→ 5th INTERNATIONAL GOCE USER WORKSHOP

GOCE/GRACE GGM evaluation over Greece with GPS/Leveling and gravity data

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Availability of several GOCE/GRACE GGMs for the Earth's potential

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- DIR (R1, R2, R3, R4, R5)
- GOCO (01s, 02s, 03s)
- EIGEN*s/c (51c, 6s/c, 6s/c2, 6c3stat)
- ITG-GOCE02s, GOGRA02s/04s, JYY_GOCE02s/04s

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- o External validation over Greece with collocated GPS/Leveling BMs and gravity anomaly data

METHODOLOGY

Combined GGM differences to $n_{max}=216{,}000$

$$\Delta N = N^{GPS/Lev} - N^i\Big|_2^{n_1} - N^{EGM2008}\Big|_{n_1+1}^{2160} - N^{RTM} - N_o$$

$N^{GOCE}\Big|_2^{n_1}$ evaluation of GOCE/GRACE GGMs every 1 degree

N^{RTM} from a 3″ DTM over Greece

Combined GGM differences to $n_{max}=216,000$

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N^{RTM} from a 3″ DTM over Greece

o Mean Tide to Tide Free conversion for orthometric heights

o GGM Zero Tide to Tide Free when necessary

o All computations in GRS80

o N_o relative to the IERS W_o of 62636856.0 m^2/s^2

METHODOLOGY

Combined GGM differences to $n_{max}=216,000$

$$\Delta g_{res} = \Delta g - \Delta g^{GOCE}\Big|_2^{n_1} - \Delta g^{EGM2008}\Big|_{n_1+1}^{2160} - \Delta g^{RTM}$$

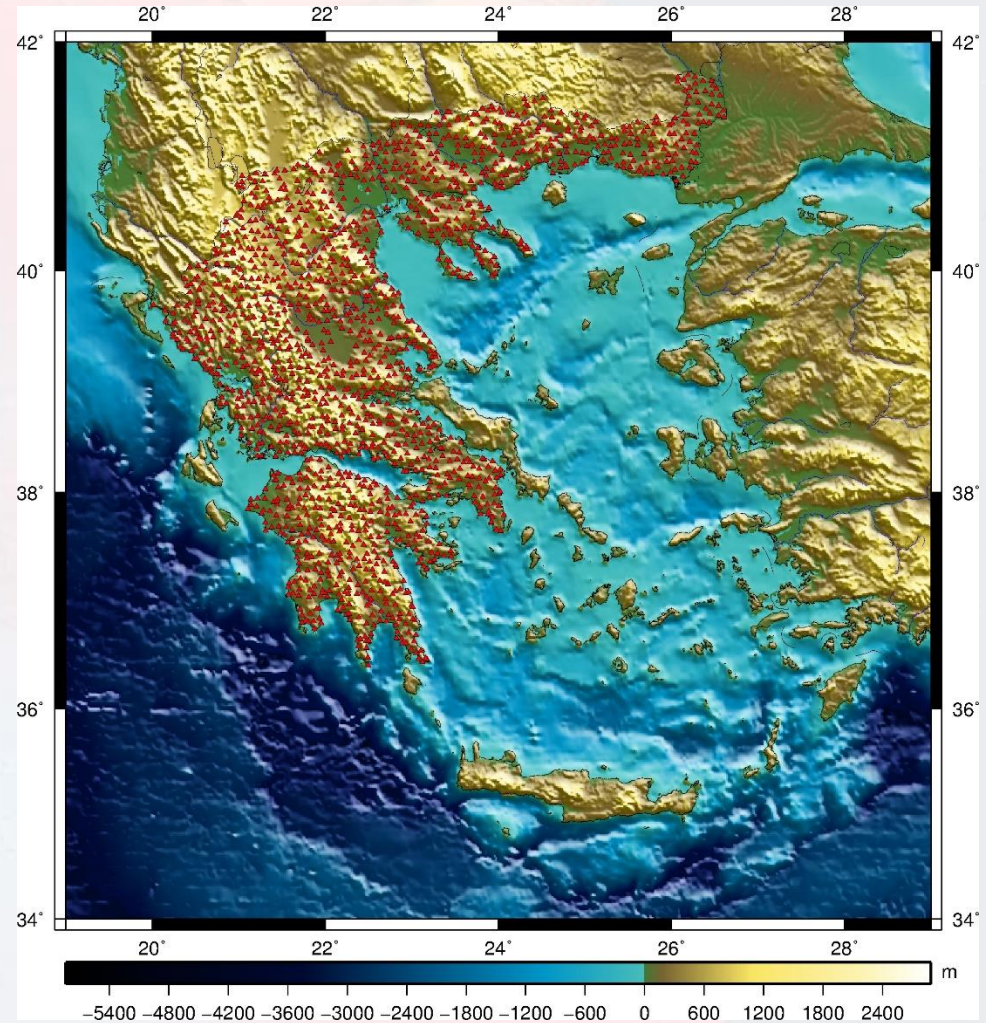$\Delta g^{GOCE}\Big|_2^{n_1}$ evaluation of GOCE/GRACE GGMs every 1 degree

Δg^{RTM} from a 3″ DTM over Greece

o Free-air gravity anomalies

o GRS80/IGSN71

o Clean database after LSC-based blunder detection and removal
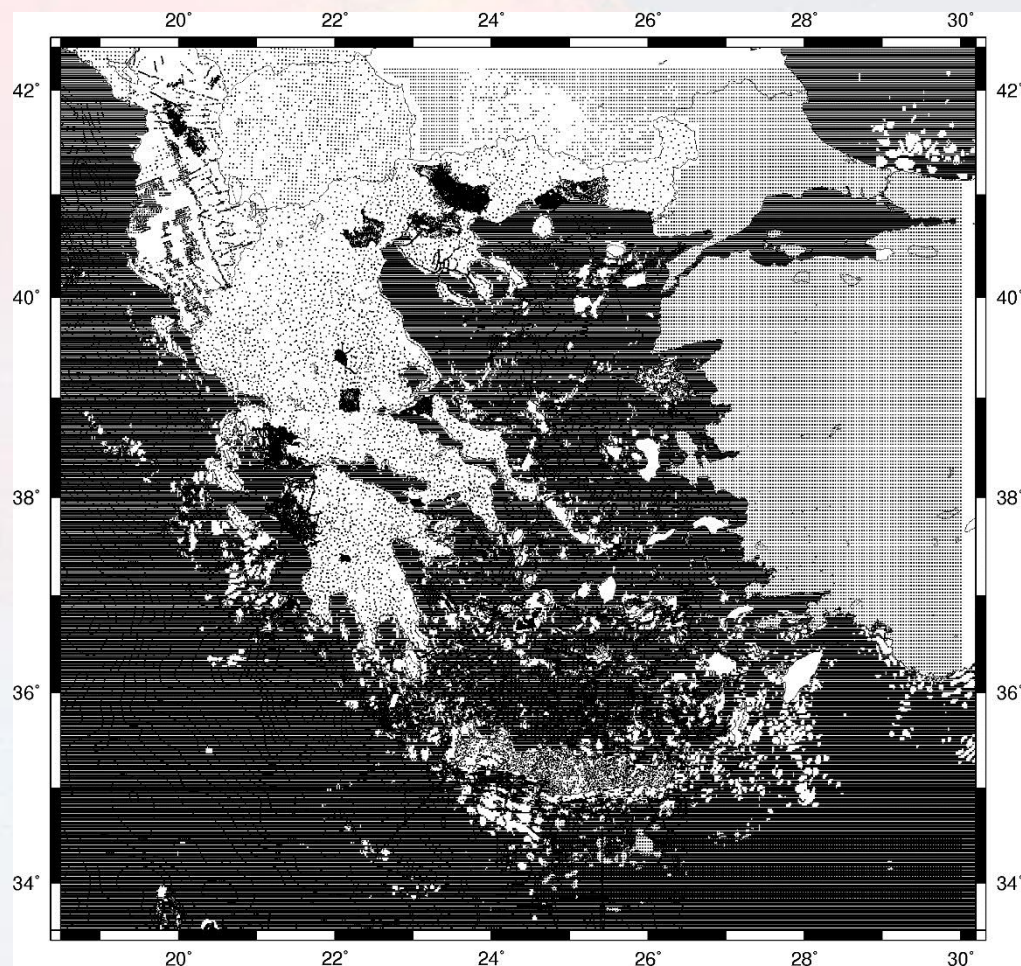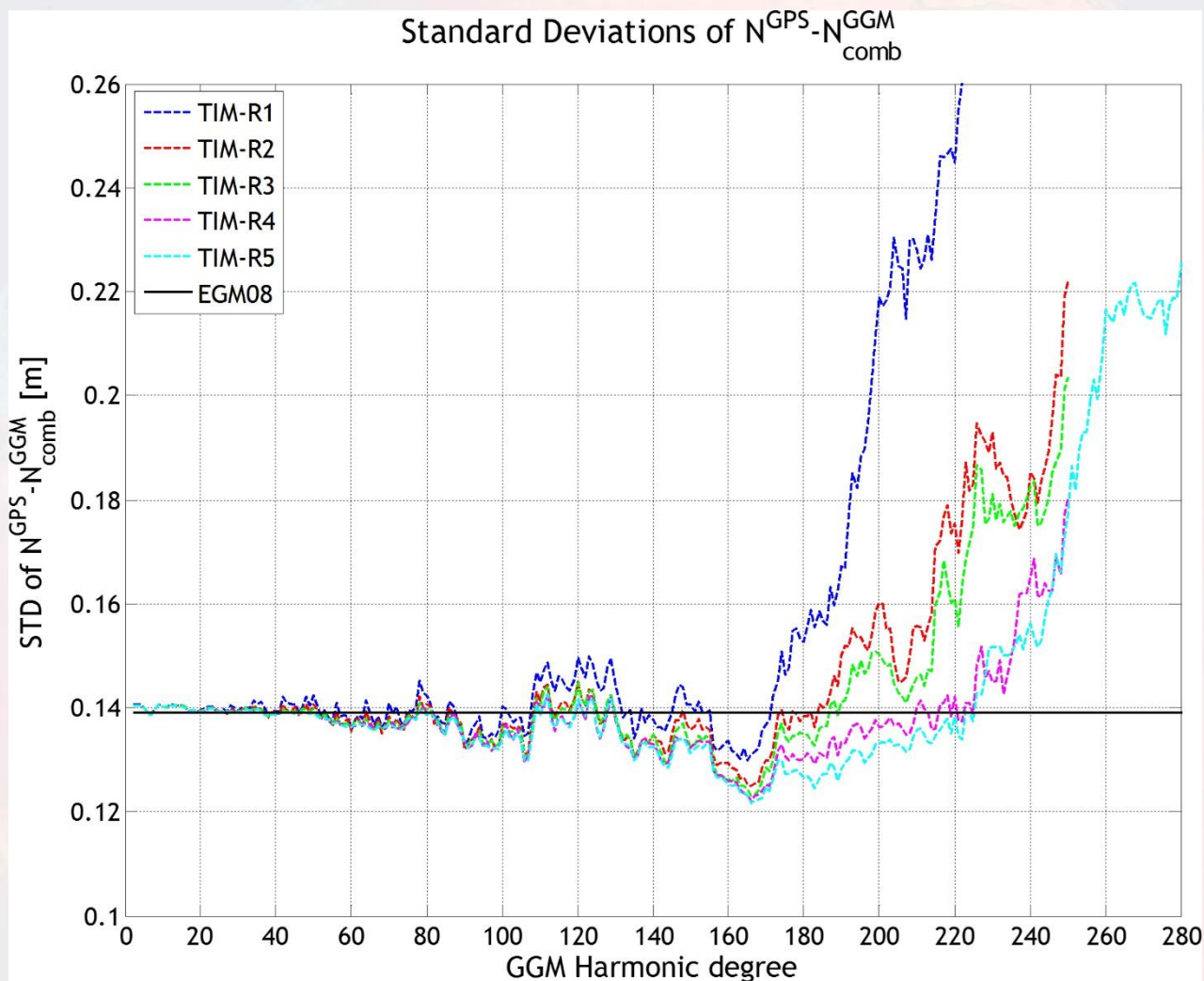
LOCAL DATA

