EGU General Assembly 2018

Reprocessed GOCE gravity gradients for gravity field recovery --- first results with the time-wise approach

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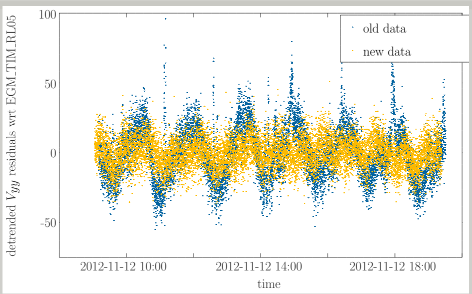
Agenda

Gravity field models from entire GOCE mission data set published in e.g. Brockmann et al. (2014)

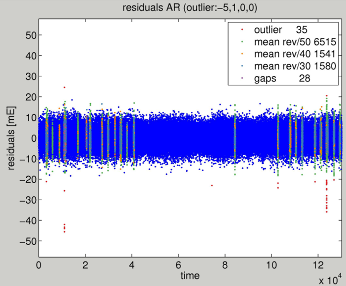
Reprocessed level 1B gravity gradient data

- improved calibration of the gravity gradients (quadratic term)
- cf. Siemes (2018), Siemes et al. EGU18-5319



Advancement within the time-wise approach

- robustification of the decorrelation filter estimation
- advanced detection of suspicious data



⇒ Will the gravity field significantly improve? Can the improvements be quantified?

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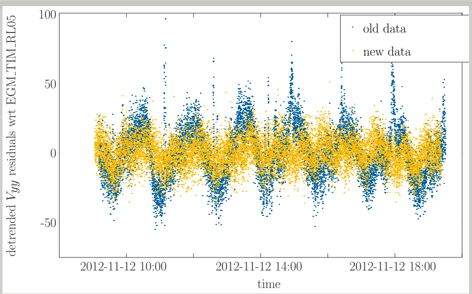

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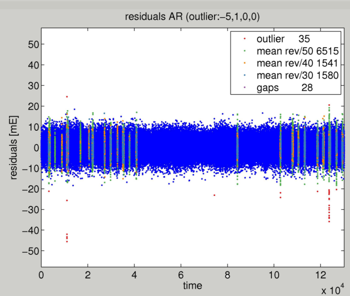
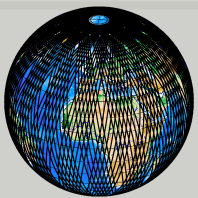


$\Rightarrow$ Will the gravity field significantly improve? Can the improvements be quantified?

Gravity field models determined with the time-wise approach: solely based on GOCE observations!

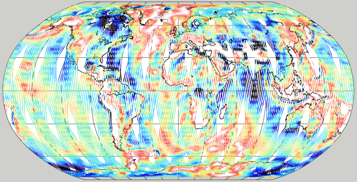
kinematic satellite orbits



+orbit error information

+

geolocated gravity gradients in GRF



+ advanced gradient error modeling

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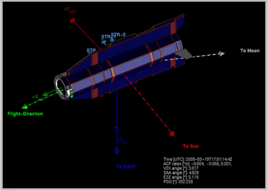
gradiometer orientation



$$V(r,\theta,\lambda) = \frac{GM}{a} \sum_{l=0}^{l_{\max}} \left(\frac{a}{r}\right)^{l+1} \sum_{m=0}^{l} \left(c_{lm}\cos(m\lambda) + s_{lm}\sin(m\lambda)\right) P_{lm}(cos\theta)\,, \tag{1}$$

Focus: solutions only derived from gravity gradients ⇒ show quality of new L1B data & algorithms
⇒ time-wise approach is well suited (advanced stochastic modeling, GOCE-only, ...)

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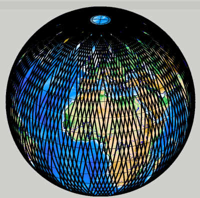

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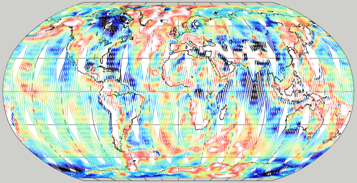

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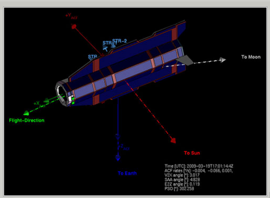

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Focus: solutions only derived from gravity gradients $\Rightarrow$ show quality of new L1B data & algorithms
$\Rightarrow$ time-wise approach is well suited (advanced stochastic modeling, GOCE-only, ...)

