Martin Lasser
Ulrich Meyer
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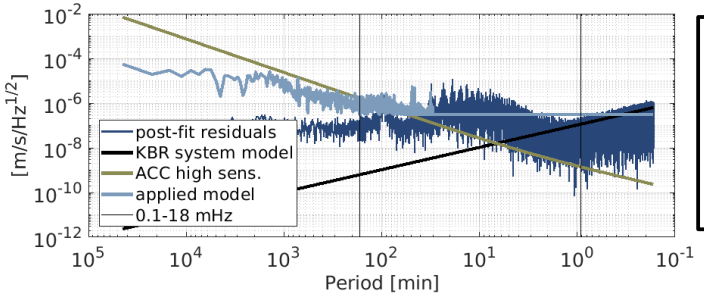
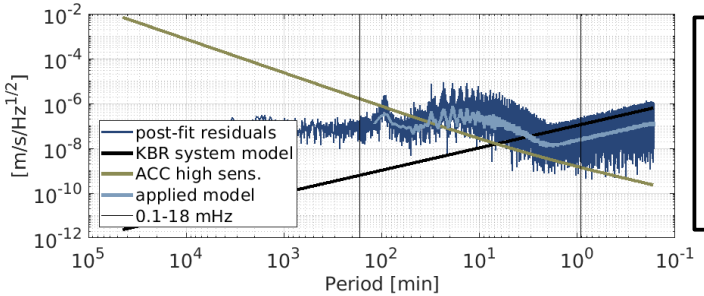
Comparison of empirical noise models for GRACE Follow-On derived with the Celestial Mechanics Approach

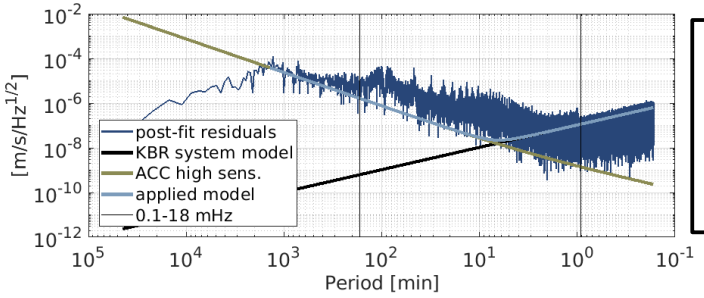
EGU General Assembly 2021



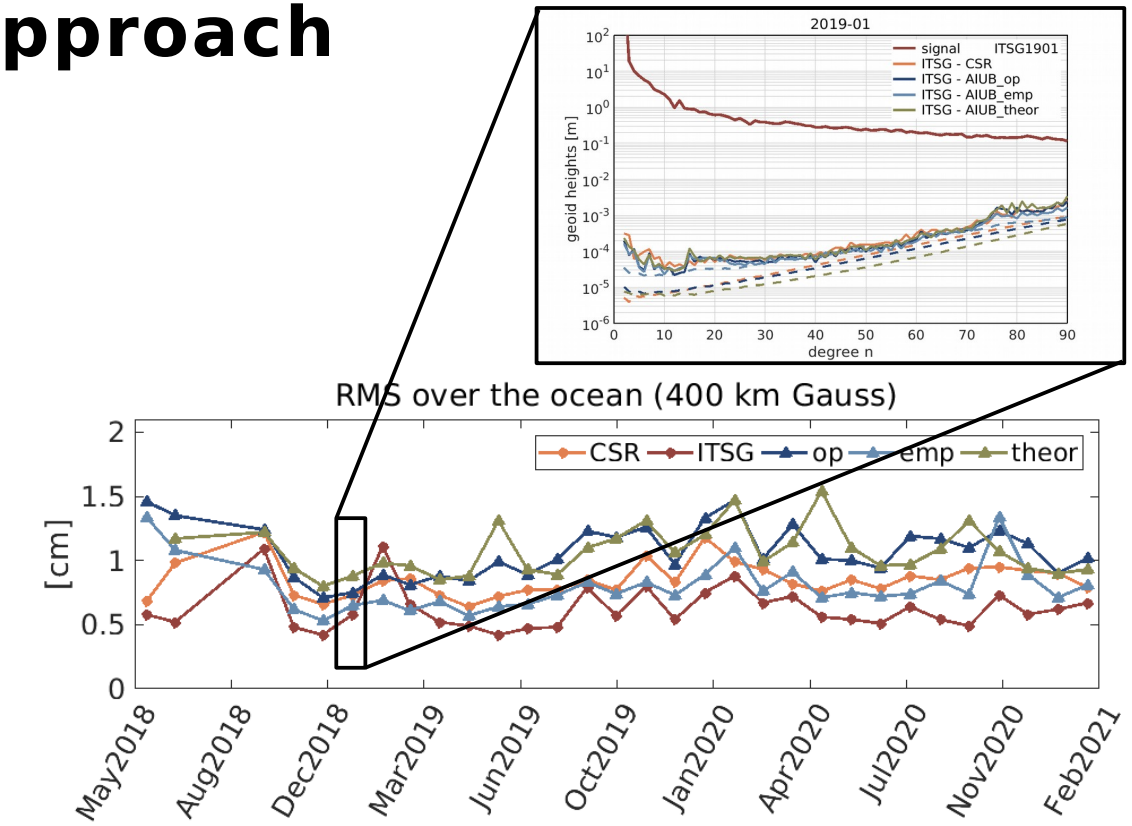
15 min piecewise-constant accelerations «op»



empirical noise model based on post-fit residuals «emp»



theoretical noise models for KBRR and ACC [Kim, 2000] «theor»



CONCLUSIONS

- Best performance for «emp»
- No severe degradation for «theor»
- Smallest residuals in «op»

