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

Spectral characteristics of the Hellenic vertical network - Validation over Central and Northern Greece using GOCE/GRACE global geopotential models

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Outline

- Description of the E.LE.V.A.T.I.ON project
- Validation methodology
- Test areas and data description
- Results
- Conclusions and future plans

E.LE.V.A.T.I.ON Project

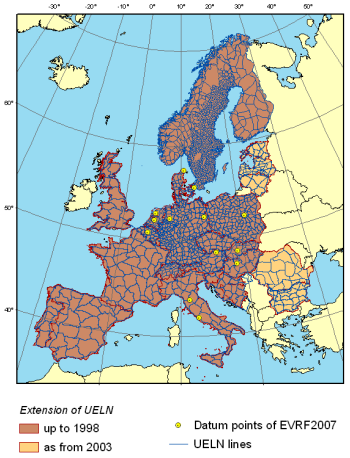
• **E**valuation of the Hel**LE**nic **V**ertical network in the fr**A**me of the European Sys**T**ems and Control Networks **I**nterconnect**ON** – Application in the areas of Attica and Thessaloniki

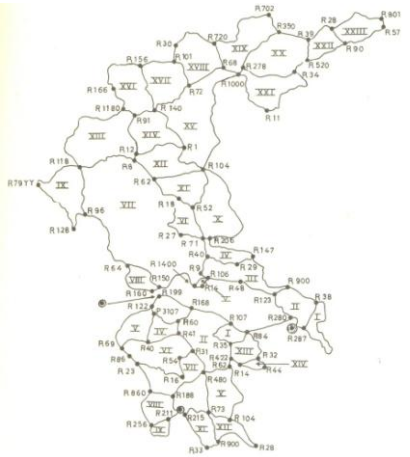
• TEI of Athens – Aristotle University of Thessaloniki – National Technical University of Athens

• Hellenic Vertical Network has not been connected with EVRS

• Validation before the connection

• GRACE and GOCE data provide valuable information





Validation methodology

- GPS/leveling benchmarks ($N^{GPS/Lev}$) over test areas and validation using spectral enhancement approach

- GRACE/GOCE GGM (N^i) to some maximum degree of expansion (n_1)

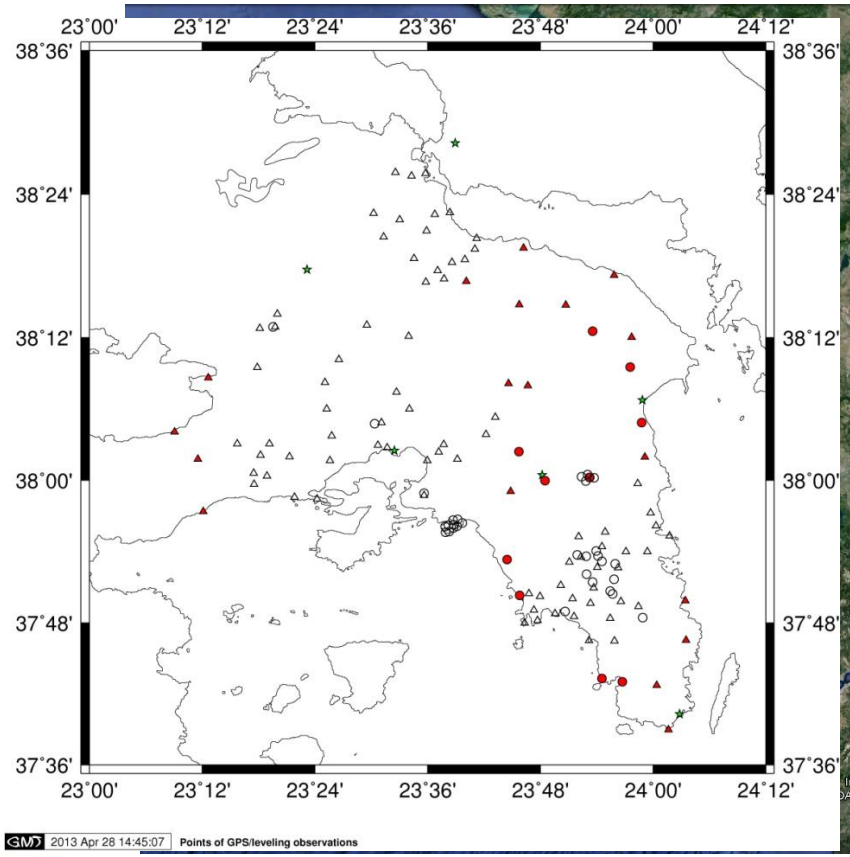
- EGM2008 is used to fill-in medium and high frequency content

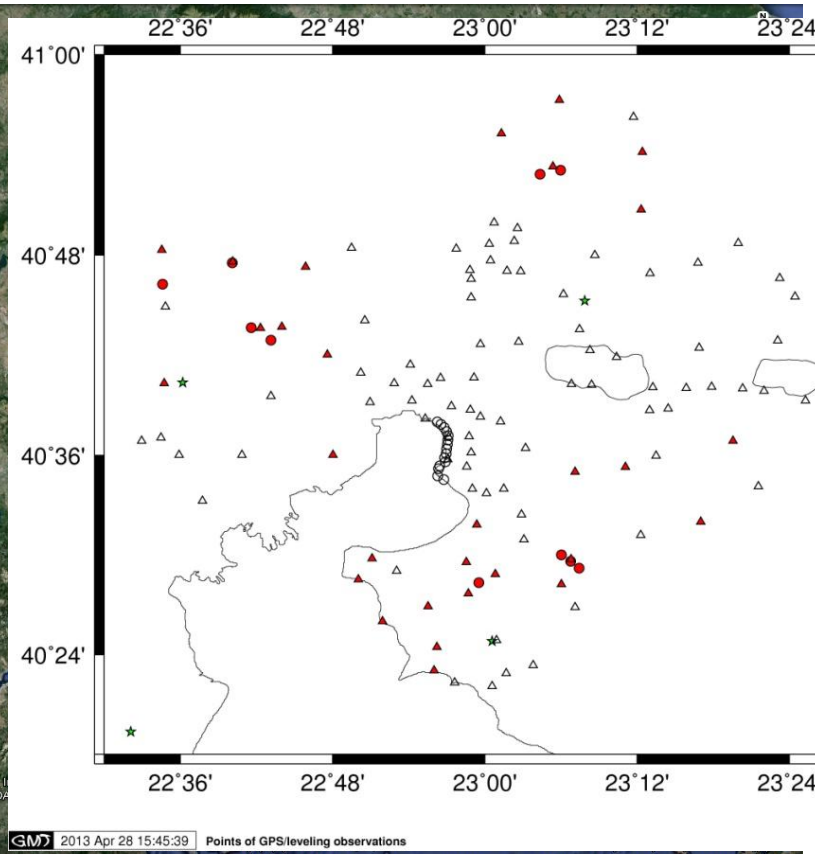
- Residual Terrain Modeling (N^{RTM}) effects complete the high and ultra high frequency information