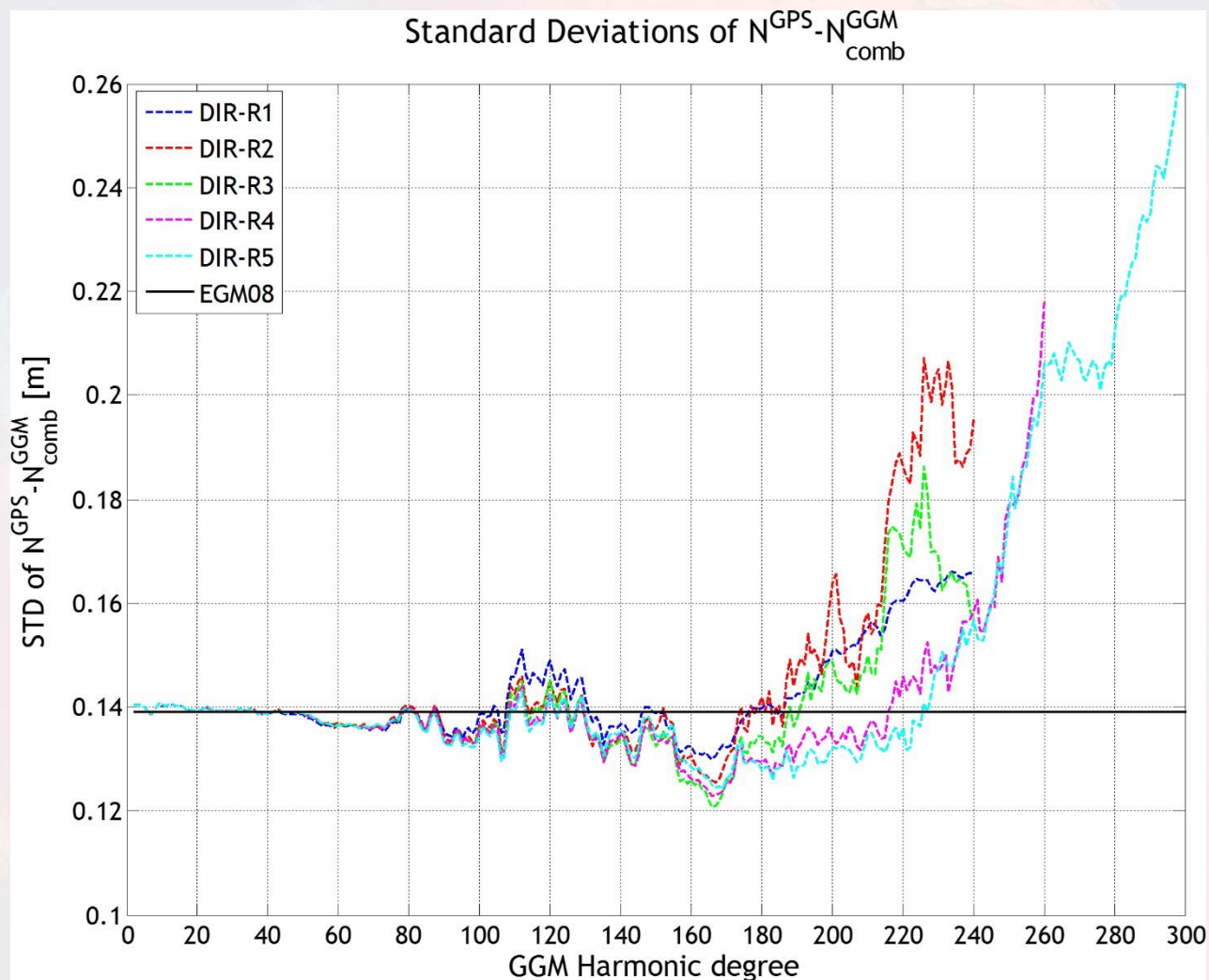**1542 collocated
GPS/Leveling observations**

