Assessment of GRACE monthly solutions by quantifying the noise level in mass anomaly time-series with the variance component estimation (PPT)

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Assessment of GRACE monthly solutions by quantifying the noise level in mass anomaly time-series with the variance component estimation

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Considered GRACE RL06 solutions

- Solution variants: JPL, CSR, ITSG
- Time interval: Jan. 2003 – Mar. 2016
- $L_{max} = 60$
- Degree-1 and C_{20} SH coefficients: from a combination of OBP estimates and other GRACE-based coefficients (Sun et al, GJI, 2016)
- 400-km Gauss filter is applied

Joint regularized data processing

Unknown parameters

$$\begin{cases} A^{(1)}x = d^{(1)} \\ \dots \\ A^{(n)}x = d^{(n)} \\ Dx = 0 \end{cases}$$

Observations

Pseuso-observations (define the regularization condition applied)

Possible regularization conditions (case of a continuous function x(t) in the time domain)

Zero-order Tikhonov regularization: $\Omega[x] = \int (x(t))^2 \, \mathrm{d}t$

First-order Tikhonov regularization: $\Omega[x] = \int (\dot{x}(t))^2 \, \mathrm{d}t$

Minimization of Year-to-year Differences:

Let $x(t) = \begin{pmatrix} \xi_1(t) \\ \xi_2(t) \\ \dots \\ \xi_K(t) \end{pmatrix}$

- $\xi_1(t)$ ← Unknown function in year 1
- $\xi_2(t)$ ← Unknown function in year 2
- $\xi_K(t)$ ← Unknown function in year K

$$\Omega[x] = \sum_{k=1}^{K-1} \int_0^1 \left(\xi_{k+1}(t) - \xi_k(t) \right)^2 dt$$

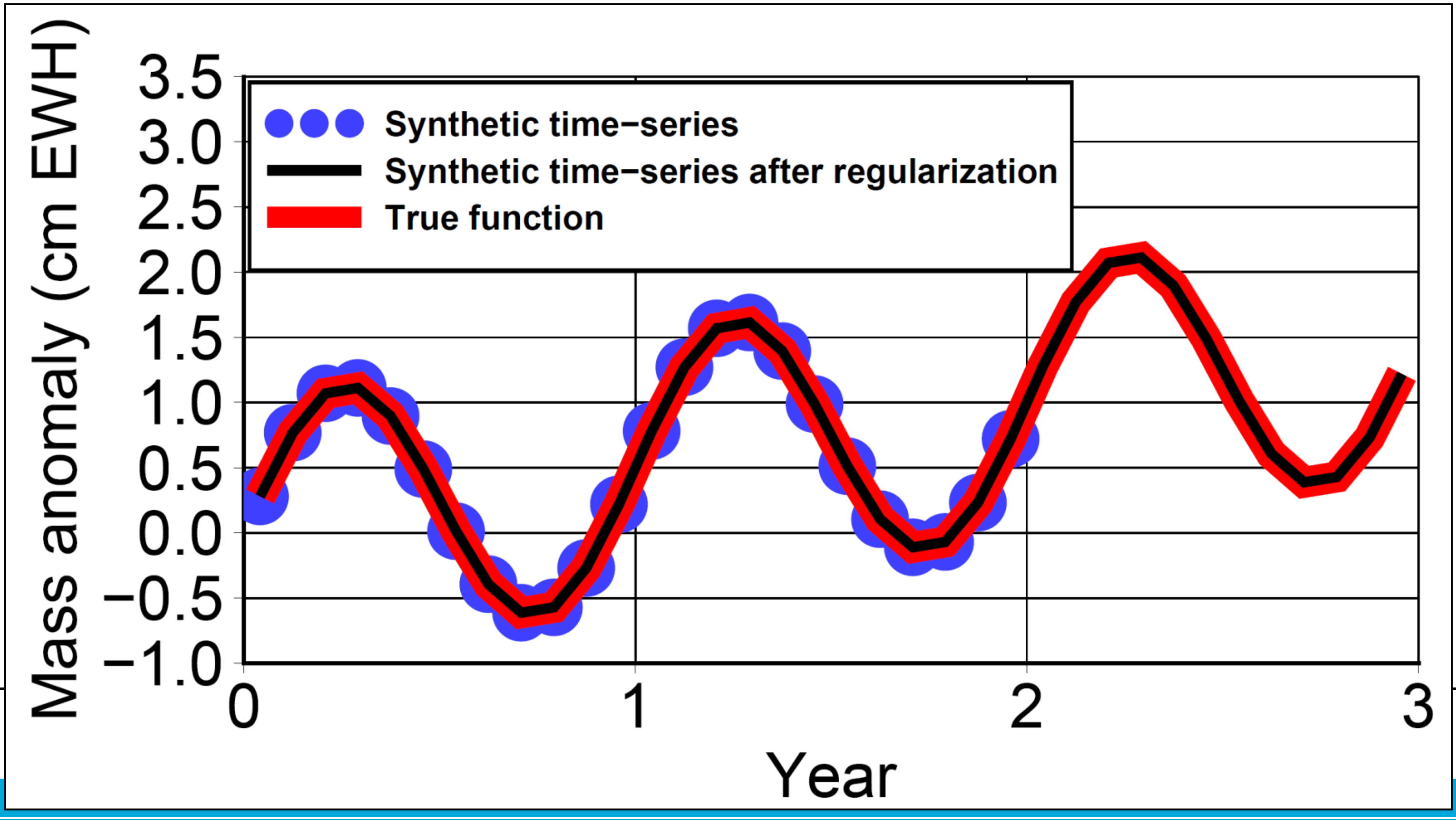
(t – time in years)

