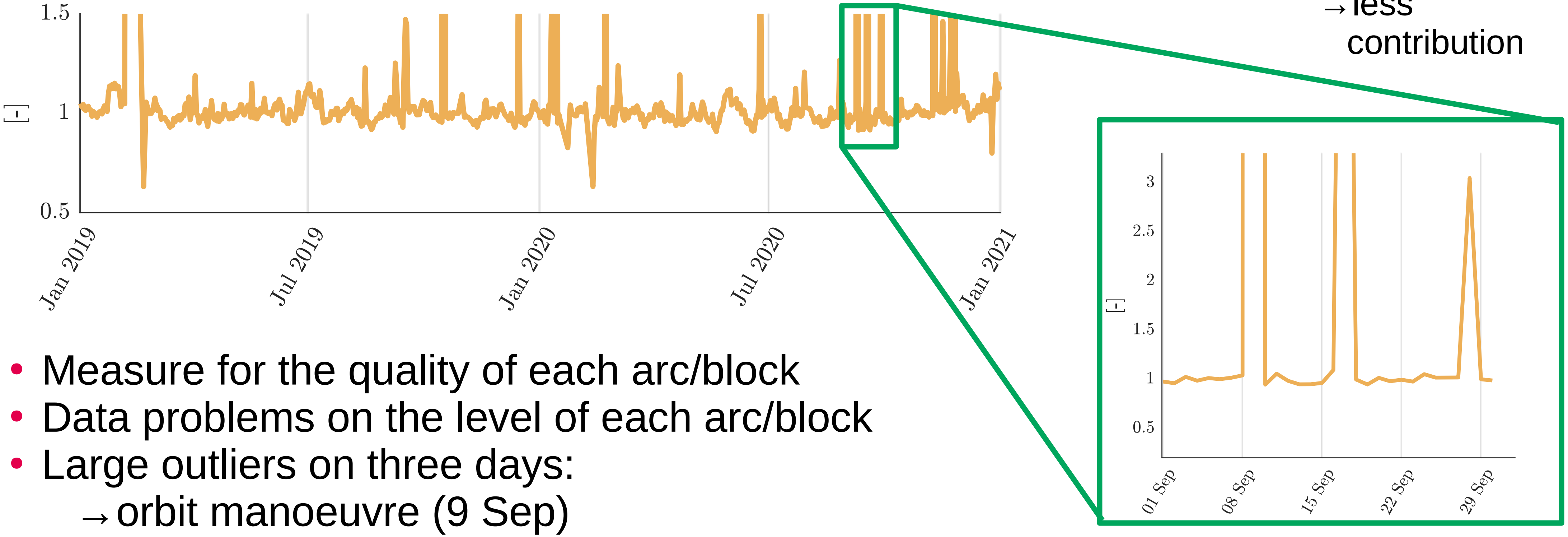

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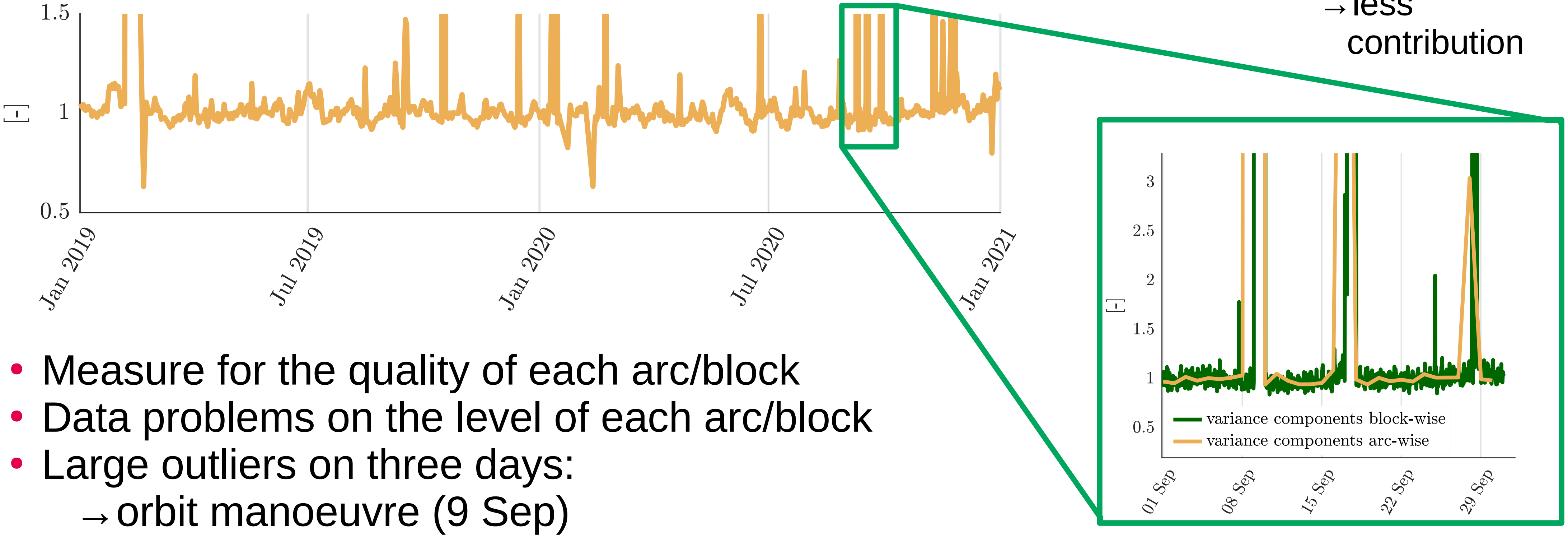

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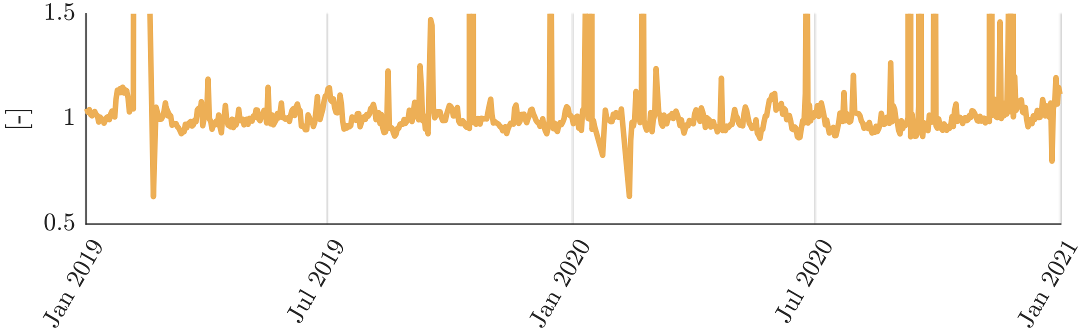
Block length of 50 min

Outlier Treatment

VCE – results (2)

Improvement in the gravity field solution



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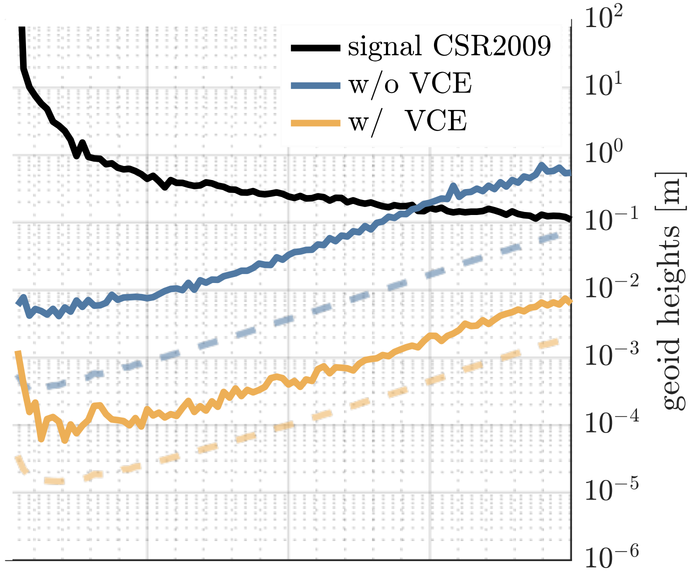

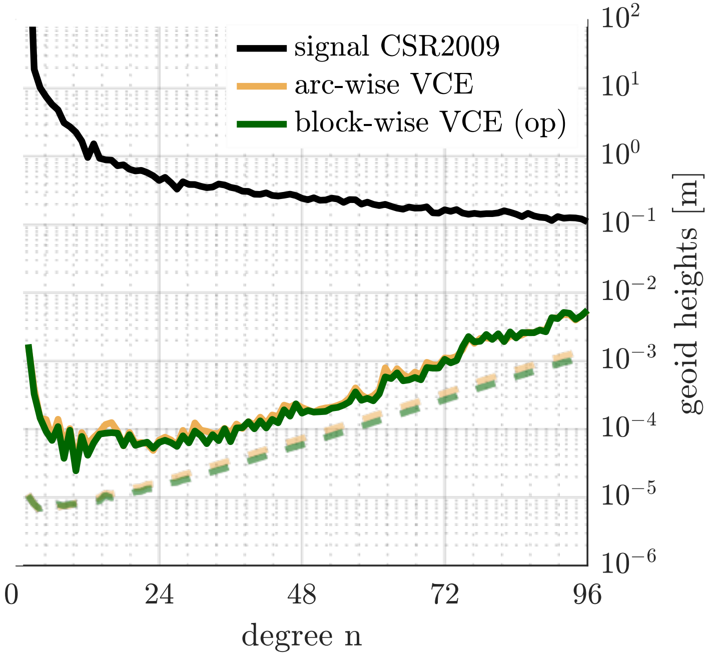

Outlier Treatment

Robust estimators

Weighting function

- check normalised residuals for exceeding a certain threshold

  → down-weight corresponding observation

  → Huber function, Hampel, IGG3 …

- $m=2$

$$p_i = \begin{cases} \dfrac{p_i \cdot m}{|\hat{e}_i / \sigma_{\hat{e}_i}|} & \text{for } |\hat{e}_i / \sigma_{\hat{e}_i}| > m \\ p_i & \text{else} \end{cases}$$