Astronomical Institute, University of Bern AIUB

Comparison of empirical noise models for GRACE Follow-On derived with the Celestial Mechanics Approach

Martin Lasser, Ulrich Meyer, Daniel Arnold, Adrian Jäggi

Astronomical Institute, University of Bern, Switzerland

EGU General Assembly 2021
Apr. 19-30, 2021
Online

Introduction

Correctly modelling the measurement noise is crucial for recovering high quality gravity fields:

- AIUB_op («op»): piecewise-constant accelerations (PCA)
- AIUB_emp («emp»): empirical noise model based on post-fit residuals
- AIUB_theor («theor»): theoretical noise models for GRACE [Kim, 2000]

Introduction

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- AIUB_emp («emp»): empirical noise model based on post-fit residuals
- AIUB_theor («theor»): theoretical noise models for GRACE [Kim, 2000]

Celestial Mechnaics Approach (CMA) with	
Gravity field	Internal AIUB static GRACE field
Astromomic bodies	JPL DE421 (all planets + Pluto)
Mean pole	Linear
Solid Earth tides, Solid Earth pole tides, Relativistic effects	IERS2010
Ocean tides	FES2014b (+ admittances from ITSG)
Ocean pole tides	Desai
Atmospheric tides, Atmospheric & oeanic dealiasing	AOD RL06
Non-conservative forces	Accelerometer L1b (from ITSG)

Noise models – piecewise-constant accelerations

«op»

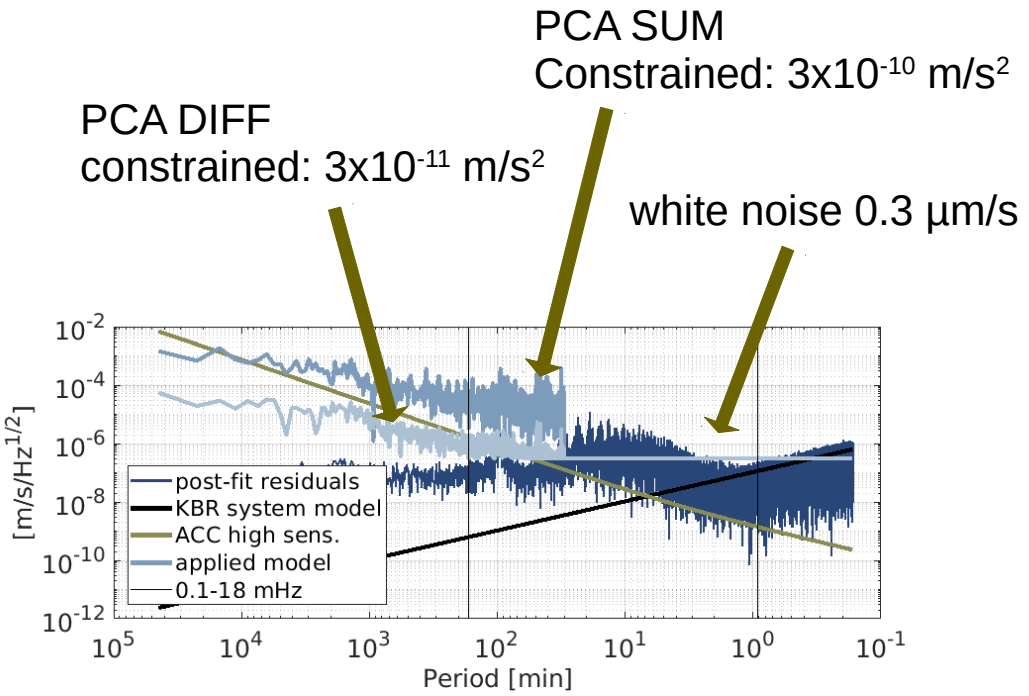
basic parametrisation:
- initial conditions 2x(6)
- accelerometer bias 2x(3)
- accelermeter scaling 2x(3)

parameters per arc 24

noise model:
- KBRR white noise 0.3 µm/s
- 15 min PCA per satellite in
  - ➔ radial 2x(96)
  - ➔ along track 2x(96)
  - ➔ Cross-track 2x(96)

parameters per arc 576

in daily arcs (30 days):
- 18000 parameter,
- 17280 for the noise model
- + gravity field



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Noise models – piecewise-constant accelerations

«op»

basic parametrisation:
- initial conditions 2x(6)
-
-

PCA SUM

no
-
-

in daily arcs (30 days):
- 18000 parameter,
- 17280 for the noise model
- + gravity field

orbit transformation (described in Beutler et al. 2010):

instead of estimating parameters for GF1 & GF2
transform orbit parameters to:

$\frac{GF1+GF2}{2}$ → SUM: referring to the mean point in space between GF1 & GF2 (driven by GPS)

$\frac{GF1-GF2}{2}$ → DIFF: referring to the difference between GF1 & GF2 (driven by K-band)

