Towards combined global monthly gravity field solutions

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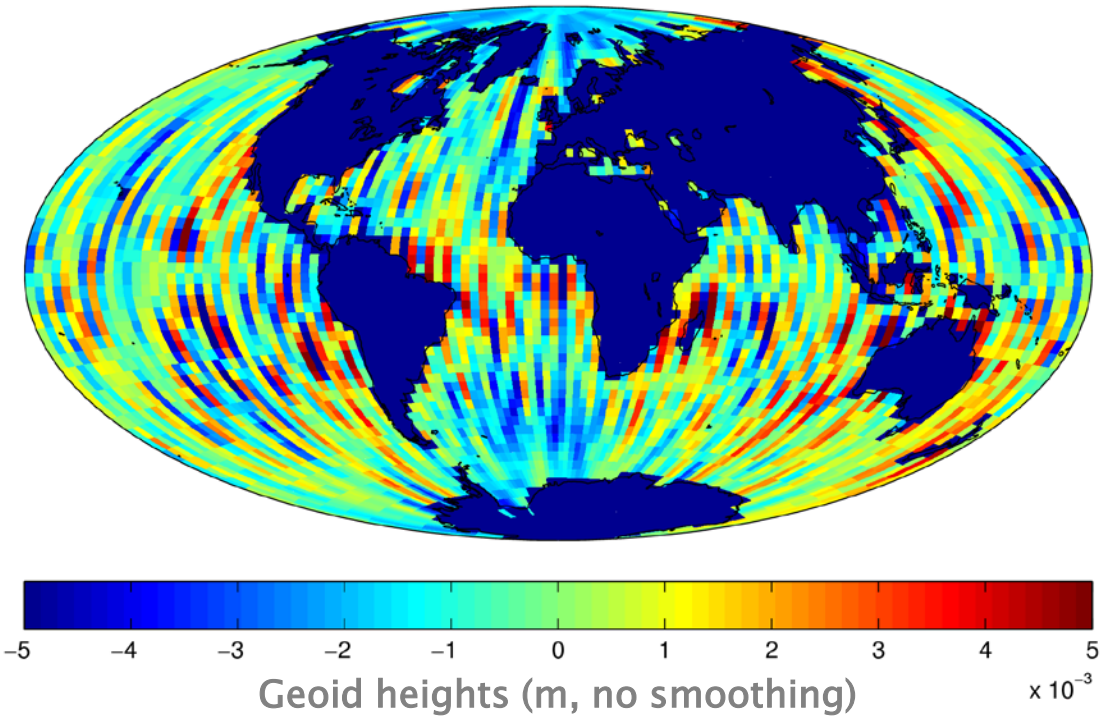
Motivation

Today, a variety of time-variable GRACE solutions are available from different groups:

- The solutions differ in terms of noise and (maybe) signal
- They may be based on different methodologies
- What can be done to make the best possible use of all these solutions?
- Is it possible to establish a meaningful combination?

Noise assessment

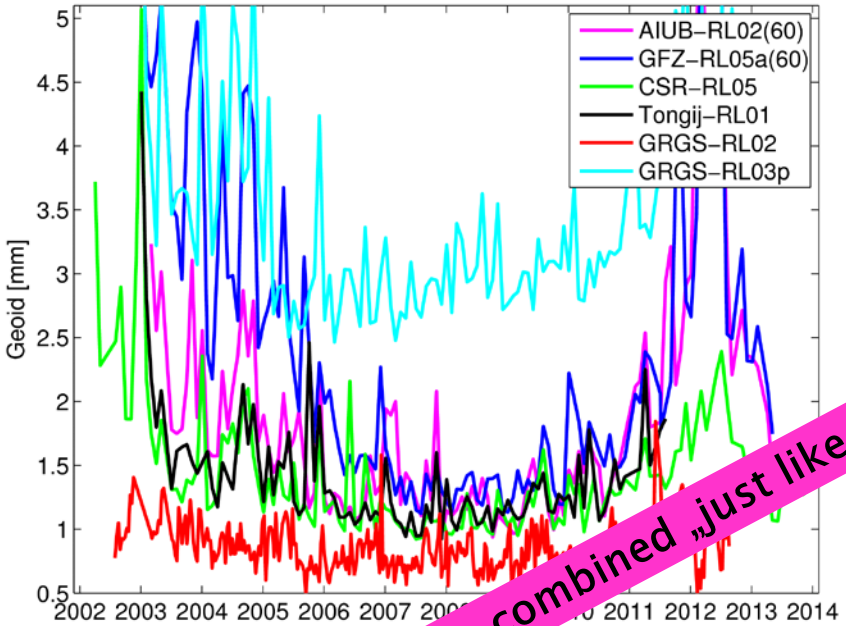
- weighted standard deviation (wSTD) over the oceans are computed to estimate the noise of the monthly solutions in a simple way



- an enlarged landmask is applied to compute the weighted STD in order to avoid leakage from continental regions with a strong hydrology signal

Noise assessment

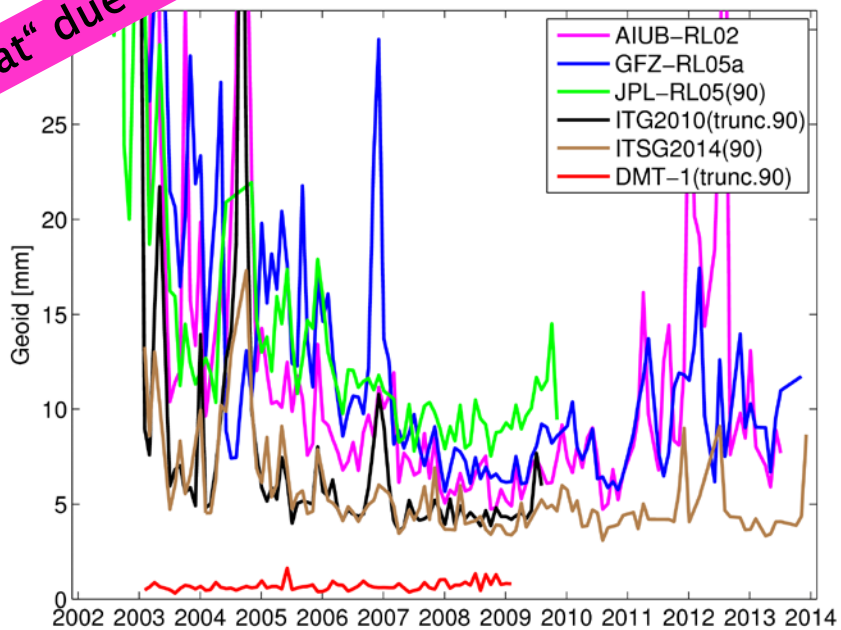
wSTD over oceans (60)



AIUB–RL02 (6 1.5 mm
GFZ–RL0 0): 1.8 mm
CSR 5: 1.3 mm
gji: 1.3 mm
GRGS–RL02 (50): 0.8 mm
GRGS–RL03p: 3.2 mm

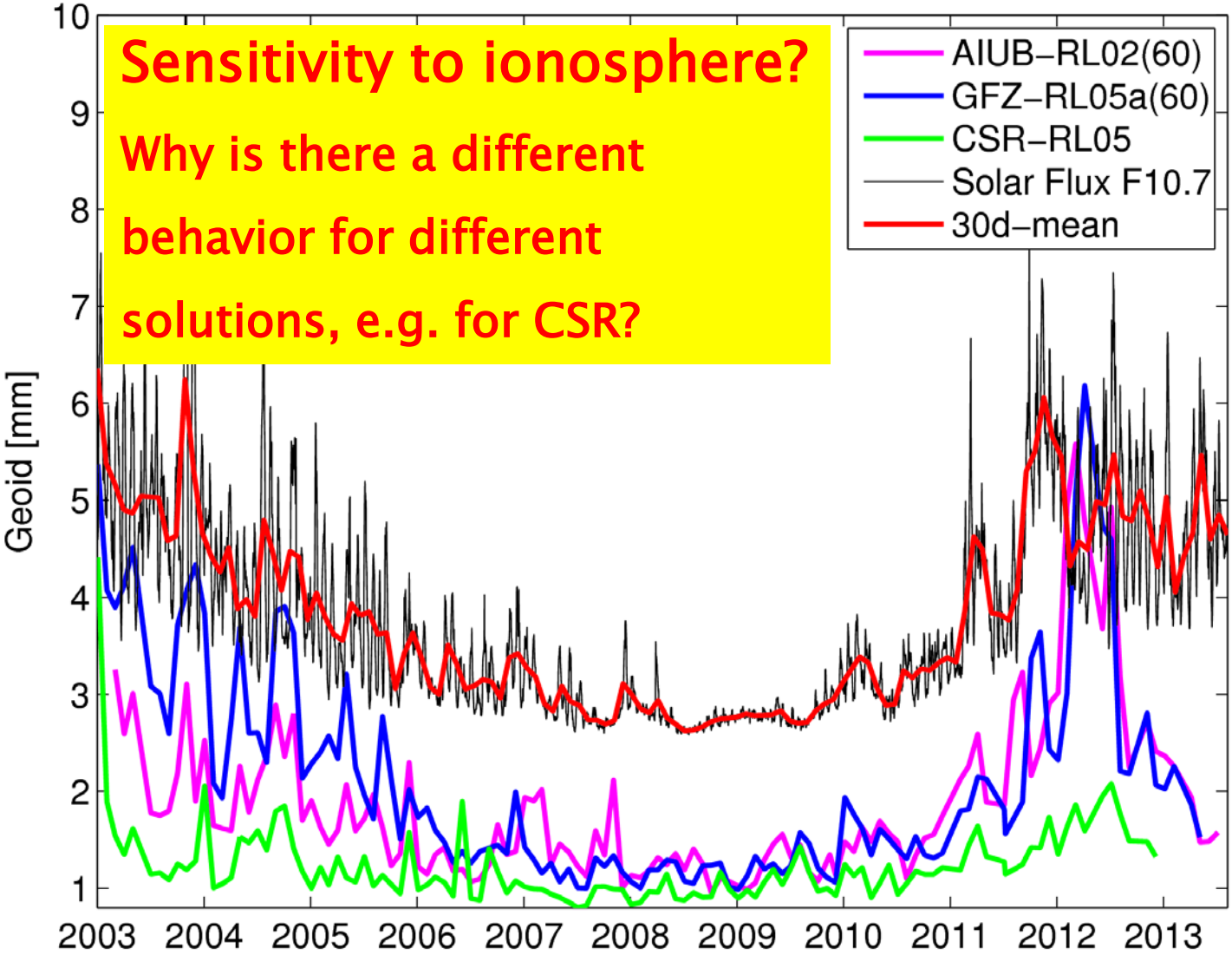
AIUB–RL02: 9.8 mm
GFZ–RL05a: 11.3 mm
JPL–RL05 (90): 11
ITG2010 (trunc. 90): 2 mm
ITSG2014 (90): 5.3 mm
DMT–1 (t 90): 0.7 mm