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G03p-223: Automated outlier detection with machine learning in GRACE-FO postfit residuals

Save ···

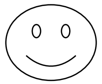
Info Schedule

Abstract

G03p-223: Automated outleir detection with machine learning in GRACE-FO postfit residuals

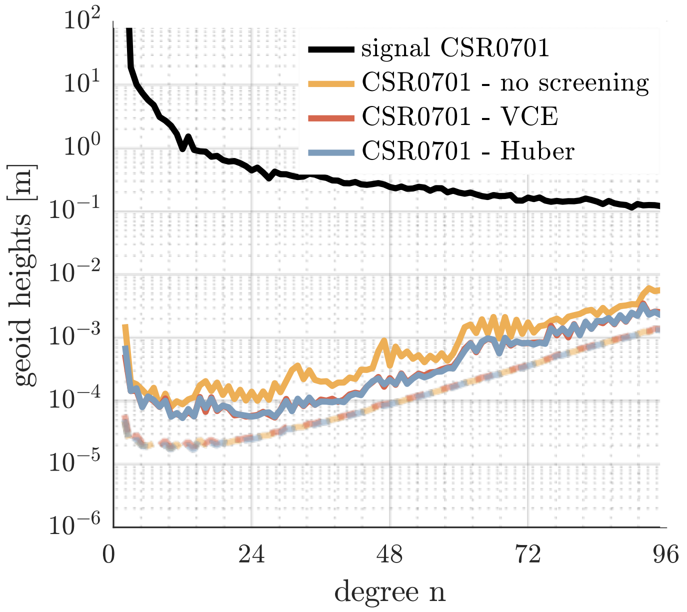
J. Zbinden[1], M. Lasser[1], U. Meyer[1], B. Panos[1], D. Arnold[1], A. Jäggi[1].
[1]University of Bern, Astronomical Institute, Bern, Switzerland.

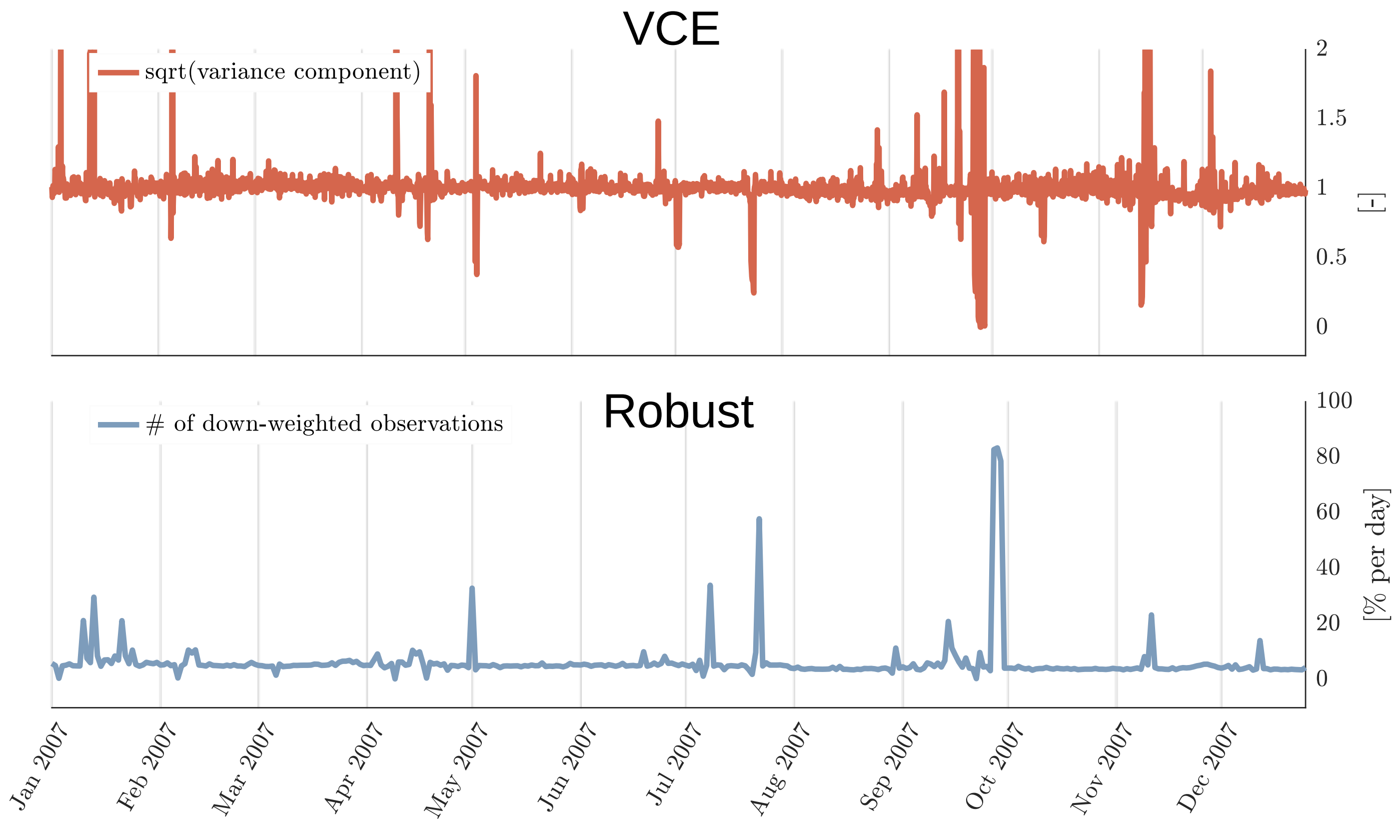
Today 17:00 …



Outlier Treatment
Robust estimators

Robust estimator vs. VCE





Stochastic Noise Modelling

Empirical model from post-fit residuals

Serial correlation of post-fit residuals

$$\hat{\boldsymbol{e}} = \boldsymbol{l} - \mathbf{A}\hat{\boldsymbol{x}} \quad \text{(post-fit residuals)}$$

$$\operatorname{cov}(\Delta t_k) = \frac{1}{N}\sum_{i=0}^{N} \hat{e}(t_i)\,\hat{e}(t_i + \Delta t_k)$$

- stationarity assumed
- biased estimation of auto-covariance
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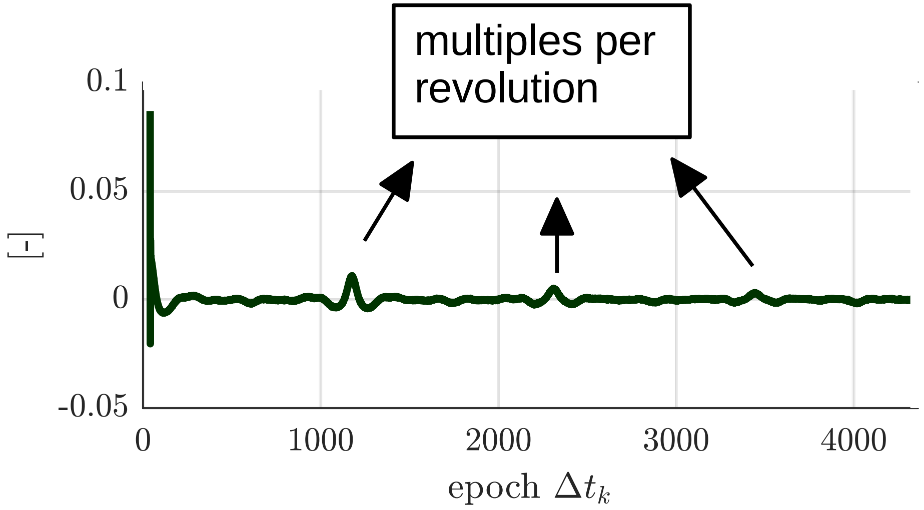

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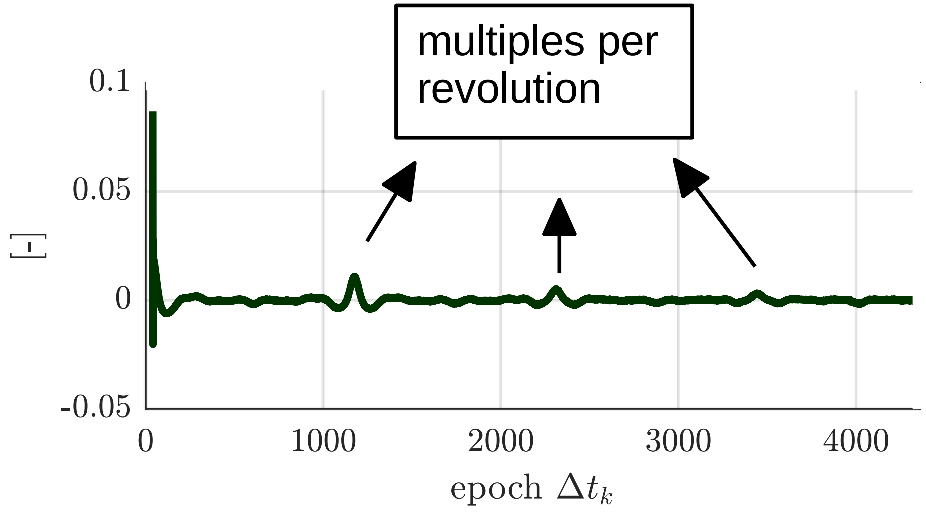
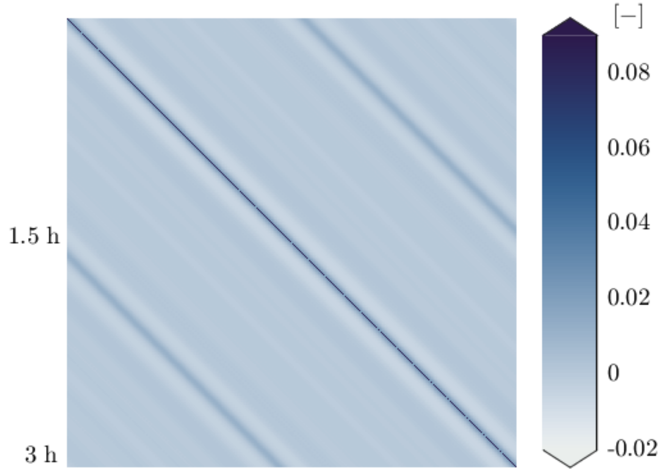


block Toeplitz matrix



→ **P**

Research Question

Test scenario

Does the a priori chosen gravity field influence our monthly solutions or can we do better by co-estimating monthly solutions (up to d/o=96) together with a static component (d/o=97..160)?