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

Data availability (1/4) – Test areas

- 2 tests areas 100 km × 100 km each – 233 benchmarks





Data availability (2/4) – Global Geopotential Models

- **18 Global Geopotential Models** used to their maximum d/o (satellite only – GOCE/GRACE – and combined information)

- **EGM2008** as reference model (Pavlis et al., 2008 - expansion to d/o **2160**)

- **EIGEN models** (5C, 6C, 6C2 and 6C3-stat – Förste et al., 2008, 2011, 2012, 2014)

- **GOCE models** (**DIR 1 – 4**, Bruinsma et al., 2010, 2013 and **TIM 1 – 4**, Pail et al., 2010, 2011)

- **GOCO models** (**01S – 03S**, Pail et al., 2010; Goinginger et al., 2011; Mayer-Gürr et al., 2012)

- **ITG-Goce02** (Schall et al. 2014)

- **GOGRA02S** (Yi et al., 2013)

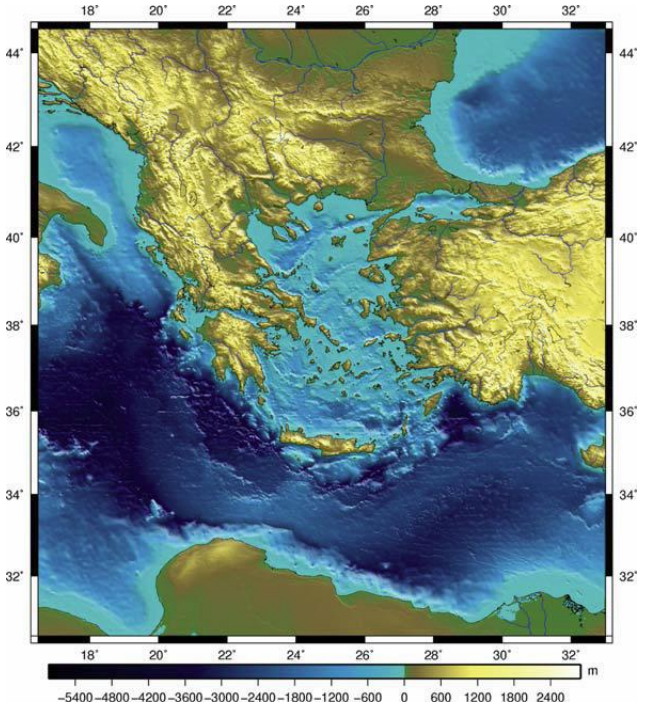
- **JYY-GOCE02S** (Yi et al., 2013)

Data availability (3/4) – High frequency (RTM effects)

- 3 arcsec resolution digital terrain and bathymetry model is used for the RTM effect on geoid heights

- the omission error is below the 1 mm level

- the d/o of expansion that these synthetic GOCE/GRACE GGMs now represent is at 216,000



Digital terrain model from Tziavos et al. 2010

Data availability (4/4) – Datum and reference system concepts

- **Tide – Free system** (Zero – Tide model ITG-GOCE02 was transformed to the Tide – Free system)

$$\delta C_{2,0}^{TF} = \delta C_{2,0}^{ZT} + 3.1108x10^{-8}\frac{0.3}{\sqrt{0.5}}$$

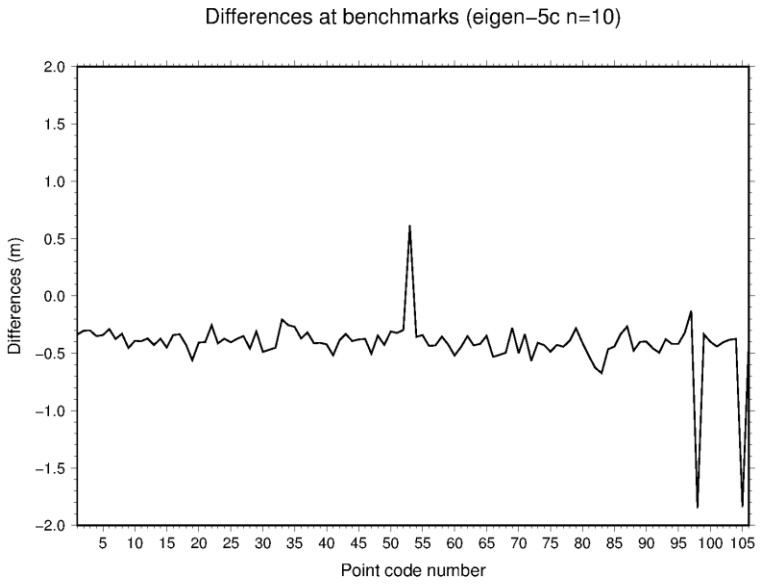
- Orthometric heights in Greece are referenced to the Mean – Tide system → conversion to Tide – Free (Ekman et al. 1989)

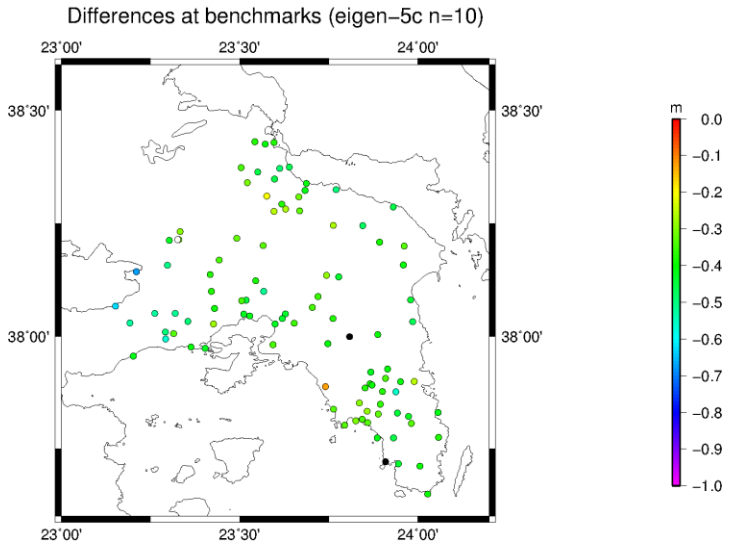
- N_0 zero-degree harmonic w.r.t. GRS80 (N_0 = -0.4376 m)

$$\zeta(r,\vartheta,\lambda) = \frac{GM}{\gamma r}\sum_{n=2}^{n_{max}}\left(\frac{a}{r}\right)^n \sum_{m=0}^{n}\left(\overline{\delta C}_{nm}\cos m\lambda + \overline{\delta S}_{nm}\sin m\lambda\right)\bar{P}_{nm}(\cos\vartheta) \qquad N^{GGM} = \zeta + N_0 + \frac{\Delta g_B}{\bar{\gamma}}H$$