Example: Climatology-tailored regularization in the absence of noise and penalized signals

$$x(t) = \sin 2\pi t + 0.5 \cdot t$$

t – time in years

$x(t)$ – Equivalent water heights (EWH) in cm



Minimization functional

$$\Phi[x] = \frac{1}{\sigma_1^2}\sum_i \left(x(t_i) - d_i^{(1)}\right)^2 + \ldots \frac{1}{\sigma_n^2}\sum_i \left(x(t_i) - d_i^{(n)}\right)^2 + \frac{1}{\sigma_s^2}\Omega[x]$$

Data noise variances

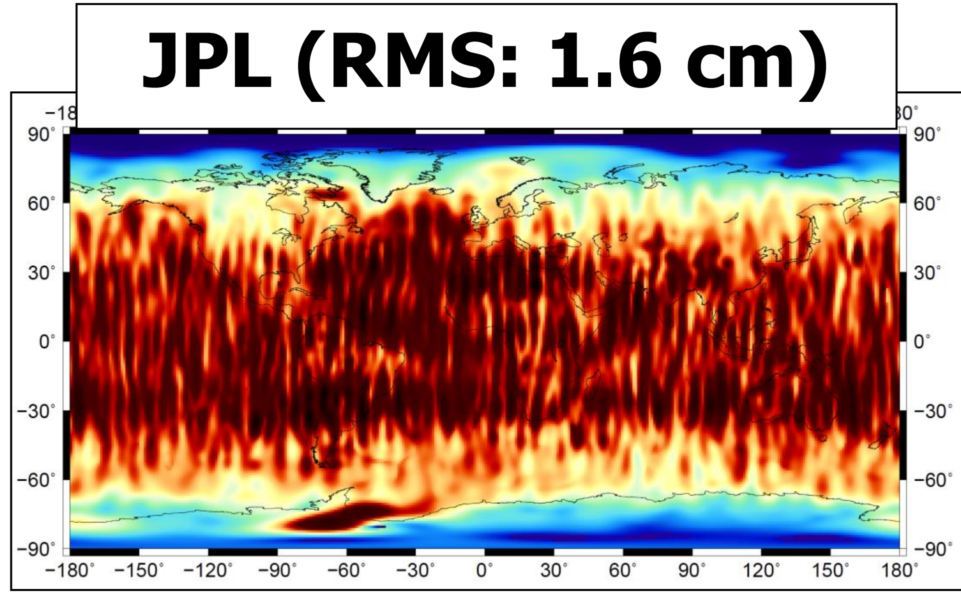
Signal variance

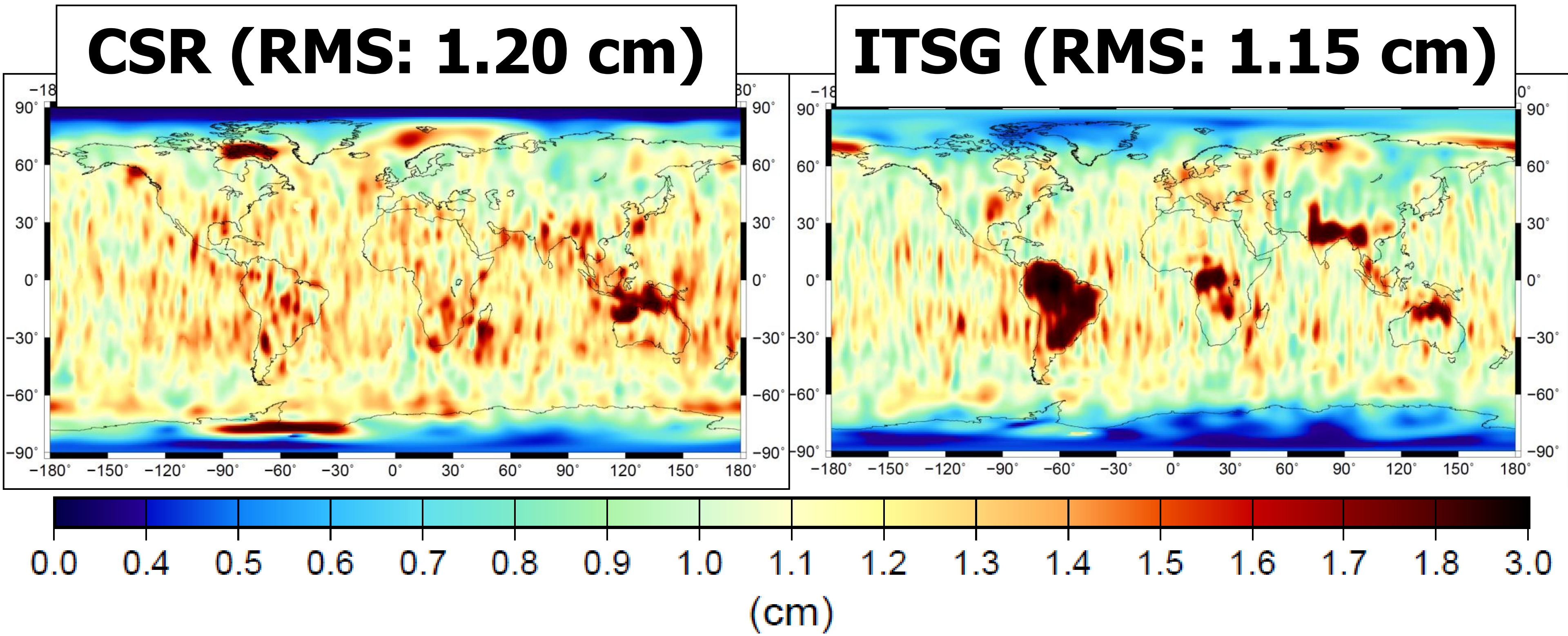
Estimation of noise and signal variances:

Variance Component Estimation (VCE) method

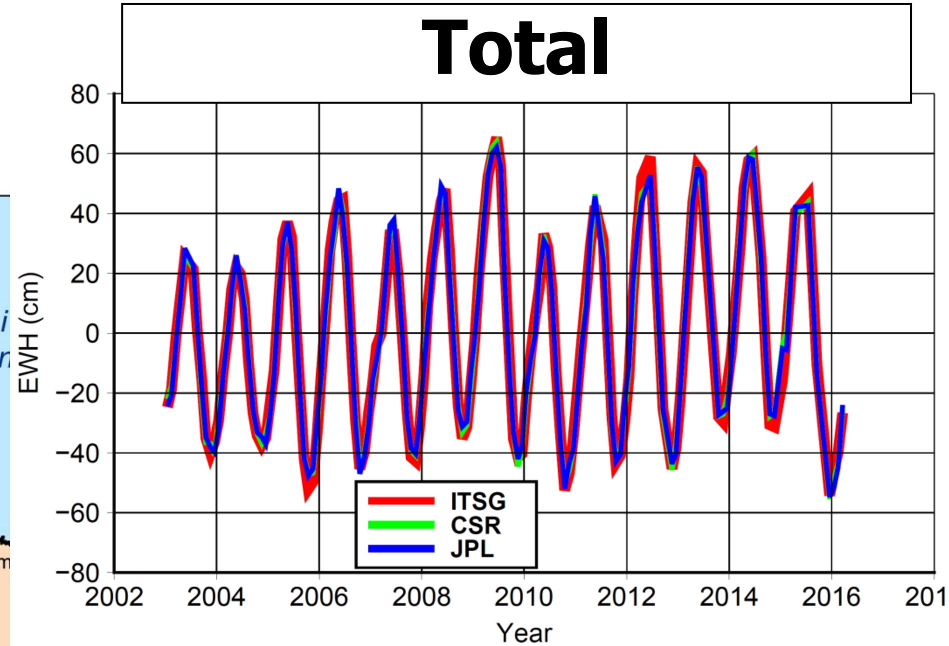
(Koch & Kusche, JoG, 2002)