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Test scenario

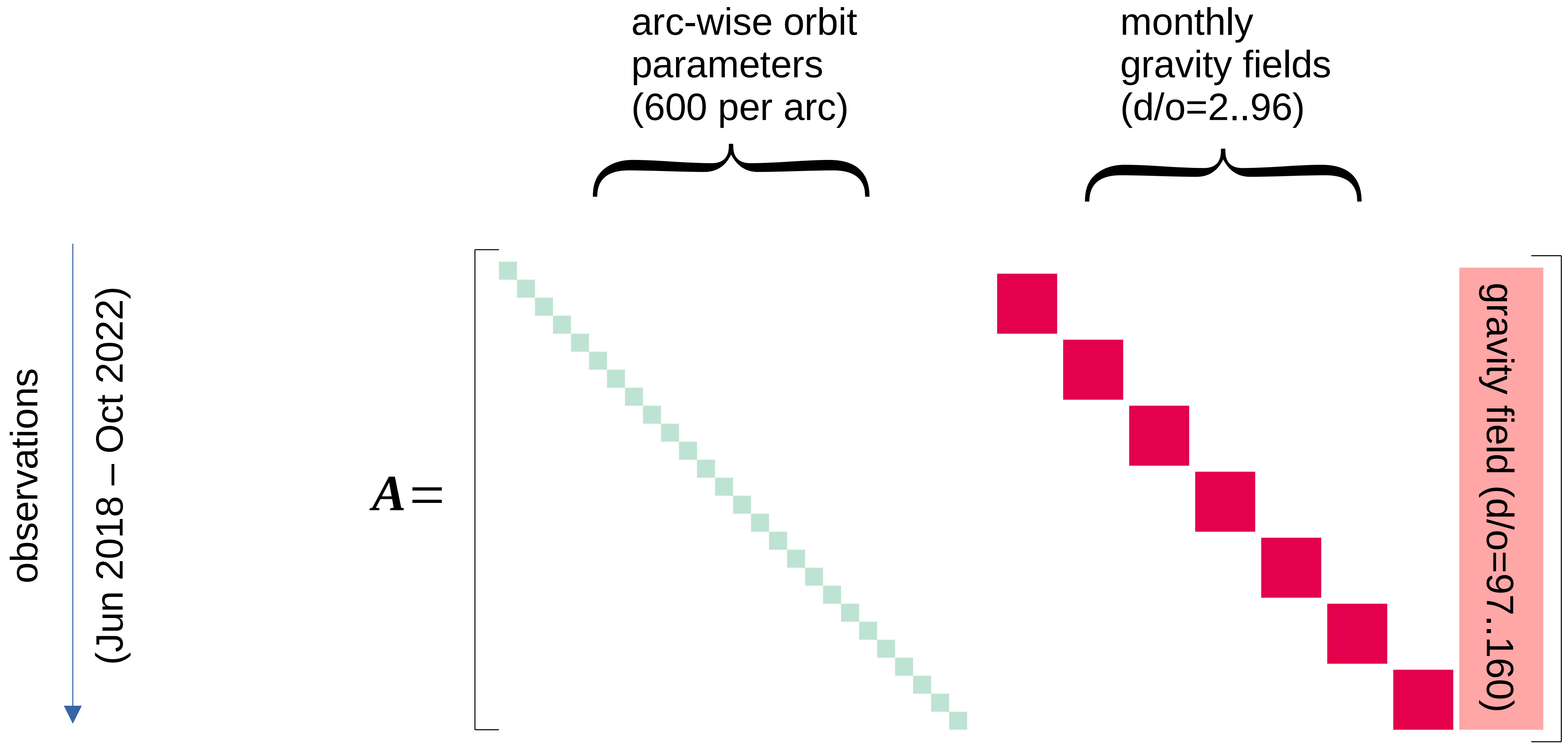
- 51 months of GRACE Follow-On (Jun 2018 – Oct 2022).
- A priori gravity field: *AIUB-GRACE-FO_op* (d/o= 2.. 96)
  + static *AIUB-GRACE03S (d/o=97..160).*
- With and without noise modelling from post-fit residuals.

1 emp monthly

2 stat co-est + emp monthly

3 stat co-est + emp full

Set-up
Design-matrix



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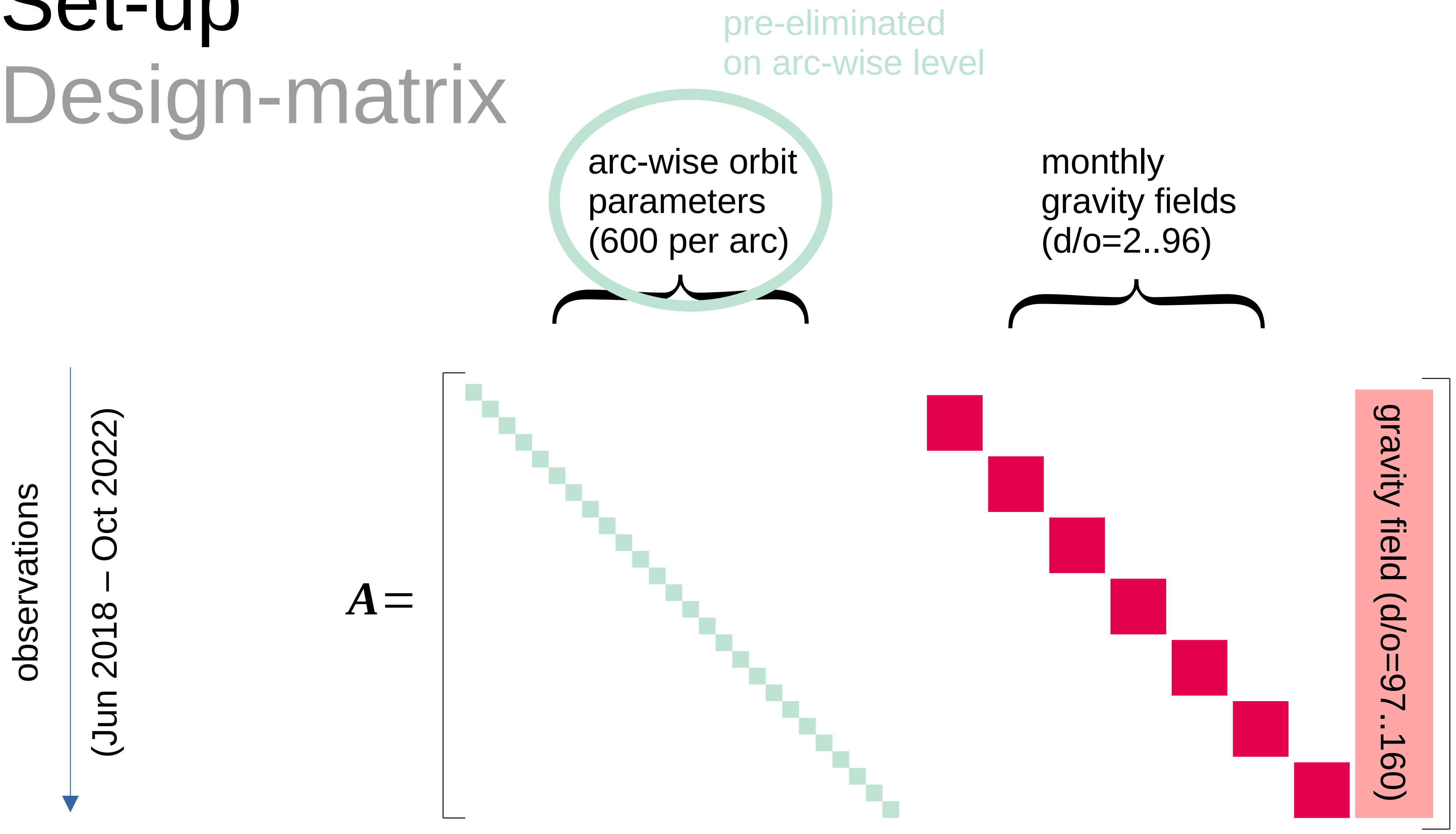

