GOCE Gravity fields established by the Celestial Mechanics Approach

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G4.2: Satellite Gravimetry: GRACE, GOCE and Future Gravity Missions

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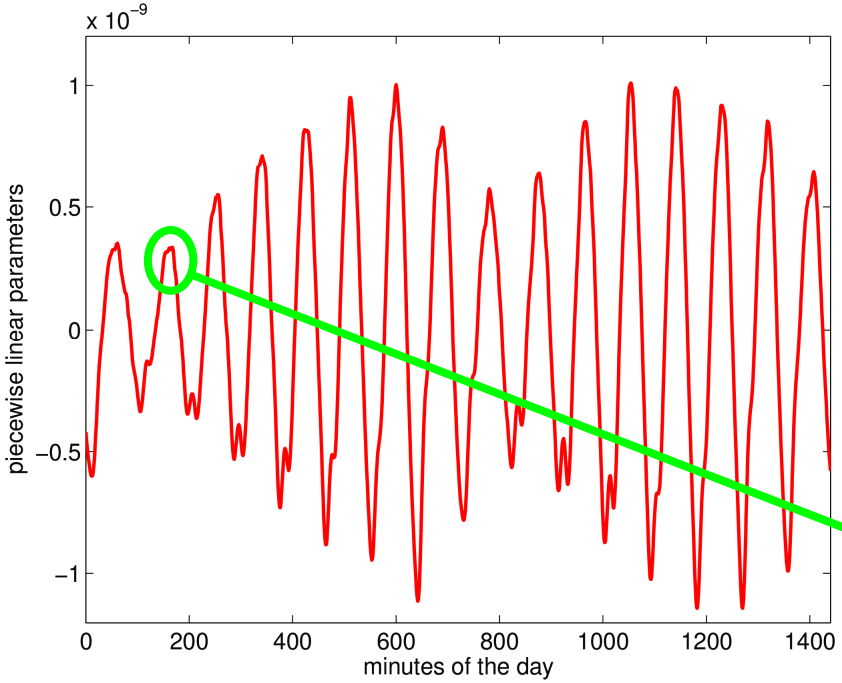
What do we show?

- GOCE gravity fields computed from 8 months of data with the Celestial Mechanics Approach (CMA)
  - GPS (l_{max}=120)
  - Gradiometer: XX, YY, ZZ (l_{max}=160)
- Combination with 7 years of GRACE (CMA)
- First results with reprocessed gradiometer and attitude data (84 d, l_{max}=200)

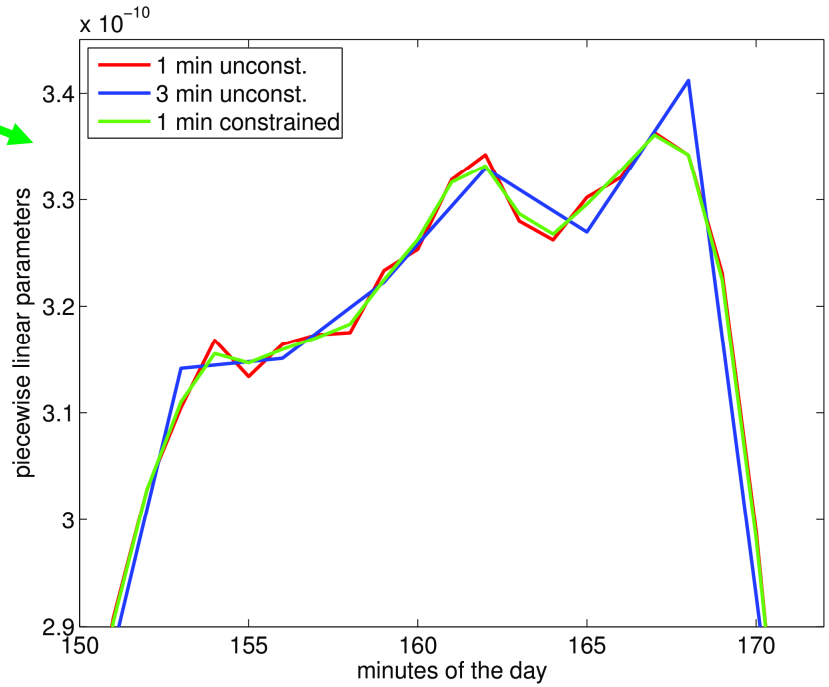
Why do we show it?

- Independent gravity field solution
- New concept to deal with gradiometer noise (no a priori knowledge on noise-PSD necessary)
- Consistent combination with GRACE
- Proof of concept: $l_{max} = 160$
- Final solution: $l_{max} = 200$ (currently limited by computing resources)
- Fair weight of GPS-part ($l_{max} = 160$)

Specialties of the CMA (applied to gradiometry)