Estimation of Decorrelation Filters

Starting point are gravity gradient residuals (per component c, per segment s)

$$\mathbf{v}_{c,s} = \mathbf{A}_{c,s}\tilde{\mathbf{x}} - \mathbf{l}_{c,s} \tag{2}$$

Estimation of an AR(q) process as a decorrelation filter from residuals $\mathbf{v}_{c,s}$

$$\mathbf{v}_{c,s}(k) + \mathbf{r}(k) = \sum_{j=1}^{q} \alpha_j \mathbf{v}_{c,s}(k-j) = \mathbf{a}_k^T \boldsymbol{\alpha} \tag{3}$$

Use the filtered, i.e. decorrelated residuals $\hat{=}$ $\mathbf{r}$, to statistically screen the data for suspicious data

Statistically test residuals in moving windows

- large outliers $>$ a threshold
- mean value significantly being different from zero
- larger variances
- statistical occurrence of signs and sign changes

$\Rightarrow$ account for clusters and gaps between clusters

$\Rightarrow$ apply tests for different windows, e.g. $\frac{1}{10} \cdots \frac{1}{80}$ orbit

$\Rightarrow$ iterate the procedure

Results

- decorrelation filter per segment s and component c
- flags for suspicious data

$\Rightarrow$ select only consistent data

Test Data Used for Analysis

Two data periods were selected and analyzed in different configurations to test the performance

id	start	end	info
1	09/Nov/2012	04/Feb/2013	-8 km
2	30/May/2013	31/Jul/2013	-30 km

new	new reprocessed data, robust filter
old	old/official data, robust filter
rl5	solution from EGM_TIM_RL05 setup

outlier statistics		obs #	V_{XX} #	%	V_{XZ} #	%	V_{YY} #	%	V_{ZZ} #	%	total #	%
1	new	7.5e6	2.9e5	3.8	3.1e5	4.1	2.5e5	3.4	2.9e5	3.8	1.1e6	3.8
	old	7.4e6	2.4e5	3.3	1.9e5	2.5	11.5e5	15.5	1.9e5	2.5	1.8e6	6.0
	rl5	7.8e6	7.8e5	10.0	8.0e5	10.3	7.2e5	9.3	7.4e5	9.5	3.0e6	9.8
2	new	5.5e6	0.5e5	0.9	0.3e5	0.5	0.2e5	0.4	0.4e5	0.7	1.4e5	0.6
	old	5.4e6	0.9e5	1.6	0.8e5	1.5	3.3e5	6.2	0.7e5	1.4	5.7e5	2.7
	rl5	5.4e6	1.6e5	3.1	1.7e5	3.2	3.3e5	6.2	0.6e5	1.2	7.3e5	3.4

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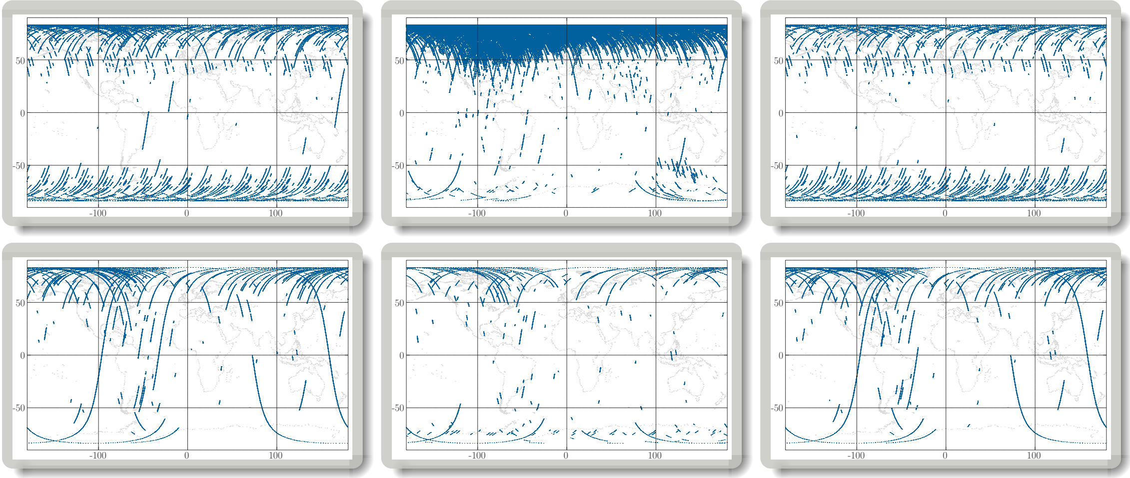
	rl5	5.4e6	1.6e5	3.1	1.7e5	3.2	3.3e5	6.2	0.6e5	1.2	7.3e5	3.4