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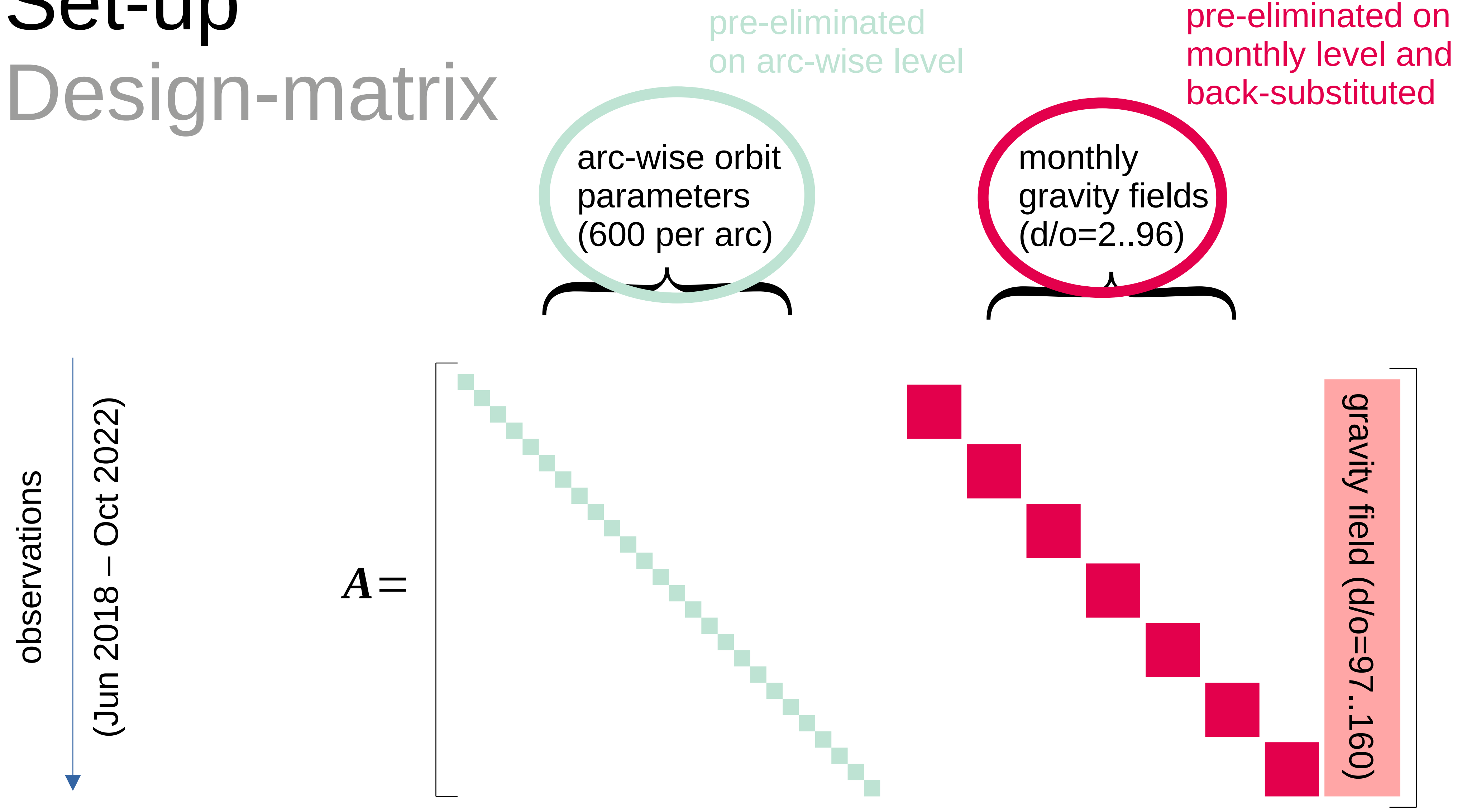
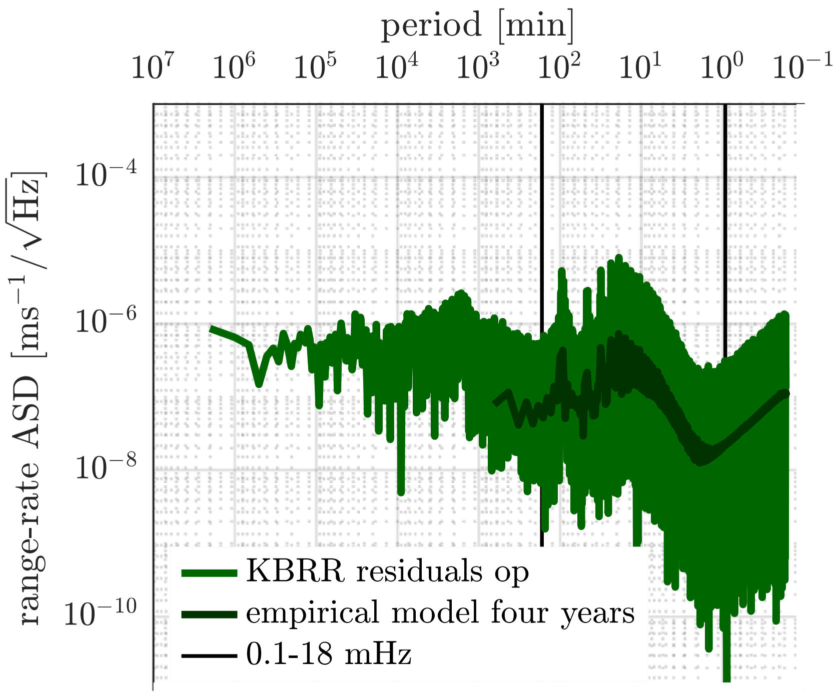


Noise Model

Based on post-fit residuals

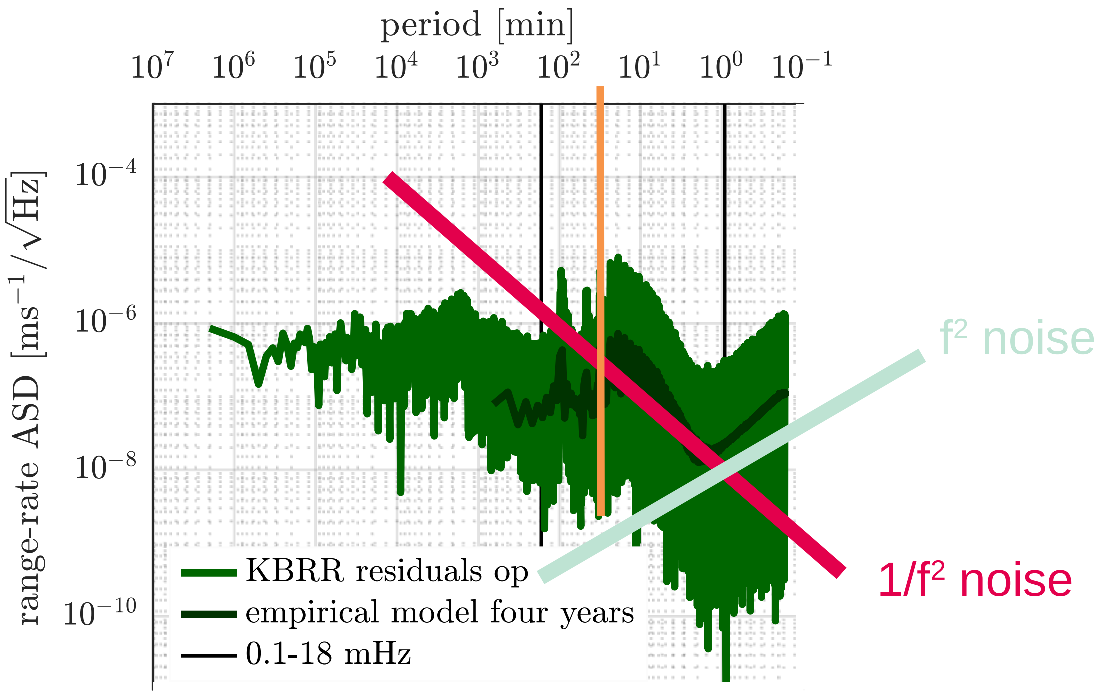


Auto covariance function → covariance matrix → weight matrix

Noise Model

Based on post-fit residuals

15 min sampling of PCAs



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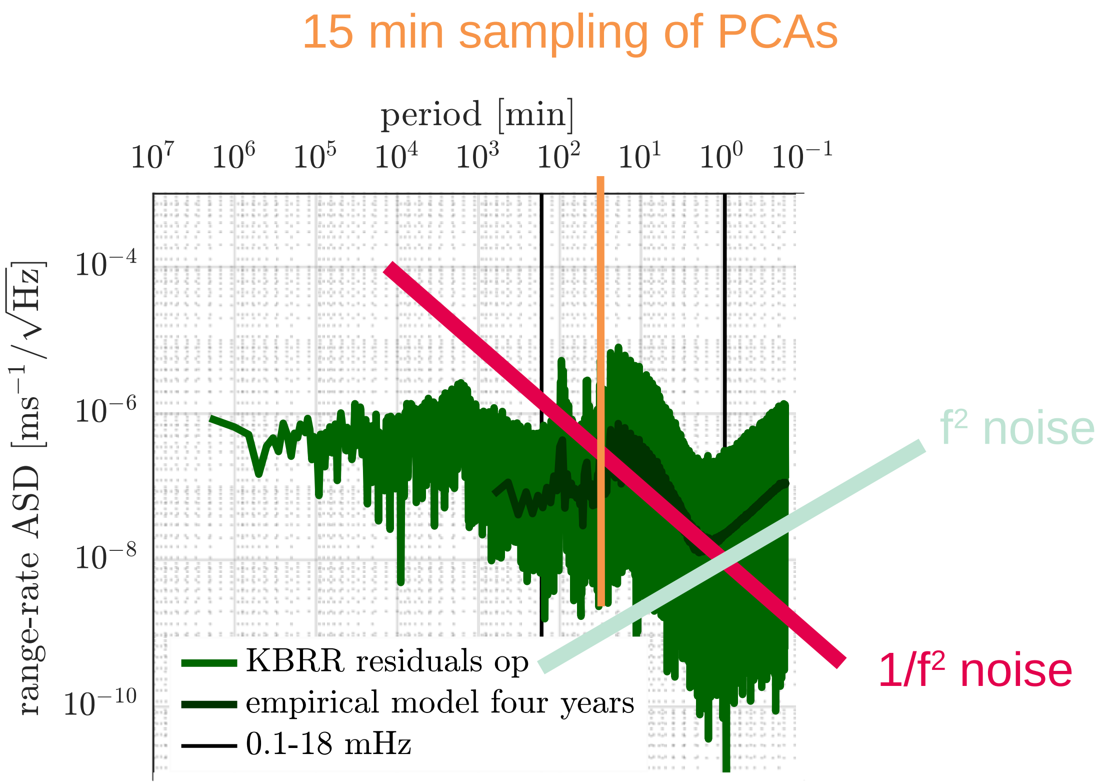

