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Uncertainty in estimated water cycle determined with atmospheric budget, water budget and total water storage

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Abstract: An intensification of the global hydrological cycle is highly determined by a climate change. But an essential part of human being is fresh water availability. The availability can be computed as a difference between precipitation and evapotranspiration, which can be taken exactly from GLDAS (from Global Land Data Assimilation System) models. For the purpose of water cycle analysis, a water storage is needed, here, observations from GRACE (Gravity Recovery and Climate Experiment) were used. GLDAS (Global Land Data Assimilation System) is based on both, simulation and prediction models and observed data in a long-term period, which are merged. The data is in a form of gridded meteorological dataset at the global scale. The aim GLDAS is integration and a land information system preparation. The result is a set of parameters, consisting of water storage, energy storage and fluxes. Post processing is carried out to Limiting bias caused by an atmosphere and constraints that are resultant of the land surface states is obtained during postprocessing. The aim of the study is to estimate atmospheric budget on a basis of precipitation and evapotranspiration differentiate, considering Poland as a case study.

Key words: atmospheric budget, precipitation, evapotranspiration, GLDAS, GRACE

1. INTRODUCTION

Due to climatic changes, there is a need of water supply constant monitoring. Currently, in Poland components of the water and energy budgets in a large scale are very sparse. Estimation large-scale P-EV budget is provided by Seneviratne et al. (2004), Roads et al. (2003), Swenson and Wahr (2002) and Ropelewski and Yarosh (1998).

In the paper I try to measure the flux of total water between the surface and the atmosphere. This can bring me information about the interaction of land and atmosphere. As a comparison, a water budget is presented, and total water storage from GRACE. Among all data, I chose GLDAS, and GRACE models.

2. COMPONENTS ANALYSES

For the purpose of the atmospheric budged computation, two parameters are considered: precipitation and evapotranspiration. Amount of rainfall/snowfall is the volume of rain/snow in an imaginary cubic container that collects rain/snow during some period. A very important part is to define the intensity of a rainfall/snowfall. It can be described as depth of water/snow received during fall, but divided into smaller periods of time (f.e. 24 hours divided into one hour periods). It is usually expressed in millimetres of water depth per hour. Among all factors that influenced an effectivity of the rainfall/snowfall we can distinguished: climate, soil texture, soil structure, depth of the rootzone, topography, initial soil moisture content, and irrigation methods.

It is important to be aware that some of water falls and stays on a soil, some is infiltrated into the soil (the amount is dependent on a soil type), and some run-off. The part of water that stagnates on a soil starts evaporating into the atmosphere. The second way of leaving water, but this time from by plant's leaves and stems is called transpiration.

Total amount of water transpired by the plants and water evaporated from a soil is called the evapotranspiration. The unit of the evapotranspiration is millimetres per period of time. The biggest influence on the volume of the evapotranspiration has: climate, type of crop and soil moisture.

For the purpose of the water budget computation, a surface runoff component needs to be added. Surface run-off mainly is dependent on the neighbourhood of flows and basins.

Computed atmospheric and water budgets are then compared to the total water storage (TWS) values taken from GRACE model. The TWS change is the sum of water components, like water stored in land, rain and snow falls, infiltrated into the soil, evaporated, transpired and stored in the basins or steam flows. The TWS values are dependent on the chosen location.

All the parameters are described, presented in the graphical form and analysed in the paper.

3. METHODOLOGY

The main factor important for climate system is a stable atmospheric budget. Monitoring the process is especially important nowadays due to climate warms (Collins et al., 2013). Atmospheric balance calculated over land lets us observe the sum of surface and sub-surface run-off. The expected magnitude changes are much smaller over land than over large basins. As stated by (Byrne and O'Gorman, 2015), analysing P-EV changes gives positive result or about zero. It is caused by the fact that precipitation is always larger than evapotranspiration in the time mean over drained surface, as land (Byrne and O'Gorman, 2015).

