Geography Compass 3/5 (2009): 1841–1864, 10.1111/j.1749-8198.2009.00256.x

Long-term Hydrological Forecasting in Cold Regions: Retrospect, Current Status and Prospect

Alexander N. Gelfan[1]* and Yury G. Motovilov[2]
[1]*Water Problems Institute of Russian Academy of Sciences*
[2]*Federal Water Resources Agency, Centre for Russian Waterworks Inventory and State Water Cadastre*

Abstract

The influence of long-term snow accumulation on the runoff conditions several months afterwards is a distinct hydrological characteristic of cold regions, which creates opportunities for long-term (seasonal and subseasonal) hydrological forecasting in these regions. We consider evolution of the long-term forecasting approaches from the deterministic data-based index methods to the hydrological model-based ensemble approaches. Of key interest in this review are the methods developed and used in operational practice in Russia and in the USA, with the emphasis being placed on the methods used in Russia, which may be less familiar to international hydrological society. Following a description of the historical context, we review recent developments that place emphasis on problems relating to the uncertainty of the weather conditions for the lead time of the forecast. We conclude with a personal view of the prospects for the future development of long-term hydrological forecasting techniques.

1 Introduction

A cold region may be broadly defined as one in which the lower temperatures have significant effects on the natural environment or on human activities. In order to try to provide a clearer focus for this broad definition, and thus define cold regions more precisely, environmental scientists suggested physical criteria such as climatology factors, the characteristics of seasonal or permanent snow and ice cover, and the seasonal freezing/thawing of the ground or permafrost, etc. By considering all these criteria, Bates and Bilello (1966) defined about a quarter of the Earth's land surface (most of Siberia, Canada and Alaska; parts of northern Europe and the Far East, as well as polar regions) as 'severely cold' regions and another quarter (most of Eurasia and the USA) as 'moderately cold'. Figure 1 shows the extent of the cold regions thus defined. It is clear that the shown boundaries are rather approximate [for instance, as Hamelin (1979) has calculated, at least 20 criteria of cold region have been employed that results in the corresponding number of separate boundaries] but nevertheless provide the general geographical context of the topics considered in this article.

In contrast with warmer regions, an important feature of cold region hydrology is associated with the fact that a significant portion of the annual precipitation is stored as snow cover for periods of several months at a time, and only becomes available as river runoff during the relatively short spring melt season. The resulting snowmelt runoff plays an important role in the hydrological cycle in cold regions and often constitutes the most significant part of the annual runoff in terms of the total volume. For example, in most of the large plain rivers in Russia (Ob, Irtysh, Yenisei, Volga, etc.), as well as in the snowmelt-dominated river basins in the western USA, snowmelt runoff can account for