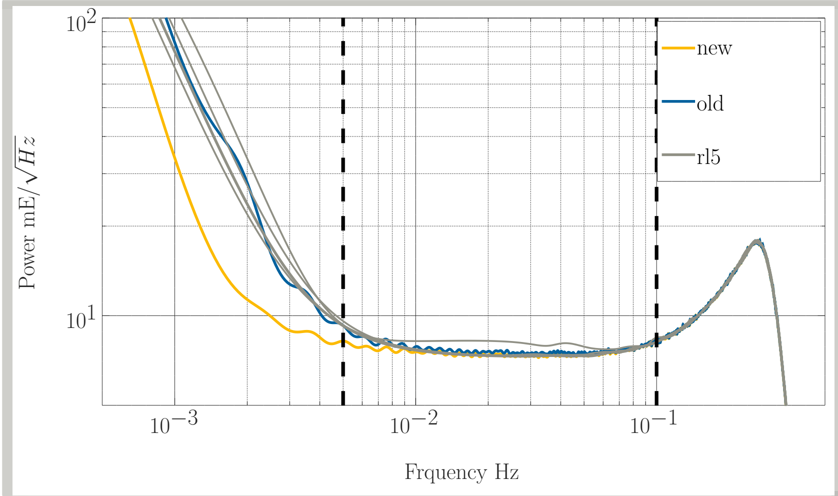
Geographical Distribution of Outliers

outliers in 2nd test period, 1st row: old data, 2nd row: new data

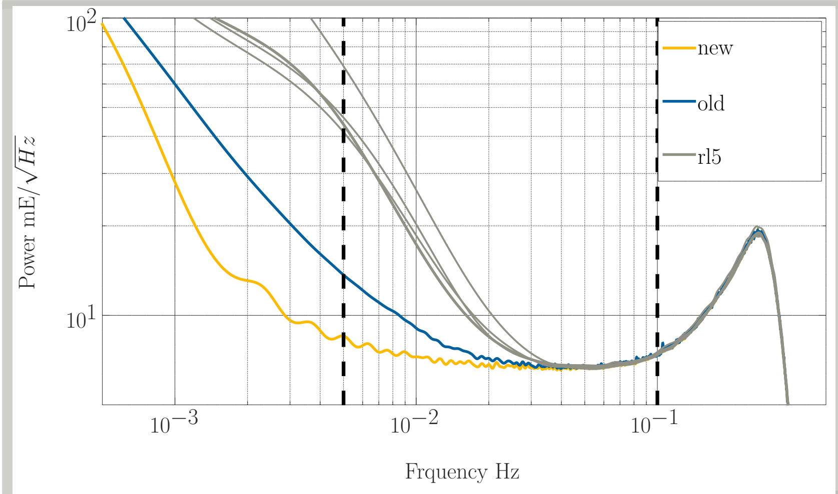


V_{XX} V_{YY} V_{ZZ}

Estimated Decorrelation Filters



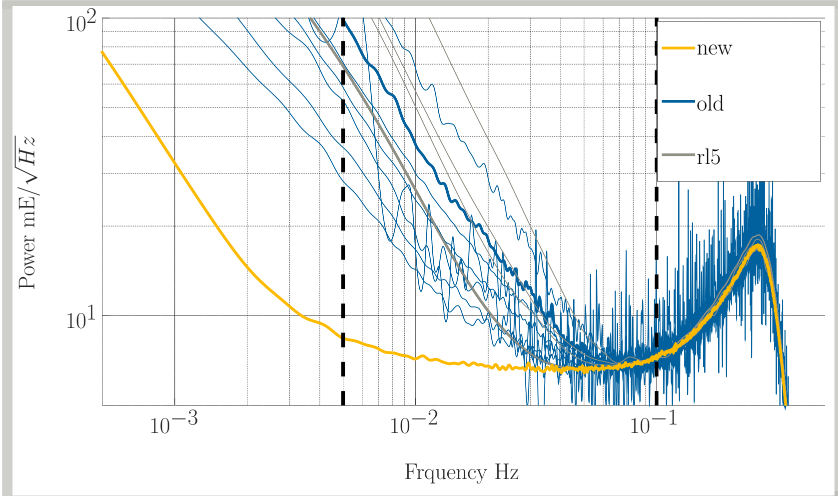
Test period: 1
example c: V_{XX}



Test period: 1
example c: V_{YY}

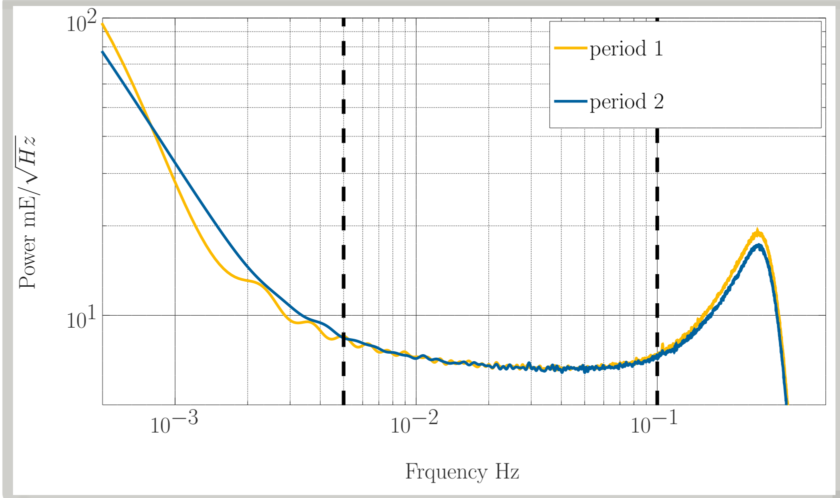
- robust filter: improvments for V_{YY}
- new data: improvments for all components

