Responses to anonymous Reviewer #2

We thank the respected reviewer for the criticism that helped us in improving the manuscript. Below our responses to all criticisms of the reviewer are presented.

Specific Comments

1. p5506/L12-16 this description is very similar to the 'ANSA' snow product suite described in Foster et al, 2009, International Journal of Remote Sensing (accepted). This paper should be referenced

The earlier paper of the same authors is referenced in the Introduction of the revised manuscript.

> "A joint U.S. Air Force/NASA blended, global snow product named 'ANSA' utilizing both MODIS, AMSR-E and QuikSCAT sensor data has been developed and presented in (Foster et al., 2007)."

Foster, J., Hall, D., Eylander, J., Kim, E., Riggs, G., Tedesco, M., Nghiem, S., Kelly, R., Choudhury, B., Reichle, R. (2007) Blended visible, passive microwave and scatterometer global snow products. Proc. 64th Eastern Snow Conf., St. Johns, Newfoundland, Canada 2007, p. 27-36

2. The detailed descriptions of the snowpack & runoff models is too detailed for this paper since the focus of this paper is on the performance of the models when used together. Since the details are previously published, just cite the appropriate papers.

Some of the details of the model were not published in English so we tried to describe them in the revised manuscript.

3. Right now, the paper has lots of detail on the input data used in the study, the models used, but too little detail on the results & the interpretation of the results.

The following details on the results and their interpretation are added in the revised manuscript

3.1 We carried out an additional test of the model to assess its ability to predict SWE. As a result, the following paragraph is added in the end of Section 3.

> "In order to test validity of the model calibrated against the snow depth measurements in predicting SWE, we used the snow survey observations within the Vyatka basin for 9 snow seasons: from 1971-1972 to 1979-1980. Both snow depth and SWE observations are available for that period. The model demonstrated satisfactory accuracy in predicting SWE for 9 seasons: the overall mean error is 1.2 mm, the root mean square error is 10.6.mm."

Figure illustrating the results of SWE simulations for 9 seasons at one of the meteorological stations is shown below (this figure is not included in the manuscript).