Under climate change there are many uncertainties of rate of seasonal and annual precipitation and evapotranspiration, and thus atmospheric budget - measured as a difference between P-EV. The second analysis was comparison between water and atmospheric budget. The amount of water entering or recharging the system is the water budget. It is well known, that water stored in the water cycle is constant. But all fluxes depend on climatic conditions (Smith and Ummerow, 2012). A water budget is computed as a difference between atmospheric budget and surface run-off.

For the purpose of water cycle understanding two sets of data are used: GLDAS (Global Land Assimilation System) and GRACE observations (Gravity Recovery and Climate Experiment). For the purpose of the research the following cells were taken into consideration:

- the cell including Olsztyn,
- the cell including Lublin, according to National Water Management Ministry Bulletin location with the highest values of the annual temperature considering a period 1951 – 2015; it is supposed to observe the highest values of the evapotranspiration,
- the cell including Jurgow, according to National Water Management Ministry Bulletin location with the highest values of the annual precipitation considering a period 1971 - 2015.

4. DATA

The GLDAS model is the kind of model globally consisting of 28 different fields, which are the geophysical parameters. GLDAS is published in a form of four sub-models (land surface models) – VIC (Variable Infiltration Capacity Model), NOAH (National Centers for Environmental Prediction/Oregon State University/Air Force/Hydrologic Research Lab Model), Mosaic Land Surface Model and CLM (Common Land Surface model. The aim of the GLDAS is to present land surface states and fluxes. The concept of the GLDAS is to distribute energy and water budget components (Rodell et al. 2004); (Zaitchik et al. 2010). GLDAS data was provided by: Mocko (2012) and Rodell and Beaudoing (2015). In the paper, the values recomputed into the total water storage (TWS) were derived from GRACE data, using CSR RL05a as source data. In the post-processing, the DDK5 filter was used and the degree of the GRACE gravity coefficients was set to 60. All measurements were prepared for the one-degree cells 1, for the period 2006.01-2010.12.

5. RESULTS

5.1 Atmospheric budget determination

The analyses aim at comparison of the values of P and EV given in the GLDAS NOAH sub-model, which is the closest to in-situ measurements among all GLDAS sub-models (Pennemann et al., 2016). Values of the precipitation P for the Olsztyn, Lublin and Jurgow cells are given in the Fig. 1. As it is seen, the values range from zero to 0.000000081 kg/m^2/s. It can be also observed that values of the precipitation are growing over years 2006-2010. It needs to be also remembered that in 2010.05 - 2010.09 a tremendous and catastrophic flood occurred in Poland, especially in the southern part. The flood was the result of a huge rainfall in Poland and that is the reason of the chosen period of the research. As it was supposed, the biggest values of the precipitation are recognized in the Jurgow cell (it is convergent with the National Water Management Ministry Bulletin). Annually, the highest values of the precipitation are observed every August, but every August bigger in the tested period. Values near zero are at the beginning of the springs and the autumns. The shape of the graph in every tested cell is similar, but the amplitude is different. The smallest amplitude is observed in Olsztyn cell.