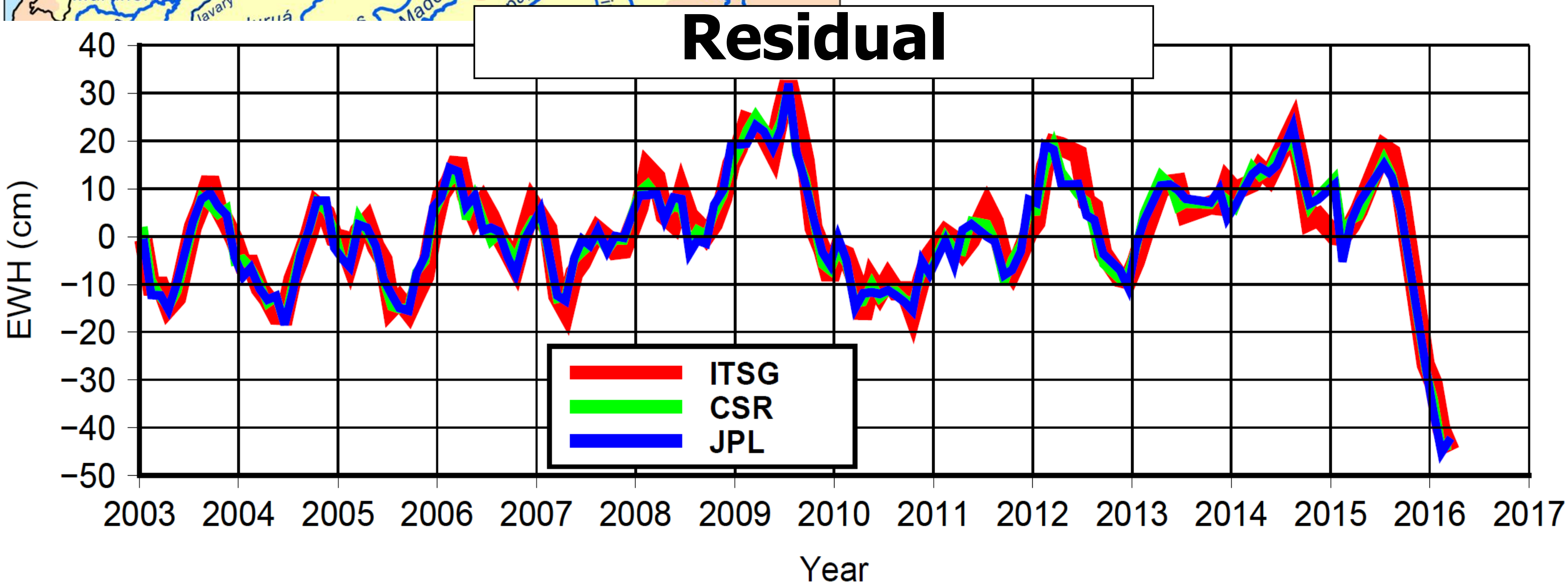
Estimated noise of GRACE monthly solution time-series (standard deviation, cm EWH)





Mass anomaly time-series at Manaus



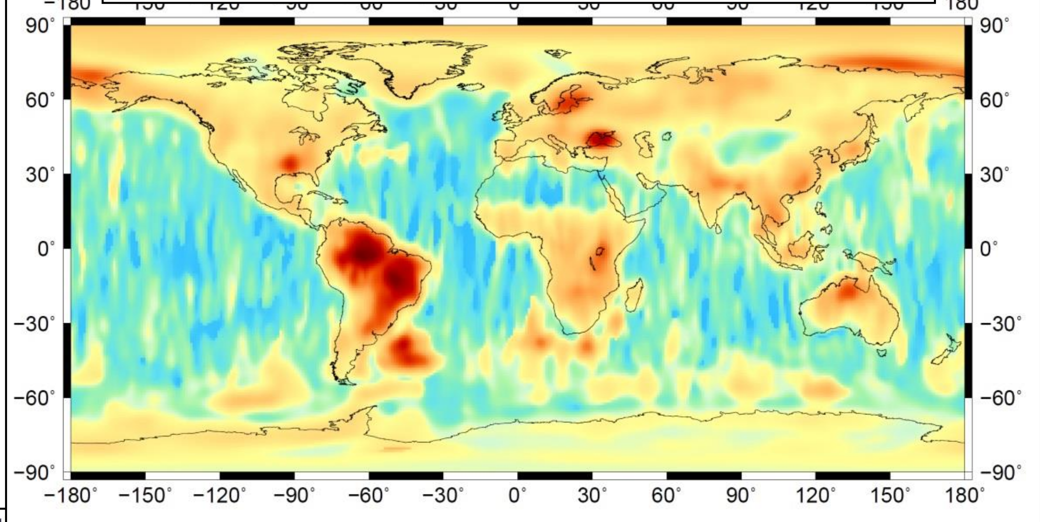


Estimated noise of GRACE monthly solution time-series (RMS, cm EWH)

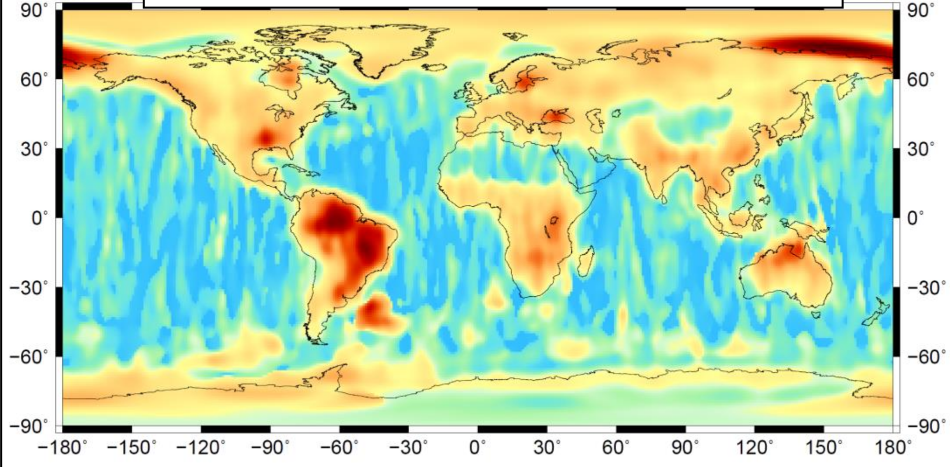
	CSR	ITSG	JPL
Global	1.20	1.15	1.63
Only Ocean	1.21	1.11	1.66
Only land	1.18	1.24	1.64
Antarctica	0.92	0.57	0.81
...			
Australia	1.35	1.26	1.81
South America	1.31	1.89	1.84
Arctic ocean	1.00	0.87	0.85
...			
South Atlantic	1.20	1.16	1.71
Southern Ocean	1.23	0.92	1.24