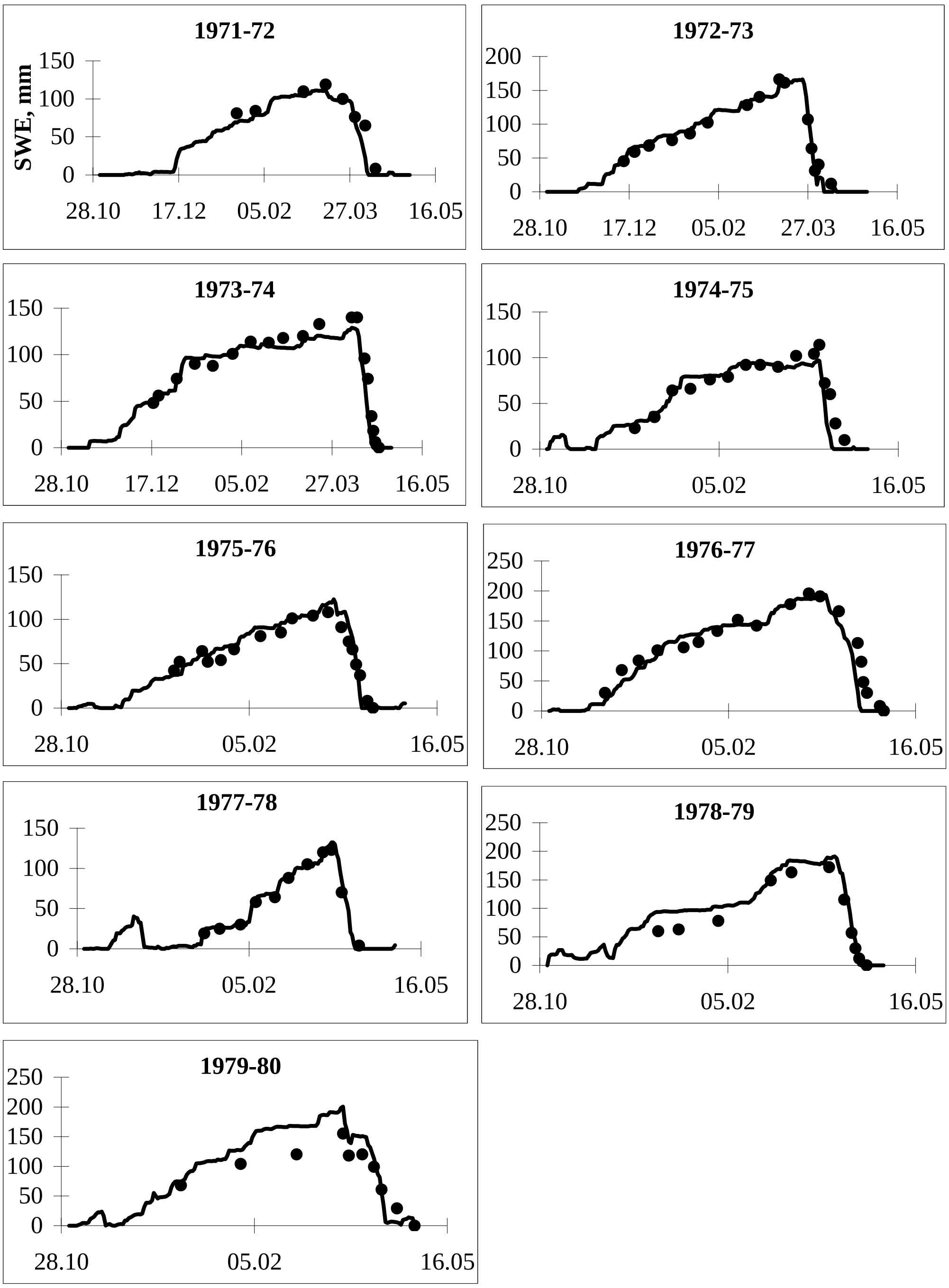

Figure Observed (points) and calculated (lines) snow water equivalent at the Kirov meteorological station.

3.2 We carried out an additional study aimed to refinement of the parameters of snow model by satellite-derived SCA data. The study is motivated by the fact that the model calibrated at point scale is not apparently ready for direct application at areal scale. The following paragraphs and new Figure 7 presenting the procedure of refinement of snow model parameters are added in the end of Section 5.

"Using the assumptions formulated above, we simulated daily maps of SCA and compared them with NASA MOD10_L2 maps for the snowmelt season of the years 2002 to 2005. The comparison was carried out in order to refine the snow model parameters adjusted against the ground-based point measurements (see previous section) and use the refined parameters for further characterization of snow fields. The region was divided on to 19 Thissen polygons according to the location of the meteorological stations. Simulated, SCA_{calc}, and satellite-derived, SCA_{sat}, values were estimated for each polygon and the dates when most of the polygons were free of cloudiness. The value of SCA was calculated as the number of open (free of forest) pixels covered by snow divided on the total number of open pixels within the polygon. When calculating SCA_{sat}, only free of cloudiness pixels were taken into account. Two criteria were applied to summarize the goodness of fit of the simulated and satellite snow maps for each selected date: (1) mean relative error $ME = \frac{1}{19}\sum_{i=1}^{19}\left(1 - \frac{SCA_{calc_i}}{SCA_{sat_i}}\right)$ and (2) root mean square error $RMSE = \sqrt{\frac{\sum_{i=1}^{19}\left(SCA_{sat_i} - SCA_{calc_i}\right)^2}{\sum_{i=1}^{19}\left(SCA_{sat_i} - \overline{SCA}_{sat}\right)^2}}$ where $\overline{SCA}_{sat}$ is the satellite SCA estimated for the whole polygon. It was appeared that minimum values of the both criteria are achieved under almost the same values of the snow model parameters (α =1.03, q_T =0.98 J m^{-2} s^{-1}, and q_E = 0.12 J Pa^{-1} s^{-1}) as the values obtained through the model calibration against the ground-based point measurements.

As an illustration of the obtained results, temporal changes of the criteria ME and RMSE are shown in Fig. 7 for 3 of 19 polygons.