Results (1/11) – Blunders detection

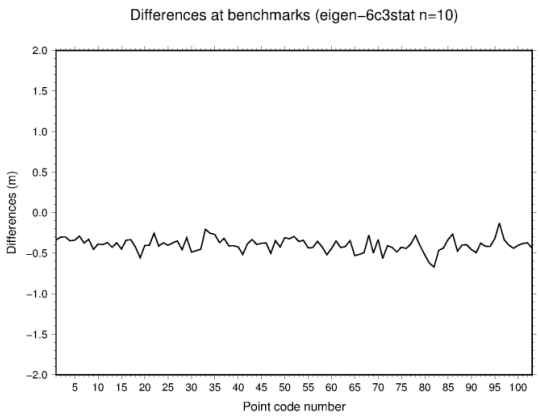
- Blunders identification in Attica using combination methodology

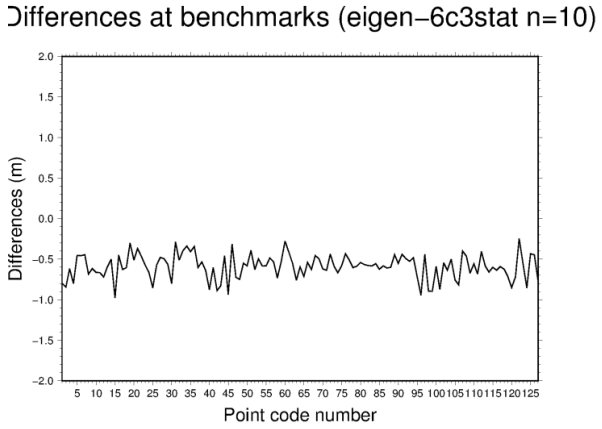


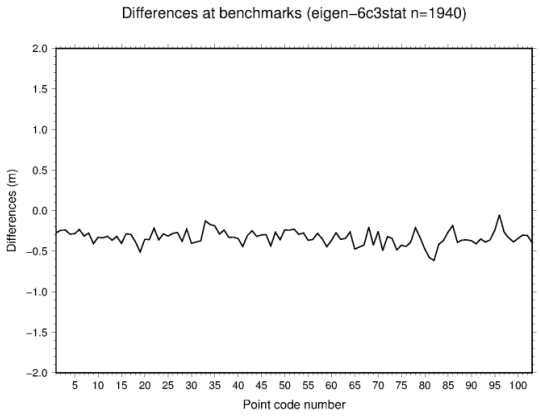


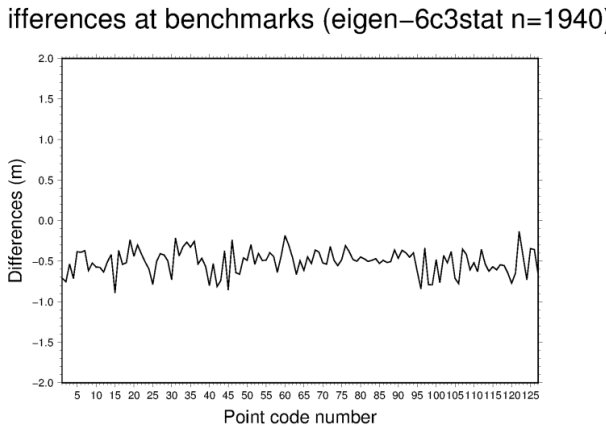
Results (2/11) – Differences in Attica and Thessaloniki

- Larger std in Thessaloniki due to rough terrain → problematic BMs
- A bias of 20 cm between the two areas → LVD inconsistencies



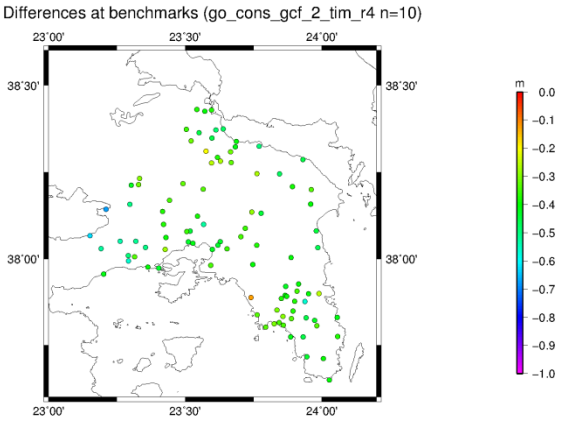


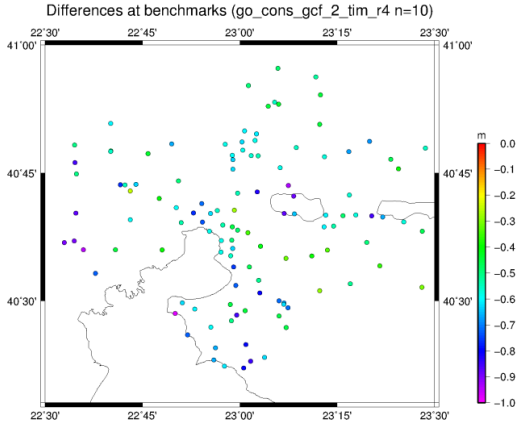


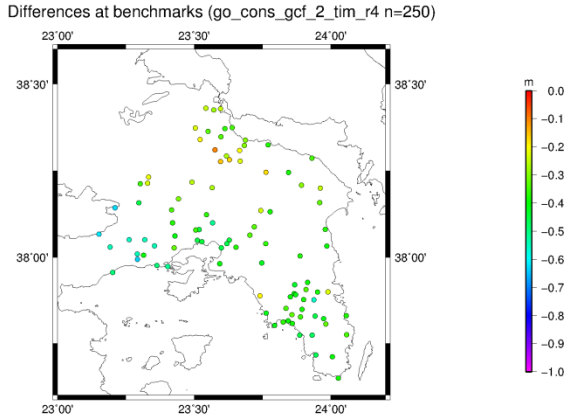


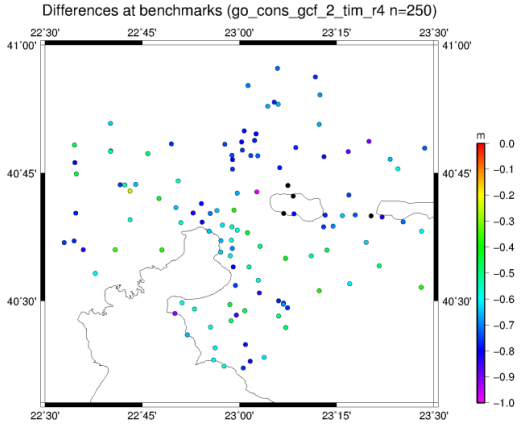
Results (3/11) – Differences in Attica and Thessaloniki