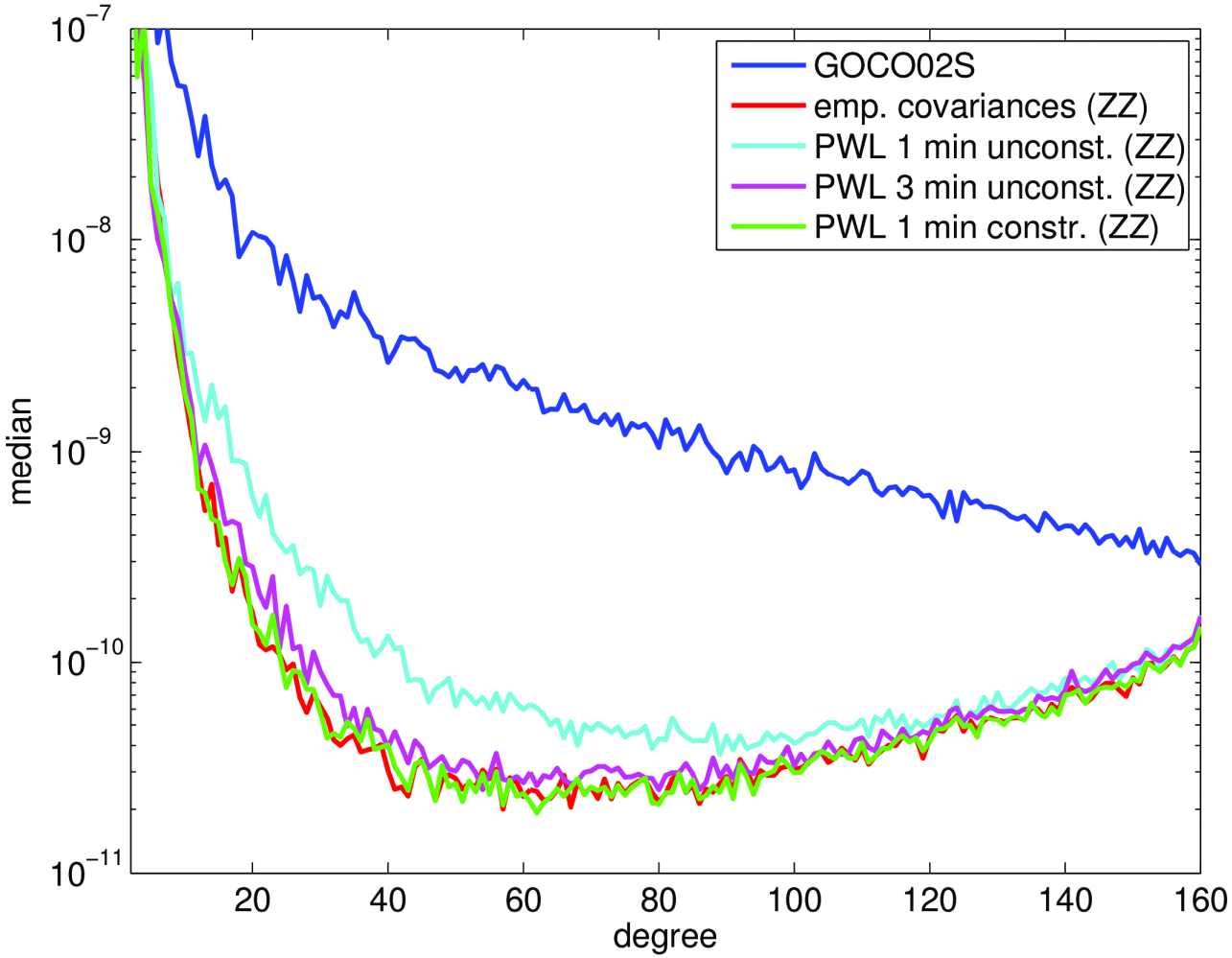
Constrained Piecewise Linear Parameters (PWL) absorb signal below measurement bandwidth of gradiometer.



Constraints on 2nd derivatives of PWL allow for:

