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The Amur River flood of 2013: analysis of genesis, frequency assessment, and modeling results

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The 2013 Amur River flood was one of the most significant and damaging natural disaster ever to hit Russia. During July-September of 2013, almost the whole basin of the Amur River, the tenth largest river basin in the world, was stricken by unprecedentedly powerful and protracted flooding. The magnitude of this flood event was extraordinary: extreme water levels were registered at the streamflow gauges along the main river and its tributaries; within the largest cities (Khabarovsk, Komsomolsk-on-Amur) the Amur River reached the record stage, 1.5-2 meters surpassing the previous records for tens years of observations. In the Russian part of the basin, damages approached $1.3 billion.

In our study, two main causes of the Amur flood of 2013 have been analysed as follows: (1) the unique atmospheric situation, which was characterised by formation of the strong extratropical blocking pattern over north-west of the Pacific Ocean during the monsoon season, and resulted in anomalously heavy and prolonged rain events over the basin; and (2) cold, snowy winter of 2012-2013 and late snowmelt season of 2013 lead to saturation of soils over the vast territory just before the heavy rains. The main observed characteristics of flood have been summarized and an attempt has been carried out to assess frequency of the extreme flood peak discharge registered in the Khabarovsk city in August 2013. It has been shown that there is a large uncertainty in statistical assessment of the observed flood hazard: the recurrence interval of the extreme discharge varies from 100 to 300 years depending on the probability distribution curve fitting the available discharge observation data.

The physically-based semi-distributed model of runoff generation in the Amur River basin has been developed and applied for reproducing the flood of 2013. The model is based on the ECOMAG modelling system and describes processes of snow accumulation and melt, soil freezing and thawing, water infiltration into unfrozen and frozen soil, evapotranspiration, thermal and water regime of soil, overland and subsurface flow. To simulate channel flow a hydrodynamic MIKE-11 model was coupled with the ECOMAG. The model was applied for the middle part of the Amur River including two largest left tributaries, Zeya and Bureya Rivers, where large reservoirs are located. The model was calibrated using streamflow discharges measured in the different gauges of the main river and its tributaries for 10 years (2000-2009). Validation of the model was carried out for the period of 2010-2013. For the flood of 2013, the Nash and Sutcliffe efficiency criterion of the river stage simulation has been obtained as 0.84-0.94 depending on the streamflow gauge.

Numerical experiments have been carried out to assess the effect of the Zeya reservoir regulation on the middle Amur River stage. It has been shown that in the absence of the reservoir, the water levels within the Blagoveshchensk city (downstream of the Zeya River mouth) would be 0.5-1.5 m higher than the levels measured during the flood of 2013.