PCA – performance

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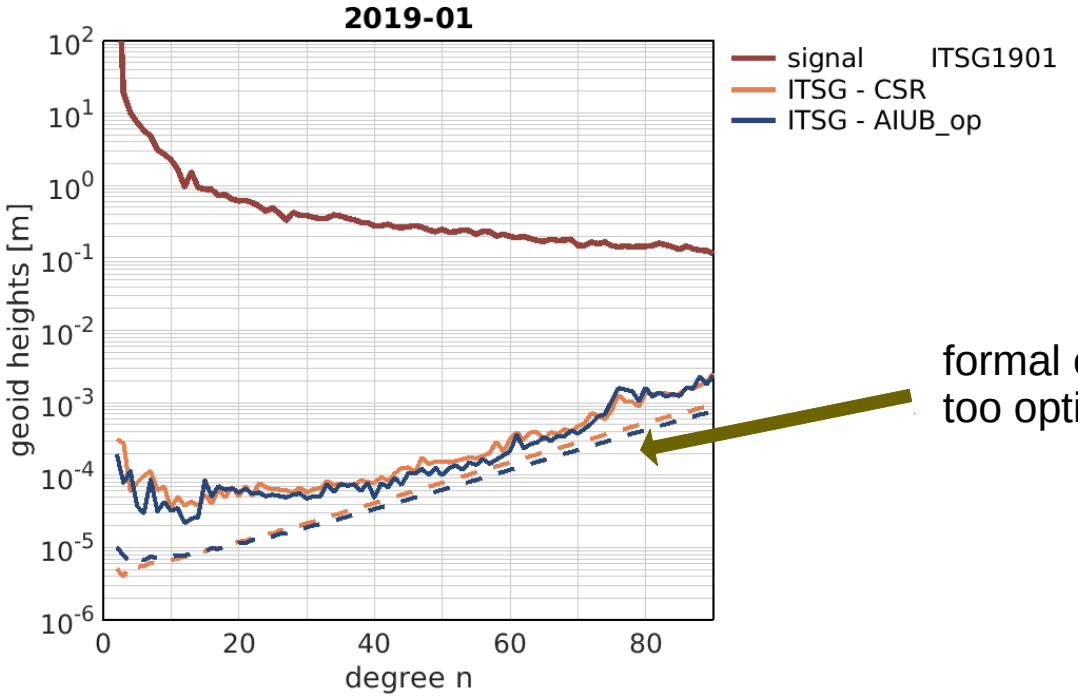
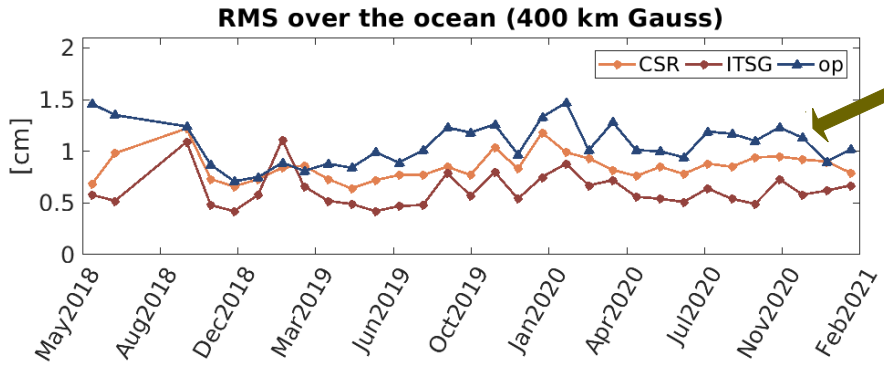


formal errors too optimistic



solution quality acceptable with room for improvement

PCA – conclusions

basic parametrisation:
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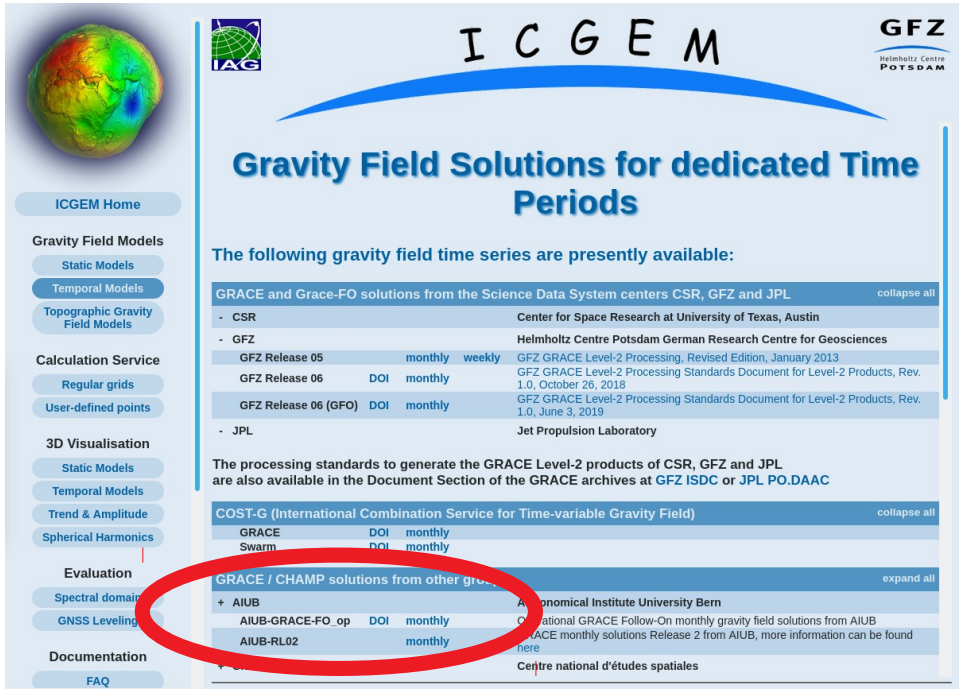
«op»

- «classical» Celestial Mechanics Approach
- no iterations required
- published at ICGEM



- extension of parameter space demands higher memory
- and CPU capacity (inversion)
- constraints need to be determined (manually, VCE)

Noise models – from post-fit residuals

«emp»