- Local characteristics depending on the d/o of each model



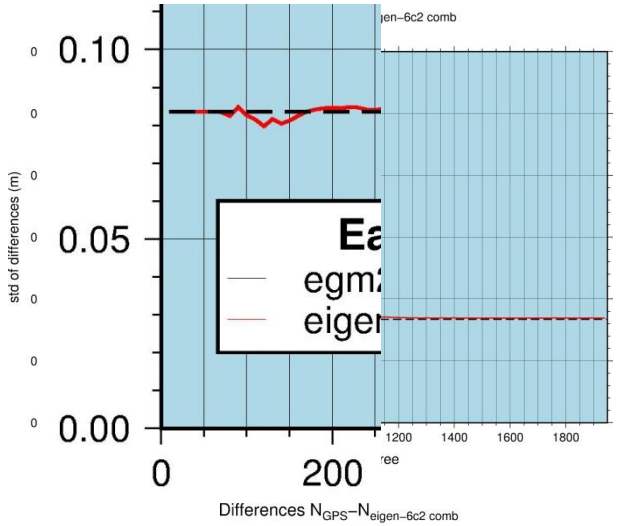


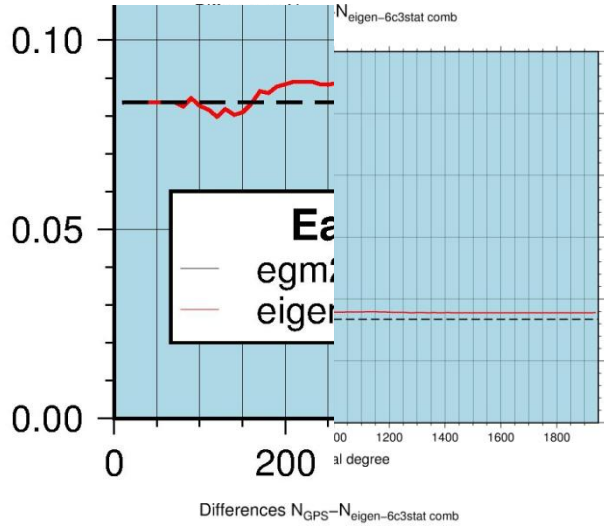


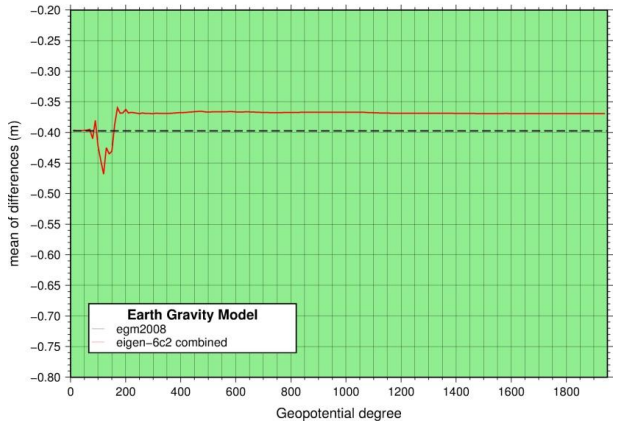


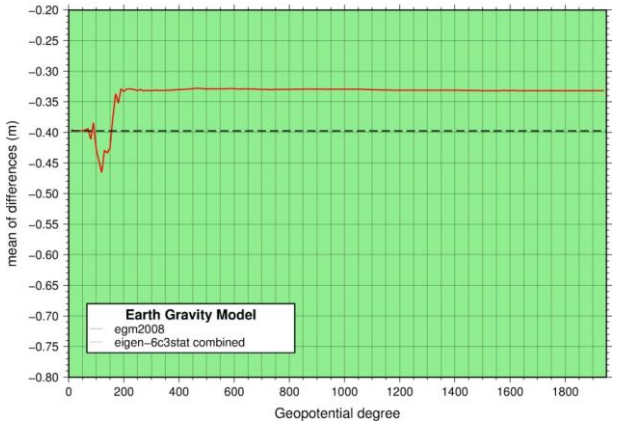
Results (4/11) – Models validation and spectral characteristics