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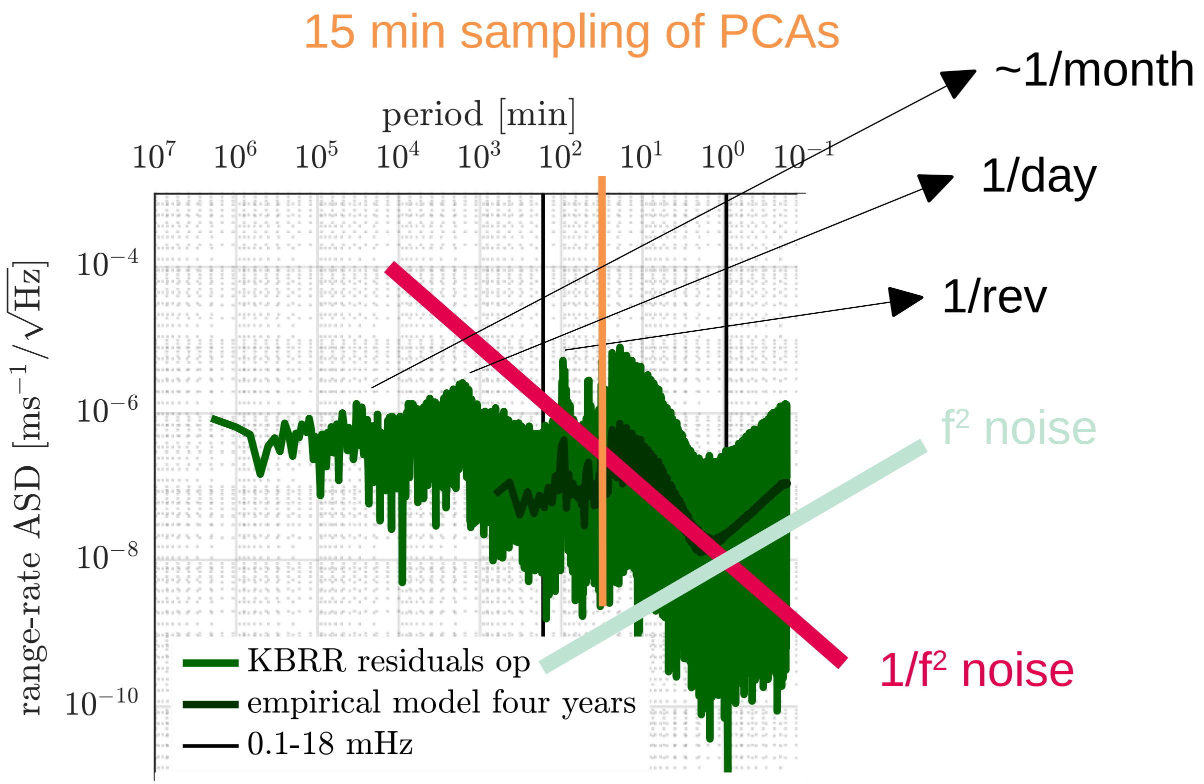

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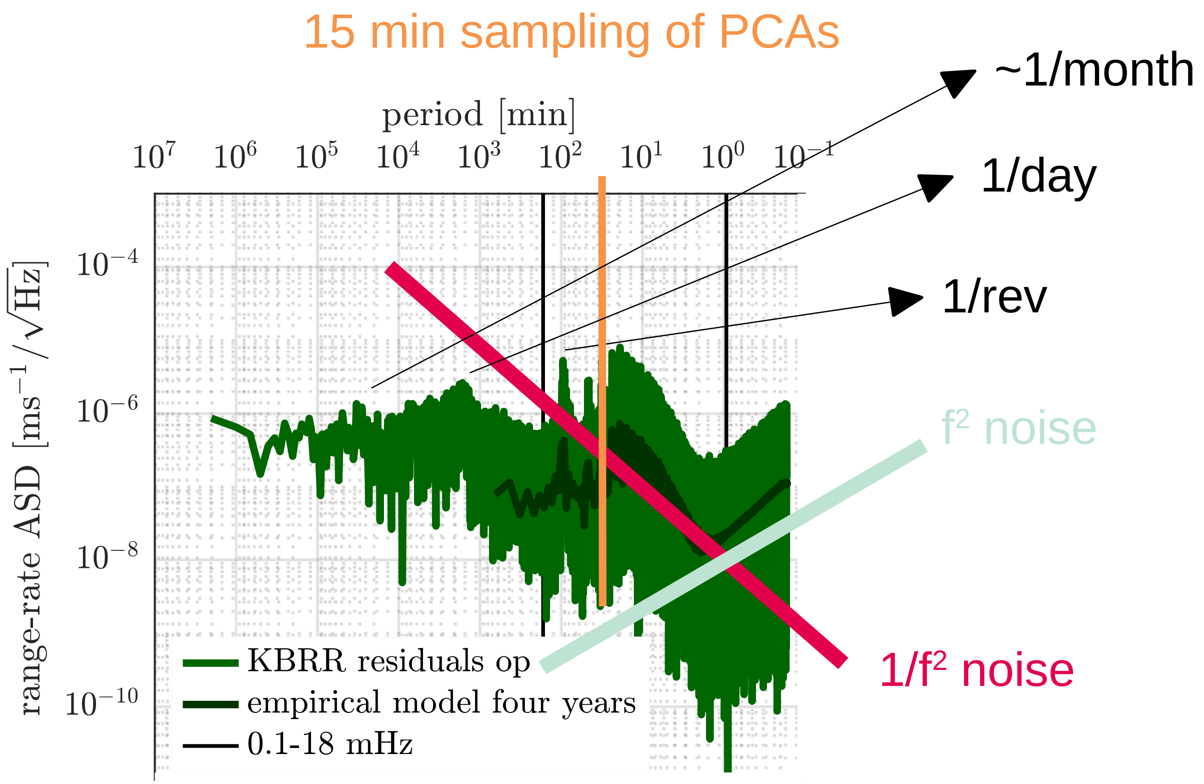
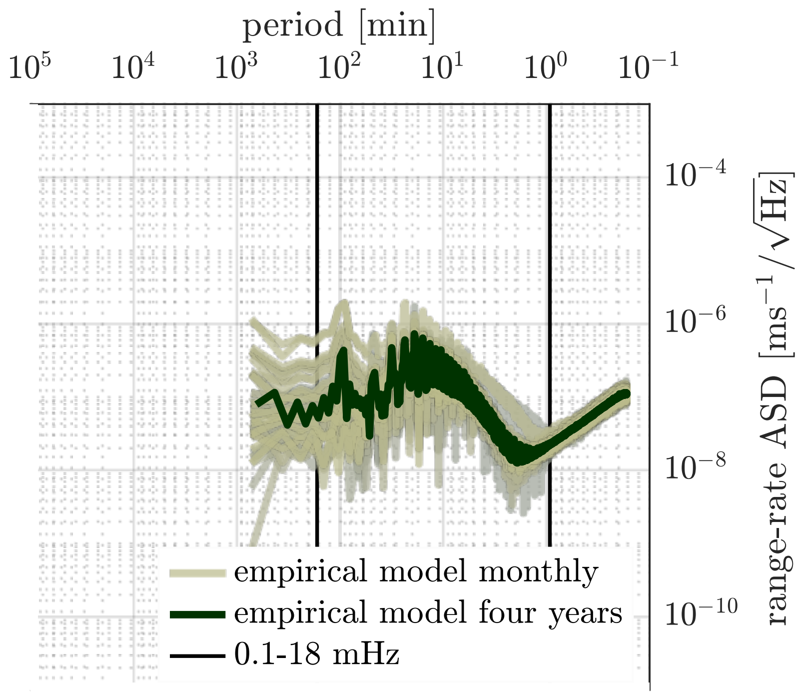




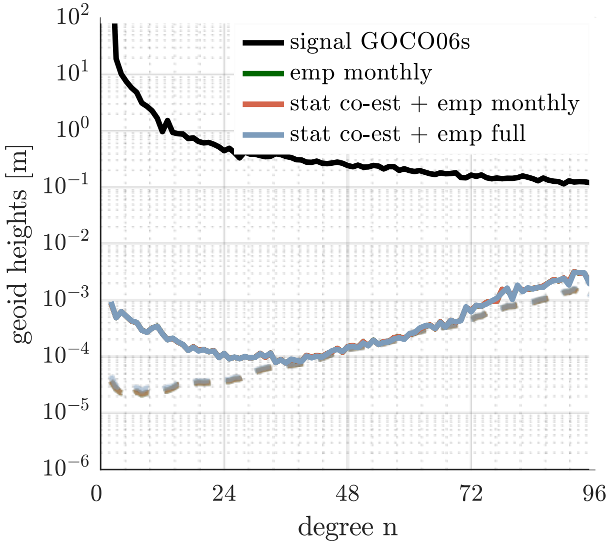
Auto covariance function → covariance matrix → weight matrix