D over oceans (90)



Solutions cannot be combined „just like that“ due to different solution strategies

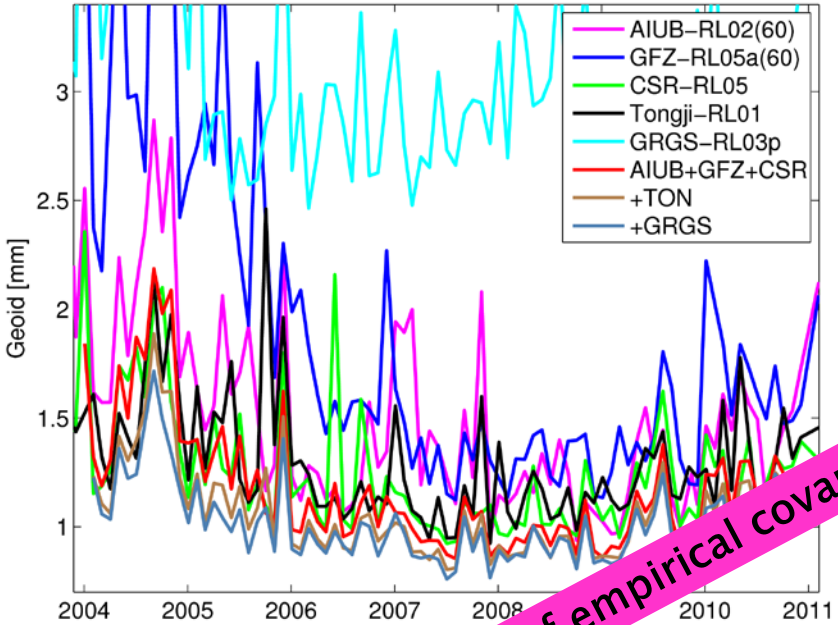
Noise assessment



Averaged monthly solutions

(input solutions based on similar strategies)

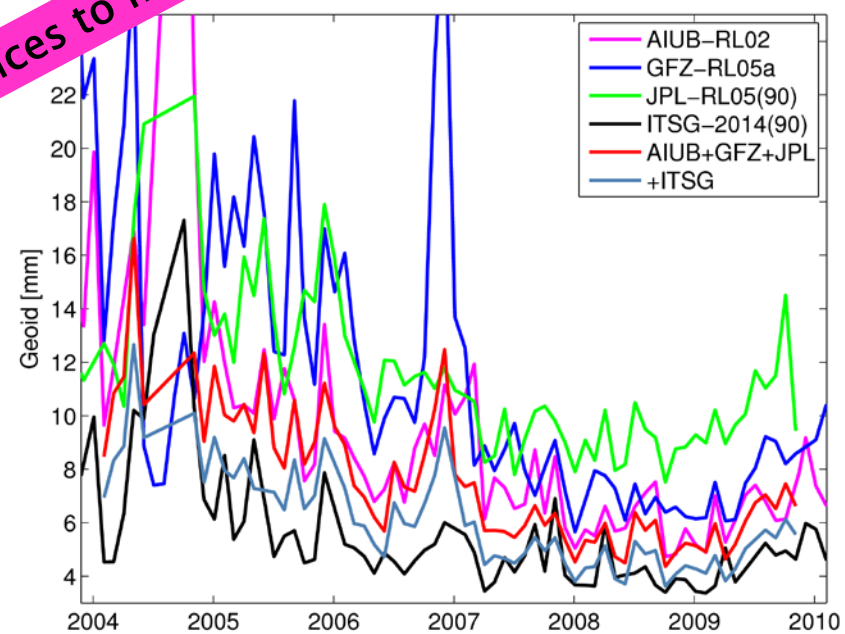
wSTD over oceans (60)



AIUB–RL02 (60): 1.5 mm
GFZ–RL05a (60): 1.8 mm
CSR–RL05: 1.3 mm
Tongji–RL01: 1.3 mm
GRGS–RL03p: 3.2 mm
Mean of 3: 1.2 mm
Mean of 4: 1.1 mm
Mean of 5: 1.0 mm

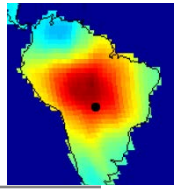
AIUB new (90): 9.8 mm
GFZ–RL05a (90): 11.3 mm
JPL–RL05 (90): [illegible] mm
ITSG–2014 (90): 5.3 mm
Mean of 3: 7.8 mm
Mean of 4: 6.4 mm

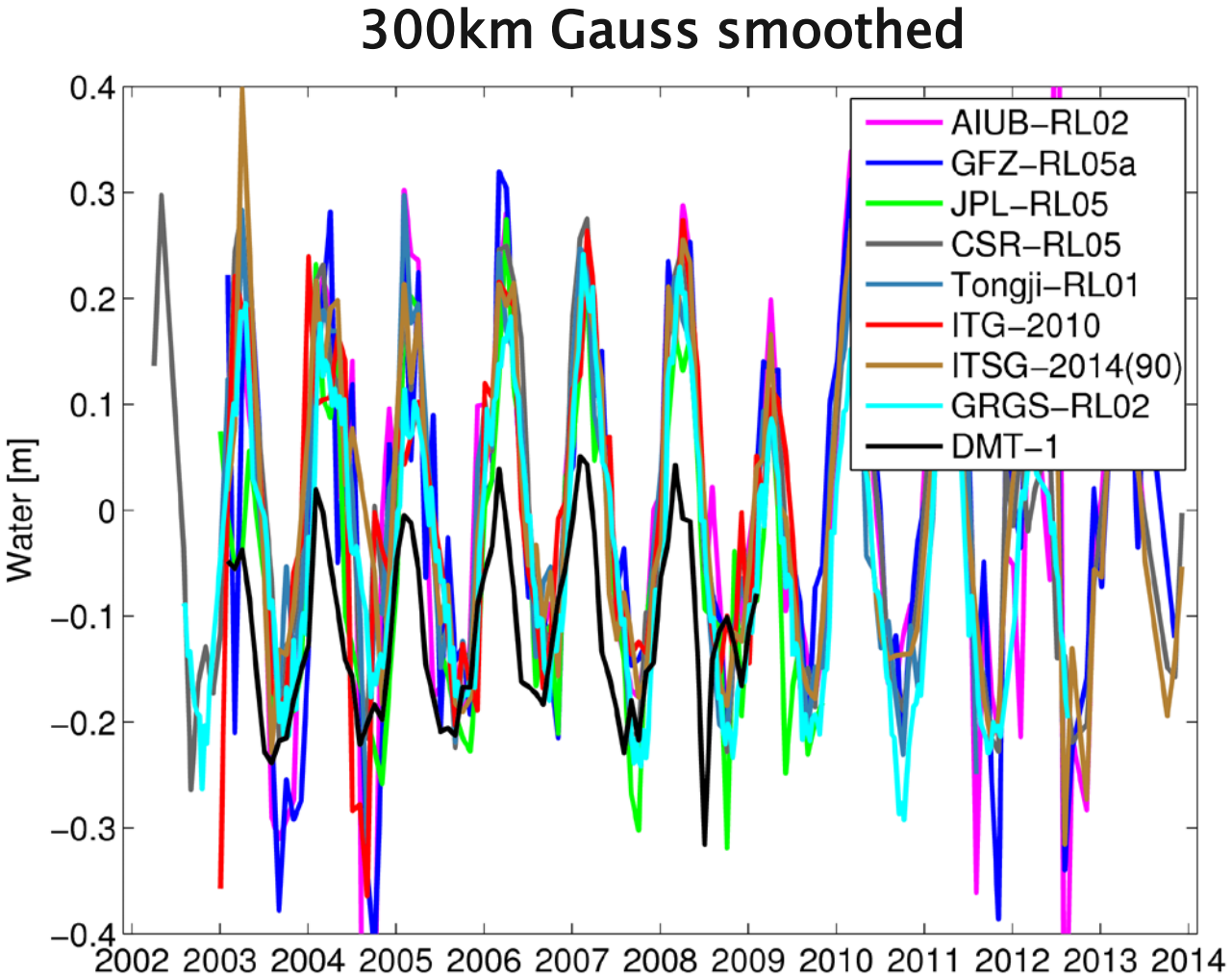
wSTD over oceans (90)



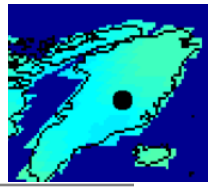
ITSG makes use of empirical covariances to model the noise behavior

Signal (hydrology in South America)

