MULTISCALE AND MULTIDISCIPLINARY ASPECTS OF SNOW COVER

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Abstract
The contribution provides an overview of preliminary results of the INTAS and NATO projects focused on multiscale and multidisciplinary aspects of seasonal snow cover. Based on the extensive database, the snow physics parameterization taking into account snow structure for the use in the Global Circulation Models (GCM) and the geographic classification of snow are being developed. Numerical experiments with a GCM are performed. The outputs of the large-scale models are compared with measured data, and correlations between snow and hydrology are studied. Finally, the economical aspects of the snow, e.g. in tourism and transport are analysed.

Introduction

Seasonal snow cover is an important natural phenomenon. It substantially influences mass and energy exchanges between the Earth surface and atmosphere and hence also the human life in the large part of the world. The snow-related processes occur at a variety of spatial and temporal scales. For example, snow albedo and effective heat conductivity are the main snow parameters used in global circulation models (GCM) that are used to simulate climate at the scale of hemispheres. While the snow albedo is the characteristics of surface (i.e. can be considered as the large-scale characteristic), the effective heat conductivity depends on the structure of snow layers, i.e. the microscale. Hence, application of a GCM involves an important multiscale aspect. This multiscale aspect of seasonal snow can be supplemented by its multidisciplinary aspect. Spatial and seasonal variability of snow cover does not influence only natural processes (e.g. floods, avalanches, landslides), but also human life (hazards, transport, tourism, etc.). Thus, both the snow cover evolution and its effects have a multidisciplinary character. The aim of this paper is to inform about some partial results of the effort of an international team devoted to climatic and economical aspects of snow cover in central and eastern Europe.

Snow-climate, society and economy in central and eastern Europe

The INTAS project "Influence of snow vertical structure on hydrothermal regime and snow-related economical aspects in Northern Eurasia" and the related NATO project "Snow-climate, society and economy in central and eastern Europe" are focused on the multiscale and multidisciplinary aspects of

the seasonal snow cover. Participants come from various institutions in Russia, Austria, Czech Republic, Slovakia, Switzerland and Uzbekistan. The main working hypothesis is that accounting for additional characteristics of the snow cover such as albedo and snow structure can be significant for the modeling of climate system by means of the global circulation model. However, detailed description of the physical processes in the snow cover is not possible in a GCM. Therefore, a geographical classification is used to describe the dominant processes in the snow cover for application in a GCM. The classification represents the main effective characteristics of snow cover in a simple form, i. e. dependence on geographic location and intra-seasonal weather changes. Existing and newly collected field snow data are used to develop and evaluate parameterization schemes that take into account internal structure of the snow. The usefulness of obtained effective parameters in large-scale models is being evaluated. The project evolves around the following main tasks:
- compilation of database of the measured snow, meteorological, hydrological and economical data
- study of spatial and temporal variability of structural properties of snow in dependence on its evolution under certain meteorological conditions.
- development of parameterization scheme of processes acting in the snow cover with consideration of its structure
- numerical experiments with a global climate models with the new snow parameterization scheme, estimates of probabilities of extreme events connected with snow and their possible economical effects.

Overview of the results

Database

The database contains meteorological, snow, hydrological and economic data from Russia, Slovakia, Switzerland and Uzbekistan.
Main **meteorological data** from Russia, include two data series - the short term synoptic data from 222 stations and period 1990-2000 and the long-term daily data from 223 stations. Climatic data from Slovakia include 19 stations from the period 1990-2000, one station with the long-term data (1951-1998) and two stations with data from the last winters.
Snow data include the following data:
- arctic stations - snow depth, density and water equivalent, measured once per 10 days (decades); years 1947/48-1991/92, 61 stations
- regular stations – snow depth, daily data from former Soviet Union, years 1881-2001, number of stations in particular years varies between 1 and 220
- snow course data – mean snow depth, density and water equivalent, total amount of water, years 1966-2000, number of stations in particular years varies between 545 and 1313
- snow pits – various additional snow data (expeditions) from Russia, Slovakia, Switzerland and Uzbekistan with varying number of sites and time periods
Hydrological data include monthly and annual runoff of major Russian rivers (e.g. Lena, Amur, Enisei, Ob, Volga, Don, Kamchatka) and one small mountain catchment in Slovakia..
Economical data contain various types of data from Russia and former Soviet Union and Slovakia, e.g. administration units, number of overnight stays in accommodation facilities, skiing lifts, etc.