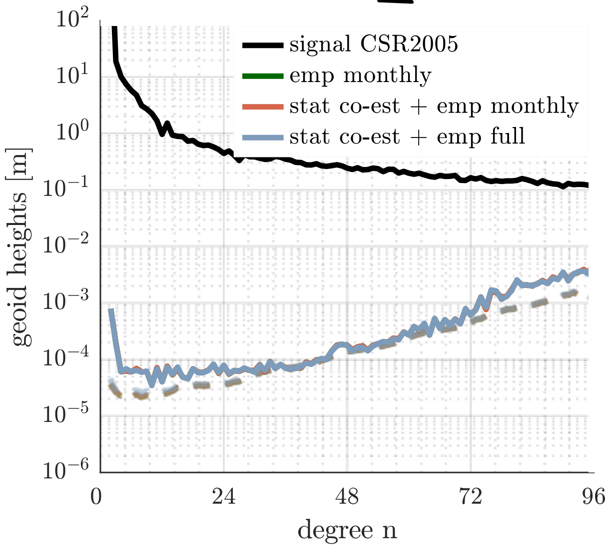
Results

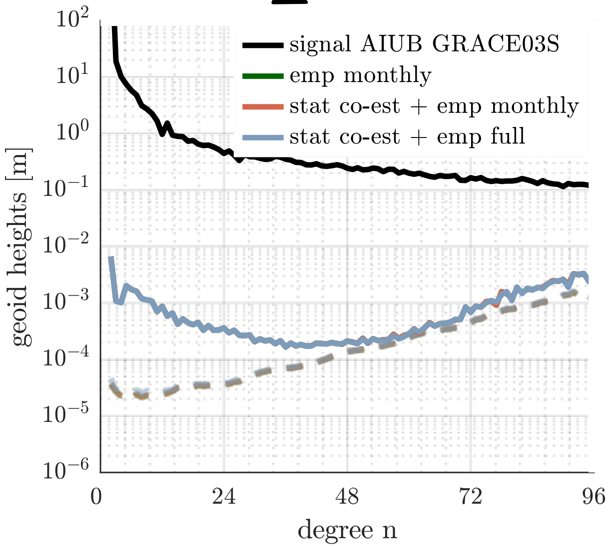
Time-variable gravity field

- Reference to CSR, AIUB GRACE03S and GOCO06s
- differences negligible

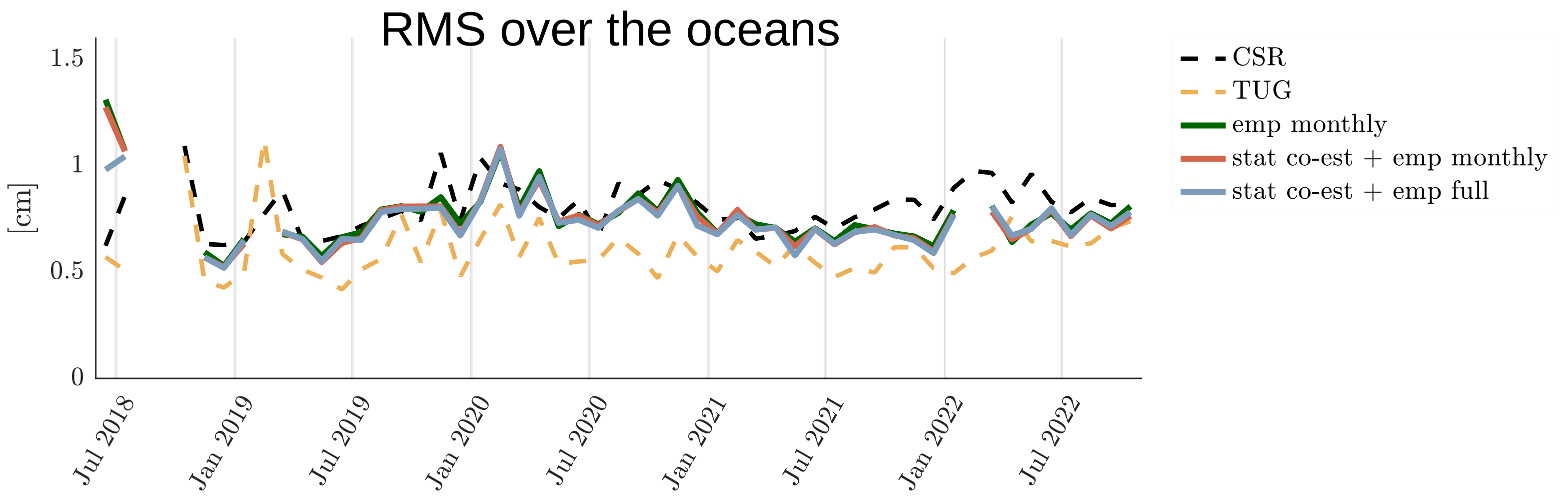
1 emp monthly
2 stat co-est + emp monthly
3 stat co-est + emp full



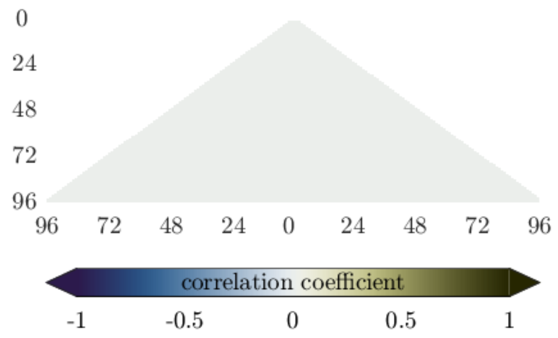




Results – Noise evaluation



max. difference
(w/ emp)
= 3.51%



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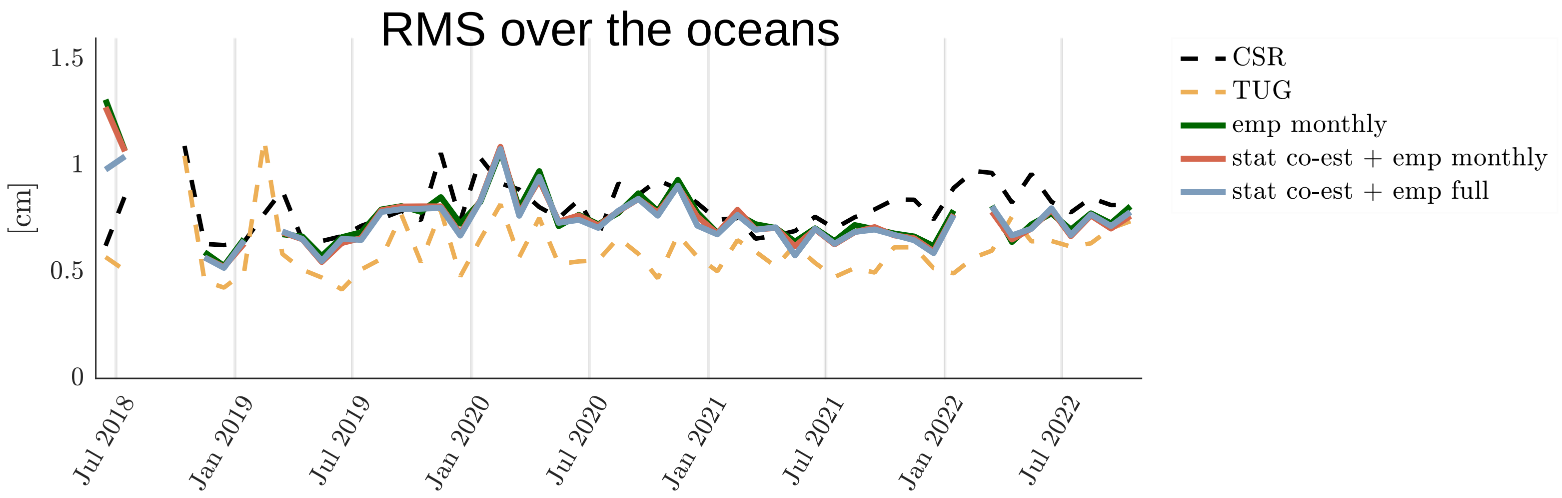

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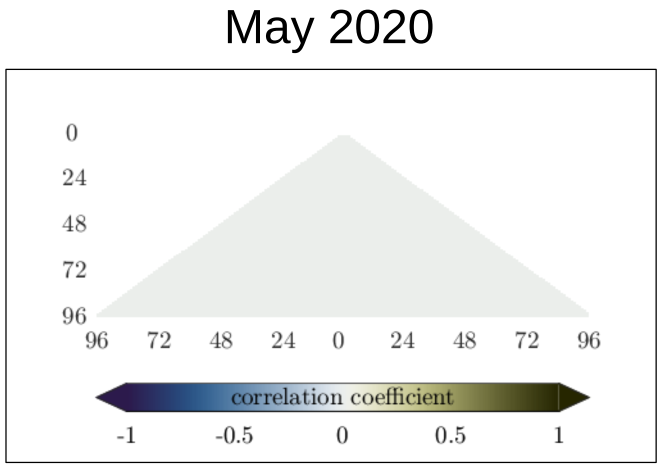
Formal correlation between ‹time-variable› coefficients and static coefficients (mean/minmax)



