A Study of the Geoid and Marine Topography in Lagoons

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Abstract

The study of geoid fluctuations in coastal areas is extremely important in understanding the changes in the extent of the Earth's crust and also in the form of the mean sea surface topography (MSST). In recent years, the GNSS-on-boat method has made important steps towards the detailed description of marine topography, achieving precision to the order of a few centimeters, which is much more significant than has been achieved with the alternative satellite and altimetric methods. In this study, the method is applied for the first time in a lagoon, a challenging but exceptionally interesting environment both from a geophysical and hydrodynamic viewpoint. The 'Papas' lagoon in Western Achaia (Greece) was chosen for field measurements. The result for the geoid form shows a peak (13-15cm) in the marine topography approximately in the center of the lagoon. If this is confirmed in other lagoons or lakes, it will constitute a significant contribution to hydrocyanic dynamic models, which currently take as a basic assumption that the surface of the water is level. At the same time, the form of the SST indicates a significant reduction in gravity in the center of the lagoon, which may be linked either with a local reduction in the thickness-density of the Earth's crust or with the existence of underground voids, faults or deposits.

Keywords: geoid, marine topography, lagoons, sea surface topography

Introduction

For the last 27 years the "GPS/GNSS on boat" method has been used to determine sea surface topography (SST) [1]. The determination of sea surface heights (SSH) relative to a reference ellipsoid is one of the problems attracting modern research interest. The evolution of the method has led it to be applied in many different environments, from coastal areas [2-4], open oceans [5-6], to closed seas and river deltas [7-12].

During these 27 years of developments since its first application, the method's accuracy and methodology have improved significantly [1], from the use of a GPS receiver on a buoy [3] to the use of an unmanned surface vehicle (USV) [13]. At the same time, several GNSS methods have been used [11] but the method has also been employed combined with other instruments [13]. All of the above have led to the claim that the method achieves accuracy in the determination of Sea Surface Topography to the order of 2-3 cm [1, 12].

The success of the method thus poses the challenge of achieving centimeter-level accuracy. Achieving such accuracy could track very small surface changes and detect local anomalies in the gravitational field.

In previous research [5-6, 12,14] it was determined that data noise due to sea waves is the main obstacle to achieving high accuracy. For this reason, in the present effort, the environment of a closed lagoon, the 'Papas' lagoon in Western Achaia (Greece), was chosen as the site where the method would be applied. This paper presents the first results from the application of this method.

METHODOLOGY

For the implementation of the "GPS/GNSS on boat" method in the 'Papas' lagoon, a small plastic boat 2.54 m long was used to which two dual frequency GNSS (Sino T300 Plus) receivers were attached at a low altitude from the sea surface (0.37 m). To correct the small oscillation a Gyro-accelerometer was used in the centre of the arrangement between the two receivers as shown in Figure 1. The day on which the experiment was conducted was chosen so that there were very low wind conditions (<3 knots) with no visible wave activity. The boat was propelled by an electric motor at a constant speed of 2.2 knots. The lake was scanned in parallel courses that were 12-18 m apart. As shown in Figure 1, the longest length of the lake was scanned.

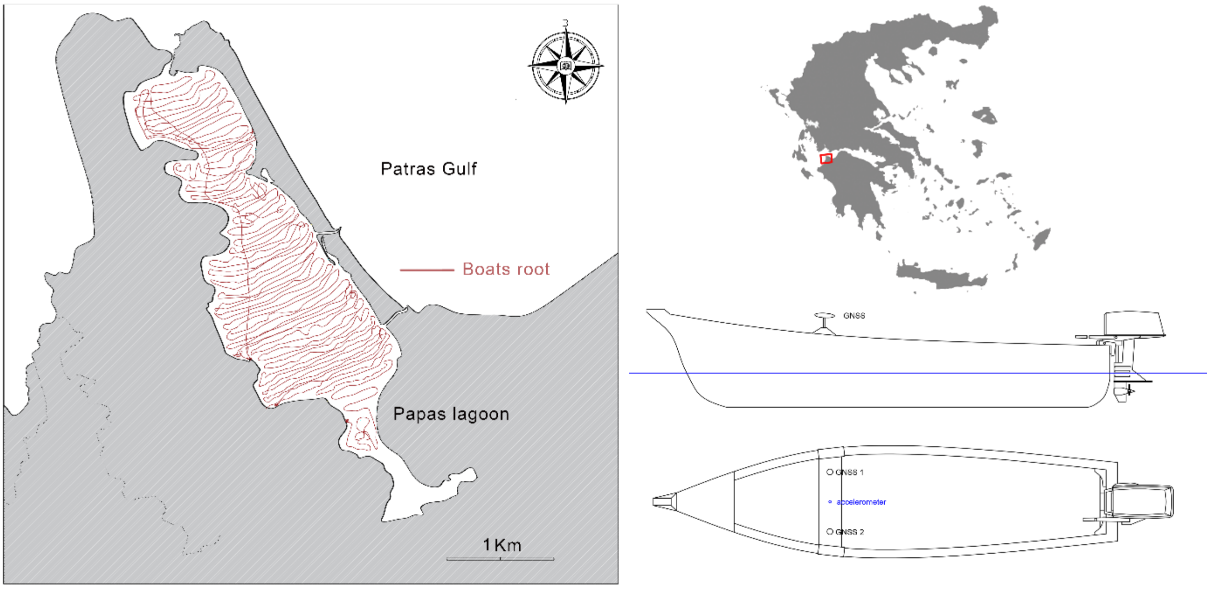

Fig. 1. Study area map, boat roots and a sketch of the boat with the location of the scientific instruments.