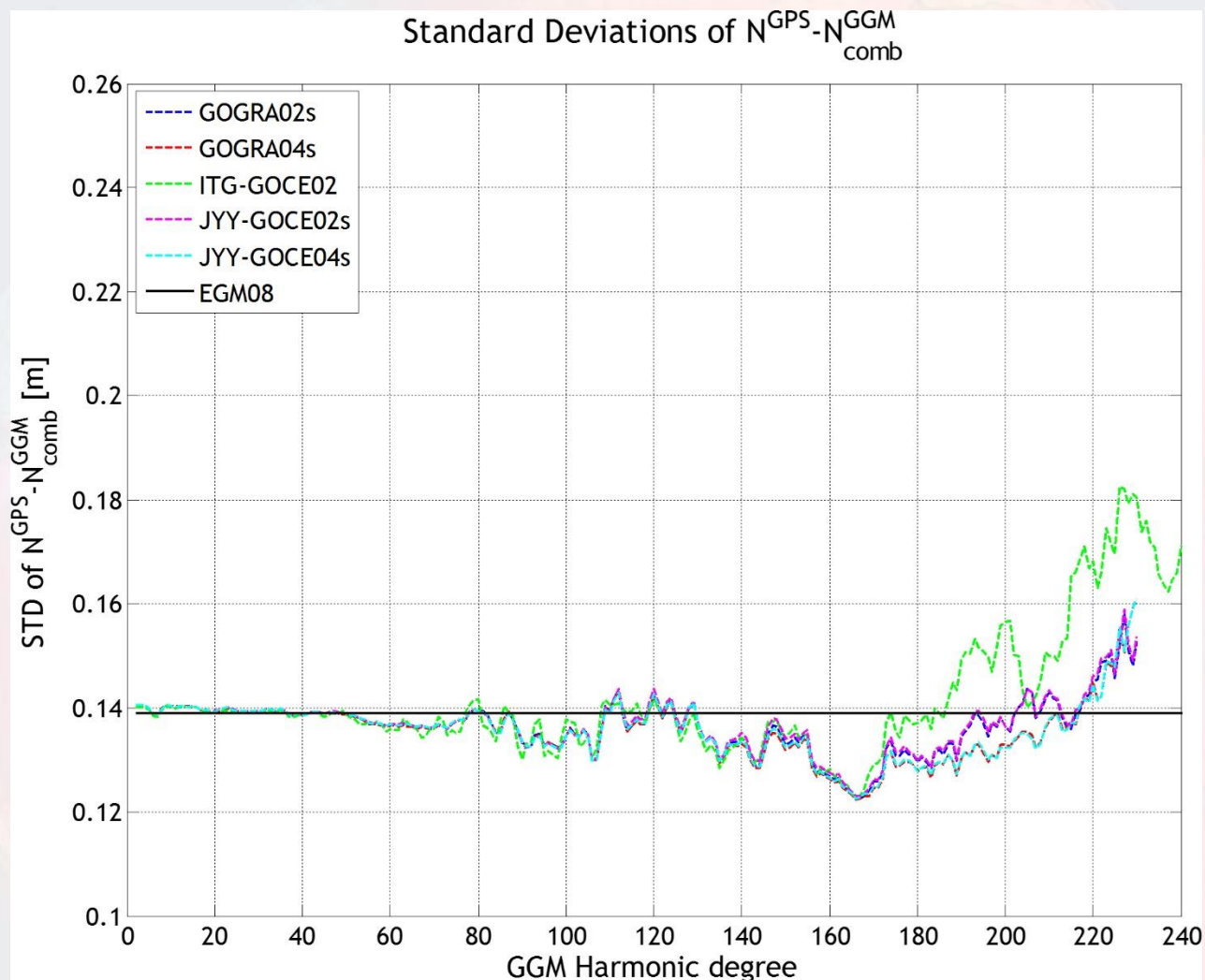# LOCAL DATA

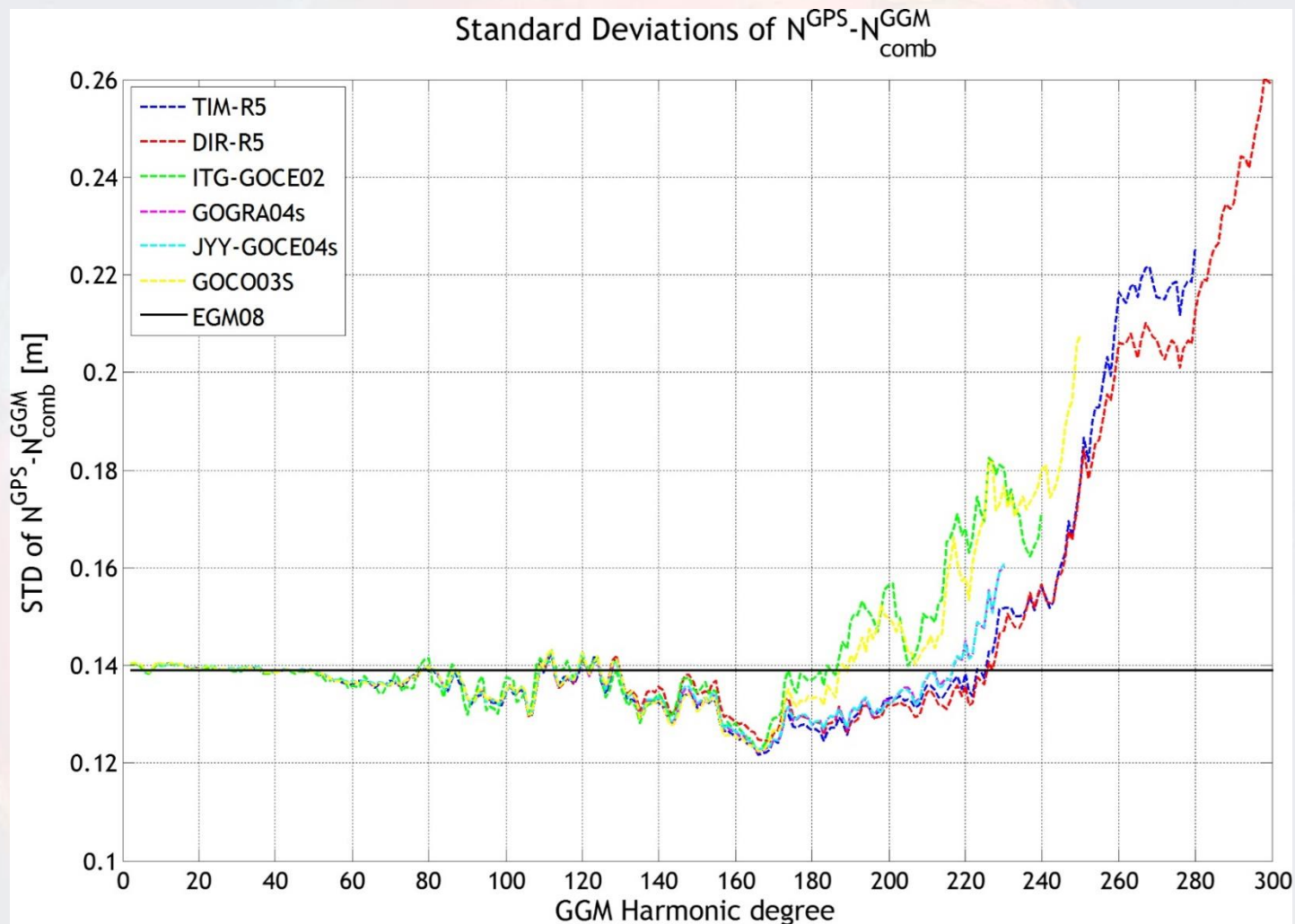**294777 free-air gravity anomalies**

GOCE GGM VALIDATION

Standard Deviations of $N^{GPS}-N^{GGM}_{comb}$

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Standard Deviations of $N^{GPS}-N^{GGM}_{comb}$

Legend:
- GOGRA02s
- GOGRA04s
- ITG-GOCE02
- JYY-GOCE02s
- JYY-GOCE04s
- EGM08

Y-axis: STD of $N^{GPS}-N^{GGM}_{comb}$ [m]

X-axis: GGM Harmonic degree

GOCE GGM VALIDATION

Standard Deviations of $N^{GPS}-N^{GGM}_{comb}$

GOCE GGM VALIDATION

Geoid height differences between GOCE/GRACE GGMs and GPS/Lev BMs. Unit [m]

GGM	d/o	range	mean	std
EGM2008	2190	0.954	-0.416	±0.139
DIR-R5	169+EGM08	0.885	-0.384	±0.123
TIM-R5	166+EGM08	0.890	-0.389	±0.121
GOCO03s	167+EGM08	0.922	-0.389	±0.122
ITG-GOCE02s	166+EGM08	0.901	-0.383	±0.122
GOGRA04s	167+EGM08	0.889	-0.389	±0.122
JYY-GOCE04s	167+EGM08	0.887	-0.382	±0.122