- "hard" constraints: resampling
- "soft" constraints: smoothing

PWL contra empirical covariances



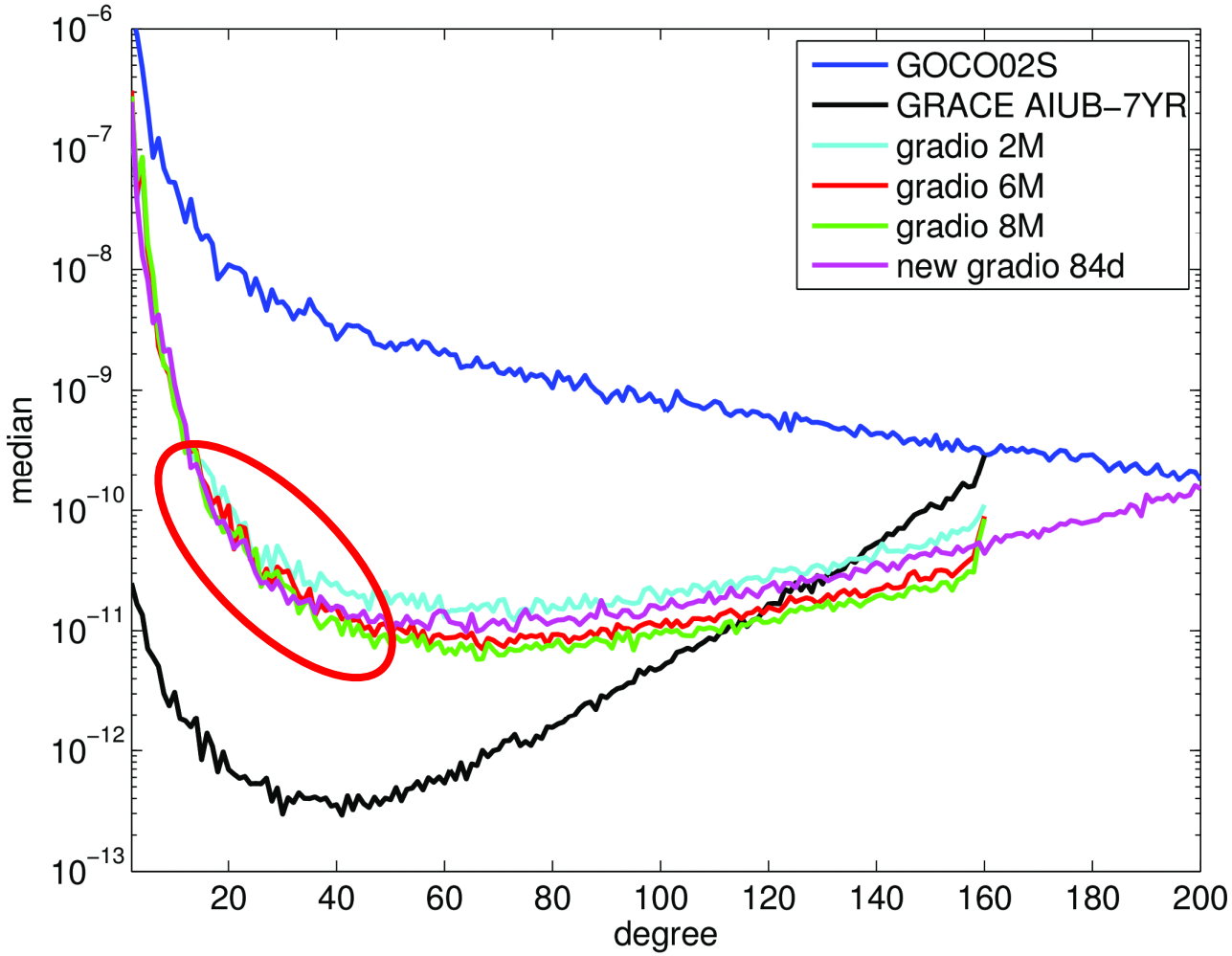
Results from 2 months of data.