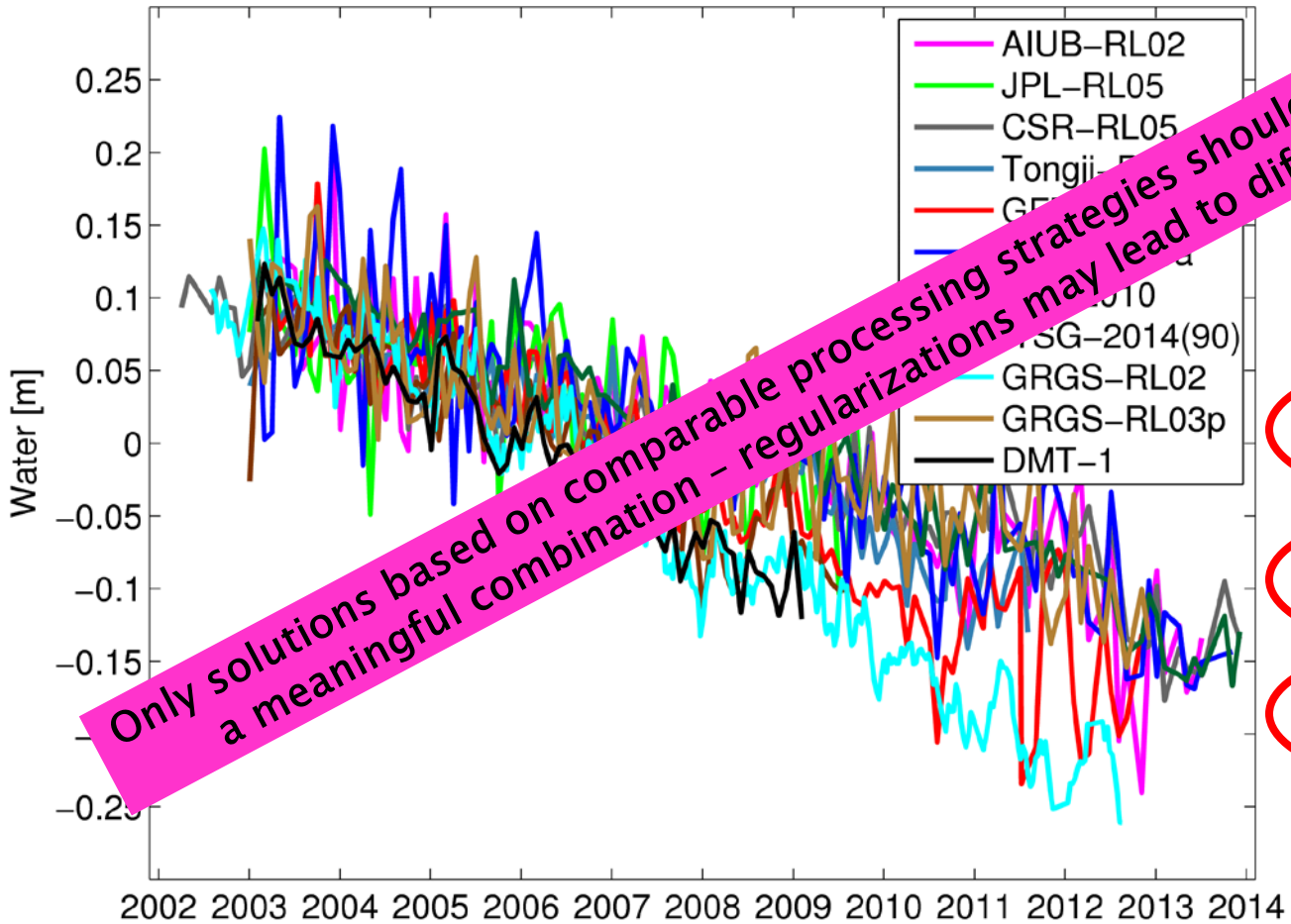




Signal (ice mass change in Greenland)



300km Gauss smoothed

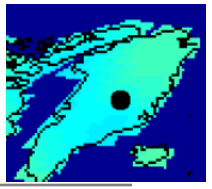


Only solutions based on comparable processing strategies should be used for a meaningful combination – regularizations may lead to different trends

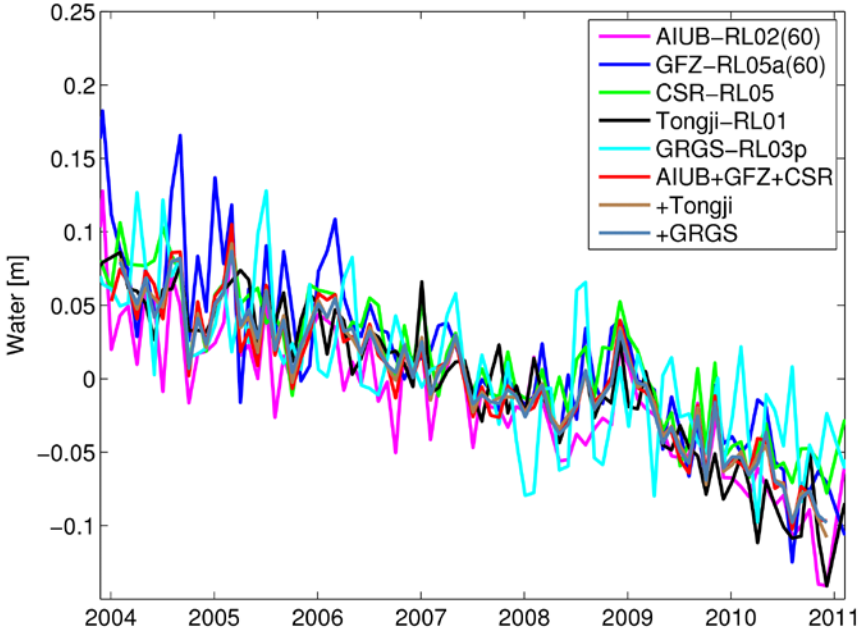
23±1.3 mm/y
JPL: −20±2.3 mm/y
CSR: −20±0.7 mm/y
TON: −22±0.9 mm/y
GFZ: −31±1.1 mm/y
GFZa: −24±1.4 mm/y
ITG: −28±1.6 mm/y
ITSG: −24±0.8 mm/y
GRGS: −36±0.4 mm/y
GRGS: −20±1.3 mm/y
DMT: −34±1.3 mm/y

Averaged monthly solutions

(input solutions based on similar strategies)



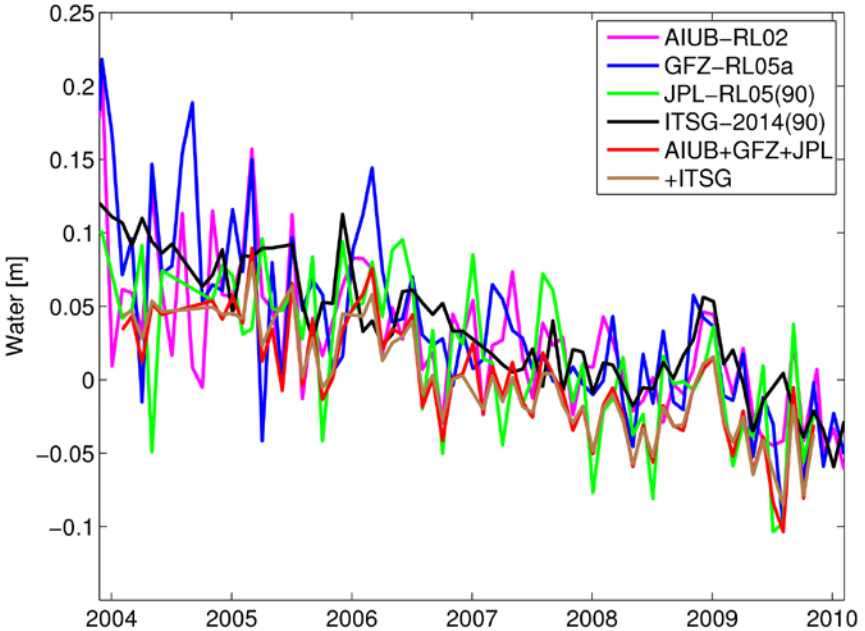
max. degree 60



AIUB−RL02 (60): −20±0.9 mm/y
GFZ5−RL05a (60): −20±1.2 mm/y
CSR−RL05: −20±0.7 mm/y
TON−RL01: −22±0.9 mm/y
GRGS−RL03: −20±1.3 mm/y
Mean of 3: −20±1.2 mm/y
Mean of 4: −20±1.1 mm/y
Mean of 5: −20±1.0 mm/y