GOCE GGM VALIDATION
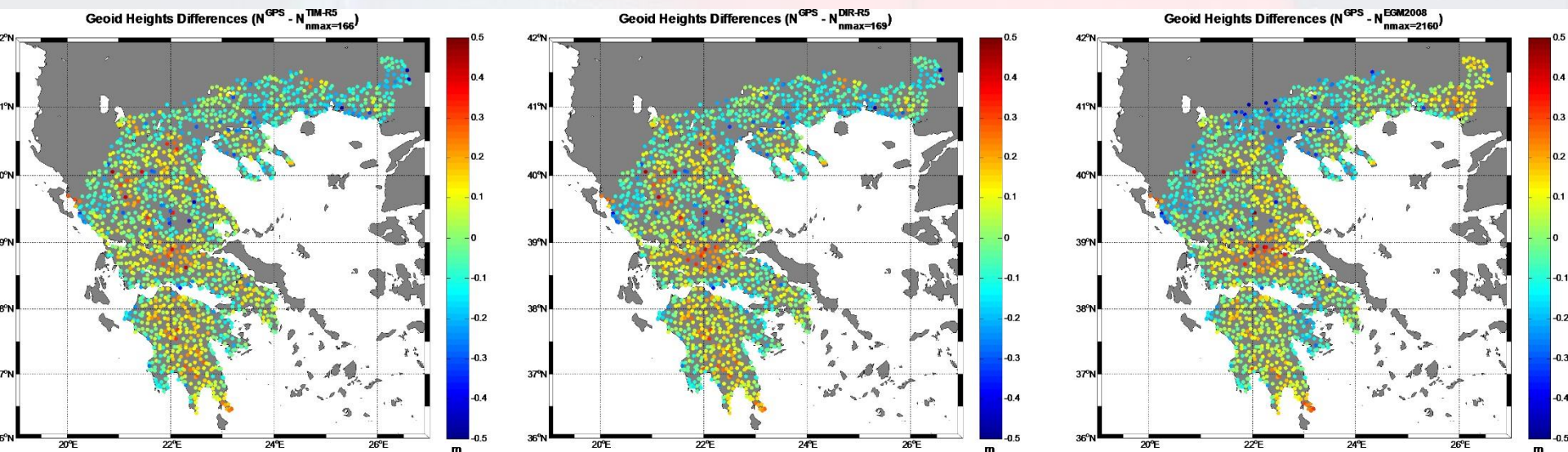
TIM-R5, DIR-R5 and EGM2008 Geoid height differences at the GPS/Lev BMs
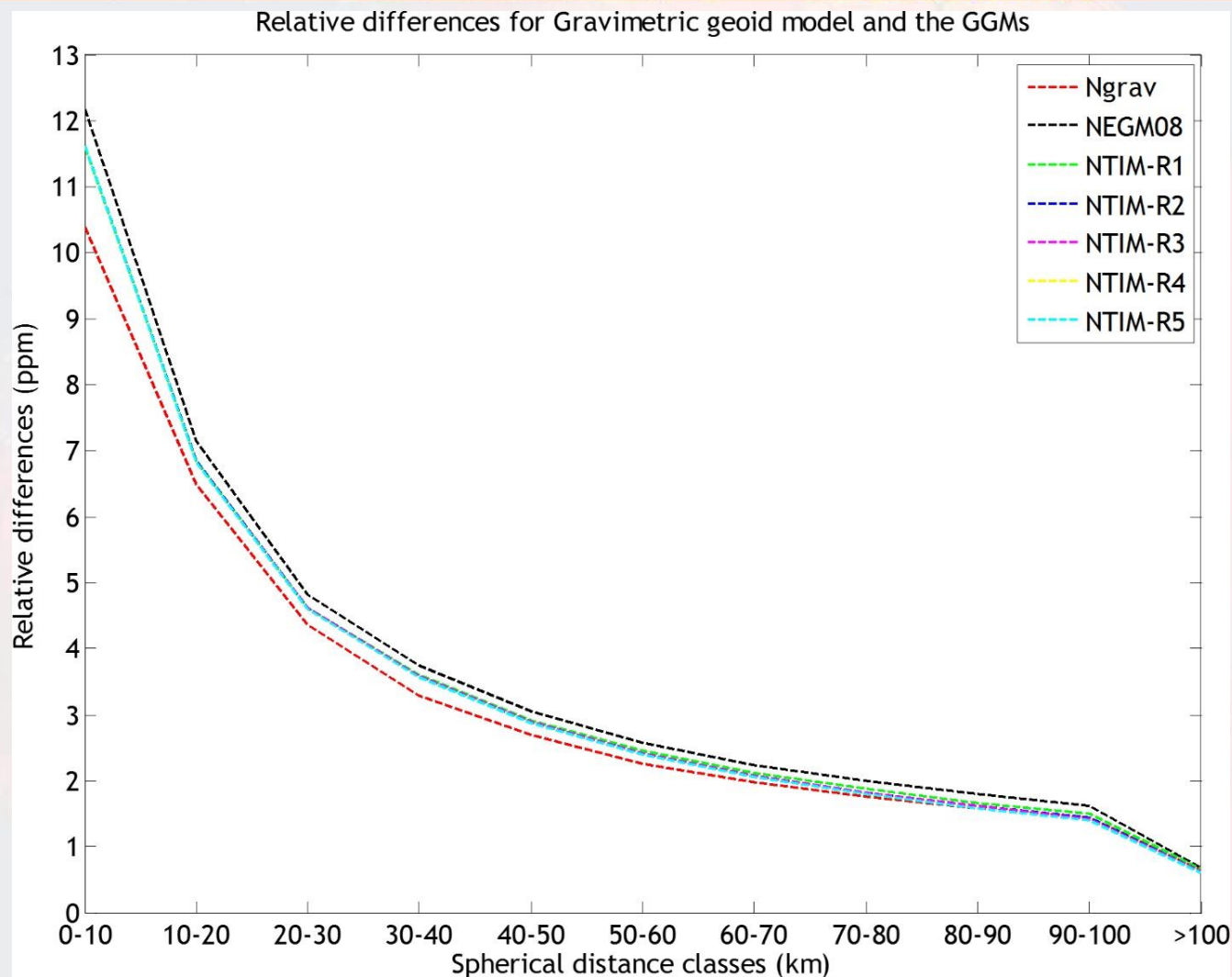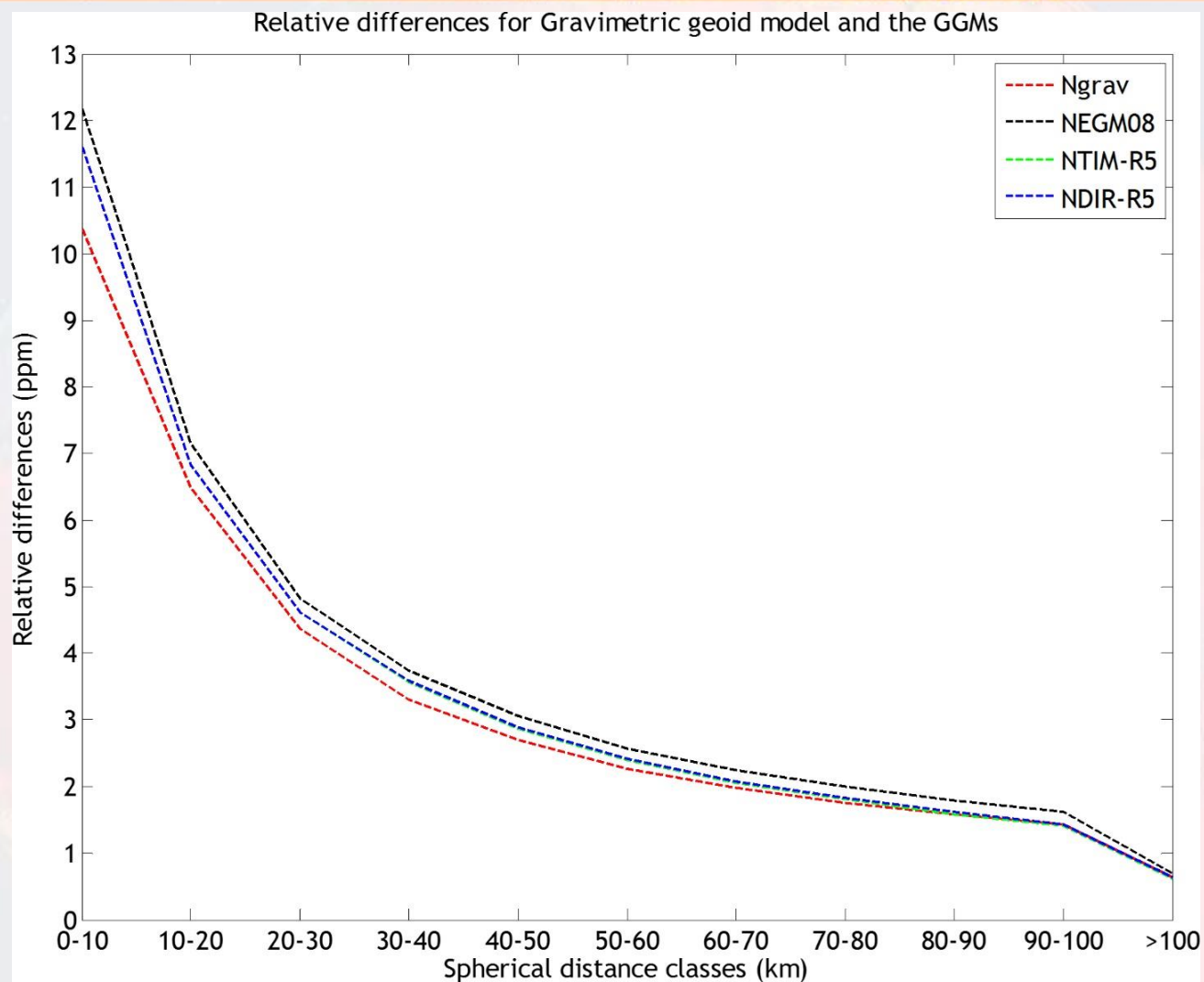
Relative differences for Gravimetric geoid model and the GGMs