smoothed 1 min PWLs

$\triangleq$

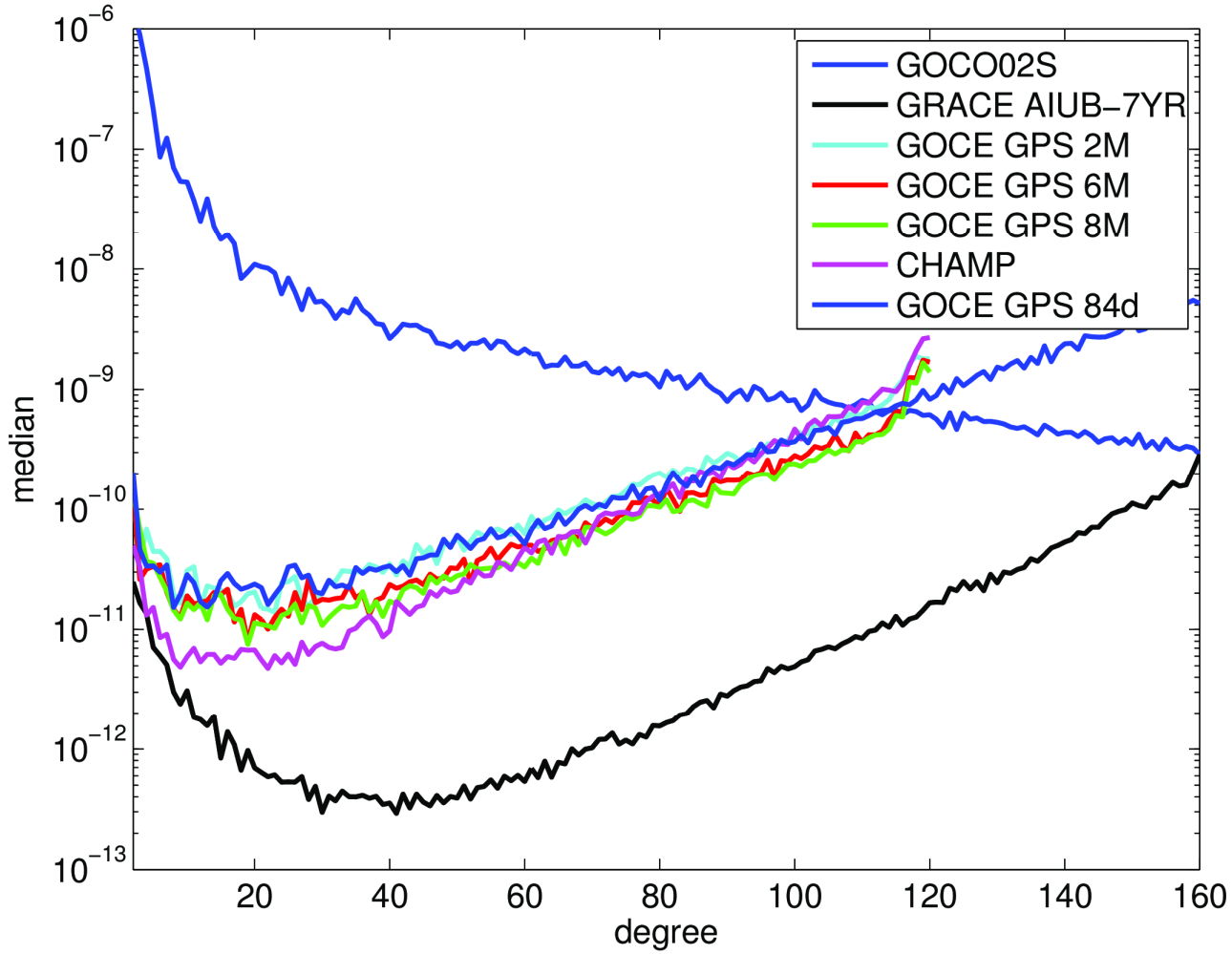
empirical covariances

Gradiometer-only solutions



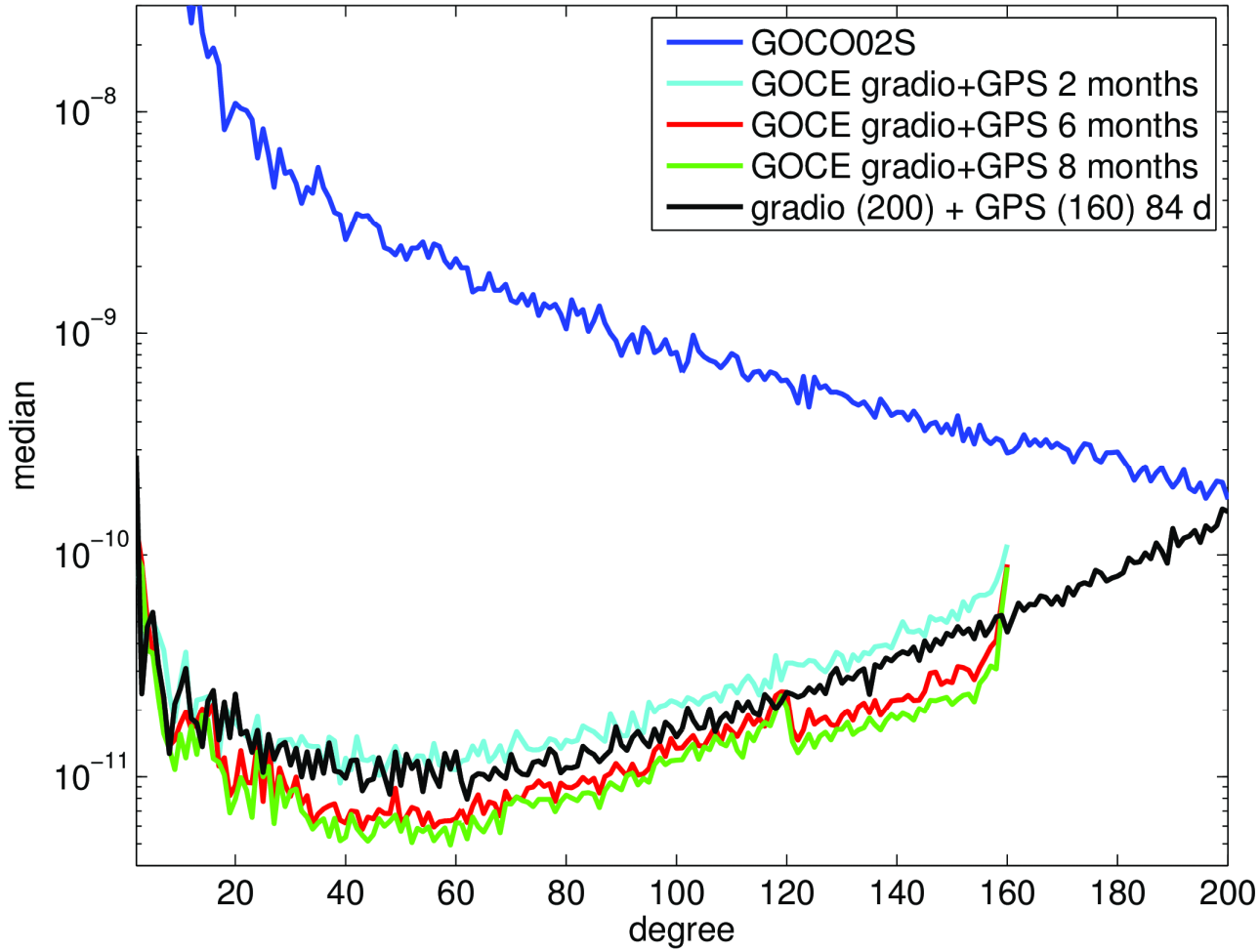
- more data => better gravity field (quality dominated by noise, not yet by background model error)
- omission error (l_{max}=160)
- improvement at low degrees (reprocessed data)