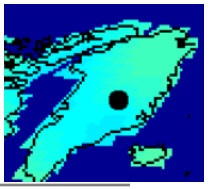
AIUB−RL02: −23±1.3 mm/y
GFZ−RL05a: −24±1.4 mm/y
JPL−RL05(90): −20±2.3 mm/y
ITSG−2014 (90): −24±0.8 mm/y
Mean of 3: −19±2.0 mm/y
Mean of 4: −19±1.6 mm/y

max. degree 90

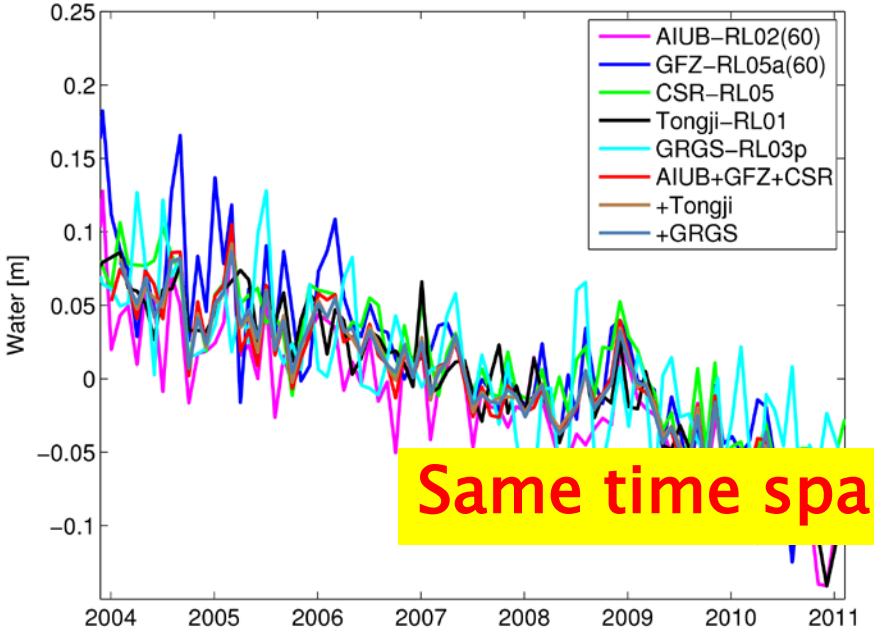


Averaged monthly solutions

(input solutions based on similar strategies)



max. degree 60

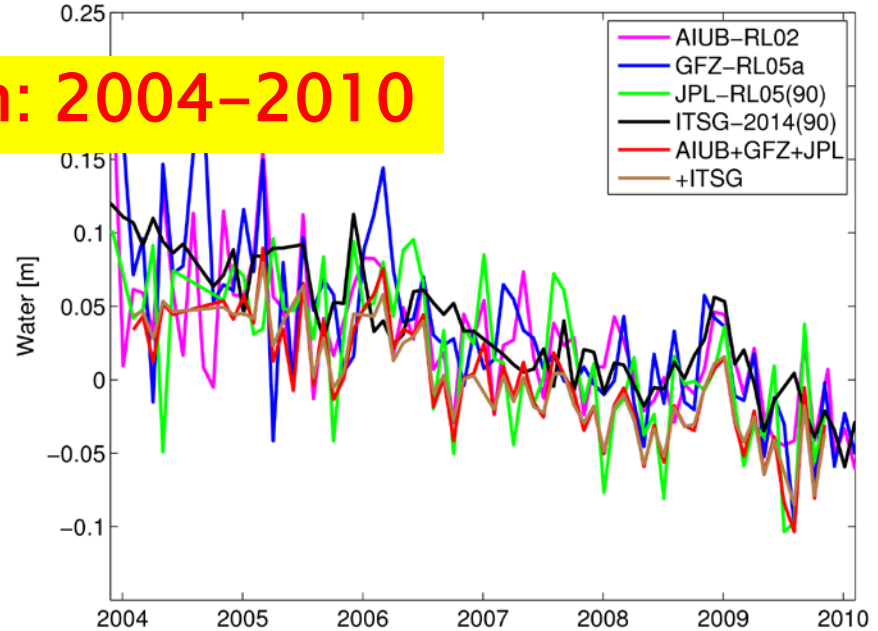


AIUB−RL02: −20±1.9 mm/y
GFZ−RL05a: −25±2.2 mm/y
JPL−RL05(90): −19±3.0 mm/y
ITSG−2014 (90): −22±1.2 mm/y
Mean of 3: −19±2.0 mm/y
Mean of 4: −19±1.6 mm/y

Same time span: 2004−2010

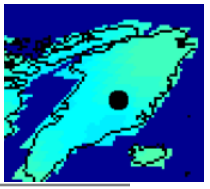
AIUB−RL02 (60): −19±1.4 mm/y
GFZ5−RL05a (60): −22±1.7 mm/y
CSR−RL05: −19±1.2 mm/y
TON−RL01: −24±1.2 mm/y
GRGS−RL03: −17±1.9 mm/y
Mean of 3: −20±1.2 mm/y
Mean of 4: −20±1.1 mm/y
Mean of 5: −20±1.0 mm/y

max. degree 90

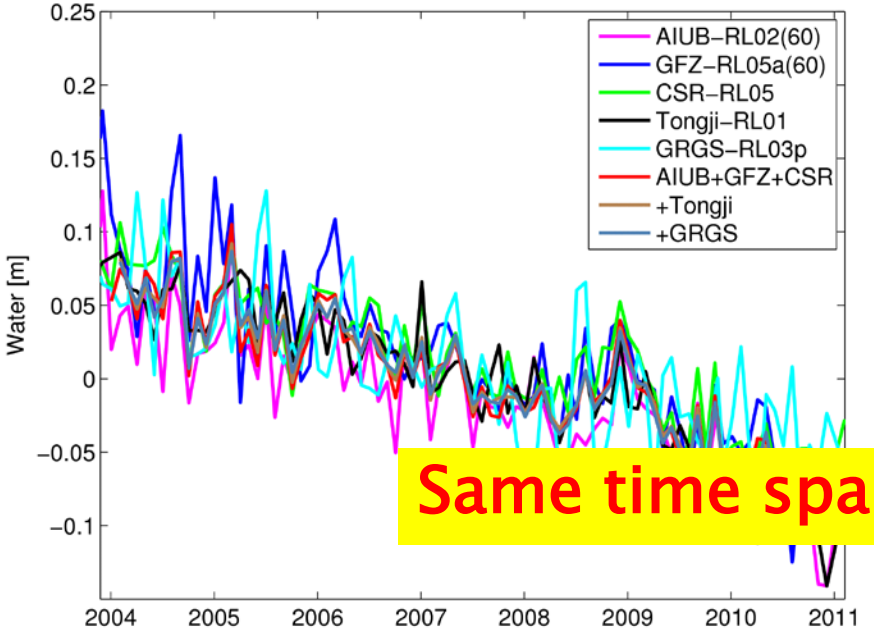


Averaged monthly solutions

(input solutions based on similar strategies)



max. degree 60

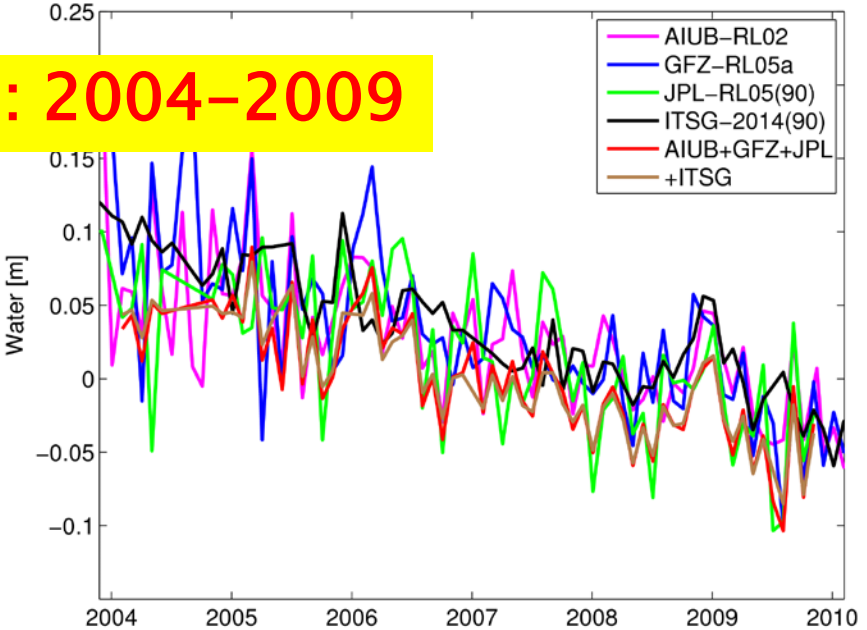


AIUB–RL02: −15±2.4 mm/y
GFZ–RL05a: −23±2.8 mm/y
JPL–RL05(90): −19±3.0 mm/y
ITSG–2014 (90): −20±1.5 mm/y
Mean of 3: −19±2.0 mm/y
Mean of 4: −19±1.6 mm/y

Same time span: 2004–2009

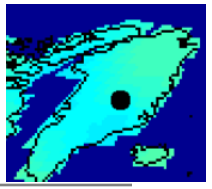
AIUB–RL02 (60): −15±1.7 mm/y
GFZ5–RL05a (60): −21±2.2 mm/y
CSR–RL05: −17±1.6 mm/y
TON–RL01: −20±1.4 mm/y
GRGS–RL03: −18±2.5 mm/y
Mean of 3: −20±1.2 mm/y
Mean of 4: −20±1.1 mm/y
Mean of 5: −20±1.0 mm/y

max. degree 90

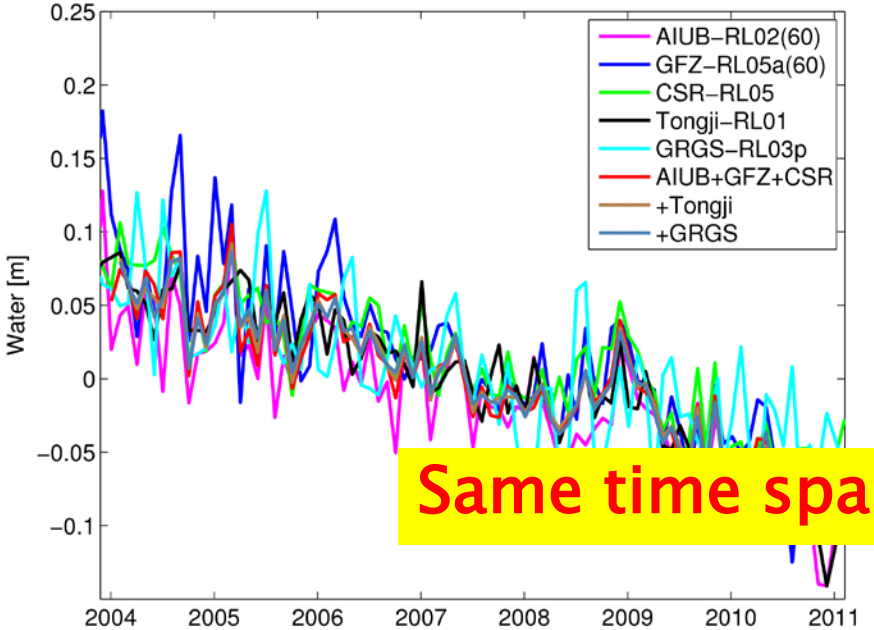


Averaged monthly solutions

(input solutions based on similar strategies)