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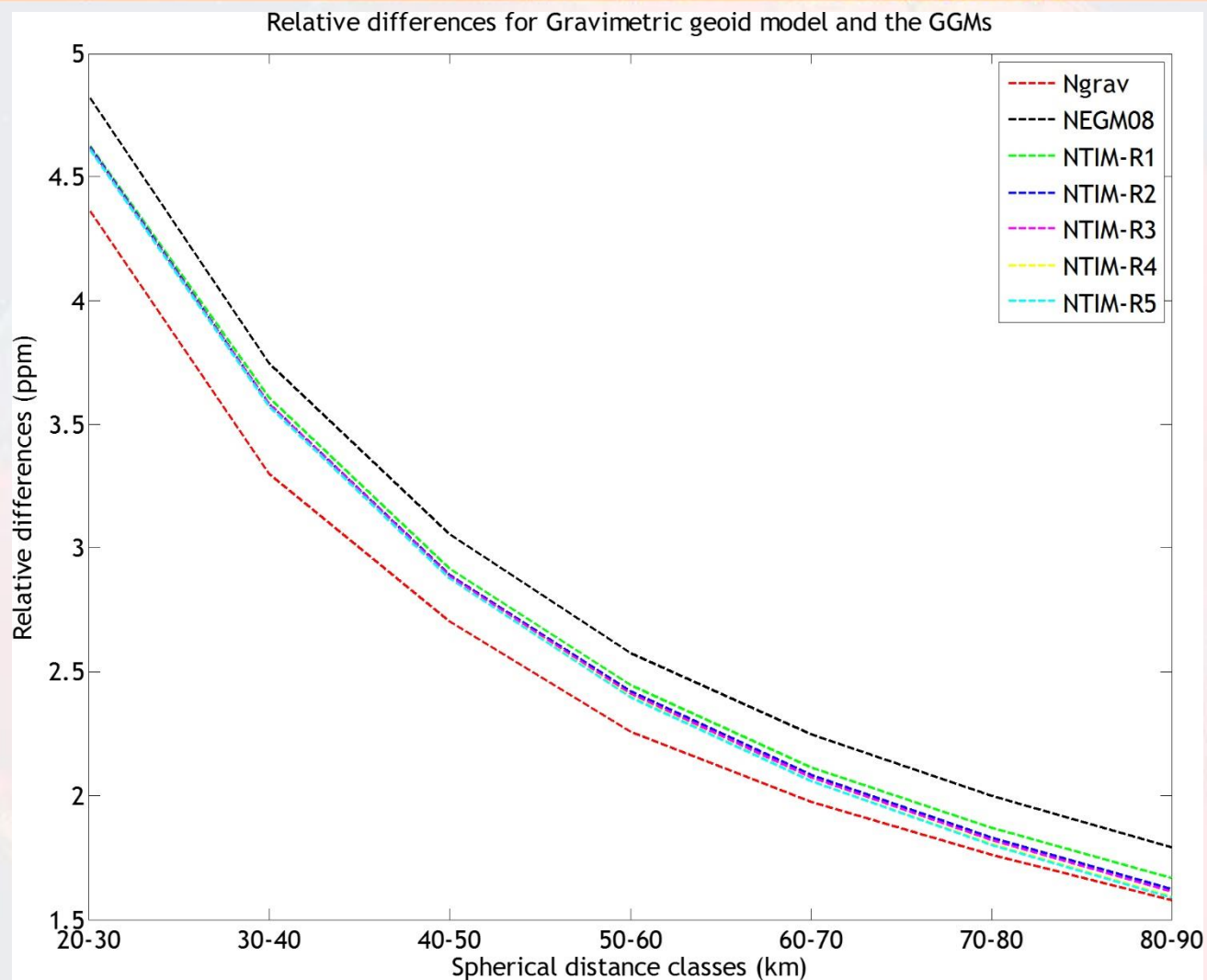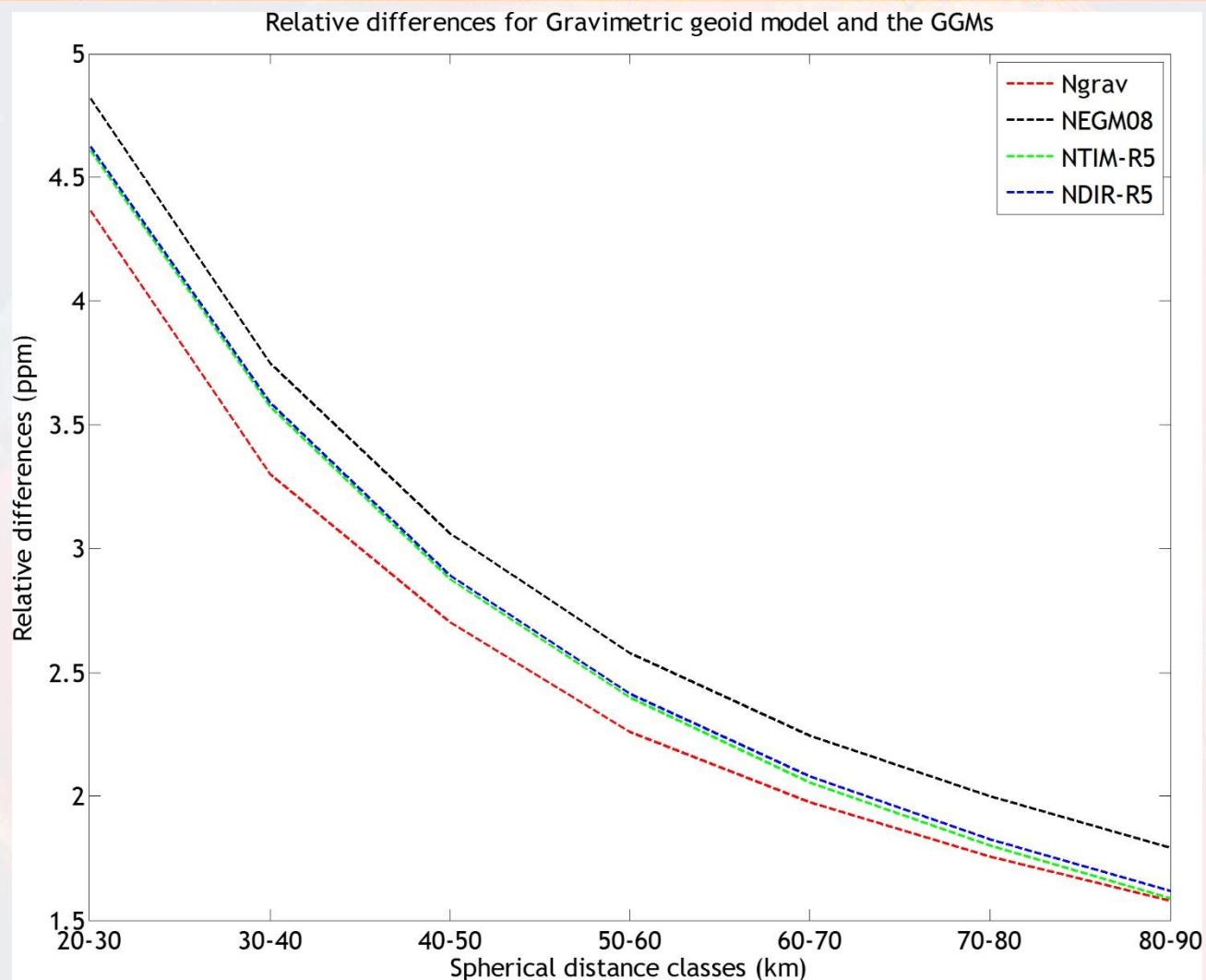
GOCE GGM VALIDATION

Relative accuracy of geoid height differences. Unit [ppm]

GGM	EGM2008	TIM-R5	DIR-R5	N^{grav}
0-10 km	12.18	11.61	11.61	10.38
10-20 km	7.15	6.83	6.84	6.49
20-30 km	4.82	4.61	4.62	4.36
30-40 km	3.75	3.57	3.59	3.30
40-50 km	3.06	2.88	2.89	2.70
50-60 km	2.58	2.39	2.42	2.26
60-70 km	2.25	2.06	2.08	1.97
70-80 km	2.00	1.80	1.83	1.76
80-90 km	1.79	1.59	1.62	1.58
90-100 km	1.61	1.41	1.43	1.43
>100 km	0.69	0.61	0.63	0.64

GOCE GGM VALIDATION
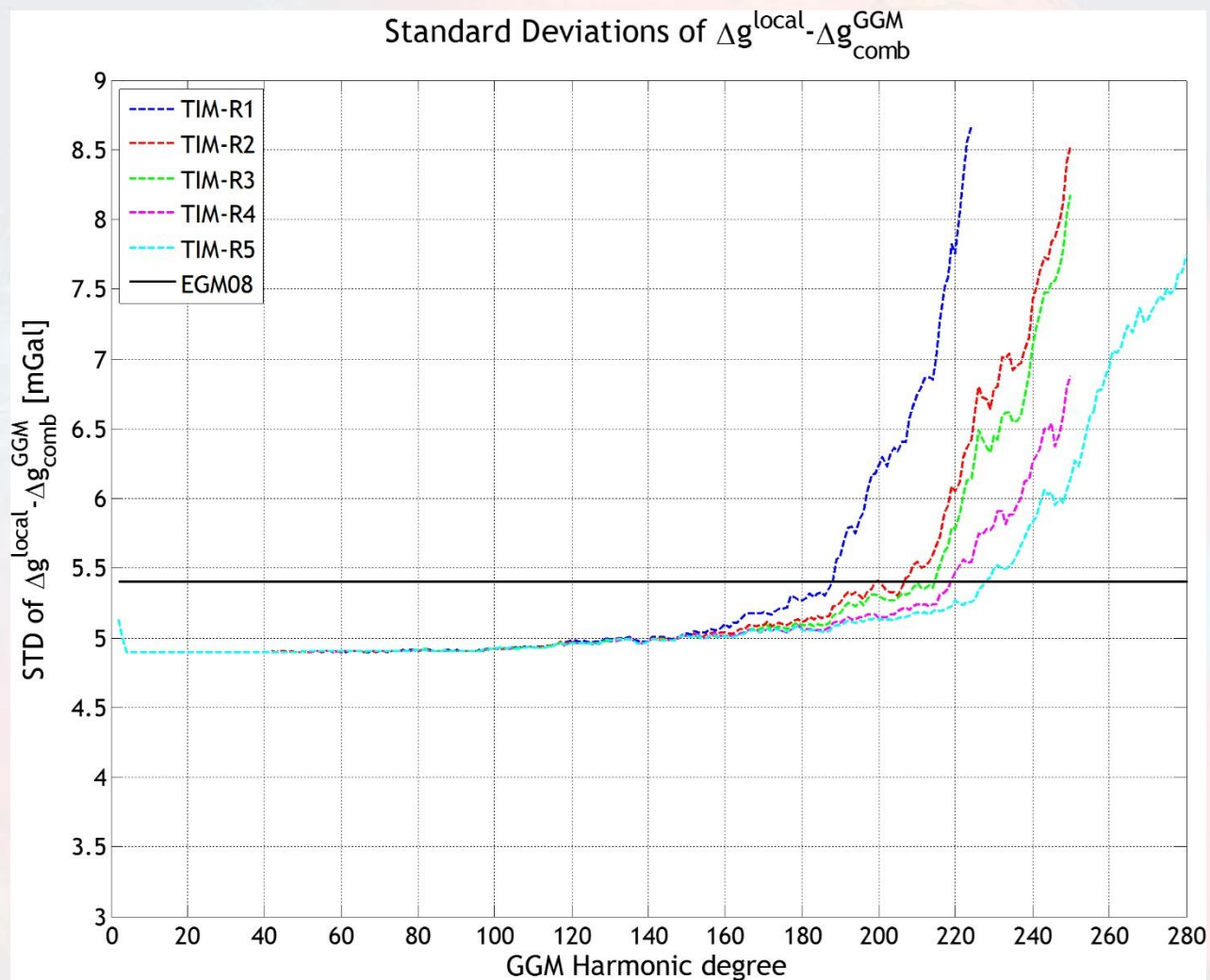
Standard Deviations of $\Delta g^{local} - \Delta g^{GGM}_{comb}$