GPS-only solutions



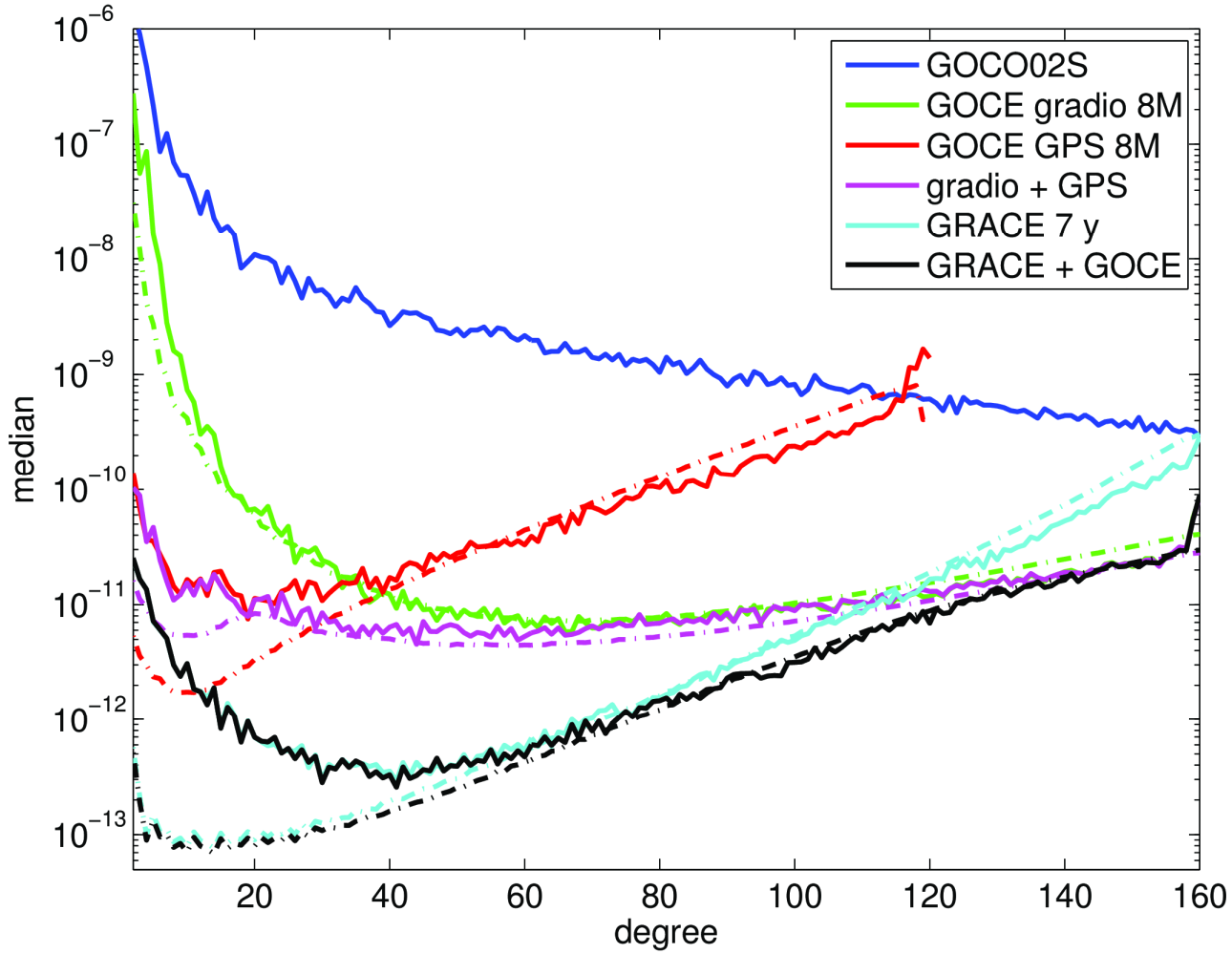
- few months of GOCE comparable to 8 years of CHAMP
- more CHAMP data
- lower GOCE orbit
- omission error (l_{max}=120)