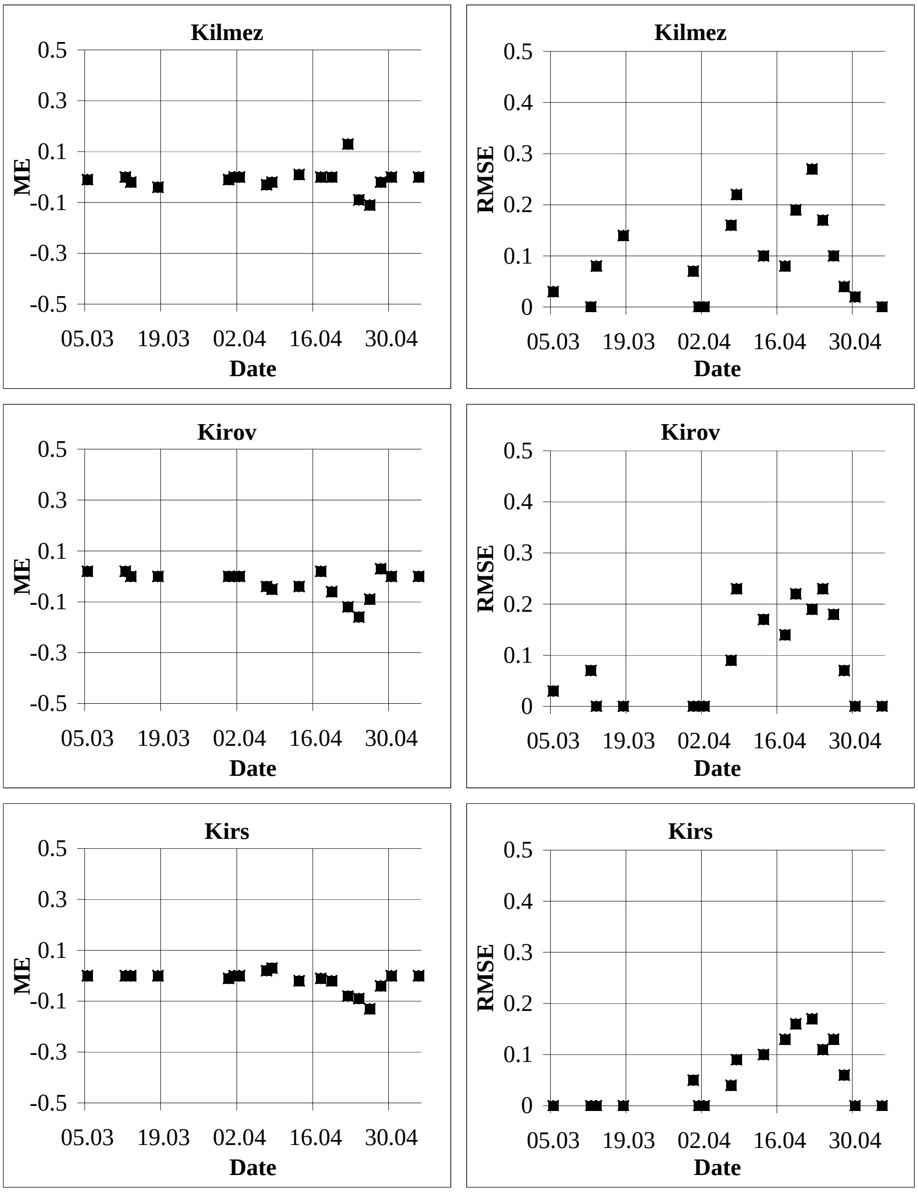

Fig. 7 Mean error (ME) and root mean square error (RMSE) of simulated snow covered area in comparison with one obtained from NASA MOD10_L2 maps for three Thissen polygons surrounding meteorological stations Kilmez, Kirov, and Kirs (forested pixels are not taken into account).

One can see from Fig. 7 that ME and RMSE are close to zero in the beginning of spring, then the both criteria increase in the period of intensive melt and return to small values in the end of melt season. In general, the model allowed us to reproduce well temporal changes of SCA for the open areas”.