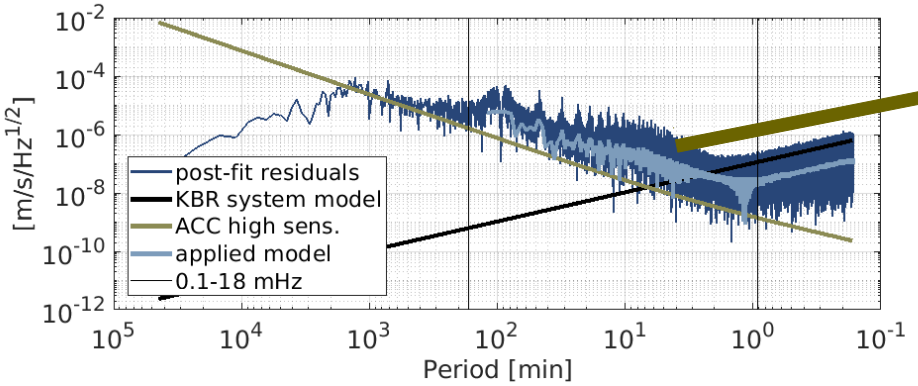
basic parametrisation:
- initial conditions 2x(6)
- accelerometer bias 2x(3)
- accelermeter scaling 2x(3)

parameters per arc 24

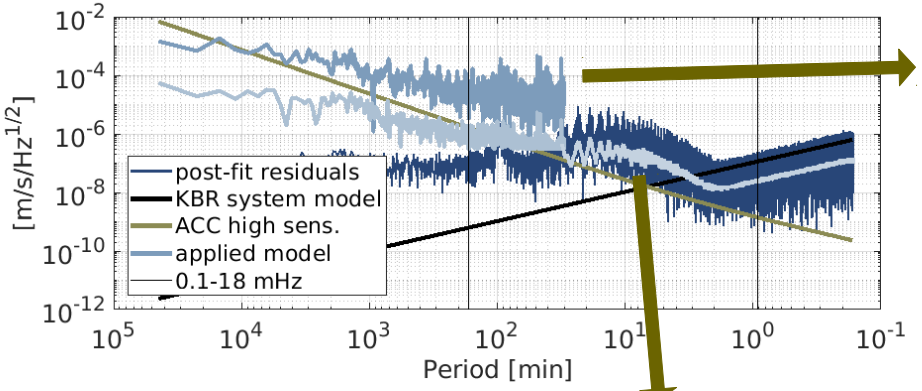
noise model:
- empirical covariances based on post-fit residuals

no additional parameters
- ➔ requires iterative procedure
- ➔ assumption of stationarity

in daily arcs (30 days):
- 720 parameters
- + gravity field



empirical model applied for 3 hours



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Empirical covariances

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parameters per arc 24

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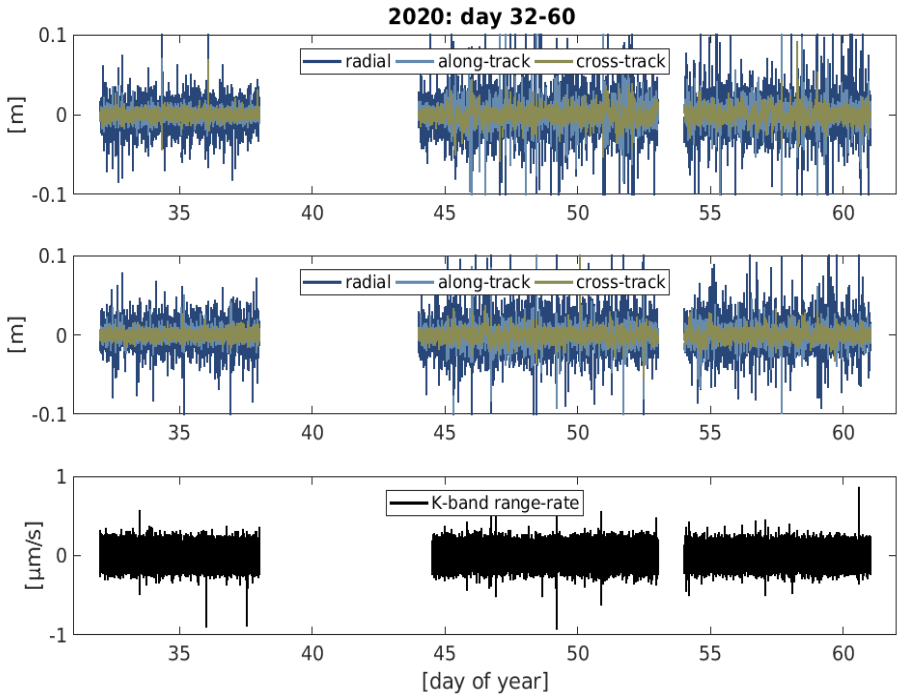

auto/cross-correlation

$\mathbf{P}_{KIN,GF1}$

$\mathbf{P}_{KIN,GF2}$

$\mathbf{P}_{Kb}$

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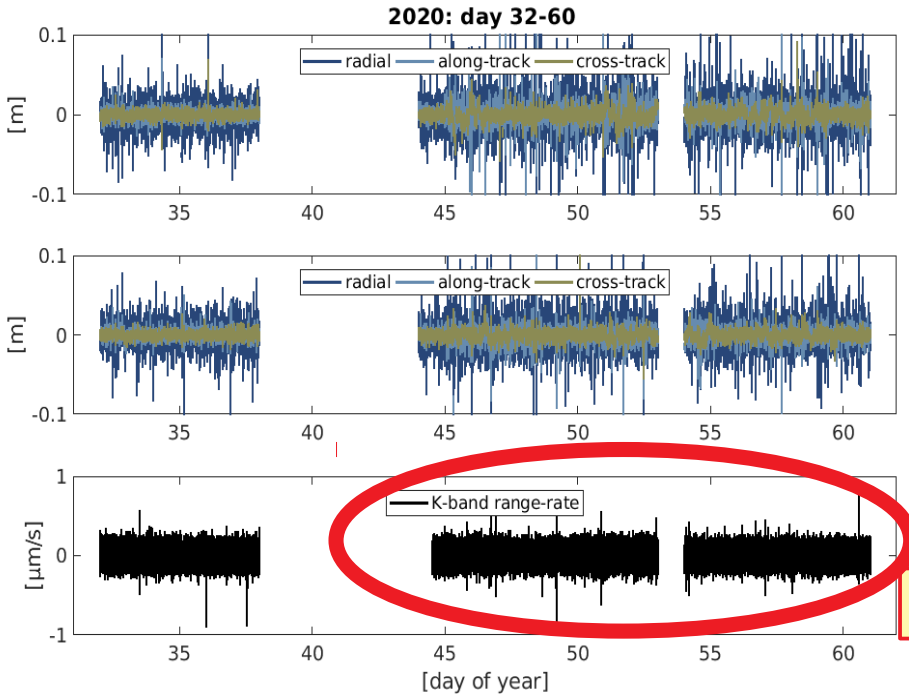

