

Sofia, 03.03.2020

**Review**  
**of the PhD thesis submitted by Eng. Othman Al-Kherayef**

Title of the thesis: Geodetic Earth Observations Combination for Vertical Reference System Definition – A Case Study for the Kingdom of Saudi Arabia  
Vertical Datum and Vertical Reference Frame

Reviewer: Prof. DSc Ivan Georgiev, National Institute of Geophysics, Geodesy and Geography

**A short note about the doctoral student**

Eng. Othman Al-Kherayef has a BSc degree in Geodesy from King Saud University in his home county, the Kingdom of Saudi Arabia (KSA), and a MSc degree from School of Military Survey of Great Britain. He had the chance to gain a good deal of professional experience during his service at Military Survey of KSA, where he was responsible for several large-scale geodetic projects.

After Eng. Othman Al-Kherayef moved to the General Commission for Survey of KSA, he transferred his knowledge and experience and contributed to implementing innovative satellite, airborne and terrestrial technologies aimed at introducing advanced geodetic reference systems and setting the most contemporary standards in the fundamental geodetic works in KSA. He is currently appointed to the position of General Director for the General Directorate of Geodesy.

Since 2018 Eng. Othman Al-Kherayef is a doctoral student at Department of Mine Surveying and Geodesy, St Ivan Rilski University of Mining and Geology, Sofia, Bulgaria.

## **General description of the thesis**

The dissertation comprises 211 pages including 3 annexes and six chapters: an introductory first chapter and conclusive sixth chapter, devoted to conclusions, recommendations and contributions resulting from the doctoral research. The research itself is placed in four chapters which form the most significant part of the dissertation. In the list of references are included 78 bibliographical sources.

The extended summary, comprising 53 pages, submitted by the author, fully corresponds to the structure and contents of the PhD thesis.

## **Detailed review**

In the introductory Chapter I is presented information on the current status of the problem how to combine geodetic Earth observations of different type in order to define vertical datums and vertical reference systems. Given are examples from all over the world which provide a proper background for reviewing the situation in this regard in KSA. That gives the author the grounds to set aims and objectives of his research, which eventually to contribute to radical improvement of the existing vertical geodetic datum in KSA.

Chapter II provides a background review of the geometric and physical fundamentals related to the research topic. Outlined are the basics of the height systems and vertical datums definitions as seen from a contemporary viewpoint, as well as the observation methodologies related to vertical reference frame definition, both terrestrial and remote.

A deeper insight into the methodologies used for KSA vertical reference frame definition and realization is given in Chapter III, where the boundary value problem approach is presented along with global geopotential modelling technique using spherical harmonic functions and possible contribution of the latest satellite gravity missions' data. Special attention is drawn to enhancement of classical leveling due to implementation of atmosphere refraction modelling using air temperature measurements. Numerical test results are also given. Following are the basics and some methodology aspects of the sea-level records analysis with regard to implementation in environment typical for the KSA, surrounded by the Red Sea and the Arabic Gulf. Next comes a review of satellite altimetry and its contribution for sea surface topography determination in the areas surrounding each existing tide-gauge.

The chapter concludes with a definition of the multiple-vertical datum problem, a modern approach for combining of heterogenous Earth observations. Three implementation strategies are proposed:

- the direct connection approach completed by levelling, gravimetry and GNSS/Leveling data used for determination of the shift of the GNSS/Leveling geoid geopotential value with regard to a global geopotential model;
- the oceanographic approach – connection of local vertical datums without common terrestrial points by means of oceanic levelling only;
- solving the geodetic boundary value problem (GBVP) for connecting the local vertical datums and computing their offsets with respect to a global equipotential surface.

Chapter IV deals with a detailed description of the data and information available for the numerical experiment which is substantial part of the doctoral research. Amongst the sources of empirical data are GNSS, vertical and gravity networks, satellite altimetry and tide-gauge data. Existing vertical datum solutions are also presented.

Chapter V is devoted to comprehensive analysis of multiple problems related to vertical datum and vertical reference frame definition in KSA: refraction coefficient determination, combining tide-gauge and satellite altimetry data for dynamic ocean and sea surface topography determination, strategies for multiple-vertical datum problem solving. After a brief description of the workflow, experiment data combination results are thoroughly analyzed in each scenario and summarized in final conclusions for the chapter.

In the final VI<sup>th</sup> chapter are placed all conclusions, recommendations and contributions resulting from the doctoral research. Of them are formed several groups:

- I. Conclusions regarding:
  - the problem statement, objectives and the developed methodology;
  - the definition of a new multi-vertical datum problem and its numerical solution;
- II. Contributions related to:
  - the developed methodology for defining and implementing an improved vertical reference frame and vertical datum in KSA;
  - the definition of new multi-vertical datum problem and its numerical solution;
  - significant findings related to the numerical solution of the multi-vertical datum problem.

III. Presentations, where results obtained in the doctoral research are published. Outlined are four works, where Eng. Othman Al-Kherayef is one of the authors.

### **Critical remarks**

The presented for evaluation doctoral thesis is developed in a quite extensive way, including in the first two chapters a lot of details which could be easily found in many textbooks. Instead, topics directly related to the research problems only must have been placed in the introductory part of the dissertation.

Besides the main idea related to solving the multi-vertical datum problem, the PhD thesis covers some subject-specific problems, such as the refraction coefficient determination, tide-gauge and satellite altimetry data analysis, etc. Instead, it would be better to put the focus of the work on the central research problem only.

The contributions included in Chapter VI of the dissertation are formulated in a quite profuse manner, which does not work for achieving a better assessment of the doctoral research.

### **Final evaluation statement**

The PhD thesis subject to this review is completed exhaustively, fully corresponding to the aim and goals set in the beginning. The topic of the research is actual, innovative, significant, and closely related to the author's professional responsibilities. The results achieved are at theoretical and practical level high enough for a doctoral thesis, fulfilling all applicable international standards. Therefore, the author of this research, Eng. Othman Al-Kherayef may be awarded the Doctor (PhD) degree.

Prof. Ivan Georgiev

ЗАПИЗЕНИ ДАНИИ СЪГЛАСНО

Ст. 2 от ЗЗЛД