Analysis of the Usefulness of GRACE, NOAA and WGHM Models for the Flood Risk Assessment

Monika Birylo [1], Pavel Ditmar [2], Marcin Uradzinski[1]

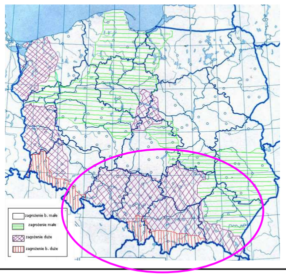
[1] University of Warmia and Mazury in Olsztyn, Faculty of Geodesy and Land Management
[2] TU Delft, Delft Institute for Earth-Oriented Space Research

1. Introduction

Water masses monitoring can have a great importance for example in connection with the implementation of tasks arising from **the Directive 2007/60/EC of the European Parliament and the Council on flood risk assessment and management**. A problem is important due to the massive floods occurring in Poland, especially in the years 1997 and 2010. The Directive introduces the obligation of risk assessment and management of floods.

In a paper the authors try to answer the question how models that are based on GRACE data can be useful in the implementation of tasks arising from the Directive.

Water-related hazards are greatest in the world. The natural water cycle has been considerably shaken by the man. Affect this: inadequate water management, construction of drainage systems, hardening of land by building roads and pavements. These treatments have reduced the retention capacity of soil. Furthermore, human activity has caused flooding limit, which destroys the natural character of the basin.



2. Objectives

Poland is characterized by large flows of water courses, the highest in spring and smallest in autumn and winter months (Fig. 1 – signed with a pink circle). The ratio of maximum to minimum flow is 2.6. The variability of rainfall and flows, and groundwater level makes many periods of water scarcity (adverse effects on vegetation) or periods of flood risk. Both one and the second factor has a negative effect and causes social and economiclosses.

Many years of observation showed that the greatest threats for the Polish cause prolonged heavy rains in parts of the upper Vistula and the Oder, and depressive Żuławy areas.

3. Purpose and Data

For mentioned reasons, it is extremely important to compare models that are based on GRACE data to the results of long-term observation. At the same time an important issue is to predict the potential flood risks. To this end, the pre-processed data obtained from TU Delft. The first study of data from the Level 1b performed by Physical and Space Geodesy, TU Delft, obtaining DMT-1b model for the years 2002 – 2010. Time series obtained for given periods of time, showing the hydrologic phenomena in Poland in monthly intervals. The data was based on interpolated half-degree grid in the five towns flooded during the floods in Poland in 2010: Wilków, Wrocław, Krakow, Warsaw and Włocławek. Since the GRACE data can not reflect millimeters of equivalent water thickness at the point, for the analysis also the closest model grid points grid DMT-1b were used (Fig. 2).

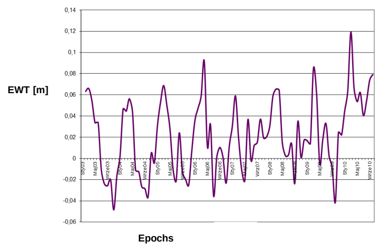


Fig. 2. Time series of equivalent water thickness for model DMT-1b (years 2002 – 2009).

4. Time series of DMT-1b model

In a picture showing the average value of millimeters of equivalent water thickness (EWT) in interpolated grid nodes, supplemented with additional grid nodes closest to five analyzed values. The greatest flow of water masses in the southern Polish occurs in March, while flows are lowest in early autumn. Moreover, the graph shows a significant increase in the value of the equivalent thickness of water in March 2010 (the south of Poland was at that time to a great extent "saturated" with water) and two to three times exceed the average value of the thickness of water in the flood months of 2010, ie in May and June . In March, the average EWT in southern Poland was 0.06 mm, while in 2010 there were twice more - 0.12 mm. In subsequent months, usually equivalent water thickness dropped to 0.02 mm, and in 2010 this state was 0.05 mm. This indicates that the heavy rains falling in March and the water flowing down by melting ice from the mountain caused a huge increase in water level in the spring months. On the basis of the GRACE satellite data, weather forecasts (April, May and June), could be predicted with very high probability of flooding of 2010.

5. Conformation and verification of assumed thesis

An additional element of controlling the accuracy of the analyzes was to include hydrological models. Two models were examined:

1.NOAA LadWorld Monthly Water Storage - National Oceanic and Atmopheric Administration,

2.WGHM - WaterGAP (Global Assessment and Prognosis) Global Hydrology Model.