auto/cross-correlation

$\mathbf{P}_{KIN,GF1}$

$\mathbf{P}_{KIN,GF2}$

$\mathbf{P}_{Kb}$

stationary?

Empirical covariance function

«emp»

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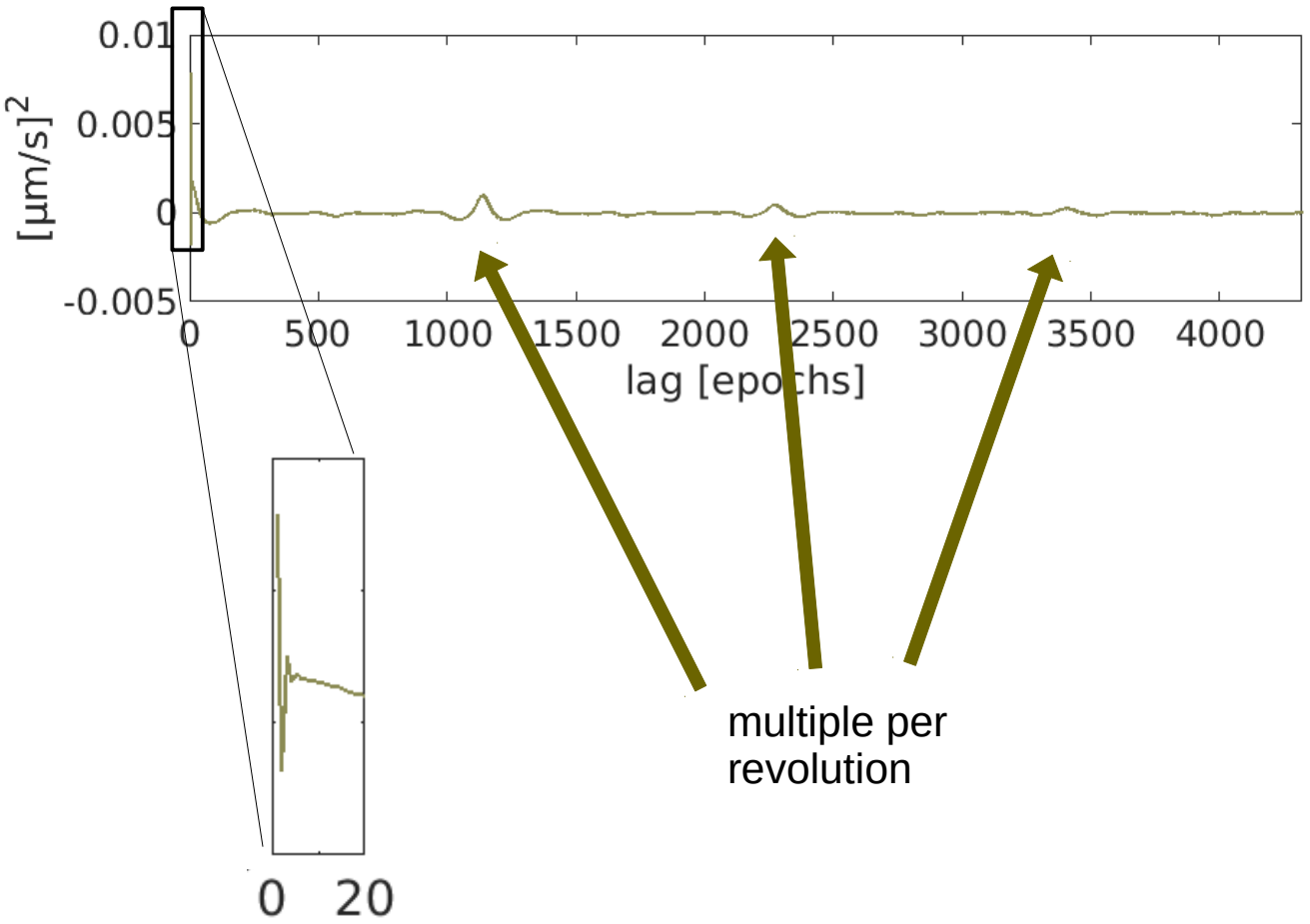