max. degree 60

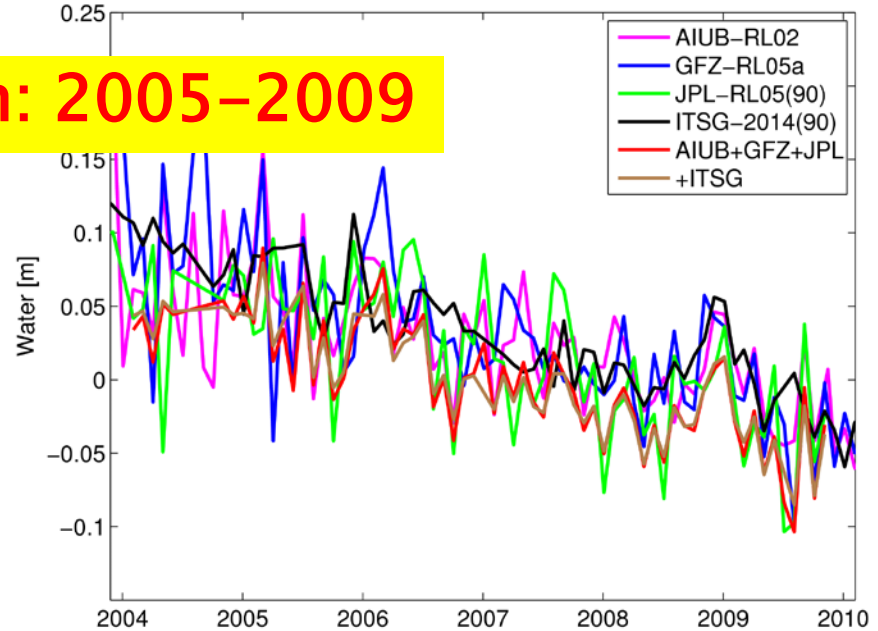


AIUB−RL02: −18±2.8 mm/y
GFZ−RL05a: −22±3.3 mm/y
JPL−RL05(90): −22±3.6 mm/y
ITSG−2014 (90): −19±2.0 mm/y
Mean of 3: −19±2.0 mm/y
Mean of 4: −19±1.6 mm/y

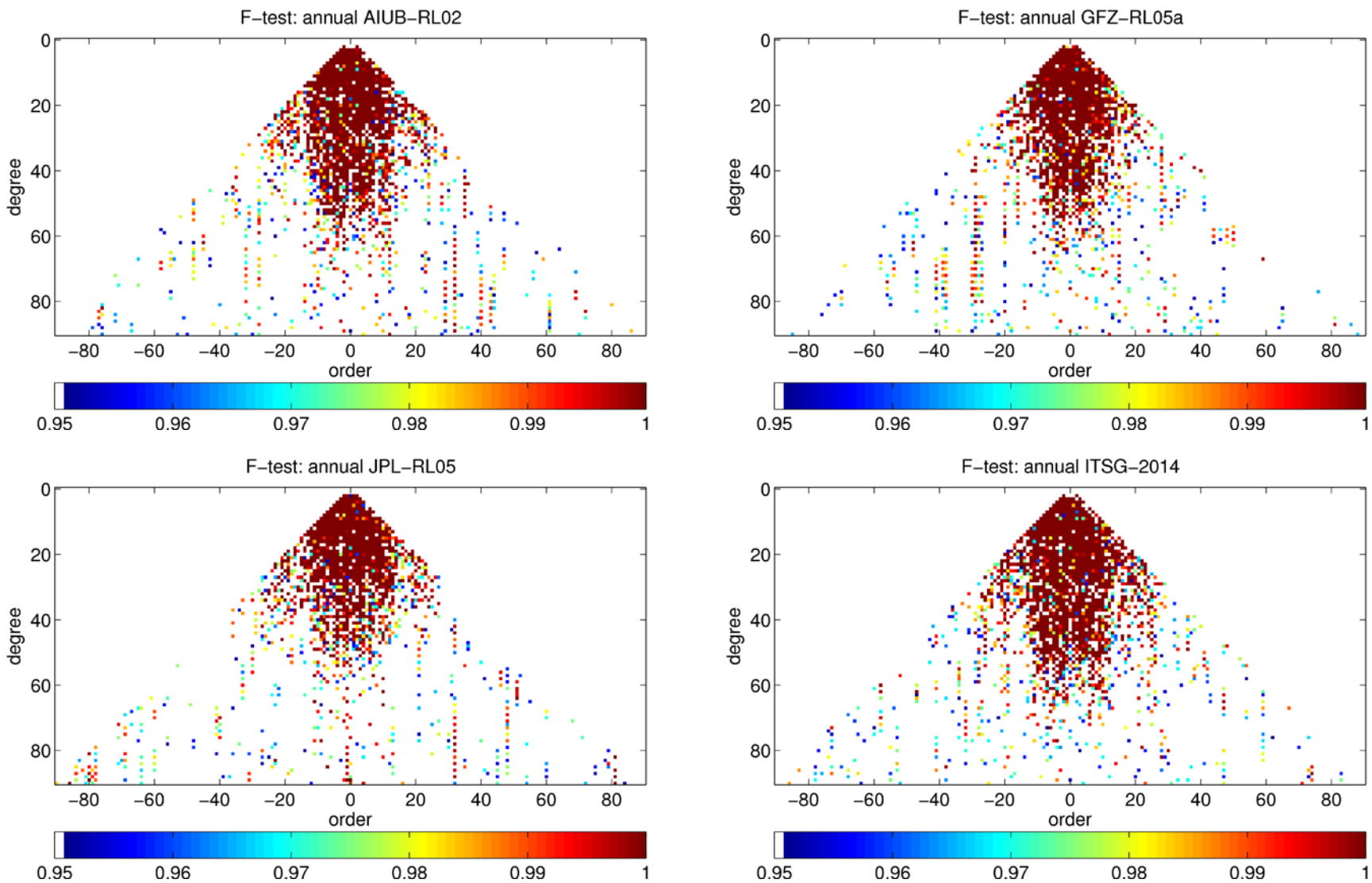
Same time span: 2005−2009

AIUB−RL02 (60): −16±2.1 mm/y
GFZ5−RL05a (60): −21±2.7 mm/y
CSR−RL05: −17±2.1 mm/y
TON−RL01: −22±1.7 mm/y
GRGS−RL03: −18±3.2 mm/y
Mean of 3: −20±1.2 mm/y
Mean of 4: −20±1.1 mm/y
Mean of 5: −20±1.0 mm/y