Estimated Decorrelation Filters



Test period: 2
example c: V_{YY}

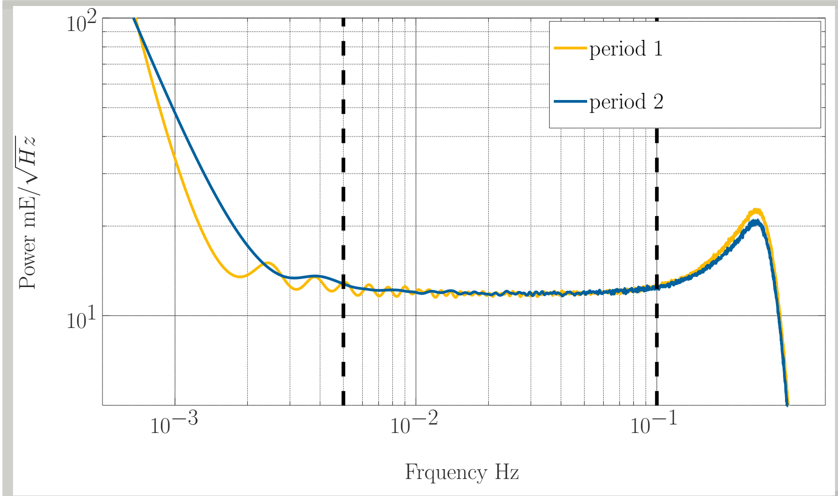
- big non-stationarity in old data
- new data: stable estimate



filters for new data:

V_{YY}

Improved Stationarity New Data

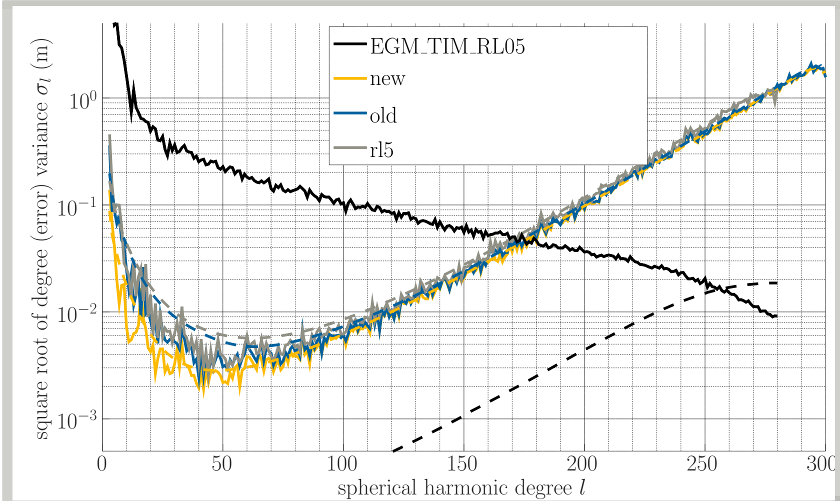


filters for new data: V_{ZZ}

very similar for period 1 (-8 km) and 2 (-30 km)!

New data have a more stationary noise characteristic $\Rightarrow$ a single filter representative