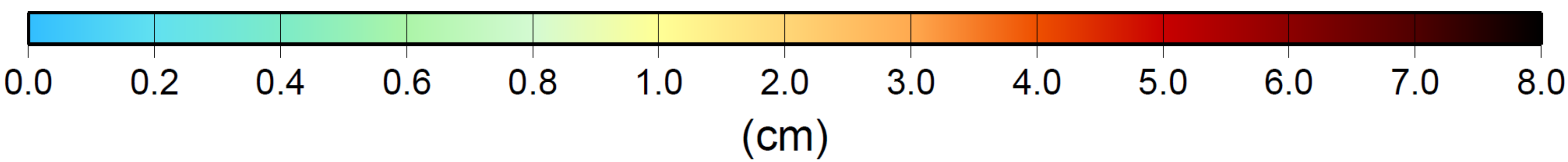
Estimated MYDD signal (standard deviation, cm EWH)

RL06 (RMS over ocean: 0.96 cm)

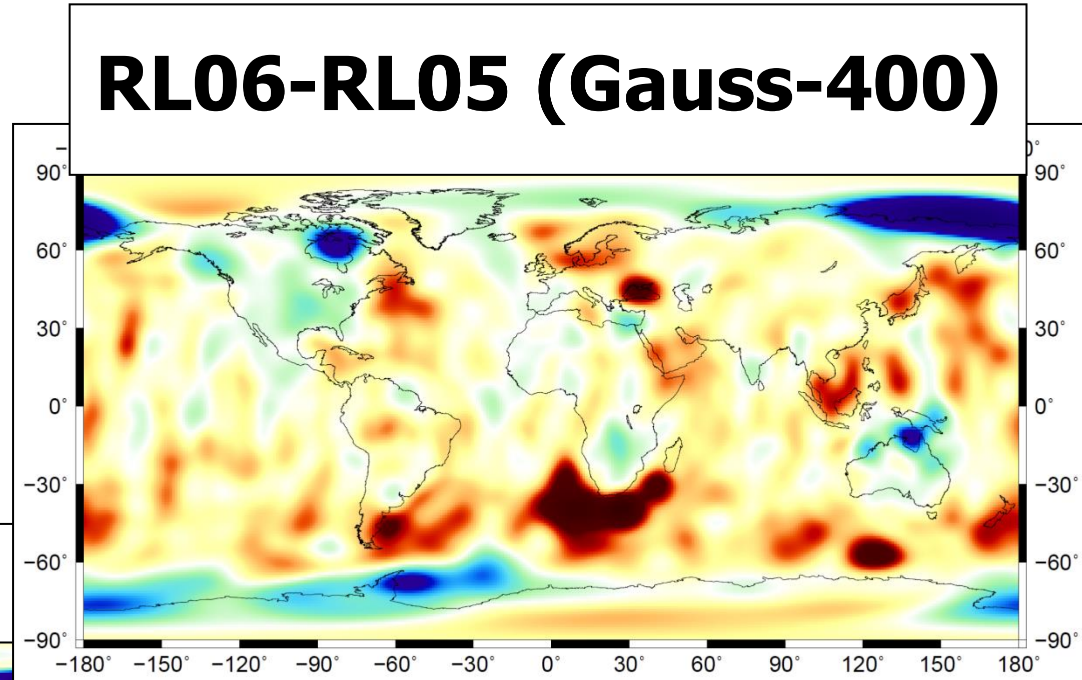