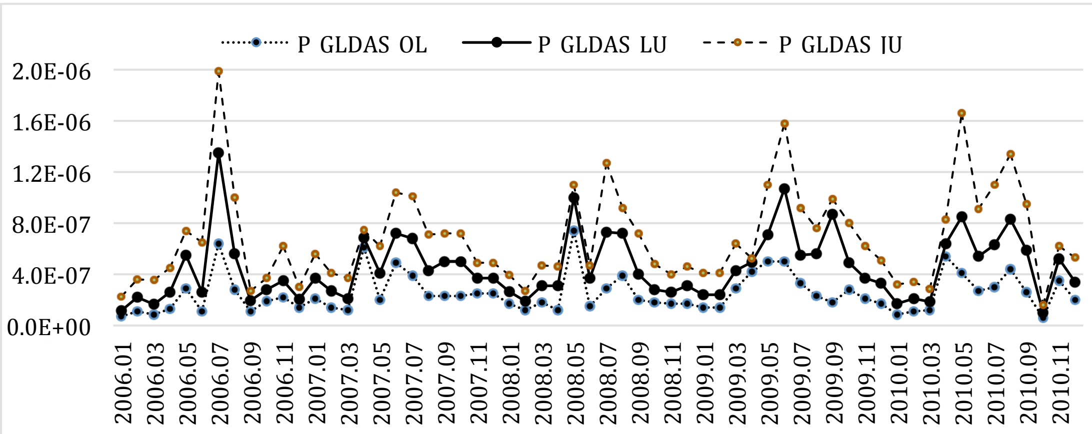

Figure 1. Precipitation values for the cell of Olsztyn, Lubin, Jurgow cells for the period 2006.01 – 2010.12. Unit: kg/m^2/s

Evapotranspiration values are presented in the Fig. 2. Samely, the highest values are observed in the Jurgow cell. Values are between 0 and 0,000034 kg/m^2/s. The highest values are in Julys. From Novembers and Marchs values achieve zero (winter, values zero or below zero Celsius degrees – almost no evapotranspiration).

Table 1 analysis let me assume and better percept that in the tested period values of the annual precipitation are growing; from 0.0001752 kg/m^2/s up to 0.0003147 kg/m^2/s in Olsztyn, from 0.0001495 kg/m^2/s up to 0.0002456 kg/m^2/s in Lubin, from 0.0002152 kg/m^2/s up to 0.000344 kg/m^2/s in Jurgow cells. But, when final values are considered, surprisingly sums are similar. Analysing annual evapotranspiration let us conclude that there is no trend. The highest values of the evapotranspiration are in 2007, the smallest in 2006. Total sum for the five researched years are similar for every location.

The aim of the research was to differentiate precipitation and evapotranspiration to achieve values of the atmospheric budget (Fig. 3). Values are between -0.000030 kg/m^2/s and 0.000060 kg/m^2/s. The shape of the graphs is similar for the three tested cells. The highest amplitudes are noticed are in Jurgow cell, while the smallest in Olsztyn cell. So, it can be concluded that in Jurgow cell precipitation values are much higher than evapotranspiration. It needs to be added that the highest month values of the atmospheric budget in Jurgow says that surface run-off values should be the highest. Other factors are not considered now. The highest values of surface run-off can be the effect of a bluff slopes and rocky soil which infiltrate small volumes of water. The smallest values of the atmospheric budget are noticed in Olsztyn cell. It can be stated that the highest values of the atmospheric budget can be observed in every tested cell in Novembers and Decembers, a little bit less in Januaries and Februaries. These are winter moths in Poland, characterized with temperatures about or below zero and with short days – low sun radiation. As it was supposed, these mentioned months can be distinguished with huge amount of precipitation (snow and rain, both) and very little evapotranspiration. On the other hand, in Junes and Julies the smallest differences between P and EV are observed – summer in Poland, log sunny days. In the researched period, in the Olsztyn cell the same values of a low atmospheric budget are noticed in Marches and Aprils. In Lubin and Jurgow cells, low values of P-EV (but a bit higher than in Jan., Feb., Nov. and Dec.) are observed in Aprils and Mays.