Component-wise Solutions for Period 1



period: 1

used data: V_{XX}

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix

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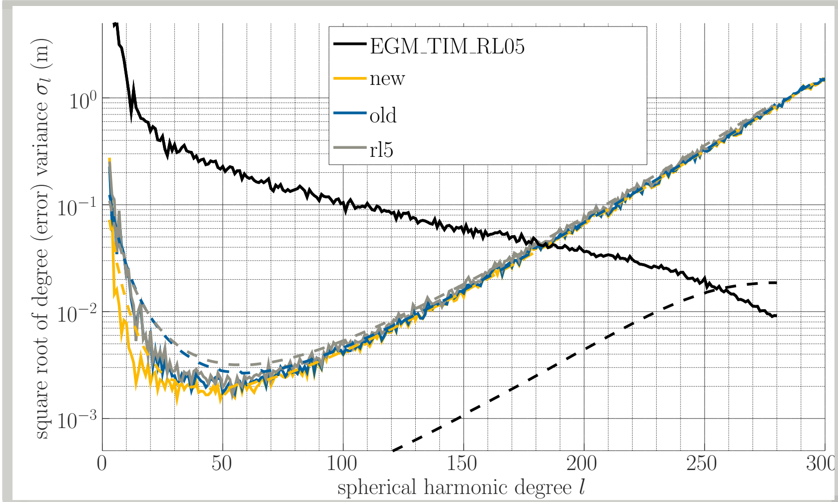
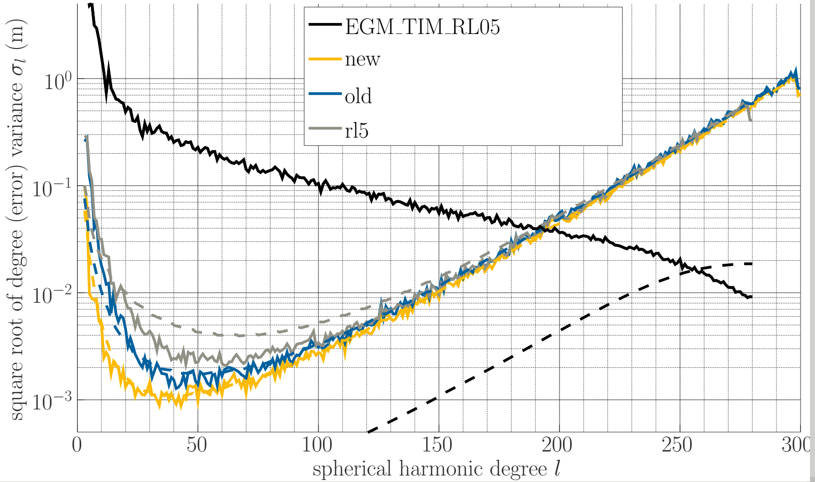


period: 1
used data: V_{XZ}

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix



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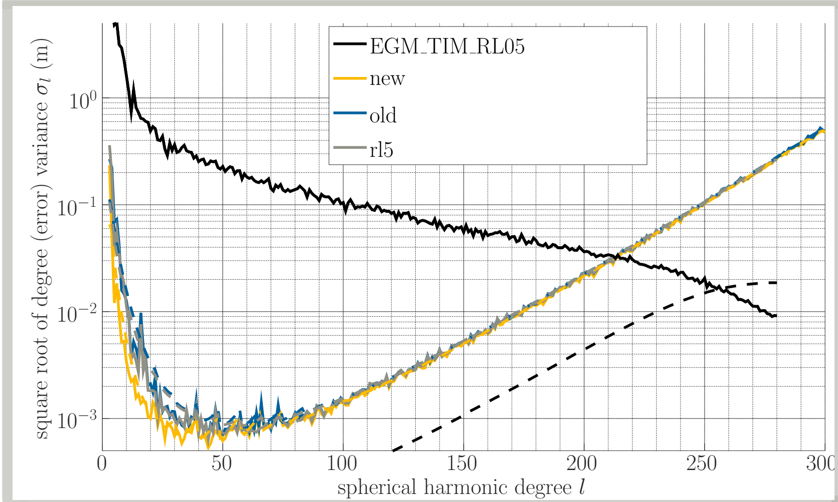

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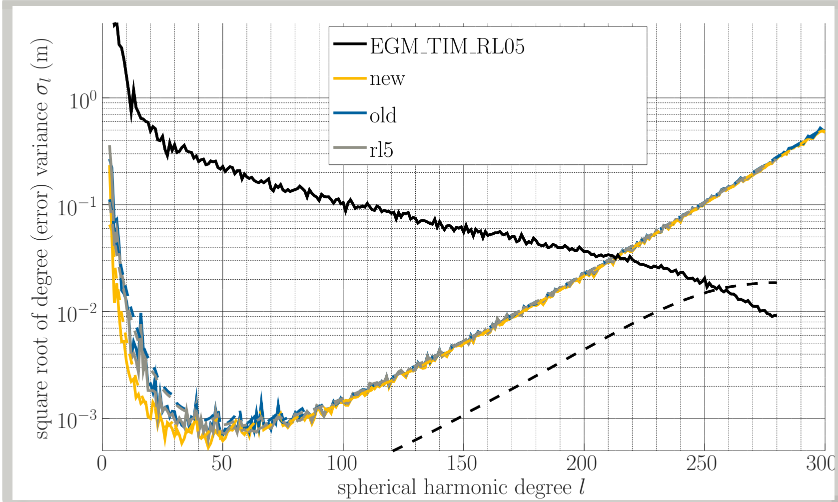
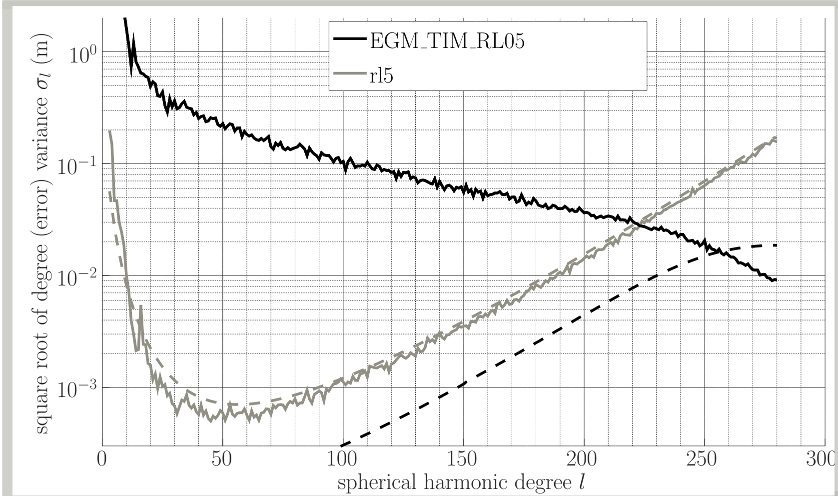


