Snow storage formation specifics for the Neman river basin

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Along with the flooding estimation, published in the Cabinet Council of Belarus Regulation «On Approve of the Republican program "Engineering hydroeconomic measures to protect population aggregares and agricultural areas from floods in most flood-unsafe regions of Polesie for 2011-2015 years", spring flood annually covers substantial territories, causing noticeable harm to national economic. Under increase of the environment landscapes technogenic transformation, problem of lands protection from natural physical and climatic effects also becomes more significant. Flood protection of territories is mainly done with use of technical (hydrotechnical) constructions controlling the water body, and planned organizational actions. Not least important is prediction of the natural and climatic acts, their evolution and economic consequences.

Main sources of peak water discharges, which provide the possibility of material loss and social injury, are snow storages at the beginning of the active snow melting period. Beside snow cover, substantial contribution to spring flooding is done by the weather conditions. Thus, having an estimation of the water amount in the form of snow on the river basin, one can predict runoff volume of the river. Midterm temperature and fallout forecast, in their turn, allow to estimate snow melting intensity and thus the maximum river discharge at flooding.

Inequality of snow cover over the basin makes it difficult to estimate the snow storage and the amount of water in it. Observed values of snow thickness and its density are corresponding to the placement of snow courses, but snow forming conditions are inhomogeneous over the territory. Beside of landscape differences (swamp, forest, field) snow accumulation is also substantially influenced by anthropogenic impact. These conditions make it non-purposeful to map or even interpolate measured depth values of the snow cover to the whole river basin.

Methods of geographical analysis and forecasting are widely used nowadays practically in all spheres of the economic activity, including appearance and evolution of dangerous hydrological phenomena, like water-logging and flooding, as shown by Volchek at al. (2010). Main information sources in this case are results of the remote scanning and sensing of the Earth surface and atmosphere. Development of microwave diagnostics in aerospace observations have become an important level of the whole remote Earth sensing. Remote images examination and understanding for the “Earth surface – atmosphere” system have carried out the new opportunity to study earth objects. Obvious advantages of microwave diagnostics, mentioned by Sharkov (2004), such as possibility to get information in any time, wide weather conditions range, and sunshine independence, have brought a lot of attention of the researchers.

Snow storage is estimated using space observations for a long time, particularly based on passive microwave radiation measurements with use of MODIS SSMR and MODIS SSM/I platforms, according to Kitaev et al. (2010). This approach allows to generally estimate the snow storage distribution over the basin. Data themselves are digital analogues of daily maps of snow storage for the whole globe with a regular grid of 25 km size. The grid size makes approach useful on large basins only (about 1000 km^2 or more). Along with Chang et al. (1982), snow storage restoration model is based on the following equation:

$$S = 4,8 \cdot \left(T18H - T37H\right)$$

where $T18H$, $T37H$ are brightness temperatures in 18 and 37 GHz channels on a horizontal polarization.
Equation was produced for SSRMR data, and further detailed for SSRM/I data in case of different frequencies:

$$S = 4,8 \cdot \left(\left(T19H - 5\right) - T37H\right).$$

Based on these formulas we have calculated the estimate of snow storage accumulation for the Neman river basin territory. Most interesting from the spring flood forecast point of view are such factors as snow accumulation maximum and summarized accumulation through the cold period of a year. Summarized accumulation is a sum of snow cover increments. Accuracy of the remote sensing results was checked by the factor of snow cover accumulation and melting balance. These characteristics are shown in table 1 in the form of a water equivalent.

Maximum of the snow storage on a basin S_Σ can be used for midterm forecast of the river maximum discharges, as these parameters are not changing after the beginning of a melting period.

At preliminary stage of the research, it was find out based on the paired linear correlation factor, that statistical connection is not high for factors individually ($r \le 0,35$). But in case of multiple correlation connection this factor is increasing up to $R = 0,65$ at its critical value of $R_{\text{krit, 5\%}} = 0,40$. In this case we have following statistical model:

$$Q'_{\max} = 254 + 22 \cdot S_{\max} + \frac{30}{1 - \dfrac{S_{\max}}{S_\Sigma}}$$

Table 1 Maximum snow discharge and accumulation over the Neman river basin

years	Maxi-mum dis-charge, Neman river, Grodno, $\bar{Q}_{\max}$, m^3/s	Maxi-mum value of snow storage, $S_{\max}$, mil. m^3	Summa-rized accumula-ted snow storage, S_{Σ}, mil. m^3	accumu-lation and melting balance, m^3
1989	262	9,78	10,92	0,0
1990	320	2,44	5,39	-34
1991	445	8,11	14,07	0,0
1992	320	1,81	5,89	0,0
1993	456	4,08	8,04	0,0
1994	845	8,24	18,58	0,0
1995	451	7,44	16,62	0,0
1996	840	7,79	16,63	0,0
1997	308	5,33	9,38	0,0
1998	350	4,98	10,59	0,0
1999	692	4,03	8,75	0,0
2000	359	3,25	7,64	0,0
2001	288	0,77	2,31	0,0
2002	475	1,24	4,81	-96
2003	424	6,16	14,66	62
2004	192	1,43	3,03	0,0
2005	455	10,85	17,78	-56
2006	631	4,94	11,44	0,0
2007	517	2,14	6,63	0,0
2008	312	5,74	10,10	0,0
2009	338	3,40	11,70	0,0
Ave-rage value	442	4,95	10,24	-6
Dis-per-sion	174	2,85	4,68	-

To check the model reliability, 2010 year data where removed from the database. Equation brought out maximum discharge of Neman river at Grodno city equal to $Q'_{\max} = 447$ m^3/s, while observed value was $Q_{\max} = 436$ m^3/s, and so predicted one is in 95 % quantile.

Statistical model allows to estimate conditions of the snow accumulation. The $\frac{S_{\max}}{S_{\Sigma}}$ ratio determines which part of the snow have been melted while the period of maximum snow store forming, so the more close is this value to 1, the biggest part of the snow would form the spring flood. The $S_{\Sigma} \geq S_{\max}$ condition may exist for snow maximum accumulation in theory, but real basins always have $S_{\Sigma} > S_{\max}$. For more accurate maximum discharges forecast one should take into account conditions of snow melting after the maximum snow storages are formed. It is possible on the basis of climate factor analysis (air temperature, atmospheric condensation, etc.). Also with snow melting intensity factor and in case of continued tendency it seems to be possible to estimate the runoff volume for a concrete year spring flooding. Maximum discharge should be determined in this case by the analysis of the typical spring flood hydrographer for the concrete river.

Presented approaches allow to predict average value of the maximum river discharge depending on the accumulated snow storage, thus providing the possibility to carry out necessary actions in advance to lower negative effect of territories flooding. Statistical models instead of complicated physical and mathematical models allow in this case to avoid rough errors caused by multiple local factors and specifics.

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