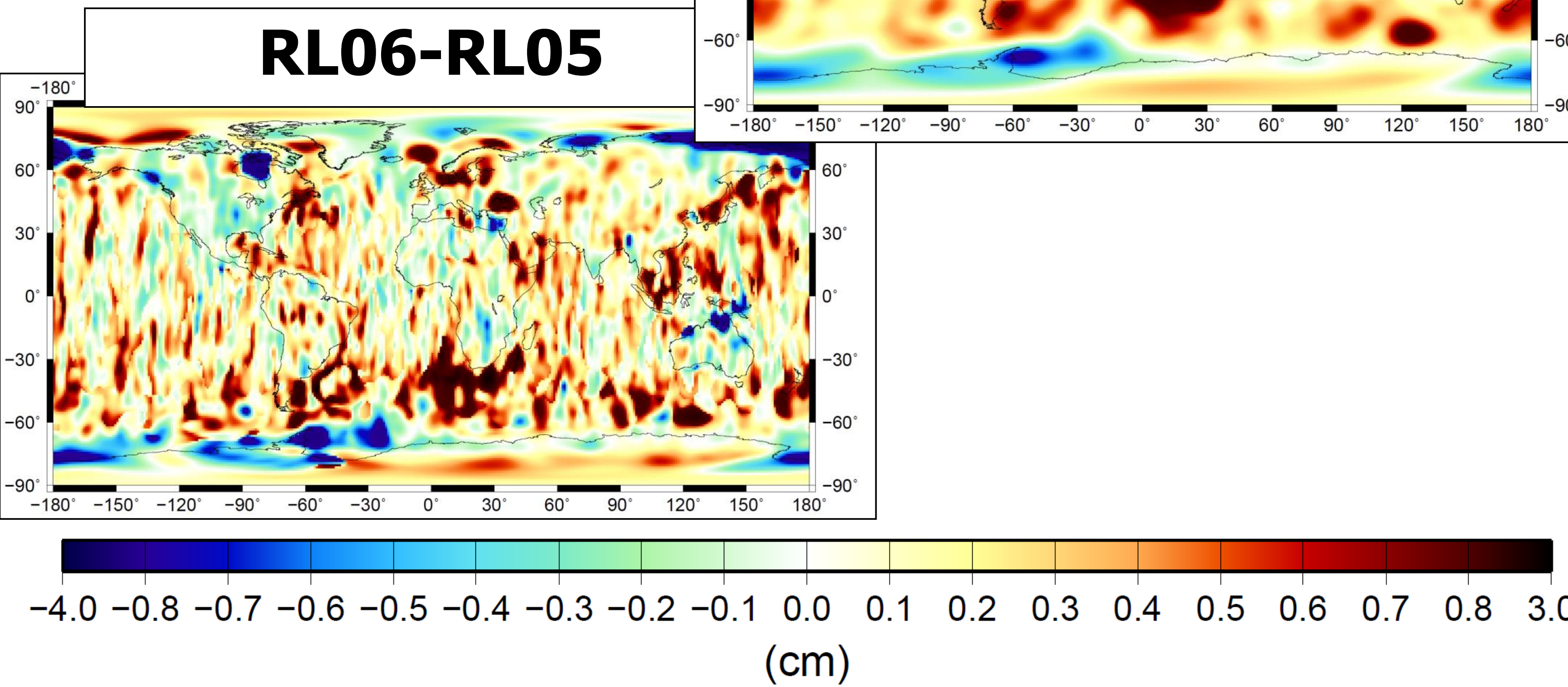
RL05 (RMS over ocean: 0.86 cm)





Estimated MYDD signal (difference of standard deviations, cm EWH)