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Standard Deviations of $\Delta g^{local} - \Delta g^{GGM}_{comb}$

Legend:
- DIR-R1
- DIR-R2
- DIR-R3
- DIR-R4
- DIR-R5
- EGM08

X-axis: GGM Harmonic degree

Y-axis: STD of $\Delta g^{local} - \Delta g^{GGM}_{comb}$ [mGal]

Standard Deviations of $\Delta g^{local} - \Delta g^{GGM}_{comb}$

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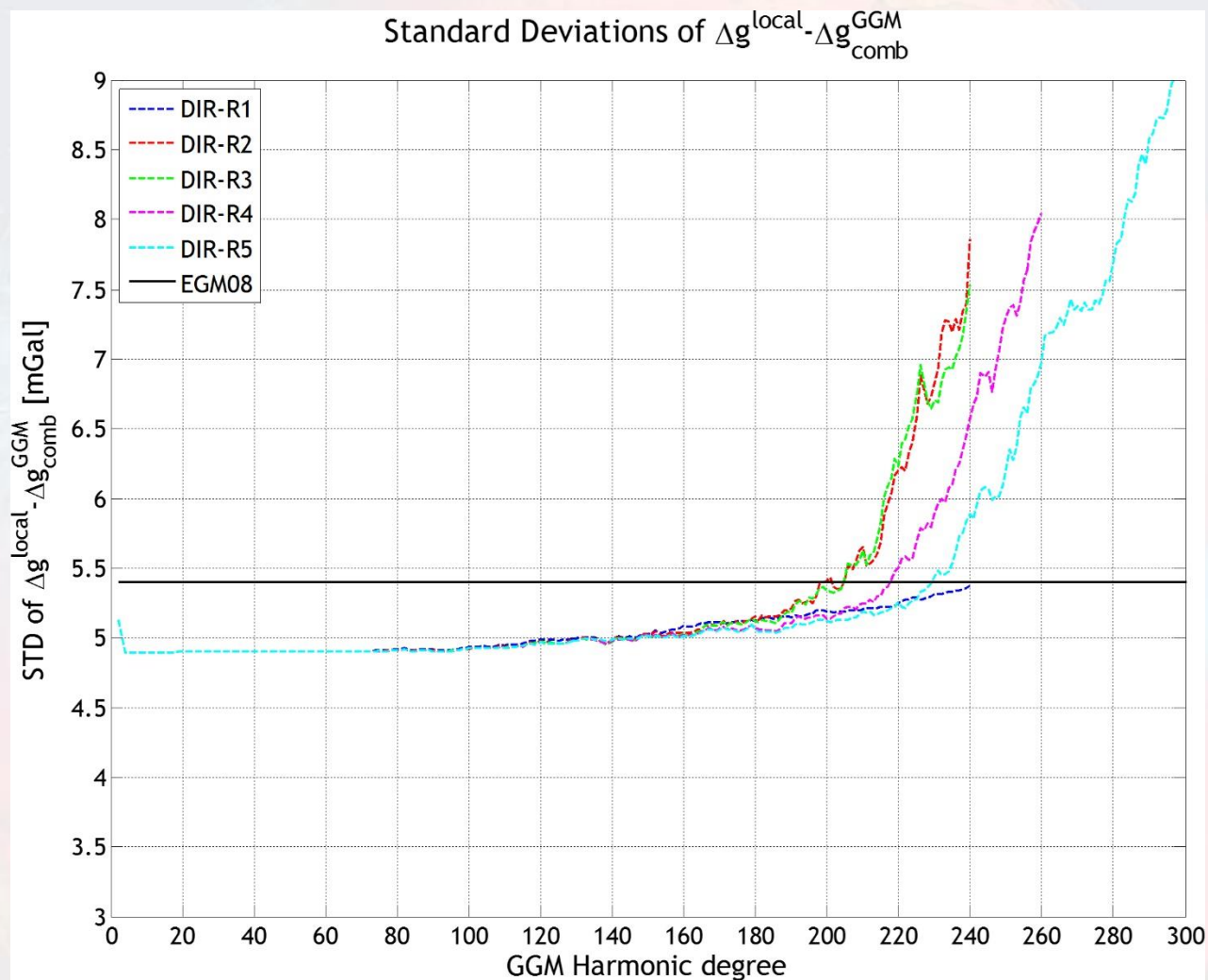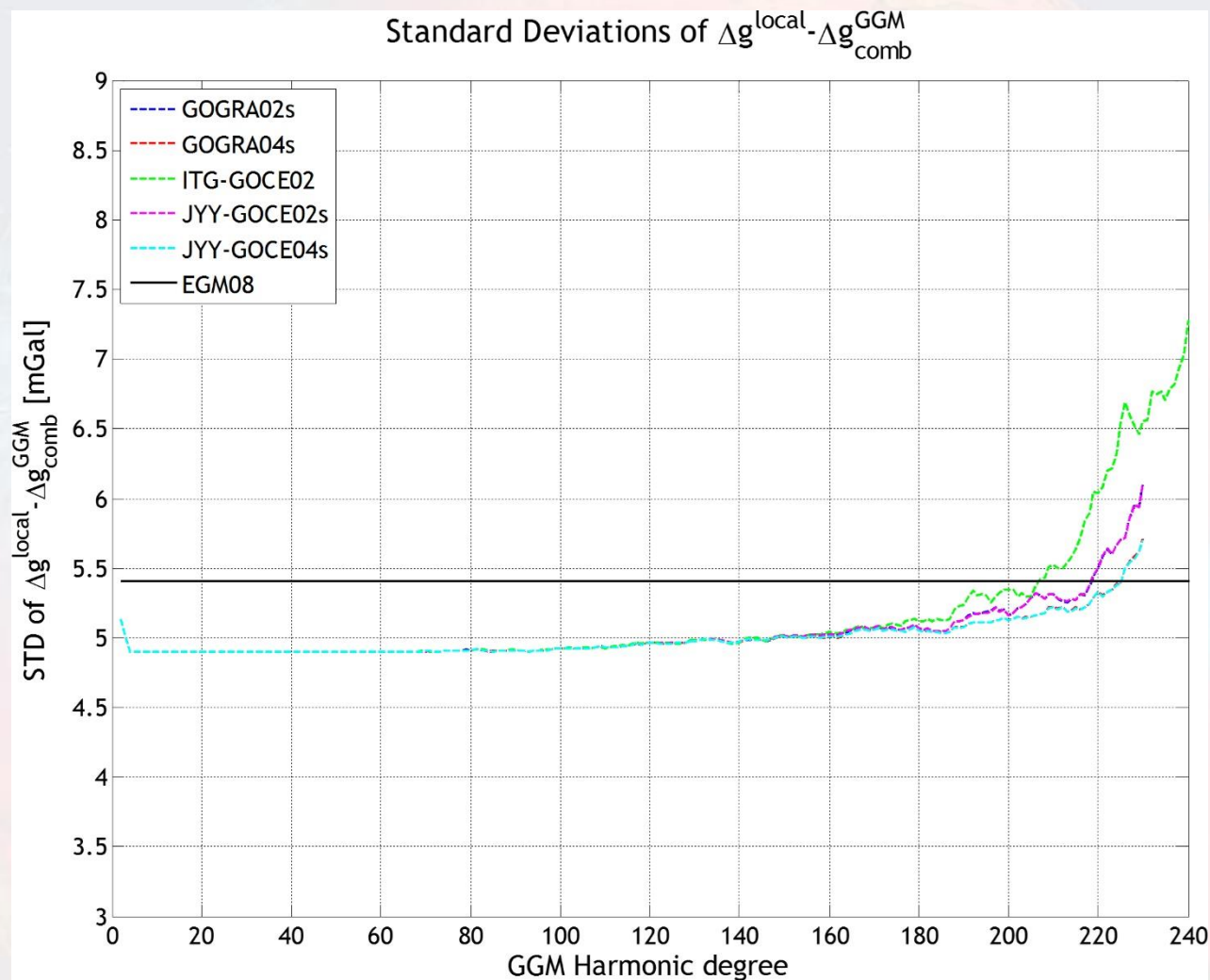