Gradiometer + GPS



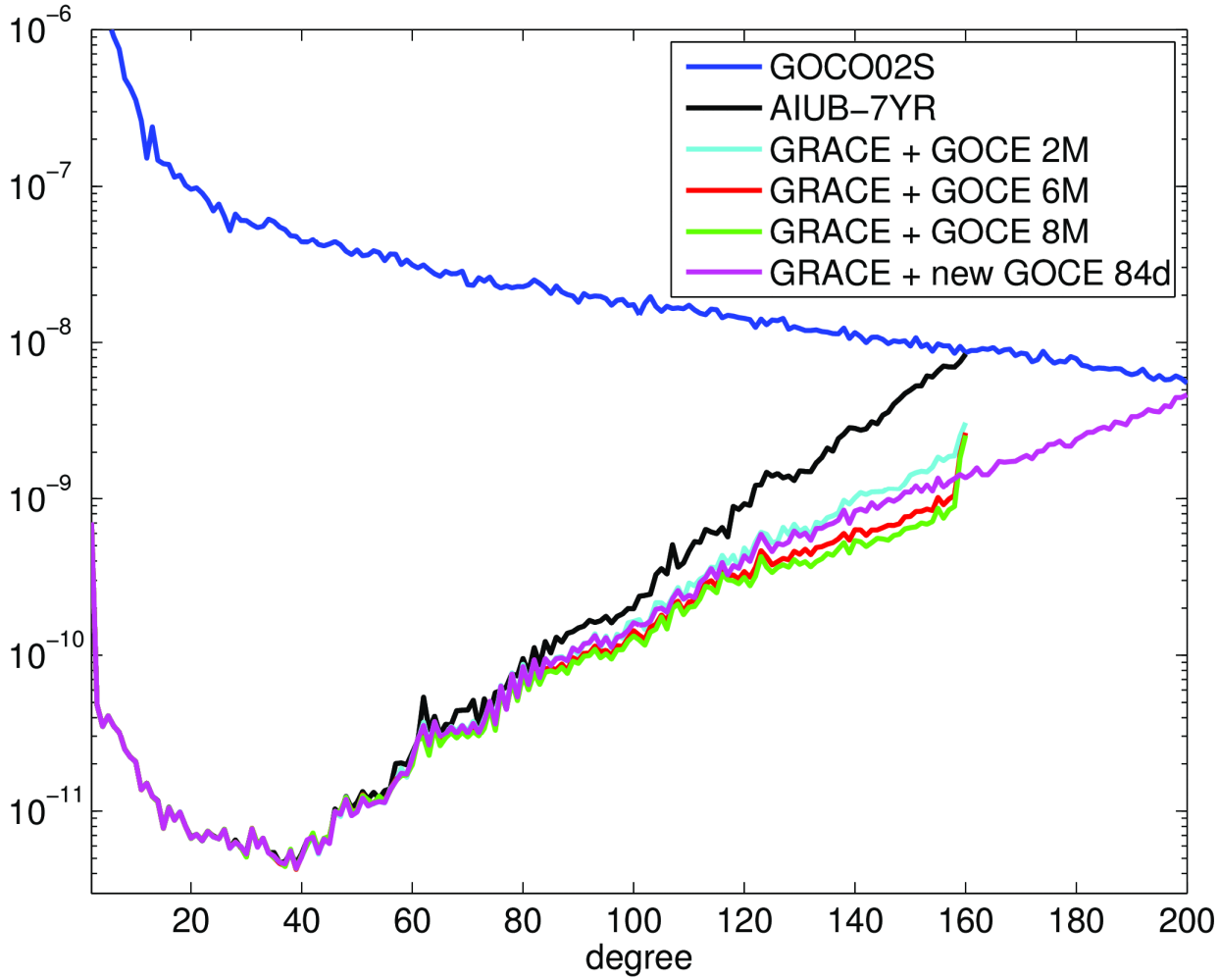
- omission error of GPS degrades gradiometer solution (rel. weights according to ratio of RMS)
- increasing l_{max} (GPS) cures the problem

Formal Errors



- relative weighting: ratio of RMS (GPS down-weighted)
- formal errors of low degrees too optimistic (GRACE), otherwise good agreement.