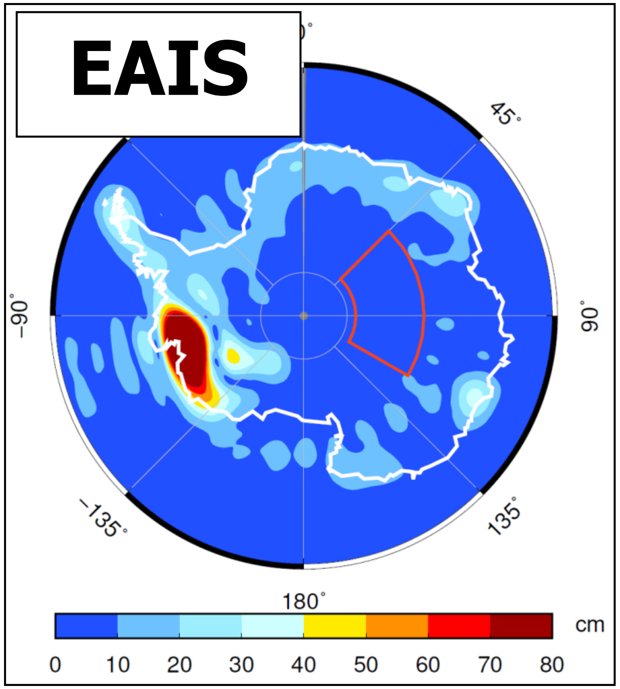


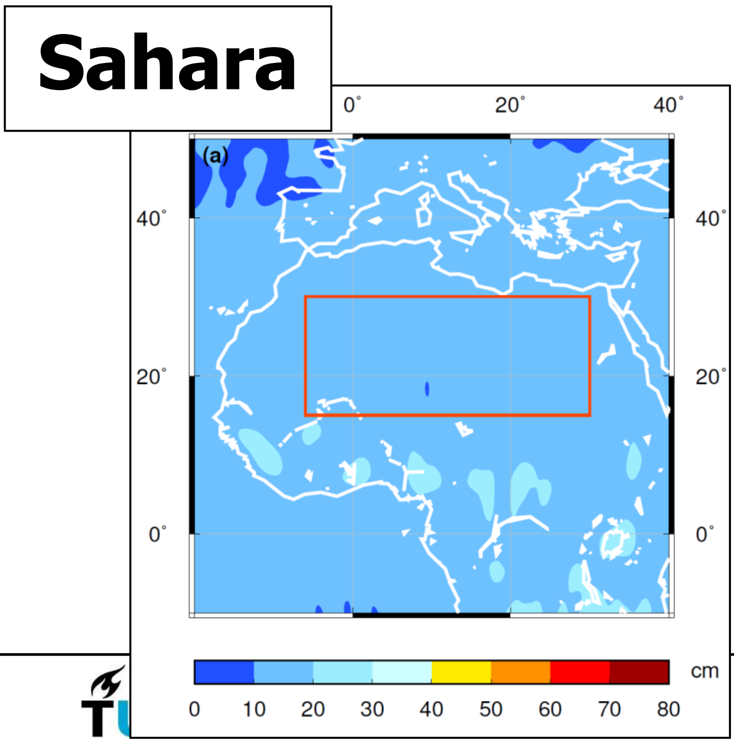


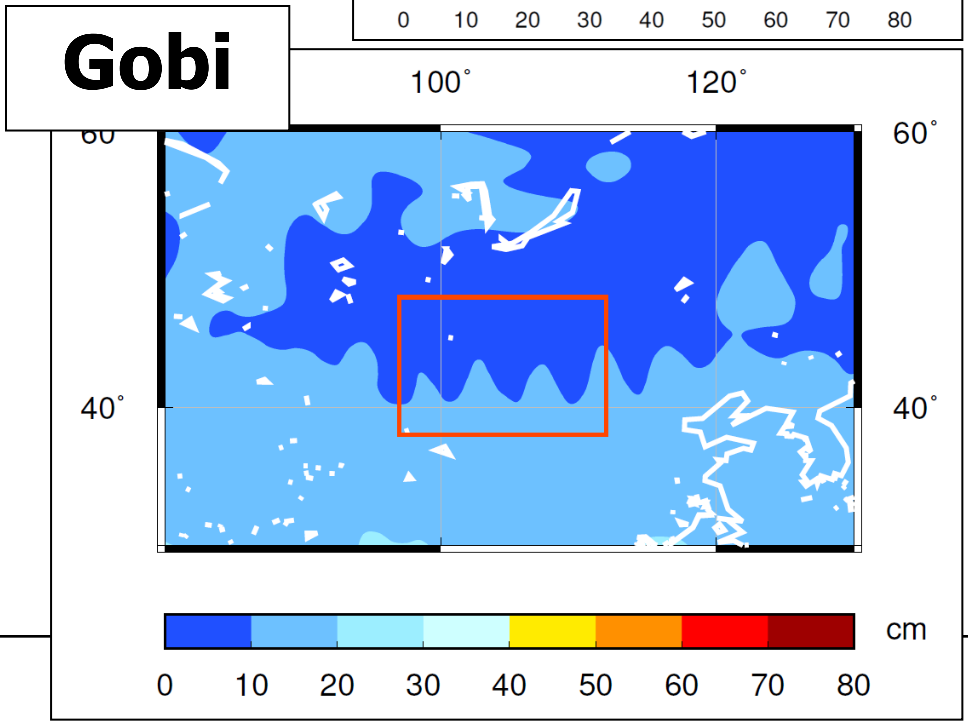
(Re-)definition of degree-1 and C20 coefficients in GRACE RL06 monthly solutions

- Major input (Sun et al, GJI, 2016):
  - OBP estimates
  - Other GRACE-based coefficients
- Major differences with respect to (Swenson et al, 2008):
  - C_{20} coefficients are co-estimated
  - SAL effects are taken into account
  - 150-km buffer zone along the coasts is excluded