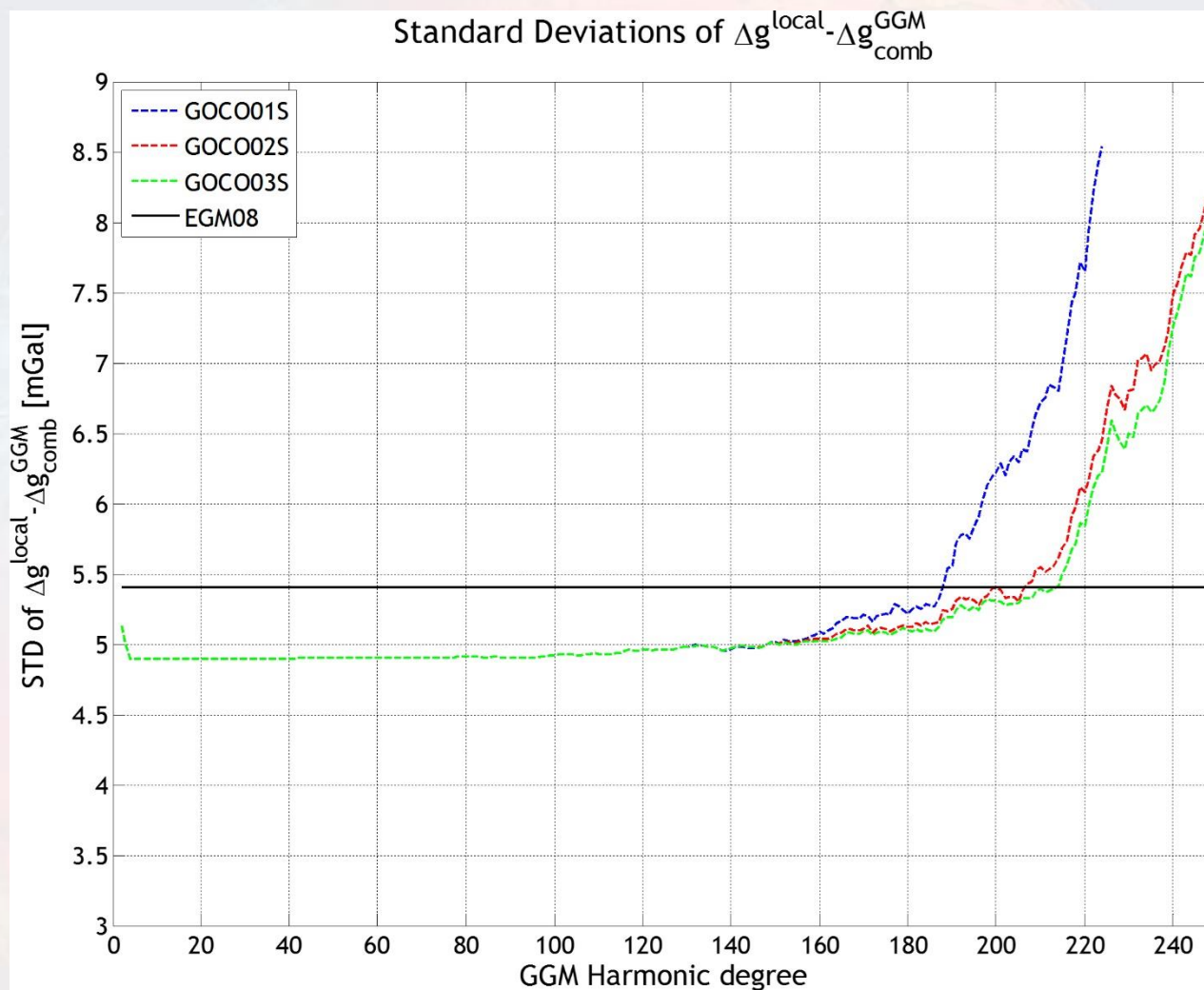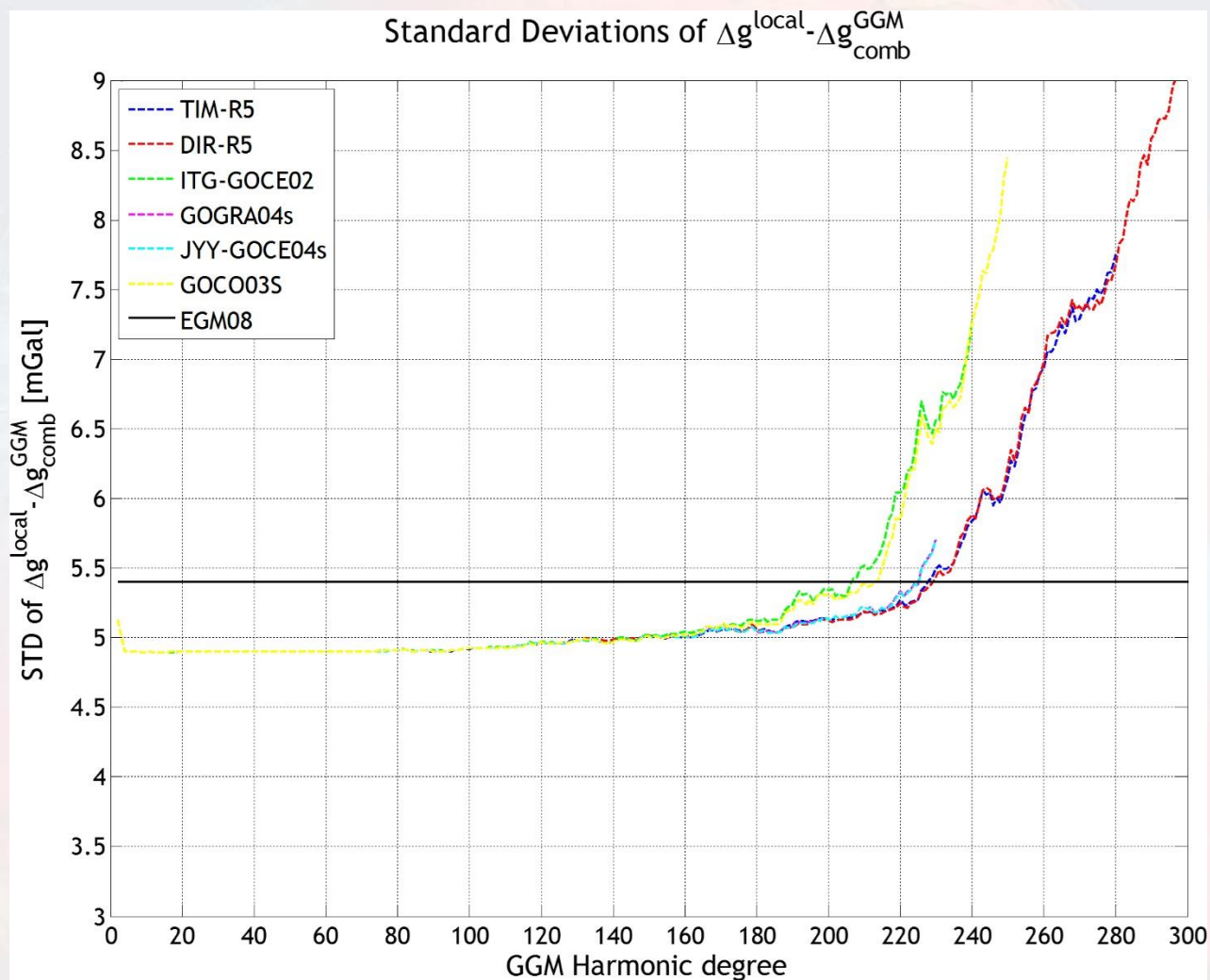
GOCE GGM VALIDATION

Gravity anomaly differences between GOCE/GRACE GGMs and local data. Unit [mGal]

GGM	d/o	range	mean	std
EGM2008	2190	184.10	0.57	±5.32
DIR-R5	214+EGM08	179.06	0.39	±4.89
TIM-R5	212+EGM08	179.16	0.45	±4.89
GOCO03s	193+EGM08	177.38	0.45	±4.89
ITG-GOCE02s	193+EGM08	177.85	0.54	±4.89
GOGRA04s	194+EGM08	177.98	0.62	±4.89
JYY-GOCE04s	194+EGM08	178.16	0.64	±4.89