Empirical covariances - performance

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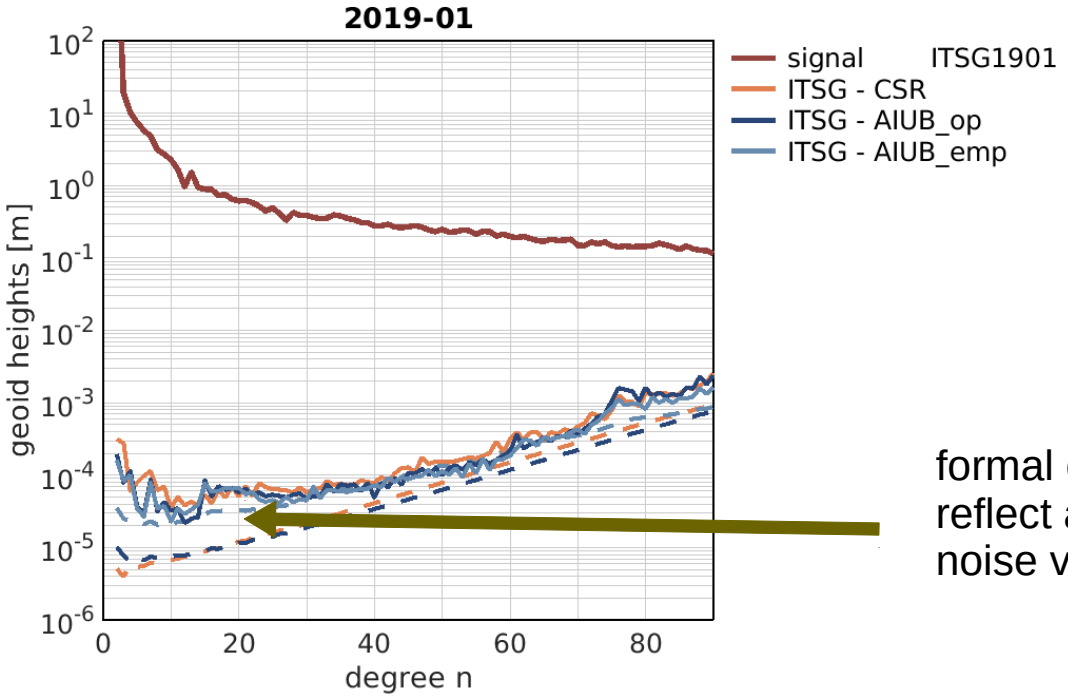
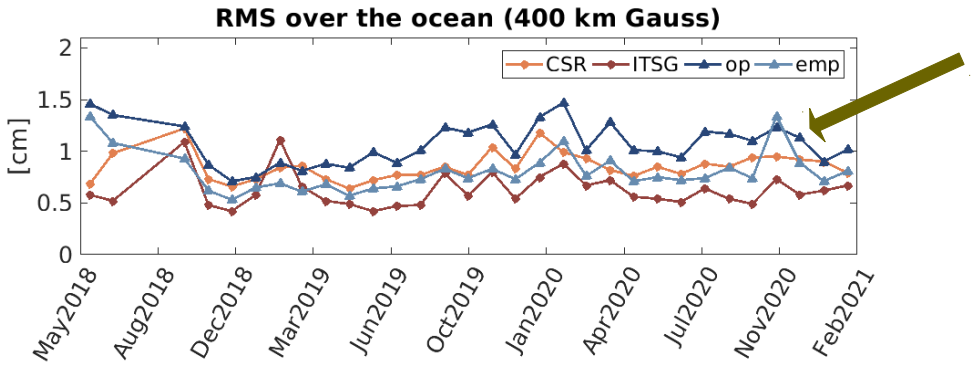


formal errors reflect assessed noise very well



clear improvement of solution quality

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parameters per arc 24

noise model:
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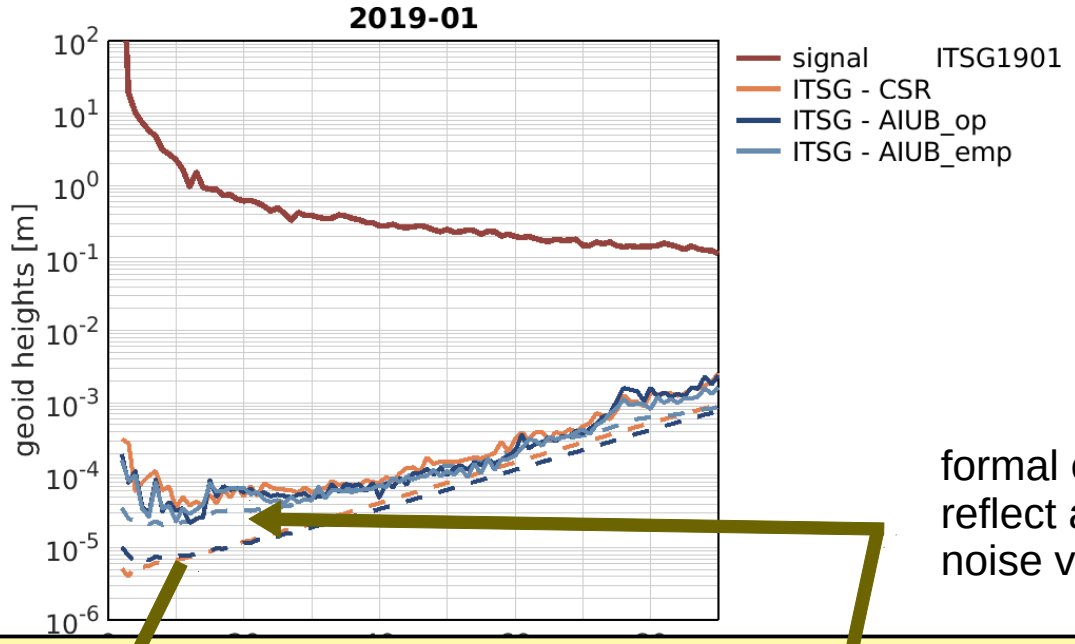
no additional parameters
- ➔ requires
- ➔ assumpt

in daily arc
- 720 para
- + gravity

«emp»