- EIGEN models over Attica → improvements below d/o 200



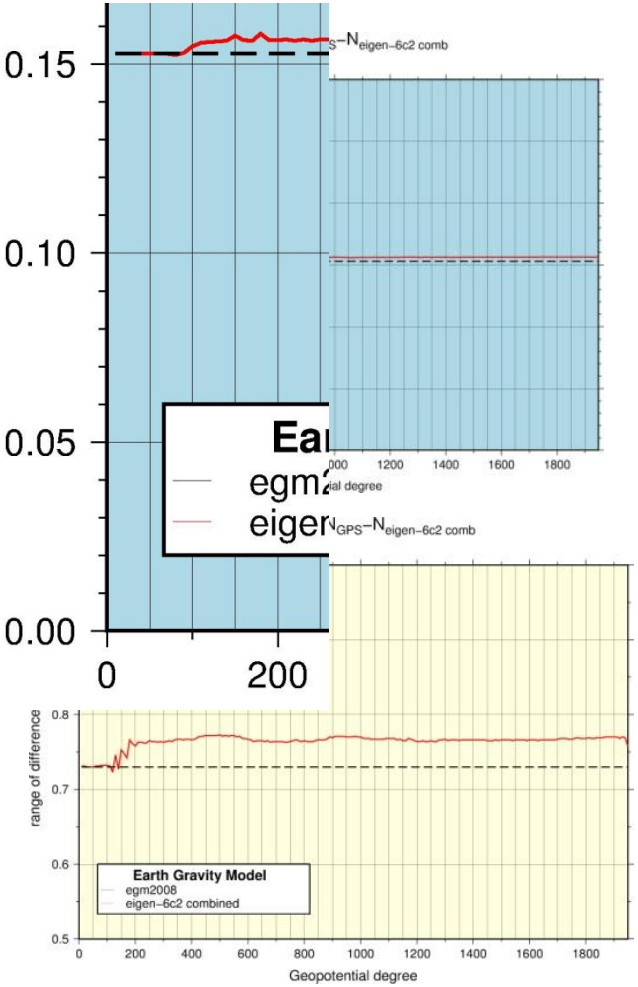


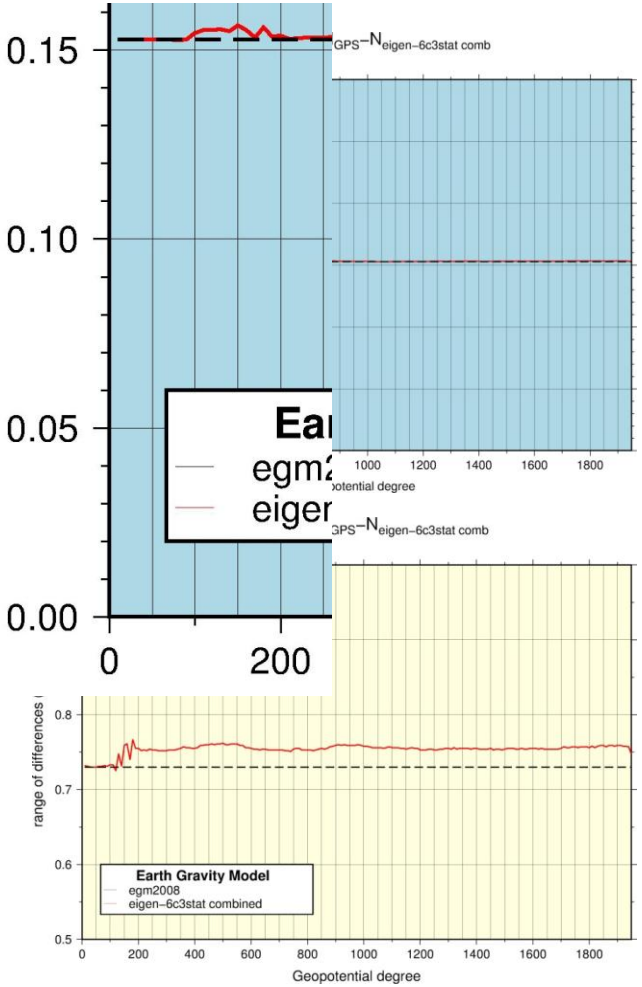




Results (5/11) – Models validation and spectral characteristics

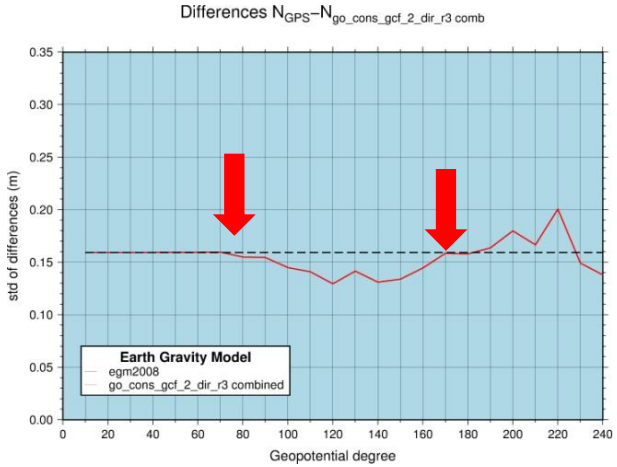
- EIGEN models over Thessaloniki

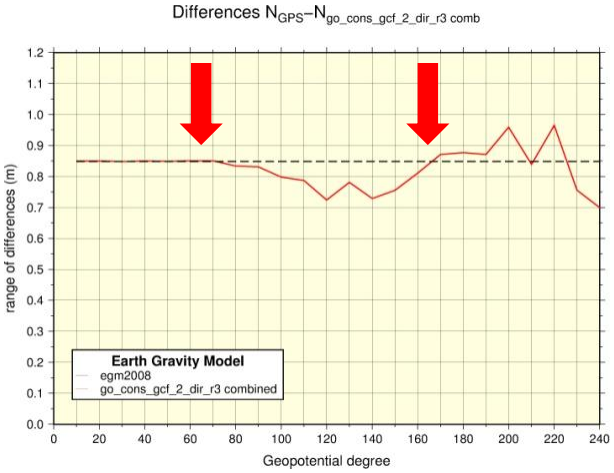


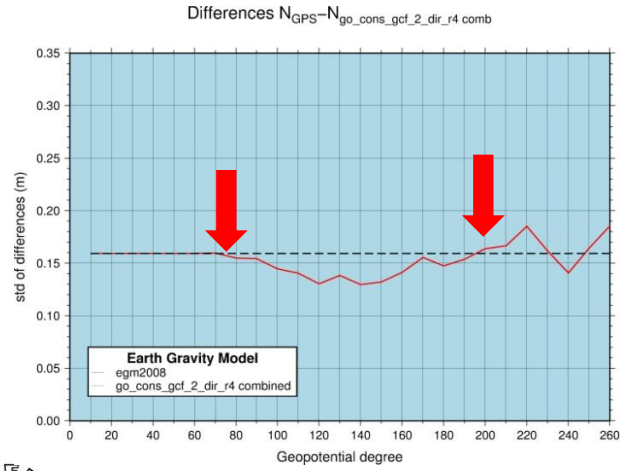


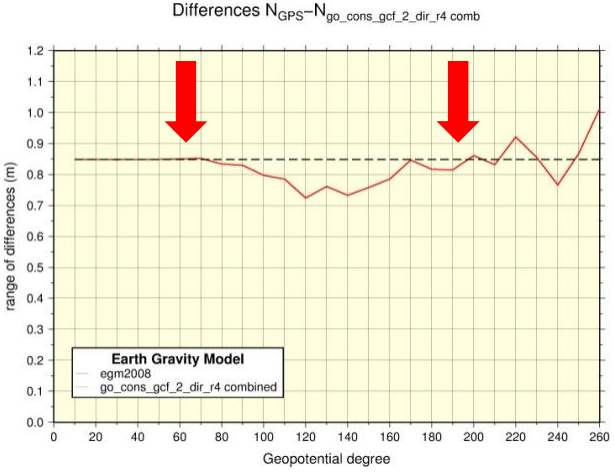
Results (6/11) – Models validation and spectral characteristics

