ACCURATE GEOID UNDULATION DETERMINATION
ALONG A 100 km LONG RAILWAY TRAVERSE
IN CENTRAL GREECE: PRELIMINARY RESULTS AND VALIDATION

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Key objectives and working principle

**diploma thesis key objectives**

- to setup, test and validate a multi-sensor system for kinematic surveying applications
- to perform a two-way survey of a railway line (100 km) in order to extract rail track axis geometry
- to compute the geoid separation profile along the railway traverse and to attempt a cross-validation against GGMs

**working principle**

\[
N^{\text{NAV}} = h - H
\]

H: orthometric heights (*from as-built plans*)

h: ellipsoidal heights (*kinematic survey*)

\[
N^{GGM}
\]

(EGM96 & EGM08)
Hellenic Vertical Datum (HVD)

- The official height system is Helmert orthometric heights.
- “Precise heights” are provided by the adjustment of the 1\textsuperscript{st} and 2\textsuperscript{nd} order leveling networks.
- The reference surface of the HVD is given by the MSL (1933-1978) at the port of Pireaus.

Orthometric heights of the railway traverse

- Along the railway track orthometric heights are provided at 20 m intervals.
- Observed heights refer to the top of the lower rail track.
- The railway track was surveyed after construction by spirit leveling techniques in loops closed traverses.
Multi-sensor kinematic surveying system: recording vehicle

rail track recording vehicle

- railway diesel coach provided by the Hellenic Railways Organization
- dimensions (11.5 × 3 × 4) m
- max operating speed 100 km/h
Multi-sensor kinematic surveying system: setting up of sensors

- GNSS receivers
- Inertial unit
- Digital odometer installation
Multi-sensor kinematic surveying: data acquisition

- two way survey at maximum running speed 90 km/h
- three GNSS receivers were set up along the travel path (baseline length <15 km)
- survey accomplished night time to ensure continuous recording
- five tunnels (max. length 2.5 km)
Multi-sensor kinematic surveying: data processing

**Input data**
- Multi-sensor (GNSS / INS / DMI) raw data
- Raw GNSS data at reference stations
- Reference stations coordinates
- Relative location of sensors (lever-arms)
- Recording vehicle wheel dimensions

**Output data**
- Rail track axis coordinates \((\varphi, \lambda, h)\) in WGS84
- Recording vehicle kinematics (velocity, acceleration) and quality measures

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**Smoothed Combined - Map TC (3)**

![Map TC (3)](image-url)
Evaluation of GGMs (EGM96, EGM08)

EGM96 - $N^{NAV}$

EGM08 - $N^{NAV}$

$\sim 0.49 \text{ m} \pm 0.06 \text{ m}$

$\sim 0.52 \text{ m} \pm 0.23 \text{ m}$
experimentally derived *geoid separation* along a 100 km railway traverse in Central Greece

a cross-comparison is attempted against GGMs

*orthometric heights* along the railway track at 20 m intervals (as-built plans)

*ellipsoid heights* compute using a multi-sensor kinematic surveying system

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comparison of the observed N (h - H) against modeled N (GGMs) reveal:

1. a good agreement in the geoid separation slope
2. a bias suggesting an offset between the equipotential surface adopted by the GGMs and the HVD
3. the superiority (improved statistical fit) of EGM08 over EGM96 for the test area

the results obtained in this study reinforce the conclusions of recent studies for Greece (*Kotsakis et al, 2008*)