3.3 Additional numerical experiments were carried out to compare hydrograph simulated by the model using satellite data and without these data. The following new discussion and new Figure 12 for illustration of this discussion are added in the revised manuscript.

Numerical experiments were carried out to assess whether or not utilizing satellite data in the model of runoff generation can result in improving hydrograph simulations when comparing with simulations utilizing meteorological observations only. Meteorological observations at the Vyatka basin were used to simulate processes of runoff generation from the beginning of snow accumulation in the previous autumn to the end of snowmelt flood. Satellite data were not used. Two sets of hydrographs were simulated distinguishing in the number of meteorological stations providing meteorological inputs into the model. The first set of hydrographs was simulated using all available 19 stations and only 4 stations were used for calculation of the second set. The results of the numerical experiment are shown in Fig. 12.

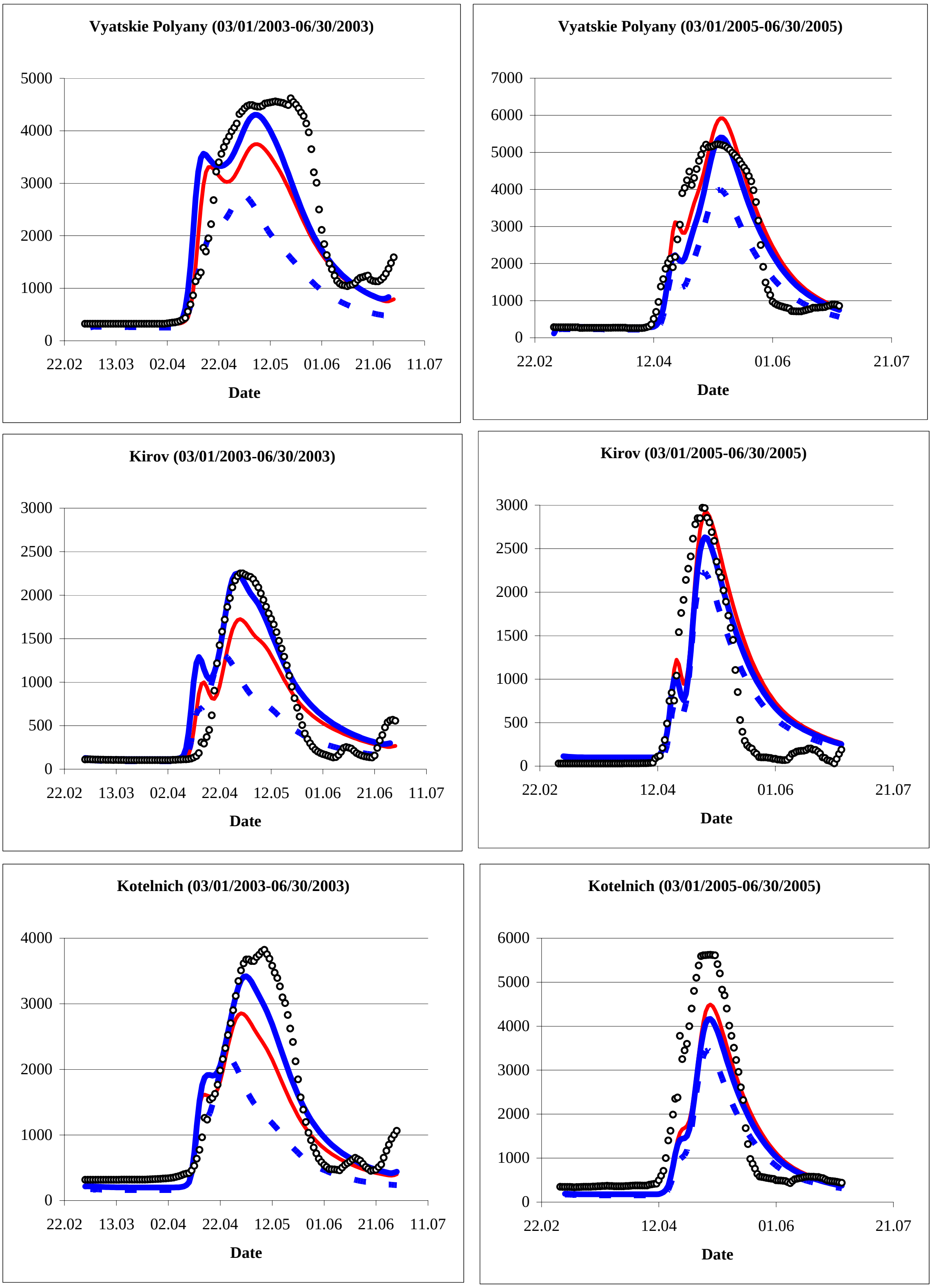

Fig. 12. Observed (circles) and calculated (lines) hydrographs of the Vyatka river: red line – calculated with satellite data blue lines – calculated without satellite data (continues line - data of 19 meterological stations are used, dashed line – data of 4 meteorological stations are used)

As one can see from Figure 12, utilizing the satellite data does not improve hydrograph simulations in comparison with the case when relatively dense network of meteorological observations exists. Moreover, hydrographs simulated from the data of 19 meteorological stations appeared to be slightly more accurate than ones calculated with the use of satellite data. This result can be explained by lower accuracy of the initial SWE field derived from satellite data in comparison with one calculated from meteorological data. However, in the case of scarce meteorological observations (only 4 stations per 120,000 km2), the result is opposite, as it is seen from Fig. 12. It means that initial SWE field taken from satellite date is more accurate than ground-based SWE data and has advantage for hydrograph simulation in the case of a catchment poorly gauged by meteorological stations.

Specific Comments

1. p5509/L8 ’3rd decade of March’ is confusing. ’decade’ usually refers to a 10-year period.

Corrected

2. p5516/L3 where did the canopy emissivity value of 0.96 come from?