period: 1
used data: V_{ZZ}

- robust solutions with old data better than rl5
- new data performs significantly better for all gradients, for entire spectrum!
- improvement for all components (most V_{YY})

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix

Combined Solution for Period 1



period: 1

used data:

$V_{XX}+V_{XZ}+V_{YY}+V_{ZZ}$

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix

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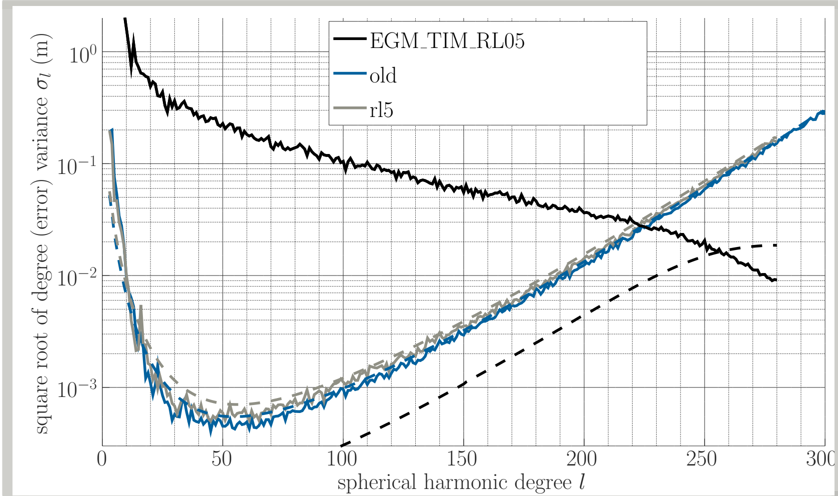

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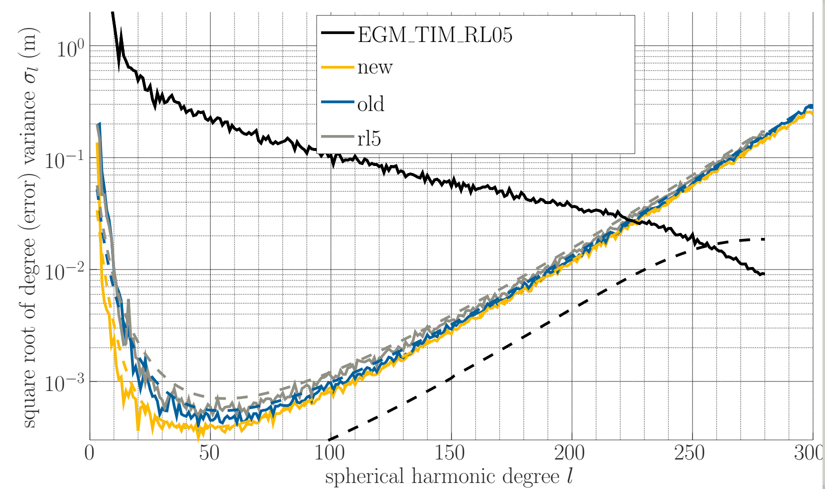

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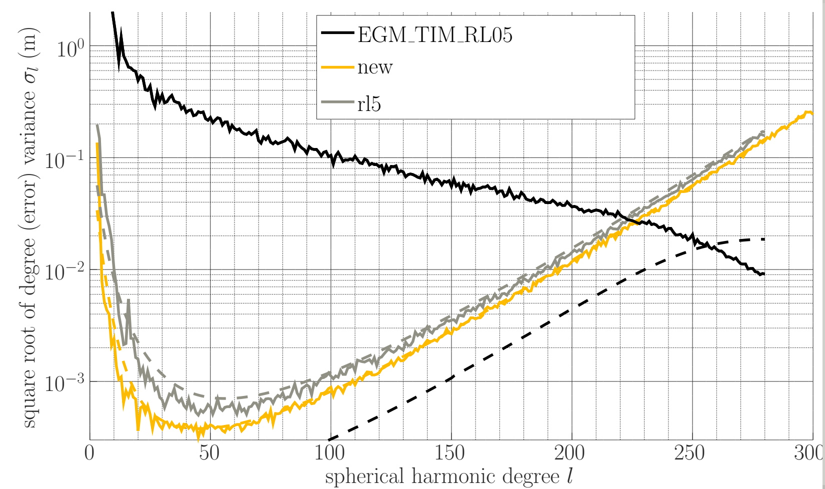