Meteorological NOAA satellites are low-orbited and can perform Earth mesurement in five-degree spectrum [www.noaa.gov]. Land hydrology model LadWorld NOAA Monthly Water Storage is published for the period: 1980.1 - 2006.11 in monthly single-grid (in the paper was taken into account period: 2003.1 - 2006.11). NOAA model includes snow cover, water, soil, ground water (shallow range), soil temperature, evaporation, water flow, the parameters of light reflection. Data obtained from Global Geophysical Fluid Center (http://geophy.uni.lu/ggfc-hydrology.html) are shown on one chart with data from GRACE measurements (Fig. 3). NOAA land hydrology data have been shifted in such a manner that includes the same reference level for measuring data models for GRACE and NOAA. Next, the scaling in the vertical direction was introduced to match the two analyzed models (Fig. 5). Scaling the NOAA model was performed using the formula below to modify the signal. The value of the coefficient *A* modified model elements (calculated value 0.016) were determined by comparing the original model, NOAA, and the ANS filter.

WaterGAP Global Hydrological Model (WGHM) is a meteorological model that contains the data in the form of half-degree grid. WGHM data are published monthly, composed of the variables on precipitation, number of rainy days in the month, temperature and cloud cover. The most important parameter is precipitation, because it has a significant impact on the water cycle. Currently, data are available for the period: 1951.1 - 2005.12. WGHM is a model which defines the abundance and use of water resources, arises from a combination of water changes caused by natural processes and human activities. The model consists of four components: surface water, snow, groundwater, soil. The data model WGHM, published by Doll et al. [2011], author of the work were made available by Dr. Heike Hoffmann-Dobrev from the Institut für Geographie Physische, Goethe-Universität Frankfurt. Modification of the coefficient (a value of 0.0065) WGHM model and used to calibrate the original model (Fig. 4). Model after calibration is shown in Fig. 6.

$$\sum_i^N (S_i^P - A S_i^F)^2 \qquad (1)$$

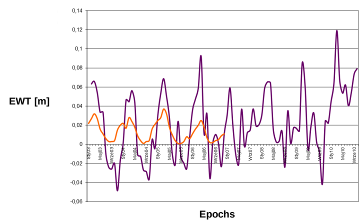


Fig. 3. Equivalent Water Thickness – GRACE model + NOAA model for period 2003.1 – 2010.12

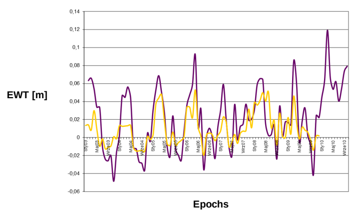


Fig. 4. Equivalent Water Thickness – GRACE model + WGHM model for period 2003.1 – 2010.12

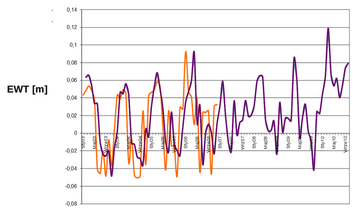


Fig. 5. Equivalent Water Thickness – GRACE model + calibrated NOAA model for period 2003.1 – 2010.12

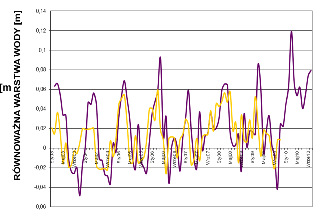


Fig. 6. Equivalent Water Thickness – GRACE model + NOAA model for period 2003.1 – 2010.12

5. Summary and conclusions

As a result of the modification and displacement convergence of NOAA hydrology model with the GRACE model, as shown in figure 5 the values of equivalent water thickness formed on the basis of time series of two developed models were characterized by a very high degree of similarity.

To check the validity of the adopted thesis, the model WGHM with observations GRACE were compared (Fig. 6), taking into account the additional resource in the ground water. The model WGHM showed even better correlation with GRACE model than the first analysis.

On the basis of the analyzes it can be stated that GRACE observations are very useful for monitoring the climate. The climate monitoring can and should be used to monitor the flood periods in Poland and the implementation of tasks arising from the Directive 2007/60/EC of the European Parliament and the Council on flood risk assessment and management.

6. Bibliography

1. Döll, P., Hoffmann-Dobrev, H., Portmann, F.T., Siebert, S., Eicker, A., Rodell, M., Strassberg, G., Scanlon, B.R. 2011. *Impact of water withdrawals from groundwater and surface water on continental water storage variations*, Journal of Geodynamics.
2. the Directive 2007/60/EC of the European Parliament and the Council on flood risk assessment and management.
3. Mioduszewski W., Pasternak A. 1995. *Ochrona przeciwpowodziowa na obszarze Żuław*. Inżynieria Morska i Geotechnika 6.
4. Klęski żywiołowe. 1993. Prognoza, zapobieganie. Warszawa, IMiGW
5. www.noaa.gov, 28 marzec 2012

7. Acknowledgements

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