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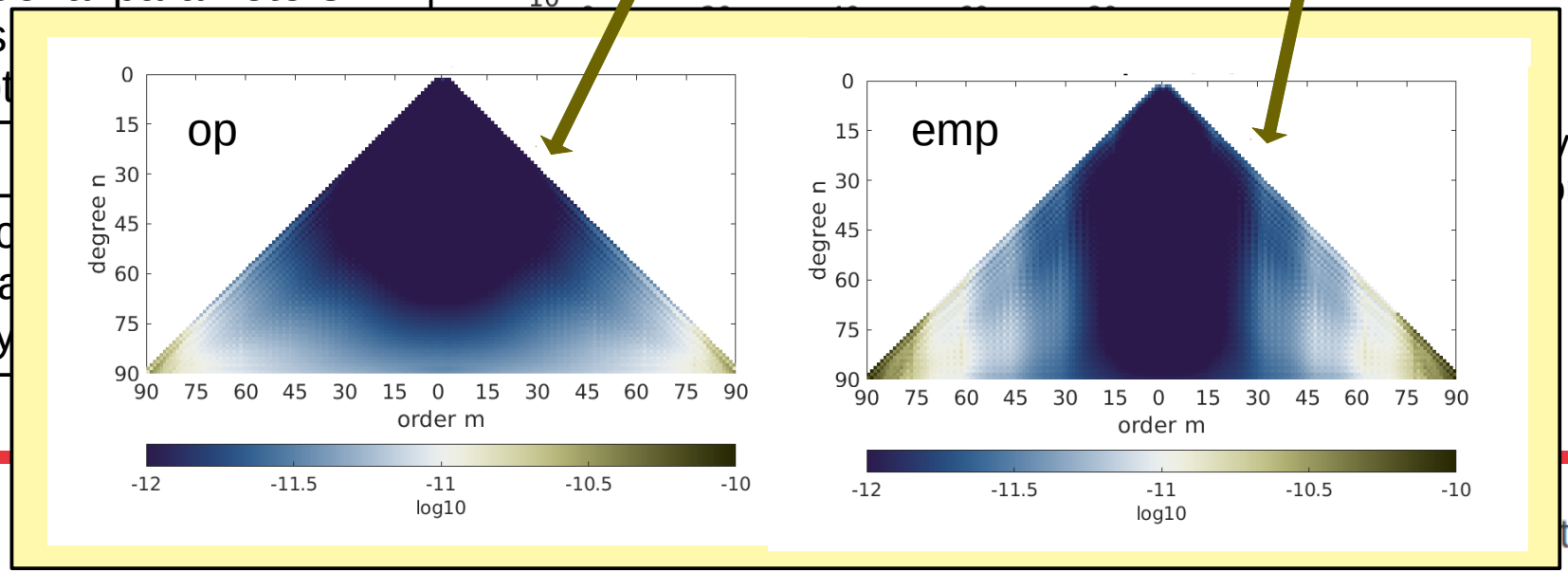

yement of
n quality

Empirical covariances - conclusions

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no additional parameters
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- ➔ assumption of stationarity

in daily arcs (30 days):
- 720 parameters
- + gravity field

- possible on any (stationary) residuals time series
- additional parameters can be reduced as stationary behaviour can be absorbed
- formal errors become much more realistic and show resonance orders (if correlation length > 3 h)
- no constraints needed
- no/few a priori knowledge needed

- iterations required (might be time consuming)
- memory consumption and inversion time dependent on length of auto/cross-correlation

Noise models – theoretical (pre-launch)

«theor»

basic parametrisation:
- initial conditions 2x(6)
- accelerometer bias 2x(3)
- accelermeter scaling 2x(3)

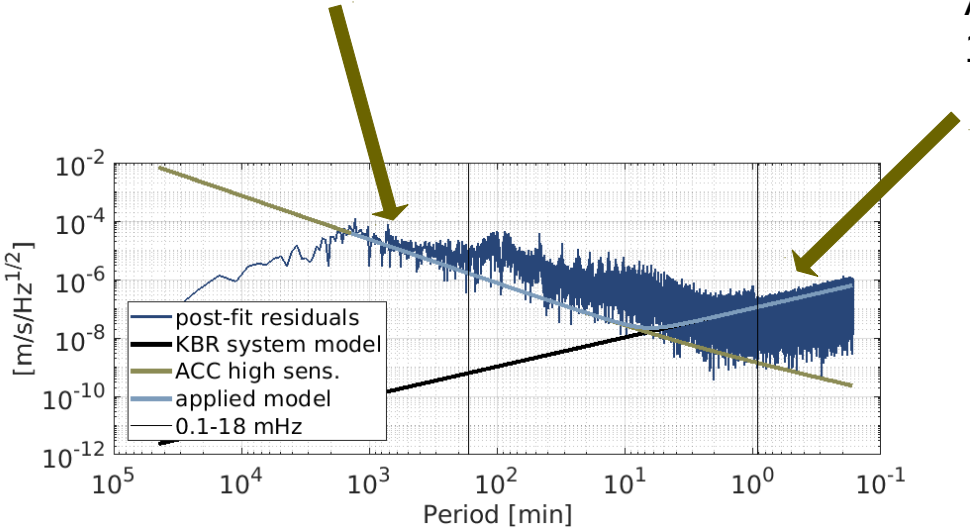
parameters per arc 24

noise model [Kim, 2000]:
- ACC high sensitivity axis
  (1 + 0.005/f) x 10^{-20} m/s^2
- KBR white noise
  1 µm range
  (differentiation to KBRR)

