# Differences Between GNSS Observations and Tide Gauge Observations in Studying Vertical Land Movements

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***Abstract – This research is devoted to the study of vertical movements of the European crust (the territory of Fennoscandia is taken as an example) on the basis of two independent methods, namely tide gauge and GNSS observations results. The diagram of the velocities of the vertical movements of the one part of European crust (the territory of Fennoscandia is taken as an example) on the basis of the tide gauge data and GNSS observations has been built.***

Key words – vertical movement of the earth's crust, tide gauge, GNSS station.

## I. Introduction

Information about slow movements of the earth's crust (especially in tectonically unstable areas) is becoming more and more necessary when creating the reference geodetic networks, the design of large long-term facilities - ports, canals, hydroelectric power stations.

Today there are different methods of observation of the movements of the earth's crust; in particular, it is explored by the use of geodetic, geophysical, oceanographic and geomorphological methods.

## II. Methods for studying vertical movements of the earth's crust

There are several techniques to study the vertical movements of the earth's crust on the basis of data from sea level. [3], in order to determine the vertical movement of the world's coastline, from the mean value of absolute global sea levels rise in the XX century, which is 1.8±0.5 mm/yr [1], subtracted the values of the relative trends in sea level, obtained from the tide gauges' records. A value of 1.8±0.5 mm/yr is obtained by averaging the tide gauges' records that are located along the world's coastlines. But it should be remembered that there are regions where the trends exceed the global mean sea level in 10 times (e.g., in the Western Pacific and Eastern Indian oceans). Therefore, this approach to the determination of the vertical movements of the crust is not fully justified.

The same technique was used [2] in the study of vertical movements of the Great Britain's crust, but the value of global mean sea level rise is considered equal to 1.5 mm/yr.

Another method [7] of study of the vertical movements of the earth's crust applies accounting oceanic "residuals" and individual seasonal cycle of the stations. Still others include a comparison of satellite altimetry data with concurrent tide gauges' data changes [5], [4]. But the results of altimetry measurements are affected by decadal variations in sea level (such as, e.g., Pacific Decadal Oscillation). So, to avoid this, we need longer time series. Another technique is the use of repeated static GNSS measurements of the datum level on the tide gauge within a certain period of time.

[6] proposed a new approach for the accurate determination of long-term vertical land movements. It is to determine double- differences of the long-term tide gauge records and short data of satellite altimetry. This approach eliminates the use of the absolute value of sea level rise, and thanks to the double subtraction of altimetric rates the authors managed to avoid minor errors in satellite altimetry such as orbital and sea surface pressure errors and altimeter drift.

Our goal is to identify the vertical movements of the crust of the European coastal areas on the basis of tide gauge and GNSS observations.

## III. Comparison of the results from tide gauge observations with the corresponding GNSS observations

Data for the study of time series and selection of tide gauges was conducted using data from the following web-site http://www.psmsl.org, and GNSS stations - using data Nevada geodetic laboratory NGL (Nevada Geodetic Laboratory) web-site http://geodesy.unr.edu/index.php. Monthly and annual series of changes in mean sea level, obtained by a global network of stations, collected and published by PSMPL (Permanent Service for Mean Sea Level). Founded in 1933, PSMSL is responsible for the collection, publication, analysis and interpretation of sea level data from the global network of tide gauges. Geographic location of tide gauges is not homogeneous, because most of them are located in the Northern Hemisphere.