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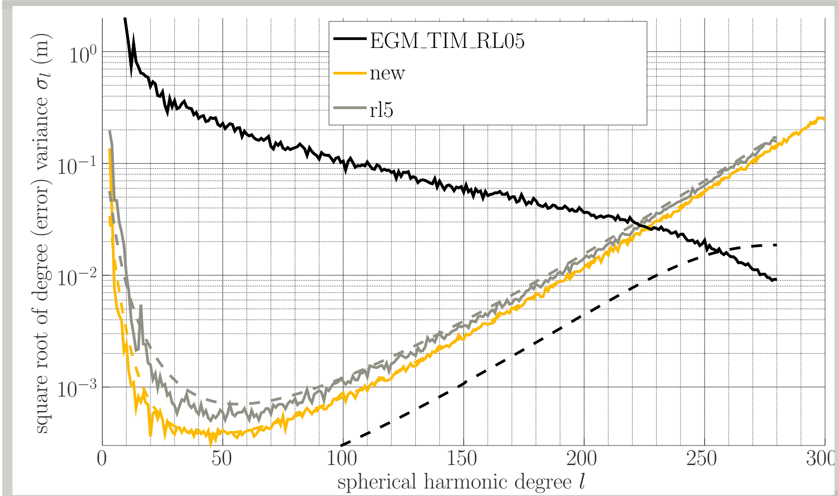


period: 1

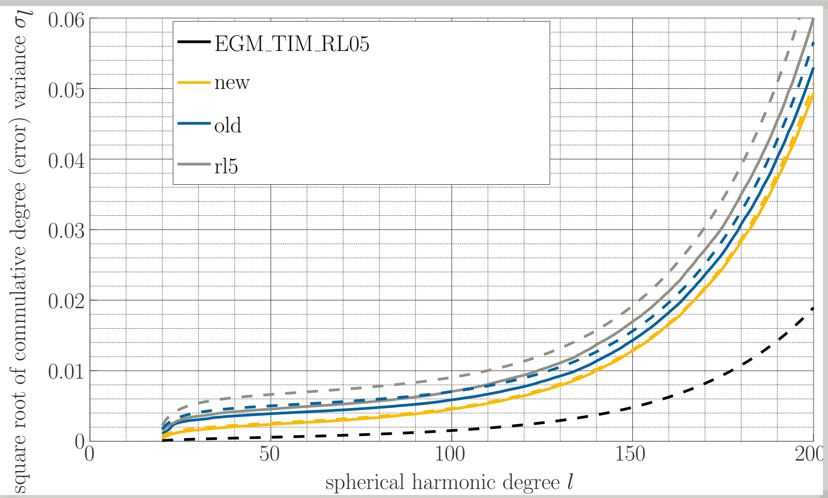
used data:

$V_{XX}+V_{XZ}+V_{YY}+V_{ZZ}$

- significant improvement for entire spectrum!
- Can we quantify?

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix

Commulative Degree Variances



period: 1

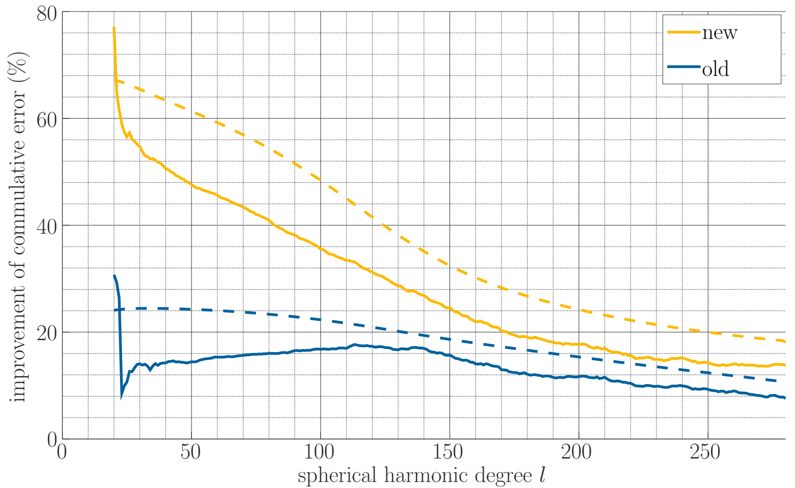
used data:

$V_{XX}+V_{XZ}+V_{YY}+V_{ZZ}$

- new data: consistency empirical/formal
- quantify: improvement in percent

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix

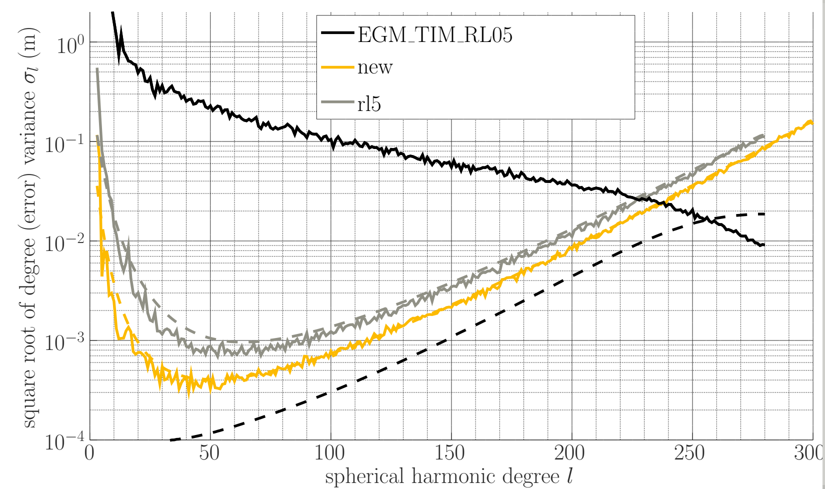
Improvements of Commulative Errors



period: 1
improvement w.r.t. rl5 solution

- formal errors: stronger improvement
- empirical errors: still 18 % at d/o 200

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix



period: 2

used data:

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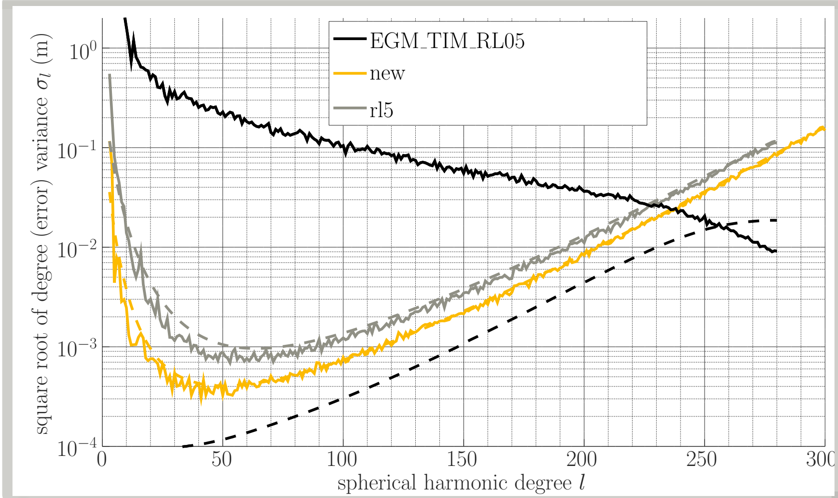
solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix



period: 2

used data:

$V_{XX}+V_{XZ}+V_{YY}+V_{ZZ}$

- significant improvement for entire spectrum!
- even more than for period 1 (>30 % at degree 200)!
- very valuable lowest orbit data

solid: empirical from difference to EGM_TIM_RL05, dashed: formal from covariance matrix

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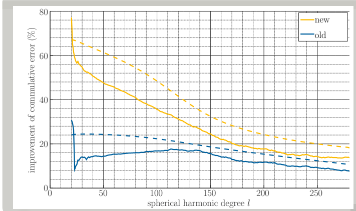
Summary and Conclusions

- reprocessing significantly improves the gravity gradient data
- the noise characteristics are more stationary
- advanced robustified decorrelation filters lead to a more realistic error description and identification of suspicious data
- for the analyzed periods gradiometer-only gravity field solutions significantly improve
- improvements in the range of 20 to 50 %, depending on the spectral resolution
- for GOCE-only models: significant improvements expected



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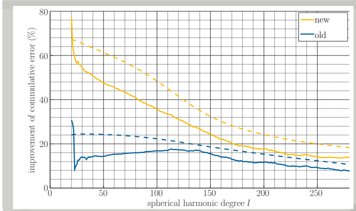

Outlook

- improvement of the nominal mission data?
- verification of identified 'suspicious' data
- reprocessing of the entire mission data set $\Rightarrow$ a release 6 of GOCE models is coming for sure
- reprocessing of high-low SST (removal of systematic effects)

We acknowledge the funding of the reprocessing campaign by the European Space Agency!

Thanks for the attention!

References

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