in daily arcs (30 days):
- 720 parameters
- + gravity field

ACC noise (red noise):
PSD: (1 + 0.005/f) x 10^{-20} m/s^2

ACC noise (violet noise):
1 µm range



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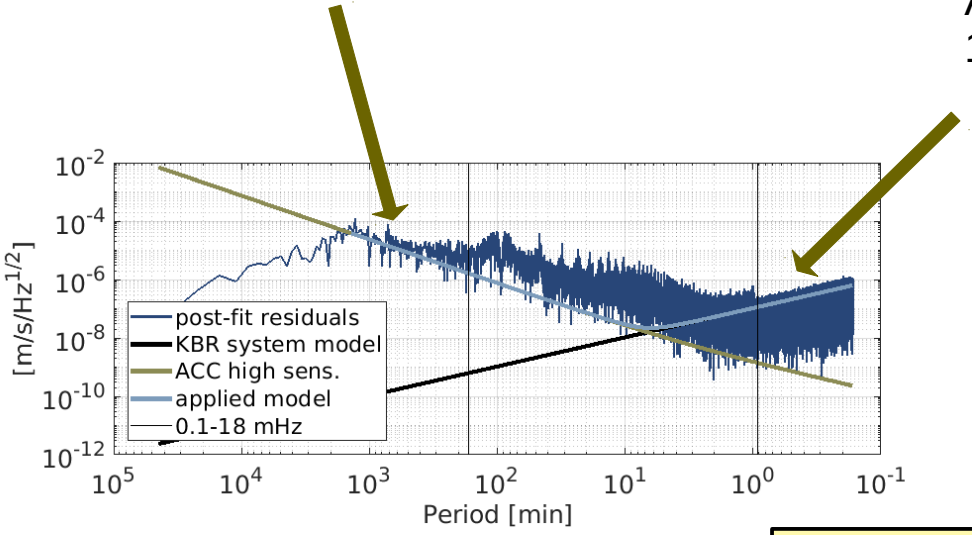

- coloured noise ~stationary
- sum at least jointly stationary

➔ Wiener-Khinchin theorem to derive auto-correlation from PSD

Theoretical (pre-launch) - performance

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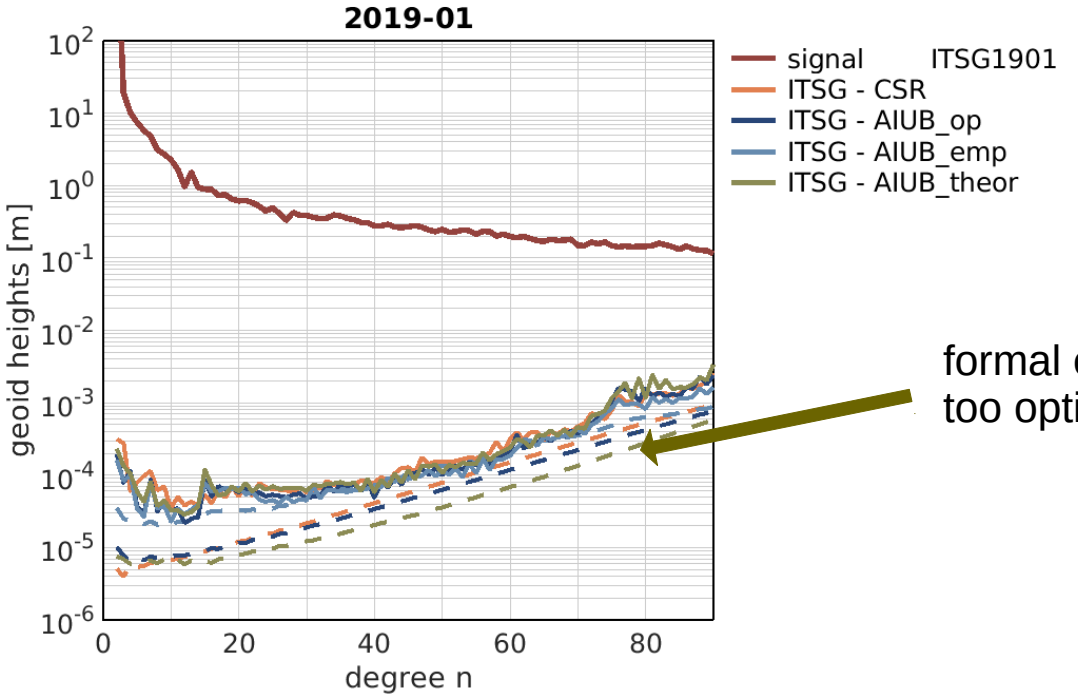
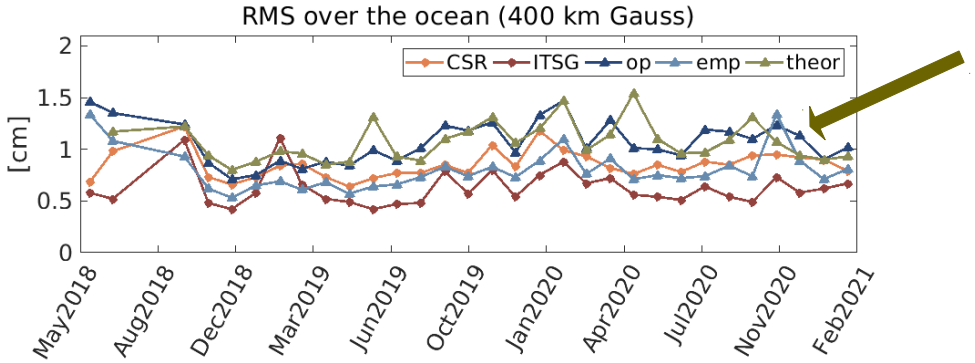
«theor»



formal errors
too optimistic



solution quality
acceptable (!)
with room for
improvement

Theoretical (pre-launch) - conclusions

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in daily arcs (30 days):
- 720 parameters
- + gravity field

«theor»

- based on priori knowledge
- additional parameters can be reduced
- provides a good solution in case observations act as a priori models state
- no constraints needed
- no iterations needed
- requirements on memory and CPU low

- might not reflect actual noise (e.g., without ACT from ITSG)
- formal errors too optimistic
- not all error sources included (e.g., backgorund models)

References

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