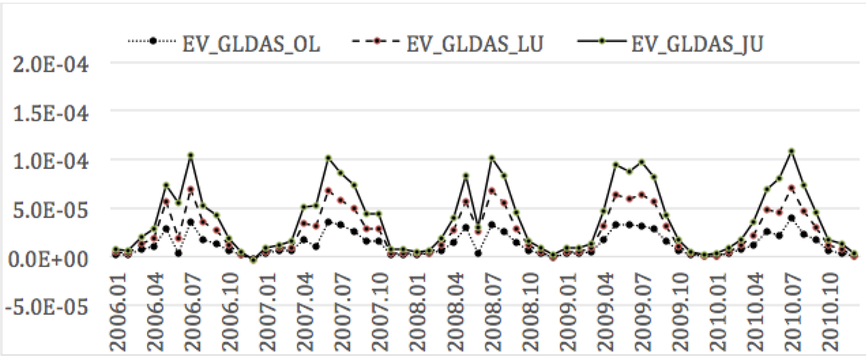

Figure 2. Evapotranspiration values for the cell of Olsztyn, Lubin, Jurgow cells for the period 2006.01 – 2010.12. Unit: kg/m^2/s

Table 1. Annual analysis of P and EV values.

	Sum P_GLDAS_OL	Sum P_GLDAS_LU	Sum P_GLDAS_JU	Sum EV_GLDAS_OL	Sum EV_GLDAS_LU	Sum EV_GLDAS_JU
2006	0.0001752	0.0001495	0.0002152	0.0001609	0.00014988	0.000164422
2007	0.0002801	0.0002165	0.000237	0.0001946	0.0001708	0.0001932
2008	0.0002214	0.0002264	0.0002272	0.00017755	0.000172241	0.0001767
2009	0.0002942	0.0002343	0.000291	0.0001809	0.00015828	0.0001746
2010	0.0003147	0.0002456	0.000344	0.000181421	0.00015006	0.0001783
Final sum	0.0012856	0.0010723	0.0013144	0.000895371	0.000801261	0.000887222

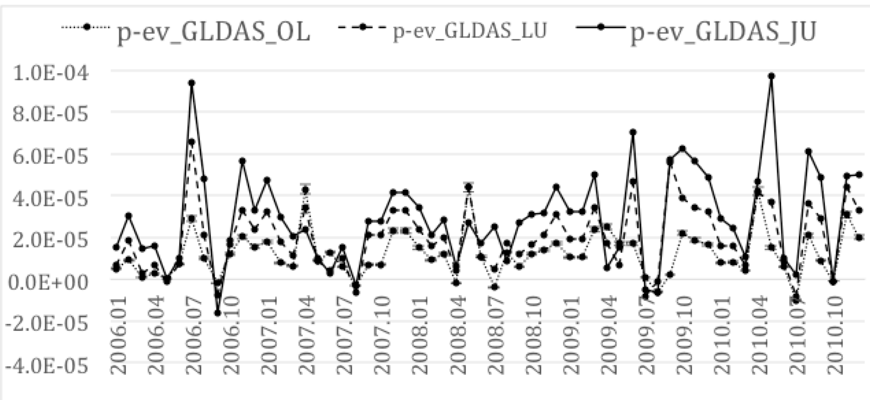

Figure 3. Atmospheric budget values for the cell of Olsztyn, Lubin, Jurgow cells for the period 2006.01 – 2010.12. Unit: kg/m^2/s

5.2 Comparison to water budget

The results of the computed atmospheric budget were compared to computed water budget. The aim of the research was to check how important is surface run-off in the three locations. Results are presented in Fig. 4 and 5. Firstly, surface run-off was analysed. In the years 2006-2008, from Julies to Januaries, values of the surface run-off are almost the same. Some peaks are observed about Mays, especially in Jurgow cell (from about zero up to 3.0 e^{-6} kg/m^2). From April 2009, many peaks are monitored, especially in May 2010 (the time of flood in Poland – a lot of rain, many water runoff).

Having three values: P, EV and SRO, I could compute the water budget for the period 2006.01-2010.12. The result is presented in the Fig. 5. Shapes of all three graphs are very like those presented in the Fig. 3. Values are the same when comparing atmospheric budget and water budget or values of water budget are a bit higher than atmospheric budget. Small differences are noticed about Mays up to 2009. From 2009.04 differences between atmospheric budget and water budget become bigger and bigger, grow up from 0.0 to 0.00005 kg/m^2/s.