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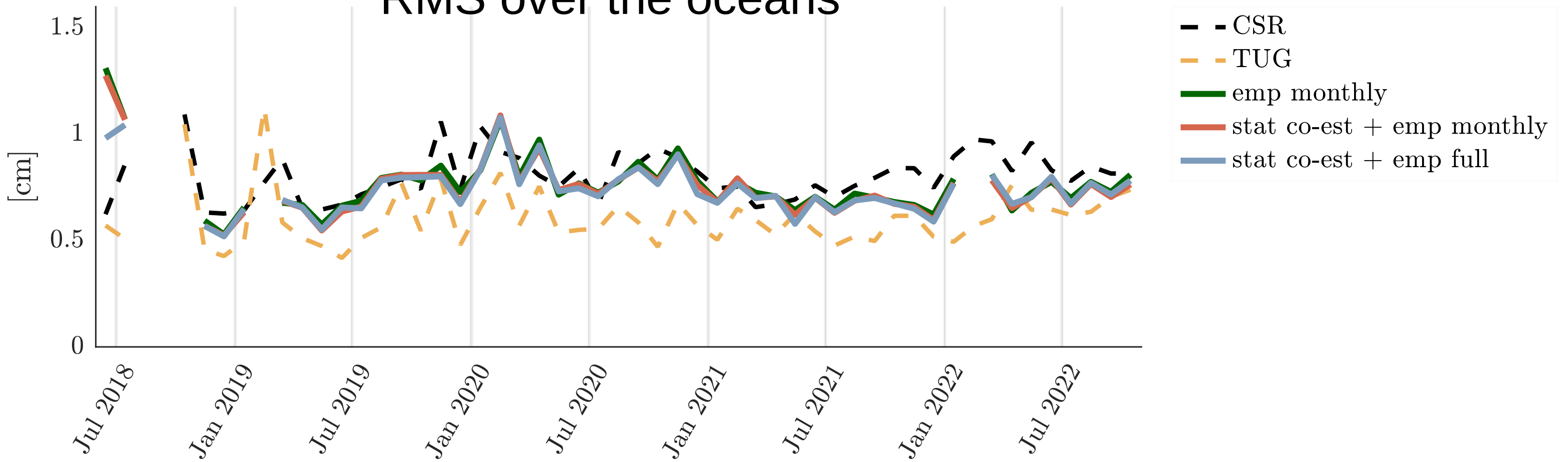

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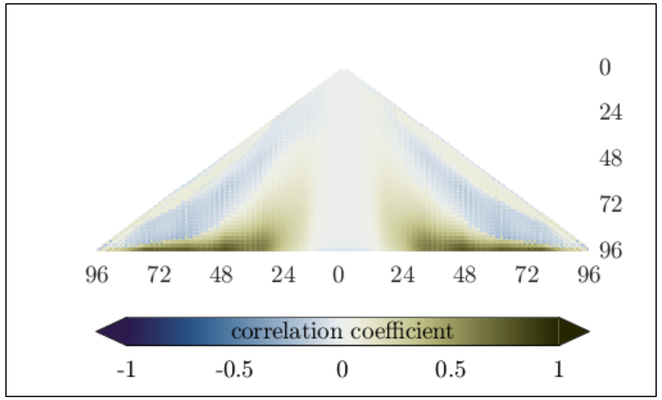
May 2020



Conclusions

Co-estimation of a static gravity field

Co-estimation of a static gravity field solution from four years of GRACE Follow-On data

- Co-estimated monthly gravity field solutions

  → no significant difference to be found

  (even tough covariance function varies)

  → for now not worth the time and effort

  → using monthly or averaged models reasonable
  (at the current level of precision)

Influence of kinematic orbits
Ambiguity resolution

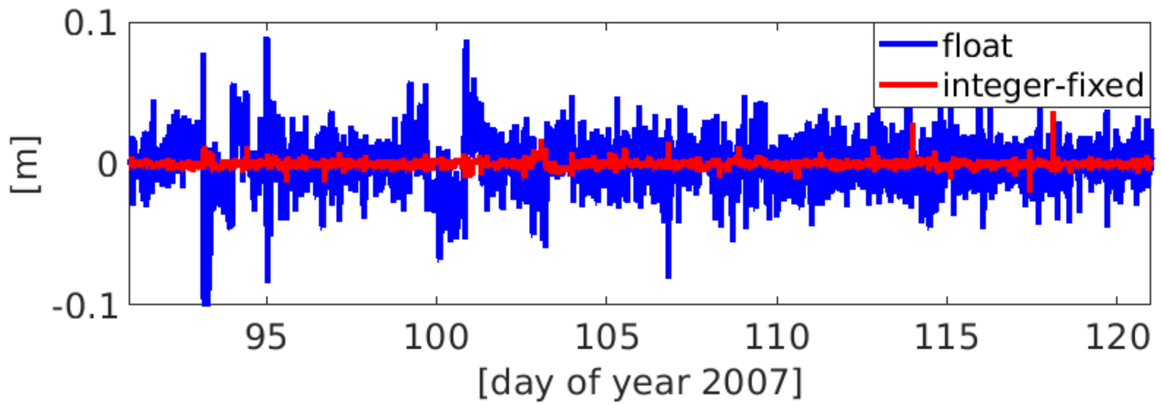
Kinematic positions from a Precise Point Positioning (PPP)

- Provide the absolute position of the satelites in space:

→ original observation: GPS carriers phase tracking
Attitude – antenna phase centre

→ GPS constellation

→ Ambiguity resolution either as float or fixed

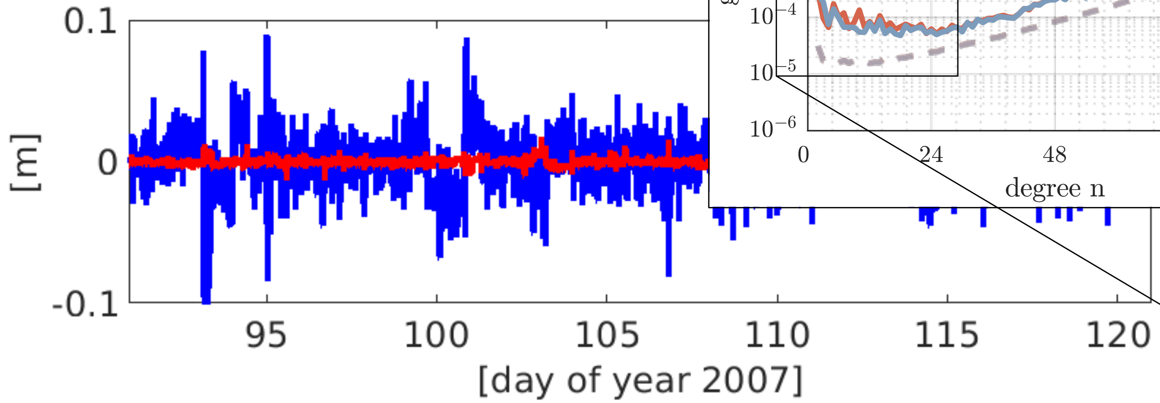


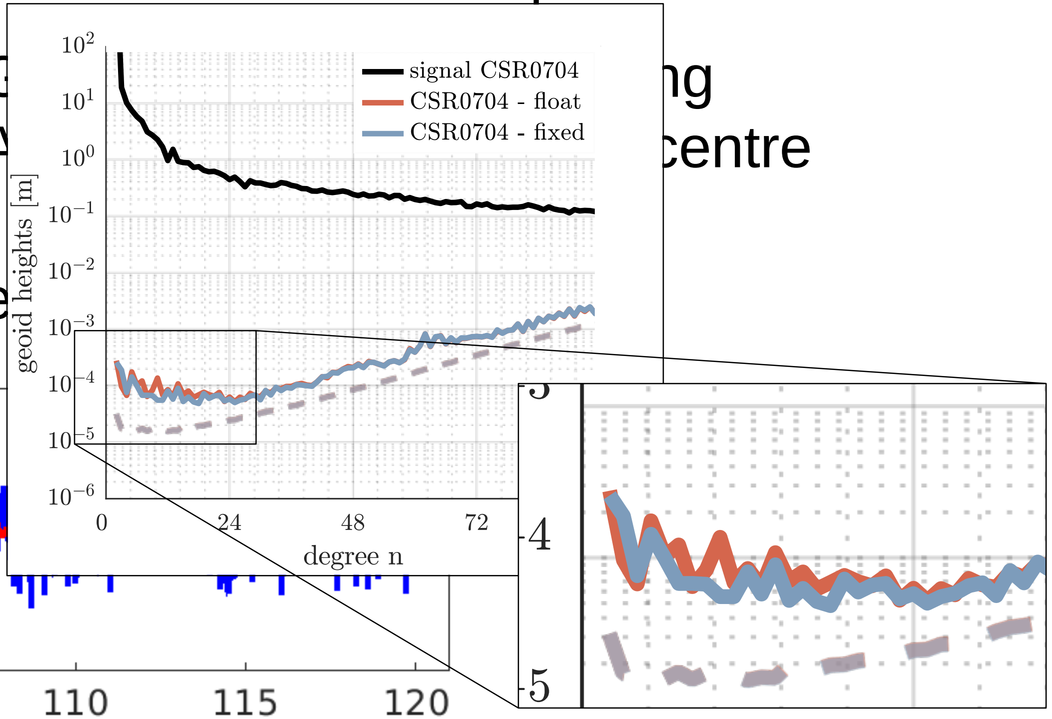
Influence of kinematic orbits

Ambiguity resolution

Kinematic positions from a Precise Point Positioning (PPP)