Study of spatial and temporal variability of structural properties of snow, development of parameterization scheme

Petrushina et al. (2006) studied regularities of spatial and temporal variability of snow cover characteristics and factors of its formation at different hierarchic scales. The investigation was based on the large-scale fieldwork, physical and mathematical modeling and analysis of meteorological data. They concluded that snow structure at regional scale is determined mainly by meteorological conditions. Several types of snow structures were identified and modeled. The most complicated snow structure is formed in mountains where the slope morphology plays a crucial role.

Shmakin et al. (2006) presented a new parameterization scheme to be used in Global Circulation Models that considers snow structure. The parameterization scheme uses interpretation of snow physics by simplified description of the effective parameters of snow cover. The modeling results for several testing sites in Eurasia showed that usage of effective parameters based on the snow vertical structure classification leads to better evaluation of the energy/water balance.

Gromov and Rubinstein (2006) developed a dynamic snow cover classification for use in a GCM. The comparison with the NOAA satellite data and reanalysis outputs demonstrated an adequate reproduction of some snow characteristics (e.g., conservation and seasonal change of snow covered area, snow mass integrals). The uncertainties were found in areas with complex topography and during spring (snowmelt) periods. In a series of accompanying papers, the Global Circulation model of the Russian Hydrometeorological Center (HMC) was compared with other GCMs (Rubinstein and Gromov, 2006), and the reanalyses data were compared with field measurements for basins of the main Russian rivers (e.g. Khan et al., 2006a; Khan et al., 2007). It was found that the HMC model performed very well compared to the results of other GCMs . The quality of the reanalyses snow products varies for different regions and time. Various types of reanalyses complement each other. Generally, the reproduction of measured snow water equivalents by the ECMWF reanalysis was better than by the JRA-25 reanalysis and significantly better than by the NCEP/DOE reanalysis. Seasonal variability of SWE in the main Russian river basins was reproduced well by the ECMWF and the JRA-25 reanalyses. Significant disagreements with observational data were observed during the period of intensive snowmelt.

Khan et al. (2006a) assessed the quality of the reanalysis data and analysed the variability of snow cover and river discharge in the Aral sea basin. Due to the drastic reduction of measurements, the reanalysis and satellite data can often be the only surrogates of the measured data. The analysis showed the discrepancy between the increasing trend of runoff in the Amudarya and the Syrdarya rivers and the decreasing trends in precipitation and snow depth.

Popova (2006, 2006a) studied the interannual variability of winter snow accumulation and river runoff in four river basins in northern Eurasia (Volga, Ob, Enisei and Lena) using the long-term data and focusing on the relationships with the North Atlantic Oscillation (NAO) anomalies and global warming. She has fonud that with respect to snow depth interannual variations, there are several spatially homogeneous regions in the Northern Eurasia. The interannual variations of snow depth in the regions correspond to changes in certain atmospheric circulation modes. For the major portion of the Eurasia territory to the north from 55°N between the White Sea and river Lena basin, increase of snow depth during 1975-1995 can be explained by positive NAO trend. Positive trends in runoff in the Volga and Enisei rivers since the 1970’ are caused by increased snow accumulation associated with positive phase of NAO. The analysis showed lower correlation between annual runoff and snow depth in the Ob and Lena rivers basins due to higher importance of summer precipitation.

Economical aspects of the snow cover

Holko and Breiling (2006) analysed the relationship between tourism and snow in Slovakia. The analysis showed that the highest number of tourists typically come to regions where winter tourism is important. Statistical data from the district of Liptovský Mikuláš (which is the district with the highest number of the overnight stays in the Zilina region) showed that although summer remains the main touristic season in Slovakia, winter tourism is almost equally important. Further analysis can be focused on the assessment of impacts of changed climatic conditions on this business.

Shmakin et al. (2006a) compared snow depth in February for each of the 89 administrative units of Russia in 1951-80 (mid-century period) and 1989-2001 (the contemporary warming). In western and south-western parts of East European plain, the amount of snow decreases, while in most of the country it has increased significantly. Also, the volume of snow falling on roads (which has to be removed by cleaning) was calculated for each of the administrative units. The largest increase in the expenses for snow removal from the roads occurs in the oil production regions of Ural and Western Siberia (Tyumen, Bashkortostan, and others), where both length of the roads and snow depth are increasing. Some reduction in the expenses takes place in north-western regions (Tver, Pskov and others).

Conclusions

There is a long way from incorporation of physical snow processes into climate modeling and assessment of its impacts on the society and economy. This paper presents partial results of the work that strives to go in such a direction.

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