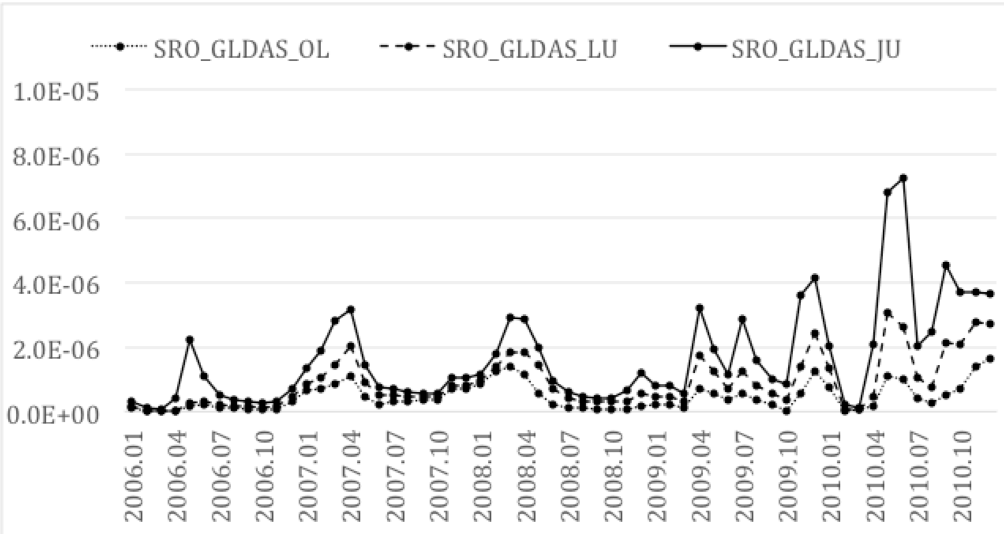

Figure 4. Surface run-off values for the cell of Olsztyn, Lubin, Jurgow cells for the period 2006.01 – 2010.12. Unit: kg/m^2/s

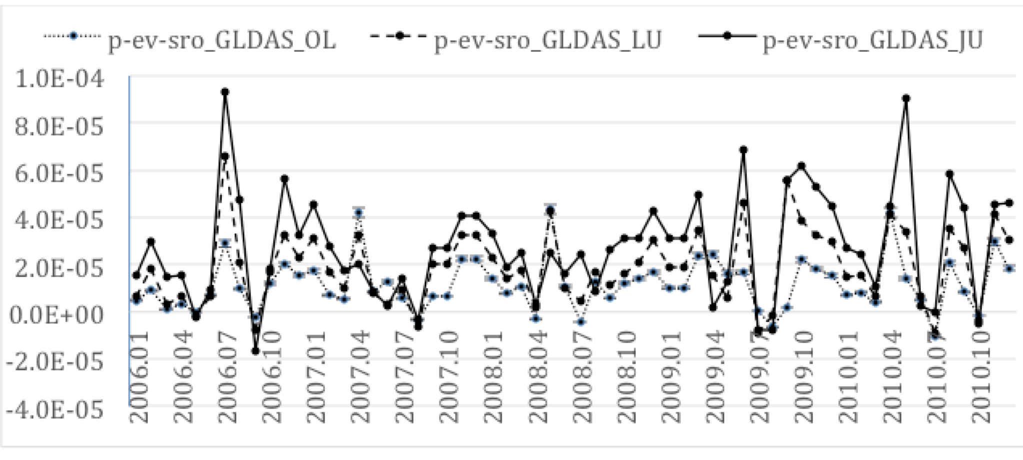

Figure 5. Water budget values for the cell of Olsztyn, Lubin, Jurgow cells for the period 2006.01 – 2010.12. Unit: kg/m^2/s