- GOCE-DIR models (R3 and R4) – Both test areas



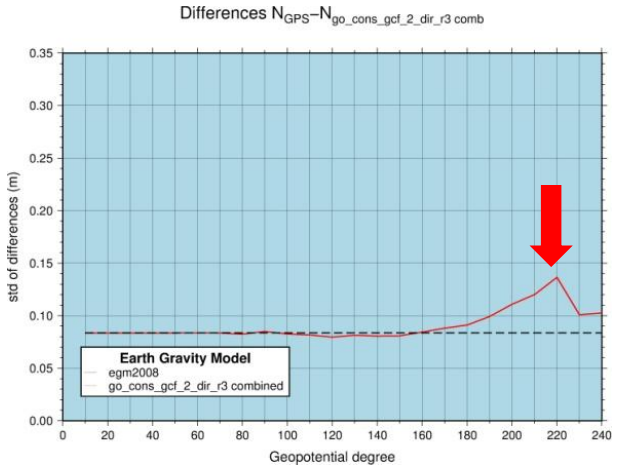


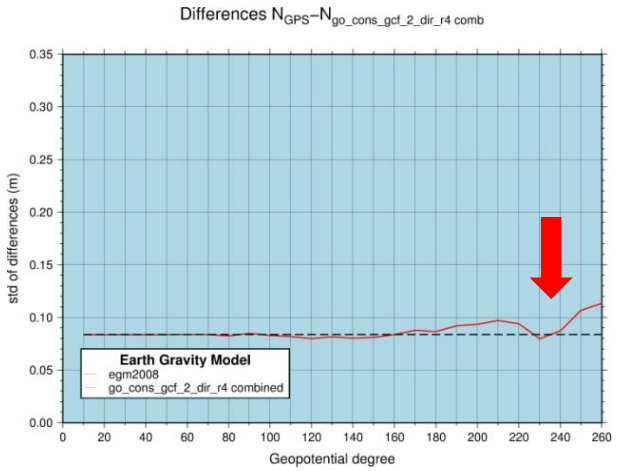


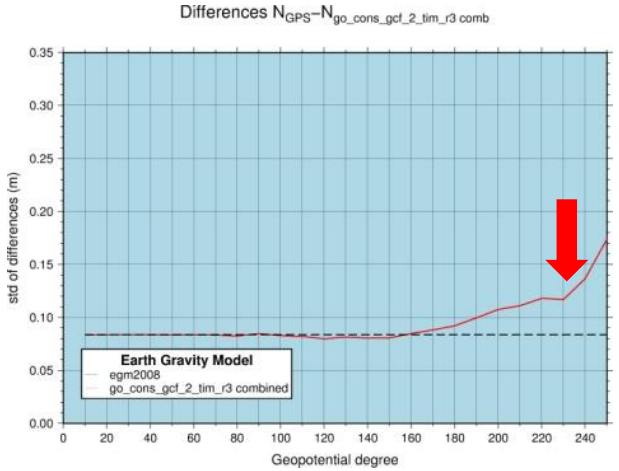


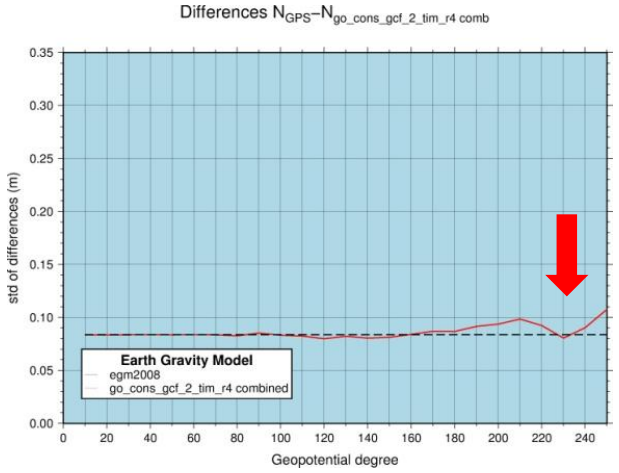
Results (7/11) – Models validation and spectral characteristics

- GOCE-DIR and TIM models (R3 and R4) over Attica



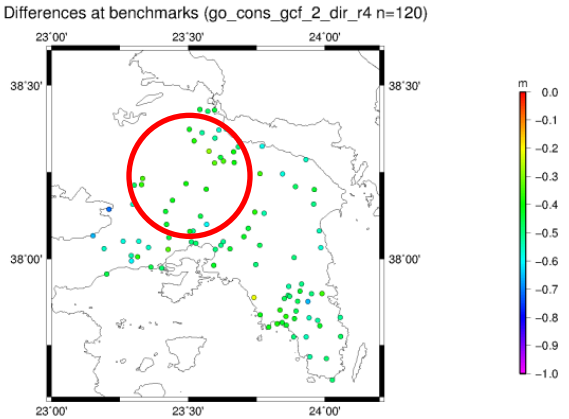


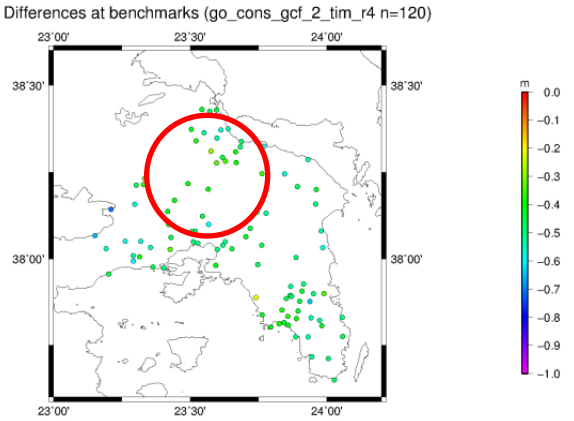


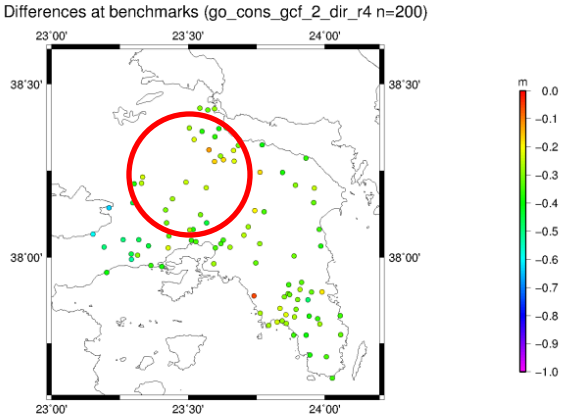


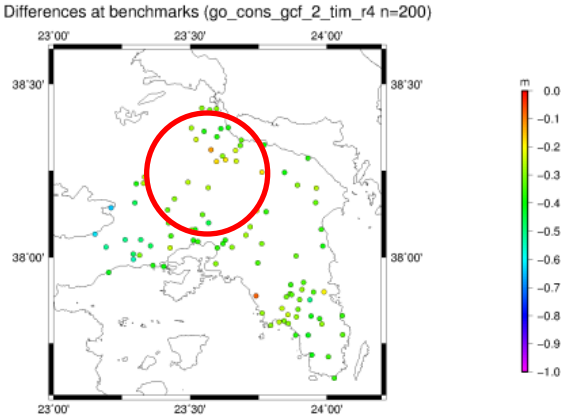
Results (8/11) – Models validation and spectral characteristics