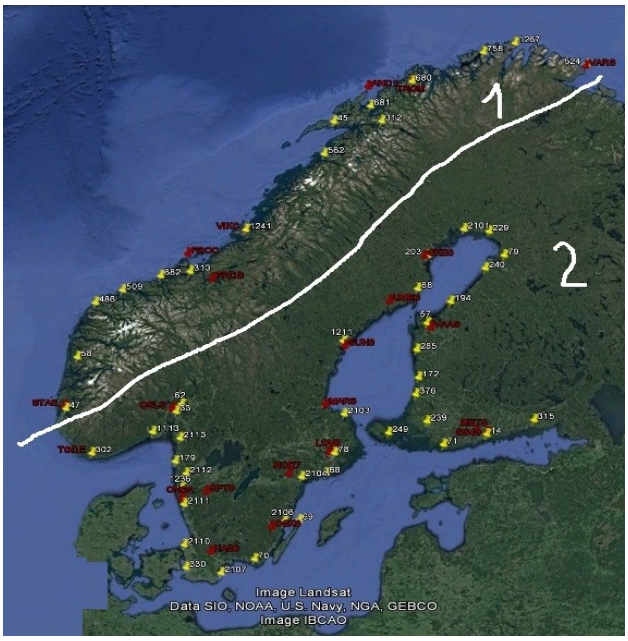


Fig. 1. Schematic placing of selected tide gauge and GNSS stations

For our study we selected all tide gauges and GNSS stations, which are located on the European coast. As an example, we illustrate the first part of the Norwegian coast (Fig. 1). Long-period records of tide gauges and GNSS stations were selected for the study. We determined linear velocity of all selected tide gauges and GNSS stations.

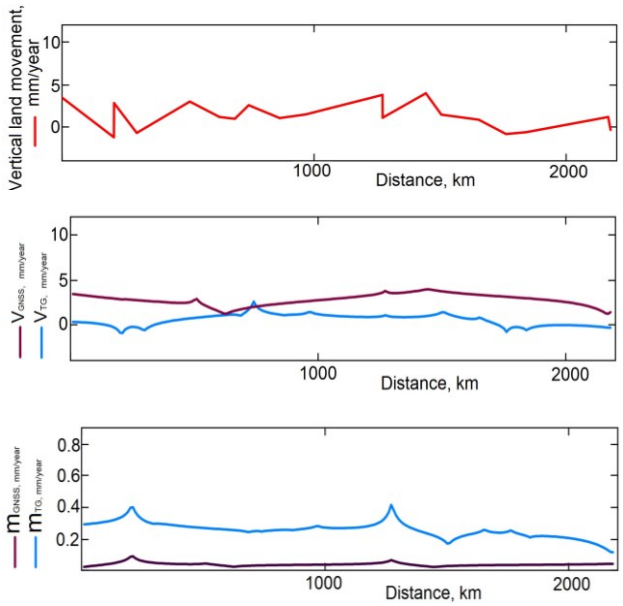


Fig. 2. Vertical land movement (mm/year) according tide gauge and GNSS observations with estimated accuracy (Territory 1)

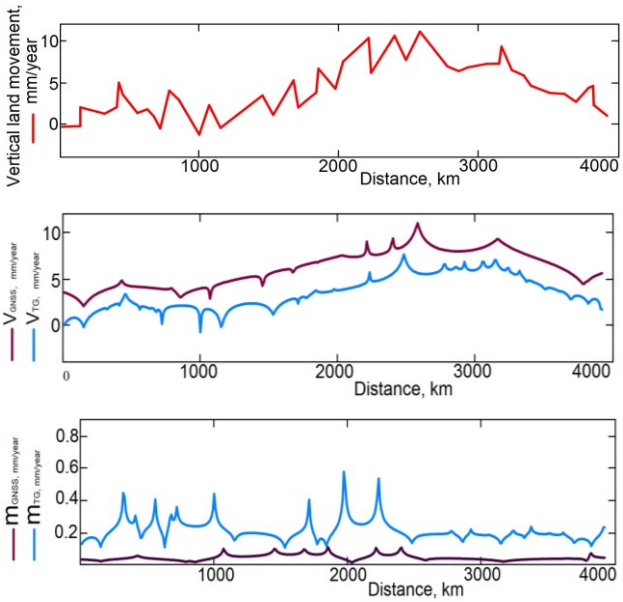


Fig. 3. Vertical land movement (mm/year) according tide gauge and GNSS observations with estimated accuracy (Territory 2)

After using the interpolation method we determined vertical land movement in increments of 10 kilometers.

As can be seen from the analysis of Figs. 1 and 2, there is a constant difference in vertical velocities, determined using GNSS observations and tide gauge observations. Vertical velocities, detrmined by using GNSS observations is greater than the velocities determined by tide gauge observations. For Territory 1 the difference is 2.3±0.9 mm/year, for Territory 2 – 2.6±0.8 mm/year. The reasons for such differences require further researches.

## Conclusion

This research is devoted to the study of vertical movements of the European crust on the basis of two independent methods, namely tide gauge and GNSS observations results. The diagram of the velocities of the vertical movements of the one part of European crust (the territory of Fennoscandia is taken as an example) on the basis of the tide gauge data and GNSS observations has been built. There is a constant difference in vertical velocities, determined using GNSS observations and tide gauge observations. The reasons for such differences require further researches.

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