The canopy emissivity value of 0.96 is taken from (Price, Petzold, 1984); it is referenced in the paper (Gelfan et al., 2004) where the model of snow accumulation and melt in a forest is presented.

Gelfan, A. N., Pomeroy, J. W., Kuchment, L. S.: Modelling Forest Cover Influences on Snow Accumulation, Sublimation, and Melt, J. Hydrometeorology, Vol. 5, No. 5, 785–803, 2004.
Price, A.G. and D. E. Petzold, 1984: Surface emissivities in a boreal forest during snowmelt. Arct. Alp. Res., 16, 45–51.

3. p5531/fig5 the model appears to overestimate depth in the beginning of the snow season. what is the reason for this?

Overestimation of snow depth in the beginning of snow season is not an essential feature of the used model. For example, in the season 2001-2002 we did not find such an overestimation (see figure below). In average, there is no visible bias both in the simulated snow depth and SWE .

4. p5518/L21 "Assuming that the spatial variability of snow density is much less than variability of SWE". Since SWE is a function of depth & density, then for this statement to be accurate, variability in the depth must be more responsible for the variability of SWE. Doesn’t this depend on whether it is near the beginning or the end of the snow season?

For plain basins of moderate area located in the zone of temporal, continental climate with cold, long winters without winter thaws, spatial variability of snow density is much less than, say, variability of snow depth in the end of snow accumulation season (e.g. Kuz’min, 1963; Kuusisto, 1984). Winters are always cold in the Vyatka region, winter thaws are very rare, period of intensive melt begins 3-4 weeks later than March 1st , thus, snowpack accumulated in the Vyatka basin on March 1st is typically deep and dry and this fact gave us opportunity to assign initial snow density as constant defined from the available measurements at single meteorological station.

Kuusisto E. 1984. Snow accumulation and snowmelt in Finland. *Pubications of the Helsinki Water Research Institute Series* **55**: 151pp.
Kuzmin PP. 1963. *Snow cover and snow reserves*. Israel Program for Scientific Translation: Jerusalem; 140pp.

5. Fig 10 it is interesting that both SWE-based approaches produce a better match to the observed hydrographs for the right column (2005) vs. the left column (2003). Is there a simple explanation?

Up to now, we have only two seasons of simulations. This information is not enough to make a conclusion on performance of the SWE-based approaches in different meteorological conditions.