5.3 Comparison to GRACE

The last part of the paper was to compare atmospheric budget and water budget with the values of the total water storage from GRACE observations. Results are presented in the Fig. 6, 7 and 8. When analysing Olsztyn cell (Fig. 6) we can observe very small differences between the three presented observations. Values are from -0.16 to 0.12 m. It can be said that other factors (like water in canopies, groundwater, basins,) are not very important in Olsztyn cell and does not play a big role when comparing to atmospheric budget and water budget. It need to be added that in 2010 there were no flood in Olsztyn. This can be seen in the graph, situation id stable over five researched years. Lubin cell (Fig. 7) is stable till the end of 2008, values of the TWS are very like atmospheric budget and water budget. The range of the differences is -0.15 – 0.10. It becomes different at the beginning of 2009. Here, TWS is even two times bigger than water budget. It need to be concluded that in Lubin cell surface run-off from 2009.01 has bigger influence and the other factors are very important in this cell and need to be considered. The same situation is observed in the Jurgow cell (Fig. 8) – a stable situation till 2008.12, many peaks and differences between presented values from the beginning of 2009. But now, values of TWS are even three times bigger than water budget. Here, also other factors are important.

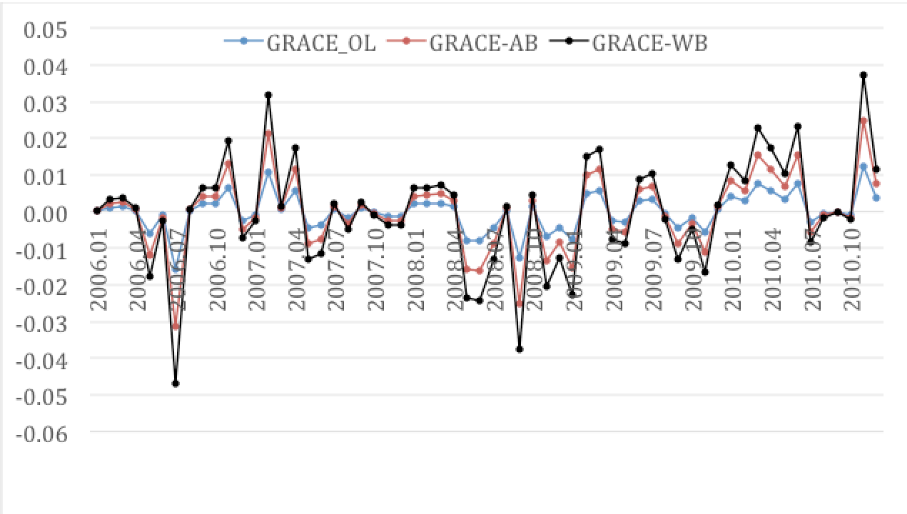

Figure 6. Total water storage derived from GRACE (unit: meter), difference between GRACE and atmospheric budget (unit: meter), difference between GRACE and water budget (unit: meter) for Olsztyn cell