Data analysis methodology based on a double-way path D-GNNS method was used in the first path and PPP (Precise Point Positioning) in the second [10, Fig 5.]. Results from the two different raw data analysis methods were compared with each other and the results from the D-GNNS were validated with PPP. To reduce the noise, a moving average Savitzky–Golay filter, based on the least square method, was used. This filter does not only correct the noise of GNSS measurements but also the wave dynamic effect.

Results and Discussion

'Papas' lagoon is a relatively shallow lake (0.5 – 3m depth) measuring approximately 1 x 3 km. It borders the Gulf of Patras and the Ionian Sea. From the analysis of the data using the above method, the SST map for the experimental area was obtained. (Fig. 2.)

As we can observe, the shape of the marine topography presents a peak of 13-15 cm, approximately in the center of the lagoon. This shape captures a small but distinct geoid anomaly in the area. Could this be based on some gravitational anomaly or some hydrogeological phenomenon of lakes? At this stage only assumptions can be made. The shape could also be linked to a local change in the thickness or density of the Earth's crust.

Based on the method we have developed in the past [11-12, 15] and using the well-known error transmission law, an accuracy of 1.3 cm was obtained for the mean SST in the lagoon area. This accuracy may be less than the goal we had set, i.e. an accuracy of less than one centimeter, but on the one hand it is very close and on the other hand it is the best that has been achieved to date. Thus, we can reasonably assume that with upcoming improvements to our method and with the addition of other experiments, the goal of <1 cm can be achieved.

From the above it can be seen that there is a need for further research in more lagoon environments with the aim of investigating this initial observation. In addition, the need for technical and processing improvement of the method is required in order to achieve the highest possible accuracy in the determination of the SST and the geoid.

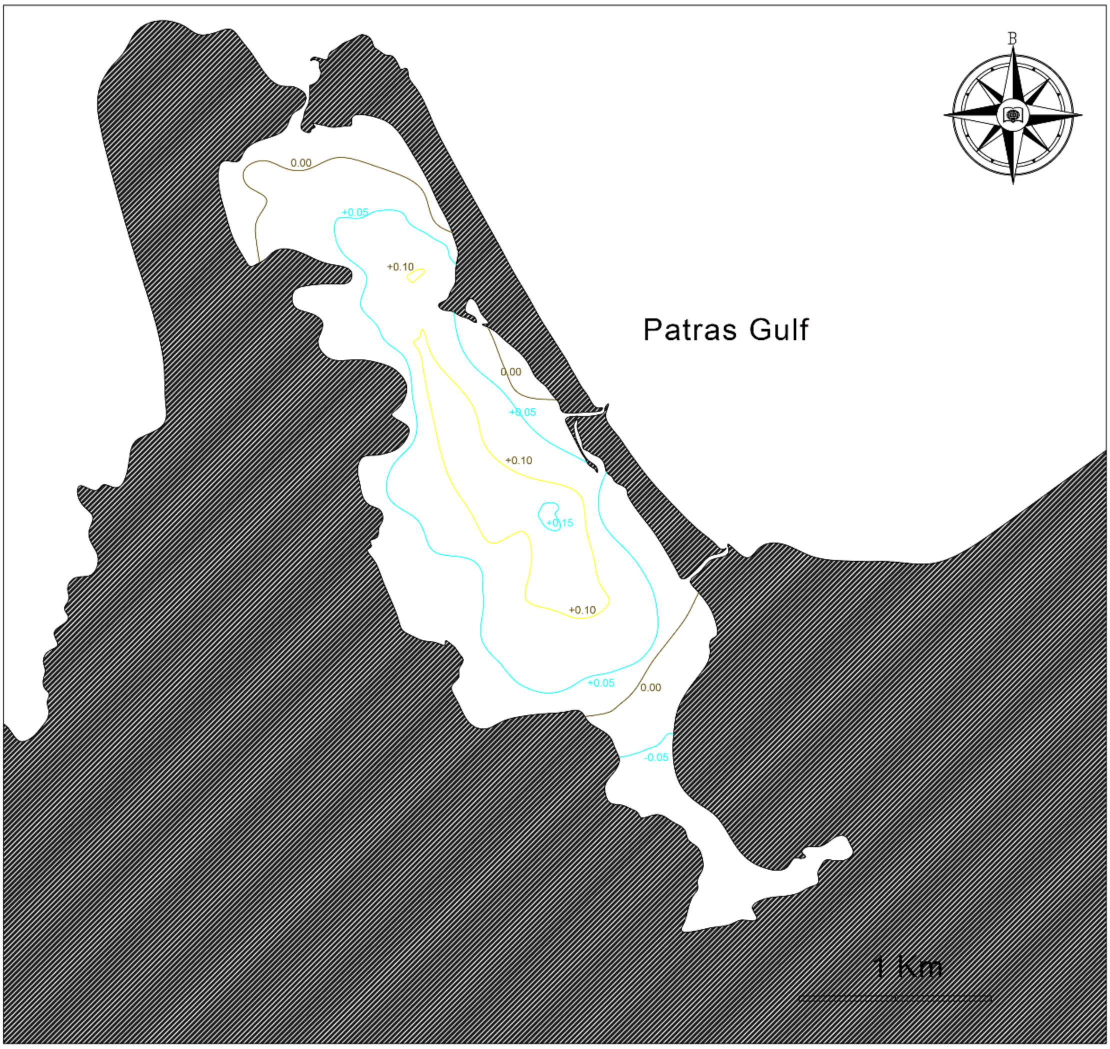

Fig. 2. Sea surface topography in the area studied. The heights were calculated taking the H value 25.21m as zero (referenced to the EGM2008 ellipsoid).

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