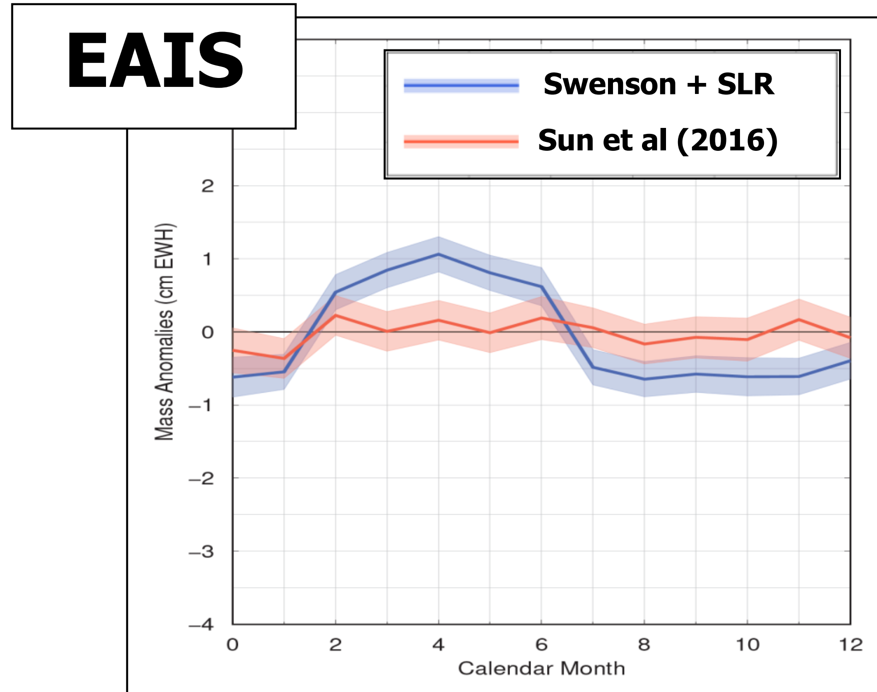
Considered test areas

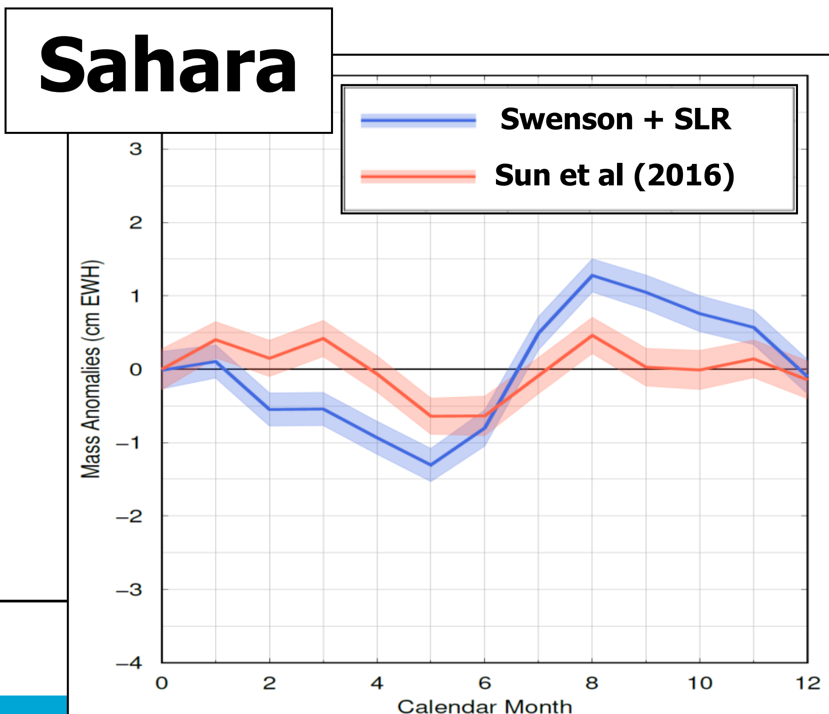


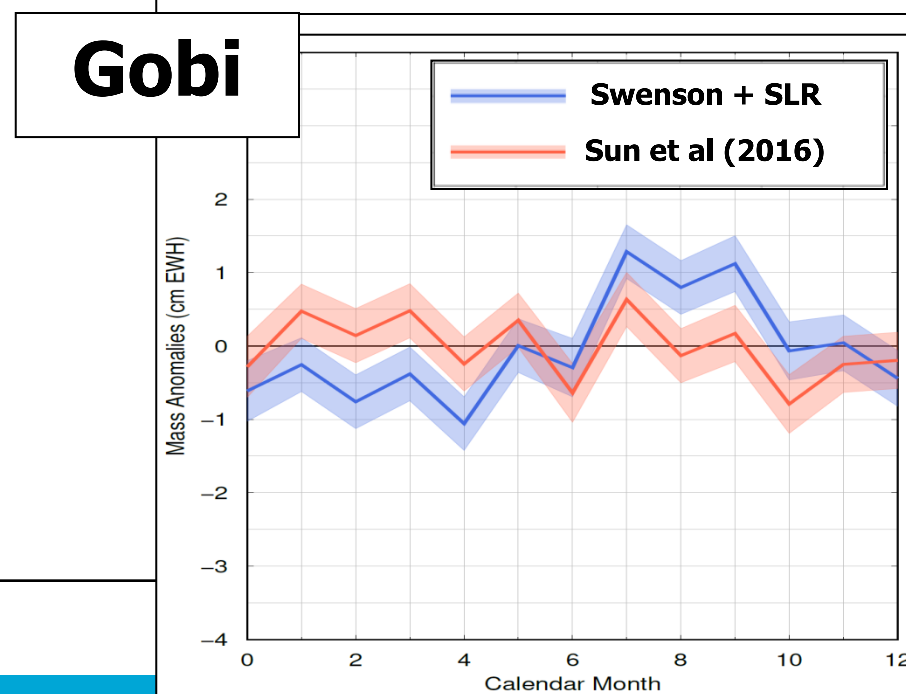




Seasonal cycle of mass anomalies in test areas: Sun et al (2016) vs Swenson et al (2008) + SLR (Cheng et al)







Conclusions

- The developed technique is a promising tool to quantify noise in mass anomaly time-series in the absence of 'ground truth'
- Application of this techniques allows one to identify various points of concern, e.g.:
  - insufficiently suppressed sensor noise
  - an insufficient accuracy of background ocean tide models
  - temporal offsets in the produced gravity field solutions
- The estimated signal magnitude (in terms of Month-to-month Year-to-year Double Differences) is another way to assess the performance of background ocean models (e.g. the performance of RL05 and RL06 at different geographical locations can be compared in this way)
- The technique of Sun et al (2016) allows for a accurate and internally consistent estimation of degree-1 and C_{20} SH coefficients