- GOCE-DIR and TIM models (R4) over Attica



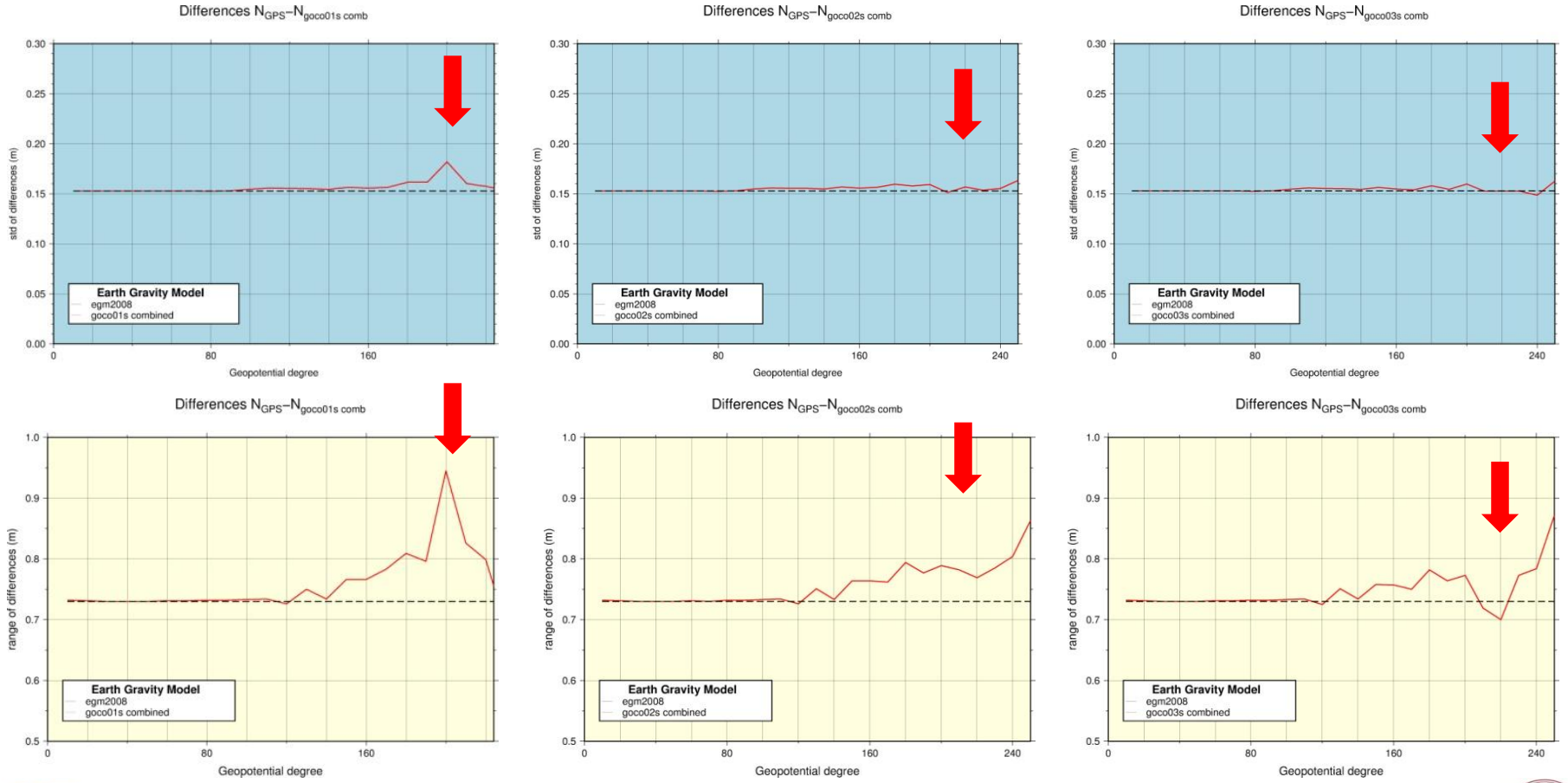






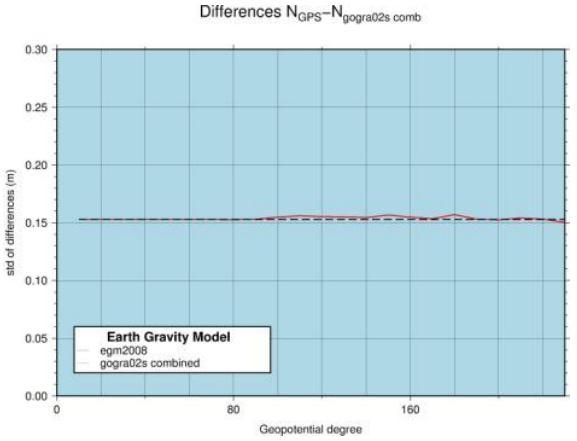
Results (9/11) – Models validation and spectral characteristics