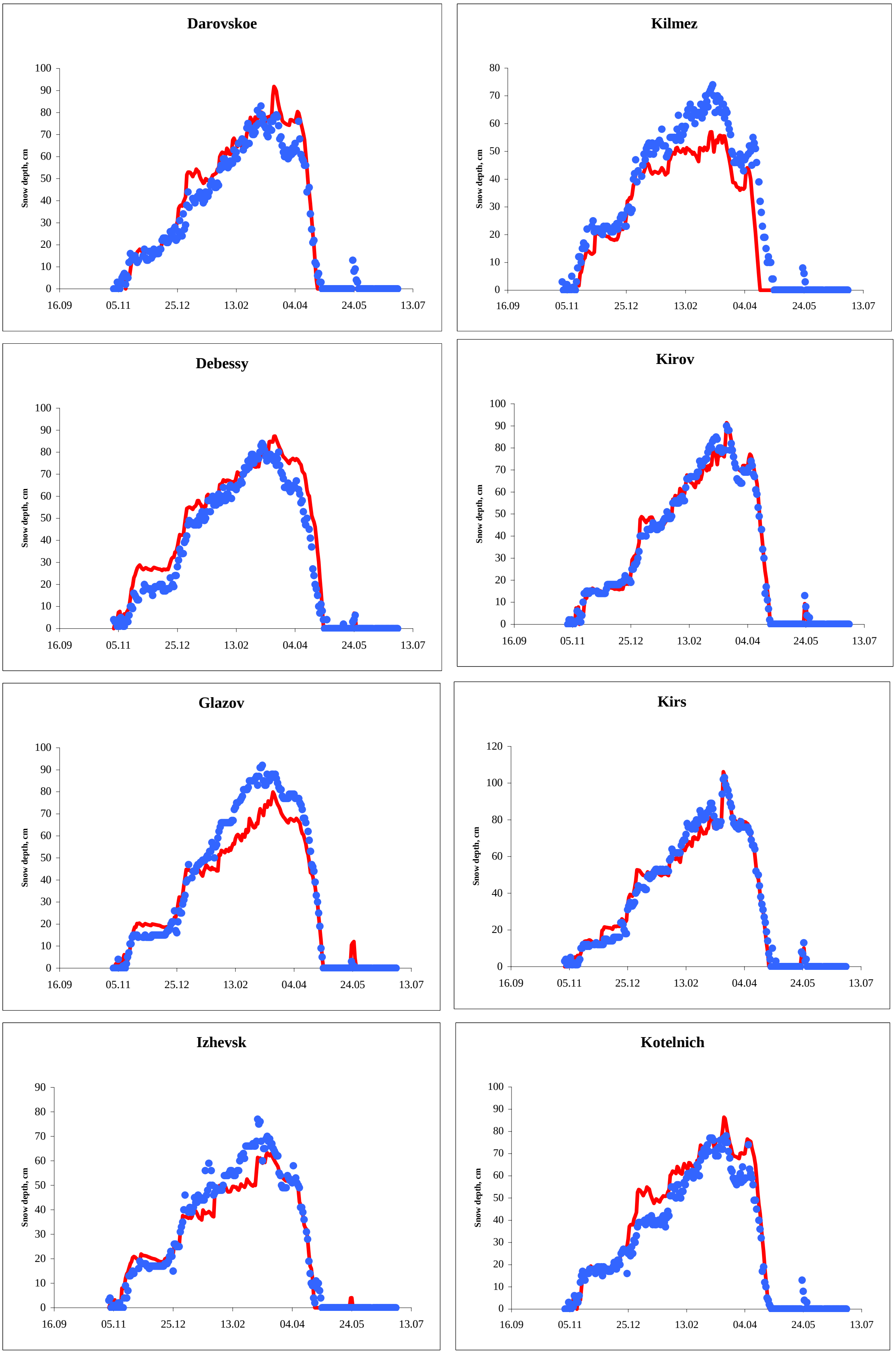

Figure. Seasonal change of the observed (points) and simulated (line) snow depths (in cm) at selected stations within the study area for the season from November 2001 to June 2002.