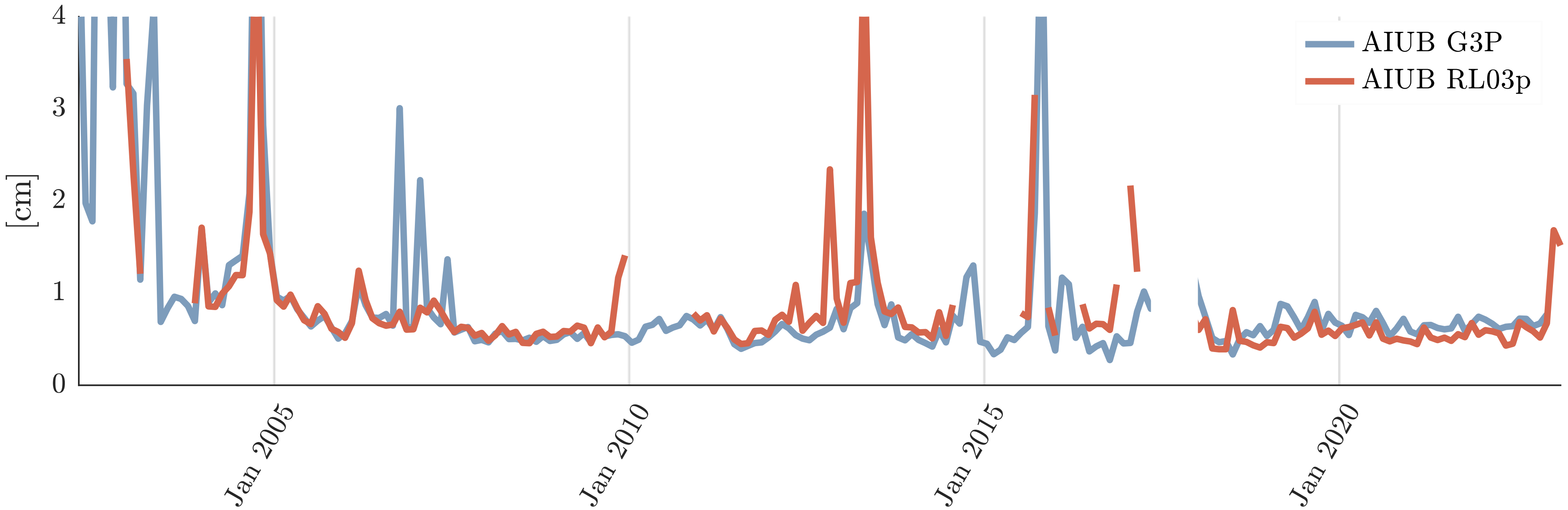
- Provide the absolute position of the satelites in space:
  - → original observation: G… …ng
    A… …centre
  - → GPS constellation
  - → Ambiguity resolution e…





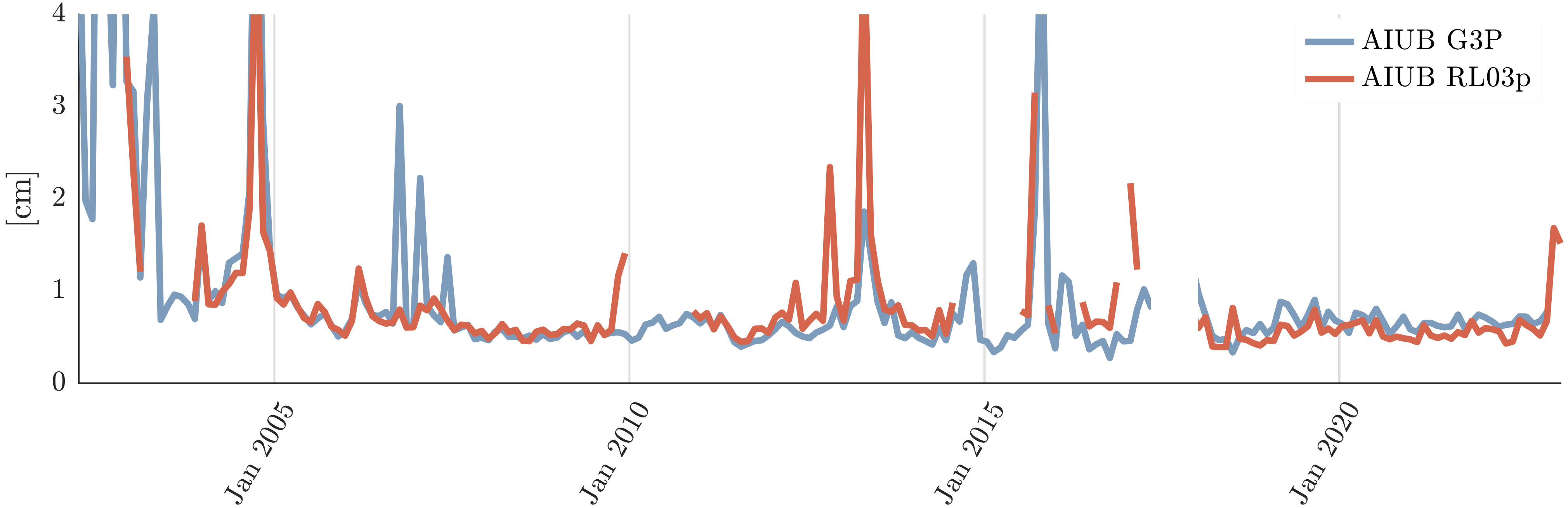
How does it look for now…

Noise evaluation



How does it look for now…
Noise evaluation

…

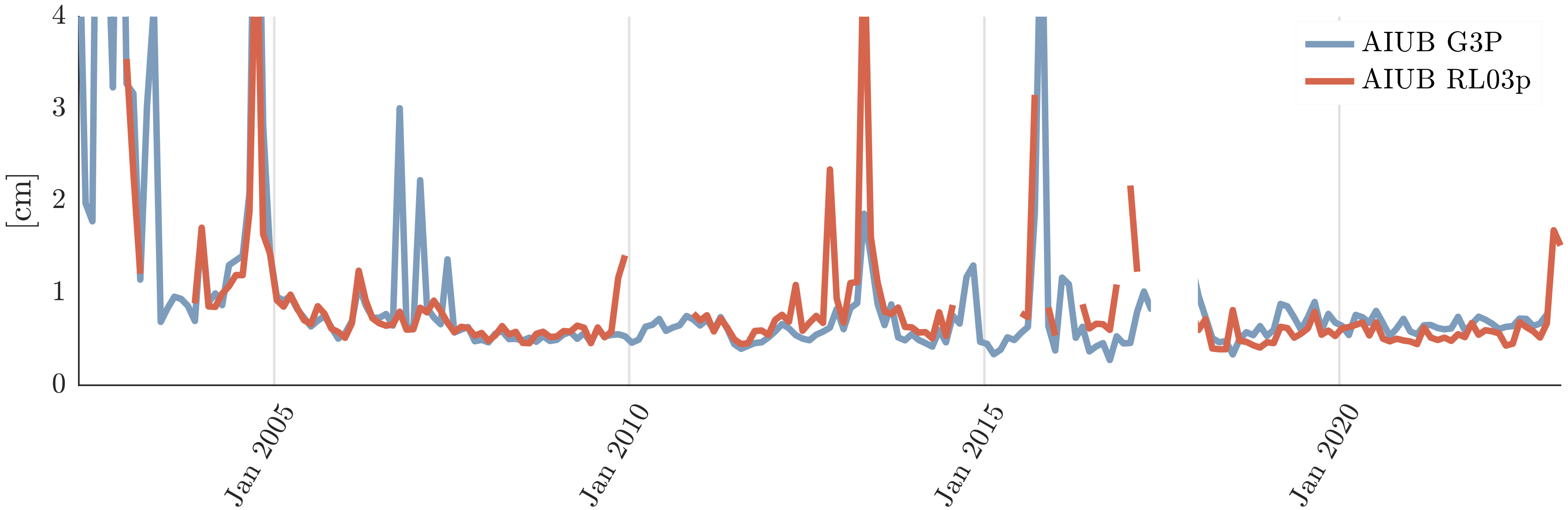


How does it look for now…

Noise evaluation

…

→ several months missing (for now)



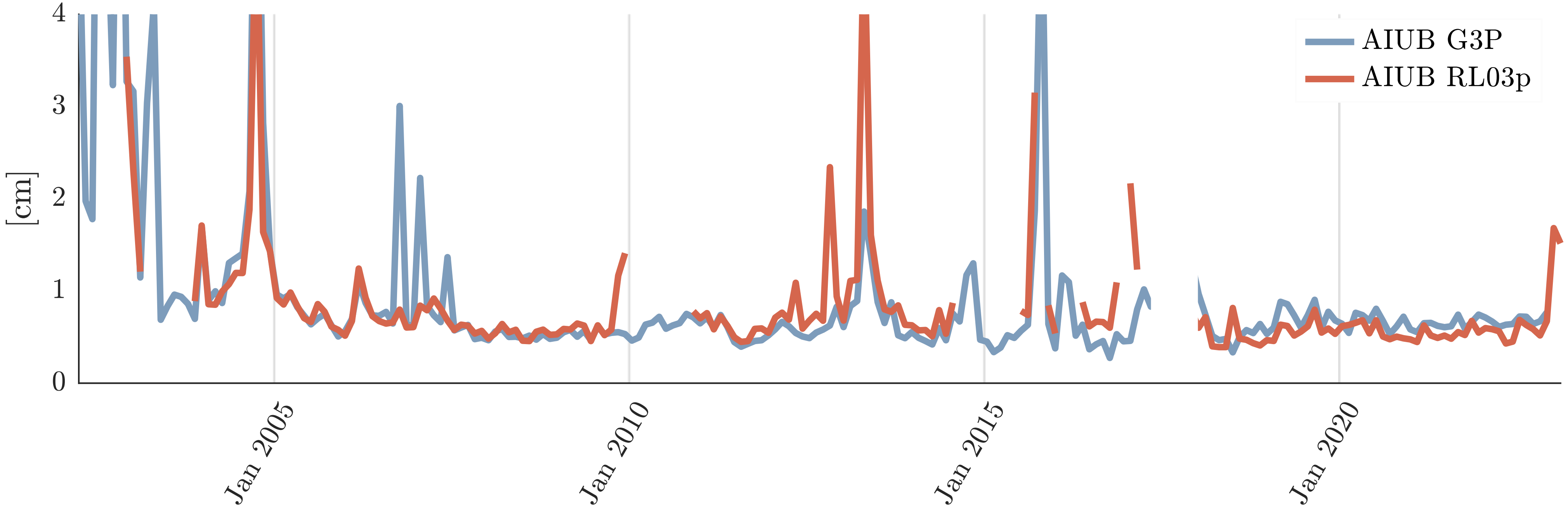
How does it look for now…

Noise evaluation

…

→ several months missing (for now)

→ processing efficiency to be improved



Thank you for your attention

Contact

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