COMBINED PARAMETERISATION OF OROGRAPHY-INDUCED PRECIPITATION AND RUNOFF FOR REGIONAL HYDROCLIMATIC STUDIES

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The processes of land-atmosphere interactions are strongly influenced by the orography from many aspects. The role of orography is suggested by scientific community to be among the most important factors which should be considered in hydroclimatic models and/or calculations.

In studies of energy/water exchange on the land-surface, it is necessary to take into account the spatial scales of orographic features most important for the processes. It is more or less known that the mutual disposition of main mountain ranges (or hill chains) and main valleys of the size of from 10 to nearly 100km results in the spatial distribution of precipitation fields. The runoff formation and secondary reflection/emission of radiation fluxes between relief slopes are mainly influenced by the structure of elementary valleys and water divides of the size of from 100m to 1km. In order to include these processes in hydroclimatic studies, one should:

1) have initial natural database containing information about relief features on a given scale; and
2) develop special parameterisation schemes describing the results of the processes action according to the external atmospheric/hydrologic conditions and internal land cover properties.

For the regional studies of energy/water exchange in mountainous areas, we used several sources of relief information. One is the ETOPO5 database obtained from UNEP/GRID. It consists of relief heights for the entire globe (including ocean depths) with a spatial resolution of 5x5 minutes, made by polynomial interpolation from 10x10 minutes of measured data. In spite of some disadvantages (obvious mistakes in separate areas, height values being divisible by some numbers only), this database gives a good general view of the main ranges and depressions disposition which is useful for the calculations of orographic precipitation.

To include the elementary valleys information into the calculations, we propose the conventional relief image on an appropriate scale. It is suggested that the profile perpendicular to a valley consists of a V-form valley and water divide which is flat in general (in a rather dissected area, the divides can be drawn as sharp "hills" without any flat part between two valleys). It is also suggested that a terrain consists of a network of valleys perpendicular to each other. Almost all types of land relief can be presented with such an image. For its numerical characteristics on the given territory, it is enough to know three morphometrical parameters of relief dissection: mean depth of elementary valleys; mean length of elementary valleys per unit square; and mean fraction of the unit profile occupied by the flat water divide. The data set containing these parameters with the spatial resolution 1x1 degree was created specially for this work for the main territory of Eurasia (except for some peninsulas) through analysis of the topographical maps.

To describe the water transport by rivers and secondary replenishment of soil water storage by rivers in the lowlands, we also created two data sets of 1x1 degree resolution: the main runoff directions between grid cells, and the fractions of incoming river runoff which can penetrate the soil in considerable areas of the cells. We also used well-known land cover data and soil data sets (Matthews 1983, Wilson and Henderson-Sellers 1985).

In the parameterisation scheme used for the regional studies (Shmakin et al. 1993), we took into account all main processes typical for the hydrological cycle in mountains: orographic precipitation, runoff formation, evapotranspiration (considering all components of the energy budget), water transport by rivers, replenishment of soil water storage by rivers in the lowlands. They were described in the scheme by considering the key mechanisms for each of the processes (vertical wind speed as a result of relief blowing, influencing the precipitation field; soil water transfer along elementary slopes and formation of contributing areas, resulting in the runoff field, etc). The scheme allows one to reproduce the temporal course of main energy/water budget components for a territory with several contrasting land cover patches connected by rivers. So, the temporal and spatial changeability of both land-surface features and heat/water fluxes is taken into account, while each patch is suggested to be spatially homogeneous yet (the land cover heterogeneity leading to the appearance of the ordered mesoscale fluxes within the atmospheric boundary layer is planned to be parameterised in future, at least for the territories without high mountains).

In this study, the scheme was realised for several mountainous territories in mean climatic regime. The average climatic values of precipitation, surface air temperature, and cloudiness, with a spatial resolution of 0.5x0.5 degrees (Leemans and Cramer 1991), were used as forcing data. The solar and incoming infrared radiation as well as the radiation fluxes between relief slopes were calculated by the methods developed earlier (Krenke et al. 1991, Shmakin and Ananicheva 1991).

The results show that even with such poor forcing data (average climatic regime only, without weather changes within a month) and a rather simple calculation scheme, the main features of water and energy cycles were reproduced quite satisfactorily and some interesting conclusions can be made. The introduction of rather detailed relief data into the calculations by a parameterisation procedure allowed more detailed field of precipitation as well as more appropriate runoff and evapotranspiration values at every grid cell to be obtained. The role of temporal changeability of fluxes was partly played by their spatial inhomogeneity in this case. At the same time, some processes were parameterised too roughly (snow and glacier melting, intensive water penetration into the soil after heavy rains) due to poor temporal resolution. This is planned to be improved in future by the "weather generator" procedure.

Then, it was found that the spatial disposition of strongly dissected and not so dissected terrains can be very important for regional hydrological-climatic interactions. Territories with large relief dissection give much more runoff production due to more active slope water movements and larger fraction being occupied by valleys. Moreover, they are usually associated with rather high mountains where the precipitation is significantly more than on the plain. Nevertheless, the strongly rugged relief itself is not responsible for the enlarged role of the water cycle in the climate system. The mutual influence of hydrologic and climatic processes becomes much more intensive in the regions where rather dissected territories are adjacent to quite flat terrains (for example, the Himalayas and Ganges lowland). In such territories, precipitation is much more heavy if the main air flows are directed from the lowlands to the mountains, as precipitation intensity is connected with upward wind speed along the slopes rather than with the absolute height of the mountains. Then, the intensive runoff processes in strongly dissected areas give rise to intensive evapotranspiration from the lowlands where a large part of the soil water is brought by rivers from uplands and mountains. The situation is even more interesting in the closed basins (e.g. in the Central Asia), where all precipitation from the mountains flows downstream and evaporates from adjacent lowlands as there is no means of water transport to the ocean there. At the same time, in other regions (for example, Scandinavia), where the intensive precipitation and runoff exist due to high and dissected mountains near the ocean, and there are no wide lowlands between them, one can see heavy precipitation and intensive runoff, too. Nevertheless, this water transfer from air to surface does not influence the climatic system so much because the evapotranspiration does not result from additional water inflow from the mountains.

Acknowledgment: The work was supported by the Russian Foundation for Fundamental Investigations (grant No. 93-05-9843).

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