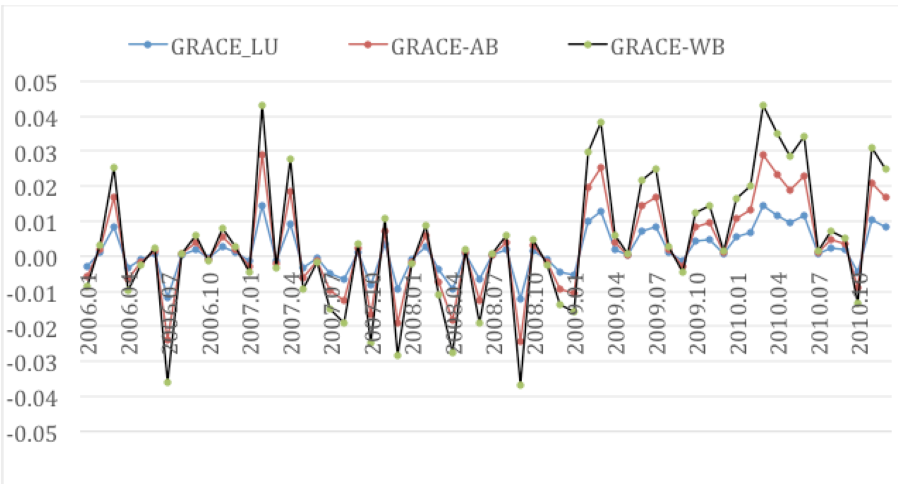

Figure 7. Total water storage derived from GRACE (unit: meter), difference between GRACE and atmospheric budget (unit: meter), difference between GRACE and water budget (unit: meter) for Lubin cell

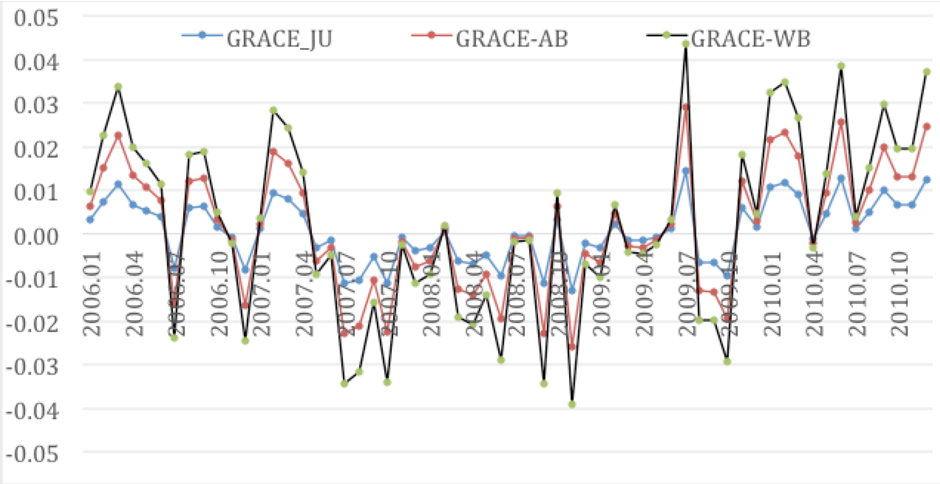

Figure 8. Total water storage derived from GRACE (unit: meter), difference between GRACE and atmospheric budget (unit: meter), difference between GRACE and water budget (unit: meter) for Jurgow cell

6. CONCLUSIONS

The research was performed relate to the area the three cells of Poland, located in Olsztyn cell, Lubin cell and Jurgow cell. The aim of the study was to determine the atmospheric budget in and analysing compatibility between atmospheric budget and water budget and total water storage. For the purpose of the research two models were used: GLDAS and GRACE. The aim of the paper was to examine three observations on this terrain, in the context of its data required for computation of variations.

It seems that the highest amplitudes of the atmospheric budget are noticed are in Jurgow cell (precipitation is bigger than evapotranspiration, while the smallest in Olsztyn cell). It can be concluded that the highest values of the atmospheric budget can be observed in Novembers and Decembers, a little bit less in Januaries and Februaries; in Junes and Julies the smallest values are observed.

Comparing atmospheric budget and water budget let me conclude that water budget values are a bit higher than atmospheric budget. Small differences are noticed about Mays up to 2009. From 2009.04 differences between atmospheric budget and water budget become bigger and bigger, grow up from 0.0 to 0.00005 kg/m^2/s.

When comparing water budget and atmospheric budget to the total water storage values I could state that another factor is very meaningful, especially from 2009. In Olsztyn cell situation of the three observations is stable during five analysed years. Lubin and Jurgow cells are stable till the end of 2008, values of the TWS are very like atmospheric budget and water budget. From 2009, in Lubin cell, TWS is two times bigger than water budget; in Jurgow cell three times bigger than water budget. Other factors are important.

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