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Coupled hydrometeorological modeling of rain-on-snow flood events in the Northern Ural using the WRF and Hydrograph models

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Snowmelt runoff is more than 60% of the annual streamflow in most of Northern Eurasia, including Northern Ural region. Northern Ural is characterized by high snow accumulation. Snowmelt floods on the Northern Ural's rivers are regularly observed in May or June (for example, in 1993, 2004, 2014, 2017 years). However, in recent years, with increasing of temperature and precipitation amount, the rain-on-snow (RoS) floods can occur in autumn, during the snow cover formation period. Such anomalous floods happened in 2006 and 2013, and we can assume that they will occur more often in the future (Freudiger et al., 2014).
A major challenge of snowmelt runoff forecasting in the Northern Ural is the lack of precipitation gauges and snow survey data. Therefore, the estimation of precipitation and SWE spatial distribution raises the uncertainty in the forecasts. Coupling mesoscale atmospheric models with hydrological models can be used to improve the flood forecast reliability in the basins with mountainous terrain and the lack of ground-based observations. Additionally, the forecast period can thus be extended when compared with traditional methods based on precipitation gauges data (Zhao et al., 2009).
The aim of this study is to assess the bene[U+FB01]ts of a high-resolution atmospheric forcing to the distributed hydrological model to simulate RoS flood events in the Northern Ural rivers basins. The studied basins of the Vishera and Yayva rivers (with basin area 31083 and 5400 km2 respectively) are characterized by mountainous terrain with elevation ranges from 100 to 1469 m, and sparse ground-based observations.
We applied the hydrological model Hydrograph (Vinogradov et al., 2011) driven by the 39-h numerical forecasts of Weather Research and Forecasting (WRF) mesoscale atmospheric model (Skamarock et al., 2008) to simulate RoS floods events. The Hydrograph model was parametrized and verified based on historical data from weather station for the period 1983-2015 with Nash-Sutcliffe (NS) criteria reaching 0.66 and 0.77 for the Yayva and Vishera rivers. We performed a comparative analysis of snowmelt runoff simulation results using the WRF-simulated and ground-based meteorological input by the example of two case studies of rain-on-snow events in 2006 and 2013.
The analysis of the WRF model data has shown that in general this model tends to underestimate precipitation in autumn period as well as air temperature for the studied region. The use of WRF data didn't allow for adequate simulation of studied flood events as low air temperature led to snow accumulation instead of snowmelt. Contrariwise, the use of weather stations meteorological data which was interpolated into calculation elements of hydrological model with the account of air temperature and precipitation elevation gradient produced rain-on-snow hydrographs with NS>0.8 for both events. The results of the study have revealed that the use of WRF model is not reliable for the studied region. Other models such as global atmospheric models GFS/NCEP, GEM/CMC ICON/DWD with a lower spatial resolution will be tested as well.
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