GOCE GGM VALIDATION
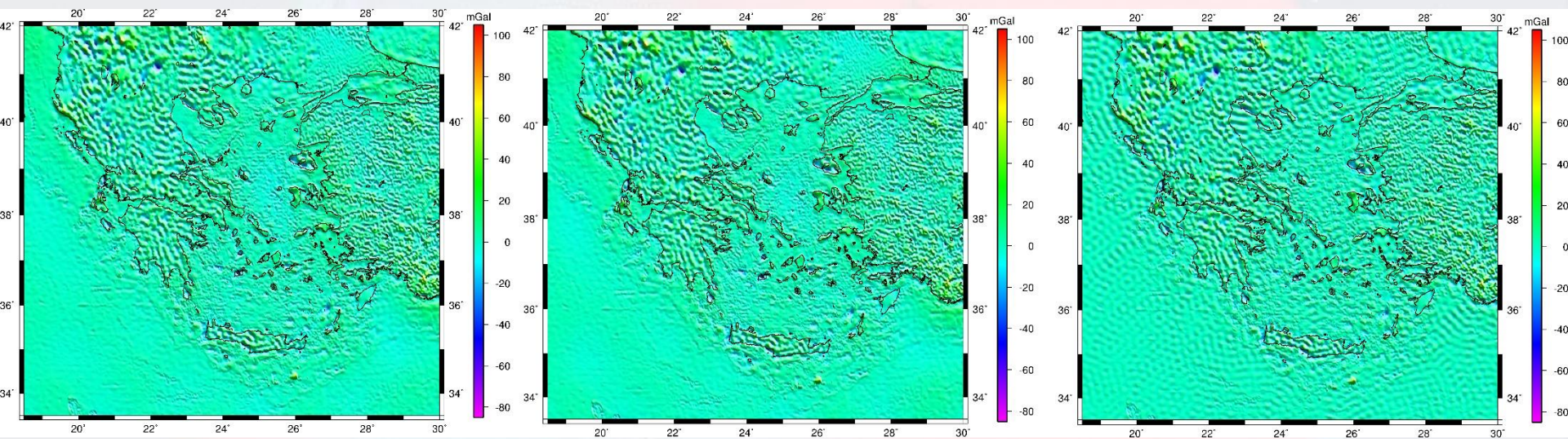
TIM-R5, DIR-R5 and EGM2008 gravity anomaly differences with the local data

GOCE GGM VALIDATION
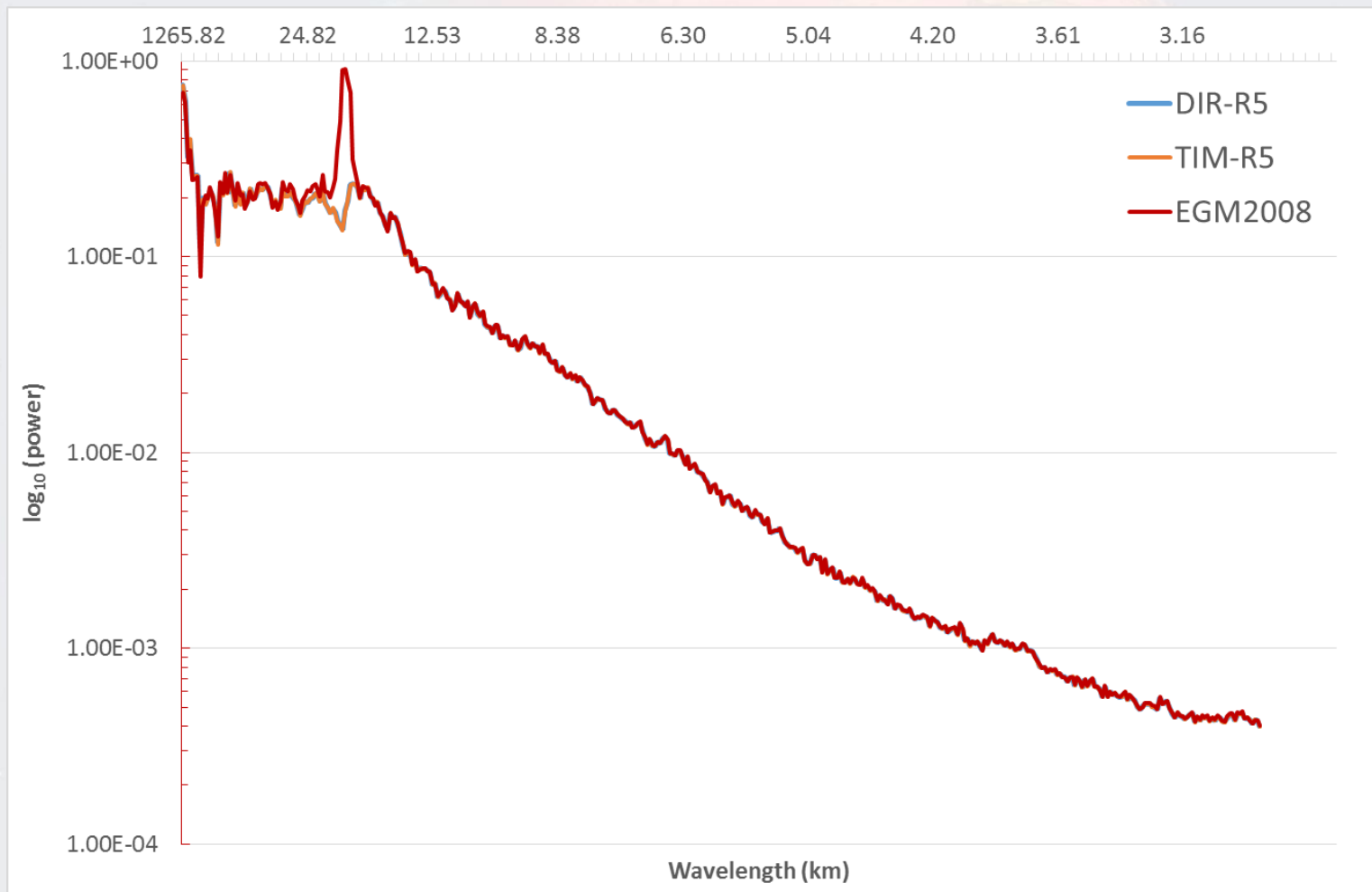
Radially averaged PSD vs spatial frequency

Basic physical model (Helmert ortho heights):

$$H_i^{helm} = \frac{W_o^{LVD} - W_i}{g_i + 0.0424 \cdot 10^{-5} H_i^{helm}} = \frac{W_o^{LVD} - W_i}{\overline{g}_i}$$

LS estimate of LVD's zero-height level

$$\hat{W}_o^{LVD} = \frac{\sum_i p_i y_i}{\sum_i p_i} \quad \longrightarrow \quad W_i + H_i^{helm} \overline{g}_i^{helm}$$

$\longrightarrow$ 'weights'

Un-weighted LS estimate & combined GOCE/GRACE GGMs

○ EGM2008 (2190)

$$\hat{W}_o^{LVD} = 62636860.07 \pm 0.02 \, \mathrm{m}^2/s^2$$

○ DIR-R5 (169)+EGM08

$$\hat{W}_o^{LVD} = 62636859.76 \pm 0.02 \, \mathrm{m}^2/s^2$$

○ TIM-R5 (166)+EGM08

$$\hat{W}_o^{LVD} = 62636859.81 \pm 0.02 \, \mathrm{m}^2/s^2$$

○ GOGRA04s (167)+EGM08

$$\hat{W}_o^{LVD} = 62636859.82 \pm 0.02 \, \mathrm{m}^2/s^2$$

Un-weighted LS estimate & combined GOCE/GRACE GGMs

- EGM2008 (2190)

$$\hat{W}_o^{LVD} = 62636\boxed{860.07} \pm 0.02\,\text{m}^2/s^2$$

- DIR-R5 (169)+EGM08

$$\delta\hat{W}_o^{LVD} \approx \boxed{3.1\,cm}$$

- TIM-R5 (166)+EGM08

$$\delta\hat{W}_o^{LVD} \approx \boxed{2.6\,cm}$$

- GOGRA04s (167)+EGM08

$$\delta\hat{W}_o^{LVD} \approx \boxed{2.5\,cm}$$

GOCE $\widehat{W}_o^{LVD}$ FOR GREECE

Un-weighted LS estimate & combined GOCE/GRACE GGMs

- DIR-R5 (169)+EGM08 $\hat{W}_o^{LVD} = 626368\boxed{59.76} \pm 0.02\,\mathrm{m}^2/s^2$

- TIM-R5 (166)+EGM08 $\hat{W}_o^{LVD} = 626368\boxed{59.81} \pm 0.02\,\mathrm{m}^2/s^2$

- GOGRA04s (167)+EGM08 $\hat{W}_o^{LVD} = 626368\boxed{59.82} \pm 0.02\,\mathrm{m}^2/s^2$

Great consistency for the GOCE/GRACE GGMs in $\hat{W}_o^{LVD}$

$$\delta\hat{W}_o^{LVD} \approx 0.1 - 0.6\,cm$$

CONCLUSIONS

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o **In terms of the gravity anomalies they are better than EGM2008 by 0.5 mGal (1σ), reducing also the mean by 0.2 mGal and the range by 7 mGal**

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o $\hat{W}_o^{LVD}$ from GOCE GGMs is very robust with $\hat{W}_o^{LVD}$ between the various GGMs at 0.1-0.6 cm

Thank you for your attention

ACKNOWLEDGEMENT

GOCESeaComb