Objective of the project

The aim of the project is to develop and test the optimal methodology for measuring the groundwater level by means of satellite and ground-based gravimetric measurements and space-time model of the dynamics of these changes

Reasons for choosing the research topic

Water is one of the basic elements needed for life and the economy. Monitoring resources and quality of water is a necessary measure to ensure the safety of the public. Both lack and excess water is a threat. Groundwater is an important source of clean water, for the whole Earth they cover approximately 50% of the drinking water needs, 40% water consumption for industrial purposes and 20% of irrigation use (Zektser i Lorne, 2004). Currently, in Poland it has been observed a lowering of the groundwater level (Barlik et al., 2007; National Water Management, Annex 1 to the draft national water policy 2030, 2010). In Annex 2 of the same draft (points 45,46,47) it has been pointed out the need to develop observation of groundwater: „(…) it is necessary to quickly perform modernization and development of groundwater monitoring system". Currently in Poland, the National Hydrologic Service performs hydrogeological groundwater monitoring tasks currently using for this purpose a network of wells drilled deep enough, equipped with conventional measuring instruments (scales, piezometers). Such measuring methods are very accurate (measure the groundwater level with millimeter accuracies), but they also have their drawbacks. They are expensive, time-consuming, invasive, the measurement results relate to the location of measurement wells. This limits the possibility of creating a global, dynamic models of water circulation.

The concept and methodology of the research

In this project it is proposed to complete the traditional measurements with measurements basing on the Earth's gravity field monitoring. Humidified ground, filled with water is heavier than dry land, without water content. Therefore, the presence of water increases the force of gravity in the area. These changes can be measured by terrestrial or satellite gravimetric measurements. The on-ground measurements, using an appropriate instrument, provide very accurate results (of the order of 1 microgal ≈ 10-8 m/s2), but – as measurements in boreholes – they refer to a specific locations. By contrast, satellite measurements currently achieve lower accuracy (of the order of 1 milligal ≈ 10-5m/s2), however they have a very important feature: they ensure the knowledge of entire Earth's gravitational field with a uniform accuracy. One of such satellite projects, performing measurements of gravity, is the mission GRACE (Gravity Recovery and Climate Experiment). The GRACE mission involves two identical satellites, acceleration of the gravity field is measured by monitoring a difference of orbits of the satellites relative to the orbit calculated for the admitted gravity field model, so you know the differences between the model and the actual field – what, with knowledge of the model field, provides the ability to calculate the actual one. Additionally, these measurements are completed with continuous (10 times per a second) very accurate measurement of the distance between the two satellites. On the basis of the monitored distance, the fluctuations in the gravity field are detected. The resulting GRACE measurements are so precise that – after appropriate processing - they allow to detect anomalies and changes in mass distribution in the vicinity of the under-satellite point , including changes in water content at different depths, also groundwater, with an accuracy of better than 1 cm (Xiao i in., 2015).

These changes reflect the change in the total water content, denoted with TWS (Total Water Storage). Over the oceans, the quantity is interpreted as ocean bottom pressure, while on land as the sum of the groundwater, soil moisture, surface water, snow and ice. From this it follows that in order to obtain changes relating to only one component, such as groundwater, it is necessary to use an additional, independent dataset, enabling the proper separation of the total mass changes budget.

In this project it is planned to use for this purpose the American model GLDAS (Global Land Data Assimilation System), which will allow separation of the observed changes of the masses only those that relate to groundwater. The data must be appropriately filtered to ensure that the measurement errors do not cause misinterpretation of results. The disadvantage of changes in groundwater levels obtained in this way, is low resolution of the results, it means that an accurate to 1 cm groundwater level changes are obtained, which are average change for an area of about 100x100 km. This causes necessity of densification of the results. It is planned to use for this purpose on-ground, highly accurate gravimetric measurements. Common elaboration of the satellite and on-ground gravity measurements will enable to get time series of changes in groundwater levels in a monthly cycle. The choice of temporal and spatial density of the on-ground measurements, as well as the way of their integration with the GRACE data, will be the subject of research in the proposed project. The results will be locally compared to the values obtained from traditional measurements in wells. The next scientific task will be statistical study of the results, the creation of dynamics models of temporal and spatial changes in groundwater levels, investigation of possibilities for reliable prediction of future values of groundwater levels and determination of the accuracy of these predictions.

The project will also deal with another non-invasive method of measuring changes in the gravitational field, which consists in the use of dependence of clock frequencies on gravity field potential. This is the effect predicted by the Einstein's general theory of relativity. In this respect, it is planned to theoretically develop an optimal strategy of clock measurement of gravity field potential changes/differences, including consideration of technical conditions that would have to be met in order for the measurement of this type could have practical significance.

Justification of basic research

Basic research concern development of theoretical principles for integration of satellite and ground gravimetric measurements, selection of the optimal satellite data filtration method, statistical research of the results obtained, theoretical studies on the use of the effects of general relativity in geodesy. The final result of the project will be optimal groundwater monitoring methodology developed and dynamics model of space and time changes of the groundwater level in the chosen area.

Literature

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