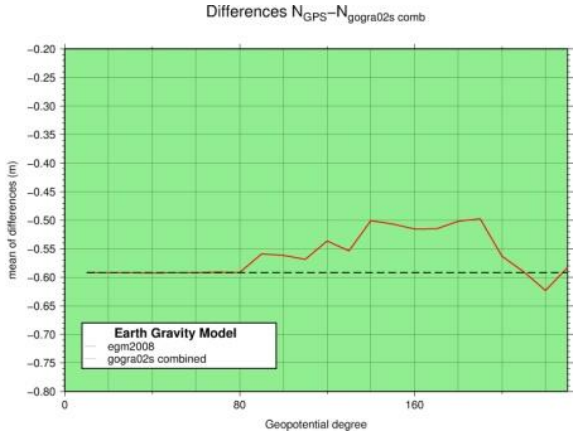
- GOCOxS models over Thessaloniki

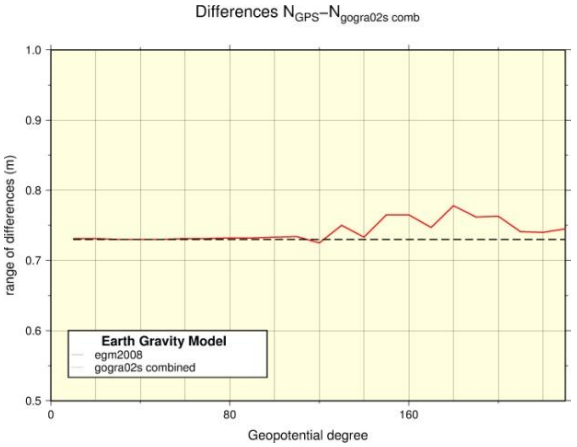


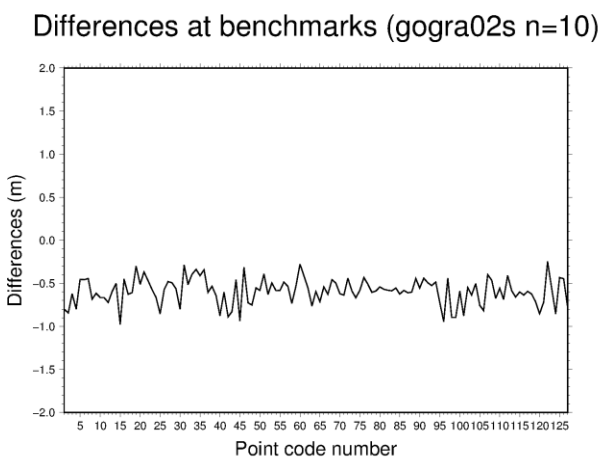
Results (10/11) – Models validation and spectral characteristics

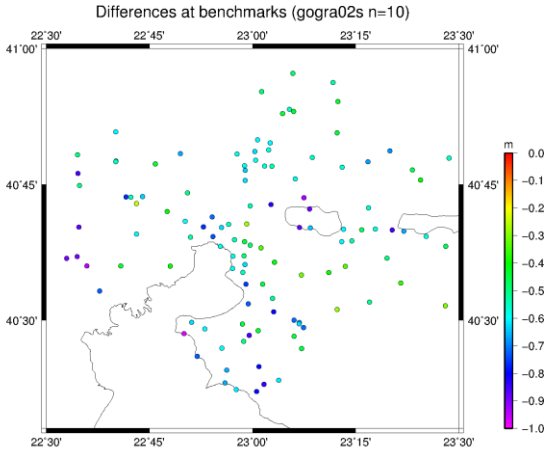
- GOGRA02S model over Thessaloniki





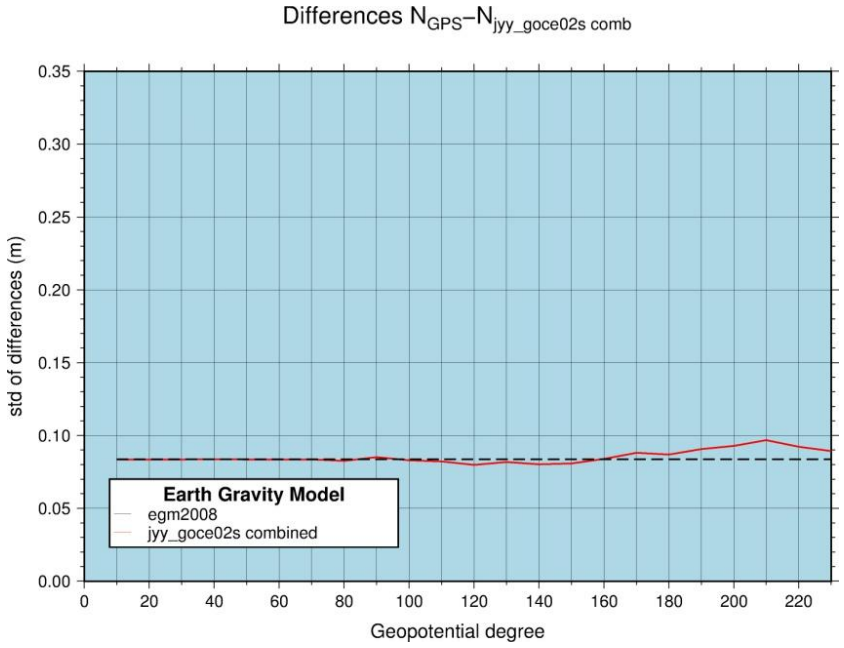


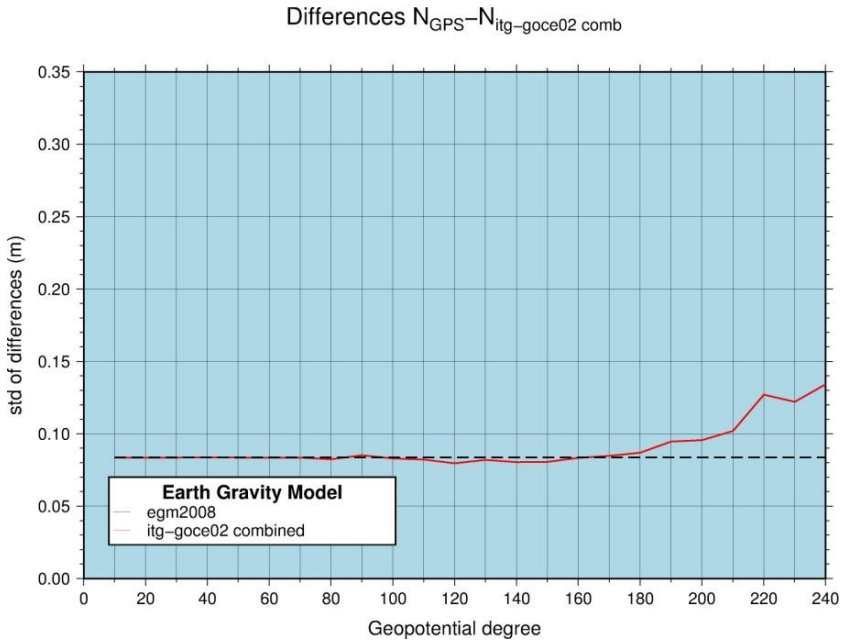




Results (11/11) – Models validation and spectral characteristics

- JYY-GOCE02S and ITG-GOCE02 models over Attica





Conclusions – Future Plans

- **Improvements** from GOCE/GRACE data at **80 – 180 d/o band**
- **2 cm** in terms of std of the differences at Thessaloniki BMs **around d/o 120**
- GOCE models evolution → optimization around **d/o 200**
- Larger std of differences → **dependence on the rough terrain** of Thessaloniki
- Bias identification between Central and Northern test areas → **LVD inconsistencies**
- Vertical Datum homogeneity → **computation of the W_0** in the area (IGFS – Shanghai, June - July 2014)

Acknowledgement

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