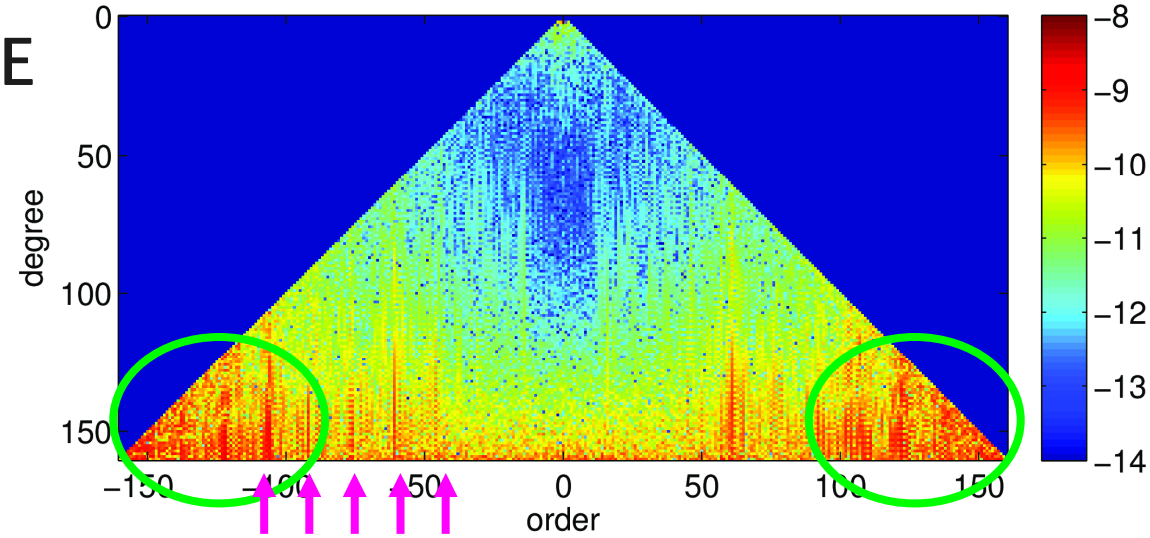
GRACE + GOCE



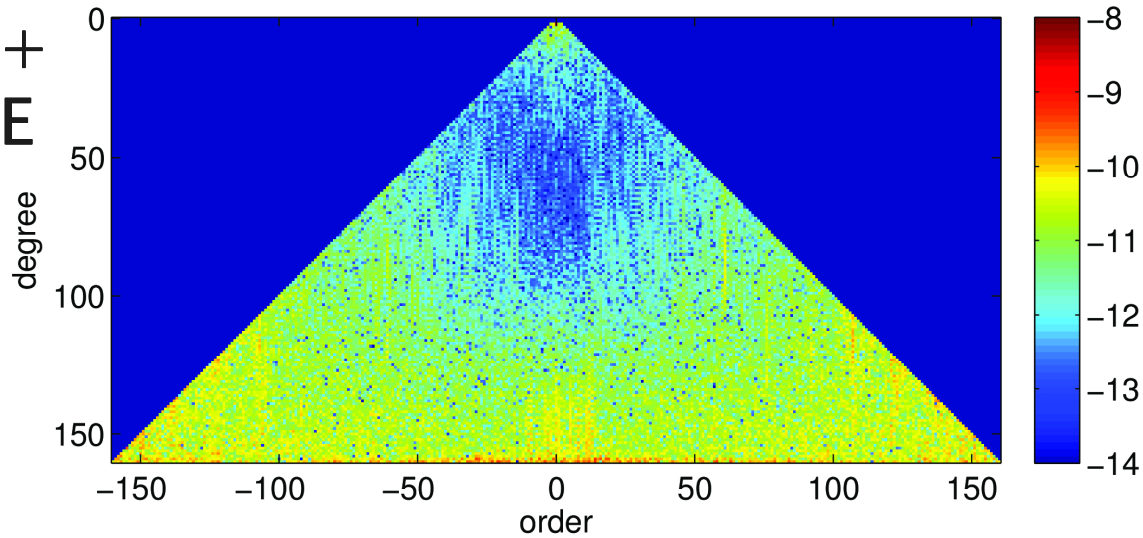
- more data => better solution
- omission error at l_{max}=160

A closer look

GRACE



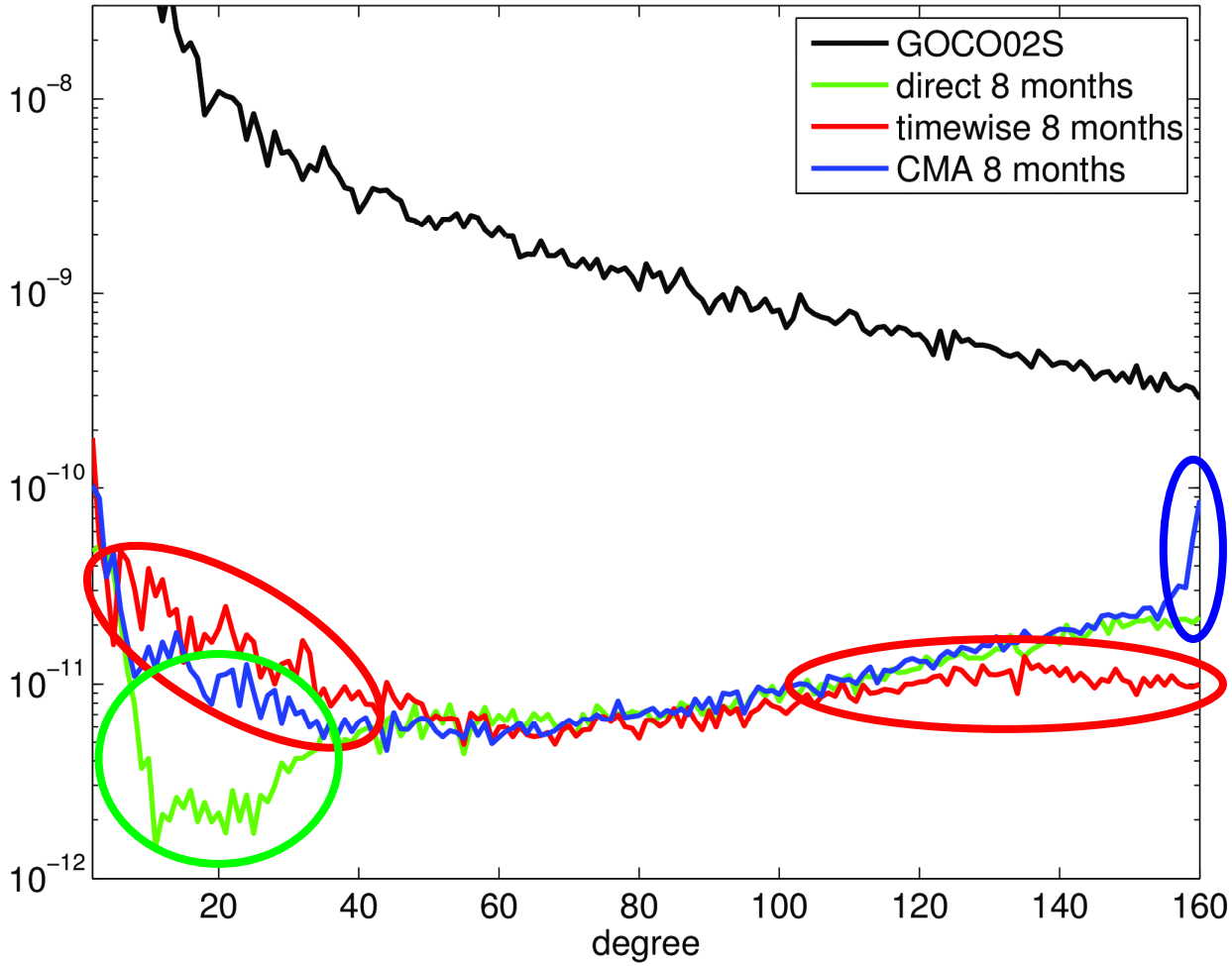
GOCE+ GRACE



GOCE helps:

- improve sensitivity
- reduce GRACE aliasing errors on resonant orders
- Reference: GOCO02S

Comparison to other solutions



- $\sqrt{3}$-gain for GPS (energy-approach in TIM is only 1D)
- a priori information in DIR
- TIM is part of GOCO02S
- omission error

External validation

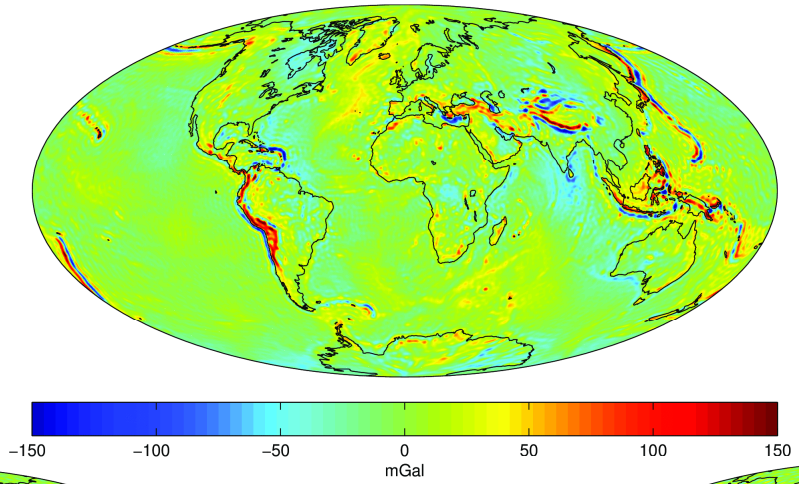
Reference	n	CMA	DIR-2	TIM-2
BRD GPS-benchmark	675 (all)	4.9 cm	5.3 cm	4.6 cm
	475 (1-σ)	2.6 cm	3.0 cm	2.4 cm
Canada GPS-benchmark	430 (all)	10.6 cm	10.3 cm	10.7 cm
	281 (1-σ)	5.7 cm	6.0 cm	6.2 cm
Japan GPS-benchmark	837 (all)	10.1 cm	10.0 cm	9.9 cm
	533 (1-σ)	5.7 cm	5.8 cm	5.6 cm

All gravity fields truncated at degree 155.

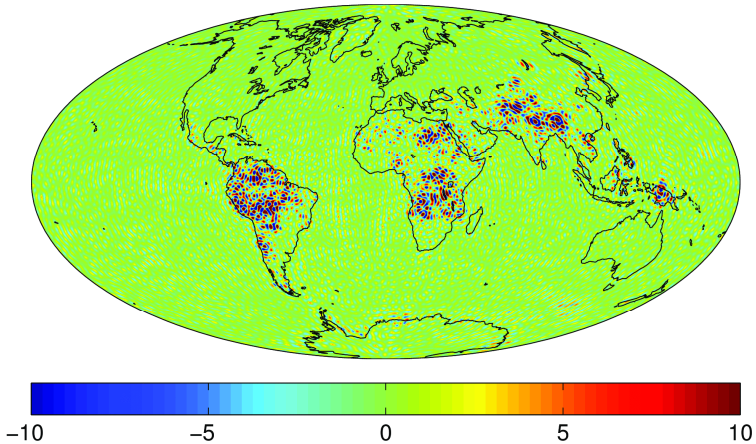
Validation performed by Thomas Gruber (only high-quality data sets shown).

Comparison to EGM2008 and GOCO02S

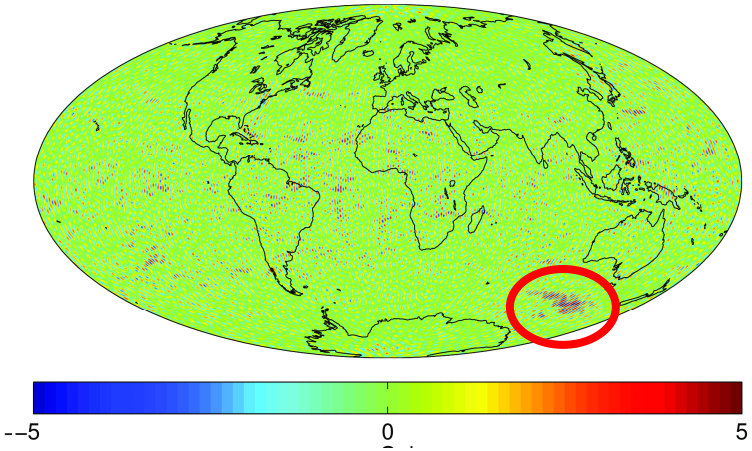
Gravity anomalies (l_{max} = 155)



Anomaly south of Australia



Diff. to EGM2008 (155)
WRMS (global): 1.39 mGal
WRMS (oceans): 0.60 mGal



Diff. to GOCO02S (155)
WRMS (global): 0.31 mGal
WRMS (oceans): 0.33 mGal

Summary and Outlook

- CMA is a powerful tool for satellite gravity gradiometry, as well.
- To avoid artifacts GPS has to be taken into account to $l_{max} > 120$ (or must be downweighted).
- GOCE contribution cures aliasing artifacts on resonant orders of GRACE.
- The CMA-derived gravity fields are currently expanded to even higher degrees (200).