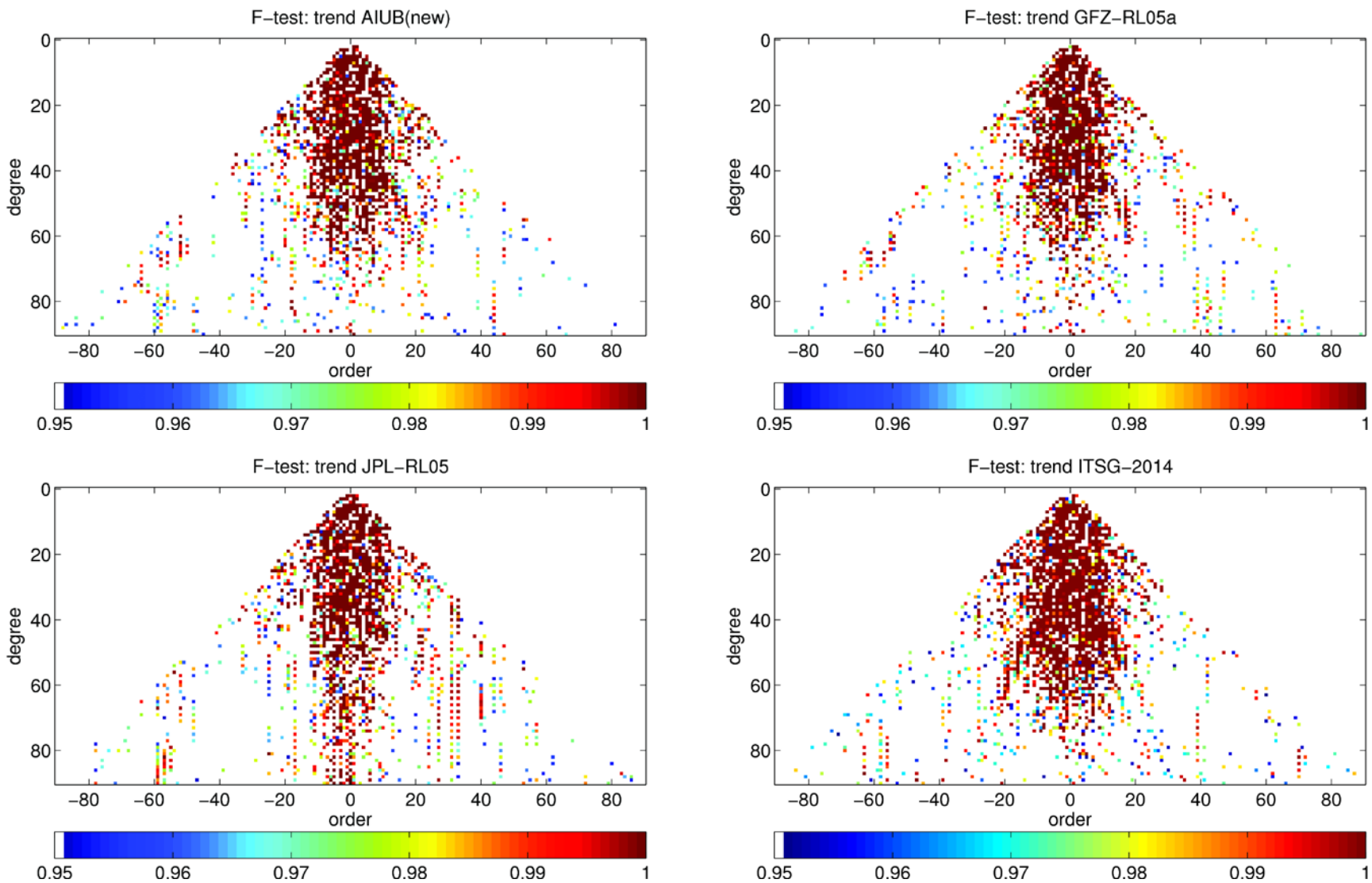
max. degree 90



Coefficient-wise significance of annual variations

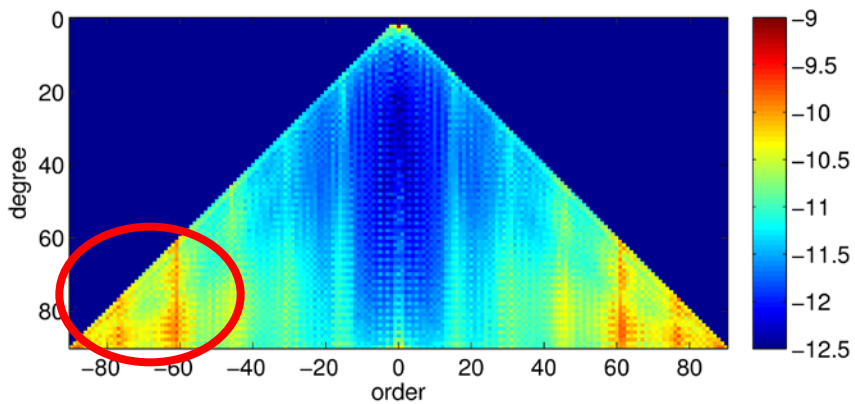


Coefficient-wise significance of trends

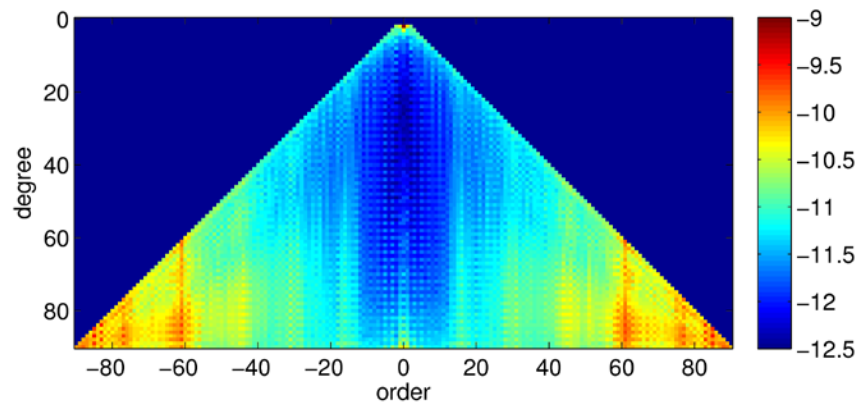


RMS of monthly differences per coefficient

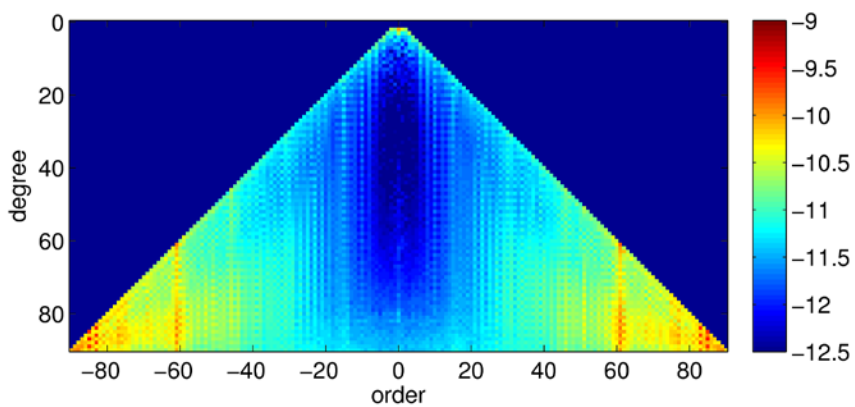
JPL-RL05 - AIUB-RL02



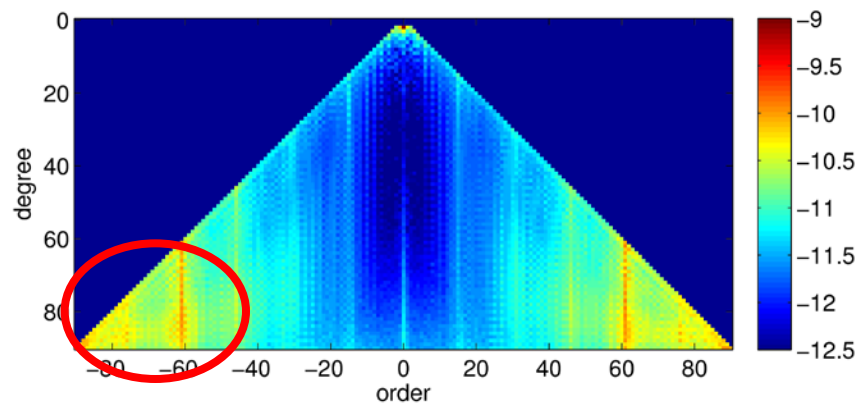
JPL-RL05 - GFZ-RL05a



GFZ-RL05a - AIUB-RL02

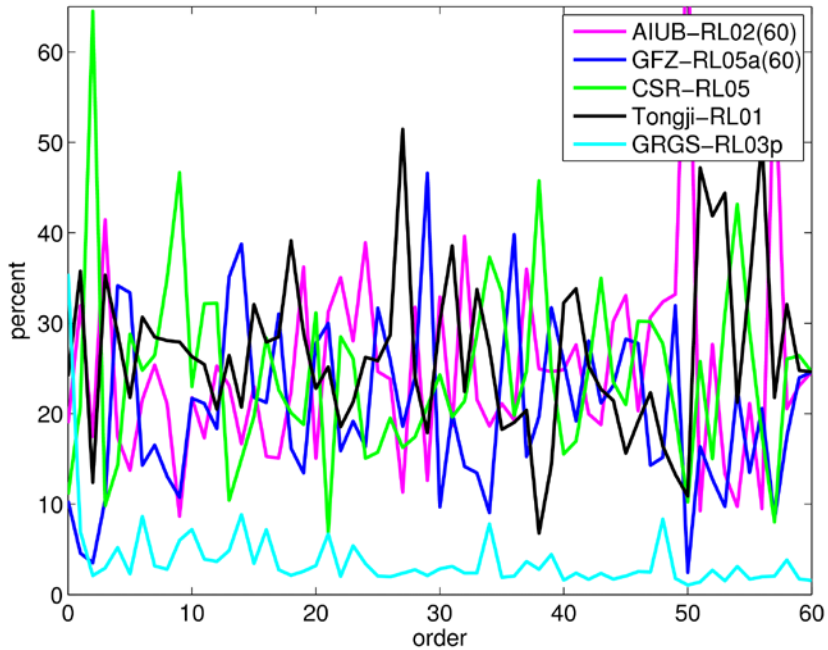


ITSG-2014 - AIUB-RL02



Monthly relative weights (example 03/2008)

Contribution per order



Mean:

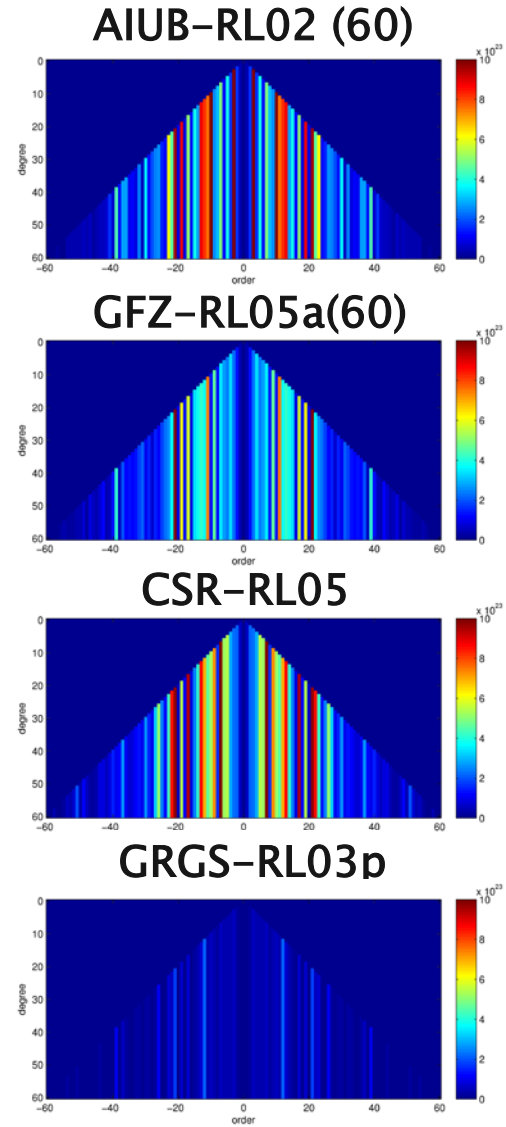
AIUB: 25 %

GFZ: 20 %

CSR: 24 %

TON: 27 %

GRGS: 4 %

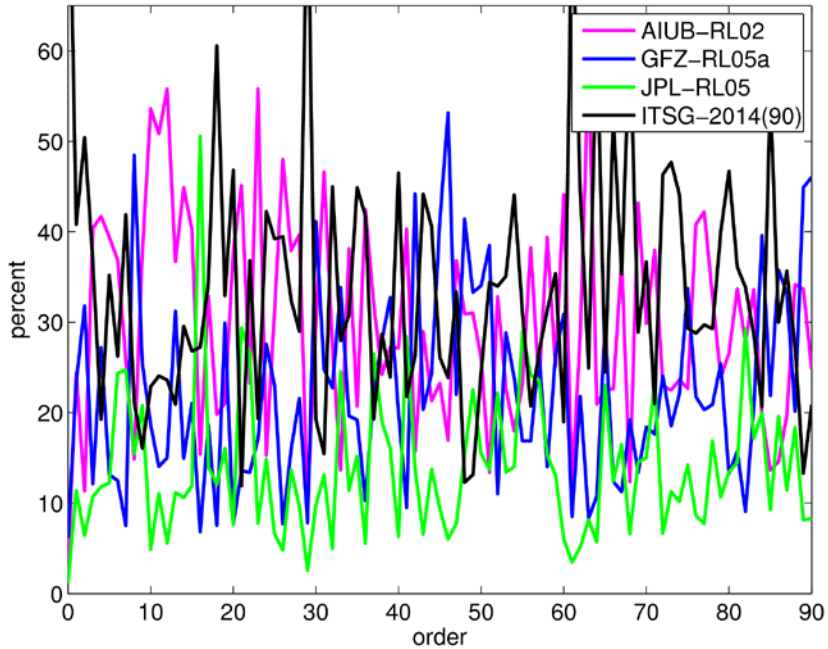


Percent: $100\% * w_i/(w_1+w_2+w_3)$

Weight matrix: $1/RMS^2$ per order

Monthly relative weights 90 (example 03/2008)

Contribution per order



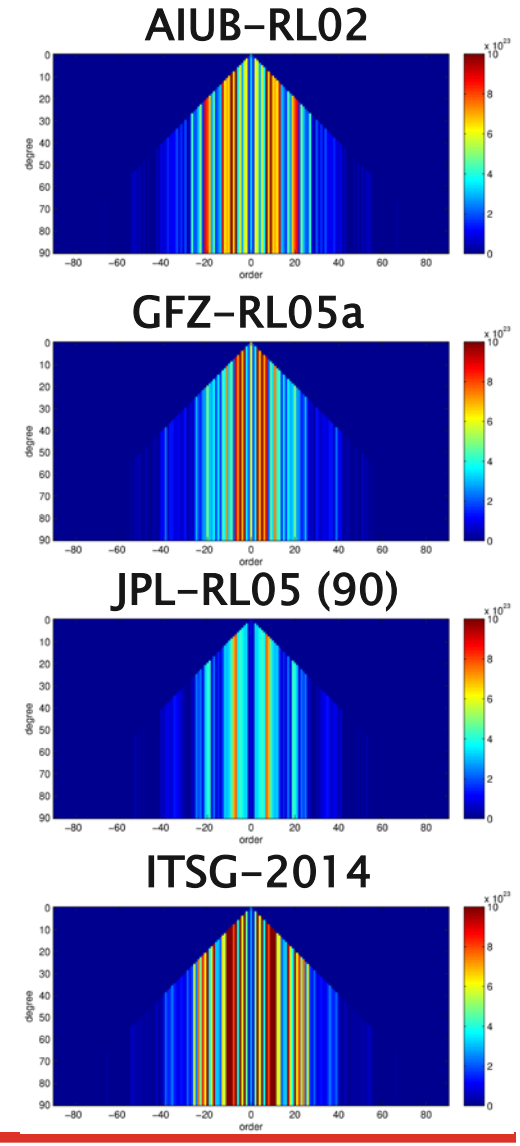
Mean:

AIUB: 30 %

GFZ: 22 %

JPL: 14 %

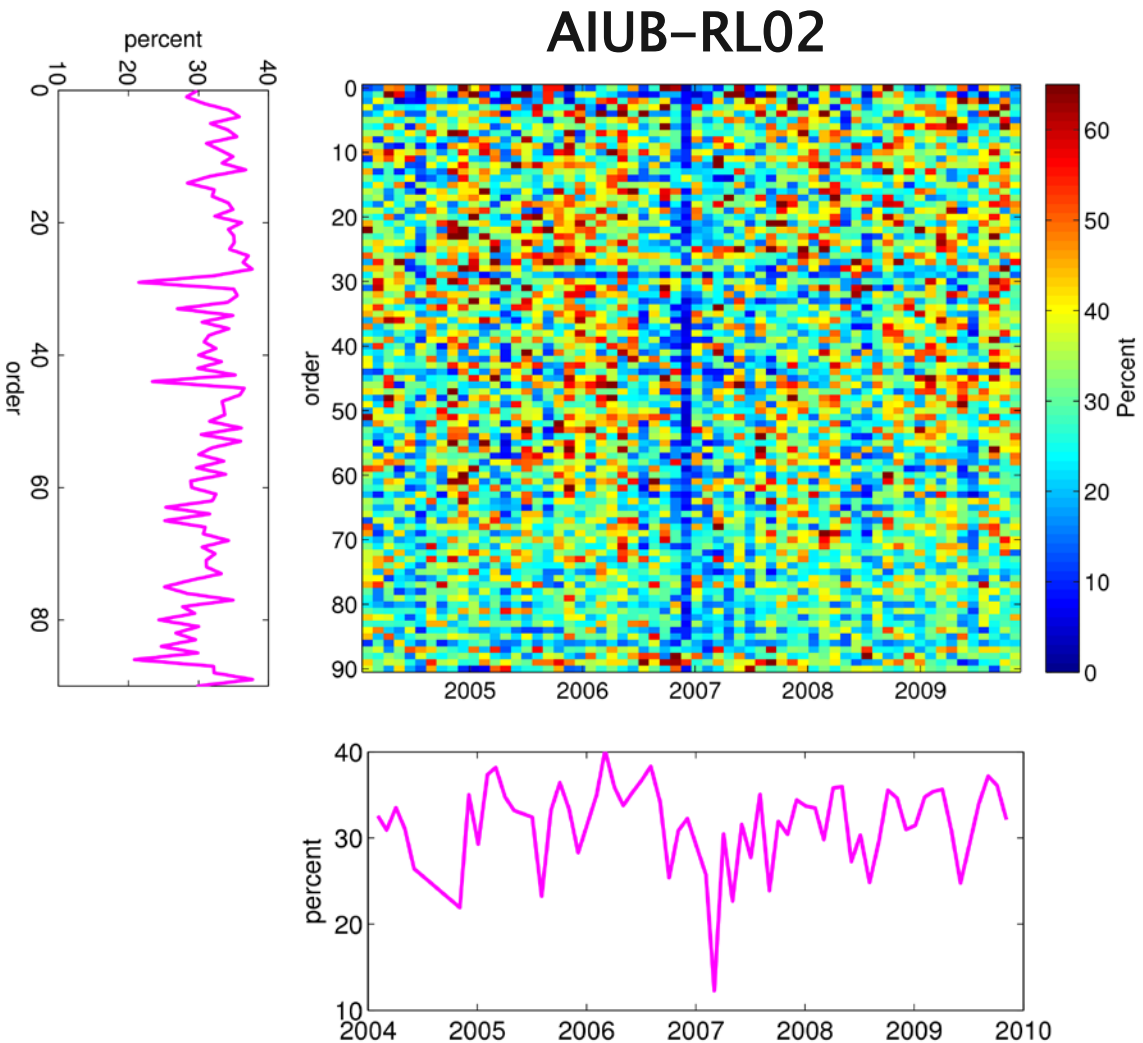
ITSG: 34 %



Percent: 100% * $w_i/(w_1+w_2+w_3)$

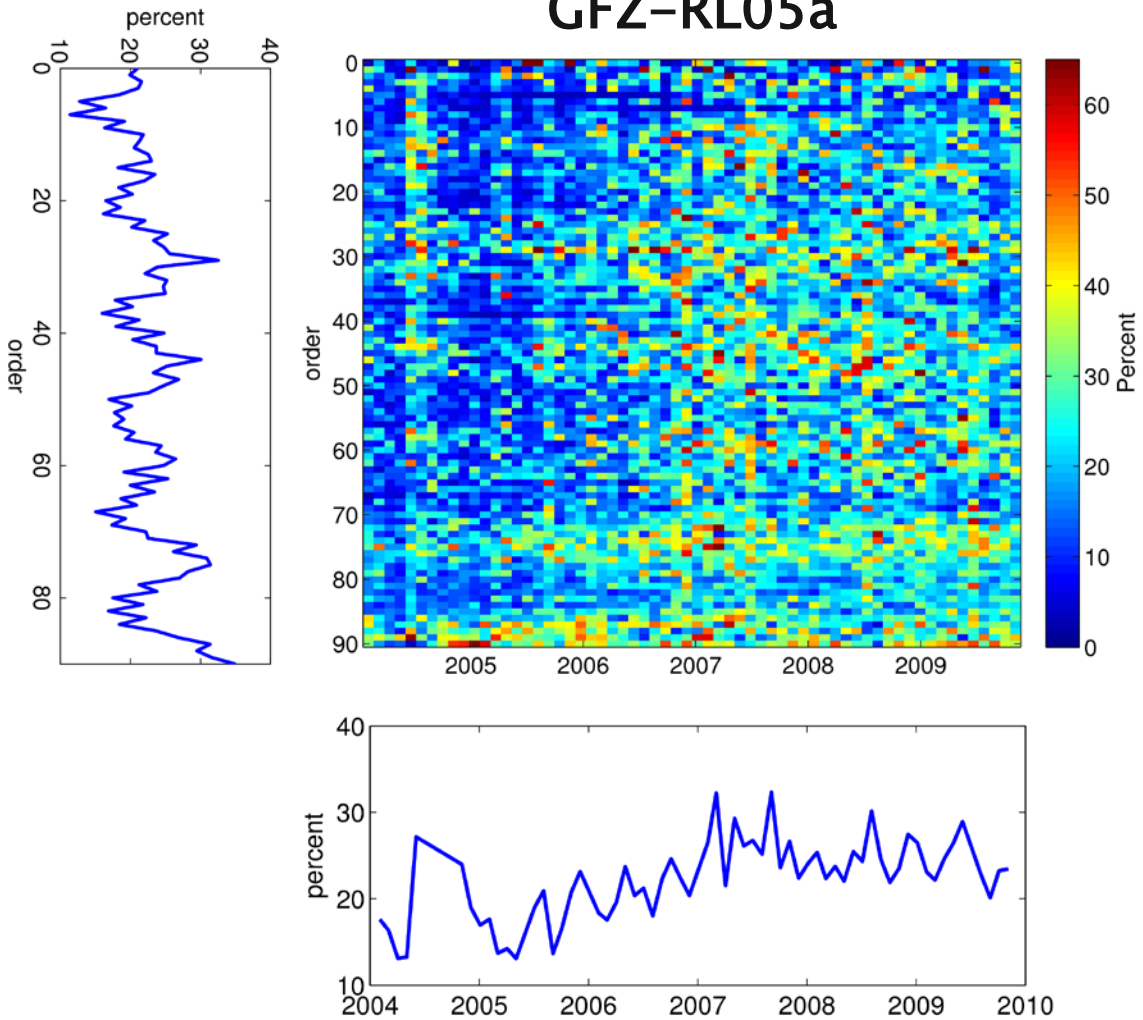
Weight matrix: $1/RMS^2$ per order

Monthly relative weights 90

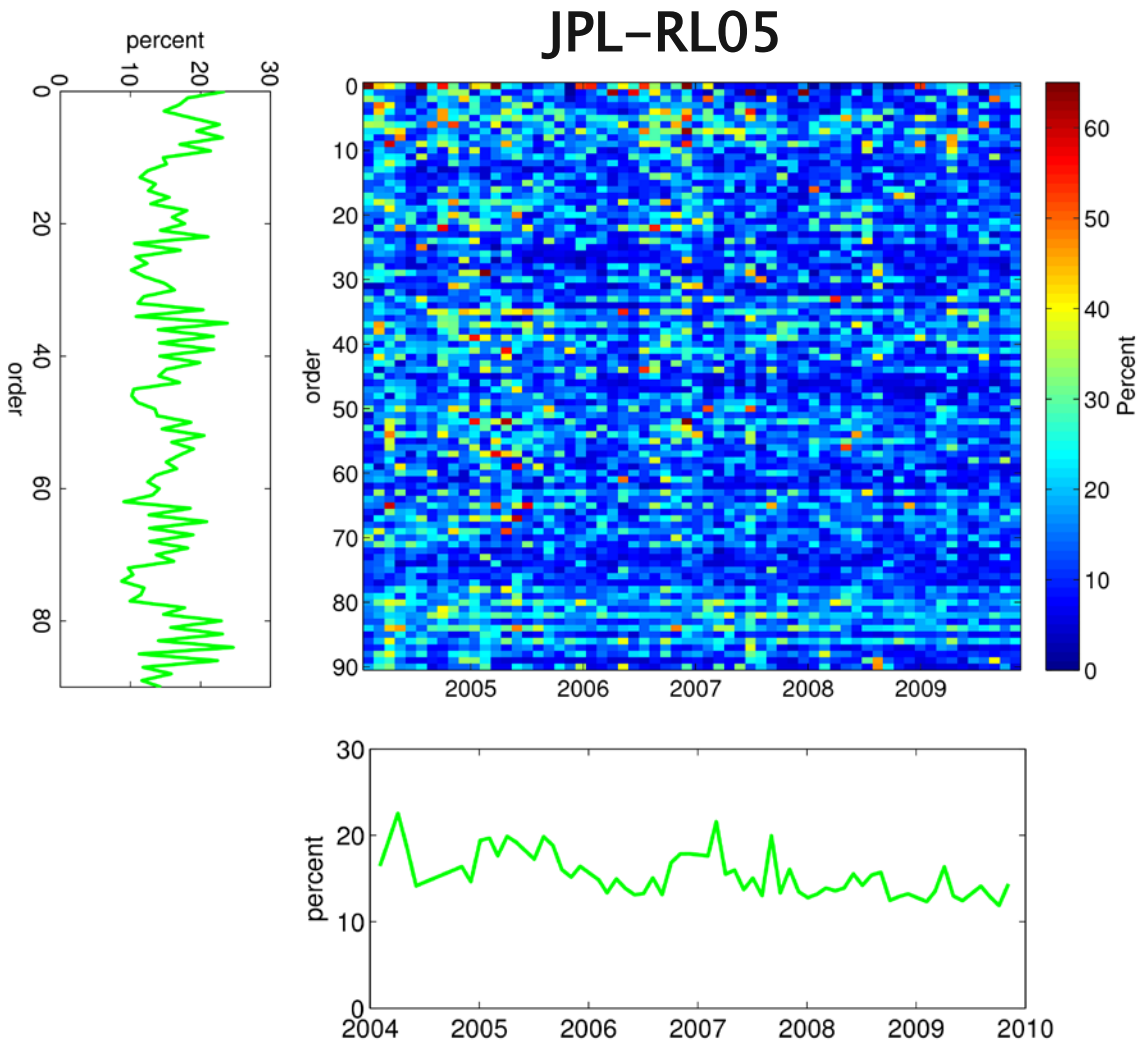


Monthly relative weights 90

GFZ-RL05a

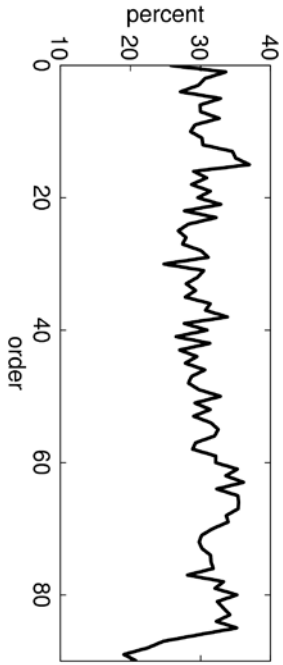


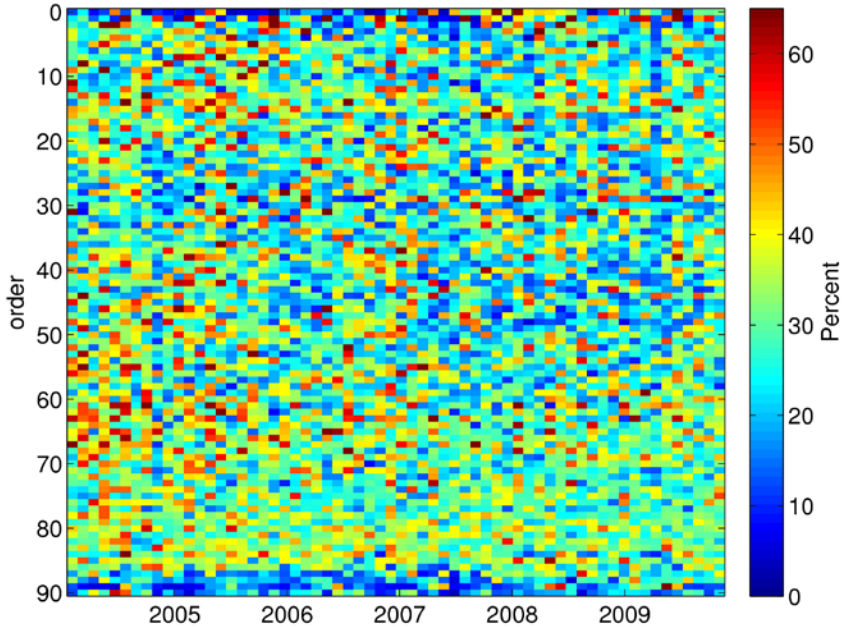
Monthly relative weights 90

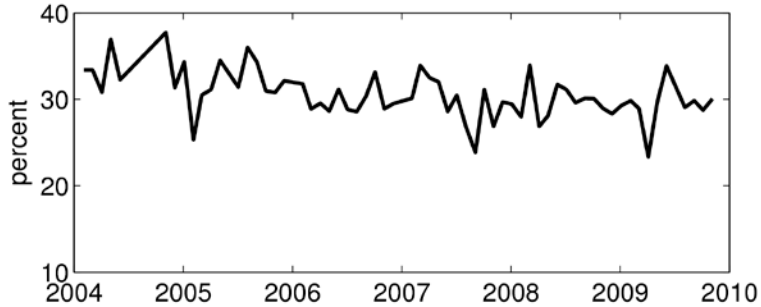


Monthly relative weights 90

ITSG-2014







Summary in view of GRACE-FO

- A service should be established consisting of:
  - A larger number of Analysis Centers (ACs) providing time-variable gravity field solutions on a regular basis
  - Analysis Center Coordinator (ACC)
- Comparable processing strategies are mandatory to ensure meaningful results of the ACC work:
  - Comparison of the AC solutions (gravity field solutions, orbits, residuals), identification of problematic solutions
  - Pairwise comparison of solutions to derive approximate empirical weights for the individual ACs
  - Combination of all AC gravity fields, either by:
    - Calculating a weighted average of the gravity field parameters based on the previously derived weights
    - Combining the solutions based on normal equations generated by the individual ACs